IMPLEMENTATION OF A NEW PARAMETERISATION OF THE SURFACE TURBULENT FLUXES FOR STABLE STRATIFICATION IN THE 3-D HIRLAM.

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Introduction. In this study, earlier developed practically oriented surface flux-calculated techniques for stable stratification, based on correction functions to the neutral drag and heat/mass transfer coefficients (Zilitinkevich et al., 2001) are implemented in three-dimensional (3-D) variant of the HIRLAM. Earlier, new techniques has been implemented in 1-D HIRLAM (Perov and Zilitinkevich, 2000). In the traditional formulation (Louis et al., 1982), the correction functions for the stable stratification depend only on the bulk Richardson number. The new correction functions depend, besides bulk Richardson number, on one more stability parameter, involving Brunt-Väisälä frequency in the free atmosphere and on the roughness lengths for wind and temperature (humidity).

The resulting flux parameterization technique is nearly as simple as the traditional one. It consists of the following straightforward calculation (for formulae and details see Zilitinkevich et al., 2001):

- Given the height z_1 of the lower model level in the HIRLAM under consideration and the roughness length $z_{0u}, z_{0T} \approx z_{0q}$ at a point on the surface, the neutral drag, heat and moisture transfer coefficients C_{Dn}, C_{Hn} and C_{Qn} are calculated.
- Using wind speed u, v at lowest model level and the increments in potential temperature $\Delta\theta$ and specific humidity Δq, the bulk Richardson number R_i is defined.
- The Brunt-Väisälä frequency N in the free atmosphere is calculated. To a reasonable approximation, it is sufficient to approximate N by its mean value within a reasonably deep layer placed immediately above the upper boundary of typical stable boundary layers (SBLs), e.g., 250 m< z <750 m.
- Then correction functions f_D, f_H and f_Q (following the formulae from Zilitinkevich et al., 2001) are calculated. These functions dependent on R_i and also on z_{0u}, z_{0T} and z_{0q}.
- Given the correction functions and the neutral drag, heat and moisture transfer coefficients, the non-neutral coefficients become functions of the neutral and the new correction functions $C_{\{D,H,Q\}} = C_{\{Dn,Hn,Qn\}} f_{\{D,H,Q\}}(R_i, N, z_{0u}, z_{0T}, z_{0q})$.
- Finally, the turbulent surface fluxes for momentum, sensible and latent heat are calculated in a conventional format.

Verification results. A data assimilation and forecast experiment was carried out for 10 days period, from 27th January to 5th February. During this period, sometimes referred as the FASTEX (Front and Atlantic Storm-Track Experiment) the radiosonde network was considerably enhanced over the North Atlantic area, mainly to test the effect on forecast performance in data sparse regions. This period is selected for comparison of the forecasts using the HIRLAM 5.0.0. version with the new parameterisation of turbulent surface fluxes and reference surface fluxes, based on the Louis parameterisation. The lateral boundary conditions and the first guess field in the beginning of the verification period are taken from the ECMWF operations.

The selected area, 114*100 grid-points, covered the North-East Atlantic, Europe and Greenland with a resolution $0.4^0 \times 0.4^0$ and 31 vertical levels. The Eulerian advection is used with time step of 4 minutes. In the data assimilation, optimal interpolation technique is used. The data assimilation cycle is six hours. From each 00UTC and 12UTC analyses a +48 hours forecast is run, altogether there are 20 two-day forecasts (06z and 018z analyses are used only for data assimilation). The verification scores obtained by forecasts with the new and the current parameterisation of the surface fluxes against observations, as well as differences of mean fields are calculated.

Figure 1 presents the bias mean (systematic) error and root mean square (RMS) of 2 meter temperature (T2M) averaged over 10 days period, for runs with the new and the current parameterization of surface fluxes. The run with the current parameterization evidently underestimates T2M (negative bias). The run with the new parameterization reduces this underestimation. The similar result is presented in Figure 2, for 2 meter relative humidity (RH2M), averaged over 10 days period. Figure 3 presents T2M bias and RMS for each day of 10 days period and Figure 4 presents RH2M bias and RMS for each day of the period. In figure 5, vertical profiles of geopotential height (gph) bias and RMS are plotted. Figure 6 presents a map of T2M differences (K), averaged over 10 days period, between the new and the current parameterization runs. It is seen the differences in T2M (1-3 K) over Greenland, Scandinavia and Alps. In figure 7, T2M differences presents for two runs after 48 hours forecast for 1 February 1997. It is seen that T2M differences in figure 7 are greater than in figure 6 over the same areas. Figure 8 represents the differences between two runs with the new and the current parameterization surface fluxes for 2 meter dew point temperature (Td2M), after 48 hours forecast for 1 February 1997.

Conclusions. As seen in all figures, the forecasts with the new flux parameterization are basically consistent with observation better than the forecasts with the current (Louis et al.,1982). The new parameterization predicts essentially higher level of turbulence than formerly recognised at large values of the bulk Richardson numbers, in good correspondence with observations. Although more validation through other case studies is needed, the proposed technique may be recommended to implement in the reference HIRLAM.

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References

Louis J.F., Tiedtke M. And Gelen J.F., 1982: A short history of the PBL parameterization at ECMWF. *Proceedings of Workshop on Boundary Layer Parameterization,* ECMWF, Reading, 59-79.

Perov V. and Zilitinkevich S., 2000: Application of an extended similarity for the stably stratified atmospheric boundary layer to the HIRLAM. *HIRLAM Newsletter*, No. 35, 137-142.

Zilitinkevich S., Perov V. and King J., 2001: Calculation technique of surface turbulent fluxes in stable stratification for numerical weather prediction models. *HIRLAM Newsletter*, No. 37, 10-19.

Figures captions

Figure 1. The 2 meter temperature bias and RMS, averaged over period 10 days, for runs with the new and the current (OLD) surface flux parameterizations.

Figure 2. Same as Figure 1, except for 2 meter relative humidity.

Figure 3. T2M bias and RMS for each day of 10 days period for two runs, with the new and the current (OLD) surface flux parameterizations.

Figure 4. Same as Figure 3, except for RH2M.

Figure 5. The vertical profiles of the geopotential height bias and RMS for two runs, with the new and the current (OLD) surface flux parameterizations.

Figure 6. T2M differences between two runs, with the new and the current surface flux parameterizations, averaged over period 10 days.

Figure 7. Same as Figure 6, except after 48 hours forecasts for 19970201.

Figure 8. The 2 meter dew point temperature differences between two runs, with the new and the current surface flux parameterizations, after 48 hours forecasts for 19970201.

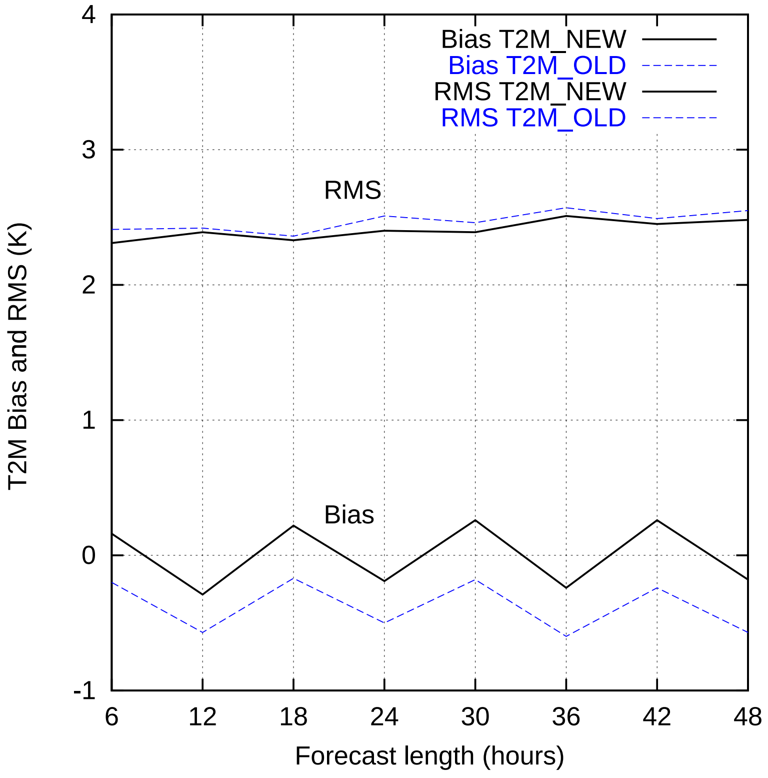


Figure 1.

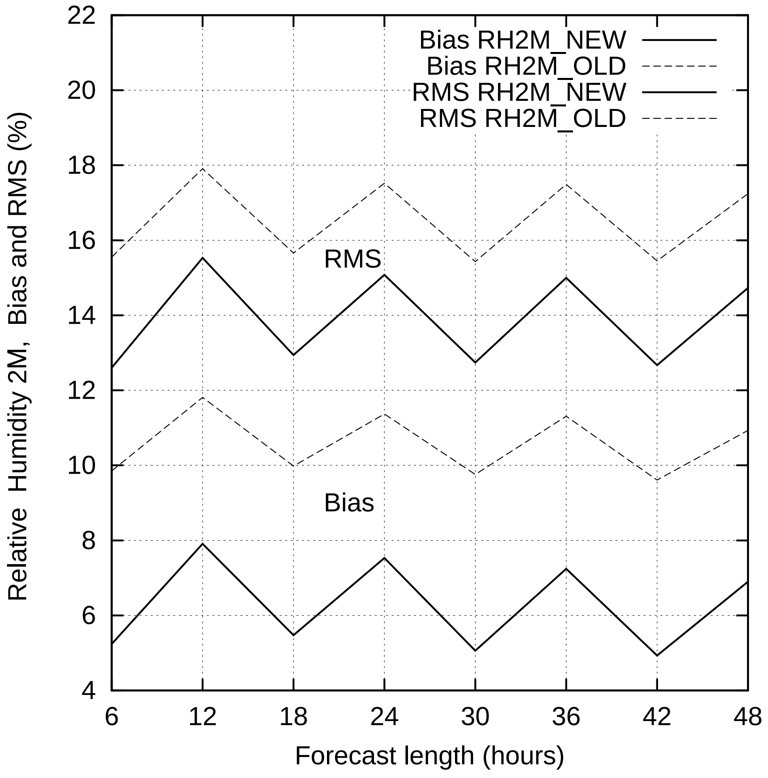


Figure 2.

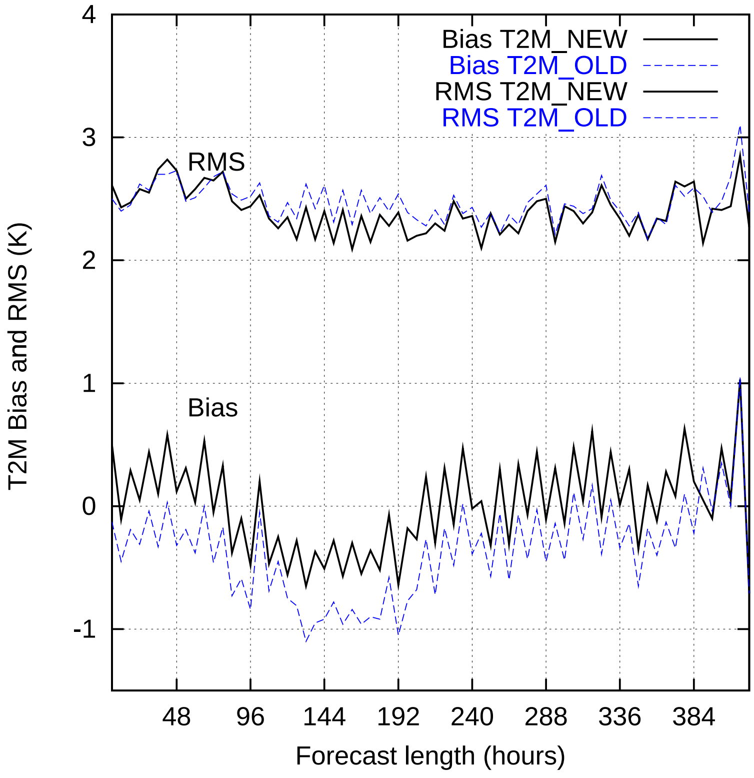
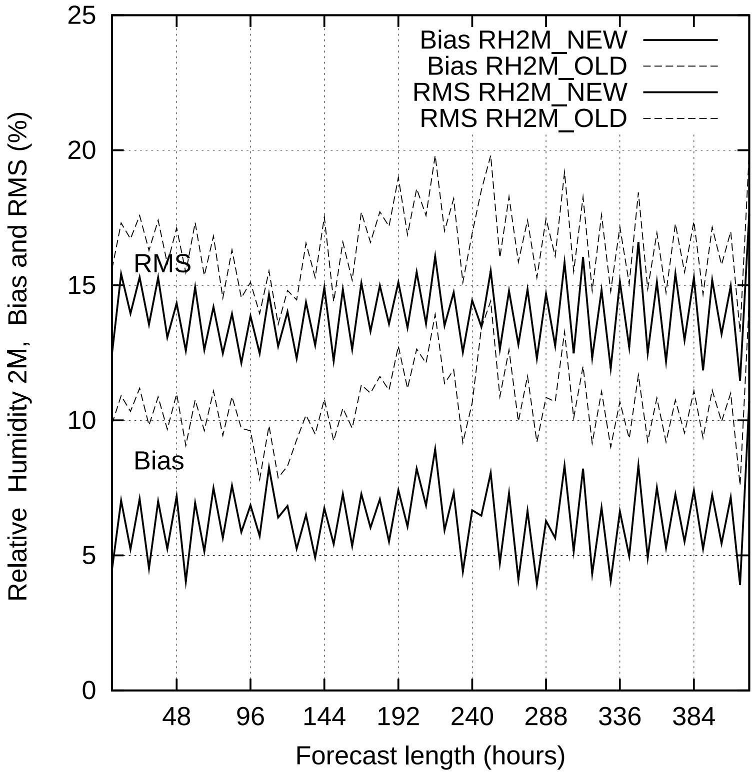


Figure 3.



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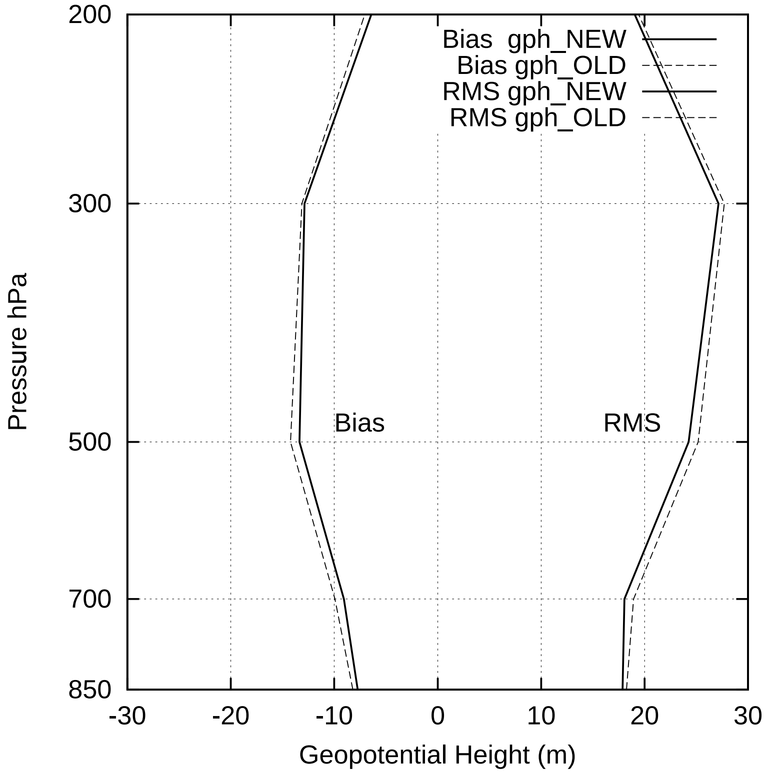

Figure 5.

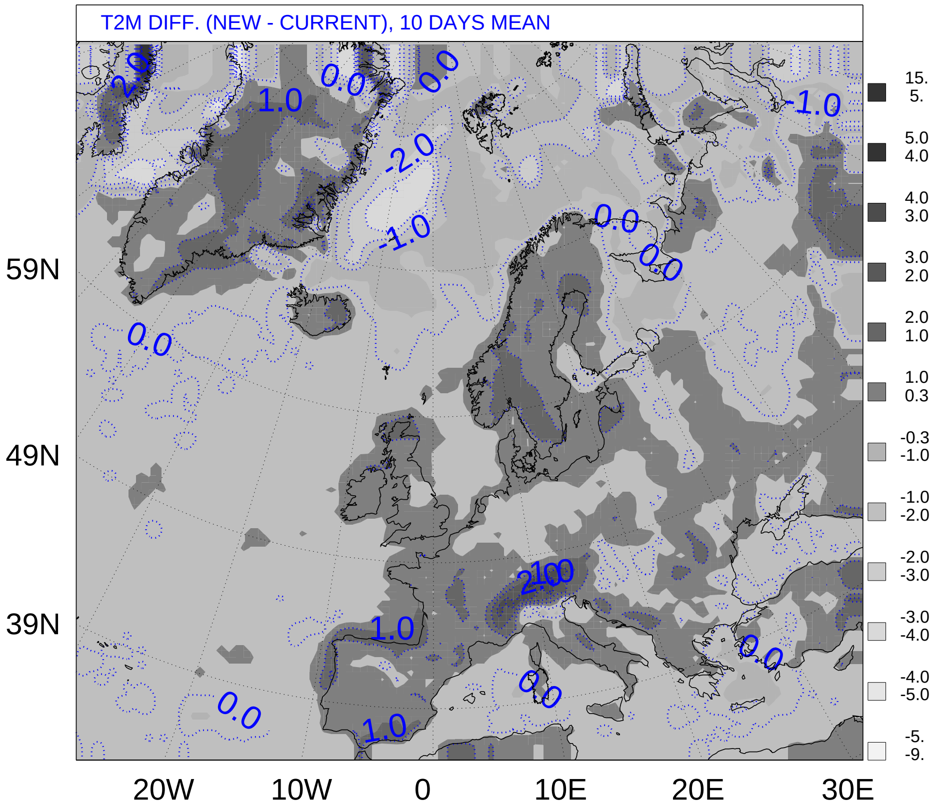

Figure 6.

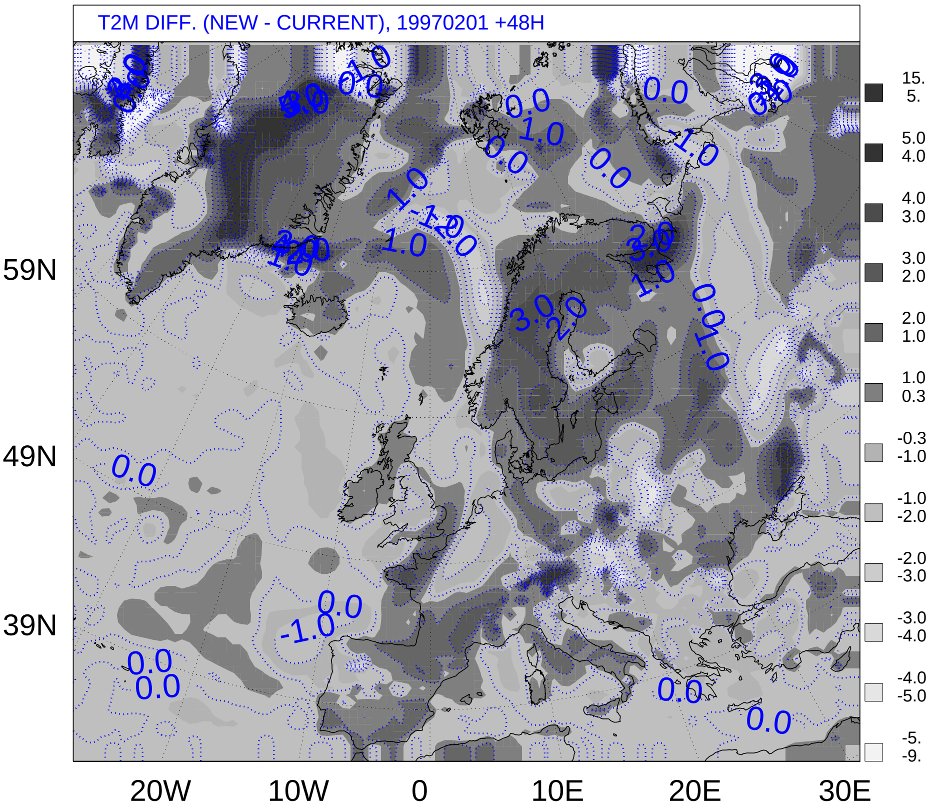

Figure 7.

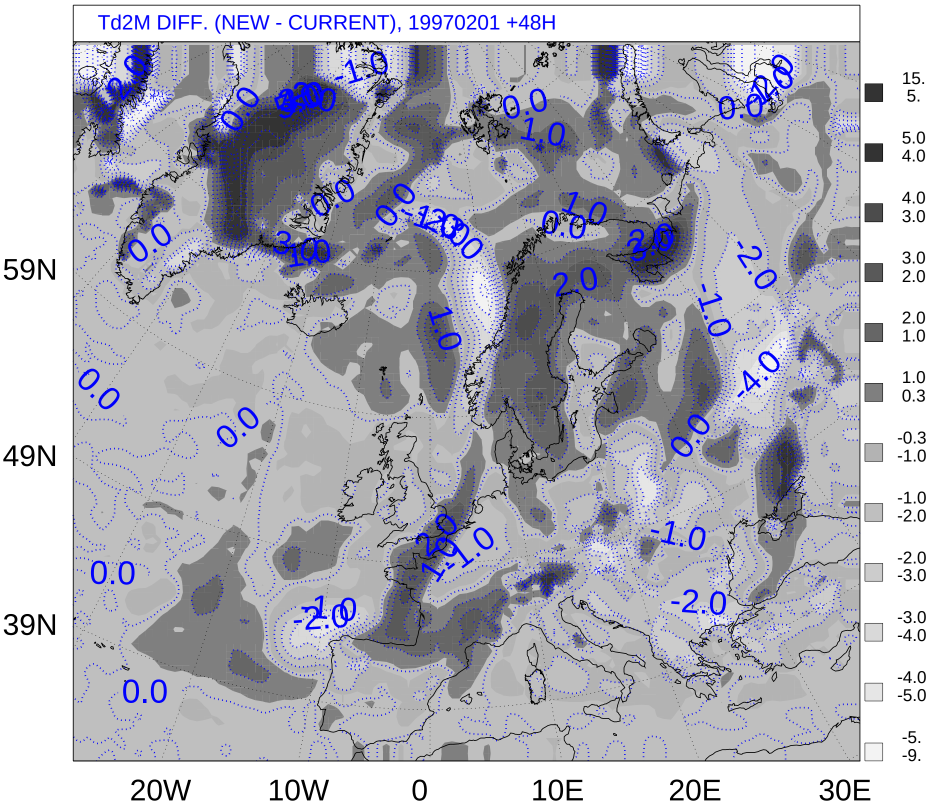

Figure 8.