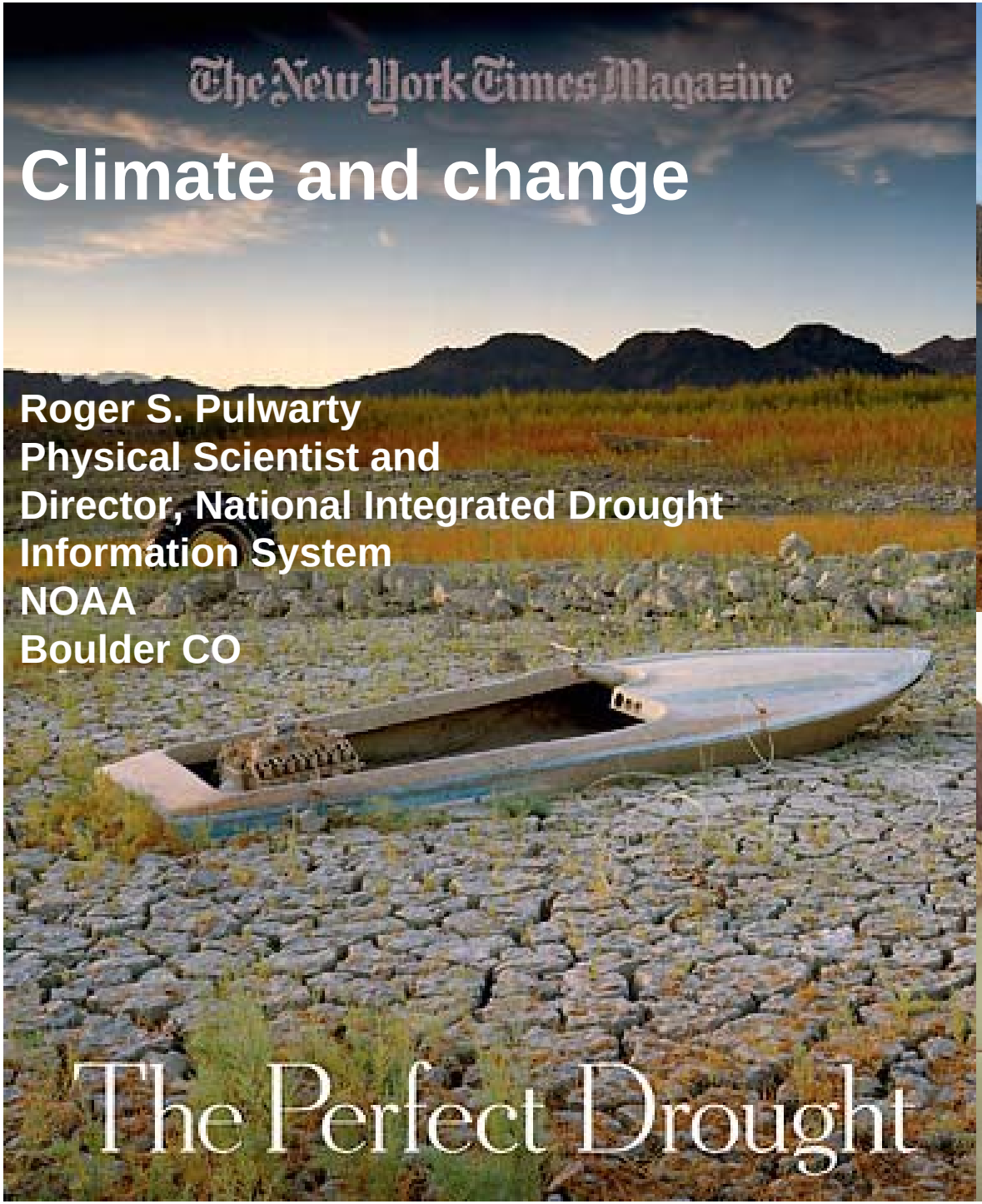


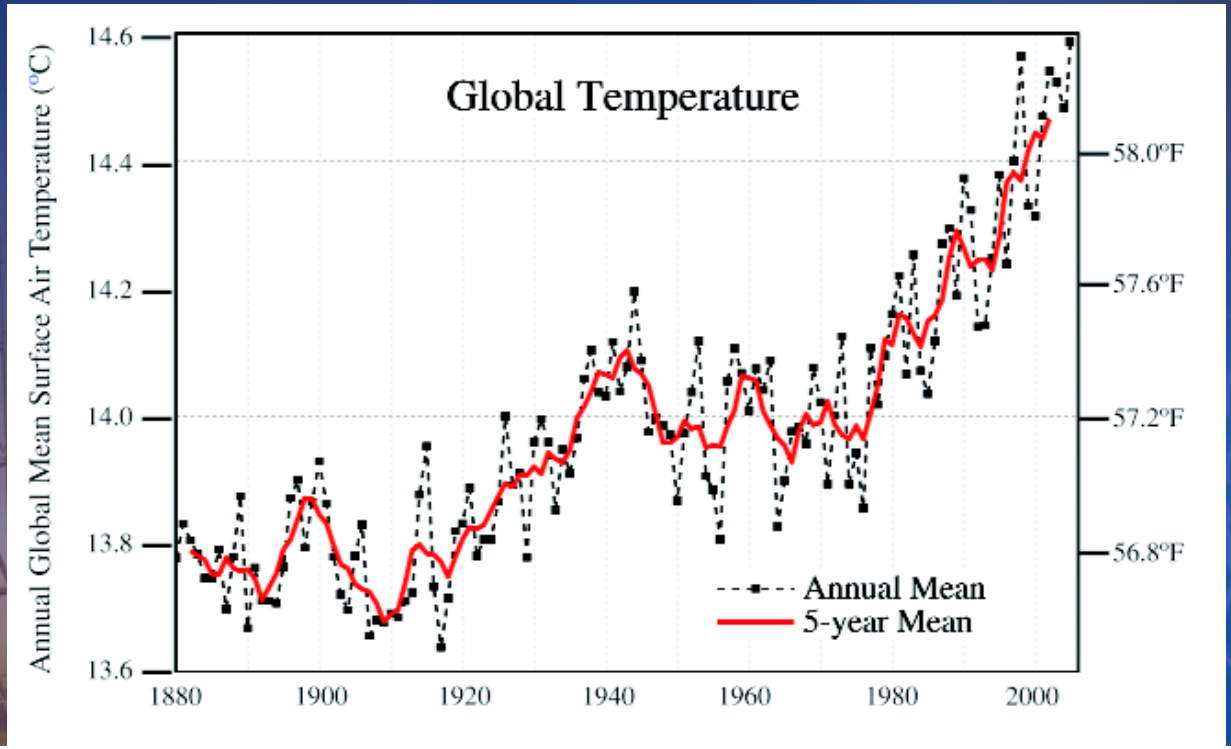

# Climate and change

**Roger S. Pulwarty**
**Physical Scientist and**
**Director, National Integrated Drought Information System**
**NOAA**
**Boulder CO**

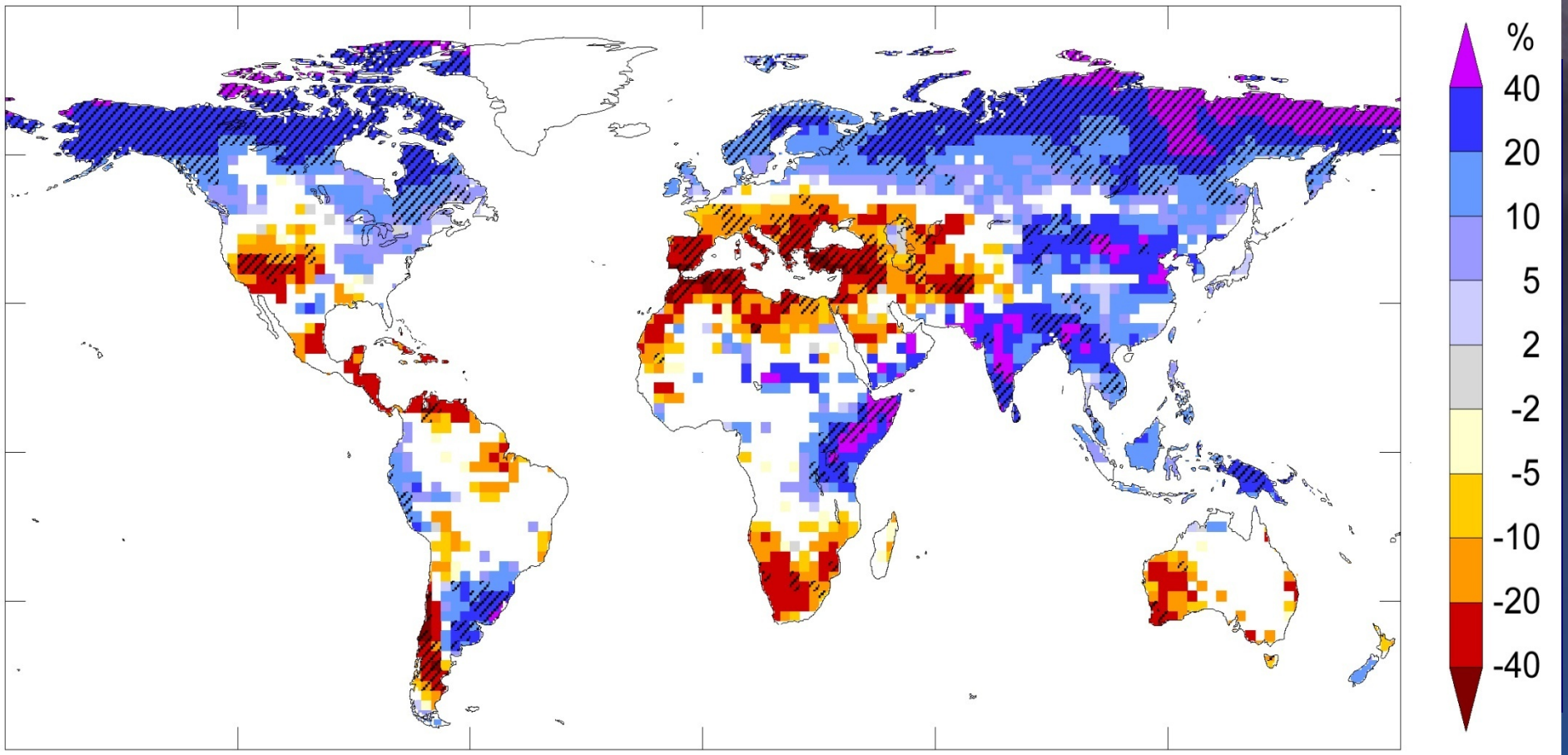
New York Times Sunday Magazine, October 21, 2007`

**“If we’re not careful we will end up where we are going”**

*6 of the 7 Warmest Years Occurred in the 21st Century*

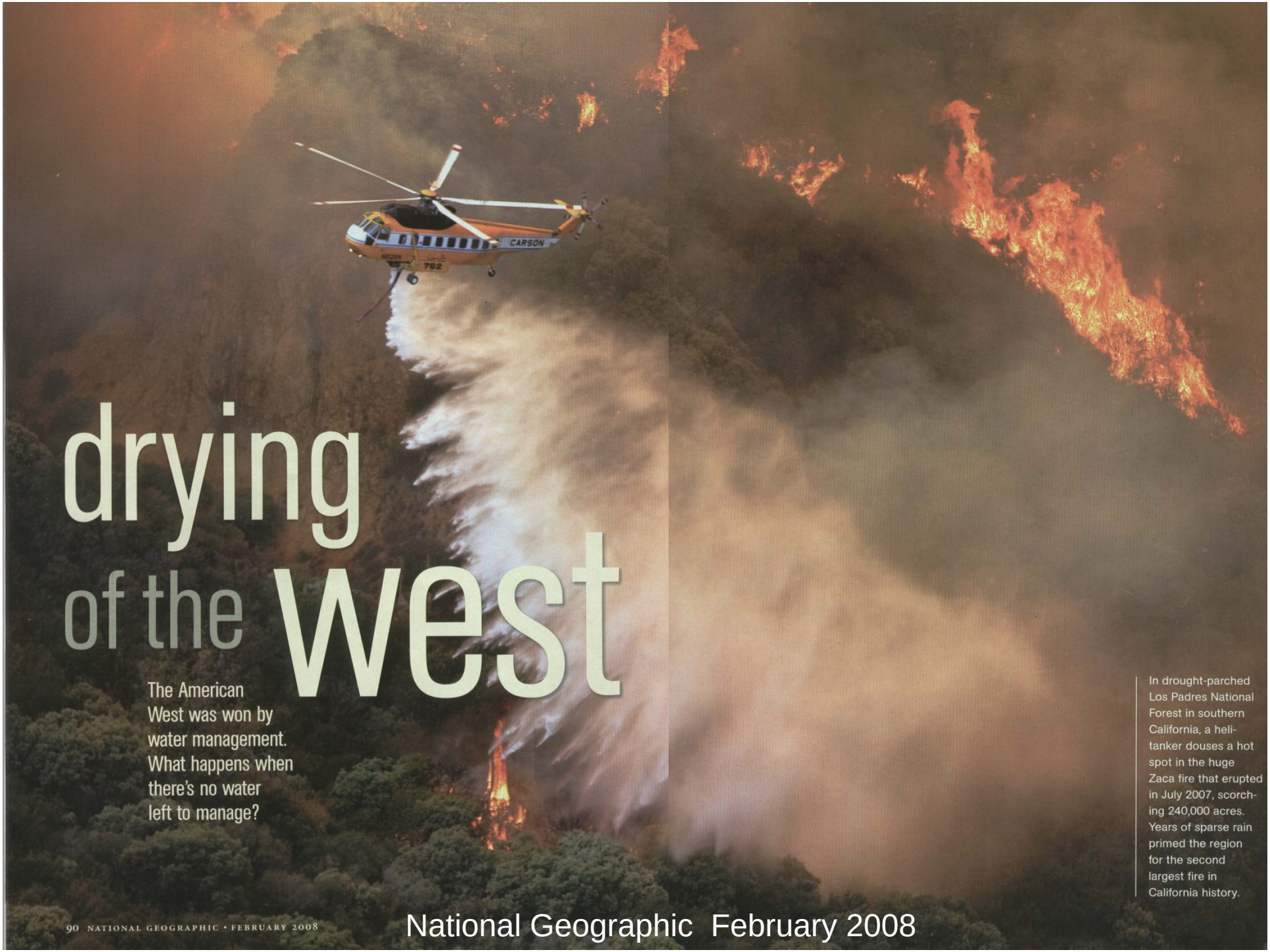


## Changes in run-off, 21st century. White areas are where less than two-thirds of models agree, hatched are where 90% of models agree




**IPCC Technical Paper on Climate Change and Water**

Released April 2008




# drying of the west

The American West was won by water management. What happens when there's no water left to manage?

In drought-parched Los Padres National Forest in southern California, a heli-tanker douses a hot spot in the huge Zaca fire that erupted in July 2007, scorching 240,000 acres. Years of sparse rain primed the region for the second largest fire in California history.



National Geographic February 2008

# Failing Health of Colorado's Forests

***"2007 alone, the infestation tore through another 500,000 high-elevation acres and embedded itself along the Front Range"***

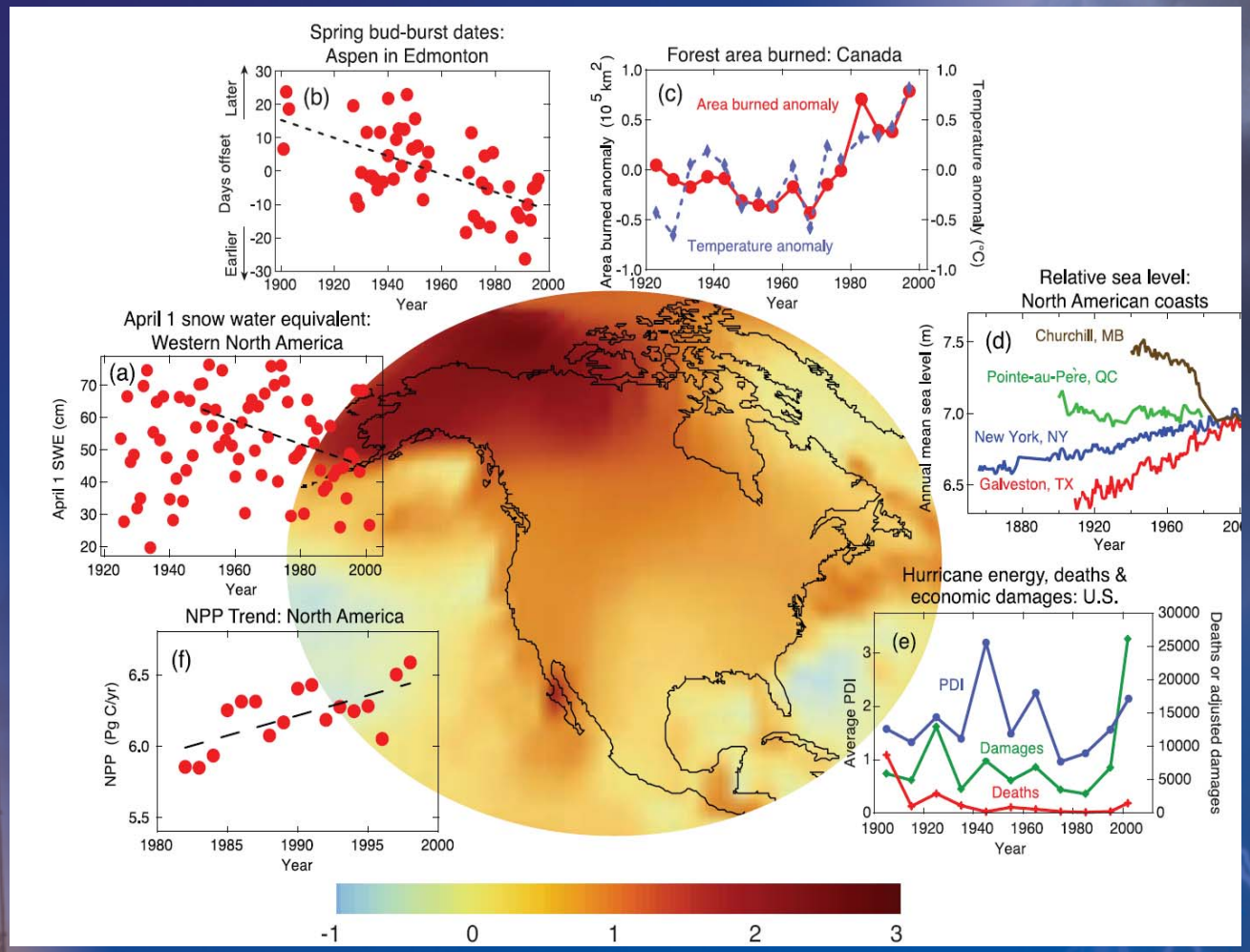
# Fish/Aquatic Ecosystem Vulnerability to Heat

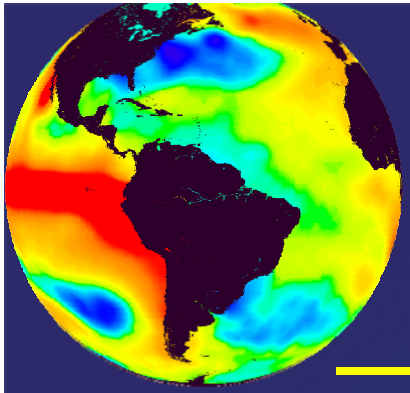
**Heat Kills Fish in Yellowstone**

**By Cory Hatch**
**July 7, 2007**

*Water temperatures of up to 82 degrees killed hundreds of rainbow and brown trout on the Firehole River this past week as warm, dry weather continues to pummel the Greater Yellowstone ecosystem.*

# Observed trends in North America





# Climatic-Drought Contributors: A continuum

## — SCALES OF DROUGHT —

**Heat Waves**

**Floods**

**Storm Track Variations**

**Madden-Julian Oscillation**

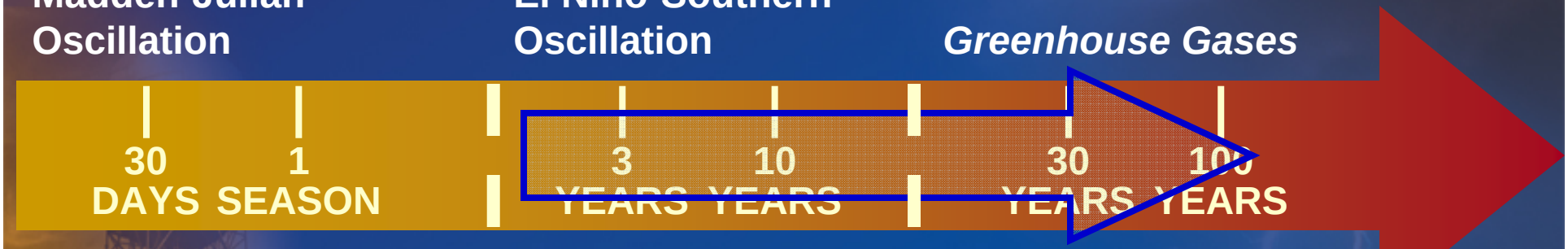
**El Niño-Southern Oscillation**

***Decadal Variability***

***Solar Variability***

***Deep Ocean Circulation***

***Greenhouse Gases***




**SHORT-TERM** **INTERANNUAL** **DECADE-TO-CENTURY**

**Droughts span a large range of temporal and spatial scales**

**Droughts are driven by a number of complex variables**

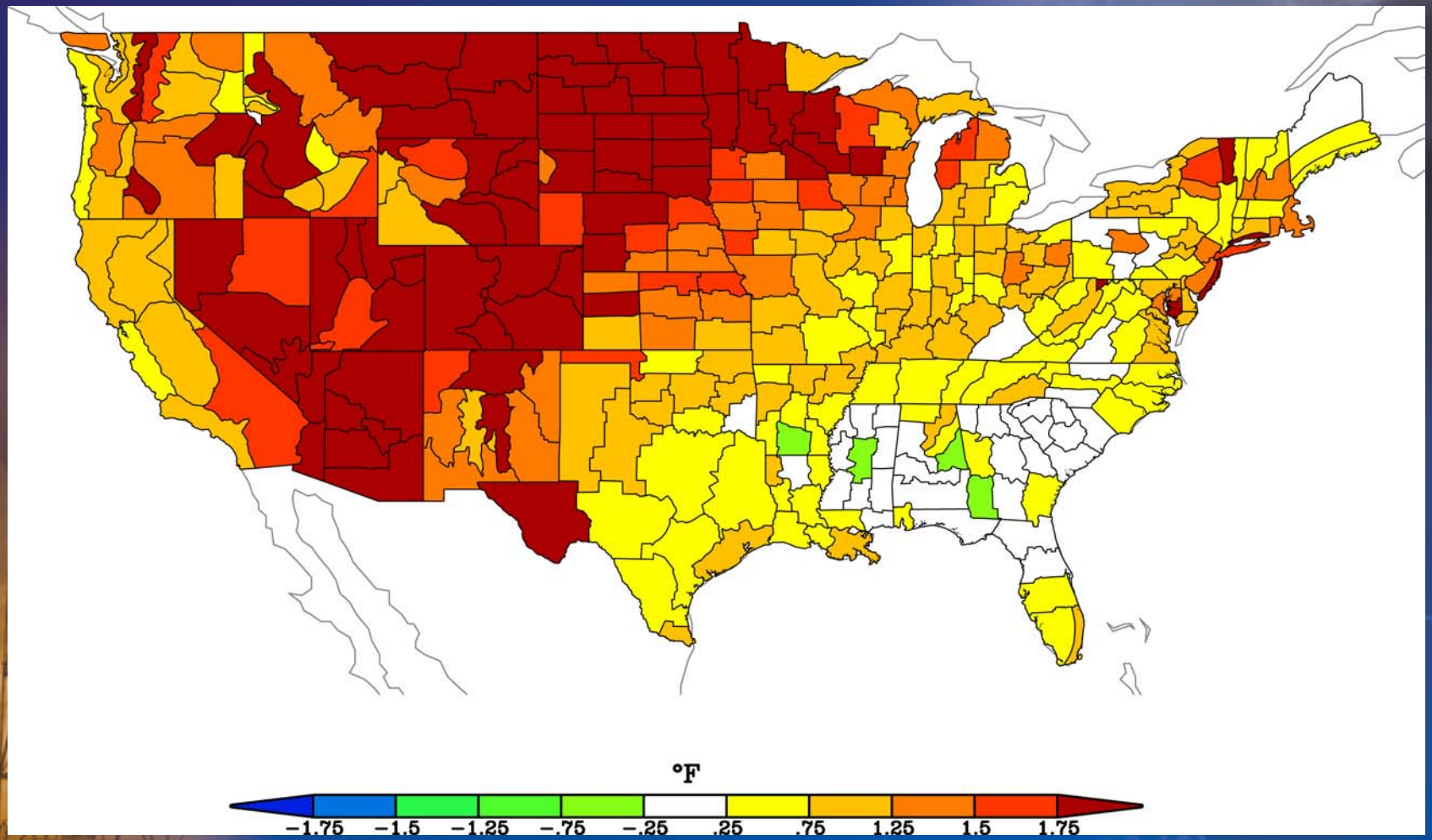
**Public and private stakeholders (incl. other agencies): Present products in need of improved coordination and in need regional and local detail for early warning**

| | |
|---|---|
| 1 to 4 week earlier peak streamflow due to earlier warming-driven snowmelt | US West |
| ↓ proportion of precipitation falling as snow | US West |
| ↓ duration and extent of snow cover | most of North America |
| ↑ water temperature of lakes (0.1 to 1.5°C) | most of North America |
| ↓ annual precipitation | central Rockies<br>Southwestern US |
| ↑ dry days/timing between rainfall events | most of North America |
| ↓ mountain snow water equivalent | Western North America |
| ↑ periods of drought | Western US, Southern Canada |

# TRENDS

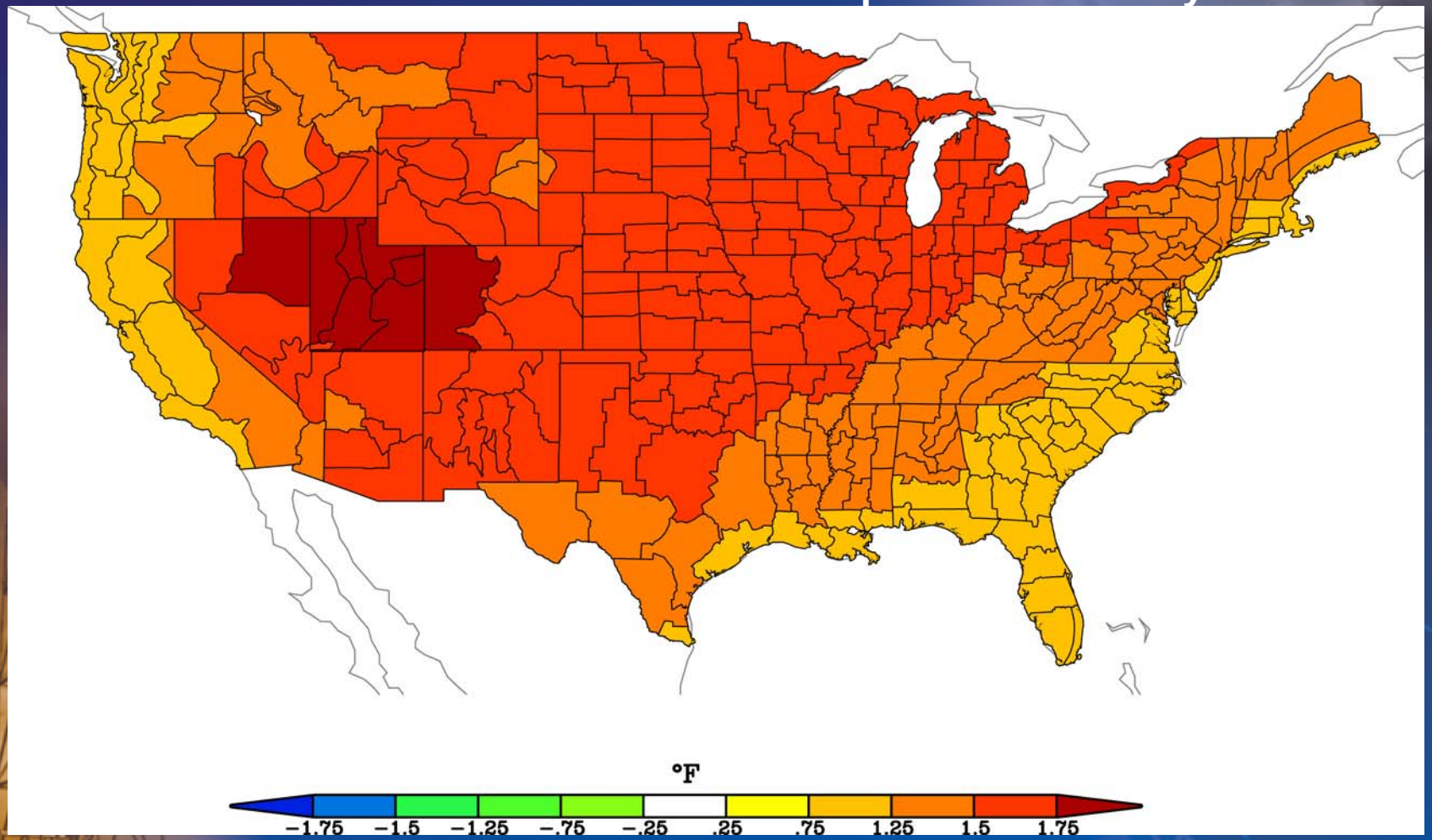
# *America's West: Epicenter for Warming*

**Observed Annual Temperature Anomaly 2000-2006**



# *America's West: Epicenter for Warming*

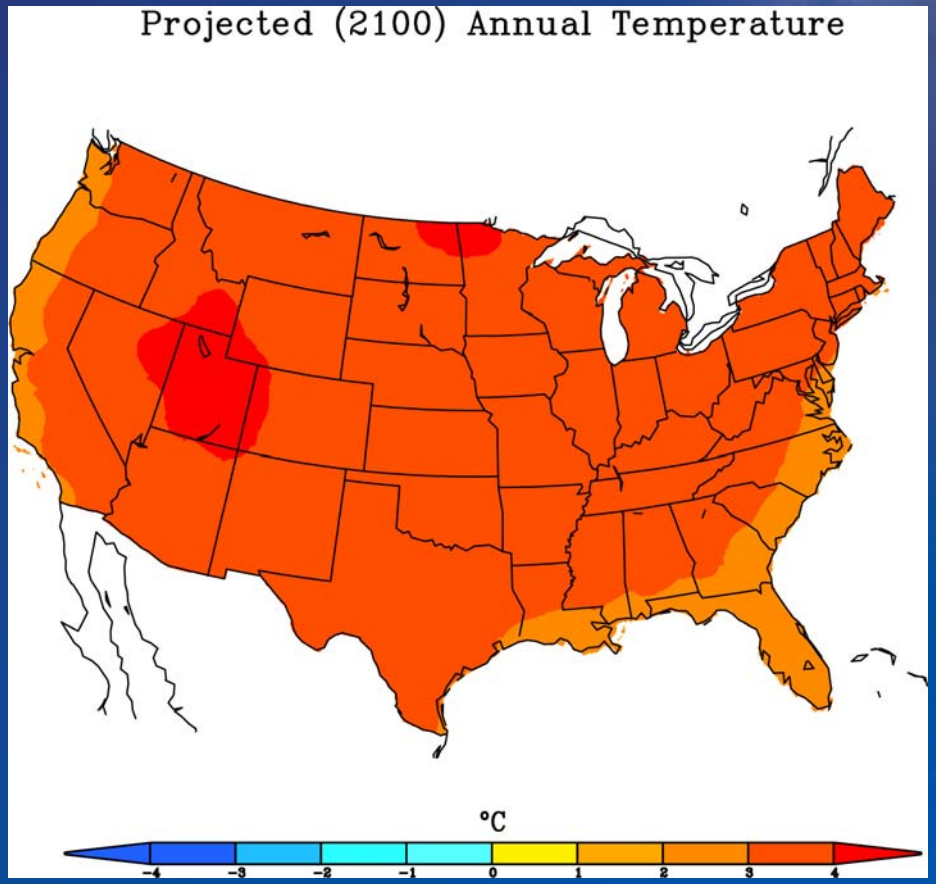
**Greenhouse Gas Forced Annual Temperature Anomaly 2000-2006**



# *Projected Western US Warming+4°C by 2100*

***For every 0.5°C warming, montane tree lines***

***advance ~300 feet***



- Some impacts can be reduced by mitigation but many cannot
- At least 0.6 deg C warming has occurred
- A further c. 0.5 deg C warming is inevitable, i.e. would occur even if emissions were stabilised at 2000 levels
- 
- The most stringent targets (not yet agreed) limit T increase to about 2 deg C (with c. 550 ppm stabilisation);

# 2004 Snowpack Vanishing Act

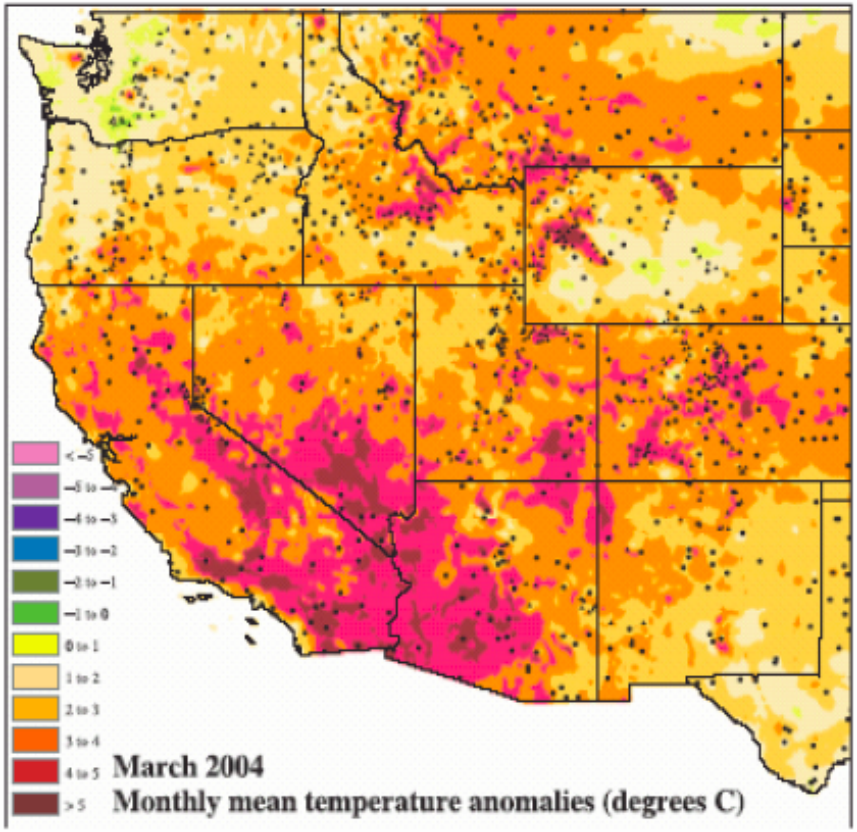



*Fig. 1. March 2004 observed monthly mean temperature anomalies in degrees Celsius. NRCS SNOTEL sites are shown as triangles, and NWS sites are shown as circles. Contours are derived using the PRISM system (http://www.ocs.orst.edu/prism/).*

**Table 1. Summary of Mountain Snowpack (Snow Water Equivalent) Changes Between 1 March and 1 April 2004.**

| *State/Area* | *Statewide % of Average, 1 March 2004* | *Statewide % of Average, 1 April 2004* | *Statewide % of Average, Change* |
|---|---|---|---|
| Arizona | 74 | 22 | -51 |
| Sierra/Tahoe | 113 | 70 | -35 |
| Colorado | 90 | 64 | -26 |
| Idaho | 105 | 81 | -25 |
| Montana | 93 | 78 | -16 |
| Nevada | 118 | 64 | -54 |
| New Mexico | 80 | 37 | -43 |
| Oregon | 126 | 96 | -30 |
| Utah | 109 | 70 | -39 |
| Washington | 93 | 86 | -7 |
| Wyoming | 91 | 71 | -19 |

Rapid snowpack reduction. Record warmth and dryness combine in March 2004. (Pagano, Pasteris, Redmond, Dettinger, EOS)

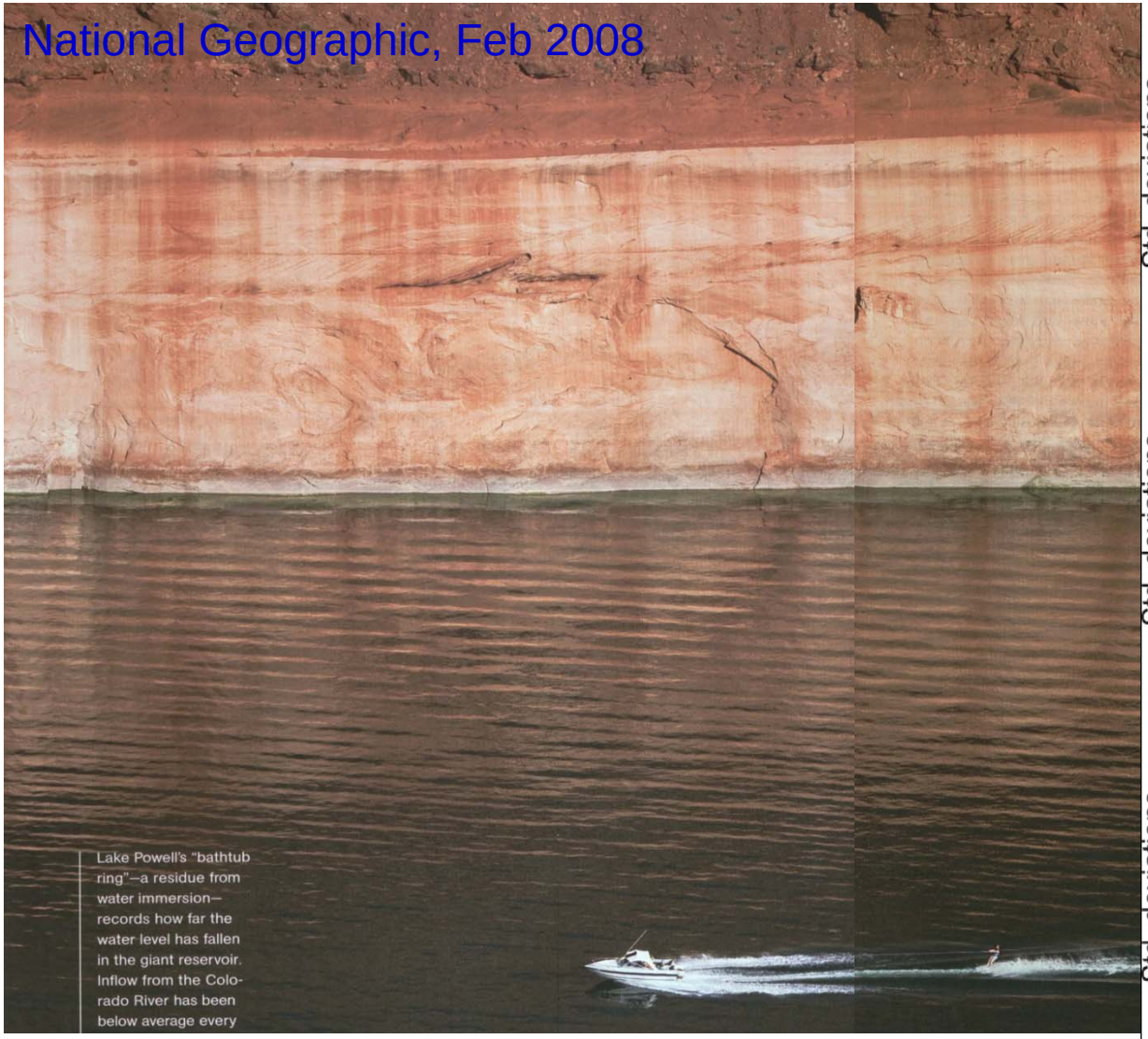
# *Projections*

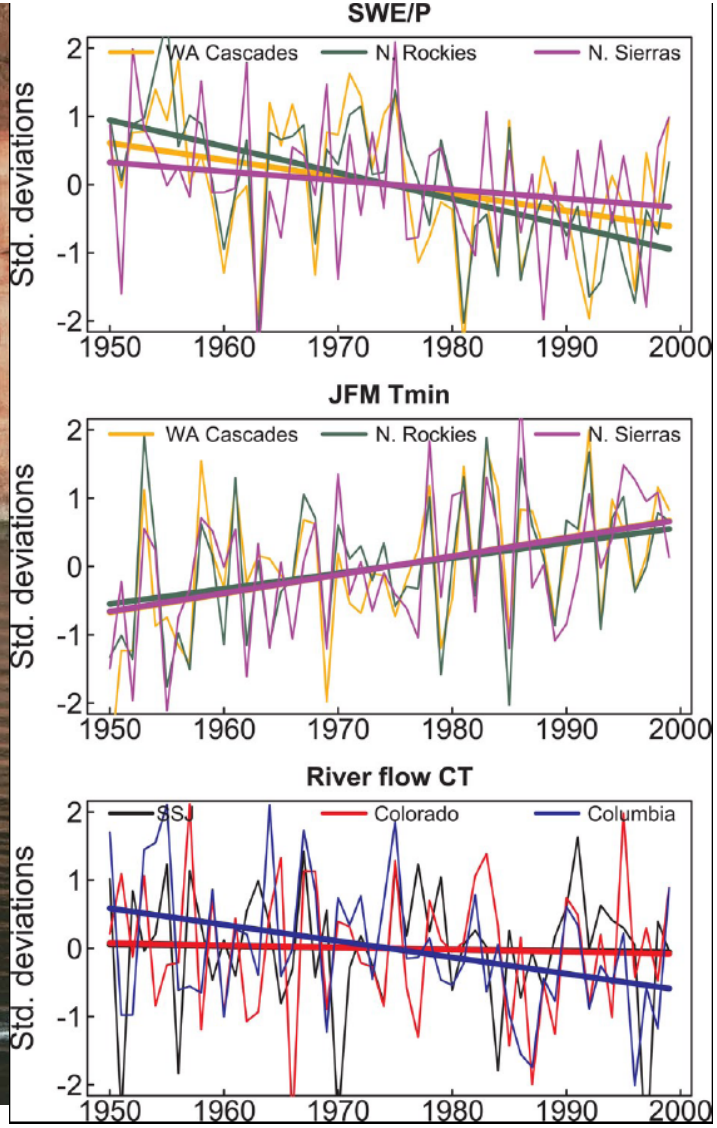
- **Alaska will likely experience precipitation increases in all seasons by 2020**
- ***Northwest will likely experience precipitation decreases in the summer by the middle of the century but increases in the spring, fall and winter by the end of the century***
- **Southwest will likely experience precipitation decreases in the spring by the middle of the century. No likelihood statements about other seasonal mean precipitation**
- **Great Plains will likely experience precipitation increases in winter by 2020. No likelihood statements about other seasonal mean precipitation changes**

# Nature and Quality of Water in a changing climate

- Increased productivity leads to increased nutrient cycling and accelerated eutrophication in lakes with sufficient nutrients and oxygen; otherwise oxygen depletion may limit overall productivity
- Possible lake stratification weakening in cold regions of country, anoxic zones could disappear
- Increased temperatures enhances toxicity of metals and increases accumulation of toxics in organisms
- Higher temps may lead to faster transfer of toxics from water column to sediments
- Not just climate, but other human actions affect WQ

National Geographic, Feb 2008



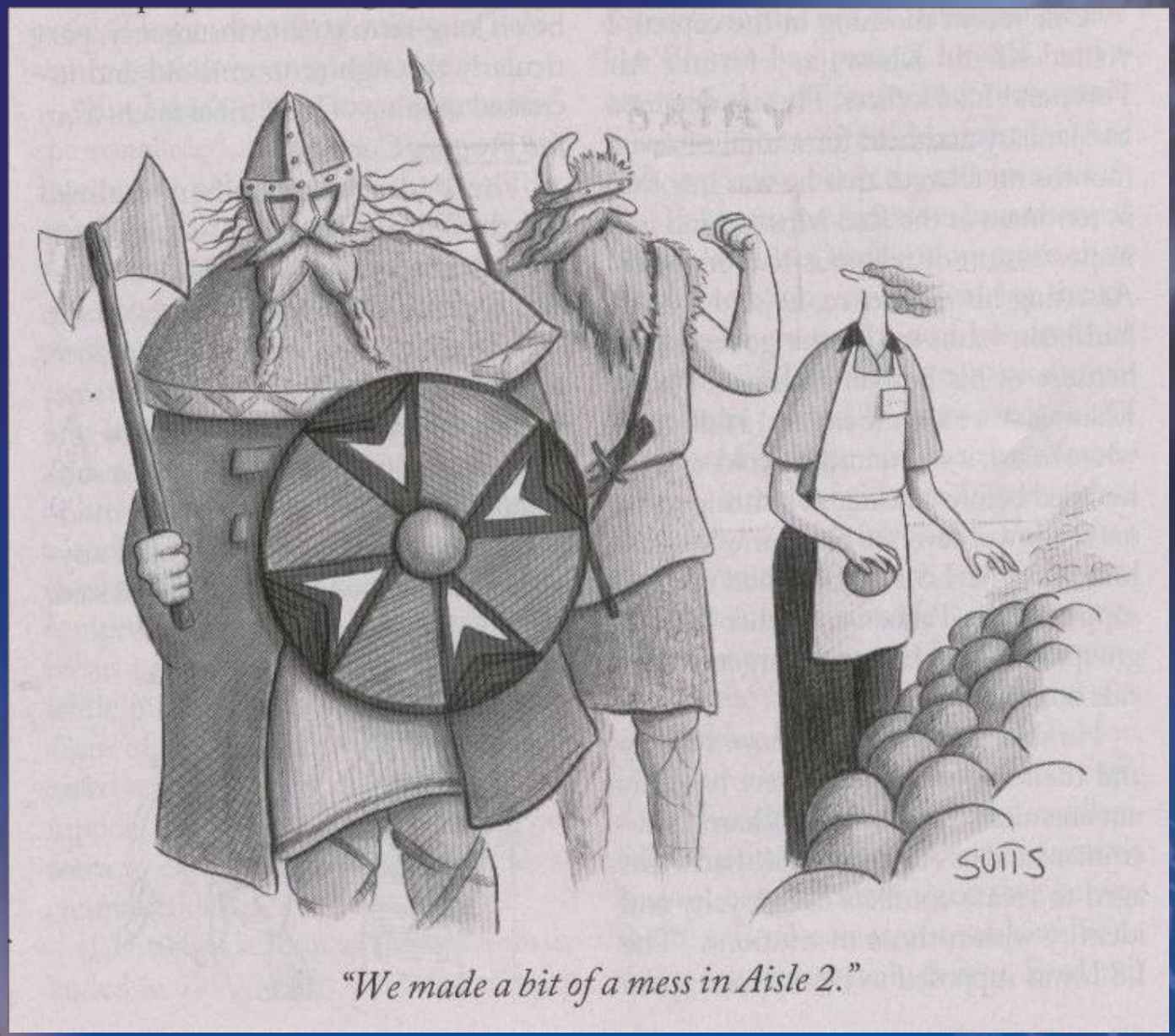




Sciencexpress

Science, February 1, 2008

# Human-Induced Changes in the Hydrology of the Western United States

Tim P. Barnett,[1]* David W. Pierce,[1] Hugo G. Hidalgo,[1] Celine Bonfils,[2] Benjamin D. Santer,[2] Tapash Das,[1] Govindasamy Bala,[2] Andrew W. Wood,[3] Toru Nozawa,[4] Arthur A. Mirin,[2] Daniel R. Cayan,[1] Michael D. Dettinger[1]




*"We made a bit of a mess in Aisle 2."*

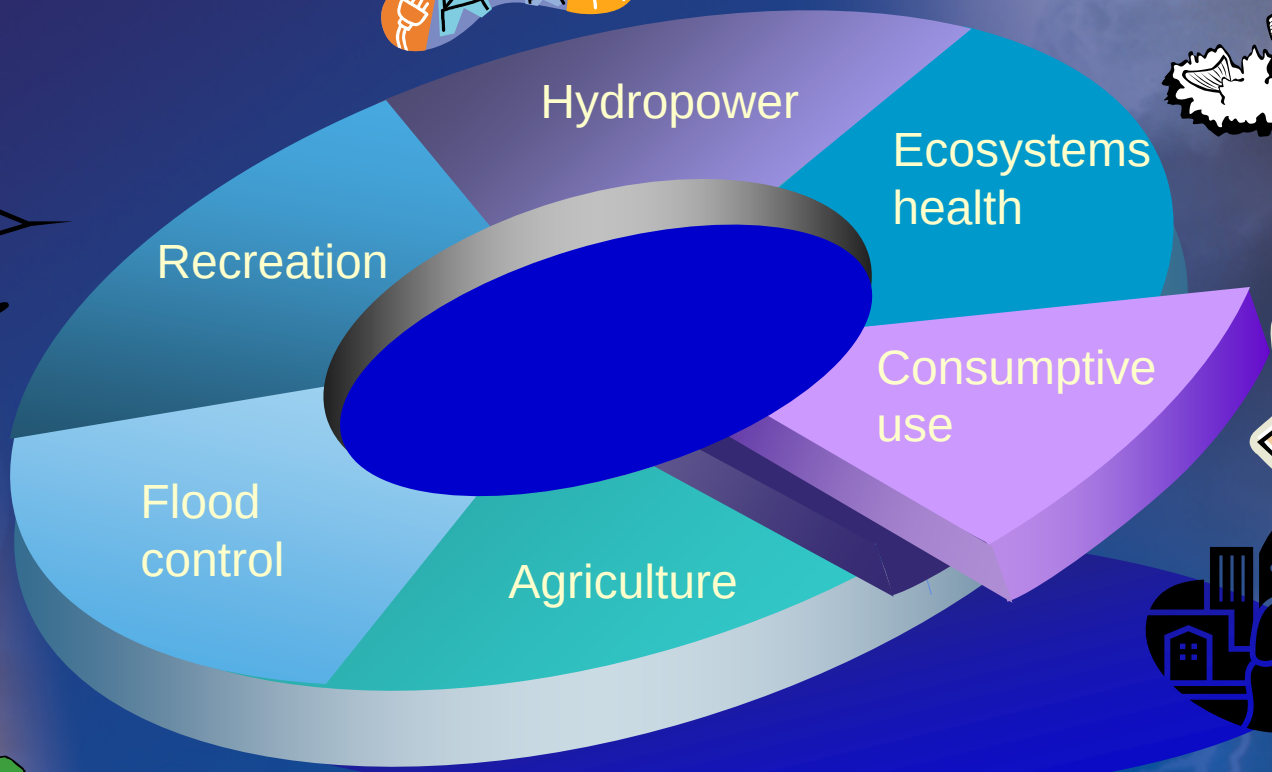
**We made a bit of a mess in aisle 2**

***If so……..***

- ***……so what ?***

- Key drivers, such as climate and technological change, are unpredictable in specific localized situations. Many change non-linearly.
- Human action in response to projections is reflexive. If important ecological or economic predictions are believed, people will react in ways that will change the future
- ***The system may change faster than the climate models can be recalibrated, during periods of transition, so forecasts are most unreliable in precisely the situations where they are most wanted for present and near-term adaptations.***

# Multiple competing values
# Multiple, competing objectives



# Adaptation: Practices, Options and Constraints

- **Supply Side**
  - ***Groundwater use***
  - ***Increase Storage Capacity***
  - ***Desal of Sea Water***
  - ***Rain-water storage***
  - ***Removal of phreatophytes***
  - ***Water Transfer***
  - ***Most have adverse environmental consequences***

- Demand Side
  - Recycle Water
  - Reduce Irrigation Demand
  - Virtual Water
  - Water Markets
  - Economic Incentives including metering, pricing
  - For many effectiveness uncertain

# Communicating……

*If it's so easy , why is it so hard?*

**Let's be "Proactive": who's first?**

- **Developing usable drought management triggers for planning in agriculture, water, energy, health, environment, and coastal zones**

- **Strengthening and expanding water conservation and efficiency programs within interstate drought plans**

- ***Adopting integrated strategies at the federal level and support a framework for collaboration between research and management***
  - **Promoting local watershed efforts**
  - **Improving ground water management strategies**

# National Integrated Drought Information System

***"A dynamic and accessible drought information system that provides users with the ability to determine the potential impacts of drought and the associated risks they bring, and the decision support tools needed to better prepare for and mitigate the effects of drought."***
***PL109-430 (2006)***

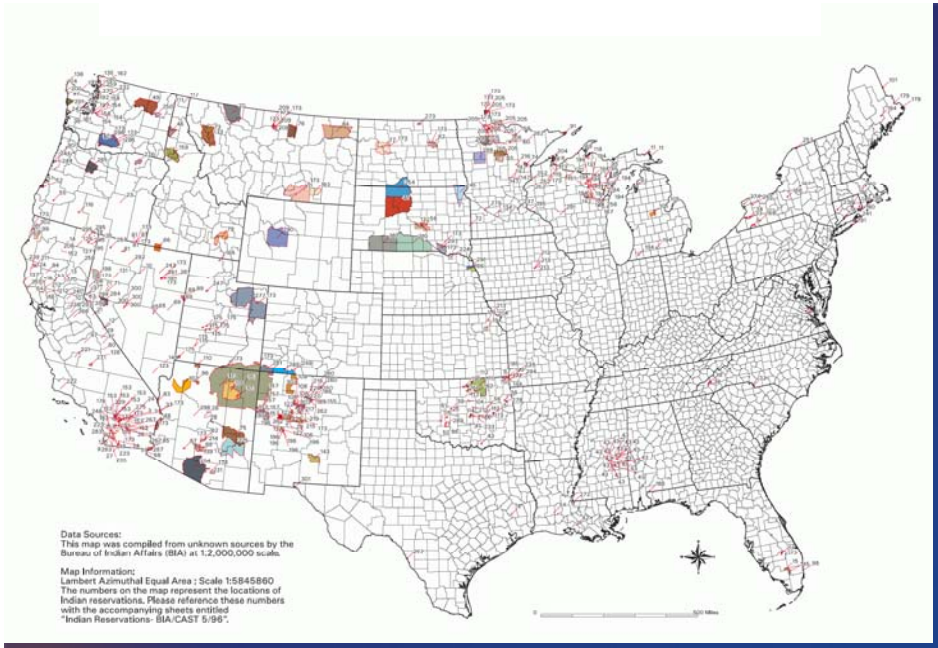
# U.S. Drought Portal
# Home Page www.drought.gov

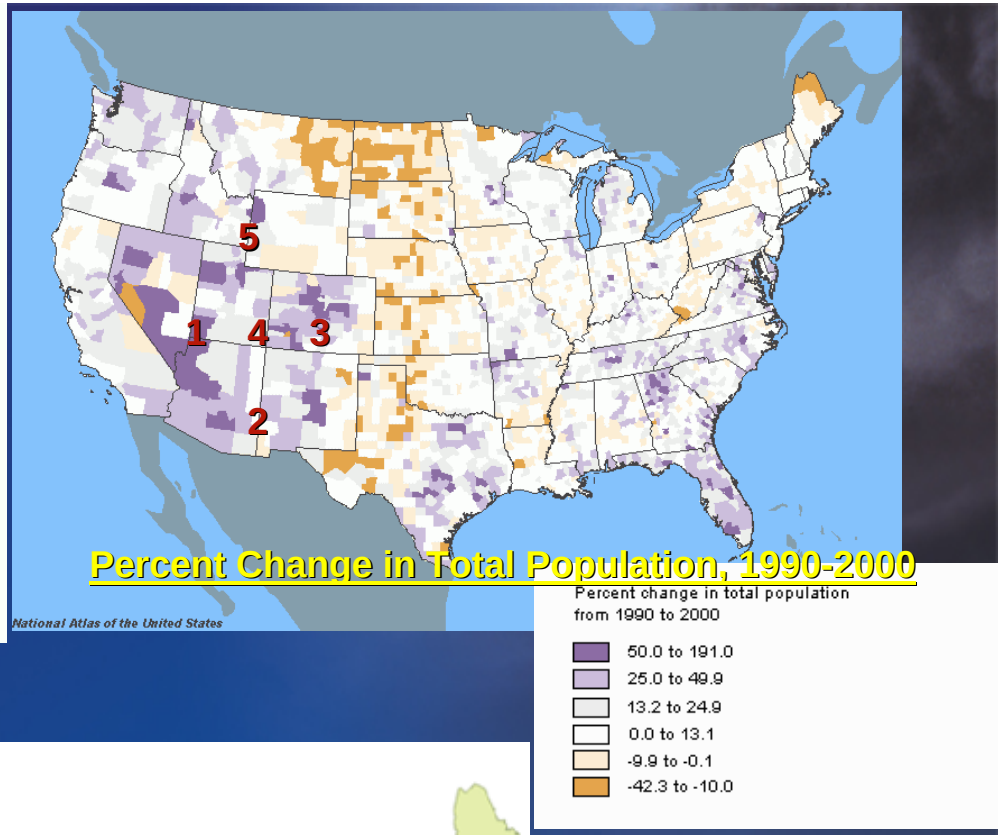
Key Clearinghouse Functions:

***Credible, Accessible, Timely***
***Drought Information***

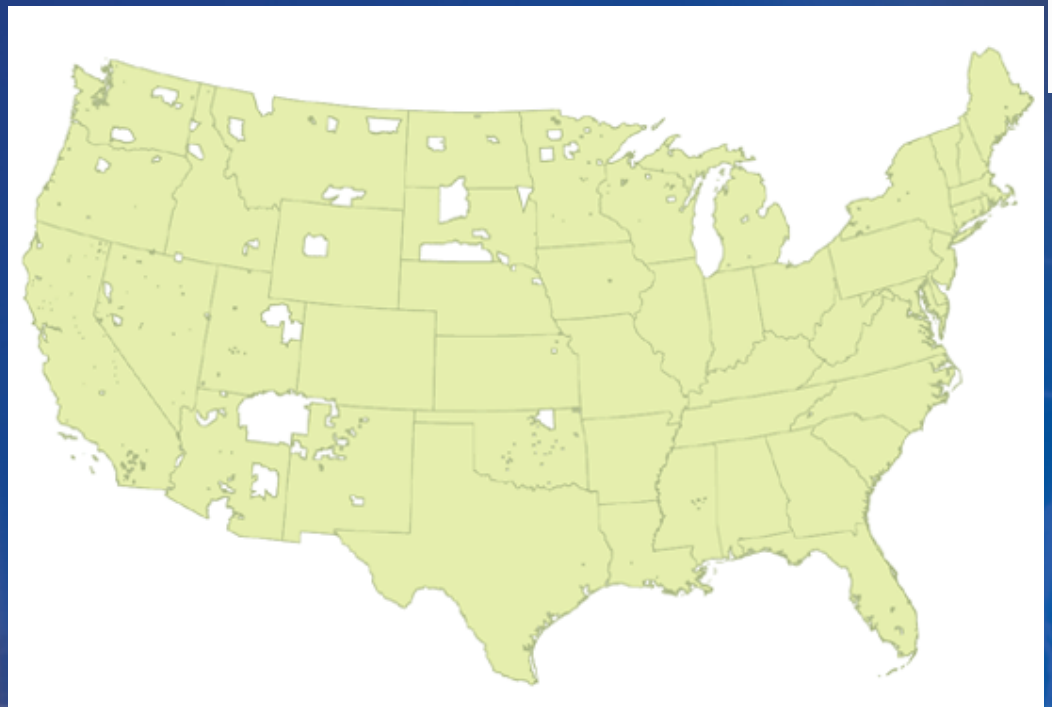
*to answer*

***Where are drought conditions now?***
***Does this event look like other events?***
***How is the drought affecting me?***
***Will the drought continue?***
***Where can I go for help?***




Percent Change in Total Population, 1990-2000



- Drought severity (also impacts on range quality,  instream conditions)

- Energy development

- Interbasin transfers

- Reserved rights to water

***"The more things change the more things stay the same"***

***"The future is not what is used to be"***

Disappearing sea ice, rising sea levels, changing weather patterns, higher temperatures, and other factors threaten to destroy native villages and many of the plant and animal species upon which people depend.

**Climate change will affect tribes differently from region to region**

Decisions as to how best to respond to the effects of climate change must begin with a clear understanding of the likely impact

- Linking Mitigation and adaptation

(Alternative energy development)

Climate change will likely force legislators to reexamine existing statutory and other law relating to tribal interests especially water

*(but rates of change will likely be faster than this process…….)*

Near-term challenges to the environment and to ESA

"Implied right" to protection of the habitat from environmental degradation

***Avenues to engage the Tribes***

***more effectively……***

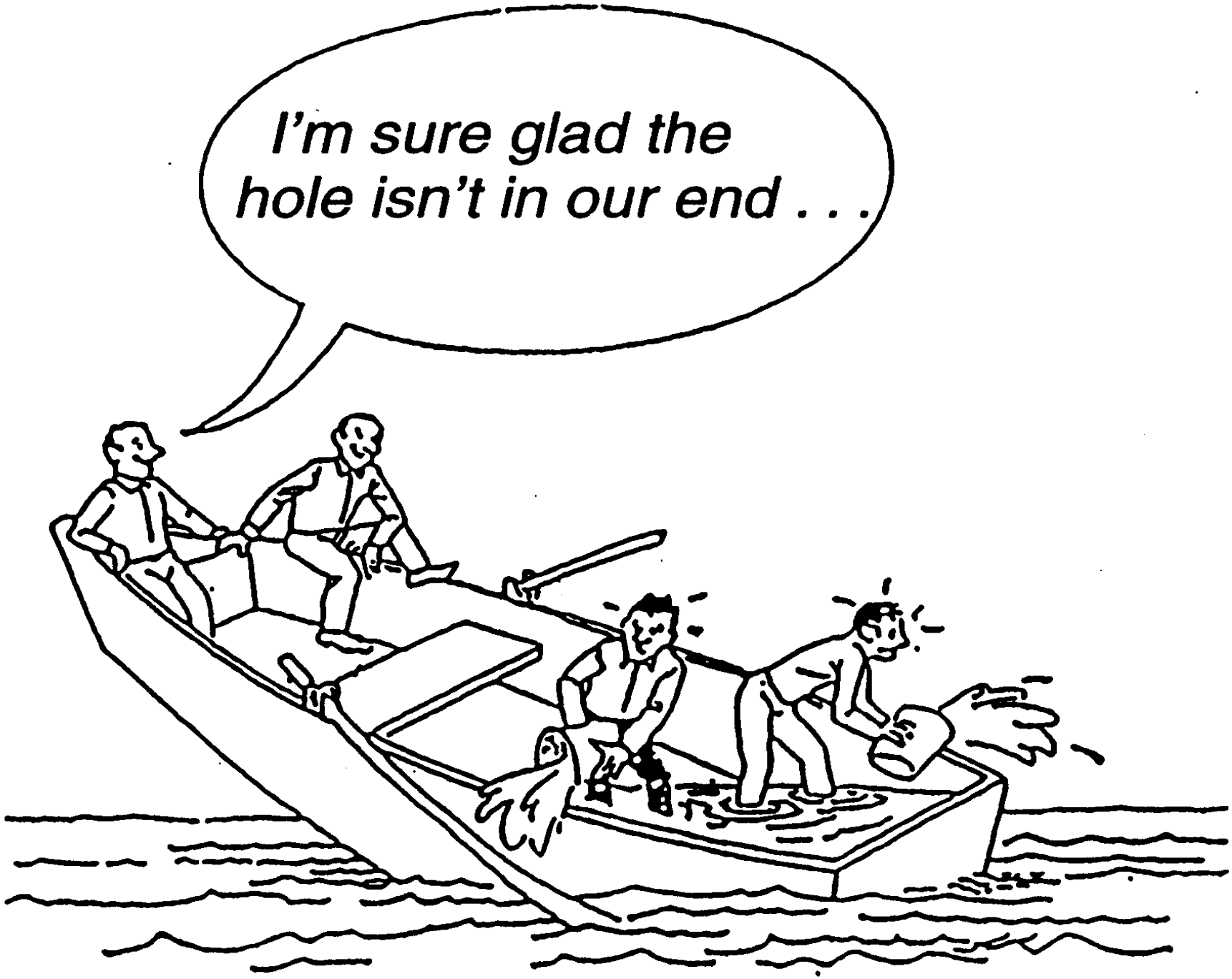
**Intergovernmental Panel on Climate Change**

**U.S. Climate Change Science Program**

**Engage Regional. State and Local Adaptation (Regional Integrated Sciences and Assessments Program CIG)**

**Information networks: NIDIS**

- Allowing space to think together and examine an issue from an empty space. Allow opportunity for joint efforts really began to take shape
- The power of language, on how such language, relationships, and interactions shape our worldviews
- Analyze the assumptions we were operating from and bring to the table in our conversations
- Share a sense of heritage, personal community including family, residing location, and the values and principles that correspond to our existence. The absolute necessity to participate and engage with the land


I'm sure glad the hole isn't in our end . . .

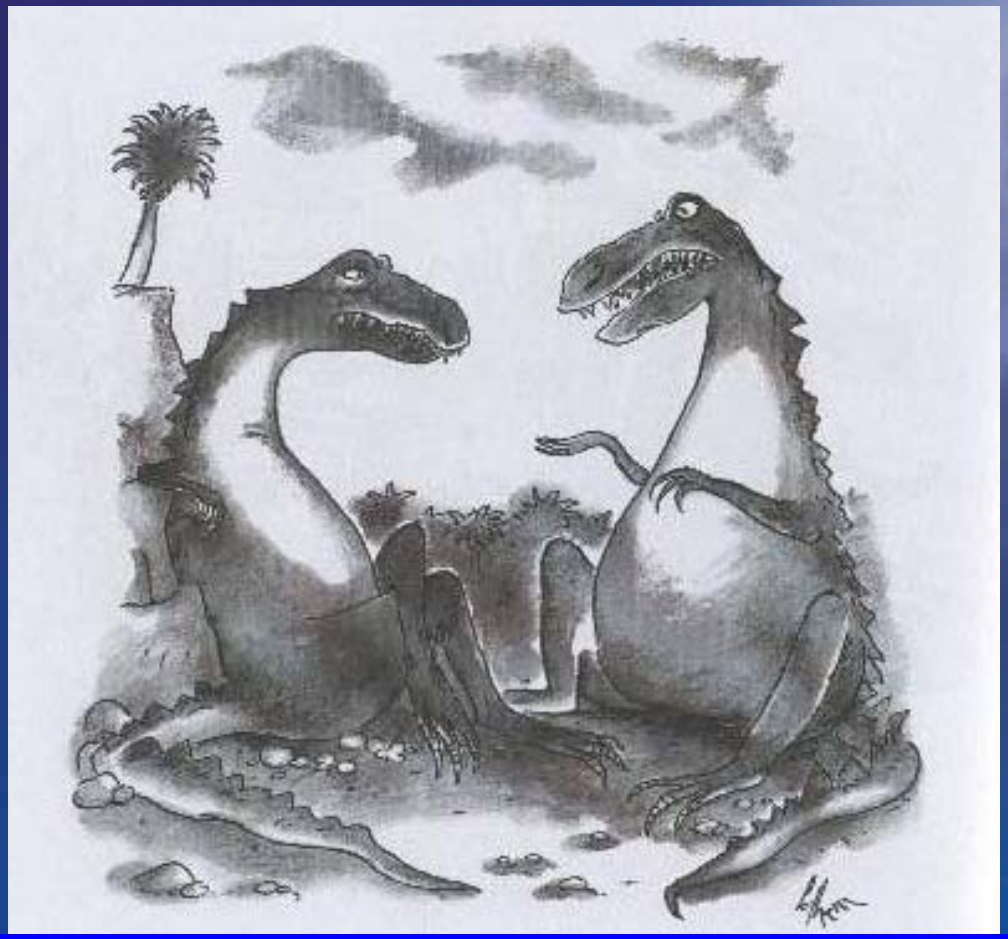
# Knowledge and information flow

Impediments to the flow of knowledge among existing components

Policies and practices that can give rise to failures of the component parts working as a system

Opportunities for and constraints to learning and institutional innovation

***National Climate Service?***



***All's I'm saying is that now might be the time to develop the technology to deflect an asteroid"***

Thank you!

## Concluding Thoughts

- **Climate Change now apparent in the West: fires, beetles, temperatures, runoff dates**
- **Many management challenges: droughts, floods, more variability**
- **Population Stresses are not going away**
- **Managing and Reducing Risk key to Future Water Management**
  - ***Assess Vulnerabilities First, Then Climate***
    - Minimize Known Risks
  - ***Relook at Yield, Flood, Env. Needs, Other 'Stationarity' Assumptions***
  - ***Models important, but used with thought***
  - ***Decision makers need to insist that CCSP address decision support issues***
  - ***Demand the Best Data Possible – NOAA, USGS, USDA - needed for management, calibrate, verify, initialize models***
- **Our ability to adapt will be a function of our flexibility and willingness to implement creative solutions.**
- **Given potential economic impacts, we are not allocating enough planning resources to regional problems.**
- **Science offerings: Data, Theory, Paleoclimate, Climate Models**

# Adaptation measures being undertaken by States and Feds

- Redefining design criteria
- Land-use and ecosystems: Limits, thresholds and buffer
- Climate, drought and ESA
- Loss estimation methodologies: third party, water transfer costs

- *Applications partnerships with end-users: Timing of adaptation intervention as climate varies and changes*
- *Collaborative framework for research and management*

# Man Bites Dog:
# How Does Water Use Affect Climate?

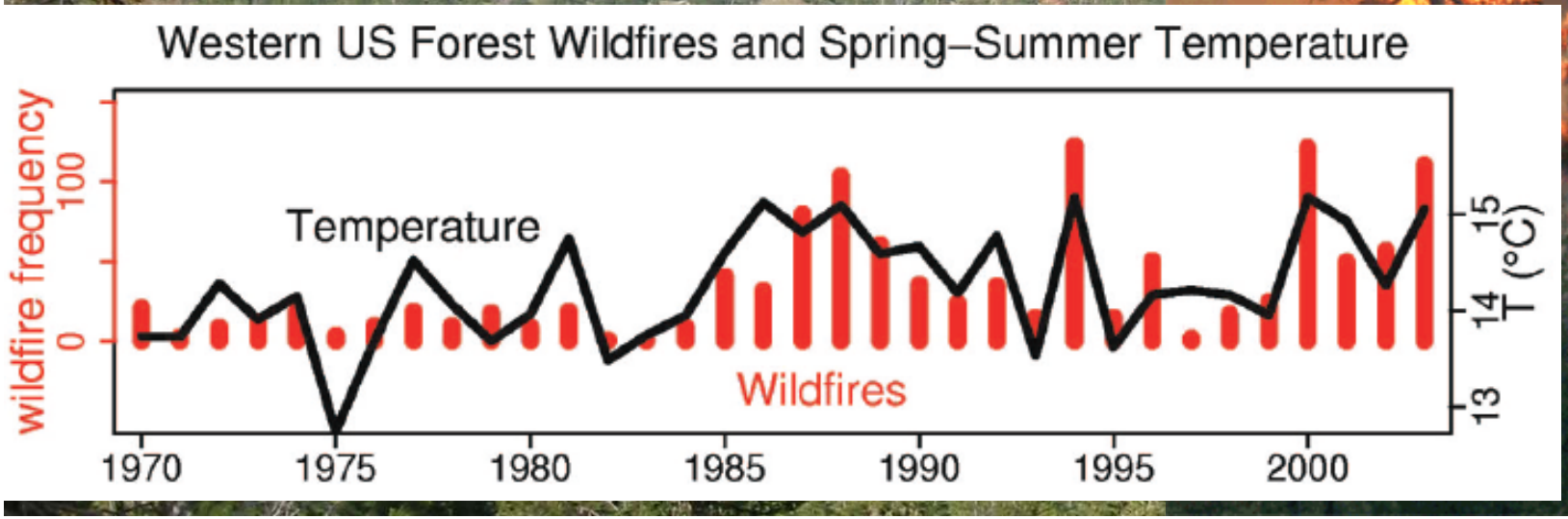
- Energy Used to Pump, Pressurize, Treat, Heat Water
- In California Water Use Consumes
  - *20% of all electricity*
  - *30% of all natural gas*
  - *Diesel for 120,000 cars/year*
- Saving Water Saves Lots of Energy
- Consider: carbon caps likely at least on electric power production
- Increased Price will reduce demand, other feedbacks possible.

NRDC
THE EARTH'S BEST DEFENSE

ENERGY DOWN THE DRAIN

*The Hidden Costs of California's Water Supply*

**Since 1986:**
**Western Fire Season 78 days longer**
**4X Increase in Fires > 1000acres**
**6X Increase in Acres Burned**
**> Increase in Forests above 6500ft**



# Reconciling Recent Studies

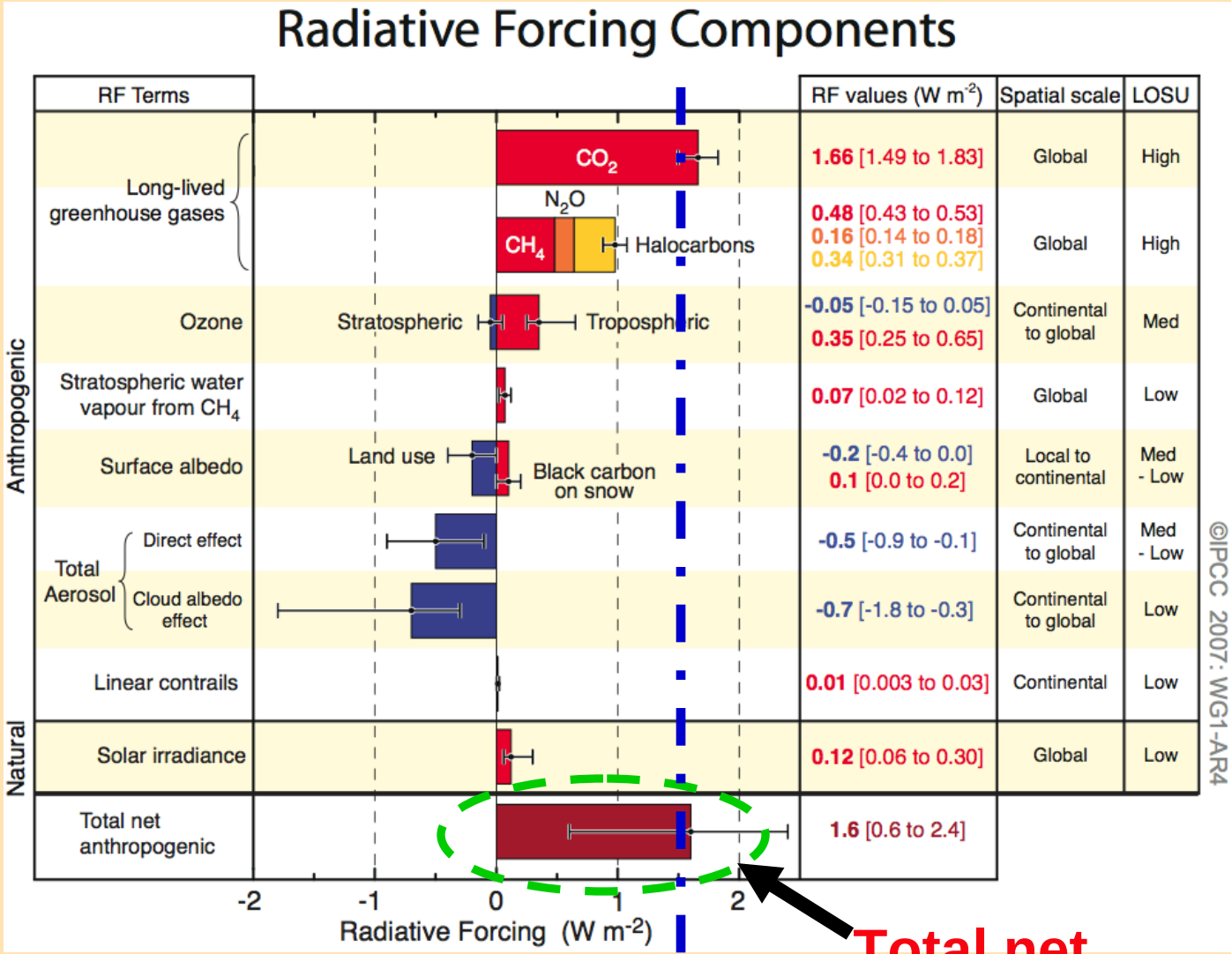
- **While there is an emerging consensus that AZ, NM likely to be drier, there is no theory for what might happen to precipitation in the Rockies.**

- **However, recent warm and dry springs are cause for concern and could counteract any additional precipitation.**
- **How summer drying affects soil moisture, land cover, groundwater probably a key part of the answer**
- ***Hoerling and Eischeid, Milly, Seager probably overstate the effect of drying on runoff.***
- ***Christensen and Lettenmaier's hydrology model probably understates the reduction of runoff by not fully considering soil moisture and groundwater.***
- ***There is a lot of work for everyone to do…***

# Human and Natural Drivers of Climate Change

1.6 W $m^{-2}$ warms like 1.6 xmas tree lights over every $m^2$ on Earth.

Carbon dioxide is causing the bulk of the forcing, and it lives a long time in our atmosphere

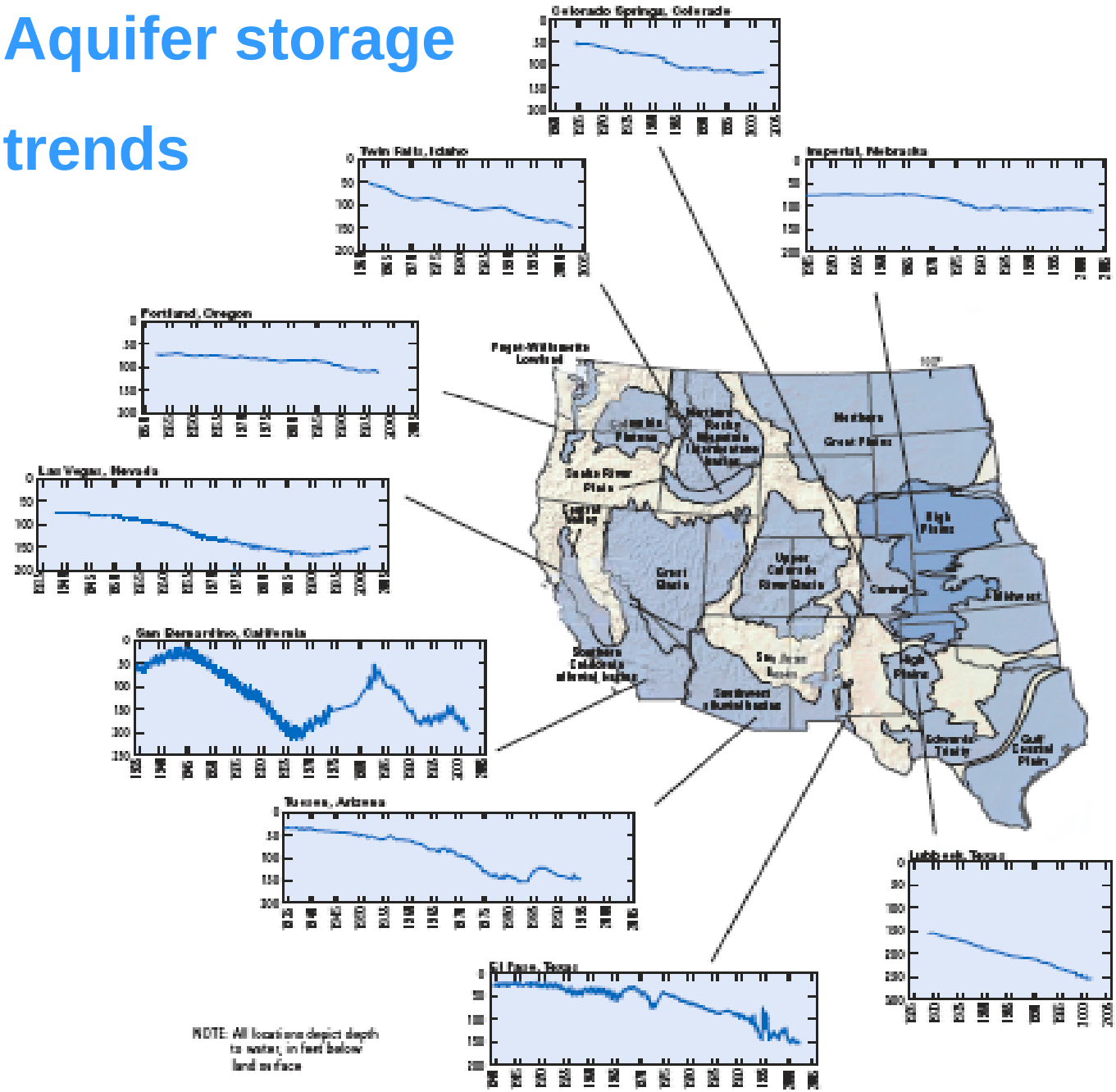
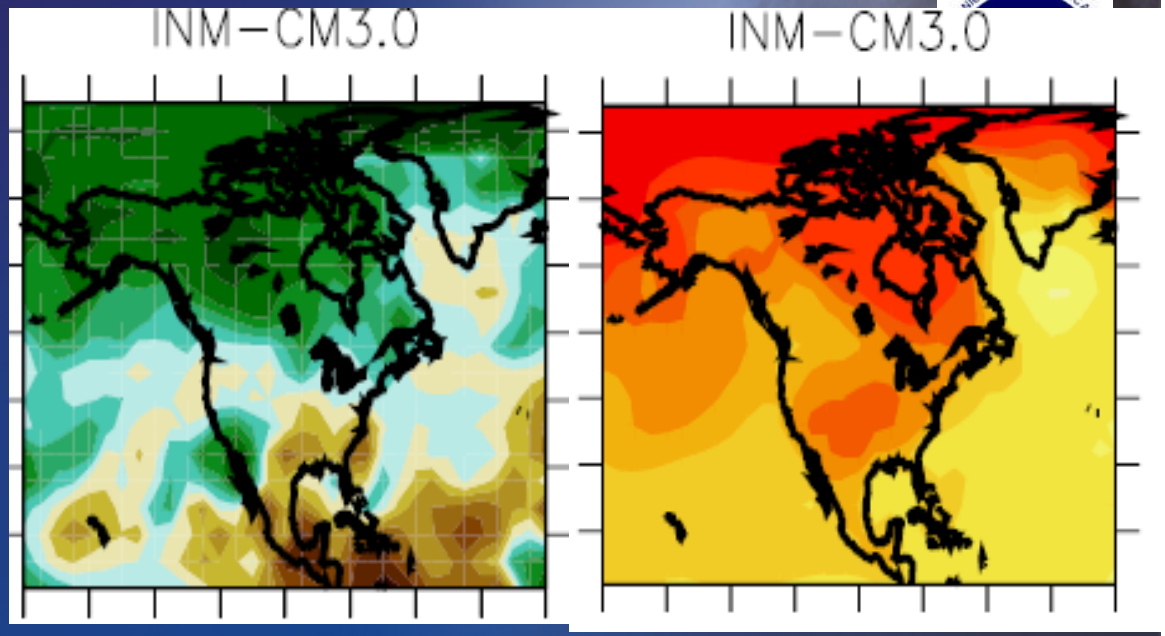
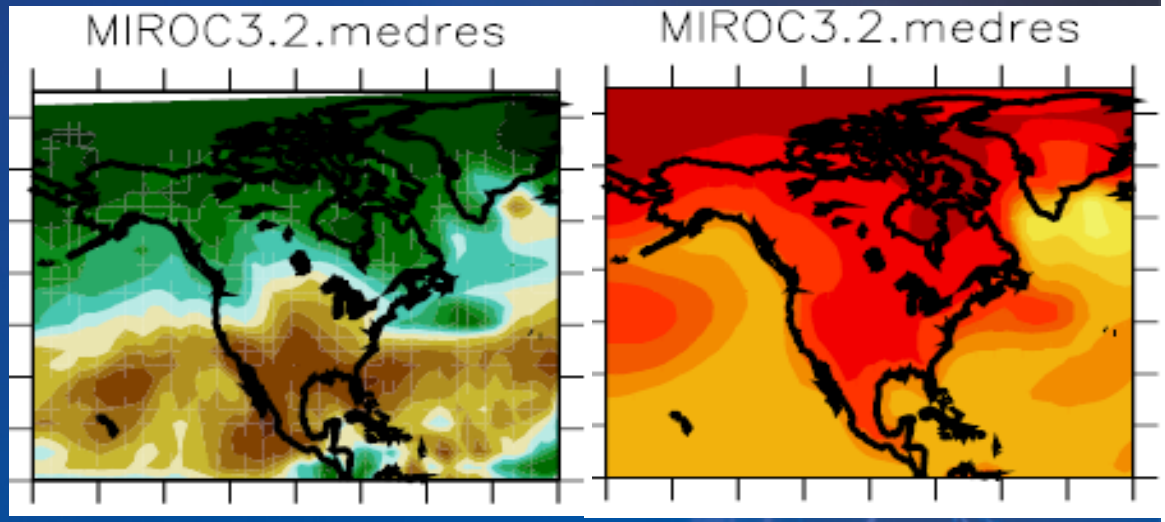
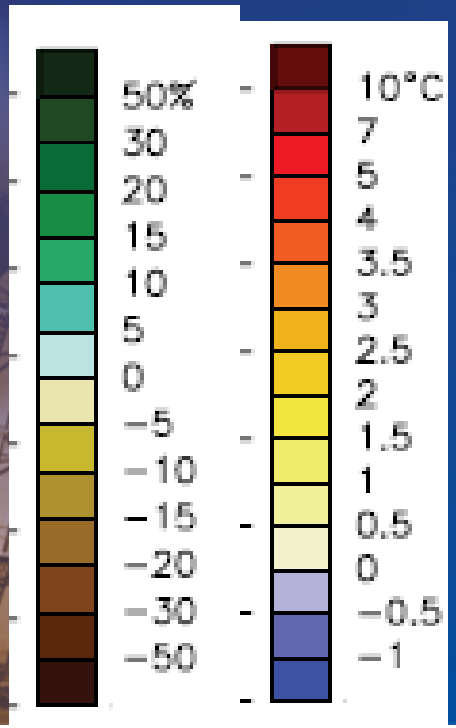



**Total net anthropogeni**

**LOSU = level of scientific understanding**

IPCC 2007: WG 1

# Aquifer storage trends



# Precip and Temp from a Wet Model and a Dry Model