STATUS OF THE AVAILABILITY AND USE OF SATELLITE DATA AND PRODUCTS BY WMO MEMBERS

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EXECUTIVE SUMMARY

This document provides the results of the evaluation of a questionnaire that was distributed in 2001 to WMO Members in order to assess the status of the availability and use of satellite data and products.

The Commission for Basic Systems (CBS) Open Programme Area Group on Integrated Observing Systems (OPAG-IOS) has the strategic goal to improve systematically the utilization of the capabilities of the space-based component of the Global Observing System with emphasis on improving the utilization of satellite data and services in developing countries. This should be assisted by means of a recurring review and monitoring activity, based on information obtained from a dedicated biennial questionnaire. The questionnaire in 2001 was part of the request for input to the biennial WMO Application of Satellite Technology Progress Reports.

Sixty-nine Members, a slightly higher number than two years before, responded in 2001, corresponding to an average of nearly 40% of WMO Members. The statistical basis for drawing conclusions from an analysis of the questionnaire is sound for some Regions, especially for Regions II, III and VI, whereas some caution should be applied for Regions I and IV. Where possible, the evaluation results have been compared with the responses given to previous questionnaires.

A summary of conclusions and recommendations is given at the end of this document. In general, the following statements can be made:

- Most Members, at least those who responded to the questionnaire, are equipped with satellite receiving facilities, most of them for the reception of analogue picture data from geostationary satellites; the number of APT systems for the reception of low earth orbit satellite data seems to be decreasing and the number of HRPT stations is still rather low;

- Typically, the number of staff involved in satellite meteorology at a NHMS is relatively small: 1-3 operators, 1-3 technicians, 2-4 meteorologist. There seems to be an increase in the number of meteorologists in RA I, but a slight reduction in a few other Regions. It is difficult to assess whether the lack of personnel was a limiting factor for improved utilization of satellite data as some contradictory responses are given - a slight decrease in limitations resulting from a reported lack of staff as opposed to no significant change in the number of staff active in satellite meteorology;

- The most frequent use of satellite data is for image interpretation with an obvious transition from the use of analogue to digital image data. Satellite sounding data and products are used in less than 50% of the responding NMHSs. An increase in the use of satellite products from other sources can also be noted;

- Cloud parameters are still the most important parameters for nearly all applications. Of equal importance is an atmospheric instability index to be obtained from either a quasi-sounding capability on all GEO satellites or LEOs with considerably higher density. The most required, but not available, parameters are precipitation rate, followed by wind profiles and cloud base.

- There is an increase in the number of responses reporting limiting factors in the use of satellite data and products. It can be assumed that more NMHSs are becoming aware of the derived benefits of satellite system data and products, but encounter difficulties in their operational use;

- In total 1,229 personnel were reported in 2001 to have been trained. There are plans to train 1,695 personnel in the following two years. Internal training was the most typical method, distant learning was utilized for less than 4% of training activities. The most frequent training was carried out in satellite image interpretation followed by the fundamentals of remote sensing. In general, the level of training activity seems to be satisfactory.

1. INTRODUCTION

1.1 WMO's Commission for Basic Systems (CBS) Open Programme Area Group on Integrated Observing Systems (OPAG-IOS) has the strategic goal to improve systematically the utilization of the space-based component of the Global Observing System's capabilities with emphasis on improving utilization of satellite data and services in developing countries. One of the means to achieve this is through a critical review and monitoring process of the availability and use of satellite data. The review and monitoring process will be performed continuously by means of a dedicated questionnaire included in the request for input from WMO Members to the biennial Application of Satellite Technology Progress Reports. The first questionnaire for this purpose was issued in 1996, a second edition in March 1999, and the present third edition in 2001. While each edition has been somewhat different, they have become more concise. The evaluation of the questionnaire was performed by a sub-group of the OPAG-IOS Expert Team on Improving Satellite System Utilization and Products. Results and conclusions from the WMO Member responses to the questionnaire are presented in the document.

2. QUESTIONNAIRE RESPONSES

2.1 The evaluation of the questionnaire is based on 69 responses, which were available to the authors of this document in December 2001. The number of responses provided a sound basis for a statistical evaluation resulting in a representative overview for some WMO Regions, but not for all. WMO Members who are part of more than one WMO Region were counted only once and were assigned to one region. The Russian Federation was included in RA VI.

2.2 In addition to the statistical analysis for the year 2001, a dynamical assessment of the status of availability of satellite data and products has been achieved through an analysis of the combined responses for 1996 and 1999, together with the responses to the 2001 edition of the questionnaire. With regard to the actual status of satellite ground receiving equipment, the best source is the WMO technical document entitled "Satellite Ground Receiving Equipment in WMO Regions (WMO TD No. 1021 (SAT-25)).

2.3 Nevertheless, a comparison is only possible when a WMO Member's report is present in at least two editions of the questionnaire where there have been standardized questions, i.e., for those questions that have remained unchanged in the two versions of the questionnaire.

2.4 Table 1 shows the number of replies to the three questionnaires (1996, 1999 and 2001). As can be seen, only 25 countries out of 184 WMO Members have answered all three editions and 53 countries have replied to at least one edition. By combining all questionnaires, it is possible to extract information from 117 countries, i.e., 64% of the total of WMO Members.

Table 1
Number of returned questionnaires

		2001	%	1999	%	1996	%	1996+ 1999+ 2001	%	1996+ 2001 or 1999+ 2001	%	1996/ 1999	%	1996/ 1999/ 2001	%
RA I	52	9	17	17	33	14	27	2	4	7	13	22	42	24	46
RA II	34	14	41	14	41	19	56	7	21	11	32	21	62	23	68
RA III	12	6	50	6	50	7	58	3	25	4	33	8	67	10	83
RA IV	22	6	27	2	9	6	27	0	0	4	18	7	32	9	41
RA V	17	7	41	2	12	8	47	1	6	3	18	9	53	13	76
RA VI	47	27	57	22	47	31	66	12	26	24	51	36	77	38	81
Total	**184**	**69**	**38**	**63**	34	**85**	46	**25**	14	**53**	29	**103**	56	**117**	64

2.5 The questionnaire was structured in the following manner with the chapter number referring to a corresponding question number:

1. Access to data at the NMHS
1.1 Summary of data availability
1.2 Access and processing of satellite data

2. Satellite data and product
2.1 Application areas and important parameters

3. Limiting factors in the use of satellite data and products
4. Education and training in satellite meteorology
5. Research and development
6. Questionnaire
7. General comments

Most of the answers could be provided by filling in prepared boxes in the questionnaire. A copy of the questionnaire is contained in the Annex.

3. EVALUATION RESULTS

3.1 As a general comment, it should be noted that some answers were unclear or confusing. If they were considered as originally submitted, i.e., without a critical analysis of the answers, the results would have been misleading and led to a large understatement of the actual capability in the use of satellite data and products which was not the case. Therefore, whenever possible, the answers have been interpreted/analysed and internal consistency has been taken into account.

3.1 Data availability

3.1.1 Data availability in general

3.1.1.1 Overall analyses of data availability are reported in Tables 2 to 7. For each region, the percentage of countries that responded to the questionnaire and having access to a certain type of data is reported for each of the three years (1996, 1999 and 2001) for which a questionnaire existed. Since the countries that responded for the different years were not necessarily the same, (very few countries responded to all questionnaires, e.g., no Member in RA IV and only one in

RA V), a comprehensive dynamical assessment of the level of availability could not be performed based on the tables.

3.1.1.2 In order to assess the evolution through the years, the countries that responded to at least the 1996 or 1999 questionnaires, as well as the countries that responded to at least one questionnaire out of the three (see also Table 1) have been considered. In Tables 2 to 7, the column labelled “Total 1999” contains the resulting percentage from Members answering at least the 1996 or 1999 questionnaires while the column labelled “Total 2001” contains the resulting percentage from Members replying to at least one questionnaire. In this respect, the “Total” columns can be considered as representative of the countries in the region and thus be compared more consistently.

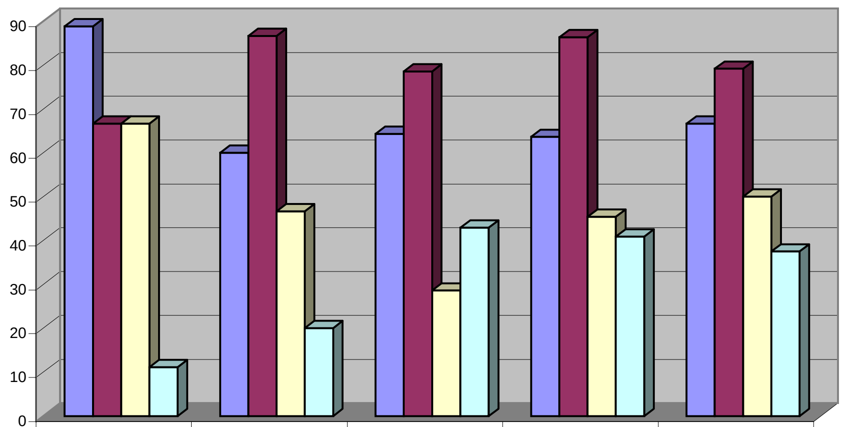
3.1.1.3 Through an in-depth analysis of the individual responses from each Member, the following statements can be made:

(1) Regional Association I (Africa)

A dynamical assessment was possible for 7 countries, while only 2 answered all of them. It should be noticed that one Member (Egypt) acquired a HRPT station. For other countries, the situation remained unchanged, the main access was still to GEO data as compared to LEO data. While the overall situation for the region showed that most countries still relied on WEFAX systems, there tended to be an increase of the number of digital systems, indicating that many countries have both systems in operation. For the polar orbiting data, there was a steady increase of HRPT systems, while the interest in APT stations continued to decrease.

Table 2

MEANS OF AVAILABILITY OF SATELLITE DATA IN RA I



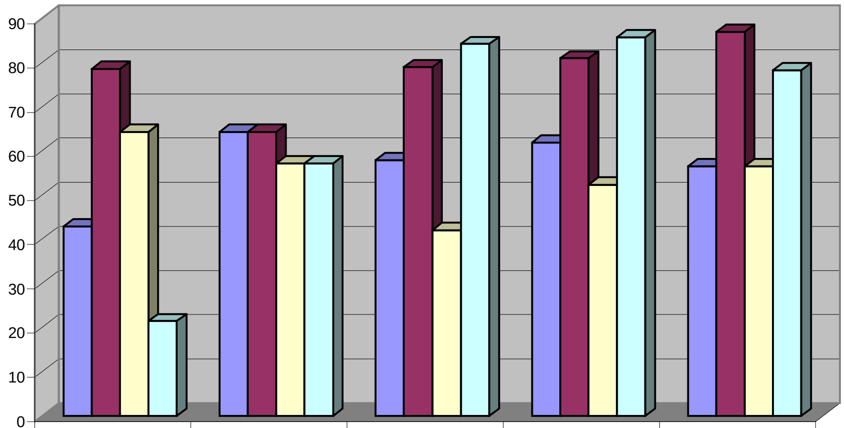
	2001	1999	1996	TOTAL 1999	TOTAL 2001
GEO HR	89	60	64	64	67
GEO WEFAX	67	87	79	86	79
LEO HRPT	67	47	29	45	50
LEO APT	11	20	43	41	38

(2) Regional Association II (Asia)

A dynamical assessment was possible for 11 countries. Two Members (Pakistan and Vietnam) have acquired a HRPT capability for NOAA. The situation remained unchanged for the others. The overall situation was still based on analogue systems (WEFAX and APT), while there was a tendency to acquire HRPT stations, compared to APT stations, leading to an estimate that half the Members in the region operate both digital systems.

Table 3

MEANS OF AVAILABILITY OF SATELLITE DATA IN RA II



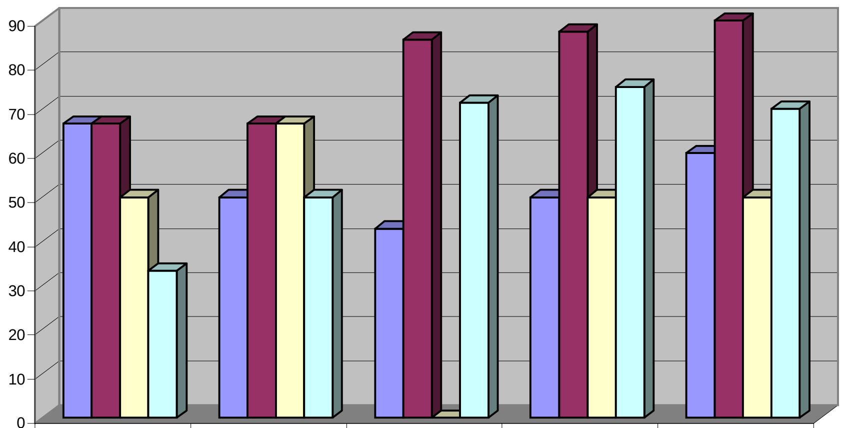
	2001	1999	1996	TOTAL 1999	TOTAL 2001
GEO HR	43	64	58	62	57
GEO WEFAX	79	64	79	81	87
LEO HRPT	64	57	42	52	57
LEO APT	21	57	84	86	78

(3) Regional Association III (South America)

A dynamical assessment was possible for 4 countries. HR stations for GOES have been implemented in 2 countries since the last edition. The situation remained unchanged for the others. In this regard, even with the lack of available information, it can be seen that there was a strong increase in the estimated number of HRPT stations since the first survey.

Table 4

MEANS OF AVAILABILITY OF SATELLITE DATA IN RA III



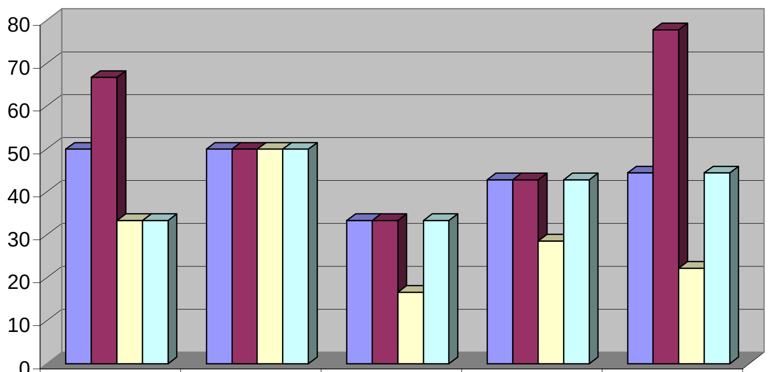
	2001	1999	1996	TOTAL 1999	TOTAL 2001
GEO HR	67	50	43	50	60
GEO WEFAX	67	67	86	88	90
LEO HRPT	50	67	0	50	50
LEO APT	33	50	71	75	70

(4) Regional Association IV (North and Central America)

A dynamical assessment was possible for 4 countries. One Member acquired a HR system for GOES (Trinidad & Tobago). The evolution of satellite data access through Internet by one country (Dominican Republic), with greater priority given to GEO data compared to LEO should be noted. However, the number of digital receiving system was still at a very low level.

Table 5

MEANS OF AVAILABILITY OF SATELLITE DATA IN RA IV



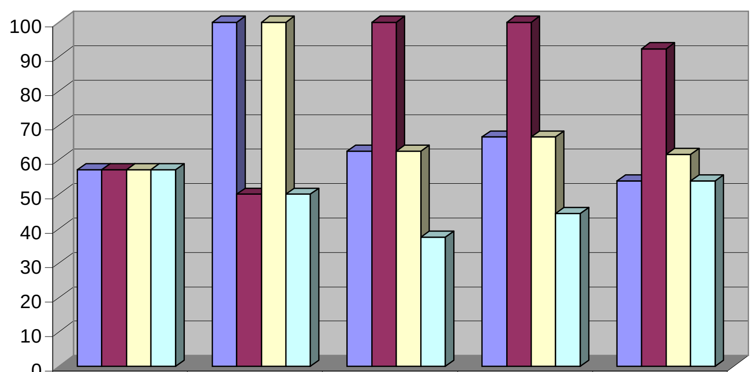
	2001	1999	1996	TOTAL 1999	TOTAL 2001
GEO HR	50	50	33	43	44
GEO WEFAX	67	50	33	43	78
LEO HRPT	33	50	17	29	22
LEO APT	33	50	33	43	44

(5) Regional Association V (South-West Pacific)

A dynamical assessment was possible for 3 countries. The situation remained unchanged for WMO Members with most having access to both WEFAX and APT images. A few Members expressed interest in Quickscat data. There was a major interest in polar satellites, whose data can be evaluated as having the same level of priority as GEO. The 100% availability for HRPT systems in 1999 was due to the lack of available information (only 2 members responded).

Table 6

MEANS OF AVAILABILITY OF SATELLITE DATA IN RA V

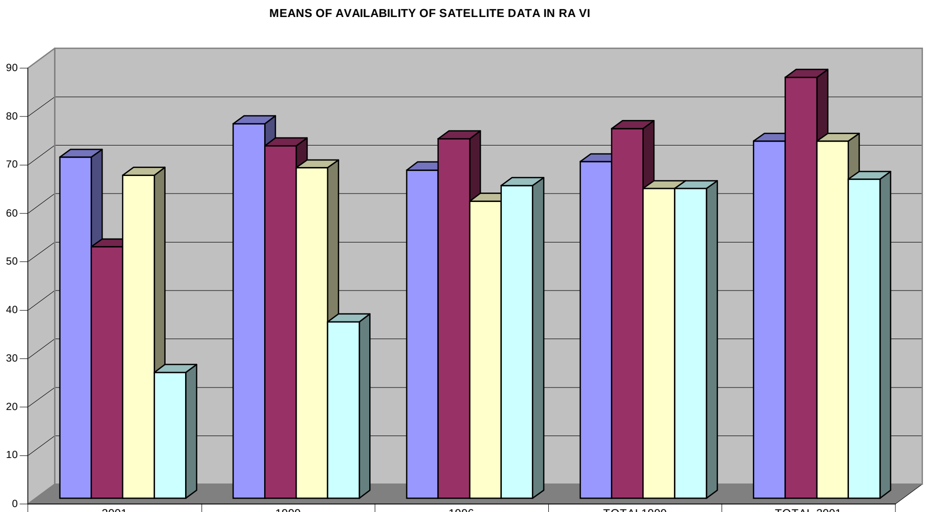


	2001	1999	1996	TOTAL 1999	TOTAL 2001
GEO HR	57	100	63	67	54
GEO WEFAX	57	50	100	100	92
LEO HRPT	57	100	63	67	62
LEO APT	57	50	38	44	54

(6) Regional Association VI (Europe)

A dynamical assessment was possible for 24 countries. RA VI was the region with the largest number of HR stations; new reception capabilities were noted with 2 new HRPT and 1 PDUS stations. Two Baltic countries rely on the TLC link with Sweden in order to have access to HR data.

Table 7



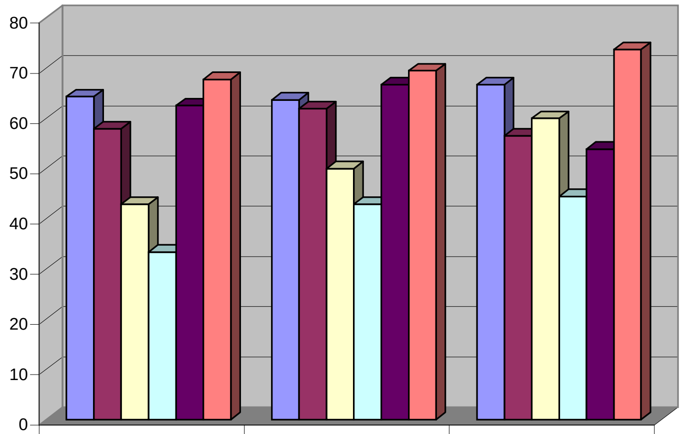
	2001	1999	1996	TOTAL1999	TOTAL 2001
GEO HR	70	77	68	69	74
GEO WEFAX	52	73	74	76	87
LEO HRPT	67	68	61	64	74
LEO APT	26	36	65	64	66

3.1.1.4 Tables 8 to 11 demonstrate the availability of various types of satellite data for each region. It should be noted that:

- GEO HR: Apart from the highest score for Region VI, a tendency to increase the use of GEO digital data can be detected mainly in RA I, IIII and IV. The estimated overall use of GEO HR data ranges from 44% (RA IV) to 74% (RA VI).

Table 8

AVAILABILITY (%) OF GEO HR DATA

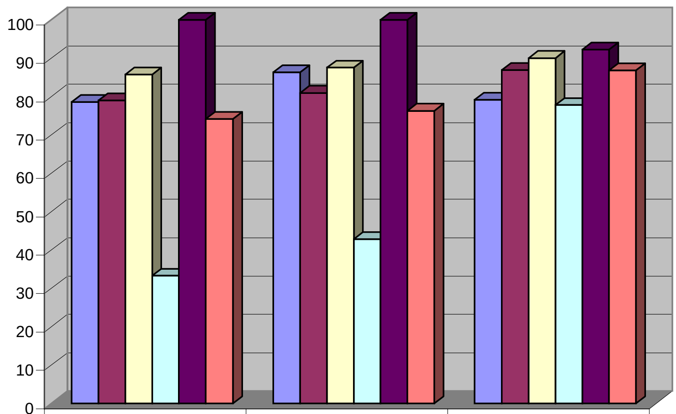


	1996	TOTAL 1999	TOTAL 2001
RA I	64	64	67
RA II	58	62	57
RA III	43	50	60
RA IV	33	43	44
RA V	63	67	54
RA VI	68	69	74

- GEO WEFAX: It was the most widely used data type with similar scores for every region. The estimated overall use of GEO WEFAX data ranges from 78% (RA IV) to 92% (RA V)

Table 9

AVAILABILITY (%) OF GEO WEFAX DATA

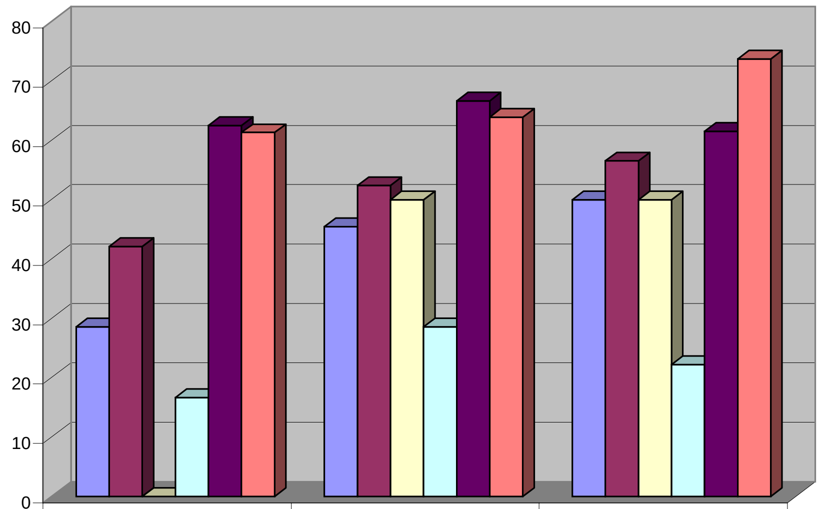


	1996	TOTAL 1999	TOTAL 2001
RA I	79	86	79
RA II	79	81	87
RA III	86	88	90
RA IV	33	43	78
RA V	100	100	92
RA VI	74	76	87

- LEO HRPT: The number of HRPT receiving systems was still rather low for all the regions, with a very low peak for RA IV. The estimated overall use of LEO HRPT data ranges from 22% (RA IV) to 74% (RA VI).

Table 10

AVAILABILITY (%) OF LEO HRPT

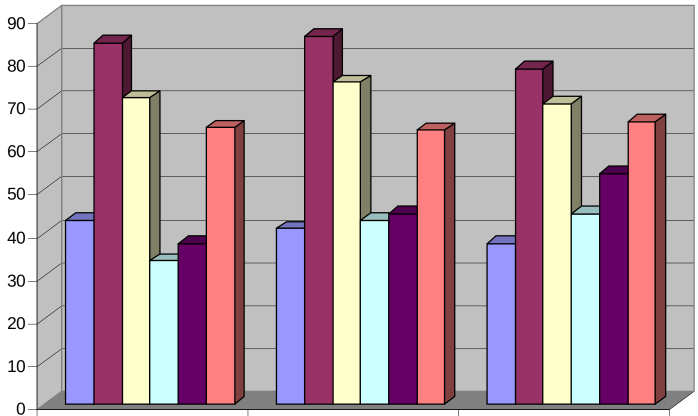


	1996	TOTAL 1999	TOTAL 2001
RA I	29	45	50
RA II	42	52	57
RA III	0	50	50
RA IV	17	29	22
RA V	63	67	62
RA VI	61	64	74

- LEO APT. The number of APT stations decreased amongst Members that were already equipped with digital systems, indicating that many NMHSs prefer to have access to digital data from polar orbiting satellites. The estimated overall use of LEO APT data ranges from 38% (RA I) to 78% (RA II).

Table 11

AVAILABILITY (%) OF LEO APT



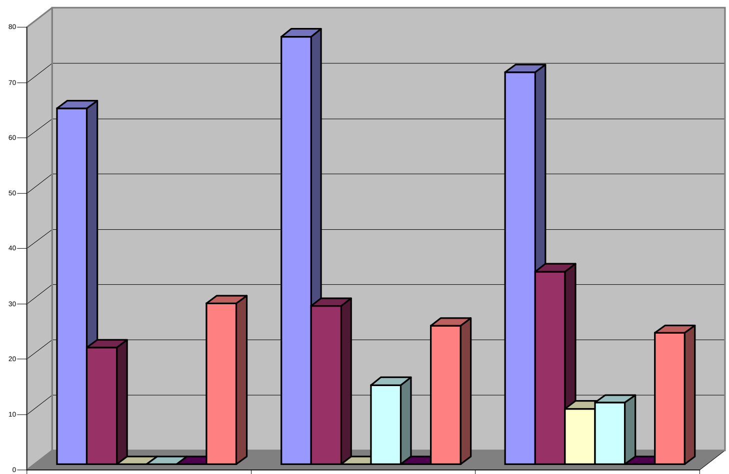
	1996	TOTAL 1999	TOTAL 2001
RA I	43	41	38
RA II	84	86	78
RA III	71	75	70
RA IV	33	43	44
RA V	38	44	54
RA VI	65	64	66

3.1.1.5 It can be concluded that most Members were equipped with satellite receiving facilities. However, there were many NMHS that neither had access to satellite data nor used them. In particular, the lack of information from Members in RA IV (mainly those from Central America) could imply a strong under-utilization of satellite data.

3.1.1.6 Regarding the access and use of other systems, the Meteosat Data Distribution (MDD) system was not only confined to RA I as a complement to the GTS, but there was growing use in RA II (Middle East) (Table 12). Quickscat data were used mainly, but not exclusively, in RA V and DMSP in RA II (Hong Kong), RA IV (USA) and VI (UK), (Table 13). The use of Internet for accessing satellite data continued to grow, mainly in RA IV and V (Table 14).

Table 12

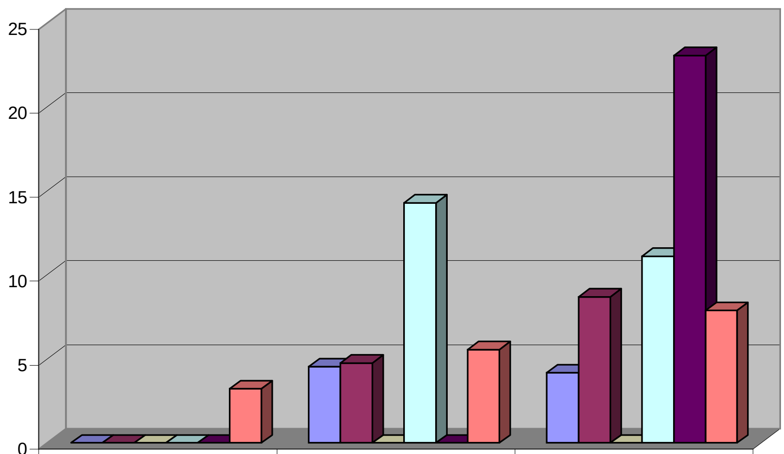
AVAILABILITY (%) OF MDD SYSTEMS



	1996	TOTAL 1999	TOTAL 2001
RA I	64	77	71
RA II	21	29	35
RA III	0	0	10
RA IV	0	14	11
RA V	0	0	0
RA VI	29	25	24

Table 13

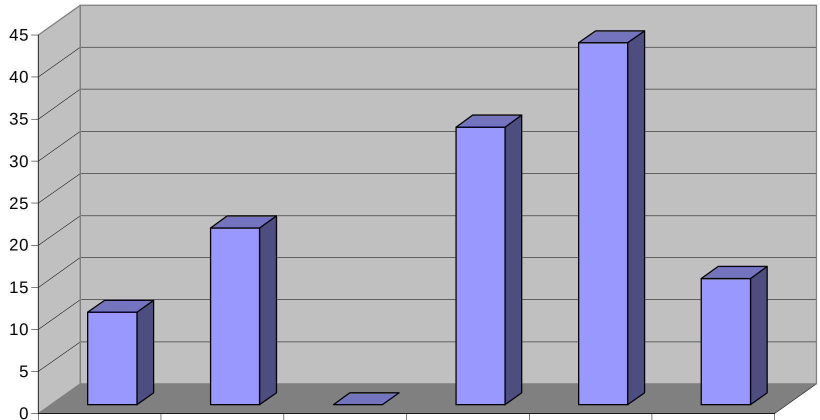
USE (%) OF DATA FROM OTHER SOURCES (SADIS, DMSP, QUICKSCAT, ERS....)



	1996	TOTAL 1999	TOTAL 2001
RA I	0	5	4
RA II	0	5	9
RA III	0	0	0
RA IV	0	14	11
RA V	0	0	23
RA VI	3	6	8

Table 14

USE OF INTERNET CONNECTION FOR ACCESSING SATELLITE DATA (FOR 2001)



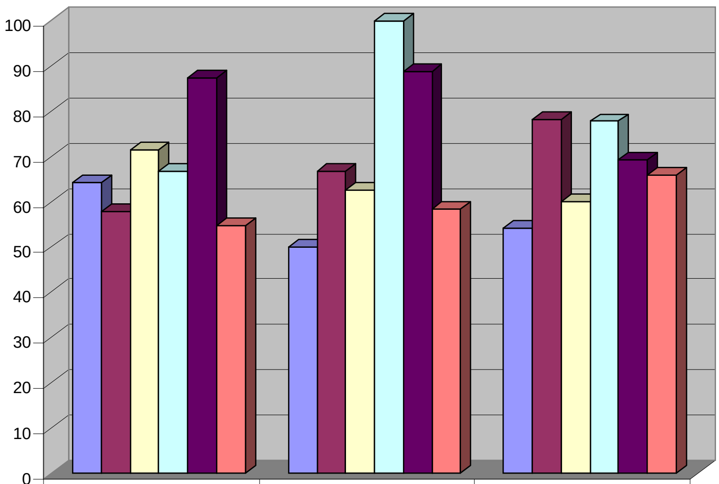
	RA I	RA II	RA III	RA IV	RA V	RA VI
TOT 2001	11	21	0	33	43	15

3.1.2 Data access and processing of satellite data

3.1.2.1 Table 15 summarizes the responses to the question **"Do you process digital data by yourself?"** and reports on the level of processing by the NMHS themselves. It should be noted that the estimated percentage level was above 50% for every region, indicating that the practice of handling digital data was well established. The peaks relative to "total 1999" for RA IV and RA V were due to the lack of available information (the countries processing their own digital data were the same in 1999 and 2001).

Table 15

OWN PROCESSING

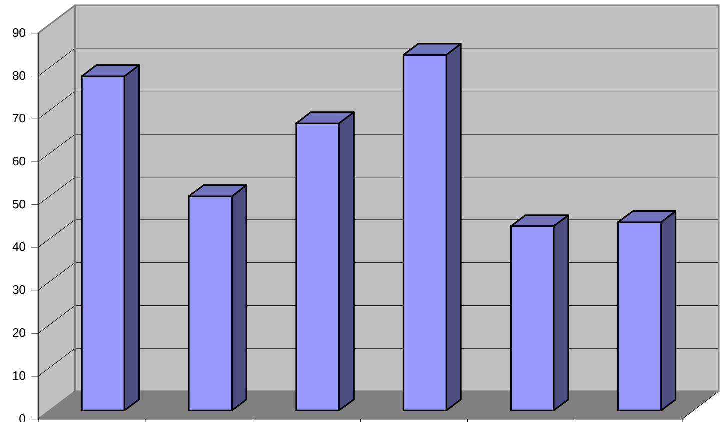


	1996	TOTAL 1999	TOTAL 2001
RA I	64	50	54
RA II	58	67	78
RA III	71	63	60
RA IV	67	100	78
RA V	88	89	69
RA VI	55	58	66

3.1.2.2 Table 16 summarizes the responses to the question **“Do you receive digital data and products from other countries?”** and reports on the level of satellite data received from other countries for 2001. A comparison with previous years was not possible. It can be noted that Members of RA II, RA V and RA VI relied more on their own receiving systems than on foreign data reception.

Table 16

RECEPTION FROM OTHER COUNTRIES

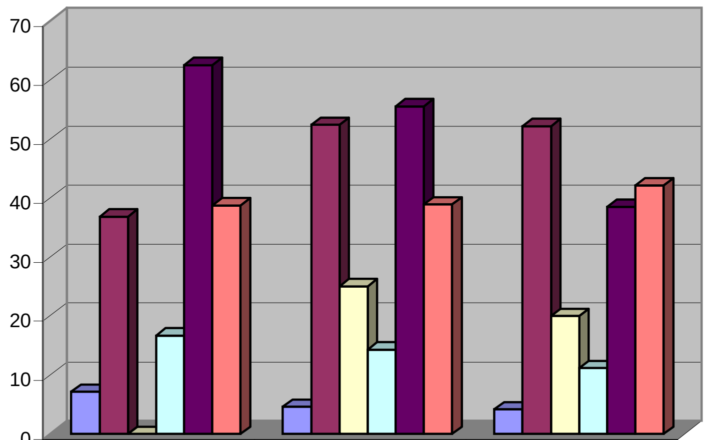


	RA I	RA II	RA III	RA IV	RA V	RA VI
TOT 2001	78	50	67	83	43	44

3.1.2.3 Table 17 summarizes the responses to the question **“Do you process TOVS/ATOVS?”** and reports on the level of TOVS processing. It should be noted that TOVS data were more widely used in RA II, RA V and RA VI, the biggest increase being in RA VI by two more Members, while in the other regions the level of use was still very low.

Table 17

TOVS PROCESSING



	1996	TOTAL 1999	TOTAL 2001
RA I	7	5	4
RA II	37	52	52
RA III	0	25	20
RA IV	17	14	11
RA V	63	56	38
RA VI	39	39	42

3.1.2.4 **Distribution to other users:** Most Members in all regions distributed satellite data and products to the meteorological offices and other users via different means (all percentages were above 70%) and the tendency was towards a continuous growth, indicating that many processed data were produced at the central office and then made available to other users.

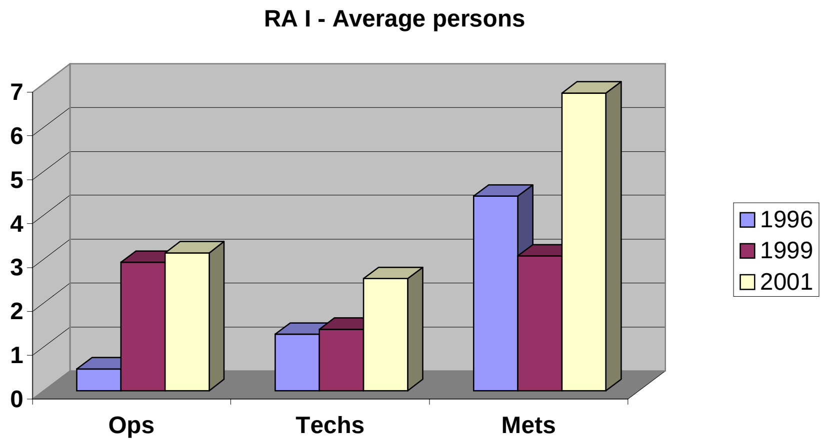
3.1.2.5 **Persons involved in satellite data reception and processing:** The distribution of staff involved in satellite data reception and processing for each WMO region is reported in Table 18. The table includes the percentage distribution for the three reported years for three categories (operators, technicians and programmers, meteorologists and scientists). Tables 19-24 show for each region the average number of people in that region involved in satellite meteorology and their distribution amongst the three categories. From an analysis of the tables, the following statements can be made:

Table 18
Distribution of staff involved in satellite data reception and processing for each WMO region

	RA I			**RA II**			**RA III**			**RA IV**			**RA V**			**RA VI**		
STAFF																		
	1996	**1999**	**2001**	**1996**	**1999**	**2001**	**1996**	**1999**	**2001**	**1996**	**1999**	**2001**	**1996**	**1999**	**2001**	**1996**	**1999**	**2001**
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
OPS																		
0	71	40	11	37	8	14	57	33	17	67	50	33	75	50	43	32	36	44
1	21	20	33	26	17	21	14	33	50	17	0	0	13	0	29	32	32	26
3	7	20	22	11	25	21	14	17	17	17	50	17	0	0	29	19	18	19
6	0	7	11	11	0	7	0	0	0	0	0	17	0	50	0	0	9	7
9	0	13	0	0	8	7	14	0	17	0	0	33	0	0	0	6	0	0
12	0	0	11	0	0	14	0	17	0	0	0	0	13	0	0	3	0	0
15	0	0	11	11	33	14	0	0	0	0	0	0	0	0	0	3	0	0
>75	0	0	0	5	8	0	0	0	0	0	0	0	0	0	0	3	5	4
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
TECHS																		
0	29	47	0	42	8	14	43	33	17	83	0	67	25	0	57	32	23	33
1	50	27	44	21	25	57	43	33	17	0	0	0	38	100	29	26	50	52
3	7	13	44	16	33	14	0	17	33	0	50	17	0	0	14	32	18	7
6	0	13	0	5	8	0	0	0	0	17	0	17	13	0	0	3	5	0
9	14	0	11	0	8	7	14	17	0	0	50	0	25	0	0	0	0	4
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	16	17	7	0	0	33	0	0	0	0	0	0	3	0	0
>75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5	4
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
METS																		
0	36	27	11	37	25	7	0	33	0	33	0	33	13	0	0	16	27	22
1	21	20	11	16	8	29	14	17	17	0	0	0	38	0	57	19	36	26
3	14	27	22	16	17	14	71	33	17	17	0	17	25	50	0	26	14	15
6	0	13	22	11	25	14	0	0	33	17	50	33	13	0	14	16	5	15
9	7	13	11	16	8	14	14	0	0	33	0	0	0	0	14	3	0	4
12	0	0	11	0	8	7	0	0	0	0	0	0	0	0	0	3	0	7
15	21	0	11	0	8	14	0	17	33	0	50	0	13	50	14	13	14	7
>75	0	0	0	5	0	0	0	0	0	0	0	17	0	0	0	3	5	4
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

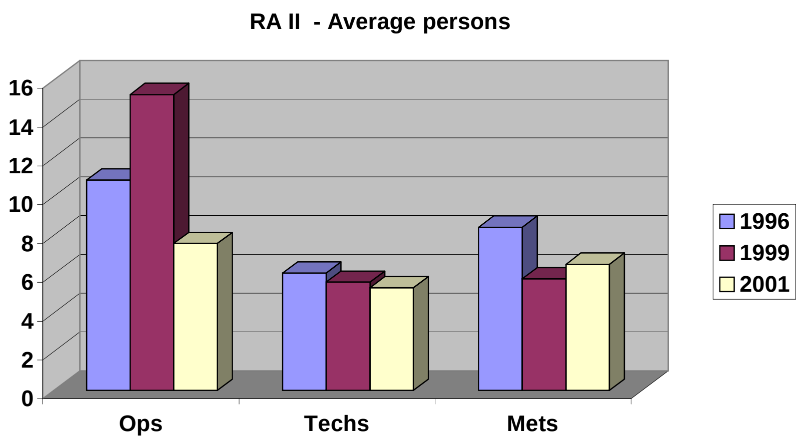
- **RA I** - Most Members have 2-4 operators, 1-2 technicians and 3-5 meteorologists. It should be noted that in recent years the number of countries with more than 10 operators has increased as has the number of meteorologists. This tendency can be seen in Table 19. The positive trend was for all categories, but primarily for meteorologists (growing from 3 to 7 people as an average). This could indicate that the use of satellite data in the region is improving, mainly for more advanced use.

Table 19



- **RA II** - Most Members have 1-3 operators, 1-2 technicians and 1-3 meteorologists. The peak in operators (more than 15) was due to the high number of staff in the NMHSs of certain countries. Regarding the average number of staff, a reduction was evident in the number of operators (from 15 to 8) and, less marked, in the other categories (both with 5-7 staff).

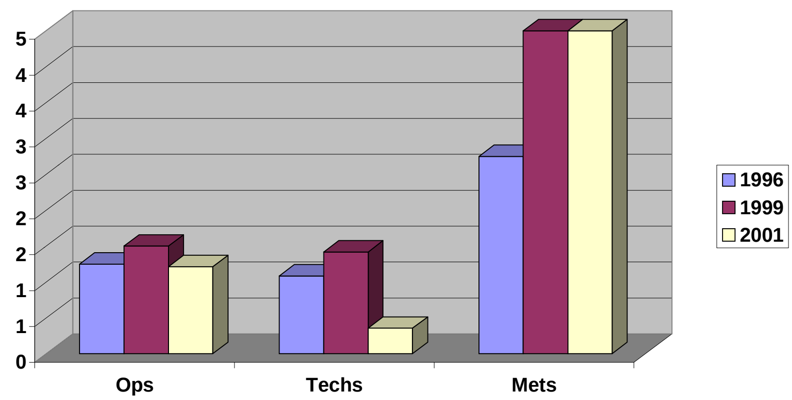
Table 20



- **RA III** - Most Members have 1-2 operators, 3-5 technicians and 6-8 meteorologists. In the last two reported years there has been a reduction in the number of technicians, while the level of 5 meteorologists remained constant indicating the importance given to satellite data processing and interpretation.

Table 21

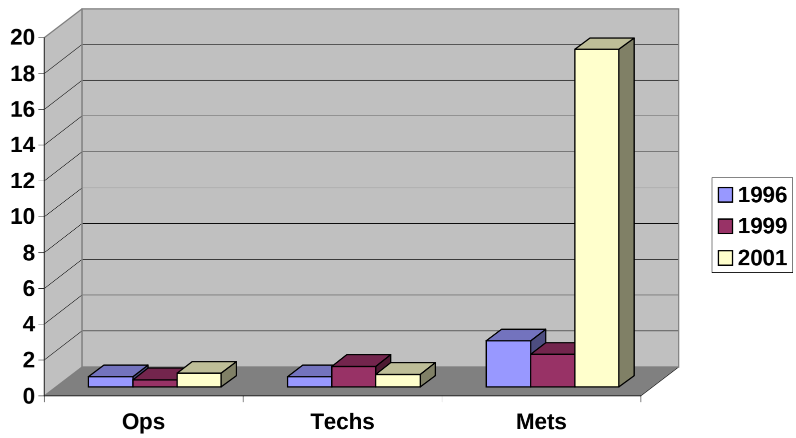
RA III - Average persons



- **RA IV** - The number of staff devoted to satellites is at a low level for most Members. The average results showed a very steep increase in the number of meteorologists in the last period due to the inclusion of USA. On the other hand, the low level of replies received from RA IV could have led to average values that were not truly representative of the situation for the whole region. Nevertheless, the level of use of satellite data is still very low.

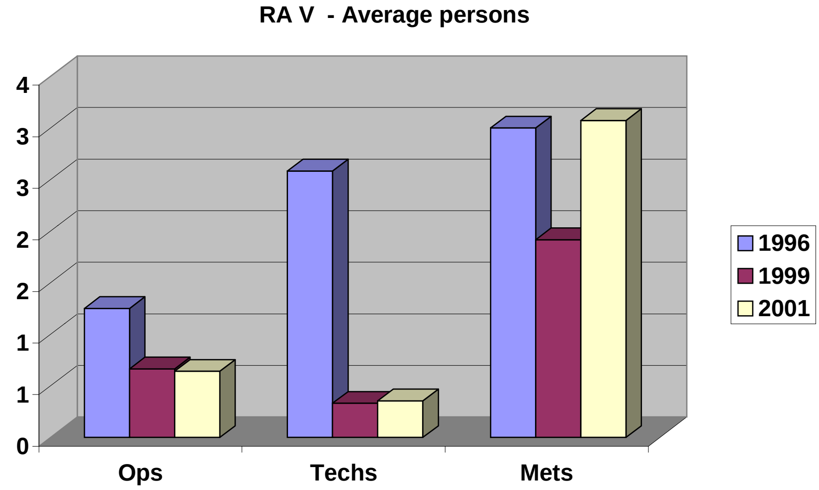
Table 22

RA IV - Average persons



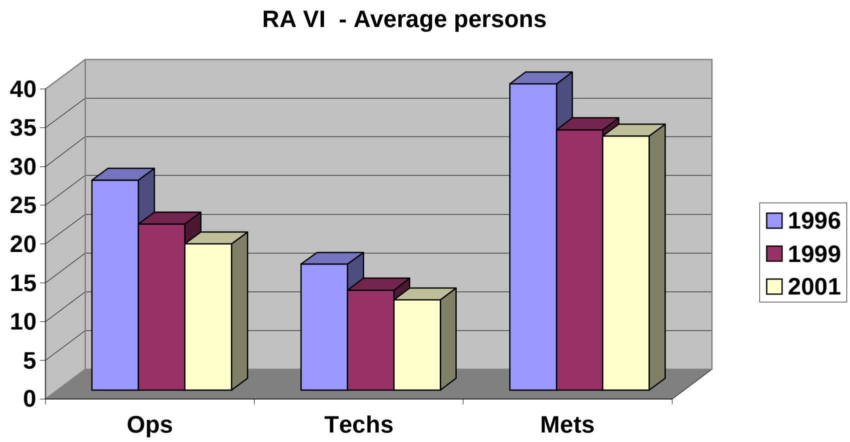
- **RA V** - Most Members have 0-3 operators, 0-2 technicians and 1-2 meteorologists. The level of use of satellite data and products is rather low (with only two Members at higher level) and this tendency has been maintained in recent years.

Table 23



- **RA VI** - Excluding a very few with higher levels, most Members have 0-2 operators, 0-2 technicians and 1-2 meteorologists. However, the total number of staff is the largest of all the regions due to the inclusion in this region of the Russian Federation with a very large staff. A slight reduction in the number for all categories can be seen although the use of satellite data and products in RA VI is very well established. Even in RA VI, therefore, the shortage of personnel is a problem for improving satellite activities.

Table 24



Conclusions and recommendation regarding the personnel:

- NMHSs most frequently reported the following number of personnel involved in satellite meteorology activities: 1-3 operators, 1-3 technicians, 2-4 meteorologists. A positive trend, especially in the number of meteorologists, could be noted for RA I indicating a higher recognition of the value of satellite data and products by Members in RA-I. However, there appeared to be a slight reduction in the number of staff active in satellite meteorology in RA II and RA VI;
- In the 1999 survey, it was clearly recognized that for effective utilization of satellite data and products the lack of personnel was a problem for many NMHSs. This seemed to still be the case in 2001 since the number of staff involved in satellite data reception and processing did not change significantly. The only Region to improve with regard to the personnel situation was RA I. However, this conclusion must be tempered with the statements in the section on reported lack of staff (section 3.3.14) which indicated an overall decrease in limitations due to a lack of staff.

Recommendation: NMHSs are strongly encouraged to increase the number of staff active in satellite meteorology in order to be able to benefit from the unique capabilities of satellite systems.

3.2 Satellite Data and Products

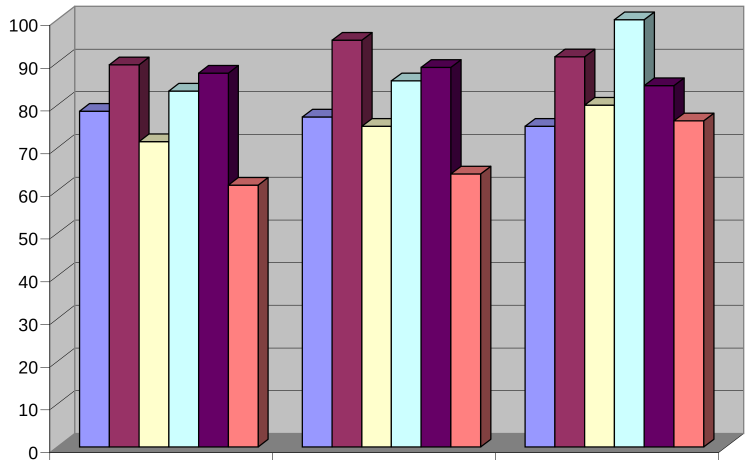
3.2.1 Use of satellite data at the NMHS

3.2.1.1 The questions on the use of satellite data and products at the NMHS were introduced only in the last edition of the questionnaire, and it was not possible to make a direct comparison with similar questions contained in the previous questionnaires. However, from questions listed in the previous surveys it was still possible to infer the same information, even with the unavoidable uncertainties. This approach allowed a dynamical assessment across the three editions of the questionnaire for all questions in this sub-section. As in the previous section, the group labelled “Total 1999” contained the resulting percentage from Members replying to at least the 1996 or 1999 questionnaires; while the group labelled “Total 2001” contained the resulting percentage from Members replying to at least one questionnaire.

3.2.1.2 **Image interpretation (qualitative use) from analogue data:** Table 25 reports on the number of countries that made use of qualitative analogue imagery. It is evident that most Members used satellite image data. Therefore, the scores were very high for all regions (more than 75% in 2001). The growth to 100% for RA IV should be noted - in fact most Members in this region only use satellite data qualitatively. The small decrease for RA I was linked to the growing use of digital data, as was the case in RA II and RA V. The growth from 61% to 76% in RA VI was not only due to new operating analogue systems but also to the fact that in the past some countries stated that they did not use analogue imagery.

Table 25

IMAGE INTERPRETATION FROM ANALOGUE DATA

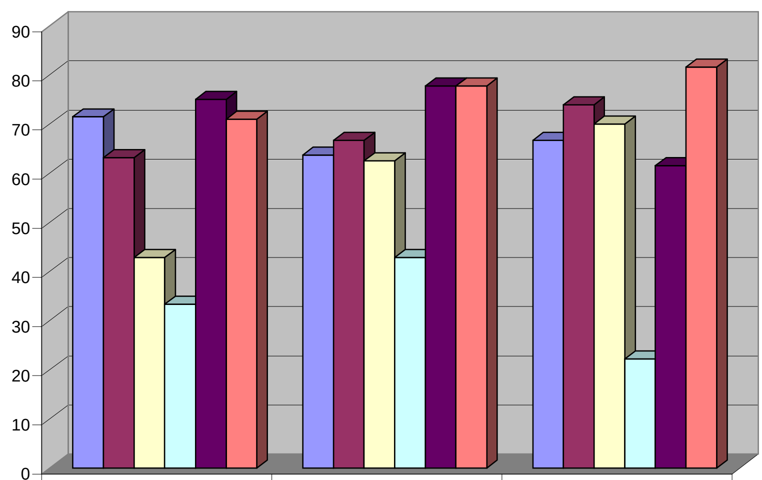


	1996	TOTAL 1999	TOTAL 2001
RA I	79	77	75
RA II	89	95	91
RA III	71	75	80
RA IV	83	86	100
RA V	88	89	85
RA VI	61	64	76

3.2.1.3 **Image interpretation (qualitative use) from digital data:** Table 26 reports on the number of countries that made use of qualitative digital data. In RA I, the reduction since 1996 (but not since 1999) was due to more recent new receiving systems not using digital data. The same occurred in RA V. RA II, III and RA VI reported a steady increase in the use of digital data (with a peak of 82% for RA VI) while RA IV was still at a lower level (an average of 22% in 2001) - although the qualitative use of imagery was completely accomplished through the use of analogue imagery.

Table 26

IMAGE INTERPRETATION FROM DIGITAL DATA

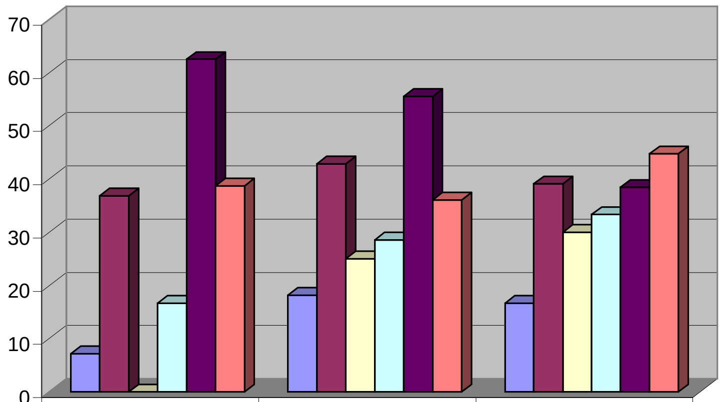


	1996	TOTAL 1999	TOTAL 2001
RA I	71	64	67
RA II	63	67	74
RA III	43	63	70
RA IV	33	43	22
RA V	75	78	62
RA VI	71	78	82

3.2.1.4 **Satellite soundings:** Table 27 reports on the use of satellite soundings. The use of satellite soundings was at a low level for all regions (less than 50%) but grew since 1999 (RA VI and RA II were the most active in this area). The decrease in RA V was due to the fact that none of the Members who responded in 1999 or 2001 used satellite soundings.

Table 27

SATELLITE SOUNDINGS

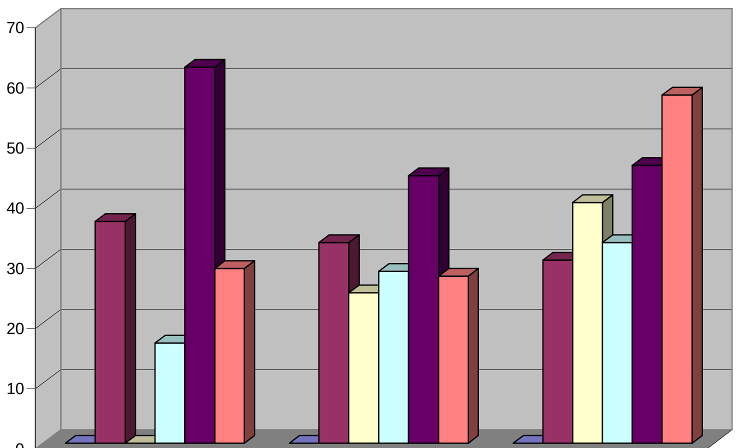


	1996	TOTAL 1999	TOTAL 2001
RA I	7	18	17
RA II	37	43	39
RA III	0	25	30
RA IV	17	29	33
RA V	63	56	38
RA VI	39	36	45

3.2.1.5 **Satellite sounding products:** Table 28 reports on the use of satellite sounding products. A similar pattern to the use of satellite soundings was found with the exception of RA I where satellite sounding products were not used at all. Of note was the very positive trend for RA III.

Table 28

SATELLITE SOUNDINGS PRODUCTS

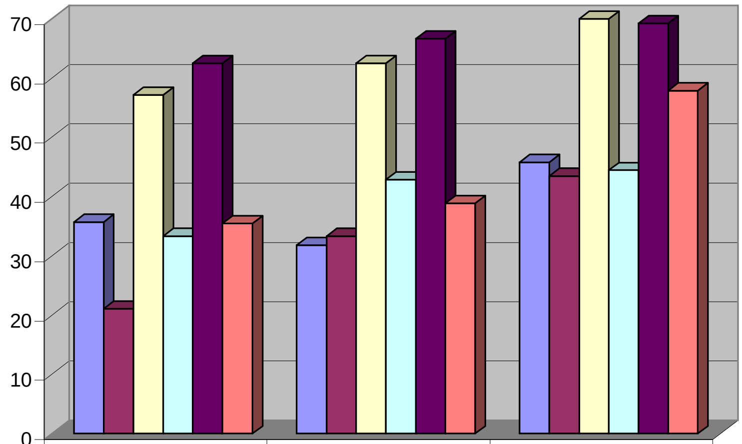


	1996	TOTAL 1999	TOTAL 2001
RA I	0	0	0
RA II	37	33	30
RA III	0	25	40
RA IV	17	29	33
RA V	63	44	46
RA VI	29	28	58

3.2.1.6 **Qualitative use of satellite products from other sources:** Table 29 reports on the qualitative use of satellite products from other sources. All regions and especially RA III and RA V experienced an increase in the use of satellite products from other sources, indicating that the practice to exchange data and products (e.g., using Internet) had become more common, also suggesting that in the future fewer centres would produce products to be used by the whole community. Thus, the main objective to improve the use of satellite systems may be through improved access to information.

Table 29

QUALITATIVE USE OF SATELLLITE PRODUCTS FROM OTHER SOURCES



	1996	TOTAL 1999	TOTAL 2001
RA I	36	32	46
RA II	21	33	43
RA III	57	63	70
RA IV	33	43	44
RA V	63	67	69
RA VI	35	39	58

3.2.1.7 Conclusions on the use of satellite data at the NMHSs:

- Nearly all Members that responded to the questionnaire in 2001 used satellite data at least for qualitative applications based on image interpretation. Analogue as well as digital data were used for this purpose, with an obvious transition from analogue to digital in at least some regions (RA I, RA II, and RA V);

- Usage of satellite sounding data and products represented less than 50% of responding NMHSs for 2001. This result was, however, not surprising since the typical application of sounding data was in NWP and only a limited number of Members operated their own NWP models and associated data assimilation systems for numerical analysis. With regard to the use of sounding data for the monitoring of the stability/instability of the atmosphere for Nowcasting purposes, it was noted that not all geostationary satellites have sounding capabilities, resulting in a limited utilization of satellite soundings;

- An increasing number of NMHSs indicated an increase in the use of satellite products from other sources. This resulted from improved data communication system capabilities, e.g., the Internet, and the recognition by the NMHSs that it was not necessary for each to create satellite products but rather could rely on the services of specialized centres.

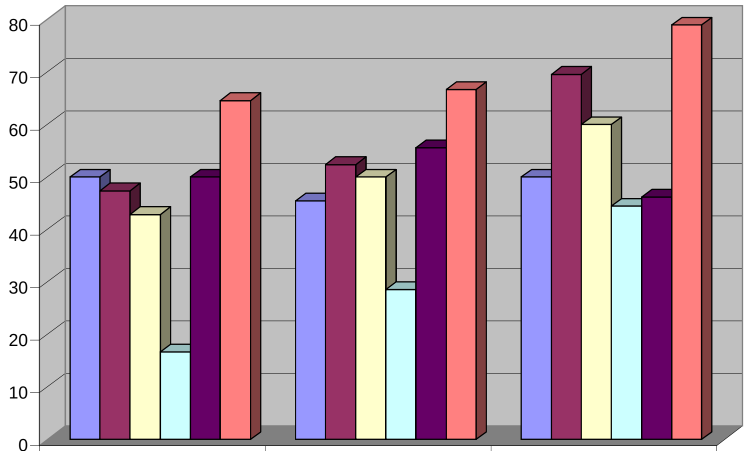
3.2.2 Extraction of products from digital satellite data at the NMHS

3.2.2.1 As for the previous sub-section a direct comparison with older questionnaires, where the questions were not present, is not possible. However, for the first three questions a dynamical analysis is still possible by considering the whole answers given to both 1996 and 1999 questionnaires. For the fourth question a comparison is possible only with the 1999 edition, while for the fifth question no comparison is possible since no similar questions were present before.

3.2.2.2 Product **derived from image data:** Results are presented in Table 30. A general increase in the level of processing of digital data and extraction of products from image data was observed. A very positive growth rate for RA VI (79%) had been reached in 2001. For RA V, this positive trend was not continued from previous years partly due to the fact that most of the responses for 2001 entries did not indicate if digital data were processed.

Table 30
Countries (%) extracting satellite derived products from digital data

PRODUCT DERIVED FROM IMAGE DATA

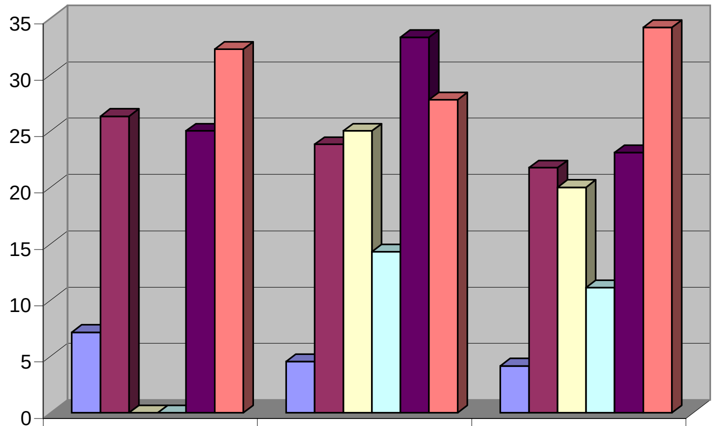


	1996	TOTAL 1999	TOTAL 2001
RA I	50	45	50
RA II	47	52	70
RA III	43	50	60
RA IV	17	29	44
RA V	50	56	46
RA VI	65	67	79

3.2.2.3 **Satellite soundings:** See results in Table 31. The responses to this question were apparently linked to the responses provided for section 3.1.2.3, i.e., (processing of TOVS data), although not completely correlated since a Member could process TOVS data while not extracting full soundings or post-processed products derived from them. Nevertheless, the pattern of responses presented in Table 31 was very similar to those for products derived from image data but with lower absolute percentage values (RA VI had the highest score with 34%).

Table 31
Countries (%) processing satellite soundings data

SATELLITE SOUNDINGS

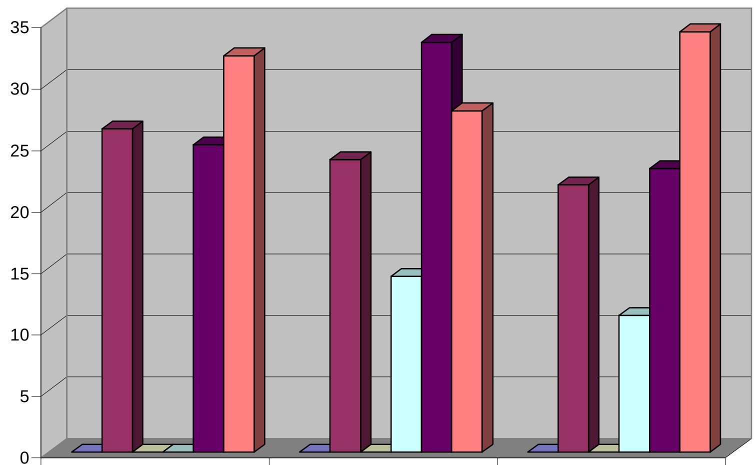


	1996	TOTAL 1999	TOTAL 2001
RA I	7	5	4
RA II	26	24	22
RA III	0	25	20
RA IV	0	14	11
RA V	25	33	23
RA VI	32	28	34

3.2.2.4 **Products derived from satellite soundings:** See results in Table 32. Most Members who extracted satellite soundings also extracted derived products. No processing was indicated by Members in RA I and III.

Table 32
Countries (%) extracting processed products from satellite soundings data

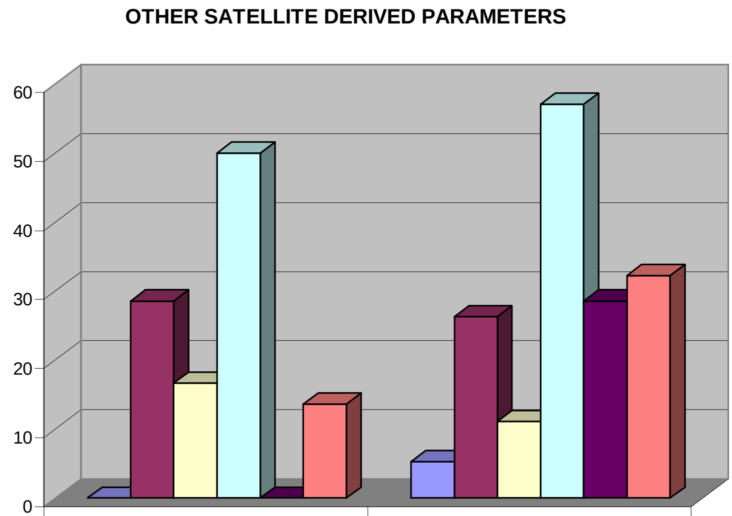
PRODUCTS DERIVED FROM SATELLITE SOUNDINGS



	1996	TOTAL 1999	TOTAL 2001
RA I	0	0	0
RA II	26	24	22
RA III	0	0	0
RA IV	0	14	11
RA V	25	33	23
RA VI	32	28	34

3.2.2.5 **Other satellite-derived parameters:** See results in Table 33. The use of other satellite derived parameters has become more important since 1999, mainly in RA I, V and VI where major improvements were observed. The situation in RA II and III remained stable (the slight decrease was due to the enlargement of the statistical basis from 1999 to 2001). An improvement in the use of such data could be detected as well in RA IV where such processing was already performed by more than 50% of the Members.

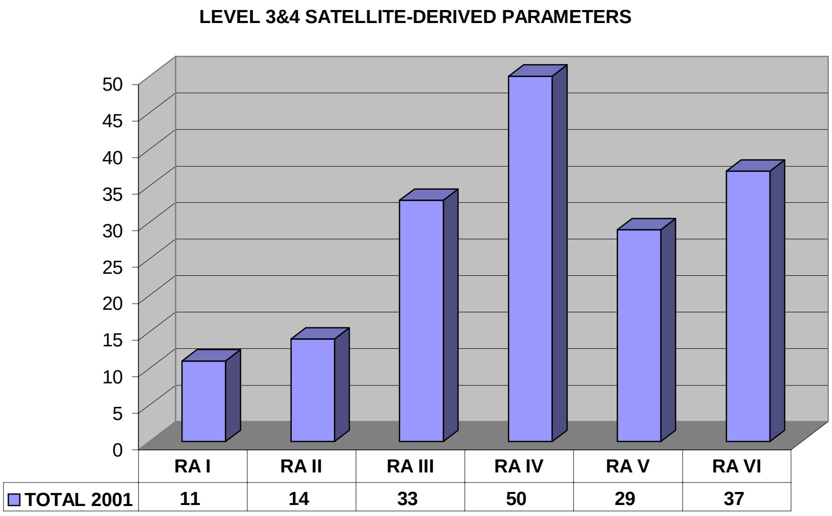
Table 33
Countries (%) extracting other satellite derived parameters



	1999	TOTAL 2001
RA I	0	5
RA II	29	26
RA III	17	11
RA IV	50	57
RA V	0	29
RA VI	14	32

3.2.2.6 **Level 3 mapped & 4 (model output) products from satellite-derived parameters (model output):** Table 34 shows the percentage of the Members by region that indicated they extracted Level 3 and 4 products from satellite data for 2001. RA IV Members indicated a limited digital data distribution system and thus depended on well-developed activities to use satellite data to extract more sophisticated products. However, this indication could be partly attributed to the limited statistics as well as that some Members that neither used use satellite data nor responded to the questionnaire.

Table 34
Countries (%) extracting level 3 & 4 products from satellite derived parameters



3.2.3 Application areas and important parameters

3.2.3.1 The purpose of this sub-section was to assess the importance of geophysical parameters, as defined in the questionnaire, for different methods of applications and application areas. It should then be possible to identify the most used and most required parameters, but which were not available. The availability of these parameters should be improved as soon as possible.

3.2.3.2 The analysis was performed for each application area to identify the top six parameters (in bold and in descending order of most useful) which were considered mandatory or useful by Members as well as the three most required parameters in bold). Thus, it was possible to assign a percentage value indicating the relative importance of each parameter. An attempt was also made to compare the responses given in the 2001 questionnaire with previous ones. A complete comparison was not possible since the list of parameters was not the same for previous questionnaires.

3.2.3.3 The following tables list the top six parameters considered mandatory or useful for the each method or application area as well as a comparison with the previous edition of the questionnaire. There were 12 application areas: Nowcasting & VSRF, Synoptic Analysis, Global & Regional NWP, Aeronautical Meteorology, Marine Meteorology, Agricultural Meteorology, Hydrology, Atmospheric Chemistry, Climatology/Global Change, Environmental/Disaster Monitoring, Research Applications and Public Weather Service. The percentages indicate the relative value of that parameter compared to all the parameters contributing to the application as well as an indication of the relative contribution of the top six parameters to all the parameters cited.

3.2.3.4 Where possible a comparison between the three surveys was made by using a percentage for each parameter and for each application as follows:

- For the 2001 survey, the number of times that a certain parameter was considered mandatory or useful;
- For the 1999 survey, the number of times that a certain parameter was considered "acceptable", according the definition reported in WMO Technical Document "Status of the Availability and Use of Satellite Data and Products by WMO Members" (WMO/TD No. 994 (SAT-23));

- For the 1996 survey, the number of times that a certain parameter was used by Members.

3.2.3.5 It should be noted, however, that the percentage values should not be compared since they were derived from different types of questions, different list of parameters and thus represented a different statistical base. Nevertheless, they provided an indication of the relative merit of a certain parameter against others for a specific application.

3.2.3.6 For each method or application area, the list of the three "most required parameters" is also reported.

3.2.3.7 Finally, it should be noted that some conclusions given in the tables were subjective and indicated only a possible interpretation of the given results.

Nowcasting and VSRF (Table 35)

3.2.3.8 All parameters related to the identification of cloud fields continued to be considered most useful for Nowcasting & VSRF methods, cloud imagery being the most used parameter, representing 25% of the answers. It should be noted that 94% of the answers indicated that cloud parameters were the most used for Nowcasting & VSRF (the remaining parameters included specific humidity profile). In comparison to previous questionnaires, two new parameters, precipitation rate and cloud base height, were considered to be in the "top six", although both parameters and primarily cloud base height, are rather difficult to retrieve from satellite observations. In fact, the same parameters (precipitation rate and cloud base height) were also among the most required. Precipitation rate was present in all years as one of the most needed parameters.

Table 35
Top six mandatory or useful and most required parameters for Nowcasting

	2001	**%**	**1999**	**%**	**1996**	**%**
1	**Cloud imagery**	**25**	Cloud imagery	9	Cloud imagery	18
2	**Cloud top temperature**	**22**	Cloud top temperature	8	Cloud type	10
3	**Cloud type**	**19**	Cloud top height	8	Cloud cover	10
4	**Cloud cover**	**18**	Cloud cover	6	Cloud top height	9
5	**Precipitation rate**	**6**	Cloud type	6	Cloud top temperature	7
6	**Cloud base height**	**4**	Land surface temperature	4	Sea surface temperature	7
	Total	**94**	Total	41	Total	61
	Most required parameters					
1	**Atmospheric instability index**		Precipitation rate		Atmospheric instability rate	
2	**Precipitation rate**		Temperature profile		Precipitation rate	
3	**Cloud base height**		Specific humidity profile		Cloud water profile	

Synoptic Analysis (Table 36)

3.2.3.10 As was the case for Nowcasting & VSRF, the Synoptic Analysis application area indicated that the cloud field, and primarily cloud imagery was the highest priority with temperature profile also considered in the "top six". The most required parameters were also the same as Nowcasting & VSRF (even in same order). A comparison with prior questionnaires was not possible since this application area was not previously listed.

Table 36

Top six mandatory or useful and most required parameters for Synoptic Analysis

	2001	%	1999	%	1996	%
1	**Cloud imagery**	26	N/A	0	N/A	0
2	**Cloud cover**	18	N/A	0	N/A	0
3	**Cloud type**	17	N/A	0	N/A	0
4	**Cloud top temperature**	16	N/A	0	N/A	0
5	**Cloud base height**	4	N/A	0	N/A	0
6	**Temperature profile**	4	N/A	0	N/A	0
	Total	**85**	Total	0	Total	0
	Most required parameters					
1	**Atmospheric instability index**		N/A		N/A	
2	**Precipitation rate**		N/A		N/A	
3	**Cloud base height**		N/A		N/A	

Global & Regional NWP (Table 37)

3.2.3.11 The analysis shows that for NWP the main information used is the vertical structure of the atmosphere (temperature and wind) and the air-sea interactions (SST and wind over sea surface). A comparison with previous surveys showed a rather different parameter selection, primarily based on cloud parameters in 1999 and on ozone detection in 1996. Temperature profile and cloud top temperature, however, have always been included in the priority list, while the fact that cloud imagery has been included in the last two survey results indicated that cloud features were beginning to be assimilated into NWP models. Regarding the most required parameters, the knowledge of wind structure, at surface and in the atmosphere, has to be improved, as was already indicated in the 1996 survey.

Table 37
Top six mandatory or useful and most required parameters for Global & Regional NWP

	2001	%	1999	%	1996	%
1	**Temperature profile**	**22**	Cloud imagery	9	Sea surface temperature	11
2	**Wind profile**	**18**	Cloud top temperature	8	Cloud top temperature	10
3	**Sea surface temperature**	**18**	Cloud top height	7	Ozone total column	8
4	**Wind vector over sea surface**	**8**	Cloud cover	5	Ozone profile	8
5	**Cloud top temperature**	**7**	Cloud type	5	Temperature profile	7
6	**Cloud imagery**	**5**	Temperature profile	5	Specific humidity profile	7
	Total	**78**	Total	40	Total	51
	Most required parameters					
1	**Wind profile**		Cloud cover		Wind profile	
2	**Wind vector over sea surface**		Ozone profile		Cloud water profile	
3	**Cloud water profile**		Land cover		Wind speed over sea surface	

Aeronautical Meteorology (Table 38)

3.2.3.12 Aeronautical Meteorology is mainly based on Nowcasting & VSRF and Synoptic Analysis methods. Therefore, the needed parameters were very close to that already indicated for those two application areas, the only difference being that cloud top height was more important than in the other application areas. Regarding required parameters, cloud base height was the most required. A comparison with previous answers showed very close agreement for parameters used although some difference for required parameters in the 1999 survey could be detected.

Table 38
Top six mandatory or useful and most required parameters for Aeronautical Meteorology

	2001	%	1999	%	1996	%
1	**Cloud imagery**	**19**	Cloud imagery	13	Cloud imagery	24
2	**Cloud cover**	**17**	Cloud top temperature	10	Cloud top temperature	12
3	**Cloud type**	**16**	Cloud top height	10	Ozone total column	10
4	**Cloud top temperature**	**14**	Cloud cover	8	Ozone profile	11
5	**Cloud top height**	**12**	Cloud type	7	Temperature profile	8
6	**Cloud base height**	**6**	Temperature profile	7	Specific humidity profile	5
	Total	**84**	Total	55	Total	70
	Most required parameters					
1	**Cloud base height**		Height of tropopause		Wind profile	
2	**Wind profile**		Cloud top temperature		Atmospheric instability index	
3	**Atmospheric instability index**		Precipitation rate		Land surface temperature	

Marine Meteorology (Table 39)

3.2.3.13 For Marine Meteorology, SST and cloud imagery were considered the most important while significant wave height and wave period/direction have become more important. This could also be expected based on the growing use of data from satellites equipped with sensors useful for oceanography, e.g., ERS, TOPEX-POSEIDON and QUICKSCAT. The availability of wave height and wind at sea surface was still considered the priority for the application.

Table 39
Top six mandatory or useful and most required parameters for Marine Meteorology

	2001	%	1999	%	1996	%
1	**Sea surface temperature**	**18**	sea surface temperature	10	Cloud imagery	17
2	**Cloud imagery**	**14**	Cloud imagery	9	Sea surface temperature	14
3	**Wind vector over sea surface**	**13**	Wind speed over sea surface	7	Cloud type	14
4	**Cloud cover**	**12**	Wind vector over sea surface	7	Cloud cover	13
5	**Significant wave height**	**9**	Ocean currents	6	Wind speed over sea surface	8
6	**Wave period/direction**	**8**	Significant wave height	6	Wind vector over sea surface	7
	Total	**74**	Total	45	Total	73
	Most required parameters					
1	**Significant wave height**		Cloud cover		Wind speed over sea surface	
2	**Wind vector over sea surface**		Cloud top height		Wind vector over sea surface	
3	**Ocean currents**		Cloud top temperature		Significant wave height	

Agricultural Meteorology (Table 40)

3.2.3.14 NDVI and land surface temperature were still considered the main parameters for Agricultural Meteorology. Soil moisture was the most required parameter. In recent years, there has been a tendency towards the growing importance of vegetation features, and parameters such as vegetation type and leaf area index were, in fact, among the most needed parameters.

Table 40
Top six mandatory or useful and most required parameters for Agricultural Meteorology

	2001	%	1999	%	1996	%
1	**NDVI**	**20**	NDVI	8	Cloud imagery	20
2	**Land surface temperature**	**16**	Precipitation index	7	Land surface features	18
3	**Cloud cover**	**13**	Land surface temperature	6	Soil moisture	13
4	**Cloud imagery**	**10**	Cloud imagery	5	Cloud type	11
5	**Soil moisture**	**8**	Fire	5	Cloud cover	10
6	**Vegetation type**	**7**	Cloud top temperature	4	NDVI	5
	Total	**74**	Total	36	Total	77
	Most required parameters					
1	**Soil moisture**		Vegetation type		Precipitation rate	
2	**Vegetation type**		Precipitation rate		Soil moisture	
3	**Lead area index**		Cloud top temperature		Cloud cover	

Hydrology (Table 41)

3.2.3.15 While previous surveys indicated that higher priority was placed on parameters linked with cloud fields (cloud imagery) and the status of vegetation (land surface features, NDVI, land surface temperature), the present survey showed a growing importance for the presence and status of snow on the ground (snow cover, snow melting conditions). This change indicated that hydrological activities were becoming dependent on water reservoirs represented by snow. The most required parameters included a deeper knowledge for fields of precipitation and the status of soil. Compared to previous surveys, snow cover was no longer on the most required list but was the most important used parameter for the application area of Hydrology. This could indicate advancements in processing techniques for this parameter and possibly be linked to the growing use of polar-orbiting satellite data.

Table 41
Top six mandatory or useful and most required parameters for Hydrology

	2001	%	1999	%	1996	%
1	**Snow cover**	**15**	NDVI	8	Cloud imagery	20
2	**Precipitation rate**	**13**	Precipitation index	7	Land surface features	18
3	**Cloud imagery**	**13**	Land surface temperature	6	Soil moisture	13
4	**Land cover**	**10**	Cloud imagery	5	Cloud type	11
5	**Cloud type**	**10**	Fires	5	Cloud cover	10
6	**Snow melting conditions**	**8**	Cloud top temperature	4	NDVI	5
	Total	**69**	Total	34	Total	77
Most required parameters						
1	**Precipitation rate**		Snow cover		Land surface temperature	
2	**Soil moisture**		Cloud base height		Soil moisture	
3	**Precipitation index**		Cloud water total column		Snow cover	

Atmospheric chemistry (Table 42)

3.2.3.16 Atmospheric Chemistry was recently included in the satellite applications list. Parameters for the application area of Atmospheric Chemistry were mainly connected with the observation of the ozone field and aerosol content. Since these parameters were also the most required, it indicated that their observed quality or extraction technique were not yet being performed in a satisfactorily way. No comparison was possible with previous surveys.

Table 42
Top six mandatory or useful and most required parameters for Atmospheric chemistry

	2001	%	1999	%	1996	
1	**Ozone total column**	**35**	N/A	0	N/A	0
2	**Ozone profile**	**28**	N/A	0	N/A	0
3	**Aerosol total column**	**21**	N/A	0	N/A	0
4	**Temperature profile**	**7**	N/A	0	N/A	0
5	**Fires**	**7**	N/A	0	N/A	0
6		**0**	N/A	0	N/A	0
	Total	**98**	Total	0	Total	0
Most required parameters						
1	**Aerosol total column**		N/A		N/A	
2	**Trace gases**		N/A		N/A	
3	**Ozone profile**		N/A		N/A	

Climatology/Global Change (Table 43)

3.2.3.17 Knowledge of the cloud field together with the radiation budget were the parameters that were most used in the application area for Climatology/Global Change. SST remained one of the most important parameters for the application, while the practice of measuring long-wave radiation continued to grow in importance, but probably not for its accuracy since it was among the most required parameters.

Table 43
Top six mandatory or useful and most required parameters for Climatology/Global Change

	2001	**%**	1999	%	1996	
1	**Cloud cover**	**18**	Sea surface temperature	7	Cloud type	8
2	**Long-wave outgoing rad. TOA**	**14**	Long-wave outgoing rad. TOA	4	Cloud top temperature	6
3	**Sea surface temperature**	**12**	Cloud top height	4	Cloud top height	6
4	**Cloud imagery**	**12**	Cloud imagery	4	Cloud cover	6
5	**Land surface temperature**	**8**	Precipitation index	4	Sea surface temperature	6
6	**Temperature profile**	**6**	Temperature profile	4	NDVI	5
	Total	**70**	Total	27	Total	37
Most required parameters						
1	**Precipitation rate**		Cloud cover		Land surface temperature	
2	**Sea level**		Cloud base height		Soil moisture	
3	**Long-wave outgoing rad. TOA**		Snow cover		Long-wave outgoing rad. TOA	

Environmental/Disaster Monitoring (Table 44)

3.2.3.18 Having included Environmental/Disaster Monitoring in the application area for the first time, fire monitoring was considered the most important parameter for the application area, possibly for its improvement. Volcanic ash and precipitation were amongst those important parameters that were most used, but at the same time were most required, probably by those Members who didn't use them. The new emphasis for disasters beyond that for environmental monitoring may explain the lower importance place on ozone monitoring and land status detected as indicated in previous surveys.

Table 44
Top six mandatory or useful and most required parameters for Environmental/Disaster Monitoring

	2001	**%**	1999	%	1996	
1	**Fires**	**24**	Fires	8	Soil moisture	13
2	**Cloud imagery**	**24**	Ozone total column	5	Cloud imagery	12
3	**Cloud top temperature**	**16**	Ozone profile	5	Land surface features	12
4	**Precipitation rate**	**14**	Land surface temperature	5	NDVI	8
5	**Land cover**	**12**	Sea surface temperature	5	Ozone profile	7
6	**Volcanic ash**	**6**	NDVI	4	Ozone total column	7
	Total	**96**	Total	32	Total	59
Most required parameters						
1	**Fires**		Ozone total column		Snow cover	
2	**Volcanic ash**		Atmospheric instability index		Land cover	
3	**Precipitation rate**		Vegetation type		Vegetation type	

Research applications (Table 45)

3.2.3.19 From the analysis of the responses received, it might be argued that research activities were mainly focused on clouds and precipitation, air sea interactions and radiation budget studies. No comparison was possible with previous questionnaires.

Table 45
Top six mandatory or useful and most required parameters for Research applications

	2001	**%**	1999	%	1996	
1	**Sea surface temperature**	**16**	N/A	0	N/A	0
2	**Cloud imagery**	**14**	N/A	0	N/A	0
3	**Cloud top temperature**	**14**	N/A	0	N/A	0
4	**Cloud cover**	**10**	N/A	0	N/A	0
5	**Precipitation rate**	**8**	N/A	0	N/A	0
6	**Long-wave outgoing rad. TOA**	**8**	N/A	0	N/A	0
	Total	**70**	Total:	0	Total:	0
Most required parameters						
1	**Precipitation rate**		N/A		N/A	
2	**Temperature profile**		N/A		N/A	
3	**Ozone profile**		N/A		N/A	

Public Weather Services (Table 46)

3.2.3.20 A rapidly emerging activity, PWS is mainly related to general weather forecasting, hence the parameters most used were cloud parameters, precipitation and land features, with precipitation monitoring (and related parameters) as an important parameter for future development.

Table 46
Top six mandatory or useful and most required parameters for Public Weather Services

	2001	**%**	1999	%	1996	
1	**Cloud imagery**	**33**	Cloud imagery	13	N/A	0
2	**Cloud cover**	**20**	Cloud cover	8	N/A	0
3	**Cloud top temperature**	**13**	Cloud type	7	N/A	0
4	**Precipitation rate**	**11**	Cloud top temperature	6	N/A	0
5	**Land surface temperature**	**11**	Cloud top height	5	N/A	0
6	**Land surface features**	**2**	Precipitation rate	4	N/A	0
	Total	**90**	Total	43		0
Most required parameters						
1	**Precipitation rate**		Land surface features		N/A	
2	**Temperature profile**		Sea level		N/A	
3	**Ozone profile**		Land cover		N/A	

Overall evaluation (Table 47)

3.2.3.21 In considering all methods and application areas, the final result showed that the use of satellite data continued to rely on cloud imagery and related parameters for the best interpretation of cloud fields (cloud cover, cloud top temperature, cloud type). Precipitation estimate and SST were also important parameters. SST was a parameter that could be easily processed and was useful for many applications.

3.2.3.22 Considered as the most required parameter, it could be argued that more effort should be devoted to precipitation monitoring, possibly by also using microwave passive observations, and for the improvement of wind extraction methods. Atmospheric instability index and cloud base height were was also considered one of the most needed parameters, for Nowcasting & VSRF and Synoptic Analysis methods and for Aeronautical Meteorology applications.

Table 47
Top six mandatory or useful and most required parameters – Overall evaluation

	2001	**%**	1999	%	1996	
1	**Cloud imagery**	**20**	Cloud imagery	13	N/A	0
2	**Cloud cover**	**15**	Cloud cover	8	N/A	0
3	**Cloud top temperature**	**12**	Cloud type	7	N/A	0
4	**Cloud type**	**9**	Cloud top temperature	6	N/A	0
5	**Sea surface temperature**	**5**	Cloud top height	5	N/A	0
6	**Precipitation rate**	**5**	Precipitation rate	4	N/A	0
	Total	**66**	Total	43		0
	Most required parameters					
1	**Precipitation rate**		Land surface features		N/A	
2	**Wind profile**		Sea level		N/A	
3	**Atmospheric instability index**		Land cover		N/A	

3.2.3.23 In analyzing the specific use of satellite data in each WMO Region, the top six most used parameters and most required parameters could be extracted for each method or application area (only those parameters most used or required are indicated and don't distinguish parameters with the same score). Blank cells indicate that no firm indication could be identified or no parameter was indicated. Relative ranking between WMO Regions for parameters should not be attempted:

<u>Nowcasting & VSRF</u>

RA I	**RA II**	**RA III**	**RA IV**	**RA V**	**RA VI**
Cloud top temp.	Cloud imagery	Cloud top temp.	Cloud cover	Cloud imagery	Cloud imagery
Cloud imagery	Cloud type	Cloud imagery	Cloud type	Cloud top temp.	Cloud cover
Prec.rate	Cloud cover	Cloud cover	Cloud imagery	Cloud top height	Cloud top temp.
Cloud type	Cloud top temp.	Cloud top height	Cloud top height	Cloud type	Cloud type
Cloud cover	Prec.rate	Cloud type	Cloud top temp.	Cloud base heig.	Cloud top height
Temp.profile	Cloud top height		Cloud wat.tot.col		Cloud base heig.
Most required parameters					
Atm.instab.index	Prec.rate	Cloud base heig	Atm.instab.index	Prec. rate	Atm.instab.index
Land surf.featur.	Wind profile		Prec.rate	Atm.instab.index	Cloud base heig.
	Rain profile		Wind vector s.s.		Prec.rate

Synoptic analysis

RA I	RA II	RA III	RA IV	RA V	RA VI
Cloud top temp.	Cloud imagery	Cloud cover	Cloud type	Cloud imagery	Cloud imagery
Cloud imagery	Cloud type	Cloud top temp.	Cloud cover	Cloud type	Cloud cover
Cloud type	Cloud cover	Cloud imagery	Cloud imagery	Cloud cover	Cloud top temp.
Rain profile	Cloud top temp.	Cloud top height	Cloud top temp.	Cloud base heig.	Cloud type
Cloud cover	Cloud top height	Cloud type			Cloud top height
S.S.T.	Prec.rate	S.S.T.			
Most required parameters					
Atm.instab.index	Prec.rate	Wind profile	Signif.wave hei.	Atm.instab.index	Atm.instab.index
Temp.profile	Wind profile				Cloud base heig.
Prec.rate	Cloud base heig.				Prec.rate

Global & Regional NWP

RA I	RA II	RA III	RA IV	RA V	RA VI
Cloud imagery	Temp.profile	Cloud wat. prof.	Cloud cover	Spec.hum.prof.	Temp.profile
Prec.rate	S.S.T.	Rain profile	L.W. rad TOA		Wind profile
Wind profile	Wind profile	Wind profile	S.W. rad. TOA		S.S.T.
L.S.T.	Cloud top temp.	Temp.profile	S.S.T.		Wind speed s.s.
	Prec.rate	Atm.instab.index	Snow cover		Wind vector s.s.
		S.W. rad. TOA	Ozone profile		Sea-ice cover
Most required parameters					
Land surf.featur.	Cloud wat. prof.		Wind vector s.s.	Wind profile	Soil moisture
			Prec.rate		

Aeronautical Meteorology

RA I	RA II	RA III	RA IV	RA V	RA VI
Cloud top height	Cloud imagery	Cloud cover	Cloud type	Cloud imagery	Cloud imagery
Cloud imagery	Cloud type	Cloud top height	Cloud cover	Cloud top temp.	Cloud cover
Height of tropop.	Cloud cover	Cloud top temp.	Cloud imagery	Cloud type	Cloud top temp.
Cloud base heig.	Cloud top height	Cloud type	Cloud top height	Volcanic ash	Cloud type
Cloud top temp.	Cloud top temp.		Volcanic ash	Cloud top height	Wind profile
Cloud type			Cloud base heig.	Cloud base heig.	
Most required parameters					
Cloud ice tot.col.	Wind profile	Cloud base heig.	Height of tropop.	Atm.instab.index	Cloud base heig.
Volcanic ash	Cloud base heig.		Wind profile	Cloud base heig.	Atm.instab.index
Wind profile					

Marine Meteorology

RA I	RA II	RA III	RA IV	RA V	RA VI
S.S.T.	S.S.T.	S.S.T.	Sig. wave height	Cloud imagery	Cloud imagery
Ocean currents	Cloud imagery	Wind speed s.s.	Wind vector s.s.	Cloud type	S.S.T.
Wind vector s.s.	Cloud type	Wind vector s.s.		Sig. wave height	Cloud cover
Wave period/dir.	Sea-ice cover			Wave period/dir.	Sea-ice cover
Cloud imagery					Sig. wave height
Cloud cover					Wind vector s.s.
Most required parameters					
Wind speed s.s.	Ocean currents	Ocean currents	Wave period/dir.	Wind vector s.s.	Sig. wave height
Sig. wave height	Wind speed s.s.		S.S.T.	S.S.T.	Sea level
Sea level	Wind vector s.s.			Ocean currents	

Agricultural Meteorology

RA I	RA II	RA III	RA IV	RA V	RA VI
N.D.V.I.	N.D.V.I.	L.S.T.	Prec. index	Cloud imagery	N.D.V.I.
Rain profile	Land surf.featur.	Cloud cover	Prec.rate	Cloud cover	Cloud cover
Cloud type	Prec. index	Cloud wat.tot.col		Cloud type	Land cover
Cloud cover	Cloud type			Fires	L.S.T.
Cloud top temp.	Cloud cover			Prec. index	Land surf.featur.
L.S.T.	Cloud imagery			Prec.rate	Veg. type
Most required parameters					
N.D.V.I.	Soil moisture	N.D.V.I.	L.S.T.	L.A.I.	Soil moisture
L.A.I.	Veg. type	Veg. type			Veg. type
Soil moisture	N.D.V.I.				Prec.rate

Hydrology

RA I	RA II	RA III	RA IV	RA V	RA VI
Prec.rate	Cloud imagery	Cloud imagery	Prec. rate	Cloud imagery	Snow cover
Soil moisture	Cloud cover	Cloud type	Cloud wat.profile	Cloud type	Snow melt.con.
	Cloud top temp.	Cloud top height		Cloud cover	Land cover
	Snow cover	Atm.instab.index		Cloud wat.profile	Prec. index
	Sea-ice cover	Land cover		Cloud wat.tot.col	Cloud imagery
		Soil moisture		Cloud ice.tot.col	S.S.T.
Most required parameters					
Rain profile	Prec.rate	Veg. type	L.S.T.	Prec.rate	Soil moisture
	Rain profile	Rain profile	Cloud type	Rain profile	Prec.rate
	Prec. index	Land surf.featur.	Prec. rate	Prec. index	Snow melt.con.

Atmospheric chemistry

RA I	RA II	RA III	RA IV	RA V	RA VI
Aerosol tot. col.		A.T.I.			Trace gases
Ozone tot.col.		Atm.instab.index			Wind profile
Prec. Index		Spec.hum.prof.e			Ozone tot.col.
Trace gases					Ozone profile
Most required parameters					
Ozone profile	Ozone tot.col.	Aerosol tot. col.			Aerosol tot. col.
Trop. Temp.	Ozone profile	Trace gases			Trace gases
	Aerosol tot. col.				Volcanic ash

Climatology/Global change

RA I	RA II	RA III	RA IV	RA V	RA VI
S.S.T.	Cloud type	Snow cover	Cloud imagery	Cloud cover	LW out rad TOA
	Cloud cover	Soil moisture	Cloud top temp.	Cloud imagery	Prec. index
	Cloud imagery		LW out rad TOA	L.S.T.	SW out rad TOA
	Sea-ice cover		Ozone profile	LW out rad TOA	SW irrad. surf.
	Sea level		Sea-ice cover	Ozone profile	LW surf .emiss.
	S.S.T.		S.S.T.	Temp.profile	L.S.T.
Most required parameters					
Sea level	Salinity	Prec. Index	Aerosol tot. col.	Prec. rate	Cloud wat.profile
Trace gases	Ozone profile	Land cover	Soil moisture		
	Aerosol tot. col.	Cloud base heig.			

Environmental/Disaster monitoring

RA I	RA II	RA III	RA IV	RA V	RA VI
Cloud imagery	Cloud imagery	Cloud top temp.	Cloud top temp.	Cloud imagery	Fires
		Fires			Cloud imagery
		Prec. Rate			Land cover
					Land surf.featur.
					N.D.V.I.
Most required parameters					
Fires	Fires	Soil moisture	Sea level	Temp. profile	Fires
Sea level	Ozone tot.col.	Veg. Type	Wave period/dir.	Wave period/dir.	Volcanic ash
		Land surf.featur.	Wind profile	Volcanic ash	Prec. rate

Research applications

RA I	RA II	RA III	RA IV	RA V	RA VI
Cloud imagery	Cloud imagery	Fires	Cloud top temp.	Cloud imagery	Cloud cover
Cloud top temp.	Cloud cover	Prec. Rate	Cloud imagery	Fires	LW surf .emiss.
S.S.T.	Cloud type	S.S.T.	Cloud type		N.D.V.I.
	Temp. profile	SW irrad. surf.	S.S.T.		Ozone profile
	Wind vector s.s.	Wind speed s.s.	LW out rad TOA		Temp. profile
		Wind vector s.s.	SW out rad TOA		
Most required parameters					
Prec. rate	Prec. rate	Temp. Profile		Fires	SW irrad. surf.
	Cloud type				SW out rad TOA

Public Weather Services

RA I	RA II	RA III	RA IV	RA V	RA VI
L.S.T.	Cloud imagery	Cloud top temp.	Cloud imagery	Cloud imagery	Cloud imagery
Cloud cover	Cloud top temp.	Cloud cover	Cloud cover	Cloud type	Cloud cover
Cloud imagery	Prec. rate	Cloud type	Cloud type	Cloud cover	Cloud type
Rain profile	Cloud type	Prec. rate	Prec. rate	Prec. index	L.S.T.
Cloud top temp.	Cloud top height	Cloud imagery	Cloud top height	Prec. rate	Cloud top temp.
Cloud type	Cloud cover	Fires	L.S.T.	Cloud top temp.	Fires
Most required parameters					
Temp. profile	Prec. rate	Wind vector s.s.	Wind vector s.s.	Atm.instab.index	Temp. profile
Prec. rate	Wind profile	Wind profile	Sig. wave height	Sea level	Cloud type
Atm.instab.index	Cloud base heig	Wave period/dir.	Wave period/dir.	L.S.T.	Snow cover

Total for all Regions

RA I	RA II	RA III	RA IV	RA V	RA VI
Cloud imagery	Cloud imagery	Cloud cover	Cloud type	Cloud imagery	Cloud imagery
Cloud top temp.	Cloud type	Cloud top temp.	Cloud cover	Cloud type	Cloud cover
Cloud cover	Cloud cover	Cloud type	Cloud imagery	Cloud top temp.	Cloud type
Cloud type	Cloud top temp.	Prec. rate	Cloud top temp.	Cloud cover	Cloud top height
S.S.T.	Prec. rate	Cloud top height	S.S.T.	Cloud top height	Wind profile
Prec. rate	S.S.T.	Cloud imagery	Prec. rate	Prec. rate	Temp. profile
Most required parameters					
Temp. profile	Prec. rate	Cloud base heig	Prec. rate	Prec. rate	Prec. rate
Atm.instab.index	Wind profile	Wind profile	Wind vector s.s.	Atm.instab.index	Cloud base heig
Fires	Cloud base heig	Cloud wat.tot.col	Wave period/dir.	Wind profile	Atm.instab.index

3.2.3.24 Finally, a complete view of the responses received for all applications for mandatory or useful and requested parameters are shown in Tables 48 and 49, respectively, below:

Table 48

Parameters mandatory or useful – all applications areas													
Parameters name	NOW VSRF	Syn	NWP	Aero Met	Marine Met	Agri Met	Hydr.	Atm. Chem	Clim. Gl.Ch	Envir. Dis.	Res.	PWS	**Total**
Aerosol total column	0	0	0	0	0	0	0	3	0	0	0	0	**3**
Apparent Thermal Inertia	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Atmospheric Instability Index	0	6	0	3	0	0	0	0	0	0	0	3	**12**
Cloud base height	8	9	1	12	0	0	0	0	0	0	0	0	**30**
Cloud cover	34	34	3	31	14	9	4	0	9	2	5	21	**166**
Cloud ice total column	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Cloud imagery	47	50	4	35	17	7	8	0	6	12	8	34	**228**
Cloud top height	0	0	0	22	0	0	0	0	0	0	0	0	**22**
Cloud top temperature	40	31	5	26	0	0	0	0	0	8	7	14	**131**
Cloud type	36	33	0	29	0	0	6	0	0	0	0	0	**104**
Cloud water profile	0	0	0	0	0	0	3	0	0	0	0	0	**3**
Cloud water total column	0	0	1	0	0	2	0	0	0	0	0	0	**3**
Fires	0	0	0	0	0	0	0	1	0	12	2	0	**15**
Height of tropopause	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Icebergs	0	0	0	0	2	0	0	0	0	0	0	0	**2**
Land cover	0	0	0	0	0	0	6	0	0	6	0	2	**14**
Land surface features	0	0	0	0	0	5	0	0	0	0	0	3	**8**
Land surface temperature	0	0	0	0	0	11	0	0	4	0	0	12	**27**
Leaf Area Index (LAI)	0	0	0	0	0	3	0	0	0	0	0	0	**3**
Long-wave surf. Emissivity	0	0	0	0	0	0	0	0	0	0	2	0	**2**
Long-wave outgoing rad. TOA	0	0	3	0	0	0	0	0	7	0	4	0	**14**
Norm. Diff. Veg. Index (NDVI)	0	0	0	0	1	14	0	0	0	0	0	0	**15**
Ocean currents	0	0	0	0	4	0	0	0	0	0	0	0	**4**
Ozone Profile	0	0	0	0	0	0	0	4	3	0	3	0	**10**
Ozone total column	0	0	0	0	0	0	0	5	0	0	0	0	**5**
Precipitation index	0	0	2	0	0	5	3	0	3	0	0	0	**13**
Precipitation rate	12	7	0	4	2	0	8	0	0	7	4	12	**56**
Rain Profile	0	0	0	0	0	0	2	0	0	0	0	0	**2**
Salinity	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Sea-ice cover	0	0	0	0	10	1	0	0	3	0	0	0	**14**
Sea-ice surface temperature	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Sea Level	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Sea surface temperature	0	8	13	0	21	0	2	0	6	0	8	0	**58**
Short-wave outgoing rad. TOA	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Short-wave irradiance at surf.	0	0	0	0	0	0	0	0	3	0	0	0	**3**
Significant wave height	0	0	0	0	11	0	0	0	0	0	0	0	**11**
Snow cover	0	0	2	0	0	0	9	0	2	0	0	0	**13**
Snow melting conditions	0	0	0	0	0	0	5	0	0	0	0	0	**5**
Soil moisture	0	0	0	0	0	6	0	0	0	0	0	0	**6**
Specific humidity profile	4	0	0	0	0	0	0	0	0	0	3	0	**7**
Specific humidity total column	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Temperature profile	0	8	16	0	0	0	0	1	3	0	0	0	**28**
Trace gases	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Tropopause temperature	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Vegetation type	0	0	0	0	0	5	0	0	0	0	0	0	**5**
Wave period/direction	0	0	2	0	10	0	0	0	0	0	0	0	**12**
Wind profile	0	0	13	8	0	0	0	0	0	0	0	0	**21**
Wind speed over sea surface	0	0	0	0	8	0	0	0	0	0	2	0	**10**
Wind vector over sea surface	0	0	6	0	15	0	0	0	0	0	0	0	**21**
Volcanic ash	0	0	0	9	0	0	0	0	0	3	0	0	**12**
Others	0	0	0	0	0	0	2	0	0	0	0	0	**2**

Table 49

Parameters requested – all application areas													
Parameters name	NOW VSRF	Syn	NWP	Aero Met	Marine Met	Agri Met	Hydr.	Atm. Chem	Clim. Gl.Ch	Envir. Dis.	Res.	PWS	**Total**
Aerosol total column	1	0	0	0	0	0	0	6	2	0	0	1	**10**
Apparent Thermal Inertia	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Atmospheric Instability Index	22	15	2	11	0	0	0	0	0	0	2	5	**57**
Cloud base height	16	12	1	17	0	0	0	0	1	0	1	4	**52**
Cloud cover	0	0	1	0	0	0	0	0	1	0	0	0	**2**
Cloud ice total column	0	0	0	5	0	0	0	0	0	0	0	0	**5**
Cloud imagery	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Cloud top height	0	4	0	6	0	0	0	0	0	0	0	1	**11**
Cloud top temperature	0	3	0	0	0	0	0	0	0	1	0	2	**6**
Cloud type	6	8	0	0	0	0	1	0	0	0	2	3	**20**
Cloud water profile	6	4	4	7	0	0	0	1	2	0	0	0	**24**
Cloud water total column	4	5	0	0	0	1	0	0	0	0	0	0	**10**
Fires	1	1	0	0	0	1	0	1	0	9	1	3	**17**
Height of tropopause	0	0	0	4	0	0	0	1	0	0	0	0	**5**
Icebergs	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Land cover	0	0	0	0	0	0	1	0	0	2	0	0	**3**
Land surface features	0	0	0	0	0	0	3	0	0	2	0	0	**5**
Land surface temperature	0	0	2	0	0	4	2	0	0	0	0	2	**10**
Leaf Area Index (LAI)	0	0	0	0	1	8	0	0	0	0	1	0	**10**
Long-wave surf. Emissivity	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Long-wave outgoing rad. TOA	0	0	0	0	0	0	1	0	3	0	0	0	**4**
Norm. Diff. Veg. Index (NDVI)	0	0	0	0	0	8	0	0	0	0	0	0	**8**
Ocean currents	2	2	0	0	13	0	0	0	1	0	0	0	**18**
Ozone Profile	0	0	0	0	0	0	0	4	0	0	2	0	**6**
Ozone total column	0	0	0	0	0	0	0	2	0	2	0	0	**4**
Precipitation index	6	7	0	1	0	3	6	0	0	0	0	2	**25**
Precipitation rate	22	15	4	2	0	4	12	0	4	3	5	6	**77**
Rain Profile	0	0	1	0	0	0	5	0	0	0	0	0	**6**
Salinity	0	0	0	0	5	0	0	0	0	0	1	0	**6**
Sea-ice cover	0	0	0	1	2	0	0	0	0	0	0	0	**3**
Sea-ice surface temperature	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Sea Level	0	0	0	0	10	0	0	0	4	3	0	3	**20**
Sea surface temperature	0	5	1	0	10	0	1	0	0	0	4	0	**21**
Short-wave outgoing rad. TOA	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Short-wave irradiance at surf.	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Significant wave height	1	2	0	1	16	0	0	0	0	0	0	0	**20**
Snow cover	0	0	2	0	0	0	5	0	1	0	0	0	**8**
Snow melting conditions	0	0	0	0	0	1	5	0	0	1	0	0	**7**
Soil moisture	0	0	4	0	0	13	8	0	3	3	2	2	**35**
Specific humidity profile	0	0	4	2	0	0	0	0	1	0	0	1	**8**
Specific humidity total column	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Temperature profile	8	11	0	6	0	0	0	0	0	3	5	6	**39**
Trace gases	0	0	0	0	0	0	0	5	0	0	0	1	**6**
Tropopause temperature	0	2	0	0	0	0	0	0	0	0	0	0	**2**
Vegetation type	0	0	0	0	0	10	0	0	0	0	0	0	**10**
Wave period/direction	0	0	0	0	13	0	0	0	0	0	0	4	**17**
Wind profile	12	11	8	13	3	0	0	1	0	3	4	5	**60**
Wind speed over sea surface	0	2	0	2	10	0	0	0	0	0	0	0	**14**
Wind vector over sea surface	1	0	6	0	14	0	0	0	0	2	0	0	**23**
Volcanic ash	0	0	0	0	0	0	0	0	2	4	0	1	**7**
Others	0	0	0	0	1	0	1	0	0	1	0	2	**5**

3.2.3.25 Conclusions and recommendations for the application areas concerning the most important and most required parameters are as follows:

- Cloud parameters were still the most important parameters for nearly all applications;
- Atmospheric instability index and cloud base height were the most frequently mentioned parameters as the most important and required parameter for a wide range of applications. Since instability indices can be derived from sounding instruments onboard satellites, the request for instability index was a clear indication that either GEO satellites should provide instability assessment capabilities or that the number of overpasses of LEO satellites with a sounding capability should be increased. A clear recommendation to the operators of satellite systems could be based on this conclusion;
- Wind profile was the second most frequently mentioned required parameter that was not available. This indicated that there was an urgent need for the development of operational wind profiling systems in space. Space agencies should be encouraged to respond to this urgent requirement and to initiate the necessary activities;
- Precipitation rate was the most required parameter but not available in a satisfactory manner. The underlying problem was precipitation's extreme inhomogeneity in space and time. Precipitation rate is best measured, in principle, in the microwave portion of the spectrum in order to minimize the effects of clouds. A logical consequence would be to develop suitable operational microwave sensors to assess precipitation rate with the required accuracy and temporal and spatial resolution from geostationary orbit. This is, however, technologically very challenging. Alternatively, increased numbers of LEO satellites with appropriate microwave instruments could serve to ameliorate the deficiency. In any case, the requirement for precipitation rate was very clearly articulated. Satellite operators and space agencies should take this requirement into account that has existed throughout all previous surveys.

Recommendation:. Operational space agencies are encouraged to provide space systems with more frequent observations of atmospheric instability parameters and develop capabilities for cloud base height observations. Possible solutions but not inclusive could be through either increased temporal frequency for LEO satellites with sounding capabilities or through sounding capabilities on all geostationary satellites.

Recommendation: Space agencies are encouraged to develop the capability to provide wind profiles that meet WMO requirements.

Recommendation: Satellites should have suitable operational sensors for the observation of precipitation rate with appropriate accuracy and temporal and spatial resolution to meet WMO requirements. Possible solutions but not inclusive could be either through microwave sensors on geostationary satellites or increased temporal frequency for LEO satellites with appropriate microwave instruments.

Recommendation: The Chair of the OPAG IOS should recommend that the Expert Team on Observational Data Requirements and Redesign of the GOS review the results of the most important and most required parameters in its work on the redesign of the GOS.

3.3 Limiting factors in the use of satellite data and products

3.3.1 Table 50 represents the numbers of responses reporting a lack of receiving equipment:

Table 50
Number NMHSs reporting a lack of receiving equipment

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	**9**	**14**	**6**	**6**	**7**	**27**	**69**
Number of responses in 1999:	17	14	6	2	4	22	65
Number NMHSs lacking receiving equipment in 2001	**4**	**6**	**2**	**4**	**3**	**10**	**29**
Number NMHSs lacking receiving equipment in 1999:	6	7	3	-	-	7	23
Percentages (2001):	**44**	**43**	**33**	**67**	**43**	**37**	**42**
Percentages (1999):	35	50	50	-	-	32	35

Note: The figures for 1999 were taken from SAT 23, Table 1b in Annex I, Row B

Compared to 1999, the 2001 analysis shows an increase in the number of NMHSs reporting a lack of receiving equipment. This does not necessarily mean that the situation has worsened during this time period, but rather more Members with insufficient satellite receiving equipment availability responded in 2001 than in 1999.

In general, however, the number of NMHSs reporting a lack of receiving equipment in 2001 is high, representing 42% of the responses. This is an area where there should be increased emphasis especially through implementation of the Strategy to Improve Satellite System Utilization.

Recommendation: WMO, based on guidance developed by the OPAG-IOS Expert Team on Satellite Systems Utilization and Products (ET SSUP) and approved by CBS, should advise NMHSs on alternative means for access to satellite data and products.

3.3.2 Table 51 represents the number of responses reporting a lack of maintenance know-how and/or services:

Table 51
Number NMHSs reporting a lack of maintenance know-how and/or services

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	**9**	**14**	**6**	**6**	**7**	**27**	**69**
Number of responses in 1999:	17	14	6	2	4	22	65
Number of reported deficiencies in 2001	**3**	**5**	**4**	**1**	**4**	**7**	**24**
Number of reported deficiencies in 1999:	5	-	-	2	-	2	9
Percentages (2001):	**33**	**36**	**67**	**17**	**57**	**26**	**35**
Percentages (1999):	24	-	-	100	-	10	14

Note: The figures for 1999 are taken from SAT 23, Table 1b in Annex I, Row D

The increase in NMHSs reporting maintenance problems was considerable. In 1999, only 14% of WMO Members responding to the questionnaire reported such problems. The figure (14%) was not a major concern at that time. However, two years later, the number of NMHSs reporting maintenance problems increased to 35 percent. Even with the statistical uncertainties associated with the survey for some WMO regions, the increase was alarming. Some receiving equipment may be too complex for some NMHSs and/or there may be insufficient funds for service contracts with outside companies. One potential solution to this problem may be that some NMHSs should not operate such satellite data receiving equipment but should utilize alternative data reception means. Thus, the recommendation is the same as in paragraph 3.3.1, i.e.:

Recommendation: WMO, based on guidance developed by the OPAG-IOS Expert Team on Satellite Systems Utilization and Products (ET-SSUP) and approved by CBS, should advise NMHSs on alternative means for access to satellite data and products.

3.3.3 Table 52 represents the number of responses reporting that required data were not disseminated:

Table 52
Number of NMHSs reporting required data were not disseminated

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	**9**	**14**	**6**	**6**	**7**	**27**	**69**
Number of responses in 1999:	17	14	6	2	4	22	65
Number of reported deficiencies in 2001	**4**	**4**	**2**	**1**	**1**	**8**	**20**
Number of reported deficiencies in 1999: (receiving equipment problems excluded	11 (5)	9 (2)	4 (1)	1 (1)	- -	10 (3)	35 (12)
Percentages (2001):	**44**	**29**	**33**	**17**	**14**	**30**	**29**
Percentages (1999):	64	64	67	50	-	45	54

Note: The figures for 1999 were taken from SAT 23, Table 1b in Annex I, Row A (in parenthesis: Row A minus B)

A comparison between the 1999 and 2001 responses concerning required data not being disseminated was difficult. In 1999, the reasons for data unavailability had been combined. The lack of data availability was largely due to either: a lack of receiving equipment availability; required data not being disseminated; required data and products not available or communication system capacity limitations. Therefore, to have comparable 1999 figures, the number of reports with receiving equipment problems were subtracted from the figures for data unavailability, the resulting figures given in Table 52 above in parenthesis. Conclusions based on the comparison between the 1999 and 2001 figures in Table 52 should be used with some caution.

An evaluation of the survey indicated that even some of the more experienced NMHSs required data not being disseminated. This could indicate that such NMHSs assumed that required data were available in principle but not distributed or they have requirements that present satellite systems cannot satisfy.

3.3.4 Table 53 represents the number of responses reporting data and products required but not available:

Table 53
Number of NMHSs reporting data and products required but not available

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	9	14	6	6	7	27	69
Number of reported deficiencies in 2001:	4	9	3	2	1	8	27
Percentages (2001):	44	64	50	33	14	30	39

Unfortunately it was not possible to compare directly the number of reports in 1999 and 2001 indicating that required data and products were not available. It was not possible to determine data unavailability from the responses. Possible but unsubstantiated reasons could include technical or scientific constraints: technical reasons could be a limitations in the data distribution systems, scientific reasons could be that satellite data and products were insufficient for the intended application, e.g., accuracy or horizontal resolution was not according to the requirements. Therefore, no definite conclusion could be drawn from the responses to this question.

3.3.5 Table 54 represents the numbers of responses reporting communication system capacity limitations.

Table 54
Number of NMHSs reporting communication system capacity limitation

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	**9**	**14**	**6**	**6**	**7**	**27**	**69**
Number of responses in 1999:	17	14	6	2	4	22	65
Number of reported limitations in 2001:	**3**	**7**	**1**	**4**	**1**	**6**	**22**
Number of reported deficiencies in 1999:	5	2	2	1	-	2	12
Percentages (2001)	**33**	**50**	**17**	**67**	**14**	**22**	**32**
Percentages (1999)	29	14	33	50	-	10	18

Note: The figures for 1999 are taken from SAT 23, Table 1b in Annex I, Row C

The increase should be noted in the number of reported communication system limitations. For Regions III and V, the situation seems to be, in general, not so serious, but is disquieting for Regions II, IV and VI. Taking into account that the volume of satellite data and products will continue to increase considerably in the near future, appropriate communication system capacity will be a key element for efficient utilization of satellite data and products.

Recommendation: NMHSs should be encouraged to establish communications systems with appropriate capacity based on the planned data volumes to be disseminated from future satellite systems.

3.3.6 Table 55 represents the number of responses reporting a lack of knowledge on use of equipment.

Table 55
Number of NMHSs reporting a lack of knowledge on use of equipment

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	9	14	6	6	7	27	69
Number of reported deficiencies in 2001:	3	3	2	2	1	6	17
Percentages (2001):	33	21	33	33	14	22	25

SAT-23 does not provide explicit numbers of NMHSs reporting a lack of knowledge on use of equipment. Therefore, a direct comparison wasn't possible between the years 1999 and 2001. However, the number of reports indicating problems with knowledge on use of equipment in 2001 was not very high and it seemed that users were trained well enough in using the equipment. Thus, this issue didn't seem to be a matter a concern in general.

3.3.7 Other factors limiting access to satellite data or products: Table 56 categorizes other factors limiting access to satellite data and products were reported in the 2001 survey as comments:

Table 56

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Lack of staff for data access:	-	-	-	-	-	2	2
Financial limitations	-	1	-	1	-	3	5
Lack of training in new technologies	-	-	-	-	-	1	1
Distribution of LEO data to regional offices	1	-	-	-	-	-	1

In general, the number of "other limiting factors" in the context of access to satellite data and products was relatively low. The five reported financial limitations correspond to 7% of the 69 completed questionnaires received.

3.3.8 Table 57 represents the numbers of responses reporting a lack of knowledge in use of satellite data and products:

Table 57
Number of NMHSs reporting lack of knowledge in use of satellite data & products

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	**9**	**14**	**6**	**6**	**7**	**27**	**69**
Number of responses in 1999:	17	14	6	2	4	22	65
Number of reported deficiencies in 2001:	**3**	**8**	**0**	**3**	**2**	**7**	**23**
Number of reported deficiencies in 1999:	5	4	1	2	1	4	17
Percentages (2001):	**33**	**57**	**0**	**50**	**29**	**26**	**33**
Percentages (1999):	29	29	17	100	25	18	26

Note: The figures for 1999 were taken from SAT 23, Table 8 in Annex I, Row A

For RA I, an improvement was noted through a decrease in the number of responses reporting a lack of knowledge in the use of satellite data and products; however, the result was considered not very statistically significant. On the other hand, there was a significant increase in the number of reported lack of knowledge in the use of satellite data and products, especially for Regions II and VI.

Taking into account the somewhat smaller statistical basis and the fact that not all the Members that responded in 2001 were the same as in 1999, in general it can be concluded that there were no significant changes in the situation regarding the lack of knowledge in the use of satellite data and products.

3.3.9 Table 58 represents the numbers of responses reporting a lack of knowledge in programming techniques:

Table 58
Number of NMHSs reporting lack of knowledge in programming techniques

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	9	14	6	6	7	27	69
Number of responses in 1999:	17	14	6	2	4	22	65
Number of reported deficiencies in 2001:	7	7	4	5	4	4	31
Number of reported deficiencies in 1999:	11	6	1	1	1	4	24
Percentages (2001):	78	50	67	83	57	15	45
Percentages (1999):	65	43	17	50	25	18	37

Note: The figures for 1999 are taken from SAT 23, Table 8 in Annex I, Row B

With the exception of RA VI, there were increases in the number of reported lack of knowledge in programming techniques. The WMO wide average reported for 2001 was very high (45% of returned questionnaires). Several Members obviously felt a need to undertake their own programming for satellite data handling and applications. An alternative solution could be that several NMHSs form networks or consortia with shared responsibilities and benefit from the activities, experience and services of others. This consideration resulted in the following recommendation:

Recommendation: Relevant Members should be encouraged to consider alternative solutions to achieve their computer programming requirements. Such an alternative could be, for example, the formation of networks or consortia with shared responsibilities, activities and services.

3.3.10 Table 59 represents the numbers of responses reporting limitations in availability of application software and methods:

Table 59
Number of NMHSs reporting limitations in availability of application software and methods

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	**9**	**14**	**6**	**6**	**7**	**27**	**69**
Number of responses in 1999:	17	14	6	2	4	22	65
Number of reported deficiencies in 2001:	**7**	**10**	**4**	**5**	**4**	**15**	**45**
Number of reported deficiencies in 1999:	13	4	3	1	2	5	28
Percentages (2001):	**78**	**71**	**67**	**83**	**57**	**56**	**65**
Percentages (1999):	76	29	50	50	50	23	43

Note: The figures for 1999 are taken from SAT 23, Table 8 in Annex I, row C

An increase in reported limitations in availability of application software and methods was noted. This declining situation was considerable for some WMO Regions and was on a statistically firm basis. This indication has two aspects: one positive one and one negative. Obviously more NMHSs were becoming aware of the benefits of satellite data and products and were interested in using them. However, a considerable number of interested NMHSs suffered limitations due to the availability of application software and methods.

Recommendation: Appropriate strategies should be developed and implemented in order to improve the availability of application software and methods based on the fact that two-thirds of the NMHSs that returned the survey indicated such limitations. Such an immediate solution would be important for increased interest in satellite data and products utilization.

3.3.11 Table 60 represents the numbers of responses reporting limited impact for the intended application:

Table 60
Number of NMHSs reporting limited impact for the intended application

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	**9**	**14**	**6**	**6**	**7**	**27**	**69**
Number of responses in 1999:	17	14	6	2	4	22	65
Number of reported limits in 2001:	**2**	**5**	**1**	**2**	**2**	**7**	**19**
Number of reported limits in 1999:	5	5	0	1	1	4	16
Percentages (2001):	**22**	**36**	**17**	**33**	**29**	**26**	**28**
Percentages (1999):	29	36	0	50	25	18	25

Note: The figures for 1999 are taken from the table in section 3.5.4 of SAT 23.

In principle, there was not a big change in the number of reported limited impact of satellite data and products for the intended application since 1999. There was a slight improvement for RA I and slight worsening for RA VI. In general, the situation appeared satisfactory with satellite data and products having the intended impact on applications.

3.3.12 Other factors that limit the utilization of satellite data or products: Table 61 categorizes factors that limited the utilization of satellite data and products as reported for 2001 in the comments:

Table 61

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Lack of staff for utilisation:	-	1	-	-	-	3	4
Financial limitations:	-	-	-	-	-	3	3
Required data & products not available (MSG, precipitation, snow water equivalent)	-	-	-	1	-	2	3
Limited knowledge in product interpretation	-	-	-	-	1	-	1
More research needed to develop operational products	-	-	-	-	-	1	1
Archive retrieval problems	-	-	-	1	-	-	1
New software version needed	-	-	-	-	-	1	1
Processing hardware problems	-	-	-	-	-	1	1

One reported hardware problem indicated a missing UNIX workstation for processing satellite data. The two most frequently mentioned additional limitations for the utilization of satellite data and products were lack of staff and funding.

3.3.13 A summary of the reported <u>lack of personnel for data access and data utilization</u> is shown in Table 62:

Table 62
Number of NMHSs reporting lack of personnel

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	**9**	**14**	**6**	**6**	**7**	**27**	**69**
Number of responses in 1999	17	14	6	2	4	22	65
Number of reported deficiencies in 2001:	**-**	**1**	**-**	**-**	**-**	**5**	**6**
Number of reported deficiencies in 1999	6	3	2	1	2	7	21
Percentages (2001):	**-**	**7**	**-**	**-**	**-**	**19**	**12**
Percentages (19999§	35	21	33	50	50	32	32

Note: The figures for 1999 were taken from SAT 23, Table 9

There was considerable improvement as concerns the number of reported lack of personnel. Only two Regions (RA II and VI) reported such problems in 2001, whereas two years before all WMO Regions indicated staffing problems. The main reason for this may be that there was a dedicated question for lack of personnel in the questionnaire for 1999, but not in the version for 2001. As a consequence, no clear conclusion should be drawn from the comparison of the year 1999 and 2001.

3.3.14 A summary of reported <u>limitations in funds</u> for data access and data utilization is shown in Table 63:

Table 63
Number of NMHSs reporting limitations in funds

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of responses in 2001:	9	14	6	6	7	27	69
Number of reported deficiencies in 2001	-	1	-	1	-	6	8
Percentages (2001):	-	7	-	17	-	22	12

No comparison with 1999 was possible as funding aspects were not requested at that time. The largest funding and personnel problems were reported by NMHSs in RA VI. It was difficult to make specific recommendations in this area.

3.3.15 General conclusions regarding the limiting factors in the use of satellite data and products:

- For 2001, the number of reports that indicated limitations in accessing and utilizing satellite data and products has increased in comparison to 1999 although not statistically significant for all WMO Regions. Nevertheless, the summary figures were representative of the situation. The situation in 2001 was less satisfactory than in 1999, and could be due, to some degree, to the following:

    - NMHSs returning the questionnaire for 2001 were not always the same as in 1999. It is possible that more services with certain problems responded in 2001 than in 1999, or that some of the services felt free to indicate problems in 2001 but hesitated to do so in 1999;

    - NMHSs were becoming aware of the derived benefits, and were starting to utilize satellite data and products but encountered certain difficulties in their operational use. In principle. this is a positive aspect and all possible means should be undertaken to enable an optimal use of the satellite data and products;

    - Several NMHSs that reported limitations in accessing satellite data and products were obviously of the opinion that it was necessary to operate their own direct satellite data receiving and processing facilities and to perform their own programming. While this may be valid for some WMO Regions, in other Regions this has changed.

3.4 Education and Training in Satellite Meteorology

3.4.1 The main emphasis for the analysis of the 1999 questionnaire was on the use of satellite data and products in different application areas. Therefore, it was not possible to conduct a dynamical evaluation covering the responses between 1999 and 2001. The following paragraphs contain a static analysis based solely on the responses for 2001.

3.4.2 The following number of staff were trained in the different **RMTCs** in the noted training areas:

3.4.2.1 Training in equipment operation and maintenance at the RMTCs:

3 NMHSs responses (1x RA I, 2x RA VI (+ RA II))
corresponds to 4% of all 69 returned questionnaires

	1 x	24 persons
	2 x	1 person
Total		26 persons

3.4.2.2 Training in software development at the RMTCs:

1 NMHS response (1x RA VI (res. RA II))
corresponds to 1% of all 69 returned questionnaires

	1 x	15 persons
Total		15 persons

3.4.2.3 Training in physical basis for remote sensing at the RMTCs (Table 64):

Table 64
Number of NMHSs reporting training on the fundamental of remote sensing at the RMTCs and number of trained staff

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting training:	2	1	-	-	-	3	6
Percentages in 2001	22	7	-	-	-	11	9
Number of trained staff	11	1	-	-	-	13	25

3.4.2.4 Number of reported trained staff in the fundamental of remote sensing at the RMTCs:

	1 NMHS	10 persons	=	10 persons
	1 NMHS	9 persons	=	9 persons
	1 NMHS	3 persons	=	3 persons
	3 NMHSs	1 person	=	3 persons
Total	6 NMHSs			25 persons

3.4.2.5 Training in satellite image interpretation at the RMTCs (Table 65):

Table 65
Number of NMHSs reporting training in satellite image interpretation at the RMTCs and number of trained staff

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting training:	3	2	1	1	-	5	12
Percentages in 2001	33	14	17	17	-	19	17
Number of trained staff	12	11	7	1	-	93	124

3.4.2.6 Number of reported trained staff in satellite image interpretation at the RMTCs:

	1 NMHS	87 persons	=	187 persons
	2 NMHS	10 persons	=	20 persons
	1 NMHS	7 persons	=	7 persons
	1 NMHSs	3 person	=	3 persons
	7 NMHSs	1 person	=	7 persons
Total	12 NMHSs			124 persons

3.4.2.7 Other training at the RMTCs:

3 NMHSs responses (1x RA II, 1x RA V, 1x RA VI (+ RA II))
corresponds to 4% of all 69 returned questionnaires

	1 x	8 persons
	2 x	1 person
Total		10 persons

3.4.2.8 Total number of trained staff at the RMTCs:

The total number of trained staff at the RMTCs as given in the paragraphs above results in the following totals:

Equipment operation and maintenance:	26 persons
Software development:	15 persons
Physical basis for remote sensing:	25 persons
Satellite image interpretation:	124 persons
Other training:	10 persons
Total:	200 persons

3.4.2.9 The total number of 200 staff trained in satellite meteorology at the RMTCs was relatively high and appeared to be sufficient. There were, however, considerable differences between the different WMO Regions. The number of NMHSs reporting training events and trained staff at the RMTCs for all the training areas together mentioned above are:

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of NMHSs reporting training at RMTS in 2001	6	4	1	1	1	12	25
Total number of persons trained at RMTC in 2001	24	13	7	1	1	154	200

3.4.2.10 More training activities took place in RA VI than any other Region, followed by RA I and RA II. One Member (the Russian Federation) reported the largest significant number of staff trained. Although the Russian Federation spans both RA VI and RA II, for purposes of the evaluation of the questionnaire, the Russian Federation was assigned to RA VI only; this may have had an influence on RA II statistics.

3.4.3 The following number of staff were trained in the different noted areas in 2001 **at WMO** (other than RMTC):

Training in equipment operation & maintenance: 0
Training in software development: 0
Training in physical basis for remote sensing: 2 staff, (1 from RA II, 1 from RA V)

3.4.3.1 Training in satellite image interpretation at WMO (Table 66):

Table 66
Number of NMHSs reporting training in satellite image interpretation at WMO and number of trained staff

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting training:	1	2	1	1	2	2	9
Percentages in 2001	11	14	17	17	29	7	13
Number of trained staff	1	4	1	2	2	6	16

3.4.3.2 Number of reported trained staff in satellite image interpretation at WMO:

	1 NMHS	5 persons	=	5 persons
	1 NMHS	3 persons	=	3 persons
	1 NMHS	2 persons	=	2 persons
	6 NMHSs	1 person	=	6 persons
Total:	9 NMHSs			16 persons

3.4.3.3 Other reported training at WMO:

NMHSs responding: 3 staff, one from RA II, one from RA III

3.4.3.4 Total of trained staff at WMO (other than RMTC)

The total number of staff trained at WMO as noted in the paragraphs was:

Equipment operation and maintenance:	0 persons
Software development:	0 persons
Physical basis for remote sensing:	2 persons
Satellite image interpretation:	16 persons
Other training:	3 persons
Total:	21 persons

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of NMHSs reporting training at RMTS in 2001	1	4	2	1	3	2	13
Total number of persons trained at RMTC in 2001	1	6	3	2	3	3	21

3.4.3.5 The total number of staff reported to having been trained at WMO (other than RMTC) was approximately 10% of the staff directly trained at the RMTCs. It was consider as a possibility that the total number of trained staff could be larger as there might have been training at NMHSs that did not respond to the questionnaire.

3.4.4 The following number of staff trained in the different training areas in 2001 **<u>at a university or in industry</u>** were:

3.4.4.1 Training in equipment operation and maintenance: 27 staff in total

(only from 2 NMHSs, 25 staff from RA II, 2 from RA VI)

3.4.4.2 Training in software development: 6 staff in total

(only from 3 NMHSs, 1 NMHS from RA IV, 2 from RA VI)

3.4.4.3 Training in the fundamentals of remote sensing (Table 67):

Table 67
Number of NMHSs reporting training in satellite image interpretation at university / industry and number of trained staff

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting training:	1	2	0	1	1	6	11
Percentages in 2001	11	14	0	17	14	22	16
Number of trained staff	5	21	0	2	1	59	88

3.4.4.4 Number of reported trained staff in the fundamental of remote sensing at university / industry:

	1 NMHS	40 persons	=	40 persons
	1 NMHS	20 persons	=	20 persons
	1 NMHS	10 persons	=	10 persons
	1 NMHSs	5 person	=	5 persons
	1 NMHS	4 persons	=	4 persons
	1 NMHS	3 persons	=	3 persons
	1 NMHS	2 persons	=	2 persons
	4 NMHSs	1 person	=	4 persons
Total:	11 NMHSs			88 persons

3.4.4.5 Training in satellite image interpretation at university / industry (Table 68):

Table 68
Number of NMHSs reporting training in satellite image interpretation at university / industry and number of trained staff

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting training:	0	3	0	1	3	2	9
Percentages in 2001	0	21	0	17	43	7	13
Number of trained staff	0	33	0	2	4	5	44

3.4.4.6 Number of reported trained staff in satellite image interpretation at university / industry:

	1 NMHS	30 persons	=	30 persons
	1 NMHS	4 persons	=	4 persons
	1 NMHS	2 persons	=	6 persons
	4 NMHSs	1 person	=	4 persons
Total:	9 NMHSs			44 persons

3.4.4.7 Other reported training at university / industry

(1 NMHS responding, 1 staff, from RA I)

3.4.4.8 Total of trained staff at university / industry:

The total for the number of trained staff at university / industry as noted in the results in the paragraphs above is:

Equipment operation and maintenance:	27 persons
Software development:	6 persons
Physical basis for remote sensing:	88 persons
Satellite image interpretation:	44 persons
Other training:	1 persons
Total:	166 persons

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of NMHSs reporting training at university in 2001	**2**	**6**	**0**	**3**	**4**	**11**	**26**
Total number of persons trained at university in 2001	6	79	0	8	5	68	166

3.4.4.9 The total number of staff trained at university / industry (166) was slightly lower than the reported number of staff trained at the RMTCs (200). RA II trained the most staff at university / industry, followed by RA VI. No training at university / industry was reported from RA III.

3.4.5 The following number of staff trained by **distant learning**, inclusive of Computer Added Learning (CAL) or the Virtual Laboratory (VL)*, in 2001 were:

3.4.5.1 Training in equipment operation & maintenance: 3 staff in total

(from 2 NMHSs, 2 staff from RA IV, 1 from RA VI)

* See footnote on page 57

3.4.5.2 Training in software development: 12 staff in total

(from 3 NMHSs, 10 staff from 1 NMHS from RA IV, 2 staff from 2 NMHSs from RA VI)

3.4.5.3 Training in physical basis for remote sensing: 11 staff in total

(from 2 NMHSs, both NMHSs from RA VI)

3.4.5.4 Training by distant learning in satellite image interpretation (Table 69):

Table 69
Number of NMHSs reporting training by distant learning in satellite image interpretation and number of trained staff

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting training:	0	1	0	1	0	3	5
Percentages in 2001	0	7	0	17	0	11	7
Number of trained staff	0	2	0	3	0	15	20

3.4.5.5 Number of reported trained staff by distant learning in satellite image interpretation:

	1 NMHS	10 persons	=	10 persons
	2 NMHS	3 persons	=	6 persons
	2 NMHS	2 persons	=	2 persons
Total:	5 NMHSs			20 persons

3.4.5.6 Other reported training by distant learning: none

3.4.5.7 Total of trained staff by distant learning:

The total number of trained staff by distant learning as noted in the paragraphs above is:

Equipment operation and maintenance:	3 persons
Software development:	12 persons
Physical basis for remote sensing:	11 persons
Satellite image interpretation:	20 persons
Other training:	0 persons
Total:	46 persons

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of **NMHSs** reporting training by distant learning in 2001:	**0**	**1**	**0**	**3**	**0**	**8**	**12**
Percentages in 2001	0	7	0	50	0	30	17
Total number of persons trained by distant learning in 2001	**0**	**2**	**0**	**7**	**0**	**37**	**46**

3.4.5.8 It appeared that distant learning was not as yet the nominal method for training in satellite meteorology since the number of staff trained by CAL or using the VL* was low in comparison to the other reported training methods. RA VI seemed to make the most intensive use of distant learning in comparison to the other WMO Regions. Regions I, III and V did not report any distant learning in 2001.

3.4.6 The following number of staff trained by **internal training** reported in 2001 were:

3.4.6.1 Training in equipment operation and maintenance: 37 staff in total

(from 6 NMHSs, 30 staff from 2 NMHSs from RA II, 7 staff from 4 NMHSs from RA VI)

3.4.6.2 Internal training in software development: 30 staff in total

(from 3 NMHSs, 19 staff from 1 NMHS from RA II, 11 staff from 2 NMHSs from RAVI)

3.4.6.3 Internal training in the fundamental of remote sensing (Table 70):

Table 70
Number of NMHSs reporting internal training in the fundamental of remote sensing and number of trained staff

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting internal training:	0	3	0	1	1	3	8
Percentages in 2001	0	21	0	17	14	11	12
Number of trained staff	0	150	0	8	3	26	187

* The VL only came into existence in October 2001 and statistics regarding it will only be meaningful after October 2003 when the VL achieves full implementation.

3.4.6.4 Internal training in satellite image interpretation (Table 71):

Table 67
Number of NMHSs reporting internal training in satellite image interpretation and number of trained staff

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting training:	0	3	1	1	1	7	13
Percentages in 2001	0	21	17	17	14	26	19
Number of trained staff	0	210	20	12	3	110	355

3.4.6.5 Number of reported trained staff by distant learning in satellite image interpretation:

	1 NMHS	143 persons	=	143 persons
	1 NMHS	60 persons	=	60 persons
	1 NMHS	45 persons	=	45 persons
	1 NHMS	40 persons	=	40 persons
	1 NMHS	20 persons	=	20 persons
	1 NMHS	12 persons	=	12 persons
	1 NMHS	10 persons	=	10 persons
	1 NMHS	7 persons	=	7 persons
	3 NMHSs	4 persons	=	12 persons
	2 NMHSs	3 persons	=	6 persons
Total:	513 NMHSs			355 persons

3.4.6.6 Other reported internal training: 7 staff, 1 NMHS from RA VI

3.4.6.7 Total of trained staff by internal training:

The total number of trained staff by internal training as noted in the paragraphs above is:

Equipment operation and maintenance:	37 persons
Software development:	30 persons
Physical basis for remote sensing:	187 persons
Satellite image interpretation:	355 persons
Other training:	7 persons
Total:	616 persons

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting internal training in 2001:	0	9	1	2	2	17	31
Percentages in 2001	0	64	17	33	29	63	45
Total number of persons trained by internal training in 2001	0	409	20	20’	6	161	616

3.4.6.8 Internal training was obviously the most favoured method for training in satellite meteorology. The total number of trained staff was high in comparison to the other training methods mentioned thus far. Approximately 60% (355) of the total staff trained by internal training were trained in satellite image interpretation. Most staff trained by internal training were from RA II. No internal training at all was reported from NMHSs of RA I in 2001.

3.4.7 The following number of staff trained by **bilateral training** reported in 2001 were:

3.4.7.1 Training in equipment operation & maintenance: 29 staff in total

from 3 NMHSs, 25 staff from 1 NMHS (RA II),
2 staff from 1 NHMS (RA V),
2 staff from 1 NMHS (RA VI)

3.4.7.2 Bilateral training in software development: 5 staff in total

from 3 NMHSs, 3 staff from 2 NMHSs (RA V), 2 staff from 1 NMHS (RA VI)

3.4.7.3 Bilateral training in the fundamental of remote sensing:

Table 72
Number of NMHSs reporting bilateral training in the fundamental of remote sensing and number of trained staff

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting bilateral training in 2001:	0	1	0	1	0	2	4
Percentages in 2001	0	7	0	17	0	7	6
Total number of persons trained by internal training in 2001	0	1	0	2	0	45	48

3.4.7.4 Number of reported trained staff by distant learning in physical basis for remote sensing:

	1 NMHS	30 persons	=	30 persons
	1 NMHS	15 persons	=	15 persons
	1 NMHS	2 persons	=	2 persons
	1 NHMS	1 person	=	1 person
Total:	4 NMHSs			48 persons

3.4.7.5 Bilateral training in satellite image interpretation:

Table 73
Number of NMHSs reporting bilateral training in satellite image interpretation and number of trained staff

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting training:	0	2	0	1	0	6	9
Percentages in 2001	0	14	0	17	0	22	13
Number of trained staff	0	2	0	2	0	49	53

3.4.7.6 Number of reported trained staff by distant learning in satellite image interpretation:

	2 NMHSs	20 persons	=	40 persons
	1 NMHS	4 persons	=	4 persons
	1 NMHS	3 persons	=	3 persons
	1 NHMS	2 persons	=	2 persons
	4 NMHSs	1 person	=	4 persons
Total:	9 NMHSs			53 persons

3.4.7.7 Other reported bilateral training: total 45 staff from 2 NMHS, both from RA VI

1 NMHS	30 persons	=	30 persons
1 NMHS	15 persons	=	15 persons

3.4.7.8 Total of trained staff by bilateral training:

The total number of trained staff by bilateral training as noted in the paragraphs above is:

Equipment operation and maintenance:	29 persons
Software development:	5 persons
Physical basis for remote sensing:	48 persons
Satellite image interpretation:	53 persons
Other training:	45 persons
Total:	180 persons

	RA I	RA II	RA III	RA IV	RA V	RA VI	Total
Number of questionnaires returned in 2001:	9	14	6	6	7	27	69
Number of NMHSs reporting bilateral training in 2001:	0	4	0	2	3	12	21
Percentages in 2001	0	29	0	33	43	44	30
Total number of staff trained by bilateral training in 2001	0	28	0	4	5	143	180

3.4.7.9 Bilateral training took place most frequently in RA VI. Eighty (80%) of staff benefiting from bilateral training came from RA VI. No bilateral training was reported from RA I and RA III.

3.4.8 **Synopsis of education and training** in satellite meteorology in each WMO Regions and an overall total:

3.4.8.1 RA I

Number of NMHSs from RA I reporting training in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	1	0	0	0	0	0	1
Software development	0	0	0	0	0	0	0
Physical basis for remote sensing:	2	0	1	0	0	0	3
Satellite image interpretation:	3	1	0	0	0	0	4
Other	0	0	1	0	0	0	1
Total	6	1	2	0	0	0	9

Number of trained staff from RA I reported in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	1	0	0	0	0	0	1
Software development	0	0	0	0	0	0	0
Physical basis for remote sensing:	11	0	5	0	0	0	16
Satellite image interpretation:	12	1	0	0	0	0	13
Other	0	0	1	0	0	0	1
Total	24	1	6	0	0	0	31

3.4.8.2 RA II

Number of NMHSs from RA II reporting training in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	0	0	1	0	2	1	4
Software development	0	0	0	0	1	0	1
Physical basis for remote sensing:	1	1	2	0	3	1	8
Satellite image interpretation:	2	2	3	1	3	2	13
Other	1	1	0	0	0	0	2
Total	4	4	6	1	9	4	28

Number of trained staff from RA II reported in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	0	0	25	0	30	25	80
Software development	0	0	0	0	19	0	19
Physical basis for remote sensing:	1	1	21	0	150	1	174
Satellite image interpretation:	11	4	33	2	210	2	262
Other	1	1	0	0	0	0	2
Total	13	6	79	2	409	28	537

3.4.8.3 RA III

Number of NMHSs from RA III reporting training in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	0	0	0	0	0	0	0
Software development	0	0	0	0	0	0	0
Physical basis for remote sensing:	0	0	0	0	0	0	0
Satellite image interpretation:	1	1	0	0	1	0	3
Other	0	1	0	0	0	0	1
Total	1	2	0	0	1	0	4

Number of trained staff from RA III reported in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	0	0	0	0	0	0	0
Software development	0	0	0	0	0	0	0
Physical basis for remote sensing:	0	0	0	0	0	0	0
Satellite image interpretation:	7	1	0	0	20	0	28
Other	0	2	1	0	0	0	2
Total	7	3	0	0	20	0	30

3.4.8.4 RA IV

Number of NMHSs from RA IV reporting training in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	0	0	0	1	0	0	1
Software development	0	0	1	1	0	0	2
Physical basis for remote sensing:	0	0	1	0	1	1	3
Satellite image interpretation:	1	1	1	1	1	1	6
Other	0	0	0	0	0	0	0
Total	1	1	3	3	2	2	12

Number of trained staff from RA IV reported in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	0	0	0	2	0	0	2
Software development	0	0	4	10	0	0	14
Physical basis for remote sensing:	0	0	2	0	8	2	12
Satellite image interpretation:	1	2	2	3	12	2	22
Other	0	0	0	0	0	0	0
Total	1	2	8	15	20	4	50

3.4.8.5 RA V

Number of NMHSs from RA V reporting training in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	0	0	0	0	0	1	1
Software development	0	0	0	0	0	2	2
Physical basis for remote sensing:	0	1	1	0	1	0	3
Satellite image interpretation:	0	2	3	0	1	0	6
Other	1	0	0	0	0	0	1
Total	1	3	4	0	2	3	13

Number of trained staff from RA V reported in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	1	0	0	0	0	2	2
Software development	0	0	0	0	0	3	3
Physical basis for remote sensing:	0	1	1	0	3	0	5
Satellite image interpretation:	0	2	4	0	3	0	9
Other	1	0	0	0	0	0	1
Total	1	3	5	0	6	5	20

3.4.8.6 RA VI

Number of NMHSs from RA VI reporting training in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	2	0	1	1	4	1	9
Software development	1	0	2	2	2	1	8
Physical basis for remote sensing:	3	0	6	2	3	2	16
Satellite image interpretation:	5	2	2	3	7	6	25
Other	1	0	0	0	1	2	4
Total	12	2	11	8	17	12	62

Number of <u>trained staff</u> from RA VI reported in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	25	0	2	1	7	2	37
Software development	15	0	2	2	11	2	32
Physical basis for remote sensing	13	0	597	11	26	45	154
Satellite image interpretation:	93	6	5	15	110	49	278
Other	8	0	0	0	7	45	60
Total	154	6	68	29	161	143	561

3.4.8.7 Total for all WMO Regions

Total number of NMHSs reporting training in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	3	0	2	2	6	3	16
Software development	1	0	3	3	3	3	13
Physical basis for remote sensing:	6	2	11	2	8	4	33
Satellite image interpretation:	12	9	9	5	13	9	57
Other	3	2	1	0	1	2	9
Total	25	13	26	12	31	21	128

Total number of trained staff reported in 2001

	RMTC	WMO	Univ./Ind	Distant	Internal	Bilateral	Total
Equipment	26	0	27	3	37	29	122
Software development	15	0	6	12	30	5	68
Physical basis for remote sensing:	25	2	88	11	187	48	361
Satellite image interpretation:	124	16	44	20	355	53	612
Other	10	3	1	0	7	45	66
Total	200	21	166	46	616	180	1,299

3.4.8.8 Synopsis for all WMO Regions: number of NMHSs reporting training in 2001 and number of trained staff

	RA I	**RA II**	**RA III**	**RA IV**	**RA V**	**RA VI**	Total
Number of NMHSs reporting training in 2001:	9	28	4	12	13	62	128
Total number of staff trained in 2001	31	537	30	50	20	561	1,229

3.4.8.9 The most intensive training in satellite meteorology was reported in 2001 from WMO Regions VI, immediately followed by RA II. The total number of 1,229 persons trained appeared to be satisfactory in general and indicated that many NMHSs were aware of the potential of satellite data and products and the need to conduct relevant training. The situation appeared to be less satisfactory for RA III from which only 4 NMHSs reported training in 2001. Additionally, the situation for RA V did not seem to be fully satisfactory: 13 NMHSs from this Region reported training in 2001, but the total number of trained staff (20) was low.

3.4.8.10 However, one noteworthy fact emerged: RA II reported a high number of staff trained but also the highest number of limitations in the lack of knowledge in the use of satellite data and products (see Section 3.3.8). Obviously more training would be desirable or better training may be necessary. However, it should be noted that the number of reported limitations was considerably lower than the number of staff trained.

3.4.8.11 The total number of 1,229 staff members reported in 2001 as having been trained was impressive. Still more impressive was the reported number of staff members planned to be trained during the next two years. The total for planned staff to be trained is 1,695. It should be noted that the intended training period cover was for 2 years whereas the reported executed training referred to one year only. The synopsis of intended training is given in the following table. It is an overall view for all Regions:

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Total number of staff to be trained during the next two year as reported in 2001

	Class 1	Class 2	Class 3	Hydrology	Environment	Total
Equipment	42	39	36	0	30	147
Software development	82	42	16	4	24	168
Physical basis for remote sensing:	168	175	8	12	7	370
Satellite image interpretation:	429	414	24	28	40	935
Other	58	8	5	4	0	75
Total	779	678	89	48	101	1,695

3.4.8.12 A majority of persons intended to be trained are Class 1 and Class 2 staff in the area of satellite image interpretation, corresponding to about 50% of the total envisaged training. The fundamental of remote sensing is next most important training area.

3.4.8.13 The largest number of staff intended to be trained was reported from Japan (RA II) with a total of 530 staff. Also, the Russian Federation (RA VI and II) intended to train a considerable number of staff, i.e., 265 in total. These two NMHSs represented approximately 50% of the total number of staff planned to be trained.

3.4.8.14 This was the first iteration of the questionnaire that included a section on education and training. It was obvious that the regional responses were incomplete and inconsistent and thus no firm conclusions could be made at that time. Through increased familiarity with this section during the next cycle of the questionnaire, it is expected the responses will provide a stable basis for recommendations concerning education and training. However, the following preliminary remarks were appropriate:

- The most typical training area was for satellite image interpretation (about 50% of the total staff were trained in this area), followed by the fundamental of remote sensing;
- In general, activities towards training were satisfactory. Nevertheless, more training is desired or better training may be needed when viewed in the context of the reported lack of knowledge in use of satellite data and products;
- Members were aware of the importance of training in satellite meteorology and planned to train more personnel in the future: the reported number of staff members to be trained in the future was approximately 1,695 (compared to the reported number of 1,229 trained staff);
- In general, the level of training activities was not an area of concern.

3.5 Research and Development

3.5.1 Section 5 of the questionnaire offered the possibility to provide information on research and development. Most of the comments received are quoted for information in the following sub-sections and are not subject of an evaluation or interpretation. Several Members indicated in a very general manner that they were performing R&D but did not enter into any details describing the activity area. Others provided simple indications of their involvement in the EUMETSAT Satellite Application Facilities (SAFs) and others recommend a visit to their Internet homepages or to refer to relevant reviewed publications.

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3.5.2 Design of payload for satellites: the following three Members explicitly reported activities in the area of payload development:

- UK: AMSU-B/MHS testing and calibration;
- Finland: Planetary and Space Physics Missions and Atmospheric Missions (e.g., GOMOS);
- USA: NESDIS/NASA activities with EMC input.

3.5.3 Design of acquisition and processing facilities: One Member from RA II indicated the monitoring of satellite products through Internet and the USA indicated that NOAA/NESDIS had responsibility with EMC sizing NWP “ingest” issues.

3.5.4 Development of methods of data processing: The following statements are quoted from the responses:

- Imagery processing for use of forecast workstations;
- Snow cover mapping by VIS and IR channels;
- Telecommunication tests for obtaining SSM/I data through GTS are now underway;
- Detection of night-time fog and dust sand from satellite image;
- Data assimilation and inversion techniques for remote sensing;
- Implementation of AAPP/IAPP;
- Rainfall estimation. Direct use of radiances in data assimilation.

3.5.5 Development of satellite derived products: The following statements are taken from the responses:

- Use of satellite imagery in conjunction with radar imagery (overlays, composites, rainfall estimates);
- Snow cover maps;
- Daily precipitation amounts;
- AMVs, deviation images, automatic classification of satellite images, Satellite Reports;
- Aerosol optical thickness and sounding products from MODIS;
- CMVs and SST from INSAT, temperature and humidity profiles from NOAA;
- Global cloud heights, rainfall estimates, ozone, temperature trends;
- Cloud products, snow, ice;
- Climate monitoring, soil moisture.

3.5.6 Assessment of quality and impact of satellite data: In total, 17 Members corresponding to approximately 25% of the returned questionnaires, indicated activities in assessment of quality and impact of satellite data. The following statements are quoted from the responses:

- Quality assessment in NWP and nowcasting;
- NWP products are continuously observed against the weather realised;
- Methods for NWP forecast corrections by means of satellite features;
- Impact study of satellite data on NWP;
- Impact studies in NWP;
- Quality assessment of assimilation of satellite data into HiRLAM;
- Study of impact of cloud coverage and SST in LAMs;
- Development of operational NWP systems;

- Programme on Improvement of Space System Utilization in 2000-2003; Reduction of negative climate change consequences; Reduction of hazards consequences and change;
- Impact study of SST, rain rate satellite-derived products on the limited area NWP mode;
- Rainfall estimate, ozone, temperature trends; OSSE's for AIRS, NPOESS, GOES, GIIFTS, surface characteristics;
- Verifications of EUMETSAT products.

3.5.7 Use of satellite data in research projects: The following statements are taken from the responses:

- Paper and case studies;
- Studies of the South Atlantic Ocean (SST and sea currents);
- Development of data assimilation for meso model;
- Short-term runoff forecasts;
- To improve applications in NWP, nowcasting, atmospheric chemistry and environmental monitoring;
- Assessing local atmospheric stability;
- Microwave remote sensing data of TRMM/TMI for identification of typhoon centre;
- Use of artificial neural networks in cloud identification;
- Data assimilation;
- Several research papers are published every year in journal of repute and international seminar proceedings;
- Discrimination of large-scale and convective precipitation using rapid-scanning imagery from Meteosat-6;
- Fire Danger Rating systems;
- Wind profiles (lidar); application of ground-based GPS data in NWP;

3.6 Improvement of the questionnaire and other comments

3.6.1 Section 6 of the questionnaire afforded the possibility to comment on the structure of the questionnaire distributed in 2001 as well as a request for suggestions on how the questionnaire could be improved. Twenty-five of the responding Members made use of this possibility and offered a wide range of comments which should be carefully taken into account for future questionnaires. However, not all comments were related to the structure and contents of the questionnaire, but to the availability of space. In some cases the space was used to explain some of the existing problems or to provide some deeper background to the responses given to questions in other sections of the questionnaire. Highlights of these comments are summarised at the end of this section (see 3.6.7).

3.6.2 Some Member States found the questionnaire positive, well balanced and didn't see a need for change. Some comments are quoted: *"The questionnaire is good, no need to add more". "The questionnaire was well done". "The questionnaire is complete in itself". "The main structure of the questionnaire covers the scientific fields in order to improve the procedures of NMHSs".*

3.6.3 At least one Member did not wish to complete the questionnaire and commented: "Use information from other sources, e.g., the EUMETSAT questionnaire. Repeat the questionnaire once every 10 years".

Recommendation: ET SSUP should consider the frequency of distribution of the questionnaire. A feedback mechanism should be developed between the "centres of excellence" and the Members they serve, to provide information on training activities during the evaluation period

3.6.4 Several Members made comments that would make the questionnaire easier or more consistent with other activities. The proposals were:

- Provide a list of definitions for all acronyms or abbreviations used. (Note: this recommendation was given by several Member States);

- Give more explanation on each section of the questionnaire. (One comment among others was e.g.: *"Table 5 is difficult to fill. Not clear whether it is required to quote only parameters used, even if they are available or potentially available, or parameter needed for the intended application in a general sense");*

- ;

- Align categories with "Application Areas" in the WMO RRR (Rolling Requirements Review) and remove WMO Commission names where they are not homogeneous applications.

3.6.5 Several Members made recommendations on the contents and structure of the questionnaire. They were:

- Separate the questionnaire into 2 categories: (1) processing and research on satellite data, (2) those only using processed data. This would enable a better identification of difficulties and problems by the latter user group;

- The questionnaire is very "forecaster user" oriented; a separate one for NWP users is requested with more options for direct use of radiances in NWP;

- Increase the amount of parameters. One Member State was more specific and recommends to add other parameters in Table 10 such as fog, dust sand;

- For hydrological purposes more emphasis should be given to high resolution satellites such as LANDSAT, SPOT, IKONOS;

- A list of training centres, region-wise, would be a useful background information;

- Internet as an option should be included for Section 1 of the questionnaire. A category could be included about the specific satellite data gathered from other sources via the Internet;
- Collect following additional information:

  - How many users are served by NHMS by satellite derived products and services?
  - Estimated number of products produced and / or used?
  - Utilisation of intended use and experienced benefit of R&D and other environmental satellites?
  - Awareness of available information, resources, references, publications, CAL, etc related to satellites and data use, to be provided by WMO, satellite operators, RMTCs (via WMO and CGMS Internet site satellite section).

3.6.6 Several Member States expressed a firm wish for electronic handling of any future questionnaires, one of them regarded this as a critical issue. The relevant proposals were:

"*Include this email to give the answers". "Submission of the questionnaire via the net using some software". "Distribute an electronic version which could be returned and evaluated directly to enhance the speed of answers". "Better to put the Questionnaire on the Web".*

Recommendation: In order to perform a dynamical assessment to provide input to the Strategy to Improve Satellite System Utilization and Products, it would be necessary to balance any change to the questionnaire with the impact it would have on its continuity. For example, continuity of certain questions may be required for assessing temporal changes on the availability and use of satellite data and products at the NMHSs and related problems.

3.6.7 Other comments were given in section 6 that were not directly relevant to the questionnaire, as follows:

- *"A meeting of NMS staff dealing with the questionnaire topics could be very interesting"* (Member State from RA VI).

- *"Table 5 of the questionnaire is suitable for MSG which is currently not in operation"* (NMHS from RA VI).

- *"No METEOSAT-5 images due to hardware/finance limitations; only getting 3-hourly PDUS images. WMO funding would help"* (NMHS from the Middle East).

- *"HPRT station is currently down, no technical skill available locally to fix it. Need to deliver more products from satellite data, thus more training of staff is required. Need for more skills in product derivation. No offer trainings available at the moment"* (NMHS from RA I).

- *"NOAA data only from APT, unusable due to severe interfering receiving influence."* Usage of a number of satellite derived products is indicated as SAR from ERS-2, DMSP SSM/I, QUICKScat. *"Although we have receiving equipment and use as much as possible, and probably have better facilities than many NMHSs, the general belief is that we could do a lot better, but are seriously hampered by financial constraints. Financial constraints and lack of personnel are limiting factors".* (NMHs from RA I).

- *"Limited knowledge in the interpretation of the received products. Need more human resource personnel upgrading knowledge and capabilities and also in maintenance"* (NMHS from RA V).

- *"Problems to refurbish hardware and software for image applications"* (NMHS from RA III).

- *"Plans to access satellite data from NOAA. No certain module to use the digital data. We need advanced training in the application software and methods, in equipment and maintenance"* (NMHS from RA I).

- *"Staff members of weather forecasting department need training courses in satellite image interpretation"* (NMHS from RA VI).

- *"Improvement of telecommunication systems, equipment acquisition and automation. Due to financial constraints, we depend on courses by WMO. For carrying out R&D programmes, computer facilities and trained personnel are needed"* (NMHS from RA I).

- *"Proper training is required. Lack of knowledge in use of satellite data and products, so proper guidance is required"* (NMHS from II).

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions on data availability:

- The most widely used system was GEO WEFAX;
- There was a tendency for increased use of GEO digital data;
- The number of LEO APT systems decreased, however the number of digital LEO HRPT was still rather low for all regions indicating that, in general, higher priority was assigned to GEO rather than LEO (excluding the polar regions);
- Most Members were equipped with satellite receiving facilities. However, there were some NMHS that did not have access to satellite data or did not use them. In particular, the lack of response from Members in RA IV (mainly those from Central America) could imply a strong under-utilization of satellite data.

4.2 Conclusions regarding personnel:

- NMHSs most frequently reported the following number of personnel involved in satellite meteorology activities: 1-3 operators, 1-3 technicians, 2-4 meteorologists. A positive trend, especially in the number of meteorologists, could be noted for RA I indicating a higher recognition of the value of satellite data and products by Members in RA-I. However, there appeared to be a slight reduction in the number of staff active in satellite meteorology in RA II and RA VI;
- In the 1999 survey, it was clearly recognized that for effective utilization of satellite data and products the lack of personnel was a problem for many NMHSs. This seemed to still be the case in 2001 since the number of staff involved in satellite data reception and processing did not change significantly. The only Region to improve with regard to the personnel situation was RA I. However, this conclusion must be tempered with the statements in the section on reported lack of staff which indicated an overall decrease in limitations due to a lack of staff.

4.3 Conclusions on the use of satellite data at the NMHSs:

- Nearly all Members that responded to the questionnaire in 2001 used satellite data at least for qualitative applications based on image interpretation. Analogue as well as digital data were used for this purpose, with an obvious transition from analogue to digital in at least some regions (RA I, RA II, and RA V);
- Usage of satellite sounding data and products represented less than 50% of responding NMHSs for 2001. This result was, however, not surprising since the typical application of sounding data was in NWP and only a limited number of Members operated their own NWP models and associated data assimilation systems for numerical analysis. With regard to the use of sounding data for the monitoring of the stability/instability of the atmosphere for Nowcasting purposes, it was noted that not all geostationary satellites have sounding capabilities, resulting in a limited utilization of satellite soundings;
- An increasing number of NMHSs indicated an increase in the use of satellite products from other sources. This resulted from improved data communication system capabilities, e.g., the Internet, and the recognition by the NMHSs that it was not necessary for each to create satellite products but rather could rely on the services of specialized centres.

4.4 Conclusions on application areas – the most important and required parameters:

- Cloud parameters were still the most important parameters for nearly all applications;
- Atmospheric instability index and cloud base height were the most frequently mentioned parameters as the most important and required parameter for a wide range of applications. Since instability indices can be derived from sounding instruments onboard satellites, the request for instability index was a clear indication that either GEO satellites should provide instability assessment capabilities or that the number of overpasses of LEO satellites with a sounding capability should be increased. A clear recommendation to the operators of satellite systems could be based on this conclusion;
- Wind profile was the second most frequently mentioned required parameter that was not available. This indicated that there was an urgent need for the development of operational wind profiling systems in space. Space agencies should be encouraged to respond to this urgent requirement and to initiate the necessary activities;
- Precipitation rate was the most required parameter but not available in a satisfactory manner. The underlying problem was precipitation's extreme inhomogeneity in space and time. Precipitation rate is best measured, in principle, in the microwave portion of the spectrum in order to minimize the effects of clouds. A logical consequence would be to develop suitable operational microwave sensors to assess precipitation rate with the required accuracy and temporal and spatial resolution from geostationary orbit. This is, however, technologically very challenging. Alternatively, increased numbers of LEO satellites with appropriate microwave instruments could serve to ameliorate the deficiency. In any case, the requirement for precipitation rate was very clearly articulated. Satellite operators and space agencies should take this requirement into account that has existed throughout all previous surveys.

4.5 Conclusions regarding limiting factors in the use of satellite data and products:

- For 2001, the number of reports that indicated limitations in accessing and utilizing satellite data and products has increased in comparison to 1999 although not statistically significant for all WMO Regions. Nevertheless, the summary figures were representative of the situation. The situation in 2001 was less satisfactory than in 1999, and could be due, to some degree, to the following:

  - NMHSs returning the questionnaire for 2001 were not always the same as in 1999. It is possible that more services with certain problems responded in 2001 than in 1999, or that some of the services felt free to indicate problems in 2001 but hesitated to do so in 1999;

  - NMHSs were becoming aware of the derived benefits, and were starting to utilize satellite data and products but encountered certain difficulties in their operational use. In principle. this is a positive aspect and all possible means should be undertaken to enable an optimal use of the satellite data and products;

  - Several NMHSs that reported limitations in accessing satellite data and products were obviously of the opinion that it was necessary to operate their own direct satellite data receiving and processing facilities and to perform their own programming. While this may be valid for some WMO Regions, in other Regions this has changed.

4.6 Conclusions regarding training:

This was the first iteration of the questionnaire that included a section on education and training. It was obvious that the regional responses were incomplete and inconsistent and thus no firm conclusions could be made at that time. Through increased familiarity with this section during the next cycle of the questionnaire, it is expected the responses will provide a stable basis for recommendations concerning education and training. However, the following preliminary remarks were appropriate:

- The most typical training area was for satellite image interpretation (about 50% of the total staff were trained in this area), followed by the fundamental of remote sensing;
- In general, activities towards training were satisfactory. Nevertheless, more training is desired or better training may be needed when viewed in the context of the reported lack of knowledge in use of satellite data and products;
- Members were aware of the importance of training in satellite meteorology and planned to train more personnel in the future: the reported number of staff members to be trained in the future was approximately 1,695 (compared to the reported number of 1,229 trained staff);
- In general, the level of training activities was not an area of concern.

4.7 Summary of Recommendations

Recommendation: NMHSs are strongly encouraged to increase the number of staff active in satellite meteorology in order to be able to benefit from the unique capabilities of satellite systems.

Recommendation: WMO, based on guidance developed by the OPAG-IOS Expert Team on Satellite Systems Utilization and Products (ET SSUP) and approved by CBS, should advise NMHSs on alternative means for access to satellite data and products.

Recommendation: NMHSs should be encouraged to establish communications systems with appropriate capacity based on the planned data volumes to be disseminated from future satellite systems.

Recommendation: Relevant Members should be encouraged to consider alternative solutions to achieve their computer programming requirements. Such an alternative could be, for example, the formation of networks or consortia with shared responsibilities, activities and services.

Recommendation: Appropriate strategies should be developed and implemented in order to improve the availability of application software and methods based on the fact that two-thirds of the NMHSs that returned the survey indicated such limitations. Such an immediate solution would be important for increased interest in satellite data and products utilization.

Recommendation: In order to perform a dynamical assessment to provide input to the Strategy to Improve Satellite System Utilization and Products, it would be necessary to balance any change to the questionnaire with the impact it would have on its continuity. For example, continuity of certain questions may be required for assessing temporal changes on the availability and use of satellite data and products at the NMHSs and related problems.

Recommendation:. Operational space agencies are encouraged to provide space systems with more frequent observations of atmospheric instability parameters and develop capabilities for cloud base height observations. Possible solutions but not inclusive could be through either increased temporal frequency for LEO satellites with sounding capabilities or through sounding capabilities on all geostationary satellites.

Recommendation: Space agencies are encouraged to develop the capability to provide wind profiles that meet WMO requirements.

Recommendation: Satellites should have suitable operational sensors for the observation of precipitation rate with appropriate accuracy and temporal and spatial resolution to meet WMO requirements. Possible solutions but not inclusive could be either through microwave sensors on geostationary satellites or increased temporal frequency for LEO satellites with appropriate microwave instruments.

Recommendation: The Chair of the OPAG IOS should recommend that the Expert Team on Observational Data Requirements and Redesign of the GOS review the results of the most important and most required parameters in its work on the redesign of the GOS.

ANNEX

QUESTIONNAIRE ON THE USE OF SATELLITE DATA AND PRODUCTS

Cover Note

For a few moments please give this questionnaire your individual attention. Answering the questionnaire may directly benefit your NMHS in the area of satellite data and satellite meteorology. It could help to provide better services, i.e., it could improve aid programmes, education & training activities, research and development of products; and it could give guidance to satellite operators.

Name of NMHS: ____

____

Country: ____

WMO Region: ______________________

List of staff and services answering this questionnaire:

____

____

____

____

Overview

1. Does your NMHS routinely obtain satellite data from any source?

Yes No

2. Do you have plans to routinely obtain satellite data for use in your NHMS in the next two years?

Yes No

If you checked "No" in question 2, comment in question 3 below and then only respond to the questions of Sections 3 to 6.

3. Why are you not interested in routinely using satellite data?

____

____

____

Section 1 - Access to data at the NMHS

Please complete Table 1 to indicate: satellite name; number of receiving stations (if any); reception frequency (enter the code in Table 2); and broadcast service (enter the code in Table 3).

Table 1

Sat Code	Satellite name	No. of receiving stations	Frequency (use code in Table X)	Broadcast service (use code in Table 3)	Sat Type
1.	Meteosat-5				Operational meteorological satellites
2.	Meteosat-7				
3.	GOES-E				
4.	GOES-W				
5.	GMS				
6.	FY-2				
7.	GOMS				
8.	NOAA-……..(specify)				
9.	METEOR…..(specify)				
10.	FY-1				
11.	ERS-2				R/D & other environmental satellites
12.	DMSP SSMI				
13.	QuickSCAT				
14.	INSAT				
15.	Others (specify)				
16.					

Table 2

Code	Frequency
1.	15 min
2.	30 min
3.	Hourly
4.	3-hourly
5.	6-hourly
6.	12-hourly
7.	Daily
8.	Other
9.	
10.	
11.	

Table 3

Code	Broadcast service
1.	APT
2.	LRPT
3.	HRPT
4.	WEFAX
5.	LRIT
6.	HR (geo)
7.	MDD
8.	Internet
9.	GTS
10.	Other
11.	

ACCESS TO AND PROCESSING OF SATELLITE DATA

Do you process digital data by yourself?	Yes	No
Do you receive digital data and products from other countries?	Yes	No
Do you process TOVS/ATOVS data?	Yes	No
Are satellite derived data and products made available to the meteorological offices and/or to other users?	Yes	No

How many persons are involved in satellite data reception and processing as one of their <u>primary</u> duties at the NMHS?

Table 4

Professional category	Number
Operators	
Technicians and programmers	
Meteorologists and scientists	

Section 2 - SATELLITE DATA AND PRODUCTS

Do you use satellite data at the NMHS for the following? (multiple answers allowed)

Image interpretation (qualitative use) from analogue data	Yes	No
Image interpretation (qualitative use) from digital data	Yes	No
Satellite soundings	Yes	No
Satellite sounding products	Yes	No
Qualitative use of satellite products from other sources	Yes	No

Do you extract products from digital satellite data at the NMHS? (multiple answers allowed)

Products derived from image data	Yes	No
Satellite soundings	Yes	No
Products derived from satellite soundings	Yes	No
Other satellite-derived parameters	Yes	No
Level 3 (mapped) & 4 (model output) products from satellite-derived parameters	Yes	No

APPLICATION AREAS AND IMPORTANT PARAMETERS

Please complete the following table to indicate the application areas and related important geophysical parameters.

Table 5

	Application area	**Using the application area code from Table 10 , list the most frequently used (up to six) and the most required but not available parameters (up to three) relevant to the duties of your NMHS**								
		Top six						**Three most required but not available**		
		Mandatory			**Useful**					
Methods	Nowcasting & VSRF									
	Synoptic Met.									
	Assimilation in Global and Regional NWP									
Applications / Services	Aeronautical meteorology									
	Marine meteorology									
	Agricultural meteorology									
	Hydrology									
	Atmospheric chemistry									
	Climatology/Climate change									
	Environmental/Disaster Monitoring									
	Research applications									
	Public Weather Services (PWS)									

Section 3 -LIMITING FACTORS IN THE USE SATELLITE DATA AND PRODUCTS

Complete Table 6 by checking if the factor limits your access to satellite data or products

Table 6

Limiting Factors	
Lack of receiving equipment	
Lack of maintenance know-how and/or services	
Required data is not disseminated	
Data and products required not available	
Communication system capacity limitation	
Lack of knowledge on use of equipment	
Other (please specify)	

Complete Table 7 by checking those factor(s) that limit your utilization of satellite data and products.

Table 7

Limiting Factors	
Lack of knowledge in use of satellite data & products	
Lack of knowledge in programming techniques	
Limitation in availability of application software & methods	
Limited impact for the intended application	
Others (specify)	

Section 4 - EDUCATION AND TRAINING IN SATELLITE METEOROLOGY

Indicate how many staff members have been on training courses of the listed skills in satellite meteorology last year, and what institution provided the courses. Indicate the number of staff members, separate for each professional category listed, you intend to train during this year and the following one.

Table 8

	Number of staff trained last year						Staff members to be trained during the next 2 years				
	RMTC	WMO (other than RMTC)	University / Industry	Distant learning incl. CAL / Virtual Lab	Internal	Bilateral	Meteorologist (Class 1)	Meteorological Technician (Class 2)	Meteorological Technician (Class 3)	Hydrologist	Others (Environment)
Equipment operation & maintenance											
Software development											
Physical basis for remote sensing											
Satellite image interpretation											
Other											

Table 9

Type /name of the course	Duration	Frequency	Language	Method of training (local teachers, through MTC, CAL …)	Develop proper learning material	Open to external students

Section 5: RESEARCH AND DEVELOPMENT

Are there research programmes in satellite data application running at the NMHS? (please specify each item)

Design of payload for satellites: ____________________

____

Design of acquisition and processing facilities: ____________________

____

Development of methods of data processing: ____________________

____

Development of satellite derived products: ____________________

____

Assessment of quality and impact of satellite data: ____________________

____

Use of satellite data in research projects: ____________________

____

Are there training courses in satellite meteorology organised by your Service?

Section 6 - QUESTIONNAIRE

Do you have any suggestions on how we could improve this questionnaire?

Table 10

Application Code	Parameters	Application Code	Parameters
1	Aerosol total column	31	Sea-ice surface temperature
2	Apparent Thermal Inertia	32	Sea Level
3	Atmospheric Instability Index	33	Sea surface temperature
4	Cloud base height	34	Short-wave outgoing rad. TOA
5	Cloud cover	35	Short-wave irradiance at surf.
6	Cloud ice total column	36	Significant wave height
7	Cloud imagery	37	Snow cover
8	Cloud top height	38	Snow melting conditions
9	Cloud Top Temperature	39	Soil moisture
10	Cloud type	40	Specific humidity profile
11	Cloud water profile	41	Specific humidity total column
12	Cloud water total column	42	Temperature Profile
13	Fires	43	Trace gases
14	Height of tropopause	44	Tropopause temperature
15	Icebergs	45	Vegetation Type
16	Land cover	46	Wave period/direction
17	Land surface features	47	Wind profile
18	Land surface temperature	48	Wind speed over sea surface
19	Leaf Area Index (LAI)	49	Wind vector over sea surface
20	Long-wave surf. emissivity	50	Volcanic ash
21	Long-wave outgoing rad. TOA	51	Others (specify):
22	Norm. Diff. Veg. Index (NDVI)	52	
23	Ocean currents	53	
24	Ozone profile	54	
25	Ozone total column	55	
26	Precipitation index	56	
27	Precipitation rate	57	
28	Rain profile	58	
29	Salinity	59	
30	Sea-ice cover	60	

General Comments

Section 1: ____

____

Section 2: ____

____

Section 3: ____

____

Section 4: ____

____

Section 5: ____

____

Section 6: ____

____

Other: ____

____

____