EXTENDING THE USE OF MICROWAVE SOUNDING DATA OVER SEA-ICE IN THE ECMWF SYSTEM

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Abstract

This paper describes assimilation experiments with an enhanced use of microwave sounding observations over sea-ice. Over sea-ice, the assimilation of surface-sensitive microwave sounding channels is more challenging due to difficulties with the specification of the surface emissivity and skin temperature. Here we summarise results from pre-operational testing of an approach that uses dynamically retrieved emissivities tailored to sea-ice conditions.

The use of dynamic emissivities improves the simulation of surface-sensitive AMSU-A and MHS data, and allows a greater number of observations to be assimilated. This significantly enhances observational coverage in an otherwise data-sparse area. For MHS, the variation of the emissivity spectra over sea-ice for the frequency range considered needs to be taken into account when adapting the dynamic emissivity method. The approach used for the treatment of MHS over sea-ice builds on the results obtained by previous work with low resolution experiments.

Assimilation experiments have been conducted over two seasons, and the enhanced data usage leads to significant gains in forecast skill. The approach is planned for operational implementation in ECMWF's forecasting system towards the end of 2013.

INTRODUCTION

We report on final pre-operational testing of a scheme to enhance and extend the use of microwave sounding data over sea-ice in the ECMWF system. Over sea-ice, the assimilation of surface-sensitive microwave sounding channels is more challenging due to difficulties with the specification of the surface emissivity and skin temperature. We adapt a dynamic emissivity retrieval scheme to sea-ice conditions, and apply it to AMSU-A and MHS data.

DYNAMIC EMISSIVITIES

In the dynamic emissivity scheme, emissivities for sounding channels are retrieved using observations from window channels (Karbou et al 2005). To do so, the radiative transfer equation is solved for the emissivity, and the atmospheric and skin temperature terms are estimated from short-term forecasts. The scheme is used successfully at ECMWF over land for AMSU-A and MHS.

Sea-ice shows considerable variations in emissivity with frequency (e.g., Fig 1). It is therefore useful to perform the emissivity retrieval with a window channel that has a frequency as close as possible to that of the sounding channels.

For AMSU-A, we use channel 3 at 50.3 GHz for the emissivity retrieval, sufficiently close to the surface-sensitive sounding channels in the 53-55 GHz range. The same channel is used for emissivity retrieval over land.

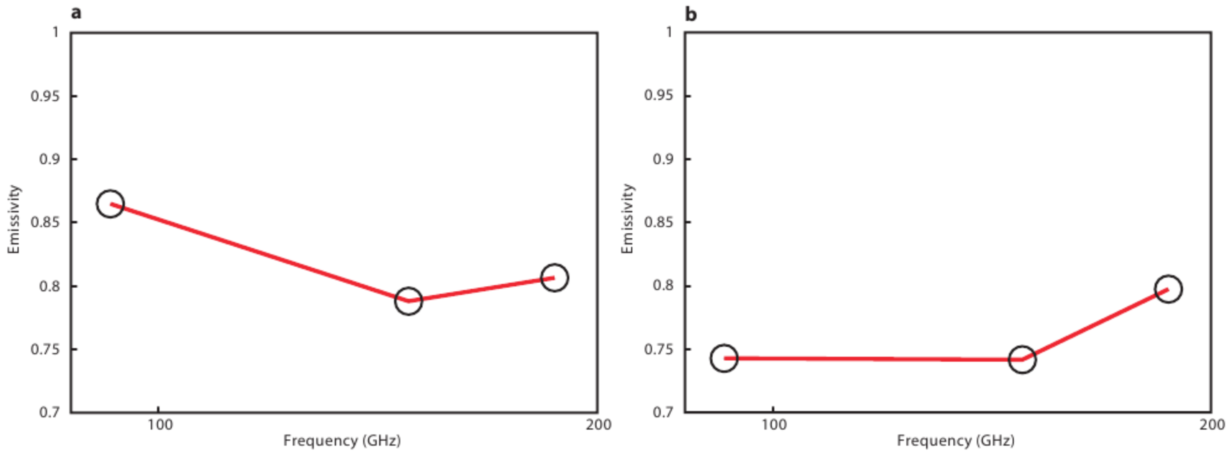

Figure 1: **Emissivity spectra for two different types of sea-ice, where the emissivities are dynamically retrieved from MHS observations at 89, 157 and 190.3 GHz.**

For MHS, we use channel 2 at 157 GHz for the emissivity retrieval, and apply the retrieved emissivity to the 183-190 GHz humidity sounding channels. This choice differs from that over land where channel 1 at 89 GHz is used instead. The choice is possible because the dry polar conditions mean that channel 2 has sufficient sensitivity to the surface to perform a reliable emissivity retrieval. This is not possible over most low- and mid-latitude land surfaces. The benefits of using channel 2 rather than channel 1 for emissivity retrieval are highlighted in Figure 2. Quality control is done based on First Guess departures of MHS channel 1, and an emissivity parameterisation is used to estimate the 89 GHz emissivities from the 157 GHz dynamic emissivities. This approach builds on the results obtained by low resolution experiments at T319 (60 km) which showed the benefit of using dynamic emissivities over sea-ice in particular with the usage of MHS channel 2 for the emissivity retrieval (Di Tomaso and Bormann 2012).

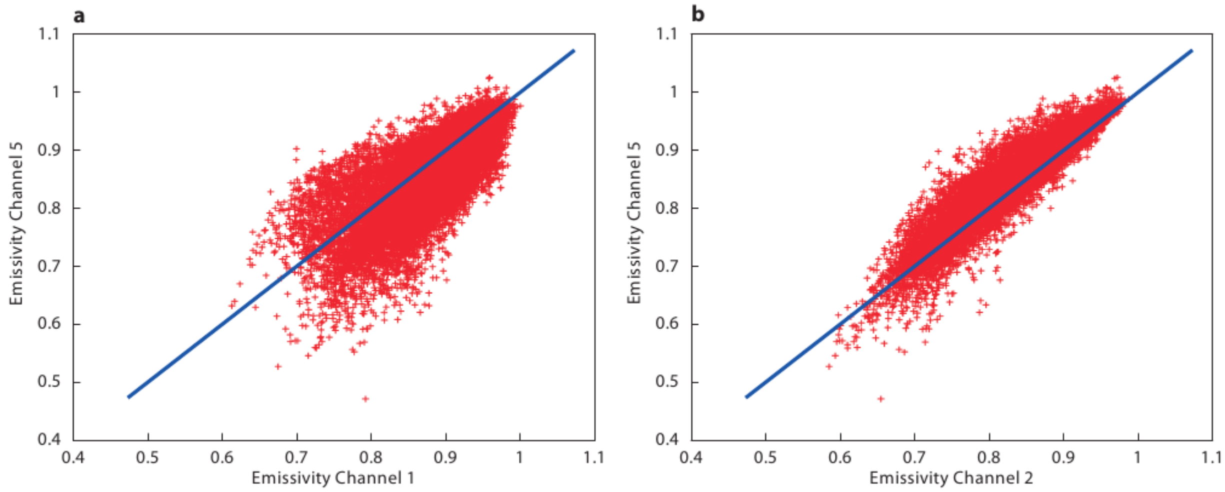

Figure 2: **Dynamic emissivities for MHS over sea-ice retrieved at channel 1 frequencies (89 GHz, left) and channel 2 frequencies (157 GHz, right) versus emissivities retrieved at channel 5 frequencies (190.3 GHz).**

ASSIMILATION EXPERIMENTS

The scheme has been tested in assimilation experiments covering January to March and July to September 2012, with a spatial resolution of T511 (40 km), and employing 12 h 4DVAR.

Two experiments were performed, a "Sea-ice" experiment and a "Control". The differences between the "Sea-ice" experiment with respect to the "Control" experiment are:

- Use of dynamic emissivities over sea-ice for AMSU-A and MHS as described above.

- Use of MHS channels 3 and 4 over sea-ice.
- Use of MHS channels 3-5 over cold sea-surfaces with temperatures of less than 278 K where previously the data were not used, with emissivities modelled by FASTEM.

The extended coverage of MHS is highlighted in Figure 3.

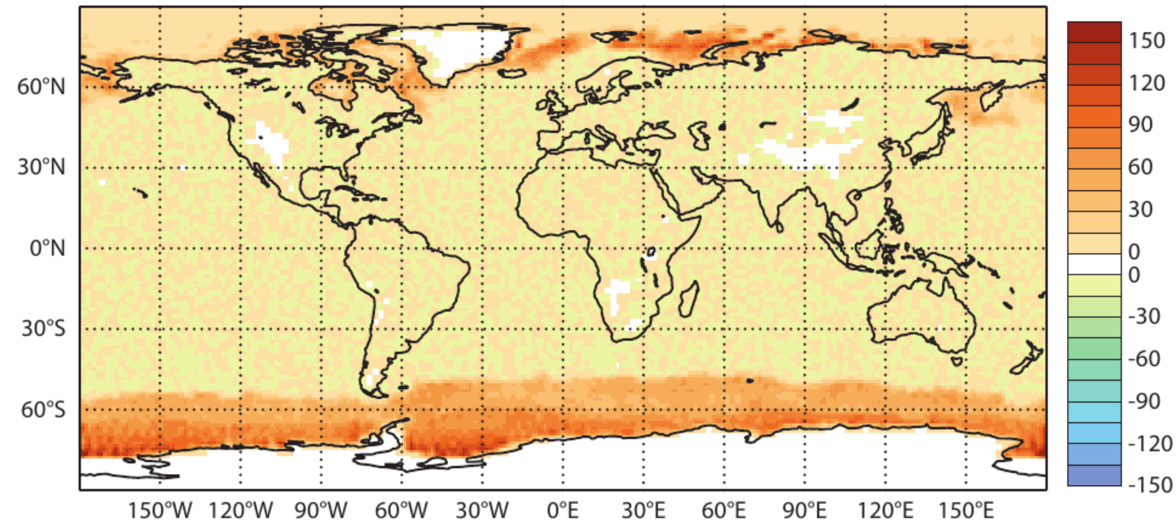

Figure 3: **Difference in the number of assimilated observations for METOP-A MHS channel 4 between the Sea-ice experiment and the Control in the Northern Hemisphere summer season.**

The use of the dynamic emissivities clearly leads to sharper histograms of First Guess departures over sea-ice both for AMSU-A channel 5 (the lowest AMSU-A sounding channel), and the MHS channels (Figure 4) compared to a static scheme. This reflects a more consistent modelling of the surface emission in the Sea-ice experiment.

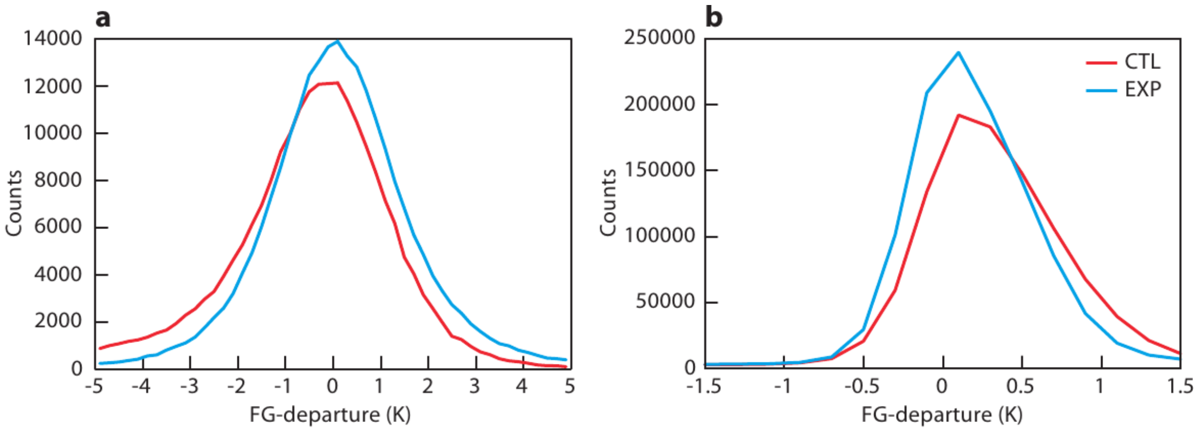

Figure 4: **Histograms of FG departures for MHS channel 4 (left) and AMSU-A channel 5 (right) over sea-ice in the summer of 2012 when emissivities are estimated by a static scheme (Control, red) or are retrieved dynamically from observations (Sea-ice experiment, blue). The histograms are based on departures before bias correction and before cloud screening has been applied.**

The Sea-ice experiment leads to improved analyses and short-term forecasts, as shown through smaller biases and standard deviations at low levels for radio-sondes over the polar regions for temperature and humidity (Fig. 5).

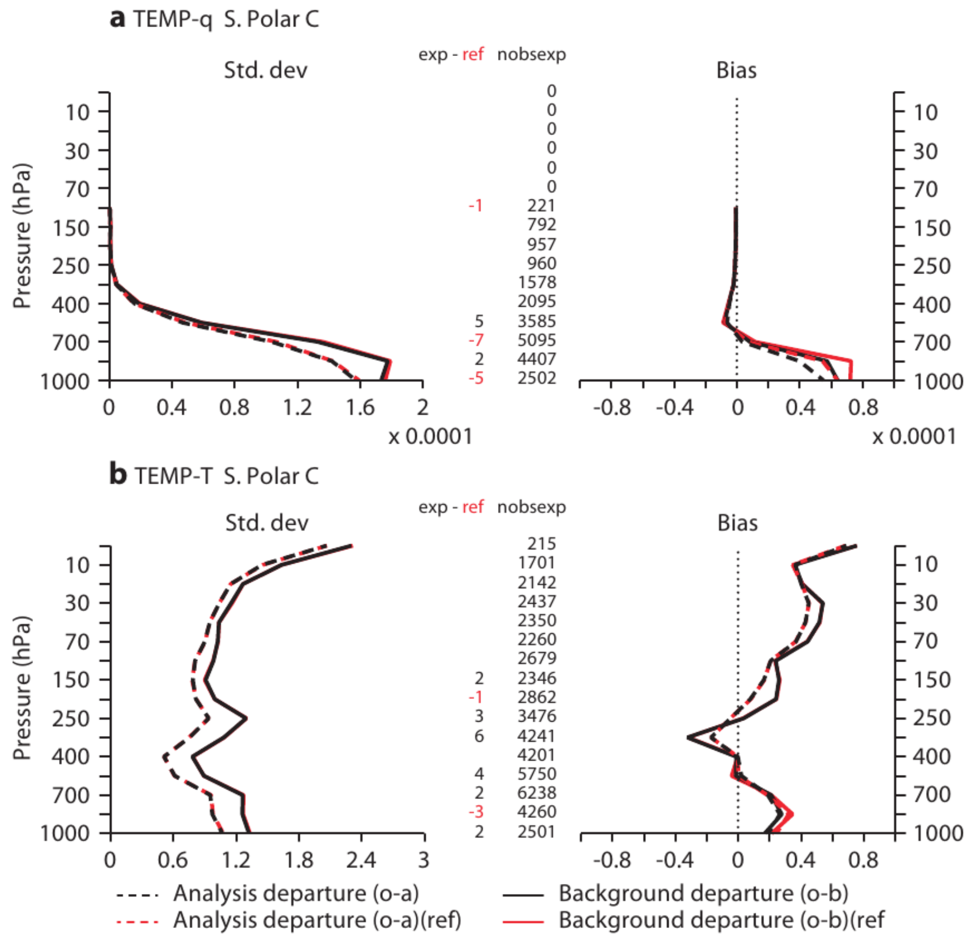

Figure 5: **Radiosonde temperature departure statistics for the Sea-ice experiment in the winter season (black) and the Control experiment (red) over the South Polar region for specific humidity (top) and temperature (bottom).**

The positive forecast impact is maintained over the first few days of the forecast, e.g., Fig. 6. This forecast impact is consistent for both seasons considered, with less impact over the Northern Hemisphere for the July-September experiment due to the reduced sea-ice coverage in these regions.

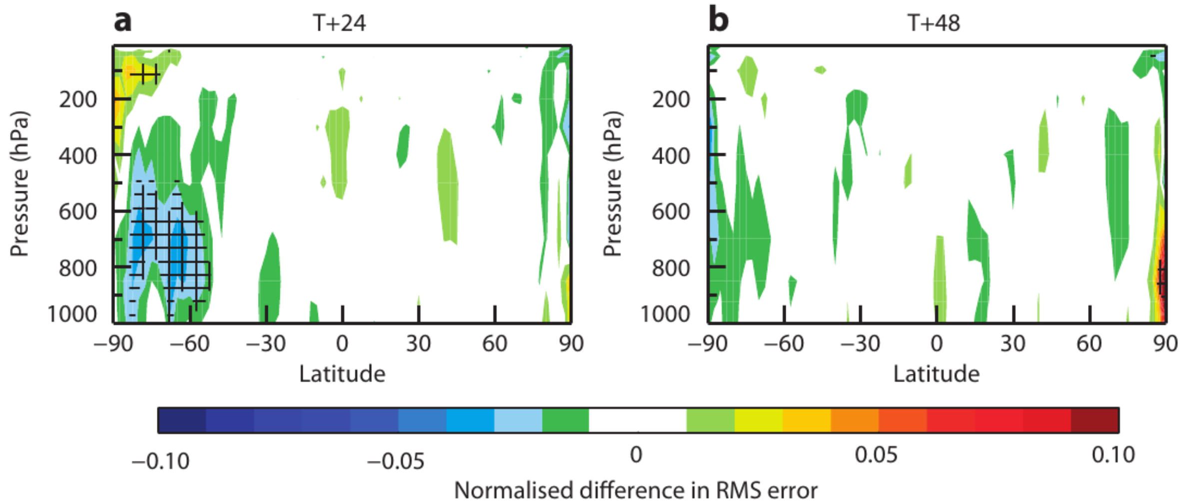

Figure 6: **Zonal means of normalised differences in the root mean square forecast error for the geopotential between the Sea-ice experiment and the Control over the summer season (July to September 2012) for the 0Z forecast for the day 1 (left) and day 2 (right) forecast ranges. Negative values indicate improvement relative to the Control experiment [%]. Each experiment has been verified against its own analysis.**

CONCLUSIONS

We have tested an enhanced assimilation of AMSU-A and MHS observations at high latitudes. A considerable number of humidity and temperature observations have been assimilated in data-sparse areas of the globe with a significant impact on forecast of all relevant atmospheric variables. The scheme will be implemented in the next operational upgrade of theECMWF system. Further details can be found in Di Tomaso et al. (2013).

REFERENCES

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