NWP SAF

Satellite Application Facility for Numerical Weather Prediction

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NWP SAF – CIMMS Liaison Meeting, 15-17 May 2006

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1. Met Office, UK
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This documentation was developed within the context of the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWP SAF), under the Cooperation Agreement dated 16 December, 2003, between EUMETSAT and the Met Office, UK, by one or more partners within the NWP SAF. The partners in the NWP SAF are the Met Office, ECMWF, KNMI and Météo France.

NWP SAF Visiting Scientists' Report

Nigel Atkinson, Pascal Brunel and Philippe Marguinaud
May 2006

NWP SAF – CIMMS Liason Meeting, 15-17 May 2006
Space Science and Engineering Center, UW-Madison

Present:

From Meteo-France: Pascal Brunel, Philippe Marguinaud
From Met Office UK: Nigel Atkinson
From CIMSS: Allen Huang, Liam Gumley, Eva Borbas, Kathy Strabala, Hal Woolf (also at times Tom Achtor, Bob Holz, Paulo Antonelli, Steve Ducher, Dave Santec, Ray Garcia, Tom Whittaker, Tom Rink)

Agenda:

Lead by NWP SAF:

Review of AAPP v6 for METOP (see slides)
Review of OPS-LRS
- experiences with porting code
- plans for running it operationally

Discuss beta testing for AAPP v6
Possibly run test cases on CIMSS computer system - including OPS-LRS
Review of requirements for NPP and NPOESS (see slides)
Navigation issues

Lead by CIMSS:

CIMSS plans for processing METOP data
Schedules and plans for NPP and NPOESS
Plans for IPOPP
- capabilities
- development schedules and progress to date
- software structure (e.g. languages)
- data formats

Dissemination of NPP and NPOESS global data

IPO issues - John Overton

General:

Relationships between AAPP and IPOPP, IAPP, IMAPP
Software compatibility
Data compatibility including global/local consistency
The way forward
Other....

The agenda items were all covered in the discussions that followed, though not necessarily in the order given above.

Review of AAPP v6

Nigel presented slides describing the capabilities of AAPP v6. This will comprise:

- Core AAPP (as in previous versions, plus METOP extensions)
- METOP tools (for L0 to L1a conversion)
- IASI tools (for configuration files, plus format conversion and reading)
- IASI OPS-LRS (Operational Software – Local Reception Station). Delivered separately.

Questions from CIMSS:

- Antenna size for receiving METOP DB? It is thought that 2m is generally sufficient.
- Encryption? EUMETSAT provide a decryption key. (Post meeting note – this appears to be a software key)
- Updates mechanism for software and coefficient files. CIMSS recommended that where possible any necessary updates or data files should all be available from one FTP site. The program could download the data files automatically and check that all components are up to date. AAPP does not currently do this, though it was pointed out that some IASI coefficient files will need to be updated regularly (from EUMETSAT) otherwise OPS-LRS would not run. (See also appendix)

Requirements for NPP/NPOESS

NA presented the NWP SAF plans, including an extract from the proposal for CDOP (Continuous Development and Operations Phase):

> R&D is required to extend AAPP to be able to exploit data from CrIS, ATMS and VIIRS on NPP and, later, these instruments and CMIS on NPOESS. New code will be provided for processing level 1b ATMS, CrIS, CMIS and VIIRS to level 1c and for processing level 1c ATMS+CrIS+CMIS+VIIRS to level 1d ATMS or CrIS. This will require merger of some of the capability developed in the IOP for SSMIS with existing AAPP satellite data re-mapping modules to create superobbed ATMS and CMIS level 1d radiance products or to map ATMS onto the CrIS data grid in an optimal way as part of a CrIS level 1d radiance product. It will also include CrIS specific preprocessing developments (i.e. modifications to IASI preprocessing for CrIS). It is assumed that software provided by US agencies for processing raw HRPT (or equivalent raw satellite data stream) to level 1b can be adapted and redistributed as part of AAPP. However this assumption may have to be revised when more is known about the US code.

The proposal assumes that US agencies would provide users with software for processing direct readout NPP and NPOESS to level 1b (i.e. IPOPP – see below). CIMSS agreed that the assumptions were reasonable. Although there would be no formal restrictions on using and redistributing the IPOPP software, all agreed that it made little sense for AAPP to re-distribute the software and that it would be better for users to get the software from the main CIMSS or NASA web site (i.e. following the model used for the ECMWF BUFR/GRIB software).

Review of IASI OPS-LRS

Philippe presented slides describing OPS-LRS. It was noted that the version of the xerces XML library that is bundled with AAPP is technically obsolete. However it is not feasible to change to a newer version. For some systems the user may prefer to use fft routines specifically optimized

for their platform – rather than the bundled fftw routine. OPS-LRS uses posix sockets to communicate between processes; the Data Server is the only process that uses posix threads.

The de-apodisation method used in atovpp (prior to computing Principal Component scores) is based on Tony Lee's technique and may be more efficient than the method used in OPS. It would be interesting to check how closely "de-apodised" IASI level 1c agrees with IASI level 1b (NA to investigate).

Ray Garcia mentioned the "Atlas" library for linear algebra. May be worth looking at the Atlas SVD function in connection with generating eigenvectors for IASI, since the currently-used NAG library may not be available at the Met Office for much longer (NA to investigate).

Review of navigation
Pascal showed slides describing the navigation issues for METOP, e.g. the use of yaw steering and the SPOT model which is used by METOP admin messages. Terra and Aqua do not use orbital elements; for Terra the satellite position and attitude are transmitted as part of the data stream, while for Aqua the attitude is transmitted. NPP and NPOESS will also transmit their position and attitude, so no propagation model will be needed.

Beta testing for AAPP v6
Eva Borbas has done this in the past for AAPP v5 and she is happy to test the main part of AAPP v6. The beta release should be available in June and we hope to get feedback during July or early August. Others in CIMSS will beta test the OPS-LRS (see below)

IPO issues
We spoke by telephone with John Overton who had just returned from Svalbard. The Norwegians are keen to make use of Terra and Aqua direct readout data, especially for polar winds. John informed us that the report on the future of NPP and NPOESS is due to be presented to the congressional committee on June 5th.

IAPP
Hal Woolf described the IAPP package. IAPP processes data from NOAA15 to NOAA18 (and will support NOAA-N'). It takes the AAPP-format HIRS level 1d files as input, requiring the AMSU-A and HIRS instruments to be present. It does not make use of any mapped AVHRR.

IAPP uses NWP profiles (NCEP GFS 1º grid), generating retrievals of temperature, humidity and ozone.

There is a similar package, ITPP, for use with pre-NOAA-K data (which does incorporate AVHRR).

IAPP is free and open-source. It was originally written for AIX and Solaris, more recently being ported to Linux (in the process of which a number of bugs were discovered).

Extension to support METOP is not currently funded, though it is technically feasible to do so – and discussions suggested that this would be straightforward. Hal agreed to update the RT model to support METOP and to liase with Paul Van Delst regarding filter functions. After the meeting Pascal sent Hal the METOP HIRS and AVHRR filter response functions. Action: CIMSS to investigate the feasibility of extending IAPP to support ATOVS retrieval for METOP.

IASI retrievals
There are no firm plans for producing a software package for IASI retrievals, though no doubt many groups will be doing this on a research basis. CMS plan to generate some IASI retrievals for their forecasters in mid 2007. There is a possibility that CIMSS could put together a science package for IASI; there are no plans for this at present, though similar work is funded for NPP (using CrIS). Jun Li and others from CIMSS could look into this if there is a requirement.

EUMETSAT will of course be making level 2 retrievals within the Core Ground Segment (CGS), for global data.

It is not clear how many users are actually interested in performing retrievals from IASI direct readout data – or indeed how many users will make use of METOP direct readout ATOVS data. It was suggested that the NWP SAF could canvass users to find out their proposed usage of METOP direct readout data, via questions such as:

- Do you plan to receive and process direct readout data from METOP?
- What instruments do you plan to process (out of AMSU-A, MHS, HIRS, AVHRR and IASI)
- If you intend to process IASI, do you intend to make retrievals (e.g. temperature, humidity, trace gases (O_3, $C0_2$), cloud products)? If so would you be interested in a software retrieval package if one were available?

It was agreed that Nigel would consult with Bryan Conway with a view to canvassing members of the ITWG and AAPP mailing lists. Action – Nigel

IMAPP
Kathy and Liam described the level 1 and level 2 processing packages for Terra and Aqua.

For conversion of raw telemetry to level 0 a package called RTSTPS is used, provided by NASA. The data are in CCSDS packets. There are currently about 150 stations capable of receiving the X band data.

For level 1 processing there have been historically three packages:

1. IMAPP MODIS level 1 package by CIMSS
2. DAAC software from NASA Goddard
3. SeaDAS software from NASA Goddard

About a year ago these sensibly converged to just one package, based on SeaDAS. The main platforms supported are Linux, Solaris and OSX (Apple), with limited support for IRIX.

The components of the level 1 package are:

- MODIS L1, provided by GSFC, source available
- AIRS L1, provided by UW (developed by JPL), no source
- AMSR-E L1, provided by UW (developed by RSS), no source

All are free of charge. External libraries are used for HDF, HDF-EOS and SDPTK.

The level 2 science software was developed by UW. It comprises several separate packages.

Features of the MODIS cloud mask package are:

- Supported on linux, Sun, IRIX, AIX and HP

- Output – flat binary files, ENVI format. There is some IDL code to convert products to HDF if required
- All required ancillary data are on a common ftp site
- Source code is available, though users download binaries by default
- Mostly FORTRAN77 (g77), with some F90 (pgf90)

Plans for IPOPP
The International Polar Orbiter Processing Package will be a collaboration between IPO, NASA Goddard, UW and users.

NPP is expected to be launched in 2009. The direct broadcast will not be encrypted. NPOESS could be encrypted, with software keys provided. Note that for continuity Aqua will be extended at least to 2010.

Level 1 processing will be based on the NISGS (NPP In-Situ Ground System) developed by Patrick Coronado's group at NASA Goddard. It is based on software developed by Northrop Grumman (subcontracted to Raytheon) for use in processing global data, and adapted by NASA for direct readout use. UW will work with NASA to evaluate the software. Level 1 products include Raw Data Records (RDR = level 1a) and Sensor Data Records (SDR = level 1b).

Level 2 processing would be partly based on NISGS software and partly developed from scratch by UW. Products include Environmental Data Records (EDR) and additional products.

Products will be in the HDF5 format. The platforms supported will be Linux, Solaris and OSX (n.b. not AIX or IRIX). Clusters are seen as a potential platform, though not a requirement.

A single web site (either UW or NASA) will be used for distribution of the software. Ancillary data would be either on an ftp site or transmitted from the spacecraft. The software would be free to users. It is likely that binaries would be distributed but it is our understanding that all source code would be available (CIMSS to confirm).

The software will be available to users at the time of NPP launch. However UW proposed that it could be released to the NWP SAF for beta testing ~1 year before public release. This will be beneficial to both parties. We should include this activity in NWP SAF work plans.

CIMSS are also starting to thing about multi-mission science retrieval software, with a view to processing different instruments with the same algorithms. This will apply to GOES also, and will be used in generating climate records. Time frame for this is soon after the first NPOESS.

The SeaDAS Ocean Color software is seen as a good role model for this sort of development.

Plans for use of METOP data at CIMSS
CIMSS plan to procure an additional X/L-band receiver system which can be used to receive direct broadcast from the METOP and FY series satellites. The current system could receive METOP but there would be overpass conflicts with Terra and Aqua, so a second system is required.

CIMSS would use the data partly as a risk-reduction exercise for algorithm development for NPP, NPOESS and GOES-R, with IASI being used to simulate CrIS. CIMSS are part of the team that has been contracted to deliver processing algorithms and proxy datasets for GOES-R.

GOES-R will include

- Advanced Baseline Imager (ABI), 1-2km resolution, 16 channels
- Hyperspectral Environmental Suite (HES), either a grating or Fourier Transform spectrometer, 8km resolution (i.e. smaller than IASI and more densely sampled), probably not so many channels as IASI.

Cloud clearing algorithms and a fast model should be ready for testing with METOP data around the end of 2006.

NPP Global Data

NPP global data will be collected at Svalbard, the data being owned by IPO. Central processing would be done by Northrop Grumman in Colorado. The NASA NPP science team (Product Evaluation and Algorithm Test Element – PEATE) may have additional access to data.

For NPOESS, global data will be archived on the NOAA CLASS system. There is no formal commitment for this to happen with NPP data; however we were informed by NASA that global data products (SDRs and EDRs) will be stored on CLASS, though the latency would be quite high – perhaps as much as a 1 day. It is not yet clear what the granularity of the data would be on CLASS – granules could be as short as 30 seconds or as long as 1 orbit. Also channels could in principle be separated.

For operational applications, e.g. NWP use, we consulted Walter Woolf by phone. Walter told us that NPP global data will be distributed to registered users through the Data Distribution Server belonging to OSDPD (www.osdpd.noaa.gov). This includes products from the IDPS, tailored products and NOAA unique products. Radiance data would be formatted in BUFR, similar to AIRS. NOAA are considering giving NPP the status of an operational system. We do not know what the time delay will be for processing within the DDS; we assume this will be similar to the current AIRS distribution service but this should be confirmed (action – US-Europe data exchange meeting representatives)

Relationship between NPP global processing and IPOPP

Three different versions of the NPP software either exist or will exist:

- Science code, written in C
- Operations version for the global processor, written in C++ (converted from the science code by Northrop Grumman). It will use some proprietary tools. Optimised; standard formats; all data held in memory while processing; etc.
- Direct readout IPOPP version from NASA/CIMSS, based on the Operations code and packaged for local implementation. Avoid proprietary tools.

The NASA NPP Science Team is currently evaluating the operations code and products; it has not yet been examined in detail by CIMSS.

Parallels with NWP SAF

There are several parallels with the development of IASI OPS, which also has 3 versions – science code (f90), operational code (C/C++) and direct readout version based on the operational code. We warned CIMSS that this process did not work well for IASI:

- The operations code had many features that were specific to the EPS Core Ground Segment

- The operations code was far more complicated that necessary, the contractor having attempted to re-use code originally developed for other applications
- The amount of work needed to create OPS-LRS was far greater than originally envisaged
- It has been very difficult for the SAF to get answers to even simple questions (the questions have to go up and down management chains)
- The final product is not easy for the user to run

By involving CIMSS and NASA Direct Readout Laboratory at a relatively early stage in the process it is hoped that the development process for IPOPP will be smoother than for IASI OPS. However CIMSS are warned that the industrial code may not be easy to work with.

For ATOVS processing we explained the relationship between AAPP and the Core Ground Segment. The specification for the CGS was based on the AAPP *documentation*; it was not based on the AAPP code. As far as we are aware there is no contractual requirement for the CGS to deliver identical results to AAPP, though the expectation is that the science content will be similar. We will find out after the launch of METOP whether the global and local data are as consistent as they should be.

CIMSS were also interested in the procedures we use to maintain products such as AAPP. Action: Nigel to send Allen the NWP SAF document "Development Procedures for Software Deliverables" (assuming Bryan and Dick are happy with this).

Installation of AAPP v6 and OPS-LRS
We took the opportunity to install AAPP and OPS-LRS on machines at CIMSS.

Both packages were installed on the "redback" system which has the spec: 64-bit, 4-CPU, "Rocks" linux (derived from Redhat Enterprise), Sun Fire V40, AMD Opteron. The g77 compiler was used, with gcc 3.2.3.

Notes from tests with core AAPP v6:

- In ksh one can source ATOVS_ENV directly, but not in other shells (maybe bash?).
- We ran the hirscl test case provided by Philippe (starting from L0). Needed to provide the satpos file. Needed to "touch" a clock error file (though it is not used for METOP). It then ran OK.
- The test cases need some further work.

Liam was interested in our PV-Wave routines to read and display ATOVS data. Action: Nigel to send them.

The OPS-LRS compiled OK but did not run. It failed without producing any warning or error message. Unfortunately this is typical of the OPS-LRS, and such problems are very hard to diagnose. Philippe eventually identified the internal call that was causing the problem and found a work-around. However he would like to investigate further. Liam arranged for him to have remote access to "redback" from CMS in order to pursue this.

We also installed AAPP v6 on an Apple OSX system. We had to edit Makefile.ARCH to change the name of the c compiler (change gcc to cc). We also needed to run "ranlib" on all libraries. The system then built OK and we ran the NOAA-16 test case successfully (using data from the AAPP v5 CDROM). Action: Nigel to add OSX to the list of supported platforms in the AAPP documentation. We do not yet know whether OPS-LRS will run on OSX.

Access to information on NPP

Liam has a copy of the Data Format Control Book for NPP, giving the specification of the various SDRs and EDRs. We asked if we could have a copy. The following reply was received from John Overton (IPO): "No it can not be released. It has not been reviewed for ITAR release yet". A similar reply was received from Robert Schweiss (NASA). Several times we have been promised that this document will be available "soon" (at Direct Readout meetings in 2004 and 2005 and at ITSC-15 in 2005). To our knowledge this is the only detailed source of information on the data content of the RDRs. *Lack of such information is therefore a significant risk for the development of AAPP v7.* Action may be needed at higher levels of management.

As far as detailed information on instrumentation is concerned, this may be more promising. After the meeting Allen sent Nigel papers describing the scan geometry and navigation for VIIRS. Other documents are available at the IPO Information Center http://eic.ipo.noaa.gov/

The subcontractors for the NPP instruments of interest to the NWP SAF are:

- CrIS: Northrop Grumman → ITT → BOMEM (for FTS part)
- CMIS: Boeing
- VIIRS: Raytheon
- ATMS: Northrop Grumman

Fuzhong Weng would be a good person to ask if we need more on ATMS. Questions can be passed through Liam and Allen.

The NWP SAF is keen to receive sample data files when these are available.

Conclusions on requirements for AAPP v7 and v8

We conclude that the basic requirements that would allow extension of AAPP to support NPP and NPOESS are met, i.e.

- US agencies will provide a software tool (IPOPP) to allow processing of NPP and NPOESS direct readout data to the equivalent of level 1b or 1c
- US agencies will make available global data for NPP and NPOESS
- AAPP will be able to accept the data for ATMS, CrIS, VIIRS and (eventually) CMIS, performing the pre-processing that is required for NWP applications.

It is likely that the interface with AAPP will be at the RDR level (similar to 1b). Thus AAPP will need to be able to accept both:

- HDF5 files from IPOPP, and
- BUFR files from global data

The AAPP developers will determine whether to read these formats directly from within AAPP or whether to implement conversion tools, e.g. HDF5 to internal format, BUFR to internal format (as is done in v6 for ATOVS) or HDF5 to BUFR.

More information on data formats is needed before coding can start.

Visualisation tools
Tom Whittaker gave a demonstration of the IDV software for visualization. This is supplied by Unidata and was developed about 2 years ago for visualizing weather data. It is based on a heritage of Gempak (primarily for gridded data) and McIdas (primarily for satellite imagery). It is available free of charge.

Gempak and McIdas were written in Fortran and C, however IDV is based on Java – so is platform-independent.

Other widely-used packages include Vis5d (based on Fortran/C) and VisAd (based on Java). Both developed by Bill Hibbard.

IDV accepts input in V5d format, GRIB and plain ASCII – not BUFR since there is no Java reader for BUFR.

There is also an IDV scripting language based on XML; you can develop your applications using the GUI then export them as a script.

Tom Rink then gave a demonstration of Hydra. This is produced by SSEC and is available at www.ssec.wisc.edu/hydra . Hydra is based on Python: Python is slower than Java but is easier to customize. Hydra is ideally suited to the display of multispectral data. Paul Menzel is very keen on the use of Hydra in conjunction with AIRS data as a teaching aid.

These tools may well be useful to the Met Office, CMS or even AAPP users if we can find a way to get them to display ATOVS or IASI data. This is something the NWP SAF could investigate further.

Concluding Remarks
The NWP SAF thanks the CIMSS for hosting this meeting. It was a valuable exchange of information and ideas. We should continue to keep in touch; the next opportunity for face-to-face discussions will probably be at ITSC-15 in October.

Appendix

Pascal, Philippe and Nigel took the opportunity to discuss what still needs to be done for the preparation of AAPP v6. This is summarized below.

Data:

- cloud mask parameters for METOP have been generated by Lydie
- subroutine for SST needs update for METOP
- IASI configuration files will probably be made available via the EUMETSAT User Service. This normally uses ftp push, which can be problematic. Scripts to retrieve the files will eventually be provided, but users should be informed that this will not be implemented in the initial release.

Scripts:

- satpos scripts should be standardized to send output to standard output rather than log file
- Clock error is not needed for METOP

- Avoid necessity of running “ranlib” by hand. Probably the “ar –s” option will achieve this
- Need UTC initial file and a script to periodically retrieve the UTC definition from IERS web site
- Philippe will provide scripts for running the OPS-LRS. The script will work on both test data and real METOP data, in granule mode or dump mode.

Test cases:

- CMS will assemble a test case from level 0, including admin data
- using METOP-4 for beta version
- and an updated test case with METOP-2 for final release
- Nigel will supply a test case based on EUMETSAT BUFR data
- Re-use the existing NOAA-18 and/or NOAA-16 test case, so that users can compare results of AAPP v5 with v6

Documentation:

- Tiphaine has received several updates will work on the documents over the next 2 weeks, assisted by Pascal as necessary
- Philippe has used Graphviz to prepare flow diagrams for the software document. This is free software but you have to write a script to extract the required information from the source code
- The Spot model is described in a GMV document – Pascal will check this
- The IASI 1c and 1d formats need to be added to the data formats document (Tiphaine to extract from iasi1c.h and iasi1d.h, or Nigel can help if needed)
- Nigel will update the Overview document and Installation Guide

We aim to issue the official beta release (which will be v6.01) in June.