The EUMETSAT Satellite Applications Facility for NWP (NWP SAF)

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Outline

- Background / Mission / People

- Projects:
  - AAPP
  - RTTOV
  - 1D-Var
  - Quickscat Data Processor/ SDP
  - Monitoring reports
  - SSMIS_Preprocessor
  - Support to EARS

- Conclusions
Other SAFs include: ocean & sea ice, climate, ozone and Gras
NWPSAF delivers software modules for use in DA systems (other SAF’s develop products)
Phases include:
  - 3 year initial operational phase (2003 -2006)
  - continuous dev and operations phase (2007 - )
Management: Steering group
Software development under quality systems (dedicated QA/QC at local level, review process)
Visiting scientists (to accelerate the development of deliverables / training 1 day -2 years)
The NWP SAF: background

- Satellite Applications Facility for Numerical Weather Prediction (NWP SAF)
  - one of 8 SAFs that form part of the distributed ground segment of EUMETSAT

- Led by the Met Office, in partnership with ECMWF, KNMI and Météo-France

- 75%-funded by EUMETSAT
MISSION

• To improve and support the interface between satellite data/products and European activities in global and regional NWP
The NWP SAF: people

• **Manager:** B.Conway

• **Project Team:**
  - **ECMWF:** T.McNally, P.Bauer, A.Collard, A.Garcia-Mendez, H.Hersbach, G.Kelly, J.-N.Thépaut, G.Van der Grijn
  - **Météo-France:** P.Brunel, T.Labrot, L.Lavanant, P.Marguinaud, A.Marsouin
  - **KNMI:** A.Stoffelen, A.Verhoef, J.Vogelezang

• **Steering Group:** J.Eyre, L.Sarlo, S.Elliott, J.Onvlee, P.Pylkko, F.Rabier, P.Schluessel, A.Simmons

• **Visiting scientists:** Many!
The NWP SAF: products

At present:

- **AAPP** - ATOVS and AVHRR Pre-processing Package
- **RTTOV** - fast radiative transfer model
  - + model-based profile data sets
- **1D-Var** retrieval schemes
- **QDP** - Quikscat Data Processor
- **Monitoring reports**
- **SSMIS pre-processor**

Under development:

- **Updates** to the above
- **SDP** - Scatterometer Data Processor
The NWP SAF: AAPP

Data Coverage: ATOVS (21/7/2005, 6 UTC, qs06)
Total number of observations assimilated: 16050

5841 NOAA-15 ATOVS, Min: 206, Max: 206, Mean: 206
8532 NOAA-16 ATOVS, Min: 207, Max: 207, Mean: 207
1677 EOS-2 AQUA ATOVS, Min: 784, Max: 784, Mean: 784
The ATOVS and AVHRR Pre-processing Package

• Performs **INGEST** and **PRE-PROCESSING** of ATOVS and AVHRR data
  • **ATOVS** = AMSU-A + HIRS + AMSU-B/MHS

• **INGEST**
  • Decommutation
  • Navigation
  • Calibration

• **PRE-PROCESSING**
  • Precipitation and cloud detection for microwave instruments
  • Mapping to common grid (e.g. HIRS fields of view)
  • Cloud analysis on AVHRR pixels within each HIRS fov
AAPP versions 1 to 5

HRPT
(NOAA satellites)

S-band

AAPP

NESDIS
Global ATOVS

EUMETCast
Regional ATOVS
(EARS)

ATOVS 1a/b

AVHRR 1a/b

ATOVS 1c

ATOVS 1d

1a = counts
1b = counts + calibration + geolocation
1c = radiances
1d = radiances mapped to common grid e.g. HIRS
AAPP version 6 – including METOP

EUMETCast Global ATOVS + EARS

or GTN

BUFR decode

ATOVS + AVHRR

ATOVS 1a/b

Existing AAPP

ATOVS 1c

ATOVS 1d

IASI Pre-processor

METOP AHRPT (CCSDS packets)

X-band

EUMETCast Global IASI

BUFR decode

IASI ‘level 0’ + AVHRR

OPS

NB: IASI 1c = calibrated, corrected & Gaussian apodised

User options (flexible):
• AMSU mapped to IASI
• Spatial thinning
• Reduced channel set and/or
• Eigenvector scores
RTTOV
RTTOV - a fast radiative transfer model

- It is used by NWP centres for several applications (e.g. radiance assimilation, data monitoring, simulated imagery)
- The NWP SAF maintains and distributes recent versions of RTTOV (currently versions 7 & 8)
- The latest version, RTTOV v8, was released in November 2004
- The next version, RTTOV v9, is now under development and will be released in Feb 2007
RTTOV functionality

- **Input profiles**: temperature and water vapour; optionally, ozone and carbon dioxide also as variable gases
- **Computes** top-of-atmosphere radiances, brightness temperatures and layer-to-space transmittances for each channel
- **Comprises**: forward, tangent linear, adjoint and K (Jacobian matrix) models, for use in variational assimilation or retrievals
- **Sea-surface emissivity**: computed internally (ISEM-6 model for IR, FASTEM for MW) or value provided by user
- **Clouds**:
  - Single-layer, spectrally-invariant
  - Multi-layer, spectrally-varying: using “wrapper” code, RTTOV_CLD
  - Microwave, with scattering: using “wrapper” code, RTTOV_SCATT
- **Fortran-90**
- Run under **unix or linux**; tested on range of platforms
- **Run-time**: ~ 0.5 ms for 20 HIRS channels for 1 profile on HP workstation
### RTTOV – sensors supported

<table>
<thead>
<tr>
<th>Platforms</th>
<th>Sensor</th>
<th>Channels simulated</th>
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<tbody>
<tr>
<td>NOAA-6-18</td>
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<tr>
<td>NOAA-2-5</td>
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<td>DMSP F-8-15</td>
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<td>GOES-8-12</td>
<td>Imager, Sounder</td>
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<tr>
<td>ERS-1/2</td>
<td>ATSR, AATSR</td>
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<td>GMS-5, MTSAT</td>
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<td>Terra Aqua</td>
<td>MODIS, AIRS, AMSU-A, HSB, AMSR</td>
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<td>TRMM</td>
<td>TMI</td>
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<td>Coriolis</td>
<td>WindSat</td>
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<tr>
<td>FY-1, FY-2</td>
<td>MVISR, VISSR</td>
<td>1-3, 1-2</td>
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RTTOV-85/87 status

- Number of licence requests = 187
- Number of users provided code ~ 180
- Number of bugs reported since release = 10 for 85 corrected in 87 and 6 for 87 all minor
- Efficient vectorisation of code still being worked on for NEC supercomputer
- Rewritten RTTOV_SCATT code for RTTOV-87
- Participated in AIRS RT comparison (see separate talk)
New coefficient files available

- **METOP** n.b. satellite id=2
  - IASI available for RTTOV-7 and 8
  - HIRS available
  - AMSU-A/MHS available
  - AVHRR available

- **MSG-2 SEVIRI** available

- **GOES-12 sounder** available

- **MegaTropiques, Saphir and Madras**
RTTOV-9 developments

What is included?

- New diverse profile dataset – inclusion of more minor gases, more levels
- Inclusion of multiple scattering for cloudy and aerosol radiance calculations
- Linear in tau mean path values
- Zenith angle dependence of path
- Include reflected solar for SWIR
- More active trace gases CO, CH₄, N₂O,
- Further optimisation of predictors
- Improvements to RTTOV_SCATT (new Mie tables)
- Change interface to allow profile input on user levels
- Change interface to avoid need to specify polarisation index
1D-VAR
One-dimensional variational retrieval – 1D-Var

Used for:

• Retrieval of atmospheric/surface variables from radiance measurements

• NWP data assimilation – pre-processing and quality control

• Research tool – rapid exploration of new data
Minimize:

\[ J(x) = \frac{1}{2} (x-x^b)^T B^{-1} (x-x^b) + \frac{1}{2} (y^o-H[x])^T (E+F)^{-1} (y^o-H[x]) \]

where \( x \) contains the NWP model state
\( x^b \) is background estimate of \( x \) (short-range forecast)
\( B \) is its error covariance,
\( y^o \) is vector of measurements
\( H[...] \) is “observation operator” or “forward model”,
    mapping state \( x \) into “measurement space”
\( E \) is error covariance of measurements,
\( F \) is error covariance of forward model.

\[ \nabla_x J(x)^T = B^{-1} (x-x^b) - \nabla_x H[x]^T (E+F)^{-1} (y^o-H[x]) = 0 \]
1D-Var: simulated IASI retrieval errors

- Background error
- Retrieval errors
- Bias
- SD

973 simulated retrievals
1000 IASI channels
Mid-latitude winter profile
3 schemes are available:

• “ECMWF”
  - generic harness – minimisation scheme with “hooks”

• “Met Office”
  - complete scheme - ATOVS, AIRS, IASI

• “SSMIS”
  - complete scheme - SSMI, SSMIS, AMSU
The NWP SAF: Scatterometer processors

QDP / SDP
The NWP SAF: Scatterometer processors

• **QDP** - Quikscat Data Processor – *available NOW*
  - Input – NOAA Quikscat product in BUFR
  - Pre-processing – sorting and spatial averaging
  - Wind retrieval
  - QC – rain detection, etc
  - Ambiguity removal
  - Monitoring and output

• **SDP** – Scatterometer Data Processor - *SOON*
  - Generic scatterometer code
  - ERS SCAT, METOP ASCAT, Seawinds (Quikscat, NSCAT)
Scatterometer Data Processor

INPUT

Ocean Surface Radar Backscatter Observations

Pre-Process

Inversion

Quality Control

Ambiguity Removal

Quality Monitor

OUTPUT

Wind Field
NOAA SDP @ 25 km

improved cold front
better around rain

50 km Plots!
Monitoring reports
The NWP SAF: monitoring products

• Observation coverage plots
• Statistics of observed-forecast differences

• Data types:
  • ATOVS, SSMI, AIRS, geo-radiiances
  • AMVs
  • Quikscat, ERS-2
  • Ozone: SBUV, Envisat
The NWP SAF: monitoring products

Example:

AMVs v. 6h forecast

Met Office

ECMWF
The NWP SAF: monitoring products

Example:
AMVs v. 6h forecast
Met Office
The NWP SAF: monitoring products

Example:

MSG 6.3µm water vapour channel

ECMWF
The NWP SAF: monitoring products

Example of link to another monitoring site:

KNMI Quikscat monitoring
Main functions:

- Remapping
- Averaging
- Reflector emission correction
- Solar intrusion flagging

Code & preprocessed data available
SSMIS Preprocessor: Averaging

• NEΔΤ for LAS channels is ~0.3K
  ⇒ require averaging to achieve NEΔΤ_{eff} = 0.1K

• Also benefit from improved scale matching?

- Operational preprocessor uses σ = 50km (FWHM = 118km)
- NEΔΤ_{eff} ~ 0.03K
- Processing time ~ 1 minute/orbit
SSMIS preprocessor: flagging and correction residual biases

The diagram illustrates the comparison between observed and background temperatures (O - B) normalized by Kelvin (K) over a 3-hour period from 9:00 PM to 3:00 AM. The top plot shows the normalized gain and intensity flag, with circles indicating significant deviations. The bottom plot depicts the uncorrected reflector temperature (K) with red circles highlighting areas of interest.
SSMIS preprocessor: flagging and correction residual biases

SSMIS Channel 4 (54.4GHz) O-B/K
QU00 15 8 2006
Support to EARS
NWP SAF support to the EUMETSAT ATOVS Retransmission Service (EARS):

- Development and maintenance of AAPP

- Real-time data monitoring:
  - for each EARS reception site
  - checks consistency with global ATOVS data
  - checks consistency with locally-received ATOVS data (Lannion)
The NWP SAF: support to EARS

Conclusions
• Collaboration between 4 European NWP centres, with support from EUMETSAT, has permitted the development, delivery and support of:
  • software modules for satellite data processing and assimilation,
  • data monitoring services,

to a large and growing user community.

• Over the next few years, the NWP SAF plans to contribute to the exploitation of data from new instruments.

• Collaboration with the international community will be needed to ensure we cover all the new instruments, in a timely manner, without unnecessary duplication.
• For information, visit:

http://www.metoffice.gov.uk/research/interproj/nwpsaf/index.html

• To obtain software, visit:

http://www.metoffice.gov.uk/research/interproj/nwpsaf/request_forms/index.html
End
Supplementary slides
AAPP - Recent updates

Updates to AAPP v4.0

**Update 4.4, 31/8/04:**
- Linux compatibility (also Windows via MS Services For Unix)
- Improved robustness in decommutation
- Utility to compare output files from different platforms (*atovsCompare*)
- Big/little-endian conversions
- Processing of **NOAA-17** to level 1d
- 1d flag for fewer collocations than expected in re-mapping AMSU-A to HIRS

**Update 4.5, 03/02/05:**
- Updated AMSU-B calibration parameters file (gross limits)
- Includes the following enhancements:
  - NOAA-N capability (including MHS)
  - New HIRS calibration method (based on NOAA v4)
  - Updated navigation – ability to use 2-line elements
  - Calibration - allow for moon contamination in AMSU-B/MHS
  - Precipitation tests - added NWC-SAF scattering index (Bennartz) to AMSU-B level 1d
  - Use of instrument-specific scan characteristics, and removal of many hard-coded parameters

- Released to users on 18 July 2005, following validation with NOAA-18 data (~2 months after launch)
The NWP SAF: 1D-Var schemes

Assimilating observations into a NWP model

OR

Retrieving atmospheric variables using a forecast profile as background (first guess)
The NWP SAF: monitoring EARS v global radiances

Example: ATOVS - Tromso