APPLICATION OF SATELLITE TECHNOLOGY

PROGRESS REPORT

1999-2000

SAT-29

TECHNICAL DOCUMENT
WMO/TD No. 1089

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INTRODUCTION

The purpose of this publication is to make Members aware of the state of development in satellite applications, as well as the operational uses of satellite data, derived products and services in the meteorological and hydrological services in different countries.

This Satellite Report has several parts including the operational status of various satellite systems, a synopsis of related satellite training events and conferences held during 1999-2000 and Progress Reports from WMO Members, ECMWF and EUMETSAT. The Progress Reports contain a review of the applications of satellite technology within three functional areas:

(1) Remote sensing of spectral radiation which can be converted into measurements for meteorological and operational hydrological applications (this includes the data and the derived products such as atmospheric soundings, sea surface temperature, satellite cloud track wind, etc.);

(2) Collection of data from *in-situ* sensors (commonly referred to as the data collection system such as Service-Argos on the NOAA polar-orbiting satellites); and

(3) Transmission of satellite data through a direct broadcast mode (APT and High Resolution Picture Transmission (HRPT) on polar-orbiting satellites; WEFAX and high resolution (S-VISSR and GVAR) to Primary Data Utilization Stations (PDUS) and Secondary Data Utilization Stations (SDUS) on geostationary meteorological satellites.

Progress reports from WMO Members, ECMWF and EUMETSAT have the following major subdivisions:

PART I Summary of the major highlights of research applications and operational changes

PART II Major research and development in the applications of satellite data, derived products and services

PART III Techniques development and applications of satellite data, derived products and services

PART IV Description of the system for satellite applications in current operational use

PART V Plans for future operational systems for satellite applications to meteorology and operational hydrology

PART VI Validation and verification of satellite data and derived products used in operations, including performance statistics

PART VII Other items (references, publications and scientists in charge)

EXECUTIVE SUMMARY

This set of country reports for 1999-2000 from 28 Members, ECMWF and EUMETSAT demonstrates the wide diversity in the applications of satellite data in the various fields of meteorology and operational hydrology. Detailed information can be found in the individual Progress Reports covering a wide range of applications. Several recurring uses and applications appear in many of the reports.

In the area of monitoring phenomena which have devastating impacts, such as tropical cyclones, severe meso-scale storms, floods and forest fires, several progress reports contain important and innovative descriptions of new capabilities. In Germany, a substantial upgrade has been introduced in the system for interactive meteorological applications for a more efficient use of all different types of remote sensing data which are available in real-time on a fully operational basis at all offices of the DWD engaged in weather forecasting activities: a combined display of Meteosat or AVHRR images, ground-based radar precipitation data and lightning data are now possible, also in animated mode, as well as a combination with other meteorological data as e.g., conventional observations, NWP fields, etc. (See Germany, paragraph 2.6). In the Russian Federation based on ScaRab data, a new method for the statistical description of appearance and consequences of dangerous natural phenomena has been developed (See Russian Federation, paragraph 2.28).

With regard to the derivation of the basic physical parameters of both the atmosphere, such as wind, temperature and moisture, and the surface, such as sea surface temperature, vegetation, ice and snow cover, sea ice, ocean states and albedo, there is a richness in the ongoing research. The research at the NIMH of Bulgaria is focused on the use of Meteosat water vapour (WV) channel data in weather analysis and prognosis over the Mediterranean (See Bulgaria, paragraph 2.1). Canada reported that algorithm development research has continued using SSM/I passive microwave satellite data for the determination of snow-water equivalent, snow extent and snow state (wet/dry) for different landscape regions of Canada (e.g. prairie, boreal, forest, tundra) (see Canada, paragraph 2.16). In Denmark, DMI notes the development of high latitude (i.e., north of 50°N) sea ice and SST products, i.e., development of sea ice concentration products based on SSM/I data (Special Sensor Microwave Imager), development of algorithms for removal of weather contamination of the passive microwave sea ice products with the use of ancillary (model) information and statistical analysis of SSM/I data to provide input to an optimization of the multi-sensor technique based on a Bayesian framework in cooperation with DNMI (Norway) (See Denmark, paragraph 2.2). At EUMETSAT, a new land surface albedo retrieval algorithm has been developed by the Space Applications Institute of the European Commission and implemented in the EUMETSAT data reprocessing environment (See EUMETSAT, paragraph 2.10). In Finland, cloud parameter studies have been made using new methods such as neural networks and fuzzy logic (See Finland, paragraph 2.1).

The number of hydrological applications of satellite data reported by WMO Members continued to increase during 1997-98. Convective rainfall, monthly river run-off and water balance are successfully determined by using more sophisticated satellite retrieval techniques. In Canada, algorithm development research has continued using SSM/I passive microwave satellite data for the determination of snow water equivalent (SWE), snow extent and snow state (wet/dry) for different landscape regions of Canada (e.g., prairie, boreal forest, tundra) (See Canada, paragraph 2.16). During the summer season of 2000, China used FY-1C and NOAA-14 data to monitor flooding in daily operational mode (See China, paragraph 2.13). In Kenya, the TAMSAT method of rainfall estimation has been applied on the Nyando catchment with the aim of producing quantitative precipitation estimates for the purpose of predicting events of short and medium duration (See Kenya, paragraph 2.3).

Satellite data are handled in a digital format at high resolution stations, most of which carry on some operations to derive quantitative information from the radiances. This information is being increasingly used as input data for numerical weather-prediction models. Atmospheric sounding data and cloud-wind vectors are input in the objective analysis scheme. Humidity estimates are made using satellite image data. The improvement of sounding retrievals has been a particular focus of many of the research efforts found in the Progress Reports. Several progress reports note ongoing research in cloud classification. In Australia, research is currently being undertaken to support the operational high-resolution regional cloud and water vapour drift wind system to ensure optimal assimilation of these high spatial and temporal resolution quantitative GMS observations into data assimilation systems (see Australia, paragraph 2.3). At ECMWF, assimilation of ozone observations has been developed, along with necessary revisions of the photochemistry model needed to make it suitable for use in data assimilation (See ECWMF, paragraph 2.14). In India, capabilities are available at the INSAT Meteorological data Processing System(IMDPS) and HRPT system installed in 1992 and 2000 respectively at New Delhi for making sounding retrievals using data from the USA polar-orbiting satellites (See India, paragraph 2.1).

Of particular interest is the use of satellite data types from new research satellites. In Australia, preparations are underway towards providing a reception and processing capability for AIRS and MODIS, using a low-cost system, based on upgrading the existing S-band antennae and in relation to the Geostationary Imaging Fourier Transform Spectrometer (GIFTS), planning and research are underway, related to the reception, product generation and dissemination of data from that instrument which will be positioned over the Indian Ocean during the last half of this decade(see Australia, paragraphs 2.12 and 2.13). In France, assimilation of ERS altimeter wind and wave data is performed in the operational global wave model (See France, paragraph 2.10). In Japan, an impact study of QuikSCAT/SeaWinds was performed with the global NWP system and results showed large positive impact over the Southern Hemisphere and small positive impact over the Tropics and the ocean in the North Hemisphere (See Japan, paragraph 2.3).

The bibliography at the end of each chapter should be an excellent reference for those Members seeking a more in-depth explanation.

EDUCATION AND TRAINING DURING 1999 AND 2000

6-17 December 1999	San José, Costa Rica Regional Training Seminar on the Use of Environmental Satellite Data in Meteorological Applications for RA III and RA IV
28 February-3 March 2000	Lorne-(Melbourne) Australia 5th International Winds Workshop (Co-sponsored by EUMETSAT, and WMO)
4-15 December 2000	Nanjing, China Regional Training Seminar on the Use of Environmental Satellite Data in Meteorological Application for RA II and RA V

STATUS REPORTS FOR SATELLITE SYSTEMS

CHINA, PEOPLE'S REPUBLIC OF

SATELLITE SYSTEM

1. The Chinese meteorological satellite programme involves both polar orbiting and geostationary satellite series. The main objective of the programme is to establish a comprehensive operational meteorological satellite system, as well as a ground monitoring and application system in order to meet the demand of various sectors in China.

2. The meteorological satellites of China are named Feng-Yun (abbreviated as FY), which stands for "Wind and Cloud" in English. The odd number series FY-1, FY-3, etc., is to indicate the polar orbiting satellite series, while the even number, i.e., FY-2, FY-4 is for the geostationary series.

CHINA'S FIRST GENERATION OF POLAR ORBITING METEOROLOGICAL SATELLITES: FY-1

3. According to the current plan, China's first generation of polar orbiting meteorological satellite system, FY-1, consists of four satellites, as well as the corresponding ground data acquisition, processing and application systems.

FY-1C and FY-1D

4. The FY-1C and FY-1D satellites are developed on the basis of the previous experimental meteorological satellites FY-1A and FY-1B. Besides the foreseen improvement on the reliability of the satellites, there are some changes in the imaging instrument and data transmission as follows:

(1) The number of channels of the Visible and Infrared Radiometer is increased to ten, enabling more useful observation over the land and ocean;

(2) The on-board satellite data storage capacity is increased to 300 minutes (60 minutes with FY-1A and B only), making it possible to acquire once per day the global CHRPT data of four pre-selected channels with 4-km resolution (defined as Delayed Global Picture Transmission-DGPT), as well as 20 minutes of ten-channel original resolution data at any region of the world (defined as Delayed Local Picture Transmission, DLPT);

(3) The FY-1C and FY-1D's High Resolution Picture Transmission is very similar to the NOAA/HRPT, except for the data transmission rate. It means that the systems receiving and processing NOAA/HRPT data can receive and process FY-1 satellite data with just a little modification. The data transmission rate is 1.3308 Mbps, double that of current NOAA/HRPT. The transmission modulation is PSK and bit format is split phase;

(4) The designed life time of FY-1C/D is two years;

(5) There is no APT in FY-1C and FY-1D.

5. The instantaneous field of view of the radiometer is 1.2 mrad and the resolution at the satellite sub- point (SSP) is 1.1 km. The scan rate is 6 lines per second and the total pixels of each scan line are 2048. The channel features of the main payload on FY-1C and FY-1D are indicated in Table 1.

Table 1
The channel characteristics of MVISR onboard FY-1C and FY-1D

Channel	**Wavelength(μm)**	**Primary Use**
1	0.58-0.68	Daytime cloud, ice and snow, vegetation
2	0.84-0.89	Daytime cloud, vegetation
3	3.55-3.95	Heat source, night cloud
4	103.-11.3	SST, day/night cloud
5	11.5-12.5	SST, day/night cloud
6	1.58-1.64	Soil moisture, ice/snow distinguishing
7	0.43-0.48	Ocean colour
8	0.48-0.53	Ocean colour
9	0.53-0.58	Ocean colour
10	0.90-0.985	Water vapour

Current status of FY-1C and FY-1D

6. FY-1C polar orbiting meteorological satellite, carrying a ten-channel radiometer as the primary sensing instrument, was launched successfully on 10 May 1999. The FY-1C satellite weighs about 950 Kg. The two solar cell arrays mounted on both sides of the main body make the total length of the satellite 8.6 metres. The attitude of the satellite is three-axis stabilized with a precision of no less than 1 degree in all three axis. FY-1C operates in a sun-synchronous orbit with the orbit parameters listed in Tables 2 and 3.

Table 2
Orbit parameters of FY-1C meteorological satellite

Satellite	**FY-1C**
Launch date	**10 May 1999**
Orbit	Sun-synchronous
Altitude (km)	863
Period (minutes)	102.332
Inclination (degrees)	98.79
Eccentricity	<0.00188
Descending Node(LST)	08:34
Average Power Output	229 Watts
Design Life	2 years
Attitude Control	Three-axis stabilized

Table 3
CHRPT parameters of FY-1C

CHRPT transmission frequency	1708.0 MHz (1704.5 MHz as backup)
DPT transmission frequency	1700.0 MHz
EIRP	39.4 dbm
Polarization	Right hand circular
Modulation	PCM-PSK
Modulation index	$67.5^{\circ} \pm 7.5^{\circ}$
Bit rate	1.3308 Mbps

7. FY-1C is in operation now and many products are produced, some products are under development FY-1C products are now used in everyday weather forecasting and environmental monitoring in China.

8. The structure of the FY-1D satellite is similar to FY-1C; it is under manufacture and scheduled to be launched in the fall of the year 2001.

GEOSTATIONARY METEOROLOGICAL SATELLITE PROGRAMME OF CHINA

9. China launched the first geostationary meteorological satellite FY-2A on 10 June 1997. Then the second geo-satellite was launched on 25 June 2000. At present, the FY-2A is at 86 ^{o}E, it only works on a part time fashion. As a main operational satellite, the FY-2B is located at the 105^{o}E. The satellite is temporarily put out of operation during the satellite eclipse time for a special maintenance.

10. FY-2 satellite data is open to international users, shareable to all countries. User stations within the FY-2 coverage can receive S-VISSR high resolution digital data and WEFAX low resolution analogue data.

Specifications of FY-2 satellite and the radiometer

Functions of the satellite

11. FY-2 meteorological satellite has the following functions:

- Obtaining visible, infrared and water vapour images by a radiometer on board satellite. Sea surface temperature, cloud analysis chart, cloud parameters and wind vectors can be derived from these data;
- Collecting and transmitting observed data from widely dispersed data collection platforms;
- Broadcasting S-VISSR data and WEFAX;
- Monitoring space environment.

Table 4
FY-2 Satellite Specifications

Dimensions	Diameter Height	2.1 m 1.6 m (cylinder)
Mass	Launch On Station	1200 kg 520 kg
Life span	Designed	3 years
Orbit	Geostationary	located at 105°E
Attitude	Spin-stabilized, Spin rate	100±1 rpm
Launch Vehicle	Long March-3	

Visible and infrared spin scan radiometer

12. The major payload of FY-2 meteorological satellite is the Visible and Infrared Spin Scan Radiometer (VISSR). The characteristics of the instrument are shown in Table 5.

Table 5
Major Characteristics of VISSR

	Visible	**Infrared**	**Water Vapour**
Wavelength	0.5-1.05 μm	10.5-12.5μm	6.2-7.6μm
Resolution	1.25 Km	5 Km	5 Km
FOV	35 μrad	140μrad	140μrad
Scan Line	2500×4	2500	2500
Detector	Si-photo-diode	HgCdTe	HgCdTe
Noise Performance	S/N=6.5 (albedo=2.5%) S/N=43 (albedo=95%)	NEDT=0.5-0.65k (300k)	NEDT=1k (300K)
Quantification Precision	6 bits	8 bits	8 bits
Scan step angle	140 μrad (N-S scanning)		
Frame time	30 minutes		

13. The VISSR performs the Earth observation from the space to obtain visible, infrared and water vapour images of the Earth and the clouds. The VISSR scans to collect through the Optical Telescope the energy emitted from the Earth and clouds, then focuses the energy onto the Focal Plane by the primary and secondary mirrors. The Visible Fibre Optics and Infrared Relay Optics System relay the energy from the Focal Plane to the visible, infrared and water vapour detectors. Si detectors convert visible light into visible analogue signals and HgCdTe detectors,

cooled by radiation coolers, convert the Earth's radiation into infrared analogue signals. The S-VISSR output is sent to a VISSR Digital Multiplexer (VDM) unit with redundancy.

- Visible Channel (0.55-1.05 μm)

14. Four Si detectors and redundant sets simultaneously convert visible light into four-channel visible analogue signals of 1.25 km resolution at the sub-satellite point (SSP) with one west-east scanning.

- Infrared Channel (10.5-12.5 μm)

15. High sensitive HgCdTe detectors with redundancy, which are kept at a temperature of 100K by the radiation cooler, convert Earth radiation into infrared analogue signals with 5 km resolution images at SSP.

- Water Vapour Channel(6.3-7.6 μm)

16. Extremely sensitive HgCdTe detectors with redundancy, which are kept at a temperature of 100K by the radiation cooler, convert Earth radiation into infrared analogue signals with 5 km resolution images at SSP.

- Imaging

17. A complete $20^{\circ}\times 20^{\circ}$ scan covering the full Earth disk can be accomplished every 30 minutes by means of combination of satellite spin motion (100 rpm from west-east) and step action of the scan mirror (2500 steps from north to south). It takes 25 minutes for taking picture, 2.5 minutes for mirror retrace, and 2.5 minutes for VISSR stabilization.

FY-2 Ground Application Facilities

18. The FY-2 ground system consists of the following parts: A Command and Data Acquisition Station (CDAS), a Data Processing Centre (DPC), a Satellite Operation Control Centre (SOCC), Ranging Stations (one primary station, three secondary stations including one in Australia), widely dispersed Data Collection Platforms (DCP), Medium-scale Data Utilization Stations (MDUS) and Small-scale Data Utilization Stations (SDUS), and a Ground Communication System etc.

19. The tasks of FY-2 ground system are as follows:

- To receive day and night cloud, water image data from VISSR;
- To produce a variety of images and products after processing by DPC;
- To receive, edit, and distribute meteorological, oceanographic, hydrological observation data collected by DCP;
- To retransmit stretched VISSR data and WEFAX;
- To extract information of solar protons and other particles from telemetry data stream and distribute them to users;
- Satellite operation management and control, VISSR scan mode selection and satellite status monitoring.

Data Broadcasting

20. One of the major functions of FY-2 system is to broadcast data including S-VISSR, WEFAX and S-FAX data via FY-2 satellite.

21. The S-VISSR data is transmitted to the Medium-scale Data Utilization Station (MDUS) through the FY-2 during the VISSR observation. WEFAX data are retransmitted to Small-scale Data Utilization Station (SDUS).

Transmission Characteristics of FY-2 S-VISSR

22. The S-VISSR data is the digital image data originated from VISSR on board satellite and is stretched at CDAS in time. The transmission rate is reduced. The S-VISSR data are retransmitted to MDUS via the FY-2 during the VISSR observation. The signal characteristics of FY-2 S-VISSR data are as follows:

- Frequency: 1687.5MHz
- Modulation: PCM/BPSK, NRZ-M
- Bit rate: 660 Kb/s (fixed)
- EIRP: 57+1 dBm
- Polarization: Linear
- Bandwidth: 2 MHz
- Data Volume: 329.872 bits/line (including SYNC code)
- Data Coding: Byte complementing and PN scrambling

23. Since the signal characteristics of FY-2 S-VISSR data is the same as GMS S-VISSR data except for frequency, the user stations for receiving GMS S-VISSR data can also receive FY-2 S-VISSR data by changing the antenna direction and frequency of local oscillator.

Transmission of the FY-2 WEFAX

24. The WEFAX is disseminated to SDUS users via FY-2 satellite. The WEFAX transmission format is completely compatible with those of other geostationary meteorological satellites in service.

25. The WEFAX is composed of gray scales, marks, annotation and earth image. The annotation signal is inserted at the head of the picture, so as to recognize the image information automatically. The Earth images contain latitude-longitude grids and coastline bases of the prediction of the satellite's orbit and attitude.

The FY-2 Data Collection System

26. There are 133 data Collection Platform(DCP) channels in FY-2 system, including 100 regional DCP channels and 33 international DCP channels, which can collect data from a wide variety of platforms. The regional DCPs are stationary DCPs that installed on buoys, isolated islands, rivers, mountains or ships for meteorology, oceanography, hydrology and other purposes. The collected data are edited at the NSMC and distributed to the user via GTS.

Future Plans

Consideration of the development of FY-3 series satellite

27. FY-3 series, the second generation of Chinese polar orbiting meteorological satellites is now in design phase, it is expected that the first satellite be launched in 2004. The main mission objectives of FY-3 are:

- To provide global sounding of 3-dimensional atmospheric thermal and moisture structures and the cloud and precipitation parameters to support global numerical weather prediction;
- To provide global images to monitor large scale meteorological and/or hydrological disasters and biosphere environment anomaly;
- To provide important geophysical parameters to support study on global change and climate monitoring;
- To perform data collection;

- To achieve above-mentioned objectives, a meteorological core payload with eight main instruments and two complementary instruments are considered as follows:

  - The Imaging Mission:

    VIRR Visible and Infrared Radiometer
    MODI Moderate Resolution Visible and Infrared Imaging Spectroradiometer
    MWRI Microwave Radiation Imager

  - The Sounding Mission:

    IRAS InfraRed Atmospheric Sounder
    MIRS Multi-channel InfraRed atmospheric Sounder (stage-II)
    MWTS MicroWave atmospheric Temperature Sounder
    MWHS MicroWave atmospheric Humidity Sounder (stage-II)
    SBUV/TO Solar Backscatter Ultraviolet/Total Ozone Sounder

  - The Complementary Mission:

    ERBU Earth Radiation Budget Unit
    SEM Space Environment Monitor

FY-2 series satellite

28. In order to meet the need of weather forecast and global climate change research, China plans to develop 3 successive satellites: FY-2C, D, and E, with necessary improvements on the basis of the two experimental satellites FY-2 A and 2B. It is expected that FY-2C will be launched in 2003, FY-2D in 2006 and FY-2E in 2009.

29. The function of FY-2C, D and E is similar to FY-2 A, B, it includes:

- Acquiring visible, infrared and water vapour cloud images;
- Transmitting S-VISSR images and low resolution images;
- Data collecting;
- Space environment monitoring.

Major improvement for FY-2 C, D and E

The number of spectral channels of Visible and Infrared Spin Scan Radiometer (VISSR) will be increased from 3 to 5

- The infrared long wave window 10.5□12.5μm will be split into two channels: 10.3-11.3μm and 11.5-12.5μm, so as to improve the capability of detecting and calculating water vapour contents, to support semi-transparent ice cloud detecting, and to have a better accuracy of atmospheric absorption correction in order to improve sea temperature estimation;

- To increase the temperature resolution of the infrared channels and the signal/noise ratio of the visible channels, and to support the application of the split window;

- To have an additional 3.5-4.0μm mid-infrared window channel. As this channel is less affected by water vapour contents, when it combines with IR long-wave window channel, more accurate surface temperature can be acquired. The channel is sensitive to heat temperature, therefore, it is helpful for detecting warm targets on surface. It is also used to obtain information of low-level cloud and fog. It is helpful to be able to distinguish low-level cloud and ice and snow coverage;

- The data quantization level of the IR and WV channel will be increased from 256 to 1024 .

Other changes

30. The S-Fax broadcasting function will be cancelled and the frequency of 1699.5 MHz will not be used. The WEFAX will be replaced by LRIT. And the power supply of the satellite will be increased.

Specifications of VISSR of FY-2 C/D/E

31. Spectral channels of VISSR are shown in table 6.

Table 6
The spectral channels of VISSR

Channel	Wavelength (μm)	
	FY-2 A,B	FY-2 C,D,E
VIS	0.50-1.05	0.50-0.75
IR1	10.5-12.5	10.3-11.3
IR2		11.5-12.5
IR3		3.5-4.0
WV	6.3-7.6	6.3-7.6

32. The major characteristics of VIS channels are shown in table 7.

Table 7
The characteristics of VIS channels of VISSR

Item	Characteristics	
	FY-2 A,B	FY-2 C,D,E
Wavelength (μm)	0.50-1.05	0.50□0.75
FOV(μr)	40	35
Space resolution (km)	1.44	1.25
Dynamic range	0-95%	0-98%
S/N	6.5 (2.5%)	1.5 (0.5%)
	43 (95%)	50 (95%)
Number of detectors	4 (main) + 4 (alternate)	4 (main) + 4 (alternate)
Quantization level	64	64
Calibration	cool-space images and solar image to realize in-orbit calibration	same as FY-2 A,B

33. The major characteristics of IR, WV channels are shown in table 8.

Table 8
The characteristics of IR, WV channels of VISSR

	FY-2 A,B		FY-2 C,D,E			
	IR	WV	IR1	IR2	IR3	WV
Wavelength(μm)	10.5-12.5	6.3□7.6	10.3-11.3	11.5-12.5	3.5-4.0	6.3-7.6
FOV (μr)	160	160	140	140	140	140
Space resolution(km)	5.76	5.76	5	5	5	5
Dynamic range	180-330K	190-290K	180-330K			180-280K
Temperature resolution	0.6K	1.0K	0.4-0.2K	0.4-0.2k	0.5-0.3	0.6-0.5
Number of detectors	1(main)+1 (alternate)	1(main)+1 (alternate)	1(main)+1 (alternate)	1(main)+1 (alternate)	1(main)+1 (alternate)	1(main)+1 (alternate)
Quantization level	256	256	1024	1024	1024	1024
Calibration	On board blackbody calibration, once every 3 disks		The ground calibration accuracy is 1K.Cool space and planet calibration is used for on-board calibration, once every 2 disks.			

EUMETSAT

Introduction

1. EUMETSAT is an independent intergovernmental organisation created in 1986 to establish, maintain and exploit European systems of operational meteorological satellites. It is governed by a Council representing 17 Member States, and since 1999 three Cooperating States: Slovakia, Hungary and Poland. The initial motivation for the creation of EUMETSAT was to provide continuity after the successful demonstration of Meteosat, the European meteorological satellite developed by the European Space Agency (ESA). The headquarters of EUMETSAT are located in Darmstadt, Germany. An amended Convention entered into force in November 2000. This has widened EUMETSAT's objectives to include the operational monitoring of the climate and detection of global climate change.

2. EUMETSAT presently has three Meteosat satellites in orbit, Meteosat-7 is the operational satellite at zero degree longitude, Meteosat-6 is the back-up satellite at 9°W and Meteosat-5 is at 63°E and provides the Indian Ocean Data Coverage.

Meteosat Transition Programme (MTP)

3. Meteosat-6 is at 9°W as the stand-by spacecraft. In early 2000 it provided operational imagery during the radiometer decontamination of Meteosat-7. It also supported the operational Data Collection Platform (DCP) service during the eclipse season of Meteosat-7. Meteosat-6 also supported the Mesoscale Alpine Programme (MAP) during its Special Observing Period (SOP) between September and November 1999 and provided rapid scan data on a reduced latitude range. As a result of this experiment this contribution to MAP, an operational Rapid Scanning Service will be introduced from mid 2001 onwards.

4. Meteosat-7, launched in September 1997, has been used for the provision of all the Meteosat operational services from the 0° position since June 1998. The spacecraft continues to perform well, with no major anomalies being detected during 1999 and 2000.

5. Meteosat-5 has been supporting operational image taking and HRI dissemination at 63° East since July 1998 as the Indian Ocean Data Coverage (IODC) system. There are, however, no DCP or MDD services provided by Meteosat-5. Its hourly full disc images are re-broadcast via Meteosat-7. The orbital inclination of the satellite is no longer controlled and at the end of December 2000 it was over 3.9° and increasing at a rate of about 0.9° per year. However, it is still possible for all data to be acquired directly by PDUS user stations with smaller antennas within the field of view of the satellite. The IODC service from Meteosat-5 is planned to be continued until at least end of 2003.

6. The Meteosat ground segment comprises a Primary Ground Station in Fucino, Italy, a Back-up Ground Station in Germany; a Mission Control Centre made up of a Core Facility, User Station Display Facility, a Meteorological Products Extraction Facility and a Meteorological Archive and Retrieval Facility, all located at the EUMETSAT headquarters, in Darmstadt, Germany.

Meteosat Second Generation (MSG)

7. Meteosat Second Generation is the follow-on programme of Meteosat. The programme includes three satellites. MSG-1 is planned to be launched in the first half of January 2002. The operational data service is foreseen in the second half of 2002, at the earliest. The launch of MSG-2 is planned not earlier than 18 months after the start of MSG-1 commissioning and MSG-3 is planned to be launched in 2007, in order to ensure a two satellite system with hot back-up.

8. Within this programme, ESA is responsible for the development of the first MSG satellite based on requirements established and maintained by EUMETSAT. ESA acts on behalf of EUMETSAT as procurement agent for the MSG-2 and -3 satellites.

9. The MSG spacecraft will rely on a spin-stabilised platform carrying an imaging radiometer, a meteorological communication package, a Search & Rescue transponder and an experimental Global Earth Radiation Budget (GERB) instrument. The main instrument is the **S**pinning **E**nhanced **V**isible and **I**nfra**R**ed **I**mager (SEVIRI), an imaging radiometer including twelve channels described in table 1:

- Eleven channels will cover the whole earth disk with a sampling distance of 3 km at the sub-satellite point and a repeat cycle of 15 minutes. They have been selected to offer maximum compatibility with those successfully experienced with the MTP imager, the GOES VAS and the NOAA AVHRR;

- The twelfth channel will be a high resolution visible broad-band channel with a sampling distance of 1 km at sub-satellite point and 15 minutes repeat cycle, mainly covering the European and African area.

10. The data and product dissemination will rely on the same frequency bands as MTP, and be based on the HRIT and LRIT digital formats internationally agreed within the CGMS. HRIT contains the full set of SEVIRI image data (lossless - apart from HRV); LRIT contains the full set of Foreign Satellite Data (lossless), a subset of lossy SEVIRI image data, DCP data, MDD data and meteorological products.

11. In addition EUMETSAT plans to introduce an Internet-based dissemination of a sub-set of the total data.

12 The MSG Programme, initiated in 1994, continued its development phase in 1999 and 2000.

13 The Satellite Qualification Result Review (QRR) was held in end 1999-spring 2000 and the Satellite Flight Acceptance Review (FAR) process started in August 2000. The MSG-1 satellite has entered into storage early in 2001, with activities continuing in parallel to the storage for final fixing of open items raised at QRR and FAR. De-storage, health checks and completion of the FAR process, planned before end of 2001, will state the satellite readiness for the Launch campaign.

14 Progress on MSG-2 and MSG-3 is nominal. GERB-1 and GERB-2 instruments have been delivered and GERB-3 will be delivered in 2001. The lifetime of the instrument is actually of some concern. Potential improvements will be decided and implemented before end of 2001.

Table 1
Spectral channel characteristics of SEVIRI providing central, minimum and maximum wavelength of the channels

Channel No.		**Channel Spectral Band in µm**		
		λ_{cen}	λ_{min}	λ_{max}
12	HRV	Broadband (silicon response)		
1	VIS0.6	0.635	0.56	0.71
2	VIS0.8	0.81	0.74	0.88
3	NIR1.6	1.64	1.50	1.78
4	IR3.9	3.90	3.48	4.36
5	WV6.2	6.25	5.35	7.15
6	WV7.3	7.35	6.85	7.85
7	IR8.7	8.70	8.30	9.1
8	IR9.7	9.66	9.38	9.94
9	IR10.8	10.80	9.80	11.80
10	IR12.0	12.00	11.00	13.00
11	IR13.4	13.40	12.40	14.40

15. The Ground Segment design and development has progressed both at system and facility levels. The architecture of the MSG ground segment comprises a central node in Darmstadt in charge of operating the satellites and processing core products, and decentralised Satellite Applications Facilities (SAFs) for more specific additional products relevant to various application areas. Some facilities have already been delivered to EUMETSAT in the second half of year 2000 for integration of the ground segment. However, activities of the most critical facilities have been hindered by delays occurred at the time of their final integration and test phases: leading to the planning of delivery in 2001. Ground Segment integration started in 2000. A re-planning of the MSG programme is under finalisation, taking also into account the remaining issues to be solved with respect to the satellite and the compatibility of the satellite to the launcher shock environment.

16. System engineering validation of the integrated Ground Segment will commence in early 2001, followed by an operational (pre-launch) validation of the system.

17. With regard to the operational transition from MTP to MSG users should prepare to receive and process MSG data from autumn 2002 onwards. However, Meteosat-7 will be operated in parallel starting from the commissioning of MSG-1 in 2002, until at least the end of 2003.

18. As part of a Ground Segment development contract, the design of the prototype User Stations have been established and tested. From the beginning of 1999 the design documentation for the user stations has been made available for potential manufacturers and users on the EUMETSAT Homepage (www.eumetsat.de). In June 2000 it was decided by the Council of EUMETSAT that the High Resolution Using Stations (HRUS) should be procured with an integrated LRIT reception. Within Africa PUMA will provide for ground stations with support of the European Commission. This should also help to reduce the cost of stations to other users.

EUMETSAT Polar System

19. The EUMETSAT Polar System (EPS) Programme is the European contribution to the joint European/USA operational polar satellite system, the Initial Joint Polar System (IJPS), which will deliver continuous global observations for meteorological applications and climate monitoring. The EPS Programme will cover 14 years of operation with three Metop satellites to be launched nominally in mid 2005, 2010 and 2014. The purpose of the EPS system is to provide an end-to-end service for the morning polar orbit (ECT 09:30), as well as back-up cross support and data exchange with the US National Ocean and Atmosphere Administration (NOAA), which will continue to provide the afternoon orbit service. In November 1998 EUMETSAT and NOAA signed the Cooperation Agreement for the implementation of the IJPS.

20. The Metop satellite is being developed in cooperation between EUMETSAT and ESA. A Cooperation Agreement on the Metop Series was signed between ESA and EUMETSAT in December 1999.

21. The Metop satellites will fly a set of operational sounding and imaging instruments:

- Advanced Microwave Sounding Unit-A (AMSU-A) *(provided by NOAA);*
- High Resolution Infrared Radiation Sounder (HIRS) *(provided by NOAA);*
- Advanced Very High Resolution Radiometer (AVHRR) *(provided by NOAA);*
- Space Environment Monitor (SEM) *(provided by NOAA);*
- Search and Rescue terminal *(provided by NOAA);*
- ARGOS Data Collection System (DCS) *(provided by CNES);*
- Advanced Scatterometer (ASCAT) for measuring wind vectors at the ocean surface *(new European instrument);*
- Global Ozone Monitoring Experiment (GOME) *(provided by NOAA);*
- follow-on instruments for ozone monitoring *(developed under ESA responsibility);*
- GPS Receiver for Atmospheric Sounding (GRAS) for monitoring troposphere-stratosphere interactions *(developed under ESA responsibility);*
- Microwave Humidity Sounder (MHS) *(developed under EUMETSAT responsibility);*
- Infrared Atmospheric Sounding Interferometer (IASI) *(developed by CNES)*.

22. Metop is equipped with two direct broadcast facilities: Low Resolution Picture Transmission (LRPT) at 137 MHz and High Resolution Picture Transmission (HRPT) at approximately 1700 MHz.

23. The procurement of the EPS core ground segment (CGS) was approved in the EUMETSAT Council in November 1998. The CGS is the main element of the EPS ground segment and will perform acquisition of platform and mission data, mission monitoring, control and planning, data processing, on-line calibration of instruments, quality control of the products, rolling archiving of data acquired at the acquisition site and near real time dissemination of data and products. It will include a communication infrastructure. The CGS elements will be distributed among various sites: the EUMETSAT headquarters, EPS Control and Data Acquisition Polar station site, EPS Back-up Control Centre site and near real-time primary user terminal sites.

24. Procurement proposals for the Core Ground Segment, LEOP and TT&C Network Service, GRAS Ground Support Network service and CAL/VAL facility, as well as the Back-up Control Centre Site Infrastructure were approved in the course of 2000 by the EUMETSAT Council. A contract for the procurement of the Core Ground Segment (CGS) was signed with Alcatel Space Industries in December 2000. The primary ground station will be in Svalbard, Norway.

Satellite Application Facilities (SAF)

25. In addition to the central ground segment facilities, EUMETSAT is developing a network of Satellite Application Facilities (SAF) in partnership with several of its Member States. The purpose of the SAFs is to make use of the Member State's expertise to process data from geostationary and polar orbiting satellites for the creation of products that will be distributed to other EUMETSAT Member States and to the meteorological data user communities. The SAFs will use data from Meteosat, MSG and EPS and in some cases data from non-EUMETSAT missions. Until such data become available, information from current satellites will be used for development.

26. The SAF on support to Nowcasting and Very Short Range Weather Forecasting, approved in 1997, involves the NMS of Spain, Sweden, France and Austria. It will produce user software packages to extract cloud and airmass parameters, precipitation rates, high resolution wind vectors and detect rapidly developing thunderstorms.

27. The development of the SAF on Ocean and Sea Ice also approved in 1997, is conducted by the NMS of France, Norway, Sweden, Netherlands and the French Oceanographic Institute. It will use MSG data to produce Atlantic Low and Mid Latitude Sea Surface, merged Atlantic Sea Surface Temperatures and Atlantic Low and Mid Latitude Surface Radiative Fluxes, as well as Merged Atlantic Surface Radiative Fluxes.

28. The SAF on Ozone Monitoring also approved in June 1997 involves Finland, the Netherlands, Belgium, France, Germany (NMS and DLR), Greece, DMI and the University of Thessaloniki. This SAF will use Metop data to derive Ozone profiles and values, trace gases and aerosols, as well as UV fields.

29. Four more SAFs were approved in 1998. The SAF on Climate Monitoring is led by DWD (Germany) in cooperation with Finland, Sweden, the Netherlands, Belgium, Free University of Brussels, the Royal Military Academy of Belgium, the German Climate Computing Centre, the Federal Maritime and Hydrographic Agency of Germany and Institute of Atmospheric Physics. It will make use of MSG and Metop data.

30. The SAF on Numerical Weather Prediction is being developed under the leadership of The Meteorological Office (UK). The SAF Consortium involves the European Centre for Medium-range Weather Forecasts (ECMWF), the Royal Netherlands Meteorological Institute (KNMI) and Météo-France. This SAF will develop techniques and software to be used in the context of the Numerical Weather Prediction (NWP) systems run by the National Meteorological Services, for improved assimilation of satellite data and, for increasing their positive impact on forecasts.

31. The SAF on GRAS Meteorology started its development in April 1999. It will derive high vertical resolution temperature and moisture sounding products from observations collected by the GRAS (Global Navigation Satellite System (GNSS) Remote Atmosphere Soundings) sensor to be flown on the three Metop satellites. Such products will be used by the operational meteorological community and also by the research community, in particular to study the troposphere-stratosphere interactions. The SAF consortium is led by the Danish Meteorological Institute and involves the UK Meteorological Office and Institut d'Estudis Espacials de Catalunya in Spain.

32. The SAF on Land Surface Analysis kicked off its development in September 1999. It will take advantage of the land observing capabilities of MSG and EPS and will derive from their data a set of land products to be used in applications such as Numerical Weather Prediction, agrometeorology, management of renewable resources and study of land-atmosphere interactions. The consortium is being led by the Portuguese Meteorological Institute (IM) and involves the

Belgian, French and Swedish Meteorological Service, as well as institutes in Germany, Greece, Italy, Portugal and Spain.

33. The SAFs on Nowcasting and Very Short Range Forecasting and the SAF on Ocean and Sea Ice are expected to start the Initial Operations Phase in 2002 when MSG data become available.

JAPAN METEOROLOGICAL AGENCY

1. The Japan Meteorological Agency (JMA) has operated and developed the Geostationary Meteorological Satellite (GMS) Series. The status of the GMS series and future plans are described below.

Operational satellite

2. JMA has operates GMS-5 at 140E degrees above the equator. GMS-5 was launched on 18 March 1995, and put into operation on 13 June 1995 as the successor to the GMS-4. Spectral bands of sensors onboard GMS-5 are summarized in Table 1.

Table 1
Spectral Bands of GMS-5

Sensor	GMS-5
Visible	0.55-0.90
Infrared (water vapour)	6.7 - 7.0
Infrared (thermal)	10.5 -11.5
	11.5 -12.5 (unit: micrometer)

Products of GMS-5

S-VISSR

3. Digital images of the full disk with the same resolution as the original imagery are disseminated to Medium-scale Data Utilization Stations (MDUS) users as shown in Table 2.

Table 2
Dissemination of S-VISSR images

Band	Resolution at SSP	Frequency of observation
Visible	1.25km	hourly
Infrared (thermal)	5km	hourly
Infrared (water vapour)	5km	hourly

WEFAX

4. Analog facsimile images with coastal lines and latitude/longitude lines are disseminated for Small-scale Data Utilization Stations (SDUS) users as shown in Table 3.

Table 3
Dissemination of WEFAX images

Type of picture	Type of image	Special resolution	Frequency
Four-sectored full disk picture	IR	8.4km (at SSP)	three-hourly
	WV	8.4km (at SSP)	twelve-hourly
Polar-stereographic picture around Japan	IR	7.2km (around Japan)	hourly
	VIS	7.2km (around Japan)	hourly (daytime)
	Enhanced IR	7.2km (around Japan)	hourly (night-time)

Other products

5. In addition to the direct dissemination of imagery, JMA retrieves the following products from imagery data and disseminates them to users concerned as shown in Table 4.

Table 4
Distribution of the other products
[Available on the GTS]

Type of data	Description	Region of interest	Output frequency
Cloud/Water Vapour motion vectors	Cloud/Water Vapour motion wind vectors data derived from time-sequential images	50N-49S, 90E-171W	00,06,12,18Z: four times / day
Typhoon analysis report (SAREP)	Location and Velocity of movement of the typhoon centre (Special hourly observation)	For typhoons in EQ-60N, 100E-180E	eight times / day (24 times / day)
	Estimation of the typhoon intensity	For typhoons in EQ-60N, 100E-180E	four times / day

[For WMO/WCRP]

Type of data	Description	Region of interest	Output frequency
ISCCP data (AC data)	Original VISSR for inter-calibration between images from different geostationary satellite	2000 x 2000 km (Area selected by the Satellite Calibration Centre in France)	five times / month
ISCCP data (B1 and B2 data)	Nominally 10km spatial resolution full disk data for B1 data, 30km for B2 data	Full Disk coverage	eight times / day
GPCP data	Three-hourly histogram of TBB in 24 classes on 1 deg x 1 deg grids	40N-40S, 90E-170W	eight times / day

6. In addition, some products such as cloud amount data, are provided for domestic users.

Data Collection System

7. GMS-5 is equipped with the Data Collection System (DCS) to collect meteorological observations from remote stations, ships and aircraft.

8. As to 31 December 2000, 462 stations are registered as regional data collection platforms and 287 stations are registered as international data collection platforms, respectively.

9. The DCS of the GMS-5 is used to relay emergency information on tsunamis and seismic intensity data.

GMS-4 re-orbiting

10. The GMS-4 had been located at 120E degrees above the equator as a backup of GMS-5. It was re-orbited on 24 February 2000 due to the deterioration of the battery.

Planned satellite

Multi-functional Transport Satellite (MTSAT) series

11. Due to the unsuccessful launch of the first Multi-functional transport Satellite (MTSAT) in November 1999, JMA will extend the service period of GMS-5 until the takeover by MTSAT-1R to be launched in early 2003 and become operational in the summer of the year. MTSAT-1R will perform improved measurements and enhanced provision of information including meteorological. The specifications of MTSAT-1R are shown in Table 5.

12. MTSAT-2, which is procured by both JMA and the Civil Aviation Bureau of the Ministry of Land, Infrastructure and Transport as well as MTSAT-1R, is to be launched in 2004.

Table 5
Specifications of MTSAT-1R

Designed life time:	more than five years (meteorological mission) more than ten years (air traffic control mission)
Orbital position:	Geostationary orbit at 140E degrees above the equator
Imaging period:	Within 30 minutes to take a full-disk image
Imager characteristics:	wavelength Visible 0.55 - 0.90 IR1 10.3 - 11.3 IR2 11.5 - 12.5 IR3 6.5 - 7.0 IR4 3.5 - 4.0 (unit: micrometer)
Signal quantization:	10 bits for both Visible and IR channels
Resolution at sub-satellite point satellite point:	1 km for Visible and 4 km for IR
Imager data transmission Rate:	under 3.0 Mbps

Telecommunication functions:

- Transmission of original image data,
- Relay of High Resolution Imager Data (HiRID), whose format is compatible with S-VISSR of GMS with the horizontal resolution of 1.25 km (VIS) and 5 km (IR),
- Relay of Low Rate Information Transmission (LRIT) signal including selected imager data, gridded numerical weather prediction products, surface, upper-air and satellite observations, and RSMC Tropical Cyclone Advisories,
- Relay of WEFAX signal until March 2005,
- Relay of DCP reports from remote stations, aircraft, ships and buoys etc.,
- Relay of DCP interrogation,
- Relay of High Rate Information Transmission (HRIT) signal with the horizontal resolution of 1 km (VIS) and 4 km (IR).

INDIA

INSAT series

1. INSAT is an operational multipurpose satellite system serving the needs of three different services, viz Television & Radio Broadcasting, Communications and Meteorology.

2. The first satellite INSAT-1A of the INSAT-1 series was launched in April 1982 and it ceased to function totally from 6 September 1982 as a result of major anomaly on the satellite. The second satellite (INSAT-1B) was launched on 30 August 1983 and it became operational on 15 October 1983. It was the main operational satellite all through the 1980s and provided services during its entire mission life. It was deorbited in July 1993. The third satellite of the series (INSAT-1C) was launched on 22 July 1988. Due to some technical problem, it lost control on 22 November 1989 after which it was not available for operational services. The last satellite of INSAT-1 series (INSAT-1D) was launched on 12 June 1990 and became operational on 17 July 1990. This satellite is working even today (October 2000) in an inclined orbit mode and provides round the clock imagery of Earth cloud cover for operational utilization. Its predicted End of Life (EOL) is the 2nd quarter of 2001.

3. The 2nd generation of INSAT satellites (INSAT-2 series) commenced in July 1992 with the successful launch of the first satellite of the series (INSAT-2A) on 10 July 1992. The 2nd satellite of INSAT-2 programme i.e. (INSAT-2B) was also launched successfully on 22 July 1993. All INSAT satellites are three-axis body stabilised spacecraft. The last satellite of INSAT-2 series i.e., INSAT-2E, was launched successfully on 3 April 1999. It has been operational since May 1999. It has a new payload, called the Charged Coupled Device (CCD) camera capable of taking 1km resolution images in 3 bands. The meteorological imaging capability has also been upgraded on this satellite, as compared to its predecessors, by providing a Water-Vapour channel with 8 km resolution in the VHRR, the imaging instrument of the satellite.

Current Operational Status

4. The imaging mission is working satisfactorily with INSAT-1D and INSAT-2B satellites, and they continue to be used operationally. High resolution (1 km) images in 3 channels are also available operationally from CCD camera onboard INSAT-2E. The Infra-Red (IR) channel data from INSAT-2B is however not available due to technical problems. INSAT-2B is used for VIS imagery data only. Service activities, such as image processing, derivation of meteorological products, data archival and dissemination of products to field stations for operational use, are being performed on routine basis.

5. VHRR images are normally received at three-hourly intervals. More frequent images are taken for monitoring the development of special weather phenomena as and when the situation demands. CCD images from 2E are also being taken every three hours for operational use during daytime. More frequent images are taken if the situation demands. However, due to some anomalies in its scan mechanism, the VHRR onboard INSAT-2E is not currently available for operational use. For the derivation of CMV's, half-hourly triplets at 00 UTC, 06 UTC and 12 UTC are also received from INSAT-1D and processed. INSAT derived CMVs are available on GTS.

6. INSAT-2E is located at 83° E Longitude and provides imaging capability at 1km resolution in 3 channels, visible, near IR and shortwave Infrared. INSAT data are processed at IMD facility "INSAT Meteorological Data Processing System (IMDPS)" located in IMD's campus at Lodi Road, New Delhi.

Future Plans

INSAT-3A

7. The next satellite of the INSAT series i.e., INSAT-3A, is scheduled for launch sometimes during the 4th quarter of 2001. For meteorological services, it will have VHRR and CCD payloads similar to INSAT-2E.

METSAT

8. A new satellite to provide meteorological services exclusively is being fabricated in India. It is scheduled for launch sometimes in the 4th quarter of 2001. It will carry a 3-channel VHRR to provide earth imaging capability in Visible, IR and WV bands with 2, 8km and 8km resolution respectively. It will also carry a Data Relay Transponder (DRT).

INSAT-3D

9. Under the INSAT-3 programme, a new Geostationary Meteorological Satellite is being designed. It will have an advanced imager with six channels and a sounder with nineteen channels for derivation of atmospheric temperature and moisture profiles. The imager will provide 1km resolution imagery in the visible band and 4km resolution in the IR bands. This new satellite is scheduled for launch in 2003-2004 time frame and will provide improved capabilities to the users of meteorological data from satellites.

10. Under the bilateral programme of co-operation with the USA, an INDO-US data Exchange Centre was established at IMD, New Delhi in November 1999 for exchange of satellite data with USA. Processed INSAT imagery data are transmitted every three hours to the USA. GOES imagery data are also received from USA.

11. Data exchange takes place through dedicated communication links. Under another collaborative programme with EUMETSAT, an agreement has been signed for reception of METEOSAT-5 data at IMD, New Delhi.

NOAA/NESDIS

Polar Operational Environmental Satellite (POES)

1. The POES spacecraft constellation includes two primary, two secondary and one standby spacecraft. These spacecraft are in sun-synchronous orbits inclined at approximately 98° (retrograde). The primary operational spacecrafts, NOAA-14 and NOAA-15, are in sun-synchronous afternoon and morning orbits, respectively. Two secondary spacecraft, NOAA-11 and NOAA-12, provide additional payload operational data, while the standby spacecraft, NOAA-10, supports minimal SAR functions and is only contacted once a week.

2. The next satellite in the series, NOAA-L, was launched on 15 September 2000. This spacecraft has been renamed NOAA-16 and replaces NOAA-14 as the operational afternoon spacecraft. NOAA-M is scheduled for launch readiness by late Spring/early Summer of 2001.

NOAA-15

3. NOAA-15 was launched on 13 May 1998. By July 1998, NOAA-15 was designated as the operational replacement for NOAA-12. As such, it operates in an orbit with a 7:30 am descending node (morning orbit) and utilizes a similar set of instruments as NOAA-12 with the addition of the AMSU and ATOVS sounding system. Recent anomalous instrument behavior and the on-orbit failure of three high gain downlink antennas on NOAA-15 prompted the recall of NOAA-12 to support the morning orbit operational mission. At the current time, NOAA-12 instrument data is used to complement the operational data from NOAA-15

NOAA-14

4. NOAA-14, which was launched in December 1994, is the operational afternoon (ascending node) spacecraft. One of the two on-board processors (OBP) is unusable due to the malfunction of an associated command demodulator.

NOAA-12

5. By the end of July, 2000, continuing instrument problems on NOAA-15, prompted the recall of NOAA-12 to operational status. Launched in May 1991, NOAA-12's AVHRR is currently being used to satisfy morning mission user data requirements

Defense Meteorological Satellite Program (DMSP)

6. Over the last three years, NOAA and the US Air Force successfully completed the safe and efficient convergence of the five Defense Meteorological Satellite Program (DMSP) military satellites into the NOAA meteorological constellation. Similar to the civilian POES program, the DMSP program designs, launches, and maintains several near polar orbiting, sun synchronous satellites monitoring the meteorological, oceanographic, and solar-terrestrial physics environments. The visible and infrared sensors collect images of global cloud distribution across a 3,000-kilometer swath during both daytime and nighttime conditions.

Geostationary Operational Environmental Satellites (GOES)

7. The current Geostationary Operational Environmental Satellites (GOES) are three-axis stabilized spacecraft in geosynchronous orbits. The current primary satellites, GOES-8 and GOES-10, are stationed over the east and west coasts of the United States. These satellites are used to provide simultaneous images and soundings of the Western Hemisphere.

8. The primary instrument payload for the current series of GOES spacecraft consists of the Imager, a multi-channel instrument designed to sense radiant and solar reflected energy and the Sounder, which provides data for atmospheric temperature and moisture profiles, surface and cloud top temperature and ozone distributions.

GOES-8

9. GOES-8, launched in April 1994, is stationed over the east coast of the United States at 75°W. The first of the series, GOES-8 retains the ability to provide the full range of products, although with some loss of redundancy of backup systems.

GOES-10

10. GOES-10 is the operational west coast satellite at 135°W. Shortly after launch in April 1997, GOES-10 suffered a near-fatal anomaly when it's solar array stopped moving, either due to a gear train jam or due to an external jam. The anomaly was studied over a period of months, and it was decided to invert the satellite (180° in relation to the Earth) and run the array drive in the reverse direction to track the sun. This operational strategy was coupled with extensive ground and spacecraft software modifications to allow the imagery to look "non-flipped" to the users.

GOES-11

11. The GOES-11 spacecraft was successfully launched on 3 May 2000 and will be used as the primary replacement in the event of a failed operational spacecraft. The GOES-11 orbit raising sequence was executed flawlessly and entered the operational mode on 14 May 2000. The first full disk visible image was taken on 18 May 2000. On August 14, 2000, GOES-11 was placed in a passive spin stabilized storage mode at 105° W. In the event that GOES-8 or GOES-10 should fail or run out of fuel, GOES-11 could be activated and be made operational within 48 hours.

GOES-9

12. Launched in May 1995, GOES-9 is now in a Z-axis Precession (ZAP) mode, a spin-stabilized storage mode that minimizes use of life-limited spacecraft components and requires little operator intervention. In the summer of 1998, GOES-9's momentum wheels started to show signs of significant lubrication starvation. GOES-9 was put into storage mode in anticipation of imminent wheel failure. Currently located at 105° W, GOES-9 can be called up to replace either GOES-8 or GOES-10 in the event of a spacecraft failure.

Future POES System

13. NOAA has in place a follow-on polar satellite program to replace current satellites as they reach the end of their operational life. The new fifth-generation POES ATN follow-on satellites are designated NOAA-K, -L, -M, -N, and –N'. NOAA-K, -L, and -M will be upgraded with new primary environmental instruments, followed by NOAA-N and N' updated to a later instrument baseline.

14. NOAA-K, now designated NOAA-15, and NOAA-L now designated NOAA-16, were successfully launched in May 1998 and in September 2000, respectively. The planning launch dates for the remaining ATN follow-on satellites are as follows:

NOAA-M	May 2001
NOAA-N	December 2003
NOAA-N'	January 2008

Future GOES System

15. GOES-M is scheduled to be available for a planned launch in the July, 2001 time frame. It has accommodations for a Solar X-ray Imager (SXI). The SXI instrument will stare at the Sun continuously and provide images in up to eight X-ray energy bands. Other instrumentation is similar to that on GOES-10. One important change is in the Imager channels. One channel at 12.0 μm will be replaced with one at 13.3 μm in order to better establish the height of winds for tropical storm predictions and for more accurate cloud optical properties. In addition, the horizontal resolution of the 6.7 μm water vapor channel will be improved from 8 km to 4 km.

16. GOES-N and GOES-O are in the hardware development and integration phase. The first set of Imager and Sounder instruments is scheduled for delivery in early 2001. The completed GOES-N spacecraft is scheduled to be available for launch in October 2002 and GOES-O in April 2004. Contractual options for GOES-P and GOES-Q are not yet exercised.

RUSSIAN FEDERATION

Status of METEOR polar orbiting meteorological systems

1. Two satellites of the METEOR-2 and -3 series are currently operated in circular orbit inclined at approximately 82°. These satellites are operating beyond their lifetime and their capabilities are limited. TV images of the MR-900 scanning instrument (resolution 2 km, swath width 2600 km, spectral band 0.5-0.7 µm) are directly disseminated from these satellites in APT mode (137 MHz) as well as from the RESURS-01 N4 satellite.

Satellite series and number	Launch date	APT radio signal characteristics			
		Carrier frequency (MHz)	Modulation	Allocated bandwidth (kHz)	Radio transmitter output power (W)
METEOR-2 N21	31/08/1991	137.30	FM	100	5
METEOR-3 N5	15/08/1991	137.85	FM	100	5
RESURS-01 N4	10/07/1998	137.75	FM	100	5

Meteorological payload on oceanographic satellites

2. Additional satellite information useful for meteorological and hydrological applications is provided by the Okean-01 N 7 (launched 11/10/94) and the Okean-O (launched 17/07/99) satellites. The core payload includes the side-looking radar RLSBO as well as an ensemble of tracking and scanning MW radiometer and multizonal scanning device of low resolution MSU-M. Besides high resolution data transmitted to Roshydromet Main Receiving Centers, low resolution data are disseminated in APT format. The APT transmission includes one of four MSU-M channels or a frame of SLR, RM-08 and MSU-M channel 4 images of the same area. Characteristics of APT signal are the following: carrier frequency - 137.4 MHz; modulation - FM; allocated bandwidth - 100 kHz; radio transmitter output power: 5 W.

3. The Meteor-2 N 21, Meteor-3 N 5, Okean-01 N 7, Okean-O and Resurs-01 N 4 satellites orbital data needed for APT data direct readout are distributed via GTS in the «ORBIT» format. Dissemination schedules are placed on the SRC Planeta Internet server <http://sputnik.infospace.ru>.

Future Polar Orbiting Meteorological Satellite System METEOR-3M

4. The first polar orbiting meteorological satellite of Meteor-3M series is presently prepared for launch in the 4th quarter of 2000. The second satellite, Meteor-3M N 2, launch is planned in 2003.

5. The orbital parameters of these satellites are the following:

Satellite	Inclination, deg.	Altitude (km)	Period (min)	Ascending node equator crossing time
Meteor-3M N1	99.6°	1024	105.3	09:15
Meteor-3M N2	99.6°	1024	105.3	10:30 (16:30)

6. The payload of Meteor-3M N1 satellite includes scanning instruments of visible and IR range MR-2000M (similar to those on Meteor-3), KLIMAT-2 (modernized scanning IR radiometer KLIMAT installed on board Meteor-3). For imaging and sounding missions, Meteor-3M N 1 will carry the microwave (MW) scanning radiometer MIVZA (5 channels in the range 18-90 GHz). Sounding mission will be supported with MW radiometer MTVZA (20 channels in the range of 18.7-

183.36 GHz). This instrument will provide data for atmospheric temperature and humidity soundings as well as for oceanographic researches such as microwave diagnostics of the active ocean layer processes.

7. New sensors for imaging and sounding mission are planned to be install onboard Meteor-3M N2. Those are: - multichannel scanning radiometer MSR (4 channels in visible and IR, similar to channels 1,2,4,5 of AVHRR, spatial resolution is close to 1 km).

8. The SAGE-III (USA, NASA) sensor is planned to be install onboard of Meteor-3M N1 satellite (in frame of the agreement between NASA and Rosaviakosmos). Both satellites of Meteor-3M series will allow standard 1.7 GHz downlink channel. HRPT mode is foreseen on Meteor-3M N2.

Future Geostationary Meteorological Satellite GOMS/Electro N 2

9. The GOMS/ELECTRO N 2 spacecraft is presently in an integration stage. Payload and mission are similar to those of GOMS/ELECTRO N 1. The spacecraft will rely on 3-axis stabilized platform carrying as a core payload the BTVK imager in the VIS and IR range (in atmospheric window and in 6.7μm water vapor absorption band) as well as meteorological communication package (DCS and ensemble of retransmitters).

10. The satellite is planned to be launched by the PROTON vehicle in 2003 and to be placed into geostationary orbit at 76° E.

ARMENIA

(Department of Hydrometeorologyof The Republic of Armenia)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 Since January 1999 have been used the NOAA-15 data instead of the information received from NOAA-12 satellite.

1.2 In the Department of Hydrometeorology upgraded satellite receiving systems to be year 2000 compliant

1.3 The Department has started to receive images from METEOR Russian satellite system since 2000 year

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

There was no scientific research in the application of satellite data, derived products and services.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Satellite data, derived products and services have been used to provide weather forecasts (nowcasting, short-range and medium range).

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

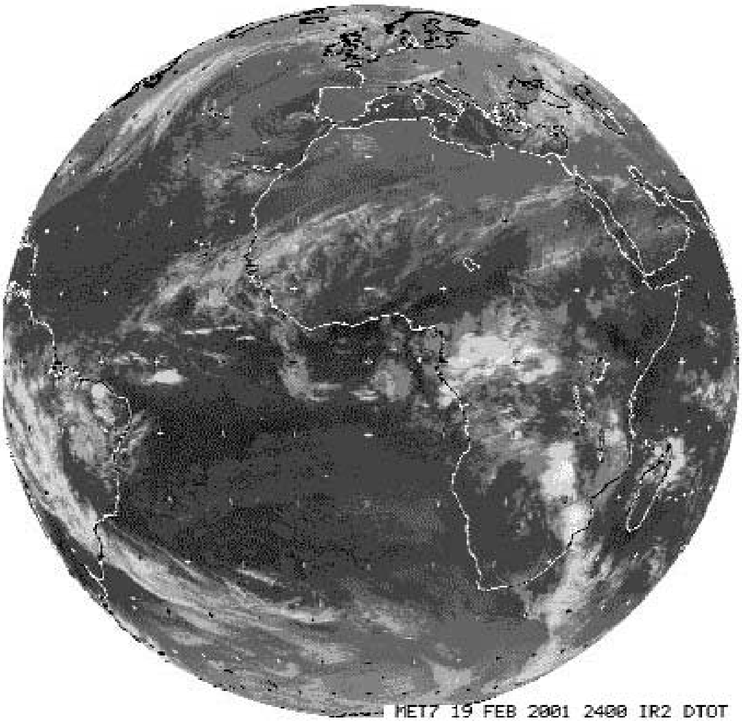
4.1 The NMHS of Armenia has been running the following satellite receiving systems:

- Skyceiver System Tecnavia;
- MESSIR-COMM meteorological telecommunication system

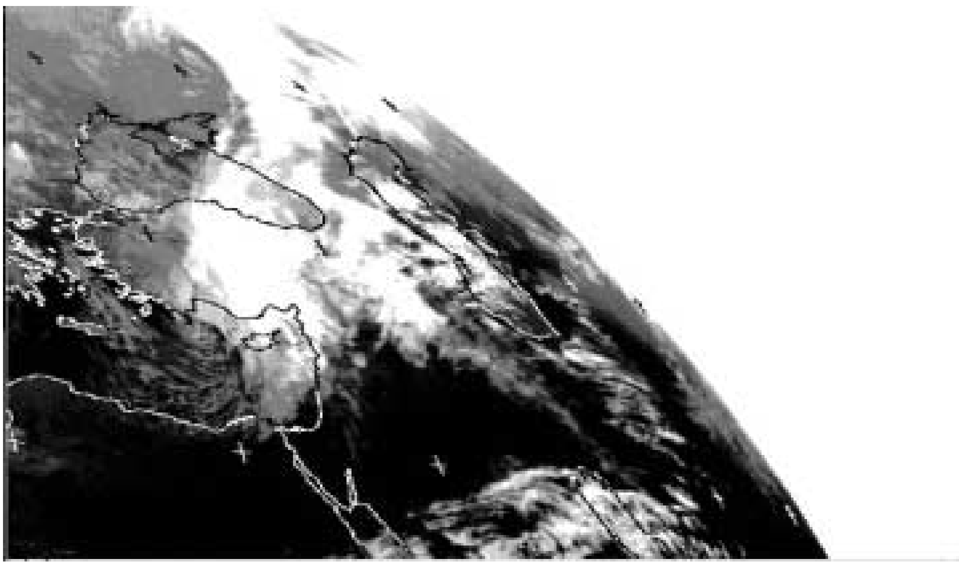
4.2 The Tecnavia Skyceiver Workstation is working operationally, providing APT and WEFAX images. The Tecnavia Skyceiver Workstation has been used for reception, viewing, animation and editing of satellite images. Receiving images has been used for forecasting.

4.3 MESSIR-COMM meteorological telecommunication system provides Automatic Message Switching in the frame of the Global Telecommunication System of WMO.

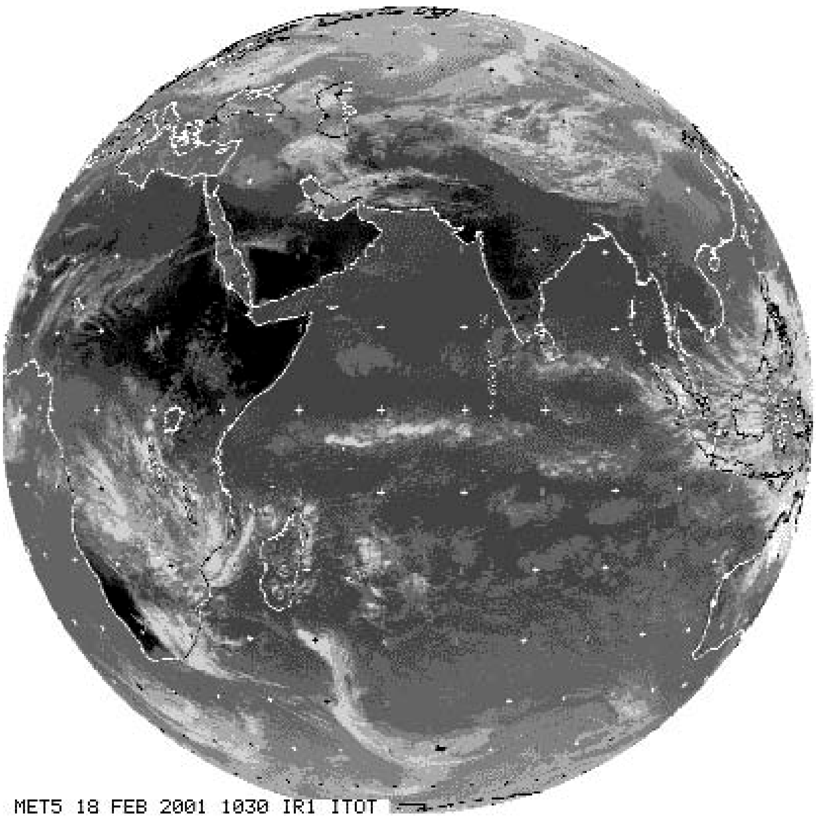
Figure 1 Examples of images receiving by Tecnavia Workstation from geostationary satellites



(A) Example of IR image received from MET-7 satellite

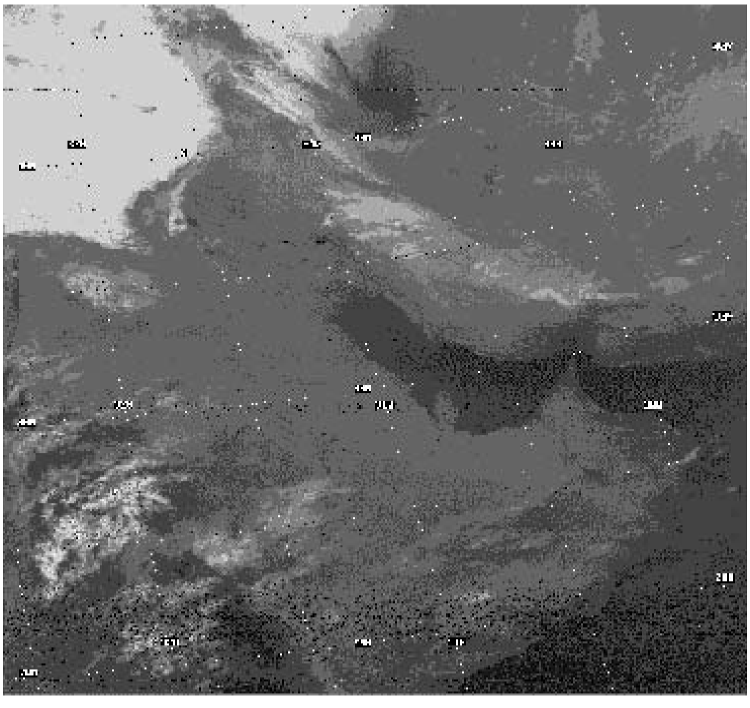


(B) Example of image received from MET 7 satellite

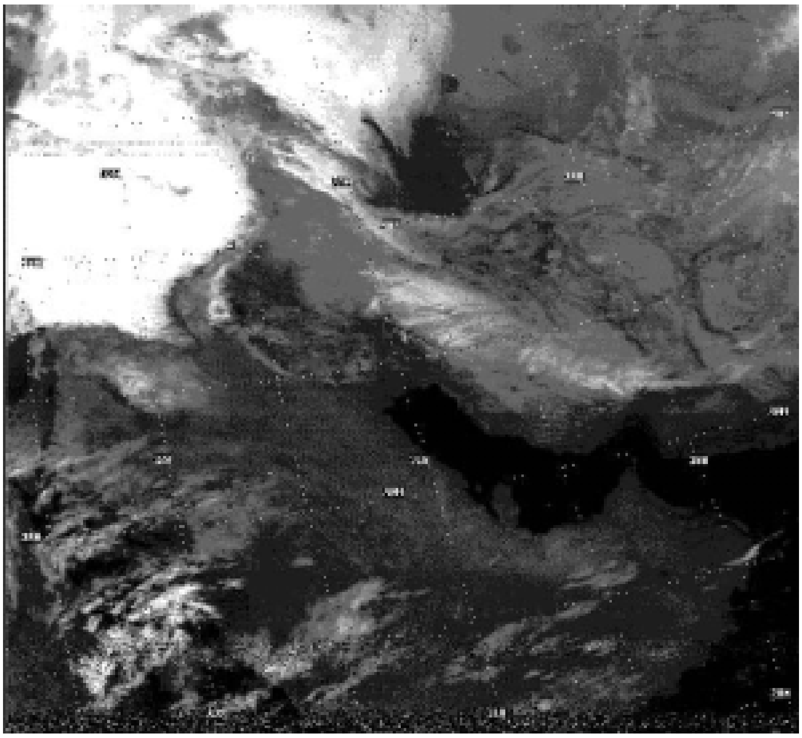


(C) Example of image received from MET-5

Figure 2 Examples of images receiving by Tecnavia Workstation from orbital satellites



(A) Example of image received from orbital satellite NOAA 12



(B) Example of image received from orbital satellite NOAA14

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

For the future it is planned

- to receive satellite data from the Indian Satellite INSAT;
- to provide by satellite data to users via Internet.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

No verification or performance statistics are available

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND SCIENTISTS IN CHARGE)

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AUSTRALIA

(Bureau of Meteorology)

PART I SUMMARY OF THE MAJOR HIGHTLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 The Australian Bureau of Meteorology operates a real-time network for the reception and processing of remotely sensed data from meteorological and related satellites. This network, which consists of facilities in Melbourne, Sydney and Darwin for reception of GMS-5 Stretched-VISSR (Visible and Infrared Spin Scan Radiometer), plus NOAA High Resolution Picture Transmission (HRPT) stations at Darwin, Perth, Melbourne, Crib Point and Casey (Antarctica), is being progressively upgraded and enhanced.

1.2 GMS-5 S-VISSR data is processed and archived in Melbourne, Sydney and Darwin using the Bureau's distributed UNIX system. Further consolidation and improvement has been made to the national satellite reception, processing, archival and distribution system. The low cost on-line satellite reception and processing system which was developed for use by the Bureau is marketed internationally through the Bureau's commercial arm, the Special Services Unit (SSU).

1.3 The Bureau continues to operate the Turn Around Ranging Stations (TARS) in support of Japan's GMS-5 and China's Feng Yun-2 geostationary meteorological satellites.

1.4 Major advances have taken place with the number of applications including cloud drift winds at high temporal and spatial resolution, solar radiation, and bushfire monitoring. Also a number of satellite derived applications now support operational products and services to external users through the Bureau's Web Service (www.bom.gov.au). The new services are daily global insolation, daily regional sea surface temperatures and Antarctic sea ice imagery.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

GMS PATHFINDER

2.1 The GMS Pathfinder project is a collaborative project involving the Scripps Institution of Oceanography (SIO), the United States National Aeronautics and Space Administration (NASA), the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Australian Bureau of Meteorology with cooperation from the Japan Meteorological Agency (JMA).

2.2 Selected data from Japan's Geostationary Meteorological Satellite (GMS-5) from the benchmark period (1 July 1995 to 30 June 1996) are being analysed to produce the GMS Pathfinder data set. High quality navigation, radiometric calibration, noise filtering and cloud screening algorithms are being used to generate a benchmark data set of the Australian continent and its surrounding seas. This data set and documentation will be released by SIO in July 2001. More information is available from the web site (http://landlub.ucsd.edu/projects/gms/gms.html) and Simpson *et al*. (1998); Le Marshall *et al*. (1999).

Atmospheric Motion Vectors

2.3 Research is currently being undertaken to support the operational high-resolution regional cloud and water vapour drift wind system and to ensure the provision of operational upgrades. The activity is aimed at ensuring optimal assimilation of these high spatial and temporal resolution quantitative GMS observations into the Bureau's data assimilation systems. During

2000/2001 real time data impact studies using automatically estimated hourly and half-hourly infrared, low and high resolution visible, infrared and water vapour image based atmospheric motion vectors (AMVs) winds have been completed and documented. During these trials, simultaneous use of all wind types generated locally was shown to improve the regional forecasts. As a result, all wind types are now used simultaneously in the operational regional assimilation system. Upgrades to the GMS-5 IR, water vapour, infrared and visible image-based AMVs continue, based on multi-channel physics. Quality control procedures for the visible, infrared and water vapour winds have also been revised. Over the past two years, error flags and quality indicators have been appended to the vectors to indicate their expected error. Examination of calibration issues related to GMS-5 has continued. Many of the issues in this regard are resolved and those remaining are being addressed by JMA, Bureau and Scripps Institution of Oceanography staff as part of the GMS Pathfinder project [see Le Marshall *et al*. 1999 and Simpson *et al*. 1998].

2.4 Research has continued to monitor, quantify and document the impact of the local high spatial and temporal resolution AMVs on tropical cyclone (TC) track forecasting. In this regard, high resolution modelling (15 km to 5 km), hourly IR and VIS cloud drift winds and continuous 4-D Var assimilation have been shown to have the capacity to significantly reduce tropical cyclone track forecast errors in the Australian Region (Le Marshall and Leslie, 1999). Work has continued on modelling TC intensity (Le Marshall and Leslie, 1999). In the current operational system, infrared, visible and water vapour drift wind systems are running in real-time producing AMVs at hourly intervals across the Australian Region. The data derived from these systems and, in particular, special high resolution data derived around tropical cyclones, are available to all Tropical Cyclone Warning Centres (TCWC), Regional Forecasting Centers (RFC) and National Meteorological and Oceanographic Centre (NMOC). A real time full disc system is also run, routinely, providing high resolution winds in the Northern and Southern Hemispheres. [Dr John Le Marshall].

TOVS and ATOVS radiance data application

2.5 Research has been undertaken to optimise the assimilation of TOVS and ATOVS radiances for NWP and develop and provide products from TIROS Operational Vertical Soundings (TOVS) radiance observations for synoptic, climate and Numerical Weather Prediction (NWP) applications.

2.6 Real time processing of TOVS data from the NOAA series of satellites over the Australian Region is long established. The system uses raw, cloudy radiances rather than the clear, limb-corrected radiances with their inherent errors. The real time TOVS can employ an inversion method which uses AVHRR data in the processing path. This scheme allows the production of clear radiances using the N^* method and other physical methods when cloud conditions are appropriate. It properly delineates clear areas and provides an appropriate retrieval path for overcast conditions. The system also produces total ozone estimates over the Australian Region. [Dr John Le Marshall]

2.7 Local reception of NOAA ATOVS data in real time is currently routinely undertaken, using the AAPP pre-processor. Locally received NOAA-15 AMSU-A radiance data have been used via a 1-D VAR assimilation methodology with the Bureau's operational Limited Area Prediction Scheme and been shown to provide positive impact on forecasts, even when the downlink of data was impaired by major aerial problems on the satellite (Le Marshall *et al*. 2001).

2.8 Global NWP modelling work includes assimilation of TOVS/ATOVS using 1-D Var (variational analysis). It involves retrieval of a temperature and moisture profile at a single location (hence the one dimension). Results showed quite appreciable improvements in skill scores so that the system has now gone operational. TOVS radiances are now being routinely assimilated into the Bureau's operational Global Assimilation and Prognosis System (GASP) after successful completion of a series of impact studies. Testing is now underway of a new 3-D Var analysis suite for operations which will use radiance data from a number of satellite instruments, including AMSU-A, AMSU-B and HIRS-3. Plans include extending the Bureau's global model (GASP) assimilation to 0.1 hPa (50 levels). There is also a move to use raw level 1C ATOVS radiances. In the future direct assimilation of radiances via 3-D Var will be undertaken. [Dr Bill Bourke, Mr Peter Steinle, Dr Chris Tingwell, Mr Brett Harris]

Satellite-derived rainfall

2.9 Research is currently being undertaken to estimate rainfall using GMS, AVHRR and SSM/1 imagery. Methods have been investigated for the reliable determination of areas of 'no rain', using hourly GMS imagery. The aim is to provide pseudo-observations of zero rainfall to fill in, to the extent possible, the areas of Australia not covered by conventional rain gauges. A 'no rain' algorithm, based on the difference between the coldest GMS brightness temperature observed at each pixel during the day, and the expected minimum surface temperature (obtained from climatology), has been tested, proven beneficial, and documented. When 10 months of estimates were verified against rain observations at synoptic stations, the overall accuracy was 98% and the average spatial coverage was about 54% of the total area of Australia [Dr Elizabeth Ebert, Dr Gary Weymouth]

Cloud top temperature and moisture data extraction from GMS-5 imagery

2.10 A major effort has been put into upgrading the scheme by which cloud top temperature (CTT) and moisture data are extracted from GMS-5 imagery for use in Tropical Limited Area prediction Scheme (TLAPS) NWP model. The result is a new system which runs in the McIDAS environment and makes use of McIDAS navigational and image reading functions. It has been designed to be flexible with regard to the domain and spacing of the latitude-longitude grid over which it extracts the CTT data, and also with regard to the size and shape of the grid cells within which it reads the image data. The code can detect and report grid cell overlap and gross navigational errors.

2.11 The moisture data is generated by the scheme of Mills and Davidson. The code has been designed to be as modular as possible, to allow for ready adaptation of the scheme to other uses of GMS imagery temperature data. The new scheme is currently being run in real time and is generating hourly CTT data from a 0.5° x 0.5° grid, and six hourly moisture data from a 1° x 1° grid. [Dr Chris Tingwell, Dr Noel Davidson, Mr Robin Bowen]

Preparation for Advanced Sounders - AIRS/GIFTS

2.12 Preparations are underway towards providing a reception and processing capability for AIRS and MODIS in the BoM, using a low-cost system, based on upgrading the extant S-band antennae. In conjunction with this activity, there has been ongoing work, developing a 1-dimensional, full physical solution of the Radiative Transfer Equation, suitable for application to many thousands of channels. An examination of techniques incorporating AI to provide geopotential parameters is also underway.

2.13 In relation to the Geostationary Imaging Fourier Transform Spectrometer (GIFTS), planning and research are underway, related to the reception, product generation and dissemination of data from that instrument which will be positioned over the Indian Ocean during the last half of this decade. Data impact studies using advanced sounder data, taken from NASA ER-2 aircraft, have recently been undertaken. High resolution (1 km), 4-D Var assimilation trials have led to successful assimilation of these high spatial and temporal resolution hyperspectral data. (Dr John Le Marshall, a member of the AIRS Science Team. Collaborators in this research include Mr Rolf Seecamp, Dr Yuri Kuleshov and Professor Bill Smith in USA).

Cloud climatology and parameterisation

2.14 A GMS-4 based climatology is complete. A new methodology for cloud masking and classification, based on GMS-5 observations, is being finished in conjunction with UCSD. It complements earlier work done by Coops and Le Marshall. [Dr John Le Marshall, Dr Jim Simpson and Mr Rolf Seecamp]

2.15 Work is being undertaken on a cloud validation/parameterisation system which compares GMS-5 satellite images with the model fields, in order to calculate what the satellite should see. The investigation has shown that there are good results in the mid latitudes, and more error in the tropics. Histograms show that model results are warmer in the tropics. Plans for further work include an improvement of the mass flux scheme, prognostic stratiform scheme, and an investigation of the radiance transfer. [Dr Lawrie Rikus]

2.16 R&D is being undertaken using GMS cloud top temperature (CTT) data to study deep convection over the maritime continent. Previous studies have shown that deep convection over the islands penetrates into the lower stratosphere, and that vertical heating profiles differ between island and maritime convection. The aim of this work is to determine whether there are two distinct modes of convection, ascertain the frequency of the two modes, and determine whether there is situational dependence. GMS-5 IR1 full disk images from a period of fourteen months were read and processed on a regular grid. Results to date have shown that there is a strong annual cycle in very deep convective activity, deep convection is closely associated with large scale monsoon activity over the seas, deep convective activity has a longer annual cycle and is more frequent over the large islands, and the largest concentrations of cold cloud are associated with tropical cyclone tracks. [Dr Chris Tingwell]

Fog / low cloud

2.17 The Bureau has commenced a research program to enhance its fog and low cloud forecasting services (including accuracy) especially for the aviation industry. This involves use of many observational and NWP techniques and the WASTAC AVHRR data will be of major importance in this. Various algorithms are being refined which use several channels in the AVHRR data to delineate low cloud and fog. For example, fog/low cloud is being diagnosed using the difference between channel 3 (3.7 micron) and channel 4 (11 micron) NOAA AVHRR imagery. These clouds typically have lower emissivity at 3.7 than 11 microns, and so appear colder in the former. The 11 micron imagery is mosaiced and date stamped, with the latest image on top, and fog/low cloud areas coloured. Work underway includes automatic quality control (for example, detection of cloud clearly distinct from the ground) and verification against surface observations. Future work involves incorporation of topographic information, surface observations, numerical weather prediction fields, and visible channel data. [Dr Gary Weymouth]

Scatterometer data assimilation and oceanography

2.18 In BMRC (Bureau of Meteorology Research Centre) assimilation studies are in progress using ERS and QuikScat scatterometer data using techniques for interpolation at 10m since the Bureau's global model normally has its lowest level at 90m. Results are encouraging in terms of comparison of first guess model speed with observed scatterometer speeds. Assimilation of the scatterometer data has highlighted areas for improvement in the assimilation schemes. [Dr Peter Steinle and Mr Jeff Kepert]

2.19 Considerable work is being done in BMRC and NMOC using satellite data for oceanography. This includes satellite-based AVHRR SSTs and Topex/Poseidon altimetry for sea surface topography anomalies. Follow-on altimeter data from Jason-1 and ENVISAT satellites will be important. The satellite data are being complemented by many conventional data including Argo, the global array of profiling floats will give ocean profiles around the globe by 2005. The Global Ocean Data Assimilation Experiment (GODAE) has its project office in the Bureau and aims to develop oceanographic assimilation systems in an analogous way to those systems currently used by atmospheric modellers. [Dr Neville Smith]

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3.1 The Bureau's main operational satellite applications include locally derived TOVS retrievals, total ozone and solar radiation estimates, atmospheric motion vectors, and cloud drift winds (CDWs) from GMS-5, and a range of products used in Regional Forecasting Centres based on NOAA HRPT data, e.g., imagery mosaics, sea surface temperatures (SSTs), sea ice maps used at Casey in Antarctica, volcanic ash, bushfire detection, fog/low cloud detection, and flood monitoring. Applications from GMS-5 and the NOAA satellites continue to be used to provide access to surface observation data from remote automatic weather stations or drifting buoys. Techniques and applications development of satellite data is continuing, as described below.

3.2 Solar radiation estimates of the Australian region became operational in 1998, and are available to external users on the Bureau Web site (www.bom.gov.au). The core of the model continues to involve a physical model of radiative transfer within the atmosphere similar to Gautier *et al* (1980) and Diak and Gautier (1983). The prime source of data is GMS-5 and for clear conditions daily global solar exposure estimates are accurate to 6% (rms) (Weymouth and Le Marshall 1999, 2001). The software is being upgraded to give hourly estimates and to incorporate other satellite data.

3.3 The Bureau has developed algorithms for fire detection using NOAA AVHRR channels 1 and 3. This data is used operationally in Regional Forecasting Centres in support of statutory obligations to supply fire weather forecasting and warning services for Australia.

3.4 NDVI data has been produced on a daily basis within the Bureau of Meteorology using the input data from the advanced Very High Resolution Radiometer (AVHRR) currently carried on the NOAA polar orbiting satellites since the mid 1990s. A stable operational procedure was adopted in September 1997 to process data from the afternoon daylight passes of NOAA-14. This procedure operated up to the end of April 2001, however problems became apparent with the data obtained during the winter of 2000. Orbital drag resulted in the satellite overpass time being progressively retarded by one hour between May 2000 and the beginning of May 2001. This in turn resulted in the reflectance data being obtained using very low sun angles (close to sunset) over the continent, the data becoming effectively of little use beyond April 2001.

3.5 Since the beginning of May 2001 the Bureau has shifted its operational processing of NDVI data to NOAA-16. The latter has an overpass time two hours earlier than NOAA-14. Intercomparison of the data received during the first nine days of May revealed the full extent of the degradation which had occurred in the NOAA-14 signal. Statistical analysis of the data obtained from NOAA-14 throughout 2000 has indicated that all published data since May 2000 should be regarded as degraded to some extent. Further work is now proceeding to ascertain whether supplementary processing of the data sets can be used to improve the quality of this data for inclusion in any long term trend analysis.

3.6 A somewhat separate project has progressed during the year despite the problems with NOAA-14. This involves the development of a complimentary processing procedure to better categorise continental water bodies using NOAA data. The procedure was initiated during the early part of 2000 to monitor daily changes apparent in the Lake Eyre basin (in south central inland Australia) during the big flood event of April/June 2000. By using additional information from the thermal emission channels already incorporated in the pre-processing cloud clearing procedures, extra information has been added to the standard NDVI product to produce an 'NDVI Plus' product which was used successfully to monitor daily changes in the surface of Lake Eyre during the flooding event and the subsequent drying out of the lake. This work is proceeding in an attempt to enhance the hydrological monitoring of the large inland lake and river systems where little or no data is currently available from stream gauging information. [Mr Guy Tuddenham]

3.7 The Bureau is also collaborating with CSIRO and others on the development and operational implementation of the Common AVHRR Processing System (CAPS). CAPS is a Tcl/Tck software system which allows accurate pre-processing of the satellite data to produce standardised data sets. In particular it will enable improved navigation accuracy for NOAA AVHRR used in the Bureau with subsequent benefits for all AVHRR applications like NDVI, SSTs, volcanic ash etc. (see www.dar.csiro.au/rs/avhrr_processing_software.htm). CAPS is being extended to process other satellite data including that from Terra MODIS and China's FY-1C polar orbiters (the Bureau has been developing an operational FY-1C ingest and processing system during 2000 and 2001) [Dr David Griersmith and Mr Anthony Rea].

3.8 NOAA AVHRR and GMS-5 satellite data received in real-time at the Bureau's Volcanic Ash Advisory Centre in Darwin are critical to the provision of timely advice on volcanic ash clouds for aviation in areas north of Australia. It is possible to identify ash clouds in visible and infrared satellite data and this enables the provision of appropriate advice on the location and movement of ash clouds. It can be difficult to discriminate ash clouds from water/ice clouds and work continues towards improving this. The brightness temperature difference between the NOAA AVHRR infrared channels at 11 microns (T4) and 12 microns (T5) has proved beneficial for discriminating areas of ash from water/ice clouds although these data are available less frequently than is operationally desirable. Japan's geostationary satellite GMS-5 provides hourly data in two infrared channels similar to the NOAA AVHRR and the brightness temperature difference for these data has also proved beneficial although the differences are less well defined because of reduced spatial and temperature resolution. MTSAT-IR is expected to lead to major improvements in that respect [Mr Rodney Potts].

3.9 The Bureau of Meteorology calculates satellite derived sea surface temperatures (SSTs) for the Australian region by combining data from the WASTAC Perth station with similar NOAA AVHRR data from its Casey, Melbourne and Darwin stations. The AVHRR data is navigated, calibrated, cloud cleared in real time and the processed orbit is available within an hour after the completion of the ingest. The resulting SSTs for a particular orbit are then sent to Melbourne for inclusion into the Bureau's national data set. The data is then quality controlled against SST data collected from ships and drifting buoys prior to being mosaiced into a national map. These data are mainly used in support of internal and defence operations (e.g., assimilation into Bureau numerical weather prediction models) but are also available to external users as metadata and browse images of daily mosaics (from November 1998) via the world wide web at http://www.bom.gov.au/nmoc/archives/SST/. A subscription service is also available for real time SST data and regional products via the Bureau's "Weather by Fax" service. The SST grid data are archived as part of Australia's National Climate Record. The processing system operates at full AVHRR resolution.

3.10 Scatterometer wind retrievals have now become a proven method of observing surface wind vectors over the oceans. The Bureau of Meteorology has been receiving data from ERS-1 and its successor ERS-2 in near real time over the GTS since 1995. While useful in aiding the location of meteorological systems the data is deficient due to its limited coverage of the globe (500 km wide swathes). The launch of the QuikScat mission in 1999 and the decision to make the wind data available in near real time through NESDIS since the beginning of 2000 provides almost global coverage every 12 hours. These data are used by analysts in the Bureau's National Meteorological and Oceanographic Centre (NMOC) in the production of surface analyses and hence in the production of pseudo-observations for the NWP system. Work is currently in progress to assess the impact of these data assimilated directly in NWP systems [Mr Graham Warren].

3.11 The Bureau continued its active involvement in the Tropical Rainfall Measuring Mission (TRMM) project. The Bureau's Darwin Climate Monitoring and Research Station polarimetric radar (CPOL) was operated in Darwin in support of TRMM activities. TRMM ground validation activities continued, and studies of tropical squall convection were undertaken jointly with scientists from the National Research Institute for Earth Science and Disaster Prevention (NIED) as part of the Japan-Australia Tropical Mesoscale Experiment (JATMEX), with two temporarily-imported Japanese X-Band Doppler/polarimetric radars augmenting the existing Darwin Dual-Doppler network. The characteristics of tropical raindrop size distributions were also studied, using Darwin Doppler profilers, the polarimetric radar and disdrometers and a technique for the automated classification of hydrometeor types within storms was developed based on polarimetric radar data. Studies of the applicability of polarimetric radar-based rainfall estimation techniques continued [Dr Tom Keenan].

Asia-Pacific Satellite Data Exchange and Utilisation Meeting No. 3 (APSDEU-3)

3.12 APSDEU-3 was held in conjunction with the 20th session of the Japan-Australia GMS Joint Committee on 29-30 January 2001. Participants from Australia, Canada, China, Hong Kong (China), Japan, Korea, New Zealand, Singapore, and USA, met in Melbourne in the Bureau's Head Office for two days to discuss and promote the exchange of meteorological satellite data in the Asia-Pacific region and international cooperation in data utilisation. The 15 international participants represented National Meteorological and Hydrological Services, plus space agencies like NOAA (National Oceanic and Atmospheric Administration) and NASDA (National Space Development Agency), and there was a representative from Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) Office of Space Science and Applications, plus about 25 participants from the Bureau especially including the Bureau of Meteorology Research Centre.

3.13 Country reports were provided on satellite activities including exchange, data format and communications issues, fostering improved integration of satellite data with other observational data types and data assimilation into numerical weather prediction models. Plans were shared on satellite systems from USA (e.g. NOAA, GOES, NPOESS, Terra and Aqua etc); Japan (MTSAT-IR and MTSAT-2); China (FY-1 and FY-2, -3 and -4 series) and Korea (e.g., future geostationary meteorological satellites). Many scientists described new techniques for satellite data applications including assimilation (e.g., of GMS-5 or scatterometer data) into Numerical Weather Prediction (NWP) models.

3.14 Recommendations from the meeting included establishment of a web site by NOAA/NESDIS to collect information on currently available data and products and requirements (including telecommunication requirements); sharing of data sets via Internet or Global Telecommunications System (GTS) exchange, for example, near real time SSM/I data, Level 1C ATOVS data, snow depth data, wind profiler data from the Japan Meteorological Agency (JMA), and AMSR data. Proceedings will be provided on CD-ROM by the Bureau (with some information via a web site) and the next meetings were tentatively planned for early 2002 in Tokyo hosted by JMA, and 2003 in Beijing hosted by the China Meteorological Administration, and are likely to be attended by more countries, owing to the success of the meetings.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

Meteorological Systems

4.1 The overall system for Bureau of Meteorology space-based observations programme is shown schematically in Figure 1. Data are received from GMS, FY-2 and NOAA polar orbiting satellites and ingested at a large number of reception stations, each using a locally developed card in a Unix machine (HP 725 or B132) which runs software that performs calibration, navigation, archive and value-added product generation. From their respective ingest machines the data are passed over the LAN to the main satellite processing (Unix) computer (HP 9000 series). Here image sectors destined for each Regional Forecast Centre (RFC) are created on the RAID, and transmitted over the WAN to RFCs. The National Meteorological and Oceanographic Centre (NMOC), which is connected by LAN to RAID has full access to satellite data and products. The RFCs are also able to access the image data on the RAID by using the McIDAS Advanced Distributed Data Environment (ADDE) facility. Other satellite data are received via Internet and the GTS and from an X-band station in Hobart, Tasmania operated by a consortium including the Bureau. Overall, the main satellite applications in operational use are atmospheric motion vectors, TOVS/ATOVS, scatterometer oceanic winds, SSTs, NDVIs, solar radiation, volcanic ash, fog/low cloud and sea ice.

4.2 For operational NWP model systems the Bureau receives about 0.5 million cloud drift wind observations per day from the GTS for GOES-8 & 10, GMS-5 and METEOSAT 5 & 7. By contrast, 40,000 synoptic observations and 1500 radiosonde measurements per day are fed into the NWP simulation scheme, hence conventional data is much smaller in volume. Locally derived CDWs from GMS-5 give 40,000 observations per day. Also both locally processed and GTS TOVS/ATOVS are used. [Mr Bruce Sumner]

Hydrological Systems

4.3 Flood Warning Centres in the capital city of each State and Territory in Australia provide a range of flood warning services to emergency management agencies within their respective regions. There is a growing, but still limited use of satellites for detecting and monitoring the extent and movement of flooding in large inland river systems (Tuddenham and Griersmith 1999). Satellite observations do however play an important role in the estimation of precipitation as a forecast input to the flood prediction process. Current research underway in the Bureau of Meteorology, in collaboration with the Cooperative Research Centre for Catchment Hydrology, is looking at the integration of satellite observations with radar and gauge observations to produce improved areal rainfall estimates for a wide range of operational hydrology and water resources assessment applications.

4.4 The INMARSAT mini-M network is used operationally for flood warning data collection in the Northern Territory and Western Australia, with test sites located in other States. At present rainfall and/or river level data is collected from a total of 24 locations (13 in Western Australia and 11 in the Northern Territory). The use of satellites for hydrological data collection is expected to grow as the temporal and spatial coverage of satellite systems improves [Mr Jim Elliot].

PART V PLANS FOR FUTURE OPERTAIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5.1 The Australian Bureau of Meteorology is continuing to plan for the launch of the Geostationary Imaging Fourier Transform Spectrometer (GIFTS) in 2005. The overall objective of the project is to provide the Bureau (and as a result, the international meteorological community via WMO) with access to leading edge satellite data for use in NWP and forecasting, by provision of ground reception and processing facilities for the efficient utilisation of data. The GIFTS Programme is a selected NASA "New Millennium Programme" and is being supported by the US Navy, NASA, NOAA and the Bureau.

5.2 The Bureau's X-band activities are proceeding well. For example the 9m Tasmanian Earth Resources Satellite Station (TERSS) antenna operationally receives, archives and processes data from SPOT, Landsat, ERS, Terra MODIS and other satellites. TERSS is a consortium including the Bureau (see www.terss.org.au). A new X-band consortium called WASTAC-X which includes the Bureau is implementing a 3.7m reception system in Perth to be operational by November 2001. The system will receive and process MODIS and AIRS from Terra and Aqua. Later satellite data acquisition will include METOP, NPP, NPOESS and possibly other systems. In the next five years there will be dramatic changes in satellite data transmissions and formats and more R&D type systems with direct broadcast capabilities. Driven by Bureau user requirements, the satellite systems operated by the Bureau will need to cope with higher data rates and different, more advanced data formats. Initially higher data rate and new format systems for acquisition and utilisation of FY-1C/D, MTSAT-IR/-2 and MODID/AIRS are being developed.

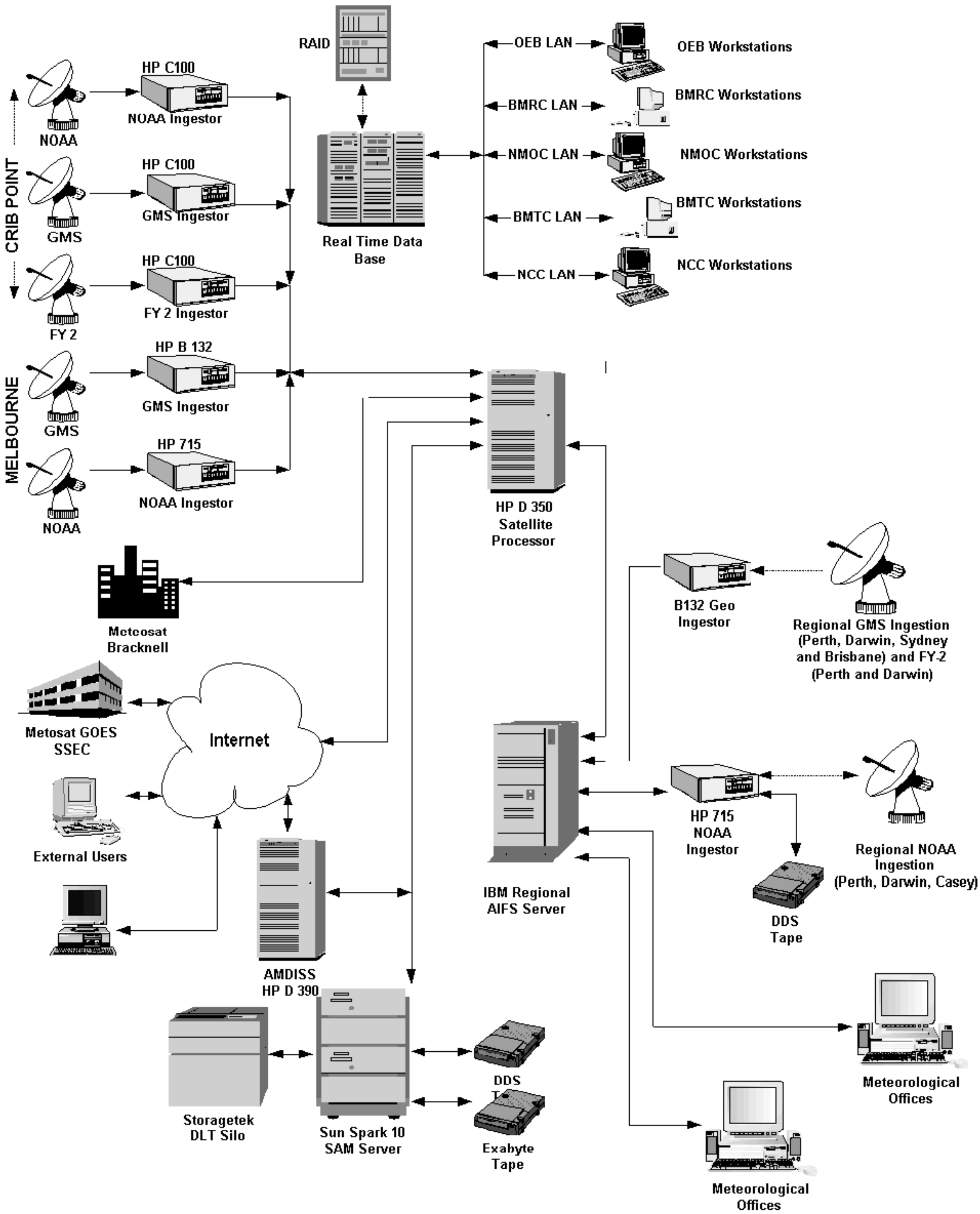

Figure 1: Diagrammatic representation of the Bureau's satellite ingest, processing and distribution system.

5.3 The operational Limited Area Prediction System (LAPS) was implemented in 1999 with a horizontal resolution of about 35km across the Australian region. The tropical version of the limited-area system (TLAPS) was implemented in September 1999, utilising detailed analysis of GMS satellite data in the initialisation process. The high resolution (12.5) mesoLAPS system was implemented for the Australian continental region in November, while the tropical cyclone version (TC-LAPS) was implemented in December 1999. The performance of TC-LAPS was excellent over the summer season when the tracks of several tropical cyclones were well predicted. An important feature of the updated LAPS is the routine generation of boundary layer fields such as screen level temperature, moisture and winds and the boundary layer height. This has been made possible through the implementation of an improved boundary layer formulation which includes non-local turbulent mixing, separate roughness lengths for momentum, heat and moisture with orographic and vegetation effects and substantially enhanced vertical resolution in the boundary layer. LAPS also includes a new land surface scheme which includes fractional vegetation and stomatal resistance.

5.4 Further development of the operational systems which involve assimilation of satellite radiances is underway. TOVS soundings at 120 km resolution are received routinely from over the globe by the Bureau's National Meteorological and Oceanographic Centre (NMOC) and are used operationally in NWP models. As soon as BMRC has finished current studies, it is expected that QuikScat scatterometer data will also be used operationally. The operational assimilation of locally derived cloud drift winds which are used in NWP over the Australian Region has been extended from use of 6-hourly IR winds to hourly winds to all types of high resolution winds.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6.1 Data from the Bureau’s satellite applications is subject to validation and “ground truthing”. AVHRR SSTs are automatically compared to co-located floating buoy and ship observations with the results published daily on the Bureau’s internal web. Warning messages are automatically sent in the event of error or failure to meet tolerances. CDW data are automatically compared to upper air observations in a similar fashion. Similar systems are in development for other AVHRR applications and for GMS-derived solar radiation estimates.

6.2 The ingest systems for both polar orbiting and geostationary satellites automatically log information relating to data quality and quantity. Statistics are available via the web immediately after ingest. Warning messages are generated in the event of errors. A preliminary system is available for the web-based display and analysis of historical data for the purposes of performance monitoring [Mr Anthony Rea].

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS, AND SCIENTISTS IN CHARGE)

Lead scientists have been identified during previous sections and may be contacted at the:

Australian Bureau of Meteorology
GPO Box 1289K
Melbourne, Victoria
AUSTRALIA 3001

Enquiries may also be directed to the following people at the same address:

Dr David Griersmith (Superintendent, Satellite Activities)
Dr John Le Marshall (Bureau of Meteorology Research Centre)

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BULGARIA

(National Institute of Meteorology and Hydrology)

PART I A BRIEF SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

A Primary Data User Station (PDUS) is working at the National Institute of Meteorology and Hydrology (NIMH), which is in charge of the National Meteorological and Hydrological Service of Bulgaria. Meteosat High Resolution Image (HRI) data are received and processed for operational and research purposes. At the Central Forecasting Bureau of NIMH in Sofia, daily imagery analysis is made subjectively for the purposes of operational forecasting.

PART II A DESCRIPTION OF THE MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Use of Meteosat water vapour channel data in short-range forecasting

2.1 The research at the NIMH of Bulgaria is focused on the use of Meteosat water vapour (WV) channel data in weather analysis and prognosis over the Mediterranean. WV imagery is used as a valuable tool for studying atmospheric circulation in the middle and upper troposphere. Since the potential vorticity (PV) analysis is used as a convenient and comprehensive method for the interpretation of the dynamical mechanisms responsible for cyclogenesis, a field of research at NIMH is the qualitative and quantitative relationship between Meteosat WV data and PV fields. The correlation between Meteosat WV data and positive anomalies of PV was investigated in a case-study involving cyclogenesis in the Alpine region and a low over north-west Africa. Correlation analyses were performed at different isobaric surfaces in the middle and upper troposphere for two latitudinal belts (25–35^0 N–'northern' and 35–52.5^0 N–'southern'). A significant correlation is obtained at 500 hPa (correlation coefficient range: 0.58-0.64). Linear regression models are fitted to the samples from the northern and southern belts (Georgiev, 1999).

2.2 The relative lack of conventional upper air data in the region of the Mediterranean-North African area tends to produce limitations of numerical modelling. This is the reason for stressing the use of satellite data as an alternative and complementary way to the only use of numerical outputs in weather forecasting. A study at NIMH has focused on the use of Meteosat WV imagery and PV fields for analyses and early forecasts of cyclone development (Georgiev & Martin, 2000). The project was performed in co-operation with the Forecasting Department of Spanish Meteorological Service, INM, Madrid and supported by the Government of Spain and WMO (a fellowship awarded to the first author). Ten cyclonic disturbances over the North Atlantic–Mediterranean area were studied. Features in potential vorticity fields were tracked in the analysis and short-range forecast of the Spanish version of HIRLAM model (HIRLAM-INM) and ECMWF model. They were superimposed on the corresponding Meteosat water vapour images with the aim to ascertain the qualitative relationship between WV imagery and PV fields that might be used to assess NWP model behaviour. It was demonstrated that comparing the absolute vorticity at the surface of PV = 2 'PV units' with WV imagery might be used for monitoring upper-level flow evolution. The field of PV anomalies at 500 hPa was compared with Meteosat WV data for monitoring the areas of dry air intrusion associated with the cyclonic disturbances. The identification of dry intrusions from WV imagery can be used to validate NWP output because of the link between (parts of) dry intrusions and high PV. Two cases predicted incorrectly by HIRLAM-INM were studied in details. It was demonstrated that HIRLAM-INM errors in both cases are seen in the comparison between Meteosat WV images and PV fields.

Retrieving of daily precipitation amount from Meteosat IR and WV images

2.3 An archive of half-hourly Meteosat HRI data over the region of south-eastern Europe is daily created and a method for retrieving daily precipitation amount by using Meteosat data is developed (V. Spiridonov).

Use of ERS2 altimeter wind/wave data for wave model verification

2.4 Recent collaboration between Météo-France and the NIMH of Bulgaria yielded the implementation of an operational wave model for the Black Sea. A major difficulty for the verification of model analyses and predictions over oceans end seas comes from the lack of conventional observations. It is particularly true for the Black Sea and satellite data are highly desirable. The interest of micro-wave sensors for the verification of numerical weather and wave predictions models has been pointed out in numerous studies. A research project in this field has been started (primary investigator J.-M. Lefevre from Météo-France, co-investigator A. Kortcheva form NIMH of Bulgaria), see <http://ers.esa-ao.org/bin/nav/projects>. The main objectives of the project are related to the use of ERS2 altimeter wind/wave data for the verification of the operational wave and atmospheric models, and for improving numerical wave forecasting in the Black Sea.

PART III A DESCRIPTION OF TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

The everyday application of IR, VIS and WV imagery is concentrated mainly on the improvement of the analyses of current synoptic situation and short range forecasting as well as the provision of some severe weather warnings.

PART IV A BRIEF DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4.1 A PDUS (UKW-Technik Electronic GmbH, Germany) is used for reception and interactive processing of HRI Meteosat data.

4.2 Interactive imagery analyses is made for the purposes of weather forecasting using a PC-Workstation. Software enables the creation and display of images of special formats, transform into a polar sterographic projection, examine and animate satellite images, etc.

4.3 A UNIX Server is used for processing and archiving HRI Meteosat data for operational and research purposes. The UNIX connection enables the forecasters of the Central Forecasting Bureau of NIMH to have immediate access to data processing products.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5.1. The reception and use of HRI Meteosat data will be continued to the end of Meteosat Transition Programme (MTP).

5.2. After the end of MTP (at least to 2003), if funds are available, NIMH is intending to be equipped with Low Rate Image Transmission (LRIT) and/or High Rate Image Transmission (HRIT) stations for reception of Meteosat Second Generation (MSG) data and products.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATION, INCLUDING PERFORMANCE STATISTICS

No validation and verification of satellite data and derived products is made at NIMH

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND NAMES OF SCIENTISTS IN CHARGE, ETC.)

7.1. Publications

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7.2. Names of scientists in charge

Assoc. Prof. Dr Latin Latinov	-	Head of Department Weather Forecasting
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CANADA

(Meteorological Service of Canada and other components of Environment Canada)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 Satellite R&D activities deal with the atmosphere, the cryosphere, water, and the land surface environment. Components of the network include the Canadian Meteorological Center (CMC), the Canadian Ice Service (CIS), the Climate Research Branch (CRB), the Air Quality Research Branch (ARQB), the National Water Research Institute (NWRI), and Natural Resources Canada (NRC).

1.2 Potential of RADARSAT data continued to be exploited in many research projects related to ice, water and soil moisture. The CRYSYS programme continued to provide a focus for many studies of the cryosphere system, with important applications of RADARSAT and SSM/I data, and the establishment of a WEB site for dissemination of cryosphere information. Methods to map snow extent, snow water equivalent, glacier and sea ice continued to be important focus. CMC, CIS, NWRI and CRB contributed to an increased research effort on Canadian water bodies in relation to their distribution, temperature, seasonal ice cover, and biology. ARQB was active in the development of instruments, satellite payloads and data assimilation methods to extract information about the chemical structure of the atmosphere.

1.3 R&D on applications of satellite technology to environmental issues is ongoing in two main research areas. The first is the application of remote sensing technologies for environmental monitoring. The second is the application of remote sensing technologies in hydrologic modelling. Both of these research directions are leading to applied information technologies which will use environmental remote sensing satellites for operational monitoring and/or modeling. The emphasis over the last few years has been on multi-sensor approaches.

1.4 The research on the variational analysis system formulated on model coordinates that had been initiated several years ago was completed and implemented in June 2000 at CMC. Since 27 September 2000, the operational 3D-Var system at CMC incorporates automated aircraft observations, (ACARS and AMDAR data), as well as satellite radiances from NOAA-14 TOVS and NOAA-15 ATOVS instead of the NOAA-14 SATEM data (temperature profiles derived from radiances). CMC also operated the Volcanic Ash Advisory Centre Montréal, one of the 9 VAAC worldwide.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Numerical Weather Prediction

2.1 The research on the variational analysis system formulated on model coordinates that had been initiated several years ago was completed and implemented in June 2000 at CMC (Chouinard *et al*. 1999, 2000). This was the first major revision of the 3D-Var since its implementation in June 1997 (Gauthier *et al*. 98).

2.2 Research, that has been ongoing for many years at CMC on the direct assimilation of TOVS radiances, was completed with the introduction of processed level-1b radiances into the operational system in September 2000. In preparation for the higher volume of data from future orbiters, and in order to take control of the processing of satellite data prior to assimilation, we have developed and tested a system that can ingest raw level-1b radiances. The quality control and bias correction procedure of the level-1b system has been completely redesigned. The current operational use of satellite data is limited to microwave channels but research mode tests have started with the introduction of water sensitive infrared channels to alleviate some of the problems with the moisture analysis. All the above should be ready in the next year and will be implemented in the operational suite at CMC. (C. Chouinard, ARMA, Hallé, CMC, Garcia, MRB)

2.3 In preparation for future high-resolution instrument data (AIRS, IASI), research has begun in the processing, quality control and monitoring of simulated high-resolution radiance data in a high-resolution experimental forecast/analysis system with extended top boundary to accommodate the assimilation of the very high peaking channels of these instruments. (C. Chouinard, ARMA, Garand, Wagneur, Turner, MRB)

2.4 Using synthetic brightness temperatures (Tb), Deblonde (2001a) studied the direct assimilation of Tb (over the open oceans) from the DMSP SSM/I and SSM/T-2 passive microwave instruments in a one dimensional (1D-Var) assimilation system (Phalippou,1996). In clear skies, it was shown that except for very dry profiles (total precipitable water, TPW < 5-6 kg m^{-2}), SSM/I Tb are superior to the SSM/T-2 Tb for the determination of TPW. Cloudy profiles should be filtered out. It was also shown that SSM/I 1D-Var retrievals of low wind speeds are erroneous (< 2-3 ms^{-1}) and so are retrievals of low cloud liquid water path (CLW < 0.1 kgm^{-2}). When both SSM/I and SSM/T-2 Tb were assimilated simultaneously (in collocation) in the 1D-Var system, the retrievals of TPW, surface wind speed (SWS) and CLW were very similar to those when only SSM/I Tb were assimilated. However, the SSM/T-2 Tb also provided specific humidity information in the upper troposphere.

2.5 To model the brightness temperature at the top of the atmosphere, the apparent surface temperature needs to be known accurately for window channels (channels that see the surface). The modelling of the surface apparent temperature at microwave frequencies is complex and requires a considerable amount of computer time. A fast model of emissivity including an effective down-welling Tb was developed by S. English (FASTEM2), and Deblonde added an approximation (Deblonde and English 2000) to allow its inclusion in the RTTOV (radiative transfer TOV) code. An extensive report on the evaluation of FASTEM and FASTEM2 for NWP has been written (Deblonde 2000), and another one was also written on the specific usage of FASTEM2 for high incidence angles as is the case for the SSM/I (Deblonde 2001b). Deblonde has also worked on comparing aircraft observations (at AMSU frequencies) with radiative transfer simulations for the (December 1999) MOTH-Arctic campaign in collaboration with Dr Tim Hewison from the Met Office. The number of observations were limited and further collaboration is planned as new aircraft observations are made available on the subject.

2.6 A paper on the intercomparison of radiative transfer models (RTM) applied to HIRS and AMSU channels is in press (Garand *et al*, JGR, 2001). An extensive report focusing on the intercomparison of line-by-line models (LBL) was also produced (Turner, MSC internal publication). Work aiming at the direct assimilation of GOES radiances using the MSCFAST RTM is progressing with a passive monitoring of the channels, including surface emissivity effects. Similarly, adaptation of MSCFAST to AIRS channels (228 channel set for NWP) has started, and will be completed upon reception of LBL simulated radiances. (C. Chouinard, ARMA).

Atmosphere and clouds

2.7 Development of a data assimilation capability around the Canadian Middle Atmosphere Model (CMAM) using the 3D-Var package continues. Results from initial experiments assimilating tropospheric data from the global network of ground-based measurements have been compared with those from the Canadian operational forecast model (GEM). Attention is currently focused on a suitable choice of background error covariances for the entire CMAM domain (0 - 90 km). Future work will involve the assimilation of temperature and ozone data obtained from satellite measurements. Additions have been made to the 3D-Var system in order to assimilate middle atmosphere observations such as those from MLS (Microwave Limb Sounder), HALOE (Halogen Occultation Experiment) and HRDI (High Resolution Doppler Imager). Work on preparing a general infrastructure for assimilating line-of-sight integrated limb measurements has also been undertaken. (S. Polavarapu, S. Ren, Y. Rochon, D. Tarasick, MSC; D. Sankey, University of Toronto).

2.8 The SWIFT (Stratospheric Wind Interferometer For Transport studies) experiment has been selected as an additional payload for the Japanese GCOM-A1 satellite (launch 2007). SWIFT will produce about 7,000 profiles daily of horizontal winds, ozone and temperature in the 15-45 km altitude range, using an ozone thermal emission line. The data are expected to have a particular impact in the tropics, where winds are poorly known. (G. Shepherd, I. McDade and W. Gault, York University; N. Rowlands, G. Buttner and A. Bell, EMS Technologies; Y. Rochon and D. Tarasick, ARQB; P. Gauthier, RPN; others).

2.9 The Ozone Research with Advanced Cooperative LIDAR Experiment (ORACLE) proposes to measure ozone and aerosol vertical distribution via a spaceborne LIDAR. Preliminary Observing System Simulation Experiment (OSSE) studies have been undertaken to investigate different scenarios proposed for the design of the instrument, using 3D ozone fields from the GEM model (P.-A. Michelangeli, G. Brunet, P. Gauthier, RPN; T. McElroy, ARQB).

2.10 Since March 2000, the Canadian MOPITT instrument on NASA's Terra spacecraft has been gathering data on carbon monoxide and methane concentrations in the troposphere. Data assimilation experiments will be undertaken with these observations, using the GEM model as well as a chemical transport model and a Kalman filter scheme (R. Menard, RPN; Y. Rochon, ARQB).

2.11 Estimating cloud from satellites is still an inexact science. As part of the First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment-Arctic Cloud Experiment (FIRE.ACE), cloud particle phase, optical depth, and particle effective radius for both water and ice phase were obtained from the visible and thermal channels of the Advanced Very High Resolution Radiometer (AVHRR) on board the NOAA-14 polar-orbiting satellite (Key, 1995, 2000; Gultepe et al., 2001). The AVHRR has five channels centered at approximately 0.6, 0.9, 3.7, 11, and 12 µm (channels 1 through 5, respectively). Global Area Coverage (GAC) data acquired from overpasses nearest to 1400 local solar time (2400 UTC) were re-gridded to a five kilometer pixel size. The standard NOAA/NESDIS method (NOAA, 1991) is used for the calibration of the thermal channels (channels 3,4, and 5), with an additional correction for non-linearity.

2.12 Main processing aspects consist in cloud detection, the determination of the cloud particle thermodynamic phase (water or ice) and the cloud optical depth. Currently, LANDSAT observations collected during the Alliance Icing Research Study (AIRS) and FIRE.ACE are being analyzed for cloud microphysical characteristics. Retrieval of cloud microphysical parameters from satellites and comparisons with *in situ* measurements is the main research area, and further analysis will be needed (I. Gultepe and G. Isaac, Cloud Physics Research Division).

Cryosphere

CRYSYS: The Cryosphere System in Canada

2.13 CRYSYS is an Interdisciplinary Science Investigation (IDS) in the NASA Earth Observing System Program, hosted and funded by Canadian agencies and universities, and led by the Meteorological Service of Canada (Goodison *et al*, 1999). CRYSYS investigations utilize remote sensing, modelling, field studies and data integration to provide improved capabilities for monitoring the state of the cryosphere, and greater understanding of cryospheric processes and variability. CRYSYS is currently supporting research on the development and validation of satellite-based approaches for monitoring several components of the cryosphere - snow water equivalent (SWE), frozen ground, lake ice (extent and freeze-up/break-up), sea ice and glaciers.

2.14 A sample of recent significant satellite-related accomplishments includes: application of RADARSAT-1 and SSM/I data to study the break-up, removal and subsequent reforming of decades-old sea ice plugs in the Canadian Arctic Islands during the extreme warm summer of 1998 (Jeffers *et al*, 2000); application of RADARSAT-1 for detecting the onset and areal coverage of melt ponds (Yackel and Barber, 2000); application of SAR data for monitoring ice freeze-up/break-up and related processes of subarctic lakes (Duguay *et al*, 2000); investigation of the influence of sensor overpass time on the derivation of snow water equivalent from SSM/I data (Derksen *et al*, 2000); the potential for monitoring wet snow with RADARSAT-1 (Baghdadi *et al*, 2000); potential and limitations of RADARSAT-1 for glacier mass balance monitoring (Demuth and Pietroniro, 1999); application of *in situ* and satellite-derived snow cover data to reconstruct NH snow cover extent variations (Brown, 2000). Further details on CRYSYS research projects and examples of products can be obtained from the CRYSYS website (http://www.crysys.uwaterloo.ca).

2.15 In 1999, a State of the Canadian Cryosphere (SOCC) website (http://www.socc.uwaterloo.ca) was established by the CRYSYS project to disseminate up-to-date information on the current state of the cryosphere in Canada, including documented variability and changes, anomalies, and future predictions. Satellite imagery and derived products document the current state of cryospheric parameters including: snow cover extent, regional snow water equivalent, Arctic sea ice extent and animations of daily sea ice motion for Canadian regions. (CRYSYS contacts: B.E. Goodison and R.D. Brown, CRB)

Snow Cover Research using SSM/I Data

2.16 Algorithm development research has continued using SSM/I passive microwave satellite data for the determination of snow water equivalent (SWE), snow extent and snow state (wet/dry) for different landscape regions of Canada (e.g., prairie, boreal forest, tundra). Algorithm development has been focused on the following Canadian study sites: Arctic islands (in collaboration with McMaster University), Quebec tundra (in collaboration with Université du Québec; see De Sève *et al*, 1999), Mackenzie River Basin (contribution to GEWEX), southern Ontario, and western Canada boreal forest. Walker and Goodison (2000) provide a summary of Canadian accomplishments and challenges in passive microwave SWE determination. Weekly SWE maps for the Canadian prairie region have been produced using SSM/I each winter since 1989; recent enhancements to the these products are the incorporation of new algorithms for the boreal forest areas (starting with 1999/2000 winter) and “deviation from normal SWE” products that are based on a 10 year average of SSM/I-derived SWE conditions (see Piwowar *et al*, 1999). The temporal and spatial variability in prairie snow cover has been investigated using principal components analysis of SSM/I derived SWE imagery to identify dominant patterns and potential relationships with atmospheric circulation (see Derksen *et al*, 2000). Airborne microwave radiometers are flown each winter to conduct special investigations in support of snow cover algorithm development and validation with a focus on the influence of snowpack properties and structure on microwave emission and seasonal variability. During the 1999/2000 winter, flights were conducted along lines in the Grand River basin in southern Ontario to investigate the basin-scale variations in snow cover and scaling to satellite (SSM/I) resolutions. This research is a major component of *CRYSYS: The Cryosphere System in Canada*, a Canadian project within NASA's Earth Observing System (EOS) Program. (A.E. Walker, CRB)

Investigation of lake-ice freeze-up and break-up processes using SSM/I data

2.17 Since 1992, SSM/I 85 GHz data have been acquired in near-real-time for the purpose of investigating the spatial and temporal variability ice formation and break-up over large lakes in

Canada, with a focus on Great Slave Lake, Great Bear Lake and the Great Lakes. Lake ice freeze-up and break-up time series (1987 to 1999) have been compiled for Great Slave and Great Bear Lakes using historical SSM/I data available from the National Snow and Ice Data Center (Boulder, Colorado) in EASE-Grid format. These time series and related analysis of spatial and temporal variations in ice formation and decay over the lakes are a contribution to the Mackenzie GEWEX Study (MAGS), and support lake energy balance studies and regional climate modelling activities by MAGS investigators. Passive microwave lake ice research activities are also being conducted as part of *CRYSYS: The Cryosphere System in Canada*, a Canadian project within NASA's Earth Observing System (EOS) Program. Research topics include atmospheric effects on 85 GHz lake ice retrieval, lake ice seasonal brightness temperature variations, and the effect of snow cover on lake emission with data acquisition using ground-based, airborne and satellite radiometers. (A.E. Walker, CRB)

Glacier snow line mapping using SAR imagery for applications in glacier mass-balance and hydrology

2.18 This work demonstrates the effectiveness of ERS-1 and RADARSAT synthetic aperture radar (SAR) imagery for mapping movement of the transient snow line in a temperate glacier basin, showing that this method is reliable for applications in alpine/glacier hydrology. Effective use of this technique requires us to normalise the topographically induced distortions (radiometric and geometric) inherent in SAR imagery of rugged terrain and delineate the snow line in the normalised imagery. The radiometric distortions are normalised with a cosine correction and the image texture is enhanced. To minimise geometric distortions and georeference the imagery, each cosine corrected SAR image is ortho-rectified to an error of approximately 60 m using a DEM and satellite orbital and ephemeris data. A supervised classification is performed on the ortho-rectified imagery to map the spatial distribution of snow and glacial ice within the basin. The visual boundary between the wet snow and glacier ice surfaces on the ortho-rectified images is within 75 m horizontally and 50 m vertically of the snow line vectors obtained from field data. The glacier boundary is also discernible to within 75 m of the surveyed glacier outline. Several isolated bare ice areas on the lower glacier give a low return, similar to wet snow, resulting in some confusion between glacier ice and wet snow. Despite the localised confusion between glacier ice and wet snow, the glacier snow line is easily identified and can be mapped in a timely manner using SAR imagery. Applications in glacier hydrology illustrate that this method is reliable and may supplement the glacier mass-balance information perhaps helping to extend mass balance analysis to other glaciers. Work on this topic will continue. (M. Demuth, Natural Resources Canada, Terrain Sciences Division and A. Pietroniro, NWRI)

Hydro-ecological Response of Eastern Flowing Rivers in the Canadian Rocky Mountains to Climate Variations(Airborne LIDAR, Landsat TM and SAR Imagery)

2.19 In an effort to use glacier cover variations and seasonal/annual mass balance assessments as hydrological and ecological indicators of the impacts of regional and global climate variation, NWRI is using remote sensing (precision aerial photography, visible LANDSAT TM and C-Band Synthetic Aperture RADARSAT) along with scanning laser altimetry (LIDAR) to delineate modern and historical limits of glacier cover. This work, coupled with a national and international network of site-specific field studies, will play a significant role in a broad variety of climate change/water resource related assessments, including: (i) determination of the energy fluxes associated with recent and past-century glacier melting in the Canadian Rocky Mountains as an indicator of global change; (ii) impacts of short-term and historical-scale variations of glacier extent on hydrologic and ecological characteristics of the eastern-slope rivers (critical habitat for Bull Trout and Pygmy Whitefish); (iii) determination of the glacier contributions to live storage and annual through-put for eastern slope hydroelectric reservoir facilities; (iv) the characterisation of recent and Little Ice Age variability of net annual accumulation (precipitation) for the easternslopes- the “*Water Tower*” of the Canadian prairie. (M. N. Demuth, Natural Resources Canada, Terrain Sciences Division and A. Pietroniro, NWRI)

Current research and development in the operational monitoring of sea ice

2.20 In the future, CIS will continue to rely on satellite-borne SAR as the prime data source for the monitoring of ice conditions across Canadian marine areas. In preparation for the launch of RADARSAT-2 and other advanced radar satellites (e.g. Envisat, ALOS), CIS is actively investigating the utility of multichannel (i.e., multiple polarization and frequency) SAR data for sea ice and iceberg detection. Towards this, research datasets are being collected and analysed to determine the optimal approach to the presentation and analysis of these new SAR datasets.

2.21 With the assistance of academic and government research facilities, the Canadian Ice Service is developing the ability to estimate the state of sea ice decay (and by proxy ice strength) using satellite SAR and visible/infrared/thermal data. Ice decay information will be used to predict ice break up and to regulate/assist the operation of ships in Arctic spring/summer ice regimes.

2.22 The Canadian Ice Service contributes to the monitoring of icebergs in Canadian and international waters. Algorithms to extract iceberg characteristics and position from RADARSAT-1 data are being developed and evaluated for implementation in CIS’s Berg Analysis and Prediction System (BAPS). (De Abreu, CIS)

Use of Satellite Data for Monitoring Large Scale Sea Ice Changes and sea ice-climate interaction

2.23 Analysis of variability and trends in sea ice cover in Canadian waters using passive microwave SSM/I satellite sensor are done and compared with changes in large scale climate variables mainly temperature, wind and atmospheric circulation. These trends and changes are then compared with projected changes in climate made by the Canadian Global Climate Model. Most recent analysis finds little or no long-term trend to less sea ice cover over the eastern Canadian Arctic and east coast and decreases in the western Canadian Arctic and Hudson Bay. This is consistent with temperature trends over Canada. However, GCM sea ice cover projections are still too preliminary to compare with observed sea ice trends. The major retreat in sea ice cover in the summer of 1998 (Maslanik *et al*, 1999) and the removal of decades-old sea ice from the Canadian High Arctic Islands has also been studied using both *in situ* observations and satellite imagery, especially RADARSAT data (Jeffers *et al*, 2000). Despite the record light sea ice cover in 1998 there is no long-term trend to less sea ice in the Canadian Arctic Islands. This is attributed to large scale sea ice dynamics caused by wind, which continually pushes the pack ice from the Arctic ocean up against the Canadian Arctic Islands replenishing any sea ice which is removed by summer melting.

2.24 Satellite passive microwave (SSM/I) and AVHRR infrared are used to study atmosphere-ice ocean interaction events to determine the importance of lead formation and ocean refreezing in the surface energy and heat budget of ice-covered arctic ocean (Agnew et al., 1999; Shokr *et al*, 1999).

Water and land

Monitoring Water Quality and Climate Change

2.25 The optical complexities of natural waters resulting from their proximity to land masses (Case 2 waters) have rendered methodologies developed for mid-oceanic (Case 1) waters inapplicable to the generation of near-surface chlorophyll concentration maps for inland and coastal waters. The bio-optical models (based on the specific inherent optical properties of indigenous organic and inorganic aquatic matter) developed at NWRI (e.g., Bukata *et al,* 1997) have enabled the simultaneous extraction of the co-existing concentrations of colour-producing agents (CPA), namely chlorophyll, suspended sediments, and dissolved organic matter, from a single remote measurement of water colour. The models are particularly attractive for use with MERIS and the upcoming hyperspectral satellite missions such as ARIES. Since dissolved organic matter and chlorophyll concentrations may be *simultaneously* estimated, time series monitoring of aquatic bioproductivity, and its response to climate change stressors, becomes a possibility. Recently, R.P. Bukata, as a member of an international expert panel assembled by the International Ocean-Colour Committee (IOCCG), co-authored a major report (IOCCG 2000) summarizing state-of-the-art remote sensing in inland and coastal waters and directed towards Space Agencies, scientists, students, managers, and policy makers. (R.P. Bukata, J.H. Jerome, NWRI)

Environmental Monitoring of a Freshwater Inland Delta

2.26 The Peace-Athabasca Delta is one of the world's largest inland freshwater deltas. Three separate flow systems continually feed alluvial deposits to the delta resulting in network of complex surface flow paths. In many of the restricted flow zones, flooding is the only means of receiving fresh-water inputs. Because these flooding events are very important for the overall health of the delta ecosystem, proper assessment of general hydrologic conditions within the delta are a necessary component for environmental monitoring of this region. This work examined the development of an extensive historical spatial database for the region using a time series of Landsat MSS, Landsat TM and SPOT data to document changes from 1974 to 1990. Results show that historic LANDSAT data are a reliable source for estimating changes in the hydrologic regime, providing a strong foundation for future studies in this region. The advent of a flood during the spring of 1996, the first since 1974, afforded the opportunity to examine flood extent using the RADARSAT satellite. Qualitative assessment of the 1996 flood imagery obtained from the RADARSAT sensor demonstrated the utility of this sensor for the purposes of flood monitoring. More recent work has demonstrated that the extent of standing water in the Peace-Athabasca Delta can be mapped during spring and summer conditions using a combination of RADARSAT and SPOT imagery. The RADARSAT signal could penetrate vegetation and detect standing water beneath a layer of willows, grasses or sedges at incidence angles between 20 and 31degrees. Canopy attenuation on the radar signal was higher during the summer period when the vegetation layer was dense. SPOT scenes alone achieved slightly better classification results compared to the RADARSAT scenes, although the difference was only significant in the summer period. The areas of dry deciduous vegetation, which was problematic for the RADARSAT channels, had very distinct reflectance values in the SPOT channels. The SPOT scenes could distinguish the dry deciduous vegetation from flooded vegetation but could not discriminate between flooded and dry willows, grasses or sedges when the vegetation layer was relatively dense. Results show that classification of the RADARSAT channel in combination with the SPOT channels achieves significantly better results compared to when the two image types are classified separately. This demonstrated the utility of a multi-sensor approach to environmental monitoring. (A. Pietroniro, NWRI).

Mackenzie GEWEX STUDY (MAGS)

2.27 As a component of the Global Water and Energy experiment (GEWEX), the Mackenzie GEWEX STUDY (MAGS) is focusing on understanding and modelling the fluxes and reservoirs governing the flow of water and energy into the Mackenzie River Basin. Further details on MAGS and data products can be found on the MAGS web site (http://www.msc-smc.ec.gc.ca/GEWEX/MAGS.html). Given Canada's vast data-sparse areas, the satellite-based remote sensing studies of surface properties, clouds, snow cover, and solar radiation budget are a critical component of the MAGS strategy for model set-up and validation. Various data based on GOES, NOAA AVHRR, LANDSAT, SSM/I and results of the RAINSAT algorithm were assembled during CAGES, a data intensive period from June 1998 to October 1999. AVHRR data was studied in relation with setting-up boundary conditions with the Canadian land surface scheme (CLASS). This included an evaluation of the effect of sub-scale water body sizes and the also the determination of seasonal lake water temperature variations (examples of products determined with this method is found on the MAGS web site:

http://www.msc-smc.ec.gc.ca/GEWEX/metadata/AVHRR/Products.html).

AVHRR/ScaRaB data were used extensively for radiation budget computations (Leighton *et al*, 2000). SSM/I derived snow water equivalent maps generated at CRB were used in diagnostic of basin average outputs from the Canadian Regional Climate Model. Other applications are given below. (N. Bussières, CRB)

2.28 A new approach for the application of remotely-sensed surface temperature data in the estimation of regional evapotranspiration has been tested. The method is based on a feedback relationship in which the surface temperature, observed using NOAA-AVHRR data, is used to obtain the vapour pressure deficit in the overlying air. The feedback relationship involved has been shown to be applicable above a wide range of natural surfaces ranging from bare soil to forest covers. This technique presents some distinct advantages over inverted energy balance method. Because the vapour pressure deficit of the air is derived from the satellite image, the method allows for the application of remotely-sensed data in conjunction with conventional evapotranspiration models and the application of such evapotranspiration estimates to hydrological models. To date, the method has been tested for the Canadian prairie and western boreal forest regions and also in the Gediz river basin in Turkey. Further testing involved the Mackenzie river basin (Granger and Bussières, 2000) and other northern regions. (R. Granger, NWRI)

2.29 A recent trend in hydrological model development is the coupling atmospheric and hydrologic models for both short-range forecasting, prediction in ungauged basins and for future-climate simulations. This has been a main focus of the hydrological modelling efforts in the Canadian GEWEX programme. The term “coupling” is used to imply any merger of existing atmospheric and hydrologic models. The common interface between the two families of models is the land surface and it is at this juncture that coupling with feedback to the atmosphere can occur. There are four levels of model coupling which have been established under the Canadian GEWEX programme. The first, “level 0” coupling, is the most commonly used interpretation of atmospheric-hydrologic coupling and involves no feedback to the atmospheric model. In contrast, the level 3 coupling involves the integration of both models with the common land surface scheme and full feedback between the land and the atmosphere. The MAGS experiment is focusing on coupling the Canadian Regional Climate model (RCM), the WATFLOOD hydrologic model and CLASS. Remote sensing should play an ever-increasing role in this new generation of hydrologic models. The most useful data set so far has for this purpose has been the land cover of these regions. The use of remotely sensed derived state variables such as precipitation, snow water equivalent or soil moisture in the context of these coupled modelling systems will be assessed. (A. Pietroniro, NWRI)

2.30 Radar satellite observations of Arctic tundra were acquired to test the use of multi temporal image sequences for hydrological monitoring in a permafrost environment. The image sequences were found to show the changing patterns of wet snow cover and soil moisture distribution. The images were acquired for the Trail Valley Creek basin, near, NWT. Methods of both single-image and multi temporal analysis were compared, using twenty five radar images acquired over two years. It was found that multi temporal radar could unambiguously separate the effects of partial-snowcover and soil moisture in the Arctic tundra. The procedure discriminated three soil moisture levels and five snow-cover levels. The soil moisture distributions were consistent with expected topographic effects. In addition, the radar backscatter from the basin was found to correlate with basin streamflow (r = +0.96, sig. 0.01%). Presumably, this is because radar backscatter is sensitive to the surface moisture content of those soils whose drainage is impeded in some way (e.g., by shallow permafrost). Single-image analysis was also tested for simple snow/no-snow discrimination. It was found that while wet snow distribution could be mapped using a single image, the snow cover was underestimated by 23% because of wet snow vs. dry soil confusion in mixed-pixels. Consequently, multi temporal imagery is preferred for mapping both wet snow cover and soil moisture distribution, in Arctic tundra. (A. Maxfield, NWRI)

Use of passive microwave data for soil moisture determination

2.31 Soil moisture has been identified as a significant weakness in climate, forecasting and hydrological models with land surface/atmosphere interaction schemes. A research program was recently initiated in the Climate Research Branch on the potential use of passive microwave data for soil moisture determination. The initial objective in this program has been to assess the potential of current satellite frequencies, specifically SSM/I, for surface soil moisture/wetness determination in Canadian regions using ground-based and airborne microwave radiometer measurements. Results have emphasized the limitation of high frequency sensors such as SSM/I for soil moisture applications with the presence of any form of vegetation. In 2000, the Climate Research Branch acquired two low frequency microwave radiometer systems (1.4 GHz single polarization and 6.9 GHz dual polarization) that have been installed on the Canadian National Research Council's Twin Otter aircraft (with previously installed 19.35, 37 and 85.5 GHz microwave radiometers). These radiometers will be flown starting in 2001 for soil moisture campaigns in Canada and the United States in support of research and satellite algorithm validation. (A.E. Walker, CRB)

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Improvements in the operational monitoring of sea ice

3.1 The Canadian Ice Service (CIS) developed a prototype sea ice break up warning service to northern communities in order to reduce the number of people stranded on breakaway ice floes in the spring. The service delivered ice advisories based on sea ice information extracted from RADARSAT and AVHRR data. Community clients have come to rely on the satellite information to support their on-ice activities (Figure 1).

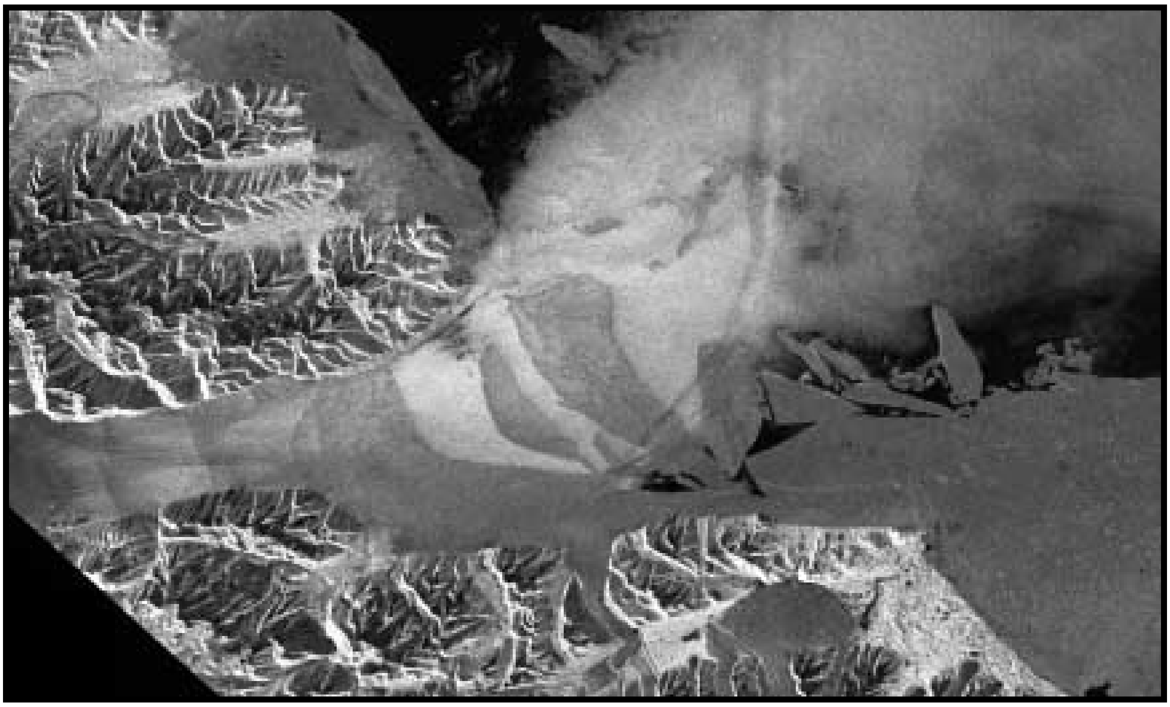

Figure 1. This subimage of a RADARSAT-1 Wide mode scene captured the destruction of the Pond Inlet ice edge on 4 July 2000. Using RADARSAT-1 and other satellite data, CIS predicted this break-up and advised community hunters to retreat from the ice edge two days prior to this event (Image Copyright 2000, Canadian Space Agency)

3.2 In order to improve CIS's ability to forecast ice freeze up and break up, a sea surface temperature product is being derived daily from NOAA AVHRR data and delivered to ice analysts. The products have improved ice forecasting and the tasking/ordering of RADARSAT-1 data.

3.3 Using wavelet compression technology, full scene, high resolution RADARSAT synthetic aperture radar (SAR) data is being sent efficiently to CIS clients over narrow band networks. This approach is now the default distribution method for satellite imagery to clients. (De Abreu, CIS)

Extracting marine winds from SAR data

3.4 Using a dedicated system (Ocean Monitoring Workstation – Satlantic Inc.) the Canadian Ice Service is routinely extracting information on marine winds (e.g., direction and speed) from its operational RADARSAT data stream for the Great Lakes and East Coast waters during the winter season. Image, graphical, and textual products are generated and forwarded to Canadian weather centres for evaluation and analysis as ancillary information for preparation of their forecast products. (De Abreu, CIS)

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

Numerical Weather Prediction

4.1 Since 14 June 2000, the operational 3D-Var system at the Canadian Meteorological Centre (CMC) is performed directly on the 28 eta vertical levels of the GEM model, rather than on the previous 16 standard pressure levels. This new version of 3D-Var uses a completely new set of model-error statistics derived from ensemble prediction of short-term lagged forecasts (NCEP

24-48 method) including better balance constraints. In addition, since 27 September 2000, the 3D-Var also incorporates automated aircraft observations, (ACARS and AMDAR data), as well as satellite radiances from NOAA-14 TOVS and NOAA-15 ATOVS instead of the NOAA-14 SATEM data (temperature profiles derived from radiances). SATOB winds and HUMSAT profiles (locally produced GOES 8 and GOES 10 moisture profiles) are also assimilated. (G. Verner, CMC)

4.2 As part of its Volcanic Ash Advisory Centre responsibilities, the Canadian Meteorological Centre uses real time, full resolution Global Area Coverage (GAC) AVHRR from NOAA-14 and -15, as well as GOES 8 and GOES 10 data to identify volcanic ash clouds in the atmosphere and to track their displacement. The difference of the brightness temperature between bands 4 and 5 is used for this purpose. The data are obtained from the CMC operational GOES and DOMSAT direct readout stations. (M. Jean, CMC)

4.3 The Canadian Meteorological Centre in Dorval receives the full global set of SSM/I data in level 1B format over a dedicated link between Montreal and the US Navy Ice Centre (NIC) in Washington, thanks to the cooperation of NOAA/NESDIS and the NIC. These data are used on an operational basis to produce global ice analyses for NWP. Ice coverage data for major lakes and coastal regions, produced by the CIS (see section on operational ice monitoring system) are also included in the operational ice analysis. (J. Hallé, CMC)

4.4 Sea surface temperature (SST) retrievals from the NOAA AVHRR data are used in the operational SST analysis. The retrievals, commonly called MCSSTs, are produced by NOAA/NESDIS, averaged onto a 2.5 degree grid and sent out on the GTS once per day. In addition, NOAA AVHRR HRPT data are received and processed in Edmonton, Alberta, to compute surface temperatures for major lakes in Canada. These are then transmitted to the CMC where they are used operationally in the SST analysis for NWP. (B. Brasnett, CMC)

4.5 Environment Canada makes extensive use of data from meteorological satellites in its regional weather forecast offices. EC forecasters use GOES and HRPT imagery in preparing severe weather warnings, aviation forecasts, and numerous other products. To provide these data to its forecasters EC operates 18 GOES receiving stations (one in every forecast office) and 3 POES-HRPT stations.

RAINSAT

4.6 GOES data and weather radar data are used in the RAINSAT algorithm. This is a bi-spectral technique that uses the visible and infrared bands of the GOES satellite and radar calibration to estimate precipitation. In practice, a climatological look-up table is built over regions covered by radar. The technique serves to extend the estimation of precipitation over vast regions that are not gauged by radar or weather stations. Precipitation rates estimated from satellite are validated and verified with weather radar data. The infrared estimates of cloud top heights are verified with various data types. Work continues towards improving the detection of precipitation, by including other bands from GOES and NOAA AVHRR. In weather forecast operations, all available bands from GOES and NOAA satellites serve to determine the cloud type, the location and development of weather systems, and to keep track of convective clouds and low level stratiform clouds. (Viateur Turcotte, Québec region weather services, MSC).

Operational Ice Monitoring System

4.7 RADARSAT SAR imagery is the primary data source used for sea ice monitoring at the Canadian Ice Service. Data received by the Prince Albert, Saskatchewan and Gatineau, Quebec receiving stations are processed at the Canadian Data Processing Facility (CDPF) in Gatineau, and delivered to CIS via a T1 link, typically in 2-3 hours from satellite acquisition. By the end of 2000, the CIS was using over 4000 images annually (primarily ScanSAR). Additionally, ERS SAR data are acquired from the CDPF. SSM/I and OLS data from the U.S. DMSP satellites are also received from NOAA in Washington via a dedicated fractional T1 link. NOAA AVHRR data are received from Atmospheric Environment Service HRPT stations in Edmonton, Alberta and Halifax, Nova Scotia via dedicated 56 kbps links. All these data are automatically processed and subsequently analysed and interpreted on advanced image analysis and GIS workstations by trained analysts. A variety of image and chart products are produced and subsequently distributed to Canadian Coast Guard icebreakers and ice offices via Inmarsat, Internet/Web, and land lines. These products are used by the Coast Guard to assist in vessel management and tactical ship navigation. Additionally, these and other specialized products are made available to a variety of marine clients numbering over 300.

4.8 In addition to sea ice monitoring, the CIS is using RADARSAT to monitor, in season, over 120 inland Canadian lakes to ascertain weekly total ice coverage. These data are provided to the Canadian Meteorological Centre in Montreal for input to heat budget calculations required for the national weather prediction modelling program. Additionally, lake freezeup/breakup dates are derived and archived for climate change monitoring. (De Abreu, CIS)

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

Numerical Weather Prediction

5.1 The assimilation of ATOVS radiances in the CMC 3D variational analysis will be modified to use level 1B format data from Nesdis. (C. Chouinard, ARMA, J. Hallé, CMC)

5.2 A new version of the CMC 3D-Var is now nearing completion and will be implemented later in 2001. It will assimilate temperature data rather than geopotential, as well as surface temperature and surface pressure. A revised quality control scheme will be implemented at the same time (background check and variational quality control). Development work is also being carried out on assimilation of a number of satellite data types into NWP systems at the CMC (ATOVS level 1B, Scatterometer winds, QuikScat-ERS, GOES radiances, SSM/I IWV, AIRS). This work is expected to result in upgrades to the operational systems in 2001 and 2002. (C. Chouinard ARMA, G. Verner CMC)

5.3 In addition, the incorporation of retrievals of SST from ATSR (ERS-2) into the operational SST analysis is under development. The spatially-averaged sea-surface temperature product with a resolution of 0.5 degrees has been tested with encouraging preliminary results. (B. Brasnett, CMC).

Atmospheric Chemistry Experiment (ACE)

5.4 The Atmospheric Chemistry Experiment (ACE) mission will be launched on the Canadian SCISAT-1 in June 2002. It will carry two instruments: the Fourier Transform Spectrometer (ACE-FTS) instrument and the Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (MAESTRO) instrument. Both instruments operate by solar occultation; the former will measure the profiles of a large number of chemical species while the latter will provide high-resolution data on the atmosphere and precise profiles of ozone concentration (P. Bernath, University of Waterloo, Mission Scientist; T. McElroy, C. McLinden, J. Kerr, ARQB; many others).

Cryosphere and its response to Climate Change (Canadian Space Agency)

5.5 “Cryosphere and its response to climate change” is a new project within the Surface Environment component of the Earth and Environment Service Line of CSA’s Canadian Space

Plan. This new initiative is led by the Meteorological Service of Canada (Environment Canada). The planned 3-year project was initiated in mid-2000.

5.6 The project aims to develop, demonstrate and validate on an operational basis the use of EO data and information to generate products for the assessment and monitoring of the cryosphere for environmental prediction, ecosystem processes and the interaction between the changing climate and the cryosphere, in Canada and globally. This requires data from many different satellite sensors capable of providing a wide range of temporal and spatial resolutions. Further development of SAR capabilities using Radarsat 1 and 2 for cryospheric science and operations (e.g., CRYSYS research on the development and operational use of Radarsat SAR to derive snow water equivalent for hydro power generation) and of higher resolution passive microwave data (e.g. AMSR-E for SWE and lake ice) are of special interest. Initiatives involve collaboration between government, university and industry scientists and practitioners (not just a single government department).

5.7 The results will: provide space-based monitoring of the cryosphere and its changes, which cannot be replicated in the required space or time resolutions by conventional information; provide data sets which will be the basis for studies on cryosphere/climate interactions, oceanic thermohaline circulation, modelling of land surface processes, including the biosphere, release of greenhouse gases such as methane and CO_2 with thawing permafrost etc.; and, provide timely and consistent information of cryospheric components which will allow regional and national planning with strategic decision making for environmental prediction, disaster management and mitigation. (B. Goodison, CRB)

Contribution to WMO/WCRP's "Climate and Cryosphere" Project (CliC)

5.8 CRYSYS and the CSA Cryosphere and Climate project will make significant Canadian contributions to the new Climate and Cryosphere (CliC) Project of the World Climate Research Program whose science and coordination plan was recently approved. The key scientific questions for WCRP-CliC are improved understanding of physical processes and feedbacks, improved representation of cryospheric processes in models, and assessment and quantification of impacts of past and future climatic variability and change on components of the cryosphere. A critical fourth issue identified by CliC was the need to "enhance the observation and monitoring of the cryosphere in support of process studies, model evaluation, and change detection." This is a cornerstone of both of the Canadian cryosphere efforts. The importance of remote sensing receives special consideration in the CliC science plan. Remotely sensed cryospheric change indicators are particularly valuable in regions where conventional observations are of short duration or completely lacking and where conventional observations may not have adequate temporal or spatial integrity. (B. Goodison, CRB)

New satellite systems

5.9 Many new generation satellites are being considered, for example, the ARIES hyperspectral mission for inland water quality. ARQB will contribute to the ACE mission to be launched on the Canadian SCISAT-1 in June 2002. For soil moisture, we are considering the AMSR sensors scheduled for launch on EOS Aqua and ADEOS-II platforms. New initiatives also include using TERRA/MODIS snow cover and other products, for cryosphere studies, and in the Global Hydrology Project (GHP) Coordinated Enhanced Observing Period (CEOP). (N. Bussières, CRB)

5.10 Development of RADARSAT-2, the successor to Canada's RADARSAT-1, is currently underway, being led by MacDonald Dettwiler Ltd., in partnership with the Government of Canada. After its launch in late 2003, RADARSAT-2 will be the most advanced SAR satellite in space, offering increased resolution and fully polarimetric capabilities. The Canadian Ice Service is contributing to the development of the mission ground segment, product specification and is expected to be one of the largest users of RADARSAT-2 data. In the event of a gap between the demise of RADARSAT-1 and the launch of RADARSAT-2, the Canadian Ice Service will utilize Envisat ASAR data received and processed at Canadian ground facilities. (De Abreu, CIS)

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6. The CIS regularly monitors the ordering and acquisition of the RADARSAT data used in its daily operations. Over the period 1998-2000, the CIS successfully acquired 11, 435 RADARSAT scenes, approximately 92% of all scenes ordered. The average time from RADARSAT-2 image acquisition to its transfer to CIS Operations was 2 hours and 41 minutes. (De Abreu, CIS)

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Acronyms

Organizations / locations

ARQB	Air Quality Research Branch, MSC
ARMA	Data Assimilation and Satellite Meteorology Division, MSC
CCRS	Canadian Centre for Remote Sensing
CDPF	Canadian Data Processing Facility
CIS	Canadian Ice Service, MSC
CMC	Canadian Meteorological Centre, MSC
CRB	Climate Research Branch, MSC
CSA	Canadian Space Agency
EC	Environment Canada
MSC	Meteorological Service of Canada, EC
MRB	Meteorological Research Branch, MSC
NCEP	National Centers for Environmental Prediction
NESDIS	National Environment Satellite, data, and Information Service
NIC	US Navy Ice Centre
NOAA	National Oceanic and Atmospheric Administration
NRC	National Resources Canada
NWRI	National Water Research Institute, EC
NWT	North Western Territories
RPN	Division de Recherche en Prévision Numérique, MRB

Other

ACARS	Aerodynamic Communication and Recording System
ACE	Atmospheric Chemistry Experiment
ACE-FTS	ACE Fourier Transform Spectrometer
AIRS	Alliance Icing Research Study
ALOS	Advanced Land Observation Satellite
AMDAR	Aircraft Meteorological Data Relay

AMSR	Advanced Microwave Scanning Radiometer
AMSR-E	Advanced Microwave Scanning Radiometer (EOS Version)
AMSU	Advanced Microwave Sounding Unit
ARIES	Australian Resource Information and Environment Satellite
ASAR	Advanced Synthetic Arperture Radar
ATOVS	Advanced TIROS-N Operational Vertical Sounder
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High-Resolution Radiometer
BAPS	Berg Analysis and Prediction System
CAGES	Canadian GEWEX Enhanced Study
CEOP	Coordinated Enhanced Observing Period
CLASS	Candian Land Surface Scheme
CliC	Climate and Cryosphere (project)
CLW	cloud liquid water
CMAM	Canadian Middle Atmosphere Model
CPA	color-producing agents
CRYSYS	the cryospheric system to monitor global change in Canada
DEM	Digital Elevation Model
DMSP	Defense Meteorological Satellite Program
DOMSAT	a collection of telecommunication satellites operated by GE/RCA
EOS	Earth Observing System
ERS	European Remote Sensing Satellite
FASTEM	fast microwave surface emissivity model
FIRE.ACE	First International Satellite Cloud Climatology Project Regional Experiment-Arctic Cloud Experiment
GAC	Global Area Coverage
GCM	General Circulation Model
GCOM	Global Change Observing Mission
GEM	(Canadian) Global Environmental Multiscale Environmental Model
GEWEX	Global Energy and Water cycle Experiment
GHP	Global Hydrology Program
GOES	Geostationnary Operational Environmental Satellite
GTS	Global Telecommunication system
HALOE	Halogen Occultation Experiment
HIRS	High Resolution Infrared Radiation Sounder
HRDI	High Resolution Doppler Imager
HRPT	High Resolution picture transmission
HUMSAT	Humidity Satellite retrieval algorithm
IDS	Interdisciplinary Science Investigation
IOCCG	Interdisciplinary Science Investigation
ISCCP	International Satellite Cloud Climatology Project
LANDSAT	Land Remote Sensing Satellite
LBL	line-by-line (models)
LIDAR	light detection and ranging
MAESTRO	Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation
MAGS	Mackenzie GEWEX STUDY
MLS	Microwave Limb Sounder
MOPITT	Measurements of Pollution in the Troposphere
MSCFAST	MASC Fast Radiative transfer model
MSS	Multispectral Scanner
NWP	Numerical Weather Prediction
OLS	Operational Linescan System
ORACLE	Ozone Research with Advanced Cooperative LIDAR Experiment

OSSE	Observing System Simulation Experiment
POES-HRPT	Polar Orbiting Environmental Satellite - High Resolution Picture Transmission
QuikScat	Quick Scatterometer
RADARSAT	Canadian RADAR satellite
RAINSAT	Satellite Rainfall Algorithm
RCM	Regional Climate model
RTM	radiative transfer model
RTTOV	radiative transfer TOV code
SAR	synthetic aperture radar
SATEM	satellite temperature profile
ScanSAR	Scanning Synthetic Aperture Radar
ScaRaB	Scanner for Radiation Budget
SCISAT	(Canadian) SCIence SATellite
SOCC	State of the Canadian Cryosphere
SPOT	Satellite pour l'Observation de la Terre
SSM/I	Special Sensor Microwave Imager
SSM/T-2	Special Sensor Microwave
SSM/I IWV	SSM/I integrated water vapor
SST	Sea surface temperature
SWE	Snow Water Equivalent
SWIFT	Stratospheric Wind Interferometer For Transport studies
SWS	surface wind speed
TERRA/MODIS	EOS TERRA satellite/Moderate-Resolution Imaging spectoradiometer
TM	Thematic Mapper
TOVS	TIROS Operational Vertical Sounder
TPW	total precipitable water
VAAC	Volcanic Ash Advisory Centre
WATFLOOD	University of Waterloo Flood forecasting and hydrologic model
WCRP	World Climate Research Program
WHYCOS	World Hydrological Cycle Observing System

CHINA, PEOPLE'S REPUBLIC OF

(National Satellite Meteorological Center)

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Applications

Snow Cover Remote Sensing with Multi-sensor Data

2.1 Snow cover is an important water resource on the Earth. It is a critical factor relating to climate and global change. In order to study and understand the impact of snow cover on climate and hydrologic budgets, it is necessary to have long-term information on the variation and distribution of snow cover.

2.2 Snow cover remote sensing has special meaning in China. Forty per cent (40%) of Chinese territory is grass covered, and nearly half of this grassland is pasture distributing mainly in Tibet, Qinghai, Xinjiang and Inner Mongolia areas where people lives on breeding animals, such as cattle and sheep, from which large amount of meat, milk and fur is produced. But frequent snow disasters during winter and early spring seasons bring serious damage to lives and properties of local people. Because of the sparse population and less developed communications in these areas, satellite remote sensing becomes the only way to provide information on snow, such as the extent of snow cover, the places where a snow disaster is likely to occur and the severity.

2.3 Since late 1980s, methods for snow cover remote sensing have been developed in NSMC. A great deal of information on snow is provided each winter. Since December 1996, an operational system for snow cover monitoring over China with NOAA/AVHRR data has been set up. Based on the analysis of the spectral characteristics between snow, cloud and other types of earth surface with AVHRR data, a multi-channel thresholds test method is worked out to separate snow from cloud. With a spatial resolution of $0.05°\times0.05°$, pixels covered with snow and the other land surface types are discriminated for China and the surrounding areas. By composite processing using satellite data from every ten days, a cloud free data set with the maximum snow cover information is able to acquire, and snow cover area in each province is calculated and analyzed.

2.4 Since the launch of FY1-C, NSMC has been calculating the snow cover information with the MVISR radiometer data. Based on the fact that snow reflects visible radiation more strongly than it does in the middle-infrared spectral regions, the Normalized Difference Snow Index (NDSI) is calculated from the reflectance of MVISR channel 1 and channel 6. This index is an effective discriminator for snow and cloud for the fact that the reflectivity of cloud remains high with MVISR channel 6, and drops nearly to zero with channel 1. FY1-C data played a very important role in snow disasters monitoring in Xinjiang and Inner Mongolia in winter 2000.

Fog Area Detection with Meteorological Satellite Data

2.5 Fog is a kind of weather phenomenon that has influences on traffic. The increasing traffic has raised high requirement for fog detection and forecasting. The distribution of meteorological observation network over land is insufficient to detect fog. Meteorological satellite has many advantages for fog detection.

2.6 During daytime, when it is free of high-level cloud, fog and low-level cloud are easily observed on the visible satellite imagery. Fog top is smooth, edge sharp but irregular, and frequently bounded by terrain features. The difficulty in detecting fog and low-level cloud at night with infrared imagery arises from the similarity of temperature and texture shown by fog, cloud and the underlying surface. It is found that cloud emissivity observed with shorter infrared band is significantly lower than the longer infrared band due to either water droplets or ice particles in the cloud. Thus, we select the brightness temperatures of a long-wave channel and a short-wave channel, to calculate the difference that is sensitive to the presence of fog and low cloud.

2.7 Our research data comes from NOAA/AVHRR, FY-1C/CHRPT and GMS data. At daytime, we use reflectivity at different visible channels and brightness temperature and brightness temperature difference between different infrared channels (3.7 and 11.0 μm or 11.0 and 12.0μm) to detect fog. While in the night we use three infrared channels to calculate brightness temperature at infrared channels and differences between them. According to different terrain and atmospheric conditions, we set up a set of threshold values to detect fog. Lastly, we use other observing data to verify detecting results. The analyzed examples showed that our method performed fine. If there have high or middle clouds above the fog, the detection methods fail. These methods still need further improvement at the distinction between fog and very low cloud.

Automatic Navigation of FY2 Geostationary Meteorological Satellite Images

2.8 Parameters and coordinates used in FY-2 spinning geostationary meteorological satellite image navigation are derived, with emphasis on attitude parameters. It is noticed that in the time series of sub-satellite line count, there is information on the direction of spinning axis of the satellite. With this information, the automatic landmark matching routines get convergence quickly, and quality control of the routine performance becomes an easy job.

2.9 An automatic image navigation system for FY-2 geostationary meteorological satellites have been developed in NSMC. The system is based on a PC workstation running windows 2000. The orbital parameters, attitude parameters, misalignment parameters and beta angle parameters are turned out automatically and routinely without any manual operation. Image navigation quality of FY-2 geostationary meteorological satellites was improved.

Natural Disaster and Environment Monitoring

2.10 Satellite meteorological application in natural disaster and environment monitoring is the focal point in 2000. FY-1C polar orbiting meteorological satellite had an evident contribution.

Natural Disaster Monitoring

2.11 In 2000, polar orbiting meteorological satellite for monitoring natural disaster is carried out in daily operational mode.

Forest and Grassland Fire Monitoring

2.12 NOAA-14 and FY-1C are the major data source in monitoring forest and grassland fire. AVHRR channel 3 of FY-1C and NOAA-14 is used to detect hot spots. The major forest and grassland areas susceptible to fires are divided into 15 sectors, covering the most part of forest and grassland regions in China. During the fire season (in the North China, the fire season is spring and autumn, and in the South China fire is likely to occur in winter), we receive and process all NOAA-14 and FY-1C data passing the monitored area. The fire monitoring products are generated if a fire spot is detected. The products include the list of fire spot location, which indicates the latitude and longitude, provincial, division, and county name, the nature of land utilization (like forest, grassland, crop field, etc) of fire spot; the multiple channel composition image, which shows the fire information, like active fire, burned and non-burned area, smoke, cloud and water body. The products are disseminated to the relevant government department, including the National Forest Administration, Agricultural Ministry and local provincial government agency. During the whole year, 1100 fires were spotted. All the fire events in 2000 were monitored.

Flood Monitoring

2.13 During the summer season of 2000, China used FY-1C and NOAA-14 data to monitor the flood in daily operational mode. The monitored regions include seven major rivers, sub-divided into 14 sectors. From May to September, all FY-1C and NOAA-14 orbits passing the monitored area in daytime were received and processed. The information of water body was derived from multiple channels of AVHRR data, and several methods were used to delete the influence of thin cloud and fog over the water body. The historical database was used to compare with the water body derived from the current image. The product image were generated and disseminated to the relevant government departments after the flooded water body was detected. The information of flood monitoring includes the rage, size and nature of land utilization of flooded water body.

2.14 The major events of flood monitoring in 2000 include:

(1) The flood happened in the east part of Henan Province in the middle of July;

(2) The check of the water body size of the lakes along Yangtse River, which shrunk abnormally by dry weather in May and August.

Snow Disaster Monitoring

2.15 FY-1C and NOAA-14 data are used to monitor the snow disaster in the operational mode in the winter. The FY-1C data is useful in this aspect. The AVHRR channel 6 of FY-1C is efficiently used to distinguish the snow coverage and lower cloud. The major product of snow monitoring includes:

(1) Ten days Composition
This product covers national wide area with the resolution of 6 km, the product uses NOAA afternoon satellite data and started from 1997.

(2) Regional Snow Disaster Monitoring
The 8 regions where snow disaster may easily happened in the country are monitored in operational mode in daytime during winter season. The information of snow cover in each region is derived from FY-1C data everyday from the early of winter season. The composite multiple scene images are generated to show how long the snow coverage remained in certain area. The administrative boundary and grassland distribution are overlapped on the composite multiple scene image.

2.16 The major events of snow disaster monitoring in the winter of 2000 include:

(1) The snow disaster happened in the Northeast China in the middle of winter season;

(2) The snow disaster happened in the West Part of China in the middle of winter season.

2.17 These snow disasters were monitored by FY-1C satellite data and a number of image products were provided to the relevant government and local provincial agencies.

Dust storm monitoring

2.18 There were several dust storm weather processes occurred in the North China in the spring of 2000. Eleven dust storm weather processes were monitored and analyzed with the satellite data during the time. The result shows that for the Beijing region the dust is mainly from the Inner Mongolia Autonomous Region and Hebei Province. This information is provided to the related Governments Departments and Provinces for the planning of environmental protects.

2.19 According to the users' requirement, two types of dust storm monitoring and forecasting techniques are developed.

- One of them is to use polar orbiting meteorological satellite data, which has the advantage of high spectral and spatial resolution. But as the time resolution is not good enough for the timely monitoring, it is suitable for the manually analysis and forecasting.

- The other technique is to accept geostationary meteorological satellite data, it is more practical and valuable in the automatic dust storm monitoring and forecasting with the good time resolution and the spilt window technique and multispectial technique. The automatic dust storm monitoring and forecasting system is on the operational running in NSMC, its accuracy is over 80%.

Environment Monitoring

Sea Ice Monitoring

2.20 The sea ice monitoring in the Bohai Sea in the North Part of China, was carried on using FY-1C and NOAA-14 satellite during the winter season of 2000. This application started from 1988. During winter, sea ice monitoring is performed everyday using FY-1C and NOAA-14 data, and products were transmitted to the users. The products include the edge line of sea ice, the size and density of sea ice, and the temperature contour lines on the sea ice and sea surface.

Environment Change

2.21 Analysis was made using FY-1C and NOAA data looking into the variation of snow coverage, water body and vegetation growth in West Part of China over 10 years time. The preliminary result showed that in the certain area of the West Part of China, the permanent snow coverage, water body and vegetation coverage were shrunken during the past ten years. This information is useful for the study of environment changing.

Vegetation Growth Monitoring

2.22 In the summer of 2000, severe droughts happened in the Northern China, especially in the Northeast part. NDVI derived from FY-1C was used to assess the influence of the drought on crops. We used the regional ten-day NDVI composition in July and August of 1999 and 2000 to compare the difference. The land utilization database was also used to refer to the crop field, grassland and forest, etc. In this way the effect on the crop field and grassland by the drought is revealed. This product was provided to the local and provincial meteorological agencies and found useful in evaluating the drought situation.

Chinese Radiometric Calibration sites for Remote Sensing Satellites

The calibration sites

2.23 China established radiometric calibration sites for remote sensing satellites in 1998. The operation of the test sites is managed by the National Satellite Meteorological Center of China Meteorological Administration. These calibration sites are open to international meteorological and environmental satellite operators and it is hoped to make contribution to future polar-orbiting observation system.

2.24 The Dun-Huang calibration site is for absolute radiometric calibration for visible, near-IR and short-wave IR band sensors. It is in the Southwest of Gansu Province (to the west of Dun Huang City), with a location of 40.1N°, 94.3E°. The size of the calibration field is 30Km^2 x 40Km^2.

2.25 The Qing-hai Lake site is for absolute radiometric calibration for thermal IR band and the absolute radiometric calibration of low reflectance target in visible and near IR band. It is in the Northeast of Qing-hai Lake of Qing-hai province, with a location of 37N°, 100E°. The size of the test is 4685 Km^2.

Field experiment at the test site

2.26 A comprehensive field experiment was made at the China Radiometric Calibration Site (CRCS) during June-July 1999. In the experiment, the ground reflectance and bi-direction reflectance (BRF) as well as the atmospheric aerosols optical depth were acquired at the Dunhuang test site. Besides the brightness temperature and off-water radiance atmospheric aerosols optical depth were also acquired at Dunhuang test site. At same time, the brightness temperature, off-water radiance and atmospheric attenuation were measured at the Qinghai lake test side.

Measuring result analysis

2.27 The measured ground reflectance results show that the Dunhuang site's ground average reflectance are between 10% and 35% from visible to short-wave infrared range. The reflectance standard deviation is less than 0.02 at the 20*20km^2 region while it is less than 0.01 at the 500*500m^2 region. The analysis of above data represents the Dunhuang site's optical uniformity is very good. The reflectance is less than 5% in the VIS band at Qinghai lake surface, it means that the water in the lake is very clean.

2.28 With the data acquired by sun photometer at Dunhuang site and the Langley method, the aerosols optical depths were estimated. It is from 0.10 to 0.18 at 0.55μm wavelength and Junge parameter is about 0.26 at Dunhuang site.

2.29 These data show that the atmosphere over the sites is clean and the aerosol type is approached to desert model at Dunhuang site. From the results at Qinghai Lake, there is a very clean atmosphere and continent aerosol model. In addition, water vapour contents around the sites were also estimated.

Synchronous satellite-ground measurement

2.30 A synchronous measurement from both satellite and ground was made at the test site in June 1999 for the in-flight radiometric calibration. The calibration coefficients from seven channels of FY-1C (centre wavelength: 455nm 505nm 555nm 630nm 866.5nm 932.5nm 1610nm) were determined. An error budget of the reflectance-based calibration method shows that the uncertainty is 6%. Comparing the calibration results with the pre-launch calibration, a better agreement at five channels is achieved except the ones in channels 9 (555nm) and channel 6 (1610nm).

2.31 In addition, the in-flight various radiometric calibrations for three satellites' sensors (FY-1C, FY-2B, CBERS-1) were also performed in August-September, 2000. Comparing the calibration results of FY-1C in 2000 with that of 1999, it was found that the sensitivity of sensors was attenuated, especially at channel 1 (0.58-0.68μm) which has an attenuation of more than 30%. By in-flight radiometric calibration in 2000, the calibration coefficient is updated.

2.32 In June of 2000, an aerial experiment was made at Dunhuang site. In order to validate the meteorological satellite data, the field investigations and measurements were made at the Inner Mongolia. In the experiment three targets were selected which include grassland, lake and sand.

The development of EOS data receiving and processing system

2.33 The first satellite in a new generation of environmental satellite EOS-AM1 was launched in December 1999. With various kinds of new instruments, it makes a comprehensive observation on the land and sea surface characters, cloud, radiation, aerosol and radiation balance etc.

2.34 To make a good use of EOS satellites data, NSMC started to develop the data receiving and processing system of EOS-TERRA/MODIS in June of 2000. The system was completed in December 2000. At present the system has been put into operation. It can receive EOS-TERRA/MODIS data and generate the projection image. The system has made its contribution to the dust storm warning and flood monitoring, etc.

COLOMBIA

(Instituto de Hidrologia, Meteorologia y Estudios Ambientales – IDEAM)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 The IDEAM, Institute of Hydrology, Meteorology and Environmental Studies operates a real-time network for the reception and processing of remotely sensed data. This network consists of 93 meteorological and hydrological stations transmitting by means of the GOES satellite.

1.2 IDEAM is using an integrated system to receive, process, manipulate and visualize imagines proceeding from GOES and NOAA satellites.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2.1 The updating of the commercial software METPRO for manipulation and processing of satellite GOES and NOAA imagines in high resolution, improving the procedures of interpretation as also the algorithms to calculate precipitation, hot spots and sea surface temperature.

2.2 It was settled an DCP station in the eastern part of Colombia, linking the river level data to the national system.

2.3 The imagines received from the GOES and NOAA satellites are used as operative tools to produce the national weather forecasts and with some enhancements are included in the IDEAM web page.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3. The operative METPRO programme used in the National Environmental Service supports three rain estimation algorithms based in the GOES channel 4, with techniques developed by Adler- Negri; Negri-Adler-Wetzel, y Arkin.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4.1 The system consists of 4 workstations, 2 with base in operational platforms PC OS-2 and two for the reception of NOAA and GOES imagines respectively, and 2 Silicone Graphics, under IRIX, for processing, manipulation and visualization of imagines. The system includes two antennas for independent reception of GOES and NOAA imagines.

4.2 A network of DCPs with 93 meteorological and hydrological stations, works with GOES satellite transmission every 4 hours. This system contains a central station with software PC-BASE 2 in Windows environment, located in the IDEAM headquarters.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5. The acquisition of a new satellite image receiving equipment to use as a reserve for the present operative system is envisaged. It is also planned to add some stations to the DCP network by mean of projects with international financing.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6. In the field of the validation and verification of satellite data and derived products used operative, daily precipitation data and temperatures of surface gathered from imagines are compared with data obtained with surface stations.

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND SCIENTISTS IN CHARGE)

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PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

Sea ice charting

1.1 The Danish Meteorological Institute (DMI) is responsible for the sea ice charting of the Greenland waters. Until 1999 the sea ice charting was mostly based on aircraft reconnaissance, but after the launch of the Canadian satellite Radarsat in 1995 it was decided to initiate a process with the aim of minimizing the number of flight hours and increase the use of satellite images. In 1999 DMI started an operational ice service based predominately on data from Radarsat, NOAA and DMSP SSM/I. Additionally, DMI has participated in a number of international projects mostly funded by the European Union (EU) with the specific purpose of promoting and facilitating the use of satellite data for sea ice charting.

Satellite Application Facility (SAF)

1.2 DMI has been involved in three EUMETSAT Satellite Application Facilities, i.e., Ocean and Sea Ice, Ozone and GRAS. Consequently the dominant part of the satellite data related research at DMI has been carried out within this framework.

Ørsted

1.3 The Danish Ørsted satellite was launched in February 1999 and carries among other instruments a high precision GPS receiver with the capability of tracking the signals from occulting GPS satellites. At DMI a production chain was established to produce sounding products, i.e., refractivity, pressure, temperature and water vapour profiles.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Ocean and Sea Ice SAF

2.1 The Ice Charting and Remote Sensing Division at DMI participates in the development of the EUMETSAT Ocean and Sea Ice Satellite Application Facility. The project team is led by Météo-France and involves the meteorological institutes from Norway (DNMI), Sweden and the Netherlands, as well as the French Institute for Oceanography (IFREMER). The SAF will be part of the future EUMETSAT Application Ground Segments for the Meteosat Second Generation (MSG) satellite and the EUMETSAT Polar System (EPS), and will deliver the following products for use in the meteorological communities and elsewhere based on the state-of-the-art algorithms and techniques:

- Surface Wind Vector,
- Atlantic Sea Surface Temperature,
- Atlantic Surface Radiative Flux,
- Regional Sea surface structures,
- Atlantic Sea Ice Edge,
- Atlantic Sea Ice Cover,
- Atlantic Sea Ice type.

2.2 DMI contributes especially to the development of high latitude (i.e., north of 50°N) sea ice and SST products, i.e., development of sea ice concentration products based on SSM/I data (Special Sensor Microwave Imager), development of algorithms for removal of weather contamination of the passive microwave sea ice products with the use of ancillary (model) information and statistical analysis of SSM/I data to provide input to an optimization of the multi-sensor technique based on a Bayesian framework in cooperation with DNMI: DMI is also collaborating with DNMI on the development of multi-sensor ice products and validation data. Recently, the team at DMI has concluded work on calibration of passive microwave ice concentration algorithms in cooperation with the National/Naval Ice Centre, (NIC), USA. Work is ongoing to prepare for pre-operational production of sea ice products from 2001.
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Ozone SAF

2.3 During recent years, the severe loss of stratospheric ozone has been detected in both Antarctica and the Northern hemisphere. The ozone loss and subsequent intensification of UV-B radiation have led to additional interest in ozone and UV research of the effects of UV radiation on biosphere and public interest towards the status of ozone layer and UV radiation exposures. The basis of the EUMETSAT Ozone SAF is ozone and related data from METOP and MSG satellites.

2.4 DMI contribution to the Ozone SAF consists of the development of a Near Real Time UV-index (NRT_UVI) processor. From our partners in SAF we receive daily global data on total ozone, presently assimilated GOME data, and calculate the clear sky UV-index at local noon with a global coverage. The output package must be available to the end users one hour after reception of the (forecast) data and no later than 4 UT. The calculations are performed with total ozone as the only dynamically input, whereas climatological parameters are used for all other atmospheric data as well as surface reflectivity. The NRT_UVI processor includes in the calculations, apart from the ozone data, the following parameters: solar zenith angle, sub-earth distance, ozone profiles, surface reflectivity (albedo), aerosol optical depth, and topography. Out output package consists of images of UVI maps for a number of pre-specified locations and a global map. Our work also includes continuous quality control and validation against ground-based measurements of the UV-index.
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Global navigation satellite system Receiver for Atmospheric Sounding (GRAS) SAF

2.5 The GRAS Meteorology SAF is responsible for the development of software and setting up a system in Near Real Time (NRT) to process meteorological products such as temperature and humidity profiles from the GRAS instrument onboard the future Metop satellite. The project is headed by the DMI in cooperation with the UK Met Office and the Institut d'Estudis Espacials de Catalunya (IEEC) in Spain. The GRAS SAF is one of seven SAFs co-funded by EUMETSAT to focus on meteorological products from the MSG and EPS programmes.

2.6 The GRAS SAF project started in April 1999 and during the period 1999-2000 has focused on the definition of user requirements and work on science algorithm development, as well as preparing the first design of the operational processing system. A first user workshop was held in connection with the EUMETSAT Satellite Data Users' Conference in Copenhagen, September 1999. In June 2000, with the following close-out meeting in October 2000, the GRAS SAF passed the first requirement review focus on the user requirements, Science Plan and Project Plan. As a baseline the processing centre will be placed at DMI in Copenhagen. The GRAS SAF development project is based on a five-year Cooperation Agreement with EUMETSAT. The operational phase of the GRAS SAF will be continued in a new cooperation agreement. The first

products from the GRAS SAF are expected following the Metop commissioning phase, which will be around mid-2006.
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Sea Ice Service

2.7 Prior to and after the transition from aircraft reconnaissance to satellite-based ice charting of the Greenland waters at the beginning of 1999, the DMI Ice Charting and Remote Sensing Division has focused on the validation and enhancement of Radarsat SAR data. Radarsat data are the dominant source of information and it has been important to verify that the satellite-based ice charts were of sufficient quality.

2.8 The interpretation of the Radarsat data is made difficult by the fact that the backscatter signatures from the open water and ice regions are not unique. The backscatter from the water regions are dominated by the local wind conditions, and those from the ice regions are dependent on the ice type, ice concentration, surface roughness of the individual floes and level of surface melting during the summer months. The backscatter signals are also critically dependent on the radar incidence angles (far- and near-range effects). For example, it is quite common during manual interpretation that the belts of ice appear nearly white (on a grey tone scale) in the far-range and nearly black in the near-range against the background of sea clutter. Manual interpretation of these data is particularly difficult in the navigationally most important Cape Farewell waters (the southern most tip of Greenland) which are characterized by strong winds (wind speeds ≈ 20 m/s – 30 m/s are common) and scattered sea ice of low concentration (≈1/10 – 3/10). This sea ice is mainly of arctic origin of thickness between 2 m . 5 5 and floe sizes typically < 50 m mixed in with the locally formed ice and icebergs from the east coast of Greenland. Detecting regions of ice in these data can also be difficult close to coasts where wind patterns are often complex or the relevant region is totally devoid of winds (lee areas)making image interpretation extremely difficult. It requires ice analysts which have high skills at interpreting SAR images and, in addition, have a knowledge of the local ice regime.

2.9 To provide fast and easy additional tools/products to the ice analysts that would help them analyse SAR images during routine operations, a number of parameters based on the first and second order statistics, probability distribution, wavelet transform and Constant False Alarm Rate have been developed at DMI.

2.10 The evaluation of the Wavelet Transform (WT) has shown that its effectiveness to detect ice edges in the marginal ice zone in the waters around Greenland depends on a number of factors: (i) the two input parameters of the WT, the scale and threshold respectively; (ii) the ice conditions, i.e., whether the ice is scattered or compressed together; and, (iii) the quality of the image, i.e., the level of speckle noise in the image due to winds. It was found that if the parameters of the WT were not chosen carefully, important regions of ice were not detected or it resulted in unwanted false edges in the open water regions containing ocean features due to natural phenomena. The algorithm makes no distinction between edges in the ice and in the open water regions. The undesired edges in the open water regions are best removed by ice analysts using manual interpretation. The algorithm worked best for those images which contained distinct ice edges, and badly for those in which ice was scattered in low concentration as is commonly found in the waters off Cape Farewell. However, the advantage of this algorithm is that it runs automatically and computational times are reasonable. For this reason, the ice edge computed using it can be used as a “first guess”. It is also useful for training ice analysts.

2.11 The problem of detecting icebergs in satellite SAR data consists mainly of identifying them against the background sea clutter and, equally important, reducing their ‘false alarms’. It has been found during previous studies that the normalized second moment of the probability distribution, the Power-to-Mean Ratio, are very useful for possible iceberg detection against the background sea clutter. To reduce the number of spurious targets, iceberg detection based on CFAR is used at DMI. In this method the statistics of the background are assumed to be described by the gamma distribution (limiting case of the k distribution). This approximation permits incoherent averaging of the background pixels to reduce the background speckle noise and thereby improve target detection. It also resulted in significant reduction in computation time which is an important issue in an operational environment. By using this method many of the false targets an be eliminated.

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Ørsted GPS temperature profiles – retrieval and assimilation

2.12 The Ørsted satellite was launched in February 1999 and carries among other instruments a high precision GPS receiver with the capability of tracking the signals from occulting GPS satellites. At DMI an End-to-End processing chain was established, taking the raw satellite data, making the orbit determination and the sounding products as refractivity, pressure temperature and water vapour profiles. Correspondingly, a system for assimilation of GPS occultation into the DMI-HRILAM numerical model has been developed using Ørsted data and other similar satellite observations. Due to a degraded reception of the L2 frequency, new techniques had to be developed for the retrieval. For the same reason, the estimation of humidity was less accurate, since the receiver lost track at higher altitudes than normal. During February 2000, a campaign was carried out resulting in the observation of more than 1,000 occultation.

2.13 The results showed that for high altitudes (> 40 deg.) the average accuracy in the profile in the altitude range 30-900 hPa (applying the new single frequency approach) was better than 3.8 degrees Kelvin compared with radiosonde and NWP analysis results. While for tropical latitudes, where tropospheric water vapour is more abundant, the average accuracy range was – 4.0 to 2.0 degrees Kelvin, with the negative difference in the lower troposphere.

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PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

Reception

4.1 Satellite data are received by three DMI receiving facilities, one Meteosat PDUS and two NOAA HRPT stations situated north of Copenhagen, Denmark and in Kangerlussuaq, Greenland. Additionally, satellite data (e.g., Radarsat and DMSP) are received NRT from foreign reception stations through Internet. DMI also receives data from the Danish research satellite Ørsted.

Processing

4.2 After reception, satellite data are processed on a set of SUN workstations using predominately in-house developed software packages. Pre-processing steps depend on the type of data, but in general pre-processing includes data unpacking and quality control, including noise removal and handling of missing data, calibration, calculation of physical values, e.g., temperature and geo-location of pixels. The pre-processing step also includes extraction of messages other than image data from the data stream, e.g., messages from data collection platforms (ARGOS). Based on the pre-processed data the following processing creates the products used internally at DMI and by external users. The processing includes among other things geo-rectification, i.e., adjustment of images to pre-defined geographical areas, generation of derived products (e.g., temperature profiles, cloud masks and filter products) and general image enhancements and reformatting so data may be displayed and used effectively by the different internal and external user groups.

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PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

Meteosat Second Generation (MSG) and NOAA

DMI will procure the necessary reception equipment and processing capability to make full use of data from MSG after the commissioning of the satellite.

Processing of NOAA AVHRR will be enhanced and DMI will use the EUMETSAT supported AAPP software package (AVHRR and ATOVS Processing Package) for pre-processing of NOAA data. Furthermore, the Automatic Navigation Adjustment (ANA) package developed be Météo-France/CMS will be used to ensure high quality navigation of AVHRR images required to produce composites in time and space. The ANA package is an add-on to AAPP. Both the availability of MSG products and data, and the AAPP products will enable production of dedicated products for assimilation into the numerical weather model HIRLAM and will provide a new range of products to the meteorologists. The renewal of the NOAA production and the use of AAPP is also a pre-requisite for future use of software products from the Nowcasting Satellite Application Facility.

Data from the European research satellite ENVISAT will be used operationally for sea ice charting of the Greenland waters. DMI expects to received ENVISAT ASAR data as a supplement to data from Radarsat.

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EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS (ECMWF)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 The Centre's strong programme to exploit the wide variety of satellite data available for operational assimilation and verification has continued.

1.2 Highlights in recent progress are:

Assimilation

- Background error statistics derived using new method;
- Use of 10m marine wind-speed retrievals from SSM/I radiances;
- Revised bias correction of MSU and AMSU-A radiance data;
- Corrected use of radiosonde and SYNOP humidity observations;
- Better suppression of humidity increments in the stratosphere;
- Revised SSM/I quality control, bias correction, thinning and use of second satellite;
- Use of more TOVS/ATOVS data (HIRS-12, AMSU-14; less constraint on AMSU-8; more off-nadir data).

Model

Introduction of 60-level vertical resolution for the analysis and deterministic forecast, and 40-level vertical resolution for the Ensemble Prediction System;

Modifications to the cloud and convection schemes;

- New global orography and associated subgrid fields.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

October 1999:

Model

- Introduction of 60-level vertical resolution for the analysis and deterministic forecast, and 40-level vertical resolution for the EPS;
- Modifications to the cloud and convection schemes;
- New global orography and associated subgrid fields.

Assimilation

- Background error statistics derived using new method
- Use of 10m marine wind-speed retrievals from SSM/I radiances
- Revised bias correction of MSU and AMSU-A radiance data
- Corrected use of sonde and SYNOP humidity observations

2.1 Extensive studies demonstrated that the changes considerably improved the quality of the summer 1999 forecasts. The winter 1999-2000 medium-range forecasts showed the lowest ever rms geopotential errors. However, the available evidence suggests that this result may be, in part, a consequence of inter-annual variability.

2.2 After a great deal of preparation, the Y2K change went smoothly, needing only minor action on the day.
2.3 The second operational change in April 2000 had modest scope and thus had modest impact on performance.

April 2000:

Assimilation
- Better suppression of humidity increments in the stratosphere;
- Revised SSM/I quality control, bias correction, thinning and use of second satellite;
- Use of coastal ship and buoy winds in the extratropical Southern Hemisphere;
- Relaxed quality control of dropsondes;
- Set of minor changes to wave model and analysis.

Model
- Limit on stratospheric tendency from gravity-wave drag parametrization;
- Bugfix for calculation of clear-sky precipitation fraction;
- Bugfix for (diagnostic) stratocumulus scheme used in calculation of low-resolution trajectory.

2.4 An operational change in June 2000 was quite substantial in scope, and defines the model to be used for the ERA-40 reanalyses, which are now in production.

June 2000:

Model
- TESSEL parametrization scheme for the land surface, lying snow and sea-ice;
- RRTM long-wave radiation scheme;
- Improved ozone model;
- Improved treatment of precipitation processes in first timestep.

Assimilation
- Revised observation and background error variances;
- Revised snow analysis;
- Use of more TOVS/ATOVS data (HIRS-12, AMSU-14; less constraint on AMSU-8; more off-nadir data);
- Use of actual buoy heights.

2.5 The TESSEL tiling treatment of the land surface offers considerable scope to improve near surface forecasts, and to improve the use of sounding data over land. The RRTM long wave radiation scheme is amongst the most accurate available. The revision of the observation and background errors puts the assimilation on a secure statistical footing. The use of the digital filter for JC means that normal mode initialisation software is no longer used in the system. The revisions to the satellite data usage were helpful, *inter alia*, in the collaborative work with EUMETSAT on monitoring the calibration of the METEOSAT-7 water vapour channel.

Recent operational changes

2.6 Early in 2000, it was found that the use of the existing version of the 12-hourly 4D-Var assimilation system was less beneficial with the 60-level version of the assimilation system than with the earlier 50-level system. The main reason appeared to be a degradation in the validity of the tangent linear hypothesis. This was not due to the sharper structure functions introduced or to spurious model instabilities, but to the sharper nature of the new version of the model, with its increased vertical resolution and revised parametrizations. The result was surprising because analysis errors were clearly reduced by use of the 60-level system, both with 6- and with 12-hourly cycling. The situation was recovered by two sets of changes that were particularly beneficial when using the longer 4D-Var time window. Extensive tests of the revised 12-hourly 4D-Var assimilation system at with T319 / T63 loops showed a largely neutral signal. The 12-hourly 4D-Var assimilation at this resolution was implementation in autumn 2000.

2.7 The main problem found with the 12-hourly cycling was the difference in resolution between the models used in the incremental inner and outer loops. There was a factor of about five between the horizontal resolutions used operationally (T63 and T319). The situation was improved when higher-resolution inner loops were used to decrease the discrepancy with the main forecast model. The validation of the adjoint of the semi-Lagrangian scheme was very important in reducing the difference in resolution.

2.8 Good progress was made in validating T511/T159 data assimilation and deterministic forecasting system with semi-Lagrangian inner loops and with T255 EPS for operations. Both these were implemented after validation with 12-hourly 4D-Var in autumn 2000. A further increase in the resolution of the inner loop of 4D-Var, to T255 was foreseen in the first half of 2001.

Data Assimilation

Operational implementation 1999 - 2000

2.9 Two important analysis changes were introduced operationally in October 1999. The first was use of new background error structure functions based on pairs of background differences from an ensemble of data assimilations in which observations were randomly perturbed and the EPS's representation of stochastic physics was used in the assimilating model. These new structure functions were sharper than those used previously, and gave smaller analysis increments and systematically reduced short-range forecast errors. Secondly, a long-standing error in the processing of humidity observations was corrected. Reported dew-point temperatures from radiosondes and surface measurements had for many years been erroneously processed at ECMWF for temperatures below 0°C as if they were observations of either a frost point or a parametrized mixed-phase saturation point. This introduced a dry bias into the analyses.

2.10 The 60 level model replaced the 50 level model in operations in October 1999, and its performance in trial assimilations and forecasts over the spring and summer of 1999 was the subject of particular investigation in view of the poor performance of the operational ECMWF system at the time. Use of cycle 21r4 gave general improvements over the period, and was particularly beneficial during the second half of August, when the operational forecasts were especially poor over Europe. Extensive reports on the investigations were prepared; tests showed that the improvement was substantial, and much of it, particularly over the hemisphere as a whole, could be seen to come from the two analysis changes. An improvement in scores resulted from using a 50-level version of the new structure functions in an otherwise standard model configuration, and beneficial impact of the correction of the humidity analysis were seen from the difference in the scores of the model versions.
Development of 4D-Var

Development of 4D-Var

2.11 The use of a 12-hourly cycle for the 4D-Var assimilation system was further validated using various resolutions. It was found to be less beneficial with the 60-level version of the assimilation system than with the earlier 50-level system. The main reason appeared to be a degradation in the validity of the tangent linear hypothesis. This was not due to the sharper structure functions introduced with the new system or to spurious model instabilities, but to the sharper nature of the new version of the model, with its increased vertical resolution and revised parametrizations. The result was surprising because analysis errors are clearly reduced by use of the 60-level cycle 21r4 system, both with 6- and with 12-hourly cycling.

2.12 The situation was recovered by two sets of changes that were particularly beneficial when using the longer 4D-Var time window. The first set reduced the inconsistencies between the models used in the inner and outer loops of the incremental 4D-Var, through an improved generation of the low-resolution background fields using the "Full-Pos" post-processing option, a better cycling of prognostic cloud fields, an update of the low-resolution physics used to define the linearization trajectory, and an internal physical initialization in 4D-Var using a digital filter penalty constraint developed in Météo-France. The second set of changes circumvented the remaining weaknesses of the incremental algorithm. A quality control step was introduced to reject observations that were poorly handled by the incremental formulation, and the low-resolution increments are added later inside the 4D-Var time window at 00 and 12UTC rather than at the start of the window at 15 and 03UTC.

Use of observations

2.13 Observation weights were carefully re-calibrated using background error departures and cross-validation methods. For most types of observation this was the first change since the days of the Optimal Interpolation system. For instance, the relative weight of aircraft data was increased. The quality control weights have been adjusted accordingly. This improves the forecasts, and the post-processed estimates of analysis and background errors are now at a realistic level. These changes were introduced into operations in June 2000.

2.14 Assimilation of ozone observations has been developed, along with necessary revisions of the photochemistry model needed to make it suitable for use in data assimilation. The initial source of ozone information will be TOVS HIRS-9, with complementary information to be obtained from SBUV retrievals. Assimilation of TOMS data is being set up for use in ERA-40.

2.15 A large set of Observing System Experiments (OSEs) has been run in order to check the behaviour of the data assimilation system and the relative usefulness of the main global observing systems. The OSEs have confirmed the growing importance of TOVS and aircraft data, and the continuing importance of the radiosonde network over much of the globe. Examination of 500hPa scores for the Northern and Southern Hemispheres for the impact of removing separately aircraft data, radiosonde data and “upper-air” satellite data showed that removing the satellite data had a similar impact to removing the radiosonde data in the Northern Hemisphere, and caused a pronounced deterioration in the accuracy of forecasts in the Southern Hemisphere.

2.16 The adjoint-based sensitivity computation system was enhanced and used in a study funded by EUMETNET to assess the climate of sensitivities of European forecast errors and identify key areas for deploying observations. Two-day forecasts over Europe appear to be sensitive to features of the analysis in areas that are as remote as the Great Lakes or Senegal.

Technical aspects

2.17 The runtime observation storage (CMA) has been migrated to a relational database (ODB) that allows greater flexibility for memory optimization, implementation of new observation types and sophisticated pre-processing methods, monitoring and bias correction. The ODB entails very little overhead and will be more efficient when larger volumes are data are assimilated in the context of AIRS, IASI and MSG. The next step will be a rationalization of the observation processing and archiving procedures, in order to make the system more open to new data types (e.g., research satellites) and to external researchers.

Satellite Research Activities

Operational implementation

2.18 Assimilation of retrievals of the 10m marine wind-speed from SSM/I radiances from the F13 DMSP satellite and a revision to the bias correction of the TOVS/ATOVS data from the NOAA polar-orbiting satellites were introduced into operations with cycle 21r4 of the forecasting system in October 1999. The model-based approach used to identify and correct the biases in the TOVS/ATOVS radiances has since been applied to SSM/I radiance data. This has allowed the assimilation of data from two DMSP spacecraft, initially F13 and F14, which provide near global coverage of wind-speed and total column water vapour information. A more sophisticated screening for SSM/I radiances influenced by precipitation was also developed. The latter changes were implemented operationally in April 2000. These developments have contributed to improvements in low-level wind forecasts over the tropics and Southern Hemisphere.

2.19 Advances in the understanding of raw-radiance error characteristics and improved quality control thresholds have allowed a much larger amount of TOVS/ATOVS data to be assimilated. Increased use of AMSU/MSU radiances together with a limited reintroduction of HIRS data, initially only channel 12 to improve the specification of upper tropospheric humidity, has resulted in improvements to analysis quality and forecast skill. These changes were introduced in June 2000. The fit of simulated radiances from operational background fields to cloud-cleared radiances from the METEOSAT-7 water-vapour channel was improved after operational assimilation of HIRS-12 data began in June 2000.

Use of "cloudy" radiances

2.13 A facility has been developed within the variational assimilation system to simulate radiances from cloudy regions of the model and compare them with measured radiances to investigate the quality of the model cloud fields. Infrared data from the HIRS instrument combined with microwave data from the MSU/AMSU instruments at the same location and time provide complementary information on cloud amount, height and liquid-water/ice content. Experiments indicate scope for improvement of the representation of high, cold cloud and the land surface. An hourly METEOSAT cloudy radiance product was defined in collaboration with EUMETSAT, to provide information about the diurnal evolution of cloud development in the model. The construction of the cloudy radiance operator within 4D-Var is a step towards the ultimate aim of cloud assimilation. In addition to generating diagnostic information for improvement of the parametrization of cloud processes, the comparison with cloudy observations should provide useful guidance on how best to design a cloud assimilation scheme in such matters as choice of cloud analysis variable and background/observation statistics.

Use of radiances over land

2.14 Radiance observations in window regions of the spectrum from HIRS, AMSU, SSM/I and TMI were used to investigate the performance of the model land surface parametrization. The wide spectral coverage provided by these instruments in polar orbit allows contributions of surface temperature and emissivity to be separated. This coverage is complemented by the high (hourly) temporal resolution of the infrared radiance observations from METEOSAT which provide information on the quality of diurnal variations of surface temperature in the model.

2.15 A system has been developed to allow the use of tropospheric sounding data over land. The contributions to the sounding channels from surface emission are analyzed directly (and, therefore, separated from the atmospheric contribution) by adjusting surface temperature and emissivity within the 4D-Var assimilation. Experiments are in progress to establish an optimal combination of tropospheric radiances and conventional data, and to tune the surface analysis parameters (such as background errors for surface temperature and emissivity). In the future it is hoped to exploit the time dimension of 4D-Var to perform a more accurate separation of surface characteristics.

2.16 Microwave window channel radiances from instruments such as TMI and SSM/I (with dual polarizations) were used to generate detailed estimates of microwave surface emissivity over various land and ice surfaces. These estimates were used to design the background model and suitable error covariances for use in the 4D-Var adjustment of surface emissivity.

Support for METEOSAT calibration

2.17 Real-time radiance monitoring against ECMWF background fields has been used by EUMETSAT to review the calibration of data from the METEOSAT MVIRI instrument. Problems of absolute accuracy and poor temporal stability (associated with the use of vicarious calibration and highlighted by the radiance monitoring) have been significantly reduced by use of the onboard black-body calibration possible for METEOSAT-7. The new calibration method has been successfully implemented in EUMETSAT operations for this satellite, and a change will be applied for METEOSAT-5 (which has to rely on cross-calibration with METEOSAT-7) in September 2000. The monitoring plots after the change in calibration of METEOSAT-7 showed quite stable statistics for this satellite (apart from the effect of the forecasting-system change on 27 June), but a quite variable fit for METEOSAT-5. As a result of these developments, experiments were made to test the assimilation of METEOSAT water-vapour radiances.

Preparations for advanced sounders

2.18 A framework has been established to acquire near-real-time AIRS radiance data (via a cooperation agreement between NASA and NOAA/NESDIS). Through the NWP-SAF in collaboration with the University of Maryland, the RTTOV radiative transfer model will be extended to process AIRS data. Following the launch of NASA's AQUA satellite (which is scheduled for December 2000) ECMWF will participate in the CAL/VAL of AIRS (and its companion AMSU instruments) by providing radiance monitoring feedback to NASA. Work continues with simulated advanced sounder observations (for IASI and more recently simulated AIRS radiances from NOAA/NESDIS) to develop assimilation strategies and cloud detection algorithms.

QuikSCAT

2.19 Experimental assimilation of scatterometer data from the QuikSCAT platform has shown a number of benefits. The number of significant meteorological events encountered by the SeaWinds instrument is larger than encountered by the ERS scatterometer due to the much wider swath of SeaWinds. This has allowed a number of interesting severe weather cases to be studied. The quality of the SeaWinds data has been shown to be generally very good, in particular far better than anticipated in the near-nadir regions of the swath. The experiments have also demonstrated the importance of identifying and screening out SeaWinds data contaminated by heavy precipitation (a feature particular to Ku-band scatterometry). Work to improve this screening process and to establish an optimal observation density for assimilation will continue.

Assimilation of TRMM products

2.10 The 1D-Var retrieval of temperature and humidity profiles from TRMM-derived surface rain rates has been included in the data assimilation system. It has been used to run two 4D-Var experiments with assimilation of 1D-Var total column water vapour (TCWV) estimates, one for the Bonnie hurricane period (from 18/08/1998 to 02/09/1998) and one for the Christmas 1999 period (from 15/12/1999 to 05/01/2000. The results for both experiments show a noticeable improvement in the humidity analysis and of the surface precipitation in the latitude band covered by TRMM. One major benefit is the reduction of the precipitation spin-down during the first 48 hours of the forecast. Because TRMM mostly samples tropical regions, forecast performance is little changed in mid-latitudes when using the 1D-Var retrieved TCWV while tropical wind scores are improved particularly at the low-levels. Results also show a clear positive impact on the analysed dynamics in areas where TRMM data are used in the assimilation. Comparison of the track of hurricane Bonnie from the analysis (location of the minimum mean-sea level pressure) and from the observations showed that in the early stage of the hurricane development the analysed track was improved compared to the observed “best-track”, in particular when TRMM overpassed the hurricane.

2.11 These two experiments were run using the NASA surface rain rate products from the TRMM microwave radiometer. Both were later rerun using the TRMM derived rain rates from a combined radar-radiometer algorithm provided through the Euro-TRMM collaboration, to assess the impact of this improved product on the assimilation.

2.12 The technical work needed for direct assimilation of TRMM surface rain rates in 4D-Var continued.

Ocean Waves

Operational Developments

2.13 The SAR assimilation software was optimised in June, when an improved quality control of Altimeter data and some minor improvements in Altimeter data assimilation was also introduced. The use of sea ice fraction for the sea ice mask was introduced in June, with a number of additional integrated parameters, related to the period of the waves and the width of the wave spectrum. Finally, in September the Wave model was adapted to produce outputs for the Boundary Condition and the seasonal forecasting projects.

2.14 As part of the operational change planned for 2001, the resolution of the wave model spectrum was increased from 25 frequencies and 12 directions to 30 frequencies and 24 directions. An improved advection scheme will be introduced which uses a more accurate spatial interpolation of the energy flux. The resolution of the stress tables in the WAM model will be improved also.

2.15 In the context of assimilation of Altimeter data, new parametric growth curves will be introduced that match the actual growth curve of the WAM model, which has gradually changed over the years because of changes to the wave model. The impact of calling the wave model assimilation in all trajectories of the 4D-Var algorithm is under test and early experiments show promising results.

2.16 Work in support of atmospheric assimilation changes included the successful validation of SSM/I winds against Altimeter winds; the use of the correct anemometer height for buoy wind data was also validated.

Verification of analysis and forecast.

2.17 The wave model performance during 1999-2000 has been monitored extensively, particularly because of the changes in the coupled atmosphere-wave model in July 1999 and the introduction of SSM/I winds in October 1999 (cycle 21r4). Surface winds have shown consistent improvements. The error is defined as the difference between analyzed wind speed and the ERS-2 Altimeter wind speed. These may be regarded as independent data as the Altimeter wind data are not used in the atmospheric or wave analysis. Over the years there has been a steady improvement of the quality of the wind speed analysis. It is noteworthy that at the end of the period (corresponding to the introduction of SSM/I winds), an additional reduction in wind speed error was noted, with the winter 1999/2000 statistics indicating a wind speed error of about 1.4 m/s. These improvements have resulted in similar improvements in the quality of the wave height validated by comparison of first-guess wave heights against Altimeter wave height data. There have also been systematic improvements in forecast skill of ocean wave height over the last 5 years for the North Atlantic, with other areas having more pronounced improvements.

2.18 In collaboration with the UKMO, FNMOC, AES and NCEP, global wave model products are exchanged to compare the performance of these models against buoy data. As in previous years, the ECMWF wave forecasting system shows a relatively slow deterioration of the forecast skill. The comparison exercise leads to improvements in the quality of wave and atmospheric forecasting.

Monitoring and assimilation of observations.

2.19 Monitoring of the quality of ERS-2 Altimeter wind and waves, and of SAR data has continued, with no exceptional problems being noted.

2.20 Work has begun on the assimilation of observed wave spectra by the SAR. These data are assimilated using an extension of the OI scheme for Altimeter data. Extensive tests have shown that presently there are no improvements when analysed wave height and peak period are compared to buoy data. This is a fairly robust result since other groups have arrived at similar conclusions. This negative result is readily understood because an extensive validation of SAR inverted spectra against buoy spectra has shown that these spectra are of poorer quality than the wave model spectra. Work to resolve this issue began in September 2000.

ERA-40

2.21 The past year's work on ERA-40 culminated with the recent commencement of the production phase of the re-analysis. The production plan is for a first, high-priority stream from 1987 onwards. This is being spun-up with assimilation from 1 September 1986, starting from the analysis produced by an earlier trial assimilation using no satellite radiance data. The start date enables an early comparison with ERA-15 over the period in November 1986 when the earlier reanalysis was corrupted by a problem with the MSU-3 data from the NOAA-9 satellite. The production system currently includes virtually all elements envisaged at the planning stage, and several more. The only significant omission is the absence of assimilation of SBUV and TOMS ozone data, the development of which is close to completion but not quite ready. It is intended to introduce this before the production system reaches 1989. In addition, radiosonde bias correction will not be switched on until a year of statistics has been gathered from the assimilation of 1987 data. These omissions are not considered to be serious, as a later phase of production will see a repeat of 1987 and 1988, including reprocessed wind data from Meteosat-2.

2.22 An earlier highlight was completion of the contract negotiations with the European Commission for its support of the project, which began formally on 1 April 2000 for a period of three years.

2.23 Specific activities in the build-up to production of the first data stream have included:

- completing the acquisition and BUFR recoding of observational data, which now include a full set of TOVS raw radiances, with data supplied by LMD and NASA to extend the set supplied by NCAR, and an enhanced set of conventional observations as a result of an exchange of data holdings with NCEP;
- implementing the ODB software to manage the observational data streams in the pre-analysis phase, including the exclusion of duplicate observations;
- developing the data assimilation system to meet the needs of ERA-40, within the PREPAN system for running research assimilations;
- testing new components of the forecasting system within the reanalysis environment;
- developing the assimilation of raw HIRS and SSU radiances needed to complement the current operational system, which is geared towards the post-1998 assimilation of raw MSU and AMSU radiances;
- including the (passive) processing of cloudy radiances discussed in section 3.2, with a cloud retrieval at HIRS spots using the CO2 slicing technique;
- developing the FGAT and linear-grid options for the 3D-Var analysis as discussed in section 2.3;
- extending bias-correction software;
- developing monitoring plots;
- preparing an archive plan and developing additional post-processing capabilities to support it;
- liaising with the validation partners in the EU project;
- beginning to build the web pages for the project, the currently incomplete pages being accessible from the Member States' web-site (wms.ecmwf.int/research) pending their installation on the public ECMWF web-site.

2.24 In addition, a thorough study has been made of the quality of the radiosonde data available since 1957, the start of the re-analysis period. Substantial work has also been carried out on the rehabilitation and assimilation of the raw VTPR radiance data that cover the pre-TOVS era from 1972 to 1979.

Seminar and Workshops

Seminar on Diagnosis of Models and Data Assimilation Systems
6-10 September 1999

2.25 The seminar provided a pedagogical review of current methods to diagnose and resolve problems in models and assimilation systems, identifying missing processes in the models and refining the representations of existing processes.

2.26 The seminar was attended by 38 participants from the Member States. There were eleven invited lecturers and eleven ECMWF lecturers. The proceedings are in print.

ECMWF/EUMETSAT Workshop on Use of ATOVS Data for NWP Assimilation
2-5 November 1999.

2.27 The purpose of the workshop was to assess the progress that has been made in the use of ATOVS data and to identify key areas for future development within:

- calibration and pre-processing
- radiative transfer
- observation error characteristics
- assimilation methods

2.28 The workshop provided guidance for the setting of research priorities and valuable feedback to the data producers.

2.29 The workshop followed the usual format of invited lectures and discussions in working groups and concluded with a plenary session. Groups were set up to consider the issues of observation pre-processing, assimilation issues and radiative transfer. The discussions and recommendations of these groups are summarized in reports which have been published together with short abstracts of all presentations.

PART VII OTHER ITEMS (references, publications and scientists in charge)

Publications

Technical Memoranda

288 J-F. Mahfouf, A. Beljaars, F. Chevallier, D. Gregory, C. Jokob, M. Janisková, J-J. Morcrette, J. Teixeira and P. Viterbo: The importance of the Earth Radiation Mission for numerical weather prediction. Sept 1999

291 C. Cardinali: An assessment of using dropsonde data in numerical weather prediction. October 1999

293 V. Marécal and J-F. Mahfouf: Variational retrieval of temperature and humidity profiles from TRMM precipitation data. November 1999

294 E. Andersson, M. Fisher, R. Munro and A. McNally: Diagnosis of background errors for radiances and other observable quantities in a variational data assimilation scheme, and the explanation of a case of poor convergence. November 1999

295 M. Janisková, J-F. Mahfouf, J-J. Morcrette and F. Chevallier: Development of linearized radiation and cloud schemes for the assimilation of cloud properties. March 2000

296 V. Marécal, E. Gérard, J-F. Mahfouf and P. Bauer: The comparative impact of the assimilation of SSM/I and TMI brightness temperatures in the ECMWF 4D-Var system. May 2000

297 C. Edis-Williams, S. Moreby, E. Kooij-Connally and U. Modigliani: Bibliography of ECMWF Publications 1975 – 2000. July 2000 in print

EUMETSAT/ECMWF Fellowship Programme Research Reports

RR7 M. Rohn, G. Kelly, R.W. Saunders: Transition to cloud motion winds from Meteosat with 90 minute sampling and the use of the MPEF Quality Indicator. December 1999

EUMETSAT/ECMWF Numerical Weather Prediction Satellite Application Facility: SAF Research Reports

RR1 F. Chevallier: TIGR-like sampled databases of atmospheric profiles from the ECMWF 50-level forecast model. May 2000

RR 2 F. Chevallier and J-F. Mahfouf: Evaluation of the Jacobians of infrared radiation models for variational data assimilation. May 2000

ECMWF Re-Analysis (ERA and ERA-40) Project Report Series

ERA PRS 7 A.K. Betts, P. Viterbo and A. C.M. Beljaars Comparison of the land-surface interaction in the ECMWF re-analysis model with the 1987 FIFE data. June 1999

ERA PRS 8 F.C. Bosveld, A van Ulden, A.C.M. Beljaars: A comparison of ECMWF Re-Analysis data with fluxes and profiles observed in Cabauw. October 1999

ERA40 PRS 1 A.J. Simmons and J.K. Gibson: The ERA-40 project plan. March 2000

ERA40 PRS2 K. Onogi: The long-term performance of the radiosonde observing system to be used in ERA-40. (In print)

Proceedings Seminars and Workshops

Workshop on Diagnosis of data assimilation systems, 2 - 4 November 1998

ECMWF/EUMETSAT Workshop on Use of ATOVS Data for NWP Assimilation, 2 to 5 November 1999

Seminar on Diagnosis of models and data assimilation systems, 6-10 September 1999

Acronyms and Abbreviations

1D-Var	One-Dimensional Variational Retrieval
3D-Var	Three-Dimensional Variational Analysis
4D-Var	Four-Dimensional Variational Assimilation
AES	Atmospheric Environment Service
AIRS	Atmospheric Infrared Sounder [EOS]
AMI	Active Microwave Instrument
AMSU	Advanced Microwave Sounding Unit
ASCAT	Advanced SCATterometer
ATOVS	Advanced TOVS
CAL/VAL	Calibration & Validation
BUFR	Binary Universal Form for data
DMSP	Defence Meteorology Satellite Program
ECMWF	European Centre for Medium-Range Weather Forecasts
ERA	ECMWF Re-Analysis project
ERS-1, -2	ESA Remote Sensing Satellites
EPS	Ensemble Prediction System

ESA	European Space Agency
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FASCODE	Fast Atmospheric Signature CODE
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FG	First Guess (for analysis)
FGAT	First Guess at Appropriate Time
GENLN2	GENeral LiNe-by-line
GOES	Geostationary Operational Environmental Satellite
GTS	Global Telecommunications System
HIRS	High Resolution Infra-Red Sounder
HITRAN	High-resolution TRANsmission
IASI	Infrared Atmospheric Sounding Interferometer
IFS	Integrated Forecast System
LMD	Laboratoire Meteorologique Dynamique
MARS	Meteorological Archive and Retrieval System
MDD	Meteorological Data Distribution via METEOSAT
MSG	METEOSAT second Generation
MSU	Microwave Sounding Unit
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NESDIS	National Environmental Satellite, Data and Information Service (USA)
NOAA	National Oceanographic and Atmospheric Administration (USA)
NWP	Numerical Weather Prediction
ODB	Observation Data Base
OSE	Observing System Experiment
OSSE	Observing System Simulation Experiment
QC	Quality Control
QuikSCAT	Sea-wind Scatterometer mission
RRTM	Rapid Radiative Transfer Model
RTOVS	New NESDIS TOVS processing system
RTTOV	Fast Radiative Transfer model for TOVS data
SAF	Satellite Applications Facility
SAR	Synthetic Aperture Radar
SBUV	Solar Backscatter UltraViolet radiometer
SSM/I	Special Sensor Microwave Imager
SMMR	Scanning Multichannel Microwave Radiometer
SST	Sea Surface Temperature
SSU	Stratospheric Sounder Unit
T106,T63 . . .	As T213 but at wavenumbers 106, 63,..
T213	Triangular truncation at wavenumber213; a measure of model horizontal resolution
T63L19	T63 resolution model with 19 levels in the vertical
TESSEL	Tiled ECMWF Scheme for Surface Exchanges over Land

TCWV	Total Column Water Vapour
TMI	TRMM Microwave Imager
TOMS	Total Ozone Mapping Spectrometer
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission
UKMO	United Kingdom Meteorological Office
VTPR	Vertical Temperature Profile Radiometer
WMO	World Meteorological Organization

EGYPT

(Egyptian Meteorolgical Authority (EMA))

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4.1 PDUS: Available 3 channels classified as IR (10.5-12.5 µm, VIS (0.4-1.1 µm), and WV (5.7-7.1 µm) converted to:

- imaging system,
- cloud coverage,
- front detection,
- cloud top temperature,
- cloud wind directions
- classification of cloud coverage types and height.

4.2 HRPT available five channels classified as VIS 1 (0.6 µm). VIS 2 (0.9 µm). Channel 3 (3.7 µm), UR 1 (10.8 µm) and IR 2 (12.9 µm). TOVS partially available converted to:

- Imaging system over available area around NADIR which covers Egypt area using maximum 3 channels,
- Sea surface temperature,
- Vegetation index,
- Water vapour,
- HIRS,
- Raw data of five channels for NWP purpose.

Collection of data from *in situ* sensors - not available.

4.3 Transmission of satellite data through PDUS (Primary Data Utilization Station). In the Remote Sensing Centre (RSC) of the EMA we receive all products from Meteosat-7 and have Tecnavia applications to be processed and displayed by the received data and we resend the data into five remotes for aviation and broadcast purposes.

4.4 HRPT (High Resolution Picture Transmission). We also have SMARTech systems to receive, process and display data by the following applications:

- SMARTrach
- SARTVue
- ERDAS Imagine

4.5 In the area of direct broadcast we have four remotes in the Egyptian TV and airports for providing immediate PDUS data for civil and aviation purposes. Convert outputs of PDUS and HRPT into Grib file and submit it to the computer centre of the EMA to resend it to a large number of airport stations for aviation purposes.

PART VII OTHER ITEMS (references, publications and scientists in charge)

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EUMETSAT

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 EUMETSAT continued its routine operation of the Meteosat satellites throughout the period. Major operational changes resulted mainly from the evolving use of the existing space segment. Throughout the period in question Meteosat-7 provided the operational 0°E Service with Meteosat-5 (located at 63° East) providing the Indian Ocean Data Coverage (IODC) Service. It is currently foreseen that the IODC Service will be continued until at least the end of 2003. Discussions are underway for a possible further extension of around two years. Meteosat-6 provided rapid-scan images in support of the international Mesoscale Alpine Project (MAP) in 1999 and, based upon the very positive user experience from MAP, in 2000 it was decided to continue the provision of rapid scan imagery on a more operational basis. The rapid-scanning service, providing 10-minute scans of European and subtropical regions, will start in the summer 2001, and will continue until at least the end of 2003.

1.2 The routine derivation of products from Meteosat imagery also continued throughout the period and included a full set of IODC products from Meteosat-5. In late 1998, manual quality control of distributed meteorological products was discontinued, which enabled an increase in the distribution of products by 1-2 orders of magnitude in terms of volume, with no appreciable loss of quality.

1.3 In March 2000, High Resolution Water Vapour Winds became an operational product. This product provides cloud-tracked WV winds at 80 km resolution and is generated every 90 minutes and distributed via the GTS in BUFR code.

1.4 From May 2000, the operational calibration of Meteosat-7 made use of the onboard blackbody. Prior to this date vicarious calibration, using sea surface temperature measurements and radiosonde data had provided the calibration data for the METEOSAT infra red channels. However, this method was highly dependent upon the quality of the external data and thus gave significant spurious fluctuations in calibration, especially for the WV channel. The blackbody calibration produces a much more consistent output, and the bias of radiance against NWP output has become small and very stable.

1.5 Over the last few years there has been a significant increase in the operational use of the Internet for routine transfers of data and information. This was particularly true for the relay of DCP messages to users, the delivery of archived data, the provision of a subset of near-real time image data and providing users with a considerable amount of information via the EUMETSAT website: www.eumetsat.de

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2.1 EUMETSAT routinely generates a range of meteorological products from its satellite data and increasingly participates in research and development activities needed to improve these products and to define new products resulting from the evolution of new satellite instruments. During the period various research activities were carried out by EUMETSAT, some in house, others through research fellowships at other locations.

Atmospheric Motion Vectors

2.2 Since April 1997, quality indicators have been included with operational Atmospheric Motion Vectors (AMV). The use of these indicators in numerical weather analysis greatly enhances the utility of this product, since wind vectors with high quality can be assigned higher confidence and lower error. The quality indicators were validated, using RMS vector differences between AMV and ECMWF first guess wind fields, by a EUMETSAT Research Fellow working at ECMWF. Agreement was found to be good, thus confirming that the quality indicators are good predictors of the quality of the operational wind vectors. The method has now been published and there is close co-operation on this subject with NOAA/NESDIS and the Co-operative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin in Madison (USA). Further work is required in the area of assimilation of the BUFR coded AMV in 4D-VAR schemes used by NWP models, and the possible use of this method for clear sky regions.

Clear Sky Water Vapour Winds

2.3 A Clear-Sky Water Vapour Wind product has been developed using an algorithm very similar to that used for the Cloud Motion Wind product, but tracking structures in non-cloudy areas. The product is derived every 90 minutes, and distributed via the GTS in BUFR code.

Clear Sky WV Radiances

2.4 A Clear Sky Radiance product has been developed containing an estimate of the mean WV channel brightness temperature from regions containing either no, or only low-level clouds which do not effect WV radiances. Approximately 1800 winds are produced per extraction from the full disk image and the product is generated hourly. Originally this product was part of the Upper Tropospheric Humidity product, however, since May 1997 it has been disseminated as a separate product.

New Meteorological Products

2.5 The following two new meteorological products have been developed:

(i) High-Resolution Water Vapour Winds (HWW)

2.6 This product consists of WV winds derived from cloudy areas on a scale of 16x16 pixels (80 km). This is twice the resolution of the current WV wind product. Prototyping has shown that good tracking of cloudy and non-cloudy areas is possible at this scale. Because of the rather smooth pattern of radiance in cloud-free areas, so far, it has not been possible to derive this product in clear-sky regions. The HWW product is derived every 90 minutes and distributed via the GTS in BUFR code which includes the quality indicators.

(ii) 80 km Clear-Sky Radiances (CSR)

2.7 This product matches the resolution of HWW, and provides clear-sky equivalent blackbody temperatures from both the WV and IR channels. It is used within 4D-VAR assimilation schemes in NWP. The method employed is essentially the same as that used for the current 160-km resolution CSR product. The product is derived hourly and distributed via the GTS in BUFR code.

2.8 The HWW product became operational in March 2000, and the CSR product is expected to be declared operational in spring 2001, following the implementation of an operational scheme for cross-calibrating the Meteosat-5 imager using blackbody measurements from

Meteosat-7. The HWW and CSR products provide an effective transition to Meteosat Second Generation products, where spatial and temporal resolutions will be similar.

Reprocessing Project

2.9 As a result of the many improvements to product algorithms over the years and the benefits of having a consistent time series of derived products, it was decided that there should be a data reprocessing project. Archived historical image data dating back to the early 1980s is being reprocessed using the latest product algorithms. The re-processed products will be made available to end-users via the EUMETSAT Meteorological Archive and Retrieval Facility (MARF). The products are primarily being produced in support of the ECMWF ERA-40 (40 years) reanalysis project.

Surface Albedo Product

2.10 A new land surface albedo retrieval algorithm has been developed by the Space Applications Institute of the European Commission and implemented in the EUMETSAT data reprocessing environment. This algorithm derives surface albedo at pixel resolution every 10 days, using the Meteosat VIS channel. The Meteosat Surface Albedo (MSA) algorithm takes account of water vapour and ozone absorption, aerosol scattering and surface anisotropy. The MSA algorithm provides two parameters:

(i) Directional Hemispherical Reflectance (DHR)

2.11 This product is the integral of the Bi-directional Reflectance Factor (BRF) over all incident and outgoing angles for direct cloud free illumination only, and computed for a solar illumination at 30 degrees. This parameter shows the capacity of land surfaces to scatter direct solar radiation and can therefore be used as an indicator of the state of these surfaces.

(ii) Daily Directional Hemispherical Reflectance (DDHR)

2.12 This product is the integral of the DHR for all possible locations of the Sun for every day. This parameter, which permanently changes according to pixel location and time of year, can be used within climate models to represent the daily average amount of solar radiation, which is absorbed by land surfaces. The MSA algorithm has been applied to 1996 Meteosat-5 data in order to record the seasonal variation of surface albedo.

2.13 An analysis of results, at continental scale over Africa, has revealed the potential influence of intense biomass burning on observed changes in seasonal surface albedo. This algorithm could, as a consequence, be used to assist the monitoring of biomass burning.

Visible Calibration

2.14 A vicarious calibration method has been developed for the MSG visible channels, which uses well characterised surfaces (e.g., desert, ocean) and a radiative transfer model. An absolute accuracy of 5% is expected.

Satellite Inter-calibration

2.15 Inter-calibration of polar orbiting and geostationary satellite systems is necessary to achieve consistency in data sets involving more than one sensor. Within the framework of CGMS, satellite operators have, therefore, begun a programme to inter-calibrate satellite IR sensors, where fields of view overlap in space and time. Expected inter-calibration accuracy is 1 K for IR and WV channels.

2.16 This activity has drawn on the considerable experience gained by the International Satellite Cloud Climatology Program (ISCCP), which has made the following recommendations:

(i) Instruments should be designed to ensure that spectral and angular responses are "simple" and onboard calibration references should be provided for all channels. The latter need not provide high absolute accuracy, only high relative stability to enable monitoring of post-launch instrument behaviour. Such onboard calibration reference measurements should, as a minimum, be made at two points, it should lie within the instrumental dynamic range and the data should form part of the imaging data set;

(ii) In order to produce high quality data, extra care is required when performing pre-launch instrument characterisation and calibration, especially for short wavelength channels;

(iii) Complete documentation of instrument characterisation and calibration should be published and kept up to date;

(iv) Instrument and satellite engineering (housekeeping) information should form part of the data set.

NOAA ATOVS data processing

2.17 The further development of AAPP software, used to process directly received HRPT (AVHRR and ATOVS data) from the NOAA-K, -L and -M spacecraft, is now the responsibility of the EUMETSAT Numerical Weather Prediction Satellite Application Facility (NWP SAF), hosted by the Met Office (UK). An on-line user forum has been established by this SAF for information exchange and user feedback.

2.18 Following the launch of NOAA-15, revised versions of the AAPP software have been released. The current version (V2.0) was released in February 2000 and includes a level 2 processing step (ICI V2.0 package), provided by Météo-France (an NWP SAF consortium member) as part of its activities. AAPP V2.0 comprises:

- Ingest code for HRPT, for TOVS and ATOVS instruments;
- Navigation code for TOVS and ATOVS instruments;
- Calibration code for TOVS and ATOVS instruments;
- Mapping code for the TOVS and ATOVS instruments;
- AVHRR cloud mask processing, including mapping to the HIRS FOV;
- Pre-processing code for TOVS and ATOVS instruments.
- AMSU-B interference correction code
- Processing for temperature and humidity retrieval, in the form of the ICI V2.0 package.

2.19 It is planned to make one major release of the AAPP software per year on CD-ROM. These releases are identified through the release number followed by a zero (e.g., V2.0). A list of known bugs and fixes is maintained on the EUMETSAT website: www.eumetsat.de. All bugs are corrected in intermediate releases, between major releases. These intermediate releases are made via the EUMETSAT ftp-server and are identified through a combination of the major release and intermediate release numbering (e.g., V2.2).

2.13 AAPP V2.2 includes updates of the AMSU-B bias correction. To date, 124 users from 40 countries have requested the AAPP V2.0 software package.

2.14 More detailed information on AAPP can be found on the EUMETSAT webpage: www.eumetsat.de/en/area4.

Satellite Application Facilities (SAF) Network Development

2.15 In November 1992 EUMETSAT adopted the concept of a distributed Applications Ground Segment, including the central Meteorological Products Extraction Facilities (MPEF) and the Unified Meteorological Archive and Retrieval Facility (U-MARF), both located in Darmstadt, Germany, and a network of elements known as Satellite Applications Facilities (SAF). The MPEF produces an agreed set of basic meteorological products, while the Satellite Applications Facilities (SAF) are more specialised development and processing centres, which, based on specific expertise in Member States, will deliver additional meteorological and geophysical products and related services, which form an integral part of the overall EUMETSAT service.

2.16 The SAFs are developed by consortia of organisations from the Member States, based in National Meteorological Services or other agreed entities, and responsible for research, development and operational activities. EUMETSAT contributes up to 50% of the development cost of each SAF, and the EUMETSAT Secretariat coordinates and manages the SAF Network level activities and all activities necessary to integrate the SAFs and the central services into coherent end-to-end systems providing the operational services expected by the end users. It provides also managerial, technical and scientific support to the SAFs, including the organisation of reviews, interface and planning meetings. A SAF Network Management Scheme has been established and agreed for this purpose.

2.17 **Seven SAFs** are currently under development and address the following topics:

- Support to Nowcasting and Very Short Range Forecasting (NWC SAF);
- Ocean and Sea Ice (OSI SAF);
- Ozone Monitoring (O3M SAF);
- Climate Monitoring (CLM SAF);
- Numerical Weather Prediction (NWP SAF);
- GRAS Meteorology (GRAS SAF);
- Land Surface Analysis (LSA SAF).

2.18 SAFs will use data from Meteosat, MSG and EPS and, in some cases, data from non-EUMETSAT missions. Until such data become available, information from current satellites will be used for development.

2.19 In consideration of the phasing needs with the MSG and EPS commissioning, the **NWC and OSI SAFs** will enter an **Initial Operational Phase** (IOP), which will be concluded after the EPS commissioning. During the IOP, the development for the EPS related products would be finalised, while MSG products will be put into operations after their validation using the real data provided by the MSG instruments. Continuous research and development will take place during IOP to sustain the needs for product improvements and innovation.

2.20 For all SAFs, the full **Operational Phase** will start on completion of the EPS products validation and will aim to:

- Put into operation the accepted SAF products and services;
- Maintain these products;
- Improve the products, based on the results of the continuous research and development effort as well as on the user feedback.

Joint EUMETSAT-ESA Research Announcement of Opportunity (RAO) for MSG

2.21 The MSG Research Announcement of Opportunity was released jointly by ESA and EUMETSAT to the world-wide scientific user community in early 1999. The aim of the RAO is to stimulate interaction between research and operational meteorological user communities early in the life of the MSG satellite programme. As a result of the RAO, 43 projects have been selected through a peer review process. The variety and innovation of the projects clearly indicates the potential of MSG data to support novel scientific investigations. A first workshop of RAO Principal Investigators was held in Bologna, Italy, from 17-19 May 2000, hosted by the Institute of Atmospheric and Oceanic Sciences (ISAO) of the National Council of Research (CNR). This workshop focused on the presentation of selected projects and on an analysis of data delivery mechanisms required to serve the needs of the scientific user community.

Research Fellowships

2.23 Four Research Fellowships are currently in place with two research fellows recruited in February and March 1999 and hosted by National Meteorological Services, and the remaining two recruited in April and June 2000 and working at ECMWF.

2.24 Research *'Towards a optimal use of QuickSCAT backscatter measurements to derive winds'* is being carried out in the Satellite Data Group of the Observations and Modelling Section of the Dutch Meteorological Service, KNMI. So far, the research has contributed to QuickSCAT calibration and validation activities, the analysis of wind information content and wind and radar backscatter quality control (including rain elimination) algorithms.

2.25 Research related to '*Mesoscale Convective Systems in Europe: getting hard facts about their series*' is carried out by Météo France CNRN/GMM/PI. The research addresses the characterisation of the life cycle of Mesoscale Convective Sytems (MCS) using a combination of satellite infrared radiances and lightning data to improve our knowledge of such systems in Europe.

2.26 The two fellows located with the Research Department at ECMWF are carrying out research on:

(i) *'Assimilation of Meteosat Radiances'*;
(ii) *'Assimilation of satellite wind observations'*.

2.27 The main purpose of the Assimilation of Radiances work is to develop the use of Clear Sky Radiances (CSR) within the 4-D VAR assimilation system of ECMWF. The main objectives are:

- Monitoring of the CSR received from the Meteosat (-7 and -5) satellites;
- Assimilation of water vapour channel radiances within 4-D VAR;
- Development of a similar approach for radiances from other satellites;
- Preparation for an early monitoring and assessment of MSG radiances.

2.29 The main objectives of the Fellowship on assimilation of Atmospheric Motion Vectors (AMVs) at ECMWF are:

- Monitoring the assimilation of wind information from geostationary satellites
- Revision of AMV observation operator and error statistics
- Preparation for an early assessment of MSG AMV
- Participation in an assessment of the use humidity and ozone AMV information versus direct assimilation of radiances.

Status of the Post-MSG User Consultation Process

2.30 The objective of the Post-MSG User Consultation Process (UCP) is to establish a set of agreed requirements, which can be used as a basis for defining possible future missions. Ultimately, the agreed user requirements would be used to derive the required performance and the technical specifications for a post-MSG system. The UCP is structured as a 2-step approach, where Phase I is concentrated on the establishment/endorsement of user requirements (technology free) and Phase II is addressing the selection of a limited number of mission concepts.

2.31 Phase I started in January 2001 and is being conducted under the leadership of two Application Experts Groups (AEGs). One Group is dedicated to Medium Range and Short Range/Mesoscale Numerical Weather Prediction (AEG-NWP) and the other to Nowcasting and Very Short Term Forecasting (AEG-NWC). Both AEGs are led by co-chairmen and comprise scientists and technical experts from Meteorological Services and relevant institutions with scientific expertise within each of the respective fields. The AEGs are supported by satellite and remote sensing experts. EUMETSAT Member States are also formally represented through the Chairpersons of the EUMETSAT Scientific and Technical Working Group and sub-Groups. Both AEGs have been tasked to establish user requirements and priorities, and to prepare a workshop (planned for 13-15 November 2001 at EUMETSAT HQ) where these will be presented and discussed. After that workshop both AEGs will prepare a report to EUMETSAT Delegate Bodies including recommendations.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Image Data Dissemination Service

3.1 Raw (uncorrected) Meteosat images are received by the EUMETSAT Ground Segment in Darmstadt where they are rectified (geometrically corrected) and then disseminated to the user community via Meteosat according to a fixed schedule. The dissemination is carried out using two channels with frequencies 1691 MHz and 1694.5 MHz.

3.2 The image data are sent as WEFAX and High Resolution Image (HRI) formats, with the channel operating at 1691 MHz being used solely for WEFAX dissemination, whilst the channel at 1694.5 MHz is mainly used for HRI dissemination. A few full earth disc WEFAX formats and a selection of foreign satellite (GOES, GMS, GOMS) image formats are also disseminated on the 1694.5 MHz channel.

The Meteorological Product Extraction and Distribution Service

3.3 The Meteorological Product Extraction and Distribution Service provides the meteorological user community with a selection of meteorological products derived from Meteosat imagery. They are distributed in near-real time and used in a wide range of applications.

3.4 The following meteorological products are routinely disseminated to National Meteorological Services:

- Cloud Motion Winds (CMW)
- Expanded Low-Resolution Winds (ELW)
- Clear Sky Water Vapour Winds (WVW)
- High-resolution Water Vapour Winds (HWW)
- High Resolution Visible Winds (HRV)
- Sea Surface Temperatures (SST)
- Cloud Analysis (CLA)
- Upper Tropospheric Humidity (UTH)
- Clear Sky Radiances (CSR)
- Cloud Top Height (CTH)

3.5 The above products, all of which are archived by EUMETSAT, are disseminated over the WMO Global Telecommunications System (GTS). The only exception is the Cloud Top Height (CTH) product which is distributed as a WEFAX format via Meteosat dissemination.

3.6 These products (except CTH) are also disseminated via the Regional Meteorological Data Communications Network (RMDCN) for Regional Association VI (Europe).

3.7 A reduced resolution Climate Data Set (CDS), based upon the results of operational image processing, is also archived and used mainly for climate research applications.

3.8 In addition, two products are operationally derived in support of two components of the WMO World Climate Research Programme (WCRP), namely:

International Satellite Cloud Climatology Project (ISCCP)

3.9 As a participant in the ISCCP, EUMETSAT routinely performs the function of a Sector Processing Centre. The ISCCP data sets consist of Meteosat image data sampled at the following resolutions:

- B1 data set 10 km resolution, full disk;
- B2 data set 30 km resolution, full disk;
- AC data set full resolution, reduced area of 400x400 pixels.

3.10 The data sets, all of which are archived by EUMETSAT, are sampled at three hourly intervals (the main synoptic hours) and visible image pixels are averaged to match infra-red pixel resolution. B1 data is retained for five months and B2 data indefinitely. AC data are used by the ISCCP for satellite inter-calibration. AC areas are selected such as to ensure collocation with overpasses of NOAA polar-orbiting satellites in areas where observation angles of NOAA and Meteosat do not widely differ.

3.11 Since the start of the Indian Ocean Data Coverage (IODC) Service in June 1998, ISCCP data sets have also been routinely generated based upon Meteosat-5 (located at 63° East) image data.

Global Precipitation Climatology Project (GPCP)

3.12 Precipitation Index (PI) data, derived from Meteosat imagery, continues to be provided in support of GPCP activities. In this regard, EUMETSAT acts as a Meteosat Sector Processing Centre. The data, produced from IR imagery and archived at EUMETSAT, are delivered to the GPCP Data Collection Centre on a daily basis.

3.13 Following an upgrade of the product algorithm in 1997, the product (now called High Resolution Precipitation Index (HPI)) has a horizontal resolution of about 1 x 1 degrees and provides an estimate of the accumulated convective precipitation in tropical regions for each day.

3.14 Since the start of the Indian Ocean Data Coverage (IODC) Service in June 1998, an HPI product has also been generated routinely from image data from 63° East.

3.15 A similar Precipitation Index product is provided by the other meteorological satellite operators and used to compile a global rainfall data set.

3.16 Detailed information on all products generated by EUMETSAT and related technical documentation can be obtained from the EUMETST website: www.eumetsat.de.

Archived Data Retrieval Service

3.17 The EUMETSAT archive contains all Meteosat image data and derived products since the start of operations. The Archive provides a comprehensive data retrieval service including on-line access to data catalogues and other information. Image data and derived products are written to Digital Linear Tape (DLT), each having the capacity to store several days' images. As this storage medium has only been used since December 1995, a different processing scheme is used to retrieve data prior to that date. Historical data, extending back to 1982, remain available in the Archive and can be retrieved upon request. An ongoing project to systematically transfer the historical data from some 40,000 magnetic tapes to DLT cartridges will be completed within the next two years.

3.19 Full details about the EUMETSAT Archive, together with information on how to request archived data, can be found on the EUMETSAT website: www.eumetsat.de.

The Meteorological Data Distribution Service

3.20 The Meteorological Data Distribution (MDD) Service, routinely disseminates alphanumeric and graphical meteorological information to meteorological services via the operational Meteosat satellite. A third MDD uplink station in Toulouse (France) became fully operational in January 1995, complementing the Service provided by the existing MDD uplink stations at Bracknell (UK) and Rome (Italy). The Toulouse uplink focuses particularly on the requirements of African meteorological services. It also disseminates products produced by certain African specialised centres, such as ACMAD, the Drought Monitoring and Locust Control Centres and the RMTCs. In addition, MDD disseminates a range of key meteorological products from European data processing centres such as ECMWF, UK Met Office, Météo-France, German Weather Service, together with a wide selection of meteorological bulletins taken from the GTS.

3.21 MDD data are encrypted but are made available to the meteorological services of WMO Members Countries free of charge. They are, however, subject to an MDD license agreement with EUMETSAT. By the end of 1996, over 100 users had been granted access to MDD data in approximately 70 countries located in Africa, the surrounding regions and Europe.

3.22 The selection of products included in MDD dissemination is based on recommendations made by a special EUMETSAT Working Group comprising representatives from the EUMETSAT Member and Co-operating States, WMO, ECMWF, and representatives from Africa. This Working Group reports directly to the delegate bodies of the EUMETSAT Council, which, ultimately, authorises the content of MDD broadcasts.

3.23 MDD data are disseminated via three broadcast channels to the user community via the operational Meteosat. The data can be directly received using dedicated MDD receiving stations. Further information on this service and related technical documentation can be found on the EUMETSAT website: www.eumetsat.de.

The Data Collection and Retransmission Service

3.24 This Service supports the relay and retransmission of Data Collection Platform (DCP) messages, either directly to users, via the GTS or the Internet.

Table 1

Meteosat Data Collection Mission (Status at the end of 2000)

Number of DCPs registered	1437
Number of DCPs actively reporting	607

3.25 DCP messages can be directly received by users located within the telecommunications field of view of the satellite (close to 80° great circle arc from the sub-satellite point). In this case, the messages are relayed via the operational Meteosat to small DCP Receiving Stations (DRS).

3.26 DCP messages destined for the GTS are processed in the EUMETSAT Ground Segment in Darmstadt and routed to the nearest RTH, located in Offenbach, where they are injected onto the GTS for global broadcast.

3.27 DCP messages can also be accessed by users via the Internet. A password controlled Service has been established by EUMETSAT in recent years. With this system users cannot only receive their DCP messages on-line but also “housekeeping” data providing information on the condition and operation of their DCPs.

3.28 Further details of these Services and related technical documentation can be found on the EUMETSAT website: www.eumetsat.de.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4.1 In June 1998 Meteosat-7 became the prime spacecraft supporting the 0° Operational Service. EUMETSAT plans to continue this service until at least the end of 2003. Subject to the approval of the EUMETSAT Council, there may be a further short extension of this service.

4.2 Meteosat-6 is the in-orbit backup satellite, located close to 10° West. This satellite provided rapid-scan imagery in support of the international Mesoscale Alpine Project (MAP) in 1999, and based on the very positive experience from MAP, there has been a decision to continue providing rapid-scan imagery on a more operational basis. The rapid-scan imaging Service, providing 10-minute scans of European and subtropical regions will start in summer 2001, and will continue until at least the end of 2003. Further details on the rapid scan service can be found on the EUMETSAT website: www.eumetsat.de

4.3 Since July 1998 Meteosat-5 has been operated over the Indian Ocean at 63° East. This relocation was originally arranged to provide imaging support to the international INDOEX project. As a result of many requests for regular imagery from this location, the EUMETSAT Council has agreed to continue the Indian Ocean Data Coverage (IODC) Service at this position until at least the end of 2003. In addition to a Meteosat-5 image dissemination service for direct reception by licensed users, a limited amount of Meteosat-5 image data is routinely disseminated via Meteosat-7 as part of the 0° Service. Meteosat-5 is now a very old spacecraft (launched in 1991) and has run out of fuel to control orbit inclination. At the beginning of 2001, the orbit inclination was around 4° and steadily increasing at a rate of around 1° per year. This means that users directly receiving Meteosat-5 image data via reception stations with large antennas will have reception difficulties at certain times of the day unless they can track the movement of the satellite. However, there are some technical solutions to this problem and further information can be found on the EUMETSAT website: www.eumetsat.de .

4.4 The 0° and 63° Service satellites provide users with digital and analogue images covering Europe, north and south Atlantic, Africa, Asia, Indian Ocean and surrounding regions. In addition, the 0° Service includes images covering the USA and the Far East taken by the American GOES and Japanese GMS satellites, respectively.

4.5 As a complement to the dissemination of images, a wide range of meteorological products, as described in Part II above, are derived from both 0° and 63° service imagery and disseminated globally.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

Meteosat Second Generation (MSG)

5.1 The meteorological community has benefited for more than two decades from the services of the current generation of Meteosat satellites, the first of which was launched in 1977. Meteosat image data are now an essential component of the Global Observing System and derived meteorological products are of great value to Numerical Weather Prediction (NWP), Nowcasting and Very Short Range Forecasting (VSRF). For NWP applications, satellite tracked winds and, more recently, radiances are used in both analysis and data assimilation. The Meteosat Second Generation (MSG) system not only provides the various user communities with continuity of services but will also significantly enhance current services and products. The main missions of MSG are:

(a) **Basic multi-spectral imagery**, with better spectral, spatial and temporal resolution than the existing Meteosat satellites, mainly in support of Nowcasting and short-range weather forecasting;

(b) **High resolution imagery**, by observing the Earth in the same visible band as Meteosat, with a spatial resolution similar to the AVHRR instrument, to support the monitoring of mesoscale phenomena over Europe;

(c) **Air Mass Analysis**, using some H_2O and CO_2 absorption channels whose importance for Nowcasting has been demonstrated from VAS experience;

(d) **Meteorological Product Extraction,** (winds, surface temperatures, etc.) upgraded according to the improved capability of the imager;

(e) **Support to climate and environment monitoring**, and Earth resources management;

(f) **Continuity of current Meteosat data collection and dissemination missions**.

5.2 The MSG Programme covers a series of three, spin-stabilised, identical satellites, MSG-1, -2 and -3, which are expected to provide observations and services over a period of at least 12 years. MSG-1 is scheduled for launch in 2002 with MSG-2 to follow around 18 months later. The MSG system is established under a cooperation between ESA and EUMETSAT. The Rutherford Appleton Laboratory (RAL), UK provides the Geostationary Earth Radiation Budget (GERB) instruments (and associated data services) for flight on all three MSG satellites.

5.3 The primary mission of MSG is the continuous observation of the Earth's full disk. This is achieved with the Spinning Enhanced Visible and Infrared Imager (SEVIRI) which is a twelve-channel imager observing the Earth-atmosphere system with a spatial sampling distance of 3 km in eleven channels. A high-resolution visible (HRV) channel covers half of the full disk in East-West (full disk in North-South) with a 1 km spatial sampling. The size of the actual field of view of the non-HRV channels is about 4.8 km at Sub Satellite Point (SSP) (1.67 km for HRV).

5.4 A repeat cycle of 15 minutes for full-disk imaging provides unprecedented multi-spectral observations of rapidly changing phenomena (e.g., deep convection) and provides better and more numerous wind observations from the tracking of cloud features. Rapid scans of limited latitude belts are possible with shorter time intervals.

Table 2

Spectral channel characteristics of SEVIRI providing central, minimum and maximum wavelength of the channels

Channel No.		Channel Spectral Band in µm		
		λ_{cen}	λ_{min}	λ_{max}
12	HRV	Broadband (silicon response)		
1	VIS0.6	0.635	0.56	0.71
2	VIS0.8	0.81	0.74	0.88
3	NIR1.6	1.64	1.50	1.78
4	IR3.9	3.90	3.48	4.36
5	WV6.2	6.25	5.35	7.15
6	WV7.3	7.35	6.85	7.85
7	IR8.7	8.70	8.30	9.1
8	IR9.7	9.66	9.38	9.94
9	IR10.8	10.80	9.80	11.80
10	IR12.0	12.00	11.00	13.00
11	IR13.4	13.40	12.40	14.40

5.5 Whilst data and product dissemination will use similar frequency bands as the current generation of Meteosat, they will follow new HRIT and LRIT digital formats internationally agreed by the Coordination Group for Meteorological Satellites (CGMS). HRIT contains the full set of SEVIRI image data (lossless - apart from HRV); LRIT contains the full set of Foreign Satellite Data (lossless), a subset of lossy SEVIRI image data, DCP data, MDD data and meteorological products. The contents of the HRIT and LRIT dissemination are summarised in table 3.

Table 3

Baseline for HRIT and LRIT dissemination

<table>
<tr><td colspan="3">The agreed baseline can be summarised as:
- HRIT containing the full set of SEVIRI image data (lossless – apart from HRV);
- LRIT containing the full set of Foreign Satellite Data (lossless), a subset of lossy SEVIRI image data, DCP data, MDD data and meteorological products.</td></tr>
<tr><td colspan="3">IN MORE DETAIL THE DATA CONTENT OF LRIT AND HRIT IS:</td></tr>
<tr><td colspan="2">LRIT</td><td>HRIT</td></tr>
<tr><td colspan="2">SEVIRI 1.5</td><td>SEVIRI 1.5</td></tr>
<tr><td>VIS (0.6)</td><td>lossy (30 mins)</td><td rowspan="9">All channels lossless (apart from HRV) full Earth disk, 15 mins</td></tr>
<tr><td>IR (6.2) WV</td><td>lossy (30 mins)</td></tr>
<tr><td>IR (10.8)</td><td>lossy (30 mins)</td></tr>
<tr><td>[NIR (1.6)</td><td>lossy (30 mins)]*</td></tr>
<tr><td>[IR (3.9)</td><td>lossy (30 mins)]*</td></tr>
<tr><td colspan="2">FOREIGN SATELLITE DATA
Lossless 3-hourly Images (full set)</td></tr>
<tr><td colspan="2">METEOROLOGICAL PRODUCTS **
MPEF AMV
MPEF CTH
MPEF CLAI</td></tr>
<tr><td colspan="2">DCP**
All DCP data</td></tr>
<tr><td colspan="2">MDD**
All MDD Data</td></tr>
<tr><td colspan="3">SUMMARY OF DIFFERENCES WITH RESPECT TO PREVIOUSLY AGREED BASELINE:</td></tr>
<tr><td colspan="3">HRIT
- SEVIRI 1.5 data: no change (just more space for uncertainty in compression factor)
- FSD: moved to LRIT
- Meteorological Products: moved to LRIT
- DCP: moved to LRIT
- BULLETINS FROM GTS (I.E. MDD): MOVED TO LRIT</td></tr>
<tr><td colspan="3">LRIT
- SEVIRI 1.5 data: 3 of original 5 channels unchanged / 2 of original 5 channels to be included if space available
- FSD: now full set and lossless (transferred from HRIT)
- Meteorological Products: augmented set from HRIT
- DCP: no change
- MDD: no change</td></tr>
</table>

* Denotes channels to be included if space is available

** DCP, MDD and Meteorological Products could be moved back to HRIT if the 3 core SEVIRI channels on LRIT cannot be accommodated

5.6 Many SEVIRI spectral channels build upon the heritage of other satellite instruments, which has the advantage that the user community can use existing know-how to utilise SEVIRI radiance observations. The heritage of channels can be summarised as follows:

- ***VIS0.6 and VIS0.8**:* AVHRR heritage. They are essential for cloud detection, cloud tracking, scene identification, aerosol and land surface and vegetation monitoring;
- ***NIR1.6**:* Discriminates between snow and cloud, ice and water clouds, and provides aerosol information. Similar observations are available from the Along Track Scanning Radiometer (ATSR) on ERS;
- ***IR3.9**:* AVHRR heritage. Primarily used for low cloud and fog detection. Also supports measurement of land and sea surface temperature at night. For MSG, the spectral band has been broadened to higher wavelengths to improve signal-to-noise ratio;
- ***IR6.2 and IR7.3**:* Continues Meteosat broadband water vapour channel observations, used for observing water vapour and winds. Two channels peaking at different levels in the troposphere provide improved vertical resolution. Also assists height allocation of semitransparent clouds;
- ***IR8.7***: Known from the High resolution Infra Red Sounder (HIRS) instrument. The channel provides quantitative information on thin cirrus clouds and assists discrimination between ice and water clouds;
- ***IR9.7**:* Also known from HIRS and current GOES satellites. Ozone radiances could be used as an input to Numerical Weather Prediction (NWP). As an experimental channel, it will be used to track ozone patterns which should be representative of wind motion in the lower stratosphere. The evolution of the total ozone field with time can also be monitored;
- ***IR10.8 and IR12.0**:* Well-known split window channels (e.g. AVHRR). Essential to measure sea and land surface temperatures and cloud top temperatures;
- ***IR13.4**:* CO_2 absorption channel known from former GOES VAS instrument. It improves height allocation of thin cirrus clouds. In cloud free areas, it will provide temperature information from the lower troposphere, which can be used to assess static instability.

5.7 The thermal IR channels of SEVIRI assume a linear relationship between counts and radiance. Any small non-linearity is corrected for on ground before applying the linear calibration. SEVIRI uses the deep space as a cold source and an internal blackbody as warm source for the calibration. While the deep space view is obtained by viewing through the complete optical path of the instrument the blackbody is moved into the optical path thus avoiding the front optics. This design necessitates a correction to be applied to the blackbody calibration to take account of any effects of the front optics, whose characteristics have been measured before launch and whose temperature is monitored continuously. The blackbody can also be heated to allow for the determination of the correction factor.

5.8 The solar (visible) channels do not have on-board calibration but have to rely on a vicarious method based on radiance observations over well-characterised targets (such as clear-sky desert, clear-sky ocean and optically thick high level clouds) and radiative transfer models. This new method of solar channel calibration is expected to achieve an accuracy of around 5% after the first year of operations, and as the characterisation of targets improves and quality control parameters become better tuned.

5.9 The design of two prototype HRIT and LRIT User Stations was established and tested within the scope of the MSG Ground Segment development activities. Comprehensive design information relating to these prototypes stations was widely distributed to manufacturers and the user community during 2000. Additional requests for information should be addressed to the

EUMETSAT User Service, and full details can also be found on the EUMETSAT website: www.eumetsat.de.

EUMETSAT Polar System

5.10 The EUMETSAT Polar System (EPS) is the EUMETSAT contribution to the joint EUMETSAT/NOAA operational polar satellite system, the so-called Initial Joint Polar System (IJPS), which will deliver continuous global observations for meteorological applications and climate monitoring. The EPS Programme will cover 14 years of operation with three Metop satellites, the first of which will be launched in 2005. The first spacecraft (Metop-1) is being developed under the ESA Metop-1 Programme, the recurring Metop-2 and Metop-3 spacecraft under EUMETSAT's EPS Programme. In addition, ESA, CNES, NOAA and EUMETSAT jointly contribute by developing and providing instruments as described below. Metop-1 and Metop-2 are formally part of the IJPS, whilst Metop-3 is expected to be part of the follow-on joint system, subject to further agreements with NOAA.

5.11 The purpose of the EPS System is to provide an end-to-end service for the morning polar orbit, as well as back-up cross support and data exchange with the US National Ocean and Atmosphere Administration (NOAA), which will continue to provide the afternoon orbit service, using its NOAA N and N' satellites. The major mission objectives of EPS fulfil the requirements of Operational Meteorology and Climate Monitoring.

5.12 The Metop satellite is a 4.3-ton class three-axis earth pointing satellite carrying a payload of instruments of about 840 kg, with a design lifetime of 5 years and generating a 3.5 Mbps data flow. The nominal orbit is sun-synchronous with an inclination of 98.7° and an Equator local crossing time at 09.30 hrs.

5.13 Metop carries eight instruments dedicated to meteorological and climatological observations as well as a Search and Rescue transponder and a Space Environment Monitor (SEM) sensor. The latter will provide continuity with the humanitarian and space environment monitoring services already available from the NOAA spacecraft. The Metop satellites will also carry an ARGOS-DCS-2 data collection system to gather information from ground-based systems.

5.14 Metop-1 and Metop-2 will fly a set of sensors identical to those flying on the NOAA-N and N' satellites (i.e., AVHRR/3, AMSU-A, HIRS/4 and MHS) and additional European sensors, namely IASI, GRAS, ASCAT and GOME-2. The European instruments aim at improving atmospheric soundings, as well as measuring atmospheric ozone and near-surface wind vectors over the ocean.

5.15 The mission objectives of the instruments are the following:

- **Advanced Very High Resolution Radiometer (AVHRR/3):** global imagery of clouds, the ocean and land surface;

- **High Resolution Infrared Radiation Sounder (HIRS/4):** measurement of temperature and humidity of the global atmosphere in cloud-free conditions (Metop-1 and -2 only);

- **Advanced Microwave Sounding Unit-A (AMSU-A):** measurement of temperature of the global atmosphere in all weather conditions;

- **Microwave Humidity Sounder (MHS):** measurement of humidity, ozone and trace gases of the global atmosphere;

- **Infrared Atmospheric Sounding Interferometer (IASI):** provision of enhanced atmospheric soundings of temperature, humidity and trace gases;

- **GPS Receiver for Atmospheric Sounding (GRAS):** measurement of temperature of the upper troposphere and in the stratosphere with high vertical resolution;
- **Advanced Scatterometer (ASCAT):** provision of near-surface wind speed and direction over the global oceans;

- **Global Ozone Monitoring Experiment-2 (GOME-2):** provision of profiles of ozone and other atmospheric constituents.

5.16 It is assumed that Metop-3, the subject of an extension of the current co-operation with the US, will accommodate the same payload as Metop-1 and Metop-2, including US instruments, with the exception of HIRS/4.

5.17 The Metop instruments will gather essential global information by day and by night, about the atmosphere, land and ocean surfaces. A primary mission objective is to measure the temperature and the humidity of the global atmosphere, using instruments capable of sounding the atmosphere throughout its depth. A second important mission objective is to obtain global images of clouds and weather systems, and information about the sea and land surfaces, in particular, on ocean surface winds. Atmospheric ozone will also be monitored.

5.18 The Metop satellites will broadcast two data streams continuously to user stations throughout the world. By this means users will receive high quality local data in real-time, each time the satellite passes. Most users can expect to receive data from at least three consecutive orbits twice a day. Data formats will be coordinated with NOAA and other satellite operators and will be evolutionary developments of current practice.

5.19 The Low Resolution Picture Transmission (LRPT) broadcast will provide data for relatively small user stations and will be the long-term replacement, using digital technology, for the analogue Automatic Picture Transmission (APT) system currently used on NOAA satellites. It will transmit a selection of instrument data, including image data which has been re-sampled on board the satellite to give an approximately constant 4 km resolution across the full swathe width.

5.20 The Advanced High Resolution Picture Transmission (AHRPT) broadcast will be an evolutionary development of the broadcast of the same name on current NOAA satellites, based on a CGMS-approved standard. The AHRPT broadcasts will include all data from the Metop scientific instruments, including image data at full resolution, around 1.1 km at the sub-satellite point.

5.21 The EPS system will assure continuity with the current polar system through the continuation of the well-proven ATOVS instrument suite and the AVHRR imager. In addition, several highly innovative features will be implemented with the EPS system, as briefly described:

- High level sounding capability will be provided and the enhanced data streams will be available for use in advanced NWP models;

- The multi-instrument payload provides a service which goes beyond operational meteorology and enables EUMETSAT to fulfil its commitments vis-à-vis climate monitoring and support to climate research;

- Instruments are embarked which build upon the heritage of Earth observation missions. The ASCAT and GOME-2 instruments are brought into the operational environment and represent EUMETSAT's commitment to provide near real time and off-line operational products from these instruments for a period of at least 14 years;

- GRAS is an alternative concept for the retrieval of temperature, moisture and electron density, with strong potential in climate monitoring. For the first time, the radio occultation principle is brought into the operational environment and will demonstrate the capability to provide high quality vertical soundings in near real time;

5.22 The long EPS mission duration of 14 years will guarantee that users are provided with long-term, near real time and off-line data services for meteorological and climate applications.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6.1 Figure 1 below indicates the percentage of images and DCP messages from the Operational 0° and 63°E (IODC) Services, which were actually acquired, disseminated or collected, compared with the number possible. Image acquisition nominally includes 48 images per day in IR, WV, and VIS channels. Figures for image dissemination are based on a comparison of actual with scheduled dissemination (i.e., mean of WEFAX and HRI dissemination performances). The number of DCP messages transmitted depends upon the status (active or otherwise) of registered DCP.

Figure 1: Overall performance of the operational services (0°) and IODC (63°E) in 2000

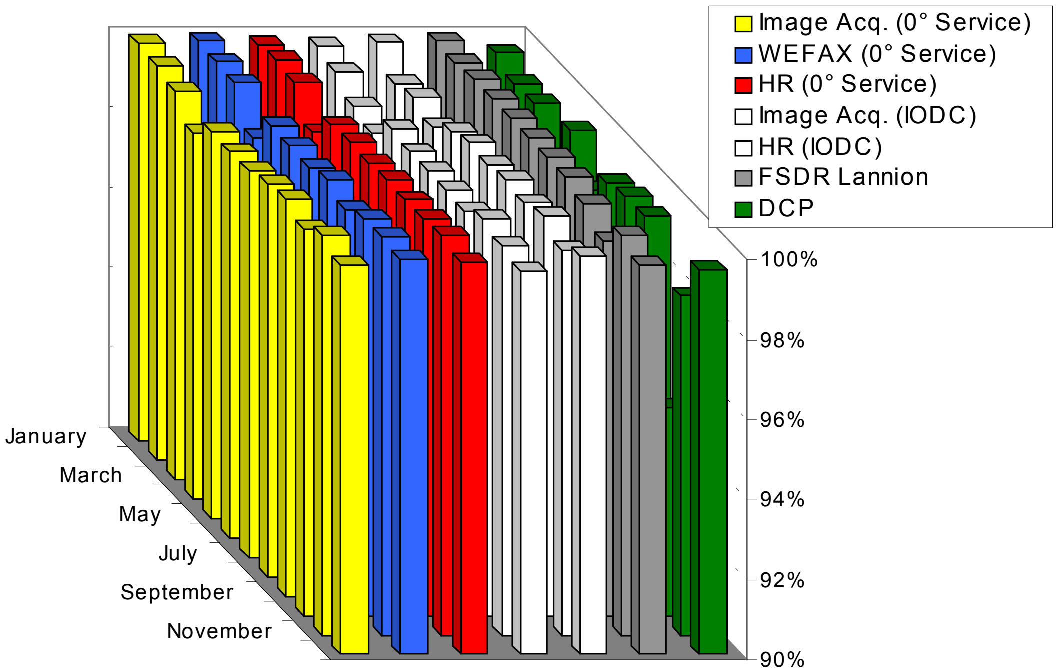


Figure 2: Development of numbers of PDUS and SDUS (i.e. WEFAX) stations

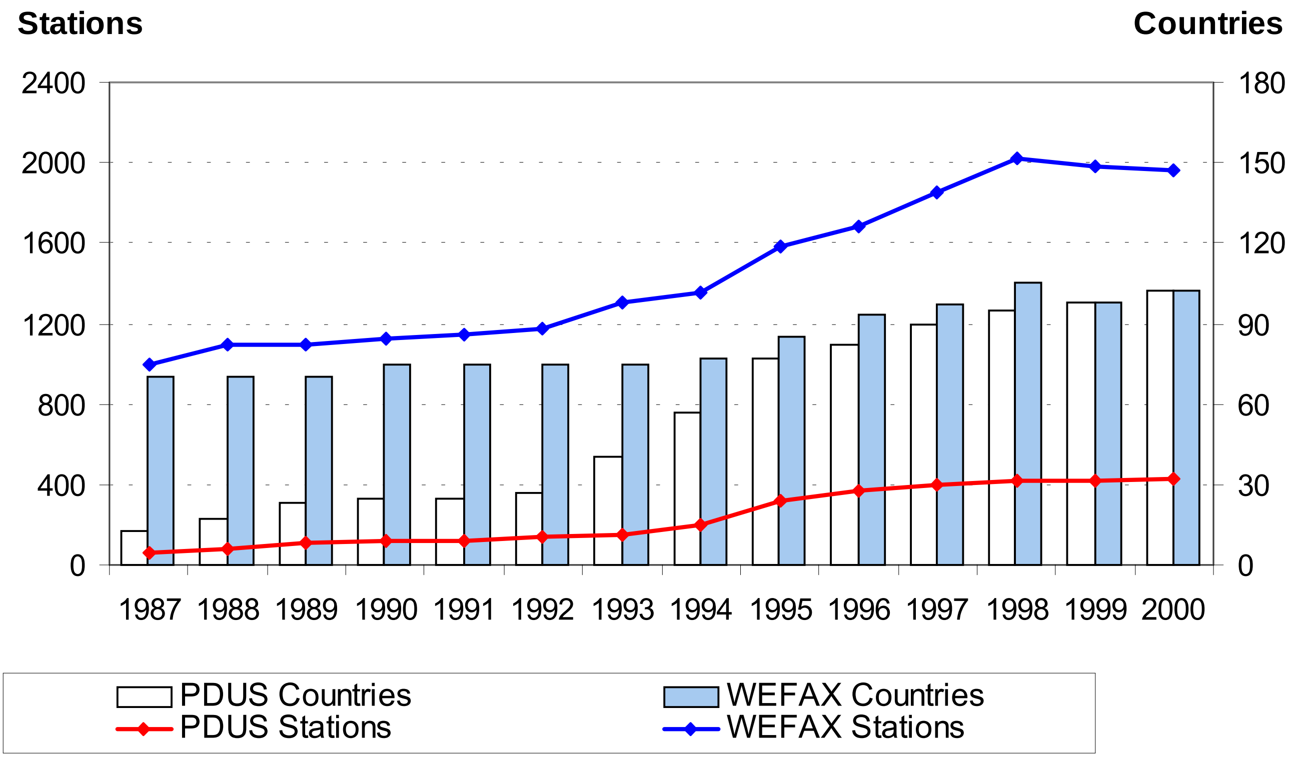


Figure 3: DCP messages (thousands) received and relayed to GTS

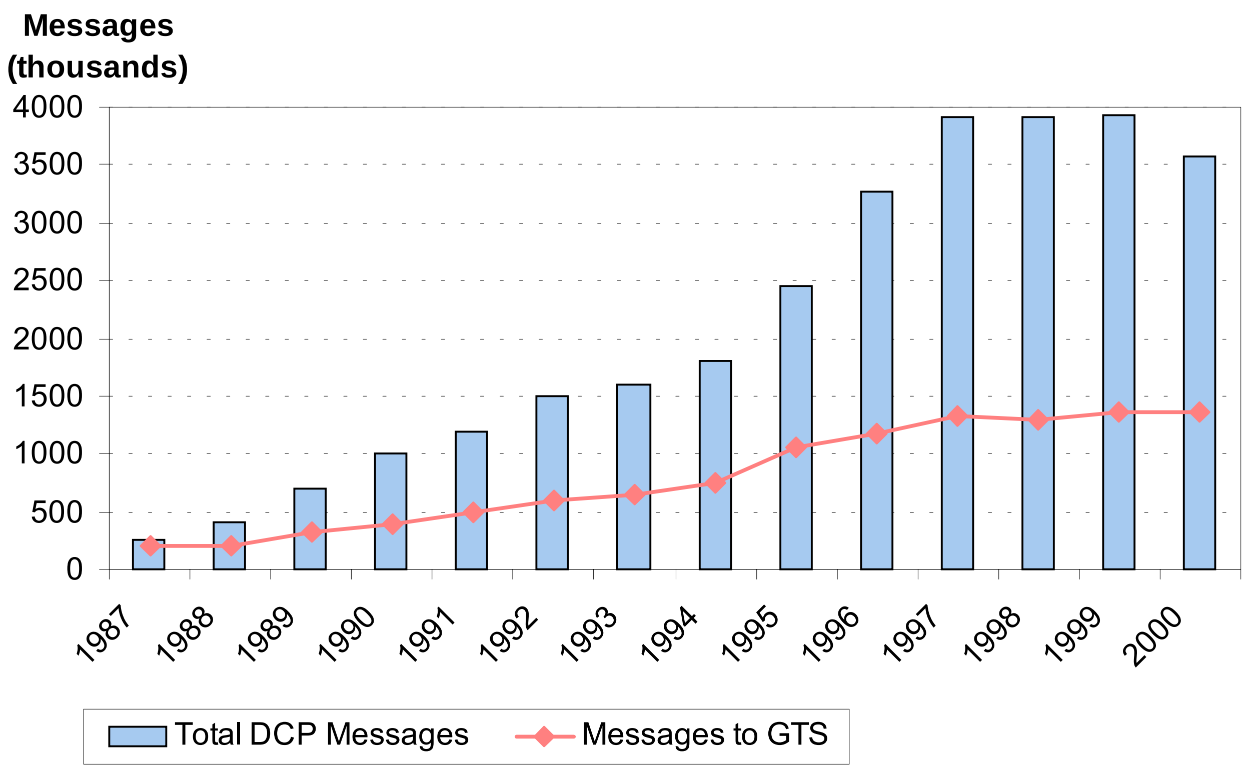
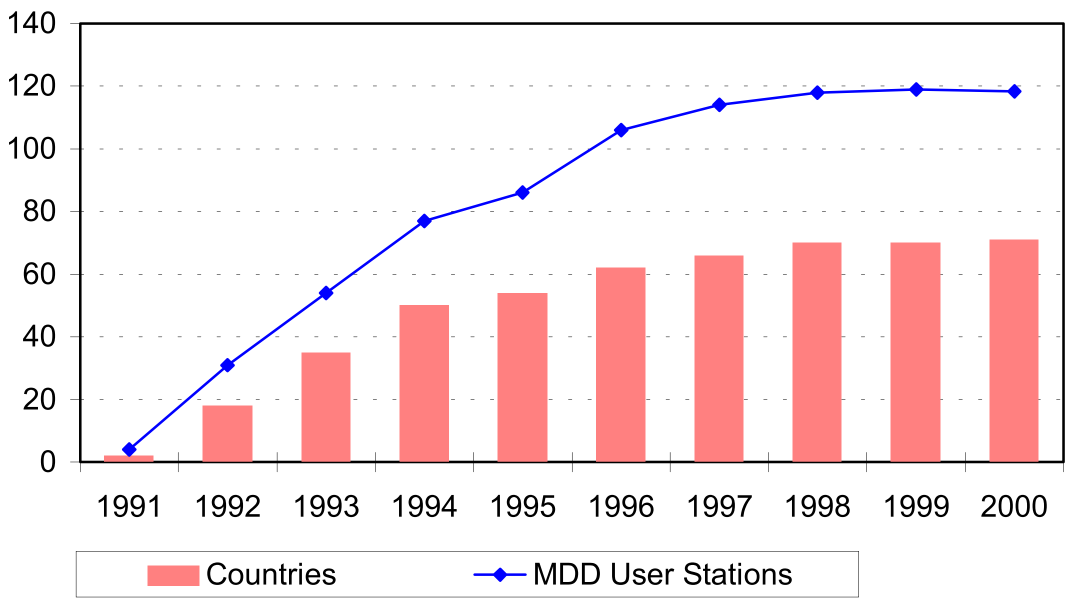


Figure 4: Development of numbers of MDD User Stations



6.2 The evolution of the Vector Differences RMS over a period of two years for the Operational Service at 0° is shown in Figures 6, 8 and 10 and in Figures 7, 9 and 11 for the IODC Service at 63° E.

Figure 6: Infrared Winds - Radiosondes (0° Operational Service)

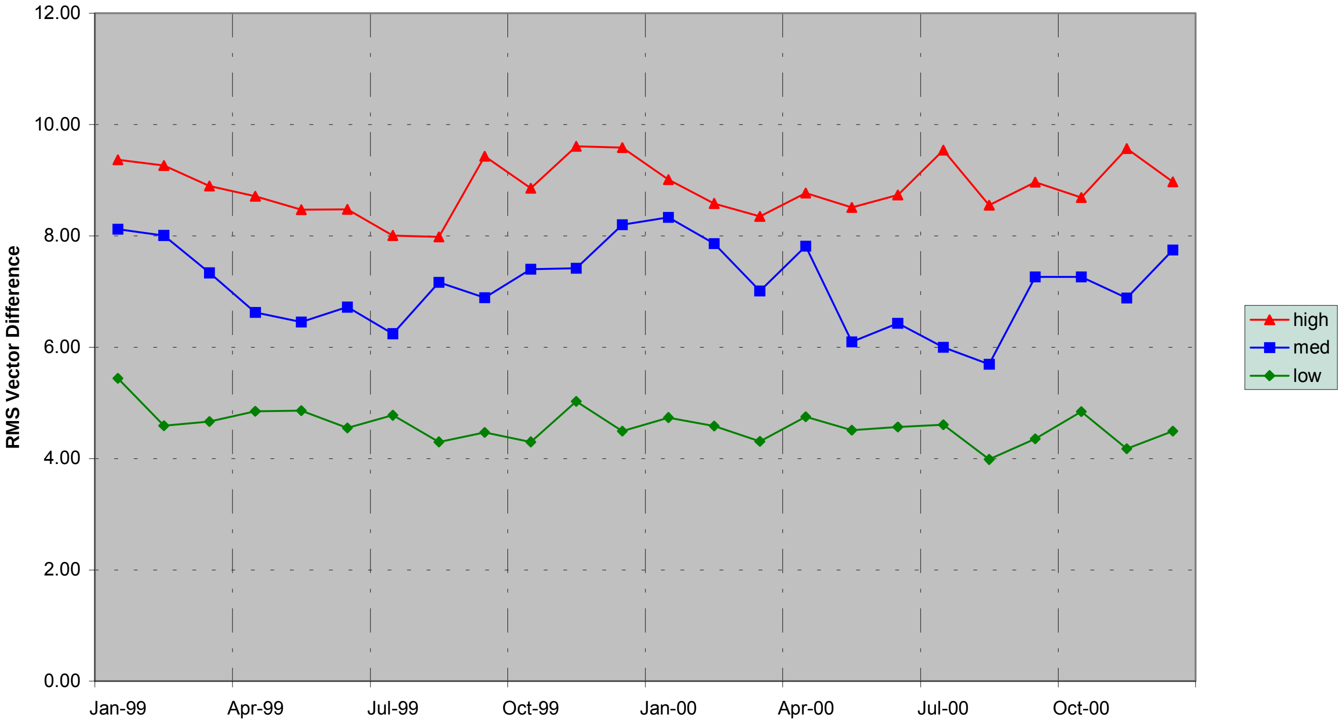


Figure 7: Infrared Winds - Radiosondes (IODC Service)

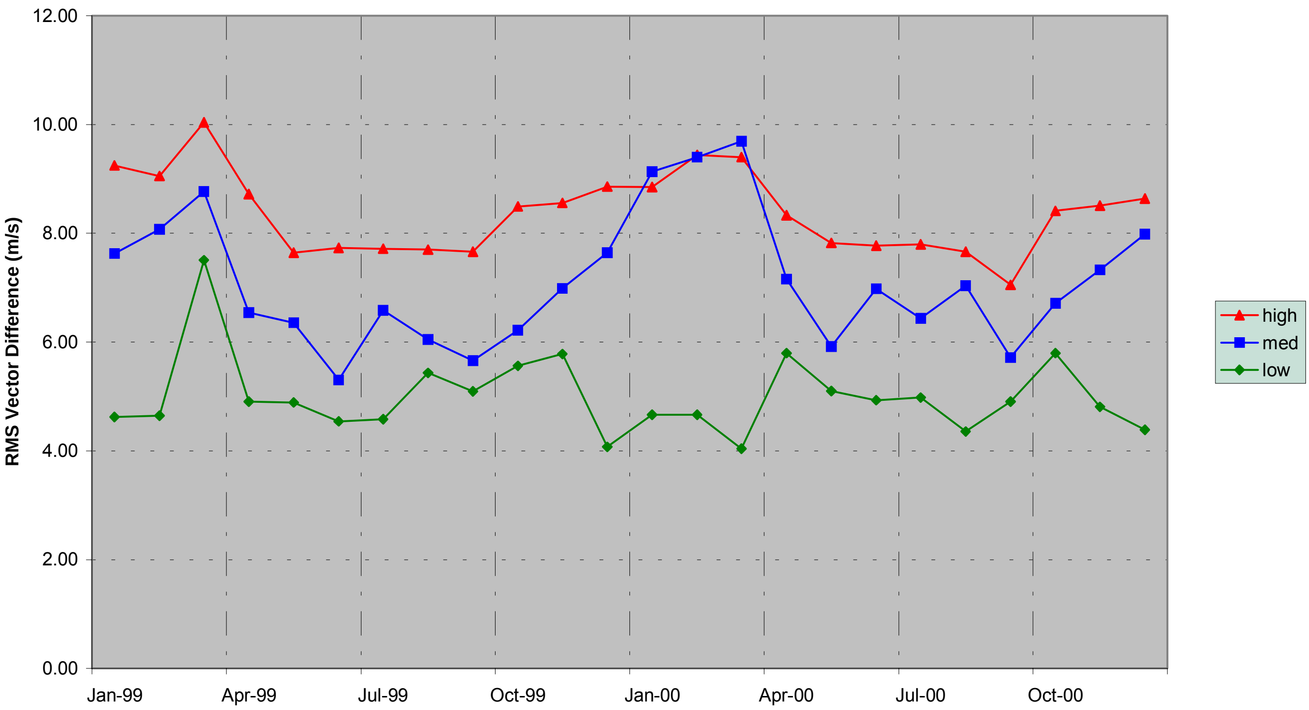


Figure 8: Low Level Visible Winds: Radiosondes (0° Operational Service)

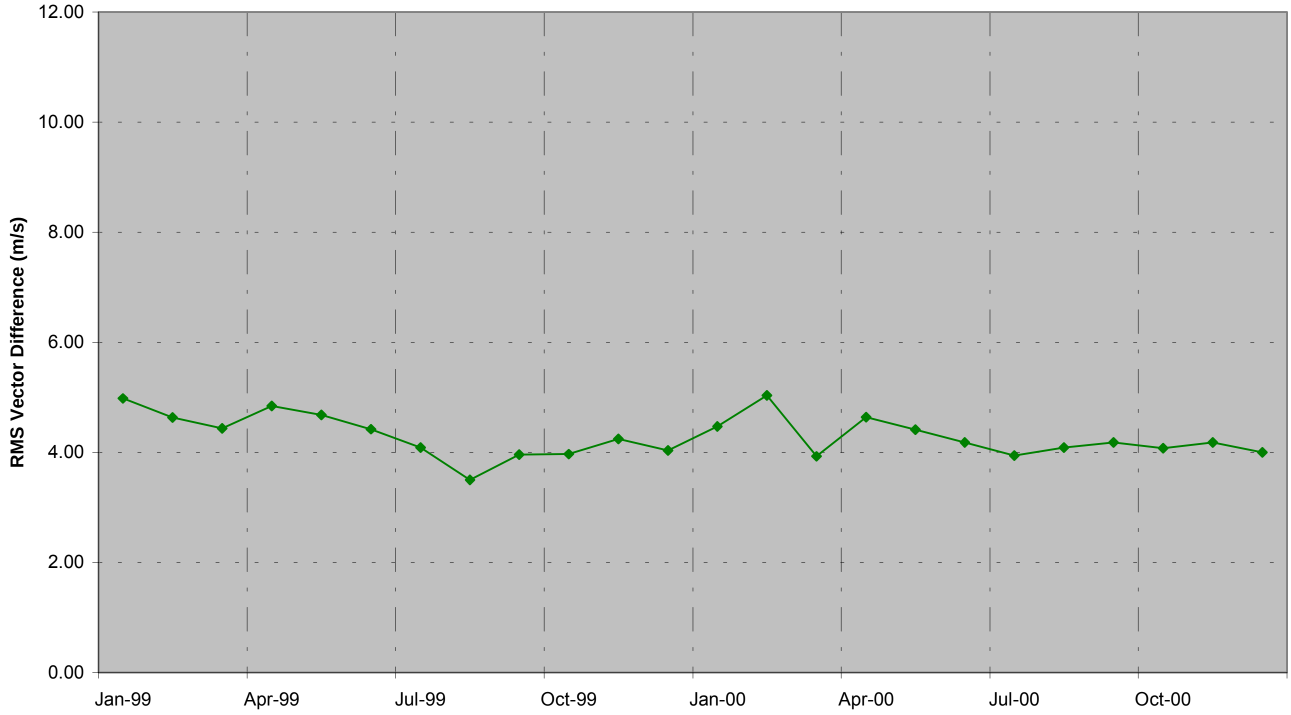


Figure 9: Low Level Visible Winds: Radiosondes (IODC Service)

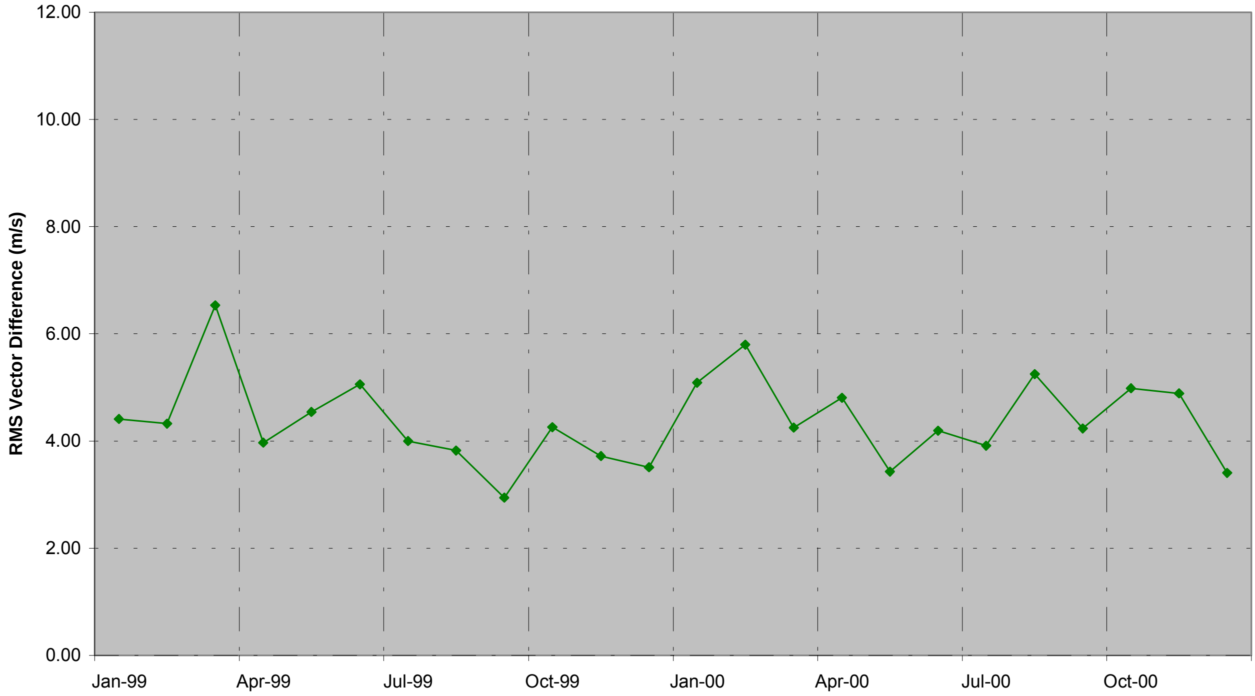


Figure 10: High Level Water Vapour Winds: Radiosondes (0° Operational Service)

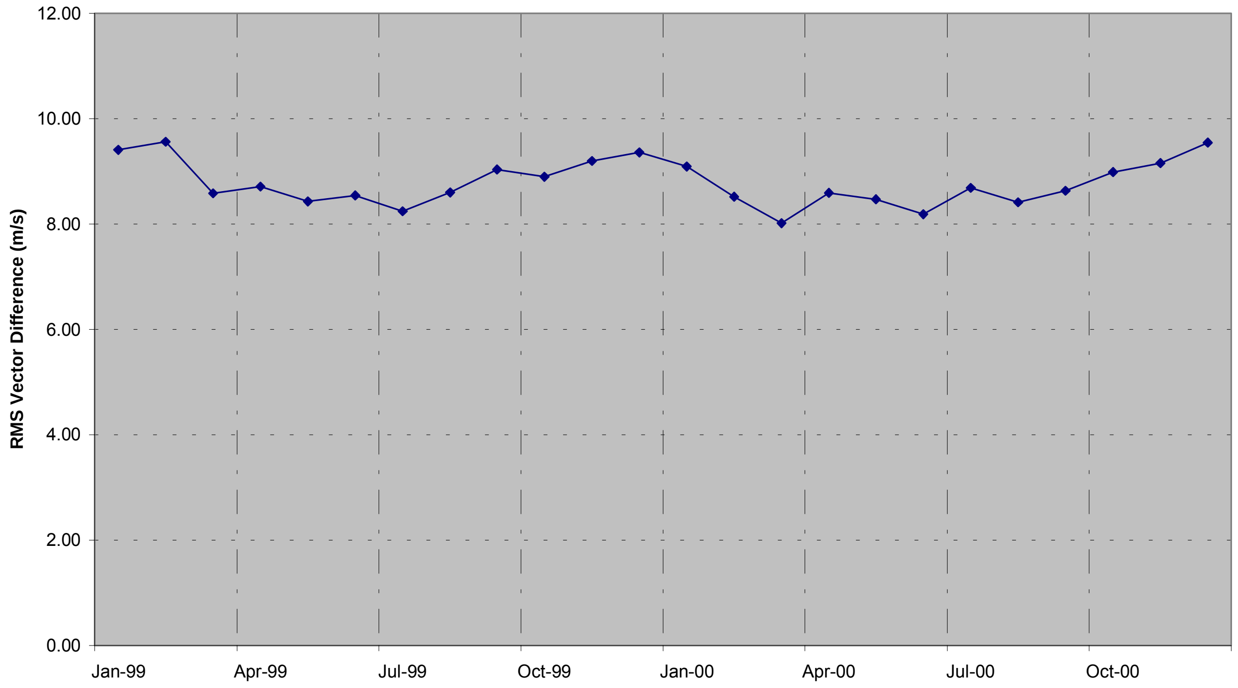
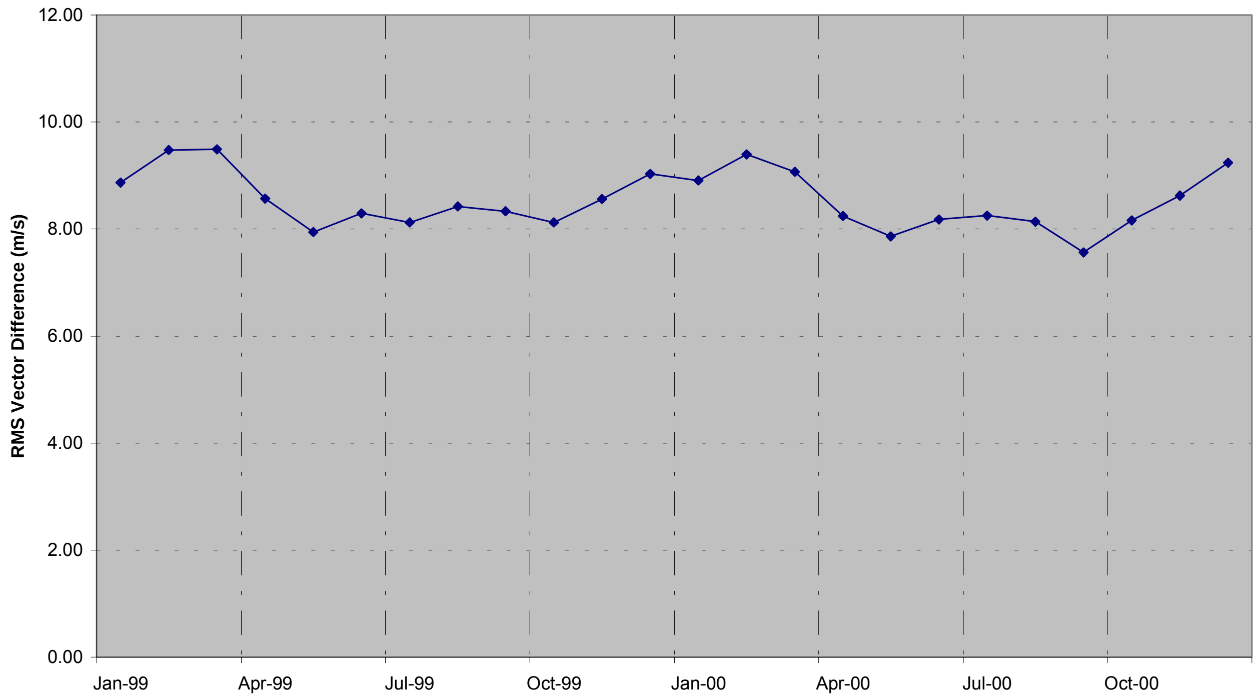


Figure 11: High Level Water Vapour Winds: Radiosondes (IODC Service)



6.3 The number of distributed Visible, Infrared and Water Vapour Cloud Motion Winds for the Operational 0° and IODC (63°East) Services are shown in figures 12 and 13.

Figure 12: Summary of IR, VIS & WV Winds (0° Operational Service)
SATOB coded winds

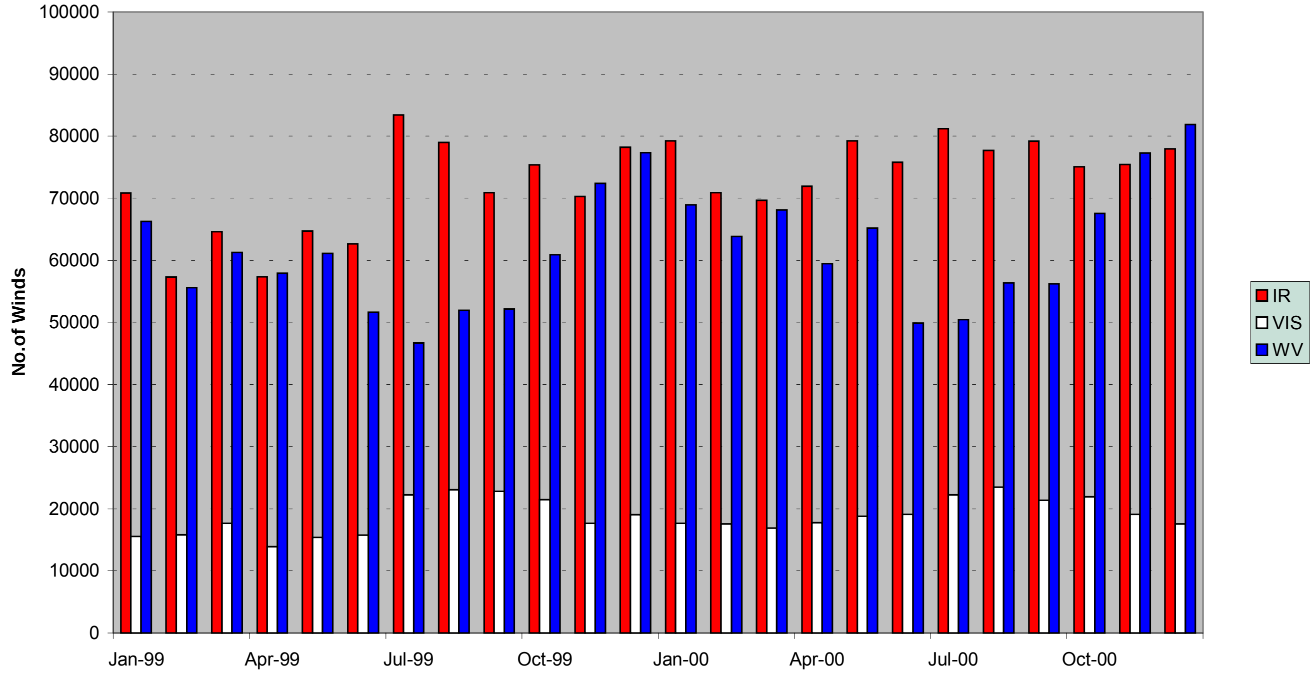
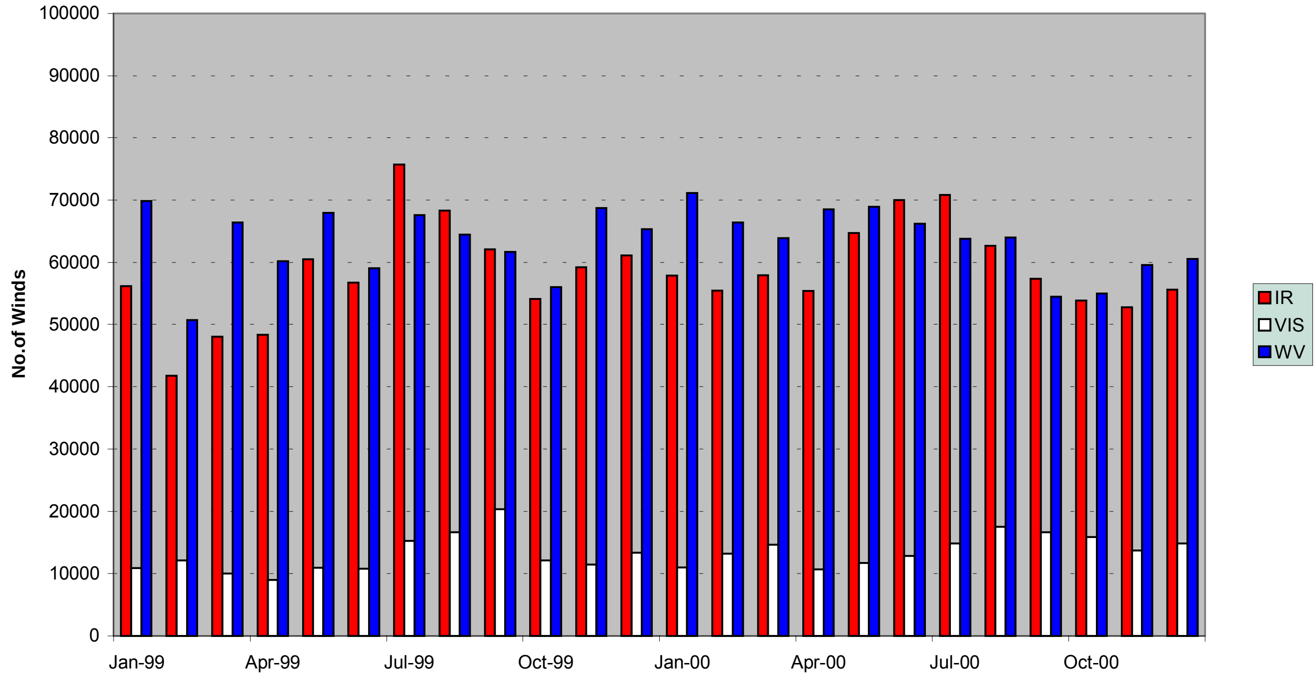


Figure 13: Summary of IR, VIS & WV Winds (IODC Service)
SATOB coded winds



6.4 The number of distributed High Resolution Visible winds for the Operational 0° and IODC (63°East) Services are shown in figures 14 and 15.

Figure 14: Summary of High Resolution Visible Winds (0° Operational Service)
BUFR coded winds

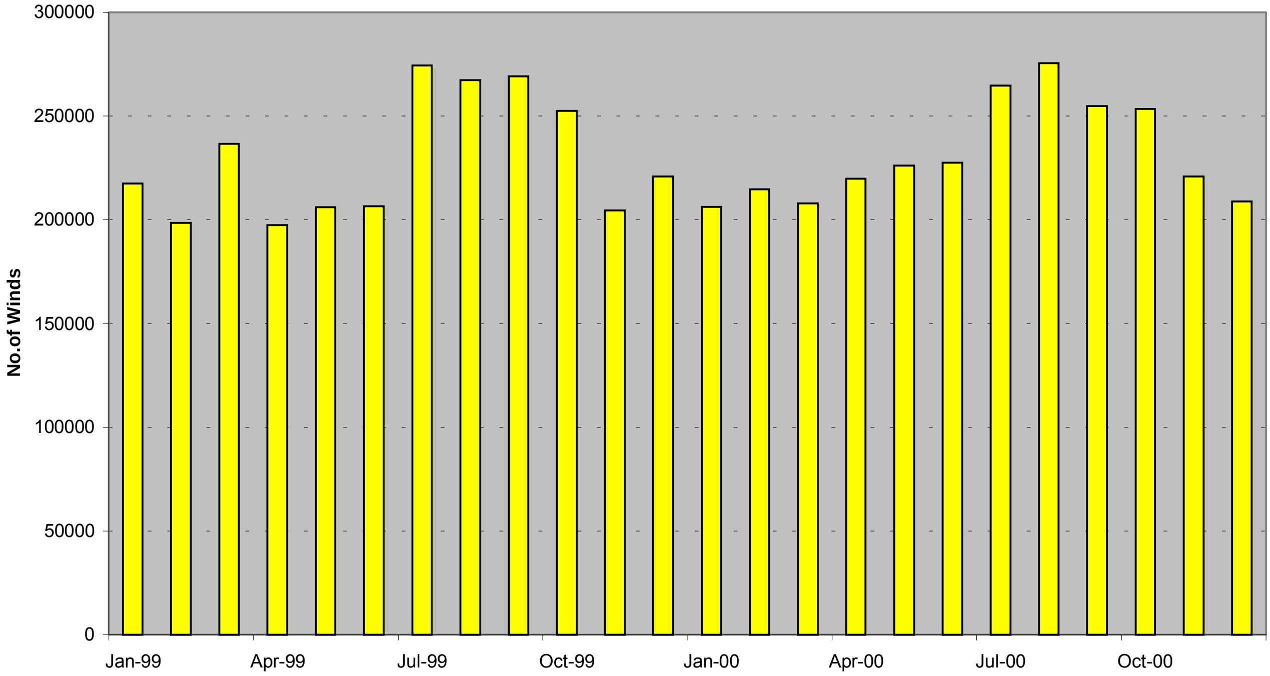
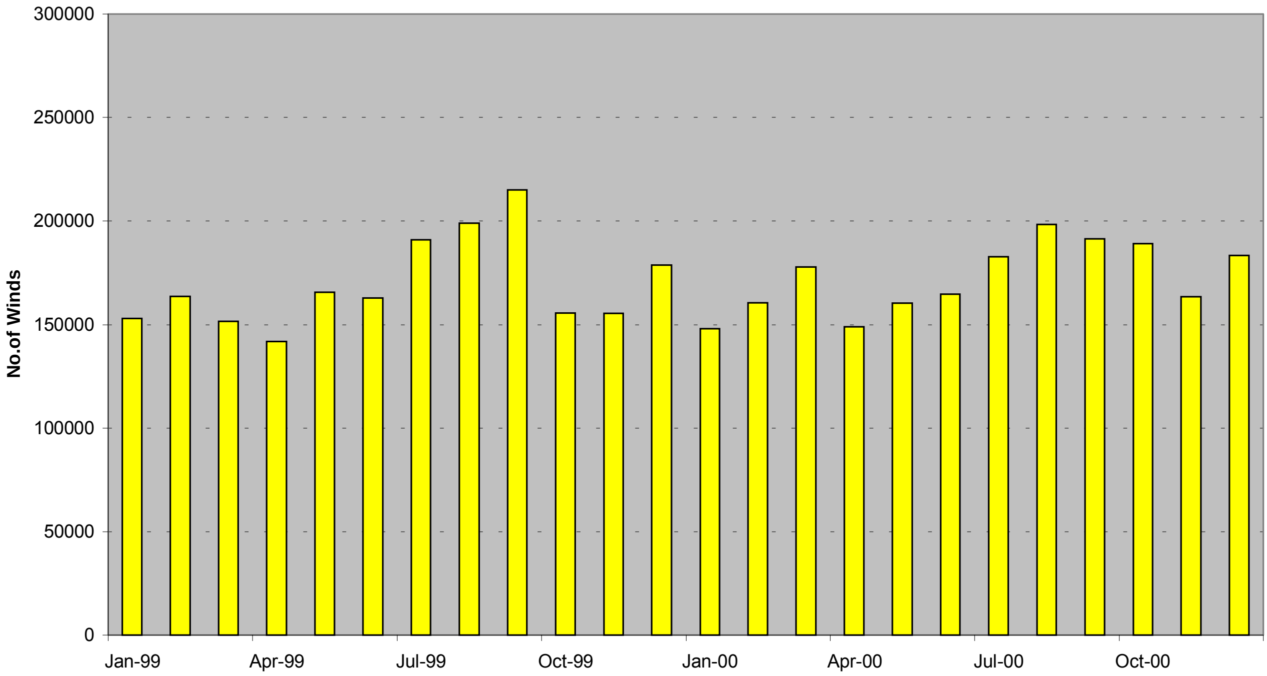


Figure 15: Summary of High Resolution Visible Winds (IODC Service)
BUFR coded winds



PART VII OTHER ITEMS (references, publications and scientists in charge)

A series of documents are available from EUMETSAT. These include EUMETSAT publications, Technical Documentation prepared by ESA and publications such as the proceedings of workshops, etc. The titles available at the end of 1998 include:

1. EUMETSAT Brochures

EUM BR 01 EUMETSAT: First Decade... Next Century - EUMETSAT ten-year brochure (published in English and French)

EUM BR 02 EUMETSAT Missions and Services - available as separate information sheets (published in English, French, German)

EUM BR 04 Europe's Meteorological Satellite Headquarters (published in English, French, German)

EUM BR 05 The Meteosat Transition Programme (published in English and French)

EUM BR 06 The EUMETSAT Polar System (published English and French)

EUM BR 07 Strategic Guidelines for the Next 25 Years (published in English and French)

EUM BR 09 Satellite Application Facility (published in English and French)

EUM BR 10 Meteosat Second Generation (published in English and French)

EUM BR 11 Support to INDOEX (published in English and French)

2. EUMETSAT Journal IMAGE

A journal containing news and articles about satellite meteorology and EUMETSAT Programmes (published in English and French twice a year)

3. EUMETSAT Technical Documentation

Technical Descriptions

EUM TD 01 Meteorological Data Distribution
EUM TD 02 Meteosat High Resolution Image Dissemination
EUM TD 03 Meteosat WEFAX Dissemination
EUM TD 04 Meteosat Data Collection and Retransmission System
EUM TD 05 The Meteosat System (published in English and French)
EUM TD 06 The Meteosat Archive User Handbook

User Guides (published in English and French)

EUM UG 01 Meteorological Data Distribution
EUM UG 02 Data Collection System
EUM UG 03 Meteosat High Resolution and WEFAX Imagery

4. EUMETSAT Annual Reports

EUM AR 01 to 10 (published in English and French)

5. Coordination Group for Meteorological Satellites

CGMS 01	Consolidated Report of CGMS Activities (1989)
CGMS 02	International Data Collection System Users' Guide (1992)
CGMS MR 16	Report of the 16th Meeting of the CGMS (1987)
CGMS MR 17	Report of the 17th Meeting of the CGMS (1988)
CGMS MR 18	Report of the 18th Meeting of the CGMS (1989)
CGMS MR 19	Report of the 19th Meeting of the CGMS (1990)
CGMS MR 20	Report of the 20th Meeting of the CGMS (1992)
CGMS MR 21	Report of the 21st Meeting of the CGMS (1993)
CGMS MR 22	Report of the 22nd Meeting of the CGMS (1994)
CGMS MR 23	Report of the 23rd Meeting of the CGMS (1995)
CGMS MR 24	Report of the 24th Meeting of the CGMS (1996)
CGMS MR 25	Report of the 25th Meeting of the CGMS (1997)
CGMS MR 26	Report of the 26th Meeting of the CGMS (1998)

6. EUMETSAT Proceedings of Conferences and Workshops

EUM P 01	The 6th Meteosat Scientific Users' Meeting (1986)
EUM P 02	Workshop on Satellite and Radar Imagery Interpretation (1987)
EUM P 03	Satellite Meteorology and its Extension to Agriculture (1986)
EUM P 04	The 7th Meteosat Scientific Users' Meeting (1988)
EUM P 05	The 1st Legal Workshop on the Protection of Satellite Images(1989)
EUM P 06	The 4th AVHRR Data Users' Meeting (1989)
EUM P 07	Workshop on the use of Satellite Data Nowcasting and Very Short Range Forecasting (1990)
EUM P 08	The 8th Meteosat Scientific Users' Meeting (1990)
EUM P 09	The 5th AVHRR Data Users' Meeting (1991)
EUM P 10	The 1st Winds Workshop (1991)
EUM P 11	The 9th Meteosat Scientific Users' Meeting (1992)
EUM P 12	The 6th AVHRR Data Users' Meeting (1993)
EUM P 13	The 2nd Data Collection System Users' Conference (1993)
EUM P 14	The 2nd Winds Workshop (1993)
EUM P 15	The 10th Meteosat Scientific Users' Conference (1994)
EUM P 16	First EUMETSAT User Forum in Developing Countries
EUM P 17	The 1995 Meteorological Satellite Data Users' Conference
EUM P 18	Third International Winds Workshop (1996)
EUM P 19	The 1996 Meteorological Satellite Data Users' Conference
EUM P 20	Report of the Second User Forum in Africa (1996)
EUM P 21	The 1997 Meteorological Satellite Data Users' Conference
EUM P 22	The 9th Conference on Satellite Meteorology and Oceanography - DM 50
EUM P 23	Report of the Third User EUMETSAT Forum in Africa (1998) – DM 50
EUM P 24	The Fourth International Winds Workshop (1998) – DM 50

7. The CGMS Directory of Meteorological Satellite Applications

EUM BR 08 – *DM 150*

8. Technical Memoranda (since 1998)

(also available on the EUMETSAT webpage):

“Radiative transfer simulations for the thermal channels of MSG”, by S. Tjemkes and J. Schmetz, EUMETSAT.

“Toward the definition of climate observing requirements in the era of MSG and EPS”, by G. L. Stephens from Colorado State University, USA, prepared during his stays as a Visiting Scientist at EUMETSAT in 1997 and 1998.

"Review on Scatterometer Winds", by J. Kerkmann, EUMETSAT.

9. Prices for single copies

No charge for single copies, except for:
EUM P 22 & EUM P 23: DM 50 per copy
EUM BR 08: DM 150 per copy

All these documents may be obtained from EUMETSAT. To order please write, stating if the English or French version is required, to:

EUMETSAT User Service
Am Kavalleriesand 31, D-64295 Darmstadt, Germany
Telephone +49 (0)6151 807-7
Fax +49 (0)6151 807-304
Email: ops@eumetsat.de

Other contact points and addresses:

EUMETSAT Strategy and International Relations
Mr. Paul A. Counet
Strategy and International Relations Officer
Telephone: +49(6151) 807-604
Fax: +49(6151) 807 555
Email: Counet@eumetsat.de

FINLAND

(Finnish Meteorological Institute)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

During 1999-2000 satellite meteorological research in the Finnish Meteorological Institute (FMI) was two-fold: satellite derived parameters (cloud types, cloud mask, albedo) to be used for further processing, (e.g., atmospheric models) and use of satellite imagery in synoptic applications and conceptual models. The forecasting office started to produce a so-called SATREP (satellite report) based on 18 UTC during the working days, from autumn 2000 onwards, and also weekends. SATREPs are on cooperation with ZAMG (Austria, the original developer of the method) and KNMI (the Netherlands.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2.1 During 1999-2000 there were two aspects of research: cloud parameters derived from satellite data (NOAA AVHRR and Meteosat HR) and land parameters derived mainly from AVHRR. Cloud parameter studies have been made using new methods such as neural networks and fuzzy logic. In 2000 the first pre-operational version of both cloud mask and cloud classification have been tested. The results were promising, but showed a need for improvement. Therefore, a new project was started at the end of 2000, where the main focus is on low clouds and fog,. Surface albedo was the first amongst the land parameters. For the past couple of years the pre-operational method has been used for short periods. On some occasions these results have been tested with the forecast model (HIRLAM). Melting snow and thus rapidly changing albedo have been a problem to the earlier model. Some of these problems can be solved by using satellite derived albedo values.

2.2 Development has concentrated on satellite applications which benefit nowcasting and very short-range forecasting. The FMI has participated in a joint project with Austria (ZAMG – project manager) and the Netherlands (KNMI) for three projects (SATREP II-III, Satmanu ongoing). Projects are partly funded by EUMETSAT and partly by the participating institutes. As a result of these projects there is a satellite application manual on conceptual models which is available either on CD-ROM or via internet (http://www.knmi.nl/satrep). The present version of the manual is 3.0.

2.3 An important factor in all research projects has been the connection and cooperation with neighbouring countries, as well as NMSs of Austria and the Netherlands. Also, the work of EUMETSAT's Satellite Application Facilities (SAF) has been followed closely, even in those cases of SAF where the FMI is not a consortium member. The FMI has been coordinating the development phase of SAF Ozone and is a member of SAF Climate (surface albedo). FMI scientists have attended several scientist actions in SAF Nowcasting.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3.1 During the reporting period these have been very little need for upgrading the technical equipment. New NOAA satellites have been operational (NOAA 15 and NOAA 16). The software for reception has been modified accordingly. The basic receiving systems have not been changed – only some upgrading of CPU (VMS) and more disk space have been needed. The operational production of derived products has been done under Silicon Graphics unix servers. The multi use servers have been upgraded during the reporting period. Archiving of raw AVHRR data on CDs has continued. Furthermore, an archive of selected end products (separate AVHRR channels and channel combinations) with simple intranet interface have been archived online since the end of 1998.

3.2 Internal distribution of derived products has been done mainly via intranet interface. The products include all AVHRR channels (including 3A) and some combinations (124. 3B-4, 3B45, 4-5) over the Nordic countries and Baltic states. All Meteosat channels and a combination of the VIS+IR channel are also available, as well as animated time series.

3.3 The forecasting office started to produce SATREPs (satellite report) based on 18 UTC weather situation since autumn 1999. For that purpose, an online editing tool was developed using Java. The user can diagnose the weather situation by marking different conceptual models over a Meteosat image. For each conceptual model the user can also write a short comment. The software then automatically collects all conceptual models and their geographical locations, as well as the comments to a text file, which is sent to the users together with an edited image. The users of these SATREPs (ZAMG produces 06 UTC, and KNMI 12 UTC) are used by all forecasting offices. They are also available via internet (http://www.knmi.nl/satrep).

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

The FMI has both PDUS and HRPT reception, which originate from the 1990s. They run under VAX/VMS. The pre-processed data is stored on running archive and post-processed under SGI IRIX servers and distributed to the users mainly using either intranet or internet. The length of the running archive is determined product by product. The raw HRPT data is stored on CDs using a similar format to that of the Dundee archive.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5.1 The FMI has already started preparations for the reception of Meteosat Second Generation (MSG) satellites. The aim is to be ready for reception as soon as data is operationally available from the satellite (summer 2002). It is also foreseen that the present PDUS will be operated over a transition period simultaneously with the XRUS system. The length of the transition will be between six months and one year, if satellites are available and working normally. The HRPT system will be at least partly renewed. The present pre-processing is done using commercially available software. It is foreseen that in future the instrument specific parts will be processed with the AAPP package.

5.2 ATOVS radiances will become one source of information to HIRLAM.

5.3 The EUMETSAT SAF results which are applicable in FMI will be made operational as soon as they are available. Nowcasting SAF software packages which aim at products at higher altitudes and the use of AVHRR data will be of interest.

5.4 AVHRR data will be used both in meteorological and hydrological applications, but furthermore, the potential of MODIS data in these applications will be studies. As well the possibility of near real-time reception of MODIS will be explored during 2001.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

The performance of PDUS and HRPT have been very good (99%) and stable during 1999-2000.

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND SCIENTISTS IN CHARGE)

Contacts:

Otto Hyvärinen	Research Scientist, Cloud parameters, FMI (otto.hyvarinen@fmi.fi)
Vesa Laine	Senior research Scientist, land surface applications, FMI, (vesa.laine@fmi.fi)
Pirkko Pylkkö	Senior Research Scientist, Satellite systems and image interpretation, FMI, (pirrko.pylkko@fmi.fi)
Yrjö Sucksdorff,	Research Manager, Hydrological and environmental applications, FEI, (yrjo.sucksdorff@vyh.fi)

FRANCE

(Météo-France)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

The TOVS (NOAA-14) and ATOVS (NOAA-15) products received from NESDIS in BUFR code with 120 km resolution are used in ARPEGE assimilation. There is no more use of NESDIS SATEM profiles with 500 km resolution. (Contact point at Météo-France: bruno.lacroix@meteo.fr; DP/PREVI/COMPAS, Toulouse).

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2.1 In cooperation with EUMETSAT, Météo-France and its Centre de Météorologie Spatiale (CMS) are participating in the development of some of the Satellite Application Facilities (SAFs), which will be part of the future EUMETSAT ground segment for Meteosat Second Generation (MSG) and Metop. The following activities are conducted in the framework of the SAF for support to Nowcasting and Very Short Range Forecasting, of the SAF on Ocean and Sea Ice, and of the SAF on Numerical Weather Prediction.

Cloud products from GOES and MSG satellites

2.2 In the framework of SAF for support to Nowcasting and Very Short Range Forecasting, Météo-France/CMS has developed, and is running in operational conditions since 1999 a software package to process cloud mask, cloud type and cloud temperature and height products from GOES-8 imager (see information and products on http://www.meteorologie.eu.org/safnwc/). This software package is now being adapted and upgraded to process data from MSG imager (SEVIRI), and will be run in operational conditions at Météo-France/CMS as soon as MSG/SEVIRI data are available (end 2002). (Contact point at Météo-France: herve.leg1eau@meteo.fr; DP/CMS, Lannion).

2.3 In addition Météo-France has developed since 1999 one more product of this SAF: the Rapid Developing Thunderstorm (RDT) product.

2.4 The RDT product is intended to provide information about significant convective systems from storm scale (isolated convective cell) up to meso-alpha scale (Mesoscale Convective Complex).

2.5 The basic objectives are twofold :

- to provide an early identification of convective systems and especially an early detection of rapidly developing convective cells:
- to track and monitor convective systems during their whole life.

2.6 The RDT product will be numerical data, coded in BUFR format, and convective systems will be presented as "objects" with their most relevant properties such as size, movement, minimum temperature, cooling rate and area extension rate. (Contact point at Météo-France: christophe.morel@meteo.fr; CNRM/GMME/PI, Toulouse).

Ocean products from GOES and MSG satellites

2.7 In the framework of the SAF on Ocean and Sea Ice, Météo-France/CMS has developed, and is running in operational conditions since 2000 a processing chain to produce Sea Surface Temperature (SST), Surface Short wave Irradiance (SSI) and Downward Long wave Irradiance (DLI) from GOES-8 imager (see information and products on http://www.meteorologie.eu.org/safo/). This processing chain is now being adapted and upgraded to process data from MSG imager (SEVIRI), and will be run in operational conditions at Météo-France/CMS as soon as MSG/SEVIRI data are available (end 2002). (Contact point at Météo-France : pierre.leborgne@meteo.fr ; DP/CMS, Lannion).

Sounding products from NOAA and Metop satellites

2.8 In the framework of the SAF on Numerical Weather prediction, and in cooperation with the Met Office and ECMWF, Météo-France/CMS has developed and is maintaining the fast direct model RTTOV, which is adapted and upgraded to work for any new infrared and microwave radiometer. With the same contributors, Météo-France/CMS has developed and is maintaining the ATOVS and AVHRR Processing Package (AAPP), for the pre-processing of HRPT direct read-out data from NOAA and later Metop satellites. Downstream AAPP, Météo-France/CMS has developed and is running operationally since 1996 a TOVS/ATOVS retrieval software for atmospheric temperature and humidity profiles, called Inversion Coupled with Imagery (ICI) (see information and products on http://www.meteorologie.eu.org/ici/). (Contact point at Météo-Franc: guy.rochard@meteo.fr; DP/CMS, Lannion). Météo-France/CMS is also developing a first processing and retrieval software for the data of the future interferometer (IASI) on board Metop (contact point at Météo-France : lydie.lavanant@meteo.fr ; DP/CMS, Lannion).

Scatterometer

2.9 The scatterometer data are used as much as possible by marine forecasters. They are plotted as other observations in the production workstation "Synergie" (contact point at Météo-France : philippe.dandin@meteo.fr ; DP/PREVI/MAR, Toulouse).

Altimeters

2.10 Assimilation of ERS altimeter wind and wave data is performed in the operational global wave model. Various studies are also carried on in order to prepare the use of Jason and Envisat altimeter data. Different studies were also made using Topex-Poseidon data but for research purposes only.

2.11 Météo-France contributes to CNES/NASA project "Jason 1", follow-up of Topex-Poseidon. Various actions are carried on, ranging from the Doris station (for the positioning system) to the supply with corrections from the atmospherical models, or preparation of the GTS transmission of real time data (contact point at Météo-France : philippe.dandin@meteo.fr ; DP/PREVI/MAR, Toulouse).

Real Aperture Radar (project SWIMSAT, former VAGSAT)

2.12 Swimsat is a mini satellite project aiming at measuring sea state spectra with a Real Aperture Radar (RAR). OSSE's (Observation Sensitivity Simulation Experiments) are currently being carried on, that help assessing the impact of wave spectrum data as measured by the RAR, in the operational wave model. (contact point at Météo-France : philippe.dandin@meteo.fr ; DP/PREVI/MAR, Toulouse).

Synthetic Aperture Radar

2.13 Contacts are maintained with different research groups in Europe working on SAR retrieval and on assimilation. A common project with the Met Office (UK) aiming at assimilating SAR data in the operational wave models has just started (contact point at Météo-France : philippe.dandin@meteo.fr ; DP/PREVI/MAR, Toulouse).

Development of ozone products derived from NOAA/HIRS and MSG/SEVIRI

2.14 In the framework of the Satellite Application Facility for Ozone Monitoring which is being developed by the Finnish Meteorological Institute and EUMETSAT, ozone products to be derived from the geostationary (MSG, 2002) as well as from the polar satellite (Metop, 2006) observing the 9.7 micron ozone band are studied and validated.

2.15 Studies include an accurate characterisation of the total ozone products in terms of their vertical weighting function, systematic and random errors. Effects of perturbations through high clouds and surface emissivity variations are modelled by radiative transfer and possible corrections of these local effects are studied. The design of an operational production has started. (Contact point at Météo-France: fernand.karcher@meteo.fr ; CNRM/GMGEC/ERAM, Toulouse).

Land surface products for MSG, NOAA and Metop satellites

2.16 Albedo fields are important to a broad range of applications and users: e.g., climate models, weather forecasting, resource and hazard monitoring efforts (drought, fire, air pollution, floods, famine, vegetation dynamics, canopy structure) and water management. This product will be delivered operationally in the near future based on Meteosat Second Generation (MSG) and Metop data. This research is being conducted in the framework of the SAF (Satellite Application Facility) on Land Surface Analysis supported by EUMETSAT. CNRM ensures the coordination of the project in partnership with the Portuguese Meteorological Institute, host organization of this SAF. The primary role of this SAF is to develop algorithms that will allow for a more effective and synergistic use of data from the two forthcoming satellites for investigations related to land, atmosphere and biosphere interactions and applications. The quality of the operational products will depend to a large extent on sensor characteristics, cloud detection, atmospheric correction, and the angular distribution of the observations. In this regard, intermediate required products for albedo determination are the Bi-directional Reflectance Distribution Function (BRDF), which measures the surface anisotropy, and aerosol typology and amount. They will be available from this SAF, as well the downwelling short-wave radiation surface, and are paramount information to derive competitive albedo products. The Scanning Enhanced Visible and Infrared Imager (SEVIRI) onboard MSG will allow for frequent daily sampling at different solar zenith angles but at a given view zenith angle. On the other hand, AVHRR-3 on Metop will provide variations of view angles. It will promote innovative and challenging research to describe land surface properties at an advanced level of detail thanks to the synergistic nature of MSG and Metop sensor systems. On the other hand, it raises new interesting issues to be solved and related to differences in spectral bands and atmospheric effects. The dissemination of semi-real time short-wave products developed or supervised by CNRM will yield new opportunities for user communities concerned with improvements in angular and temporal resolutions, thereby competing with forthcoming satellite deliverables of this new millennium.
(Contact point at Météo-France: jean-louis.roujean@meteo.fr ; CNRM/GMME/MATIS, Toulouse).

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

The TOVS (resp. ATOVS) radiances (120 km resolution) and the retrieved profiles above 5hPa from NOAA-14 (resp. NOAA-15), the cloud motion winds (infrared, visible and water-vapor channels) from GOES-8 and 10, METEOSAT 5 and 7, and GMS are used in the ARPEGE assimilation. (Contact point at Météo-France: bruno.lacroix@meteo.fr; DP/PREVI/COMPAS, Toulouse).

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

The ATOVS raw radiances (NOAA-15, NOAA-16), and SSM/I (F13, F14, F15) radiances should be used in ARPEGE 4DVAR assimilation in 2001, via 1DVAR preprocessing for the later. (Contact point at Météo-France: bruno.lacroix@meteo.fr; DP/PREVI/COMPAS, Toulouse).

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

All the data involved in the assimilation are monitored against first guess field, and statistics are performed daily. A monthly report is sent to other numerical weather prediction centers. (Contact point at Météo-France: bruno.lacroix@meteo.fr; DP/PREVI/COMPAS, Toulouse).

GERMANY

Deutscher Wetterdienst (DWD)
Federal Institute of Hydrology (BfG)
Federal Maritime and Hydrographic Agency (BSH)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 The main objective of satellite data use at the BfG is the improvement of runoff forecasts in the navigable, mostly big rivers of Germany. For this purpose, the benefit of the use of remote sensing data has to be closely compared to that of other, often more traditional, data sources. Clear benefits of the satellite data are evident for large-scale basin-wide modelling.

1.2 The BfG uses a SDUS to evaluate qualitatively METEOSAT image data to assess changes in weather conditions for large basins like the River Rhine (approximately 150,000 km²). Furthermore, the extraction of a Soil Moisture Product from Meteosat Second Generation (MSG) thermal infrared data is a major component of development and research. Besides these data of mainly meteorological satellites, land use derived from data of LANDSAT Thematic Mapper ™ and selected Digital Elevation Models (DEM) derived from stereoscopic satellite data are currently a major use of satellite data.

1.3 The primary focus of the satellite related activities at DWD were in three areas: (a) improvements in the services for the operational application of satellite data for weather monitoring, nowcasting and warnings of severe weather events and provision of satellite data to internal and external users; (b) activities for a better use of satellite data in NWP; and (c) development activities for the application of satellite data for climate monitoring purposes.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2.1 **Soil Moisture:** Within the framework of the Satellite Application Facility on Land Surface Analysis (”Land-SAF”), funded in part by EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) and hosted by the Portuguese Meteorological Institute (IM) for the development phase between 1999 and 2004, BfG is developing, together with the Meteorological Institute of the University of Bonn (MIUB), a Soil Moisture Product derived from Meteosat Second Generation (MSG) data. The sensor to be used is the SEVIRI (Spinning Enhanced Visible and Infrared Imager), yielding 3 km x 3 km geometric resolution at the sub-satellite point (about 5 km x 5 km for Germany).

2.2 The algorithm will be based on the thermal characteristics of the surface depending on the soil moisture content. The approach to be used, taking into account the steepness of the Land Surface Temperature (LST) rise in the morning, was first developed for the central part of the United States of America by Wetzel *et al*. (1984) and Wetzel & Woodward (1987) and will be adapted for Europe by MIUB and BfG. It is planned that the central model should use a Soil Vegetation Atmosphere Transport Scheme (SVAT). The Soil Moisture Product will be generated daily in the SEVIRI horizontal ground resolution for the European Low and Mid Latitude MSG Coverage. Besides the LST, other data derived from satellite measurements or ground observations, e.g., wind speed, and ancillary data, such as Digital Elevation Model (DEM) and land cover, will be evaluated for their relevance with respect to the product. It is planned to use soil moisture estimations from different sources and *in situ* measurements as well as an Antecedent Precipitation Index (API) for calibration and validation.

2.3 The results are expected to improve in particular flood and low-flow forecasts, weather forecasts, and possibly also agricultural practices.
(Contact: F. Portmann, BfG - portmann@bafg.de)

2.4 **Hydrography: Maritime and hydrographic monitoring:** The Federal Maritime and Hydrographic Agency (BSH) has been using its own HRPT satellite receiving and processing facility for evaluating data from the NOAA polar orbiting satellites since 1990. The investigations of marine physical properties carried out by the BSH form the basis for its hydrographic services and for the development of information material for shipping and fisheries. The marine investigations are carried out with a wide range of oceanographic instruments which are tested and maintained, sometimes also developed and manufactured, at the BSH. Remote sensing techniques are an integral part of the investigative work. Although the view from the NOAA satellite in the visible and infrared window is restricted by clouds, fog and darkness (for the visible), the NOAA/AVHRR image is the standard product for providing a synoptic overview on sea ice condition and sea surface temperature.
(Contact: K.Strübing, BSH Hamburg – klaus.struebing@bsh.d400.de or sat@bsh.d400.de).

2.5 **Ice service:** The BSH's ice service issues warnings when shipping lanes, coastal waters and sea areas are affected by ice. Satellite imagery of the earth's surface is an important source of information for the ice service. Daily ice reports and sea ice charts published regularly inform shipping on ice conditions in territorial waters as well as in the Baltic Sea and its passages. The operational constraints within an ice service, i.e., fixed, rather short-term dead-lines for the dissemination of products, do not allow time-consuming processing of the satellite data. In most cases a quick-look version of the image is almost sufficient for an experienced interpreter to extract from it the important information for the production of an ice chart. Up-to-date information and statistics on ice conditions in non-European and polar waters are also available.
(Contact: K. Strübing, BSH Hamburg – klaus.struebing@bsh.d400.de, ice@bsh.d400.de, http://www.bsh.de/Oceanography/Ice/Ice.htm)

2.6 **Support to weather monitoring, nowcasting and warnings of severe weather events:** A substantial upgrade has been introduced in the system for interactive meteorological applications for a more efficient use of all different types of remote sensing data which are available in real-time on a fully operational basis at all offices of the DWD engaged in weather forecasting activities: a combined display of Meteosat or AVHRR images, ground-based radar precipitation data and lightning data is now possible, also in animated mode, as well as a combination with other meteorological data as e.g., conventional observations, NWP fields, etc. Improvements for a better identification of convective systems and their displacement in Meteosat image data have been introduced in the 'CINESAT' module which has been procured by the Austrian company Gepard and is operationally used for satellite and radar image classification, interpolation and extrapolations. The DWD receives the so-called 'rapid scan images' from EUMETSAT, transforms them to the polar-stereographic projection and makes them available to most of the weather forecasting offices under real-time constrains. The rapid scan images are images of the northern quarter of the earth taken by METEOSAT-6, which is EUMETSAT's operational hot stand-by satellite. Further improvements have been introduced in the processing of multispectral AVHRR images and the cloud detection and classification scheme. New AVHRR products in full resolution for central Europe, the Alpine region and for the south-western parts of Europe are made available to all weather forecasting offices and to certain user groups, specifically in support of aviation services.
(Contact: J. Asmus, DWD – joerg.asmus@dwd.de).

2.7 **Cloud and weather analysis:** Further refinements have been introduced into the method for generating a three-dimensional analysis of clouds and precipitation areas for Europe and parts of the North Atlantic. Based on Meteosat IR and VIS data, SYNOP observations (rain, snow, drizzle, showers, thunderstorms and their intensities and data on visibility and cloud base and layers), radiosonde data and some information from NWP output, the method transfers the

single point (SYNOP and radiosonde) data to full area-covering information by means of the satellite data and the cloud structure in them. The method is now operated on a fully operational basis, based on 1-hourly Meteosat image data. The results, which enjoy a very high interest rate and are assessed to be very useful, are available to all offices involved in weather monitoring and forecasting activities, but also via Internet to other authorised users and, to some extent, to the general public. Preparations are ongoing to use the results for climatological purposes and for NWP model validation. A simplified example of this originally coloured cloud and weather analysis product is given in figure 1.
(Contact: W. Rosenow, DWD – wolfgang.rosenow@dwd.de or http://www.dwd.de/research/satmet for more examples).

2.8 **Satellite climatology:** The EUMETSAT Satellite Application Facility (SAF) on Climate Monitoring is an international project with participation of the NMHSs' of Belgium with the University of Brussels and the Royal Military Academy as subcontractors, Finland, the Netherlands, Sweden and Germany. Partners from Germany are the DWD with the GKSS Research Centre as subcontractor, as well as the BSH and their subcontractors the Max-Planck-Institute for Meteorology with its German Climate Computer Centre and the University of Bremen. The DWD is the responsible host of this project, performing management tasks and scientific development activities. The purpose of the presently on-going 5-year development phase is the preparation of the operational generation of precise, homogenous and consistent data sets for climate monitoring purposes based primarily on data of Meteosat Second Generation and the operational polar orbiting meteorological satellites (NOAA POES and in the future EUMETSAT EPS/MetOp). The SAF on Climate Monitoring focuses on the following climate relevant parameters: clouds (fractional cloud cover, cloud type, cloud top height and temperature, cloud phase, cloud optical thickness and cloud water path), radiation fluxes (short-wave and long-wave; at the earth's surface and at the top of the atmosphere), on ocean sea state parameters (SST, sea ice cover and others) and on the water in the atmosphere. The activities during the reporting period concentrated on the definition, selection, tests and modification of the algorithms which are considered for future operational applications and on the engineering aspects. Relevant studies have been performed in cooperation with several research institutes, the generation of the engineering documentation was partially contracted to industry. In November 2000 the EUMETSAT SAF Training Workshop 'Climate Monitoring' took place in Dresden which was sponsored to a considerable extent by EUMETSAT and by WMO and DWD. It was attended by nearly 100 experts from all parts of Europe, the Middle East and the USA. More details on the SAF on Climate Monitoring can be found under the URL http://www.dwd.de/research/event.htm or www.eumetsat.de.
(Contact: M. Werscheck, DWD – martin.werscheck@dwd.de).

2.9 **Exploitation of ATOVS data**: Pre-processing of ATOVS data is performed at the DWD operationally based on the latest versions of AAPP provided by EUMETSAT. Tests on the extraction and mapping of snow and ice cover for Europe based on AMSU data were performed with encouraging results. One product, which is extracted operationally from the HIRS data, is total column of ozone. This is done by means of a neuronal network which has been updated, improved and provided by the Solar Energy and Hydrogen Research Centre (ZSW). The ozone information is required for the generation of UV-B forecasts. For this purpose tests with ozone data extracted from the ERS-2 GOME instrument and provided by the German Space Research Establishment (DLR - DFD) have been carried out. The ozone data from HIRS are, however, as yet the primary ozone data source for the UV-B forecasts.
(Contact: Th. Böhm, DWD – thomas-marian.boehm@dwd.de).

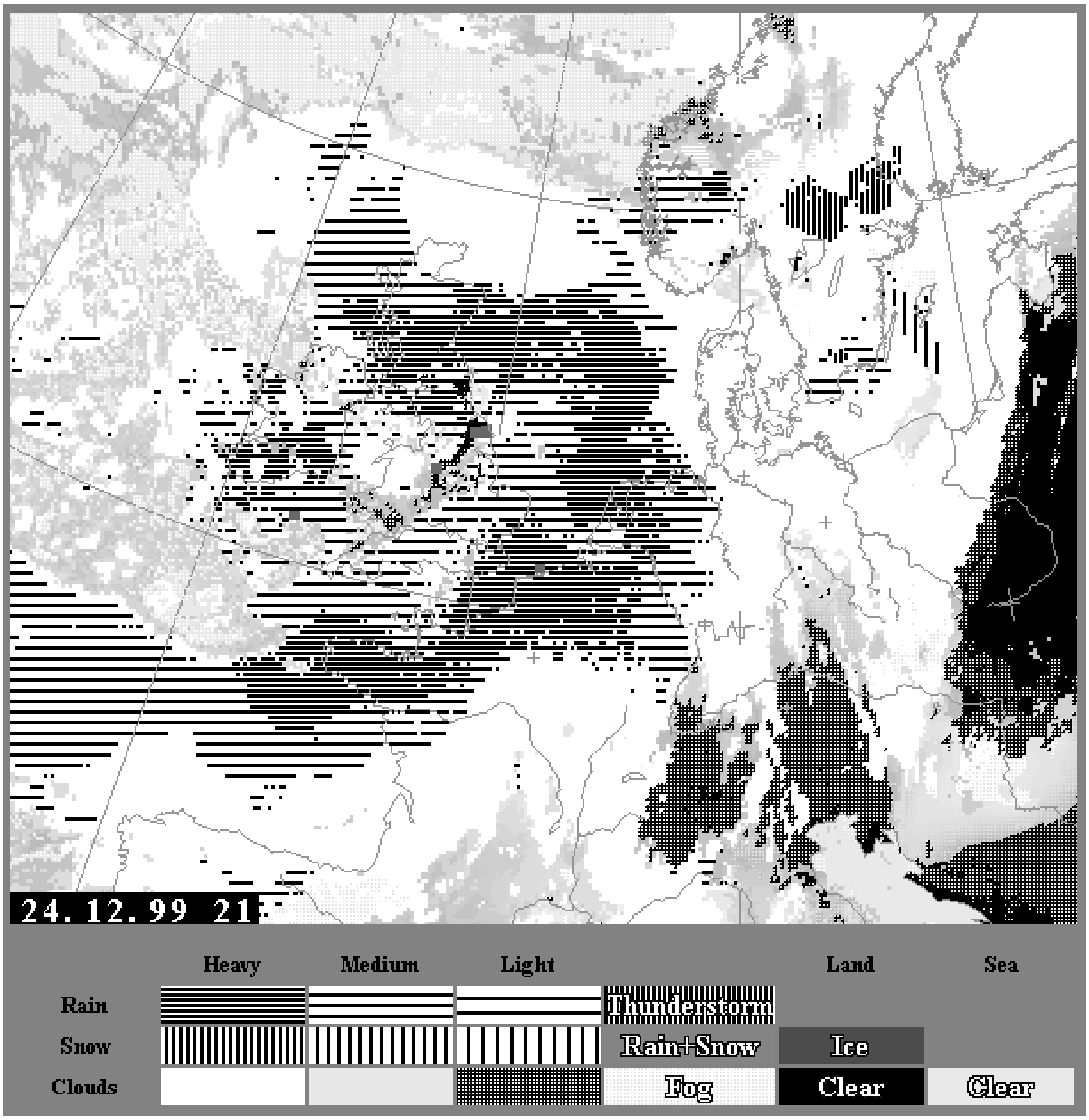


Figure 1: Clouds and weather analysis, 24 December 1999, 21 UTC, based on Meteosat, SYNOP and radiosonde data.

2.10 **Plant Cover:** A method has been developed to extract the plant cover from NOAA AVHRR data for usage in the NWP models of the DWD. After implementation of some improvements and NWP model specific adaptations the method has been operated on a fully operational basis. A somewhat more detailed information on this method was given in the previous Progress Report (WMO TD No. 995 (SAT-24)). Work is ongoing to achieve the most benefit from the resulting plant cover information in the numerical modelling of the land surface. (Contact: A. Gratzki, DWD – annegret.gratzki@dwd.de).

2.11 **Exploitation of GPS signals from ground-based stations in NWP:** The DWD is contributing to the COST-716 project entitled "Exploitation of ground-based GPS for climate and numerical weather prediction application". COST stands for European Co-operation in the field of Scientific and Technical Research and is under the responsibility of the Directorate General XII Science, Research and Development of the Commission of the European Countries. The purpose of COST-716 is to develop and test the methods for an operational exploitation of the signals from ground-based GPS receiving stations in NWP and climate applications and to prepare an

operational network of relevant ground systems. Details on COST-716 can be found under the URL http://www.oso.chalmers.se/geo/cost716.html. The activities of the DWD in this project are: assessment of the quality of the integrated water vapour derived from the GPS signals provided from geodetic processing centres and the development and testing of methods for the assimilation of these data into the LM, the regional NWP model of the DWD. The first activities concentrated on a quality assessment and on the preparation of NWP model impact studies. The DWD works in close collaboration with the Geodetic Research Centre Potsdam (GFZ) as regards the activities in COST-716.
(Contact: M. Tomassini, GFZ/DWD – maria.tomassini@dwd.de ; W. Benesch, DWD – wolfgang.benesch@dwd.de).

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3.1 **Automatic observing stations:** A network of automatic observing stations operating in the German Bight and in the western Baltic Sea measures water temperature, salinity, current velocity and oxygen content. Data from the observing stations are transmitted to the BSH mainly via the METEOSAT satellite. Research, merchant and fishery protection vessels and ferries on scheduled services also transmit sea surface temperature data to the BSH, again partly by satellite. (Contact: F. Holzkamm, BSH Hamburg)

3.2 **Land-SAF Soil Moisture Product:** At BfG, there is currently no specific technical development for satellite data. However, within the EUMETSAT Land-SAF (see 2.1), some technical integration effort could be necessary for the Soil Moisture Product during the pre-operational or operational phase of the Land-SAF (see 5.1).
(Contact: F. Portmann, BfG - portmann@bafg.de).

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4.1 **Clouds and Precipitation – METEOSAT imagery*:*** BfG currently uses a Secondary Data User Station (SDUS) for receiving and displaying retransmitted METEOSAT images. The images are evaluated qualitatively for forecasting purposes, the cloud cover and cloud top temperature being the most important feature to estimate if precipitation is occurring or will do so in the near future in basins or areas of interest. (Contact: P. Krahe, BfG - krahe@bafg.de).

4.2 **Land use – LANDSAT TM imagery*:*** BfG used LANDSAT Thematic Mapper data to classify land use in the original geometric resolution, from which a dataset reduced in geometric resolution to 1 km x 1 km, but still maintaining the original frequency distribution of the land use classes, was generated. This latter dataset is now used as a basis for hydrological modelling at basin scale within Germany and for the big basins shared with neighbouring countries, especially those of the Rivers Rhine and Elbe. (Contact: P. Krahe, BfG - krahe@bafg.de).

4.3 **DEM – SPOT stereoscopic imagery:** Digital Elevation Models (DEM) were derived from stereoscopic SPOT data within the project "New Opportunities for Altimetry in Hydrology" (NOAH), financed by the European Union and with the participation of BfG. The DEM of the international River Moselle, a large tributary of the River Rhine with its basin shared by France, Germany and Luxembourg, is used for basin-wide rainfall-runoff modelling for flood forecasting. (Contact: P. Krahe, BfG - krahe@bafg.de).

4.4 **Satellite Data Receiving and Processing System at BSH:** HRPT data has been received at the BSH in Hamburg since 1990. The NOAA/AVHRR data are processed by professional software and standard algorithms to generate output images of sea surface temperature and overview images for the ice service. Four to eight passes of a certain elevation

are received daily. The routine SST (Sea Surface Temperature) map covers the North and Baltic Seas as shown in figure 2. The map is transferred via LAN to the ice service and the hydrographic service for sea surface temperature, where the composition with in-situ measurements is completed.
(Contact: P. Löwe, BSH Hamburg – peter.loewe@bsh.d400.de,
http://www.bsh.de/Meereskunde/Klimafragen/946.htm)

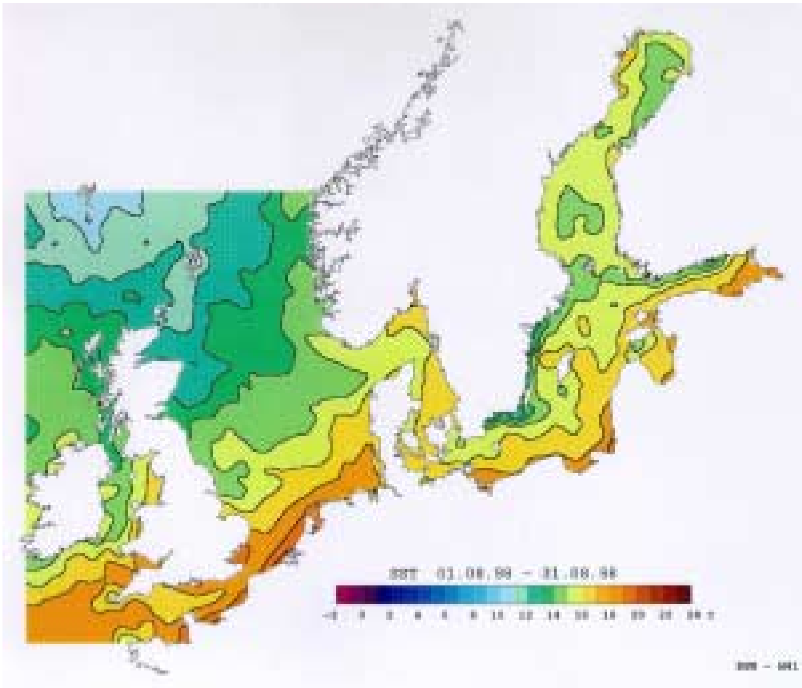


Figure 2: Example of a composite SST map showing the area of the North and Baltic Seas from which HRPT data have been archived since 1990.

Satellite data receiving, processing and distribution system at DWD

4.5. **Satellite data availability:** No significant changes have been introduced in the operational satellite data receiving and processing system of the DWD during the past few years. A PDUS at the central facilities in Offenbach is in operation for the reception of the high resolution METEOSAT data and all the data of other geostationary satellites which are distributed by EUMETSAT via METEOSAT. An HRPT station is operated at Offenbach as well for the direct reception of NOAA AVHRR and ATOVS data. Rapid scan data from METEOSAT-6 are available from EUMETSAT via the Internet. Most of the de-centralised weather forecasting offices still have an SDUS for the reception and display of the analogue METEOSAT images in addition.
(Contact: H. Knottenberg, DWD – heinrich.knottenberg@dwd.de).

4.6 **Processing:** The DWD applies in-house developed software for the processing of image data from the geostationary satellites. The CINESAT software from the Austrian company Gepard is used for pattern recognition, interpolation and extrapolation of satellite and precipitation radar data. The processing of AVHRR data is based on in-house developed software; some applications are based on the commercial software TeraScan by SeaSpace Corp., others on the APOLLO software from DLR. The AAPP software provided by EUMETSAT is applied for the pre-processing of ATOVS data and the ITPP-5 package of the University of Wisconsin is used for the processing of level-2 products. The total number of satellite images and products generated and distributed fully operationally to internal and external customers exceeds 3000 per day. The total

number of workstations at the DWD in which satellite data, specially derived products and other meteorological data are available for display and interactions is more than 150.
(Contact: for METEOSAT data: J. Asmus, DWD –joerg.asmus@dwd.de ; for AVHRR data: A. Gratzki, DWD – annegret.gratzki@dwd.de ; for ATOVS data: Th. Böhm, DWD – thomas-marian.boehm@dwd.de).

4.7 **Data distribution:** All digital satellite data received and processed at the DWD in Offenbach are distributed together with a lot of other meteorological information to the decentralised facilities of the DWD and to other NMHSs by means of FAX_E (Facsimile_Europe), which is a digital data distribution system based on commercial telecommunication satellite services (EUTELSAT). A wide variety of products based on satellite data is also made available to users via the internet, some generally, others to dedicated closed user groups.
(Contact: for FAX_E: H. Knottenberg, DWD - heinrich.knottenberg@dwd.de ; for Internet services: Datenservice@dwd.de).

4.8 **Use of satellite products in NWP:** In the data assimilation of the global NWP model of the DWD (GME), which is based on a 3D multivariate optimal interpolation (OI), those products are used operationally which are extracted by the different satellite operators and distributed via the WMO telecommunication systems, the GTS, and in RA VI the RMDCN (Regional Meteorological Data Communication Network). These are satellite winds from the different operators of the geostationary satellites and temperature profiles from ATOVS and humidity information distributed by NOAA-NESDIS in SATEM code with 500 km horizontal resolution. Because of certain technical problems with some instruments of the NOAA satellites, specific activities were necessary to monitor the quality of the resulting products in NWP. Impact studies were also performed in order to use the temperature profiles in the most efficient way in the global model: as one of the consequences the time window for the use of the SATEMs in the data assimilation was reduced from 3 hours to 11/2 hours.
(Contact: Th. Böhm, DWD – thomas-marian.boehm@dwd.de or W. Wergen, DWD – werner.wergen@dwd.de).

4.9 **SDUS functionality:** A system has been taken into full operation for a simple display of METEOSAT, AVHRR and radar data. This system is replacing the old SDUS, with improved capabilities, and is typically used for a permanent automatic presentation of the actual weather situation at regional offices of the DWD without the need for interactive actions. Input satellite data are the data received via the PDUS and HRPT stations at Offenbach, data distribution is performed by means of FAX_E. (Contact: A. Meyer, DWD – arnold.meyer@dwd.de).

4.10 **Data Collecting Platforms (DCPs):** At the end of the reporting period, the total number of DCPs in operation under the responsibility of DWD and BSH was 77, 48 on land, 25 on ships and 4 Automatic Shipboard Aerological Programme (ASAP) units. In addition, the Federal Environmental Agency of Germany operates a large number of DCPs for the transmission of environmental and geophysical data. (Contact: R. Götsch, DWD – reinhard.goetsch@dwd.de).

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5.1 **Land-SAF Soil Moisture Product:** Within the EUMETSAT Land-SAF development phase (see 2.1), the operational generation and distribution of the daily MIUB/BfG Soil Moisture Product is envisaged for the Land-SAF pre-operational stage, currently planned for the year 2004. (Contact: F. Portmann, BfG - portmann@bafg.de).

5.2 **HRUS for reception of MSG data:** The DWD has initiated preparatory measurements for the procurement of a High Resolution User Station (HRUS) for the reception of the full data stream, which will be distributed via the Meteosat Second Generation (MSG) satellites. The activities have, however, been slowed down because of the delays in the MSG programme. The

MSG data will be used for the operational activities of the DWD including the future operational phase of the SAF on Climate Monitoring.
(Contact: H. Knottenberg, DWD – heinrich.knottenberg@dwd.de).

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6.1 **Land-SAF Soil Moisture Product:** At BfG, no specific validation and verification is being performed for meteorological satellite data at present. The planned Soil Moisture Product will be validated, however, within the EUMETSAT Land-SAF (see 2.1).
(Contact: F. Portmann, BfG - portmann@bafg.de).

6.2 **Incoming short-wave radiation:** Since 1985, the DWD has been calculating the incoming short-wave radiation at the surface from METEOSAT data for Germany and the neighbouring areas. For the time period 1985 to 1997, the data were validated with surface measurements from the German radiation network. The validation shows that during this period monthly means of solar radiation were derived with a mean deviation below 3 per cent and a root mean square deviation of 8 per cent. Starting in September 1993, all available hourly METEOSAT images were used instead of a maximum of 5 images per day. This reduced the mean deviation to below 1 per cent and the root mean square deviation to 6.4 per cent.
(Contact: A. Gratzki, DWD – annegret.gratzki@dwd.de).

6.3 **Other meteorological products:** It is recommended to contact the experts listed below for detailed validation and verification results:

- Use of satellite data in operational NWP: W. Wergen, DWD – werner.wergen@dwd.de .
- Precipitation estimates used in the Global Precipitation Climatology Centre: B. Rudolf, DWD – bruno.rudolf@dwd.de .
- Ozone data: The Meteorological Observatory Hohenpeissenberg of the DWD contributes to the validation of nearly all existing space-borne ozone instruments by means of ozone radio soundings, ground-based lidar, Dobson and Brewer Spectrometers. The observatory is one of the partners of the EUMETSAT Satellite Application Facility (SAF) on Ozone Monitoring, which is hosted by the Finnish Meteorological Institute (FMI). The contributions of the DWD to this SAF are in the area of the validation of satellite measured ozone profiles by means of ground-based lidar data. (Contact: H. Claude, DWD – hans.claude@dwd.de).

PART VII OTHER ITEMS (references, publications and scientists in charge)

7.1 **Training:** Several very successful training activities in satellite meteorology have taken place in cooperation with the EUMETSAT Secretariat at the Training and Conference Centre of the DWD in Langen. Two of them were focused on the application of satellite data for weather monitoring, nowcasting and very short-range forecasting, one was dedicated to the future EUMETSAT satellite systems Meteosat Second Generation (MSG) and EUMETSAT Polar System (EPS). Participants came from EUMETSAT Member States and non-member States. Additional training events are being considered for the future.
(Contact: M. Jaeneke, DWD, matthias.jaeneke@dwd.de or W. Benesch, DWD – wolfgang.benesch@dwd.de).

7.2 **Considerations on future satellite systems:** Studies have been initiated regarding future operational satellite systems for meteorology and climate and environmental monitoring. One study, financed by the German Space Agency (DLR), is to investigate a concept for a Third

Generation Meteosat (MTG), another, also financed by DLR, investigates the possibilities, advantages and disadvantages of small operational meteorological satellites in polar orbit (PKMet). (Contact: W. Klein, DLR – wolfgang.klein@dlr.de).

7.3 Another study, kicked-off during the reporting period and financed by the Federal Ministry for Transport, Building and Housing, has the purpose of investigating possibilities for potentially cheaper procurement and operation of future meteorological satellite systems. (Contact: M.Klöppel, BMVBW – manfred.kloeppel@bmvbw.bund.de).
The results of all the studies mentioned here will be available during the year 2001.

7.4 An important and successful specific workshop on Follow-on Systems for MSG and EPS, jointly organised by DLR and DWD, chaired by Prof. Grassl and supported among others by the WMO, took place in November 2000 in Walberberg. The results of this workshop can be grouped into three categories: (a) requirements on the future operational satellite systems in the time frame 2015 to 2025; (b) satellite systems with demonstrated capabilities which should become operational before 2015; and (c) new technological developments required.
(Contact: W. Klein, DLR – wolfgang.klein@dlr.de or W. Benesch, DWD – wolfgang.benesch@dwd.de)

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7.6 Addresses

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HONG KONG, CHINA

(Hong Kong Observatory)

PART I A BRIEF SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1,1 In respect of numerical weather prediction, satellite data are extensively used in the Operational Regional Spectral Model (ORSM) at the Hong Kong Observatory. Data from both geostationary and polar-orbiting satellites are ingested into the ORSM to improve the model's performance.

1.2 Satellite data from both geostationary and polar-orbiting satellites are also being ingested into a high resolution non-hydrostatic numerical model (NHM) under development for local heavy rainfall forecast.

1.3 The Observatory started receiving images from the Fengyun-2B (FY-2B) geostationary satellite of the China Meteorological Administration following its launch in June 2000. Figure 1 shows a visible image from FY-2B received at 08 UTC on 6 September 2000.

1.4 Near-surface wind speed and direction in the form of ocean surface wind charts from the QuikSCAT satellite are made available to forecasters. The information is useful for determining the center of tropical cyclones and for monitoring the occurrence of high winds associated with the monsoon.

1.5 Data from the QuikSCAT satellite and from the Special Sensor Microwave Imager (SSM/I) onboard the Defense Meteorological Satellite Program (DMSP) satellites were decoded and made available for a study on their use in numerical model. Utilization of these data for operational use and research purpose is being explored.

1.6 All satellite reception systems of the Observatory were tested to be year 2000 compliant. They operated smoothly before, during and after the transition into year 2000.

PART II A DESCRIPTION OF THE MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2.1 Digital data, including total cloud amount, mean cloud top temperature and its standard deviation, obtained from GMS-5 are routinely ingested into the ORSM for moisture bogus to improve analysis and forecast of the humidity field.

2.2 GMS-5 cloud motion vectors are also ingested into the ORSM during tropical cyclone situations resulting in more accurate forecasts of the wind field around tropical cyclones.

2.3 Temperature and humidity profiles derived from TOVS data are received through GTS and are also used by ORSM for improving the analysis over the ocean areas.

PART III A DESCRIPTION OF TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3.1 ORSM weather and rainfall forecast charts are animated and displayed side by side with the real time GMS-5 satellite imageries on the Observatory's Intranet for validation of model outputs by the forecasters. A study is underway to adjust the ORSM short-term forecast rain distribution by comparison with the actual observed satellite cloud patterns.

3.2 Using QuikSCAT and SSM/I data, algorithms for automatic identification of tropical cyclone centers and analysis of tropical cyclone wind field structure are being developed.

PART IV A BRIEF DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

Operational Ground Reception System

4.1 Figure 2 is a schematic diagram of the operational ground reception system of the Observatory. The system consists of a 5-metre diameter antenna and a 3.7-metre diameter antenna located at the Observatory Headquarters for the reception of GMS-5 and FY-2 broadcasts respectively. Signals from GMS-5 and FY-2 are separately received and processed by two workstations. The received images are made available to forecasters at the Observatory's Central Forecasting Office and at the Airport Meteorological Office in the Hong Kong International Airport.

4.2 The system allows users to manipulate the satellite images in a number of ways: cursor readout of cloud information, automatic animation sequence update, selection of look-up tables, composite image from different channels using different colours, histogram and scatter plot of albedo/brightness temperature levels and edge enhancement.

4.3 The satellite images are passed to the TV Studio of the Observatory for TV weather presentation. A selection of satellite images is displayed on the Observatory's Homepage on the Internet (http://www.info.gov.hk/hko/wxinfo/intersat/satpic.htm).

4.4 By means of a separate receiver, GMS-5 signals are routed to a PC-based system as backup. Basic image manipulation functions such as cursor readout, automatic animation sequence update, selection of look-up tables are available in the backup system. The backup system is installed at the Central Forecasting Office and the Airport Meteorological Office for forecasters' use.

4.5 Low-resolution WEFAX signals of GMS-5 are also received and displayed on a PC.

Ground Reception Stations for World Area Forecast System

4.6 A ground reception station for satellite broadcast of meteorological data from the World Area Forecast Centre (WAFC) at London is in operation at the Observatory Headquarters and at the Hong Kong International Airport. Similar equipment is in operation at the Hong Kong International Airport for receiving meteorological data from the WAFC at Washington.

4.7 Each ground reception station comprises a 2.4-metre diameter antenna, a satellite signal receiver and a workstation for processing and display of the following data:

- Global gridded upper wind/temperature data in GRIB code;
- T4 facsimile weather charts including wind/temperature charts for standard flight levels and SIGWX (significant weather) charts; and
- Alphanumeric OPMET (operational meteorological) data including TAF, METAR and SIGMET messages.

4.8 Commencing March 2000, the ground reception station for WAFC London also obtains global significant weather information in BUFR format.

4.9 Relevant T4 charts from both WAFC London and WAFC Washington are provided to airlines as part of the flight documentation.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5.1 To backup reception of images from geostationary satellites, a plan is in hand to install a new reception system for meteorological data from polar-orbiting satellites. The new system is expected to be operational by the end of 2001.

5.2 Acquisition of a ground reception system for the MTSAT-1R satellite will start closer to the satellite's launch, now scheduled for 2003.

5.3 Development of non-hydrostatic numerical model (NHM) using satellite data for rainfall forecast will continue. A variational data assimilation system in association with the NHM will also be developed. Impact studies of satellite data on NHM will be conducted.

5.4 Algorithms for assessing local atmospheric stability using satellite data will be developed to improve HKO's rainstorm nowcasting system.

5.5 Plan for operational use of BUFR-formatted significant weather charts from WAFC London is being developed.

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND THE NAMES OF SCIENTISTS IN CHARGE, ETC.)

7.1 The focal point for satellite related activities at the Hong Kong Observatory is :

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Hong Kong Observatory
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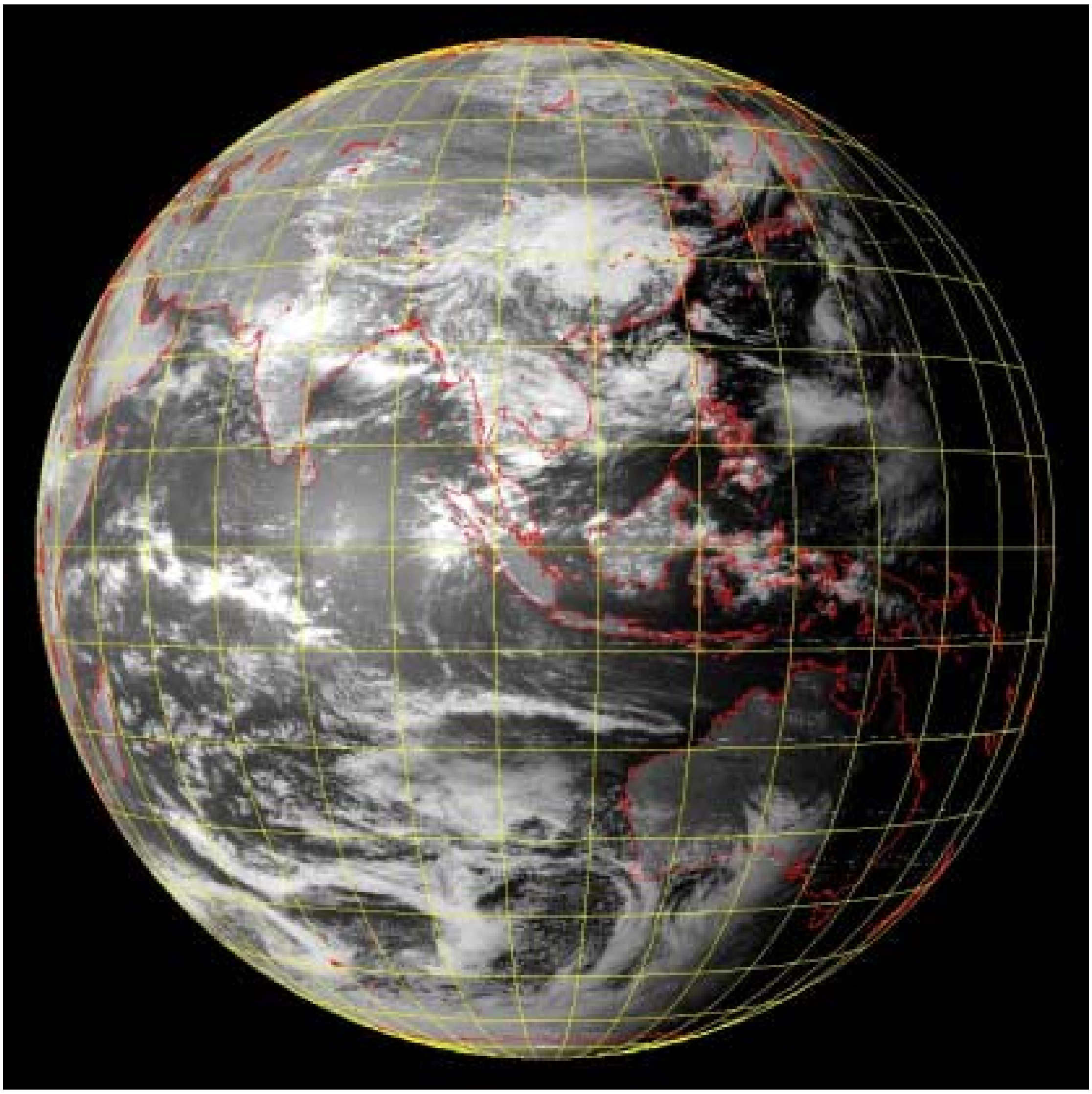
Kowloon
Hong Kong, China

Fax no. : (852) 2721 5034
Email address: cmcheng@hko.gov.hk
Home page: http://www.info.gov.hk/hko/ or
http://www.weather.gov.hk

Figure 1 Visible Cloud Image Captured by the Chinese Fengyun-2B Geostationary Satellite at 08 UTC on 6 September 2000



HUNGARY

(Meteorological Service)

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Processing of METOSAT Images

Reception and archiving

METEOSAT digital images have been received at the Satellite Research Laboratory of the Hungarian Meteorological Service(HMS/SRL) since September 1991. At HMS/SRL we archive the images of the Atlantic-European region for IR, WV and the Central-Western European sub-image for VIS.

Animation

The visualisation of a series of consecutive images for the same area made from visible and infrared images are sent to the Weather Forecasting Department.

Cloud detection and cloud top temperature

The purpose of cloud detection is the automatic separation of cloudy and clear pixels by computer programmes. Both visible and infrared images are used in the algorithm. From the IR image brightness temperature is calculated after calibration. In case of thick cloudiness this brightness temperature approximates well the cloud top temperature, for thin clouds further calculations are necessary.

Cloudiness

Cloudiness is the rate of cloudy and cloud free areas. At the SRL we calculate this parameter for 20x20 km boxes from the results of the mentioned cloud detection algorithm. The size of this box corresponds to the human observations of cloudiness, but the advantage of calculating this parameter from satellite data is that it is much more objective with a better spatial resolution.

Cloud classification

The cloud classification algorithm separates and determines the different cloud types on the images. The calculations combine statistical tools and thresholds using the visible and infrared data. other meteorological parameters are used as well, such as albedo maps and predicted temperature fields.

All of these parameters are sent operationally for the Weather Forecasting Department.

Energy budget

Energy budget calculations are also performed to estimate the energy input by solar irradiation and output caused by the long wave emission of the surface. Both process are influenced by the cloud amount and types. Presently, we make maps of monthly and yearly averages from a five-year period (1992-1996) which are valuable in climate change research and energies.

Processing of NOAA/AVHRR images

Reception and archiving

NOAA/AVHRR digital images have been received at HMS/SRL since January 1992. After reception of the AVHRR images we extract the sub-image for the Carpathian Basin and archive the raw data.

Cloud detection

The cloud detection algorithm differs from that for the MUTEST images. The more spectral channels enable us to derive better and more accurate cloud mask. Apart from the separation of cloudy and cloud free pixels, it is possible to identify fog and low layer clouds (stratus) separately. On daytime images snow detection - separation from cloud pixels - is also possible with the same algorithm.

During the autumn and winter periods these parameters are sent operationally for the Weather Forecasting Department.

Cloud parameters

We derive cloud top temperature from the brightness temperature values. The visible and the 3.7 µm channels are used to calculate cloud optical depth and effective cloud drop size from the measured values of reflected solar radiation. These parameters will be used in a precipitation estimation procedure which is presently being developed.

Surface parameters

From data measured in the short-wave band (channels 1 and 2) reflectivity, albedo and the vegetation index are calculated. For determining land surface temperature using long-wave bands (channels 4 and 5) the split window method is used. The net radiation on the surface is transformed mainly into evapotranspiration, sensible heat flux and solid heat flux. If we determine the latter two, the evapotranspiration can be computed as residual. The method uses data from surface meteorological measurements, the vegetation index and the land surface temperature.

When the results of the daily image processing are already available, averages (or maxima, minima) from longer periods can be produced for climate research. For this purpose the data should be transformed and represented in map projections. At HMS/SRL monthly maps of vegetation indexes have been made operational since the summer of 1997, but without atmospheric correction. The production of 10 daily and monthly atmospherically corrected land surface temperature and vegetation index maps started in spring 1998.

TOVS instrument of NOAA satellites

At the HMS/SRL the TOVS data are received and archived for the whole satellite overpass. The processing of the data is made operational by the Inversion Coupled with Imager (ICI). Using this software the temperature profile is derived operationally.

INDIA

(India Meteorological Department))

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 The two series of geostationary satellites i.e., INSAT-1D (INSAT-1 series), INSAT-2B and INSAT-2E (INSAT-2 series) continued to be operational. These satellites are located at 74°E , 93.5°E and 83°E longitudes positions respectively over the equator.

1.2 The major operational and research applications include: monitoring cyclone systems and their structural changes from satellite imagery; monitoring build up of moist and dry regions in water vapour imagery; monitoring local severe storms and convective activity over India during the pre-Monsoon season; monitoring of various weather systems, viz., depression/lows, western disturbances, etc., during the year; estimation of large-scale precipitations; retrieval of temperature and humidity profiles; derivation of Cloud Motion Vectors (CMVs), Sea Surface Temperatures (SST) and Outgoing Long-wave Radiation (OLR).

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Research and Development Retrieval of Vertical Temperature Profiles

2.1 Capabilities are available at the INSAT Meteorological data Processing System(IMDPS) and HRPT system installed in 1992and 2000 respectively at New Delhi for making sounding retrievals using data from the USA polar-orbiting satellites. These data were continued to be utilized for research purposes. For this purpose, two options were used (i) climatological guess; and (ii) 1000 hpa analysis.

2.2 The high density wind data derived from METEOSAT-5 Satellite over the Indian ocean received from INTERNET, is being utilized to estimate the chances of recurvature of a tropical cyclone during next 6 to 12 hrs. The middle and upper level wind data are used in conjunction with water vapour imagery to provide guidance on chances of further development / weakening of a tropical cyclone. It has been seen that these data are quite useful in case of tropical cyclones over Bay of Bengal.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3.1 Satellite derived products were continued to be generated on an operational basis with the IMDPS system and further improvements in the quality of the derived products were made. Derivation of Cloud Motion Vectors (CMVs) based on three consecutive half hourly INSAT imageries centred at 00, 06 and 12 UTC was continued and this product was disseminated to the users on the GTS. The quality of Cloud Motion Vectors (CMVs) and Sea Surface Temperature (SSTs) derived over the areas of the Bay of Bengal, Arabian Sea and Indian ocean using INSAT data was further improved. Quantitative Precipitation Estimates (QPE) are being derived operationally with a horizontal resolution of 2.50 x 2.50 and 10 x 10 (from 1.1.2000) and over 35 meteorological sub-divisions of India.

3.2 Synoptic meteorologists have easy access to animation and looping facilities for routine operational use through the interactive processing sub-system (work station) of IMDPS work stations established at the field forecasting centres have also such capabilities. This, together with the capabilities of manipulation of images viz., sectorization, roam and zoom, Cloud Top

Temperature (CTT) contouring and enhancement etc., increased their ability for detailed analysis and tracking of tropical cyclones and other weather systems.

3.3 Geo-physical parameters derived from Indian Remote Sensing Satellite IRS-P4 became available from middle of 1999. IRS-P4 has a Multi-frequency Scanning Microwave Radiometer (MSMR) which is used to derive surface wind speed, total precipitable water content, sea surface temperature and cloud liquid water content over the oceanic regions. Algorithms have been developed to assimilate sea surface wind speed and total precipitable water content in the existing operational data assimilation system (Rizvi, *et al.*, 2000). There was a positive impact of MSMR data on the globally analyzed surface winds specially over the oceanic region during the study period (July 1999). The impact of MSMR total precipitable water content data was noticed at all the levels in the wind and moisture field. In the lower levels the impact is dominated by the surface wind speed data. The impact of MSMR wind speed data is more in the southern hemisphere while the total precipitable water content have more influence on the global analysis between 50° on both sides of the equator. For the Indian oceanic region, the impact of MSMR data is seen more in the 06 and 18 UTC analysis as compared to 00 and 12 UTC analysis. A dynamic quality control technique is developed to filter out the MSMR wind speed data having large residuals as compared to the background field, with the data analysis system. These efforts lead to the generation of near surface wind analysis over the Indian seas for ocean sea state forecasting applications groups working at other organizations within India.

3.4 The daily rainfall analysis procedure was being used earlier to provide gridded rainfall values by merging satellite and rain gauge values at T80 model resolution. Now it is modified to use 10 x 10 resolution 'Quantitative Precipitation Estimates' available from INSAT IR data from June 2000, as the first guess to the rainfall analysis procedure.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4.1 Under the meteorological Data Dissemination (MDD) Scheme, so far MDD stations have been installed at 32 field stations in India and neighbourhood (one each in the Maldives and Sri Lanka). The MDD stations receive the multiplexed data viz., cloud imagery, facsimile charts and conventional meteorological data directly from the satellite. These MDD stations have been equipped with PC-based interactive work stations for manipulating image data from INSAT satellites and analysis of various weather systems.

4.2 Under the meteorological Applications Programme of INSAT, 250 Cyclone Warning Dissemination System (CWDS) stations have been installed and commissioned in the coastal areas for real-time dissemination of cyclone warning to the affected areas. These stations are working satisfactorily.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5.1 The last satellite of INSAT-II series, viz., INSAT-2E with improved meteorological payloads, has been operating since July 1999. The VHRR onboard INSAT-2E provides imaging capabilities in the water vapour channel (WV) 5.7 to 7.1 micron, besides visible (VIS) and thermal infrared (TIR) bands with a ground resolutions, at the sub-satellite point, of 2 kms in VIS and 8 kms in WV and TIR bands. A Charged Couple Device (CCD) payload is also provided for reception of imageries at 1 km resolution in the visible, short wave IR and near infrared channels. Due to some technical reasons only CCD is operational in INSAT-2E. data from VHRR is not available for operational use.

5.2 The IMDPS at New Delhi has been upgraded for the reception and processing of INSAT-2E meteorological data.

5.3 Under the expansion programme of the MDD scheme, 3 more MDD stations will be installed at different Meteorological Offices in India, thus bringing the total number of MDD stations over the country and neighbourhood to 35.

5.4 Under the INDO-US collaboration programme, INSAT data is being transmitted in real time to the United States of America. Data from USA's GOES satellite are being transmitted to IMD.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6.1 Validation of vertical temperature profiles and humidity profile data obtained operationally, from NOAA satellites was continued. Recently, initial guess data for surface and upper-air was used from model forecasts. The retrievals when compared with analysis showed marked improvement in retrieval of humidity profiles and appreciable improvement in the vertical temperature profiles. It is planned to use model forecasts operationally and make improved retrievals using initial guess. Efforts are on to set up inter-connectivity of the computer system in IMDPS and Cyber computer at NHAC to make the forecasts available on line.

6.2 The parameters for quality control of CMVs were made more stringent which improved the quality of CMVs to some extent. Efforts are being made to increase the number of good quality CMVs over the cloudy regions also. As a result of certain changes introduced operationally from November 1999 the quality of INSAT-CMVs has improved considerably. Detailed comparison of INSAT CMVs and METEOSAT-5 was also done, (P. N. Khanna *et.al*) METEOSAT-5 derived winds were used to diagnose the motion of two tropical cyclones over India (R. C. Bhatia *et.al*). The winds are found to be useful for track forecasts in a qualitative manner. Monthly mean data of sea surface Temperature (SST) and Outgoing Long-wave Radiation (OLR) derived from NOAA-AVHRR for the period 1980-1985 over tropical region have been analyzed (V. Rajeshwara Rao *et.al*). It is observed that the highest values of SSTs are generally associated with diminished convection and Maximum convection occurs at SSTs of about 29.5°C. Use of SSM/I derived products like total precipitable water (TPW) and sea surface winds was made for Diagnostic studies of Heavy rainfall events over coastal areas of India (Bhatia *et.al*). There is a good potential for using SSM/I derived quantitative data products for operational use in day-to-day weather forecasting, particularly for heavy rainfall events occurring along the west coast of India.

6.3 Validation of SSTs derived from NOAA AVHRR data with observed SSTs from drifting buoys was done. The satellite derived SSTs are found in good agreement with buoy SSTs (Devendra Singh *et. al*.). OLR data available from HRPT station at New Delhi was compared with INSAT OLR values and also with the NWP model's values. The study shows that in general the HRPT OLR values are slightly higher than the INSAT OLR values. The model forecast values are slightly higher than the HRPT OLR values (Rajan *et al*., 2000). The cloud liquid water content (CLW) from MSMR were compared with the climatological distribution of CLW derived from SSM/I as well as those obtained from the ECMWF model. Results showed that the CLW derived from MSMR are often overestimated as compared to the SSM/I and NWP model outputs. Results indicate that the magnitude of the CLW estimated from the model range up to 300 gm/m*m, while observations from the MSMR show much larger values over the Indian Ocean region. The MSMR values also showed many spurious values of the CLW, which had to be filtered out during the analysis (Das, *et al*., 2000).

6.4 Taking the T80 model's operational analysis of total precipitable water content as the first guess, objective analysis was done by introducing the IRS-P4 water vapour data as observations for a 20 days period of August 1999 using the standard Cressman's technique. The new reanalysis could capture the signatures of total precipitable water content (TPW) data obtained from IRS-P4 satellite (Mitra *et al*., 2000). In general the observed values from IRS-P4 are having a positive bias as compared to the NCMRWF analysis over the region of satellite passes.

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND SCIENTISTS IN CHARGE)

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Rizvi, S. R. H., R. Kamineni, R. K. Paliwal and U. C. Mohanty 2000 "Assimilation of MSMR data in the global data assimilation system and its impact on the medium range weather forecast", Proceedings of the International conference PROSEC at NIO, Goa, India, 5-8 December 2000, pp 520-523.

Singh, Davendra., R. C. Bhatia, V. Rajeshwara Rao and H. V. Gupta, " Validation of SST derived from NOAA AVHRR data with observed SST from drifting buoys," PORSEC proceedings, Vol. I : 163-166, Goa , India, December 5-8, 2000 pp 197-203.

ITALY

(Italian Meteorological Service)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

Operational facilities

1.1 During the period 1999-2000 a maintenance programme of satellite area has been carried out. The aim of the programme was to assure the operational activity and to improve the capability to use the satellite products. This project extends the use of the geostationary systems up to the advent of the 2nd generation satellites. The integration of satellite data with radar observations is also under implementation. The planning for a structure of the whole satellite area in the view of the new generation satellite (front end area, data processing area and archive area) has been performed.

1.2 A programme for the broadcast system started. This system will allow the distribution and the use of satellite information by all peripheral offices.

1.3 Following the moving of the NMC from Rome to all satellite facilities to the new seat of NMC at Pratica di Mare air base, the relocation of all satellite facilities, have been performed. The moving of the MDD uplink station is underway and will be completed by mid 2001.

Applications

1.4 The following main new application and processed products have been implemented:

- Calibration of Sea Surface Temperature with buoy temperature and operational production of a daily temperature map of Italian seas;
- Automatic tool to detect and forecast the convective system. This tool, named NEFODINA, produces a map of convective clouds in the Mediterranean area every 30 minutes;
- New procedure to retrieve digital data from MARF archive;
- New algorithm to retrieve the Cloud Top Height maps from Meteosat IR data;
- Installation of AAPP on an alpha unix station.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Image processing

2.1 SST maps are used to define the thermal structures of the sea, and to recognize areas subject to hypothermia risk.

2.2 Maps with the convective clouds are used for monitoring the evolution of intense systems. This product is useful for alert message production.

2.3 The impact of rapid scan (every 5 minutes) data on the NEFODINA tool has been evaluated and the rapid evolution of convective systems has been studied.

Data assimilation

2.4 IN connection with the assimilation of satellite data in the local area model, it's possible to retrieve SST fields also in the cloudy areas through an automatic algorithm. Cloudy fields are also produced from IR data to be used in LAM.

Analysis of air mass and cloud classification

2.5 A classification of clear air mass trough the water vapour channel and thermodynamic profiles data is under development.

2.6 An automatic multispectral cloud classification, using AVHRR data has been produced. A spatial operator is also used to better distinguish between convective and stratiform clouds. The assignment of clouds to height classes, is performed by means of the Cloud Top Height analysis method. The automatic systems has been improvement with a sea-land mask.

Training tools for the use of satellite data

2.7 Electronic pages with explanation of characteristics, performance and application of every satellite product have been realized. These pages are available to every forecaster of the Italian Met Service via the intranet service.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Systems

Satellite data reception and processing

3.1 During 1999-2000 there have been many changes in the satellite area, in particular the following activities have been carried out:

- conclusion of satellite receiving structure relocation from Rome to the new seat of the NMS at Pratica di Mare airport;
- renewal of METEOSAT Front End;
- renewal of TIROS antenna controller;
- acquisition of a new alpha computer for the back up of the station dedicated to data processing and to METEOSAT Front End;
- planning of all satellite facilities for the advent of the new satellite generations (front end area, data processing area and archive area).

3.2 On the SDUS side a general refurbishment has been realized at the peripheral offices. In particular the graphical systems are upgrade for a best employment of satellite pictures.

3.3 Regarding the distribution of satellite images and products to peripheral offices an inquiry system based on intranet protocol has been performed, allowing all authorized users to access satellite derived information.

MDD stations

3.4 The moving of the MDD uplink from Rome to Pratica di Mare station is underway and will be completed by mid-2001.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

Operational facilities

4.1 Operational satellite facilities at the Italian Meteorological Service are the following:

- The ANDROMEDA system, for reception and processing of digital data from METEOSAT AND NOAA, located at the NMC in Pratica di Mare;
- 50 SDUS stations located in any other meteorological offices and in various sites.

ANDROMEDA system

4.2 The ANDROMEDA system is inclusive of a PDUS and a HRPT station backed by a processing system (ISIDE, Interactive System for Image Data Elaboration) for research and development, archiving and product distribution.

4.3 An outline of the ANDROMEDA system, that is also connected via ETHERNET link to the TLC system (RTH) and the Host Computer (Meteorological Data Bank), is shown in fig. 1.

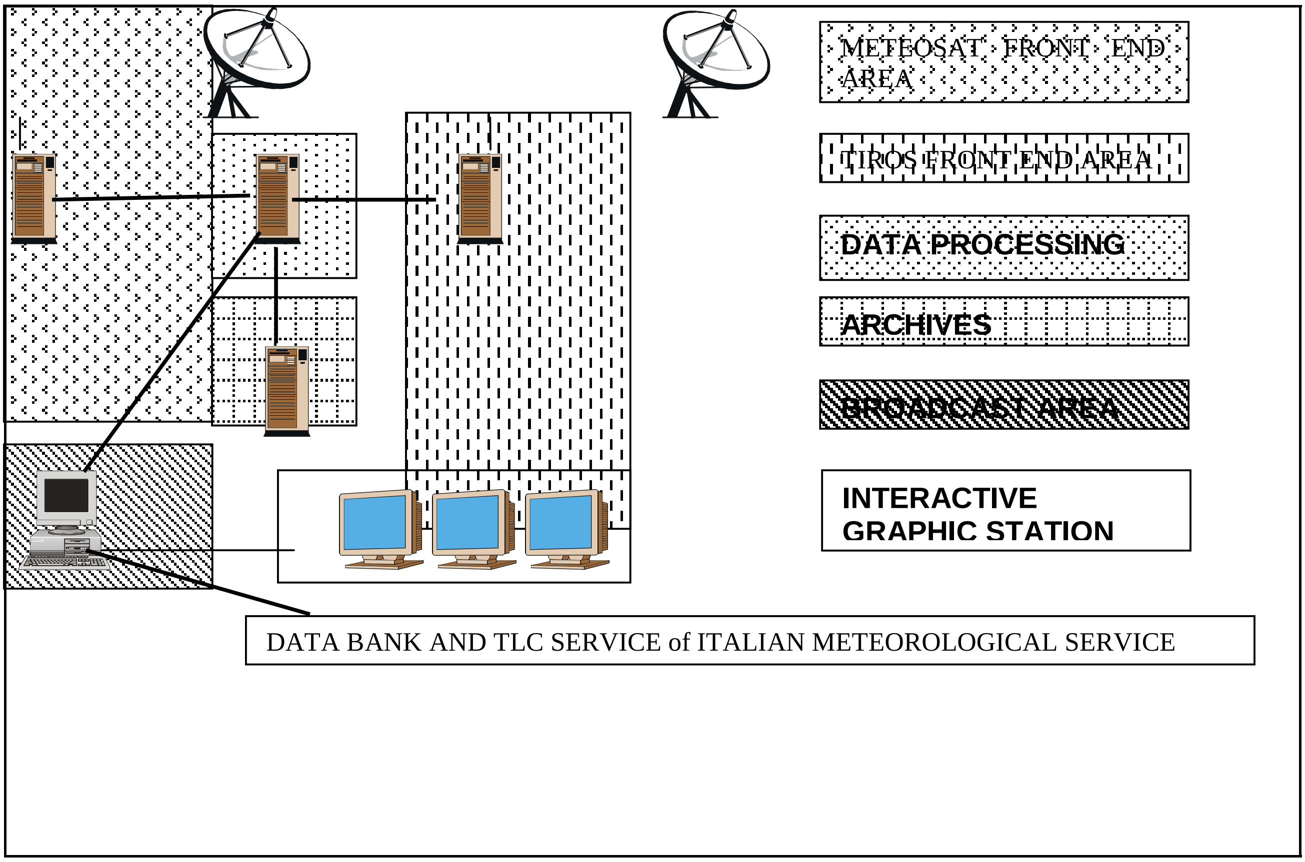

Fig.1 - Lay-out of the ANDROMEDA system

PDUS station: FEM (Front End Meteosat)area

4.4 The PDUS station is inclusive of the following sub-systems:

- receiving system, based on a 5 m parabolic antenna and devices for digital signal handling;
- computer system, based on a COMPAQ au 500, DAT units for archiving data, one disk unit (4 Gb) for supporting data processing;
- mass storage (two disk units, 13 Gb) to collect B format images acquired in the last 20 days and A format in the 4 last days;
- animation facility that produces sequences up to 64 images, 800x600 pixels. The sequences are shown in a movie-loop, and automatically updated. The operator has various graphic facilities such as panning, zooming, false colours, variable movie-loop speed, etc. The graphical system shows the IR and WV movie-loop together with other satellite products.

HRPT station: FET (Front End TIROS)area

4.5 The HRPT station is inclusive of the following sub-systems:

- receiving system, based on a parabolic steering antenna, 3.5 m diameter, and devices for tracking and digital signal handling;
- computer system based on a VAX processor, tape units, two disk units (8 Gb);
- mass storage (two disk units, 4 Gb each) for storing the last 5 NOAA passage (or more shorter passages), and over 100 images, 800x800 pixels;
- photorecorder for high quality hard copies (wet-chemical development);
- DAT drive for archives.

ISIDE system: the interactive graphic station

4.6 The ISIDE system is inclusive of the following sub-systems:

- Compaq Pentium 3 (128 Mb RAM) with 3 monitors interlaced for an integrated presentation of all satellite products and image display facility;
- two high capacity tape unit (EXABYTE) for long-term archive;
- two colour printers high quality and four plotter-printer.

General Processing area

4.7 An alpha 4000 server is dedicated to general processing area. Here processing of satellite data is performed to obtain added value products.

4.8 One DEC 3000/400 ALPHA work station, with 32 Mby RAM, 1 Gby mass storage, 4 Gby streaming tape, CD-ROM is dedicated to AAPP processing, and to transfer of products to the data bank of NMC.

SDUS stations

4.9 Various types of SDUSs are operational at the peripheral offices of the Italian Meteorological Service, and at other sites needing satellite information. However, to complement the image data provided by the SDUSs an intranet network is used to broadcast satellite products, radar information, forecast maps, meteorological messages. This system supplies all I.M.S. products while commercial SW allows animation, false colours, zooming and hard printing of the images.

Remote terminals

4.10 The old system for the access through an analogue network to satellite images and products generated by the ANDROMEDA system will be replaced by a satellite broadcast. The new system, named National Unified Broadcast Integrated System (NUBIS), will allow the dissemination of all graphical and numerical production according to a predefined schedule. A server at NMC of Pratica di Mare retransmits, via satellite, the products to final users. All are equipped with a reception system (antenna and receiver) and a work station to display the received products.

MDD station

4.11 According to EUMETSAT programmes, the Rome uplink station has been operational during 1999-2000. The station is connected to the message switching system of Rome RTH and is transmitting routinely alphanumeric data. In spring 2001 the system will be relocated to the new seat of Pratica di Mare air base.

ERS-1 data distribution

4.12 Since May 1991 the Italian Meteorological Service is acting as a node for ERS-1 FD data distribution. ERS-1 data received from ESA/ESRIN are routinely transmitted to Bracknell and the ECMWF.

Operational products

4.13 The following operational products from processed satellite data are available:

- animation of METEOSAT images;
- remapping of METEOSAT images in stereographic projection and merging with analysis fields and sfloc messages;
- remapping of AVHRR images;
- Cloud Top Height from METEOSAT images, every half an hour;
- detected convective systems maps in Mediterranean area;
- TOVS retrieved profiles;
- integrated WV and IR maps every 3 hours, to distinguish the clear area (WV) from cloudy zones (IR);
- daily SST maps;
- top temperature of cloudy area at synoptic time for assimilation into the operational local area model.

Other applications

(a) from METEOSAT:

- monthly mean of total cloud cover, in percent, every three hours, plus daily total average;
- daily soil thermal excursion, every ten days;

- albedo, every ten days;
- apparent Thermal Inertia, every ten days.

(b) from NOAA:

- Normalized vegetation Index, every ten days;

Archiving

4.14 Satellite data are archived at NMC according to the following strategy:

(a) METEOSAT data:

- 20 days archive on line: BV, BI AND BW formats every 30 minutes;
- 4 days on line of AI, AV , AW formats every 1 hour;
- 3 months on line of VIS, IR and WV Europe images every 3 hours;
- permanent archive: window over Europe in VIS, IR and WV every 30 minutes;
- everything during selected periods.

(b) NOAA data:

- all TIP data, selected area of HRPT and images of AVHRR permanently.

All data are available on EXABYTE, DAT, Floppy Disks, Slides and Prints.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

Systems

5.1 Short-term development of the ANDROMEDA system at NMC will include:

- the back up of front-end computers of HRPT;
- improving of the archiving facilities with the inclusion of optical disc units;
- improving of the system for satellite data dissemination with a satellite broadcast system;
- the preparation at MSG data;
- merging of satellite, radar data and typical observations.

5.2 The NUBIS system, described in § 4.10, will be implemented by end 2001.

Applications

5.3 The main items for development of new applications have been identified in the areas discussed further in this section.

ATOVS processing

5.4 The development of ATOVS processing is performed along the following lines:

- impact of data in the local area model in the Mediterranean area;
- use of ATOVS-derived products to nowcasting application;

- use of ATOVS-derived ozone maps for supporting synoptic applications.

Analysis of Air Masses

5.5 A continuous investigation between temperature profiles and absorption observations will be studied to define the patterns to sign air masses.

Multispectral analysis and cloud classification

5.6 A cloud classification from multispectral analysis of NOAA images will be operative to support the nowcasting.

Precipitation and convective clouds identification

5.7 A merging of satellite and radar data will be developed for the identification of heavy convective clouds. A subsequent linear evolution for nowcasting will be developed. The application of algorithms for determination of rainfall intensity and amount in an operative procedure will be investigated.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

The validation and performance verification of NEFODINA (see1.4) system and the impact of rapid scan images on NEFODINA is being studied.

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND SCIENTISTS IN CHARGE)

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7.2 Contacts

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JAPAN

(Japan Meteorological Agency (JMA))

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 Assimilation of NOAA-15 SATEM data was implemented in the operational NWP system in July 1999.

1.2 Assimilation of NESDIS-retrieved ATOVS/BUFR data from NOAA-15 was started in January 2000.

1.3 One-dimensional variational assimilation (1D-Var) of RTOVS radiances from NOAA-14 was introduced to the global analysis in March 2000.

1.4 High resolution TBB data from GMS-5 has been assimilated for preparation of initial conditions of mesoscale NWP since March 2000.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Development of a One-dimensional Variational Scheme of TOVS Radiance data

2.1 A one-dimensional variational (1D-Var) scheme to assimilate TOVS radiance data into the global NWP system was developed. Several improvements have been made in the bias correction scheme, specification of background error covariance and quality control procedures. Preliminary experiments using TOVS 1D-Var retrieved data showed neutral or positive impacts on the forecast score against that with NESDIS retrieved data. This scheme was introduced to the global analysis in March 2000.

Development of a Global Snow Depth Analysis System

2.2 A global snow depth analysis system with a two-dimensional optimum interpolation method was developed to provide an initial condition of snow depth for the global NWP system. The snow coverage distribution observed by GMS-5 and the land-surface parameters of soil and vegetation are used to mask snow void areas prior to the snow depth analysis. As the result of experiments in April 1999 using T63L30 version of global NWP model, it was recognized that the forecast score on temperature at lower atmosphere, especially over Eurasian Continent was better than the previous scheme using climatological snow depth distribution.

QuikSCAT/SeaWinds ocean surface wind data

2.3 An impact study of QuikSCAT/SeaWinds was performed with the global NWP system. The assimilation method is the same as that for the ERS-2 scatterometer used operationally at JMA, in which not only wind but sea level pressure retrieved from the wind field with in-situ pressure observations of ships and buoys are assimilated. Results showed large positive impact over the Southern Hemisphere and small positive impact over the Tropics and the ocean in the North Hemisphere.

Total Precipitable Water from the TMI data

2.4 JMA and NASDA performed an observation system experiment (OSE) of assimilating TMI total precipitable water (TPW) into the global NWP system. Using an analysis system based on three-dimensional optimum interpolation, the results revealed clear positive impacts on forecasted wind fields of 850hPa and 250hPa height over the Tropics and small positive impacts on temperature fields of the same levels and region. Improvements of the one-day forecasted rainfall over the tropical region were also recognized.

Total Precipitable Water derived from the GPS network over Japan

2.5 An impact of GPS-TPW on NWP is being investigated. The TPW is derived from atmospheric delay measured by the ground based GPS receivers operated by the Geographical Survey Institute of Japan (GSI). Three-hour averaged atmospheric zenith delay derived from precise orbit of GPS satellites, that is operational product of GSI and can be obtained about 10days later, are used in the experiment. Specific humidity of initial condition is adjusted to be consistent with TPW analyzed beforehand with two-dimensional optimum interpolation method. Two out of nine cases of the precipitation forecast over Japan with a mesoscale NWP model showed clear improvement, and remaining cases didn't seem to be worse. GPS data has been operationally decoded for NWP since November 1999.

Direct Assimilation of SSM/I TBs

2.6 A direct assimilation procedure using vertical 1D-VAR to incorporate vertically polarized brightness temperatures (TBs) and rain flag data (index of existence of precipitation) from the Special Sensor Microwave Imager (SSM/I) into a mesoscale NWP model was developed in the Meteorological Research Institute of JMA (Aonashi and Liu, 1999). To test the impact of assimilation on NWP forecasts, experiments were conducted assimilating TB data during the IOP period of Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment (TOGA COARE).

Inter-calibration between GMS-5 and NOAA-14

2.7 Inter-calibration of the infrared channels between GMS-5 VISSR and NOAA-14 AVHRR was carried out in MSC in 1998. The results showed that the GMS-5 VISSR temperature was about 1.2 K colder than the NOAA-14 AVHRR temperature and almost satisfied the value of within 1.0 K that was a goal of CGMS.

2.8 In 1999 and 2000, inter-calibration of the visible channels for both clear and cloudy conditions was performed. Albedos of GMS-5 and NOAA-14 AVHRR ch-1 have linear relationship with approximately 0.99 of correlation coefficient, and this is similar to that of inter-calibration of ISCCP calibration centre France.

Investigation on MTSAT window channels' potential for distinguishing volcanic ash clouds

2.9 GMS-5 infrared window channels [IR1 (10.5 – 11.5 microns) and IR2 (11.5 – 12.5 microns)] have been successfully used to distinguish volcanic ash clouds from ice/water clouds. The Brightness Temperature Difference of the two channels [BTD (IR1-IR2)] caused by each response functions is negative for volcanic ash clouds and positive for ice/water clouds.

2.10 The trial calculation of BTD using response function of MTSAT-1 imager was carried out. In this trial, BTD of quartz (volcanic ash) and ice cloud were calculated in various conditions such as cloud thickness/height and atmospheric temperature with response functions of MTSAT, GMS-5 and NOAA-14/AVHRR (the response function of MTSAT-1R is equivalent to that of

MTSAT.) The results indicate that the BTD is the greatest for MTSAT, lesser for NOAA-14/AVHRR, and the lowest with GMS-5 for every case. The larger capability of MTSAT-1R imager for distinguishing volcanic ash cloud is therefore expected.

An Estimation of the Accuracy of Sea Surface Temperature derived from MTSAT Imager by using the simulation data

2.11 An impact study of improved imager on MTSAT-1R to SST estimation is performed with a simulation data set derived from a radiation transfer model and NWP data of JMA. The investigation showed following results:

(i) improved response function of the sprit window channels reduced the root mean square error (RMS) of SST about 0.1K from that of GMS-5;

(ii) extension of brightness resolution (8bit to 10bit) reduced RMS about 0.5K:

(iii) RSM of SST derived from 3.7microns channel data was 0.16K less than that from 11 and 12 microns channel data.

2.12 Accuracy of cloud detection with the split window channel, which is used in SST estimation algorithm, is also expected to be improved because of the characteristic of the response function.

Renewal of the cloud amount normal

2.13 For the climate monitoring, MSC has produced anomaly contour maps of high cloud amount with 5-day mean, monthly mean and past three months mean since July 1988. In 2000, the cloud amount normal was recalculated using 14 years data (from 1987 to 2000). The new normal is calculated not only over the sea but also over the land which was not included in the former normal, and coverage area is extended from 50N-50S, 90E-170W to 60N-60S, 80E-160W. The new normal has used for producing anomaly contour maps of high cloud amount since January 2001.

Investigation on direct assimilation of TBB brightness temperature by GMS-5

2.14 As a preparation to introduce a direct assimilation of brightness temperature into the global NWP system, MSC has improved the calculation scheme of brightness temperature from GSM data based on RRTOV and investigated its accuracy and the cause of error. The investigation so far showed that the spatial distribution of simulated TBB match the observation well but is larger than observed TBB except over land.

Calibration method for emergency case when calibration shutter data are not available

2.15 For in-flight calibration of GMS-5 infrared (IR) channels, calibration shutter data are used as a reference of higher temperature. However, GMS-5 is now being operated beyond its design life, and probability of shutter trouble that cause the missing of calibration shutter data is increasing. Hence an alternative calibration method without calibration shutter data has been developed.

2.16 In this method the calibration shutter radiance is estimated using effective shutter temperature calculated from shutter temperature and VISSR inner temperature such as scanning mirror temperature and primary mirror temperature. In addition to the effective shutter temperature, IR detector temperature control voltage is used to reduce the effect of IR detector's temperature change during eclipse period.

2.17 The estimation of calibration shutter radiance temperature by this method has good accuracy of within 1 digital count of RMS in comparison with current method. A trend was found with this new method that Mean Error of estimated shutter radiance slightly increases on each channel year after year. The method was introduced in the data processing system as a back up in 2000.

Development of ATOVS products

2.18 MSC has been producing images to analyze sea ice distribution using Advanced Microwave Sounding Unit-B (AMSU-B) 89GHz channel data of NOAA-15 satellite since March 2000. Some other products using AMSU data, such as vertical temperature, total precipitable water, cloud liquid water and intensity of precipitation are also being developed.

Development of Satellite Cloud Grid Information Data (SCGID)

2.19 MSC started to disseminate SCGID to meteorological offices in Japan in March 2000. SCGID is a set of grid data derived from GMS-5 image data and consists of five elements i.e., total cloud amount, upper level cloud amount, convective cloud amount, cloud top height and cloud type. The interval of the grid is 0.25 deg. (EW) and 0.20 deg. (NS). This product strongly supports operational weather forecasting at meteorological offices.

Derivation of the aerosol optical thickness from GMS-5 visible data

2.20 MSC has been developing an algorithm for aerosol optical thickness derivation from visible data of GMS-5 in cooperation with Meteorological Research Institute (MRI) of JMA since April 2000. It is derived from looking up tables, which are calculated beforehand with a radiation transfer model. Based on the tests calculating on real cases such as yellow sand phenomenon, the algorithm is expected to be just about reasonable.

Application of TOPEX/POSEIDON altimetry data into the operational ocean data assimilation systems in JMA

2.21 JMA is operating global and regional ocean data assimilation systems to monitor oceanic conditions of the North Pacific and to monitor and predict El Niño/La Niña. Currently, sea surface heights (SSHs) observed by the TOPEX/POSEIDON are used after converting them into temperatures by the correlation method in the regional assimilation system. Global ocean assimilation of SSH data based on a three-dimensional variational method is under development.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Improvement of CAL Systems

3.1 A Computer Aided Learning system of MSC (MSC-CAL) has been developed to provide an environment for effective training in the field of satellite imagery applications. It is used in the training of nephanalysis and typhoon intensity analysis. MSC-CAL comprises various functions; overlaying imagery with meteorological data such as radar and NWP data, making a cross section, measuring on the images, so that the users can examine the data from various perspectives. It contributes greatly to the improvement of trainees' understanding and to simplifying trainers' preparation.

3.2 Besides training, MSC-CAL is also used as an image viewer on electronic publications. Since 1996, “The Monthly Reports of MSC” has been issued on a CD-ROM and its contents were enriched. It has become more useful and easy to handle. Since 1998, the "Nephanalysis Case Study Reports CD-ROM" has been issued annually as the self-learning material about noticeable weather phenomena for meteorologists in domestic weather stations. It includes explanation or interpretation of satellite imagery, as well as meteorological data such as weather charts or NWP data. In 2000, a special edition of case study reports CD-ROM for aviation meteorology was published. As an appendix of "Annual Report on Activities of the RSMC Tokyo-Typhoon Center", the database CD-ROM has been attached to the report from the 1999's, which includes satellite images of typhoons and all the contents of the report.

3.3 In addition to the satellite imagery, meteorological observation data and NWP products are to be disseminated by Low Rate Information Transmission (LRIT) when MTSAT-1R, the successor to GMS series, is in operation. The LRIT data browser based on MSC-CAL has already been developed, and will be provided to national meteorological services that intend to use LRIT.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

Use of satellite data for numerical weather prediction

4.1 In December 2000, the JMA operational NWP system made use of following satellite products:

- SATEM,
- TOVS,
- ATOVS,
- SATOB,
- VISSR digital cloud data from the Geostationary Meteorological Satellite (GMS),
- Surface wind data and surface pressure data by Scatterometer on ERS2,
- Visible cloud motion wind of (since August 1999).

4.2 JMA has been using SATEM thickness since March 1982 and TOVS thickness since March 1993 for NWP. The NOAA-15 SATEM data has been used since July 1999, and the NOAA-15 ATOVS reports since January 2000. Temperature profile derived from TOVS TBB data by 1D-Var scheme has been used since March 2000.

4.3 GMS moisture bogus has been operationally used for NWP since June 1986. VISSR digital cloud data from GMS are combined with ship or surface observations, and they are used as proxy data to generate vertical moisture profile for NWP.

4.4 ERS-2 scatterometer data has been assimilated as sea surface wind and pressure since July 1998 for global NWP. Assimilation of surface wind data and sea surface pressure data from the QuikSCAT/SeaWinds data will be started in the middle of 2001.

4.5 JMA started a snow depth analysis for the global NWP system in March 2000. Snow depth data at 1 x 1 degree lat.-lon. grids is derived from SYNOP snow depth data observed in past one day. GMS snow coverage data provided by MSC is used to mask snow void area prior to the snow depth analysis.

4.6 Since March 2000, hourly high resolution TBB data from GMS-5 has been used to give upper limit of diabatic heating in physical initialization for mesoscale NWP model which is pre-operational phase.

4.7 Since December 2000, JMA has performed a series of telecommunication tests to obtain SSM/I data of DMSP-13 and 14 from WMC Washington through GTS using FTP.

Analysis of sea ice conditions in the Sea of Okhotsk

4.8 JMA uses visible images of GMS, visible and infrared images of NOAA and SSM/I of DMSP to analyze sea ice conditions in the Sea of Okhotsk. JMA issues analysis charts of sea ice in the Sea of Okhotsk twice a week. The analyzed sea ice data are also used for initial conditions of numerical sea ice prediction model, and sea ice prognosis charts are issued twice a week. The analyzed sea ice data are also utilized for monitoring climate change, especially associated with global warming.

Analysis of global sea surface height anomaly using TOPEX/POSEIDON altimeter data

4.9 JMA analyzes global sea surface height anomaly using TOPEX/POSEIDON altimeter data. A space-time optimum interpolation scheme is applied for the analysis, in which decorrelation scales representing anomaly propagation are used. The mapping method gives smaller analysis error than previous method and it is adopted in the JMA's operational ocean data assimilation systems. The procedures are proposed in Kuragano and Kamachi (2000).

Application of data by ERS-2 and TOPEX/POSEIDON for analysis of ocean waves

4.10 For the daily analysis of ocean waves in the western North Pacific, JMA uses wave height, two dimensional wave spectrum and sea surface wind data with Radar Altimeter, the Synthetic Aperture Radar and the Wind Scatterometer of ERS-2 within six hours of the analysis time (00, 12UTC). Wave height data with Radar Altimeter of TOPEX/POSEIDON within six hours of the analysis time, which can be obtained 7-10 days after the observation, are used for the reanalysis of ocean waves.

Monitoring of global and North Pacific oceanic conditions by using TOPEX/POSEIDON altimeter data

4.11 JMA uses TOPEX/POSEIDON altimetry data to produce sea surface height(SSH) maps every 5 days with 2 degree grid for the global and 0.25 degree grid for the Pacific ocean by an space-time optimum interpolation on an operational basis. The temperature and salinity distribution in the North Pacific derived from SSH maps are combined with in-situ observations and used in the ocean data assimilation model. The results are used to monitor El Niño/La Niña and/or oceanic conditions of North Pacific.

Daily sea surface temperature monitoring in seas around Japan using NOAA/AVHRR data

4.12 MSC produces grid point data of sea surface temperature (SST) on 0.25 x 0.25-degree from the NOAA/AVHRR data using the Multi-Channel SST (MCSST) retrieval algorithm developed by NOAA/NESDIS. JMA produces a daily SST map in the vicinity of Japan using the grid point SST data and in situ observations.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

Highly developed application of satellite data

5. JMA is developing an assimilation system of satellite data (wave height, two dimensional wave spectrum and sea surface wind data) from ERS-2 and TOPEX/POSEIDON into the operational wave models and the analysis of ocean waves.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

Validation of sea surface temperature derived from GMS-5 imagery

6.1 Sea surface temperature (SST) has been routinely derived from GMS data by Multi-Channel Sea Surface Temperature (MCSST) retrieval algorithm. Several improvements were made in this algorithm, especially in the process of cloud screening and quality check in August 1997. A validation of SST was carried out using buoy data from 1998 to 1999 (105,612 match up data).

6.2 The validation showed that the SST has latitudinal characteristics of differences from buoy measurements, and the cloud screening technique with only infrared data is not sufficient during night-time. In the tropical region, differences from buoy data caused by large amount of water vapour over the sea are recognized. A non-linear sea surface temperature (NLSST) method, which is temperature-dependent algorithm, was found to be effective to correct these differences. A new cloud screening technique using 3.7-micron imager data to be available on MTSAT-1R is also being developed.

Accuracy of MSC's solar irradiance estimation over Australian region

6.3 MSC has been operationally performing hourly solar irradiance estimation at the earth's surface with GMS-5 visible data since March 1995. The accuracy of this product is evaluated for Australian region using surface observation data from April to November 1998. The results show that hourly correlation coefficients of this product over Australian region are almost the same as that of over Japan, but root mean square error and mean bias error are quite large over the Australian region. These larger errors are likely to be caused by applying only one climatological coefficient representing the condition of Japan to the calculation of whole area. Improvements are now being carried out.

Assimilation of SATEM and ATOVS reports by NOAA-15 satellite

6.4 Observing system experiments (OSEs) have been conducted to reveal the impact of NOAA-15 data with experimental global NWP system of a reduced resolution of T63L30. Since the operational objective analysis scheme of JMA is a three-dimensional optimum interpolation method, the geopotential height data converted from the thickness retrieved by NESDIS are assimilated. The OSEs of SATEM data in May 1999 were conducted. It was found that the variance of the observation departure from the first guess in cloudy area is lager than that of clear-sounding. Therefore, OSEs were designed to use only the clear-sounding data. A large positive impact of the forecast scores is found mainly in the Southern Hemisphere.

6.5 The OSEs of ATOVS data in September 1999 were conducted. A large improvement in the forecast score over the Southern Hemisphere was obtained. However, the score of humidity forecast was worse in the lower troposphere. Further investigation on the way to assimilate humidity data is needed.

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KENYA

(Kenya Meteorological Department)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

- METEOSAT data used for weather analysis and rainfall forecasting;
- The HRPT data used for vegetation monitoring;
- Utilization of Sea Surface Temperatures (SST) and Outgoing Long-wave Radiation (OLR);
- Calibration and Validation of rainfall Estimates;
- The utilization of satellite rainfall estimate data for early warning purposes and its application in Water Resources management in the country.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Rainfall Estimation (RFE)

2.1 METEOSAT satellite imagery either as single pictures (all three channels and multi-channel composite) or animated sequences is used operationally in combination with synoptic data to produce daily forecasts.

2.2 The Kenya Meteorological Department and the sister Department of Meteorology at the University of Nairobi, have made various attempts to develop relationships between rainfall and satellite data that can be used to estimate rainfall. The satellite data used included the Cold Cloud Duration and satellite-derived outgoing long-wave radiation (OLR). Useful relationships have been observed between rainfall and CCD at – 50°C threshold. The correlation coefficients ranged between 0.52 and 0.56. Significant relationships between OLR and seasonal rainfall have been observed for the period, Mach-May, June-August and September-November over East Africa. The largest correlation observed with point and areal rainfall were 0.88 and 0.97 respectively.

Hydrological Application

2.3 The Department Researcher have been carrying out rainfall-runoff modelling using satellite data. For example, the TAMSAT method of rainfall estimation has been applied on the Nyando catchment in Kenya with the aim of producing quantitative precipitation estimates for the purpose of predicting events of short and medium duration. A conceptual rainfall-runoff model (PITMAN) was selected and calibrated. It was found that over 70 per cent of areal rainfall for each year tested could be accounted for by estimates with the TAMSAT method. Flow simulation using satellite rainfall with the two-year satellite data set for 1993/94 , shows the potential of the TAMSAT rainfall estimates in hydrological modelling of the Nyando catchment. For example, the observed peak flow for 1993 is 33 m^3/s, whereas the simulated peak flow when satellite rainfall estimate3s are used as input is 30 m^3/s (Figures 1.1 and 1.2).

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3.1 The products of the NOAA HRPT , and METEOSAT PDUS are very helpful to forecasters in their regular weather forecast and assessment over the country. The Department has been producing seasonal forecasts through regression equations between rainfall data and Sea Surface Temperatures (SST) and Outgoing Long-wave Radiation (OLR).

3.2 The products produced by the Department through the Nairobi Drought Monitoring Centre and disseminated to users include:

(i) Ten-day rainfall distributions, drought severity, agrometeorological conditions, general impact and weather outlook;

(ii) Monthly and seasonal climatological summaries, drought severity, dominant synoptic systems, weather outlook and socio-economic conditions and their impact.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

High Resolution Picture Transmission (HRPT) and Primary Data User Stations (PDUSs) in Kenya

4.1 This is a résumé of the current status of the satellite ground receiving equipment within the Kenya Meteorological Department (KMD) and various aspects on applications of satellite technology in meteorology and hydrology, as an aid to weather analysis, forecasting, drought and environmental monitoring for Kenya and Africa in general.

Current status

4.2 The PDUS facility is currently capable of receiving and processing data on all the available channels from METEOSAT. The Department has installed a new HRPT as a replacement to the old one, which has been in operation for more than ten years.

PDUS

4.3 The Primary Data User Station (PDUS) was installed at KMD in 1990 and has been in operation since then. The station receives full imagery from the METEOSAT satellite on a half-hourly basis in Infrared (IR) and Visible (VIS) channels. The new PC-based station has the following capabilities:

- Displaying images in real-time,
- Image enhancement by false colouring,
- Panning and scrolling,
- Zooming,
- Storing 24 hour images,
- Animation.

4.4 The images received are particularly useful in aiding analysis of conventional data, especially in detecting the position of the Inter-Tropical Convergence Zone (ITCZ), and frontal systems together with Cyclone.

Local Area Network (LAN)

4.5 The HRPT and PDUS stations are currently linked to the Drought Monitoring Centre (DMC), Department of Resource Survey and Remote Sensing (DRSRS) and the Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS) on an Ethernet Local Area Network (LAN). This has ensured rapid transfer of real-time data to the sister departments.

Application of PDUS

4.6 The METEOSAT images are useful in operational forecasting, rainfall estimation and as a database for future research work.

4.7 A lot of scientific research work is presently being undertaken by both the Department’s personnel and other end users (mainly from the remote sensing centres within the country. International organizations and university students) using the NOAA/AVHRR data and its derived products.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5.1 On acquiring the new HRPT, the Department anticipates to benefit greatly from the expected improved data reception. This will be very useful in many applications, viz,

- Drought monitoring has become a major priority for most African countries and, therefore, the station will provide deKedal (10 days) vegetation index images (NDVI) for use by the Drought Monitoring Centre (DMCN) in Nairobi;

- The Department will be in a position to process the TOVS data which is very useful in forecasting.

5.2 A satellite rainfall estimation training workshop for Easter, Central and Southern Africa was held at the Drought Monitoring Centre, Nairobi (DMCN) Kenya from 19 to 24 February 2001, where the participants received practical hands-on experience in the running of two principal methodologies of estimating rainfall from satellite-derived data. The two methodologies were the CPC and TAMSAT methods. The Department has embarked upon a programme to calibrate and validate the satellite rainfall estimation techniques and has proposed a workshop to address applications of satellite rainfall estimates in both Agriculture and Hydrology to be held as soon as the validation and calibration of the techniques are complete. DMCN is to design a project proposal for the procurement and installation of the relevant computer hardware and software to facilitate the calibration and validation exercise.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6. Validation of RFE methods has not been done on a national level, hence the technique(s) is/are not operational. However, RFE methods have been used in the research mode. From the recent satellite rainfall estimation training workshop held in the DMCN it is hoped that the Department will carry out calibration and validation in order to make the method(s) operational.

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND SCIENTISTS IN CHARGE)

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Mwangi Meteorologist, National Meteorological Centre, Nairobi

Gitonga, I. Meteorologist in charge of PDUS/HRPT

KOREA, REPUBLIC OF

(Korea Meteorological Administration)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

Acquisition of Meteosat-5 WEFAX data

1.1 The Korea Meteorological Administration (KMA) began to receive infrared image data from Meteosat-5 located at 63E, in WEFAX format from April 2000 which extended satellite coverage up to the European Continent. By combining with the GMS-5 data, about a half of entire earth is monitored every hour. The extension of coverage enables us to monitor the development of weather system occurring further west and thus in early stage.

Installation of Receiving System for DB Terra/MODIS data

1.2 KMA set up MODIS ground receiving system in January 2001 for real time acquisition of MODIS data from Terra launched by NASA in 1999. The American company, SeaSpace, manufactured the ground receiving system. KMA at present generates high-resolution geo-located MODIS image data twice a day by using the IMAPP (International MODIS/ASTER Processing Package). The imageries are distributed to local weather forecasting office in real time through the Intranet system. The MODIS data is very useful to detect small-scale cloud area, dust storm area and snow cover and to derived other parameters for weather applications.

The Utilization of Quikscat data

1.3 KMA acquires ocean wind vector analysis data which is generated from Quikscat data and opened to public. We acquire the data by through a ftp site at NASA. As the analysis data is available about 6 hours later from the satellite observation, the real time utilization of the data are limited. However, the wind vectors are extremely useful for the analysis of the status of ocean surface, such as storm area and identification of the front and cyclonic system over the ocean. It also has widely been used for the research purpose, such as the estimation of heat flux over the ocean, prediction of wind surge by using of a mesoscale atmospheric model, and so on.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Development of Sea fog/stratus detection algorithm using GMS-5

2.1 For a continuous monitoring of sea fog/stratus, KMA has developed a new algorithm which uses the GMS-5 infrared data to discriminate low lying fog/stratus from high cloud or clear sky. The performance of the new algorithm depends highly on the generation of an accurate background clear sky map which is accomplished by adopting spatial-temporal uniformity methods. Although the algorithm generate some false alarms, it has been used for the real time continuous monitoring of sea fog in conjunction with more accurate information such as from the polar orbiting NOAA satellite or from the in-situ observations.

Development of Regional Sea Surface Temperature Retrieval

2.2 To obtain high resolution sea surface temperature (SST) from the GMS-5, KMA has derived a new multi-channel SST coefficient apt for the east Asia region. The so-called regional coefficients have less root mean square error than the global coefficients and better coverage than the data derived from the polar orbiting satellite. A weekly composite map is derived routinely and has been used for public distribution and for the initial boundary conditions for a high-resolution numerical prediction model.

Derivation of hourly rain rate from GMS-5

2.3 By using a regression method, an hourly rain rate is derived from the GMS-5 IR data only. For the independent variable of the regression, we use the rainfall amount obtained from the Automatic Weather Station scattered around the Korean Peninsula. To improve the performance of the rain rate estimation, we tested hourly rainfall estimation made by the Japan Radar network, which is delivered from Japan Meteorological Agency to KMA in real time. A preliminary result shows more stable production of rain rate and better statistics than the case when AWS measured rainfall is used.

Development of Objective Parameters to determine the Tropical Cyclone centre position from TRMM/TMI

2.4 Using the differential response of the intensity and polarization characteristics between TC centre and surrounding area, two objective parameters, normalized intensity difference between 37 and 85 GHz and differential polarization in 37 GHz of TRMM Microwave Imager, has been derived. The two parameters are especially helpful when the clouds cover the TC centre. Comparison with the best tracks reported by the operational tropical warning centre shows a good agreement.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Detection of dust storm by using split window infrared data

3. KMA developed the technique for detection of dust storm by using split window infrared data of GMS and NOAA. The hourly product from the GMS-5 data is especially useful for the monitoring of the occurrence and movement of dust storm, although the accuracy is less than the NOAA. To compensate lesser accuracy, the report from surface observation of the desert area of northern part of China is used together. The satellite-derived product of the dust storm area makes a great roll on the forecast of the dust storm phenomena over the Korean Peninsular. By comparison with the concentration of total suspended particle observed at western coastal area of Korea, dust storm area identified by using satellite data give good guidance for the analysis of dust storm track.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

Routinely generated satellite-derived product of KMA

4. KMA acquires data from geostationary satellites GMS-5 and Meteosat-5, and polar orbiting satellites NOAA, FY-1C, MODIS in real time. Other satellite data are obtained a few hours to days later the data is received either through ftp, GTS, or tape. Table 1 shows the major products from the real time acquisition of the satellite data at ground stations of KMA. All of the satellite-derived products are distributed to all organization of KMA, while many parts of the products are distributed to public in real time by through the web-page or anonymous ftp.

Table1

Satellite-derived products of KMA

Satellite	Type	Product Name	Area	Cycle
GMS-5	Image	Infrared Visible Composite Enhanced Water Vapour	Korea East Asia Earth disk	1h
	Products	Cloud Top Temperature Cloud Top Height Cloud Top Pressure Rain Rate Dust Storm Area Sea Fog Cloud Height for Local Air Route	East Asia	1h
		Water Vapour Drift Wind Cloud Motion Vector	East Asia Earth disk	1h
		Cloud Type Classification	East Asia	6h
		Outgoing Long-wave Radiation	80E-160W	6h
		Sea Surface Temperature	80E-160W	6h
Meteosat-5	Image	Infrared	10E-160W	1h
NOAA	Image	Infrared Visible Composite Enhanced	Korea East Asia Earth disk	6h
	Products	TOVS(GPH/Temp, Wind) Dust Storm Area Fog/Low Level Cloud Sea Surface Temperature	East Asia	6h
FY-1C	Image	Infrared Visible Composite Enhanced	Korea East Asia Earth disk	12h
	Products	Fog/Low Level Cloud	East Asia	12h
TERRA	**Image**	Composite	East Asia	12h

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

Generation of Atmospheric Parameters from MODIS data

5.1 KMA lays emphasis on the generation of quantitative products from MODIS level 2 such as atmospheric sounding, sea surface temperature, and aerosol concentration distribution and so on.

Acquisition of data from Aqua satellite

5.2 KMA has a plan to receive data from Aqua which will be launched in 2001. It is expected to generate atmospheric parameters from microwave sensor AMSR such as rain rate and wind over ocean in real time.

Upgrade of SDUS for LRIT receiving

5.3 KMA operates several SDUS systems at local weather offices and has a plan to modify those SDUS systems to get the extended information, which will be provided by MTSAT-1R, such as GPV, and typhoon analysis information.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

Validation of GMS-5 derived SST

6. The SST derived from the GMS-5 has been validated by comparison with the collocated buoy data. For 1999, the bias is about 0.1°C with the RMSE of 1.1°C for the regional algorithm.

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND SCIENTISTS IN CHARGE)

7. Names of Scientists in charge

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MADAGASCAR

(Direction de la météorologie et de l'hydrologie)

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4.1 The Meteorology and Hydrology Directorate has an MDD station for domestic and international data reception (Mascarene Islands, Austral Islands, Réunion, Mauritius, Pretoria, etc.).

4.2 This also provides products for numeric forecasting from the major forecasting centres: Bracknell, Météo-France, European Centre. These products are used to draw up weather forecasts for ranges up to 72 hours for Malagasy territory. This station, which was not Y2K compatible, was replaced by the British Government with new equipment, thanks for the Voluntary Cooperation Programme (VCP).

4.3 The Directorate also has a PDUS which makes it possible to receive images from Meteosat-7 every 30 minutes and from Meteosat-5 every three hours. These satellite images, in disk and segment format allows us to analyse the situation in order to draw up a weather forecast for the national territory, as well as to analyse and follow tropical cyclones.

4.4 The HRPT station, makes it possible to receive images from NOAA-12 and NOAA-14 satellites every 12 hours. These images give additional details for the analysis, follow-up, monitoring and forecasting of tropical cyclones.

4.5 In conclusion, the data obtained by satellites and corresponding products are very useful to us. For future years we request equipment to allow for the reception of images from second generation Meteosat satellites to improve our forecasts.

PAKISTAN

(Pakistan Meteorological Department)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1. This report summarizes the satellite applications in the functional area of transmission of satellite data. HRPT equipment established at Quetta is receiving pictures from polar orbiting satellites NOAA-12, -14 and -16 by using two line elements data. The latest pictures, which are received form these satellites, are updated on web site (met.gov.pk) of the Pakistan Meteorological Department (PMD).

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2. No major research work has yet been done. However, the utility of satellite data towards identification of weather systems and its use in tracking monsoon depressions and westerly waves was made by the PMD.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3. No significant work pertaining to this part has been done. However, PMD has been trying to improve its capabilities to make full use of satellite data in the field of meteorology and operational hydrology.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4. A new SADIS system for aviation forecasts has been installed at the Meteorological Office, Quaid-e-Azam International Airport, Karachi which receives the data transmitted by the satellite INTALSAT 604. Through this system PMD receives the aviation charts of two kinds – Grib and T4 charts – and all other related information twice in 24 hours.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5. The PMD intends to install SADIS also at other places.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6. Satellite data was verified using QPM Radar and Weather Charts and reasonably food correlation was found.

PART VII OTHER ITEMS (References, Publications and Scientists In Charge)

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(Institute of Meteorology and Water Management - Satellite Research Department)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

During last two years the main efforts in application of remote sensing in meteorology and hydrology were directed to the development of satellite products distribution in the Institute of Meteorology and Water Management (IMWM) internal network. Also, substantial progress in research projects using satellite information was carried out. Research activity concerned: cloud and rain rate investigation, ozone and UV radiation monitoring, determination of solar radiation at the ground level, atmosphere sounding, storm analysis. Many efforts were directed to the development of satellite data archiving. An important part of IMWM's activity is the preparation of new systems for reception and processing of future MSG and METOP satellite data. The project was started in year 2000.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2.1 The Satellite Research Department in the Krakow branch office of the Institute of Meteorology and Water Management has been receiving operational satellite information since 1967. Many various scientific projects were conducted here. Most of the projects concerned application of the satellite data in meteorology, hydrology, oceanography and agriculture. In the last two years the research activities concentrated on following projects:

(a) Operational reception and processing of METEOSAT and NOAA satellite data for hydrological and meteorological research project needs as well as weather service in IMWM;

(b) Development of the system for distribution of satellite products in IMWM computer network, putting into practice a new products;

(c) The construction of a database holding information about archived satellite data - design and software were finished, and the database was completely filled with records concerning geostationary satellite data in our archive, partially filled with polar orbiting satellite data records;

(d) Cloud classification and cloudiness degree determination from METEOSAT satellite data - the prepared method was tested by using SYNOP data and ground observation;

(e) The method and software for determination of rain rate by using AMSU/NOAA data was prepared and initial tests were carried out. The promising results were obtained in convective precipitation cases, poor results concerned stratiform precipitation cases;

(f) The methodology and software for satellite atmosphere sounding were finally tested. The intranet web page was prepared for distribution of such a products. They will become available for IMWM forecasters in first months of 2001;

(g) Application of new NOAA sensors (channel 1.6 μm) for fog and low stratus detection, snow and ice investigation;

(h) Analysis of solar radiation reaching the ground surface, by using METEOSAT data. The method and software were developed, the comparison of ground and satellite retrieved solar flux were done in the period October 1999-October 2000. The best results were obtained for total solar energy per day. The project is ongoing;

(i) Stratospheric Ozone monitoring over Central Europe;

(j) Determination and forecasting of UV-B radiation at the ground level. The method based on stratospheric ozone retrievals from satellite data was developed and tested. Operational forecasts will be distributed starting from spring 2001;

2.2 Early detection of storms and investigation of their severity - project including determination of possible convection occurrence by satellite-derived instability indices, early detection and monitoring of storm cells, nowcasting of storm trajectories. The project was started in 2000. The second form of our activity was close cooperation with EUMETSAT. In December 1999, the Cooperating Agreement between Poland and EUMETSAT was signed. During last two years the cooperation with EUMETSAT concerned not only training, seminars, workshops and conferences, but also participation in projects. The IMWM played a certain role in following projects:

- SATREP,
- HRUS/LRUS Procurement,
- MSG-CAL.

2.3 Our Institute is also involved in EUMETSAT SAF (Satellite Application Facility) activity. In 2000 we prepared together with the Hungarian Meteorological Service, Slovak Hydrological and Meteorological Institute and the Danish Hydraulic Institute the initiative of a new SAF for Hydrology. The proposed purpose of this new SAF covers different applications of meteorological satellite data to operational hydrology, flood protection, hydrological modelling. One specific benefit of a SAF consortium which includes Central/Eastern Europe countries is that, in Western Europe, traditionally, meteorological and hydrological institutes are separate and speak different languages. In Eastern countries, meteorological and hydrological services are fully integrated, therefore, the transfer of understanding within the hydrological modeling teams and satellite teams will be greatly facilitated.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

The main efforts in this field were directed to the development of satellite regional forecasting offices in Poland (6 offices of IMWM) have access to satellite information. The METEOSAT and NOAA images are automatically distributed to the users. The forecasters have the possibility to analyse and animate the images. Also, a number of available products is continuously increasing.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4.1 Since July 1997 a new satellite data receiving station for both Meteosat HRI and NOAA/HRPT operates in Krakow. The new receiving system consists of:

- METEOSAT receiving system (VCS): parabolic antenna ∅3m, LNA and down-converter, receiver, Meteosat Key Unit, pre-processor;

- NOAA receiving system (manufacturer Dundee Satellite Systems): parabolic antenna ∅1.8m, LNA and down-converter, receiver, bit & frame synchroniser, PC for antenna tracking;

- DEC AlphaStation computer for data reception, processing and system control;
- DEC AlphaStation computer for processing and visualisation of satellite images (Forecasting Office);
- PC network for processing and distribution of NOAA images using IMWM software;
- Laser Colour Printer.

4.2 During the period 1999-2000 METEOSAT receiving and processing system was used operationally without any technical problems. The NOAA receiving system was only partially used due to long lasting (repeating) failure of antenna control.

4.3 Our archive of HRPT/NOAA data registered in Krakow began in 1988. Until 1996 the 1/2 inch CCT were used as media. After installation of VCS receiving station CD-ROMs are used for archiving purposes. Also, Meteosat images are archived since 1997 for future investigations in the framework of different research projects

Registered satellite data are processed to different products:

- Calibrated and navigated (polar stereographic projection) Meteosat images for forecasters use;
- Baltic Sea surface temperature from AVHRR/NOAA;
- Total ozone content distribution over central Europe (isoline maps transmitted to Warsaw);
- NDVI distribution on the area of Poland, daily and 10 day compositions during vegetation season (not continuously);
- Baltic sea ice and snow cover in Poland (during winter in non cloudy situation).

4.4 Depending of scientific projects progress, some other products are occasionally available (cloud classification, rain rate estimation, soil thermal inertia, sea surface albedo, surface type classification etc.).

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5.1 The new project for hydrological and meteorological service modernisation was started in year 2000. In the frame of this project, modernisation of satellite receiving and processing equipment will be done in years 2001-2002. The new receiving station will be capable of receiving receive data from new Meteosat Second Generation (MSG) geostationary satellite.. Both HRIT and LRIT data will be received. The processing platform will be HP workstations with software for satellite data processing (AAPP and NWC SAF software). Also an existing HRPT/NOAA receiving station will be rebuilt to METOP specifications. The project concerns also data and products distribution among IMWM meteorological and hydrological services. The satellite products from MSG and polar orbiting satellites will be available for all forecasters in our service. Realisation of the project will start in the beginning of 2001. The products developed in the framework of existing research projects will be included.

5.2 The research projects which will be continued in nearest future are:

- Improvement of systems for reception, processing and distribution of satellite information in IMWM;

- The use of METEOSAT and NOAA information for precipitation detection and rain rate determination;
- Use of GIS systems in satellite meteorology;
- Application of new sensors of MSG and NOAA-K,L,M;
- Further investigation of stratospheric ozone - influence of clouds on ozone retrievals;
- Use of satellite information in agrometeorology.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

The satellite products validation is one of our permanent activity. Investigation of products quality and comparison with ground measurement and observations is not a trivial task. Our activities in this field in years 1999-2000 focused on cloud detection, cloudiness estimation, stratospheric ozone retrievals, solar radiation. The examples of results are presented below.

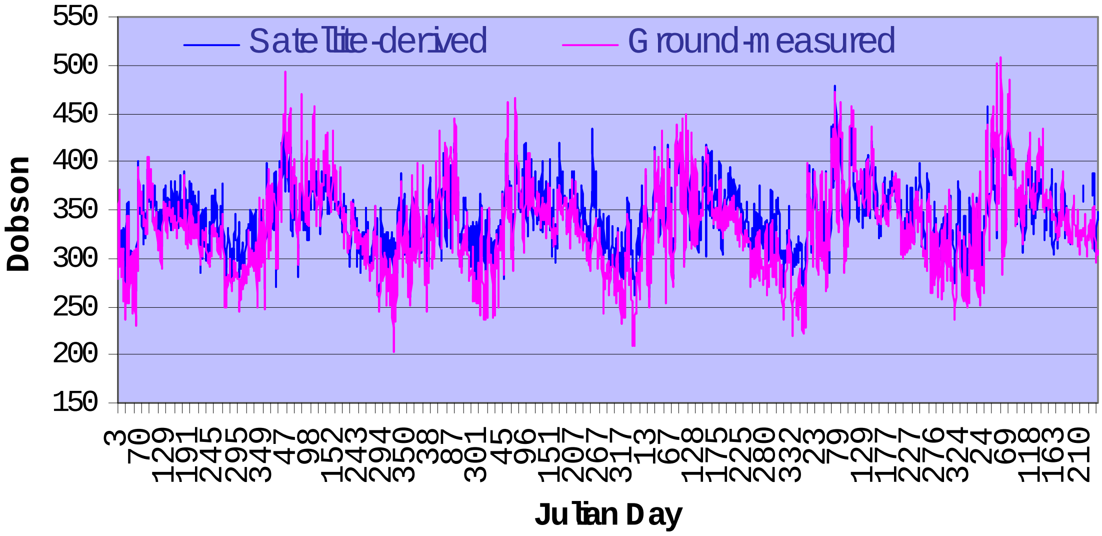

Figure 1 Total ozone amount derived form NOAA/TOVS satellite data and measured in Belsk from 1993 to 1999.

Table 1

The comparison total cloud amount from satellite data with conventional synoptic data (selected periods of 1999)

satellite SYNOP	0	1/8	2/8	3/8	4/8	5/8	6/8	7/8	8/8
0	11	1	2						
1/8	3	2	2						
2/8	4		1	1					
3/8				4	10			3	
4/8		1			3	12		1	
5/8						6		12	2
6/8			1	1	2		11	2	16
7/8						1		16	10
8/8							5	12	17

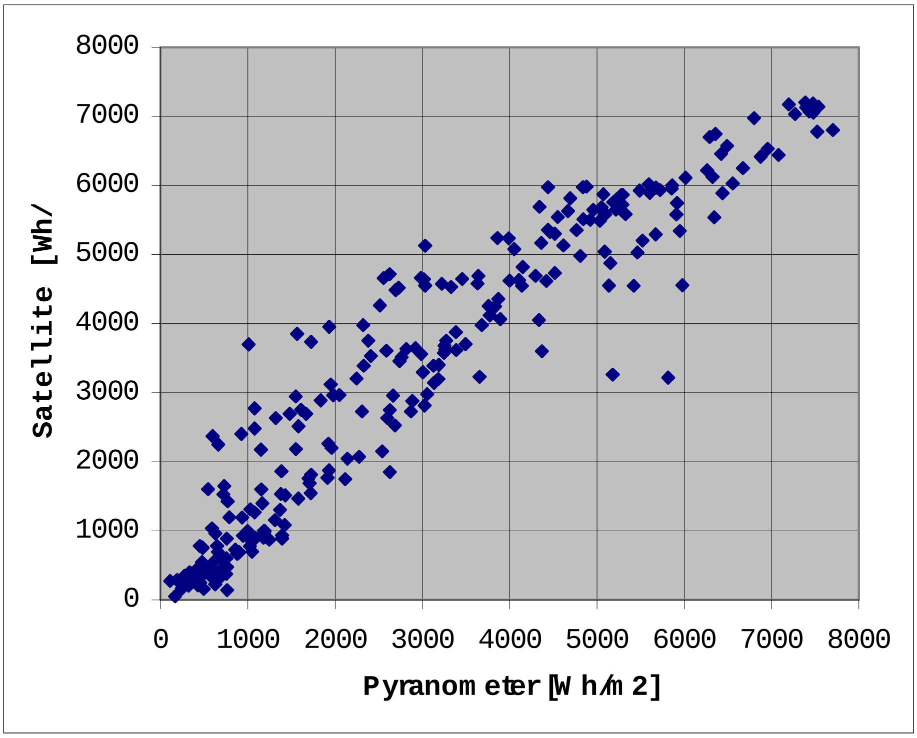

Figure 2 Comparison of daily solar energy reaching the ground measured by pyranometer and estimated from satellite data - period Nov.1999 - Oct. 2000.

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND SCIENTISTS IN CHARGE)

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SINGAPORE

(Meteorological Service)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

Research and development on applications of satellite data are focused on the following areas:

- Use of satellite data in weather analysis and forecasting and provision of severe weather warnings for shipping and aviation;
- Assimilation of satellite-derived data into numerical weather prediction models;
- Development of processing techniques for smoke haze, forest fires and associated hotspot monitoring in the Asean region;
- Developing techniques in rainfall estimation using satellite data.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

(1) Study on assimilation of ERS-1 scatterometer wind data into limited area NWP model;

(2) Refinement of techniques in the use of NOAA satellite data for regional forest fires and smoke haze detection and monitoring;

(3) Experimental use of NOAA satellite data for computation of vegetation index (NDVI);

(4) Development of techniques for rainfall estimation using satellite data.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Development of image processing techniques to use multi-channel data on NOAA-14 and -12 for monitoring hotspots from forest fires in the Asean Region.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

The system consists of 2 PC-based sub-systems, one for receiving and processing GMS-5 satellite data and the other for NOAA HRPT data.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

A new system for receiving and processing FY.2B data will be installed by June 2001.

Sub-systems for receiving FY-1C, Mutest-5 and MTSAT/LRIT data are expected to be implemented in 2002/2003.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

Currently not carried out.

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND SCIENTISTS IN CHARGE)

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SWEDEN

(Swedish Meteorological And Hydrological Institute (SMHI))

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1. SMHI is continuously strengthening the processing of satellite data in order to broaden its application in meteorology, hydrology and oceanography. Important areas are Nowcasting, NWP production and climate monitoring applications (cloud parameters). The development activities are to a high degree related to the new EUMETSAT programmes, MSG and EPS.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2.1 R&D efforts have for some years been dedicated mainly to EUMETSAT's Satellite Applications Facility (SAF) activities. SMHI is engaged in four different SAF's:

- SAF for Nowcasting and Short-range Forecasting (SAFNWC), where SMHI is developing the products Cloud Mask, Cloud Type, Cloud Top Temperature/Height and Precipitating Clouds based on the AVHRR/AMSU sensors and Precipitating Clouds based on MSG SERVI;
- SAF for Ocean Sea Ice (SAFOSI), where SMHI provides the Cloud Mask and Cloud Type;
- SAF for Climate Monitoring (SAFCLM) where SMHI participates in the development and verification of the cloud parameter products;
- SAF for Land Surface Analysis (SAFLSA) where SMHI will develop the Snow Cover and Snow Albedo based on AVHRR and SEVIRI;

2.2 Beside the SAF activities, there are also important oceanographic developments with a coupling to meteorological and climate applications such as:

- Generation of operation SAR routines for ice concentration;
- Within the EU project MAIA study the climate sensibility of sea ice in the Barents Sea;
- Further special investigations on SST from AVHRR data.

2.3 Furthermore, there are R&D activities related to assimilation (3-D Var and 4-D Var) of satellite data in the Numerical Weather Prediction models. This work is executed with national as well as international cooperation.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3.1 Users of the operationally received data are the meteorological, hydrological and oceanography services where satellite data are used in different ways for further processing and integration in the total process chain (NWP so-called objective automatic Mesoscale analyses in real-time and delayed mode, etc.).

3.2 Meteorological applications include visual interpretation of special satellite images by forecasters as well as by trained customers and the general public (TV, Newspapers, and Internet).

3.3 Oceanography applications include Sea Surface Temperature (SST) analysis, sea ice monitoring and detection of algae blooms.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4. SMHI has been receiving operational satellite data from METEOSAT and NOAA satellites for a long time. This is achieved by using the reception and processing systems of SMHI.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5. In cooperation with other Nordic NMSs, plans are underway for the procurement of a Meteosat Second Generation (MSG) receiving station. Other plans involve preparation for the operational phases of the SAFNWC and SAFOSI, as well as other SAF products.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6. As part of the activities during the planned 5-year operational phase of the EUMETSAT SAFNWC will be the extensive validation of the cloud products SMHI will have developed.

SWITZERLAND

(Météo-Suisse)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1. Regular reception and distribution of Meteosat and NOAA satellite imagery to internal and external users has continued. Meteosat imagery also continues to be used to check operational limited-area model cloud forecasts. Rapid-scanning image sequences from MAP are studied to distinguish between large-scale and convective precipitation.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2. Study of heavy precipitation events on the southern side of the Alps are underway, based on the rapid-scanning imagery of METEOSAT-6, sequences of 5-minute long scans centred over latitude of the Alps and recorded in autumn 1999 during the Mesoscale Alpine Programme (MAP). One central issue the study is the possible use of satellite imagery to discriminate between large-scale and convective precipitation.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3. A Primary Data User Station (PDUS) for the reception of Meteosat at 0 deg and a reception facility for High-Resolution Picture Transmission (HRPT) NOAA satellite data are installed at MeteoSwiss' main office in Zurich. The image data are suitably processed and formatted on the servers of the receiving stations and then disseminated to local file servers at the user sites over the Swiss-wide LAN/WAN of MeteoSwiss. Some 10 servers receive imagery. Geostationary image coverage extends to GOES-E/W, GMS, and Meteosat-5/IODC (all received via Meteosat at 0 deg).
Training of all forecasters towards a more objective image interpretation has taken place, with the assistance of EUMETSAT, ZAMG and KNMI.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4.1 At the regional forecasting offices the software package iX-SAT (by VCS, Bochum/Germany) running on SUN workstations is used to inspect single images and to animate image sequences. A scheduler and a specially written device driver allow for the printout of B/W copies in photographic quality (ALDEN9315CTP). Forecasters also have access to the imagery of "Satellite Report", a regular product by ZAMG, KNMI and FMI. Via Internet the forecasters also consult product prototypes extracted from METEOSAT data by EUMETSAT's Satellite Application Facility for Nowcasting and Very-Short-Range Forecasting (SAFNWC).

4.2 Meteosat VIS images of slot 24 are processed in order to estimate a cloud index for each grid-cell of the Local Model LM, the non-hydrostatic limited-area run operationally twice a day at 7km horizontal resolution for MeteoSwiss model, a joint development by the consortium COSMO (<www.cosmo.org>). This "observed" total cloud cover allows verification of the model forecasts and it may, eventually, be valuable for determining initial conditions of the model. The method has been adapted to LM from the pre-cursor model SM (Zelenka *et al.*, 1997).

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5. It is planned to further integrate satellite data in the environment of the meteorological workstations and access to Meteosat rapid-scanning data will be given to the forecasters. Preparation for a much-improved use of satellite data will be started, with a focus on applications based the enhanced data set from Meteosat Second Generation. In particular the software package from SAFNWC will be installed, and it is planned to enhance insight into the dynamics of the alpine weather. Through the use of the ATOVS Application Programme Package (AAPP - distributed by EUMETSAT) extraction of parameter fields useful to alpine meteorology will be tested as well.

PART VII OTHER ITEMS (references, publications and scientists in charge)

Zelenka A., Binder P., and Schubiger F., 1997. Total cloud cover derived from the Meteosat VIS channelé for monitoring the Swiss NWü model's performance. Proc. EUMETSAT 1997 Meteorological Satellite Data Users' Conference, brussels, belgium. EUMETSAT Publ. No. EUM P 21, Darmstadt, Germany, pp. 155-161.

UNITED KINGDOM

(Met Office (MO) and Centre for Ecology and Hydrology (CEH))

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 Major changes were made in the use of satellite data within the Met Office's operational global NWP system in 1999-2000, resulting in substantial improvements in forecast accuracy. In the year April 1999 to March 2000, the overall performance improved more than in any previous year, with the impact coming roughly equally from two innovations: the introduction of a new data assimilation system, 3D-Var, and the assimilation of ATOVS radiances. The impact of ATOVS data comes mainly through the increased amount of high-quality tropospheric temperature information that the AMSU-A instrument provides in cloudy areas. Whilst most improvement has come from the use of data over the oceans, the assimilation of tropospheric channels of AMSU-A over northern Asia has also led to measurable improvements, giving expectations of further improvements in future through more extensive use of ATOVS data over land.

1.2 Other advances in the use of satellite data in global NWP have included:

- improvements in the use of satellite winds, with positive impacts found from the assimilation of Meteosat-5 (Indian Ocean) winds and GMS water vapour winds;
- assimilation of surface wind speed retrieved from SSM/I data, with positive impact particularly in the southern hemisphere;
- improved analysis of sea ice through use of the NCEP sea-ice analysis, which is derived from SSM/I data.

1.3 In our mesoscale NWP model (UK area), the SST analysis has been improved through the use of SSTs retrieved from locally received AVHRR data.

1.4 The AMSU-B instrument provided by the Met Office was launched on the NOAA-16 satellite as part of the ATOVS set of temperature/humidity sounding instruments.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2.1 ATOVS data from NOAA-15 were first assimilated into the operational global NWP model in March 1999, following impact trials that demonstrated significant positive impact in both hemispheres. Between March and October 1999, ATOVS radiances were first processed to temperature/humidity profiles, using a 1D-var retrieval scheme, and then assimilated into the NWP model using the new 3D-var data assimilation system. In October 1999, a further change was made to assimilate TOVS (NOAA-14) and ATOVS (NOAA-15) radiances directly within the 3D-var system, with further substantial improvements in forecast skill, particularly in the southern hemisphere. In July 1999, the operational assimilation of AMSU radiances was extended over land, using tropospheric data in the region 30E-130E, 50N-70N. Pre-operational trials showed modest but consistent positive impacts. (S. English, R. Renshaw, A. Smith, C. Poulsen, MO)

2.2 The use of TOVS/ATOVS radiances has also been improved in new stratosphere-troposphere configuration of the 3D-var system, which was implemented operationally in November 2000. In this new system, the data are also assimilated as radiances, rather than as retrievals. One of the main aims of this work is to demonstrate the beneficial impact of additional stratospheric levels on the processing of the satellite radiances, with a view to extending the main global NWP model in this way. (R. Swinbank, P. Boorman, B. Ingleby, R. Renshaw, MO).

2.3 In addition to their important role in NWP, AMSU data are also being used in synoptic meteorology. New imagery products, showing areas of precipitation and high cloud liquid water content over the North Atlantic, have been developed using AMSU radiances. These images are now used operationally by forecasters. (D. Jones, MO)

2.4 SSM/I radiances are processed using a 1D-var scheme to retrieve simultaneously: water vapour profiles, sea surface wind speed and total column water vapour. The wind speed retrievals have been assimilated into the global NWP model since October 1999, following impact trials demonstrating positive impact of forecast skill, particularly in the southern hemisphere. (J. Ridley, MO)

2.5 Following the change to a 3D-var data assimilation system, trials have been conducted demonstrating improved assimilation of ERS-2 scatterometer data. "Ambiguous" wind pairs retrieved from scatterometer backscatter observations are assimilated directly, and the 3D-var system resolves the directional ambiguity. Impact trials in the global NWP model have confirmed the positive impact of these data. (B. Candy, MO)

2.6 In Spring 1999, new satellite wind types were assimilated into the global NWP model - winds from Meteosat-5 over the Indian Ocean, and water vapour winds from GMS – with positive impacts on forecast accuracy. (P. Butterworth, MO)

2.7 The global sea-ice analysis has been substantially improved through use of the new sea-ice product derived from SSM/I data by the NCEP in the USA. (C. Jones, MO)

2.8 The cloud analysis in the mesoscale NWP model (covering the UK and surrounding areas) was known to be deficient at times as a result of a poor SST analysis, leading to errors in detection of cloud in night-time satellite imagery. To address this problem, a system has been developed to provide high-resolution (5 km) retrievals of SST from locally-received AVHRR imagery. These data are now assimilated into the mesoscale SST analysis.
(B. Candy, A. O'Carroll, C. Jones, MO)

2.9 A new scheme has been developed to detect radiatively active clouds in AMSU-B radiances. It uses microwave radiances and NWP short-range forecast fields. Assimilation experiments have begun on AMSU-B radiances using this cloud detection method. (J. Hutchings, D. Jones, S. English, MO)

2.10 A scattering microwave radiative transfer model has been interfaced to fields from the operational mesoscale model and a research cloud-resolving model. This is being used to validate mesoscale large-scale cloud and precipitation fields and will be used as a test bed for ATOVS and SSM/I pre-processing schemes. (D. Jones, D. Wilson, P. Brown, MO)

2.11 A routine processing scheme has been established to estimate tropical convective rain rates from composites of geostationary satellite infra-red imagery. Trials have begun on the assimilation of these data in the global NWP model using a "latent heat nudging" technique.
(P. Butterworth, S. Pullen, MO)

2.12 Composite infra-red imagery is also being used to validate the cloud distribution and its variability in the global forecast model. Infra-red brightness temperatures are simulated using the Edwards-Slingo radiation code applied to 3 dimensional fields from the operational analyses every six hours. In this way we have already built up several months of data which is proving very useful for assessing the model's simulation of the global cloudiness distribution. (Ringer, MO)

2.13 A trial has been conducted assimilating high-density Meteosat winds into the mesoscale model in place of low-density 6-hourly data. Coverage after quality control was improved, including in the area of the Bay of Biscay, which is often important for short-range forecasts for the UK. Impact was small but positive. (P. Butterworth, R. Renshaw, MO)

2.14 Initial investigations have been carried out, using a radiative transfer model and AVHRR data, into the future detection of volcanic ash clouds using the infra-red channels of the SEVIRI instrument to be carried on MSG. The purpose of the work is to test the feasibility of automatic prompt detection of eruptions likely to present hazards to aviation. (S. Watkin, M. Ringer, A. Baran, MO)

2.15 Various investigations of the use of neural network pattern recognition techniques were completed. Topics included a probability-of-precipitation classifier based on Meteosat imagery, to help remove unwanted anomalous propagation echoes from rainfall radar imagery, and work on the potential for using Meteosat water vapour images to modify fields of potential vorticity in the global forecast model. (G. Pankiewicz, D. Harrison, C. Johnson, S.Swarbrick, MO)

2.16 Contributions have been made to research at NASA in which data from the "Arrival Time Difference" lightning detection system have been used along with precipitation estimates retrieved from microwave imagery in data assimilation experiments to investigate the impact on forecasts. (A. Lee, MO)

2.17 The scattering properties of cirrus clouds have been modelled using a range of techniques and validated against satellite and aircraft measurements. This has led to a new retrieval scheme for optical depth, ice water path, effective radius and cloud top height, derived from ATSR data. The improved scattering models are also being tested to improve physical parameterisations in the global climate model. (A. Baran, MO)

2.18 The MOTH project measured *in situ* humidity combined with upwelling microwave and infra-red radiances in tropical and cold air masses. These data are being used to validate the radiative transfer modelling of water vapour for use with data from current sounders, such as AMSU, and future sounders, such as IASI. (J. Taylor, MO)

2.19 Microwave measurements were made in flights over agricultural land in northern Germany as part of the "STAAARTE-D" EU Framework IV funded programme in collaboration with the University of Bonn and Free University Berlin. The data will be used to validate land surface emissivity models. (T. Hewison, MO)

2.20 The EUMETSAT Satellite Applications Facility (SAF) for NWP was launched in February 1999. This SAF is led by the Met Office in partnership with ECMWF, Météo-France and KNMI. Its aim is to improve the exploitation of satellite data within European NWP systems by improving the interfaces between them. This will be achieved mainly through the provision of new and improved satellite data processing packages and "observation operators" for data assimilation systems. (B. Conway, MO)

2.21 A new version of the ATOVS and AVHRR Processing Package (AAPP) was completed and integrated with contributions from NWP SAF partners. Version 2.0 of the package was released in February 2000 and has now been distributed internationally by EUMETSAT. It is in routine use at the Met Office for processing of ATOVS radiances from NOAA-15 and NOAA-16. (K. Whyte, S. English MO)

2.22 A portable, modular version of the 1D-Var retrieval scheme for SSM/I data (see 2.4) was developed and tested, prior to release in September 2000 as a deliverable of the NWP SAF. (J. Ridley, MO)

2.23 Also as part of NWP SAF activities, the general-purpose fast radiative transfer model, RTTOV, has been further developed. At the Met Office, RTTOV is used for operational processing and assimilation of TOVS and ATOVS radiances. Modules were developed for the version

RTTOV-5, which is available from ECMWF. RTTOV-6 has been developed and released to the international user community. This version includes fast sea surface emissivity models for both infra-red and microwave channels. Instruments currently supported include: TOVS, ATOVS, AVHRR, SSM/I, Meteosat, and GOES Imager and Sounder. A copy can be obtained on request. Contact details can be found at
www.metoffice.com/sec5/NWP/NWPSAF/rtm
(R Saunders, P Rayer, V. Sherlock, S English, MO)

2.24 Wave energy spectra are retrieved globally from fast-delivery Synthetic Aperture Radar (SAR) from ERS-2, using an iterative scheme developed at MPI Hamburg, taking first guess spectra from the Met Office global wave model. (J. Gunson, MO)

2.25 The programme to supply four AMSU-B flight models (FM) continues. FM-1 and FM-2 are both now operational on NOAA-15 and NOAA-16. FM-3 is installed on NOAA-M and is expected to undergo pre-launch testing soon. Funded by NASA, the Engineering Model is being upgraded to flight status to support the programme. (A. Kirkman, MO)

2.26 The second flight model of the AMSU-B humidity sounder instrument incorporates the Met Office modifications required to reduce instrument biases caused by radio frequency interference from spacecraft transmitters. Analysis of data has shown that the modification was successful. (A. Kirkman, MO)

2.27 CEH are investigating the use of ERS SAR data to derive simple catchment wetness indices for use in the conventional operational hydrological models used for reservoir management. (R. Ragab, CEH)

2.28 In collaboration between the NERC-Environmental Systems Science Centre (ESSC) and the UK Environment Agency, ERS SAR data are being used to map flood extent for comparison with model generated estimates of flood extent. Airborne LIDAR measurements are used to derive the topography and hydrodynamic roughness. (D. Mason, ESSC)

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4.1 In December 2000, the Met Office operational global NWP system made use of the following data and products:

NOAA-14 TOVS and NOAA-15 ATOVS radiances;
Satellite winds from Meteosat, GOES and GMS;
Surface wind speed from SSM/I on DMSP F-13;
SSTs derived from AVHRR data by NOAA/NESDIS, via an in-house SST analysis;
Sea ice analyses derived from SSM/I by NCEP.

In the operational mesoscale model, the following data and products were used:

Satellite winds from Meteosat;
Cloud amount and height derived from Meteosat, via the MOPS cloud analysis scheme;
AVHRR SST from locally received AVHRR data.
(J.Eyre, MO)

4.2 The Nimrod automated nowcasting system has been in operational use since 1997. It uses cloud amount derived from Meteosat visible and infra-red imagery by comparison with NWP model surface temperature and climatological albedo maps; cloud top height derived from Meteosat infra-red imagery using NWP model temperature and humidity profiles; rainfall rate derived from Meteosat visible and infra-red imagery using a correlation with recent radar imagery at four rain rate thresholds; probability of rain derived from Meteosat visible and infra-red imagery using historical comparisons; and low cloud/fog presence derived from AVHRR imagery using the infra-red and 3.7 micron channels. (B. Golding, MO)

4.3 The operational global wave model assimilates fast-delivery altimeter wave height data from ERS-2. The altimeter wind speed observation is used to partition the wave energy increments between "windsea" and "swell". (M. Holt, D. Holmes, MO)

4.4 Gridded datasets of sea ice concentration from the Canadian Met Centre, based on SSM/I data, are assimilated into the global Forecast Ocean Atmosphere Model (FOAM). (M.J. Bell, A. Hines, MO)

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5.1 The Met Office is a partner in the GRAS SAF, launched in 1999 and led by DMI. GRAS (the GNSS Receiver for Atmospheric Sounding) is the radio occultation instrument to be flown on METOP. The role of the SAF is to prepare the scientific and technical base for exploiting GRAS data. The Met Office's main contribution concerns the software tools needed for assimilation of radio occultation data into NWP models, and research has continued on the development of these tools and other aspects of the assimilation problem for radio occultation data. (D. Offiler, S. Healy, MO)

5.2 Work has started on the design and development of processing modules to derive cloud parameters from data from the SEVIRI instrument on MSG. These modules will form part of the overall satellite data reception and processing system being developed by the Met Office. (F. Smith, MO)

5.3 Enhancements to the use of satellite imagery in Nimrod are being prepared for use of data from MSG. In particular, this is expected to deliver enhanced cloud detection, especially at night. Improvements are also expected in the cloud top height and rainfall rate estimates, arising both from the additional imaging channels, and from the enhanced spatial resolution. (B. Golding, MO)

5.4 A new processing system capable of handling the large increase in satellite data volumes from MSG as well as the data from the existing satellites is being developed and is due to become operational by the last quarter of 2001. Work will continue on some MSG-specific aspects of the development until real MSG data becomes available. (R. Carter, MO)

5.5 A EUMETSAT-funded study on "The impact of aliasing on MSG images" was delivered in October 2000. This identified the manipulations that need to be applied to MSG raw-instrument imagery to optimise trade-off between beamwidth and sidelobe ripple. It also examined the impact of missing MSG detectors on MSG imagery. (A. Lee, N. Atkinson, MO)

5.6 Preparations for exploitation of AIRS and IASI data have continued. Work has included: assessment of the information content of IASI data, development of radiative transfer models for AIRS, and investigation of options for the interface between AIRS data and NWP systems. Feedback to NASA and NESDIS on the AIRS radiance statistics will be given. It is planned to assimilate into the global NWP model an AIRS near real-time radiance product generated by NESDIS. (R. Saunders, A. Collard, V. Sherlock, J. Eyre, MO).

5.7 A scheme has been designed for formatting IASI data to reduce data volume and to facilitate data use. (A. Lee, MO)

5.8 Studies have been conducted on appropriate properties of sounder instruments (mainly in the context of IASI) and on estimating the impact of changes in instrument design. Pseudo-noise within IASI has been identified as a possible limit to performance, and techniques described for eliminating it have been examined. (A. Lee, MO)

5.9 Analyses of airborne and ground-based infra-red interferometer measurements were carried out in the VIRTEM programme to improve the infra-red spectroscopy of the atmosphere in preparation for data from IASI. This collaborative project, with the Max-Planck-Institut für Meteorologie, the Laboratoire de Météorologie Dynamique and Rutherford Appleton Laboratory, is funded under EU Framework IV. (J. Taylor, MO)

5.10 Infra-red interferometer data were gathered by ARIES during transit flights between the UK and Ascension Island. The data are being used in research on a cloud detection scheme in the context of the processing of IASI data. (J. Smith, J. Taylor, MO)

5.11 A satellite data volume plan was prepared to provide information on future processing and archiving of satellite data within the Met Office. (R. Saunders, MO)

5.12 Following validation of SAR wave energy spectra against the global wave model, the potential for assimilation of spectral wave energy into a global wave model is to be assessed. This is of particular interest for the prediction of long travelled, low amplitude, long period swell. (J. Gunson, MO)

5.13 As near-real time datasets of satellite altimeter sea surface height anomaly become available, these data will be assimilated into the FOAM, along with the data sets of sea surface temperature and temperature profile already assimilated. (M.J. Bell, A. Hines , D. Storkey, MO)

5.14 The 50 km AVHRR SST product from NESDIS for the North Atlantic will be processed twice weekly and used by the FOAM ocean model. (R. Saunders, M.J. Bell, MO)

5.15 The Met Office is acting as a subcontractor to Météo-France in the setting up and running of a new satellite data relay service to provide EUMETSAT with data from other geostationary satellites. The data will be disseminated from MSG at three-hourly intervals at a higher resolution than is currently available from Meteosat. The Met Office will relay GMS data. (R. Carter, MO).

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6.1 As a deliverable of the NWP SAF, the Met Office, in cooperation with ECMWF, publishes an integrated satellite winds monitoring report (ISWMR). The ISWMR presents monthly statistics of differences between AMVs and NWP-predicted winds from the two centres in similar graphical formats so that they can be easily compared. By observing the similarities and differences in the results from different centres, it may be possible to make deductions about the sources of those differences. By making the ISWMR (and analyses of its content) available to NWP centres and satellite operators, the eventual objective is to improve both the NWP models and the quality of satellite AMVs. It is hoped that other NWP centres will be willing to participate and contribute data. The ISWMR can be found at www.metoffice.com/sec5/NWP/NWPSAF/satwind_report
(P. Butterworth, B. Conway, MO, A. Garcia-Mendez, ECMWF)

6.2 The radiometric calibrations of the Microwave Humidity Sounder (MHS) instrument series was successfully completed by the Met Office. In total, four MHS flight models and one MHS engineering model have been calibrated under contract from Astrium Ltd. The flight instruments will follow the AMSU-B series and fly on the NOAA and METOP series of polar orbiting satellites. (A. Kirkman, MO)

6.3 Wave energy spectra are retrieved daily from fast-delivery SAR data from ERS-2 in pre-operational mode, with global coverage. The observations are being used to validate global wave model output. (M. Holt, J. Gunson, MO)

PART VII OTHER ITEMS (INCLUDING REFERENCES, PUBLICATIONS, AND SCIENTISTS IN CHARGE)

7.1 References

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7.2 Acronyms and abbreviations

1D-var	one-dimensional variational analysis
3D-var	three-dimensional variational analysis
AAPP	ATOVS and AVHRR Processing Package
AIRS	Advanced InfraRed Sounder
AMSU	Advanced Microwave Sounding Unit
AMV	Atmospheric Motion Vector
ARIES	Airborne Research Interferometer Evaluation System
ATOVS	Advanced TOVS
ATSR	Along-Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
CEH	Centre for Ecology and Hydrology
DMI	Danish Meteorological Institute
DMSP	Defense Meteorological Satellite Program (of the USA)
ECMWF	European Centre for Medium-range Weather Forecasts
ENVISAT	Environmental Satellite (of ESA)
ERS	European Remote Sensing satellite (of ESA)
ESA	European Space Agency
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites

FM	Flight Model
FOAM	Forecast Ocean Atmosphere Model
GANDOLF	Generating Advanced Nowcasts for Deployment in Operational Land-based Flood forecasts
GMS	Geostationary Meteorological Satellite (of Japan)
GNSS	Global Navigation Satellite System
GOES	Geostationary Operational Environmental Satellite (of USA)
GRAS	GNSS Receiver for Atmospheric Sounding
GRAS SAF	EUMETSAT-sponsored collaboration led by DMI, with partners: the Met Office and the Institut D'Estudis Espacials Catalunya, Spain
HIRS	High-resolution Infrared Radiation Sounder
IASI	Infra-red Atmospheric Sounding Interferometer
IR	Infra-red
ISWMR	Integrated Satellite Winds Monitoring Report
KNMI	Royal Dutch Meteorological Institute
LIDAR	Light Detection and Ranging
METOP	METeorological OPerational satellite (of EUMETSAT)
MHS	Microwave Humidity Sounder
MO	Met Office
MOPS	Moisture Observation Preprocessing System
MOTH	Measurement Of Tropospheric Humidity
MPI	Max Planck Institute
MSG	METEOSAT Second Generation
NASA	National Aeronautics and Space Administration
NERC	Natural Environmental Research Council
NESDIS	National Environmental Satellite Data and Information Service (of NOAA)
NCEP	National Centers for Environmental Prediction (USA)
NIMROD	Nowcasting system at the Met Office
NOAA	National Oceanic and Atmospheric Administration (of USA)
NWP	Numerical weather prediction
NWP SAF	EUMETSAT-sponsored collaboration led by the Met Office, with partners ECMWF, KNMI and Météo-France
RTTOV	Radiative Transfer model for TOVS
SAF	Satellite Application Facility
SAR	Synthetic Aperture Radar
SEVIRI	Spinning Enhanced Visible and Infra Red Imager
SSM/I	Special Sensor Microwave / Imager
SST	Sea surface temperature
STAAARTE-D	Scientific Training and Access to Aircraft for Atmospheric Research Throughout Europe - "D"
TIROS	Television and Infrared Observation Satellite
TOVS	TIROS Operational Vertical Sounder
UK	United Kingdom
USA	United States of America
VAR	Variational analysis
VIRTEM	Validation of IASI Radiative Transfer: Experiments and Modelling

UZBEKISTAN, REPUBLIC OF

(Main Administration of Hydrometeorology)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 Operational use of satellite data for cloud moving and evolution monitoring. Cloud images were used for weather forecasting in operational and research activity.

1.2 Snow cover mapping for the mountain region. Snow cover maps are used for runoff forecasting and avalanches research.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

2.1 The cloud moving and evolution monitoring is a part of researches of Main Administration on Hydrometeorology which is based on NOAA APT and METEOSAT WEFAX images. This satellite data application is a real time application and all output products involved to operational weather forecasting. Scientists of the Central Asian Research Institute use this satellite data application in our regional weather research.

2.2 The research of water surface objects which is based on navigated NOAA AVHRR HRPT images of Central Asian region.

2.3 Snow cover mapping for Snowmelt Runoff Model (SRM). The SRM is based on the degree-day method and requires daily information on air temperature, precipitation and snow-covered areas within several elevation zones.

2.4 The evaluation of biomass on desert pastures, and the assessment of the state and forecast of the yield capacity of grain crops.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3. The software for use satellite data was prepared. It includes the geographical data correction with interface, brightness normalization using digital elevation and slope model for mountainous regions, cloud cover masking. Estimation of snow-covered areas. Transfer of snow-cover maps to GIS and SRM.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

Automated software “SPUTNIC” for cloud moving and evolution monitoring by using NOAA AVHRR APT and METEOSAT WEFAX images

4.1 Automated software “SPUTNIC” was developed to work in DOS operation system. In the framework of this activity the special APT&WEFAX receiving board was developed and implemented. In addition, the experts of the Main Administration of Hydrometeorology of the Republic of Uzbekistan developed the software for analogue satellite data processing. During 1999-2000 years Main Administration of Hydrometeorology of Republic of Uzbekistan used this application for routine receiving and processing satellite data from NOAA and METEOSAT satellites.

Snow cover mapping for the Central Asian mountains by use NOAA AVHRR HRPT data.

4.2 The SRM is used operationally in the Main Administration of the Hydrometeorological Survey of the Republic Uzbekistan for Snowmelt runoff forecasting in several Central Asian river basins. The AVHRR (Advanced Very High Resolution Radiometer) data from the meteorological satellite NOAA-14 are used.

4.3 Operational snow cover mapping scheme is based on the experience in the European Alps with Alpine Snow Cover Analysis System. The scheme include radiometric calibration< geometrical correction and geocoding of satellite data. The GIS (Geo.-information system) for estimation of the snow cover are used.

4.4 Snow cover mapping system for the Central Asian mountains was developed based on SML macro-language of ERDAS Imagine 8.3.1 – 8.4 and another language in the framework of cooperation between Main Administration of Hydrometeorology of Republic of Uzbekistan and Swiss Aral Sea Mission. The scheme of this software can be seen in Figure 1.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5. In the framework of cooperation between Main Administration of Hydrometeorology of Republic of Uzbekistan and USAID, NOAA HRPT ground receiving station POLAR TRACER of GLOBAL IMAGING, USA was installed in the city of Tashkent. There is the possibility of integration of this ground receiving station into the operational and research activity for meteorology, operational hydrology and agrometeorology.

PART VI VALIDATION AND VERIFICATION OF SATELLITE DATA AND DERIVED PRODUCTS USED IN OPERATIONS, INCLUDING PERFORMANCE STATISTICS

6.1 All necessary verification of satellite data and derived products was performed during the implementation of developed systems in operational use.

PART VII OTHER ITEMS (REFERENCES, PUBLICATIONS AND SCIENTISTS IN CHARGE)

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VIETNAM, THE SOCIALIST REPUBLIC OF

(Hydrometeorological Service)

PART I SUMMARY OF THE MAJOR HIGHLIGHTS OF RESEARCH APPLICATIONS AND OPERATIONAL CHANGES

1.1 A new high resolution HRPT NOAA and GMS-5 PDUS receiving and pre-processing system was installed at the Hydrometeorological Service of Vietnam on 1 May 1997. The use and application of GMS WEFAX was replaced by the new system.

1.2 The Satellite Meteorology Group belonging to the national Centre for Hydrometeorological Forecasting, Hydrometeorological Service of Vietnam developed the software SIP ver. 1.1, The main functions of the software are:

- Image Display;
- Image Looping;
- Image Planning;
- Image Zooming;
- Obtaining the information for the image pixels;
- Colour enhancement;
- Creation and display of secondary products;
- Tools for identifying the centre of a typhoon;
- Split screen display of images;
- Overlaying of the weather maps on satellite images;
- Archiving of satellite data.

1.2 Some research applications have been implemented as follows:

- Normalization of visible images;
- Classification of clouds from GMS-5 image;
- Rainfall estimation using GMS-5 data;
- Flood monitoring in the Mekong River Delta using NOAA/AVHRR data.

PART II MAJOR RESEARCH AND DEVELOPMENT IN THE APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

Normalization of visible images

2.1 The visible images are received at different times of the day, on different days of the year, and at different conditions of the solar zenith angle. For the same visible image the gray value of different pixels is received at different scanning times, and at different solar zenith angle. The normalization of visible images has been made for improving the quality of VIS images, for the higher number for use in the operational process and research work.

2.2 Except for the calculations, based on astronomical and mathematical formulae the statistical analysis has been applied for the correction of albedo values at different times in the year, and at the different geographical location of Vietnam and surrounding areas.

Classification of clouds from GMS-5 images

2.3 The multi-channel technique has been applied for classification of different kinds of clouds from GMS-5 images. For the daytime composite images from the VIS channel and from 11 μm infrared channel are created. Through these techniques major types of clouds as thick convective clouds, high thin clouds, low clouds and free cloud areas can be distinguished.

Rainfall estimation using GMS.5 data

2.4 The 11 μm and visible images are used for the daytime analysis and the 11 μm and 12 μm and water vapour images are used for the night-time. The final rainfall maps are created after the composite analysis of satellite estimations and conventional rainfall measuring data from the station network.

Flood monitoring in the Mekong River Delta using NOAA/AVHRR data

2.5 The Mekong River Delta is lowland plain area. Every year this area suffers a lot of floods. Multi-channel analysis has been applied for identification of water body pixel and mixed pixel with different ranges of mixing between water and land.

2.6 Derived products:

- Normalised visible images (for operational process);
- Map with classification of clouds (for operational process);
- Map of rainfall estimation (for research work);
- Map of flooded areas in the Mekong River Delta (for research work.)

2.7 Service:

Providing products to the weather analysis and forecasting section.

PART III TECHNIQUES DEVELOPMENT AND APPLICATIONS OF SATELLITE DATA, DERIVED PRODUCTS AND SERVICES

3. Vietnam is situated in a special geographical area: the ocean in the east and south; high mountain and forest areas in the west, where hydrometeorological observations are very sparse. Every year, tropical storms, torrential rains and floods caused serious damage. In such a situation, high resolution meteorological satellite data plays a very important role in observing, analyzing and forecasting hydrometeorological phenomena, as well as in investigating another in land phenomena for disaster prevention and mitigation. Understanding the importance of hydrometeorological information for weather analysis and forecast, especially in strengthening abilities to observe, analyse and predict hazardous weather phenomena such as tropical storms, torrential rains and cold fronts, the Vietnamese Government permitted the Hydrometeorological Service of the Socialist Republic of Vietnam to install a high resolution meteorological satellite image receiving station in Hanoi, which was put into operation in April 1997. This station receives digital pictures from the geostationary meteorological satellite GMS-5, as well as the NOAA polar-orbiting satellites. The station is located at 21 01°N, 105 51°E.

PART IV DESCRIPTION OF THE SYSTEM FOR SATELLITE APPLICATIONS IN CURRENT OPERATIONAL USE

4. The use and applications of GMS WEFAX was replaced by the new above-mentioned system. The research work, applications of satellite data and creating of different products are made at the National Centre of Hydrometeorological Forecasting.

PART V PLANS FOR FUTURE OPERATIONAL SYSTEMS FOR SATELLITE APPLICATIONS TO METEOROLOGY AND OPERATIONAL HYDROLOGY

5. In the future it is planned to increase the research on the application of meteorological satellite data in the monitoring of large rain causing systems, convective cloud subsystems, flooding, and especially the research on the application of tropical storms. With the new high resolution meteorological satellite receiving system to be installed it is hoped to enhance the service for weather forecasting and natural disaster monitoring, as well as to participate in the common activities of the region.

PART VII OTHER ITEMS (references, publications and scientists in charge)

7.1 References:

Hoang Minh Hien, 1998, "Use of GMS-5 Satellite data for estimation of the rainfall" The Fifth ASEAN Science and Technology Week. Proceedings of the conference on "Meteorology and Geophysics for Mitigation of natural Disaster", Hanoi, Vietnam, 13-15 October 1998.

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