Issues in Downscaling

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Downscaling can be considered with respect to 4 basic types of models: one type that is strongly dependent on larger-scale numerical weather prediction lateral boundary conditions, bottom boundary conditions[1], and on initial conditions. A second type has forgotten the initial conditions but is dependent on the observed lateral and bottom boundary conditions. A third type is where a large scale model is run which is only forced with surface boundary conditions, and the output used to downscale with a regional model. A fourth type is when a true global climate model (with coupled ocean-atmosphere-continental sea ice-landscape processes, etc) is used to provide lateral boundary conditions to a regional model. This is the IPCC type of downscaling except only a limited set of Earth system forcings (e.g. the radiative effect of CO2, solar insolation) is included in the IPCC approach. To summarize with examples (IC=initial conditions; LBC= lateral boundary conditions; and BBC=bottom boundary conditions; with the recognition that BBC includes bottom interfacial fluxes):

Type 1 Eta (uses observed IC, LBC and BBC)
Type 2 PIRCS (uses observed LBC and BBC)
Type 3 ClimRAMS forced by CCM3 integrated with observed SSTS (uses observed BBC)
Type 4 Earth system global model downscaled using a regional model.

Observational constraints on the solution become less as we move from Type 1 to Type 4. Thus forecast skill will diminish from Type 1 to Type 4.

With respect to current generation models, such as atmospheric-ocean global circulation models (AOGCMs) neither AOGCMs or the regional models (Type 4 models) include all of the significant human effects on the climate system. The combined effects of human landuse change, the biogeochemical effect on the atmosphere due to increased CO2, and the microphysical effect of pollution aerosols, for example, have not yet been included in these models. Thus the existing model runs should only be interpreted as sensitivity experiments, not forecasts, projections, or even scenarios (Pielke 2000).

[1] More appropriately the bottom boundary should be considered as Earth surface interfacial fluxes, some of which change slowly enough during the period of integration to be considered boundaries - terrain is a good example of a fixed boundary condition on all the time scales we are working with.

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In addition, with respect to dynamic downscaling, as currently applied, there is not a feedback upscale to the AOGCM from the regional model, even if all of the significant large-scale (GCM scale) human-caused disturbances were included. The AOGCM also has a spatial resolution that is inadequate to properly define the lateral boundary conditions of the regional model. As shown by Anthes and Warner (1978), the lateral boundary conditions are the dominant forcing of regional atmospheric models as associated with propagating features in the polar westerlies. With numerical weather prediction (Type 1 and 2 models), the observations used in the analysis to initialize a model retain a component of realism even when degraded to the coarser model resolution of a global model. This realism persists for a period of time (up to a week or so), when used as lateral boundary condition for a regional numerical weather prediction model. This is not true with the AOGCMs where observed data does not exist to influence the predictions. A regional model cannot reinsert model skill, when it is so dependent on lateral boundary conditions, no matter how good the regional model.

If this conclusion is disagreed with, the first step to demonstrate that the regional climate model has predictive skill is to integrate an atmospheric GCM with observed SSTs for several seasons into the future. The GCM output would then be downscaled using the regional climate model. There is expected to be some regional skill and this needs to be quantified. This level of skill, however, will necessarily represent the maximum skill theoretically even possible with AOGCMs as applied for forecasts years and decades into the future since, for these periods, SSTs must also be predicted, and not specified. Such experiments have not been systematically completed. Indeed, does the concept of predictive skill even make sense when we cannot verify the models until decades into the future?

The statistical downscaling, besides requiring that the AOGCMs are accurate predictions of the future, also require that the statistical equations that are used for downscaling remain invariant under changed regional atmospheric and land-surface conditions. There is no way to test this hypothesis. In fact, it is unlikely to be valid since the regional climate is not passive to larger-scale climate conditions, but is expected to change over time and feedback to the larger scales. More details of this concern regarding downscaling (and the need to replace this approach with a vulnerability perspective) are reported in Pielke and Guenni (1999).

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