Changing Drought in the Upper Missouri and Yellowstone River Basin

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Yellowstone Drought Focus Group, 29 Oct 2018, Livingston, MT

ROADMAP

- Missouri and Yellowstone Basin Overview
  - General Basin Statistics
  - Main Water Management Agencies
- The changing nature of drought
- Summary on utilizing this information in drought planning work

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RIVER STATS

- Longest River in the US.
- Largest Watershed in the US.
  - More than 500,000 square miles
  - 10 states and two Canadian provinces
  - One sixth of the area of the US
- More than 17,000 dams/reservoirs/ diversions
- Annual Flow Vol. ~ 40 million acre feet

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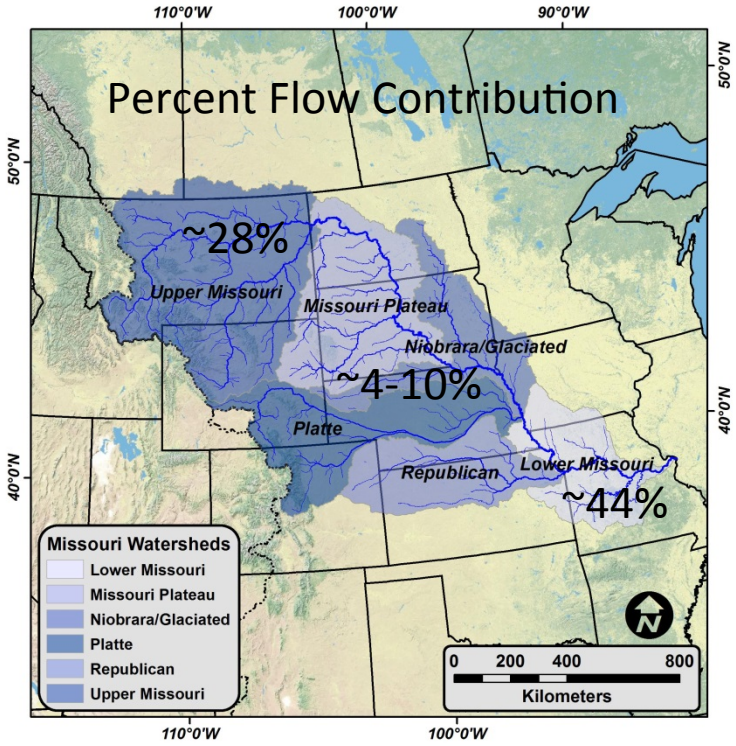
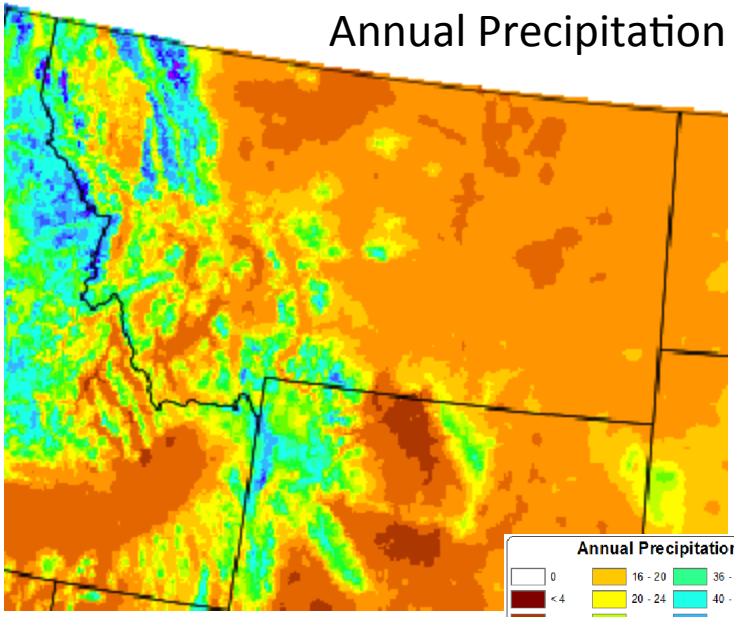
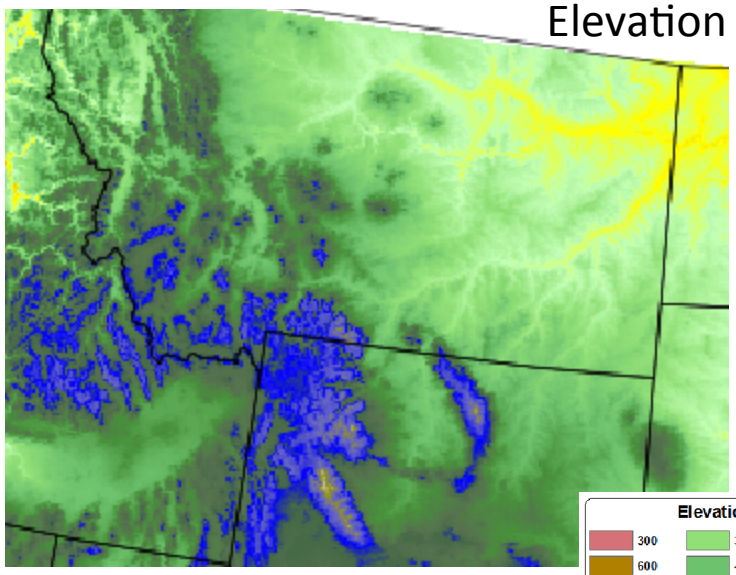
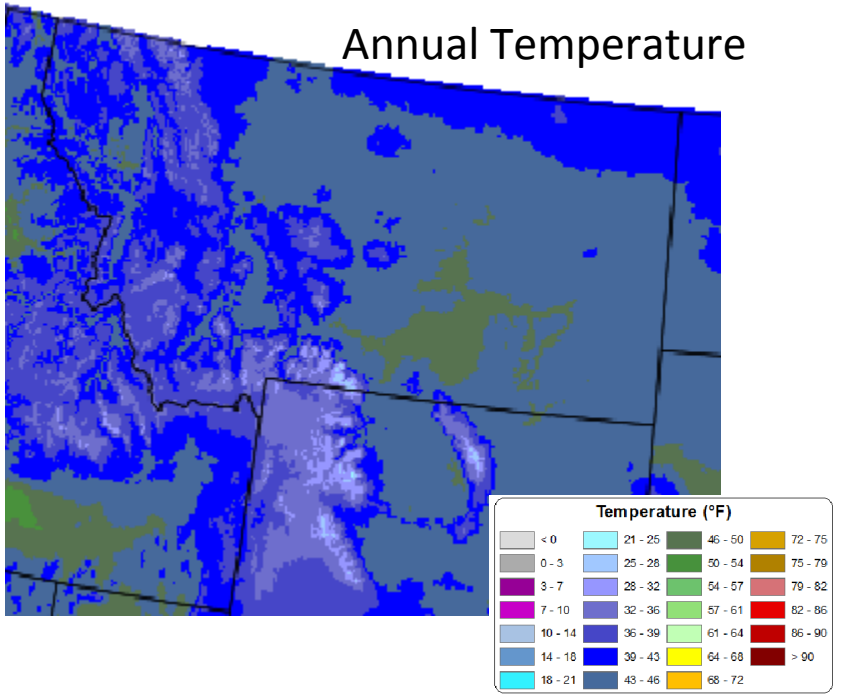




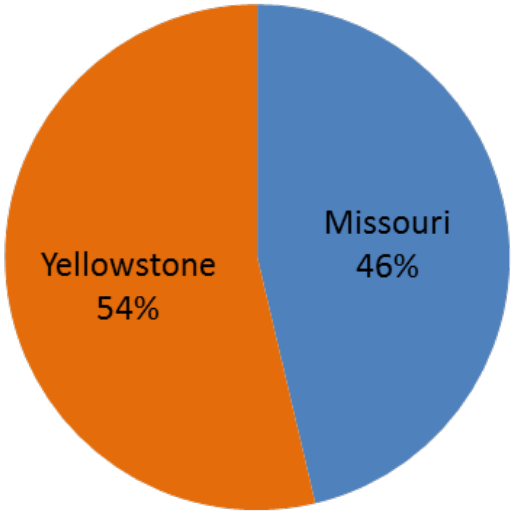


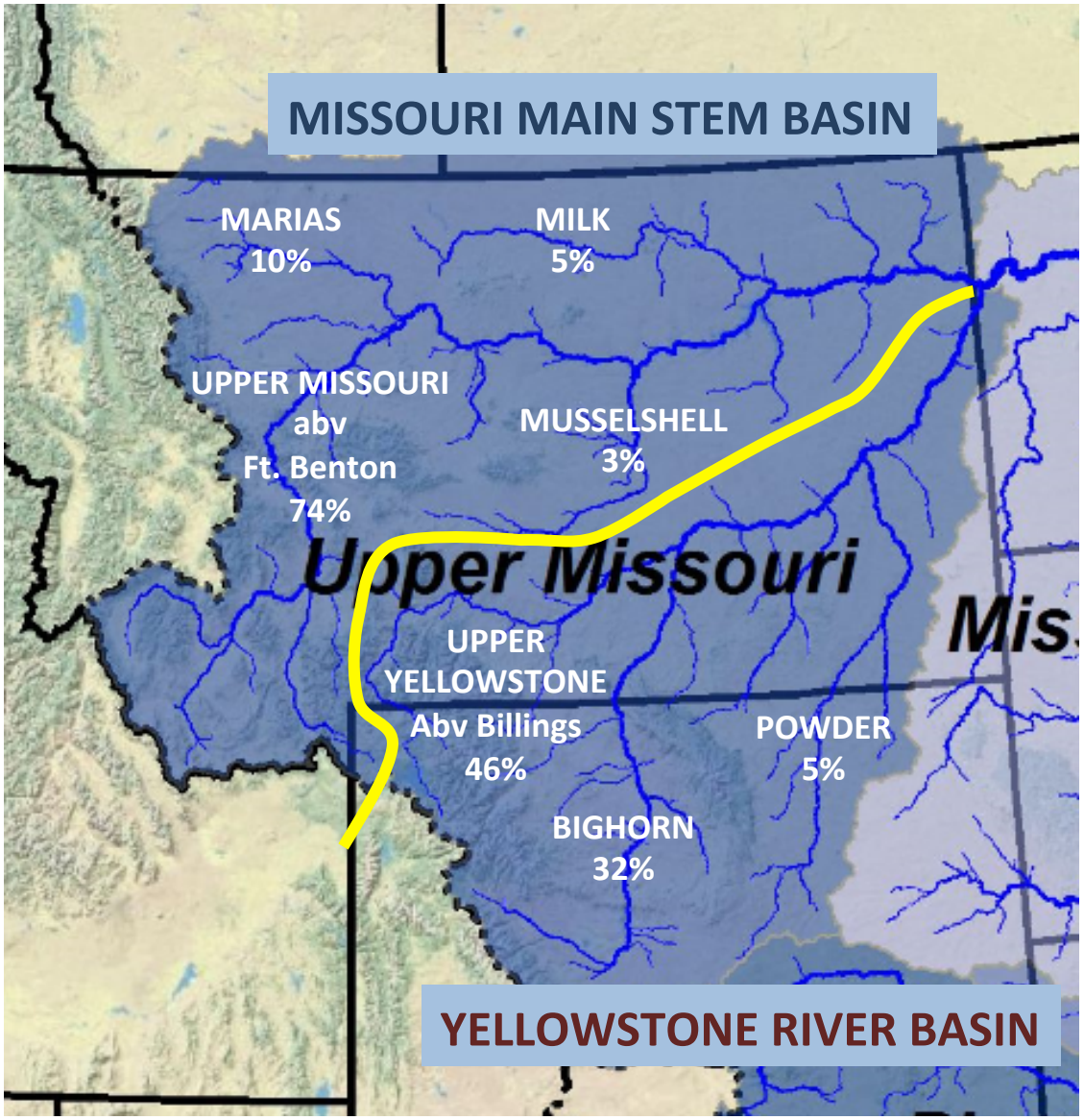


Maps and data: PRISM

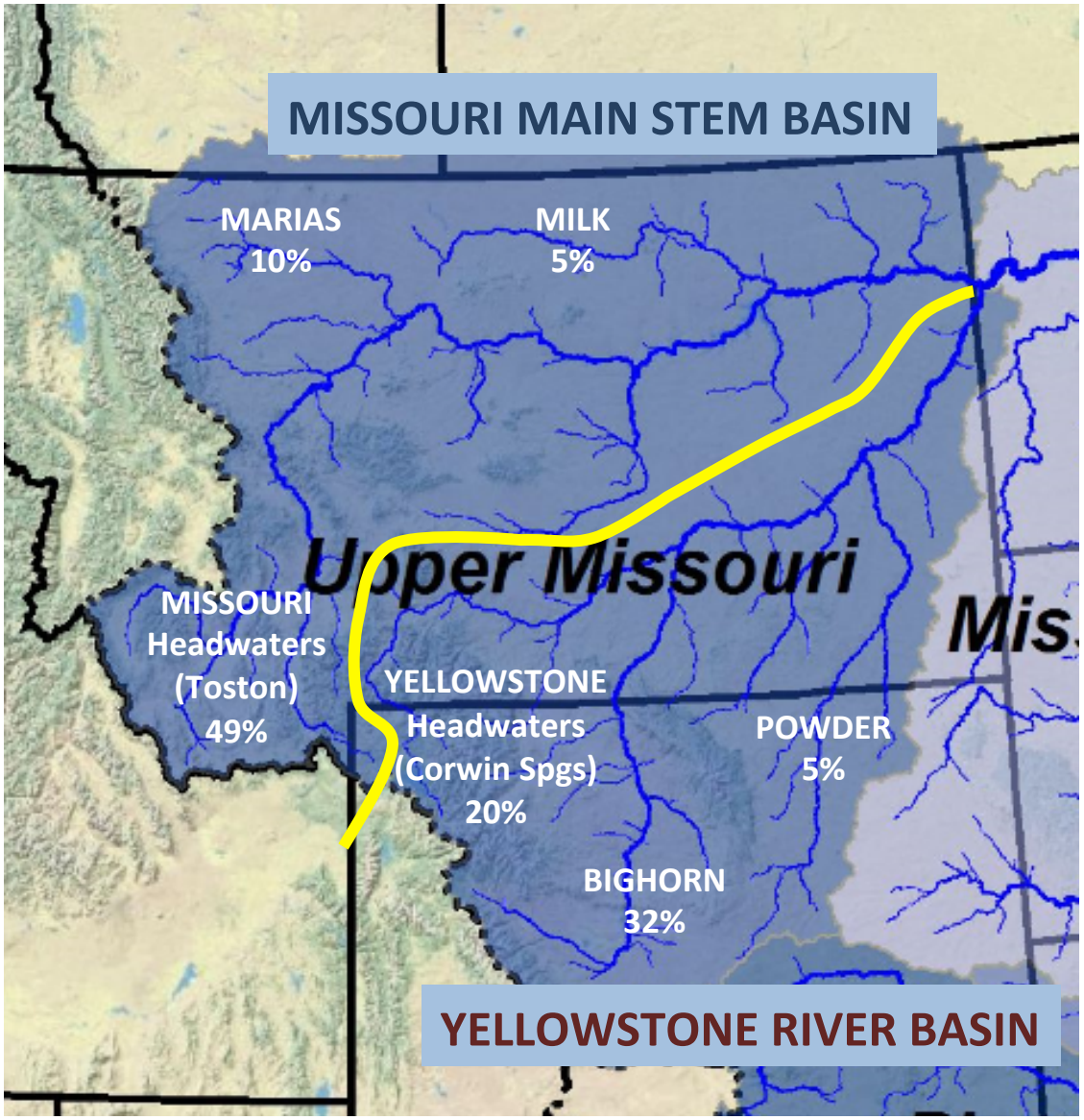
Surface water supplies come from two main watersheds:

The Missouri main stem & Yellowstone





The Missouri and Yellowstone headwaters gages reflect the relatively large proportion of flows that originate in the highest basin elevations



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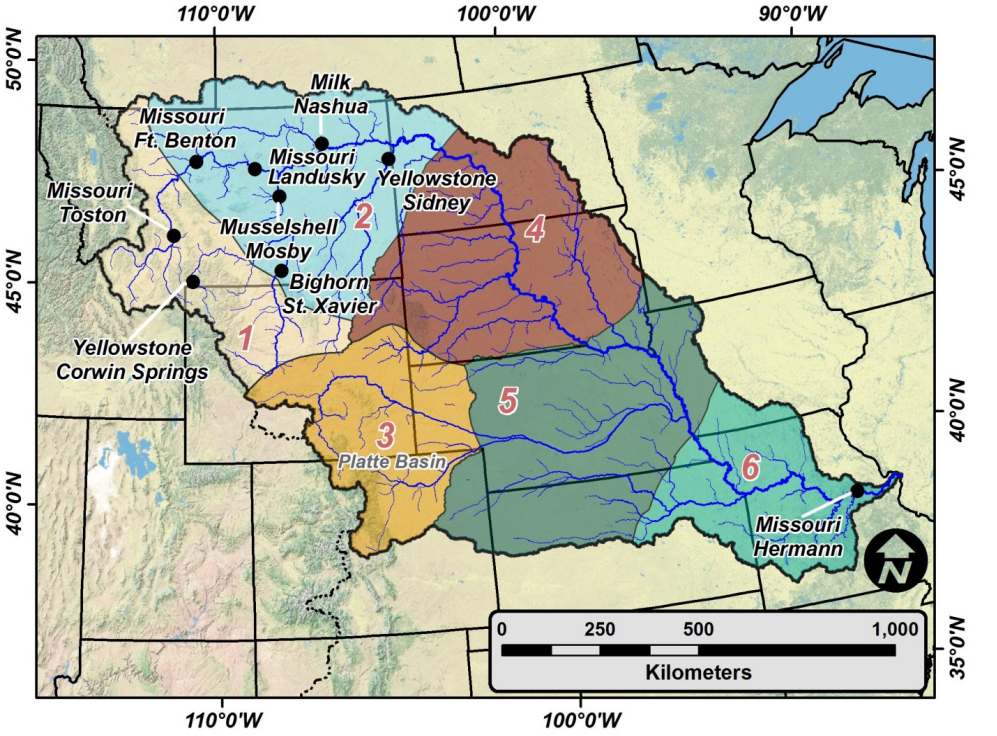
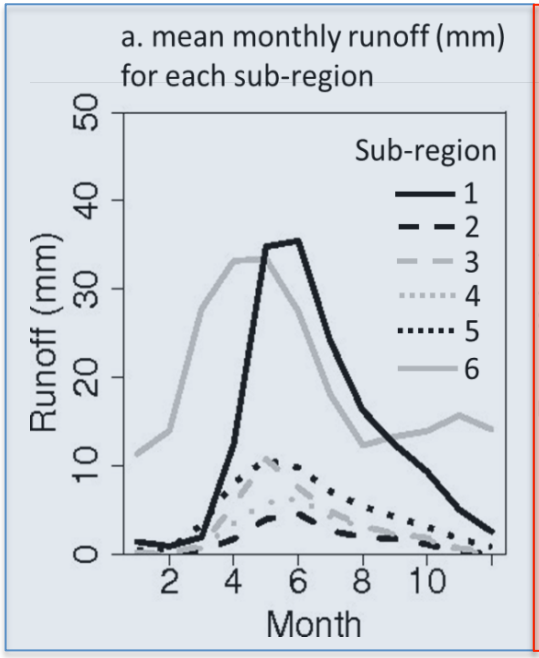
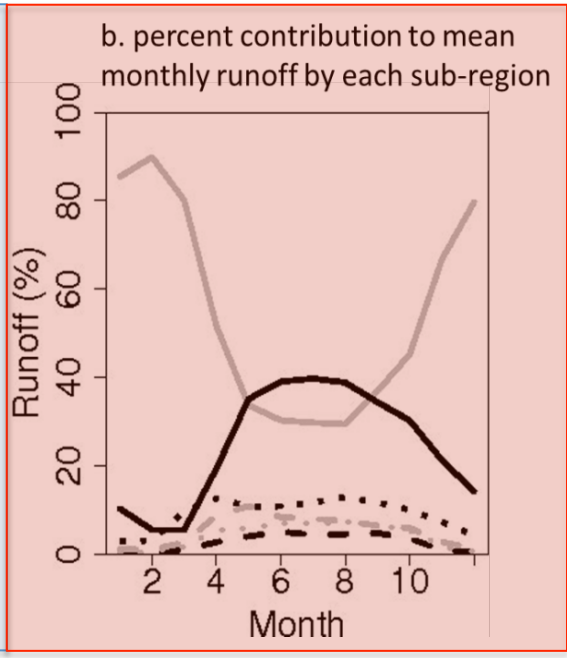
During the **Winter**, the Lower Missouri Basin (region 6) provides the majority of the sustaining outflow contributions

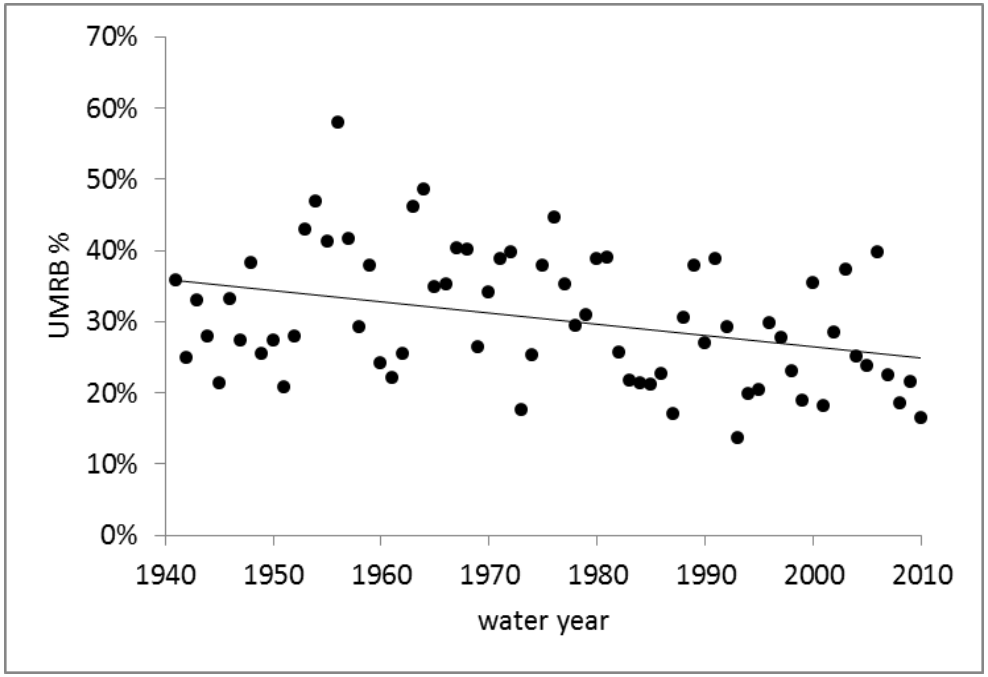
Over the **Summer**, flow contributions from the Upper Missouri Basin (region 1) provide the majority (~50%) of the total outflows reflecting the spring snowmelt contribution.







Wise, E. K., C. A. Woodhouse, G. J. Mccabe, G. T. Pederson, and J.-M. St-Jacques (2018), Hydroclimatology of the Missouri River Basin, *J. Hydrometeor*, *19*(1), 161–182, doi:10.1175/JHM-D-17-0155.1.



Percent flow contributions from the Upper Basin to total basin outflows have been declining over the 20th century

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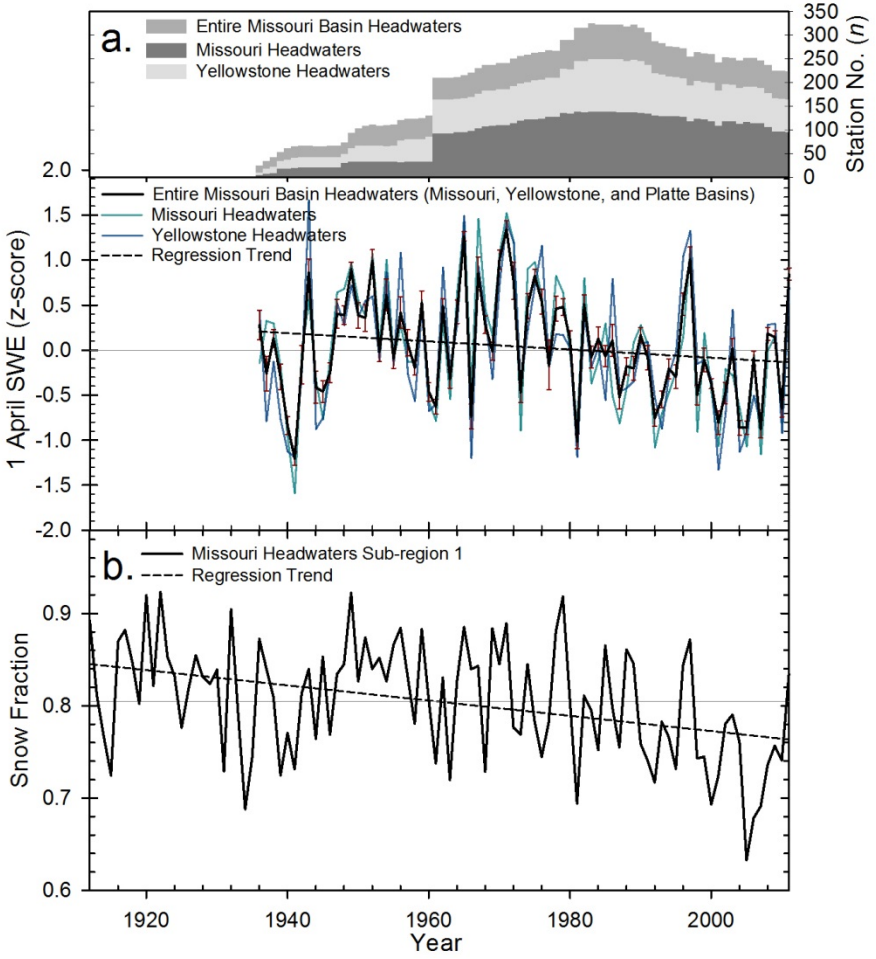

Which is in large part due to declining winter snowpack that melts out earlier in the spring.

BUT, its also related changes in precipitation form.

More Rain and Less Snow

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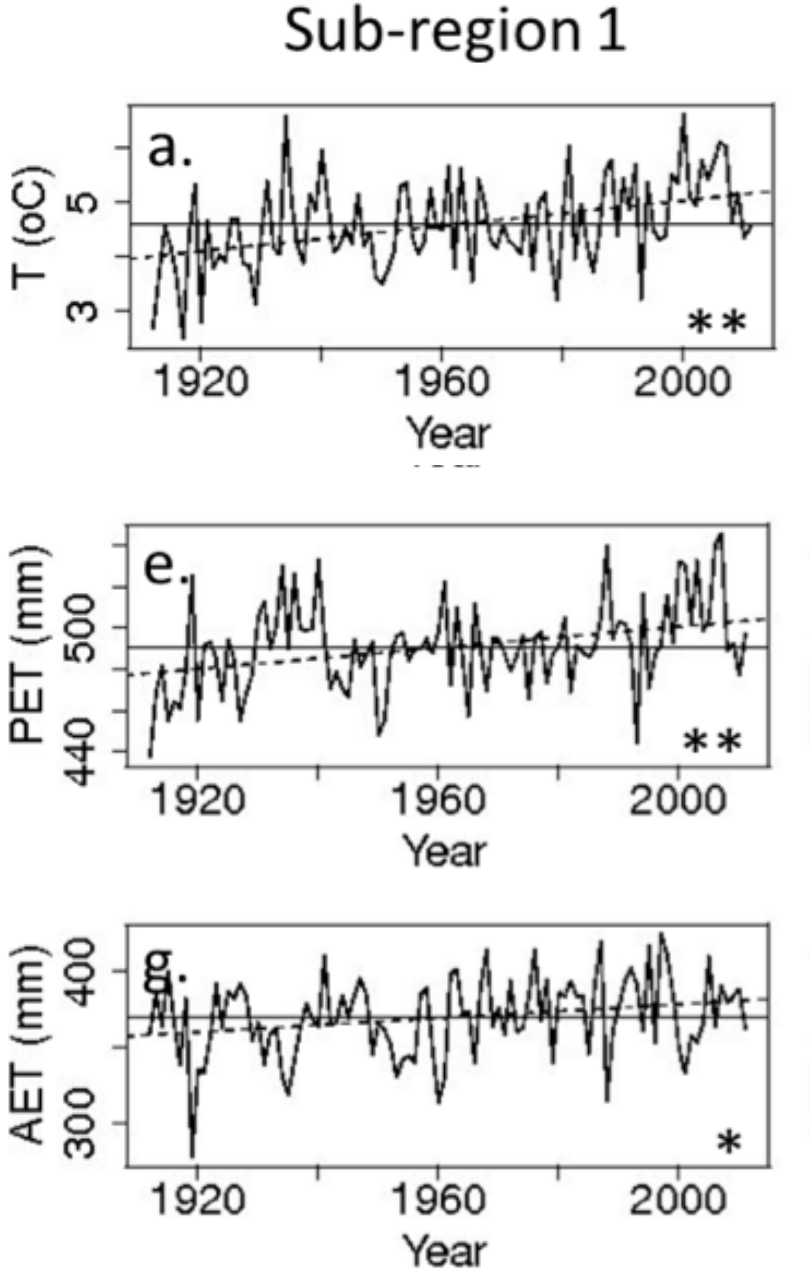
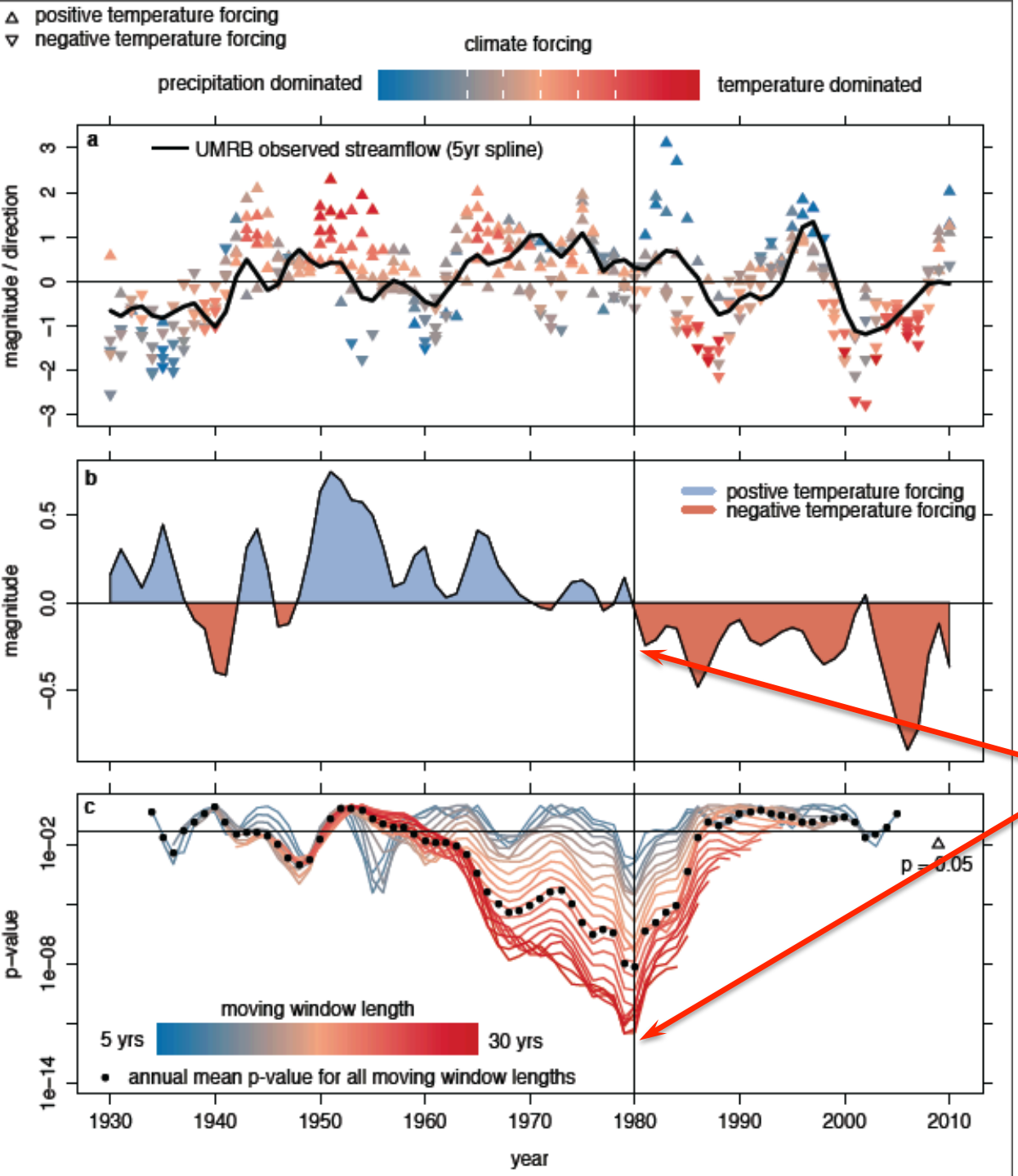


AND, Enhanced Evapotranspiration

Wise, E. K., C. A. Woodhouse, G. J. Mccabe, G. T. Pederson, and J.-M. St-Jacques (2018), Hydroclimatology of the Missouri River Basin, *J. Hydrometeor*, *19*(1), 161–182, doi:10.1175/JHM-D-17-0155.1.

So what does this mean for Drought?

Vernon Evans, a Montana dust bowl emigrant (1936)



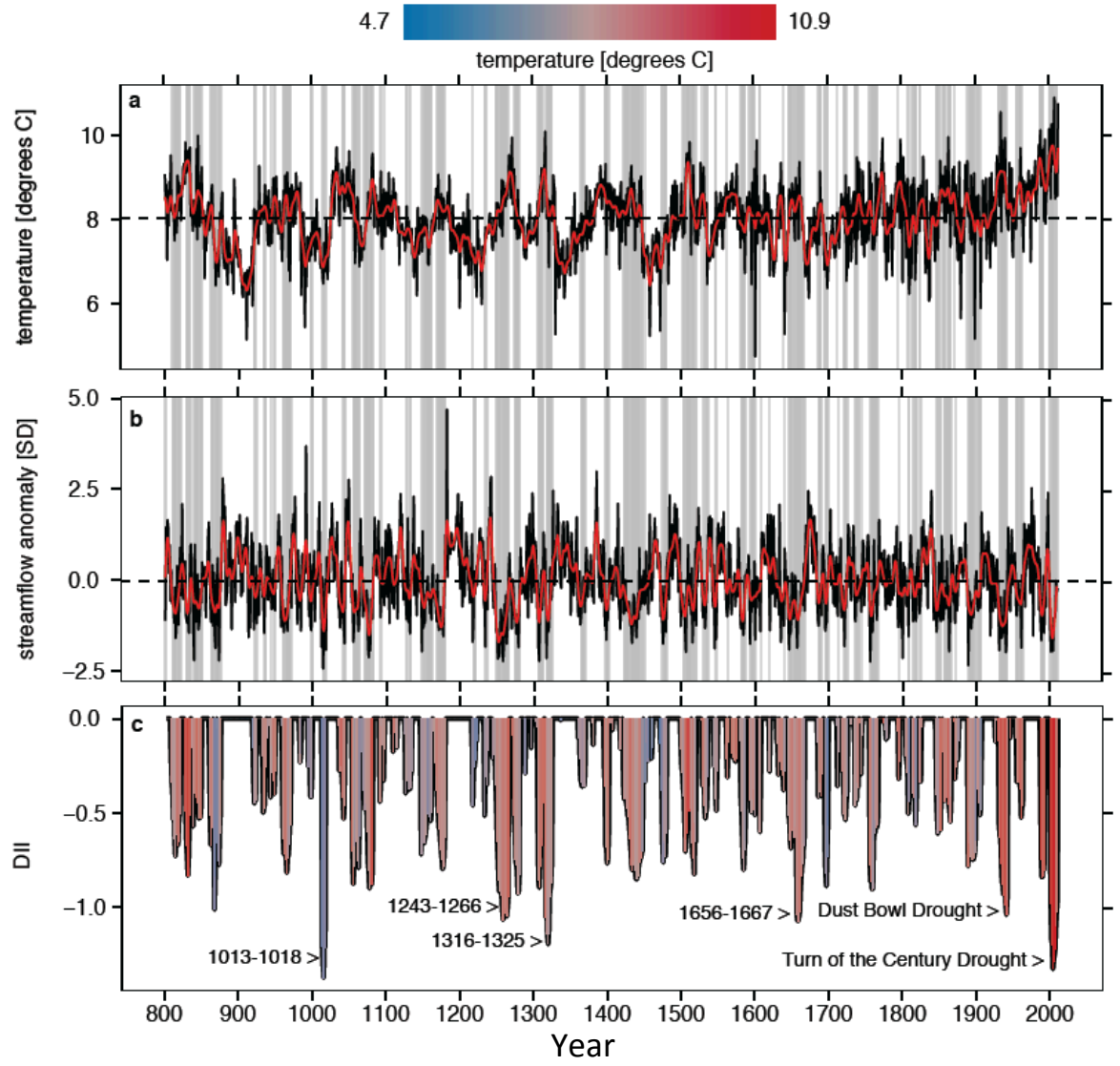
An Increasingly **Negative Temperature Influence** is evident in driving droughts

With a sustained shift in influence beginning in 1980

Martin, J., Pederson, G.T., et al., (*in review)*, Increased drought intensity driven by warming in the United States' largest river basin, *Nature Climate Change*, submitted, p. 1-38.

*Preliminary Data, do not cite or reproduce until published.

Modern Drought Intensity in Perspective



Resulting in the Turn-of-The-Century Drought (2000-2010) ranking as one of the hottest and most intense droughts in the past 1,200 years

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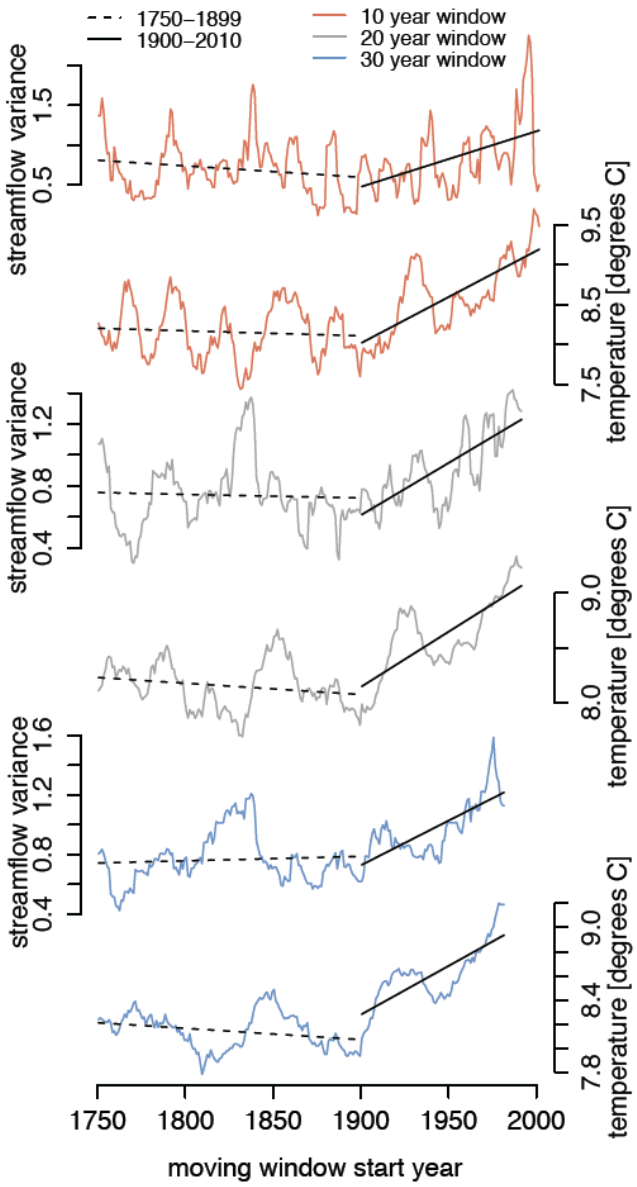
Modern Drought Variability in Perspective



Warming Temperatures
and **Increased**
Precipitation Variability
appear to also be causing
Increased Variability in Streamflow

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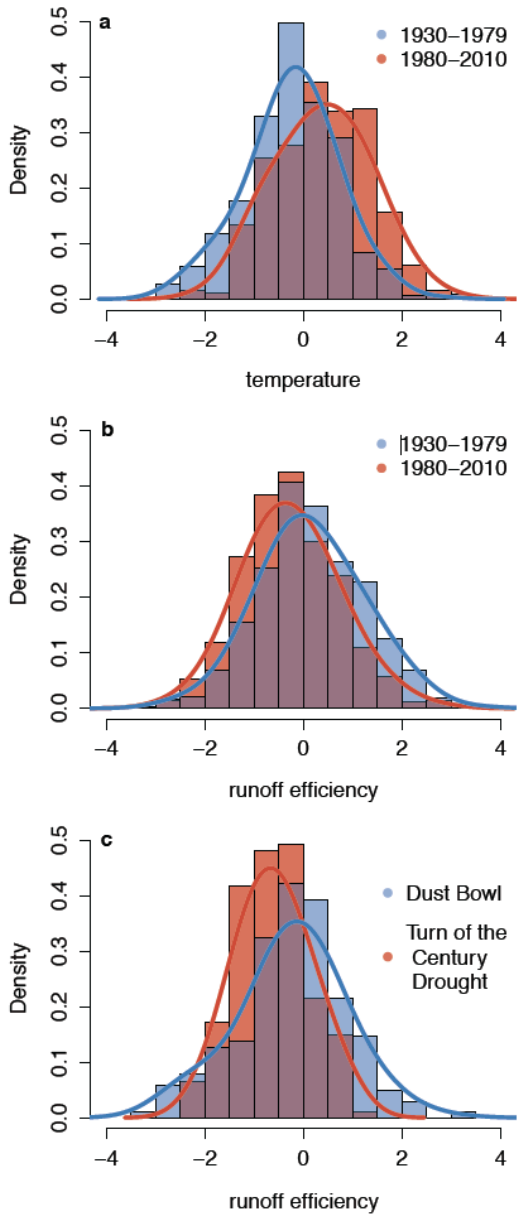
The Changing Character of Modern Drought



Warming Temperatures are leading to reduced runoff efficiency during droughts causing them to be more intense than even historic severe events like the 1930s Dustbowl Drought

A Silver Lining: Increased variance perhaps means droughts will tend to be shorter in duration, however they'll also be increasingly hard to predict

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SUMMARY

Historic Observations and Paleo- Streamflow & Snowpack Records Demonstrate:

- Less snowpack that melts and runs off earlier
- More rain and less snow
- Reduced runoff efficiency (precipitation is less effective at generating streamflow / surface water resources)
- A Sticky System (Wet/Dry conditions can last years to decades) is becoming less sticky
- Temperature and Precipitation play an important role, sometimes moderating drought & sometimes intensifying drought
- Expect all of these relationships to continue into the future

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SUMMARY

Future Projections of Streamflow & Snowpack Suggest:

- Increased cool season precipitation
- Flat to decreasing summer season precipitation
- More rain less snow
- Low snowpack and earlier melt out and runoff
- Increased potential for mid-winter flooding
- Lower summer flows
- Counterintuitively, increased total water year flows

These patterns are already apparent in the observed snow and streamflow data – So it's safe to start planning for this…

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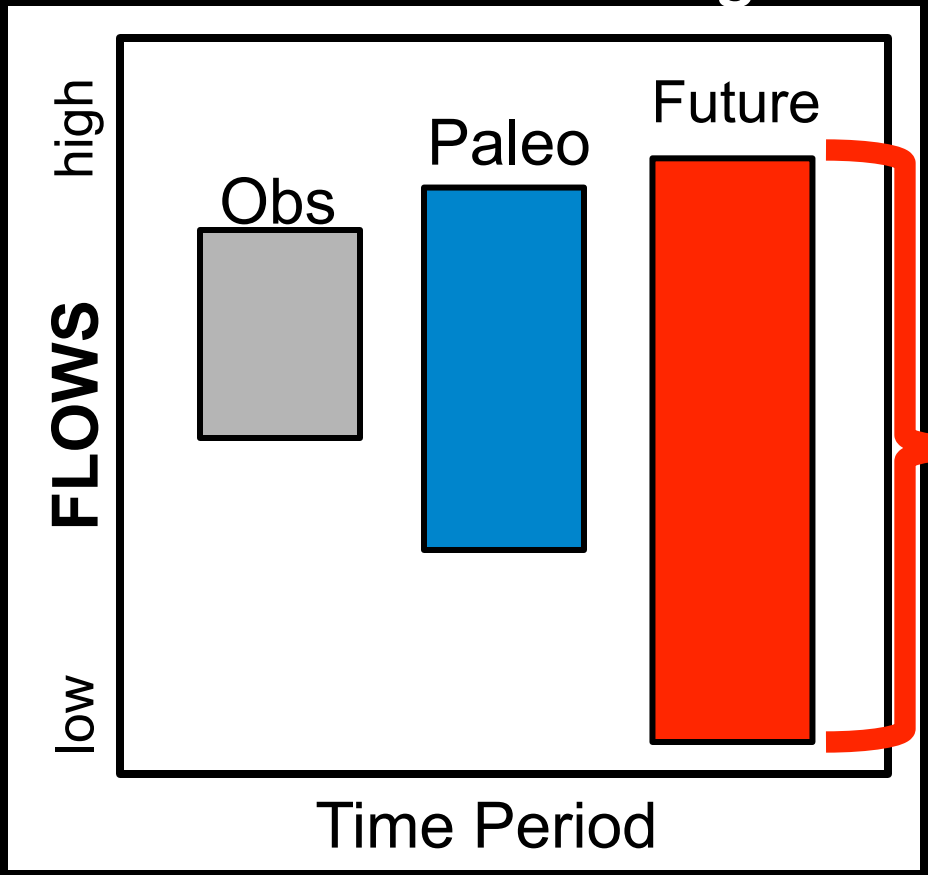
Example: Potential for Future Variability Outside Range of Observations

Generalized Runoff Regimes



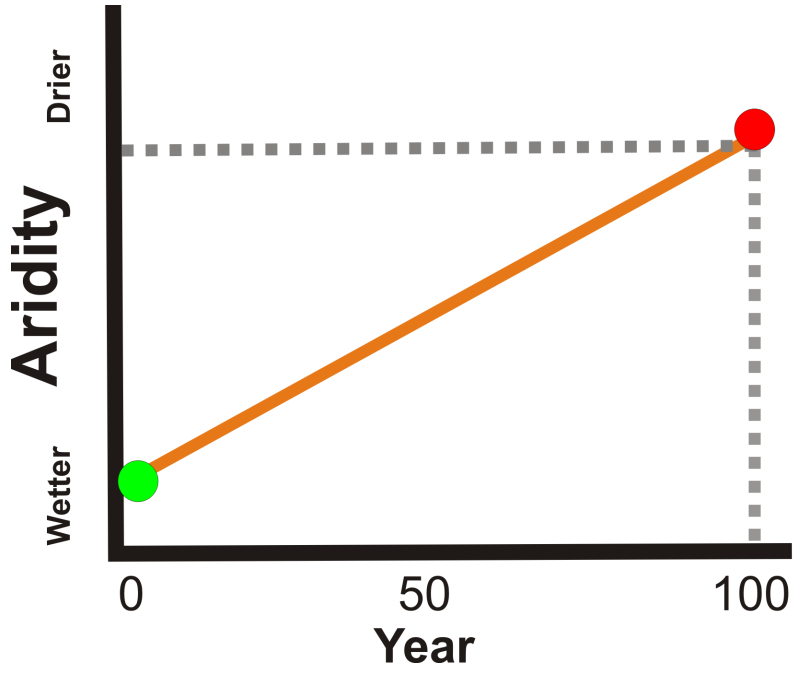
After Lutz et al. 2011 and Littell et al. in press

-Reconstructions show the potential for runoff variability outside the bounds of observations (wetter, dryer or both)

- Hydro modeling based on future climate scenarios suggesting a potential for greater flooding and more intense droughts

What do we know?

Future Climate = Natural Variability + Warming



We tend to think of future climate change as a simple linear trend…

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Gray et al. (2006), *Ecology* 87:1124-1130

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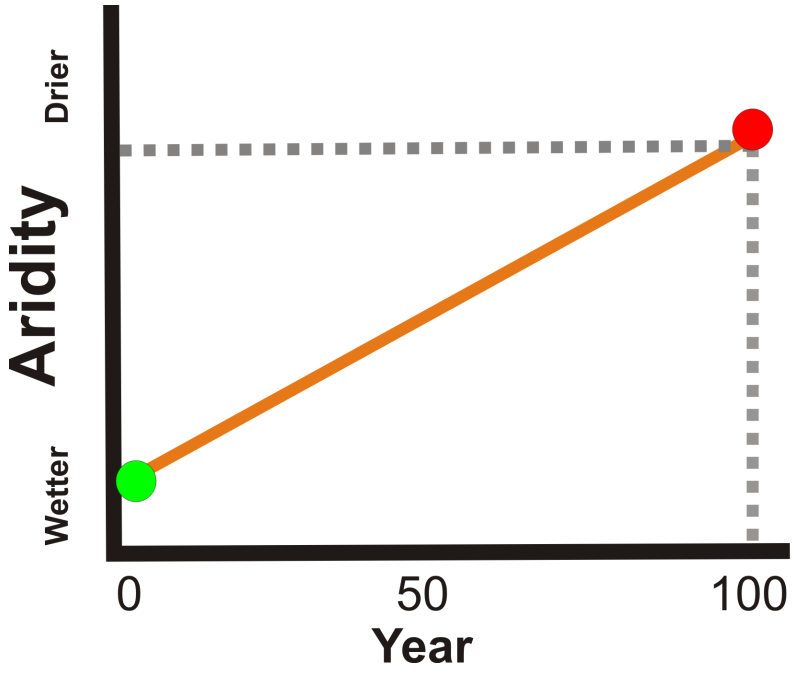

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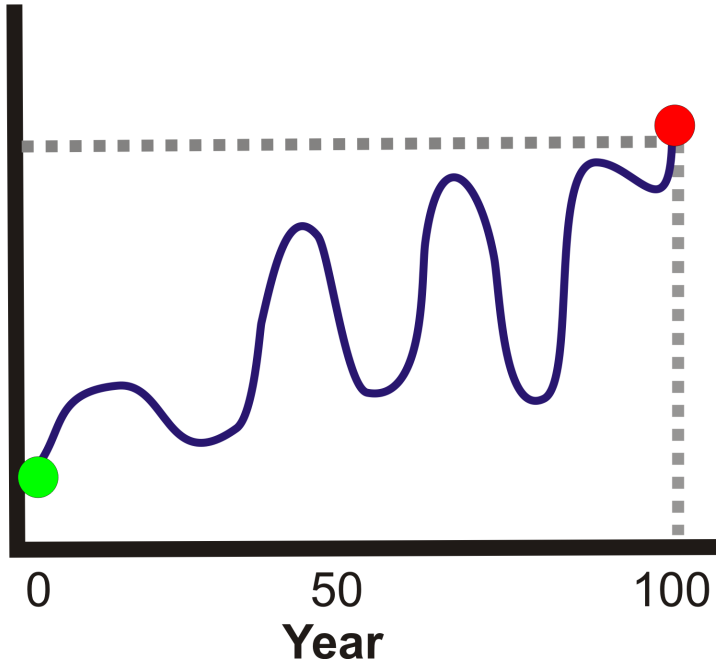

Future climate will be a combination of human-induced trends and natural variability

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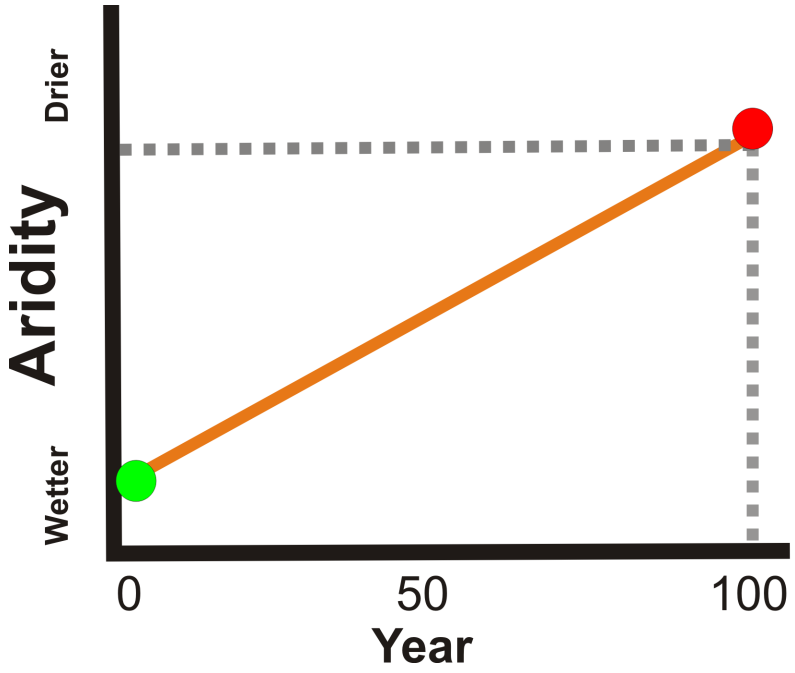
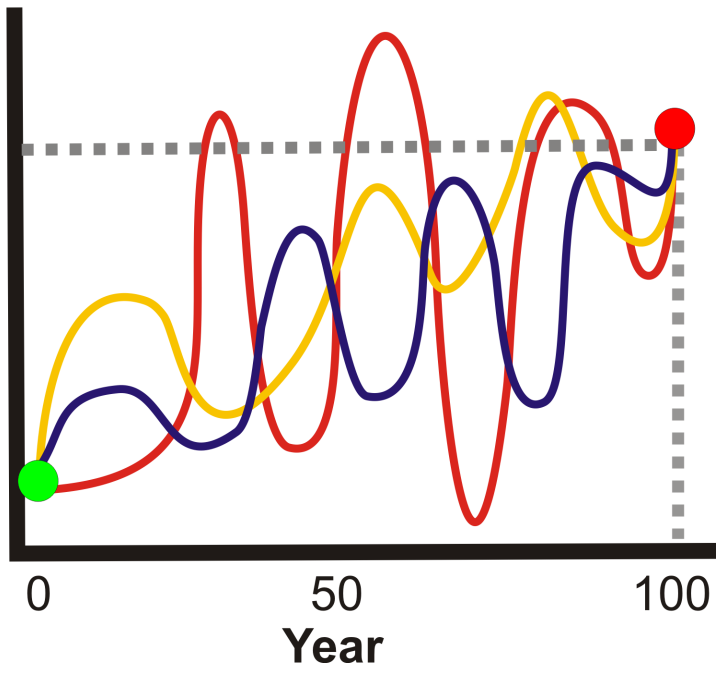




We tend to think of future climate change as a simple linear trend…

Future climate will be a combination of human-induced trends and natural variability

So no, a changing climate is not all bad for Montana. When we are getting ample precipitation things will actually be pretty darn good. Example, recent Ag production increases…

Gray et al. (2006), *Ecology* 87:1124-1130

Thanks for Listening. Questions?

More forthcoming work on the Missouri and Yellowstone…

See: http://www.nrmsc.usgs.gov/MissouriRiverWater for more project information, data and publications.

Paleohydrology

Develop long records (1,000+ years) of water year streamflow at stakeholder selected stream gage locations

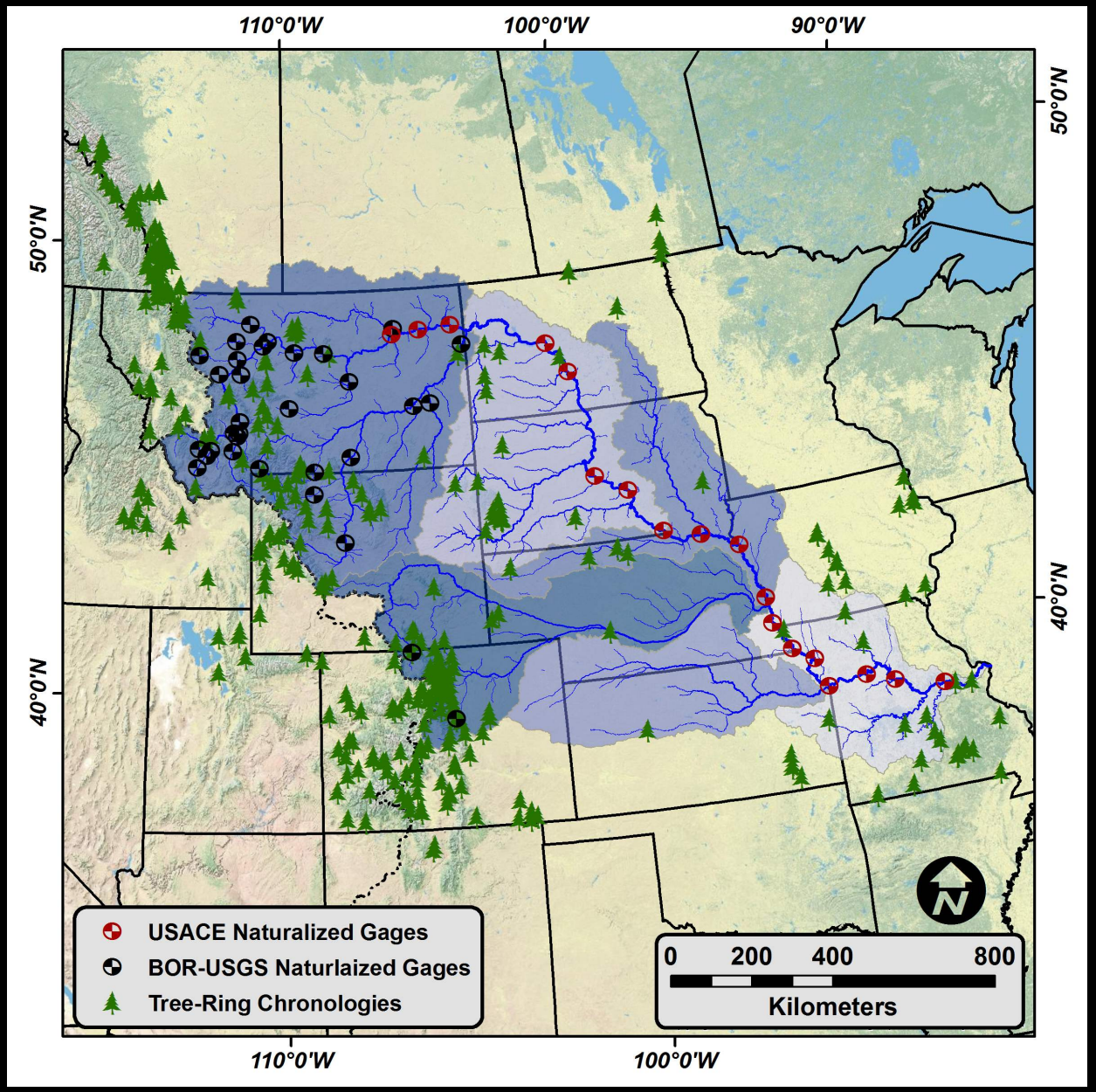
Use the records to drive and test current flow management operations with State and Federal Water Managers* (caveats on future slides)

Contextualize projections of future streamflow and with paleohydrologic records, and develop drought (i.e. climate change) adaptation plans with local watershed groups

Project Website: Missouri River Paleohydrology Project


So when a hydrologic system has strong decadal persistence, how do we contextualize change and natural variability in short observational flow records?
TREE RINGS

Tree Rings

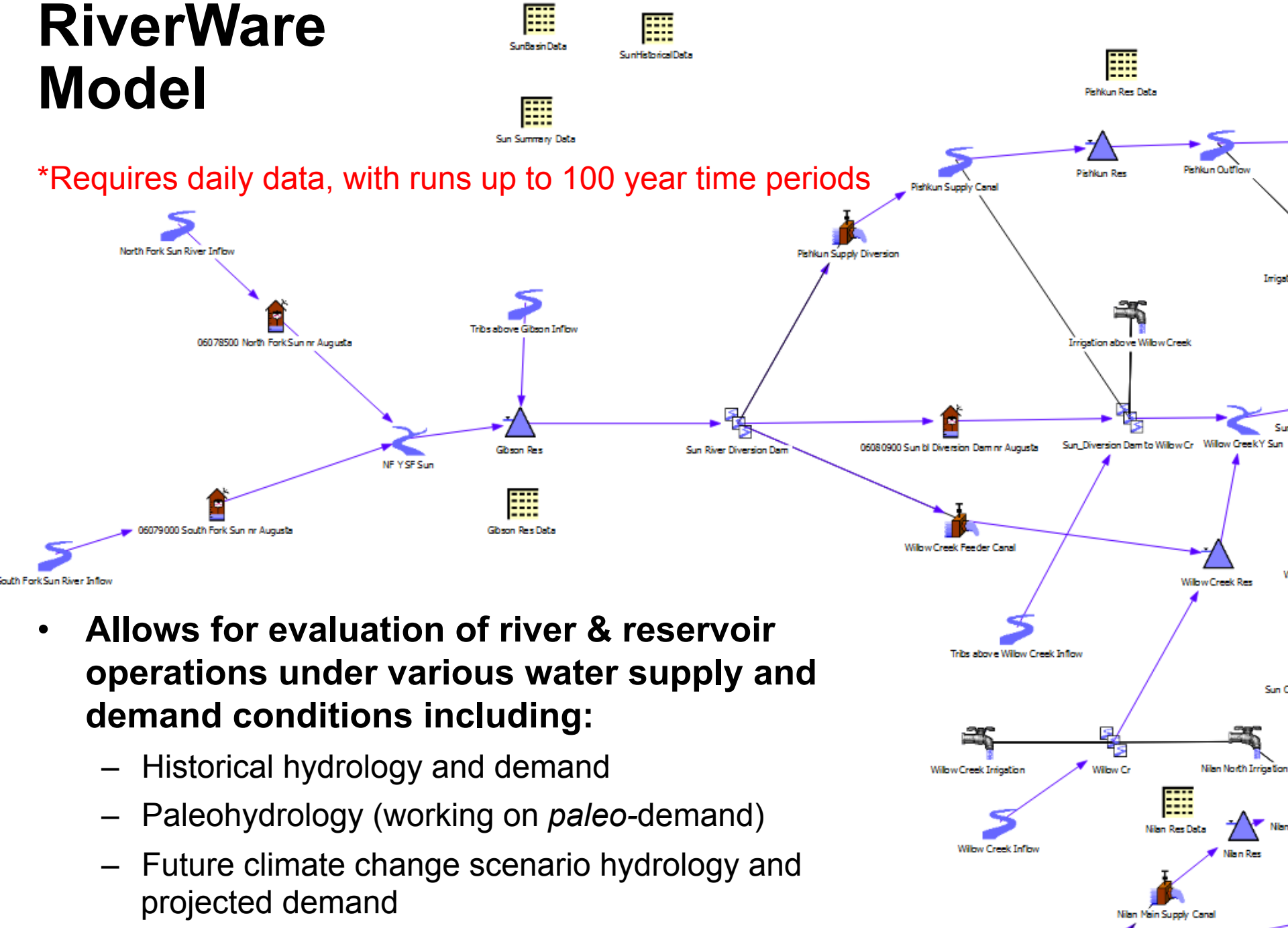


374 Tree-Ring Chronologies from 20 Species

Approximately 116 of the Chronologies are new or updated

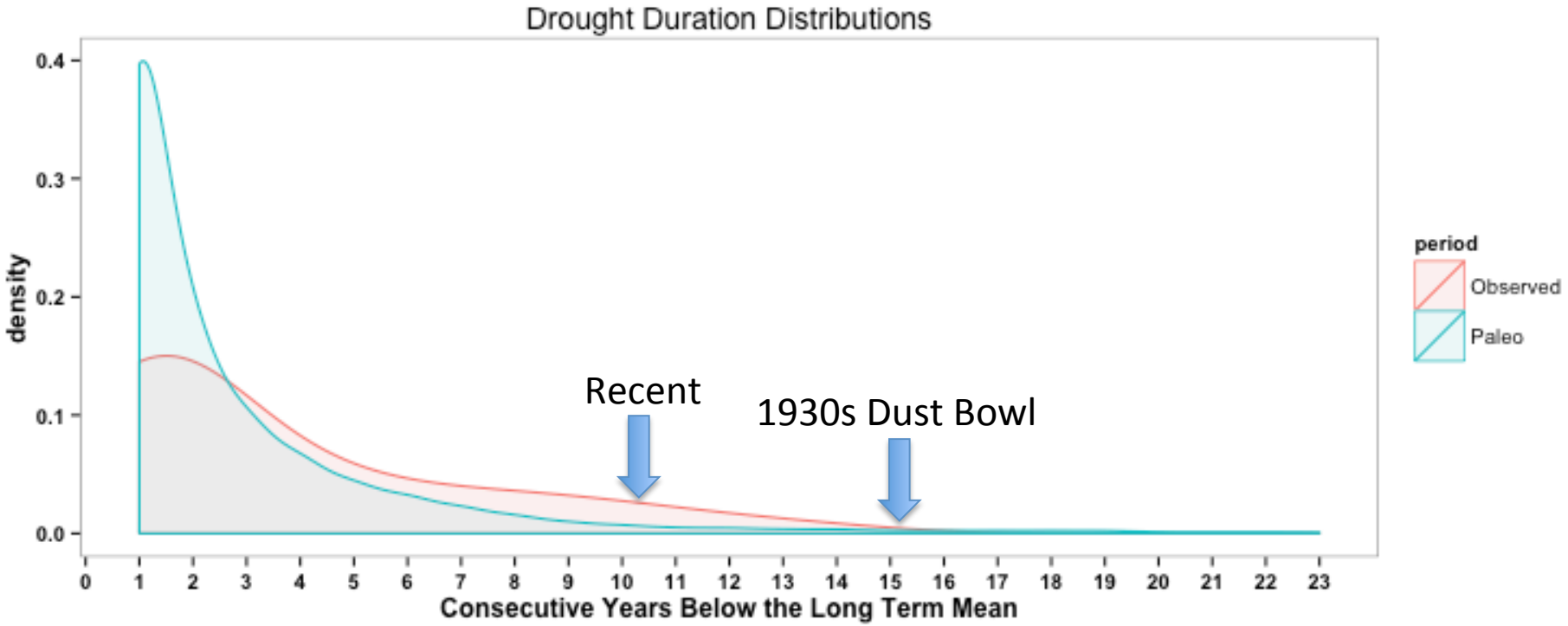
RiverWare Model

*Requires daily data, with runs up to 100 year time periods

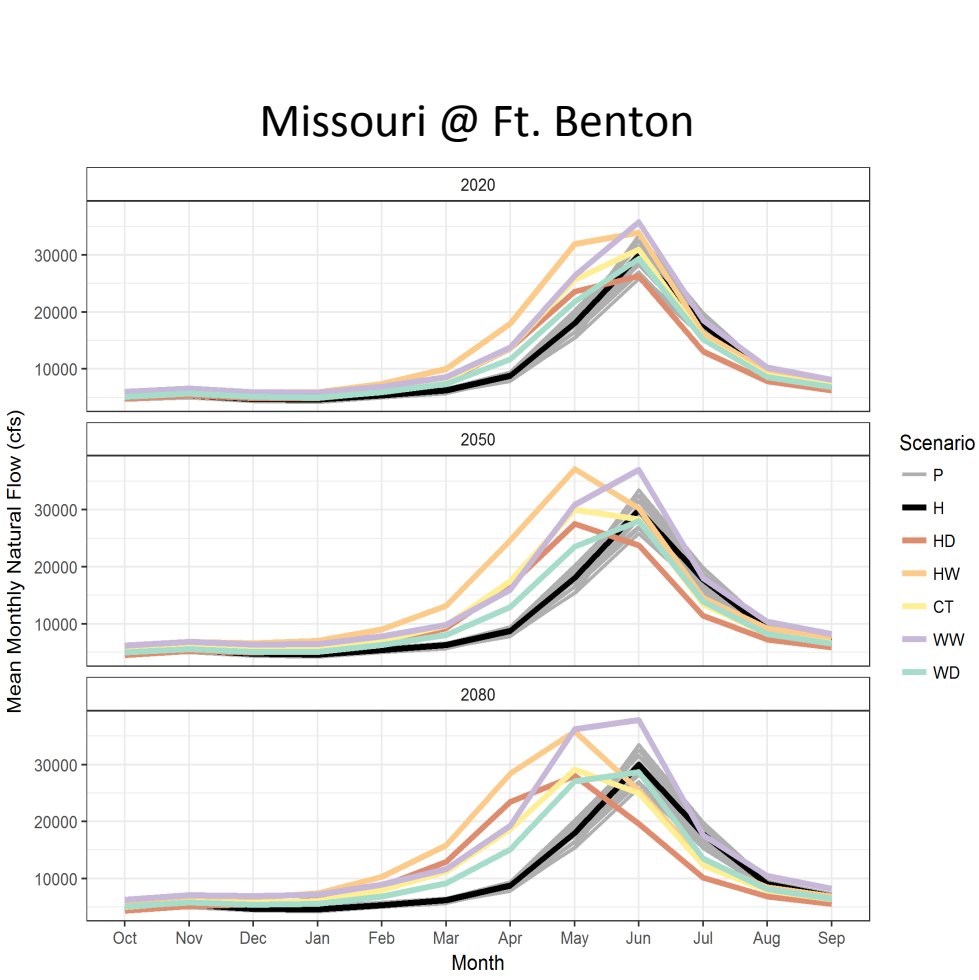


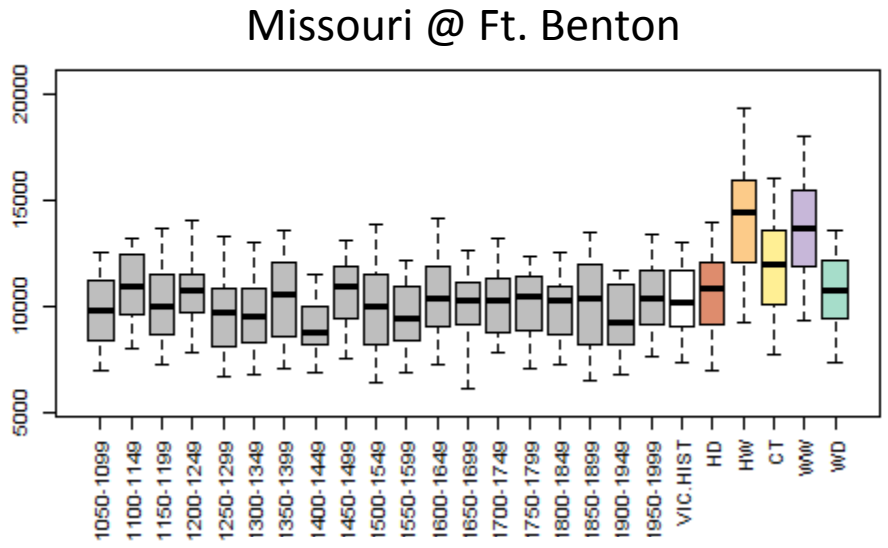
- **Allows for evaluation of river & reservoir operations under various water supply and demand conditions including:**
  - Historical hydrology and demand
  - Paleohydrology (working on *paleo*-demand)
  - Future climate change scenario hydrology and projected demand

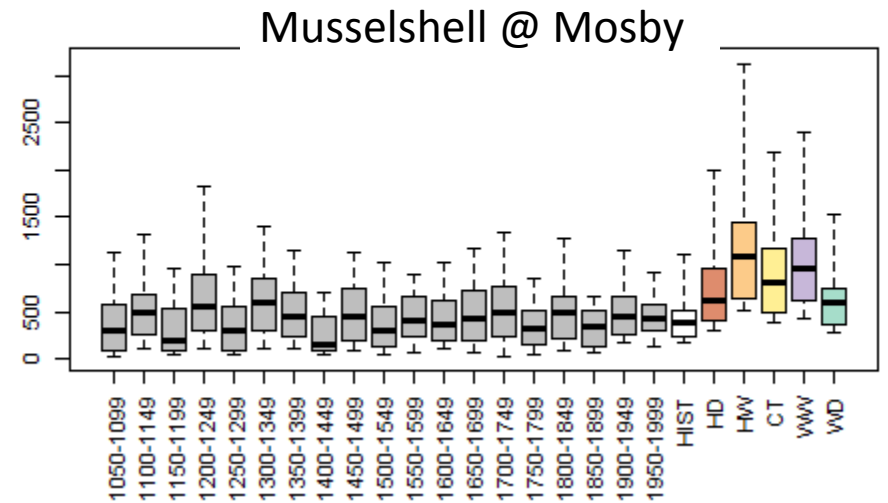
Long-Duration Drought Risk



Context For Future Flow Projections







Annual streamflow reconstructions disaggregated in time (daily) and space to all RiverWare inflow nodes upstream