Current use of satellite data in the Met Office Global NWP model

Brett Candy

Nigel Atkinson, William Bell, Carlo Buontempo, James Cameron, Paul Earnshaw, Stephen English, Fiona Hilton, Mike Thurlow and David Walters

ITSC15
Outline

- Overview of our assimilation/forecast system
- Major changes to satellite data assimilation since ITSC-14
  - Main focus on microwave data. Advanced IR sounders follows this talk.
  - NAE improvements covered in a poster B03
- Planned improvements for the coming year
Our Assimilation/Forecast System

- The global model is non-hydrostatic, with a finite difference lat-long grid, resolution N320 (~40km), with 50 levels (hybrid in height) and model top at 60km.

- The operational suite contains 4 update assimilation cycles for 6-hour data windows, with 2 main 6-day forecasts run daily from 00Z and 12Z.

- Assimilation algorithm: 4D-Var. Inner loops contain linear Perturbation Forecast (PF) model.

- **Timeliness is critical**: the main forecasts have a data cut-off at T+2 hours; and T+7 hours for update runs.
Motivation for changes

I. Take advantage of developments in space hardware to obtain new measurements of the atmosphere.

II. Increase redundancy in system by introducing similar instruments to those already providing forecast impact.

III. Use existing observations in ‘difficult’ areas by improving the forward modelling and or taking advantage of developments in remote sensing science.

….with the constraint that the system must run within a certain time.
## Summary of Satellite Data Usage

<table>
<thead>
<tr>
<th></th>
<th>Last Conference</th>
<th>This Conference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ATOVS</strong></td>
<td>NOAA-15 AMSU (4-10,18,20)</td>
<td>NOAA-15 AMSU (4-5,7-10,12,13,18)</td>
</tr>
<tr>
<td></td>
<td>NOAA-16 AMSU (4-8,10,18-20)</td>
<td>NOAA-16 AMSU (4-8,10-14,18-20)</td>
</tr>
<tr>
<td></td>
<td>EOS Aqua AMSU (4-6,8-10)</td>
<td>NOAA-18 AMSU (4-14,18-20)</td>
</tr>
<tr>
<td><strong>AIRS</strong></td>
<td>EOS Aqua Central field (50 channels)</td>
<td>EOS Aqua Warmest field (50 channels)</td>
</tr>
<tr>
<td><strong>SSM/I</strong></td>
<td>F13 &amp; F15 windspeeds</td>
<td>F13 only</td>
</tr>
<tr>
<td><strong>Scatterometer</strong></td>
<td>QuikScat ambiguous winds</td>
<td>QuikScat ambiguous winds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ERS-2 (North Atlantic only)</td>
</tr>
<tr>
<td><strong>AMVs</strong></td>
<td>Meteosat-5,7 GOES-9,10,12, MODIS</td>
<td>Meteosat-5,8 GOES-11,12 MTSAT, MODIS</td>
</tr>
<tr>
<td><strong>SSMIS</strong></td>
<td></td>
<td>F16 (2-7,23)</td>
</tr>
<tr>
<td><strong>GPS Radio Occultation</strong></td>
<td></td>
<td>CHAMP/GRACE refractivity profiles</td>
</tr>
</tbody>
</table>
Forecast Improvements since ITSC-14

Cumulative Impact of NWP

- Total Impact
- Satellite Impact

GOES-BUFR, NOAA-18, Scat bias correction
50 Levels, AIRS WF, ERS-2, Met-8
GPS RO, SSMIS
NOAA-18 Introduction
Introduce NOAA-18 AMSU-A, MHS and remove Aqua AMSU-A.

Data received via local antenna allowed us to get a head start. Fed results back to the NOAA-18 project team at NESDIS.

First use of generic radiance pre-processing code ‘SatRad’ which performs QC, channel selection and 1D-Var for a range of instruments (both operational and research).

- Operational: ATOVS (AMSU-A, B, HIRS), SSMIS
- Development: SSM/I, IASI, Geostationary radiances,…
NOAA-18 Impact

PMSL improved globally

- Mid tropospheric humidity also improved by up to 4%
- NOAA-18 into operations with four months from first local data overpass
Raising the model top and introducing
AMSUA 12-14
50 Level model

- Removes need for separate stratosphere model
- Main level increase in stratosphere
- Better dynamical coupling between stratosphere/troposphere
- Better use of AMSU-A channels, including introduction of 12-14.
Analysis Diagnostics

NOAA-16 ATOVS channel 10

Better Ob-Background fit

Improved Ob-Analysis fit

Sonde Temperatures

Improvements above ~100hPa

OPS: obs model background

sctxd sctxg
Forecast Verification

VERIFICATION VS OBSERVATIONS

OVERALL CHANGE IN NWP INDEX = 0.992

OVERALL PERCENTAGE CHANGE IN RMSE = -20.040

PERCENTAGE CHANGE IN RMSE

PMSL T+24 PMSL T+48 PMSL T+72 PMSL T+96 PMSL T+120 H500 T+24 H500 T+48 H500 T+72 W250 T+24 W250 T+48 W250 T+72 PMSL T+24 PMSL T+48 PMSL T+72 PMSL T+96 PMSL T+120 H500 T+24 H500 T+48 H500 T+72 W250 T+24 W250 T+48 W250 T+72

NHSM TROP SHEM

Better

Worse
VERIFICATION VS OBSERVATIONS

Overall percentage change in RMSE = -1.400

50 hPa fields
Introduction of GPS RO & SSMIS
• Initially concentrate on AMSU-A equivalent channels 2-7,23
• Considerable work on instrument biases see A12 Poster by Swadley
• Preprocessing to regrid instruments and perform spatial averaging
• Channel selection for assimilation based on ATOVS methods e.g. Rain flagging using 91/183 GHz scattering
Research trials using refractivity profiles from the CHAMP mission showed forecast improvements to temperature fields in upper tropopause *Healy et al.*, *GRL* 2005

Data is now available in real time ~40 profiles per six hour cycle. Also using occultations from GRACE mission

COSMIC (and then GRAS on METOP) will increase the amount of data
RO & SSMIS Package Performance

- Shows modest improvement in PMSL forecasts in SH and NH
- 33 days verification
- Switched to operations 26th September
What’s Next

- Analysis of cloud using AMSU-A window channels and use of sounding channels in the presence of cloud (see poster A3 English et al.)

- Introduce METOP ATOVS into system & RARS

- Reintroduce HIRS (N17 HIRS is showing humidity benefits)

- Take advantage of the imaging channels on SSMIS and assess F17 (launch date Nov)
Usefulness of EARS retransmission

External company outage of Comms link ~12 hours

Data Coverage: SatRad ATOVS (29/9/2006, 6 UTC, qg06)
Total number of observations assimilated: 1858

1307 NOAA-15, Min: 206, Max: 206, Mean: 206
551 NOAA-16, Min: 207, Max: 207, Mean: 207

© Crown copyright 2006
Conclusions

- Introduced three two new sounding satellites SSMIS F16 & NOAA-18 to the operational system with resulting improvements to forecast accuracy.

- Robustness and timeliness still important

- For the first time we have exploited GPS data operationally at the Met Office

- Future upgrades will seek to use more sounding data in difficult regimes
Additional Slides
Increase of Local Data

Control

Exp

![Map showing localized data increase]

### Improvement in PMSL Forecast

<table>
<thead>
<tr>
<th>Forecast Time (hrs)</th>
<th>Surface Obs</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>48</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>72</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>96</td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>120</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>144</td>
<td>1.7</td>
<td>1.4</td>
</tr>
</tbody>
</table>
Initial Results NOAA17 (4x ATOVS)

- Neutral on index
- Sufficient time left over to process 5 ATOVS
- Humidity impacts.....
MO 4DVar N320 trials: winter 2005/06

- Modest, but consistent, reduction in SH PMSL (~1%)

- Subsequent summer 2006 ‘package’ (SSMIS+GPSRO) trial more mixed
Averaging

- NEΔT for LAS channels is \(~0.3\)K
  \(\Rightarrow\) require averaging to achieve
  \(\text{NEΔT}_{\text{eff}} = 0.1\)K

- Also benefit from improved scale matching?

- Operational preprocessor uses
  \(\sigma = 50\)km (FWHM = 118km)

- \(\text{NEΔT}_{\text{eff}} \sim 0.03\)K

- Processing time \(~1\) minute/ orbit

© Crown copyright 2006
Background: Accuracy Requirements and Initial Performance

SQRT (HBHT) / K

Q SOUNDING

T SOUNDING

CHANNEL

SSMIS Channel 1 O - B
\[ \sigma = 5.718 \]

SSMIS Channel 2 O - B
\[ \sigma = 1.543 \]

SSMIS Channel 3 O - B
\[ \sigma = 0.7245 \]

SSMIS Channel 4 O - B
\[ \sigma = 0.5074 \]

SSMIS Channel 5 O - B
\[ \sigma = 0.6115 \]

SSMIS Channel 6 O - B
\[ \sigma = 0.6872 \]

SSMIS Channel 7 O - B
\[ \sigma = 0.99 \]

SSMIS Channel 24 O - B
\[ \sigma = 1.637 \]

O - B / K

© Crown copyright 2006