Western Watersheds and Climate Change:
Water and Aquatic System Tools Workshop
Evaluation Results

Prepared by

University of Colorado, Boulder &
National Oceanic and Atmospheric Administration
Western Water Assessment (WWA)

University of Arizona &
National Oceanic and Atmospheric Administration
Climate Assessment for the Southwest (CLIMAS)

K. Averyt (WWA), G. Owen (CLIMAS)
C. Alvord (WWA), L. Barros (CLIMAS), Z. Guido (CLIMAS), E. Gordon (WWA), J. Barsugli (WWA)

Workshop Objectives & Summary

The USFS Rocky Mountain Research Station, in collaboration with USFS Region 2 and NOAA hosted the Western Watersheds and Climate Change: Water and Aquatic System Tools workshop on November 17–19, 2009 in Boulder, Colorado. This workshop, funded by the FY08 Forest Service Global Change Program, brought together 25 USFS National Forest (NF) staff working in western water and aquatic ecosystems, and 19 scientists from both other agencies and the academic community. **The purpose of the workshop was to begin a dialogue among USFS managers and scientists about knowledge and tools that are currently available or needed to address water and climate change.**

The workshop was structured in three sections: 1) an introduction to available climate information and data products; 2) presentation of tools for assessing the implications of climate change on watershed and aquatic system management; and 3) interactive sessions to engage managers and scientists in prioritizing needs for new data products and tools.

The NOAA-funded Western Water Assessment (WWA), based at the University of Colorado, worked with the workshop organizers to integrate methods for evaluating participant use of climate information into the workshop framework. This is reflected in the agenda (Appendix 1). In addition, social scientists from the Climate Assessment for the Southwest (CLIMAS) were brought into the project to work with WWA. The collective goals of WWA and CLIMAS were to:

1. Assess the climate literacy of USFS personnel before and after the workshop;
2. Determine what climate information USFS personnel currently use and what they think they need (pre-workshop);
3. Evaluate what information presented during the meeting USFS participants think they would and would not need based on their perceptions of what will be presented at the meeting;
4. Evaluate the relevance of climate information (as identified by climate scientists) to climate-relevant USFS decisions (as determined by USFS personnel).

The suite of responses to the pre-workshop evaluation questions about the use of climate information in decision-making supports the need for training on the time scales of climate variability and change, and further instruction about available resources and information to support informed decision-making.

Methods

Several strategies and methodologies were integrated into the workshop in order to achieve the goals (1–4) outlined above.

Breakout Group Discussion

Participants were split into assigned groups based on regional affiliation. The groupings were assigned by region so as to allow interactions among those who will likely be working together on climate-related problems in the future. Only USFS personnel actively participated in the breakout discussions; participants from outside entities were invited to observe.

Two breakout sessions were scoped in the original agenda; however, due to time constraints, the second breakout session was eliminated. During the first breakout session, participants were asked to brainstorm the most pressing issues their respective forests may face in the future as a consequence of climate change. The information from each breakout was compared so as to highlight regional differences and similarities in future challenges.

Pre- and Post-Workshop Evaluation

The intent of the pre- and post- workshop evaluations was twofold: (1) to identify the saliency and use of climate information in decision-making; and (2) to evaluate the climate literacy of the participants. The pre- and post-workshop evaluation asked participants to identify the climate indicators and resources they were currently using and familiar with. The second component of the evaluation addressed the climate literacy of participants, with specific questions aimed to test knowledge of climate concepts. The climate concepts tested included global and Western US climate fundamentals, hydrology and climate connections, and climate variability and change. The climate literacy questions were framed in a way to evaluate common misconceptions surrounding climate, particularly climate change implications for the Western US, in order to identify gaps in understanding.

The comparison of pre- and post-workshop evaluation results was intended to provide the basis to evaluate the workshops' effectiveness in communicating climate information, as well as information to improve future climate literacy exercises and evaluations. By comparing the responses to the same questions in the pre- and post-workshop evaluations, specific weaknesses in understanding of climate concepts could be identified.

Before the workshop, registered participants were invited to participate in a pre-workshop evaluation online. The post-workshop evaluation was handed out in hardcopy form at the conclusion of the workshop and was available online for participants who were unable to complete the evaluation at the workshop. Of the 25 USFS participants, 22 completed at least a portion of the pre-workshop evaluation, and 14 responded to the post-workshop evaluation.

Scenarios & Decision-Making

This part of the workshop included two exercises, both of which were conducted in small groups with a facilitator, a note-taker, and 5-7 participants. The first exercise was a series of scenario-based decision games and the second involved a facilitated group discussion session. The goal of these exercises was to foster critical thinking about the influence of climate information and forecasts on short- and long-term management decisions. The games were designed to help researchers understand if and how seasonal climate forecasts influenced decisions made by Forest Service employees and to test their thresholds for uncertainty in climate forecasts. During the exercises, historical climate and climate forecast products were introduced to stimulate discussion about how these particular products could be useful for making planning decisions.

<u>Exercise 1: Decision Games</u>
The first exercise was comprised of a series of five dice rolling games (see Figure 1). The games revolved around a resource management scenario in which participants had to determine their top priorities for an action plan. The scenario dealt with Sudden Aspen Decline (SAD) in the Rocky Mountains and was based on an existing U.S. Forest Service project. Participants were tasked to minimize the risk of SAD in susceptible aspen groves by determining the best plan of action, given various pieces of climate information.

In the first two games, participants were asked to decide which of seven options would be their highest management priority. They then rolled a die to determine the piece of climate information (if any) they would receive. Participants were then asked if and how their top priority changed based on the information they received.

The other three games dealt with uncertainty in climate forecasts and the impact that different levels of uncertainty had on participants' decisions. In these games, participants were given climate information and then asked to choose their highest priority. Based on their role of the die, they were informed of the certainty forecasters attached to the climate forecast received. Participants were once again asked if their top priorities changed based on the information they received. Participants were asked to write down all their decisions on a worksheet, including a brief explanation of their choices.

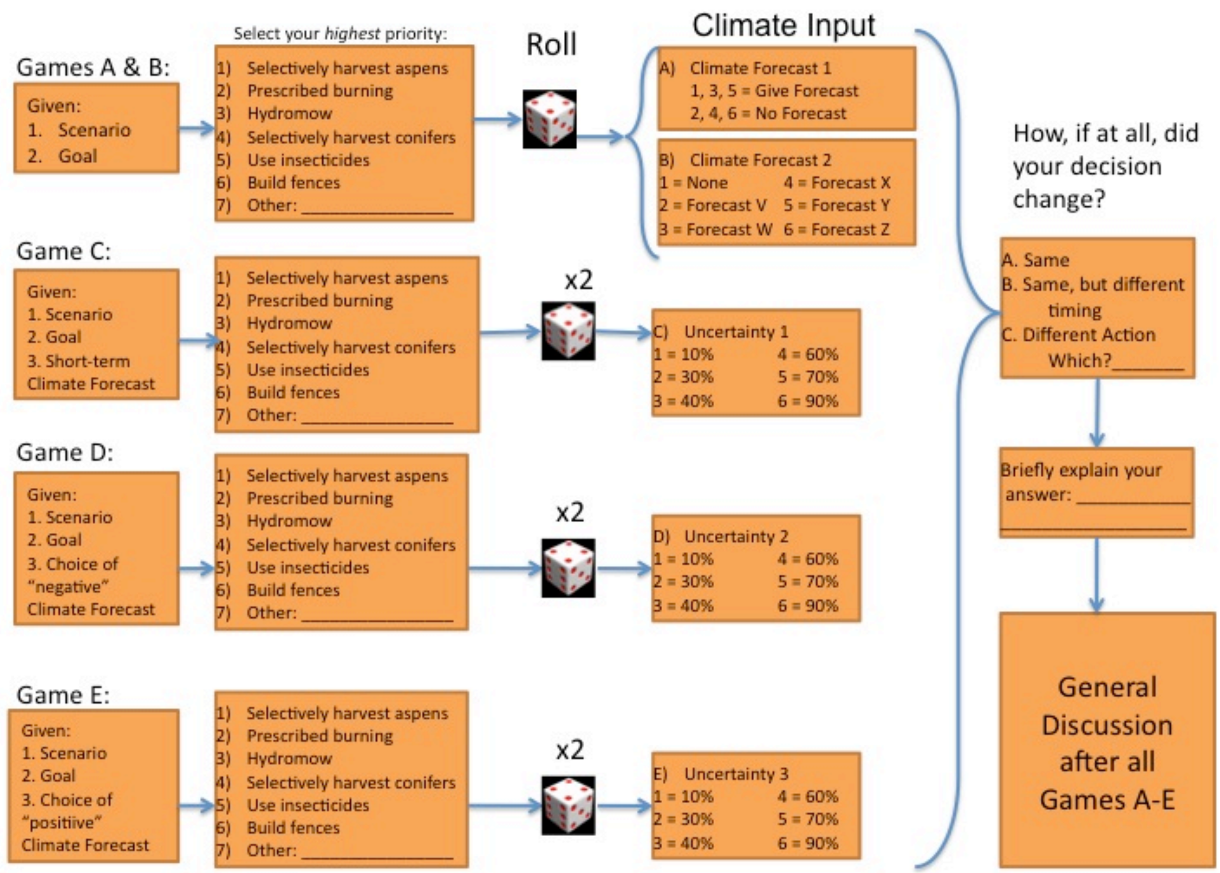


Figure 1. Schematic of five decision games used in Exercise 1 of the Scenarios & Decision-Making Section

After the games were finished, the facilitator led a group discussion about the decisions people made and the reasons for those decisions. The facilitator also introduced eight climate products to stimulate discussion about how these could be useful in decision-making. Products included: 3-month precipitation and temperature forecasts (Climate Prediction Center), the Outlook for Seasonal Fire Potential (National Interagency Fire Center), a streamflow forecast (Natural Resource Conservation Service), the Seasonal Drought Outlook (Climate Prediction Center), the Probabilistic ENSO Forecast (International Research Institute), and river-basin tree-ring reconstructions of streamflow and climate (TreeFlow).

<u>Exercise 2: Group Scenario Planning and Discussion</u>

In the second exercise, the same groups were given a general scenario to serve as the framework for a discussion about how climate change information may influence U.S. Forest Service management plans.

The scenario involved re-designing culverts along road next to a river so that migration patterns of native fish were not impacted. Each group was asked to come up with an action plan to address this issue, including the timing of the action, the locations of the culverts, and the design of the road.

Next, the group was given a set of historical climate trends. For each trend, groups were asked about how this information might influence their management action plan. Climate information included the following:

- In the last 30 years, average temperatures of the Rocky Mountain region during June–August have increased by about 1.5 degrees Fahrenheit
- During the last 60 years, there has been a trend toward longer dry spells between rain events in June–August
- Maximum daily temperatures in the summer have been increasing
- Observed warming has increased the severity of droughts
- Based on long-term monitoring of snow, In comparison to time periods before 1950, winter snowpack in the West is melting earlier in the year, a greater fraction of winter precipitation now falls as rain rather than snow, and the April snowpack is containing less water (i.e. snow is melting earlier in the year).
- In many rivers in the West, the date when 50 percent of the average annual streamflow passes a measurement station has advanced by 10 to 30 days over the observational period of 1948 to 2000—the center of water mass is currently occurring earlier than the mid-20th century.

The above exercise was designed as a hopping-off point for the following discussion questions, to better understand how U.S. Forest Service personnel were thinking about climate change and about long-term planning:

1. How do historical climate trends influence the way you think about long-term decisions?
2. Given the above historical trends and your knowledge of climate change, what are the critical issues the Forest Service faces moving forward?
3. Given these historical trends, what are the impacts to forests? How can the Forest Service use this information to make forests less susceptible to the impacts of climate change?
4. Is the monitoring network in your region (stream gauges and weather/climate stations) adequate to enable the use of historical trend analysis?
5. What information would you most like to have at your fingertips?
6. What kind of climate information is most useful and how?
7. How should the Forest Service address climate change under NEPA? How will the need to incorporate climate change into EIS alter this process for the Forest Service?

Workshop Results: Participant Demographics

Figure 2 shows the breakdown by regional representation of USFS Employees responding to both the pre-workshop and post-workshop evaluations. The lack of similarity of the two distributions implies that the pre- and post- respondents represent two different populations, meaning that the pre-workshop and post-workshop evaluation results cannot be meaningfully compared and any changes do not necessarily represent a change in understanding about climate issues before and after the workshop.

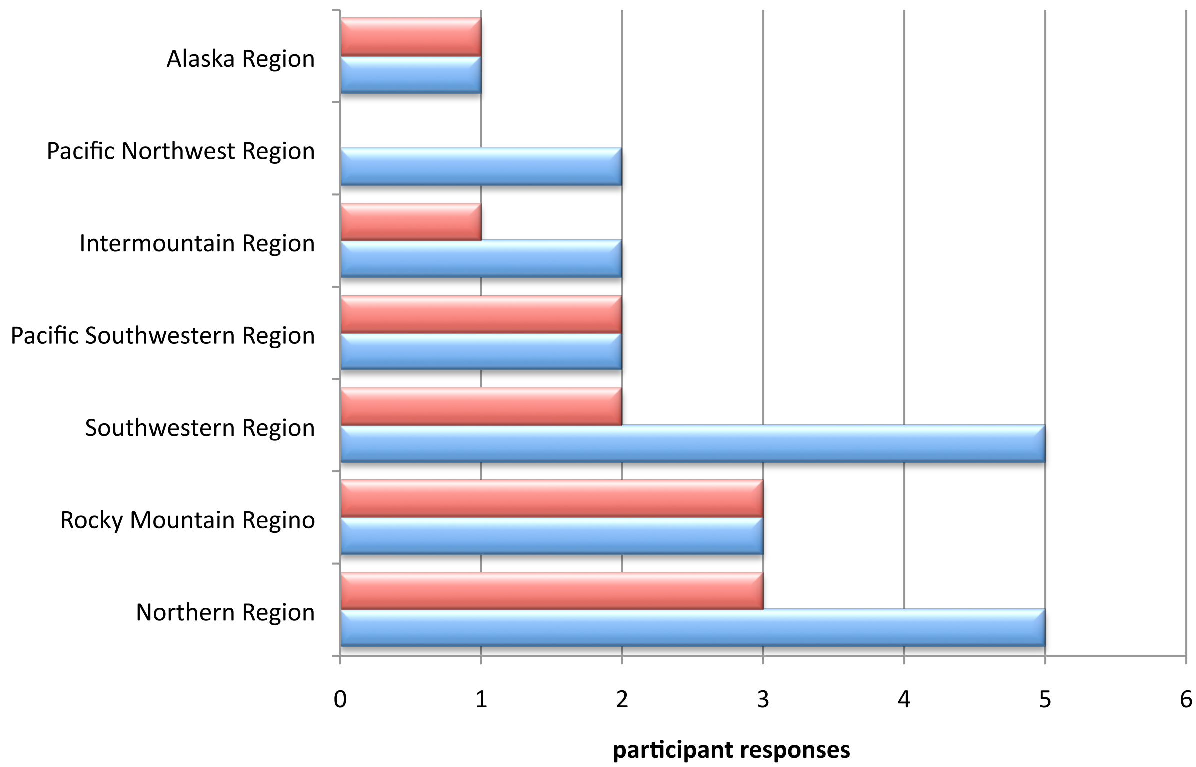


Figure 2. Sectors (self-identified) Represented by Participants Completing the Pre- (blue) and Post-workshop (red) Evaluations.

Based on comparison of the 22 pre- and 16 post-workshop respondents with the 25 USFS participants as identified by job title and organizational affiliation provided at registration, the pre-workshop respondents are more representative of the workshop participants than those responding to the post-workshop evaluation. For this reason, interpretation of results based on responses to the post-workshop evaluation may not necessarily represent attitudes of workshop participants as a whole.

Workshop Results: Climate Literacy

A climate literate individual is best defined as one who understands the basics of global climate and how climate variability and change are manifest regionally, and can recognize reputable sources of climate information and how that data might be applied. The workshop evaluation results were intended to evaluate the degree to which respondents met these criteria.

Participants were asked questions about fundamental climate and hydrology concepts both before and after the workshop. Table 1 lists the concept being tested and the percentage of correct responses to each question in the pre- and post-workshop evaluation. The average score was 71% correct on the pre-workshop survey, compared with 80% on the post-workshop survey.

In the pre-workshop evaluation, major misperceptions about climate science were as follows:

- Land-use is a less important control on climate than the ozone hole.
- Climate variability is synonymous with climate change.
- The recent decline in global average temperatures means that climate change is no longer occurring.
- Major declines in high elevation snowpack (>8000 ft) have been observed and are projected by 2025.
- Precipitation has decreased across the West.
- Climate change will result in less frequent heavy precipitation events, more frequent hurricanes, and more frequent El Nino events.
- Climate projections improve as spatial scales decrease.
- Atmospheric water vapor content has not changed.

A particularly interesting result is that all the respondents to both the pre- and post- workshop evaluations indicated that observed climate change is driven by human activities.

Table 1. Pre- and Post-Workshop Climate Literacy Scores.

Concept	BEFORE	AFTER
Scientific Process	82	91
Weather and Climate	94	92
Controls on Climate	56	33
Climate Variability	29	50
Greenhouse Effect	88	91
Historical Global Temperature Trends	94	100
Anthropogenic Climate Change	100	100
Recent Global Temperature Trends	71	100
Emissions and Concentrations	94	92
Regional versus Global Climate Change	94	100
El Nino	76	83
Western US climate	76	100
Hydrologic Observations & Climate in the West	18	40
Precipitation Observations in the West	77	70
Precipitation Observations in the West	94	100
Snowpack Observations in the West	35	46
Paleoclimate	94	100
Drought in the West	77	73
Climate Models & Projections	82	91
Climate Projections & Extremes	35	80
Climate Projections & Hydrology	24	55

Numbers represent the % of respondents answering with the correct answer. Instances where scores were below 50% in the pre-workshop evaluation are highlighted in red.

Workshop Results: Use of Climate Information

Participants were asked before the workshop whether they currently use climate information to inform resource management decisions and planning. Most of the respondents (91%) chose “Yes”; only 1 indicated that s/he has all the climate information s/he needs to make a well-informed decision. Those indicating “No” (2 respondents) were asked why they did not use climate information. The responses were “Don’t know what information I need”, “Can’t find the information”, “Information is too complicated”, and “Don’t have access to the information.” No respondents indicated that climate information is NOT relevant to their decisions and planning, suggesting that all the respondents understand the connection between climate and forest hydrology.

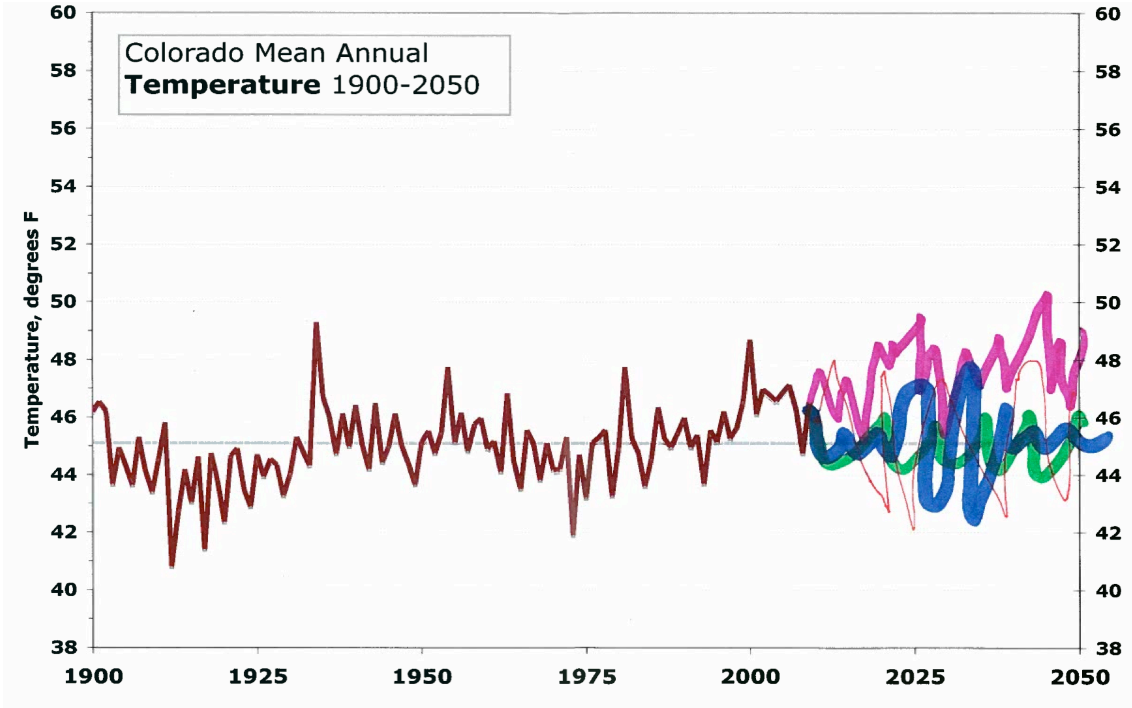
Post-workshop evaluation results indicate respondents intend to use climate information to inform decisions and planning. In the post-workshop evaluation, 77% of participants indicated they would be “somewhat more likely” or “more likely” to use climate information to inform resource management and planning after having participated in the workshop; the remainder (23%) said they would not change their use of climate information compared to before the meeting. Although it is unclear if the latter set of respondents may include those who will continue to *not* use climate information, the post-workshop evaluation suggests that respondents intend to use climate information in decision-making in the future.

Temperature and Precipitation in 2050

An exercise was implemented to determine in more detail participant (mis)perceptions about climate projections for regions in the West. The exercise was intended to refocus the attention of the participants from the presentations focusing on historical climate to projections of future climate.

In the exercise, each breakout group was presented with a graph showing historical annual-average temperature and precipitation in the region particular to each group. Each individual in the group was then asked to draw a line on each graph indicating how each parameter would evolve from present out to 2050. Subsequently, participants were presented with ensembles of climate model projections of temperature and precipitation for these regions, at which time they were asked to show their graphs to the whole group. The facilitator commented on salient features of the graphs, including trend, variability (or lack thereof), and used the exercise to illustrate the “ensemble” concept.

In general, participant-drawn projections demonstrated an understanding of climate variability and change (Figure 3). Participant projections were mixed with regards to replicating upward trends in temperature as predicted by climate models.



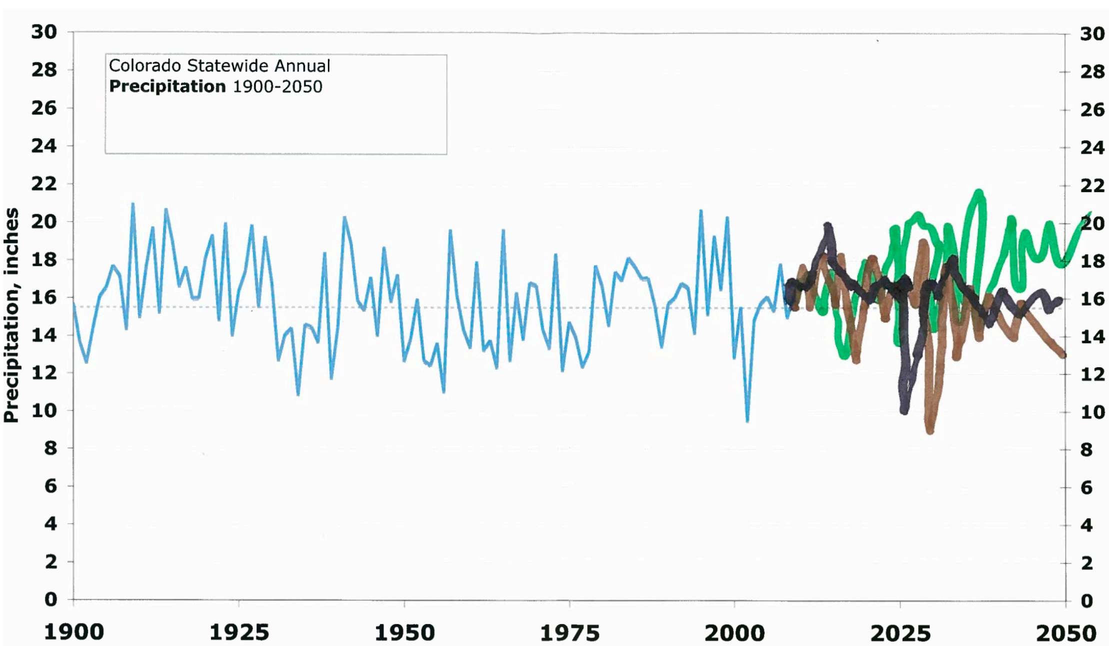


Figure 3. Example of Participant Graphs Created During the 2050 Projection Exercise.

Workshop Results: Climate Indicators and Tools

Prior to the workshop, participants were asked to indicate which climate observations and forecasts they consult to help guide decisions. Each climate-related indicator or forecast listed in Tables 2 and 3 was introduced during the course of the workshop. At the end of the workshop, participants were asked to indicate whether they were more likely than before to consult a given indicator.

Table 2 shows pre-workshop evaluation respondents' use of observational data before the workshop (left columns), compared with the likelihood of post-workshop evaluation respondents to use the same information after the workshop (far right column). The same information as it applies to seasonal forecasts is shown in Table 3, and for climate tools, products, and datasets in Table 4.

Table 2. Use of Current Conditions to Help Guide Decisions.

	Not familiar with this indicator	Heard of this indicator, but never use it	Consult Yearly	Consult Seasonally	Consult Monthly	Consult Weekly	Consult More than Weekly	Depends on the Application		Post-workshop: % more likely to use indicator
Observed Precipitation Amounts	0% (0)	0% (0)	0% (0)	31.3% (5)	12.5% (2)	6.3% (1)	6.3% (1)	**43.8% (7)**		**55.6% (5)**
Observed Temperature Observations	0% (0)	0% (0)	5.9% (1)	23.5% (4)	5.9% (1)	11.8% (2)	5.9% (1)	**47.1% (8)**		**55.6% (5)**
Observed Streamflow Amount	0% (0)	5.9% (1)	0% (0)	**35.3% (6)**	17.6% (3)	0% (0)	5.9% (1)	**35.3% (6)**		**55.6% (5)**
Observed Reservoir Storage	0% (0)	**37.5% (6)**	12.5% (2)	12.5% (2)	0% (0)	6.3% (1)	0% (0)	31.3% (5)		**33.3% (3)**
Observed Reservoir Inflow Amounts	0% (0)	**46.7% (7)**	6.7% (1)	20.0% (3)	0% (0)	0% (0)	0% (0)	26.7% (4)		**22.2% (2)**
Observed soil moisture levels	0% (0)	35.3% (6)	5.9% (1)	11.8% (2)	0% (0)	0% (0)	0% (0)	**47.1% (8)**		**22.2% (2)**
Observed Snow Water Equivalent (SWE) Levels	0% (0)	5.9% (1)	0% (0)	23.5% (4)	23.5% (4)	5.9% (1)	0% (0)	**41.2% (7)**		**33.3% (3)**
Observed Snowpack Amounts	0% (0)	5.9% (1)	0% (0)	23.5% (4)	17.6% (3)	11.8% (2)	0% (0)	**41.2% (7)**		**33.3% (3)**
Observed Evapotranspiration (ET)	0% (0)	**43.8% (7)**	12.5% (2)	12.5% (2)	0% (0)	0% (0)	0% (0)	31.3% (5)		**11.1% (1)**
Observed ENSO signal	25% (4)	**31.3% (5)**	12.5% (2)	18.8% (3)	0% (0)	0% (0)	0% (0)	12.5% (2)		**33.3% (3)**

Boxes highlighted in orange indicate the most frequent temporal scale used by participants for each climate indicator listed. Boxes highlighted in blue indicate the largest percentage of participants who took the post-workshop survey that are now more likely to use the listed indicator after attending the workshop.

Table 3. Use of Forecasts to Help Guide Decisions.

	Not familiar with this indicator	Heard of this indicator, but never use it	Consult Yearly	Consult Seasonally	Consult Monthly	Consult Weekly	Consult More than Weekly	Depends on the Application		Post-workshop: % more likely to use indicator
Precipitation Forecasts	0% (0)	0% (0)	0% (0)	29.4% (5)	5.9% (1)	5.9% (1)	11.8% (2)	**47.1% (8)**		**33.3% (3)**
Temperature Forecasts	0% (0)	0% (0)	0% (0)	23.5% (4)	5.9% (1)	5.9% (1)	11.8% (2)	**52.9% (9)**		**33.3% (3)**
Streamflow Forecasts	0% (0)	5.9% (1)	0% (0)	35.3% (6)	5.9% (1)	5.9% (1)	0% (0)	**47.1% (8)**		**55.6% (5)**
Reservoir Storage Forecasts	0% (0)	**56.3% (9)**	6.3% (1)	6.3% (1)	0% (0)	0% (0)	0% (0)	31.3% (5)		**22.2% (2)**
Reservoir Inflow Forecasts	0% (0)	**62.5% (10)**	6.3% (1)	6.3% (1)	0% (0)	0% (0)	0% (0)	25.0% (4)		**22.2% (2)**
Snow Water Equivalent (SWE) Projections	0% (0)	23.5% (4)	5.9% (1)	17.6% (3)	23.5% (4)	0% (0)	0% (0)	**29.4% (5)**		**33.3% (3)**
ENSO Forecast	12.5% (2)	**43.8% (7)**	12.5% (2)	6.3% (1)	6.3% (1)	0% (0)	0% (0)	18.8% (3)		**44.4% (4)**

Boxes highlighted in orange indicate the most frequent temporal scale used by respondents for each climate indicator listed. Boxes highlighted in blue indicate the largest percentage of participants who took the post-workshop survey that are now more likely to use the listed indicator after attending the workshop.

Table 4. Use of Specific Tools, Products, and Datasets.

	Not familiar with this indicator	Heard of this indicator, but never use it	Looked at it, but never used it	Consult Yearly	Consult Seasonally	Consult Monthly	Consult Weekly	Consult More than Weekly		Post-workshop: % more likely to use indicator
US Drought Monitor	**33.3% (5)**	26.7% (4)	20.0% (3)	6.7% (1)	13.3% (2)	0% (0)	0% (0)	0% (0)		**27.3% (3)**
US Seasonal Drought Outlook	26.7% (4)	**40.0% (6)**	20.0% (3)	6.7% (1)	6.7% (1)	0% (0)	0% (0)	0% (0)		**45.5% (5)**
US Hazards Assessment	**68.8% (11)**	25.0% (4)	6.3% (1)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)		0% (0)
Palmer Drought Severity Index	**50.0% (8)**	18.8% (3)	0% (0)	6.3% (1)	25.0% (4)	0% (0)	0% (0)	0% (0)		9.1% (1)
Surface Water Supply Index	**53.3% (8)**	13.3% (2)	26.7% (4)	0% (0)	6.7% (1)	0% (0)	0% (0)	0% (0)		0% (0)
Standardized Precipitation Index	**46.7% (7)**	20.0% (3)	20.0% (3)	0% (0)	13.3% (2)	0% (0)	0% (0)	0% (0)		0% (0)
Vegetation Drought Response Index	**87.5% (14)**	6.3% (1)	6.3% (1)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)		9.1% (1)
Crop Precipitation Index	**68.8% (11)**	18.8% (3)	6.3% (1)	0% (0)	6.3% (1)	0% (0)	0% (0)	0% (0)		0% (0)
WWA Intermountain West Climate Summary	**56.3% (9)**	6.3% (1)	25.0% (4)	6.3% (1)	6.3% (1)	0% (0)	0% (0)	0% (0)		**45.5% (4)**

Climate Assessment for the Southwest Outlook	**56.3% (9)**	25.0% (4)	6.3% (1)	0% (0)	12.5% (2)	0% (0)	0% (0)	0% (0)		**9.1% (1)**
Climate Prediction Center Temperature Products	**86.7% (13)**	6.7% (1)	6.7% (1)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)		0% (0)
Climate Prediction Center Precipitation Products	**86.7% (13)**	6.7% (1)	6.7% (1)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)		0% (0)
NRCS State Basin Outlook Reports	12.5% (2)	18.8% (3)	12.5% (2)	**25.0% (4)**	**25.0% (4)**	6.3% (1)	0% (0)	0% (0)		**18.2% (2)**
Multivariate ENSO Index	**43.8% (7)**	37.5% (6)	0% (0)	6.3% (1)	6.3% (1)	6.3% (1)	0% (0)	0% (0)		**9.1% (1)**
Climate Prediction Center ENSO Update	**50.0% (8)**	18.8% (3)	12.5% (2)	6.3% (1)	6.3% (1)	6.3% (1)	0% (0)	0% (0)		**18.2% (2)**
Denver Water Watch Report	**87.5% (14)**	12.5% (2)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)		0% (0)
River Forecast Center Water Basin Outlook Reports	**43.8% (7)**	6.3% (1)	18.8% (3)	6.3% (1)	18.8% (3)	6.3% (1)	0% (0)	0% (0)		**9.1% (1)**
Tree ring paleohydrology reconstructions	——	——	——	——	——	——	——	——		**54.5% (6)**
Freezing Level Tool	——	——	——	——	——	——	——	——		**27.3% (3)**
GSFlow Model	——	——	——	——	——	——	——	——		**18.2% (2)**
VIC Hydrology Model	——	——	——	——	——	——	——	——		**54.5% (6)**
PRISM using Westmap	——	——	——	——	——	——	——	——		**54.5% (6)**
IRI for Climate and Society Maps	——	——	——	——	——	——	——	——		**9.1% (1)**
SNOTEL data	——	——	——	——	——	——	——	——		**27.3% (3)**

Workshop Results: Climate Information Resources

A key component of the evaluation was to survey the extent to which climate resources are accessible to and useful for participants. Participants were asked in the pre-workshop evaluation where they access climate information, and about their familiarity with particular resources, tools, and products designed for climate end-users. Those who indicated before the workshop that they do use climate information in decision-making primarily access information from Federal- or state-supported sources, as opposed to popular media, to inform their decisions. Post-workshop respondents indicated they would be even more likely to access such resources (Table 5).

Table 5. Having completed the workshop, how likely are you to use the following sources to find climate information…

	Less Likely	No Change	More Likley
TV	23.1% (3)	**76.9% (10)**	0% (0)
Newspaper	23.1% (3)	**76.9% (10)**	0% (0)
Magazine or Popular Journal	15.4% (2)	**76.9% (10)**	7.7% (1)
Scientific journals	0% (0)	**69.2% (9)**	30.8% (4)
Federal or state supported web sites, data portals, or publications	0% (0)	38.5% (5)	**61.5% (8)**
University web sites, data portals, publications, or products	0% (0)	46.2% (6)	**53.8% (7)**
Non-governmental organization (NGO) web sites, data portals, or publications	7.7% (1)	**61.5% (8)**	30.8% (4)

The median (50%) of responses is highlighted in yellow.

A follow-up question on the pre-workshop survey about specific sources found that only the National Weather Service, NOAA Climate Prediction Center, and State Climate Office resources were consulted by a majority of participants (Table 6). During the workshop, a broad suite of climate information resources were presented, and in the post-workshop evaluation, at least some to most of the participants indicated that they were now more likely to use many of the resources (Table 6, right hand column).

Comparison of the pre- and post-workshop evaluation responses suggests that the participants did not know about most of the available repositories of climate information, but respondents believe the information may be useful in the future.

Table 6. Participant Familiarity with Climate Information Sources.

	Never heard of it	Heard of this indicator, but never use it	Looked at it, but never used it	Consult Yearly	Consult Seasonally	Consult Monthly	Consult Weekly	Consult More than Weekly		**Post-Workshop: % indicating more likely to use resource**
NOAA Climate Prediction Center Forecasts	0% (0)	11.8% (2)	23.5% (4)	5.9% (1)	**35.3% (6)**	5.9% (1)	11.8% (2)	5.9% (1)		**54.5% (6)**
NOAA River Basin Forecast Center	6.3% (1)	18.8% (3)	**31.3% (5)**	6.3% (1)	18.8% (3)	6.3% (1)	6.3% (1)	6.3% (1)		**45.5% (5)**
NOAA, ESRL Southwest Experimental Precipitation Forecasts (K.Wolter)	**75.0% (12)**	6.3% (1)	18.8% (3)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)		**18.2% (2)**
National Weather Service Forecasts (NWS)	0% (0)	0% (0)	6.3% (1)	0% (0)	18.8% (3)	6.3% (1)	12.5% (2)	**56.3% (9)**		**9.1% (1)**
State Climatologist/Climate Center Websites	13.3% (2)	20.0% (3)	13.3% (2)	6.7% (1)	**33.3% (5)**	13.3% (2)	0% (0)	0% (0)		**45.5% (5)**
National Integrated Drought Information System Portal	**33.3% (5)**	26.7% (4)	13.3% (2)	0% (0)	26.7% (4)	0% (0)	0% (0)	0% (0)		**54.5% (6)**

Western Water Assessment Intermountain West Climate Summary	**50.0% (8)**	25.0% (4)	0% (0)	12.5% (2)	6.3% (1)	6.3% (1)	0% (0)	0% (0)		**54.5% (6)**
Climate Assessment for the Southwest Outlook	**66.7% (10)**	13.3% (2)	6.7% (1)	0% ())	0% (0)	6.7% (1)	0% (0)	6.7% (1)		**18.2% (2)**
Western Regional Climate Center (WRCC)	**43.8% (7)**	18.8% (3)	12.5% (2)	6.3% (1)	6.3% (1)	0% (0)	6.3% (1)	6.3% (1)		**90.9% (10)**
High Plains Regional Climate Center (HPRCC)	**93.8% (15)**	6.3% (1)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)		**9.1% (1)**
Southern Regional Climate Center (SRCC)	**87.5% (14)**	12.5% (2)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)		**0% (0)**
National Drought Mitigation Center (NDMC)	**64.3% (9)**	21.4% (3)	7.1% (1)	0% (0)	0% (0)	0% (0)	0% (0)	7.1% (1)		**0% (0)**
TreeFlow Website	—	—	—	—	—	—	—	—		**63.6% (7)**
USGS Groundwater Level Networks	—	—	—	—	—	—	—	—		**36.4% (4)**

Workshop Result: Participant Concerns about Climate

In the breakout session on day 1 of the workshop, participants were asked to brainstorm the most difficult and important challenges climate variability and change will pose for US Forests in the future. The list of potential climate impacts identified by participants is shown in Table 7. The colored "Xs" represent the different breakout groups/regions. The challenges highlighted in blue were challenges common to all the Western forests.

Table 7. What will be the Most Difficult and Important Challenges Climate Variability and Change will pose for US Forests in the Future?

Identified future challenges tied to climate variability and change	Region 1	Regions 10 & 2	Regions 5 & 6	Region 3 & 4
Reduction in surface and groundwater flows, corresponding impacts to recreation, energy, agriculture rights, municipal drinking water, aquatic species	X	X	X	X
Changes in reservoir operation procedures	X	X	X	X
Increase frequency and intensity of fires, average acres burned/fire event	X	X	X	X
Change in average snowpack (spatially, temporally)	X	X	X	X
Changes in species compositions especially in forest species, especially cold-water dependent fish, riparian and terrestrial ecosystems	X	X	X	X
Changes in forest health mortality and habitat and corresponding management practices	X	X	X	X
Endangered fish species tied to increase in stream temperatures, decrease in base lows, increase in peak flows, increase in forest	X	X	X	X
Impacts to water supplies tied to increase in hydrologic variability, increase in demand	X	X	X	X
Impacts to public health tied to increase disturbances, disease, toxic algae	X	X	X	
Increased occurrence and intensity of drought and resulting impacts on tree stress, beetle kills	X	X		
Threat to public safety resulting from impacts to infrastructure	X	X		X
More rain on snow events	X		X	X
Hydrograph shift resulting in: earlier peak flows, change in peak flows more rain on snow, earlier falling limbs, lower late season flow, lower summer flows	X			X
Increased water competition will result in shifting management objectives, new mitigation and adaptation planning efforts, new storage projects, increased water transfers	X			X
Loss of springs and wetlands tied to reduction in groundwater, slower recharge		X		X
Increased uncertainty in community & infrastructure planning		X		X
Glacial recession		X		
Increase in wet winters, dry summers		X		
Impact to groundwater recharge		X		X
Political, economic stress			X	X
Increase in flooding events tied to erosion			X	
Reduced water quality due to impacts to surface and groundwater supplies				X
Earlier streamflow peaks				X
Impacts to vegetation and affiliated impacts to wildlife, biodiversity stresses, beetles, grazing, invasives				X
Legal impacts, increase in litigation suits against USFS and other federal agencies				X

Subsequently, the breakout groups were asked to what would be needed to deal with the major challenges outlined in Table 7. These needs fell within four major categories (Table 8) and ranged from informational and data requirements, to adaptation initiatives, but predominately focused on monitoring, planning, and management needs instead of legal and policy approaches.

Table 8. Needs Identified by Participants for Dealing with Challenges Posed by Climate.

Climate, Hydrologic, and Drought Information and Monitoring Needs	Water Management
Emerging information and monitoring, of stream temperatures, earlier snowmelt trends, rain on snow occurrence,	Shift in water management objectives tied to changes in snowpack and hydrograph: increase incentive to focus on adaptation planning
Examine temporal and spatial changes in snowpacks	Need for increased storage projects
Determine cross-regional similarities and differences in changes in hydrographs	Need for increased water transfers as adaptation effort
Better understanding of the relationship between shift in hydrograph and impact on native species composition and habitat	Need for increased coordinated reservoir operations
	Assessment of current hydroelectric capacities, identify future areas of expansion

Public Education	Forest & Ecosystem Management
Increased education with public on projected changes to forest composition and corresponding state and national forests, parks	New restoration objectives: How to prioritize efforts? Where?
Increased education on hazards associated with increased disturbances: disease, water quality, toxic algae	Increase need for native species conservation
Increased public education during drought, high fire danger	Changes in forest composition requires change in management practices and objectives
Increased need for education and marketing campaigns during drought, fire events to maintain desirability of state and recreational resources	Need to direct funding into riparian, aquatic species monitoring and conservation
	Increase in erosion management: build channel resiliency, reduce river and riparian vulnerability to erosion
	Water system erosion, (headwaters area), decrease in channel stability (subsequent road and bridge issues), bank instability from grazing, decrease in grazing density
	Need for invasive species management

The overall trend in the breakout and subsequent group discussions reflected a central concern with non-stationarity in climatic and hydrologic systems and corresponding uncertainty. But despite the hurdles posed by using climate information, the challenge of overcoming institutional barriers within the USFS in order to use and implement climate-informed plans and management strategies was identified as a major challenge and highlighted as a major need in order to address other challenges.

Workshop Result: Participant Concerns about Bark Beetle Infestations

In the pre-workshop survey, participants were asked about the impact of bark beetle attacks in their area, partly to inform a separate WWA project. 15 of 17 respondents reported facing current or anticipated challenges posed by the bark beetle. Responses about the specific nature of those challenges varied widely, likely representing geographic and occupational differences among respondents. Many respondents discussed concerns about the impact of dead trees on fire behavior, the potential for forest cover changes to impact stream temperatures and other aspects of aquatic habitats, public safety, and the need to manage public expectations. 11 respondents also expressed the need for further scientific information to better inform planning and management decisions, including maps of areas vulnerable to future beetle infestations, potential treatment and mitigation options, changes in evapotranspiration due to canopy loss, and alternative vegetation management strategies to increase trees' resistance to beetle attacks.

Workshop Results: Scenario Activities

During the scenario exercises, participants wrote down their decisions on a worksheet, which were collected for analysis after the activity. After each game, the facilitator asked each person to discuss his or her thought process as they made their decisions. Notes were taken during the discussion, which were also used in the analysis.

Game A.

This game tested whether or not a fire forecast for increased fire potential would make a difference in the Sudden Aspen Decline (SAD) scenario. Individuals were asked to choose one priority action item to prevent the spread of SAD. Then they rolled a die. On a die roll of 1, 3, or 5, participants were given the following forecast: "Above-average fire potential is forecast for the project area for the period May–September. Above-average fire potential means that the region will likely experience long durations of fuel conditions and fire weather that support large fire activity, with the potential for multiple large fires at the same time." Participants who rolled a 2, 4, or 6 were given no additional information.

After rolling and receiving the information, participants were asked if they would change their priority action item or the timing of implementation of this action item. Table 9 shows that 5 out of 13 people given a forecast used it to change their decision. However, Table 10 shows that 10 out of 13 people incorporated the forecast into their decision. Sometimes the information influenced people to change their decision, and sometimes the information reinforced the decision they had already made. Even if someone did not change their decision based on the climate information, many were still incorporating it into their decision. By having participants describe their decision process, researchers were able to discern the participants who incorporated the information into their decision process, from those who did not.

Table 9: Change in Action Plan due to climate information

Forecast Info	Total	Change Action Item	Change Timing of Action	No Change
Forecast given	13	3	2	8
No forecast given	10	N/A	N/A	N/A

Table 10: Incorporating climate information into decision

Forecast Info	Total	Incorporated into Decision	Not Incorporated into Decision
Forecast given	13	10	3
No forecast given	10	N/A	N/A

Game B.

In this game, those who rolled a 2, 3, 4, 5, or 6 received one of five different climate forecasts, including: above average temperature, below average temperature, above average precipitation, below average precipitation, and above average drought forecast. Each forecast was for June, July, and August with a lead-time of three months.

Results suggest that the climate forecasts had even less influence in Game B than in Game A. Table 11 shows that only 3 out of 19 people who received a climate forecast changed their decision based on this information. Table 12 shows that more people (10 out of 19) incorporated the forecast into their decision, again because the information reinforced their original decision. Further research would be necessary figure out if and why there is a significant difference between the incorporation of some forecasts over others. For example, everyone who received the drought forecast incorporated it into his or her decision, while no one who received the above average temperature forecast incorporated it into his or her decision. This may suggest that the drought forecast was more easily interpreted or more easily incorporated into the decision necessary for this scenario than the temperature forecast. These results may point to the need for training on specific types of forecasts on how to interpret them and apply them to decision-making. Alternatively, these results could mean that the producers of forecasts need to better communicate the information in their forecast.

Table 11: Change in Action Plan due to climate information

Die Roll	Total	Change Action Items	Change Timing of Actions	No Change
1 No additional info	3			3
2 Drought likely	4		1	3
3 Temp below avg	5		1	4
4 Temp above avg	4			4
5 Precip below avg	4	1		3
6 Precip above avg	2			2

Table 12: Incorporating climate information into decision

Forecast Info	Total	Incorporated into Decision	Not Incorporated into Decision
1 No additional info	3	N/A	3
2 Drought likely	4	4	0
3 Temp below avg	5	2	3
4 Temp above avg	4	0	4
5 Precip below avg	4	3	1
6 Precip above avg	2	1	1

Games C-E.

These games aimed to test individual thresholds for uncertainty in climate forecasts. For each game, participants were given a climate forecast and asked to select their top management priority in the SAD scenario. Next they each rolled a die to determine the percent of certainty above equal chances that forecasters had in that forecast. Percents ranged from 10-90%. If someone rolled a 10%, this meant 10%

better than equal chances and 90% meant 90% better than equal chances. Participants were asked to write down any changes to their original management decision.

Each participant rolled the die again to receive a different percent of certainty that forecasters put into the forecast, and again write down any changes to his or her original management decision. The goal was to see if different levels of certainty in a forecast would determine whether or not the forecast would be incorporated into the decision process.

These three games produced inconclusive results. Most people did not change their decision based on the change in percentage of certainty in the forecast (see Table 13). These results suggest that most people based their decisions on the forecast itself rather than the level of certainty forecasters had in the forecast.

Table 13. Changes in decisions based on a change in percentage of certainty in the forecast.

	Number of participants who:	
	changed their decision	did not change their decision
Game C	3	15
Game D	3	15
Game E	1	16

Qualitative Results from the Decision Games and the Facilitated Group Discussion

Through qualitative analysis of the scenario activities and discussion sessions, researchers made the following observations about climate forecast use and organized them into five themes:

- How forecasts are used;
- Limitations and boundaries to forecast use;
- Usability and interpretation;
- Observations about historical trends; and
- Decision processes.

How forecasts are used:

- Climate forecasts are used best in conjunction with weather forecasts. Climate information may be useful to get a sense of the upcoming season, but Forest Service personnel currently seem to make decisions on a timescale closer to weather forecasts (1-7 days). As one participant said, “Climate information is too vague to make a decision on – we’d be watching what’s happening during the season and adjust, but really we’d be watching what’s happening on the ground.”
- People are more reliant on climate forecasts that are digested for them, such as climate summaries and emails from colleagues, rather than looking at the products themselves. For example, a participant wrote, “I definitely consider the drought outlook going into the seasons. I consider precipitation forecasts. But I don’t look at the maps, but I look at emails that come to me.”

Limitations and boundaries to forecast use

- There is a mismatch between the timescales of available climate information (monthly or seasonally) and the timescales of the decision-making process surrounding many Forest Service projects (daily or weekly).

- There is a spatial mismatch between climate information and local decisions. Climate forecasts generally refer to large regions, rather than specific locations. Many Forest Service resource management decisions are made at a local scale, rather than a regional scale.
- Climate forecasts are seen as more relevant to policy-making, funding requests, and public relations than to resource management decisions (except for fire management).
- Other factors, such as agency policies and economics, generally trump forecast use. Many participants suggested that agency protocol, timelines, and budgets determine the long-term decisions made, rather than climate information.

Usability and interpretation

- Many workshop participants misinterpreted the Climate Forecast Center's 3-month Temperature and Precipitation forecast maps during the first scenario exercise. While tercile probability maps are difficult to interpret, an alternative has yet to be produced. Without proper training, these maps could be used incorrectly or deemed useless.
- We were unable to test people's thresholds for uncertainty (or certainty) in climate forecasts. In the game exercises, most participants did not change their answers when informed of new levels of certainty forecasters had in the forecast. They made their decisions based on the climate forecast itself, despite the percentage of certainty in the forecast.

Observations about historical trends

- Historical climate information can serve as a tool of evaluation and assessment, to help the decision-maker choose what to prioritize.
- Even the best historical climate information is not fully trusted. Most participants said they would need to compare it with other historical records and on-the-ground monitoring.
- When looking at historical climate trends, most people focused on the extreme wet and dry periods.

Decision processes

- Most participants stuck to their decisions regardless of what the climate forecast looked like, but in their decision process, many people actually considered the climate information. Participants often used the forecasts to reaffirm their original decision; in a few cases, the forecasts caused people to modify their decisions.

Climate information is often used in the creation of a mental model, or the creation of an idea or feeling about an upcoming season. As one participant put it, "The forecast is just something you're aware of. If [weather] conditions actually occur, this may trigger action." Climate forecasts seem to play a supporting role in the decision process, but this makes the value of climate forecasts difficult to separate from other types of information used in the decision process.

APPENDIX I: AGENDA

Western Watersheds and Climate Change - Water and Aquatic System Tools Workshop
November 17-19th; Boulder CO

The workshop will be structured in three sections: 1) an introduction to available climate information and data products; 2) hands-on introduction to tools for assessing the implications of climate change on watershed and aquatic system management; and 3) interactive sessions to engage managers and scientists in prioritizing needs for new data products and tools.

November 17

1:00 pm	Greetings Chuck Rhoades, USFS; Session Moderator
1:15 pm	Group Participation - Manager's experience with weather/climate challenges Linda Joyce, USFS
2:00 pm	USFS Project Screening Tool Linda Joyce
2:15 pm	Climatology and the Readily Available Observational Data Kelly Redmond Western Regional Climate Center, DRI
3:15 pm	Break
3:40pm	Quick Activity (Kristen Averyt)
3:45 pm	Climate Models and Climate Scenarios Joe Barsguli, NOAA-CIRES Western Water Assessment
4:45 pm	Discussion (Kristen Averyt) Identify Potential Regional Climate Challenges
5:30 pm	Close for the Day
7:00 pm	Keynote Address Eric Kuhn - Colorado River Water Conservation District

November 18

8:00 am	Greetings – Existing Tools, Session Moderator (Polly Hays)
8:15 am	Thermal regimes and aquatic systems Dan Isaak, USFS Rocky Mountain Research Station
8:45 am	Collecting, organizing, and applying stream temperature data: examples from central Idaho Dan Isaak, USFS Rocky Mountain Research Station
10:00 am	Break
10:15 am	Adapting the VIC hydrologic model for headwater streams in the West Seth Wenger, Trout Unlimited
11:00 am	Western Water and Climate Change: A Utility's Perspective David Yates, NCAR
12:00	Lunch
1:00 pm	Greetings – Climate Challenges – Few Tools, Session Moderator (Andrea Ray)
1:15 pm	Using Climate Change Information in Reclamation Planning - Case Study Examples Levi Brekke, Bureau of Reclamation
2:00 pm	Dendrochronology – Using trees to reconstruct historic streamflow records Jeff Lukas, NOAA-CIRES Western Water Assessment
2:45 pm	Examples of USGS groundwater activities related to western watersheds and climate change

Pete McMahon, USGS

3:30 pm Influence of dust on snowmelt and high elevation hydrology
Chris Landry, Center for Snow and Avalanche Studies

4:15 pm Break

4:30 pm Panel Discussion: Management and Legal Challenges
Addressing Climate Change in Water Resources Management: User Priorities for Improving Tools and Information
(Levi Brekke, Bureau of Reclamation)
Climate change litigation
(Randy Bramer; USDA Office of General Council)
Engineering concerns
(Bill Schelmerdine, USFS)

5:15 pm Discussion
What tools can be used to address climate impacts?

5:30 pm Close for the day

November 19

8:00 am Greetings – Pulling the Information Together, Session Moderator
(Ashley Cobb)

8:15 am Vulnerability Assessment for hydrologic and aquatic systems
Michael Furniss, USFS Pacific Northwest Research Station

9:15 am Adaptation Planning Frameworks – synthesizing information for a decision
Linda Joyce, USFS Rocky Mountain Research Station

10:15 am Break

10:30 am Challenges for Conserving and Managing Aquatic Systems under a Changing Climate
Bruce Rieman, Keynote Speaker, USFS Rocky Mountain Research Station

11:00 am Discussion

12 noon Lunch

1:00 pm Greetings – Developing a Regional Strategy

1:15 pm Scenario Gaming Activity: SOPA Activity: led by Gigi Owen

2:30 pm Break

2:45 pm Scenario Planning Exercise: led by Gigi Owen

3:30pm Discussion (Chuck Rhoades and Linda Joyce)
What information tools are needed to manage for climate change?

4:00 pm Panel Discussion - What is on the Horizon?
Integrated Water Resources Science and Services NOAA/NWS
Kelly Elder, RMRS & Don Cline, NOAA/NWS
National Climate Service
(Andrea Ray or Robin Webb)
USFS climate change research
Frank McCormick, USFS Air, Water and Aquatics Program

4:45 pm Workshop Follow-up

5:30 pm Close out

APPENDIX II: USFS Participants

Name	Title	Location	Region	Unit	Email
Baker, Sarah	EMS Representative	Albuquerque, NM	3	RO	sbaker02@fs.fed.us
Barndt, Scott	Fishery Biologist	Bozeman, MT	1	Gallatin NF	sbarndt@fs.fed.us
Bennett, Karen	Regional Soil Scientist	Portland, OR	6	RO	kabennett@fs.fed.us
Callery, David	Forest Hydrologist	Helena, MT	1	Helena NF	dcallery@fs.fed.us
Coleman, Angela J.	Hydrologist	Ketchikan, AK	10	Ketchikan-Misty Fiords RD, Tongass NF	ajcoleman@fs.fed.us
Gritzner, Jason	Hydrologist	Sandpoint, ID	1	Idaho Panhandle NF	jgritzner@fs.fed.us
Hopson, Rick G.	Hydrologist	Ogden, UT	4	Wasatch-Cache NF, Ogden RD	rhopson@fs.fed.us
Howe, Carol	Hydrologist	Delta, CO	2	Grand Mesa, Uncompaghre, Gunnison NFs	chowe@fs.fed.us
Jemison, Roy	Regional Hydrologist	Albuquerque, NM	3	RO	rjemison@fs.fed.us
John, Tommy	Assistant Regional Soil Scientist	Golden, CO	2	RO	tjohn@fs.fed.us
Konnoff, Deborah L.	Regional Fish Habitat Relationship Specialist	Portland, OR	6	RO	dkonnoff@fs.fed.us
Mitchell-Bruker, Sherry	Forest Hydrologist, Watershed Program Manager	Susanville, CA	5	Lassen NF	smitchellbruker@fs.fed.us
Morrison, James F	Staff Assistant to Deputy Director	Missoula, MT	1	RO	jfmorrison@fs.fed.us
Norman, Sue	Forest Hydrologist, Physical Sciences Group Leader	South Lake Tahoe, CA	5	Lake Tahoe Basin Management Unit	snorman@fs.fed.us
Overton, Kerry	Fisheries Technology Transfer	Boise, ID	1&4	1&4 RMRS	koverton@fs.fed.us
Prussian, Katherine	Hydrologist	Cour d'Alene	1	Coeur d'Alene River RD, Idaho Panhandle NF	katherineprussian@fs.fed.us
Regan, Claudia	Regional Vegetation Ecologist	Lakewood, CO	2	RO	cregan@fs.fed.us
Schroder, Eric	Soil Scientist	Boulder, CO	2	Arapaho-Roosevelt NF, Boulder RD	eschoder@fs.fed.us
Spaulding, Scott	Fish Program Manager	Missoula, MT	1	RO	scottspaulding@fs.fed.us
Staab, Brian	Regional Hydrologist	Portland, OR	6	RO	brianstaab@fs.fed.us
Unthank, Amy	Fisheries Program Manager	Albuquerque, NM	3	RO	aunthank@fs.fed.us
Whitacre, Heath W.	Hydrologist	Petersburg, AK	10	Tongass NF, Petersburg RD	hwhitacre@fs.fed.us