Do the IPCC AR4 climate models simulate the Dust Bowl of the 1930s?

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1. Introduction

The U.S. Great Plains experienced a number of multiyear droughts during the twentieth century, notably the droughts of the 1930s and 1950s. These droughts were characterized by decades of rainfall deficits and high temperatures that destroyed much of the land surface of the Great Plains. The 1930s drought was also associated with severe dust storms that led to its characterization as the "Dust Bowl." Drought in the Great Plains is not unique to the last century. Proxy records show that multiyear droughts similar to those of the 1930s and 1950s have occurred approximately once or twice a century over the past 400 years. It is also probable that multiyear droughts will occur in the Great Plains in the future (Schubert et al. 2004).

With the increasing demand to understand how global warming may influence the climate system, it is an interesting exercise to determine if the IPCC AR4 coupled ocean-atmosphere climate models are capable of simulating drought in the Great Plains with the same frequency and intensity as the observations. It is also important to determine what mechanisms cause drought to occur in the models, and if these are the same mechanisms by which drought occur in the observations of the Great Plains.

2. Data

The twentieth century climate simulations of five IPCC AR4 models were chosen for this study (Table 1). The necessary data was collected from the PCMDI web archive. The twentieth century climate simulations were initialized from a preindustrial control run so that the atmospheric content of trace gases and the solar irradiance was representative of the late nineteenth century. In general, the models included a historical timeseries of atmospheric greenhouse gases, sulfate aerosol direct effects and volcanic eruptions as external forcings.

A gridded monthly mean precipitation data set from the Climate Research Unit was used for comparison with the models. The data set has a horizontal resolution of 0.5° x 0.5° and is available for the period 1901-1998 (New et al., 2000).

Model Name	Center/country	Atmospheric Resoltuion lat x lon
BCM2.0	Bjerknes Centre for Climate Research (BCCR)/Norway	~ 2.8 x 2.8
CCSM3	National Center For Atmospheric Research (NCAR)/United States	~1.4 x 1.4
CGCM3.1	Canadian Centre for Climate Modelling and Analysis(CCCma)/Canada	~3.75 x 3.75
HadCM3	Met Office/United Kingdom	~2.5 x 3.75
MIRCO3.1-hires	Center for Climate System Research (CCSR)/National Institute for Environmental Studeis(NIES)/ Frontier Research Center for Global Change (FRCGC)/Japan	~1.125 x 1.125

Table 1. Climate models selected for this study.

3. Climatological Precipitation

Great Plains domain - 30-50 N, 95-105 W

Created time series of precipitation anomalies averaged over the Great Plains domain.

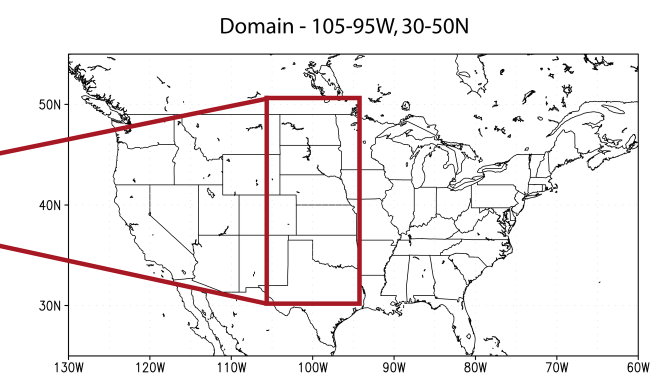

Figure 1. Great Plains Domain

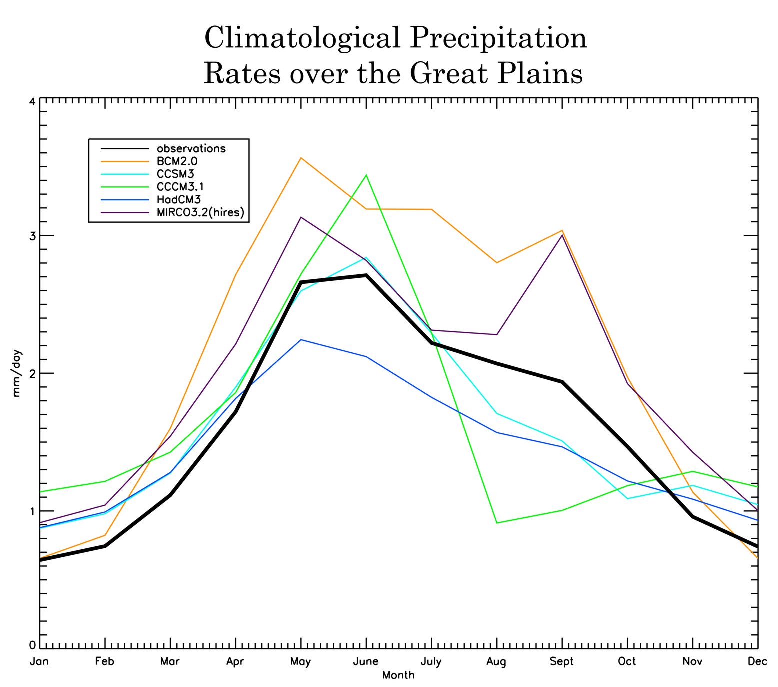

Figure 2. Monthly mean climatological precipitation averaged over the Great Plains ((30°-50°N, 95°-105°). Units are in mm/day. Observations are represented by the thick black line.

	DJF	MAM	JJA	SON
Observations	0.71	1.83	2.33	1.45
BCM2.0	0.71	2.63	3.06	2.05
CCSM3	1.17	2.00	2.21	1.15
CGCM3.1	0.97	1.92	2.27	1.26
HadCM3	0.93	1.78	1.84	1.25
MIRCO3.1-hires	0.98	2.30	2.47	2.11

Table 2. The time mean precipitation averaged over the Great Plains (30°-50° N, 95°-105°). Unites are in mm/day. Note greatest precipitation rates occur during JJA

According to the observations, average precipitation rates over the Great Plains tend to be greatest during the spring and summer and peak at approximately 2.7mm/day in June. During the fall and winter, precipitation rates are much lower (typically less than 1mm/day) (Figure 2).

Approximately 40% of the annual mean precipitation occurs during the summer moths (JJA) (Table 2). This is why precipitation deficits during the spring and summer can have devastating effects on the Great Plains.

In general, the models also show maximum precipitation rates occurring in spring/summer, although both BCM2.0 and MIRCO3.2(hires) also show second precipitation maximums occurring in the fall. As figure 2 shows, HadCM3 typically underestimates precipitation rates in the Great Plains while BCM2.0 tends to overestimate precipitation rates. Overall, CCSM3 has the most accurate representation of the seasonal cycle of precipitation over the Great Plains.

During the summer, the western United States is dry (receiving <10mm of precipitation), the eastern United States is very wet (receiving >200mm of precipitation) while the Great Plains tend to be somewhere in the middle (~60-100 mm)(Figure 3, upper left). All of the models show a similar pattern for JJA precipitation, although HadCM3 tends to overestimates the moisture over the eastern United States and BCM2.0 overestimates the dryness of the western United States (Figure 3).

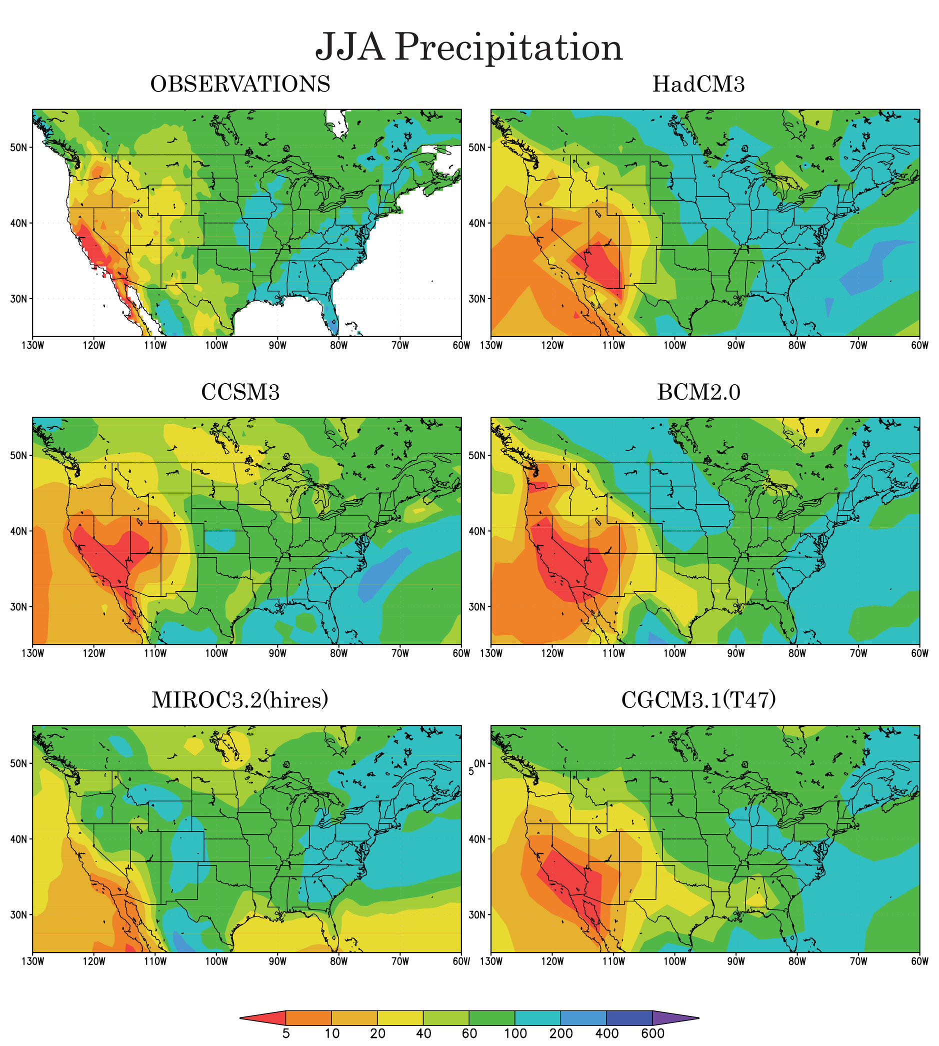

Figure 3. Climatological preciptation for JJA over the United States. Note that units are mm.

4. Drought in the Great Plains

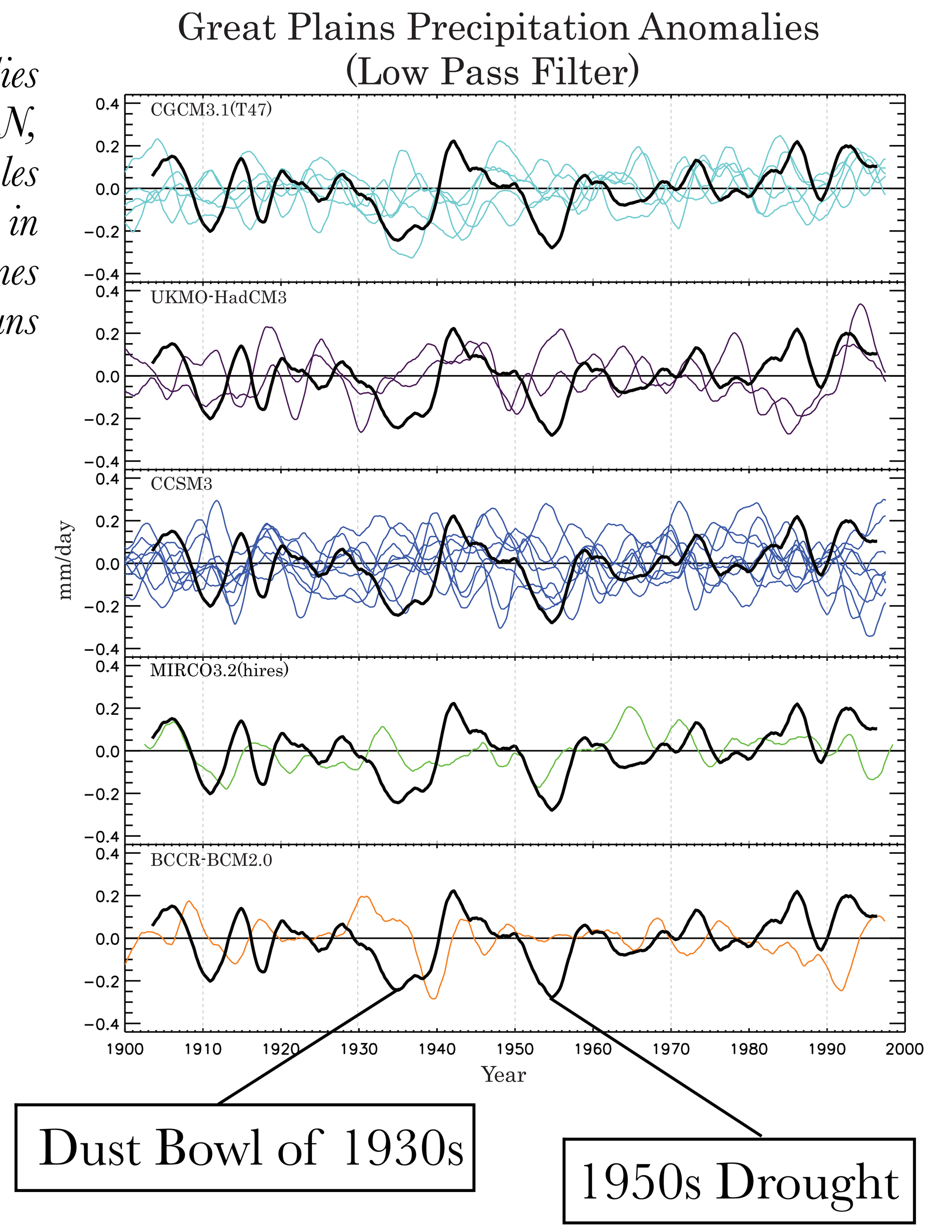

Figure 4. Time series of precipitation anomalies averaged over the Great Plains (30-50N, 95-105W. Filter is applied to remove time scales shorter than about 6 years. Thick black curve in all figures is the observations. Thin colored lines are model results. Some models have multiple runs of data.

The time series of precipitation anomalies averaged over the Great Plains were filtered using a low-frequency filter described by Zhang et al. 1997. This filter retains time scales of approximately 6 years and longer and effectively removes the effects of ENSO. This allows us to focus more attention on the longer scale fluctuations of precipitation that occurred during the droughts of the 1930s and 1950s.

Overall, the models do not experience drought at the same time as the observations, but typically each model run does experience one or two extremely dry periods throughout the twentieth century. It is apparent that different initial conditions result in dramatically different time series of precipitation anomalies (see CCSM3, Figure 4).

5. Conclusion and Future Work

Using five coupled ocean-atmosphere climate models from the IPCC AR4 we are investigating the nature of drought over the Great Plains. We are particularly interested in understanding why drought occurs over the central United States and if the models are capable of accurately simulating drought with the same frequency and intensity that occurred during the twentieth century. Preliminary results suggest that the models do experience droughts with the same intensity as the 1930s and 1950s, but possibly not with the same frequency.

Future work includes: Determine the spatial characteristics of drought over the Great Plains, investigate why drought occurs over the Great Plains in the models and the observations, and look into the role that vegetation has on sustaining drought conditions over the Great Plains.

6. References

New, M., M. Hulme, and P. Jones, 2000: Representing Twentieth-Century Space-Time Climate Variability. Part II: Development of 1901-96 Monthly Grids of Terrestrial Surface Climate, *J. Climate*, **13,** 2217-2238

Schubert, S.D., M.J. Suarez, P. J. Pegion, R. D. Koster, and J. T. Bacmeister, 2004: Causes of Long-Term Drought in the U.S. Great Plains, *J. Climate*, **17,** 485-503

Zhang, Y., J. M. Wallace, and D. Battisti, 1997: ENSO-like interdecadal variability:1900-93. *J. Climate*, **10**, 1004-1020