Progress of bias correction for satellite data at ECMWF

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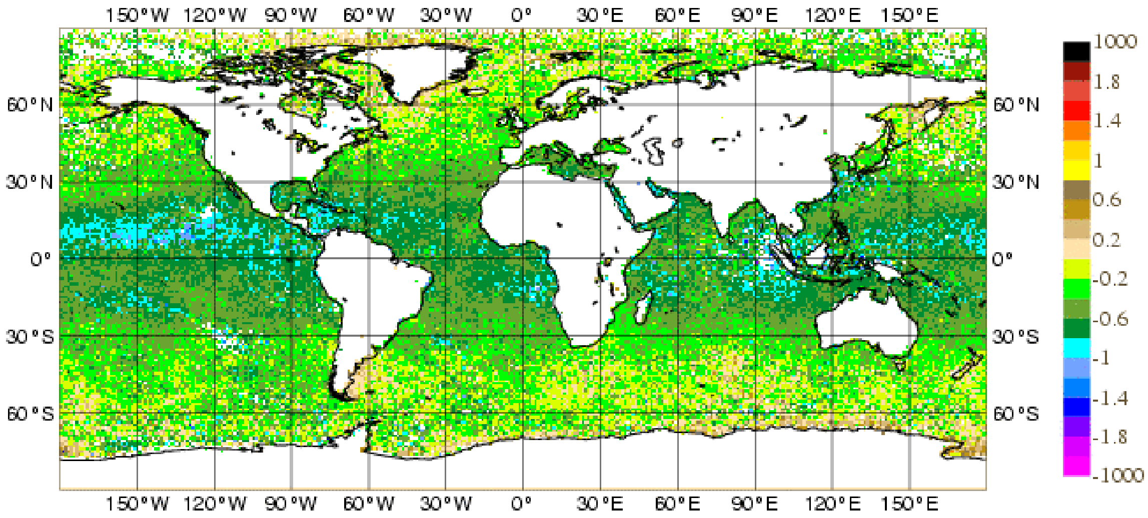
Acknowledgments to Phil Watts, Dick Dee

Introduction

ECMWF 4DVar assimilation system requires that model and observations are unbiased with normally distributed errors.

But first-guess departures (*i.e.* observation minus equivalent from the model guess) show systematic errors.



Average departures over 2 weeks for NOAA17/HIRS14

- Bias model
- Adaptive bias correction
- Variational bias correction

Bias model: correction strategy

- Scan correction

- Air-mass regression (Harris & Kelly)

Linear regression with a limited set of predictors P_i derived from the NWP model: Bias = $\sum \beta_i . P_i(x)$

- [γ,δ] model: Radiative Transfert Model correction

(for errors in absorbing gas density, SRF, absorption coefficient).

For each channel, definition of

δ: global constant

γ: fractional error in layer absorption coefficient

Transmittance from level p to space: $\Gamma(p) \rightarrow \Gamma(p)^{\gamma}$

Physically based scheme, discriminating observation bias from model error.

Bias model: [γ,δ]

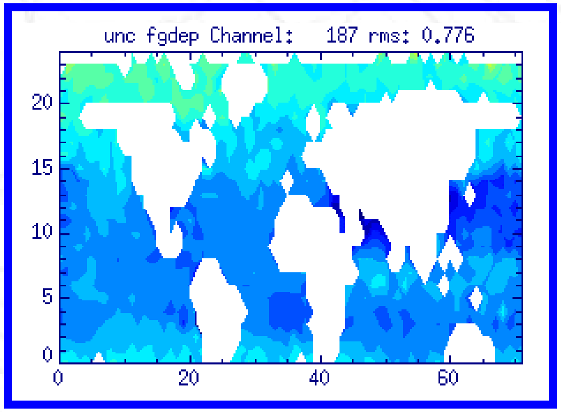
Simulate γ = +5% transmission error – air-mass dependent bias: ***A***

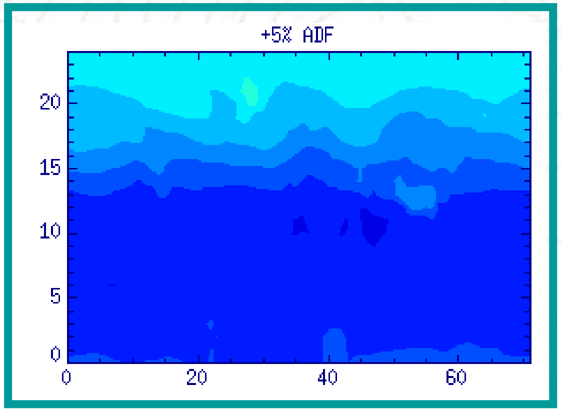
Monitor biases in operational System: ***B***

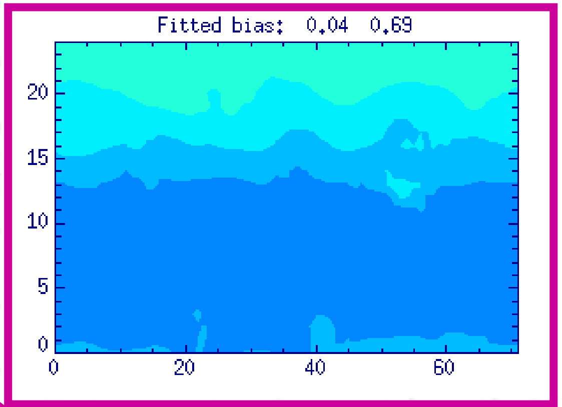
Assume bias model:

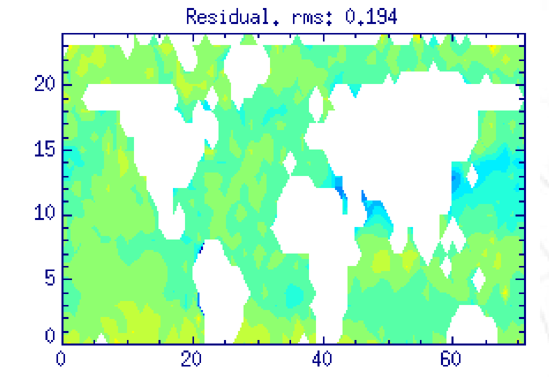
$$B = \delta + \gamma . A$$

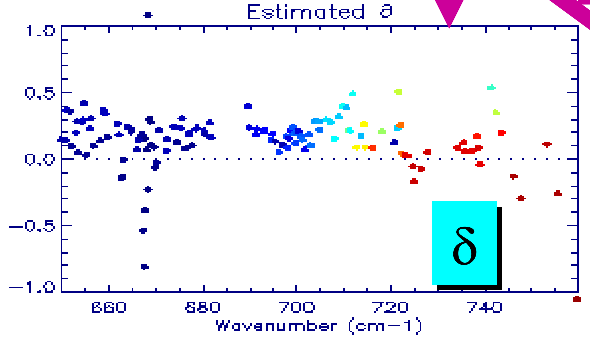
Get best estimates of δ and γ

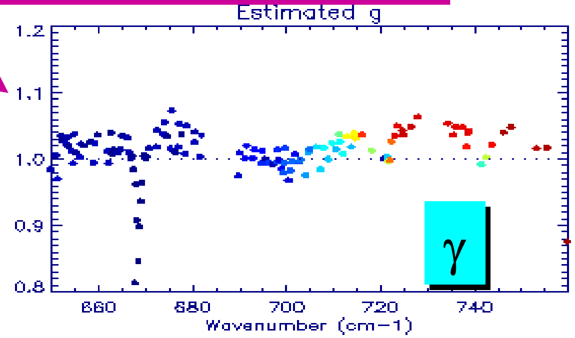










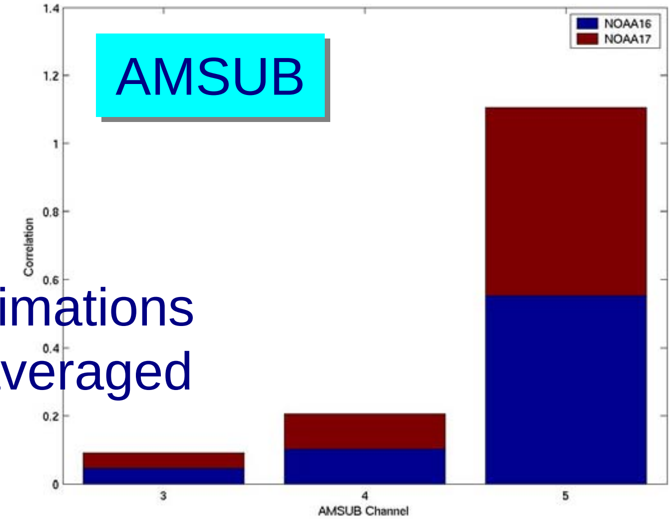


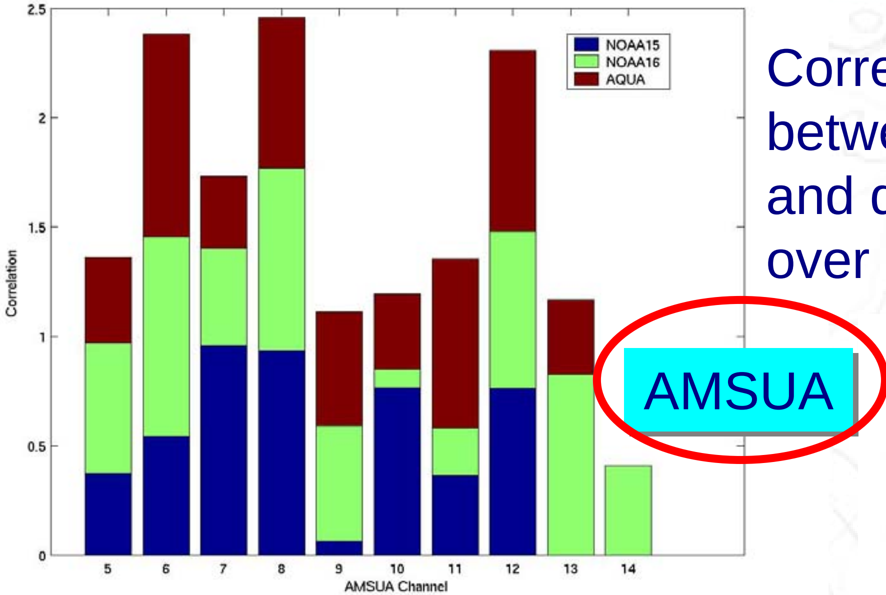
AIRS 15 μm channels

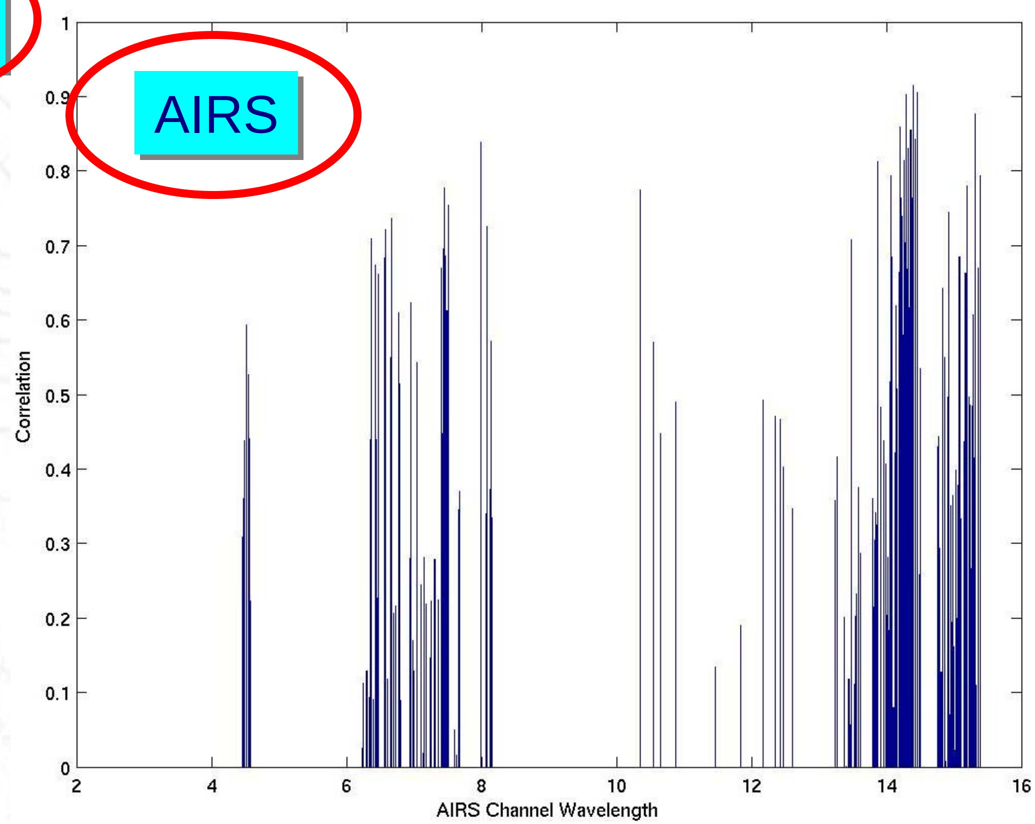
Credits: P. Watts

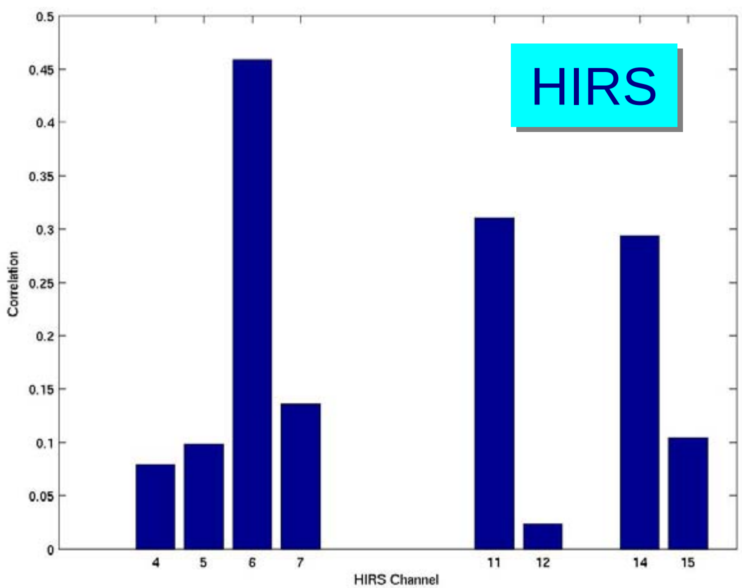
Bias model: [γ,δ]

Correlations between bias estimations and departures averaged over one month









Adaptive bias correction

A static bias correction cannot correct an instrument failure/drift.
Problem of identifying manually a drift within hundreds of data types in real time.

Adaptive bias correction = bias estimate is updated for every cycle.

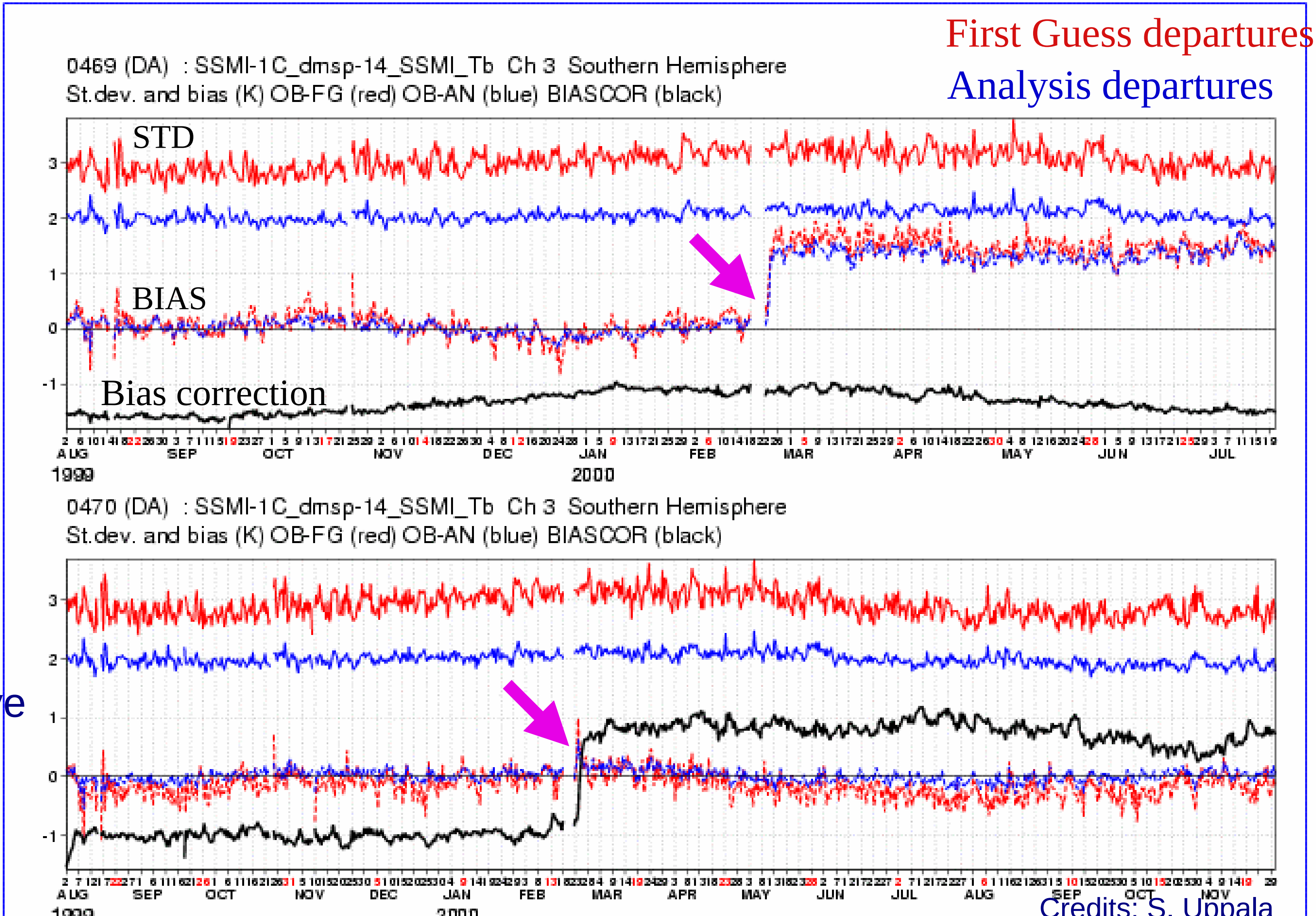
Pros:
Automatic, thus much easier to handle for new instruments or drifts.
Continuity in time series (interesting for climate simulations).
Based on the same bias model (Harris&Kelly).

Cons:
Prone to wrongly mapping systematic errors of the NWP model into radiance bias correction. Relies even more on the ability of the bias model to separate observation bias from model error.
Need for a background term : reduces the reactivity of the system.

Adaptive bias correction

Static

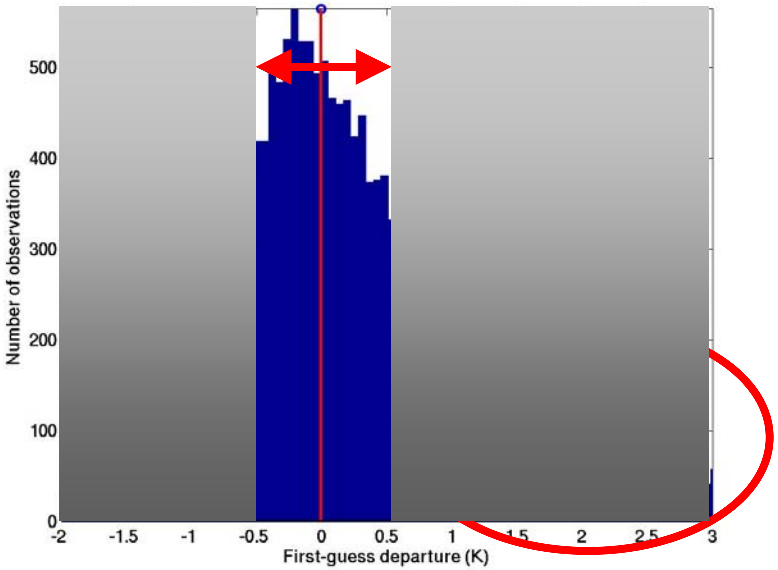
Adaptive



Credits: S. Uppala

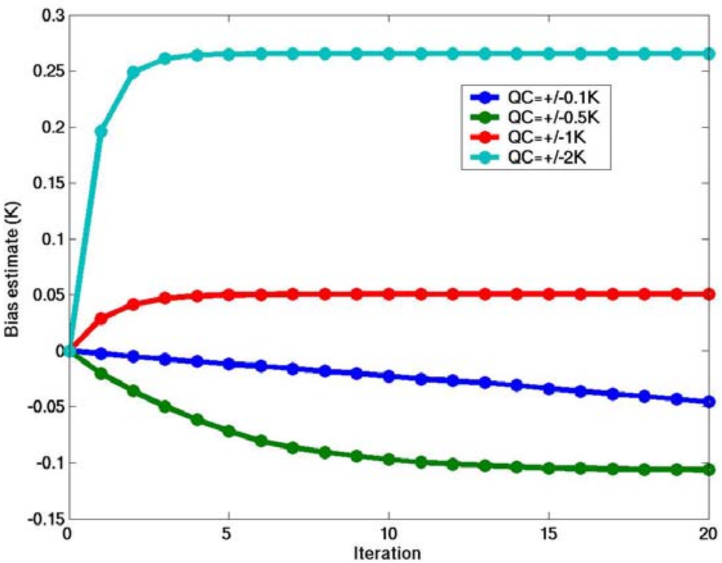
Adaptive bias correction (and quality control)

Aqua
AMSUA-4
over sea
2005/03/01



A typical distribution of departures has a cold / warm tail (IR / MW) due to cloud contamination.
Quality Control based on departures is often applied to remove the tail and outliers (bad quality data) BEFORE estimating the bias.

Single (static bias correction) and successive (adaptive) applications lead to different estimates.
The value of the estimate and speed of convergence depend on the size of the boxcar window QC.
We are evaluating the use of the MODE for bias estimation as opposed to the mean.



Variational bias correction

VarBC = adaptive bias correction INSIDE the assimilation system

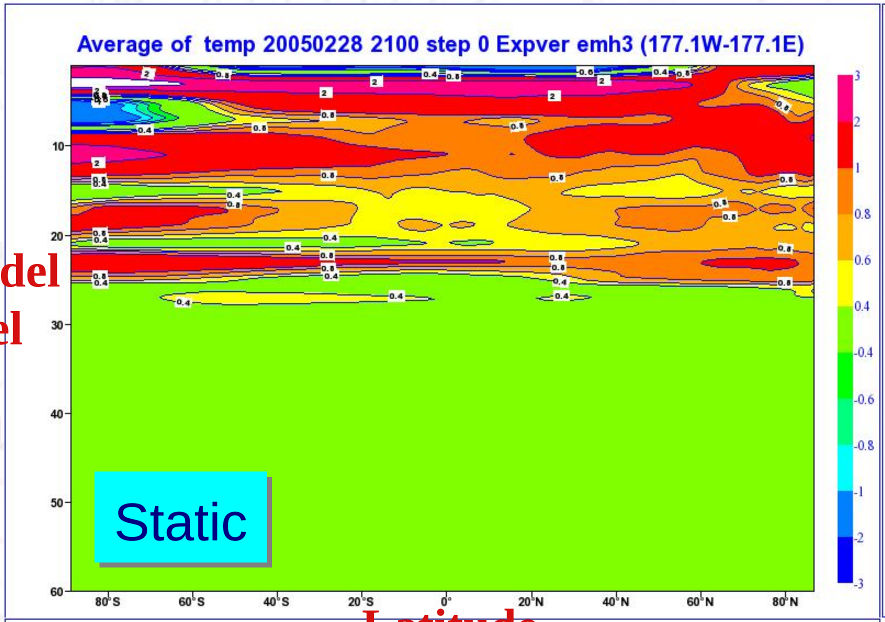
bias parameters β_i (*i.e.* coefficients for the bias model) become part of the 4DVar control variable

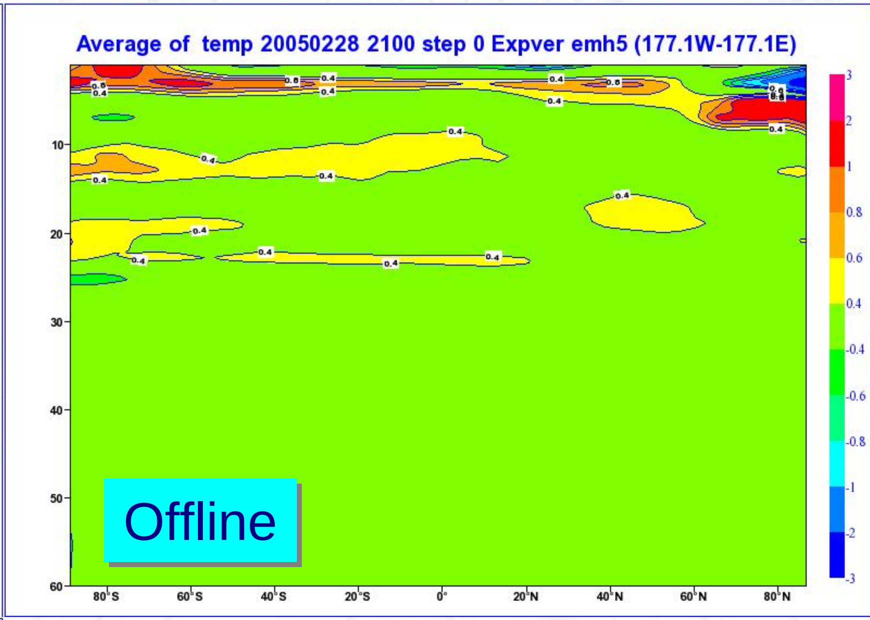
→ $\underline{H}(x,\beta) = H(x) + \sum \beta_i . P_i(x)$ (H: observation operator, P_i: predictors)

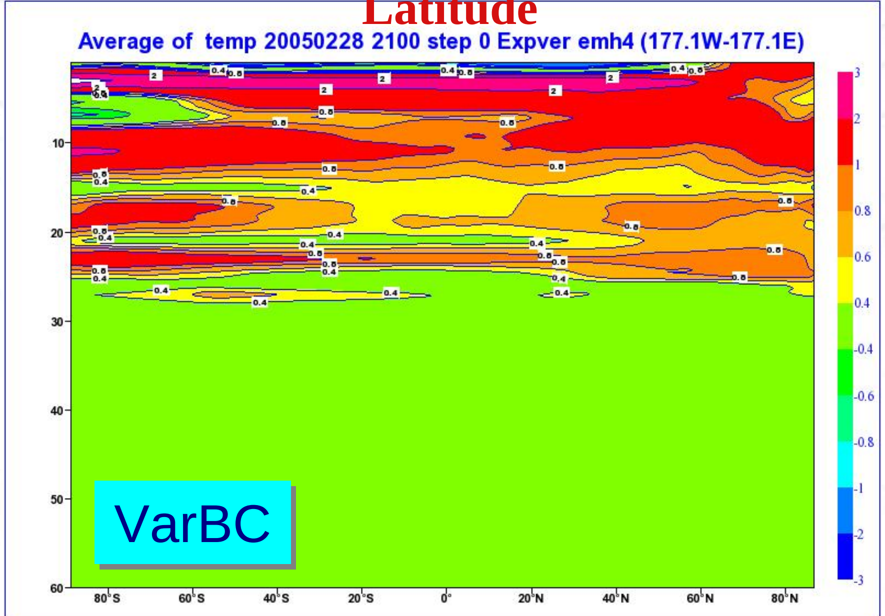
***Cons**:*
(Small) overhead of computer calculation during NWP assimilation.
Data used for QC but not assimilated must go through minimisation to estimate the bias.

***Pros**:*
Estimation is constrained by other information inside the analysis, *i.e*. model, other data (Radiosondes, aircraft, surface, …).

Variational bias correction





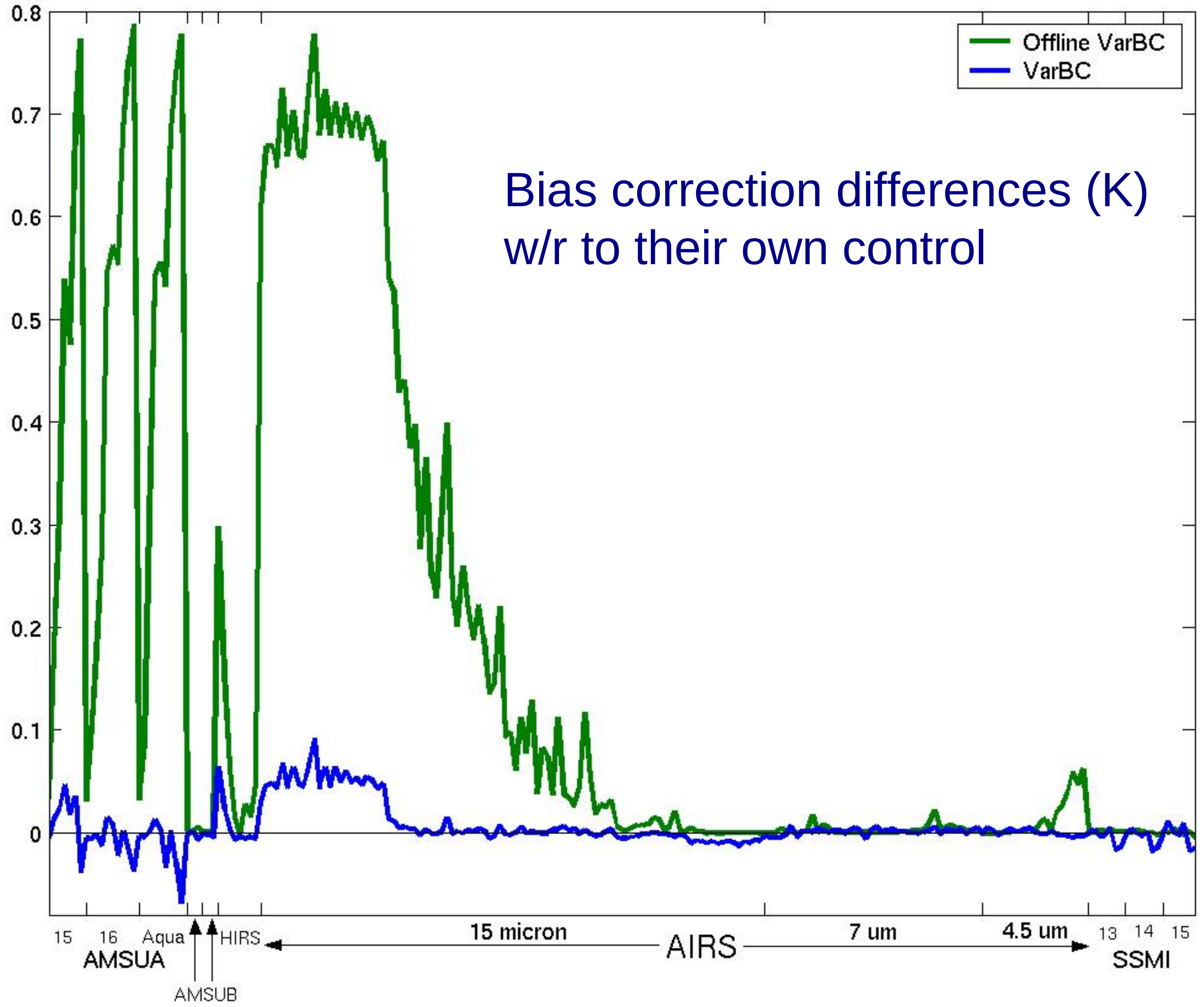


Flat artificial model perturbation:

-1K for levels 1→25 (above 100hPa)

Zonal means of temperature analysis differences for experiments with different bias correction schemes w/r to their own control (*i.e.* same scheme without perturbation)

Variational bias correction



Conclusion

[γ,δ] bias model used operationally for AIRS and AMSUA.

Technical and scientific advantages of adaptive bias correction.

Mapping of NWP error into bias estimate is greatly reduced with VarBC, due to the constraint of other data.

Feedback process b/w QC (first-guess check, cloud detection) defining the active population and adaptive bias correction modifying next cycle’s departures.

Investigation on the use of the mode of the departures distribution as bias estimate.

Potential benefit of GPS Radio Occultation data.

Thank you for your attention

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International TOVS Study Conference, 14th, ITSC-14, Beijing, China, 25-31 May 2005. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2005.