The impact of lateral boundary data errors on the simulated climate of a nested Regional Climate Model

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1. Introduction

The primary tools to study anticipated climate changes are the coupled global and nested regional climate models. General Circulation Models (GCMs) provide a global-scale view of projected climate at typically coarse horizontal resolution and hence cannot be used directly by most impacts studies that require grid scales of 10 to 100 km or finer. Information at regional scales can be simulated with limited-area, high-resolution Regional Climate Models (RCMs) driven by the large-scale information from GCMs. But the GCM–simulated data are not perfect; they contain errors due to model imperfections. In this study, we investigate the response of a Regional Climate Model (RCM) to errors in the atmospheric data used as lateral boundary conditions (LBC) using a perfect-model framework nick-named the "Big-Brother Experiment" (BBE).

2. The "Big-Brother Experiment"

The BBE has been designed by Denis et al. (2002b) and it permits to evaluate the errors due to the nesting process excluding other model errors. First, a high-resolution (45 km) RCM simulation is made over a large domain. This simulation, called the Perfect Big Brother (PBB), is driven by reanalysis from the National Centres for Environmental Prediction (NCEP); it serves as reference virtual-reality climate to which other RCM runs will be compared. Errors of adjustable magnitude are introduced by performing RCM simulations with increasingly larger domains at lower horizontal resolution (90 km); such simulations are called the Imperfect Big-Brother (IBB) simulations and they are used, after removing small scales in order to achieve low-resolution typical of today's General Circulation Models (GCM), as LBCs for smaller domain high-resolution RCM runs. These small-domain high-resolution simulations are called Little Brother (LB) simulations. The climate statistics of the LB are compared to those of the PBB in order to estimate the errors resulting solely from nesting with imperfect LBCs, while the difference between the climate statistics of the IBB and those of PBB simulations mimic errors of the nesting model.

The simulations are performed over the East Coast of North America for five consecutive February months (from 1990 to 1994) using the Canadian RCM. To facilitate calculations, display and intercomparison between the fields, the simulations are interpolated onto a common 45-km resolution 100 x 100 polarstereographic grid, excluding the sponge zone, for the statistical analysis. A spatial decomposition is applied to separate fields into their large-scale and small-scale components using a 2-D discrete cosine transform filtering technique, suitable for non-periodic data (Denis et al. 2002a). A temporal decomposition of fields is also performed to separate stationary and transient components, and the Taylor diagrams (Denis et al. 2003, Taylor 2001) are used to analyse the errors in the IBB and LB fields, relative to the PBB reference, for each of the four components of the fields.

3. Results and discussion

The results for the precipitation rate field are summarized in figure 1.

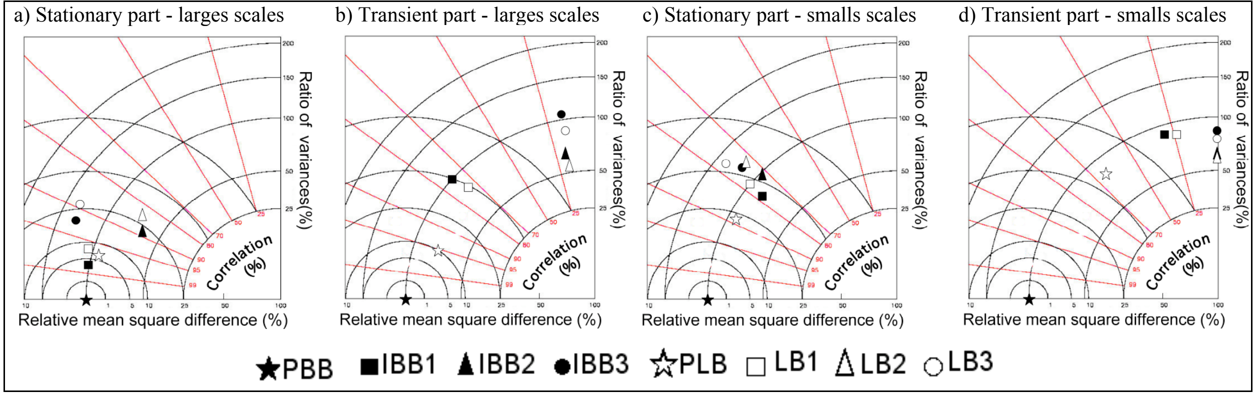
a) Stationary part - larges scales
b) Transient part - larges scales
c) Stationary part - smalls scales
d) Transient part - smalls scales

Fig. 1. Summary Taylor diagrams showing the errors induced in the IBB and LB precipitation rate fields, for the stationary and transient parts of the large- and small-scale components of the field.

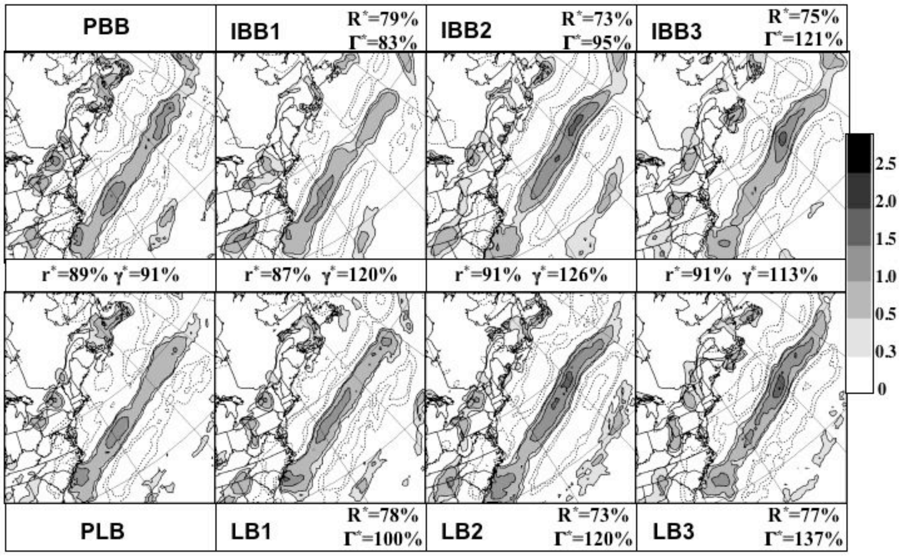

Fig. 2. Time-average small-scale precipitation rate fields (mm/day) for PBB and IBBs are shown in the top panels and that for the LBs in the bottom panels. Negative contours are shown dotted. Spatial correlation coefficients (R^*) and ratio of spatial variances (Γ^*) between PBB and IBBs are given in the subtitles. Spatial correlation coefficients (r^*) and ratio of spatial variances (γ^*) between each IBB and corresponding LB are indicated between the top and bottom panels.

Errors are present in both stationary and transient parts for the IBB simulations, but the transient components of the field exhibit the largest errors due to rather weak temporal correlation. The points corresponding to the LB fields are close to those corresponding to the driving IBBs for all four components of the fields, indicating the presence of similar errors in the precipitation rate fields of LBs to those contained in the corresponding fields of IBBs. For the stationary component of the large scales (Fig.1. a), LBs have almost the same ratio of spatial variances as the IBBs and a slightly smaller spatial correlation coefficient. In general, the LB reproduces the amplitude of its IBB precipitation rate and the shape of LB field is closer to that of the corresponding IBB than to the reference field (figure not shown). However, the spatial extent is found to be smaller for all LBs. This feature is noted in the PLB too and is due to the fact that, at the boundaries, the vertical velocity is set to zero in CRCM. This setting hinders the development of precipitations in the south-west part of the domain and delays the onset of precipitation, pushing the maximum further North. In spite of this the correlation coefficient between the LB and its IBB are approximately the same for all LBs, irrespective of the errors of its corresponding IBBs. This suggests that most part of stationary large-scale errors of the IBBs are reproduced by the corresponding LBs. For the stationary small scales (Fig. 1c), the LB fields are characterised by spatial correlation coefficients that are similar to the corresponding IBB fields and there is a little increase in the LB spatial variability in comparison with corresponding IBBs, irrespective of the spatial variance of the IBB fields. Fig. 2 shows the stationary small-scale part of the precipitation rate fields. The LBs represent better the small-scale features over the Great Lakes and the Maritimes regions through its finer horizontal resolution, which permits better representation of the coastline and the orographic features. But for the ocean region, where the small scales are mostly located, LB develops small scales that are closer to those of the IBB that drives it than those of the reference field. The spatial correlation coefficient between LB and its IBB is almost the same for all four cases. Therefore, irrespective of LBC errors, LB reproduces a great part of the stationary small-scale field of its IBB. This result suggests that the large scales precondition the small scales and therefore it is necessary to provide the accurate large-scale circulation at the lateral boundary of RCM in order to obtain accurate small scales. Similar results were observed for the mean sea level pressure and temperature at 850 hPa fields (Diaconescu et al. 2005).

In conclusion, the study indicates that the quality of lateral boundary data plays a critical role in regional climate modelling for the winter period, highlighting the need for good LBCs and hence the necessity for a credible GCM.

References

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