Differences in CMIP model simulations of central U.S. precipitation

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Background

The state of Illinois has initiated long-range strategic planning efforts to address growing concerns about the future adequacy of water resources as the state's population continues to grow. Global climate change is a major part of this concern since some model projections indicate substantially drier conditions. However, the wide range of uncertainties about future precipitation makes it difficult to take concrete actions. The Illinois State Water Survey (ISWS) is the lead state agency for addressing water-related climate issues and has a 50-yr history of hydro-climatological research. In recent years, the ISWS has responded to state concerns and expanded its efforts to address the climate change issue by developing a regional climate modeling capability.

Although decision-makers are accustomed to planning in the context of uncertainty, the wide range of precipitation outcomes makes it almost impossible to take long-range concrete actions. However, an understanding of these differences may be very valuable, particularly if we identify models that most faithfully simulate the key processes that affect precipitation variability in the central U.S.

This proposal is in the context of a short-term (6-month) state project to assess uncertainties in future projections. We have already obtained data from AMIP and from several GCM simulations used in the IPCC Third Assessment Report. Data from CMIP would substantially enhance the value of the information in this project. The state of Illinois has provided the resources to fund substantial portions of the subproject leaders' time plus several graduate students. However, the funding will terminate on June 30, 2003. In order to include CMIP data in this project, it will be critical to receive the data in a very timely manner.

Objectives

The key scientific objective is to identify and (to the extent possible) quantify differences and similarities in precipitation patterns and the major processes that affect precipitation variability in the central U.S. centered on Illinois for those models available through the "CMIP2+ subproject" program. In this region of North America, precipitation variability is affected most strongly by moisture advection from the Gulf of Mexico, the frequency and strength of extratropical cyclones, and the status of soil moisture (determining the availability of recycled moisture). We hope to increase understanding of the ability of models to faithfully represent these processes and to better explain differences between model-simulated precipitation and observations. Particular areas of emphasis for the diagnostic analysis will be the low-level jet stream, thickness gradients, and surface energy budget components (particularly sensible and latent heat fluxes).

While the proposed work has inherent scientific interest, a companion objective is to provide information to those making decisions regarding water resources. Thus, in addition to scientific papers we plan to interpret the scientific findings in a way that is both understandable and potentially useful to decision-makers. The ISWS, as part of its ongoing activities and mission, interacts with and supplies information to a variety of water-related agencies at the local, regional, and statewide levels. It is in an opportune position to provide useful information.

Methodology

The validation data will be a set of observational proxies, which include the latest available NCEP-DOE AMIP-II reanalysis (R-2; Kanamitsu et al. 2002), the precipitation analyses from PRISM (Daly et al. 1997; Maurer et al. 2001) and NCEP (Xie and Arkin 1998), outgoing longwave radiation (OLR) satellite measurements (Liebman and Smith 1996). Spatial correlation analyses using the R-2 data have already been performed to define key features of the geopotential height and flow fields that relate to precipitation variability in Illinois. These analyses will be repeated for the CMIP simulations. Pointwise correlations between Illinois precipitation and the following fields over the globe will be calculated:

1. Precipitation (as an indicator of spatial coherence)
2. OLR and clouds (as an indicator of convective activity)
3. Soil moisture (as an indicator of land memory)
4. Sea surface temperature (as an indicator of remote ocean impact)
5. 850 hPa winds (as an indicator of the low level jet)
6. 200 hPa winds (as an indicator of the upper level jet stream)
7. Moisture flux integrated between the surface, 700 hPa, 400 hPa, and the top
8. 1000-500 hPa thickness
9. Sea-level pressure

In addition, we will perform mass and energy budget analyses over the Midwest and in Illinois. These analyses will require additional surface fields, including latent and sensible heat fluxes, longwave and shortwave radiation, runoff, and evaporation. All model results will be compared with corresponding NRA analyses. Furthermore, we will use the ensemble of all CMIP model biases (departure from observations) to conduct correlation analyses to better understand the possible causes that explain the biases. This method has been proved to be useful for our AMIP intercomparisons (Liang et al. 2001; Liang et al. 2002).

Given that we have been performing similar analyses on the AMIP-II data, intercomparsions between CMIP and AMIP results will be valuable to understand the role of coupled oceans on central U.S. precipitation and corresponding model biases. We will pay particular attention to those models that participate in both CMIP and AMIP.

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