ENSEMBLE DISPERSION SPECTRA AND THE ESTIMATION OF ERROR STATISTICS FOR A LIMITED AREA MODEL ANALYSIS

Simona Ştefănescu [1] , Loïk Berre [2]

1. Introduction

Deriving background error statistics can be done using an ensemble of perturbed assimilation systems. Houtekamer et al. (1996) combined two complementary approaches into a system simulation experiment, namely an ensemble prediction based on a perfect-model approach, for which only the observations that enter in the assimilation cycle are randomly perturbed, and model sensitivity experiments. The analysis ensemble approach was also implemented at the ECMWF (Fisher, 1999) and Meteo-France (Belo Pereira, 2002).

In the present study, the ensemble approach is used to sample the forecast error covariances to be used in a 3D-Var data assimilation for the limited area model ALADIN. A generalized formulation of this 3D-Var is considered, in which the analysis of the coupling model, namely ARPEGE, is included as an additional source of information (Bouttier, 2002). This is related to the idea of relying on the "fresh" ARPEGE analysis for the large scales, while still extracting the small scale information of the ALADIN background. The evolution of dispersion spectra in the perfect-model framework has been investigated. The ARPEGE/ALADIN model differences have been also evaluated, and a decomposition of them is proposed. Finally, the implications for the specification of the error statistics in the generalized formulation of the ALADIN 3D-Var data assimilation are pointed out. A comparison with the statistics derived through the NMC method has been carried out too.

2. Contributions to the evolution of dispersion spectra in a perfect-model framework

From the ARPEGE ensemble of perturbed assimilation cycles, it is possible to run the operational ALADIN limited area system (currently in dynamical adaptation mode): this provides an ensemble of limited area states, whose evolution of dispersion can be studied.

The effect of ARPEGE analysis is to reduce the error variance, especially in the large scales (see figure 1). The reduction of the ARPEGE first guess variance is about 30 percents for the wavenumber 1.

After applying a digital filter initialization (DFI), a reduction of the error variance for ARPEGE analysis and first guess, especially in the small scales, has been observed. This can be explained by the fact that DFI removes some unbalanced components of the error variance, namely the structures artificially created in the small scales by the horizontal interpolation of the ARPEGE fields into the ALADIN grid.

Compared with the ARPEGE 6h forecast, the effect of ALADIN 6h forecast is to increase the error variance in the small scales. The ALADIN 6h forecast and ARPEGE 6h forecast error variance curves start to depart significantly at wavenumbers greater than 13-17, i.e. corresponding to length scales smaller than 220-170 Km, as can be seen from figure 2. This means that the limited area model builds up its own structures beyond these wavenumbers. The smaller errors of ARPEGE (than those of ALADIN) that are suggested in the small scales can be understood on one hand, knowing its low resolution and the effect of diffusion, but it can also be seen as a paradox on the other hand, as we would expect that the higher resolution model (ALADIN) should give a better solution in the small scales.

3. Model difference evaluation and decomposition

We have calculated the differences between the ARPEGE and ALADIN models, when these two models are subject roughly to the same initial state. The potential of these model differences is to give informations about some of the involved model errors.

The ARPEGE/ALADIN model differences appear to be relatively small scale compared with the differences that are related to the initial condition perturbations, but there are also some significant contributions in the large scales. This suggests that the model differences arise not only from the differences in resolution, but possibly also from the coupling inaccuracies and from the interactions between the small and large scales. One may wonder therefore if it could be possible to distinguish these different possible contributions.

A parameter α has been defined, in order to estimate the part of the model differences that is related to the resolution differences. α is defined as the percentage of ALADIN dispersion that is unrepresented by ARPEGE:

$$\alpha = [var(ald06) - var(arp06i)]/var(ald06) \qquad (1)$$

[1]National Institute of Meteorology and Hydrology, Sos. Bucuresti-Ploiesti 97, sector 1, 013686 Bucharest, Romania, e-mail: simona.stefanescu@meteo.inmh.ro

[2]Meteo-France CNRM/GMAP, 42 av. G. Coriolis, 31057 Toulouse Cedex 01, France, e-mail: loik.berre@meteo.fr

Further, the model differences variance $var(\epsilon^m)$ can be decomposed as follows:

$$var(\epsilon^m) = \underbrace{\alpha \cdot var(\epsilon^m)}_{var(\epsilon^{ss})} + \underbrace{(1-\alpha) \cdot var(\epsilon^m)}_{var(\epsilon^{ls})} \qquad (2)$$

$var(\epsilon^{ss})$ corresponds to the small scale structures that are represented by ALADIN and not by ARPEGE: they may be interpreted as some ARPEGE model errors, with respect to the truth at the ALADIN resolution.

The residual $var(\epsilon^{ls})$ corresponds to some large scale structures, that are related e.g. to some coupling inaccuracies and to some small scale/large scale interactions. In the future, a refined decomposition of this residual could be obtained by comparing some global and limited area models with similar resolutions, and also by comparing some global models with different resolutions.

The decomposition of the ARPEGE/ALADIN model differences variance into small scale and large scale parts is represented in figure 3.

4. Implications for the specification of the error statistics in the generalized formulation of the ALADIN 3D-Var

The variances of the decomposed model differences have been added to the respective dispersion variances of the ARPEGE analysis and of the ALADIN background (see figure 4). A multiplying factor 2 is used for these model difference variances, to be consistent with the corresponding factor 2 that is implicit in the variance estimates provided by the ensemble of analyses with a perfect model.

The variance of the small scale structures that are unrepresented by the ARPEGE model has been added to the variance of the ARPEGE analysis dispersion. This increases strongly the small scale dispersion, while leaving the large scale dispersion mainly unchanged.

The variance of the large scale model differences may be added to the variance of the ALADIN background dispersion, if they are interpreted as being caused by ALADIN (due to coupling errors for instance); this increases mostly the large scale dispersion.

The comparison between the two final dispersion spectra suggests that in the large scales, the ARPEGE analysis errors are smaller than those of the ALADIN background, while the reverse holds in the small scales.

This ensemble approach, based on some perturbed assimilation cycles and model differences, appears therefore to be a good framework for the evaluation of the error statistics that are involved in the generalized formulation of the ALADIN 3D-Var.

References

Belo Pereira M., 2002: Improving the assimilation of water in a NWP model. Reports for ALATNET Newsletters 4 and 5.

Bouttier F., 2002: Strategies for kilometric-scale LAM data assimilation. Hirlam workshop report on variational data assimilation and remote sensing 21-23 January 2002, Helsinki, p.9-17.

Fisher M., 1999: Background error statistics derived from an ensemble of Analyses. ECMWF Research Department Technical Memorandum No. 79, September 1999, 12pp.

Houtekamer et al., 1996: A system simulation approach to ensemble prediction. Mon. Wea. Rev., 124. 1225-1242.

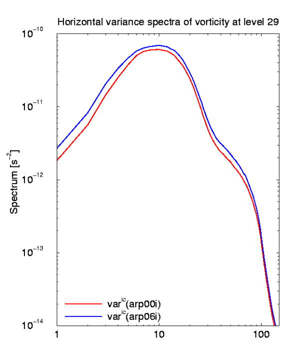

Figure 1: Dispersion spectra related to the initial condition perturbations for initialized ARPEGE analysis and first guess fields

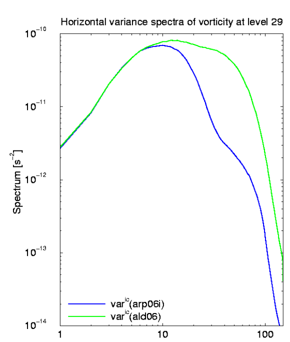

Figure 2: Dispersion spectra related to the initial condition perturbations for initialized ARPEGE first guess and ALADIN background fields

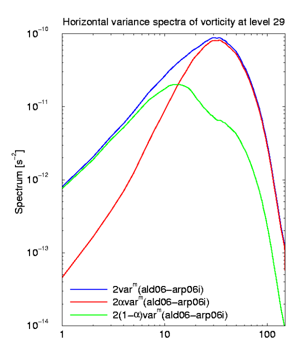

Figure 3: Decomposition of initialized ARPEGE first guess / ALADIN background differences variance

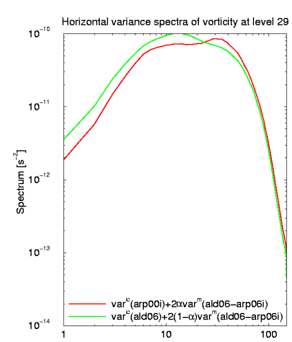

Figure 4: The final dispersion spectra for initialized ARPEGE analysis and ALADIN background fields