PREDICTABILITY OF LONG-TERM DROUGHT IN THE UNITED STATES GREAT PLAINS

Siegfried Schubert: NASA/GSFC, schubert@dao.gsfc.nasa.gov
Max Suarez: NASA/GSFC, max.suarez@gsfc.nasa.gov
Philip Pegion: GSC NASA/GSFC, pegion@janus.gsfc.nasa.gov

1. Introduction

The United States Great Plains experienced a number of devastating droughts during the last century (Bark, 1978; Woodhouse,and Overpeck 1998). The 1930s drought was the most severe, lasting for almost a decade, and affecting about 2/3 of the country and parts of Canada. A second major drought occurred during the 1950s. While also extensive, this drought was most severe in the southern and central Great Plains.

In this study, we present recent progress in understanding the nature of these multi-year droughts in the Great Plains and provide some insight into their predictability. The results are based on an ensemble of nine 70-year (1930-1999) simulations carried out with the NASA Seasonal-to-Interannual Prediction Project (NSIPP-1) atmospheric-land general circulation model (AGCM) run at a horizontal resolution of 2° latitude by 2.5° longitude, and forced by observed sea surface temperatures (SSTs). We also present results from some runs with idealized SST forcing. The model is part of the NSIPP coupled atmosphere-land-ocean model; however, for these experiments, it was run uncoupled from the ocean.

2. Results

The nine 70-year runs were forced with identical SSTs (the observed) and differ only in their initial atmospheric conditions: the initial conditions were chosen arbitrarily from previously completed simulations. Figure 1 shows the simulated precipitation over the Great Plains from all nine runs. The results are filtered to isolate time scales longer than about six years. There is considerable scatter among the nine ensemble members, nevertheless, the runs do show some similarities. For example, during the 1930’s almost all the runs show a tendency for dry conditions, consistent with the observations. This is followed, in the early 1940's, by wet conditions, again consistent with the observations. On the other hand, during the 1950's, the runs show a mixture of dry and wet conditions. Only one of the nine runs is as dry as what was observed. In general, it appears that the model results are not inconsistent with the observations in the sense that the observations tend to fall within the spread of the ensemble members.

We can obtain some idea of the connection between the Great Plains precipitation and the SST by correlating the ensemble mean filtered Great Plains precipitation (green curve in Figure 1) with the similarly filtered SST at all points. The correlations, with a sign change to emphasize the connection with dry conditions over the Great Plains (lower panel of Figure 2), show a large-scale coherent structure that has some similarity to the cold phase of an El Nino/Southern Oscillation (ENSO) event. Reduced precipitation in the Great Plains on these long time scales is associated with negative SST anomalies throughout the central tropical Pacific Ocean, extending northward toward the west coast of North America. The negative SST anomalies are flanked by positive anomalies that extend poleward and eastward from the western tropical Pacific. We show in Figure 2a, the correlation between the ensemble mean filtered Great Plains precipitation and the filtered ensemble mean 200mb height field at all points. This shows that Great Plains precipitation is associated with global scale height anomalies. Dry conditions are associated with positive height anomalies in the middle latitudes of both hemispheres, and reduced heights in the tropics and the high latitudes. We note that the zonally-symmetric structure of the height anomalies found here is similar to the dominant structure found on interannual time scales during northern summer (Schubert et al. 2002).

The above results suggest that low frequency variations in Great Plains precipitation are, at least in part, controlled by large scale pan-Pacific SST anomalies that resemble the correlation pattern shown in Figure 2b. It turns out that the pan-Pacific SST pattern shown here is the dominant pattern of SST variability on these very long time scales (based on an empirical orthogonal function analysis – not shown). To further support this Great Plains/SST link, we have carried out several additional AGCM simulations in which the model is forced for 40 years by the positive and negative versions of the pan-Pacific SST anomalies shown in Figure 2b (we actually use +/- 2 standard deviations of the dominant SST empirical orthogonal function). A third 40-year run was done with seasonally varying climatological SSTs (no anomalies). The results, shown in Figure 3, confirm that the cold phase of the pan-Pacific SST pattern tends to produce drier than normal conditions in the Great Plains, while the warm phase tends to produce wetter than normal conditions. Here normal is defined as the average of the case with no SST anomalies (the straight black line in Figure 3).

One rather remarkable and unexpected result from these idealized SST runs is that the case without SST anomalies (the black curve) exhibits rather pronounced multi-year precipitation variations. For example, during years 10-20 the Great Plains are nearly as dry as for the cold SST run, while during years 30-40 the Great Plains are wetter than that for the warm SST run. This suggests that the model is capable of producing multi-year (even decade-long) droughts in the absence of any non-seasonal SST variations.

3. Conclusions

The results of this study show that the NSIPP-1 model, when forced by observed SSTs, does produce low-frequency (multi-year) variations in the Great Plains precipitation similar to those observed. In particular, the model produces the dry conditions of the 1930s “dust-bowl” era. On the other hand, the model does not show a strong tendency for the dry conditions that were observed during the early 1950s (only one of the nine ensemble members reproduced the dry conditions). A correlative analysis suggests that the low frequency variations in the Great Plains precipitation are linked to variations in a pan-Pacific decadal SST pattern. This was confirmed by further AGCM simulations, in which the model was forced by the 2 polarities of the Pacific SST pattern. These runs, as well as the nine 1930-1999 runs, show that when the Pacific decadal SST pattern is in its warm phase, the Great Plains tends to have above normal precipitation, while there is a tendency for drought during the cold phase. Our results also suggest that precipitation in the Great Plains can exhibit very low frequency (decadal time scale) variations even in the absence of SST anomalies. The nature of these variations and the implications for the predictability of drought in the Great Plains are currently under investigation.

References

Bark, D.L., 1978: History of American Droughts. *North American Droughts*. AAAA Selected Symposia Series. Westview Press, Boulder Colorado, N.J. Rosenberg, Ed., pp 9-23.
Felch, R.E., 1978: Drought: Characteristics and assessment. *North American Droughts*. AAAA Selected Symposia Series. Westview Press, Boulder Colorado, N.J. Rosenberg, Ed., pp 25-42.

Schubert, S.D., M.J. Suarez, P.J. Pegion, M.A. Kistler, and A. Kumar, 2002: Predictability of zonal means during boreal summer. J. Climate, 15, 420-434.

Woodhouse, C.A. and J.T. Overpeck 1998: 2000 years of drought variability in the central United States. Bull.Amer.Meteor.Soc., 79, 2693-2714.

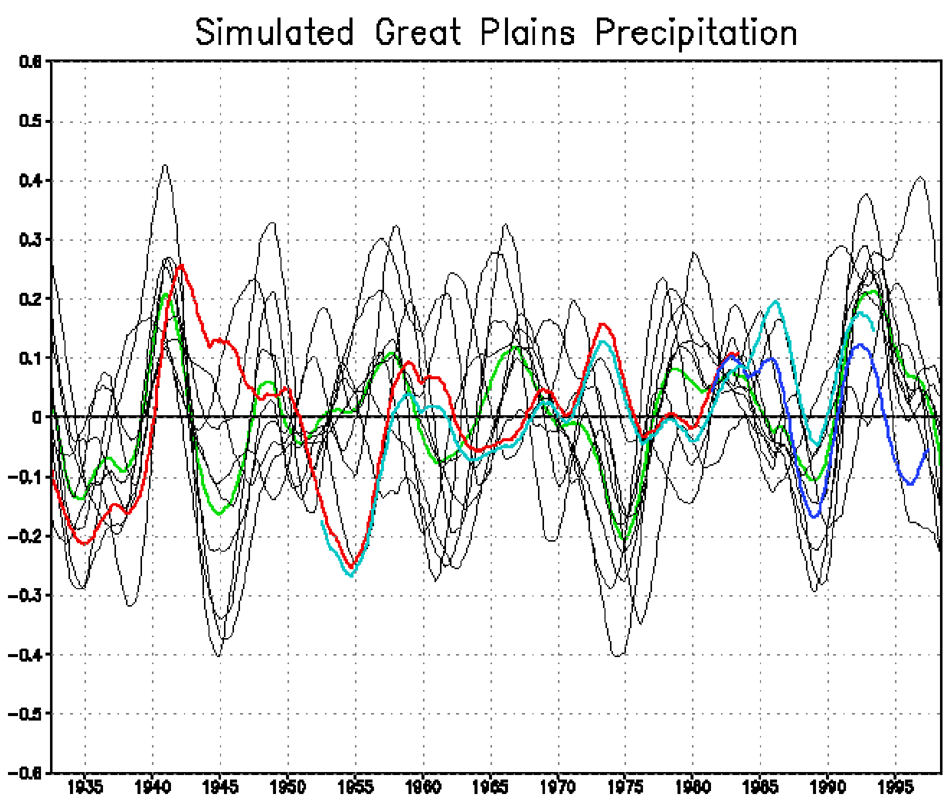

Figure 1: Time series of precipitation anomalies over the Great Plains (30°-50°N, 95°-105°W). A filter is applied to remove time scales shorter than about 6 years. The black curves are the results from the nine ensemble members produced with the NSIPP-1 model forced by observed SST. The green curve is the ensemble mean. All the other colored curves are various observational estimates.

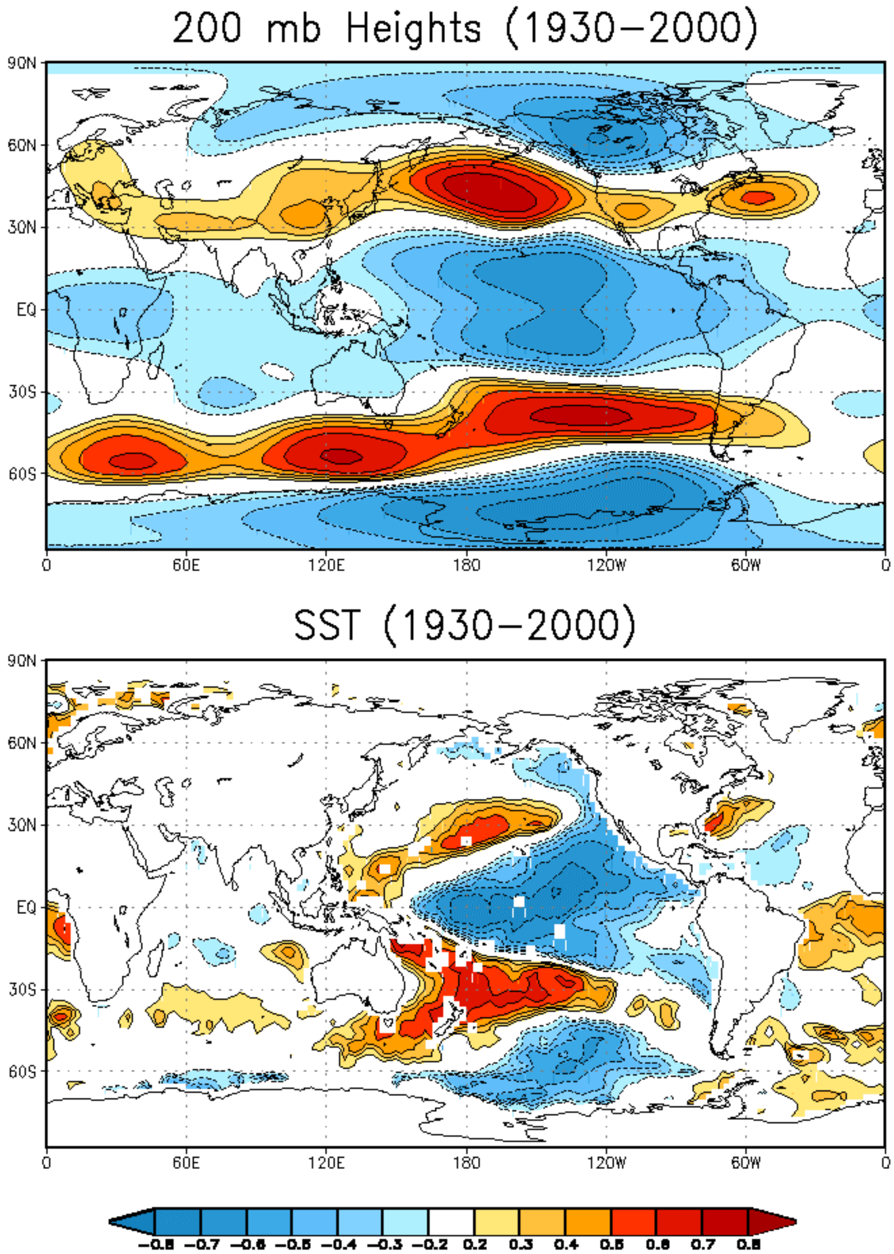

Figure 2: The negative of the correlation between the low-pass filtered ensemble mean simulated precipitation anomalies over the Great Plains (green curve in Fig. 1) and 200mb height (top panel), and SST (bottom panel) for the period 1930-1999.

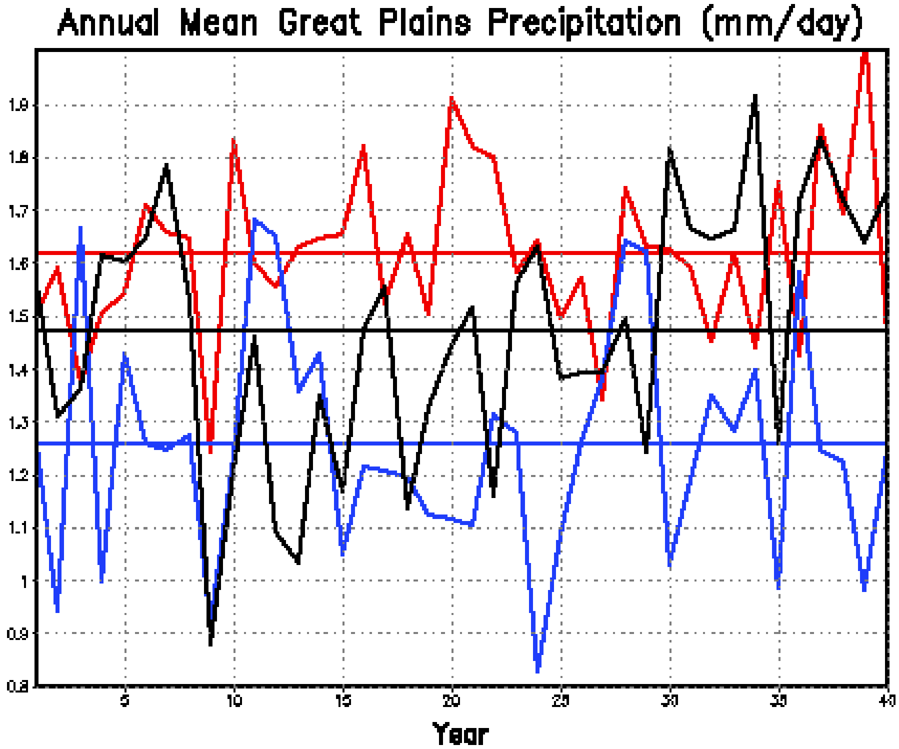

Figure 3: Model simulations of the annual mean precipitation over the United States Great Plains region (30-50°N, 95°-105°W). In these idealized runs the model is forced by the global SST anomalies resembling those shown in Fig. 2 (+/- 2 standard deviations). The red curve shows the results for the run forced by SST with positive anomlaies in the tropical central Pacific (the warm phase). The blue curve shows the results for the run forced by SST with negative anomalies in the tropical central Pacific (the cold phase). The black curve is for the case with no anomalies. The straight lines are the corresponding 40-year means.