

**JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA
PROCESSING AND FORECASTING SYSTEM (GDPFS) AND NUMERICAL
WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2006**

COUNTRY: **Australia** CENTRE: **NMOC Melbourne**

1. SUMMMARY OF HIGHLIGHTS (2006)

Meteorological, Oceanographic and Computer Systems:

- 10 January: Resolution of GASP input to EER system upgraded (to: 0.75⁰ horizontally and 33 levels vertically)
- 16 February: IAEA/EER Test - RSMC Melbourne the Lead Centre.
- 10 April: NOAA-18 data used in GASP.
- 19 April: Operational TXLAPS_PT375 upgraded to 51 levels.
- 3 May: Operational LAPS_PT375 upgraded to 51 levels.
- 16 May: Volcanic ash products, associated with Mt. Merapi eruption, generated at request of RAV NMHS.
- 17 May: Operational implementation of Marine Surface Wind verification system.
- 27 June: TOVS problem, due to changes in BUFR decoder on 23 May, rectified.
- 10 July: Reintroduction of 14-day bias correction files for NOAA data into GASP.
- 21 August: PME operational.
- 22 August: ECMWF observation rejection list incorporated in LAPS_PT375.
- 24 August: The GASP 14-day bias correction files for NOAA data used in TXLAPS_PT375.
- 30 August: GOES-11 data used in operational LAPS_PT375.
- 14 September: UV system upgraded (featuring: increase in horizontal resolution to T79, from R53, use of new retrievals).
- 5 October: Serious relational database problem in NMOC, affected many systems.
- 16 November: IAEA/WMO EER Test: ConvEx-2c
- 27 November: Significant level data assimilated in TXLAPS_PT375.
Surface temperature initialisation improved in GASP.
MPI code used for GASP.
- 6 December: Significant level data assimilated in LAPS_PT375.

7 December: Operational dissemination of enhanced ATAS (Australian Tsunami Alert Service) Bulletins by NMOC commenced.

18 December: Operational upgrade of TCLAPS, improving the representation of synthetic observations.

2. EQUIPMENT IN USE AT CENTRE

The following table shows the main computer systems used in NMOC Melbourne, with their basic functions:

FUNCTION	COMPUTER	NO. OF CPUS	MEMORY	OPERATING SYSTEM	DISK STORAGE
Supercomputing (Assimilation and Prediction)	Multi-Node NEC SX-6	8 cpu / node 28 Nodes	64 GB / node	SUPER-UX 15.1 SX-6	22 TB (GFS) 133 GB (Local: total of all nodes)
Interface to Supercomputer	NEC TX7/i9510	16 cpu / node 2 Nodes	32 GB / node	NEC Linux R3.4	22 TB (GFS) 140 GB (Local: total of both nodes)
Communications / Message Switching	(i) HP RP7410 (ii) HP RP7410	(i) 8 (ii) 8	(i) 16 GB (ii) 16 GB	(i) HP-UX 11.11 (ii) HP-UX 11.11	200 GB
Scheduling / Data Base / Satellite Post-Processing / Graphics	(i) HP RP8400 (ii) HP RP8400 (iii) HP RP8400	(i) 16 (ii) 16 (iii) 16	(i) 32 GB (ii) 32 GB (iii) 32 GB	(i) HP-UX 11.11 (ii) HP-UX 11.11 (iii) HP-UX 11.11	600 GB 10 TB (SAN)
Horace	(i) HP C3600 (ii) HP C3600 (iii) HP C3600	(i) 1 (ii) 1 (iii) 1	(i) 512 MB (ii) 512 MB (iii) 512 MB	(i) HP-UX 11.11 (ii) HP-UX 11.11 (iii) HP-UX 11.11	(i) 27 GB (ii) 35 GB (iii) 30 GB
RADAR and Visualisation	(i) SGI Octane (ii) SGI-O2	(i) 1 (ii) 1	(i) 512 MB (ii) 128 MB	(i) IRIX 6.5 (ii) IRIX 6.5	(i) 17 GB (ii) 8.5 GB
web / ftp	8 x Dell PowerEdge 2650	8 x 2	8 x 6 GB	Linux RH EL 3	8 x 120 GB
MARS	2 x IBM p690	2 x 18 cpus (total) (MARS: 8 cpus)	128 GB (total) (MARS: 24 GB)	AIX 5.2	3 TB
Development	HP RP8400	16	32 GB	HP-UX 11.11	1.8 TB 22 TB (uGFS)

Peripheral Equipment:

Magnetic Cartridge Archive System:

StorageTek Mass Store 9310 ACS (Automatic Cartridge System)
 16 drives, for 9840 fibre channel tapes, in silo (4 for SAM-FS, 8 for MARS, 2 for backup and 2 others); tape capacity (uncompressed): 20GB
 14 drives for 9940B tapes (6 for SAM-FS and 8 for backup), tape capacity (uncompressed): 200GB

Hardcopy Printers/Plotters:

HP DesignJet 1055cm plus and 650C plotters

HP LaserJet 5 SiMX printers
HP LaserJet 8150DN
HP Color LaserJet 5500dtn
HP Color LaserJet 4500DN

Facsimile Machines:
RICOH FAX 4420NF

Software in use at Centre:

The overall computer environment in the NMOC is mainly Unix. A real-time data base, currently using ORACLE 8.1.7.4.0, is used for storage of observational data and grids from the various NWP systems. The U.S. Navy's Environmental Operational Nowcasting System (NEONS) software is commonly used for accessing the data base. The operational NWP models are written mainly in Fortran, with many of the associated files having the NetCDF structure. Most displays are produced using the NCAR graphics package and IDL. The UK Met. Office's Horace (V4.1) system is used to prepare, in an on-screen mode, manual-computer products for: significant weather prognoses, Australian Region surface analyses and prognoses and Southern Hemisphere surface analyses. Sam-fs is currently being used for magnetic cartridge archives in the NMOC. The Meteorological Archive and Retrieval System (MARS from the ECMWF) is being gradually integrated into operations, along with METVIEW for the display of products.

Other Systems in use at Centre:

The DIFACS system is used to disseminate a selection of basic analysis and prognostic charts, and some satellite imagery, to the Bureau's regional offices and some outside users. MCIDAS is used for comprehensive interaction and display of satellite imagery and products, observational and gridded data, and is also a major component of the Australian Integrated Forecast System (AIFS). Products from the NWP systems are written to internal and external (www.bom.gov.au) web servers. Magnetic cartridge archives are kept of various numerical analysis and prognosis products with Australian region analyses available back to 1970 and Southern Hemisphere analyses back to 1972. Hard copy and microfilm archives of charts also exist. An aviation system, which interacts with the WAFS data, is used to view and display the data and prepare the various flight and route forecasts. Regular statistics (including S_1 skill scores, root mean square errors and anomaly correlations), monitoring and comparing the performance of the NMOC's NWP systems (and also some NWP models from overseas centre), are also produced.

3. DATA AND PRODUCTS FROM GTS IN USE

The following table gives a list of the major observation report types used in the NMOC Melbourne and the approximate numbers received in a 24-hour period (during 2006):

Observational Data Type or Report Type	Approximate number received during 24 hour period (unless otherwise stated)
SYNOP	49374
SHIP	9018
TEMP	1282
PILOT	753
BUOY	34068
AIREP / AMDAR	46954
SATOB	230050
ATOVs (SATEM)	30607
ATOVs (BUFR)	138409
METAR (Australian stations only)	17217
CLIMAT	2200 / month
SATOB_SST	3092
BATHY / TESAC	571
WAVEOB	671
TRACKOB	79
AMV	766176
SAT_ALT	13991
QUIKSCAT	1218012
JASON	67213
HYREP	537
ONE_MIN_AWS	206697
TEN_MIN_AWS	13397
MDF	4081
MTSAT_MOIS	38406
SEA_LEVEL	19598
RA2_WWV	40608

The following Gridded Products are also received in NMOC Melbourne:

GRIB (ECMWF, EGRR, KWBC)
GRIB (JMA, CMC, DWD)
[GRID (EGRR,KWBC,EDZW)]

Data Input Stream:

Automated. (Some manual intervention is available for correction of reports.) The observational data, along with NWP gridded data, is stored in a real-time relational data base system (ORACLE/NEONS). An increasing proportion of operationally-produced NWP gridded data is also being stored in MARS.

Quality Control System:

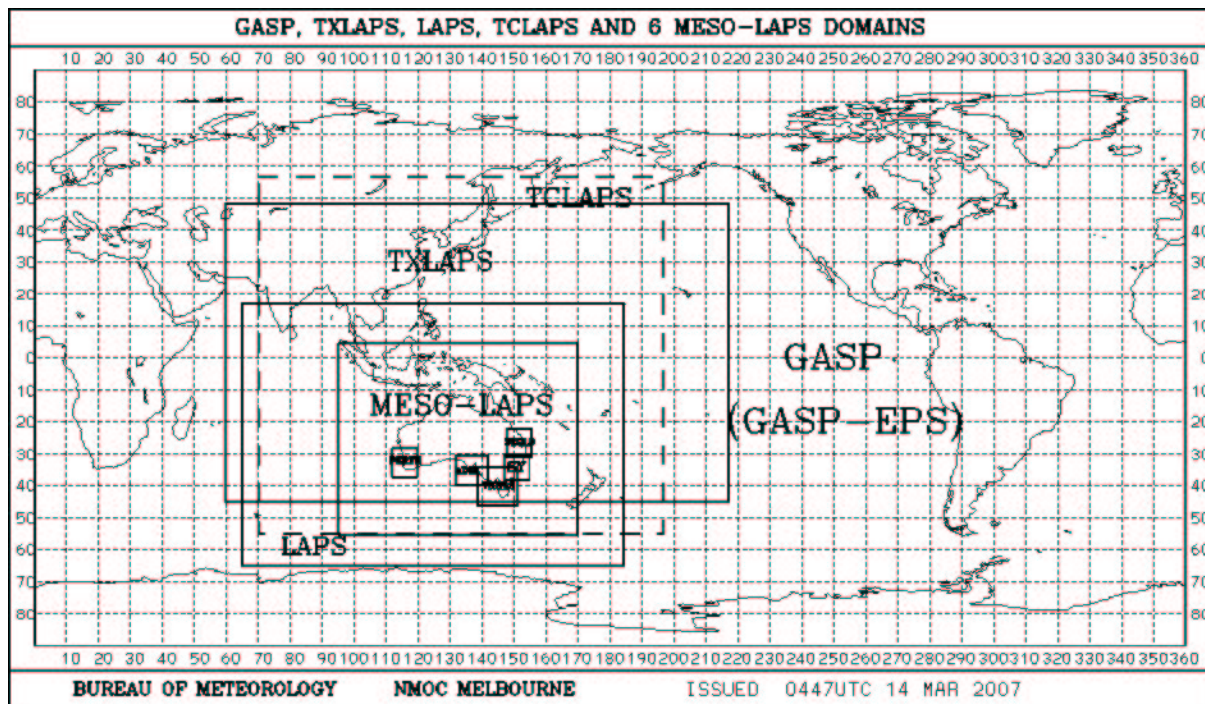
Validity checks are currently confined to within the respective assimilation or analysis schemes. Some gross checking outside these schemes may eventually be installed.

Monitoring of the Observing System:

Monitoring of the observing system is carried out. The quantity of data available is monitored in real-time to ensure that reports are being received reliably and are passed on to the operational systems. For the global system, statistics on the difference between observations and the first guess and analysis fields are routinely generated to identify any problems with either the analysis system or individual data types. Lists and displays of rejected data are also used to identify unreliable reporting from particular observing platforms.

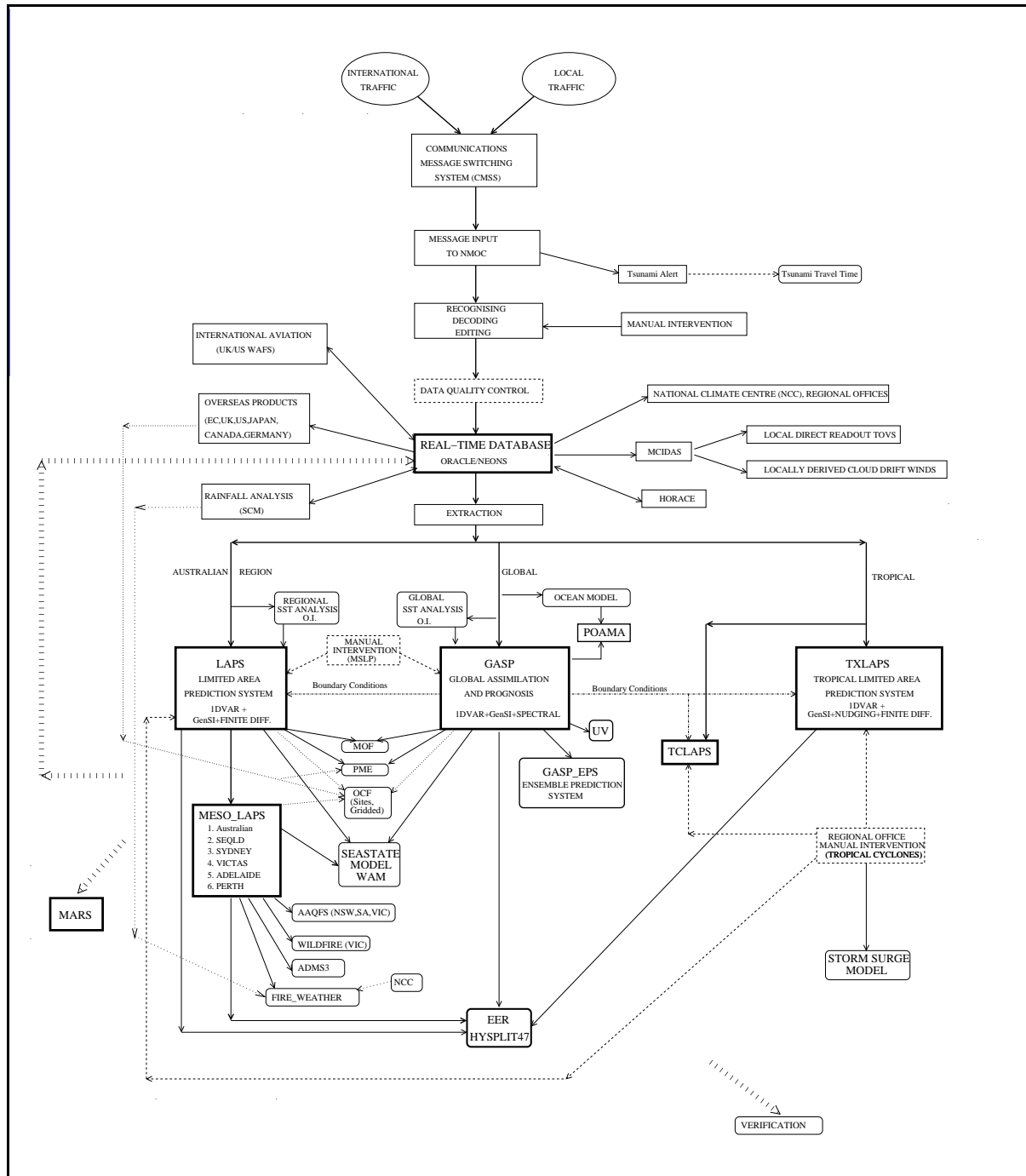
4. FORECASTING SYSTEM

There are three major operational analysis and forecast systems (viz. the global GASP, regional LAPS and the tropical TXLAPS) in the NMOC Melbourne. A mesoscale version of LAPS, called MESO_LAPS, provides additional high resolution forecast products over 6 smaller domains (viz., Australia, SE Queensland, Sydney, Victoria/Tasmania, Adelaide and Perth). The domains for each of these systems are shown in the figure below. The regional and tropical systems are dependent on the global system for their lateral boundary conditions, whereas the 6 MESO_LAPS systems are all nested in LAPS. An additional system, called TCLAPS, is run to provide tropical cyclone, and other tropical guidance, for the region. (The possible lateral extent of this guidance is also depicted in the figure below.)



Domains of the operational NWP systems in NMOC Melbourne.

Manual intervention is used for mean sea level pressure in the global and regional systems. The resulting hemispheric "pseudo-observations" for mean sea level pressure are disseminated on the GTS. The tropical and Australian region limited area systems both use a tropical cyclone synthetic specification scheme. An additional feature of the tropical system is its dynamical nudging. Output from the global system is also used in the cold start procedure for the Australian region LAPS and tropical TXLAPS. It is noted that the MESO_LAPS systems do not have their own separate analyses but currently use initial (and boundary) conditions derived directly from LAPS (i.e. interpolated laterally from 37.5 km to either 12.5 or 5 km).



Schematic representation of the operational analysis and prediction system in NMOC.

The global, Australian region and mesoscale streams have associated sea-state systems. There are a large number of additional systems including sea surface temperature analysis, environmental emergency response, generation of weather elements from model output (OCF), amendment and dissemination of aviation products, MCIDAS, archives, verification, display and dissemination of products. A schematic representation of the overall system is shown in the accompanying figure.

4.1 System Run Schedule and Forecast Ranges

At the present time, the centre produces major analyses at 00 and 12 UTC daily for the globe, Australian region and tropical domains. Global forecasts to 10 days, Australian region and tropical forecasts to 72 hours, mesoscale forecasts to 48 hours for the Australian and 36 hours for the 5 other smaller domains, and special tropical cyclone forecasts to 72 hours are produced from these major analyses. The ECMWF's Supervisor Monitor Scheduler (SMS) is used to manage the major part of the operational system and to initiate and monitor the various tasks in the operational NWP suite. An approximate daily schedule for the main operational, and near-operational, numerical systems is shown in the table below (with the times during the daylight saving months, November to March, shown in brackets).

System Run Schedule and Forecast Ranges

SYSTEM	BASE TIME (UTC)	APPROXIMATE START TIME (UTC)	FORECAST AVAILABILITY (UTC)	FORECAST RANGE FROM BASE DATE/TIME (HRS)
SSTANAL (REGIONAL)	1200	0100	0115	0
LAPS_PT375	0000	0145 (0045)	0230 (0130)	+72
MESO_LAPS_PT125	0000	0220 (0120)	0420 (0320)	+48
MESO_LAPS_PT050(VICTAS)	0000	0230 (0130)	0300 (0200)	+36
MESO_LAPS_PT050(SYDNEY)	0000	0230 (0130)	0300 (0200)	+36
MESO_LAPS_PT050(SEQLD)	0000	0230 (0130)	0315 (0215)	+36
MESO_LAPS_PT050(ADELAIDE)	0000	0230 (0130)	0330 (0230)	+36
MESO_LAPS_PT050 (PERTH)	0000	0230 (0130)	0330 (0230)	+36
EER PREP (LAPS)	0000	0240 (0140)	0250 (0150)	+72
OCF (LAPS)	0000	0235 (0135)	0245 (0145)	+72
WAVES (REGIONAL)	0000	0230 (0130)	0300 (0200)	+48
EER PREP (MESO_LAPS_PT050 5 DOMAINS)	0000	0240 (0140)	0345 (0245)	+36
ADMS3 (MESO_LAPS_PT050 5 DOMAINS)	0000	0245 (0145)	0325 (0225)	+24
OCF (MESO_LAPS_PT050 5 DOMAINS)	0000	0245 (0145)	0355 (0255)	+36
AAQFS (VIC)	0000	0300 (0200)	0350 (0250)	+36
AAQFS (NSW)	0000	0345 (0245)	0505 (0405)	+36
AAQFS (SA)	0000	0505 (0405)	0605 (0505)	+36

TXLAPS	0000	0320	0440	+72
EER PREP (MESO_LAPS_PT125)	0000	0400 (0300)	0500 (0400)	+48
WAVES (MESO_LAPS_PT125)	0000	0410 (0310)	0510 (0410)	+48
ADMS3 (MESO_LAPS_PT125)	0000	0410 (0310)	0415 (0315)	+24
OCF (MESO_LAPS_PT125)	0000	0410 (0310)	0430 (0330)	+48
OCF (DAILY COMPOSITE)	0000	0410 (0310)	0415 (0315)	+168
FIRE_WEATHER (DROUGHT FACTORS)	0000	0345 (0245)	0405 (0305)	0
TCLAPS	0000	0400	0420	+72
OCF (HOURLY COMPOSITE)	0000	0500 (0400)	0645 (0545)	+48
RAINFALL_ANALYSIS	2300 (2200)	0400	0415	0
EER PREP (TXLAPS)	0000	0445	0455	+72
GASP	0000	0545 (0445)	0800 (0700)	+240
FIRE_WEATHER (DROUGHT FACTORS)	0000	0615	0635	0
GASP_EPS	0000	0640 (0540)	0740 (0640)	+240
WAVES (GLOBAL)	0000	0730 (0630)	0810 (0710)	+96
EER PREP (GASP)	0000	0740 (0640)	0900 (0800)	+240
OCF (GASP)	0000	0755 (0655)	0800 (0700)	+168
PME	0000	0900 (0800)	0935 (0835)	+192
LAPS_PT375	0600	1045 (0945)	1200 (1100)	+6
TXLAPS	0600	1045	1200	+6
TCLAPS	0600	1100	1120	+6
GASP (EARLY)	0600	1200 (1100)	1230 (1130)	+24
LAPS_PT375	1200	1345 (1245)	1430 (1330)	+72
MESO_LAPS_PT125	1200	1420 (1320)	1620 (1520)	+48
MESO_LAPS_PT050(VICTAS)	1200	1430 (1330)	1500 (1400)	+36
MESO_LAPS_PT050(SYDNEY)	1200	1430 (1330)	1500 (1400)	+36
MESO_LAPS_PT050(SEQLD)	1200	1430 (1330)	1515 (1415)	+36
MESO_LAPS_PT050(ADELAIDE)	1200	1430 (1330)	1530 (1430)	+36
MESO_LAPS_PT050(PERTH)	1200	1430 (1330)	1530 (1430)	+36
EER PREP (LAPS)	1200	1440 (1340)	1450 (1350)	+72
OCF (LAPS)	1200	1435 (1335)	1445 (1345)	+72
WAVES (REGIONAL)	1200	1430 (1330)	1500 (1400)	+48
EER PREP (MESO_LAPS_PT050 5 DOMAINS)	1200	1440 (1340)	1545 (1445)	+36
ADMS3 (MESO_LAPS_PT050 5 DOMAINS)	1200	1445 (1345)	1525 (1425)	+24

OCF (MESO_LAPS_PT050 5 DOMAINS)	1200	1450 (1350)	1530 (1430)	+36
AAQFS (VIC)	1200	1500 (1400)	1610 (1510)	+36
AAQFS (NSW)	1200	1610 (1510)	1710 (1610)	+36
AAQFS (SA)	1200	1705 (1605)	1805 (1705)	+36
TXLAPS	1200	1520	1640	+72
EER PREP (MESO_LAPS_PT125)	1200	1600 (1500)	1700 (1600)	+48
WAVES (MESO_LAPS_PT125)	1200	1610 (1510)	1700 (1600)	+48
ADMS3 (MESO_LAPS_PT125)	1200	1610 (1510)	1615 (1515)	+24
OCF (MESO_LAPS_PT125)	1200	1610 (1510)	1645 (1545)	+48
OCF (DAILY COMPOSITE)	1200	1610 (1510)	1615 (1515)	+168
TCLAPS	1200	1600	1620	+72
EER PREP (TXLAPS)	1200	1645	1655	+72
OCF (HOURLY COMPOSITE)	1200	1800 (1700)	2050 (1950)	+48
GASP	1200	1745 (1645)	2000 (1900)	+240
GASP_EPS	1200	1840 (1740)	1940 (1840)	+240
WAVES (GLOBAL)	1200	1930 (1830)	2010 (1910)	+96
EER PREP (GASP)	1200	1940 (1840)	2100 (2000)	+240
OCF (GASP)	1200	1955 (1855)	2000 (1900)	+168
PME	1200	2215 (2115)	2240 (2140)	+192
LAPS_PT375	1800	2245 (2145)	0000 (2300)	+6
TXLAPS	1800	2245	0000	+6
TCLAPS	1800	2300	2320	+6
GASP (EARLY)	1800	0000 (2300)	0030 (2330)	+24
OCEAN_MODEL	(Daily)	1000	1010	+24
POAMA	(Daily)	0930	1430	+10 months
SSTANAL (GLOBAL)	(Mid-week)	2300 (Sundays only)	0010 (Mondays only)	0
SST (SUB-SURFACE)	(Monthly)	2200 (Mondays only)	2230 (Mondays only)	0
<u>AD HOC (TOP PRIORITY):</u>				
EER	ANYTIME	ANYTIME	ANYTIME + 30 mins	+72

WILDFIRE (VICTAS)	ANYTIME	ANYTIME	ANYTIME + VARIABLE AMOUNT (dependent on number of fire sources)	+36
TSUNAMI ALERTS	(1-minute check)	ANYTIME		
ADMS3	ANYTIME	ANYTIME	ANYTIME + 30 mins	+24
TCLAPS	0000 or 1200	ANYTIME	ANYTIME + 45 mins	+72

4.2 Medium-range Forecasting System (4-10 days)

The acronym **GASP** is given to the **Global ASimulation and Prognosis** system, which produces medium-range forecast products to 10 days. Post-processed products from this system are disseminated on the GTS in GRIB form, externally and internally via the web, "DIFACS" and MCIDAS, and also via Radio-facsimile broadcasts (VMC and VMW).

4.2.1 Data Assimilation, Objective Analysis and Initialization

4.2.1.1 In operation

Assimilated data: Mean sea level pressure (surface network, ships, drifting buoys, PAOBs), thickness (radiosondes, satellite retrievals), moisture (dew points), wind (rawinsonde, aircraft, geostationary satellites), cloud-clear radiances (from NOAA orbiting satellites), QuikSCAT (Kepert et al (2005), METARs.

Observation Reject List: Included.

Assimilation cycle, including cut-off time: 6 hourly cycling. H+6 cut-off.

Method of analysis: Generalised Multivariate statistical interpolation (GenSI) + univariate O.I. for moisture, one-dimensional variational retrievals (1DVAR).

Analysed variables: Geopotential, temperature, wind, moisture, surface pressure.

First guess: 6 hour forecast from previous cycle.

Coverage: Global.

Horizontal resolution: Triangular 239.

Vertical resolution: 33 sigma levels (0.9984, 0.9972, 0.9950, 0.9911, 0.9841, 0.9720, 0.9500, 0.9250, 0.9000, 0.8750, 0.8500, 0.8000, 0.7500, 0.7000, 0.6330, 0.5660, 0.5000, 0.4330, 0.3660, 0.3200, 0.2900, 0.2600, 0.2300, 0.2000, 0.1700, 0.1400, 0.1100, 0.0900, 0.0700, 0.0500, 0.0300, 0.0200, 0.0100)

Initialization: Incremental non-linear normal mode.

4.2.1.2 Research performed in this field

Experiments with a new 60-level version of GASP included the:

- . use of 1d radiances from UK Met Office (with a model top of 0.1hPa)
- . successful testing of an increased number of polar orbiting satellites (NOAA 15, 16, 17, 18 and Aqua)
- . use of AMSU-B / MHS
- . thinning of data based on simple estimates of information content of each instrument.

The ability to directly utilize radiances within 3dVAR was demonstrated, but further development ceased pending implementation of ACCESS (Australian Community Climate Earth System Simulator).

An Ensemble Kalman Filter (EnKF) using perturbed observations and 1dVAR satellite retrievals, was shown to produce results comparable to the current system when both are run at the same resolution (T119L19).

A modified EnKF has been developed that improves the balance of the analysis increments by explicitly accounting for the localization function during the formulation of the background error covariances (rather than applying the localization after the calculation of the ensemble covariances).

4.2.2 Model

4.2.2.1 In operation

Basic equations: Spectral primitive equations.

Independent variables: latitude, longitude, σ , t

Dependent variables: $\log p_*$, T , q , vorticity, divergence.

Numerical technique:

horizontal: Spectral.

vertical: Finite difference.

time: Semi-implicit semi-Lagrangian.

Integration domain (in horizontal and vertical): Global, surface to 10 hPa (approx.).

Horizontal and vertical resolution, time step: Triangular 239, 33 sigma levels,
600 sec.(approx.).

Orography, gravity wave drag: Both included.

Horizontal diffusion: Included.

Vertical diffusion: Included.

Planetary boundary layer: Included.

Treatment of sea surface, earth surface and soil: Included. [Uses Viterbo and Beljaars (1995) land-surface scheme and soil moisture nudging.]

Radiation: Diurnal cycle, diagnostic clouds, interactive optical properties.

Convection (deep, mid-level and shallow): Included.

Atmospheric moisture: Included.

Boundaries: Stand alone.

Albedo: Climatology.

SST Analysis: Weekly ($1^0 \times 1^0$).

4.2.2.2 Research performed in this field

Tuning of a multinode MPI version of GASP was carried out.

An initial implementation of the ACCESS global model, running daily from UKMO initial conditions at 80km horizontal resolution with 50 vertical levels, has been investigated.

4.2.3 Operationally available Numerical Weather Prediction (NWP) Products

The following table lists some of the post-processed fields that are available from GASP:

Mean sea level pressure	Pressure at cloud top	Net solar radiation
Surface pressure	Temperature tendency	Net downward radiation at surface
Temperature	Mixing ratio tendency	Outgoing longwave radiation
Wind	Radiative tendency	Albedo
Mixing ratio	Vorticity surface flux tendency	Surface wind stress
Geopotential height	Divergence surface flux tendency	Evaporation
Vorticity	Solar heating tendency	Roughness length at surface
Divergence	Precipitable water	Sub-surface temperature
Velocity potential	Soil moisture	Sensible heat flux
Precipitation	Snow depth, melt, cover	Latent heat flux
Stream function	Runoff	UV index
Cloud amount	Topography	

4.2.4 Operational Techniques for Application of NWP Products

4.2.4.1 In operation

GASP output fields are used to drive a number of systems including the global components of the sea-state and EER systems. In addition, GASP fields are used in the generation of OCF and meteogram products.

4.2.4.2 Research performed in this field

Research is being carried out on OCF, along with preparation for use of the Graphical Forecast Editor (GFE), and is described in Section 4.3.4.2.

4.2.5 Ensemble Prediction System (EPS)

4.2.5.1 In operation

An Ensemble Prediction System based on the GASP system (with the acronym GASP_EPS) is currently being run in a near-operational test mode in real-time in NMOC Melbourne. The 33-member ensemble system is running at the resolution: T119L19 (ie Triangular 119, 19 vertical levels), with a timestep of 1200 sec., and producing forecasts out to 10 days, off 00 and 12 UTC. Singular vectors are used to perturb the initial state derived from GASP. These perturbed states are then used as the initial conditions for each of the ensemble members.

4.2.5.2 Research performed in this field

Global EPS forecasts, from GASP_EPS, are in the process of being included in the TIGGE program.

4.2.5.3 Operationally available EPS Products

GASP_EPS, run in real-time mode in NMOC, generates the graphical products:

- . rainfall probabilities - chance of exceeding certain (5mm, 20mm) thresholds;
- . 850 hPa high and low temperature anomaly probabilities;
- . 200 hPa and surface (10m) high speed wind probabilities;
- . spaghetti diagrams (5600m contour);
- . meteograms (of MSLP, total precipitation, 10m wind speed, 2m temperature) for Australian cities;
- . tubing forecasts (MSLP/Thickness, precipitation);
- . ensemble members: mean and thumbnails (MSLP/thickness and precipitation);
- . standard deviations;
- . comparisons with last 3 runs of system;
- . ensemble spread plots;
- . verification statistics.

4.3 Short-range Forecasting System (0-72 HRS)

The Australian region Limited Area Prediction System (LAPS), the Tropical eXtended domain Limited Area Prediction System (TXLAPS) and the MESOscale Limited Area Prediction System (MESO_LAPS) provide short-range forecasting guidance and products that are disseminated externally and internally via the web, "DIFACS" and MCIDAS, and also via Radio-facsimile broadcasts (VMC, VMW). TXLAPS and TCLAPS, for specific tropical cyclone guidance, are run on behalf of RSMC Darwin. Again it is noted that the 6 MESO_LAPS systems do not have their own assimilation, or analysis, but use an initial starting condition derived directly from LAPS. It is also noted that TCLAPS runs in 2 steps. The first preparatory step produces analyses and prognoses over a large domain, or what is called the Large Scale Environment (LSE), and the second step then generates analyses and forecasts at a higher resolution on a relocatable domain centred on the tropical cyclone (and nested within the LSE part).

4.3.1 Data Assimilation, Objective Analysis and Initialization

4.3.1.1 In operation

Assimilated data: Surface synop, ship, drifting buoy, radiosonde, rawinsonde, GTS TOVS, GTS cloud drift winds, aircraft single level winds, bogus MSLP ("pseudo-observations"), tropical cyclone synthetic data, cloud-clear radiances (from NOAA orbiting satellites), QuikSCAT, METARs.

Observation Reject List: Included.

Assimilation cycle, including cut-off time: 6 hourly cycling; cut-off: LAPS: H+2 hr,
TXLAPS: H+3 hr.

Method of analysis: Generalised Multivariate statistical interpolation (GenSI) + univariate statistical interpolation for moisture, one-dimensional variational retrievals (1DVAR). LAPS and TXLAPS are initiated from GASP 12 hours prior to target analysis, with two successive 6-hour assimilation steps.

Analysed variables: Geopotential, temperature, wind, moisture, surface pressure.

First guess: 6 hour forecast from previous cycle.

Coverage: LAPS: 17.125⁰N-65.0⁰S, 65.0⁰E-184.625⁰E
TXLAPS: 48.375⁰N-45.0⁰S, 60.0⁰E-217.125⁰E

TCLAPS: 56.75⁰N-55.0⁰S, 70.0⁰E-163.25⁰W (LSE), 27.0⁰x27.0⁰ (Relocatable)
Horizontal resolution: LAPS and TXLAPS: 0.375⁰

TCLAPS: 0.75⁰ (LSE) and 0.15⁰ (Relocatable)

Vertical resolution: LAPS, TXLAPS: 51 sigma levels (0.99880, 0.99740, 0.99500, 0.99110, 0.98410, 0.97200, 0.95000, 0.92500, 0.90000, 0.87500, 0.85000, 0.82500, 0.80000, 0.77500, 0.75000, 0.72500, 0.70000, 0.67500, 0.65000, 0.62500, 0.60000, 0.57500, 0.55000, 0.52500, 0.50000, 0.47500, 0.45000, 0.42500, 0.40000, 0.37500, 0.35000, 0.32500, 0.30000, 0.27500, 0.25000, 0.22500, 0.20000, 0.17600, 0.15350, 0.13300, 0.11500, 0.09900, 0.08450, 0.07150, 0.05940, 0.04800, 0.03750, 0.02840, 0.02070, 0.01452, 0.00980)

TCLAPS: 29 sigma levels (0.9988, 0.9974, 0.9943, 0.9875, 0.9750, 0.9625, 0.9500, 0.9250, 0.9000, 0.8750, 0.8500, 0.8000, 0.7500, 0.7000, 0.6000, 0.5000, 0.4500, 0.4000, 0.3500, 0.3000, 0.2750, 0.2500, 0.2250, 0.2000, 0.1750, 0.1500, 0.1000, 0.0700, 0.0500)

Initialization: LAPS and MESO_LAPS: Digital filtering technique.

TXLAPS and TCLAPS: diabatic dynamical nudging scheme incorporating MTSAT IR imagery.

(For Tropical Cyclones: Synthetic vortex specification.)

4.3.1.2 Research performed in this field

Using a 61-level version of LAPS (with a top level of 0.1 hPa), experiments have been carried out using the 1d radiances from the UK Met Office and those from local reception.

A Mesoscale Assimilation and Prediction System (MAPS), with a horizontal resolution of 0.1⁰ and 61 vertical levels, is being investigated which includes:

- . use of 3-hourly intermittent analysis;
- . linear interpolation of the first guess to the correct time (to calculate observation increments);
- . the projection of a greater percentage of the total wind variance onto the divergent component;
- . warm running.

The use of carefully selected wind observations from SYNOP reports was investigated.

The use of automatic bogus data, to fill in missing data in data sparse areas for the Mesoscale Surface Analysis System, was investigated. The bogus data is generated from regressions against "nearest" observations and forecasts from LAPS.

A new daily SST analysis, with a horizontal resolution 0.083⁰, was tested in MESO_LAPS over the Australian and Sydney domains.

4.3.2 Model

4.3.2.1 In operation

Basic equations: Grid primitive equations.

Independent variables: x,y,z,t

Dependent variables: P*,T,q,u,v.

Numerical technique:

horizontal: Finite difference.

vertical: Finite difference.

time: Explicit.

Integration domain (in horizontal and vertical):

LAPS: 17.125°N-65.0°S, 65.0°E-184.625°E, surface to 10 hPa (approx.)

TXLAPS: 48.375°N-45.0°S, 60.0°E-217.125°E, surface to 10 hPa (approx.)

MESO_LAPS:

Australian: 4.875°N-55.0°S, 95.0°E-169.875°E, surface to 50 hPa (approx.)

SYDNEY: 30.05°S-38.00°S, 147.00°E-154.95°E, surface to 50 hPa (approx.)

VICTAS: 34.05°S-46.00°S, 139.00°E-150.95°E, surface to 50 hPa (approx.)

SEQLD: 22.05°S-31.00°S, 148.00°E-155.95°E, surface to 50 hPa (approx.)

ADELAIDE: 30.55°S-39.50°S, 132.00°E-141.95°E, surface to 50 hPa (approx.)

PERTH: 28.05°S-37.00°S, 112.00°E-119.95°E, surface to 50 hPa (approx.)

TCLAPS:

LSE: 56.75°N-55.0°S, 70.0°E-163.25°W, surface to 50 hPa (approx.)

Relocatable: 27.0°x27.0° , surface to 50 hPa (approx.).

Horizontal and vertical resolution, time step:

LAPS: 0.375° , 51 sigma levels, 40 sec

TXLAPS: 0.375° , 51 sigma levels, 40 sec

MESO_LAPS:

Australian: 0.125° , 29 sigma levels, 10 sec

SYDNEY: 0.05° , 29 sigma levels, 5 sec

VICTAS: 0.05° , 29 sigma levels, 5 sec

SEQLD: 0.05° , 29 sigma levels, 5 sec

ADELAIDE: 0.05° , 29 sigma levels, 5 sec

PERTH: 0.05° , 29 sigma levels, 5 sec

TCLAPS:

LSE: 0.75° , 29 sigma levels, 40 sec

Relocatable: 0.15° , 29 sigma levels, 15 sec.

Orography, gravity wave drag: Included.

Horizontal diffusion: Included.

Vertical diffusion: Included.

Planetary boundary layer: Included.

Treatment of sea surface, earth surface and soil: Included.

Soil moisture analysis: Included in LAPS, TXLAPS, TCLAPS and MESO_LAPS.

Radiation: Diurnal cycle, diagnostic clouds, interactive optical properties.

Convection (deep and shallow): Included.

Atmospheric moisture: Included.

Boundaries: LAPS, TXLAPS and TCLAPS (LSE): Lateral boundaries from GASP.

MESO_LAPS (6 domains): Lateral boundaries from LAPS.

TCLAPS (Relocatable): Lateral boundaries from LSE TCLAPS.

Albedo: Climatology.

SST Analysis: Weekly (1°x1°) - in LAPS, MESO_LAPS (Australian), TXLAPS and TCLAPS.

Daily (0.25°x0.25°) - in MESO_LAPS (SYDNEY, VICTAS, SEQLD, ADELAIDE, PERTH).

4.3.2.2 Research performed in this field

Tuning of a multinode MPI version of LAPS was carried out.

Experiments were carried out using an initial implementation version of the ACCESS limited-area model, over the current LAPS domain at a horizontal resolution of 0.375° and 38 vertical levels. Daily runs were done using UKMO initial conditions.

Additional runs of ACCESS, using all current LAPS resolutions, were done primarily to provide timing-data for use in the determination of future domain configurations.

4.3.3 Operationally available Numerical Weather Prediction (NWP) Products

The following table lists some of the post-processed fields that are available from the Limited Area Prediction Systems:

Mean sea level pressure	Stream function	Saturation deficit
Surface pressure	Wind shear	Cloud amount
Temperature	Boundary layer convective energy flux	Surface wetness
Wind	Shearing deformation	Atmospheric boundary layer height
Mixing ratio	Stretching deformation	Surface sensible heat flux
Geopotential height	Temperature gradient	Surface latent heat flux
Dew point temperature	Temperature advection	Surface wind stress
Dew point depression	Q vector	Surface total heat flux
Ageostrophic wind	Moisture convergence	Boundary layer convective energy flux
Potential temperature	Moisture advection	Skin temperature of boundary layer
Equivalent potential temperature	Wet bulb potential temperature	Pressure at cloud top
Wet bulb potential temperature	Total precipitation	Frontogenesis function
Layer thickness	Convective precipitation	Total totals index
Vorticity	Non-convective precipitation	Lifting index
Divergence	Lifting condensation level	Forest fire danger index
Vorticity advection	Topography	Grassland fire danger index
Relative humidity	Precipitable water	

4.3.4 Operational Techniques for Application of NWP Products

4.3.4.1 In operation

LAPS and MESO_LAPS output fields are used to drive the sea-state system for the Australian and a smaller domain. In addition they, along with TXLAPS, are used to drive the respective components of the EER system, and are also used in the generation of OCF and meteogram products. Fields from the Australian domain version of MESO_LAPS are used in the NTFGS decision tree system.

4.3.4.2 Research performed in this field

OCF and GFE:

Using the OCF approach, specific site methodology was applied to the prediction of moored buoy measurements of significant wave height up to 24 hours ahead. In this work, OCF uses past observations and forecasts of significant wave height from 5 numerical wave models available in real-time at the Australian Bureau of Meteorology. In addition to OCF, different adaptive weighting and forecast combination strategies are investigated. At deep-water sites (ocean depth > 25m) all the interpolated raw model forecasts outperformed 24hr persistence and, after bias-correction, one model was clearly best. Significant improvements over raw model significant wave height forecasts were achieved by bias correction, linear regression methods and combination strategies. The best forecasts were obtained from a "composite of composites" in which models with highly correlated errors were combined before being included in the performance weighted bias corrected forecast. This technique slightly outperformed the linear regression corrected best model. At shallow-water sites (ocean depth < 25m) all raw models perform poorly relative to 24hr persistence. The composited, corrected forecasts significantly improved on raw model significant wave height forecasts but only slightly outperformed 24hr persistence. The raw models generated unrealistically large biases that tended to be amplified with larger observed significant wave heights.

The main research effort has been to expand from the OCF site-based daily and hourly forecasts to gridded forecasts for use as first guess fields in a graphical editor. The Bureau of Meteorology is adapting the US developed Graphical Forecast Editor (GFE) for use as the main production engine for operational weather forecasts. Work has progressed on :

- . developing gridded bias corrected consensus model forecasts as the first guess fields for the GFE;
- . defining a grid based forecast process by which human forecasters modify the NWP derived grids in a systematic way to improve their utility as the basis of our suite of weather products;
- . developing text formatters to produce high quality natural language text forecasts and warnings from the gridded numerical forecast database developed by forecasters within the GFE.

Minor modifications to public weather OCF allow them to automatically commence or cease according to available observations.

4.3.5 Ensemble Prediction System (EPS)

4.3.5.1 In operation

An EPS based on the LAPS system is currently being run by research in near real-time. The system has 24 members and is run with a horizontal resolution of 0.50° and 29 levels in the vertical, with a forecast period of 72 hours.

4.3.5.2 Research performed in this field

Further developments associated with LAPS_EPS include the generation of probability products for severe thunderstorms and tropical cyclone tracks.

4.3.5.3 Operationally available EPS Products

Currently the LAPS_EPS system, run in research mode only, generates products from the 1200UTC base time only. A wide range of graphical products is available from the system including:

- . probability forecasts (related to various threshold values) of precipitation, 10m wind, 2m maximum temperatures, thunderstorm occurrence;
- . ensemble thumbnail forecast plots of precipitation, mean sea level pressure, and thunderstorm occurrence;
- . TC forecast positions (control and mean), and probability plumes;
- . spaghetti plots (for 5600m contours);
- . meteograms (Australian Capital cities) - total cloud cover, total precipitation, 10m wind speed, 2m temperatures;
- . HYSPLIT trajectories;
- . forest and grassland fire danger indices.

4.4 Nowcasting and Very Short-range Forecasting Systems (0-6 hrs)

4.4.1 Nowcasting system

4.4.1.1 In operation

The Australian Nowcasting System is primarily based on radar data and consists of three components:

- (1) the radar data serving infrastructure;
- (2) the Nowcast Server, that runs various radar algorithms on the radar data;
- (3) the Nowcast Client systems and services, where the algorithm output is used by clients to display information or to create products.

The radar algorithms used are those for thunderstorm tracking, viz.: NCAR's TITAN (Thunderstorm Identification Tracking Analysis and Nowcasting), and NSSL's WDSS (Warning Decision Support System) and that for rainfall estimation: The Australian Bureau's Rainfields.

The current Nowcast client systems and services that use the Nowcast Server output are:

- . radar data viewing systems such as 3D-Rapic and Webradar;
- . TIFS (Thunderstorm Interactive Forecast System) - a severe thunderstorm warning product generation system that has as inputs: TITAN tracks, lightning data and model guidance. It produces graphical, textual and meteogram warning outputs;
- . ATSAS (Automated Thunderstorm Alerting Service) - an automated thunderstorm alerting service for airports, using TITAN tracks and lightning data as inputs.

4.4.1.2 Research performed in this field

Research activities include:

- . determining the suitability of the WDSS velocity-based algorithm output for Australian radars;
- . developing an optimal blend of radar and raingauge data.

4.4.2 Models for Very Short-range Forecasting Systems

4.4.2.1 In operation

None at present.

4.4.2.2 Research performed in this field

Development of a radar-mesoscale model blended forecast rainfall product is in progress.

4.5 Specialized Numerical Predictions

4.5.1 Assimilation of specific data, analysis and initialization (where applicable)

4.5.1.1 In operation

Rainfall Analysis:

A daily rainfall analysis is run for both an Australian (10.00°S-44.50°S, 112.00° E-156.25°E) and a South East Australian (32.50°S-44.00°S, 134.50° E-152.40°E) domain. The analysis uses a Barnes' successive correction method applied to observational data derived from SYNOP, telegraphic and AWS reports. The analysis is performed on a latitude/longitude grid at a horizontal resolution of 0.25° for the Australian and 0.10° for the South East Australian domains.

Sea Wave Models:

The following table summarises the characteristics of the sea-state system in the NMOC:

Domain	Global	Australian Region	Australian MESO_LAPS Region
Numerical Scheme	Deep water 3rd generation (WAM)	Deep water 3rd generation (WAM)	Shallow water 3rd generation (WAM)
Wind data source	GASP (10m)	LAPS_PT375 (10m)	MESO_LAPS_PT125 (10m)
Grid	Latitude/longitude	Latitude/longitude	Latitude/longitude
Resolution	1°	0.5°	0.125°
Nesting	Stand alone	Within Global	Within Regional
Start time of forecast	00, 12 UTC	00, 12 UTC	00, 12 UTC
Forecast Period	+96 hrs	+48 hrs	+48 hrs
Initial state	12 hr hindcasting and assimilation of satellite altimeter data		No assimilation
Model output	Wind and swell significant wave height, period and direction. Significant wave spectra and probabilities.		
Verification	With respect to rigs and buoys		

Specialized sea-state forecasts are provided for the North West Cape and Bass Strait gas and oil fields.

Solar Ultraviolet (UV) Radiation Forecast System:

Forecasts out to 36 hour forecasts of a UV index (defined as the product of the UV irradiance and a human skin response function) are produced operationally. The system analyses 120km GTS ATOVS data, using an ozone retrieval mechanism and 2-dimensional univariate statistical interpolation. Forecasts of the ozone distribution are then computed using isentropic fields derived from GASP output. From vertical profiles of pressure, temperature and ozone, the UV index (defined according to the WMO standard categories) is calculated.

4.5.1.2 Research performed in this field

Solar Ultraviolet (UV) Radiation Forecast System:

Features of the Solar Ultraviolet (UV) forecasting system, in NMOC, which was upgraded in September 2006 included:

- . an increase in horizontal resolution from R53 to T79 with 33 vertical levels;
- . implementation of a new ozone retrieval, in which the upper ozone contribution is given as a function of latitude and seasons.

4.5.2 Specific Models

4.5.2.1 In operation

Storm Surge System:

A system capable of forecasting storm surges caused by tropical cyclones is currently driven by wind and pressure field distributions defined according to the central pressure and maximum wind radius bogussed for tropical cyclones by Darwin RFC.

Atmospheric Transport Model - EER System:

An air dispersion, or transport, system is available for running on demand and can produce forecast trajectories, concentrations (or exposures) and depositions for nuclear accident, volcanic ash, smoke, air-borne virus and other episodes. Currently, the operational Environmental Emergency Response (EER) system consists of the Hybrid Single_Particle Lagrangian Integrated Trajectories (HY-SPLIT using Version 4.7) system, developed at the NOAA Air Resources Laboratory, with meteorological input from the operational NWP systems in NMOC (viz., GASP, LAPS, TXLAPS, and MESO_LAPS). Analysed backward trajectories, and retro-plumes, are also available from GASP, LAPS and TXLAPS in operations.

National Thunderstorm Forecast Guidance System (NTFGS):

The NTFGS is a decision tree system that uses diagnostic fields derived from MESO_LAPS (Australian domain) together with defined thresholds to provide forecast guidance on likely storm or severe weather areas over Australia. Storm types considered include thunderstorms, supercells and tropical squall lines. Severe weather classifications include events associated

with large hail and heavy rain, tornadoes and severe convective gusts. The system is updated twice a day, after the runs of MESO_LAPS.

Operational Consensus Forecasts (OCF):

The OCF system generates forecasts of weather elements using a consensus of direct model output and model output statistics. A bias correction (with a 30-day adaptation period) is applied to the component forecasts and then a composite forecast (based on the mean absolute error, using a weighted average algorithm) is generated. The system currently uses model output from GASP, LAPS, MESO_LAPS (all 6 domains), and a number of overseas models (UK, US, JAPAN and ECMWF). OCF is run in a daily and an hourly mode. For the daily mode, forecast elements include temperature (maximum, minimum, ground minimum), rainfall (amount and probability), sunshine hours and evaporation. In this mode, forecasts are produced for over 600 sites throughout Australia, where the available forecast period can be up to 7 days, depending on the weather elements. For the hourly mode, the forecast weather elements produced include: screen-level air and dew point temperatures, relative humidity, QNH, wind speed and direction, and precipitation - with forecasts up to 42 hours for approximately 280 stations.

Poor Man's Ensemble (PME) Precipitation Forecasts:

PME uses the precipitation forecasts from a number of models (LAPS, GASP, CMC, DWD, UK, US, JAPAN and ECMWF) to generate mean precipitation fields and the probability of precipitation for various thresholds. It uses a probability-matched mean approach to combine the precipitation fields.

Fire Weather system:

The Fire Weather system, in the NMOC operational context, uses the daily rainfall and maximum temperature (from the National Climate Centre) analyses to generate a set of gridded soil moisture deficit (eg Keetch-Byram Drought Index and Mount's Soil Dryness Index) and associated drought factor fields, and other derivatives. These products are used to support fire weather services throughout the regions. By combining some of these products with output from MESO_LAPS, a number of additional products (eg forest and grassland fire danger indices) are also made available.

Microscale Dispersion Modelling System:

A microscale dispersion system: ADMS3 (Atmospheric Dispersion Model Version 3), from CERC (UK), is in a near-operational state. This system is a skewed Gaussian plume model, which has the capacity of allowing the definition of a variety of sources in terms of shape and pollution types. Currently, MESO_LAPS (all 6 domains) provides the meteorological input for driving the system.

Australian Air Quality Forecast System (AAQFS):

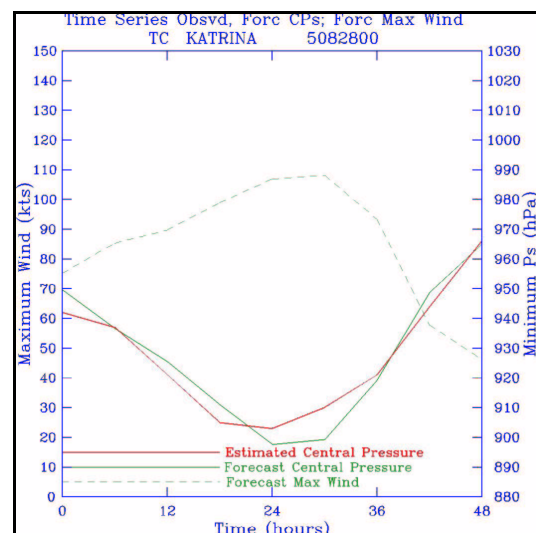
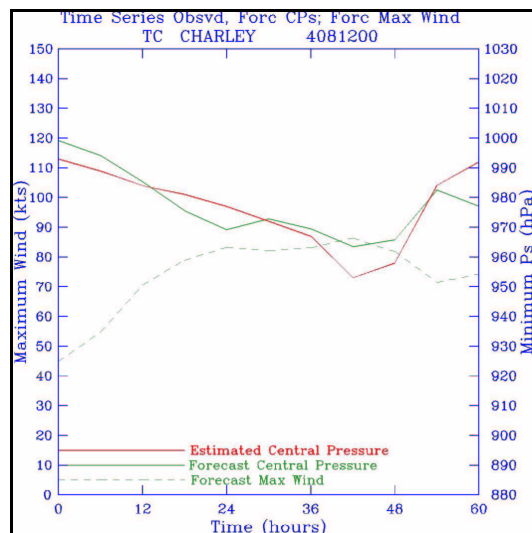
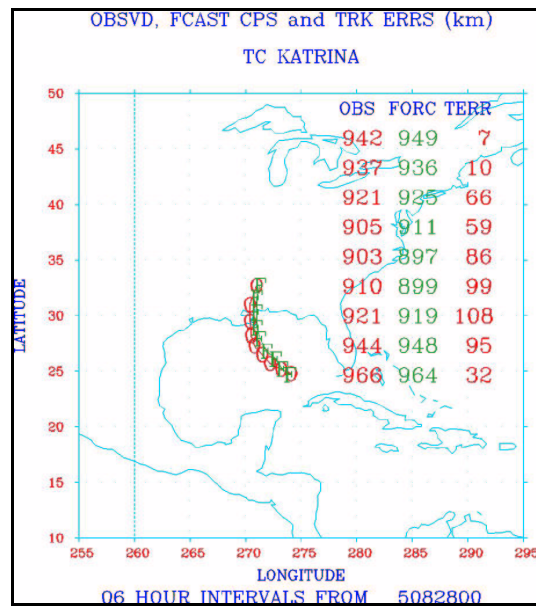
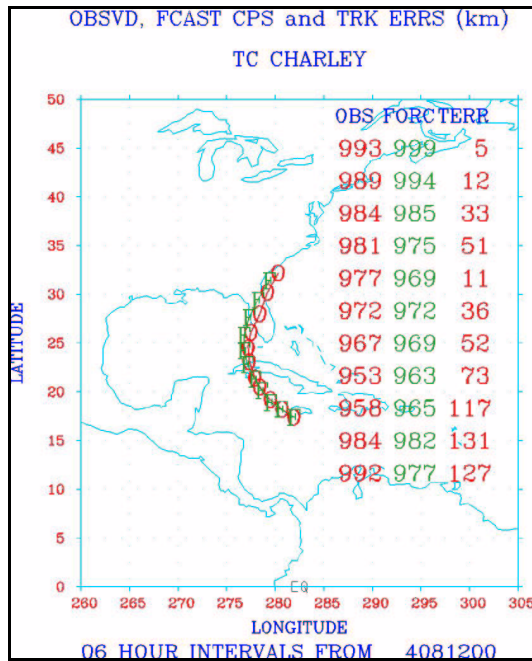
The AAQFS, currently in a near-operational state, provides a facility for generating air quality forecasts for regions including and surrounding the Australian capital cities. The system features a Chemical Transport Model (using the Generalised Reaction Scheme), an emissions data base or inventory and, eventually, an evaluation module. The system is an Eulerian

numerical forecasting system. Currently, the system is run over 6 airsheds: Sydney, NSW, Melbourne, Victoria, Adelaide and South Australia. The SYDNEY, VICTAS and ADELAIDE runs of MESO_LAPS provide the meteorological input to the system.

4.5.2.2 Research performed in this field

Tropical Cyclone Prediction:

The Australian Bureau of Meteorology's Tropical Cyclone Limited Area Prediction System (TCLAPS, Davidson and Weber, 2000) has been operational over the Australian Region and northwest Pacific since 1999. Forecast verification has been encouraging and has generally



Observed and forecast tracks and intensities for Charley (left panels) and Katrina from base times 00 UTC 12 August 2004, and 00 UTC 28 August 2005, respectively. The 3 columns in each of the upper panels show observed and forecast central pressures in hPa and track errors in km, respectively.

improved throughout the period. Long-term mean track and intensity errors at 48 hours are ~261 km and 22 hPa. Some remarkable forecasts of intensity have been obtained, but the quality tends to be inconsistent, suggesting that the system is capable of making skilful intensity forecasts, but the skill is often limited by errors in either initial vortex structure or the large-scale environment.

Prompted by these deficiencies, three main areas of Research and Development have been targeted:

- (1) a new vortex specification technique (Weber, 2007, a personal communication to BMRC), is being tested to improve initial vortex structure and fit observational data more consistently;
- (2) revised initialization methods have been developed to balance the vortex and introduce convective asymmetries into initial conditions based on satellite cloud imagery;
- (3) detailed diagnostic studies are being made of rapid intensification and the role of asymmetries, with a longer-term aim of possibly including features such as secondary wind maxima and other asymmetries in the vortex specification.

Testing has been mostly performed over the North Atlantic (Davidson et al., 2006), where more comprehensive observational data sets are available to define the large-scale environment and vortex structure and, importantly, for use in verification. An example of the quality that can be achieved is shown in the accompanying plots. The forecasts, showing track and intensity for Hurricanes Charley and Katrina, are most encouraging.

Dispersion Studies:

Evaluation of the relative performance of HYSPLIT and AAQFS was performed for 2 case studies, viz.: a dust storm in 2002 (Wain et al 2006) and a bushfire on King Island in 2001 (Hess et al 2006). User experiences, with smoke dispersion forecasts made with HYSPLIT, were also evaluated (Wain et al. 2007). Research on dynamic plume height specification, for WA Smoke forecasts, led to its operational implementation.

Wind Energy:

Research into downscaling methods for point forecasts of wind, with particular application to wind energy prediction, was carried out.

4.5.3 Specific products operationally available

Rainfall Analysis:

Daily rainfall analysis products are generated for the Australian and South-east Australian domains.

Sea Wave Models:

Products from the sea wave models include:
. charts of wind wave and swell wave heights;
. significant wave spectra and probabilities.

Solar Ultraviolet (UV) Radiation Forecast System:

Currently, forecasts of the UV index and UV alerts are produced, once per day, after completion of the 1200 UTC run of GASP.

Atmospheric Transport Model - EER System:

Products from the EER system include:

- . forecast forward and backward trajectories and dispersion;
- . analysed backward trajectories;
- . analysed retro-plumes.

Dispersion products are available for different nuclear and non-nuclear scenarios (eg air-borne viruses, smoke and volcanic ash) and different domains ranging from the meso to the global scale. Forecast products out to 10 days ahead can be produced. Retro-plumes going back 20 days are available operationally. Products for external use are made available through a number of password-protected registered users.

National Thunderstorm Forecast Guidance System (NTFGS):

Graphical products, covering the Australian continent, are generated to depict areas of likely thunderstorms, severe convective weather, supercells and tornadoes.

Operational Consensus Forecasts (OCF):

Forecasts from OCF are generated for temperature (maximum, minimum, and ground minimum), rainfall (amount and probability), sunshine hours and evaporation, for a large number of sites (~650) throughout Australia.

Poor Man's Ensemble (PME) Precipitation Forecasts:

PME generates forecasts out to +5 days of simple ensemble means, probability-matched means, and probability of precipitation for thresholds of 1, 5, 10, 15, 25 and 50 mm/day.

Fire Weather system:

Products generated by the operational FIRE_WEATHER system, for both Australian and South-East Australian domains, include:

- . Keetch-Byram Drought Index;
- . Mount Soil Dryness Index;
- . low and high vegetation Soil Dryness indices;
- . drought factors based on KBDI and SDI;
- . forest fire danger indices based on KBDI and SDI;
- . grassland fire danger index (100% curing factor).

Microscale Dispersion Modelling System:

Forecast dispersion plots for specific locations within the various MESO_LAPS domains can be generated on demand. Horizontal domains are limited in extent to 1x1, 4x4 and 20x20 km². Plots are also available for horizontal and vertical spread, mean plume height, mean concentration at ground, and travel time against distance from the source.

Australian Air Quality Forecast System (AAQFS):

AAQFS products include forecasts (up to 36 hours) of: Air Quality Index and Air Particle Index, and concentrations of: O₃, SO₂, CO, NO, PM_{2.5}, PM₁₀, ROC, C₆H₆ and Tracer gases, for each of the 6 airsheds.

4.6 Extended Range Forecasts (ERF) (10 days to 30 days)

4.6.1 In operation

BMRC continues to support real-time monitoring and empirical prediction of tropical convectively coupled wave modes, including the MJO (Madden Julian Oscillation).

4.6.2 Research performed in this field

BMRC has been involved in the US CLIVAR MJO Metrics working group, who are developing basic metrics of the MJO to be used for verification of model simulations and forecasts.

The POAMA (Predictive Ocean Atmosphere Model for Australia) dynamical seasonal prediction system is being extended to also provide predictions on shorter (~weeks) time scales. A key component that has been developed, likely to lead to increased skill on these shorter time scales, is an Atmosphere-Land Initialisation (ALI) scheme. In this scheme the atmospheric 3D structure is nudged to pre-existing analyses (e.g. ERA40 in hind-mode or Bureau NWP in real-time) and the land surface is left to adjust to atmospheric forcing. This allows the same land and atmosphere model to be used for initialisation and coupled forecasts and also allows consistency between real-time forecasts and hind-casts.

4.6.3 Operationally available ERF products

Diagnostics and predictions associated with tropical convectively coupled wave modes, including the state of the MJO and its expected behavior for the next 3 weeks, are made available on a web page and are updated in near real-time.

4.7 Long Range Forecasts (LRF) (30 days up to 2 years)

4.7.1 In operation

A three-month rainfall seasonal climate outlook is prepared. Each month, a risk-assessment for three-month total rainfall across Australia is issued mid-month for the three-month period starting the following month. Probabilities are calculated for the three-month total rainfall being in the lowest one-third of historical falls (tercile 1), the middle one-third (tercile 2), and the upper one-third (tercile 3). The technique used is discriminant analysis, with the inputs being derived from recent Sea Surface Temperature (SST) patterns. Subsidiary techniques involved in the forecast model include principal component analysis of SSTs for the Pacific Ocean, Indian Ocean and Southern Ocean, and principal component analysis of rainfall patterns across Australia. SST EOF (Empirical Orthogonal Function) loadings, at one and three months lag, for the Pacific Ocean ENSO pattern and the Indian Ocean pattern are the current predictor inputs. The tercile probabilities, computed across Australia on a 1⁰x1⁰ grid are published in the form of contoured maps, tabulated averages for the 107 Australian rainfall

districts, and tabulated interpolations for cities and towns around Australia. Similar outlooks are also provided for above/below median seasonal rainfall and additionally for both maximum and minimum (three-month average) temperatures (tercile and median probabilities).

Additional guidance at the rainfall district level is presented in the form of stratified rainfall climatologies based on recent values of the SOI (Southern Oscillation Index). Rainfall outcomes for eastern Australia, obtained from SOI analogues, are also described.

An ocean model for climate monitoring and seasonal prediction is run daily with forcing provided by GASP. Assimilation of ocean (sub-surface) observations is performed every three days.

Ocean-Atmosphere Coupled Model:

The same ocean model, referred to above, is also used to provide the ocean initial conditions and ocean component of a seasonal to interannual coupled ocean/atmosphere general circulation model known as POAMA (Predictive Ocean Atmosphere Model for Australia). Atmospheric initial conditions are obtained from the operational runs of GASP. The atmospheric component of the coupled system is essentially the same model as the operational GASP but run at the reduced resolution: T47L17 (ie Triangular 47, 17 vertical levels). Ten month forecasts are produced daily from this system and used as monthly, or last 30 day, ensemble forecasts for the seasonal outlooks.

4.7.2 Research performed in this field

The POAMA (Predictive Ocean Atmosphere Model for Australia; Alves et al 2003) system continues to be developed. The POAMA-1.5 system has now been assembled and is an interim version between POAMA-1 (that went operational in 2002) and POAMA-2 (due for operational implementation in 2007/8).

The main modules in POAMA-1.5 that have evolved from POAMA-1 include the ocean model ACOM2, the atmospheric model BAM3 and the OASIS2 coupler. These modules include some re-tuning/improvements, for example, improved stress/current coupling, higher coupling frequency and re-tuned ocean vertical mixing.

A new component is an atmosphere and land initialisation scheme (ALI), described previously in Section 4.6.2. This has been designed to initialise the atmosphere and land in a way that is consistent with existing re-analyses in hind-cast mode and real-time operational analyses in real-time mode. This is expected to lead to improved intra-seasonal and seasonal forecasts. A detailed evaluation of the impact of this scheme is underway.

Preliminary hind-casts from the POAMA-1.5 system show increased skill in SST. A comprehensive set of hind-casts is underway and more thorough analyses of skill, including skill of regional rainfall and temperature, will be performed before operational implementation.

4.7.3 Operationally available products

A comprehensive hind-casts set will be produced for the past 25 years from POAMA-1.5.

For each month, a 10 member, 9-month forecast will be generated, thereby producing a hindcast set of some 27,000 months. Statistical calibration and bridging techniques are being developed as part of the South East Australian Climate Initiative that will deliver improved forecasts of SST, rainfall and other products. Operational trials will start in mid 2007.

Another focus of POAMA-1.5 will be a trial intra-seasonal forecast system. Because the hind-casts are initialised with true atmospheric and land states the system doubles as an intra-seasonal forecasts system. Skill will be explored on time scales of weeks and products made available, for example, for the Madden Julian Oscillation (MJO) and monsoon onset.

POAMA-2 builds on POAMA-1.5, and includes increased atmospheric resolution and a new ocean data assimilation system called POAMA Ensemble Ocean Data Assimilation System (PEODAS). PEODAS is based on an extension of the BODAS (Bluelink Ocean Data Assimilation System) (Oke et al 2005) into a pseudo-ensemble Kalman Filter. In this system a multi-variate three dimension OI approach is used and takes covariances from a time evolving ensemble (Alves and Robert, 2005). For the first time, salinity data will be assimilated. PEODAS will be used to perform a 25-year re-analysis and will be run in real-time and will provide initial conditions for the POAMA-2 system.

5. VERIFICATIONS OF PROGNOSTIC PRODUCTS

5.1 Annual Verification Summary

An annual summary of verification statistics for 2006, for the Australian regional and global schemes, is given in the following tables.

The following abbreviations have been used in the tables:

- S1 - 30 day mean Teweles skill score over Australian verification area
- r - anomaly correlation coefficient between forecast heights and climatology over Australian verification area
- PERSIS - 24, 36 or 48 hour persistence prediction
- REGN - Australian Regional LAPS (Limited Area Prediction System)
- GASP - Global Assimilation and Prognosis model
- RMSE - Root Mean Square Error

Note:

The LAPS and GASP results are with respect to their own analyses, but on a common grid.

Skill Scores and Anomaly Correlation Coefficients:

24 HR VERIFICATION STATISTICS - AUSTRALIAN REGION 2006

BASE TIME: 0000UTC - VALID TIME: 0000UTC

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
M S L P	S1	PERSIS	54	56	56	54	54	51	57	58	54	58	58	58
	S1	REGN	19	19	20	20	20	20	18	17	17	18	19	18
	r	REGN	.96	.96	.97	.98	.96	.95	.98	.97	.97	.98	.97	.97
5 0 0 h p a	S1	PERSIS	44	52	53	47	50	49	50	46	50	48	45	49
	S1	REGN	13	16	16	14	16	17	14	11	12	14	12	13
	r	REGN	.98	.97	.98	.98	.98	.97	.98	.98	.98	.97	.98	.98
2 5 0 h p a	S1	PERSIS	40	47	45	40	42	39	38	36	38	42	41	45
	S1	REGN	12	13	13	12	12	12	10	8	9	11	10	11
	r	REGN	.98	.97	.98	.98	.98	.97	.98	.98	.98	.98	.98	.98

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
M S L P	S1	PERSIS	55	56	56	54	54	51	57	59	54	58	59	58
	S1	GASP	17	17	18	18	17	18	16	15	15	16	17	17
	r	GASP	.97	.97	.98	.98	.98	.96	.98	.98	.98	.98	.98	.98
5 0 0 h p a	S1	PERSIS	44	51	53	47	50	50	51	46	49	49	46	49
	S1	GASP	12	15	14	13	15	15	13	11	12	12	12	12
	r	GASP	.98	.97	.98	.98	.98	.98	.99	.98	.98	.98	.98	.98
2 5 0 h p a	S1	PERSIS	41	48	46	41	42	40	39	37	39	43	42	45
	S1	GASP	11	12	12	11	12	12	9	8	10	10	10	11
	r	GASP	.98	.97	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98

36 HR VERIFICATION STATISTICS - AUSTRALIAN REGION 2006

BASE TIME: 1200UTC - VALID TIME: 0000UTC

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
M S L P	S1	PERSIS	60	62	65	66	62	61	68	69	61	66	69	66
	S1	REGN	24	24	25	26	26	26	23	22	21	22	23	22
	r	REGN	.93	.93	.94	.96	.93	.91	.96	.95	.95	.96	.96	.96
5 h 0 e 0 i h g p h a t	S1	PERSIS	51	59	62	55	57	58	59	53	55	55	54	59
	S1	REGN	17	21	20	19	22	21	18	15	17	18	16	18
	r	REGN	.96	.94	.96	.96	.95	.94	.96	.96	.96	.95	.97	.97
2 h 5 e 0 i h g p h a t	S1	PERSIS	46	53	53	47	48	45	46	42	44	49	49	54
	S1	REGN	15	18	17	16	17	16	13	11	13	15	14	16
	r	REGN	.96	.93	.96	.96	.96	.95	.96	.96	.95	.95	.96	.96

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
M S L P	S1	PERSIS	61	63	66	66	63	62	69	69	60	67	70	66
	S1	GASP	22	23	24	22	24	24	22	20	19	21	22	21
	r	GASP	.95	.94	.95	.97	.95	.93	.96	.95	.96	.97	.96	.96
5 h 0 e 0 i h g p h a t	S1	PERSIS	52	60	63	55	58	59	60	53	54	56	54	59
	S1	GASP	16	19	19	17	20	20	17	15	16	17	16	17
	r	GASP	.97	.95	.97	.97	.96	.95	.97	.96	.97	.96	.97	.97
2 h 5 e 0 i h g p h a t	S1	PERSIS	47	54	55	48	49	46	47	43	43	50	49	54
	S1	GASP	14	16	16	14	17	16	12	11	13	15	14	15
	r	GASP	.97	.95	.97	.97	.96	.95	.97	.97	.96	.95	.97	.96

48 HR VERIFICATION STATISTICS - AUSTRALIAN REGION 2006

BASE TIME: 0000UTC - VALID TIME: 0000UTC

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
M S L P	S1	PERSIS	64	65	69	73	65	65	75	71	65	69	74	73
	S1	REGN	29	29	31	31	32	31	29	28	27	29	26	26
	r	REGN	.88	.88	.91	.93	.88	.85	.93	.90	.92	.93	.94	.94
5 0 0 h p a	S1	PERSIS	57	61	66	60	61	60	65	56	58	57	57	64
	S1	REGN	22	25	26	23	27	26	23	20	22	23	18	21
	r	REGN	.93	.90	.93	.94	.92	.89	.93	.92	.93	.91	.95	.95
2 5 0 h p a	S1	PERSIS	51	55	58	50	52	46	51	45	46	51	51	59
	S1	REGN	18	21	22	19	21	20	16	14	16	20	16	19
	r	REGN	.93	.90	.92	.93	.92	.91	.93	.93	.92	.91	.95	.94

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
M S L P	S1	PERSIS	65	65	70	73	65	65	75	72	64	70	75	73
	S1	GASP	26	27	28	28	29	29	27	24	24	26	26	24
	r	GASP	.91	.91	.93	.94	.91	.89	.94	.93	.94	.95	.95	.94
5 0 0 h p a	S1	PERSIS	57	61	67	60	61	61	65	56	57	57	57	64
	S1	GASP	19	23	22	20	25	25	21	18	20	21	18	19
	r	GASP	.95	.92	.95	.96	.93	.92	.95	.94	.95	.93	.95	.95
2 5 0 h p a	S1	PERSIS	52	55	58	51	52	47	51	46	46	52	51	60
	S1	GASP	17	20	19	18	20	20	15	13	16	17	17	18
	r	GASP	.95	.92	.94	.95	.94	.93	.95	.95	.93	.93	.95	.95

Root Mean Square Errors (Annual 2006):

(a) Verification against GASP analyses:

AREA	FIELD	RMSE or RMSVE UNIT	+24HR		+72HR		+120HR	
			00UTC	12UTC	00UTC	12UTC	00UTC	12UTC
Northern Hemisphere	500 hPa Height	m	16.2	16.2	42.0	42.6	70.6	70.9
	250 hPa Wind	m/s	5.4	5.4	11.7	11.7	17.0	17.0
Southern Hemisphere	500 hPa Height	m	17.9	17.6	47.6	46.9	77.5	76.8
	250 hPa Wind	m/s	5.7	5.7	12.1	12.1	17.3	17.2
Tropics	850 hPa Wind	m/s	2.8	2.9	4.1	4.2	4.7	4.7
	250 hPa Wind	m/s	4.6	4.6	7.3	7.3	8.8	8.8

(b) Verification against radiosondes:

AREA	FIELD	RMSE or RMSVE UNIT	+24HR		+72HR		+120HR	
			00UTC	12UTC	00UTC	12UTC	00UTC	12UTC
North America	500 hPa Height	m	19.2	19.4	50.3	52.7	82.5	82.8
	250 hPa Wind	m/s	17.2	17.2	19.3	19.4	21.8	22.0
Europe	500 hPa Height	m	23.7	22.0	48.0	47.2	82.6	80.8
	250 hPa Wind	m/s	15.2	15.1	16.5	16.5	19.3	18.5
Asia	500 hPa Height	m	22.1	23.3	42.1	43.4	63.3	64.0
	250 hPa Wind	m/s	18.3	18.1	17.0	16.9	17.7	17.8
Australia/NZ	500 hPa Height	m	17.4	21.3	29.2	40.5	45.0	63.2
	250 hPa Wind	m/s	13.6	14.1	14.2	14.9	15.8	16.8
Tropics	850 hPa Wind	m/s	4.5	4.4	4.4	4.3	4.4	4.3
	250 hPa Wind	m/s	7.1	7.3	7.7	7.9	8.2	8.6
Northern Hemisphere	500 hPa Height	m	22.8	22.6	49.7	50.8	80.6	80.2
	250 hPa Wind	m/s	16.1	16.0	17.0	17.0	19.1	19.0
Southern Hemisphere	500 hPa Height	m	20.7	22.9	36.0	43.6	55.1	65.9
	250 hPa Wind	m/s	14.5	15.5	15.3	16.6	16.9	18.4

5.2 Research performed in this field

The use of fuzzy (multi-scale) neighbourhood techniques to verify high resolution precipitation forecasts against radar observations is being investigated. The aim is to use objective methods to give credit to "close" forecasts at lead times exceeding the limit of deterministic predictability. Preliminary results are described by Ebert (2007).

6. PLANS FOR THE FUTURE (NEXT 4 YEARS)

6.1 Development of the GDPFS

6.1.1 Major changes in the Operational DPFS which are expected in the next year

Plans for operational systems in the NMOC Melbourne include:

- . the setting up of MESO_LAPS (Australian domain) to run off the additional base times 06 and 18UTC;
- . enhancements to GASP incorporating: increased vertical resolution to 60 levels (up to 0.1 hPa), multi-node MPI version, locally derived cloud drift winds;
- . ongoing improvements to LAPS and TXLAPS including: more vertical levels (61), multi-node MPI version, warm running;
- . an increase in the number of vertical levels to 61 for all the MESO_LAPS configurations;
- . the operational implementation of a high resolution surface analysis;
- . the introduction of a gridded version of OCF, and an extension OCF to provide sea-state forecast guidance;
- . the implementation of the Australian Digital Forecast Database (ADFD), incorporated within the current real-time relational database;
- . the introduction of the Graphical Forecast Editor (GFE) into NMOC and Regional Offices;
- . the full operational implementation of the GASP Ensemble Prediction System, along with an appropriate verification scheme;
- . an upgrade to the coupled ocean-atmospheric model (POAMA) for seasonal analysis and prediction, along with further development of products;
- . the introduction and development of a tsunami operational modelling capability using scenario selection initially (with input bathymetry);
- . the operational implementation of the AAQFS (Australian Air Quality Forecasting System) for an Australian-wide airshed, initially for smoke and dust forecast guidance;
- . an ongoing improvement to the operational Environmental Emergency Response System featuring: a unified wind input system, inclusion of a number of chemical transformations, time-dependent sources, ATM ensembles, automatic initiation of forecast plumes (when remotely sensed) and analysed retro-plumes (when CTBTO initiated);
- . the full implementation of a gaussian-type plume model (ADMS3) for the microscale;
- . the introduction of the HPAC (Hazard Prediction and Assessment Capability) system;

- . the further development of the air-borne virus facility within the EER system and extensions to the microscale dispersion and air quality systems;
- . implementation of LSDSS (Large Scale Data Storage System);
- . a move toward the use of a Linux cluster infrastructure;
- . preliminary work on the operational development and implementation of ACCESS.

6.1.2 Major changes in the Operational DPFS which are envisaged within the next 4 years

Long term plans for operational systems in the NMOC Melbourne include:

- . the operational implementation of ACCESS (Australian Community Climate Earth System Simulator), which incorporates the UK Met Office's Unified Model and 4DVAR, to replace the current global (GASP) and limited area systems (LAPS, TXLAPS and MESO_LAPS) run in NMOC with, maybe, some rationalisation of domains;
- . building and implementing the necessary operational interfaces between ACCESS and the many downstream systems (eg seastate, EER, AAQFS, POAMA, UV);
- . the operational development and implementation, within the ACCESS framework, of global and limited area ensemble systems, a very high resolution relocatable severe weather system, a TC-genesis system, and an associated storm surge system;
- . an upgrade of the rainfall analysis to use the Kriging method;
- . the implementation of a rainfall verification scheme;
- . the introduction of a National Rainfall Forecasting System;
- . the implementation of the MOST (Method of Splitting Tsunami) model, followed by an assimilation and forecast system (incorporating tidal gauge observations);
- . the rationalisation and upgrade of verification systems;
- . building an effective interface between the EER system and the decision support system ARGOS-CBRN, used by various agencies;
- . the ongoing improvement and generalization of data processing and graphical display (including the full integration of MARS and METVIEW and, eventually, a GIS, and the development of high-resolution background products);
- . the improvement in data monitoring systems;
- . the improvement in product dissemination methods.

6.2 Planned Research Activities in NWP, Nowcasting and Long-range Forecasting (for next 4 years)

6.2.1 Planned Research Activities in NWP

ACCESS:

All effort will be directed towards ACCESS development, and the implementation and testing of the associated assimilation and forecast systems, in the chosen configurations.

Work will be carried out on MOGREPS (Met Office Global and Regional Ensemble Prediction System) with an appropriate choice of configurations. Associated research work will be carried out on ensemble and probabilistic forecasting systems.

Particular emphasis will be placed on development of the physical parameterisations, for example, the feasibility of incorporating the local "SES2" radiation scheme inside ACCESS will be determined.

Extensions of ACCESS, in collaboration with Met Office, with respect to assimilation, will include:

- . dynamic Diabatic Initialization for Tropical Cyclones;
- . improved use of satellite sounding data - in particular AIRS and IASI;
- . use of WindSAT;
- . investigation in to use of satellite data at high resolution within regional and meso-scale modelling systems;
- . use of remotely sensed soil moisture data from AMSR-E and SMOS;
- . improved use of near surface temperature, dew point and wind in the Australian region;
- . dynamic background error covariance specification;
- . use of upgraded ground based GPS receiver network over Australia (increase current network by over 120 stations) to estimate integrated Water Vapour;
- . use of precipitation affected microwave radiances;
- . improved use of SSM/I and SSMIS radiances in regional models.

GFE and GRIDDED OCF:

Development will be completed with a national rollout occurring during 2008.

Tropical Cyclones:

Research support for the Tropical Cyclone genesis forecast system is planned.

Solar Ultraviolet (UV) Radiation Forecast System:

Plans for the operational UV forecasting system include:

- . the "nudging" of OMI total ozone data into the assimilation and ozone forecast step;
- . the building of an interface to the new ACCESS global atmospheric model and data assimilation system.

Smoke Dispersion:

The development and testing of ensemble smoke forecasts is planned. Research on smoke dispersion forecast verification, using real fire events including multi-day fires, will continue.

6.2.2 Planned Research Activities in Nowcasting

Nowcasting:

Research, associated with the use of radar, includes:

- . improved identification and removal of anomalous propagation in radar data
- . developing techniques to mosaic multiple radars together
- . ensemble thunderstorm tracking
- . phenomena probability forecasting based on radar algorithm output.

Meso-Scale Assimilation:

A meso-scale assimilation system for the south-eastern Australia domain (SA, NSW/Vic/Tas) is being evaluated using horizontal resolution of 10 km with 60 levels in the vertical.

6.2.3 Planned Research Activities in Long-range Forecasting

In the longer term the POAMA system will be built from components developed as part of ACCESS. ACCESS aims to develop an Australian earth system model for a range of applications, including seasonal prediction. New components developed by the ACCESS project include a new atmospheric model based on the UK Met Office atmospheric model and the CABLE land-surface model. The exact configuration of these systems remains to be decided and will depend on computational costs and scientific performance. The ocean model developed as part of the ACCESS project will be based on the GDFL MOM4 code and will have a configuration called AusCOM (Australian Climate Ocean Model) which will be used for a range of climate studies.

In the longer term there will be a focus on coupled data assimilation, with ocean data being assimilated directly into the ocean model using the PEOODAS approach while, at the same time, constraining the atmosphere and land to pre-existing analyses.

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