On the limitations of variational bias correction

Isaac Moradi^{1,2}, Will Mccarty¹, Ronald Gelaro¹
1. GMAO/GSFC/NASA, 2. ESSIC, University of Maryland

98th AMS Annual Meeting | 7–11 January 2018 Austin Convention Center | Austin, TX, U.S.A

January 10, 2018







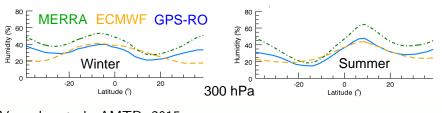
No reliable water vapor measurements



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

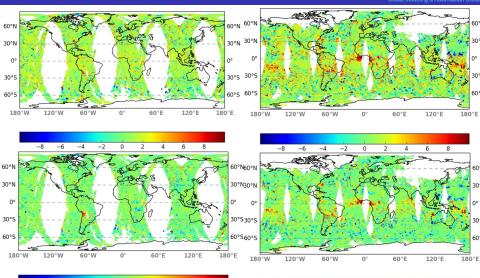
No reliable long-term data record



Vergados et al., AMTD, 2015

MW Water Vapor Channels

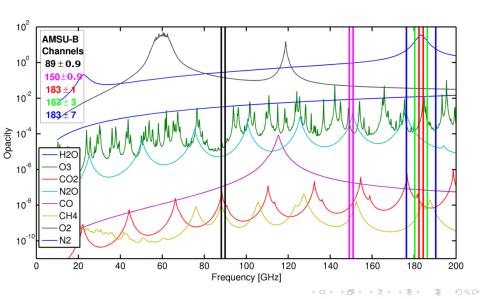




Left: Era Interim, Right: MERRA-2; Top: MHS Chan 3, Bottom: MHS Chan 4

MW Water Vapor Channels





Variational Bias Correction



Cost function for 3D-Var Data Assimilation:

$$J(\vec{x}) = \overbrace{\frac{1}{2}(\vec{x} - \vec{x_b})^T \vec{B}^{-1}(\vec{x} - \vec{x_b})}^{J_b} + \overbrace{\frac{1}{2}(H(\vec{x}) - \vec{y})^T \vec{R}^{-1}(H(\vec{x}) - \vec{y})}^{J_o}$$

$$y = Tb + \epsilon_r + \epsilon_s$$

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

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

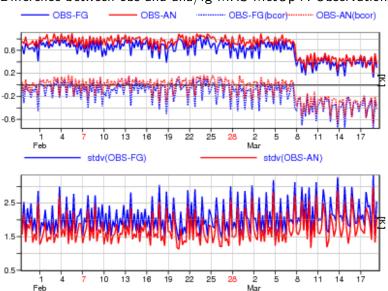
The control variables (p_k) include cloud liquid water (CLW); temperature lapse rate; and the square of the temperature lapse rate.



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 T, 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_L639 / N320 to T_{CO}639 / O640 for ENS (Days 0 15) and from T_L319 / 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_L399 to T_{CO}639 with its two inner loops increased from T_L159 / T_L159 to T_L191 / T_L191, respectively;
- Horizontal resolution of the three 4DVar inner loops is increased from T_L255 / T_L255 to T_L255 to T_L255 / T_L319 / T_L399, 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.

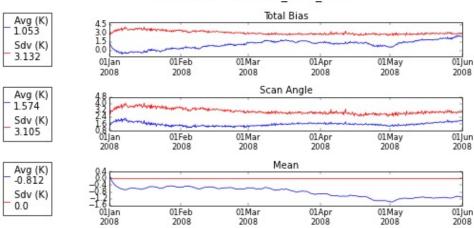
During the Release Candidate test phase forecast data will be made available close to real time via

- · product dissemination
- ecCharts
- MARS

Variational Bias Correction

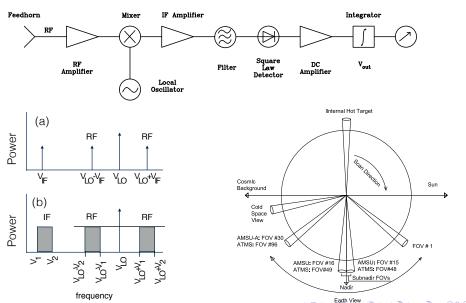


AMSUB_N15 20080101-20080601 Channel 4 183.312GHz Assimilated Global All amsucdr_conv_C180



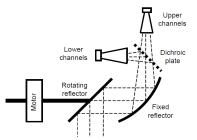
Heterodyne MW Receivers

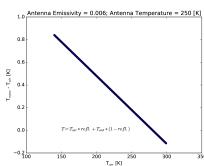


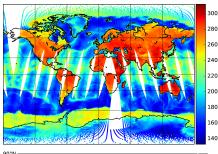


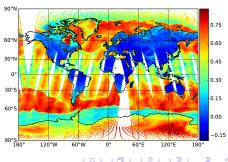
Uncertainty in Antenna Emissivity







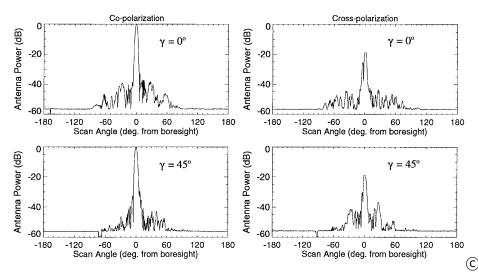




January 10, 2018

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

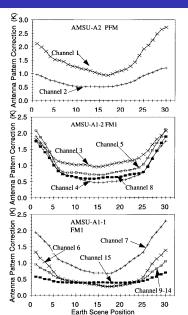
$$T_A = \frac{1}{N_\eta} [f_e \, \bar{T}_e + f_c \, \bar{T}_c + \eta f_s \, \bar{T}_s]$$

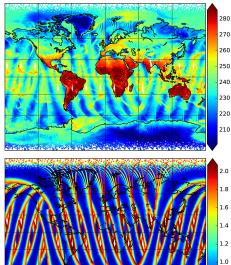
 η is a small correction factor (less than 0.1) which accounts for near field contribution from the satellite platform; f and T denote the efficiency and temperatures, and e, c, and s denote to Earth, Cold Space, and Satellite platform.

Angle β 48.33 41.67 35.00	fe (%) 98.70 98.89	fsat (%) 0.37 0.31	fc (%) 0.93	fe (%) 99.38	fsat (%)	fc (%)	fe (%)	fsat	fc	fe	fsat	fc	fe	fsat	fc
48.33 41.67	98.70 98.89	0.37	0.93	-		(%)	(%)	(0/)							
41.67	98.89			99.38				(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
		0.31			0.19	0.42	98.54	0.67	0.79	98.89	0.27	0.84	98.81	0.31	0.88
35.00	00.07		0.80	99.46	0.17	0.37	98.66	0.67	0.67	99.09	0.23	0.68	99.01	0.28	0.71
	99.07	0.26	0.67	99.53	0.15	0.32	98.81	0.65	0.54	99.34	0.21	0.46	99.26	0.25	0.49
28.33	99.15	0.22	0.63	99.60	0.13	0.28	98.90	0.63	0.48	99.48	0.19	0.33	99.43	0.23	0.34
21.67	99.25	0.18	0.56	99.65	0.11	0.24	98.92	0.63	0.46	99.52	0.19	0.29	99.45	0.22	0.33
15.00	99.32	0.16	0.52	99.66	0.11	0.23	98.92	0.63	0.45	99.56	0.19	0.25	99.46	0.21	0.33
8.33	99.36	0.16	0.49	99.66	0.11	0.23	98.92	0.64	0.44	99.59	0.19	0.22	99.48	0.21	0.31
1.67	99.41	0.16	0.44	99.66	0.11	0.23	98.92	0.66	0.42	99.60	0.19	0.21	99.48	0.22	0.30
-1.67	99.43	0.15	0.42	99.67	0.11	0.22	98.91	0.66	0.43	99.60	0.19	0.21	99.48	0.22	0.30
-8.33	99.42	0.14	0.44	99.66	0.11	0.23	98.88	0.66	0.46	99.59	0.19	0.22	99.45	0.22	0.33
15.00	99.37	0.14	0.49	99.63	0.11	0.26	98.86	0.66	0.48	99.57	0.20	0.23	99.43	0.22	0.35
-21.67	99.29	0.15	0.56	99.58	0.12	0.30	98.83	0.67	0.50	99.53	0.20	0.27	99.40	0.23	0.36
-28.33	99.11	0.15	0.74	99.49	0.14	0.37	98.77	0.69	0.54	99.48	0.21	0.31	99.36	0.24	0.39
-35.00	98.92	0.18	0.90	99.40	0.17	0.44	98.65	0.71	0.64	99.33	0.23	0.44	99.20	0.28	0.52
41.67	98.68	0.23	1.09	99.30	0.20	0.49	98.46	0.75	0.79	√99.13	0.24	0.63	98.98	0.31	0.71
1 1 2 2 2	28.33 21.67 15.00 8.33 1.67 -1.67 -8.33 15.00 21.67 28.33	28.33 99.15 21.67 99.25 15.00 99.32 8.33 99.36 1.67 99.41 -1.67 99.43 -8.33 99.42 15.00 99.37 21.67 99.29 28.33 99.11 35.00 98.92	28.33 99.15 0.22 21.67 99.25 0.18 15.00 99.32 0.16 18.33 99.36 0.16 1.67 99.41 0.16 1.67 99.43 0.15 18.33 99.42 0.14 15.00 99.37 0.14 21.67 99.29 0.15 28.33 99.11 0.15 29.39 99.12 0.18	28.33 99.15 0.22 0.63 21.67 99.25 0.18 0.56 15.00 99.32 0.16 0.52 18.33 99.36 0.16 0.49 1.67 99.41 0.16 0.44 -1.67 99.43 0.15 0.42 -8.33 99.42 0.14 0.44 15.00 99.37 0.14 0.49 21.67 99.29 0.15 0.56 82.33 99.11 0.15 0.74 15.00 98.92 0.15 0.79	28.33 99.15 0.22 0.63 99.60 21.67 99.25 0.18 0.56 99.65 15.00 99.32 0.16 0.52 99.66 8.33 99.36 0.16 0.49 99.66 1.67 99.41 0.16 0.44 99.66 -1.67 99.43 0.15 0.42 99.67 8.33 99.42 0.14 0.44 99.63 15.00 99.37 0.14 0.49 99.63 21.67 99.29 0.15 0.56 99.58 82.33 99.11 0.15 0.74 99.49 95.00 98.92 0.18 0.90 99.40	28.33 99.15 0.22 0.63 99.60 0.13 21.67 99.25 0.18 0.56 99.65 0.11 15.00 99.32 0.16 0.52 99.66 0.11 1.8.33 99.36 0.16 0.49 99.66 0.11 1.67 99.41 0.16 0.44 99.66 0.11 1-8.33 99.42 0.14 0.44 99.66 0.11 15.00 99.37 0.14 0.49 99.63 0.11 21.67 99.29 0.15 0.56 99.58 0.12 28.33 99.11 0.15 0.74 99.49 0.14 35.00 89.92 0.18 0.90 99.40 0.17	28.33 99.15 0.22 0.63 99.60 0.13 0.28 21.67 99.25 0.18 0.56 99.65 0.11 0.24 15.00 99.32 0.16 0.52 99.66 0.11 0.23 8.33 99.36 0.16 0.49 99.66 0.11 0.23 1.67 99.41 0.16 0.44 99.66 0.11 0.23 8.33 99.42 0.15 0.42 99.67 0.11 0.23 8.833 99.42 0.14 0.49 99.66 0.11 0.23 15.00 99.37 0.14 0.49 99.66 0.11 0.26 21.67 99.29 0.15 0.56 99.58 0.12 0.30 28.33 99.11 0.15 0.56 99.58 0.12 0.30 28.33 99.11 0.15 0.56 99.49 0.14 0.37 28.33 99.12 0.18 0.90 99.40 0.14 0.37 28.35 99.27 0.18 0.90 99.40 0.14 0.30 28.35 99.12 0.18 0.90 99.40 0.14 0.44	28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 21.67 99.25 0.18 0.56 99.65 0.11 0.24 98.92 15.00 99.32 0.16 0.52 99.66 0.11 0.23 98.92 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 8.33 99.42 0.14 0.44 99.66 0.11 0.22 99.91 8.83 99.42 0.14 0.44 99.66 0.11 0.22 98.91 91.65 0.12 0.23 98.83 0.11 0.25 98.96 91.67 0.14 0.49 99.66 0.11 0.22 99.91 98.92 0.14 0.49 99.66 0.11 0.22 98.91 98.93 0.14 0.49 99.66 0.11 0.22 98.91 98.60 0.11 0.25 98.91 0.11 0.26 98.86 99.57 0.14 0.49 99.66 0.11 0.23 98.83 98.03 99.57 <td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 21.67 99.25 0.18 0.56 99.56 0.11 0.24 98.92 0.63 18.33 99.36 0.16 0.52 99.66 0.11 0.23 98.92 0.64 1.67 99.41 0.16 0.49 99.66 0.11 0.23 98.92 0.64 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.91 0.66 15.00 99.37 0.14 0.49 99.66 0.11 0.23 98.88 0.66 15.00 99.37 0.14 0.49 99.66 0.11 0.23 98.88 0.66 15.00 99.37 0.14 0.49 99.66 0.11 0.22 98.86 0.66 16.7 99.29 0.15 0.56 99.58 0.12 0.30 98.83 0.67 21.67 99.29 0.18 0.94 0.14 0.37 98.77 0.69 28.33 99.11 0.15 0.5</td> <td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 21.67 99.25 0.18 0.56 99.65 0.11 0.24 98.92 0.63 0.46 15.00 99.32 0.16 0.52 99.66 0.11 0.23 98.92 0.63 0.45 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 -8.33 99.42 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 -8.33 99.42 0.14 0.49 99.66 0.11 0.23 98.92 0.66 0.42 -167 99.49 0.14 0.23 98.81 0.66 0.43 15.00 99.37 0.14 0.49 99.66 0.11 0.26</td> <td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 21.67 99.25 0.18 0.56 99.55 0.11 0.24 98.92 0.63 0.45 99.52 18.33 99.36 0.16 0.52 99.66 0.11 0.23 98.92 0.64 0.44 99.59 1.67 99.41 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.59 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.91 0.66 0.42 99.60 1.500 99.37 0.14 0.49 99.63 0.11 0.23 98.86<td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 21.67 99.25 0.18 0.56 99.65 0.11 0.24 98.92 0.63 0.46 99.52 0.19 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.59 0.19 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 1-6.7 99.43 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 1-6.7 99.43 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.88 0.66 0.46 99.59 0.19 15.00<td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 21.67 99.25 0.18 0.56 99.55 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.25 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.56 0.19 0.25 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.86</td><td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 99.43 21.67 99.25 0.18 0.56 99.56 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.29 99.45 18.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.63 0.45 99.56 0.19 0.25 99.48 1.67 99.41 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.59 0.19 0.22 99.48 1.67 99.43 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 15.00 99.42</td><td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 99.43 0.23 21.67 99.25 0.18 0.56 99.65 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.29 99.45 0.22 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.63 0.45 99.56 0.19 0.22 99.48 0.21 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.22 99.48 0.21 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 0.22 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.91 0.66 0.43 99.50 0.19<</td></td></td>	28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 21.67 99.25 0.18 0.56 99.56 0.11 0.24 98.92 0.63 18.33 99.36 0.16 0.52 99.66 0.11 0.23 98.92 0.64 1.67 99.41 0.16 0.49 99.66 0.11 0.23 98.92 0.64 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.91 0.66 15.00 99.37 0.14 0.49 99.66 0.11 0.23 98.88 0.66 15.00 99.37 0.14 0.49 99.66 0.11 0.23 98.88 0.66 15.00 99.37 0.14 0.49 99.66 0.11 0.22 98.86 0.66 16.7 99.29 0.15 0.56 99.58 0.12 0.30 98.83 0.67 21.67 99.29 0.18 0.94 0.14 0.37 98.77 0.69 28.33 99.11 0.15 0.5	28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 21.67 99.25 0.18 0.56 99.65 0.11 0.24 98.92 0.63 0.46 15.00 99.32 0.16 0.52 99.66 0.11 0.23 98.92 0.63 0.45 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 -8.33 99.42 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 -8.33 99.42 0.14 0.49 99.66 0.11 0.23 98.92 0.66 0.42 -167 99.49 0.14 0.23 98.81 0.66 0.43 15.00 99.37 0.14 0.49 99.66 0.11 0.26	28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 21.67 99.25 0.18 0.56 99.55 0.11 0.24 98.92 0.63 0.45 99.52 18.33 99.36 0.16 0.52 99.66 0.11 0.23 98.92 0.64 0.44 99.59 1.67 99.41 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.59 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.91 0.66 0.42 99.60 1.500 99.37 0.14 0.49 99.63 0.11 0.23 98.86 <td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 21.67 99.25 0.18 0.56 99.65 0.11 0.24 98.92 0.63 0.46 99.52 0.19 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.59 0.19 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 1-6.7 99.43 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 1-6.7 99.43 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.88 0.66 0.46 99.59 0.19 15.00<td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 21.67 99.25 0.18 0.56 99.55 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.25 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.56 0.19 0.25 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.86</td><td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 99.43 21.67 99.25 0.18 0.56 99.56 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.29 99.45 18.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.63 0.45 99.56 0.19 0.25 99.48 1.67 99.41 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.59 0.19 0.22 99.48 1.67 99.43 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 15.00 99.42</td><td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 99.43 0.23 21.67 99.25 0.18 0.56 99.65 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.29 99.45 0.22 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.63 0.45 99.56 0.19 0.22 99.48 0.21 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.22 99.48 0.21 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 0.22 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.91 0.66 0.43 99.50 0.19<</td></td>	28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 21.67 99.25 0.18 0.56 99.65 0.11 0.24 98.92 0.63 0.46 99.52 0.19 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.59 0.19 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 1-6.7 99.43 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 1-6.7 99.43 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.88 0.66 0.46 99.59 0.19 15.00 <td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 21.67 99.25 0.18 0.56 99.55 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.25 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.56 0.19 0.25 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.86</td> <td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 99.43 21.67 99.25 0.18 0.56 99.56 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.29 99.45 18.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.63 0.45 99.56 0.19 0.25 99.48 1.67 99.41 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.59 0.19 0.22 99.48 1.67 99.43 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 15.00 99.42</td> <td>28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 99.43 0.23 21.67 99.25 0.18 0.56 99.65 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.29 99.45 0.22 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.63 0.45 99.56 0.19 0.22 99.48 0.21 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.22 99.48 0.21 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 0.22 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.91 0.66 0.43 99.50 0.19<</td>	28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 21.67 99.25 0.18 0.56 99.55 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.25 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.56 0.19 0.25 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 8-8.33 99.42 0.14 0.44 99.66 0.11 0.23 98.86	28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 99.43 21.67 99.25 0.18 0.56 99.56 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.29 99.45 18.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.63 0.45 99.56 0.19 0.25 99.48 1.67 99.41 0.16 0.49 99.66 0.11 0.23 98.92 0.64 0.44 99.59 0.19 0.22 99.48 1.67 99.43 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 15.00 99.42	28.33 99.15 0.22 0.63 99.60 0.13 0.28 98.90 0.63 0.48 99.48 0.19 0.33 99.43 0.23 21.67 99.25 0.18 0.56 99.65 0.11 0.24 98.92 0.63 0.46 99.52 0.19 0.29 99.45 0.22 8.33 99.36 0.16 0.49 99.66 0.11 0.23 98.92 0.63 0.45 99.56 0.19 0.22 99.48 0.21 1.67 99.41 0.16 0.44 99.66 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.22 99.48 0.21 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.92 0.66 0.42 99.60 0.19 0.21 99.48 0.22 1.67 99.43 0.15 0.42 99.67 0.11 0.23 98.91 0.66 0.43 99.50 0.19<

Impact of APC on AMSU-A 50GHz







0.8

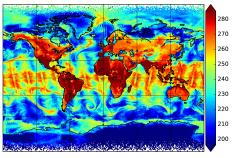
Non-linearity in Calibration

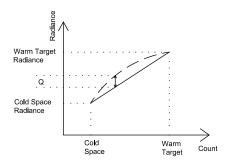


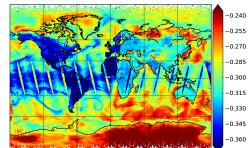
$$I_{E} = \frac{C_{E} - C_{H}}{C_{H} - C_{S}} (I_{H} - I_{S}) + I_{H} + Q$$

$$Q = \mu (I_{H} - I_{S})^{2} \frac{(C_{E} - C_{H}) (C_{E} - C_{S})}{(C_{H} - C_{S})^{2}}$$

$$G = \frac{C_{H} - C_{S}}{I_{H} - I_{S}}, \frac{count}{mW.m^{-2}.sr^{-1}.Hz^{-1}}$$

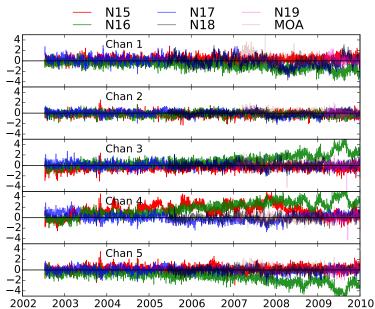






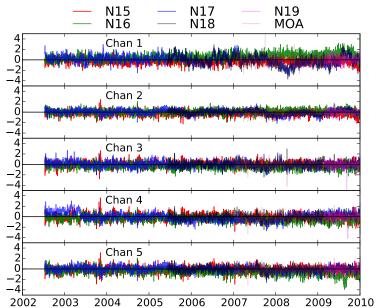
Level 1b MHS/AMSU-B





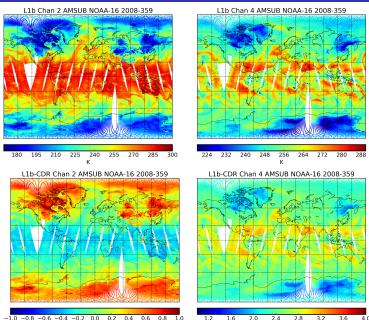
Corrected MHS/AMSU-B





Spatial Distribution of Error Correction







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!