Space based Global Observing System Requirements for Satellite Sounders

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Abstract
Satellite sounders play an important role in global observing system. It can offer very valuable information on temperature, humidity, wind, cloud, precipitation and so on. All these are key variables in Numerical Weather Prediction and climate research. This paper reviewed some information on space based observing capability and user requirements for sounders.

Introduce
Satellite sounders play an important role in global space based global observing system. Satellite sounders can offer more valuable information, especially detailed information on temperate, humidity, wind, cloud and precipitation. The accuracy of NWP has improved very significantly in recent years. Satellite data has been a major contributor to this improvement and of the various satellite data available to NWP centres ATOVS is found, at present, to have the largest impact. So the requirements for sounders, either from observing system, or from user applications, become more and more strong.

This paper reviewed the current status of space based observing system, user requirements for sounders and sounding data distribution and related training event.

Space based sounders’ capabilities
The WMO Global Observing System (GOS) is composed of surface based systems and space based systems. The space based systems also can be divided into two parts, operational satellite system and R&D satellite system. The operational meteorological geostationary satellite system includes the following series:

- The European Meteosat;
- The United States of America’s GOES;
- The Japanese MTSAT;
- The Russian GOMS-Electro;
- The Chinese FY-2 to be replaced by FY-4;
- The Indian INSAT and Kalpana (formerly MetSat);
- The Korean COMS currently being developed.

The operational meteorological sunsynchronous satellite system includes the following series:

- The United States of America’s POES, supported by DMSP, to converge into NPOESS;
- The European Metop;
- The Russian Meteor;
- The Chinese FY-1 and FY-3.
Table 1 listed sounders of operational satellites and related instruments properties (CGMS- XXXIII, 2005).

### Table 1a sounders on operational satellites (September, 2005)

<table>
<thead>
<tr>
<th>Sounder</th>
<th>GEOSTATIONARY</th>
<th>GOES</th>
<th>MTSAT</th>
<th>Elektro-L</th>
<th>FY-2</th>
<th>INSAT-3A and 3D</th>
<th>Kalpana</th>
<th>COMS</th>
</tr>
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<tbody>
<tr>
<td>Advanced sounder</td>
<td>Meteosat</td>
<td>GOES</td>
<td>MTSAT</td>
<td>Elektro-L</td>
<td>FY-2</td>
<td>INSAT-3A and 3D</td>
<td>Kalpana</td>
<td>COMS</td>
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<td>Advanced sounder</td>
<td>MTG Sounder</td>
<td>SOUNDER</td>
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<td>SUNSYNCHRONOUS</td>
<td>NOAA</td>
<td>DMSP</td>
<td>NPOESS</td>
<td>Metop</td>
<td>Meteor-3M / Meteor-M</td>
<td>FY-1 / FY-3</td>
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<tr>
<td>IR sounder</td>
<td>HIRS 3/4</td>
<td>SSMIS</td>
<td>CrIS</td>
<td>HIRS/4</td>
<td>IASI</td>
<td>IRAS</td>
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<tr>
<td>IR advanced sounder</td>
<td>HIRS 3/4</td>
<td>SSMIS</td>
<td>CrIS</td>
<td>HIRS/4</td>
<td>IASI</td>
<td>IRAS</td>
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<td>MW imager/sounder</td>
<td>HIRS 3/4</td>
<td>SSMIS</td>
<td>CrIS</td>
<td>HIRS/4</td>
<td>IASI</td>
<td>IRAS</td>
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<tr>
<td>MW sounder (temperature)</td>
<td>HIRS 3/4</td>
<td>SSMIS</td>
<td>CrIS</td>
<td>HIRS/4</td>
<td>IASI</td>
<td>IRAS</td>
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<tr>
<td>MW sounder (humidity)</td>
<td>HIRS 3/4</td>
<td>SSMIS</td>
<td>CrIS</td>
<td>HIRS/4</td>
<td>IASI</td>
<td>IRAS</td>
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<td>MW advanced sounder</td>
<td>HIRS 3/4</td>
<td>SSMIS</td>
<td>CrIS</td>
<td>HIRS/4</td>
<td>IASI</td>
<td>IRAS</td>
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<tr>
<td>Radio-occultation sounder</td>
<td>HIRS 3/4</td>
<td>SSMIS</td>
<td>CrIS</td>
<td>HIRS/4</td>
<td>IASI</td>
<td>IRAS</td>
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<tr>
<td>Research and Development satellites</td>
<td>EOS/AQUA</td>
<td>EOS/AURA</td>
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<td>IR sounder</td>
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<tr>
<td>High-Resolution Dynamics Limb Sounder</td>
<td>HIRDLS</td>
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<tr>
<td>Microwave Limb Sounder</td>
<td>EOS-MLS</td>
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It may be observed that there are three typologies of sounding systems, depending on the IR component being a radiometer or a spectrometer, and the MW sounder being of the MSU or the AMSU class:

- TOVS-like: IRAS + MWTS + MWHS on FY-3A;
- ATOVS: HIRS + AMSU-A + AMSU-B/MHS on NOAA and Metop;
- advanced sounders: ATOVS + IASI on Metop, CrIS + ATMS on NPP, IRFS-2 + MTVZA on Meteor-M-1.

The WMO Global Observing System (GOS) baseline configuration includes four operational LEO satellites “optimally spaced in time” and six geostationary satellites, 60 degrees spaced, at any time. As of 2006, there are 11 GEO satellites, 7 satellites located between 60 E and 140E. But only 3 GEO satellites located between 115E and 75W, payload sounders. For LEO satellites, it plans up to 5 MW and 6 IR sounders around 2 orbits. RO sounders are plan to payload on operational satellites and 6 experimental RO satellites for 3 years running. Compared with WMO GOS baseline requirements, the Implementation Plan (IP) for the Evolution of the GOS suggested:

- S3.GEO Sounders - All meteorological geostationary satellites should be equipped with hyperspectral infrared sensors for frequent temperature/humidity sounding as well as tracer wind profiling with adequately high resolution (horizontal, vertical and time).
• S5.LEO data timeliness - More timely data are needed to improve utilization, especially in NWP. Improved communication and processing systems should be explored to meet the timeliness requirements in some applications areas (e.g. Regional and Global NWP).

• S12.RO-Sounders - The opportunities for a constellation of radio occultation sounders should be explored and operational implementation planned. International sharing of ground support network systems (necessary for accurate positioning in real time) should be achieved to minimize development and running costs.

“User” requirements

CBS has agreed to a procedure whereby WMO can assess how well observing system capabilities (both in situ and space-based) meet their user requirements. Pursuing that work, the Expert Team on Observational Data Requirements and Redesign of the Global Observing System (ET-ODRRGOS) within the Open Programme Area Group on Integrated Observing Systems (OPAG-IOS) of the Commission for Basic Systems (CBS) has been continuing the collection of the requirements for observations to meet the needs of all WMO Programmes and also cataloguing the current and planned provision of observations from environmental satellites and in situ systems. (ET-ODRRGOS was changed to ET-EGOS at CBS-XIII). The database resulting from these efforts is called the Database on User Requirements and Observing.

Users have been requested to state their requirements/performances in terms of "Level II" products, wherever possible. The user requirements are user oriented, not system dependent; they are intended to be technology free in that no consideration is given to what type of measurement characteristics, observing platforms, or data processing systems are necessary (or even possible) to meet them. The requirements are aimed at the 2005-2015 time frame.

In general, satellite data provide very good horizontal resolution and coverage but limited vertical resolution and coverage. Sounders mainly offer observation on temperature, humidity and wind profile, cloud and precipitation. All these are key variables for NWP model and weather forecasting. Positive impacts were already being experienced at NWP centres based on the early availability of ATOVS radiances.

• **3D wind field**: Advanced geostationary imager-sounders (e.g. GIFTS) offer wind profile information in cloud-free areas through tracking of highly resolved features in water vapour channels. The horizontal resolution of retrieved wind profile is 40km and vertical resolution can get 2km.

• **3D temperature field**: Polar satellites provide information on temperature with global coverage, good horizontal resolution and acceptable accuracy. However, vertical resolution is currently marginal. Until recently performance in cloudy areas was poor, but the new microwave measurements from AMSU have provided substantial improvements here, and strong positive impact has been demonstrated by several NWP centres. Geostationary infrared soundings (GOES) are also helping to expand coverage in some regions by making measurements hourly and thus creating more opportunities for finding
cloud-free areas. Vertical resolution will be substantially improved in cloud-free areas with the launch of high resolution infrared sounders on EOS-Aqua, METOP and NPOESS.

- **3D humidity field:** Polar satellites provide information on tropospheric humidity with global coverage, good horizontal resolution and acceptable accuracy. However, vertical resolution is currently marginal. Until recently performance in cloudy areas was poor, but the new microwave measurements from AMSU offer substantial improvements.

Geostationary infrared soundings (GOES) are also helping to expand coverage in some regions by making measurements hourly and thus creating more opportunities for finding cloud-free areas. Vertical resolution will be substantially improved in cloud-free areas with the launch of high resolution infrared sounders on EOS-Aqua, METOP and NPOESS.

Satellite sounding data are currently under-utilised over land, but progress in this area is anticipated in the near future.

- **Clouds:** Satellite instruments offer a wealth of information on cloud. Infrared imagers and sounders can provide information on cloud cover and cloud-top height of good horizontal and temporal resolution and good/acceptable accuracy. Microwave imagers and sounders offer information on cloud liquid water of good horizontal resolution and acceptable temporal resolution, with an accuracy that is probably acceptable (though validation is difficult).

- **Additional observations for model validation:** Advanced infrared sounders (e.g. AIRS, IASI, CrIS), providing complete or near-complete spectral coverage of the thermal infra-red at high spectral resolution, should offer the opportunity to monitor the infra-red spectrum of surface emissivity with good horizontal resolution and accuracy, although further research is required.

Satellite provides a vital and important means of obtaining observations of the climate system from near-global perspective and assessing the behavior of different parts of the global. For satellite data to contribute fully and effectively to the determination of long-term records, they must be implemented and operated in an appropriate manner to ensure adequate stability, accuracy and homogeneity.

In past years, GCOS had established GCOS Climate Monitoring Principles (GCMP) towards the delivery of global, long-term, high-quality, sustainable and reliable climate products. These GCMP were adopted by WMO Congress, CEOS and the UNFCCC. The GCOS Second Adequacy Report identified gaps in the systematic observation of climate, established a priority list of 44 Essential Climate Variables (ECV) and called for Integrated Global Analysis products. The GCOS Implementation Plan defines priorities and identifies 131 actions to fulfil these requirements.

WMO/CEOS database contains summary requirements from different climate application areas and space borne instruments capabilities.

**Data dissemination**

There are many data dissemination project, such as IGDDS, WIS, RARS, Geneticist. All environment-related programmes collect and exchange data, generate products, transmit information to users, and archive data. Beyond the GTS that is dedicated to time-critical operational data, products and warning, the various WMO Programmes had developed information systems, with a resulting multiplicity of systems and practices, generating incompatibilities. The Fourteenth World Meteorological Congress (Cg-XIV, 2003) adopted the concept of a WMO Information System (WIS) as an overarching, integrated system, which would meet the requirements of all WMO Programmes, affiliated
international organizations and programmes, as well as relevant national non-NMHS users such as disaster prevention and mitigation agencies and research facilities.

The WMO Integrated Global Data Dissemination Service (IGDDS) is a component of the WMO Information System (WIS) responsible for data circulation of satellite data and products. IGDDS is both a system and a project.

- IGDDS, as a system, is the circulation scheme of space-based observation data and products for WMO programmes. The IGDDS concept was initially proposed by WMO satellite user expert groups and refined by satellite operators within CGMS. Since WMO has defined the concept of a WMO Information System (WIS) as an overarching framework for all its data exchange and management, IGDDS is one of the components of the WIS.
- IGDDS, as a project, is the set of activities directed towards the definition and operational implementation of the IGDDS system.

The ultimate goal for IGDDS was to facilitate timely access to satellite data and products on a global basis by WMO Members while noting it was a specific objective assigned to the WMO Space Programme. In so doing, near-term IGDDS activities should be focused on extending regional advanced dissemination methods (ADM) to an integrated global data dissemination service for operational and R&D satellites.

The Third Global Regional ATOVS Retransmission Service (RARS)/IGDDS Workshop was held on 31 August-1 September 2006, Geneva. The Asia-Pacific RARS had commenced collection and injection of ATOVS retrievals into the GTS at both the Tokyo and Melbourne as a collection centres. The RARS network in Asia–Pacific area had 10 HRPT stations, located in China, Korea, Japan and Australia. By the end of 2006, another 5 HRPT stations were expected to be added. South-America RARS was the new priority to increase the global coverage. With regard to ADM, plans need to be finalized in the Asia-Pacific and the Americas. EUMETSAT’s EUMETCAST was fully operational and now covered Europe, Africa, Eastern America area through Ku and C band. It would continue to cover North and South-America until, for the time being 2008 in C band. In the near future, China’s FengYunCast will be in operational and cover Asia-Pacific area.

WMO High Profile Training Event (HPTE)

The concept of a Virtual Laboratory (VL) was initially developed during the 1995 Regional Satellite Training Seminar at the RMTC in Costa Rica. In 2001, CGMS-XXIX formally adopted the Virtual Laboratory for Satellite Data Utilization, which was thus established as a joint WMO-CGMS initiative to improve the utilization of satellite data and products by WMO Members. The VL became the core component of the WMO Strategy for Education and Training in Satellite Meteorology. In May 2003, the Fourteenth WMO Congress (Cg-XIV) expressed its pleasure with the Virtual Laboratory for Education and Training in Satellite Meteorology. In 2004, CGMS-XXXII confirmed and noted the importance of the roles of the VL partners and enthusiastically supported the three-year VL goal of staging a Global VL High-Profile Training Event (HPTE). The purpose of the HPTE was to support
the training component of the WMO Strategy to Improve the Utilization of Satellite Data and Products by WMO Members.

Anticipated Outcomes For The HPTE

- VL capacity building:
  - Increased awareness and use of the VL;
  - Increased involvement in the VLMG by existing members and further proposals for Centres of Excellence (CoEs) and satellite partnerships;
  - New regional focus groups instigated;
  - Increased activity in the VL from the science groups (IPWG, ITWG, IWWW);
  - Increased Member participation in regional focus groups.
- Improvements in Education and Training options
  - Increased demand and use of collaborative online training sessions;
- Provide practical experience in planning, implementing and delivering online training events for WMO Members as well as other groups such as GEOSS, JCOMM and CEOS.
- Improved utilisation of satellite data and products
  - Improvements in the participants use of satellite data and products
  - Improvements in the WMO Members knowledge of the use and application of environmental satellite data and products from R&D and operational satellites

Firm plans have been developed for the HPTE to be held during 16-27 October 2006, in conjunction with the APSATS 2006 in Melbourne, Australia, and the Regional Training Seminar in Nanjing, China. All of the core lectures have been developed and are now in Visitview format (in English) ready for final review by each of the partners, prior to distribution to the registered participants in each Region. The Central and South American groups, in conjunction with NOAA/NESDIS, are in the process of translating the lectures into Spanish and Portuguese.

Summary

Sounders play a key role in global observing system. They can provide valuable data for operational NWP and climate research. Current sounders and their retrieval products may have some gaps in vertical resolution and global coverage. Further satellite system and its sounders will fill in these gaps at some extent. It is also noted that HPTE and IGDDS would help to improve sounders application on operational NWP and climate research area.

Reference

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Maratea, Italy
4 October - 10 October 2006