Assimilation of the IASI data in the HARMONIE data assimilation system

Roger Randriamampianina

Acknowledgement: Andrea Storto (met.no), Andrew Collard (ECMWF), Fiona Hilton (MetOffice) and Vincent Guidard (Météo France)
Outline of the talk

- IASI data (pre-)processing
  - channel selection

- Specific assimilation problem over high latitude in winter

- IASI assimilation
  - Use of channels with respect to cloud condition/properties

- Impact study trial
  - case study

- Conclusions and future plans
IASI instrument

- IASI is a new instrument onboard METOP satellite
  - multi-spectral instrument with 8461 channels
  - we extract 366 channels, as proposed by Andrew Collard (ECMWF)

![Graph showing wavenumber vs. brightness temperature][1]

<table>
<thead>
<tr>
<th>Channel Range</th>
<th>Gas/Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>650-770</td>
<td>CO₂</td>
</tr>
<tr>
<td>790-980</td>
<td>O₃ Atm. window</td>
</tr>
<tr>
<td>1000-1070</td>
<td>H₂O</td>
</tr>
<tr>
<td>1080-1150</td>
<td>CO₂</td>
</tr>
<tr>
<td>1210-1650</td>
<td>O₃ Atm. window</td>
</tr>
<tr>
<td>2100-2150</td>
<td>N₂O &amp; CO₂</td>
</tr>
<tr>
<td>2150-2250</td>
<td>CO₂</td>
</tr>
<tr>
<td>2350-2420</td>
<td>O₃ Atm. window</td>
</tr>
<tr>
<td>2420-2700</td>
<td>CH₄</td>
</tr>
<tr>
<td>2700-2760</td>
<td>Temp. profile</td>
</tr>
</tbody>
</table>

- Temperature profile
- Surface & cloud properties
- O₃ sounding
- Surface, cloud properties
- Humidity profile, CH₄, N₂O column amount
- CO column amount
- Temp. profile, N₂O column amount
- Temp. profile
- Surface & cloud properties
- CH₄ column amount

[1]: #/image.png
The assimilation system (3D-VAR)

The analysis is obtained by minimizing the cost function

**Variational cost function**

\[ J(x) = J_b(x) + J_o(x) \]

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

- \( x \) is the control variables vector
- \( y \) is the observation vector
- \( H \) is the observation operator
- \( B \) is the background error covariance matrix
- \( R \) is the observation error covariance matrix
HARMONIE and its assimilation system

(Hirlam Aladin Regional/Meso-scale Operational NWP In Europe)

Model domain:

Small domain: rotated Lambert pr.
Dx=dy= 11 km, 60 vertical levels up to 0.2 hPa
HARMONIE analysis and forecast system

Upper-air analysis
- Three-dimentional variational (3DVAR) assimilation system
- Use of conventional and satellite data
- Operator for radiance data: RTTOVS-8.7

Surface analysis
- Optimum interpolation
- Univariate analysis of 2m T and 2m Hu
- Diagnosis parameters are skin T and water content

Forecast system
- Hydrostatic (IFS/ARPEGE/ALADIN/HARMONIE) CY33T1
- Initialisation technique: Digital filter
- Radiation scheme: ECMWF FMR
- Advection: using semi-lagrangian interpolation
- Lateral boundary files: IFS analyses and forecasts
Type of observations actually in use

**Conventional Observations**
- Surface data:
  - Synop, Ship
  - Bathy, Tesac
  - Buoy
- Upper-air data:
  - Airep, Amdar, Acar
  - Temp, Temp-ship, Temp-mobil, Temp-drop *(New)*
  - Pilot, Pilot-ship, Europrofil, Profiler

**Satellite Observations**
- NOAA Atovs:
  - Amsua, Amsub
- METOP:
  - Amsua, Mhs, Iasi
- METEOSAT and MODIS
  - Satob, Satgeo, geowind
The pre-processing of the data is almost ready
-- Reads a restricted number of channels
-- Uses 1 of the 4 FOV’s (field of view) in FOR (field of regard)
Radiance data assimilation monitoring
Multistep channel selection method – first step
Monitoring the extracted IASI channels (100 ch/page)

Time series of bias and STDV for obs-guess in observation space
→ Choosing the channels “obeying” the system

93 channels were chosen after this monitoring
Radiance data assimilation monitoring
multistep channel selection method – second step

- 83 active channels were selected first
  (no separation of land/sea statistics)

- 60 active channels were selected
  (with separation of land/sea statistics)

- it is also important to see the vertical
distribution of the sensed atmospheric
thickness by each selected channel
The problems we had to face and channels usage

- We observed large stratospheric model error, resulting in large observation increments in winter
  → Any disbalance at any model level can produce large model error in the troposphere after 2-3 days.

- IASI channels are used in the following way:


  - Over Land: 70, 133, 154, 180, 214, 217, 219, 301, 303

  - Over ice: None

- Channels having peak above the cloud top are assimilated
Assimilation in polar region
seasonality of the background statistics

Black- summer stats
Red - winter stats
using „NMC” technique

Statistics for balanced and unbalanced T

Statistics for balanced and unbalanced Divergence

Statistics for Vorticity
Assimilation in polar region estimation of ensemble based statistics

![Graphs showing average total vorticity, divergence, temperature, and specific humidity standard deviations for NMC, DGE, and LEA](image)

- Statistics used in the assimilation trial
  → Computed using downscaled ensemble fields

- This small increase in background error can produce a very large observation increment

**Figure 7:** Vertical profiles of total standard deviations of vorticity (a), divergence (b), temperature (c) and specific humidity (d) for the three statistics (NMC: NMC-derived background-error standard deviations; DGE: background-error standard deviations from downscaled global ensemble analysis; LEA: background-error standard deviations from limited area ensemble variational assimilation).
Exploring the impact of IASI data during the campaign period

**A winter assimilation test**

Four experiments have been performed using 41 active channels

**Period:** 2008022000 – 2008031512

(Warming period 5 days)

<table>
<thead>
<tr>
<th>Run withcampaign data</th>
<th>Run without campaign data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run with IASI data</td>
<td>THCL1</td>
</tr>
<tr>
<td>Run without campaign data</td>
<td>THCL2</td>
</tr>
<tr>
<td>Run with campaign data</td>
<td>THCL3</td>
</tr>
<tr>
<td>Run without campaign data</td>
<td>THCL4</td>
</tr>
</tbody>
</table>

THCL1 vs THCL2 and THCL3 vs THCL4 will show the impact of IASI data with and without aide of campaign observations, respectively

THCL1 vs THCL3 and THCL2 vs THCL4 will show the impact of the campaign observations with and without presence of IASI data in the assimilation system, respectively
Impact of IASI data

Comparison against analyses

Comparison against ECMWF analyses
RMSE of Temperature (K) (TCL4 – TCL3)
Period 2008022500 – 2008031512

Impact on T exps without campaign data

Comparison against observations
RMSE of Temperature (K) (TCL4 – TCL3)
Period 2008022500 – 2008031512

Mean RMSE difference TCL3–TCL4
Period: 25.02.2008–15.03.2008 Run: 00,12 UTC
Variable: T 925
90% two sided confidence interval

Mean RMSE difference (°C)
Forecast ranges

Mean RMSE difference T 925
90% two sided confidence interval

Forecast ranges
Impact of IASI data

Comparison against analyses

Comparison against observations

Impact on Geo exps without campaign data

Mean RMSE difference TCL3–TCL4
Period: 25.02.2008–15.03.2008  Run: 00,12 UTC
Variable: Geo 700

Mean RMSE difference (m)
90% two sided confidence interval
The impact on geopotential at 700 hPa for 24-hour forecast – coloured patterns show positive impact
Case study
Very fast developing polar low from 16-17 March 2008

Position and intensity at 00:50 UTC 17 March 2008
12-hour forecasts valid for 20080316 12UTC
24-hour forecasts valid for 20080316 12UTC
36-hour forecasts valid for 20080316 12UTC
Conclusions and future plans

→ We found the optimal way to assimilate the IASI data in the HARMONIE assimilation system:
  -- *Tropospheric peaking channels are under test now*;
  -- *To improve the system, a better analyses of skin temperature is needed*;
  -- *Using the current analysis system, but with restriction over high altitude terrain can be an alternative solution*.

→ We showed that IASI data improved the analyses and forecasts in the conditions with and without campaign observations:
  -- the relative impact is slightly reduced with additional campaign data.

→ The impact of the IASI data on temperature (in the lower troposphere) and geopotential (in the middle troposphere) is significantly positive;

→ Significant impact on the humidity was observed around 700-850 hPa;

→ An overall neutral impact (comparison against analyses) on wind speed was observed, but comparison against radiosonde showed positive impact in lower troposphere.

→ Case study showed positive impact of IASI data on the analysis and forecasts of polar lows
  -- with campaign data, the positive impact is up to 36-hour forecast;
  -- without campaign data, the positive impact is up to 24-hour forecast “only”.

→ Please visit our poster to see more case studies and other developments related to the assimilation of satellite observations, including the use of IASI data in high resolution.
Thank you for your attention!