

The ATOVS and AVHRR Product Processing Facility of EPS

**Dieter Klaes, Jörg Ackermann, Rainer Schraidt, Tim Patterson, Peter Schlüssel,
Pepe Phillips, Arlindo Arriaga, and Jochen Grandell**

EUMETSAT

Am Kavalleriesand 31, 64295 Darmstadt, Germany

Abstract

The operational ATOVS Level 1 and Level 2 processors will be part of the EPS Core Ground Segment. Starting with instrument source packets from the AVHRR, HIRS/4, AMSU-A, and MHS the Level 1 processors generate calibrated and navigated data, as well as a scenes analysis. These are fed into the Level 2 processing which generates temperature and water vapour profiles along with tropopause height, surface temperature, cloud fraction and cloud-top pressure.

Introduction

The ATOVS (Advanced TIROS (Television and Infrared Operational Satellite) Operational Vertical Sounder) instrument package was first flown on the NOAA-KLM Satellite series operated by NOAA. They are in orbit since 1998 as NOAA-15 (1998), NOAA-16 (2000) and NOAA-17 (2002). ATOVS is composed of the Advanced Microwave Sounding Units A and B (AMSU-A, AMSU-B) and is complemented by the High Resolution Infrared Radiation Sounder (HIRS/3). To provide continuity the ATOVS and AVHRR instruments will be exploited in the EUMETSAT Polar System (EPS) (Klaes et al., 2001) in the frame of the Initial Joint Polar System (IJPS). The current AMSU-B sounder will be replaced by the Microwave Humidity Sounder (MHS) on the future NOAA-N, N', and Metop satellites. An upgraded version HIRS/4 of the Infrared Sounder will be embarked as well. The Advanced Very High Resolution Radiometer (AVHRR/3) will support the ATOVS Product Generation. The global processing of the ATOVS and AVHRR data will be carried out in the EPS Core Ground Segment (CGS) in the ATOVS and AVHRR Product Processing Facilities (PPF). This paper outlines the features of these facilities and the produced products.

The ATOVS and AVHRR Product Processing Facility

The development of the ATOVS and AVHRR PPF for the EPS Core Ground Segment (CGS) is performed by an industrial contractor in the frame of the development of the CGS. The development is based on Product Generation Specifications (PGS), Product Format Specifications (PFS) and test data sets, provided through prototype processors.

The ATOVS/AVHRR processing in the EPS Ground Segment comprises as a first step the Level 1 (L1) processing of the ATOVS sounding instruments AMSU-A, MHS and HIRS/4, and also the AVHRR/3 instrument. The second step is the Level 2 processor, which uses as input the Level 1 product output and some intermediate products (e.g. Cloud mask from Scenes Analysis). Output are products delivered in Near Real Time (NRT) to Users and also products distributed over the Global telecommunications System (GTS). Hence there are five PPFs, one per instrument for Level 1, and one for the ATOVS Level 2 (L2) processing (Figure 1).

Prototype processors have been established to verify the specifications and also to generate the required test data. The prototype processors of the ATOVS and AVHRR instrument processors are based on two well-known and well-established software packages, which have been in use with the international community for some years: AAPP and ICI. (Klaes, 1999, NWP SAF web page, ICI web page). They were extended with functionality required for global operational processing.

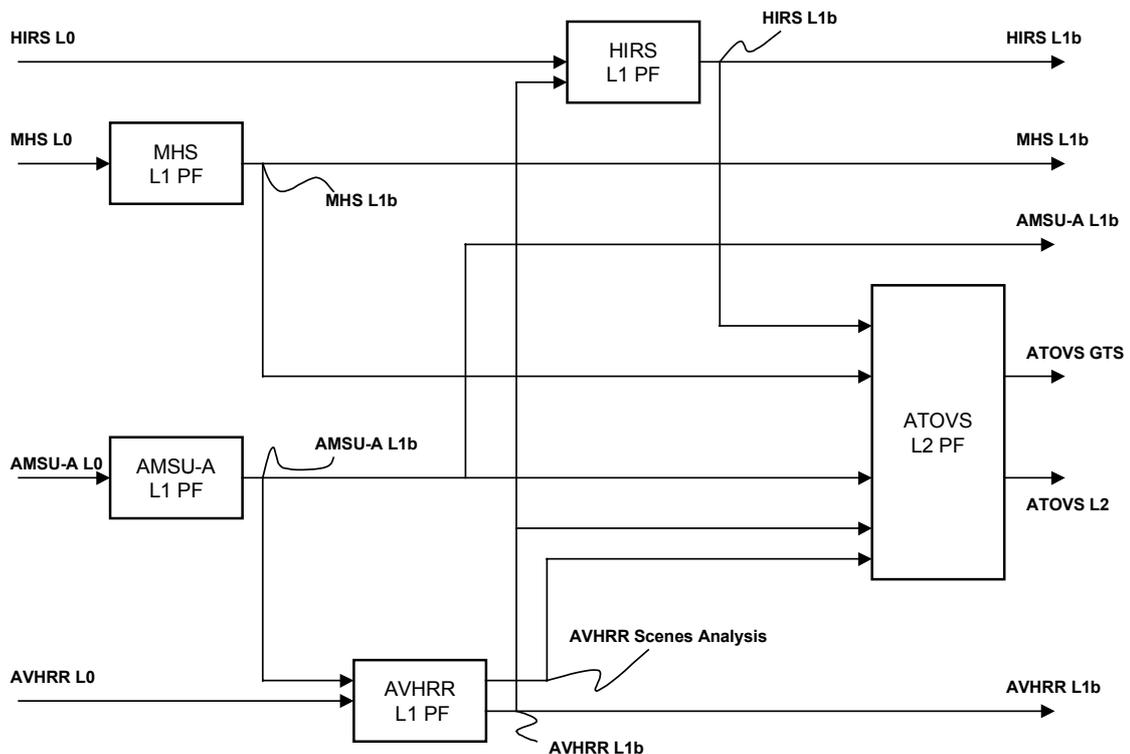


Fig. 1 ATOVS and AVHRR PPF

For the Level 1 processing of the sounding instruments (HIRS, AMSU-A and MHS), the basic structure of AAPP has been kept. The individual chains for each instrument have been completely separated. The prototype is able to process HRPT data, Global Area Coverage (GAC) data from the NOAA satellite active archive (SAA), and also Local Area Coverage (LAC) data. GAC data processing means that the processing of whole orbits is possible, while the AVHRR horizontal resolution is limited to the GAC resolution of about 4 km (at nadir).

The AVHRR Level 1 prototype was completely developed in-house. In particular, landmark processing, to assure the requirements on the Earth location, was developed from scratch. AVHRR processing is performed at full pixel resolution (1 km at nadir) – to reflect the full AVHRR resolution available from Metop - and also at GAC resolution – to reflect the AVHRR resolution available from NOAA satellites. Besides the landmark processing, cloud and surface information are derived from AVHRR data.

Level 1 Processing

AVHRR/3

AVHRR/3 calibration follows the calibration procedure specified for NOAA-KLM, as described in the respective user guide (Goodrum et al., 2000). This provides radiances at pixel location, which are part of the Level 1b product. New features developed are:

- Landmark processing;
- Renewed scenes analysis with new thresholds;
- GAC data processing.

The scientific basis for the landmark navigation processing is described in detail in Bordes (1992), the implementation for EPS is described in Ackermann (2002).

The objective of the landmark processing is to improve the accuracy of the AVHRR/3 pixel geolocation that is provided by the orbit, attitude, and scanning models. The automatic adjustment procedure of landmark processing is based on the correlation of small windows of an AVHRR image (actual windows) and small windows of selected coastal landmarks (reference windows). In principle the landmark processing consists of four steps: the identification of the landmark centre, the creation of binary images from the actual scene (actual binary windows), the generation of the reference binary images from the selected coastline data (reference binary windows), and the determination of the geographical distortions for the distinct landmarks. Figure 2 shows an example of the landmark processing done with the prototype. The second supporting task performed with AVHRR is the scenes analysis. The approach is following the MAIA algorithm, available in the AAPP software (Lavanant, 1999b). The principle of the cloud detection consists of a sequence of threshold tests that is applied to every AVHRR/3 FOV. For a distinct test situation depending on surface type, daylight conditions and season, a threshold is computed which is an estimate for the actual value of the radiometer measurement that would be expected under cloud free conditions. This threshold is compared to a physical quantity (target reflectance factor, brightness temperature difference, sea surface temperature, brightness temperature) deduced from the real value of the radiometer measurement for the considered pixel. The tested AVHRR/3 FOV is declared 'cloudy' if one of the tests is not passed. Consequently, an AVHRR/3 FOV shall be declared 'not cloudy', if all tests are passed. The tests applied and the thresholds used depend on the surface type (Land/Sea/Coast), the solar zenith angle, which determines the daylight conditions (day, twilight, night) and over sea, if there is specular reflection present or not (Sun-glint). Consequently, 11 different test situations are considered and treated separately:

- Day over sea (Test 1)
- Day over coast (Test 2)
- Day over land (Test 3)
- Sun-glint over sea (Test 4)
- Sun-glint over coast (Test 5)
- Night over sea (Test 6)
- Night over coast (Test 7)
- Night over land (Test 8)
- Twilight over sea (Test 9)
- Twilight over coast (Test 10)
- Twilight over land (Test 11)

Landmark Result

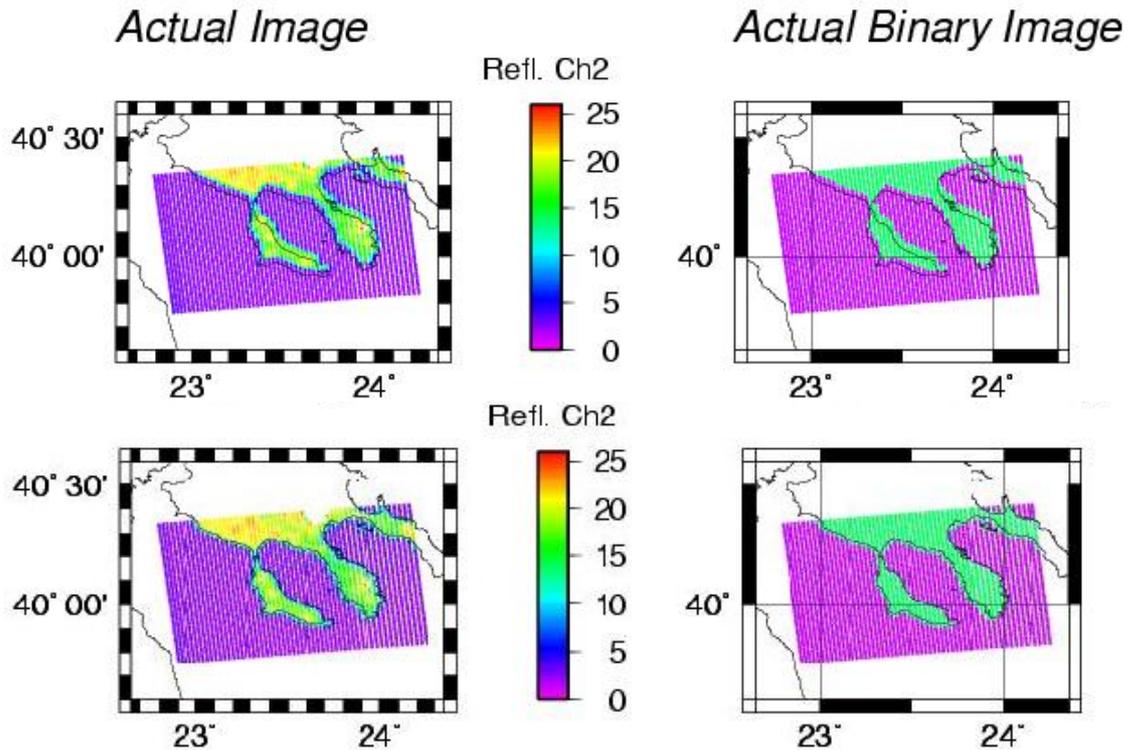


Fig. 2 Landmark processing before correction (top) and after correction (bottom)

An example for a derived cloud mask is shown in figure 3.

HIRS/4

For HIRS/4 processing the global operational calibration used by NOAA/NESDIS (NOAA KLM User Guide, Goodrum et al., 2000) was implemented, in addition to the algorithm provided by AAPP.

Cloud information for HIRS is obtained through mapping AVHRR cloud information into the HIRS FOV. The determination of the cloud coverage means to determine which AVHRR pixels fall into the field of view (FOV) ellipses of the HIRS pixels and calculate from the cloudy/clear information given for each AVHRR pixel in the AVHRR Level 1b data set the percentage of the clear AVHRR pixels. The algorithm for mapping the AVHRR FOV grid into the HIRS FOV grid has been generalised to allow for any ATOVS instrument grid to be

mapped onto any other one (except AVHRR). It has also been extended to allow the processing of GAC data. Figure 4 shows an example of the HIRS Level 1 b product. In order to have cloud information available in the case of non-availability of AVHRR a standalone HIRS cloud detection scheme has been included, following Li et al. (2000).

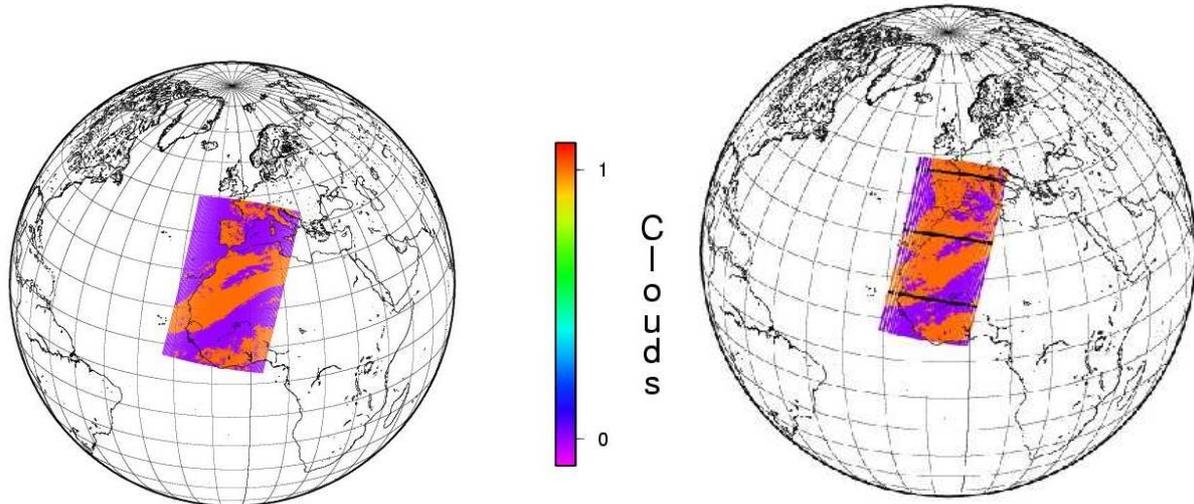


Fig. 3 HRPT derived cloud mask, derived from AVHRR (left) and HIRS (right)

AMSU/A

The AMSU-A processing is following the specifications given by NOAA, which have also been implemented in the AAPP. Figure 4 provides an example. It has turned out (Saunders et al., 2002) that the moon, if visible in the cold space view of the AMSU-A and MHS instruments, can cause considerable problems in the calibration, which may in the case of MHS amount to several tens of K in brightness temperatures. Hence there is a need to correct for this effect. The Moon contamination correction was specified and implemented into the prototype. A method provided by Atkinson (2002) was used.

MHS

The MHS calibration differs from the AMSU-B calibration in its first steps: The instrument's on-board warm-target temperature is calculated from high precision thermistors in the instrument base plate. For the calculation of the thermistor temperatures the resistances have to be explicitly calculated, using a high precision reference resistance measurement. The following calibration steps are similar to the AMSU-B calibration.

For MHS the Moon contamination correction was implemented similar to AMSU-A.

For the time being AMSU-B data have replaced MHS in the prototype processor. No MHS simulator was available, and it was decided to wait until real MHS data are available from NOAA-N. The calibration algorithm was specified and code was generated for the prototype, it is being tested with thermal vacuum test data from NOAA-N and N'.

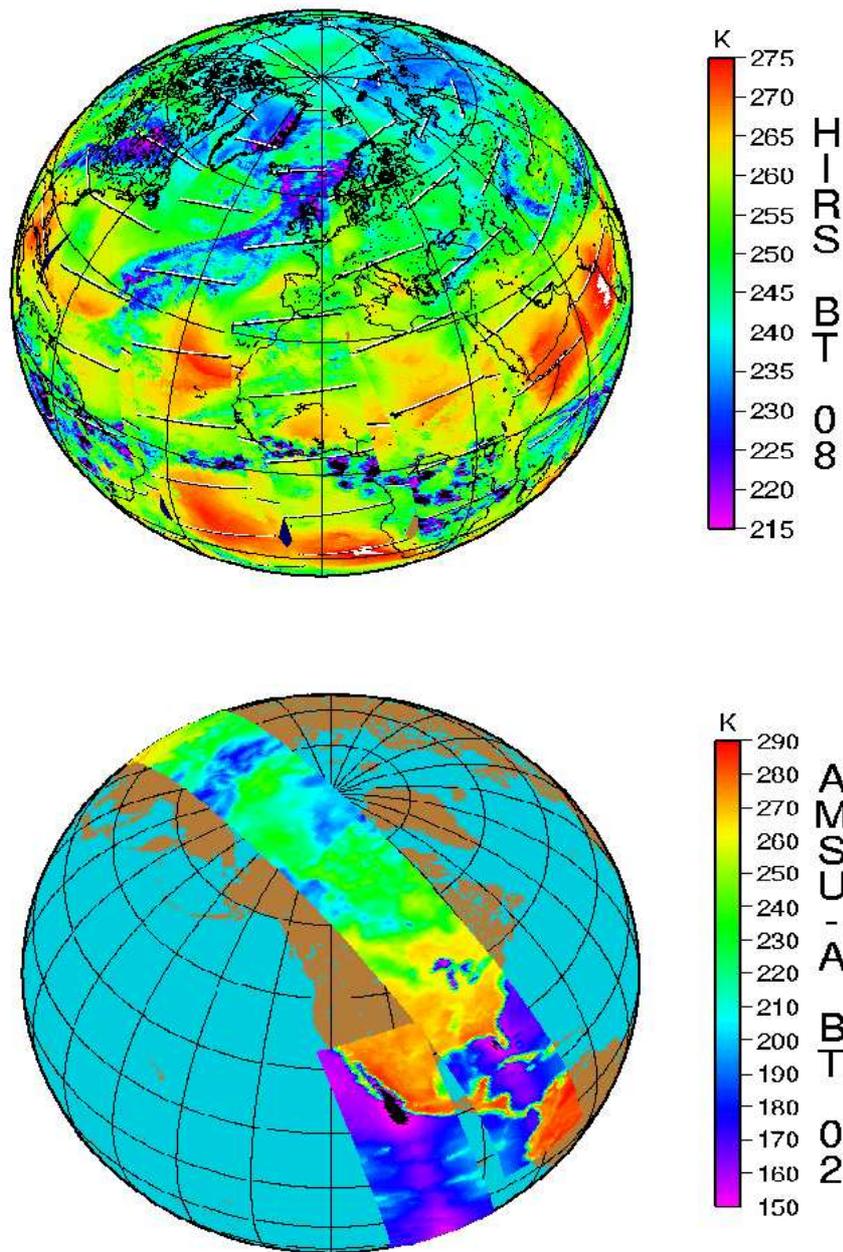


Fig. 4 Examples of Level 1b products: HIRS channel 8, 26 February 2000, NOAA-15 (top) and AMSU-A Channel-2, 30 March 1999, NOAA-15 (bottom)

Level 2 Processing

The Level two processor was specified based on the ICI package (Lavanant et al., 1999a). Through the logic of EPS Product generation the Level 2 processor is divided into two sections. The first section performs all contamination checks on the data, which are in AAPP part of the pre-processor. The second part contains the essential ICI processor, which generates atmospheric profiles of temperature and water vapour, tropopause height, surface temperature, cloud fraction and cloud top pressure. New features included in the Level 2 specification include:

- The capability to process full orbits
- The inclusion of GAC data processing
- The Mapping of GAC data on the HIRS FOV
- The inclusion of RTTOV7 instead of RTTOV6 as radiative transfer model.

Figure 5 shows an example output from the prototype processing.

As a backup to the Level 2 processor an AMSU-A standalone retrieval for temperature was implemented, following the regression algorithm specified by Goldberg et. al. (1999).

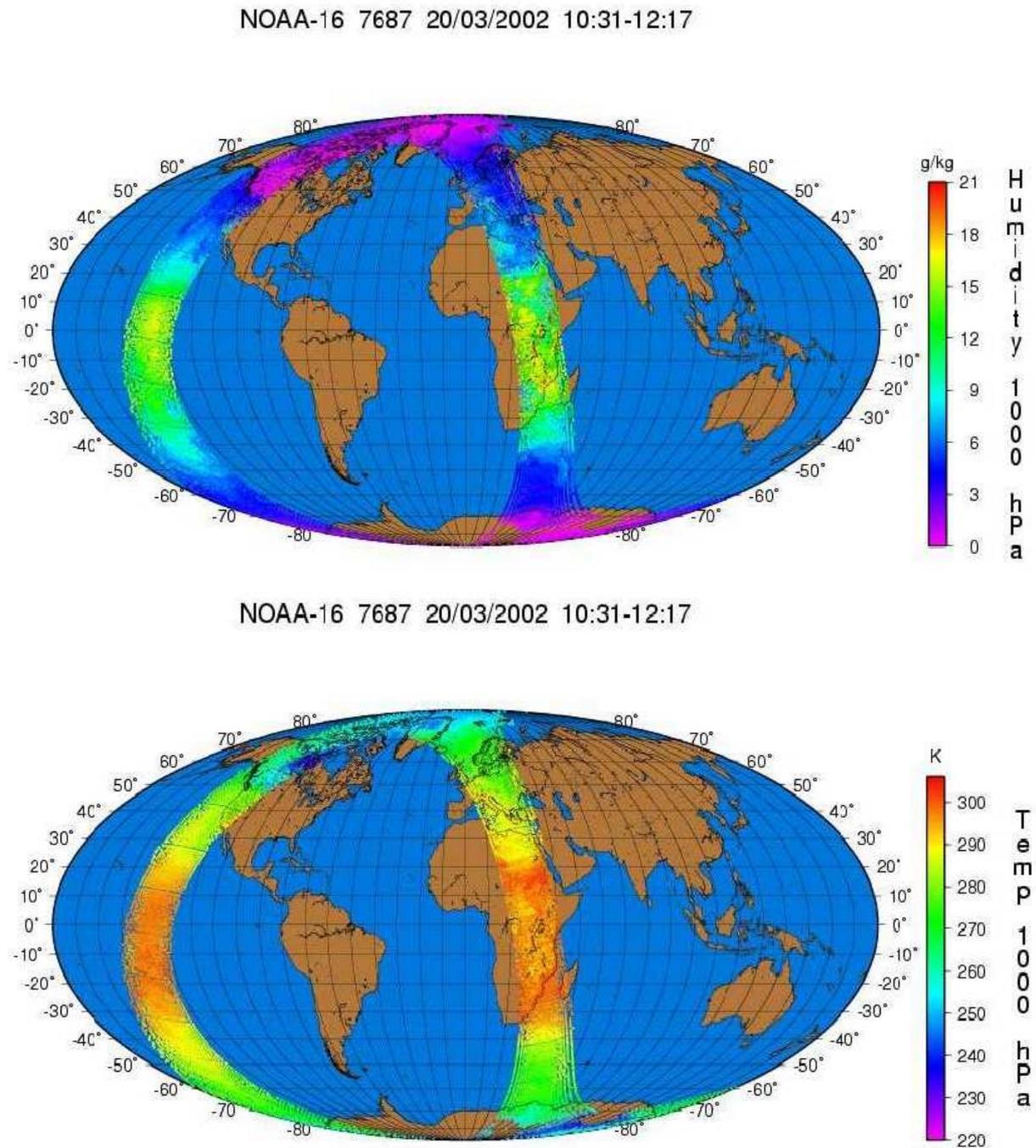


Fig. 5 ATOVS Level 2 product output, humidity at 1000 hPa (top), temperature at 1000 hPa (bottom).

Summary and Lookout

EUMETSAT has specified the full ATOVS and AVHRR processing chain and has implemented an end-to-end prototype for ATOVS Level 1 and Level 2 processing. It processes all instruments as specified with the exception of MHS – in its place AMSU-B data are processed currently. One full orbit can be processed end-to-end in about one hour on a standard workstation (HP9000).

Current work is aimed to assess the quality of the Level 2 retrievals. Prototype code for the MHS data processing was integrated and is awaiting testing with thermal vacuum data from NOAA-N and N'. Once launched NOAA-N data will provide real in-orbit MHS data for testing of the processor.

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