Geographical Distribution of Internal Variability in Regional Climate Downscaling

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1. Introduction

Regional Climate Models (RCMs), are commonly used to overcome Global Climate Models (GCMs) poor resolution by adding fine-scale details upon the GCMs large-scale flow. Due to nonlinearities in the model physics and dynamics, RCMs can produce different time evolutions of simulated fields if a small perturbation affects the initial conditions (IC). This sensitivity, usually called internal variability, is partially controlled by the lateral boundary forcing, and hence size and geographical location of the integration domain play an important role. Internal variability of RCMs is in general smaller than that of GCMs. It is important to evaluate the internal variability of the RCMs, because it can mask physically forced signals and hence disturb the assessment of climate sensitivity to forcings.

2. Methodology

The model used in the present study is the Canadian RCM (CRCM).The CRCM is a limited-area model based on the fully compressible Euler equations solved by a semi-implicit and semi-Lagrangian numerical scheme. The model uses the physical parameterization package of the second generation CGCM with Bechtold-Kain-Fritsch deep and shallow convective parameterization. The computational points are fixed on a three-dimensional staggered grid projected onto polar-stereographic coordinates in the horizontal and Gal-Chen terrain-following levels in the vertical (for a detailed description of the model, see Caya and Laprise 1999).

The domain contains 121×121 grid points located over eastern North America and part of the Atlantic ocean at 45-km resolution. In the vertical, 18 Gal-Chen levels are distributed from the ground to the model's lid at 30 km. The integration time step is 15 minutes and the model is driven by 6 hours NCEP reanalyses.

An ensemble of 20 simulations began between May 1st and 20th,1993 at 00 UTC and ending on September 1st, 1993 at 00UTC is used in this study. All the runs overlap in June, July and August of 1993 and have a spin up period varying from 11 to 30 days. The integrations share exactly the same lateral boundary conditions (LBC) and have a delay of 24 hours between the beginning of one run and the beginning of the next.

The internal variability was estimated by computing the ensemble inter-member standard deviation (spread) as:

$$\sigma_{en}(x,y,t) = \sqrt{\frac{1}{M}\sum_{m=1}^{M}\left(X_m(x,y,t) - \langle X\rangle(x,y,t)\right)^2} \qquad (1)$$

where M is the number of ensemble members and $X_m(x,y,t)$ refers to the value of the variable X on grid point (x,y) at time t for the member m of the ensemble. The term $\langle X\rangle(x,y,t)$ is the ensemble mean defined as

$$\langle X\rangle(x,y,t) = \frac{1}{M}\sum_{m=1}^{M} X_m(x,y,t). \qquad (2)$$

In addition, the time average of σ_{en}^2 gives an estimation of average spread for the entire season and its geographical distribution:

$$\sigma\ (x,y) = \sqrt{\frac{1}{NT}\sum_{t=1}^{NT}\sigma_{en}^2(x,y,t)}, \qquad (3)$$

where NT refers to time step number.

3. Results and analyses

Figure 1 shows the time evolution of inter-member standard deviation (averaged on the entire domain) for the precipitation and geopotential fields. It is interesting to note the pulsating behavior of internal variability for both precipitation and geopotential and that the most important maxima for the both fields are recorded at the middle and ending of the season. An analysis of the synoptic situation at the time of these maxima shows that heavy precipitation in the south of the US induced not only an important divergence between the precipitation ensemble members, but also a divergence among the geopotential ensemble simulations which continues to develop following the general circulation and reaches its maximum toward the northeast of the domain. This perturbation pattern is repeated several times during the three months (mostly concentrated in July) and leaves its trace in the seasonal average (Fig.2). Average precipitation spread maximum (14 mm/day is located in the south of the US where it was recorded a large quantity of precipitation (Fig.2a), while the average geopotential spread maximum is located at the northeast of the domain (Fig.2b).

4. Discussion

The results show that the CRCM's internal variability, estimated as standard deviation between 20 ensemble simulations differing slightly only in the IC, depends strongly on synoptic events. The dependence is clearly observed in the pulsating behavior of the time evolution of the inter-member spread. These variations have a preferential region, depending on the variable. We showed that in convective areas (e.g., south of the US), large quantities of precipitation induce important differences between the simulations. Also, we noticed that the geopotential spread is maximized to the northeast of the domain, region abundant in extra-tropical cyclones. Evaluation of time evolution of synoptic patterns suggests that the maximum in precipitation and geopotential are linked: the former being the trigger of a perturbation that develops in cyclonic circulations and attains the maximal spread before leaving the domain (not shown).

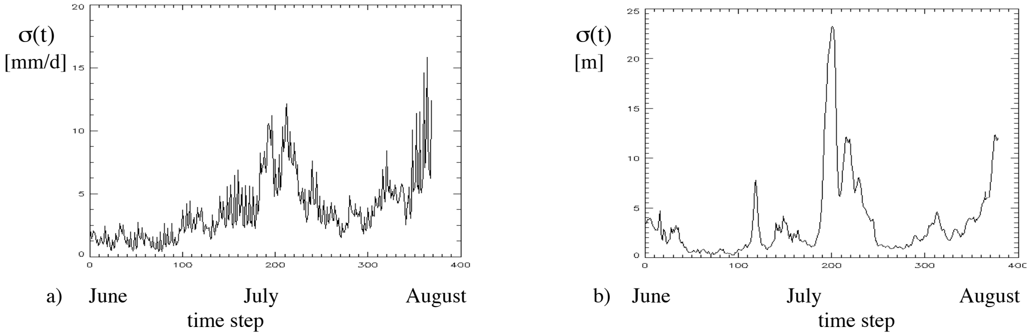

Figure1 : Time evolution of inter-member standard deviation for the precipitation a) and for the 850-hPa geopotential b).

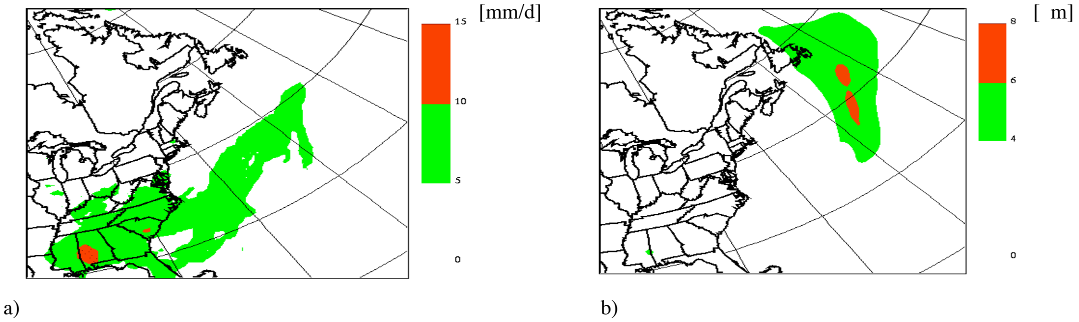

Figure 2 : Square root of 3-month time average of inter-member variance for the precipitation a) and for the 850-hPa geopotential b).

References :

Caya, D. and R. Laprise, 1999; Mon. Wea. Rev., 127, 341-362.