Sensitivity of short simulations to the various parameters in the new CRCM spectral nudging

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1) Introduction and experimental design

The basic idea behind the use of Regional Climate Models (RCM) to downscale outputs of Global Circulation Models (GCM) consists in adding high-resolution details on the GCM large-scale flow without altering long waves. However, for particular circulation patterns, the Davies (1976) approach used in most RCMs to specify their lateral boundaries over a given sponge zone is insufficient to insure the coherence between the large-scale circulations of the driving and driven models. To correct this problem in the Canadian RCM (CRCM, Caya and Laprise, 1999), a spectral nudging (Biner *et al*., 2000) of the large-scale wind was applied over the whole model domain in addition to the Davies' specifications of the lateral boundaries. The filter used by Biner *et al*. (2000) to select the large-scale part of the circulation was quite crude and cannot accurately select the wanted scale. However, the proof of concept was made and their spectral nudging prevented the CRCM simulation from drifting from its driving data. A new version of the spectral nudging in the CRCM was developed using a more sophisticated spectral filter based upon cosine functions (Denis *et al*., 2001). The experiment reported in this paper aims at defining the adjustable parameters of the CRCM spectral nudging in order to minimize the strength of the forcing while keeping the large-scale circulation of the nested model coherent with its counterpart from the driving data. The adjustable parameters in the new version of the CRCM spectral nudging are: the wavenumber of the shortest wave that is included in the nudging procedure, the intensity of the nudging and the vertical profile of the nudging. The spectral nudging is only applied to the top most levels of the model with an increasing value as we go upward in altitude. In this short note, only the number of waves required in the nudging and its intensity at the top level is investigated.

Simulations were performed on a 96*96 points polar-stereographic grid covering the continental US. The distance between gridpoints is 60 km in the horizontal using a 900 s timestep and there are 15 vertical levels up to about 20 km. Simulations are 15-day long initialised on May 15th 1988 at 00 GMT. Initial and boundary conditions are taken from 2.5° NCEP analyses. The second half of May was selected because of a large-scale closed low-pressure system that is totally missed by the CRCM when the regular Davies nesting is used. This results in RMS difference between CRCM and NCEP 250 hPa geopotential that remains large for 4 days. The spectral nudging keeps the CRCM large-scale flow close to its driving data.

2) Sensitivity to the shortest wave included in the nudging

Different experiments are made to establish the shortest wave that must be nudged to keep the CRCM large-scale circulation similar to the driving one. In order to keep the CRCM ability in developing the high-resolution details of the flow, the nudging must be limited to long waves.

In order to assess the shortest wave needed, the difference between the CRCM and NCEP 250 hPa kinetic energy is computed for a spectral nudging using an increasing number of waves starting with the fundamental. Figure 1 shows that nudging only wave number 1 has a very weak influence on the RMS difference. The insertion of waves 2, 3, 4 and 5 in the nudging decreases the RMS difference and peaks disappear with the nudging of wave 4. There is no additional reduction of the RMS difference after wave 5 is included. Therefore it seems that nudging the four longest waves (from 1450 km to 5750 km) are needed to anchor the CRCM large-scale circulation to its driving data.

Supplemental experiments were made and the results show that nudging smaller waves doesn't improve the simulation and have negative effects by reducing the variance of smaller waves simulated by the CRCM.

3) Sensitivity to the intensity of the nudging

The intensity of the forcing is not uniform in the vertical keeping the model as free as possible in the low levels. Therefore, the spectral nudging is null from the surface to a given level (adjustable) and then, increases with altitude to reach its maximum value (adjustable) at the top of the model. The sensitivity of the model to this maximum value is investigated.

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Experiments are made with a maximum value of 1, 0.5, 0.25, 0.2, 0.15 and 0.1 (where for example, 0.25 is the weight of the driving data used in the computation of the CRCM long waves at the topmost level). The same diagnostics are presented for these new simulations. Figure 2 shows that an intensity of 0.1 seems sufficient to reduce the RMS difference to an acceptable value but inspection of the simulated fields (Figure 3) made evidence for using a value of 0.2. Various simulations were then performed to select the level from which the nudging is applied and results showed that the model is almost insensitive to this parameter when varying from 500 hPa to 900 hPa.

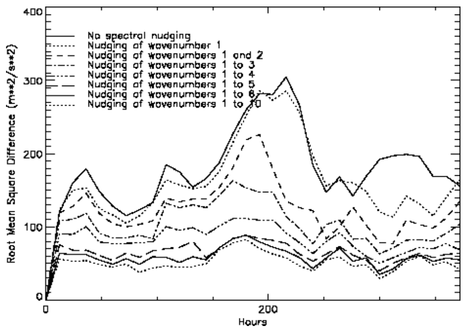

Figure 1. Time series of domain averaged RMS difference between CRCM and NCEP 250 hPa kinetic energy for various waves nudged.

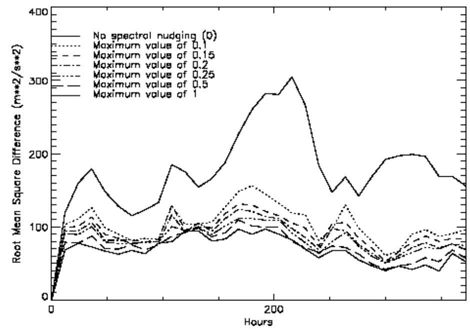

Figure 2. Same as figure 1 but for various maximum values of the spectral nudging strength.

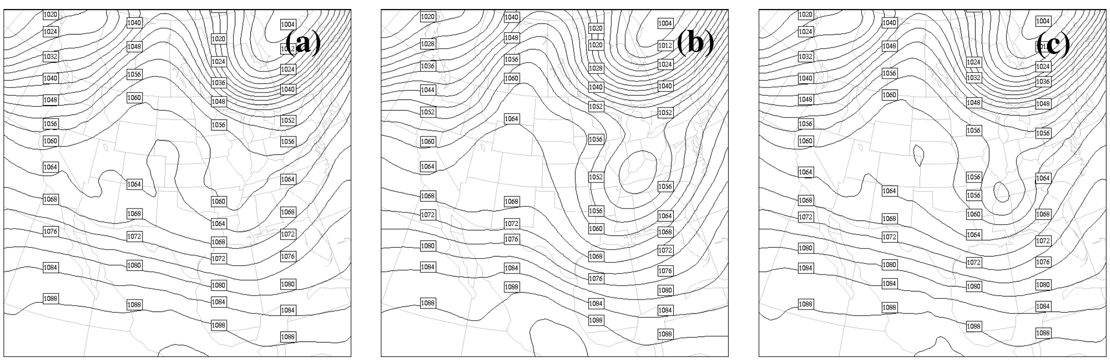

Figure 3. 250 hPa geopotential height on 24 May at 12 GMT for (b) the NCEP analysis and for the CRCM with (a) 0.1 or (c) 0.2 as maximum value for the spectral nudging.

4) Conclusion

A set of simulations was generated to select the wave that have to be retained, the maximum intensity and its vertical profile in the new CRCM spectral nudging. From these simulations, it has been found that wave 1 to 4 need to be included in the nudging with a weak maximum value of 0.2 applied at the top level of the model. The model appears to be quite insensitive to the location of the lowest level to be nudged when chosen between 500 hPa and 900 hPa. However, these tests were performed over a single grid, for short simulations and for a given set of objective analyses. More thorough experiments are needed to infer the complete behaviour of the new spectral nudging scheme.

Moreover, it should be kept in mind that the spectral nudging is not physical and should be kept to much weaker value than what is present in the dynamic and the physic of the model. Results from this study are in this direction but a comparison of the amplitude of the various forcings is required.

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