Geophysical Research Abstracts
Vol. 15, EGU2013-5963, 2013
EGU General Assembly 2013

Megadroughts in Southwestern North America: A data-model comparison using last-millennium GCM simulations and the proxy-derived North American Drought Atlas

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Some of the starkest features of proxy-estimated hydroclimate variability in the North American Southwest (NASW; 125°W–105°W, 25°N–42.5°N) are the severe and multidecadal drought periods that have existed in the region. These so called megadroughts are a prominent and well-established feature of the NASW's hydroclimate history. Given the prominence of these features in our recent past, it is imperative to consider whether Atmosphere-Ocean General Circulation Models (AOGCMs) are capable of simulating these events and if such features of past hydroclimate change are forced or the product of internal variability. Simulated hydroclimate variability in millennium-length forced transient and control runs from the ECHO-G coupled AOGCM is analyzed and compared to reconstructed Palmer Drought Severity Index (PDSI) variability from the North American Drought Atlas (NADA). Megadroughts in the ECHO-G AOGCM are found to be similar in duration and magnitude to those estimated from the NADA. The droughts in the forced simulation are not, however, temporally synchronous with those in the paleoclimate record, nor are there significant differences between the megadrought features simulated in the forced and control runs. These results indicate that model-simulated megadroughts can result from internal variability of the modeled climate system, rather than as a response to changes in exogenous forcings. Although the ECHO-G AOGCM is capable of simulating megadroughts by means of persistent La-Nina-like conditions in the tropical Pacific, other mechanisms can produce similarly extreme NASW moisture anomalies in the model. In particular, the lack of low-frequency coherence between NASW soil moisture and dominant modes of variability in the model simulations during identified drought periods, suggests that stochastic atmospheric variability can contribute significantly to the occurrence of simulated megadroughts in the NASW by means of storm track displacement. Using the ECHO-G results as a framework, we also present results for multi-model comparisons using 7 simulations from the collection of last millennium experiments in the CMIP5/PMIP3 archive. Results similar to those determined from the ECHO-G simulation are derived from the CMIP5/PMIP3 collection of model runs, indicating that the stochastic characteristics of megadroughts in NASW are robust across multiple model experiments. These findings indicate that either an expanded paradigm is needed to understand the factors that generate multidecadal hydroclimate variability in the NASW or that AOGCMs may incorrectly simulate the strength and/or dynamics of the connection between hydroclimate variability in the NASW and the tropical Pacific. Assessment of future risks associated with hydroclimate change and variability in the NASW is critically dependent on which of these possibilities is ultimately the correct interpretation of our findings.