Met Office

All-sky assimilation of moisture-sensitive radiances at the Met Office

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Introduction

Since September 2018, all-sky (non-precipitating scenes only) radiances from AMSU-A channels 4 and 5 have been assimilated operationally at the Met Office. For assimilation purposes, the uncertainty of observations in these channels was increased from their clear-sky values by a factor linearly dependent on the liquid water path (LWP) within a given range of values as inferred from both observed and simulated AMSU-A channels 1 and 2 radiances. Our assimilation results over two trial periods showed reductions in forecast RMSE of about 1% up to day 2 and longer range reductions for 2-m temperatures and 10-m winds in the Tropics (Migliorini and Candy, 2018).

Our current work is focused on extending the all-sky approach to include the water-sensitive MHS channels 3, 4 and 5. Figure 1 shows the increased data yield for Metop-B Microwave Humidity Sounding (MHS) instrument channel 5 on 1 December 2018 0600 UTC. The inclusion of cloud-affected observations, however, lead to a larger observation-minus-background (OmB) error standard deviation and larger deviations from Gaussianity, at both low (cloudy obs and clear-sky background) and high (clear-sky obs and cloudy background) OmB values (see Figure 2).

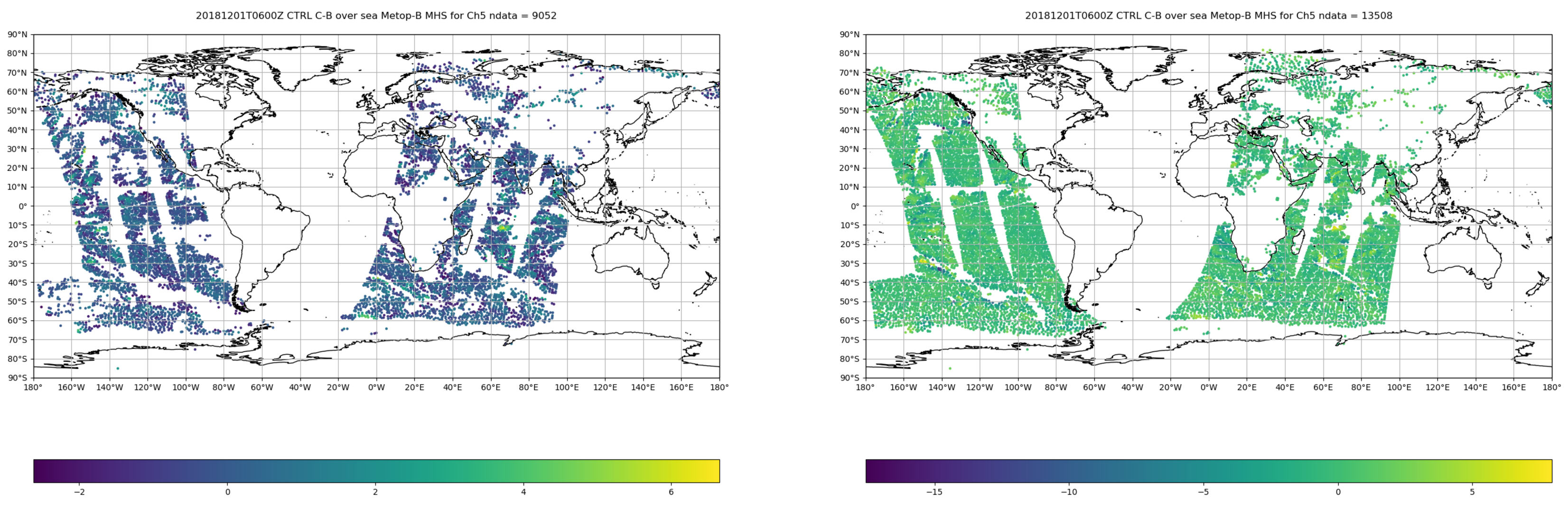

Figure 1 Innovations for Metop-B MHS channel 5 on 1 December 2018 0600 UTC in clear-sky (left panel) and in all-sky (non-precipitating) conditions (right panel). When cloud-affected radiance are included, we are in this case able to assimilate 49% more data.

Error estimation procedure

Radiative transfer calculations were performed using RTTOV-SCATT (Bauer et al., 2006). Liquid cloud particles are assumed spherical, with a modified gamma particle size distribution (PSD) and Rosenkranz (2015) permittivity model; ice particles are here also modelled as spherical, with a midlatitude version of the Field et al. (2007) PSD.

The moderate level of correlation (0.35) between LWP and IWP estimated using 1D-Var at each observation location over a two-month-long trial shows the need for an observation error model that depends on both LWP and IWP (see Figure 3). A new error augmentation strategy was adopted, where LWP and ice water path (IWP) are estimated using 1D-Var and the observation error standard deviation in a given channel σ_i is then expressed as

$$\sigma_i = \sigma_i^{clr} + a_i\,LWP + b_i\,IWP \qquad (1)$$

where σ_i^{clr} is the clear-sky value of the error standard deviation and a_i and b_i are regression coefficients determined using a training data set. In Figure 4 are shown the standard deviations for MHS channels 4 and 5 binned for given values of LWP and IWP and the best fit using Eq. 1.

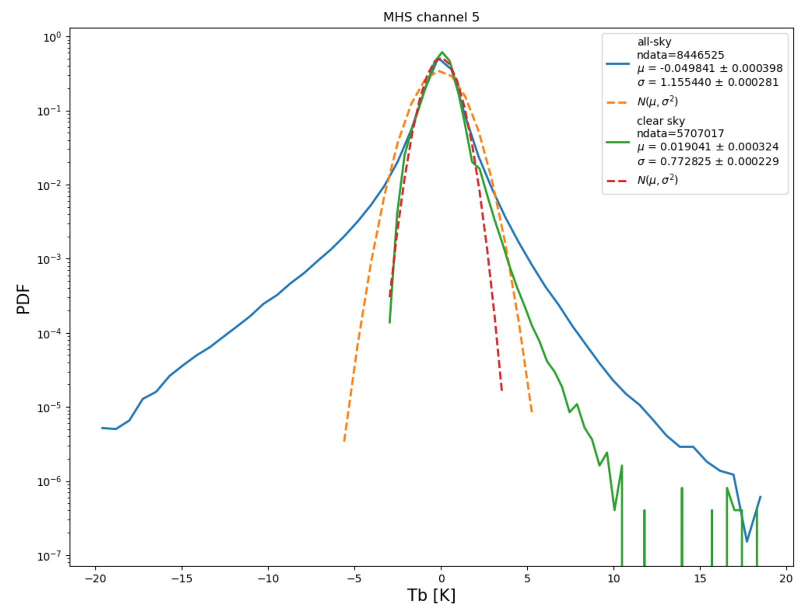

Figure 2 Distribution of the OmB innovations from a two-month-long trial experiment from 1 December 2018 0600 UTC. The all-sky experiment makes use of 48% more MHS channel 5 data than the clear-sky control experiment. The all-sky OmB distribution has a 67% larger standard deviation and a 0.2720 Kullback-Leibler (K-L) distance from Gaussian (bits) than in the clear-sky case, with a 0.0525 K-L distance.

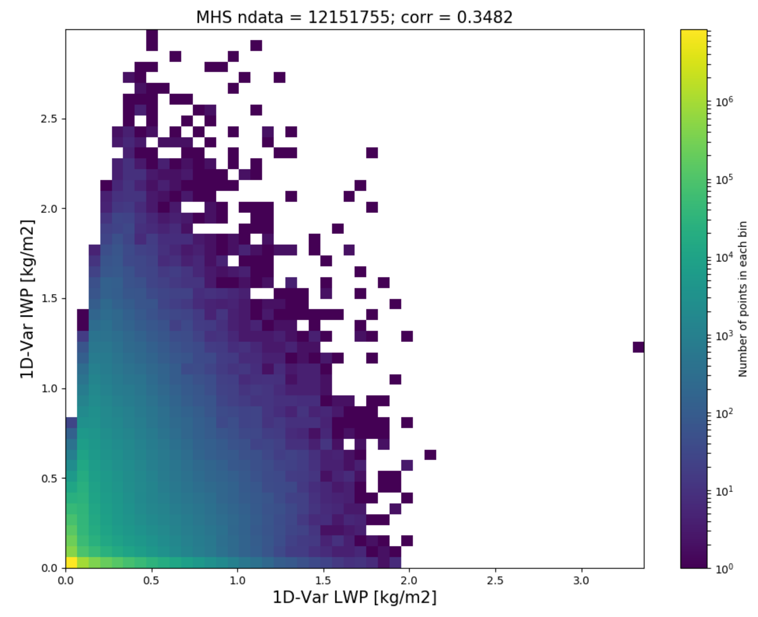

Figure 3 2-D histogram of liquid water path (LWP) and ice water path (IWP) as retrieved from 1D-Var during a two-month-long trial experiment.

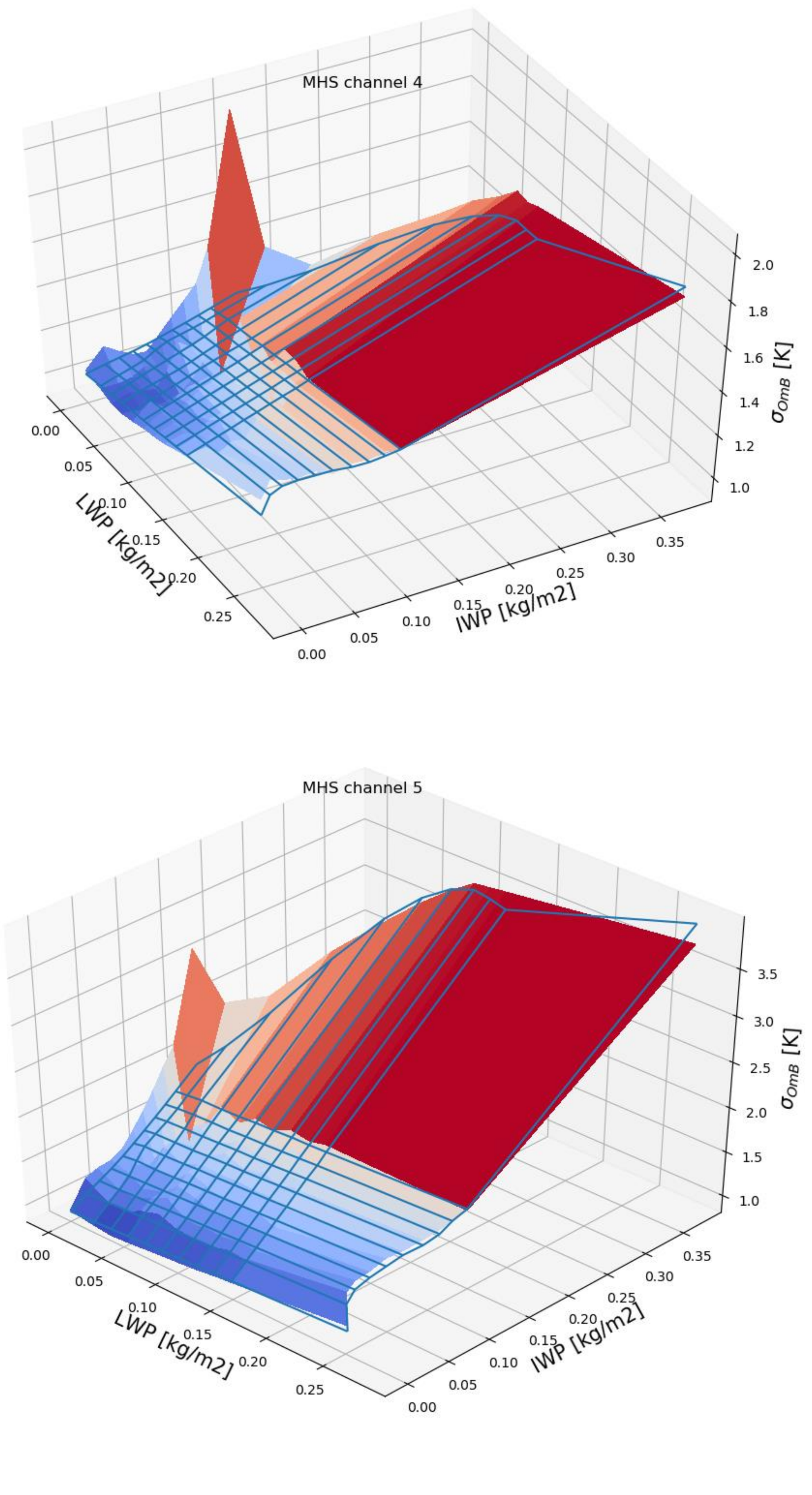

Figure 4 Observation error standard deviation for MHS channels 4 (top panel) and 5 (bottom panel) as a function of LWP and IWP.

Screening of precipitating scenes

In order to check whether a given observation is affected by precipitation so that we can discard it entirely or for a subset of (lower-peaking) channels, we compute the difference between the brightness temperature (BT) in MHS channel 1 (centred at 89 GHz) and that in channel 2 (centred at 157 GHz). This difference, which increases as a function of the amount of scattering by hydrometeors in the instrument field of view (e.g., Bennartz, 2002), depends on the satellite zenith angle (SZA, see Figure 5). A scattering index (SI), defined as

SI = BT(89 GHz) – BT(157 GHz) – (a + b SZA)

is used to discard given channels when SI > 15 K.

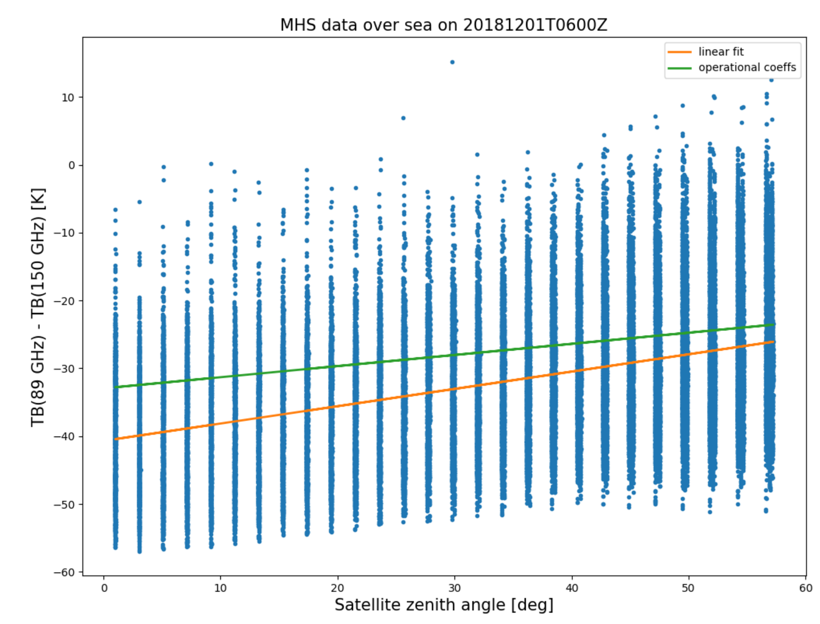

Figure 5 Brightness temperature difference between MHS channel 1 and MHS channel 2 as a function of satellite zenith angle for data over sea on 1st December 2018 0600 UTC (blue dots); linear fit using currently-operational coefficients (green solid line); best linear fit as calculated from this data sample (orange solid line).

Figure 6 Score card results for a trial experiment in winter 2018-2019 wrt observations (left panel) and ECMWF analyses (right panel). Green (purple) triangles denote improvements (degradations) proportional to their size (maximum size here represents a 20% skill change). Shading denotes statistical significance.

Initial evaluations of forecast skill

To evaluate the impact on forecast skill of the all-sky assimilation of MHS channels 4 and 5, a three-month-long trial experiment was performed between 1 December 2018 and 28 February 2019. Results in Figure 6 show an overall 0.12% and 0.18% RMSE reduction wrt observations and ECMWF analyses, respectively. Consistent and significant improvements are found particularly in extratropical wind and temperature forecast skill.

A degradation in the fit of AMSU-A channel 11, 12, and 13 radiances (not shown) is currently under investigation, which seems to be due to shortcomings in modelling the scattering of microwave radiation by high-cloud ice particles.

Summary and conclusions

The all-sky data assimilation system currently operational at the Met Office is being extended to include the assimilation of cloud-affected radiances from MHS moisture-sensitive channels. This has required the use of a new observation error model, which depends on LWP and IWP estimates from 1D-Var. Preliminary evaluation results show that it is possible to get significant improvements in tropical and, to a larger extent, extratropical winds and temperatures.

References

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