A Framework for Establishing *Climate Resilient Communities*

Planning for an Uncertain Future

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Fundamental Issues – Climate Change

- A planning problem at local, national and global levels
- The degree, nature, and timing of the impacts are potentially large, but uncertain
- "Policymakers look to climate change science to answer two critical questions:
  - *What can we do to prepare for the impacts of climate change (adaptation);*
  - *What steps might be taken to slow it (mitigation)?"*

  \- Richard Alley, Professor, Penn State University

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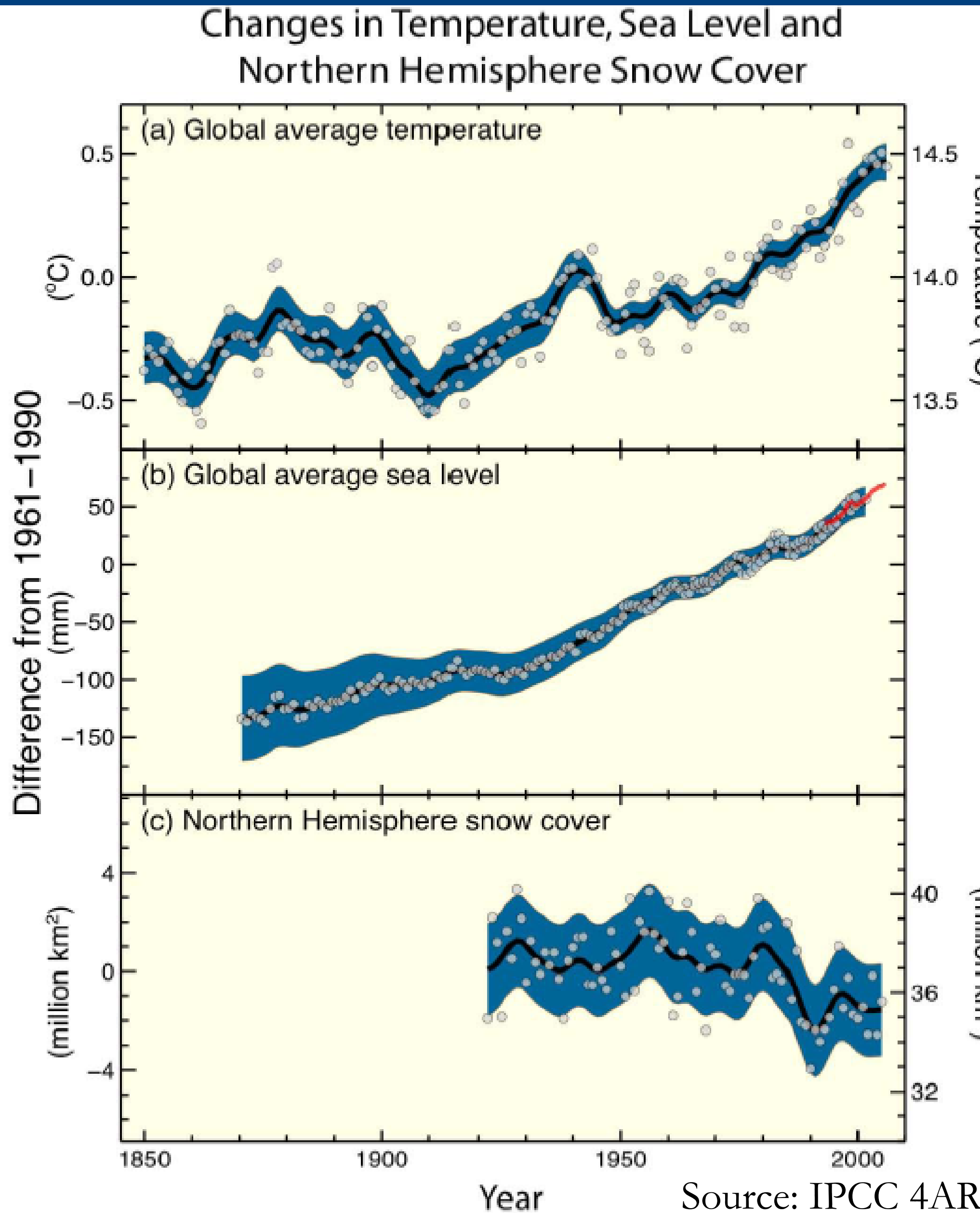
Is Climate Changing?

A Brief Recap of Climate *Observations*

Global Temperatures, Sea Levels, and Snow Cover



+ 1 deg. C

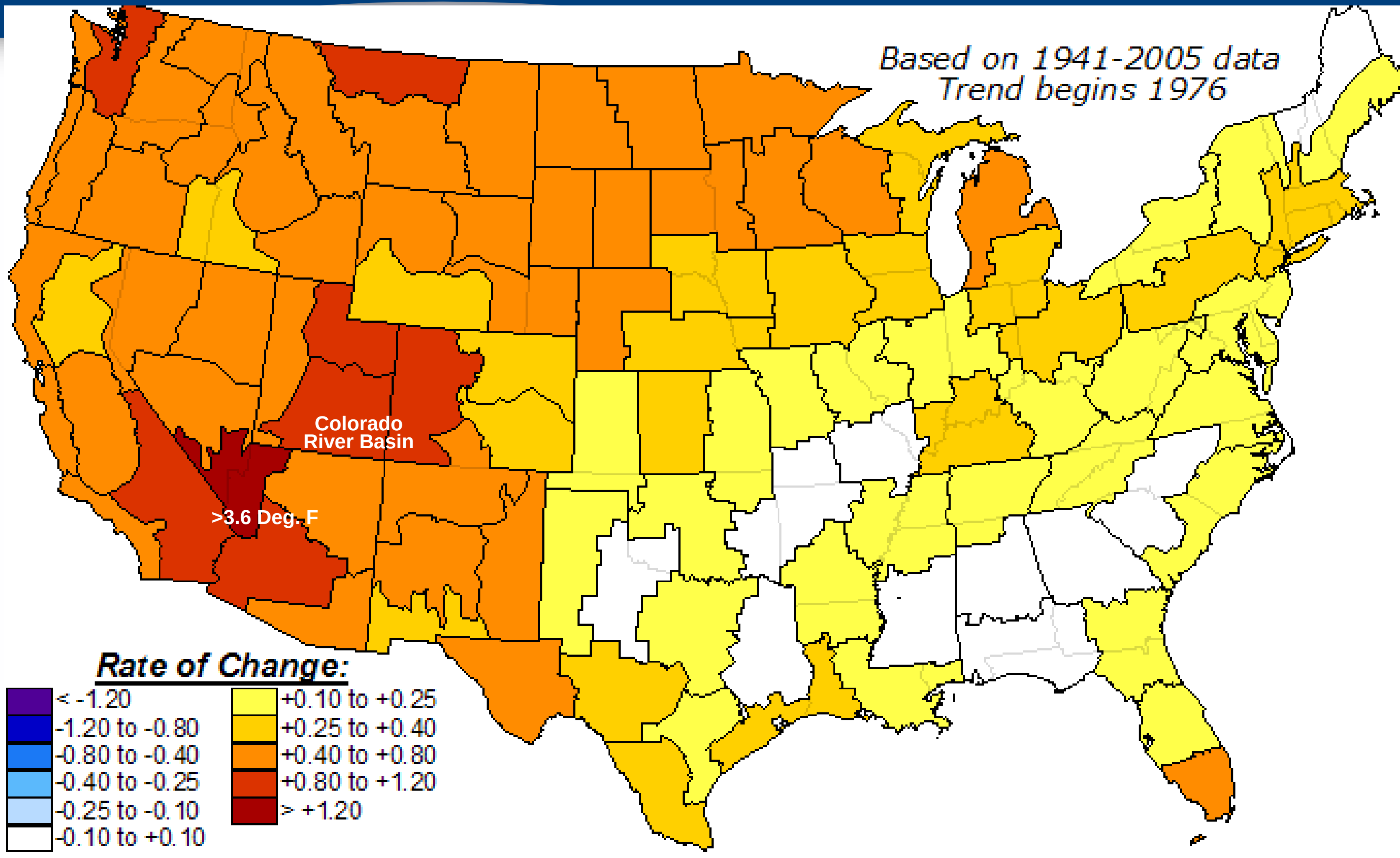
+ 175 mm

-1.5 m km2

Source: IPCC 4AR (2007)

Observed U.S. Temperature Trends

Rate of Change Long-Term Temperature Trend
Degrees F / Decade, Starting in 1976



Source: Climate Prediction Center (2008)

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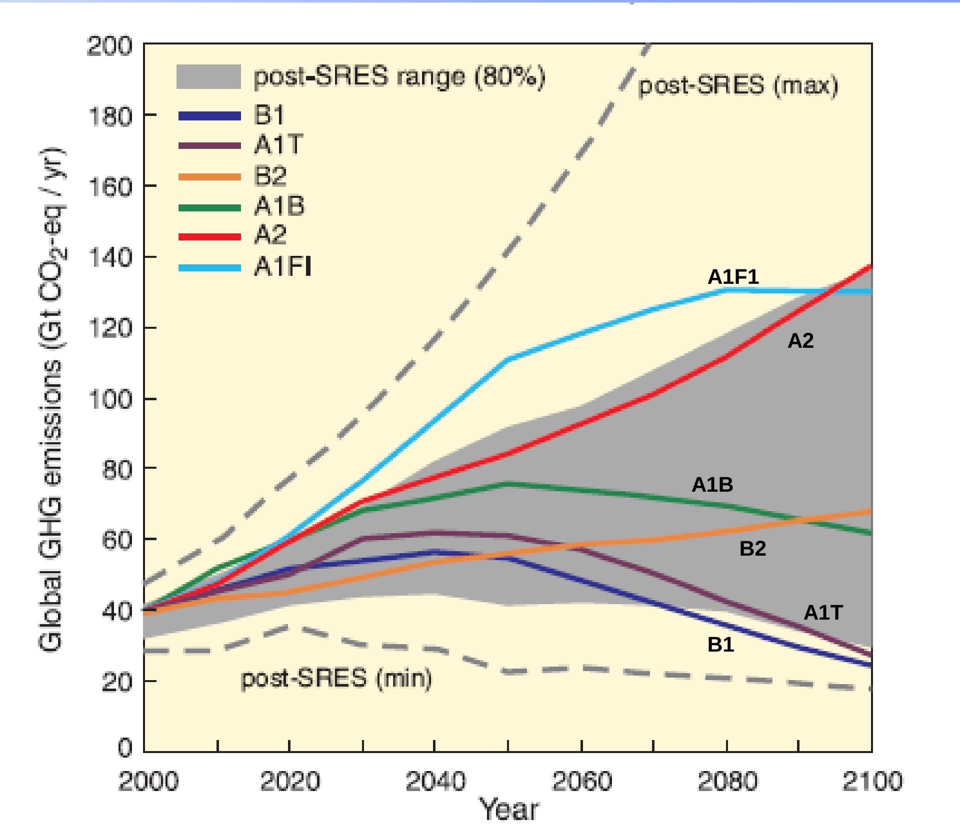
Is Climate Changing?

A Brief Recap of Climate Change *Projections*

Emission Scenarios Developed by Intergovernmental Panel on Climate Change

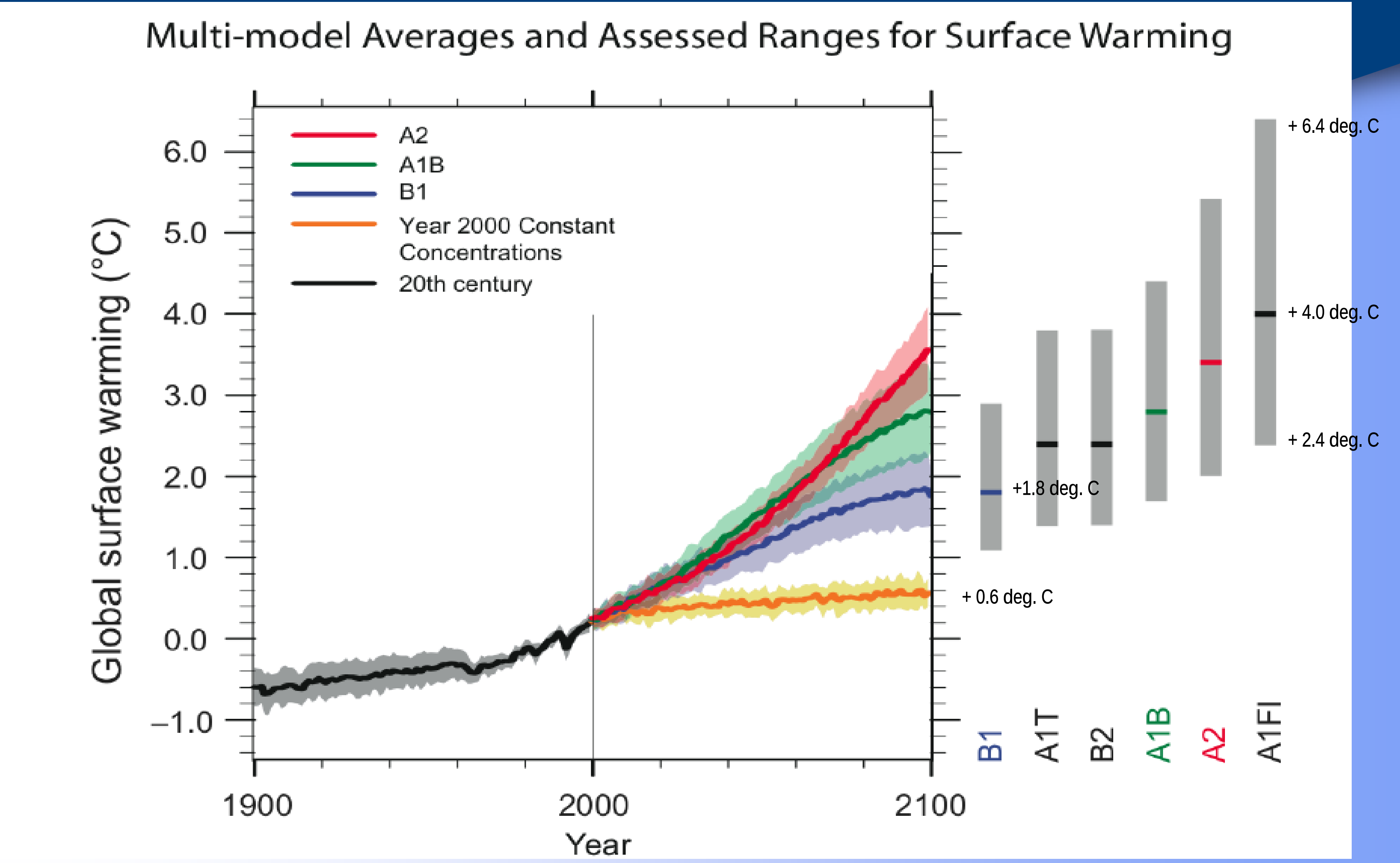
"Scenario Family"	Description
A1 – Rapid Growth A1F1 - Fossil Intensive A1T - Non-fossil A1B – Balanced	Second Highest Greenhouse Emissions
A2 – Heterogeneous High Population Growth Slow Economic and Technology Change	Highest Greenhouse Emissions
B1 – Convergent World Same Population as A1, more service and information technology.	Lowest Greenhouse Emissions
B2 – Intermediate Population growth, local solutions.	Second Lowest Greenhouse Emission

SRES (Special Report on Emission Scenarios, IPCC 2000)



Scenarios for GHG emissions from 2000 to 2100 in the absence of additional climate policies.

Multi-Model Projected Temperature Increases



Source: IPCC 4AR (2007)

Multi-Model Projected Temperature & Sea Level Increases

Table SPM.3. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a] Best estimate	*Likely* range	Sea Level Rise (m at 2090-2099 relative to 1980-1999) Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Table notes:

[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth System Models of Intermediate Complexity and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs).

[b] Year 2000 constant composition is derived from AOGCMs only.

Source: IPCC 4AR (2007)

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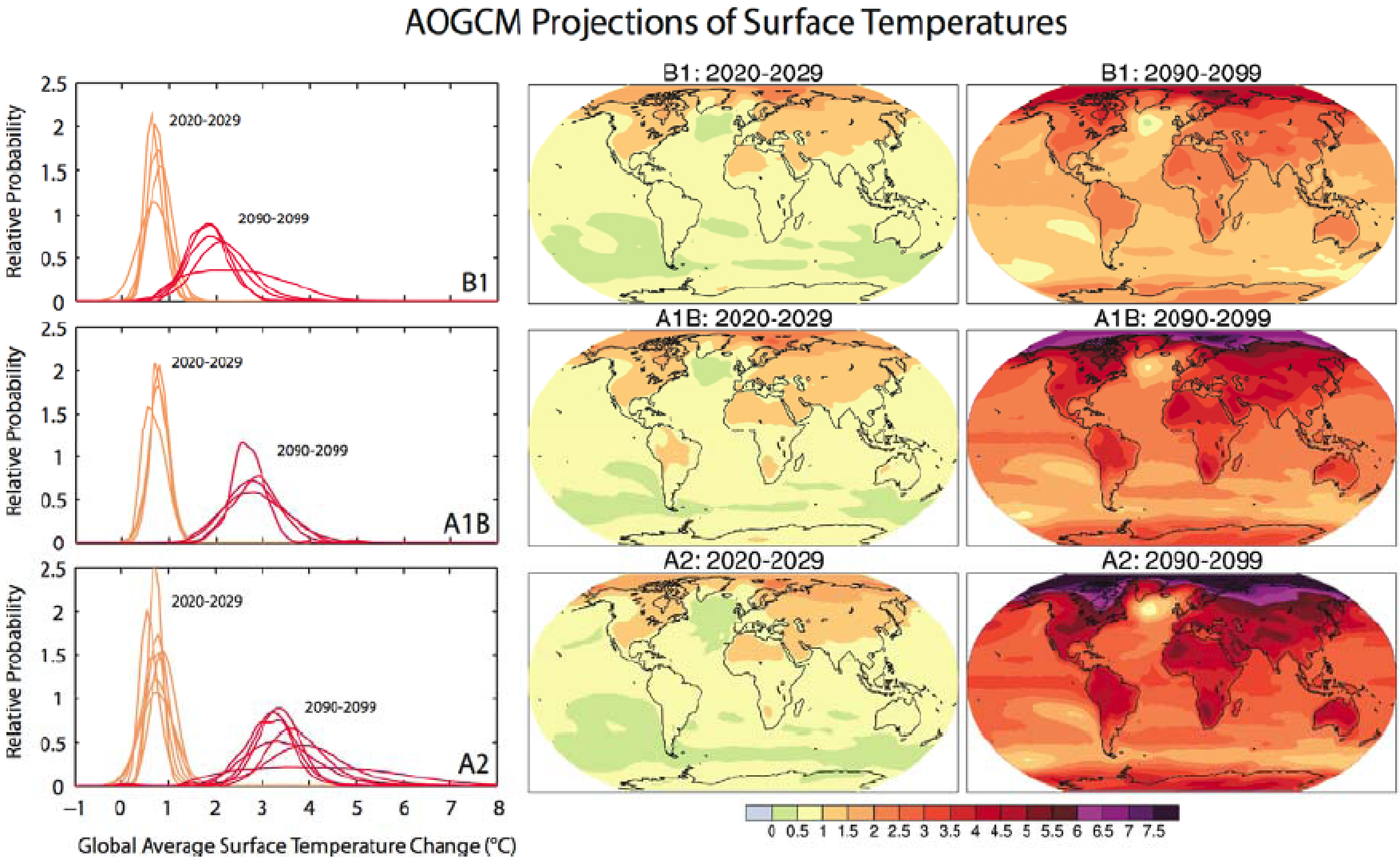
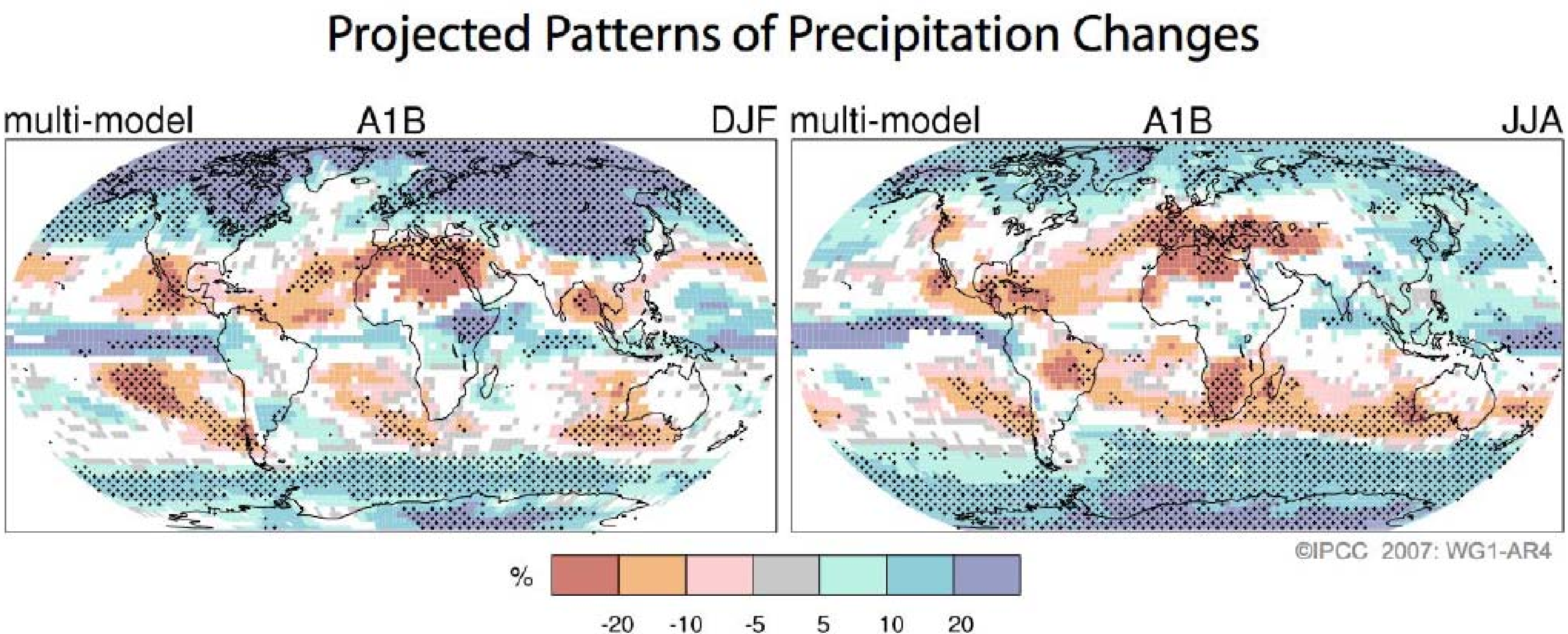
Spatial Temperature Projections (Atmosphere-Ocean GCM)



Source: IPCC 4AR (2007)

Spatial Precipitation Projections

- ***Very likely*** **increases at high-latitudes, while decreases are *likely* in most subtropical areas**
- **Indications that wet regions will be wetter and dry regions drier**
- **Prediction is complex and still not consensus for many regions**



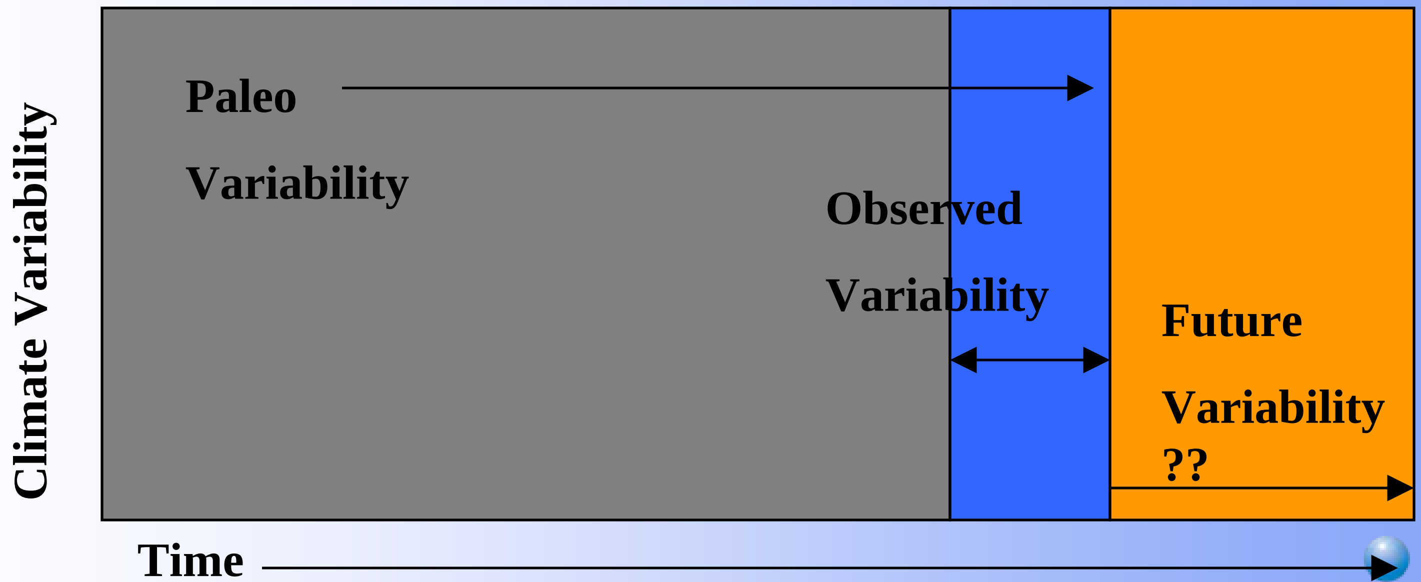
Some Sectors will be Impacted More than Others

Source: NAS 2006

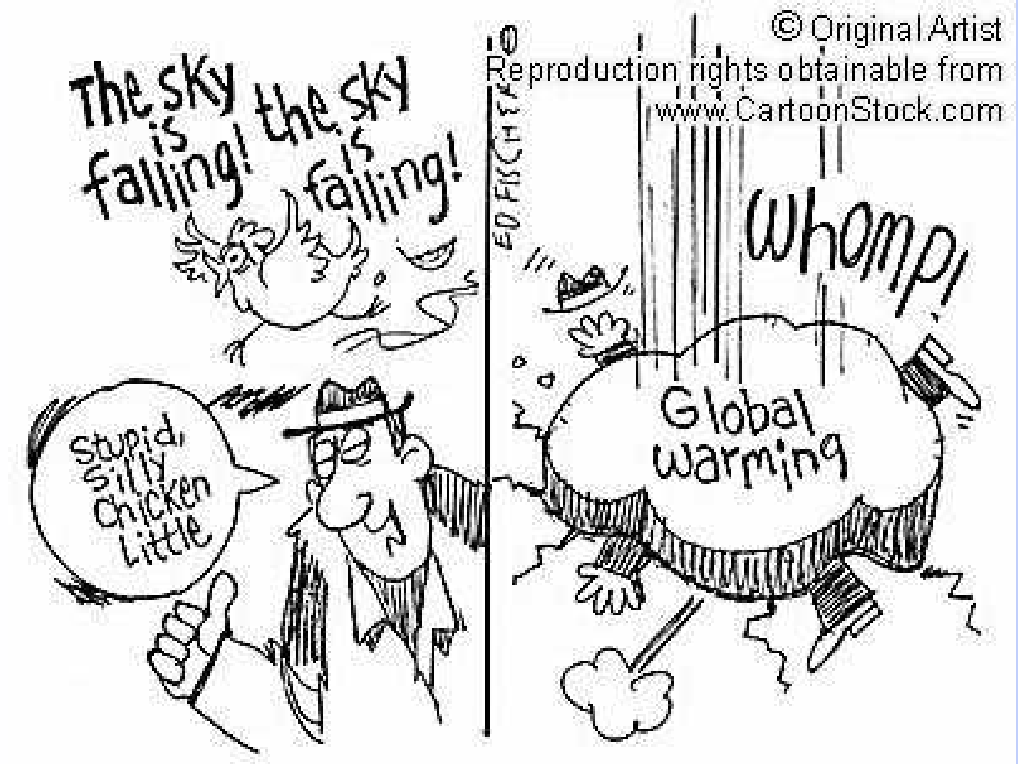
Climate Variability and Uncertainty

Climate Variability: Past, Present, Future

- Observed climate and hydrology is only a small piece of the puzzle
- Must recognize that insights to hydroclimatic variability come from paleo, observed, and future views of variability



Dealing with Time - Climate “Sudden Impact?”



Flood

Confluence of Mississippi and Missouri Rivers, August 1993. Extensive floods in the Mississippi River Basin during the spring and summer of 1993 caused $20 billion in damages. (Photograph, Srenco Photography, St. Louis, Mo.)

USGS Kansas

Dealing With Time - Climate "Un-Sudden Impact?"

Muir and Riggs Glaciers, Alaska 1941 - 2004

"An American public that is more informed about global warming isn't necessarily one that is more concerned about it." - Researchers at Texas A&M University

http://www.usatoday.com/weather/climate/globalwarming/2008-04-07-climate_N.htm

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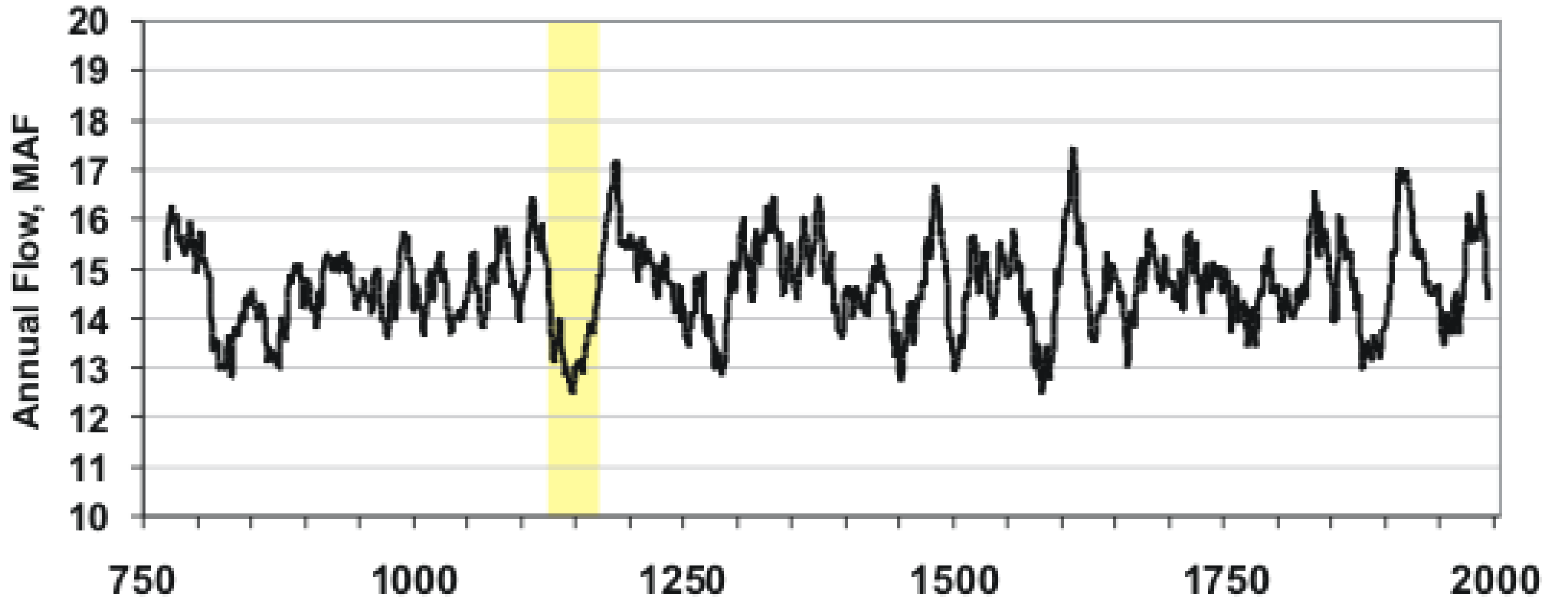
Paleo Climate Record – Colorado River



Meko et al. (2007) reconstruction of annual streamflow for the Colorado River at Lees Ferry, 762-2005, 20-year running mean in black (annual values not shown). The yellow bar highlights the severe and sustained mid-1100s drought.

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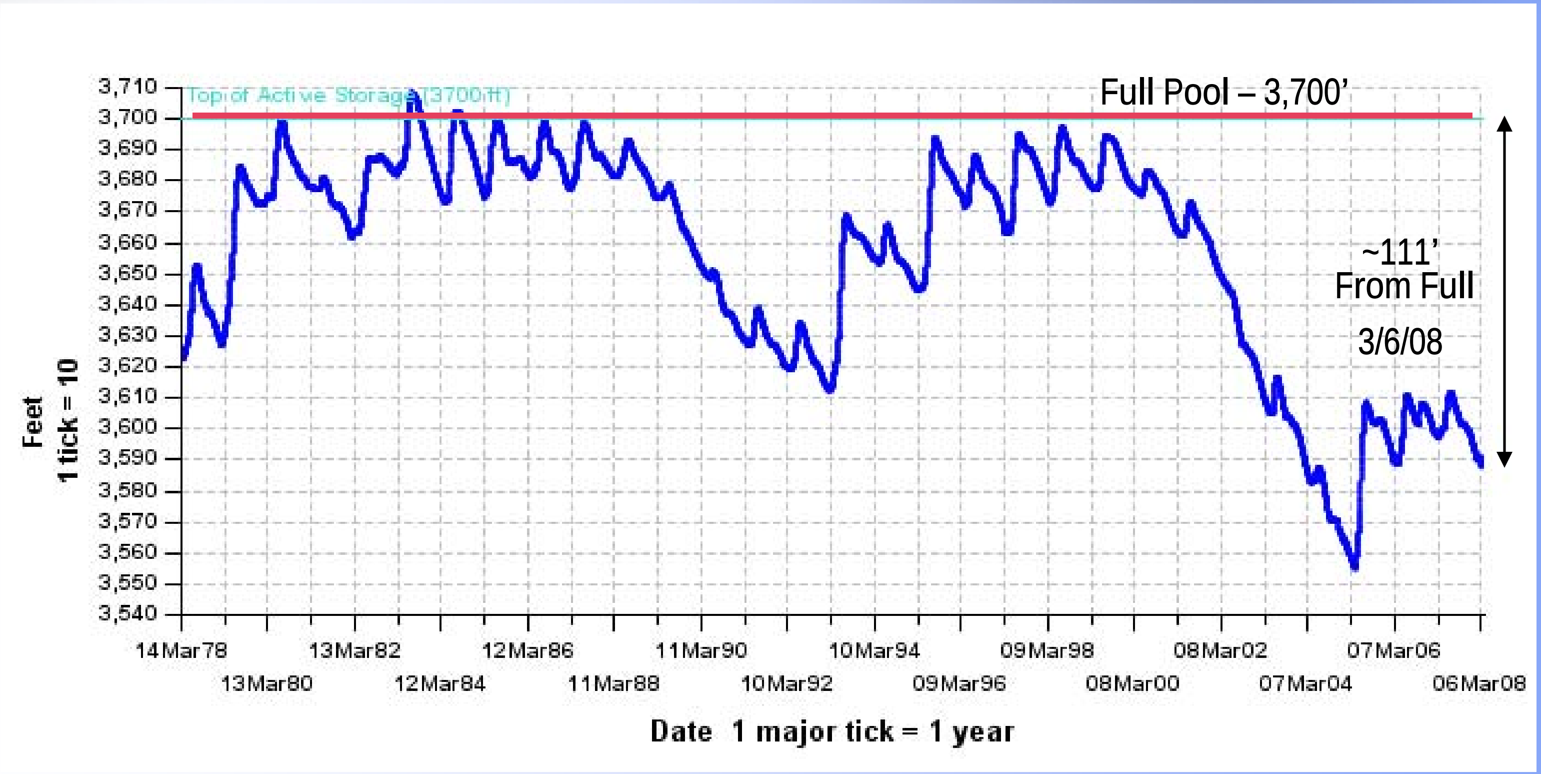
Recent Data – Colorado River



Reservoir storage in Lake Powell and Lake Mead has decreased during the past 8 years. Reservoir storage in Lake Powell is 45 percent of capacity. Storage in Lake Mead is 50 percent of capacity.

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April 1, 2008 WSF – Colorado River

Potentially the Highest Inflow Since 1997 (142%)

United States Department of Agriculture
NRCS Natural Resources Conservation Service

NWCC Home | About Us | Products | Publications | News | Partnerships | Contact Us

April, 2008 Streamflow Forecast Probability Chart for California

COLORADO RIVER BASIN Percent Exceedance Forecasting Charts

DATA CURRENT AS OF: 4/09/08 09:28:37

Lake Powell Inflow (2) APR-JUL Average = 7930.0	90% Exceedance	88%
	70% Exceedance	109%
	50% Exceedance	122% (9700.00)
	30% Exceedance	136%
	10% Exceedance	156%

These forecasts are coordinated between NRCS and other State and Federal agencies.
Forecast values are in 1,000s acre feet unless otherwise noted.

The average is computed for the 1961-1990 base period.

(1) - The values listed under the 10% and 90% Chance of Exceeding are actually 5% and 95% exceedance levels.

(2) - The value is natural volume - actual volume may be affected by upstream water management.

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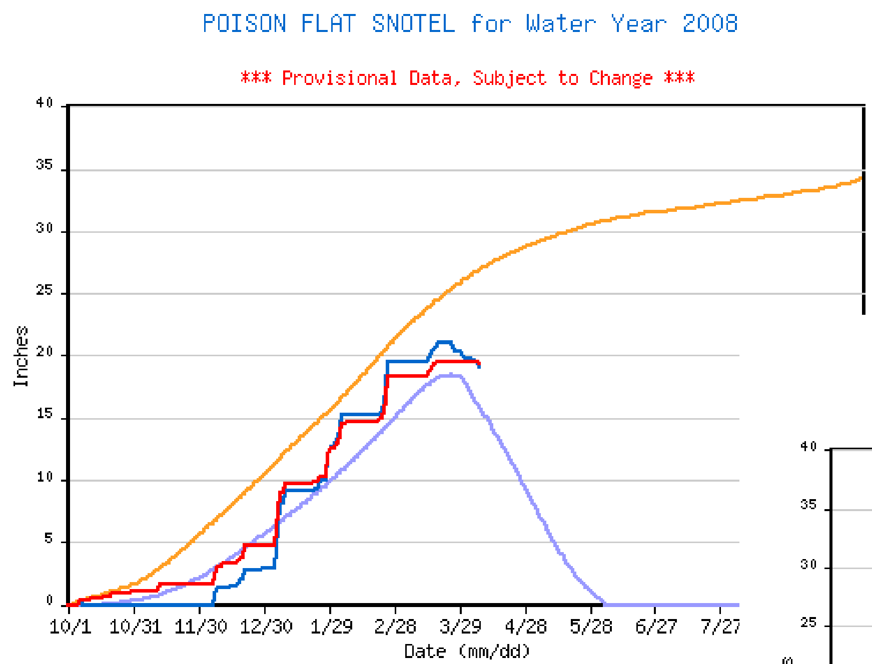
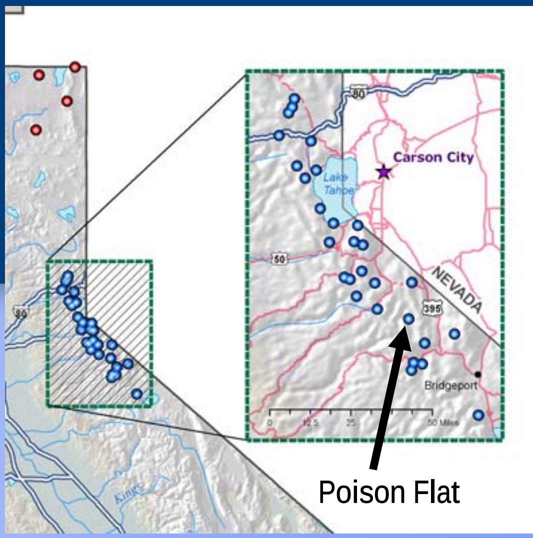
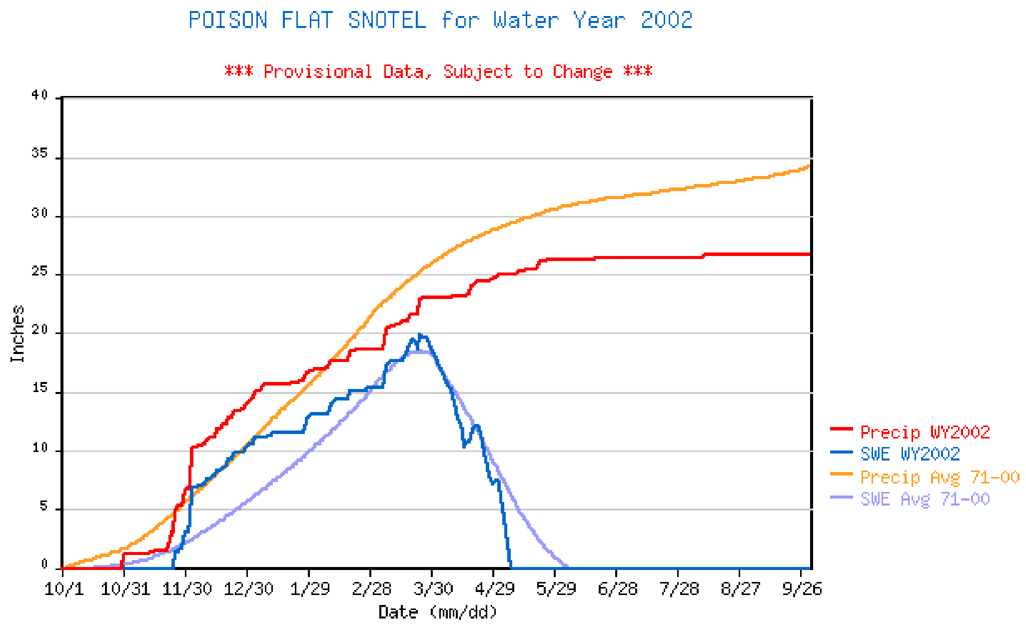
A Closer Look at the West

Is Western Snowpack Changing?

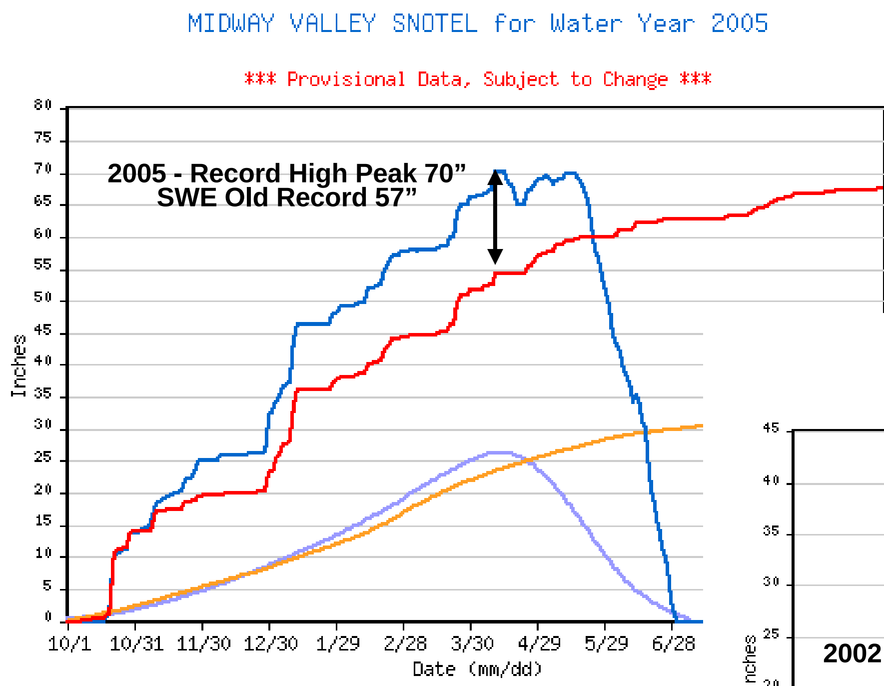


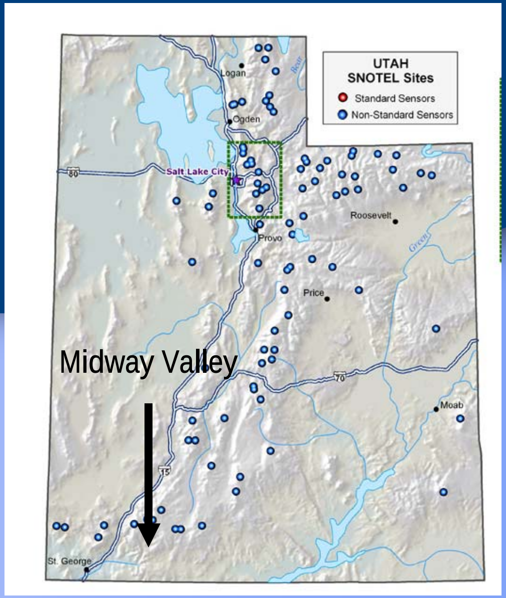


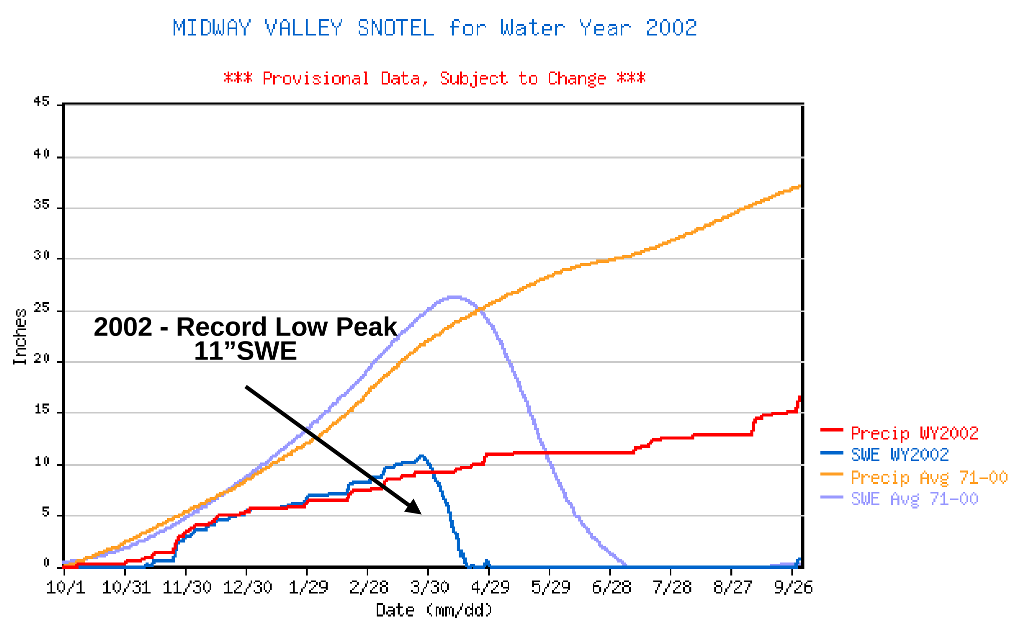


What happened to the "smooth" snowpack accumulation?

Is Western Snowpack Changing?







Wide variations in peak snowpacks.

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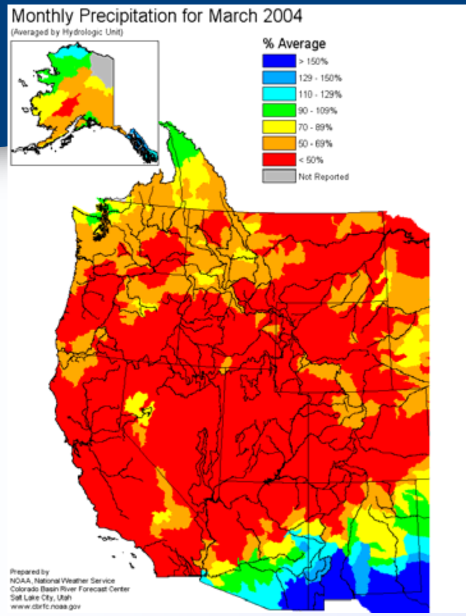
Rapid Intra-Annual Changes? – March 2004



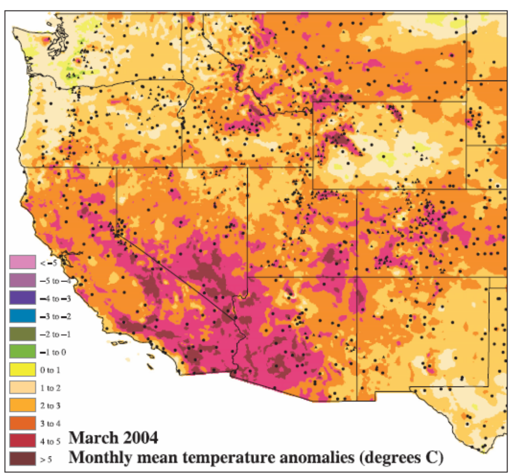


Fig. 1. March 2004 observed monthly mean temperature anomalies in degrees Celsius. NRCS SNOTEL sites are shown as triangles, and NWS sites are shown as circles. Contours are derived using the PRISM system (http://www.ocs.orst.edu/prism/).

Lack of precipitation

+

Warm temperatures

=

Perfect storm for snowpack reduction

(Pagano, Pasteris, Dettinger, Redmond EOS 2004)

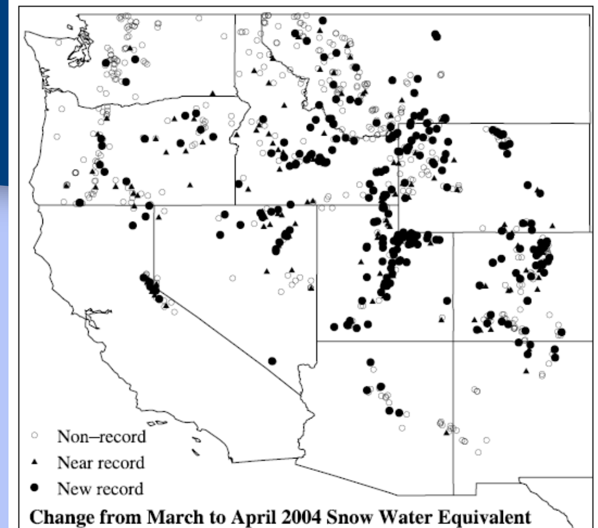


Fig. 2. The 1 March to 1 April 2004 change in SWE at NRCS snow course and SNOTEL sites. Sites that set new records for the greatest decrease or smallest increase are shown as filled circles. Sites that had the second largest change on record are shown as filled triangles, and all remaining sites are shown as hollow circles.

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

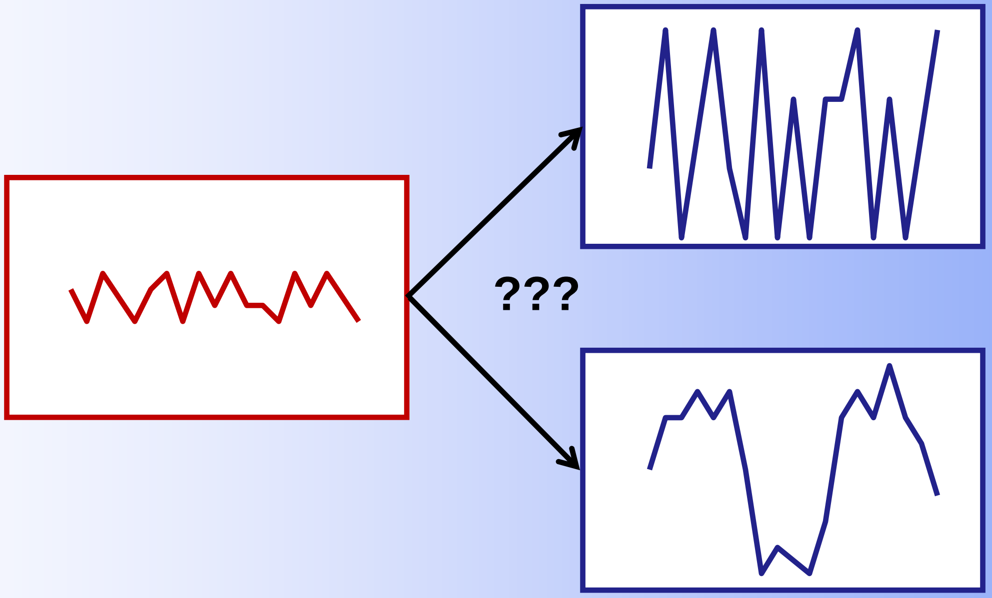
State/Area	Statewide % of Average, 1 March 2004	Statewide % of Average, 1 April 2004	Statewide % of Average, Change
Arizona	74	22	-51
Sierra/Tahoe	113	70	-35
Colorado	90	64	-26
Idaho	105	81	-25
Montana	93	78	-16
Nevada	118	64	-54
New Mexico	80	37	-43
Oregon	126	96	-30
Utah	109	70	-39
Washington	93	86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

Many things are still unknown, hard if not impossible to project

Precipitation: will there be more or less?

Patterns of variability:
will the climate get "stuck" or swing between extremes?

"Today's" Variability

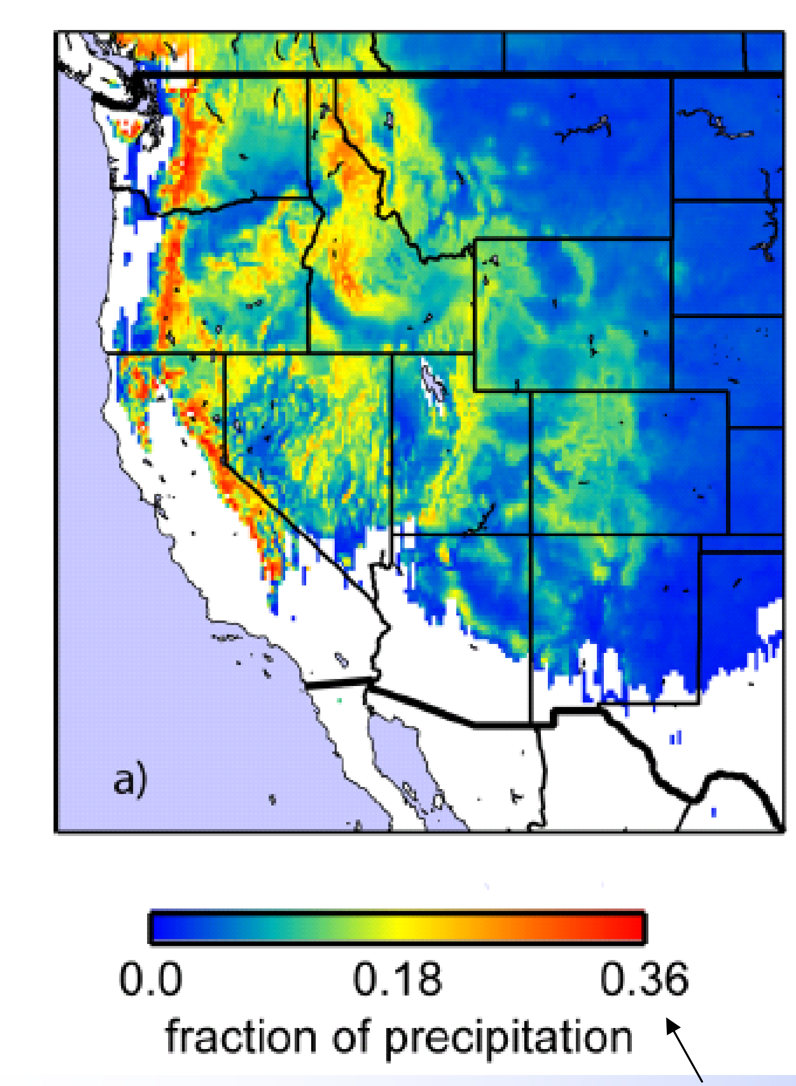


Future Variability?

Are there thresholds, tipping points, surprises?

(Pagano, Garen 2005)

Annual fraction of snow + rain that would fall as rain instead of snow



Most vulnerable

A +3ºC change (+5.4ºF… as soon as 2060-2100?) in average temperature means less snow (**red areas** mean more vulnerable)

Pagano, 2008; Maurer et al, 2002

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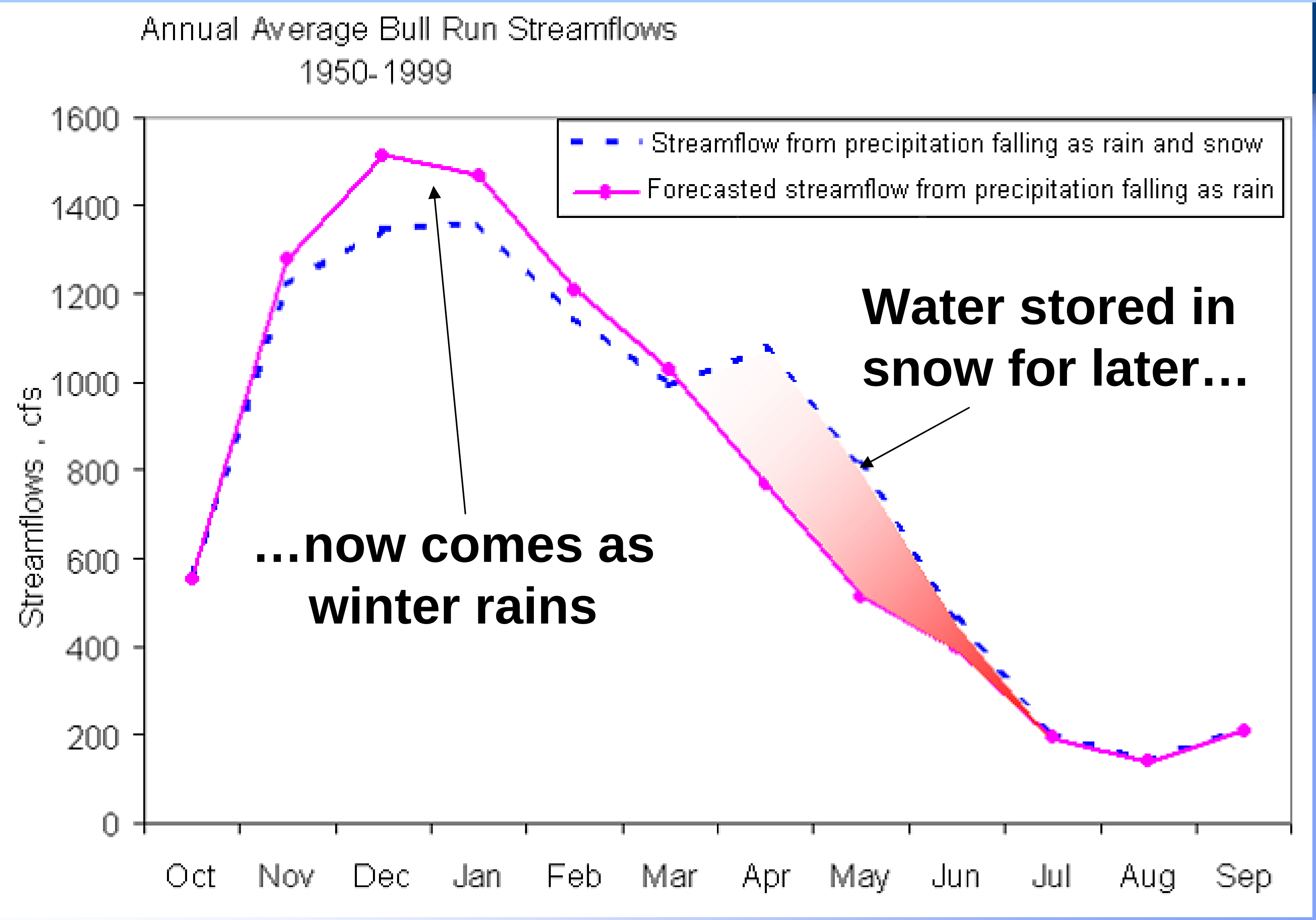
Bull Run Study: Streamflow impacts from snow changes



Pagano, 2008

From Stickel, WGA/WSWC Water Policy Conf, 2007, based on Palmer et al

Integrating GCC With Water Resources

Global Climate Change Integration
A Continuous Process With Water Managers

1. Establish Climate Access

- Observed historical datasets (station data)
- Observed gridded datasets (PRISM, GCM)
- Projected climate change datasets (GCMs)
- Applications that integrate observed and projected data to produce client-driven scenarios

ACIS Daily/Monthly Data
(NOAA Regional Climate Centers)

http://climod.nrcc.cornell.edu/runClimod/e7957fc242434a33/4

Daily Lister

Station: PINNACLE PEAK
State: AZ
ID: 026603
Latitude: 33.73 degrees
Longitude: -111.86 degrees
Elevation: 2565 feet
Station period of record: 04/22/2002-03/23/2008

CLIMOD product: Daily Lister
Creation Time: 03/24/2008 13:19 EDT
Column Delimiter: tab

Date mm/dd/yyyy	Max Temp degF	Min Temp degF	Precip inch
01/01/2008	63	40	0.00
01/02/2008	64	51	0.00
01/03/2008	63	48	0.00
01/04/2008	67	49	0.01
01/05/2008	64	53	0.04
01/06/2008	55	49	0.08
01/07/2008	51	45	0.79
01/08/2008	58	38	0.00
01/09/2008	56	41	0.00
01/10/2008	58	39	0.00
01/11/2008	58	42	0.00
01/12/2008	62	42	0.00
01/13/2008	63	43	0.00
01/14/2008	62	45	0.00
01/15/2008	60	42	0.00
01/16/2008	58	40	0.00
01/17/2008	54	31	0.00
01/18/2008	54	31	0.00
01/19/2008	59	36	0.00
01/20/2008	61	41	0.00
01/21/2008	55	38	0.00
01/22/2008	60	42	0.00
01/23/2008	62	43	0.00
01/24/2008	59	40	0.05
01/25/2008	58	40	0.09
01/26/2008	64	43	0.00
01/27/2008	56	44	0.85
01/28/2008	56	46	1.71
01/29/2008	53	36	0.00
01/30/2008	54	35	0.00
01/31/2008	51	32	0.00

http://climod.nrcc.cornell.edu/runClimod/e7957fc242434a33/3

Monthly Time Series

Station: PINNACLE PEAK **State:** AZ **ID:** 026603
Latitude: 33.73 degrees **Longitude:** -111.86 degrees **Elevation:** 2565 feet
Station period of record: 04/22/2002 - 03/23/2008

CLIMOD Product: Monthly Time Series **Creation Time:** 03/24/2008 13:17 EDT
Element: Precipitation **Units:** inch **Analysis:** Sum
Max allowable missing days: 3
Lowest Acceptable Quality of Data: Raw data

Year(s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2002	-999z	-999z	-999z	-999u	0.00	0.00	1.30	0.46	1.66	0.57	0.45	0.70	-999d
2003	0.60	4.33	2.27	0.25	0.00	0.00	0.65	1.67	0.05	1.34	1.38	0.53a	13.07
2004	0.74	1.54	2.69	2.15	0.00	0.00	0.22	0.63	0.73	1.38	1.35	3.78	15.21
2005	4.00	6.64	0.67	0.51	0.00	0.00	2.09	2.50	0.04	0.95	0.00	0.00	17.40
2006	0.00	0.00	2.04	0.09	0.43	0.11	2.48	1.20	3.19	0.86	0.00	0.37	10.77
2007	1.49	0.46	1.62	0.56	0.00	0.00	0.57	1.58	0.20	0.21	0.52	4.72b	11.93
2008	3.62	0.41	-999h	-999z	-999z	-999z	-999z	-999z	-999z	-999z	-999z	-999z	-999j
Normals	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
Max value	4.00	6.64	2.69	2.15	0.43	0.11	2.48	2.50	3.19	1.38	1.38	4.72	17.40
Min value	0.00	0.00	0.67	0.09	0.00	0.00	0.22	0.46	0.04	0.21	0.00	0.00	10.77
Mean	1.74	2.23	1.86	0.71	0.07	0.02	1.22	1.34	0.98	0.89	0.62	1.68	13.68
Median	1.12	1.00	2.04	0.51	0.00	0.00	0.98	1.39	0.47	0.91	0.49	0.62	13.07
Std Dev	1.68	2.67	0.77	0.83	0.18	0.04	0.91	0.75	1.25	0.45	0.62	2.02	2.65
Skewness	0.66	1.13	-0.95	1.94	2.45	2.45	0.49	0.40	1.40	-0.41	0.46	1.00	0.56
# years	6	6	5	5	6	6	6	6	6	6	6	6	5

Flags:
a = 1, b = 2, c = 3, ..., or z = 26 or more missing days in a month or missing months in a year.
A = Accumulation over more than one day, S = Subsequent

Notes:
Long-term means based on columns. Thus, the sum (or average) of the monthly values may not equal the annual value.

http://www.rcc-acis.org/

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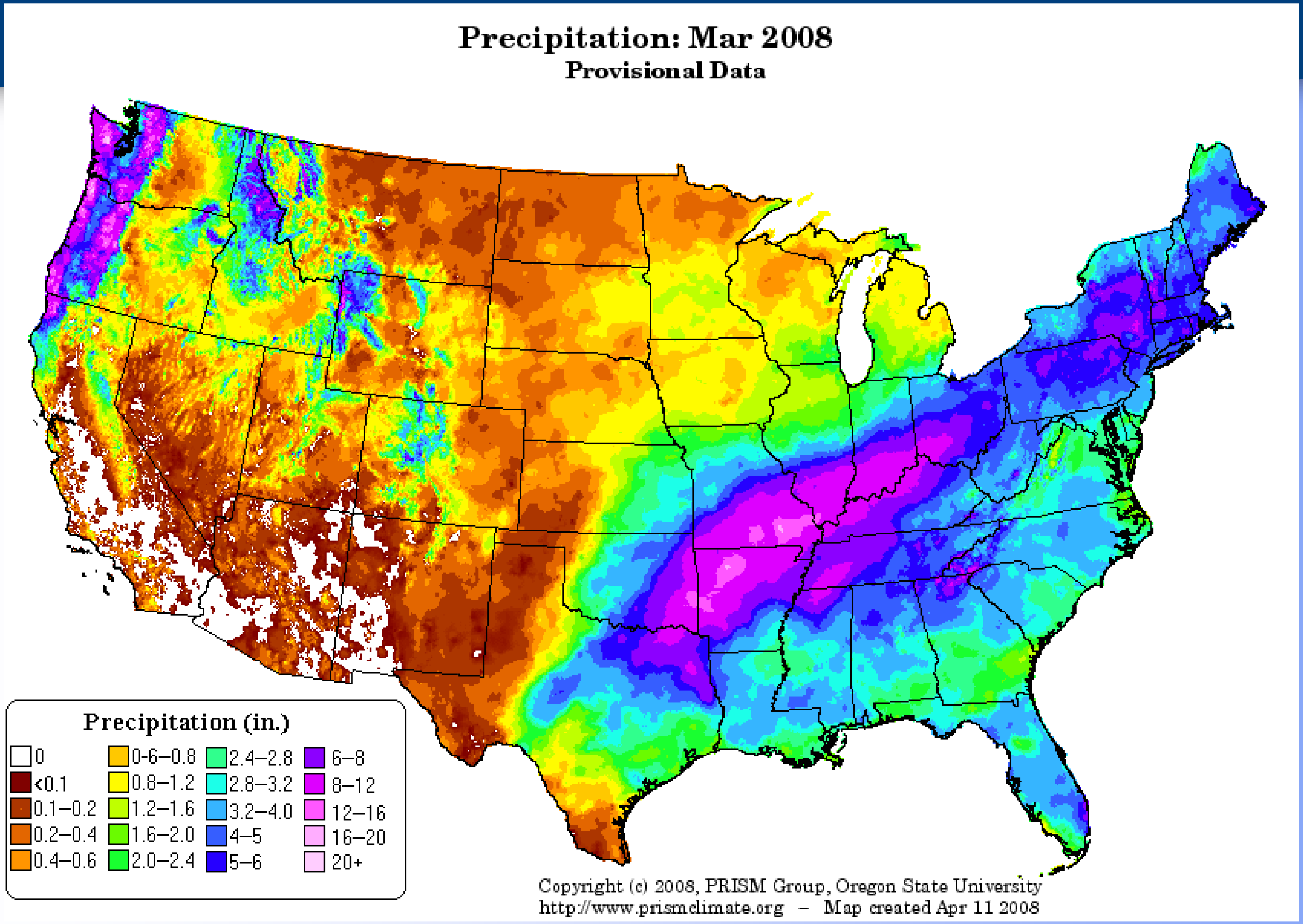
Gridded Climate Information

The PRISM Group



http://www.prism.oregonstate.edu/

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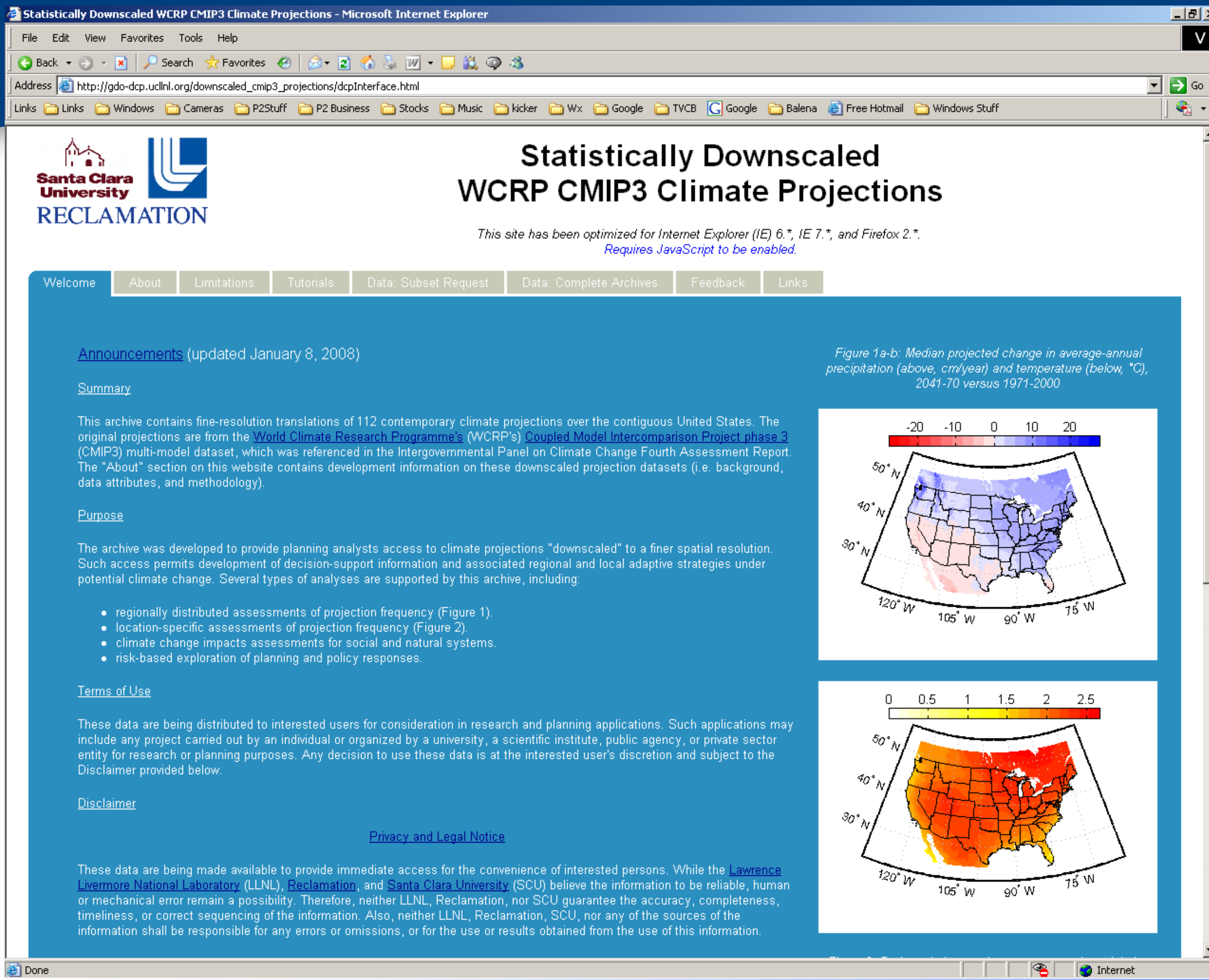
Statistically Downscaled Climate Projections
Ed Maurer, et al.



Statistically Downscaled WCRP CMIP3 Climate Projections - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html

Santa Clara University

RECLAMATION

Statistically Downscaled WCRP CMIP3 Climate Projections

This site has been optimized for Internet Explorer (IE) 6., IE 7.*, and Firefox 2.*.*
Requires JavaScript to be enabled.

Welcome | About | Limitations | Tutorials | Data: Subset Request | Data: Complete Archives | Feedback | Links

Announcements (updated January 8, 2008)

Summary

This archive contains fine-resolution translations of 112 contemporary climate projections over the contiguous United States. The original projections are from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset, which was referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report. The "About" section on this website contains development information on these downscaled projection datasets (i.e. background, data attributes, and methodology).

Purpose

The archive was developed to provide planning analysts access to climate projections "downscaled" to a finer spatial resolution. Such access permits development of decision-support information and associated regional and local adaptive strategies under potential climate change. Several types of analyses are supported by this archive, including:

- regionally distributed assessments of projection frequency (Figure 1).
- location-specific assessments of projection frequency (Figure 2).
- climate change impacts assessments for social and natural systems.
- risk-based exploration of planning and policy responses.

Terms of Use

These data are being distributed to interested users for consideration in research and planning applications. Such applications may include any project carried out by an individual or organized by a university, a scientific institute, public agency, or private sector entity for research or planning purposes. Any decision to use these data is at the interested user's discretion and subject to the Disclaimer provided below.

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Figure 1a-b: Median projected change in average-annual precipitation (above, cm/year) and temperature (below, °C), 2041-70 versus 1971-2000

http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html

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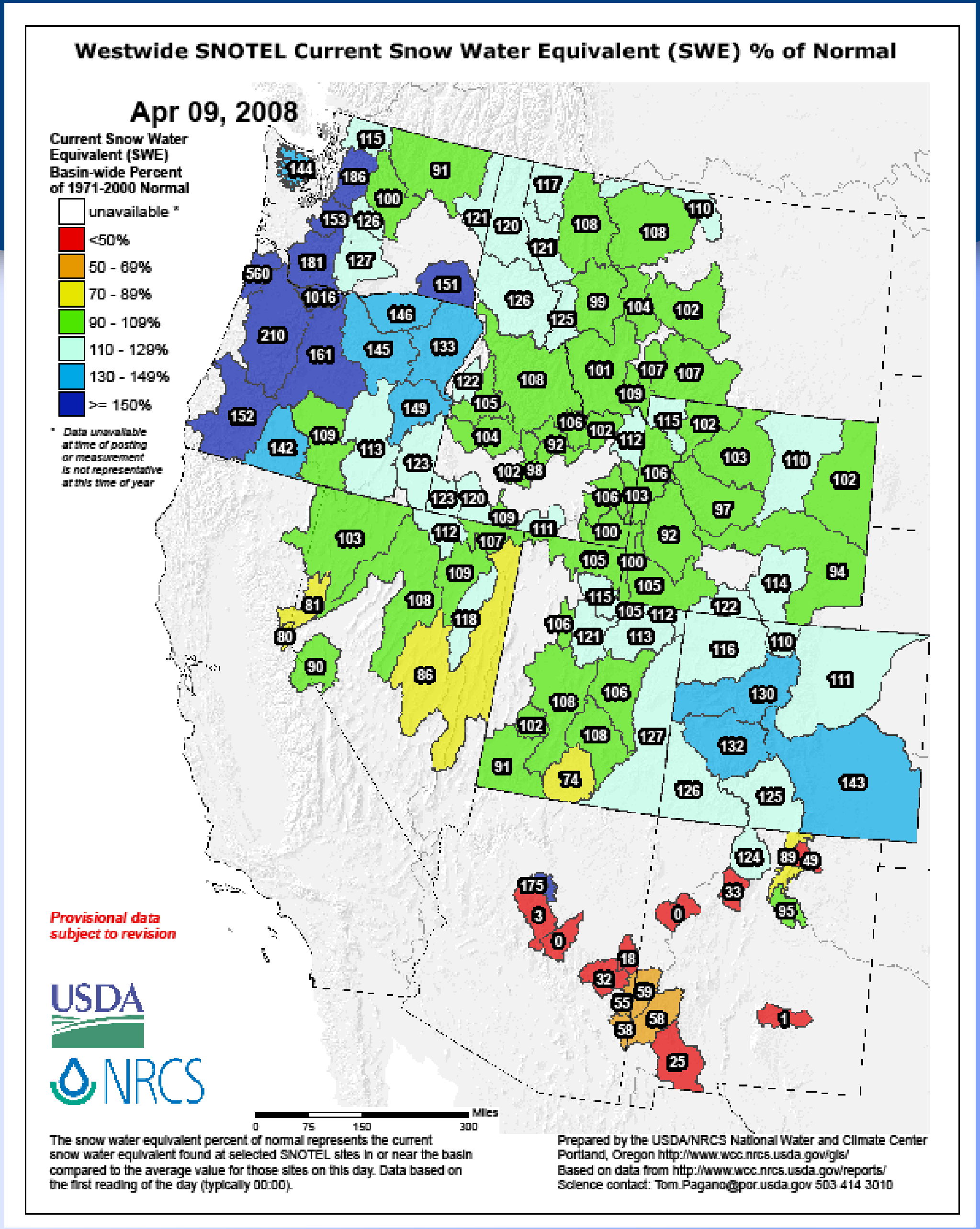
Westwide Snowpack Map
(NRCS, NWCC)

http://www.wcc.nrcs.usda.gov/



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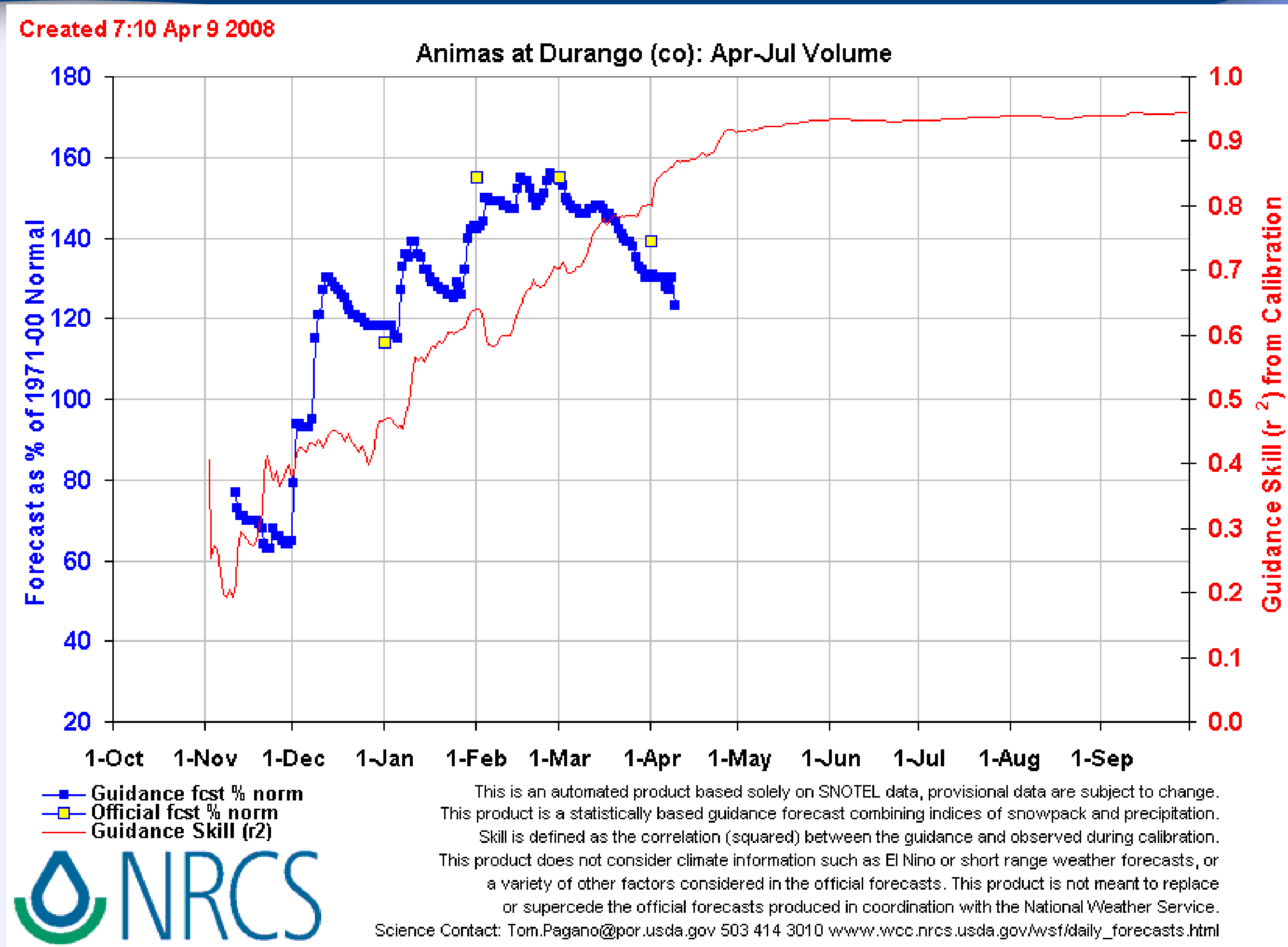
Daily WSF Guidance Update - NRCS

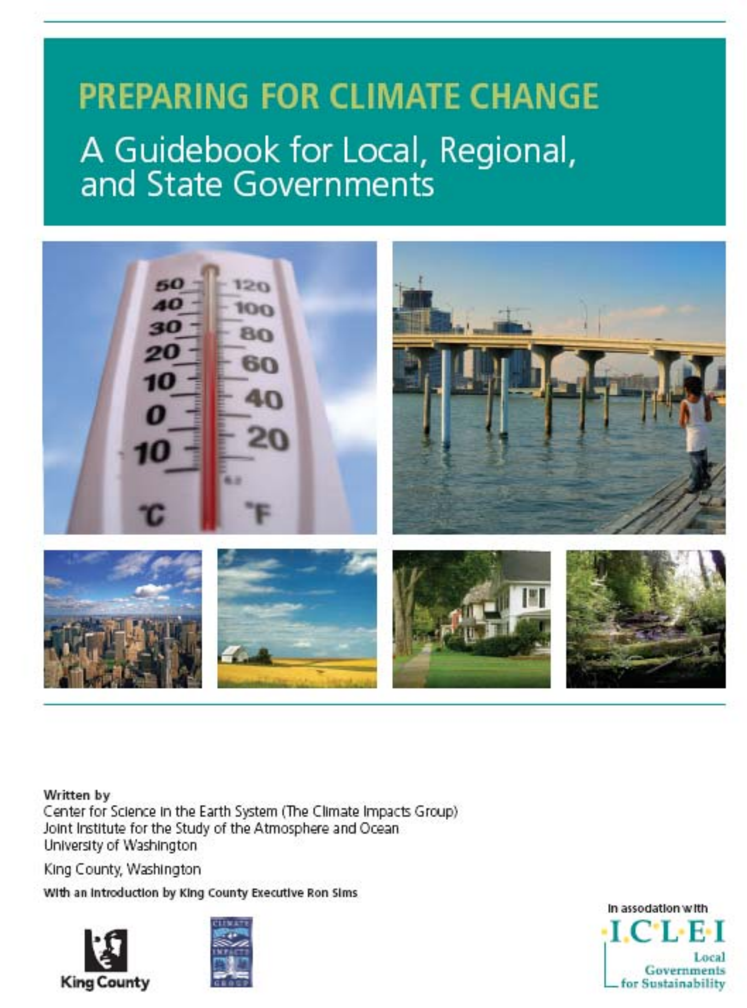
- **Uses the SNOTEL data network**
- **Captures intra-month trends**
- **Answers the questions "how has this 'big storm' or 'extended dry period' affecting my WSF?"**



http://www.wcc.nrcs.usda.gov/

2. Develop Risk Analysis and Scenario Planning

- **"Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments"**
- Establishing ***"Climate Resilient Communities"***
- Focuses on the process to assess climate impacts and risk.
- Designing a response
- Workbook-style with checklists, milestones



http://cses.washington.edu/cig/fpt/guidebook.shtml

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What is a "Climate Resilient Community?"

- One that takes proactive steps to prepare for (i.e. reduce the vulnerabilities and risks associated with) climate change impacts
- Creates preparedness plans that examine sectors that may be impacted by climate change
- King County, WA (water supply, floods)
- Olympia, WA (sea level rise / stormwater)

http://cses.washington.edu/cig/fpt/guidebook.shtml

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3. Develop Adaptive Strategies

1. Initiate a climate resiliency effort (scope, sectors, and resources)
2. Conduct a climate resiliency study (sensitivity, adaptive capacity, vulnerability, risk, thresholds, and prioritization)
3. Set preparedness goals and develop your preparedness plan (vision and principles)
4. Implement your preparedness plan (make sure you have the right tools and information)
5. Measure your progress and update your plan (track resilience measures)

http://cses.washington.edu/cig/fpt/guidebook.shtml

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3. Adaptive Strategies Planning Process

- Identify local climate vulnerabilities by “sector”
- Develop and implement preparedness plan

2. Planning Area	3. Current and Expected Stresses to Systems in This Planning Area	7. Projected Climate Change Impacts to Systems in This Planning Area	VULNERABILITY ASSESSMENT		
			8. Degree of Sensitivity of Systems in This Planning Area (see Table 8.1)	10&11. Adaptive Capacity of Systems in This Planning Area (see Table 8.2)	12. Vulnerability of Systems in this Planning Area
Water supply	Managing summer drought *(current and expected)*	More drought, summer water stress likely due to lower winter snowpack and warmer, drier summers. Population growth will compound this problem.	High – water supply is very sensitive to changes in snowpack.	Low – numerous regulatory constraints on reallocating water, options for expanding supply limited, summer demand already greater than supply.	High
Stormwater man-	Combined sewer overflows (CSOs)	More localized flooding,	High – CSO events are	Medium – can upgrade the	Medium

http://cses.washington.edu/cig/fpt/guidebook.shtml

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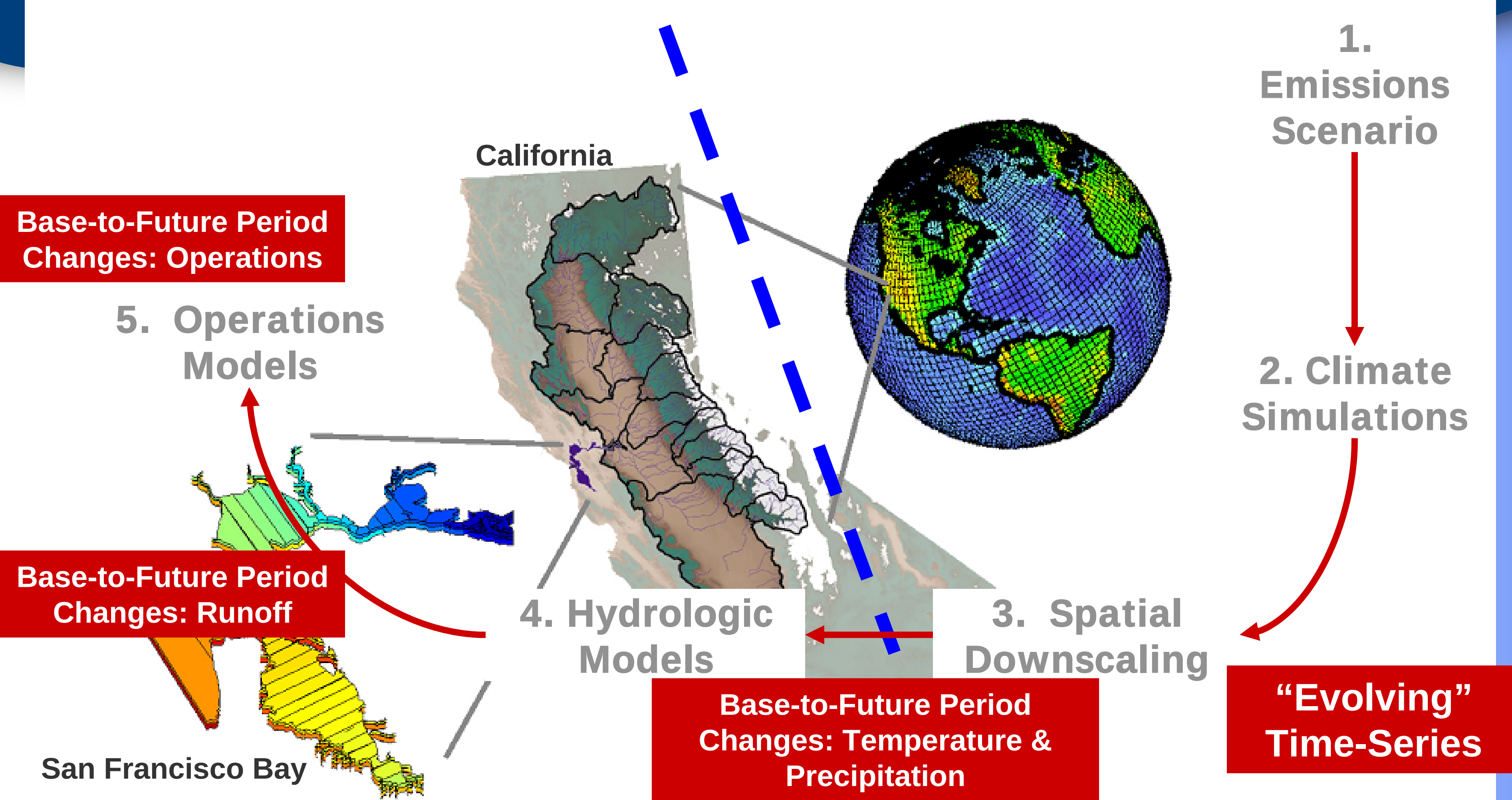
4. Implementing an Adaptive Strategy – Example Water Supply



Adapted from Cayan and Knowles, SCRIPPS/USGS, 2003

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5. Assess Effectiveness, Update and Manage Operations

- Periodically review your basic assumptions
  - Vulnerability and risk based on recent events
  - Goals and sectors affected by recent events
- Update the data used for your risk model using observed and new GCC model information
- Review action plan based on recent events and potential GCC projections
- Educate those affected by your plan about necessary changes based on recent events or new GCC projections

Global Climate Change Integration
A Continuous Process With Water Managers

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Summary

- The data, technology, and expertise are now available to help create "Climate Resilient Communities."
- A process and framework can be implemented that can provide water managers with realistic steps to
  - Assess climate risk and vulnerabilities
  - Develop resilient climate change preparedness plans.
  - Manage resources
- A significant amount of work remains
- Never been an opportunity of this magnitude to meet customer's needs.

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Thank You!