

# The Vulnerability of U.S. Water Resources to Climate Change

Capitol Hill AMS/AAAS Briefing

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Pacific Institute, Oakland, California  
May 2011



**PACIFIC  
INSTITUTE**

Research for People and the Planet



**Health**



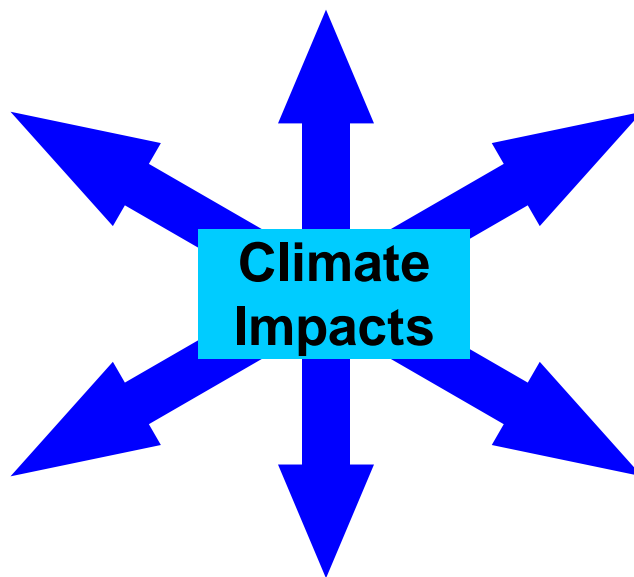
**Water**



**Forestry**



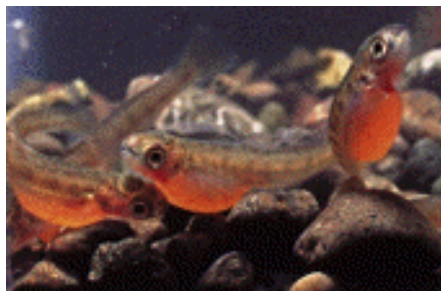
**Energy**



**Climate  
Impacts**



**Agriculture**



**Environment**



Increased  
air temperature

## Climate Change Effects on Water Resources

Total precipitation may increase or decrease



More precipitation as rain than snow  
due to higher temperatures



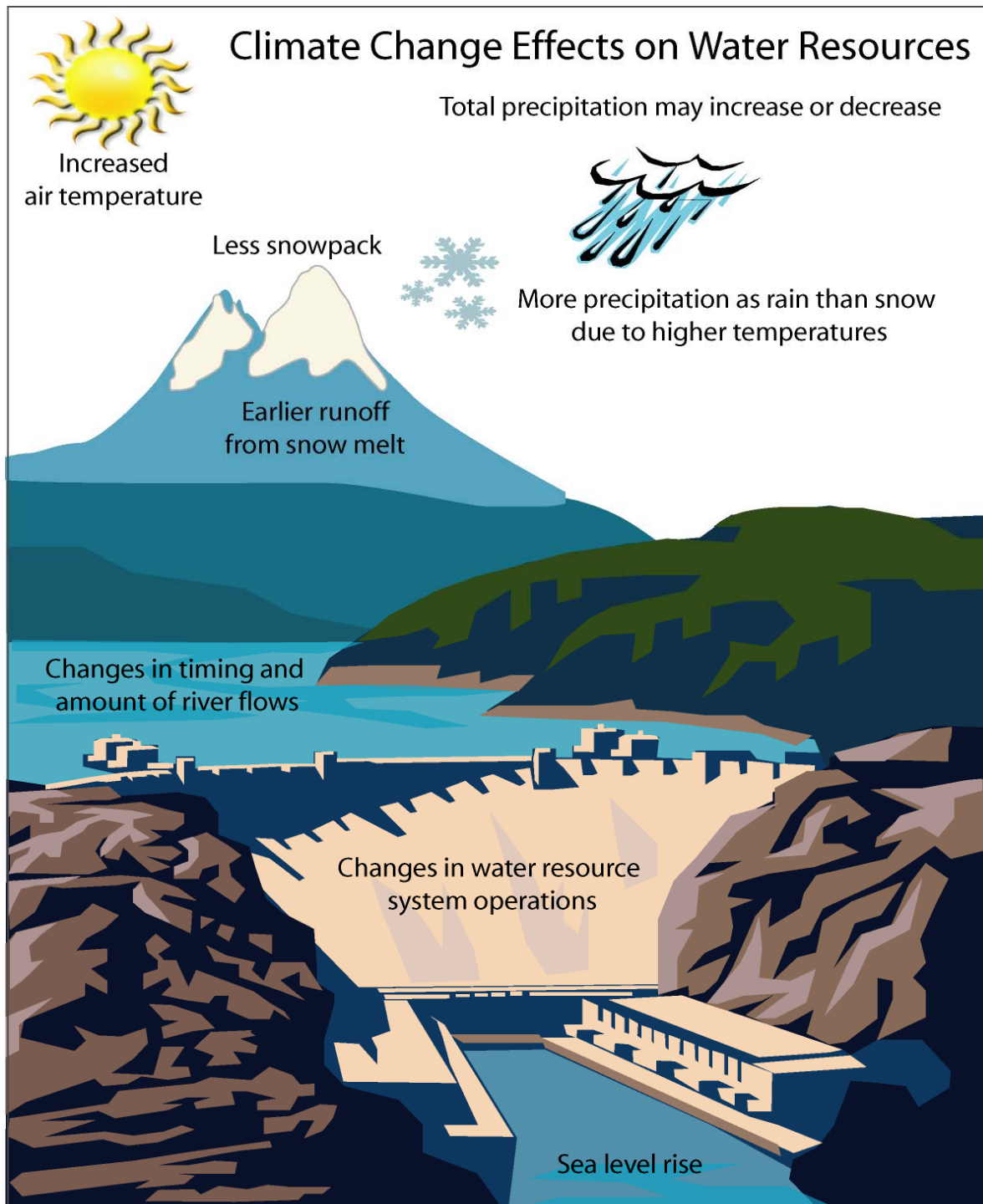
Less snowpack

Earlier runoff  
from snow melt

Changes in timing and  
amount of river flows

Changes in water resource  
system operations

Sea level rise



# What Can We Expect for Water from Climate Change?

- A hotter world.
- Mixed changes in precipitation (both by region and time period).
- Dramatic reductions in snowfall and accelerating snowmelt; related changes in runoff *timing*.
- Rising sea-level with impacts on groundwater quality and coastal/delta ecosystems.
- Accelerating influence on extreme events: including floods and droughts.

# Climate Changes are Already Affecting U.S. Water Resources

- More than 10 years ago, the US National Climate Assessment water report concluded that

*“The evidence that humans are changing the water cycle of the United States is increasingly compelling.”*

*(National Climate Assessment Water Report, 2000)*

# Observed Changes: Atmospheric Moisture is Increasing

- Total atmospheric moisture content over oceans has increased significantly since 1988.
- ***“Increases of this magnitude cannot be explained by climate noise alone.”***
- These findings are evidence of an ***“emerging anthropogenic signal*** in the moisture content of earth’s atmosphere.”

(Proceedings of the National Academy of Sciences, Santer et al. 2007)

# Observed Changes In Precipitation

- Decreases in precipitation are evident in the Mediterranean, southern Asia, and throughout Africa.
- Increases in land precipitation are occurring, notably over North America, Eurasia, and Argentina.
- In the north, more precipitation is now falling as rain rather than snow. (Mote 2003, Knowles et al. 2006)
- Earlier onset of spring over the last 50 years means the liquid precipitation season is 3 weeks longer. (Trenberth et al. 2007a)

# Observed Changes in Droughts; Intense Rain

- Drought has generally increased throughout the 20th century. (Dai et al. 2004, Trenberth et al. 2007a)
- Very dry land areas across the globe have more than doubled in extent since the 1970s. (Dai et al. 2004)
- Increases in heavy rains are generally found to be occurring in most places.
- Extreme flooding has increased in the 20th century. (Milly et al. 2002)



## Munich Re: (one of the world's leading reinsurers)

- ***“The only plausible explanation for the rise in weather-related catastrophes is climate change. The view that weather extremes are more frequent and intense due to global warming coincides with the current state of scientific knowledge”.***

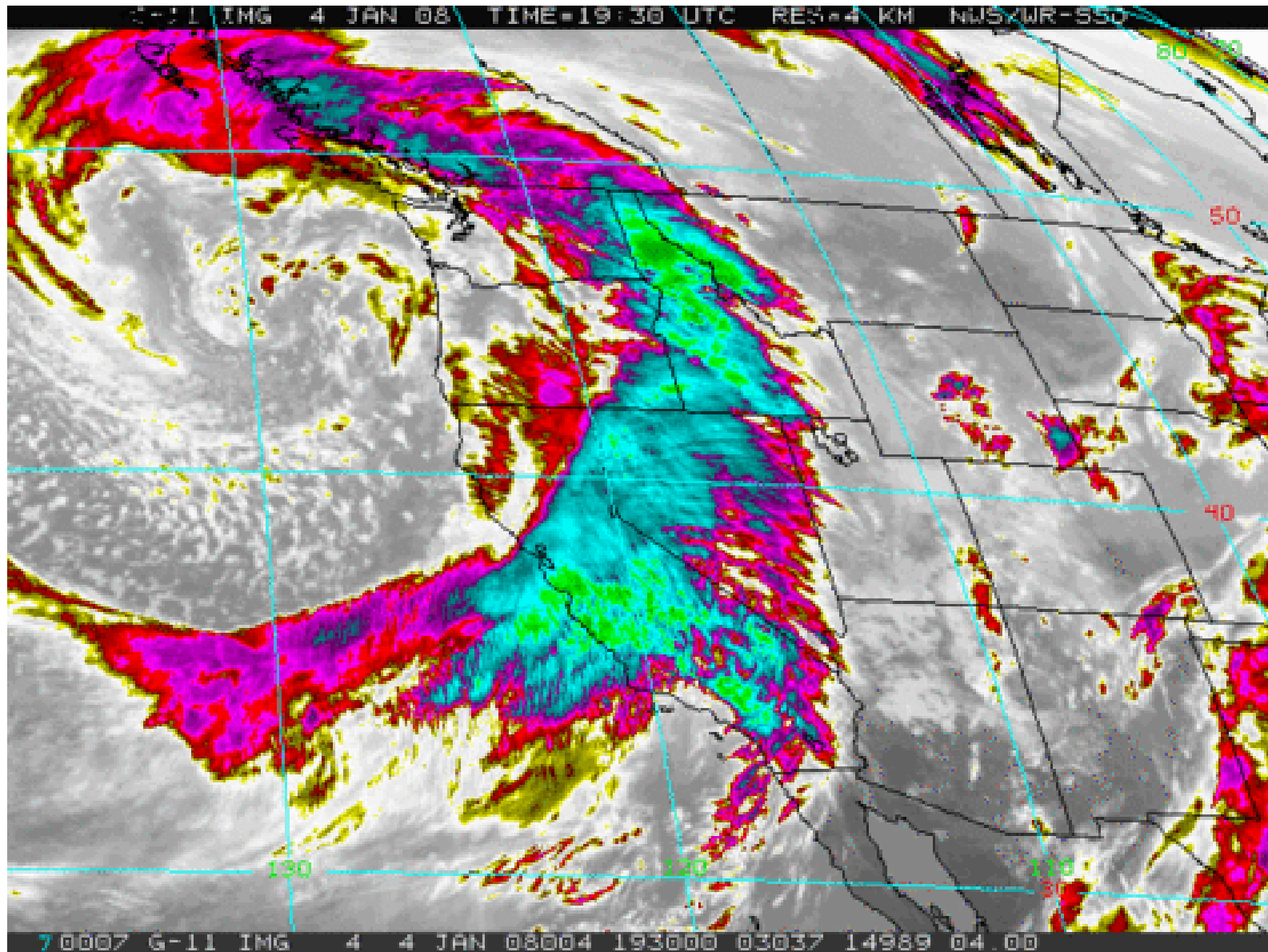
[http://www.munichre.com/en/media\\_relations/press\\_releases/2010/2010\\_09\\_27\\_press\\_release.aspx](http://www.munichre.com/en/media_relations/press_releases/2010/2010_09_27_press_release.aspx).

All extreme weather events are now  
subject to human influence.

We are loading the dice and painting  
higher numbers on them.



# Extreme Weather is Influenced by Climate Change

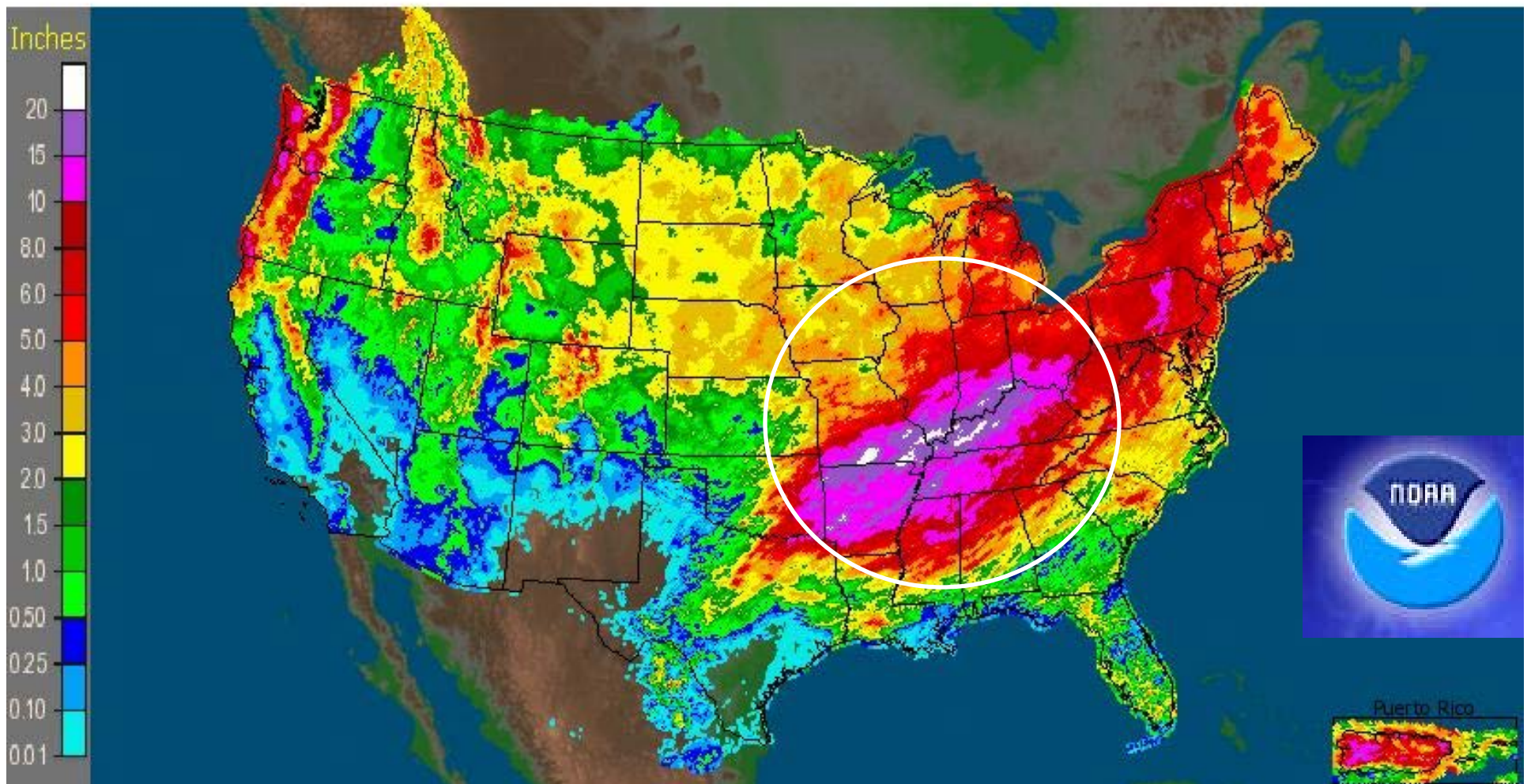


# Scientific Evidence for Growing Climate Risks of Flooding in Mississippi Basin

- “Floods are becoming more frequent and more severe over much of the Mississippi River basin.” R. Criss and W. Winston (Washington Univ. St. Louis): <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2599774/>
- “climate- or land-use-driven discharge changes were detectable” along the river. N. Pinter et al., <http://www.agu.org/journals/ABS/2008/2008GL035987.shtml>.
- “Human-induced increases in greenhouse gases have contributed to the observed intensification of heavy precipitation events found over approximately two-thirds of data-covered parts of Northern Hemisphere land areas.” Seung-Ki Min et al., <http://www.nature.com/nature/journal/v470/n7334/full/nature09763.html>.

# Precipitation *Intensity* is Rising Above Historical Norms in Northern Hemisphere

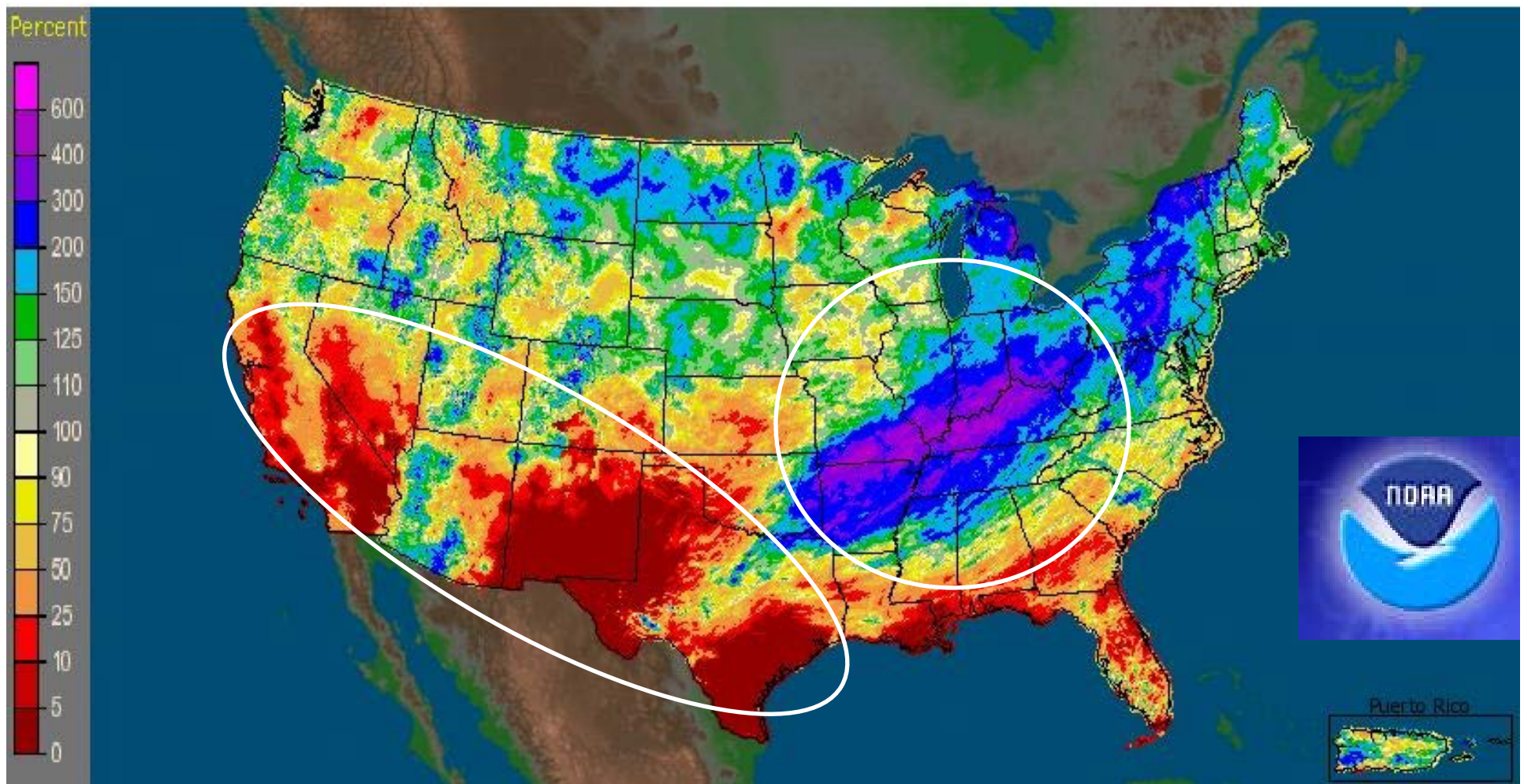
CONUS + Puerto Rico: Current 30-Day Observed Precipitation  
Valid at 5/7/2011 1200 UTC- Created 5/7/11 23:38 UTC





# Over the Past 30 Days? **300 to 600%** of Average Precipitation (Mississippi Basin)

CONUS + Puerto Rico: Current 30-Day Percent of Normal Precipitation  
Valid at 5/7/2011 1200 UTC- Created 5/7/11 23:38 UTC





Flooding on the Mississippi: There were two “1-in-500 year” flood events within a few years of each other (1993, 2000) in parts of the Basin...

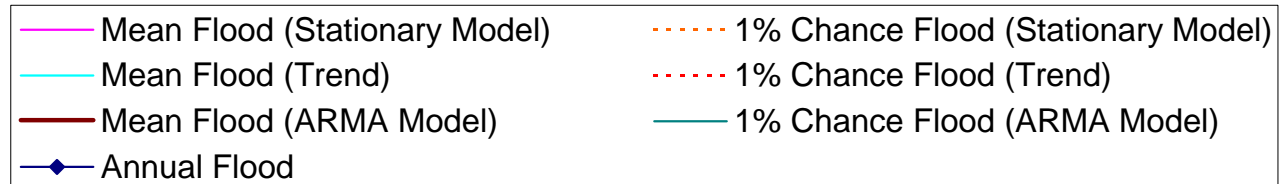
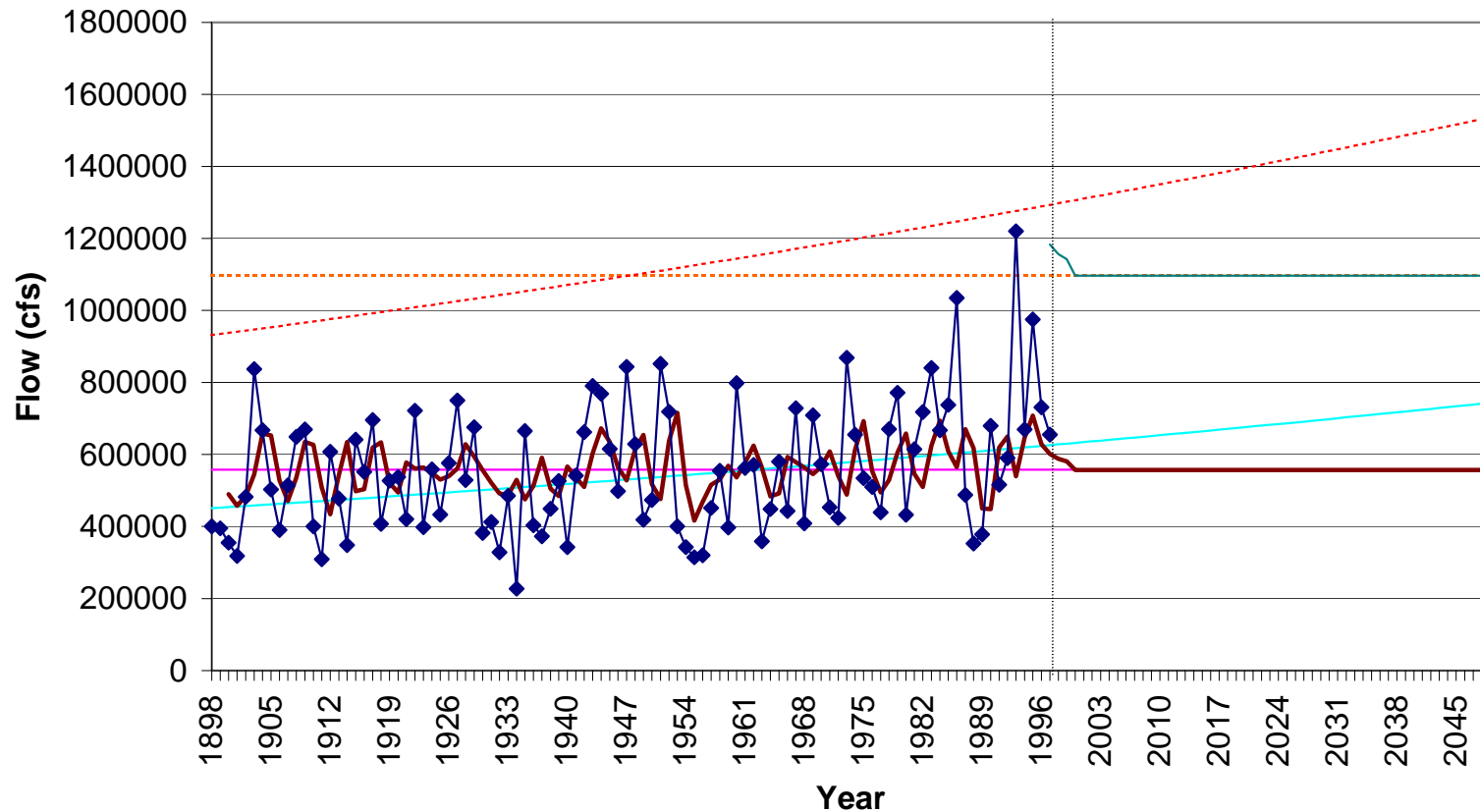
Then again in 2008.

And now: 2011

AP 2000



# U.S. Army Corps: Flood Risk is Growing on Mississippi

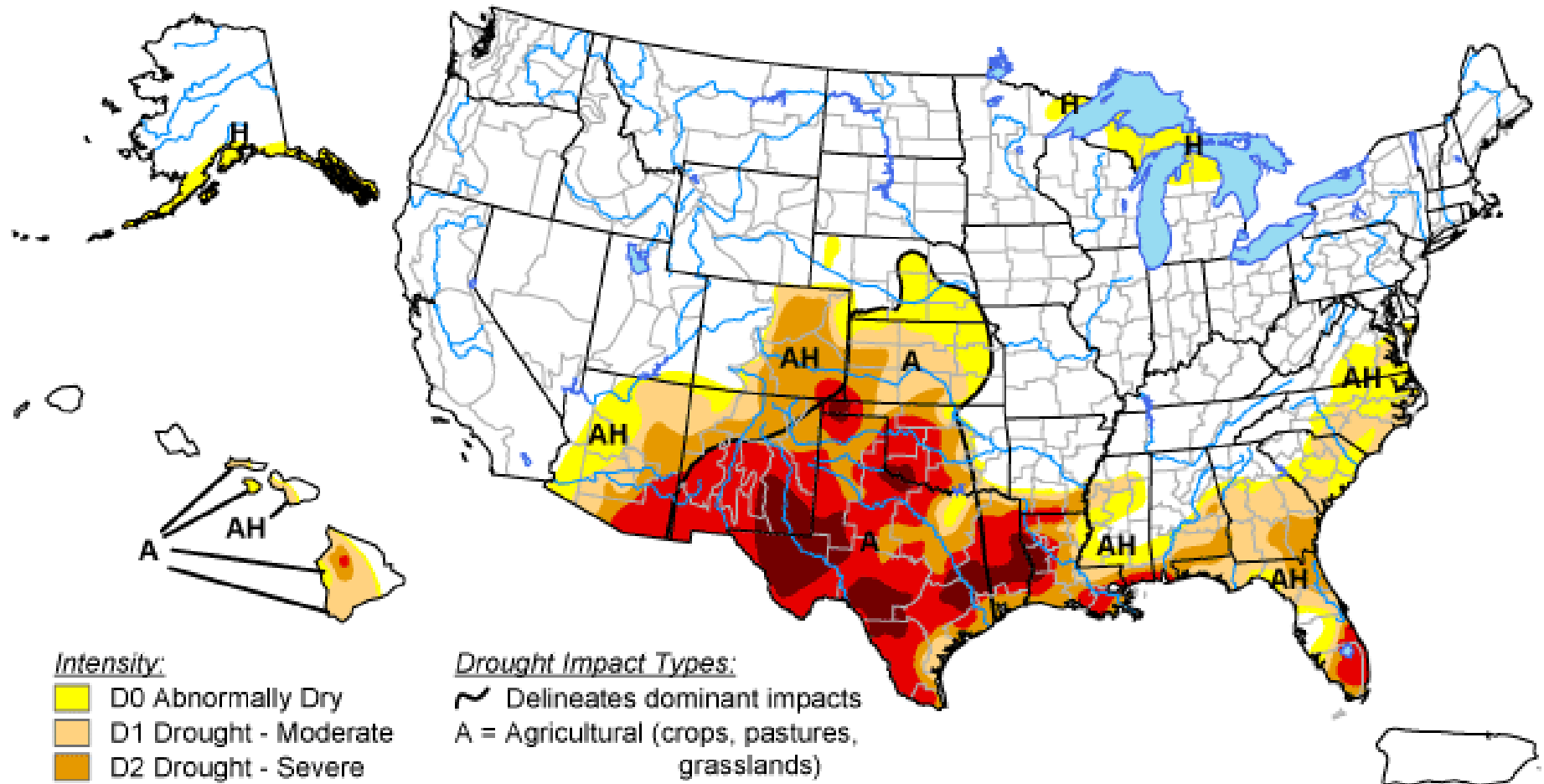




# U.S. Drought Monitor

May 3, 2011

Valid 8 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
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)

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

<http://drought.unl.edu/dm>



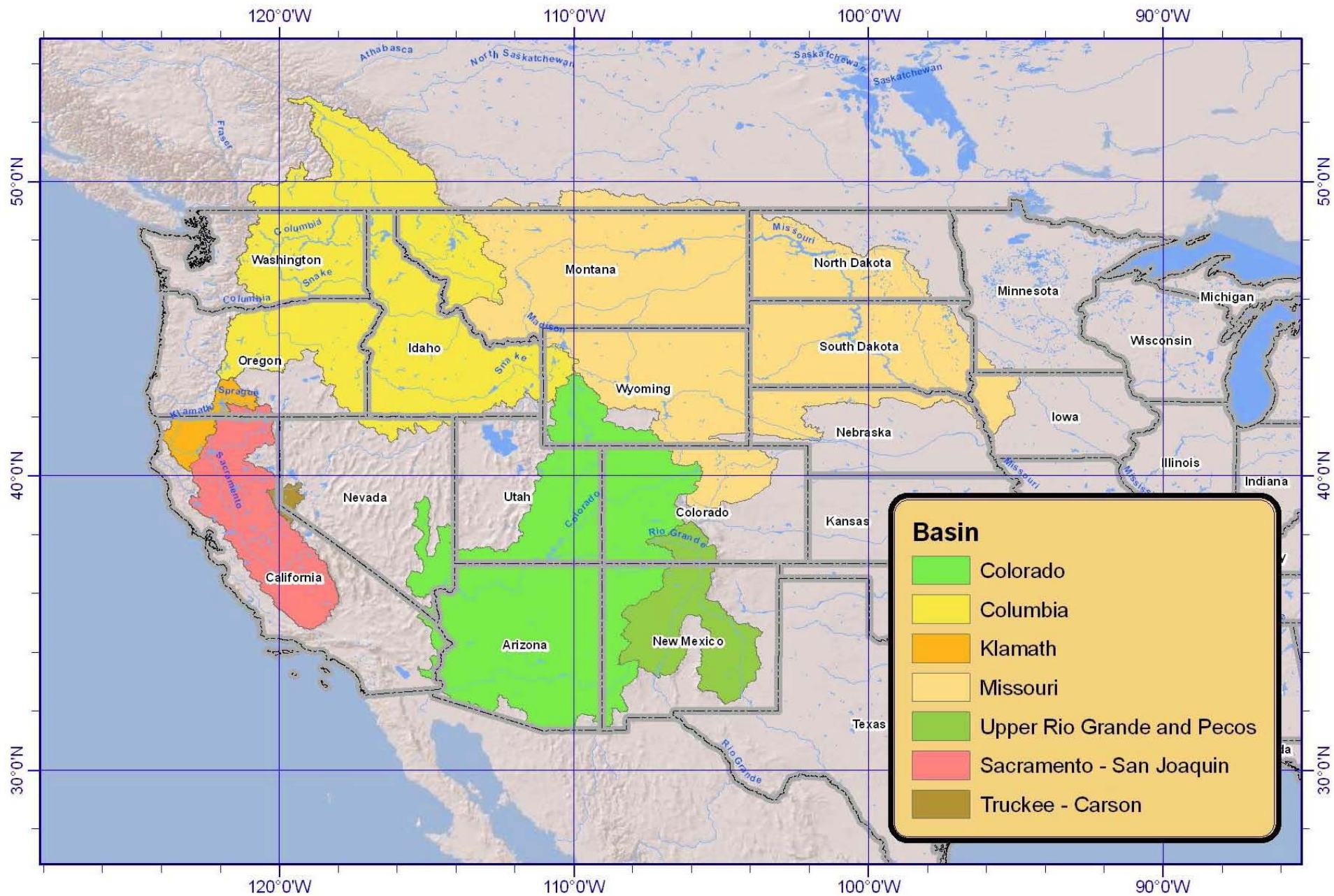
**Released Thursday, May 5, 2011**

**Author: Rich Tinker, NOAA/NWS/NCEP/CPC**

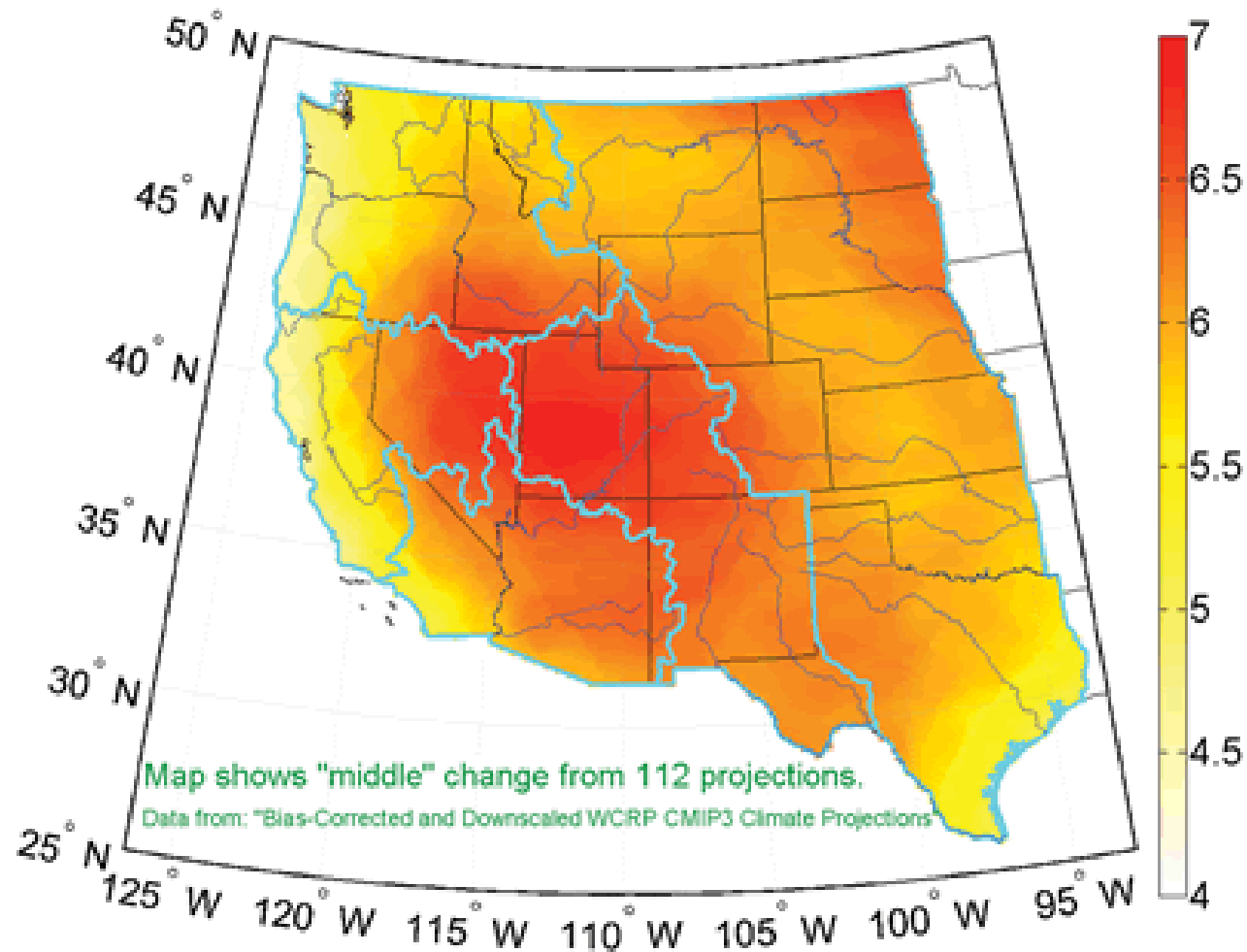
# Examples of What is to Come with Expected Climate Change

- New western river basin assessment (Dol, April 2011)
- Looked at eight major western river basins
- Analyzed expected changes in temperature, precipitation, snowfall, snowmelt.
- Assessed flood and drought risk, impacts on water demand, agriculture, and more.

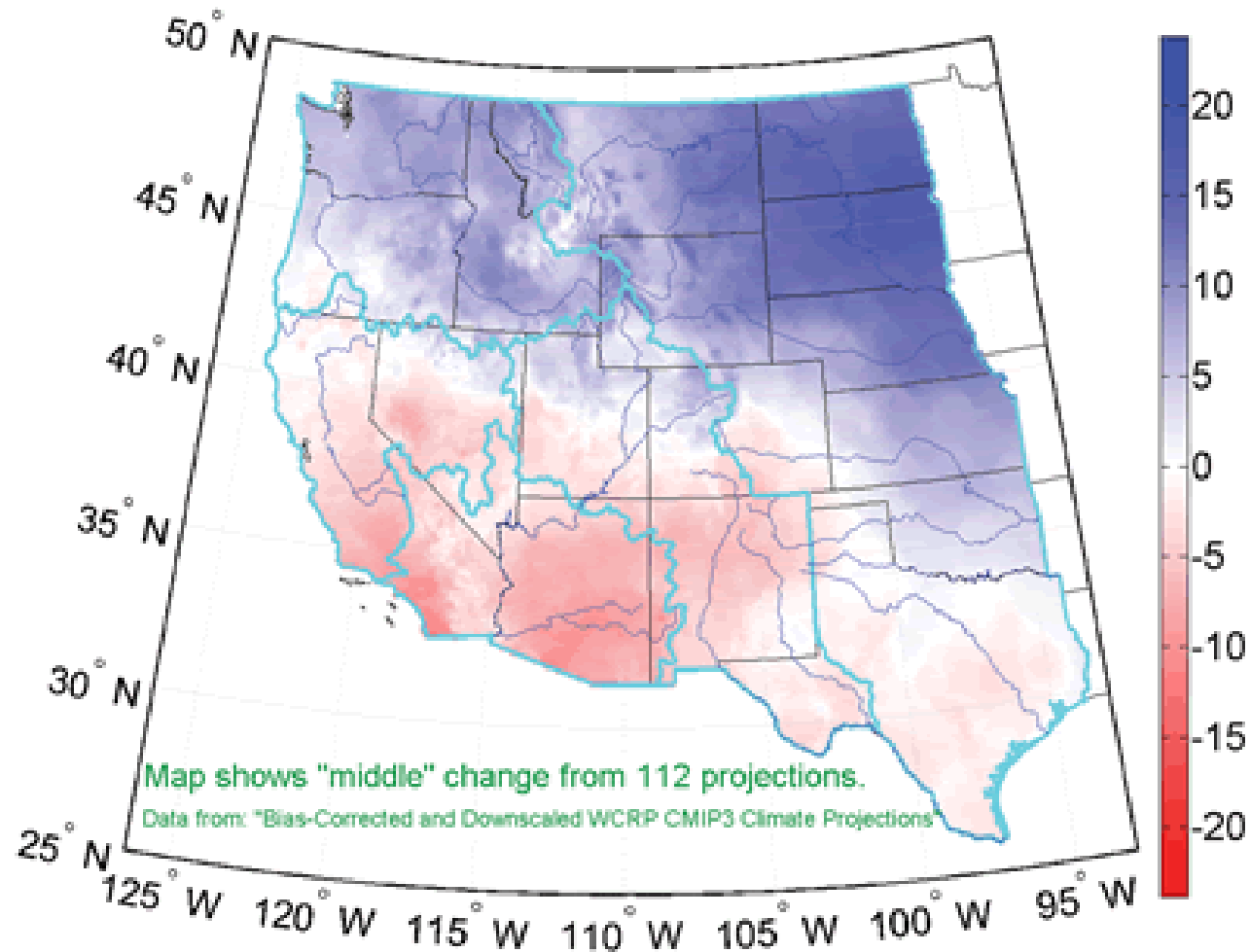
*Reclamation, SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water, Report to Congress, April 2011, P. Alexander et al.*



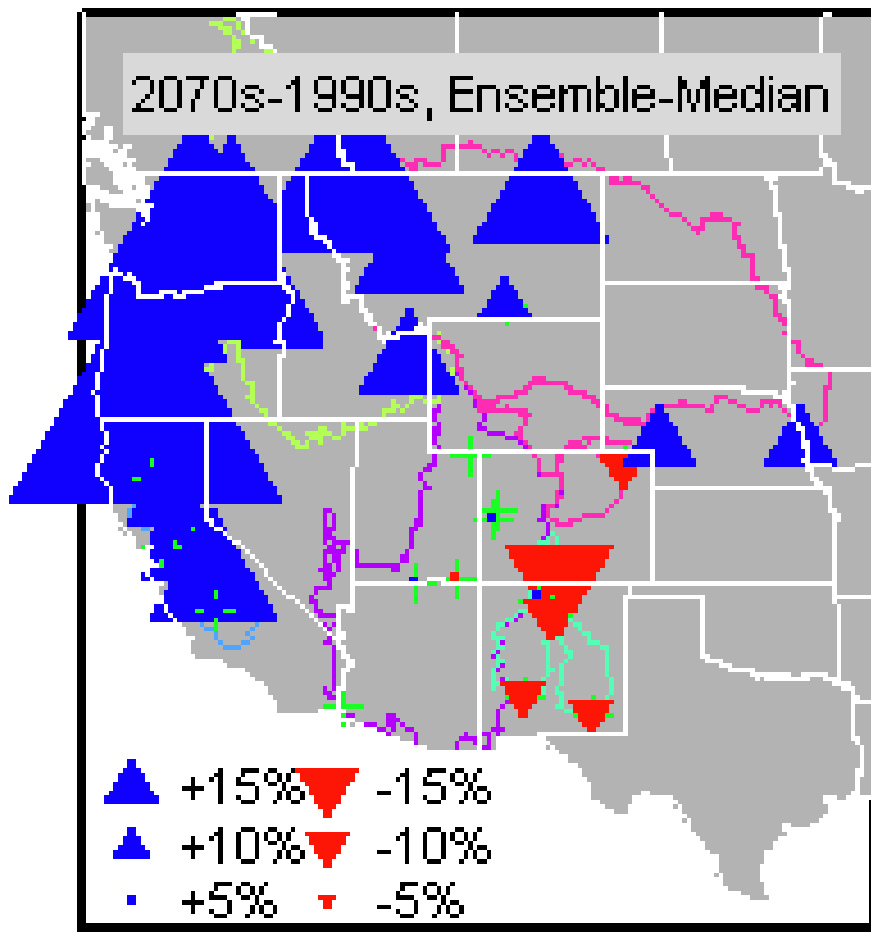
# Changes in Mean Annual Temperature (deg F) from 1950-1979 to 2070-2099



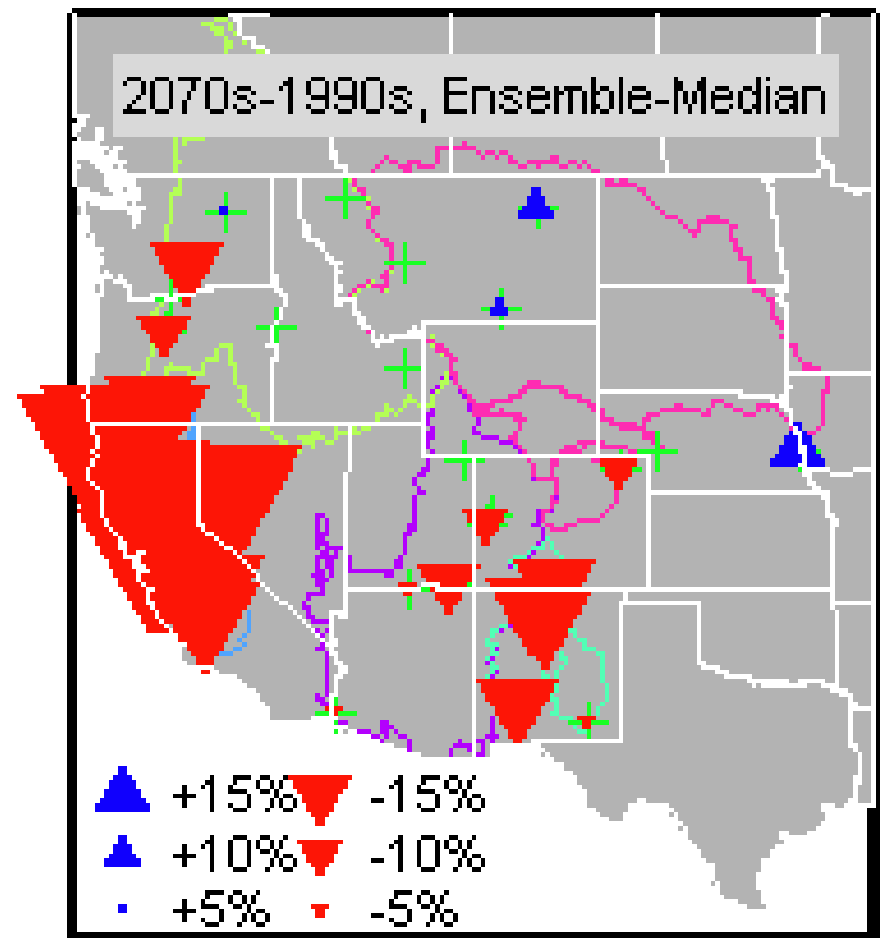
# Changes in Mean Annual Precipitation (%) from 1950-1979 to 2070-2099



# Increased Risk of Winter Floods *and* Summer Droughts



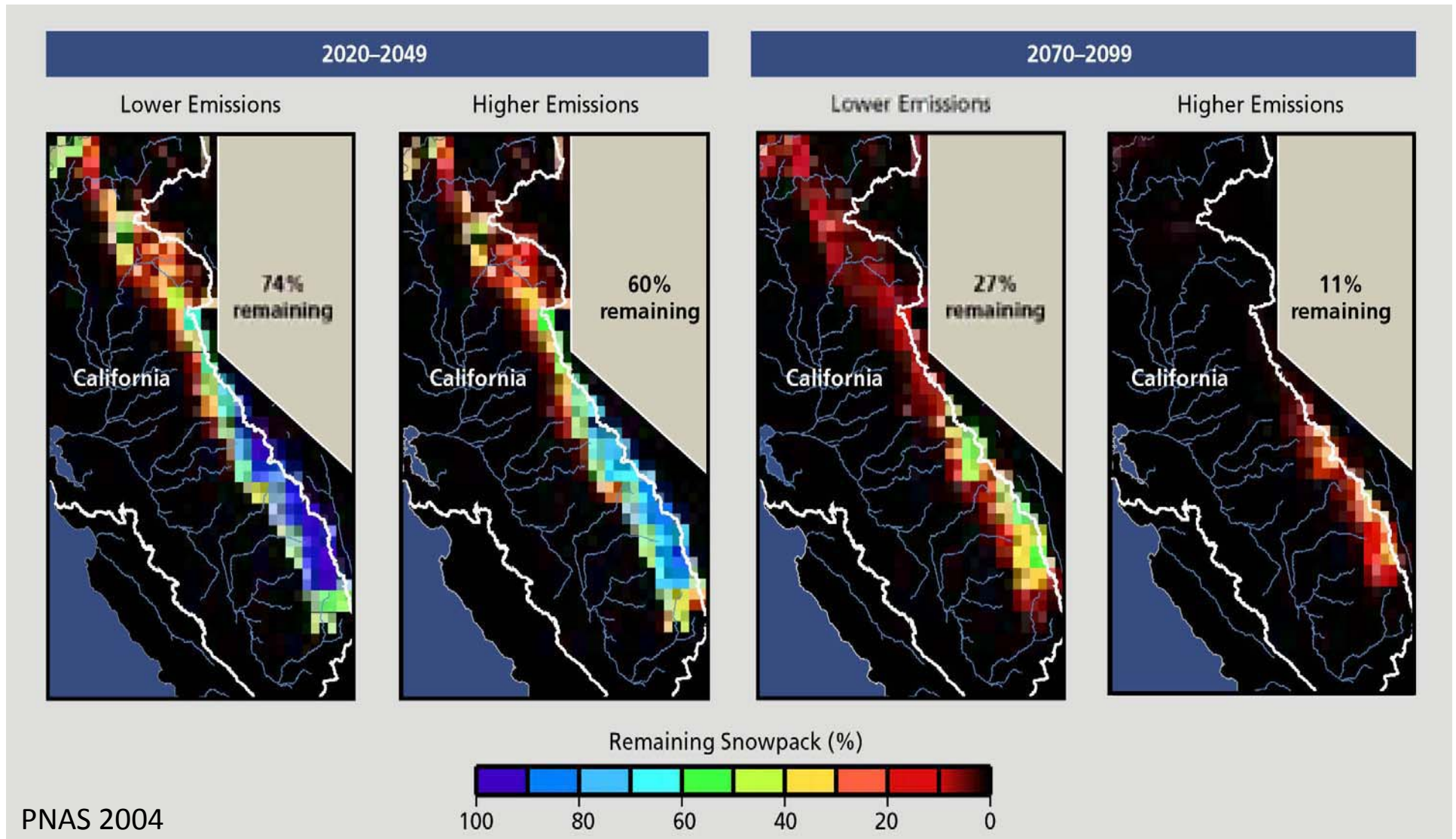
December to March Runoff



April to July Runoff

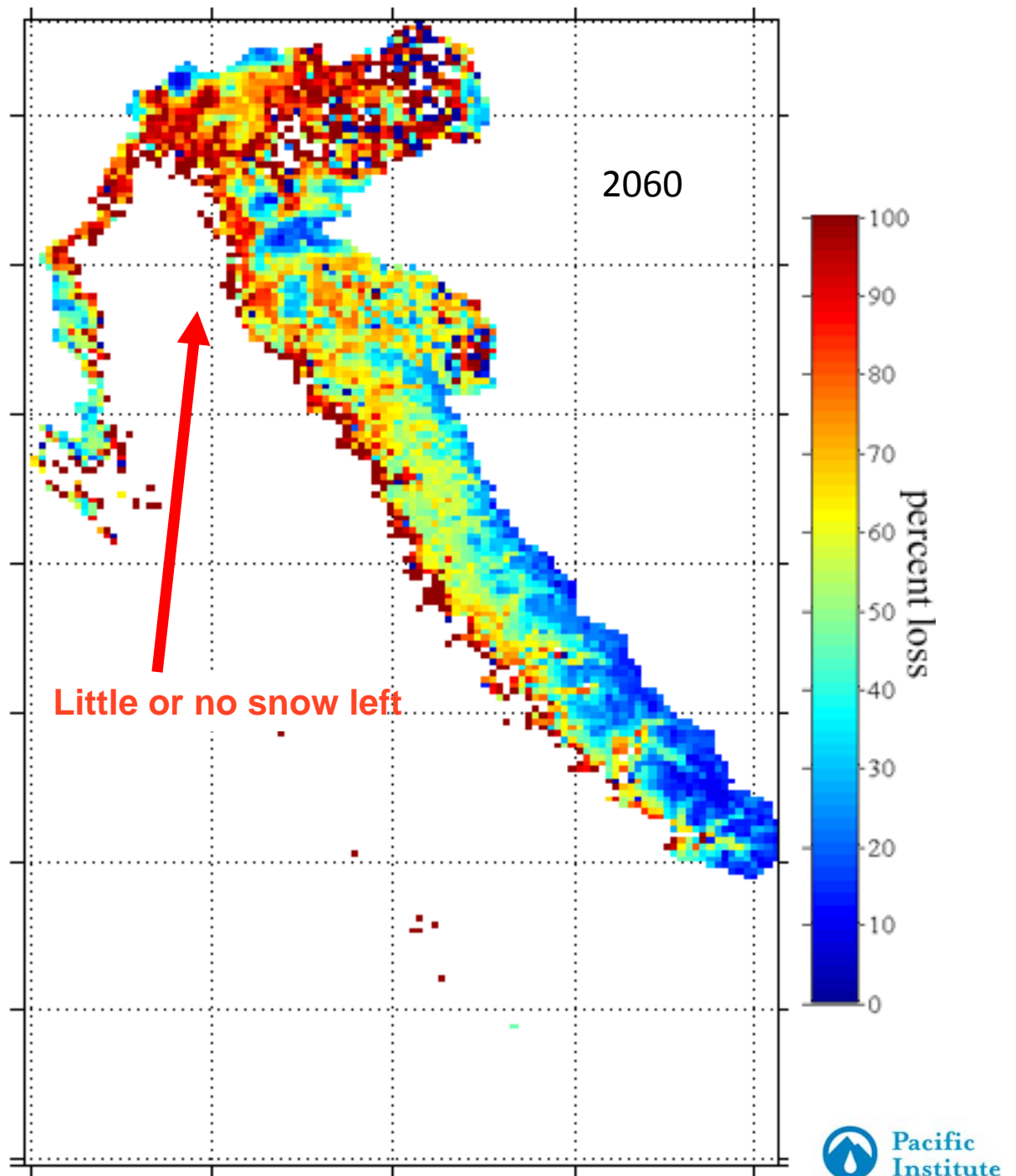


# Very High Confidence that Snowpack in Mountains will Dramatically Shrink



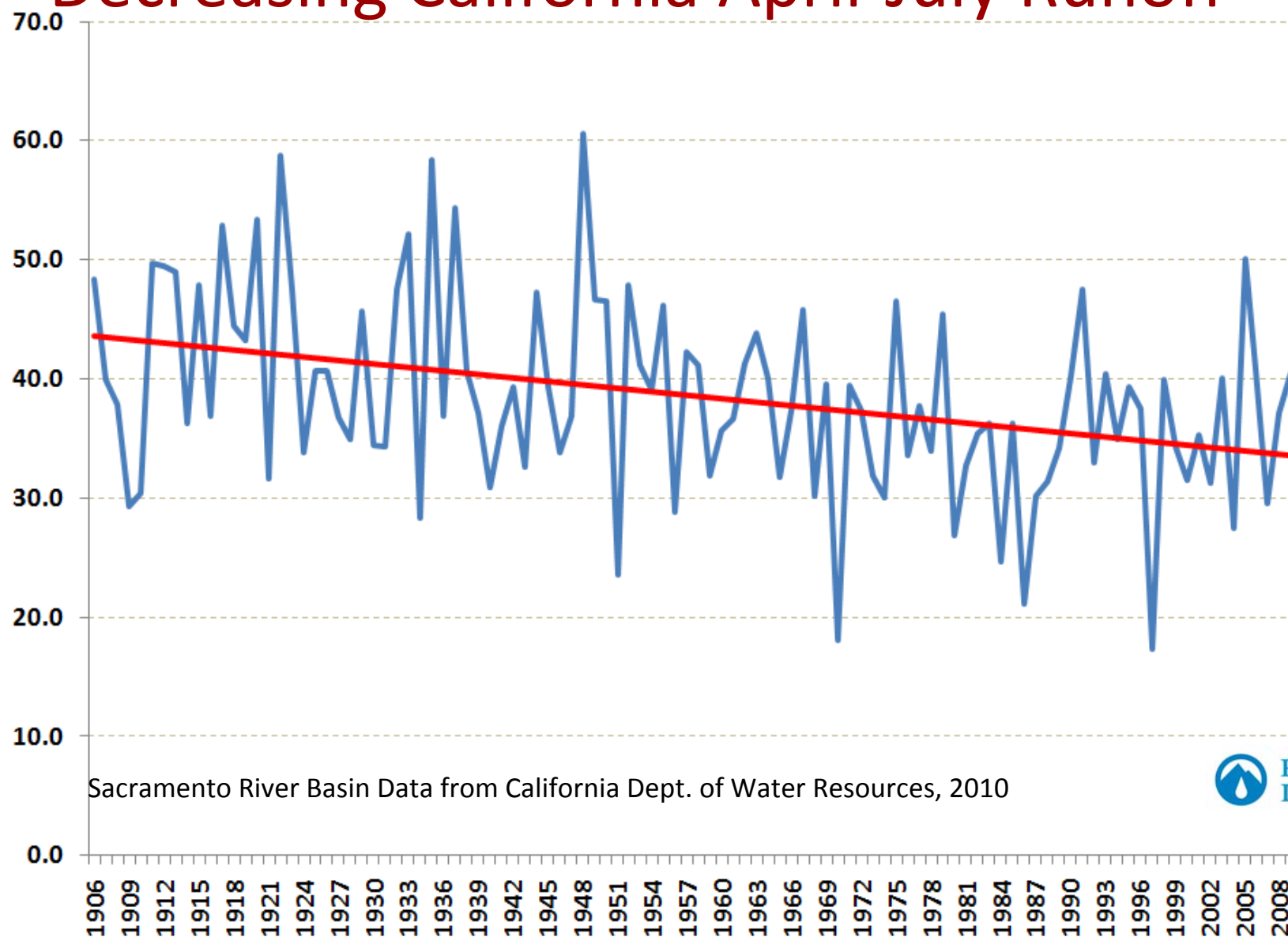
By the middle  
of this century,  
many parts of  
the California  
Sierra will  
entirely lose  
the snowpack.

Knowles & Cayan, 2004

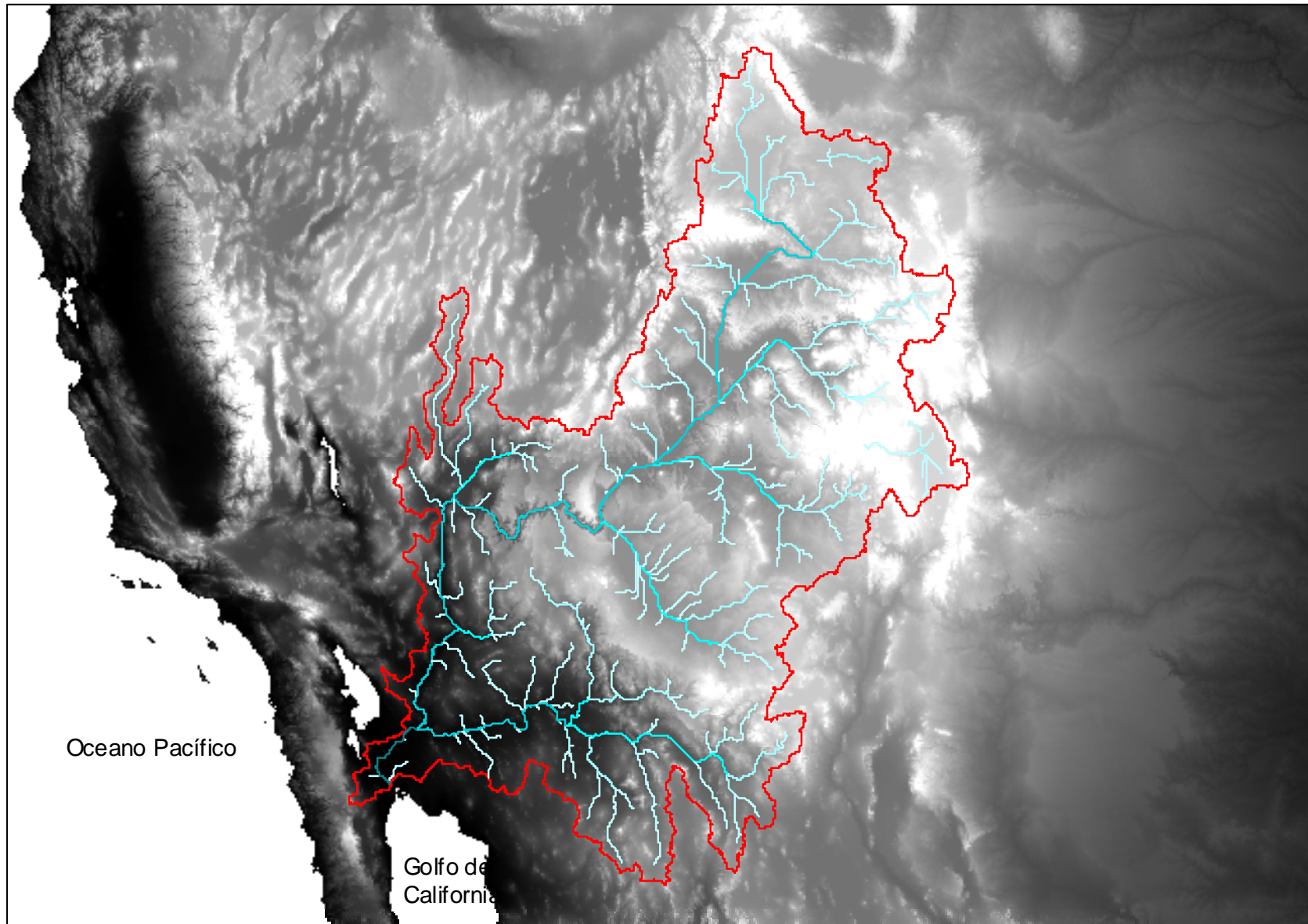




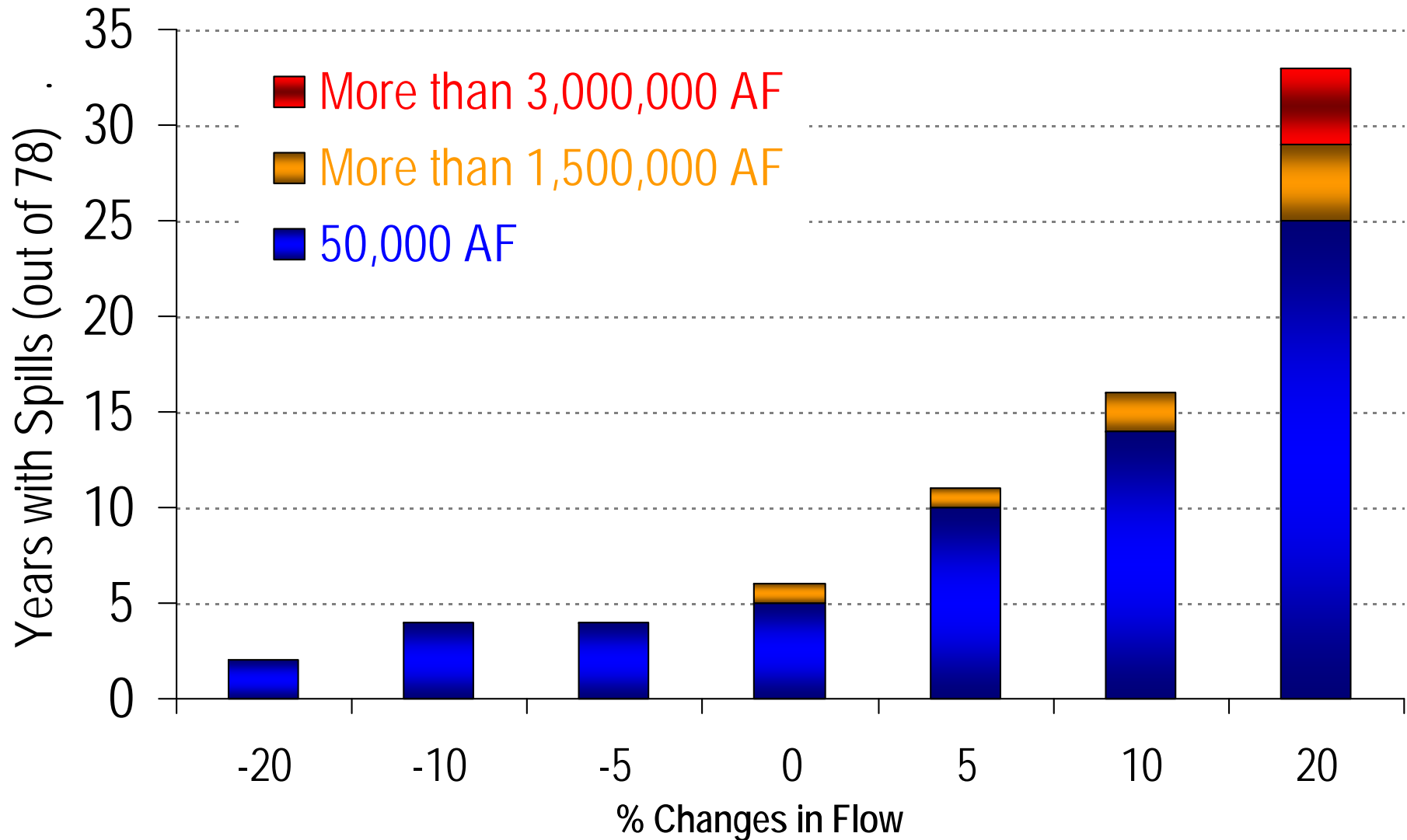
# These Changes are Already Evident: Decreasing California April-July Runoff



# Colorado River Basin

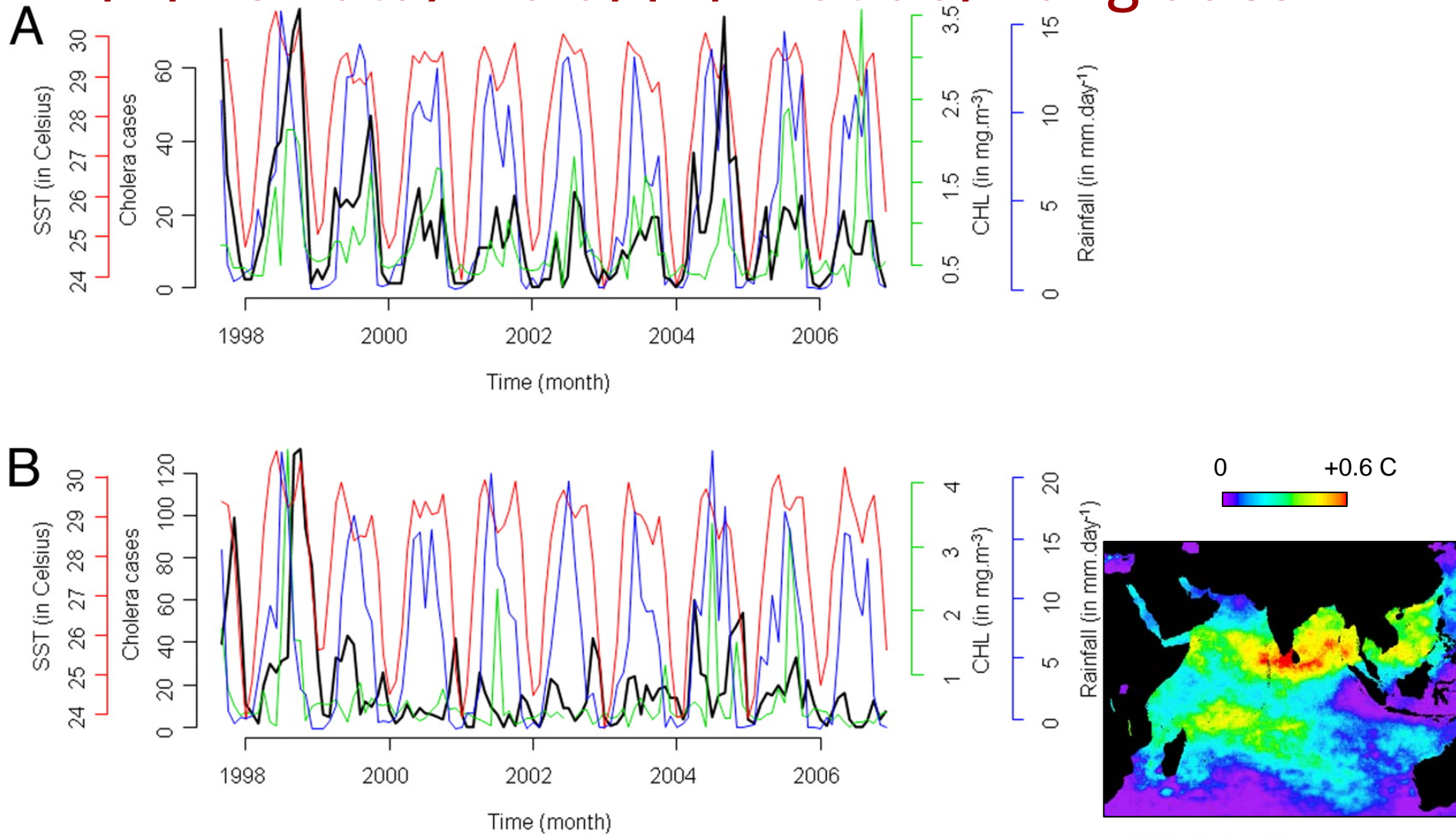


# Climate change in the Colorado River Basin: Non-linear and threshold effects



Nash and Gleick 1993

# Cholera and Sea-Surface Temperature (A) Kolkata, India, (B) Matlab, Bangladesh

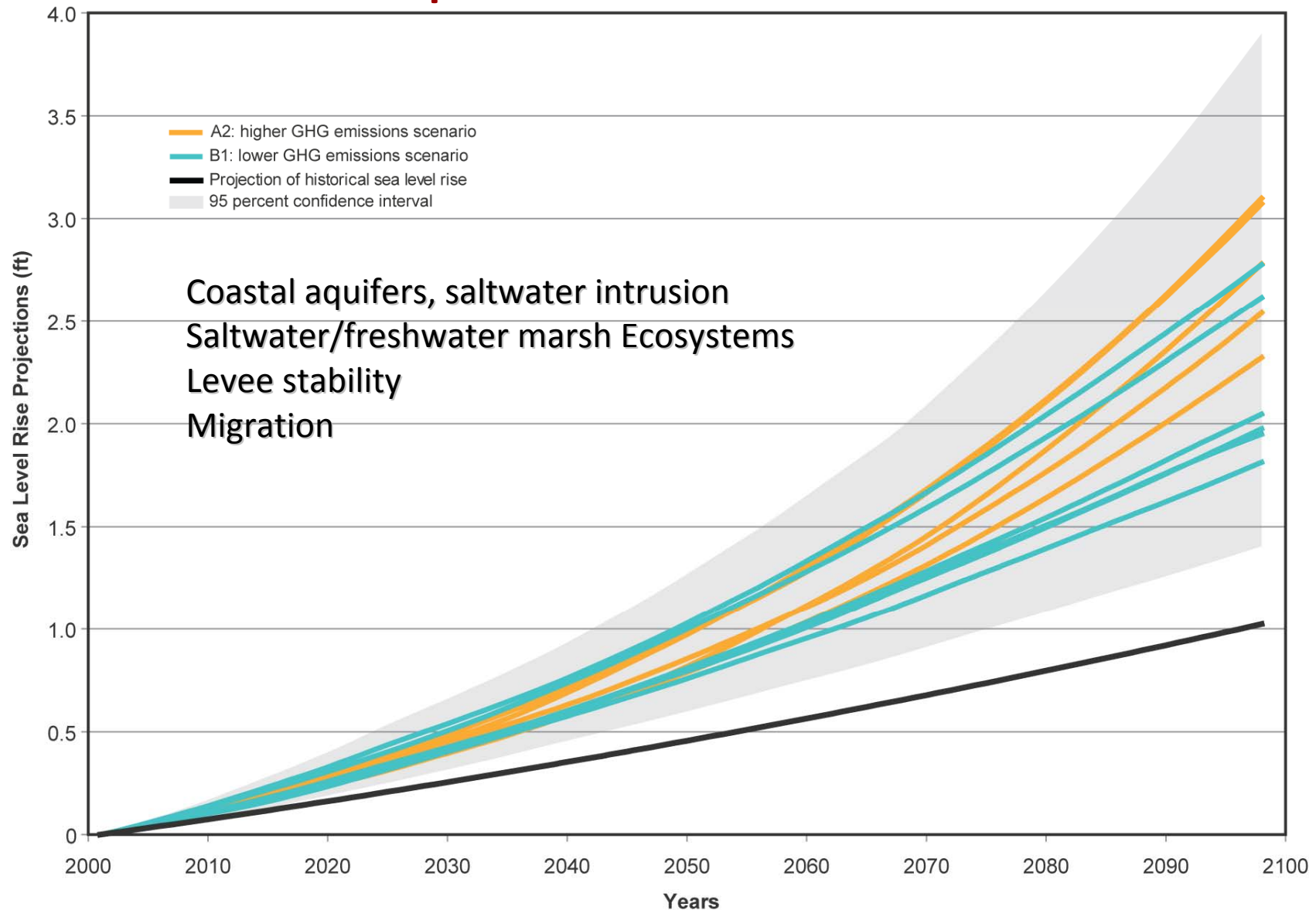


Constantin de Magny G et al. PNAS 2008;105:17676-17681

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PNAS

# Sea-Level Rise is Unavoidable, and the Consequences will be Dramatic



# Reducing the Risks of Climate Change

- Nearly 15 years ago, the American Water Works Association recommended that

*“while water management systems are often flexible, water agencies should re-examine water system designs and operating rules under a wider range of climatic conditions than traditionally used.”*

*(AWWA 1997)*



The Continued Delay in Taking Action Now  
Means:

Rapidly Worsening Impacts, and  
Unavoidable Adaptation

# Adaptation Strategies

- Integrate and coordinate mitigation and adaptation measures.
- Review the advantages and disadvantages of *existing* policies that prepare for unavoidable impacts.
- Explore ways to incorporate adaptation into new planning processes.
- Develop and implement adaptation strategies.
  - Economic
  - Technological
  - Institutional
  - Regulatory
  - Educational



# 2011 Congressional Budget Cuts Will Cripple Vital Weather and Climate Services

- Among the cuts: support for replacement long-term weather forecasting polar satellites (JPSS) that provide precisely the kind of early warning that saved lives in the recent Snowmagedon event, the tornado disaster, and the Midwestern floods.
- According to the National Oceanic and Atmospheric Administration, these cuts will cause an [18-month gap in U.S. satellite weather observations](#) crucial for military preparedness, emergency storm and drought warnings, marine conditions critical to fishermen, farm weather services, and far more.
- For every \$1 saved, the nation will suffer \$3 to \$5 in additional costs.
- Without these replacement satellites, the nation will take a step backwards in its ability to forecast and respond to inevitable weather and climate-related disasters.



# THE WORLD'S WATER

2008–2009

The Biennial Report on Freshwater Resources

**Peter H. Gleick**

Heather Cooley

Michael J. Cohen

Mari Morikawa

Jason Morrison

Meena Palaniappan

- Water and Climate Change
- Water in China
- Status of the Millennium Development Goals for Water
- Peak Water
- Efficient Urban Water Use
- Business Reporting on Water

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[www.worldwater.org](http://www.worldwater.org)

## No scientific body of national or international standing rejects the findings of human-induced effects on global warming

- American Academy of Pediatrics
- American Association for the Advancement of Science (AAAS)
- American Chemical Society
- American College of Preventive Medicine
- American Geophysical Union
- American Institute of Biological Sciences
- American Institute of Physics
- American Medical Association
- American Meteorological Society
- American Physical Society
- American Public Health Association
- American Quaternary Association
- American Society for Microbiology
- Australian Coral Reef Society
- Australian Medical Association
- Australian Meteorological and Oceanographic Society
- Canadian Foundation for Climate and Atmospheric Sciences
- Canadian Meteorological and Oceanographic Society
- Ecological Society of America
- European Academy of Sciences and Arts
- European Federation of Geologists
- European Geosciences Union
- European Physical Society
- European Science Foundation
- Federation of Australian Scientific and Technological Societies
- Geological Society of America
- Geological Society of Australia
- Geological Society of London
- Institute of Biology (UK)
- Institute of Professional Engineers New Zealand
- Institution of Engineers Australia
- InterAcademy Council
- International Association for Great Lakes Research
- International Council of Academies of Engineering and Technological Sciences
- International Union for Quaternary Research
- International Union of Geodesy and Geophysics
- National Academies of Science of: Australia, Belgium, Brazil, Cameroon, Royal Society of Canada, the Caribbean, China, Institut de France, Ghana, Leopoldina of Germany, of Indonesia, Ireland, Accademia nazionale delle scienze of Italy, India, Japan, Kenya, Madagascar, Malaysia, Mexico, Nigeria, Poland, Royal Society of New Zealand, Russian Academy of Sciences, Senegal, South Africa, Sudan, Royal Swedish Academy of Sciences, Tanzania, Turkey, Uganda, The Royal Society of the United Kingdom, the United States, Zambia, and Zimbabwe.
- National Association of Geoscience Teachers
- Network of African Science Academies (The science academies of Cameroon, Ghana, Kenya, Madagascar, Nigeria, Senegal, South Africa, Sudan, Tanzania, Uganda, Zambia, Zimbabwe, as well as the African Academy of Sciences)
- Royal Meteorological Society (UK)
- World Federation of Public Health Associations
- World Meteorological Organization