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Introduction

Assimilation of observed brightness temperatures (BTs) with variational methods requires calculation of the equivalent first guess BTs. At ECMWF, they are calculated from the 4DVar first guess forecasts using the RTTOV radiative transfer code. In case of surface sensitive channels, a good emissivity estimation is needed for RT calculations. Accurate land emissivity models usually require input parameters describing surface characteristics, rarely available globally. **Retrieving emissivities** directly from the microwave window channel observations is investigated at ECMWF as an alternative approach.

Current use of AMSU at ECMWF

AMSU-A	AMSU-B
channel usage	
sounding channels 5-14: clear-sky BTs assimilated in 4DVar (channels 5, 6 over low orography only) channel 4: fg-departures used for quality control window channels 1,2,3,15: used for cloud detection (LWP estimation) and rain detection (scattering signatures); also for emissivity estimation over land and sea-ice (Kelly & Bauer scheme)	sounding channels 3,4,5: clear-sky BTs assimilated in 4DVar (channels 3 and 4 over sea and low orography, 5 over sea only) channel 2: not used window channel 1: fg-departures used for quality control including detection of cloud and rain contaminated observations
land surface emissivity modeling	
Kelly & Bauer algorithm: surface type identification followed by emissivity estimation; emissivity model used depends on the identified surface type [Kelly & Bauer, 2000]	surface type classification based on the IFS skin temperature, soil moisture and snow cover; each surface type has an assigned emissivity value.

Known issues

- Variation of the emissivity with the polarization (scan position) not taken into account
- Unrealistic diurnal variations (around 0.05) in emissivity were observed for AMSU-A for dry/wet land surfaces.

Dynamic emissivity retrievals

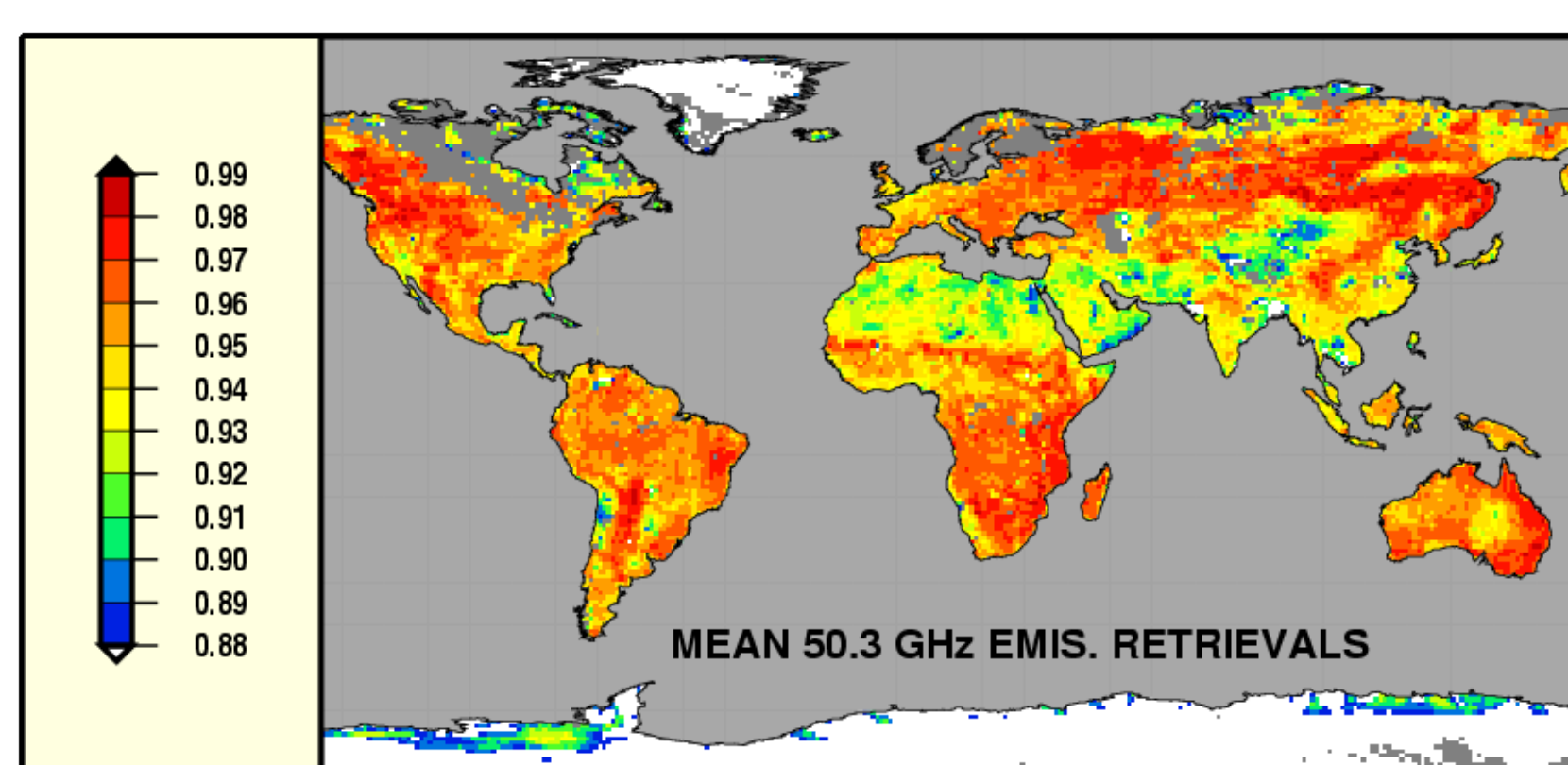
At microwave frequencies, under certain assumptions, observed BT can be expressed as

$$BT = T_s \epsilon \Gamma + BT_{up} + (1 - \epsilon) BT_{down} \Gamma$$

where T_s is the skin temperature, ϵ is the surface emissivity, BT_{up} and BT_{down} are the atmospheric upwelling and down-welling brightness temperatures respectively and Γ is the surface-to-space atmospheric transmissivity. By rearranging the above equation, surface emissivity can be calculated:

$$\epsilon = \frac{BT - BT_{up} - BT_{down} \Gamma}{(T_s - BT_{down}) \Gamma}$$

The method was implemented at Météo France within the ARPEGE 4Dvar system and later ported to the IFS 4Dvar [Karbou et al., 2005]. BT_{up} , BT_{down} and Γ are estimated with the RTTOV radiative transfer code from IFS first guess forecast profiles. A selected window channel provides the observed BT. The retrieved emissivity is then used within the variational framework to assimilate AMSU sounding channels over land.



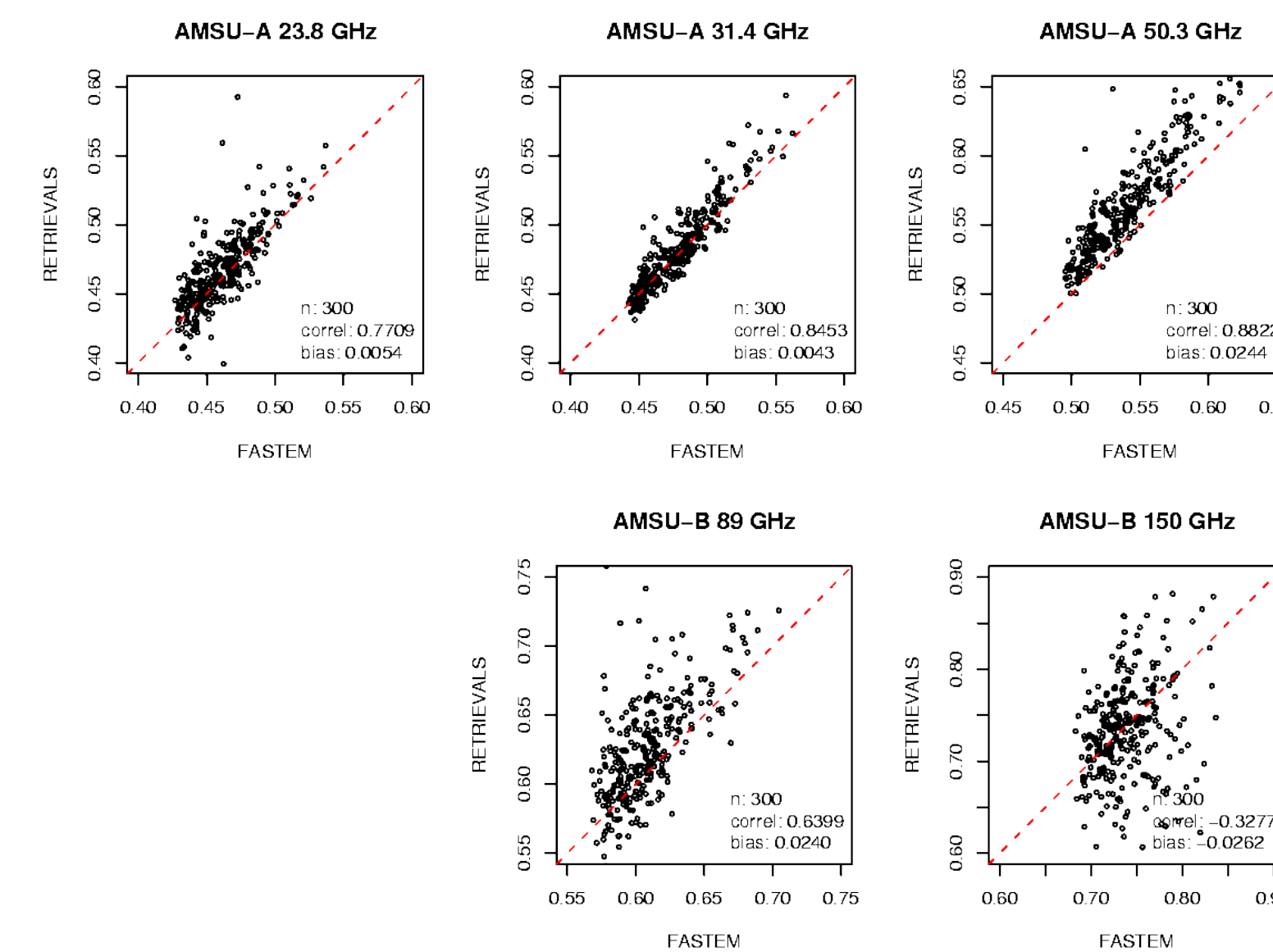
Emissivity retrievals averaged over 1 month: NOAA-16 AMSU-A channel 3 observations close to nadir were used to retrieve emissivities. The period shown is from 26 Sep 2006 to 26 Oct 2006

References

- Kelly, G., and Bauer, P. (2000): The use of AMSU-A surface channels to obtain surface emissivity over land, snow and ice for numerical weather prediction. In Proceedings of 11th International TOVS Study Conference, pages 167-179, Budapest, Hungary
- Prigent, C., Chevallier, F., Karbou, F., Bauer, P., and Kelly, G. (2005): AMSU-A land surface emissivity estimation for numerical weather prediction assimilation schemes. Journal of Applied Meteorology, 44:416-426

Comparison with FASTEM emissivities

Retrieved emissivities were validated against FASTEM over sea for clear-sky conditions. AMSU-A emissivities generally show a good correlation. The retrieval scheme occasionally gives higher emissivities than FASTEM - possibly due to the residual cloud/rain signal in the observations over the radiatively cold ocean background. AMSU-B emissivities are less consistent - they are sensitive to the errors in the water vapour profiles of the first guess forecast.

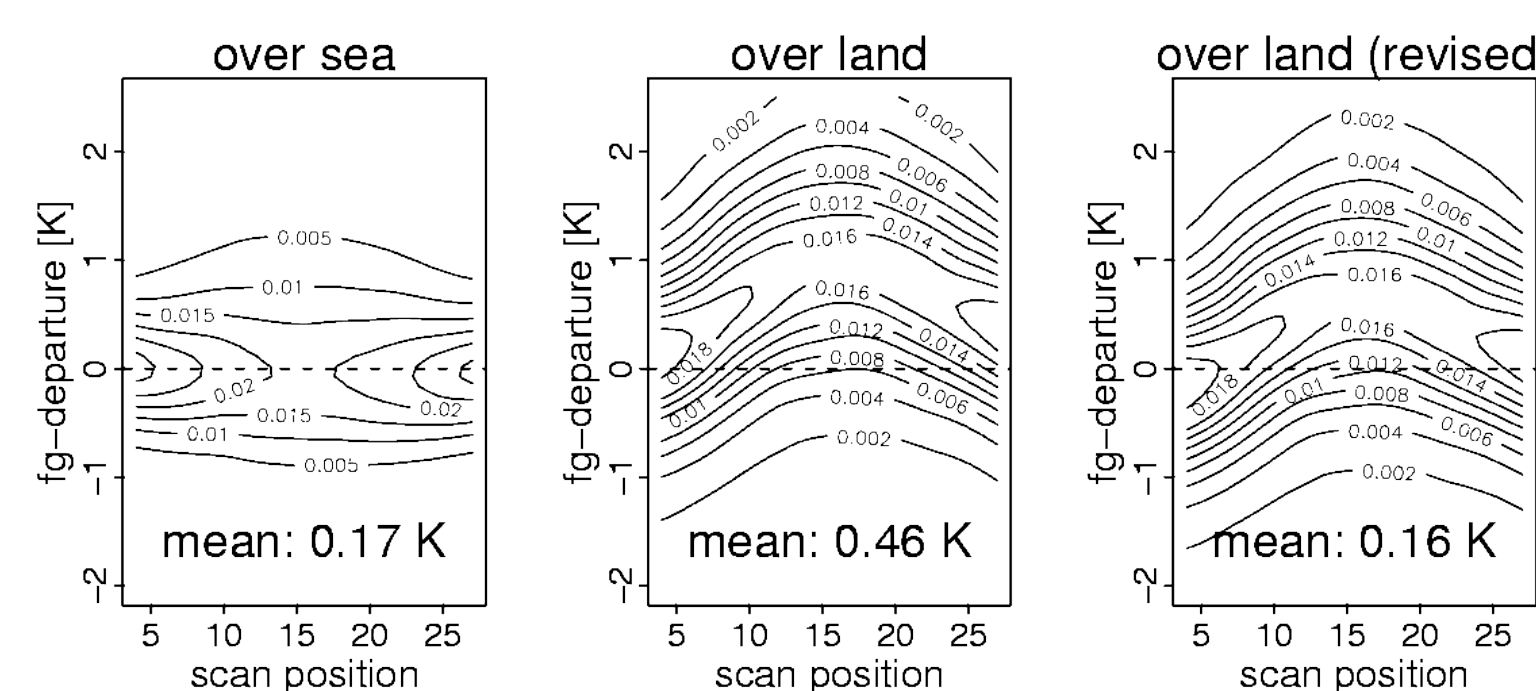


Comparison of FASTEM and retrievals: A sample of NOAA-16 observations over sea after cloud and rain screening spanning 2 days, together with collocated IFS first guess profiles, was used for the retrievals.

Changes in the bias correction

In the operational setup, systematic errors in the fg-departures are corrected globally using variational bias correction. However, residual biases over land were found in AMSU-A channel 4 and 5 fg-departures both with the operational and the experimental emissivity scheme.

A separate correction of the bias was introduced over land for these channels. As a result, the flat component of the bias over land was reduced. Further analysis revealed a residual scan dependent bias component over land, although much smaller compared to operations. A separate correction of the scan bias over land is currently under investigation.

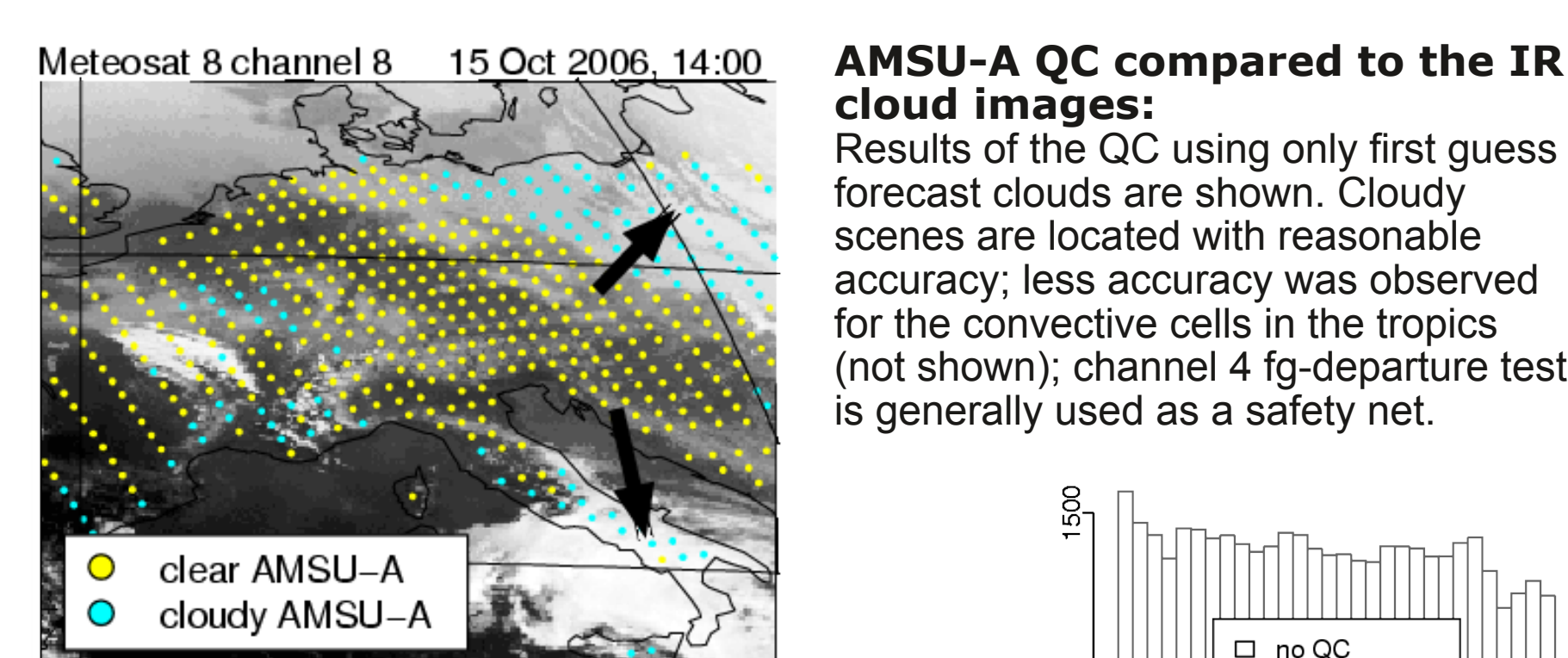


Distribution of the channel 5 fg-departures for different scan positions NOAA-16 fg-departures after bias correction are shown. Emissivity over land was calculated from channel 3 BTs. A residual scan bias is evident over land. The flat bias component is reduced with the revised bias correction.

Changes in the quality control

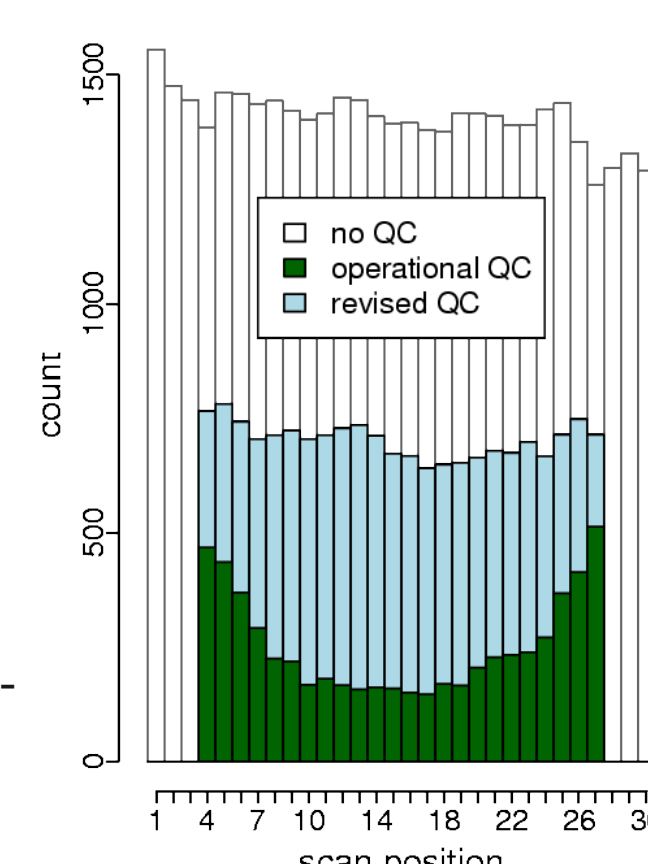
AMSU observations must pass quality control prior to their assimilation. For example +/-0.7K threshold test is applied to the AMSU-A channel 4 fg-departures to detect "warm" clouds over the radiatively cold ocean background. However, the clear-sky land surface emission is very similar to the cloud emission making cloud detection difficult.

An additional QC test was applied experimentally over land - IFS modeled liquid water profiles were used to screen cloudy scenes. The AMSU-A fg-departure threshold was also relaxed to +/- 1.2K over land. Results of the modified QC were compared with the METEOSAT cloud images.



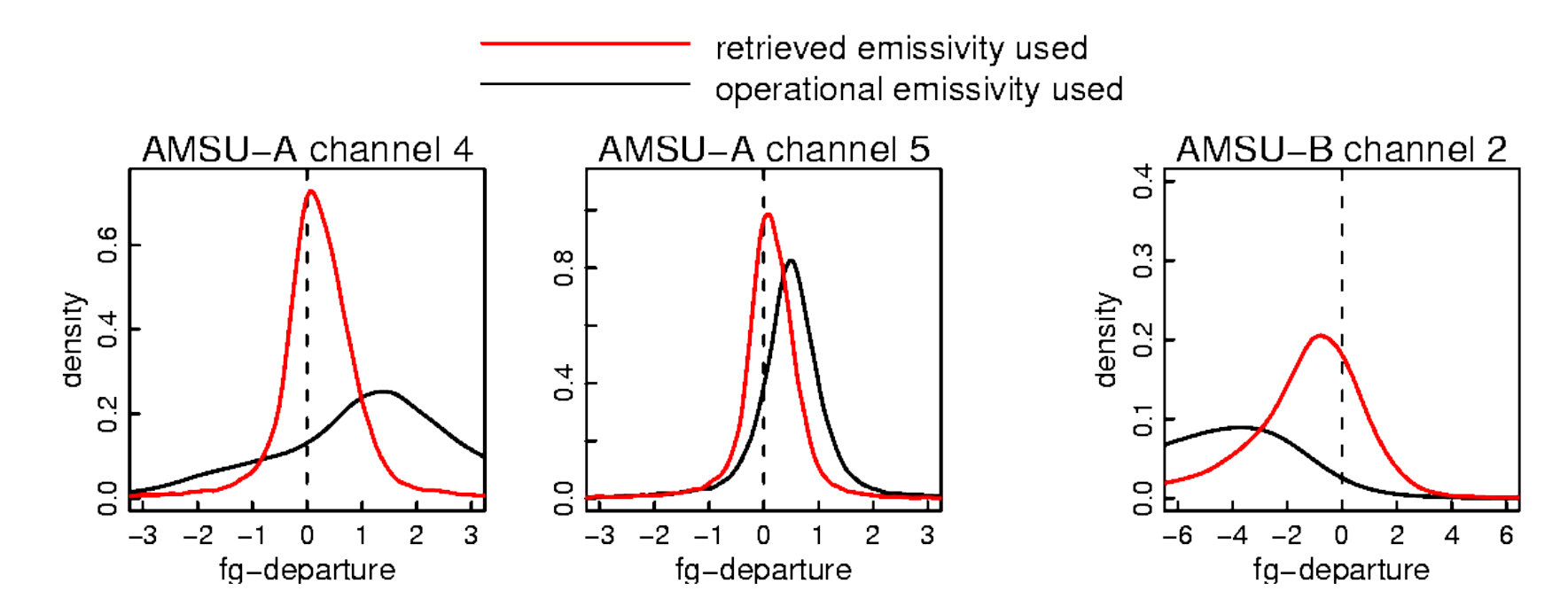
Number of observations passing QC:

The revised quality control for AMSU-A rejects less observations compared to the operational QC. The strong residual scan bias in channel 4 fg-departures over land is responsible for large variations of the operational QC performance with the scan position. This effect is reduced in the revised QC and with emissivity retrievals.

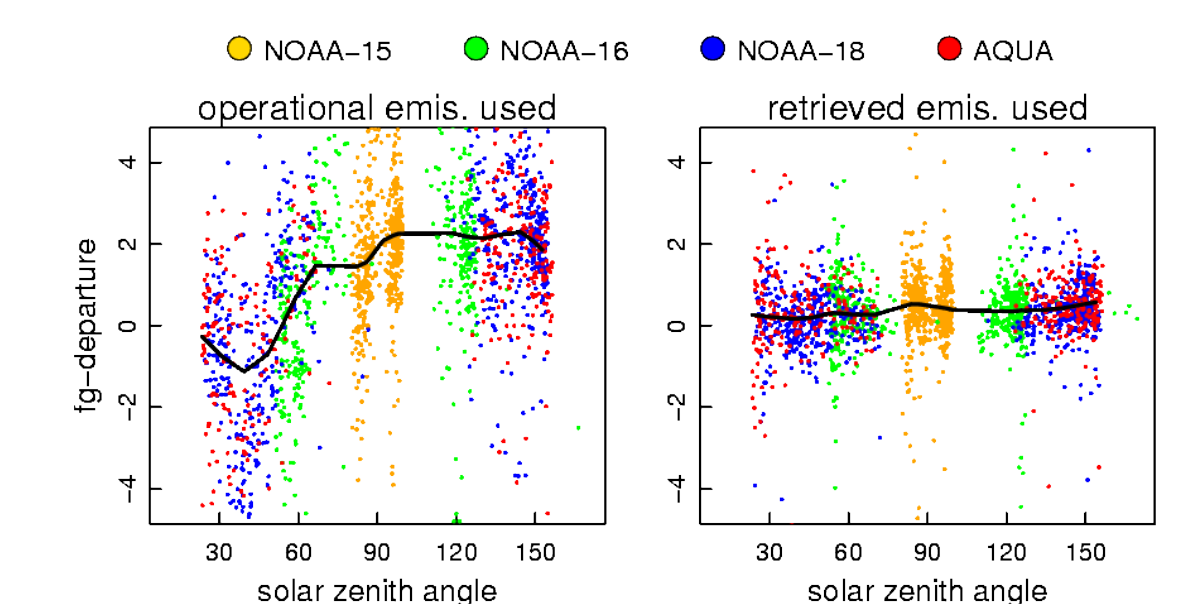


Improved RT simulations

The dynamic emissivity retrievals seem to improve the a-priori estimations of the observed BTs for the surface sensitive channels. The differences between observed and simulated clear-sky BTs (fg-departures) are reduced compared to the operational emissivity model. The accuracy of RT simulations is improved for AMSU-A channels 4 and 5. AMSU-B channel 2 simulated BTs also benefit from the new emissivity scheme.



Normalized histograms of the fg-departures of NOAA-16 AMSU-A/B surface sensitive channels for the operational and experimental emissivity scheme. AMSU-A channel 3 and AMSU-B channel 1 observations were used in emissivity retrievals.



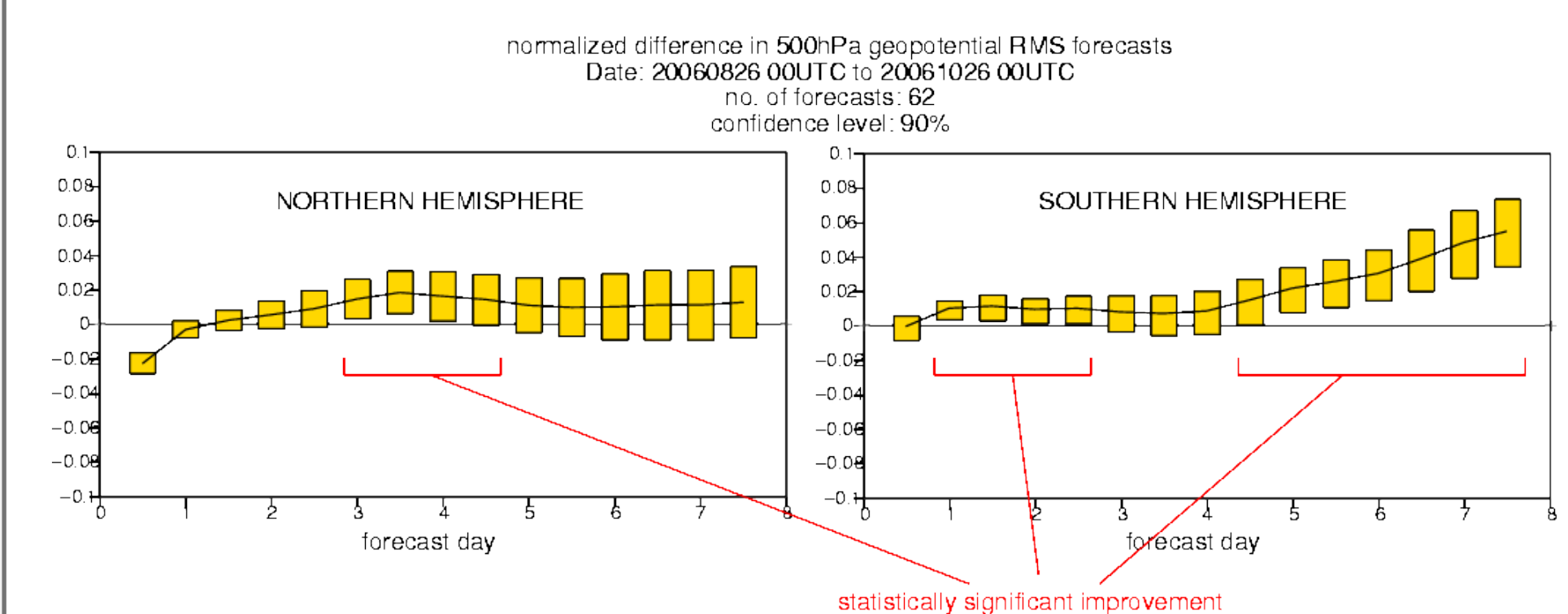
AMSU-A channel 4 fg-departures for day/night: diurnal tendencies in the emissivity and fg-departures are eliminated when the emissivity retrievals are used. Channel 3 BTs were used for retrievals.

Impact on forecasts

A series of forecast experiments with the AMSU observations assimilated over land was conducted. for the period 26-Aug-2006 to 26-Oct-2006. Influence of the emissivity retrievals on the forecasts was analysed. AMSU-A channels 2, 3 and AMSU-B channel 1 were used to retrieve emissivities. Response of the forecast system to the changes in the bias correction and quality control was also examined.

Forecast scores were improved over the southern hemisphere with the dynamic emissivity retrievals compared to the operational system. For AMSU-A emissivities retrieved from channel 3, also the northern hemisphere saw positive impact.

Changes in the quality control essentially had neutral impact on the forecasts. Introduction of the separate flat bias correction over land actually degraded the forecast quality compared to the experiment with no bias separation. The scan bias correction over land is under investigation.



Normalised difference in 500 mb geopotential RMS forecast error for experiments with operational emissivity and emissivity retrievals. AMSU-A channel 3 and AMSU-B channel 1 were used to retrieve emissivities.

Summary

- Using dynamic emissivities over land resulted in a significant reduction of noise and systematic errors in the fg-departures for surface sensitive channels, compared to the operational emissivity scheme.
- Forecast scores are improved with the new emissivity.
- Decoupling of the bias correction over land and sea reduces flat biases in the fg-departures over land, however no improvement in the forecast scores was observed. Decoupling of the scan bias correction is under investigation.

Plans

- Use the Kalman filter to reduce the effects of random errors in the first guess atmospheric profiles, model skin temperature errors and cloud contamination on the retrieved emissivities.
- Emissivity retrievals are intended to replace the current emissivity scheme in operations (by the end of 2008).