6. Raluca RADU : "Extensive study of the coupling problem for a high resolution limited area model"

Introduction

The hypothesis behind different treatments of the lateral boundary conditions could be as following: supplying large-scale flow information (at low resolution from a global model) to a limited-area model (LAM) as initial and lateral boundary conditions will allow the LAM to develop meaningful fine-scale structures (high-resolution information) inside its domain. The research topic of the project was to investigate the deficiencies of the present coupling method, the Davies' relaxation scheme (boundary relaxation of the flow towards the large scale solution in a transition zone, Davies 1983), and to introduce a new one based on the spectral representation of the fields (see previous ALATNET reports).

In our trial to find the best way how to tune the spectral coefficients of the spectral coupling method it looks reasonable to perform experiments with the 1D model and apply the conclusions to the 3D limited area model afterwards.

1D Shallow-Water tests :

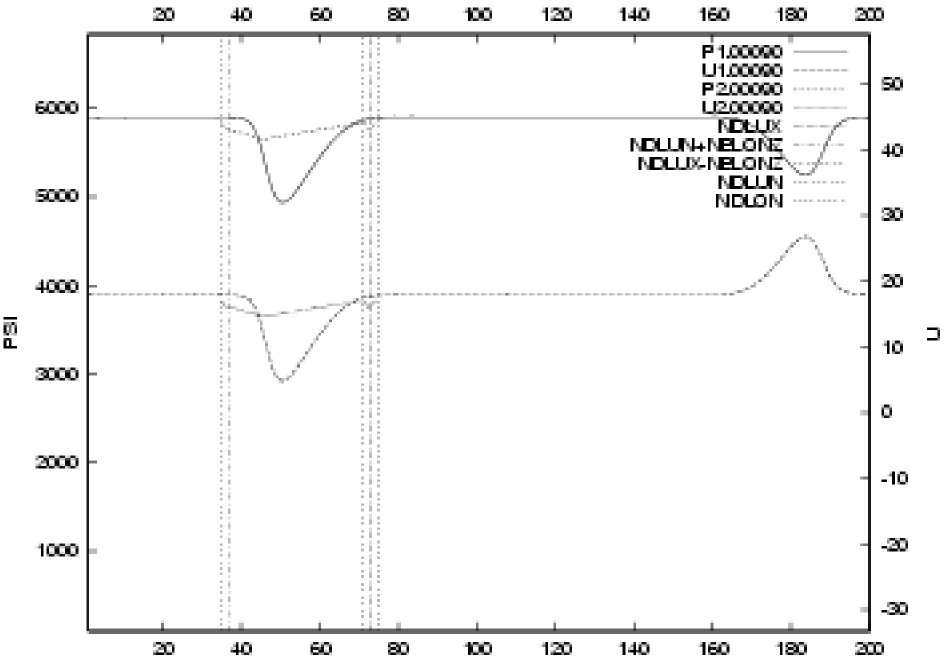
The sensitivity of the new method is studied using the 1D spectral shallow-water model developed by I. Gospodinov and P. Termonia, similar to the 3D model but simplified. The model fields are shallow-water velocity and shallow-water height, and it is running on two types of domains, a global and a limited-area ones. It is integrated with a two-time-level semi-implicit semi-Lagrangian scheme and a trajectory scheme proposed by I. Gospodinov with a second-order-accurate treatment of the nonlinear residual.

The calculation of the large-scale fields is generally done by using linear or quadratic gridpoint interpolations, but many tests were done before in order to find the optimum interpolation method. The relaxation takes place at the end of the gridpoint calculations, as in ALADIN. The first step concerning 1D tests was the introduction of the spectral coupling method in the shallow-water code, at the end of the routine which performs the calculation at the end of the time-step, where the fields are already stabilized. I tried the linear interpolation in time between the spectral coefficients of the large-scale fields. The spectral coupling is designed so that, for large scales, only long waves from ARPEGE are taken into account and, for small scales, short waves from ALADIN are considered with a smooth linear transition in between. The 1D shallow-water tests, coupling the global model with the LAM using the same initial conditions, consist in a depression of Gaussian shape which propagates from west to east with constant speed through the whole domain. This can be considered as the 1D version of the Christmas storm , December 1999, even if the propagation speed in the 1D model is higher.

Several experiments were performed, with the following setup :

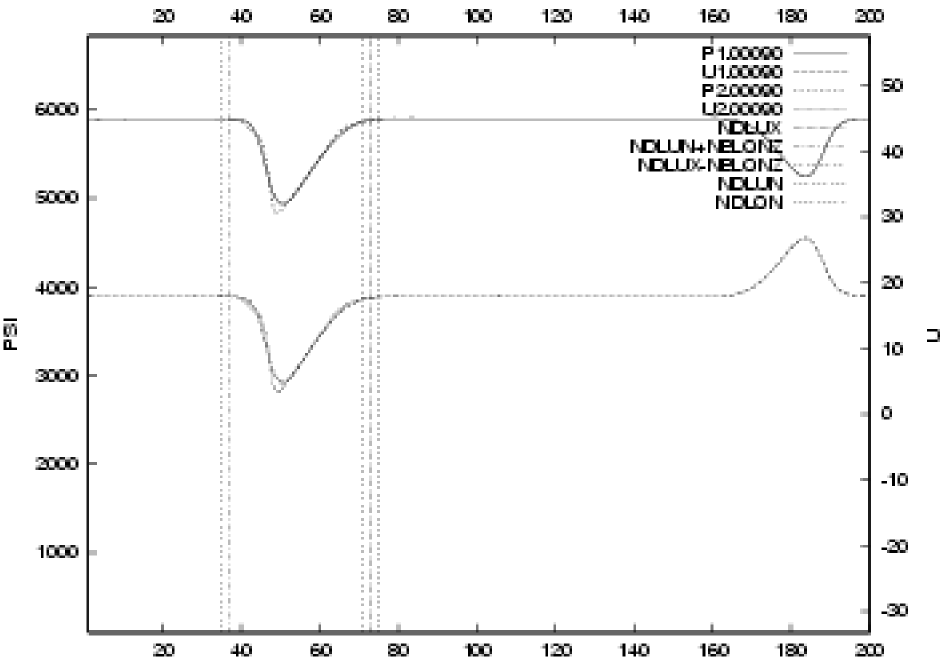
Global model : 200 gridpoints, Δx=50km, Δt=300s (length of the time step)
LAM : 200 gridpoints, 8 points E-zone, Δx=10km, Δt=300s
Time integration up to 36 h.

In Figures 1 to 6 the x-axis indicates the grid of the global model (200 points). The LAM is nested inside and the vertical lines represent the borders of the LAM's different zones (e.g. the extension zone is between the last two vertical lines). At the chosen forecast range, the depression should be completely inside the LAM domain. The upper curves show the geopotential, with the corresponding scale on the left y-axis, while the lower ones show the horizontal wind, with scaling on the right y-axis. The curves strictly inside the LAM borders represent the LAM forecast, while the other ones show that of the global model, which serves as a reference.



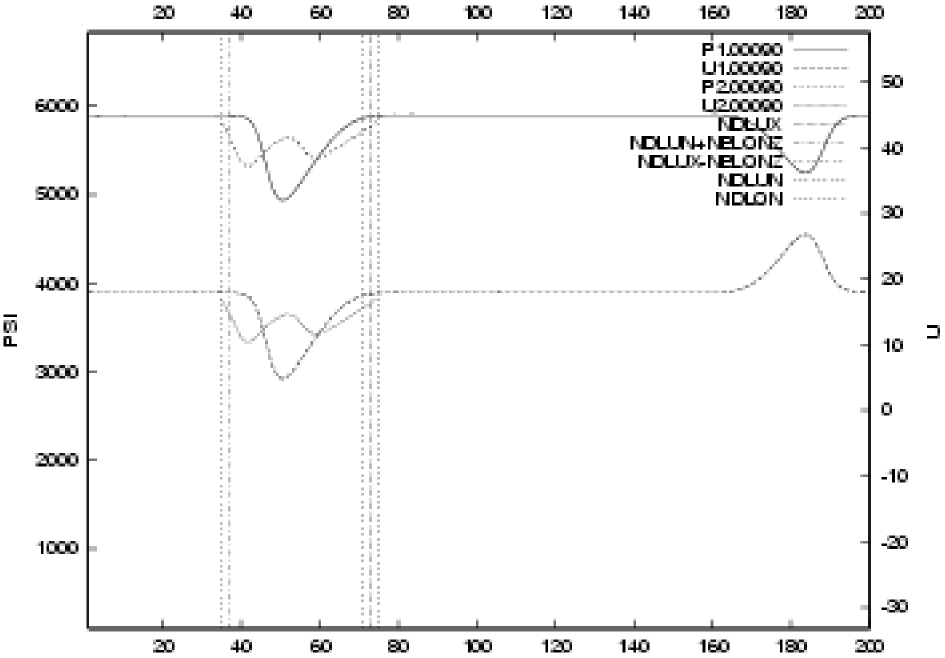
(A) <u>LAM forecast failure case</u> (Figure 1) - 3 h Davies relaxation

The cyclone is missing in the forecast.



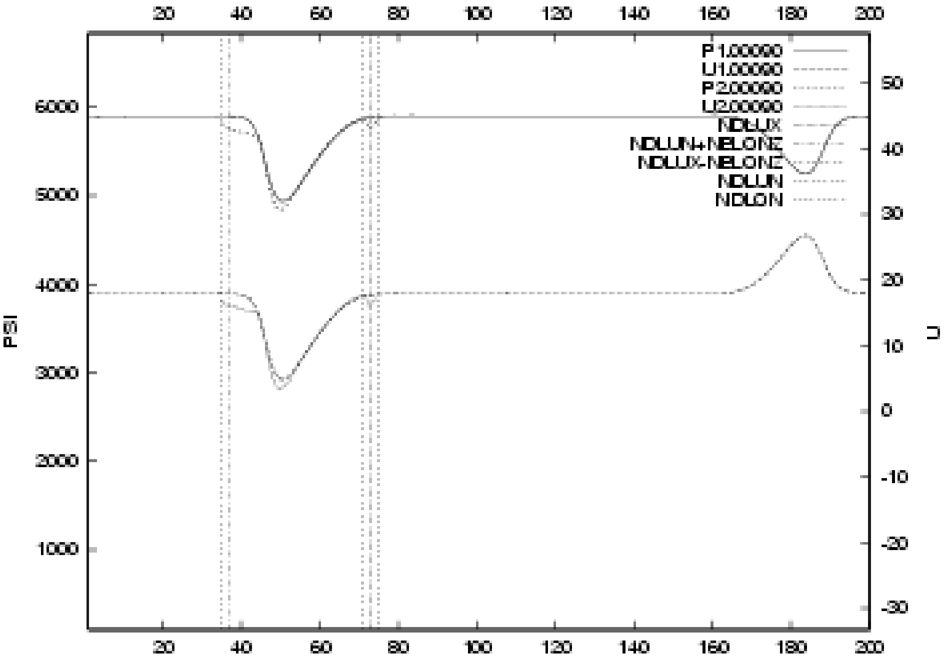
(B) <u>Reference case</u> (Figure 2) - 1 h Davies relaxation

By increasing the coupling frequency , the LAM is able to receive and keep the information from the large-scale model. The given LAM forecast is considered as the ideal one, but it is too expensive for operational use.



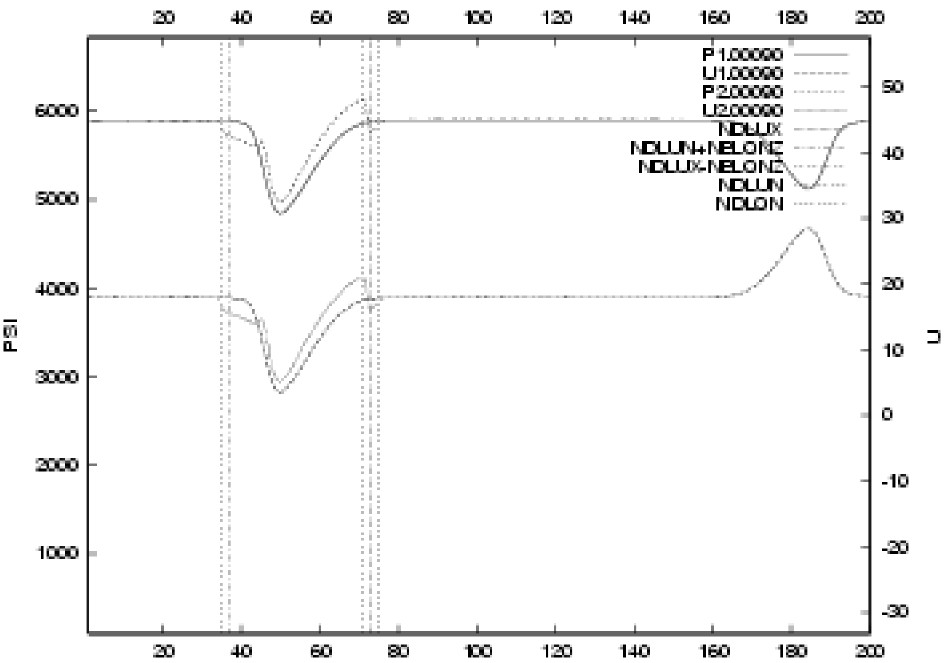
(C) Forcing, jumps, dipole case (Figure 3) -
3 h Davies relaxation combined with spectral coupling every time step

It gives too strong large-scale forcing. The cyclone oscillates inside the LAM domain, due to the external large-scale forcing. The LAM develops a dipole structure.



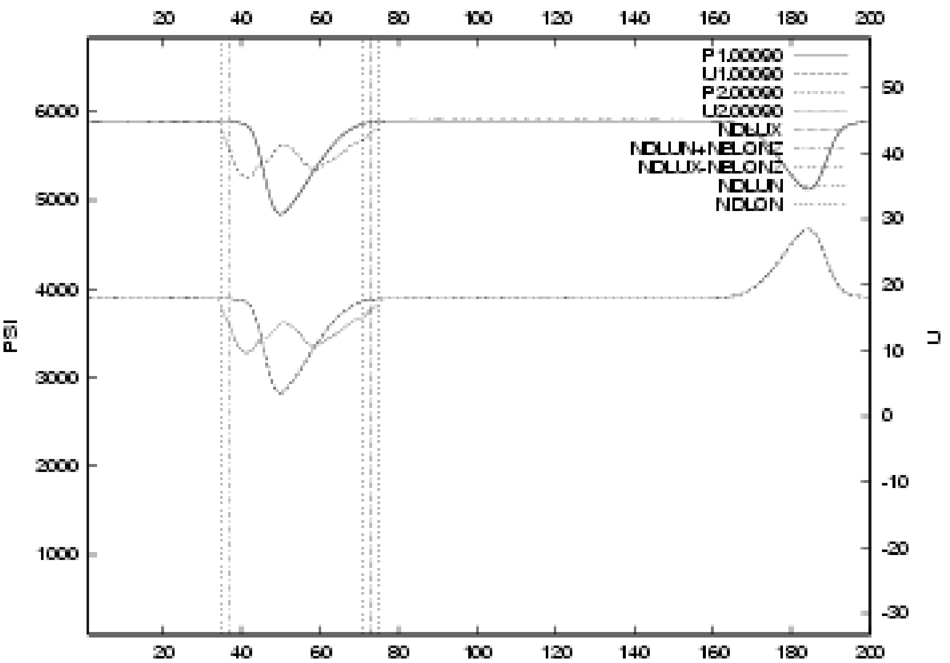
(D) Small jumps case (Figure 4) - 3 h Davies relaxation with 3 h spectral coupling

By decreasing the spectral frequency of coupling, the dipole structure is not present any more because of less forcing from large scales, which is a good sign. Still questionable is that the cyclone is not captured at the first spectral coupling time, but just at the second one when it suddenly appears inside the LAM domain.



(E) One time spectral coupling case (Figure 5) -
3 h Davies relaxation with spectral coupling at one time-step after 6 h

No dipole in the LAM solution, but the cyclone appears later because of the chosen spectral coupling time, and its lifetime is uncertain inside the LAM. We cannot be sure that the LAM keeps and resolves the problem correctly. If the spectral coupling is applied only once, the time has to be close to the real entering of the cyclone into the LAM domain.



(F) Time relaxation case (Figure 6) -
3 h Davies relaxation, spectral coupling every time-step with time relaxation

We observe the dipole structure again, and a strange evolution of the LAM solution as well. Introduction of the wavenumbers time-dependence proves that the idea to get large-scale information varying in time during the integration is far to be considered as a positive result.

Discussions

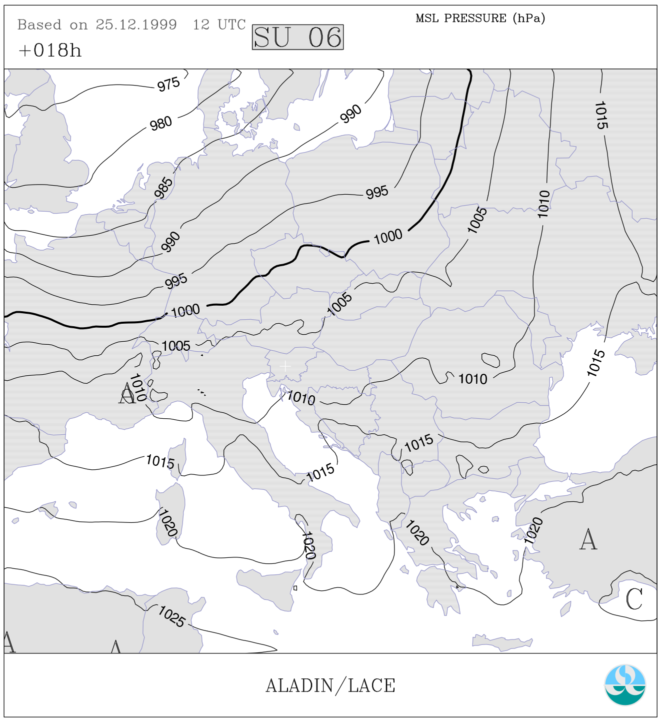
When introducing spectral coupling at every time-step, we are confronted to a dipole structure. The explanation can be found in the fact that, at the first coupling step, the LAM gets information from the linearly interpolated spectral coefficients between the two coupling files. This disturbs the dynamical evolution of the large-scale information inside the LAM during the integration time.

The forcing-dipole case raises the idea to introduce a spectral-coupling frequency, providing spectral features from large scales not at every time-step, but at a lower frequency . It can be tested together with the retuning of the relaxation coefficients of the Davies' method.

The 1D tests prove that the spectral coupling method succeeds to provide possibly missing large-scale spectral information, like it would be needed in the Christmas storm case, but the way to realize this should be tested further, in order to find a suitable way to keep and solve the information. We got the idea to provide the spectral information smoother into the LAM domain by tuning of the spectral α function shape and of the spectral parameters for relaxation.

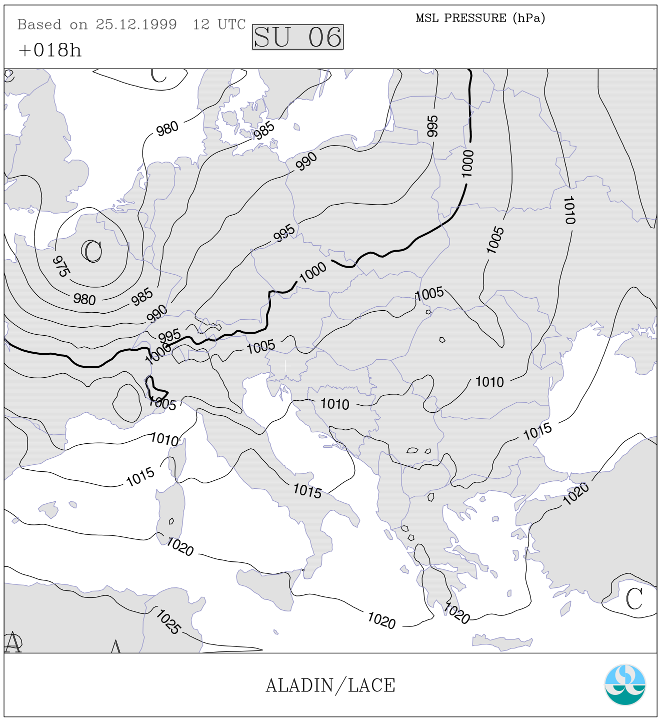
3D tests with ALADIN

Several tests with the ALADIN model were performed, with similar conditions as in the 1D shallow-water model. The results were very close to those of the 1D tests. As initial conditions we use the Christmas' storm case of 1999.



(G) Figure 7- <u>Davies relaxation failure case</u>- 6 h Davies relaxation coupling

The cyclone is missing



(H) Figure 8 - Spectral coupling -
6 h Davies relaxation coupling, spectral coupling every 3 time-steps

The cyclone is inside the domain.

Spectra of the vorticity were computed for elliptical wavenumbers (Figures 9 to 11), in order to identify the wavenumbers from the large-scale which represent the missing cyclone in the LAM :

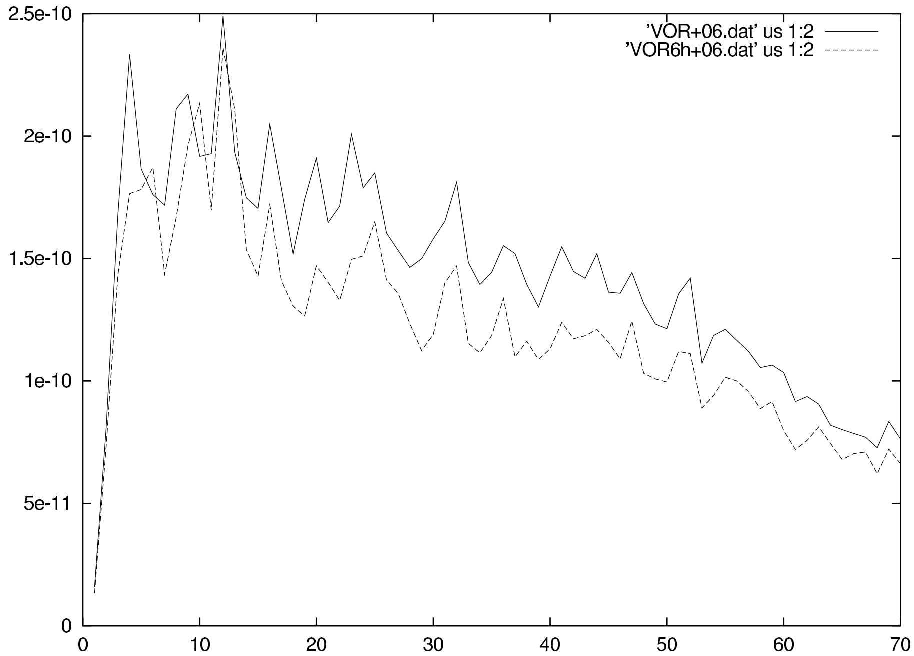


Figure 9 : comparison of the vorticity spectra of 1 h gridpoint coupling frequency, ideal case with cyclone inside (full line) with 6 h gridpoint coupling frequency, missing cyclone (dashed line) .

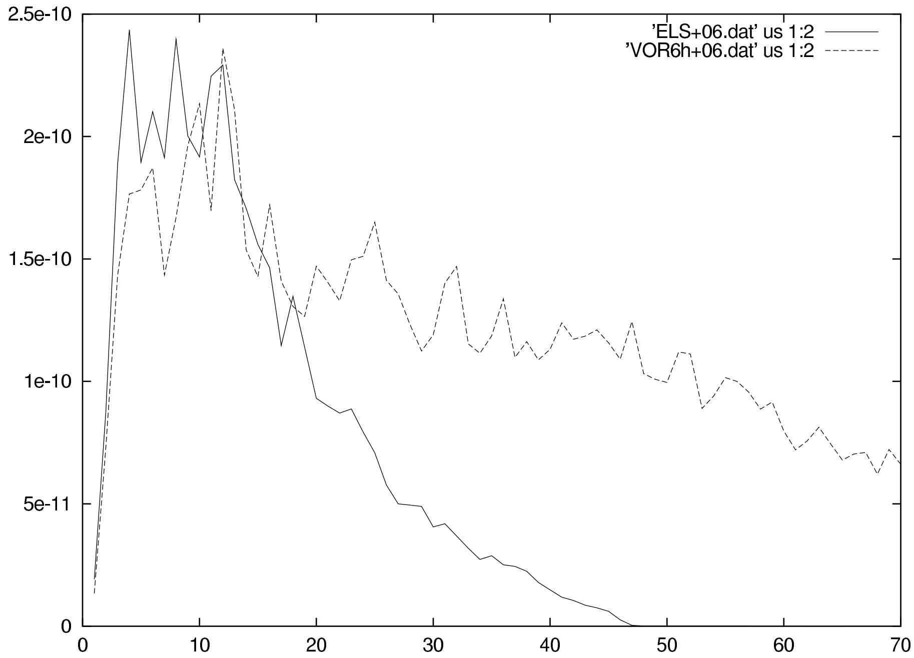


Figure 10 : comparison of the vorticity spectra from the coupling file at +6 h (full line) and 6 h gridpoint coupling frequency, missing cyclone (dashed line)

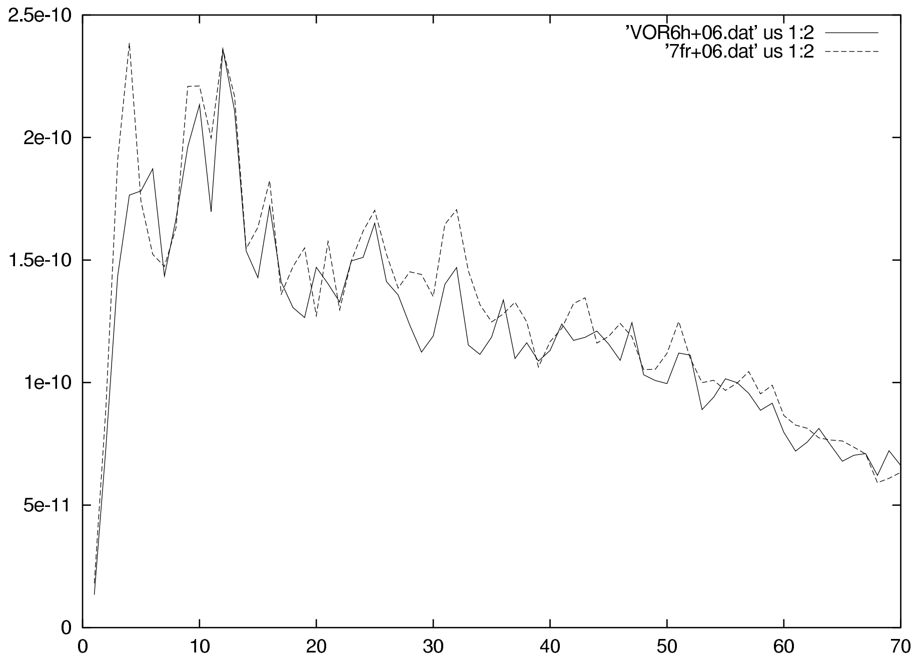


Figure 11 : comparison of the vorticity spectra with spectral coupling at 1 h frequency, cyclone is inside (dashed line) and 6 h gridpoint coupling frequency, missing cyclone (full line).

From these three figures it can easily be seen that the energy of the cyclone is carried only by the lowest wavenumbers . Future work :

- retuning of α function of gridpoint coupling together with tuning for spectral coupling
- tests with the 3D model for time relaxation
- tuning of spectral parameters for relaxation
- examination, with the 1D model, whether the large-scale information from spectral coupling might affect already present small-scale features inside the LAM domain.