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Developing a Framework to Incorporate Climate Information and Climate Change Projections in Water Planning for Texas

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1. Introduction

The report summarizes some key aspects of climate research designed and undertaken to support decision-making in the water planning sector in Texas. The research was carried out during a UCAR PACE (University Corporation for Atmospheric Research - Postdocs Applying Climate Expertise) postdoctoral fellowship where the PACE Fellow worked with the Texas Water Development Board (TWDB) and the University of Texas at Austin to improve current understanding of the predictability of flash droughts over the southern Great Plains and how climate projections could be incorporated in water availability modeling.

2. Water planning and drought management in Texas

Climate information is needed at two timescales for planning purposes. The first is the short-term timescale where drought information can be provided to the state Drought Preparedness Council [1]. The second is the long-term timescale feeding into the State Water Plan [2] that addresses water needs over the next 50 years within the state. This plan is updated every five years.

Given the magnitude and extent of the 2011 drought event over Texas and its rapid intensification over the late-spring of 2011, much emphasis was given to understanding factors that led to the drought taking on the characteristics of a "flash drought" and to developing a summer drought early warning indicator to support drought management through the Texas Drought Preparedness Council. The possibility for using climate information for long-term water planning was investigated at a purely exploratory basis because climate change projections are not, as yet, factored into water resources planning in Texas.

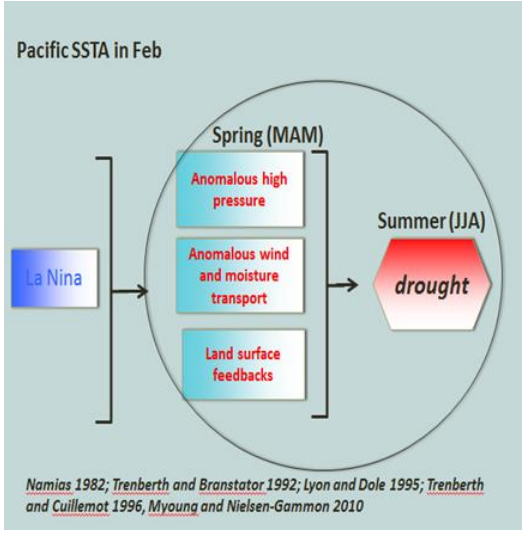

Fig. 1 Physical mechanisms known to drive summer drought over the US Great Plains.

3. Summer drought early warning indicator

"Flash" droughts refer to those droughts that intensify rapidly in spring and summer, coupled with strong increase of summer extreme temperatures, such as those that occurred over Texas in 2011 and the Great Plains in 2012. Climate models failed to predict these "flash" droughts in 2011 and 2012 and are ambiguous in projecting their future changes, largely because of models' weakness in predicting summer rainfall and soil moisture feedbacks. By contrast, climate models are more reliable in simulating changes of large-scale circulation and

[1] www.txdps.state.tx.us/dem/CouncilsCommittees/droughtCouncil/stateDroughtPrepCouncil.htm
[2] http://www.twdb.texas.gov/waterplanning/swp/index.asp

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warming of temperatures during winter and spring seasons. Prior drought research based on observational data indicates that severe-to-extreme summer drought events over Texas are preceded by dry springs (Fernando *et al.*, 2013). Thus, we propose to develop and test a physical climate indicator of the risk of "flash" droughts in summer by using the large-scale circulation and land surface conditions in winter and spring based on observed relationships between these conditions and their underlying physical mechanisms established by previous observations and numerical model simulations (Figure 1).

Figure 2 shows a prototype drought indicator averaged over the US southern Great Plains (90-110˚W, 24-40˚W), indicating "flash" drought risk during June-August (JJA) based on climate information in April of each year for the period of 1951-2011. The prototype indicator was developed by regressing JJA percent normal rainfall with April geopotential height anomalies, the difference between April temperature at 700 hPa and April surface dewpoint, and the cumulative difference between precipitation and evaporation from November to April. The indicator (blue bars) generally match observed drought events in JJA, especially the multi-year strongest drought events, such as those in 1950s, mid-1960s and after 2006, especially 2011. The prototype indicator missed three summer drought events in 1978, 80 and 84. We find that the prototype process-based statistical model demonstrates considerable potential for an early warning indicator of summer flash droughts. This indicator is based on anomalous climate conditions and land surface characteristics in the spring.

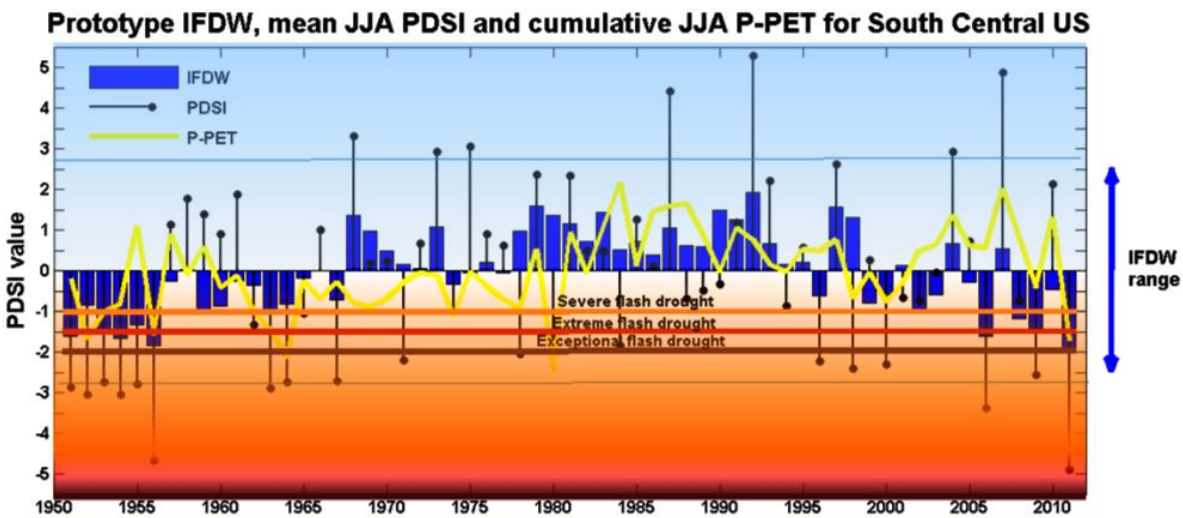

Fig. 2 Prototype drought hindcast (1951-2011) over the Southern Great Plains.

4. Climate information for long-term water planning

Surface water supply in Texas is heavily reliant on reservoir water storage. There are 176 reservoirs in the state representing approximately 70% of the water supply in the state. Water planning in the state of Texas comes under the aegis of the Texas Water Development Board. Water Availability Models (known as WAM) that use naturalized stream flow, pan evaporation and water rights as input to form the basis of water planning in the state. The WAM models are used to assess firm yield at all reservoirs in the state. Firm yield of a reservoir is the amount of water that can be supplied without system failure under a repeat of the worst drought conditions experienced by the state during the 1950s drought-of-record.

We approach the issue of how climate change might affect the availability of surface water by asking the question: "How might climate change affect the sensitivity of reservoir firm yield?" There is a mismatch between the information needs of WAM model users and the format in which climate change information is presently available. We propose a framework by which climate change projections could be incorporated into WAM models if, in the near future, the Texas Water Development Board is mandated by the Texas Legislature to incorporate climate change in water resource planning.

As the first step, we will explore the empirical relationship between naturalized flow in 14 rivers and rainfall over these river basins over the historical period. Second, we will explore the empirical relationship between pan evaporation and potential evaporation. Third, we will obtain ranges of possible naturalized flows and pan evaporation in the mid- and late-21st centuries using rainfall and evapotranspiration from the CMIP5 RCP4.5 and RCP8.5 projections and the empirical relationships obtained in steps 1 and 2. We will then use these ranges to estimate the sensitivity of reservoir firm yield in all 14 river basins. As a preliminary step, we applied the framework to the Brazos river basin using quadrangle precipitation and pan evaporation from the TWDB [3], potential evaporation from NCEP CDAS1 and naturalized flow at the outflow station of the Brazos. Naturalized flow refers to streamflow where anthropogenic influences on the river basin have been factored out. The outflow station is one of the control points at which naturalized flow is entered into the WAM model. We first aggregated all data to the annual time step and checked the annual naturalized flow and pan evaporation for normality. If they were non-normally distributed, we used a box-cox transformation to normalize the data. Next, assuming a linear relationship between precipitation and (normalized) naturalized flow and evaporation, we used linear regression analysis to derive the beta values for each parameter. We next obtained projected mean values of naturalized flow and pan evaporation over the Brazos basin for 2021-2050 using RCP4.5 and RCP8.5 projected rainfall and potential evaporation from the CCSM4 model.

References

Fernando, D. N., R. Fu, K. C. Mo, B. R. Scanlon, R. Solis, L. Yin, A. Bowerman, and R. Mace, 2013: Factors influencing the persistence of ENSO-led winter rainfall deficits into late-spring and early-summer over Texas. NOAA Climate Prediction Science and Technology Digest, January 2013, 103-106. http://issuu.com/climatesti/docs/37cdpwdigest.

[3] http://www.twdb.texas.gov/surfacewater/conditions/evaporation/index.asp