8.3 Simulations of the 1988 Drought and 1993 Floods in North American using the Eta Regional Climate Model

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1. ABSTRACT

To examine climate predictability on seasonal time scales (3-6 month forecasts) using regional models, in this study we continue our advancement and testing of a high resolution (32-km), Eta model-based Regional Climate Model (Eta RCM). The model is an adaptation of the NCEP operational Eta NWP model as of 24 July, 2001 (which is the Eta model version used in the NCEP 25-year Regional Reanalysis), with changes made to make the configuration of the model execution consistent with the longer time scales of seasonal forecasts, including daily updates to the fields of sea surface temperature (observed), sea ice cover (observed), green vegetation cover (climatology), and albedo (climatology).

To test the skill of the Eta RCM in predicting warm-season anomalies of precipitation, two summertime cases were chosen: 1988 and 1993, where 1988 is known for severe drought in the most part of the U.S., whereas 1993 manifested heavy flood-producing rainfall in the central United States. In contrast to many previous RCM studies driven by analysis lateral boundary conditions and initialized from one single date (i.e., one member realization), we used ensemble approach and both analyzed and predicted lateral boundary conditions. For each year, the model was run from three different initial dates starting from late May. For each run, analyzed lateral boundary conditions from the NCEP Global Reanalysis II and observed sea surface temperature (SST) were used. Our focus in this study is the total precipitation and interannual variability.

We examine the resulting ensemble mean and individual members to demonstrate a) whether the Eta RCM successfully captures both wet and dry anomalies in total precipitation over the U.S. in the two years, and b) the predictability of such extreme events relative to the choice of initial land states. The results show that the Eta RCM can capture the dry/wet bias in the precipitation during both years and has notable sensitivity to the choice of convection schemes and lateral boundary conditions with substantial member-to-member variability (not shown). However, the sensitivity of the model to initial land states was not evident; indicating that something else in the systems plays a bigger role. Also the large member-to-member variability suggests that previous RCM studies that employed only "one member" initialized from one single date may be misleading by overlooking inherent internal variability.

2. INTRODUCTION

Moisture availability is very important to many things on earth including agriculture, human life and human activities. The right amount of precipitation is thus the ultimate goal of modern weather forecast and climate prediction. Too much rainfall can cause severe damages to the people's well being such as those experienced in the U.S. Midwest in the summer of 1993. Too little rainfall can produce drought, for instance, the summer of 1988. Several tens of millions of dollars were lost through damage in that event. Therefore the most important goal of current climate prediction is to better understand the processes in the atmosphere involved in these major events and an improved understanding of the physics behind these processes should advance the accuracy of hydroclimate forecasts.

It is well established that seasonal climate anomalies over continental regions are forced in part by slowly varying boundary conditions of sea surface temperature (SST) and land surface conditions. It is also well established that the SST anomalies, especially in the tropical oceans, can be predicted by the coupled ocean-atmosphere model. It is therefore reasonable to expect that accurate prediction of boundary conditions would allow prediction of regional climate for a lead time beyond the limit of a deterministic predictability.

3. EXPERIMENTS, DATA AND CASES CHOSEN

To evaluate if regional climate modeling can add values to existing climate modeling using downscaling technology, here we developed and tested a high-resolution Regional Climate Model. The regional climate model used in this study is a slightly modified version of the NCEP EMC Eta model that became operational in November of 2001. The Eta model is a state-of-the-art mesoscale weather forecast model, with an accurate treatment of complex topography using the eta vertical coordinate and step-like mountain (Mesinger, 1984; Black, 1994), which eliminates errors in the pressure gradient force over steeply sloped terrain present in the sigma coordinates. The model employs s semi-staggered Arakawa E-grid in which wind points are adjacent to mass points., configured in a rotated spherical coordinates. The model physics has been described by Janjic (1990, 1994), and includes a modified Betts-Miller scheme (Betts and Miller, 1986) for deep and shallow convection, and predicted cloud water. The GFDL scheme is used for radiation. Free atmospheric turbulent exchange above the lowest model layer is via Mellor-Yamada level 2.0, and the surface layer similarity functions are derived from Mellor-Yamada level 2.0 (Mellor and Yamada, 1982). A viscous sublayer is used over water surfaces. The land surface is a version of the Oregon State University scheme modified by Chen et al (1997) and Ek (2003).

To test how the model performs in the simulation of warm season precipitation, the Eta Regional Climate model developed here at National Centers for Environmental Prediction (NCEP) was used. The Eta RCM was based on the operational Eta model as of July 24, 2001 and as implemented in the Regional Reanalysis (RR). Currently, the model has a horizontal resolution of 32 km with 45 levels. To make the model run over a longer period of time, we update sea surface temperature on a daily basis. We also update monthly greenness fraction based on satellite NDVI based products, and seasonal 1 degree snow free albedo climatology.

Two sources of initial land states were used. The first is from the NCEP Global Reanalysis II, and the other is from the just completed NCEP Regional Reanalysis. The initial snow depth data were from the US Air Force 47 km daily snow depth analysis.

In contrast to traditional "one member" method, we use 3 ensemble members, whose starting dates vary by 1 and a half day. For 1988, they are 28, 29, and 31 of May, and for 1993, they are 27, 28, and 30 of May respectively. The integration is about 4 months long, starting from late April to the end of September.

The results shown here are ensemble means using different land states: Global Reanalysis II versus Regional Reanalysis for both years. Our focus is two-fold. One is the total precipitation. The other is interannual variability.

4. RESULTS

Figure 1 shows the ensemble mean of total precipitation (in mm) for the summer of 1988 using Global Reanalysis II as land states. Figure 2 is the same as Figure 1 except using Regional Reanalysis as land states. Inspection of the two Figures finds out that the bulk of the features on Figure 1 also exist on Figure 2. However, the one using RR land states seems to be drier in both June and July, especially over the North American Monsoon Area, demonstrating that the difference in initial soil moisture can make a difference in the first couple of month's warm season precipitation simulations. However, when the months go to August and September, the difference in precipitation arising from using different initial land states is not evident.

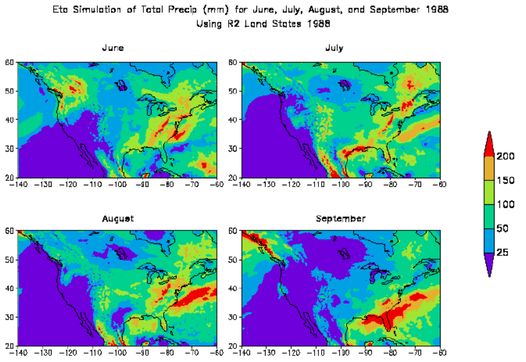

Figure 1. Ensemble Mean Precipitation for June, July, August, and September, 1988 using Global Reanalysis II as land states

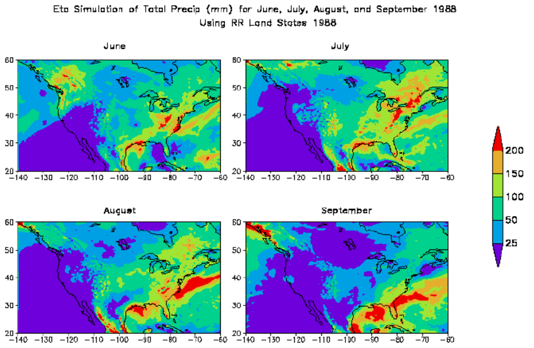

Figure 2. Ensemble Mean Precipitation for June, July, August, and September, 1988 using Regional Reanalysis land states

Figure 3 show the corresponding ensemble mean of total monthly precipitation for June, July, August, and September for 1993 using Global Reanalysis II as land states. Whereas Figure 4 is the same as Figure 3 except that Regional Reanalysis land states were used. Similar to what we have seen on both Figures 1 and 2. The tendency that the model with Regional Reanalysis land states generates less rainfall than the model with Global Reanalysis II land states. Also, the differences in precipitation caused by the choice of initial land states were damped out of the system as the integration goes on.

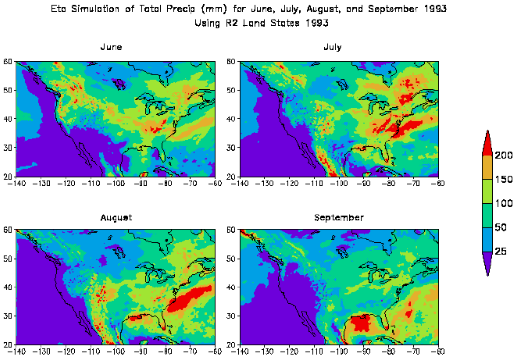

Figure 3. Ensemble Mean Precipitation for June, July, August, and September, 1993 using Global Reanalysis II land states

Figure 5 shows that the observed difference in precipitation for June, July, August, September between the two years (1993 minus 1988). It is evident that 1993 had more rainfall than 1988 for the most central part of the country. However, it should also be pointed out that for the most part of Southeast U.S., they experienced severe droughts in 1993. Figure 6 shows the difference in ensemble mean precipitation between the two years using the Global Reanalysis II land states, and Figure 7 shows the same thing as the Figure 6 except that Regional Reanalysis land states were used. These figures indicate that the Eta RCM tends to produce more rainfall when the Global Reanalysis II land states were used, especially for June and July.

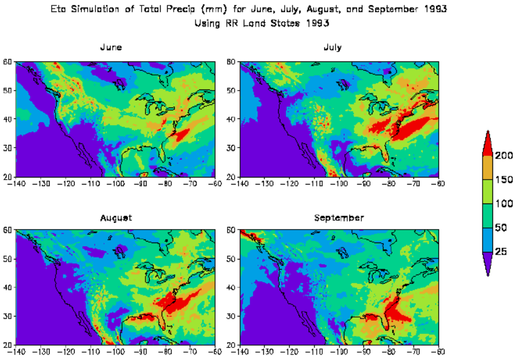

Figure 4. Ensemble Mean Precipitation for June, July, August, and September, 1993 using Regional Reanalysis II land states

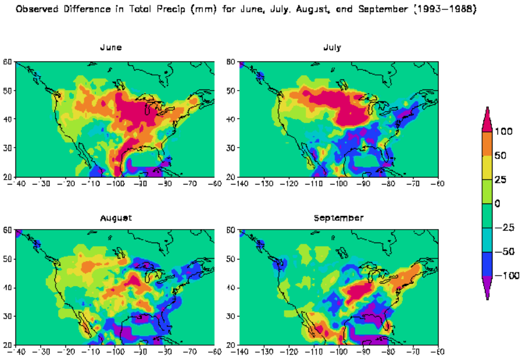

Figure 5. Observed Difference in Precipitation for June, July, August, and September, between 1993 and 1988

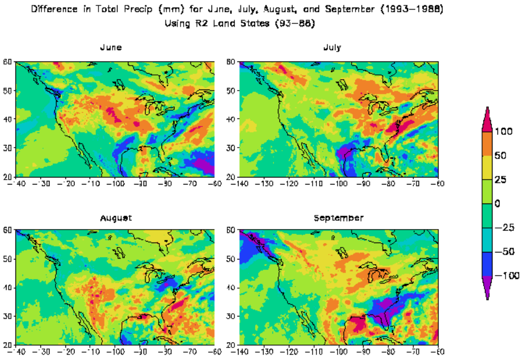

Figure 6 Difference in Ensemble Mean Precipitation for June, July, August, and September between 1993 and 1988 using Global Reanalysis II land states

Compared to observation, the difference in precipitation between the two years was well simulated by the model using both sources of land states. However, the one with RR land states seems to do a better job on July, especially over South Carolina, North Carolina, Virginia, Florida, and West Virginia where the direst seasons occur from June to August in 1993.

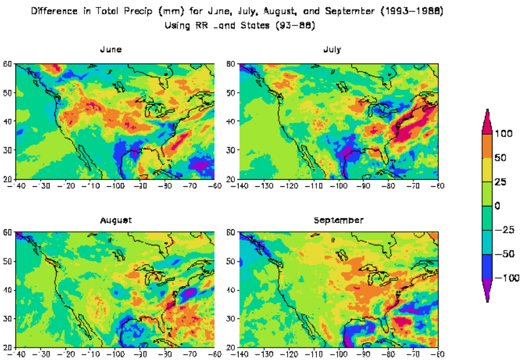

Figure 7 Difference in Ensemble Mean Precipitation for June, July, August, and September between 1993 and 1988 using Regional Reanalysis land states

5. CONCLUSIONS

This study presents the simulation results of the Eta RCM runs for both 1988 and 1993. The model is able to capture the dry/wet anomalies between the two years, demonstrating that the lateral boundary conditions do play an important role in the extremes. However, the impact of difference in initial prescribed land states is only evident for the first couple of month, indicating that the contribution of land surface to precipitation anomalies is only part of the story and needs to be investigated further. Weak coupling of precipitation anomalies to initial land states at a later time implies that the initialization and monitoring of soil moisture may have limited improvement of seasonal precipitation forecasts over a longer time scale in the Eta RCM modeling system.

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