Gazing into the Crystal Ball: Climate Change and Future Challenges for Arizona's Water and Environment

Arizona Chamber of Commerce
2009 Environmental and Sustainability Summit
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Phoenix, Arizona

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Institute of the Environment

CLIMAS
Climate Assessment Project for the Southwest

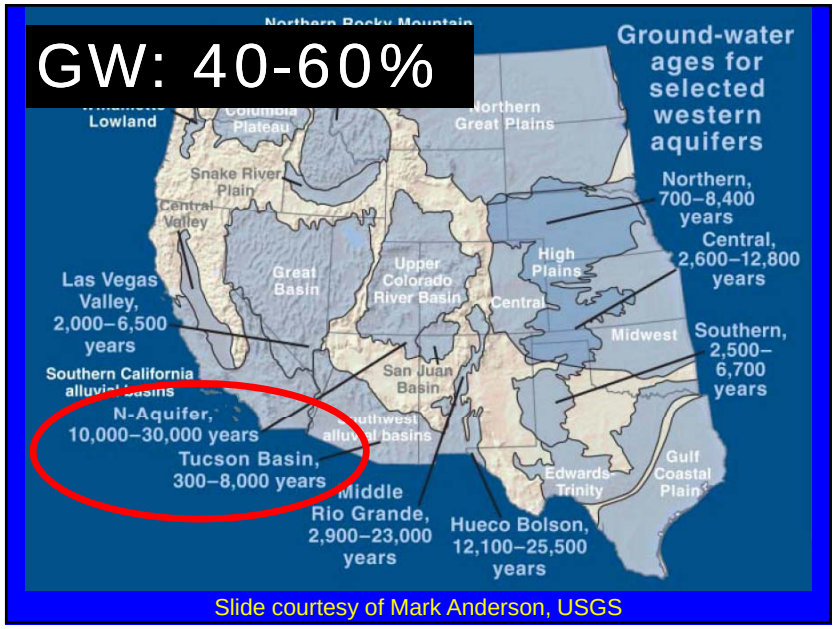
RISA
Building Bridges Between Climate Sciences and Society

Outline

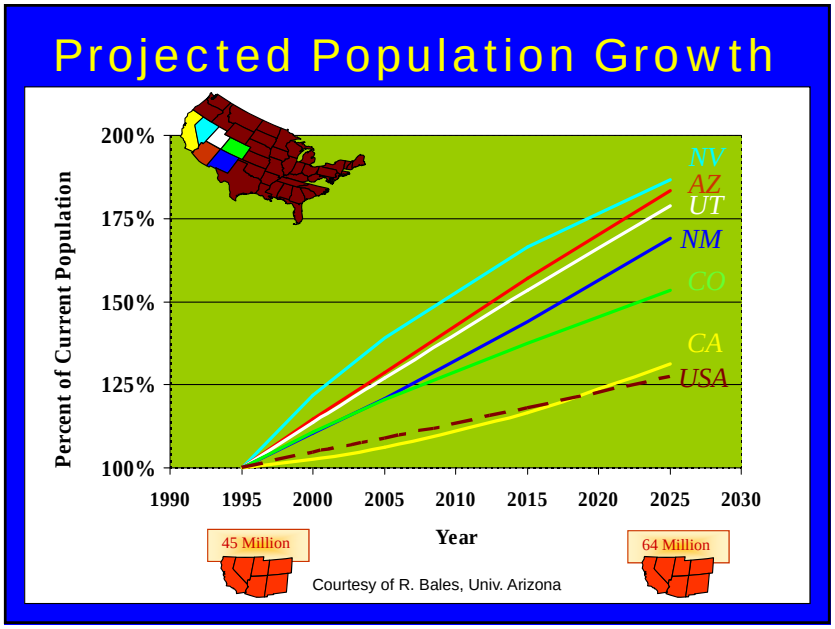
Outline
- Growth, urban heat island, vulnerability
  - The elephant in the room
- Uncertainty
- Observed changes and concerns
- Climate change projections:
  - Another straw
- Are we doomed?

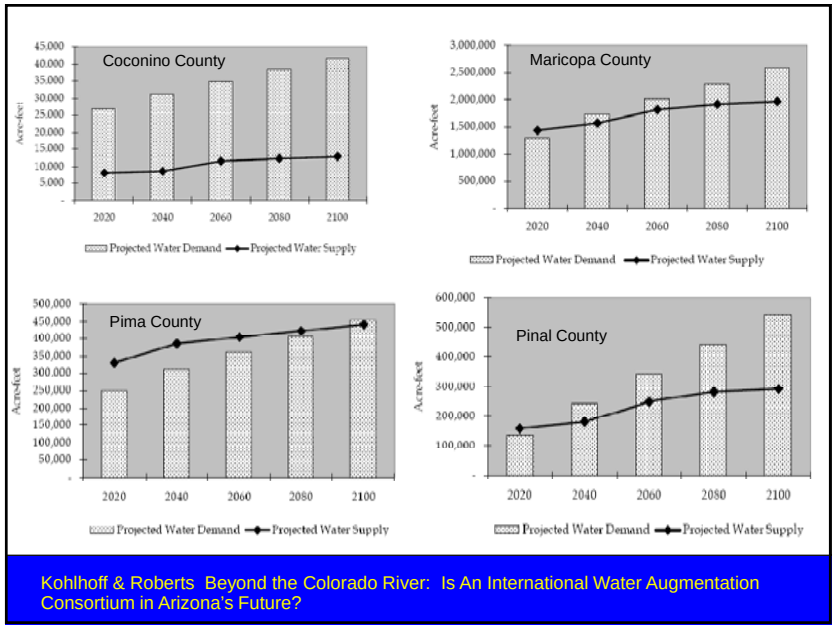
Growth

Urban Heat Island Vulnerability



Slide courtesy of Mark Anderson, USGS


Projected Population Growth
Percent of Current Population
200%
175%
150%
125%
100%
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
NV
AZ
UT
NM
CO
CA
USA
45 Million
64 Million
Courtesy of R. Bales, Univ. Arizona

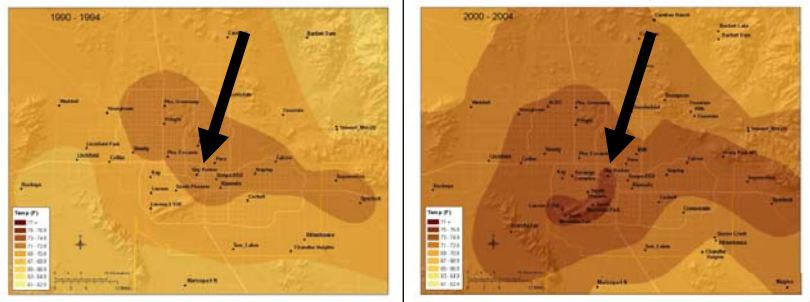

Coconino County
Maricopa County
Pima County
Pinal County
Acre-feet
2020
2040
2060
2080
2100
Projected Water Demand
Projected Water Supply
Kohlhoff & Roberts Beyond the Colorado River: Is An International Water Augmentation Consortium in Arizona's Future?

Growth-Related Concerns

Water quality
- Reuse and turf
- Repeated agricultural use (CRB)
- Declines with depth to groundwater
- Chemical pollution
- Endocrine disruptors

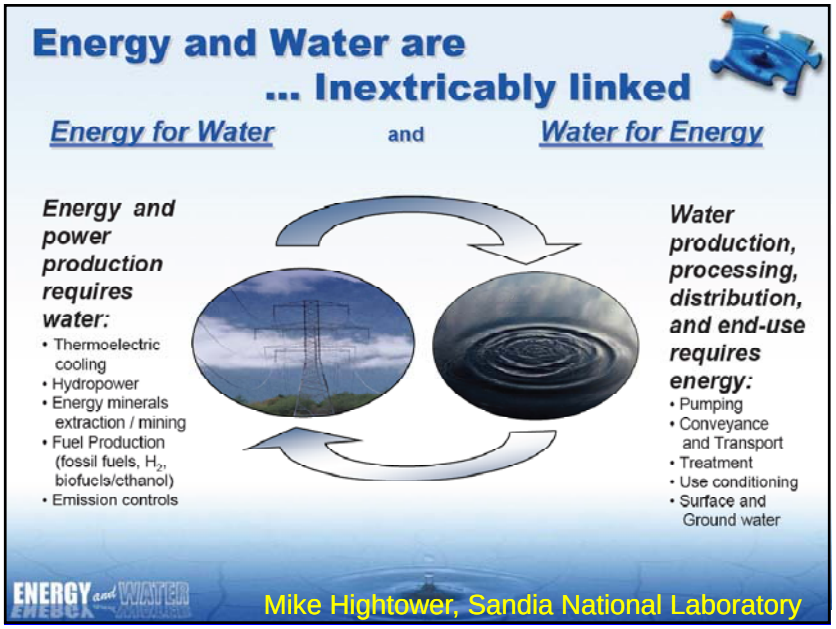
Phoenix Urban Heat Island

June Min TEM 1990-94 | June Min TEM 2000-04



4°F Warmer than surrounding desert
8°F increase in since 1970

Brazel et al., 2007 *Climate Research*



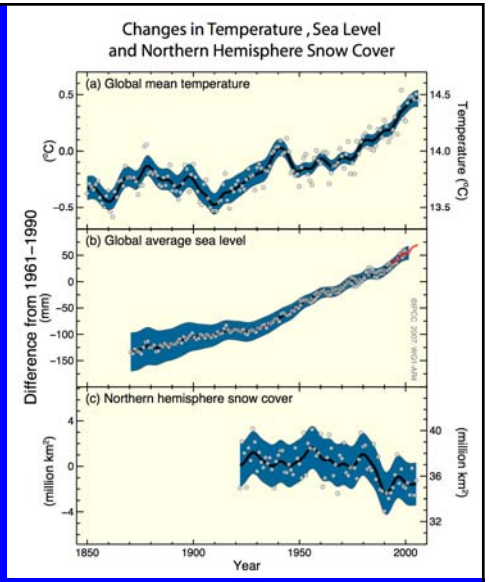
Growth-Related Vulnerabilities

- Greater exposure to hazards
- Reduced resiliency in assumptions
  - Unaccounted for changes in demand
- Reduced water supply or environmental resiliency
  - The water has to come from somewhere
- Unresolved issues
  - Indian water rights

Climate Change and Uncertainty

IPCC 4th AR

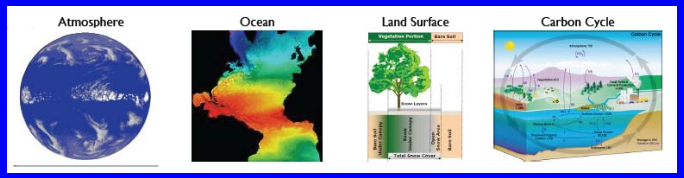
- Warming is **unequivocal**
- Increased water vapor
- Very likely due to human activity – GHGs



http://www.ipcc.ch

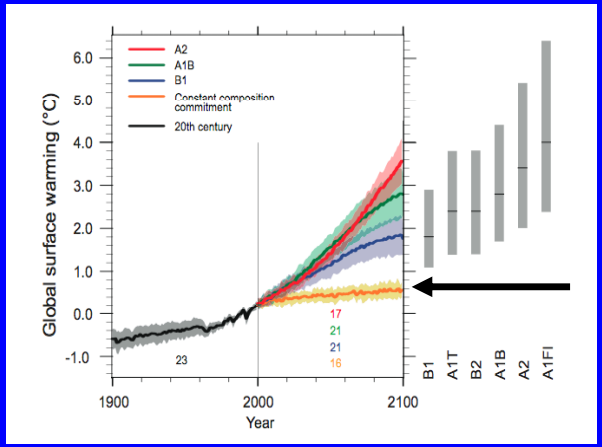
Understanding and Accepting Uncertainty

- Measurement Uncertainty
- Randomness: chaos in the climate system
- Limitations to knowledge: imperfect modeling
  - Cloud physics, model resolution
  - "Unknown Unknowns"
- Human Actions: exceedingly difficult to predict



Todd Ringler, Los Alamos National Laboratory

Our Energy Future: Largest Source of Uncertainty



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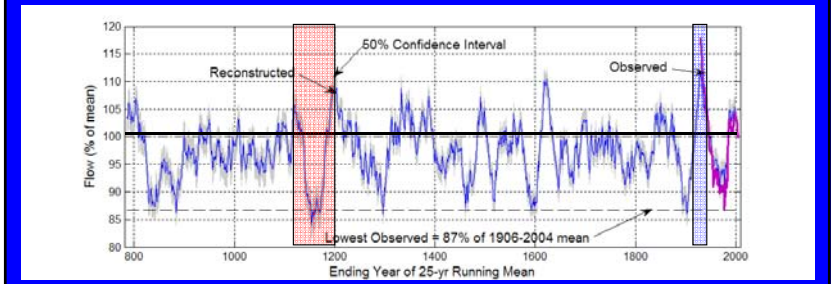
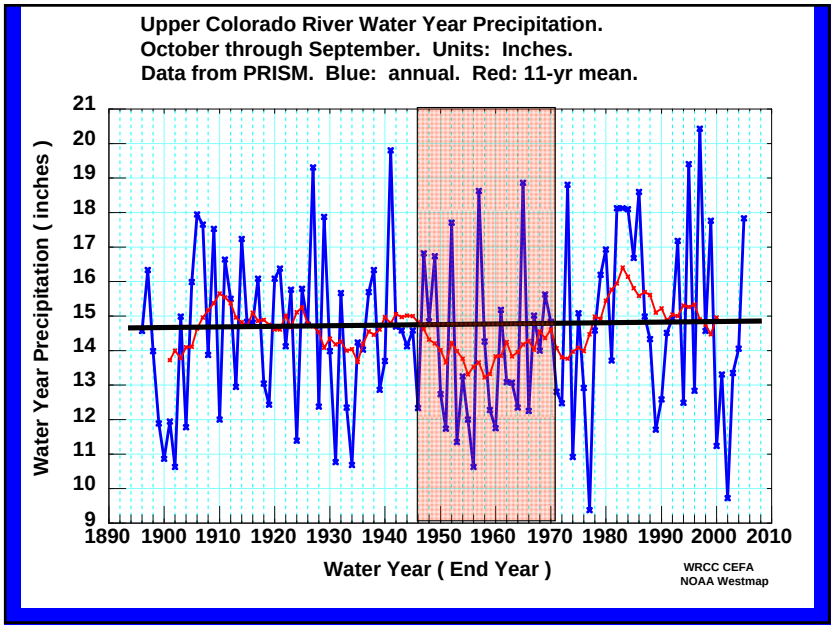
Observed Climate Changes In the Southwest

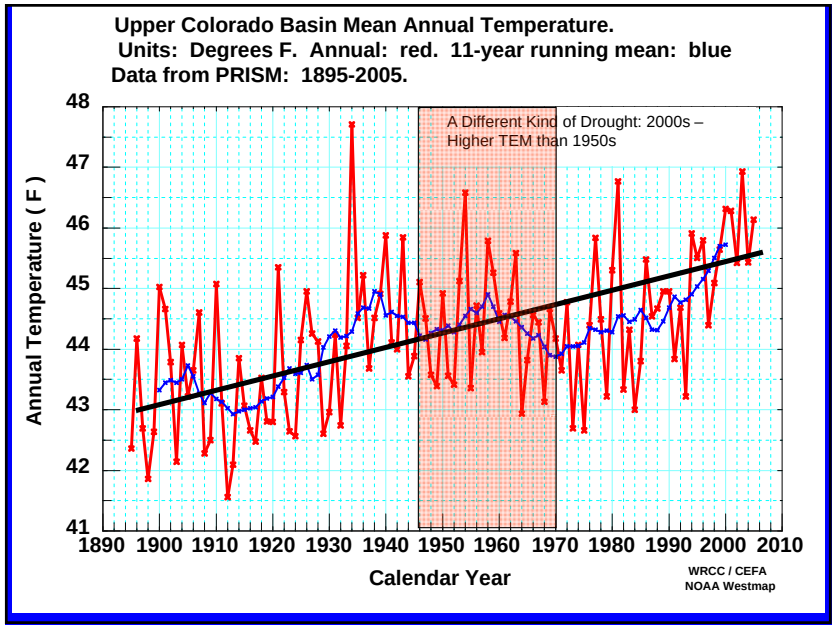
Colorado River Flow, 762-2005



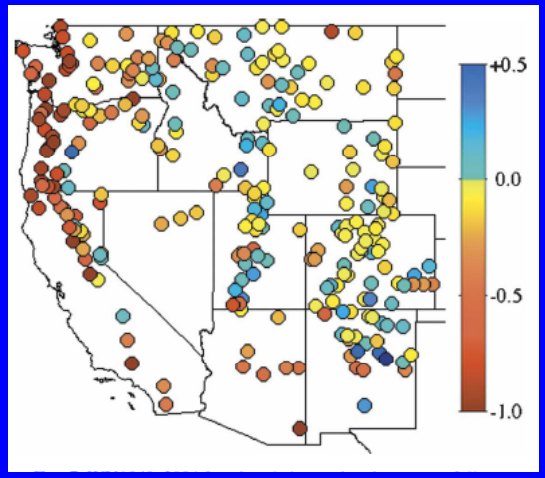
16.5 maf allocated based on early 20th
14.3 – 14.7 maf tree-ring estimated average
15.2 maf is the historic average
Bottom line: the Colorado is overallocated

Dave Meko, UA Laboratory of Tree-Ring Research


Upper Colorado River Water Year Precipitation.
October through September. Units: Inches.
Data from PRISM. Blue: annual. Red: 11-yr mean.
Water Year Precipitation (inches)
21
20
19
18
17
16
15
14
13
12
11
10
9
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
Water Year (End Year)
WRCC CEFA
NOAA Westmap


Upper Colorado Basin Mean Annual Temperature.
Units: Degrees F. Annual: red. 11-year running mean: blue
Data from PRISM: 1895-2005.
A Different Kind of Drought: 2000s –
Higher TEM than 1950s
Annual Temperature (F)
48
47
46
45
44
43
42
41
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
Calendar Year
WRCC / CEFA
NOAA Westmap

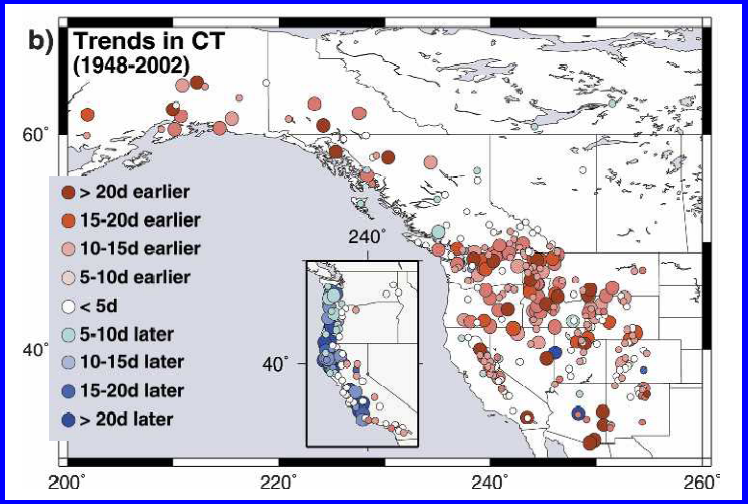
Winter Trends: Less Snow, More Rain



Strongest at elevations <8,000 and in March

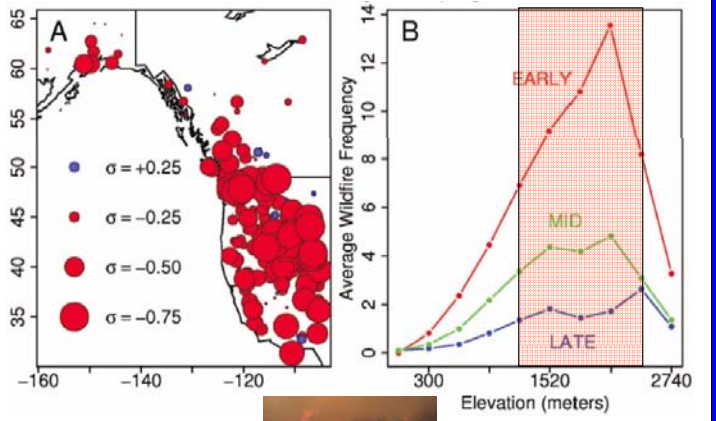
Knowles, et. al, 2006 Journal of Climate

Earlier Peak Streamflow



Stewart et al. 2005 Journal of Climate

Earlier Snowmelt = More Fires

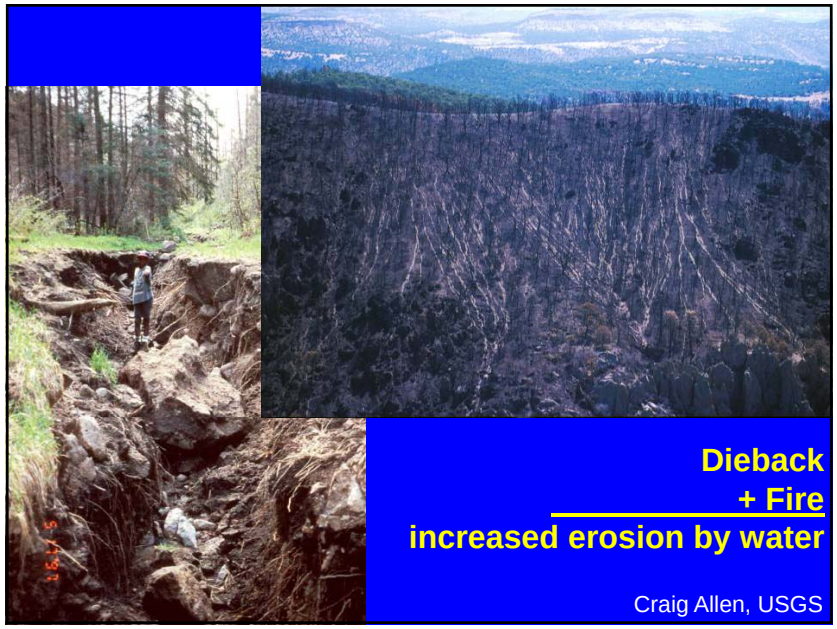


Courtesy of Tom Swetnam, UA LTRR

Massive pinyon pine dieback 2002-2004

Increased temperatures, decreased soil moisture, result in greater stress, longer insect breeding cycles. Once a threshold is crossed massive mortality occurs.

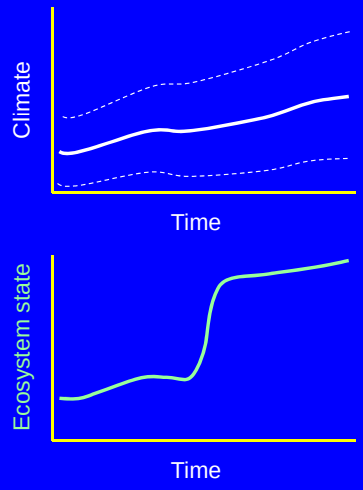
Near Flagstaff
N.S. Cobb



Dieback
+ Fire
increased erosion by water

Craig Allen, USGS

However, gradual climatic change may trigger abrupt ecosystem change (threshold response).

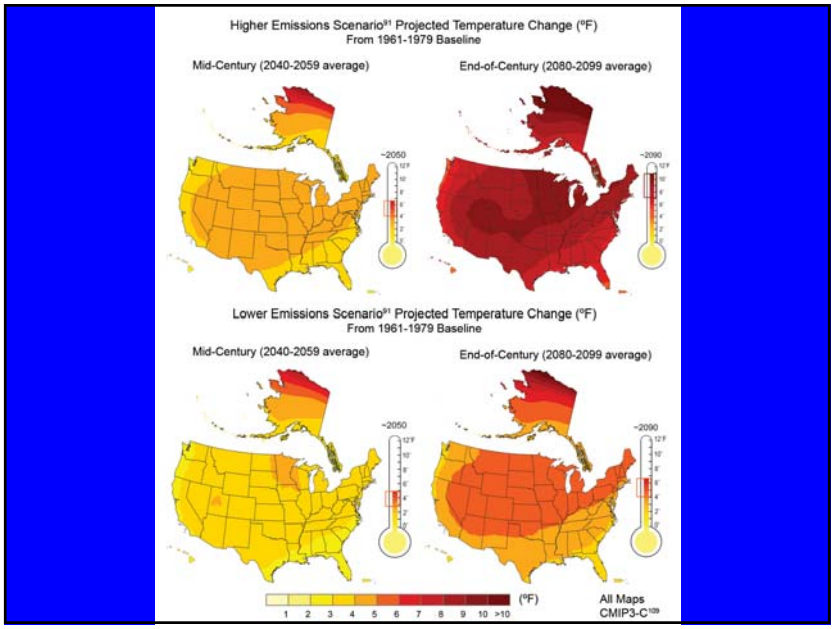


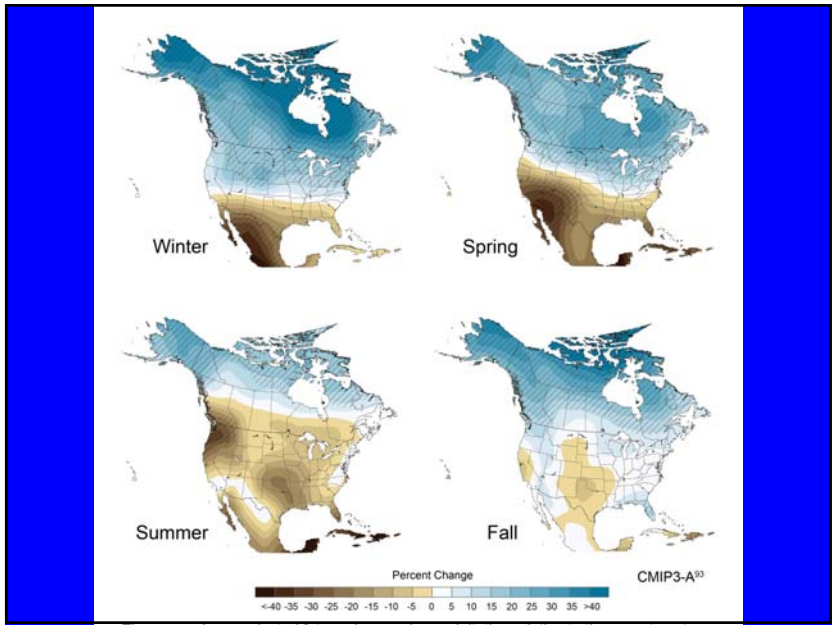
Craig Allen, USGS Bandelier National Monument

Key Regional Concerns

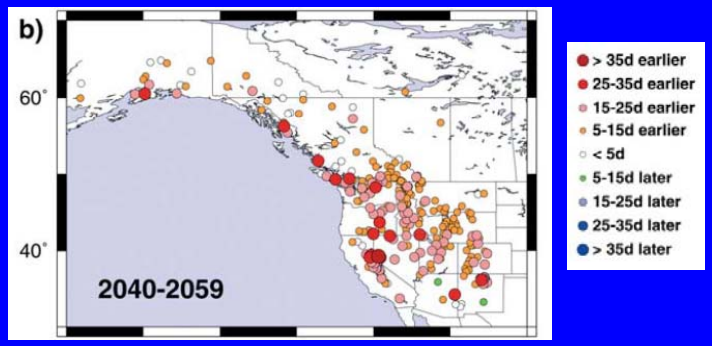
- Altered snow hydrology
- Severe and multi-decade drought
- Threshold surprises
- Temperature is a hydrologic variable

Projected Climate Changes for the Southwest


Higher Emissions Scenario[91] Projected Temperature Change (°F)
From 1961-1979 Baseline
Mid-Century (2040-2059 average)
End-of-Century (2080-2099 average)
~2050
~2090
Lower Emissions Scenario[91] Projected Temperature Change (°F)
From 1961-1979 Baseline
Mid-Century (2040-2059 average)
End-of-Century (2080-2099 average)
~2050
~2090
1 2 3 4 5 6 7 8 9 10 >10
(°F)
All Maps
CMIP3-C[109]


Winter
Spring
Summer
Fall
Percent Change
<-40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 >40
CMIP3-A[93]

Earlier Peak Streamflow



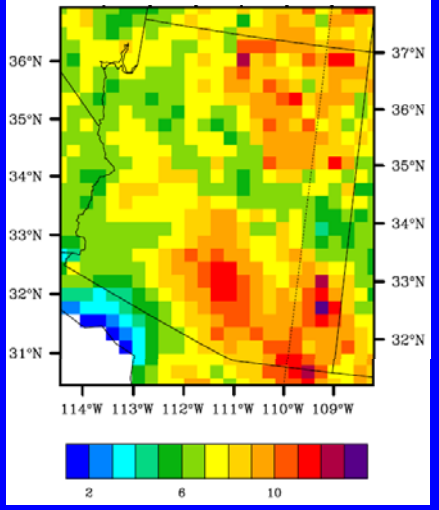
From: Stewart et al., 2004 *Climatic Change*

Heat Waves

Increased Length of Average Heat Wave (days)

4 models and A2 "Business as Usual" emissions scenarios in a Regional Climate Model

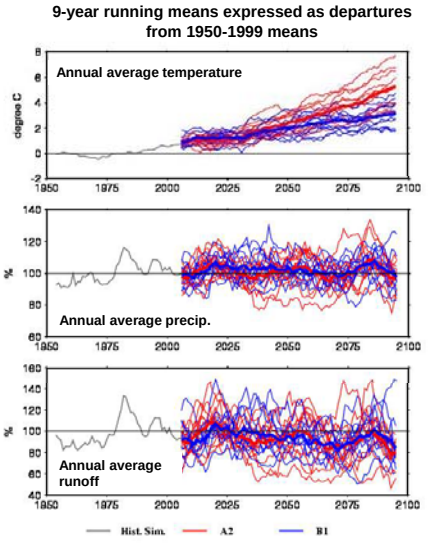
2071-2095
Minus
1961-1985



Diffenbaugh et al., 2005
Proceedings of the National Academy of Science

6-7% Decrease in runoff, 2040-2069
8-11% Decrease in runoff, 2070-2099
Decreases in hydropower
Treaty implications

11 models and 2 emissions scenarios downscaled to the Colorado River Basin



Christensen & Lettenmaier, 2006

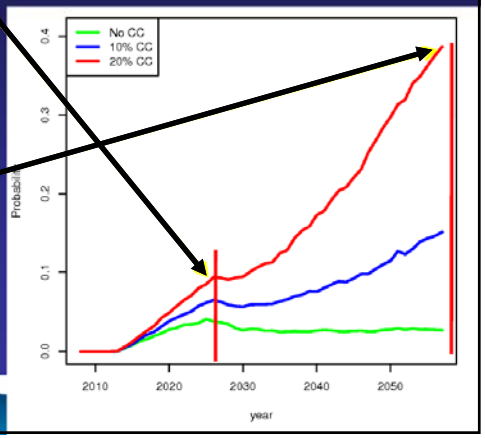
Risk of Reservoir Drying at 2026 and 2050

Rajagopalan, et al., 2009 Water Resources Research

Risk of Empty Reservoirs in at 2026…
Low = 5-10% For All Flows

at 2058….
No Flow Change = 3%
-10% Flows = 10%
-20% Flows = 40%

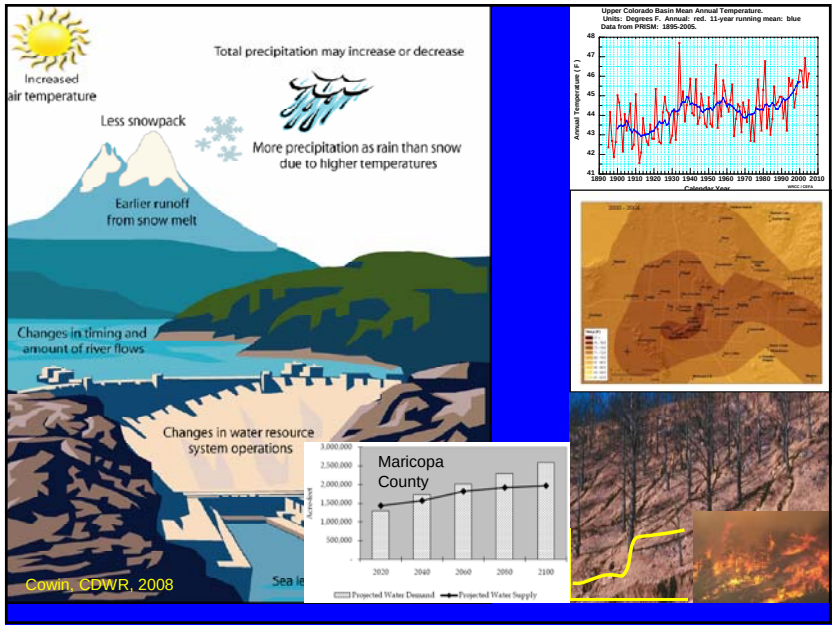
Key Lesson: Large Non-linear increase in risk with 20% CC – Understanding -10% vs -20% is Important!



Western Water Assessment

Summary

Are we doomed?



Climate Change Challenges

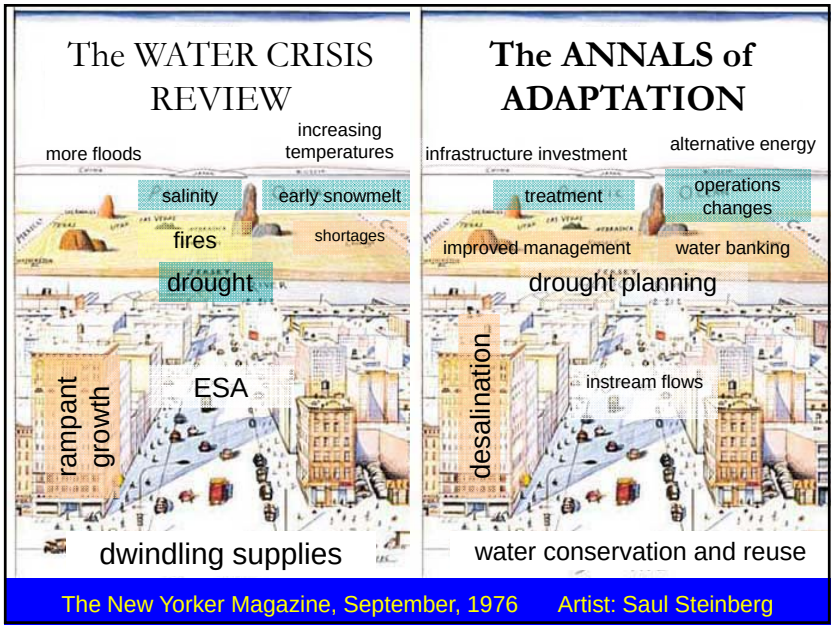
- Long-term and human-caused
- Multivariate
- Geographically pervasive
- Notably rapid
- Likely to remain uncertain
- Interactions with other variables and systems
- Surprises and abrupt changes

http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art5/

Management for Resilience

- Identify critical thresholds
- Identify vulnerabilities
- Conduct scenario planning
- Diversify portfolio
- Secure backup supplies
- Build flexible interconnections
- Develop adaptive management capacity

Holway, 2008



Are we doomed?

Only if we ignore these issues and do nothing

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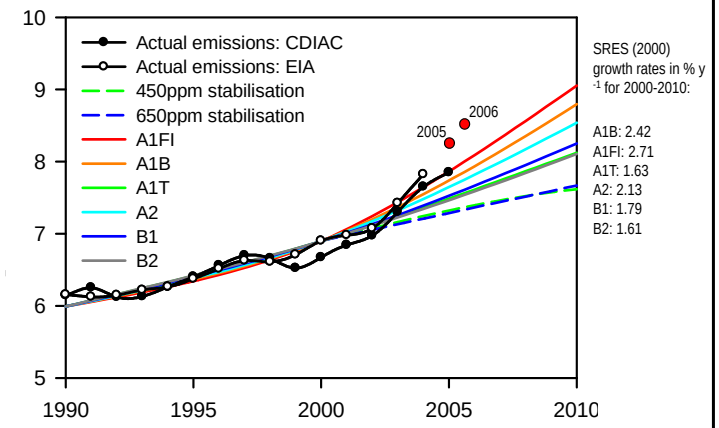
http://www.climate.noaa.gov/cpo_pa/risa/

Trajectory of Global Fossil Fuel Emissions



Raupach et al. 2007, PNAS

Joellen Russell, UA Geosciences

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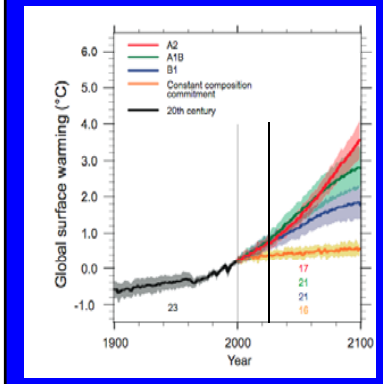

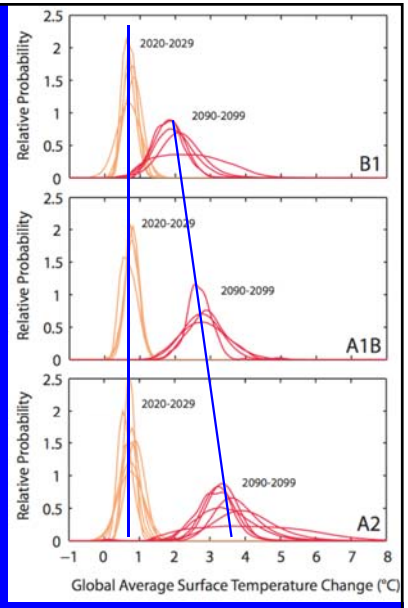

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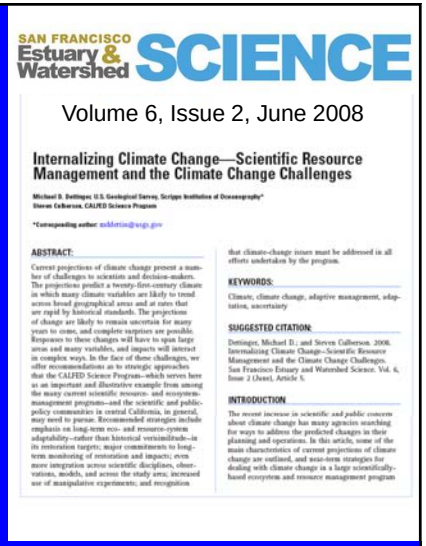
Internalizing Climate Change—Scientific Resource Management and the Climate Change Challenges

Michael D. Dettinger
USGS, CAP, SIO
Steven Culberson
CALFED Science Program


SAN FRANCISCO Estuary & Watershed SCIENCE
Volume 6, Issue 2, June 2008
Internalizing Climate Change—Scientific Resource Management and the Climate Change Challenges

ABSTRACT:

KEYWORDS:

SUGGESTED CITATION:

INTRODUCTION

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