IMPROVED HARMONIE SURFACE TEMPERATURE FORECASTS FOR NORDIC WINTER CONDITIONS

SMHI

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Background

HARMONIE surface data assimilation

The HARMONIE forecasting system is running daily at several HIRLAM institutes. A major weakness of HARMONIE in its present form is the systematically too warm surface temperature forecasts during cold Nordic winter conditions. For the forecast model we use the SURFEX externalized surface scheme together with a three layer ISBA scheme. Snow effects are parameterized in accordance with Douville *et al*. (1995). Surface data assimilation is handled by CANARI and OImain. Temperature and humidity information from observations are spatially spread by CANARI and then the information is vertically distributed by OImain. For nature tiles the vertical spread of observed two meter temperature and relative humidity information (T_{2m} and RH_{2m}), into surface temperatures and moisture (T_s and w_g) as well as into the layer two moisture and temperature (T_2 and w_2), is given by:

$$\begin{aligned} w_g^a &= w_g^b + \alpha_1\left(T_{2m}^o - T_{2m}^b\right) + \alpha_2\left(RH_{2m}^o - RH_{2m}^b\right)\\ w_2^a &= w_2^b + \beta_1\left(T_{2m}^o - T_{2m}^b\right) + \beta_2\left(RH_{2m}^o - RH_{2m}^b\right)\\ T_s^a &= T_s^b + \mu_1\left(T_{2m}^o - T_{2m}^b\right) + \mu_2\left(RH_{2m}^o - RH_{2m}^b\right)\\ T_2^a &= T_2^b + \nu_1\left(T_{2m}^o - T_{2m}^b\right) + \nu_2\left(RH_{2m}^o - RH_{2m}^b\right) \end{aligned} \qquad (1)$$

where superscript ^{a}, ^{b} and ^{o} denotes analyzed, background and observed value respectively. Furthermore, α_1, α_2, β_1, β_2, μ_1, μ_2, v_1 and v_2 are empirically derived coefficients. Surface layer three have climatological constant values.

Modification

Mahfof *et al*. (2009) studied the sensitivity of surface properties to the two meter temperature and relative humidity when comparing OI and EKF surface data assimilation methods. The sensitivities were demonstrated to be highly variable and the v_1 coefficient in Eq. (1) was shown to be significantly underestimated in OI as compared to EKF. The coupling through the v_1 coefficient has been found to be stronger during night-time and winter-time with low temperatures. Based on these findings we decided to increase the current value of v_1 in OImain from $1/(2\pi)$ to $1/2$. This will also compensate for limitations in forecast model surface scheme to satisfactorily represent the isolating effect of snow.

Experimental Set-Up

Extended parallel data assimilation and forecasts experiments for winter and summer periods have been run both on the local Gimle SMHI computer using HARMONIE cy36h1.4 SMHI branch and on ecgate/c1a ECMWF computing system using HARMONIE cy37h1b1. All experiments were run over the Swedish ALARO domain (Fig. 1), with 5.5 km horizontal resolution and 60 vertical levels. There were always two parallel runs: one reference run and one additional run with the only modification being the modified v_1 coefficient.

Fig. 1. Swedish ALARO domain.

Results

Scores from SMHI branch CY36h1.4

The parallel experiments on the local Gimle computer were carried out for two 2 months periods. The winter period was from from 1st of January to 28th of February 2010 and the summer period was from 1st of July to 31th of August 2009. Upper-air and surface data assimilation were run within a 6 h data assimilation cycle and from 00 and 12 UTC also forecasts up to 30 hours range were carried out. ECMWF operational forecasts were used as lateral boundaries. The first assimilation cycle was started from an ECMWF forecast, interpolated to the SMHI ALARO geometry. To minimize spin-up effects the first 10 days are not included in the calculation of verification scores.

For wintertime scores there is a clear reduction in area averaged bias and RMSE of 2 meter temperature when applying the new values of the v_1 coefficient (Fig. 2a). There is a small positive impact on verification scores for surface pressure (Fig. 2b). Note in particular the significant reduction of the winter-time warm 2 meter temperature bias over Finland (Fig. 3). Regarding forecasts of upper-air parameters the impact is neutral (not shown). For summer-time scores the impact of the new values of the v_1 coefficient is neutral (not shown).

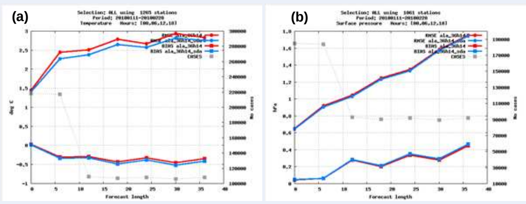

Fig. 2. Winter-time area averaged bias and RMSE of (a) 2 meter temperature forecasts (unit: K) and (b) surface pressure forecasts (unit: hPa) as function of forecast range. Red curve is for control and blue for run with the modified v_1 coefficient.

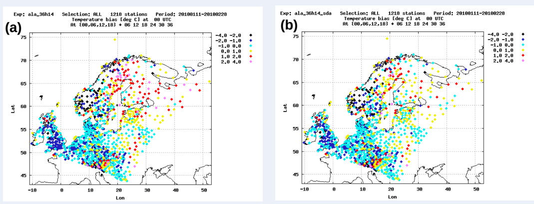

Fig. 3. Winter-time bias of 2 meter temperature forecasts (unit:K) for (a) control and (b) run with the modified v_1 coefficient.

Scores from CY37h1b1

The parallel experiments on the ECMWF computing system ecgate/c1a were carried out for two one months periods. The winter period was from from 1st to 31 of January 2010 and the summer period was from 1st of July to 29th of August 2010. For both periods there was a 10 day spin-up period before the experiment was started. ECMWF lateral boundaries were used and all recent development concerning improved cold start conversions between ECMWF surface fields and HARMONIE surface fields were applied.

There is a clear positive impact on 2 meter temperature (Fig 4a) and surface pressure winter-time verification scores (Fig. 4b). For forecast of upper-air variables the winter-time verification scores are neutral (not shown). Summer-time verification scores are neutral both for surface (Fig 5.) and upper-air (not shown).

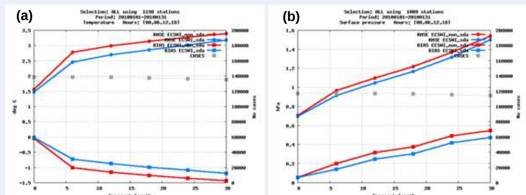

Fig. 4. Winter-time area averaged bias and RMSE of (a) 2 meter temperature forecasts (unit:K) and (b) surface pressure forecasts (unit: hPa) as function of forecast range. Red curve is for control and blue for run with the modified v_1 coefficient.

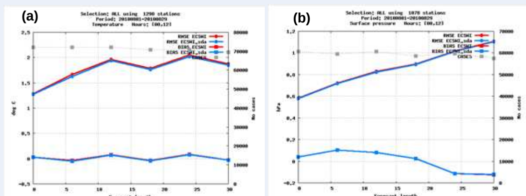

Fig. 5. Summer-time area averaged bias and RMSE of (a) 2 meter temperature forecasts (unit:K) and (b) surface pressure forecasts (unit: hPa) as function of forecast range. Red curve is for control and blue for run with the modified v_1 coefficient.

Conclusions

Nordic 2 meter temperature winter-time forecasts are significantly improved by modifying a coefficient in the surface analysis scheme. No negative impact of the modification on summer-time scores is found.

References

Douville, H., *et al*., 1995. A New Snow Parameterization for the Meteo-France Climate Model .1.Validation in Stand-Alone Experiments. *Climate Dyn*., **12**, 21-35.

Mahfouf, J.-F. *et al*., .2009. A comparison of two off-line soil analysis schemes for assimilation of screen level observation. *J. Geophys. Res*., **114**. doi:10.1029/2008JD011077.