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

AMSU-B Channels

89 ± 0.9
150 ± 0.9
183 ± 1
183 ± 3
183 ± 7

Frequency [GHz]

Opacity

H2O
O3
CO2
N2O
CO
CH4
O2
N2
Variational Bias Correction

Cost function for 3D-Var Data Assimilation:

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

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

\( \epsilon_s \) 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
Change in ECMWF Model Resolution

Detailed information of implementation of IFS cycle 41r2

Created by Umberto Modigliani, last modified by Paul Dando on Mar 10, 2016

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 T₈L1279 / N640 to T₈C01279 / O1280, where subscript C stands for cubic and O for octahedral;
- Horizontal resolution of the ENS increased from T₈L639 / N320 to T₈C0639 / O640 for ENS (Days 0 - 15) and from T₈L319 / N160 to T₈C0319 / 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 T₈C0639 / 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 T₈L399 to T₈C0639 with its two inner loops increased from T₈L159 / T₈L159 to T₈L191 / T₈L191, respectively;
- Horizontal resolution of the three 4DVar inner loops is increased from T₈L255 / T₈L255 / T₈L255 to T₈L255 / T₈L319 / T₈L399, 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
Variational Bias Correction

AMSUB_N15 20080101-20080601
Channel 4 183.312GHz
Global All amsu_cdr_conv_C180

Total Bias
- Avg (K): 1.053
- Sdv (K): 3.132

Scan Angle
- Avg (K): 1.574
- Sdv (K): 3.105

Mean
- Avg (K): -0.812
- Sdv (K): 0.0
Heterodyne MW Receivers

On the limitations of VarBc

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Uncertainty in Antenna Emissivity

Antenna Emissivity = 0.006; Antenna Temperature = 250 [K]

\[ T = T_{\text{air}} \times \text{refl.} + T_{\text{ant}} \times (1 - \text{refl.}) \]
Antenna Pattern Correction

Hewison and Saunders 1996
Antenna Pattern Correction

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

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

\( \eta \) 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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<tr>
<td></td>
<td></td>
<td>fe (%)</td>
<td>fsat (%)</td>
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<td>fsat (%)</td>
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<tr>
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Impact of APC on AMSU-A 50GHz

AMSU-A2 PFM

AMSU-A1-2 FM1

AMSU-A1-1 FM1

On the limitations of VarBc

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Non-linearity in Calibration

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

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

\[ G = \frac{C_H - C_S}{I_H - I_S}, \quad \text{count} \]

\[ mW.m^{-2}.sr^{-1}.Hz^{-1} \]
Corrected MHS/AMSU-B

- Chan 1
- Chan 2
- Chan 3
- Chan 4
- Chan 5

Year: 2002 to 2010

Lines:
- N15
- N16
- N17
- N18
- N19
- MOA
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!