AAPP status report and review of developments for NOAA-N and METOP

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Introduction

The ATOVS and AVHRR Pre-processing Package (AAPP) is a software package 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 status of the current AAPP release, version 4, which is in use routinely at many NWP and research centres worldwide. A new release, version 5, is in preparation and this will include a number of enhancements, the most important of which is the capability of processing data from the NOAA-N and NOAA-N´ satellites (in addition to data from the current operational satellites). Version 5 is scheduled to be released about two months after the launch of NOAA-N (renamed NOAA-18 after launch).

Looking further ahead, preparations are underway for AAPP version 6, which will handle METOP data. The new IASI instrument in particular poses a number of challenges for pre-processing systems and for numerical weather prediction.

Finally we consider the extension of AAPP to new satellites such as NPP and NPOESS.

AAPP Version 4

Version 4.0 was released in October 2003. Since then there have been 5 updates, as detailed on the AAPP web site. Of these, updates 4.1, 4.2 and 4.3 have been superseded and are no longer required. Update 4.4 is an important update that contains the following enhancements:

- Linux compatibility, including ability to run on Windows systems via Microsoft Services For Unix
- Improved robustness in the decommutation program, allowing a higher proportion of passes with noisy HRPT data to be processed.
- Utility to compare output files from different platforms (*atovsCompare*)
- Big/little-endian conversions
- Processing of NOAA-17 (which has a broken AMSU-A1 instrument) to level 1d
- Extra 1d flag for fewer co-locations than expected in re-mapping AMSU-A to HIRS (useful when comparing EARS data with global ATOVS)

Update 4.5 is a routine AMSU-B gross limits update – the instrument calibration counts for certain channels have drifted outside the original range.

In addition to the code changes there have been some administrative changes in the way AAPP is maintained and distributed:

- Formal responsibility for maintaining and distributing AAPP has been passed to the NWP SAF. Previously this was handled directly by EUMETSAT.
- Enquiries and licensing are dealt with by the NWP SAF helpdesk.
- Update versions of AAPP are held on a Met Office FTP server.
- The AAPP web page has been integrated with the NWP SAF web page (see Introduction).
- The "L-aapp" email forum, to which anybody can subscribe, is still hosted by EUMETSAT. The NWP SAF also maintains separately a list of the email addresses of licensed AAPP users.

AAPP version 5 for NOAA-N and N´

A beta release of AAPP version 5 is currently under test. The full version is expected to be released to users about two months after the launch of NOAA-N. The main changes in AAPP-5 compared with AAPP-4 are as follows:

1. NOAA-N capability (including MHS)
2. New HIRS calibration method (based on NOAA 'version 4' algorithm)
3. Updated navigation – ability to use 2-line elements
4. Allow for moon contamination in AMSU-B and MHS
5. Added NWC-SAF scattering index (Bennartz et. al., 2004) to AMSU-B level 1d
6. Use of instrument-specific scan characteristics, and removal of many hard-coded parameters

These are discussed briefly below.

MHS

A new calibration module, *mhscl*, has been introduced, together with a new level 1b fomat – as defined by NOAA. The format of MHS level 1c is the same as that of AMSU-B level 1c, except for the instrument identifier. Similarly, changes are minimal at level 1d.

Users should be aware that the polarisations for the 183.31±1 and 183.31±3 GHz channels are different from the equivalent channels in AMSU-B. In both AMSU-B and MHS there is a known small scan-dependent bias due to the fact that the reflectivity of the main reflector is not quite unity, and depends on polarisation. This effect is allowed for in AAPP-5 for MHS. For consistency with previous AAPP versions, it is not applied by default for AMSU-B.

HIRS calibration

In April 2005 NOAA introduced into operations the new HIRS calibration algorithm described by Cao and Ciren (2003). A very similar algorithm has been introduced into AAPP-5, which should improve the consistency between global and local HIRS calibration.

There will inevitably be some calibration discrepancies in the HIRS 'partial superswaths' at the beginning and end of a local pass. However, by archiving statistics of the correlation between calibration slope, calibration offset and telescope temperature it is hoped to minimise these errors. The addition for HIRS/4 of a new Tertiary Telescope temperature sensor may help.

2-line elements

As part of the navigation step when processing from level 1a to level 1b, an orbital prediction model is used in order to determine the position and attitude of the satellite as a function of

time. AAPP-5 includes the option to use 2-line element data (see http://celestrak.com/ for a description) as an alternative to TBUS. The data can be obtained from http://www.space-track.org/ (once the user has registered). A script is provided to download automatically the latest data from the space-track web site.

Experiments show that the accuracy of the orbital prediction is considerably better using 2-line elements than for TBUS – though the difference is only significant for users who process AVHRR.

Moon contamination in AMSU-B and MHS

AAPP version 4 included code to predict and correct for the presence of the moon in the AMSU-A space view – but not AMSU-B. If AMSU-B saw the moon in its space view then the affected scan lines were rejected by quality control, so data gaps of up to 5 minutes could occur. For AAPP-5 we use the computed position of the moon to predict which, if any, of the 4 space view samples are likely to be contaminated, choosing the remaining samples for use in the calibration. The 4 space samples have an angular separation of 1°, so there is always at least one that is uncontaminated. This improves the availability of the data and also its reliability since we are not relying on quality control thresholds for rejecting bad data.

The same method is used by NESDIS in generating AMSU-B and MHS level 1b data, and will also be used in the EPS ground segment.

NWC-SAF scattering index

As well as the AMSU-B scattering index that is already present in AAPP, an alternative AMSU-B based scattering index has been developed by Bennartz et. al. (2002) in the framework of the EUMETSAT Satellite Application Facility to support Nowcasting and Very Short Range Forecasting (NWC SAF). This code has been integrated in AAPP and is activated when an AMSU-B level 1d product is requested. Unlike the existing scattering index, which is only valid over the sea, the new index is designed to work equally well over land. At this stage it is considered an experimental tool, as the results have not been validated quantitatively on a global scale. To avoid disturbing existing applications, the scattering index and precipitation probabilities are written to words in the AMSU-B 1d format that were previously spare (i.e. amb1d_prepro(6,*)).

Instrument-specific scan parameters

To allow for the fact that some of the instruments have unique spot sizes and scan characteristics (e.g. HIRS scan position displacements for NOAA-16 and 17), a dedicated 'satid.txt' file has been set up to ensure the correct values are used. This also simplifies the introduction of new instruments and platforms, such as METOP. Fundamental and physical constants have been standardised in AAPP-5 – previously there were multiple hard-coded definitions.

AAPP version 6 for METOP

There are three main changes for METOP that must be allowed for in the design of AAPP-6: (i) the new IASI instrument, (ii) a new direct broadcast format (Advanced High Resolution Picture

Transmission, or AHRPT) and (iii) new mechanisms and formats for the distribution of global data. The top-level design of AAPP-6 is shown in Fig. 1.
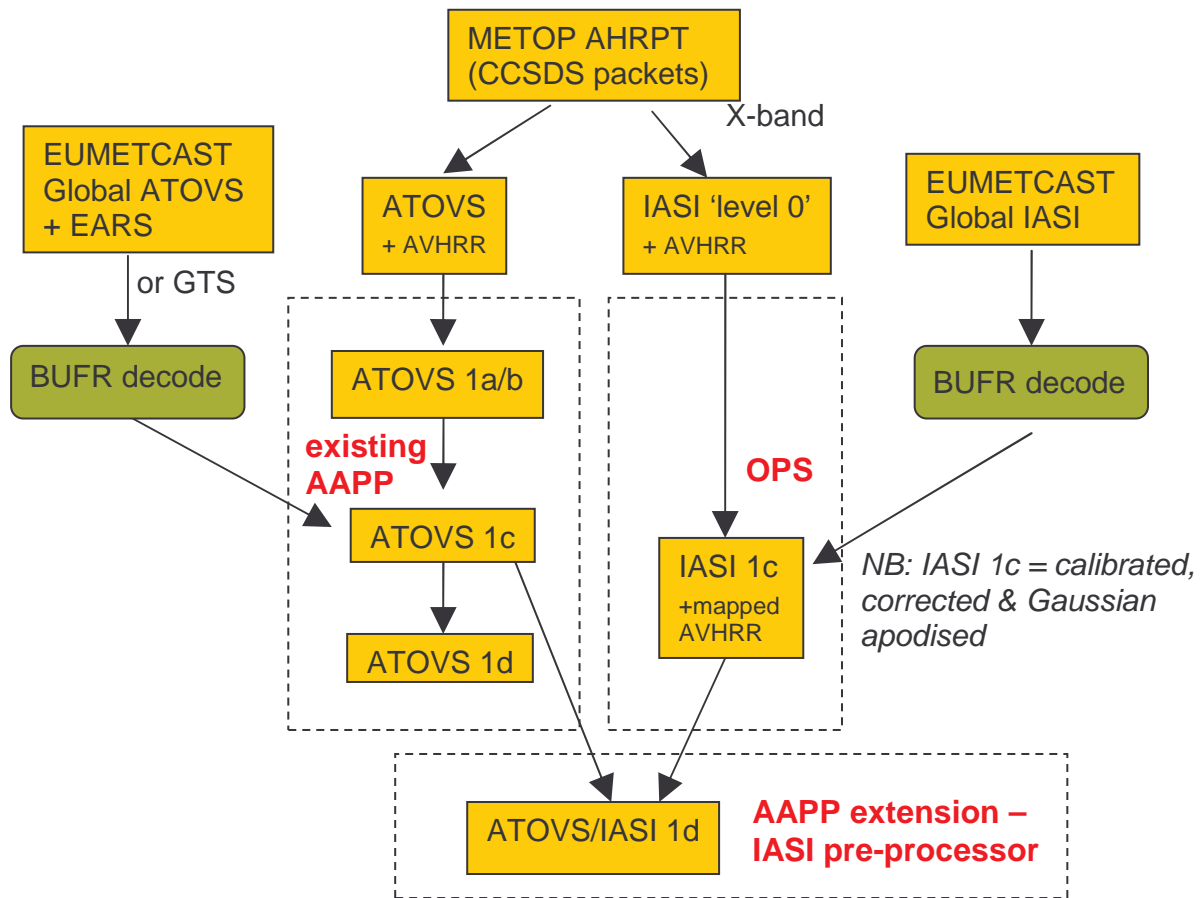

Fig. 1: Schematic for AAPP version 6, showing main data flows for METOP

AAPP-6 will include new 'front-end' modules for the acquisition and decoding of the AHRPT data packets that are transmitted at X-band. These modules will convert the ATOVS and AVHRR data into standard AAPP level 1a format which can be processed by the existing AAPP calibration and pre-processing modules. For IASI, the AHRPT data are converted to 'level 0' format, defined by EUMETSAT. They are then processed to level 1c by a software suite based on the 'IASI OPS' (OPerational Software) supplied by CNES, the instrument supplier, for EUMETSAT. Level 1c comprises IASI data that have been calibrated, spectrally corrected and Gaussian apodised, together with AVHRR data mapped to the IASI grid.

For global data distribution, ATOVS and IASI will be converted to BUFR at EUMETSAT and then transmitted to European users via EUMETCast. Regional ATOVS data will also be provided (as in the present EARS system). Users outside Europe will have access to ATOVS data via the Global Telecommunications System (GTS) or via the internet. AAPP will need to be able to decode these BUFR messages.

For the final *atovpp* pre-processing stage, several new options will be provided:
1. Map AMSU and MHS to the IASI grid
2. IASI channel sub-set, based on a pre-selected list of channels, in order to reduce data volume

3. Produce IASI eigenvector scores, i.e. the signal to noise ratio for the presence of certain pre-computed eigenvectors. The number of eigenvectors will be selected by the user. This is a more sophisticated way of reducing data volume than simple channel selection, as it attempts to preserve as much useful information as possible.
4. Spatial thinning, e.g. select 1 spot in 4, either a fixed spot or on the basis of a cloud test. Clear spots are generally preferred for NWP
5. IASI cloud detection tests (to be defined)

The eigenvector scores, $\mathbf{c}$, will be generated via

$$\mathbf{c} = \left(\mathbf{U^T N}\right)\mathbf{y}$$

where $\mathbf{U}$ are the pre-computed fixed eigenvectors (probably generated from a mixture of theoretical and observed noise-normalised spectra), $\mathbf{y}$ is the radiance spectrum and $\mathbf{N}$ is a matrix that converts $\mathbf{y}$ to a noise-normalised de-apodised form. $\mathbf{U^T N}$ has the same dimensionality as $\mathbf{U^T}$ and can be pre-computed – so there is no need to de-apodise spectra in real time. Simulations suggest that about 300 eigenvectors will be adequate to retain most of the useful information in the IASI spectra.

The data volume for raw IASI 1c BUFR is approximately 16 Gbytes per day (EPS test data available from EUMETSAT). If we store 300 channels plus 300 eigenvector scores for 1 spot in 4 (as planned at the Met Office) and BUFR encode then the data volume of the IASI 1d product will be about a factor 30 lower than that of IASI level 1c – but still a factor 10 higher than the existing HIRS 1d.

NPP and NPOESS
NPP (with a launch scheduled for 2008) will contain a new suite of instruments, including CrIS, ATMS and VIIRS. It is planned to extend AAPP to accept data from these instruments – i.e. to develop 1d products for ATMS and CrIS that are analogous to the 1d products for AMSU/MHS and IASI.

The NWP-SAF probably does not have the resources to develop a complete end-to-end system for direct readout, but it is hoped to accept Temperature Data Records from the NASA direct readout software (see http://directreadout.gsfc.nasa.gov/), and also global NPP data – with distribution formats yet to be defined.

Conclusions
AAPP version 4 is currently available from the NWP-SAF, with about 200 registered users worldwide. Version 5, supporting NOAA-N and NOAA-N´, is in the final stages of testing and is planned to be released to users about 2 months after the launch of NOAA-N.

Preparations are under way for AAPP version 6, supporting METOP. New modules will be added to AAPP to accept the AHRPT data stream and to process IASI data – with various user-configurable options to control the output data volume. BUFR decoding and encoding modules will be added.

In the longer term, it is planned to extend AAPP to handle the sounding data from NPP and NPOESS – in conjunction with direct readout packages developed elsewhere.

Acknowledgements

References

Changyong Cao and Pubu Ciren, 2003, Operational High Resolution Infrared Radiation Sounder (HIRS) Calibration Algorithms and Their Effects on Calibration Accuracy, ITSC XIII Proceedings (2003), cimss.ssec.wisc.edu/itwg/itsc/itsc13/session3/3_2_ciren.pdf

Bennartz, R., Thoss, A., Dybbroe, A. and Michelson, D.B., 2002. Precipitation analysis using the Advanced Microwave Souunding Unit in support of nowcasting applications, *Meteorol. Appl.*, **9**, 177-189