Bias correction of satellite data at the Met Office

Nigel Atkinson, James Cameron, Brett Candy and Steve English

ECMWF/EUMETSAT NWP-SAF Workshop on Bias estimation and correction in data assimilation, 9th November 2005

Contents

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

Strategy

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 $\Sigma(C\text{-}B)^2$
  (C = corrected radiance, B = forward model radiance from Background)

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

Modelling the bias

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).

Model based predictors

Operationally (ATOVS + AIRS):

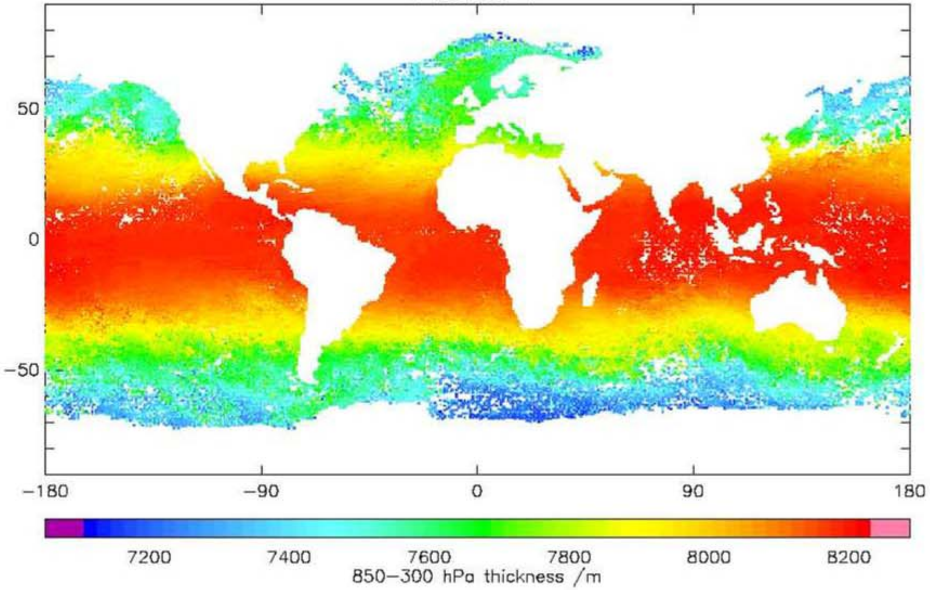
1. Stratospheric thickness, 200-50 hPa
2. Tropospheric thickness, 850-300 hPa

Other predictors considered:

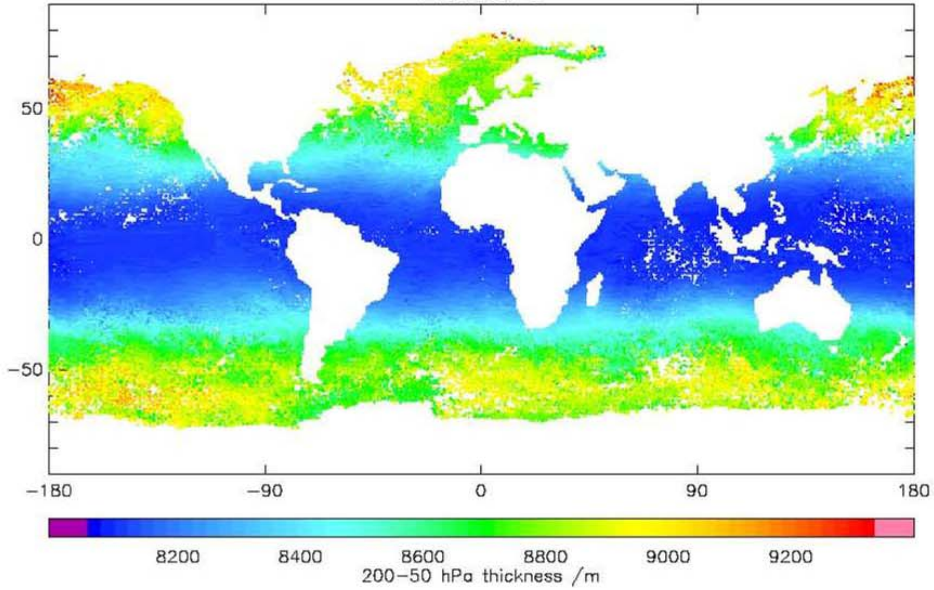
3. Skin temperature (difficult over land)
4. Total column water vapour (could interfere with real signal)
5. Background brightness temperature, per channel (gave a degradation in trials)
6. Temperature lapse weight convolved with weightning function per channel (to correct RT errors – but requires some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

Predictors

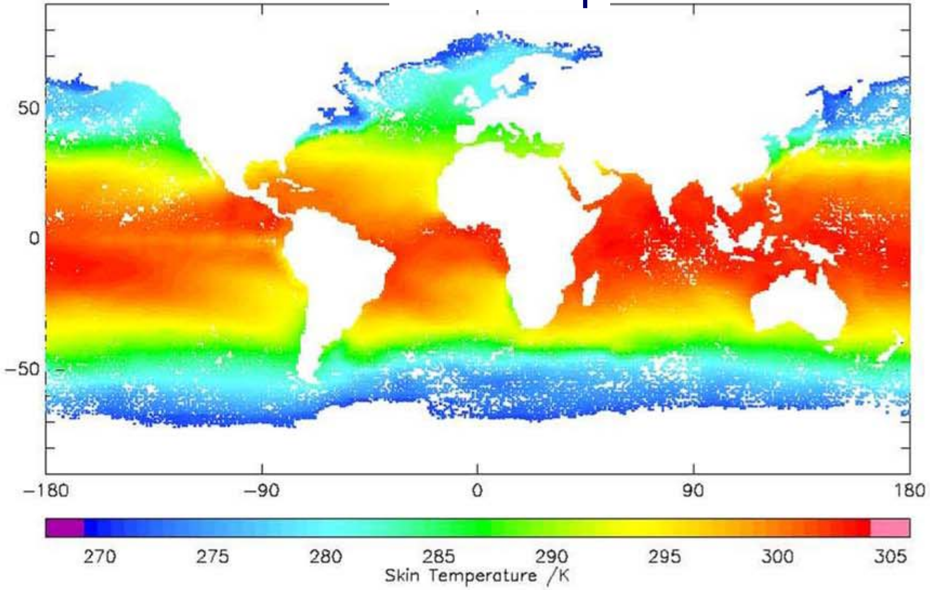
200-50 hPa thickness



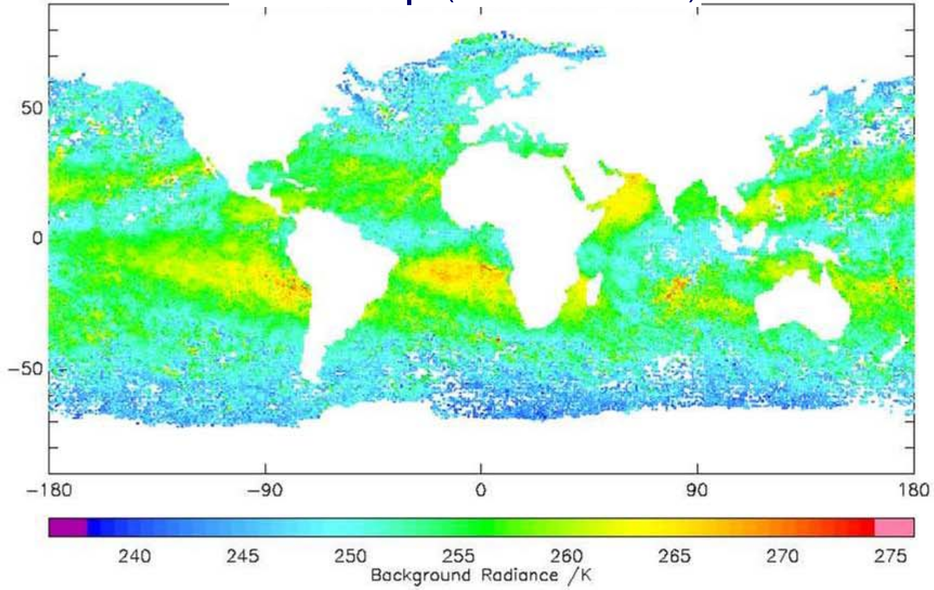
850-300 hPa thickness



Skin temp



Br. Temp (AIRS chan 1574)



Computation of bias coefficients

Solve simultaneously for air mass and scan coefs – linear regression

Air mass coefficients:

Predictor covariance   Cross covariance

$$\mathbf{a}_i = \left(\overline{\mathbf{p}\mathbf{p}^{\mathbf{T}}} - \overline{\mathbf{p}}\ \overline{\mathbf{p}}^{\mathbf{T}} \right)^{-1} \left(\overline{\mathbf{p}y_i} - \overline{\mathbf{p}}\ \overline{y_i} \right)$$

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:

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

where $\mathbf{p}_{\mathbf{s}}$ 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 $(O-B)^2$	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

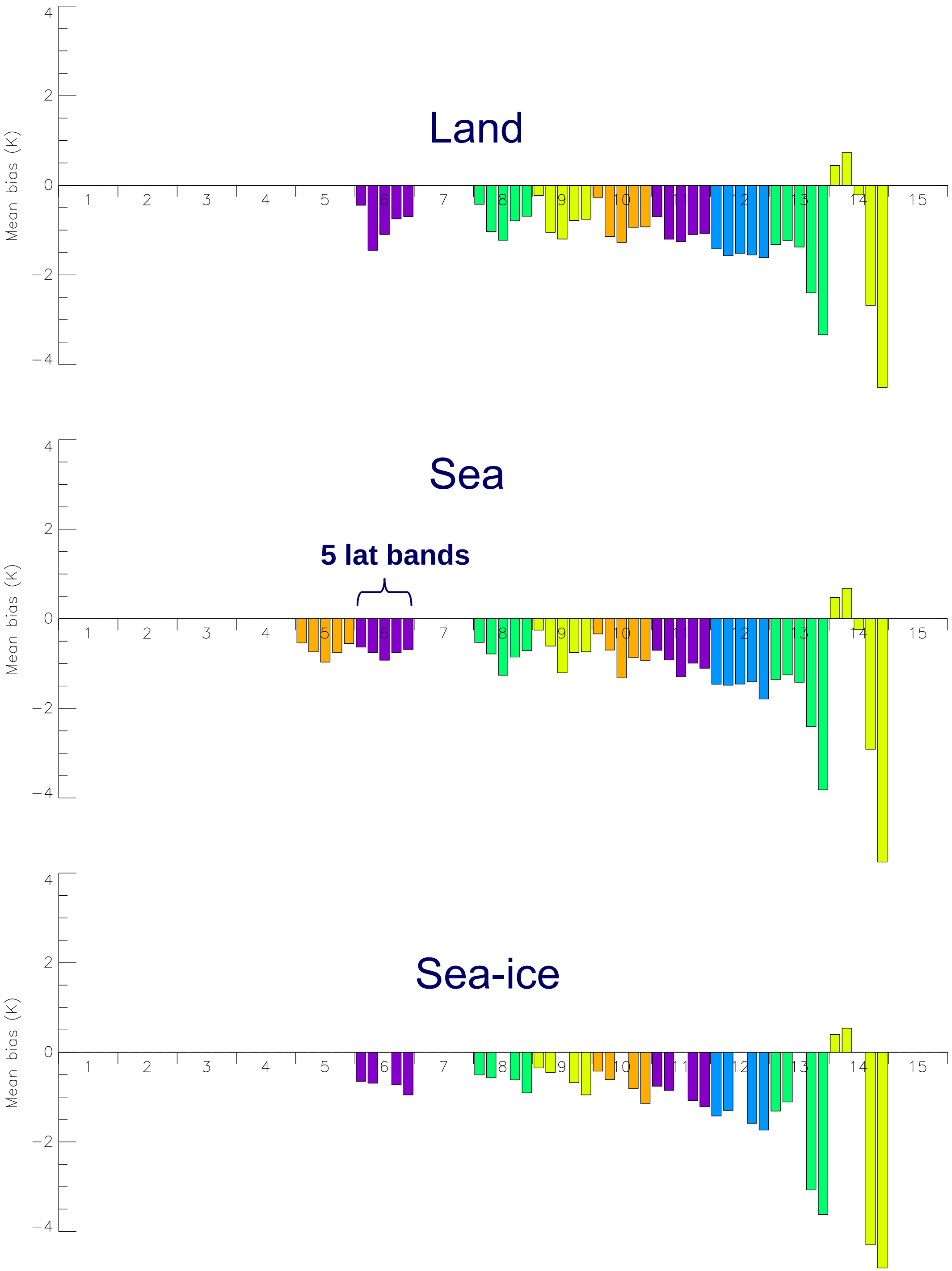
- Before computing coefs, weight stats to give effective no of obs in each band = 1 : 1 : 1.5 : 1 : 1
- Alternative to Bstats is to archive all required quantities for all obs (currently used for AIRS).

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.

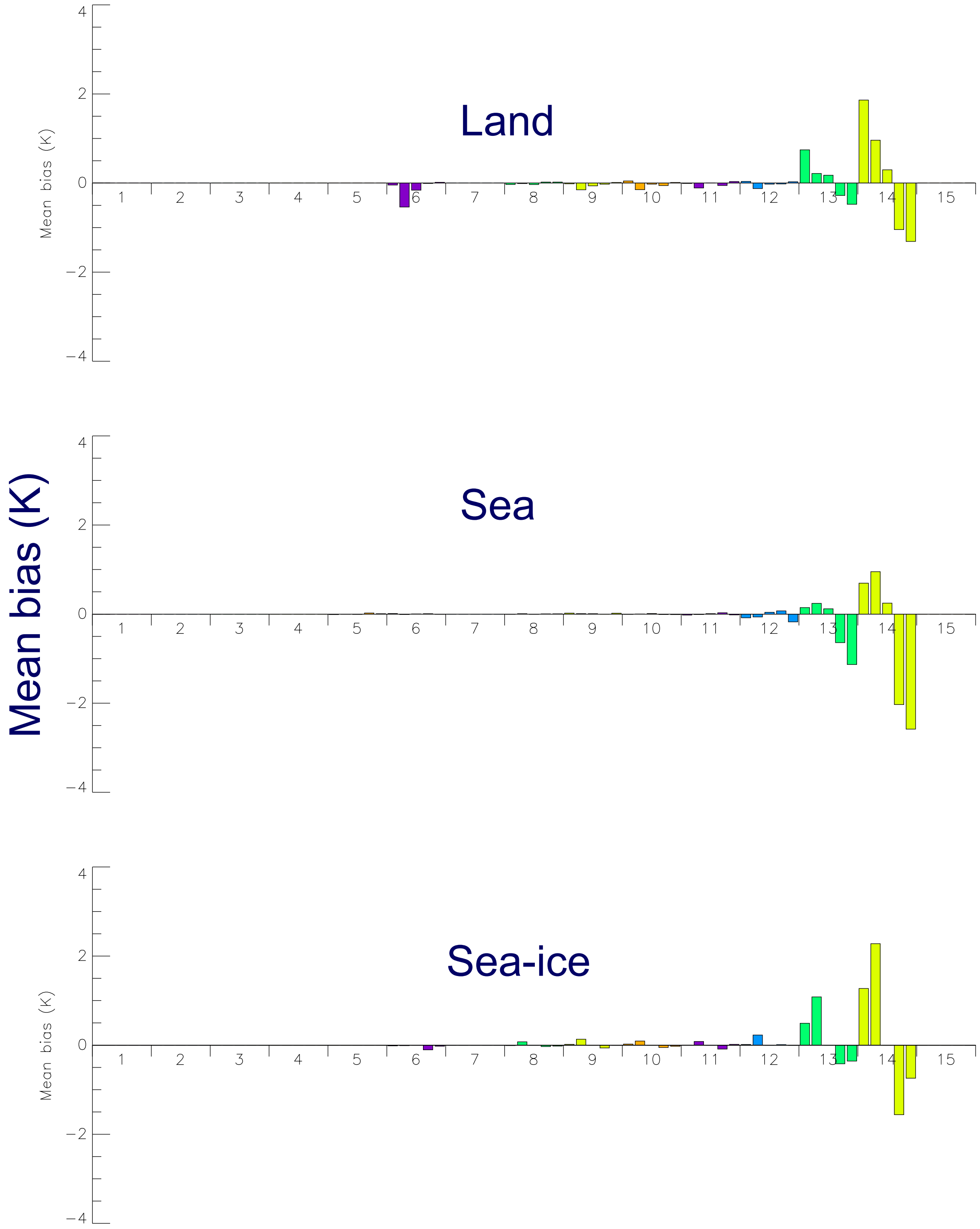
Example -Aqua

Uncorrected

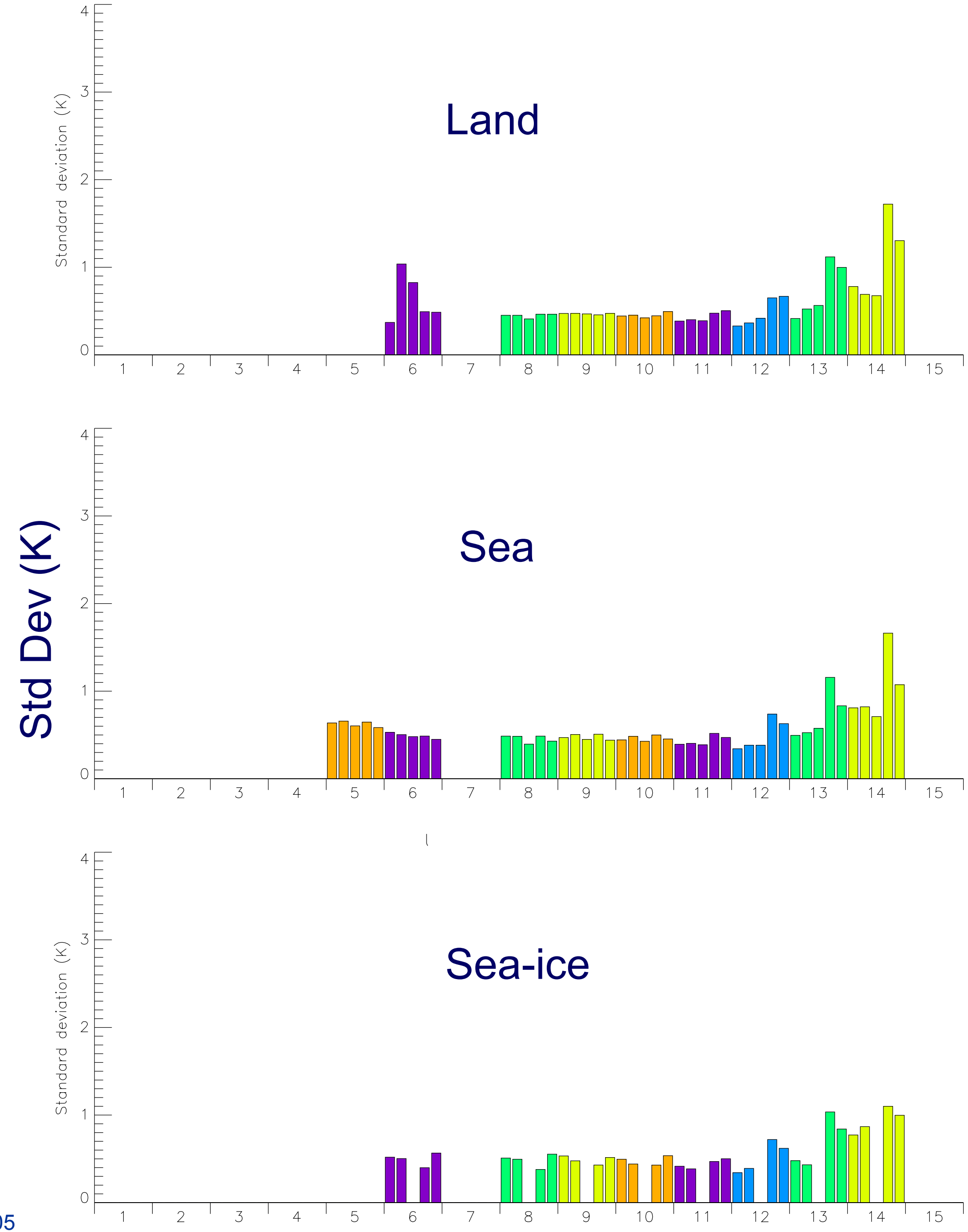


Corrected

2 air mass
Predictors +
Scan term

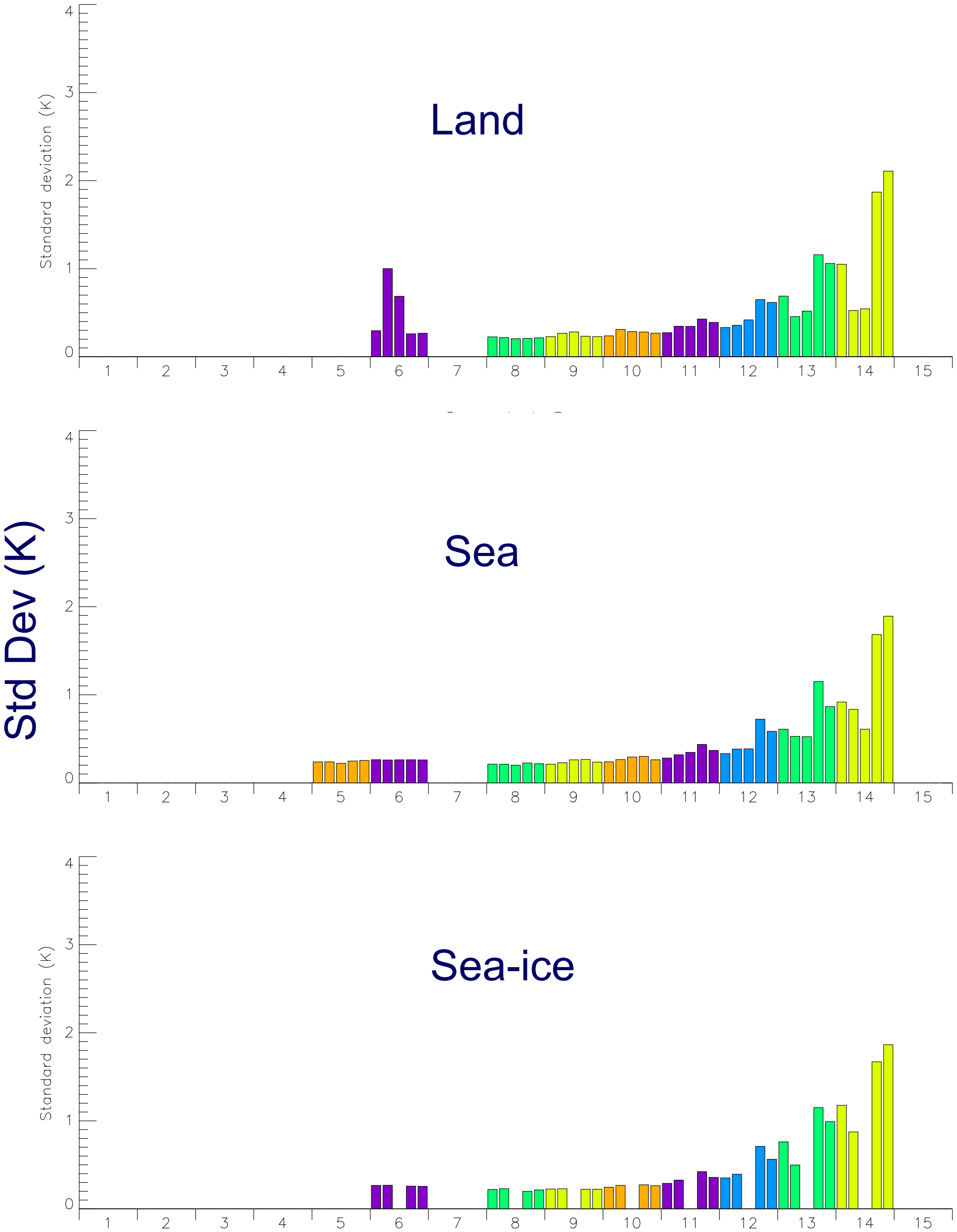


Uncorrected

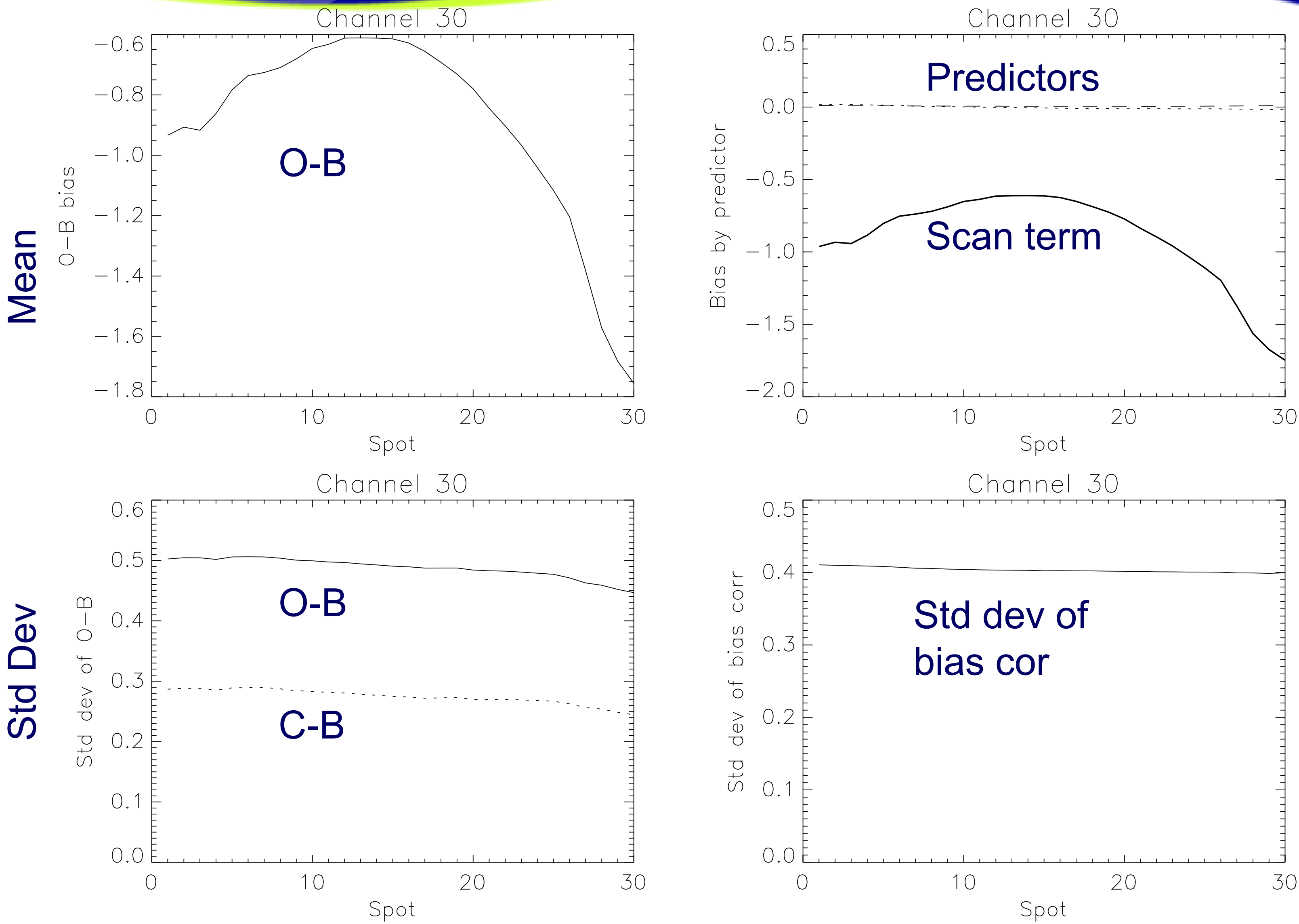


Corrected

2 air mass Predictors + Scan term



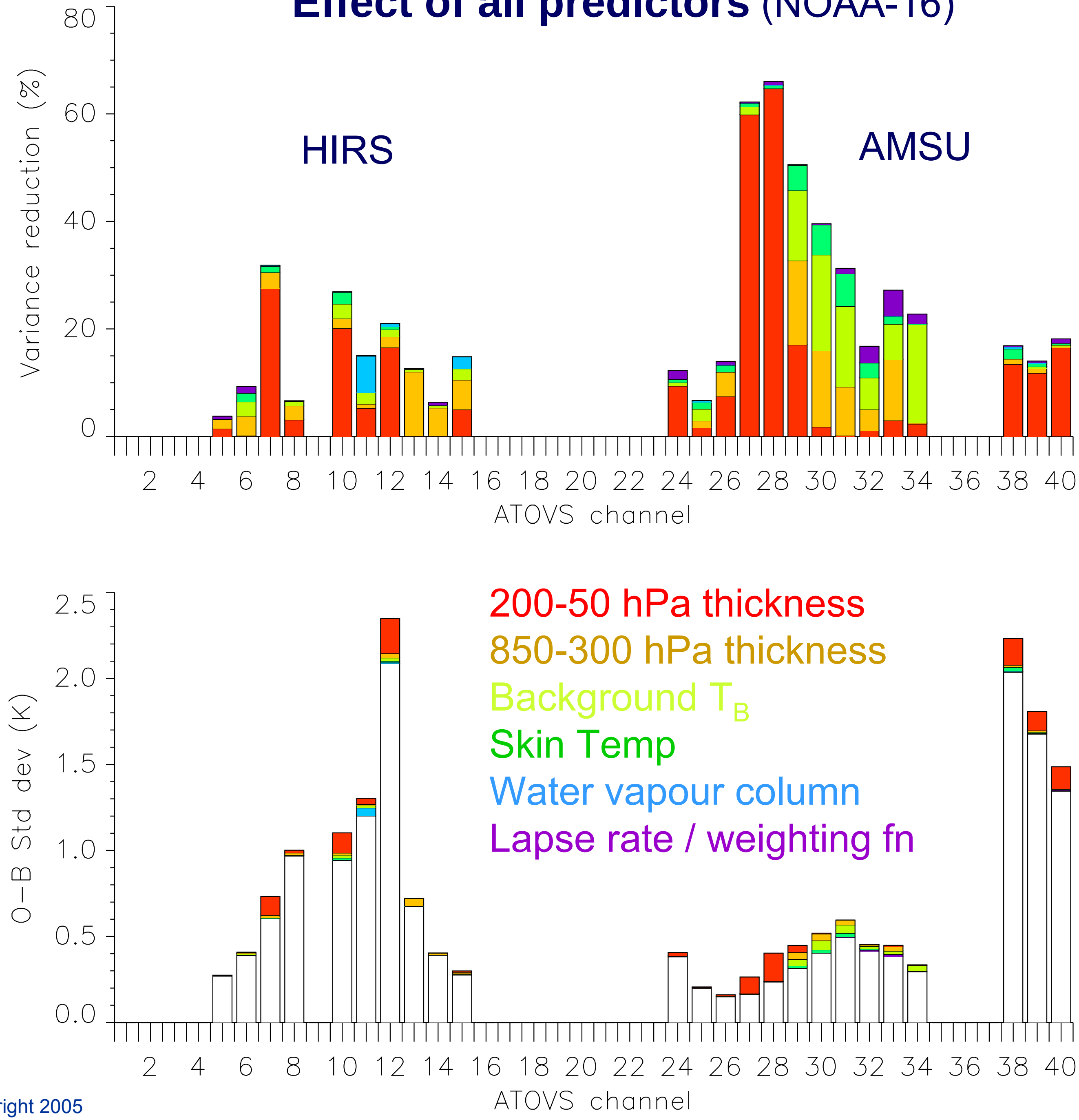
Cross scan biases (example - AMSU ch 10 on Aqua)



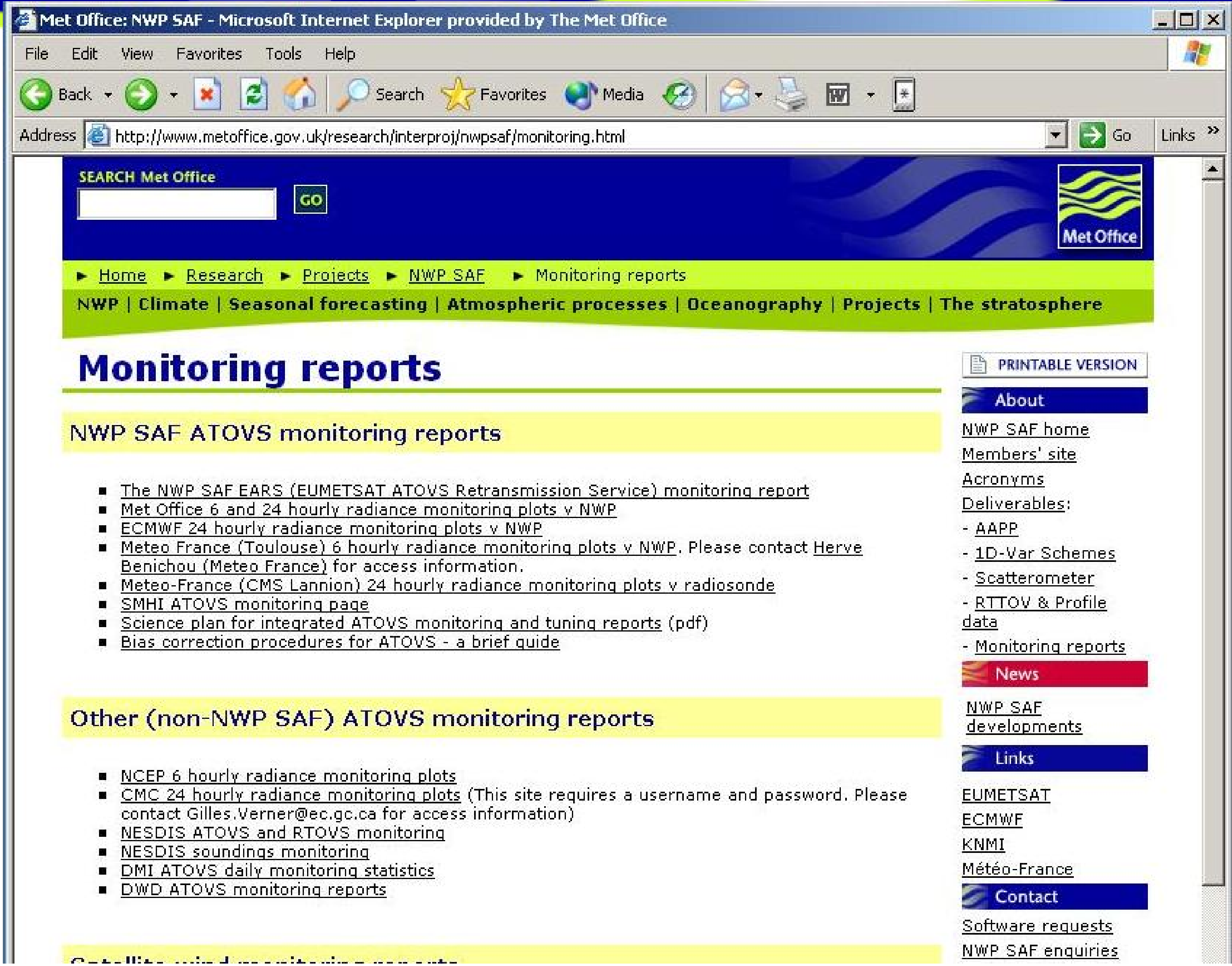
Strategy in the stratosphere

- 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)

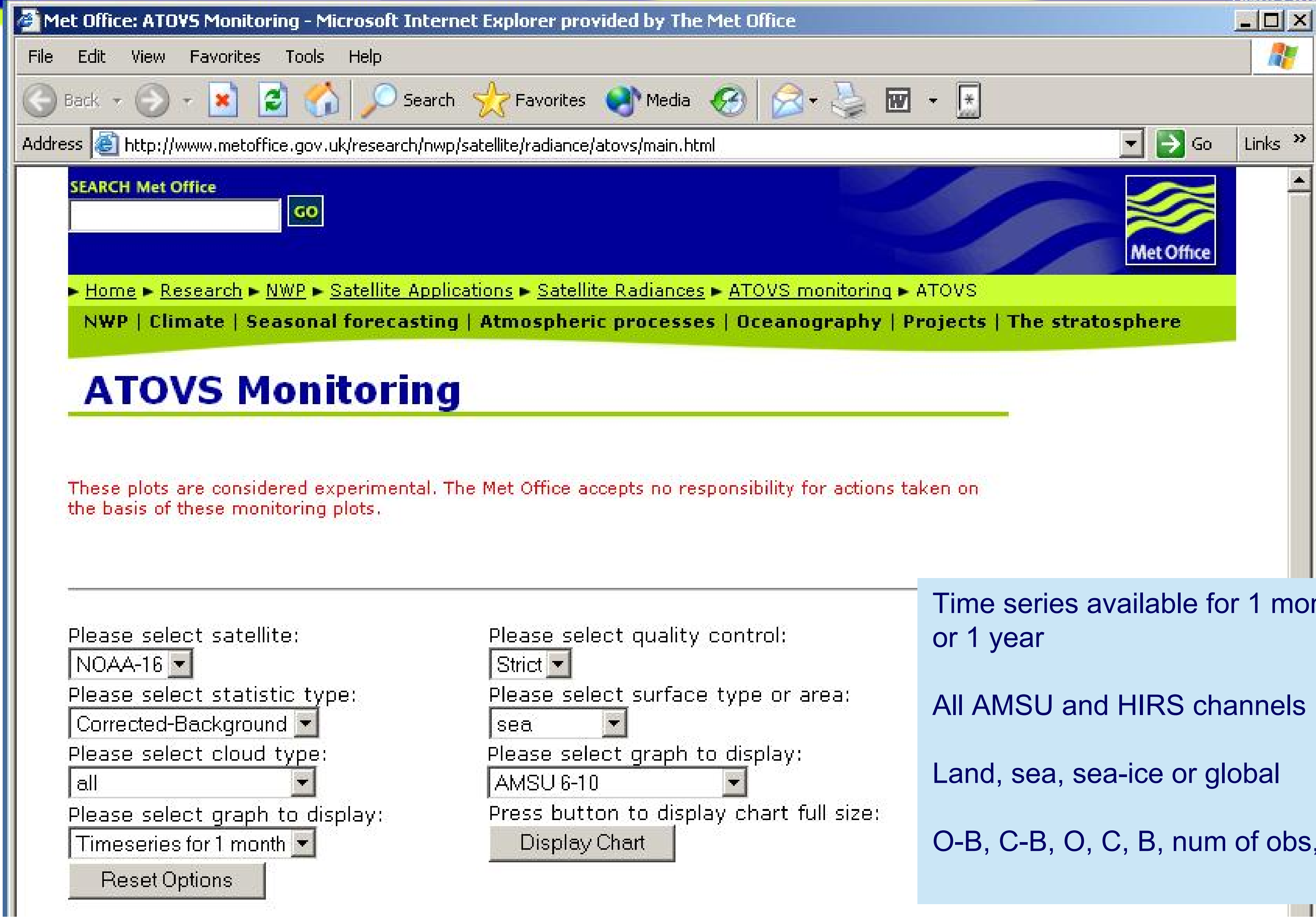
Effect of all predictors (NOAA-16)



NWP SAF monitoring web page



Met Office ATOVS monitoring page



Time series available for 1 month or 1 year

All AMSU and HIRS channels

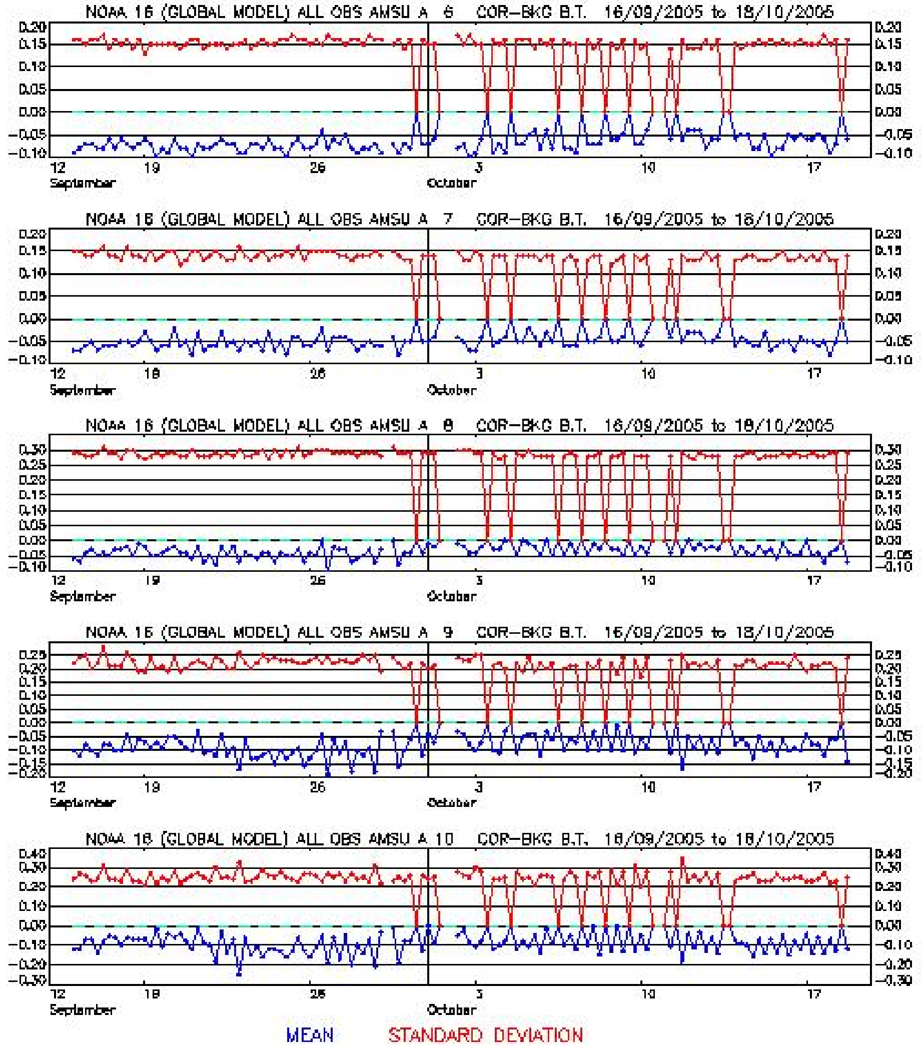
Land, sea, sea-ice or global

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

Time-Series plot - Microsoft Internet Explorer provided by The Met Office

ATOVS Time Series Plot

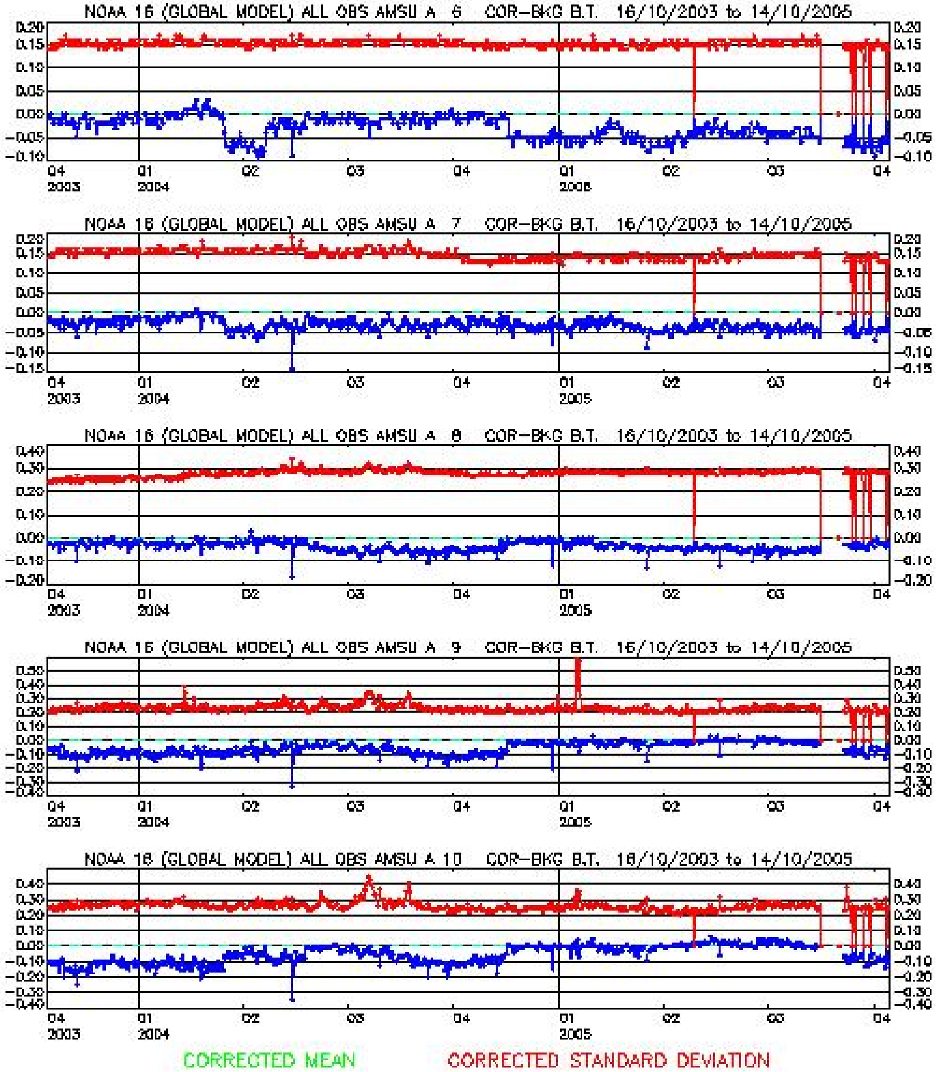
Time series for NOAA-16 Corrected - Background AMSU6-10 sea



Time-Series plot - Microsoft Internet Explorer provided by The Met Office

ATOVS Time Series Plot

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



When to update bias coefs?

<u>Operationally</u>

- 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)

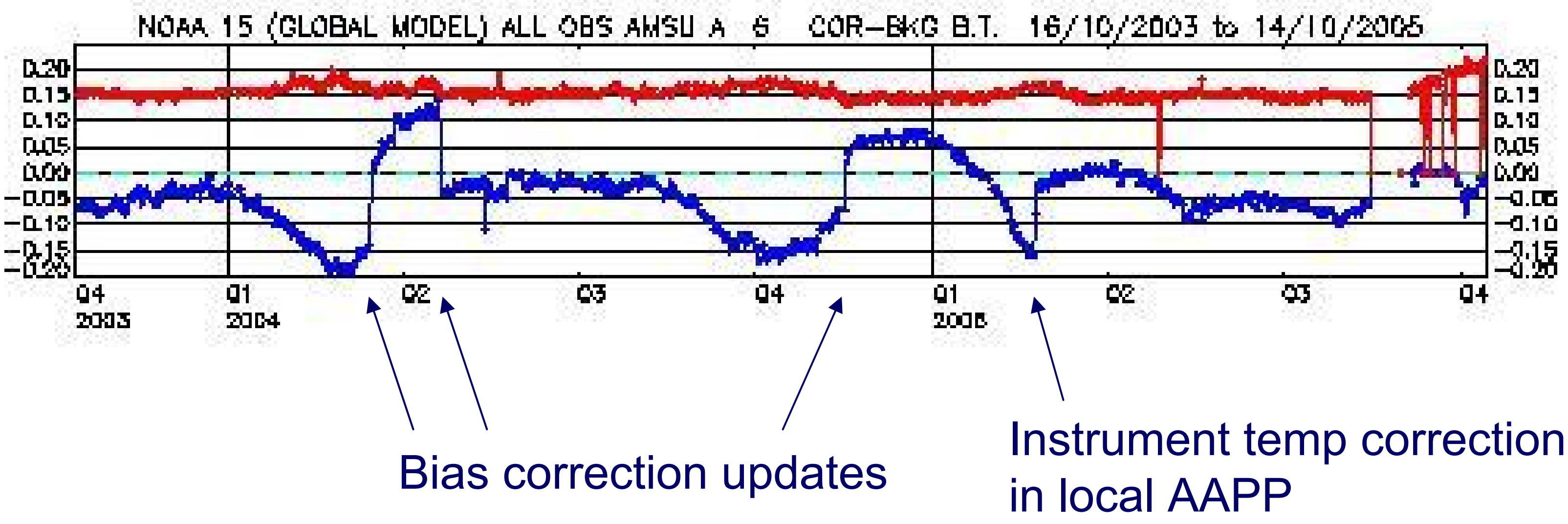
<u>For trials</u>

- ‘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



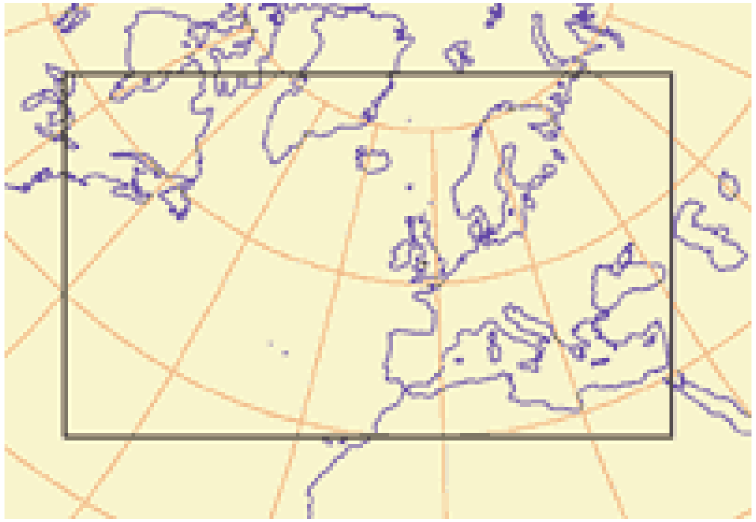
Further examples of instrument effects in Bill Bell's talk, e.g. SSMIS

Regional models

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

Future enhancement

- Variational bias correction
  - Bias coefficients introduced as additional Control Variables in VAR
  - Effect is to mimimise $\Sigma(C-A)^2$ 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)