Regional Modeling with Variable-Resolution GCMs: Stretched-Grid Model Intercomparison Project (SGMIP)

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Variable-resolution GCMs using a global stretched grid (SG) with enhanced resolution over the region(s) of interest have proven to be an established approach to regional climate modeling providing an efficient means for regional down-scaling to mesoscales. This approach has been used since the early-mid 90s by the French, U.S., Canadian, Australian and other climate modeling groups along with, or as an alternative to, the current widely-used nested-grid approach. Stretched-grid GCMs are used for continuous/autonomous climate simulations as usual GCMs, with the only difference that variable-resolution grids are used instead of more traditional uniform grids. The important advantages of variable-resolution SG-GCMs are that they do not require any lateral boundary conditions/forcing and are free of the associated undesirable computational problems. As a result, SG-GCMs provide self-consistent interactions between global and regional scales of motion and their associated phenomena, while a high quality of global circulation is preserved, as in uniform grid GCMs.

The international SGMIP-1 (Stretched-Grid Model Intercomparison Project, phase-1), using variable-resolution SG-GCMs developed at major centers/groups in Australia, Canada, France, and the U.S., has been successfully conducted in 2002-2005. The results of the 12-year (1987-1998) climate simulations for a major part of North America are available at the SGMIP web site: http://essic.umd.edu/~foxrab/sgmip.html, and are described by Fox-Rabinovitz et al. (2006). The climate simulation results obtained with the SGMIP-1 SG-GCMs have shown the maturity of the SG approach.

The multi-model SGMIP-1 regional climate simulations were conducted with enhanced 0.45° - 0.5° regional resolution for SG-GCMs, with the same or a similar number of global grid points as in a 1° x 1° global grid. The multi-year SGMIP-1 SG-GCM simulations were analyzed in terms of studying the impact of high regional resolution on efficient downscaling to realistic mesoscales and regional climate variability. We focused mostly on studying the quality of the multi-model ensemble results. The differences between the models have been also determined. The SGMIP-1 multi-model ensemble results for the region compare well with reanalysis and observations, in terms of spatial and temporal diagnostics.

This is what has been learned from SGMIP-1:

(a) the appropriate *moderate stretching* design for long-term climate simulations has been defined;

(b) the SG-approach works well and is *robust* for SG-GCMs with *different dynamics and physics*; namely, for dynamics using spectral and grid-point schemes, with spherical and geodesic grids, and for physics calculated at intermediate uniform or variable resolution for the resolution range of 0.5º to 2º- 4º (with a moderate stretching);

(c) the SGMIP-1 SG-GCMs provide *high quality regional and global* climate simulation products, with differences between the models documented by producing the Taylor diagrams;

(d) the *advantage of using the multi-model ensemble* mode has been demonstrated, in the sense that the multi-model ensemble means are closer to reanalyses and observations than the individual ensemble members;

(e) improvements associated with better resolved land-sea differences may be obtained when using larger ensembles, (see also e.g. Fox-Rabinovitz et al. 2005).

Other major SGMIP-1 results are as follows:

1. Efficient regional *downscaling to realistic mesoscales* is obtained with small/limited regional biases, for time averaged model products, that are a fraction (~50% or less) of reanalysis or observational errors. Biases are larger, up to twice the reanalysis or observational errors (but only for the southern polar domain); note that our SGs have the North American area of interest. *Overall, biases are within the uncertainties of available reanalyses.*

2. Both seasonal and interannual *climate variability* are *well represented*. Namely, annual cycles, seasonal differences, time series, and variances are close to those of observations or reanalyses.

3. Orographically induced precipitation and other products are well simulated at meso- and larger scales due to high-resolution regional forcing. The *major positive* regional impact *from stretching* is directly obtained from *better resolved* model dynamics and regional *enhanced resolution stationary boundary forcing*, i.e. orography and land-sea differences. In that sense, the improvements are obtained near small-scale terrain features and coastlines, and are reflected, for example, in the Appalachian and coastal precipitation.

The future SGMIP plans, SGMIP-2 (phase-2), include comparisons of high resolution stretched and uniform grid GCMs, with the prime area of interest over the major part of North America. These SGMIP-2 experiments will provide the possibility for a *comprehensive analysis of enhanced variable and uniform resolution GCMs* and their *high resolution multi-model ensembles* against reanalysis and observations. The SGMIP-2 experiments will be conducted for the 25-year period of integration, from 1979 to 2003. SGMIP-1 and SGMIP-2 have been endorsed by the WMO/WGNE at its 2004 annual meeting and the progress report has been presented at its 2005 annual meeting. The SGMIP products are available to national and international programs such as WMO/ WCRP/WGNE, CLIVAR, GEWEX, IPCC. The SGMIP effort, aimed at introduction of the SG-GCMs to a broader regional and global climate modeling community, contributes to a better understanding of the efficient SG-approach to climate modeling and the variety of applications.

References

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