Short-Term Downscaling with a Limited-Area Model: Diagnostic Verification in a Perfect-Model Approach

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1. Introduction

Nested limited-area models (LAMs) have been used by the scientific community for a long time with the implicit assumption that they are able to generate meaningful small-scale features that were absent in the initial and in the lateral boundary conditions. A number of studies in the past have evaluated the validity of the mentioned hypothesis, with a variety of results (e.g. Anthes et al., 1985). In spite of the lack of conclusive results in this area, it is commonly argued that LAMs simulate meaningful mesoscale features (Peagle et al., 1997).

The experiment carried out in de Elia et al.(2002) increased the evidence that challenges this widespread notion. For doing this, a perfect-model approach was followed. A high-resolution large-domain LAM was driven by global analyses producing a long simulation that was used to drive a high-resolution small-domain LAM. Spatial filtering to remove the fine scales in the driving data provided to the small-domain LAM (as lateral boundary and initial conditions) was performed in order to mimic the low-resolution atmospheric fields that usually drive LAMs. This setup permitted a comparison between the simulations of both LAMs over the same region. Results showed that the small-domain LAM was incapable of reproducing the small scales present in the large-domain LAM with the precision required by a root-mean-square (RMS) measure of error for most of the length scales removed by filtering.

As discussed in de Elia et al.(2002), comparisons between forecast (small domain) and reference run (large domain) through the use of RMS might be too demanding to fairly evaluate results. It is well known that the RMS is highly sensitive to phase errors. It has been argued several times that even when models score very badly in terms of RMS, forecasters have benefited from the information provided by these models. For this reason, in this study an attempt to use a less stringent measure is intended. In addition, the scale analysis that was a natural sophistication of the RMS study, is abandoned in order to put more emphasis into the physical space. The reason is that localized small-scale systems loose representativeness in a spectral approach, and hence, large values in a spectral RMS error may hide successful predictions of important phenomena.

The technique used in this analysis is derived from the "Diagnostic verification" developed by Murphy and Winkler (1987), and it consists in a distribution-oriented approach. Although familiarity with it would facilitate the understanding of this note, it is not essential.

2. Experimental framework

The Canadian Regional Climate Model (CRCM) described in Caya and Laprise (1999) is used for a series of simulations with 45-km horizontal grid spacing, 18 levels in the vertical, and a 3-h nesting frequency. A first integration is made for a month in a domain of 196x196 grid points in the horizontal (centered in New England), nested with NCEP analyses of February 1993. This high-resolution simulation reference run becomes our "truth" to which other runs will be compared to.

The output fields produced by this reference run are then filtered to remove smaller scales in order to simulate a low-resolution dataset. These low-resolution fields are then used to drive simulations performed over a smaller domain (100x100 in the horizontal, keeping the vertical and horizontal resolution untouched) located in the centre of the larger domain. This setup permits the comparison of the output of both simulations in the same region and therefore assesses the ability of the one-way nesting to reproduce the results of the larger domain. Since both simulations use the same formulation (dynamics, physics, resolution, numerics, etc), differences in results can be attributed unambiguously to the nesting technique.

In order to make values statistically stable, results were obtained for 24 runs of the small-domain model integrated during 4 days, each one starting on successive days of February 1993. In this way, for example, the 48-hour integration ensemble average, implies the average over 24 different 48-hour integrations, one day apart. A more detailed description of this experiment can be found in de Elia et al. (2002).

3. Results

For reasons of brevity, only results from 96-hour integration for vorticity at 850 hPa are presented. An enhanced scattergram is displayed in Fig. 1. Pairs of points from both the forecast and the reference runs at each grid point and for all 24 runs are considered to build the distributions represented in the diagram. Following the ideas discussed by Murphy and Winkler (1987), it is possible to think this diagram in terms of conditional and marginal distributions. Histograms of the forecast and reference variables are represented at

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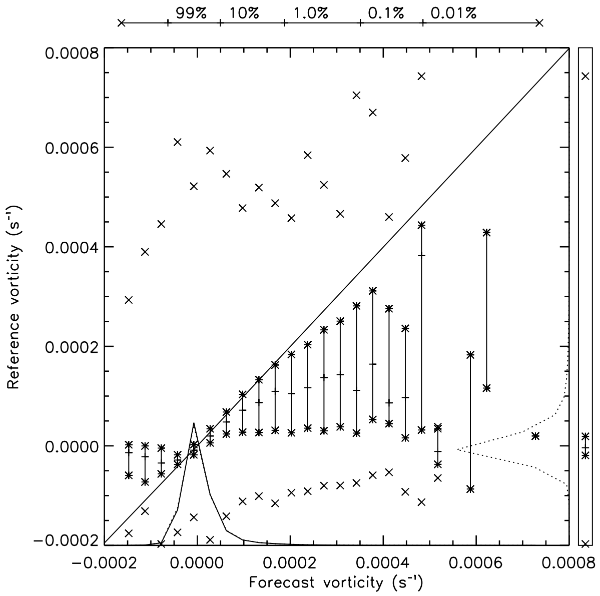

Figure 1: *Conditional and marginal distributions for large- and small-domain 850-hPa vorticity fields after 96-hour integration.*

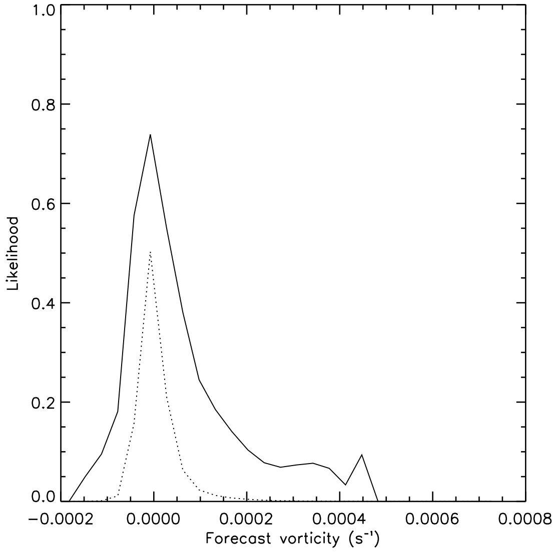

Figure 2: *Likelihood of success for small-domain integration (solid line) and random forecasts (dotted line).*

the sides without scale. In the same way, values in the scattergram are thought of as belonging to distributions of the reference values conditional to the forecast values. These distributions are represented following a standard way denoting the extremes (with an "X"), the first and third quartile (with asterisks connected by a line), and finally the median (with a dash). Used together, these symbols divide each distribution in quarters.

It can be seen in the histograms that the maximum amount of data in both the forecast and the reference run occurs around zero vorticity. It can also be seen that both distributions are virtually identical. This is somewhat expected since both fields were generated with the same model, although in different grids. It is worth noting that the similarity of distributions between large- and small-domain runs suggests an unbiased statistics (identical averages, variances, etc.).

The figure also shows that, for larger values of forecast vorticity, the conditional distributions tend to be biased towards lower values of the reference vorticity, while interquartile distances become longer (larger variance). This should not be interpreted as an inability of the model of producing high levels of vorticity (as we have discussed in the previous paragraph, the model is unbiased), but simply as the inability of producing it at the right place. The conditional bias towards lower values appear because high vorticity levels are a low probability phenomena, and when wrongly forecasted, tend to be replaced with more common phenomena (lower levels of vorticity, as seen in the histogram).

It is very illuminating to compare the likelihood of obtaining the right solution with this forecast model and with a random generator with the same statistics. This can be done by using the distributions already obtained and ignoring the estimation problem. Figure 2 displays the likelihood of obtaining the right forecast, within a given interval, for the small-domain run (solid line) and for the random forecast (dashed line). As we can see the small-domain run performs always better than the random model, although its likelihood becomes small for large vorticity values and hence of dubious utility.

4. Conclusions

It is clear from these results that, although the 96-hour forecast is by no means deterministic, the small-domain runs generate solutions whose distribution provides more information than the one obtained with the random model. This probability of success is notably increased if the verification allows a phase error of 1 or 2 grid points (not shown). These results are more optimistic than those of de Elia et al. (2002) discussed in the introduction, although both are derived from the same set of data. Less stringent constraints as well as a more meteorological approach may explain the difference. These results tend to confirm also the advantage of the probability framework even for interpreting Limited-Area Models.

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