CHAPTER 2

Understanding the user context: decision calendars as frameworks for linking climate to policy, planning, and decision-making

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2.1 Introduction

Advances in climate research over the past few decades have led to significant improvements in the understanding, attribution, and prediction of climate variability. In parallel, advancements in interdisciplinary research have examined if and how subseasonal to interannual climate information has been, or could be, used and the value of this information in policy, planning, and decision-making in agriculture, energy, water management, and other sectors, to manage risks and mitigate impacts [1]. Within these sectors, research has identified cultural and institutional barriers that have limited the use of subseasonal to interannual climate information in resource management and operations [2]. Specific barriers relative to decision needs include the following: that climate information relative to the decision needs is not available at the right time [2,3], and that time scales are not meaningful to potential users [4], do not meet their temporal needs [5], or are not at the appropriate spatial scales [2]. *Useful* as defined by scientists' assumptions of what users need, has been distinguished from *usable* as defined by users' perceptions of their needs [5], by the user's context [6], and produced to directly contribute to the design of a policy or solution of a problem [7].

Thus, a major factor in understanding and clarifying users' needs is dependent on understanding the user context. Scientists must better understand contextual factors such as the organizational and institutional setting, and decision rules [6] in which information is used in order to develop

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usable information. Sustained interactions and deliberate engagement have been found to be essential to understand the user context, and, based on that understanding, to identify user needs for decision-making, planning, and policy processes, ([7] and Chapter 1). A coproduction model [6] in which scientists and potential users iterate about the state of understanding of climate variability, predictive skill, and potential users' needs is found to be more successful in understanding users' needs. This sustained interaction needs to be iterative among three groups: between users and climate information providers, researchers and providers, and researchers and users [8]. Engagement strategies include the participatory and user-centric approaches used by boundary organizations [9,10] and knowledge brokering [11], and others discussed in Chapter 1. While this deliberate engagement is crucial, it is also time and labor-intensive, and there is little guidance on how to organize and analyze the information collected in order to understand user contexts. Analytical frameworks for organizing information about the user context, and from that, refining user needs, are not well documented (see Chapter 1 for RISA approaches to this challenge).

Informed by over a decade of work, this chapter describes decision calendars as a practical framework to organize information gathered from a variety of engagement and methods. By organizing information about a user context, decision calendars can help overcome constraints and barriers that are relative to incorporating climate information in the decision-making process by identifying entry points and opportunities that influence the use of climate forecasts, for example, the timing when products are most likely to be used by resource managers and their stakeholders. Thus, the decision calendar can also be thought of as a boundary tool (see Chapter 5), intended to move past first-order questions regarding if and how stakeholders use climate information, to more sophisticated and contextual second-order questions to assess what is needed for the information to be usable. Furthermore, beyond identifying usable information, the decision calendar framework identifies entry points in the decision process for usable and actionable information. In this chapter, we define *actionable information* as a science-based knowledge, which is transformed to be readily understandable and immediately available to be incorporated into decision-making.

The introduction to this volume raises several challenges to understanding user needs that the decision-calendar framework can address. Decision calendars provide an efficient way to organize and refine the climate science needs of users as described in the presented case studies of reservoir and fire management. Decision calendars also help users or researchers discern differences between initially "perceived" and "actual" needs for how people could use or take action with science information in the decision process. In so doing, a decision calendar can help decide where to invest resources in the next stage of research or product development. Furthermore, with an expanding array of sectors and potential users seeking climate information, decision calendars can organize the needs of multiple groups to identify common needs, as described below in the monsoon example. Finally, the process of developing decision calendars also provides a space to foster engagement and communication among researchers, potential users, and climate information providers, to provide feedback to climate scientists on usable information products, and to guide use-inspired research. Thus, the value of decision calendars is twofold: the calendar as a research product itself, which illuminates user needs; and the process of development, which fosters engagement.

Our decision calendar approach builds on several analytical frameworks that each contribute to the analysis of the user context, including the critical water problems approach [12], policy sciences [13], and institutional dynamics [14]. These approaches are problem focused [15], versus a theoretical inquiry, recognizing that no explanation covers every case. By developing an understanding of the user's context, perspectives, and time frames it becomes possible to develop or coproduce usable information to address these problems. These frameworks were selected because they address key considerations in climate-related decisions for a particular user context, that is, the users' critical issues and problem focus; their planning horizons and goals; basis for decisions, and, as described in Jacobs and Pulwarty [16], differences in perspectives of different stakeholders as well as between scientists and stakeholders.

Many analytical frameworks lack a temporal dimension of use of products and information. Adding the temporal analysis—a distinguishing feature of decision calendars—to insights from other social science tools provides a way to organize annual and other recurring cycles of decision-making, to understand the role and influence of the longer-term planning cycles, and to evaluate the decision-making process in a climate context [17]. Our decision calendar approach allows identification of critical time periods (so-called "entry points") and formats to provide climate forecasts and information, as well as to infer climate information that is potentially useful, but not currently used. In short, a decision calendar is a framework for organizing information about a user context and related climate knowledge. This information may be collected using a variety of formal and informal methods, including those discussed in Chapter 1. In turn, the decision calendar has informed the work by NOAA RISA programs with stakeholders by guiding climate research priorities and pragmatic decisions on where to focus engagement efforts.

We present three cases of RISA work where decision calendars were created, and also examine the role of decision calendars in developing usable and actionable information. Diverging from the sector orientation common to many studies, these cases focus on specific climate-sensitive societal problems and assess how climate information may inform management responses to address the problem. These projects by the Western Water Assessment (WWA) and the Climate Assessment of the Southwest (CLIMAS) RISAs linked climate information and decision-making. Decision contexts include: (1) reservoir management, from annual to longer-range operations, situated in larger societal and environmental problems that the water systems serve; (2) fire management, and (3) scoping applications of a research program on the North American Monsoon. We then describe several steps in the development of decision calendars. We conclude with a discussion of the contributions of the decision calendar framework, which we believe can provide practical insight into understanding user needs in many contexts.

2.2 Reservoir management

The WWA, one of the early RISA programs (described in more detail in Chapter 11), began in the late 1990s soon after a new generation of dynamical forecasts of El Niño-Southern Oscillation (ENSO) and seasonal climate outlooks were being issued by the NOAA Climate Prediction Center. An early goal of the WWA was to understand how these predictions could be used in water management in the Colorado Basin and the state of Colorado, including its Front Range water providers. However, understanding the climate needs of water managers was in its infancy. We anticipated constraints and barriers similar to those identified in the then-recently-published paper by Pulwarty and Redmond [2]. We needed to understand the particular context of the barriers and constraints for this region, such as water laws and institutions, in order to move on to entry points and opportunities, including who might use the new information and in what decisions.

As a relatively new program, an early task was to narrow the many potential partners in water management and the many potential water problems to address, that is, to make pragmatic choices on who to work with and where to invest time and other resources. A critical water problems approach [12] proved useful to identify topics of most concern to water managers, which were also sensitive to climate. Critical water management problems included changing reservoir operating plans to provide flows for environmental purposes; implementation of the Salinity Control Act; equity issues such as Indian water rights; and competition among uses, such as transbasin water diversions and new uses of water for recreation or aesthetics [17].

Climate variability and change appeared to be most relevant to reservoir operating plans, although climate variability was of more interest at the time.

The primary decision-makers in this case were the U.S. Bureau of Reclamation, Denver Water, and the Colorado River Water Conservancy District. Each management organization was both the decision-maker for its own reservoirs and a stakeholder in management of the basin. But the larger decision context includes who is involved or influences the decisions and what is important to them [13,21], that is, the multiple agencies with "stakes" in the management of the reservoirs and water releases upstream of the critical habitat for endangered species near Grand Junction on the Colorado River. The "stakeholders" in reservoir management include the U.S. Fish and Wildlife Service with authority under the Endangered Species Act (ESA); Xcel Energy, which holds a large, senior water right for hydropower generation; the irrigation districts downstream in the Grand Valley; and recreational uses then without formal water rights such as trout fishing and rafting. Furthermore, two external federal environmental mandates were challenging the reservoir managers to provide water for environmental purposes [18]: the ESA requirement to provide water from reservoirs to assist with habitat restoration and recovery of endangered native fish, and a Federal reserve right for flows for the Black Canyon of the Gunnison (now a national park).

According to the institutional dynamics framework [14], when some fundamental change in policy and/or management has or is likely to happen, the system may be in a release and reorganization phase, and more open to consider new ideas or new technologies such as climate information, and more likely to be open to interacting as partners. Reservoir managers were anticipating that the flow recommendations for endangered fish, under development for several years, would be finalized and changes to operations required to meet the recommendations would be made. These looming requirements provided urgency, or criticality [20] to expand management to meet the new water needs. In fact, reservoir managers had already agreed to try new operating strategies: under an agreement called Coordinated Reservoir Operations (CROS), reservoir managers agreed to evaluate each spring whether if their reservoir supply included flows that might otherwise be spilled that spring and, if so, that year they would voluntarily to coordinate releases with the timing of the peak flows at the critical habitat reach of the river upstream of Grand Junction on the main stem of the Colorado River [17].

From initial conversations, we knew that reservoir operators were considering seasonal climate outlooks, but were not using them in formal operating models. Thus, they knew about the forecasts, but had only progressed to the first stage in a process described by Rogers [21] through which individuals or organizations decide to adopt an innovation. They had passed Rogers' knowledge stage, and had formed an initial favorable opinion that the forecasts might be useful (persuasion stage). A workshop in October 1999 (also described in Chapter 11) was held to provide a forum to explore potential uses and to encourage them to move into the decision and implementation stages, and to engage in activities where they might adopt or reject the seasonal outlooks as an innovation.

At the 1999 workshop, an engineer from Denver Water sketched their decision process and challenge (Figure 2.1). Reservoir managers seek to fill the reservoir by the end of the April–July runoff season, by balancing two competing goals of maintaining some storage space for potential heavy runoff events to avoid floods, but avoid "spilling" water that might have been stored. The CROS program added another goal for the managers: intentionally saving water that might have been spilled to be released or "bypassed" through the reservoirs in a coordinated way to create higher flows in critical habitat reaches of the river. Reservoirs farthest from the critical habitat would release water ahead of those closest to the critical habitat, so that the bypassed flows reach the target area at the same time. This scheduling highlighted the need for accurate flow forecasts made by the NOAA Colorado Basin River Forecast Center (CBRFC), for the volume forecasts for the reservoirs, as well as for the flow levels in the target reaches. Both of these

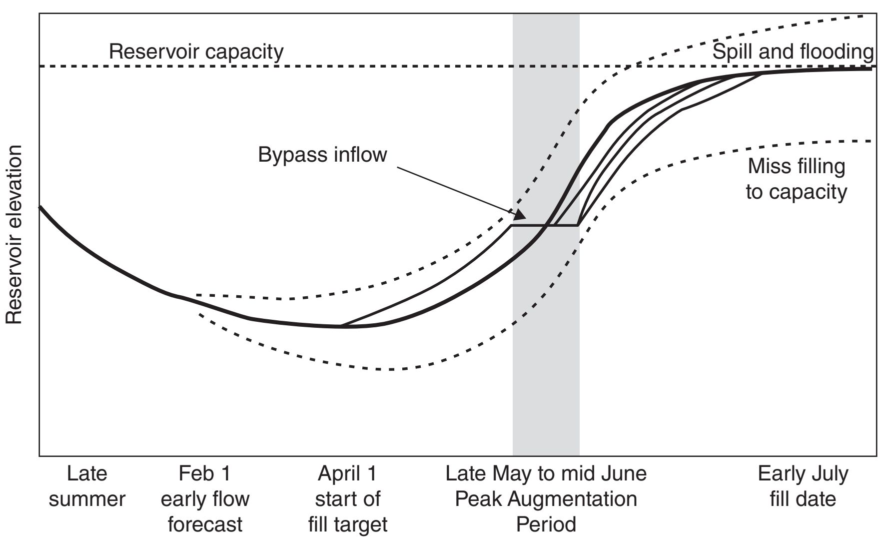

Figure 2.1 Conceptual reservoir hydrograph. Key points in managing inflows into reservoirs, based on engagement with reservoir managers at a workshop and subsequent discussions.

river outlook products were already in use by these water managers, but they thought that other climate predictions, if incorporated into the CBRFC products, might give them an outlook of the wet or dry conditions, and thus more time and flexibility to prepare and manage options.

The workshop participants then outlined what products might be needed and when in their annual decision process [17]. NOAA long-lead precipitation and temperature forecasts in the fall could improve the outlooks of winter snowpack accumulation and estimates for subsequent April–June runoff. Through fall and winter, an understanding of the influences of ENSO on the seasonal evolution of snowpack could lead to more accurate estimates of runoff and the "start of fill" target reservoir level. Throughout the spring, a one-to-two week precipitation and temperature forecast could provide improved estimates of volume and timing of spring peak flows needed to plan peak flows for habitat restoration as well as to enhance flood mitigation operations. By late spring, the NOAA long-lead forecasts could improve demand forecasts for summer irrigation and other water demands. Throughout the summer, 1–2 week precipitation and temperature forecasts could improve estimates of releases for both hydropower generation and, in order to schedule irrigation, mitigation of low flows in the river.

Subsequent to the workshop, a decision calendar (Figure 2.2) was constructed to organize these needs and identify other potential uses, indicating the timing of select planning processes, operational issues, and the timing of potential uses of several types of climate and weather forecasts that could be used to inform planning and operational concerns. The resulting decision calendar identified climate information needs in the reservoir management context and identified other potential uses. The evolution of the decision process was documented throughout the water year (and longer timescales) to identify the timing of needs as well as the potential entry points for climate information.

Another result of this work with reservoir managers was to broaden our conception of "use" of climate information beyond simply incorporating a prediction into an operational or planning model. In our reservoir management studies, we have observed four types of use: (1) Consult: the product is looked up on a web page or received from other source; (2) Consider: after consulting the product, the information is integrated into management deliberations as a factor that could potentially influence decisions, but was not used in operational models; (3) Incorporate: the forecast is assimilated into an operational model that is used in operational decisions; and (4) Dialogue about risks: the forecast is used to communicate with other managers and stakeholders about the risk of certain conditions, the need to take actions, or to justify actions [17].

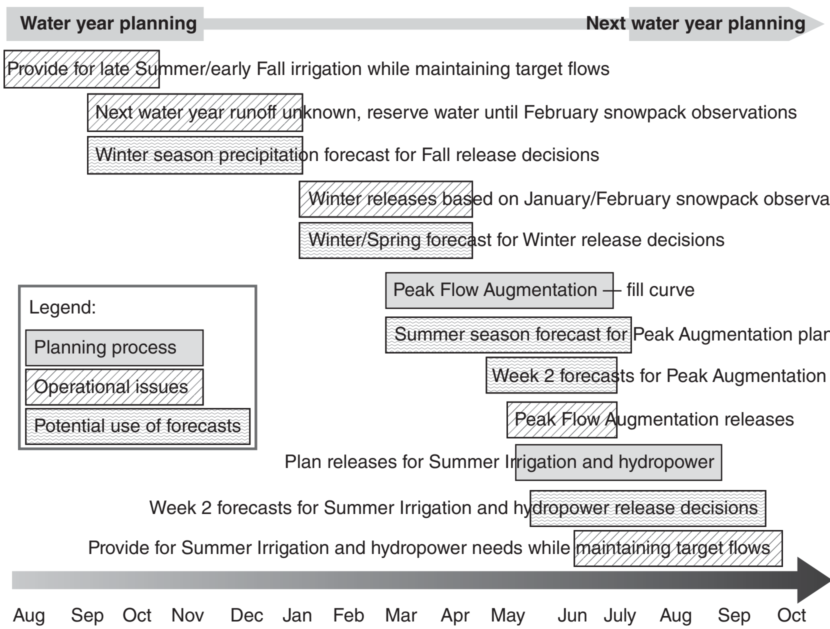

Figure 2.2 Reservoir management decision calendar. Timing of select planning processes (gray bars), and operational issues (dotted bars), for Upper Colorado River reservoirs. Stippled bars indicate the timing of potential use of several types of weather and climate outlooks to address these planning and operational concerns. The width and position of the bars indicates the relevant time periods. For example, in the late winter, improved forecast of the runoff volume (after [17]).

Understanding the ways climate information is used into the decision-making process (consult, consider, incorporate, or dialogue) can provide insights into both its value and limitations. For example, predictions that are not in an appropriate form or are thought to lack an acceptable level of skill for use in an operational model (type 3) may still be used subjectively (type 2) in mental models via the judgment and experience of water managers as described by Jacobs and Pulwarty [16]. It may also still be used in a dialogue about risk (type 4) to convey the climate risks behind a management action intended to minimize impacts while gaining the agreement or support of management or stakeholders. In types 2 and 4, the use of the information may be qualitative or subjective even when information is quantitative [16]. Consulting the information (type 1) is a kind of use. For example, a forecast may be consulted for situational awareness, but no other use may be needed if it raises no concerns that need to be followed up on such as, if drought or high flows are unlikely. On the other hand, a user may consult the information and not use it further because it is not usable for some reason. As part of a decision calendar analysis, the types of use may show different entry points and opportunities for a particular information product. In addition, the decision calendar framework can identify entry points and opportunities for information that is not currently available, or not available as a usable product.

As an outcome of the 1999 workshop and the decision calendar, WWA and its NOAA partners developed ongoing engagement with Reclamation and its stakeholders, which included presentations and participation in water managers' own management meetings and the related Colorado Drought Task Force, WWA-hosted meetings. As described in Chapter 11 WWA's early efforts as a boundary organization were informed and shaped by this early work with reservoir managers and included efforts intended to help water managers understand the available seasonal to interannual forecast information. The efforts also targeted the stakeholders in reservoir management, so they would also understand the potential use of predictions and forecast information and the rationale behind the resulting management actions. WWA and PSD conducted applied research targeted at improving the understanding of climate at key points; for example, work to connect longer-range (8–14 days) weather outlooks to the CBRFC river products [22] and to understand the impacts of multidecadal variability on regional water resources [23].

2.3 Wildfire management

The CLIMAS RISA focuses on assessing climate variability and longer-term climate change in terms of impacts on human and natural systems in the Southwestern United States (http://www.climas.arizona.edu). In early 2000, CLIMAS identified wildfire as a critical management problem and fire managers as ready and willing potential user groups for engagement. The combined impacts of the challenges of increases in acreage burned, growing costs, and greater variations in the magnitude and severity of wildfire seasons in the western United States was making wildfire management an increasingly complicated and resource-intensive endeavor. CLIMAS embarked on workshops and discussions with natural resource and fire decision managers to explore what climate information was needed to manage wildfire, and when and where the information was needed (see Chapter 7). Their engagement process included training to ensure that the basic knowledge and skills needed for interpreting and using climate information were available [24]. CLIMAS's engagement with the wildfire community reaffirmed the strong link between fire danger in the western United States and winter precipitation, the need for a change from reactive to proactive management strategies, various planning horizons for preparedness, and improvement in the use of extended weather forecasts and climate outlooks by agencies to strategically plan wildfire resource allocation and fire use opportunities [24].

To better understand the decision-maker's context, Corringham *et al.* [25] surveyed wildfire management officers and decision-makers in 2002–2003. They asked different individuals and groups to construct annual decision calendars identifying when their own fire prevention and suppression decisions were made, how/if climate information supported these decisions, what information was used, the sources of information, and what other information could have been useful. Survey information was combined with local, regional, and national inputs from the primary federal wildfire management agencies, U.S. Forest Service (USFS) and National Park Service (NPS), and insights from the perspective of broader interagency coordination. Four primary types of wildfire management decisions were common across three states (California, Arizona, and New Mexico): fire suppression, prescribed fire and fuel management, seasonal staffing, and budgeting. Specific decisions involved the Santa Ana winds in southern California, presuppression pile burning in northern California, and onset of monsoon rains in Arizona and New Mexico. Institutional barriers identified included constraints in retargeting funds within a 2-year budget cycle, inflexible authorizing legislation, organizational inertia, temporal mismatches between decisions and forecasts, and risk aversion. These barriers were obstacles in using climate forecasts and other information to better manage wildfire risk.

A wildfire decision calendar was created based on the information from surveys and interviews, and the annual cycle of wildfire decision-making by USFS and NPS management units in California, Arizona, and New Mexico [25]. The sequencing of decisions by region is summarized in Figure 2.3. Weather/climate information for managing wildfire ranged from historic data to provide perspective, to real-time information and short-term spot forecasts and 1- to 5-day-lead forecasts of weather conditions to support tactical decisions, to seasonal and annual outlooks to long-term climate products to support preparedness and strategic planning decisions. As the fire season progresses, outlook and assessments can be updated with shorter-term forecast products while year-to-date conditions are compiled and compared with historical climate averages to determine when more active monitoring and management activities are required.

The decision calendar framework was used to identify entry points for improved use of climate information to guide wildfire management decision-making. The analysis by Corringham *et al.* [25] indicated that

Southern California

Decisions	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Suppression						■■■	■■■	■■■	■■■	■■■	■■■	
Rx and fire use	■■■	■■■	■■■	■■■	■■■	■■■						
Season staffing					■■■	■■■	■■■	■■■	■■■	■■■		
Budgeting			■■■	■■■								
Special: Santa Ana	■■■								■■■	■■■	■■■	■■■

Northern California

Decisions	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Suppression							■■■	■■■	■■■			
Rx and fire use				■■■	■■■	■■■	■■■	■■■	■■■			
Season staffing				■■■	■■■	■■■	■■■	■■■	■■■			
Budgeting			■■■	■■■								
Special: pile burning	■■■	■■■	■■■							■■■	■■■	■■■

ARIZONA AND NEW MEXICO

Decisions	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Suppression			■■■	■■■	■■■	■■■	■■■	■■■				
Rx and fire use			■■■	■■■	■■■		■■■	■■■	■■■			
Season staffing				■■■	■■■	■■■	■■■	■■■	■■■			
Budgeting			■■■	■■■								
Special: monsoon						■■■	■■■	■■■				

Figure 2.3 Regional aggregated wildland fire management decision calendars. Months during the annual cycle when information is needed for each of the decisions are indicated by ■■■ (after [25]).

reliable wintertime La Niña outlooks prior to a fire season would allow decision-makers to adjust budget allocations to manage risks. An improved prediction of the probability of dry lightning strikes prior to summer rains and the timing and magnitude of monsoon rains were highlighted as important for resource allocations. At shorter timescales, 8-14 day forecasts were found to be useful for planning prescribed burn activities. They also identified opportunities for extended weather forecasts and short-term climate outlooks that were critical for fire suppression decision-making and to identify opportunities for fire use to reduce fuel loads and for landscape restoration. Evaluation and communication of weather forecast and climate outlook skill, reliability, and uncertainty in conjunction with wildfire management actions and outcomes would improve decision-makers' understanding of strengths and challenges of using this information to manage wildfire risk. Even as advances in climate information are combined with improved understanding of the decision-making processes, the combination of multiple objectives and differing priorities challenges the use of climate information in wildland fire management practices.

As a result of the engagement and the information needs identified using the decision calendar framework, an ongoing national seasonal fire assessment process has been institutionalized as a partnership among CLIMAS, the National Interagency Fire Coordination Center's Predictive Services, and the Program for Climate, Ecosystem and Fire Applications at the Desert Research Institute in Reno, Nevada with involvement by WWA [26] (see Chapter 7). In recent years, the scope of these regional efforts has expanded to cover all of North America and to provide monthly updates during the wildfire season [27]. These assessments of significant wildland fire potential are used by decision-makers for proactive wildland fire management to better protect lives and property, to reduce firefighting costs, and to improve firefighting efficiency.

2.4 Applications of monsoon research

In the early 2000s, the NOAA-funded North American Monsoon Experiment (NAME), prompted interest on how improved understanding and forecasts of the monsoon might be used, and how to target potential users of the information about this phenomenon. In this case, climate scientists had identified the monsoon as the target of a multiyear process study designed to improve understanding and simulation of the monsoon in coupled climate models in order to predict monsoon features such as onset and decline months to seasons in advance [28]. Around the same time, the National Research Council had recommended that NOAA should "ensure a strong and healthy transition of U.S. research accomplishments into predictive capabilities that serve the nation," [29], and NOAA also was actively seeking strategies to transition research results to operational products and applications provided by the agency [30]. Although the impacts of the monsoon were recognized as being societally important, there was no clear understanding of what was needed by potential users for the results of the NAME program to be used and transitioned to operational products and applications.

A team of CLIMAS and NOAA social and physical scientists assembled to assess this question of how NAME program results could inform users, that is, who might use the knowledge produced by the program, what kinds of decisions would be informed, and when those decisions would need to be informed. They also hoped to provide feedback on priorities to the research planning process for NAME and related programs like the NOAA Climate Test Bed. The CLIMAS RISA was already engaging with stakeholders, studying potential uses of predictions of seasonal climate variability including the monsoon, as well as societal vulnerability to ENSO-driven variability, and drivers of fire risk (discussed in the case above). CLIMAS and NOAA had cosponsored workshops in 2001 and 2006 on monsoon applications that engaged potential users with climate and social scientists [31].

This case of developing a decision calendar differs from the two described above because it focused on the monsoon, which was a more societally relevant weather and climate event, rather than starting with a management problem. Furthermore, rather than developing new engagement, the process built on knowledge of users from existing long-term engagement with stakeholders by the CLIMAS RISA and from the two monsoon-applications workshops. The findings of those engagement efforts were integrated with published studies documenting climate-related stakeholder exposures, sensitivities, and adaptive capacities (see discussion in [31]), as the basis for analysis of needs crossing several different applications sectors.

The multidisciplinary team reviewed and synthesized the available studies and identified five distinct planning and decision applications likely to be sensitive to the monsoon, and their climate- and monsoon-sensitive critical management problems [31]. The five applications likely to benefit from better monsoon outlooks and within-season information were: natural hazards (fire, flood, drought), agriculture in Sonora, ranching in Arizona, urban water management in Arizona and northwest Mexico, and public health. The team identified the key decision-makers, their monsoon information needs, and the potential use of that information (see Table 1 in [31]). A decision calendar framework was used to organize and synthesize the cross-application spectrum of climate sensitivities and vulnerabilities and to identify the timing and common needs or uses of improved understanding of the North American Monsoon (see Figure 3 in [31]).

The monsoon applications decision calendar was intended to identify and guide efforts of future scientists to link user needs for monsoon information to monsoon forecasts and information products. By identifying common, or shared, needs across several application sectors (water, fire, ranching, agriculture, health), this study provided guidance to NOAA on priorities for research and development to advance operational delivery of the needed monsoon information. Ray *et al.* [31] concluded by recommending a regularly issued product focused on the monsoon, and engagement activities to build capacity to use monsoon information, through approaches such as experimental climate products and services that introduce potential users to actionable information. As an outcome of this analysis, CLIMAS and its partners began conducting monsoon outlook webinars and an online Monsoon Tracker for many of these applications groups, as a way to continue engagement, and the monsoon is a regular feature in their Climate Summary, another CLIMAS engagement tool. The NOAA Climate Prediction Center developed a North American Monsoon page with monsoon metrics as part of its suite of their experimental products. The process of developing a decision calendar for the southwest Monsoon identified specific applications areas and management questions for further study and engagement, as well as provided feedback to guide NAME research development, and the development of use-inspired products.

2.5 Developing decision calendars

Developing decision calendars requires, at a minimum, documenting who the decision-makers and their key stakeholders are, key decisions and the timing of those decisions, and their needs as they describe them. In summary, decision calendars provide an analytical framework for organizing information about a user context, including timing of decisions and climate information needs, and then identifying entry points and opportunities for use of climate information. The contextual information may be collected using a variety of social science methods (see also Chapter 1). Developed from experience over more than a decade, the approach described here has been a key tool for RISAs to address second-order questions, that is, moving beyond identifying barriers to understanding how to get beyond or through these barriers.

The use of decision calendars to develop usable and actionable climate information is based on the premise that knowing the issues confronting users (challenges, current use of information, decision process, operations, and planning processes) can guide the development of information products that better inform decision-making, and also inform use-inspired research questions and the co-production of knowledge. Furthermore, climate products desired by a spectrum of users can be identified through collecting and integrating contextual knowledge about different users on what kind of climate information is needed, when, and how, and by conducting needs assessments while recognizing that climate needs are often embedded in decision contexts not exclusively related to climate. No explanation covers every case [32], but by creating decision calendars aggregated across distinct management groups (as in the fire management case), or across multiple applications (as in the monsoon case), common needs for information can be identified.

Methodologies used in developing decision calendars are primarily qualitative and context-sensitive [32], and triangulation among observations from different methods may be used to build confidence in the findings [33]. In contrast to methods that are intentionally detached and observing, engagement and iteration are intentional and crucial in the process of developing a decision calendar. Surveys may be used, but context-sensitive methods are likely to be required to gather more detailed information on the user context (or reanalyze it from prior studies, as in the monsoon case). These methods include interviews with open-ended questions, text analysis, and participant-observation.

Ongoing engagement, or iteration, with users is a critical part of developing decision calendars in order to refine, and over time, update conclusions about information uses. While creating ongoing engagement is not typical practice in many types of social science research, engagement—especially as participant observation—it is a recognized practice in anthropology, along with acknowledging the fact that the system studied is changed by the participation of researchers [34]. Workshops and collaborative projects with decision-makers, participant-observation, and ongoing communication through webinars and other communication tools are all strategic methods to develop and maintain engagement. The development of decision calendars can also be a collaborative mechanism for climate scientists, information providers, and decision-makers to interact iteratively and learn from each other in the co-production of knowledge. The steps in developing a decision calendar are discussed in the following text.

2.5.1 Document decision-makers and their key stakeholders

For a given critical management problem, identifying both the decision-makers and their key stakeholders is required. Methods include analyses of records of past decision processes and other documents (such as minutes of management meetings), public documents or webpages, or prior studies related to a case. Even in a new context or working with a new user group, this analysis can quickly identify problems that are most likely to motivate decision-makers to work with climate scientists. Identifying the key stakeholders who influence decisions is important because climate needs are often embedded in decision contexts not exclusively related to climate and are often related to concerns outside the direct control of the primary decision-maker. For example, in the reservoir management case, although the Bureau of Reclamation had formal authority to operate several reservoirs, they had to do so in a complicated milieu of other concerns, including the recovery of endangered fish and local interests for recreation and trout fishing in the river.

This step may begin with existing documents to develop a general sense of the context, then use in-depth and context-sensitive methods such as interviews or participant-observation at meetings, or through a workshop convened by the RISA, to confirm initial findings and to give a more detailed picture of the decision-maker context. This context may give insights to the reasons behind the use of information, and can assess the potential of that decision environment to take on new information.

2.5.2 Document key decisions, needs expressed for climate, and the timing

This step involves collection of detailed and contextual information about specific decisions and climate information that potentially support decision-making. It builds on the information collected in developing the decision-making context, and as in the first step, context-sensitive methods are needed, such as in-depth interviews with the decision-makers and their stakeholder organizations and others involved in the problem, participant-observation, or engagement through workshops. Information is also collected about the timing of planning and decision processes of key stakeholders because their concerns may significantly affect the primary decision-maker.

2.5.3 Organize information into a decision calendar

In collaboration with the decision-makers and their stakeholders, documenting the evolution of the decision process over time (such as the water year or annual planning), and at longer timescales if appropriate. Engagement is crucial in this step and may occur in a workshop, in conjunction with meetings organized by the users for their own purposes, or in repeated meetings with one or more of the decision-makers and stakeholders. In some cases, the engagement may have occurred during prior studies, and in such cases, the results are re-analyzed. The resulting decision calendars identify critical time periods for climate forecasts and information, and from this analysis, researchers can infer climate information that is potentially useful, but not currently used.

In this step, climate scientists and providers contribute their understanding of potentially predictable aspects of climate, and engage in a dialogue about what climate knowledge might inform the user's deliberations and decisions. The decision calendar framework can be used to document: (1) when and for what decisions and planning processes climate predictions were currently used in any way, (2) needs that have been expressed, and (3) whether the information needed was available or not. Analysis of the decision calendar identifies entry points for climate information that might be used, that is, when and for what decisions and planning processes that climate predictions may be useful. Critical time periods for climate forecasts and information can be identified, and climate information that is potentially useful, but not currently used, may be suggested. The decision calendar then provides an understanding of recurring (such as annual) cycles of decision-making and the longer-term planning cycles they are embedded within.

2.5.4 Continue engagement and iterate to confirm and refine initial findings

The process of developing decision calendars has been a mechanism for creating and sustaining ongoing engagement. In this step, climate scientists and users may identify potential collaborative projects or experimental climate services, such as testing improvements to existing products or new desired products. These activities help to create and sustain ongoing engagement, while also fostering a deeper understanding of needs and two-way learning based on that engagement, thus satisfying two important broad goals of the RISA program.

2.6 Discussion and contribution of this framework

This chapter illustrates how decision calendars can be used to organize and analyze information about the user context and, through this process, address challenges to providing usable climate information to decision-makers and other users. These challenges include moving beyond barriers to forecast use, fostering engagement with user groups, identifying use-inspired research topics, and ultimately, the development of climate products that are usable and actionable.

2.6.1 Moving beyond barriers to use

An understanding of the user context is crucial to moving beyond barriers to make use of climate information. The decision calendar approach allows RISAs to explore more sophisticated and contextual second-generation questions beyond a simple documentation of decision-makers and their stated needs, thus providing insights into cultural and institutional barriers, as well as the temporal and spatial barriers of the information itself [1–5]. Mapping out the perspectives of the broader decision context, for example, the manager's own stakeholders, can point to institutional entry points for climate information. The cases discussed demonstrate where entry points for climate information were used in endangered species recovery plans and opportunities to strategically plan the seasonal and/or geographic allocation of resources such as in the management of wildfire in the western United States. A decision calendar analysis may uncover aspects of the decision process that may not be obvious in formal operating plans, such as the need to reconcile the adaptive management process with existing annual operating plans to achieve ecological restoration [20] or the need to include other participants in the process of identifying potential uses of climate predictions [4,18].

2.6.2 Fostering engagement

A deliberate part of developing decision calendars is fostering ongoing engagement, and documenting the resulting opportunities. Ongoing engagement and partnerships in each of the cases presented have provided opportunities when key climate or societal events occurred. For example, as the drought of 2002 evolved in the western United States, understanding the decision context and calendar informed the rapid response to drought activities in partnership with water managers, which was an explicit effort in experimental services that year. Engagement included participation in water management meetings to provide climate observations and predictions, beginning early in the spring and through the water year. Interest in the climate information was heightened, including both paleoclimate and climate change data. Thus, beyond simply providing information about perceived needs, the ongoing engagement created a dialogue about climate risks and raised the level of climate literacy across time scales among decision-makers and their stakeholders.

2.6.3 Informing RISA work with stakeholders

We have used this approach to assess the needs and opportunities as the RISA program and its partners work in new regions and on new user contexts. A decision calendar approach was applied to scope uses of decadal climate information and predictability [35], and in developing projects with public lands and ecosystem managers involved in the DOI North Central Climate Science Center [Ray *et al.*, in preparation]. The decision calendar framework was recently used to identify critical information needs and lead times in a NOAA and the U.S. Army Corps of Engineers partnership to understand, explain, and assess the predictability of climate extremes in the Missouri River Basin associated with 2011 flooding. As part of an ongoing user-needs assessment in the Missouri Basin, this approach could serve as a baseline to document and understand how needs evolve over time.

2.6.4 Informing usable and actionable climate products and services

An understanding of the context described here gives insight for making a product that is useable in any of the four ways we have identified: consulted, considered, incorporated formally, or in a dialogue about risks. To be usable information, defined as science-based knowledge transformed to be readily understandable and immediately available to be incorporated into decision-making, products must respond to the temporal, spatial, and institutional needs of users. There are increasing numbers of user groups and demands for information, but by considering the decision calendars and types of climate products desired by different user groups, this analysis has provided information to climate services by identifying the common types of information needed across multiple groups.

The temporal aspect of the decision-calendar framework identifies entry points for products that were previously not available or not usable in operations, planning, and policy processes, by providing a better understanding of annual cycles of decision-making and the longer-term planning cycles they are embedded in. Analysis of the decision calendars identifies critical time periods for climate forecasts and information, as well as to infer climate information that is potentially useful, but not currently used. When desired information is not available, this analysis reveals what information is considered, what information might be important but is not considered now, and may indicate the information that would meet user needs. Thus, new products that better meet users' needs may be derived from existing products. Alternatively, if the knowledge is not available, use-inspired research may be identified. Thus, the development of decision calendars also has been an effective practice for supporting use-inspired research and guiding climate research priorities, because users needs identified can be used to drive research and product development in addition to scientists' own identification of the research questions.

Decision calendars can also help inform climate services by identifying areas where there is overlap of predictability or certainty in climate understanding with information desired by users. It may reveal new types of climate services needed, beyond the current spectrum of climate information products and services. Where products are not available, the decision calendar approach points to needs for use-inspired climate science research or applied research to develop usable science.

2.6.5 Other examples of the decision calendar approach

A decision calendar integrating adaptive management decision-making and hydroclimate information was used to identify entry points in the planning and operational decision-making processes for the Upper Colorado River and Glen Canyon Dam and to map the needs for climate-related information relative to ecologic restoration decision-making [19]. An annual agro-climate decision calendar was developed to document the influence of external forces such as the impact of ENSO on the seasonality of precipitation in Trinidad during key activity periods and to identify the types of climate information needed as well as the time frame during the decision-making process [36]. In the Central Rift Valley of Ethiopia, an agro-climate calendar was used to better understand the relationship between information needs and opportunities among farmers, resource providers, and climate forecast providers, to explore the improved use of climate information to guide agricultural decisions, and to evaluate the feasibility of tailoring seasonal rainfall forecasts for different cropping systems [37]. The annual cycle of farming and livestock production in the Arkansas Valley, Colorado, was recorded in a decision calendar, which identified the time frame for information on critical climate conditions and processes, opportunities for forecasts and other products to inform decisions and resulting benefits; simple improvements in forecasting and forecast applications were shown to be financially important [38]. In each of these studies as well as the cases presented, the development of decision calendars had value both as a collaborative process for scientists and decision-makers to engage iteratively and learn from each other in the coproduction of knowledge, as well as the decision calendar as a research product.

2.7 Conclusion

Decision calendars have proven useful in linking resources management planning processes and operational issues with potential uses of climate information and forecasts at various lead-times. Decision calendars are both a research product and an effective process for developing sustained and systematic engagement for scientists and decision-makers to interact iteratively and collaboratively. The RISAs and their partners continue to use the decision calendar approach for integrating information needs and climate science to identify entry points for climate information and forecasts, to assess the current and potential roles of climate information in policy, planning, and decision-making to manage resources and reduce the impacts, and to motivate and guide use-inspired research throughout the weather and climate science communities.

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