Informing Decisions with a Climate Synthesis Product: Implications for Regional Climate Services

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ABSTRACT

The demand for regional climate information is increasing and spurring efforts to provide a broad slate of climate services that inform policy and resource management and elevate general knowledge. Routine syntheses of existing climate-related information may be an effective strategy for connecting climate information to decision making, but few studies have formally assessed their contribution to informing decisions. During the 2010–11 winter, drought conditions expanded and intensified in Arizona and New Mexico, creating an opportunity to develop and evaluate a monthly regional climate communication product—*La Niña Drought Tracker*—that synthesized and interpreted drought and climate information. Six issues were published and subsequently evaluated through an online survey. On average, 417 people consulted the publication each month. Many of the survey respondents indicated that they made at least one drought-related decision, and the product at least moderately influenced the majority of those decisions, some of which helped mitigate economic losses. More than 90% of the respondents also indicated that the product improved their understanding of climate and drought, and that it helped the majority of them better prepare for drought. The results demonstrate that routine interpretation and synthesis of existing climate information can help enhance access to and understanding and use of climate information in decision making, fulfilling the main goals for the provision of climate services.

1. Introduction

The impacts of climate change and variability are well documented. In the western United States, increasing temperatures (USGCRP 2009) and changing precipitation patterns (Knowles et al. 2006; McAfee and Russell 2008) are influencing the size and frequency of wildland fires (Westerling et al. 2006), the timing of peak streamflows (Stewart et al. 2005; Hidalgo et al. 2009), the water content in April snowpacks (Mote et al. 2005), and the severity of drought (Weiss et al. 2009), among other impacts. These changes directly impact resource management and can be costly, underscoring the need for a steady and accurate flow of climate-related information to help decision makers prepare for and adapt to evolving conditions (Miles et al. 2006). Although connecting emerging science to decision makers does not always lead to better outcomes (Moser 2010), climate information has little chance of being incorporated into the decision process when it is communicated poorly or not at all (e.g., Vogel et al. 2007).

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Weather and climate information can influence economic and social activity across broad spectrums of society. While the National Weather Service (NWS) primarily focuses on providing information to consumers on time scales germane to weather issues (i.e., hours to weeks), the creation and delivery of longer-term climate information relevant to decision making (i.e., seasons to decades) has received less attention and organization. Over the past few decades, however, the skill of seasonal climate forecasts has increased, knowledge of the social and environmental impacts of climate variability and change has expanded, and climate models have become capable of generating useful information over seasonal to century time scales. These advances have stimulated the use of climate information and are escalating its demand (Solomon and Dole 2009; NRC 2009; DeGaetano et al. 2010). As a result, many academic and federal programs are emerging in the United States to help satisfy this demand, including the Department of the Interior's Climate Science Centers and Landscape Conservation Cooperatives, the National Oceanic and Atmospheric Administration's (NOAA) creation of regional climate service directors and climate service focal points within the NWS, and a proposed new office in charge of coordinating U.S. federal climate services (Solomon and Dole 2009; NRC 2009).

The goals of climate services articulated by the World Meteorological Organization (WMO 2009, p. 162) are to "enable climate adaptation and climate risk management through the incorporation of science-based climate information and prediction into policy and practice at all levels". To accomplish this, a broad array of activities is needed, including data stewardship and analysis, provision of seasonal climate outlooks, and downscaling global climate models (e.g., Miles et al. 2006). Aside from these more well-known climate services, the creation and dissemination of synthesized and translated climate information is also necessary—a particularly acute need since climate outlook products are frequently misinterpreted (Steinemann 2006; Hartmann et al. 2002)—as is research on effective information delivery mechanisms (NRC 2009). However, in the emerging literature on climate services, synthesis and translation of climate information in routine summaries are often overlooked as useful activities, perhaps because of a lack of empirical evidence that documents their contributions to decision making.

This paper presents results from the evaluation of a monthly climate summary—*La Niña Drought Tracker* (hereafter *Tracker*)—that amalgamated and interpreted existing information focused on climate and drought for decision makers in Arizona and New Mexico. The *Tracker* was developed as an experimental climate service to understand if and how it helped the region prepare for and respond to widespread and extreme drought conditions. Results from this study demonstrate that the *Tracker* contributed to many drought-related decisions and helped the respondents better understand and prepare for climate changes and drought, suggesting that climate summaries can be effective services to improve understanding of, access to, and use of climate information.

In this paper we present evidence, for the first time to our knowledge, that value-added syntheses fulfill main goals of the provision of climate services, bolstering our contention that efforts like the *Tracker* should be part of a diverse portfolio of climate service activities. While we recognize that our evaluation reveals more about the process of information transfer than the outcomes spurred by reading the *Tracker*, certain qualities of the *Tracker* appear to favor improved understanding and decision quality. Therefore, we also present the characteristics of the *Tracker* that facilitated its use, providing general guidance for future efforts that synthesize existing climate-related information for decision makers.

2. *Tracker*

In June 2010, a La Niña event rapidly developed. Historical statistics and seasonal outlooks produced by the NOAA Climate Prediction Center (CPC) suggested the U.S. Southwest would likely experience below-average precipitation during the ensuing winter. Anticipating expanding and intensifying drought conditions in Arizona and New Mexico, and based on increases in demand for climate information during past drought events in the West (Lowrey et al. 2009), the Climate Assessment for the Southwest (CLIMAS) developed the *Tracker* with the dual purpose of helping regional stakeholders better prepare for drought and testing the efficacy of a climate service. CLIMAS is one of 11 NOAA-funded Regional Integrated Sciences and Assessments (RISA) programs charged with connecting climate science to regional decision making. Between December 2010 and May 2011, CLIMAS published six issues of the *Tracker,* a period when precipitation in Arizona and New Mexico was 65% and 39% of the 1971–2000 average, respectively, and drought expanded and intensified widely across both states (Fig. 1). The success of the *Tracker* led to six more publications during the ensuing winter when La Niña returned.

The *Tracker* was a two-page document focused on Arizona and New Mexico and published in portable document format (PDF) and hypertext markup language (HTML) format (http://www.climas.arizona.edu/outlooks/drought-tracker). It contained five sections:

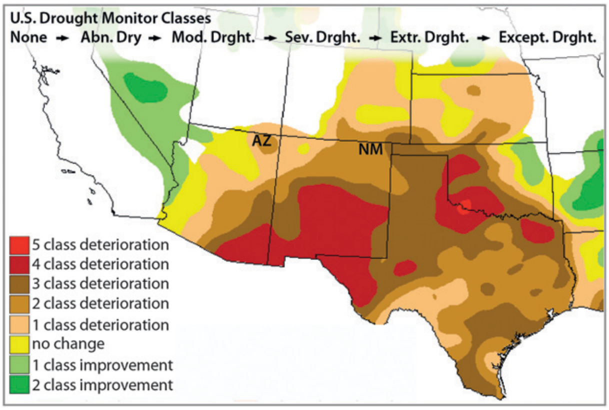

FIG. 1. Change in the U.S. Drought Monitor class between 30 Nov 2010 and 26 Apr 2011. Deterioration in drought conditions moves from left to right between classes, following the arrows at the top of the figure; improvements move in the opposite direction. Regions colored in white where not classified with drought on 30 Nov 2010 and 26 Apr 2011. Figure is modified from NOAA's Climate Prediction Center.

a 350-word summary of current drought conditions, an explanation of snowpack conditions, an explanation of the current 3-month seasonal precipitation outlook issued by the CPC, a list of take-home messages, and supplemental figures (published only online). The supplemental figures bolstered written statements, providing more details without compromising the document's brevity. Contributing authors consulted numerous data sources and routinely talked to regional experts, including state climatologists, university scientists, NWS meteorologists, and Cooperative Extension System specialists. These conversations provided insights for the written material that otherwise were not easily accessible.

CLIMAS disseminated the *Tracker* to its listserv of about 1400 active e-mail addresses; the listserv grew by 56 during the time of the six publications. Monthly e-mails briefly highlighted each section (excluding supplemental figures) and included links to the document's full PDF and HTML versions. E-mail tracking documented that, on average, 417 people opened the summary e-mails and an average of 160 people clicked on the PDF or HTML links. This represents a minimum estimate of the number of *Tracker* users; we did not track visits to the webpages or downloads of the PDF from the webpages. The survey also revealed that some respondents forwarded the e-mails or broadcasted the publications via their social network channels, metrics that we were also unable to quantify.

3. Evaluation method

We conducted an online survey that contained 36 questions: 13 Likert-scaled questions (5 points), 12

TABLE 1. These 14 questions provided quantitative and qualitative data predominantly used in the analysis. The type of question and number of respondents who answered the question are indicated; contingent analysis reduced these numbers for some of the analysis presented.

Survey question	Format	No.
1. Did the *Tracker* help you be more prepared for drought conditions?	Likert	140
2. Did your understanding of drought conditions improve by reading the *Tracker*?	Likert	140
3. Did the *Tracker* improve your understanding of climate?	Likert	140
4. Through the course of last winter, did you make a decision(s) based on drought conditions or expectations?	Fixed	120
5. In the absence of the *Tracker*, would you get the information presented in the *Tracker* from another source or sources?	Fixed	120
6. Of all the things you used to influence your job-related decision(s), the *Tracker* was of ____ importance.	Fixed	120
7. Can you provide an example of how you used the *Tracker*?	Fixed	120
8. Did reading the *Tracker* lead you to investigate/consult other climate or drought-related sources?	Fixed	121
9. During La Niña winters, would you prefer the *Tracker* be available______?	Fixed	121
10. What decisions (if any) did you make based on drought conditions or drought expectations?	Open	51
11. What was most useful about the *Tracker*?	Open	100
12. Why did you read the *Tracker*?	Open	107
13. In what positive and negative ways was the *Tracker* different from other drought summaries?	Open	81
14. What useful information was missing?	Open	81

fixed-item questions, and 11 open-ended questions. All fixed-item and Likert-scaled questions were mandatory.

We sent three solicitation e-mails to the listserv during a 3-week span that began in June 2011 about six weeks after the final publication for the 2010/11 winter. The initial solicitation was sent to 1432 active e-mail addresses that had been assembled from the monthly dissemination, a climate newsletter called the *Southwest Climate Outlook* (*SWCO*, first published in 2002). A total of 140 people responded to the survey (10% response rate), and 117 people completed all mandatory questions. Only one respondent had not read the *Tracker* at least once.

The results presented here are based on the 14 questions listed in Table 1. The questions helped determine 1) whether the respondents perceived the *Tracker* to have improved their understanding of drought and climate, 2) if and how they perceived the *Tracker* to have helped inform their decisions, and 3) the characteristics

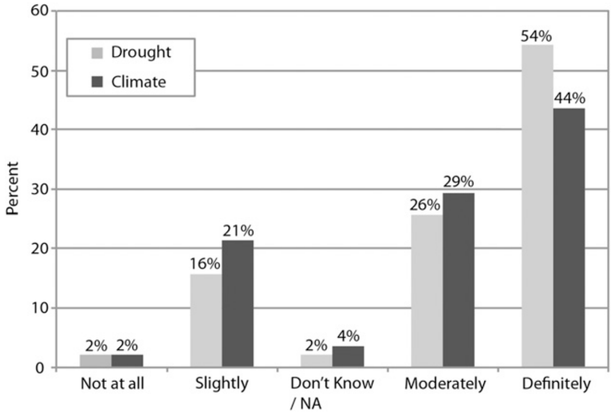

FIG. 2. The percentage of respondents whose understanding of drought and climate changed by reading the *Tracker*, out of 140 total responses. Questions 2 and 3 in Table 1 present the language of the corresponding survey questions.

respondents liked about the publication. Table 1 also reports the corresponding response frequency because the number of respondents for the open-ended, non-mandatory questions differed. For clarity, we present only the response rates in the text and refer the reader to Table 1 for further details. In some cases, contingent analysis partitioned the data we analyzed. For these results, we note in the text the number of responses analyzed.

The survey sampled diverse users. The 117 respondents who answered the mandatory questions self-identified themselves in 19 different specified sectors. Many respondents represented government (18%), academia/research (14%), and water management (13%). Three respondents also identified themselves as working in the media.

Quantitative analysis of the fixed-item and Likert-scaled questions was predominantly based on descriptive statistics and, where appropriate, was combined with contingent analysis to a subset of the data. For non-mandatory, open-ended questions, two authors independently performed content analysis coded by key themes. Coding consistency was very high, and the authors subsequently reconciled the few differences.

4. Results

a. Improved understanding of drought and climate

Survey results show that most respondents self-reported an improved understanding of both climate and drought by reading the *Tracker* (Fig. 2). The *Tracker* at least ''slightly'' improved understanding of climate for 94% of the respondents, while 44% indicated it ''definitely'' improved their understanding. For drought, the *Tracker* improved understanding at least ''slightly'' for 96% of the respondents and ''definitely'' for 54%.

During the 2010–11 winter, 58% of the respondents reported making at least one drought-related decision. Of this group of 67 respondents, only three stated the *Tracker* either did not improve their understanding of drought or they did not know if it improved their understanding. With respect to climate, four respondents in the group stated the *Tracker* either did not improve their understanding of climate or they did not know if it did.

b. Informing decisions

Respondents ranked the importance of the information in the *Tracker* relative to all other sources that influenced their decision(s). Of the 67 people who made a drought-related decision, 84% stated the *Tracker* was at least ''slightly'' important for the decision. It played a ''moderate'' and ''significant'' role for 36% and 21% of the respondents, respectively. Only 16% said it was not influential. Moreover, 98% of the decision-making respondents stated the *Tracker* was at least ''slightly'' important in helping them be more prepared for drought, and 54% indicated the *Tracker* ''definitely'' helped them be more prepared.

The *Tracker* also improved respondent's access to information. For example, of the 67 respondents who made a drought-related decision, 31% stated they would not have had time to search for the information presented in the *Tracker* in its absence. Another 58% indicated they would obtain elsewhere only some of the information presented in the *Tracker*.

The respondents used the *Tracker* in different ways. In a fixed-response question, more than 60% of the survey respondents stated they used the *Tracker* to monitor the evolving drought, learn about seasonal precipitation forecasts, and/or stay abreast of current weather conditions (Table 2). These uses helped inform many drought-related decisions. While we are unable to assess the impact of these decisions on welfare and resource management, Table 3 summarizes notable decisions that appear to have important outcomes and/or economic implications and highlights the diversity of decisions this climate synthesis informed. Table 3 also lists the qualitative measure of influence the *Tracker* had on the corresponding decision relative to all other sources of information consulted and documents whether the respondent would have obtained the information presented in the *Tracker* had it not been published.

For the 67 respondents who made a least one drought-related decision during the winter, reading the *Tracker* prompted 61% of them to seek more information. For 58% of these people, reading the *Tracker* increased their

TABLE 2. Frequencies and response rates corresponding to uses of the *Tracker* identified to the fixed-response question, ''Can you provide an example of how you used the *Tracker*?'' The language of the survey question is presented in the first row. One hundred twenty respondents answered the survey question, and the respondents could select multiple uses. Response rate corresponds to the percentage of respondents who selected the corresponding use.

Fixed-response options	Frequency	Response rate (%)
To keep track of evolving drought conditions	98	81.0
To learn about seasonal precipitation forecasts	85	70.2
To stay abreast of weather conditions	73	60.3
To aid in teaching and communicating climate and weather to others	53	43.8
To assess water supply	49	40.5
To assess fire hazard	38	31.4
To assess impacts on agriculture	26	21.5
Other	23	19.0
To anticipate groundwater recharge	19	15.7
To properly tend my garden	13	10.7

concern for drought. This suggests the *Tracker* may have acted as a siren that instigated additional inquiry to aid their decision making.

c. *Beneficial characteristics of the* Tracker

In a fixed-response question, 69% of the respondents said they preferred that the *Tracker* be published monthly, while 21% stated bimonthly, 7% stated weekly, and 3% noted that one ''summary'' per season was preferred. This conformed to the frequency in which respondents consulted the *Tracker*—77% stated they viewed it almost every month or once a month. Also, 23% indicated seasonal precipitation forecasts were the most useful (respondents often indicated numerous ''most useful'' qualities). Survey respondents also highlighted the usefulness of the graphics (22%); the clarity, translation, and explanation of the text (22%); and the concise and summary nature of the publication (16%). In a separate question, respondents identified characteristics of the *Tracker* that differentiate it from other drought summaries they consulted. Table 4 summarizes the results for that question.

5. Discussion

a. *Information brokers*

Dilling and Lemos (2011) summarize traditional models of the creation and application of science that have been developed from a long history of scholarship. On one end is ''science push,'' which occurs when questions are defined and pursued by scientists who are driven by the pursuit of knowledge and not explicitly by the application of the information. The other end is characterized as ''demand pull,'' which occurs when research is commissioned by stakeholders so that results can inform particular problems. A third mode, referred to as the coproduction of science, resides in the middle and incorporates concepts of each. Its ideal form is an iterative collaboration between the producers and users of science.

TABLE 3. Select survey responses to the question, ''What decisions (if any) did you make based on drought conditions or drought expectations?'' combined with the importance the respondents assigned to the information presented in the *Tracker* (survey question 6, Table 1) and whether the information in the *Tracker* would be obtained had it not been published (survey question 5, Table 1).

Survey responses	*Tracker* importance	Obtain information elsewhere
Drafting a [tribal] nation drought affirmation and submitting proposal to Bureau of Reclamation drought authority	Significant	Yes, some
Provide recommendations on moving cattle to [healthier] areas	Significant	Yes, some
Preparations for assisting local farmers and ranchers in Farm Bill disaster programs	Significant	Yes, some
Adjusting ranch stocking rates for anticipated drought	Significant	Yes, some
Education program for ranchers; delayed irrigation as long as possible	Significant	Yes, some
Prepare emergency response plans and vulnerability assessments with rural utilities; plan conservation measures for rural utilities	Significant	No, no time
We correctly cancelled our rafting season even though some of our competitors opened for a miserable low water season.	Significant	Yes, some
Water system operations and budget planning	Significant	Yes, some
Drought status for the [city's water utility] is, in part, dependent on drought conditions reported in the *Tracker*	Moderate	Yes, some
Prescribed fire go or no-go decisions	Moderate	Yes, all
Postponed some large capital expenditures; moved others forward	Moderate	Yes, some
Reservoir operation decisions based on expected worsening drought conditions	Moderate	Yes, some
Selling cattle; watering crops	Moderate	Yes, some
Fire restrictions	Slight	Yes, some

TABLE 4. Characteristics identified in an open-ended question that differentiated the *Tracker* from other drought summaries and their attendant frequency and response rate. Eighty-one respondents answered the survey question, ''In what positive and negative ways was the *Tracker* different from other drought summaries?'' Content analysis determined the themes (see methods). Response rate corresponds to the percentage of respondents who identified the corresponding theme. Responses could relate to multiple themes.

Survey response themes	Frequency	Response rate (%)
Regionally specific	26	32.1
Easy to understand	20	24.7
Combined information from multiple sources	17	21.0
Concise	12	14.8
Other	12	14.8
Visually aesthetic	10	12.3
Do not know	10	12.3
Synthesized and analyzed information	8	9.9
Comprehensive	7	8.6
Relevant and timely	6	7.4

It is generally acknowledged that climate information is less useful for decision making if it follows the science push mode (Dilling and Lemos 2011; Lemos and Morehouse 2005; McNie 2007; NRC 2009; Sarewitz and Pielke 2007) because it can create a mismatch in the spatial and temporal scales of the information produced by scientists and needed by decision makers (Srinivasan et al. 2011) and generate inaccessible information (Steinemann 2006), among other reasons. However, potentially useful information has been, and will continue to be, created in the science push mode. It is a role of climate services to make this information more useable by traversing the middle ground between science push and demand pull. This interaction can take many different forms. The *Tracker,* for example, was not explicitly coproduced with end users. Rather, it leveraged CLIMAS's institutional knowledge of regional issues, information needs, and decision-support tools cultivated from more than 12 years of applied research and stakeholder engagement. This includes drawing insight from experience with the publication of the *Southwest Climate Outlook* (http://www.climas.arizona.edu/outlooks/swco) as well as an unpublished, internal assessment of it. The regional utility of the *Tracker,* revealed through the evaluation presented here, demonstrates that boundary organizations like CLIMAS can apply their contextual knowledge to develop useful products without engaging in the ideal version of coproduction, which can be time consuming and costly (Lemos and Morehouse 2005).

b. *Utility of synthesized and interpreted information*

Useful climate services often are those that develop and deliver timely, relevant, and credible information at spatial and temporal scales that mesh with different decision contexts and that convey meaning and significance of climate information (e.g., NRC 2001, 2009; Miles et al. 2006). Our results demonstrate that the synthesis and translation of climate information in routine summaries can provide relevant information that informs decisions. Specifically, the *Tracker* improved understanding of climate and drought for nearly all of the people who responded to the survey. Although we did not quantify how this enhanced understanding translated into actions, increasing the climate knowledge of decision makers can help advance climate adaptation (Howden et al. 2007) and foster successful climate policy and planning (Solomon and Dole 2009; Moser 2010). In addition, the *Tracker* helped respondents better prepare for drought conditions by contributing, sometimes ''significantly,'' to many decisions (Table 2). Some of these decisions improved resource management and mitigated economic losses, such as preparing emergency response plans for rural utilities; informing mediators who helped farmers take advantage of economic assistance programs during drought; and influencing the early termination of a rafting company's seasonal operations, which likely saved labor and other costs.

Climate summaries can also improve the accessibility of information. The *Tracker*, for example, provided information that would otherwise not be obtained for 91% of the respondents who made at least one drought-related decision. Many respondents also stated they would not have time to obtain the information in the *Tracker* had it not been published. This suggests an important role of climate summaries is to amalgamate information from disparate sources, which reduces the burden on the information consumers. The NRC (2009) notes that inaccessible information is often not incorporated into the decision-making process, which can potentially leading to less desired outcomes. Lowrey et al. (2009) inferred from the experience of providing climate information to water managers during a protracted dry period that increasing the availability of climate information can help water managers better comprehend and use climate information. Also, the *Tracker* prompted many people—including those who made a drought-related decision—to seek additional information that potentially could have enhanced decision quality.

c. *Developing climate summaries*

Many climate summary products are produced and disseminated, and a typology of their characteristics is beyond the scope of this paper. However, because these efforts have either not been evaluated or the evaluations are unpublished, it is unknown to what extent users value the characteristics unique to each. Our results provide evidence of the qualities respondents deemed useful about the *Tracker*. Caution, however, should be exercised when generalizing these results because different users and uses will require different characteristics.

The *Tracker* likely informed many decisions because of a combination of factors, some of which were more important than others depending on the individual and decision context. Characteristics identified as ''most useful'' included the translation of information, clear explanations, and its concise format. However, only 6% of the respondents stated they found the Southwest focus most useful and in a separate, open-ended question, only 19% stated they read the *Tracker* because it focused on the Southwest. These results were surprising, given that 32% of the respondents identified ''regionally specific'' as a quality that differentiated the *Tracker* from other drought summaries, and other researchers have noted that decision makers often desire information placed within regional contexts (Dow et al. 2009) and want decision-support tools that focus on specific areas (e.g., Miles et al. 2006; NRC 2001, 2009). We suspect the lower-than-expected percentage of people who expressed the regional value of the *Tracker* (6%) stemmed from the fact that the information in it was too coarse to be considered the ''most useful'' characteristic. In a separate, open-ended question, for example, some respondents articulated the need for more site-specific information (see next section). Also, the low response rate of 19% may have resulted because we did not explicitly ask about the appropriateness of the scale of information presented, a more specific question that might have provided different results. Nonetheless, respondents did not identify the regional scale (i.e., too large a scale) as a reason for disregarding the *Tracker*.

Publication of the *Tracker* required approximately 15–20 h of labor each month; substantially more effort was needed to develop the template and produce the first issue. The bulk of the work involved researching current and future conditions, obtaining and modifying graphics, writing and editing text, and producing HTML and PDF versions. A key element to adding value to these synthesis efforts is identifying and leveraging local expertise, a task that boundary organizations like CLIMAS are well positioned to achieve. We believe this is a relatively small investment given the number of people who consulted the *Tracker* and some of the decisions informed by it.

The *Tracker* also provided other benefits. These included spurring dialog (readers often contacted CLIMAS following publications), building relationships (the *Tracker* inspired a collaborative project between CLIMAS and two federal organizations), developing CLIMAS capacity in climate services, and increasing media exposure (authors routinely provided interviews related to the content of the *Tracker*).

d. Challenges and opportunities with synthesis products

Climate synthesis products are not as easy to produce as they might appear to be. Although they do not require creating new information, for most audiences they should artfully translate scientific jargon and concepts into less technical language while retaining sufficient detail. Vogel et al. (2007), for example, stated that if information is difficult to understand and interpret, then even the most valuable information might not be noticed. Hartmann et al. (2002) also noted that even the best forecasts can be useless if users misinterpret them. A main objective of the *Tracker* was to avoid recapitulating technical language, and many survey respondents stated the *Tracker* was useful because it was clearly and concisely written, devoid of jargon, and included explanations and interpretations of the information presented. These characteristics required blending capacity in climate science (to understand the source information), knowledge of regional needs (to know what information to present), and skills in science communication.

Climate summaries also require committed time and financial resources and present outputs and rewards that often do not mesh with traditional academic incentives. Climate synthesis products, for example, often do not lead to peer-reviewed publications on which academic tenure is primarily based. The mismatch between incentives and outputs is also a challenge for other climate services activities (Jacobs et al. 2005). While peer-review publications about climate summaries are scant, they do involve the systematic collection of information, interpretation, reflection, and production of knowledge, all of which meet academic criteria necessary for publishing. There are also many examples of meshing service and research, including evaluating decision-support tools (i.e., Hartmann et al. 2002), testing effective dissemination strategies, quantifying outcomes, and communicating science (i.e., Moser 2010).

Additionally, most academic research occurs on master's degree and doctoral degree time scales, which require planned timelines and projects to secure funding and graduate students. This can inhibit responding to unanticipated events, such as the rapid transition to La Niña that instigated the publication of the *Tracker*.

While academic incentives can impede some climate services, associations with universities have advantages. Importantly, climate services (including climate summaries) are most effective when the information is perceived as salient, credible, and legitimate (Cash et al. 2003). Universities can help boost the credibility of the services provided (Sprecker 2002) because scientists are often the most trusted sources of climate information (Leiserowitz et al. 2010).

Finally, climate summaries are likely to be only one of many sources of information decision makers utilize, and it is difficult with a diverse audience to meet everyone's needs. Many survey respondents, for example, stated a desire for more site-specific information than what was presented in the *Tracker*, including the following comments: "I would like to see more data for specific watersheds," "more information on Colorado Plateau (Colorado River watershed) would be helpful," and "runoff/snowmelt predictions for the Salt River." This underscores a trade-off between the breadth and depth of information presented in pithy summaries, and highlights a need for information products to be tailored to specific users.

e. Climate services

Creating flexible approaches that enable service providers to evolve with changing user needs and environmental situations is a desired characteristic of climate service programs (NRC 2009). For organizations tied to academic incentives—and their associated challenges noted above—CLIMAS offers one example of a model that has been effective at meeting the demand for some climate services. CLIMAS, like other RISA programs, has tenured (or tenure track) faculty, graduate students, and postdoctoral researchers. While these groups predominantly focus on stakeholder-relevant research, CLIMAS also employs professional "core office" personnel who are not tied to the tenure system. The core office has the flexibility and expertise required to address emerging needs, like the *Tracker*, that would otherwise be neglected.

This model, however, is not without restraints. CLIMAS has limited capacity to turn successful, experimental services into operational activities because these efforts would consume finite resources that would inhibit its ability to address emergent research and service needs. Moreover, CLIMAS's mission is more inline with research and development than operations, like many other organizations within university systems. The U.S. Cooperative Extension System, for example, has been mentioned as an ideal entity to assess and deliver climate-related decision-support services (NRC 2009; McNie 2007). However, the Extension is primarily charged with conducting applied research and outreach, not operations. While transitioning research into operations is often an objective, the Extension does this by training resource managers and producers to adopt best practices. Protracted climate services, such as an enduring climate summary, require data processing and interpretation tasks that cannot be "handed off" to the end user. Ideally, CLIMAS, the Extension, and other programs housed at universities would develop and test experimental climate services. The most successful efforts would then be passed on to operational organizations that would continue the activities. It has been noted, however, that the swift transfer of outcomes into enduring decision-support tools has been challenging (Overpeck et al. 2009).

Climate services should also be designed for learning and engaging in the continual evaluation of the use and effectiveness of the services (NRC 2009). Evaluations help refine services to better meet user needs, which ultimately can lead to desired outcomes (Moser 2009) and, in turn, help move the service away from supply push. Evaluations also can help develop a clear understanding of purpose, audience, and messaging, which can help information reach intended audiences (e.g., Moser 2010). Moreover, evaluations become increasingly valuable in environments in which demand for climate services outpaces supply. Knowing what does and does not work can foster efficient allocation of limited resources, enabling programs to better maximize the return on investment. Our evaluation, for example, revealed that many people used the *Tracker*, justifying the production of a second round of monthly publications during the 2011/12 winter when La Niña returned.

6. Conclusions

As the supply of and demand for climate information increases, services that connect information to end users also will need to expand. Part of this climate service portfolio should include activities that broker information created in the science push mode. In these cases, region-specific, contextual knowledge can facilitate the development of services that enhance understanding of, access to, and use of climate information without necessarily engaging in time-consuming collaborative processes that could prevent the timely production of the services.

The *Tracker* was an example of an experimental, regional climate service developed by CLIMAS to respond to a rapidly intensifying drought. A formal evaluation of the product and process of disseminating information demonstrates that the synthesis and translation of existing climate and related information in routine summaries can inform decisions. Because the main goals of providing climate services are to help diverse users prepare for and respond to climate changes, efforts like the *Tracker* should be part of a broad assortment of activities. The collective effort of these services should be flexible in order to respond to opportunities created by climate events as well as shifting information needs instigated by economic, social, and policy changes. Evaluations, like the one presented here, can also help organizations engaged in climate services stay abreast of these changes. Documenting the efficacy of activities will not only help ensure that resources are efficiently allocated and benefits are maximized but also provide key insights that will inform how climate information can be effectively connected to decision making. Moreover, the usefulness of summarized information likely extends to many decision-making spheres, not just those in need of climate information. For projects and programs with outreach and service components, evaluating and developing ''best practices'' on the routine synthesis and interpretation of information can support other knowledge transfer activities.

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