Development and Persistence of North American Mid-Continental Aridity

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ABSTRACT

The 40-year-long NCAR/NCEP reanalysis data set was analyzed to determine the interactions among the surface energy- and water-balance and atmospheric circulation that controlled mid-continental aridity during the Holocene. Composite anomaly maps of climatological time scales for soil moisture, precipitation, temperature, and circulation patterns, which prevail during extreme dry and wet years, were calculated based on precipitation and 500 mb height time series to identify the mid-continent of North America. Anomalously low precipitation rates are associated with increased soil moisture content, above-normal temperatures, and establishment of upper-level ridge over central North America. The mid-continent persistence of anomalously dry conditions suggest a feedback in created where less moisture available in the surface elevations dry conditions. Anomalously dry years are also related to decreased precipitation rates in the Great Plains and increased precipitation in the Great Lakes region. Wet years are associated with below-normal surface temperatures, upper-air trough, and increased precipitation from the Gulf of Mexico and eastern Pacific Ocean. Wet years also exhibit higher-than-normal soil surface temperatures associated with El Niño events. These results offer important implications for understanding the genesis of aridity during the Holocene.

OBJECTIVES

- To determine the interactions between surface energy- and water-balance and circulation during extreme dry and wet years;
- To provide mechanistic perspective on the controls of Holocene mid-continental aridity.

DATA

- The NCAR/NCEP reanalysis data consists of hundreds of climate variables at daily, monthly, and climatological time scales (Kalnay, et al., 1995, Bull Am Met Soc 77 (3): 437-471);
- Gridded monthly data from 1959-1997 for 16 circulation and surface variables are used here;
- Spatial resolution for circulation variables is 2.5x2.5 degrees and ca. 1.875x1.899 degrees for surface variables.

METHODS

- A time-series index based on precipitation rate was created for selection of extreme dry and wet years;
- The moisture index represents a homogeneous region within the mid-continent of North America that was identified by examining correlation fields;
- Composite anomalies are an average of extreme wet and dry years were calculated to show patterns between circulation and surface processes;
- Monthly anomalies for 12 surface energy- and water-balance components were calculated to illustrate the variations of the seasonal cycle of these variables.

RESULTS

- Composite anomaly dry years are 1963, 1964, 1966, 1971, 1976, 1979,
- Dry composite anomaly maps show low soil moisture, decreased precipitation, increased temperatures, and sinking air associated with an upper-level ridge over central North America;
- Wet composite anomaly maps show higher soil moisture, increased precipitation, decreased temperatures, and rising air associated with an upper-air trough.

DISCUSSION

- Monthly surface energy- and water-balance variables for both composite dry and wet years emphasize the characteristics and persistence of surface conditions in the seasonal cycle during anomalously dry and wet periods;
- Factors that cause anomalously dry years are not always inversely related to those that cause anomalously wet years;
- During dry years increased short-wave radiation leads to more direct heating of the surface, and this combined with lower precipitable water in the atmosphere creates dry conditions, decreased soil moisture, decreased latent heating, and consequently further warmth from increased sensible heating;
- This behavior of the present climate system demonstrates the potential for biophysical amplification of externally forced (e.g. by insolation) climate anomalies in the interior of North America during the Holocene.

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