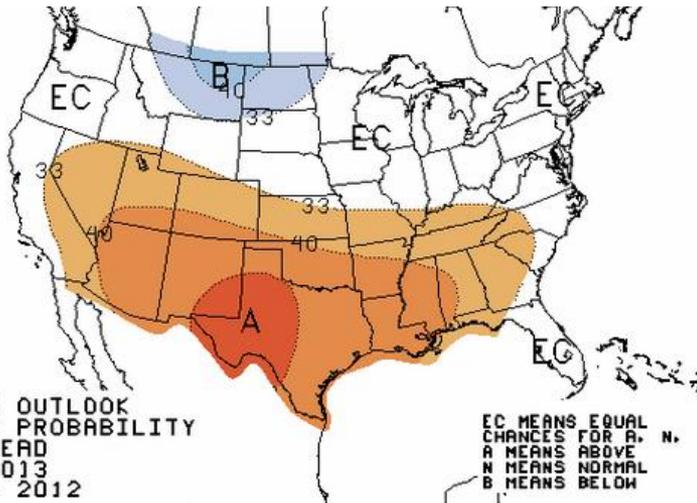


# Linking Forecast Applications and Evaluations



Holly C. Hartmann, University of Arizona

hollyoregon@juno.com

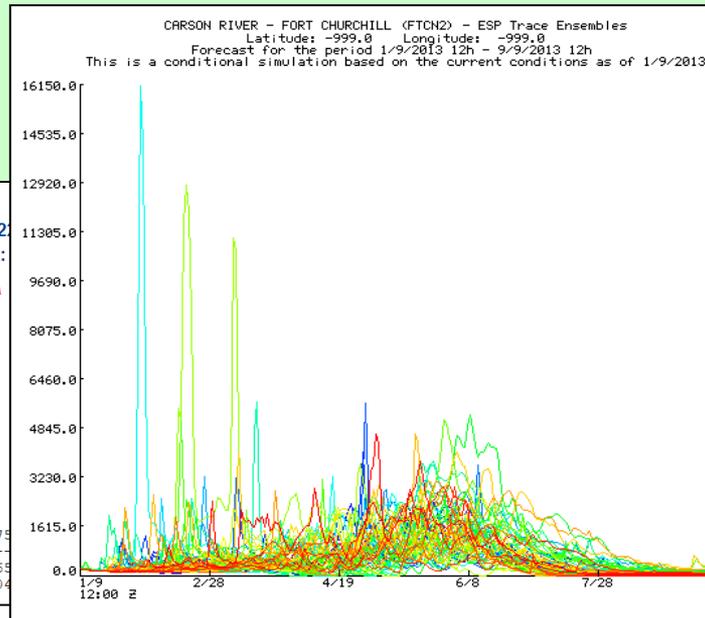
# So Many Decisions, Actors, Impacts!



# 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

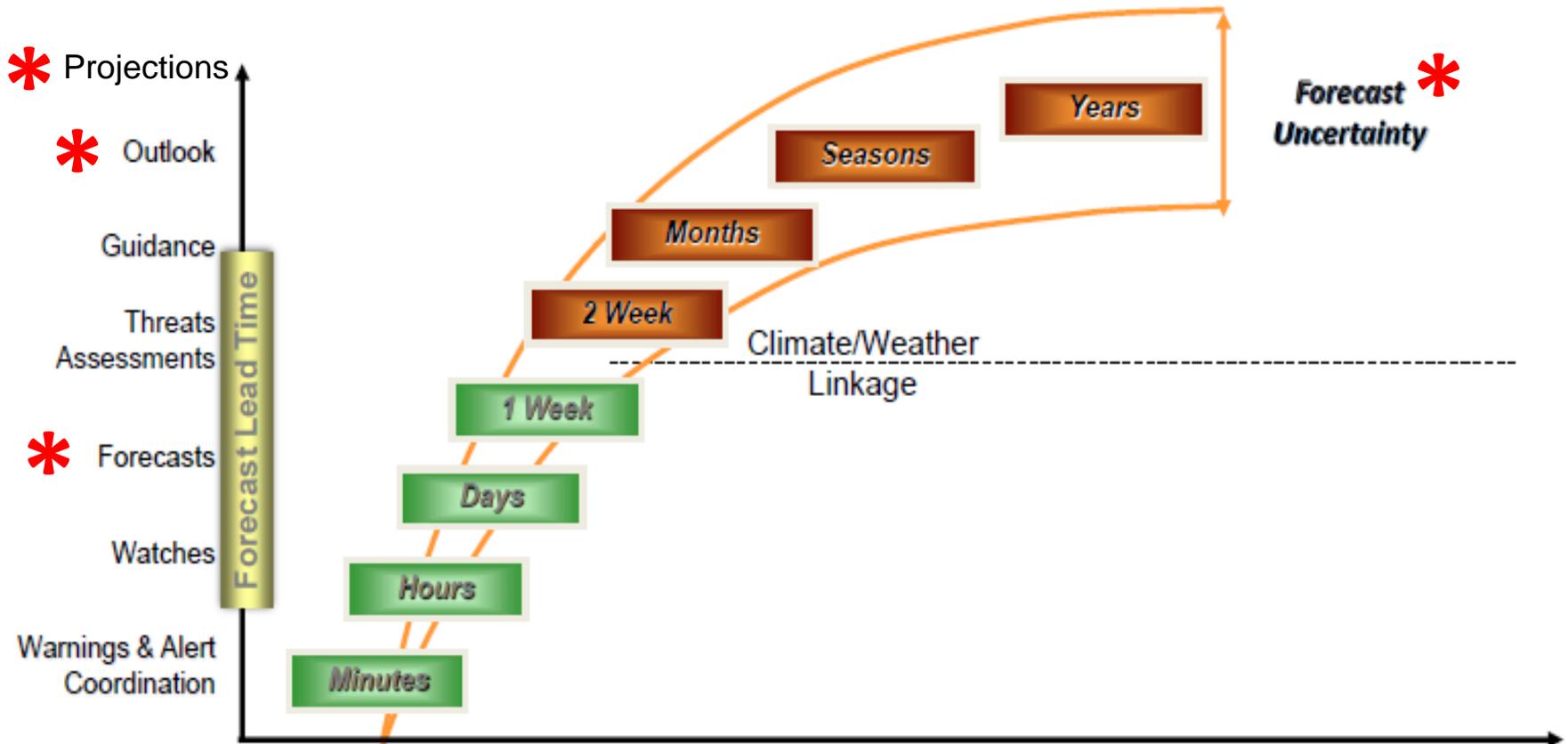
<<

Information

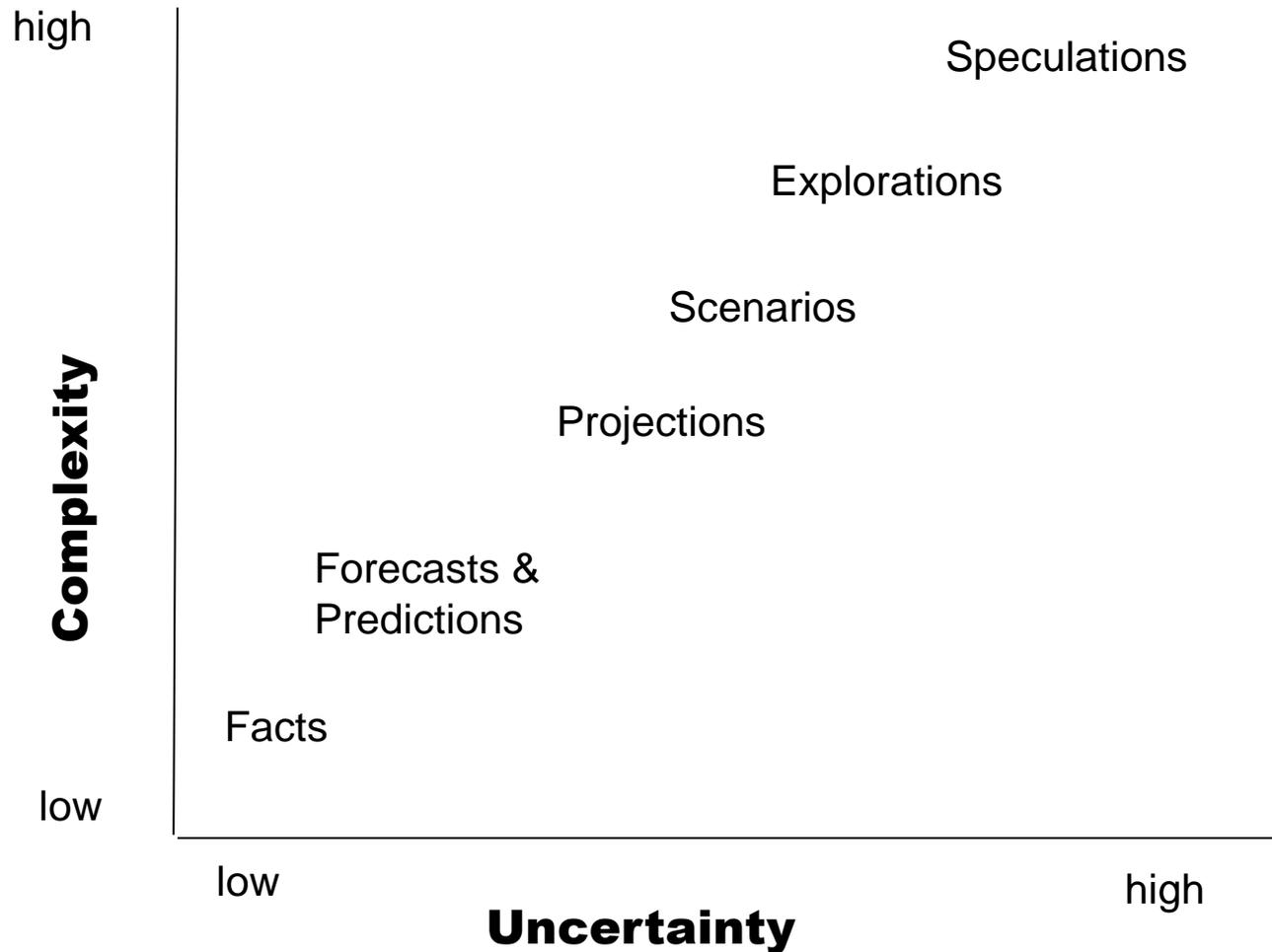
<<

Knowledge << Wisdom

# Continuum of Weather and Climate Products

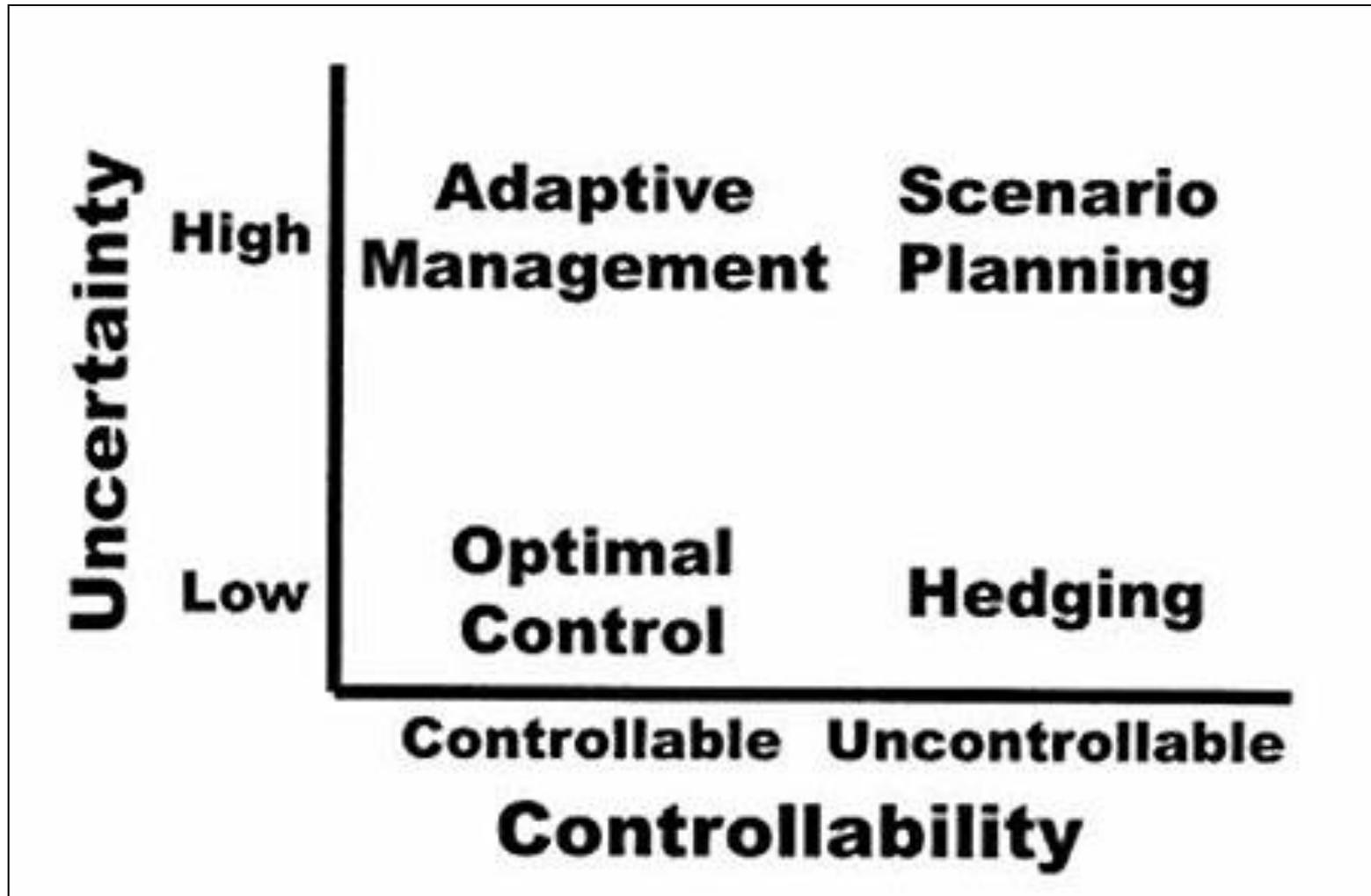


# Alternative Continuum of Climate Products



Adapted from Zurek and Henrichs, 2007

# Decision Approaches Vary Too



# 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



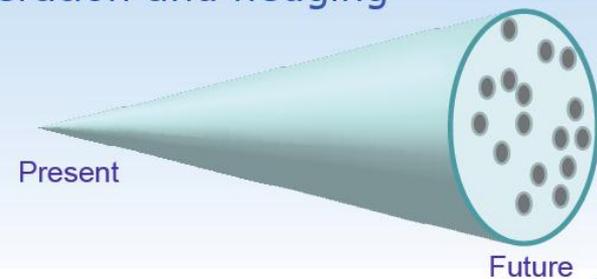
## Real Options

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

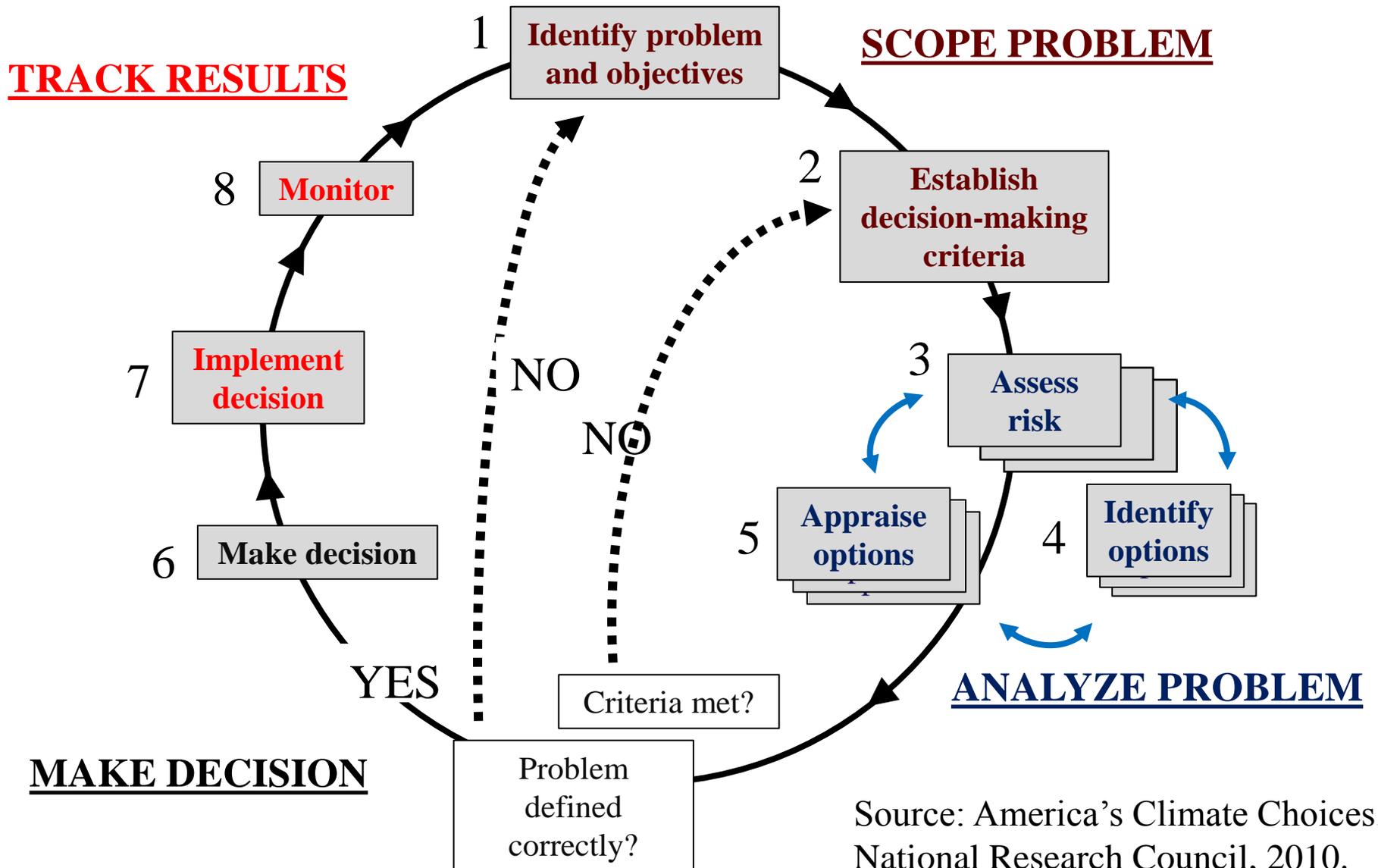
Flexible Investments   Real Options   Cost Analysis

## Robust Decision Making

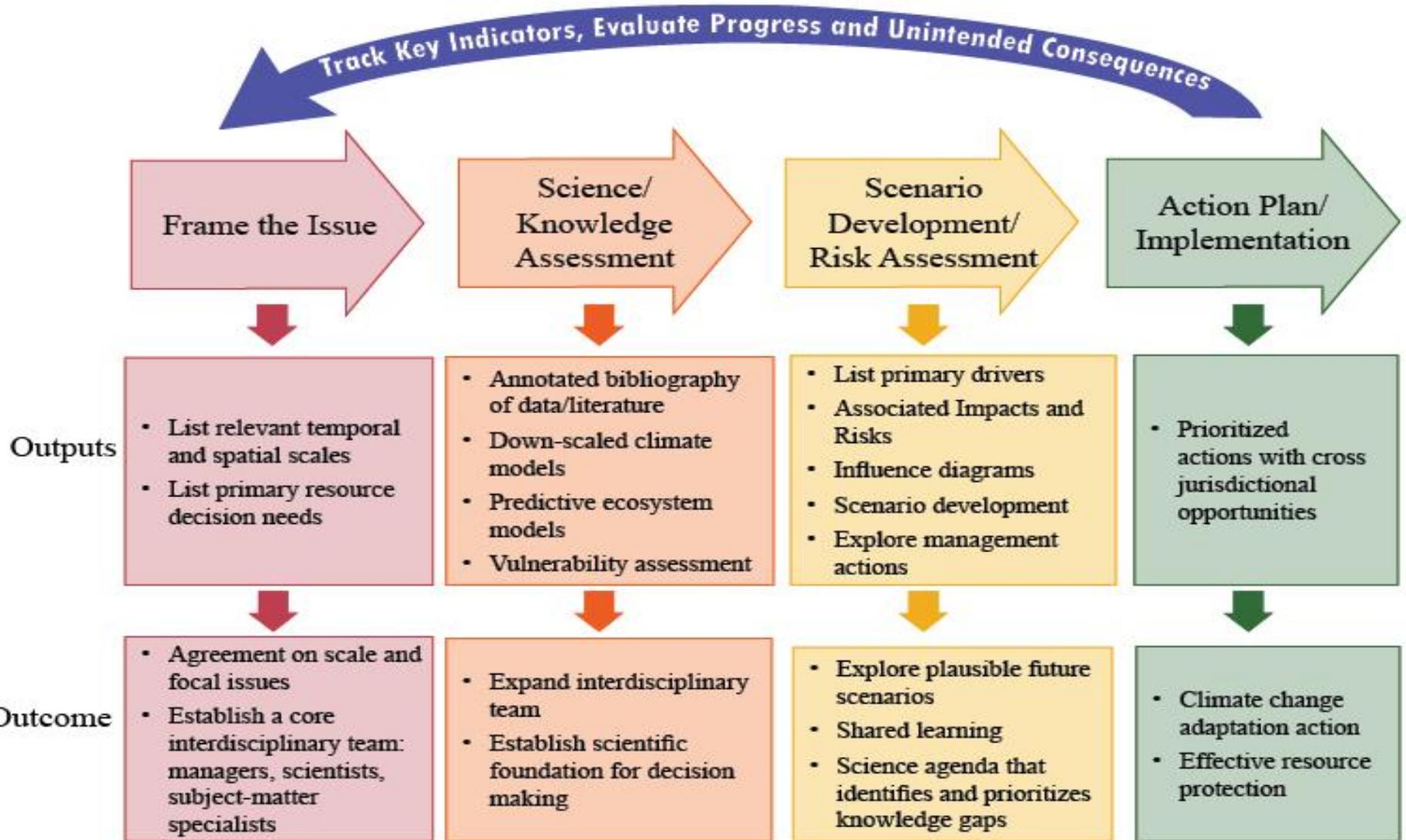
- Computer analysis of many plausible likely scenarios
- Iteration and hedging



# Decisions are made within a framework

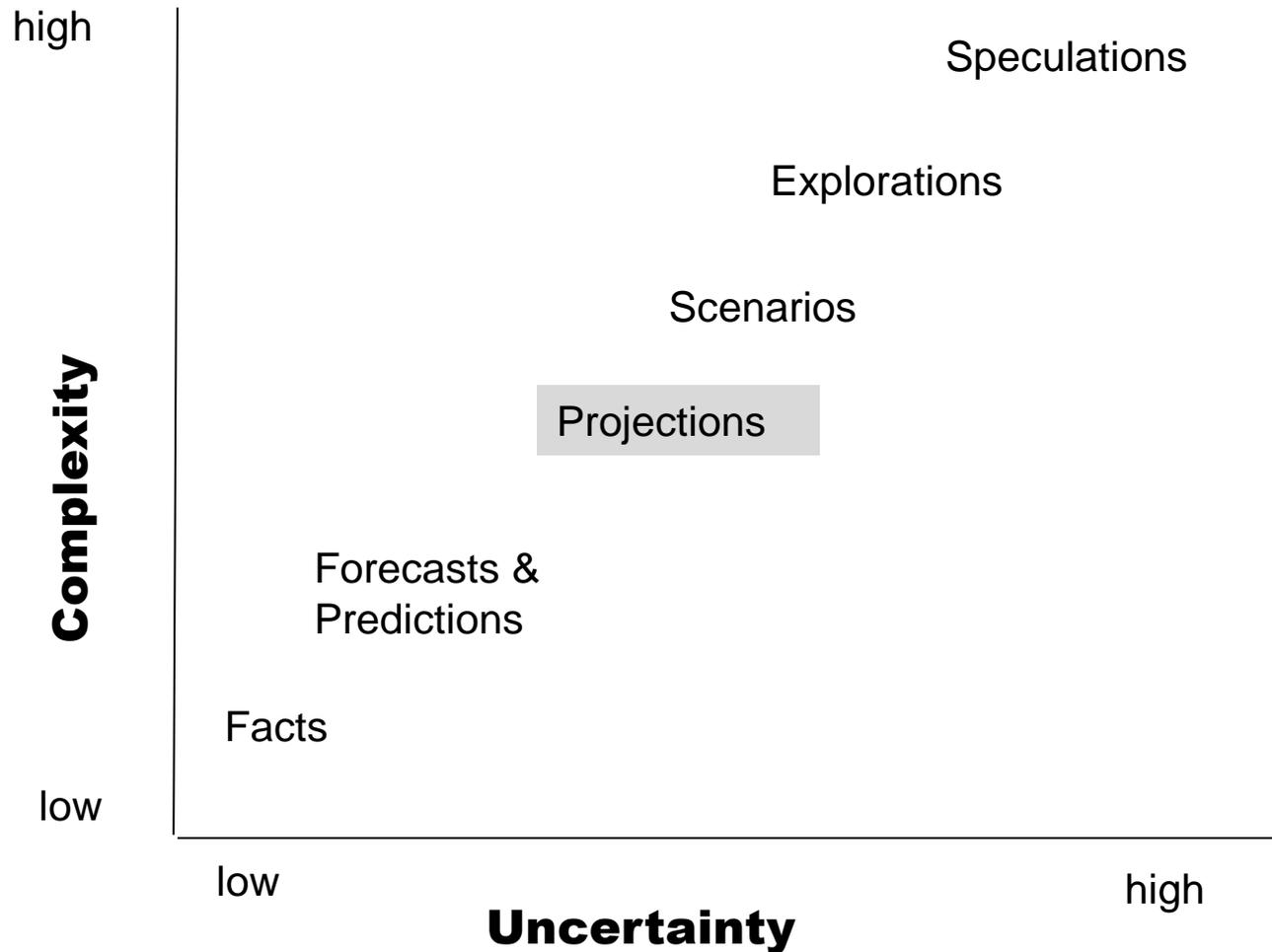


# KEY ELEMENTS OF AN ADAPTATION PLANNING FRAMEWORK



National Park Service, 2010. Climate Change Response Plan

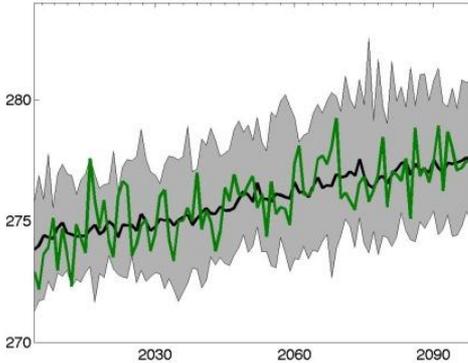
# Alternative Continuum of Climate Products



Adapted from Zurek and Henrichs, 2007

# Projections to Impacts

SRES A1B Winter Temperature CRB



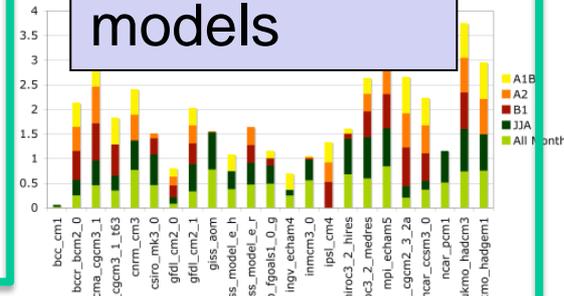
IPCC AR4 GCM projections

Hydrologic projections at watershed scale.



Water Management Models

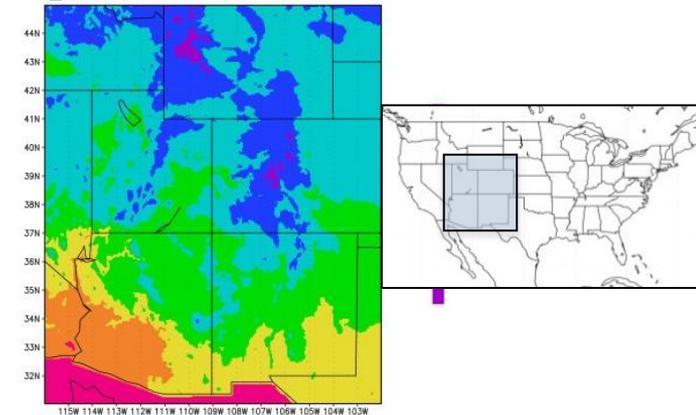
Select the "best" models



Hydrologic models



MPI\_ECHAM5 SRESA1B Winter 2075-2098



Spatial Downscaling

From approx. 200 km to 4 km.

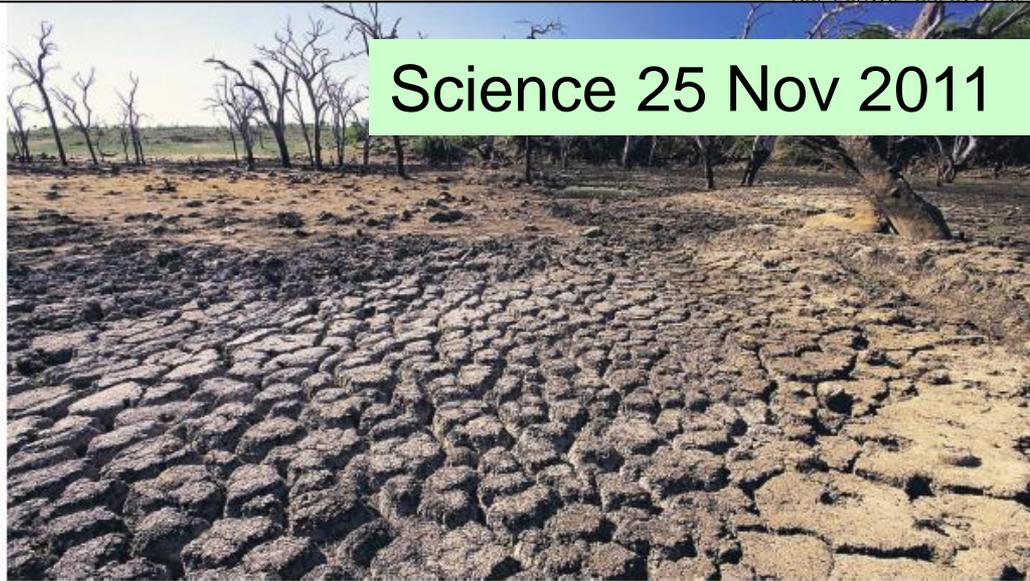
Temporal Downscaling

From Seasonal to Daily

Evaluate Management Options

# Actionable Science

Science 25 Nov 2011



## ADAPTATION TO CLIMATE CHANGE

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

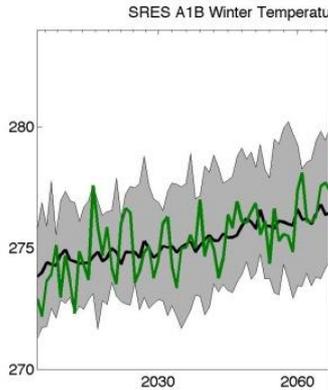
With dangerous global warming seemingly inevitable, users of climate information—from water utilities to international aid workers—are turning to climate scientists for guidance. But usable knowledge is in short supply

**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."



IPCC AR4 projections

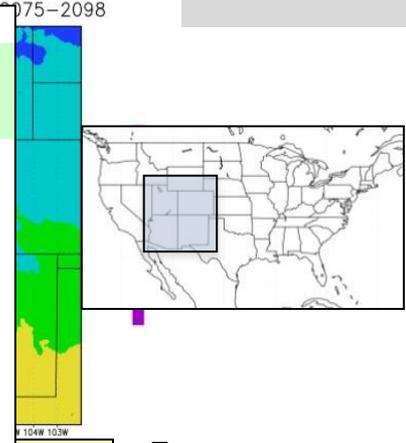
Hydrologic projections watershed scale.



Water Management Models

?!?!?

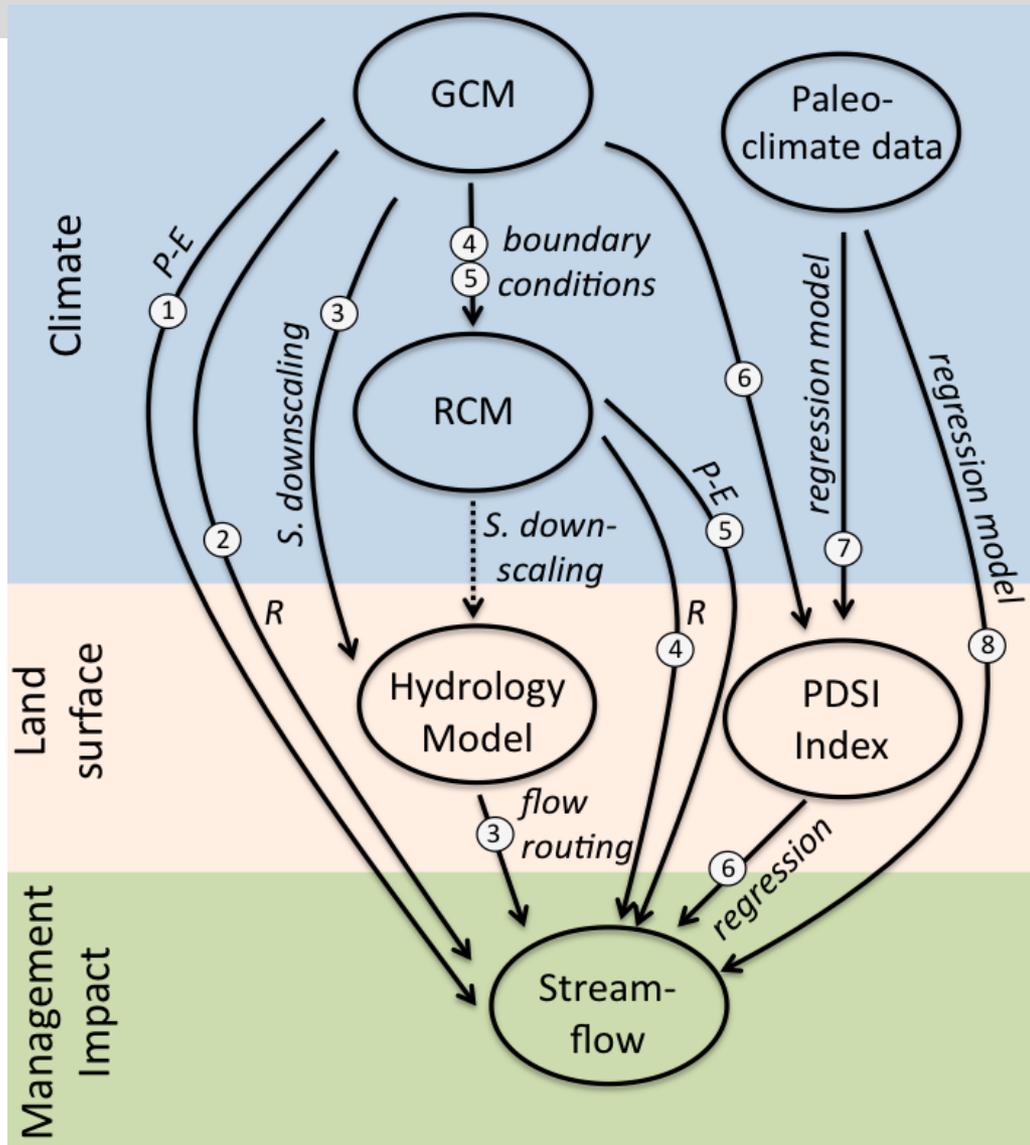
Evaluate Management Options



ng From approx. 200 km to 4 km.

ng From Seasonal to Daily

# Projection Lineages



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

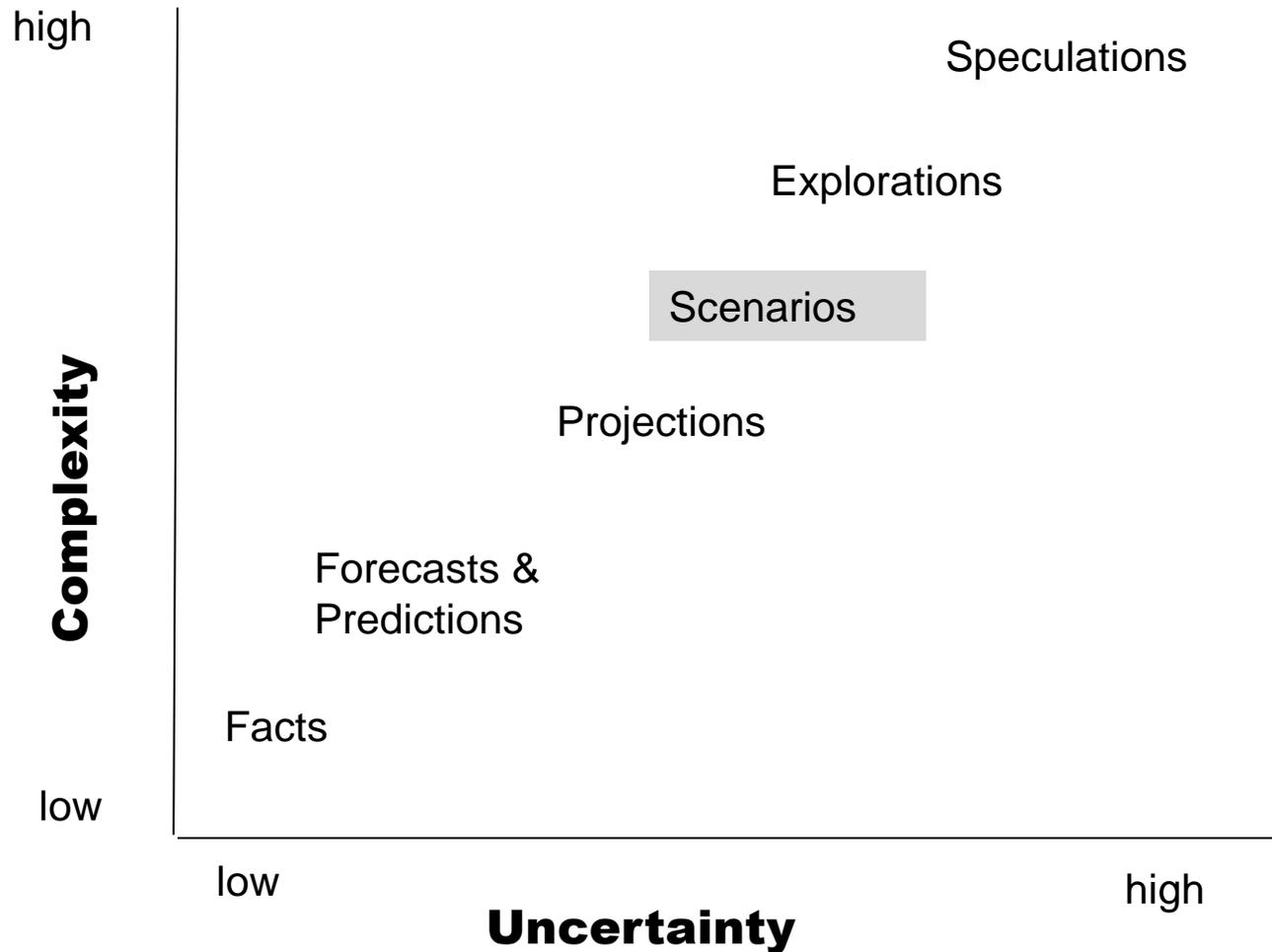
R – Runoff

E – Evaporation

S. downscaling – statistical downscaling

**GCMs, Emission scenarios,  
Spatial resolution  
Land surface representation**

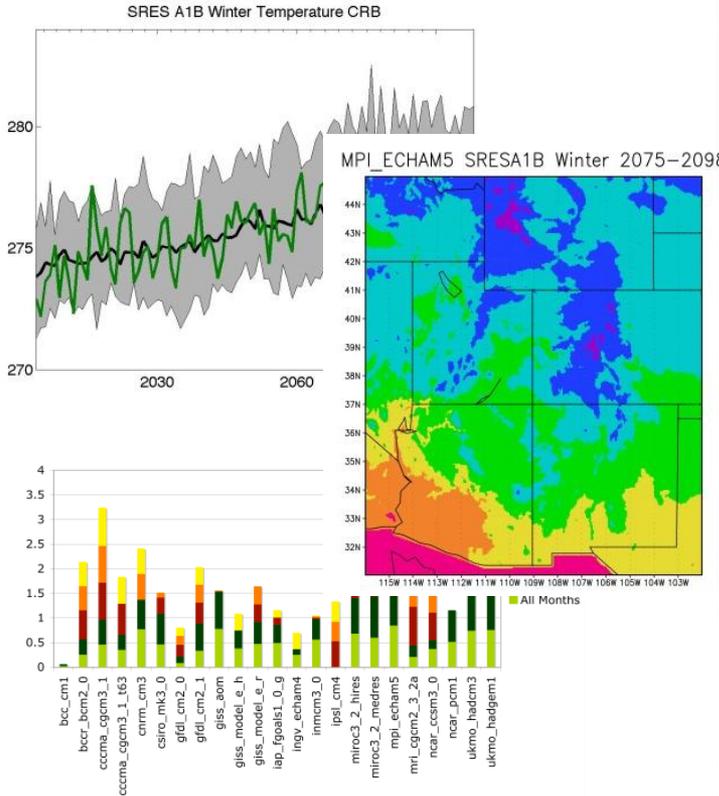
# Alternative Continuum of Climate Products



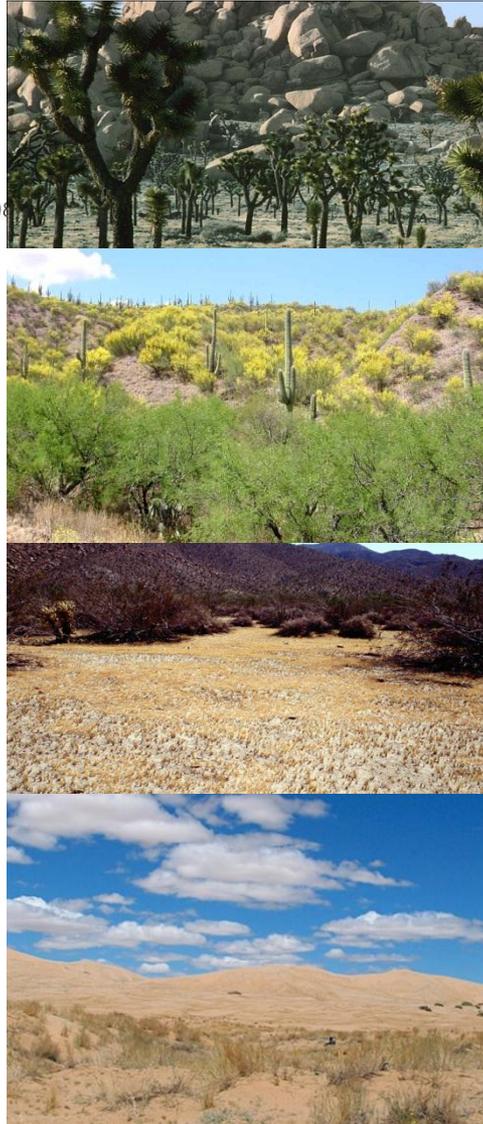
Adapted from Zurek and Henrichs, 2007

# Different Scenario Approaches

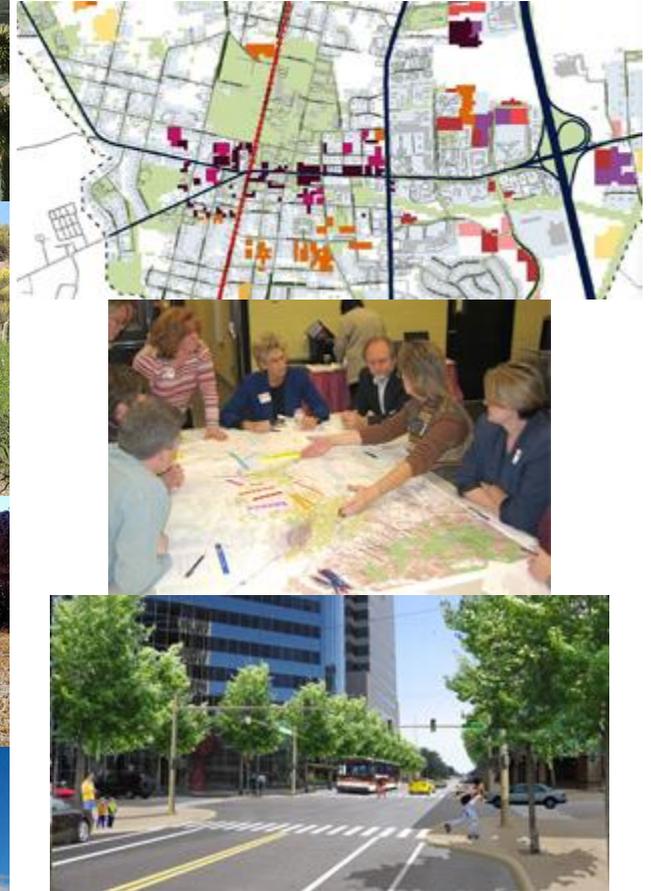
## Characterizing Uncertainty



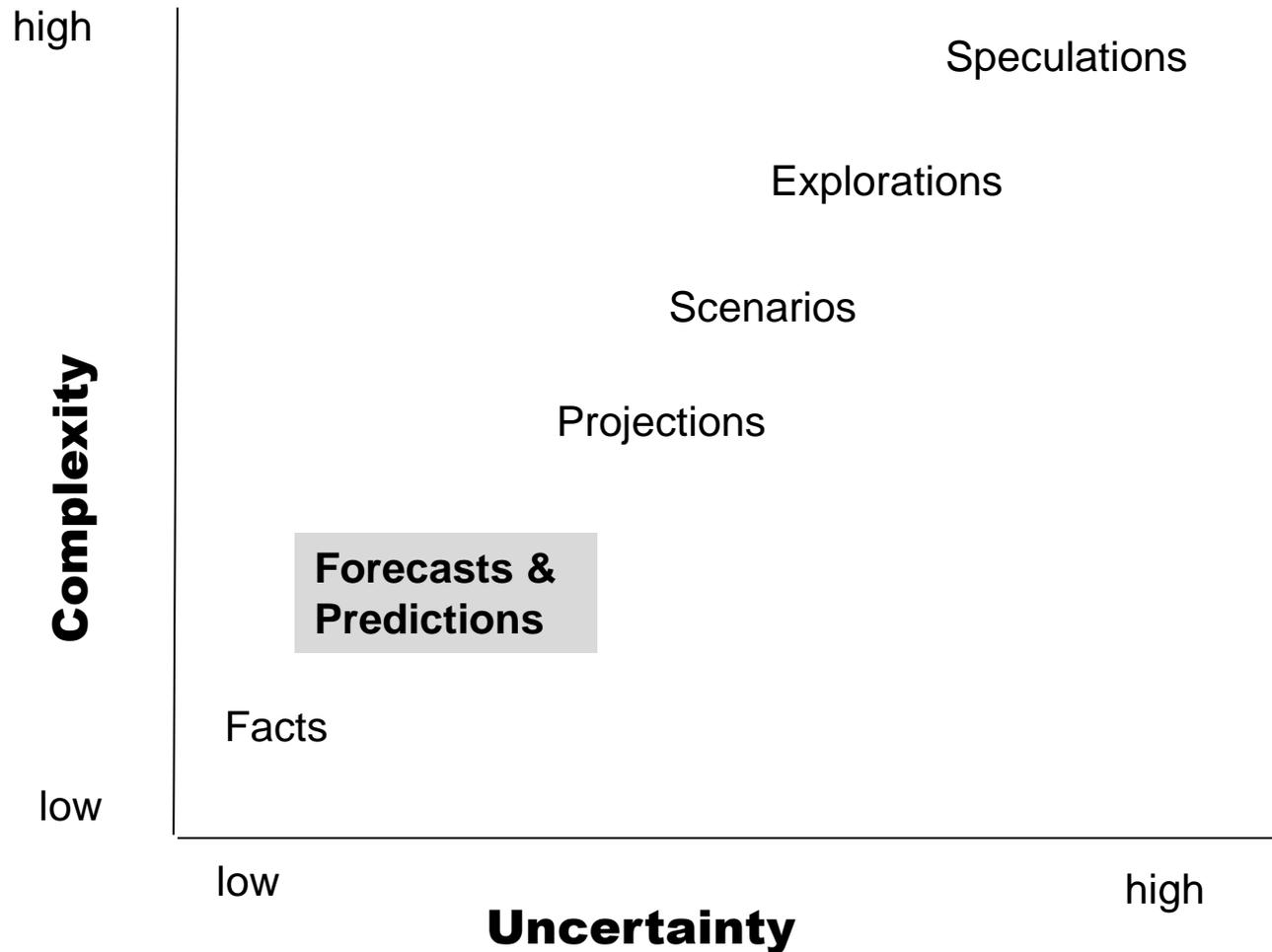
## Embracing Uncertainty



## 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

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

## Three Category Forecast

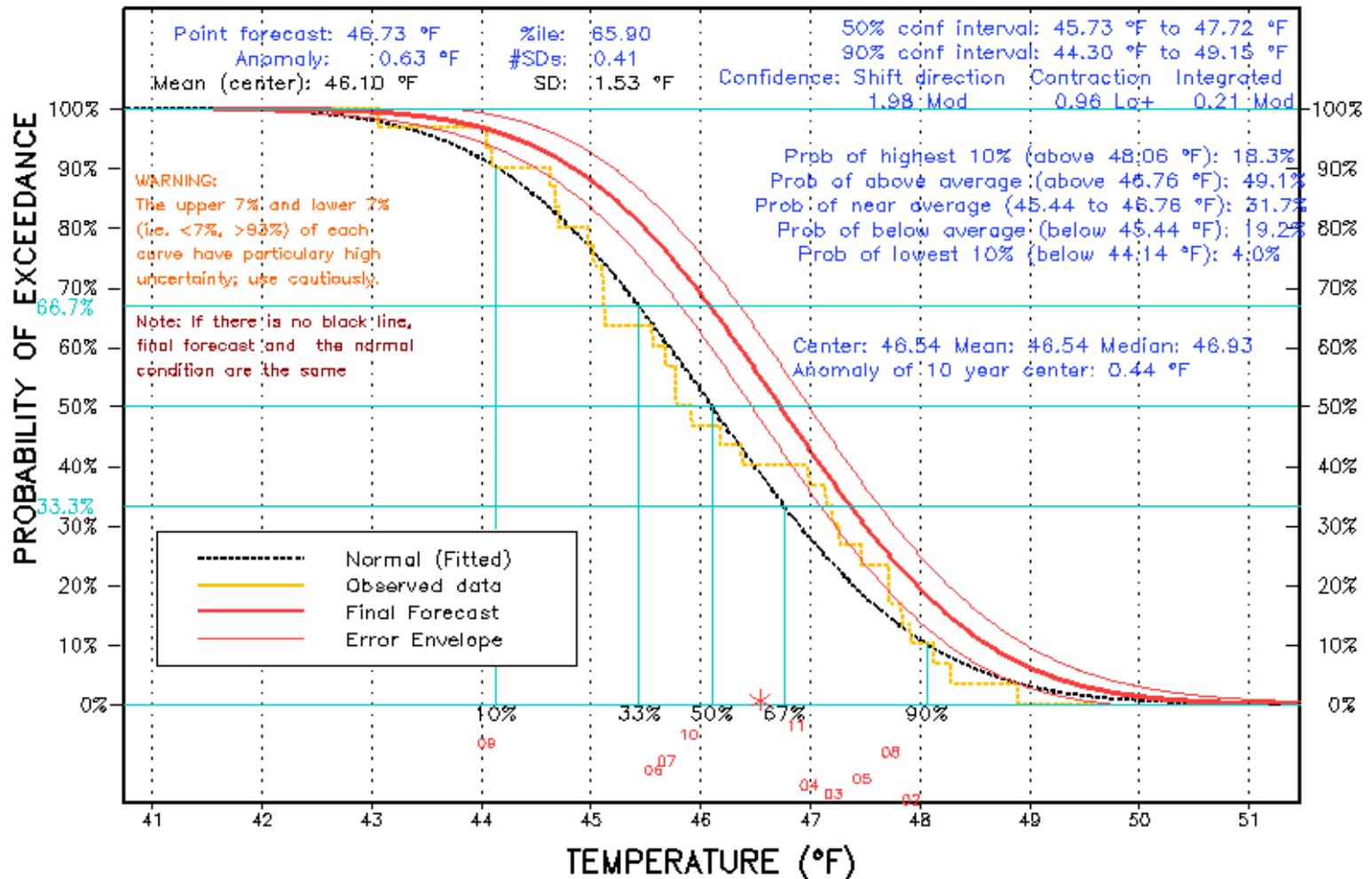
$$\text{Decision} = F ( .13[I_{\text{quantile}<33}} ] + .33[I_{\text{quantile}33-66}} ] + .53[I_{\text{quantile}>66}} ] )$$

**Strategies: benefit from more categories, if sufficient skill**

**Ideal: customized percentile categories**

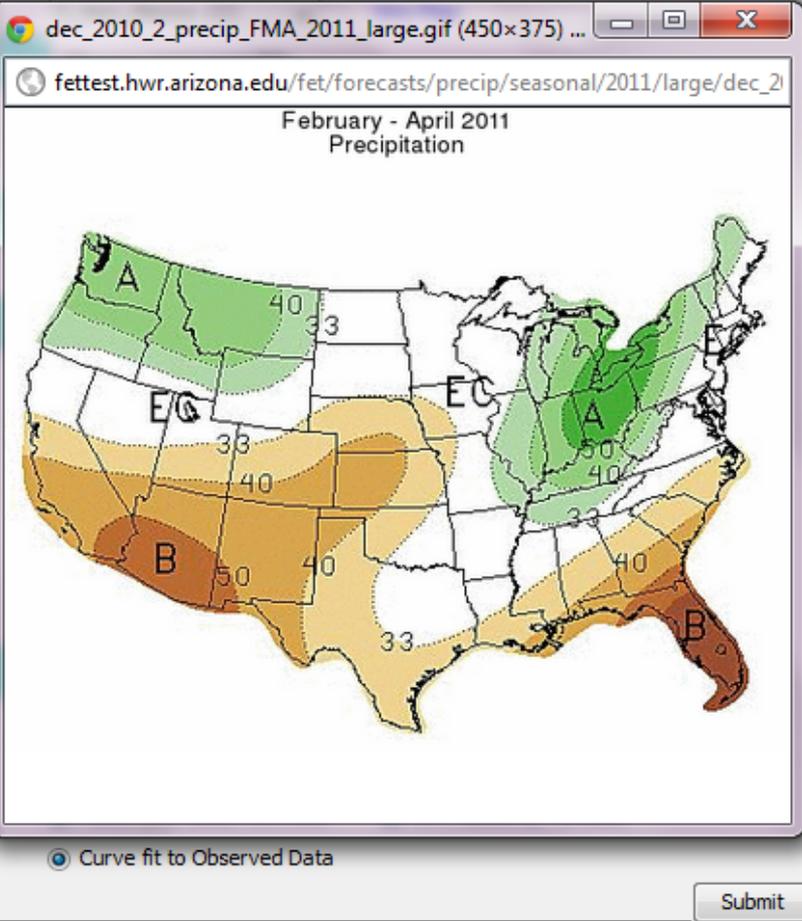
# Probability of Exceedance Outlook

## MEAN TEMPERATURE OUTLOOK FOR JFM 2013 0.5 MONTH LEAD OUTLOOK – MADE Dec 20 2012 Climate Division 102 (Southern New Mexico)



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

## 1 Choose your U.S. climate division

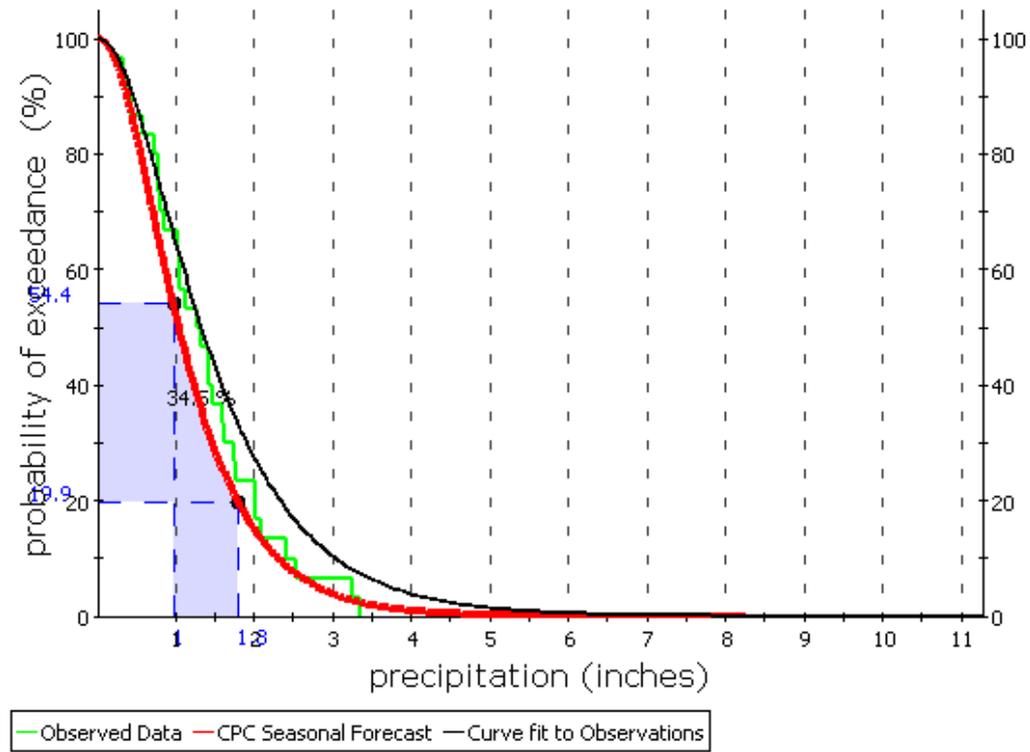


## 3 MONTH MEAN PRECIPITATION OUTLOOK

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”

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

Where all quantities are based on 1981-2010

Forecast for “Equal Chances”

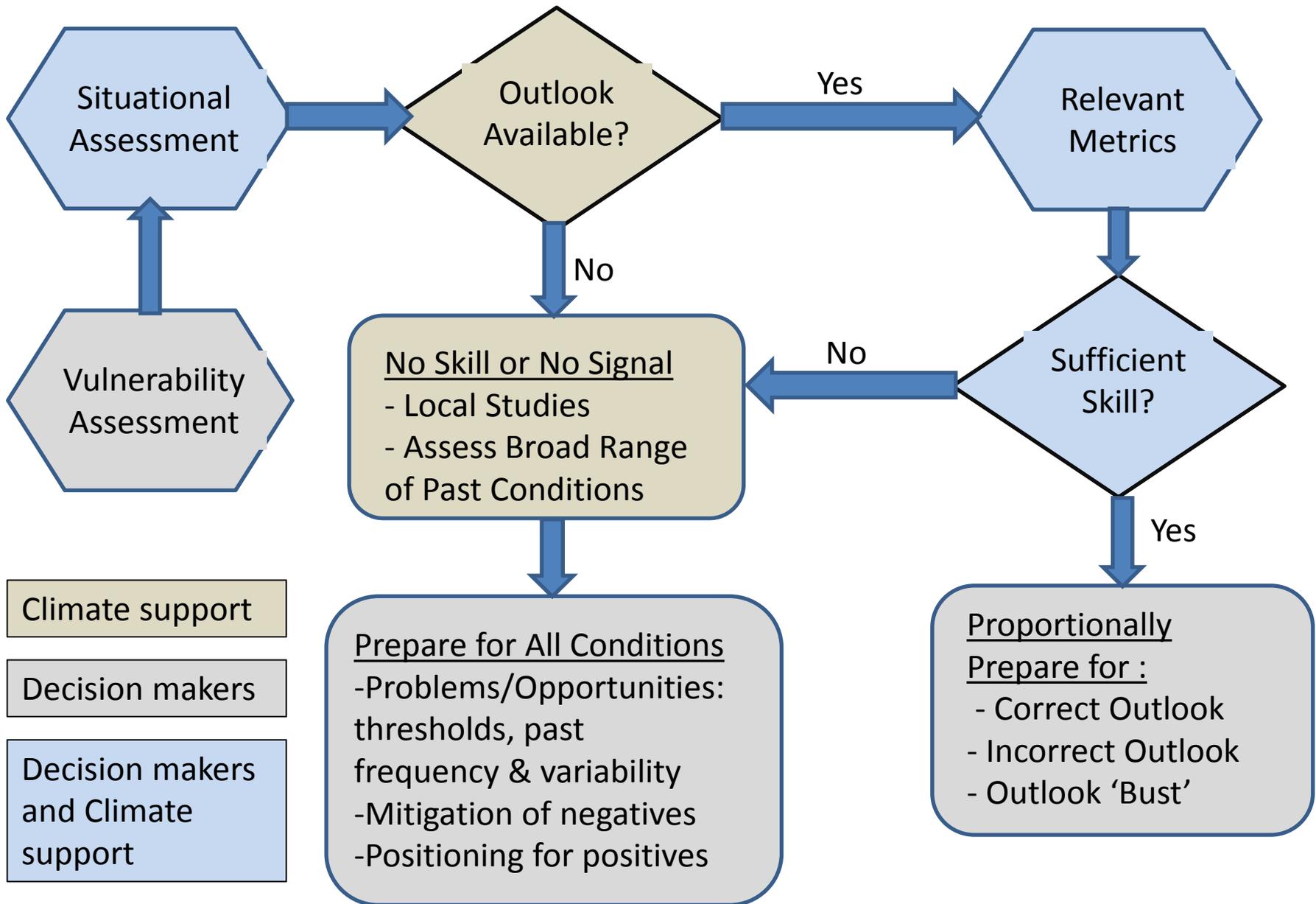
$$\text{Decision} = F ( .33[I_{\text{quantile}<33} ] + .33[I_{\text{quantile}33-66}] + .33[I_{\text{quantile}66>}] )$$

Forecast for “Unknown Chances”

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

**Strategies: hedging, local studies, new research**

# Flow Chart for Using Outlooks



## Online Forecast Evaluation Tool

### Take the Tutorial



#### Forecast Interpretation Tutorial

To get the most out of forecasts, it's important that you interpret them correctly. But some forecasts can be confusing. Use our tutorial or take a quiz to make sure you understand the forecasts.

Begin Tutorial

We are interested in improving the dialogue between researchers, forecasters, and users of their products. We encourage you to e-mail us with questions and comments

Advance warning of climate or hydrologic events can help you avoid losses or allow you to take advantage of unique opportunities. This website will help you get the most use out of a variety of different forecasts.

#### Which forecasts are you interested in?

- Seasonal Climate Forecasts
- Seasonal Water Supply Forecasts (coming)
- Seasonal Snow Forecasts (coming)

#### What aspect of the forecasts are you interested in?

##### Explore the Forecasts

Take a look at some of the forecasts. You select the seasons and lead times that are important to you.

##### How do the forecasts relate to my specific situation?

See how a forecast for your location compares to recent conditions and historic data. Use examples from the past to see what the future might bring.

##### Forecast Performance

Researchers have a lot more to learn about how our forecasts have worked. Although past performance does not guarantee future performance, we want to know how well forecasts have worked for your particular location.

##### Forecast Decisions (coming)

How do you use probabilistic forecasts? This section shows examples of how we have used different forecasts.

Learn more about the challenges we face and what researchers are doing to improve the forecasts.

Get Forecast Info

## Forecast Performance

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

# CPC Verification Web Tool

## URL: to be released soon!

### CPC Verification Web Tool (VWT)

This is an interactive tool that allows users to calculate the skill of forecasts, which is a relative measure of how the forecasts performed. Knowledge of forecast skill can help users when using forecasts for decision making.

#### Instructions for use:

1. Select type of skill score output display desired ("Chart" or "Map").
2. For "Chart", select region(s) to verify ("Climate Regions", "States", "Climate Divisions"). For "Map", select dates(s) to verify ("Date Range", "Months/Seasons & Years", "Climate Phenomena").
3. Select Forecast and Verification Options.
4. Click the "Get Scores" button.

[Click here for more information](#)

Chart | Map | Tutorial

Scroll down the page to see the results, error messages, and information panel.

**1 Options**

**Forecast options**

Field [?]

Period [?]

Lead time [?]  8 days

Data format [?]

Forecast(s) (Select up to 4) [?]

CPC Official (Manual)

CPC Official (Auto)

[Select forecast models](#)

**Verification options**

Start date [?]

End date [?]

Region(s) [?]

Skill Score [?]

Forecast categories [?]

**2 Select region**

To unselect, you must clear all regions by clicking verified by default.

Climate Regions | States | Climate Divisions



### New Features

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

### CPC Verification Web Tool (VWT)

This is an interactive tool that allows users to calculate the skill of forecasts, which is a relative measure of how the forecasts performed. Knowledge of forecast skill can help users when using forecasts for decision making.

#### Instructions for use:

1. Select type of skill score output display desired ("Chart" or "Map").
2. For "Chart", select region(s) to verify ("Climate Regions", "States", "Climate Divisions"). For "Map", select dates(s) to verify ("Date Range", "Months/Seasons & Years", "Climate Phenomena").
3. Select Forecast and Verification Options.
4. Click the "Get Scores" button.

[Click here for more information](#)

Chart | Map | Tutorial

Scroll down the page to see the results, error messages, and information panel.

**1 Options**

**Forecast options**

Field [?]

Period [?]

Lead time [?]  8 days

Data format [?]

Forecast(s) (Select one) [?]

CPC Official (Manual)

CPC Official (Auto)

[Select forecast models](#)

**Verification options**

Skill Score [?]

Forecast categories [?]

**2 Valid Dates**

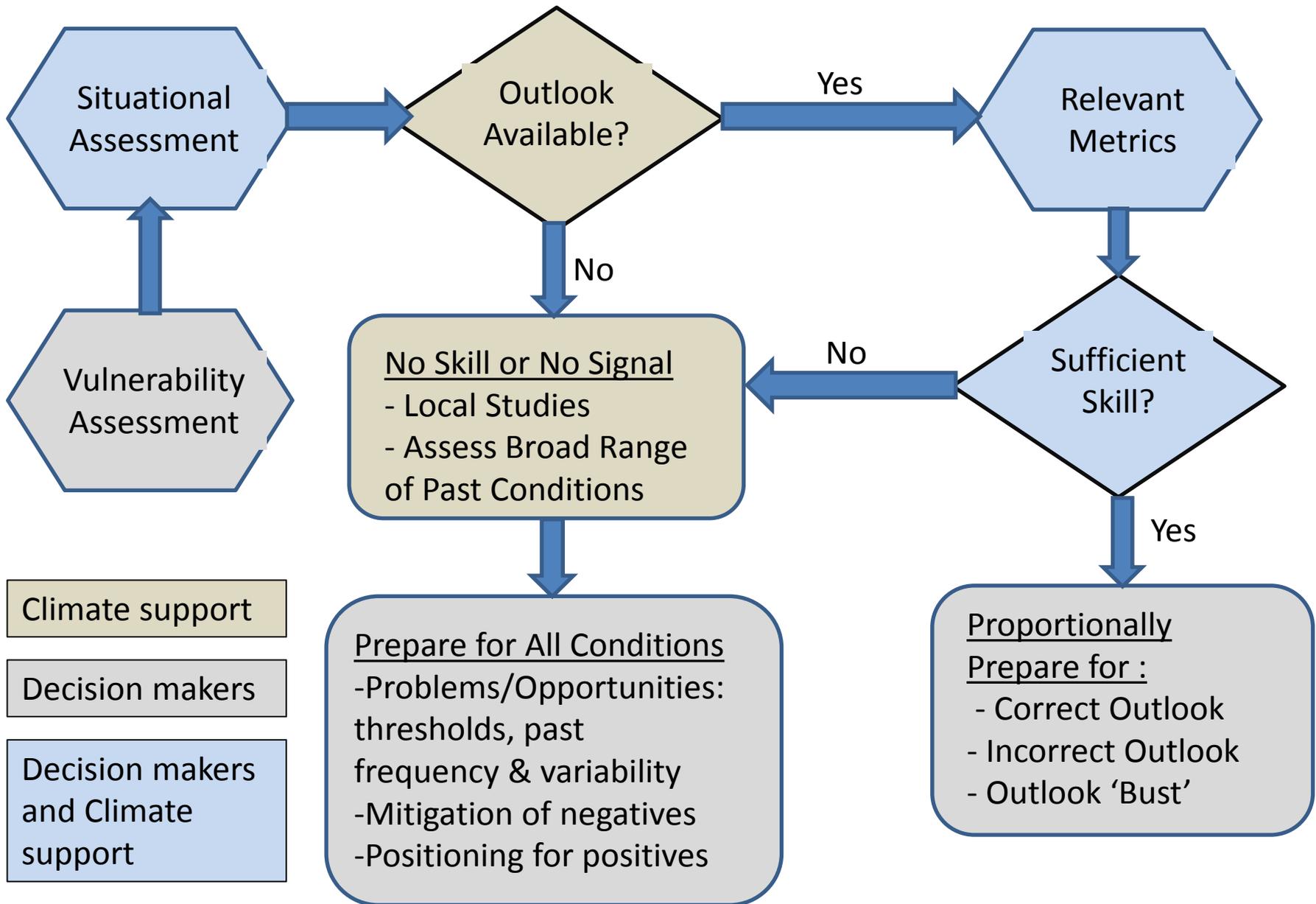
Date range  or  Months/Seasons & Years  or  Climate Phenomena

Dates represent the center of the valid period of the forecast(s) to verify.

• Start date [?]

• End date [?]

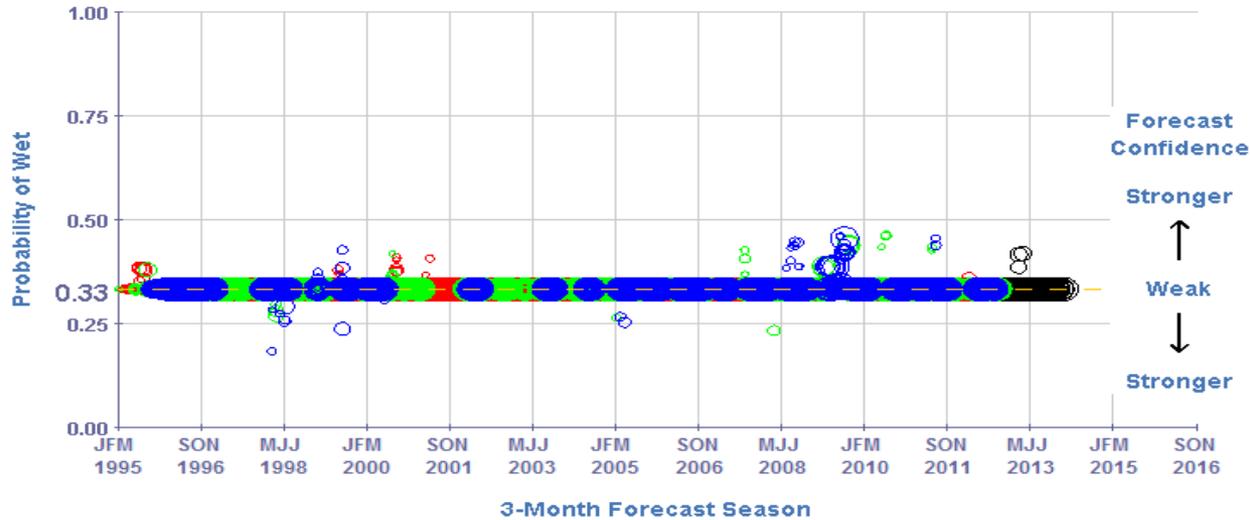
# Flow Chart for Using Outlooks



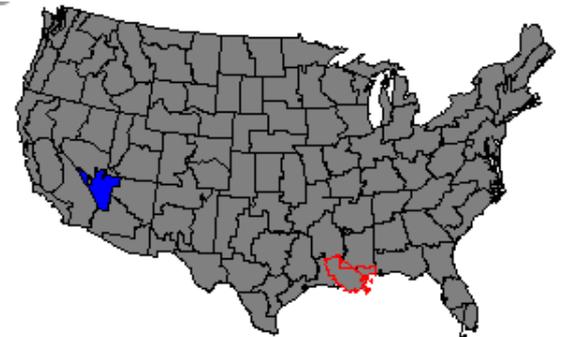
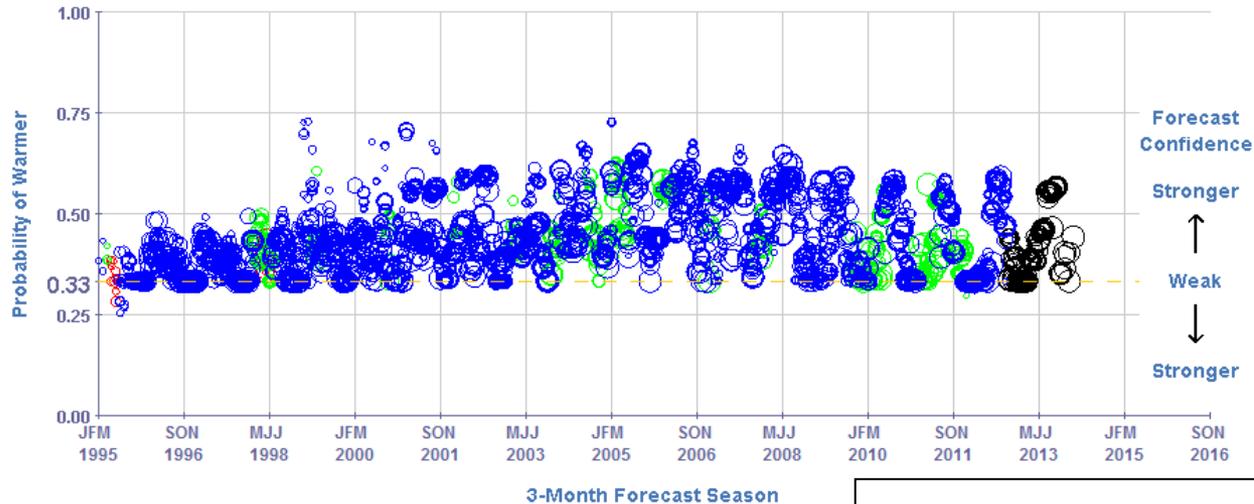


# Outlook Performance History – All in One Plot!

All Precipitation Forecasts for CPC region 2, NorthEast New England

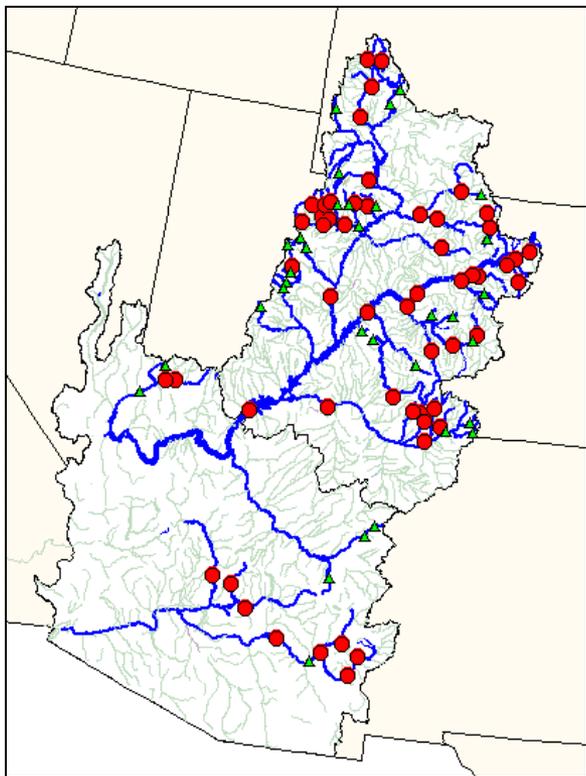


All Temperature Forecasts for CPC region 95, Las Vegas Nevada Area



Categories: Wet ■ Neutral ■ Dry ■ No Observations Yet ■  
 Bubbles: Smallest o = Shortest Lead Time (1 month) Largest O = 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).

