2.5 PROJECT TO INTERCOMPARE REGIONAL CLIMATE SIMULATIONS (PIRCS): SIMULATION OF THE 1993 FLOOD OVER THE CENTRAL U.S.

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1. INTRODUCTION

The Project to Intercompare Regional Climate Simulations (PIRCS) provides a framework for evaluating dynamical models of regional climate. These comparisons take the form of a series of experiments in which the models are compared with each other and, more important, with observations. PIRCS Experiment 1 evaluates two 60-day simulations for strongly contrasting hydrometeorological regimes, the 1988 drought over the U.S. Midwest (Experiment 1a), and the 1993 flood over the upper Mississippi River basin (Experiment 1b). Previously we reported results for Experiment 1a (Takle et al. 1999). Here we discuss initial results from Experiment 1b.

The motivation and experimental design for PIRCS Experiment 1 have been discussed elsewhere (Takle et al. 1999), so that only a brief overview will be given here. Further details are available through the PIRCS Web site, http://www.pircs.iastate.edu

2. DESCRIPTION OF EXPERIMENT 1B

(a) Domain and period

The spatial domain for Experiment 1 covers the continental United States with a focus on the central region. An assumption in PIRCS is that in order for a regional climate model to give added value compared to a relatively coarse-resolution global simulation, there must be important mesoscale features in the targeted domain. (Note that this perpective applies equally to nested limited-area models and to variable-resolution global models.) In the central U.S. a mesoscale circulation, the nocturnal, low-level jet (LLJ; Stensrud, 1996) plays an important role in the region's water and energy cycles. The central U.S. was also chosen because it contains a dense observing network, along with data from field campaigns such as the First ISLSCP Field Experiment (FIFE) (Sellers et al., 1992) and new instrument networks such as wind profilers. Finally, the central U.S. includes much of the focus region for the Global Energy and Water Experiment's Continental International Project (GCIP, 1998).

The period of simulation for Experiment 1b is 1 June – 31 July 1993 which includes the peak precipitation episode of the 1993 flood. The most intense precipitation during the flood occurred from about 28 June through 10 July, which is several weeks after the start of the simulation. Effects of atmospheric "spinup" thus should be negligible. The same cannot be said for the influence of initial soil moisture, which evolves on a time scale that probably is longer than the experiment period considered here.

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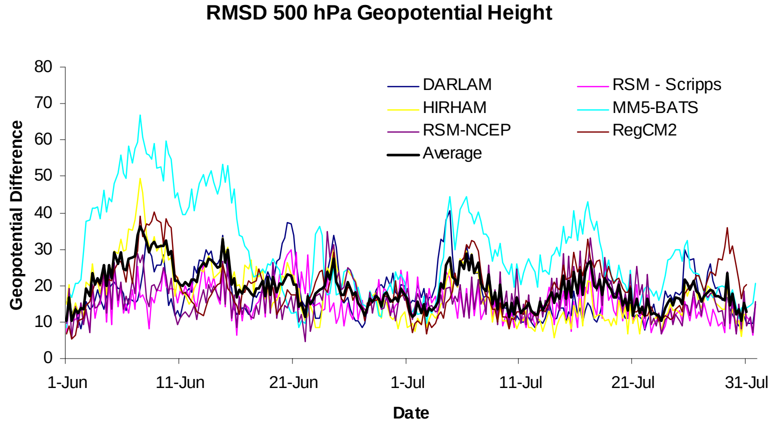

Figure 1: Time series of six-hourly root-mean-square deviation (m) of 500 hPa height fields for regional models compared with the NCEP/NCAR reanalysis.

(b) Initial and boundary conditions

Atmospheric initial and boundary conditions were derived 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 assume the reanalysis is a "perfect" model of the large-scale behavior of the atmosphere for the periods simulated. Thus, we conservatively assume that differences between the reanalysis and regional model results *for the large scale* represent errors in the simulations due to factors such as ingestion of boundary conditions and internal shortcomings in the models.

Initial and boundary conditions for the regional models used the finest output resolution available, sigma-layer fields on the T62 gaussian grid of the data assimilation cycle's forecast model. The PIRCS coordinating group at Iowa State extracted initial and boundary conditions for the models by interpolating reanalysis output to a 25 hPa vertical grid spanning 25-1050 hPa and a horizontal resolution of 0.5^o latitude-longitude. Nominal horizontal grid spacing for the regional models is 50 km, though there is some variation from model to model because the models use a variety of map projections. Boundary values are updated every 6 hours.

Sea-surface temperatures (SSTs) were derived from the reanalysis SST data, 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. Soil moisture is not observed regularly over most of the PIRCS domain, 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. 1999) and thus must be viewed with caution as an initial condition.

(c) Participating models

Participation in PIRCS is open to all modeling groups willing to perform the simulations within constraints required for a controlled experiment (i.e., source of initial/boundary data, domain size, resolution, and other parameters). Participants also agree to furnish output in a standard format.

To date 12 modeling groups from Europe, Australia and North America have completed or are presently engaged in performing Experiment 1b. For this preliminary report, results are discussed from six models.

3. PRELIMINARY RESULTS FOR THE 1993 FLOOD

a. 500 hPa height field

We assess consistency of the regional models with large-scale boundary forcing by evaluating the root-mean-square deviation (RMSD) of the regional model 500 hPa height fields from the height fields for the reanalysis. The RMSD is computed by analyzing the regional model values to the locations of the reanalysis values using a Barnes (1994) objective analysis scheme. The Barnes scheme was configured to give a response of e^{-1} at a wavelength corres-

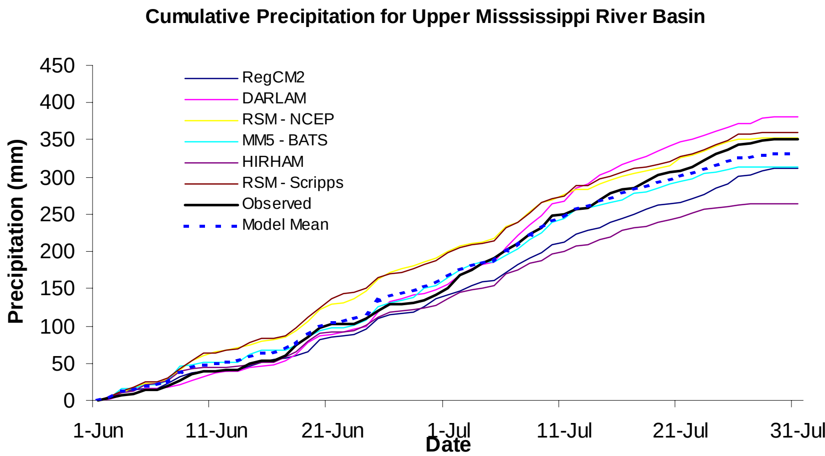

Figure 2: Time series of cumulative precipitation for regional models compared with gridded analysis of Higgins et al. (1996).

ponding to $2\Delta x$ of the reanalysis grid. Our intent is to match the spatial scales of the reanalysis and the regional models. If RMSD were computed by first interpolating the reanalysis heights to the regional model grids, realistic small-scale features resolved by the regional models but not by the reanalysis would contribute to RMSD.

Time series of six-hourly RMSD, spatially averaged for each model over a region covering most of the continental U.S., indicate that typical values of RMSD are around 10-20 m (Figure 1). MM5-BATS has a few sustained periods with RMSD noticeably higher than the other models. We suggest that this discrepancy can be attributed in part to the relatively small lateral boundary forcing region used in the standard version of the MM5 code, on which MM5-BATS is based (four gridpoints, compared to 10 gridpoints for the other models). It is planned to evaluate this possibility in followup sensitivity studies with MM5-BATS. Examination of the trend of RMSD averaged over the participating models suggests that episodes of high RMSD are associated with the propagation of short wavelength lows, consistent with results for Experiment 1a (Takle et al. 1999). An example is the period around 2—6 July when an intense low pressure system propagated along the U.S.-Canada border.

b. Precipitation

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. Analysis of simulated precipitation focuses on a portion of the Upper Mississippi River basin (37-47^{o}N, 89-99^{o}W) that includes the region of greatest observed precipitation during the 1993 flood. This region is well resolved by the PIRCS models (several hundred grid points) but poorly resolved by most GCMs or the reanalysis.

All models except HIRHAM produce cumulative precipitation within about 10 percent of observed values. HIRHAM is the driest of the models; it is noteworthy that we have also found HIRHAM to produce the lowest incidence of low-level jets (defined as in Bonner 1968) over the central U.S. compared with the other models (not shown). This correspondence between the model's precipitation and its treatment of low-level jets is consistent with observational studies showing the importance of low-level jets for precipitation in the 1993 flood (Arritt et al. 1997).

We also find that models from the same "family" in terms of their basic dynamical framework tend to produce similar cumulative precipitation. There is especially close correspondence between the two versions of the NCEP Regional Spectral Model (RSM), which have similar temporal trends and accumulated precipitation at the end of the simulation that differs by only 8 mm (about 2 percent). RegCM2 and MM5-BATS share a common heritage although the MM5 differs in some ways such as the inclusion of non-hydrostatic effects (which may not be significant at the horizontal scale considered here). RegCM2 and MM5-BATS produce similar cumulative precipitation at the end of the period though their trends during the course of the simulation do not agree as closely as the RSM versions. This type of agreement was not found for Experiment 1a. We note that Dirmeyer and Brubaker (1999) found evaporative recycling to be lower in the 1993 flood than in the 1988 drought, so that atmospheric moisture flux convergence played a more dominant role in the flood. As a hypothesis for further study, we propose that models with similar dynamical frameworks will be similar in the way that they handle convergence and moisture convergence, and thus tend to produce similar rainfall for the 1993 flood. In contrast, since evaporative recycling was greater for the 1988 drought, influences of differing physical parameterizations may be more important for the drought period.

4. DISCUSSION

Preliminary results from several regional climate models for PIRCS Experiment 1b indicate that most models produce accumulated precipitation during the 1993 summer flood over the upper Mississippi River basin within about 10 percent of observed amounts. When compared with results for the 1988 drought in Experiment 1a (Takle et al. 1999), the *absolute* magnitudes of differences among models are larger, as are the differences between the models and observations, but the *relative* differences are smaller. Evaluation of root-mean-square deviation (RMSD) of the models' 500 hPa heights versus the NCEP/NCAR reanalysis suggests that synoptic events are handled well by the models. Consistent with previous results for Experiment 1a, the largest RMSD values tend to occur for strong short-wavelength low pressure systems.

Analysis is presently underway to investigate various aspects of the models' representations of the hydrologic cycle, such as intermodel variation in the relative importance of evaporation and moisture flux convergence in producing rainfall during the flood. We also are studying model behavior with respect to important mesoscale features during the flood, such as the incidence of low-level jets and the location of a persistent quasi-stationary front that focused the development of mesoscale precipitation systems. These results will be reported at the conference and in forthcoming publications.

5. ACKNOWLEDGMENTS

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REFERENCES

Arritt, R.W., T.D. Rink, M. Segal, D.P. Todey, C.A. Clark, M.J. Mitchell, and K.M. Labas, 1997: The Great Plains low-level jet during the warm season of 1993. *Mon. Wea. Rev.*, 125, 2176-2192.

Barnes, S.L., 1994: Applications of the Barnes objective analysis scheme. Part I: Effects of undersampling, wave position, and station randomness. *J. Atmos. Ocean. Tech.*, 11, 1433-1448.

Bonner, W.D., 1968: Climatology of the low-level jet, *Mon. Wea. Rev., 96,* 833-850.

Dirmeyer, P.A., and K.L. Brubaker, 1999: Contrasting evaporative moisture sources during the drought of 1988 and the flood of 1993. *J. Geophys. Res.*, 104, 19,383-19,398.

GCIP, 1998: GCIP: Global Energy and Water Cycle Experiment (GEWEX) Continental-Scale International Project. A Review of Progress and Opportunities, National Academy of Sciences, Washington, D.C., 93 pp.

Higgins, R.W., J.E. Janowiak, and Y. Yao, 1996: A gridded hourly precipitation data base for the United States (1963-1993). NCEP/Climate Prediction Center Atlas No. 1, 47 pp. [Available from NCEP/Climate Prediction Center, W/NP52, Washington, DC 20233.]

Kalnay, E., M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, J. Woollen, Y. Zhu, M. Chelliah, W. Ebisuzaki, W. Higgins, J. Janowiak, K.C. Mo, C. Ropelewski, J. Wang, A. Leetma, R. Reynolds, R. Jenne, and D. Joseph, 1996: The NCEP/NCAR 40-year reanalysis project, *Bull. Am. Meteor. Soc.,* 77, 437-471.

Roads, J.O., S.-C. Chen, M. Kanamitsu, and H. Juang, 1999: Surface water characteristics in NCEP global spectral model and reanalysis. *J. Geophys. Res.*, 104, 19,307-19,327.

Stensrud, D. J., 1996: Importance of low-level jets to climate: A review. *J. Clim.*, **9**, 1698-1711.

Takle, E.S., W.J. Gutowski, Jr., R.W. Arritt, Z. Pan, C.J. Anderson, R. Silva, D. Caya, S.-C. Chen, F. Giorgi, J.H. Christensen, S.-Y. Hong, H.-M. H. Juang, J.J. Katzfey, W.M. Lapenta, R. Laprise, G. Liston, P. Lopez, R.A. Pielke, Sr., J. McGregor, and J.O. Roads, 1999: Project to Intercompare Regional Climate Simulations (PIRCS): Description and initial results. *J. Geophys. Res.*, 104, 19,443-19,461.