J8.16 IMPORTANCE OF WINDS AND SOIL MOISTURES TO THE U.S. SUMMERTIME DROUGHT OF 1988: A GCM SIMULATION STUDY

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1. INTRODUCTION

The climate version of NASA's GEOS 2 GCM did not simulate a realistic 1988 summertime drought in the central United States (Mocko *et al.*, 1999). Despite several new upgrades to the model's parameterizations, as well as finer grid spacing from 4x5 degrees to 2x2.5 degrees, no significant improvements were noted in the model's simulation of the U.S. drought.

2. MODEL DESCRIPTION

The climate version of the GEOS 2 GCM (DAO, 1996) was configured with 20-sigma levels at a grid spacing of 2x2.5 degrees. Several major upgrades to the model include Microphysics of Clouds with Relaxed Arakawa-Schubert (McRAS, Sud and Walker, 1999) which contains changes in the cloud dynamics and microphysics of the model. The land-surface model used is HYSSiB (Mocko and Sud, 2001), which is based on SSiB (Xue *et al.*, 1991) and includes major changes to the model's land-surface processes, hydrology, and snowmelt physics (Sud and Mocko, 1999).

Observed sea surface temperature and sea ice data from both 1987 and 1988 were used. Initial soil moisture values were taken from a multi-year spin-up of an offline simulation of HYSSiB forced with ISLSCP Initiative I data using the procedure followed in the Global Soil Wetness Project (GSWP, Dirmeyer *et al.*, 1999. Initial atmospheric conditions were taken from ECMWF reanalysis.

3. EXPERIMENT DESIGN

To understand the influence of winds and soil moisture drift on the simulated climate, the following investigation was performed. An ensemble set of four simulations were produced with the GCM from 1 January to 31 August each for 1987 and 1988 served as control (Case 1). Each member of the ensemble was identical except for the date of the initial atmospheric conditions (IACs), taken to be Dec 30, Dec 31, Jan 1, or Jan 2. Four additional parallel cases of ensemble sets (each with four simulations with the above IACs) were performed as follows. The Case 2 set of simulations replaced the model's wind values every 6 hours with reanalysis winds from the NASA Goddard Data Assimilation Office. Case 3 replaced the model's soil moisture values every day with the offline HYSSiB soil moisture values. The Case 4 set of simulations replaced both wind vectors and soil moisture values. Case 5 replaced both winds and soil moisture, but no values were replaced within a box over North America from 23–61N; 129–65W.

4. RESULTS

Figure 1 shows that for Case 1 and Case 3, when the wind was allowed to vary freely, a Great Plains low-level jet stronger than observed developed, and a Midwest U.S. drought was not produced. For Case 2, with simulated wind being replaced with the reanalysis but with naturally varying soil moisture, a drought was simulated, although it was more severe than observed. The most realistic simulation of this drought occurred with Case 4 when both wind vectors and soil moisture values were updated during model integration. Well-simulated moisture convergence (through winds) and local evaporation (through soil moisture) produced a moisture distribution leading to well-simulated precipitation. Case 5 simulated a realistic low-level jet, although the simulated precipitation is only slightly improved from the control over Case 1, showing that the circulation outside of North America has a strong effect on the U.S. summertime circulation. Similar results were found for other months as well as for 1987.

Figure 2 shows that for Case 1, the simulated drought is too far to the eastern U.S. and there is relatively little difference in the wind pattern between 1987 and 1988. With Case 4, the effect of assimilat-

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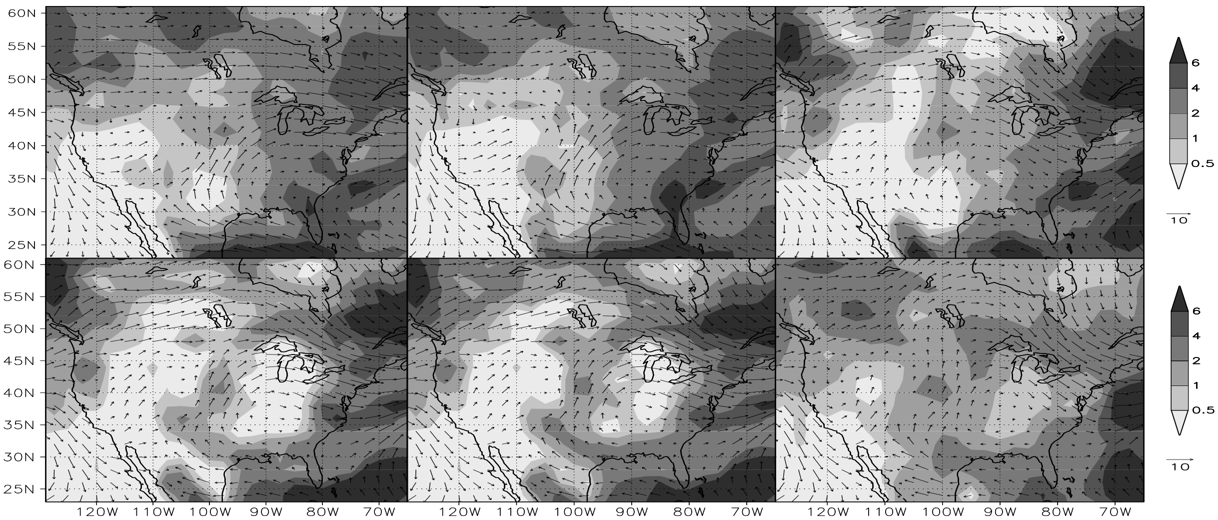

Figure 1: June 1988 ensemble mean precipitation (mm/day) and average surface to 800mb wind vectors (m/sec) for (top, L-R) Case 1, Case 3, Case 5 and (bottom, L-R) Case 2, Case 4, GPCP precipitation estimates/DAO reanalysis wind vectors.

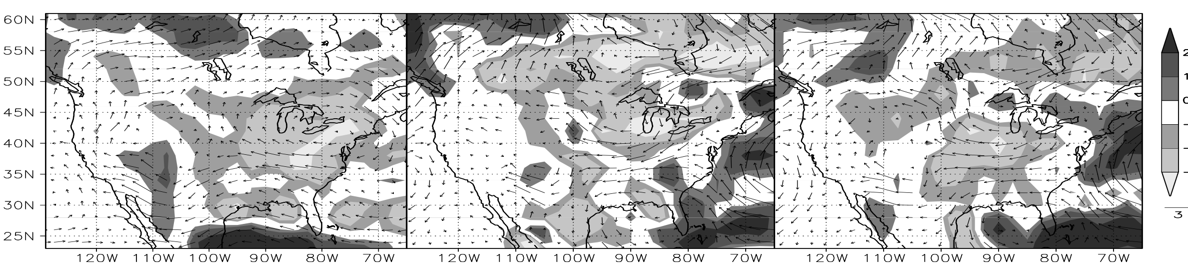

Figure 2: Same as Figure 1, except for JJA 1988–1987 for (L-R) Case 1, Case 4, GPCP precipitation estimates/DAO reanalysis wind vectors.

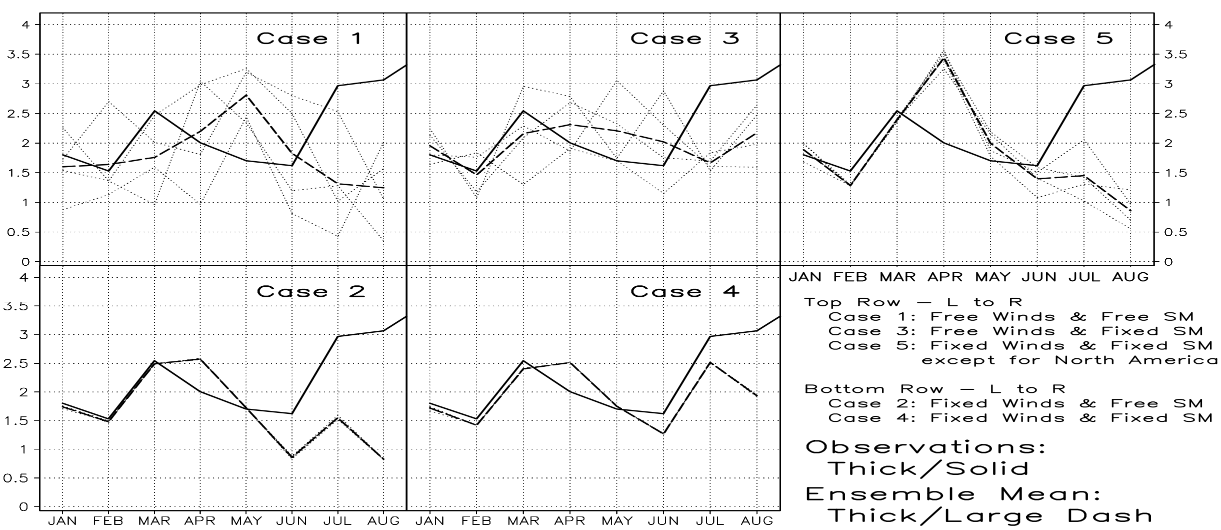

Figure 3: 1988 precipitation (mm/day) averaged from 30–50N; 100–85W for (top, L-R) Case 1, Case 3, Case 5 and (bottom, L-R) Case 2, Case 4. GPCP precipitation estimates (thick and solid); Ensemble Mean (thick and large dashes); Ensemble Members (thin and small dashes).

ing winds of the strong Bermuda high in 1988 leads to a better simulation of the 1988 drought, both over the Midwest and the area near Hudson Bay.

Figure 3 shows that for Cases 1 and 3, considerable scatter exists among the ensemble members, with Case 3 precipitation closer to the observed as a result of replacing soil moisture values. There was virtually no scatter in the simulated precipitation for Cases 2 and 4, showing the strong influence of the wind pattern on the precipitation. For Case 2, however, the mid-to-late summer precipitation was lower than observed. The simulated soil moisture for this case dried too much during the summer which fed back on the local precipitation. A similar behavior was noted for 1987 (not shown). When soil moisture values were replaced with the analyzed during model integration as in Case 4, the early summer drought followed by a slightly wetter late summer was well-simulated. Case 5 showed much less scatter of the simulated precipitation inside the box, although the magnitudes did not match well with the observed.

5. CONCLUSIONS

The results show that replacing the wind vectors had a strong effect on the resultant moisture transport and precipitation in the targeted region of the Midwest U.S. The drought simulated in June 1988 in Cases 2 and 4 was much more realistic as compared to GPCP estimates of precipitation. The Great Plains low-level jet in 1988 was weak in the wind reanalysis. The control Case 1 produced too strong of a low-level jet that brought in too much moisture producing very similar precipitation for both years in this region. Case 3 with replaced soil moisture values slightly improved the 1988 drought simulation. The circulation wind pattern was somewhat improved; however, the low-level jet was still stronger than observed and was able to bring in more moisture. Case 4 with both reanalysis winds and soil moistures simulated the most realistic precipitation for 1987 and 1988 in the central U.S. as compared to GPCP. For Case 5, with winds and soil moistures not replaced over North America, the low-level wind pattern was better simulated than the control, although the simulated precipitation was not much improved. This study shows that drifts in the wind patterns are largely responsible for the realism (or lack thereof) of simulated rainfall. Although physical parameterizations, which may in part be responsible for wind drifts, also contribute to climate drifts, eliminating wind drifts allows the divergent circulation to develop realistically.

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