2. Margarida BELO PEREIRA : "Estimation and study of forecast error covariances using an ensemble method in a global NWP model"

Introduction

The background error covariance matrix is one very important element in a data assimilation system, since it determines the filtering and propagation of observations. In operational ARPEGE assimilation system the covariance coefficients of this matrix are estimated using the NMC method (Parrish and Derber, 1992). In this method the background errors are given by the differences between 12 h and 36 h forecasts valid at the same time. In 2001, another method, known as Analysis Ensemble Method, hereafter referred as Ensemble method, which was tried before in Canada (Houtekamer et al., 1996) and at ECMWF (Fisher, 1999) was implemented and tested in ARPEGE 3d-var (Belo Pereira, 2002). Presently, the Ensemble method was implemented in ARPEGE 4d-var.

The results presented in the current document are derived from an ensemble which contains five 4d-var cycles of the non-stretched version of ARPEGE model with T299 and 41 levels, for the period from 1st of February to 24th of March of 2002. The members of this ensemble were arbitrarily numbered from 33 to 37. The differences between the 6-hours forecasts for consecutively numbered members were computed for each 12 UTC cycle between 04/02/2002 and 24/03/2002. This provides 4 x 49 = 196 differences between background fields, from which the global standard deviation, the vertical and horizontal correlations of the background error are diagnosed.

Ensemble Method versus NMC method

Several statistics of the background errors were analysed, in order to study the differences between the two methods, both in spectral and in gridpoint space. This document will make reference only to the spectral space results.

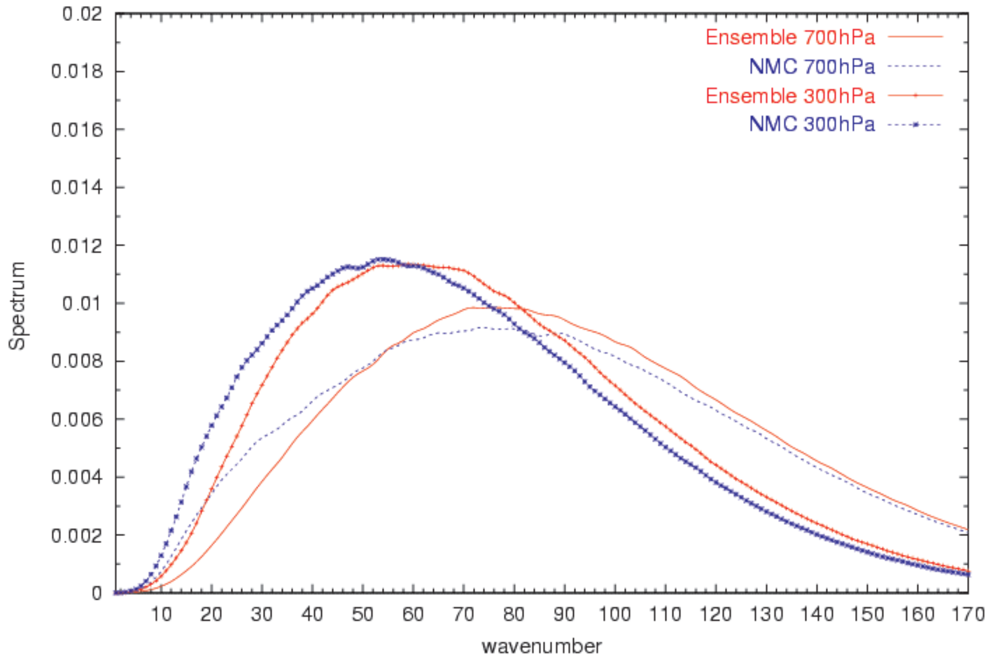

Figure 1. Auto-correlation spectra of vorticity at levels 27 (near 700 hPa) and 16 (near 300 hPa) for NMC and Ensemble methods.

Figure 1 shows the auto-correlation spectra of vorticity estimated by the two methods. It can be seen that both at 700 hPa as near the jet level, the auto-correlation spectra show that the variance maximum is shifted towards the smaller scales in the Ensemble method. This means that the variance of vorticity background error has a larger contribution from mesoscale phenomena, when estimated by the Ensemble method than by the NMC method. This occurs also for the other atmospheric variables.

It is also interesting to mention that according to the NMC method the larger contribution for the background error of surface pressure comes from the synoptic scales, while in the Ensemble method the contribution from the planetary scales seems to be so important as the one from synoptic scales.

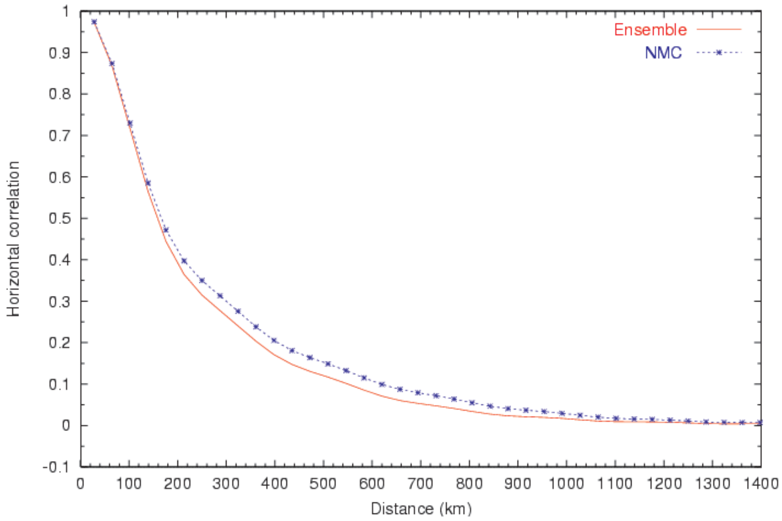

Figure 2. Horizontal auto-correlation of surface pressure background error estimated by Ensemble and NMC methods.

Figure 2 shows the mean horizontal correlations for surface pressure for the two methods. When the Ensemble method is used the correlation is sharper than in the NMC method. This result is valid also for the other variables, except for divergence.

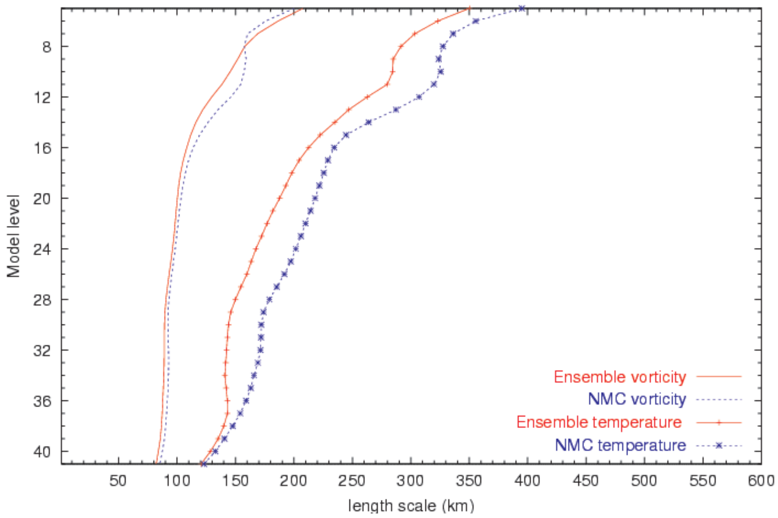

Figure 3. Horizontal length scale of auto-correlation function of temperature and vorticity estimated by NMC and Ensemble methods.

Figure 3 shows the horizontal length-scale of auto-correlation function of temperature and vorticity estimated by the two methods. The results show that for both methods the length-scale of vorticity is smaller than the one of temperature, as it would be expected. Moreover, it can be seen that according to the Ensemble method the horizontal length-scale is smaller than when estimated by the NMC method. This difference is more notorious for temperature. On the contrary, the horizontal length-scale of divergence is very similar in the two methods.

The mean vertical correlations and the North-South variation of the vertical correlations were both analysed. The results show that the Ensemble method produces much sharper vertical correlations than the NMC method, mainly for middle and high latitudes (see figure 4).

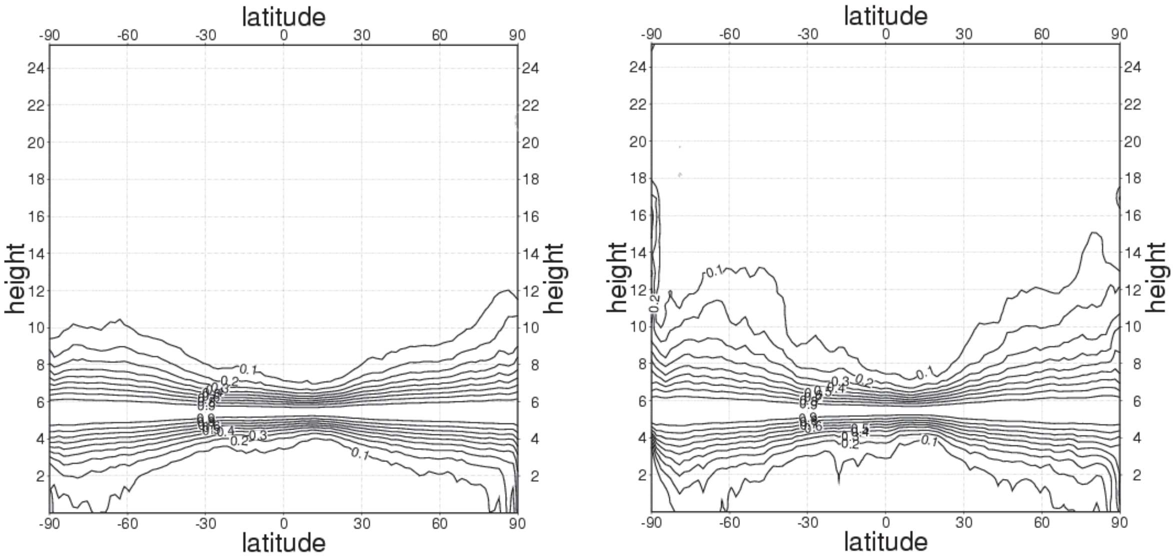

Figure 4 - North-South variation of vertical correlation (at level 21) of vorticity background error estimated by the Ensemble method (left side) and by the NMC method (right side).

Impact on forecasts

On operational 4d-var assimilation system, the vertical profiles of total standard deviation of the background errors are rescaled by a factor of 0.9 in order to account for mismatch between the magnitudes of the 12 / 36-hours forecast differences and the 6-hour forecast errors. In order to study the impact of the statistics from the Ensemble Method against the ones from NMC method (operational), some tests were performed to find out the optimal factor to rescale the vertical profile of the standard deviation of the background errors. Figure 5 shows the vertical profile of the standard deviation of vorticity and temperature for the NMC method and for the Ensemble method, multiplied by different factors.

For both methods the largest errors of vorticity are located at the jet level. However, if the factor of 1.3 is used, the Ensemble method gives larger errors in the middle troposphere, but smaller error in the low troposphere than the NMC method. On the other hand, if the factor of 1.5 is used, the background errors of vorticity given by the Ensemble method are larger in all troposphere than the ones given by the NMC method.

Both methods agree that the largest errors of temperature are located in the top level. Nevertheless, the Ensemble method produces larger errors at this level than the NMC method. Moreover, according to the NMC method the second maximum of the temperature background error is located at tropopause, while according to the Ensemble method the second maximum error occurs in middle troposphere.

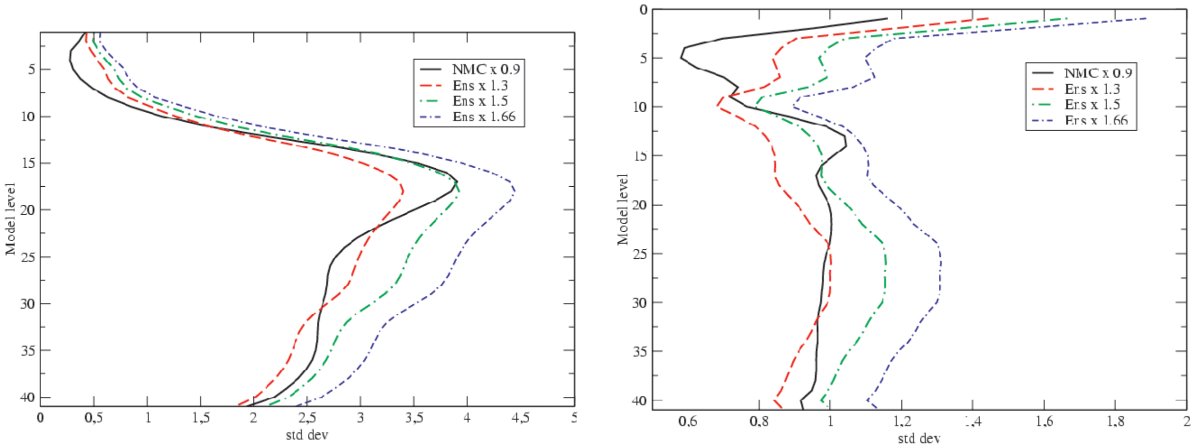

Figure 5 : Vertical profile of rescaled standard deviation of vorticity (left side) and temperature (right side) background error estimated by NMC and Ensemble methods.

The impact of the statistics derived from the Ensemble method against the ones from NMC method were tested for two different periods; from 5 of February to 4 of March of 2002 (here referred as first period, which includes the period from which the statistics were computed) and from 24th of October to 20th of November of 2002 (referred as second period). The results of the impact experiences revealed that the factor of 1.5 is the optimal value, since the scores were clearly better than when using factor of 1.3 and the differences between using factor of 1.5 or 1.66 were neutral.

The wind scores against ECMWF analysis are clearly positive over the regions of North America, Europe and North Atlantic, for forecast ranges larger than 24 hours. This positive impact is larger in the middle and upper troposphere and increases with the forecast range. In the tropics, the scores for wind are positive on stratosphere and on middle and upper troposphere, for all forecast ranges. On the other regions, the scores for wind are slightly positive or neutral. The positive impact is less impressive for the second period.

For both periods, the scores for geopotential are clearly positive on the stratosphere over the first day of forecast and on the troposphere for forecast ranges larger than 36 hours. For the first period, the scores of geopotential are strongly positive in the stratosphere in the North Hemisphere, for all forecast ranges. In the South Hemisphere and in the tropics the scores are positive on the high troposphere. However, for the second period, the scores for geopotential are negative in the South Hemisphere for all forecast ranges.

The temperature scores are slightly positive (for instance near the 10 hPa) or neutral.

References

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