A study of the flow-dependence of background error covariances based on the NMC method

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Modern data assimilation systems such as the 4D-Var and the Ensemble Kalman Filter (EnKF) use the dynamics of the forecast model to evolve the covariance matrix of background error $\mathbf{B}$ in time either implicitly (4D-Var) or explicitly (EnKF). As a consequence, these schemes effectively use flow-dependent structure functions [1], although at correspondingly high computational costs. Nevertheless, the initial $\mathbf{B}$-matrix still has to be specified, like for any simpler assimilation system (e.g., OI, 3D-Var). The 4D-Var also does not transfer the dynamical background covariances to subsequent assimilations.

In order to explore the variability of the $\mathbf{B}$-matrix with respect to flow pattern explicitly, we applied the NMC method at DWD to the global model GME. The NMC method uses differences of short-range forecasts verifying at the same time but with different starting dates as proxies for background error. The method assumes that the spatial structure of background error does not strongly vary with forecast time, so that the correlations obtained from forecast differences are reasonable approximations to the true background error correlations, at least for the mid-latitudes.

For the present study we used the differences of 48h and 24h forecasts of geopotential height verifying at 00Z during the winter period from Dec. 1, 2003, until Feb. 29, 2004. The forecast fields were taken from the archived main runs of the operational GME model. The evaluation of covariances shown here was performed on a regular grid at fixed reference latitude and with zonal averaging. The isotropic part of the empirical correlation of geopotential height of the 500 hPa surface at 45°N is shown as the blue curve in fig. 1.

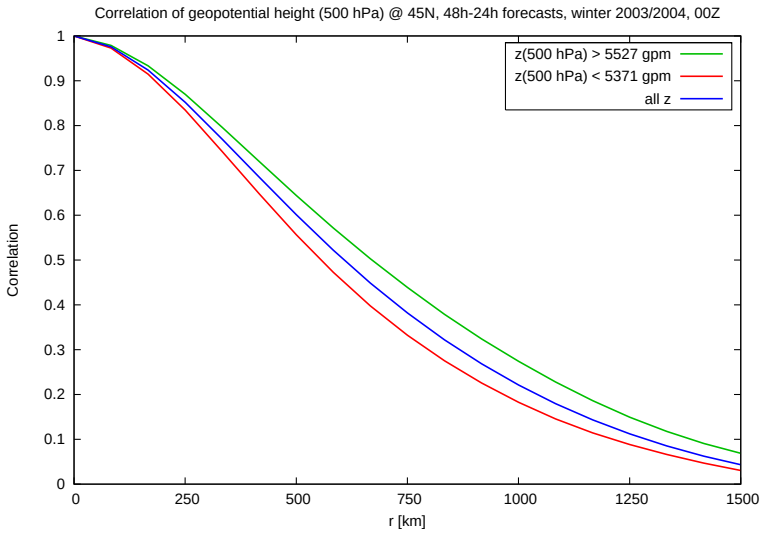

Figure 1: Correlation of the 500 hPa height from 48h–24h forecast differences

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For the exploration of the flow-dependence, we took the 24h forecast of the 500 hPa height as an indicator for the meteorological situation. Based on the statistics of the geopotential height at fixed latitude over the whole period, we distributed the contributions into three classes of approximately equal sample sizes. For our forecast sample and at 45°N, a data point was associated with a region of "high" and "low" pressure if $z(500\,\mathrm{hPa}) > 5527\,\mathrm{gpm}$ and $z(500\,\mathrm{hPa}) < 5371\,\mathrm{gpm}$, resp., otherwise it was assigned to the "neutral" class. The resulting horizontal correlation functions obtained from contributions in the classes "high" and "low" are shown in fig. 1 as green and red curves. Clearly the correlations for "highs" are significantly broader than for "lows".

We extended the above analysis also to other pressure levels. In order to keep a uniform criterion for the selection of meteorological situations, we chose the geopotential height of the co-located 500 hPa surface. The corresponding dependence of the horizontal correlation scale on vertical level is shown in fig. 2. The data demonstrate that there clearly is a considerable variation of correlation scale with flow pattern.

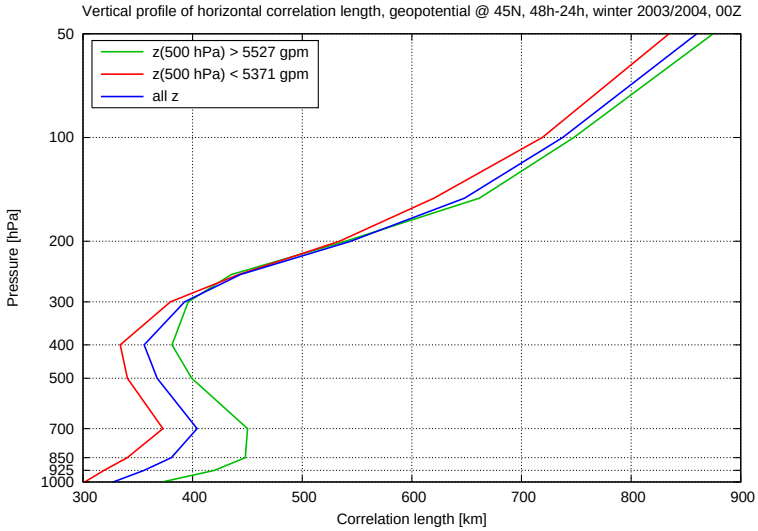

Figure 2: Vertical profile of the horizontal correlation scale of geopotential

We have also analyzed the flow-dependence of cross-correlations with other forecast fields and vertical correlations, as well as the variation with location and season. The corresponding results will be presented elsewhere.

References

[1] J.-N. Thépaut, P. Courtier, G. Belaud and G. Lemaître, *Dynamical structure functions in a four-dimensional variational assimilation: A case study*, Q. J. R. Meteorol. Soc. **122** (1996) 535-561.