An evaluation of radiative transfer modelling error in AMSU-A data

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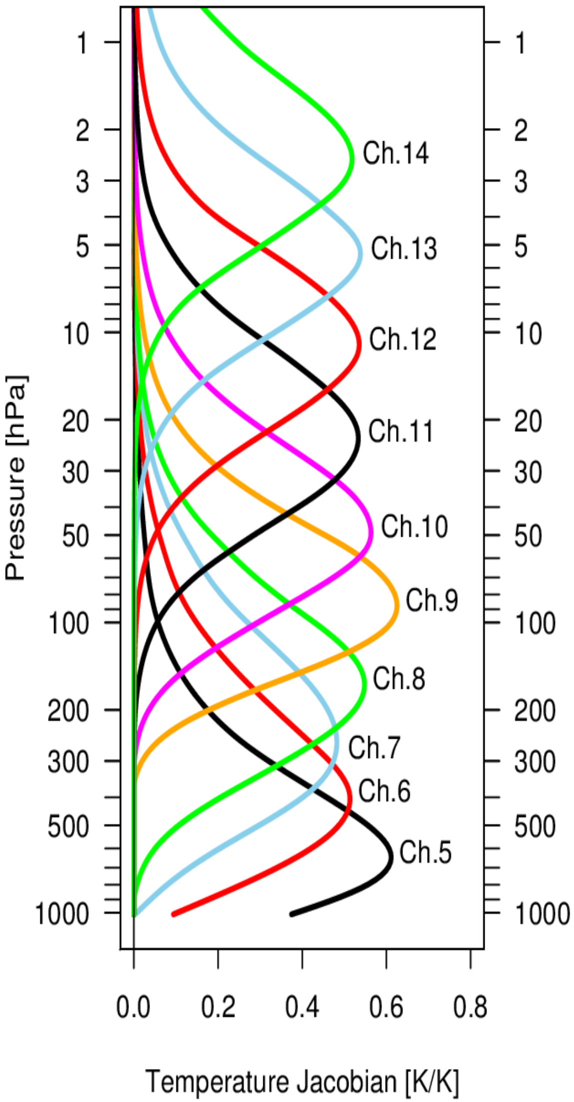
Overview

- Background & Motivation
- Two approaches to correct AMSU-A air mass dependent bias
- Assimilation studies: analysis & forecast impact
- Summary and conclusion

Background

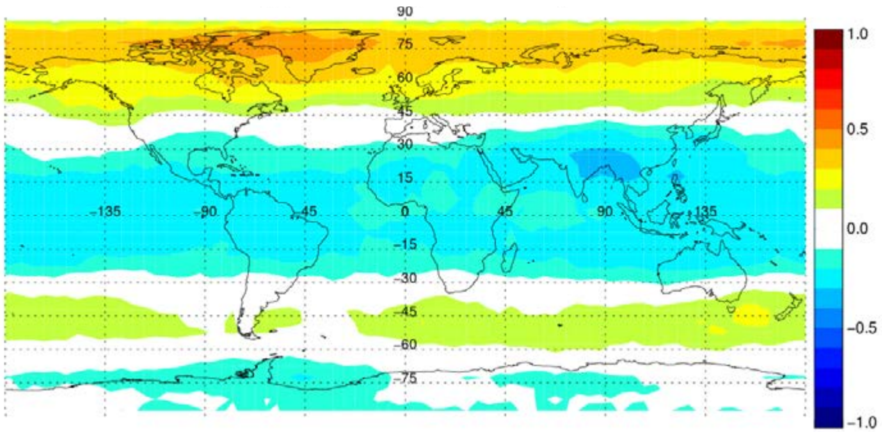


- AMSU-A instruments:
  - flown on different satellites over many years (NOAA-15/16/18/19, MetOp-A/B, Aqua).
  - provide important input to DA systems for NWP and contribute substantially to today's forecast skill.

Motivation

- Systematic biases relative to NWP model are observed in AMSU-A channels sensing in the 50-58 GHz in the O_2 absorption band;

AMSU-A/MetOp-A Ch. 8: First-guess departures [K]



- Inaccuracies in the RTTOV calculations used to simulate radiance observations from model state (e.g., errors in the spectroscopic database, etc…)
- Instrument errors (e.g., poor instrument calibration or characterization).
- NWP forecast model errors

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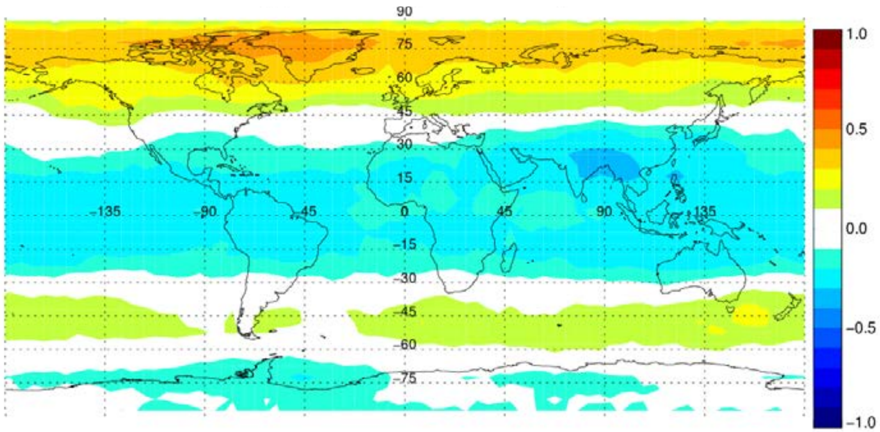

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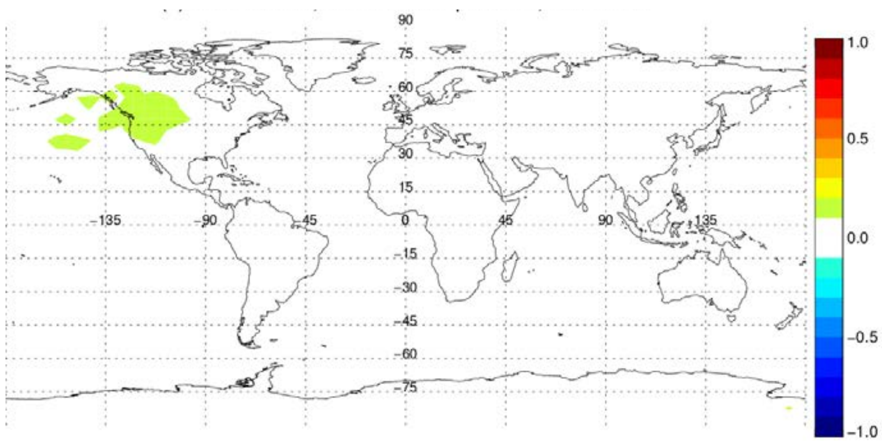
VarBC corrects systematic differences in (OBS-FG)[K]



- AMSU-A – an air mass bias correction and a scan bias correction;
- Residual biases still persist in observations and the NWP model;

Two approaches to correct AMSU-A biases

- The effect of correcting air mass dependent biases by two more physically-based approaches is investigated:

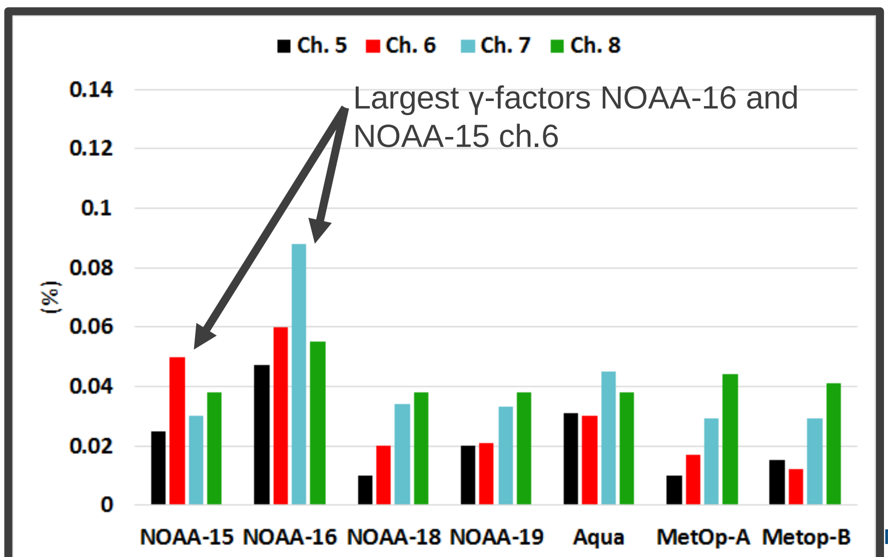
  - Empirical gamma-correction *(Watts & McNally, 2004):* Accounts for biases arising from errors in the absorption coefficients and in the weighting function for lower tropospheric AMSU-A observations by scaling the optical depths in the radiative transfer model with a channel/satellite specific γ absorption factor;

  - Modified RT coefficient files using analysed pass band (*Lu & Bell, 2014*): The bias is due to shifts and drifts in the AMSU-A center frequencies caused by instability in the local oscillator;

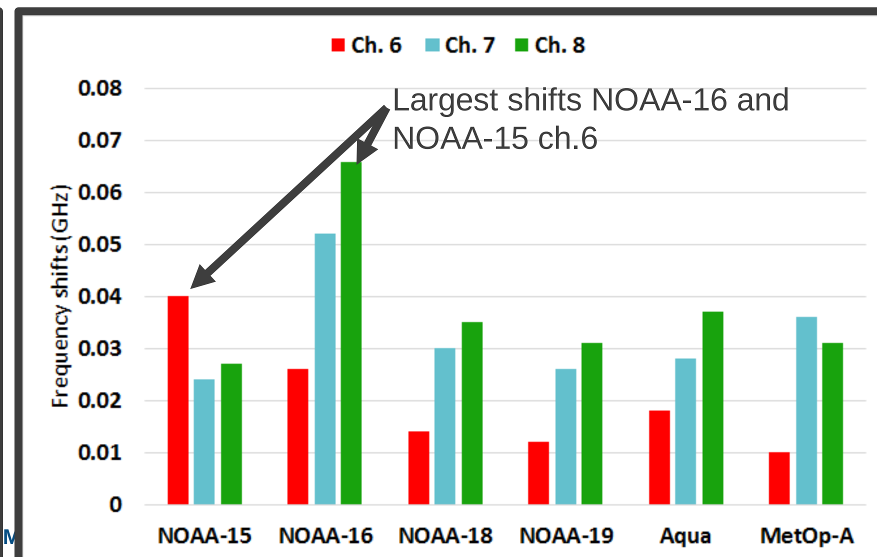
Assimilation studies in the IFS

- Experiments set-up: ECMWF 12-h 4D-Var, T511/137 vertical levels; 8 months period July 2013 –February 2014;
  - **'Reference run‘:** use uncorrected AMSU-A coefficient files;
  - **'Gamma run‘:** use γ adjustments to transmittance values for AMSU-A chs. 5-8 (γ is calculated by minimising the geographical variation in the bias against the background);
  - **'Shifted run‘:** use optimised center frequency estimates for AMSU-A chs. 6-8 on six platforms (except MetOp-B);

Relative change in the γ absorption coeff. [%]



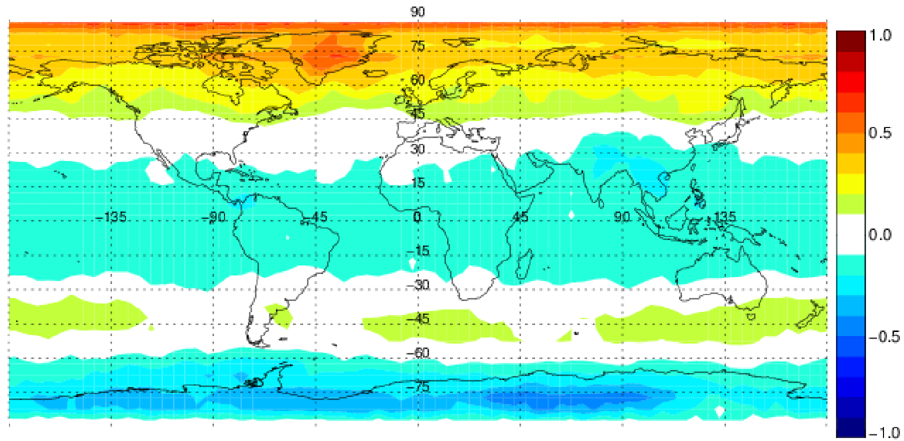
The derived pass band shifts [GHz]



Impact on first-guess departures before VarBC

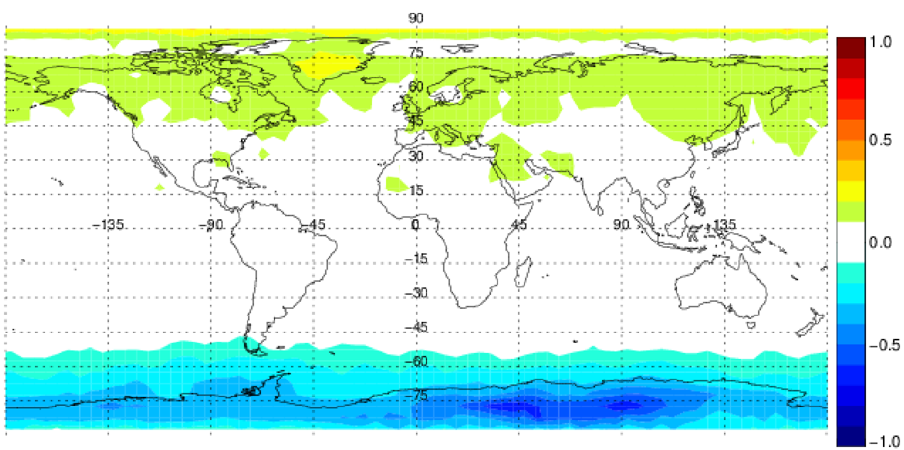
AMSU-A/NOAA-18 ch. 7: Mean(OBS-FG), but with global mean removed;

Reference run; Global mean=-0.497K

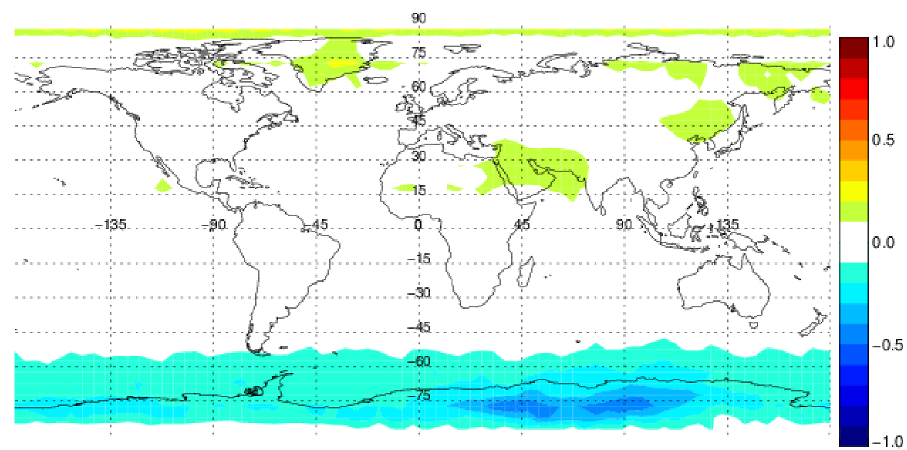


- The fit between observation and model is improved when the γ-factor or the pass band shifts corrections are used;

Gamma run; Global mean=0.007K



Shifted run; Global mean=0.001K

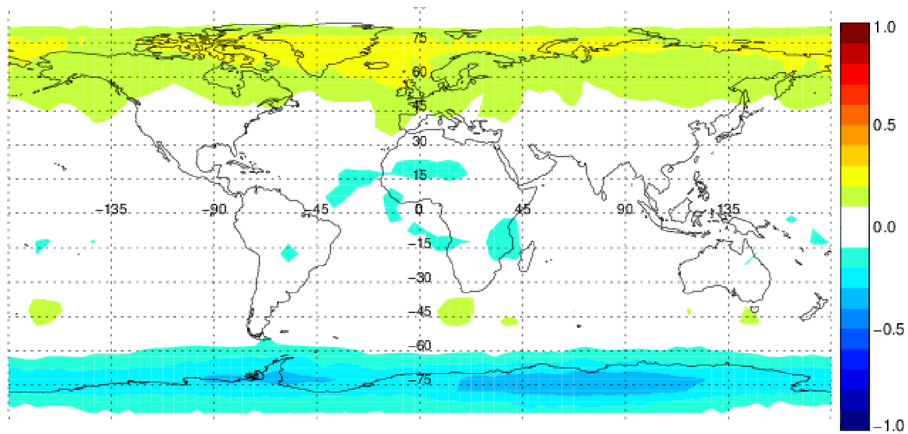


Period: August 2013

Impact on first-guess departures before VarBC

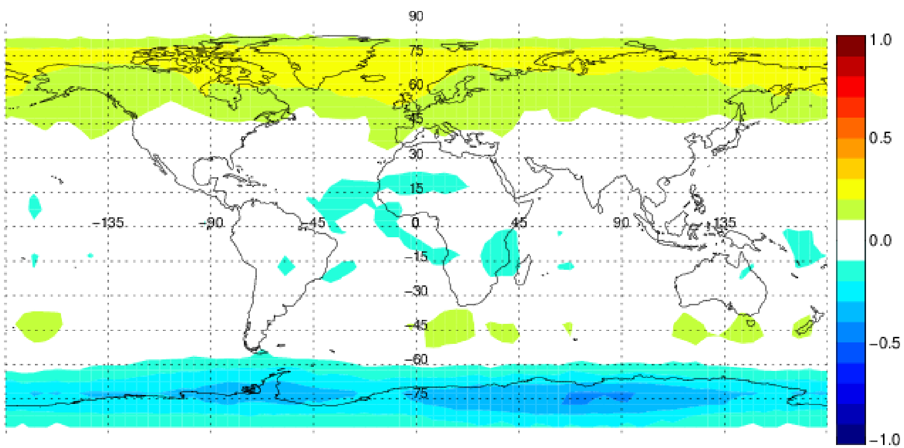
AMSU-A/NOAA-18 ch. 9: Mean(OBS-FG), but with global mean removed;

Reference run; Global mean= -0.627 K

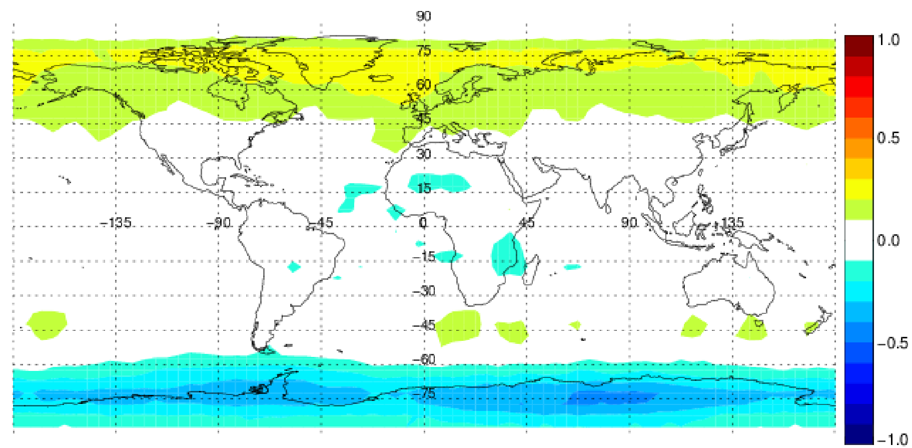


- The fit between observation and model is degraded for channel 9 (and above) when the γ-factor or the pass band shifts corrections are used;

Gamma run; Global mean= -0.679 K



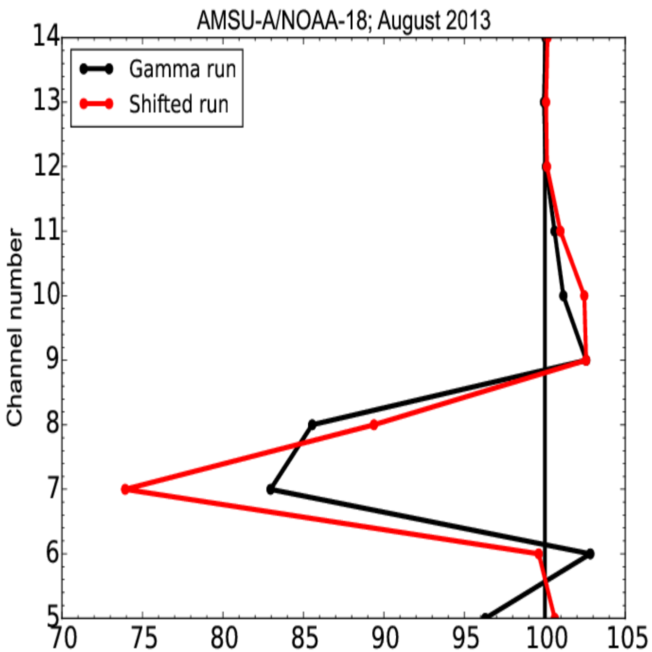
Shifted run; Global mean= -0.662 K



Period: August 2013

Std. dev. of first-guess departures before VarBC

- For almost all AMSU-A instruments, accounting for a γ-correction or for the pass band shifts corrections results in:
  - reductions in the variance of the first guess departures (channels 6-8).
  - increase in the variance of the first guess departures (channels 9 and above).



Std. dev. of FG-departures [%] normalized by the Reference run.

Std. dev. of first-guess departures before VarBC

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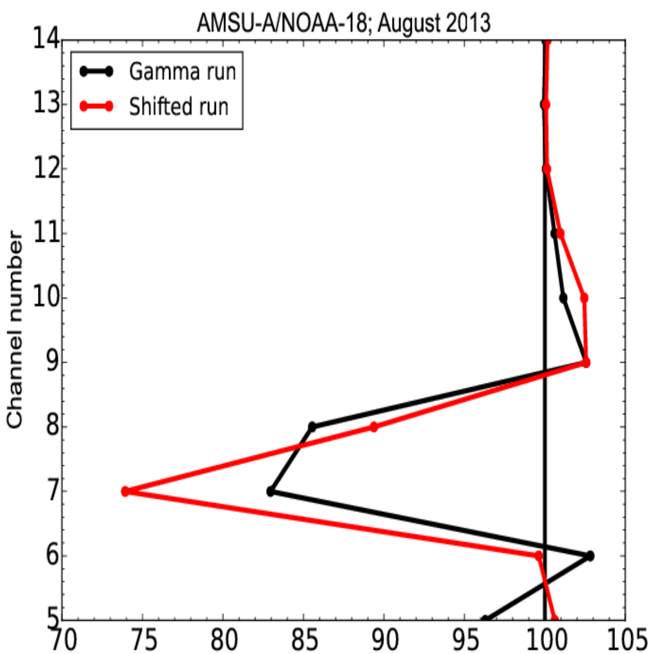


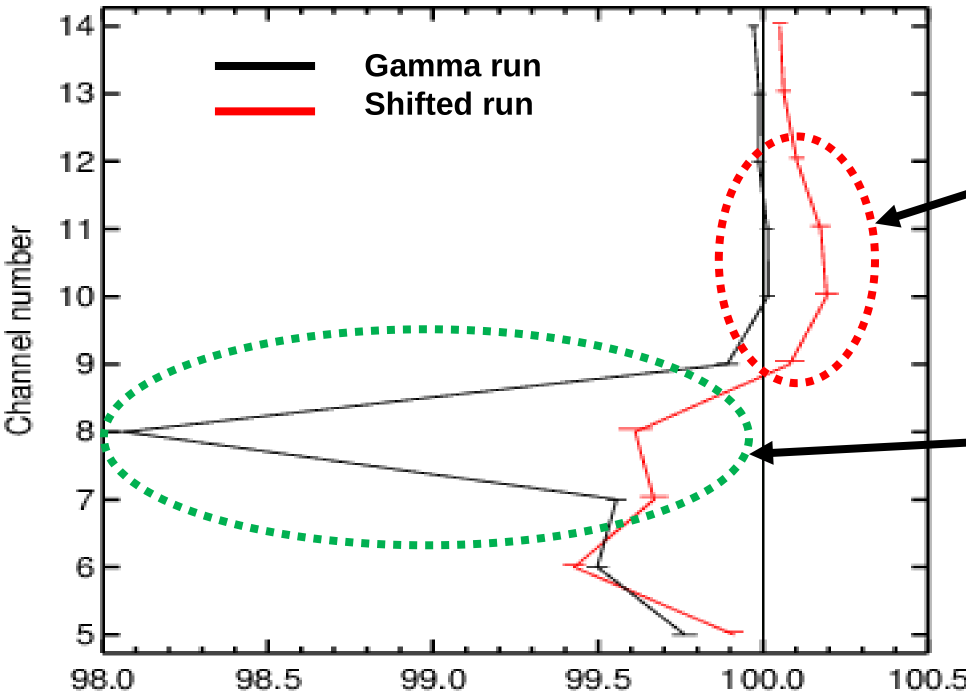
Std. dev. of FG-departures [%] normalized by the Reference run.

	Gamma run				Shifted run			
AMSU-A ch	5	6	7	8	5	6	7	8
NOAA-15	🟢	X	🟢	🟢	🟡	X	🟢	🟢
NOAA-16	🟢	🟢	🟢	X	🟡	🟢	🟢	X
NOAA-18	🟢	🔴	🟢	🟢	🔴	🟡	🟢	🟢
NOAA-19	🟢	🔴	X	X	🔴	🔴	X	X
Aqua	X	🟡	X	🟢	X	🟡	X	🟢
MetOp-A	🟡	🔴	X	🟢	🔴	🔴	X	🟢
MetOp-B	🟢	🔴	🟢	🟢	🔴	🔴	🔴	🔴

Std. dev. of first-guess departures after VarBC

AMSU-A: all 7 satellites

Period: 1 Aug. 2013 - 28 Feb. 2014



Std. dev. of FG-departures normalized by Reference run. 95% confidence bars.

"Shifted run": Degradations of ~0.2% in the std. dev of FG in AMSU-A ch.9 and above. Also seen in ATMS fits, Temp-T radiosondes observations..

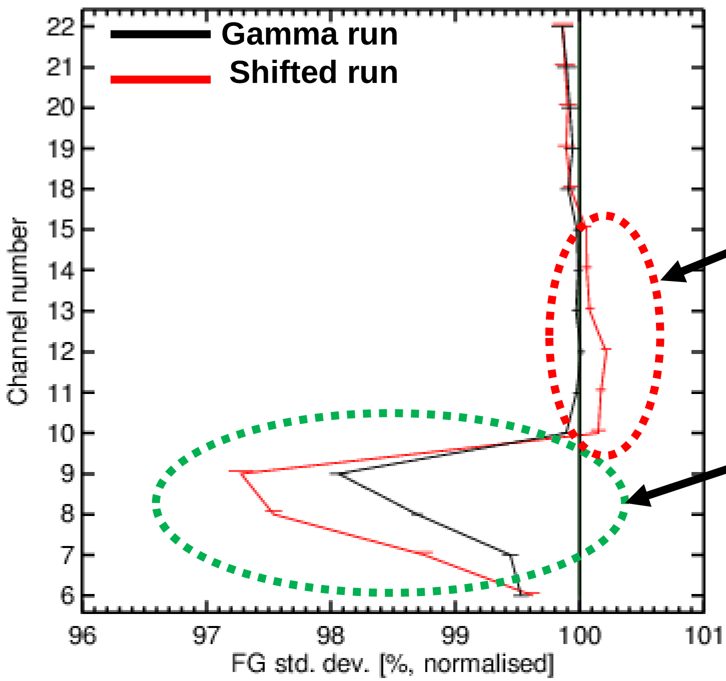
UTLS temperature improved:
(~2% Gamma run, ~0.5% Shifted run)

Std. dev. of first-guess departures after VarBC

- RTTOV coefficient files are the same for ATMS for all three experiments;
- ATMS channels share all the same phase-locked oscillator as AMSU-A chs. 9-14;

ATMS

Period: 1 Aug. 2013 - 28 Feb. 2014



"Shifted run": Degradations of ~0.2% in the std. dev of FG in ATMS chs. 10-15.

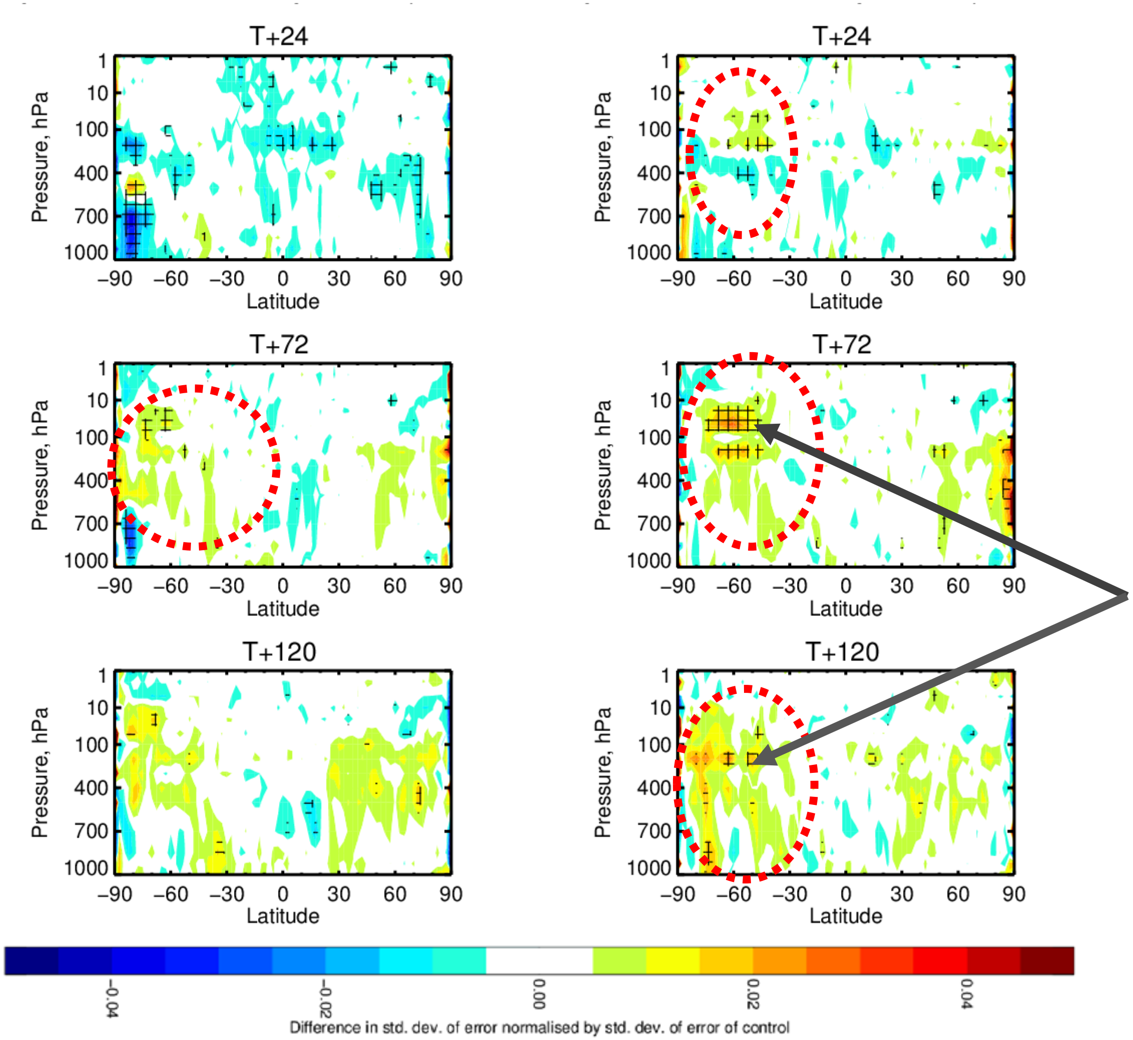
UTLS temperature improved:
(~1.8% Gamma run, ~2.7% Shifted run)

Std. dev. of FG-departures normalized by Reference run. 95% confidence bars.

Forecast impact

Normalised change in the std. dev. of errors in T forecast error between:

Gamma run – Reference run **Shifted run – Reference run**



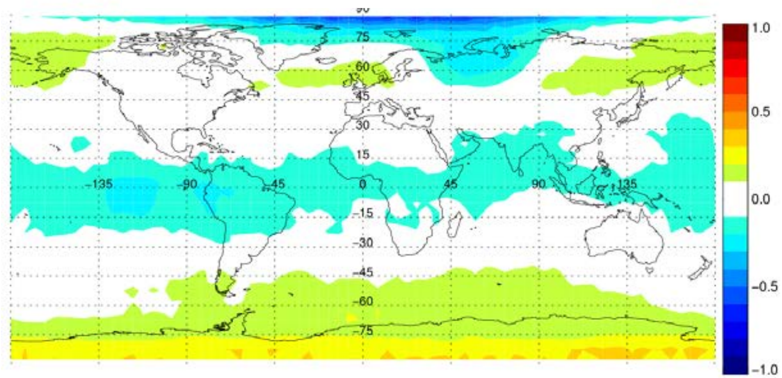
Significant detrimental impact in forecast scores of temperature (and wind);

Beneficial impact Detrimental impact

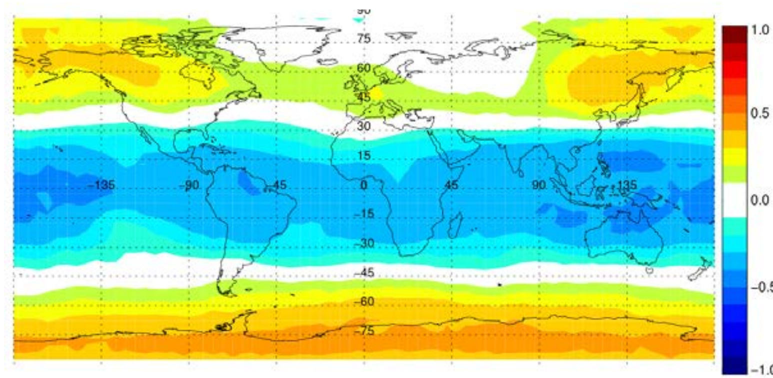
Mean FG-departure statistics: AMSU-A/MetOp-B

- The pattern of the bias is consistent between channels (e.g., ch. 8 and ch. 9);

Channel 7

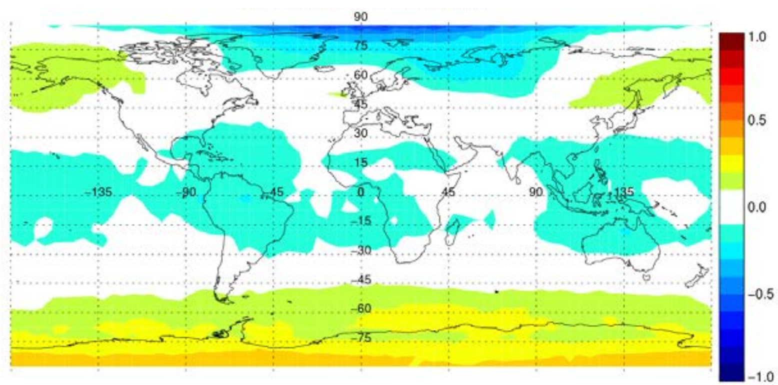


Channel 8

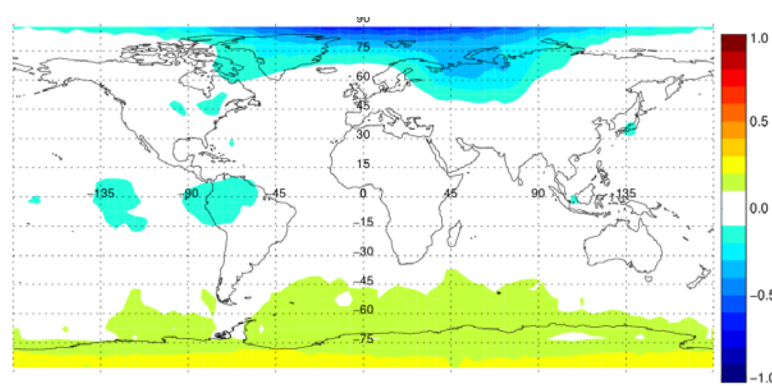


Free running oscillator

Channel 9



Channel 10



Single LO, phased locked

Summary

Reducing systematic errors in AMSU-A simulations using:

- Empirical models – biases originate from inaccuracies in the underlying spectroscopic parameters.
    - Improvement in the first guess departures;
    - Forecast scores of temperature show significant degradation at T+72h;
- Modified pass band shifts of the central frequency - observed biases are due to inaccurate instrument characterisation.
    - The derived pass-band adjustments lead to some improvements for channels sensing the lower troposphere, but also produce degradations in higher sounding channels;
    - Very significant negative impact in forecast scores of temperature and wind (T+24h → T+120h);
- The empirically derived gamma-corrections and optimised pass band shifts erroneously absorb NWP model biases, that are otherwise corrected ;
- More work needed to understand AMSU-A biases !

Thank you for listening!