On the limitations of variational bias correction

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No reliable water vapor measurements

Uncertainties in our knowledge of the tropospheric humidity

- factors influencing the amount of water vapor
- concentration of water vapor in many regions of the atmosphere
- trend of tropospheric water vapor

No reliable long-term data record

Vergados et al., AMTD, 2015
MW Water Vapor Channels

Left: Era Interim, Right: MERRA-2; Top: MHS Chan 3, Bottom: MHS Chan 4
MW Water Vapor Channels

![Graph showing the opacity of various gases over frequency](Image)

- AMSU-B Channels
  - 89 ± 0.9
  - 150 ± 0.9
  - 183 ± 1
  - 183 ± 3
  - 183 ± 7

- Frequency [GHz]
- Opacity

- Gases:
  - H2O
  - O3
  - CO2
  - N2O
  - CO
  - CH4
  - O2
  - N2
Cost function for 3D-Var Data Assimilation:

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

\[y = Tb + \epsilon_r + \epsilon_s\]

\(\epsilon_s\) is the random error (R) and \(\epsilon_s\) is known as observation bias or representativeness error that is taken into account using the variational bias correction:

\[\epsilon_s = \sum_{k=1}^{N} \beta_k p_k + b^{angle}\]

The control variables \((p_k)\) include cloud liquid water (CLW); temperature lapse rate; and the square of the temperature lapse rate.
Change in ECMWF Model Resolution

Difference between obs and ana/fg MHS MetOp-A Observations
On 8 March 2016, ECMWF upgraded the horizontal resolution of its analyses and forecasts. The upgrade has a horizontal resolution that translates to about 9 km for HRES and the data assimilation (the outer loop of the 4D-Var) and to about 18 km for the ENS up to day 15. The resolution of the ENS extended (day 16 up to day 46) is about 36 km.

A new cycle of the IFS has been introduced to implement the horizontal resolution upgrade. This cycle is labelled 41r2 and includes a number of enhancements to the model and data assimilation listed herein. The detailed specification of the resolution upgrades included in IFS cycle 41r2 are:

- Introduction of a new form of the reduced Gaussian grid, the octahedral grid, for HRES, ENS and ENS Extended;
- Horizontal resolution of the HRES increased from T_l 1279 / N640 to T_CO 1279 / O1280, where subscript C stands for cubic and O for octahedral;
- Horizontal resolution of the ENS increased from T_l 639 / N320 to T_CO 639 / O640 for ENS (Days 0 - 15) and from T_l 319 / N160 to T_CO 319 / O320 for ENS Extended (Days 16 - 46);
- For the medium-range ENS there will no longer be a decrease of resolution at day 10: the ENS Days 11 - 15 will be run at the same T_CO 639 / O640 resolution as ENS Days 0 - 10;
- Increase of the HRES-WAM resolution from 0.25 to 0.125 degrees and the ENS-WAM Days 0 - 15 from 0.5 to 0.25 degrees;
- Horizontal resolution of the EDA outer loop is increased from T_l 399 to T_CO 639 with its two inner loops increased from T_l 159 / T_l 159 to T_l 191 / T_l 191, respectively;
- Horizontal resolution of the three 4DVar inner loops is increased from T_l 255 / T_l 255 / T_l 255 to T_l 319 / T_l 319, respectively.

These upgrades

- do not include any increase in the vertical resolution;
- do not apply to the ECMWF seasonal forecasting system;
- do not apply to the standalone wave model (HRES-SAW);
- do apply to products from the Boundary Condition Optional Programme.

During the Release Candidate test phase forecast data will be made available close to real time via

- product dissemination
- ecCharts
- MARS
Heterodyne MW Receivers

Feedhorn → Mixer → IF Amplifier → Integrator

- RF Amplifier
- Local Oscillator
- Filter
- Square Law Detector
- DC Amplifier

\[ \nu_{\text{LO}} + \nu_{\text{IF}} + \nu_{\text{IF}} = \nu_{\text{LO}} + \nu_{\text{1}} \]

\[ \nu_{\text{LO}} + \nu_{\text{2}} \]

\[ \nu_{\text{IF}} - \nu_{\text{LO}} \]

(a) Power

(b) Power

Scan Direction

Earth View

Internal Hot Target

AMSU-A: FOV #30
ATMS: FOV #96

AMSU: FOV #16
ATMS: FOV #49

AMSU: FOV #15
ATMS: FOV #48

Cold Space View

Nadir

Subnadir FOVs
Uncertainty in Antenna Emissivity

Isaac Moradi (98th AMS Annual Meeting)

On the limitations of VarBc

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Antenna Pattern Correction

Hewison and Saunders 1996
Hewison and Saunders 1996 for AMSU-B, Mo 1999 for AMSU-A, EUMETSAT for MHS

\[ T_A = \frac{1}{N_\eta} [f_e \bar{T}_e + f_c \bar{T}_c + \eta f_s \bar{T}_s] \]

\( \eta \) is a small correction factor (less than 0.1) which accounts for near field contribution from the satellite platform; \( f \) and \( T \) denote the efficiency and temperatures, and \( e, c, \) and \( s \) denote to Earth, Cold Space, and Satellite platform.

<table>
<thead>
<tr>
<th>Beam Position</th>
<th>Scan Angle</th>
<th>Ch. 1</th>
<th>Ch. 2</th>
<th>Ch. 3</th>
<th>Ch. 4</th>
<th>Ch. 5</th>
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<td></td>
<td>( \beta )</td>
<td>( f_e )</td>
<td>( f_{sat} )</td>
<td>( f_c )</td>
<td>( f_e )</td>
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Impact of APC on AMSU-A 50GHz

AMSU-A2 PFM

AMSU-A1-2 FM1

AMSU-A1-1 FM1

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Non-linearity in Calibration

\[ I_E = \frac{C_E - C_H}{C_H - C_S} (I_H - I_S) + I_H + Q \]

\[ Q = \mu (I_H - I_S)^2 \frac{(C_E - C_H)(C_E - C_S)}{(C_H - C_S)^2} \]

\[ G = \frac{C_H - C_S}{I_H - I_S}, \quad \text{count} = \frac{mW \cdot m^{-2} \cdot sr^{-1} \cdot Hz^{-1}}{mW \cdot m^{-2} \cdot sr^{-1} \cdot Hz^{-1}} \]
Corrected MHS/AMSU-B

Chan 1
Chan 2
Chan 3
Chan 4
Chan 5

N15
N16
N17
N18
N19
MOA

2002 2003 2004 2005 2006 2007 2008 2009 2010
Spatial Distribution of Error Correction

L1b Chan 2 AMSUB NOAA-16 2008-359

L1b Chan 4 AMSUB NOAA-16 2008-359

L1b-CDR Chan 2 AMSUB NOAA-16 2008-359

L1b-CDR Chan 4 AMSUB NOAA-16 2008-359
Conclusions

- Variational bias correction technique does not distinguish between error sources - errors may compensate for each other.

- Variational bias correction does not especially work for water vapor channels because of large error in the NWP water vapor fields.

- More robust and physical bias correction techniques are available that can quantify the observation errors.

- Some preliminary results are presented but more work is required to properly validate the impact of bias corrected observations on the DA system.
Thank you for your attention!