Improved 2 m temperature forecasts from assimilation changes at ECMWF

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Overview

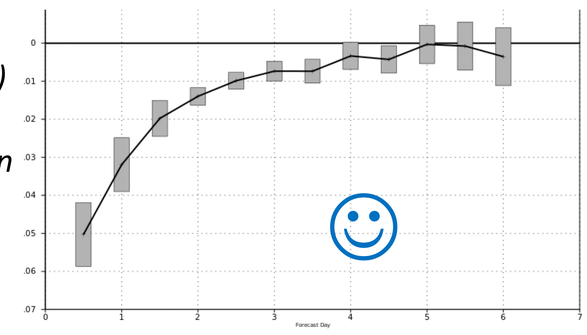
Two metre temperature (T2m) is a key forecast variable and we describe how assimilation changes at ECMWF, expected to become operational in 2024, improve short-range forecasts of T2m. Currently screen temperature and humidity from SYNOP and METAR reports are assimilated in a separate surface analysis - primarily to update soil moisture - but only daytime screen humidity is assimilated in the main 4D-Var. Adding the assimilation of T2m in 4D-Var required a lot of testing/tuning but is beneficial

Improvements in the snow data assimilation system as well as in the T2m and soil moisture land data assimilation are also applied. Overall this gives better short-range T2m forecasts especially in northern hemisphere winter. Model changes (not shown) also benefit T2m forecasts and possible future changes to improve further are being investigated.

Atmospheric assimilation of T2m

Tests assimilating T2m in 4D-Var gave large improvements in short-range T2m forecasts, but in some winter regions 850hPa temperatures were degraded, partly due to unrealistic coupling in stable conditions. Remedies aimed at retaining the T2m benefits, while reducing the problems were explored. Reducing the weight given to T2m data with very large departures from background (often in strong winter inversions) and limiting the assimilation of data to the first 6 hours of the 12-hour 4D-Var window to produce more localised increments both helped. Following these modifications, a large impact is still seen in Northern Hemisphere winter (Figure 1): a 5% reduction in RMS error at T+12, decreasing with lead-time when verified against SYNOP data. The benefit in summer and in the tropics is smaller, but still useful.

Figure 1 The improvement (negative) in T2m forecasts, from December 2021 to February 2022, for the region 20-90 N. Percentage change in RMS, verified against Synop observations.



Soil moisture and T2m land assimilation

The 2D Optimal Interpolation two-metre temperature (T2m) assimilation and the Simplified Extended Kalman Filter (SEKF) soil moisture DA were revised, bringing improvements in both winter and summer forecasts, especially significant for T2m (Figure 2) and near surface forecasts. The revisions include the implementation of a lapse rate correction in the T2m analysis to account and correct for altitude differences between the model grid points and the SYNOP observations. A correction of 5.5 K (red line in Figure 2 top) is introduced, consistent with the lapse rate correction used in the 4D-Var T2m analysis. In the SEKF soil analysis, the background error standard deviation has been doubled, to 0.02 m3 m-3 , giving more weight to the observations used in the SEKF to constrain the soil moisture analysis. Both changes have a substantial positive impact in the tropics and northern hemisphere during summer.

Snow data assimilation

Several major developments were made to improve the snow analysis. The use of the NOAA/NESDIS Interactive Multi-sensor Snow and Ice mapping System (IMS) snow cover product was revised enabling the exploitation of satellite-based snow cover information in mountainous areas. It reduces the IFS positive biases in snow cover and snow depth, with a strong positive impact on atmospheric forecasts. Other changes include the relaxation of the maximum allowed snow depth value from 1.4 m to 3m in the analysis, the reduction of the vertical structure function scales from 800 m to 500 m, which increases the weight of observations with lowest altitude difference with the model. The snow data assimilation changes were extensively evaluated for Winter and Summer as well as in Spring which is key for snow data assimilation, see Figure 3. Other results (not shown) indicate a strong positive impact on T2m especially in the Rocky Mountains and the Tibetan Plateau areas, with widespread improvements in the troposphere in geopotential hight, vector wind and humidity forecasts in the Northern hemisphere in Winter.

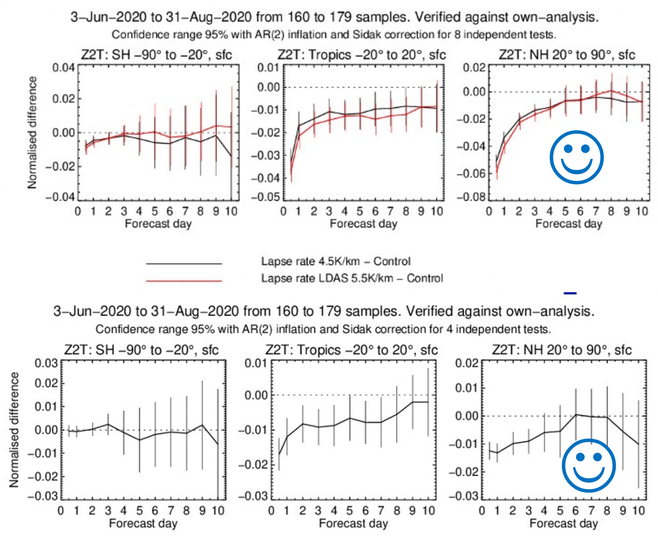


Figure 2 Normalised RMSE impact on T2m forecasts errors (verified against own analysis) of: T2m lapse rate correction in the land DA system (top) and increased soil moisture background error in the SEKF analysis (bottom), for June-August 2020

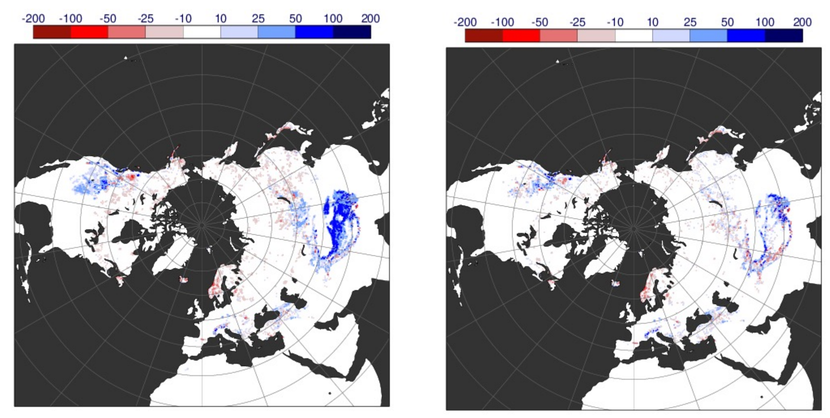


Figure 3. Biases of snow duration (days) compared to IMS in March-May 2022 before (left) and after (right) the snow DA changes. The mostly positive biases are reduced in most regions.

Combined impact

Figure 4 shows the scorecard of the overall impact of T2m and snow assimilation changes, combined with T2m lapse and soil moisture background error revisions in the surface analysis. The land surface assimilation changes also give slight benefits beyond day 10 (not shown). Figures 5 and 6 shows verification against Synops for NH winter. All 3 illustrate the widespread positive impact of the changes on T2m and atmospheric forecasts.

Notes. In the testing of the new package (49r1) changes were combined sequentially. The results presented here include changes to radio occultation usage, stratospheric balance in the analysis and quality control – which have very little impact on verification against observations in the troposphere.

- The package also includes extensive improvements to surface vegetation fields and boundary layer physics that gives further improvements to T2m – not shown here.
- The results presented had forecast/analysis grid spacing of 28/80 km. The whole 49r1 package is now being tested at 9/40 km grid spacing, still with very good impact on T2m forecasts.

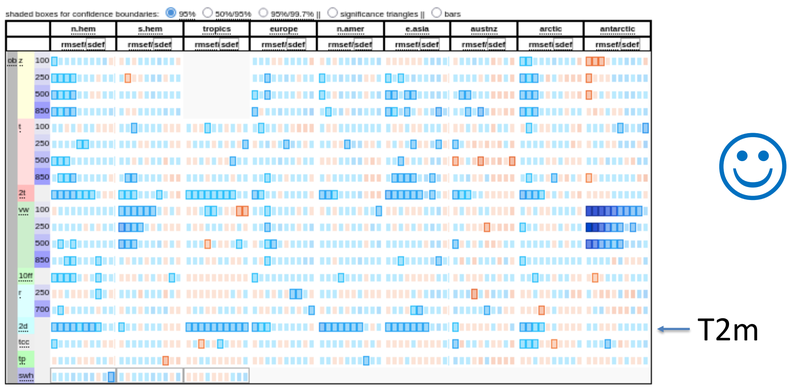


Figure 4. Scorecard vs observations for Dec 2021 – Feb 2022 and Jun-Aug 2022 combined, blue improved, orange worse. Changes in rms fit for days 1-10 shown in a row.

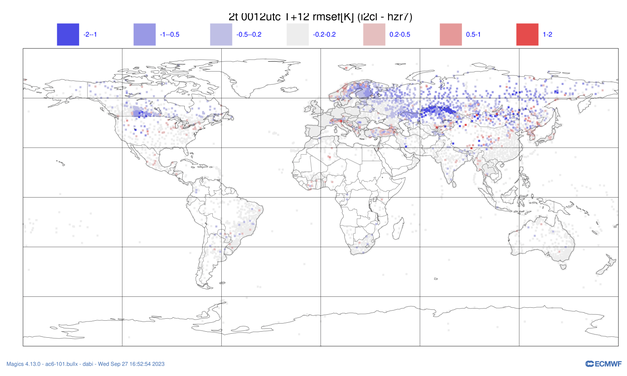


Figure 5. Impact on 12-hour verification against Synops, Dec 2021 – Feb 2022. Blue improved.

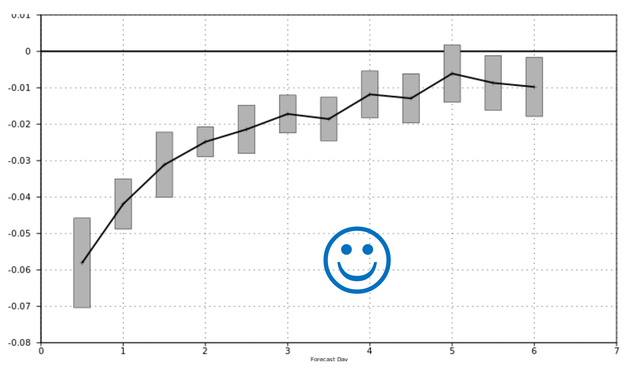


Figure 6. Combined impact on T2m forecasts verified against Synops, 20-90N, Dec 2021 – Feb 2022