On the limitations of variational bias correction

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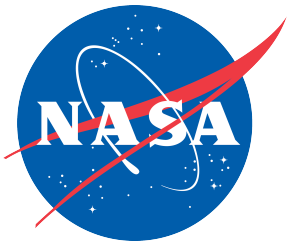

No reliable water vapor measurements

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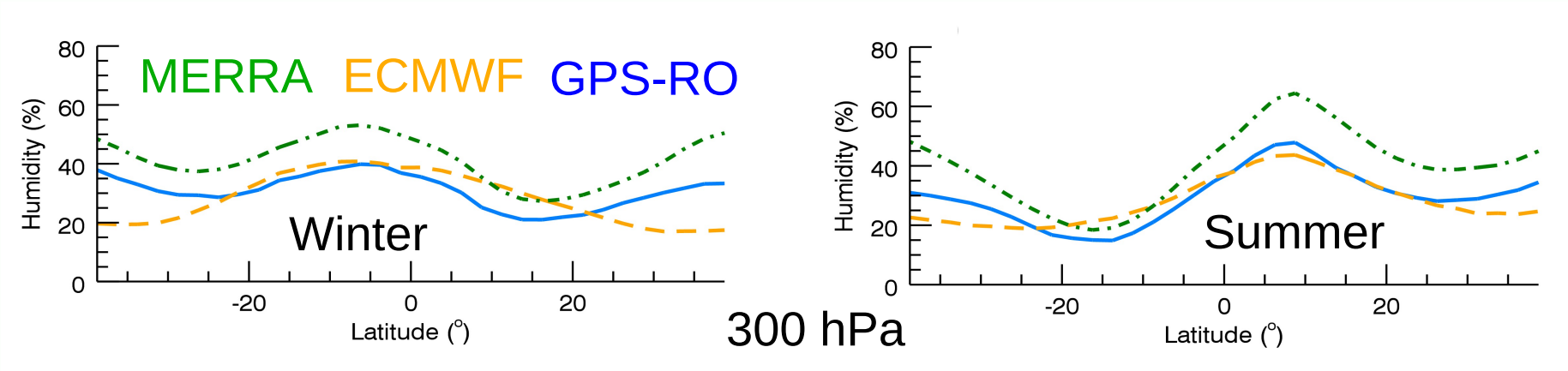
Uncertainties in our knowledge of the tropospheric humidity

- 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

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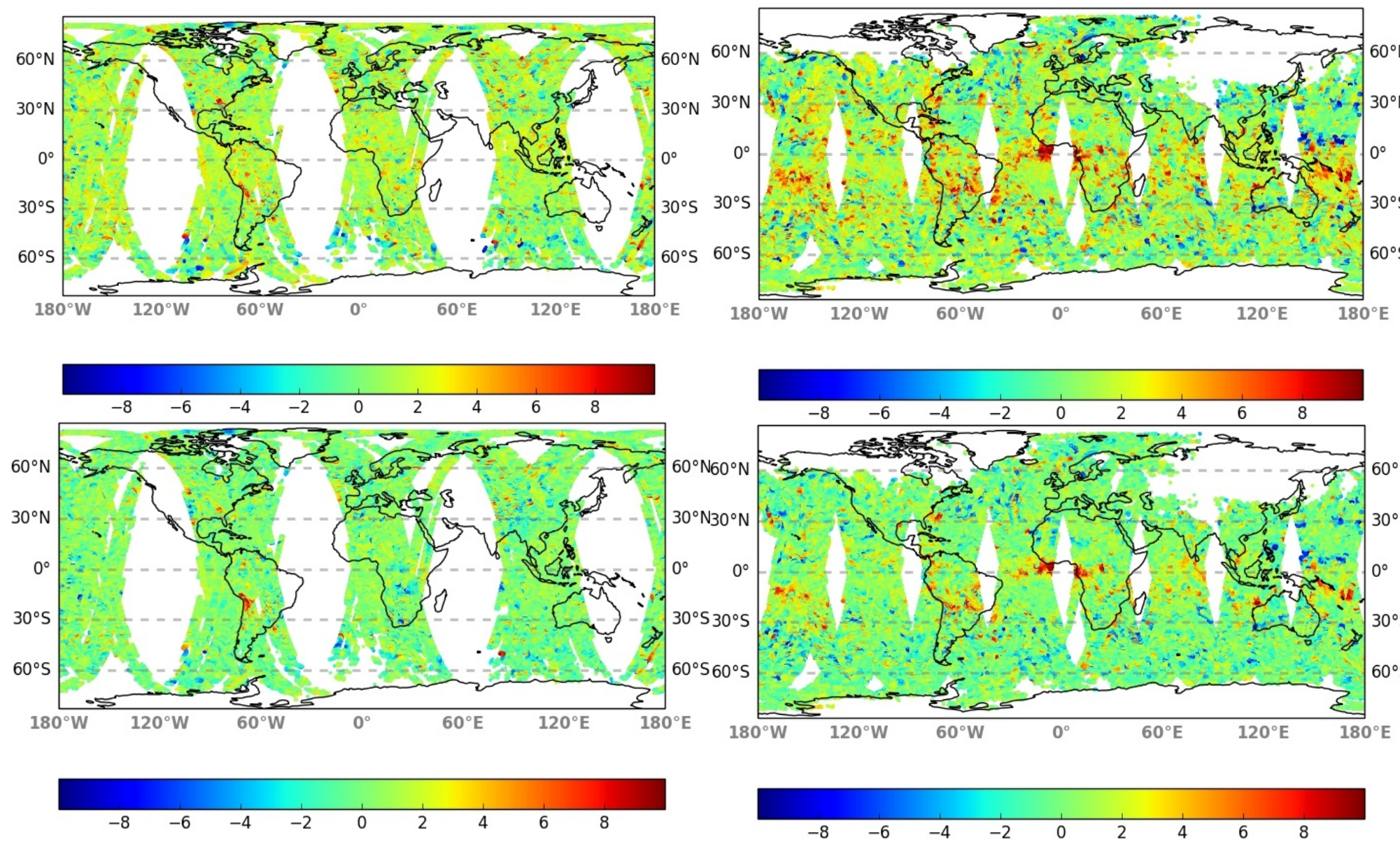
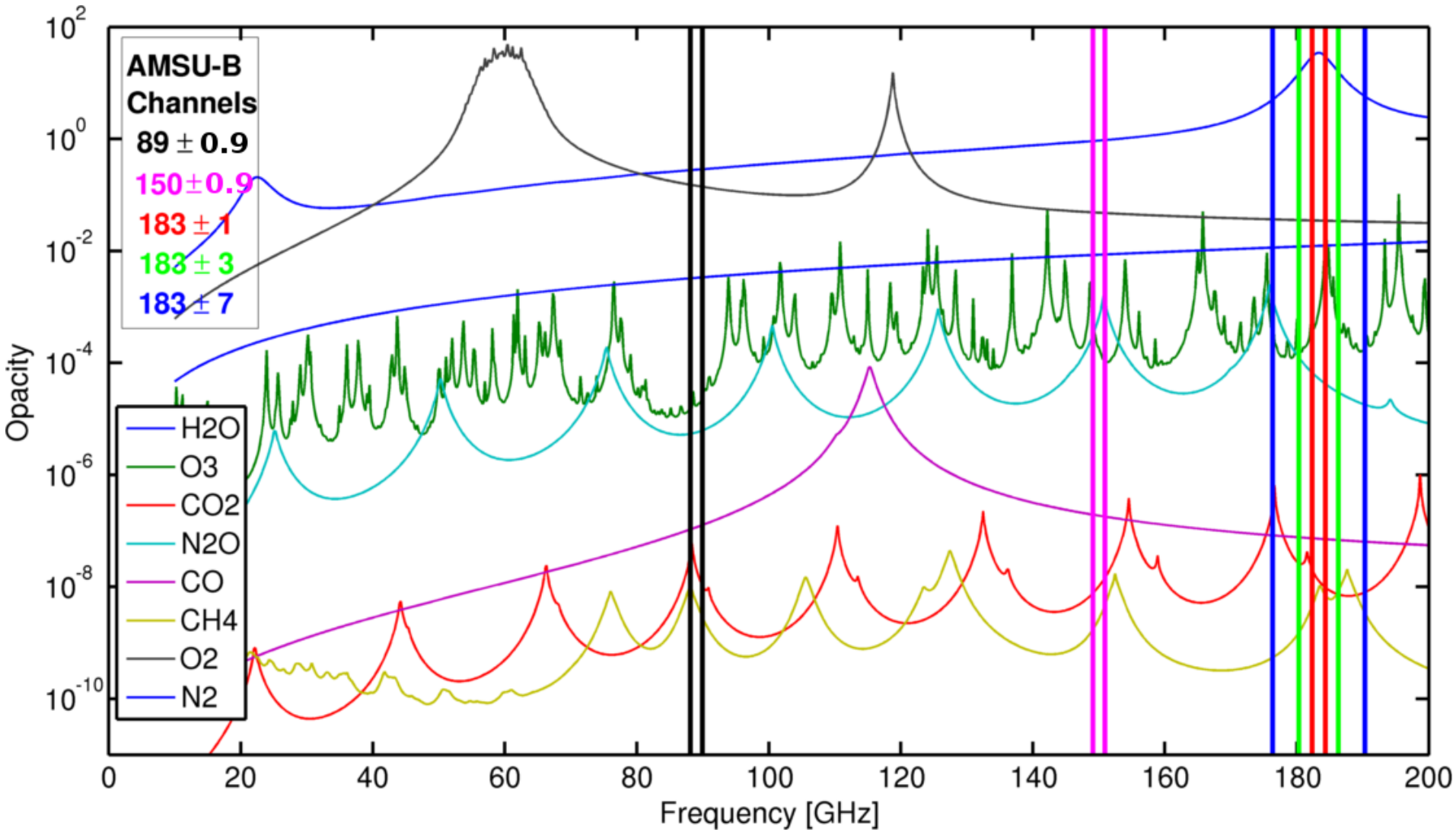


Left: Era Interim, Right: MERRA-2; Top: MHS Chan 3, Bottom: MHS Chan 4

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

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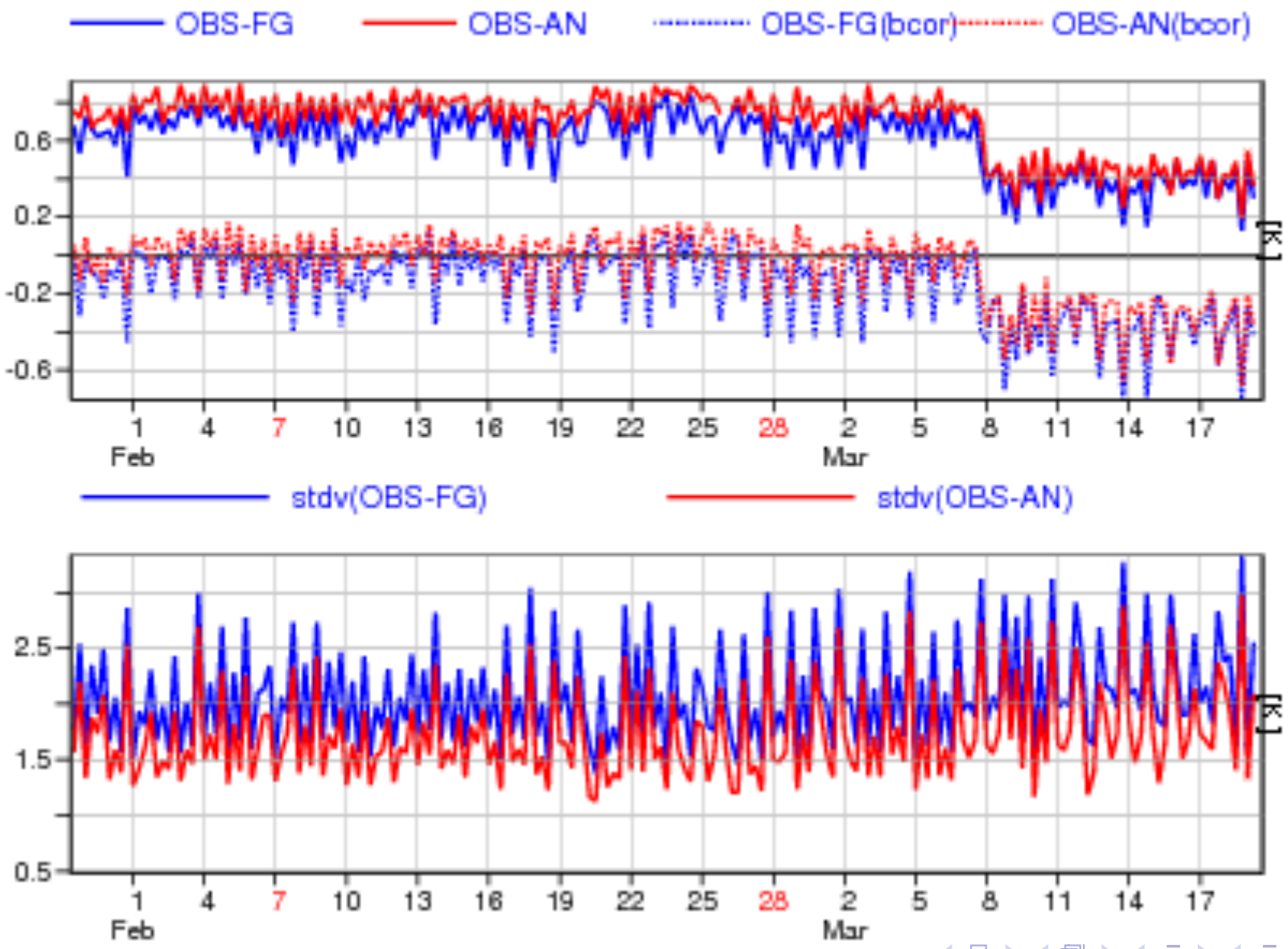
Difference between obs and ana/fg MHS MetOp-A Observations



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_L1279 / 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 / T_L255 to T_L255 / T_L319 / T_L399, respectively.

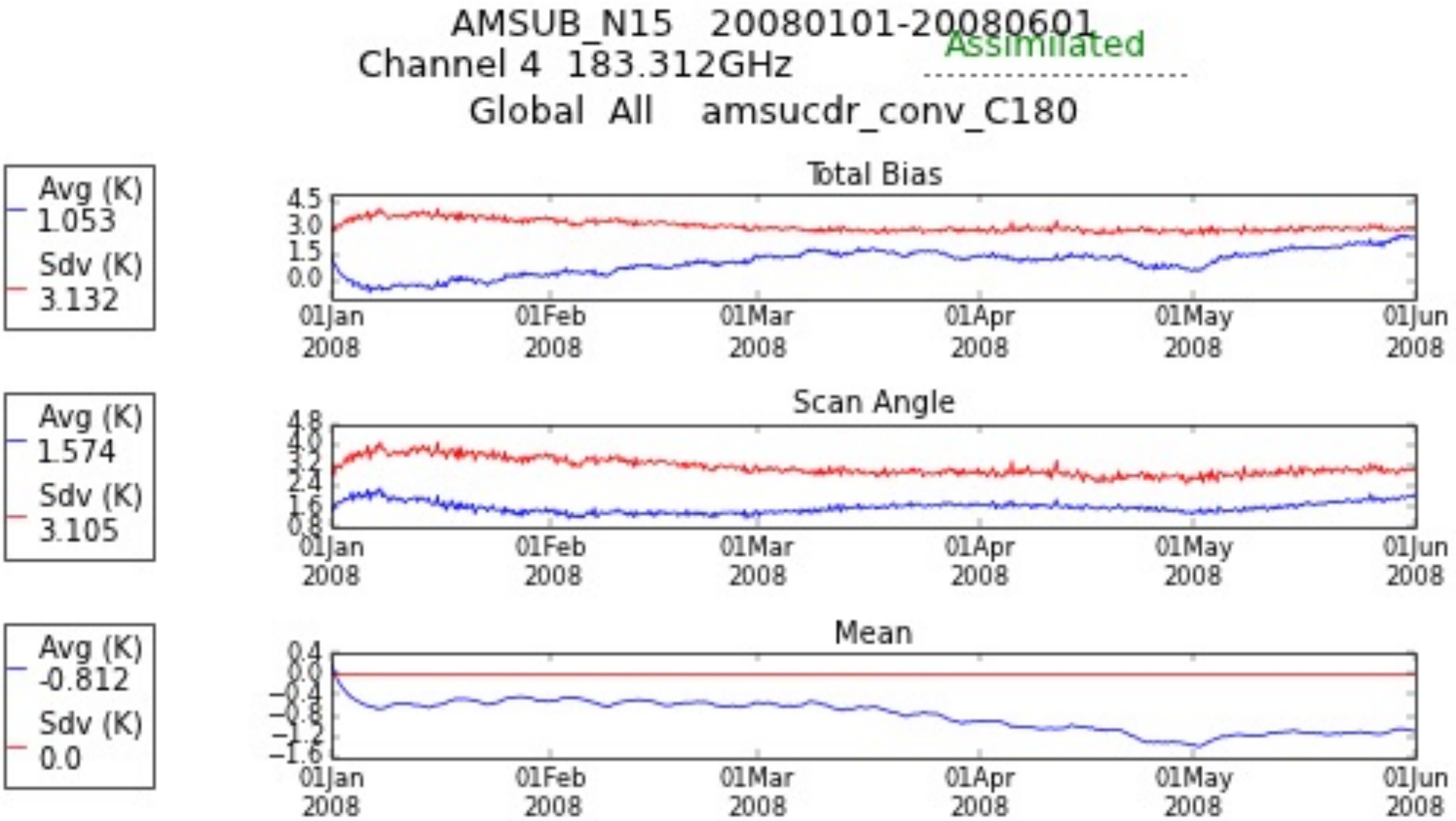
These upgrades

- **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.

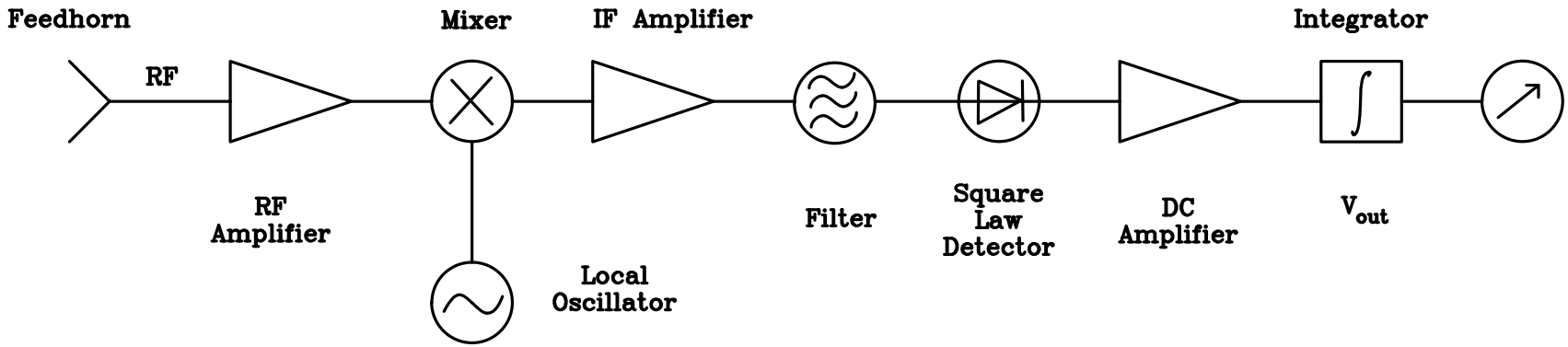
During the Release Candidate test phase forecast data will be made available close to real time via

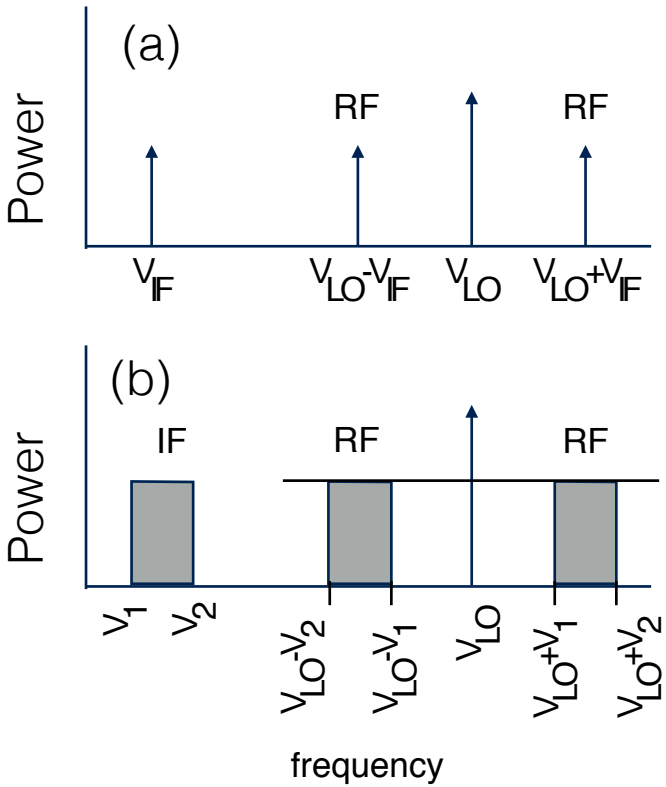
- product dissemination
- ecCharts
- MARS

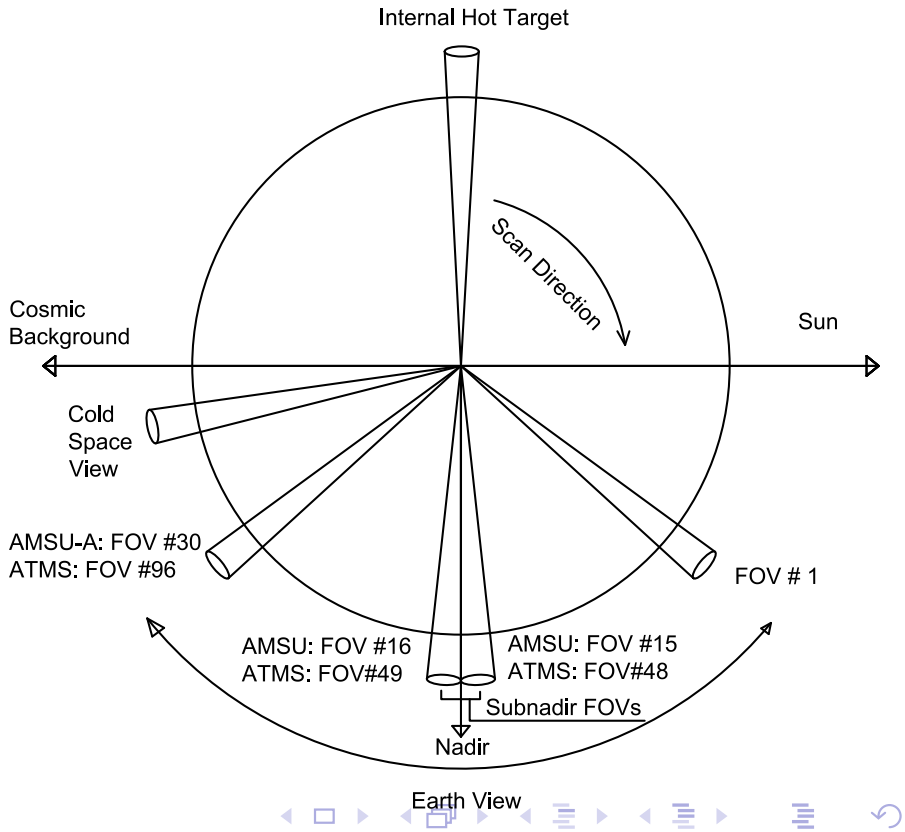
Variational Bias Correction



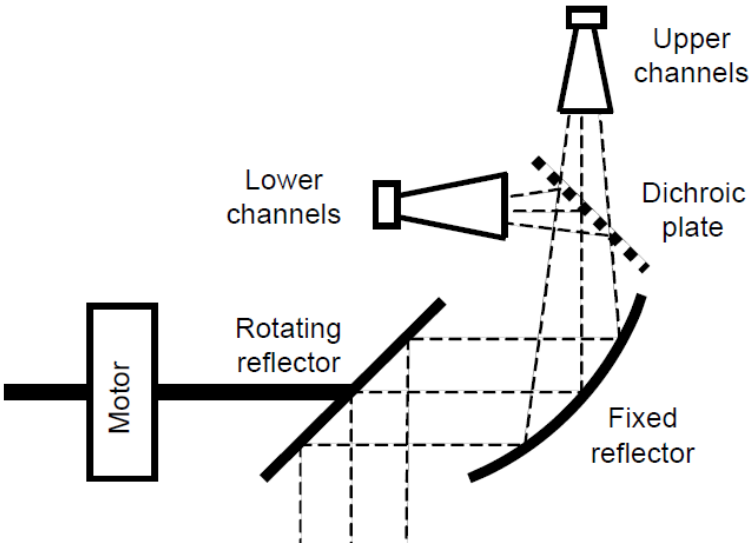
Heterodyne MW Receivers

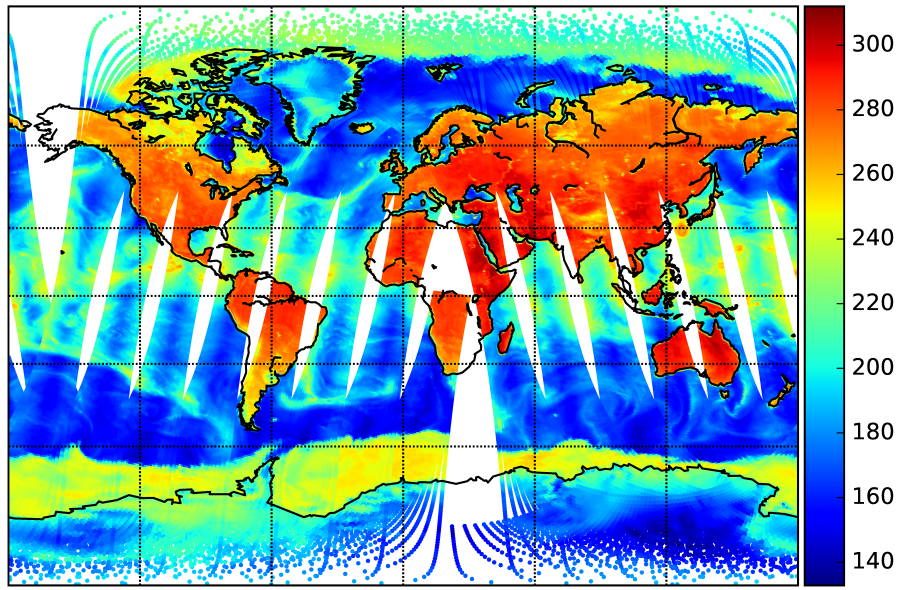


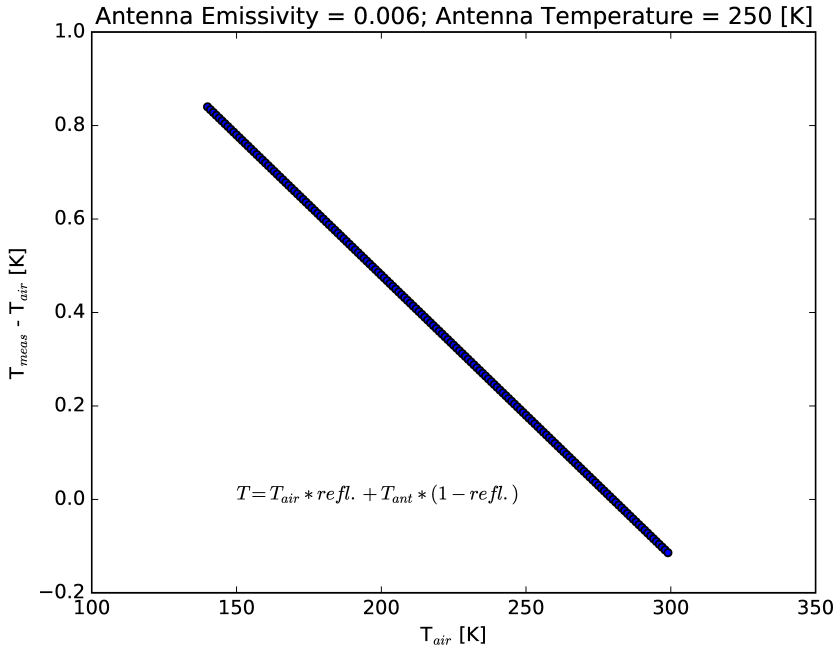


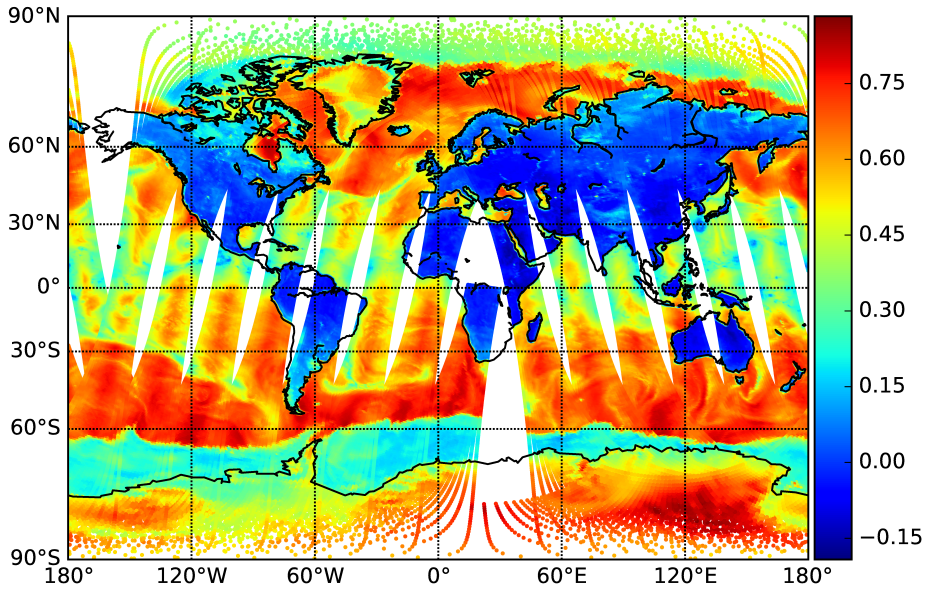


Uncertainty in Antenna Emissivity

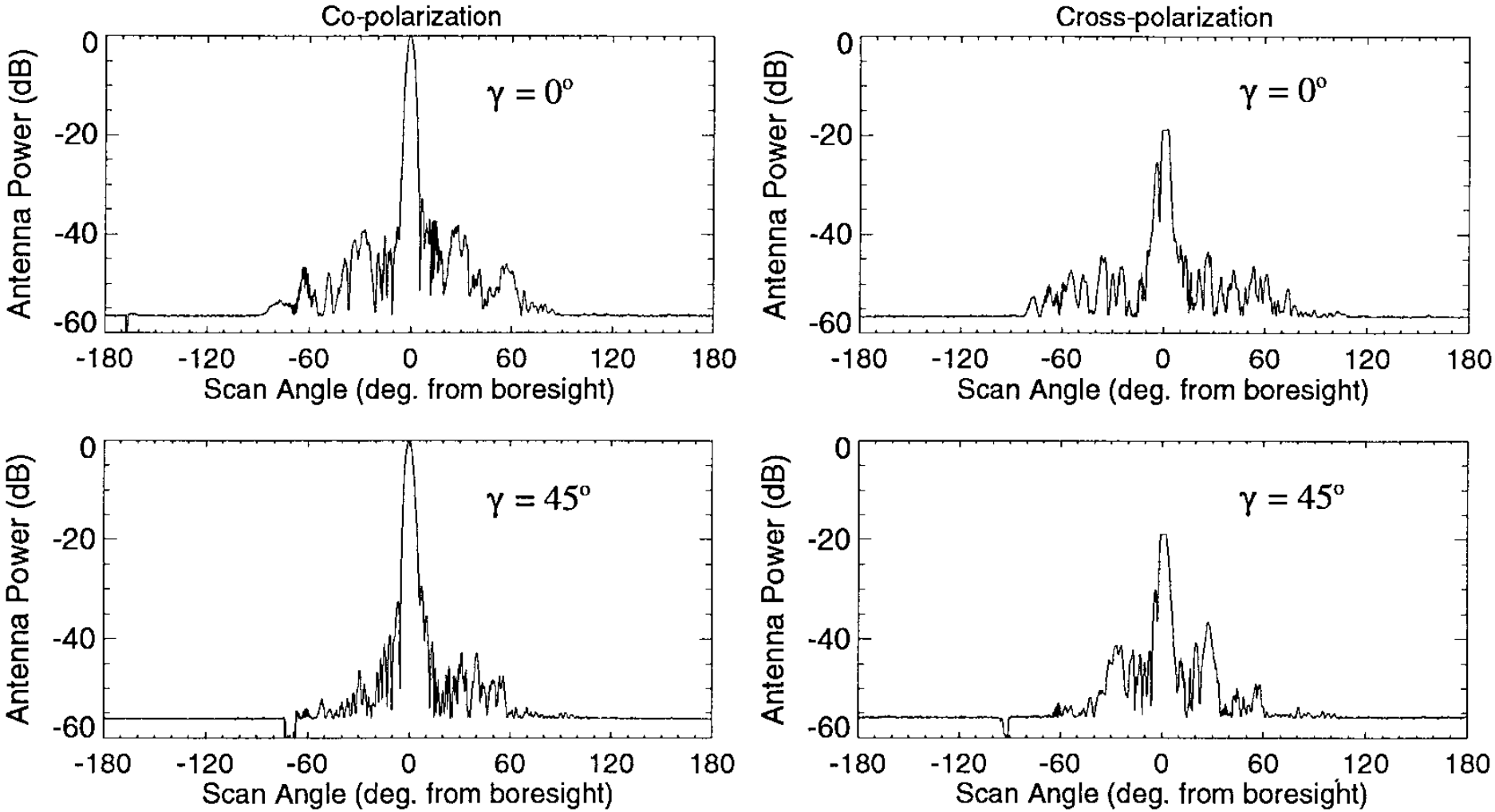








Antenna Pattern Correction



Hewison and Saunders 1996

Antenna Pattern Correction

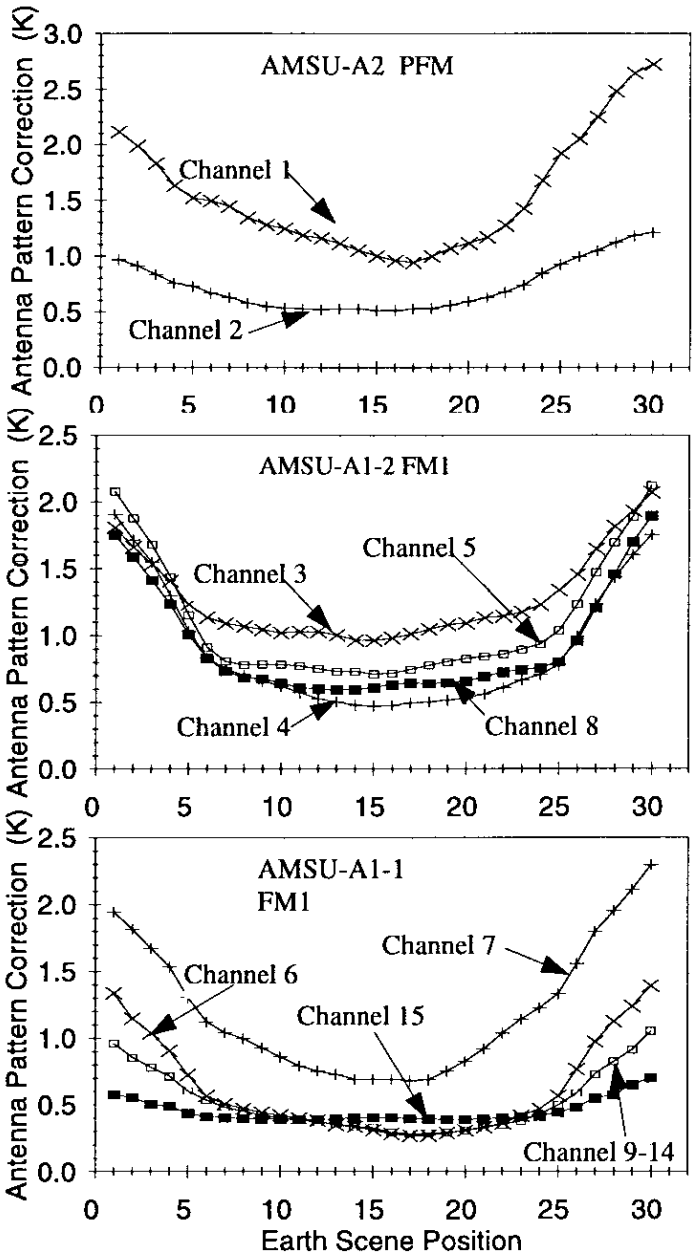
Hewison and Saunders 1996 for AMSU-B, Mo 1999 for AMSU-A, EUMETSAT for MHS

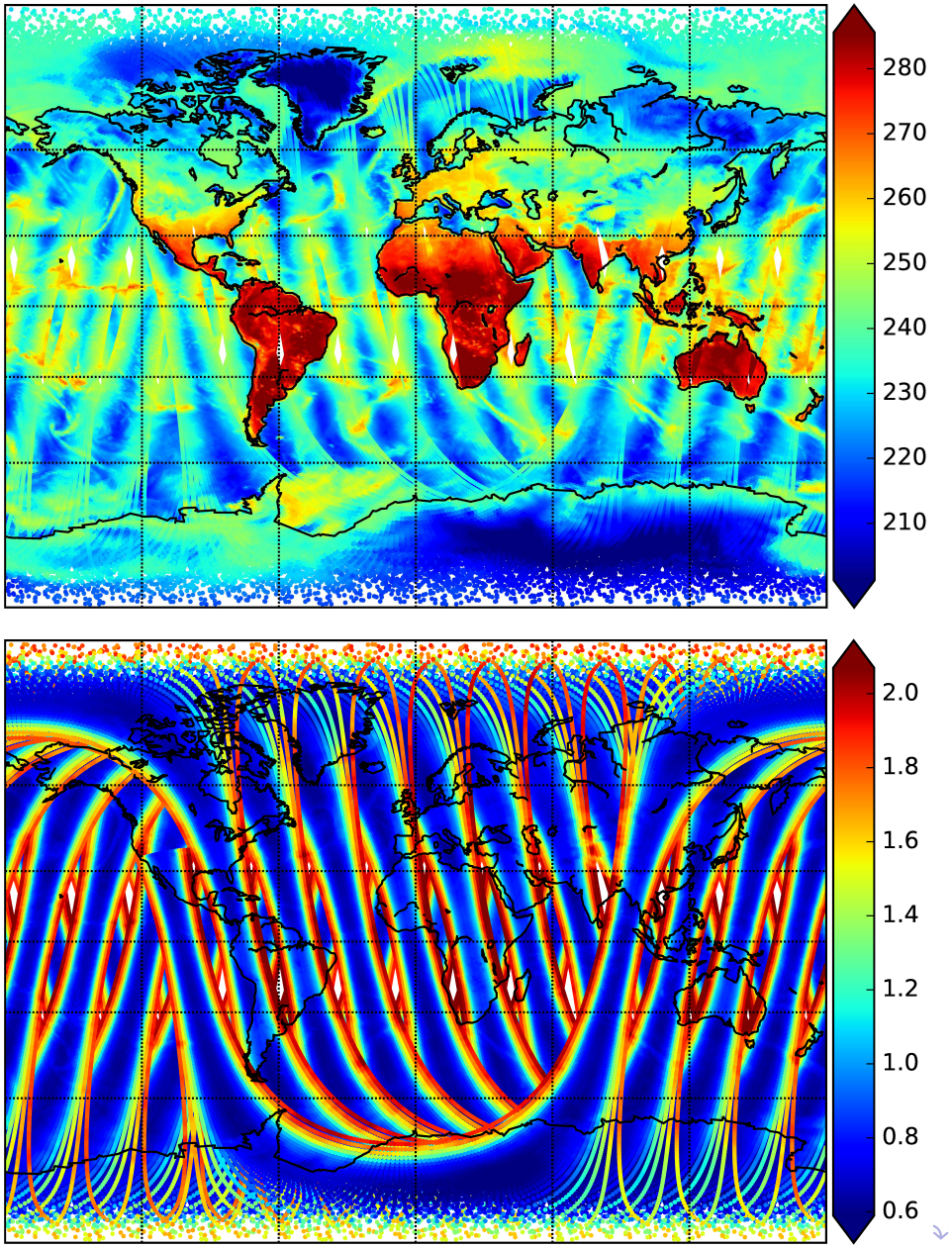
$T_A = \frac{1}{N_\eta}[f_e \bar{T}_e + f_c \bar{T}_c + \eta f_s \bar{T}_s]$

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.

Beam Postion	Scan Angle β	Ch. 1			Ch. 2			Ch. 3			Ch. 4			Ch. 5		
		fe (%)	fsat (%)	fc (%)	fe (%)	fsat (%)	fc (%)	fe (%)	fsat (%)	fc (%)	fe (%)	fsat (%)	fc (%)	fe (%)	fsat (%)	fc (%)
1	48.33	98.70	0.37	0.93	99.38	0.19	0.42	98.54	0.67	0.79	98.89	0.27	0.84	98.81	0.31	0.88
3	41.67	98.89	0.31	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
5	35.00	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
7	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
9	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
11	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
13	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
15	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
16	-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
18	-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
20	-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
22	-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
24	-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
26	-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
28	-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

Impact of APC on AMSU-A 50GHz



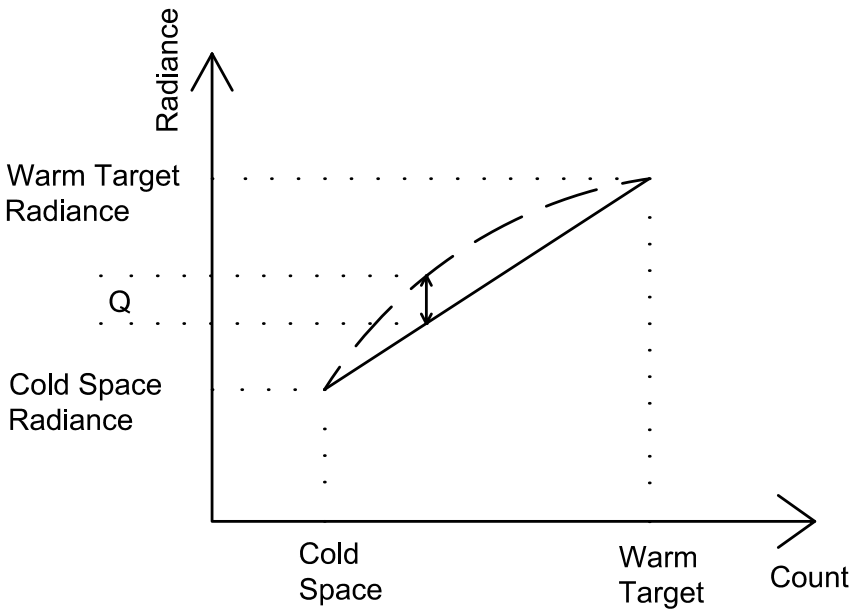


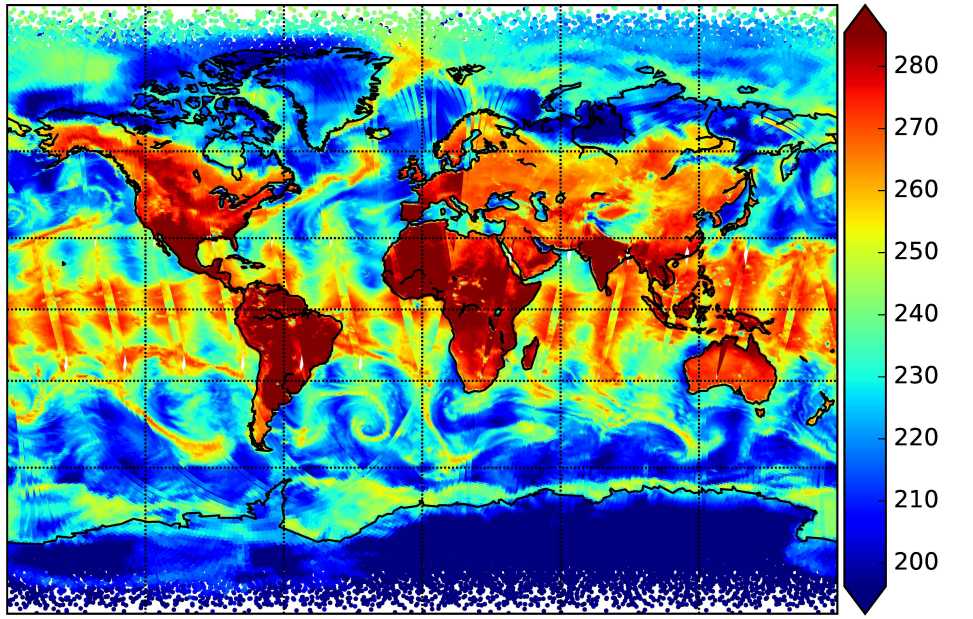
Non-linearity in Calibration

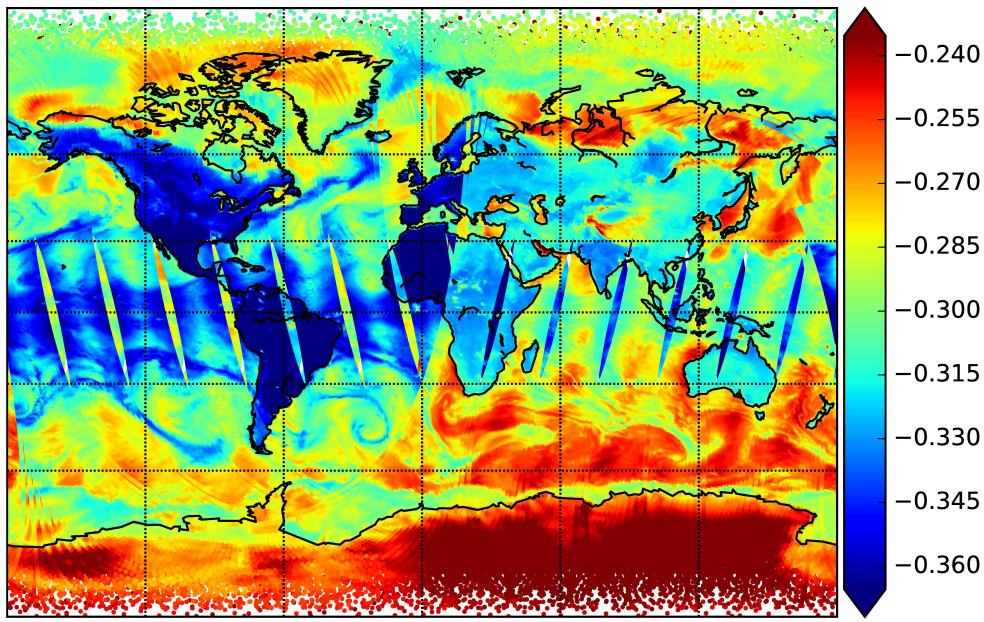
$$I_E = \frac{C_E - C_H}{C_H - C_S}(I_H - I_S) + I_H + Q$$

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

$$G = \frac{C_H - C_S}{I_H - I_S}, \qquad \frac{count}{mW.m^{-2}.sr^{-1}.Hz^{-1}}$$







Level 1b MHS/AMSU-B

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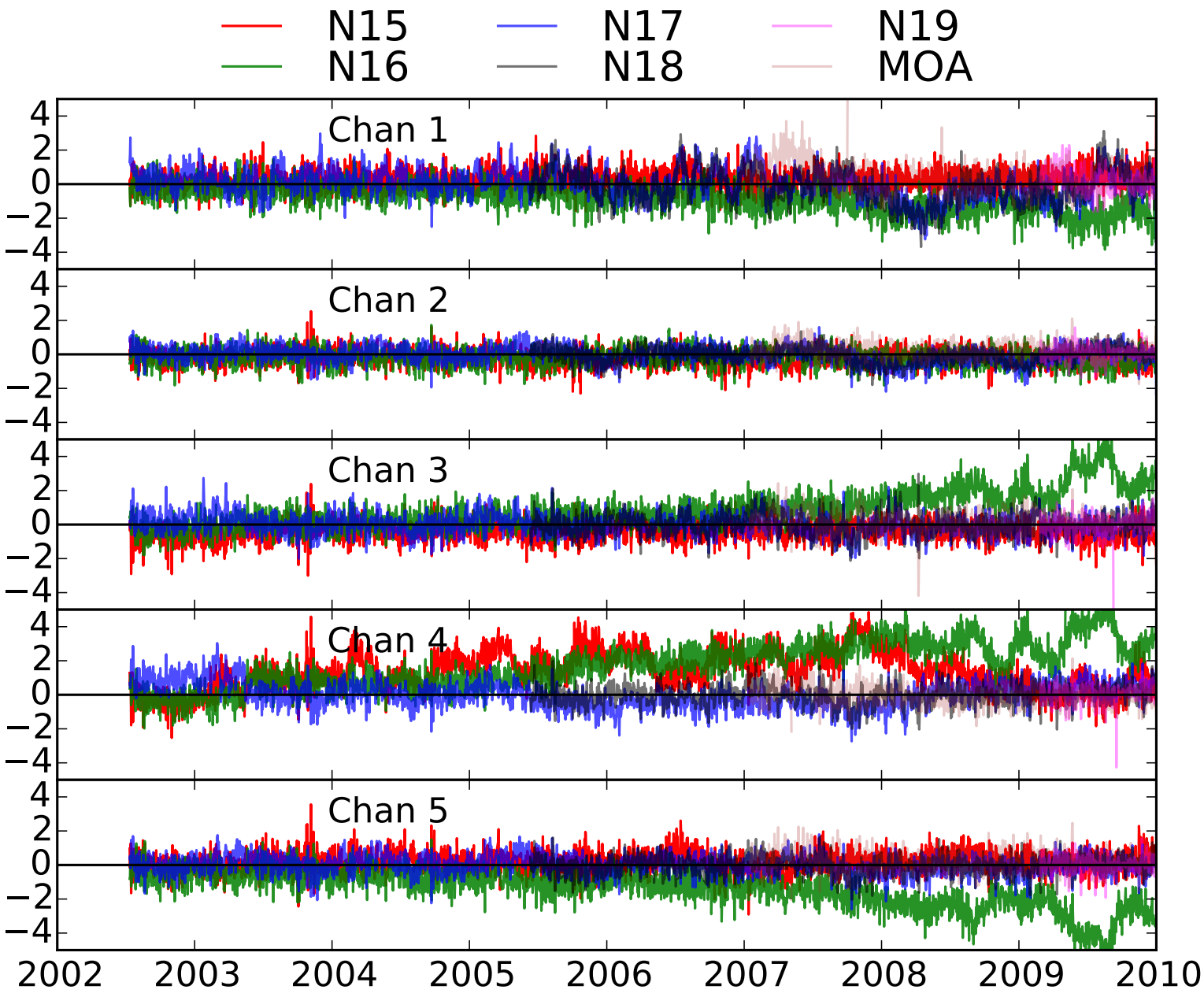

Corrected MHS/AMSU-B

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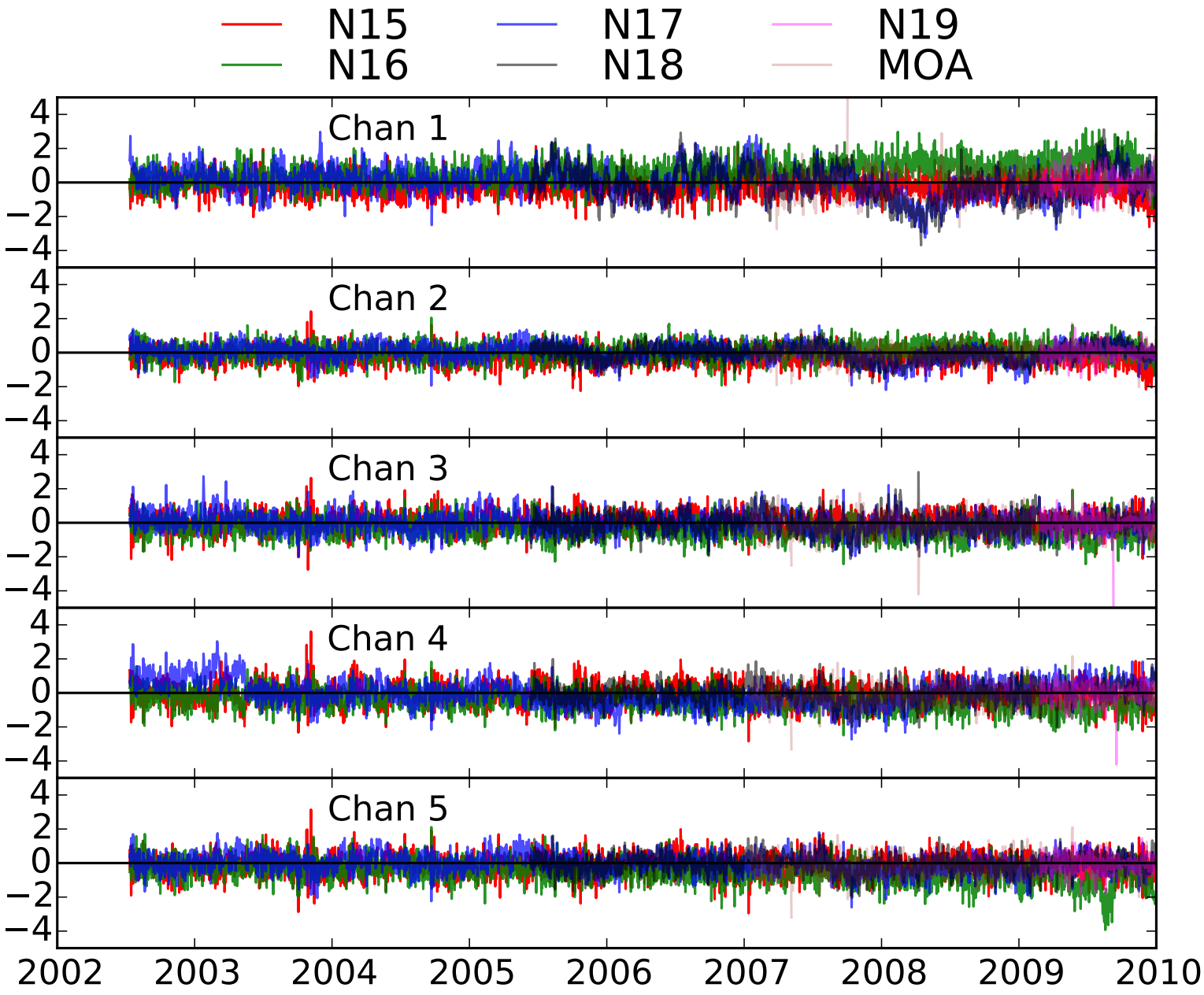

Spatial Distribution of Error Correction

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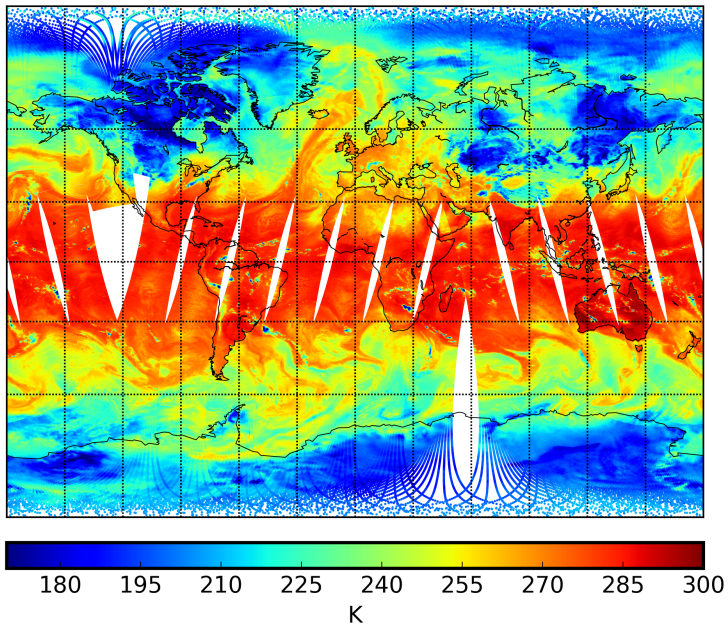
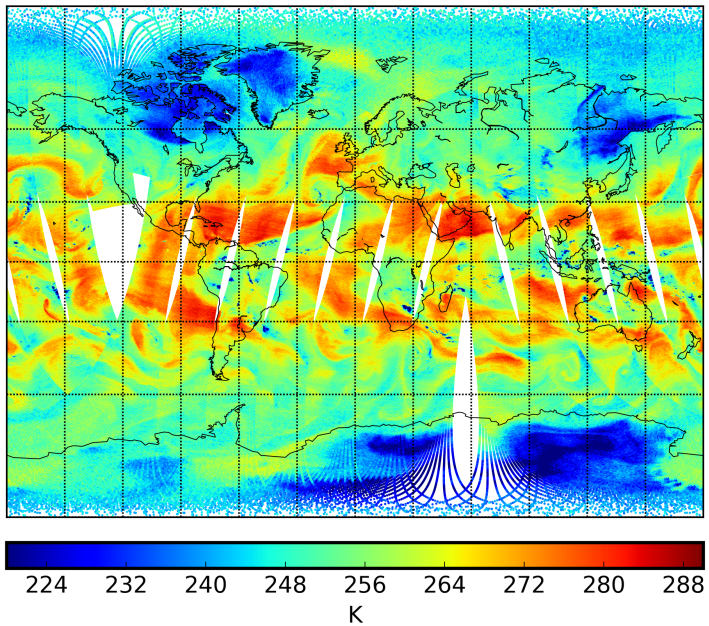
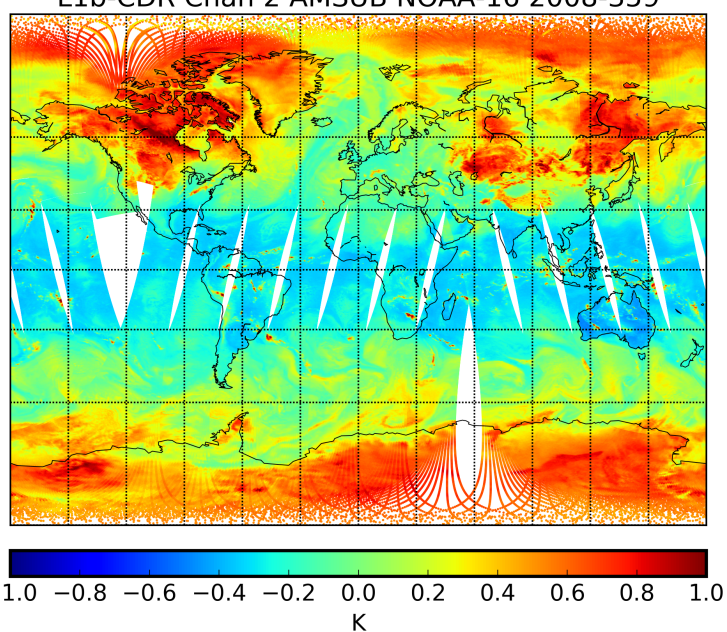
L1b Chan 2 AMSUB NOAA-16 2008-359



L1b Chan 4 AMSUB NOAA-16 2008-359



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



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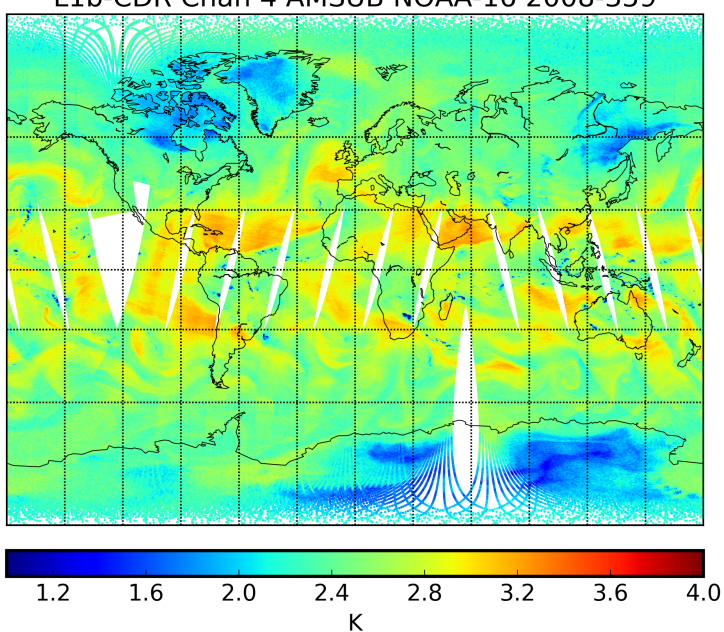

Conclusions

- 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!