Impact of future hydrologic extremes on water supply and irrigation water demand under changing climate in Texas

Final Report for 2016-17 TWRI Mills Scholarship

Kyungtae Lee

Water Resources Engineering,

Zachry Department of Civil Engineering,

Texas A&M University

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1. Development of improved long-term hydrologic datasets for Texas

While battling these extreme events, Texas has become a water deficient state where the demands for fresh water have been exacerbated by a rapidly growing population. These water issues are further challenged by climatic and land use changes, both of which may alter the natural hydrologic processes. With a changing climate, hydrologic extremes are projected to become more frequent, more severe, and more uncertain (Goodess 2013, Luber and McGeehin 2008, Trenberth et al. 2015). Due to the importance of water resources for Texas—and its vulnerability to water-related extreme events—it is necessary to understand how future changes may impact Texas' water resources and (river system) water budgets (Wurbs and Ayala 2014). In this context, comprehensive and reliable hydrologic datasets which can support the analysis of historical hydrologic extreme events are essential. Furthermore, such datasets can serve as a benchmark to evaluate future extreme events, and to prevent record setting disasters in advance.

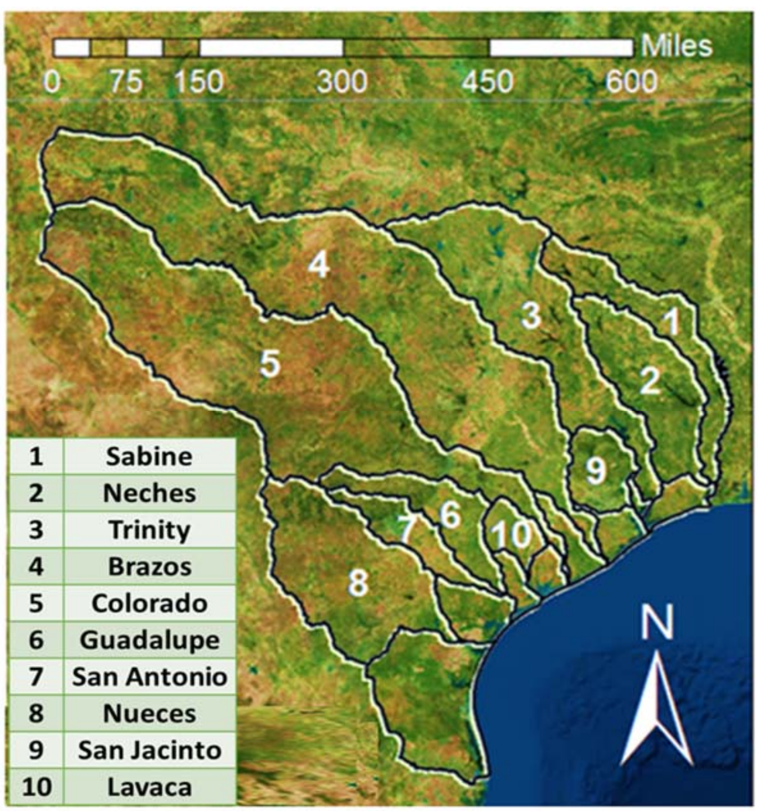

Figure 1. Major River Basins in Texas

Driven by the meteorological forcings of Livneh et al. (2013, hereafter L13), we hereby provide a calibrated and validated hydrological dataset for 10 major Texas river basins (Figure 1). The dataset is deemed high quality because of its relatively high spatial (1/8°) and temporal (daily) resolutions, and its evaluated skill compared to observed hydrological variables. The dataset includes evapotranspiration, runoff, and soil moisture records from 1918 to 2011. The L13 meteorological forcings are available from 1915 to 2011, but we used the first three years for model spin-up (and then analyzed from 1918 onward).

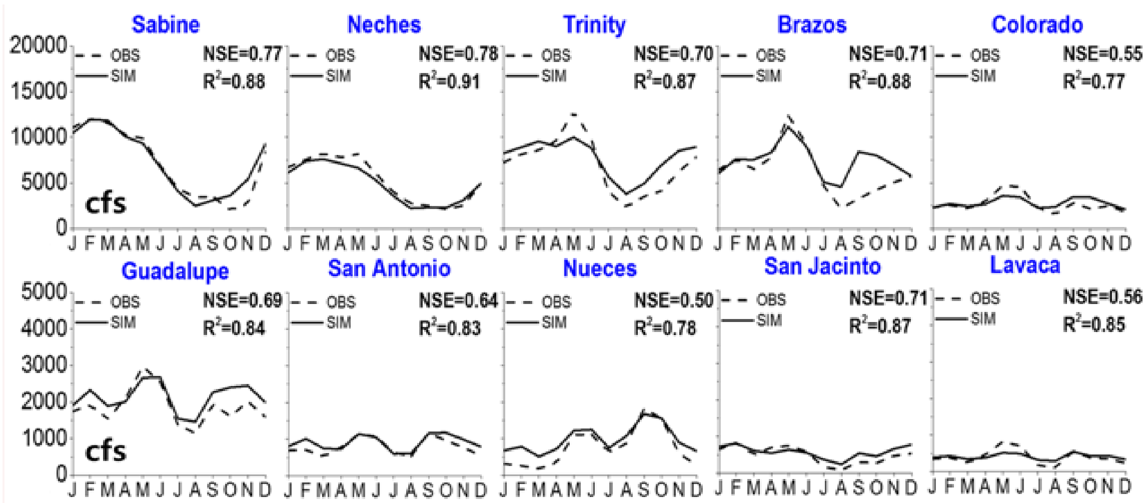

Figure 2. Monthly Calibrated (SIM) and Observed (OBS) streamflow (1960-1985)

An automated optimization technique, Multi-Objective Complex evolution (MOCOM-UA, Yapo et al. 1998), was employed to calibrate the VIC model over the 10 major rivers in Texas (Figure 2). During the calibration process, the mean absolute error (MAE) and the Nash-Sutcliff coefficient (Nash and Sutcliffe 1970) were used as the objective functions to minimize the difference between the simulated and observed streamflow. The monthly streamflow observations at the U.S. Geological Survey (USGS) stations closest to the river outlets were used for both calibration and validation purposes (Lee et al. 2017).

2. Future Climate Trends in Texas

The following table contains the list of future climate change models (scenarios).

Model	Center
BCC-CSM1.1	Beijing Climate Center, China Meteorological Administration
CSIRO-Mk3.6.0	Commonwealth Scientific and Industrial Research Organization in collaboration with the Queensland Climate Change Centre of Excellence
IPSL-CM5A-LR	Institute Pierre-Simon Laplace
IPSL-CM5A-MR	
MIROC5	Atmosphere and Ocean Research Institute, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
MIROC-ESM	
MIROC-ESM-CHEM	
CCSM4	National Center for Atmospheric Research
NorESM1-M	Norwegian Climate Centre
GFDL-CM3	Geophysical Fluid Dynamics Laboratory
GFDL-ESM2G	
GFDL-ESM2M	

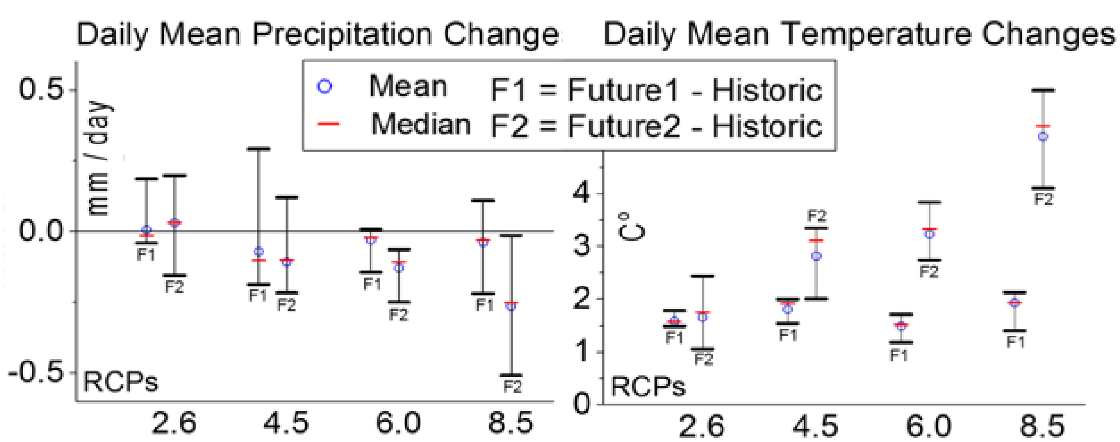

Figure 3. Future precipitation and temperature changes for 4 RCPs ensemble

The daily precipitation ensembles mean decreases from F1 (2020-2049) to F2 (2070-2099) except for RCP2.6 (Figure 3). The daily temperature ensembles mean increases significantly as RCP increases. Overall, precipitation decreases and temperature increases significantly for RCP8.5. The ranges of precipitation and temperature ensembles increase from F1 to F2.

3. Hydrologic extremes in Texas (Agricultural drought)

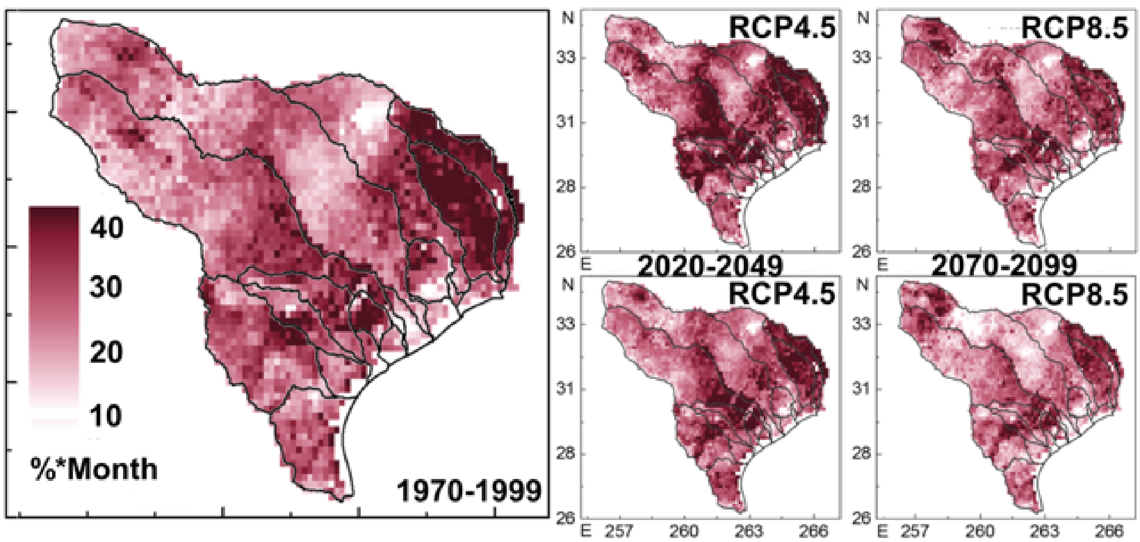

Figure 4. RCP 4.5 and 8.5 Ensembles Median: Drought Severity

Drought Severity is defined as monthly soil moisture deficit (Figure 4). Drought events due to SM deficit do not have a clear future trend. Sabine and Neches will have less severe droughts in the future. For RCP 8.5, the Brazos will have the least severe drought in F2. Soil moisture and drought areal extent are calculated using future climate models (Figure 5). The range of ensembles is larger in RCP 4.5 than in RCP 8.5. The annual soil moisture tends to decrease in the future. The variation of soil moisture will decrease in the future. The areal extent of drought has a large variation in F1 for RCP 4.5. The variation of the drought areal extent is larger in RCP 4.5 than in RCP 8.5.

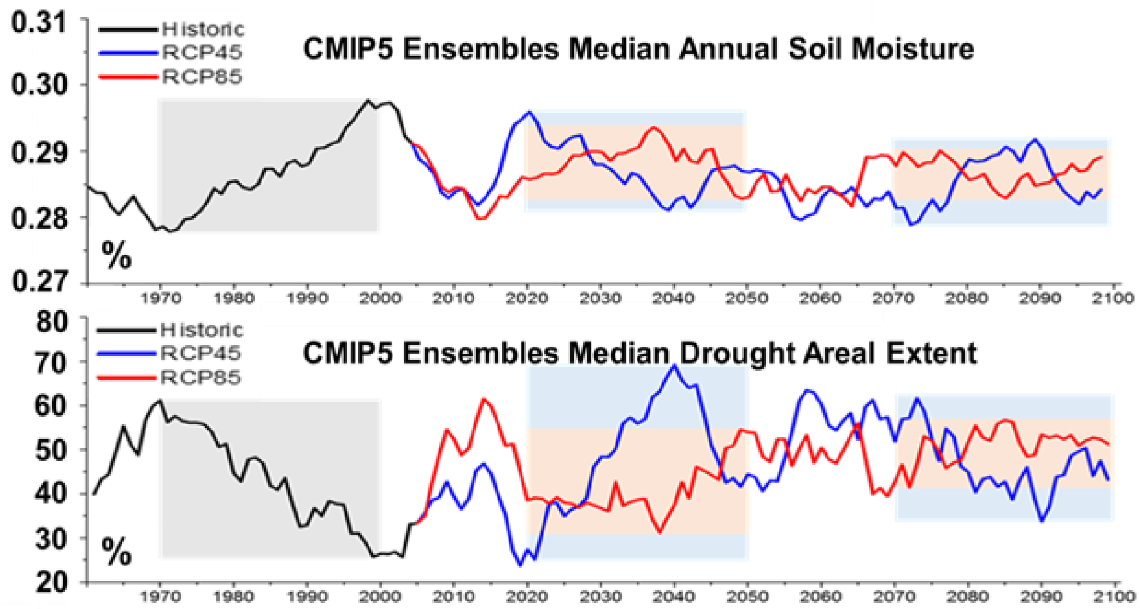

Figure 5. Annual Soil moisture and Drought Areal Extent

4. Future Irrigation Water Demand under changing climate

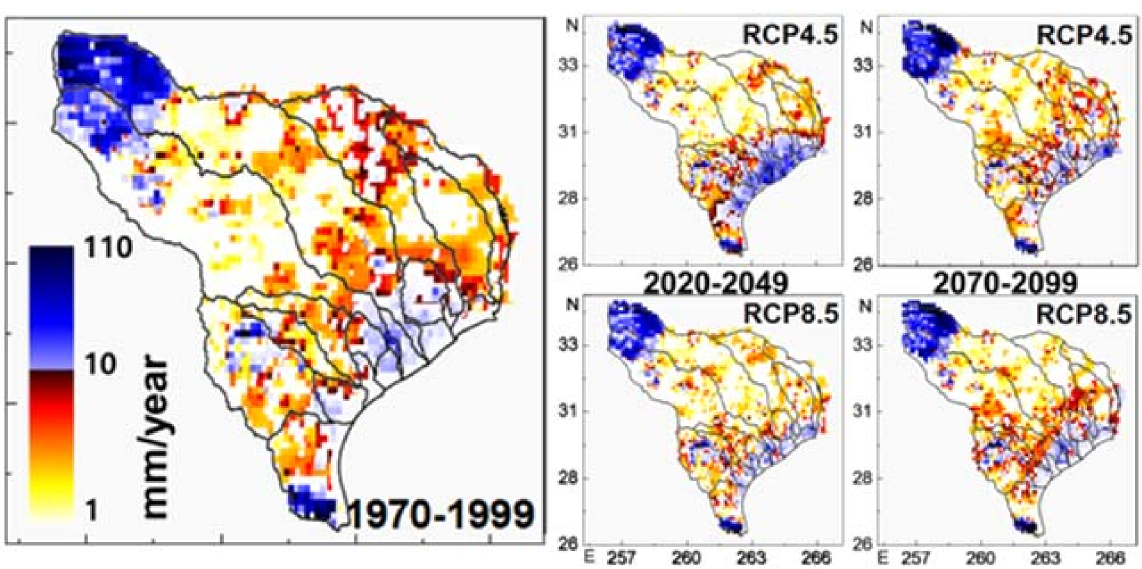

Figure 6. Simulated irrigation water demand under future climate scenarios

Irrigation Water Demand under Future Climate is projected using future climate models (Figure 6). Future irrigation demand over most of Texas will increase, particularly along the Gulf Coast and the North-west high plains. Irrigation water demand will decrease in central Texas under the RCP4.5 scenario during the F1 period.

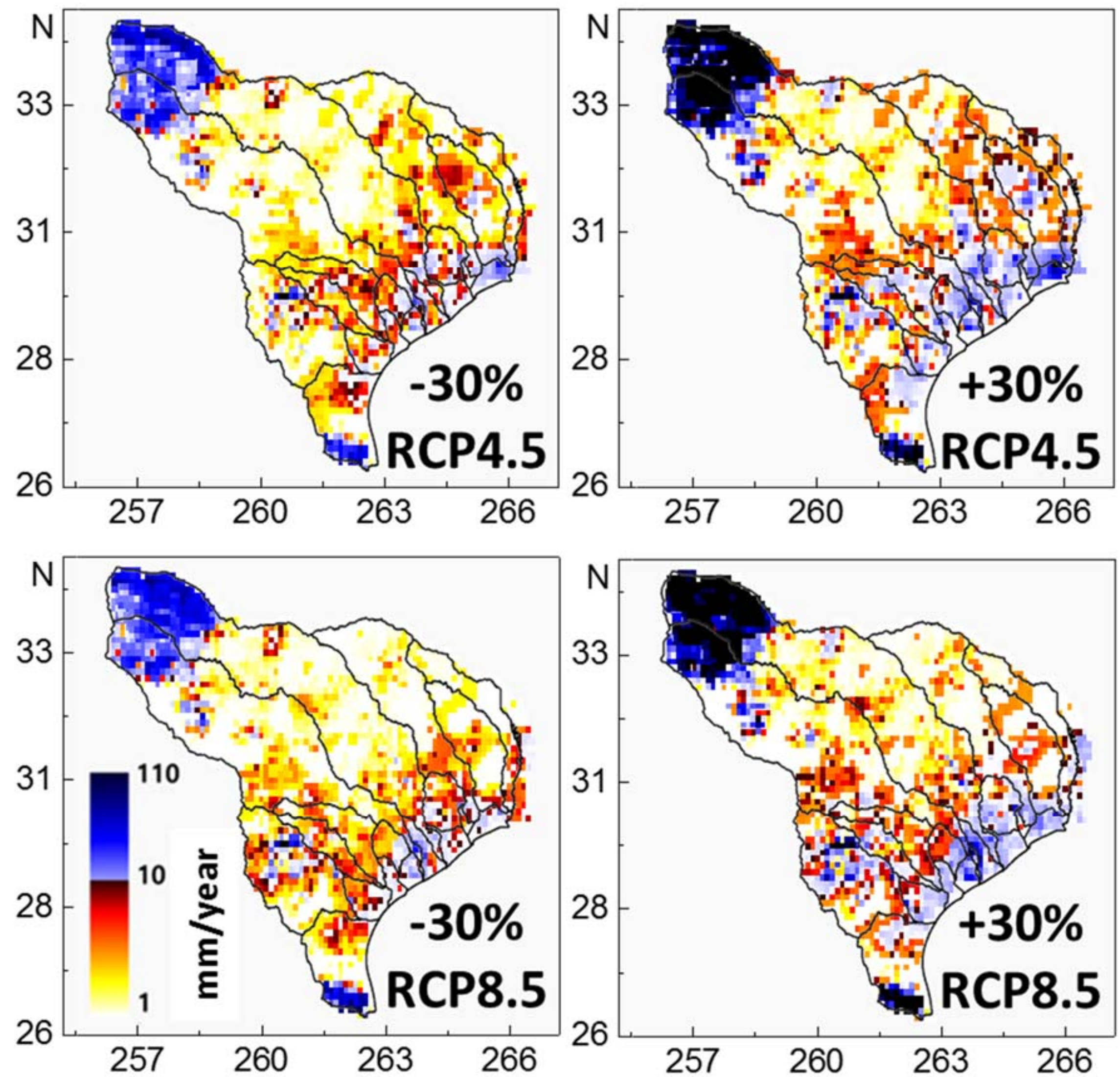

Figure 7. Joint impacts of climate and crop fraction on irrigation water demand

Irrigation Water Demand (combination of climate change and agricultural expansion) is calculated over Texas (Figure 7). Irrigation water demand in Northwestern Texas is the most sensitive to climate change and crop fraction change under both RCPs. The change of irrigation fraction has a larger impact than the different RCPs on water demand. The Gulf Coast, which is heavily populated, may be affected the most by these changes.

References

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