Regional Climate Model sensitivity to domain size

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1 Introduction

Regional Climate Models are increasingly used to add small-scale features that are not present in their lateral boundary conditions (LBCs). It is well known that the computational domain of RCMs must be large enough to allow the development of small scales (Jones et al., 1995). On the other hand, integrations on very large domains have shown important departures from the driving data, unless large-scale nudging is applied (e.g., Castro and Pielke, 2005).

Here the effects related to the domain size will be examined using the "Big-Brother" approach developed by Denis et al. (2002a).

2 Experimental framework

The Canadian Regional Climate Model (CRCM; Caya and Laprise, 1999) is first driven by NCEP reanalyses to simulate a winter-month, the Big Brother (BB) as illustrated on Fig. 1. A low-pass filter based on discrete cosine transform (DCT; Denis et al., 2002b) that retains all wavelengths longer than 2160 km and removes those smaller than 1080 km (with a gradual transition in between) is then applied on this dataset to emulate coarse-resolution LBC that are usually taken from GCMs or reanalyses. These data are then used to drive five simulations called the "Little Brothers" (LB1 to LB5 on Fig. 1) with different grid sizes but centred on the same location. The DCT decomposition is applied on the five LB simulations to separate the large (nested) and small (added) scales. Climate diagnostics of the various LB are compared to those of the BB over the verification area noted VA on Fig. 1.

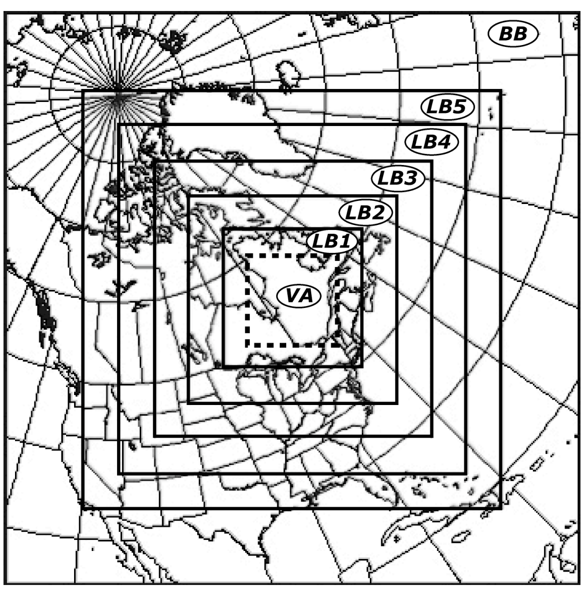

Fig. 1 Domain sizes used for simulations LB1 to LB5, and BB, the reference. Statistics are computed on the VA window.

3 Results

The temporal correlation, variance ratio and normalized mean-square difference are summarized on a Taylor diagram (Taylor, 2001). Fig. 2a displays the results for the large-scale component of the 850-hPa geopotential height. All LB simulations have excellent variance ratios, with a slight underestimation for the largest domains LB4 and LB5. The temporal correlation of the large scales improves slightly when the LB domain is reduced from 144x144 to 72x72, but little when further reduced to 48x48.

A reduction of the mean-square error is also noted for fields such as temperature (not shown) when the domain is made smaller. More turbulent fields such as vorticity or relative humidity (not shown) also exhibit similar behaviours at large scales; a difference with fields such as geopotential and temperature, however, is a small loss of correlation (4%) when passing from LB2 to the smallest domain size LB1. All these comments on large scales also apply to the fields at 700 hPa.

The statistics for the small-scale component of the 850-hPa geopotential height are shown on Fig. 2b. There is a continuous gain of correlation in shrinking domain size from LB5 to LB2. When compared to Fig. 2a, correlation improvements suggest that consistence of small-scale features is in some way helped by the increased correlation in the large-scale flow.

Fine-scale statistics are affected differently when reducing the domain size beyond 96x96. Normalized mean-square difference stops to reduce at a grid size of 72x72, and shows a

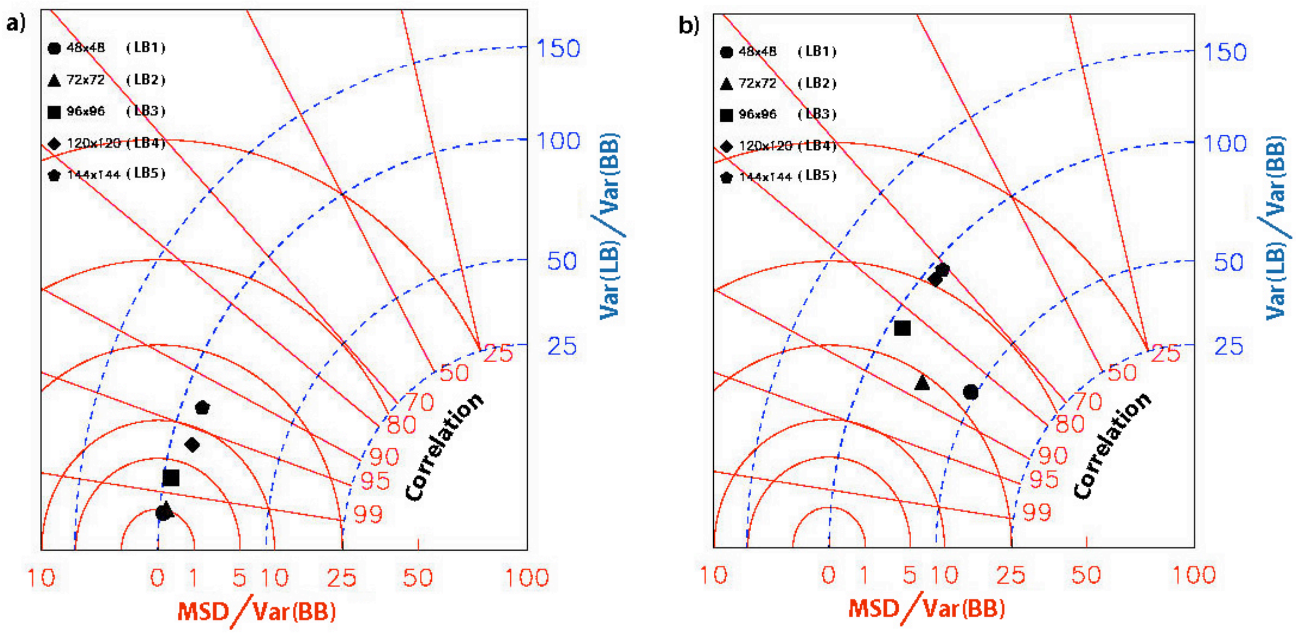

Fig. 2 Taylor diagrams for the transient component of 850-hPa geopotential height, showing the mean-square difference, temporal correlation and variance ratio for (a) large scales (driven) and (b) small scales (added). The three quantities are normalized by and compared with the Big Brother values.

subtle increase for the smallest domain. It is worth noting that an important underestimation of variance occurs when the domain size is reduced beyond 96x96. Other fields such as relative humidity and vorticity (not shown) exhibit similar behaviours when the domain is reduced. Temperature (not shown) exhibits large variance under-estimation for the smallest domain LB1 (66.0%) only, while the four other simulations stay between 82% and 91% of the BB's variance. At 700 hPa, the analysis (not shown) reveals an even larger variance underestimation for the three smallest domains. Since winds are stronger at this level, it suggests that small-scale features are advected out of the domain area before they have time to fully develop.

4 Conclusions

Driven (large) and added (small) scales in simulations of an RCM using different domain sizes were studied. Large scales show some sensitivity to the domain size, with best results for smaller domains, owing to the better control exerted by LBC. Some underestimation of the large-scale variance was noted for the two larger domains. This fact seems to be consistent with large-scale kinetic energy underestimation observed by Castro and Pielke (2005).

Two effects of domain-size reduction were observed on the small-scale component of fields. The temporal correlation improves when reducing domain sizes from LB5 to LB2. This improvement in small scales appears to be linked to the better control of the large scales in smaller domains. But temporal variance is largely underestimated when the domain becomes smaller than 96x96, particularly at higher levels. This loss can be partly explained by considering the period that small scales need to develop sufficiently and the time scale of the ventilation through the domain by the large-scale flow. This phenomenon is most clearly visible on variance-ratio maps (not shown) where low values are in general distributed along the inflow boundary.

5 References

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