Assessing the thinning scale for humidity sounding observations at ECMWF

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1. Introduction

Observations from microwave humidity sounders are thinned prior to being assimilated, to reduce the impact of spatially-correlated observation errors which are not explicitly accounted for in 4D-Var.

The thinning scale for microwave humidity sounders has remained constant for many years, but with increased computing power, and the increasing resolution of ECMWF's forecasting model and 4D-Var scheme, there is the potential to use data more densely. A balance must be made though, as using observations too densely while neglecting spatial error correlations can result in a degraded analysis.

Here we investigate the optimal thinning scales for the all-sky microwave humidity sounders MHS and MWHS-2, which are aboard six different satellites.

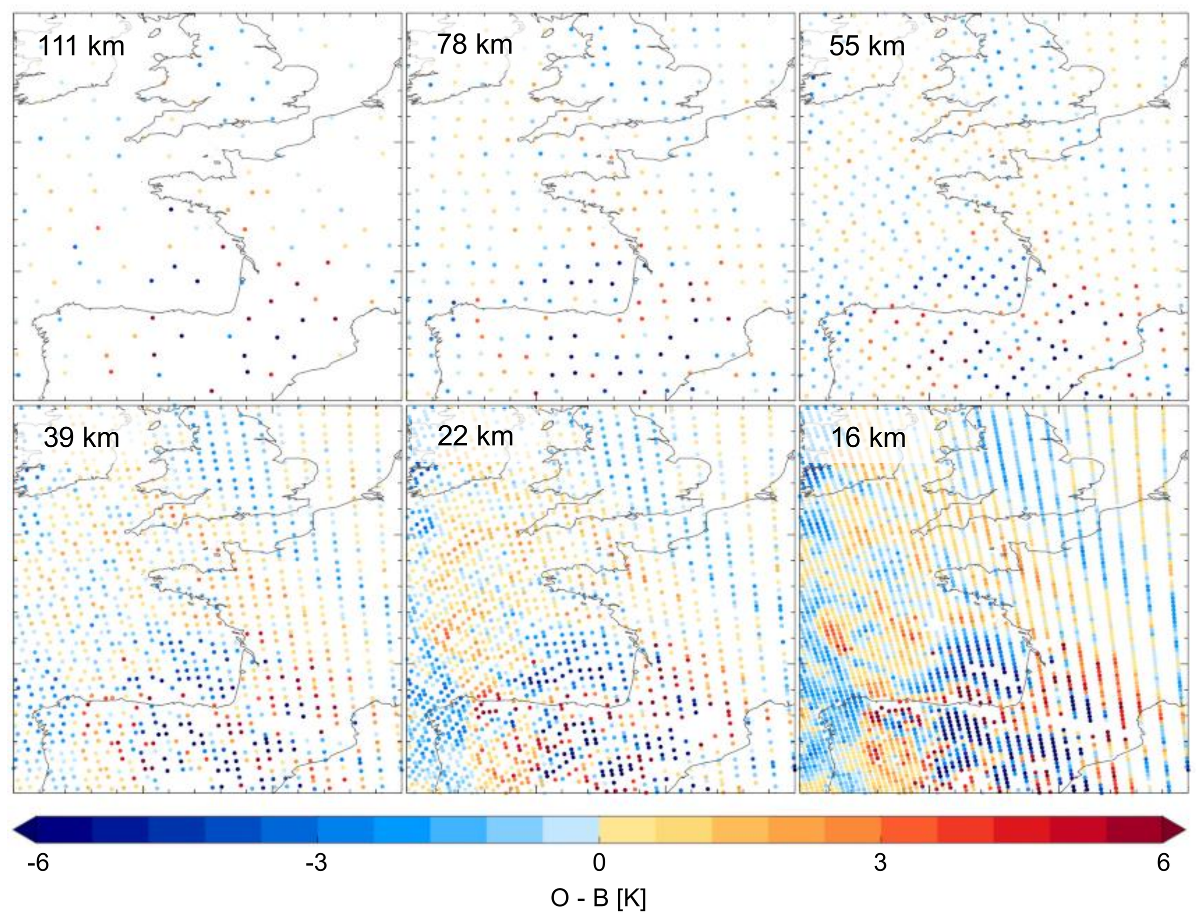
2. Thinning scales

Figure 1
Example of the different thinning scales used, from FY-3D channel 12 data on 1 June 2021

Our experiments use thinning scales ranging from ~111 km down to ~16 km.

The number of observations roughly doubles between each panel in **Figure 1**.

16 km thinning essentially uses all available observations



3. Impact on short-range forecasts

Experiments were performed at two model resolutions, with grids of ~28 km and ~9 km, the latter of which is the same resolution as the operational model.

Figure 2 shows comparisons of the O–B standard deviation between the model and different observations, normalised by a control experiment that excludes MHS and MWHS-2 data. Values < 100% represent forecast improvements.

Results are shown for different resolutions (blue/red), and different pressure/altitude levels (solid/dotted). Vertical lines show the 95% confidence range, and for clarity are only shown for one atmospheric level. All statistics are based on global data from JJA 2021 and DJF 2021/2022.

Figure 2
Short-range (12-hr) forecast comparisons between different observation types at different atmospheric levels. Values < 100 represent forecast improvements

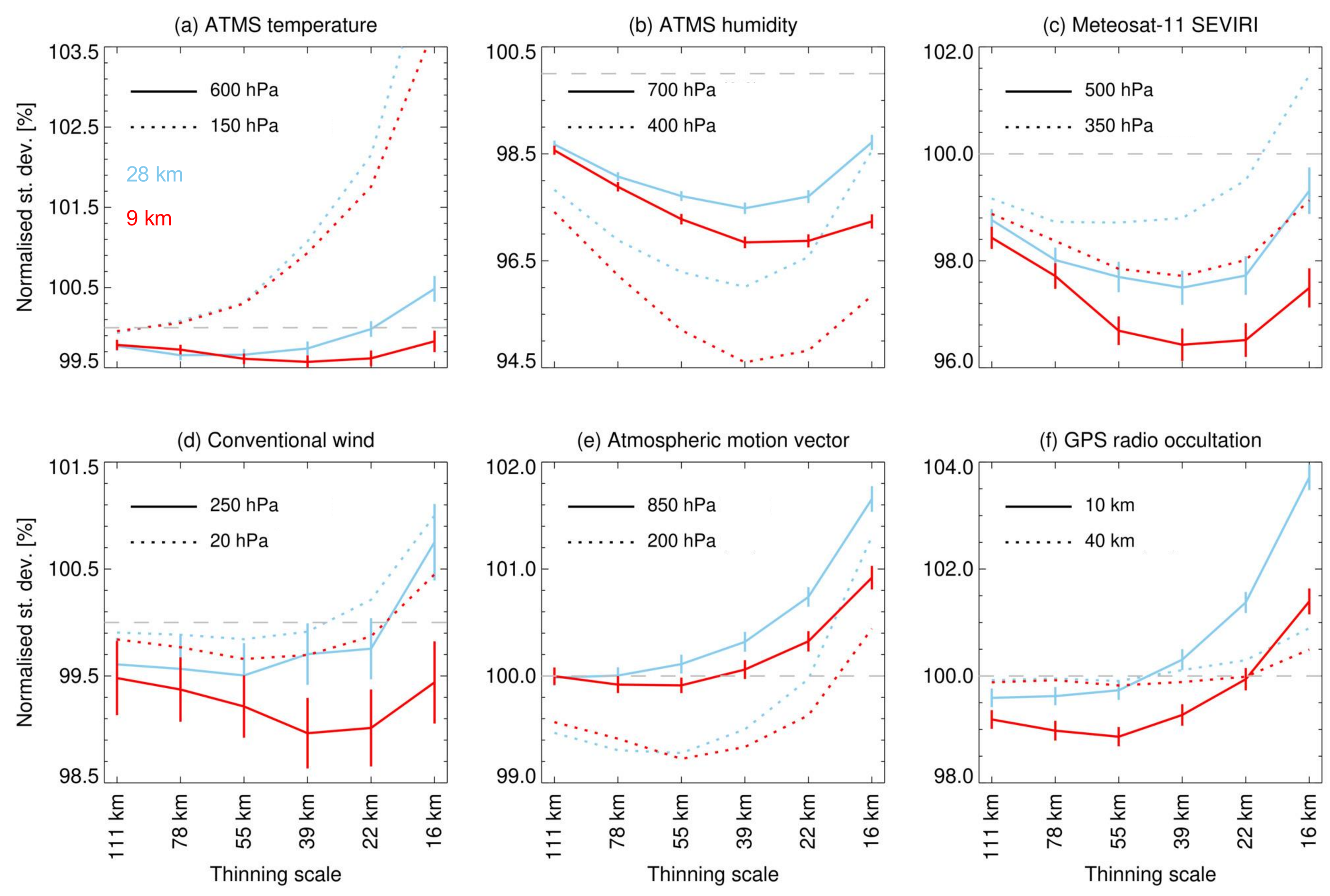


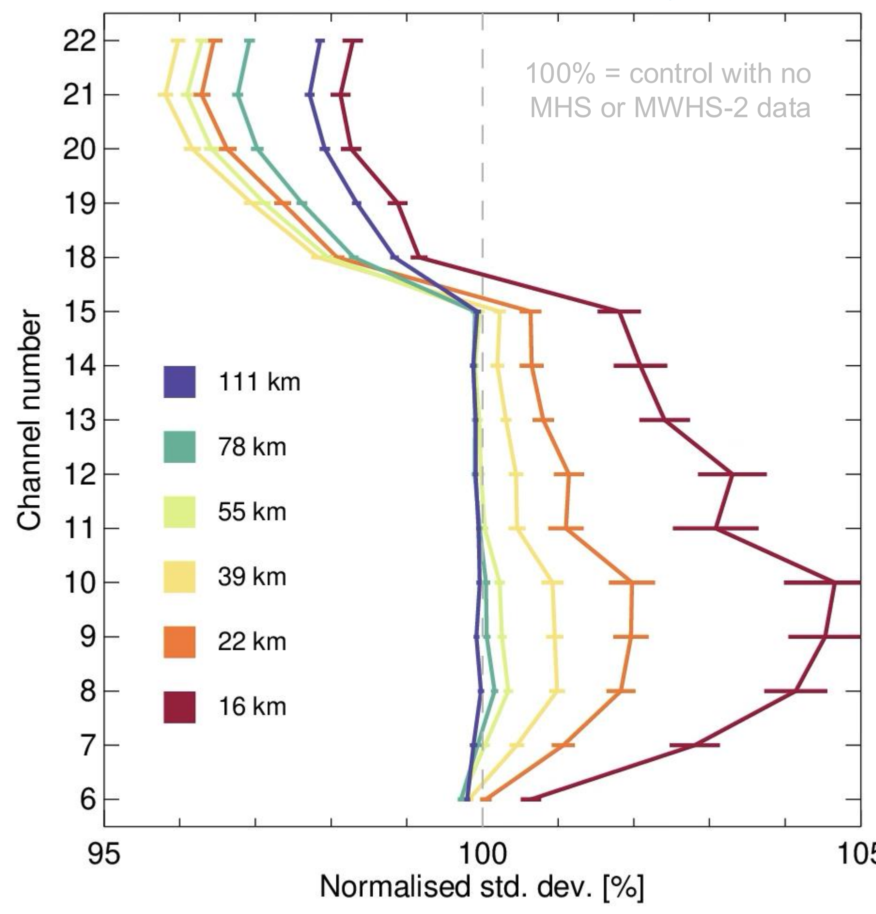
Figure 2 shows:

- The higher-resolution model (red line) shows greater improvements from altering the thinning scale.
- The biggest improvements are seen for humidity-sensitive observations (panels b,c).
- Temperature observations (a) and winds close to the surface (e) show little benefit from altering the thinning scale of humidity observations.

Figure 3 shows a more detailed comparison of the 12-hour model forecasts vs all assimilated ATMS channels, with values < 100% representing improvements.

As the thinning scale reduces from 111 km to 39 km there is a better fit to the humidity channels (18-22). However, at the same time the fit to temperature channels (6-15) degrades, with 55-78 km being the best thinning scale range.

Figure 3
Comparison between short-range forecasts and ATMS observations for different thinning scales. Results are from the experiments at 28 km grid resolution



4. Impact on medium-range forecasts

Figure 4 shows that benefits are seen out to around day 5 when using 55 km thinning vs 111 km. Using 16 km thinning gives worse forecast scores than when the humidity data are excluded. **Figure 5** shows that the biggest impact is seen in the southern hemisphere.

Figure 4: Normalised difference in RMS error over 10 days from three 9 km resolution experiments. Comparisons are against the control with no MHS or MWHS-2 data. Values < 0 represent forecast improvements

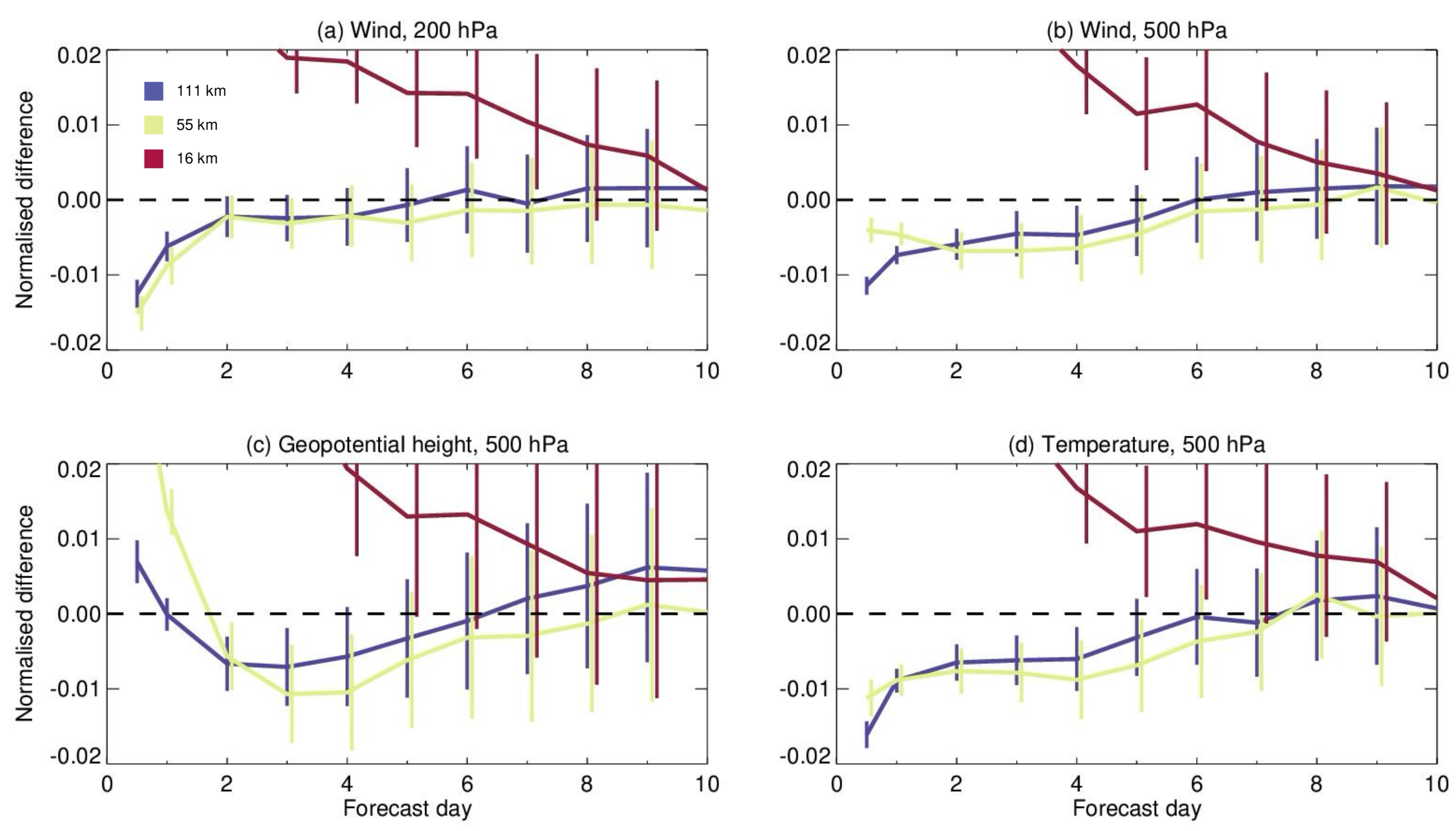
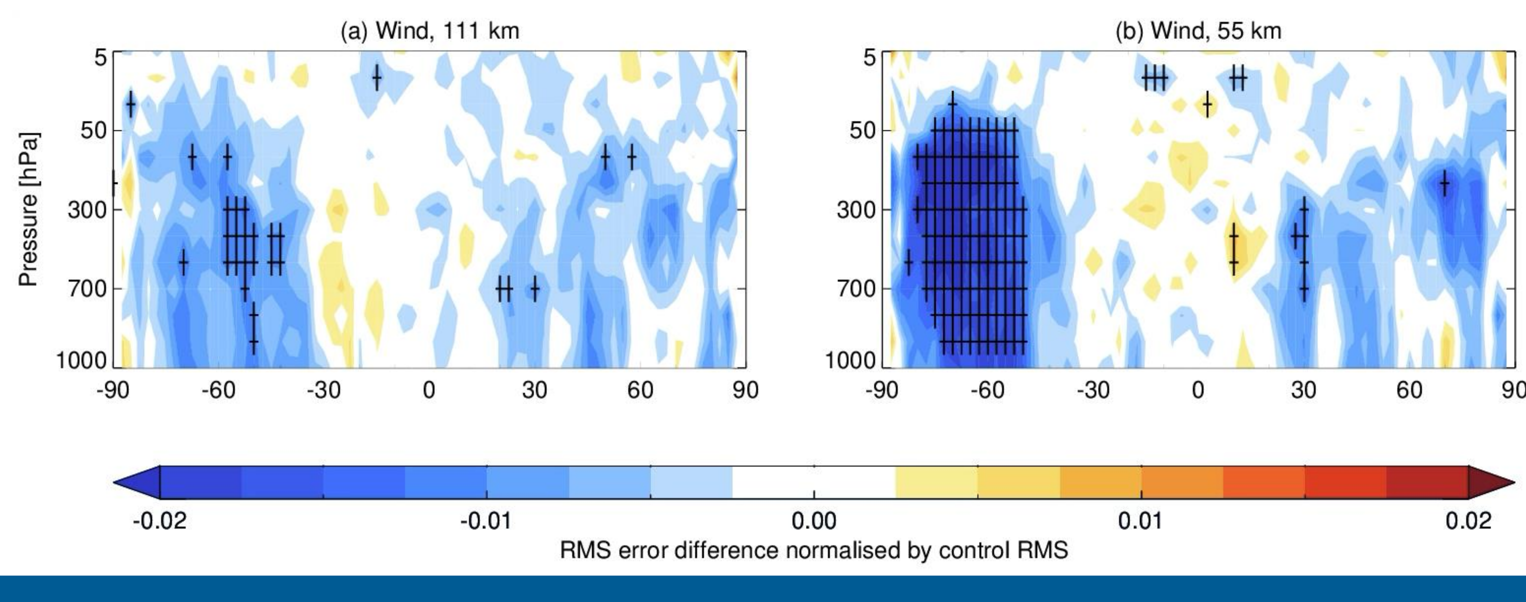


Figure 5: Normalised difference in RMS error from two 9 km resolution experiments vs the control, for forecast day 3. Values < 0 represent forecast improvements. Dashed lines show regions with statistically-significant results



5. Summary

Our experiments show we can gain forecast benefits by reducing the thinning scale to around 55-78 km. If we use data spaced more closely than this the forecasts get worse, particularly for temperature. This is likely due to neglecting correlated errors. We also found that a higher-resolution model (with a 9 km vs 28 km grid) can gain benefit from smaller thinning scales.

In cycle 49r1 of ECMWFs Integrated Forecasting System, implemented in 2024, we adopted a thinning scale of 70 km with 50 km resolution superobbing.

These results help inform on the use of future observations, such as those from the Microwave Sounder on EUMETSATs Metop second generation satellites, and the microwave radiometer on the EPS-Sterna constellation. They also highlight the need for revisiting thinning choices over time as the resolution of assimilation systems increases.