INTRODUCTION
The World Meteorological Organization (WMO) is comprised of Members normally represented by the Head of the National Meteorological and Hydrological Service (NMHS) of each country or territory. The NMHSs place great importance and depend upon soundings derived from TOVS for use in Numerical Weather Prediction. Consequently, WMO is fully committed to supporting the goals of the International TOVS Study Conferences.

Several important meetings have occurred which demonstrate WMO's commitment towards which the ITOVS Study Conference aim. The meetings include the First Session of the WMO Commission for Basic Systems (CBS) Working Group on Satellites (CBS WG/SAT-I), the WMO CBS Global Data Processing Task Team on Data Requirements (CBS DPS/TI on DR), the WMO Forty-fifth Executive Council (EC-XLV) and the Extraordinary Session of CBS (CBS Ext. 94).

CBS WG/SAT-I

2.1 Observational goals for global NWP
The working group discussed a document prepared by the Rapporteur on Satellite Soundings entitled "Observational goals for global NWP" that proposed guidance on the range of observations that, if available, would be useful in global NWP, either for assimilation into models or for model validation. The document addressed "goals" rather than "requirements." It did not address issues of feasibility, nor was it limited to observations from satellites. It attempted to look 7-10 years ahead, and thus to provide guidance about the planning of new or improved satellite systems. Goals were specified for a range of atmospheric and surface variables in terms of horizontal and vertical resolution, accuracy, frequency and timeliness. However it was stressed that these geophysical variables were not observed directly from satellites, and that new methods of data assimilation are increasingly able to make direct use of quantities as observed (e.g., radiances).

The working group agreed that the document was most valuable that required official WMO status. In this regard, the working group was pleased to note that the document would be presented to the forthcoming meeting of the joint Task Team of the CBS Working Groups on Observations and Data Processing addressing data requirements. The working group also strongly suggested that co-ordination of such requirements was required with the full Working Group on Data Processing. One additional characteristic was suggested to cover flexibility that was meant to imply the limits under which data would become useless or even harmful. The working group also suggested that the "Goals" should include a description of incremental improvements expected given that a stated improvement in data observation quality was achieved.
2.2 Satellite Soundings

The Rapporteurs on Satellite Soundings presented their report, which summarized recent developments in the application of data from operational satellite sounding instruments and recorded some activities about the implementation of improved satellite sounding systems on future satellites. It listed areas of recommendation and action for the consideration of the CBS Working Group on Satellites (CBSWGSAT).

Developments in this area had previously been reported through the Rapporteurs to the EC Panel of Experts on Satellites. Their last report was contained in Annex III of the Report on the tenth session of the Panel. It included discussion on the status and plans in data reduction methods, data applications, and trends in instrumentation and ground processing. Their reports drew heavily on the activities of the International TOVS Working Group (ITWG). A summary report on the Seventh International TOVS Study Conference can be found in Annex IV. The working group was informed that ITWG was a working group of the International Radiation Commission. The present report provided an update on developments in these areas.

The Seventh International TOVS Study Conference (ITSC-VII) had been held in Innsbruck, Austria, from 10-16 February 1993. A "Report on the Seventh International TOVS Study Conference" records the scientific exchanges and outcomes of the meeting. This report had been copied to all CBSWGSAT members, along with the document "ITWG: A Strategy for the 1990s." These documents provided background on recent international activities in development and exploitation of satellite sounding systems.

The working group noted that, at ITSC-VII, considerable progress and positive results were reported in many areas, including:

*The use of TOVS data in climate studies:* Significant progress was reported by many institutions on the application of TOVS data in climate research, and in particular in studies of the inter-annual variability of temperature, humidity and cloud cover. Advances have also been made in the extraction of total column ozone information from TOVS data.

*The use of TOVS data in numerical weather prediction (NWP):* TOVS data have been shown to have consistent positive impact on NWP in both hemispheres. In the Northern Hemisphere, this has been achieved through new methods in which radiance data are assimilated more directly into the models. Promising experimental results have also been obtained with 3- and 4-dimensional variational assimilation of TOVS radiances.
Preparations for Advanced TOVS (ATOVs) data.

While considerable work is still required in this area, inter-agency planning is now under way towards the goal of an international software package for ATOVS data processing.

*Future systems:*

Progress was reported towards the implementation of advanced infrared sounding instruments on operational satellites.

Besides their report, the Rapporteurs for Soundings made the following comments:

(a) The ITWG has about 100 active members representing 25 countries; they have been meeting every 18 months since 1983. The focus of past activities has been (1) improving satellite products via calibration refinements, retrieval method comparisons, verification, and case studies; (2) expanding the TOVS user community through distribution of processing software, information exchange, and development of software for low cost processing systems; (3) investigating the growing number of applications of satellite products in NWP and climate studies; (4) making recommendations to national agencies regarding the development of future satellite sounding instruments for both polar and geostationary platforms; and (5) encouraging an effective level of international co-operation on these activities for the mutual benefit of the participating countries.

(b) Through the efforts of the LMD (Laboratoire Météorologie Dynamique) and CIMSS (Co-operative Institute for Meteorological Satellite Studies) two processing packages (the, 3I, Improved Initialization Inversion, and the ITPP, International TOVS Processing Package) have been distributed and implemented at about 100 locations. Documentation, bench mark data processing sets, and user familiarization programmes now accompany these packages. Ongoing efforts are supported by user donations.

*Small processing systems:*

(c) It was noted at the last ITWG that with recent developments in personal computer (PC) and UNIX workstation technology, there was the opportunity to implement low cost ground receiving systems suitable for use in developing countries and in field experiments. PC and workstation activities within the sounding community have rapidly progressed to the point where nowcasting can be supported by TOVS data processed in real-time in a standalone mode. In addition, PCs are used for collaborative research through case study distribution and data analysis and for educational programmes.
An enhanced PC-version of the ITPP has been recently prepared and the ability to process TOVS data locally for operational purposes, on a PC using this system, has been shown at PAGASA in the Philippines. In this implementation, the TOVS system has been installed in an interactive workstation environment where, besides providing temperature and moisture soundings, estimates of TC intensity, SSTs and ozone amount, the AVHRR stream provides NDVI, SSTs and an experimental volcanic ash detection scheme. This NOAA groundstation and attendant applications have been used for operational support since 1991;

**ATOVS data processing:**

Slow progress on preparing software, together with an advance in the scheduled launch of NOAA-K, represented a significant problem in the readiness of the international user community to process these data. A two-phase approach now seemed most realistic, by which ad hoc adaptations to existing TOVS system will be developed to ensure operational continuity at the launch of NOAA-K, and improved ATOVS software packages will be developed later to exploit more fully the capabilities of the new instruments;

Working group members expressed concern over the problems relating to ATOVS software. They commented on the number of existing TOVS users who would be adversely affected if software were not available and widely distributed at the launch of NOAA-K. It was pointed out that existing TOVS processing packages now in worldwide use were derived from research packages. Although they had been successfully converted for operational use in many centres, such use could not be supported by the distributing institutes that provided the research package with present resources. The working group also drew attention to the need to consider carefully the requirements of climate research for homogeneity of data across the transition from TOVS to ATOVS.

The working group made the following recommendations:

**Regarding the use of TOVS data in climate studies:**

(a) TOVS data (from 1978 to the present) represent a unique source of information for climate studies. It is important that the archive of Level 1B data at full resolution be maintained and made accessible for use in these limited studies. Access to long-period, global TOVS data sets remains a significant impediment to climate studies at many institutes. A policy of open access to data at reasonable cost should be encouraged. It is also important that appropriate "housekeeping" information accompany the Level 1B data, to make the processing to this level reversible (as far as possible) and to allow correction for instrument drifts, etc.;

(b) Operational centres are encouraged to include the generation of products for climate studies from TOVS (and other environmental satellite) data in their real-time processing;
Regarding the use of TOVS data in NWP:
(c) To enable continued operational use of satellite sounder and imager data in local and regional NWP models, real-time direct-broadcast data are required. Present plans of NOAA, EUMETSAT and NASA to continue direct broadcast of such data are strongly encouraged;
(d) With the anticipated wider use of global satellite radiances at NWP centres, the present limited bandwidth of much of the GTS will prevent their full utilization. Increased bandwidth is required to accommodate these data;
(e) Providers of sounding products, including (but not limited to) brightness temperatures and temperature/humidity profiles, should supply users with the expected error characteristics (biases and covariances) of their products;

Regarding preparations for ATOVS data:
(f) The plans of NESDIS and EUMETSAT to collaborate on the production of an "international ATOVS processing package" (including ingest modules) are noted and welcomed. Full international availability of the source code is highly desirable. Support for the development and maintenance of such software is recognized as an important issue requiring long-term resourcing by WMO Members;
(g) Increased international activity is required on the science of ATOVS data pre-processing and retrieval to produce algorithms of high quality and to exploit these data fully. The revised schedule for the launch of NOAA-K (currently planned for 1995) represents a significant problem in terms of the readiness of the user community to use these data immediately after launch because of a possible software delivery delay;

Regarding future systems:
(h) For future operational sounding and imaging instruments, it is desirable that common meteorological requirements and compatible instrument specifications and data formats are developed;
(i) There is an urgent need for an operational infrared sounder of high spectral resolution, along with complementary imaging and microwave sounding instruments. Satellite agencies' plans to implement such systems are strongly encouraged;
(j) Full exploitation of advanced sounder data will require improvements in atmospheric transmittance modelling. The development and validation activities of the IRC Working Group on the Inter-comparison of Transmittance and Radiance Algorithms (ITRA), in collaboration with ITWG, are endorsed;
Regarding education and training:

(k) With the rapid and continuing growth in the user community for satellite sounding data, there is a growing need for co-ordinated international training programmes. The offer of ITWG to help with appropriate workshops and/or training sessions was noted.

3. CBS DPS/TT on DR

The updated observational data needs for GDPS centres for global and regional exchange including three tables of data needed to obtain optimum results from NWP by the year 2000 as clarified by the Task Team are given at the end of this section.

Data needed to obtain optimum results from NWP by the year 2000

The following tables list the observational data which will be needed to obtain optimum results from NWP systems by the year 2000. They include the needs for data assimilation and for analysis and model validation for global short and medium-range forecasting (excluding extended-range forecasting).

Requirements for regional modelling have also been considered. They have been mentioned in the explanatory text where appropriate, but they have not been listed in the tables. Meso-scale modelling has not been considered.

It is most likely that data of the given specifications would benefit global NWP if available; however, it does not mean that NWP could not be carried out without such data, as NWP models produce useful products even with the observational data set currently available. It does not mean either that data of higher specification would not be useful, on the contrary, when and where such data are produced they should be made available.

The problem of the feasibility of observing all the variables listed in these tables is not addressed. Most of the requirements stated here could only be met by satellite-borne observing systems. However, in many cases a combination of satellite and insitu data is needed to obtain adequate resolution and to ensure stability of calibration of remote sensing systems.

The following notes provide some explanation of how the lists were prepared and some provisos on their use:

Variables:

Following past convention, the observational requirements for data assimilation are stated in terms of geophysical variables. This is thought to be useful since, from a user's perspective, these are the variables on which information is required. However it is important to note that these variables are not always observed directly (satellite systems observe none of them directly, with the exception of top-of-the-atmosphere
radiation). Also it is no longer true that the users need their data exclusively in the form of geophysical parameters; recent developments in data assimilation have demonstrated the potential and the benefits of using data at the engineering level (e.g. radiances, brightness temperatures).

*Horizontal resolution:*
In general (and with some over-simplification), data are useful for assimilation and validation on spatial scales which the models are attempting to represent. 100 km is given as the requirement for the variables listed in the tables. However, it is possible to benefit from higher resolution data, considering the current developments towards global models with a grid length of less than 50 km.

Regional models attempted to represent spatial scales above the meso-scale. Observational data are required at a resolution of 10 km.

*Vertical resolution:*
The same rationale is applied here: global NWP models are expected to have a resolution of less than 1 km throughout the troposphere and lower stratosphere, with considerably higher resolution in the planetary boundary layer. In the mid and upper stratosphere, a resolution of 2 km is likely to be sufficient. The requirements for observations should be comparable.

For regional models, observations are required at a resolution of 100 m (50 m in the planetary boundary layer).

*Temporal resolution:*
Just as with spatial resolution, data will be useful for assimilation and validation on temporal scales which the models are attempting to represent. In the past this has not been the case; so-called "four-dimensional" assimilation systems would more appropriately be described as "intermittent three-dimensional" systems, and they have not been able to make proper use of observations more frequent than the period of the data assimilation cycle (typically 6 hours). However, continued progress towards truly four-dimensional data assimilation is making it possible to extract useful information from observations at higher temporal frequency. With such systems, higher temporal resolution can compensate to some extent for poor horizontal resolution when the atmosphere is moving. A requirement of 3 hours for upper-air data and 1 hour for surface data has been specified. However, like in the case of spatial resolution, upper-air data of higher specification (up to 1 hour) should also be made available (e.g. cloud motion wind data from geostationary satellites, wind profiles from wind profilers).

For regional models, both upper-air and surface data are required at a resolution of 1 hour.
**Accuracy:**
The values given are intended to represent the RMS of the observation errors. The assessment of accuracy should include not only the true instrumental error but also the representativeness error (i.e. the characteristics of some observing systems, particularly in situ systems, which sample spatial and temporal scales which are not represented by the models). For NWP applications, such effects appear as though they were observation errors.

**Timeliness:**
In NWP, the value of data degrades with time, and it does so particularly rapidly for variables which change quickly. Operational assimilation systems are usually run with a cut-off time of about 3 hours for global models, 1.5 hour for regional models. For observations which are expected to be used for validation, and not for analysis/assimilation in near real-time, the timeliness is less critical.

**Table 1 - Three-dimensional fields**

<table>
<thead>
<tr>
<th></th>
<th>Horizontal res. (km)</th>
<th>Vertical res. (km)</th>
<th>Temporal res. (hours)</th>
<th>Accuracy (RMS error)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind (horizontal)</td>
<td>100</td>
<td>.1 up to 2km</td>
<td>3</td>
<td>2 m/s in stratosphere</td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.5 up to 16</td>
<td></td>
<td>3 m/s in the troposphere</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 up to 30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>100</td>
<td>.1 up to 2km</td>
<td>3</td>
<td>.5K in the troposphere</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.5 up to 16</td>
<td></td>
<td>1K in the stratosphere</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 up to 30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative humidity (RH)</td>
<td>100</td>
<td>.1 up to 2km</td>
<td>3</td>
<td>5% (RH)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.5 up to tropopause</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:

(1) Accuracy specified as RMS vector error
(2) Hourly wind data from geostationary satellites and from wind profilers are also required.
(3) Geopotential height can be retrieved from specified T and RH with sufficient accuracy
Table 2 - Surface fields

<table>
<thead>
<tr>
<th></th>
<th>Horizontal res. (km)</th>
<th>Temporal res.</th>
<th>Accuracy (RMS error)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>100</td>
<td>1h</td>
<td>0.5 hPa</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>100</td>
<td>1h</td>
<td>2 m/s</td>
<td>(1)</td>
</tr>
<tr>
<td>Temperature</td>
<td>100</td>
<td>1h</td>
<td>1 K</td>
<td></td>
</tr>
<tr>
<td>Relative humidity</td>
<td>100</td>
<td>1h</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Accumulated precipitation</td>
<td>100</td>
<td>3h</td>
<td>0.1 mm</td>
<td>(2)</td>
</tr>
<tr>
<td>Sea surface temperature</td>
<td>100</td>
<td>1 day</td>
<td>0.5 K</td>
<td></td>
</tr>
<tr>
<td>Soil temperature</td>
<td>100</td>
<td>3h</td>
<td>0.5 K</td>
<td></td>
</tr>
<tr>
<td>Sea-ice cover</td>
<td>100</td>
<td>1 day</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Snow cover</td>
<td>100</td>
<td>1 day</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Snow equivalent-water depth</td>
<td>100</td>
<td>1 day</td>
<td>5 mm</td>
<td></td>
</tr>
<tr>
<td>Soil moisture, 0-10 cm</td>
<td>100</td>
<td>1 day</td>
<td>0.02 m³/m²</td>
<td></td>
</tr>
<tr>
<td>Soil moisture, 10-100 cm</td>
<td>100</td>
<td>1 week</td>
<td>0.02 m³/m²</td>
<td></td>
</tr>
<tr>
<td>Percentage of vegetation</td>
<td>100</td>
<td>1 week</td>
<td>10% (relative)</td>
<td></td>
</tr>
<tr>
<td>Soil temperature, 20 cm</td>
<td>100</td>
<td>6h</td>
<td>0.5 K</td>
<td></td>
</tr>
<tr>
<td>Deep soil temperature, 100 cm</td>
<td>100</td>
<td>1 day</td>
<td>0.5 K</td>
<td></td>
</tr>
<tr>
<td>Albedo, visible</td>
<td>100</td>
<td>1 day</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Albedo, near infra-red</td>
<td>100</td>
<td>1 day</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Longwave emissivity</td>
<td>100</td>
<td>1 day</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Ocean wave height</td>
<td>100</td>
<td>1h</td>
<td>0.5 m</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
(1) Wind at 10 metre over land. Over sea, height in the range 1 to 40 metres (to be transmitted with the observation)
(2) Required principally for model validation, not time critical.

Table 3 - Other two-dimensional fields

<table>
<thead>
<tr>
<th></th>
<th>Horizontal res. (km)</th>
<th>Temporal res.</th>
<th>Accuracy (RMS error)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud fractional cover</td>
<td>100</td>
<td>3 h</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Cloud top height</td>
<td>100</td>
<td>3 h</td>
<td>0.5 km</td>
<td>(1)</td>
</tr>
<tr>
<td>Cloud base height</td>
<td>100</td>
<td>3 h</td>
<td>0.5 km</td>
<td>(1)</td>
</tr>
<tr>
<td>Total liquid water content</td>
<td>100</td>
<td>3 h</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>TOA net shortwave radiation</td>
<td>100</td>
<td>3 h</td>
<td>5 W/m²</td>
<td>(2)</td>
</tr>
<tr>
<td>TOA net longwave radiation</td>
<td>100</td>
<td>3 h</td>
<td>5 W/m²</td>
<td>(2)</td>
</tr>
<tr>
<td>Multi-purpose IR/VIS imagery</td>
<td>5</td>
<td>30 min.</td>
<td>-</td>
<td>(3)</td>
</tr>
</tbody>
</table>

Notes:
(1) Accuracy higher in planetary boundary layer.
(2) Required principally for model validation; not time critical.
(3) Required to assist real-time observation monitoring and analysis/forecast validation.
4. **EC-XLV**

The Executive Council noted with satisfaction the formation, terms of reference and membership of the CBS Working Group on Satellites and agreed that the transfer of responsibilities on satellite matters should occur at this time. The Council decided, therefore, not to constitute an EC Panel of Experts on Satellites. The Council recognised the importance of satellites for both meteorology and hydrology and recommended that the membership of the CBS Working Group on Satellites should specifically include a representative of the Commission for Hydrology.

5. **CBS Ext. 94**

The Commission endorsed the following recommendations concerning satellite soundings:

*Regarding the use of TOVS data in climate studies:*

(a) TOVS data (from 1978 to the present) represent a unique source of information for climate studies. It is important that the archive of Level 1B data at full resolution be maintained and made accessible for use in these studies. Access to long-period, global TOVS data sets remains a significant impediment to climate studies at many institutes. A policy of open access to data at reasonable cost should be encouraged. It is also important that appropriate "housekeeping" information accompany the Level 1B data, to make the processing to this level reversible (as far as possible) and to allow correction for instrument drifts, etc.;

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*Regarding the use of TOVS data in NWP:*

(c) To enable continued operational use of satellite sounder and imager data in local and regional NWP models, real-time direct-broadcast data are required. Present plans of NOAA, EUMETSAT and NASA to continue direct broadcast of such data are strongly encouraged;

(d) With the anticipated wider use of global satellite radiances at NWP centres, the present limited bandwidth of much of the GTS will prevent their full utilization. Increased bandwidth is required to accommodate these data;

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Regarding preparations for ATOVS data:

(f) The plans of NOAA and EUMETSAT to collaborate on the production of an "international ATOVS processing package" (including ingest modules) are noted and welcomed. Full international availability of the source code is highly desirable. Support for the development and maintenance of such software is recognized as an important issue requiring long-term funding by WMO Members;

(g) Increased international activity is required on the science of ATOVS data pre-processing and retrieval to produce algorithms of high quality and to exploit these data fully. The revised schedule for the launch of NOAA-K (currently planned for 1995) represents a significant problem in terms of the readiness of the user community to use the full data stream immediately after launch because of a possible software delivery delay;

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TECHNICAL PROCEEDINGS OF

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