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3.4 TEN-YEAR U.S. REGIONAL CLIMATE SIMULATIONS FOR IMPACT ASSESSMENTS

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1. INTRODUCTION

Present-day computational resources needed for multi-decadal simulations limit the spatial resolution of global climate models (GCM) to scales larger than the scale of typical impacts of climate extremes. We used regional climate models (RCM) with higher spatial resolution to downscale dynamically results of global climate models to scales more likely to be of importance for impact studies.

We have used two regional climate models, RegCM2 (Giorgi et al.,1993) and the Danish Meteorological Institute's HIRHAM (Christensen et al., 1997), to produce suites of 10-year climate simulations for the continental U.S. at approximately 50 km horizontal resolution. Three sets of driving boundary conditions - NCEP/NCAR reanalysis, and Hadley Centre coupled atmosphere-ocean GCM (HadCM2) output of contemporary climate, and HadCM2 scenario climate (Johns et al. 1997), - have been used to produce six 10-year simulations (2 models x 3 sets of boundary forcing). These simulations are referred as to RegCM2's and HIRHAM's reanalysis, HadCM2 control, and HadCM2 scenario runs, respectively.

Simulations with reanalysis as boundary conditions provide a basis for evaluating RCM capability to produce mesoscale climate details over the U.S. The HadCM2 control and scenario runs provide climate changes. In addition, comparison between the reanalysis-driven and HadCM2 control runs provides estimates of biases caused by the GCM output forcing the RCMs. Finally runs from two RCMs give a preliminary view of uncertainty in regional climate simulations from using different regional models.

2. MODEL AND SIMULATION CONFIGURATION

These hydrostatic RCMs are forced by the same boundary conditions in similar buffer zones that are 10 (HIRHAM) and 15 (RegCM2) grids in width. Although horizontal resolution is similar, the RegCM2 has 14 vertical layers while HIRHAM has 19. The land use and convective schemes are BATS and Grell (for RegCM2), and simple bucket for soil moisture (but five temperature layers and Arno scheme for runoff) and Tiedke mass flux (for HIRHAM).

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The NCEP/NCAR reanalysis boundary conditions are obtained from the 28 σ-level Gaussian grid (1.875^{O} lat/lon) data set. The simulation period (1979-1988) for the reanalysis runs coincide with AMIP experiments (Gates 1992) in order to facilitate comparisons with those GCM simulations. The simulated 10-year periods roughly correspond to years around 1990 and 2050 for HadCM2 control and scenario runs, respectively. It should be noted that aerosol effects are not included in this HadCM2 scenario run. The GCM simulation has a horizontal resolution of 2.5^{O} lat x 3.75^{O} lon. All three runs update their boundary conditions six hourly.

The RCM output for upper-air data is archived every 6h, whereas surface variables are saved every 3h. This abstract presents preliminary results summarizing 10-yr means and monthly time series for precipitation and daily maximum/minimum temperature.

3. PRIMARY RESULTS

3.1 Definitions of Biases

Coupled GCMs and high resolution RCMs are widely used for projecting climate changes. Before accepting model projections, it is necessary to examine the relative magnitudes of climate changes to the model biases. A low ratio of model bias to projected change adds credibility to model results. We evaluate three model biases compared with projected climate change:

- model (performance) bias - difference between model simulation and corresponding observation,
- forcing bias - difference between the GCM driven and reanalysis driven runs, and
- intermodel bias - difference between runs from different models.

Model bias depends on dynamics and physics of the individual models and reflects model systematic errors and drift. Forcing bias measures imperfection of GCM output in driving RCMs. Intermodel bias indicates simulation spread range from different model groups. Climate change is defined as the difference between the GCM scenario and control runs. Projected climate changes will carry more weight when each of the model biases is relatively small.

The HadCM2 control run corresponds roughly to contemporary climate, not exactly our simulated 1979-88 period. Nevertheless, forcing comparison between the Hadley Centre present climate run, which is not time specific, and 1979-88 reanalysis has statistical meaning (with 10 years as sample sizes). The climate change here specifically refers to the difference over a roughly 60-year period (1990-2050), which should be distinguished from the so-called double CO_2 scenario.

3.2 Precipitation

Precipitation is a key climate variable that dictates surface hydrology and energy budgets. It is also an end product of all the dynamic and thermodynamic processes in the atmosphere. Partly for this reason precipitation is one of the variables simulated with least skill. In this subsection we will discuss precipitation characteristics as simulated by two regional climate models.

Both regional models simulated precipitation climatology reasonably well by capturing major characteristics, including heavy amounts along coasts, light amounts in the interior U.S., east-west gradient, etc. They also reproduced mountain precipitation along the Appalachians which would have been missed by typical GCM simulations. However, both models failed to capture the heavy rainfall in the lower Mississippi River basin in autumn, which appears to be caused by rainfall not penetrating inland enough from the Gulf of Mexico. Nevertheless, the models did a good job in the central part of the domain where our main interests are.

We focus on the upper Mississippi River basin (UMRB, 89-99^{O}W, 37-47^{O}N) because this region is far from the forcing boundaries, is the focus of intense study of current climate (GCIP), has important mesoscale processes (low-level jet), and has seasons when either synoptic or convective precipitation dominates. Seasonally, both models overestimate winter and underestimate summer precipitation in the UMRB whereas they perform better in spring and in autumn (Fig.1).

Precipitation change as simulated by RegCM2 is positive over the west coast and the northeast states (Fig. 2. top), in agreement with Giorgi et al. (1994). Precipitation increase would exceed 2 mm/d over the west coast, which occurs mostly in winter, suggesting more frequent or stronger winter storms over the eastern Pacific. Precipitation would decrease over northeastern Texas, Alabama, and Mississippi. The simulated precipitation change is small ($\pm$ 0.5 mm/d) over the central U.S. HIRHAM simulated similar trends to RegCM2, but with weaker amplitude along the west coast. It also did not produce the negative change over Texas (Fig. 2, bottom).

Figure 3 depicts various biases and change defined earlier for the UMRB in the RegCM2 simulation. The positive precipitation change is evident (about 0.1-0.8 mm/d) with maximum in spring and minimum in winter. This result is in general agreement with typical GCM simulations. The model bias is positive in winter/spring and negative summer/autumn. The forcing bias and intermodel bias (RegCM2-HIRHAM) show somewhat large errors in summer and winter. Interesting to note is that in summer all biases are large while change is small. These large errors could be related to the convective character of summer precipitation. Small-scale information can be quite different between GCM generated and reanalysis forcing. Also, the convective parameterization schemes differ between the two models.

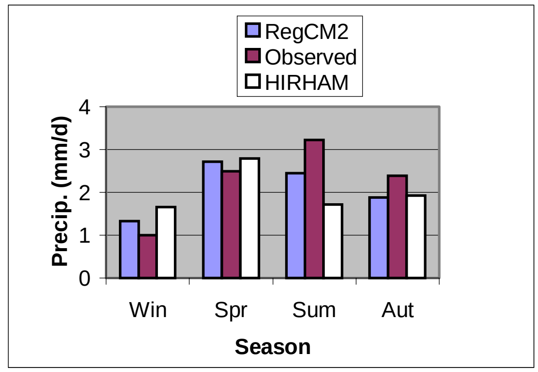


Fig.1. Simulated and observed seasonal distribution of daily precipitation averaged over UMRB.

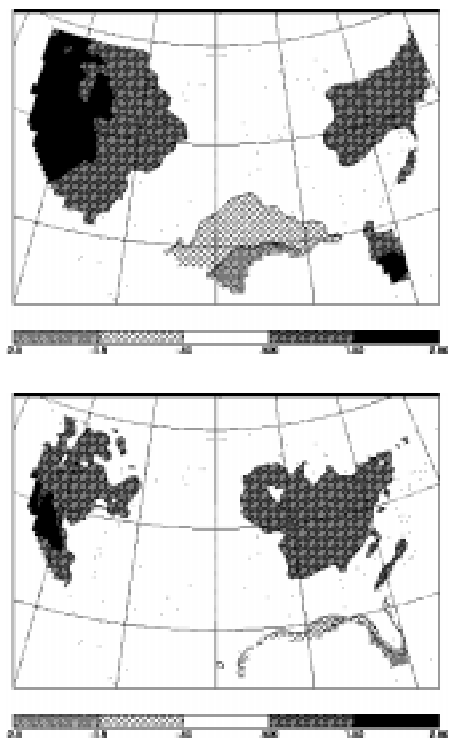


Fig. 2. Simulated climate changes in daily precipitation (mm): (top) RegCM2 and (bottom) HIRHAM.

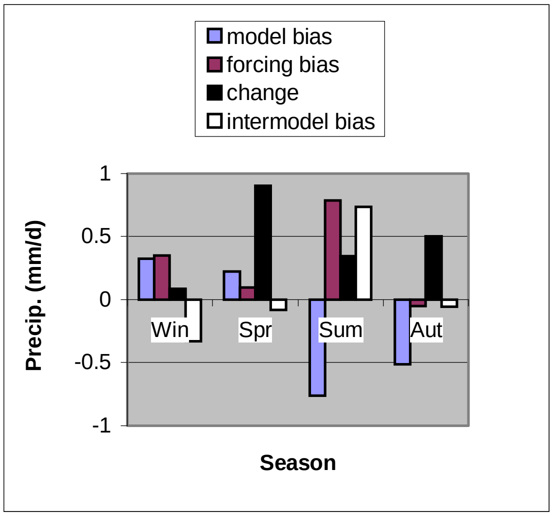


Fig. 3. Seasonal distribution of climate change and various biases in daily precipitation averaged over UMRB based on the RegCM2 simulations.

3.3 Daily Maximum/Minimum Temperature

Surface temperature, especially daily max/min temperature, has significant agricultural importance. Despite overall biases, the two models simulated daily max/min temperature distribution quite well. The largest errors are located along the east and west coasts.

RegCM2 simulated strong warming along almost all forcing boundaries with the strongest over the west coast and along the Mexican border. The Largest July *Tmax* increases reach 4-5K (Fig. 4, top). HIRHAM showed relatively weaker warming for July *Tmax*, with maximum in southwest U.S. (Fig. 4, bottom). Over the north-central U.S. the warming is relatively small. Minimum temperature increase is generally larger than *Tmax* by about 0.5K, but the spatial pattern is similar for both models (not shown).

It can be seen from Fig. 5 that over UMRB: (1) increase in *Tmin/Tmax* is consistently 2-3K, with *Tmin* increase larger, (2) RegCM2's temperatures are typically 2-4K lower than HIRHAM, and (3) RegCM2 has cold bias on *Tmax* and warm bias on *Tmin* for almost all seasons. RegCM2 has large cold bias in *Tmax* whereas HIRHAM has large warm bias in *Tmin*, resulting in reduced annual/diurnal amplitudes of temperature variations in both models.

The temperature change reported in this study is smaller than that reported in Giorgi et al. (1994) for double CO2 scenario. This is reasonable since our future climate is only corresponding to ~2050 when atmospheric CO_2 content is not doubled yet.

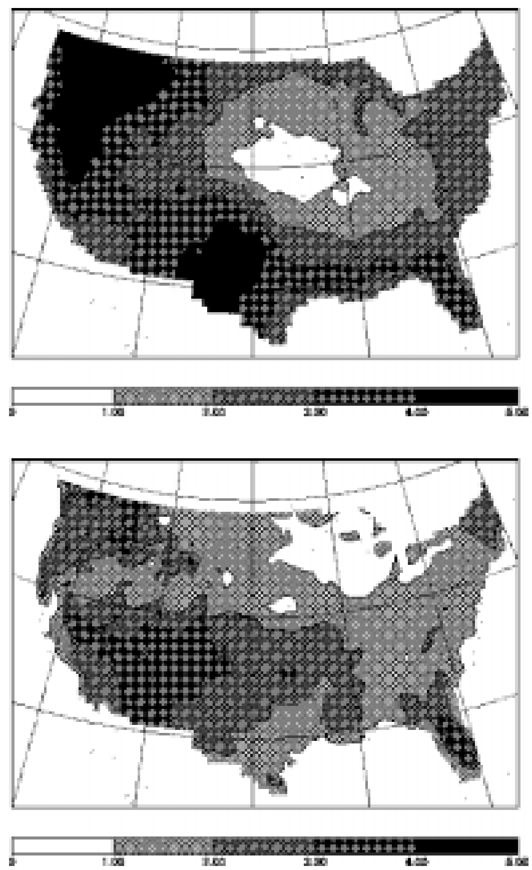
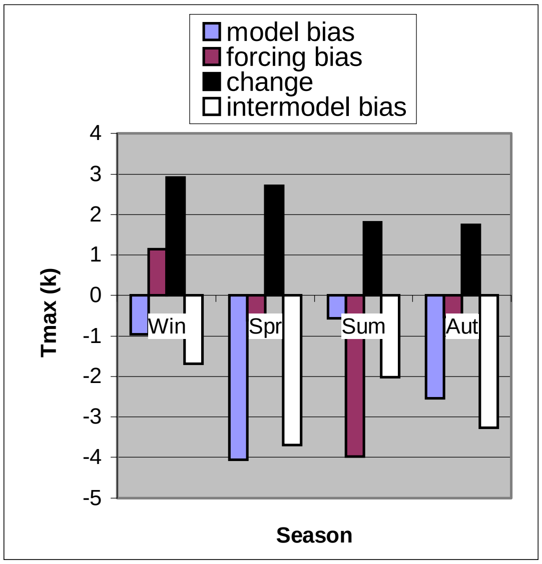


Fig. 4. Simulated changes in July *Tmax* (K): (top) RegCM2 and (bottom) HIRHAM.



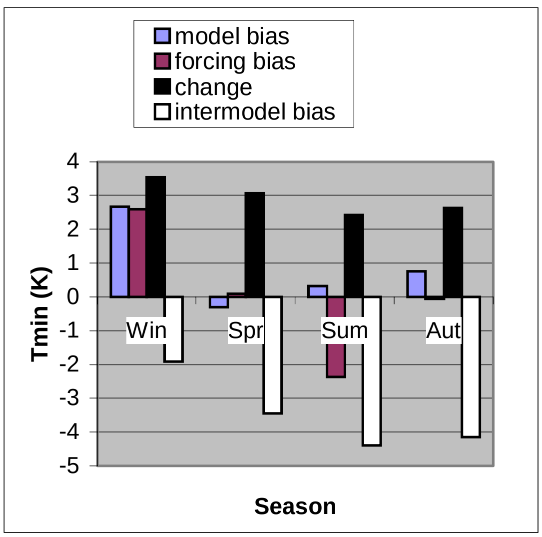


Fig. 5. Seasonal distribution of climate changes and biases of *Tmax* (top) and *Tmin* (bottom) over UMRB based on RegCM2.

4. SUMMARY AND DISCUSSION

We have used two nested regional climate models, RegCM2 and HIRHAM, to produce six 10-year climate simulations for the continental U.S. at approximately 50 km resolution. Driven by common boundary conditions, the two models produced similar overall patterns in precipitation, although they differ in details in their spatial distribution and seasonality. Surface temperature in RegCM2 is 2-4K lower than HIRHAM.

For projecting climate changes, the models are more in agreement for precipitation than surface temperature, possibly due to stronger constraints of boundary forcing on moisture. The top boundary, which strongly affects radiation, is not constrained in the model simulation.

While agreeing with typical GCM simulations in terms of general distribution and seasonality, RCMs provided more spatial variability. One evaluation yet to be made is a comparison of RCM results with corresponding HadCM2 simulations to determine the added value to the global simulations.

Acknowledgements

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