



# Bias correction of satellite data at the Met Office

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in data assimilation, 9<sup>th</sup> November 2005

# Contents

Instruments to be corrected

Modelling the bias

Computing coefficients

Example of bias characteristics

Monitoring – NWP SAF web pages

Future improvements

Conclusions

# Satellite data types for bias correction



## Operational now:

- AMSU-A, AMSU-B, MHS
- HIRS (not currently assimilated)
- AIRS
- SSM/I
- AMVs (assimilated but not bias corrected)

## Future:

- SSMIS
- IASI
- SEVIRI

## Sources of error (discussed in other talks):

- Instrumental (e.g. antenna sidelobes viewing space)
- Radiative transfer
- NWP model errors
- For AMVs – cloud height estimate

NWP analysis will be influenced by:

1. Radiosonde profiles and other observations
2. Satellite radiances
3. Requirement for internal dynamical consistency

**Strategy:**

- Use remainder of Global Observing System (e.g. radiosondes) as “truth”
- Adjust satellite radiances to minimise global  $\Sigma(C-B)^2$   
(C = corrected radiance, B = forward model radiance from Background)

This will work provided there is a reasonable geographic coverage of non-satellite data.

Express the brightness temperature correction in terms of an “air mass” correction and a “scan” correction

For channel  $i$ , scan position  $s$ ,

$$\Delta T_{i,s} = \sum_j a_{i,j} p_j + c_{i,s}$$

Where we have air mass predictors  $p_j$ , with coefficients  $a_{i,j}$ , and global scan dependent constants  $c_{i,s}$ .

Predictors can be **observation based**

- e.g. observed brightness temp for AMSU channels 5 and 9, as used at Met Office prior to May 2004

or **model based** (Harris & Kelly).

## Operationally (ATOVS + AIRS):

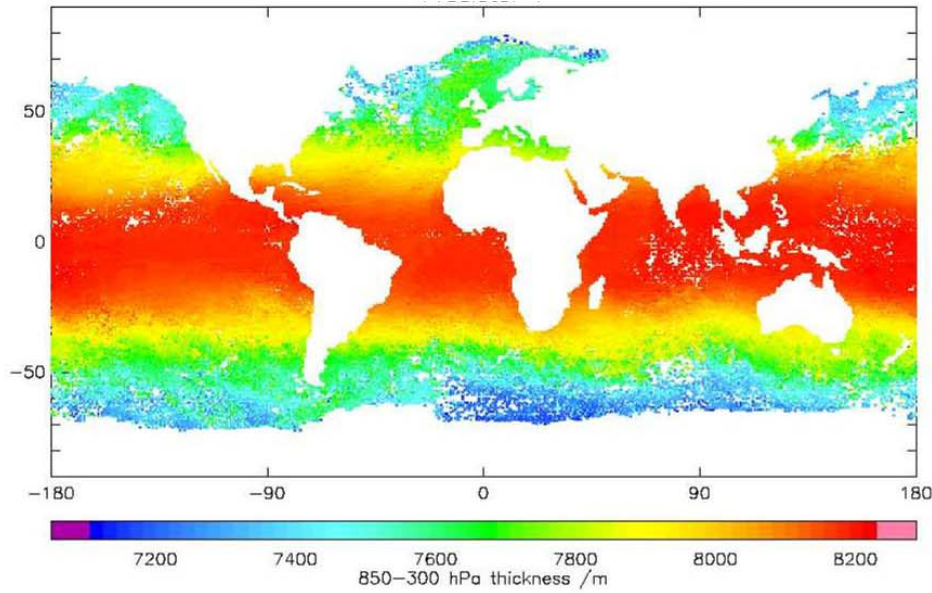
1. Stratospheric thickness, 200-50 hPa
2. Tropospheric thickness, 850-300 hPa

## Other predictors considered:

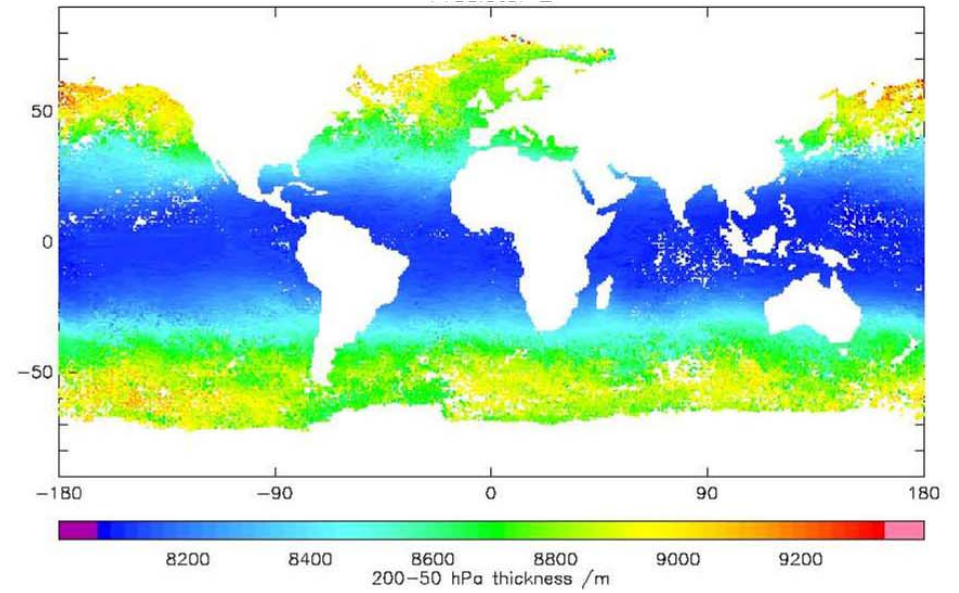
3. Skin temperature (difficult over land)
4. Total column water vapour (could interfere with real signal)
5. Background brightness temperature, per channel (gave a degradation in trials)
6. Temperature lapse weight convolved with weighting function per channel (to correct RT errors – but requires some extra computation)

# Predictors

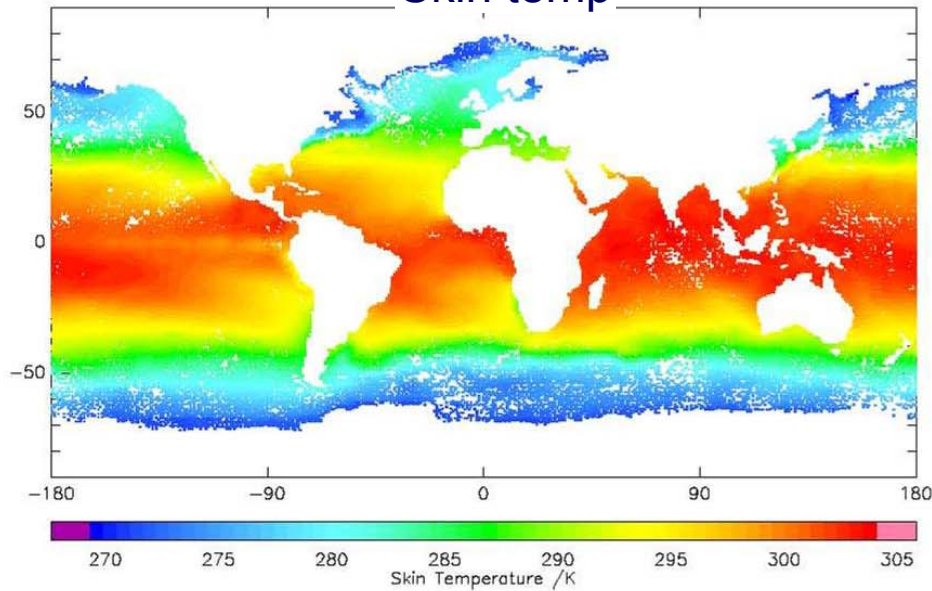
## 200-50 hPa thickness



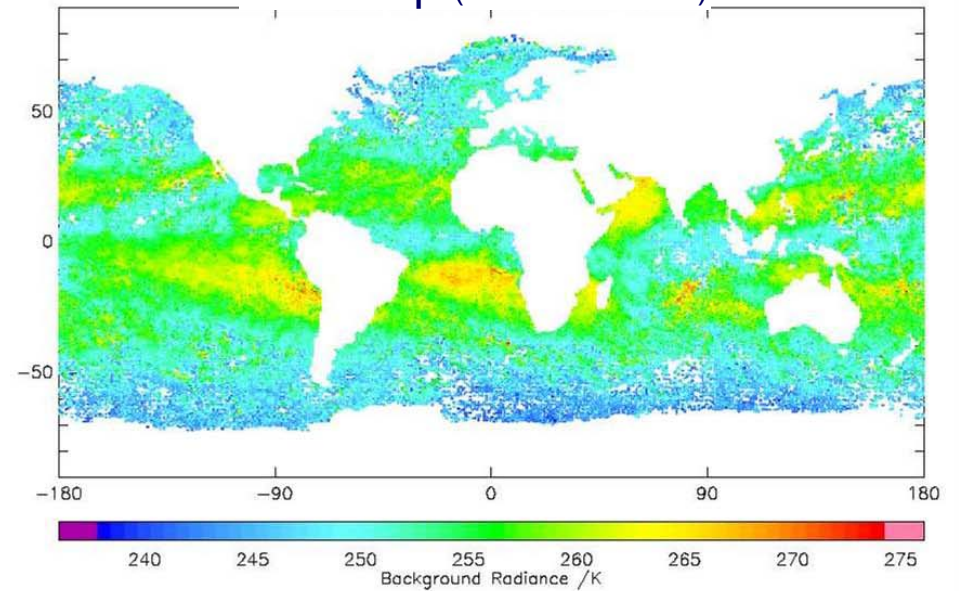
## 850-300 hPa thickness



## Skin temp



## Br. Temp (AIRS chan 1574)





# Computation of bias coefficients



Solve simultaneously for air mass and scan coeffs – linear regression

Air mass coefficients:

$$\mathbf{a}_i = \begin{pmatrix} \overline{\mathbf{p}\mathbf{p}^T} - \overline{\mathbf{p}} \overline{\mathbf{p}^T} & \overline{\mathbf{p}y_i} - \overline{\mathbf{p}} \overline{y_i} \end{pmatrix}^{-1} \begin{pmatrix} \overline{\mathbf{p}y_i} - \overline{\mathbf{p}} \overline{y_i} \end{pmatrix}$$

where  $y_i$  is O-B for channel  $i$ ,  $\mathbf{p}$  are the predictors (column vector), and the means are global

Scan coefficients for scan position  $s$ :

$$c_{i,s} = \overline{y_{i,s}} - \mathbf{a}_i^T \overline{\mathbf{p}_s}$$

where  $\mathbf{p}_s$  are predictors for scan position  $s$

- *NB the operational thickness predictors do not have a scan dependence, but other choices could do.*



# Accumulating statistics



- Use 'on the fly' method – “Bstats”
- Accumulate statistics for each channel, spot and latitude band
  - For ATOVS - 40 channels, 56 spots
  - 5 bands: 90-60S, 60-30S, 30S-30N, 30-60N, 60-90N
  - 3 surfaces: land, sea, sea-ice
- Each model run, update file containing
  - Number of obs 40×56×5×3
  - Mean O-B 40×56×5×3
  - Mean (O-B)<sup>2</sup> 40×56×5×3
  - Mean P×(O-B) 40×56×5×3×2
  - Mean P (40×)56×5×3×2
  - Mean P×P (40×)56×5×3×2×2
- Before computing coefs, weight stats to give effective no of obs in each band = 1 : 1 : 1.5 : 1 : 1
- Alternative to Bstats is to archive all required quantities for all obs (currently used for AIRS).

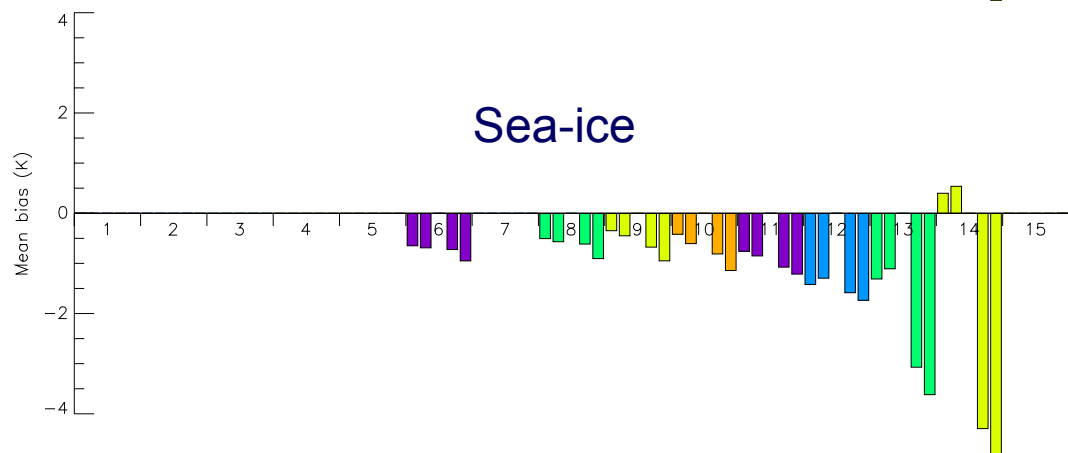
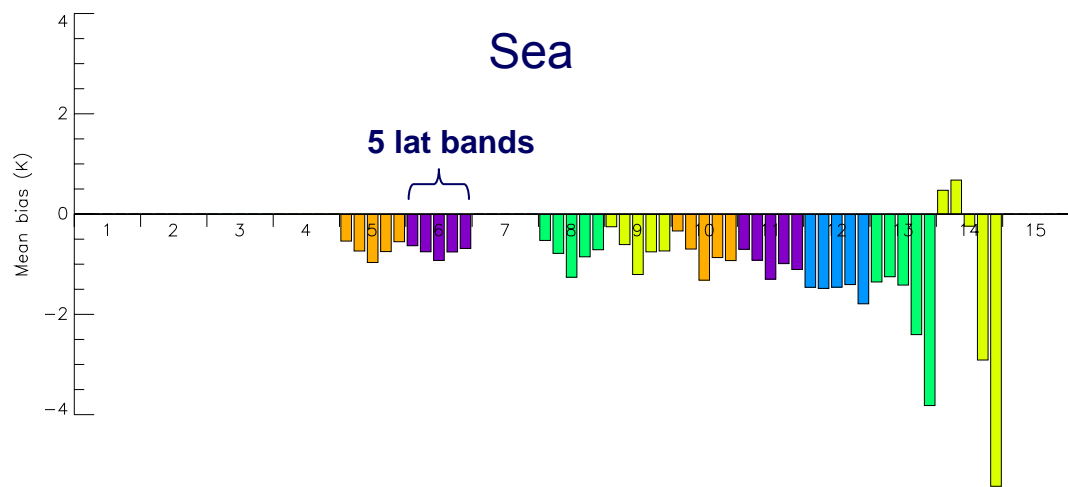
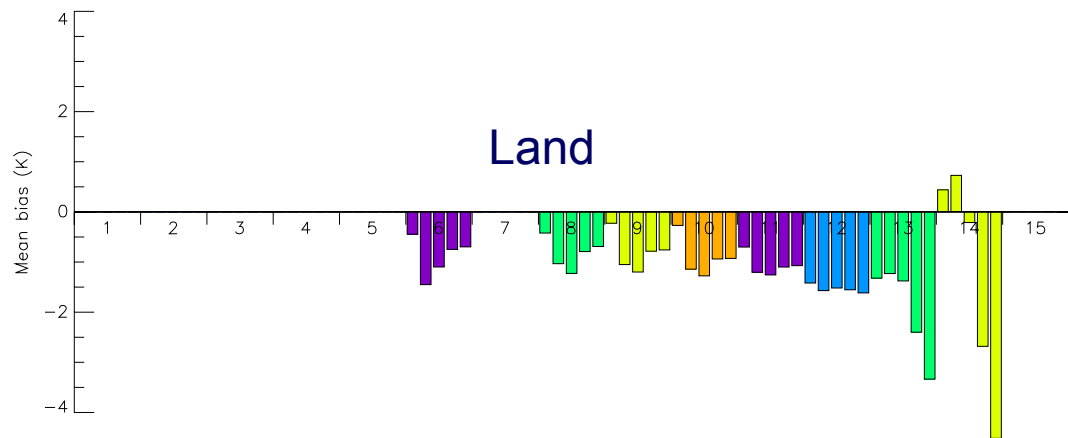
# Accumulating statistics (2)



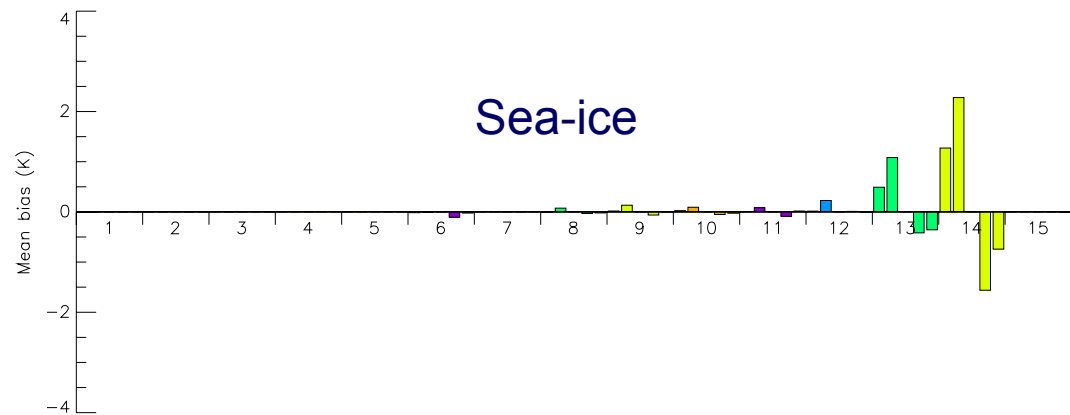
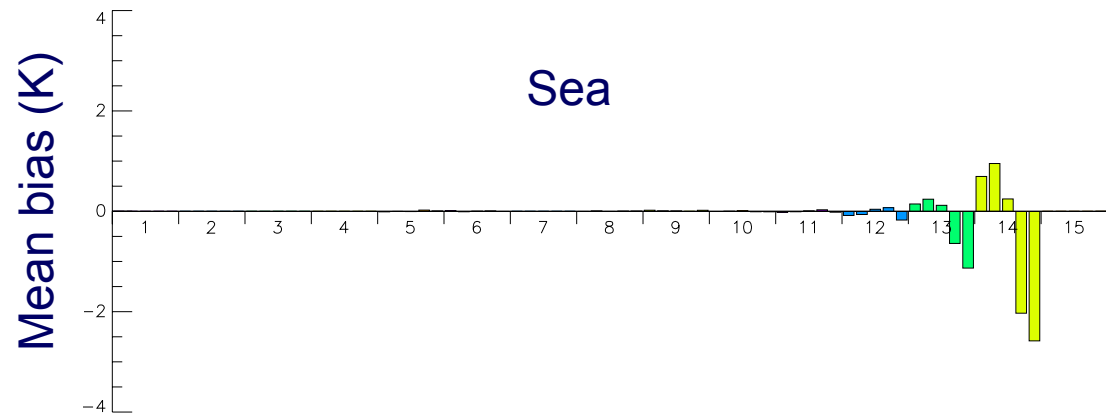
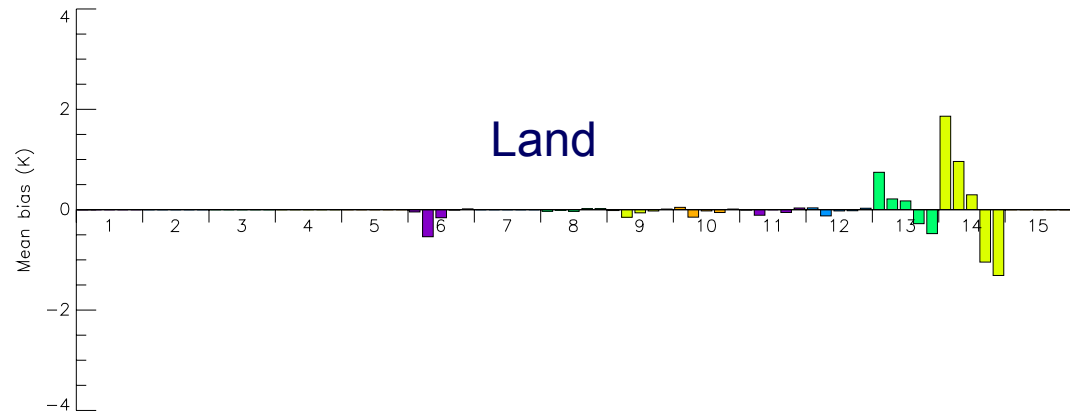
- Which observations?
  - Global (no sonde mask, but some centres use one)
  - Use all channels/obs that are used in 1D-Var – plus some extra Q/C
  - Land, sea and sea-ice, as appropriate for each channel, e.g.
    - AMSU 1-3, 15-17 not used at all
    - AMSU 4, 5, 18-20 only used over sea
    - In rain - stratospheric channels only
  - Include high land (old predictors did not work over high land)
  
- Also maintain 'Mstats' file – for monitoring. Includes all observations for all channels, as a function of lat/lon. Various cloud categories.

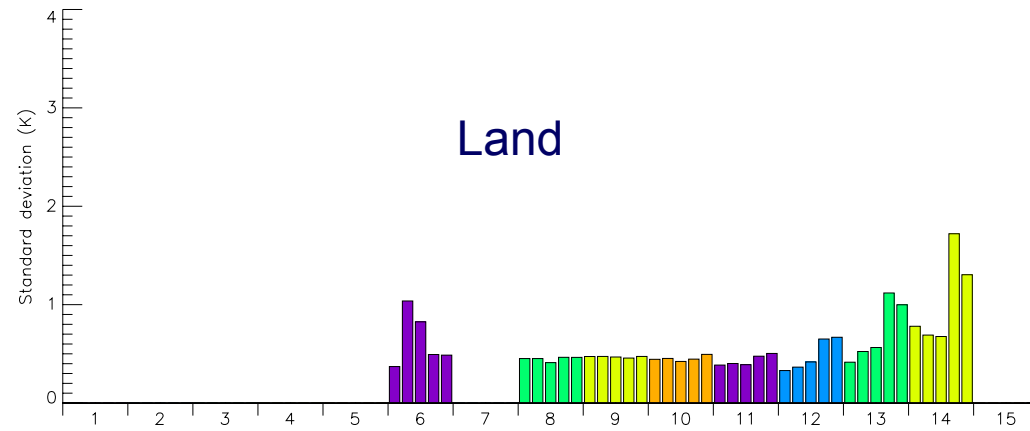
# Example -Aqua

Uncorrected

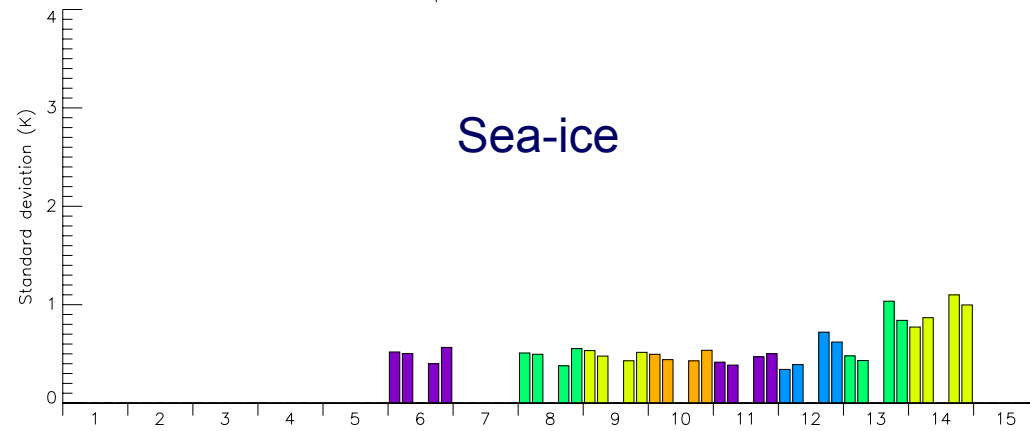
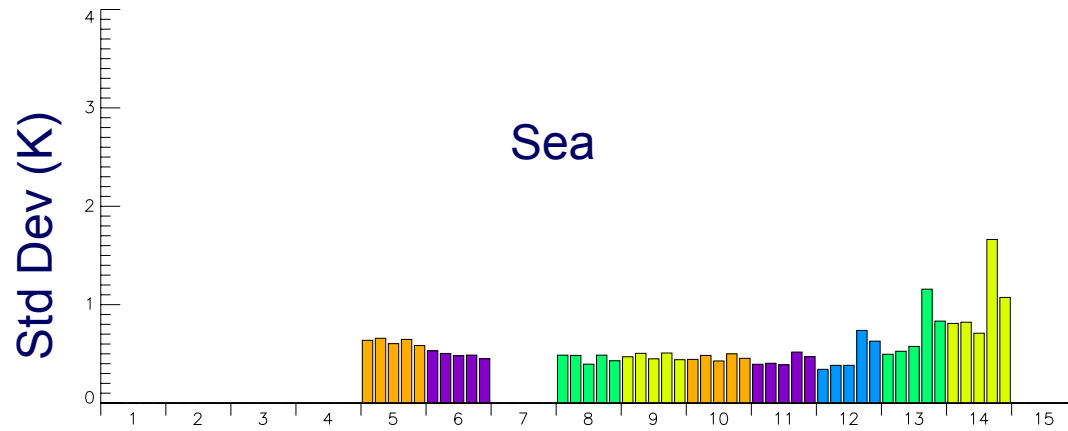


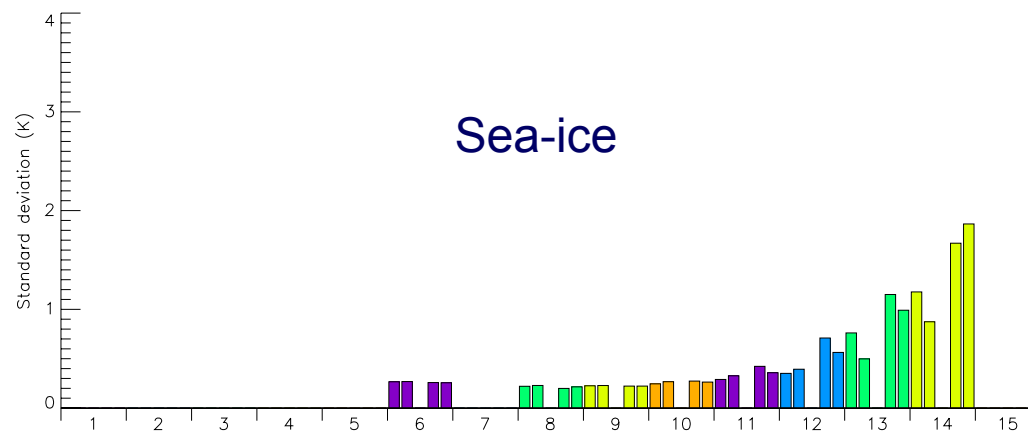
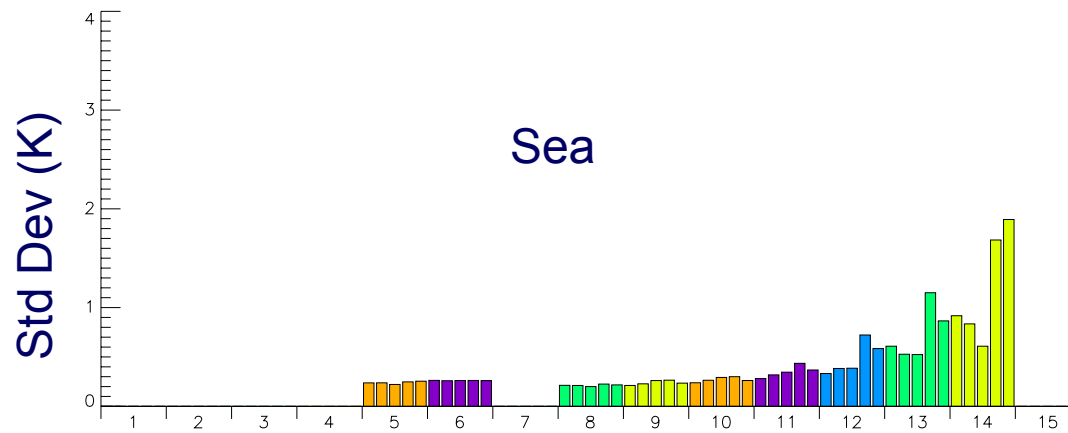
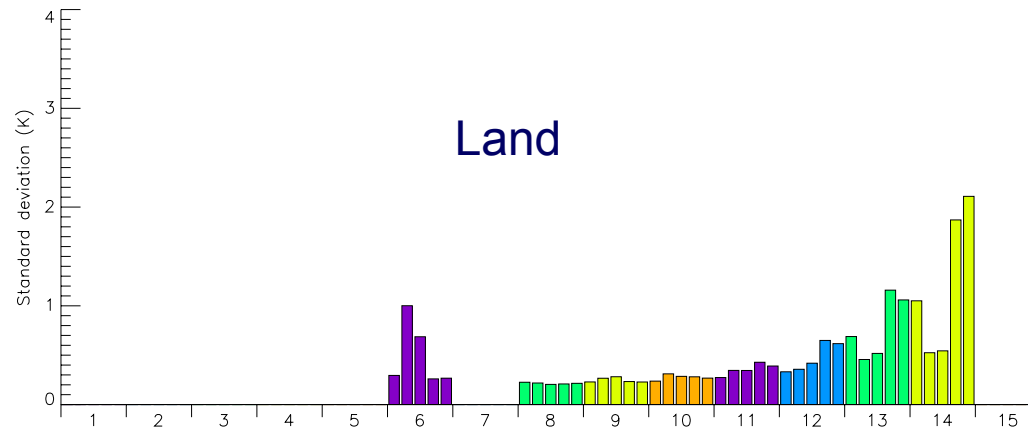
Corrected  
2 air mass  
Predictors +  
Scan term





Uncorrected

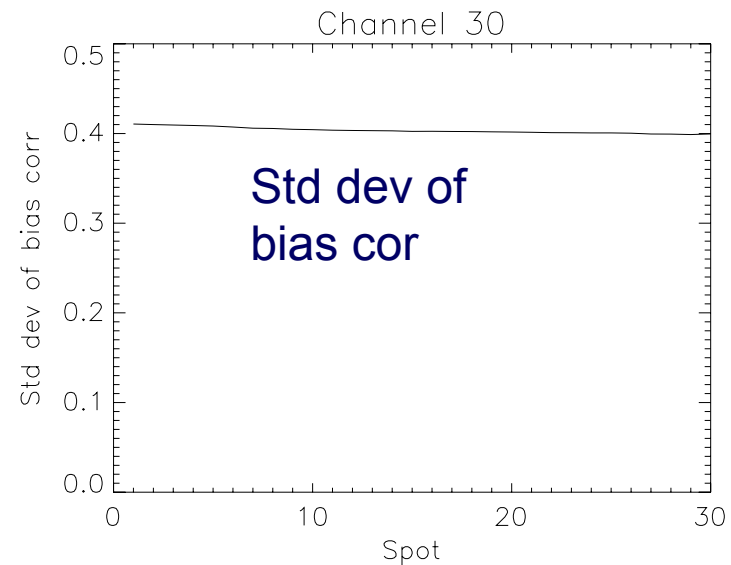
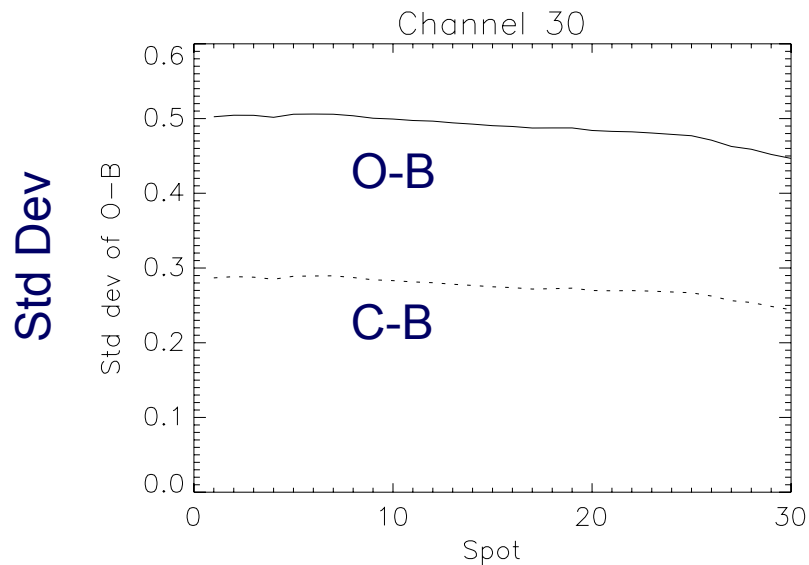
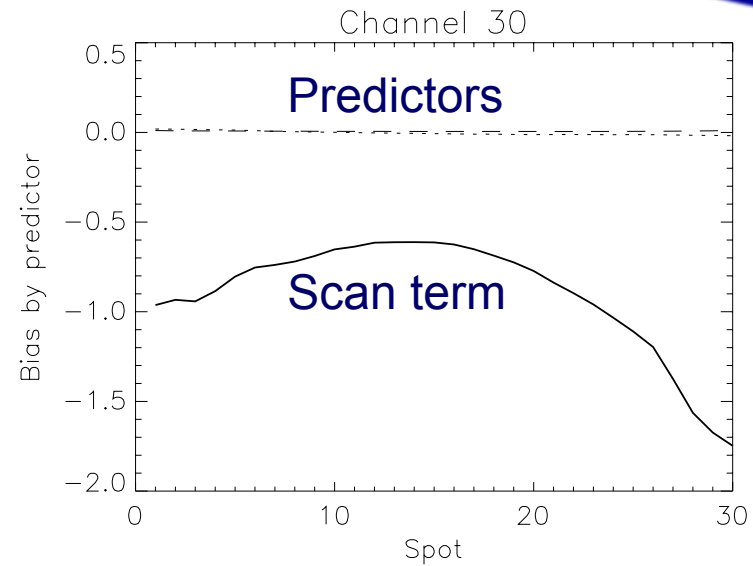
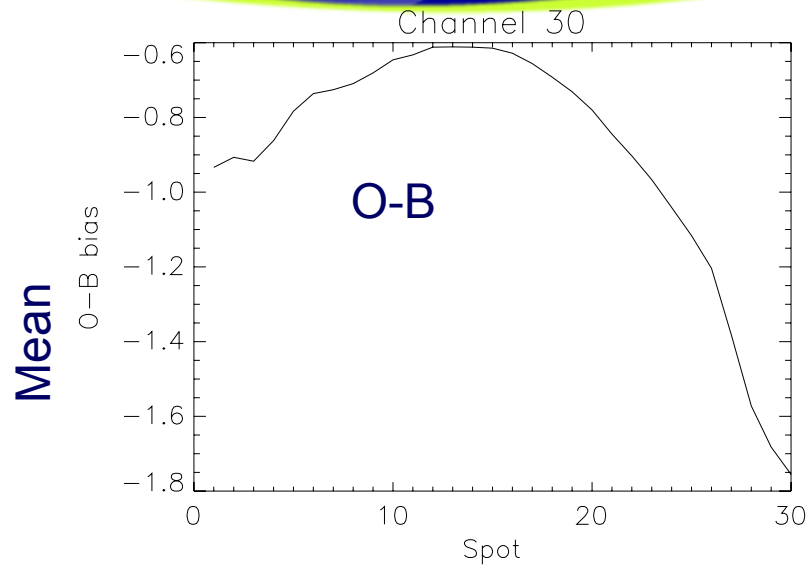




Corrected

2 air mass  
Predictors +  
Scan term

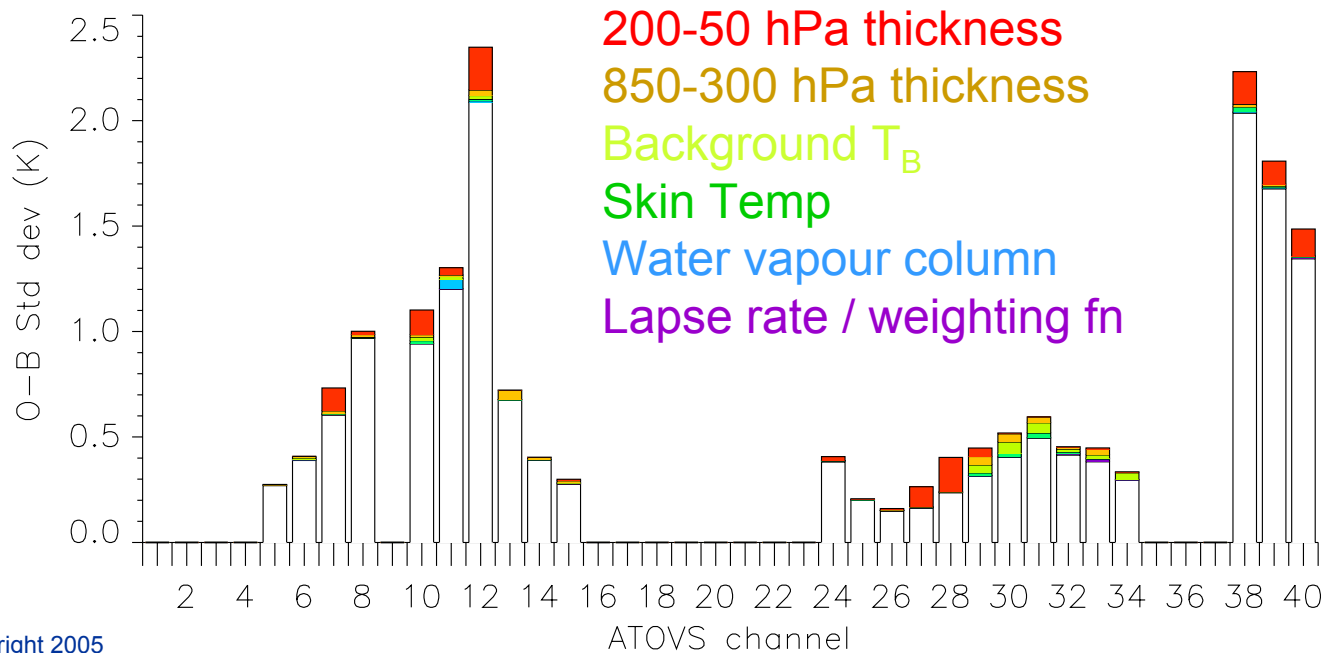
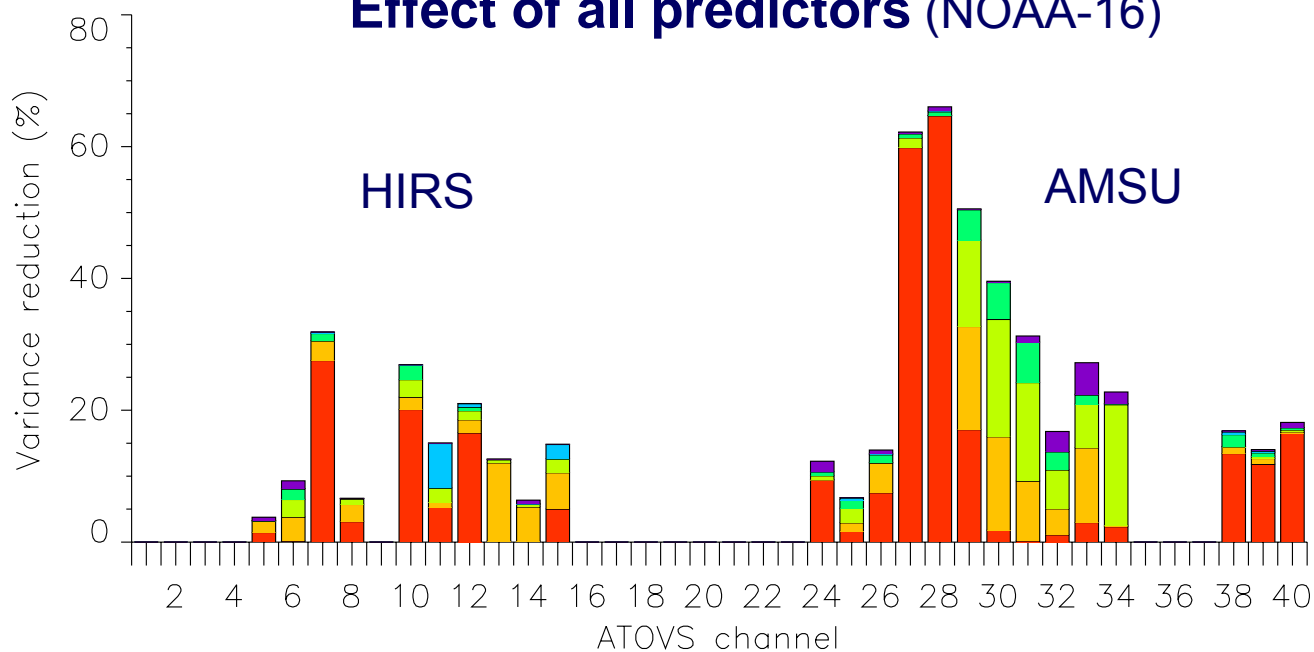
# Cross scan biases (example - AMSU ch 10 on Aqua)





- No obvious “truth”
  - Radiosondes have systematic errors, and limited height coverage
  
- Use satellite radiances as truth:
  - Correct for scan dependence only
  - Zero correction in the swath centre
  - No air mass correction
  
- Current operational global model has ceiling at ~6hPa (36km)
  - Compare AMSU-14 peak at ~3hPa
  - Extrapolate above model top
  
- Testing new 50 level model up to 0.1hPa (65km)

# Effect of all predictors (NOAA-16)



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- [Met Office 6 and 24 hourly radiance monitoring plots v NWP](#)
- [ECMWF 24 hourly radiance monitoring plots v NWP](#)
- [Meteo France \(Toulouse\) 6 hourly radiance monitoring plots v NWP. Please contact Herve Benichou \(Meteo France\) for access information.](#)
- [Meteo-France \(CMS Lannion\) 24 hourly radiance monitoring plots v radiosonde](#)
- [SMHI ATOVS monitoring page](#)
- [Science plan for integrated ATOVS monitoring and tuning reports \(pdf\)](#)
- [Bias correction procedures for ATOVS - a brief guide](#)

### Other (non-NWP SAF) ATOVS monitoring reports

- [NCEP 6 hourly radiance monitoring plots](#)
- [CMC 24 hourly radiance monitoring plots](#) (This site requires a username and password. Please contact Gilles.Verner@ec.gc.ca for access information)
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## ATOVS Monitoring

These plots are considered experimental. The Met Office accepts no responsibility for actions taken on the basis of these monitoring plots.

Please select satellite:

Please select statistic type:

Please select cloud type:

Please select graph to display:

Please select quality control:

Please select surface type or area:

Please select graph to display:

Press button to display chart full size:

Time series available for 1 month or 1 year

All AMSU and HIRS channels

Land, sea, sea-ice or global

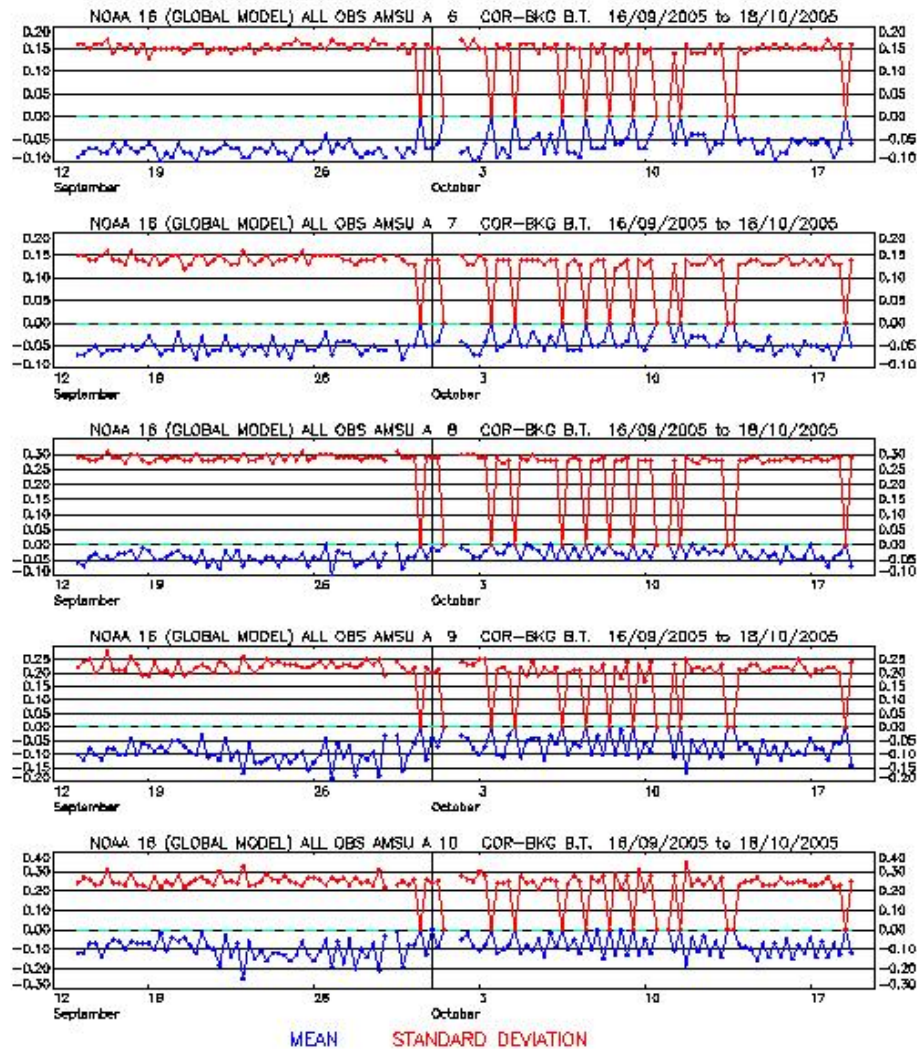
O-B, C-B, O, C, B, num of obs, etc





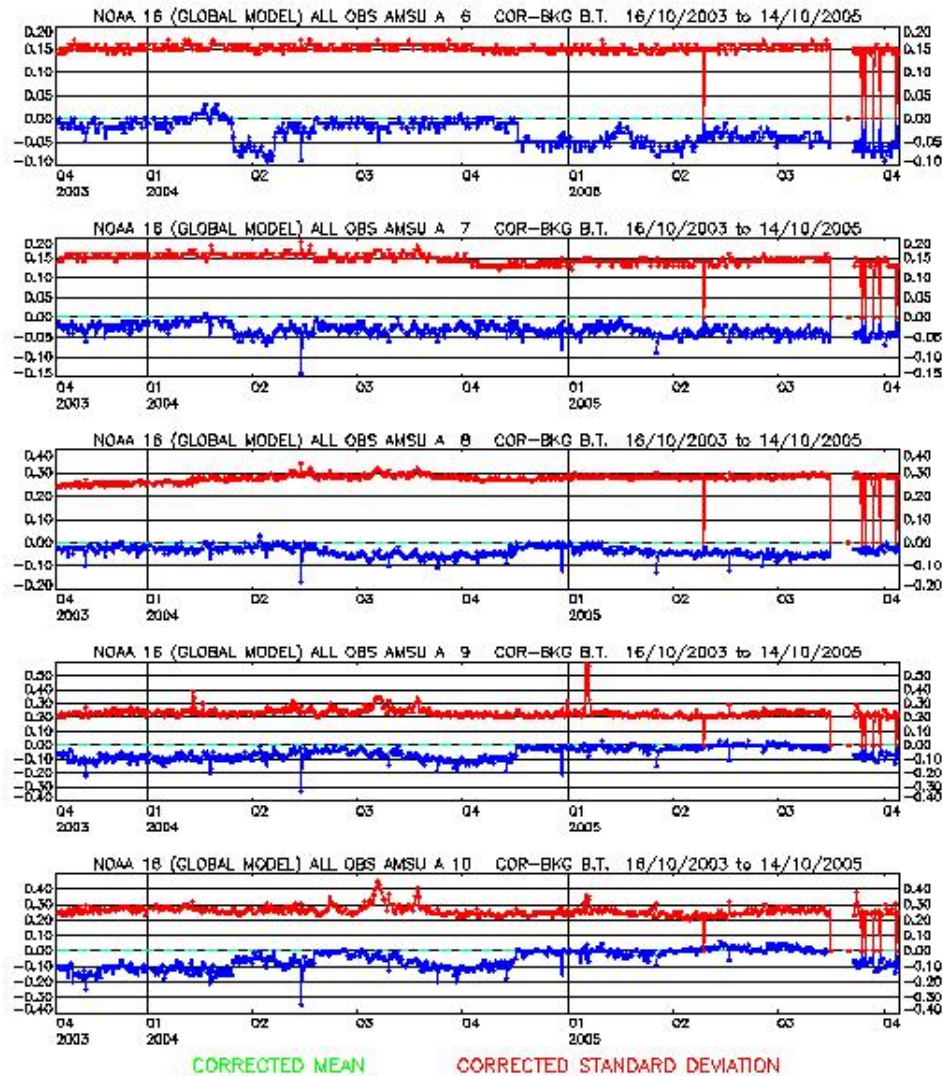
# ATOVS Time Series Plot

Time series for NOAA-16 Corrected - Background AMSU6-10 sea



# ATOVS Time Series Plot

Time series for NOAA-16 Corrected - Background AMSU6-10 sea



# When to update bias coefs?



## Operationally

- In the past, we have updated coefficients monthly
- Now only update when there is a significant change (e.g. in time series)
- Use statistics from previous month (plus ~2 week delay to get change into operations)

## For trials

- 'Spin up' bias corrections – iterate if needed.
- Accumulate statistics for typically 10 days before final update
- Changes involving significant bias changes may need “dual” processing (i.e. run old version initially but generate bias corrections using new)



# Problems

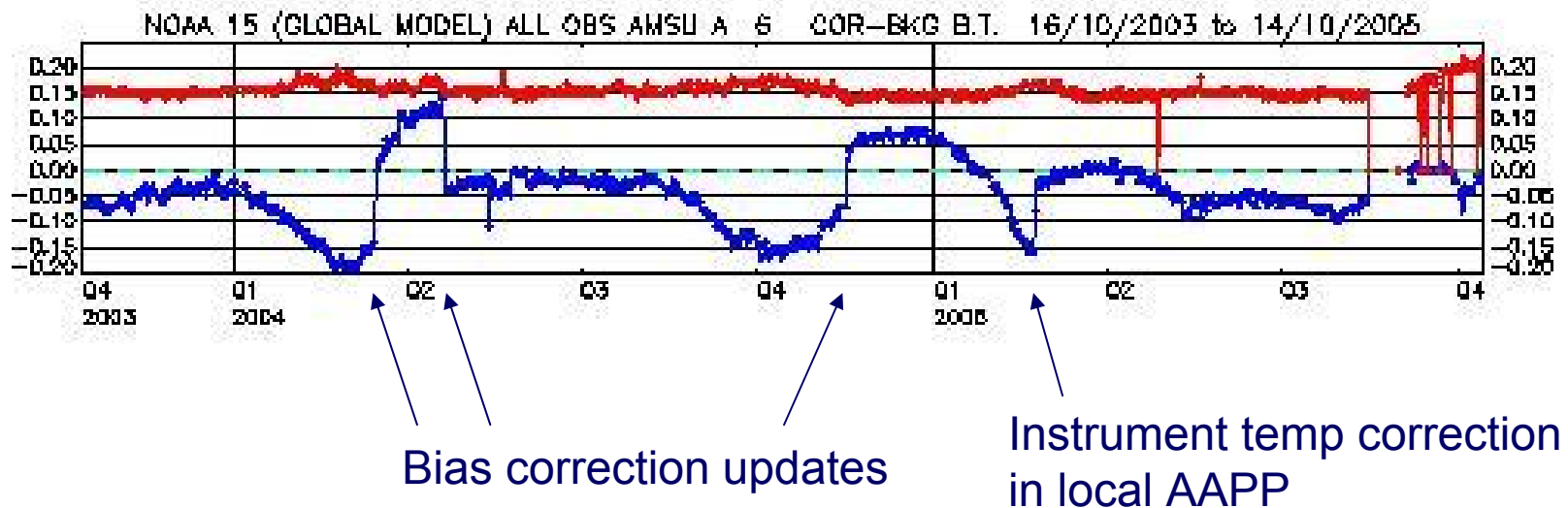


NOAA15 – AMSU-A channel 6 (54.4 GHz)

Bias varies with instrument temperature

Oscillator frequency varying? (not expected from pre-launch measurements)

Time scales for changes too short to correct effectively



Further examples of instrument effects in Bill Bell's talk, e.g. SSMIS

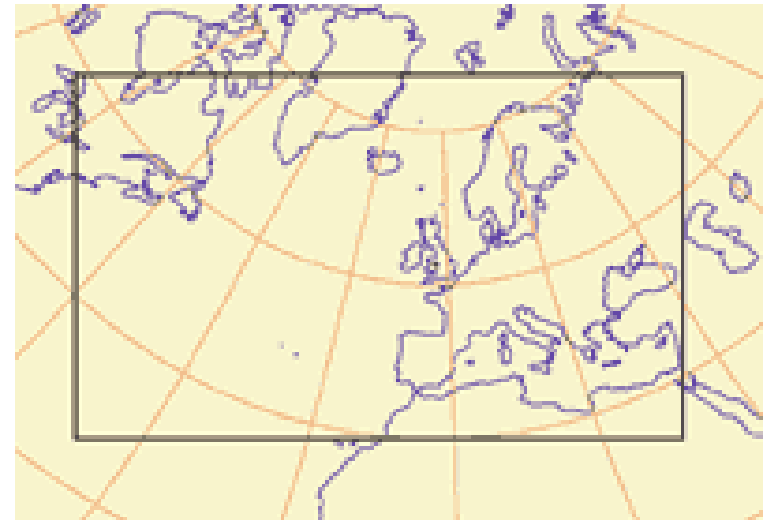
Standard approach - use the bias coefs from global model

Problems:

- Assumes global and regional models behave similarly – not necessarily true
- Would like to use some instruments used in regional model but not global (e.g. NOAA-17 AMSU-B)
- Would like to use AMSU-B at full resolution

In future we expect to generate bias coefs from at least 1 regional model, e.g. North Atlantic-European (NAE) model

Need substantially longer to accumulate statistics than for global model



- Variational bias correction
  - Bias coefficients introduced as additional Control Variables in VAR
  - Effect is to minimise  $\Sigma(C-A)^2$  rather than  $\Sigma(C-B)^2$  where A is analysis
  - Better able to track instrument drifts
  - Biases automatically adjust as changes are introduced in trials
  - Response to sudden changes can be tuned – with care!

# Conclusions

Bias correction is a key part of assimilation system

Global model uses air-mass (model based) and scan angle predictors

Being extended to regional models

Monitoring plots available on NWP-SAF web page

## Acknowledgements:

Brett Harris (BoM), Andrew Collard (ECMWF)