Bias correction of satellite data at the Met Office

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

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 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:

\[
\mathbf{a}_i = \left( \bar{\mathbf{p}}\bar{\mathbf{p}}^T - \bar{\mathbf{p}}\bar{\mathbf{y}}^i \right)^{-1} \left( \bar{\mathbf{p}}\bar{\mathbf{y}}^i - \bar{\mathbf{p}}\bar{\mathbf{y}} \right)
\]

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 \( s \):

\[
c_{i,s} = \bar{y}_{i,s} - \mathbf{a}_i^T \bar{\mathbf{p}}_s
\]

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
  - Mean O-B
  - Mean (O-B)^2
  - Mean P×(O-B)
  - Mean P
  - Mean P×P

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

Land

Sea

Sea-ice

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Corrected

2 air mass
Predictors +
Scan term

Mean bias (K)

Sea

Mean bias (K)

Land

Mean bias (K)

Sea-ice
Corrected

2 air mass Predictors + Scan term

Land

Sea

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

Mean

Scan term

Predictors

Std Dev

Std dev of bias cor

O-B

C-B
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)
Monitoring reports

NWP SAF ATOVS monitoring reports

- The NWP SAF BEARS (EUMETSAT ATOVS Retransmission Service) monitoring report
- Met Office 6 and 24 hourly radiance monitoring plots v NWP
- ECMWF 24 hourly radiance monitoring plots v NWP
- Météo France (Toulouse) 6 hourly radiance monitoring plots v NWP. Please contact Herve Berthou (Météo France) for access information.
- Météo France (MNM Lannion) 24 hourly radiance monitoring plots v radiosondes
- SML 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)
- MERRA ATOVS and RTTOV monitoring
- NESDIS sounding monitoring
- DMI ATOVS daily monitoring statistics
- DWD ATOVS monitoring reports

Satellite retrieved monitoring reports
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:
NOAA-16

Please select statistic type:
Corrected-Background

Please select cloud type:
all

Please select graph to display:
Timeseries for 1 month

Please select quality control:
Strict

Please select surface type or area:
sea

Please select graph to display:
AMSU 6-10

Press button to display chart full size:
Display Chart

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 AMSU-A sea
ATOVS Time Series Plot

Time series for NOAA-16 Corrected - Background AMSU-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)
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:

- Assumess 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 minimize $\sum (C-A)^2$ rather than $\sum (C-B)^2$ 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

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