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INTERCOMPARISON OF INTERANNUAL VARIABILITY OF NORTH AMERICAN MONSOON IN REGIONAL CLIMATE MODEL SIMULATIONS

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1. INTRODUCTION

Intercomparison of results from regional climate models (RCMs) with observations and one another has been limited to analysis of short climatic periods by the computational expense of RCM simulations. With advances in computing technology and storage media, it is now feasible to generate multi-year simulations. The goal of the Project to Intercompare Regional Climate Simulations Experiment 1C (PIRCS-1(c)) is to apply an intercomparison methodology to multi-year simulations, covering the period 1 July 1986 through 31 December 1994. (Any modeling group is welcome to submit simulations for analysis. See www.pircs.iastate.edu for details.) By doing so, PIRCS-1(c) will facilitate analysis of the fidelity of interannual variability of regional climate simulations.

Data analysis for PIRCS-1(c) is in a very preliminary stage. At the conference, we will present results of an intercomparison of interannual variability of the North American Monsoon in RCM simulations. In what follows, we present analysis of a segment of PIRCS-1(c) simulations that is valid during the time of the Midwest drought of 1988. Short simulations (60-day simulations) of this event were examined during PIRCS Experiment 1A (PIRCS-1(a); Takle et al. 1999). This previous analysis serves as a benchmark for the multi-year simulations.

2. DATA

Thus far five modeling groups are generating simulations of the PIRCS-1(c) period (Table 1). Data for initial and boundary conditions are made accessible to each modeling group through a web interface maintained by PIRCS scientists. Atmospheric initial and boundary conditions are taken from the NCEP/DOE AMIP-II Reanalysis (Kanamitsu et al. 2002), as are the initial soil conditions. The evolution of sea surface temperature is prescribed for all large bodies of water, including the Great Lakes, from the Reynolds optimal interpolation sea surface temperature (Reynolds et al. 2002). A subset of each model's output is archived at Iowa State University.

3. RESULTS

RCM simulations valid during the PIRCS-1(a) period of 00 UTC 15 May 1988 through 00 UTC 15 July 1988 are analyzed. Results are presented from three short (60-day) and two long (multi-year) simulations made with MM5, and one long (multi-year) simulation made with the Scripps RSM (Table 2). Long simulations are initialized at 00 UTC 1 July 1986, whereas short simulations are initialized at 00 UTC 15 May 1988.

The 1988 drought affected an extensive area within the central United States (Figure 1). The intensity of the drought was greatest in the Ohio Valley, where only 20–50 mm of rainfall had accumulated. In Kansas, Iowa, and Oklahoma, accumulated rainfall ranged 50–150 mm.

The severity of the 1988 drought was related to the large-scale atmospheric circulation (Trenberth and Branstator 1992) and the soil water content at the beginning of the drought period (Pal and Eltahir 2001). The correlation coefficient of 500 hPa and 200 hPa heights between pairs of short and long MM5 simulations exceeds 0.95 across the contiguous United States (not shown). Minimum correlation occurs over the Gulf of Mexico, but even in this region correlation exceeds 0.90. Thus, by using common boundary conditions, differences among the simulations due to alternative representation of the large-scale circulation are much reduced.

Soil water content is a predicted quantity in these simulations, so that soil water conditions in the long simulations on 15 May 1988 are generated by the simulations themselves. In contrast, the initial soil water content in the short simulations are prescribed from reanalysis data. The initial volumetric soil water content in the short simulations shows a longitudinal gradient with values <0.2 $m^3 m^{-3}$ in the western Plains states and < 0.25 m^3 m^{-3} in the Midwest (Figure 2a). Soil water content on 15 May is larger in the long compared to short simulations. Results from both MMANL1 and MMISU1 simulations show volumetric soil water content > 0.3 m^3 m^{-3} in the Midwest and

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Model Name	Modeling Group Institution
CRCM	University of Quebec at Montreal
MM5	Iowa State University (ISU)
MM5	Argonne National Laboratory (ANL)
SweCLIM	Swedish Met. and Hyd. Institute
Scripps RSM	Scripps Institution of Oceanography
WRF	Iowa State University (ISU)

Table 1. Models participating in PIRCS-1(c)

Ohio Valley and > 0.25 m^3 m^{-3} in the western Plains states (Figure 2b and 2c). Thus, gradients of volumetric soil water content are established in both latitudinal and longitudinal directions in the long simulations.

Precipitation results from the short simulations show the sensitivity of precipitation to choice of convective parameterization and computer architecture. Accumulated precipitation ranges 300 to 400 mm throughout the upper Midwest in the short simulations of MMANL1 and MMISU2 (Figure 3a; results for MMISU2 are omitted). Much less rainfall accumulates in and northeast of Illinois. In the short MMISU1 results, accumulated precipitation in the upper Midwest does not exceed 400 mm, except in Nebraska and western Iowa, and a minimum extends northeastward from northern Illinois. The position of the minimum is displaced southward compared to the short MMANL1 results. However, the largest difference of accumulated precipitation between short simulations from MMANL1 and MMISU1 occurs in the southeastern United States where MMISU1 accumulates > 400 mm but MMANL1 produces < 200 mm.

Comparison of accumulated precipitation from long and short simulations shows the sensitivity of precipitation to initial soil water content. Accumulated rainfall in the long compared to short simulations from MMANL1 is greater in Minnesota and the Ohio Valley and less in the western Plains states (Figure 3a and Figure 4a). A similar result is found when comparing long and short simulations from MMISU1 in that more rainfall occurs in the Midwest and the Ohio Valley in the long duration simulation (Figure 3b and Figure 4b). Thus, the long simulations underestimated the intensity of the drought over much of the drought region.

These results are consistent with what was reported for PIRCS-1(a). An older version of MM5 (MM5-BATS) that used the Grell convective parameterization and BATS land surface model participated in PIRCS-1(a) (Takle et al. 1999). However, the pattern of accumulated precipitation from MM5-BATS is similar to MMANL1 with > 250 mm in the Midwest, a minimum extending northeastward from Illinois, and > 200 mm in southeastern United States. The bias of accumulated precipitation that is reported for MM5-BATS is > 150 mm in the Midwest and > 50 mm in the Ohio Valley.

Comparison of the difference between short simulations (Figure 3a and 3b) and of the difference between long simulations (Figure 4a and 4b) shows

Simulation	Description
MMANL1 (2 simulations)	MM5 (ANL); Grell convective parameterization; short and long simulations
MMISU1 (1 simulation)	MM5 (ISU); Grell con. par.; short sim. only
MMISU2 (2 simulation)	MM5 (ISU); Kain-Fritsch conv. par.; short and long sims.
ECPCRS (1 simulation)	Scripps RSM; relaxed Arakawa-Schubert con. par.; long sim. only

Table 2. Labels of simulations analyzed herein.

the RCM variability due to the combined influences of convective parameterization and initial soil condition. The differences are more pronounced in the long simulations. However, the differences between the long duration simulations are not as large as the variability reported in PIRCS-1(a) for which eight different RCMs provided short simulations.

Comparison of ECPCRS and MM5 output facilitates sensitivity analysis of a more pronounced difference of RCM design. ECPCRS updates large-scale atmospheric conditions within the domain every 6 hours rather than within a forcing frame as is done in MM5 (Roads 2003). Thus, the reanalysis atmospheric data exerts more control over the representation of the atmospheric dynamics in the interior of the domain for ECPCRS than MM5 simulations. The ECPCRS soil condition at the start of the PIRCS-1(a) period (Figure 5a) has spatial pattern in the central United States that is similar to the initial condition of the short MM5 simulations even though the ECPCRS simulation was initialized at 00 UTC 1 July 1986. The soil condition is generally drier by 0.05 m^3 m^{-3} in the central U. S., and the dry condition is more pronounced in the southeastern United States. The land surface scheme used in ECPCRS is known to be overly aggressive in drying the upper 10-cm soil layer in an ETA model implementation (Betts et al. 1997). This may partially explain the relatively dry conditions. Accumulated precipitation, however, is much less in ECPCRS (Figure 5b) than in MM5 simulations, ranging 20–100 mm throughout much of the central United States and Ohio Valley. This range of accumulated precipitation is consistent with results from a short simulation from ECPCRS reported in PIRCS-1(a) that had a range of accumulated precipitation of 50–100 mm.

4. DISCUSSION

The model sensitivity to soil moisture demonstrated in these results is consistent with findings from Bosilovich and Sun (1999) and Pal and Eltahir (2001). Results from both studies show that by reducing the amplitude of soil moisture anomaly the intensity of hydrological extremes is reduced in the central United States, and vice versa. Further, the results of Takle et al. (1999) and Anderson et al. (2003) show a tendency for the intensity of hydrological extremes to be underestimated in most RCM simulations (RSM simulations did not exhibit this deficiency). An important outcome of PIRCS-1(c) will be a determination of whether the variability that arises from the use of alternative models will mask the natural variability of the hydroclimate. The results presented in Section 3 suggest this would not be the case for alternative versions of MM5, although the magnitude of interannual variability might be reduced, but it might be the case if a more diverse set of RCMs is considered.

The results show that improvements to RCMs are needed in order for RCM simulations to accurately represent interannual variability of central U. S. hydroclimate. In particular, variability due to alternative model design has magnitude comparable to model sensitivity to soil wetness. Further sensitivity tests in support of PIRCS-1(c) will provide a potential lower bound on model variability by calculating the magnitude of variability of results from a single model. This lower limit will be obtained by varying the size of the time step for the MMANL1 simulations. This raises a challenging question. Is it realistic to set this lower bound of variability as a target for intermodel variability?

5. ACKNOWLEDGEMENTS

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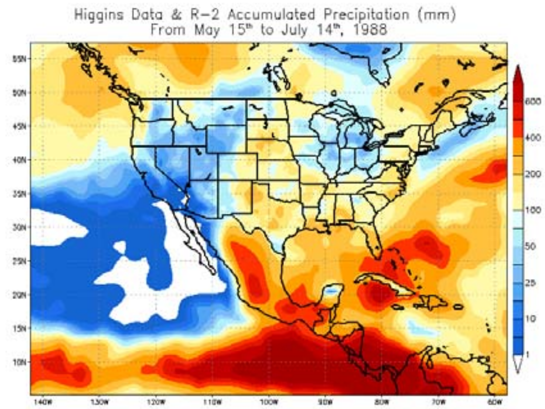

Figure 1. Accumulated precipitation from CPC 0.25°x0.25° daily U. S. unified precipitation (plotted at land points in the United States) and NCEP/DOE AMIP-II Reanalysis (plotted elsewhere in the domain).

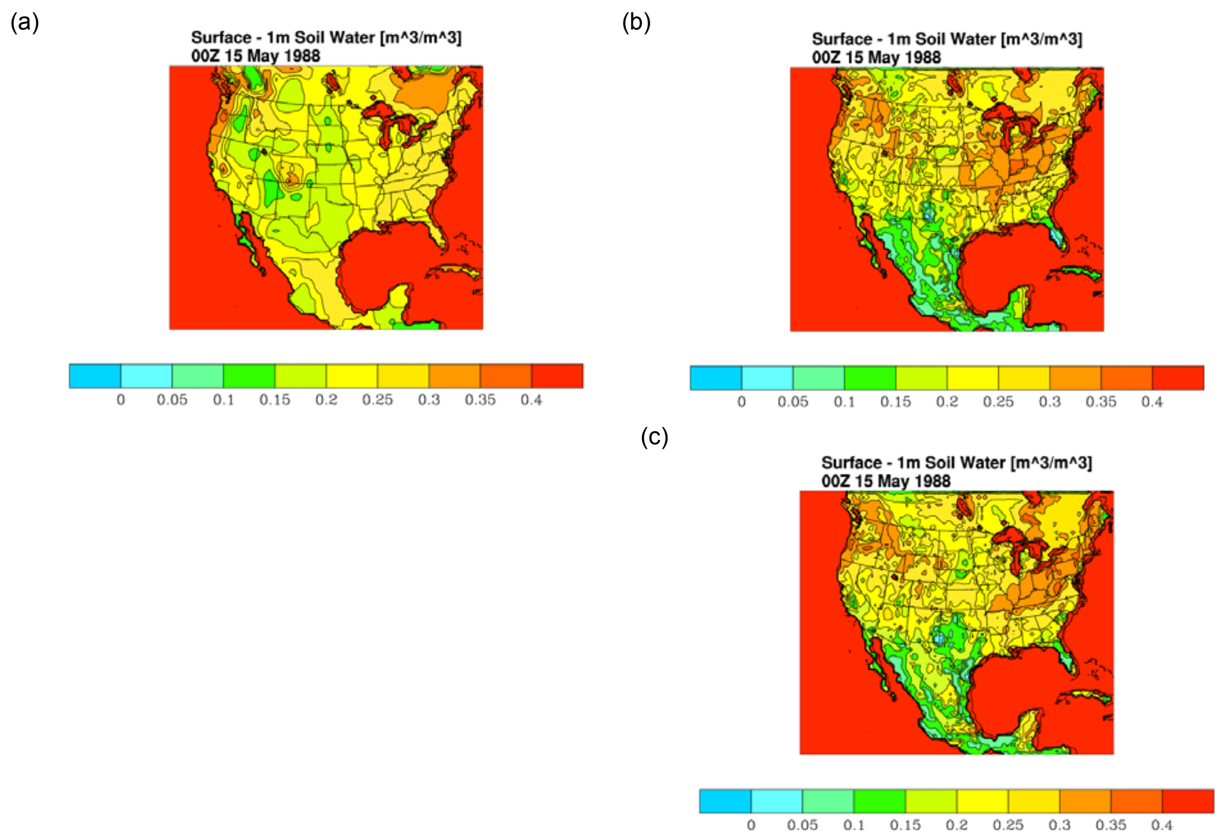

Figure 2. Volumetric soil water content (m^3 m^{-3}) on 00 UTC 15 May 1988 for (a) MMANL1 short simulation, (b) MMANL1long simulation , and (c)MMISU2 long simulation.

(a) (b)

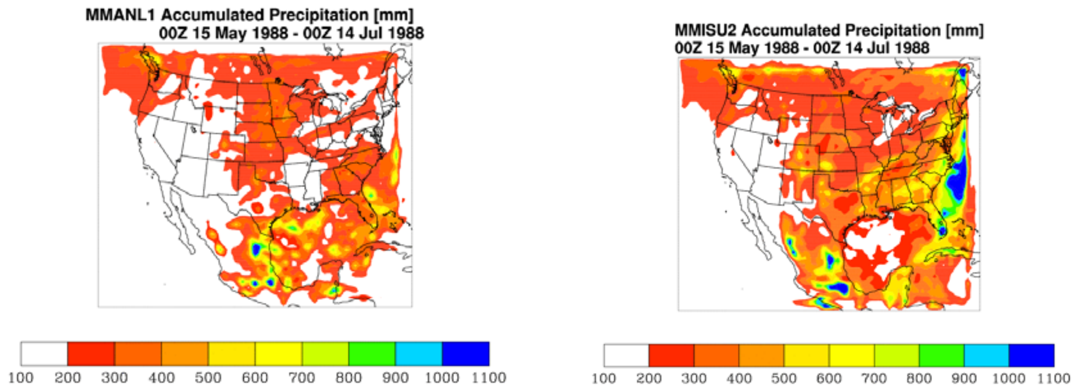

Figure 3. Accumulated precipitation from short simulations (a) MMANL1 and (b) MMISU2.

(a)

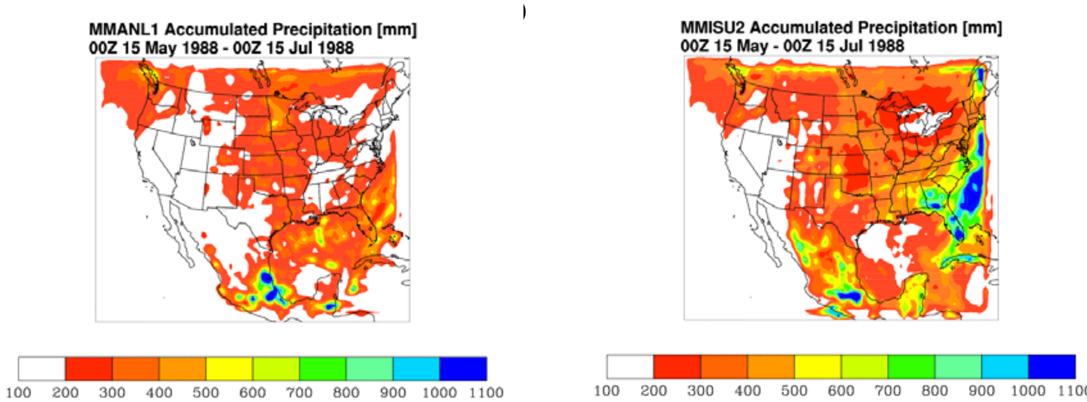

Figure 4. Accumulated precipitation from long simulations (a) MMANL1 and (b) MMISU2.

(a) (b)

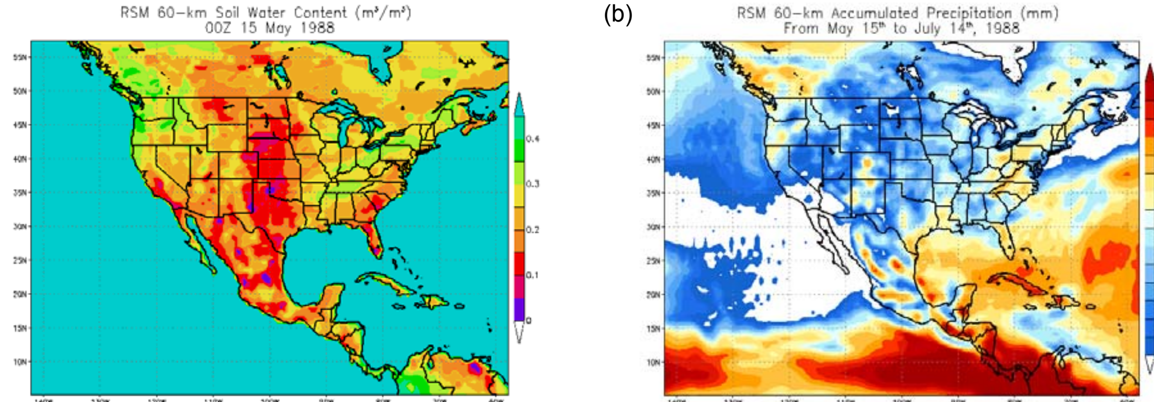

Figure 5. (a) Volumetric soil water content ($m^3\ m^{-3}$) valid at 00 UTC 15 May 1988 and (b) accumulated precipitation from long simulation by ECPCRS valid for the period 00 UTC 15 MAY 1988 through 00 UTC 14 July 1988.