

*Use of sub-seasonal to seasonal (S2S) rainfall forecasts by the Texas Water Development Board**

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**Unless specifically noted, this presentation does not necessarily reflect official Board positions or decisions.*

Texas: *a land of hydrological extremes*



Source: Texas Parks and Wildlife Department

Lake Travis during the 2010-2014 drought



**Fischer Store Bridge
Memorial Day Flood of 2015**

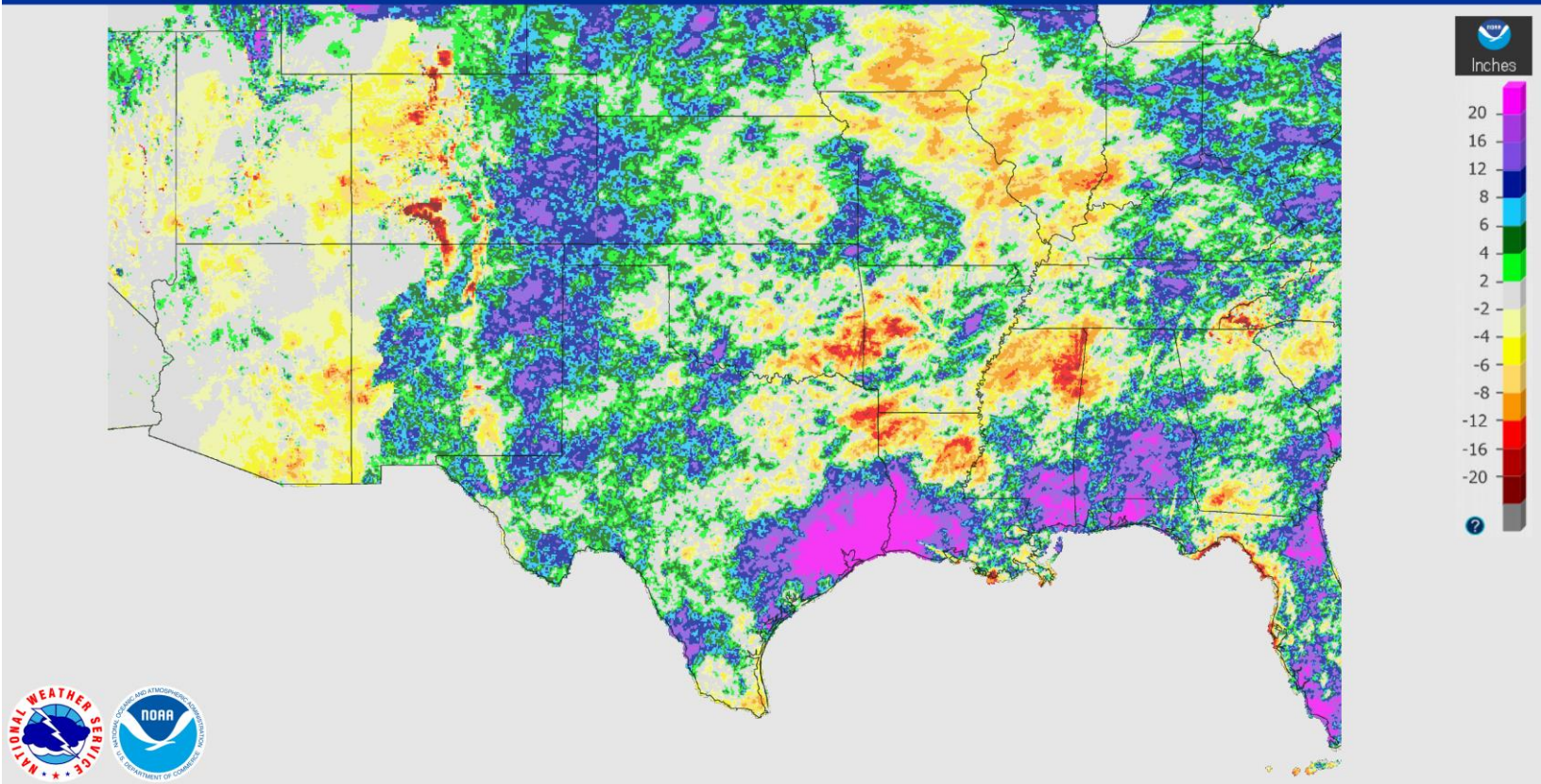
<http://www.mysanantonio.com/news/local/article/TXDoT-Two-bridges-wrecked-in-the-Central-Texas-6294892.php#photo-8047612>

Drought and flood at the same time?

October 01, 2017 Water Year (Oct. 1) Departure Precipitation

Created on: January 17, 2018 - 12:48 UTC

Valid on: October 01, 2017 12:00 UTC

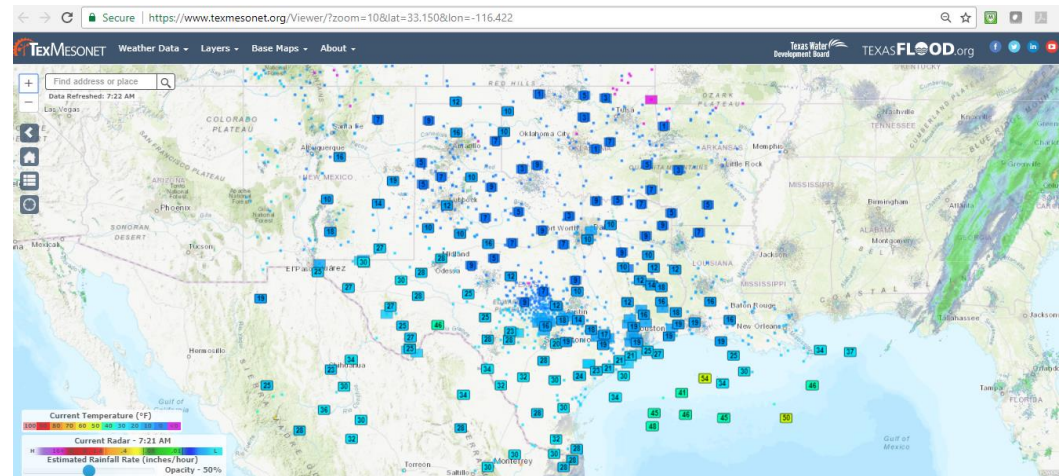


Rainfall departures for the 2016–2017 Water Year

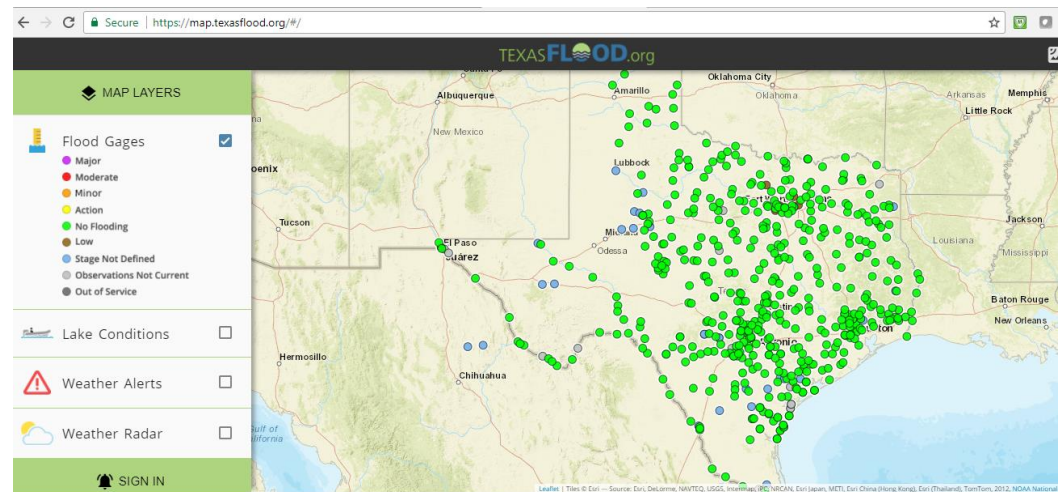
Drought and flood: TWDB's role



- State/regional water planning
- **New: State Flood Plan (underway)**



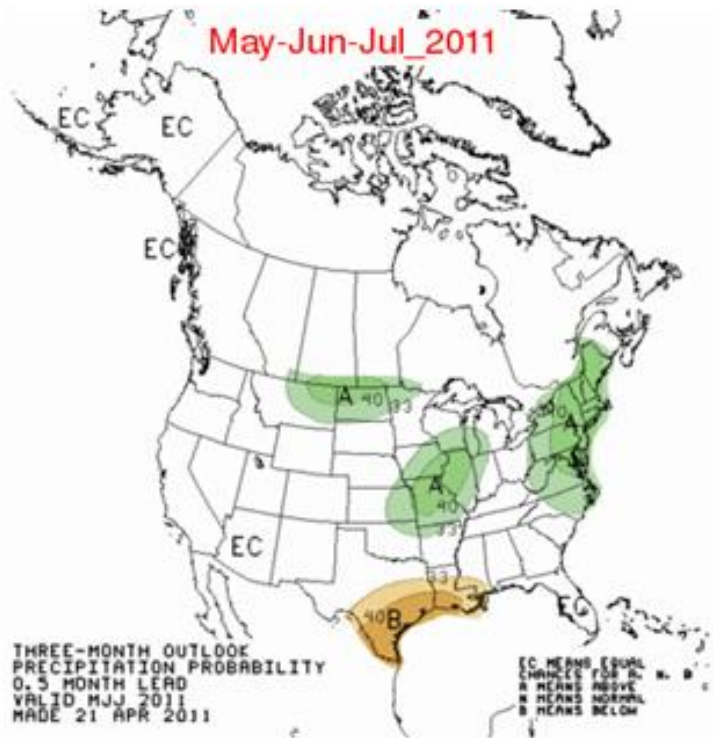
TexMesonet (www.texmesonet.org)



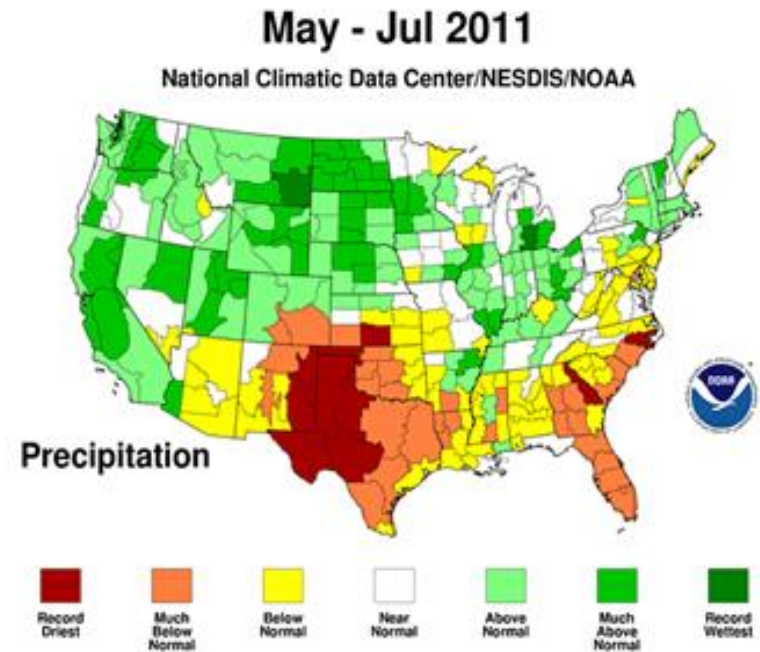
map.texasflood.org

2011: record drought

NOAA forecast of May–July (MJJ) 2011



Observed MJJ 2011

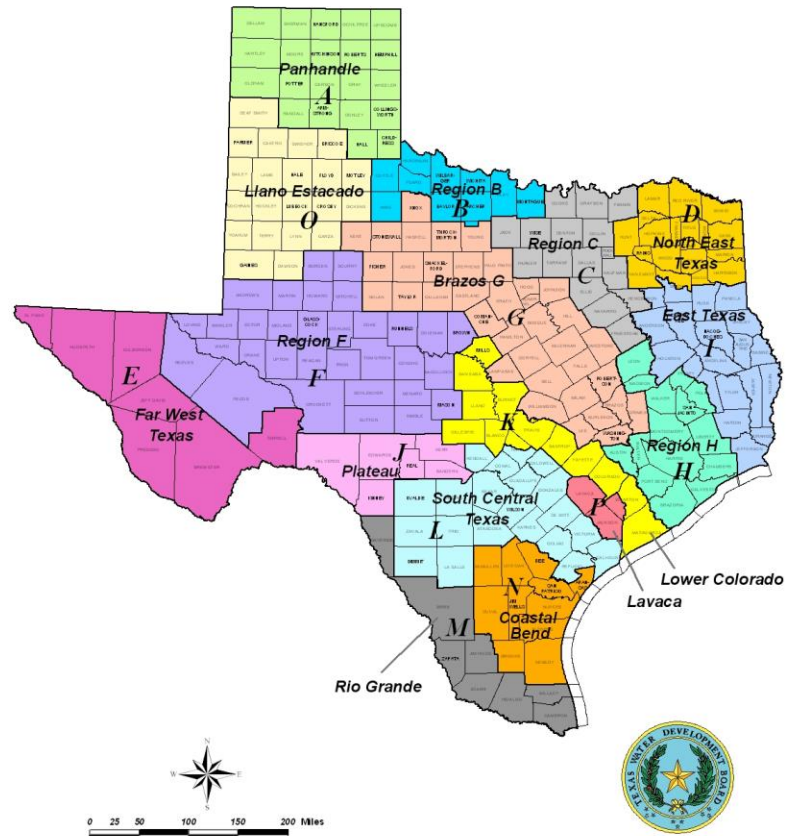


Spring intensification was not forecast.

Changes to drought planning after 2011

- Post 2011 drought (TAC § 358.3 (1) rule modification):
 - Plans must provide for the preparation for, and response to, drought conditions.
 - Water User Groups must:
 - *Have drought response triggers for all water sources*
 - *Have a drought water management strategy*
 - Information on forecasted/persistent drought conditions needed.

Regional Water Planning Areas



Background on drought in Texas

- Strong summer droughts are characterized by the rapid intensification in the spring/early-summer.
- 92% of strong summer droughts (going back to 1895) had anomalously low rainfall in the spring.
- Dry springs > anomalously high atmospheric pressure system over Texas > subsidence and a reduction in rainfall.
- Once set up, the high pressure system tends to persist (i.e. hotter, less rainfall, even hotter, etc.) through the summer.

Reference: Fernando et al. (2016), What caused the spring intensification and winter demise of the 2011 drought over Texas?. Climate Dynamics, pp.1-14. (doi:[10.1007/s00382-016-3014-x](https://doi.org/10.1007/s00382-016-3014-x))

Process-based statistical rainfall forecasts: MJJ

- Failure of the MJJ rainfall season > intense summer
forecast of MJJ rainfall serve as early warning of summer drought
- Model to predict MJJ rainfall over domain 110W–92W; 24N–40N
- Key processes (also predictors in forecast model) active in the spring (April) that drive summer rainfall deficits:
 - *Mid-tropospheric (500 hPa) high pressure, Enhanced convective inhibition energy, and low soil moisture*
- **Data:**
 - Climate Forecast System Reanalysis (Saha et al., 2010)
 - Have tested with MERRA data, SMAP soil moisture, CCI-ECV soil moisture
- **Model development:**
 - Matlab and Climate Predictability Tool (CPT, <http://iri.columbia.edu/our-expertise/climate/tools/cpt/>)

Reference: Fernando et al. (2015),

http://www.twdb.texas.gov/publications/reports/technical_notes/doc/TechnicalNote15-02.pdf

Automation of the MJJ rainfall forecast tool

- We further developed the forecast tool with a WaterSMART grant from the U.S. Bureau of Reclamation's Drought Response Program.
- Products created to aid summer drought preparedness in Texas:
 - **Automated MJJ rainfall forecast tool**
 - Provides **county-level** forecasts of MJJ rainfall from January 16 through May 1, with updates every two weeks.
 - Forecasts made from mid-January through end-March based on forecasts fields of April from the Climate Forecast System version 2 (CFSv2).
 - Forecasts made on April 16 and May 1 are based on reanalysis.
 - **Experimental MJJ reservoir storage forecasts for three reservoirs in the Brazos river basin.**
 - **Experimental MJJ reservoir evaporation rate forecasts.**

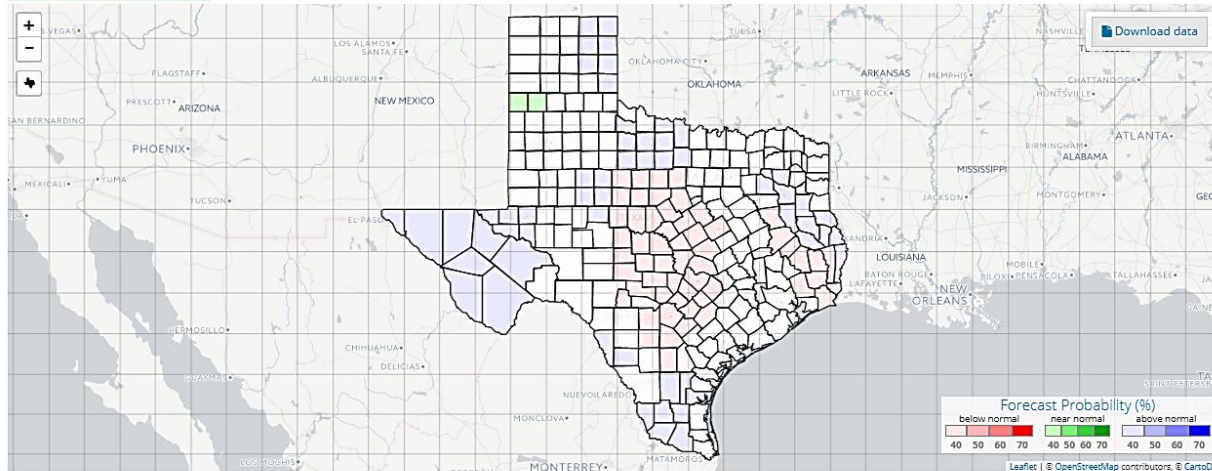
Rainfall (“Drought”) forecast tool



Forecast of Average May–July Rainfall

Current (3.0-Month Lead) Forecast

Click on county for forecast details



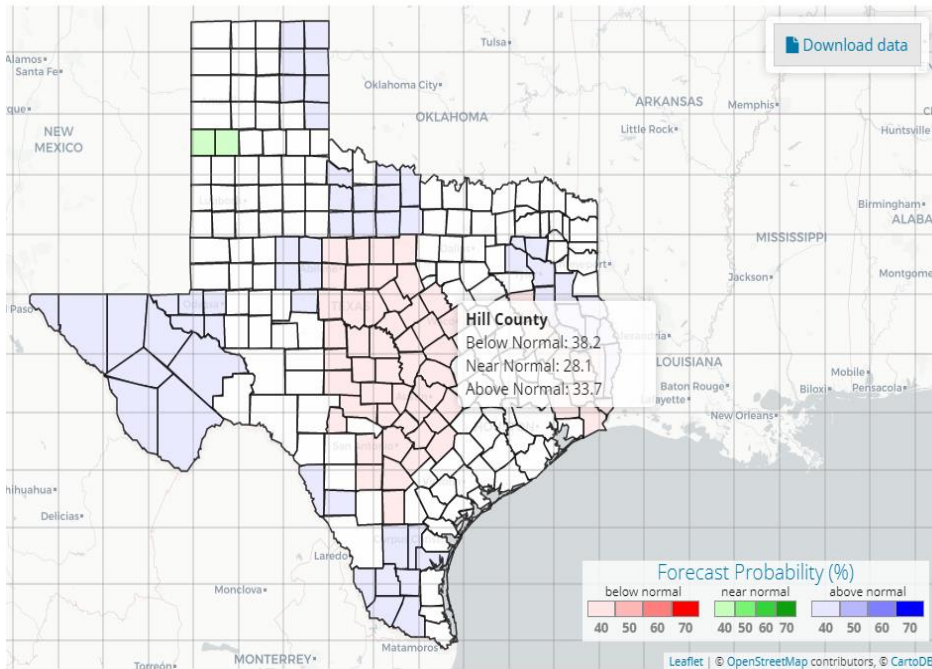
- The Texas Water Development Board issues these May–July forecasts of seasonal rainfall using a statistical forecast technique (Fernando et al., 2015) based on large scale atmospheric circulation patterns at approximately 5,500 meters above sea level, atmospheric stability influencing the development of convective weather systems, and soil moisture in April known to influence May–July rainfall.
- The statistical rainfall forecasts are issued from January through end-April. The forecasts are updated every two weeks.
- The forecasts from January through March are based on predicted values of April atmospheric circulation patterns and soil moisture over Texas known to influence May–July rainfall. The predictions are obtained from the Climate Forecast System version 2 (CFv2, Saha et al., 2014), which is the operational dynamical seasonal forecast model of the National Oceanic and Atmospheric Administration-National Centers for Environmental Prediction.
- The forecasts issued in April are based on actual observations of April atmospheric circulation patterns and soil moisture over Texas obtained from the Climate Forecast System Reanalysis dataset (Saha et al., 2010).
- The rainfall forecast provides information on whether the average rainfall for the May–July will be above-normal, near-normal or below normal. Red indicates chances for below-normal (dry) conditions, blue indicates chances for above-normal (wet) conditions, green indicates chances for near-normal (average) conditions, and white indicates that we do not know which way the season might pan out. For more information on how to interpret the forecasts click here.

**Probabilistic forecasts
by county**

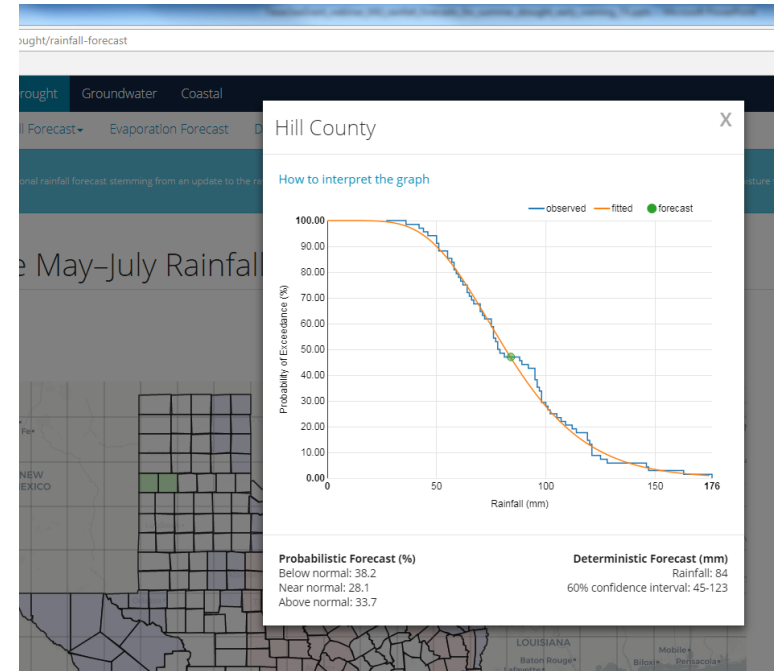
<http://www.waterdatafortexas.org/drought/rainfall-forecast>

<http://www.waterdatafortexas.org/drought/rainfall-forecast-info>

Rainfall forecast: *information products*



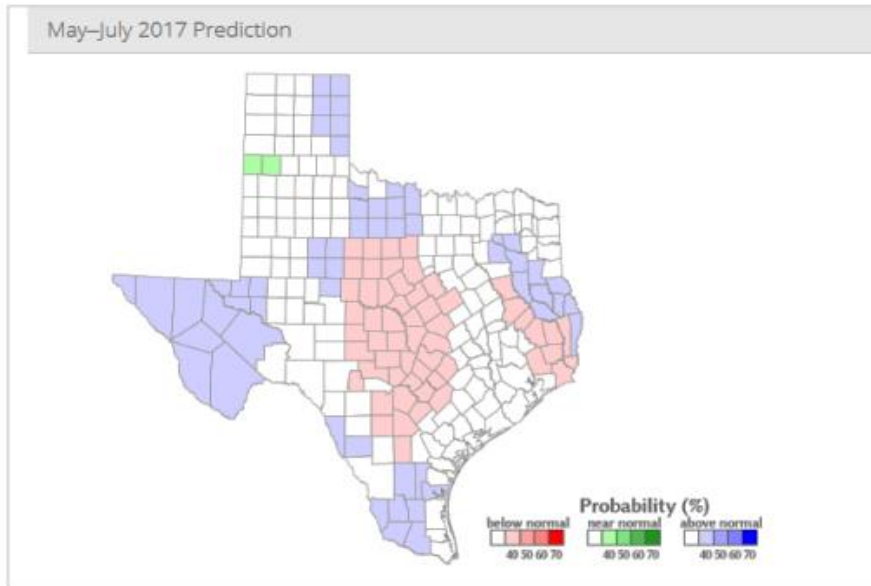
Left: Hover over county to obtain a **probabilistic forecast** to ascertain whether upcoming season will be below-, near-, or above-normal.



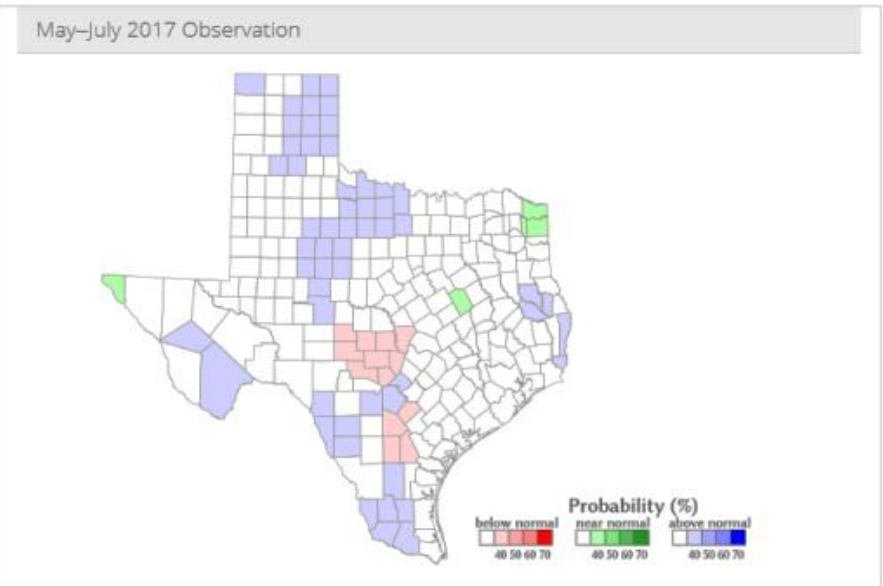
Right: Click on county to obtain **probability of exceedance (POE)** plot for historical rainfall over location. Forecast rainfall quantity shown as green dot.

Tool performance in 2017

Prediction



Observation



Skill metrics:

- **Heidke Skill Score (overall score of forecasts) = 0.48**
- **Brier Skill Score for the three forecast categories**
 - Below normal: 0.24
 - Near-normal: 0.13
 - above-normal: 0.34

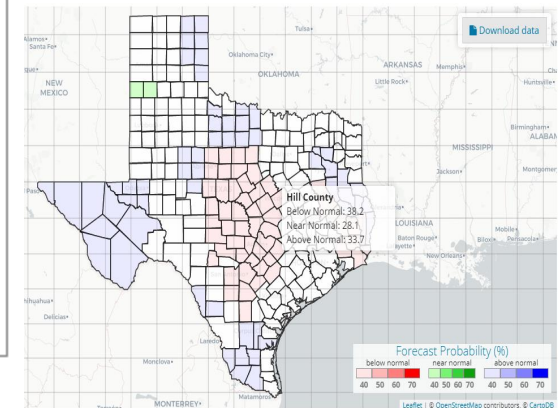
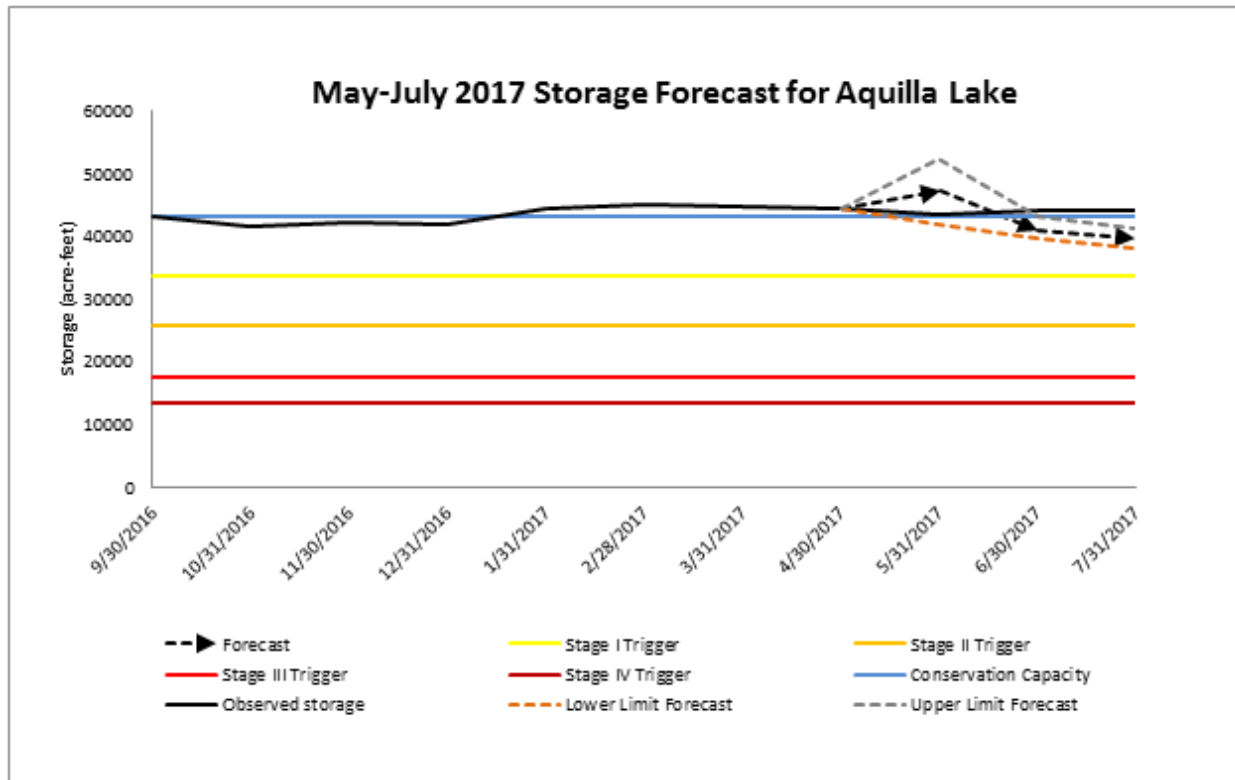
Skill

$-\infty$ to 0: skill worse than climatology

= 0: no skill over climatology

0 to 1: skill better than climatology

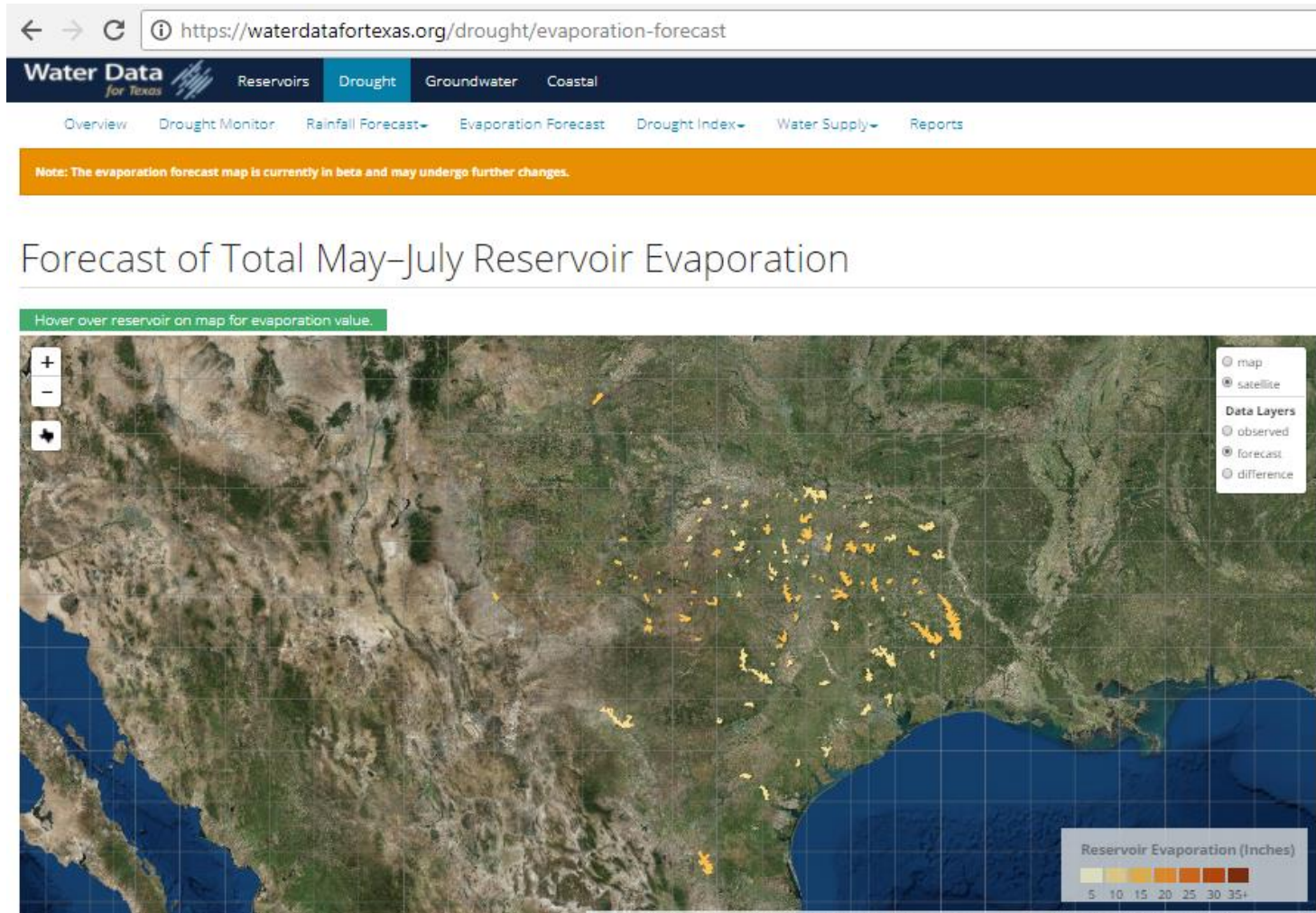
Forecast and observed storage: Aquilla Lake



https://waterdatafortexas.org/reservoirs/reports/MJJ2017_reservoir_storage_forecasts_Aquilla_Limestone_Proctor.pdf

Trigger levels for each water source available at: https://www.brazos.org/Portals/0/generalPdf/DCP_10-2012.pdf

Reservoir evaporation rate forecast



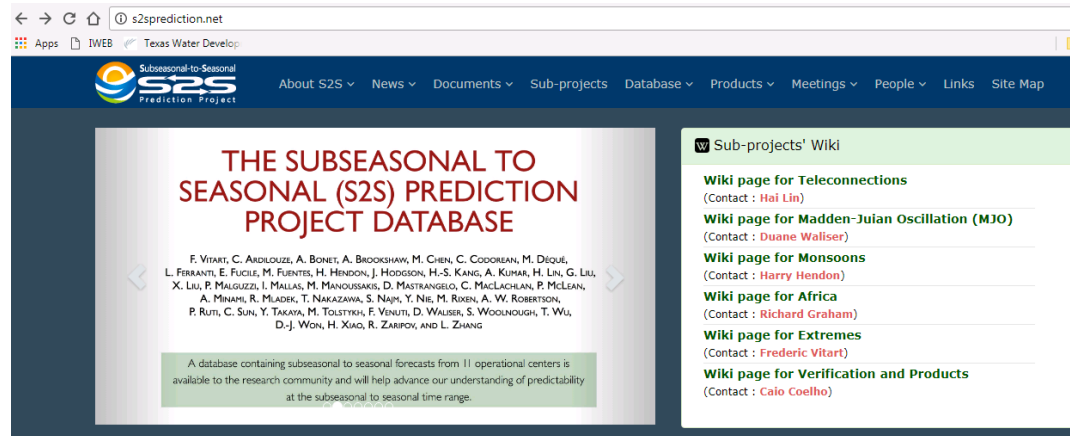
<http://waterdatafortexas.org/drought/evaporation-forecast>

Tools/libraries for forecast automation

- **Data processing and simulation runs**
 - Production environment: an Amazon cloud server running Linux OS
 - Final forecast data are stored in and served on the website from hdf5 file (<https://support.hdfgroup.org/HDF5/>)
- **Key Python libraries we use in data processing**
 - requests: make http requests to download input data files (from IRI Data Library, <http://iridl.ldeo.columbia.edu>)
 - netCDF4: read input data files
 - numpy: Empirical Orthogonal Function analysis on input data
 - pandas and geopandas (post-process forecast, generate visualizations)
- **leaflet.js**: interactive map
- **nvd3.js**: exceedance probability chart
- **subprocess**: running CPT (linux version) from a python script

Planned sub-seasonal forecast experiments

- Use sub-seasonal (two week to three month) forecast fields from the SubX database (<http://iridl.ldeo.columbia.edu/SOURCES/.Models/.SubX/>) and from the Sub-seasonal to Seasonal (S2S) Prediction Project database (<http://iridl.ldeo.columbia.edu/SOURCES/.ECMWF/.S2S/>) for bi-weekly updates of the MJJ rainfall forecast from mid-May onwards.



- Analyze sub-seasonal forecast skill at 2 week to one month lead times for 500 hPa geopotential height anomalies within the MJJ season.

Planned sub-seasonal forecast guidance

- Use the Climate Prediction Center's 3–4 week experimental forecasts of rainfall and temperature to obtain guidance on impending heat waves/rainfall deficits.
 - <http://www.cpc.ncep.noaa.gov/products/predictions/WK34/gifs/WK34prcp.gif>
 - <http://www.cpc.ncep.noaa.gov/products/predictions/WK34/gifs/WK34temp.gif>

Conclusions

- Developed, tested and deployed an automated tool to provide county-level rainfall forecasts for the May–July season.
 - Tool available at: <https://waterdatafortexas.org/drought/rainfall-forecast>
 - **Infrastructure in place to ingest forecasts for other seasons**
- Demonstrated tool applications to support drought contingency planning
- Hope to increase tool's utility
 - bi-weekly timescale from mid-May through mid-July
 - finer resolution input data (e.g. soil moisture)
- Use rainfall forecasts from the North American Multi-model Ensemble (<http://www.cpc.ncep.noaa.gov/products/NMME/seasanom.shtml>) for other seasons (e.g. December–February). **[Collaborating with Prof. Rong Fu, UCLA, on skill assessments for other seasons]**

Questions?

Contact information

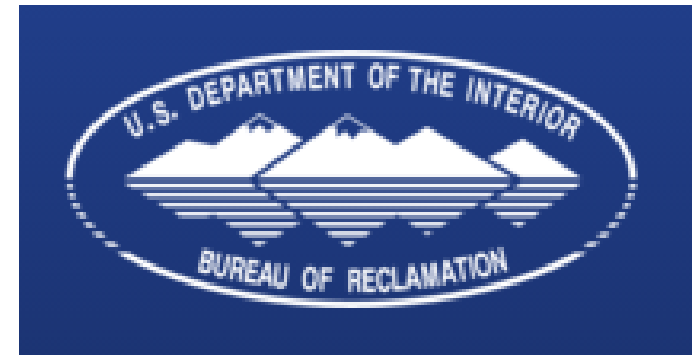
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<http://www.usbr.gov/drought/applications.html>

Grant: R15AP00184, FY 2015