Further development of the ATOVS and AVHRR Processing Package (AAPP), including an initial assessment of EARS radiances

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Introduction

AAPP is a retrieval and analysis package for ATOVS and AVHRR. The package is maintained by the EUMETSAT Satellite Application Facility for Numerical Weather Prediction (NWP SAF). The host centre for the NWP SAF is the Met Office, with partners ECMWF, KNMI and Météo-France (see http://www.metoffice.com/research/interproj/nwpsaf/index.html).

This paper describes the latest updates to AAPP which are incorporated into the newly-released version 4.0. It also describes the changes being implemented for future releases, firstly to allow for processing of data from the NOAA-N and N′ satellites and secondly for the METOP era.

A recent development in the acquisition of ATOVS data is the establishment of the EUMETSAT ATOVS Retransmission Service (EARS), in which data from a network of HRPT receiving stations are collected by EUMETSAT and re-transmitted to users in a timely manner suited to the needs of European operational short-range NWP (see http://www.eumetsat.de/en/dps/atovs.html). EARS data from up to 8 receiving stations are currently being received and processed routinely at the Met Office using AAPP, in order to assess the data quality, with any anomalies being automatically reported to EUMETSAT. The paper includes some examples of comparisons between global (NESDIS) and EARS data, and discusses the potential contribution of EARS data in the context of NWP.

AAPP Version 4

Version 4.0 of AAPP is scheduled for release in October 2003. It includes the following enhancements compared with Version 3:

1. Rationalised documentation. The following documents are now included:
   - Scientific description
   - Software description
   - Data formats document
   - AAPP overview
   - Installation guide (html)

2. Compatible with both Fortran 90 and FORTRAN 77 compilers.

3. Correction for the presence of the moon in the AMSU-A space view. When the moon passes through the AMSU-A space view the space-view brightness temperature increases by typically 2K, causing errors in the calibrated scene radiances. The predicted position of the moon is computed using standard astronomical formulae, and a correction is applied for those scans for which the moon is within 3.5° of the space view, by interpolating the calibration gain from the neighbouring uncontaminated scans. The correction forms part of the AAPP pre-processing stage (atovin) and therefore applies to both global and local data. The method has been in operational use in the Met Office implementation of AAPP since 2002.

   Note that NESDIS are planning to introduce a moon correction at 1b level based on antenna patterns, i.e. the space-view brightness temperature error is estimated and subtracted prior to computing the calibration coefficients (Kigawa and Mo, 2002). Both methods are expected to be effective in reducing the errors to below 0.1K.

4. Allow different antenna efficiencies for different satellites (in subroutine *infdf*). Previously only one set of antenna efficiencies could be used. The antenna efficiencies are used in the pre-processing to correct for contamination of the AMSU Earth views by cold space.

5. Correct 'bug' in subroutine *surfelev*. Use of real variable in DO loop caused different results for F90 and F77.

Developments for NOAA-N and N'

AAPP version 5 will include the ability to process data from NOAA-N and N'. It is intended that version 5 will be released shortly after the NOAA-N launch, currently scheduled for summer 2004. The NOAA-N satellite includes two new instruments:

- Microwave Humidity Sounder (MHS) replaces AMSU-B
- HIRS/4 replaces HIRS/3

The differences between MHS and AMSU-B include the following:

1. Channel 20 is a single band centred on 190.31 GHz; AMSU-B has bands at 183.31±7 GHz.
2. Channel 17 is moved to 157 GHz; AMSU-B uses 150 GHz.
3. Channels 18-19 have horizontal polarization at nadir; AMSU-B has vertical polarization
4. MHS has spare local oscillators, referred to as LO-A and LO-B. The nonlinearity coefficients are characterized separately
5. MHS has spare processing electronics (PIE-A and PIE-B)
6. The method of computing the internal target temperature is different, involving the use of three precision resistors for MHS.
7. The MHS instrument itself outputs data in 'packet' format, as required by METOP. The NOAA satellites use an on-board MHS Interface Unit (MIU) to convert the packet data to a form that the satellite can handle. For the HRPT transmission, the MIU writes the MHS data into the same data slots as are currently used for AMSU-B.

The changes needed in AAPP to process MHS are as follows:

- Updated decommutation program, to read the new MHS data format within the HRPT stream
- New level 1b format (*mhs1b.h*)
- New calibration and navigation program, *mhscl*
- Updated pre-processing to allow conversion of MHS level 1b into a level 1c format that is common to MHS and AMSU-B (i.e. *amb1c.h* is unchanged)

The differences between HIRS/3 and HIRS/4 are relatively minor, but do require a new level 1b format.

Other enhancements planned for AAPP version 4 include:

- Capability of using the new HIRS calibration algorithm (version 4.0 – Changyong Cao, pers. comm.)
- Correction for moon contamination in AMSU-B/MHS space views, as part of *amsubcl* and *mhscl*. Currently the affected scan lines are rejected by quality control. The positions of the 4 space view samples will computed and compared with the predicted position of the moon. Any samples that are too close to the moon will be rejected – up to 3 samples may be rejected by this method, but the calibration will still be valid, albeit slightly noisier than normal. NESDIS currently allow for moon contamination by rejecting space-view samples with significantly elevated counts (i.e. a diagnostic method), but are planning for MHS to implement the prognostic method described above.
- Navigation updates, including capability of using 2-line orbital elements, with SGP4 propagation model.

Developments for METOP

The NWP SAF is currently working with EUMETSAT in order to develop AAPP for the METOP era. It is anticipated that developments for METOP will form part of AAPP version 6. Receiving stations and software for the direct broadcast HRPT signal will be supplied by EUMETSAT, with the output data being interfaced to AAPP at EUMETSAT level 0 (which is equivalent to NOAA level 1a). Developments required for AAPP will include:

- Reading in the level 0 data
- New orbital prediction and attitude prediction software. Note that METOP will normally operate in yaw-steering mode, in which the satellite attitude is controlled such that it is always pointing towards the local normal to the Earth's surface (as compared with NOAA satellites which point at the centre of the Earth).
- Use of 'Admin' messages to provide navigation information, and also to provide warnings of imminent spacecraft manoeuvres. In-plane manoeuvres have only a small impact as far as the data are concerned, but out-of-plane manoeuvres require the satellite to be rotated through 90º, with consequent loss of data for a period of a few hours.

The NWP SAF are responsible for providing near-real-time data from AMSU-A, MHS, AVHRR, HIRS and IASI. For IASI, the pre-processing code is being developed by CNES and will be kept separate from AAPP where possible.

Use of EARS data in the Met Office

AAPP is used operationally in the Met Office for the pre-processing of ATOVS data from the following sources:

1. Global data from NOAA/NESDIS, received via the Global Telecommunications Service network (GTS)
2. HRPT direct from the NOAA satellites, received at West Freugh (Scotland)
3. EARS data transmitted via the EUMETCast service. Both levels 1a and 1c are currently received, though 1c is not routinely processed.

The EARS data are potentially useful for both global and local forecasting because the service provides data over a wide area, with much shorter delays than is the case for global data. EARS data are typically available within 30 minutes of the start of the satellite over-pass – as compared with 3 to 6 hours for global data. However, before they can be used in NWP it is necessary to ensure that the data are reliable and that the radiances are consistent with the global radiances. Therefore a system of monitoring has been implemented based on AAPP, as shown in Fig. 1.
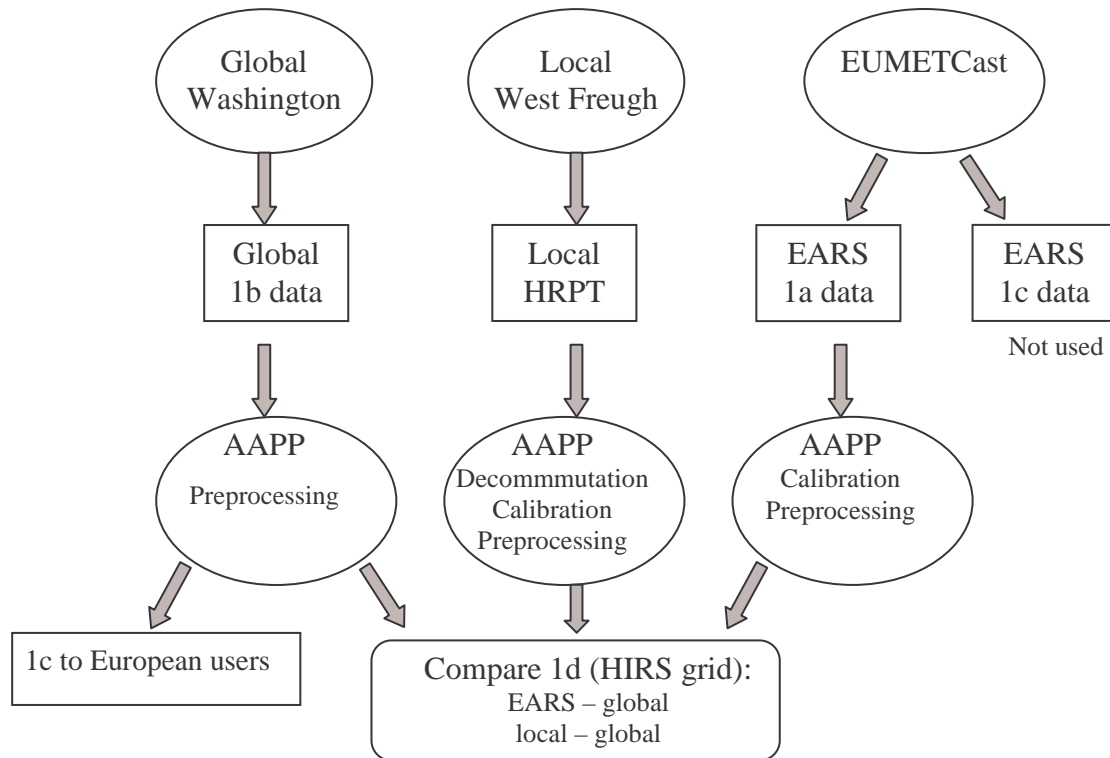
Fig. 1: Use of AAPP in the Met Office for processing global, local and EARS ATOVS data.

Data are received and processed routinely from the following stations in the EARS network:
- Tromsø (Norway)
- Kangerlussuaq (Greenland)
- Maspalomas (Canaries)
- Edmonton (Canada)
- Athens (Greece)

Data are also received from Bedford (Canada), Gander (Newfoundland) and Monterey (California), but not processed routinely.

Figs 2 to 5 show examples of comparisons between global data, local data and EARS data from Tromsø. Fig. 2 compares the geolocation of the HIRS footprints for global data and EARS. There are differences of about 10% of the cross-track sampling distance, for reasons that will be explained below. Fig. 3 and Fig. 4 compare the brightness temperatures of AMSU channel 15 (89GHz), for Tromsø and local data respectively. Note that this comparison is at level 1d, i.e. after mapping to the HIRS grid.
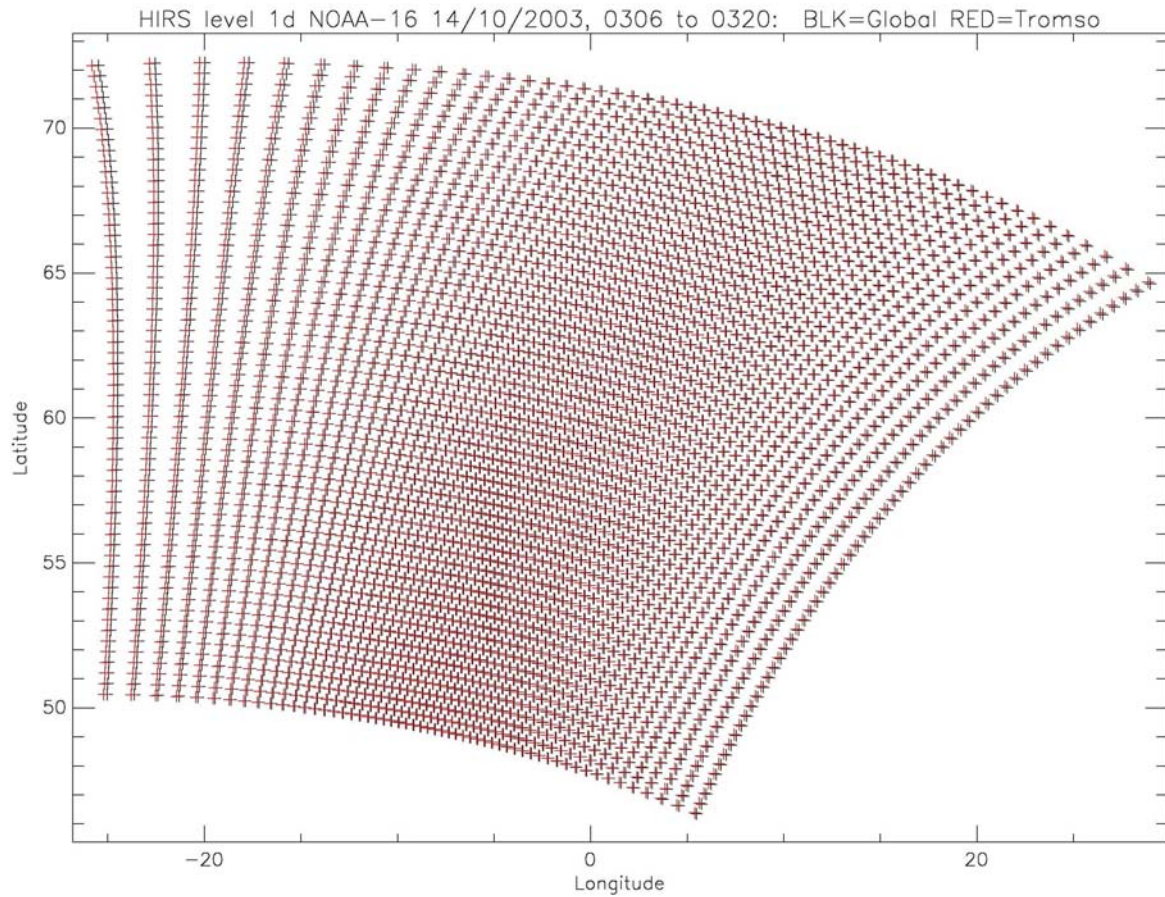
Fig. 2: HIRS Geolocation for Tromsø EARS data processed to level 1d, compared with global data.
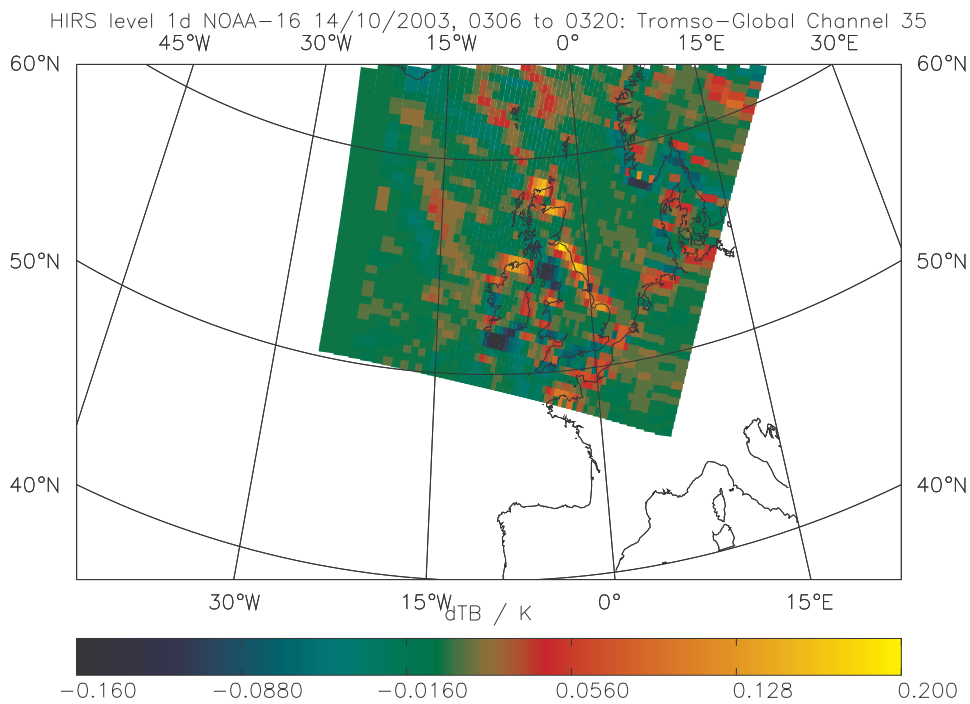

Fig. 3: Brightness temperature for AMSU channel 15 (89GHz):EARS Tromsø compared with global, at level 1d.
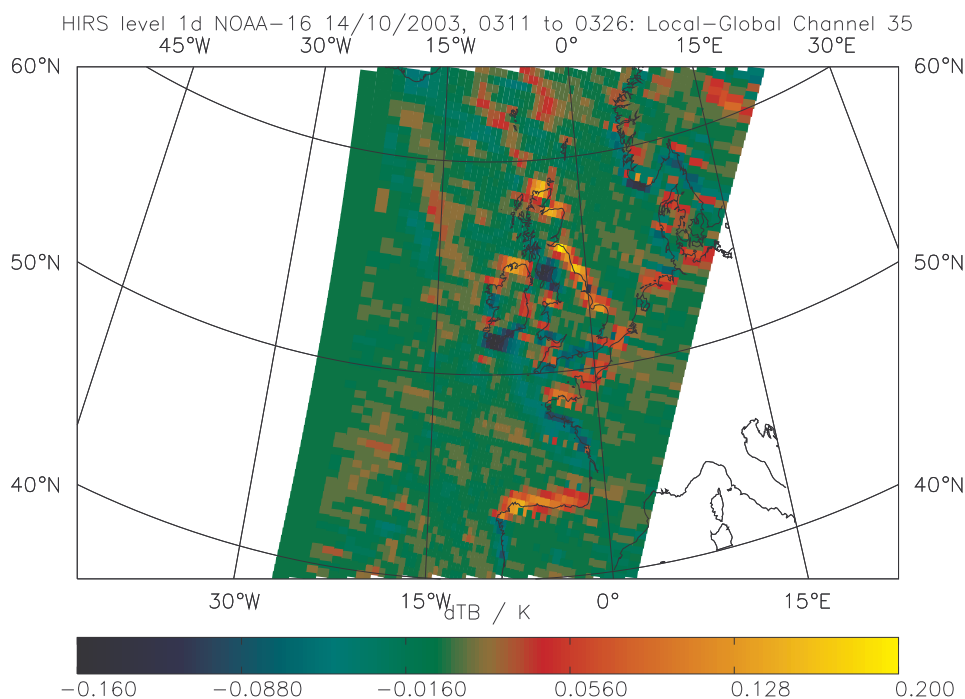
Fig. 4: Brightness temperature for AMSU channel 15 (89GHz):local compared with global, at level 1d.

For mapping, differences between global and EARS (or local) data can be caused by the following:

1. Orbit and attitude prediction method. The Met Office implementation of AAPP uses TBUS bulletins from NOAA which are updated daily via the GTS. For global data, NOAA uses a more sophisticated method which is not available to users. Finally, EARS data processed to level 1c by EUMETSAT use TBUS bulletins obtained from the NOAA web site. For more information on TBUS bulletins, see http://noaasis.noaa.gov/NOAASIS/ml/navigation.html.

2. Re-mapping to the HIRS grid. The HIRS instruments on NOAA-16 and NOAA-17 have a cross-track pointing error of approximately one sample. For global data, NOAA assume a fixed offset of 1.8° compared with nominal; AAPP currently assumes offsets of 2.0° for NOAA-16 and 1.7° for NOAA-17, these values having been determined from comparisons with AVHRR (see `include/timang.h` in the aapp code)

Brightness temperature differences can be caused by the following:

1. Re-mapping to HIRS grid (as above)

2. Differences in the calibration coefficients.

For the microwave radiometers (AMSU-A, AMSU-B) the calibration has been found to be consistent between global and local data to ~0.01K (i.e. at level 1c), so the global-local differences in Figs 3 and 4 are due almost entirely to the HIRS misalignment in the re-mapping process. The differences shown (up to 0.2K) are generally acceptable, and would be expected to be reduced for the higher sounding channels that are not sensitive to surface features.

For HIRS itself, a calibration is only performed every 256 seconds, so significant calibration differences can result for those parts of the local over-pass that are not bounded by calibrations. This is a drawback with the use of locally-received HIRS data.

Potential impact of EARS data in NWP

The timeliness of EARS data makes it valuable in the context of operational NWP. In the Met Office, the main 12Z global forecast run is performed at approximately 1400 GMT, accepting observations valid between 0900 and 1500 GMT. Fig. 5 shows an example of the global ATOVS observations that have been received and pre-processed by that time, over Europe and the northern Atlantic. We see that not only is there a large data void between 30°W and 10°E, but no NOAA-17 data are available in the displayed area.

By contrast, Fig. 6 shows the EARS observations that are available, completely filling the data void and providing several passes of NOAA-17 data.

It is planned to start assimilation trials using EARS during autumn 2003.
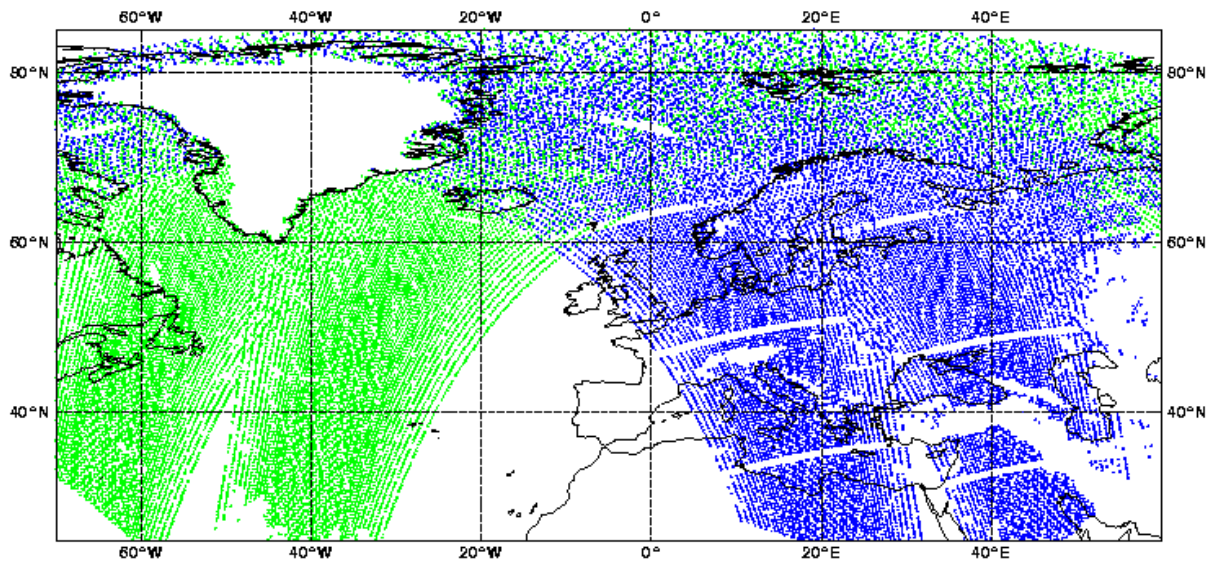

Fig. 5: ATOVS observations available for forecast run at 14:00, accepting observations between 09:00 and 15:00 GMT. Green: NOAA-15; blue: NOAA-16.
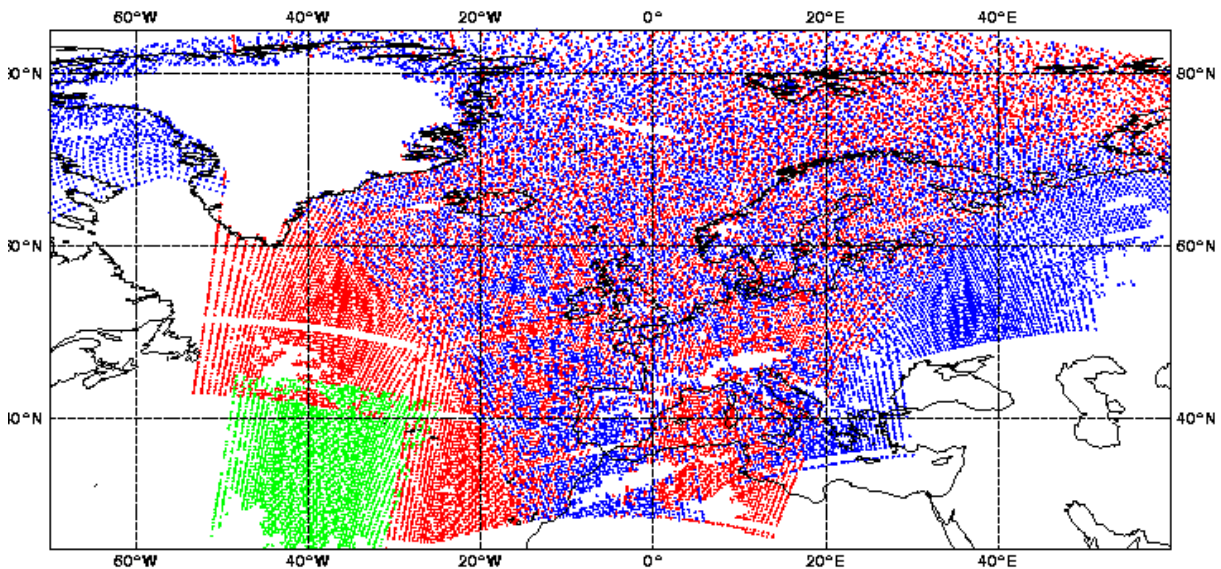

Fig. 6: EARS observations available for forecast run at 14:00, accepting observations between 09:00 and 15:00 GMT. Green: NOAA-15; blue: NOAA-16; red: NOAA-17.

Conclusions

AAPP version 4 includes a number of enhancements compared with version 3, including Fortran 90 compatibility, improved documentation and a correction for lunar contamination in AMSU-A. Version 4 is being released by EUMETSAT in October 2003.

Preparations are underway for the launch of NOAA-N in 2004. AAPP version 5 will include the ability to process the NOAA-N instruments, as well as enhanced navigation modules. The NWP SAF is working with EUMETSAT in order to ensure continuation of a direct reception capability in the METOP era.

Data from the EUMETSAT EARS system are being received routinely at the Met Office, and monitored for data quality. The consistency between global NESDIS data and EARS data processed via AAPP is generally good, and the excellent timeliness of EARS means that it should have a useful impact in NWP. Trials are expected to start in autumn 2003 in order to quantify the impact.

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Thanks also to Brett Candy and Una O'Keeffe (Met Office) for their work in analysing and monitoring the EARS data.
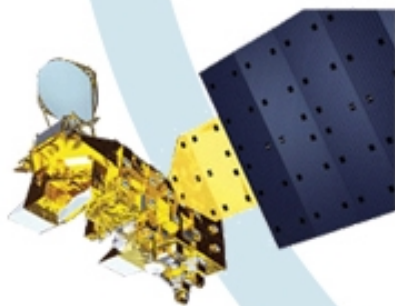
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