Spectral coupling: implementation in the cycle 30 ARPEGE/ALADIN

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1.Presentation

A presentation with title: "Spectral coupling for high resolution limited area models" was prepared and took place in the conference room of the CNRM with the aim of introducing to the spectral coupling issues (mainly developed in the ALATNET framework).

2.Introduction

2.1.What is about?

The background is mainly described in ALADIN /ALATNET Newsletters [1] as well as in ALATNET Final Report [2].
In order to summarize, the main idea of "spectral coupling" was to improve the actual coupling scheme used to join the global model (ARPEGE) with the limited area one (ALADIN) in the terms of the lateral boundary conditions, but in spectral space. As known, ALADIN is a spectral limited area model with bi-Fourier representation, using information from Arpege (or lower resolution ALADIN) about the state of the atmosphere outside the integration area, at a certain interval of hours through coupling schemes. The received information is interpolated in order to obtain coupling fields necessary at each model's integration time step. The lateral boundary conditions are prescribed by means of the usual coupling scheme Davies relaxation (1976) and (1983) [3], which is performed in physical space. In this scheme prognostic variables are subjected to a forcing in the marginal zone that constrains them to relax towards the specified field. The relaxation is done at the end of time step, after gridpoint calculations by Radnoti (1995) [4]. The prescribed lateral boundary conditions have their own limitations coming either from numerical formulation as LBC are ill-possed mathematically or from temporal resolution of LBC. The aim of this approach is to configure the coupling scheme in order to minimaze the negative effects of the LBC on forecast and simulations.

2.2. Problems of the operational coupling scheme

The operational coupling scheme was proved to be inefficient in the case of fast propagating cyclones as in the 25-26th of December 1999 case, when the limited area model (ALADIN) had failed in forecasting the storms, although the global model Arpege was able to give a resonable forecast.
The problem of the LAM in that case for the first cyclone was that at the first coupling time the system was completely outside the domain, at the next coupling time being completely inside the domain. In Davies scheme the global model forces the LAM only at a „narrow" bend at the lateral boundaries of the LAM domain. The width of this zone is typically at the range of 100 km. As in the coupling zone the information was missing, the LAM was unable to pick it up correctly. All happened due to too long coupling interval by the operational version of ALADIN, due to interpolation of information between the two available coupling files and also to the fact that the coupling model passes information to the LAM only by its fields over the coupling zone at discrete times. The LAM can know about the entry of a system inside its domain only if it had any trace on these spatially and temporally reduced sub-fields, but the information in that case was missing, as consequence LAM failed in forecast.

2.3. Proposed solution

An alternative to overcome those forecast failures was to develop a method for treating the lateral boundaries by taking advantage of spectral model formulation of ALADIN. A spectral coupling scheme was built on the same analogy with the Davies relaxation scheme, but as an additional coupling step.
Spectral coupling method consists in blending of the large scale spectral state vector with the state vector of the coupled model in such a way that the blended state vector is equal to the large scale one for small wavenumbers and equal to the coupled one for large wavenumbers with a smooth transition in between.

The proposed procedure proves scale selection where the large scales are dominated by the spectra of the coupling model and the LAM dominates only the small scales poorly, or not at all resolved by the forcing model. In such a scheme scales resolved by the coupling model are forced to the LAM, no matter if the location of a system of the given scale is within the domain. Therefore the LAM surely captures any system resolved by the coupling model and not only at the time of passage through a narrow lateral zone. Spectral coupling cannot eliminate spurious inward propagation through the lateral boundaries. Without the damping by the standard Davies scheme all waves that exit on one side of the domain would freely enter on the opposite side. But by using simultaneous Davies scheme and spectral coupling the advantages of both coupling methods are combined.

Firstly the 3D spectral dynamic fields: vorticity, divergence, temperature and humidity and a 2D spectral field: surface pressure, were coupled, but with the option to add the NH fields afterwards. The practical implementation of this scheme was done in the last part of the time step after finishing the semi-implicit scheme, so there is a guaranty that the coupled fields are stabilized by the SI treatment.
An alpha function for coupling was introduced and the coupling equation could be written as:

$$Xc(m,n) = alpha(m,n)*X(m,n) +[1-alpha(m,n)]*X_{LS} (m,n)$$

X_{LS} (m,n) – large scale fields , Xc(m,n) – resulted coupled fields, X(m,n) – LAM fields , m,n- wavenumbers
Alpha becomes dependent by time by multiplying it with beta function:

$$\beta = \max\left[\left(\frac{STEP - NETLS1}{NETLS2 - NETLS1} - TSTARTSC\right)\frac{1}{1 - TSTARTSC},0\right]$$

The total wavenumber is **:**

SQRT((m/M)**2 + (n/N)**2) < K0, alpha(m,n)=1

SQRT((m/M)**2 + (n/N)**2) > K1, alpha(m,n)=0

and alpha is expressed by : alpha(m,n)=Real((K1-total wavenr.)/(K1-K0)), where K0, K1- namelist parameters based on models resolution, STEP- time step, NETLS1, NETLS2- first, second coupling time, TSTARTSC- fixed threshold for spectral relaxation

3. Technical documentation

The following routines contribute to main tasks:

1. Create a new dm-local large scale spectral buffer and reading it

2. Coupling of spectral variables.

Code modifications:

/arp/module/yemspcpl.F90 (new) : Module for spectral coupling

/arp/ald_inc/namelist/nemspcpl.h (new)

/ald/setup/suect0.F90: Setup routine for initialisation

/ald/setup/suesc2.F90 : Setup routine for initialise control of scan2

/ald/inidata/elswa3.F90: Transferring the spectral state variable to arrays

/ald/inidata/epak3wsp.F90 (new): Transferring spectral data variables to GT3SPBUF for coupling of spectral data

/ald/adiab/espchor.F90: Spectral space computations for ALADIN; horizontal diffusion and spectral coupling

1. Firstly we deal with the implementation of large-scale spectral buffer and its manipulations. For gridpoint coupling we had the former GT3BUF dm-local buffer keeping the large-scale values in packed mode. The tree looks like:

cnt3.F90 –>elsrw.F90

| at initial time

-->elswa3.F90 -- > epak3w.F90

cnt4.F90 ->elsrw.F90

| at swapping time

--> elswa3.F90 → epak3w.F90

→ epak3wsp.F90 (new)

calling sequences. This structure was kept as much as possible so that the control of spectral coupling to be similar to the gridpoint one (control of swapping times, interpolation weights, etc.). Moreover, the suspec.F90 routine returns dm-local spectral arrays (spectral size is NSPEC2), so there is another constraint to implement large-scale spectral buffer dm-locally. New epak3wsp.F90 routine was implemented similarly with epak3w.F90 (which transfers spectral data variables to GT3SPBUF for coupling of spectral data). As input, this routine would get the dm-local spectral arrays SPVOR, SPDIV, SPT, SPQ, SPSP, +SPSPD, SPSVD for the non-hydrostatic model. Control of the 2 or 3 (quadratic coupling) time slots would be the same in the code, but epak3wsp.F90 has not to do compacting (what is skipping of central zone in epak3w.F90).

The summary of this point include the following tasks:

- introduction of a main control switch of spectral coupling (LESPCPL)

- initialisation of new large scale buffer GT3SPBUF together with its characteristics

- writing the new routine epak3wsp.F90 for transferring the spectral data to large scale buffer; filling new GT3SPBUF buffer

- calling epak3wsp.F90 from elswa3.F90

2.Spectral coupling itself

Location of the logical switch is just before the horizontal diffusion (espchor.F90). In this point the model spectral state variable is dm-global (PSPVORG, PSPDIVG, etc), so after reading the dm-local large scale spectral arrays the etrmtos.F90 transposition routine has to be called on the analogy of espcm.F90, with the SPVOR, SPDIV, etc structure which is transposed to the ZSPVORG, ZSPVORG, etc. global structure. On the other hand one has to identify the actual wavenumber pair from the spectral array index (see IN=NVALUE (JSP+IOFF) in espchor.F90, etc). Setup of alpha function for spectral coupling is done with the help of K0 and K1 (namelist parameters), TSTARTSC is the threshold parameter for relaxation, BETAEXP is the exponent of the beta function for relaxation in time, NEFRSPCPL being the frequency of the spectral coupling. The coupling of the spectral variables is performed at the end of the time step in espchor.F90 .

Those routines can be found on tora:/u/gp/mrpe/mrpe719/pack/src/local, they have not been written in Clearcase yet.

References

[1] Radu R. ALADIN /ALATNET Newsletters no. 22-28

[2] Radu R. “Extensive study of the coupling problem for a high resolution limited area model”, ALATNET Final Report, November 2003

[3] H. Davies, 1983: "Limitations of some common lateral boundary schemesused in regional NWP models", Mon.Wea.Review., 111, 1002-1012

[4] Radnoti, G. “Comments on ‘’A spectral limited-area formulation with time-dependent boundary conditions applied to the shallow-water equations””, Mon. Wea. Review.,123, 3122.