9. Cornel SOCI : "Sensitivity study at high resolution using a limited-area model and its adjoint for the mesoscale range"

The development of the adjoint model is primarily oriented towards data assimilation and predictability applications. However, since it is able to relate the origin of a numerical forecast failure to the errors in the initial data, it has been used in diagnostic studies such as sensitivity experiments. The latter approach was proven to be successful for studying phenomena linked to baroclinic instability when using a low resolution model. For a high resolution limited-area model, the moist processes which are strongly nonlinear start playing a crucial role. Furthermore, numerical instabilities can occur. Thus, both the physical description of the atmospheric processes and the numerical robustness must be checked and possibly improved in the adjoint model.

In this study, the gradients of the forecast-error cost-function with respect to the initial conditions are investigated. The norms utilized are the so-called dry and moist total energy. The norm is called dry when there is no explicit term in it involving specific humidity. The gradients were computed using a package of simplified and regularized physical parameterizations including vertical diffusion, gravity wave drag, large-scale precipitation, deep convection and radiation. This package was developed for the global model ARPEGE with the aim of being used in four-dimensional variational data assimilation.

Sensitivity experiments for selected cases were performed intending to investigate the failure of precipitation forecasts. As an example of sensitivity analysis, we consider a case of overestimated precipitation forecast covering the period 0-12 UTC, 3 May 2001. However, we have tried to correct the total precipitation generated by the model within 6-12 UTC. One important feature for this experiment is that we have tried to improve the forecast using the 6 hours gradients of the forecast error cost-function with respect to the initial conditions. Usually, the forecast-error norm is computed at the end of the period under consideration, in our case at 12 hours, and not in-between.

Before performing the sensitivity integration we have analysed the gradient field. The adjoint model enfolded the parameterization of vertical diffusion, gravity wave drag, and large-scale precipitation. Results have shown that the large-scale precipitation scheme triggers numerical instability in the adjoint model. Indeed, as one may see in Figure 1 which illustrates the gradients of the forecast error cost-function with respect to the temperature on model level 20, there is a very wavy and noisy pattern. After investigations the problem was cured by modifying the shape and shift of the regularization function. A stable solution of the adjoint model is shown in Figure 2.

By modifying the model initial conditions using the gradients computed as described above, we have tried to ameliorate the precipitation field shown in Figure 3. This was produced by the operational forecast. In this figure a maximum of 27 mm / 6 h over an area situated in the north-western part of France is shown up, while the measured amount was less than 10 mm / 6 h. Although, in reality a convective system developed in the Northern part of France and the numerical forecast missed it. In that area 24 mm / 6 h were measured. The results of sensitivity integration are promising for this case. Analysing the corrected precipitation forecast shown in Figure 4, one may see that the maximum has diminished from 27 to 18 mm / 6 h and, more important that a precipitation core with 24 mm / 6 h has appeared in the proximity of the area were the convective storm did generate in reality.

However, several case studies were performed and not all of them were sensitive to the modification in the initial conditions. Also, there were results with neutral impact. For these, the misforecast may come not only from the errors in the initial conditions but from the errors in the lateral boundary conditions or the model formulation. The results have shown that the precipitation forecast can be improved if the failure is dominated by the fastest growing structures in the initial data.

This study gives a first experimental frame for the evolution and performance of an adjoint model for the mesoscale range. Further studies are needed in order to better understand the behaviour of the mesoscale gradients computed with a package of simplified and linearized physical parameterizations.

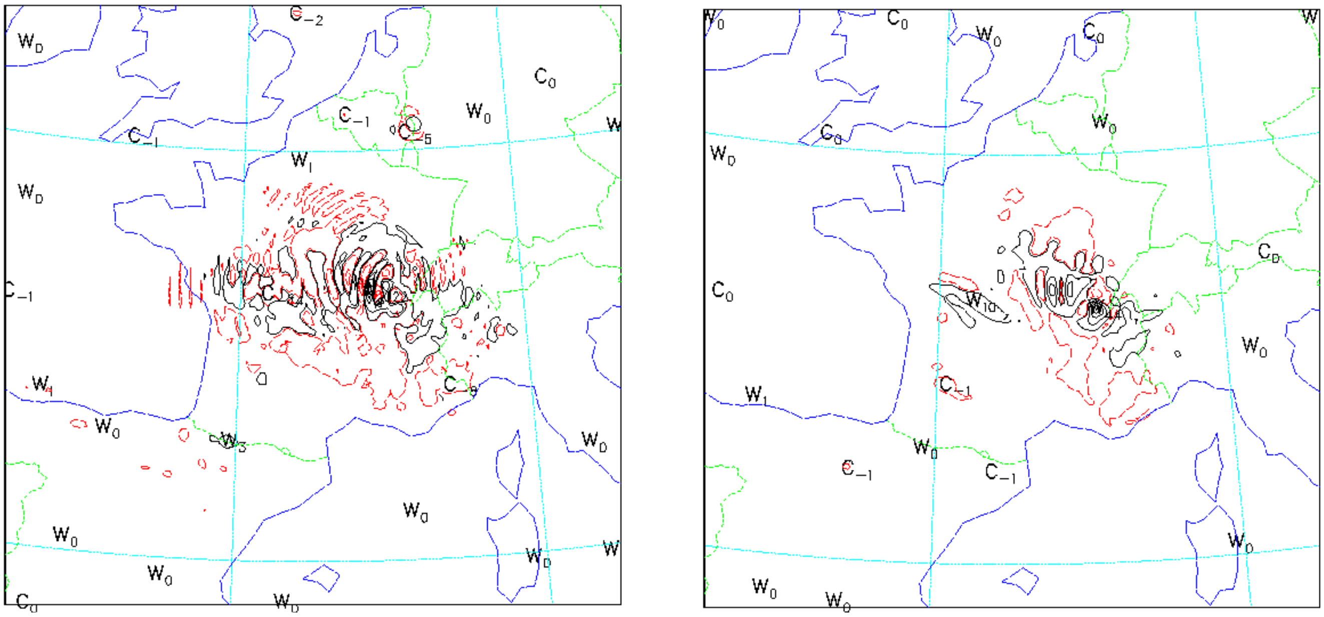

Figure 1. Gradients of the forecast error cost function with respect to the temperature at model level 20, computed with an adjoint model including simplified schemes for vertical diffusion, gravity wave drag and stratiform precipitation processes : before (left-hand side), and after (right-hand side) stabilization of the large-scale precipitation scheme.

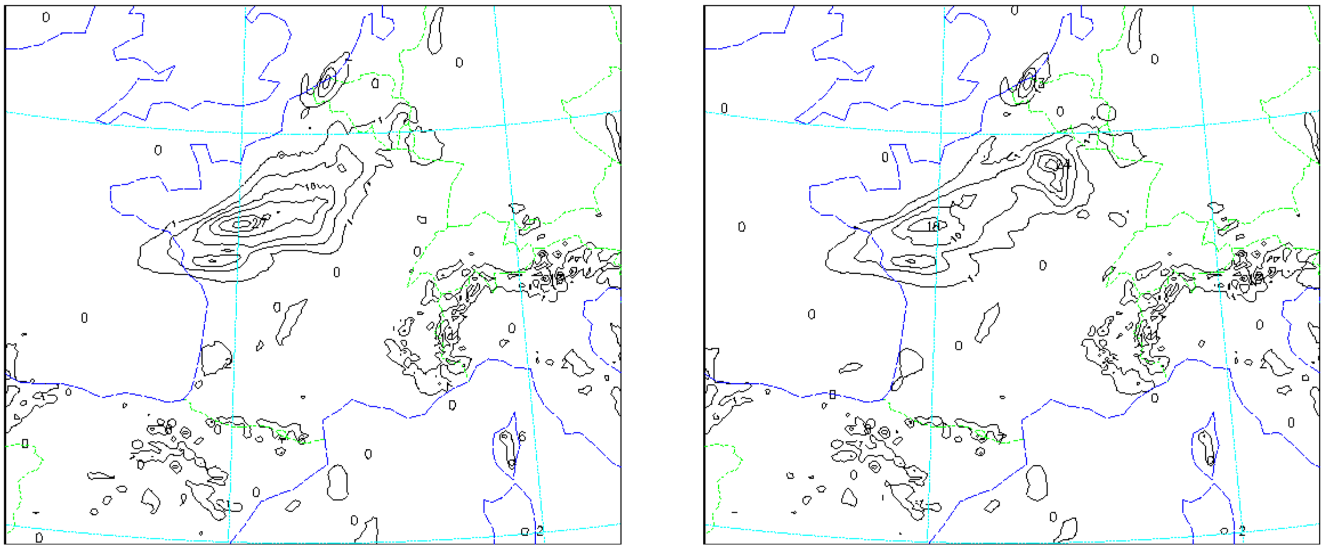

Figure 2. 6 hours precipitation forecast : operational (left-hand side), and after "improving" the initial conditions using the gradient of the 6 hours forecast error cost function (right-hand side).