Climate and Future Water Availability

Bradfield Lyon

2014 Texas Water Summit

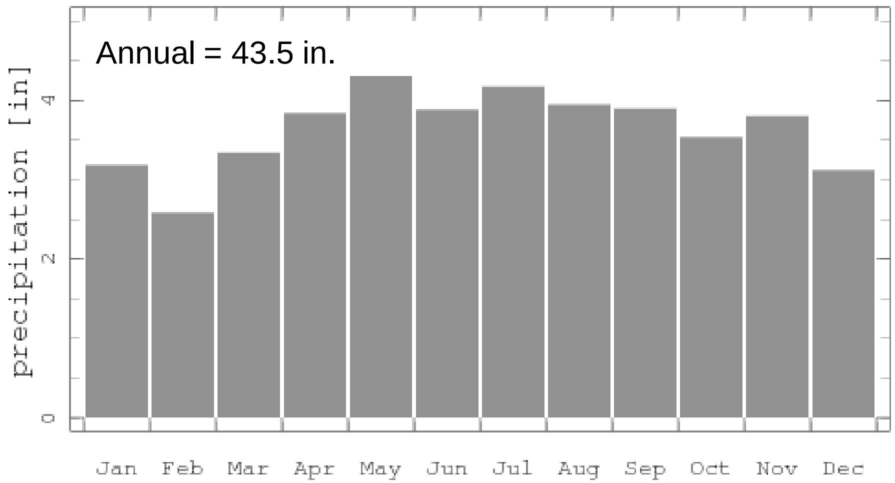
Austin, TX
19 May 2014

International Research Institute
for Climate and Society
EARTH INSTITUTE | COLUMBIA UNIVERSITY

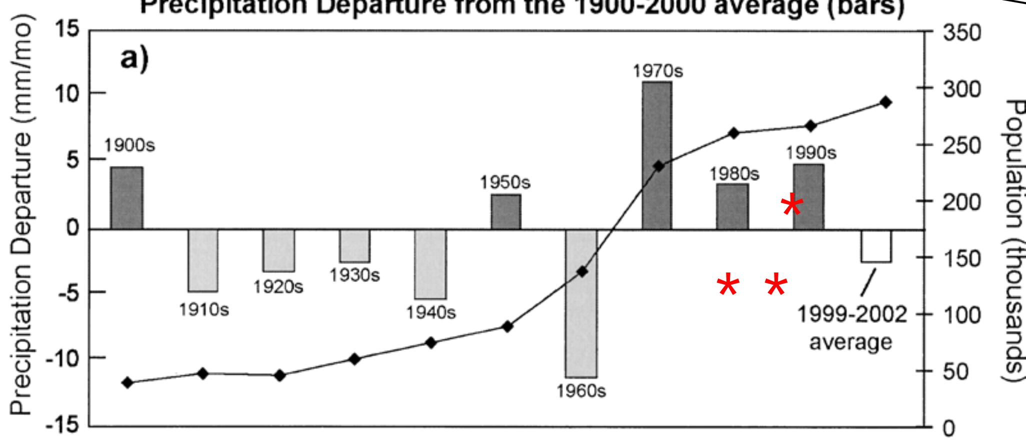
The Earth Institute
AT COLUMBIA UNIVERSITY

The Water-Abundant Northeast US

Rockland County (in Southeast NY State)



Rockland County Population (line) and Precipitation Departure from the 1900-2000 average (bars)



Rockland County Legislature Approves Desalination Plant Hearings

Posted October 18th, 2012 www.rocklandtimes.com

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The New York Times nytimes.com

January 30, 2007

Looking to the Hudson for Rockland's Water Needs

By ANAHAD O'CONNOR

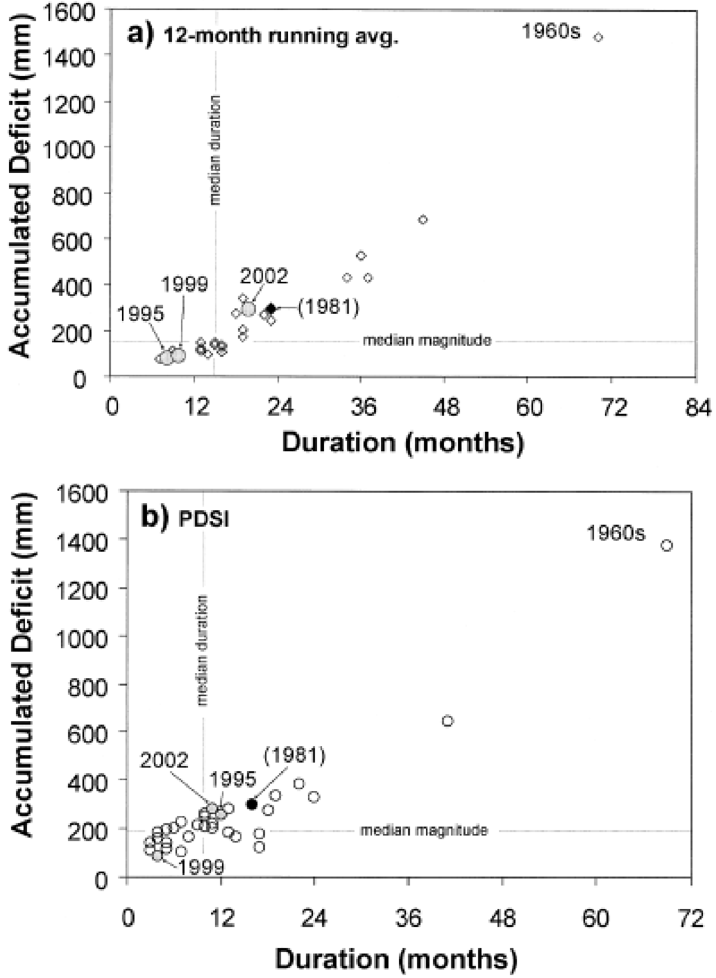
STONY POINT, N.Y., Jan. 24 — There was a time not long ago when the Hudson River was littl it as New York's open sewer. But Rockland County residents may soon be drinking its water.

A regional water supply company that serves Rockland County submitted a plan this month to United Water New York, would build the plant by 2015 and supply Rockland residents with 7.5

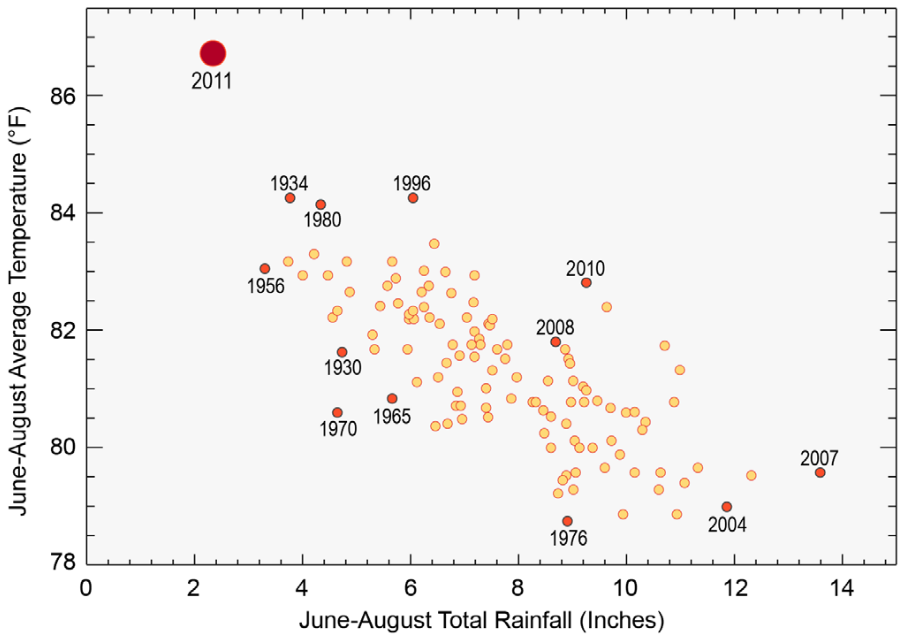
Figures: Lyon et al. (2005) JAWRA

Historical Perspective of Inevitable Droughts

Rockland County, NY



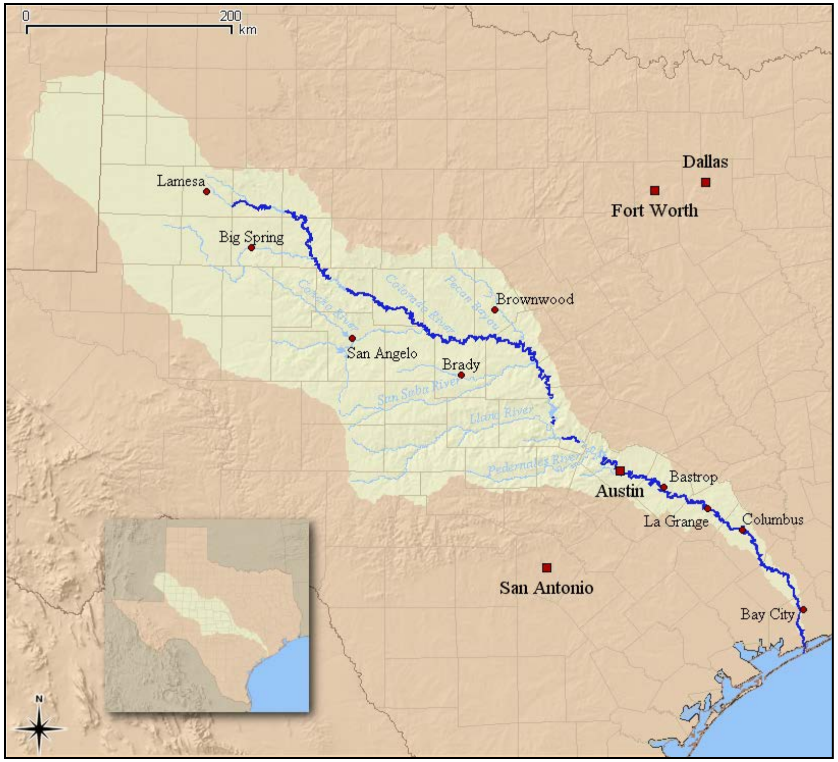
Texas

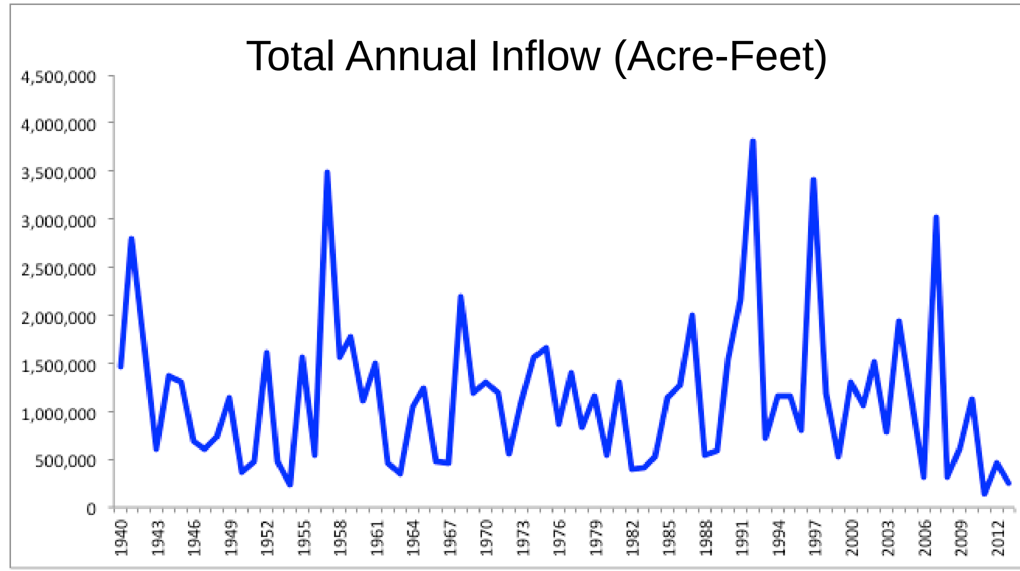


Source: Prof. John Nielsen-Gammon

Figures: Lyon et al. (2005) JAWRA

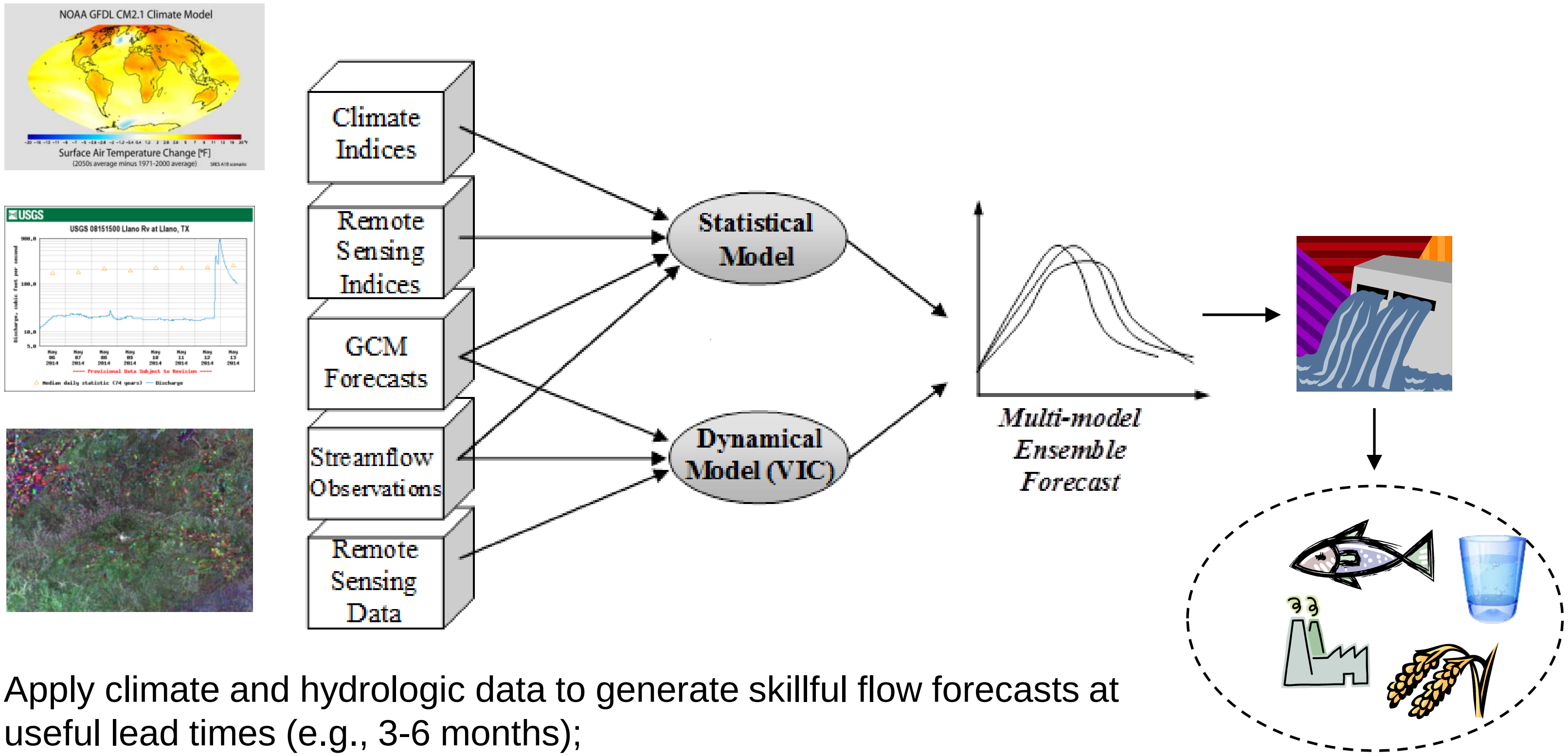
Integrated Seasonal Drought Forecast-Adaptive Management System for the Lower Colorado River Basin





Data Courtesy of Ron Anderson, LCRA

Integrated Seasonal Drought Forecast-Adaptive Management System for the Lower Colorado River Basin

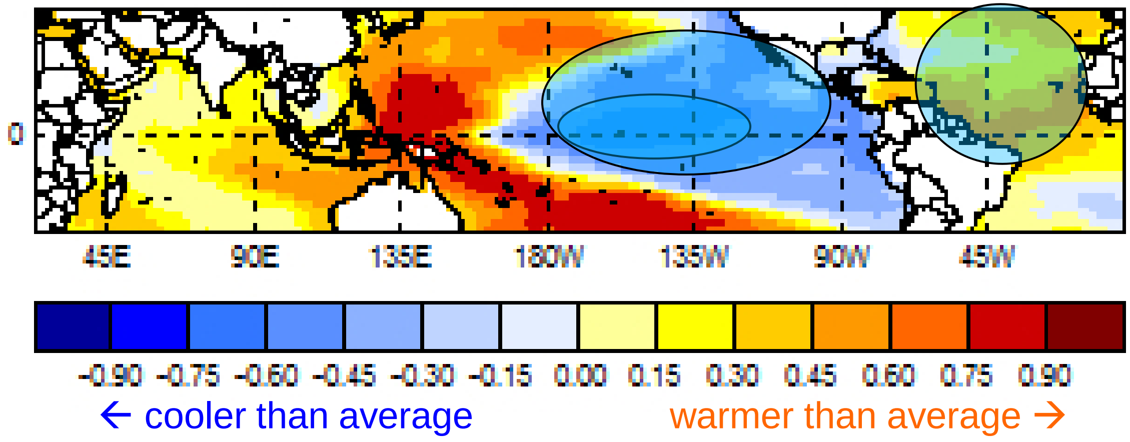


- Apply climate and hydrologic data to generate skillful flow forecasts at useful lead times (e.g., 3-6 months);
- Conduct research on the potential value of using the forecasts along with risk-sharing policies and financial instruments; and
- With LCRA, incorporate forecasts into operational water resource management models.

Multiple Timescales of Climate Variability

→ Looking for predictors for inflow to the LCRB watershed

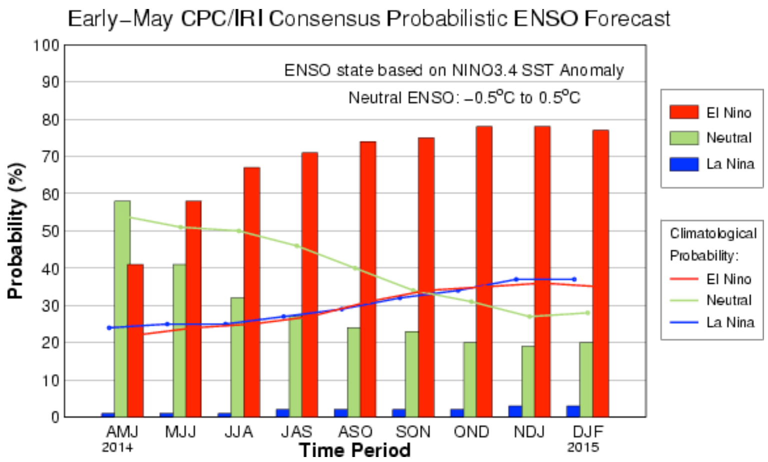
Sea Surface Temperature Pattern Associated with Low Flows

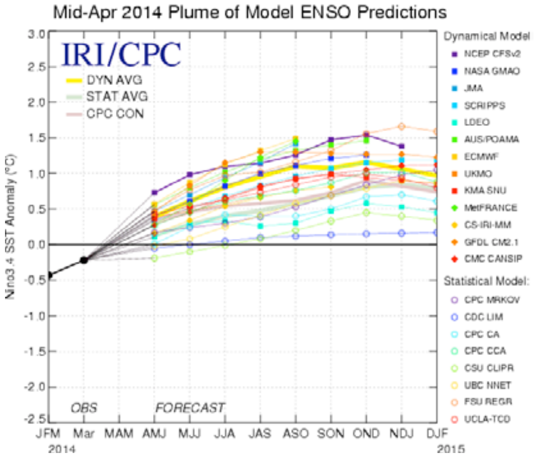


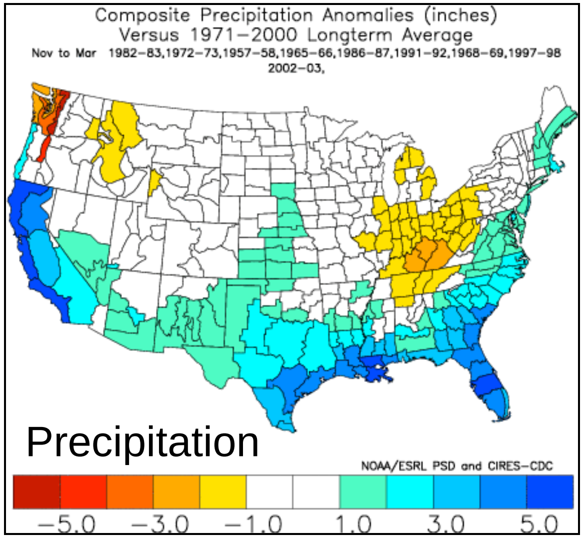
- La Niña conditions favor drought and low flows on the seasonal to interannual time scale (El Niño favors wetter conditions)

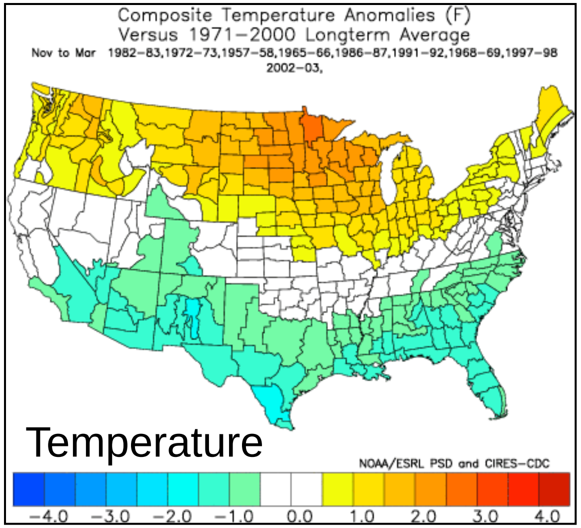
- Decadal periods of cooler conditions in the Pacific and warmer conditions in the Atlantic *favor* multi-year periods of drought

Seasonal-to-Interannual Timescales… An El Niño Likely



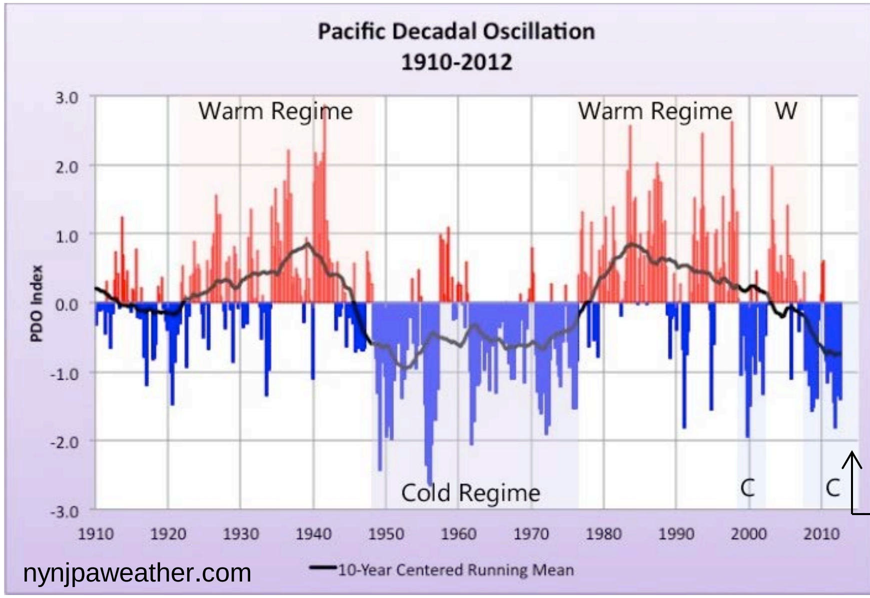




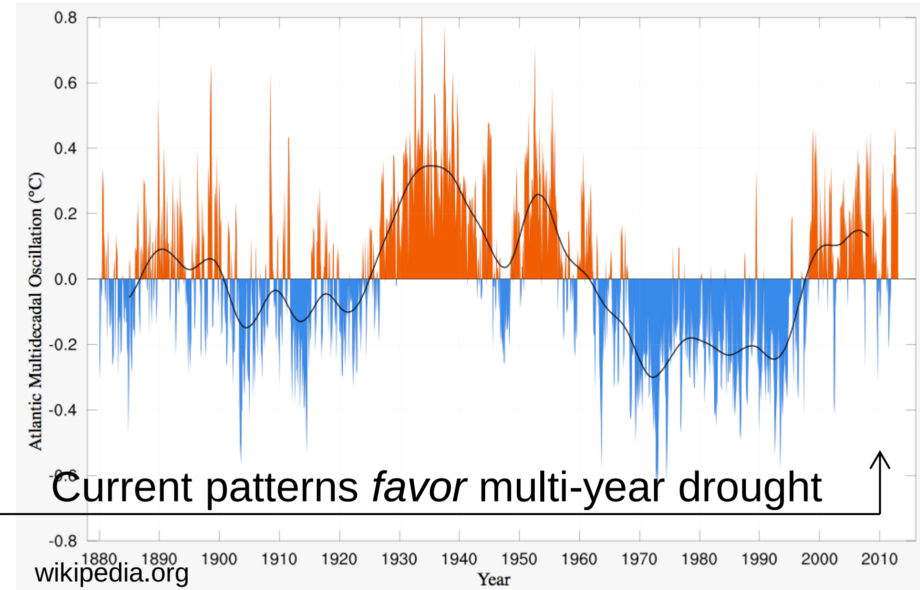


On Decadal Timescales…

Pacific



Atlantic

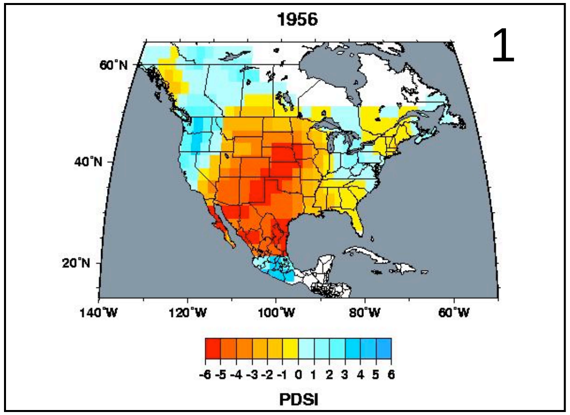


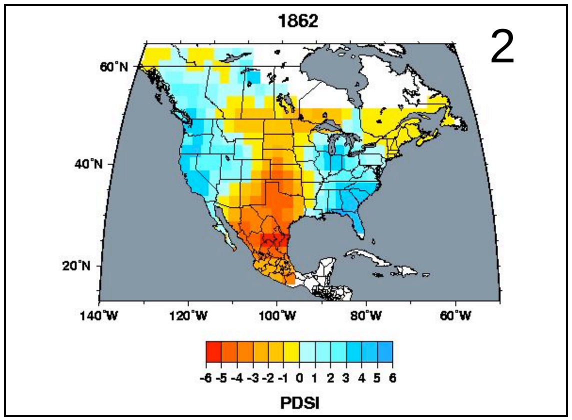
Current patterns *favor* multi-year drought

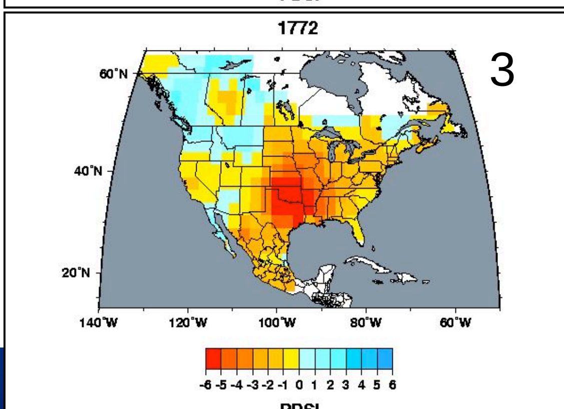
- Certainly not the only factors leading to drought, but tilt the odds towards drier conditions, possibly for the next 10+ years

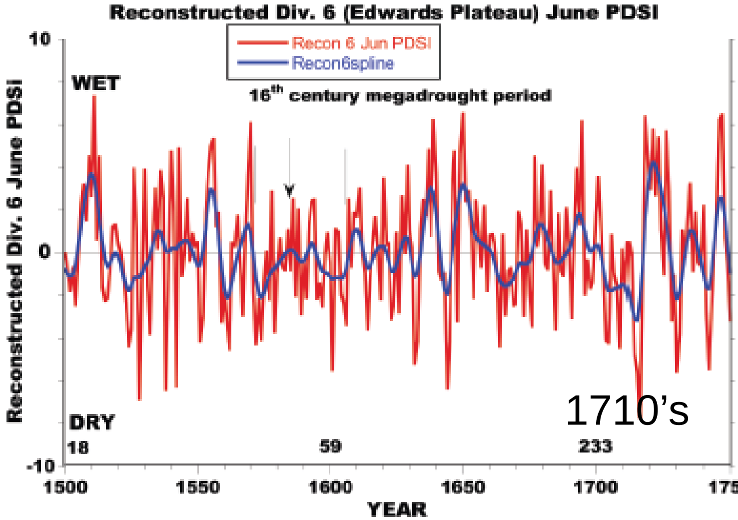
- Year-to-year inflow variations are still expected. We have a developing El Niño, which will favor enhanced rainfall this coming winter. After that… *little skill in predicting shifts in the PDO and AMO back to opposite phases*

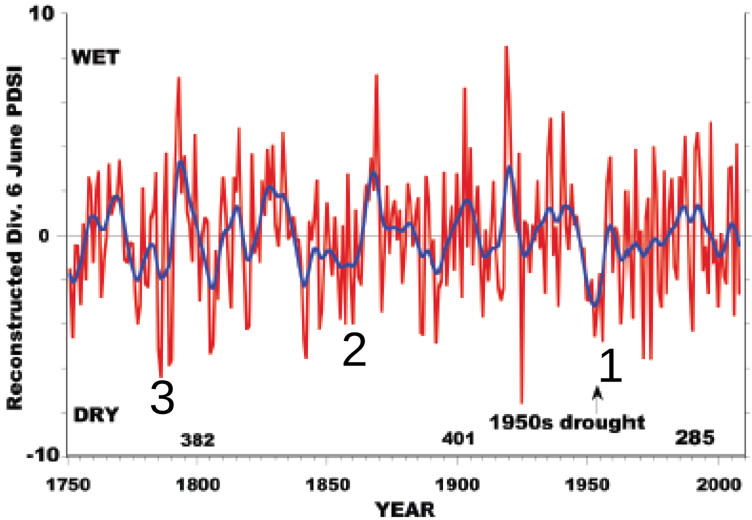
Tree Rings: A Long History of Drought in Texas







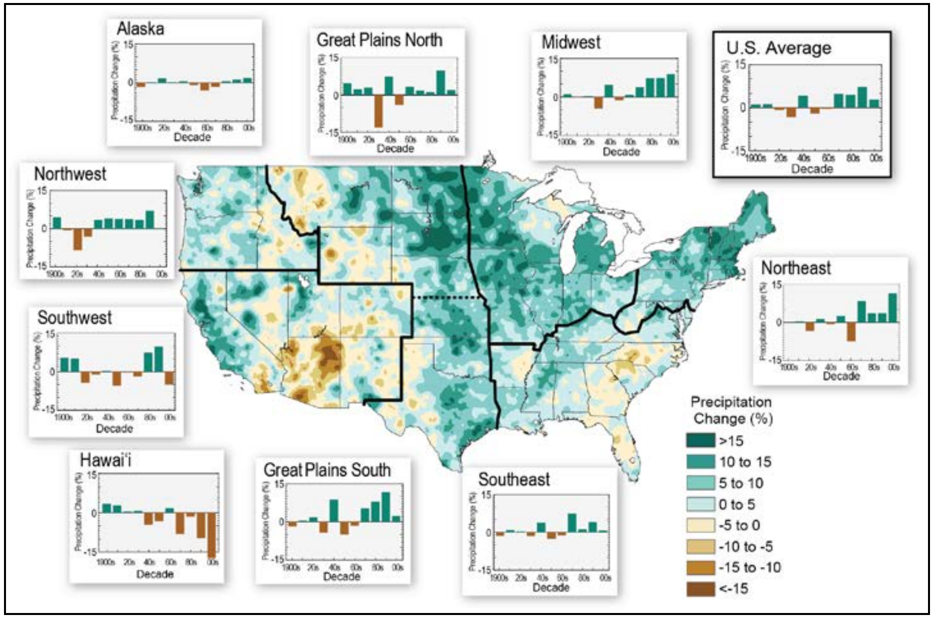


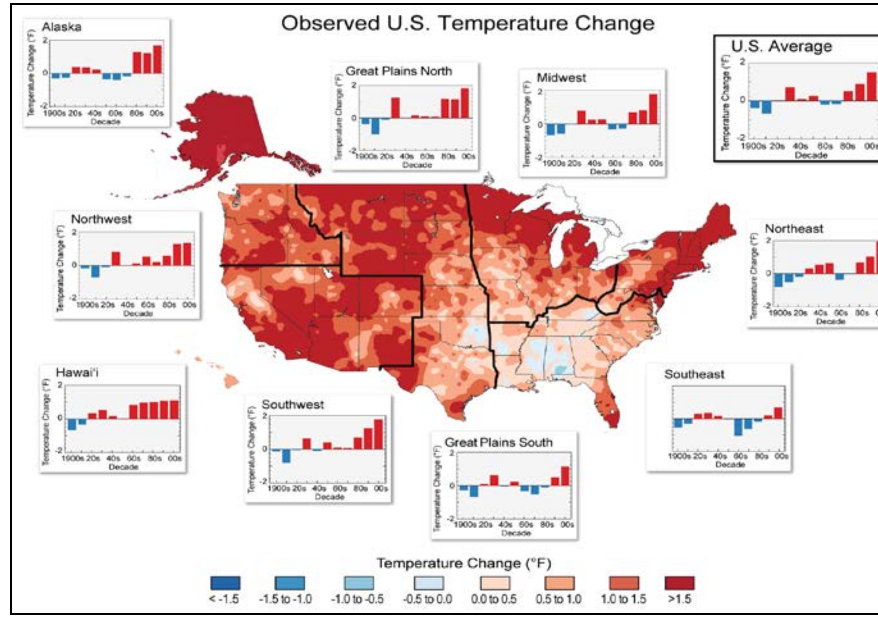


Cleaveland et al. (2011), Texas Water Journal

Data: Cook et al., *North American Drought Atlas*

Climate Trends-I: Contributions from Natural Variability and Anthropogenic Influences



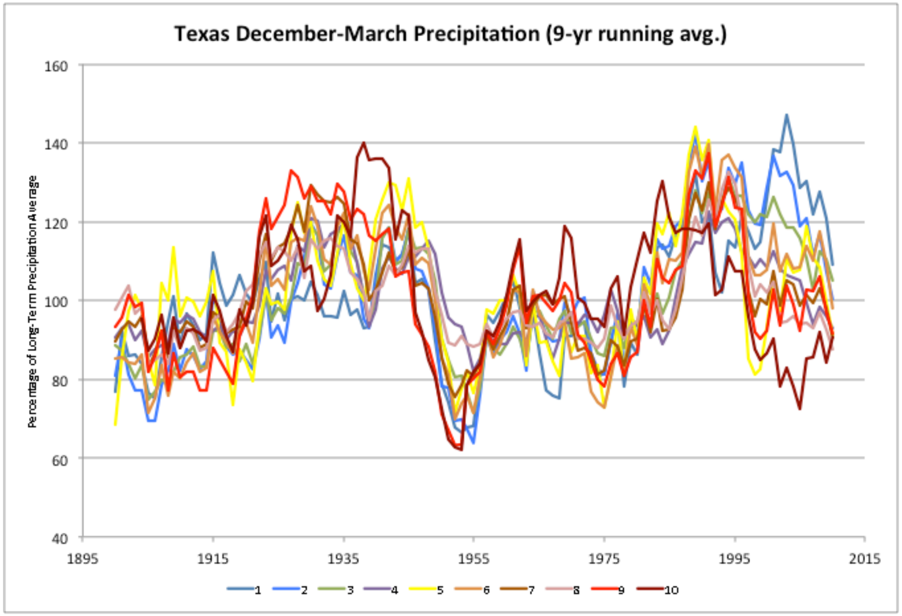


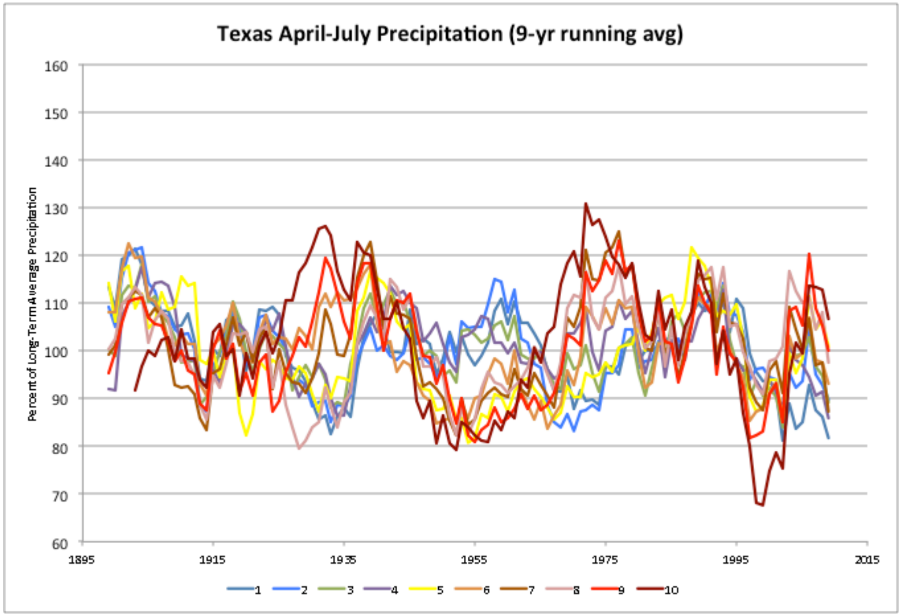
Colors on the maps show precipitation and temperature changes over the past 22 years (1991-2012) compared to the 1901-1960 average.

→ On short time scales (e.g., 20-30 years), natural variability can reduce or enhance the global warming signal.

Figures: National Climate Assessment, 2014

Climate Trends-I: Contributions from Natural Variability and Anthropogenic Influences



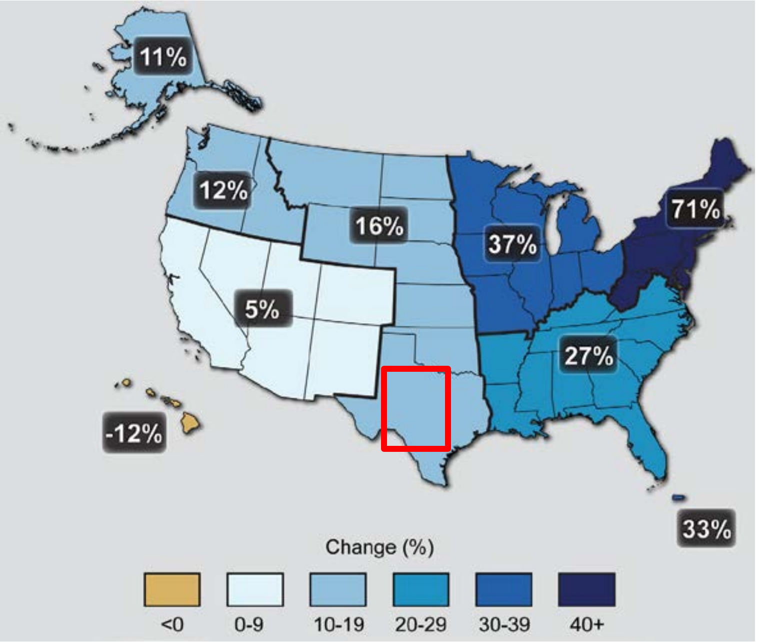


→ A study by Zhang et al. (2007) finds that, averaged around the Northern Hemisphere, subtropical regions have been drying, consistent with many climate model projections that include anthropogenic forcing.

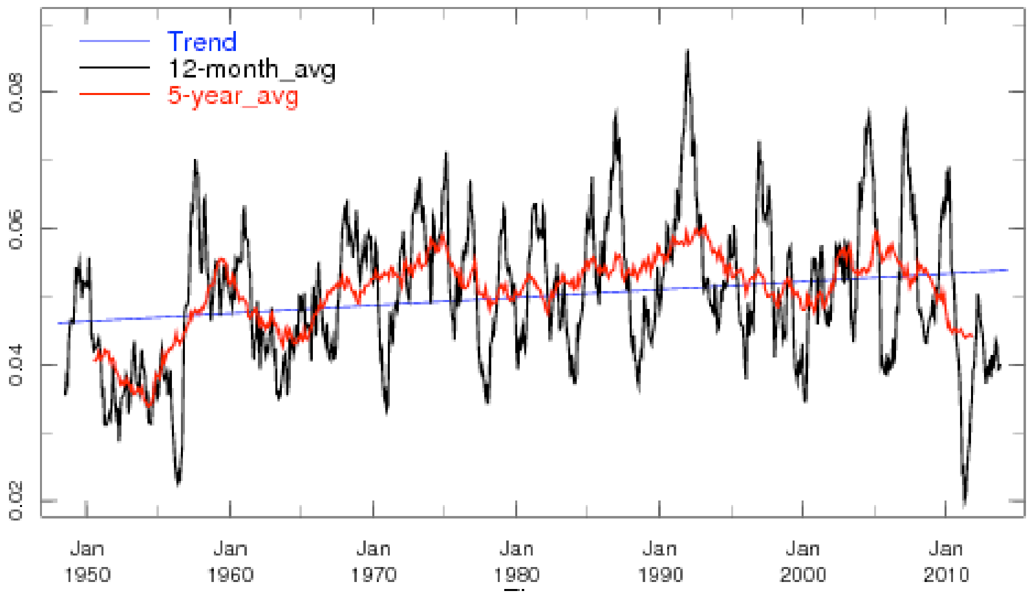
→ Across Texas, a slight upward trend in precipitation obs. over the 20th Century. Why? Anthropogenic masked by natural variations? Drying in the pipeline?

Data courtesy of Prof. John Nielsen-Gammon

Climate Trends in Context-2: Extremes Are Important to Water Availability



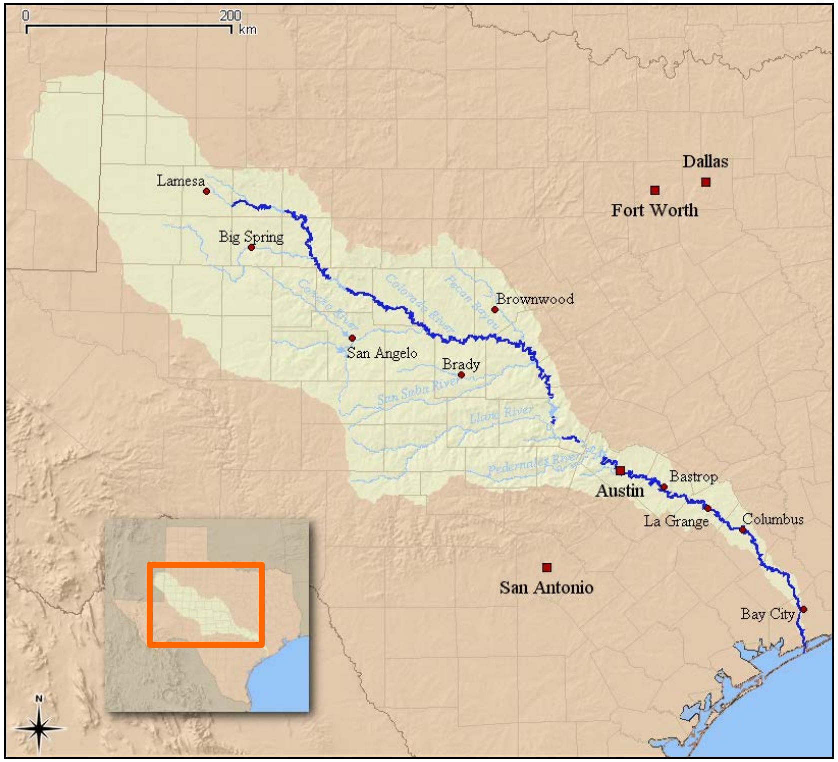
Percent changes in the amount of precipitation falling in very heavy events (the heaviest 1%) from 1958 to 2012 for each region. (Figure source: updated from Karl et al. 2009c, taken from NCA3, 2014).

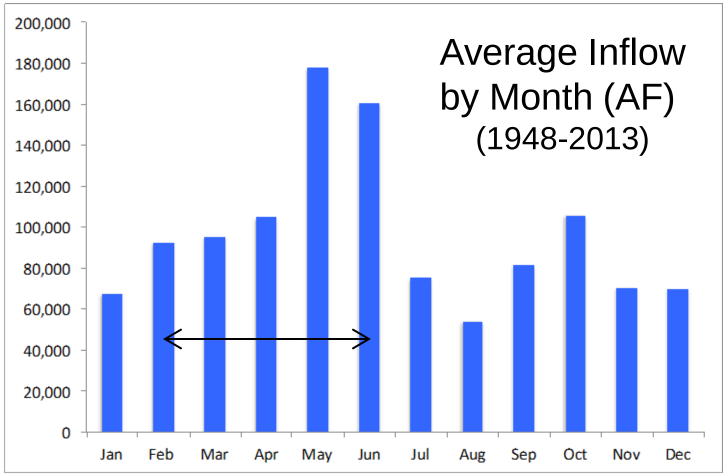


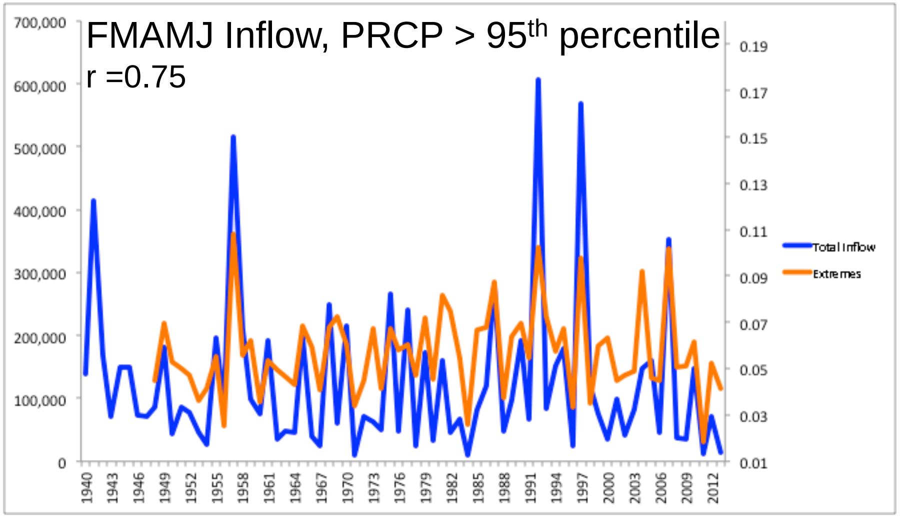
Average occurrence of daily precipitation being > 95th percentile in Texas (box region at left). Data from CPC, *Unified Analysis*, 1948-2013.

[Note: Preliminary result, not part of NCA3]

Climate Trends in Context-2: Extremes Are Important to Water Availability



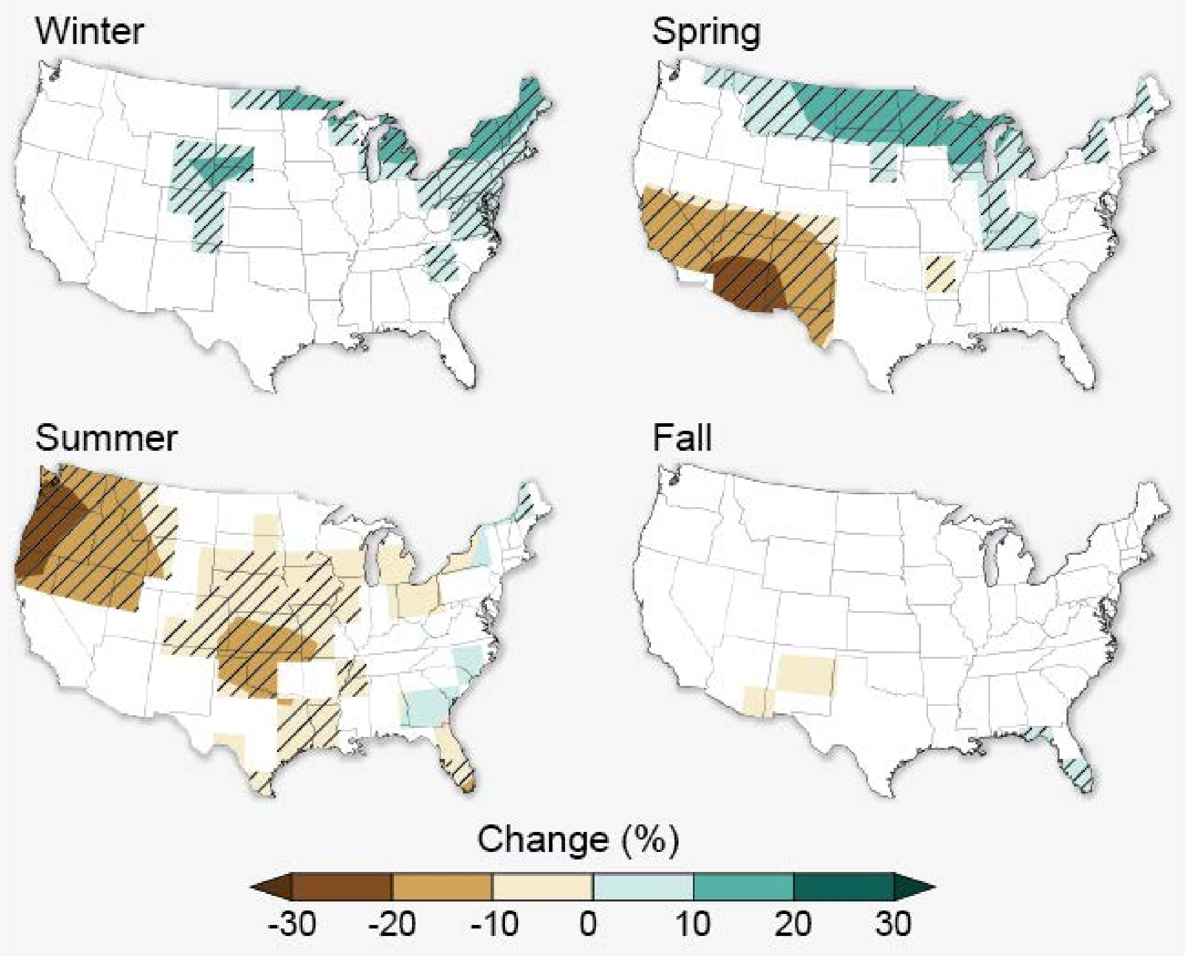




Inflow data Courtesy of Ron Anderson, LCRA

Precipitation Data: CPC Unified dataset

Climate Projections: Precipitation (2041-2070)



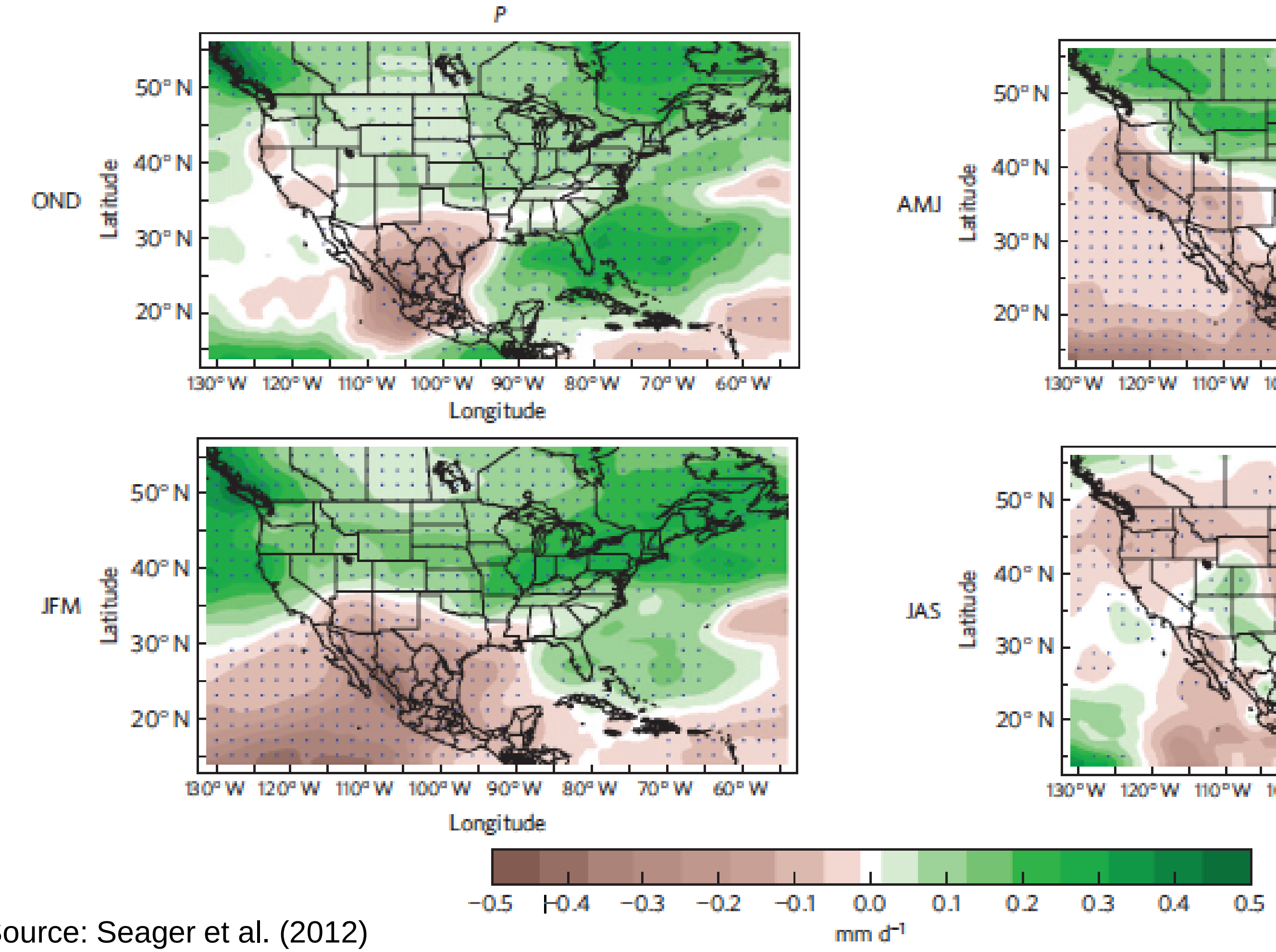
Projected changes in average precipitation by season for 2041–2070 compared to 1971–1999, assuming emissions of heat-trapping gases continue to rise (A2 scenario).

Hatched areas indicate that the projected changes are significant and consistent among models. White areas indicate that the changes are not projected to be larger than could be expected from natural variability.

Figure source: National Climate Assessment, 2014. CMIP3 models.

Climate Projections: Precipitation (2021-2040)

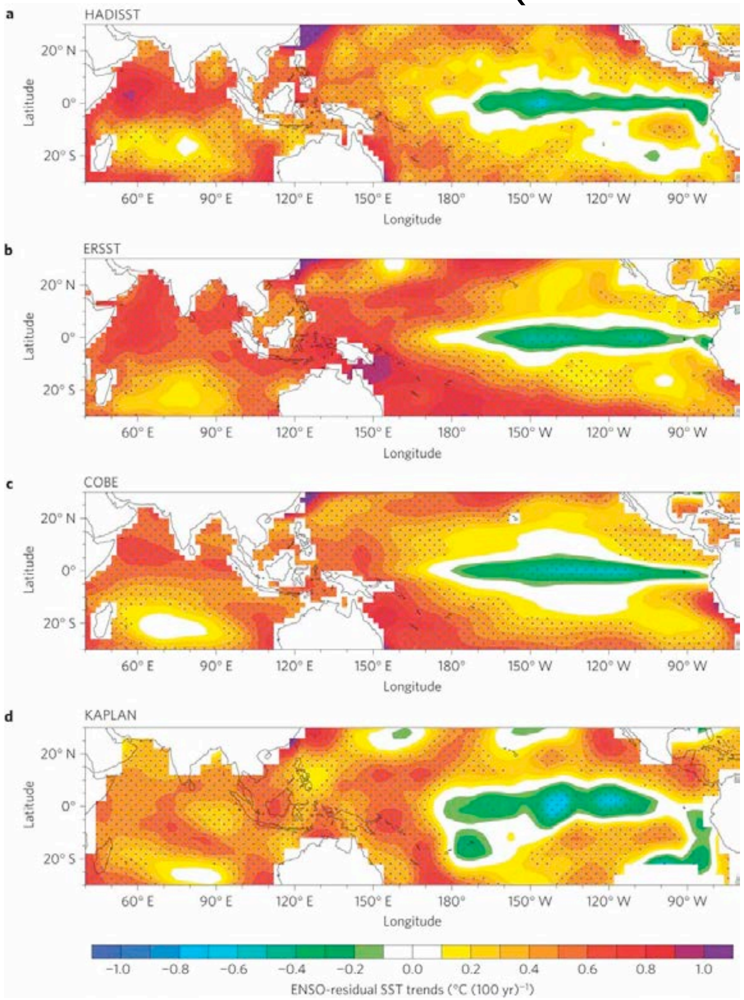
RCP8.5 Scenario, 16 Models from CMIP5 (Relative to 1950-1990 observations)



Source: Seager et al. (2012)

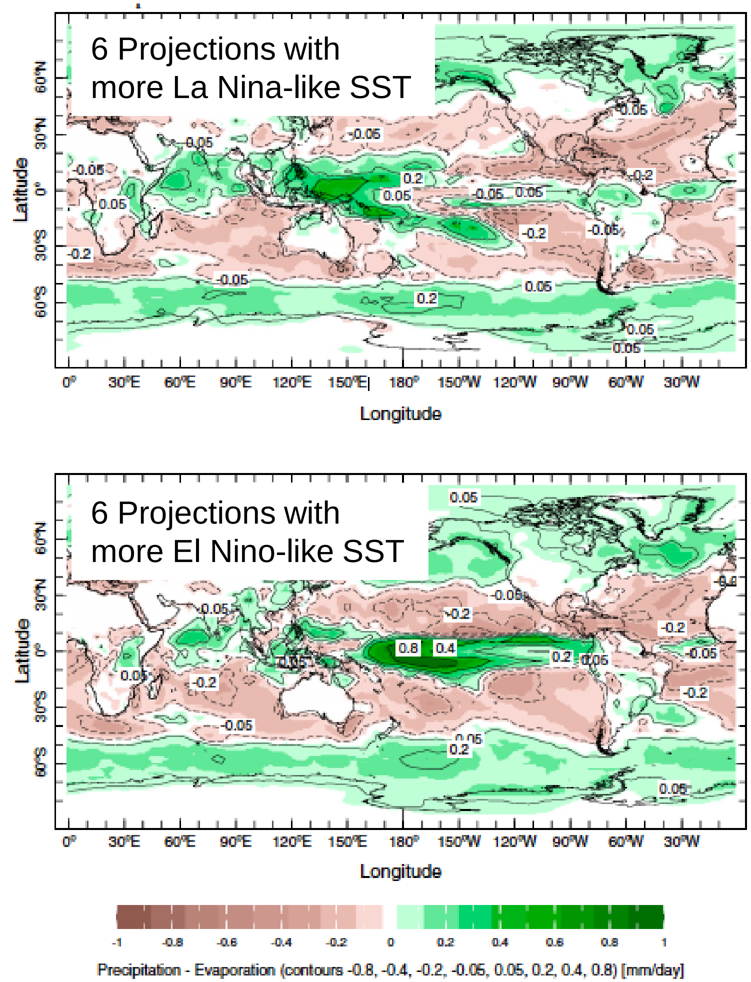
(Aside) Will Global Warming Lead to a *Cooler East Pacific*?

Observed SST Trends (1900-2010)



Solomon and Newman (2012)

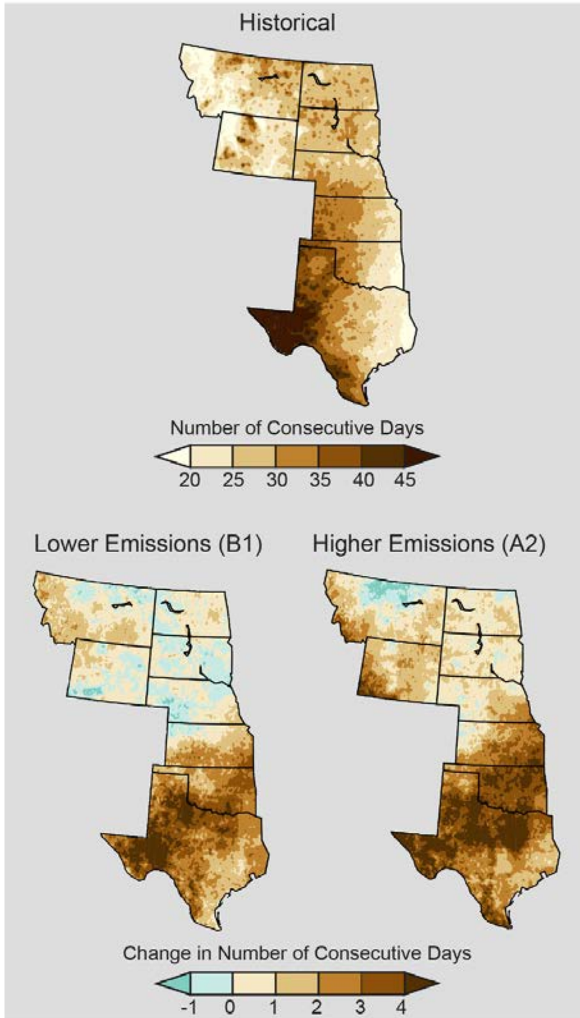
Model Projections 2021-2040

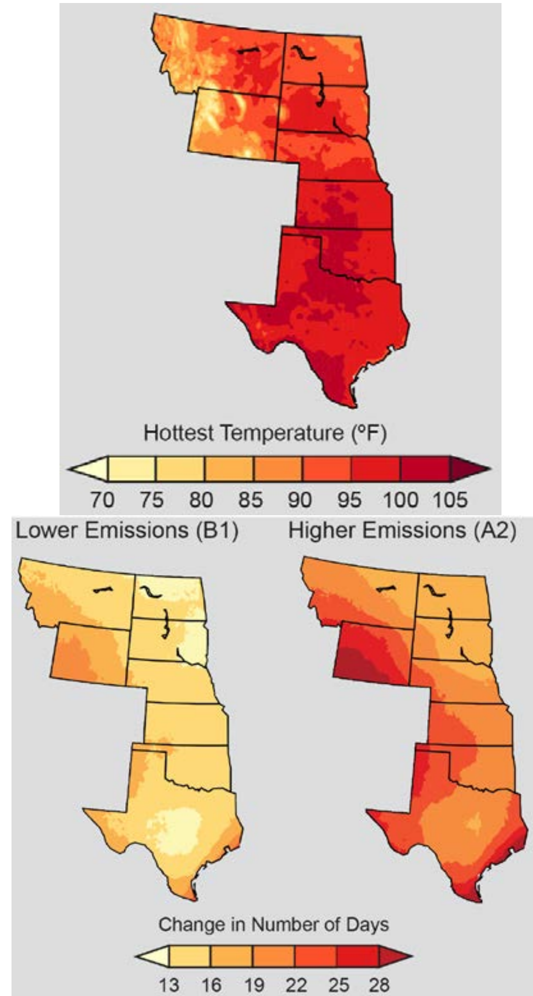


Seager and Vecchi (2010)

National Climate Assessment Projections

Changes by 2041-2070 (relative to observations for 1971-2000)





Atmospheric Water Demand

FIGURE 4.4. AVERAGE ANNUAL PRECIPITATION FOR 1981 TO 2010 (INCHES) (SOURCE DATA FROM TWDB, 2005 AND PRISM CLIMATE GROUP, 2011).

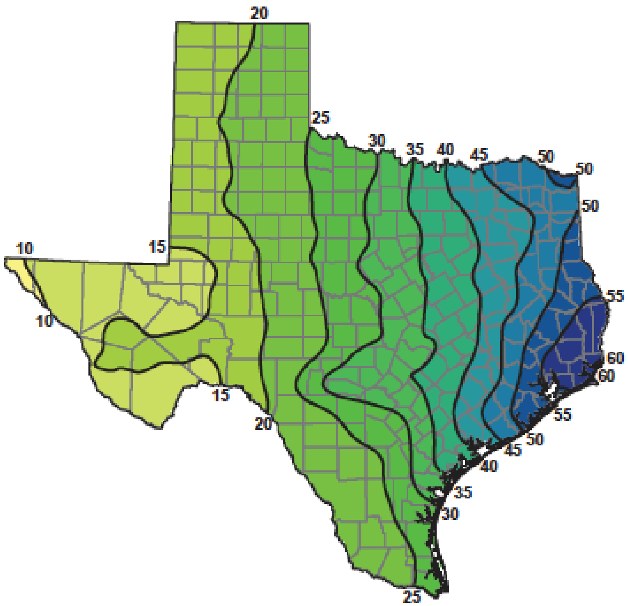


FIGURE 4.5. AVERAGE ANNUAL GROSS LAKE EVAPORATION FOR 1971 TO 2000 (INCHES) (SOURCE DATA FROM TWDB, 2005).

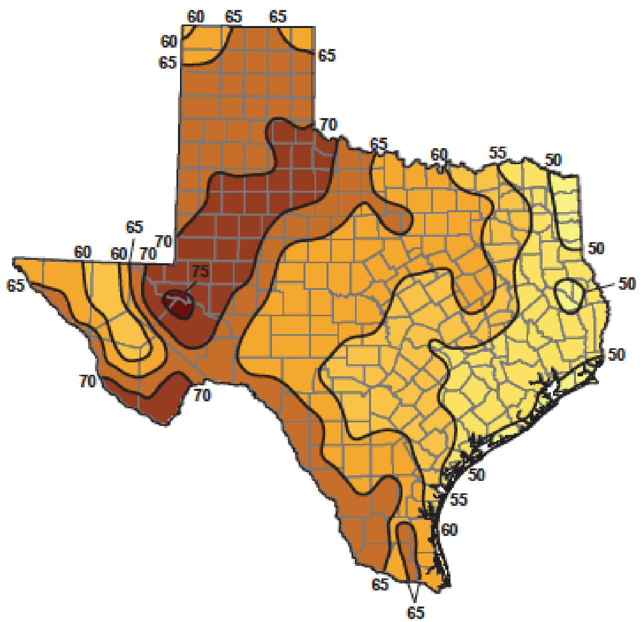


Figure: Texas Water Development Board, 2012 State Water Plan

Drought, Heat, and Heating

Less rain → Drier Soil → Less Evap. → Higher Temp.

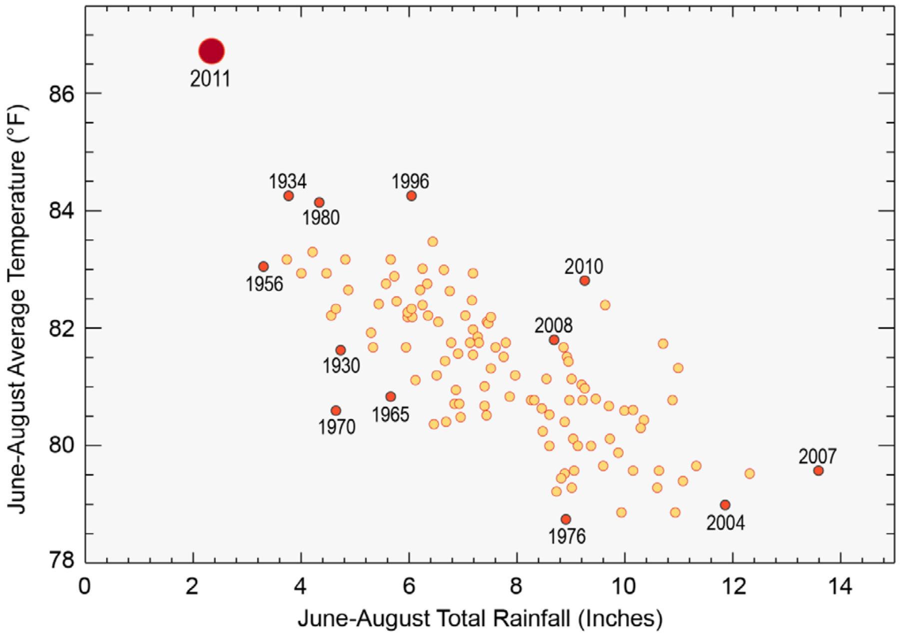


Figure source: National Climate Assessment 2014

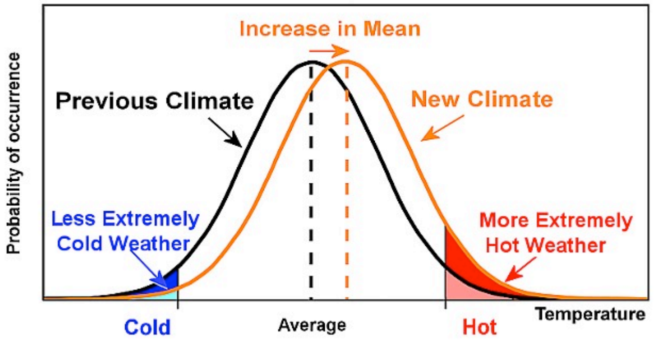
An increase in “background” temperature due to global warming is the result of additional heating at the surface.

The additional heating exacerbates the severity of drought through additional drying of the surface and thus heating of the air.

A recent study of the 2011 Texas drought/heat (Hoerling et al. 2013) wave finds ~1/5 of the warming (1° F) from anthropogenic forcing. The PRCP deficit was indistinguishable from natural variability.

Daily Municipal Water Demand During Dry Days

Versus Daily Temperature (College Station, Austin, Dallas)



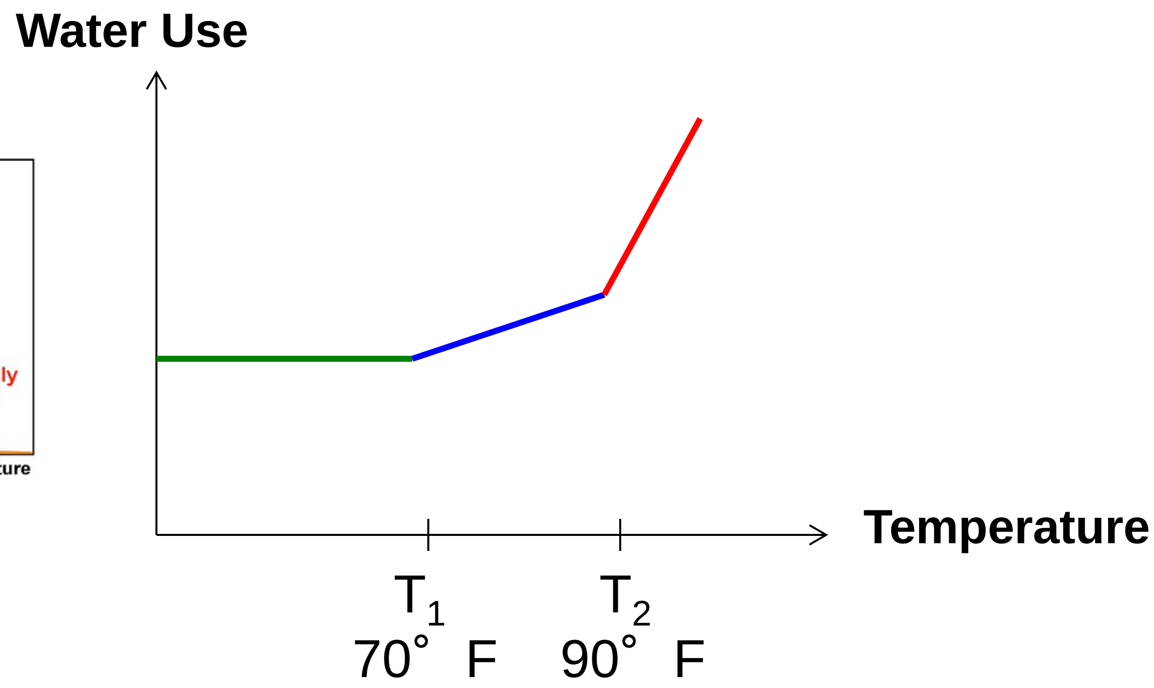


Figure: IPCC AR4

Adapted from Maidment and Miaou (1986)

Daily Municipal Water Demand
(Austin)

Water demand increases as supply decreases:
Changes of “weather within the climate” matter

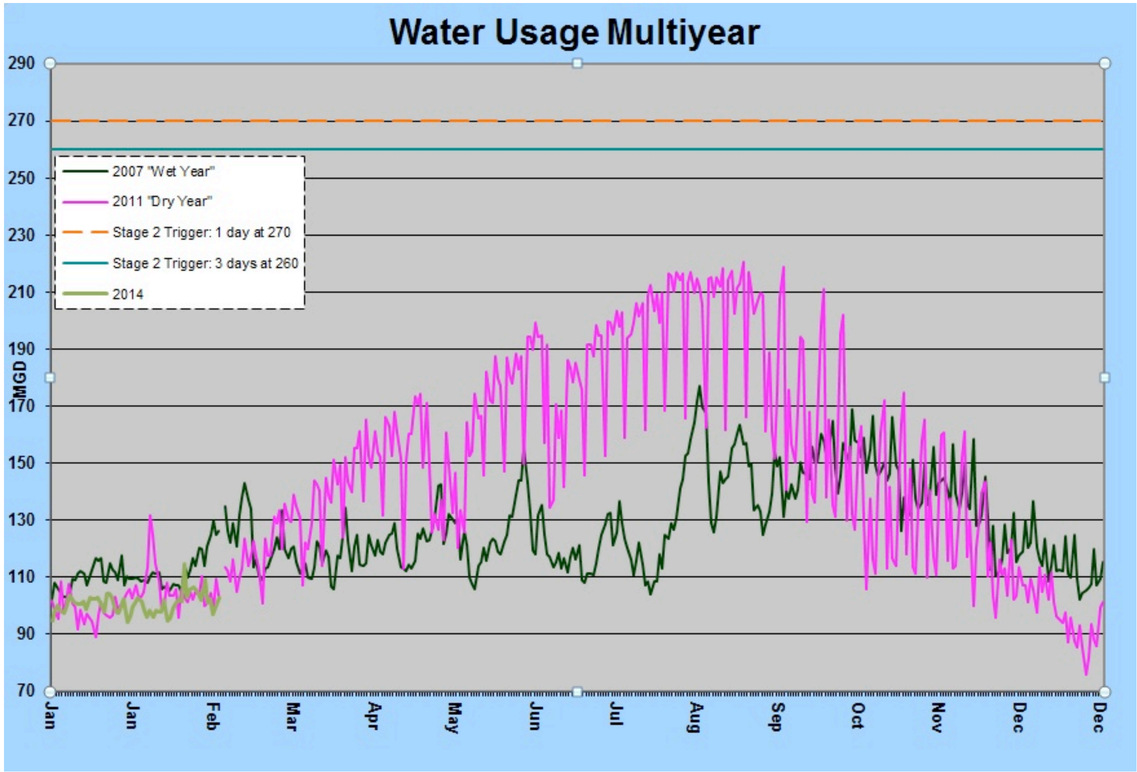


Figure Source: Austin Water, http://www.austintexas.gov/department/austin-daily-water-usage

Conclusions

- Natural variations in the climate system will continue to be the major contributors to fluctuations in water availability in the coming 40 years:

  → Seasonal-to-interannual variations, some associated with La Nina and El Nino, others not (i.e., due to “internal variability” of the climate);

  → Decadal-scale climate variations, some linked to behavior of the Pacific and Atlantic Ocean sea surface temperatures;

  → The “character” of precipitation (e.g., heavy events or lack thereof) matters

- Climate projections:

  → It is very likely that average temperatures and extreme high temperatures will increase, intensifying heat waves and droughts that arise naturally and accelerating evaporative water loss;

  → Much more uncertainty for precipitation, though models favor drying;

  → Summer is a key season from an atmospheric water demand perspective, with evaporation already exceeding precipitation (climatologically)

- When climate change and variability are in the same direction, extremes are more likely. By itself, climate change is pushing towards increased water stress.