RCM's internal variability as function of domain size.

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Caya and Biner (2004) studied the Canadian RCM's (CRCM; Caya and Laprise, 1999) internal variability over an annual cycle using a small ensemble of three simulations. The CRCM domain for these simulations covers eastern North America (Fig. 1). The perturbations for each simulation in the ensemble were introduced by using different initial conditions for the atmosphere and/or the surface. The atmospheric fields used to drive the CRCM at the lateral boundary domain were taken from a GCM simulation. Annual time series of root-mean-square difference (RMSD) for various fields were chosen to quantify the CRCM internal variability. Fig. 2a presents a typical result where high values of spatial root-mean-square differences (RMSD) for the mean-sea-level pressure (mslp) are found in summer season (associated with high internal variability) and low values during the rest of the year. This means that CRCM simulations started with different initial conditions generate very similar evolution of the atmospheric fields during fall, winter and spring, but to different states during summer. A possible explanation for the summer high internal variability can be the strong summer convective activity compared to winter where the low RMSD could be associated with the less stochastic atmospheric activity. The strong winter jet stream also enhances advection through the RCM lateral boundaries and could result in a greater control on the simulations by the lateral boundary conditions (LBC) from the driving data. The opposite situation appears in summer when weaker atmospheric circulation reduces the LBC control and increases the internal variability.

Christensen et al. (2001) have shown that RCM's internal variability depends on the integration area (size and location). The present investigation aims at verifying this by making pairs of simulations with different initial conditions for various driving fields and domain sizes.

The first experiment (E1) consists in generating a pair of simulations using the same domain and driving data as Caya and Biner (2004) but with the latest version of CRCM. It can be seen by comparing Fig. 2a and 2b that the behaviour are the same in the two versions of the model. The experiment is then repeated (to generate E2) but this time with the CRCM driven by a different simulation of the Canadian GCM and over a two-year period. Fig. 2c shows a similar pattern in the RMSD for the second year but with a weaker annual cycle for the first year. A very strong peak is present at the beginning of the second year. This peak is associated with a very particular circulation making it almost unpredictable. We suspect the surface initial conditions of being responsible for the different behaviour of the first year; this aspect is currently under study. In a third experiment (E3), the driving data were taken from the NCEP reanalysis instead of a GCM simulation. Again, the analysis is performed over two years and the results appearing in Fig. 2d are very similar to what is obtained in Fig. 2c.

The next step is to investigate the influence of the domain size on the evolution of the CRCM internal variability. A fourth experiment (E4) similar to E3 was generated over a domain size nearly 2 times larger covering most of North America (Fig. 3). Large values in the RMSD time series indicate high internal variability all year long with very high values in winter season (Fig. 2e). This strong influence of the domain size might be explained by the longer residence times of the synoptic systems in the E4 domain compared to E3. These longer residence times allow for larger differences to grow in the evolution of each simulation. The generally more intense weather systems in winter added to the long residence time result in the very high RMSD values of Fig. 2e.

The results of experiment E4 suggest that as the CRCM domain gets larger, important internal variability can develop and large mismatches can also appear between the CRCM and the driving fields at the outflow boundary. An fundamental assumption in using RCM states that the large-scale atmospheric circulation in the driving data and in the RCM should remain the same at all time. A closer look at the two simulations revealed that associated to these large RMSD are differences in the large-scale atmospheric circulation. Therefore, a last experiment (E5), identical to E4 is performed using a large-scale spectral nudging inspired from von Storch et al. (2000) to force the large-scale RCM fields toward those of the driving data. RMSD time series for E5 (Fig. 2f) showed a reduction compared to E4 but kept the higher values in winter.

These results suggest that RCM’s internal variability is quite sensitive (over the first year) to the driving data used and to the size of the domain. Further investigation will be required to explain the apparent different behaviour for each year of the simulation when the CRCM is driven by the NCEP reanalysis or the outputs from the second GCM simulation.

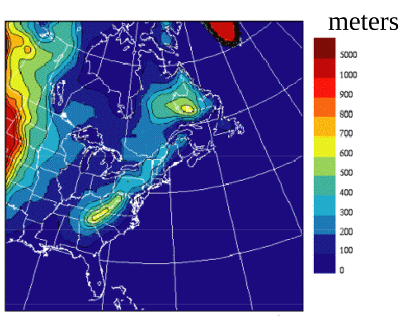

Figure 1. The CRCM domain used for Caya and Biner (2004), E1, E2 and E3. The domain contains 121X121 grid points at 45 km. RMSD time series are computed in the inner 101X101 grid points. Topographic height is shown as different shades of gray.

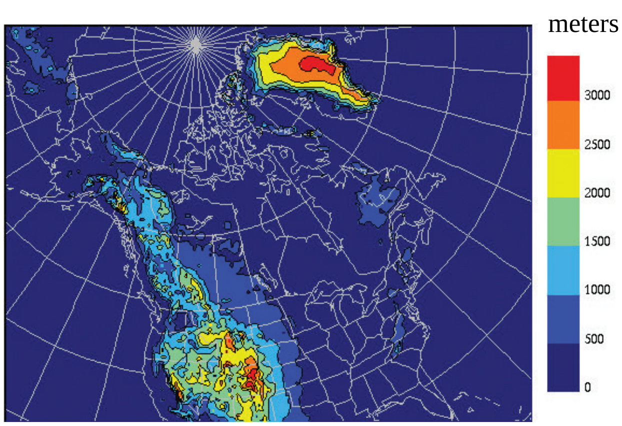

Figure 3. The CRCM domain used for E4 and E5. The domain contains 193X145 grid points at 45 km resolution. RMSD time series are computed over the inner 173X125 grid points. Topographic height is shown as different shades of gray.

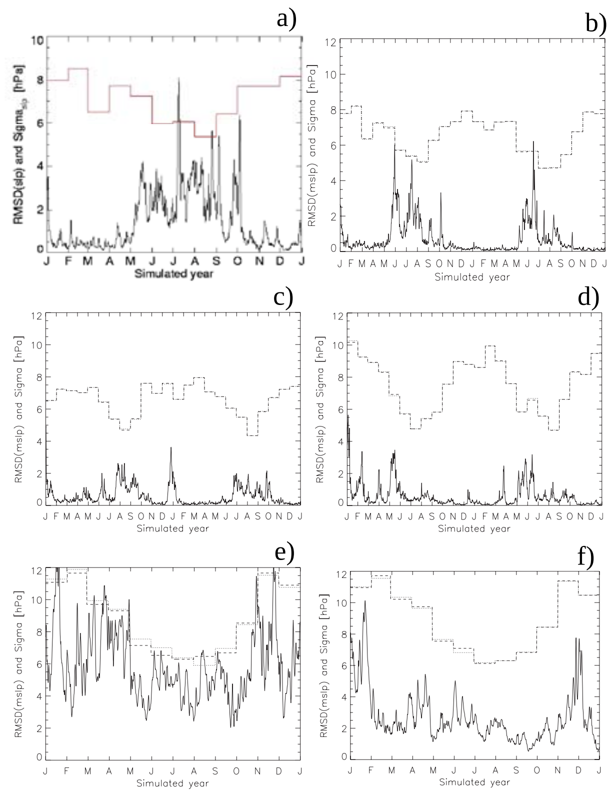

Figure 2. RMSD time series of MSLP for a) Caya and Biner (2004), b) E1, c) E2, d) E3, e) E4 and f) E5. The dotted lines show the monthly spatial standard deviation of each simulation, which are representative of the climatological value of the variability.

References

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