Title

An Assessment of Water Availability in Texas using the NOAH Land Surface Model

Focus Category: Climatological Processes, Drought, Hydrology

Keywords: Climate variability and change, ENSO, PDO, AMO, Wavelet, Drought

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Congressional District where Project will Occur: 17th TX

Abstract

The state of Texas suffers from both short term and long term droughts, which have resulted in losses equivalent to several billions of dollars. Several studies have shown that precipitation and indeed drought are strongly related to climate teleconnection patterns. Spatial correlation between climate and drought indices shows that the state is not uniformly affected by droughts – instead some areas are more vulnerable than others. While this qualitative information is useful to the water manager, it does not help the latter to plan adequately. A quantitative assessment of changes in the water availability on the other hand will allow planners to develop optimal adaptation strategies to cope with these extreme events. In this study we propose to use the NOAH land surface model along with the NLDAS2 forcing data to assess water availability in the state. The study will look at the effect of climate indices on each of the 10 climate divisions and identify the most vulnerable regions. Wavelet analysis will be used to identify the correlation and lag difference between climate events and the impact on water in each climate division. The results from this study will help give an early warning to water managers and thus limit losses from droughts.

Statement of Critical Regional Water Problems

Water plays a critical role in the economic activities in the state of Texas. However, the state is extremely vulnerable to droughts. Hydrologic records indicate that the state suffers from both long-term and short-term droughts and these have a direct impact on the economy of the state. The 1996 drought caused an estimated agricultural loss of about $5 billion and that of 1998 caused a loss of $ 6 billion (Water for Texas, 2007). Several studies indicate that these events are strongly associated with climate variability patterns.

Climate teleconnections are known to affect precipitation and temperature among other climatic variables. The main ones shown to have a noticeable effect on the climate of the southern US are the El Niño – Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Atlantic Multidecadal Oscillation (AMO). ENSO has a recurrence pattern of 3–6 years and every event normally lasts for around a year (Trenberth, 1997). The PDO, often described as a longer lived El Niño, lasted for 20 to 30 years in the 20th century. The warm-phase of the PDO tends to coincide with anomalously cool temperatures and wet periods in the southern US (*Mantua and Hare*, 2002). The AMO has a meridionally antisymmetric pattern in the tropical Atlantic and spans the intertropical convergence zone (Enfield and Mestas-Nuñez, 1999). Delworth and Mann (2000) showed that the AMO has a frequency of 50 to 70 years.

Kurtzman and Scalon (2007) studied the effects of ENSO and PDO on precipitation in the southern and central US and found that there is a continuous region across where there is a **statistically significant increase (decrease) in winter precipitation related to El Niño (La Niña)** events. They also noted that El Niño and La Niña decadal modulations (which is the strengthening of the effects of El Niño during the warm phase of the PDO and that of La Niña during the cold phase of the PDO and vice versa) exist in Texas and the latter is stronger. Quiring and Goodrich (2008) studied drought events in the southwestern US and found that **multiyear La Niñas events are associated with multi year drought events** and they are more likely to occur during cold phases of the PDO. Enfield et al. (2001) found that **there is a significant negative correlation between AMO and rainfall on the continental US**. Quiring and Goodrich (2008) noted that the correlation is stronger when the PDO and AMO are in opposing phase.

Özger et al. (2009) studied **climate variability and droughts**, using the Palmer Drought Severity Index, for each climate divisions in Texas and found **drought occurrences are strongly associated with climates indices with different lag times**. ***No study, however, has quantified the change in water availability in Texas with respect to these climate variations.*** We therefore propose to conduct such an assessment and believe that it will support water planners and managers in developing optimal adaptation strategies for the state.

NATURE, SCOPE, AND OBJECTIVES OF THE RESEARCH

The main objectives of this research are to (i) investigate the effects of ENSO and PDO and (ii) to quantify changes in water availability, in the state of Texas using a Land Surface Model (LSM).

Our ***first hypothesis*** is that climate teleconnection patterns have a noticeable effect on the hydrology and consequently on water availability. Our ***second hypothesis*** is that these teleconnection patterns do not have the same effect on the whole state of Texas but rather some climate divisions are more affected than others. Our ***third hypothesis*** is that climate change will affect the timing and duration of these events and subsequently long-term water availability.

Therefore an understanding of the influence of these teleconnection patterns on each of the 10 climate regions in the state will **help in the earlier identification of the onset of a drought (or flood)** and thus **help in the planning and management of the water resources** in the state. LSMs offer an exceptional approach to answer the above questions. Of the numerous LSMs available, the NOAH LSM seems to be most suited for this study as previous studies demonstrated its ability to accurately model the water and energy budgets for regions with similar climatic zones and land cover (Lohmann et al., 2004; Luo et al., 2003; Robock et al., 2003)

NOAH (Chen el al., 1996; Ek et al., 2003; Koren et al., 1999) is the product of the joint collaboration between the National Centers for Environmental Protection (NCEP), Oregon State University (Department of Atmospheric Sciences), Air Force (both AFWA and AFRL - formerly AFGL, PL), and the Hydrologic Research Lab (now Office of Hydrologic Development – OHD).

The LSM simulates soil moisture, soil temperature, skin temperature, snowpack depth, snow water equivalent, canopy water content, and energy flux and water flux of the surface energy and water balance (Mitchell, 2001). This LSM builds upon the Oregon State University Planetary Boundary Layer model, developed between 1980 and 1990. The model was compared to a set of LSMs (the simple bucket model, the Simplified Simple Biosphere Model, and the simple water balance model) and was deemed to perform better and was therefore chosen for further refinement and implementation into NCEP's regional and global coupled weather and climate models.

The driver routine of the LSM include reading of the atmospheric forcing data, interpolation of the monthly-mean surface greenness and albedo to Julian day of the time step, assigning downward solar and longwave radiation from the input forcing, calculation of actual and specific humidity from atmospheric forcing, and assigning wind speed. Further description of the model physics is available in Grunmann (2005).

DATA

The hydrological cycle is governed by processes occurring in the atmosphere, the land surface and subsurface and their interaction. Thus to hone their predictions, numerical weather prediction (NWP) centers have incorporated land surface schemes into their model. However, it has been found that errors in forcing accumulate in the surface and energy stores leading to incorrect surface water and energy partitioning (Gottschalck et al., 2005; Oki et al., 1999). The Land Data Assimilation Scheme (LDAS) developed by NASA in collaboration with Princeton University and the University of Washington is not affected by forcing biases as it consists of uncoupled models forced with observations. It synergistically applies Surface Vegetation Atmosphere Transfer Schemes (SVATS) in near real time at $^{1}/_{8}$ degree resolution for North America and $^{1}/_{4}$ degree globally with LDAS model prediction, satellite data, gauge data, and radar precipitation measurements. The model parameters are derived from existing soil and vegetation maps and assess water and energy balances which are validated with in-situ observations. In this study, we propose to use North American Land Data Assimilation Scheme (NLDAS2) which is a free product from NASA. The dataset extends back to 1979.

ANALYSIS

The two most important output from the model, surface runoff (which is a measure of the surface water availability) and soil moisture will be analyzed using continuous wavelet transform (CWT) and cross-wavelet transform (XWT). Wavelet analysis is a refinement of spectral analysis and is well suited for this study as it preserves both the time and frequency information (Adamowski, 2008). Cross-wavelet analysis can be used to assess whether there is a positive or negative relationship between the climate indices and output variables. The outputs from the model can be decomposed and correlated with climate teleconnection time series to determine the lags between the latter and surface runoff and soil moisture.

RESULTS EXPECTED FROM THIS PROJECT

This study will utilize an LSM to (i) ***quantify water availability over the different climate divisions*** of Texas, and (ii) how they are affected by climate teleconnection patterns and (iii) ***determine the lag relationship*** between these events. This information would help water planners in Texas develop optimal water management strategies to cope with extreme events such as droughts and floods that the state faces on a regular interval.

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