Operational implementation of AIRS and SSM/I assimilation at MSC

Data Assimilation and Satellite Meteorology Division

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Contents of planned implementation

Context: New NWP model configuration (to become OPE in Nov. 2006):
800 X 600 (~35 km), 58 levels, top 10 hPa

- 100 AIRS channels
- 7 SSM/I channels
- Added extreme scans for AMSU-A-B
- Quickscat (from KNMI)
- RTTOV-8 (major change to code structure)
- New vertical interpolator (from NWP to RTTOV coordinate)
- Revised background and observation errors
- Automated radiance bias correction (ATOVS, AIRS, SSM/I, GOES)
- Added levels for RAOBS, added AIREPS, SATWIND from GOES 3.9 µm
- GPS RO (CHAMP, COSMIC) possible
Assimilation cycles strategy

• Need of 2-month assimilation cycles for winter and summer periods + forecasts up to 5 days

Strategy:

• 3Dvar FGAT (first guess interpolated at time of observation), 1 month for each component (turn around: ~2-3 days per day)
• 1 month 4D-var (turn around ~1 day per day) for major components
• Incremental adding of components (partial packages of several elements)
• Full 2 month 4Dvar on combined package only

Planned parallel run at CMC: mid March 2007
Planned operational: April 2007
New approach for background and observation error determination

• **Observation error statistics**
  – Desroziers method which uses assimilation system and optimality criteria to tune variances
  – used for all obs types (except GOES, Profiler, SatWind ◊ kept as in operational system)
  – results in large reductions for AMSU data, slight increase for radiosonde

• **Background error statistics** (replaces NMC method):
  – system simulation approach applied to lower resolution version of model with 3D-FGAT analysis
  – perfect model assumption (i.e. only obs perturbed) therefore variances underestimated ◊ must be inflated
  – 2 months, 2 perturbed members ◊ total of ~480 realizations of background error (correlations still homogeneous/isotropic)

• **Tuning of background error variances:**
  – Computed cov(O-P) and HBHT (background error) for all obs types
  – Similar to Hollingsworth-Lonnberg approach: compare cov(O-P) with HBHT+R
Background error spatial correlations

- Analysis increment from single zonal wind observation at 500hPa over Atlantic ocean
- New approach gives sharper spatial correlations for all variables
- Sharper vertical correlations for temperature results in smaller background error variance in space of AMSU observations, partly compensates reduction in $\sigma_{\text{obs}}$

![Graph comparing NMC method and System simulation method](image)
Impact of new statistics on fit to AMSU data
(K4H5F1R4(current) vs K4H5STR4 (new) )

Vertical axis: channel number from low to high peaking

O-A AMSU-A World

O-A AMSU-B World

O-P6h AMSU-A World

O-P6h AMSU-B World
Impact of new statistics vs old
**ATOVS: end of scans are no more eliminated**

**AMSU-A: BT (O-P) std vs scan position**

BT (O_P) STD vs scan does not justify elimination of end of scan pixels. For AMSU-A, 6 pixels out of 30 were not used. The 25% increase end up in a ~35% increase in assimilated data because the thinning eliminates less pixels at large angles. Similar increase for AMSU-B.
New vertical interpolator + TL/AD

Problem: Need of an interpolator from N NWP model levels to M RTM (e.g. RTTOV) levels. If N > M, not all input levels participate if only nearest bracketing levels are used. This introduces distortions when mapping back Jacobians from RTM to NWP coordinate.

Solution proposed: Interpolator using all input levels with good TL/AD properties (see Y. Rochon’s talk next Monday).

• Impact most visible near tropopause and above where density of levels differs the most
• Problem went unnoticed because partially masked by vertical correlation of background errors
• Code (forward/TL/AD) to become available on ITSC site
Example of dynamic (within cycle) bias correction

O-P corrected and uncorrected (January 2005)

Drift in NOAA-15 AMSUB-5 bias

If the drift is relatively slow, the system adapts well to that drift
Correction updated every 6-h based on last 15 days
Verifications wrt Analyses CNTL vs EXP

2004121500-2005012612 4D-var

EXP = CNTL + new statistics + added AMSU scans + new interpolator + RTTOV8 + dynamic bias correction

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**Northern Hemisphere CZ 500 hPa**

**Southern Hemisphere CZ 500 hPa**

**Tropics CZ 500 hPa**
Impact on 6-h forecasts

New interpolator vs old

New interpolator+extended AMSU vs CNTL
+ new stats + RTTOV8 + dynamic bias

Tropics, 13 days
3D-FGAT
SSM/I: Imager: 7 channels

<table>
<thead>
<tr>
<th>Channel</th>
<th>Frequency (GHz)</th>
<th>Resolution (km)</th>
<th>Assimilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.35 V</td>
<td>25</td>
<td>Ocean</td>
</tr>
<tr>
<td>2</td>
<td>19.35 H</td>
<td>25</td>
<td>Ocean</td>
</tr>
<tr>
<td>3</td>
<td>22.235 V</td>
<td>25</td>
<td>Ocean</td>
</tr>
<tr>
<td>4</td>
<td>37.0 V</td>
<td>25</td>
<td>Ocean</td>
</tr>
<tr>
<td>5</td>
<td>37.0 H</td>
<td>25</td>
<td>Ocean</td>
</tr>
<tr>
<td>6</td>
<td>85.5 V</td>
<td>12.5</td>
<td>Ocean</td>
</tr>
<tr>
<td>7</td>
<td>85.5 H</td>
<td>12.5</td>
<td>Ocean</td>
</tr>
</tbody>
</table>

Zenith angle = 53°
Apply filters (treat DMSP-13, 14, 15 separately):
1. Remove “stray” scans
2. Remove obs outside $T \pm 3h$ assim. window
3. Remove obs over land/ice/near coast
4. Compute $T_B = f(T_a)$ & remove unphysical $T_B$
5. Remove precip/cloudy obs

Group remaining data from DMSP-13, 14, 15

Background Check:
1. Compute O-P (3D-Var)
2. Apply bias corrections
3. Remove obs with large O-P

Thinning and sorting:
1. Remove overlapping orbits (3D-Var only)
2. Thin data to 200 km resolution

Assimilation-ready SSM/I brightness temperatures ($T_B$)
Impact of SSM/I

7 channels (ocean only)
+ removal of AMSU-A-3
Std of T-Td at 850 hPa

See poster A02, Anselmo et al.
10/27/06
Impact of Quickscat (ocean winds)

NH 120h

SH 120h

~8000 obs per 6h
3D-FGAT 26 days
AIRS processing

- 100 channels considered for assimilation
- Uses warmest pixel within 3X3 array
- CO₂ slicing for cloud height and emissivity
- Land emissivity based on CERES land types + spectral interpolation
- Ocean emissivity from Masuda
- Ozone background from monthly climatology (19 latitudes)
- RTTOV8 (variable CO2 capability)
- Dynamic bias correction based on previous 15 days
- 250 km thinning (~80,000 radiances per 6h, ~3500 locations)

See poster A02, Beaune et al.
Separation of observation and background errors

Total (O-P) std: full line
B: background (P) error std
O: observation error std
Hollingsworth-Lonnberg method:
(O-P) vs pixel separation
AIRS inter-channel obs. error correlation (IOEC)

Highest IOEC found in surface-sensitive channels, notably 4-4.5\(\mu\) and water vapor channels.

Higher amplification of obs. Error is justified in these channels, short of explicitly considering IEOC in AIRS assimilation.
AIRS: temporal series

3D-var, 30 days, in 100 km 28 level system:
AIRS vs NOAIRS
SH 500 hPa Anomaly correlation

Period 14-25 Feb 2004, 100 km res. model

- 4D var larger impact than AIRS up to day 3
- AIRS larger impact than 4D-var for days 4-5
- ~6h predictability gain at day 5
Impact of AIRS on Temperature structure

500 Hpa T difference (AIRS-NOAIRS)

Between the mean analysis over a period of 2 weeks:

- Colder in tropics
- Warmer in SH extra-tropics
Conclusion

- Major upgrade with new data sources (SSM/I, AIRS, Quickscat, possibly GPS RO) + improved error statistics is planned at MSC (spring 2007)
- Modest, but systematically positive impact from most components.
- Largest impact expected from AIRS in SH based on results obtained in previous model configuration. Adaptation to IASI should be relatively straightforward.
- Validation of forecasts in radiance space is a new feature
- Stratospheric version with top at 0.1 hPa planned in 2008 with added data sources.
(O-P) bias using R7 and R8 AIRS coefficients

15.5µm

4.1µm
STD for R7 and R8 coefficients

Calc-Obs std. dev. bande global

15.5 µm  4.1 µm

10/27/06
Difference in STD (R7_coef – R8_coef)

15.5μm  4.1μm
Verifications wrt RAOBS data M4DH05F1 vs K4H5F1R4 2004121500-2005013100

<table>
<thead>
<tr>
<th>Hemisphere</th>
<th>Start Date</th>
<th>End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nord</td>
<td>2004121500</td>
<td>2005013100</td>
</tr>
<tr>
<td>Sud</td>
<td>2004121500</td>
<td>2005013100</td>
</tr>
</tbody>
</table>

Hemisphere Nord 24h

Hemisphere Sud 24h
Verifications wrt RAOBS data M4DH05F1 vs K4H5F1R4 2004121500-2005013100

Hemisphere Nord
48h

Hemisphere Sud
48h
Verifications wrt RAOBS data M4DH05F1 vs K4H5F1R4
2004121500-2005013100

Hemisphere Nord
120h

Hemisphere Sud
120h
Verifications wrt RAOBS data M4DH05F1 vs K4H5F1R4

2004121500-2005013100

Tropiques 24h

Tropiques 48h
Impact attributed to new interpolator

Anomaly correlation versus forecast time

6 weeks of 4D-var cycles: CNTL vs CNTL+RTTOV8 + new interpolator + automated bias cor + ATOVS end of scans included

10/27/06
Verifications wrt Analyses M4DH05F1 vs K4H5F1R4
2004121500-2005012612
Verifications wrt RAOBS data K4H5F1R4 vs K4H5STR4

2004121500-2005013100

Hemisphere Nord
24h

Hemisphere Sud
24h
Verifications wrt RAOBS data K4H5F1R4 vs K4H5STR4
2004121500-2005013100

Hemisphere Nord
48h

Hemisphere Sud
48h
Verifications wrt RAOBS data K4H5F1R4 vs K4H5STR4
2004121500-2005013100

Hemisphere Nord
120h

Hemisphere Sud
120h
Verifications wrt RAOBS data K4H5F1R4 vs K4H5STR4

2004121500-2005013100
Verifications wrt AMSU data $K4H5F1R4$ vs $K4H5STR4$

2004121500-2005011500
Verifications wrt Analyses K4H5F1R4 vs K4H5STR4

2004121500-2005012612

Impact of new statistics only
SSM/I coverage after thinning

Date 2005110400