THE EPS/METOP SYSTEM

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Summary: EUMETSAT is currently developing, jointly with ESA the EUMETSAT Polar System (EPS). The EUMETSAT Polar System is the European contribution to the U.S./European Initial Joint Polar System (IJPS) and will assure the morning orbit (AM) of the two- satellite system. The NOAA POES system will continue to assure the afternoon (PM) orbit. The Metop spacecraft will provide imagery and sounding information, with innovative capabilities, in particular through the Infrared Atmospheric Sounding Interferometer (IASI), developed by CNES. Three Metop spacecraft are foreseen within EPS.

1 INTRODUCTION

The EUMETSAT Polar System (EPS) has been approved as one of the improvements of the Global Satellite Observation System of the World Weather Watch (WWW). Currently EPS is under development in co-operation with ESA, NOAA and CNES.

2 EUMETSAT POLAR SYSTEM (EPS)

With the EUMETSAT Polar System (EPS) Europe contributes to the Initial Joint Polar System (IJPS) established in co-operation with NOAA. EUMETSAT has taken the commitment to cover the morning orbit (AM), assuming this service from NOAA, who will continue to cover the afternoon (PM) orbit. The thus established IJPS will provide global satellite data from sun-synchronous polar orbiting satellites (Figure 1).

2.1 Space Segment

The EPS Space Segment includes a series of three Metop satellites, which are developed jointly with ESA under the responsibility of a joint team. The Metop satellites are foreseen for an equator crossing time of 9:30 AM (descending node). The orbit is sun-synchronous with an inclination of 98.7 °. The weight of the Metop satellites is about 4200 kg, including a payload of about 840 kg. The designed lifetime is 5 years. The generated data rate is around 3.5 Mbps.

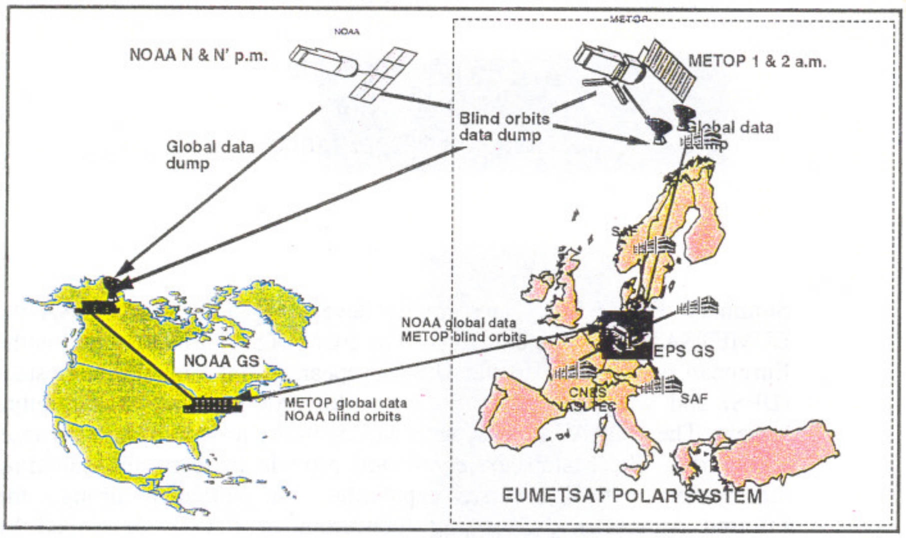

Fig. 1: The Initial Joint Polar System (IJPS).

The Metop payload relates to the main mission objectives, which are operational meteorology and climate monitoring (Figure 2).

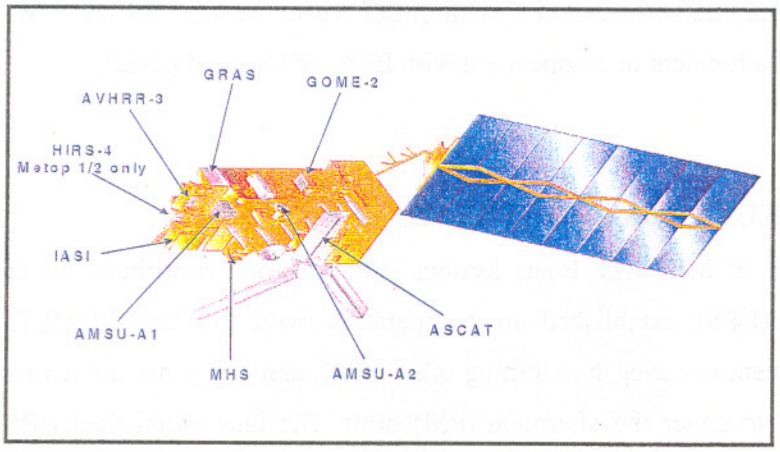

Fig. 2: Metop Satellite and payload.

2.1.1 Sounding and imaging capability

The HIRS/4 (High Resolution Infrared Radiation Sounder), the AMSU-A (Advanced Microwave Sounding Unit – A) and the MHS (Microwave Humidity Sounder, as follow on instrument to the AMSU-B), will provide continuity to the current polar sounding capabilities onboard the NOAA-K, L, M spacecraft and will also provide the commonality of instrumentation with the afternoon satellite. Significantly improved sounding capability (see

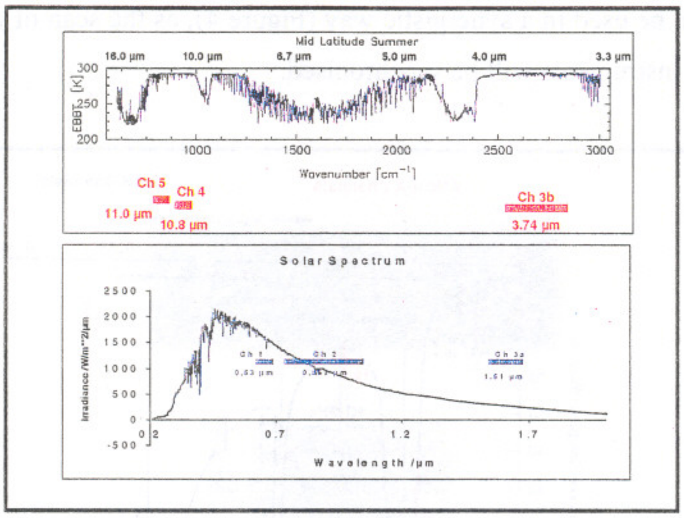

Fig. 3a: AVHRR/3 Channel characteristics.

section 2.1.2 below for details) will be provided by IASI (Infrared Atmospheric Sounding Interferometer), both in accuracy and also in vertical and horizontal resolution. The sounding

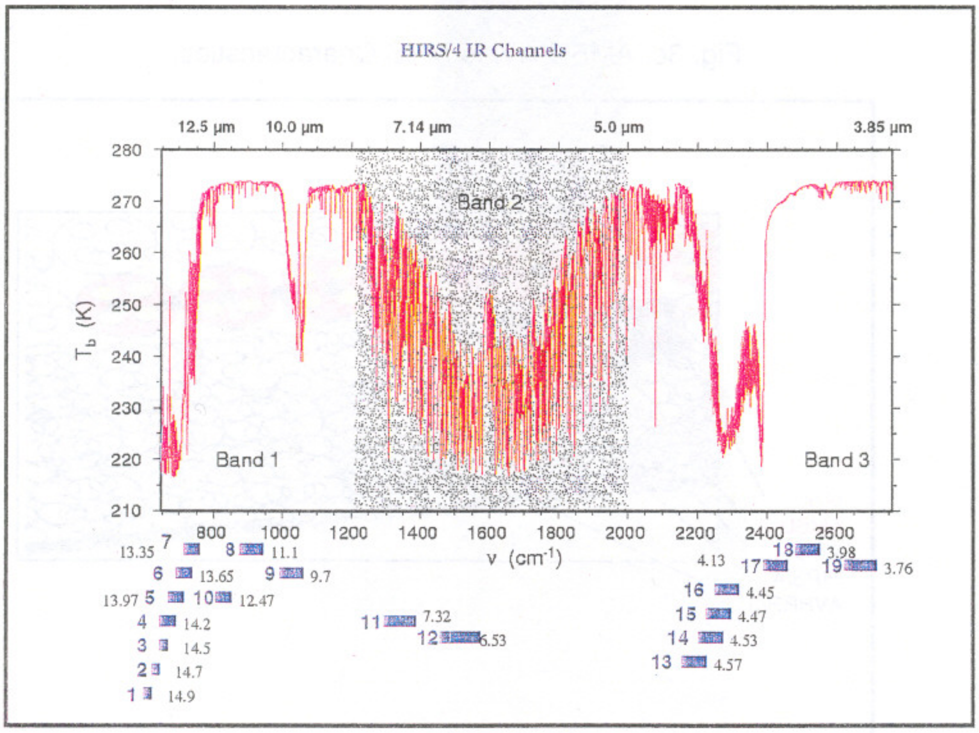

Fig. 3b: HIRS/4 Channels and IASI Bands.

payload is complemented by the AVHRR/3 (Advanced Very High-Resolution Radiometer) multi-spectral imager, which provides the continuity in global visible and infrared imagery at high horizontal resolution. Figures 3a - c summarise the channel characteristics and sounding characteristics of AVHRR/3, IASI, HIRS/4, AMSU-A and MHS. The sounding and imager instruments can be used in a synergistic way (Figure 4), as the scan of the AMSU-A, MHS and IASI sounding instruments will be synchronised.

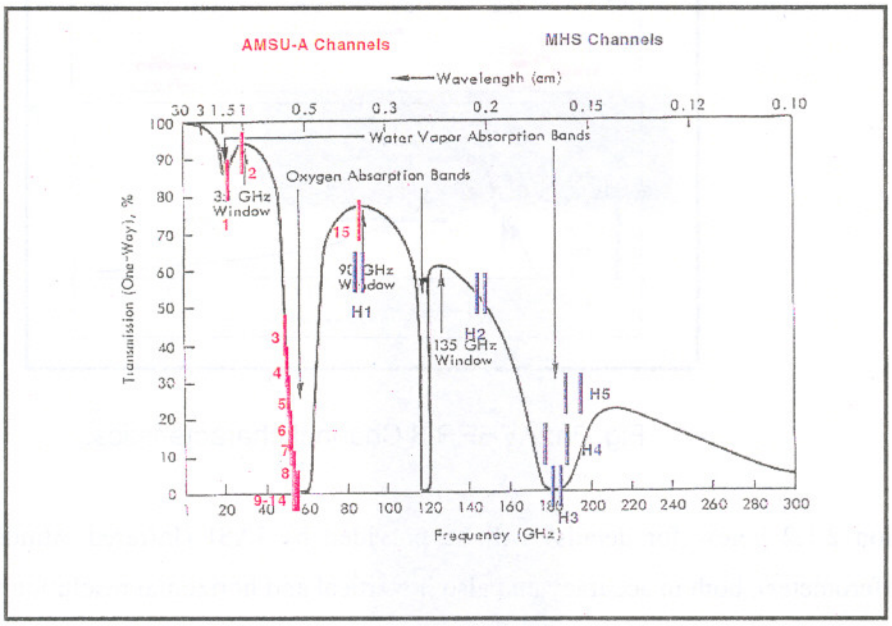

Fig. 3c: AMSU-A and MHS Characteristics.

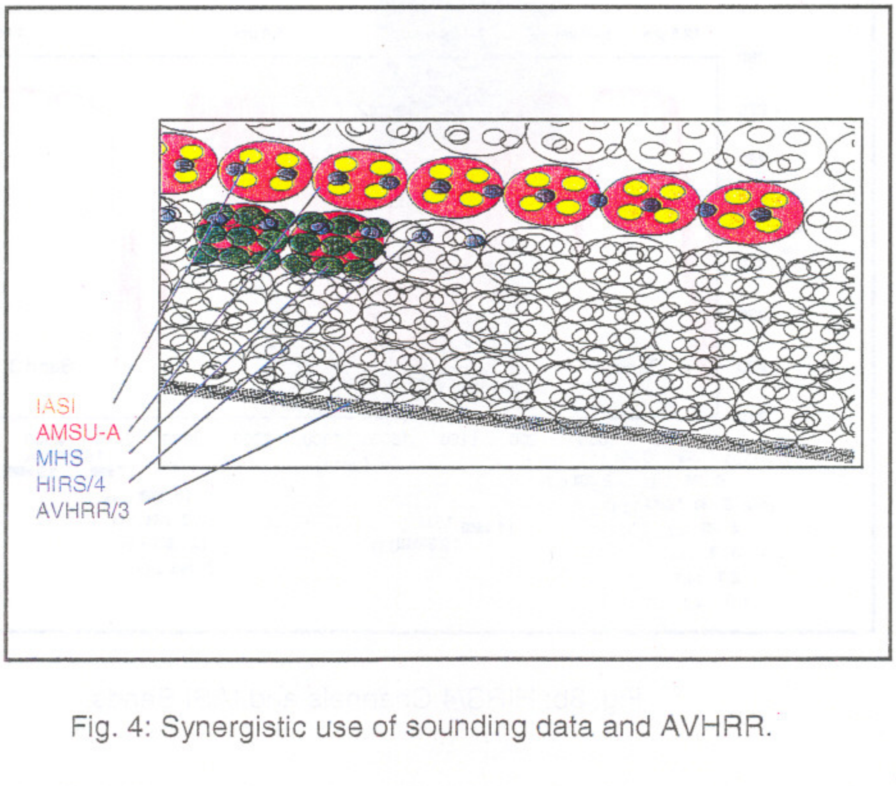

Fig. 4: Synergistic use of sounding data and AVHRR.

The GOME-2 instrument for Ozone and trace gases sounding will provide additional sounding capabilities. The GOME-2 instrument is developed in the heritage of the GOME-1 instrument on ERS-2. It covers four frequency bands from 240 to 790 nm (see Figure 5) and has and increased swath width of 1920 km, which allows better global coverage (Figure 6). GOME will map ozone total column and profiles, methane columns and additional species,

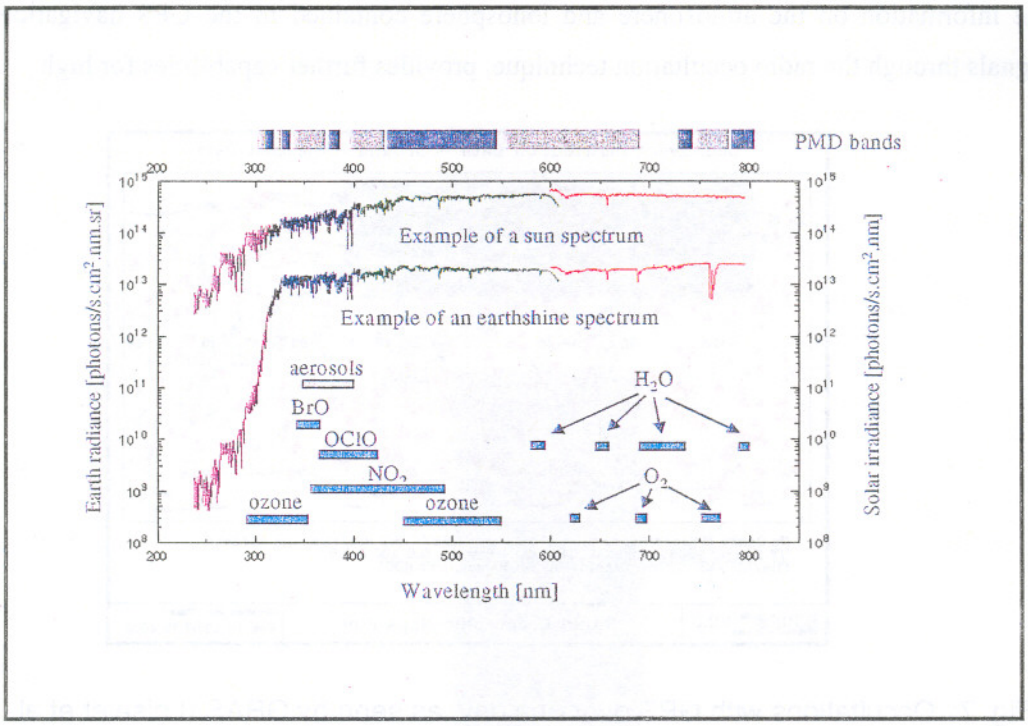

Fig. 5: GOME-2 bands (Callies et al., 2000).

which are relevant for atmospheric chemistry and climate processes.

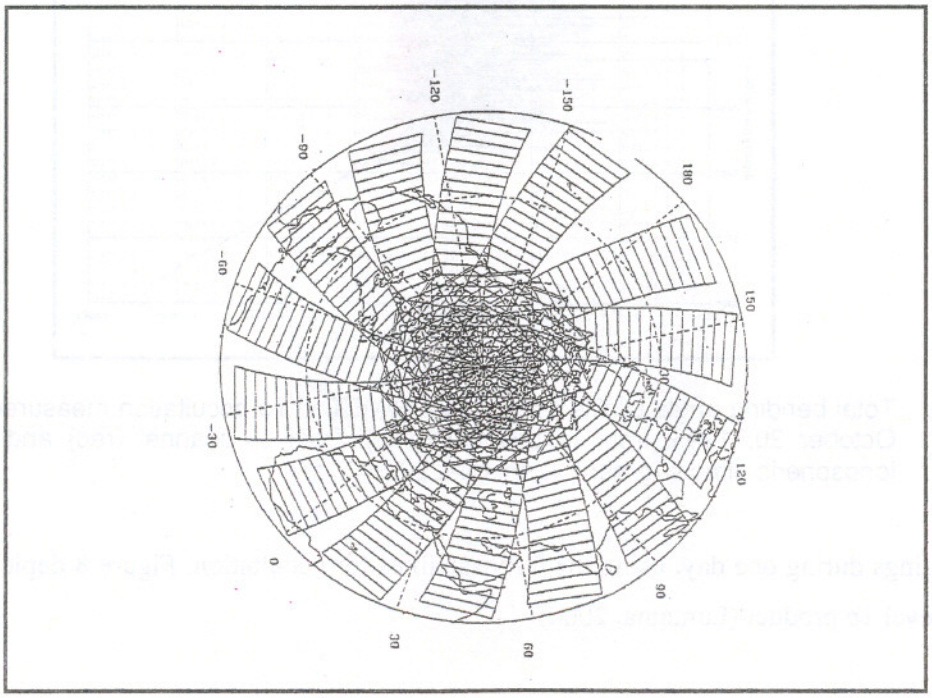

Fig. 6: GOME-2 coverage after one day (ESA, 1996).

The GRAS (GPS Radio Occultation Atmospheric Sounder) instrument, which will make use of the information on the atmosphere and ionosphere contained in the GPS navigation satellite signals through the radio occultation technique, provides further capabilities for high

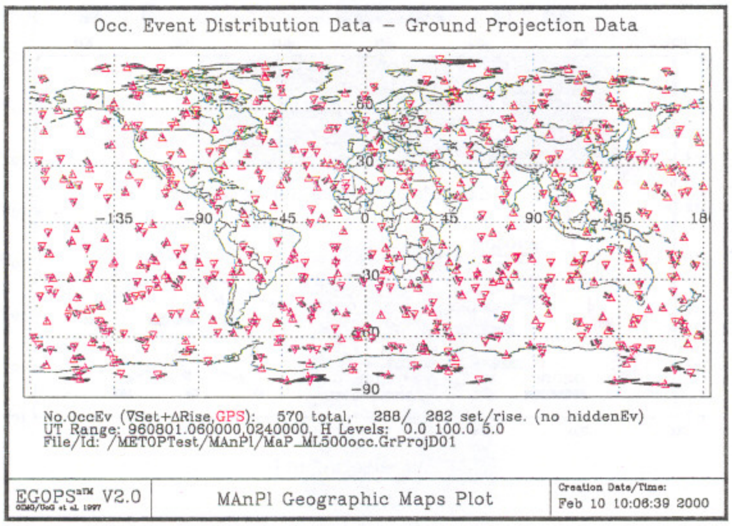

Fig. 7: Occultations with GPS over one day, as seen by GRAS (Loiselet et al., 2000).

resolution temperature and moisture sounding. Figure 7 depicts the coverage achieved by GRAS

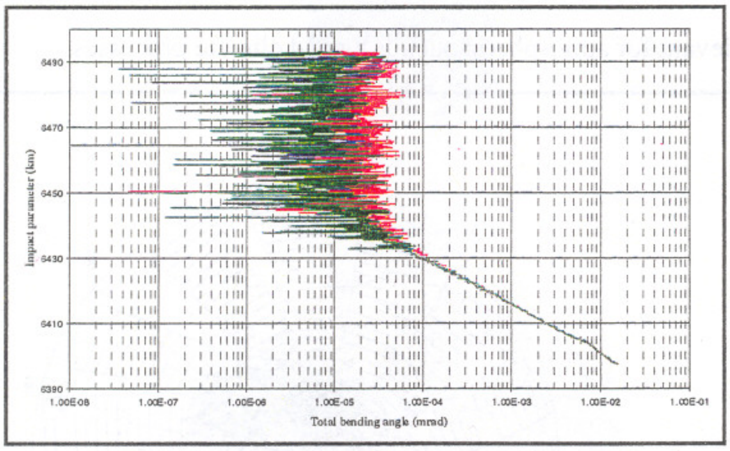

Fig 8: Total bending angle profile from the GPS/MET radio occultation measurement 0029 on October 20, 1995, from L_1 channel (blue), from L_2 channel (red) and corrected for ionospheric effects (green). (Luntama, 2000)

soundings during one day, using the GPS satellites for occultation. Figure 8 depicts an example of a level 1b product (Luntama, 2000).

2.1.2 The IASI Instrument

The IASI (Infrared Atmospheric Sounding Interferometer) instrument will provide improved infrared tropospheric soundings of temperature, moisture and of some chemical compounds involved in atmospheric chemistry or contributing to additional greenhouse effect, and measure the radiative and infrared spectral properties of surfaces and clouds. Primary mission objectives are:

- Retrieve profiles of temperature in the troposphere and lower stratosphere with an accuracy of 1 K, a vertical resolution of 1 km in the low troposphere and a horizontal sampling of typically 25 km at nadir, at least under cloud free conditions,
- Retrieve profiles of water vapour in the troposphere with an accuracy of 10% on relative humidity, a vertical resolution of 1 to 2 km in the lower troposphere and a horizontal sampling of typically 25 km at nadir, at least under cloud-free conditions,
- Retrieve total amount of O_3 with an accuracy of 5% and a horizontal sampling of typically 25 km at nadir, possibly also O_3 vertical distribution with an accuracy of 10% and a vertical resolution providing as a minimum two to three pieces of independent information, at least under cloud free conditions,
- Retrieve fractional cloud cover and cloud top temperature/pressure.

These requirements in term of geophysical measurements have led to the following requirements in term of radiometric measurements:

The useful spectral range extends from the edge of the thermal infrared at 3.62 μm (corresponding to 2760 cm^{-1}), where solar backscatter begins to contribute, up to 15.5 μm (645 cm^{-1}) covering the peak of the thermal infrared and particularly the intense CO_2 ν_2 band with Q branch around 666 cm^{-1} (see Figure 3b above). The spectral resolution requirements are driven by the line spacing in the 15 μm and 4.3-μm CO_2 absorption bands. This spacing is equal to 1.5 cm^{-1} in most of the bands and to 0.75 cm^{-1} in some parts. The necessity to resolve CO_2 absorption bands led to require an apodised resolution of 0.5 cm^{-1}. As a consequence the instrument was specified with a maximum optical path difference of 2 cm leading to an unapodised resolution of 0.3 to 0.4 cm^{-1} and a sampling interval of 0.25 cm^{-1}.

Due to the very sharp spectral patterns present in atmospheric spectra it is essential to obtain a very accurate spectral calibration. The IASI spectral calibration shall be in the order of 1% of the apodised spectral resolution, i.e. have an accuracy $\delta\nu/\nu$ better than $2 \cdot 10^{-6}$.

With the spectral resolution specified above, IASI shall measure equivalent temperature in the range 180 K to 315 K. Radiometric noise is specified in terms of noise equivalent temperature difference (NEΔT). This specification is only meaningful in terms of engineering units if associated to a reference temperature. A unique reference temperature of 280 K has been chosen over the entire spectral range. The required values are given in the following table

NEΔT < 0.2 K at 280 K	from	645	to	1650	cm^{-1}
NEΔT < 0.35 K at 280 K	from	1650	to	2400	cm^{-1}
NEΔR < 12.5 $\mu W/(m^2\ sr\ cm^{-1})$	from	2400	to	2760	cm^{-1}

The quality of the radiometric calibration may be a factor limiting the capability of the user to exploit IASI data. The requirements on calibration are therefore rather stringent. In order to comply with the foreseen simultaneous use of bands and pixels, the requirements are broken in three terms:

a) The calibration system shall allow the determination of equivalent temperature with an accuracy better than 0.5 K at 280 K;

b) Calibration stability/repeatability shall be such that its random variations (short term) and drifts (long term) will not induce errors larger than 0.3 K on the determination of the equivalent temperature at 280 K;

c) Calibration differences due to various instrument/observing conditions (inter-band calibration, inter-calibration between pixels observed simultaneously, inter-calibration between different scan angles...) shall not cause an error larger than 0.2 K at 280 K. The large impact of cloud contamination on the quality of retrieved profiles led to include in IASI an imager having a single channel in the 11μm atmospheric window.

At this stage most performance budgets meet the requirements with minor exceptions in some limited spectral domain as illustrated by Figure 9 which overlays the expected Level 1c noise (typique) to the required values (specification).

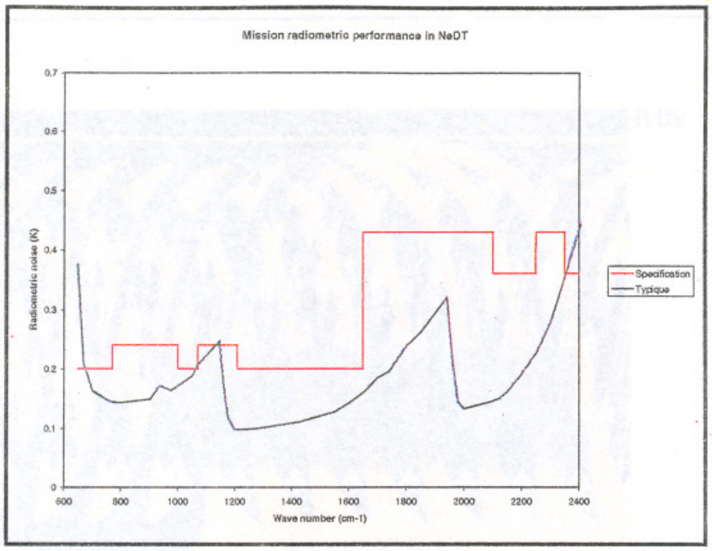

Fig. 9: Expected IASI Level 1c noise (blue) compared to the specification (red).

2.1.3 Advanced Scatterometer

A further payload component is the Advanced Scatterometer (ASCAT) will provide improved capability to retrieve wind vectors at the ocean surface. It is a C-band radar (5.255 GHz), with a

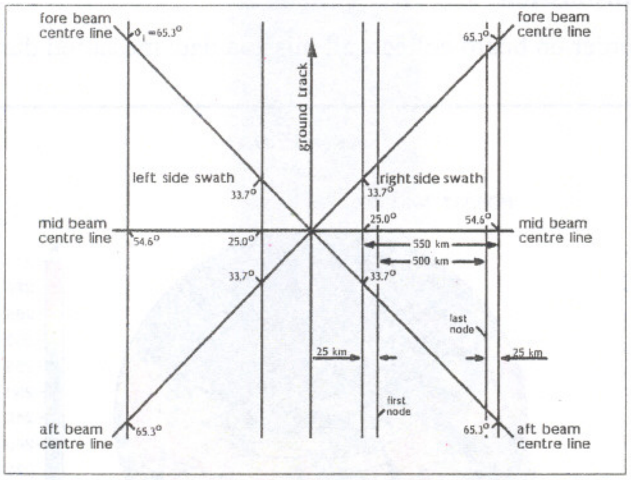

Fig. 10a: ASCAT geometric characteristics.

dual swath (500 km, separated by a gap of 600 km) geometry and incidence angles from 25° – 65 ° (Figure 10a), providing increased coverage over the globe (see Figure 10b).

2.1.4 Further missions

Further payload components comprise the Space Environment Monitor, the Data Collection System (DCS-2/ARGOS) and the humanitarian Search and Rescue (SAR) mission.

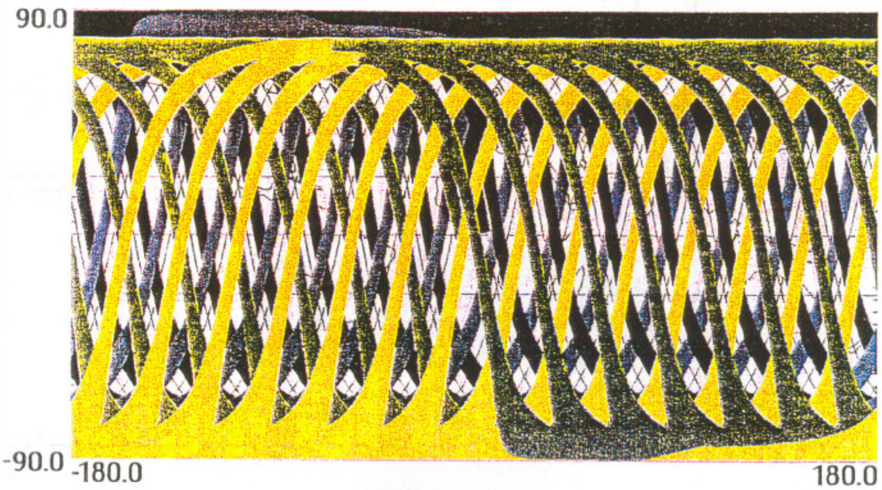

Fig. 10b: Global coverage over one day, achieved by ASCAT.

2.1.5 Data transmission

A solid state recorder on board collects all mission data measured during the duration of one

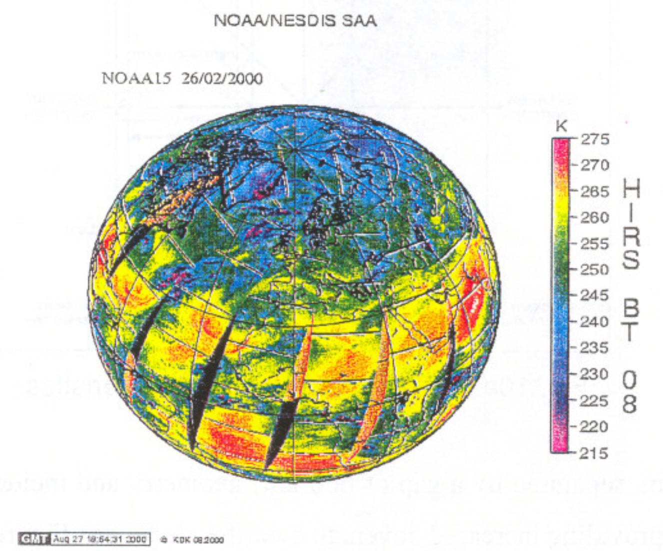

Fig. 11a: Global data coverage, displayed are seven orbits, HIRS channel 8 Brightness Temperatures for 26/02/2000.

orbit (about 102 min). These data, dumped to the northern latitude station, located at Svalbard via X-band, assure the global coverage of the mission data (see Figure 11a).

Local Users may, via the High Resolution Picture Transmission (HRPT), receive the full resolution data stream of all instruments, once the satellite is in range of the receiving tracking antenna (Figure 11b). This data stream includes the orbit information needed to navigate the

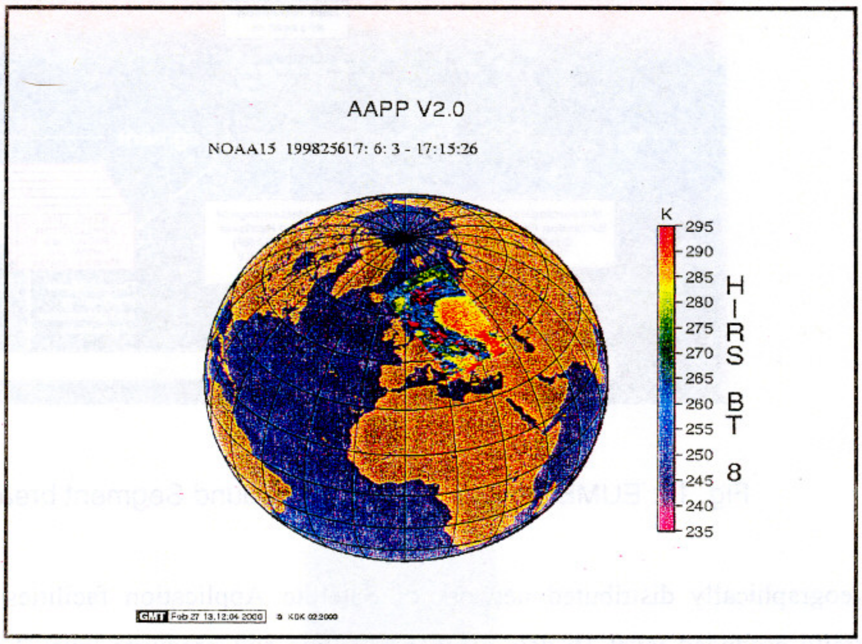

Fig. 11b: Local data coverage through HRPT.

data. The Low resolution Picture Transmission (LRPT) service provides the digital continuation of today's APT (Automatic Picture Transmission) service and comprises the full resolution set of the ATOVS sounding instruments (HIRS, AMSU-A and MHS), and three JPEG compressed (8 bit) selected AVHRR channels.

2.2 Ground Segment

The multi-mission Ground Segment is composed of a central component and distributed components, for mission control, data acquisition and processing, both for all EUMETSAT missions (Figure 12). The central facilities are located at EUMETSAT headquarters at Darmstadt, Germany, and provide services for satellite monitoring and control, processing of all mission data to level 1b (Metop and NOAA), and selected meteorological or geophysical products at level 2. The northern latitude acquisition station is located at Svalbard (Spitzbergen, Norway) and collects all Metop mission data, and provides blind orbit support for the NOAA afternoon spacecraft. Nominally the Svalbard station can receive all mission data of one day (14.3 orbits).

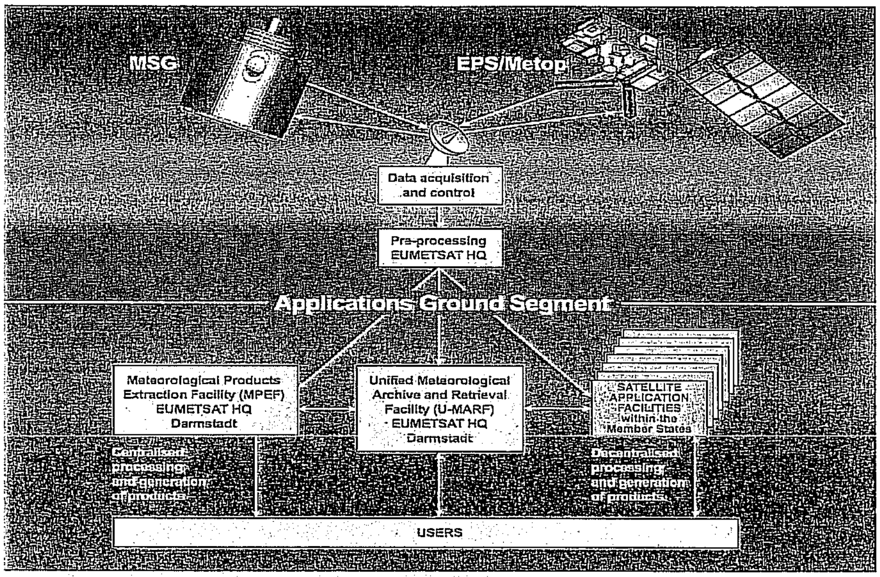

Fig. 12: EUMETSAT multi-mission Ground Segment breakdown.

A geographically distributed network of Satellite Application facilities (SAF) receives the centrally produced level 1b data in near real time and produces level 2 and higher products. These SAF capitalise on specialised scientific expertise available in Europe. The services provided to Users by SAF are operational, real time or off-line products; distribution of application software packages, data and user services, including the archiving of the SAF produced products.

Seven SAF are currently under development. Those, which will deliver products related to EPS, are the SAFs on Ozone Monitoring, Ocean and Sea Ice, Climate Monitoring, GRAS meteorology and Land Applications. The SAF are supported by a visiting scientist programme, which allows the involvement from expertise outside of the SAF.

The Unified Meteorological Archive and Retrieval Facility (UMARF) is EUMETSAT's facility for the storage of all mission data, processed centrally. It provides the unique interface to Users for the off line use of data. The UMARF catalogue includes the catalogue information of the SAF products, which will be archived at the SAF themselves. UMARF services also comprise User interface and retrieval services interface (Figure 12).

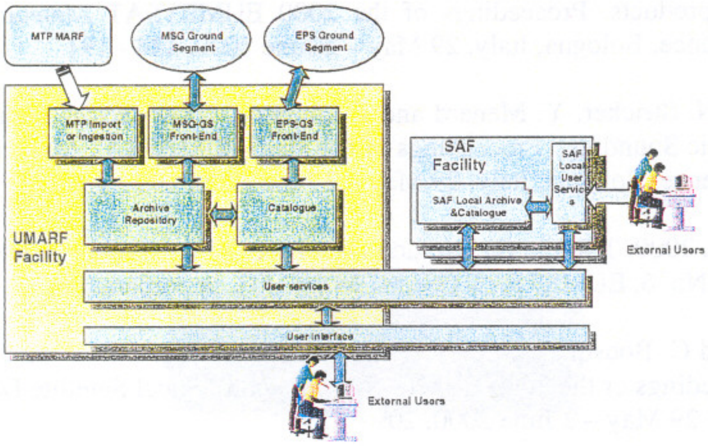

Fig. 13: UMARF - multi-mission Archive and retrieval facility.

3 CONCLUSION

With its highly improved capabilities, in particular the sounding performances, both in precision and resolution, the EPS answers the enhanced needs of numerical weather prediction and to contributes to improve the capabilities of NWP system like the one operated by ECMWF. The multi-instrument capabilities will satisfy requirements in climate monitoring, hence providing a service beyond the operational meteorology. A considerable effort will be needed to assure the calibration and validation of the products and instrument data.

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