Western Water and Climate – Threats to Western Water Availability

Migration of Agriculture as One Path to Sustainability Workshop

Boulder, Colorado
October 21-23, 2015

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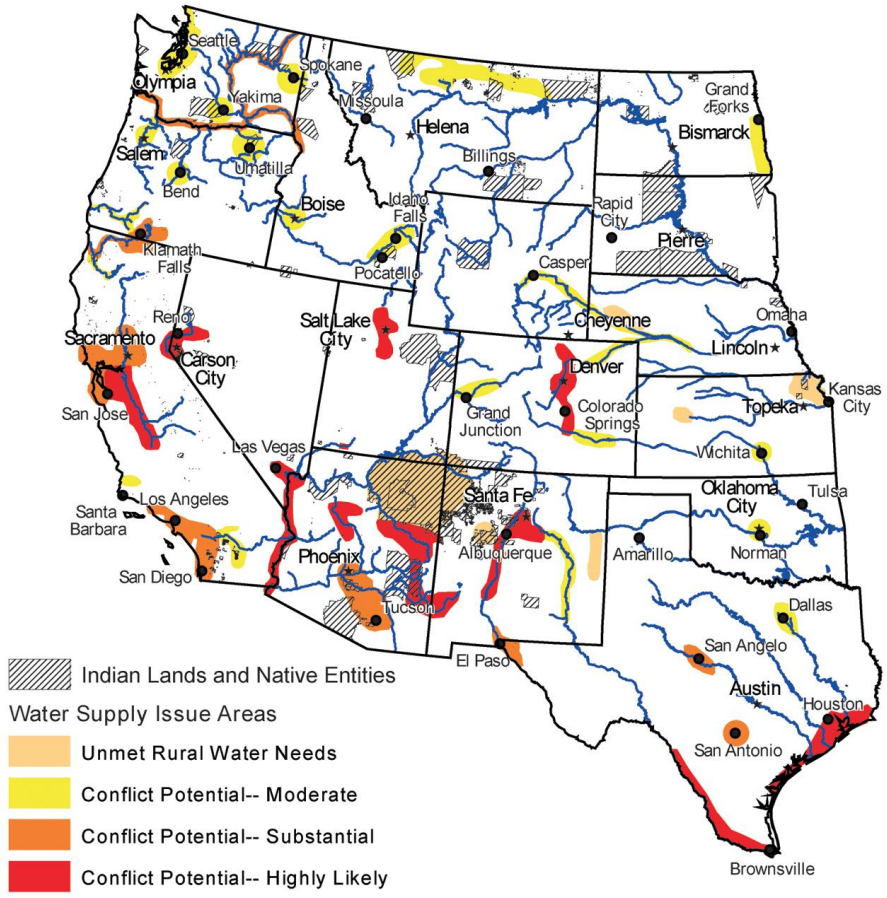
Heron Reservoir, NM, April 2014

2004 View of Western Water Conflicts by Reclamation

Note:
1)north to south gradient

2)does not include climate change.



USBR[171]

The map shows regions in the West where water supply conflicts are likely to occur by 2025 based on a combination of factors including population trends and potential endangered species' needs for water. The red zones are where the conflicts are most likely to occur. This analysis does not factor in the effects of climate change, which is expected to exacerbate many of these already-identified issues.[171]

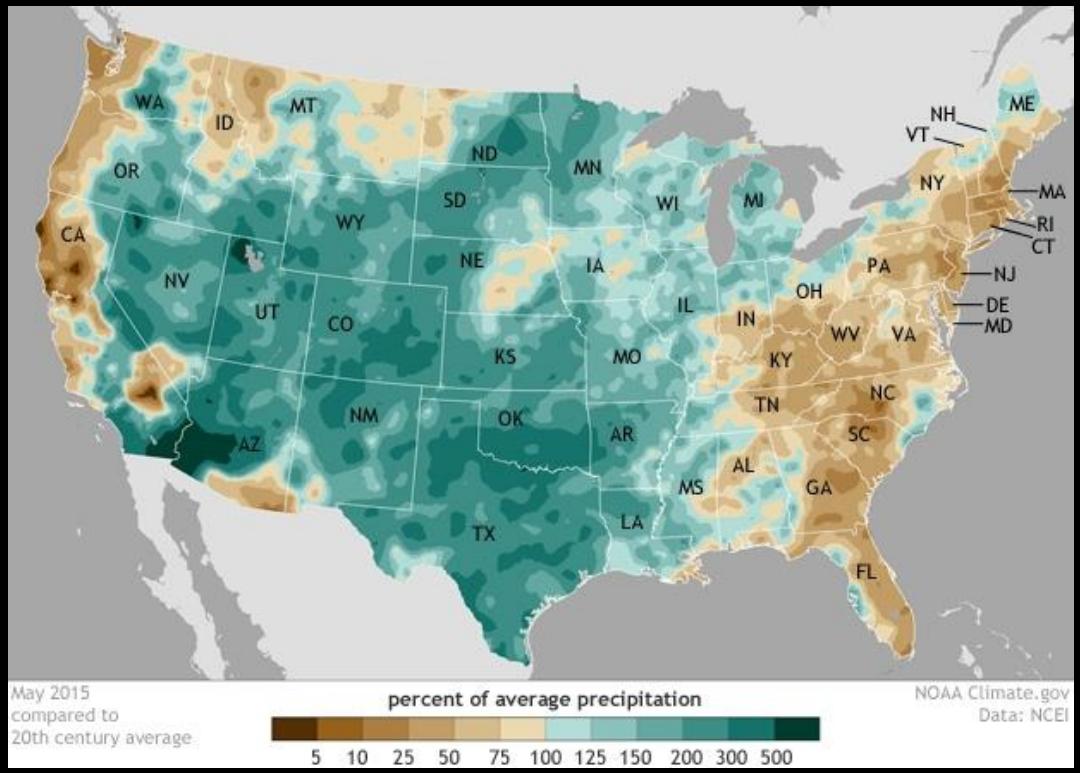
California Drought Lessons

- Temperatures
  - Sierra Winter Above 32 F, (1st in 120 years)
- Sierra Precipitation
  - Rain, not Snow
  - Not the driest! (40% to 90% of normal)
- Snowpack
  - Lowest Ever - 5% on April 1, (1977 at 25%)
  - 500-Year Return Period ?
- Drought
  - Worst in 1200 Years ?
- Water Deliveries
  - Record Low to CVP Contractors
- El Nino no guarantee of salvation
  - N. Cal precip critical

May 2015 was wettest month ever recorded in U.S.

Friday, June 12, 2015

Last month, much of the United States was wet. How wet? When climate scientists at NOAA's National Centers for Environmental Information averaged the observations of rain, snow, and other precipitation from across the country, they found out it was the country's wettest May since records began 121 years ago. In fact, it was the wettest month ever recorded!



https://www.climate.gov/news-features/featured-images/may-2015-was-wettest-month-ever-recorded-us

CLIMATE CHANGE

Dry Times Ahead

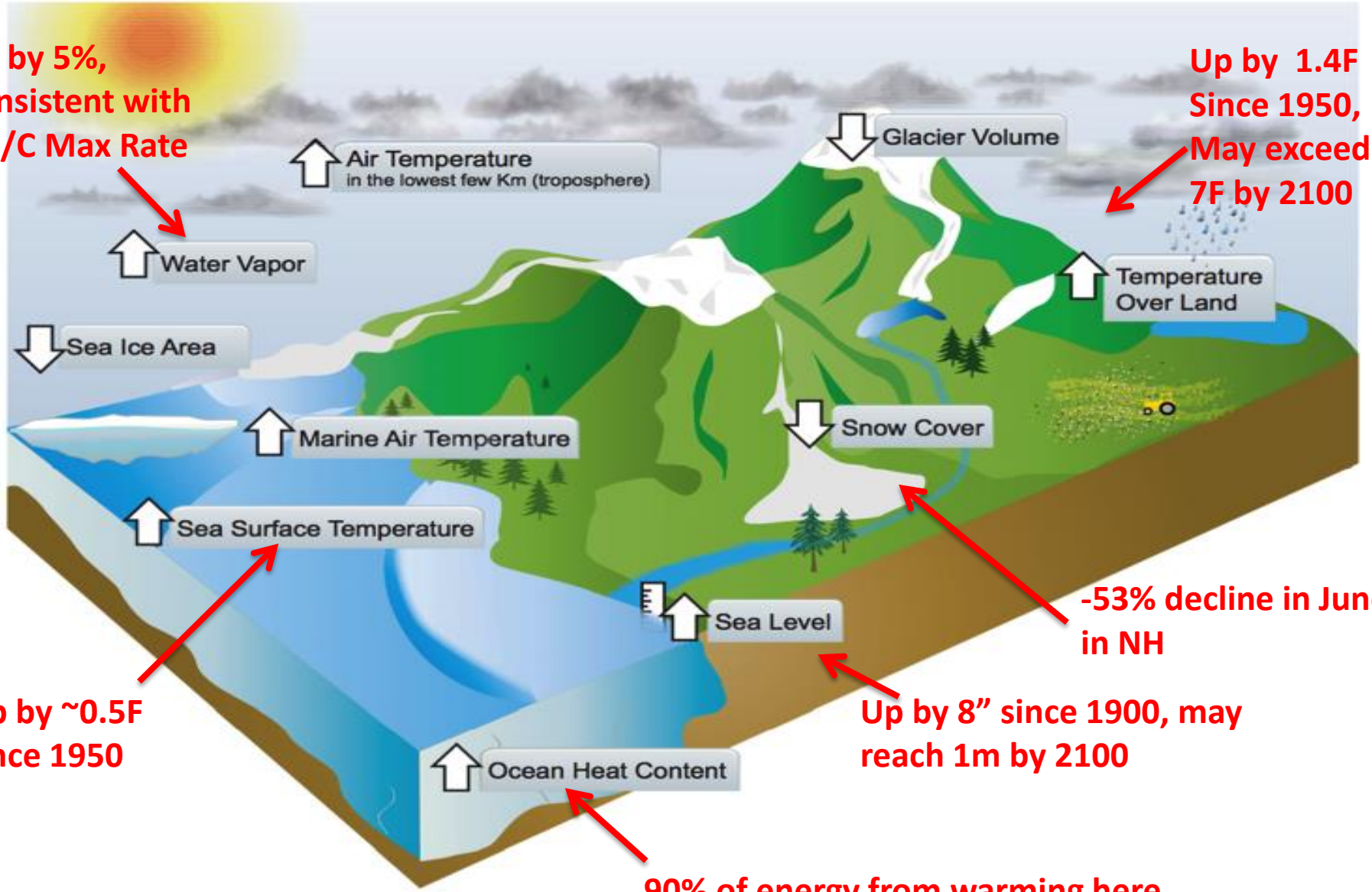
Jonathan Overpeck[1] and Bradley Udall[2]

The climate of the western United States could become much drier over the course of this century.

- 2F Warming since 1900
- Snowpack Reductions and Changes in Runoff Timing Already Present
- Most Severe Drought since records kept
- Powell and Mead at 50% of capacity now, full 2000
- Tree Mortality Rates High
- Increase in Wildfire Frequency
- Drought may be natural, but exacerbated by higher temperatures
- Snowpack Reductions and Runoff Timing attributed to climate change
- Continued drying likely as temperatures increase and storm tracks shift
- Megadroughts independent of climate change a possibility with severe consequences if combined with warming

Science, 2010

IPCC: All Kinds of Observations are Consistent with Climate Change Expectations. 7 out of 10 are water cycle related here…



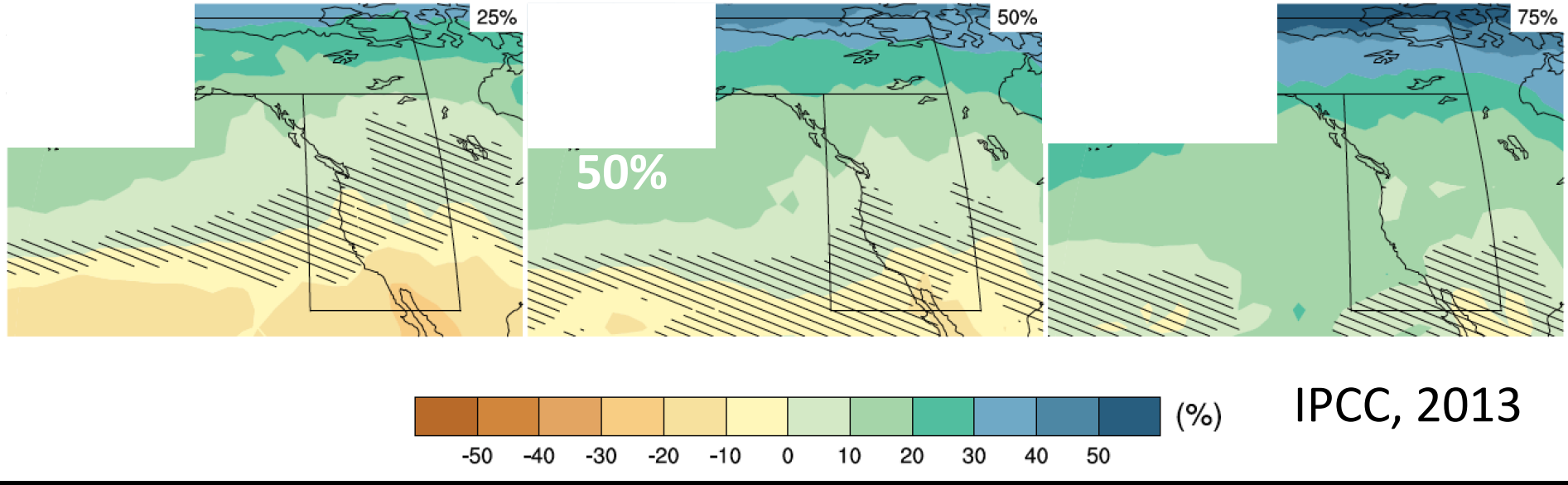
Climate Change is Water Change

- Heat Drives the Water Cycle –
  1000 km3 evaporates daily from the oceans

- The Water Cycle mixes heat from areas of too much to too little
- As the Atmosphere Warms it Holds More Moisture:
  ~5F warming is 20% increase
- Heating Up the Earth (and uneven heating) results in Water Cycle changes
  - More Evaporation, More Precipitation, More Moisture
  - Changes in weather patterns
  - Wet Wetter, Dry Drier Standard Rule
  - More Intense Floods and Droughts
- All Kinds of Water Changes Already Noted
  - More rain/less snow, Earlier Runoff, Higher Water Temps, More Intense Rain
- Many of the most critical impacts of climate change will arise through water cycle changes driven by higher temps, not just higher temps rising temperatures

Latest IPCC/CMIP5 Climate Model Projections
(Ensemble average of 39 global models)

Projected Annual Precipitation Change by the End of Century
Given Continued High Emissions (RCP8.5)



IPCC, 2013

Bottom-line: North gets wetter, South drier. But note that precip is not runoff.

Latest IPCC/CMIP5 Climate Model Projections
(Ensemble average of 39 global models)

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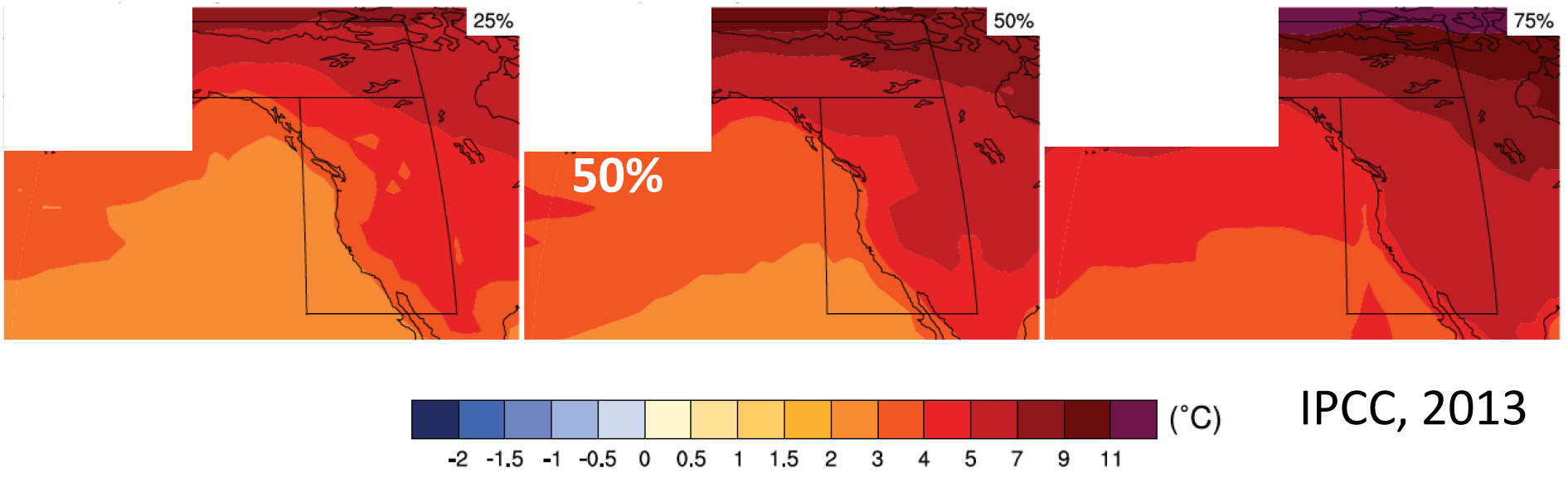
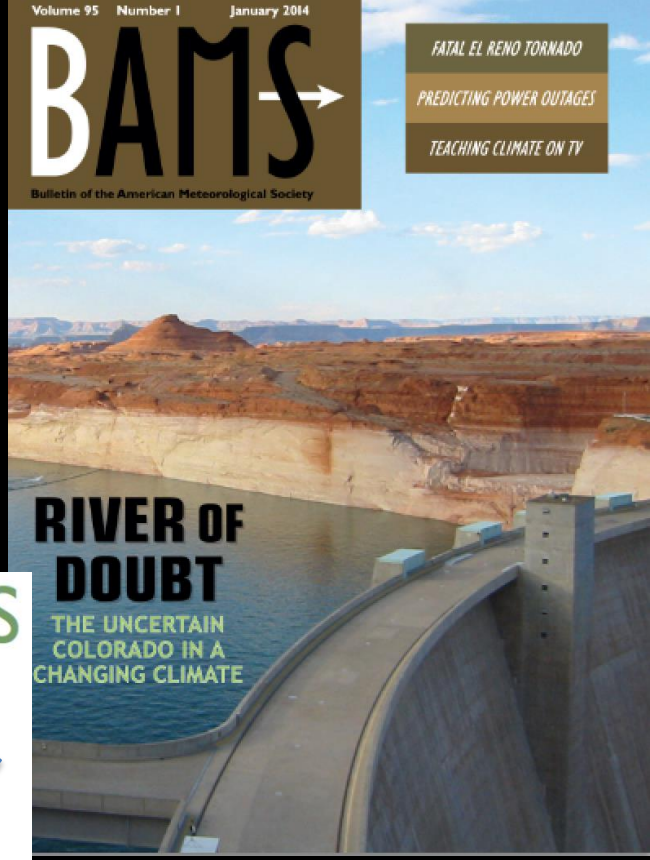
Given Continued High Emissions (RCP8.5)



IPCC, 2013

Bottom-line: Western US will get hotter for sure, perhaps much hotter

A recent interdisciplinary team reconciles future of the Colorado River…



UNDERSTANDING UNCERTAINTIES IN FUTURE COLORADO RIVER STREAMFLOW

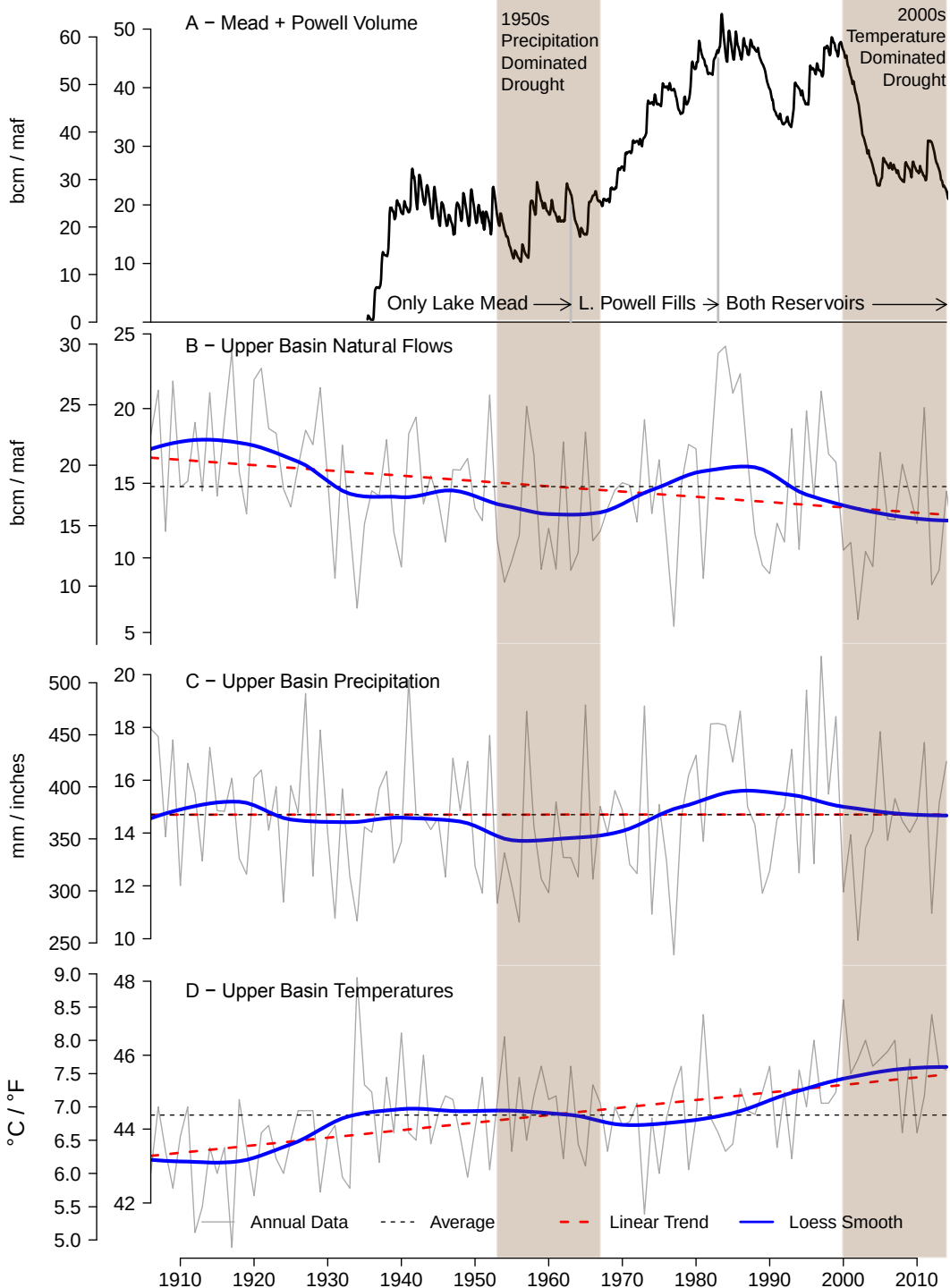
BY JULIE A. VANO, BRADLEY UDALL, DANIEL R. CAYAN, JONATHAN T. OVERPECK, LEVI D. BREKKE, TAPASH DAS, HOLLY C. HARTMANN, HUGO G. HIDALGO, MARTIN HOERLING, GREGORY J. MCCABE, KIYOMI MORINO, ROBERT S. WEBB, KEVIN WERNER, AND DENNIS P. LETTENMAIER

Future warming *alone* will drive Colorado River streamflow declines of 6.5% +/- 3.5% per □C

Current 15-Year Colorado River Drought only has 40% of the Precipitation Decline associated with similar 1950s drought.

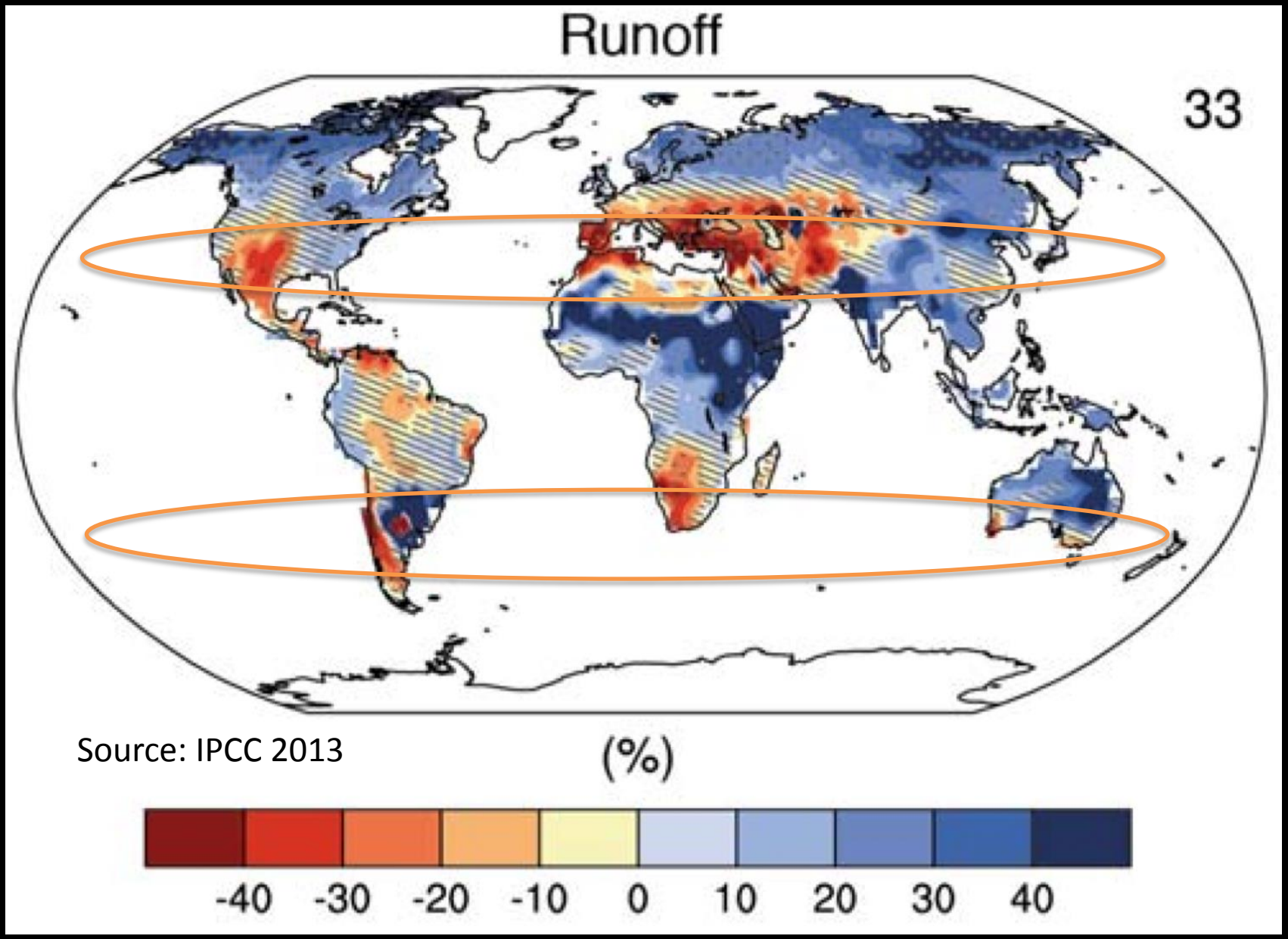
You have to invoke temperatures to explain current drought.

Source: Udall & Overpeck 2015, in review



IPCC 5th Results RCP 8.5 at 2081 to 2100

Repeat after me: Precipitation is not runoff!

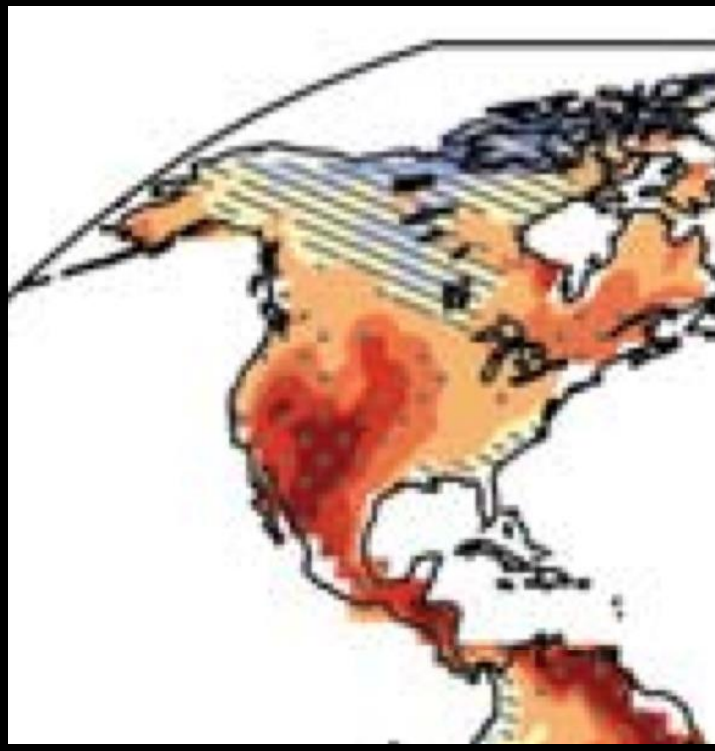


Source: IPCC 2013

Projected Drying in U.S. Southwest

- "Regional to global-scale projections of soil moisture and drought remain relatively uncertain compared to other aspects of the water cycle. Nonetheless, drying in the Mediterranean, southwestern U.S. and south African regions are consistent with projected changes in Hadley circulation, so drying in these regions as global temperatures increase is likely for several degrees of warming under the RCP8.5 scenario."

Soil Moisture
CMIP5 RCP 8.5 @2100



Source: Water Cycle Box in IPCC 2013 WG1 Technical Summary, also Summary for Policy Makers

Projected Changes in Snow, Runoff, and Soil Moisture

2041-2070 with 1971-2000 baseline, A2 Emissions

- Declines in April 1 SWE indicate the start of runoff has already occurred
- May or May Not indicate declines in total maximum SWE which will occur earlier in the year
- Not shown: increases in runoff during the Winter

Source: 2014 National Assessment

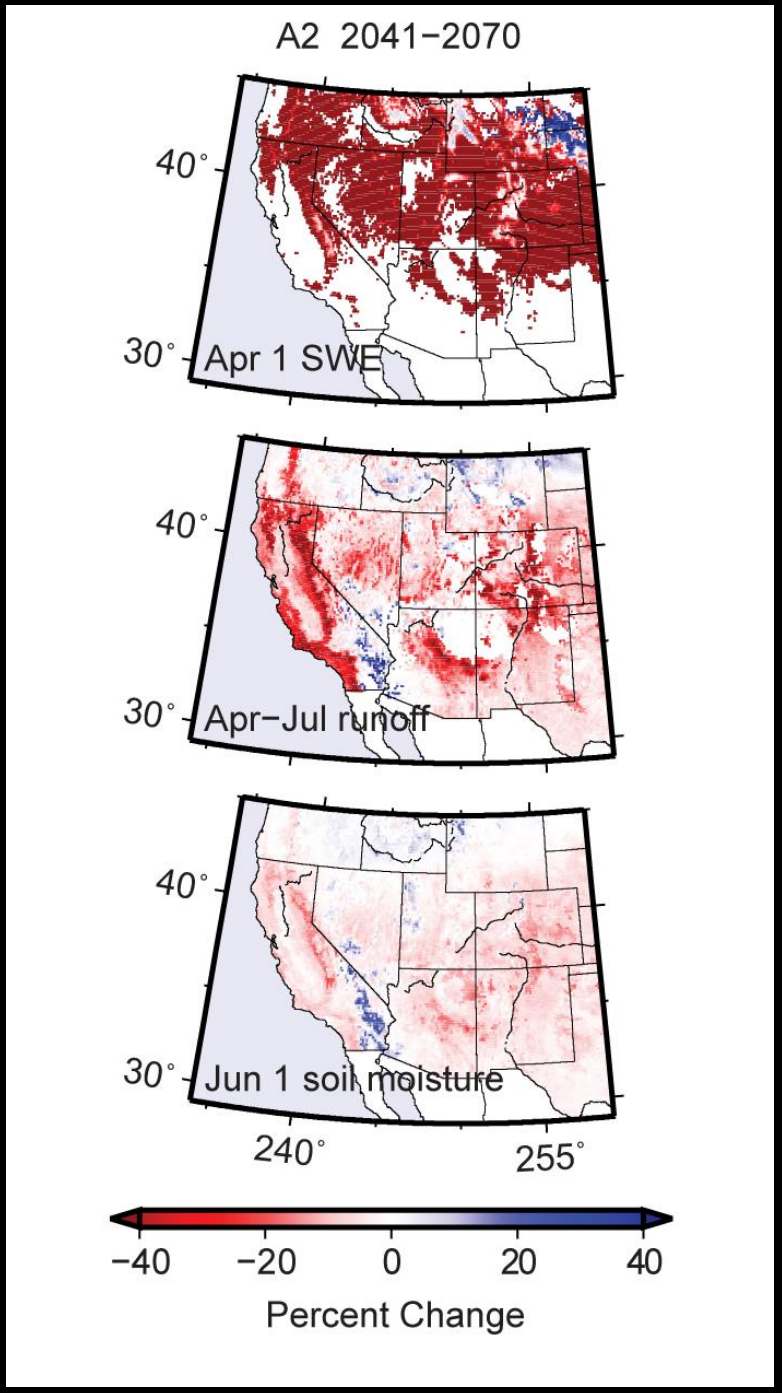


Figure source: Cayan et al. 2013

Dust on Snow Reduces Runoff, Shifts Timing

Dust-on-snow – modern dust loading is causing earlier snowmelt and runoff, and may be reducing UCRB flow by ~5% compared to pre-1850 conditions and causing runoff to occur 3 weeks earlier (Painter et al. 2010)

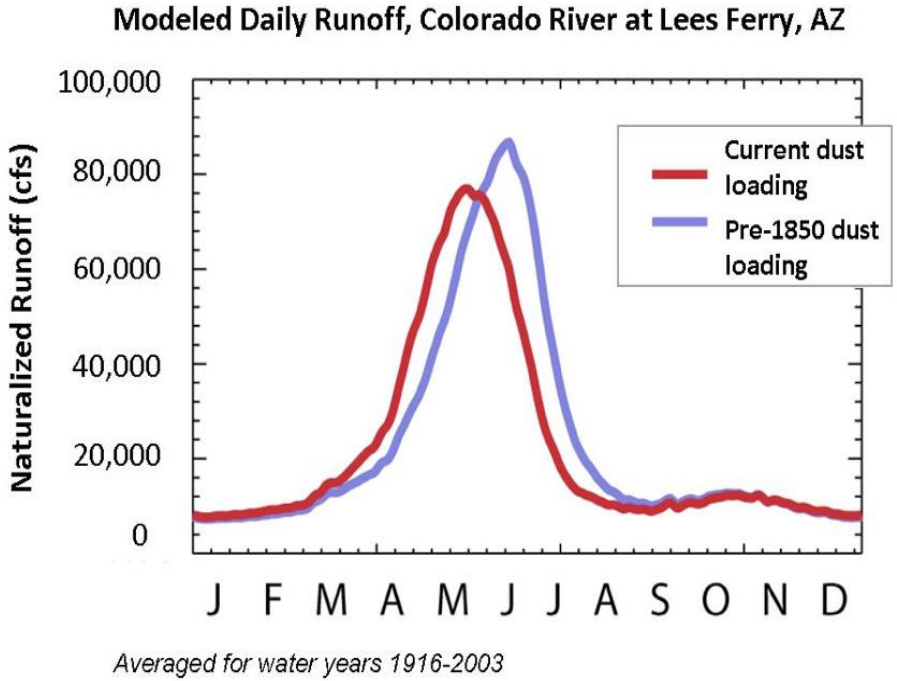
Super Dusty Conditions advance runoff by 6 weeks, reduce flow by about ~6%

Why: dark surface absorbs more energy

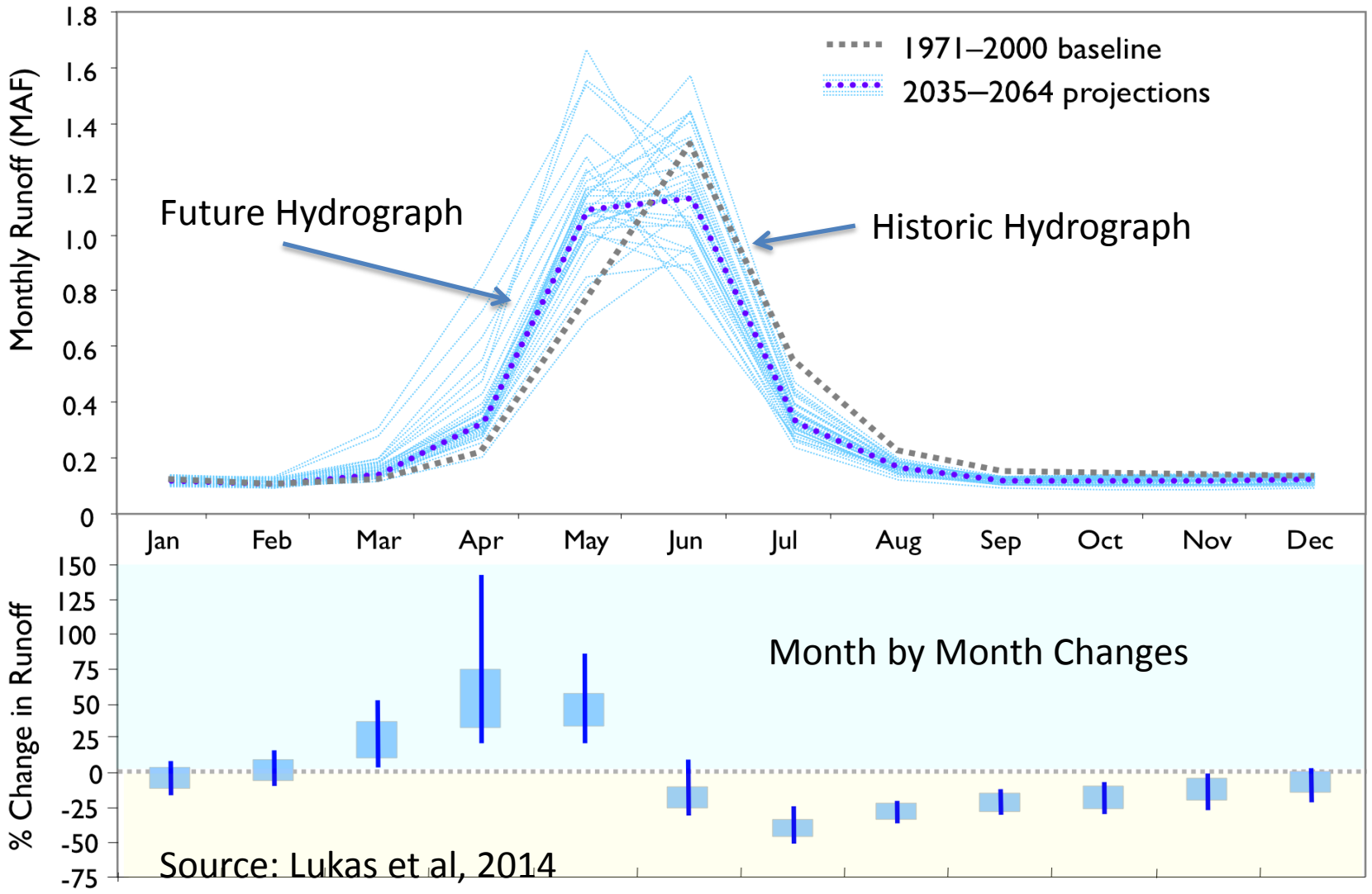
Dust Source: NE Arizona, S. Utah

Source: Chris Landry, CSAS

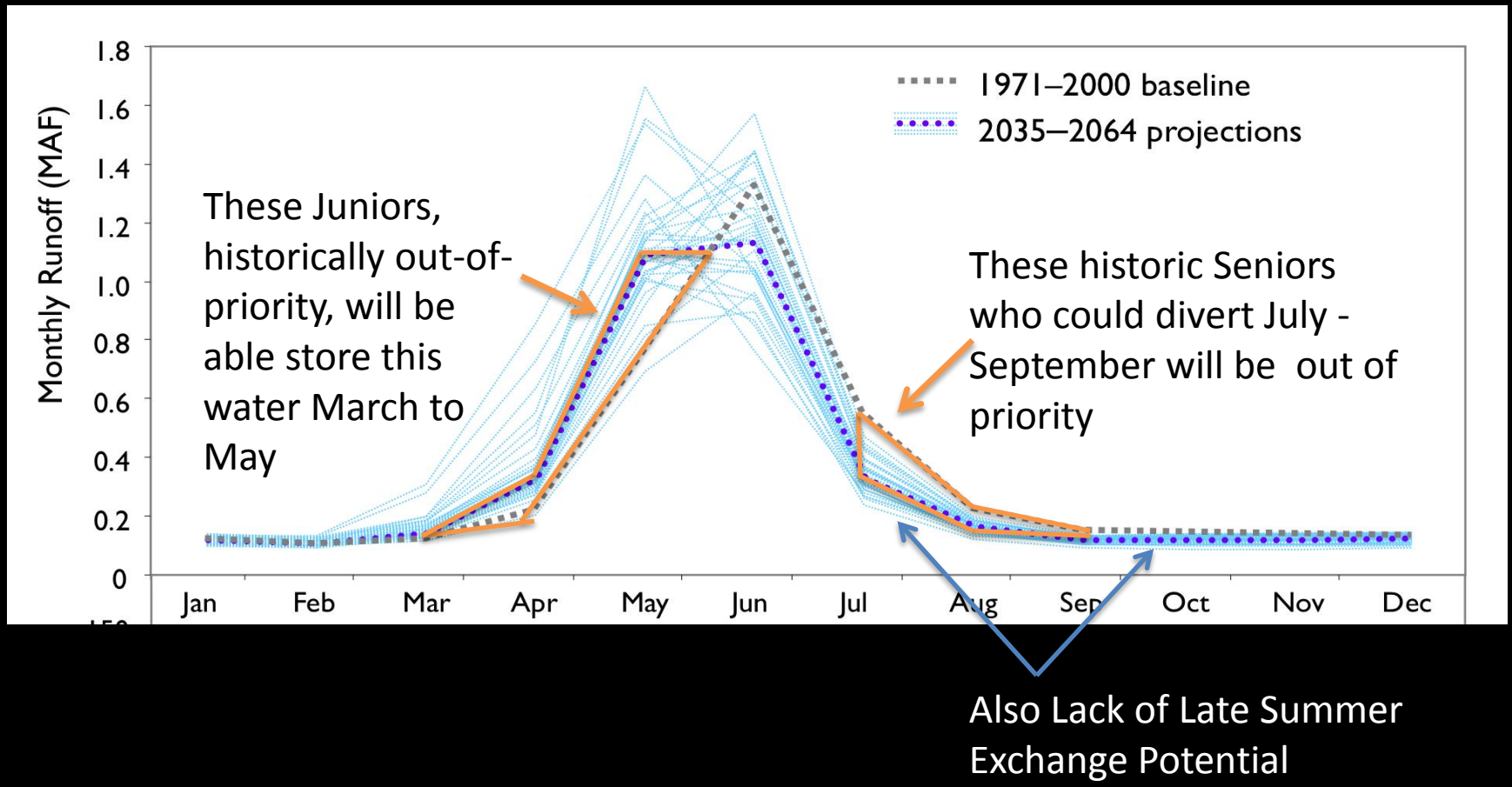
Source: Painter et al. (2010), PNAS, Deems et al. (2013) HESS



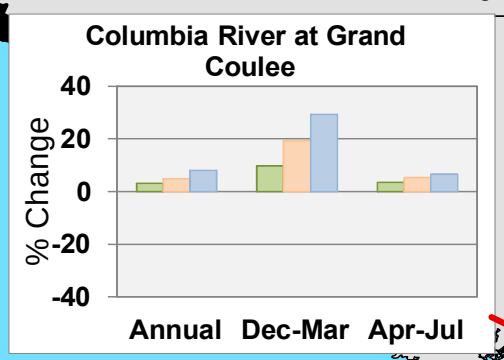
Sample Shifted Hydrograph in the Future



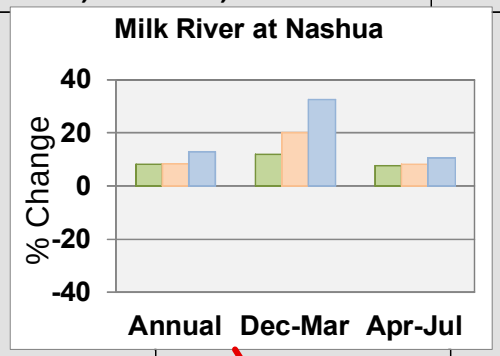
Shifting Hydrograph will create winners and losers in Prior Appropriation.

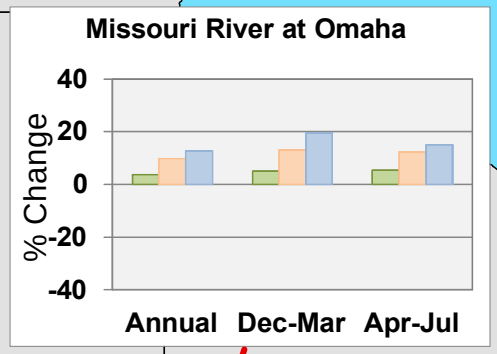


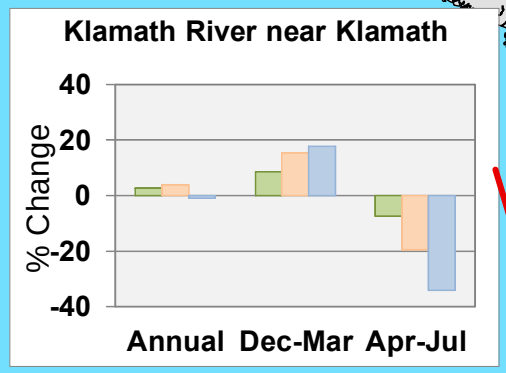
Runoff Projections 2020s, 2050s, 2070s

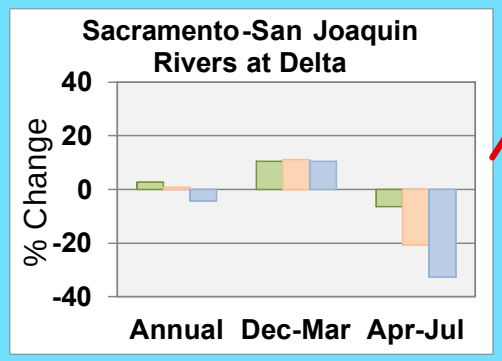


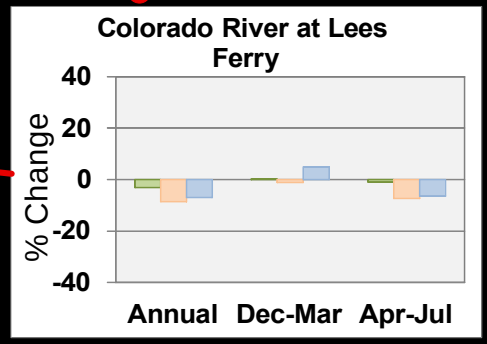
3 Periods
1. Annual
2. Winter
3. Spring

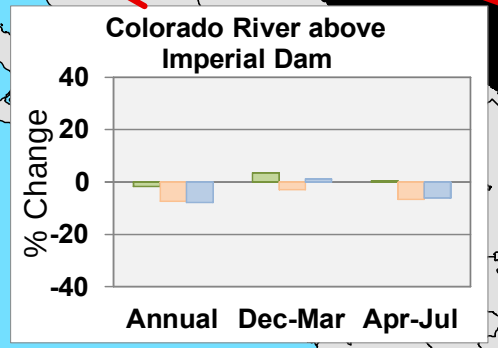


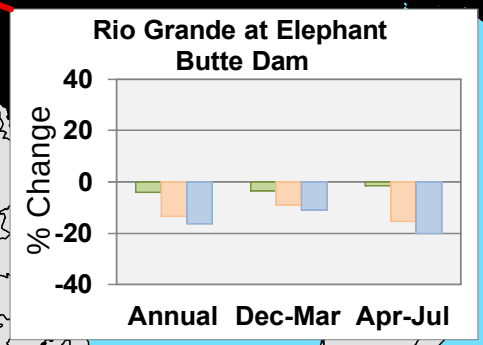








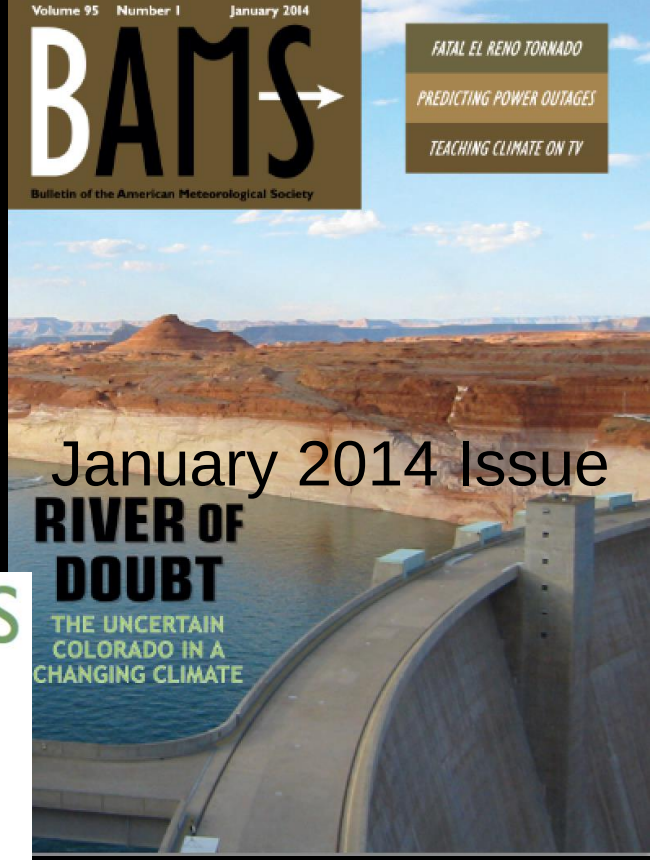




2020s 2050s 2070s

Source: Reclamation

A recent interdisciplinary team reconciles future of the Colorado River…



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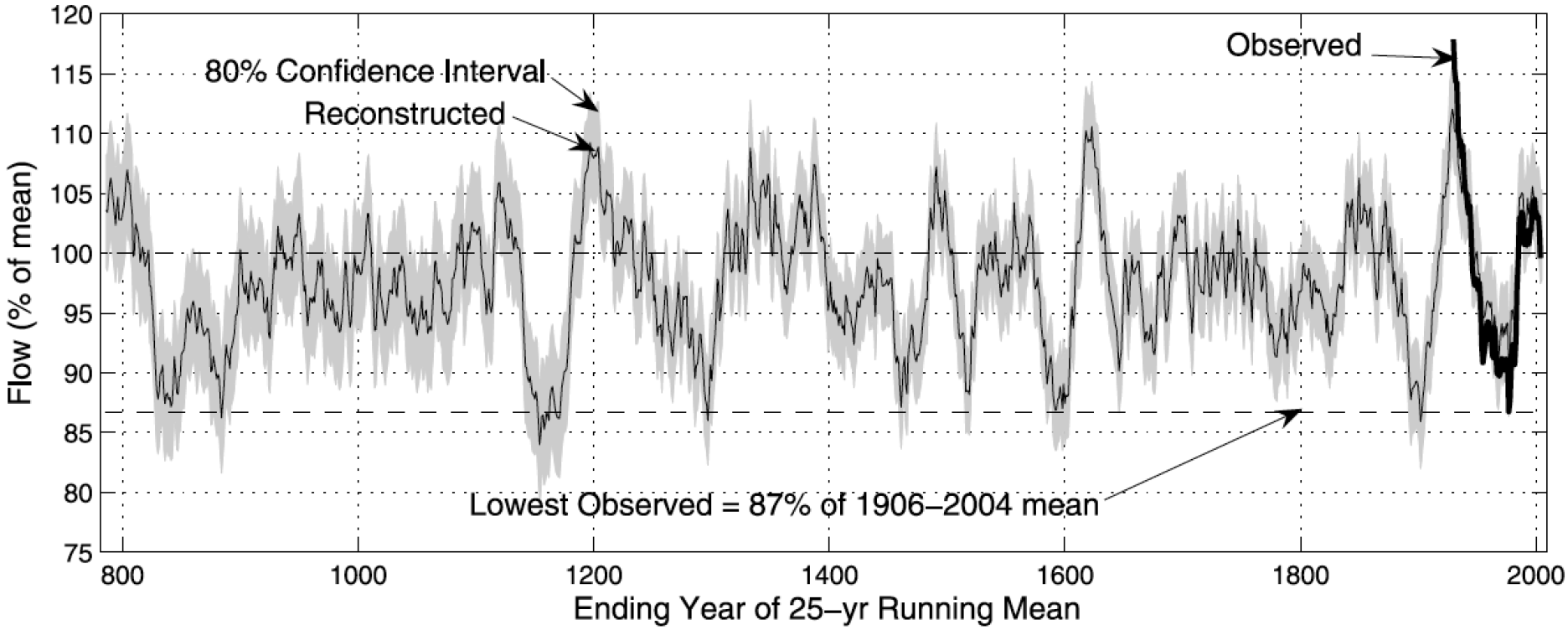
Multi-decadal megadroughts also likely, and will be on top of any warming-related declines we will get…

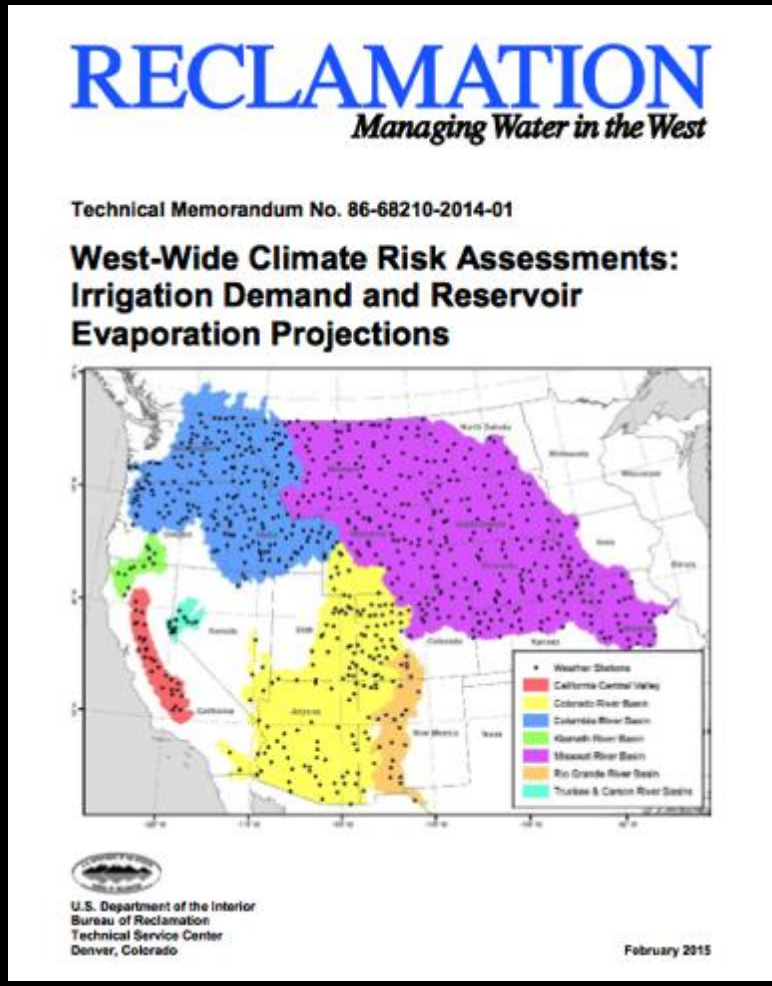
The Upper Colorado River Basin is Megadrought Country



Meko et al., (*Geophysical Research Letters*, 2007)

Reclamation Demand Projections

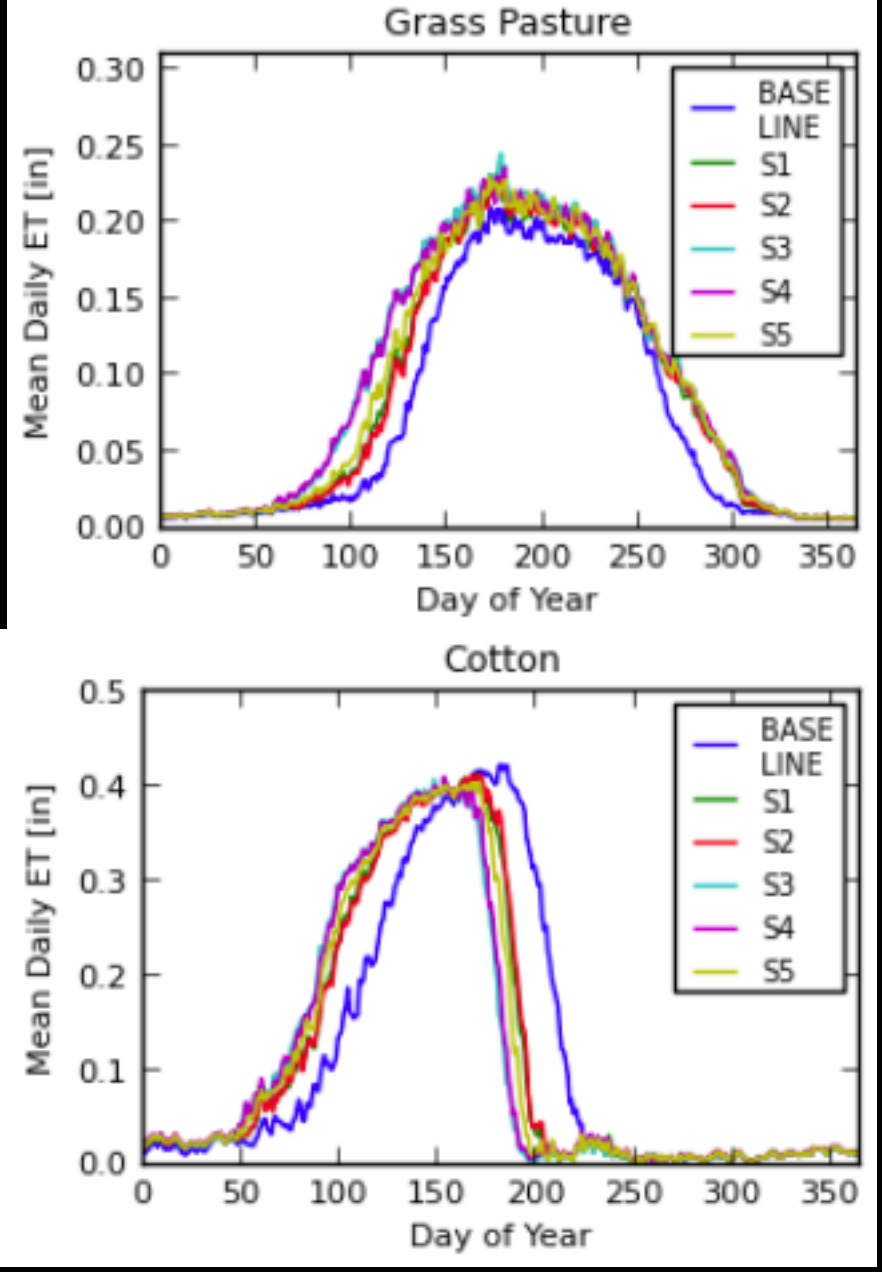
- Modeled Changes in Irrigation Demands in 8 Basins
- Up to 12% increases in ET by 2080 (more in south, less north)
  - Perennial crops show highest increases
  - Annual crops show smaller increases (some slight decreases)
- Modeled Changes in Reservoir Evaporation at 12 locations
  - Net Evap increases range from 2 to 6 inches/year
  - But precip increases add water thus many sites overall show only slight increases in evap and some sites show decreases
-



Source: Reclamation, 2015

Expansion of Water Use

- Historically farmers allowed to divert when needed in spring to water crops
- Longer growing seasons could allow additional cuttings of hay/alfalfa
- "Senior" Seniors could benefit at expense of "junior" seniors in late season
- Some ideas about quantifying rights in terms of consumptive use to ease transfers could apply here, too
  - See Squillace, Water Transfers for a Changing Climate, 2013



Source: Reclamation, 2015

Rio Grande Climate Change

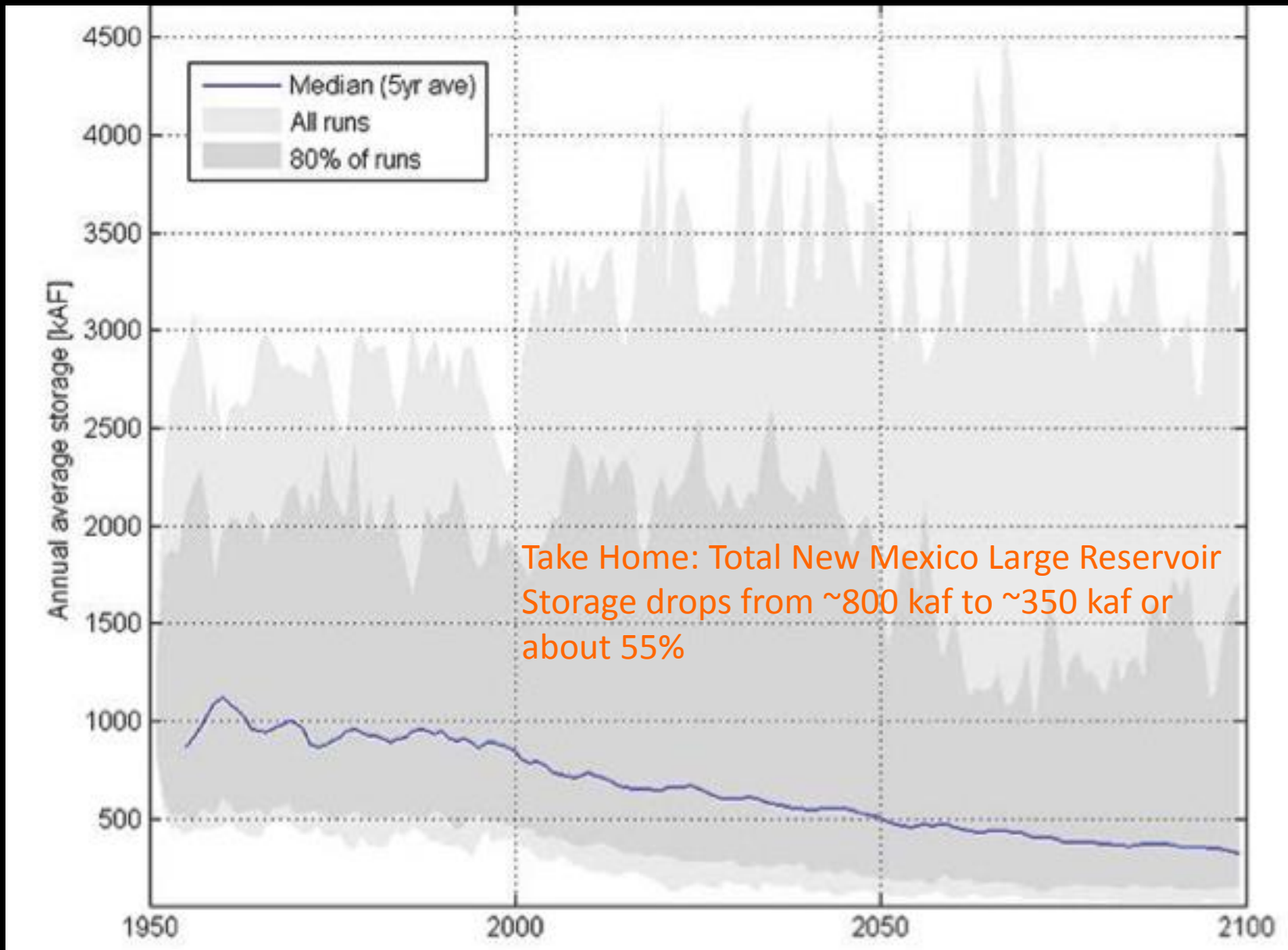
- Historical Trends over last 40 Years
  - Temps up by almost 3F
  - No changes to annual precip totals
- Projections
  - Additional 4-6F by 2100
  - Declines in RG flow of approximately 1/3 by 2100
  - SJC inflows decline by only (?) 25%
  - Decreases in summer flows, less in winter
  - Increases in variability and evaporative demand
- Water Management Implications
  - 50% less water for NM and Texas
    - Less Everything: Ag, Muni, Hydropower, Env Flows, Recreation
  - 'Only' 25% less for Colorado
- My Brief Analysis
  - Of all the Climate Change stream flow projections in the Southwest that I've seen, this is by far the most serious

RECLAMATION
Managing Water in the West

West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment

Source: Reclamation, 2013

Total New Mexico Water Storage



A Summary

- Climate Change is Water Change
- Wetter North, Drier South
- More Rain, Less Snow
- Precipitation is not Runoff
- Temperatures Drive Lower Runoff
- Earlier Runoff, Lower Late Season Flows
- Dust on Snow advances runoff timing
- Fires, Megadroughts Additional Risks
- Water Demands Increase
- Climate Change makes _____ Worse

"Perhaps you'd like a second opinion?"

Second century megadrought in the Rio Grande headwaters, Colorado: How unusual was medieval drought? GRL (2011)

Cody C. Routson,[1] Connie A. Woodhouse,[2] and Jonathan T. Overpeck[1,3,4]

Longest megadrought in Colorado and Rio Grande headwaters…

50 years with 1 break year

Lee Ferry Projected Flows from Basin Study

Bottom Line: 75% Models Show Declines, Median Decline -9% at Mid - Century

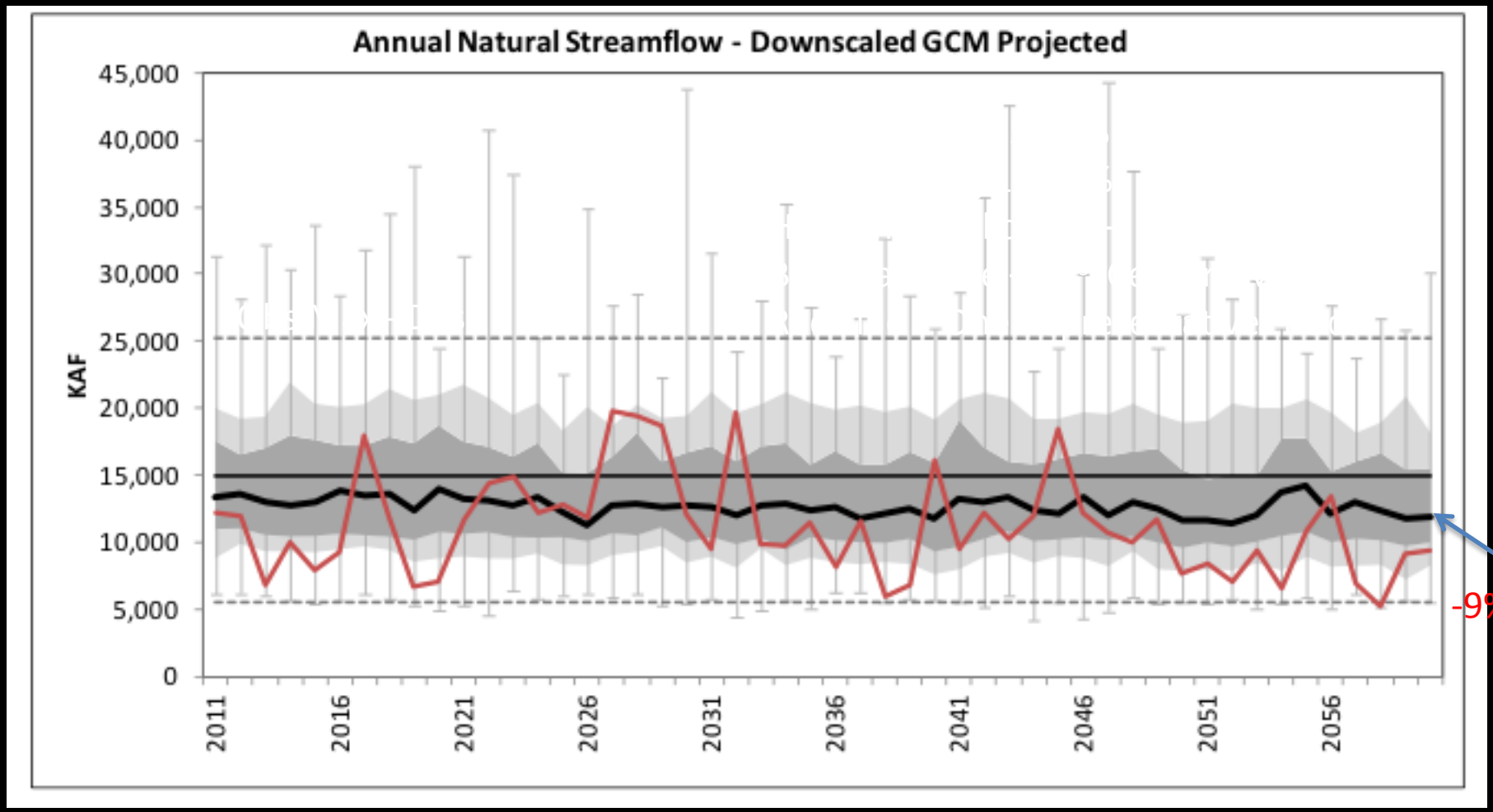


Figure B-45 Tech Appendix B
Each Year has 112 Projections

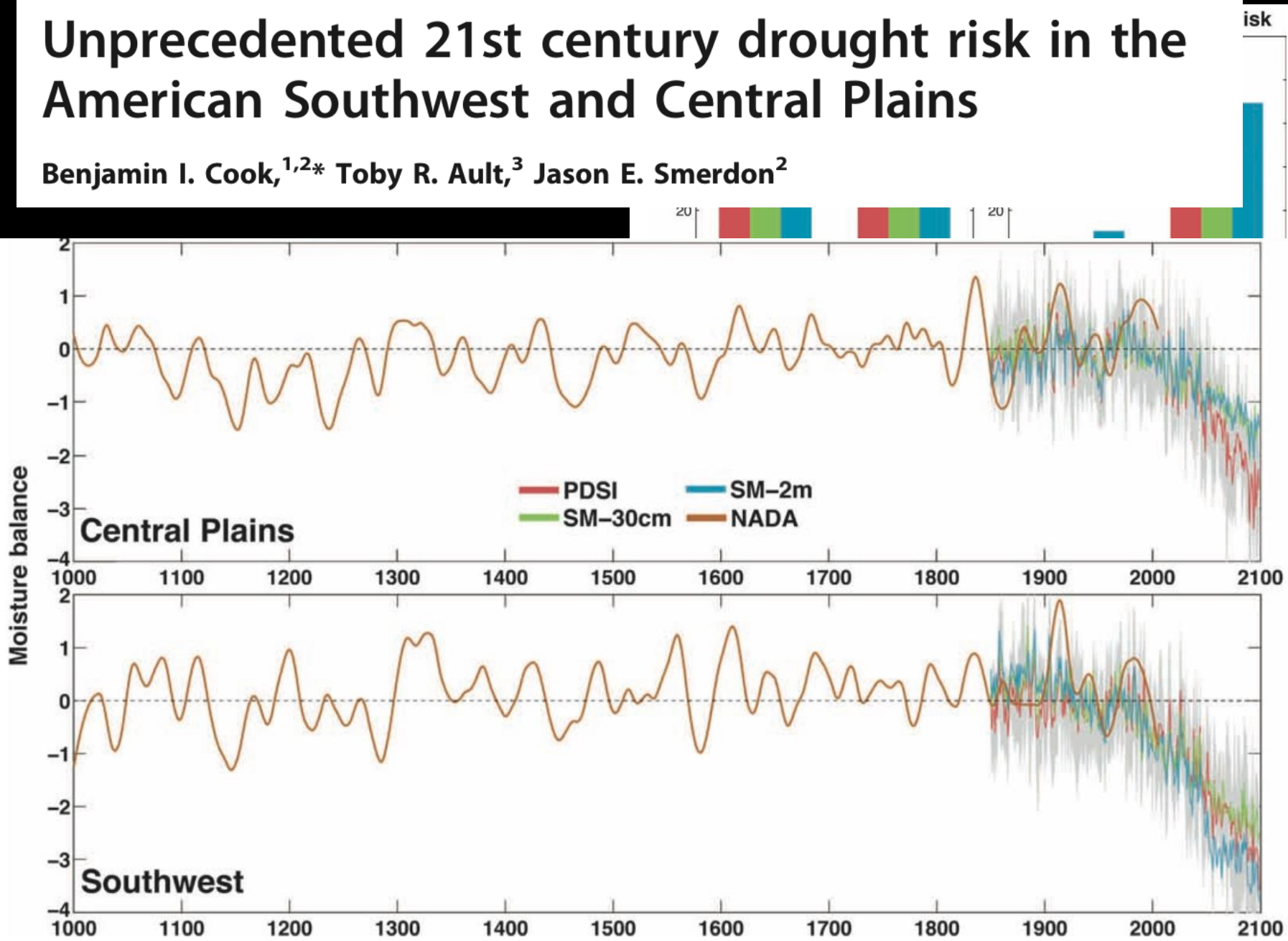
At 45 maf/year flood control may be an issue

Source: Reclamation, 2012

CLIMATOLOGY

Unprecedented 21st century drought risk in the American Southwest and Central Plains

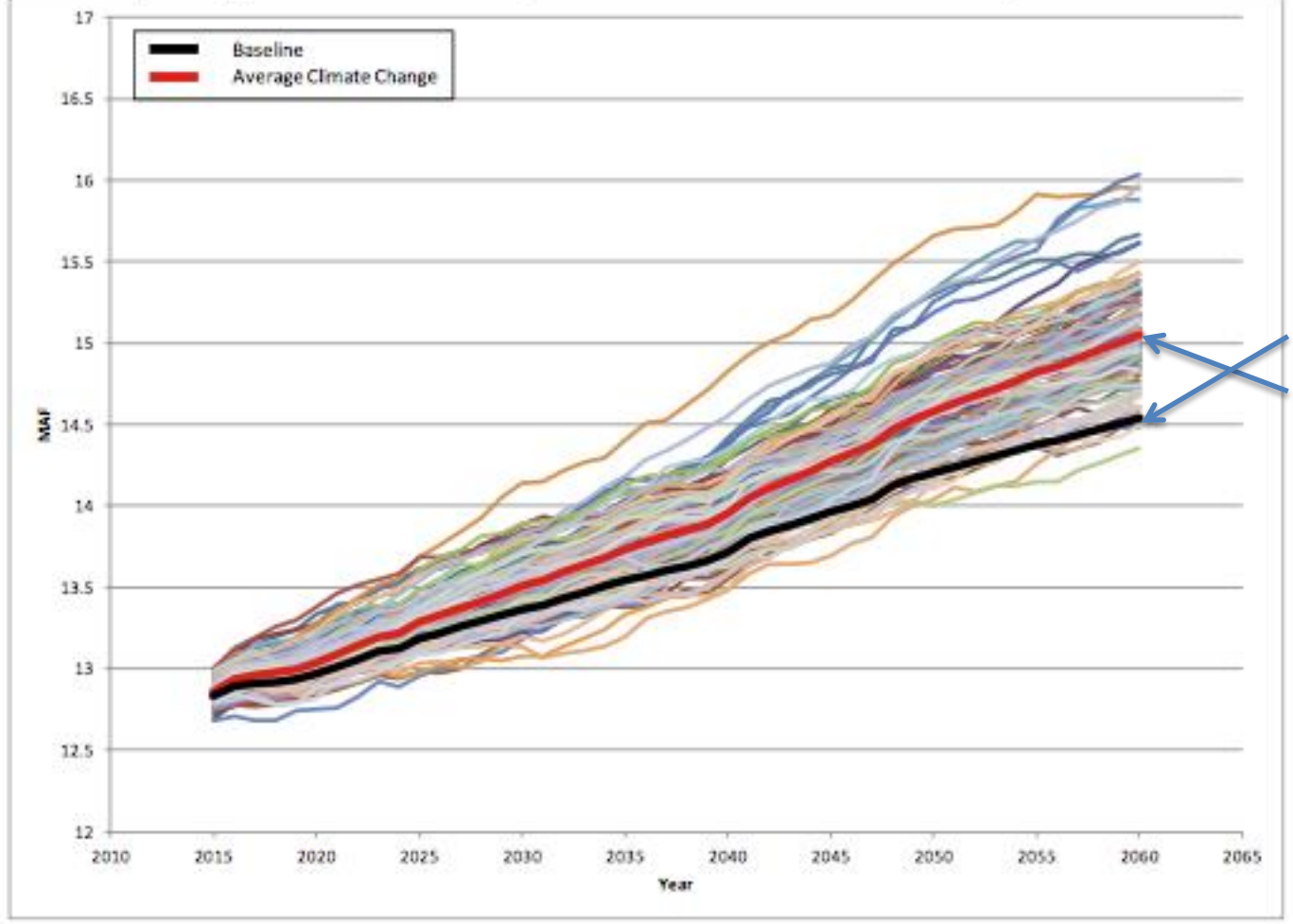
Benjamin I. Cook,[1,2]* Toby R. Ault,[3] Jason E. Smerdon[2]



Increased Demands Due to Climate Change

Bottom Line: A Variety of Demand Increases Possible by Mid-Century, Average is 4%

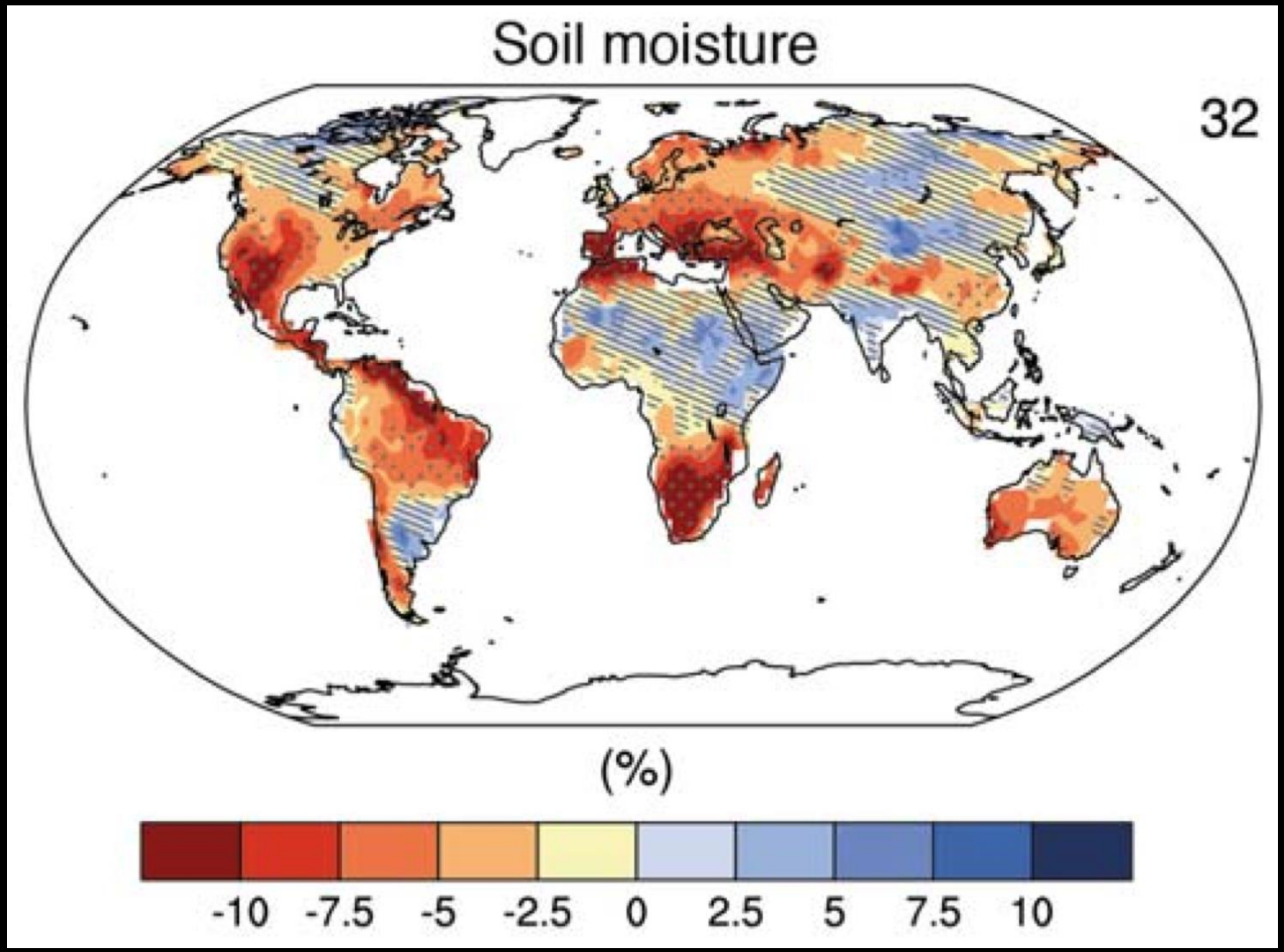
FIGURE 11
Current Projected (A) Scenario Demands Adjusted for Possible Future Climate Change



4% More Annually Basin Wide

Source: Reclamation, 2012

IPCC FAR Results RCP 8.5 at 2081 to 2100



How Climate Change affects Event Intensity (How Far Right), Frequency (How Far Up), and Duration (Not shown)

- Shifted Distribution Shows Increases in Frequency of Hot Events AND New All Time Hot Records.
- Actual Events are Difficult to Formally Attribute to Climate Change for a number of reasons.
- New Climate Curve will be moving to the right throughout the 21st Century.