The Fickle Flow

Aston Tennefoss
28 February 2018
ECL 290

What Do Climate Reconstructions and Forecasting Tell Us About the Future of Colorado River Flow?

Presentation Stream

- Drought Defined
- Dendrochronology
- Paleoreconstructions
- Global Climate Models
- Policy Implications

−19%

average flow 2000-2014 compared to 1906-1999

Udall, B. & Overpeck, J. (2017). The twenty-first century Colorado River hot drought and implications for the future. *Water Resources Research*, *53*, 2404– 2418. doi:10.1002/2016WR019638

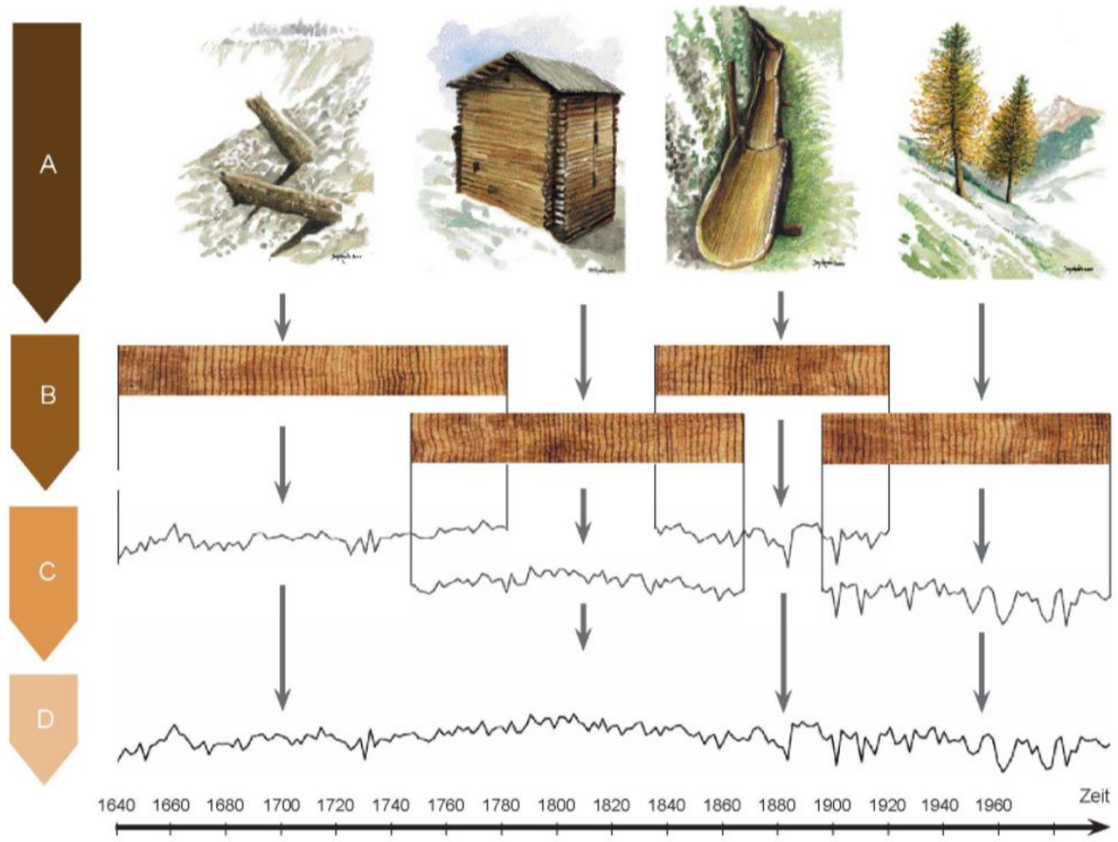
Drought

A period of drier-than-normal conditions that results in water-related problems

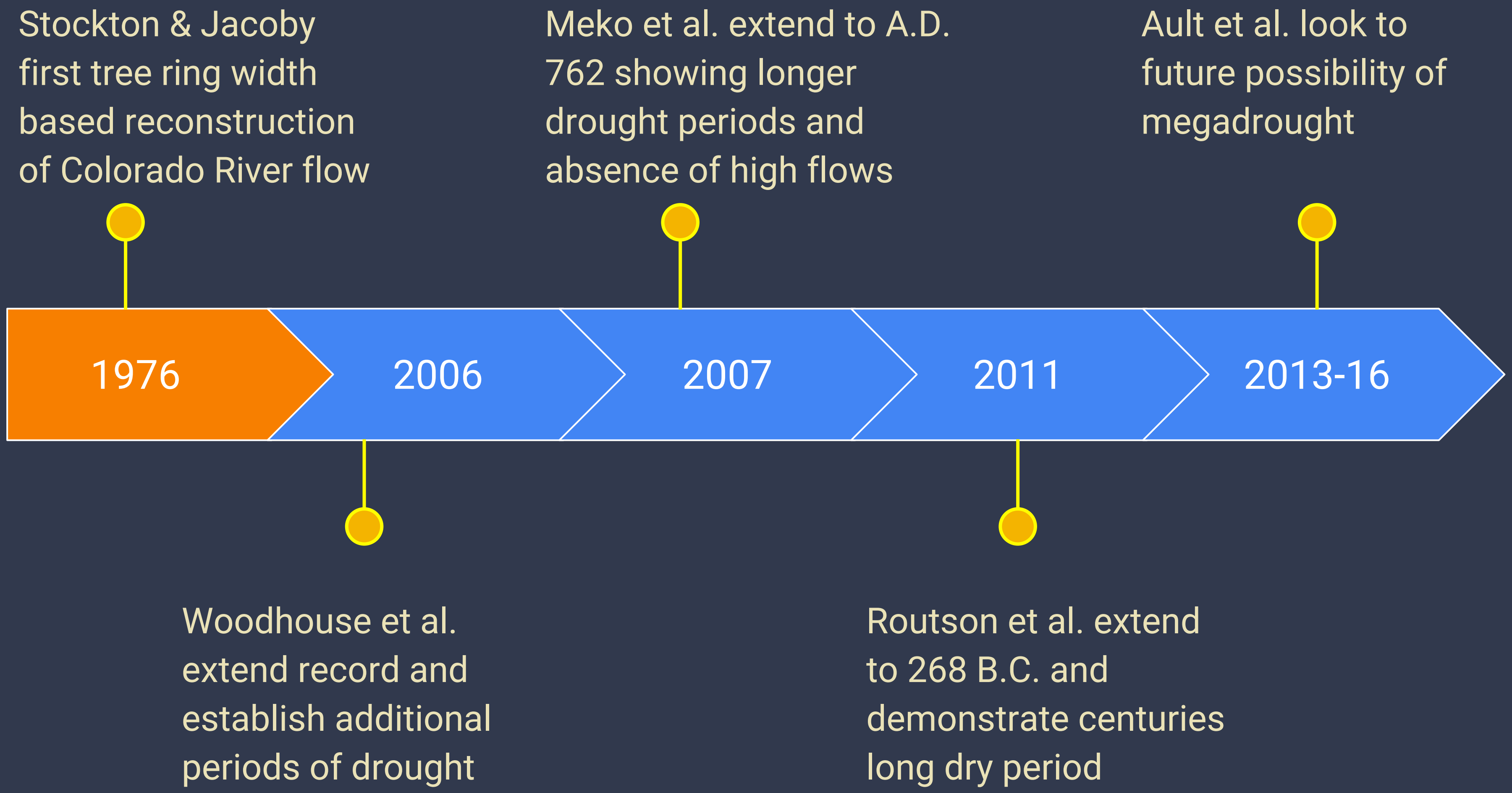
- meteorological drought
- agricultural drought
- hydrologic drought

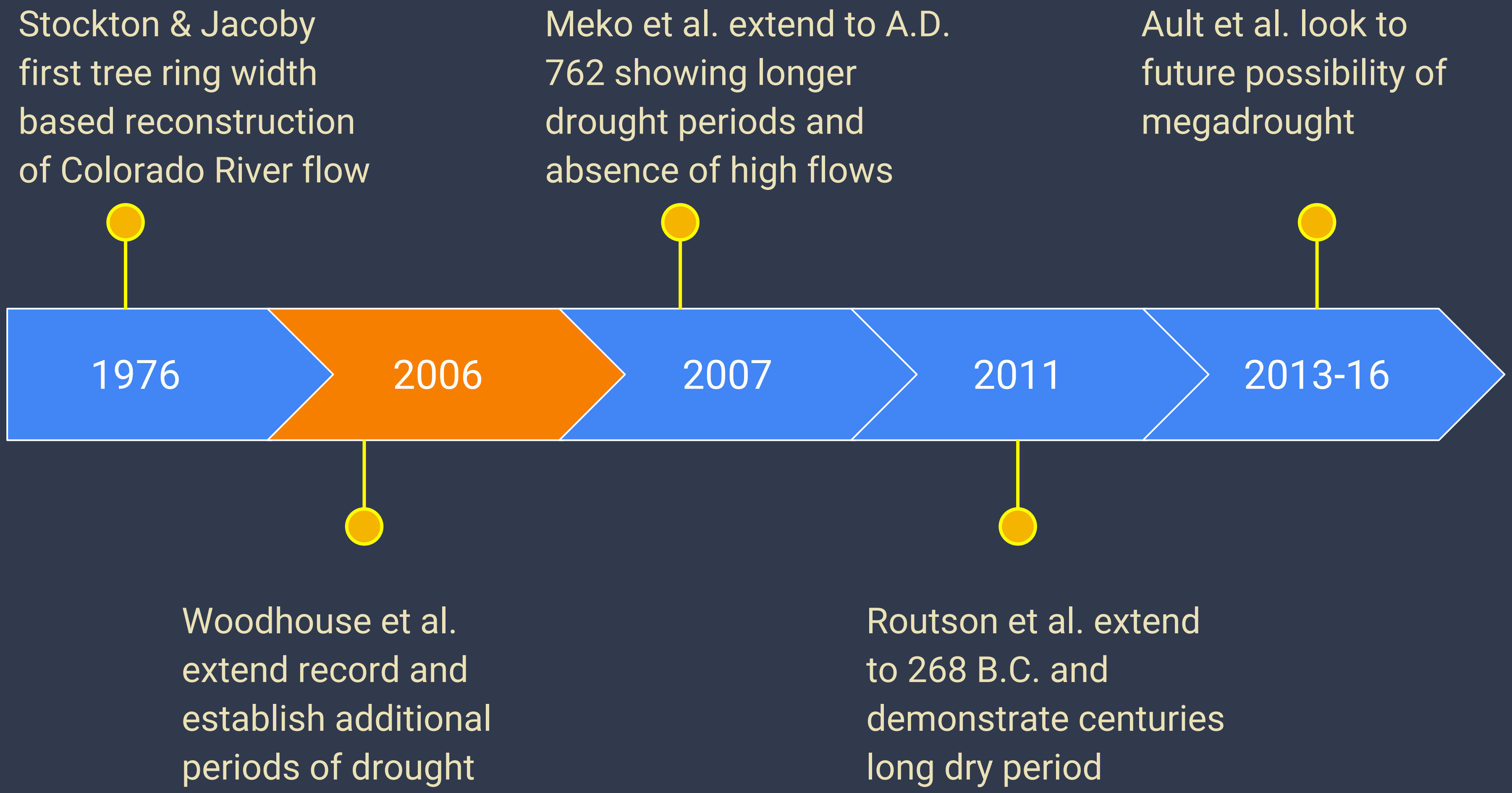
USGS - Retrieved Feb 26, 2018 from https://ca.water.usgs.gov/california-drought/what-is-drought.html

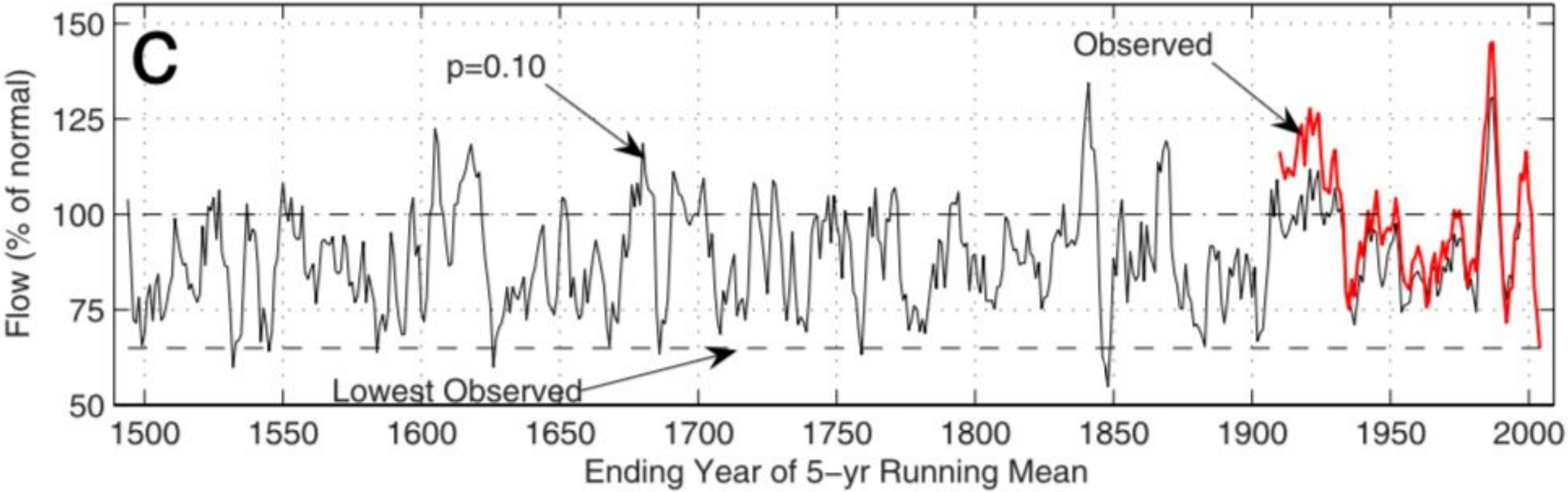
Dendrochronology



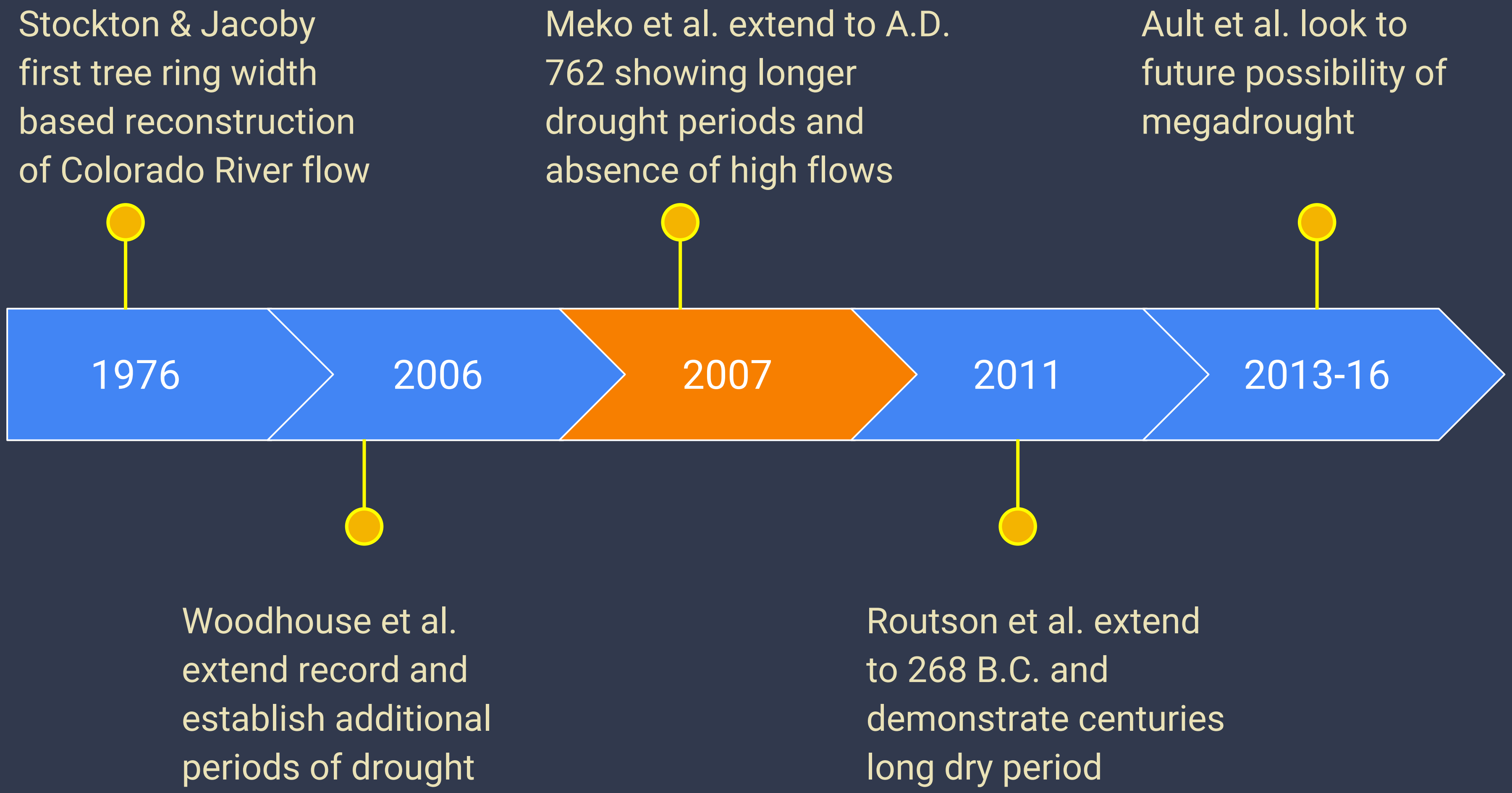
Zeichnungen von Deyrmon, La Salamandre Nr. 141, 2000

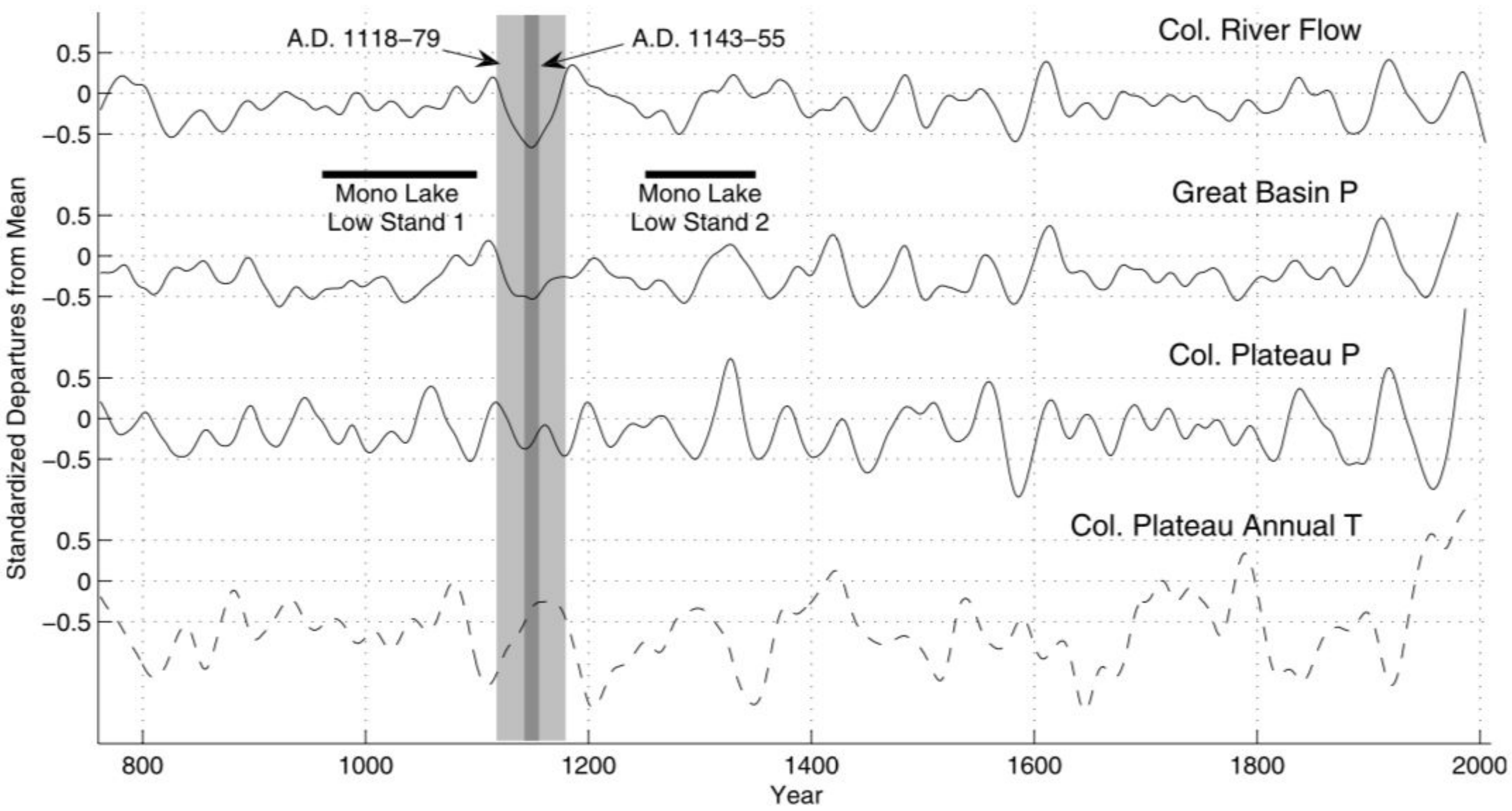

Stockton & Jacoby first tree ring width based reconstruction of Colorado River flow
1976
Woodhouse et al. extend record and establish additional periods of drought
2006
Meko et al. extend to A.D. 762 showing longer drought periods and absence of high flows
2007
Routson et al. extend to 268 B.C. and demonstrate centuries long dry period
2011
Ault et al. look to future possibility of megadrought
2013-16


Stockton & Jacoby first tree ring width based reconstruction of Colorado River flow
Meko et al. extend to A.D. 762 showing longer drought periods and absence of high flows
Ault et al. look to future possibility of megadrought
1976
2006
2007
2011
2013-16
Woodhouse et al. extend record and establish additional periods of drought
Routson et al. extend to 268 B.C. and demonstrate centuries long dry period

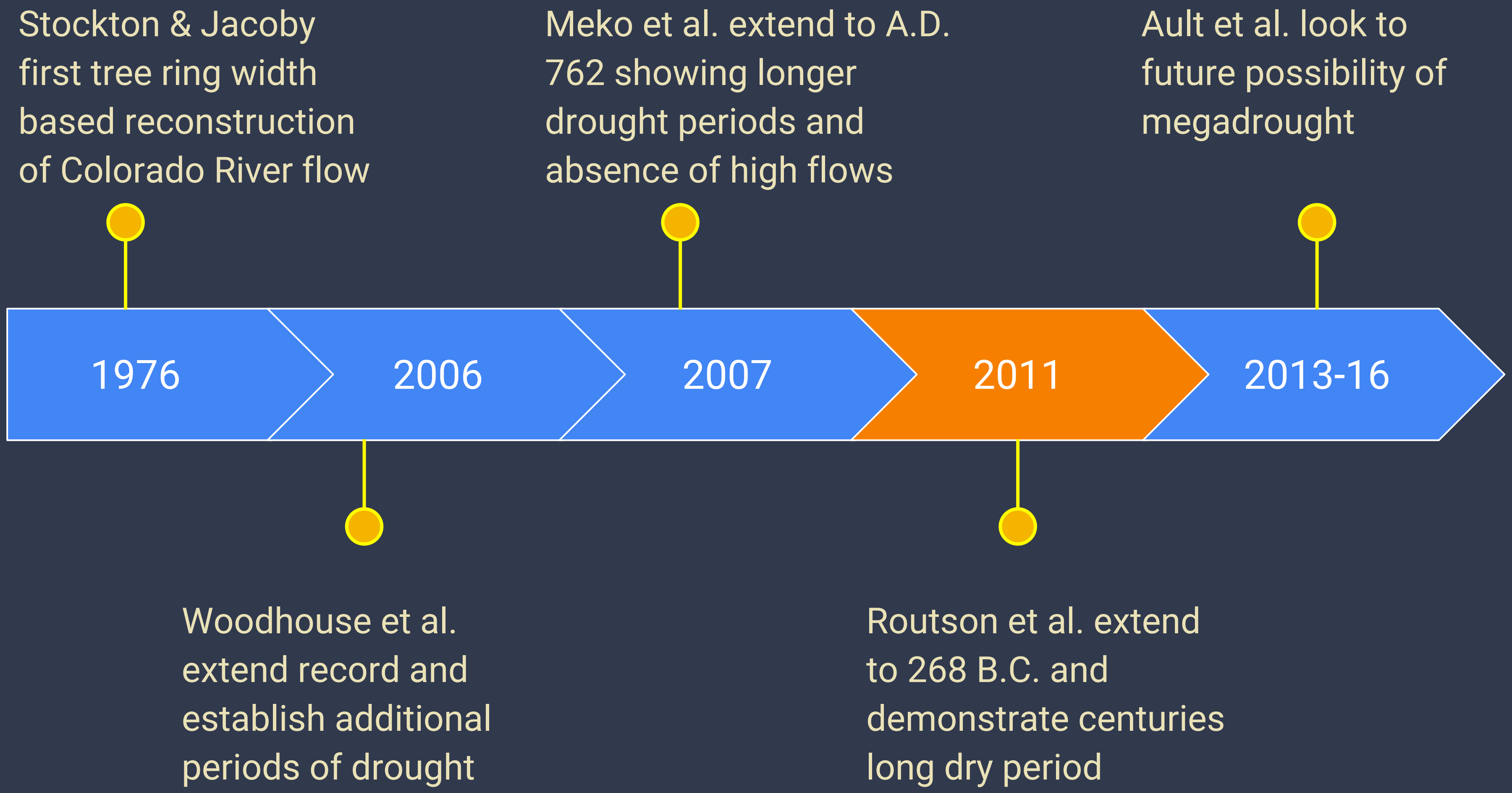


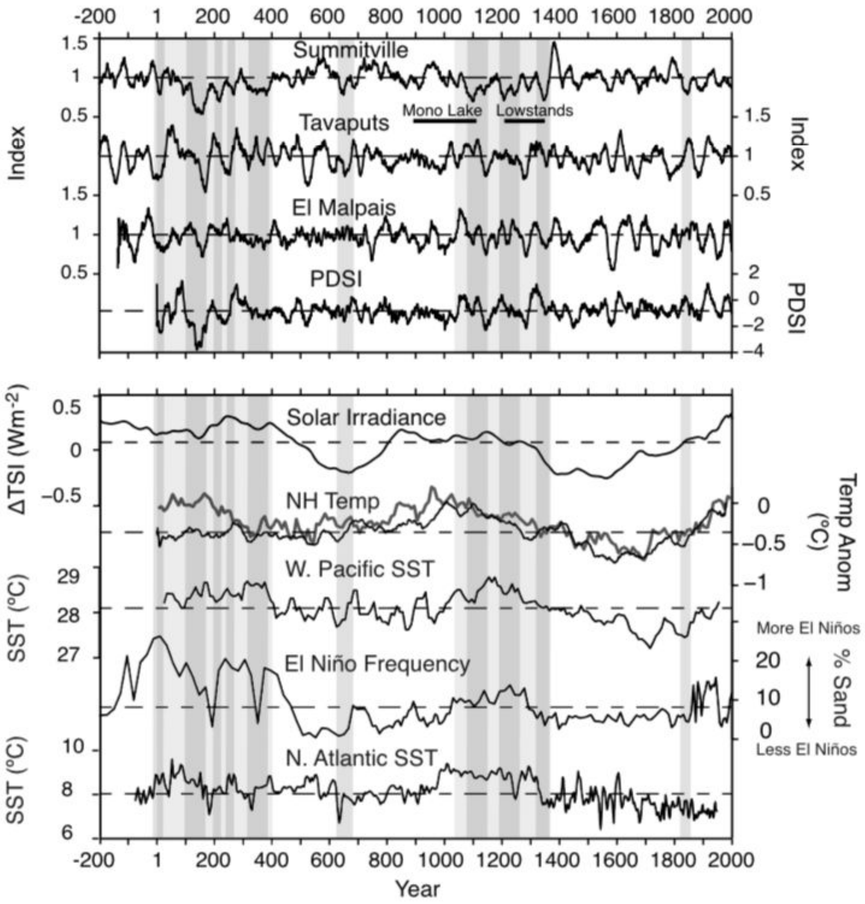
Woodhouse, C. A., Gray, S.T., & Meko, D.M. (2006). Updated streamflow reconstructions for the Upper Colorado River Basin, *Water Resources Research*, 42, W05415. doi:10.1029/2005WR004455


Stockton & Jacoby first tree ring width based reconstruction of Colorado River flow
Meko et al. extend to A.D. 762 showing longer drought periods and absence of high flows
Ault et al. look to future possibility of megadrought
1976
2006
2007
2011
2013-16
Woodhouse et al. extend record and establish additional periods of drought
Routson et al. extend to 268 B.C. and demonstrate centuries long dry period

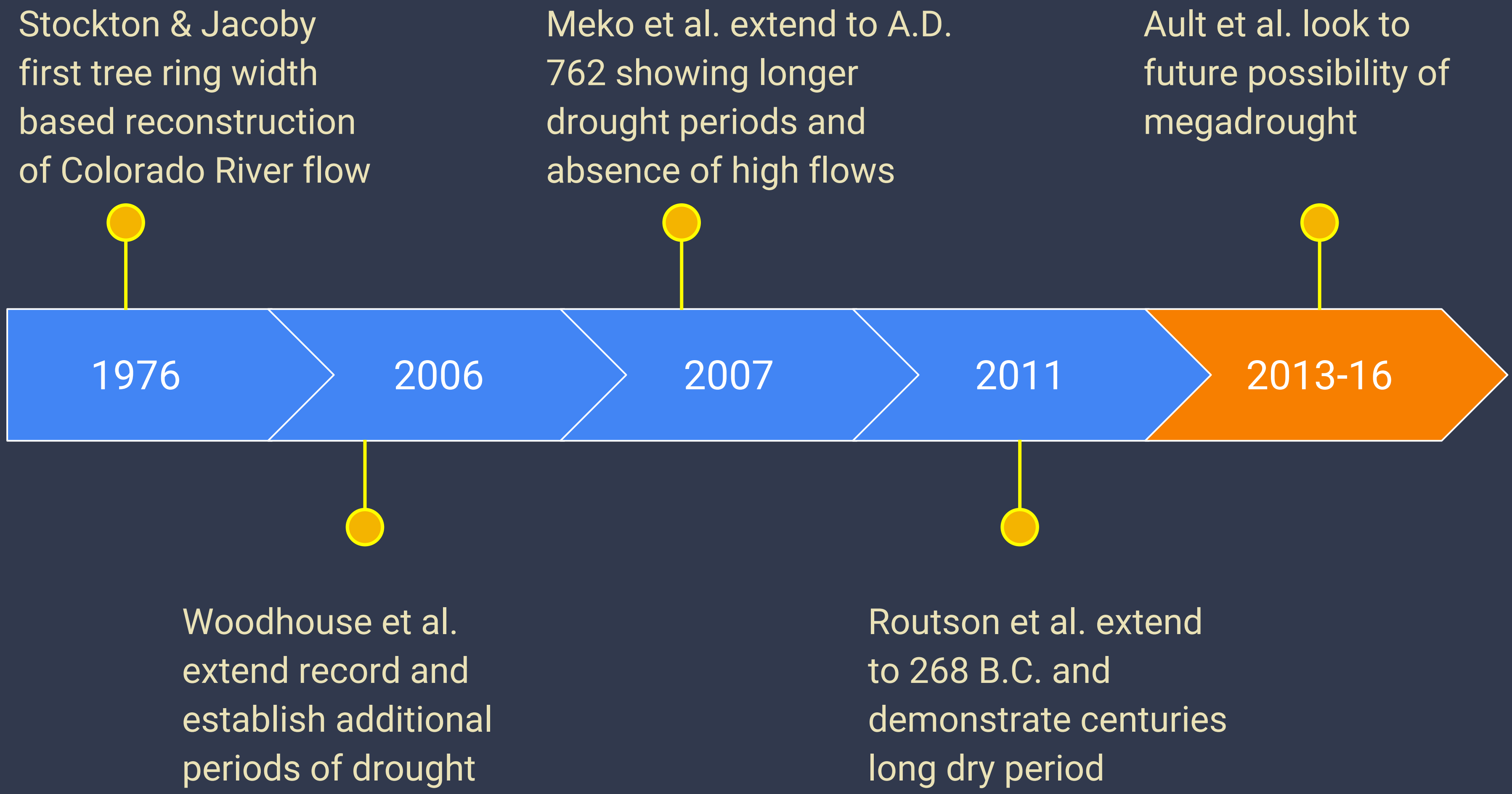


Meko, D., Woodhouse, C.A., Baisan, C.A., Knight, T., Lukas, J.J., Hughes, M.K. & Salzer, M.W. (2007). Medieval drought in the upper Colorado River Basin, *Geophysical Research Letters, 34*, L10705. doi:10.1029/2007GL029988

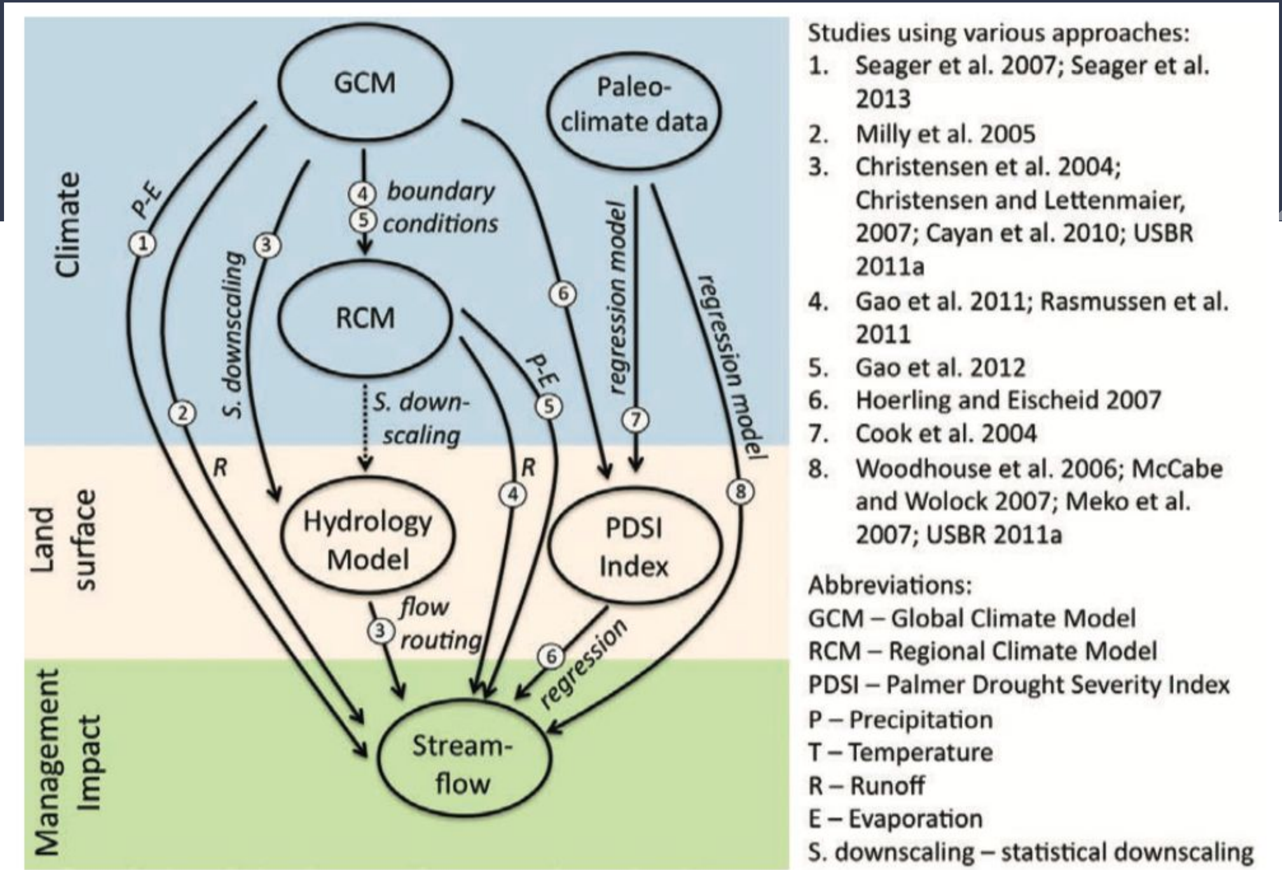

1976
Stockton & Jacoby first tree ring width based reconstruction of Colorado River flow
2006
Woodhouse et al. extend record and establish additional periods of drought
2007
Meko et al. extend to A.D. 762 showing longer drought periods and absence of high flows
2011
Routson et al. extend to 268 B.C. and demonstrate centuries long dry period
2013-16
Ault et al. look to future possibility of megadrought



Routson, C. C., Woodhouse, C.A., & Overpeck, J.T. (2011), Second century megadrought in the Rio Grande headwaters, Colorado: How unusual was medieval drought?. *Geophysical Research Letters, 38*, L22703. doi:10.1029/2011GL050015


1976
Stockton & Jacoby first tree ring width based reconstruction of Colorado River flow
2006
Woodhouse et al. extend record and establish additional periods of drought
2007
Meko et al. extend to A.D. 762 showing longer drought periods and absence of high flows
2011
Routson et al. extend to 268 B.C. and demonstrate centuries long dry period
2013-16
Ault et al. look to future possibility of megadrought

Forecasting - Global Climate Models



Vano, J. A., Udall, B., Cayan, D. R., Overpeck, J. T., Brekke, L. D., Das, T., . . . Lettenmaier, D. P. (2014). Understanding uncertainties in future Colorado River streamflow. *Bulletin of the American Meteorological Society, 95*(1), 59-78.

Climate Change Impact on Streamflow

Udall, B. & Overpeck, J. (2017)

Primary areas of impact:

- Precipitation
- Temperature

Temperature Sensitivity

The percent change in annual flow per degree rise in annual temperature

Vano et al. method

-6.5 % / ºC

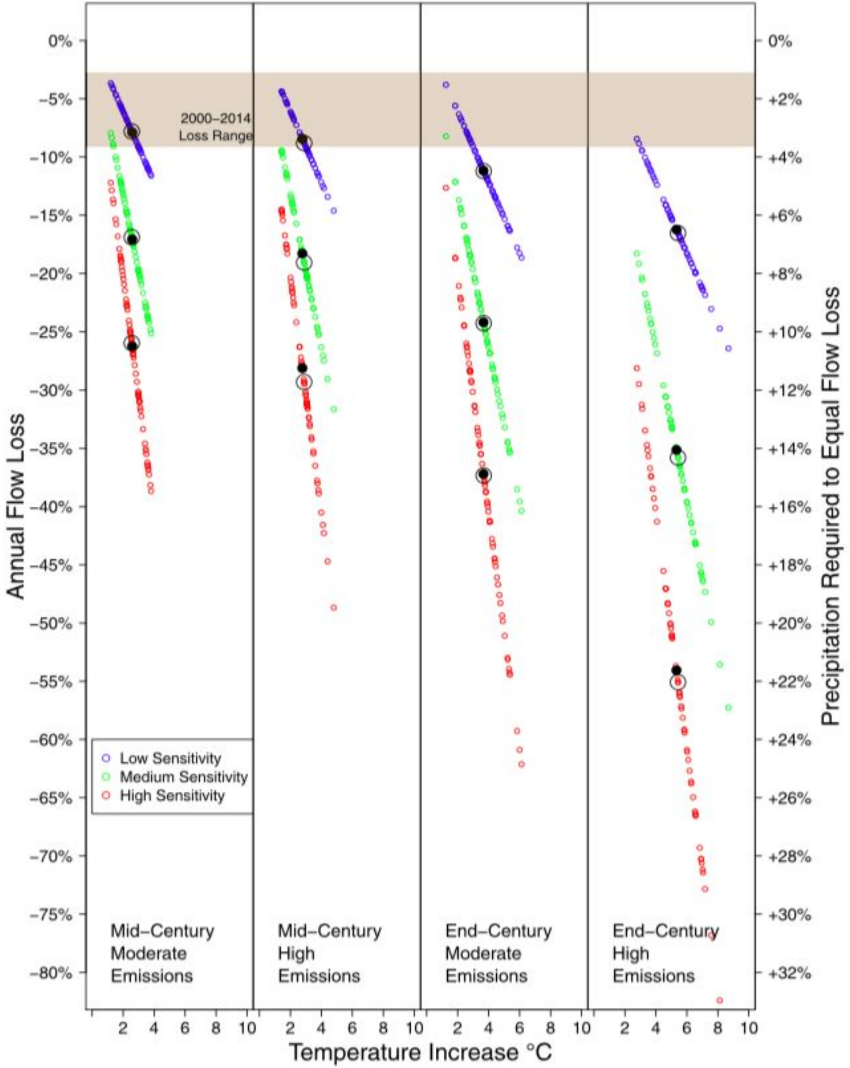
[One SD = -3% / ºC to -10% / ºC]

Study Summary

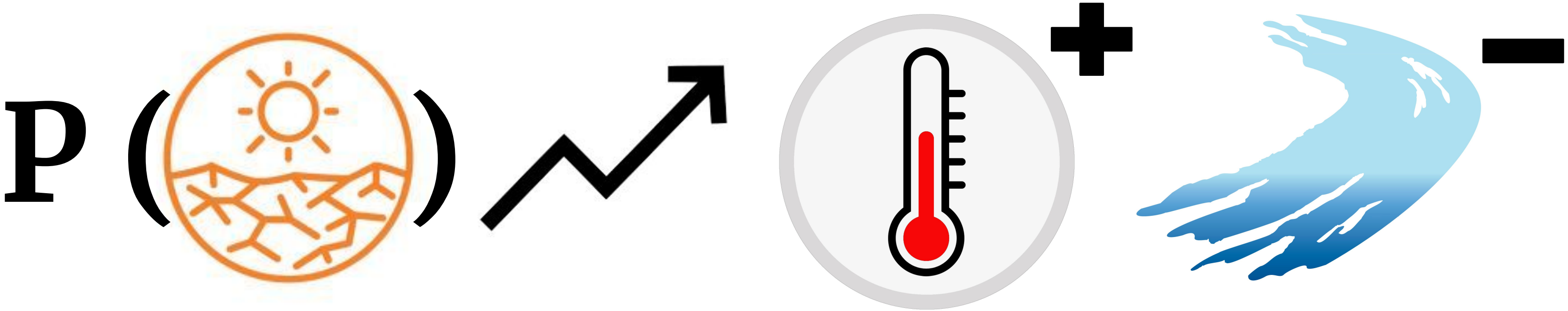
Emissions	Year 2050	Year 2100
Moderate (SRES A1B, RCP4.5)	+2.6 - 2.8 °C	+3.6 °C
High (SRES A2, RCP8.5)	+2.6 - 2.8 °C	+5.4 °C
Mean Flow Loss	- 17 %	-25% to -35%

Model Data: Reclamation CMIP3 and CMIP5

Udall, B. & Overpeck, J. (2017)



What Do Climate Reconstructions and Forecasting Tell Us About the Future of Colorado River Flow?



Policy Suite

- Decrease Emissions
- Decrease Demand
- Need for more information
  - Shared science
  - More refined modeling of GCM and hydrologic models
- Reduce consumptive use
- More implementation of adaptive management methods
- Give flexibility to states for what works
- Establish integrated agencies for land and water management

References

Eidgenössische Technische Hochschule ZEidgenössische Technische Hochschule Zürichürich (2018). Crossdating. Retrieved from http://www.fe.ethz.ch/en/tree-ring-lab/crossdating.html

Meko, D., Woodhouse, C.A., Baisan, C.A., Knight, T., Lukas, J.J., Hughes, M.K. & Salzer, M.W. (2007). Medieval drought in the upper Colorado River Basin, *Geophysical Research Letters, 34*, L10705. doi:10.1029/2007GL029988

Routson, C. C., Woodhouse, C.A., & Overpeck, J.T. (2011), Second century megadrought in the Rio Grande headwaters, Colorado: How unusual was medieval drought?. *Geophysical Research Letters, 38*, L22703. doi:10.1029/2011GL050015

Udall, B. & Overpeck, J. (2017). The twenty-first century Colorado River hot drought and implications for the future. *Water Resources Research, 53*, 2404– 2418. doi:10.1002/2016WR019638

University of Arizona Laboratory for Tree-Ring Research (2018). Retrieved from http://ltrr.arizona.edu/

U.S. Department of the Interior (2018). Drought in the Colorado River Basin. Retrieved from https://www.doi.gov/water/owdi.cr.drought/en/

USGS - Retrieved Feb 26, 2018 from https://ca.water.usgs.gov/california-drought/what-is-drought.html

Vano, J. A., Udall, B., Cayan, D. R., Overpeck, J. T., Brekke, L. D., Das, T., . . . Lettenmaier, D. P. (2014). Understanding uncertainties in future Colorado River streamflow. *Bulletin of the American Meteorological Society, 95*(1), 59-78.

Woodhouse, C. A., Gray, S.T., & Meko, D.M. (2006). Updated streamflow reconstructions for the Upper Colorado River Basin, *Water Resources Research*, 42, W05415. doi:10.1029/2005WR004455

The Fickle Flow

Aston Tennefoss
28 February 2018
ECL 290