Impact of satellite sounder data on global forecasts, including the benefit of using the Direct Broadcast Network (DBNet)

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Introduction

In the studies presented here we investigate the relative impact of all the main observation types used in the Global Model data assimilation scheme at the Met Office. This was performed through a series of data denial experiments in which each observation type is removed from the deterministic data assimilation (DA) step. Note that in these results we do not investigate the indirect impact on the forecasts through the ensemble part of the DA scheme, although an investigation showed that neglecting this effect is small, but tends to underestimate forecast impact.

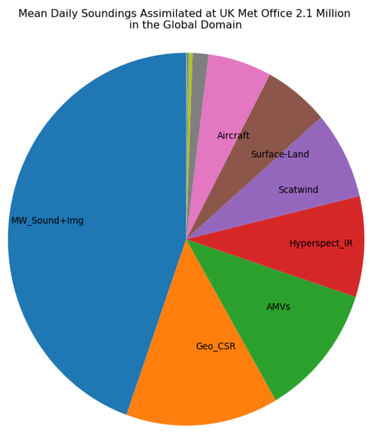
• Period used 15th August 2019- 15th November 2019

• Data usage follows the operational configuration during late 2019 (notably includes Allsky AMSU-A, 5 ATOVS instruments, 2 CrIS, 2 ATMS, 2 IASI.)

• Conventional data sources (radiosondes, surface stations, aircraft, etc) are also tested in this work allowing the relative forecast benefit to be seen. The only observation types not tested were windprofilers and tropical cyclone bogus observations.

1. Relative Amounts of each observation type

Figure 1. *Mean number of daily soundings assimilated for each observation category during the period 15th August 2019 to 15th October 2019. Here were treat a "sounding" as a profile or set of channels at the same latitude and longitude. Over 50% of the soundings assimilated are made by satellites operating at microwave and infrared wavelengths. A description of each observation category is shown on the far right*



Category	Description	Category	Description
Aircraft (5.8% of total daily soundings)	temperatures,U,V & RH from aircraft	**Hyperspectral IR (8.7%)**	radiances sensitive to temperature and humidity
AMVs (11.6%)	wind vectors from visible and IR imagers onboard geostationary and polar platforms	**MW sounders and imagers (44.6%)**	radiances sensitive to temperature and humidity
Geostationary CSR (13.8%)	clear sky radiances from geo IR imagers	**Radiosondes (0.1%)**	profiles of temperature, winds RH
Ground-based GNSS (0.3%)	total zenith delay, sensitive to total column water vapour and surface pressure	**Scatwind (7.6%)**	wind vectors over ocean
		Surface – land (5.9%)	temperature, RH, pressure, winds
GNSS RO (0.1%)	bending angles sensitive to temperature and humidity	**Surface – ocean (1.4%)**	temperature, RH, pressure and winds

2. Data Denial Results for IR hyperspectral & MW observations

Forecast score cards for hyperspectral data denial (*Figure2* -left) and microwave sounders and imagers (*Figure 2-right*) denote a majority of parameters have *degraded* in the forecast when these observation categories are *withdrawn*. In particular for the geopotential height(Z) throughout the troposphere in the southern hemisphere (SH) when the microwave data is removed. These results confirm the large forecast benefit when passive sounders are assimilated.

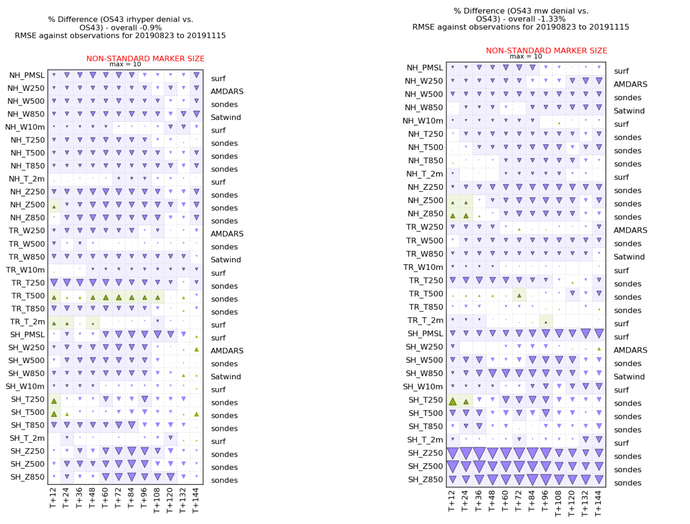


Figure 2. *Forecast score cards for the hyperspectral data denial (left) and the mw sounders & imagers (right). Each element in the scorecard shows the percentage change in forecast error for a particular variable separated into three latitude bands (N hemisphere extratropics, Tropics and S hemisphere extratropics); blue down ward triangles denote forecast detriment, whereas green triangles show improvement. The forecast error is derived through comparison to surface, aircraft, AMV and radiosonde observations*

3. Relative Forecast benefits

Figure 3 shows the mean change in the forecast errors (across all variables in the scorecard) for each observation category. Nearly all observation types show a forecast detriment when the data is denied. Results indicate that microwave, radiosondes and hyperspectral infrared data are the most beneficial to the forecast. GNSS radio occultation and Aircraft observations are also very important.
Forecast Sensitivity to observations (FSOI) results are shown in Figure 4. This metric confirms the large benefit of the sounding data. Interestingly, the strong impacts from GNSSRO are not reflected in the FSOI.

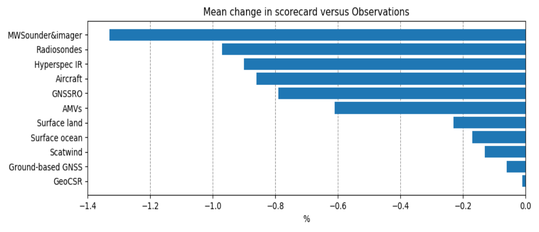


Figure 3. *Mean change in Forecast error due to data denial of each observation category.*

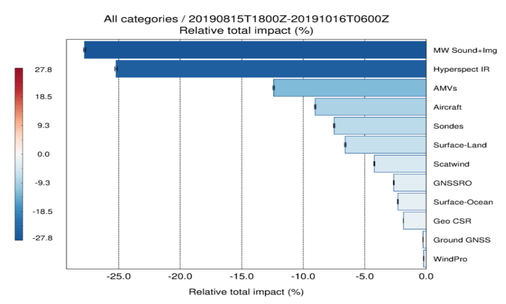


Figure 4. *FSOI results for the same period as the data denial trials.*

4. Forecast Benefit from DBNet

Timely forecasts require that the NWP assimilation/forecast cycle runs close to real time. In practice the assimilation step for the main forecast runs of the global model at the Met Office start 160 minutes after the analysis time (e.g. 12 UTC analysis starts at 14:20). Observations which arrive after this time are not used to constrain the analysis. Acquisition of timely observations via the DBNet are very important in this respect. The following study looks at the forecast impact of using DBNet data to supplement the global datasets for ATOVS & ATMS. Figure 5 below shows that there is a large proportion of the global datasets that do not arrive in time, but this can be recovered through use of observations supplied by DBNet (Figure 6). Figure 7 highlights the regions where the data is being used.

Figure 5. (*right) shows observation coverage from NOAA19 AMSU for a typical 6 hour window. Grey swath indicates all possible observations whilst the Blue swath shows which observations arrive in time to be used in assimilation.*

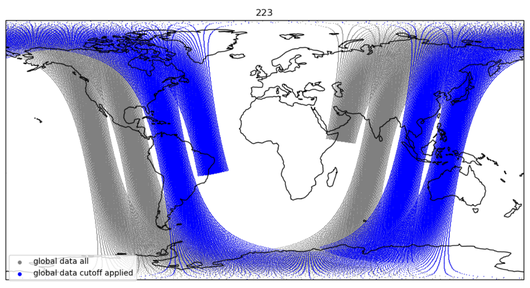


Figure 6. (*right) shows observation coverage from DBNet (green) for the same 6 hour window.*

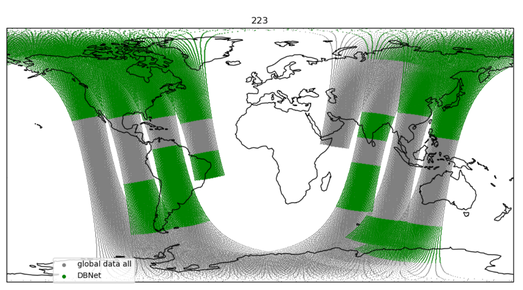
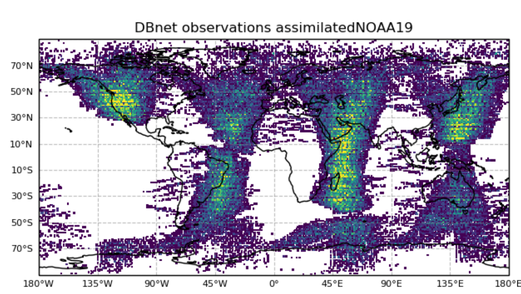


Figure 7. Is a one-week accumulation of all the NOAA19 data used from DBNet to supplement the global data in Met Office operations.



A Forecast impact study was performed using the NWP global system to measure the benefit of the additional data arising from DBNet in the main forecast runs. The observations tested were ATOVS & ATMS. For technical reasons, although CrIS and IASI are also available via DBNet, it was not possible to exclude these data in the impact study. Consequently the total impact is underestimated. Despite this the resulting scorecard (Figure 8) showing the change between using DBNet and ignoring this data highlights useful reductions to the RMS forecast error, in both the Tropical and NH regions. Shading indicates statistical significance and it can be seen for example, that the NH 500 hPa temperature forecasts improve throughout almost all of the forecast range (out to T+6 days).

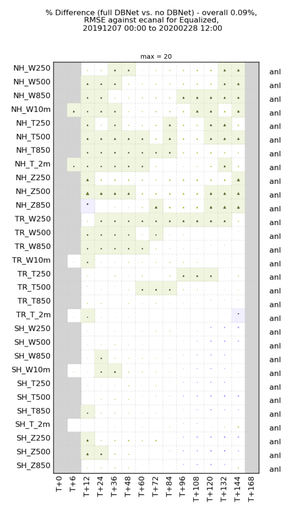


Figure 8 (right**)** Scorecard for the DBNet impact experiment. As before the percentage change in RMS error is shown, with green triangles highlighting improvement. Experiment period: 1st December 2019 – 28th Feb 2020.

Summary:

Data denial experiments have been carried out for all of the main observation types:

- MW sounders & Imagers, hyperspectral sounders both continue to give a large forecast benefit. This is confirmed by FSOI diagnostics.
- GNSSRO and radio sondes also important. Interestingly, FSOI underestimates importance of GNSSRO. Possible cause maybe that GNSSRO has a secondary role as an anchor for bias correction. A future study will look at this in more detail.

DBNet supplements the global datasets with observations that would normally miss the data assimilation step.

- These data continue to have a useful positive benefit to forecasts.
- In the last year new stations have been added to DBNet and so the benefit shown here is likely to be an underestimate.

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