6A.6 PROJECT TO INTERCOMPARE REGIONAL CLIMATE SIMULATIONS (PIRCS): PRELIMINARY ANALYSES OF PRECIPITATION PROCESSES

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1. INTRODUCTION

Potential impacts of climate change on agriculture, water resources, human health, and ecosystems are tied to climates of regions (e.g., provinces, counties or states) rather than to changes in broad continental or global averages. It is therefore imperative to understand and, ideally, to predict how global climate change is manifested at these regional scales. Using GCM output to drive limited-area atmospheric simulations of climate change on regional scales is a promising approach for simulating regional climate change. The overall strengths and weaknesses of this method have been difficult to assess, in part because the disparate applications (such as those reviewed by Giorgi and Mearns, 1991 and McGregor, 1996) lack a common framework.

The Project to Intercompare Regional Climate Simulations (PIRCS) provides a common simulation framework for evaluating mesoscale models run in climate mode, both versus each other and, more important, versus observations. Here we describe the motivation and structure for the first PIRCS simulation experiment. We present some preliminary results from the first experiment that give an initial indication of the collective capabilities of the participating models and of this approach to climate simulation. Additional details can be found at the PIRCS Web site, http://www.pircs.iastate.edu.

2. DESCRIPTION OF EXPERIMENT 1

(a) Domain and period

The simulation domain for Experiment 1 covers the continental United States with a specific focus on the central region. The domain extent was chosen to minimize as much as possible the presence of mountain ranges near the boundaries, as rapidly varying topography can interfere with translating coarse-resolution driving data into mesoscale resolution boundary conditions. Simulations cover two periods of hydrologic extremes in the central US: 15 May - 15 July 1988 (drought) and 1 June - 31 July 1993 (flood). These periods were chosen to give strong signals of climate variability that a model should be able to capture. Periods of only two months were initially chosen to balance limitations in computational and personnel resources for a largely volunteer effort against the need for simulations long enough to capture climatic behavior.

A fundamental assumption in PIRCS is that there must be important mesoscale features in the targeted domain for climate simulation by a mesoscale model to give added value to the global simulation driving it. The central United States contains a significant mesoscale circulation, the nocturnal, low-level jet (LLJ; Stensrud, 1996) which plays an important role in the region's water and energy cycles. The central U.S. was also chosen because it contains a dense climatic observing network, along with field campaigns such as the First ISLSCP Field Experiment (FIFE) (Sellers et al., 1992) and new instrument networks such as wind profilers. Finally,

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partly for the same reasons as given here, the central U.S. is the focus region for the Global Energy and Water Experiment's Continental International Project (GCIP, 1998). One goal of GCIP is to improve simulation of climatic water and energy cycles. PIRCS is helping GCIP attain this goal by providing a framework for assessing mesoscale model simulation of these cycles.

(b) Initial and boundary conditions

Atmospheric initial and boundary conditions were extracted from the reanalysis produced by the National Centers for Environmental Prediction (NCEP) and the National Center for Atmospheric Research (NCAR) (Kalnay et al., 1996). We treated the reanalysis as output from a "perfect" model of the atmosphere for the periods simulated and thus conservatively assumed that differences between model output and observed behavior represent errors in the simulations due to factors such as construction of boundary conditions and internal shortcomings in the models. This assumption is most reasonable for large-scale mass, temperature and momentum fields and less so for humidity (Trenberth and Guillemot, 1995).

The initial and boundary conditions used the finest output resolution available, sigma-layer fields on the T62 gaussian grid of the data assimilation cycle's forecast model. PIRCS scientists at Iowa State extracted initial and boundary conditions for the mesoscale models by interpolating reanalysis output to a 25 hPa vertical grid spanning 25 - 1050 hPa and three sets of horizontal grids: 0.5^o latitude-longitude grid, 60 km polar-stereographic projection, and 60 km Lambert conformal projection.

The oceanic portions of the simulation domain used sea-surface temperatures (SSTs) derived from the reanalysis SST data set. These were supplemented by direct observations of surface temperature in the Great Lakes and satellite observations of SST in the Gulf of California, where the reanalysis grid gave only crude resolution.

The most problematic initial condition was soil moisture. Over most of the PIRCS domain, this field is not observed regularly, necessitating use of an indirectly estimated soil moisture field. For consistency with the atmospheric driving conditions, PIRCS used the soil moisture produced by the surface parameterization of the reanalysis forecast model. Because participating models use a variety of soil-layer resolutions, PIRCS supplied a vertically uniform available water fraction, ranging from 0 at wilting point to 1 at field capacity. The reanalysis soil moisture is subject to relaxation toward an estimated annual climatology (Roads et al., 1998) and thus must be viewed with caution as an initial condition.

(c) Output archive

Anticipated analyses of model output have guided the development of the structure of the output archive. A general goal of the archive is to permit analysis of key mesoscale features, such as the low-level jet, and energy and water cycles linked to mesoscale behavior. Therefore most fields are saved at least four times daily to allow analysis of diurnal variability. Archived output will be available to the general community, though interested users are required to maintain contact with PIRCS and participating modelers to ensure clear understanding of what the models can and can not do.

Participation in PIRCS is currently open to all modeling groups willing to perform the simulations and furnish the output in a standard format. For this initial report, output is available from seven models. Results presented here are based on output selected from the models' contributions to the PIRCS archive for the 1988 PIRCS simulation.

3. PRELIMINARY RESULTS FOR THE 1988 DROUGHT

Evaluation of simulated precipitation uses gridded observations of Higgins et al. (1996) for comparison. These observations are analyzed onto a fairly coarse grid (2^o latitude x 2.5^o longitude). While the mesoscale features of the precipitation distribution are thus averaged out, the analysis provides a basis for assessing broad features of the precipitation distribution. Note that the Higgins data set uses only precipitation observed over the 48 contiguous states and thus provides no basis for evaluating precipitation over Canada, Mexico or the oceans.

The geographic distribution of cumulative precipitation in the models (not shown) reflects some general features of the observed precipitation distribution, namely, wet Pacific Northwest, dry southwestern US, and wet Atlantic/Appalachian region, though the magnitudes vary with respect to the Higgins data set. However, the models give mixed results for the central U.S. They have difficulty capturing both the relatively large amount of precipitation in Texas and the region of smallest precipitation in Illinois and Indiana during the 1988 drought.

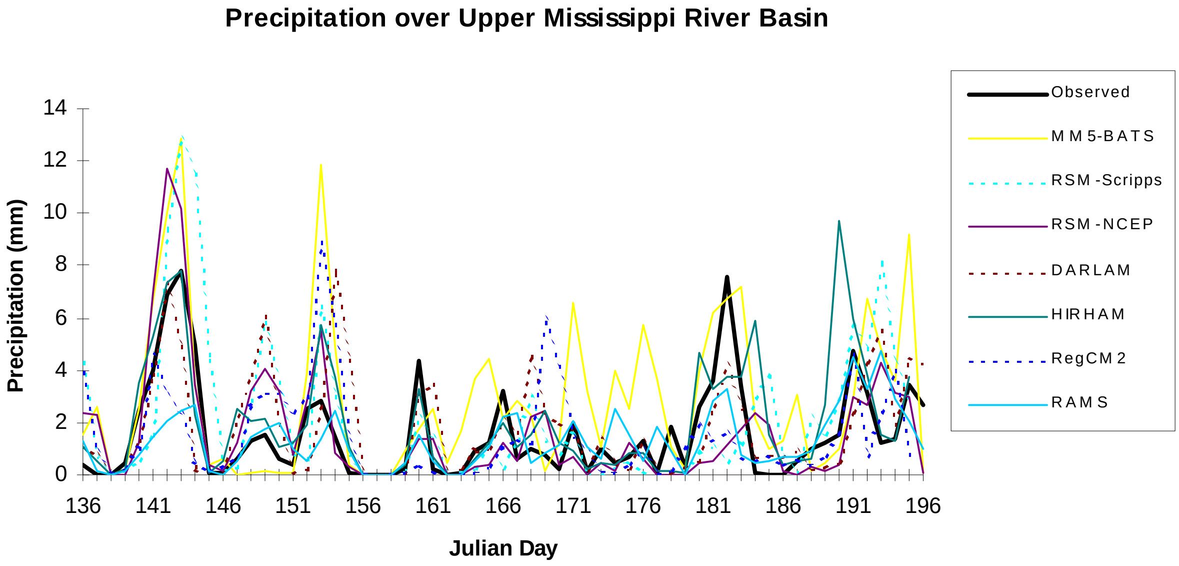

Figure 1: Observed and predicted precipitation averaged over the region 37 N - 47 N, 89 W - 99 W for the PIRCS experimental period

Analysis of temporal variability of predicted precipitation focuses on a portion of the Upper Mississippi River basin (37 N - 47 N, 89 W - 99 W) that is well resolved by the PIRCS models (about 400 grid points) but poorly resolved by a GCM or the reanalysis. Two prominent episodes occurred during the experiment period: Julian days 139 - 158, dominated by large-scale, synoptic systems, and Julian days 164 - 178, primarily local variability, especially in precipitation. During the former episode, external boundary conditions should exert substantial influence through their guidance of large-scale flow. During the latter episode, external forcing should be weak, with much if not most of the simulated precipitation resulting from mesoscale systems or local quasi-random convection.

Although the models differ in precipitation magnitudes, they do capture the frequency of synoptically forced precipitation (Fig. 1), particularly for the four precipitation events during the episode dominated by large-scale, synoptic systems (Julian days 139 - 158). Equally important for hydrologic considerations, the models also capture dry periods with reasonable fidelity during this episode. All models thus effectively ingest influences of large-scale, lateral boundary forcing on precipitation. For Julian days 164 - 178, the observed precipitation is frequent in small amounts, with no clearly definable precipitation events. The models represent this stochastic behavior well, although again they differ from each other and the observations in precipitation magnitude.

The isolated precipitation event on Julian day 160 is particularly noteworthy. This was a transient event within an overall dry period created by a strong omega block, during which a well-defined precipitation region (likely a mesoscale convective system) migrated across the evaluation subdomain. This event is particularly revealing because its limited spatial and temporal existence 15 days from model initialization and far from forcing boundaries offers challenges for models to simulate. The models capture the existence of this episode, including its temporal isolation within a generally dry period, although as before the precipitation amount tends to vary from that observed.

These preliminary results suggest that regional models run in climate mode are capable of transporting remotely introduced water vapor and producing precipitation that, on average, matches observed spatial and temporal patterns reasonably well.

4. SUMMARY

Limited-area models forced by large-scale information at the lateral boundaries are able to reproduce the bulk temporal and spatial characteristics of meteorological fields during the 1988 drought. Model simulations of precipitation episodes vary depending on the scale of the relevant dynamical forcing. Organized synoptic-scale precipitation systems are simulated deterministically, in that precipitation events occur close to the oberved time and location (though the amounts vary). Episodes of mesoscale and convective precipitation are represented in a more stochastic sense: general periods of scattered convective precipitation tend to be captured in the models, though with less precise agreement in temporal and spatial patterns than for the synoptically organized events. There is evidence that at least in some cases the models represent mesoscale convective systems deterministically. Given the importance of mesoscale convective systems for growing season precipitation over the central U.S., this aspect of the models deserves more detailed study.

Although there are some common strengths and deficiencies among the models, no single model stands out as best in all comparisons. Rather, each model has individual strengths and deficiencies in addition to characteristics of the ensemble output. This feature illustrates the importance of archiving a variety of output fields that can be compared with observations. Furthermore, in keeping with the goals of PIRCS, the side-by-side assessments here help highlight more clearly specific areas where modeling groups individually and collectively may want to focus efforts to improve model performance.

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