

Extending humidity sounding over land

Radiances from AMSU-A and MHS are assimilated as co-mapped ATOVS observations in the Met Office 4D-Var system. A preliminary quality control step includes the 1D-Var retrieval of atmospheric and surface parameters, such as spectrally varying microwave emissivity over land. This has allowed AMSU-A channels 4 and 5 to be assimilated over land despite some surface sensitivity.

To date microwave humidity soundings have been assimilated over ocean only at the Met Office, with the exception of SAPHIR in the Tropics. As Fig. 1 shows, humidity channels may have significant surface sensitivity depending on the column water vapour amount. We describe here recent work to expand our use of microwave radiances over land to include 183 GHz water vapour channels on MHS, ATMS and MWHS-2.

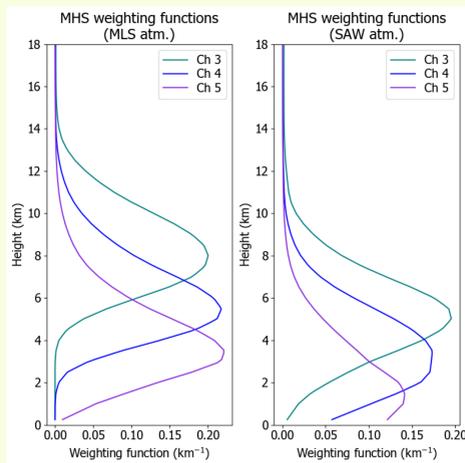


Fig. 1 Example weighting functions for MHS channels 3-5. Left: for a midlatitude summer profile. Right: for a subarctic winter profile.

Land surface emissivity retrieval

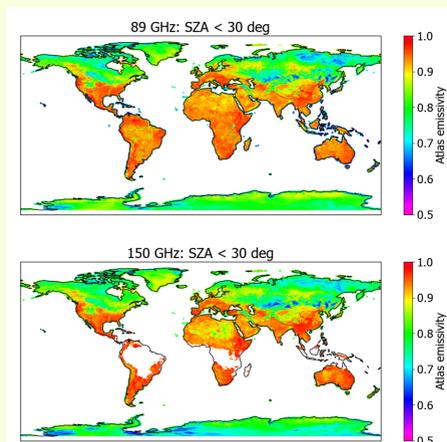


Fig. 2 Emissivity gridded atlases for AMSU-B/MHS channel 1 (upper panel) and channel 2 (lower panel). Data are shown for January 2014. Monthly data sets are combined for available years 2014 and 2015 in operations. Where data are missing at 150 GHz in the tropics 89 GHz data are substituted.

In operations (Newman and Bell, 2015) microwave emissivity is estimated over land in 1D-Var for AMSU-A channels at 23.8, 31.4, 50.3 and 89 GHz along with surface skin temperature. The retrieval is initialised using emissivity atlas data from CNRM, France (Karbou et al., 2005, see Fig. 2). We extend the scheme to MHS frequencies by retrieving emissivity at 157 GHz (MHS channel 2).

We use gridded uncertainties provided with each map to scale 1D-Var B matrix covariances for emissivity. Retrieved microwave emissivity values at five frequencies are mapped to adjacent sounding channels. This means that the retrieved emissivity at 157 GHz is applied unchanged to 183 GHz humidity channels in 4D-Var.

We specify variable errors per channel as a function of atmospheric transmittance. Therefore for channels sensitive to the surface (e.g. MHS channel 5 at high latitudes where the atmosphere is dry) observation errors are inflated.

Improved land QC

The Met Office microwave surface emission retrieval scheme is currently applied to ATOVS observations only. For ATMS and MWHS-2 humidity soundings there is therefore greater uncertainty in surface contributions to the satellite radiances. In order to exploit ATMS and MWHS-2 183 GHz channels over land we have introduced updated quality controls:

- Humidity soundings are screened out where the transmittance to the surface exceeds a certain threshold.
- Cloud detection has been updated, including the extension of a microwave scattering test used over sea to land surfaces (Bennartz et al. 2002, see Fig. 3).

Observations are removed where the effects of clouds or surface emission are difficult to model. This allows the assimilation of ATMS and MWHS-2 channels from 183.3±1 GHz to 183.3±4.5 GHz.

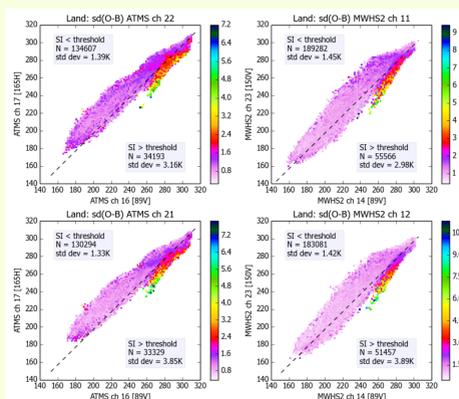


Fig. 3 Colour maps of standard deviation in O-B for humidity sounder channels, binned by 89 GHz channel value (x-axis) and [165/150] GHz value (y-axis). The channels in the top row are the highest peaking at 183.3±1 GHz for ATMS and MWHS-2. Below, the channels at 183.3±1.8 GHz are shown. The dashed line in each plot represents the boundary at which scattering index SI < threshold.

Forecast experiments and verification

Global NWP forecast experiments were performed for Northern Hemisphere winter (20171201T06 -20180228T12) and summer (20180715T06 - 20181015T12) on a full observing system baseline. The trials were run at low resolution (N320/L70 Unified Model and N108/N216 4D-Var uncoupled hybrid assimilation). Relative to the baseline, the experiments tested the assimilation of MHS, ATMS and MWHS-2 humidity sounding channels over land.

Verification against observations and analyses showed some reductions in root mean square error (RMSE) for geopotential height and temperature fields at short forecast range, particularly in the Northern Hemisphere (Fig. 4 shows 500 hPa geopotential height). Impacts in the Southern Hemisphere were more modest, and there were mixed indications in the tropics for temperature and winds (verification against observations was negative, against own analyses positive).

We can also assess changes in observation-background (O-B) statistics. For independent observations, where there has been no change in data selection, a reduced std dev in O-B may indicate an improved short range forecast as the background state is closer to the observations.

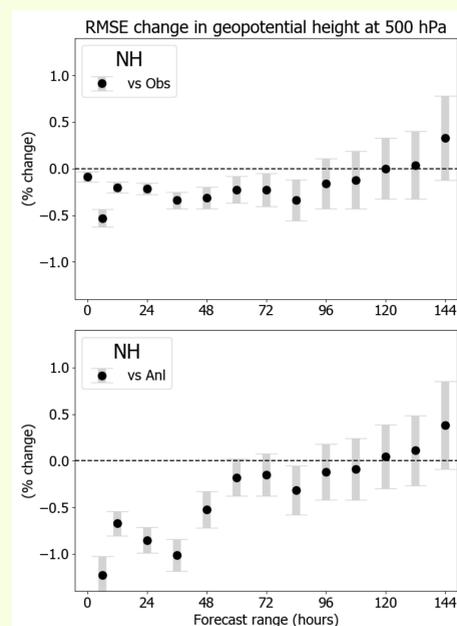


Fig. 4 Verification for winter season experiment adding humidity sounders over land, relative to the control. The change in 500 hPa geopotential height RMSE is shown as a function of forecast range verified against observations (top panel) and own analyses (lower panel). Confidence intervals are ± 1 standard error calculated assuming no correlations.

Fig. 5 shows aggregated differences (experiment minus control) of O-B std dev for observations sensitive to humidity. Water vapour channels on AIRS, CrIS, IASI and SEVIRI all show improved background fits (reduced std dev in green), suggesting improved short range forecasts for humidity fields. Some, but not all, channels on the SAPHIR humidity sounder show better fits for observations confined to the tropics. Radiosonde RH O-B std dev is reduced for model levels in the troposphere, indicating better fits to humidity fields over land.

The combination of beneficial forecast impact as evidenced by verification against observations and analyses, together with improved background fits for independent humidity observations, resulted in these assimilation changes being adopted as part of the next Met Office operational NWP suite.

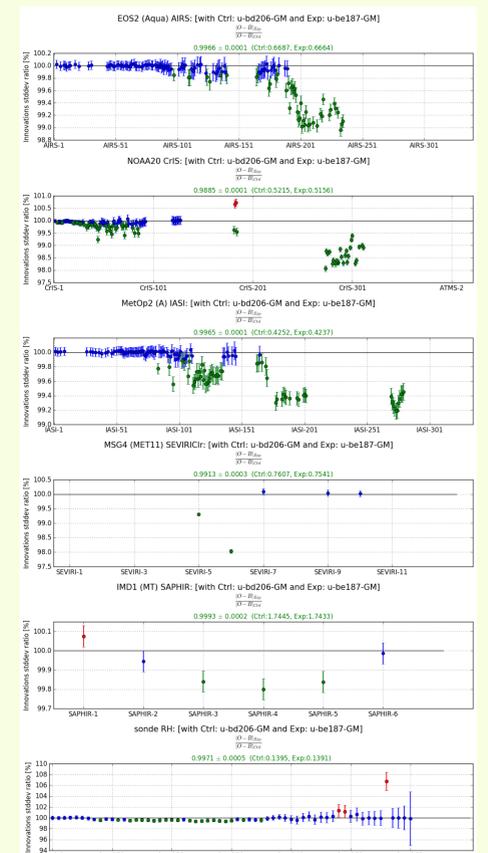


Fig. 5 O-B standard deviation ratios for summer season experiment versus control. Statistics are shown for observations (top to bottom) Aqua AIRS, NOAA-20 CrIS, MetOp-A IASI, Meteosat-11 SEVIRI clear sky radiances, Megha-Tropiques SAPHIR and radiosonde RH. Key channels most sensitive to water vapour are (MetDB channel numbers) AIRS-188 to AIRS-235; CrIS-274 to CrIS-312; IASI-168 to IASI-280; SEVIRI-5 and SEVIRI-6.

Summary

The assimilation of humidity sounder radiances over land has been tested successfully at the Met Office. Key developments include extending the retrieval of surface emissivity to MHS frequencies and improving quality control measures over land. Humidity observations from MHS, ATMS and MWHS-2 are added over land in the current Met Office Parallel Suite which is due to go operational shortly in November 2019.

References

- Bennartz, R., A. Thoss, A. Dybbroe, and D. B. Michelson (2002), Precipitation analysis using the Advanced Microwave Sounding Unit in support of nowcasting applications, *Meteorological Applications*, 9(2), 177-189, doi:10.1017/S1350482702002037.
- Karbou, F., C. Prigent, L. Eymard, and J. R. Pardo (2005), Microwave land emissivity calculations using AMSU measurements, *IEEE Transactions on Geoscience and Remote Sensing*, 43(5), 948-959, doi:10.1109/tgrs.2004.837503.
- Newman, S. M. and W. Bell (2015), Enhanced use of AMSU-A radiances over land, presented at ITSC-XX, Lake Geneva, Wisconsin.