

## Tree-ring reconstructions of streamflow: West-wide perspectives on their interpretation and use

Tree-ring reconstructions of streamflow and applications in Wasatch water management

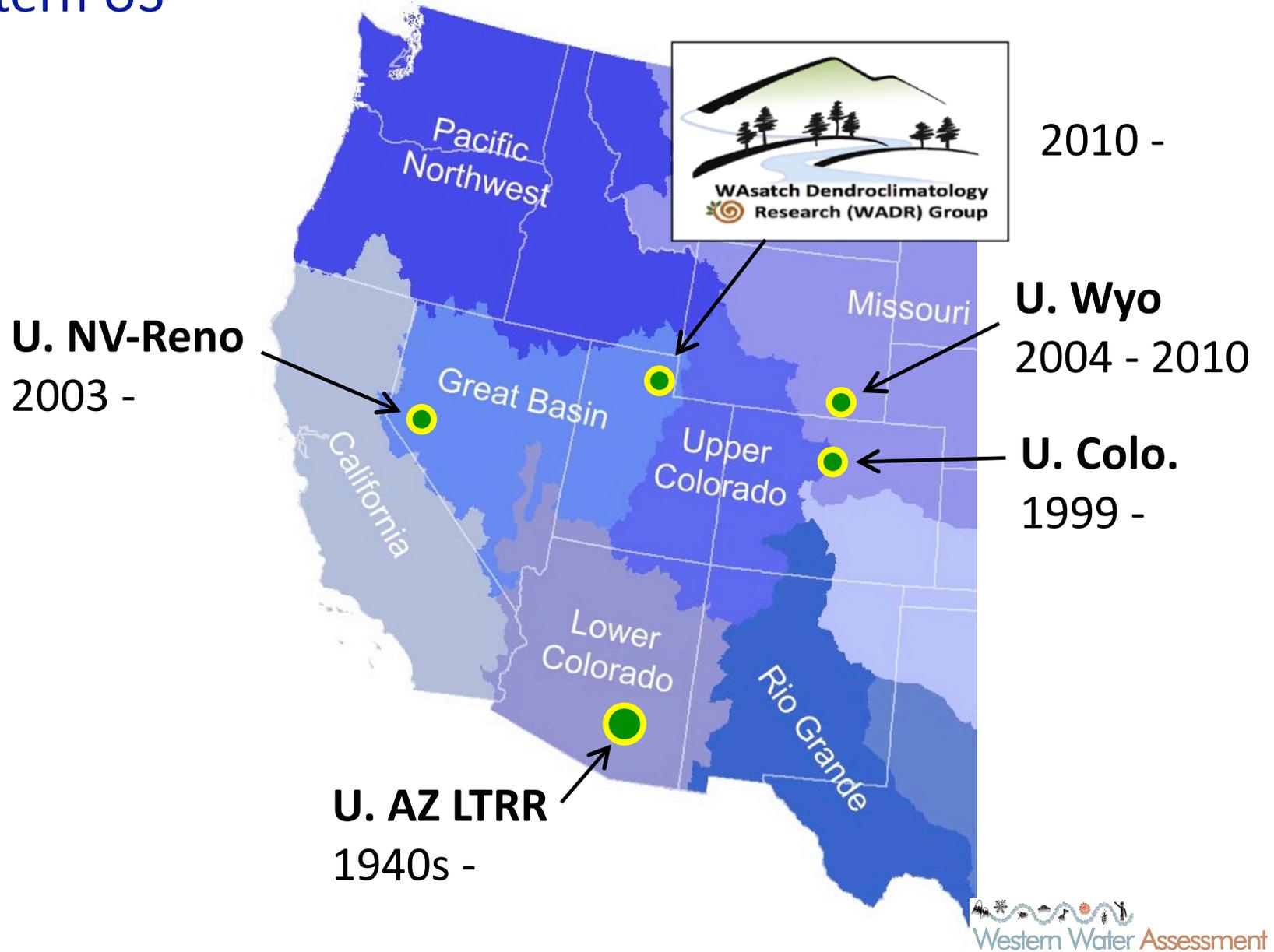
Wednesday, October 2, 2013 - Salt Lake City, UT

**Jeff Lukas**

CIRES Western Water Assessment

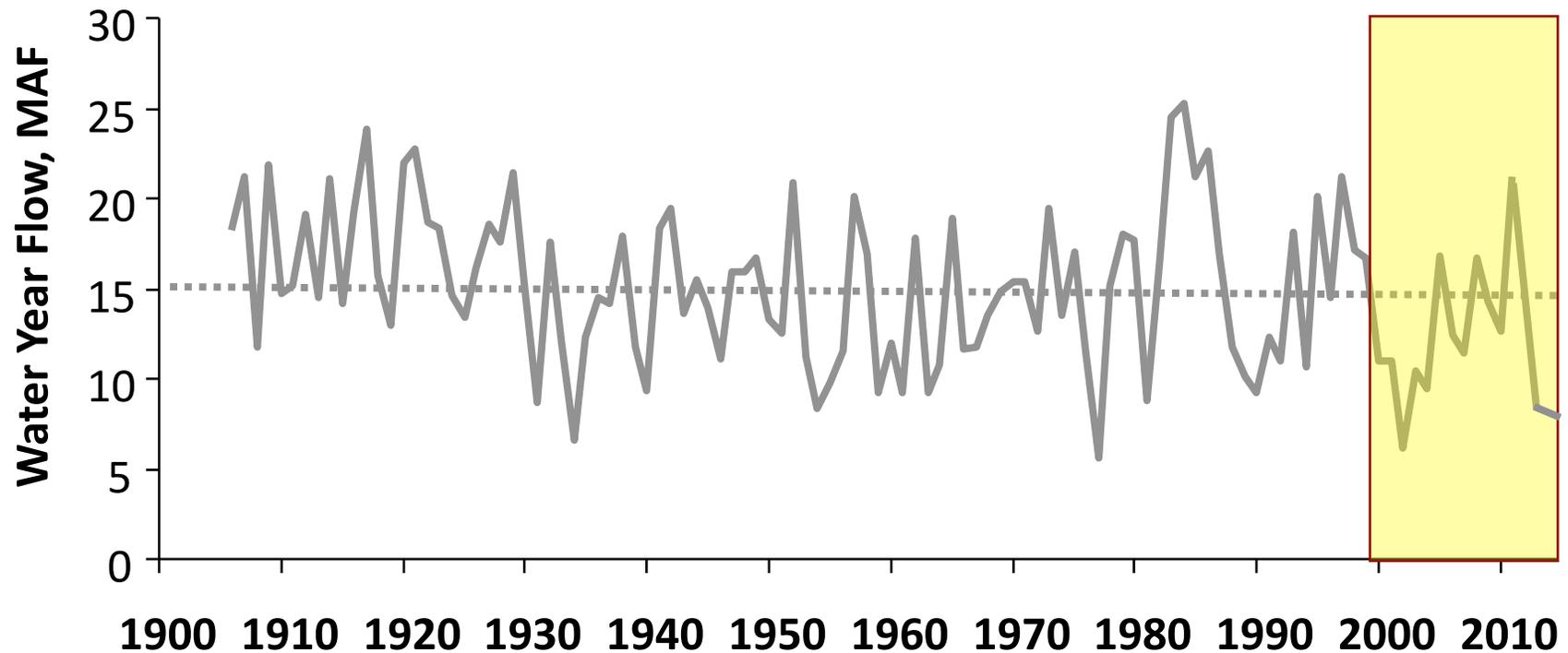
University of Colorado Boulder

# Tree-ring research applied to water resources in the western US



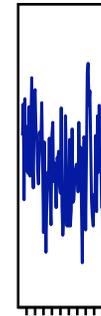
“Unprecedented” events indicate the limitations of the observed record

Colorado River at Lees Ferry, AZ - Natural Annual Flow, 1906-2013

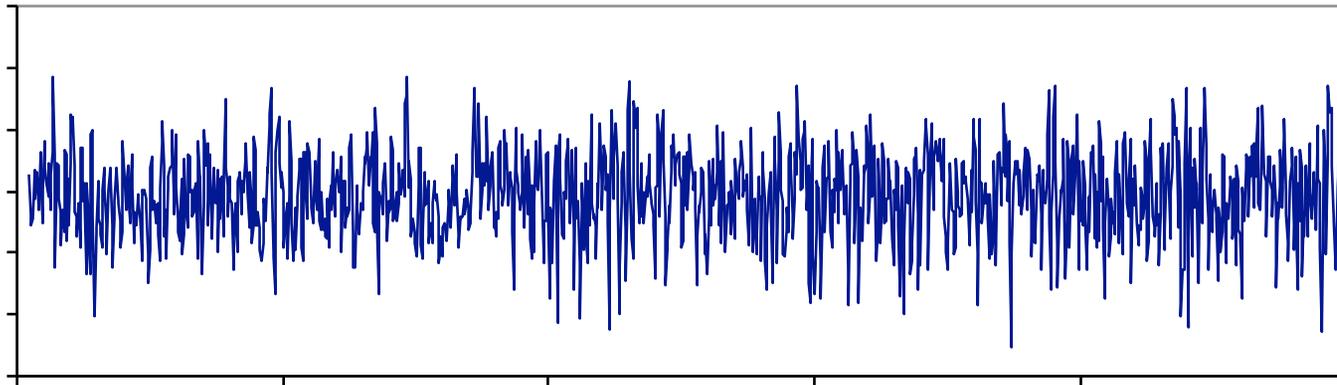


Data: Reclamation (1906-2010); 2011-13 values estimated from preliminary Reclamation data

# Tree rings = A much longer window onto past hydroclimatic variability



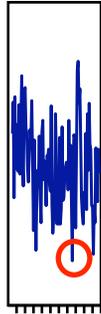
Gaged  
record  
**30-100**  
years



Tree-ring  
reconstruction  
**300-1000+**  
years

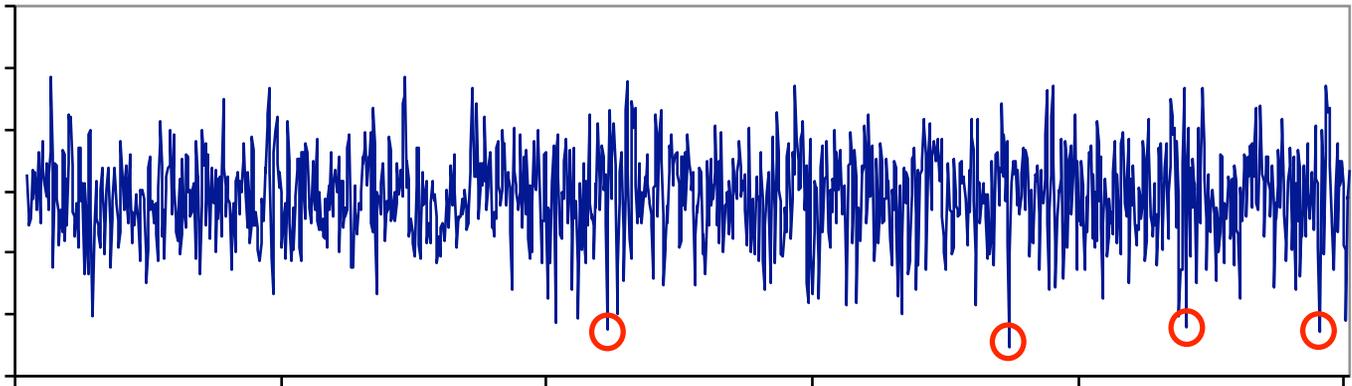
# Tree rings = A much longer window onto past hydroclimatic variability

Unprecedented!



Gaged record  
30-100  
years

Nope...

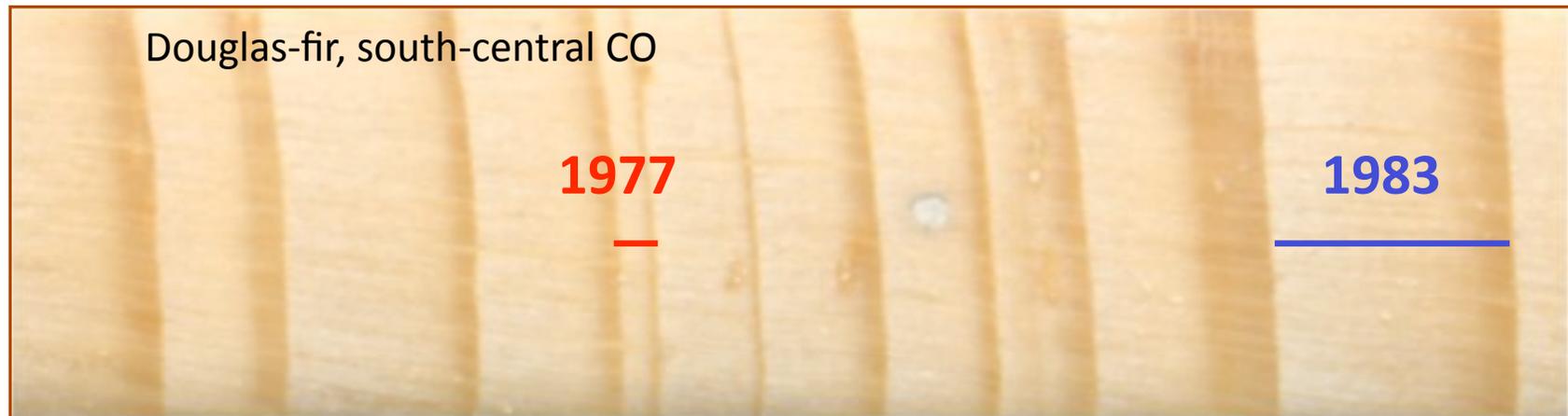


Tree-ring  
reconstruction  
300-1000+  
years

*For most trees across the western US:*

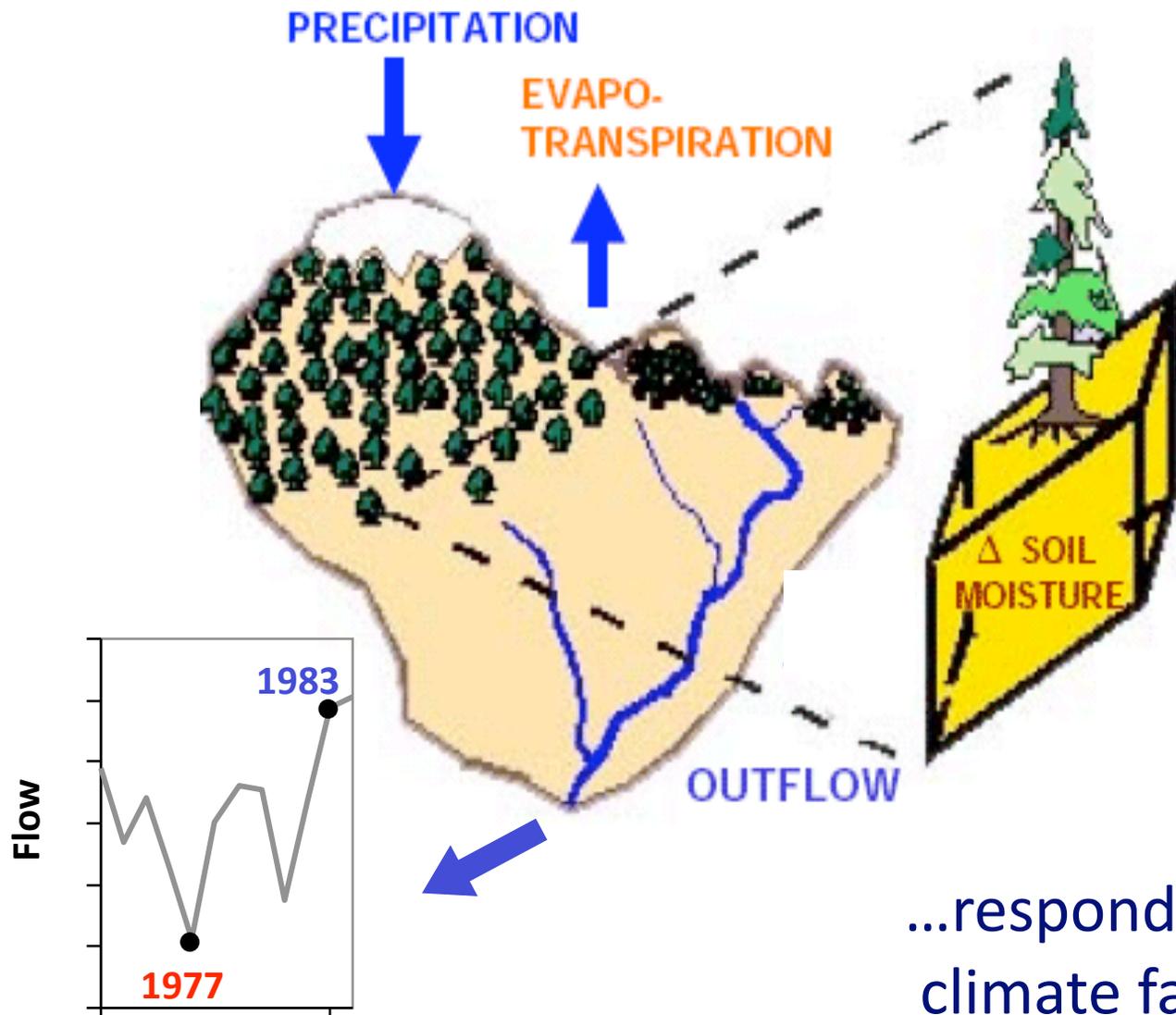
**Dry conditions = Narrow ring**

**Wet conditions = Wide ring**



This **moisture signal** integrates both precipitation and evapotranspiration

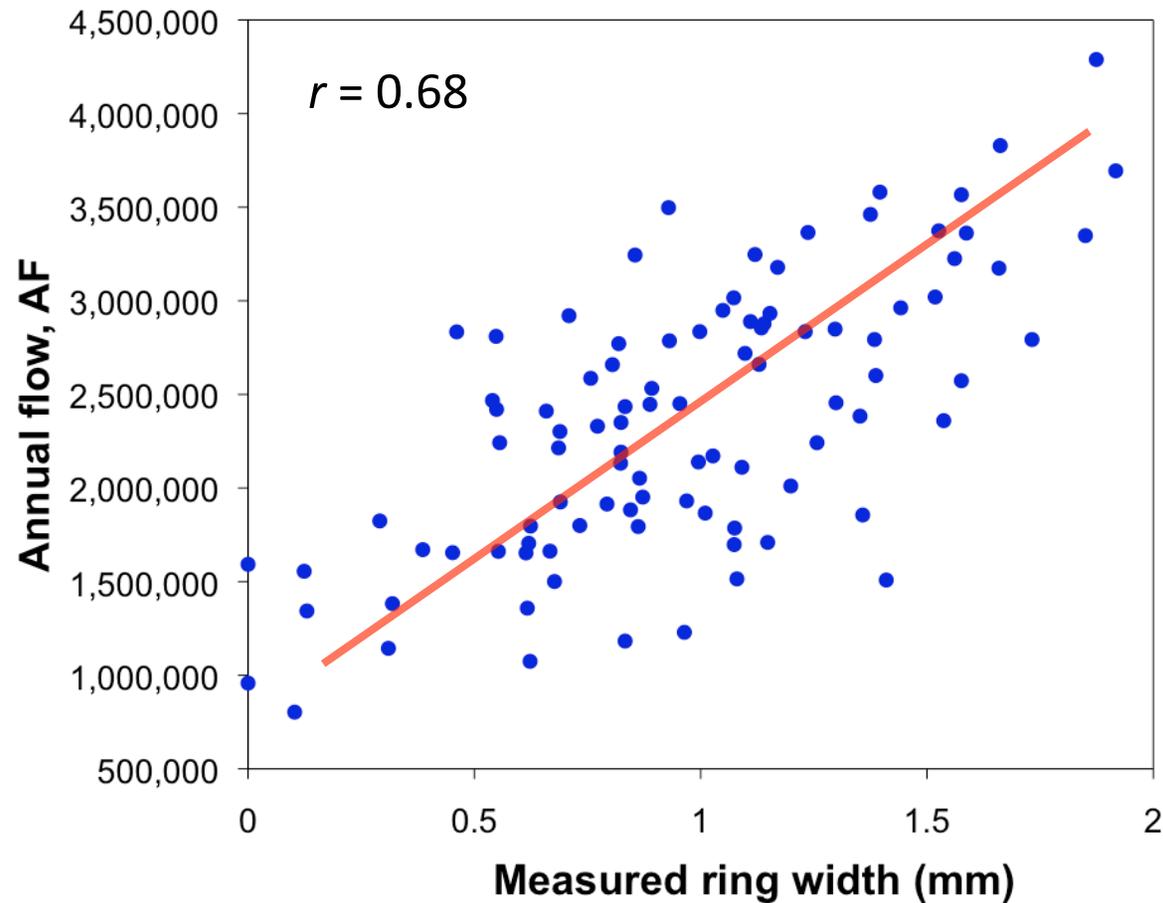
# Tree rings and streamflow...



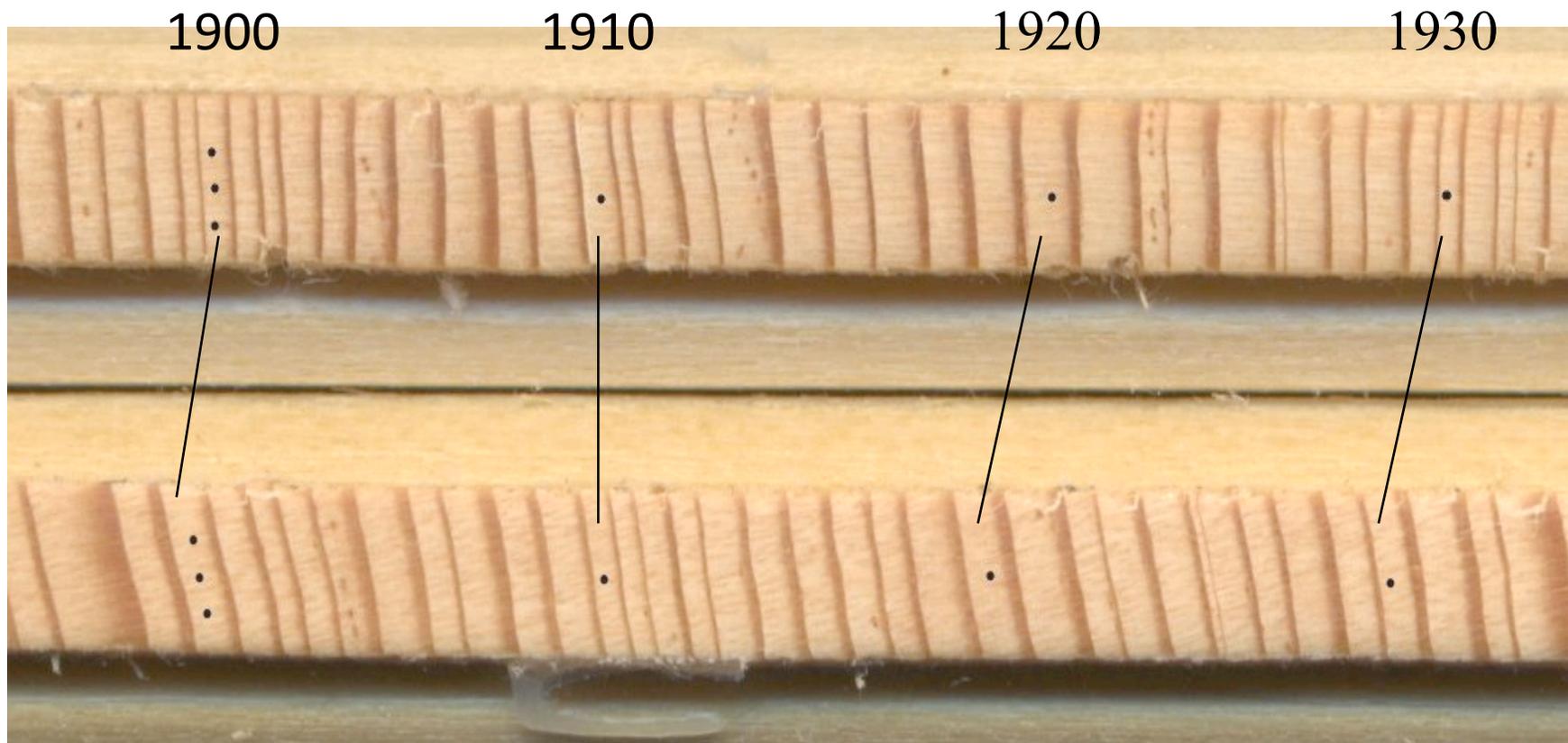
...respond to the same climate factors

# Tree-growth–streamflow relationship in the Rocky Mountain West: generally linear and highly significant

Scatterplot of ring widths from *one* pinyon pine on Grand Mesa, and annual flow of Gunnison River above Grand Junction, 1906-2002

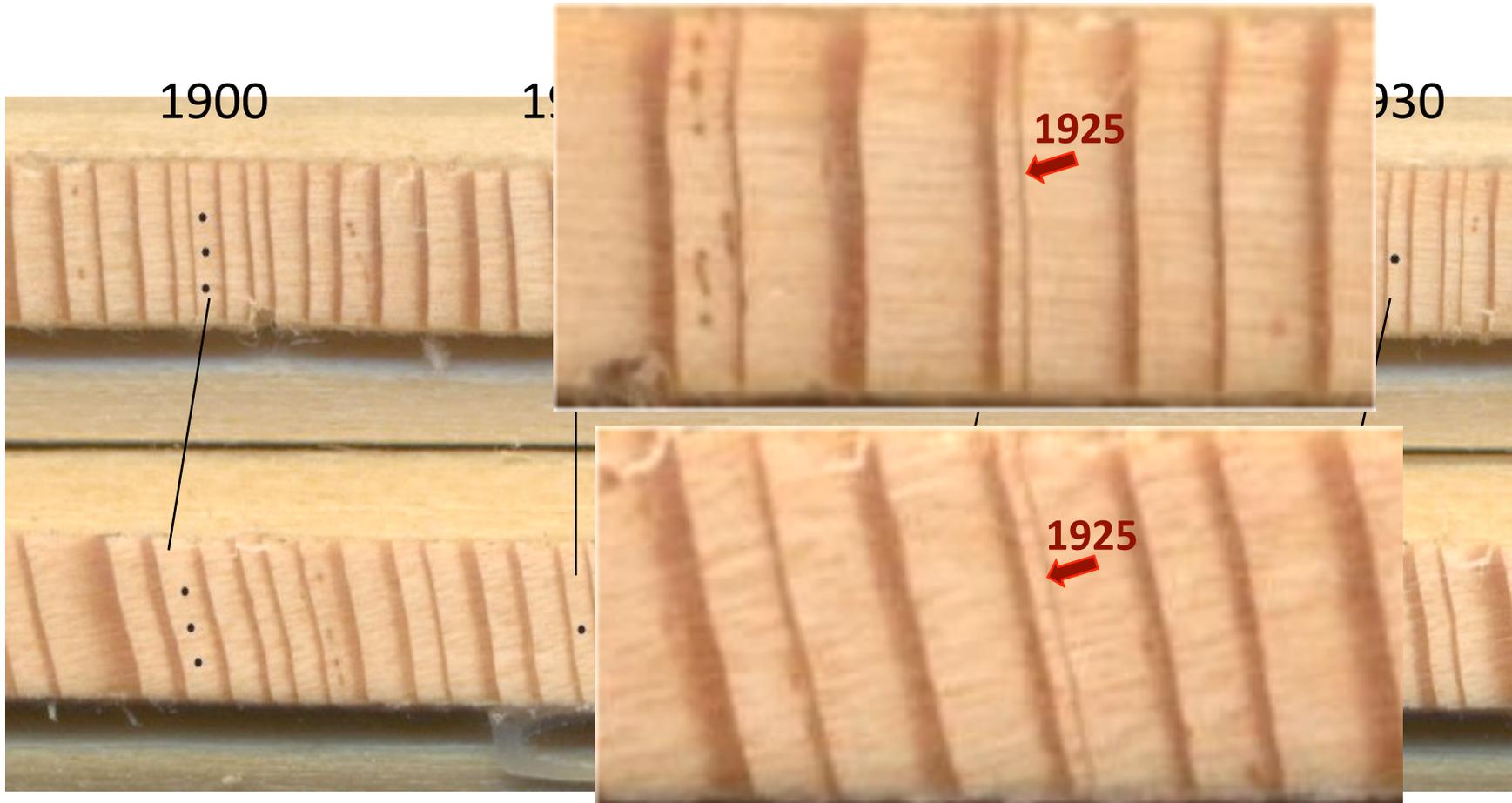


Same climate influences the growth of all trees at a site = **cross-dating**



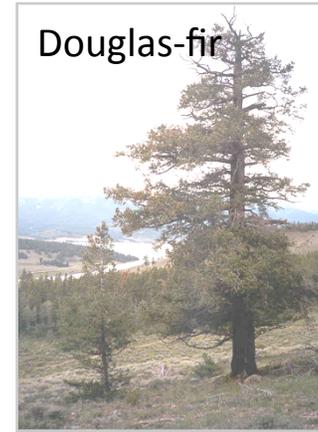
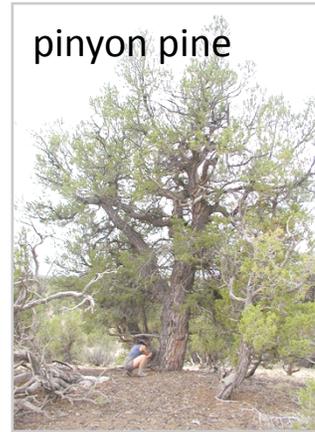
Two Douglas-fir trees near Eldorado Springs, CO

Same climate influences the growth of all trees at a site = **cross-dating**

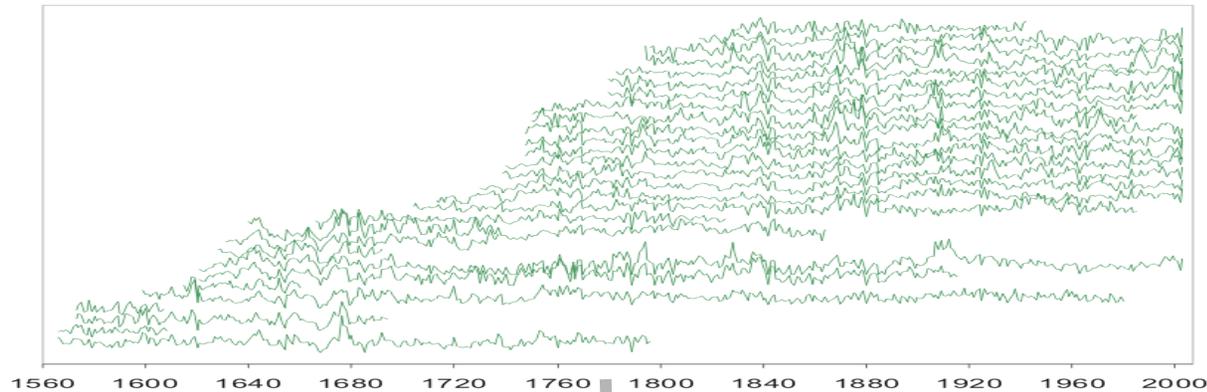


Two Douglas-fir trees near Eldorado Springs, CO

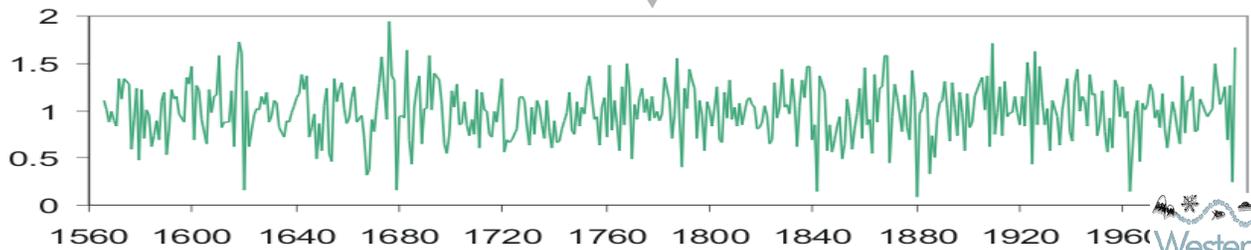
# Developing moisture-sensitive tree-ring records in the Rocky Mountain West



Multiple trees, same species, one site



Site chronology



Over 1800 moisture-sensitive tree-ring chronologies across North America as of 2009; ~40 from Utah (now >50)

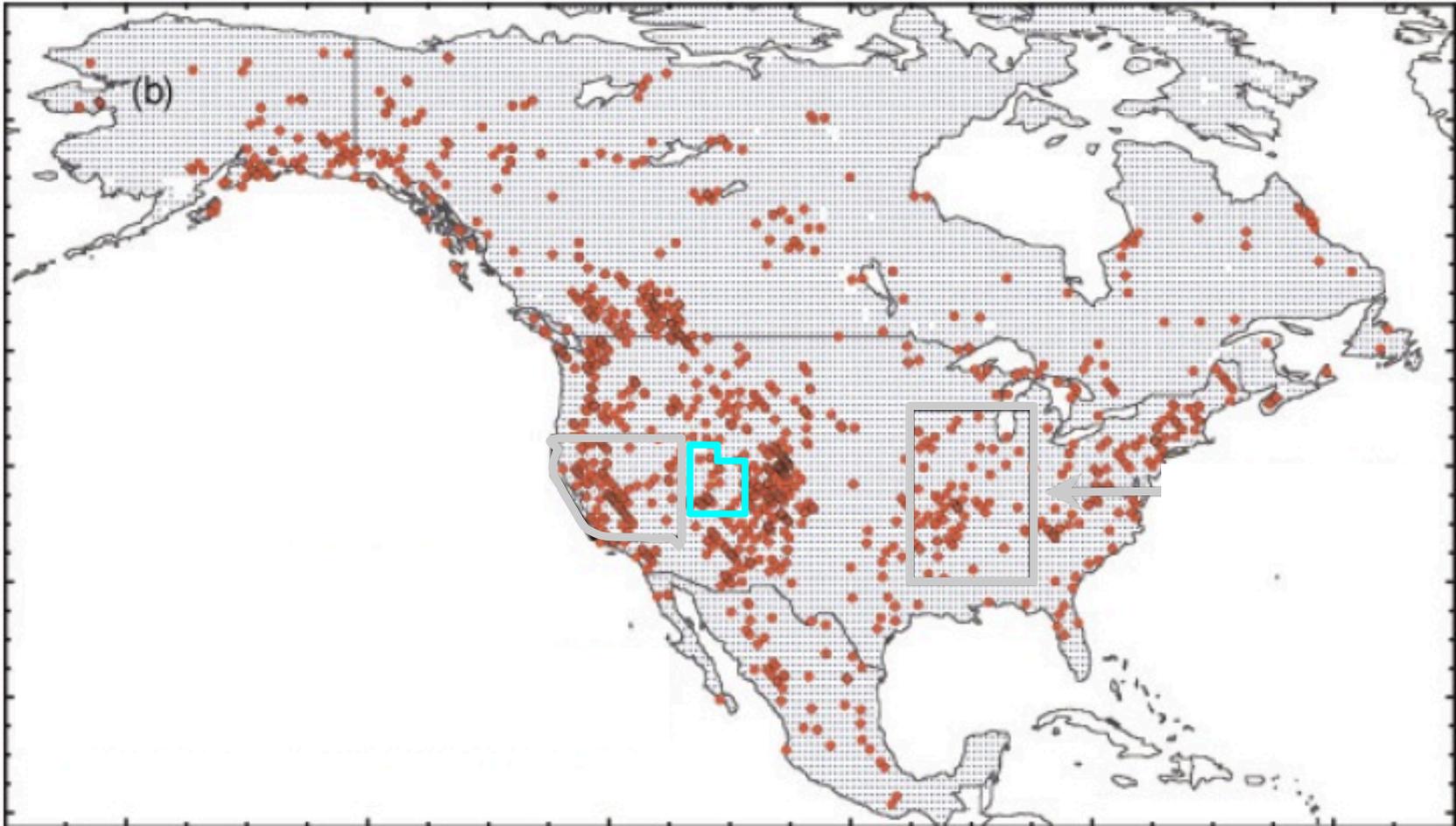
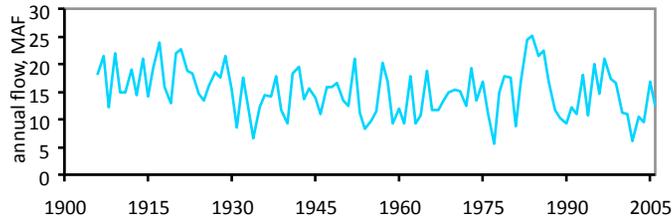


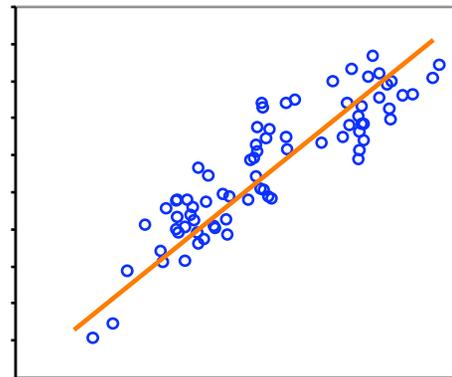
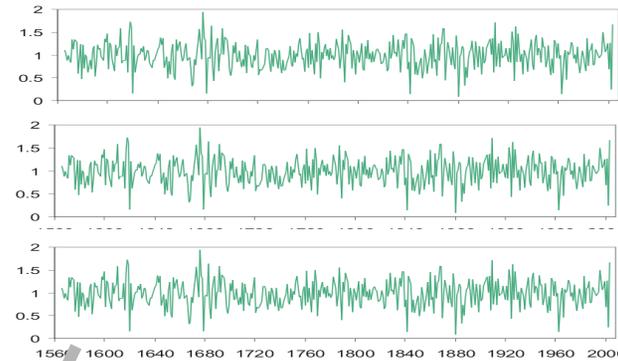
Figure: Cook et al. (2009), J. Quaternary Science

# Generating tree-ring reconstructions

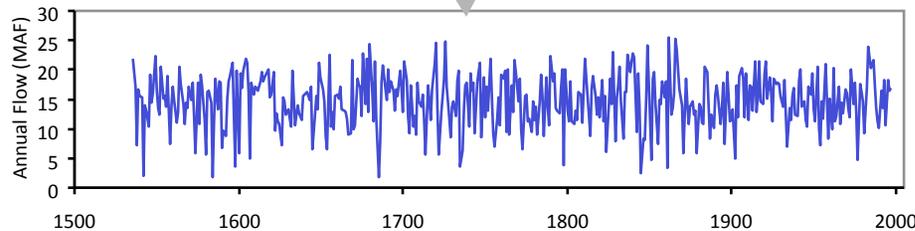
Observed (natural) streamflow record



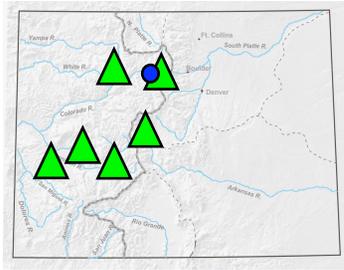
Set of tree-ring chronologies



Best-fit using regression modeling or other method + validation



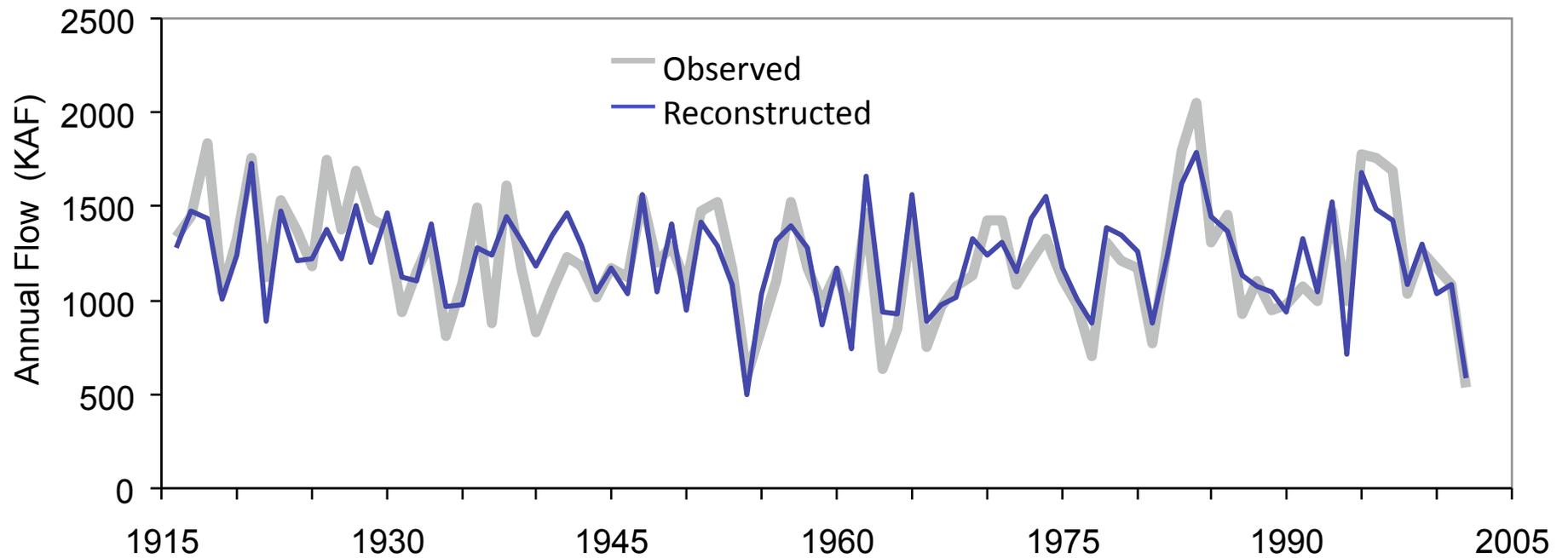
Tree-ring reconstruction of streamflow



## Colorado at Kremmling, CO

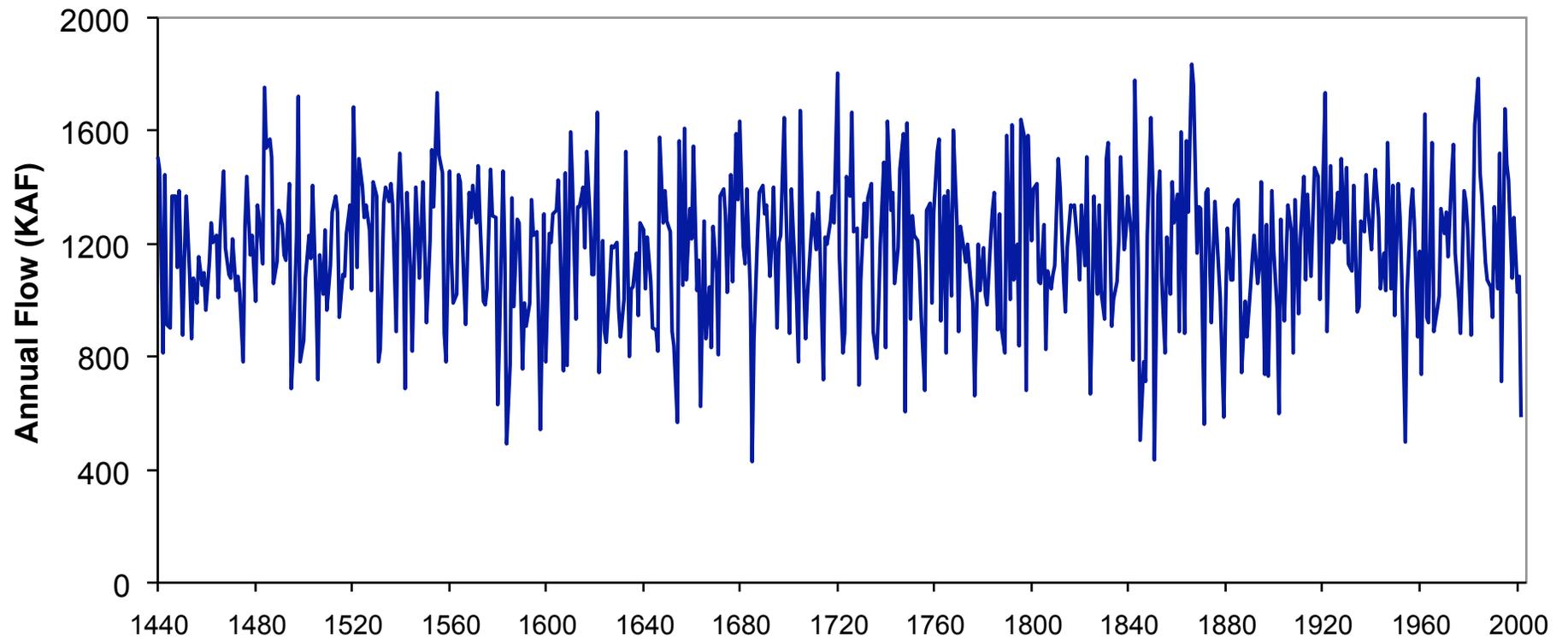
Calibration of reconstruction model, 1916-2002

▲ = chronology/predictor in model

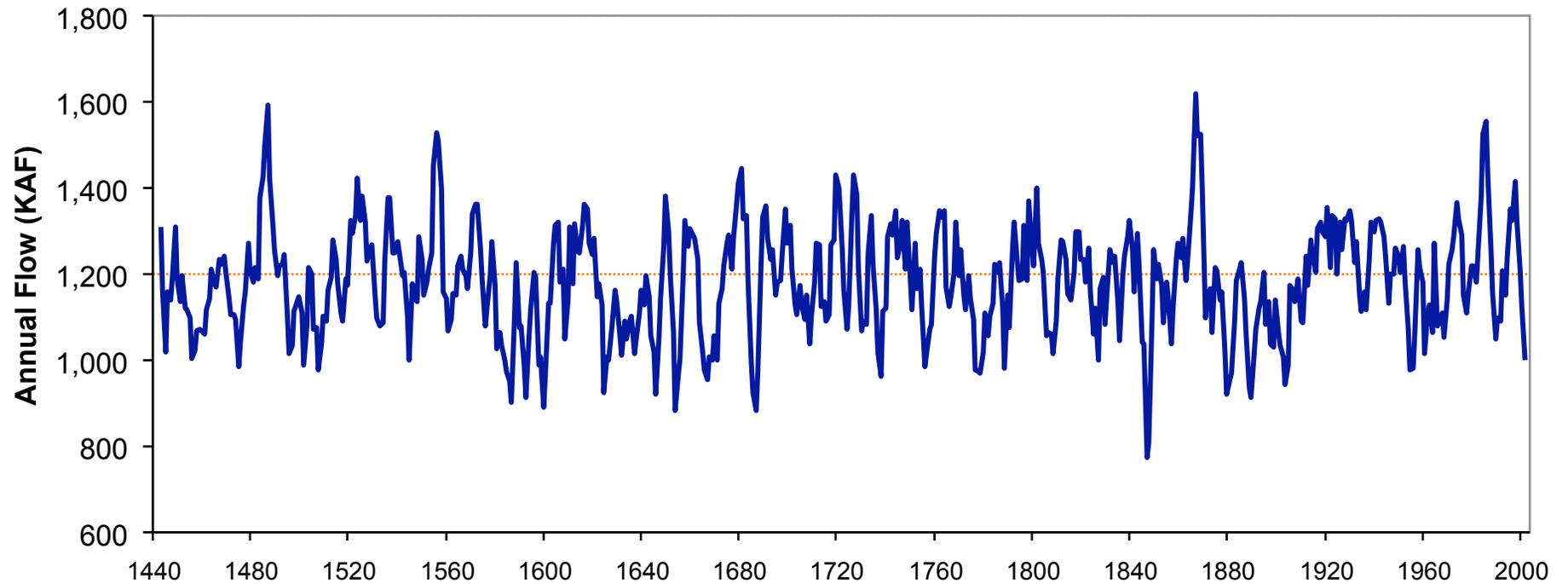


Calibration:  $R^2 = 0.70$

# Full reconstruction of Colorado at Kremmling annual streamflow, 1440-2002



# Full reconstruction of Colorado at Kremmling annual streamflow, 1440-2002, with 4-year running average



# The “fine print” - sources of error and uncertainty in tree-ring reconstructions

1) Observed streamflow records have errors, especially if they have been naturalized

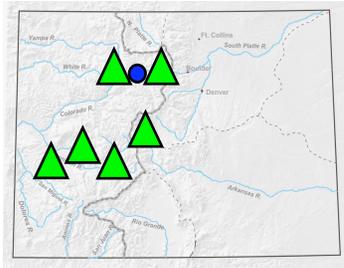


2) Trees are imperfect recorders of climate and thus streamflow



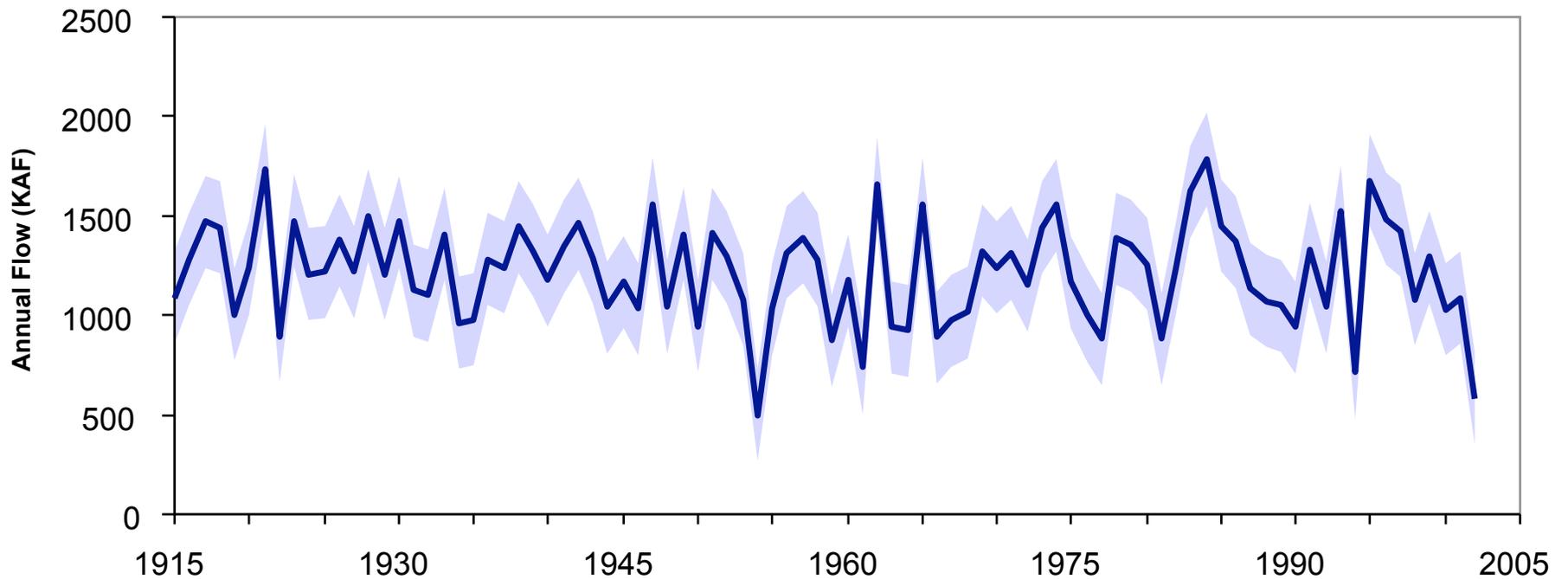
3) Researchers make subjective choices during the modeling process





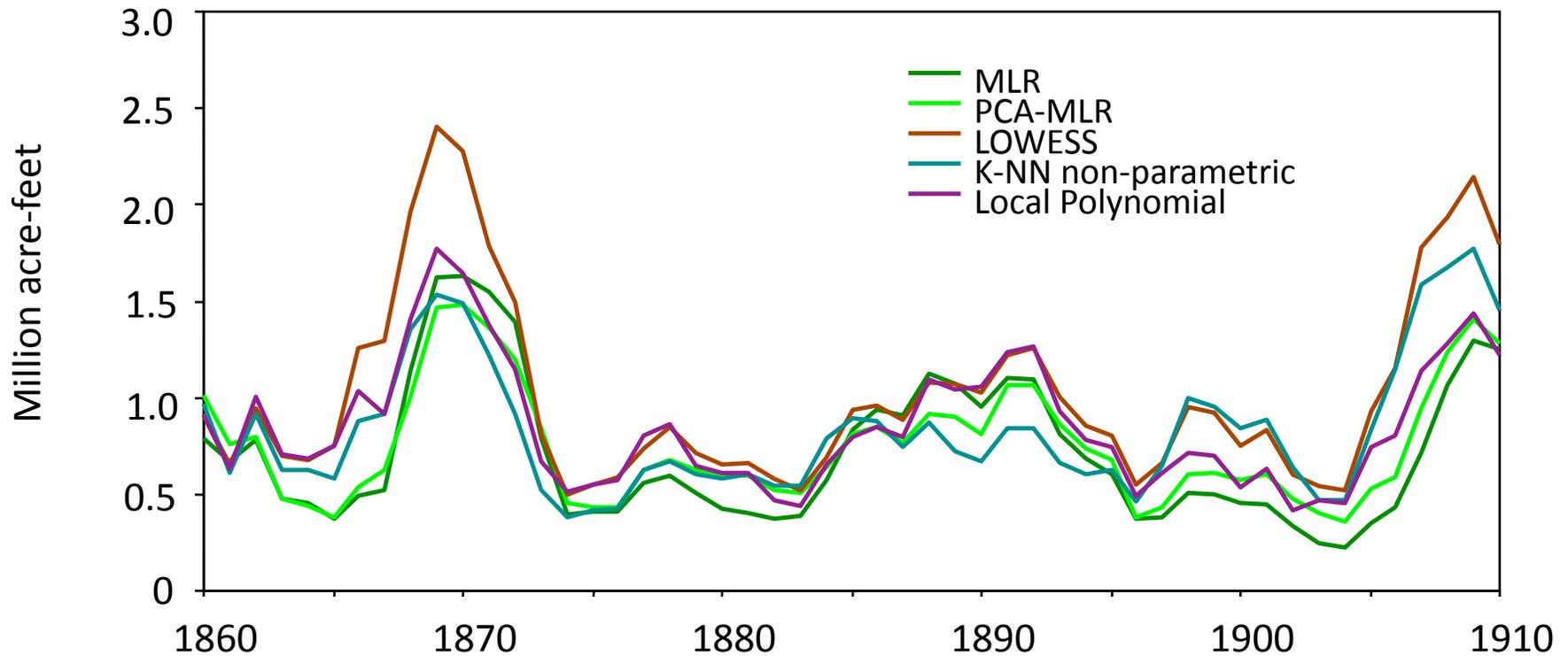
## Uncertainty related to calibration/validation errors

Colorado at Kremmling, CO - Reconstruction with 80% confidence intervals, 1916-2002



## Uncertainty related to modeling choices

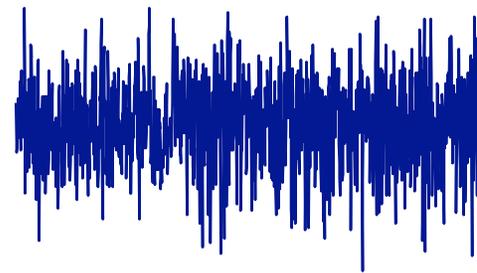
Gila River near Dome, AZ , reconstructed **5-year running mean flows** 1860-1910 using 5 different modeling approaches and same tree-ring data



Modeling by C. Woodhouse, D. Meko, and L. Wade; see Wade (2012) and Lukas et al. 2012

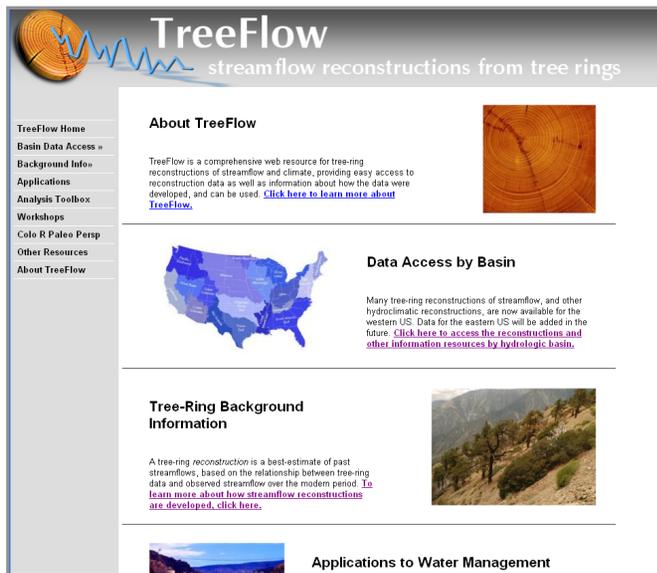
## The bottom line:

- ▶ Any tree-ring reconstruction is a *plausible estimate* of past streamflow, not a final truth



...more or less

# Over 60 streamflow reconstructions archived on the *TreeFlow* web resource - <http://treeflow.info>



**TreeFlow**  
streamflow reconstructions from tree rings

TreeFlow Home  
Basin Data Access »  
Background Info »  
Applications  
Analysis Toolbox  
Workshops  
Colo R Paleo Persp  
Other Resources  
About TreeFlow

**About TreeFlow**

TreeFlow is a comprehensive web resource for tree-ring reconstructions of streamflow and climate, providing easy access to reconstruction data as well as information about how the data were developed, and can be used. [Click here to learn more about TreeFlow.](#)

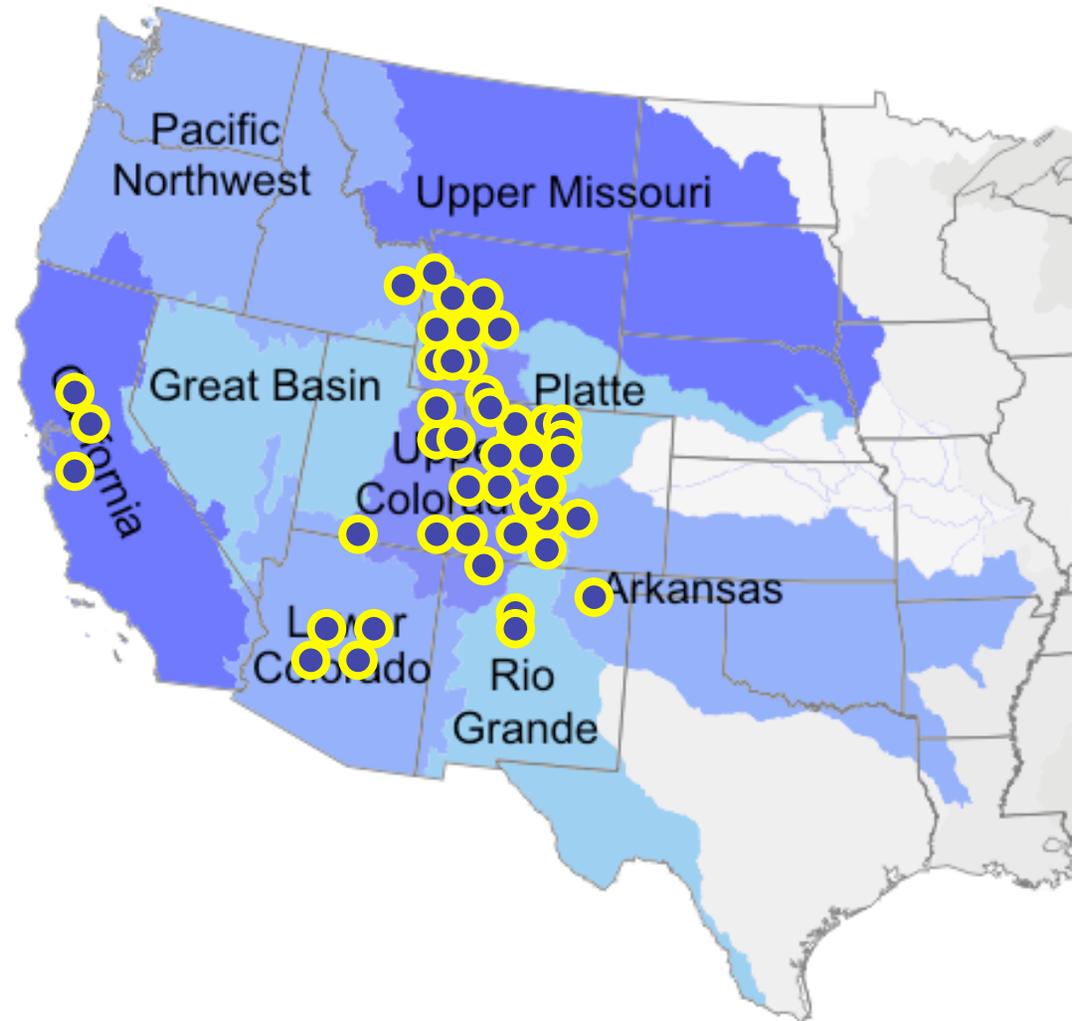
**Data Access by Basin**

Many tree-ring reconstructions of streamflow, and other hydroclimatic reconstructions, are now available for the western US. Data for the eastern US will be added in the future. [Click here to access the reconstructions and other information resources by hydrologic basin.](#)

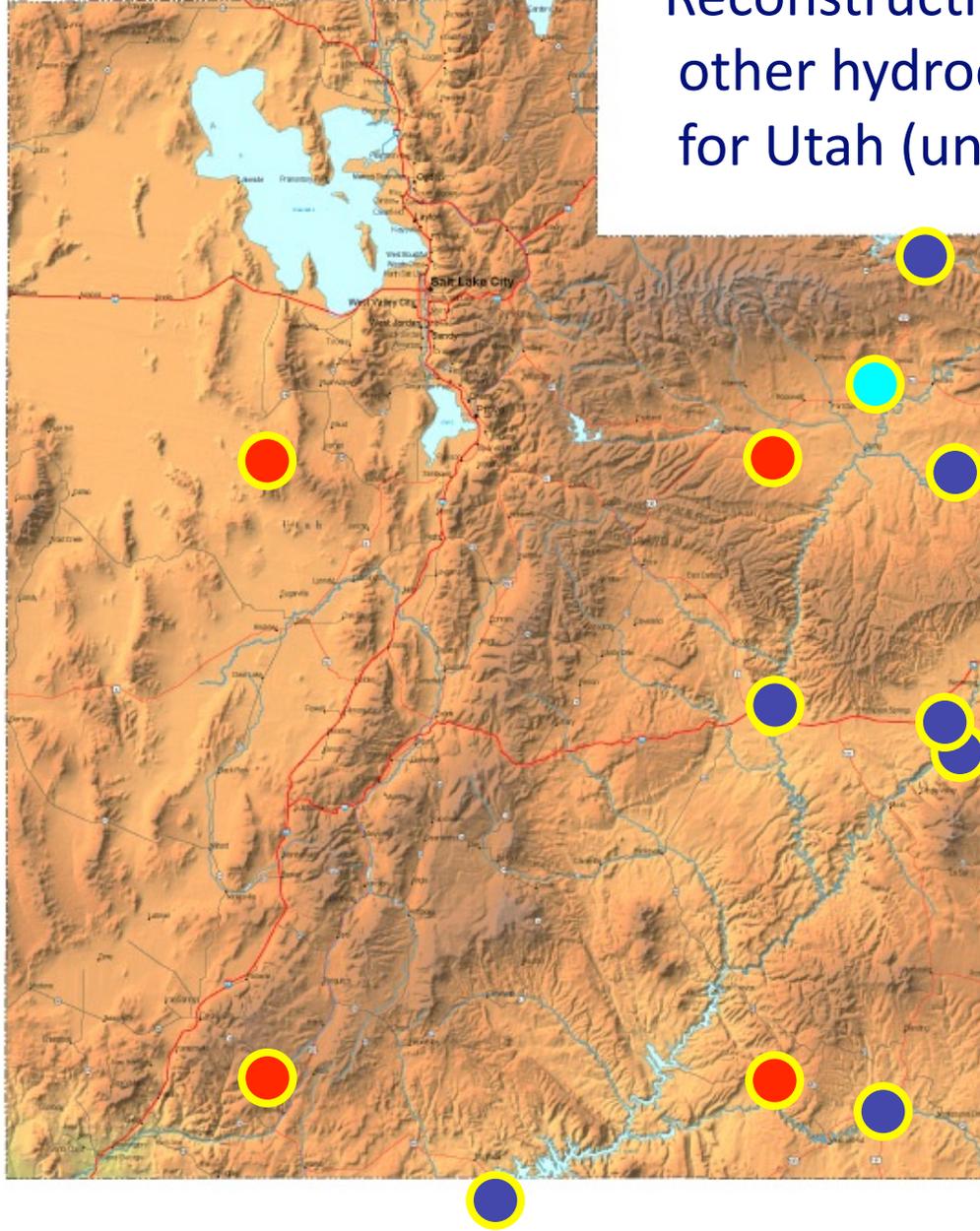
**Tree-Ring Background Information**

A tree-ring reconstruction is a best-estimate of past streamflows, based on the relationship between tree-ring data and observed streamflow over the modern period. [To learn more about how streamflow reconstructions are developed, click here.](#)

**Applications to Water Management**



## Reconstructions of streamflow and other hydroclimate variables available for Utah (until now)

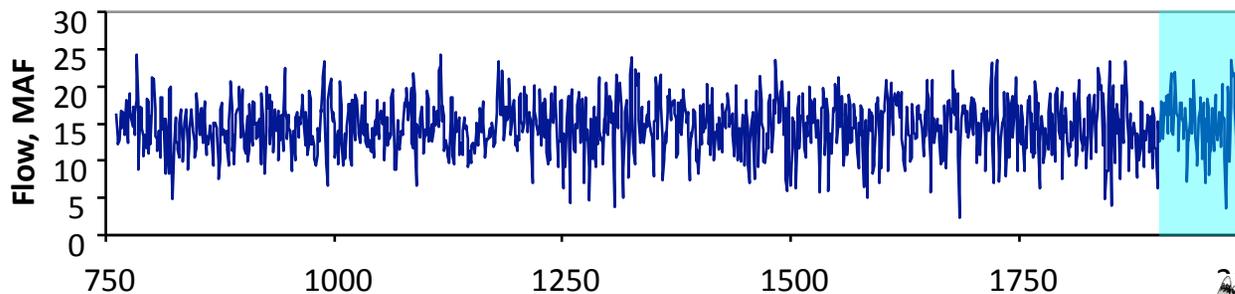


-  Stream gage  
**Annual Flow**
-  Gridpoint  
**Summer PDSI**
-  Climate Div. 6  
**Annual precipitation**

See <http://treeflow.info>  
for access to these data

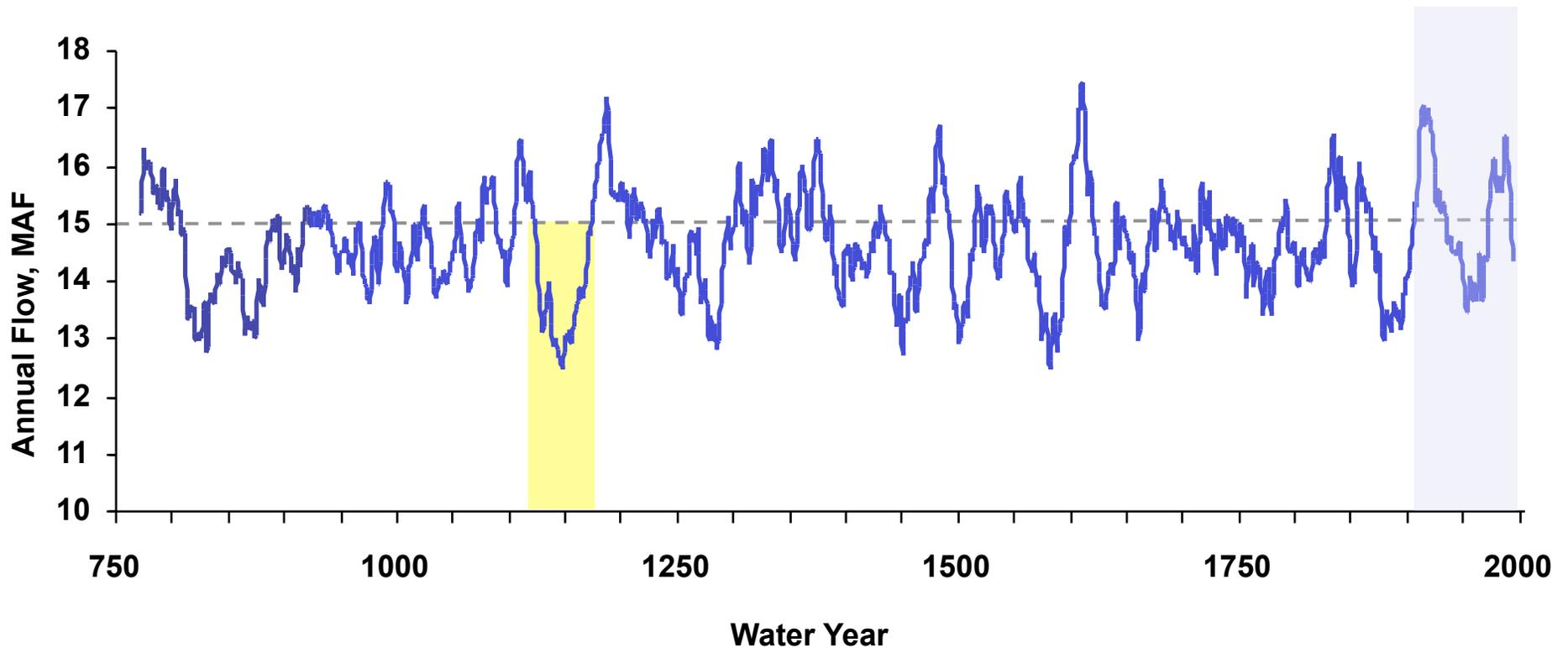
# Useful things that water managers and researchers in the West have done with tree-ring reconstructions

- Place the 20<sup>th</sup> century and early 21<sup>st</sup> century variability in a longer context
- Examine and characterize the most extreme and persistent dry and wet events (e.g., drought of record)
- Conduct risk assessment/modeling with more data and a richer variety of sequences and events
- Investigate the behavior of quasi-cyclical climate modes (ENSO, PDO, QDO, etc.)



### 3 examples of use of a reconstruction:

Tree-ring reconstructed annual flows, Colorado River at Lees Ferry, 762-2005, with **20-year** running average



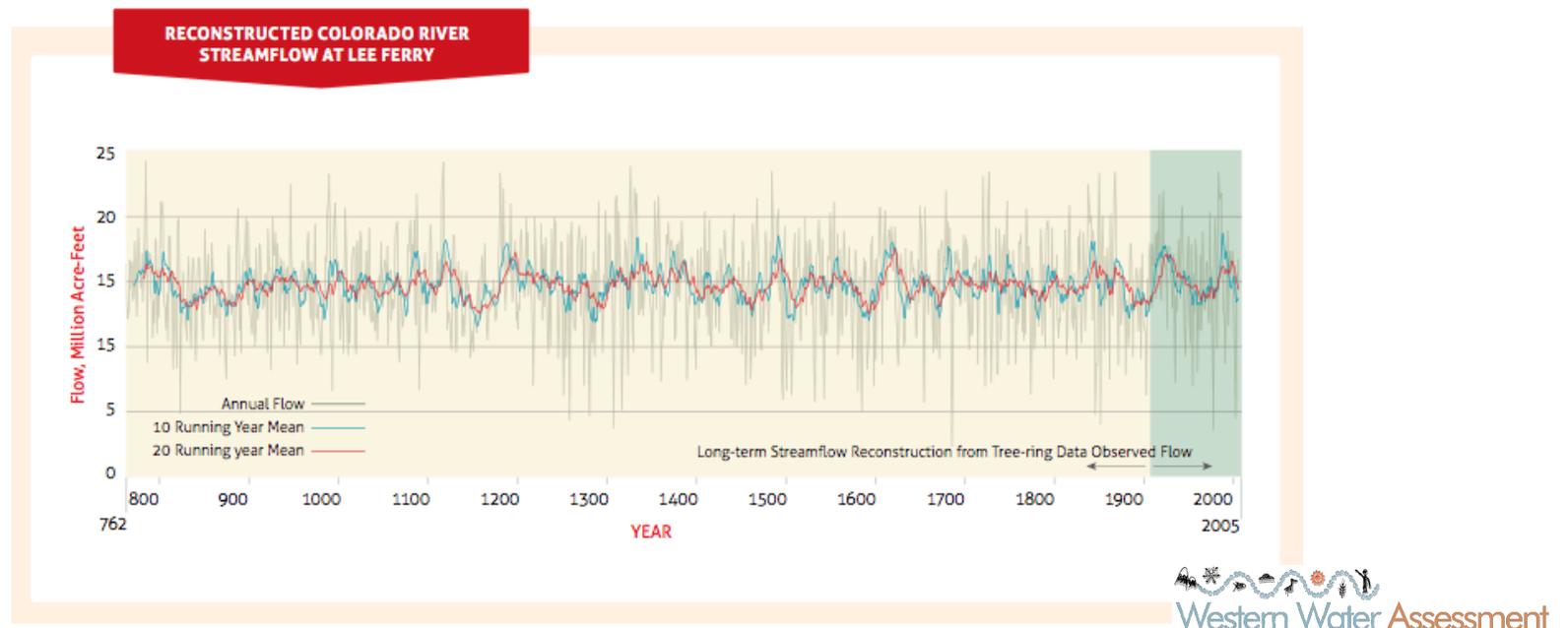
Data: TreeFlow website, <http://treeflow.info/upco/coloradoleesmeko.html>

Reference: Meko et al. (2007), Medieval Drought in the Upper Colorado River Basin, *Geophysical Research Letters*

## 1) *Drought in California* (Pamphlet for water users, California DWR, 2012)

“Paleoclimate information, such as streamflow reconstructions based on tree-ring data, shows that natural variability can be far greater than that observed in the historical record.

These reconstructions have identified droughts prior to the historical record that were far more severe than today’s water institutions and infrastructure were designed to manage.”

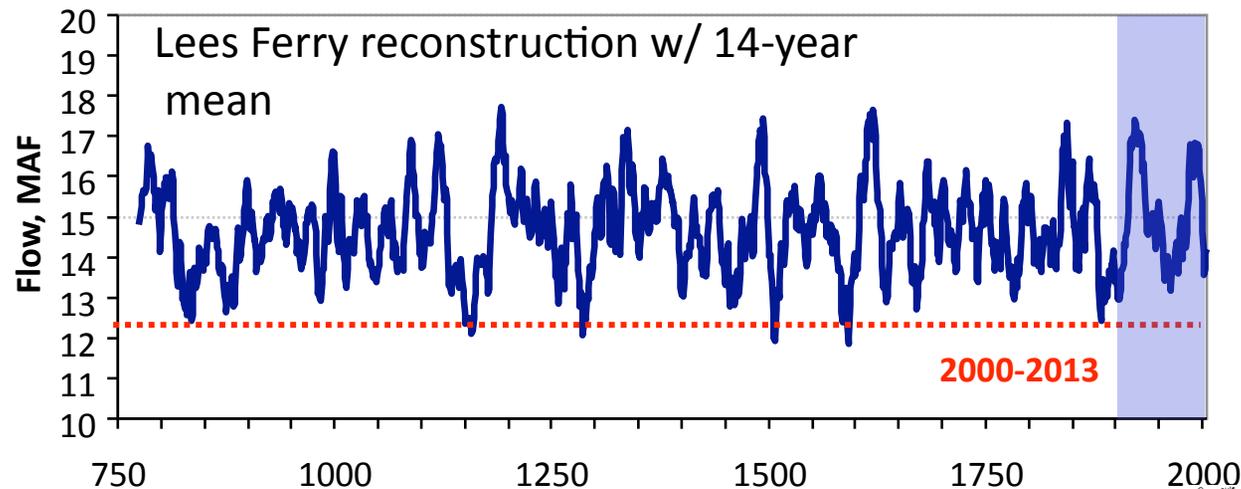


## 2) Testimony to Senate Comm. on Energy and Natural Resources

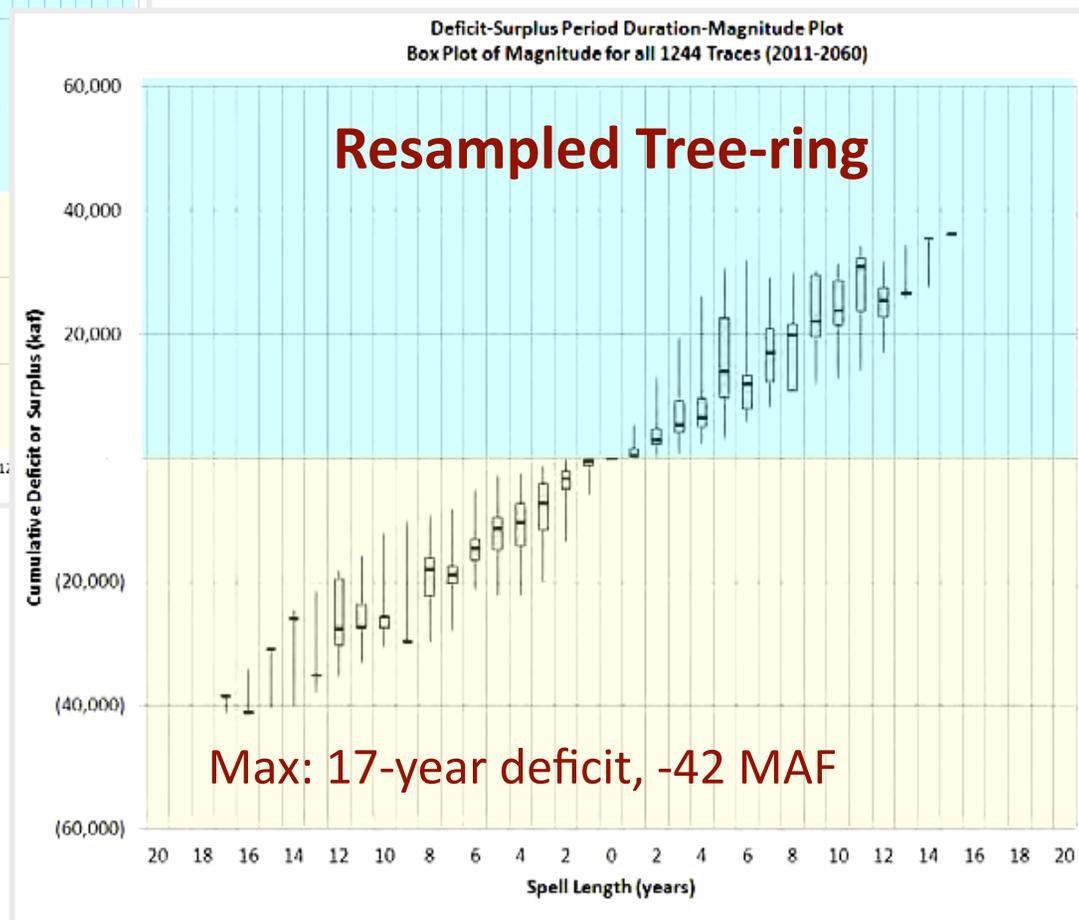
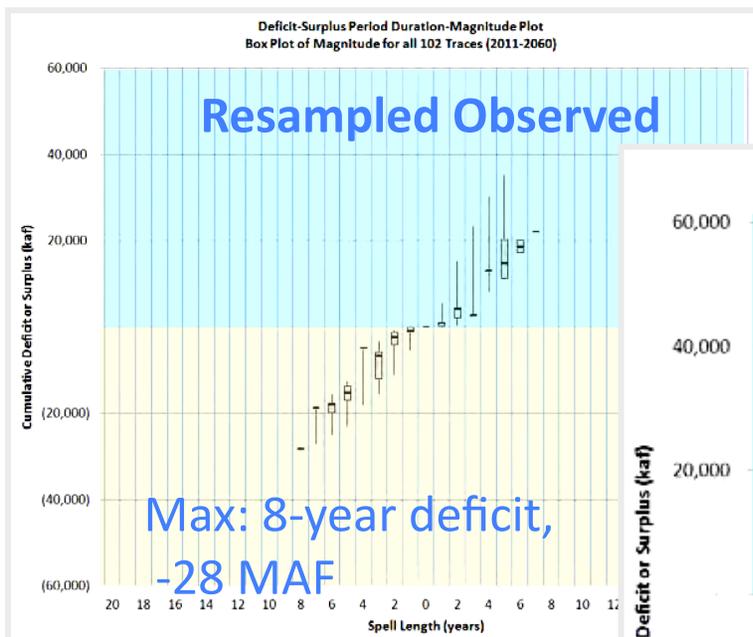
- Michael Connor, Commissioner, Reclamation – July 16, 2013

“Today the Colorado River is facing a record drought. The period from 2000 to 2013 is shaping up to be the lowest 14-year period in the over 100-year historical record for the Colorado River.

Tree-ring reconstructions of streamflow indicate that the current 14-year period, which began in 2000, is one of the lowest in the Basin in over 1,200 years.”

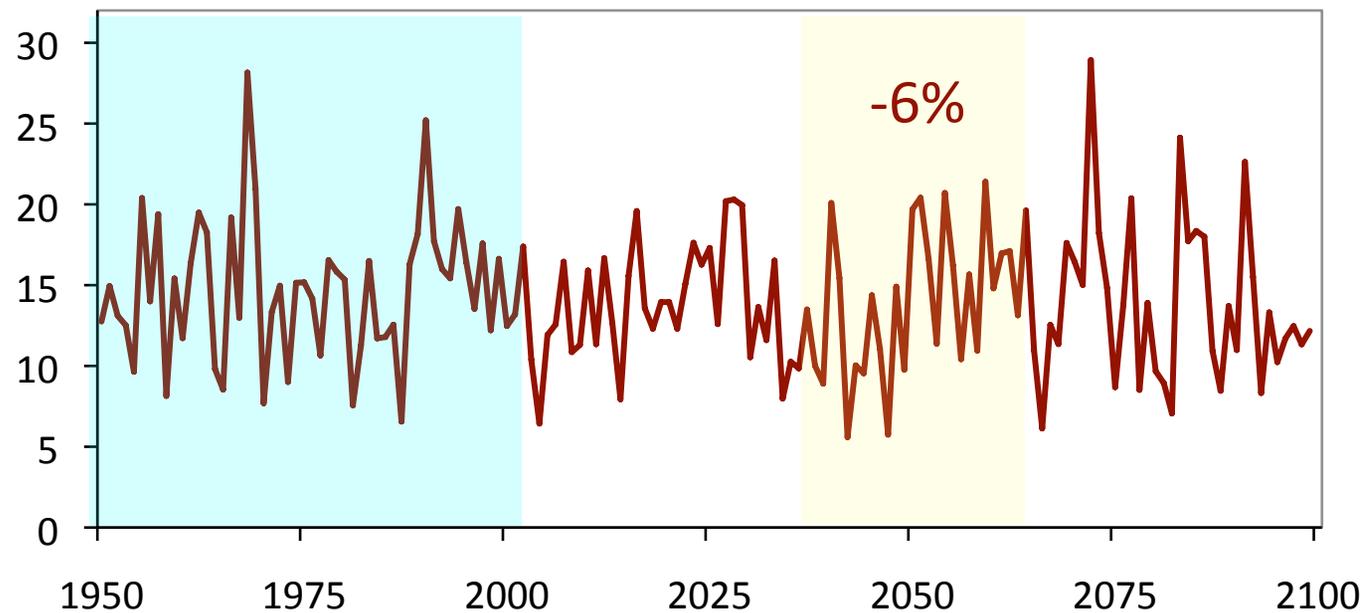


### 3) Colorado River Basin Supply & Demand Study (Reclamation, 2011) – Deficit and Surplus Spell Length and Magnitude



# Tree-ring reconstructions and climate change

Modeled annual streamflow, Colorado River at Lees Ferry  
1950-2100 (**single** downscaled GCM run + VIC hydrology model)



- Interannual to decadal variability will likely continue to be the main source of vulnerability through mid-century for most systems

# Recap

## *Tree-ring reconstructions of streamflow:*

- Exploit a robust relationship between tree growth and moisture to provide a broader perspective on past hydrology
- Capture variability and extreme events not fully reflected in observed hydroclimatic records
- Are versatile tools for expanding planning perspectives and applying harsher but still plausible tests to systems

## Questions?



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