Title: Multimodel ensemble reconstruction of drought over the continental United States
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Authors List with E:
Aihui Wang*[1] wangaihui@mail.iap.ac.cn
Theodore J. Bohn[1] tbohn@hydro.washington.edu
Sarith P. Mahanama[2] sarith.p.mahanama@nasa.gov
Randal D. Koster[2] Randal.D.Koster@nasa.gov
Dennis P. Lettenmaier[1] dennisl@u.washington.edu

ABSTRACT

Retrospectively simulated soil moisture from an ensemble of six land surface/hydrological models was used to reconstruct drought events over the continental United States for the period 1920 to 2003. The simulations were performed at one-half-degree spatial resolution, using a common set of atmospheric forcing data and model-specific soil and vegetation parameters. Monthly simulated soil moisture was converted to percentiles using Weibull plotting position statistics, and the percentiles were then used to represent drought severities and durations. An ensemble method, based on an inverse mapping of the average of the individual model's soil moisture percentiles, was also used to combine all models' simulations. Major results are: 1) all models and the ensemble reconstruct the known severe drought events during the last century. The spatial extents and severities of drought are plausible for the individual models although substantial among-model disparities exist; 2) The simulations are in more agreement with each other over the eastern than over the western United States; 3) Most of the models show that soil moisture memory is much longer over the western than over the eastern United States. The results provide some insights into how a hydrological nowcast system can be developed, and early results from a test application within the University of Washington's real-time national Surface Water Monitor, and a review of the multi-model nowcasts during the southeastern drought beginning in summer, 2007, are included.

POPULAR SUMMARY

Droughts are a recurrent, and costly, natural hazard. According to a report of the Western Governors Association (2003), an "extreme" or "severe" drought has been experienced in some part of the United States in every year since 1895. The 1988 drought alone cost nearly $62 billion, more than the cost of the 1993 Mississippi River flood and Hurricane Andrew combined (National Climate Data Center 2003). Historically, droughts of decadal length or longer, such as the Dust Bowl drought of the 1930s, have occurred one or two times per century on average. Droughts can be classified according to their

*First author now at : *Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China.*
[1] *Department of Civil and Environmental Engineering, University of Washington, Seattle, WA 98195*
[2] *Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt MD 20771*

characteristics and impacts as falling in one of four categories: agricultural, meteorological, hydrological, and socioeconomic (American Meteorological Society 1997); however most droughts are classified, based on their physical characteristics, into one of the first three categories. Two methods have been used to assess and reconstruct past droughts. The first is based on indices derived from meteorological and hydrological data. The most prominent drought index is the PDSI which is driven by precipitation and temperature, but essentially reconstructs a soil moisture index. The second method of assessing drought severity is to analyze simulated variables from atmospheric or hydrological models. The major advantage of this approach is that it is based on variables (soil moisture, runoff) that are directly related to drought properties. A further advantage of this approach is a direct link (i.e., by providing model initial conditions) to predictions of future droughts. A drawback of using coupled land-atmosphere models to reproduce drought-related variables is that they are reliant on the accuracy of the parameterizations and land-atmosphere feedback mechanisms incorporated in the model – for instance, model errors in cloud and radiation parameterizations affect both precipitation and evapotranspiration, however.

An alternative approach is to use land surface models (LSMs) off-line (that is, forced by surface meteorological variables such as precipitation, temperature, and downward shortwave and longwave radiation), an approach which removes the effects of atmospheric model errors. The drought-related variables so produced can provide insights into possible characteristics, and perhaps mechanisms, of future drought. This paper deals with reconstructing major droughts of the 20th century over the continental United States using a suite of LSMs. Six LSM were forced offline using the same meteorological forcings and model-specific soil and vegetation parameters on 1/2 –degree grid for the period 1920-2003. Monthly simulated soil moisture was converted to percentiles using Weibull plotting position statistics, and the percentiles were then used to represent drought severities and durations. An ensemble method, based on an inverse mapping of the average of the individual model's soil moisture percentiles, was also used to combine all models' simulations. Major results are: 1) all models and the ensemble reconstruct the known severe drought events during the last century. The spatial extents and severities of drought are plausible for the individual models although substantial among-model disparities exist; 2) The simulations are in more agreement with each other over the eastern than over the western United States; 3) Most of the models show that soil moisture memory is much longer over the western than over the eastern United States. The results provide some insights into how a hydrological nowcast system can be developed, and early results from a test application within the University of Washington's real-time national Surface Water Monitor, and a review of the multi-model nowcasts during the southeastern drought beginning in summer, 2007, are included.