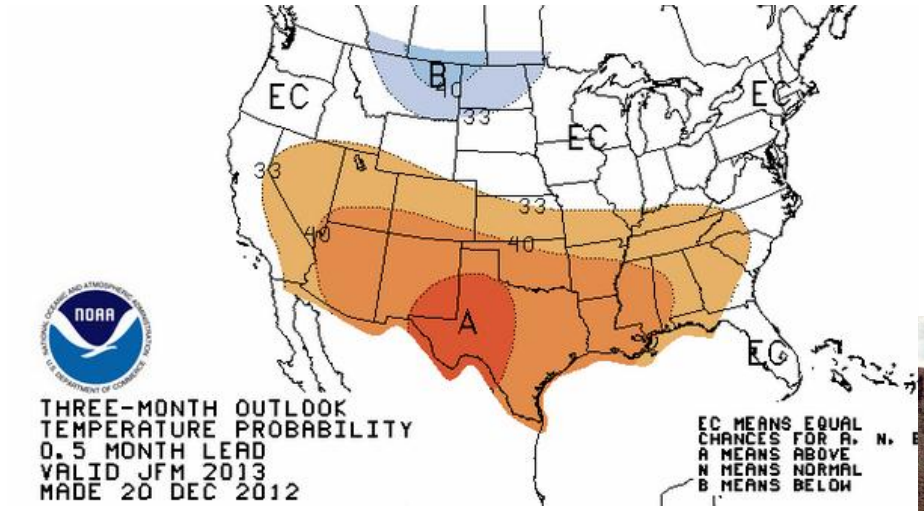
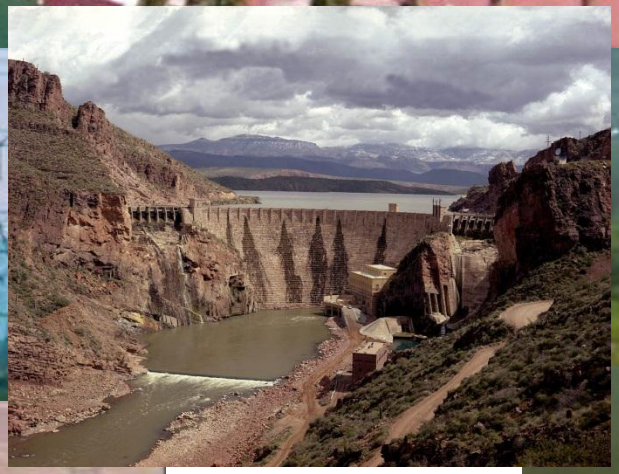
Linking Forecast Applications and Evaluations



Holly C. Hartmann, University of Arizona

hollyoregon@juno.com

So Many Decisions, Actors, Impacts!



Linking Via Decision Support

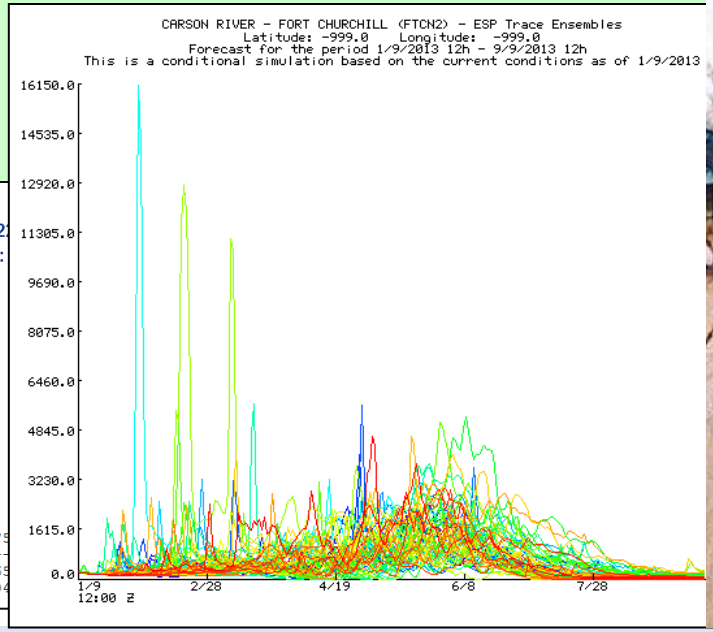
Decision support: **organized efforts to produce, disseminate, and facilitate the use of data and information in order to improve the quality and efficacy of decisions** (adapted from NRC 2009, Informing Decisions in a Changing Climate).

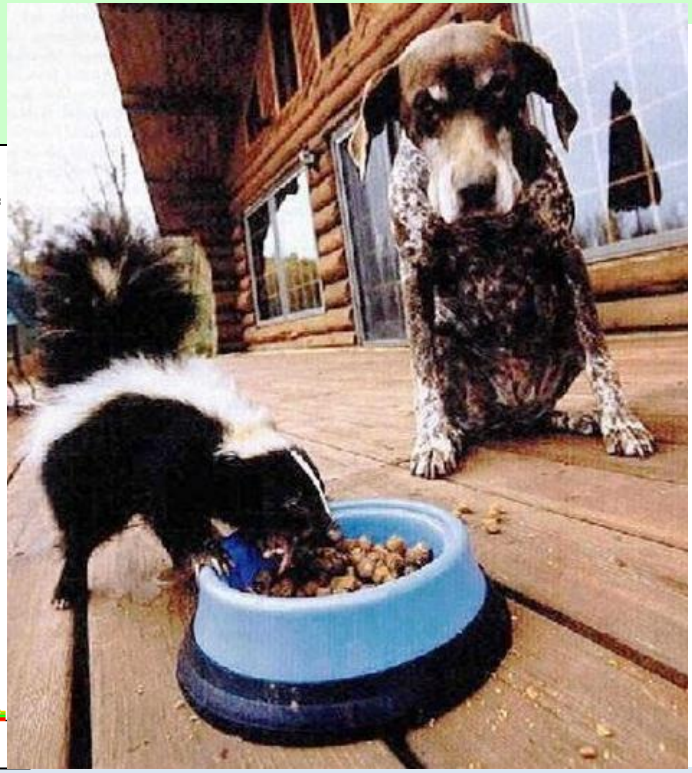
Are forecasts and data DSS? If they are embedded within systems to **disseminate and facilitate their use in order to improve the quality and efficacy of decisions.**

CARSON RIVER - FORT CHURCHILL (FTCN2)
Latitude: 39.29° N Longitude: 119.31° W Elevation: 42
Location: Lyon County in Nevada River Group:
Monitor Stage: N/A *Flood Stage: N/A*

CAUTION:
The Information Obtained Has NOT Been Reviewed by the CNRFC.
Some Forecast Points Need a Bias Adjustment Before Use.

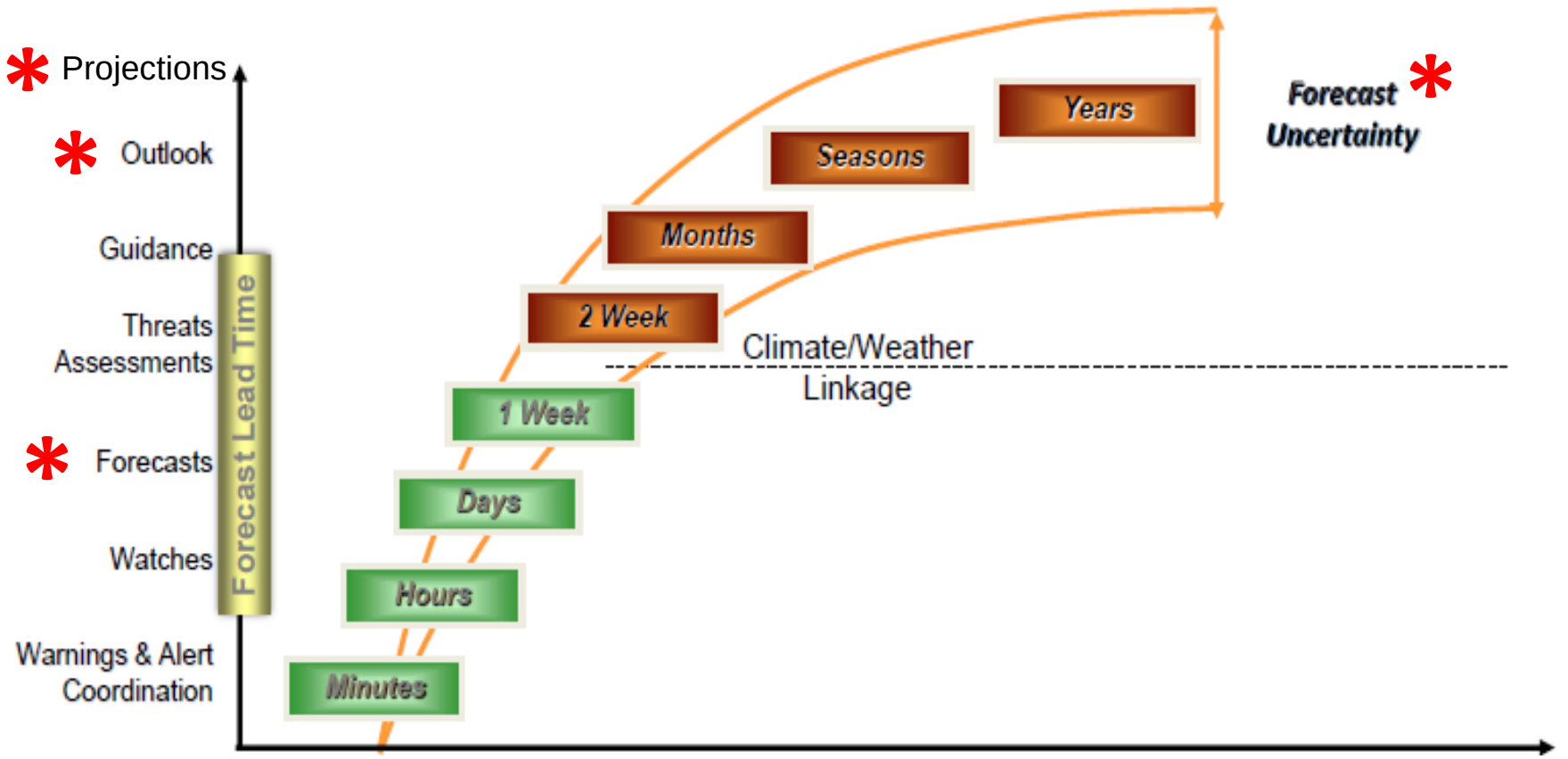
```
# ESP Forecast Information
#
# Analysis Period: 1/9/2013 12 - 4/9/2013 12 (Z)
# Forecast Parameters: River Flow (Mean) - (CFS)
#
# Forecast Interval: 1 Month
# Forecast Point: ON - FORT CHURCHILL,
#
# ON - FORT CHURCHILL,                    0.90          0.75
# ------------------------------------------------------------
  02/01/2013 - 02/28/2013                167.68        224.65
  03/01/2013 - 03/31/2013                219.89        321.04
```



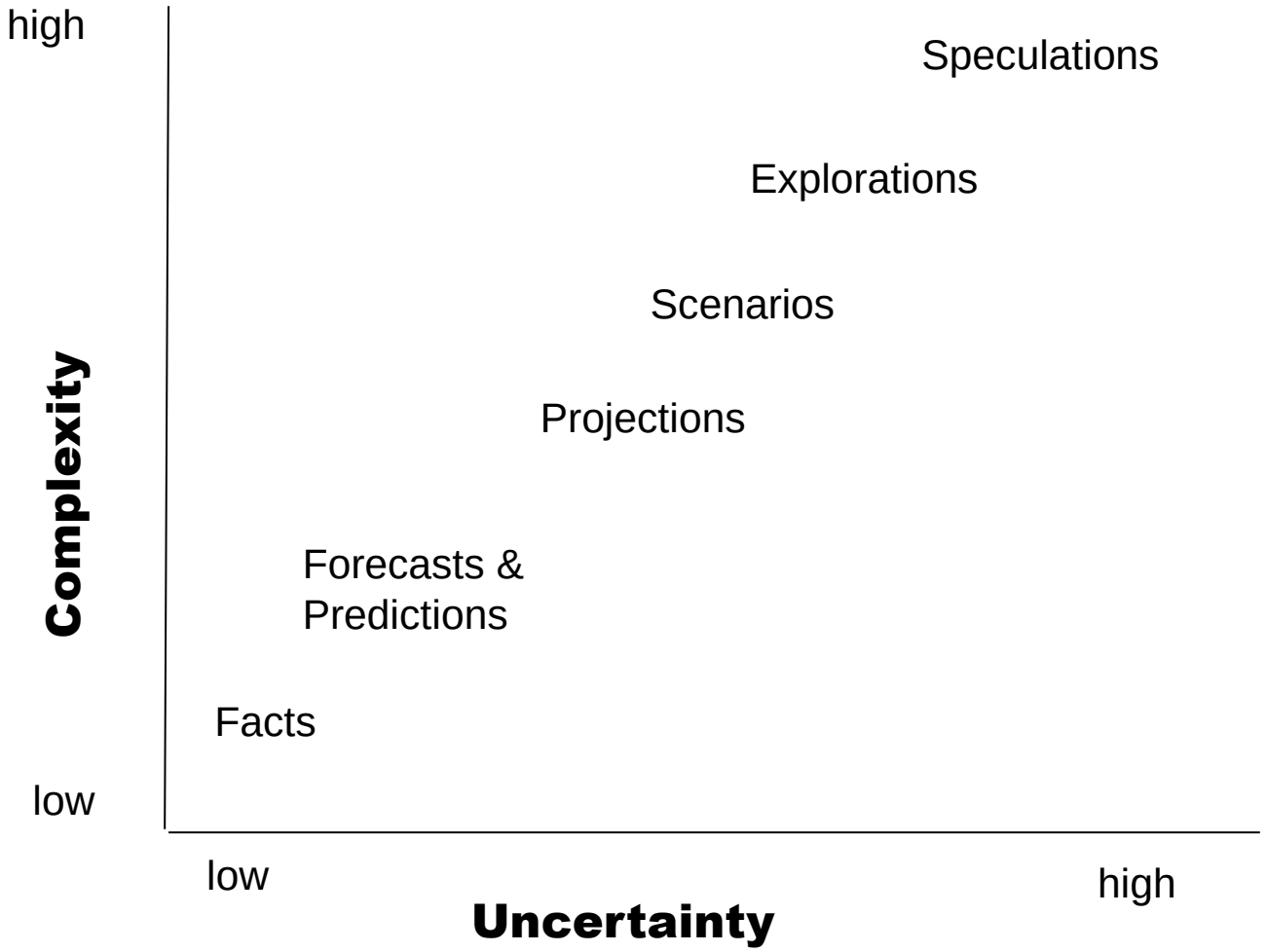


Data << Information << Knowledge << Wisdom

Continuum of Weather and Climate Products

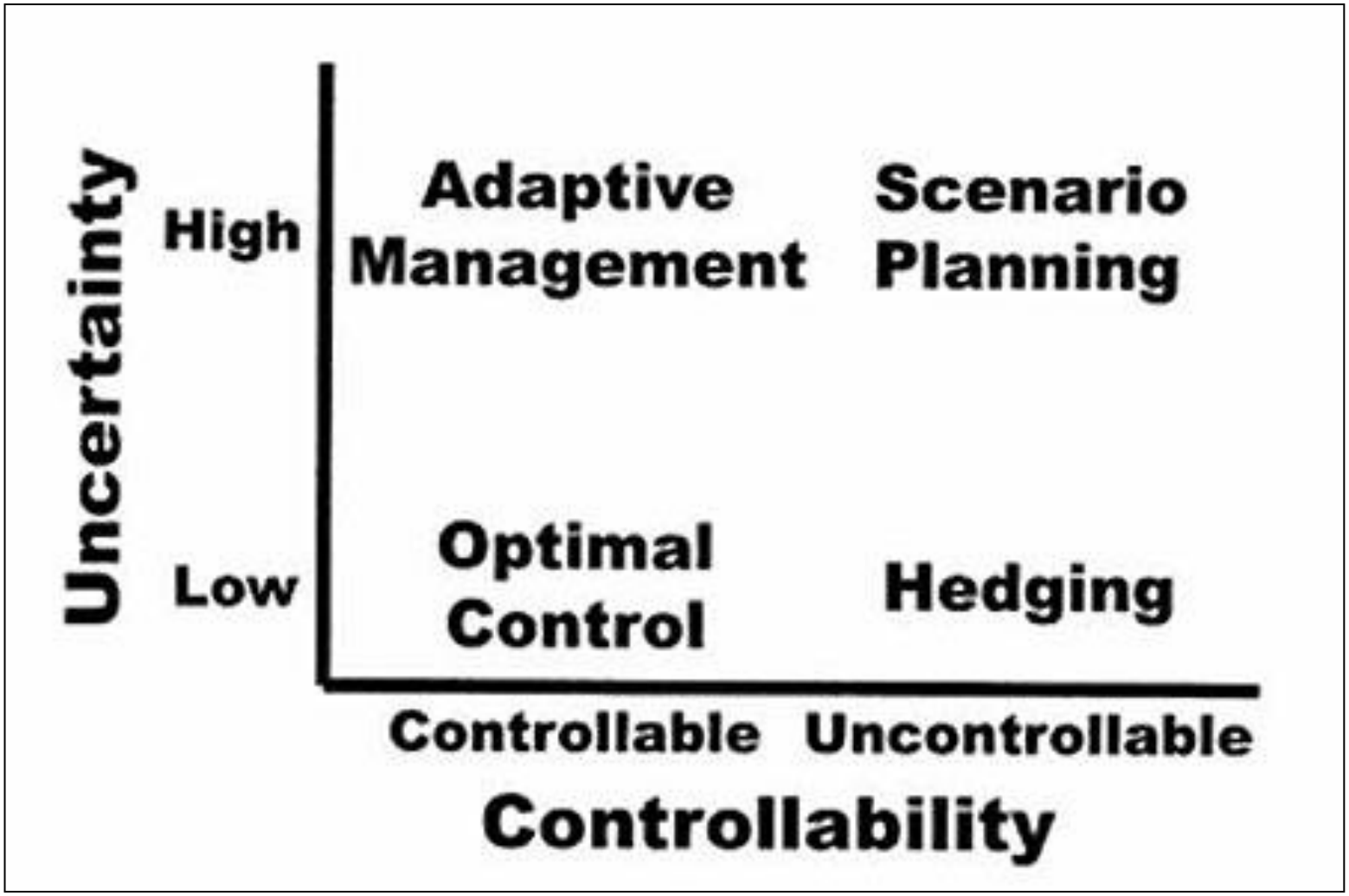


Alternative Continuum of Climate Products



Adapted from Zurek and Henrichs, 2007

Decision Approaches Vary Too



Peterson et al., 2003. Conservation Biology

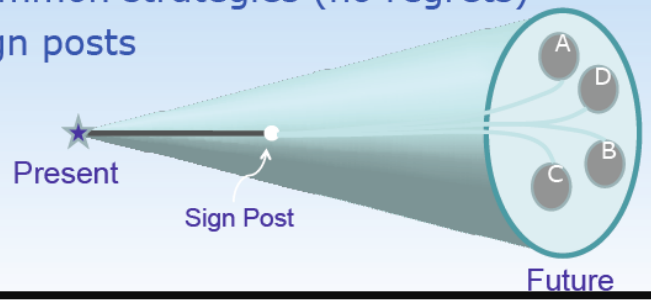
Decision Support Approaches for Water Management

Decision Analysis

- Decision trees, probabilities and costs
- Minimize expected costs

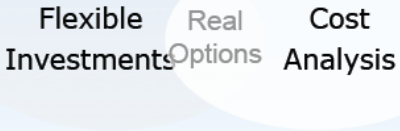
Scenario Planning

- 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

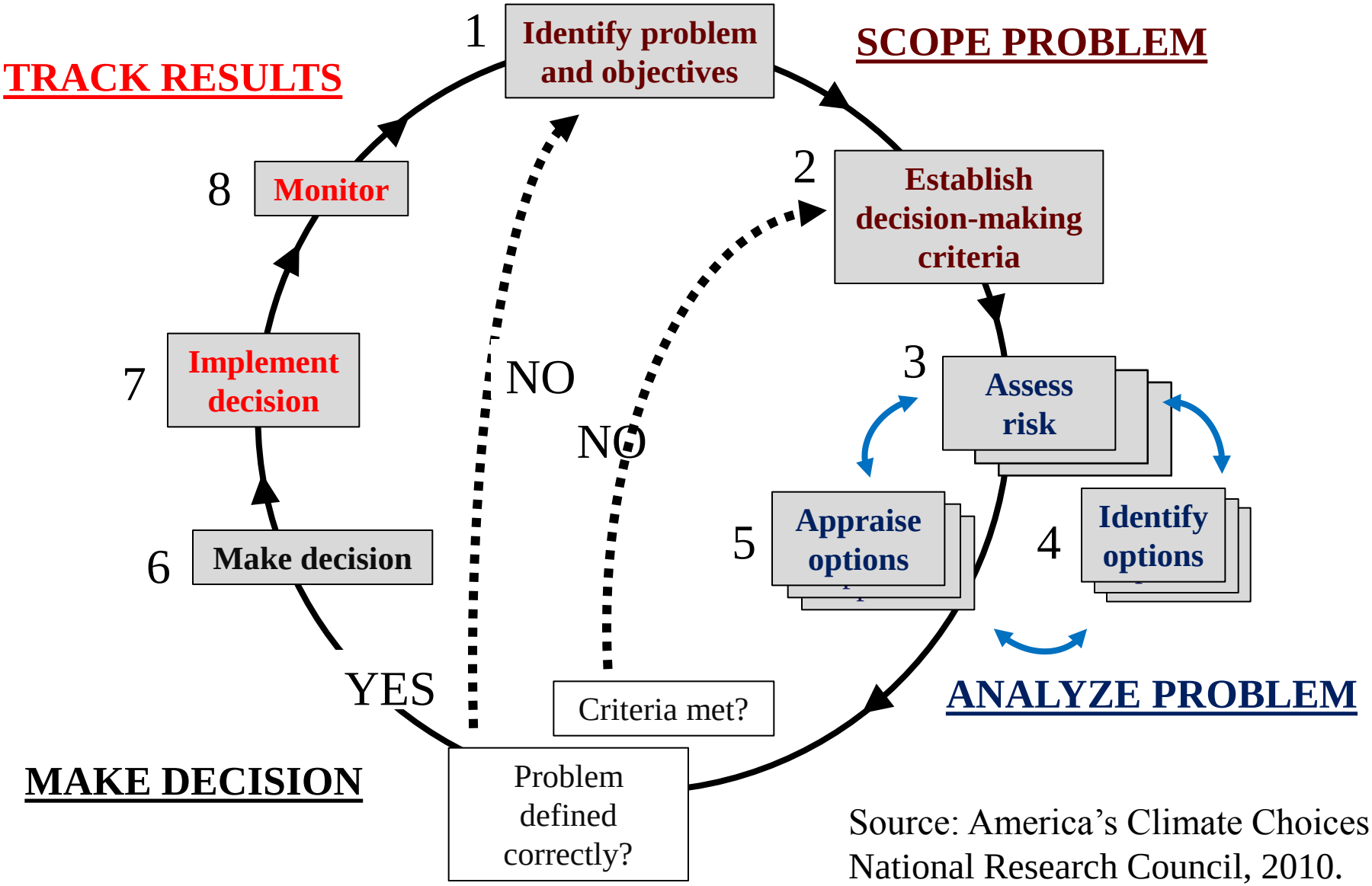


Robust Decision Making

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

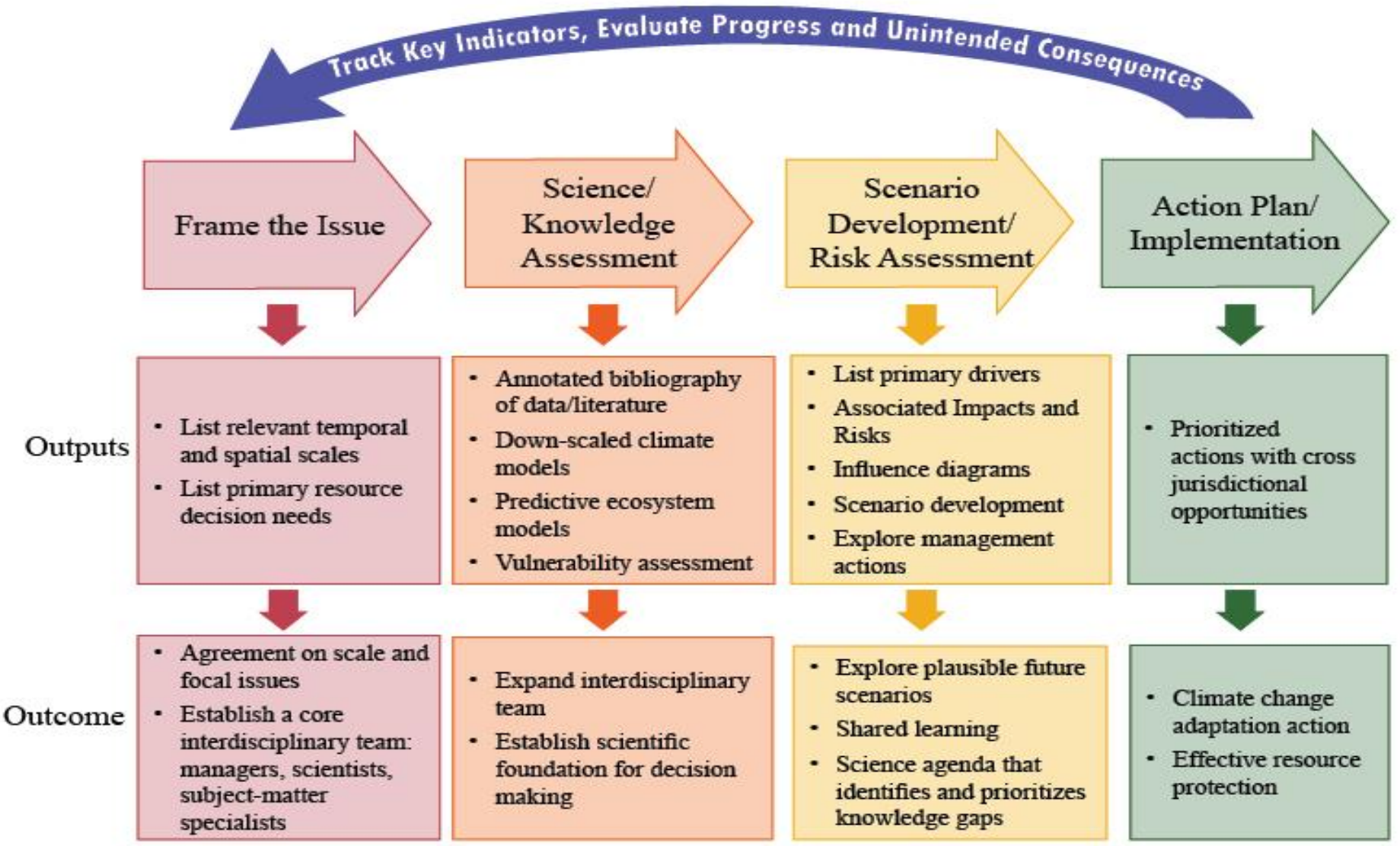
Figures from Stickel, 2010. See www.wucaonline.org

Decisions are made within a framework



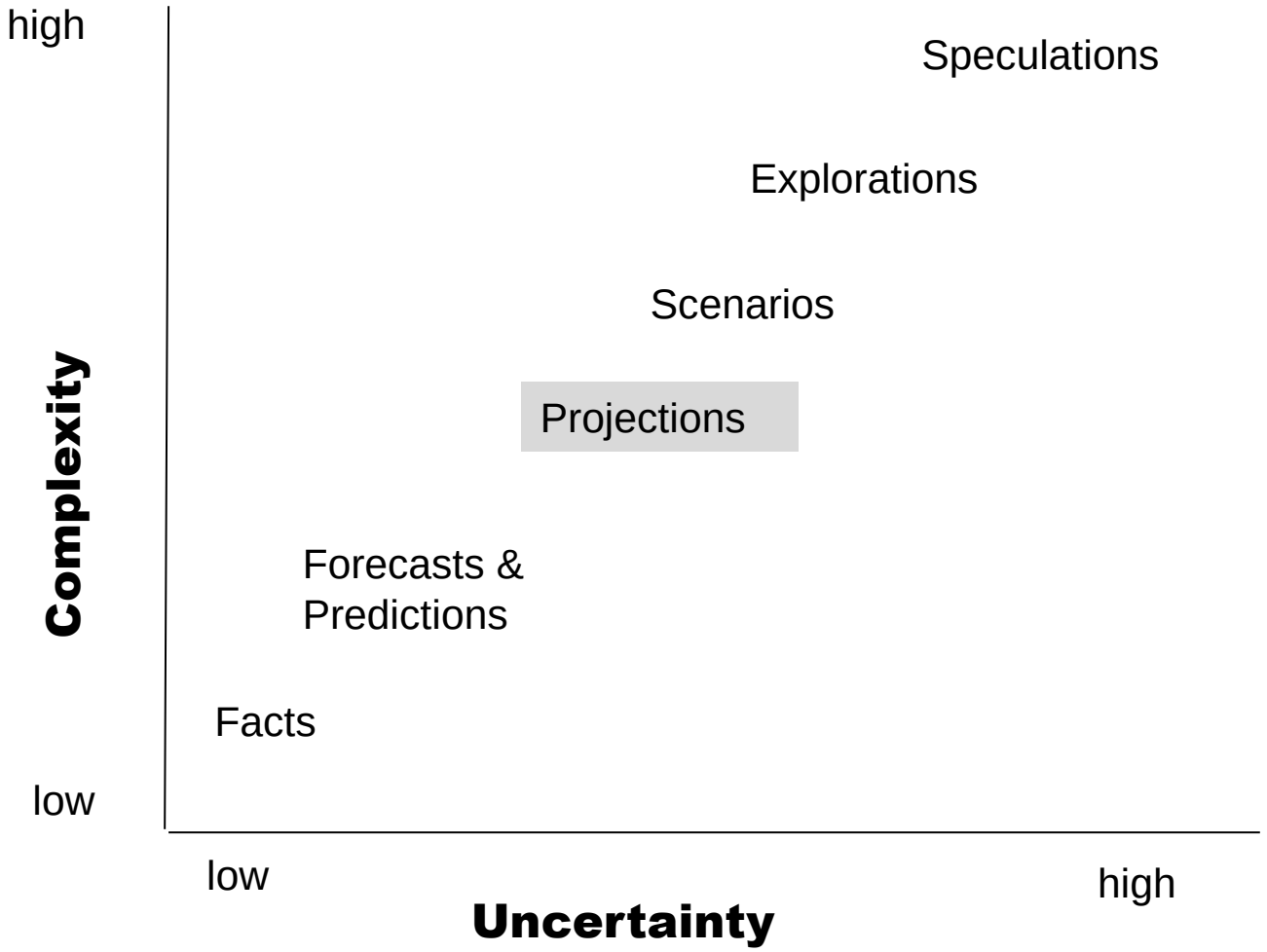
Source: America's Climate Choices. National Research Council, 2010.

Key Elements of an Adaptation Planning Framework



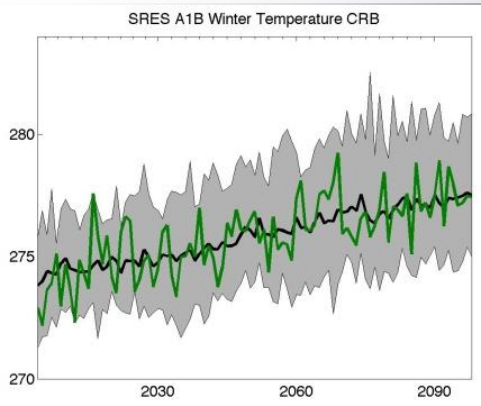
National Park Service, 2010. Climate Change Response Plan

Alternative Continuum of Climate Products



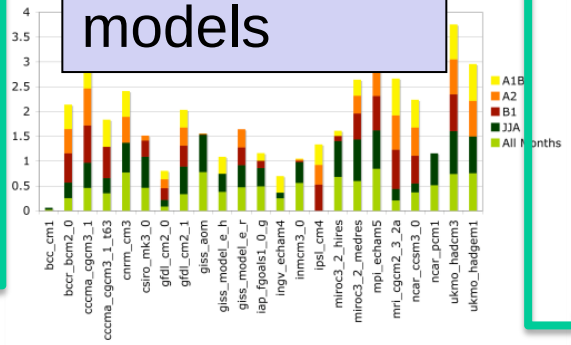
Adapted from Zurek and Henrichs, 2007

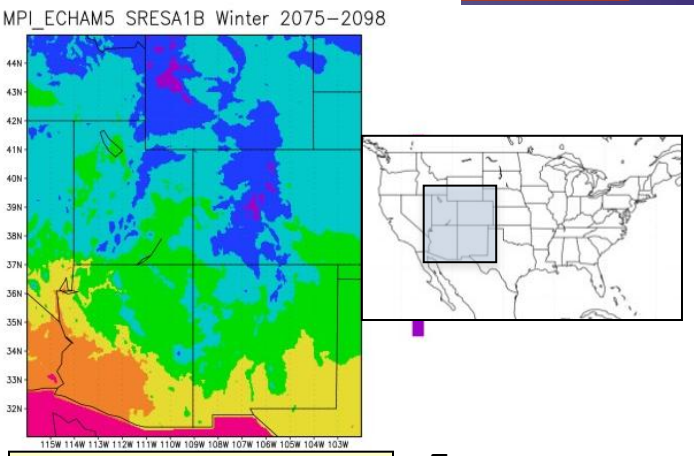
Projections to Impacts



IPCC AR4 GCM projections

Select the "best" models



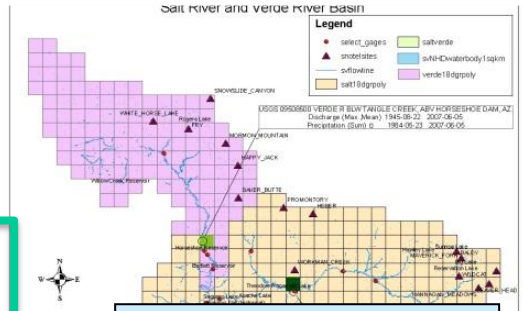


Spatial Downscaling

From approx. 200 km to 4 km.

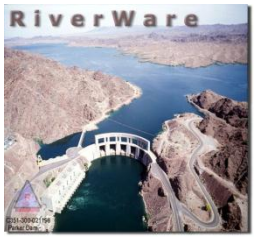
Temporal Downscaling

From Seasonal to Daily



Hydrologic models

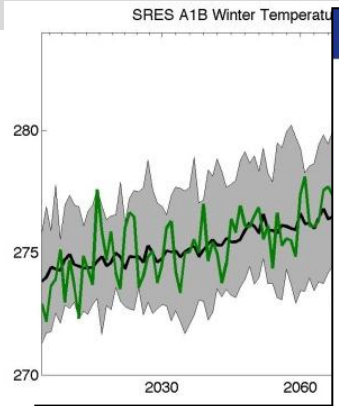
Hydrologic projections at watershed scale.



Water Management Models

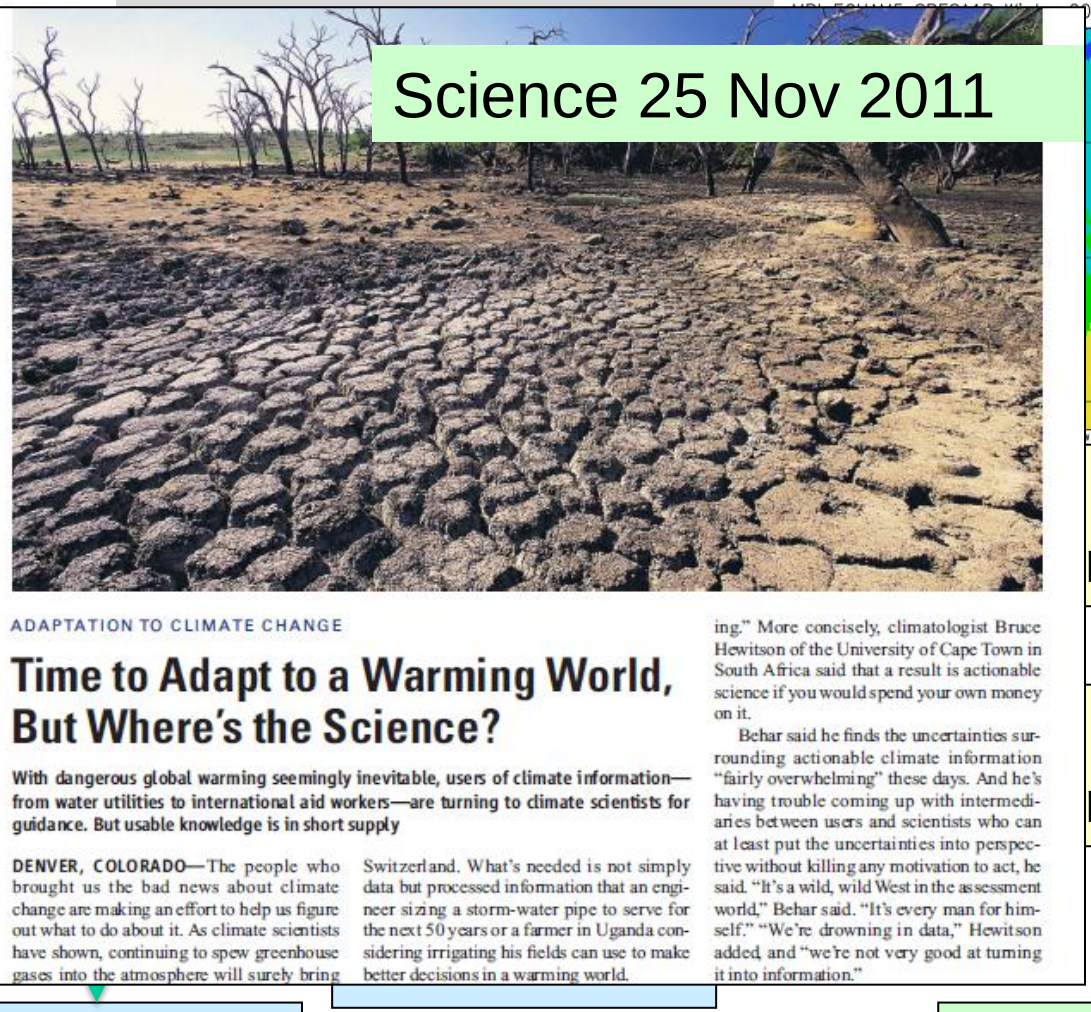
Evaluate Management Options

Actionable Science



IPCC AR4 projections

Hydrologic projections watershed scale.



Science 25 Nov 2011

ADAPTATION TO CLIMATE CHANGE

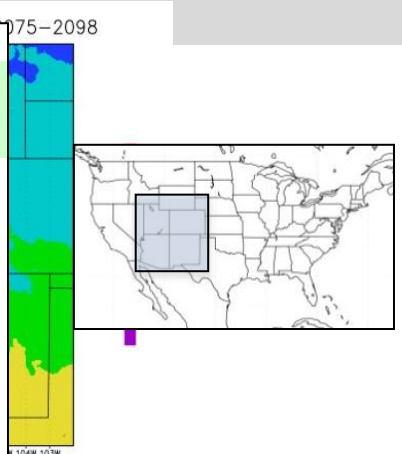
Time to Adapt to a Warming World, But Where's the Science?

With dangerous global warming seemingly inevitable, users of climate information—from water utilities to international aid workers—are turning to climate scientists for guidance. But usable knowledge is in short supply

DENVER, COLORADO—The people who brought us the bad news about climate change are making an effort to help us figure out what to do about it. As climate scientists have shown, continuing to spew greenhouse gases into the atmosphere will surely bring Switzerland. What's needed is not simply data but processed information that an engineer sizing a storm-water pipe to serve for the next 50 years or a farmer in Uganda considering irrigating his fields can use to make better decisions in a warming world.

ing." More concisely, climatologist Bruce Hewitson of the University of Cape Town in South Africa said that a result is actionable science if you would spend your own money on it.

Behar said he finds the uncertainties surrounding actionable climate information "fairly overwhelming" these days. And he's having trouble coming up with intermediaries between users and scientists who can at least put the uncertainties into perspective without killing any motivation to act, he said. "It's a wild, wild West in the assessment world," Behar said. "It's every man for himself." "We're drowning in data," Hewitson added, and "we're not very good at turning it into information."



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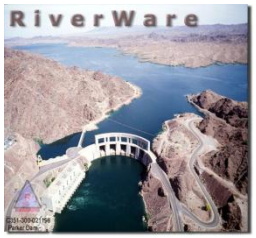
From approx. 200 km to 4 km.

From Seasonal to Daily



Water Management Models

?!?!?

Evaluate Management Options

Projection Lineages

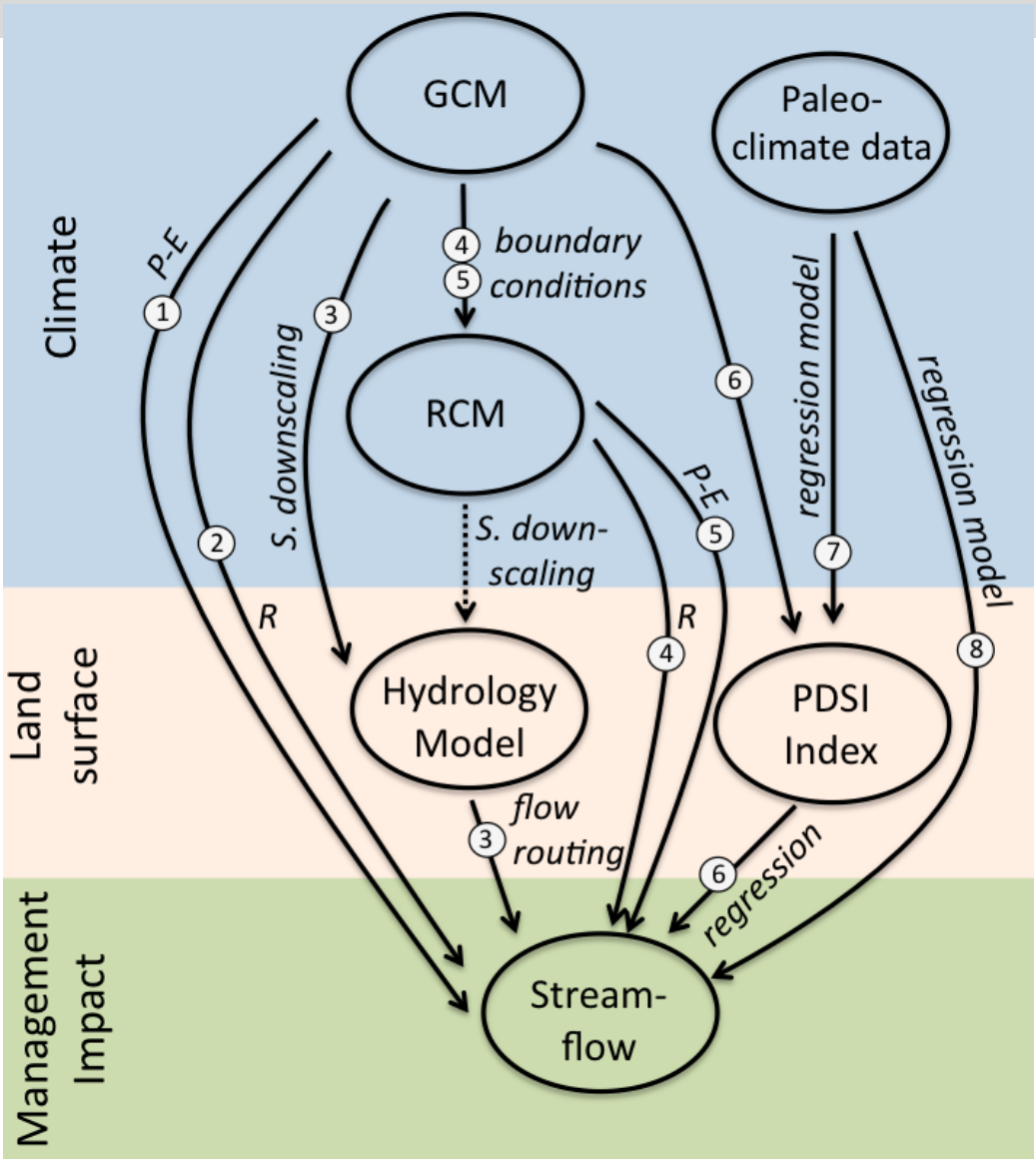


Figure from Vano et al., BAMS, 2013

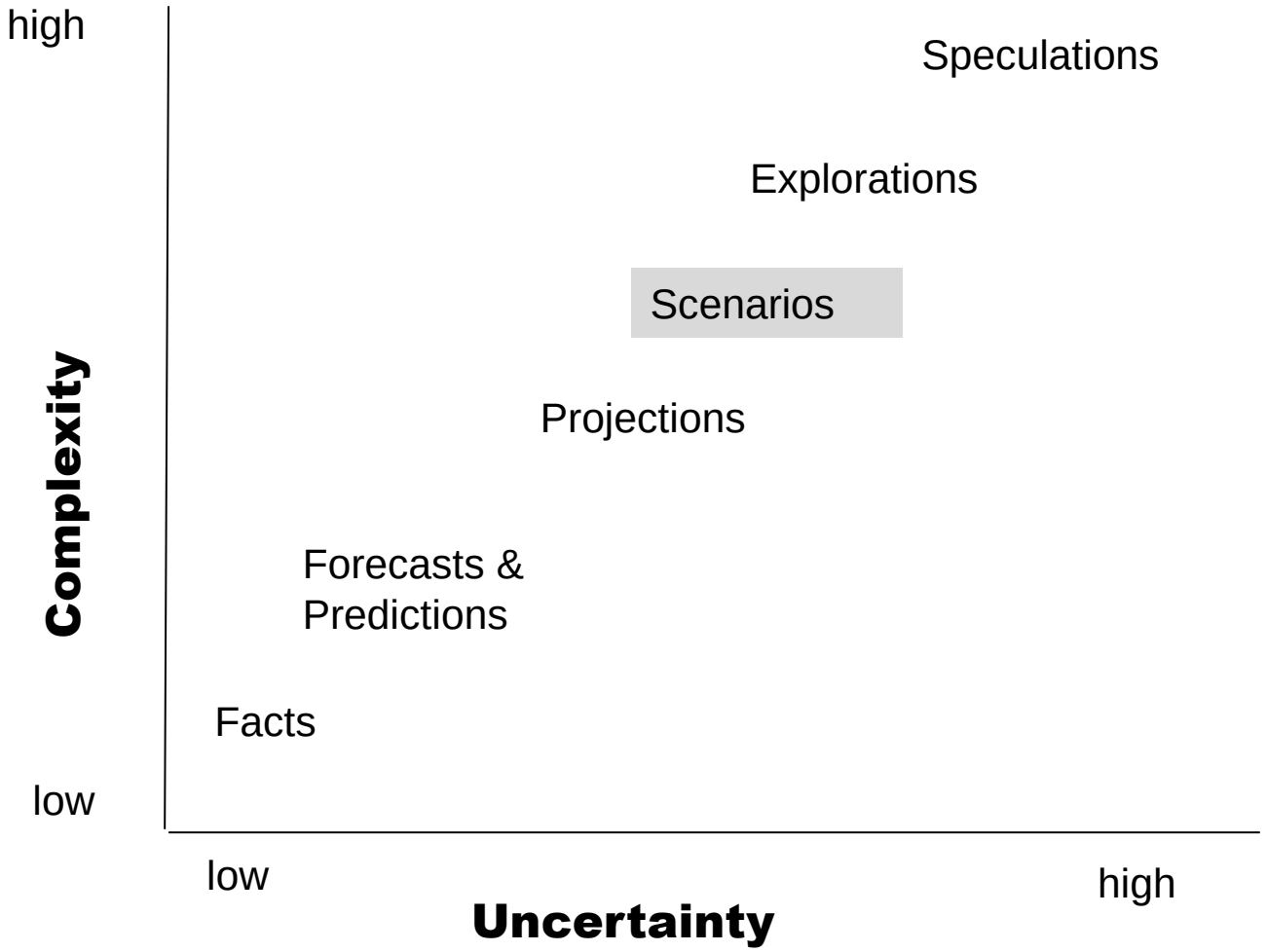
Studies using various approaches:

1. Seager et al. 2007; Seager et al. 2013
2. Milly et al. 2005
3. Christensen et al. 2004; Christensen and Lettenmaier, 2007; Cayan et al. 2010; USBR 2011
4. Gao et al. 2011; Rasmussen et al. 2011
5. Gao et al. 2012
6. Hoerling and Eischeid 2007
7. Cook et al. 2004
8. Woodhouse et al. 2006; McCabe and Wolock 2007; Meko et al. 2007; USBR 2011

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

GCMs, Emission scenarios,
Spatial resolution
Land surface representation

Alternative Continuum of Climate Products



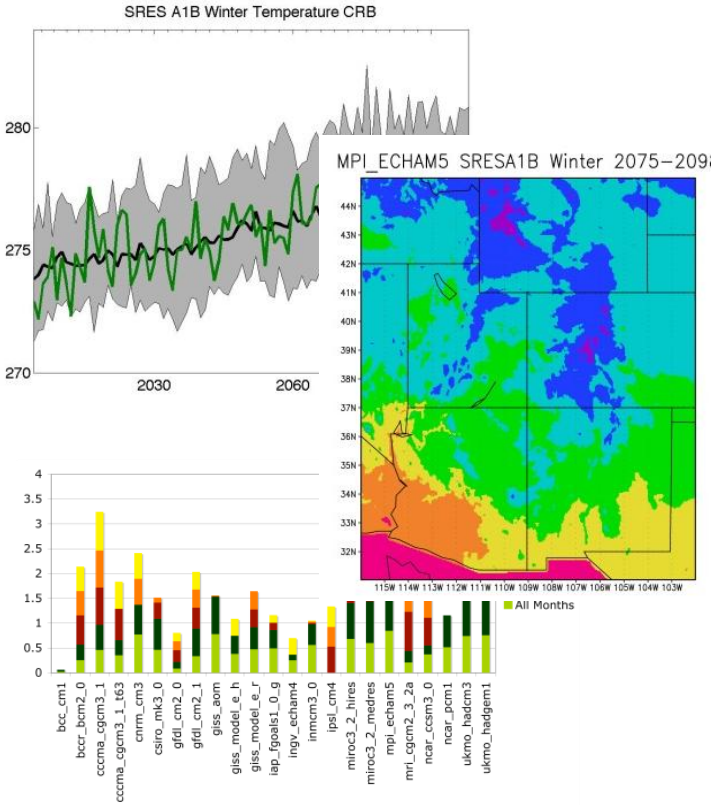
Adapted from Zurek and Henrichs, 2007

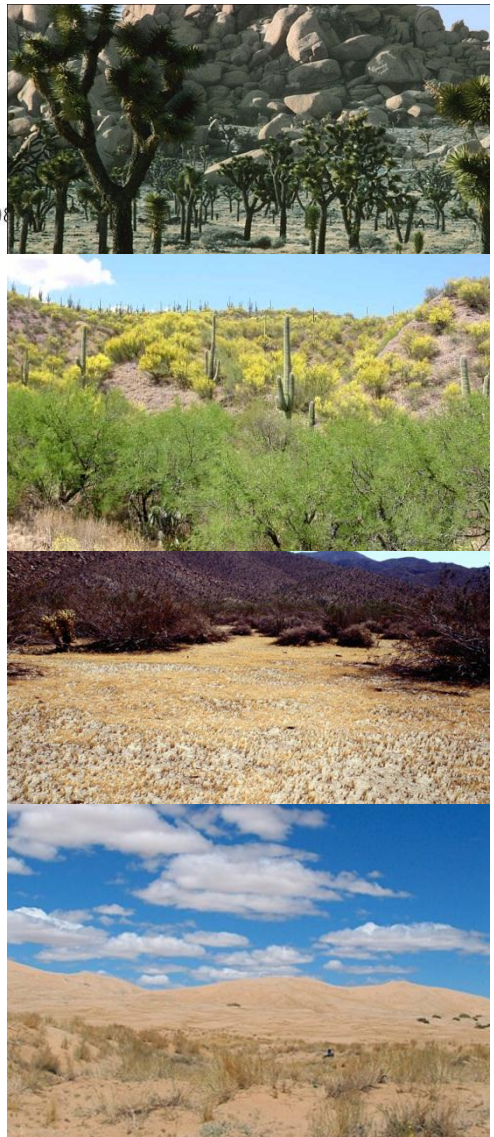
Different Scenario Approaches

Characterizing Uncertainty

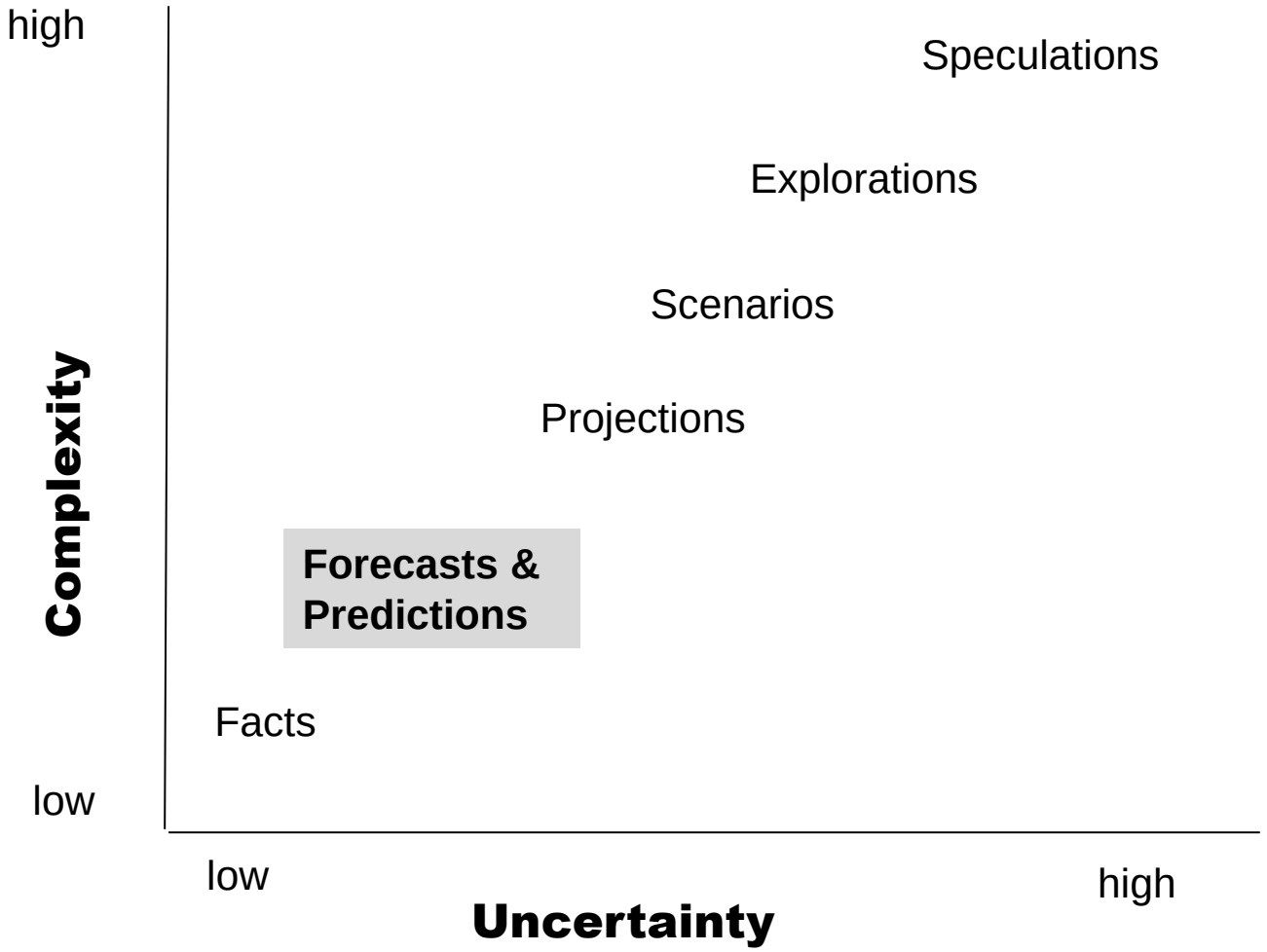
Embracing Uncertainty

Reducing Uncertainty





Alternative Continuum of Climate Products



Adapted from Zurek and Henrichs, 2007

Risk Management Perspective

Where all quantities are based on 1981-2010

Two Category Forecast

$$Decision = F\left(.25[I_{quantile<50}] + .75[I_{quantile50>}] \right)$$

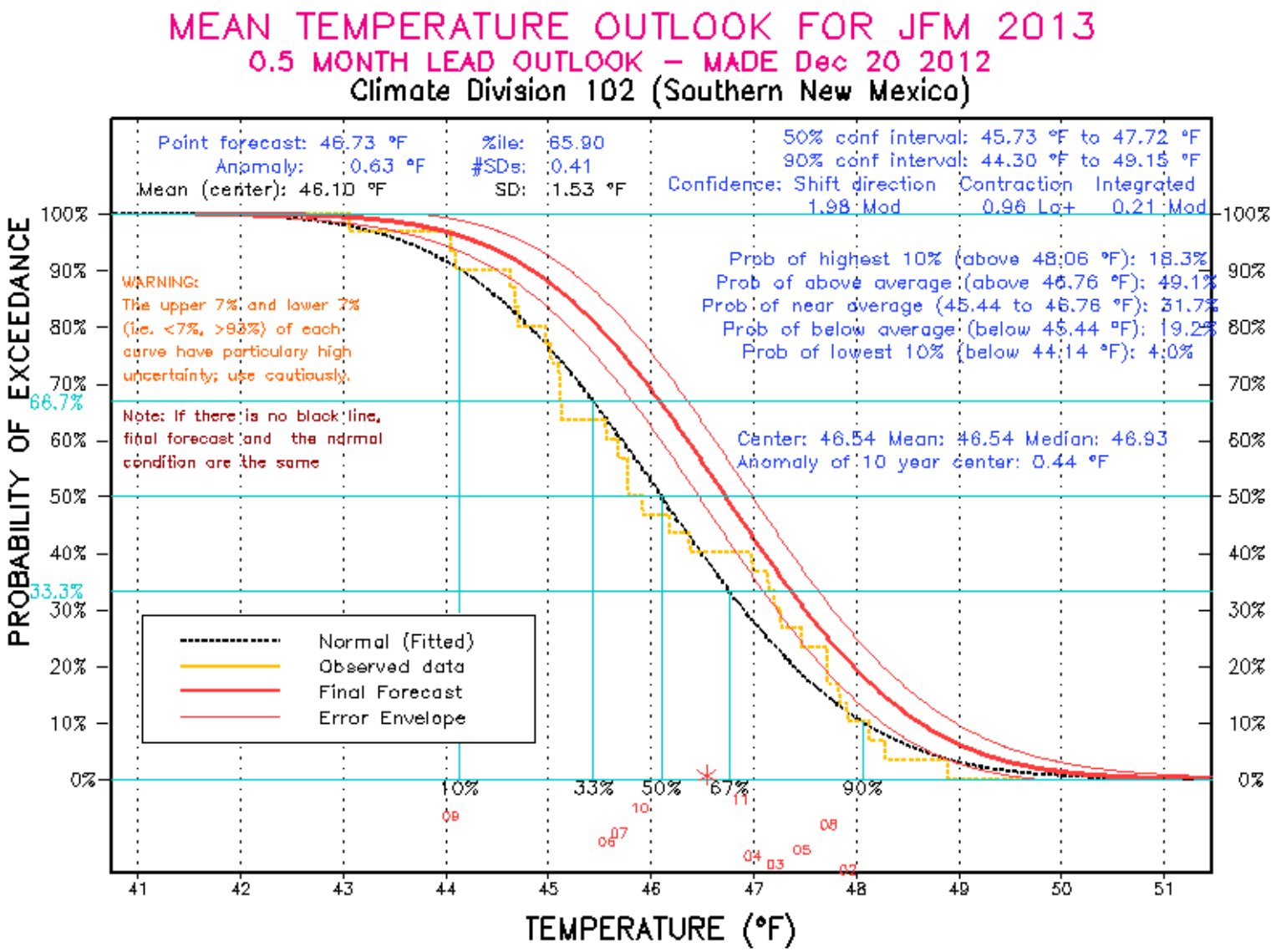
Three Category Forecast

$$Decision = F\left(.13[I_{quantile<33}] + .33[I_{quantile33\text{-}66}] + .53[I_{quantile>66}] \right)$$

Strategies: benefit from more categories, if sufficient skill

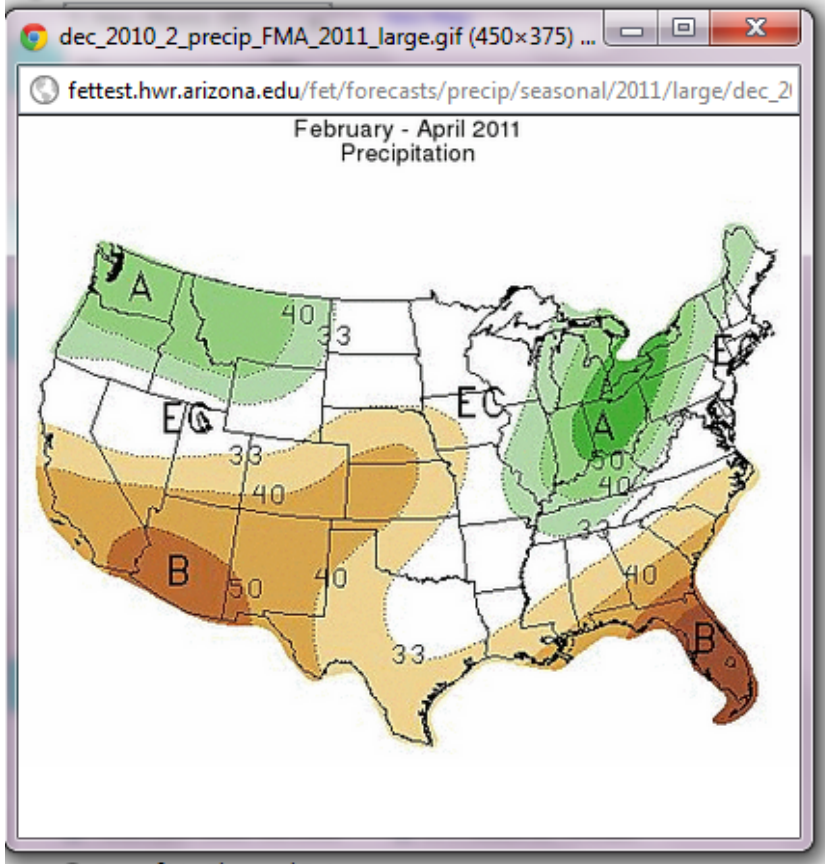
Ideal: customized percentile categories

Probability of Exceedance Outlook



Dynamic POE Outlook: http://forlond.arid.arizona.edu/DynamicPOE/

1 **Choose your U.S. climate division**



Curve fit to Observed Data

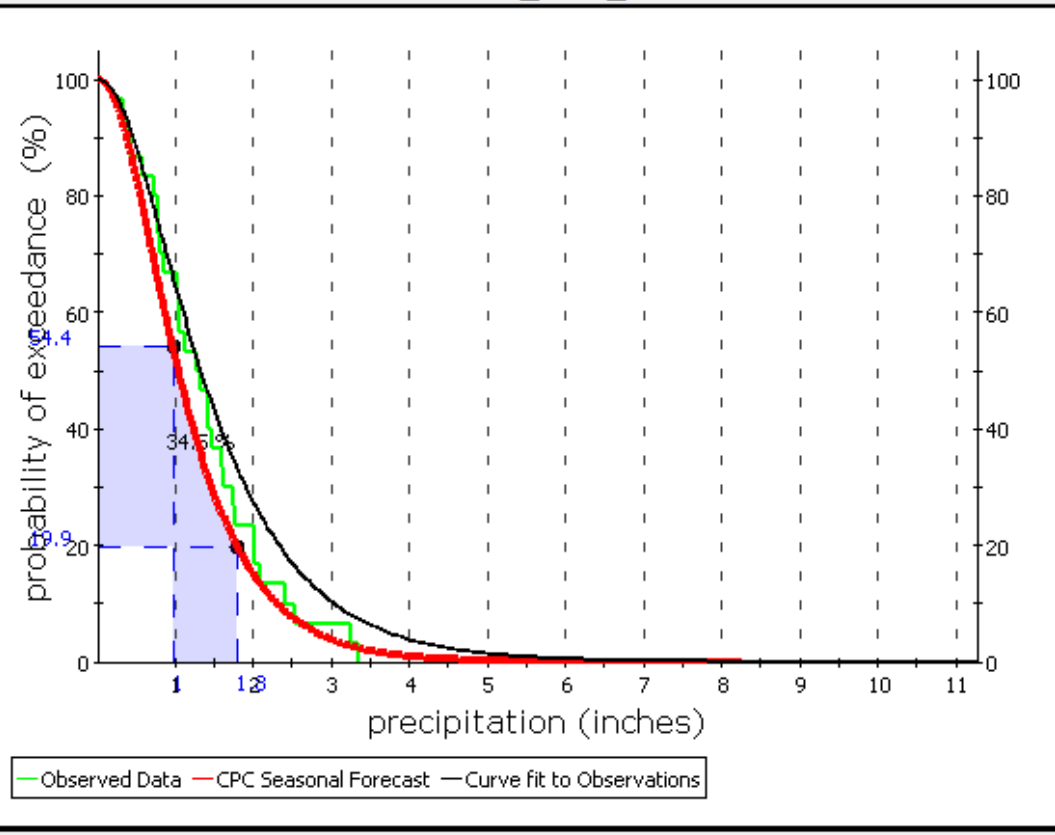
Submit

3 MONTH MEAN PRECIPITATION OUTLOOK

1.5 Month Outlook for Feb-Mar-Apr 2011

Issued Dec 2010

Climate Division S_New_Mexico 102



6 **Customize your graph**

- *Interval analysis* lets you focus on information between two values
  - Select the probability (%) interval:
  - Select the variable (Temp, Precip) interval:
  - 3-category (tercile) forecast. Similar to the linked products (link1) (link2)
- *Threshold analysis* lets you focus on information above or below a single value

Forecast Statements

There is a 54.4 % chance that the total seasonal precipitation will exceed 1 inches (the bottom third of observations from the climatological reference period, i.e. the below median category) and a 19.9 % chance that it will exceed 1.8 inches (the middle third of observations from the climatological reference period, i.e the near median category). There is a 34.5 % chance that it will be within 1 inches and 1.8 inches .

Comparative Statements

The chance of precipitation greater than 1 inches (the bottom third of the observations from the climatological reference period, i.e. the below median category) differs by -12.3 % from the probability based on the observed climatological reference period, and the chance of it greater than 1.8 inches (the middle third of the observations from the climatological reference period, i.e. the near median category) differs by -13.5 %.

Risk Management Perspective

Forecast for “Normal Conditions”

$$Decision = F\ (\ 1.00[I_{mean}]\ )$$

Where all quantities are based on 1981-2010

Forecast for “Equal Chances”

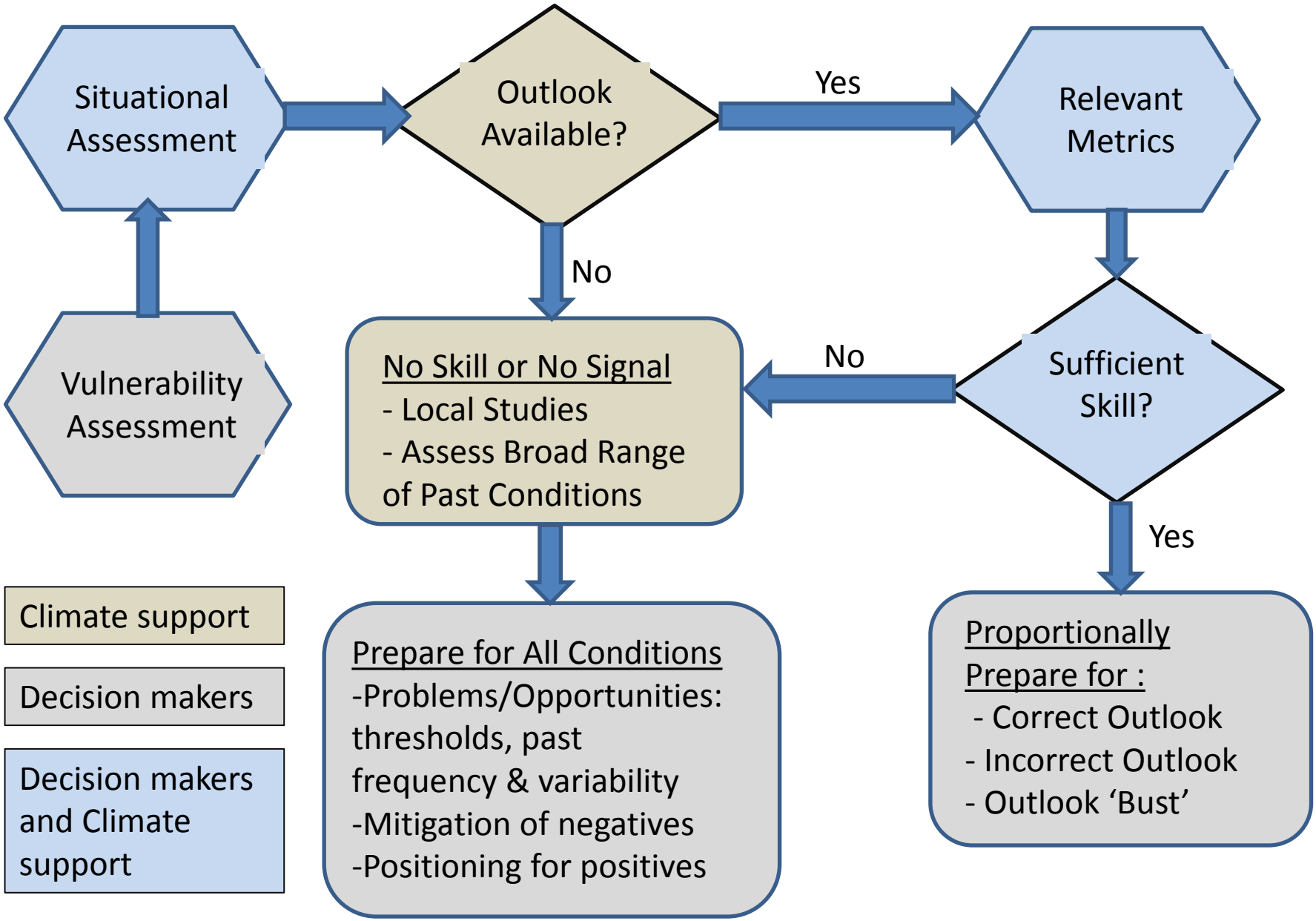
$$Decision = F\ (\ .33[I_{quantile_{<33}}]+ .33[I_{quantile_{33\text{-}66}}]+ .33[I_{quantile_{66>}}])$$

Forecast for “Unknown Chances”

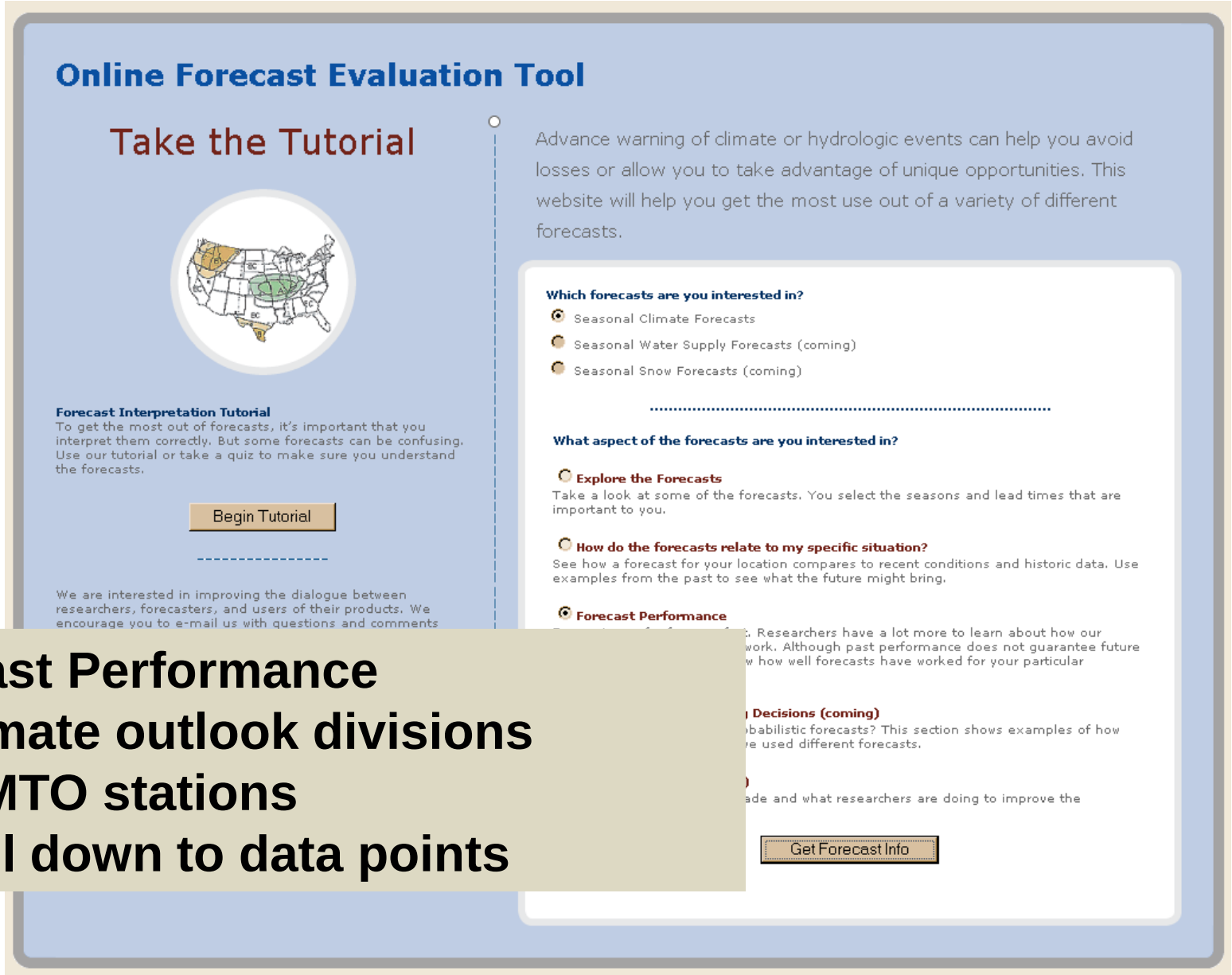
$$Decision = F\ (?[I_{quantile_{<33}}]+ ?[I_{quantile_{33\text{-}66}}]+ ?[I_{quantile_{66>}}])$$

Strategies: hedging, local studies, new research

Flow Chart for Using Outlooks



http://fet.hwr.arizona.edu/ForecastEvaluationTool/



Forecast Performance

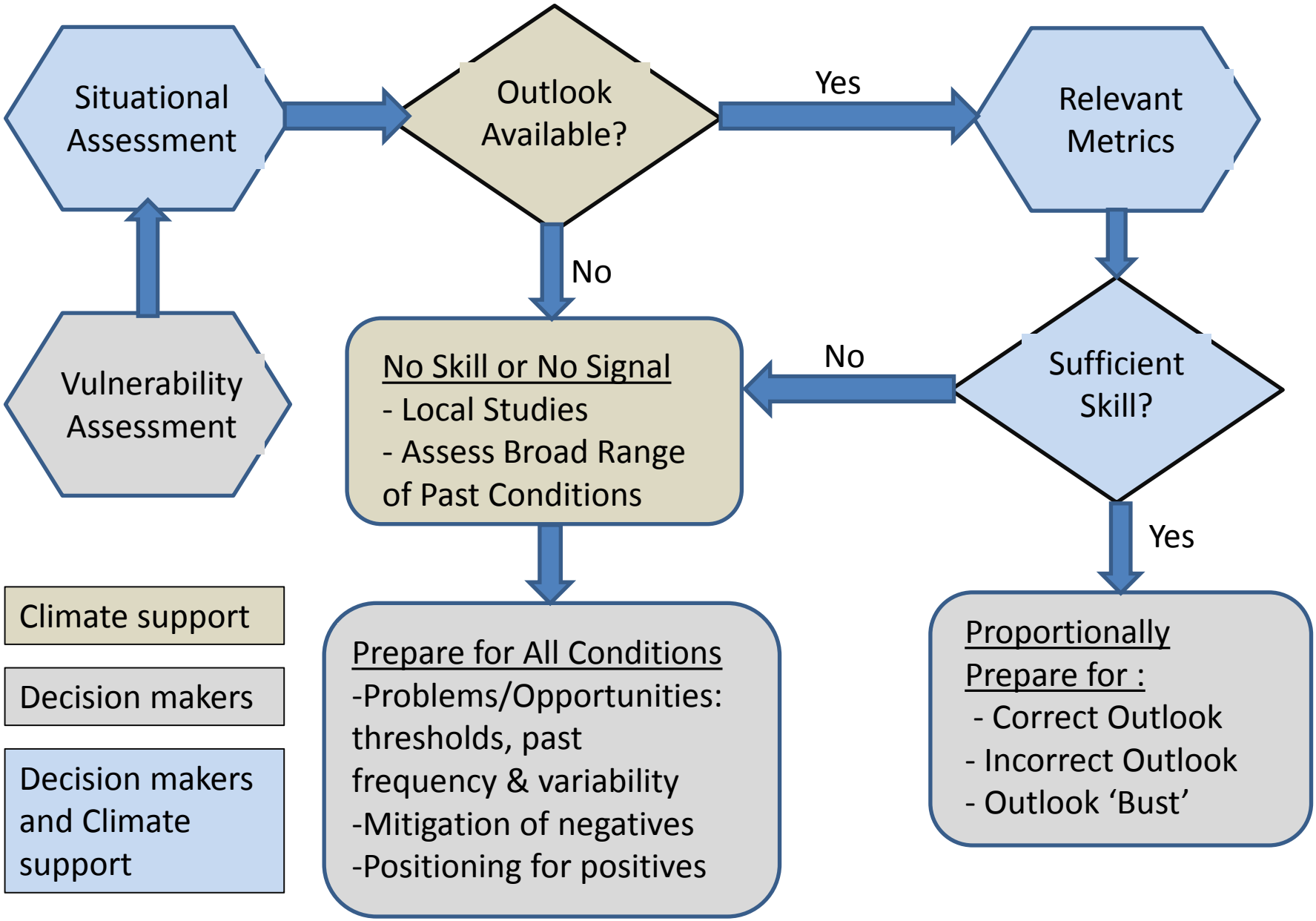
- Climate outlook divisions
- L3MTO stations
- Drill down to data points

CPC Verification Web Tool
URL: to be released soon!

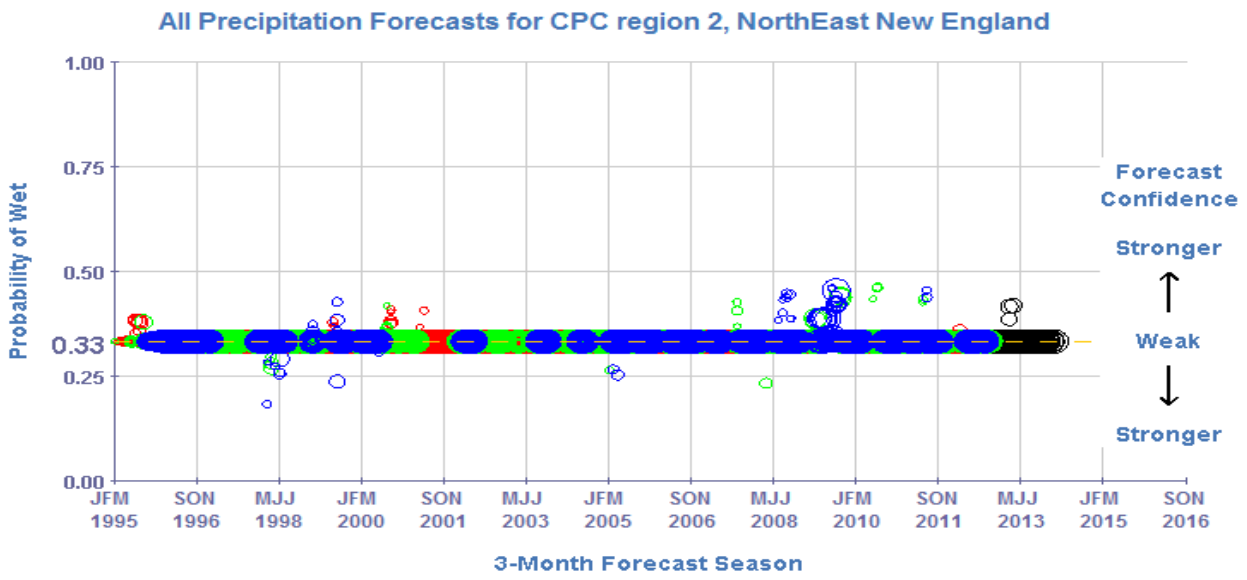
New Features

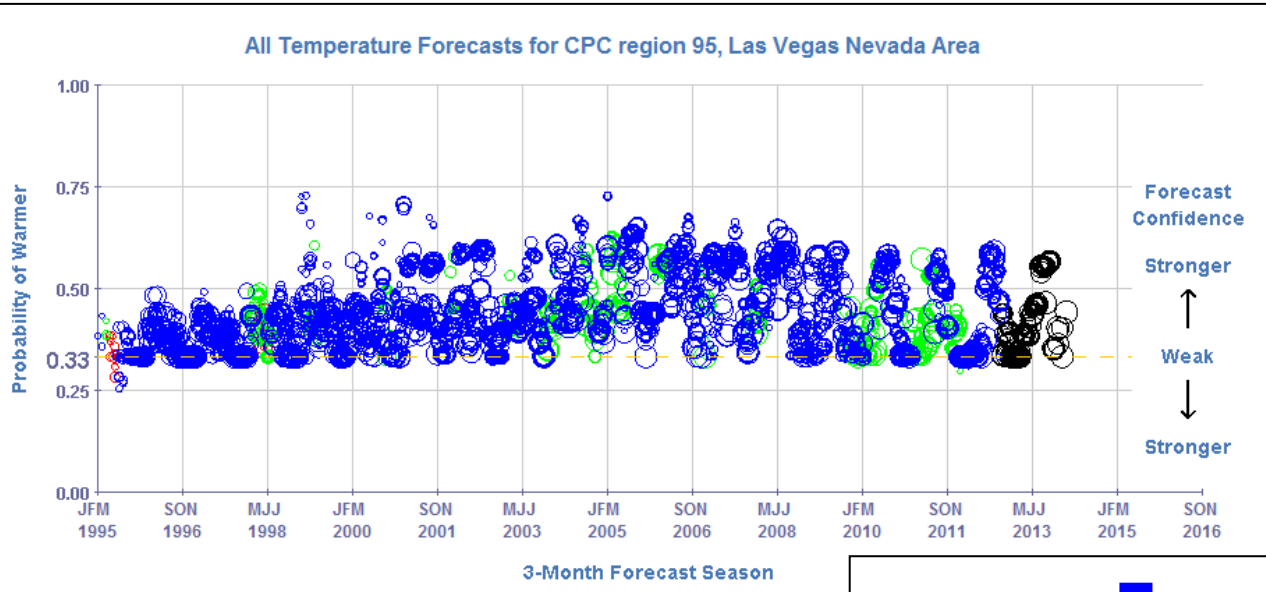
- Grid based
- 6-10 day, 8-14 day outlooks
- Monthly, Seasonal outlooks
- Additional metrics (reliability)

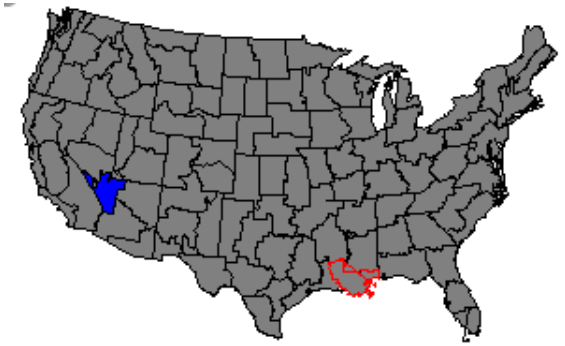
Flow Chart for Using Outlooks



Outlook Performance History – All in One Plot!



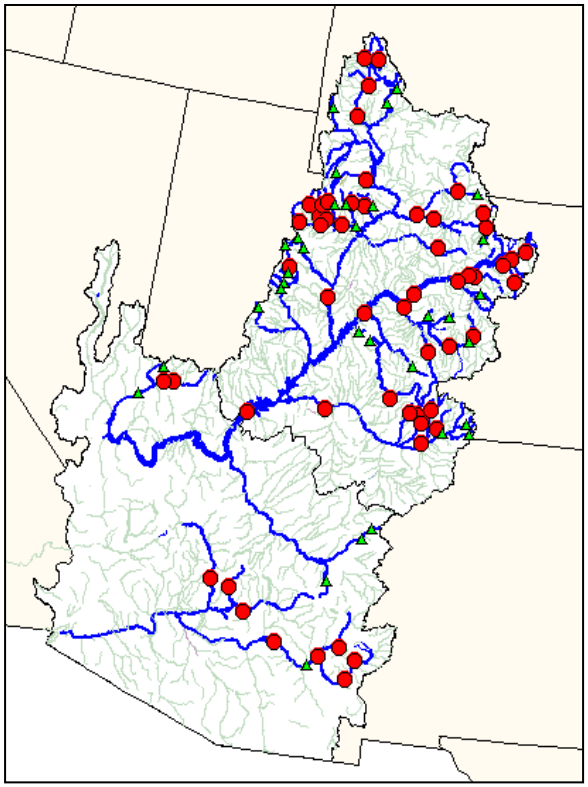




Categories: Wet Neutral Dry No Observations Yet

Bubbles: Smallest o = Shortest Lead Time (1 month) Largest ○ = Longest Lead Time (13 months)

Visualization of Hydrologic Outlook Performance



Evaluated historical water supply outlooks from 54 forecast points within the Colorado River Basin that forecast and observation records longer than 10 years (red circles).