Representation of forecast error spatial covariances for a variational assimilation in an atmospheric limited area model

Loik BERRE
Météo-France, CNRM/GMAP, 42 av. G. Coriolis, 31057 TOULOUSE CEDEX
loik.berre++at++meteo.fr

Summary:

In the framework of data assimilation, observations and a background are combined in order to obtain an estimation of the atmospheric state that is as accurate as possible. The background that is used is in general a short range forecast. The variational data assimilation consists in minimizing a cost function that measures the distance between the estimated state and the different information sources that are used, weighted by the accuracy of each of these information sources.

The implementation of a variational data assimilation thus involves the spatial covariance matrix of background errors, noted B. The role of this matrix is to filter the observed information and to propagate it spatially and in a multivariate way. In this work we are interested in the representation of the matrix B for a limited area three-dimensional variational assimilation (3D-Var), and in particular in the possibilities that are offered by a bi-Fourier approach in this perspective.

We have first considered the spectral and vertical variabilities of these covariances on a limited area. Under the assumption that spatial covariances are homogeneous horizontally, the bi-Fourier approach allows indeed to study and to represent these variabilities in an economical way: in this case the covariances between spectral coefficients whose wavevectors differ are equal to zero, and the matrix B of three-dimensional spatial covariances reduces thus in spectral space to a block-diagonal matrix. The data basis that is used to study these covariances consists in a set of differences between forecasts that are valid at the same time for different ranges. In accordance with what was found in global models, it appears that the error structures that correspond to small horizontal scales tend to have also a small vertical extension. In addition to this, horizontal auto-correlation functions present a vertical variability: they tend to broaden with height. Regarding multivariate features, small scale error structures are moreover less geostrophic than large scale ones. We have been also interested in cross-covariances involving humidity, which are usually neglected, and whose spectral variability is also noticeable.

A bi-Fourier formulation of the background error constraint term for a limited area 3D-Var assimilation has been studied then. This formulation allows to resolve the analysis globally (without the problem of data selection of the Optimal Interpolation), with an adequate preconditioning, non-separable forecast error covariances and non-zero increments near lateral boundaries. An incremental approach can be introduced easily moreover. The periodicity of Fourier functions is likely to lead to artificial analysis increments near lateral boundaries. Assimilation experiments with a single observation indicate that this problem is limited when the width of the extension zone (that is used to ensure the biperiodicity) is larger than the horizontal decorrelation length of forecast errors. When compared with the Optimal Interpolation, the 3D-Var assimilation system that is obtained in this way appears to have a positive impact on the forecast quality.

We have finally compared two different approaches regarding the multivariate formulation of a limited area 3D-Var assimilation. The first one is based on a tangent-linear calculation of geostrophic wind errors and on the assumption that errors on mass, ageostrophic wind and humidity have horizontally homogeneous auto-covariances and zero cross-covariances. The second one uses a calculation of errors on vorticity, linear regressions and the assumption that the errors on vorticity and on the different regression residuals have horizontally homogeneous auto-covariances and zero cross-covariances. It appears that the second approach allows to relax the geostrophic assumption to a larger extent as a function of latitude, height and horizontal scale. The behaviour of the tangent-linear calculation of geostrophic wind increments near orographic regions and of the humid balance are moreover examined, in addition to their respective impacts on the forecast.