WORKING PAPER

Knowing Climate: The Anatomy of Experienced Climate Knowledge in Colorado's Gunnison Basin

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People interact with climate on a daily basis, and a growing literature examines climate in terms vulnerability, risk, adaptation, and human perception and beliefs (Moser and Boykoff, 2013). But approaches to understanding what could broadly be termed "climate perception" range widely across multiple, often poorly demarcated, conceptualizations of climate perceptions, cognition, attitudes, etc. Two dominant loci of research attend to political attitudes towards, and beliefs about, anthropogenic climate change *per se* (Lorenzoni et al., 2006 ; Leiserowitz 2005; Kellstedt, Zahran, & Vedlitz, 2008), and to perceived risk of climate change (Hulme, 2009; Kahan et al., 2012). Much of this important work is rather removed from the study of perception of climate or climate change per se, for example focusing on perceptions of the scientific consensus about climate change (Kahan et al., 2010). An earlier thread of climate perception research, focused more closely on how individuals and institutions understand climate itself (e.g., Whyte and Harrison 1981), has been largely neglected, despite a simple logic that adaptation to climate change must entail some operationalization of how climate change works. We refer to this formulation as climate knowledge, and argue that better understanding of the character of climate knowledge can offer insights about *why* people hold particular beliefs and take certain actions. Study of climate knowledge has tended to focus on indigenous people (e.g., McNeeley and Shulski, 2011), often in developing contexts (e.g., Green and Raygorodetsky, 2010; Orlove et al., 2010), and there is much to learn from such work. Indeed, we structure this study of climate perception in Colorado's Gunnison basin with insights from such studies, recognizing however that residents of a Colorado mountain valley, replete with broadband, a jetport, ski resort, residents with advanced degrees, a college, and a world-class ecological research station, makes this study of a "rural" area somewhat different than studies of an Arctic or African village even in this age of telecommunications and rapid transportation.

This research was designed to examine how people build, and act on, their climate knowledge through in-depth interviews. Participants were chosen based on livelihoods connected to natural resources, which makes them "experts" of climate based on deep experience. Because of this selection, we would expect our interviewees to have formed a finely tuned cognitive climate (that is, a mental model of climate), making this selection especially helpful to building theories of climate knowledge and to sorting out usefulness of climate information, which has been another theme of climate perception research.

The Structure of Climate Knowledge

We briefly review here the two main threads of climate cognition research, perception of climate itself and attitudes about climate change, in order to situate this effort to plumb knowledges. The limited literature on climate cognition helped us establish a roster of cognitive climate structure and characteristics to be tested in analyzing local knowledge.

Environmental perception studies evolved in most of the social science disciplines in the 1970s (Altman). Our more place-based approach draws from perception research especially in Geography. Lynch (1960), who explored mental maps of urban landscapes in one of the cannons in environmental perception (*The Image of the City*), asserted that an individual's perception of a place is directly related to their functional relationship with that place. Ittelson (1973) expanded this notion by exploring the different scales of environment to which people relate and argued that people do not merely build perception through observation, but also through interaction with others familiar with multiple dimensions of a place. This argument was important to our work in the Gunnison Basin, where terrain, altitude, and climate vary greatly across space, and people experience different parts of this manifold at different times and in different ways (e.g., a rancher operating in the lower reaches of the basin, about which they develop a keen sense of climate, may also be a skier who occasionally travels to the very highest part of the basin on a ski lift). Following this early work, environmental perception research grew to encompass many dimensions of environment, including natural places and processes (Zube,), hazards and risks (Sonnenfeld and Saarinen). Recent work has focused more on change in the environment, including for example perceptions of ecosystem dynamics ( ) and understandings of how landscapes change under different pressures ( ).

For climate itself, Whyte and Harrison (1981) made one of the earliest attempts to study perception of climate change based on daily engagement and profession. They used telephone-administered surveys to explore how people interpreted past weather, predicted future conditions, and understood climate trends. Three groups of participants were chosen to represent a range of hypothesized climate sensitivities: (1) snowplow operators were hypothesized to hold a finely textured cognition mostly at the weather scale; (2) rural residents were expected to have more seasonally-contingent climate knowledge, and (3) urbanites were assumed to have the least rich notions of weather or climate due to their insulation by the built environment. More recently, Wolf and Moser (2011) found that nonscientists' understandings of climate were built on how they understood weather through direct observation, historical reference, and weather impacts on the environment. Scientists and other professionals may also utilize these cognitive building blocks, but also incorporate formal observation, institutionalized procedures, and scientific method to formulating climate conclusions. Similar notions were used to select participants in this research except we focused only on people expected to have high sensitivity to climate. Additionally, we included professional land managers and ecosystems scientists who both apprehend the basin's climate through full or part-time residence as well as their training and professional activities.

Recent research has focused less attention to how climate – not just climate change – is perceived, despite its importance to planning and decision-making. Instead, perception research has focused on anthropogenic climate change largely in an attempt to understand why lay communities are skeptical of global warming. A number studies have used large scale surveys to study climate change perception that include a focus on skepticism correlated to demographics (Poortinga et al. 2011), influence of place and spatial risk (Brody, Zahran, and Vedlitz 2007), accuracy of educated populations' knowledge on climate change (Reynolds et al 2010), and comparisons among countries (Lorenzoni et al., 2006). These surveys have produced generalized information that helps explain attitudes about climate change of large populations, but speak less to the nuances of how people understand climate processes, including climate change.

Connor and Higginbotham (2013) re-bridged the gap between climate perception and attitudes via interviews to examine how people understood climate change. Key to their findings was the discovery that lay people perceive climate as a cyclical process. Interviewees' values and culture shaped their perception of climate acting in "natural cycles," which they understood as a process that showed resiliency, the climate swinging back and forth around some central tendency, in contrast to fragility or mutability. They also found two narratives of climate change affecting people's cognized climate; the "scientific narrative" explained climate change as anthropogenic and based on models and climate research, while the "natural cycles" explanation suggested variation around an underlying balance and was built on personal experiences and monitoring. They argued that this offered an alternative to arguments that skepticism, denial and politics shape the climate change discourse. Instead, Connor and Higginbotham (2013) find that the notion of "natural cycles" was based on "a reassuring deeper conviction of how nature works" (p. 1852), and this could be misinterpreted in attitudes research as skepticism.

Thus Connor and Higginbotham's findings reconcile climate attitudes and knowledge, and support the more nuanced frame developed by Hulme (2009), Kahan (2012), Hultman et al. (2010), and others in which climate is part of dynamic conceptions of nature and society harkening back to Hollings (   ) four views of nature, intersected with four main categories of individual worldviews: hierarchist, egalitarian, individualist and fatalist (Kahan, 2012). Their research offers clues as to how people understand their climate, but further research is needed to tease apart perceptions of climate and climate change.

Dimensions of Climate Knowledges

Our first cut through the cognitive structure of climate knowledges is based on *a priori* dimensions we developed from the literature and pilot interviews, and guided by arc of research reviewed above. . Like early climate perception studies, we expect people to identify *features* and *processes* of their climate and be able to assign attributes to these features and processes. We expect, based on the few early climate perception studies and on contemporary lay discourse, that interviewees would link some of their knowledge to various climate-relevant benchmarks, like seasonal changes and particularly memorable, often extreme, episodes or years. Given the land-based nature of our interview sample, we expected links to landscape and place, with, in this case of mountain geography, heightened notions of elevation zones, and the interaction of terrain (slope and aspect) with climate.

The fuller set of climate dimensions we expected to find in our interviews are listed in Table 1. In this analysis we focus on three of these dimensions: *features, processes, and benchmarks*:

Table 1. Abbreviated Coding Chart

Code	**Description**
Attributes	Descriptions given to different event, features, processes, both concrete (quantity, wet) and evaluative (negative, normal, etc.).
Benchmarks	Anchoring of an event, process, or occurrence to some other event, time, or observation. These could be visual cues, holidays, social constructs, ecological indicators or atmospheric processes.
Change	Discussions of trends, trajectory or changes. This is primarily climate related, but also could include other processes (social, economic, etc.).
Climate Info Need	Any case in which an interviewee talked about what they wanted to know about climate or about reactions to past experiences with climate information
Features	Elements and components used to construct climate knowledge, the building blocks or structures, typically atmospheric, ecological, or hydrological.
Knowability	People talking about *how* they know something, their certainty, and tensions among knowledges.
Place	Specific geographies discussed, or when climate was anchored to a certain part of the landscape. Not abstract or generalized.
Processes	When people explained "how something worked," primarily in terms of climate, but any system.
Reference Event	Years, seasons and events and were referenced and used as an example, or evidence of an argument. Similar to benchmarks, but specific to a historic date or event.
Decisions	All decisions that people made based on climate effects, expectations or information.
Seasonality	Discussions of inter-annual climate, and what people expected from different seasons, and how they understood seasons.

Thresholds	Identified points where a system changed, or was no longer resilient or adaptable to changes and variation.

1) *Features* capture the different climate elements and components that people use to construct their climate knowledge. This is the most basic structure, the building blocks that shape climate interactions and are key elements that feed into *processes* and *benchmarks.* Understanding what features are central to the cognized climate gives insight into what parts of climate are important to people and what they understand as climate as opposed to other aspects of the natural world. Features provide a common grounding for modeled and cognized climate and can act as markers that allow us track the circulation of knowledge. Features include static elements that might be the product or driver of a process, but that are one entity. The interviews provided a range of features to examine including: snowpack, drought, storms, and streamflow.
2) *Processes* reflect "how climate works" and the mechanisms driving climate. They are dynamic and engage with multiple features and were often tied to *benchmarks* in the mental models revealed by the interviews. Processes explain how features are created and what relationships exist among features, like snowpack and runoff. These dynamic operations drive the impacts felt by interviewees and were an important part of how they made sense of an abstract, dynamic climate. Interviews captured a number of processes including: snowmelt and runoff, human impacts, and green-up/plant growth.
3) *Benchmarks* are the anchors, both human and physical, with which people bind their climate knowledge. People use benchmarks as temporal structure to help order the messy climate around them, and to help them read the climate for achieving specific goals.

They are often imbued with instrumental and affective meaning and can also include processes, especially when benchmarks help inform the timing of particular seasonal changes. Benchmarks tended to be very specific to the interviewee's livelihood and included, for example: the road to Gothic, holidays, reference years and events like the drought of 2012, and sensory cues of seasonal changes.

We expected to find these three components elaborated in various ways, yet still providing the skeleton for structuring climate knowledges. We also expected that people might recognize some aspects of climate change, especially as this is now routinely mentioned in media coverage and in government reports like the National Climate Assessment (USGCRP, 2014….). By "recognize" we mean they might include some dimensions of climate change in their cognitive models of climate, not necessarily because they have experienced change but because change has become a pervasive narrative. Finally, we designed the interview coding to be open to other dimensions of climate knowledges that transcended this three-part structure, as described below.

Methods

We designed a survey to probe local knowledge of climate and climate information needs for application during a summer fieldwork season. The survey was approved by the university's IRB for human subjects, and administered by the first author in the field during July-August, 2013. Twenty-six of the 28 interviews were transcribed in their entirety using "intelligent verbatim" protocol to maintain the rich quality of each interview and capture participants' opinions and insights, while dispensing with non-essential words. These documents ranged from 1297 to 4310 words per interview transcript. Transcribed interviews were entered into the qualitative coding software NVivo (see: http://www.qsrinternational.com/products_nvivo.aspx) , and coded according to the set of hypotheses and themes described above while seeking also to capture unforeseen dimensions of climate perception.

Study Area and Interviews

The Gunnison Basin in south-central Colorado was chosen as the case study both for its similarities and differences to the larger region. It is representative of many communities in the rural West. Public land dominates the landscape, the economy is dependent on natural resources, amenity migrants and recreation are changing the region, and residents, especially many of the interviewees, reflect a connection to, and sense of, place described by Adger et al. (). It is also, like all geographical cases, unique place, falling into the "unusual case" category (Yin 2014), as a noteworthy example to study and to focus on in-depth. This is because of the current climate adaption planning efforts in the Basin and because of its specific biological and social landscape. Very few rural, western communities are engaged in planning for climate adaptation because of low budgets, the political nature of climate change, and barriers to planning. This makes the Gunnison Basin at the forefront of such efforts and an important case from which to learn about the role of climate knowledge in adaptation. The four embedded stakeholder groups offer diversity and comparison within the case study. The range of climate and vegetation zones, and complex socio-demographics in the community, made the Basin an opportune case study to investigate local climate knowledge and climate information needs.

Interview Coding

Table 2 shows the codes used in qualitative analysis.

Table 2: An abbreviated table of the first order codes and their description. This excludes second and third order codes that were used in NVivo. See Table 2 for complete set of codes.

Code	Subcode	2nd Subcode
Attributes	Aspect	
	Balance	
	Flexibility	
	Important	
	Aspect	
	Abnormal	
	Flexibility	
	Mismatch	
	Moisture	Dry,
		Wet
	Negative	
	Normal	
	Positive	
	Predictable	
	Quantity	Increase,
		Decrease
		Within a day
	Timing	Late,
		Early
	Variation	
Benchmarks		
Change		
Climate Info Need		
Features	Avalanche	
	Drought	
	Dust	
	Fire	
	Extreme	
	Freeze	
	Inversion	
	Monsoon	
	Rain	
	Shoulder Season	
	Snow/Snowpack	
	Storms	
	Water	Water Temp
	Wind	
Knowability		
	Certainty	

	Uncertainty
	Tensions
Place	Upper Basin
	Lower Basin
	Gunnison Basin
Processes	Cycle
	Ecology
	Human
	Snowmelt/Runoff
	Sunlight
	Temperature
	Green-up
Reference Event	
Decisions	
Seasonality	Fall
	Winter
	Summer
	Spring
Thresholds	

Table 1: Codes and subcodes used in NVivo analysis. This includes a combination of *a priori* and emergent codes. See Table 1 for description of codes.

Findings: Ways of Knowing Climate

Components of the structure of climate knowledge were present across interviews, though expression of climate elements varied among the participants. Some of our expected findings held up (e.g., keying on elements important due to occupation and avocation), some did not (e.g., keying on extremes events, seasons or years), and analysis of the interviews revealed new insights that went beyond structure, to the nature of what we call "experienced climate knowledge." The most surprising of these results was how social knowledge, ecological knowledge, and atmospheric knowledge were blended into complex and dynamic climate knowledges that appeared more than the sum of the parts, as discussed later.

Climate knowledge is shaped by, and a product of, livelihoods

Experienced climate knowledges are tailored to their producer and shaped through daily actions and experiences. Fly fishers cue on riparian ecosystems, mountain guides on the alpine, and ranchers on the meadows and pastures. Their daily practices focus their climate knowledges to specific landscapes and are enshrined through the repetition of certain actions associated with those landscapes. As these personalized climate knowledges are created, they are focused to specific times of year, key features and processes, and they in turn shape climate rubrics that help people interpret and respond to their landscape.

Specific times of year

Natural resource livelihoods are based on elements of climate keyed to distinct times of year. Peoples' focus on important and critical climate processes, as well as adverse climate or risky thresholds, related directly to the type of work they did. People did not express a uniform knowledge of climate and its impact. Instead, areas pertaining to their livelihoods were robust, sharply described, and supported through evidence. They focused much less on parts of climate that they still experienced, but were not tied to their livelihood. This was true across stakeholder groups.

In one striking example, the timing of larkspur flowering was seen as especially important by ranchers. One rancher explained the challenge of timing when to move his cattle based on the blooming of larkspur because the flowers are poisonous. Cattle movement must be timed to wait until the grass has developed enough to provide optimal grazing without damaging the grasses, but before the larkspur grows enough to bloom and be deadly to the cows. A rancher explained that when the seasons transition quickly from winter to spring to summer, with warm temperatures and rain, everything grows more quickly, including the larkspur. The ranchers struggle to find the "sweet spot," which is made more challenging by the logistics of having to schedule trucks in advance to move cattle off pastures with blooming larkspur. The only interviewee to mention larkspur outside of the ranching community was a RMBL scientist who was discussing it as one of the flowers that were susceptible to invasive species. They did not speak of its flowering at all or think of its timing as critical to their investigations or to possible land management decision-making. This shows how people have different resolutions when it comes to timing depending on their livelihood.

In another example, ranchers were very focused on timing of the onset of what is regionally known as "the monsoon", which for most of the interviewees was synonymous with the onset of summertime, convective rains. Some offered specific days on which they would expect the rains to start whereas others only discussed their presence in a broad, seasonal manner. High-resolution knowledge was tied to how summer rains disrupt haying operations. Multiple ranchers told the same joke that the rains seem to know just when to come and ruin the haying. A part-time rancher, when describing summer climate, explained the narrow window he would expect for the monsoon onset that elicits frustration from his community.

> *"Monsoons normally come around the 4th of July, sometime between the 4th and 10th of July. In most years it will start raining here and drive everybody nuts because then our hay doesn't mature until the middle of July and so we are in the middle of the monsoon season trying to put up hay."*

Despite the consensus that the Basin's climate is highly variable and challenging to predict, this comment shows both how attentive ranchers are to monsoon timing and, due to this focus, their confidence in their knowledge as well as their sense that the climate exhibits a regular sessional pattern. This joke and narrative was so common that interviewees outside the ranching community shared it with us. *"Monsoon [occurs] in July, early to mid July on through* *hay making season,"* a land manager shared with us laughing. Rancher interviewees tended to speak at length and in in great detail regarding the monsoon start.

For the RMBL community, seasonal changes were salient because they triggered the arrival and departure of researchers to and from Gothic. Researchers' field seasons are almost entirely determined by the climate and ecology of the area, with specific observation goals dependent on seasonal timing. Most of the ecologists need to be at the laboratory when the snow melts for the final time in the late spring, and getting this right proves to be very difficult. Many spoke of rubrics they used to help predict this, and of attentive monitoring of the local weather station in hopes of timing their visit successfully. A number of scientists reported that this timing had become much less predictable and that the variability had increased. A RMBL staff member and scientist explained how problematic this could be for the laboratory.

> *"The way that RMBL works for the science, it works well for the scientists because the entire growing season is June to August, which is the opposite of the academic calendar. And that is why it works, because you can come out, you can get your plants entire growing season, you can see everything that's affecting the life of that plant. So they can do all their fieldwork and then go back to school. So, if climate change is that things are growing earlier, then it definitely disrupts that easy arrangement for the scientists. So it either means that they wont get the full lifetime information about a plant, they will get a subset of it. Or, it means they will change their system. Or it means they will have to adjust their schedule to come out [to do their fieldwork at RMBL]. "*

This fear was echoed across interviews with RMBL scientists, and many felt they were unable to adapt to changes because of their university teaching schedules. They all had very specific memories as to the timing of spring and summer for each year at a much higher resolution than other seasonal timing. One senior researcher felt very confident that the current climate was different than in his previous four decades.

> *It's changed. The context that I know its changed is that typically I can't get out of the University… until about the 20th or 25th of May. And it used to be that worked out fine. I could get out here before much happened. But now, when the snow melts in April, I have already missed a month of the field season when I get out here. So that's a change in context, I guess, when I hire a postdoc. A research assistant now, I say well 'can you be out here when the snow melts… I don't know exactly when its going to be, but it may be somewhere between the middle of April and middle of May that I am going to need you to be out here because I can't be out.*

This response shows a higher confidence in climate knowledge, with a high resolution of specific dates. Other seasonal changes did not engender such high resolution knowledge among the RMBL researchers.

Specific sub-sets of climate features, events and processes

Climatic necessities of livelihoods, and threats to that livelihood, made people focus on select features and processes. Livelihoods are built upon the foundation of specific processes and key features of the environment specialized to type of work. For example, every person we talked to discussed snow in winter as a key element of climate, but the ski guide elaborated in much greater depth and differentiated between different types of snow throughout the winter. In other words, his conceptual climate had very high resolution of this area, but low resolution and a fuzziness regarding other processes that ranchers or land managers had expertise in. The mountaineering guide we interviewed had a very deep notion of climate change that he experienced through his years of guiding and seeing tangible changes in the snow and ice climbing routes he used.

"I was in a range and I had a guidebook that's 20 years old now 30 years old, and the routes in the guidebook aren't even there any more. They have completely melted away. And I think that trend is continuing."

He continues to explain climate needs in his own livelihood and localized climate impacts :

Every spring we try to run ski mountaineering camps in April and they are really corn skiing based. And the last couple of years we've either cancelled them or they've been powder skiing camps because it's still like full-on dumping snow and it's late April. Or, we haven't had that dependable spring clear weather, cold at night, warm in the day, that does the melt-freeze-thaw to produce the corn skiing. That window used to be a couple of weeks and now it feels like some years it's a couple days or a week or it doesn't happen at all. It just goes from winter and then it stops freezing at night and then we never have the corn skiing because it's not freezing.

Elements like "corn skiing" and "corn snow" are very specific to skiing, and knowledge of them is not required for other livelihoods; the terms did not come up in other interviews. This guide also articulated seasons differently than the calendar. For him, there were two long dependable seasons in the valley: winter and summer. The seasons between these two, the so-called "shoulder seasons," are not as salient to his recreation business. He also communicated that these shoulder seasons, which used to be short but dependable windows, were now less reliable, which was detrimental to his business.

Another quite specific manifestation of climate in the basin, stream temperature, was mentioned by only one group: fly fishers. As they responded to the question asking about a typical year of climate, the three fly fishers we interviewed all included seasonal changes in water temperature. Like many, they spoke to changes in stream flow and runoff, but were the only people to pair that with how water temperature responded. One rancher mentioned it once, in a list of possible changes in an adverse climate, but the fly fishers came back to the feature of water temperature throughout the interviews. The fly fishers explained all the processes involved, how water temperature changes, what impacts it has on the system, and thresholds that emerge. The rancher merely listed it. A fishing guide of more than 20 years explains why he and fellow fishesn are tracking the water levels in steams.

> *The lower the water is, the more it warms up. Then you start to see a lot of, oh… fish, not necessarily kills, but if you start catchin' fish and stress them they don't recover as well. So, say last year, temperatures were getting so warm on the lower river that we just wouldn't go fishing anymore.*

This quote shows that they understand water temperature as a feature attached to processes of runoff and snowmelt, and they connect the impacts to other features, such as fish health. In the summer of 2012 (a frequently-mentioned reference year), steam levels dropped so low that water temperature increased until it halted fishing on the lower elevation steams. Some of these restrictions were imposed by the U.S. Fish and Wildlife Service, but most of the fishers talked about it being a personal or community decision. When they felt the system was at risk, they voluntarily stopped fishing and had informal agreements with other guides to move to higher elevation streams so as not to further stress the fish. They expressed this as an ethic imbued in their profession, and said that their livelihoods were dependent on the health of the system, so they would not jeopardize it, even if some of their competitors continued to fish the warmer areas. Water temperature was important throughout the guiding season, and along with water levels, was tracked for key thresholds. The guides offered specific temperature thresholds that were detrimental to fish. Another guide shared an absolute threshold that he watched for:

> *Once the water temperature gets above 65 degrees, its pretty much over. The fish are struggling to survive. Its better for them not to be fished.*

This is an example of a highly sophisticated, and even quantitative, expertise in the climate-ecological system. The guides were very certain of their riparian system knowledge and of the thresholds that existed within the system.

Rubrics that aid in interpretation and anticipation of climate

People use climate rubrics, based on their -or others'- experienced knowledge of climate. Rubrics took the form of narratives surrounding holidays, guidance passed down across generations, or visual cues in the landscape. People often used benchmarks of holidays and other events to anchor climatic events. Specific climatic events were said to "always" fall on holidays such as Halloween, Christmas, and Thanksgiving. These holidays might be easier to remember due to specific memories of a holiday, or were easier to separate from the rest of the days in a season that blurred together. This response of a land manager to seasonal changes was typical of other interviews that pegged processes to holidays.

> *"Here in Gunnison itself, you expect, well Halloween is a great time to peg your first snow because all the kids have their costumes on and they are covered by parkas."*

People whose family had lived in the basin for generations –primarily ranchers- offered rubrics formed and tweaked and handed down along with land. Trial and error and experienced knowledges of climate shaped these rubrics to help people anticipate processes and aid in climate-sensitive decision-making. An older rancher from a long line of cattle producers in the basin shared a rubric that helps him decide when to move cattle to different pastures at different elevations. This is a very important decision because a narrow window exists between when the grass is ready for grazing and when the poisonous Larkspur blooms, which can kill cattle. Unlike his father and grandfather, he must schedule trucks to transport his cattle to variouslylocated pastures, and this scheduling must be done days in advance. To help him decide when to move the cattle, he recalls a phenological marker- a climate rubric- that his father used.

> *"My dad had a saying up here, just this side of Almont where one of our big head gates is. We get all the water for these meadows up here, and there is a bunch of chokecherries up there and he's saying used to be 'when the chokecherries bloom at the headgate, you are ready for cows at brush creek.' And it's pretty damn close to always being that way."*

Another rancher created a new climate rubric based on new benchmarks. In our interview, his wife prodded him to explain how he used snow depth on a mountain pass as an indicator for the season. This SNOTEL site (a "Snow Telemetry" gage that can be tracked on the web) was not what his father used- and was likely not there when his father ranched- but he can use it to help order his climate and inform his landscape decisions.

> *"Wife: Are you looking for visual clues?*
> *Husband: Just watching the SNOTEL. The marker on Monarch and SNOTEL.*
> *W: The marker is a physical measuring stick. And he, every time we go over, we check that and then he kinda correlates that to 'Okay, if its only at 4 feet, we are in trouble, but if its at 5 ft, we'll be Okay' … he would have liked 7*
> *H: I want 7. 6 Feet the first of May…*
> *W: It's a good year*
> *H: Even if it gets hot, and you can go back. I mean if you have 7 feet the 15th of March and then you have a hot spring, you are still going to make it. Or if you have 5.5 feet the first of may, then you are going to be OK, but if you are 3 feet the first of May, then you are probably going to be in trouble. You can start to know you can't kid yourself that well even if we get a big storm in May, but the marker was at 2 feet, its not going to be enough. You still can't because you have seen it enough, years, its going to help, but its not.*

> *W: See? I told you he was amazing. This is like in his blood. He'll just watch that and say 'oh its 4.5 feet, oh OK here is how much hay I will be able to produce.' If the weather is 70 that day, he's like 'oh, OK, we are in trouble.'"*

Some groups shared benchmarks that acted as rubrics for decision-making. For the RMBL community, the main benchmark was whether the long dirt road to Gothic was snow-covered, and they used this as a rubric to infer seasonal changes throughout the upper basin. Additionally, they use the status of this road to aid in decisions on research design and implementation, as well as fieldwork timing. A senior researcher describes a drought year, *"when there was very low snowfall, very early snowmelt, you could drive the road in early to mid April, the road melted out. There were days in the 80s when the road would still be snowed in on say the 8th or 10th of June."* He recounts that he carefully tracks the snow level on the road to plan his field season, but also that he can make hypotheses regarding the entire summer's ecology based on the road's melt date. This response is similar to those by ranchers who "know," to the day, when the monsoon comes. A researcher who lived at RMBL since her graduate research, and now works for the laboratory full-time, describes the focus on the road.

> *"We used the road, when we plow the road to Gothic as a measure of how big a snow year it was, so in a big snow year, we have to plow the first week of June. In a light snow year, like two years ago, the road was plowed in mid April. And a typical year, the road is plowed in mid May. So it's a two month variation, but average is about mid May. "*

Ecological dimensions matter to land managers

Timing of Climate Events

Timing of climate events matter and are critical to the ecosystem processes that coevolved in response to climate. Problems occur when the tethered ecological and atmosphere processes unravel and create a "mismatch" in timing, and this effect cascades through the socio-ecological system. A number of RMBL scientists study the phenology of plants and pollinators, and initial findings indicate that changes in climate and weather are disrupting these long-standing relationships. Even the scientists who are not specifically studying phenology and climate impacts were very aware of this phenomenon because of its potential to shock other elements of the biological system. One of the most obvious impacts was damage to plant growth at the beginning of the season. We spoke with one scientist who had been coming to the laboratory for more than four decades to study the timing of plants and pollinators explained how important the winter season was for the rest of the year and gave a pertinent example, or benchmark, of the drought of the 2012 "drought summer."

> *"What happened [in 2012] year there was a hard frost in the end of April, and another one towards the end of May, and another about the 10th of June or so. But that was five weeks, six weeks, after the snow had melted and the plants were pretty well developed with buds, and that ended up killing a lot of the buds that made the flowering pretty poor last year."*

He contrasted this with the current summer that had an early, but not extremely early, snowmelt. The key difference was that early snowmelt was not accompanied by later freezes to kill the plants. Killing frosts will impact plant communities across the Basin, and can have significant economic impacts via effects on wildflowers and cultivated plants. He explains that nearby agricultural areas like Paonia will be, and have been, impacted by the mismatch, and that the wildflowers, which attract tourism to Crested Butte, are also vulnerable to these changes. Furthermore, changes in plant communities and timing of climate processes will influence other systems.

Interviewees who mentioned changes in the timing of climate elements and processes felt that it threatened the local ecology. We spoke with two scientists who have been coming to RMBL for decades as research collaborators. While they did not explicitly study this phenomenon, they were very concerned and curious about what it might mean for their research and the ecology in general. First, they discussed how important both "amount and timing" of water are to the system in terms of snow, runoff, and the summer monsoon, and their impacts on the ecology.

> *"[The mismatch is] pulling apart those two events so that snowmelt is earlier and maybe the rain isn't changing, but the time between the snowmelts and the rains starting is getting bigger. That's the worrisome thing. Whether these animals and plants can make it through that."*

They continued to explain how these changes are likely to cascade through different sectors of the ecosystem.

> *"Whether the whole system collapses past a threshold or whether it just starts to unravel, we don't know… One of the things that we know from about the last twenty years, its now really realized how much of a network of connections there are. Things are not very specialized in this [system], not a linear connection. Much more of a network. So there is a lot of interest… in thinking about that and how things might unravel with a change in climate."*

Both felt unsure of what to expect from such changes despite their expertise in the system and its response to climate. Other ecologists were especially worried about how this "unlinking" would impact pollinators. If the snow melted early and plants grew earlier, but the in-migration of pollinators remained on the original timing, they might miss the key window for pollination.

We expected to hear a significant amount about this in our interviews with RMBL scientists, but it was unexpected to find that other communities throughout the basin also discussed this climate impact that locals termed a "mismatch." This was one of the only examples where people across the basin discussed RMBL research in interviews, and they seemed to view it as a risk to the entire basin across multiple livelihoods. Recreationalists, as a whole, were less focused on the phenomenon than the three other subgroups; a naturalist discussed it, but the rest of the recreationalists whose livelihoods were less tied to the terrestrial ecology (fly fishers, ski guide), did not mention it explicitly. They did note other ecological changes and interconnections that impacted riparian areas. A wildlife-focused land manager described the same worry as the RMBL ecologists, specifically regarding lack of snow paired with cold temperatures.

> *"We still have the capacity for cold spring nights, so where we have historically had snow cover that would provide an insulating blanket for plants or animals. We are going to have a lack of snow cover, but we are still going to have those cold periods, and we may start losing significant ecosystem components. Things are stimulated to start growing and bud, and then they are very vulnerable at that point. And then they get hit by a cold snap."*

A part-time rancher who had lived in the Basin for decades and was quick to describe the political disconnect between ranchers and RMBL, notes how applicable their work is regarding the mismatch. He describes that experiments show that when:

> *"runoff starts coming in weeks earlier, but temperatures, long term temperatures, stay down, and…, [what] they are finding at RMBL is affecting plants. [When] the snow cover goes off the plants start greening-up, and then it freezes. It's very cold because the plants are adapting to that. The plants are adapted to being under snow for a longer period of time. Once it melts, then it gets so cold that it froze."*

This demonstrates that despite frustrations that RMBL findings are not communicated throughout the Basin, this was important enough to circulate among groups. He felt that these findings, unlike other esoteric research topics at RMBL, were very connected to the ranching community because of runoff timing and threats to grazing. His responses about the mismatch were very similar to the land manager and the RMBL ecologists, which marks this as a cross-Basin narrative about eco-climatic change.

Dimensions of Climate Dominated by Variability

The Gunnison Basin experiences a highly variable continental, montane climatology. Both inter-annual and intra-annual variability is large, encompassing 100-degree F (xx degree C) temperature ranges and annual precipitation changes of 50-100% among years. with a temperature range of over 150 degrees F through the year. Residents frequently remark on this variability, with one year having double the average precipitation and a winter that would "never end," and two years later severe drought conditions, with falls that "never end", poor skiing through the winter, and springs that "come too soon." They experience climate variability and weather fluctuations that are rivaled by very few other places on the continent, and because their livelihoods require them to be outdoors, they experience that variability directly. Those who were interviewed and believed that climate was changing, articulated that it created greater climate variability. A mountain guide who was very focused on environmental issues, including climate change, explained how unpredictable the climate was.

> *"The biggest thing I've seen here is just the unpredictability of it. One spring, it might be super-snowy and super-wet and the next spring it might be super-hot and super-dry, you just don't know anymore. "*

A land manager discussed the same variation, , using reference years as evidence to support his claim.

> *"I mean it's extremely variable. We can go from years like we had the winter before last where there is very little precipitation, that was an*

> *incredibly unusual year, then in 2000 we had a very similar year, in between in 96 and in, what was it… 2010, we had these huge winters."*

Variability, observed by all groups in the Basin, shapes how they interpret climate and the knowledges they build to address it. Two key findings emerged that relate to how climate variability influences experienced climate knowledges. The large range and frequency of change makes people pay more attention to daily weather.

Weather, and short-term climate variability, require residents to take notice, and shapes even mundane day-to-day activities in contrast to places with very low variation. Presumably, people in mild climates without strong seasonality, might not constantly track and evaluate weather or form as detailed climate rubrics to aid in decision-making; their climates do not demand the time and thought that variable climates require. It is this variability, the inability to easily and thoughtlessly predict climate and weather, as well as the possibility of extreme ranges, that mold climate knowledges in the Basin. A part-time rancher spoke to how well people knew their own climate and weather through experience, in part because of how challenging it made their life.

> *"You are talking about people who every day they walk out the door and it's a battle with the weather. Everyday."*

When discussing variation, people used evidence from their own experience to support their claims, and many used benchmarks, and change in benchmarks, to show how much variability there was. RMBL scientists described the large range in timing of the Gothic road melting out. Others recounted specific seasons and reference years that were extreme in terms of temperature, precipitation, or climate impacts. Some had examples of variation that collided with personal landmarks. A land manager explained how challenging this variability made planning her wedding. She had just moved to the Basin and polled her neighbors about when to plan an outdoor wedding, a risky endeavor in this climate. She selected August because most agreed that it was the safest and most predictable month, but despite her best efforts did not evade disruptive weather.

> *"I remember that year, that we got married, we did have monsoons still, like at the beginning of August. We had hail [at our wedding]. We had hail on August 7…In the afternoon for like an hour."*

Noise generated from climate variability obscures trends and makes it difficult to recognize patterns

All the interviewees recognize that their climate is extremely variable, and that detecting a trend is challenging. Even attempting to pinpoint "normal" or "typical" climate was very challenging for Basin residents. This was the sentiment regardless of how much time they had spent in the Basin. When we asked what a typical or normal climate was, many of the participants simply baulked at the question because typical was so hard to determine. One land manager interviewee refused to even engage the question because it was impossible for long time residents, who were viewed as local experts, to define a "normal" state of the Gunnison Basin climate.

> *"When I first got here I asked an old rancher what a typical, what we should expect from a typical year weather wise and he said 'I don't know… In the 72 years I have lived here I have never seen a normal year yet…' I think it's really difficult to say what's an average year. [The rancher] has lived his whole life here, hasn't ever seen one, then I am not going to…"*

The interviewee continued by explaining how the variable climate will be challenging for even the models to predict. This was even the case among locals who strongly believed that climate was changing. Climate change was identified as one of the most critical issues in the Basin by one mountain guide, but he was unable to detect a trajectory of changes because they were obscured by variability.

> *"I think the general consensus among the long-time residents and guides is like things aren't as dependable as they used to be. People could kind of bank on 'this is the kind of weather we get' and 'this is the kind of history of what things are like' and more and more that is kind of getting thrown out the window, and we have to think on our feet a little bit more and just be prepared for the unexpected."*

An "Earth Systems" View of Climate Pervaded the Climate Knowledges

Another component of an integrated social-ecological-atmospheric climate, was how land management decisions were part of the climate impacts that people felt. Impacts were a hybrid of climate drivers and human drivers. Decisions could exacerbate climate's influence on ecology, or they could alleviate it. One land manager who worked specifically with endangered species discussed how climate change was likely to produce thresholds in the system that would threaten focal species.

> *"I think the tipping points, I think there are indicators that can tell us about those tipping points. They are somewhat exacerbated by land management decisions."*

He discussed how managing a landscape for one specific species, such as the sage grouse, disregards how interconnected ecological systems are, but his work is focused on narrow conservation goals that require the distilling of complex systems into management targets. He believed that this can create cases where the very acts meant to improve ecology backfire when they interact with a changing climate.

A fly fisher in the valley described an adverse climate as one with an unknown water future. Instead of focusing on future droughts and the timing of snowmelt, as one might expect, he saw the system as dominated by social hurdles. He gave the example of streamflows downstream of the Taylor Reservoir. In 2012, a year of intense drought, natural resource managers used traditional methods to release one large peak flow, mimicking the natural regime. The following year, where there were similar water limitations, they used two smaller peak flows that helped extend water resources. For him, climate risk was determined by the human component.

> *"There is a large people factor. You know this year, for instance, we really haven't had that significantly more precipitation. We have had some in the last year, but still not even close to average. And we are in a lot better situation with the major waterways because the Forest Service and the USGS have planned better for that."*

He saw the actions of land managers as easing climate stress and therefore viewed them as critical actors. When pushed further about climate impacts, he responded:

> *"I would have to say the human aspect is the bigger factor. The biggest factor for me is downstream water demand. That's the biggest one. That's probably the biggest concern in the West. You know as a headwater area, the demand on all the water by everyone downstream. It grows exponentially every year. And the way that is managed is probably the most significant question. "*

When asked what information he wanted in climate scenarios, his request was for something akin to integrated models that include humans [and landscape dynamics??] in a more robust way than just future climate conditions, instead taking into account future human actions and demands. He wanted predictions of a social-atmospheric climate because he does not distinguish between the two.

Throughout the interviews when people were asked about climate, , risk, decisions, and information needs, they often responded by bringing in the human elements of change. This suggests that they do not separate people from atmosphere in the same way that models (or policy-makers) do. The way people understand climate, and climate impacts, is likely to look different from academic definitions and scientists' interpretations. These responses about the social and ecological impacts of climate were not tangential, but rather illuminating of experienced climate knowledges and help explain why nonscientists engage with climate (and climate change) the way they do. Knowing that people integrate social, ecological, and atmospheric components of climate helps us build a greater understanding of this experienced knowledge. Experienced knowledge would be less likely to be dismissed on the basis of not understanding climate, if it discusses climate as a social process. This finding suggests that stakeholders do have a deep understanding of climate, but that it is composed differently.

Conclusions

Climate for the people of the Gunnison Basin is the rain that waters their pastures, the heat driving tourists and newcomers to the Basin, the hummingbirds that migrate to Gothic and pollinate wildflowers, and the water scarcity due to erratic precipitation, early runoff, and legal doctrines. Climate impacts their daily lives, but not just in the ways that climate models predict. Climate was an integrated social-ecologic-atmospheric process and this cognition is different than traditional climate models that primarily focus on atmospheric process.

This chapter explored the structure of climate knowledges, focusing on benchmarks, processes and features, and my findings were centered on the notion of an integrated, broadly defined climate. I found that knowledges are built through daily experiences, and therefore *how* people engage with their climate inevitably shaped their knowledges. Livelihoods shaped climate knowledges' structure, their focus on seasonality, and how they formed rubrics to aid in decision-making. Another finding, one of my most salient, was the notion of a mismatch.

People did not just feel vulnerabilities to changes in climate, but in how those changes eroded links between climate driven processes and events. This may offer a new lens with which to explore climate change impacts. Additionally, I also found that variability shapes peoples' climate knowledges and notion of change. Variability was felt in all the stakeholder communities in the basin; people felt that climate was changing but not linearly. They expressed that climate was getting erratic and unpredictable, and this influenced their views of a "normal" climate. These findings offer insight into how people know climate and the structure and content of these knowledges.

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Appendix 1: Interview Guide and Questions

Background Information:

Q: How long have you lived in the Gunnison Basin and what do you do for work?
Q: How much do you interact with natural resources in your work?
Q: Can you please describe your daily routine?
Q: Can you talk me through (or show me) how your environment works here and tell me what are important to the system you work with? (rain and snow melt? Animal grazing?)

Seasonality/Local Climate:

Q: What do the different seasons in the Gunnison look like?
Q: What type of weather you do you expect in each season?
Q: How do you know when seasons change? What does this look like for different seasons?
Q: What climatic/weather changes are there and what are the impacts to the natural environment?
Q: What parts of climate/ weather are most important to your livelihood or life in general? And why?
Q: Has any aspect of weather been different in recent times?
Q: How does climate and weather vary from year to year and has that variation impacted you?

Climate Decisions:

Q: How does climate and weather impact decision making for you?
[Ranchers] Q: What types of decisions do you make for ranching based on climate or weather? (when to graze, where to graze, need to buy hay?)
[Recreationalists] Q: Does climate impact when and how you run guiding trips?
[Land Managers] Q: What management decisions are based on climate or the impact of climate?
Q: Where do you get information to make these decisions?
Q: Have you altered your typical decisions based on weather and climate?

Adverse Climate:

Q: What type of long or short term climatic conditions hurt (or will hurt) your livelihood or way of life?
Q: What aspects of climate are you most concerned with in terms of risk? Temperature? Precipitation? Snowmelt? What impacts does this cause?
Q: What time of year are you most worried about an adverse/unpredictable/different climate?
Q: How would this impact your livelihood or way of life?

Analogs:

Q: What is an example of a year or a season that had an extreme (not "normal") climate? This could be extreme based on temperature (hot or cold), length of season, timing of season, amount of precipitation (drought or flood), or climate patterns (irregular monsoons v. constant drizzle).
Q: Do you remember specific quantities that were part of this extreme weather (amount of rain, temperature)?
Q: What about extreme weather makes it challenging?
Q: How did you cope with this?
Q: How would you respond if these extreme events became more common in the near future?

Thresholds: (This section needs work!)

Q: What type of tipping points or thresholds do you encounter in the Basin and which ones are important to you? (This means are there some processes that need a set input- whether precipitation, etc.- to exist and without that input they do not exist or are fundamentally different?)
Q: Are their important thresholds in your life?
Q: What type of decision do you make based on them?
Q: What kinds of changes would be good or bad?