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

Capitol Hill, Washington DC
AMS/AAAS Briefing

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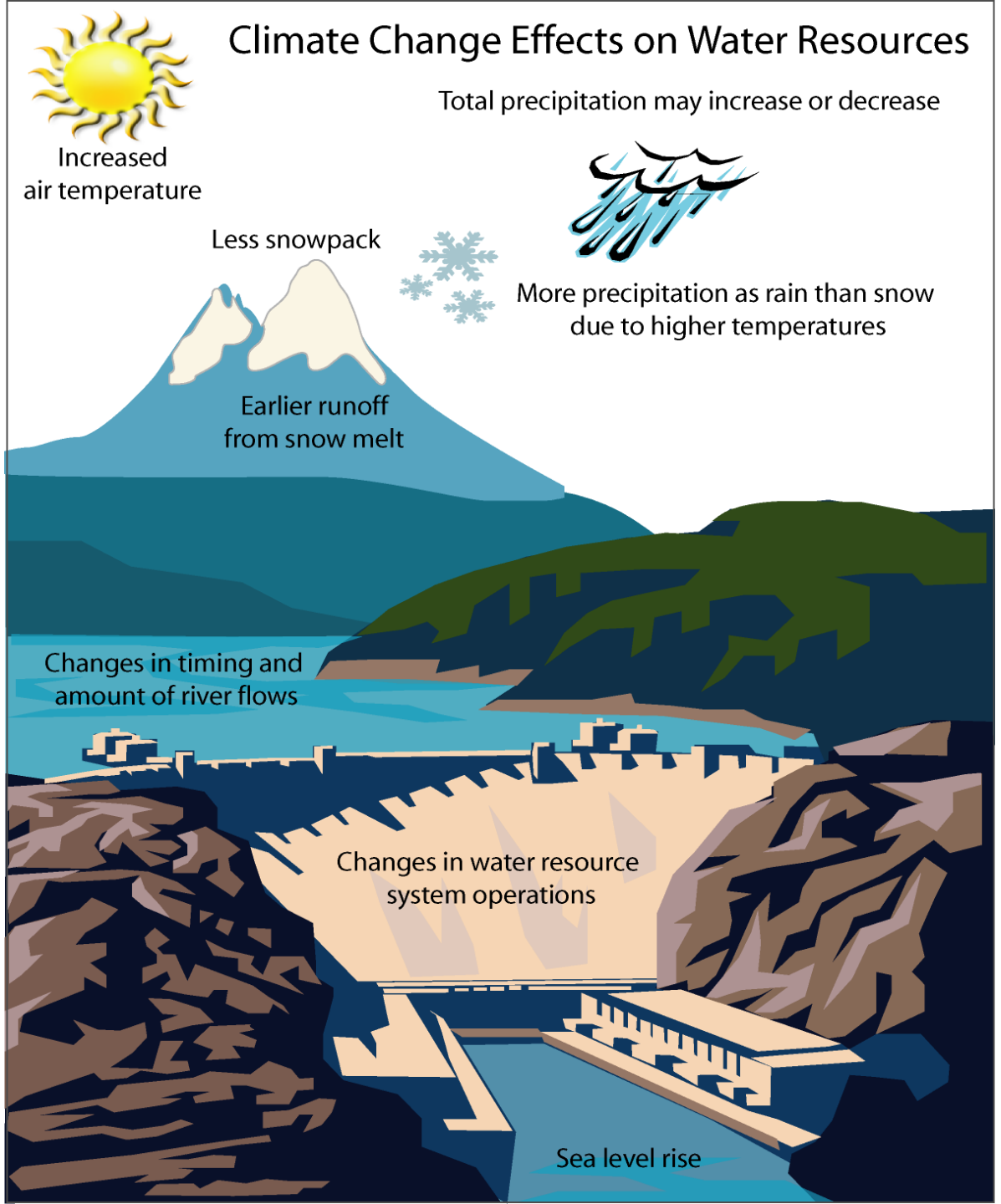
Climate Change Effects on Water Resources



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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.

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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*)

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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)

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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.

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All extreme weather events are now subject to human influence.

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

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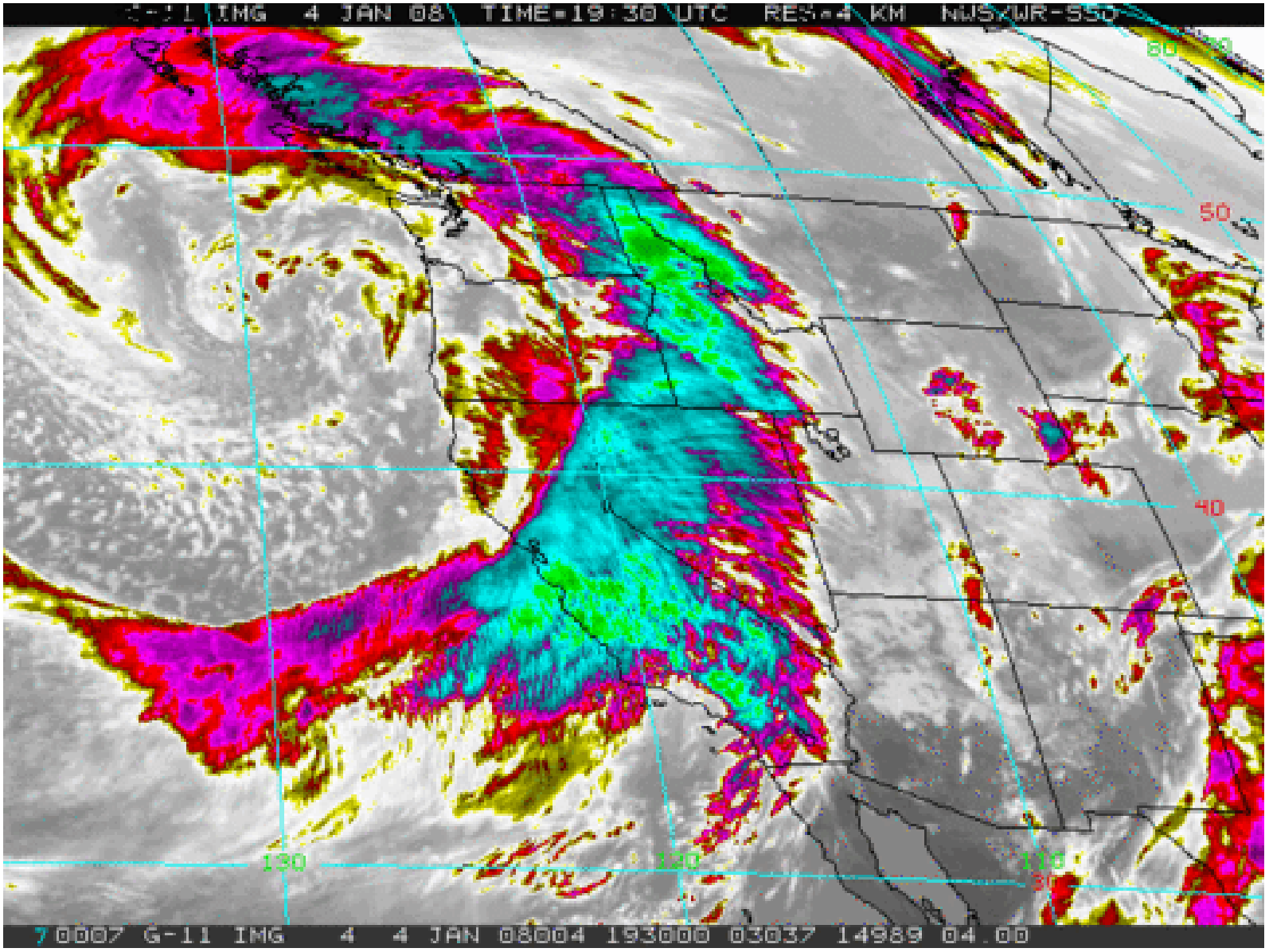
Extreme Weather is Influenced by Climate Change



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.

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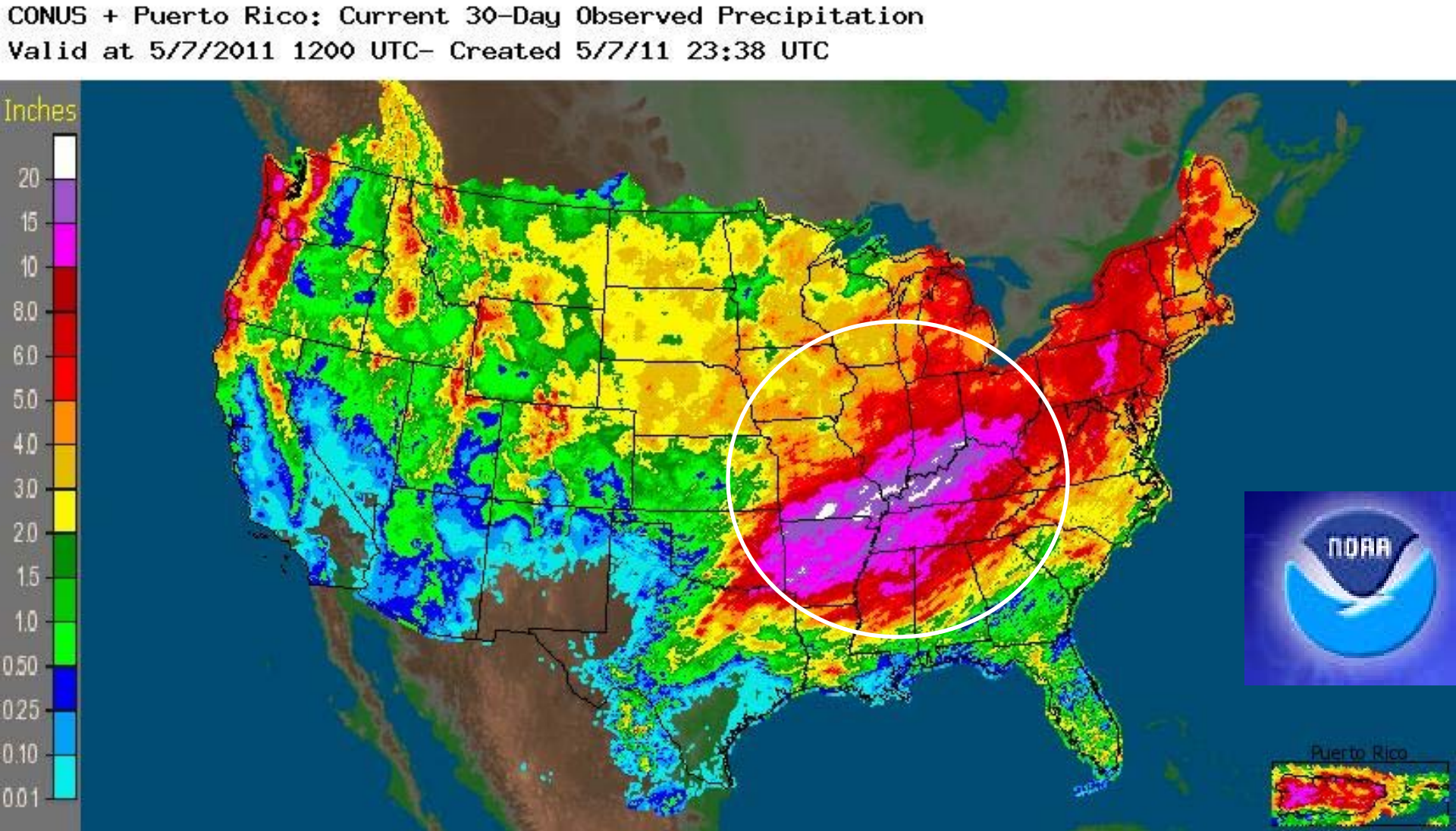
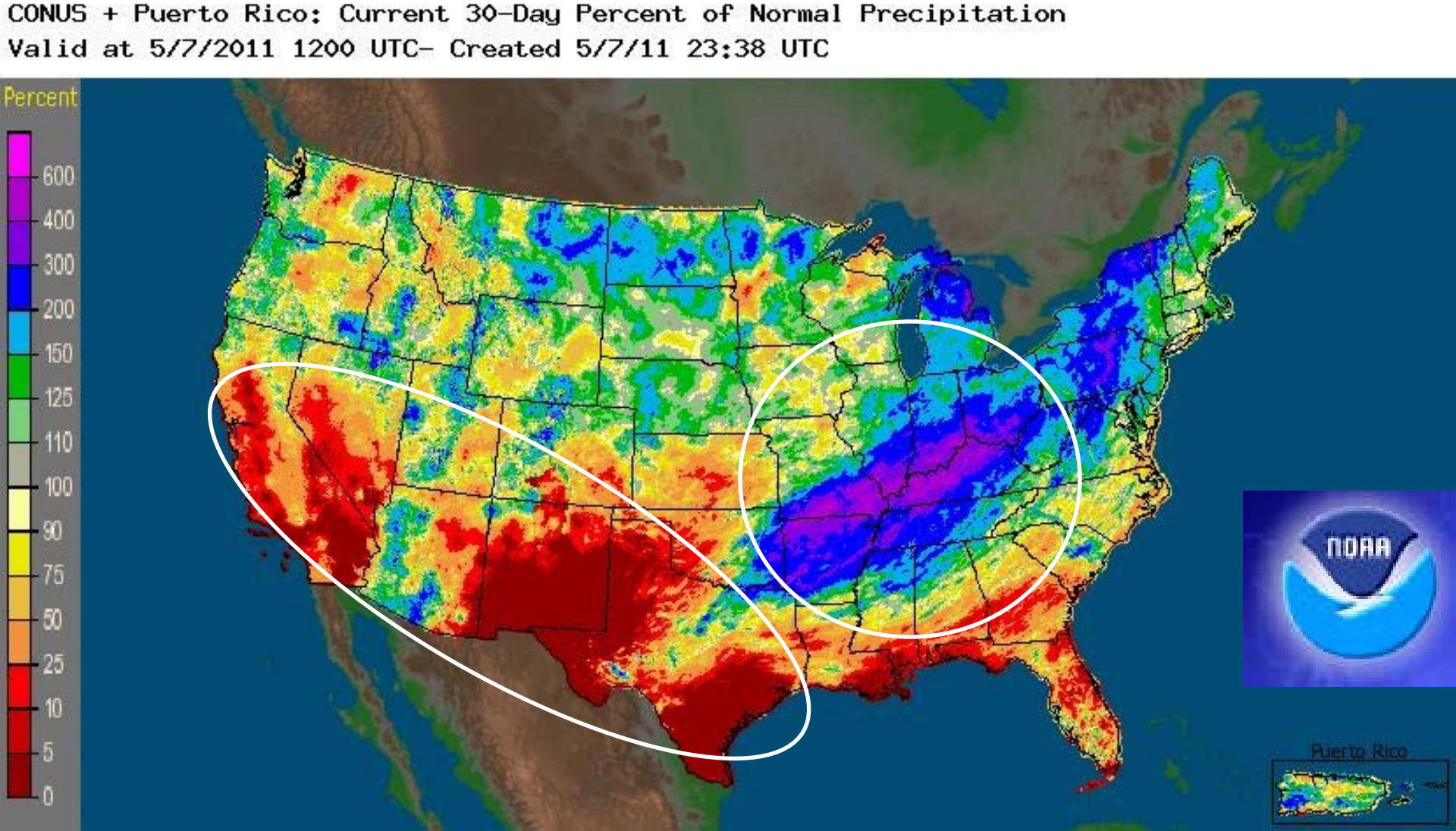
Precipitation ***Intensity*** is Rising Above Historical Norms in Northern Hemisphere



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



Flooding on the Mississippi

There have been multiple "1-in-500 year" or "1-in-100 year" flood events in different parts of the Mississippi Basin in recent years, raising serious concerns about growing flood risks.

AP 2000

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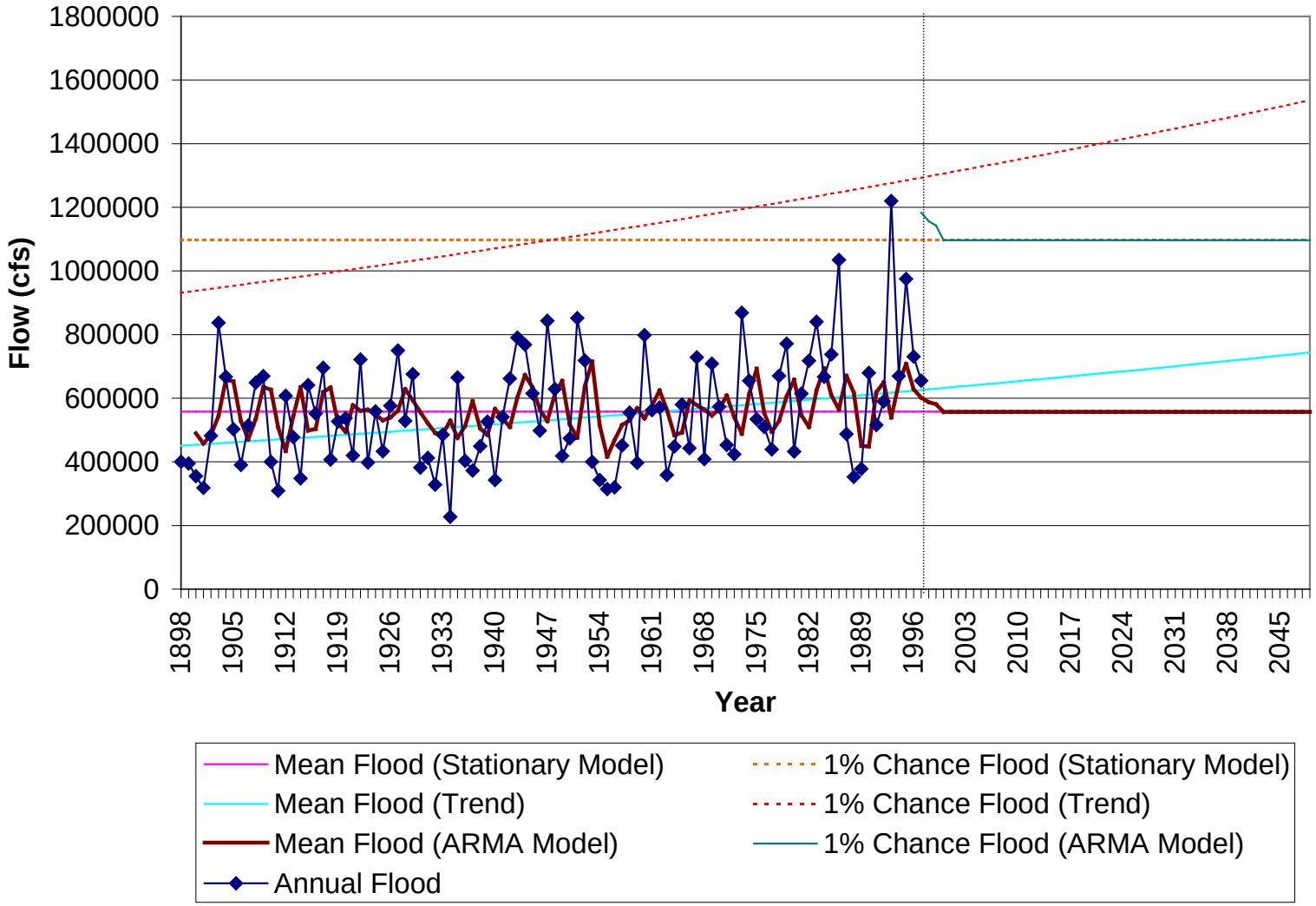
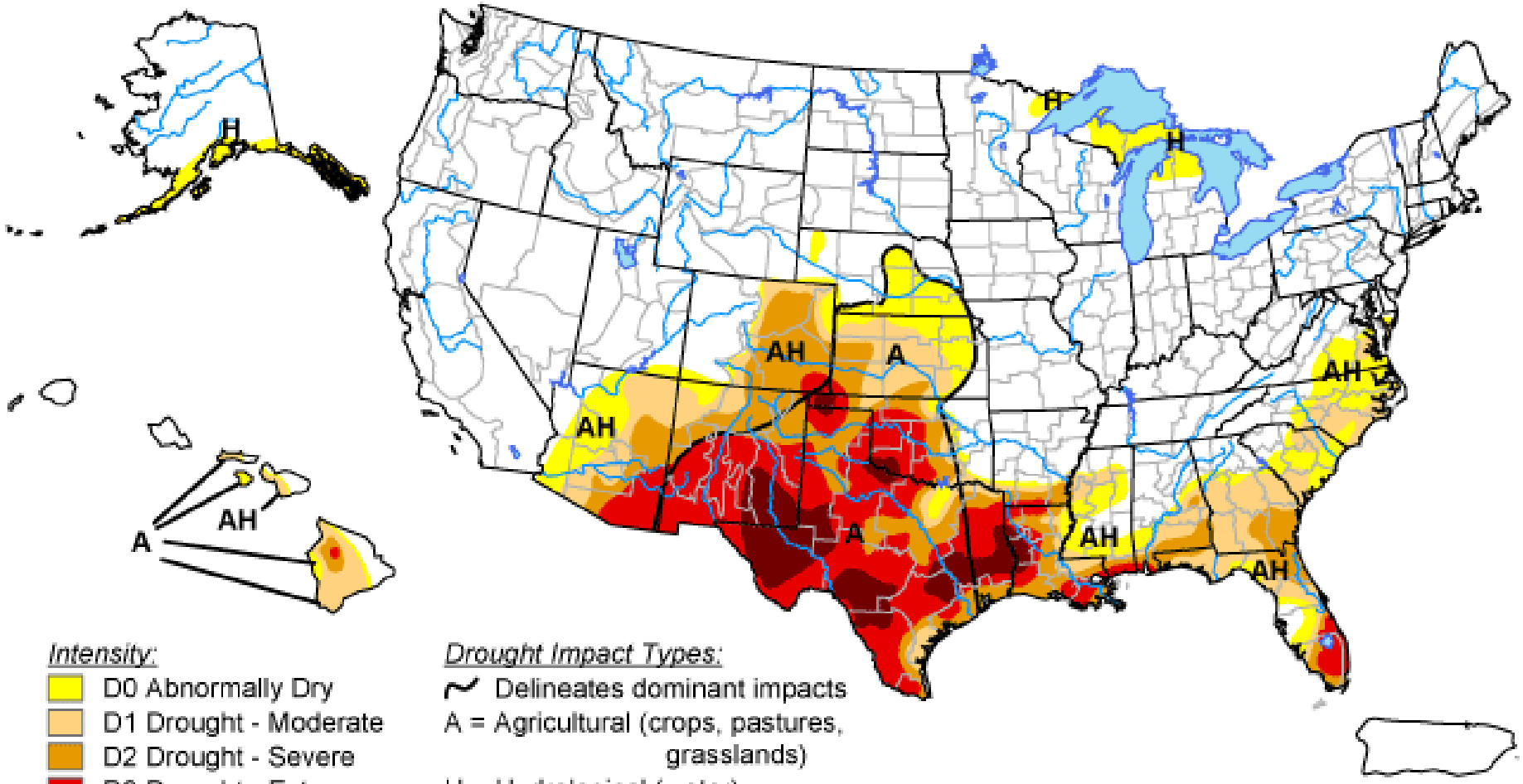
U.S. Army Corps: Flood Risk is Growing on Mississippi



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 (DoI, 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.

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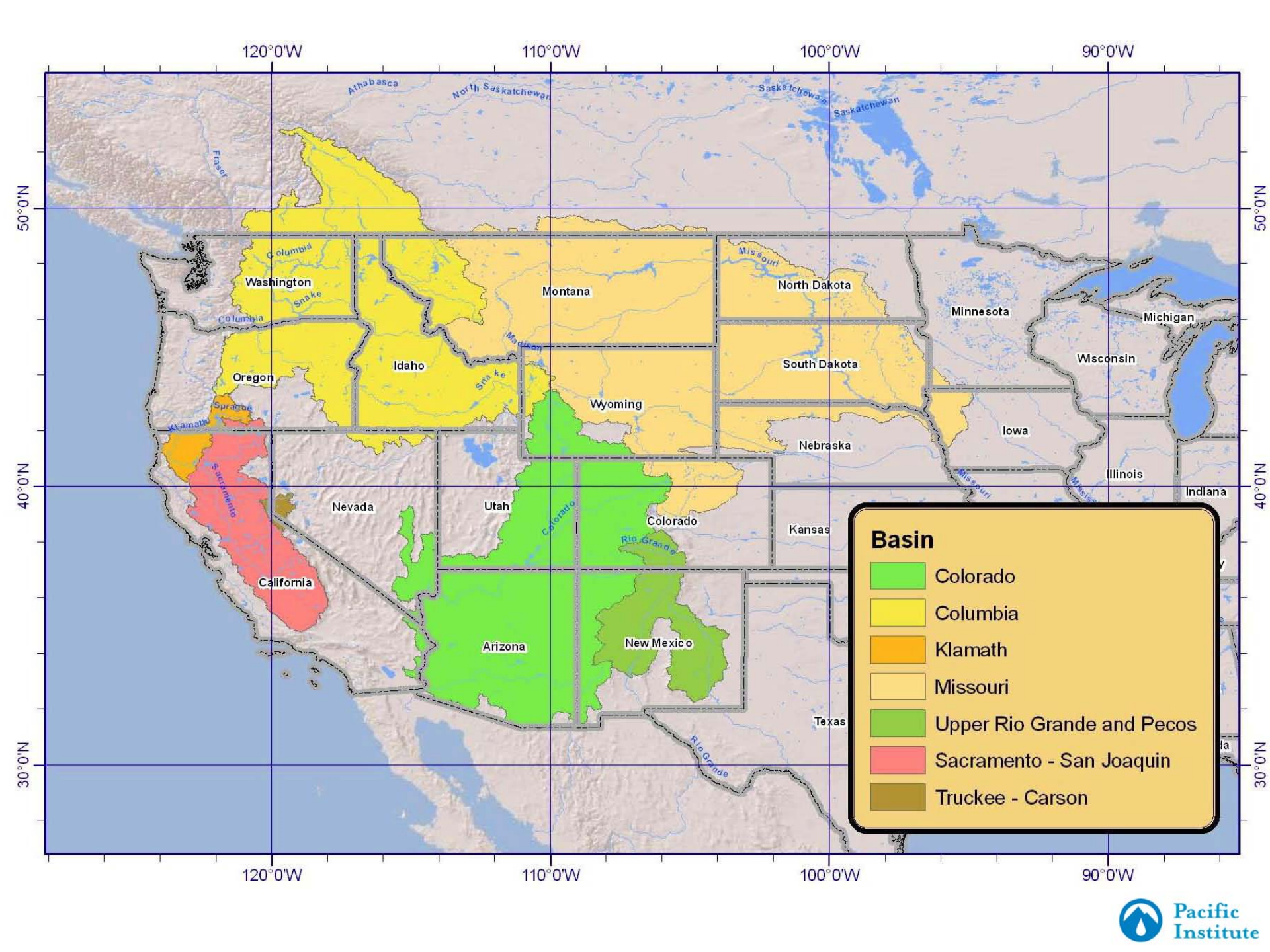
120°0'W
110°0'W
100°0'W
90°0'W
50°0'N
40°0'N
30°0'N
Athabasca
North Saskatchewan
Saskatchewan
Fraser
Columbia
Washington
Snake
Columbia
Oregon
Spragrue
Klamath
Sacramento
California
Nevada
Idaho
Snake
Madison
Montana
Missouri
North Dakota
Minnesota
Michigan
Wisconsin
South Dakota
Wyoming
Iowa
Nebraska
Illinois
Indiana
Missouri
Missis
Utah
Colorado
Colorado
Rio Grande
Kansas
Arizona
New Mexico
Texas
Rio Grande
Basin
Colorado
Columbia
Klamath
Missouri
Upper Rio Grande and Pecos
Sacramento - San Joaquin
Truckee - Carson
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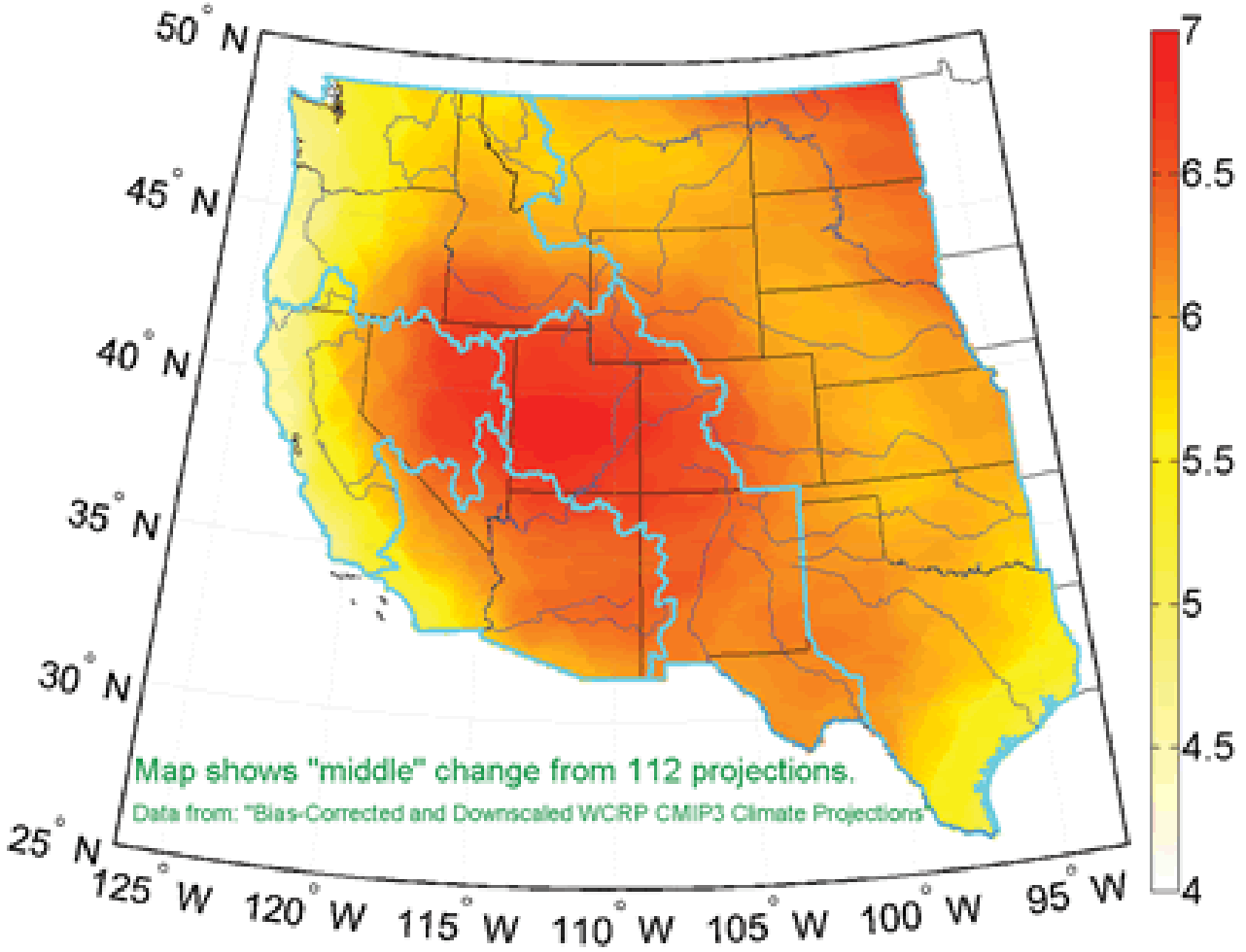
Change in Mean Annual Temperature (deg F) from 1950-1979 to 2070-2099



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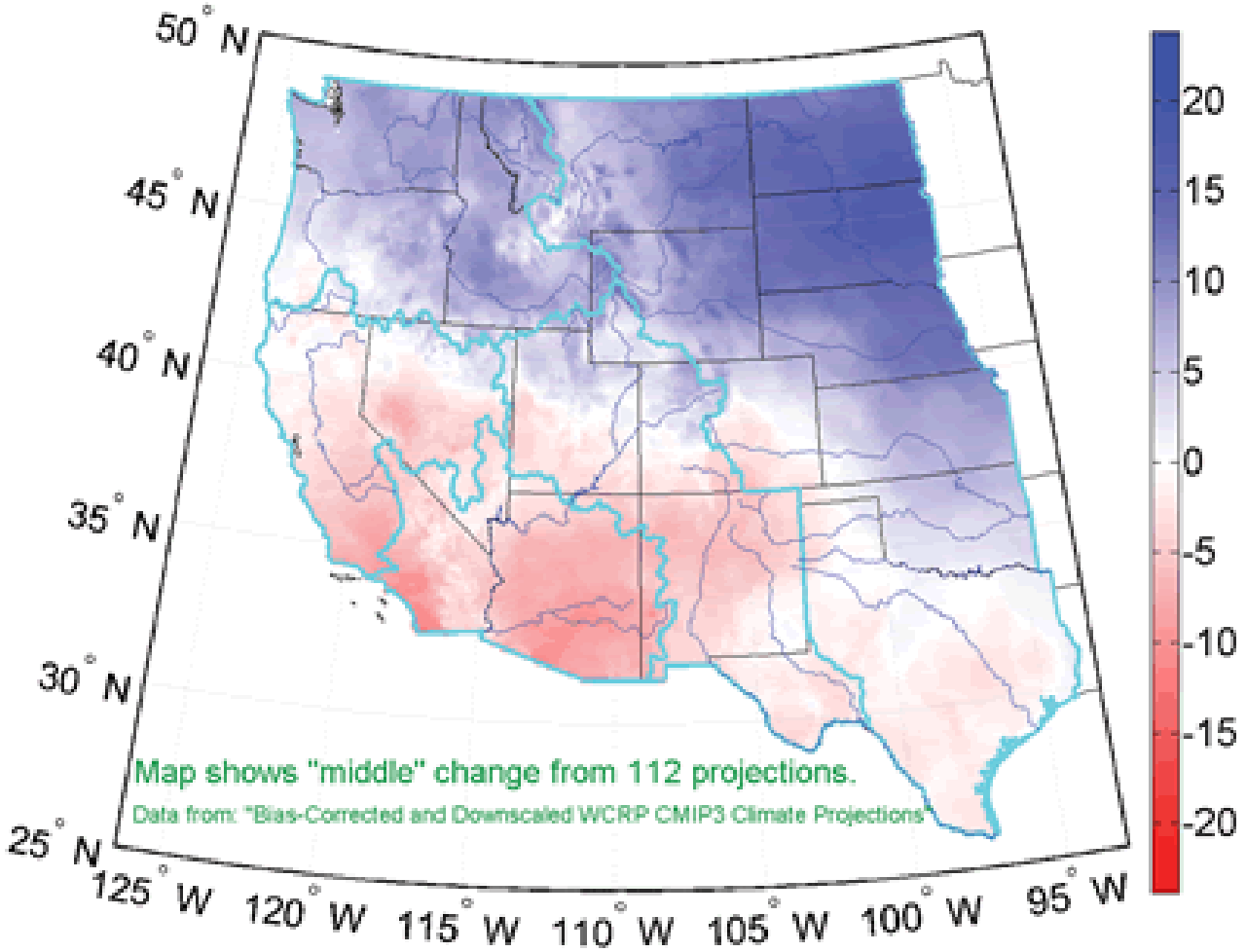
Change in Mean Annual Precipitation (%) from 1950-1979 to 2070-2099



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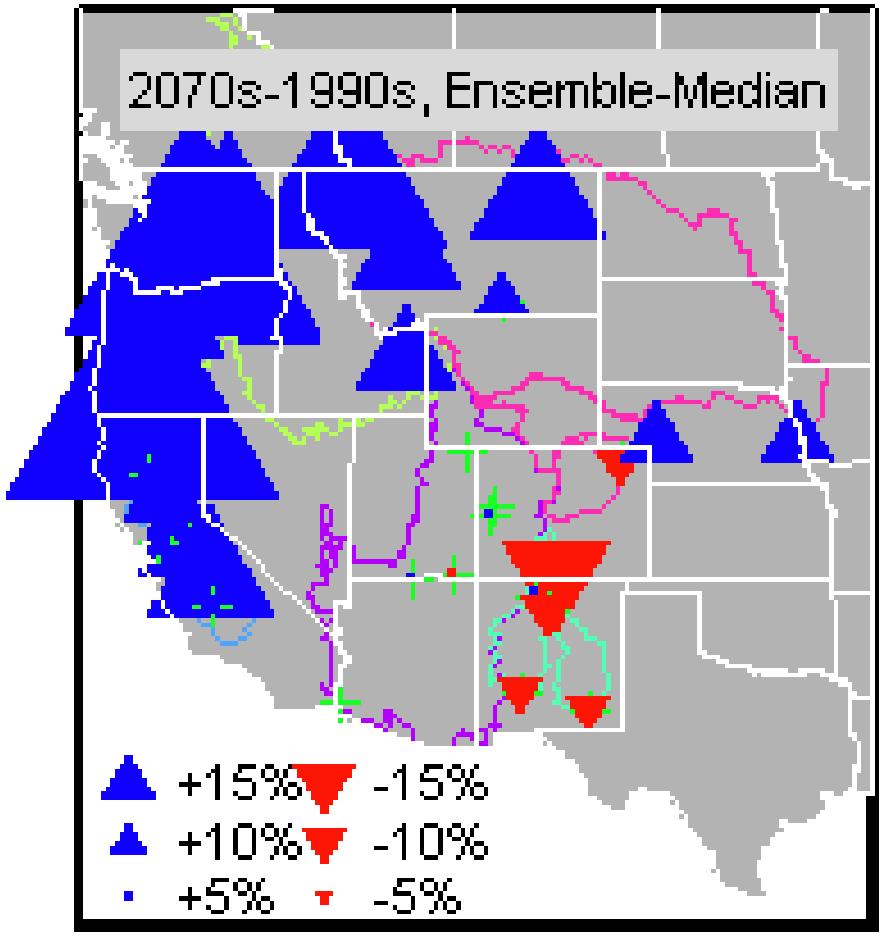
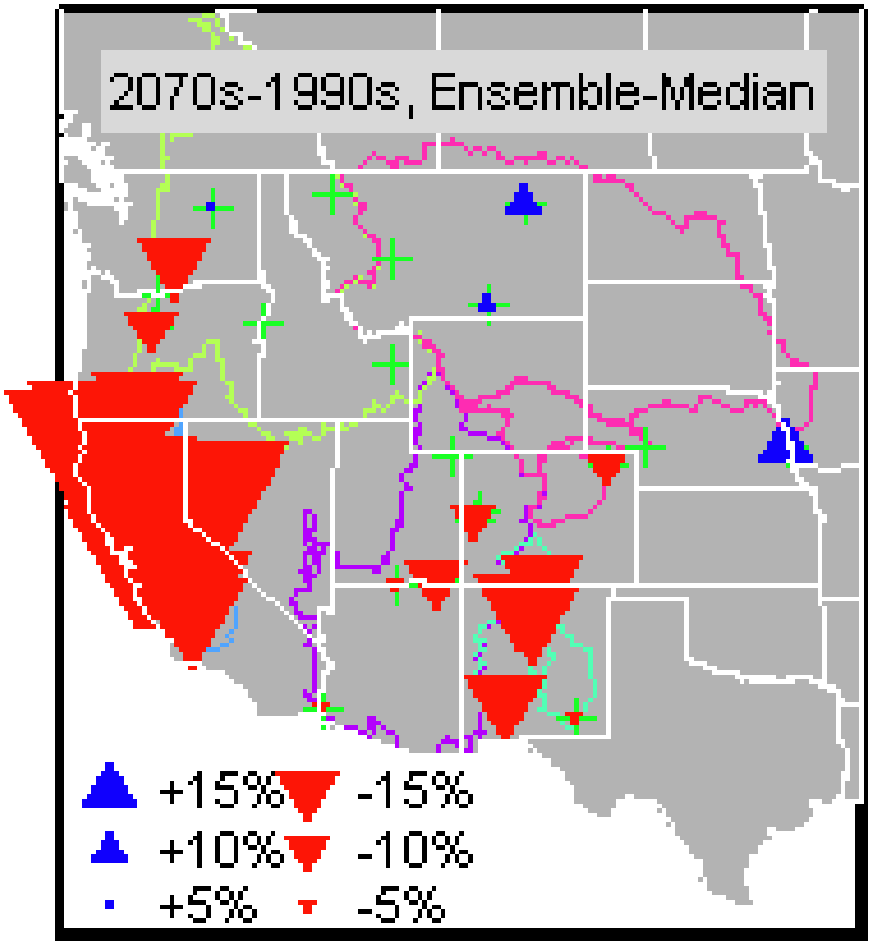
Increased Risk of Winter Floods *and* Summer Droughts



December to March Runoff



April to July Runoff

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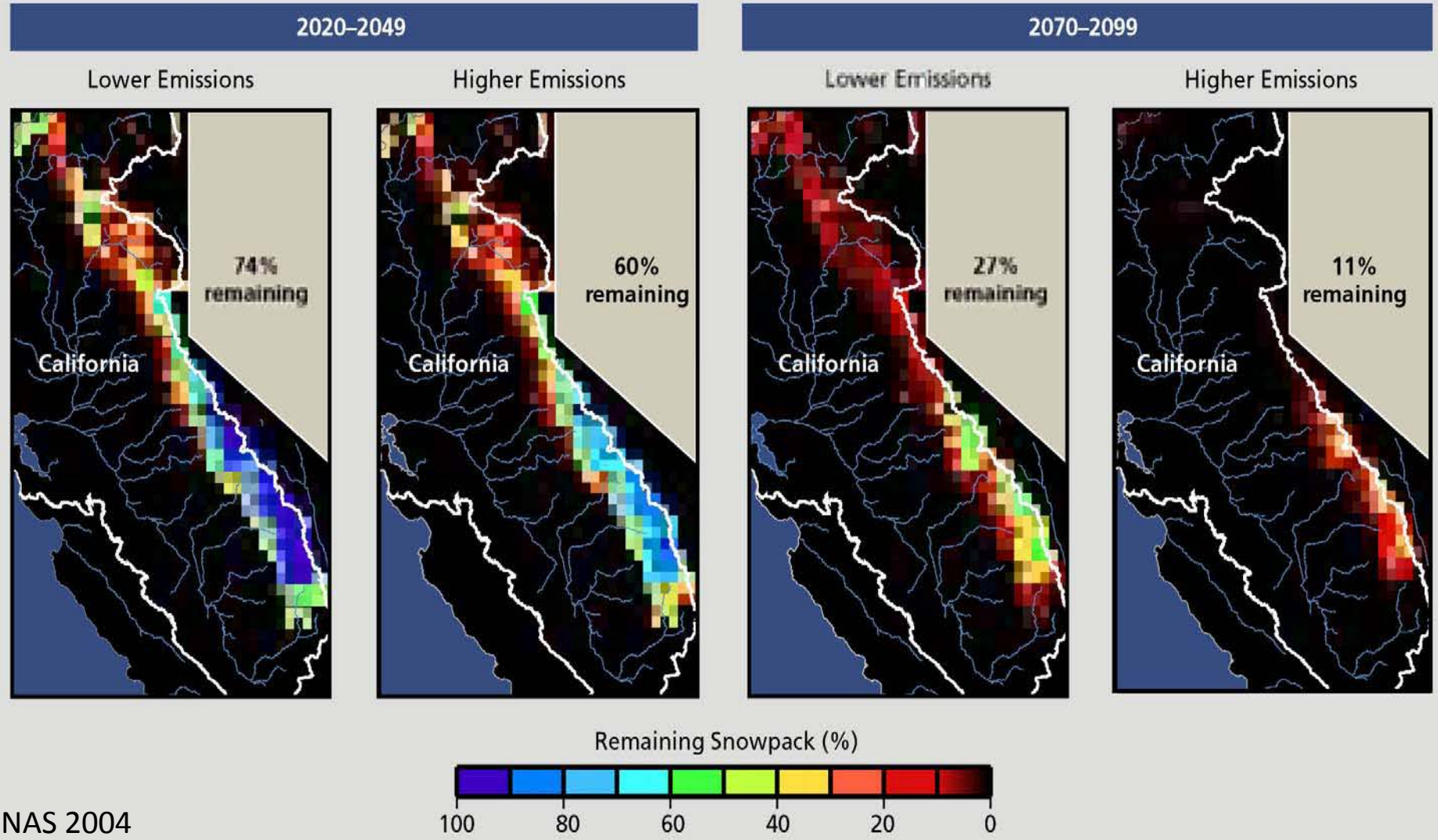
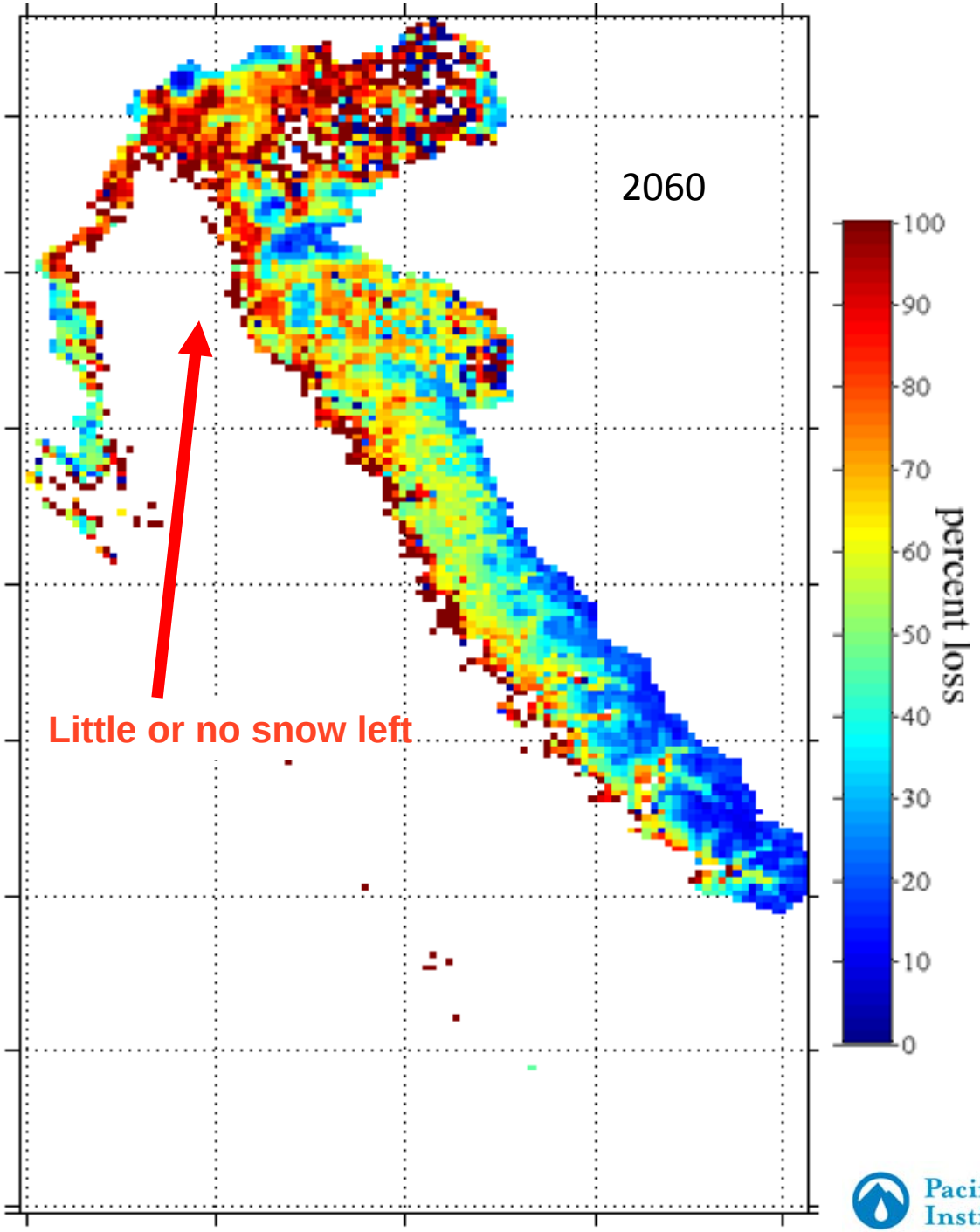
Very High Confidence that Snowpack in Mountains will Dramatically Shrink



PNAS 2004

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



Knowles & Cayan, 2004

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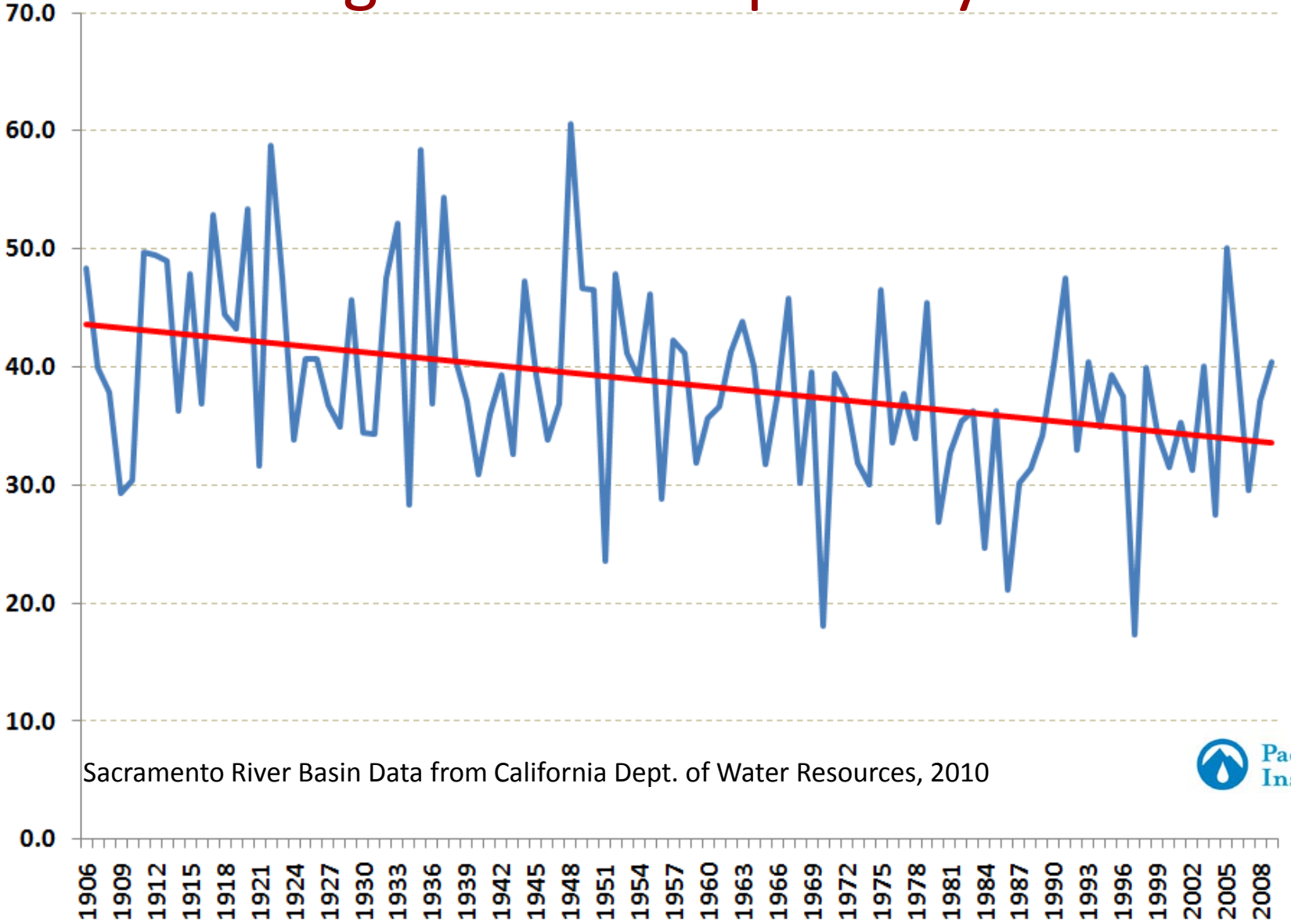
These Changes are Already Evident: Decreasing California April-July Runoff



Sacramento River Basin Data from California Dept. of Water Resources, 2010

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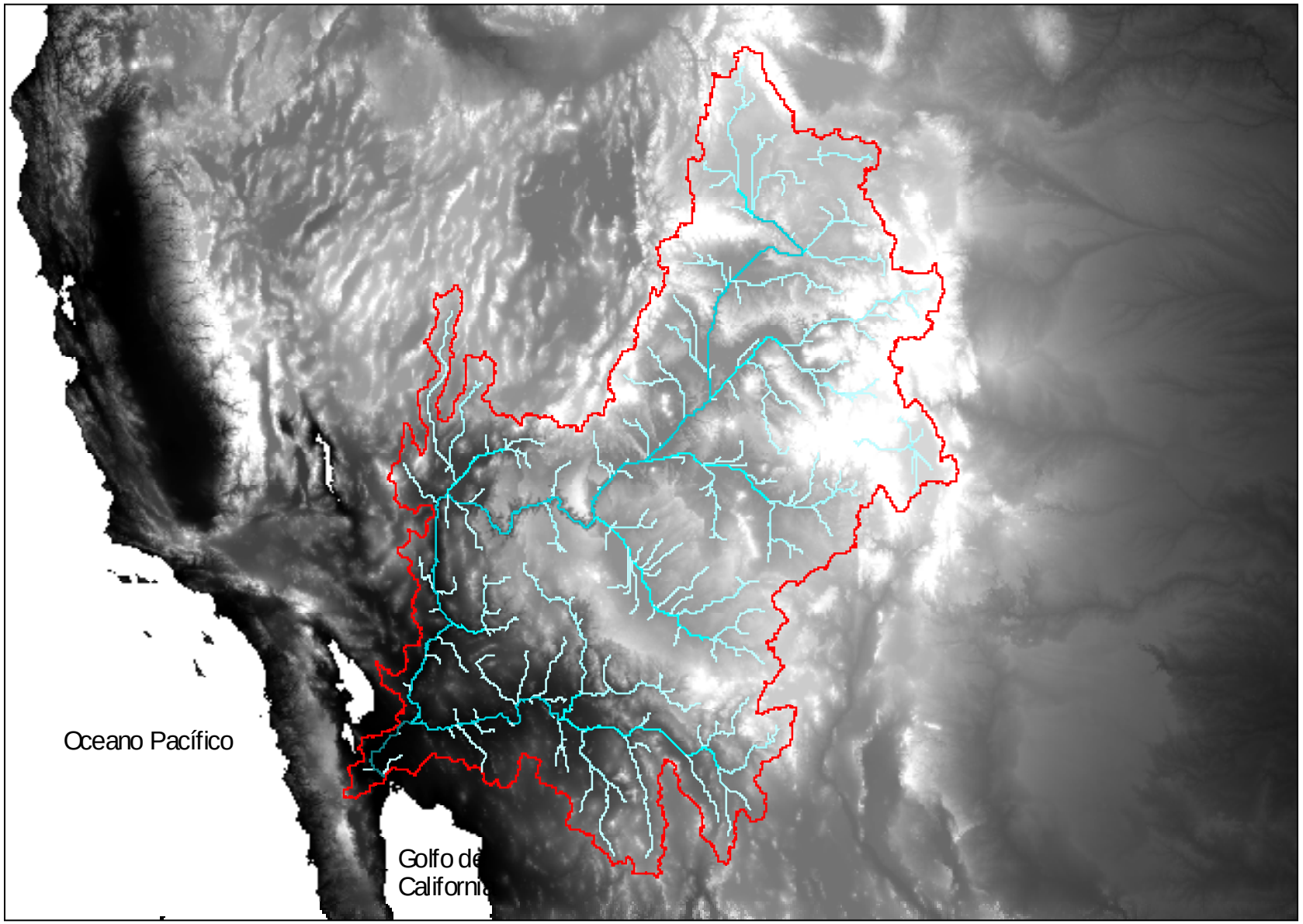
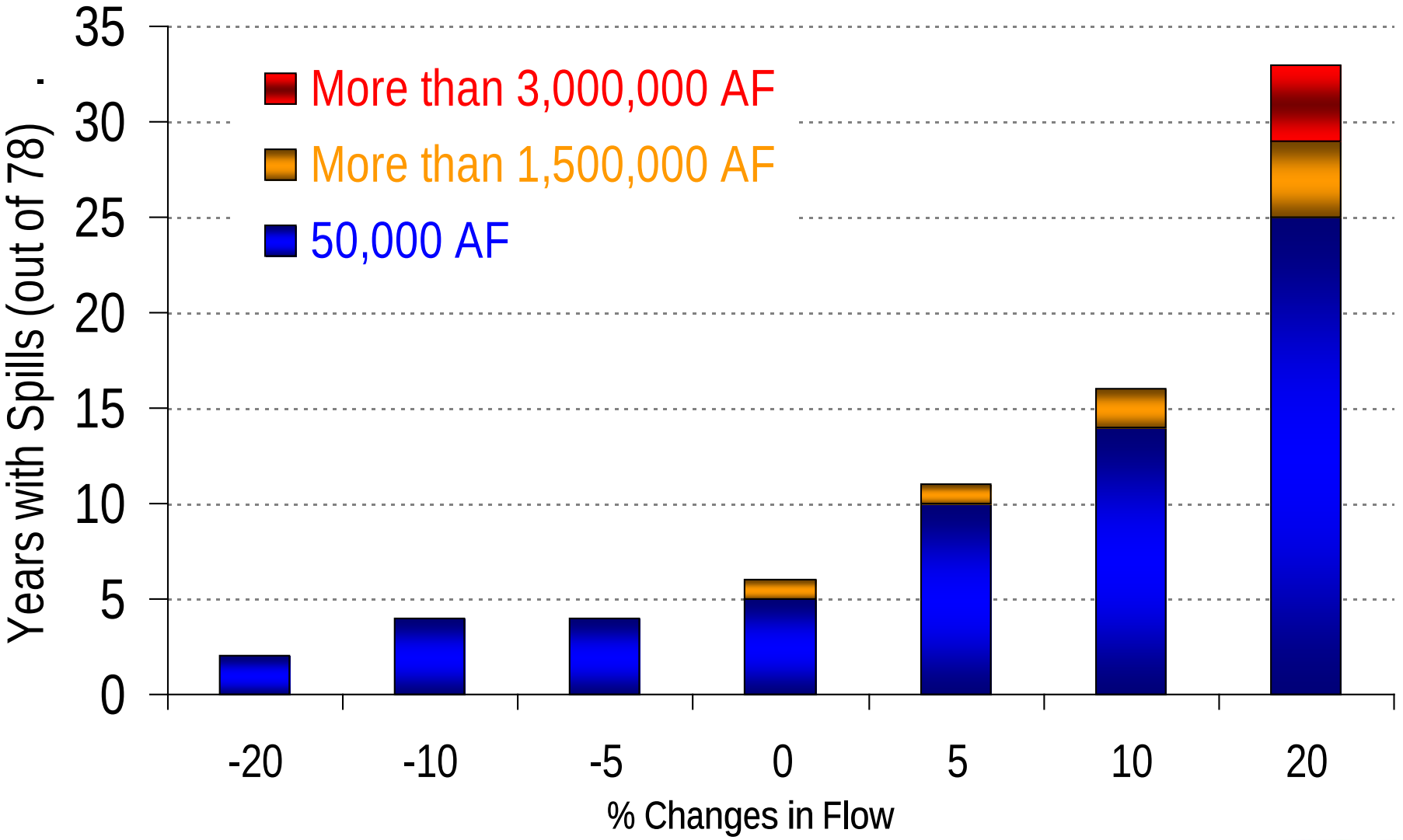
Colorado River Basin



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



Nash and Gleick 1993

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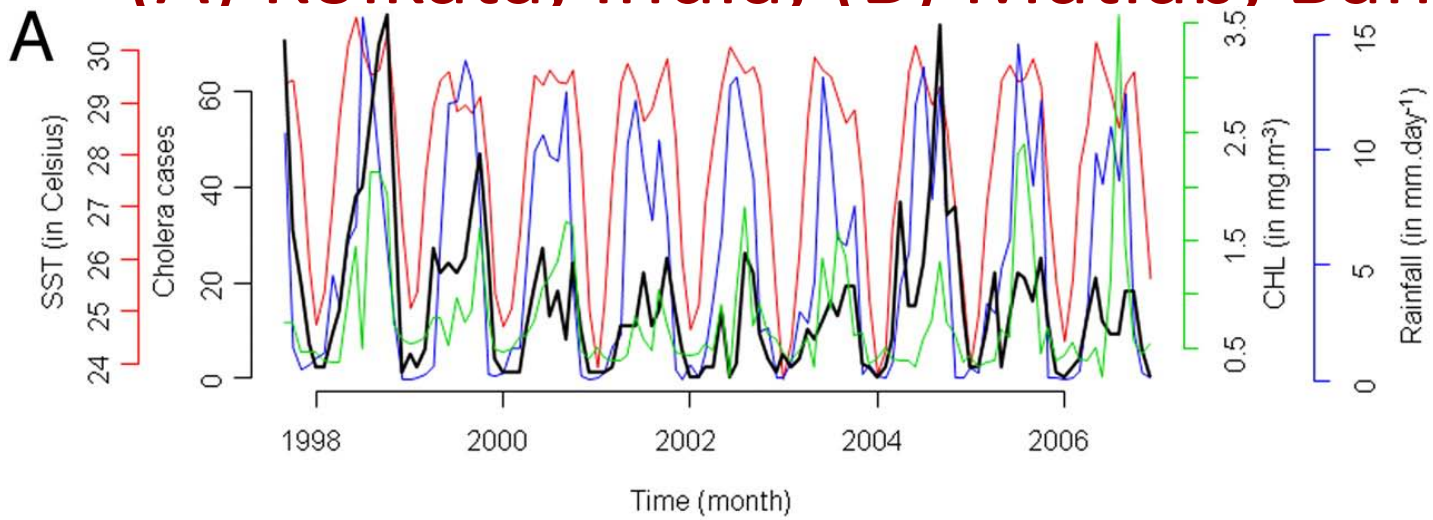
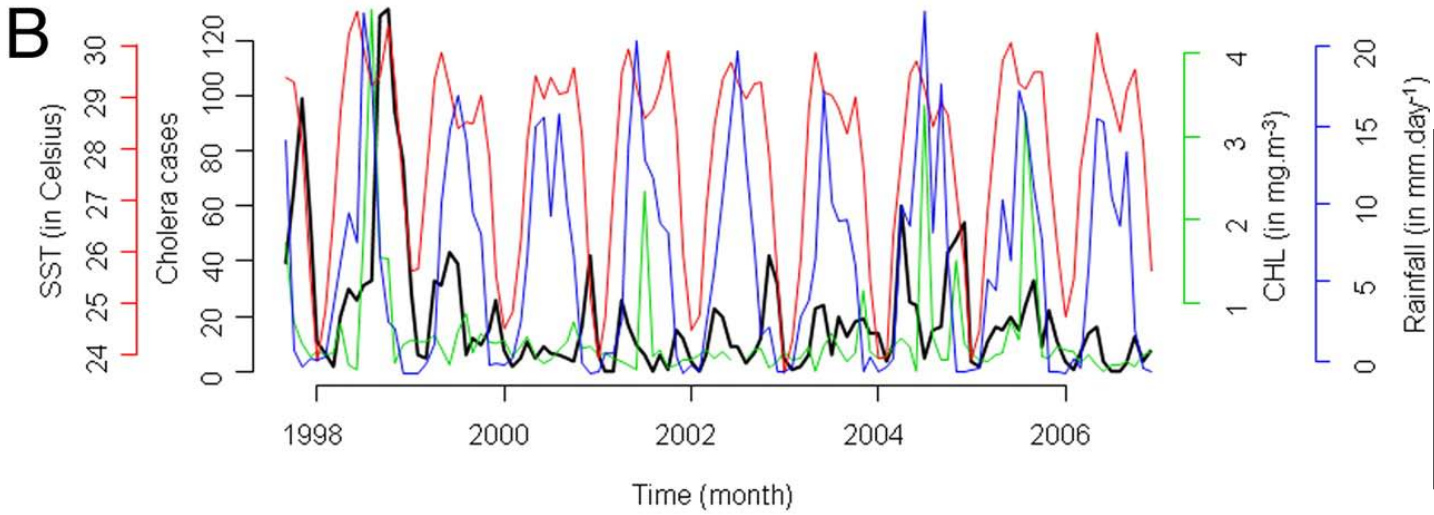
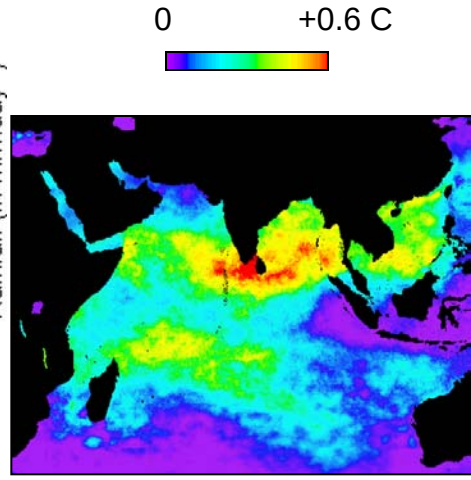
Cholera and Sea-Surface Temperature
(A) Kolkata, India, (B) Matlab, Bangladesh



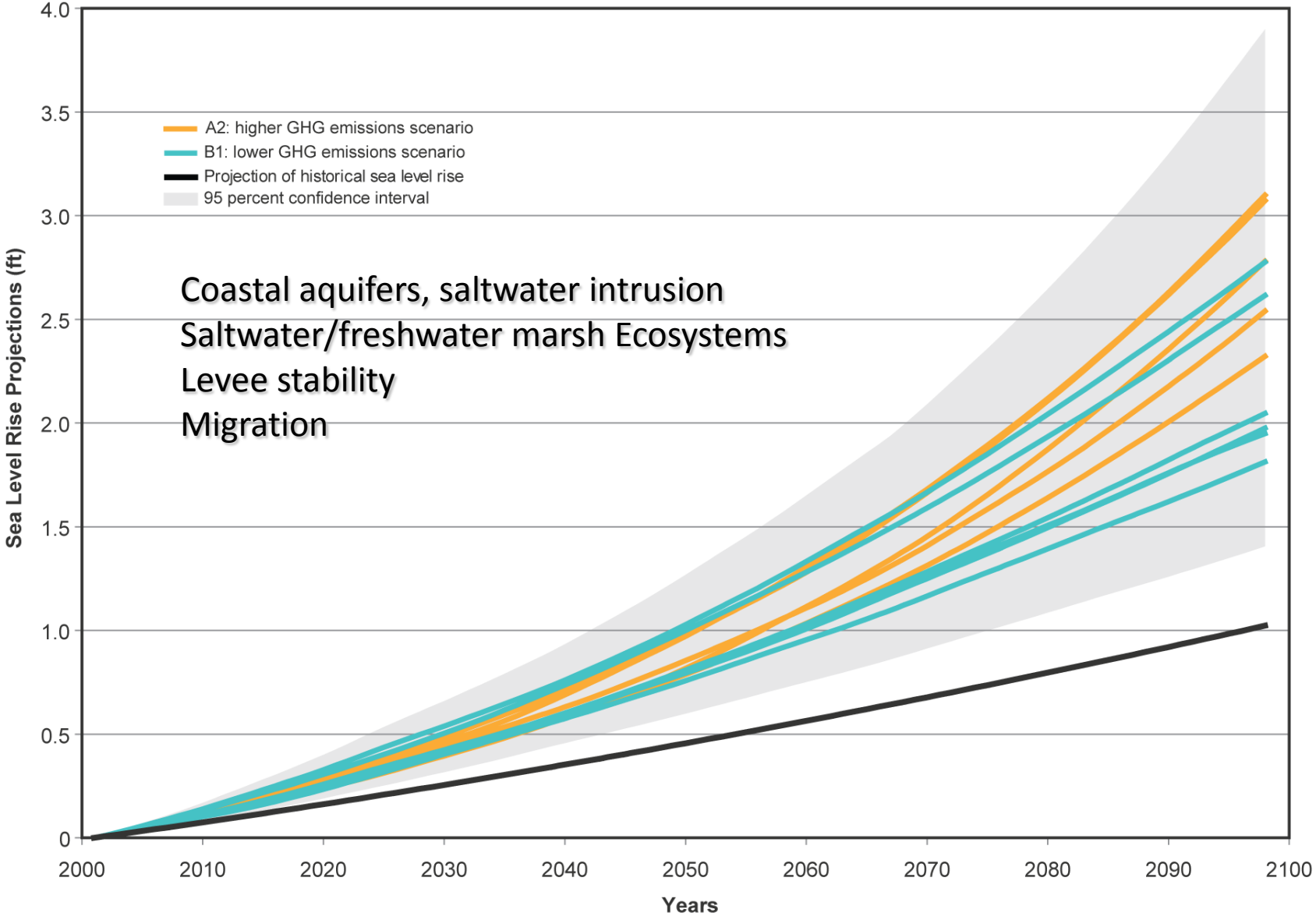




Constantin de Magny G et al. PNAS 2008;105:17676-17681

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)*

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The Continued Delay in Taking Action Now Means:

Rapidly Worsening Impacts, and Unavoidable Adaptation

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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

Instead, What Are We Doing?

- Refusing to act to reduce greenhouse gas emissions. This leads to exponentially accelerating consequences;
- Refusing to fund research to assess impacts to the U.S. or to provide funds for adaptation;
- Cutting funds for earth observing, early warning, data collection.

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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 Snowmaggedon 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.

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Every scientific body of national or international standing accepts the findings of human-induced effects on climate

- **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**

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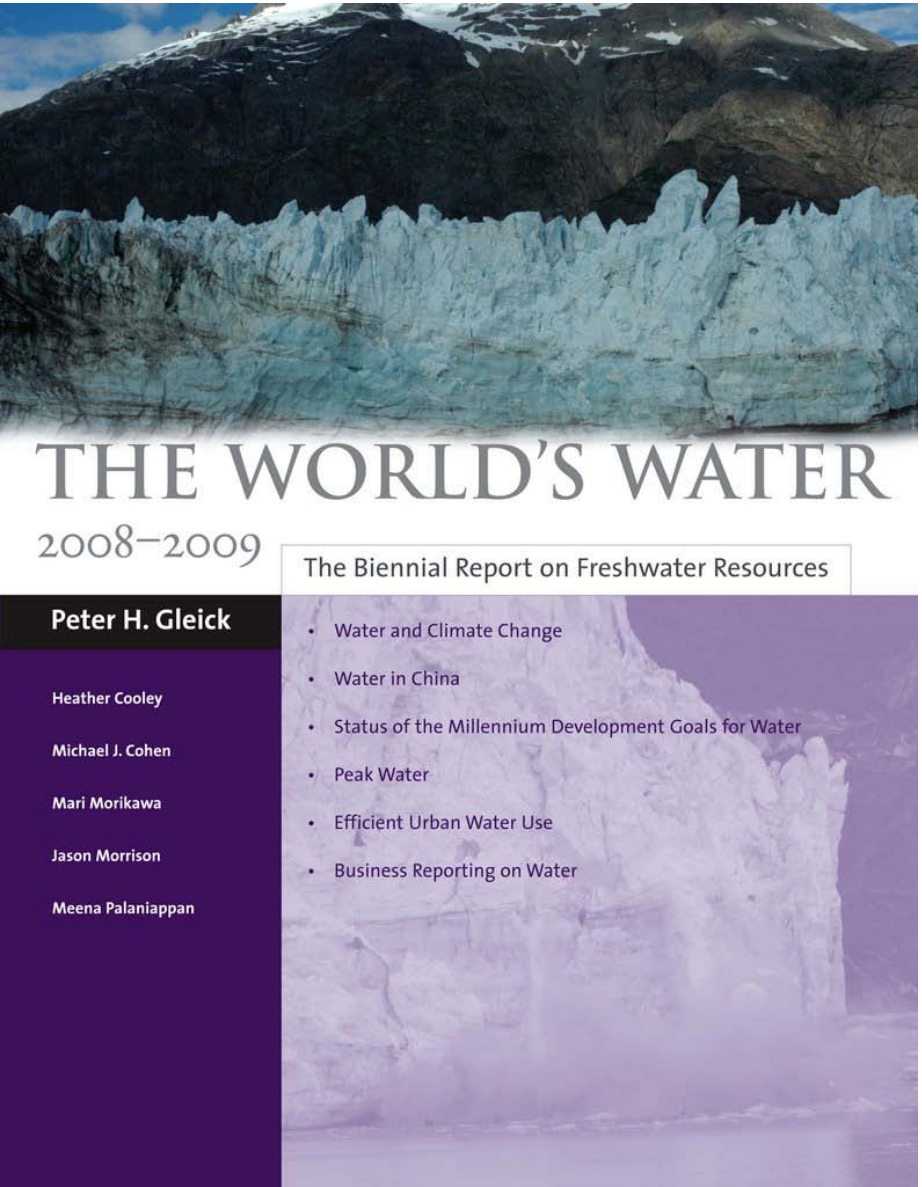

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