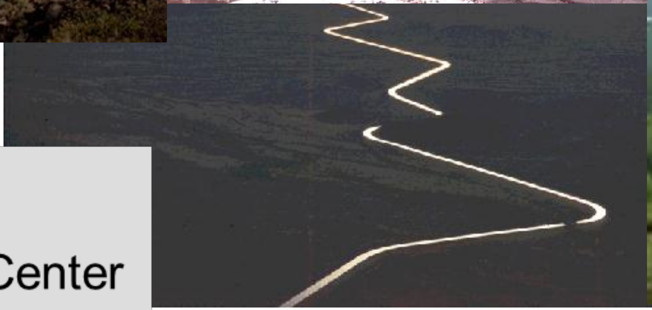
Communicating Climate Change Scenarios to Decision Makers



Holly C. Hartmann

Arid Lands Information Center
University of Arizona

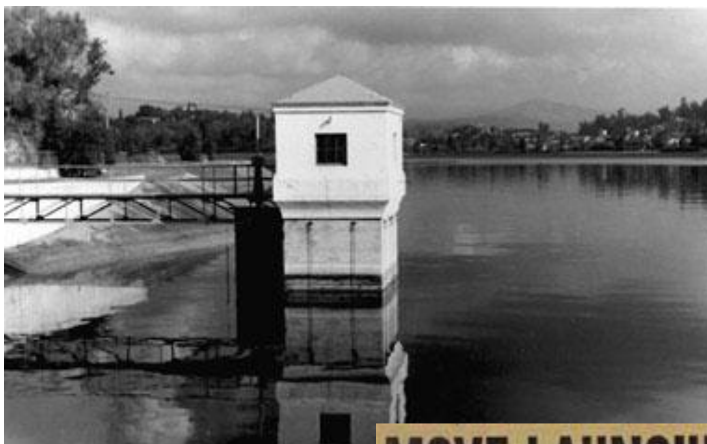
hollyoregon@juno.com

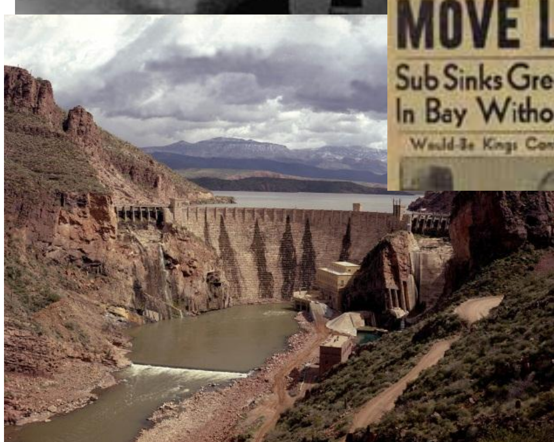
CLIMAS
Climate Assessment for the Southwest

ARIZONA

Water Management Has Long Used Climate Information

Reservoirs, levees, irrigation systems, groundwater development, water allocation & transfer agreements are all designed to mitigate climate variability – across many time/space scales.





MOVE LAUNCHED TO TAP COLORADO

Sub Sinks Greek Warship In Bay Without Warning

Would-Be Kings Confer

Fear Attack Heralds Italy

PHOENIX GAZETTE

15 Million Water Project Proposed

Hitler Steps Up Blitz

"Stationarity is Dead" – Our fundamental assumption!

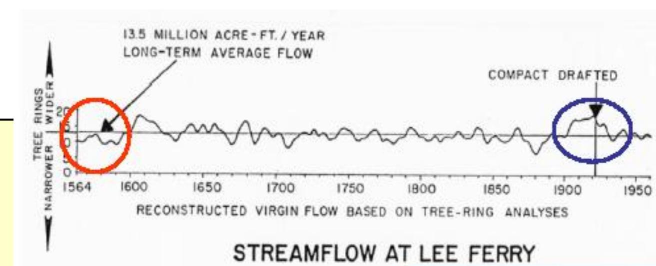
Stationarity Is Dead: Whither Water Management?

P. C. D. Milly,[1*] Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Science 2008

Stationarity

- Time invariant statistics
- Different parts of historic record equally likely
- Statistical definition of probability distribution faithfully represents expectations for the future



Woodhouse, UA

Meaning for Water Management

- Risks are stationary/stable over time
- Observed flow records are the best estimate of future variability
- Systems that are robust to past variability are robust to future variability

A. Hamlet, CIG/UW

Decision Makers Must Confront Two Realities

Intractable Uncertainty, Irreducible Uncertainty

- trends, regimes
- paleoclimatological evidence of extended or regional drought
- other human impacts on hydrologic systems, ecosystems
- global warming impacts – beyond past experience?

Non-stationarity: the past doesn't represent the future

- no 'standard approach' for handling non-stationarity
- models more informative than historical statistics alone
- temperature is a hydrologic variable

Supporting Adaptation: Effectively, Efficiently

What is decision support ?

Climate change decision support refers to **organized efforts to produce, disseminate, <u>and</u> facilitate the use of data and information in order to improve the quality and efficacy of climate-related decisions** (NRC 2009, Informing Decisions in a Changing Climate).

Weather Conditions for:

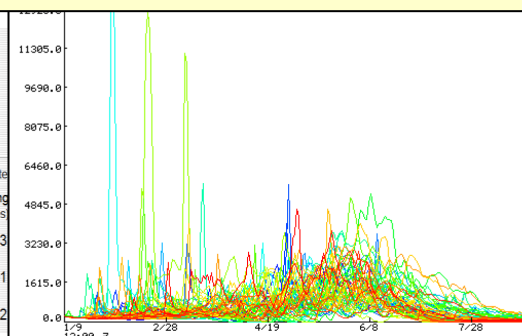
Eugene, Mahlon Sweet Field, OR (KEUG)

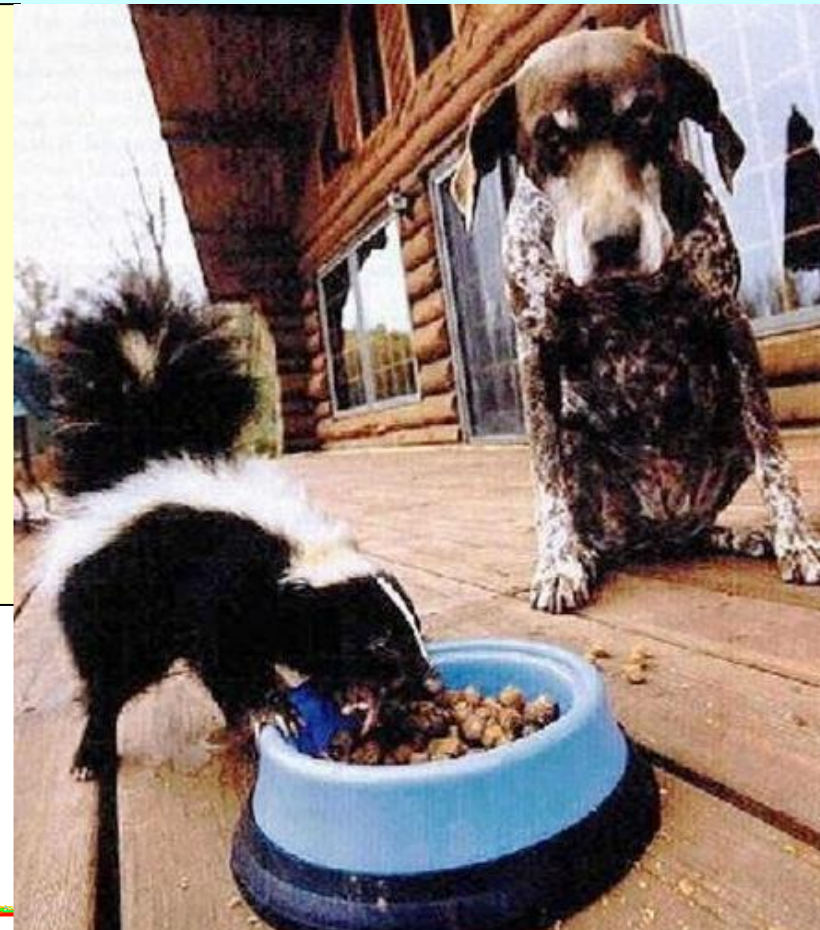
Elev: 364 ft; Latitude: 44.13333; Longitude: -123.21444

Current time: Fri, 10 Dec 7:27 am (PST)

Most Recent Observation: Fri, 10 Dec 6:54 am (PST)

Time (PST)	Temp. (f)	Dew Point (f)	Relative Humidity (%)	Wind Direction	Wind Speed (mph)	Visibility (miles)	WX	Clouds	Sea Level Pressure (mb)	Altimete Setting (inches)
10 Dec 6:54 am	47	44	90	S	15	10.00		SCT028 BKN044 OVC060	1016.9	30.03
10 Dec 5:54 am	46	43	89	SSE	7	7.00	RA	FEW027 BKN036 OVC050	1016.4	30.01
10 Dec 4:54 am	46	43	89	SSE	8	10.00	-RA	FEW033 BKN040 OVC060	1016.6	30.02





Images: NWS, NWS, Iopix.com

Data << Information << Knowledge << Wisdom

VUCA is the “New Normal”

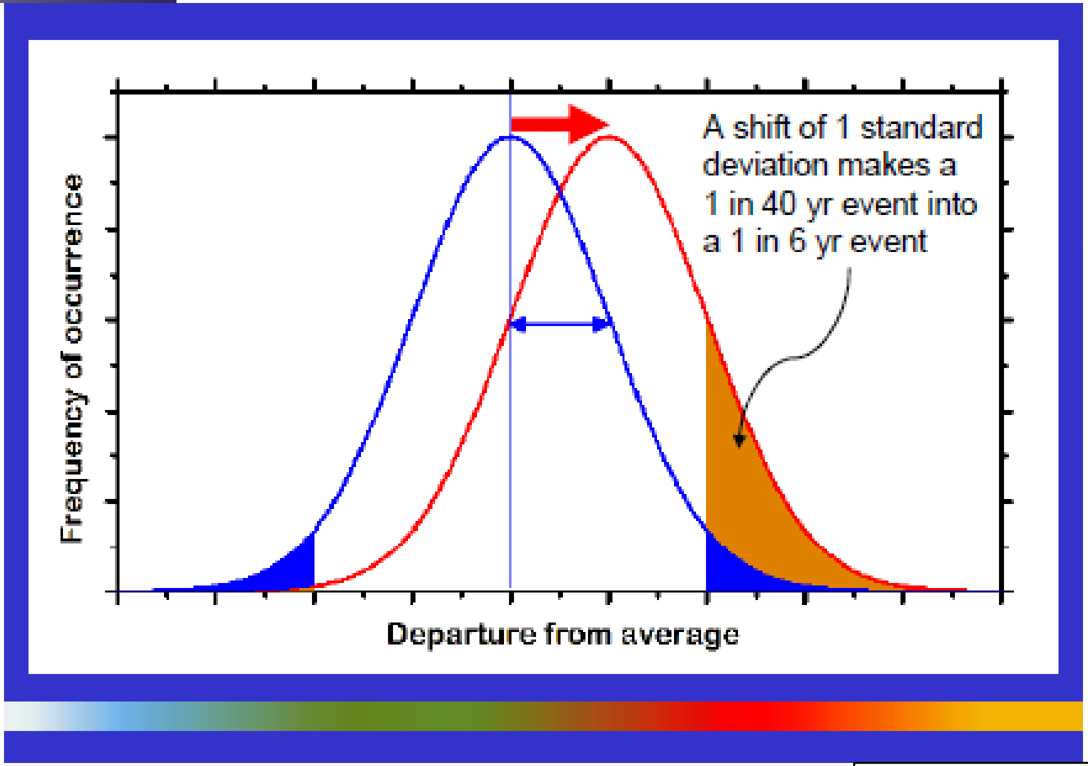
Volatility

Uncertainty

Complexity

Ambiguity

Institute for the Future



IPCC WG1

VUCA is not new but scale and intensity are increasing.

Policy/management dilemma: committing too soon vs. deciding too late.

R.K. Craig: “Accept – really accept – that climate change will often be painful.”

The ADAPTATION BOTTLENECK

… shifting from awareness to adaptation

Adaptation: Deliberate Change in System Behavior, Function, or Design

1. **Resistance:** defend against change (Homeland Security)
2. **Resilience:** ‘bounce back’ after disturbance (Health Care)
3. **Response:** facilitate change (Beginners Mind), e.g., regional approaches, interconnections, diversity
4. **Realignment**: accept different systems, focus on function (Auto Mechanics)
5. **Reduce:** *mitigation* of GHG (Good Samaritan)
6. **Triage:** let go (Pragmatic)

Adapted from Millar et al, 2007. Ecological Applications. 2008, Forest Guild presentation

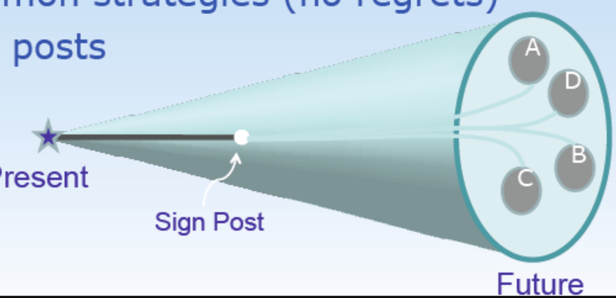
Decision Support Approaches for Water Management

Decision Analysis

- Decision trees, probabilities and costs
- Minimize expected costs

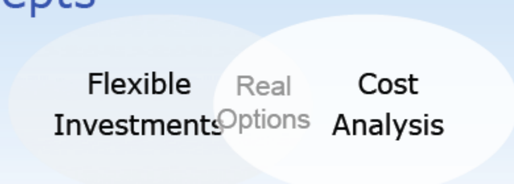
Scenario Planning

- Small number of equally likely scenarios [A, B, C, D]
- Common strategies (no regrets)
- Sign posts



Real Options

- Combines decision analysis and financial theory
- Decision tree and financial hedging concepts



Robust Decision Making

- Computer analysis of many plausible likely scenarios
- Iteration and hedging

Figures from Stickel, 2010. See www.wucaonline.org

Overall Approach: Iterative Risk Management

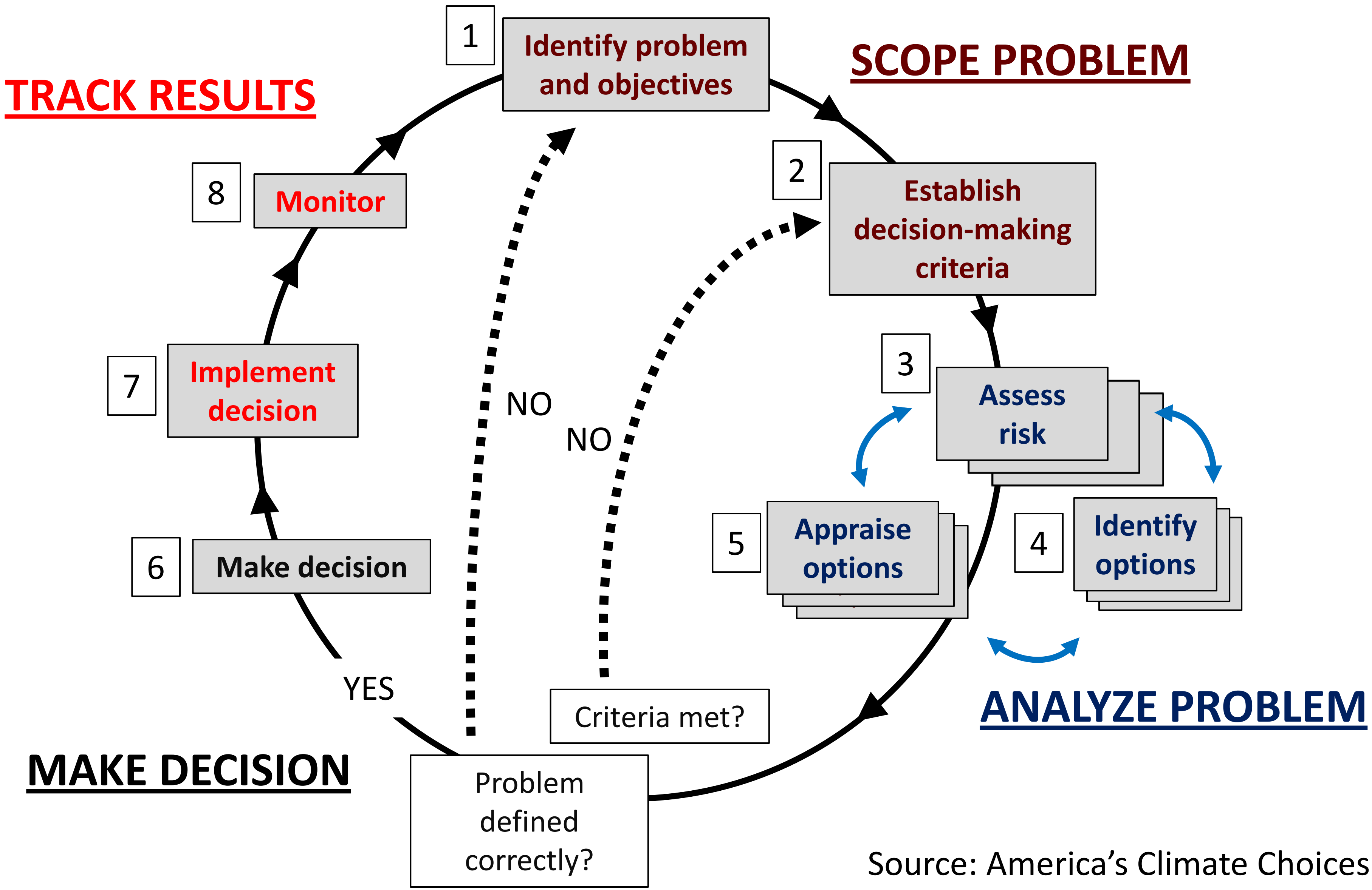
Consequence x Likelihood

ITERATIVE

RISK MANAGEMENT

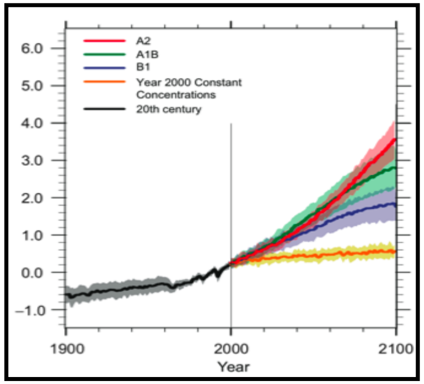
Irreducible uncertainty

Iterative Risk Management Framework



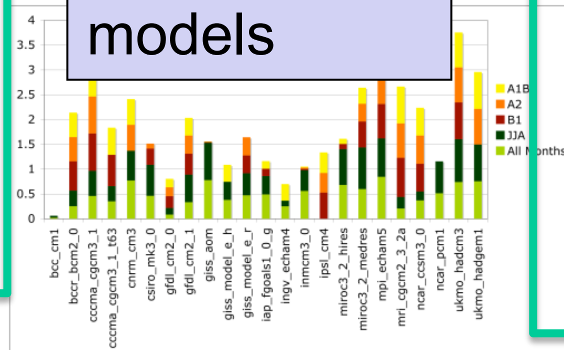
Source: America's Climate Choices. National Research Council, 2010.

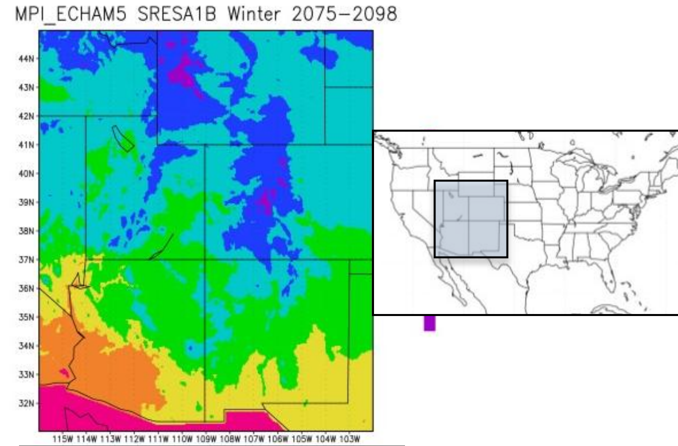
Model Chain: Rapidly Increasing Output!



IPCC AR4 GCM projections

Select the "best" models



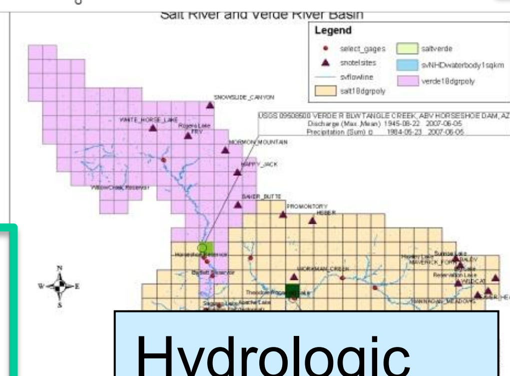


Spatial Downscaling

From approx. 200 km to 4 km.

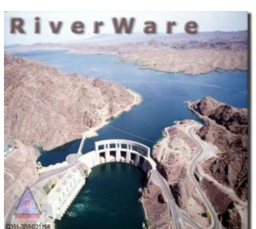
Temporal Downscaling

From Seasonal to Daily



Hydrologic models

Hydrologic projections at watershed scale.



Water Management Models

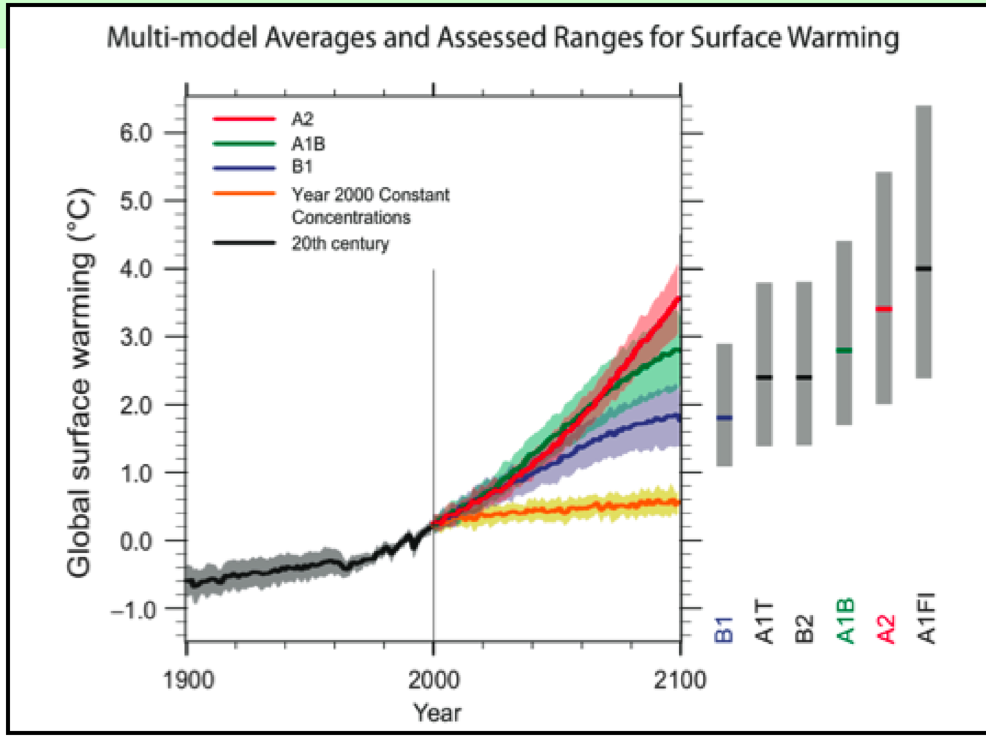
Evaluate Management Options

Irreducible Uncertainty of Climate Change

A1: Rapid economic growth, population 9B in 2050 then decline, quick spread of efficient technologies, convergent world

- **A1F: fossil fuels**
- **A1B: mix of fuels**
- **A1T: non-fossil fuels**

A2: more divided/diverse world, continual population increases, regional economic development, slower and fragmented technological and economic gains



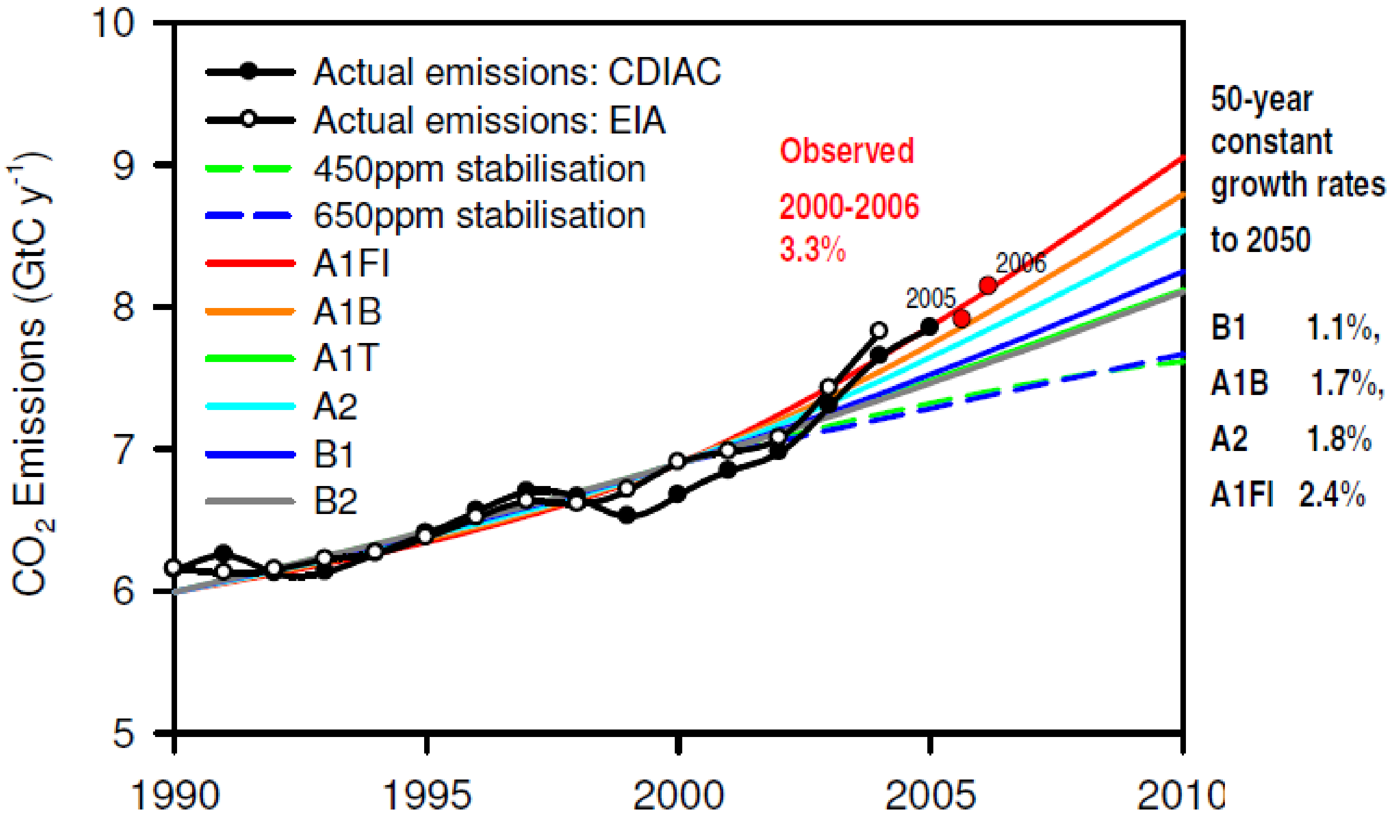
IPCC Fourth Assessment Report May 2007

B1: Same as A1, but change toward service and information economies, reductions in material intensity

B2: More divided world but ecologically friendly, slower population growth than A2, intermediate economic development, less rapid technological change, more fragmented change at more local level

Moving Beyond IPCC 4 Scenarios

Trajectory of Global Fossil Fuel Emissions



Raupach et al. 2007, PNAS

Liverman et al., 2009: planning should consider 4 deg C rise by 2060

Moving Beyond IPCC 4 Scenarios

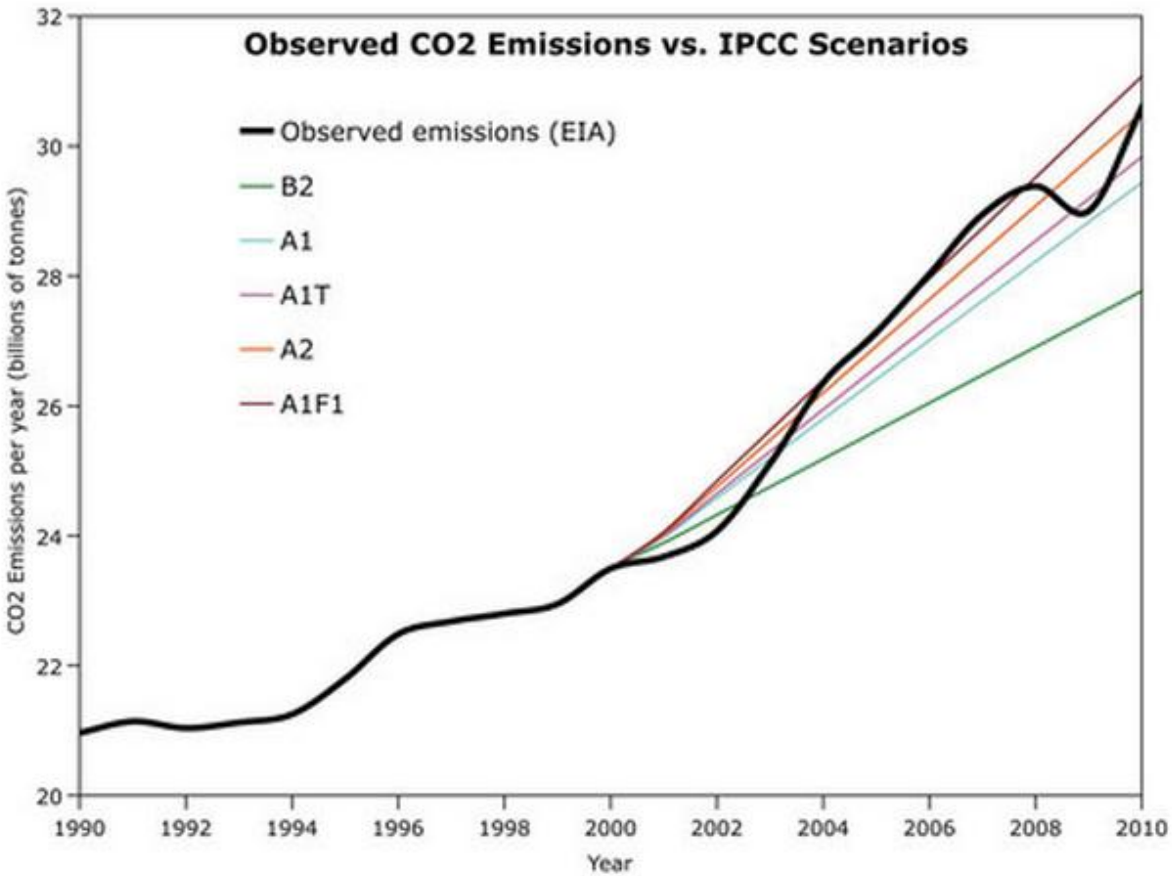
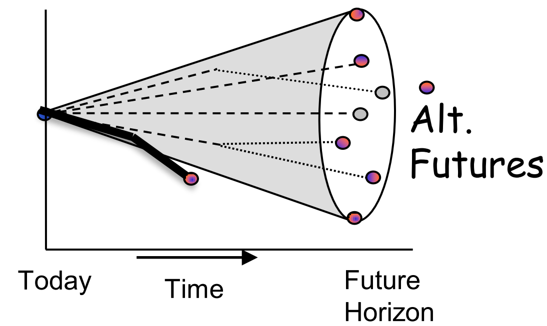


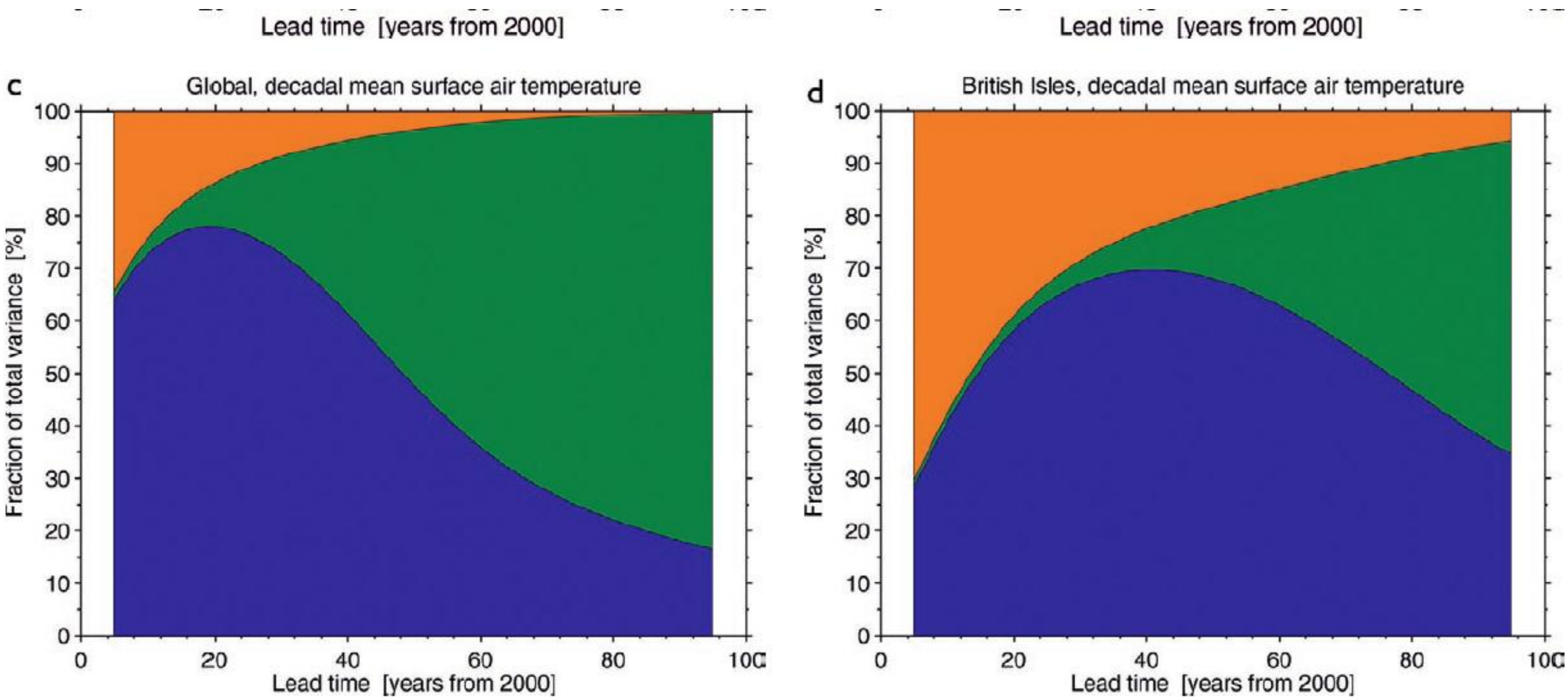
Figure 1: US Energy Information Administration (EIA) global human CO_2 annual emissions from fossil fuels estimates vs. IPCC SRES scenario projections. The IPCC Scenarios are based on observed CO_2 emissions until 2000, at which point the projections take effect.



Abraham, 2012, http://theconversation.edu.au

Liverman et al., 2009: planning should consider 4 deg C rise by 2060

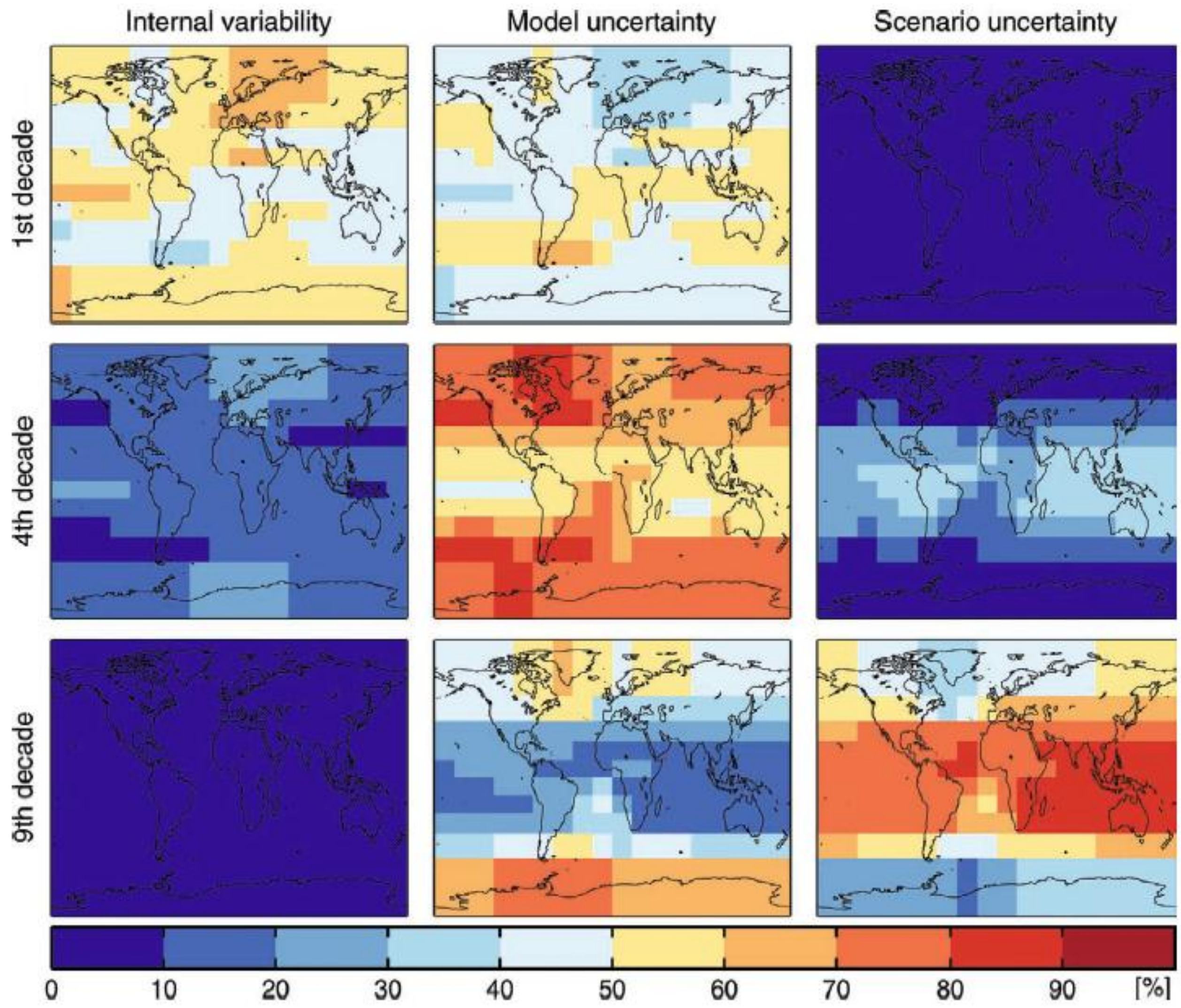
Relative Importance of Sources of Uncertainty on Decadal Surface Temperature



Climate internal variability
Climate models
Emissions scenarios

Hawkins and Sutton, BAMS 2009

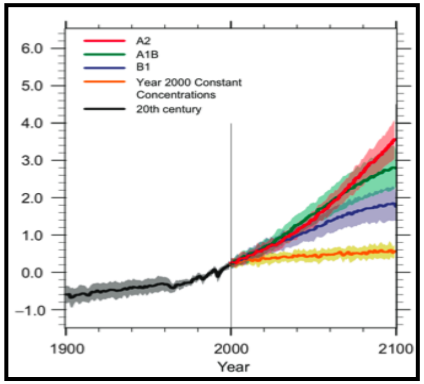
Relative Importance of Sources of Uncertainty on Decadal Surface Temperature

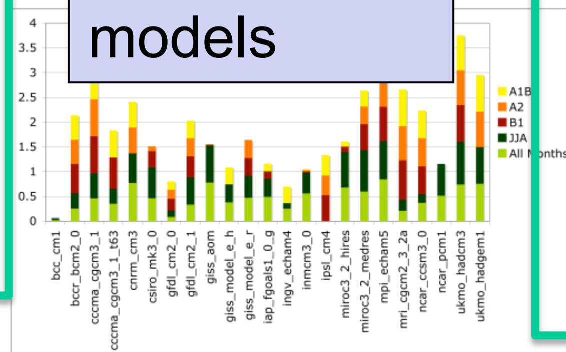


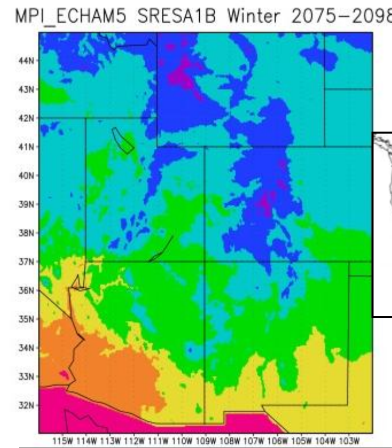
Hawkins and Sutton, BAMS, 2009

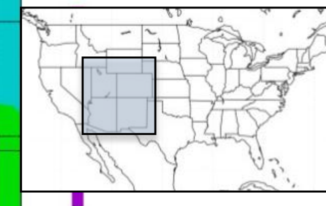
Variance explained vs. time

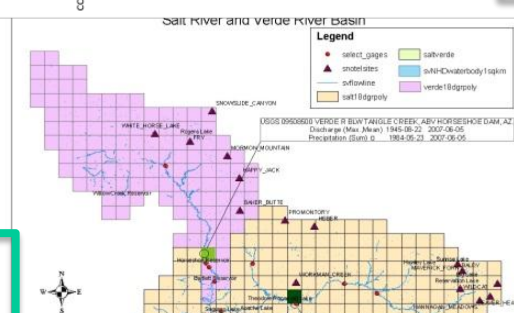
Model Chain: More Isn't Always More Certain

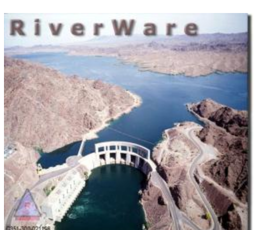






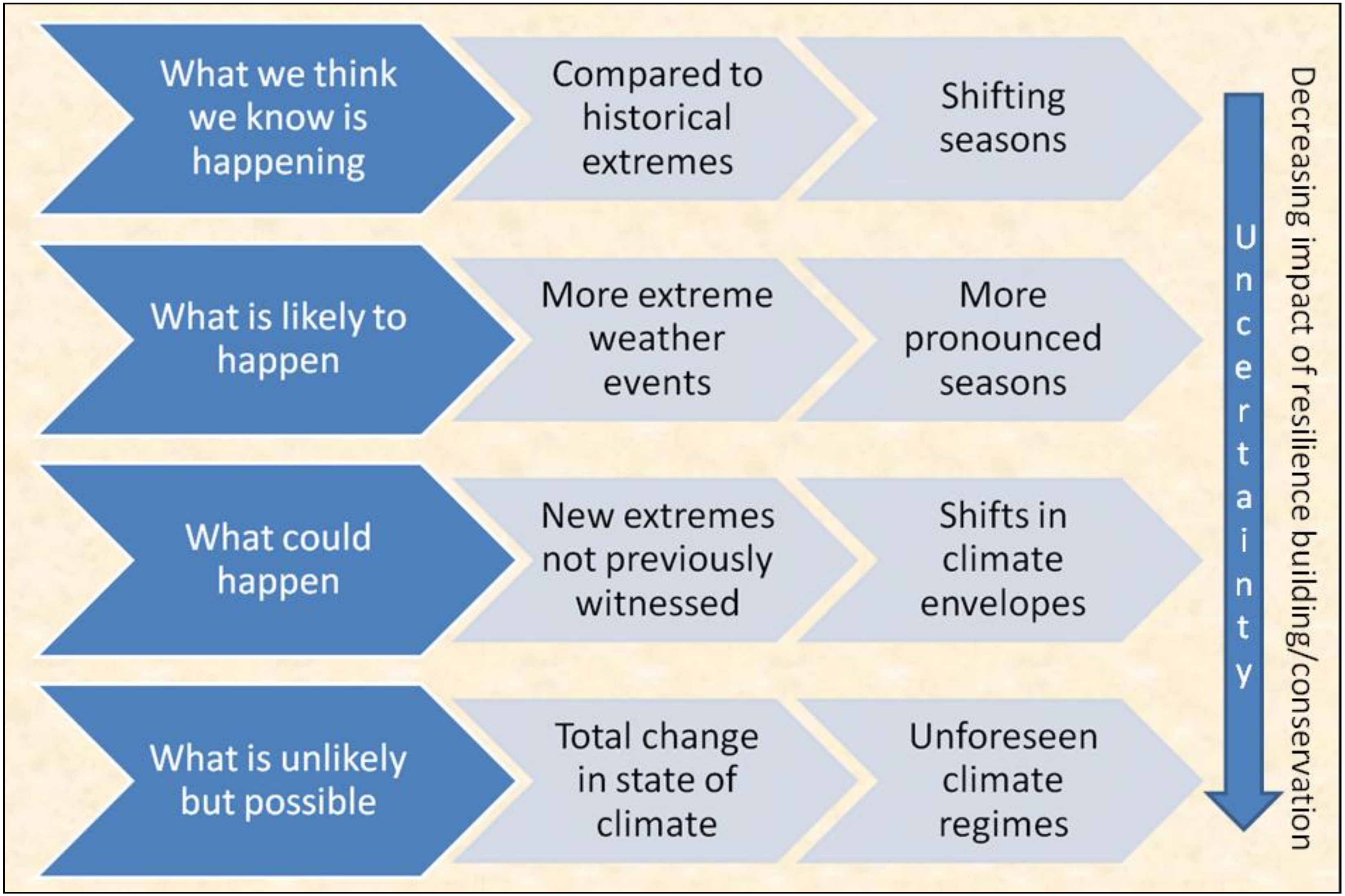






- IPCC AR4 GCM projections
- Select the "best" models
- Spatial Downscaling — *From approx. 200 km to 4 km.*
- Temporal Downscaling — *From Seasonal to Daily*
- Hydrologic models
- Hydrologic projections at watershed scale.
- Water Management Models
- Evaluate Management Options

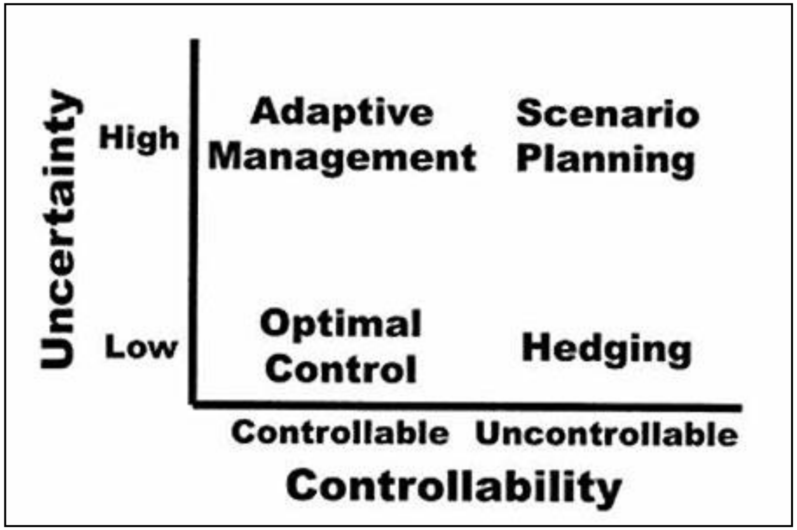
The Adaptation Challenge



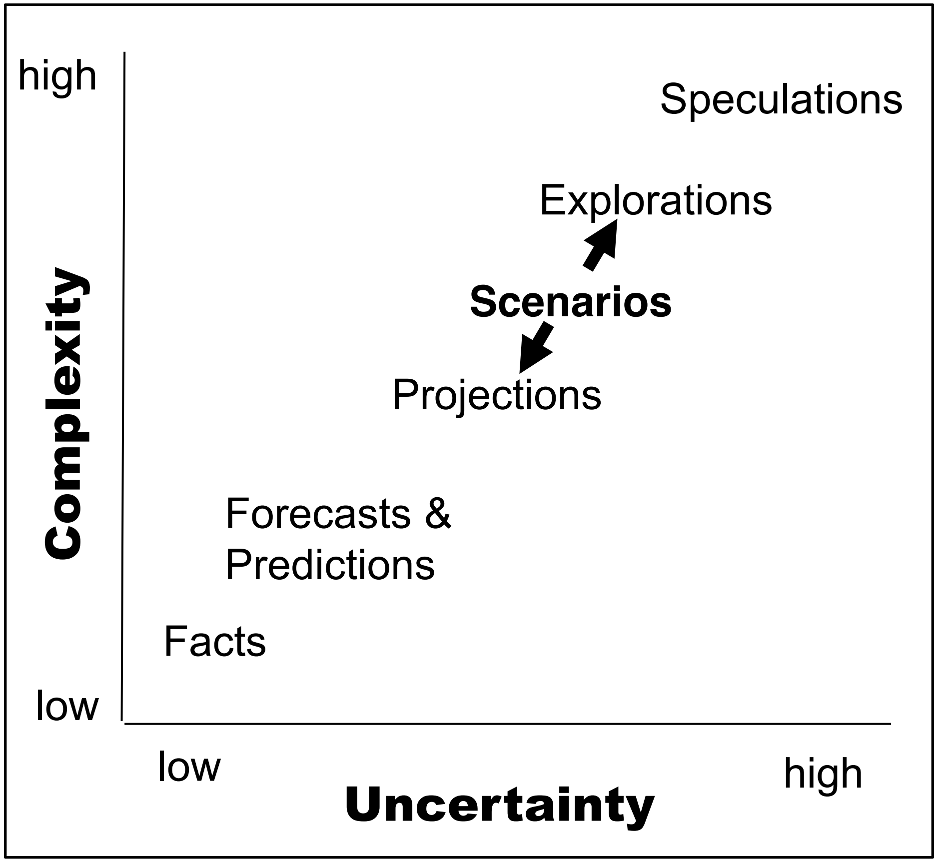
From Wickel et al, 2009

Projections: Lower Bound on Uncertainty!

Goal: Challenge thinking about the future; foster strategic thinking about responses to different possibilities. “Worst case” is beyond the projections.



Peterson et al., 2003.
Conservation Biology



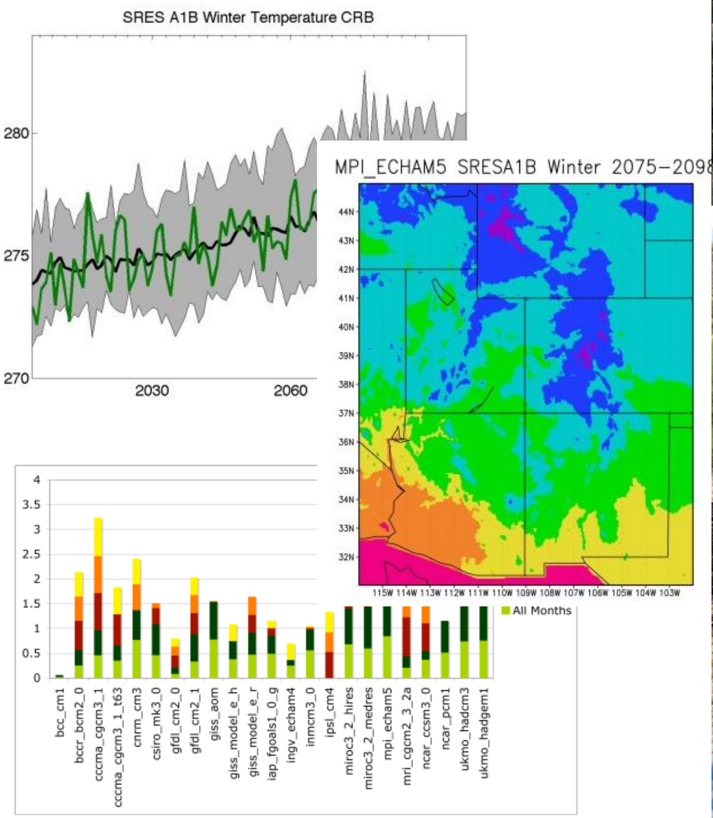
Adapted from Zurek and Henrichs, 2007

Use of Scenarios and Scenario Thinking

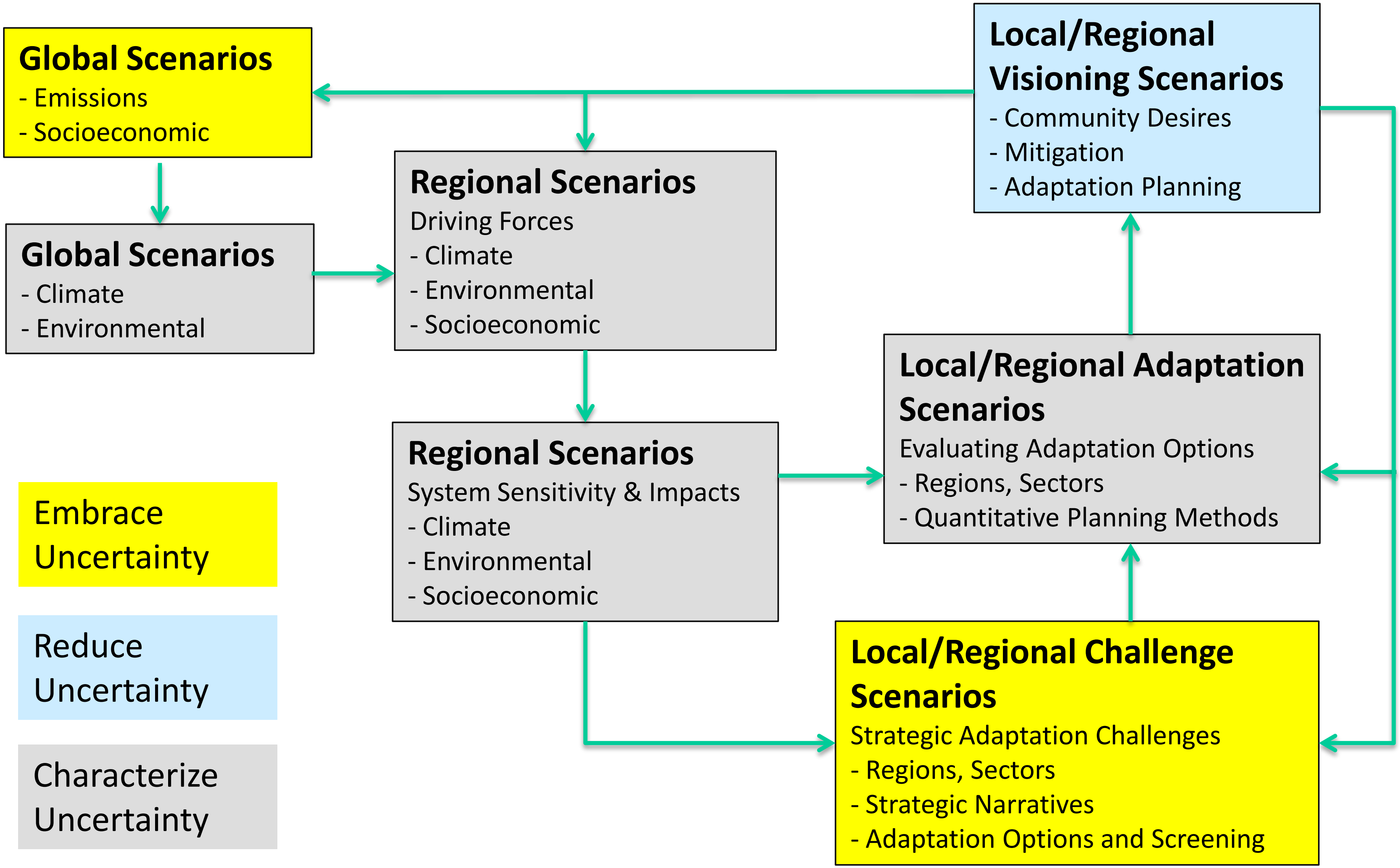
Characterizing Uncertainty

Embracing Uncertainty

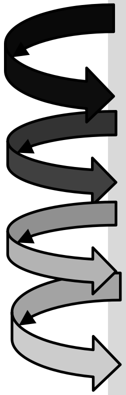
Reducing Uncertainty



Ecology of Scenarios



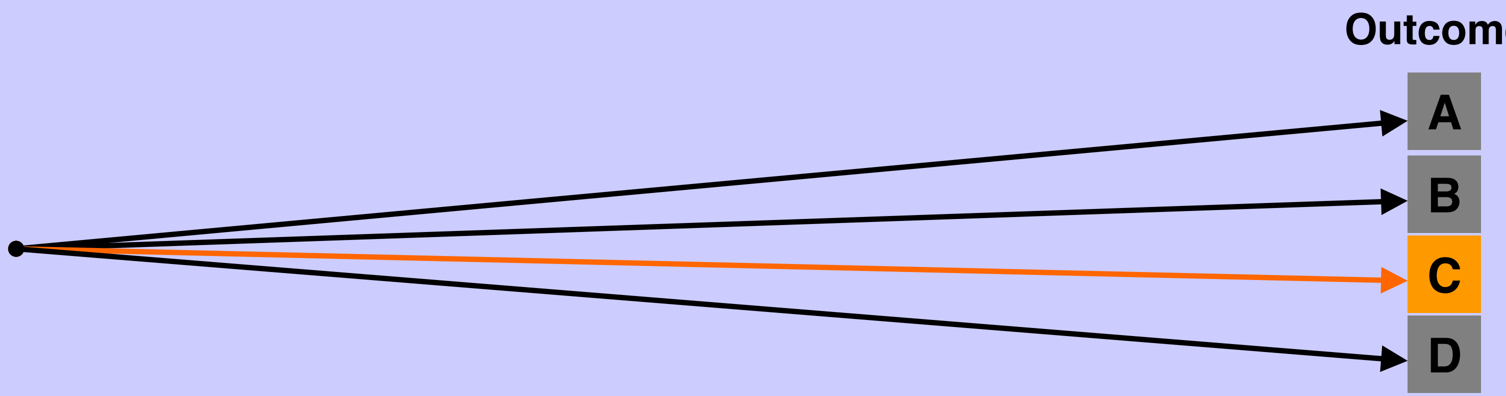
Typical Planning: Are Targets /Goals Achievable?



Planning for a Desired Future

- Defining goals
- Taking stock
- Examining trends
- Setting targets, thresholds
- Directing management

Choosing Among Alternatives



Decision Making: Priority Setting

No Regrets: benefits regardless of climate change

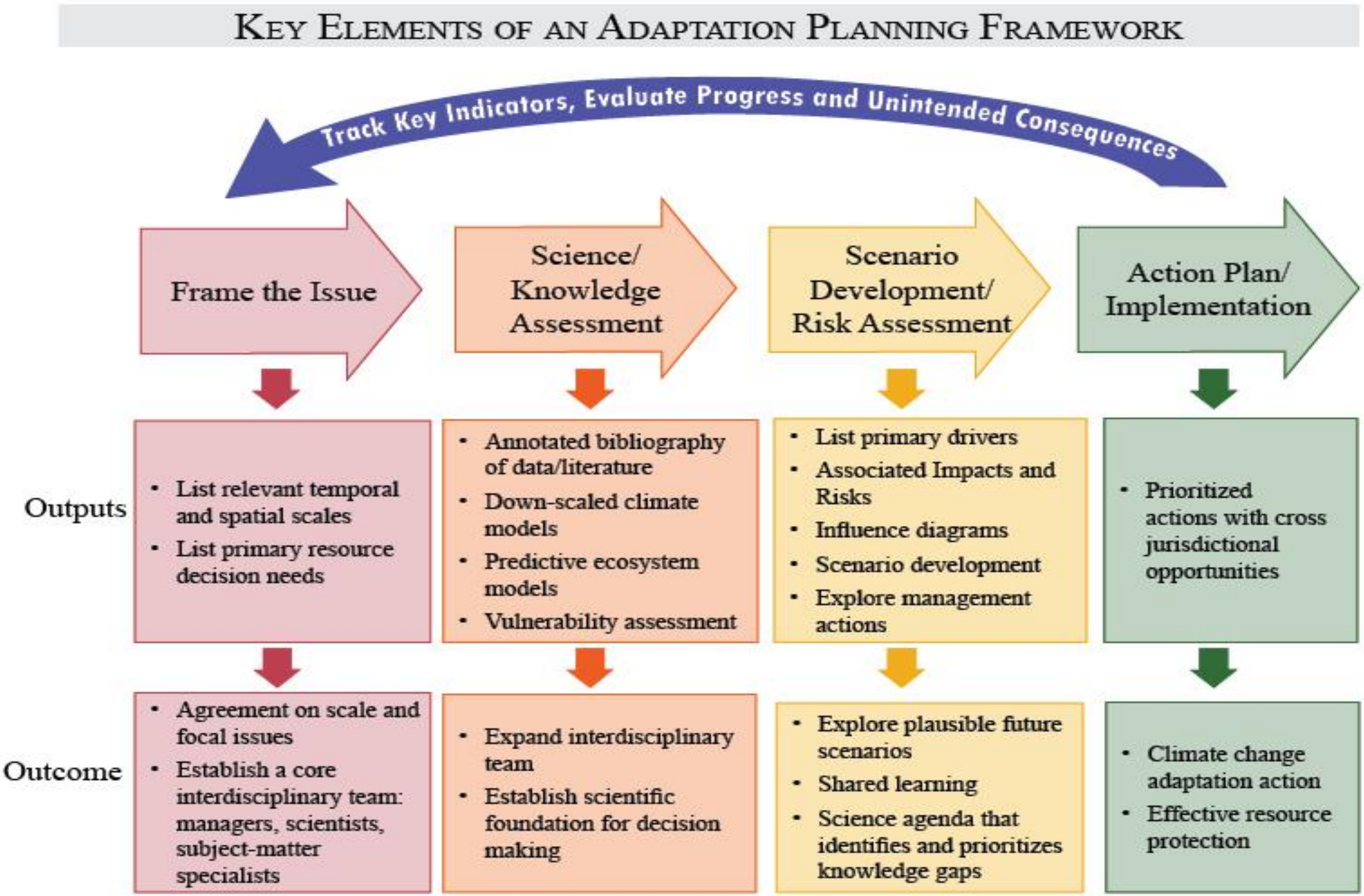
Low Regrets: important benefits with little additional cost or risk

Win-Win: reduce climate change impacts and provide other benefits

Adapted from Luers and Moser, 2006

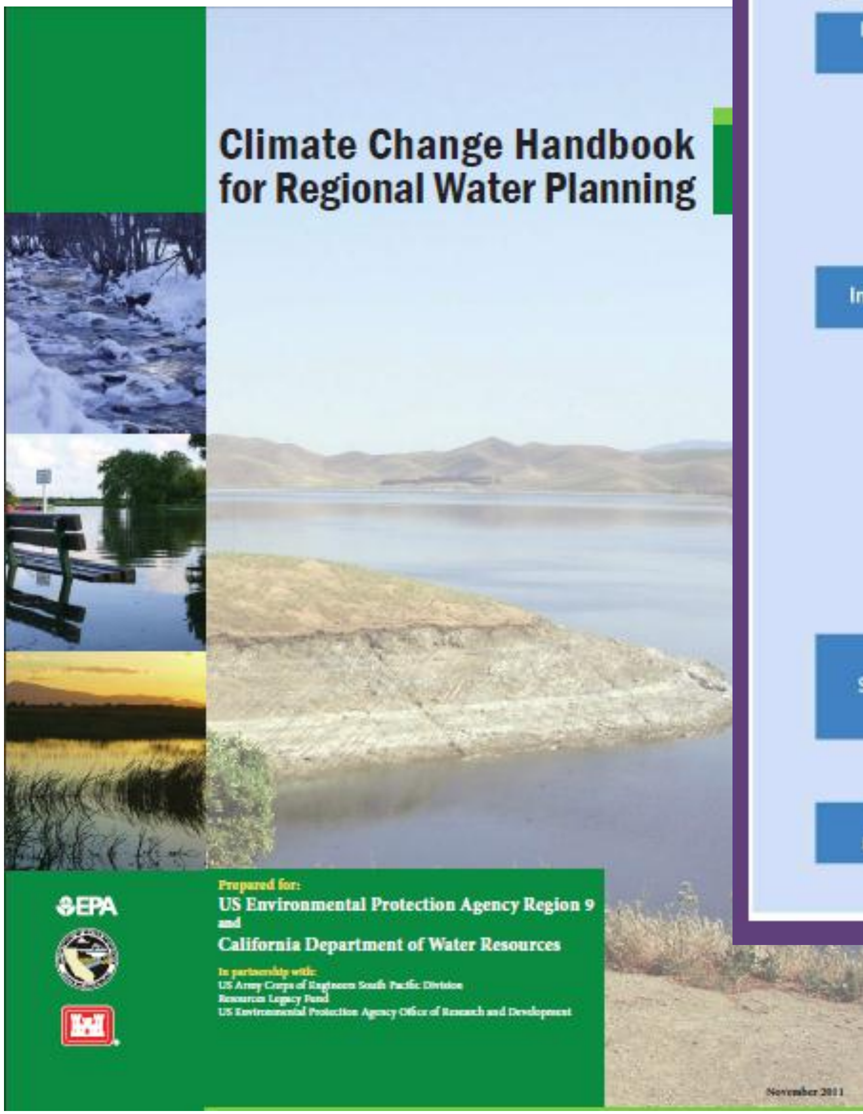
Limitations: Especially at long term/emissions driven
- Uncertainty incompletely specified
- Difficult choices not addressed

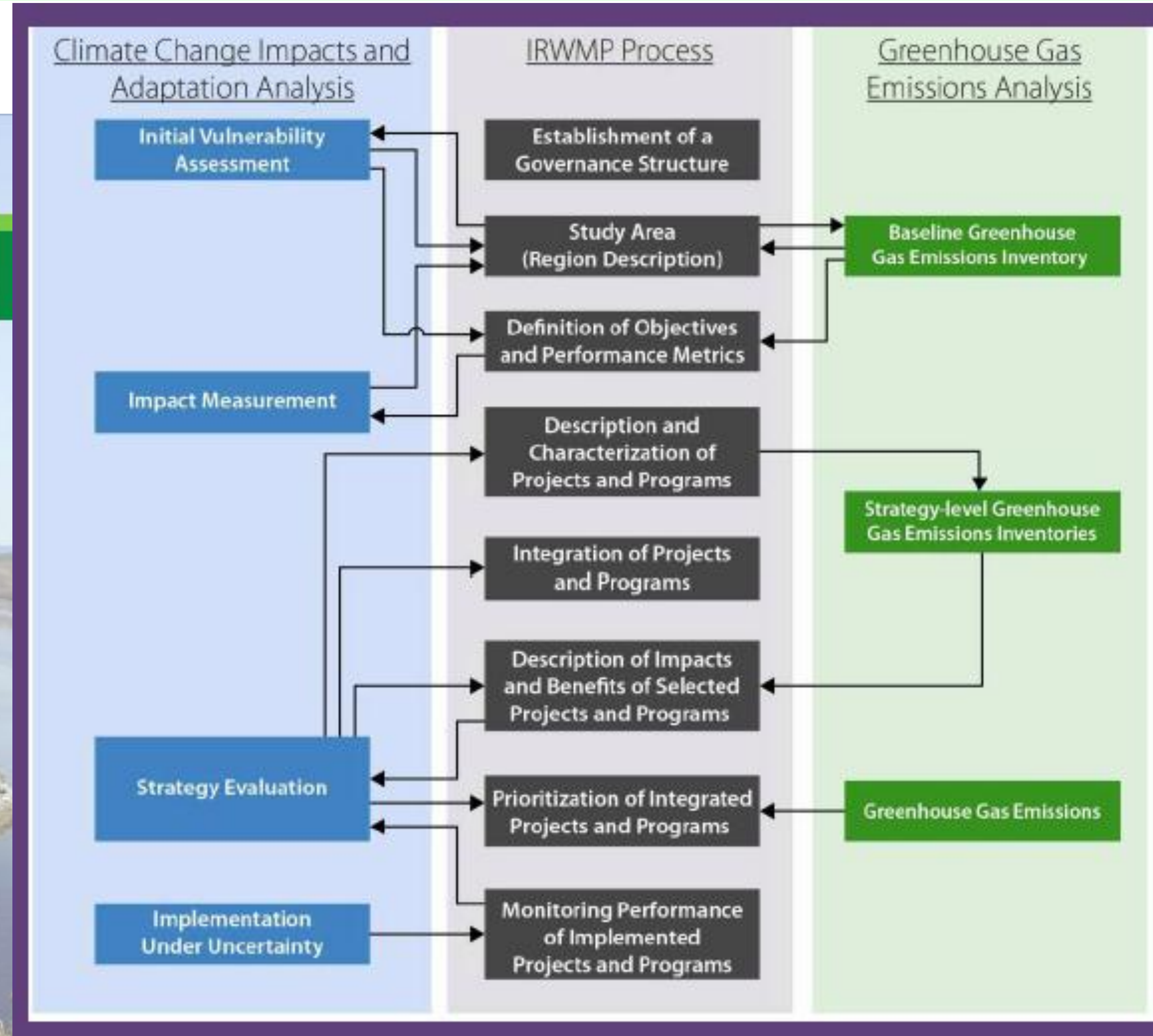
Challenge:
- Acting too soon vs. too late
- Surprise vs. false alarms



National Park Service, 2010. Climate Change Response Plan

CA Integrated Regional Water Management Planning





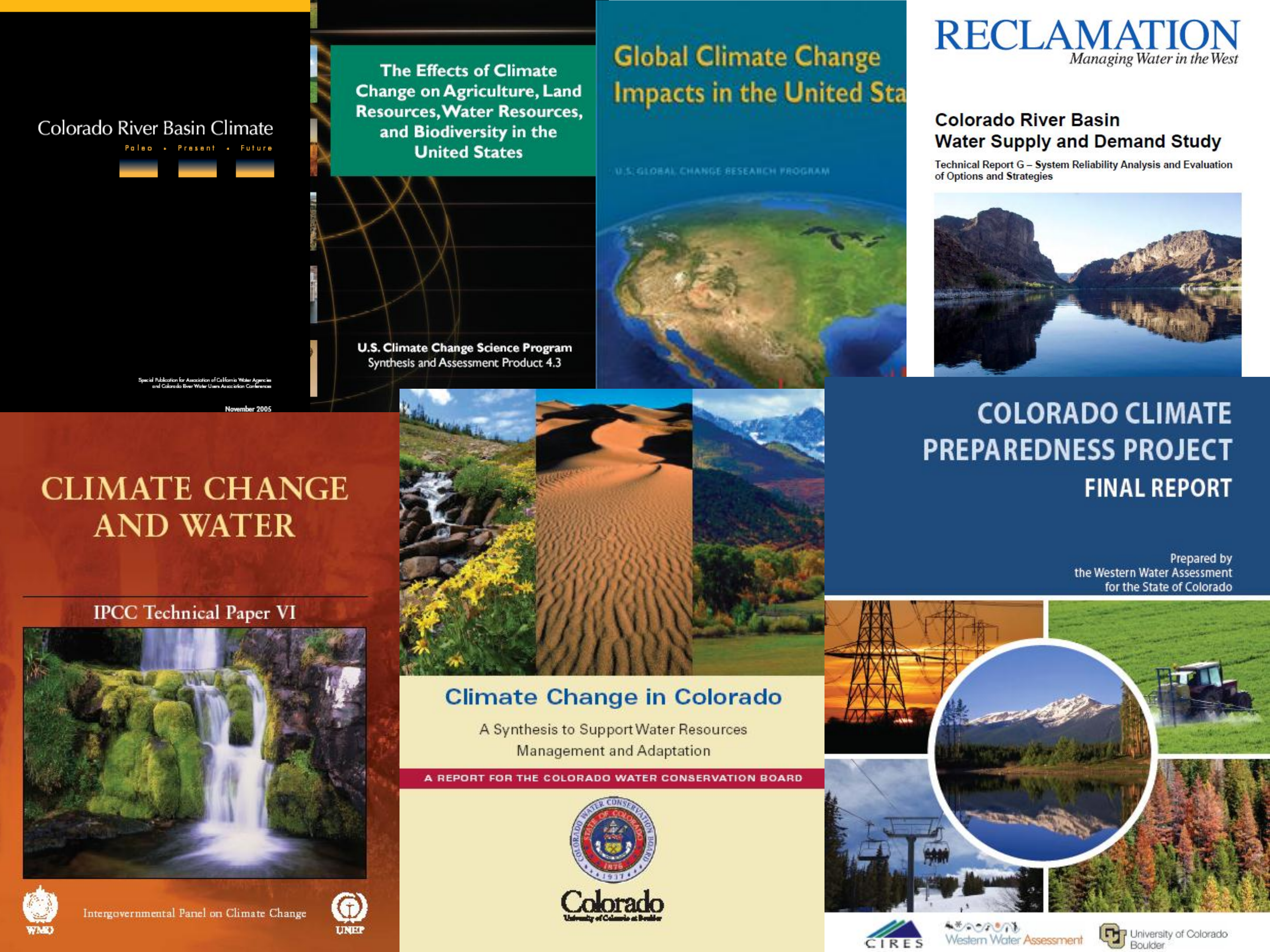
Schwarz, 2011California Department of Water Resources, Division of Statewide Integrated Water Management

Assess Vulnerability – Supplies and Beyond

Thresholds, cascades, surprising results!

- Assessment of infrastructure, policies, procedures
- Linkages: water supply infrastructure, land management, fire management, energy, communities

Photos: R. Meade, J. Moody: USGS, Mike McHugh, Aurora Water

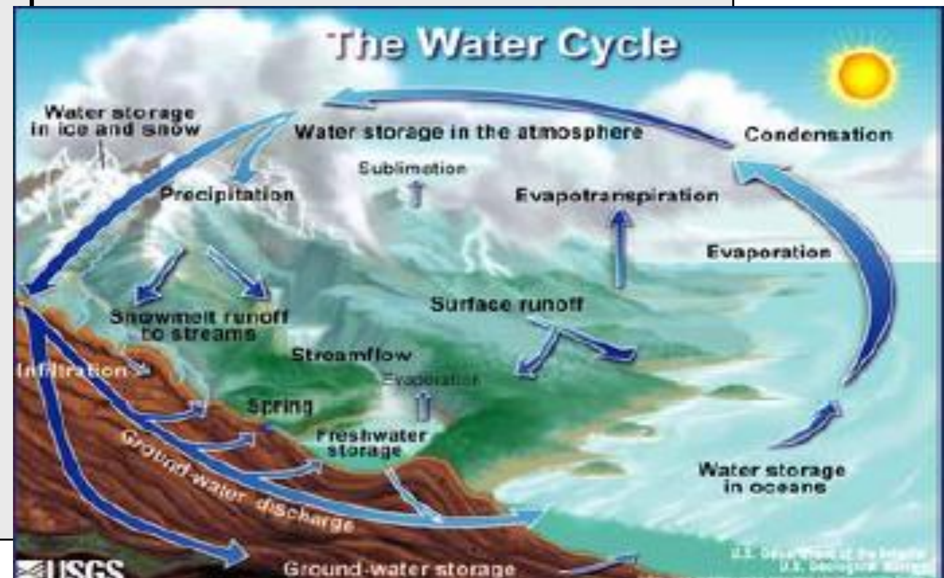


Colorado River Basin Climate
Paleo • Present • Future
Special Publication for Association of California Water Agencies and Colorado River Water Users Association Conference
November 2005
The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States
U.S. Climate Change Science Program
Synthesis and Assessment Product 4.3
Global Climate Change Impacts in the United Sta
U.S. GLOBAL CHANGE RESEARCH PROGRAM
RECLAMATION
Managing Water in the West
Colorado River Basin Water Supply and Demand Study
Technical Report G – System Reliability Analysis and Evaluation of Options and Strategies
CLIMATE CHANGE AND WATER
IPCC Technical Paper VI
Intergovernmental Panel on Climate Change
WMO
UNEP
Climate Change in Colorado
A Synthesis to Support Water Resources Management and Adaptation
A REPORT FOR THE COLORADO WATER CONSERVATION BOARD
Colorado
University of Colorado at Boulder
COLORADO CLIMATE PREPAREDNESS PROJECT
FINAL REPORT
Prepared by the Western Water Assessment for the State of Colorado
CIRES
Western Water Assessment
University of Colorado Boulder

Focus on 'Actionable Information' (Hydrology)

Extra Energy: Enhanced Hydrologic Cycle

– Higher temps increase atmosphere moisture holding capacity
– Higher temps imply globally increased evaporation
– Precipitation must increase globally
(but not necessarily regionally)
– More intense precipitation - Floods
– More intense drying - Drought
  • Mid-continental summertime drying
  • Increased evaporation increases water demand
– More rain, less snow
– Earlier spring runoff



IPCC 2007 Southwest North America Regional Findings

- Annual mean warming likely to exceed global mean
- Western NA warming likely between 2C and 7C at 2100
- In Southwest greatest warming in summer
- Precipitation likely to decrease in Southwest
- Snow season length and depth very likely to decrease

Can decision makers act on these levels of information?
-- Some, YES! --

Past Reports Provide a Foundation

Water cycle has already been altered by climate change.
The past century is no longer a guide to the future for water management.
- 2009 *Global Climate Change Impacts in the United States*

Modest declines for Colorado's high-elevation snowpack.
Shifts in timing, intensity of streamflows and runoff.
Decreases in runoff.
Reductions in late-summer flows.
Increases in drought.
-- 2010 Climate Change Preparedness Project

Multi-model average reductions for the Colorado River runoff range from -6 to -20 percent by 2050.
- 2008 Climate Change in Colorado

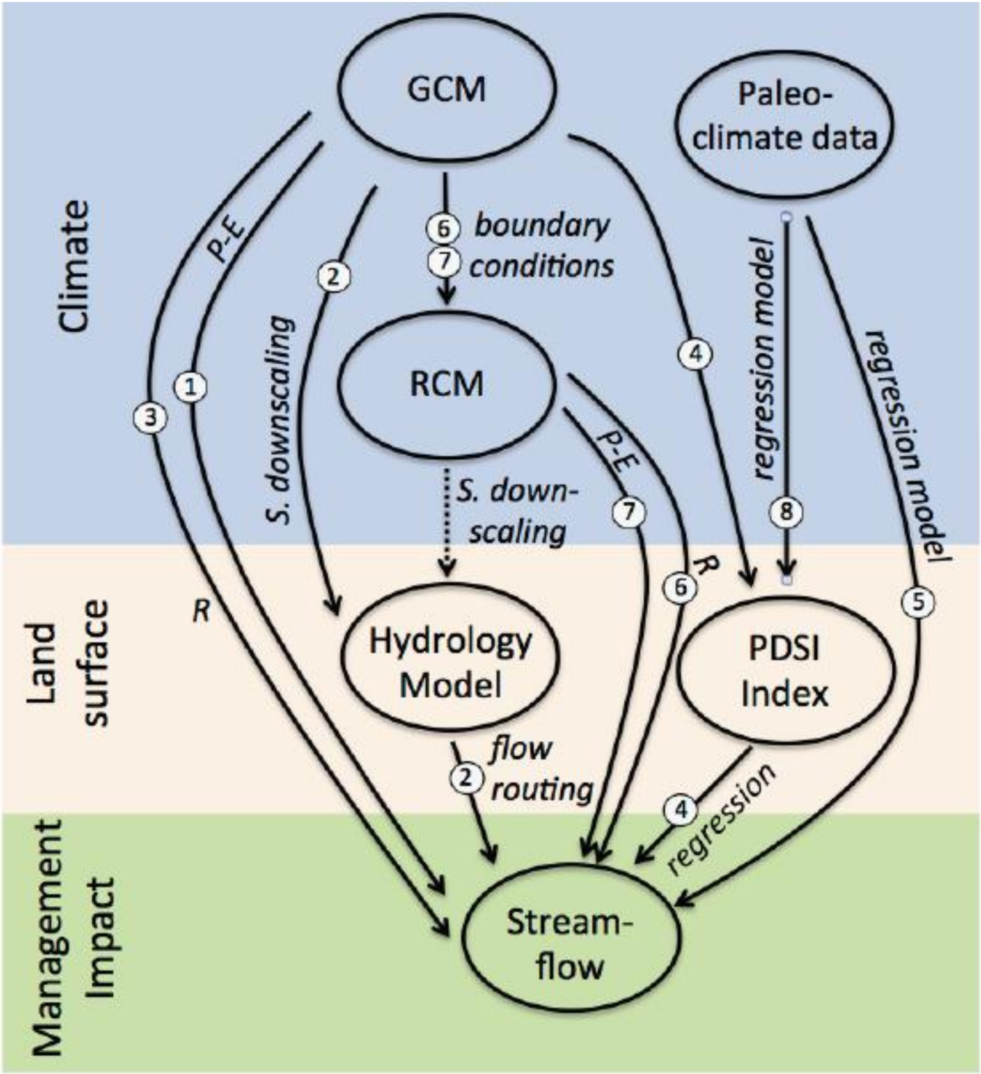
Check Interpretation, Communicate Uncertainty

Recent Studies of Mid-century Climate Change Impacts on Colorado River flows (Lee's Ferry)

Recent Studies	**Projected Annual Flow Reductions**
Christensen et al., 2004	~18%
Christensen and Lettenmaier, 2007	~6%
Milly et al., 2005	10 to 25%
Hoerling and Eischeid, 2007	~45%
Seager et al., 2007	"an imminent transition to a more arid climate"
McCabe and Wolock, 2008	~17%
Barnett and Pierce, 2008	assumed 10-30%

Genealogy and 'MetaData' of Studies

- Dates
- Scales
- Base data
- Models and versions
- Methods of bias adjustment & downscaling
- Which GCM projections
- Underlying assumptions



Studies using various approaches:

1. Seager et al. 2007
2. Christensen et al. 2004; Christensen and Lettenmaier, 2007; USBR 2011
3. Milly et al. 2005
4. Hoerling and Eischeid, 2007
5. Woodhouse et al. 2006; McCabe and Wolock 2008; USBR 2011
6. Gao et al. 2011; Rasmussen et al. 2011
7. Gao et al. 2012
8. Cook et al. 2004

Abbreviations:

GCM – Global Climate Model
RCM – Regional Climate Model
PDSI – Palmer Drought Severity Index
P – Precipitation
T – Temperature
R – Runoff
E – Evaporation
S. Downscaling – statistical downscaling (studies above use BCSD)

Reconciling Colorado River Flow Projections Project: Vano et al., BAMS, 2013

Check Interpretation, Communicate Uncertainty

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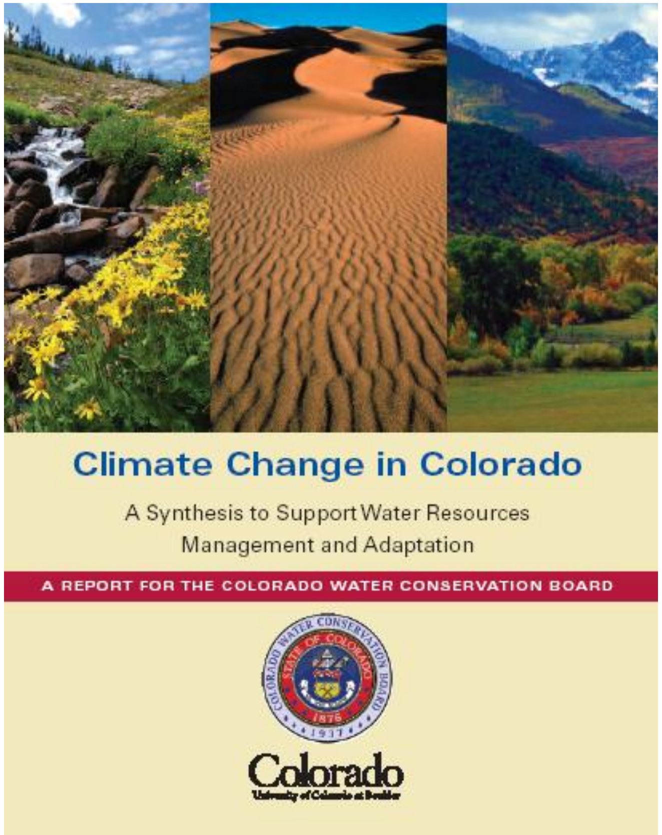
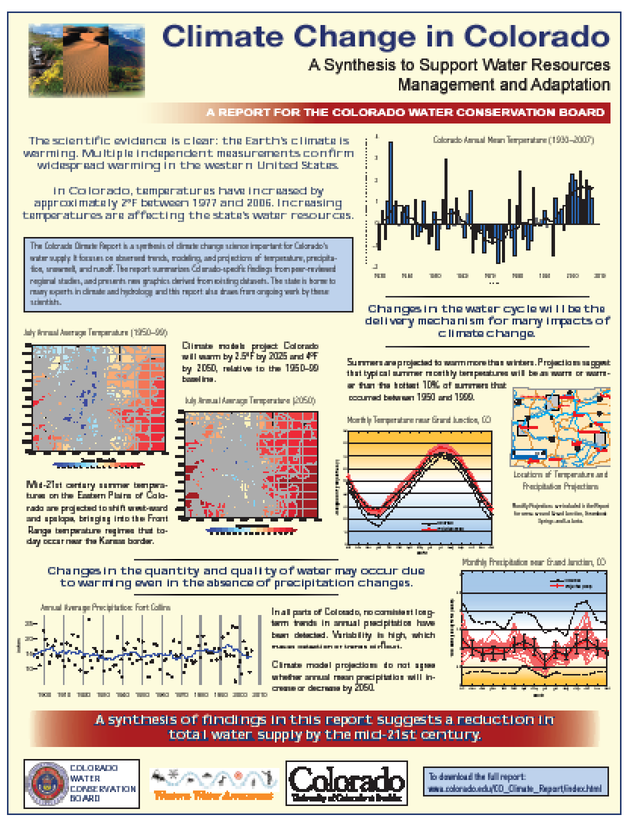
Response One: These are so different, we can't trust any of them…

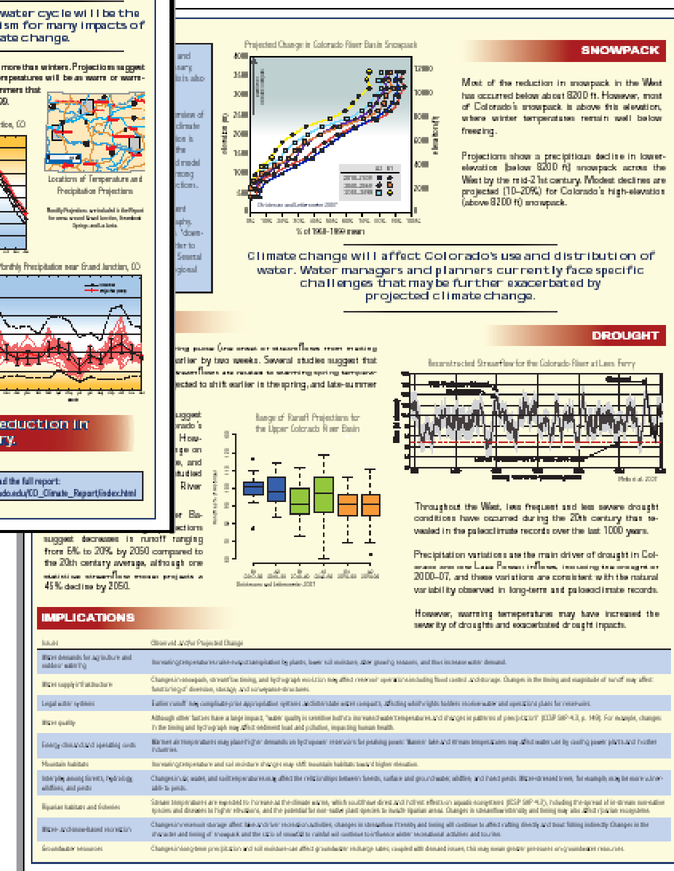
Response Two: We need to resolve these differences! Are the differences due to climate uncertainty or different models and methods?

Response Three: None of these studies show increasing flows. Any decrease is a source of concern.

Follow Good Examples in Reporting



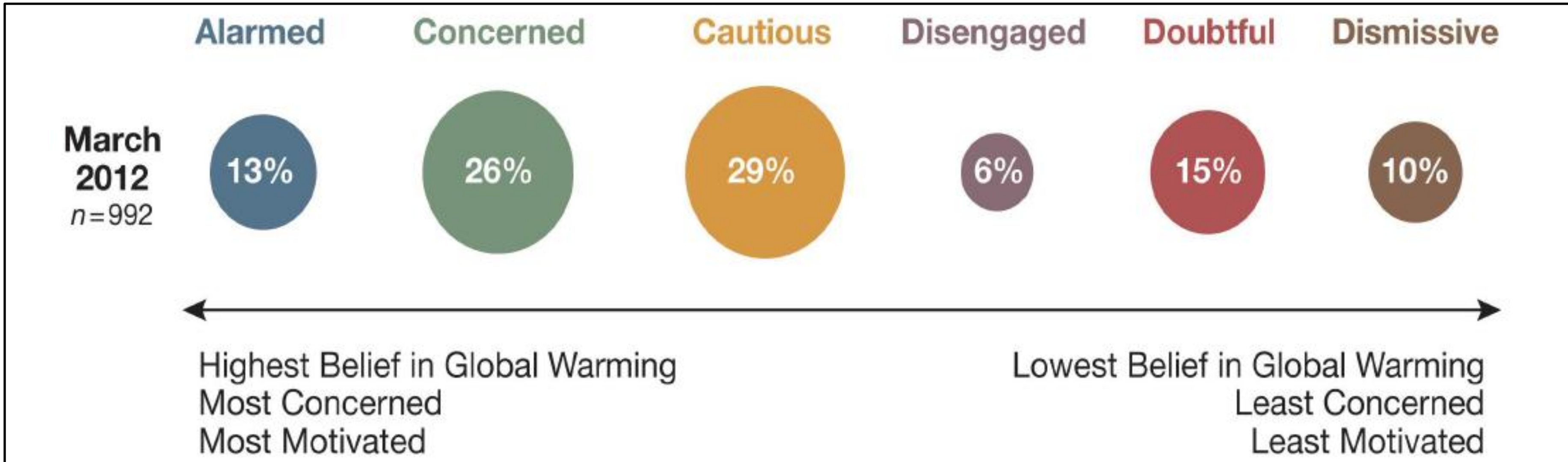




Technical Report, Summary Version

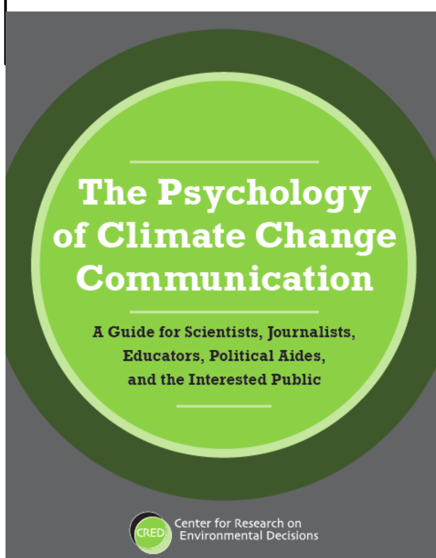
Links past, present, future

Match Audience, Message, Messenger



Proportion of the U.S. Adult Population in the Six Americas, March 2012

Yale & George Mason University



CIRES
Cooperative Institute for Research in Environmental Sciences

Connect with values: security, family
Connect with impacts and implications
General public: offer path of positive action

Language Matters

Scientific Jargon	Common Translation	Better Language
Bias	Unfair distortion	Offset from the observed value
Positive trend	A good trend	Upward trend
Error	Wrong, incorrect	Uncertainty associated with a model or measuring device
Spatial, Temporal		Space, Time
Anthropogenic		Human
Positive feedback		Amplifying effect
Uncertainty	We don’t know	Range

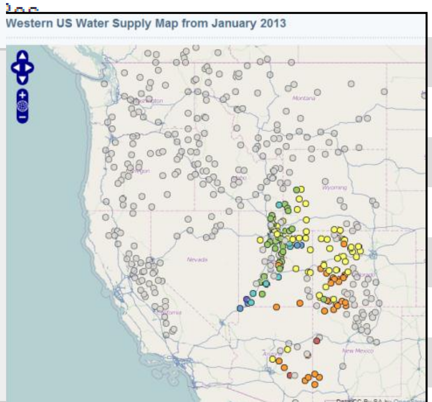
Hassol, 2010 and CRED, 2012

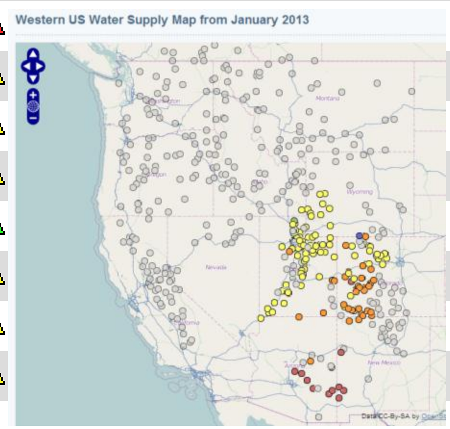
Normal, Mean, Average vs. Median: Implications for Risk Perception

	NWS ID	Location	Percent Avg/Med	Official Forecast Date	Official Min 90%	Official MP 50%	Official Max 10%	Official Percent Average	Official Percent Median	Average	Median
121	SMPC2	San Miguel - Placerville Nr	△ (yellow)	2013-01-01	50	90	150	70%	74%	128	122
122	SOMC2	Nf Gunnison - Somerset Nr	△ (red)	2[illegible]							
123	SRKU1	Ef Sevier - Kingston Nr	△ (yellow)	2013-01-01	19	31	40	89%	89%	35	35
124	SRYU1	Sevier - Gunnison Nr	△ (red)	2013-01-01	37	60	110	61%	146%	99	41
125	STAU1	Strawberry - Starvation Res Duchesne Nr	△ (yellow)	2013-01-01	27	92	142	82%	116%	112	79
126	STCU1	Santa Clara - Pine Valley Nr	△ (yellow)	2[illegible]							

Legend

- > 150% of median
- 130% - 150% of median
- 110% - 130% of median
- 90% - 110% of median
- 70% - 90% of median
- 50% - 70% of median
- < 50% of median
- No median
- No Forecast

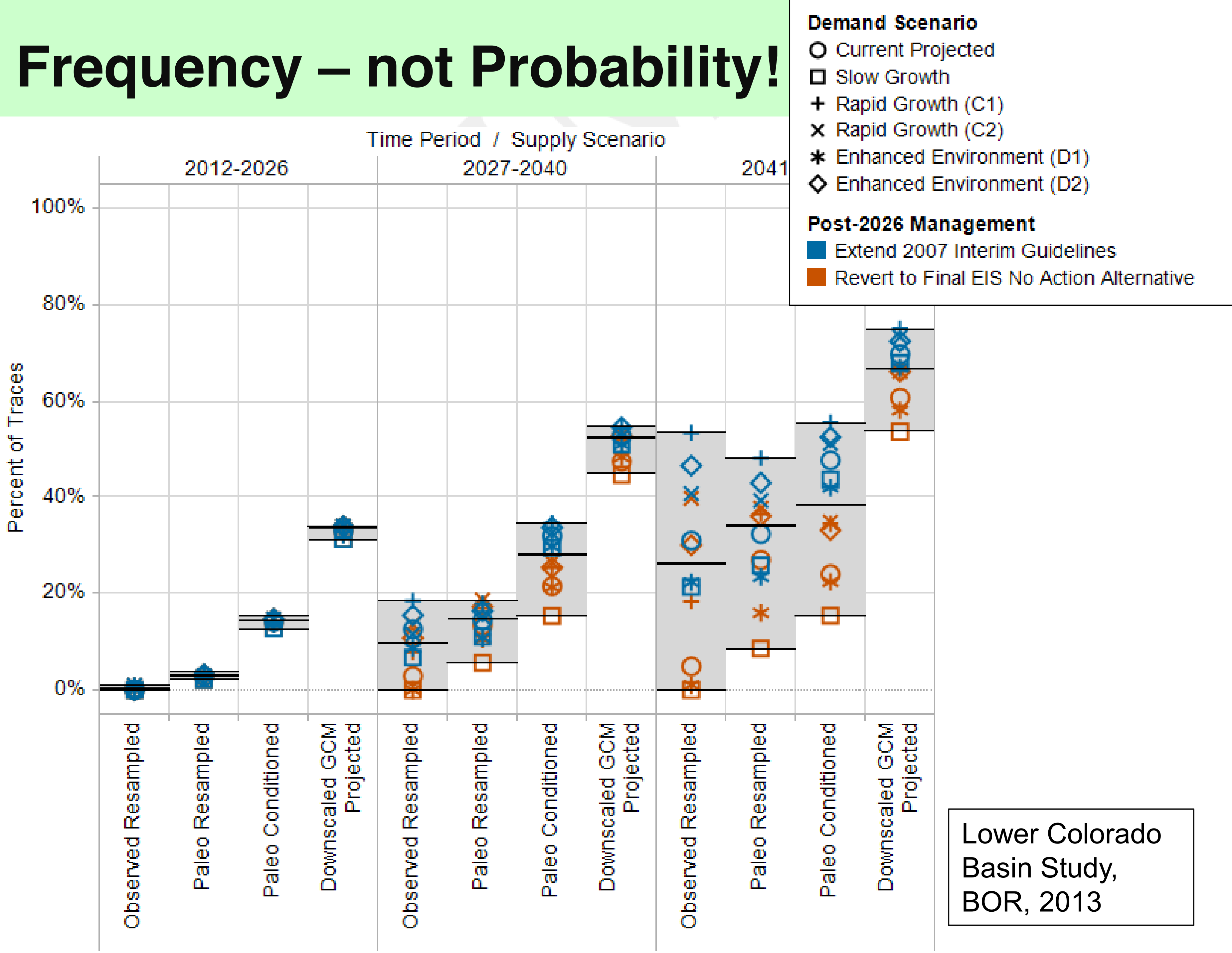




Legend

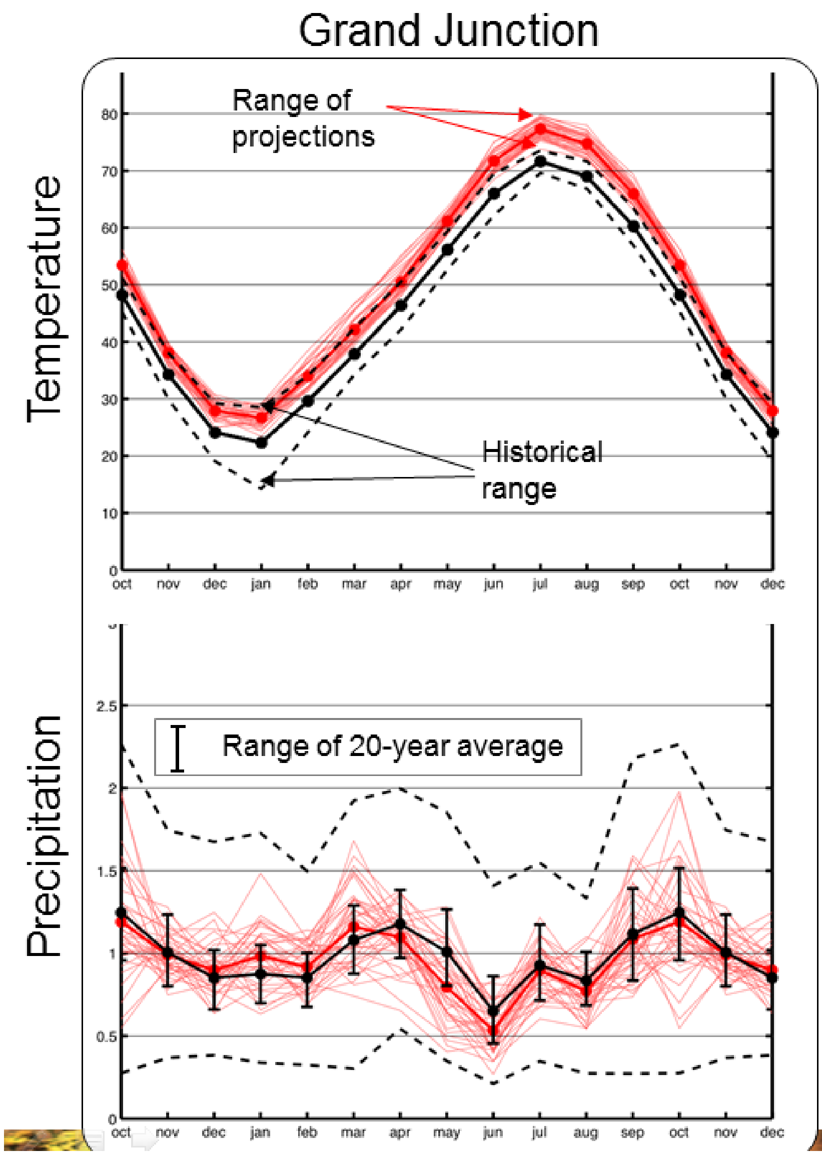
- > 150% of mean
- 130% - 150% of mean
- 110% - 130% of mean
- 90% - 110% of mean
- 70% - 90% of mean
- 50% - 70% of mean
- < 50% of mean
- No mean
- No Forecast

Frequency – not Probability!

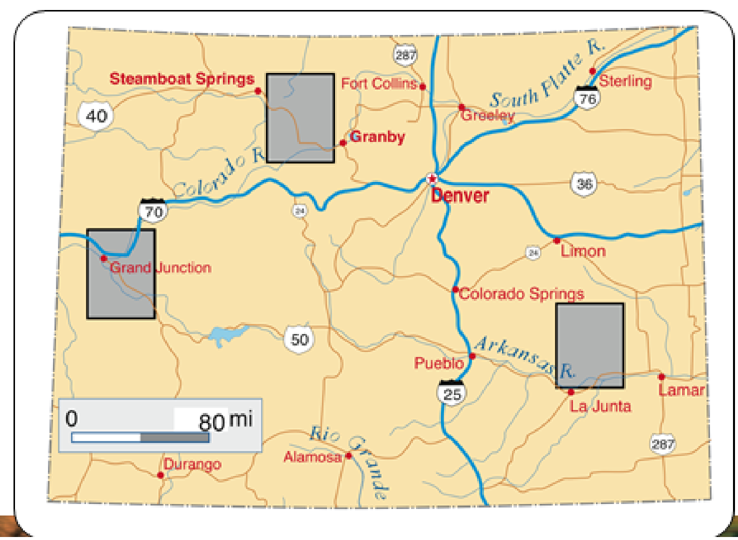


Lower Colorado Basin Study, BOR, 2013

Period-Change Results

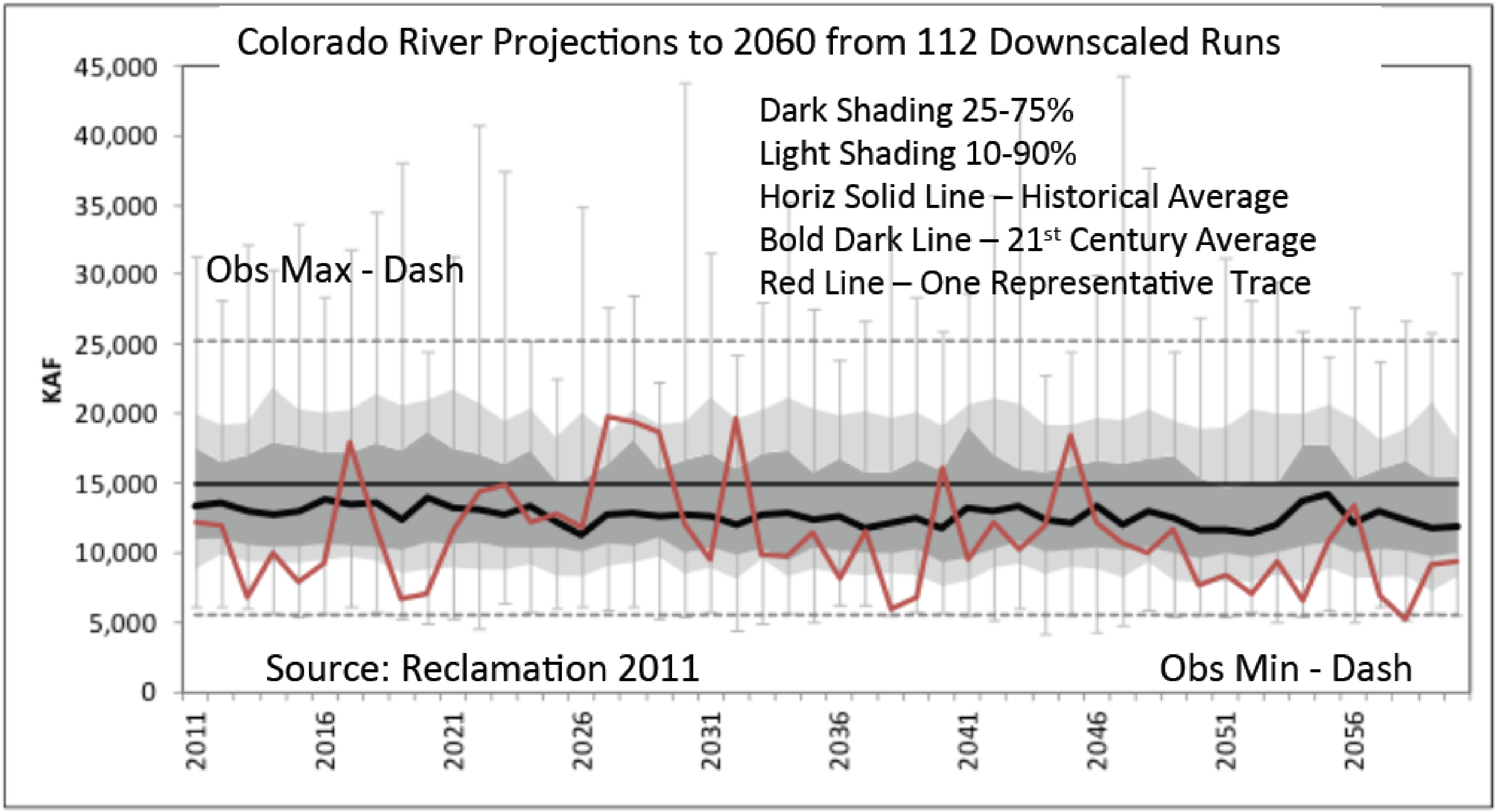


- Summers warm more than winters
- Average summer temperatures similar to the hottest months in the past fifty years.
- Heat waves; fewer cold winters
- Projected precipitation trends small compared to the variability.



Source: CO Climate Report, 2008

Time-Developing Results



From Udall, 2012, CI Water Symposium

Diagnostics Approach to Results

All Models Are Wrong – Some Are Useful
Ability to compute is not accuracy or precision
Specific numerical results - temporary, evolving, “loosely held”

Learning your system
Sensitivities
Thresholds, cascading impacts
Surprising Results

Consistent Messages
Counter-Intuitive Messages
Unresolvable Uncertainties

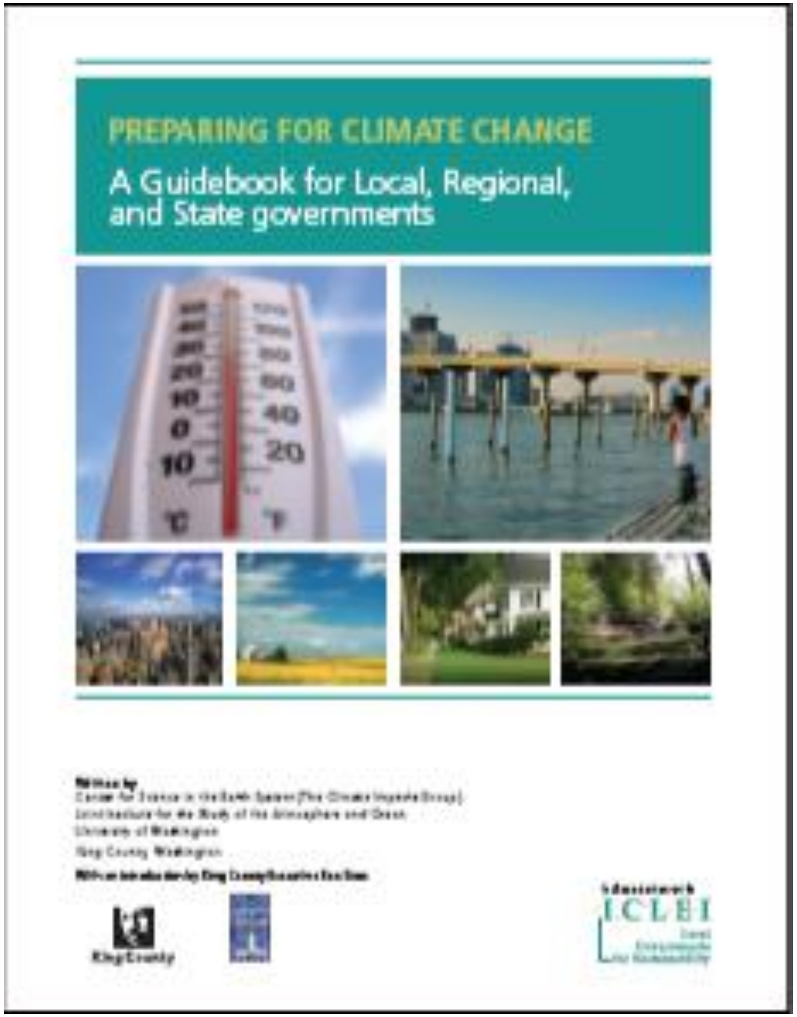
A prepared team is essential

Webinar on Use of Models and Scenario Studies

- "Downscaling, upscaling, and a few things in between"
- 8 Nov 2011
- Brad Udall: Western Water Assessment
- Laura Briefer: Salt Lake City Public Utilities

Carpediemwestacademy.org

Steps Toward Climate Action Plans



1. Listen to the Science
2. Build support and a team
3. Assess – risk, vulnerability, adaptive capacity
4. Set goals and develop a plan
5. Implement your plan
6. Measure progress

Practical Decision Support Activities

1. What adaptation planning/implementation is in your region?
   - how does climate information fit in?
   - provide a menu for new stakeholders
   - share learning across users/sectors
   - Use common information

2. Develop base information for your region
- driver and impact tables (CIG/ICLEI guidebook)
- update with new science

Practical Decision Support Activities

3. Honest broker for ‘best practices’, common pitfalls
- there’s not a new normal
- projections alone are important but insufficient
- non-climatic factors are changing, too
- lessons from other sessions!

4. Local climate studies
- local variables
- extremes
- trends
- relationships among variables, sectors

Practical Decision Support Activities

5. Monitoring
- track trends
- evaluation of adaptation effects

6. Help decision makers practice dealing with uncertainty
- use seasonal-to-interannual forecasts to gain experience with iterative risk management

7. Stay up-to-date
- with science (IPCC, National Assessments, NRC)
- with tools: a challenge!

Enjoy the Journey…
Friends and Humor are Important