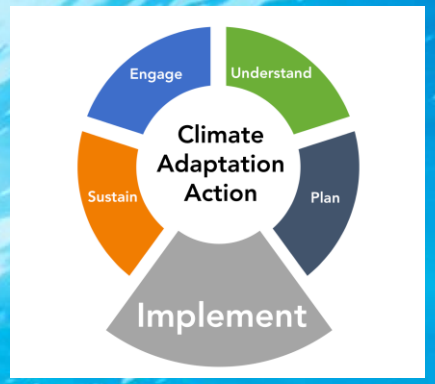
Integrating Climate Data Into Forecasting Hydrologic Inflow

WUCA Technical Training

December 3, 2019



Tarrant Regional Water District

in collaboration with

Hydros Consulting

Hydros Consulting

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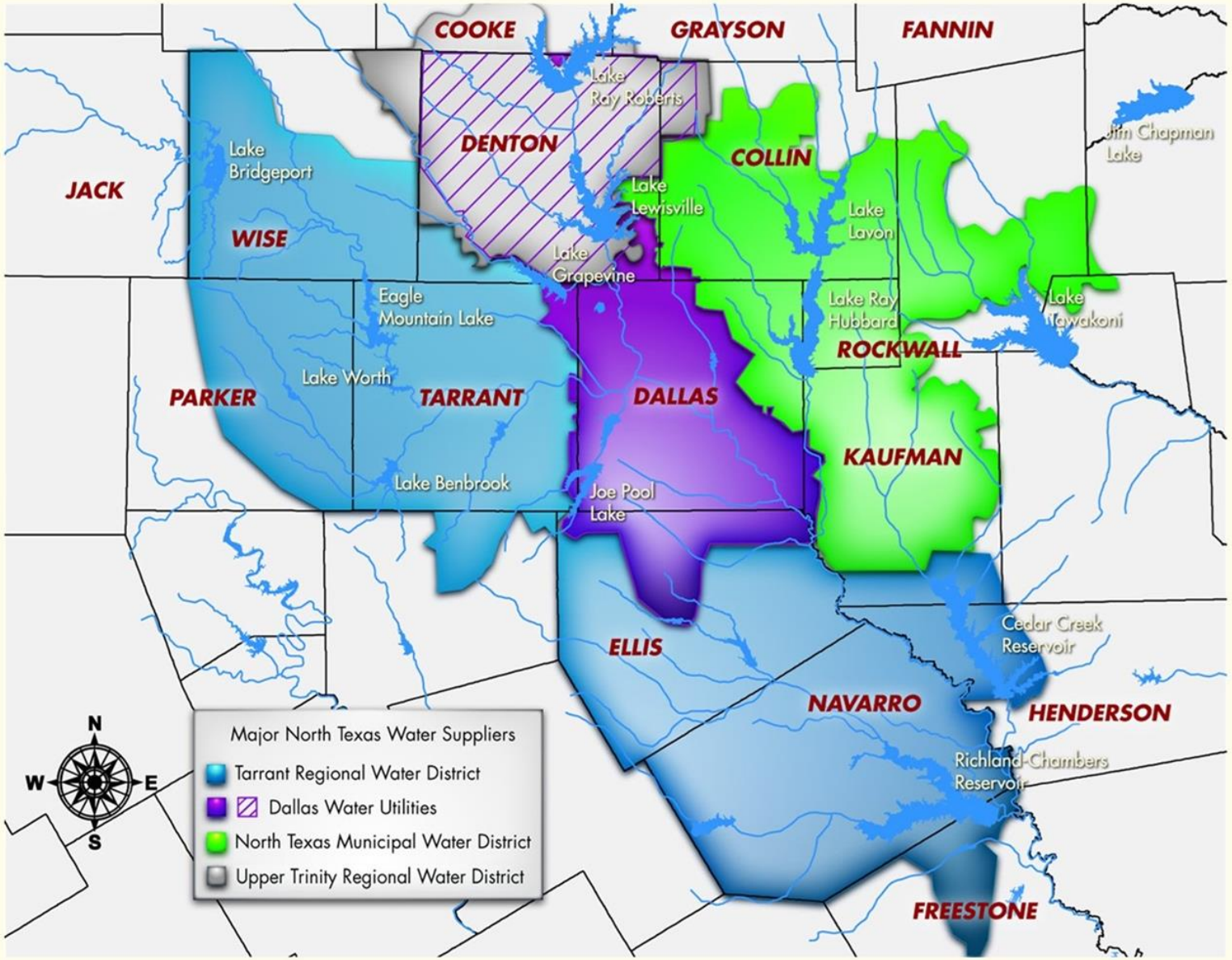

One of 3 Large Raw Water Suppliers in North Central Texas

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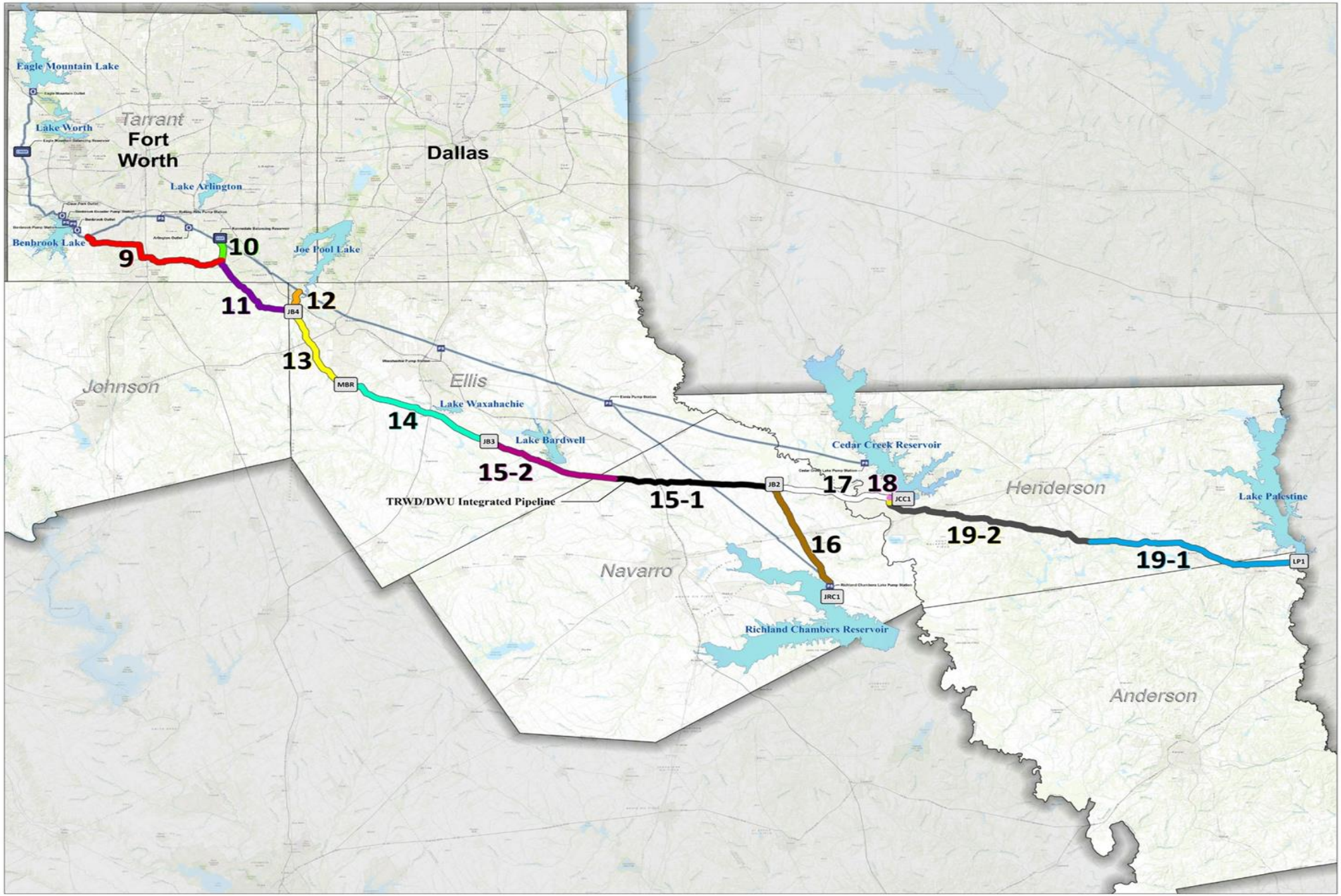

INTEGRATED PIPELINE PROJECT

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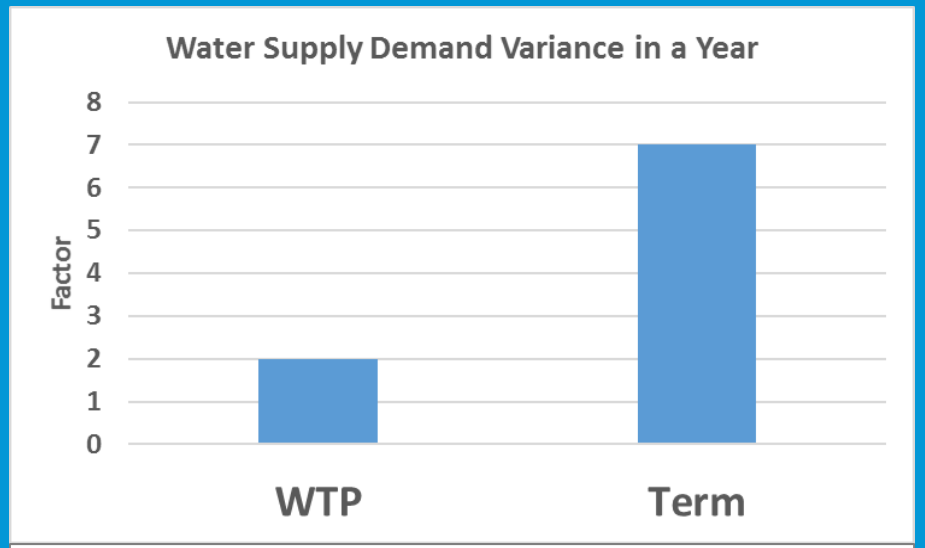
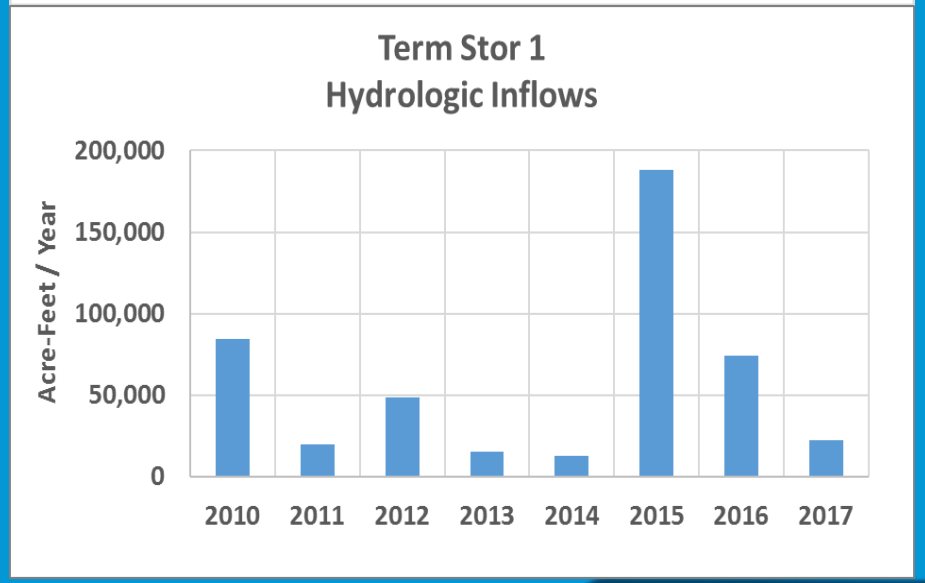
RiverWare

- "It's tough to make predictions, especially about the future." – Yogi Berra

- Uncertainty exists in water planning
  - Climate variation
  - Population growth
  - Relatively Short Hydrologic Records
  - Modeling Tools





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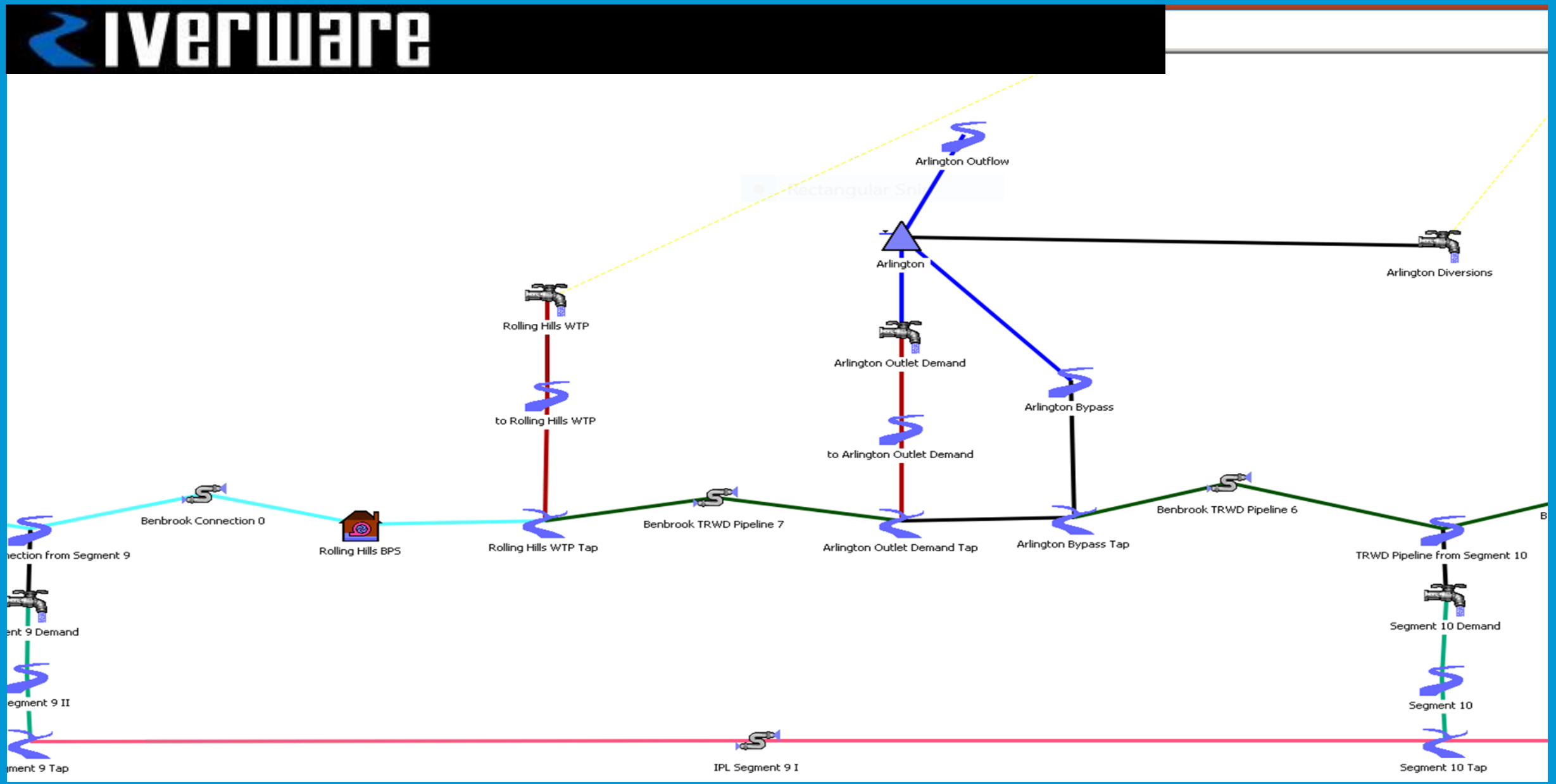
RiverWare
Arlington Outflow
Arlington
Arlington Diversions
Rolling Hills WTP
to Rolling Hills WTP
Arlington Outlet Demand
to Arlington Outlet Demand
Arlington Bypass
Benbrook Connection 0
Rolling Hills BPS
Rolling Hills WTP Tap
Benbrook TRWD Pipeline 7
Arlington Outlet Demand Tap
Arlington Bypass Tap
Benbrook TRWD Pipeline 6
TRWD Pipeline from Segment 10
Segment 10 Demand
Segment 10
Segment 10 Tap
IPL Segment 9 I
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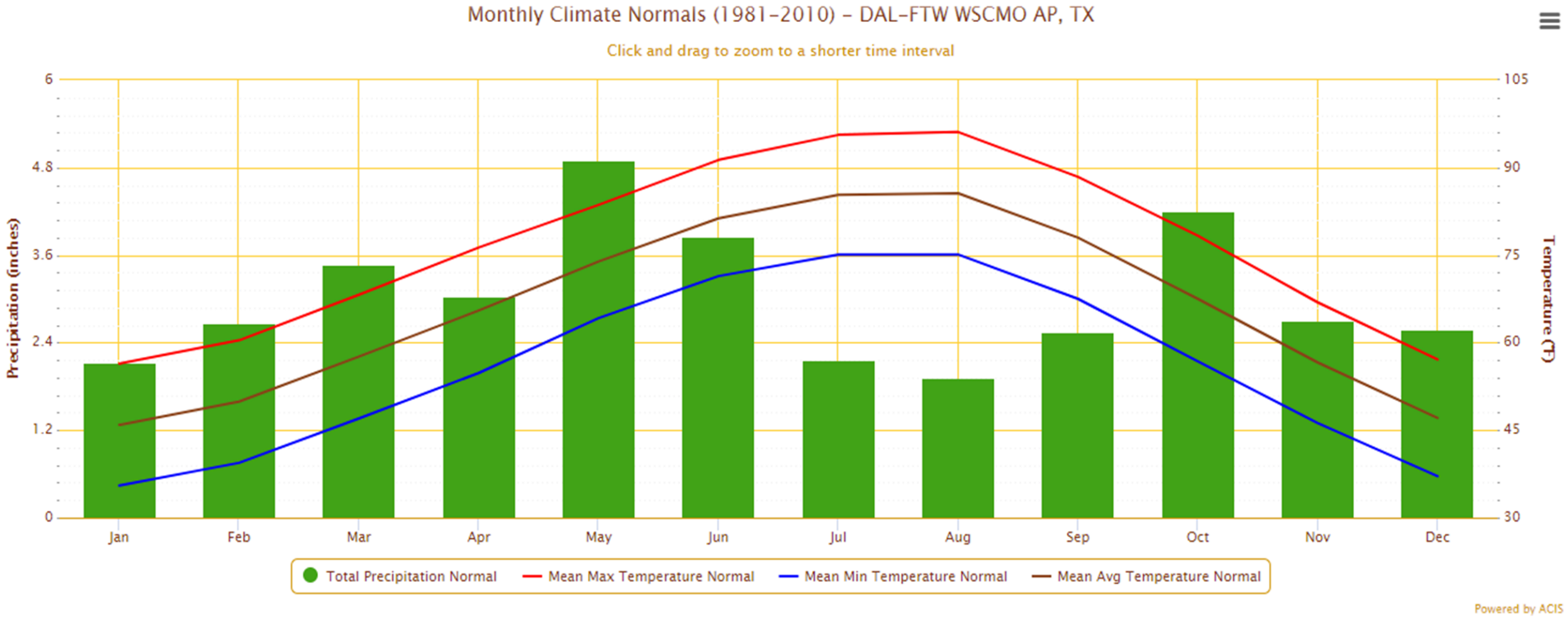
Dallas Fort Worth Monthly Climate Normals



SOURCE: ACIS NOAA REGIONAL CLIMATE CENTER

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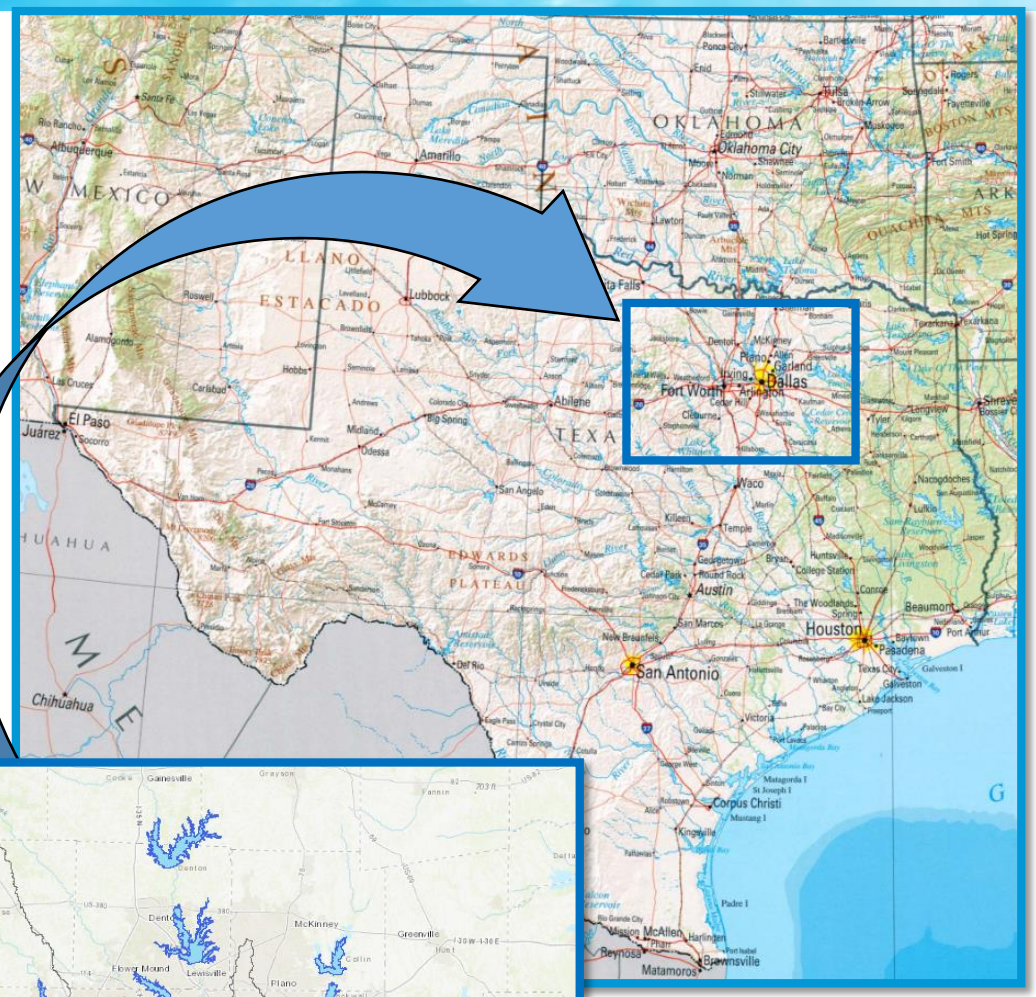
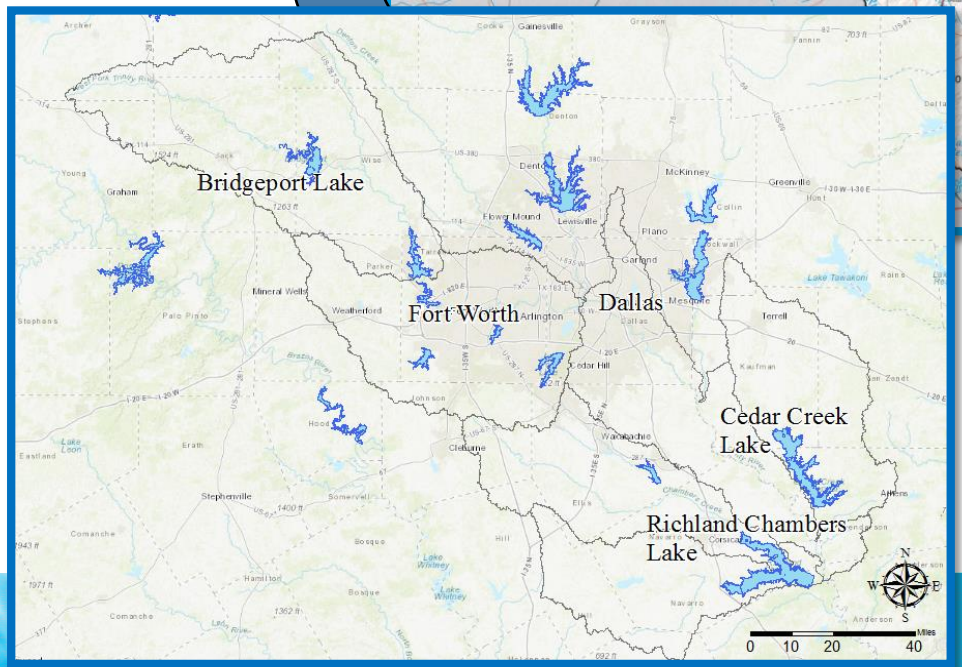




How Much Rain Has Fallen in Texas?

According to the National Weather Service in Fort Worth, Texas, over **35 trillion gallons** of rain have fallen in the month of May. Here's some perspective on that number:

35,000,000,000,000 GALLONS

Enough to cover the entire state of Texas in **8 inches** of water.

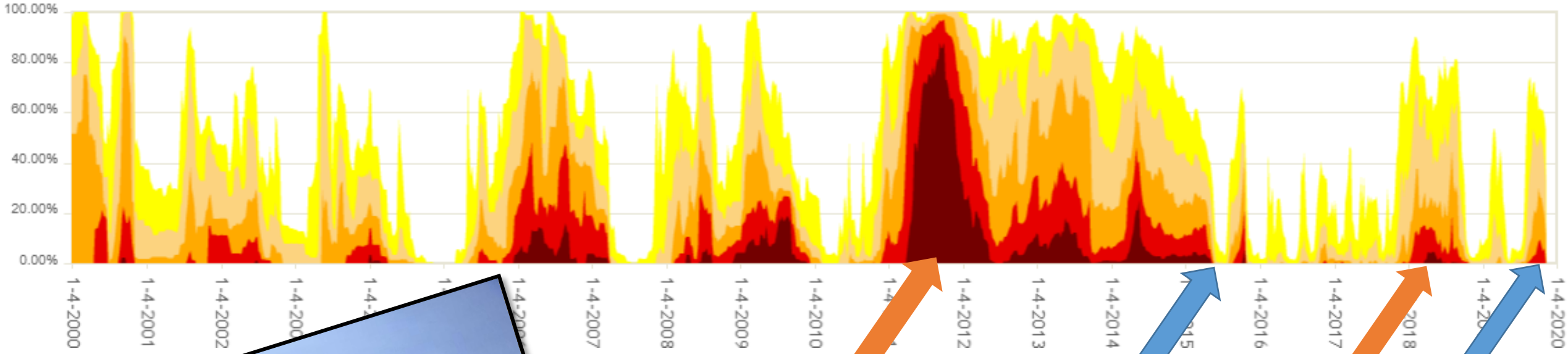
Enough to fill up California's 200 largest surface reserviors **3X** to capacity.

Enough to cover the island of Manhattan almost **4X**

Enough to supply the entire world's population with **10,000 days** of water if everyone drank eight 8-ounce glasses a day.

Sources: National Weather Service Fort Worth, California Department of Water Resources
Credit: Nelson Hsu / NBC

Texas Percent Area



2011 Drought More than 85% of the state in the D4 Category

Drought of Multiple Years Eradicated in a Month

Drought Briefly Returned in 2018

Drought returning to some of the state. What will 2020 bring?

Source: United States Drought Monitor, Image Source: LM Otero/AP

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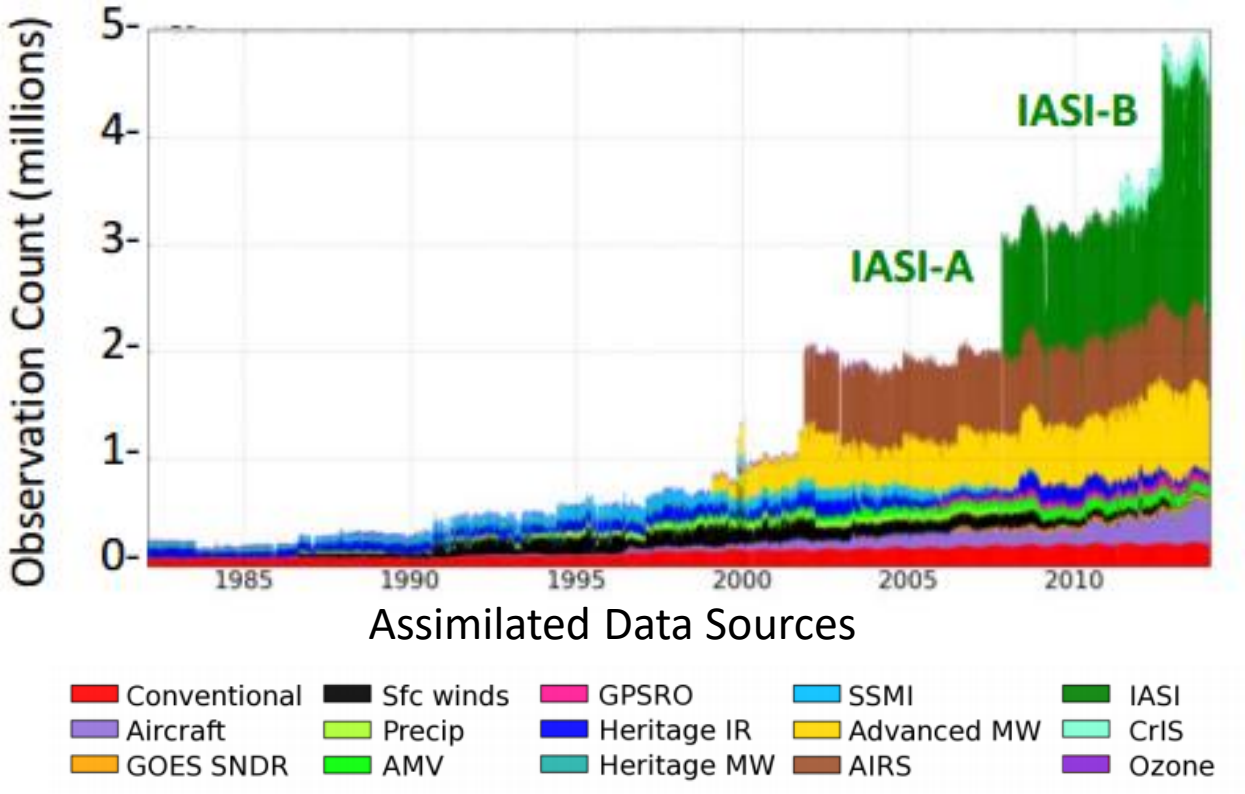
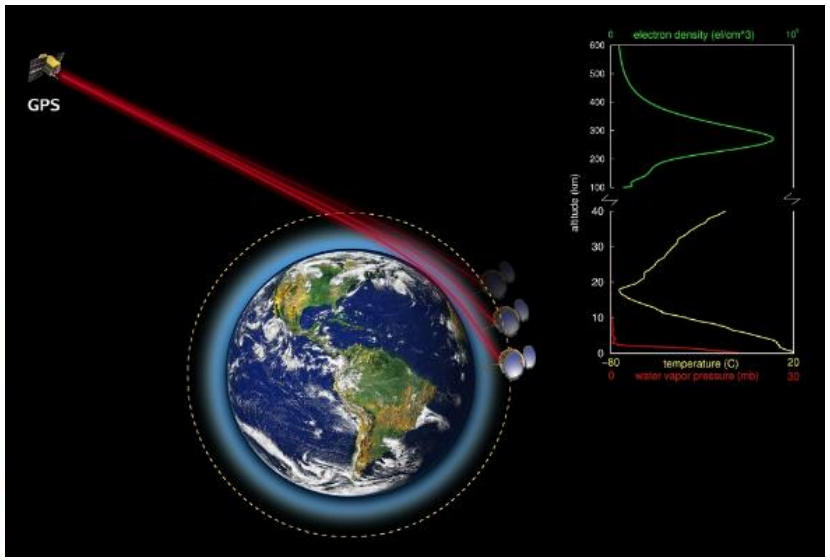
Climate Reanalysis Data

- MERRA-2 Data from NASA
  - Monthly Data (~70,000,000 Data Points)
  - “Assimilated” Observations from Ground, Air, & Space
  - https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/



Assimilated Data Sources

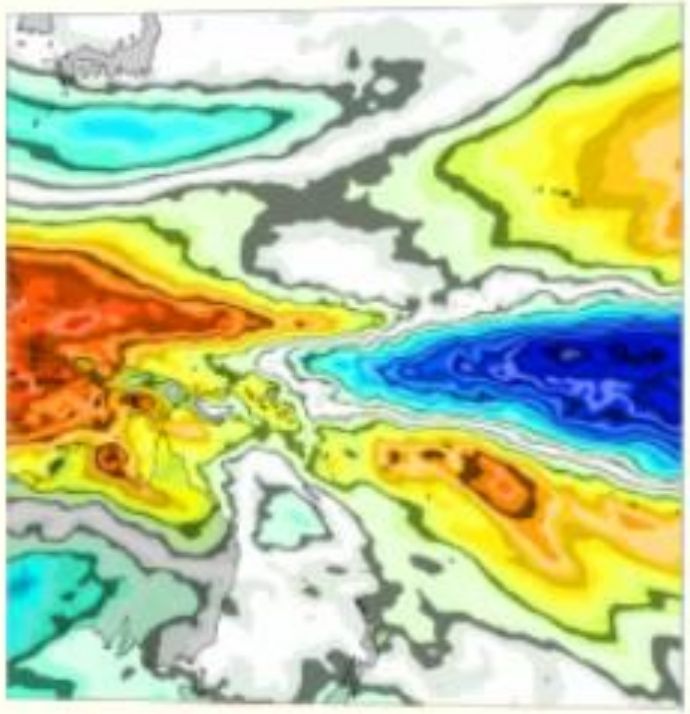


Example: GPS Occultation

Image Sources: NASA Global Modeling and Assimilation Office & UCAR COSMIC

Atmospheric Variables Used at TRWD

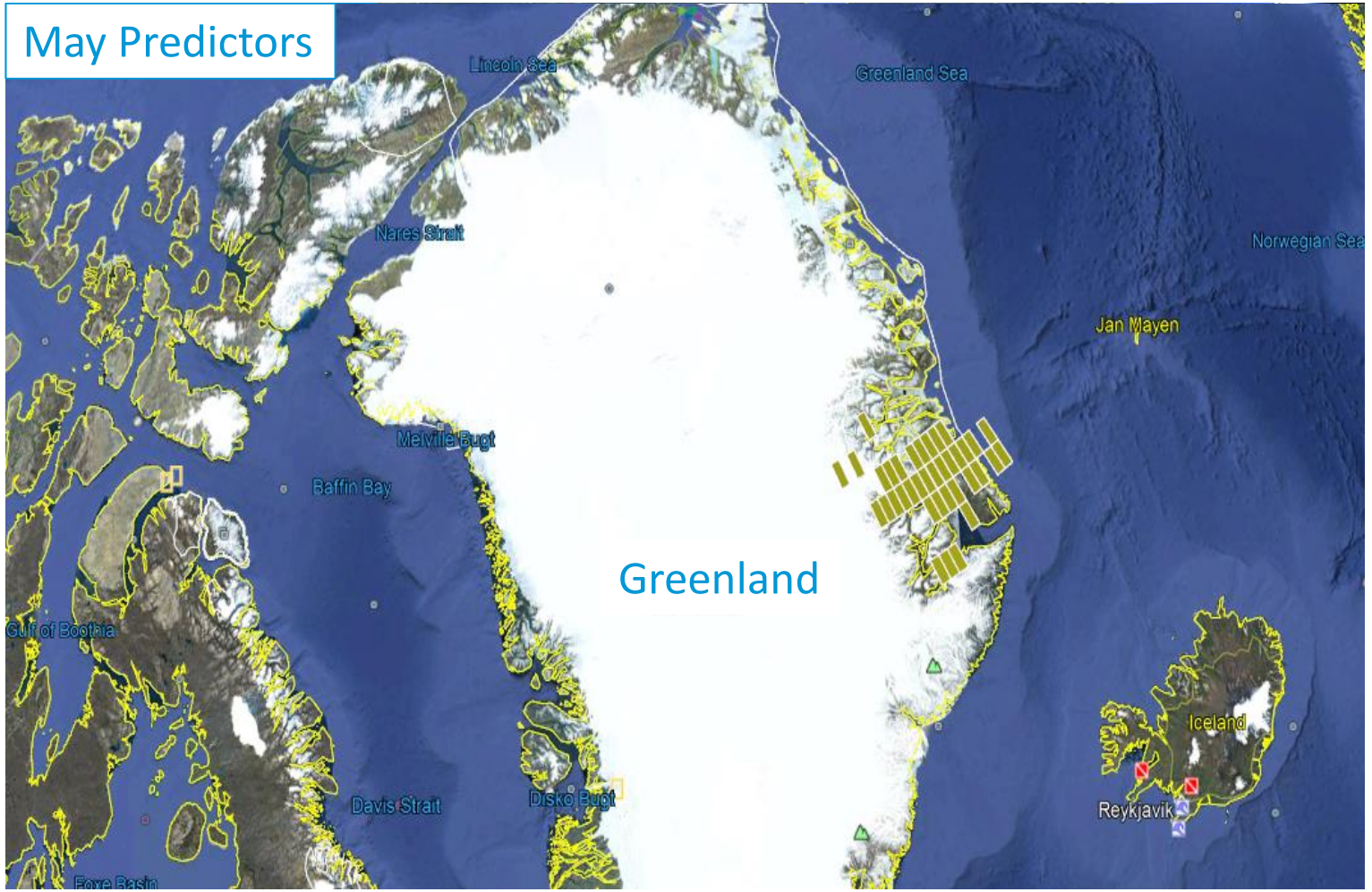
Parameter Description
Relative Humidity
Zonal (E-W) Wind
Meridional (N-S) Wind
Product of Wind Speed Anomalies
Covariance of Relative Humidity and Zonal Wind
Covariance of Relative Humidity and Meridional Wind
Geopotential Height
Temperature



- Wide range of predictors available for each month that correlate to the inflow at TRWD's Reservoirs
- The number of predictors vary from 15 in September to 246 in May

Image Source: NASA Global Modeling and Assimilation Office

Correlations to the Arctic Oscillation (AO) Found in the Predictors



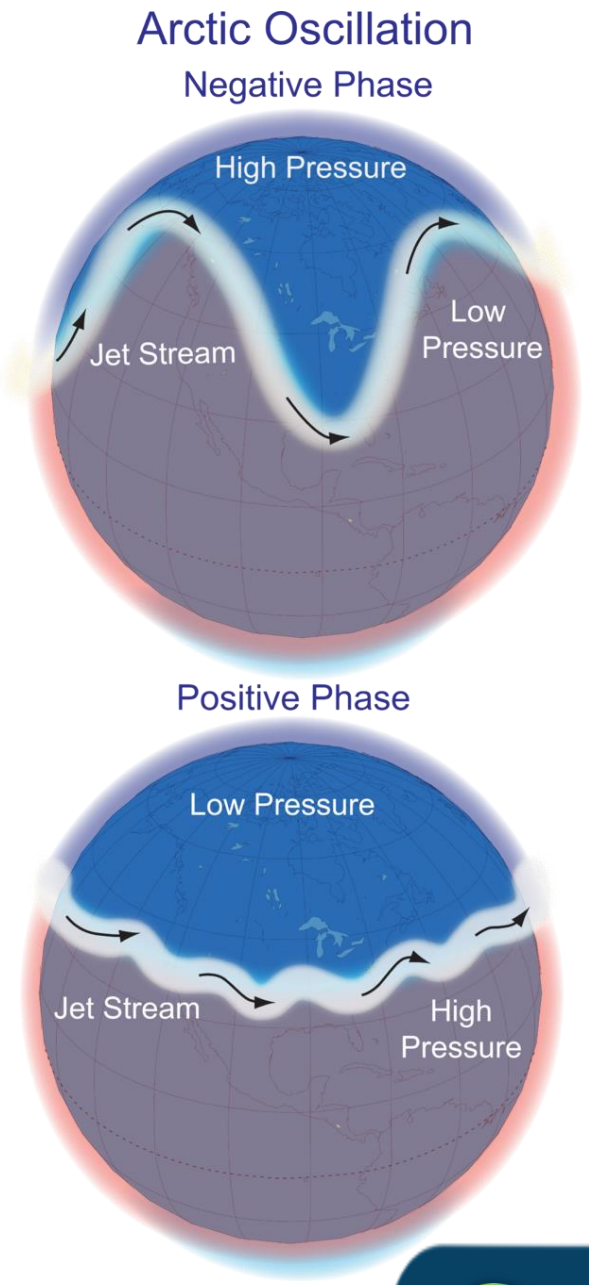
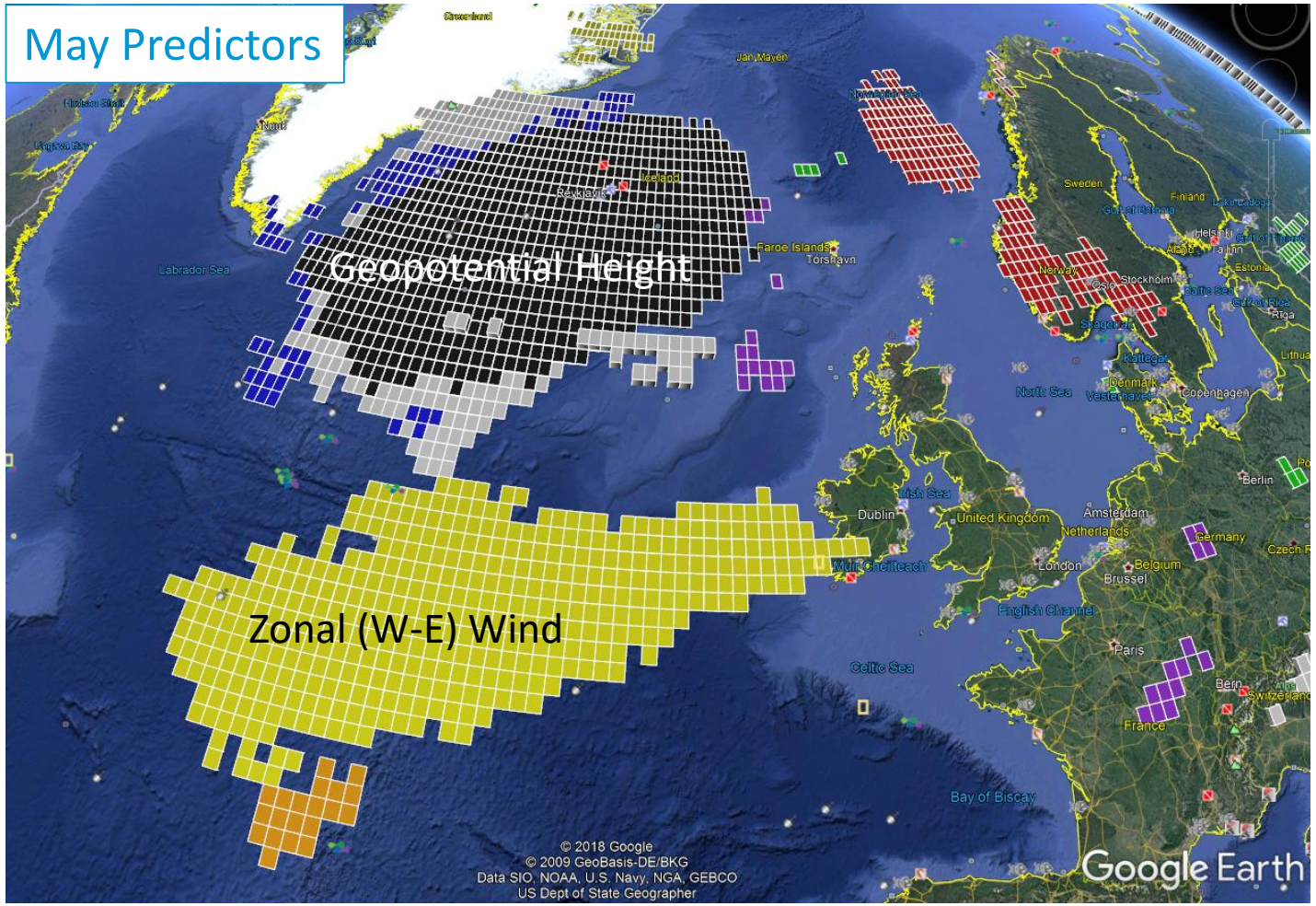


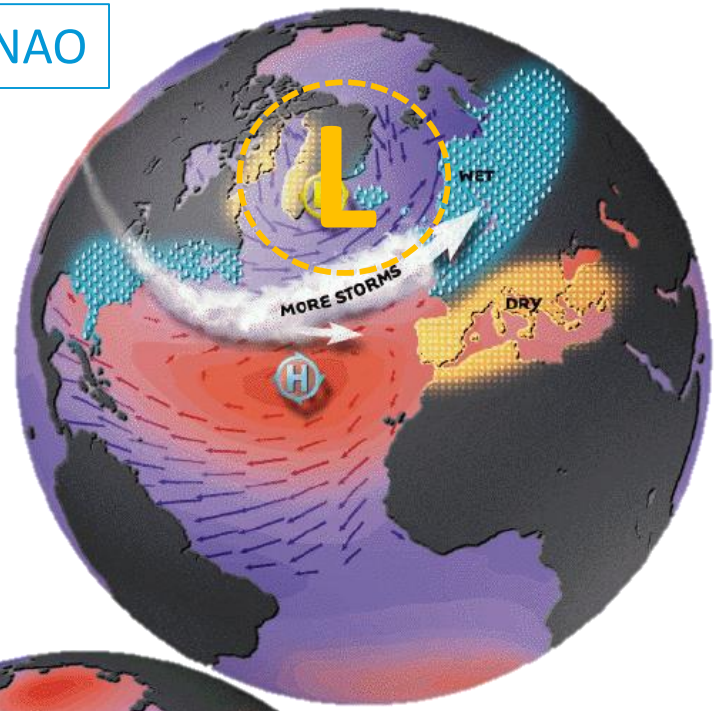
Image Sources: Google Earth and the National Climatic Data Center, National Oceanic and Atmospheric Administration

Correlations to the North Atlantic Oscillation (NAO) Found in the Predictors

May Predictors



+NAO



-NAO

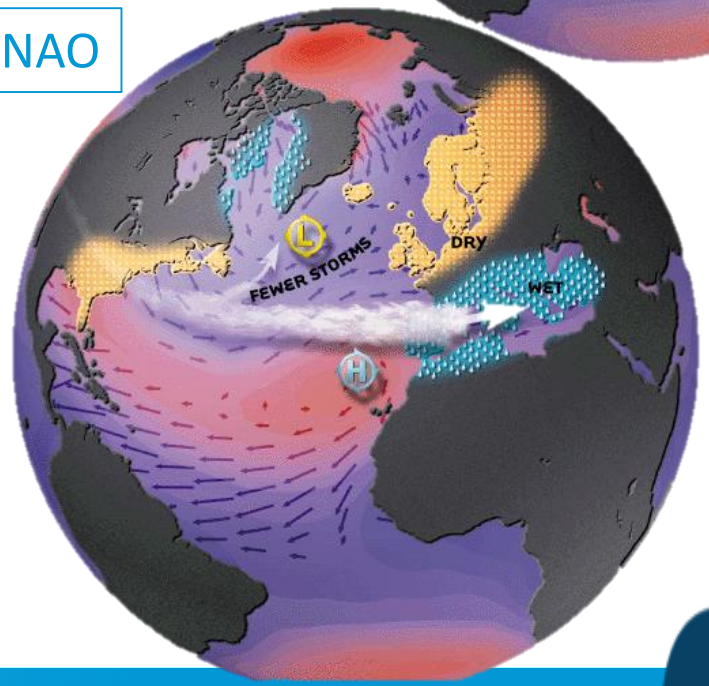


Image Sources: Google Earth & Ideo.Columbia.edu

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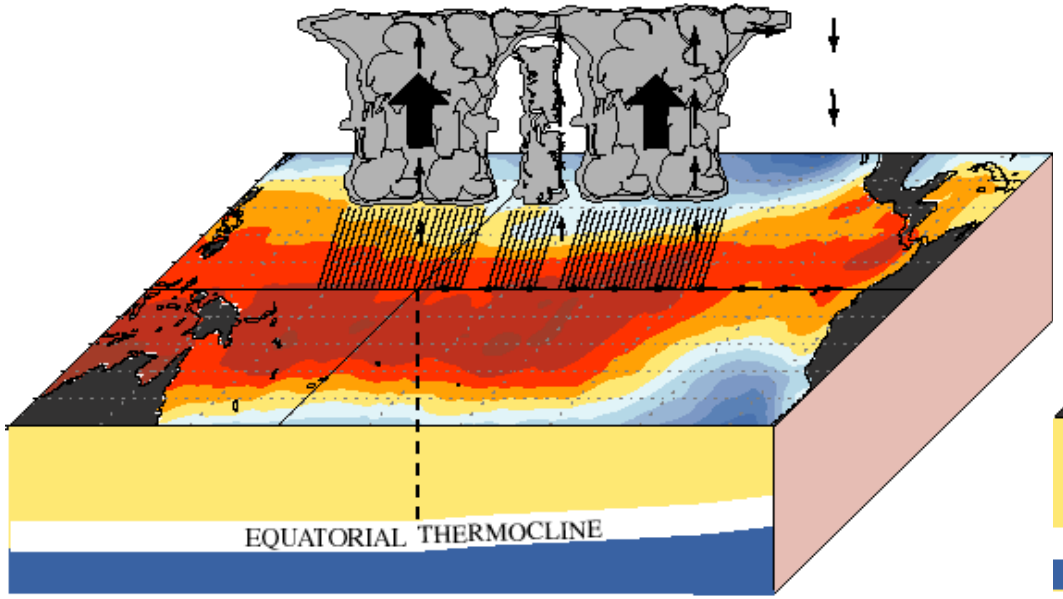
El Nino Southern Oscillation (ENSO)

The Other Half of the ENSO Equation => Air Pressure

- The changes in ocean temps during El Niño & La Niña are accompanied by even larger changes in air pressure. This is tracked by the Southern Oscillation Index (SOI), and is calculated based on the differences in air pressure anomalies between Tahiti & Darwin, Australia.

December - February El Niño Conditions



December - February La Niña Conditions

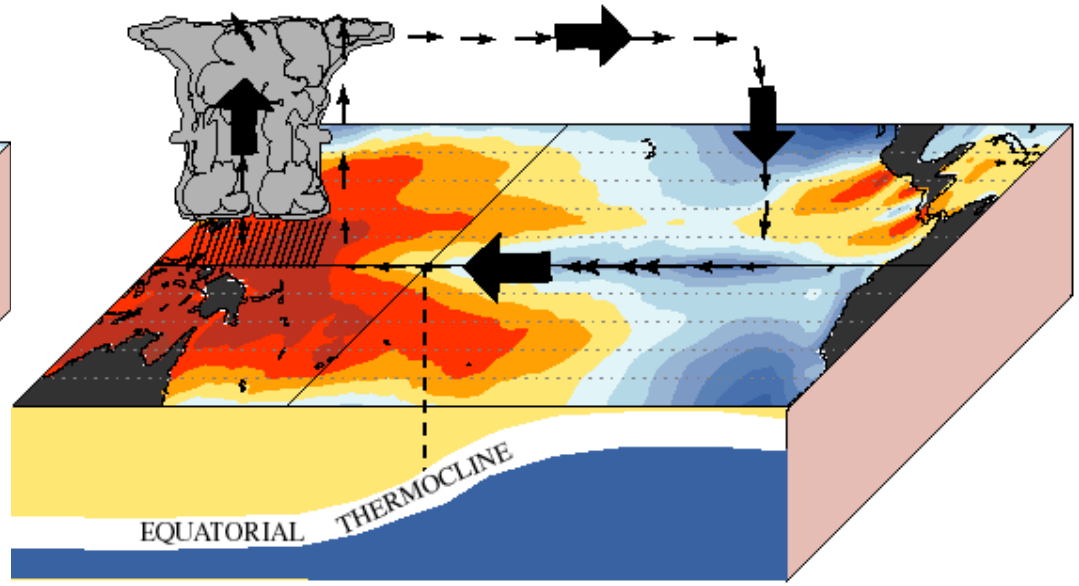
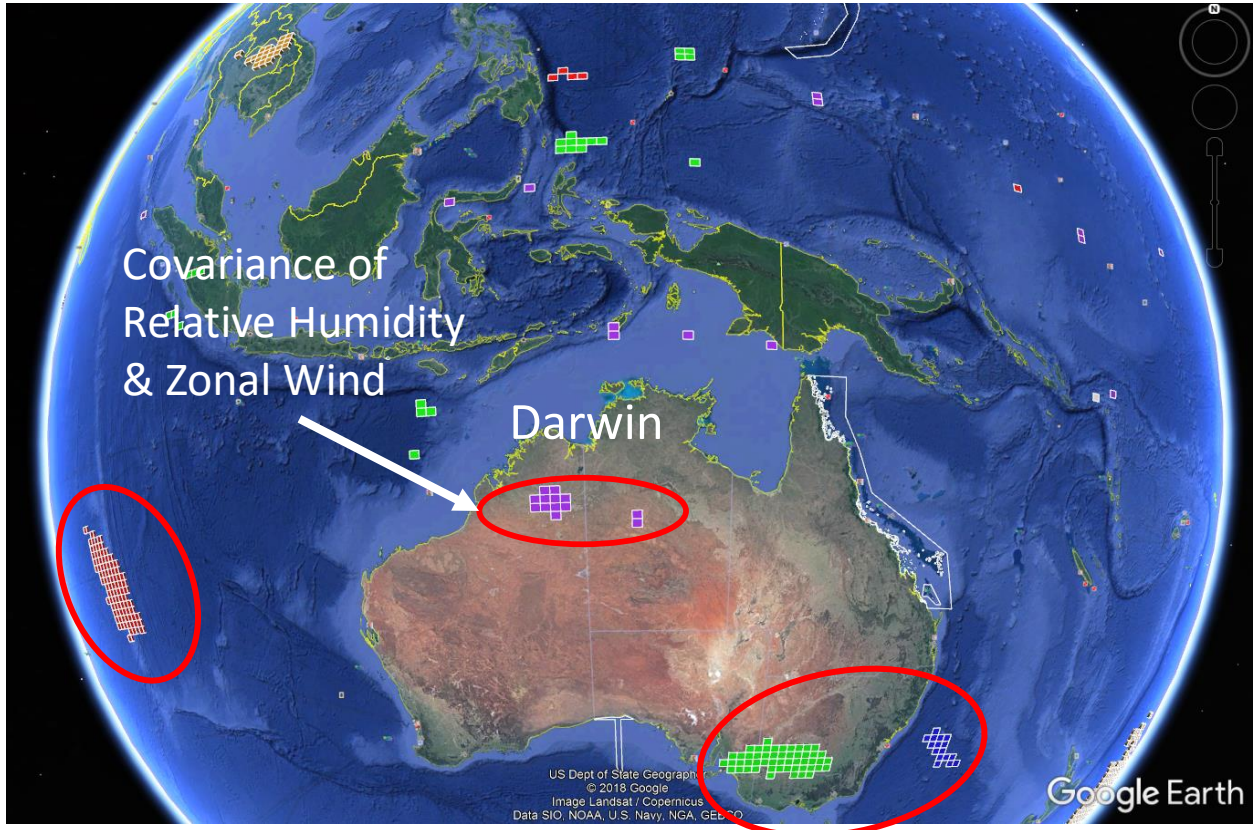


Image Sources: Google Earth & The National Weather Service

Correlations to ENSO Found in the Predictors



Covariance of
Relative Humidity
& Zonal Wind

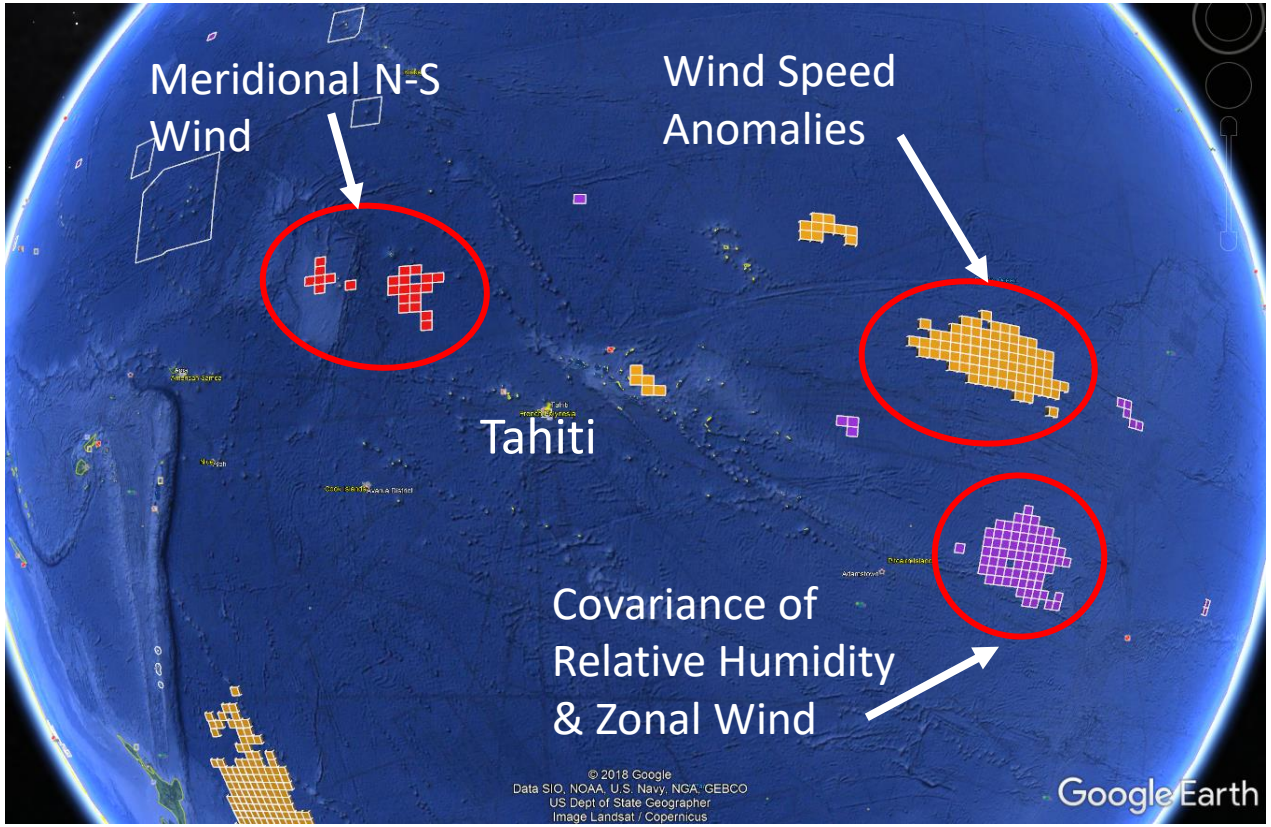
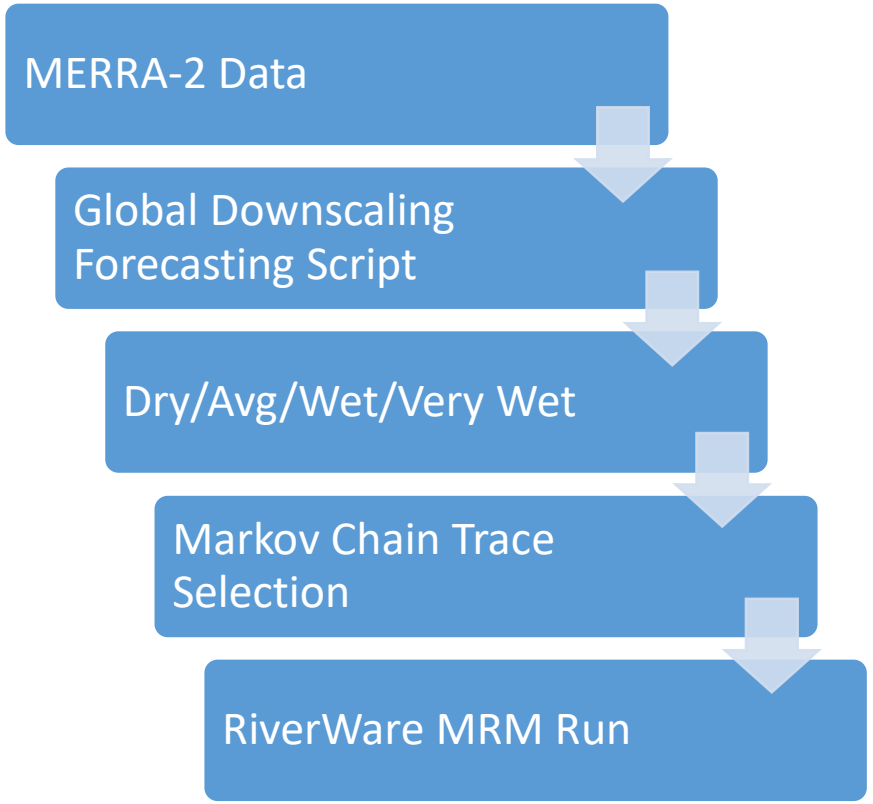


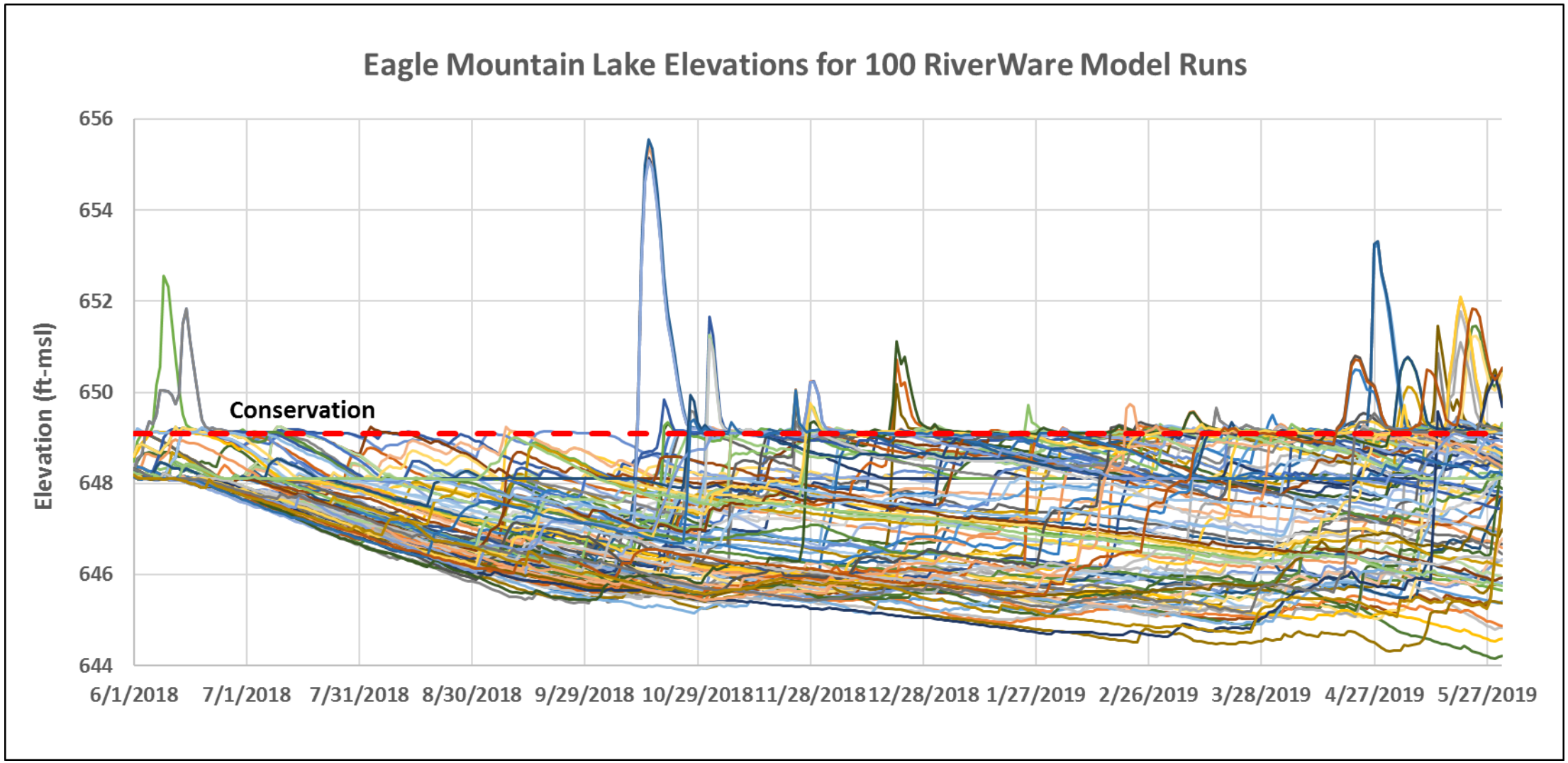
Image Source: Google Earth

RiverWare Implementation

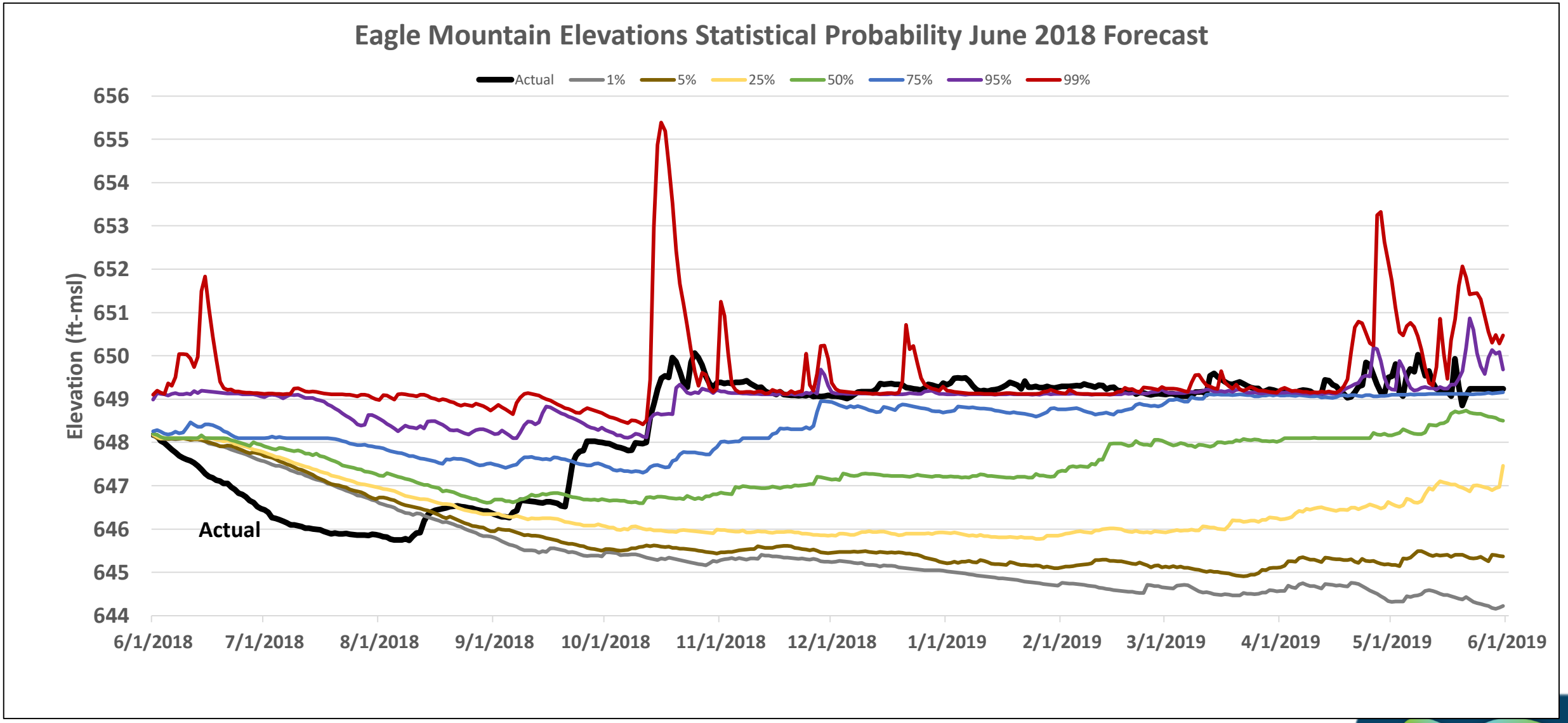
- GCM Forecast Initial Climate State
  - Climate State Probability Distribution
  - Dry, Avg, Wet, Very Wet binning
- Generate 100 Markov Chain Traces
  - Number of Traces for Each Bin Match Probability Distribution
  - Observed Hydrologic Data Resampled
  - Historical Transition Probabilities Used to Simulate Likely Climate Progression
  - 100 Runs Simulated in RiverWare Planning Model
- Review Results



RiverWare Output



Operations Planning and Communication

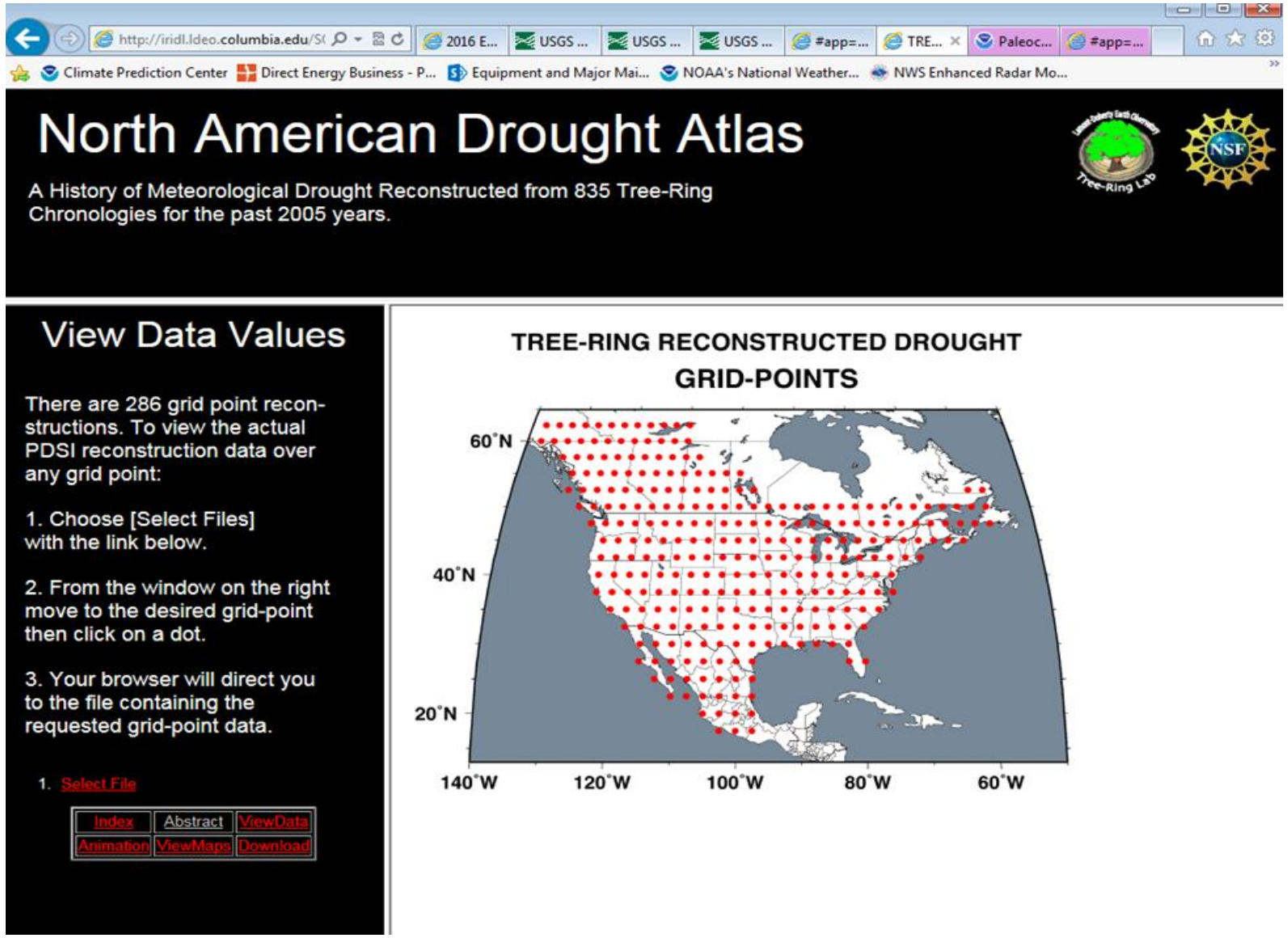


RiverWare Studies

- Climate Progression
  - Realistic versus Disaster

- "Any statistics can be extrapolated to the point where they show disaster." — Thomas Sowell

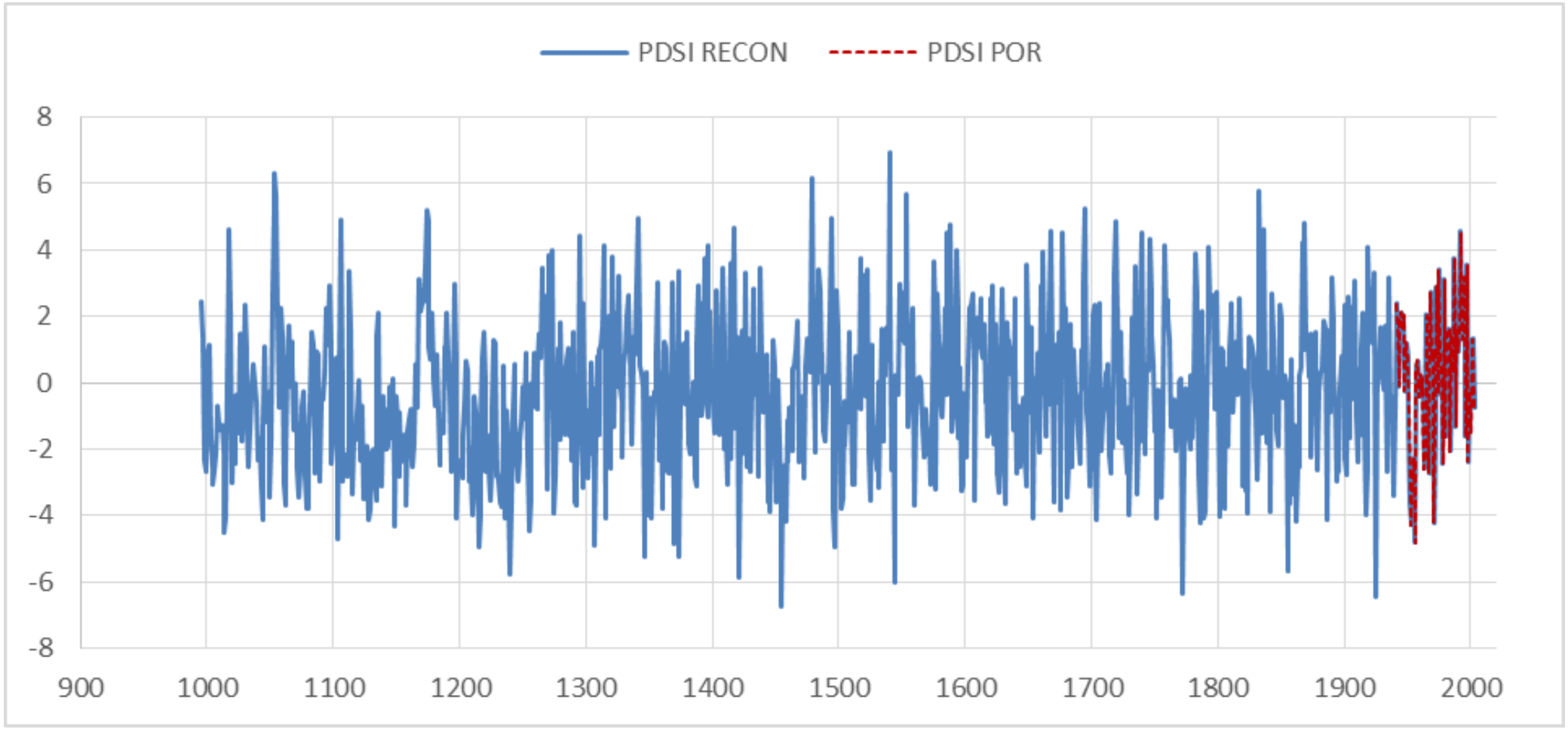
NOAA Grid Point Map



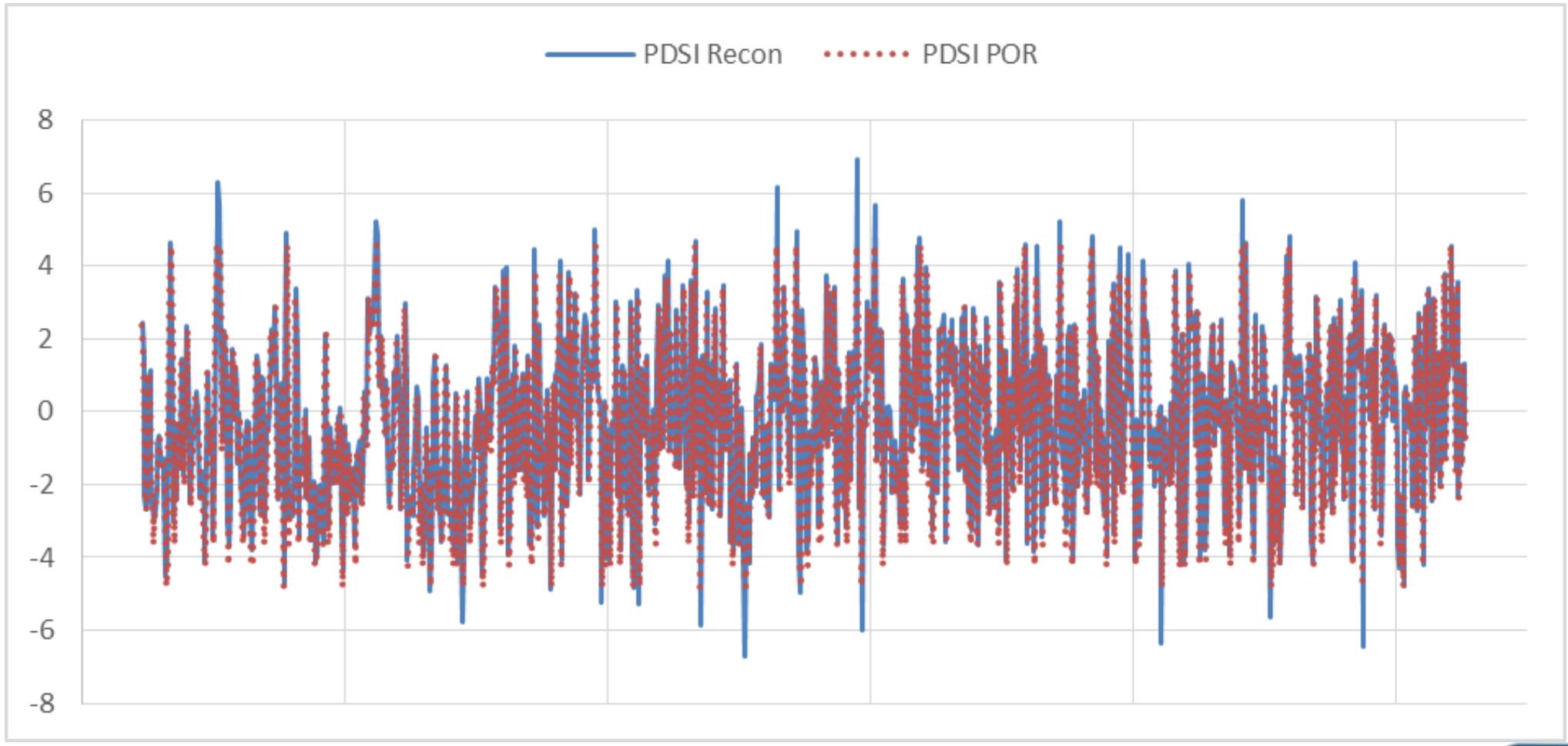
- Grid Point 180

Image Credit: NOAA.gov

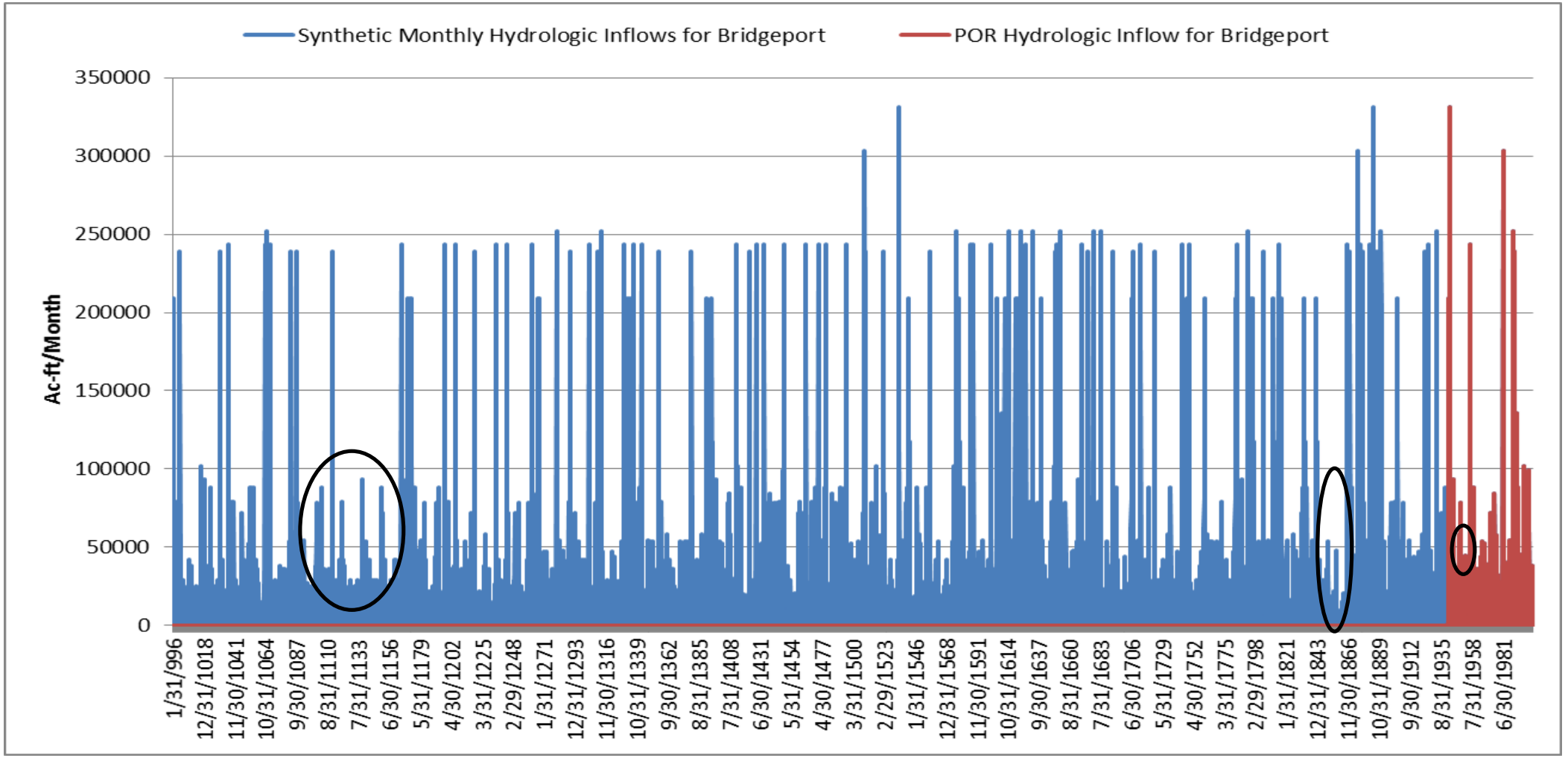
Reconstructed and Instrumental Annual PDSI



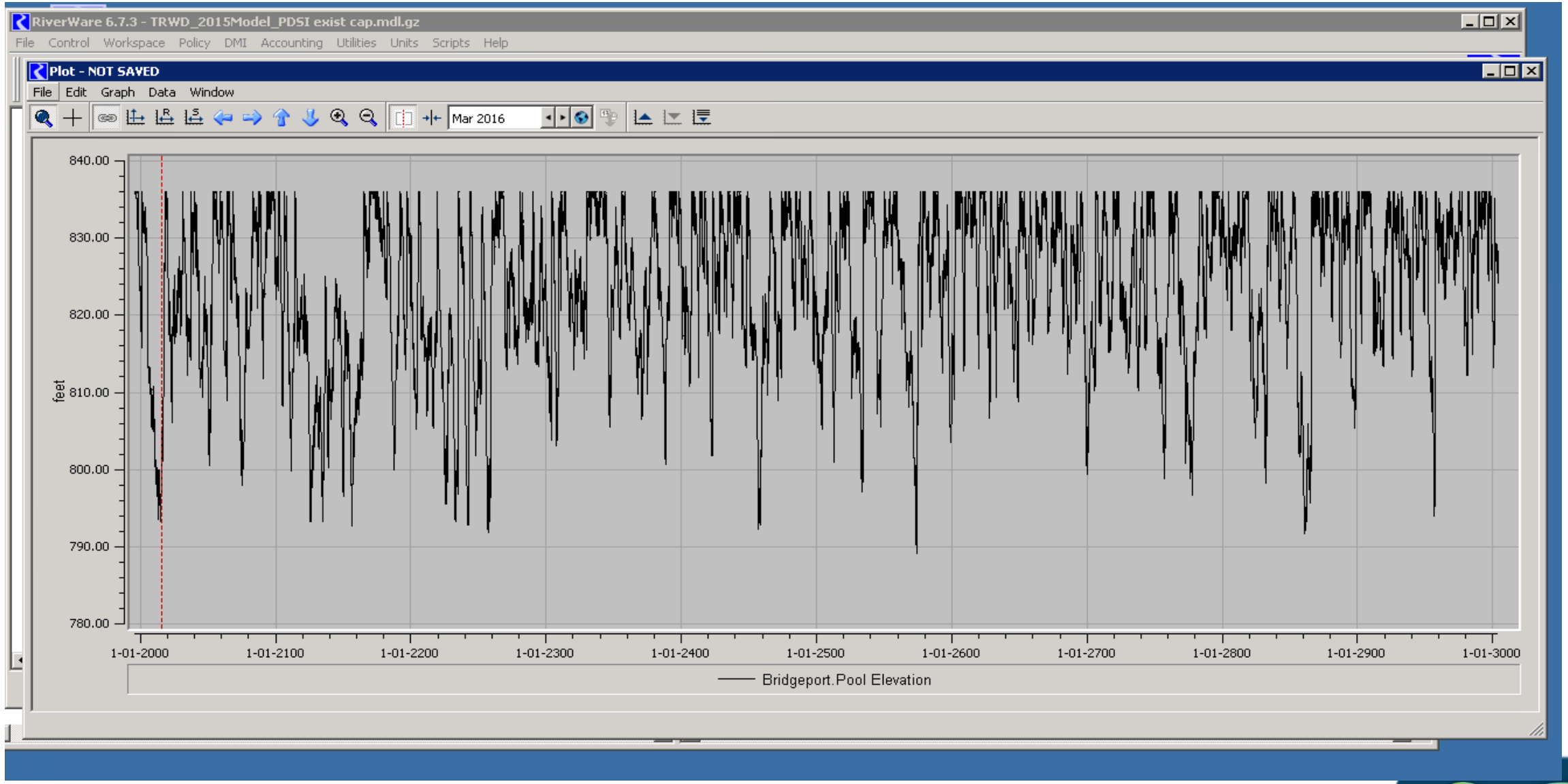
Instrumental PDSI Mapped over Extended Period



Developing Hydrologic Record 996-2003



Extended Hydrologic Simulation



Selecting GCMs for Changed-Climate Conditions

Annual anomaly plot:

- Includes all GCMs for future projections of carbon concentrations:
  - RCP8.5 status quo carbon concentration
  - RCP6.0 moderate reduction in carbon emissions
- Grid cell at DFW Airport
- Projection Year 2070

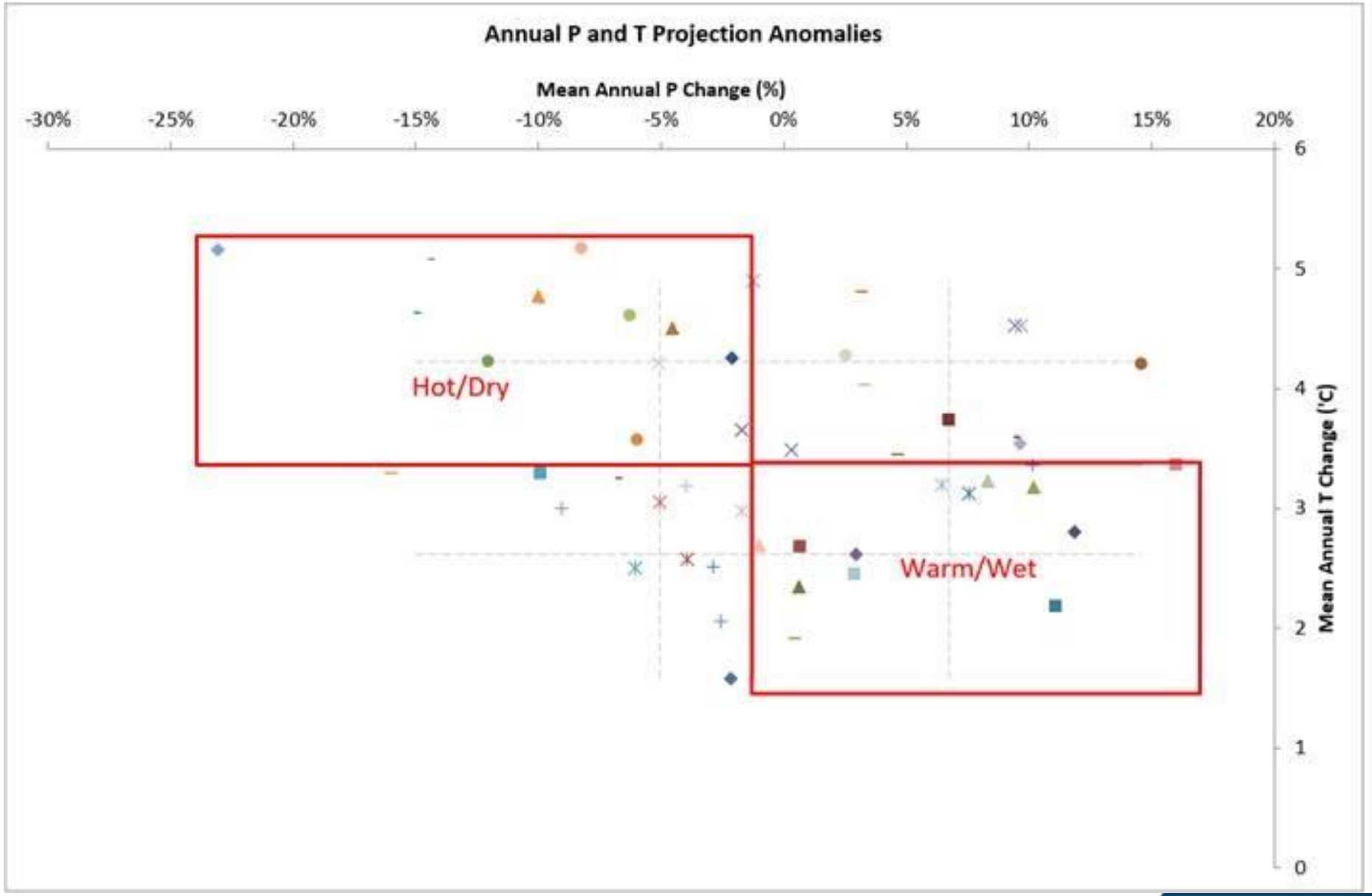
Standard protocol:

- "Hotter/Drier" ensemble = upper 50th percentile temperature and lower 50th percentile precipitation
- "Warmer/Wetter" ensemble = lower 50th percentile temperature and upper 50th percentile precipitation

Anomaly Plots of GCMs

Future projections of change in precipitation (P) and temperature (T) plotted for all GCMs.

Hot/Dry and Warm/Wet ensembles indicated.



Slide credit – CDM Smith

Multiple GCM Analysis Applications

Short Term Ops Forecasting

- Initial Climate State Near Future

Long Term Planning Studies

- Climate Progression

Climate Change

- Climate Variation Extended Future

Thank You for The Opportunity

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