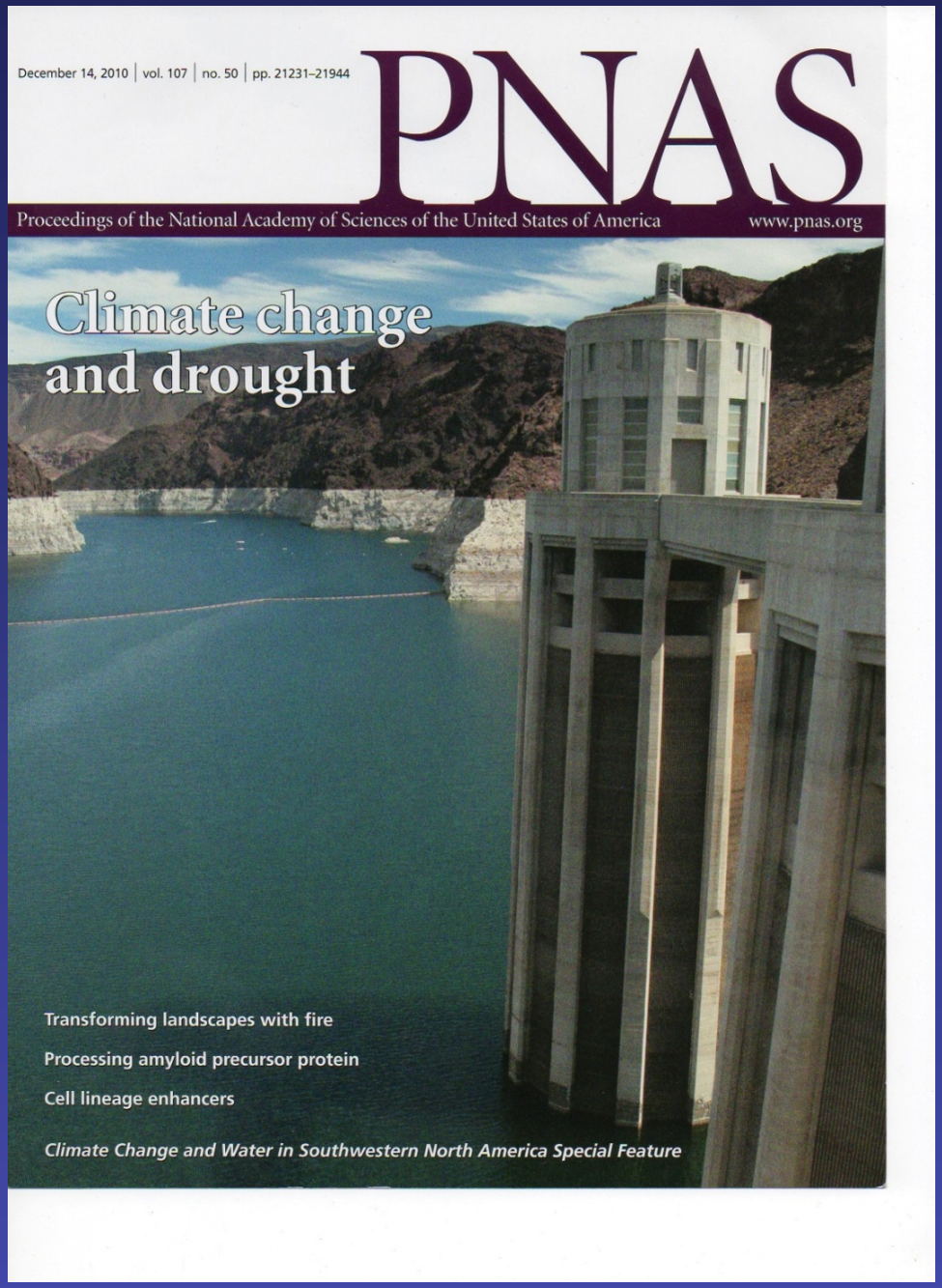
Future Sustainability of Southwestern Water: Lessons from the Past and Best Practices for the Future

Aspen 2012

Glen M. MacDonald

UCLA Institute of the Environment and Sustainability


LOS ANGELES

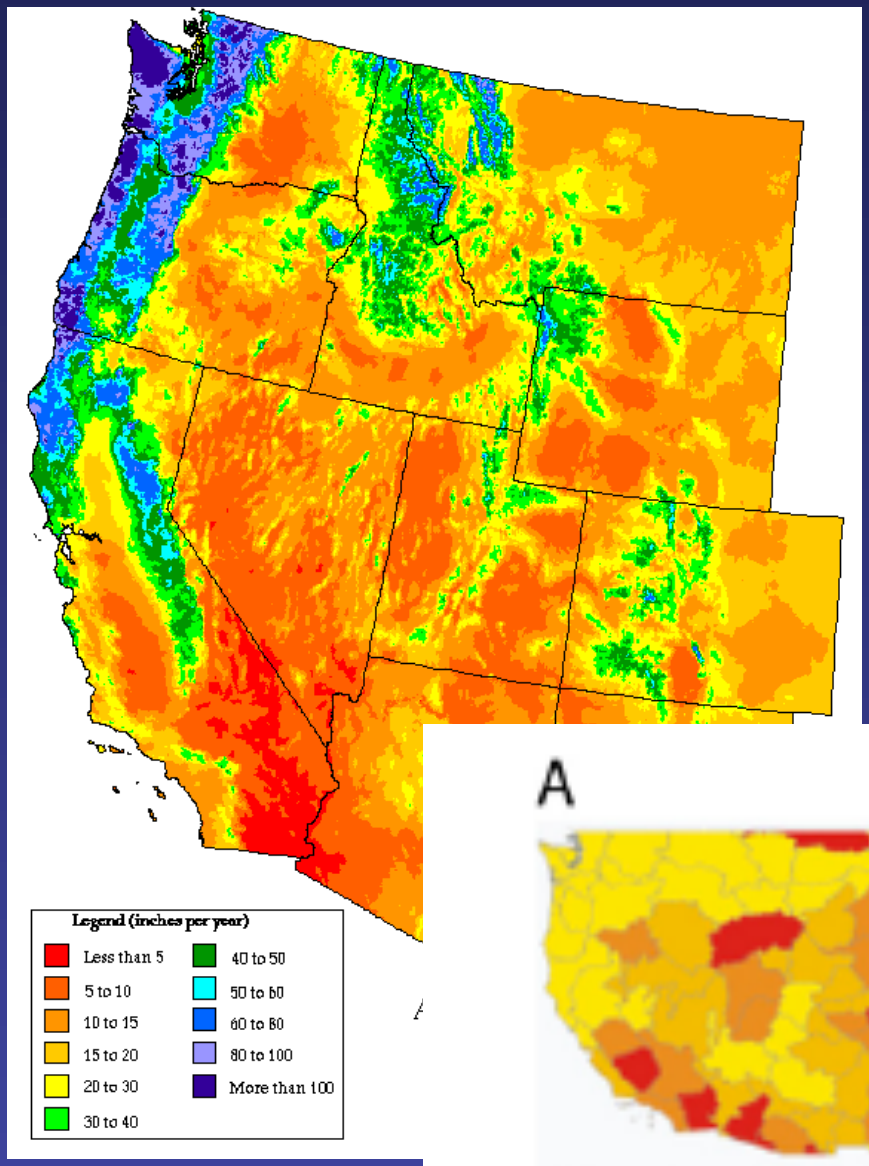


What is the nature of the 21st Century Drought?

Is it attributable to increased greenhouse gasses and anthropogenic climate change?

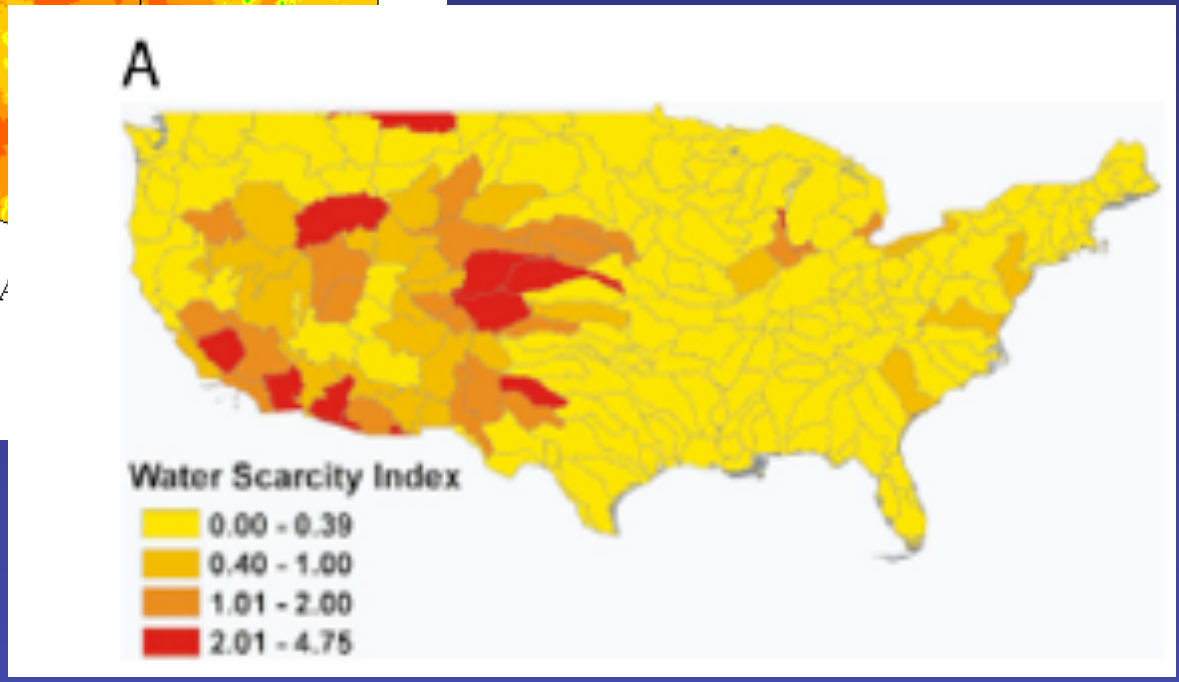
Could climate warming induced aridity in the Southwest be exacerbated by Pacific SST changes?

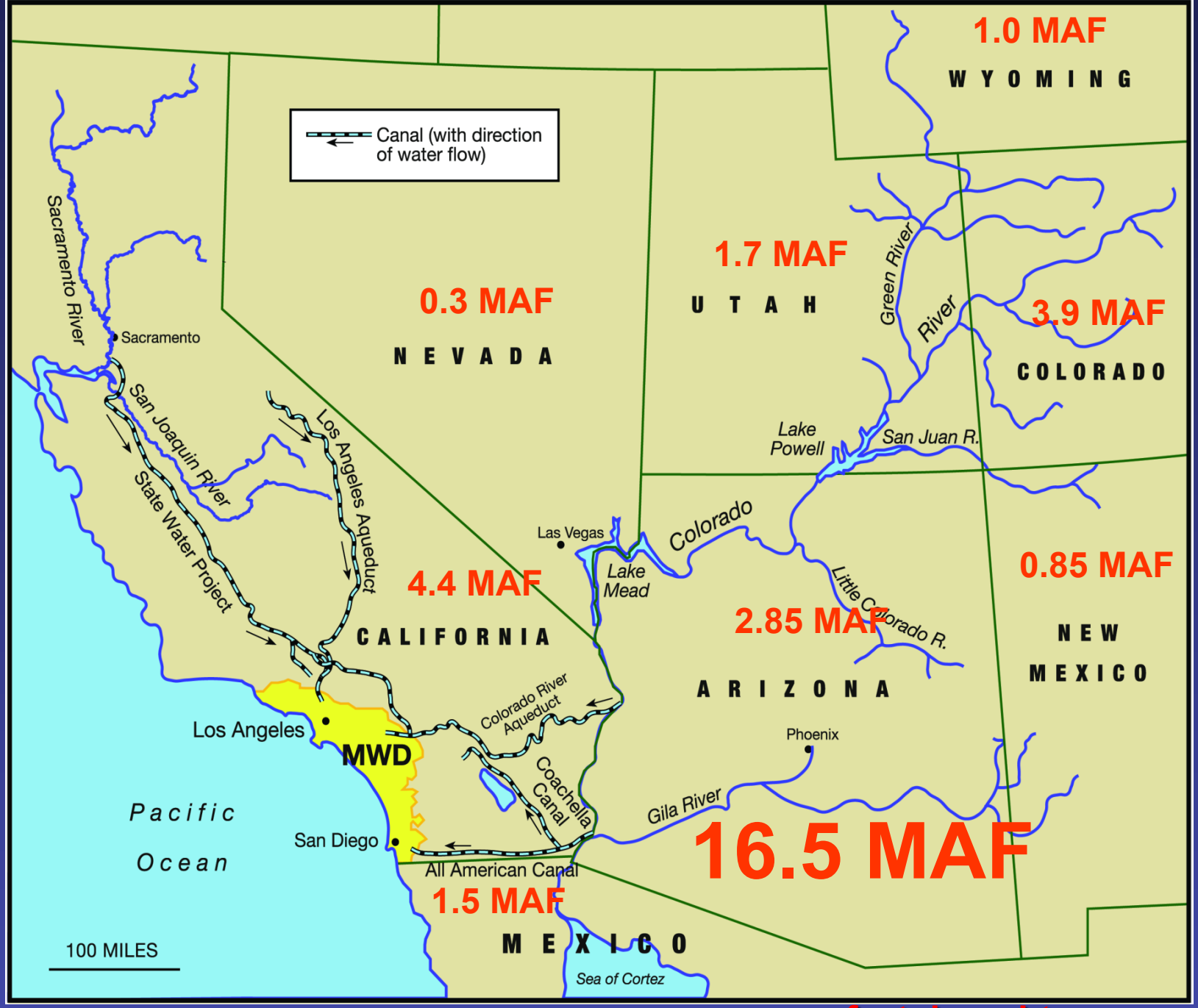
Challenges ?



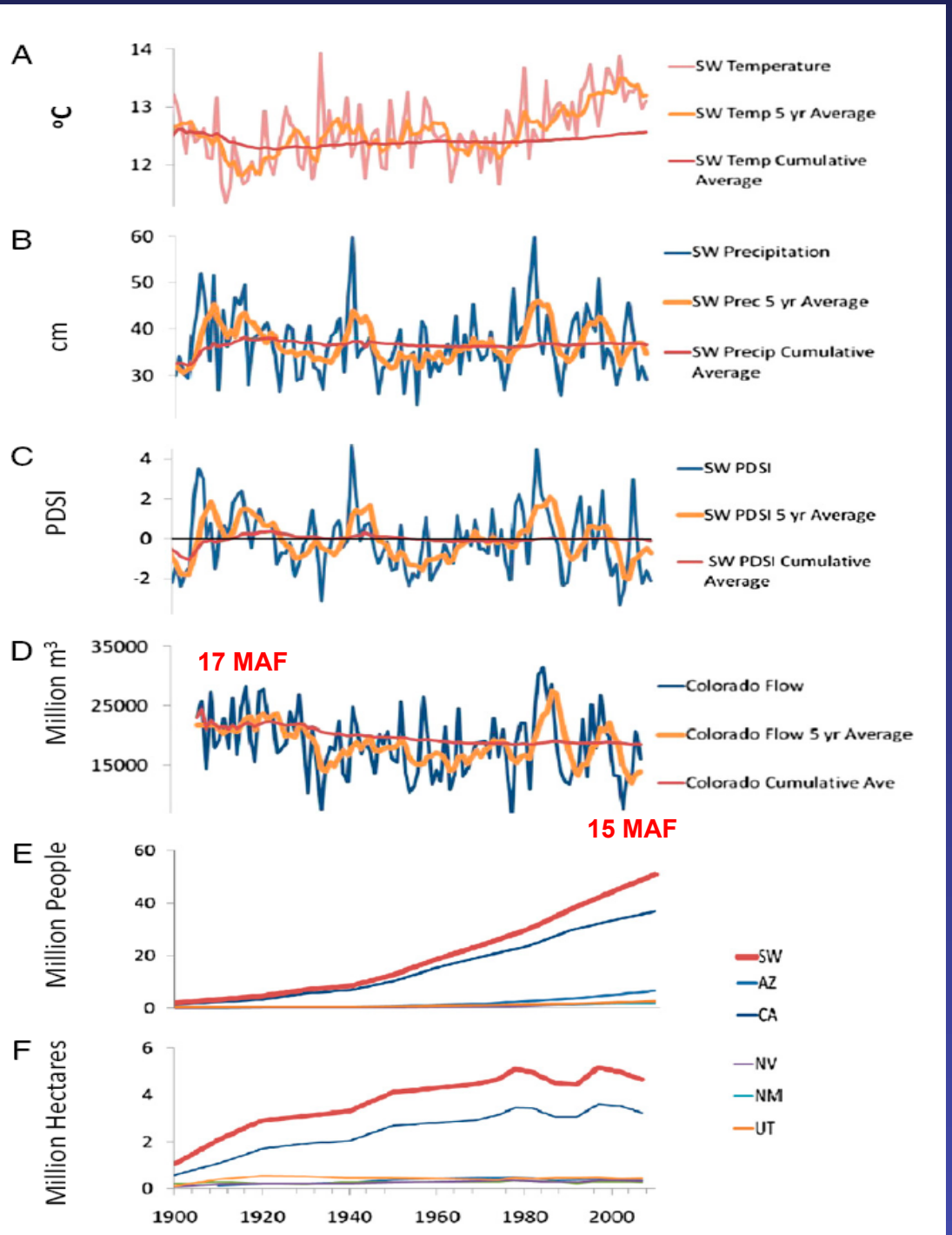
What is the nature of the 21st Century Drought?

Sabo et al 2010 PNAS



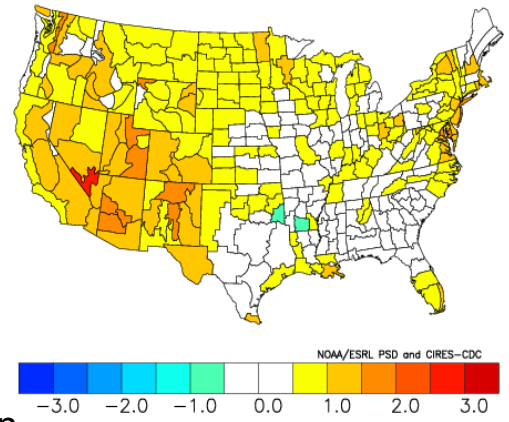


MacDonald, G.M., Rian, S. and Hidalgo, H. 2005. Southern California and the perfect drought. Colorado Basin Climate. California Department of Water Resources. pp 50-57 (Map).

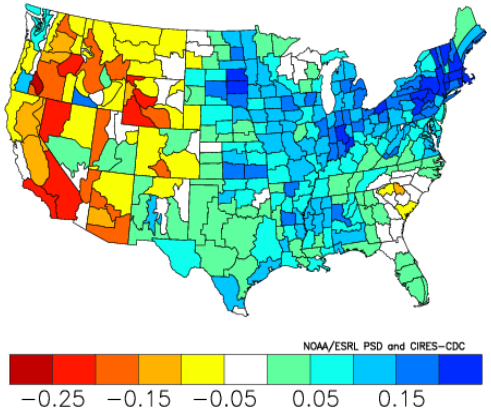


MacDonald 2010 PNAS

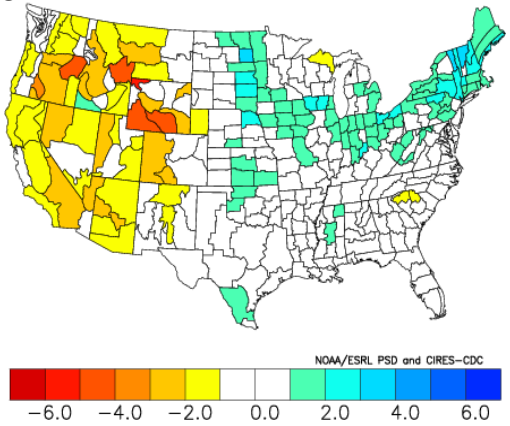
Temperature 2001-2009



Precipitation



Drought Index



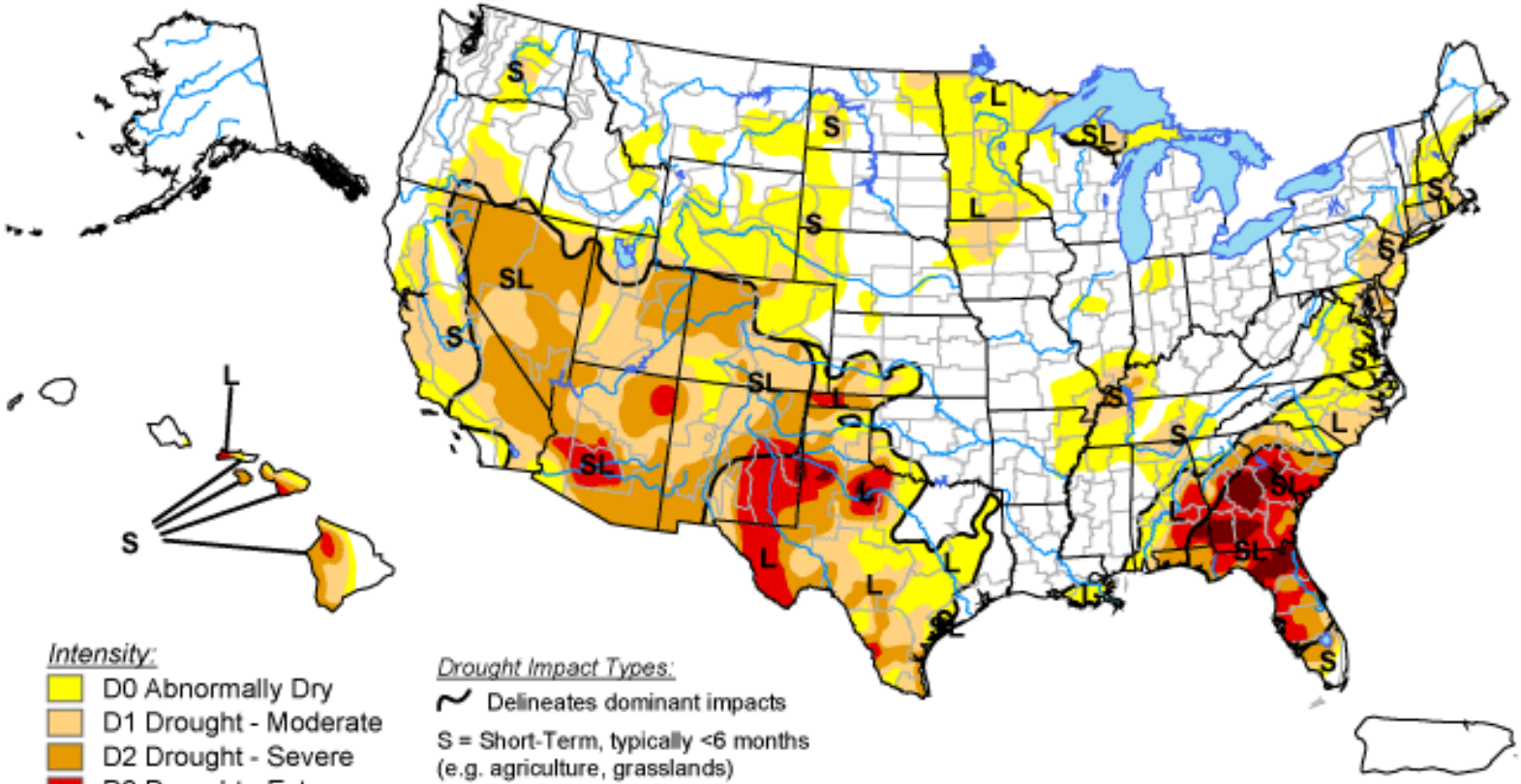
a

c

MacDonald 2010 PNAS

U.S. Drought Monitor

May 15, 2012
Valid 7 a.m. EDT



Intensity:
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:

~ Delineates dominant impacts

S = Short-Term, typically <6 months (e.g. agriculture, grasslands)

L = Long-Term, typically >6 months (e.g. hydrology, ecology)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

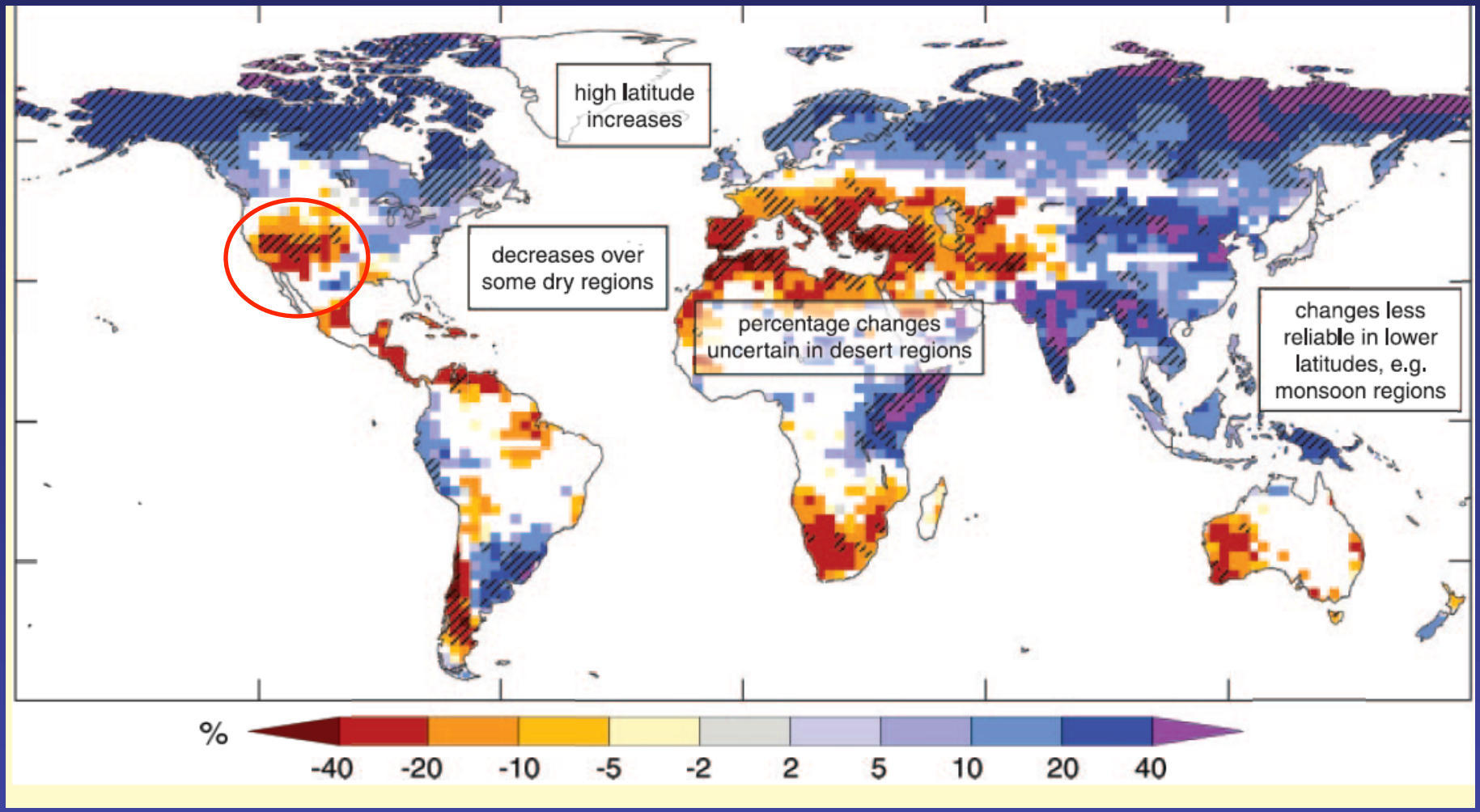
http://droughtmonitor.unl.edu/

Released Thursday, May 17, 2012

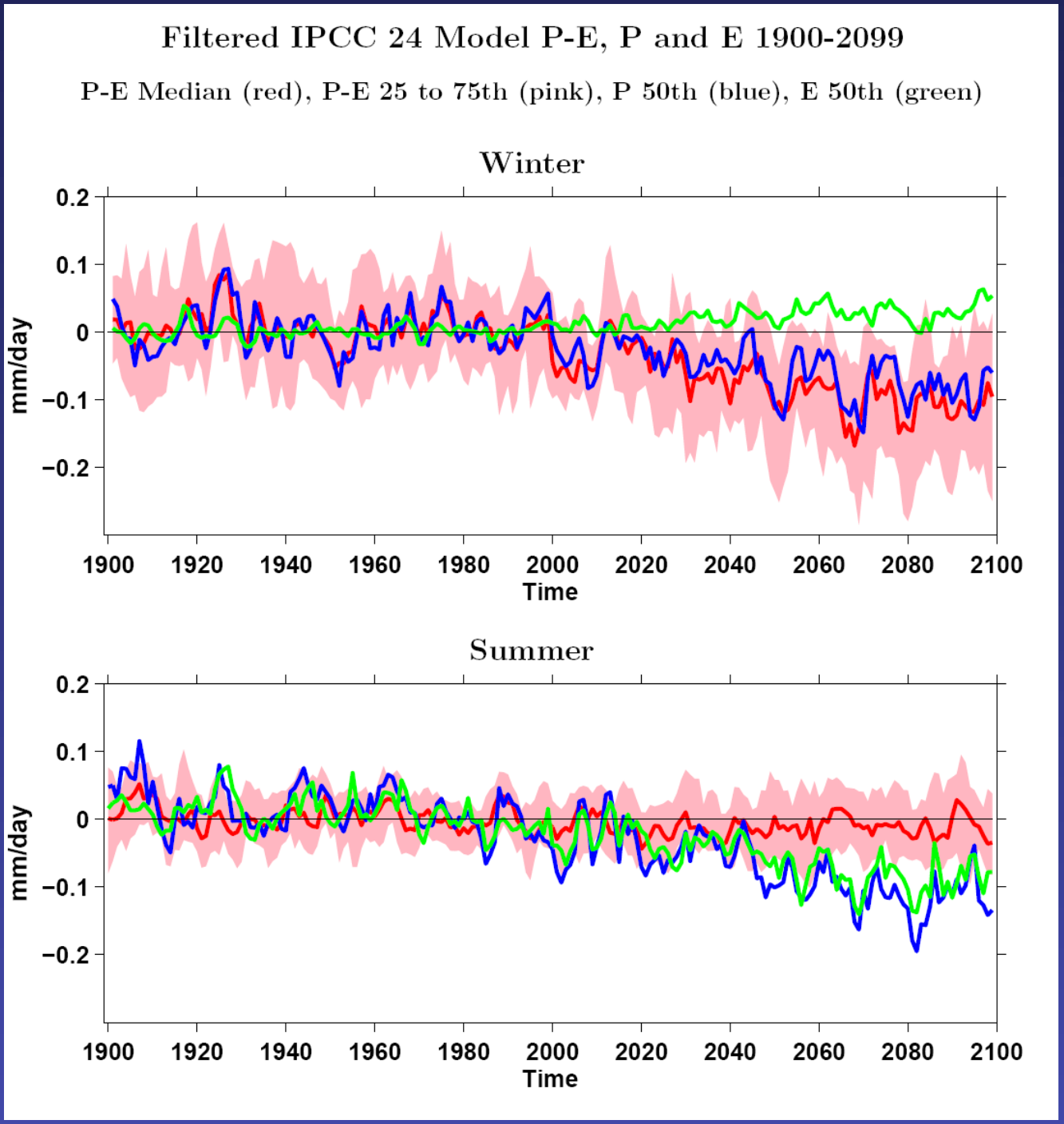
Author: Brad Rippey, U.S.Department of Agriculture

Is it attributable to increased greenhouse gasses and anthropogenic climate change?

IPPC 4 Projections -

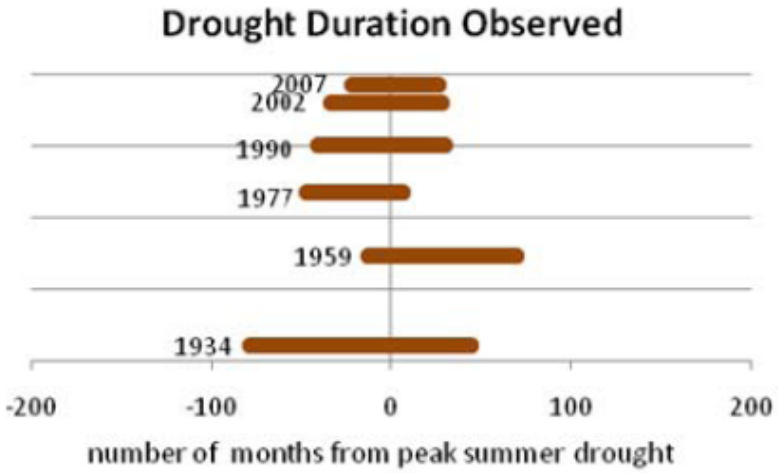


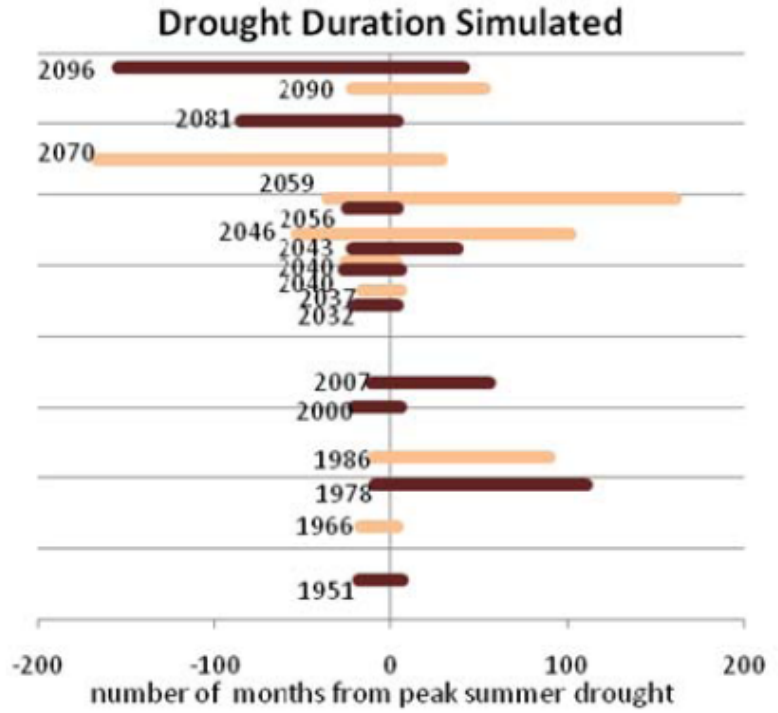
A warmer world and drier subtropics and wetter tropics?



"Due to the presence of large amplitude decadal variations of presumed natural origin, observations to date cannot confirm that this transition to a drier climate is already underway,
but it is anticipated that the anthropogenic drying will reach the amplitude of natural decadal variability by midcentury."

Seager and Vecchi, PNAS 2010



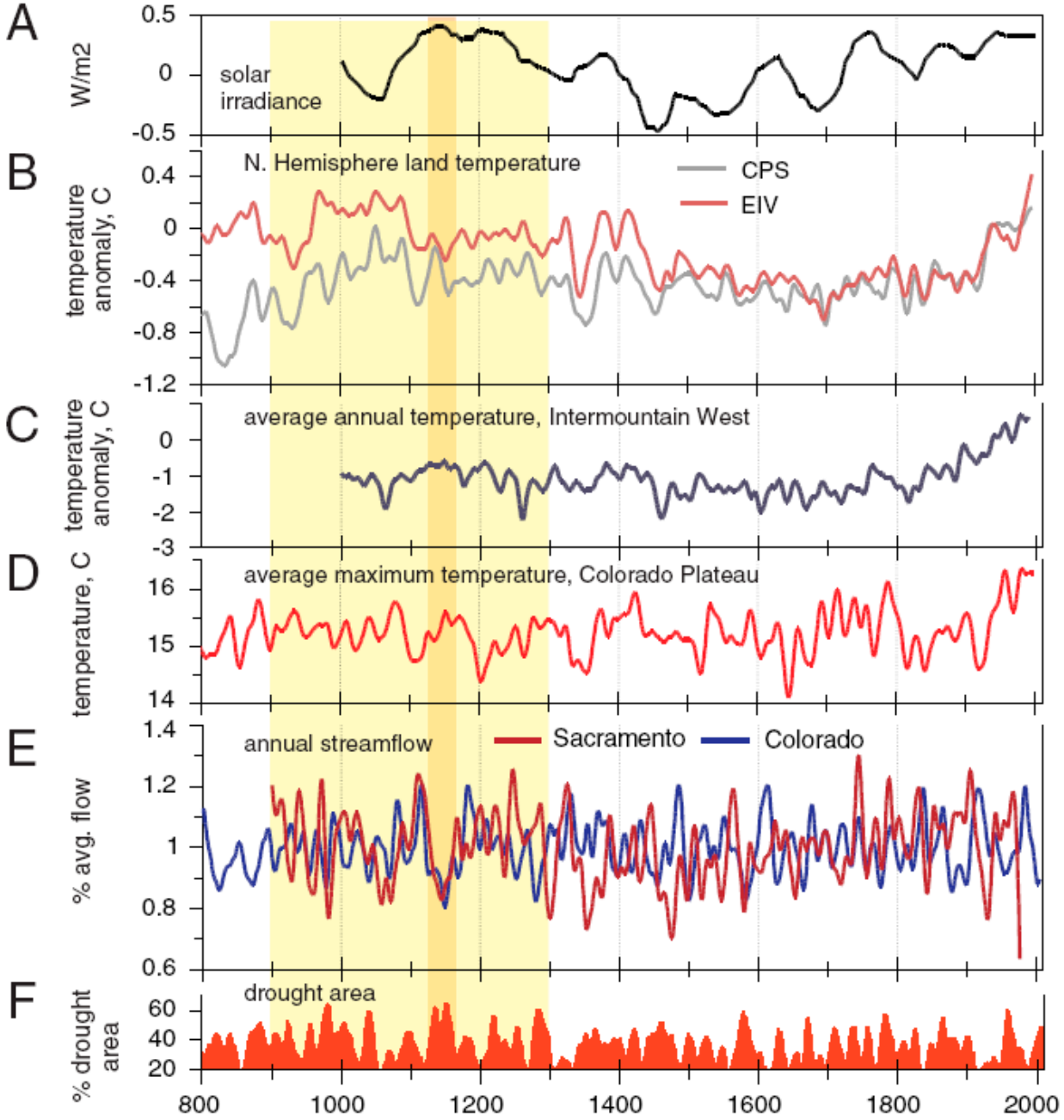


Duration of observed dry intervals associated with extreme drought, determined as those months with persistent negative soil moisture anomalies for Southwest region.

Simulated dry intervals over Southwest associated with extreme drought from VIC hydrological model runs from downscaled CNRM and GFDL simulations, historical period and projected from SRES A2 21st Century simulations. Drought duration determined as for Figure 1a. Light/dark bars designate CNRM and GFDL dry spells, respectively.

"At this point, it is not possible to say which mechanism (chance or warming) is responsible for the observed dryness in the Colorado basin during the first years of the 21st century."

Cayan et al. PNAS 2010

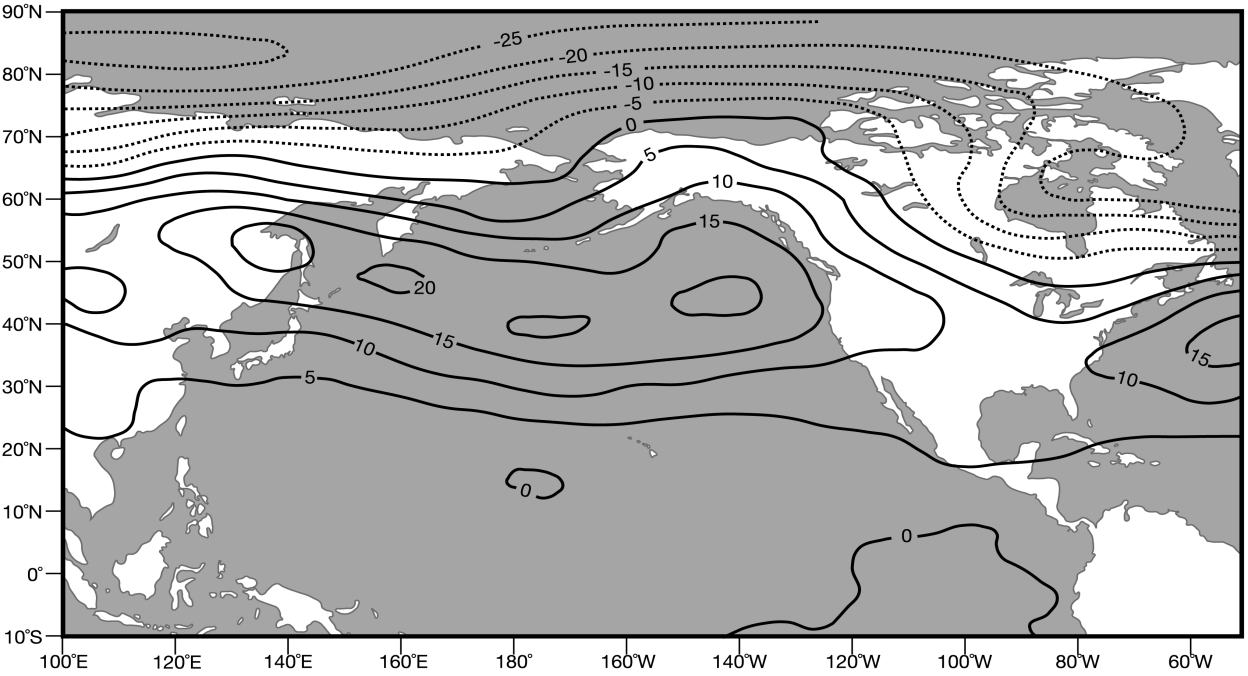


"The recent drought, thus far, pales hydrologically in comparison to the worst-case drought documented in the medieval period in both spatial extent (Fig. 3) and duration."

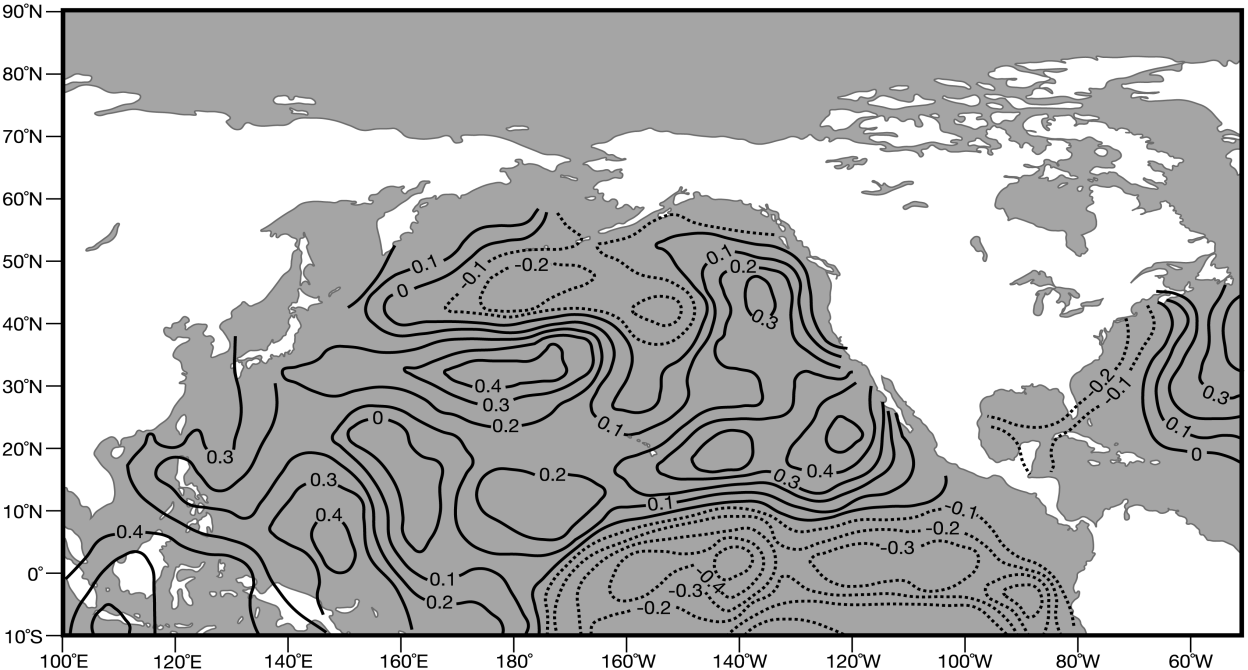
Woodhouse, Meko, MacDonald, Stahle and Cook PNAS 2010

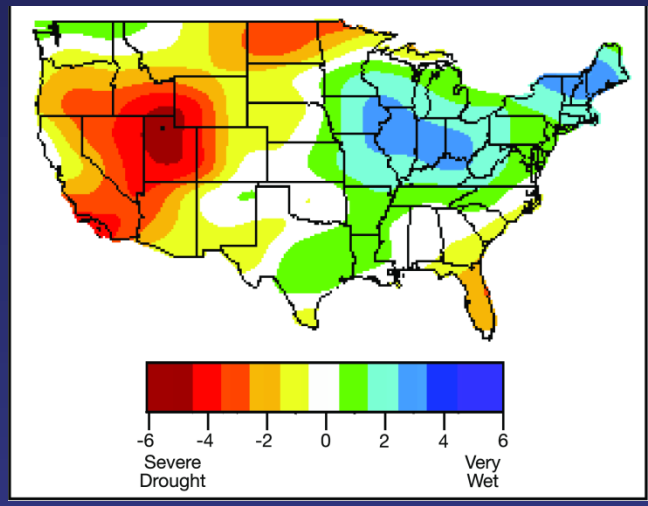
Could climate warming induced aridity in the Southwest be exacerbated by Pacific SST changes?

a. 700 mb height anomolies (m)



b. Sea surface temperature anomolies (°C)





ANATOMY OF A PERFECT DROUGHT

700 mb height anomalies (top panel) and SST anomalies (bottom panel) for the period January 1988 to December 1990 (NCEP Reanalysis and Kaplan Extended SST V2 data from NOAA/ESRL Climate Data Center). –

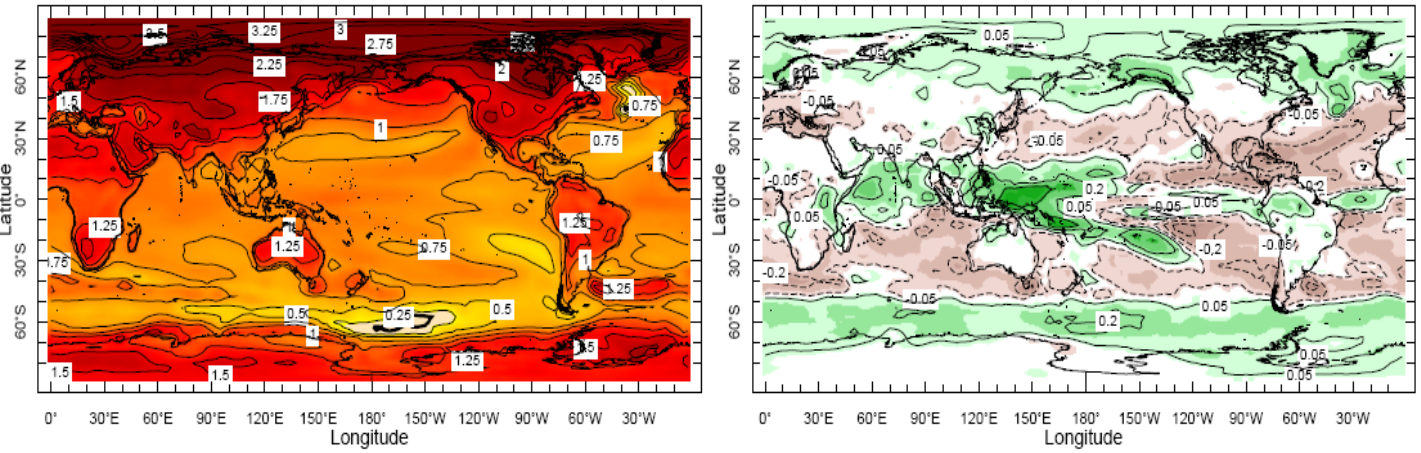
MacDonald, G.M., Kremenetski, K.V. and Hidalgo, H. 2007. Southern California and the Perfect Drought: simultaneous prolonged drought in Southern California and the Sacramento and Colorado River systems. Quaternary International. doi:10.1016/j.quaint.2007.06.027

IPCC (2021 to 2040) - (1950 to 1999)

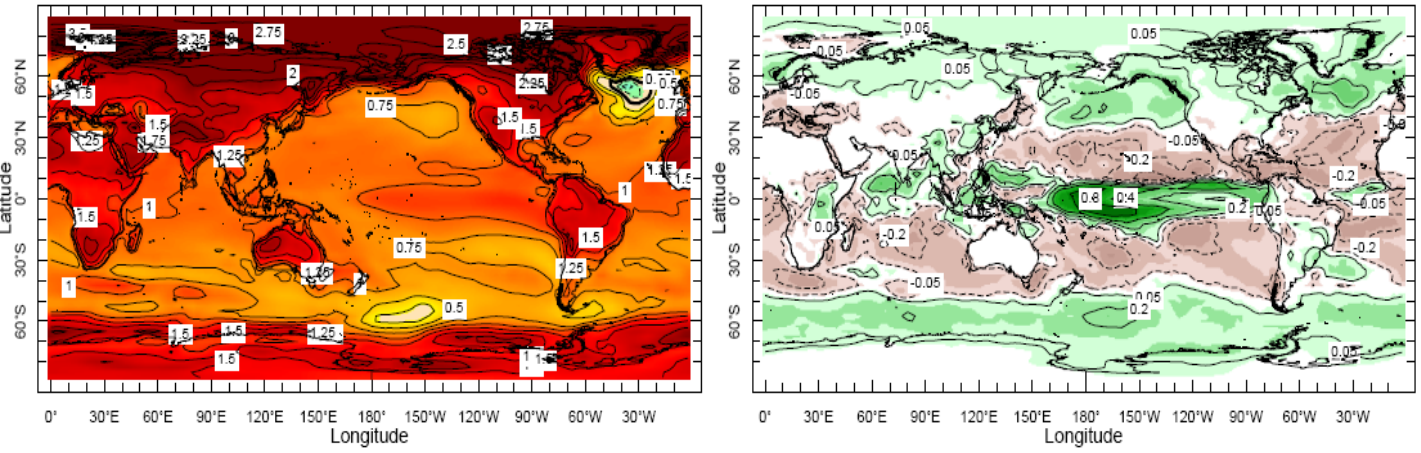
Temperature

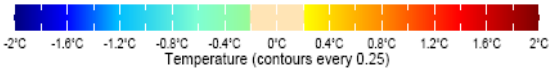
Precipitation - Evaporation

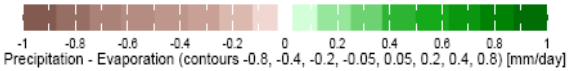
Positive Temperature Gradient Composite



Negative Temperature Gradient Composite

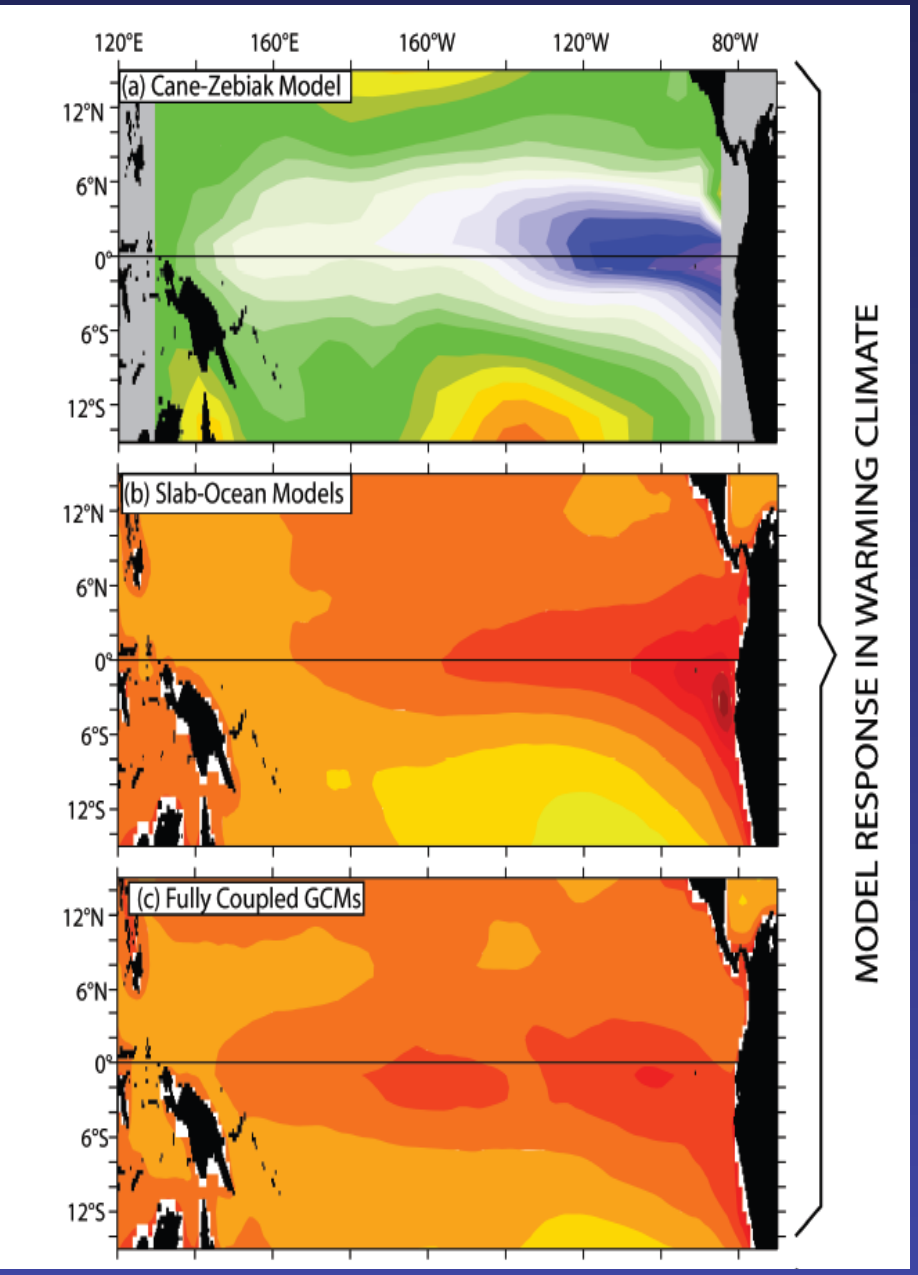


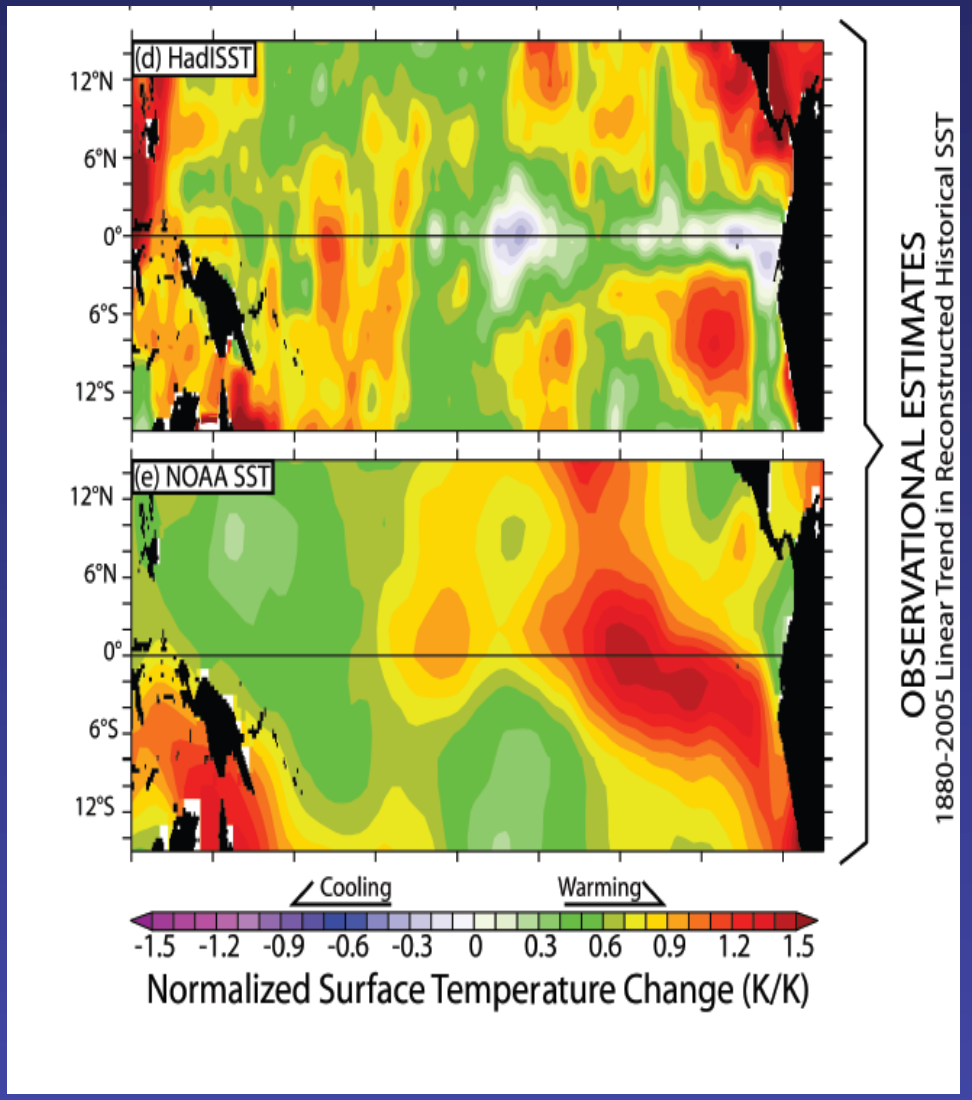




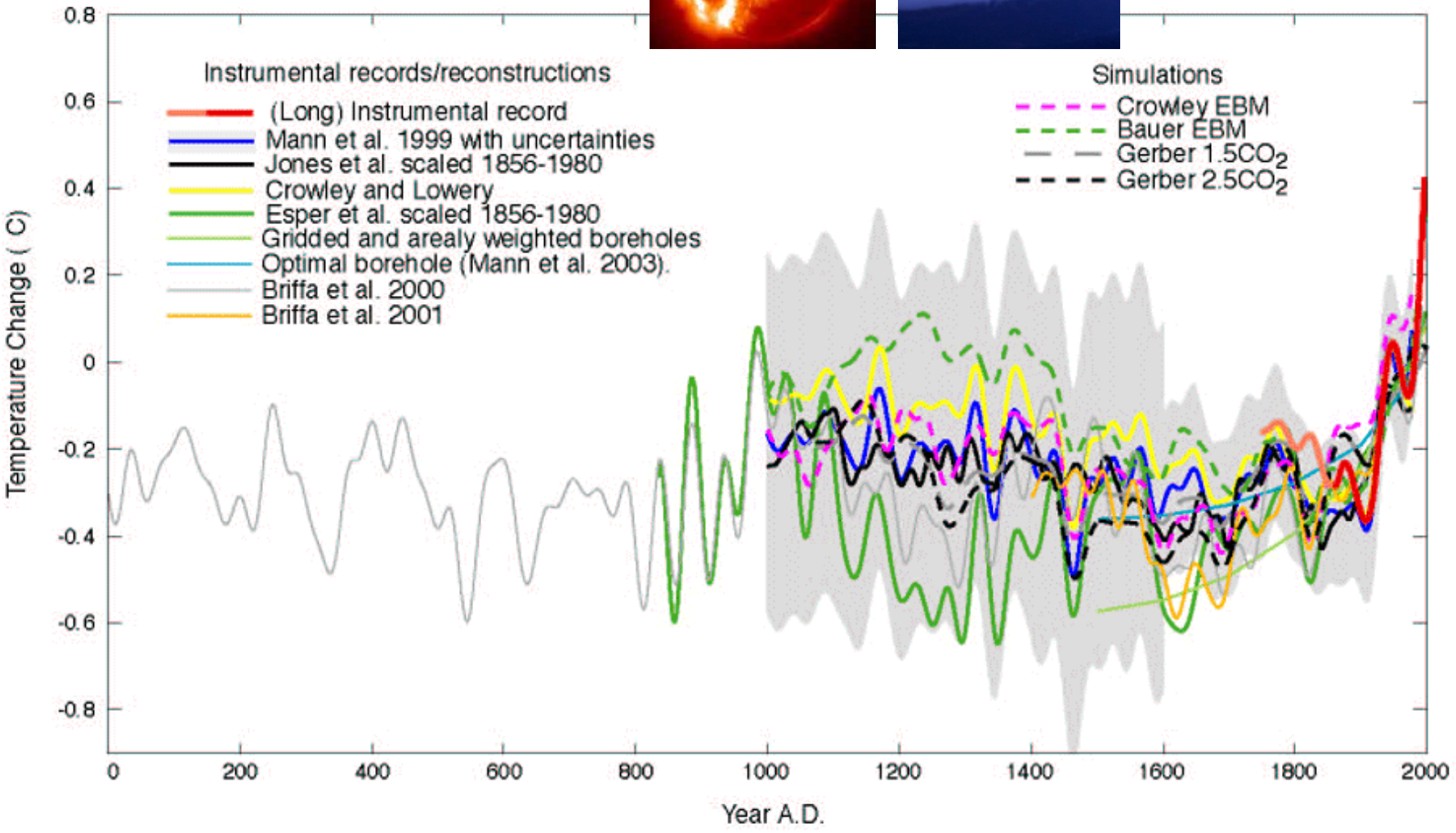
"This result is quite alarming, because the severity of the drying of SWNA that will occur in the near term future will depend on tropical Pacific climate change, but the current generation of climate models simulate the tropical Pacific very poorly (30). We have little confidence in their widely varying projections of how the tropical Pacific climate system will respond to radiative forcing."

Seager and Vecchi, PNAS 2010

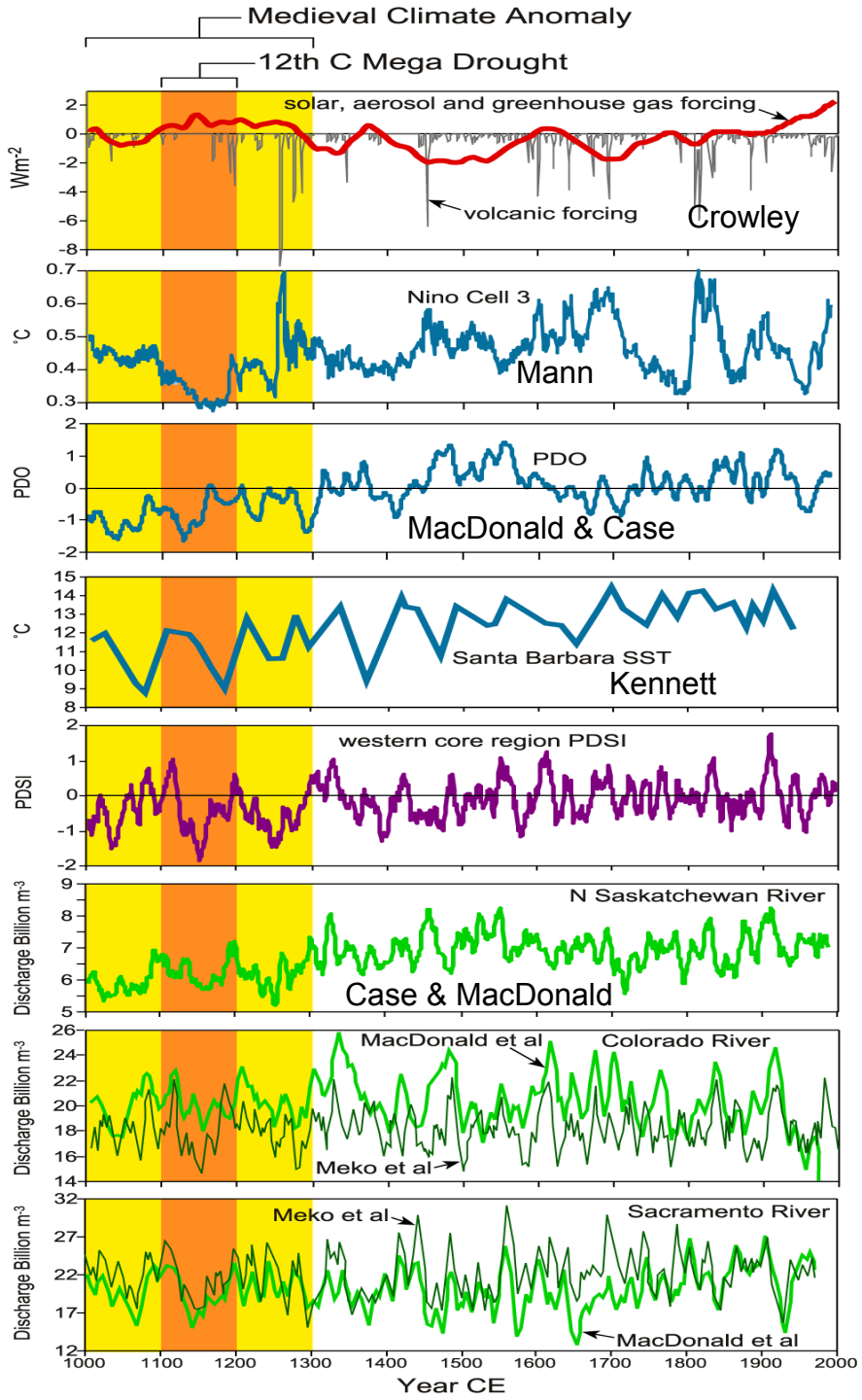


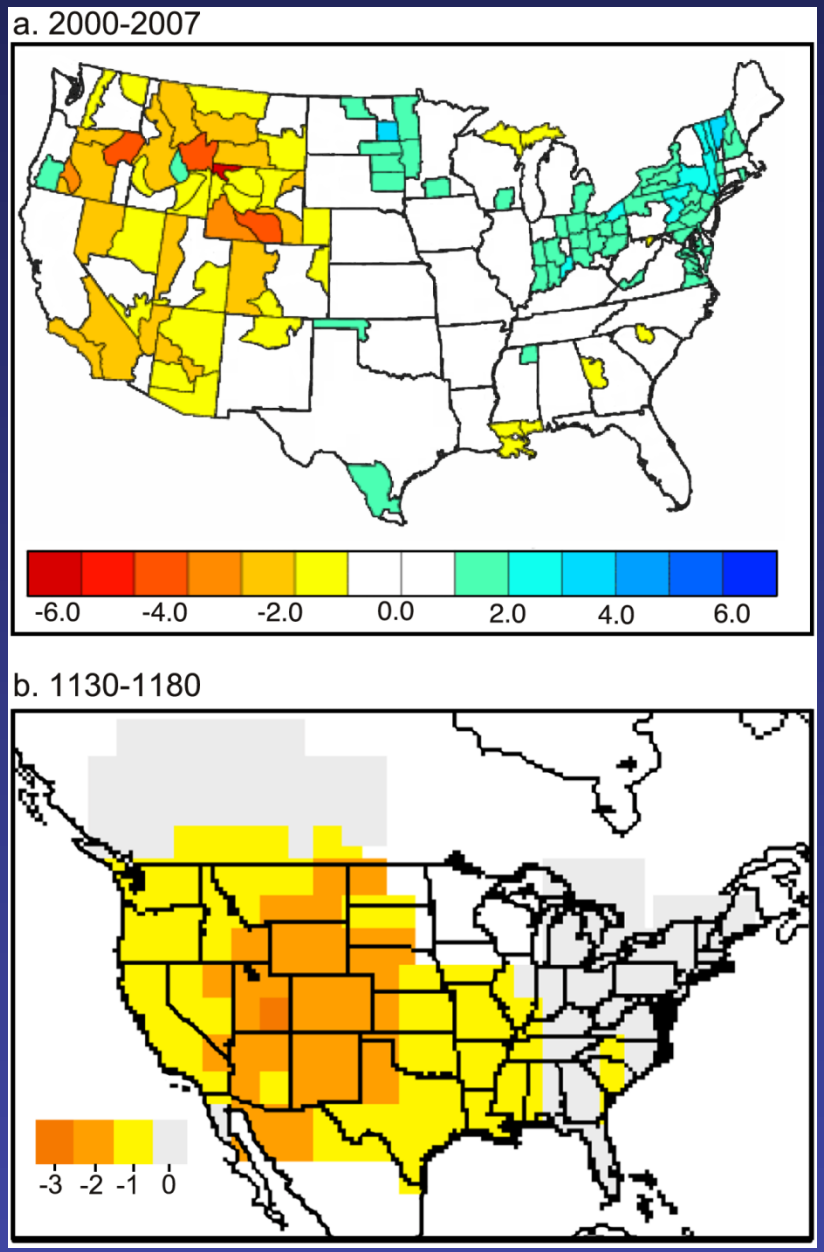


Vecchi et al. 2008 EOS



Mann et al. 2003





MacDonald et al 2008 EOS

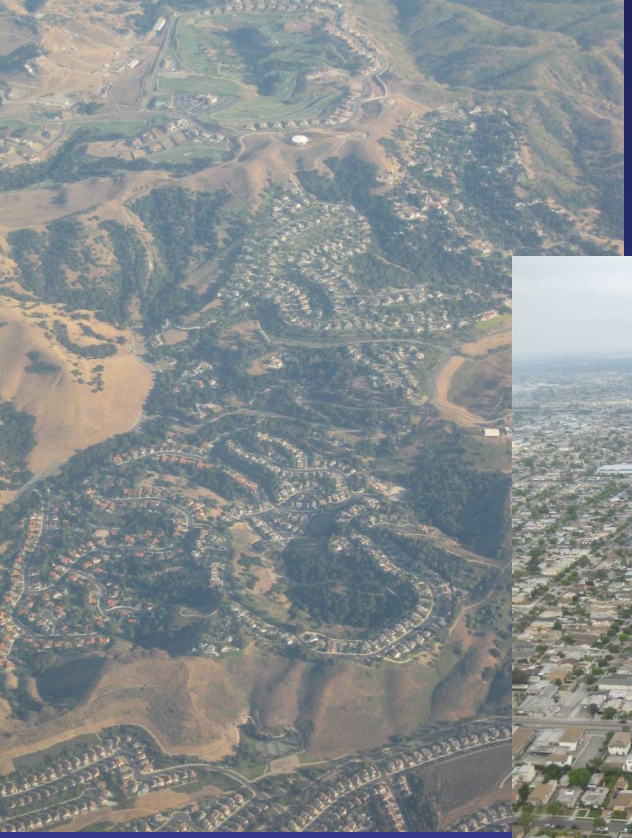
You betcha!

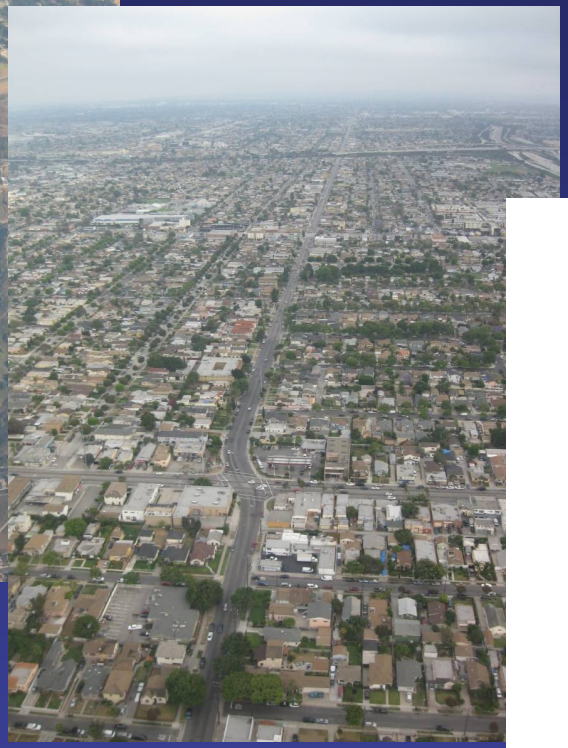
Challenges

Contribution of Residential Outdoor Water Use to Total Annual Residential Water Use, from Data-logged Samples

(adapted from REUWS)

Study Site	Sample Size	Outdoor Annual Use (kgal/home)	Indoor Annual Use (kgal/home)	Total Annual Use (kgal/home)	Percent of Annual Consumption due to Outdoor Use
Boulder	100	73.6	54.4	128.0	57.5%
Denver	99	104.7	61.9	166.6	62.8%
Phoenix	100	161.9	70.8	232.7	69.6%
Scottsdale	59	156.5	60.1	216.6	72.3%
Tempe	40	100.3	65.2	165.5	60.6%





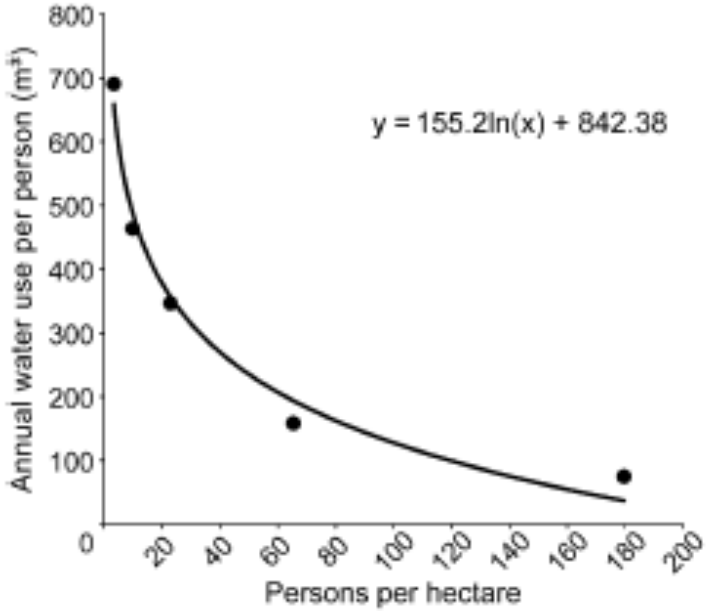


Fig. 2. Estimated water required to support residential densities. Water duties from Salt River Project (2003) Canal Available Capacity Report, table 2, 1995 Urban Water Duties in Acre Feet/Acre. Population densities based on land-use classifications from Maricopa Association of Governments 1995 Land Use Classifications (http://www.mag.maricopa.gov/).

Gober and Kirckwood, 2010 PNAS

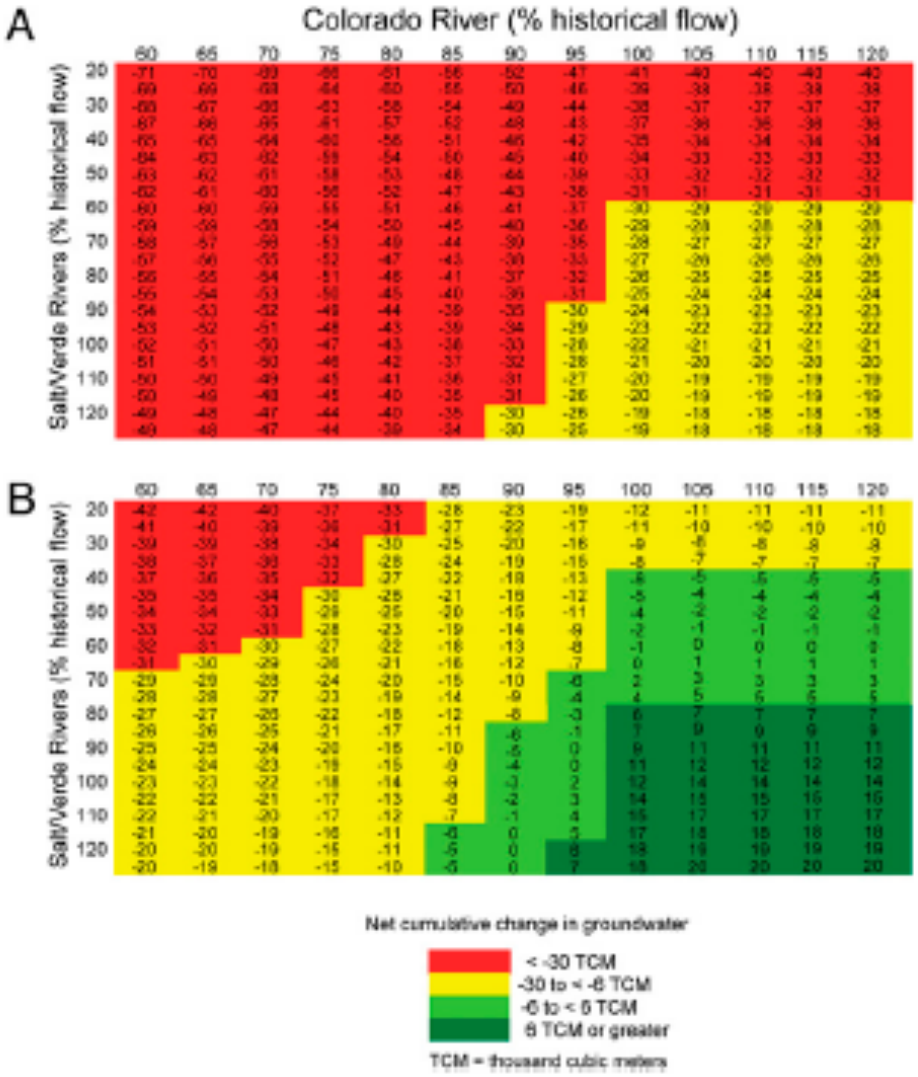
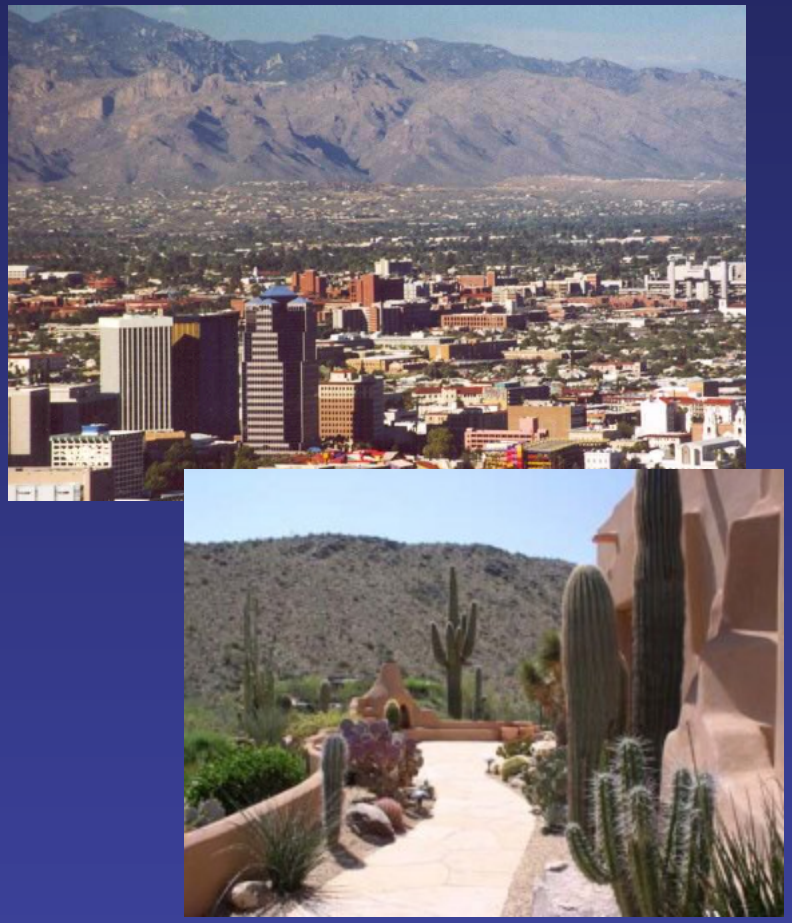
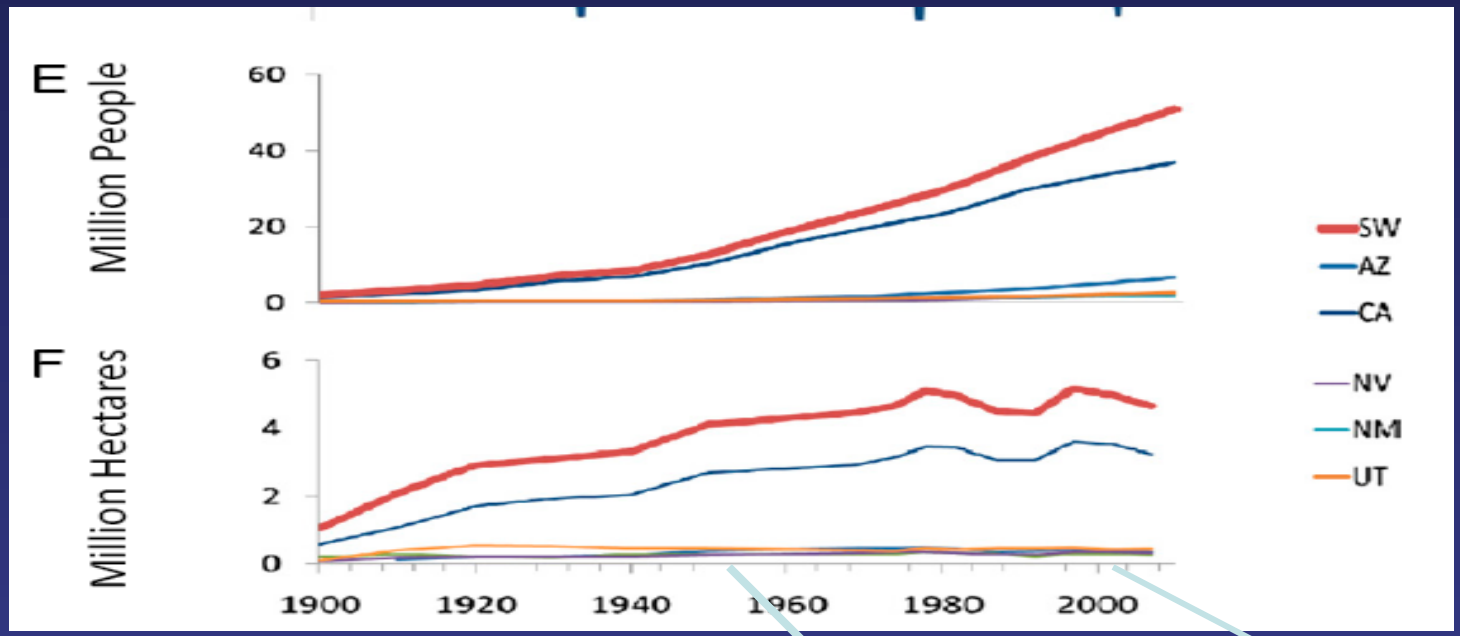
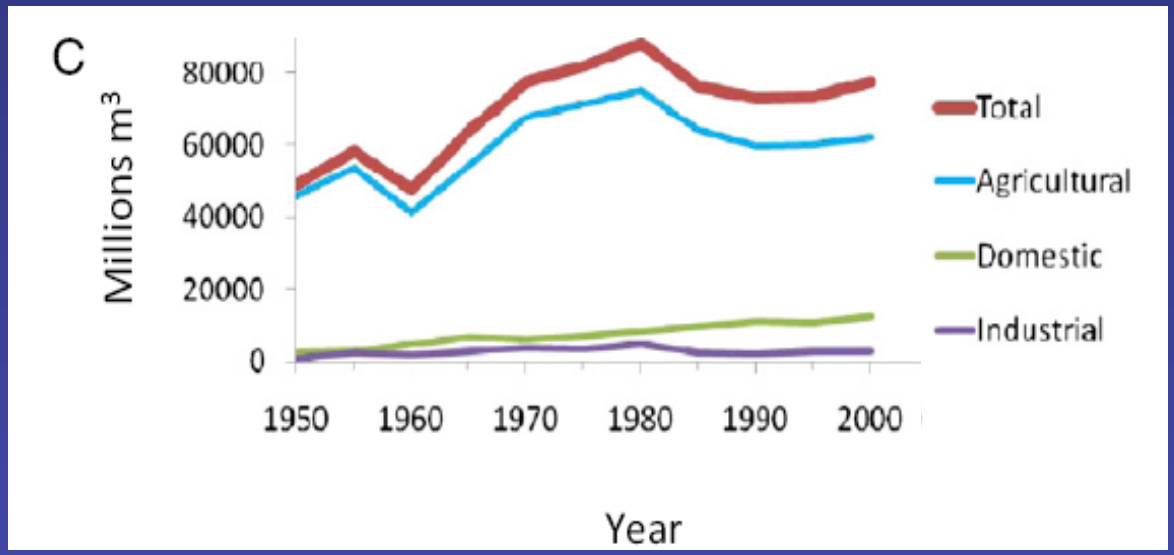


Fig. 5. WaterSim results for cumulative groundwater change (thousand cubic meters) under combined runoff conditions for the Colorado and Salt/Verde Rivers with (*A*) 100% of projected growth with current levels of mesic landscape and private backyard pools and (*B*) 50% of projected growth and elimination of mesic landscaping and private backyard pools.



Gober and Kirckwood, 2010
PNAS





MacDonald 2010 PNAS

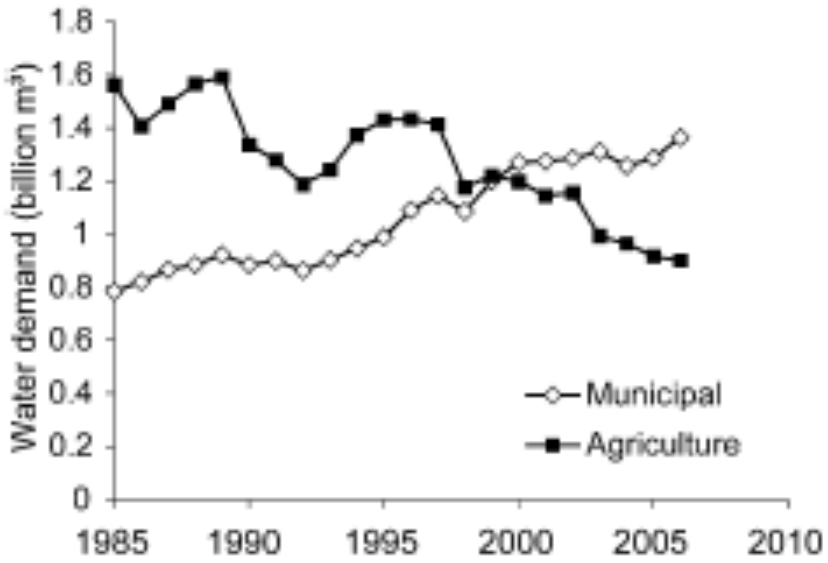


Fig. 1. Municipal and agricultural demand in billion cubic meters from 1985 to 2006. Source is the Arizona Department of Water Resources (http://www.azwater.gov/AzDWR/WaterManagement/Assessments/default.htm).

Gober and Kirckwood, 2010 PNAS

North American Drought Monitor

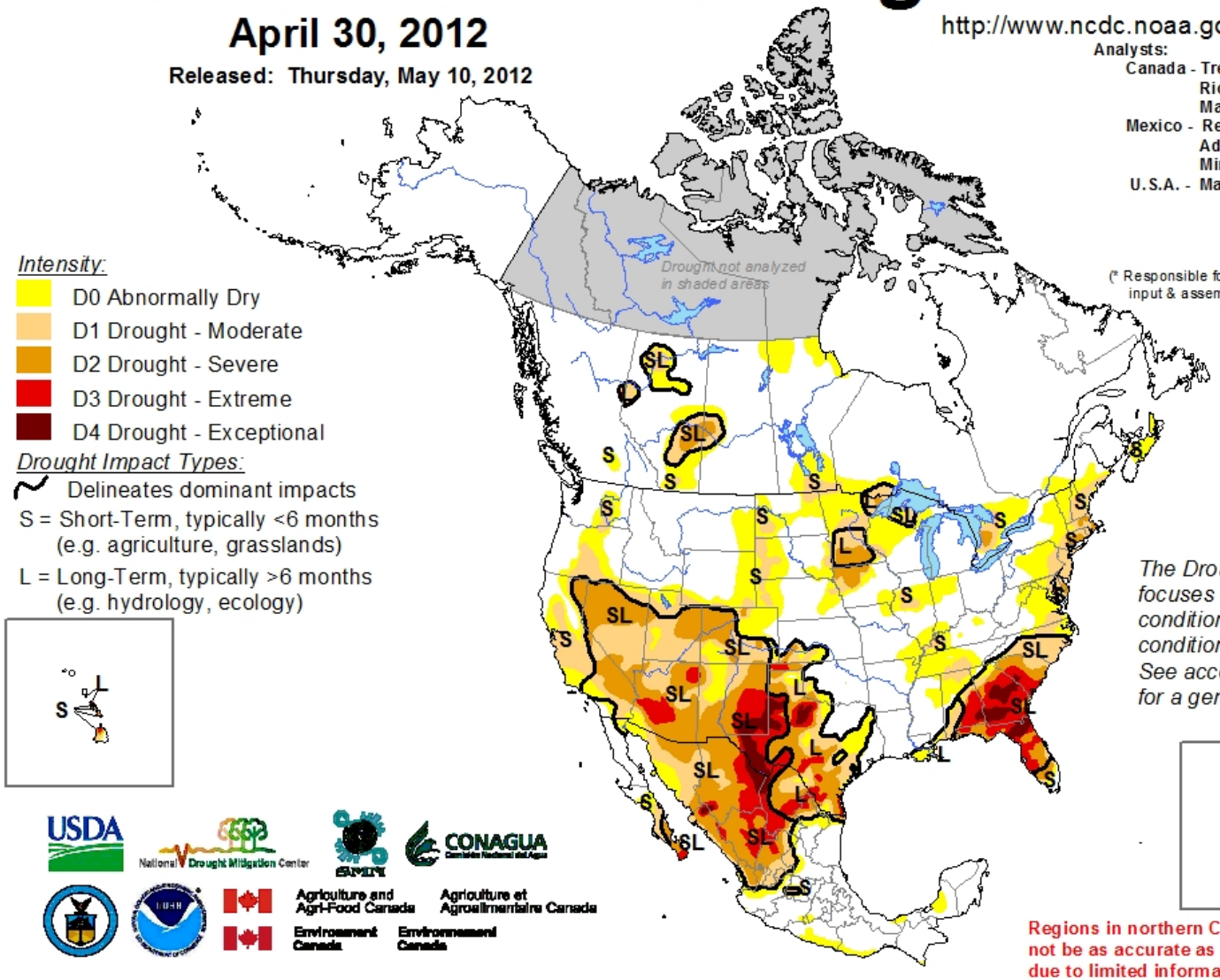
April 30, 2012

Released: Thursday, May 10, 2012

http://www.ncdc.noaa.gov/nadm.html

Analysts:
Canada - Trevor Hadwen
Richard Rieger
Mallory MacDonald
Mexico - Reynaldo Pascual*
Adelina Albanil*
Minerva López*
U.S.A. - Matthew Rosencrans

(* Responsible for collecting analysts' input & assembling the NA-DM map)



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

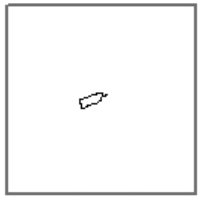
Drought Impact Types:

Delineates dominant impacts

S = Short-Term, typically <6 months (e.g. agriculture, grasslands)

L = Long-Term, typically >6 months (e.g. hydrology, ecology)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text for a general summary.

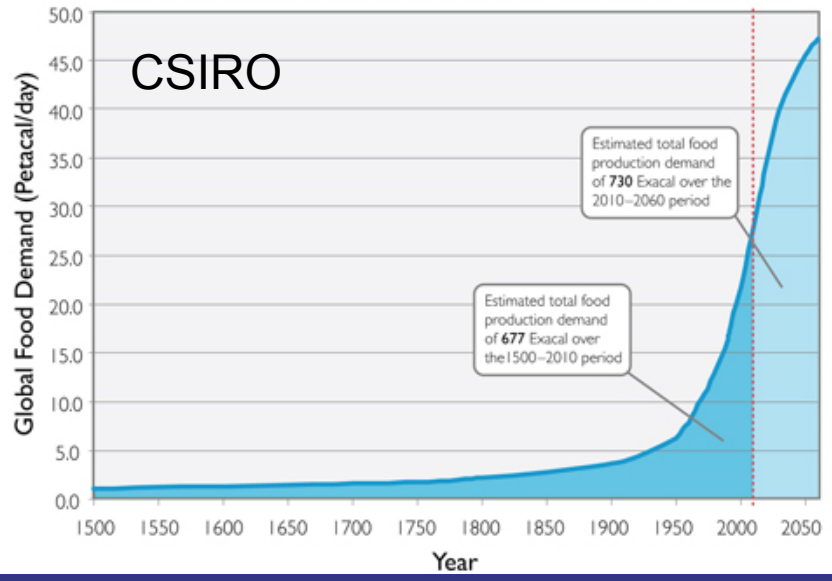


Regions in northern Canada may not be as accurate as other regions due to limited information.

USDA | National Drought Mitigation Center | CONAGUA | Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada | Environment Canada | Environnement Canada

Thank you

The challenge to produce enough food will be greater over the next 50 years than in all human history



ASSUMPTIONS

- Continued growth in per capita food consumption in developing countries to equal developed countries (3330kcal/day) by 2050
- Diversion of land & water etc for biofuels grows to 15% by 2050
- No food wastage prior to 1920, increasing to current levels of 30%, then flat (i.e. no reduction in food waste in future)

NOTE: a Petacal is 10^{15} calories
an Exacal is 10^{18} calories