KNOWING CLIMATE:
EXAMINING CLIMATE KNOWLEDGES IN THE GUNNISON BASIN

by

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Climate perception and local climate knowledges are an important area of scholarship within social dimensions of climate change as they influence how people respond to and make decisions about change. Climate perception research has largely focused on beliefs about and attitudes towards climate change. Such research fails to ask the preceding question of how people understand climate, not just climate change. This research investigates perception and knowledge of climate and asks three questions: 1) What is the political ecology of climate knowledges in the Gunnison landscape, and how is it influenced by the production and circulation of knowledges? 2) What is the structure and content of experienced climate knowledge? 3) How can the understanding of experienced climate knowledges inform us of stakeholder climate information needs? The Gunnison Basin in western Colorado provided case study for this research with 28 semi-structured interviews and observations made over two months of fieldwork. Findings revealed that climate knowledges are political and that the mode of production, producers, and context shape climate knowledges. Experienced knowledges bound climate differently than knowledges from climate models; climate is a socio-ecological-atmospheric process marked by human processes, and interaction between all three types of processes. Ingestion of new climate information—and whether it’s deemed useful and credible— is equally complex; it is a product of how people understand their climate. An understanding of climate knowledges is critical to scholarship on the social dimensions of climate change, and this research can offer a new lens for future research and provide new insights into past research. It can allow researchers to better interpret attitudes, beliefs, and decisions about climate change, to ascertain why past efforts of climate mitigation and adaptation were unsuccessful, and gain insight into applications for climate information.
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Chapter 1: Introduction

Climate perception is receiving greater attention in the literature, but it has primarily focused on peoples’ attitudes towards and beliefs about climate change. This line of research eclipses the basic perception research of how people understand climate, and it makes conclusions regarding beliefs about climate change, before understanding beliefs about climate itself. Instead of trying to understand the politics of climate change, I address the preceding question that was missed in search of politics. This research asks: how do people understand climate?

This is a foundational social science question and engages local knowledges, which is its own body of research. Local knowledge is not one homogenous entity, but instead multiple knowledges, each shaped and formed by individuals based on their experiences, perceptions and worldviews. I recognize that there are multiple ways of knowing climate, and that each are situated based on their production and environment, but they are not a random collection and can be analyzed for structure and themes. Climate knowledges include the knowledges built through experience and observation of a landscape, and they also encompass knowledges produced in climate models. Neither one is universal, both have biases and uncertainties, and both represent important climate information.

I am specifically interested in experienced climate knowledge that people construct through daily practices and engagement with their landscape. In everyday routines people build relationships with and learn about their environment. This is particularly the case with weather and climate. Climate, as manifested through short-term
weather patterns, is planned for on a daily basis, discussed in small talk, and cursed over when it becomes problematic. People make decisions everyday based on their climate and how they expect weather patterns to play out. How warm of a sleeping bag should I own for my climate? Do I need to buy flood insurance? Fire insurance? When should I plant my garden? What types of flowers will grow here? Where should I live?

Climate decisions become even more complex and embedded in the daily life of rural communities that rely on climate-driven natural resources for livelihoods, in contrast to their urban counterparts. What type of crops should be planted? When will snowmelt occur? When should I move my herds to higher ground? These decisions have higher consequences than being caught without a rain jacket or growing lackluster tulips. These decisions impact livelihoods and require knowledge and expertise.

Experienced climate knowledges are not equally robust. Like with all knowledges, there are expert and lay understandings of experienced knowledges. Not all daily routines and experiences build the same depth of climate knowledge. People who work inside and whose job and activities focus on topics other than their environment, do not develop and refine as intricate of a climate knowledge. In contrast, rural communities that engage more with their climate, have livelihoods dependent on climate, and make high stakes decisions based on climate, build a sharper climate knowledge. They have expertise. Experts not only have a greater “dataset” of experiences with climate, but climate knowledge also plays a much more central role in their lives.

The main focus of this research was experienced climate knowledge of local experts in the rural, American West. Public lands dominate the Gunnison Basin, like other places in the American West, and many of the residents have natural resource based livelihoods.
The four stakeholder groups I chose due to their natural resource livelihoods were: ranchers, recreationalists, public land managers, and field scientists. I argue that all of these groups have expertise in experienced climate knowledge and therefore offer rich data with which to examine how people know climate. I conducted in-depth interviews and made observations in two months of fieldwork in the Gunnison Basin, a rural community the Rocky Mountains of Colorado. I used verbatim interview transcripts and fieldnotes about climate knowledge and coded them for key themes and structures.

To understand climate knowledges, I concentrated on the content, structure and character, the political nature of multiple knowledges, and how people ingest and act upon new information about climate. I examined climate knowledges by coding interview transcripts and fieldnotes for themes and structures. Each of these components of climate knowledges are important as you cannot isolate a knowledge from its political environment or assess information needs without knowing how people understand their climate. This research provides insight into these multiple dimensions of experienced climate knowledge. It specifically asks:

1) What is the structure and content of experienced climate knowledge?
2) What is the political ecology of climate knowledges in the Gunnison landscape, and how is it influenced by the production and circulation of knowledges?
3) How can the understanding of experienced climate knowledge inform us of stakeholder climate information needs?

I hypothesized that there was a distinct structure of experienced climate knowledges, made up of features, processes and benchmarks. This structure allowed experienced climate knowledges to be examined in a novel way and produced a number of findings.
Foremost, this research found that experienced climate knowledges bounded climate differently than climate knowledges from models. Climate models primarily focus on atmospheric processes, but my interviewees viewed climate more complexly, as a socio-ecological-atmospheric process marked by human processes, and interaction between all three types of processes. Secondly, this research found that climate knowledges are political and that the mode of production, producers, and context shape climate knowledge. Thirdly, this research discovered ingestion of other climate information is equally complex, and a product of how people understand their climate.

I conjecture that understanding climate knowledge is critical in human dimensions of climate change research. Findings from this research can offer a new lens to study climate change for future research and provide new insight into past research. By understanding more about how people know climate, we may be able to better interpret attitudes and beliefs, diagnose why past efforts to encourage adaptation have been unsuccessful, and gain some insights into limits on the application of climate information.

Noteworthy results emerged from previous research on attitudes about climate and climate skepticism, however my research can provide new interpretation of their results. Surveys of attitudes toward climate change fail to address the underlying question of how people understand climate, much less why and how it changes. The study of beliefs about climate change misses the critical foundation of how people understand climate and is incomplete without first addressing climate knowledges. A myopic lens keyed on climate skepticism assumes that climate change beliefs are based on politics and assumed political motivations, when differences in experiences could lead to these differences in understandings.
Connor and Higginbotham (2013) asked how people understand climate change processes. They argued, based on initial findings from their research, that the numerous surveys studying beliefs in climate change (Leiserowitz, 2005; Lorenzoni et al., 2006; Lorenzoni & Pidgeon, 2006) are oversimplifying the story to one of red and blue politics, as just another political disagreement, which misses important nuances. People’s denial of climate change might be more based on how they understand their climate in terms of natural cycles or ideas of balance, rather than the product of politics. My research suggests that Connor and Higginbotham (2013) were correct in their assertion that belief in climate change might run deeper than political motivations, and be imbued by personal understanding of environmental processes themselves. People who understand climate as a cycle, through experiences of variation and notions of ecological balance, might not assert a political ideology in challenging climate change, but rather a different understanding of complex atmospheric processes.

This research was motivated by a well-intentioned, but less than effective, efforts to spur local level adaptation planning in a rural community in the American West. The Nature Conservancy (TNC) wanted to incorporate climate change into its own planning, recognizing their privately-owned parcels were linked to the entire Basin, and impacted by all the actors and processes on the landscape.

Projections of future climate impacts spurred greater recognition of planning for climate at different scales. This recognition led to the creation of a climate working group, made up of a range of stakeholders in the basin. TNC utilized the best practices in the literature by assembling a team of diverse locals in a collaborative process. They first inventoried climate vulnerabilities, expanding their preliminary focus from the ecological
factors to include social factors as well. They solicited NOAA climate scientists who specialized in stakeholder outreach to produce more focused climate information for the Basin. These scientists even went into the community to present and explain their findings to the diverse decision-makers.

This is an example of collaborative land and climate management practices that are better than the status quo. TNC’s project had engagement, co-production and inclusiveness, but still did not obtain the goals they sought according to interviews and stated working group goals. I argue this is in part because the processes lacked a greater understanding of how people understand climate, which influences ingestion of outside climate information, and because, despite its stakeholder focus, it still employed a top-down approach of producing the climate information. Instead, starting with the knowledges and moving up could provide better information, or yield a better system.

The Gunnison Climate Working Group is a TNC pilot study, which they hope to replicate on other landscapes. Thus, these insights might help alleviate “speed bumps” in future climate planning efforts. Findings of this research are not definitive, and instead engage in theory building, but they can still offer insights into cognized climate and help illuminate the confluence and divergence of knowledges.

The thesis works to explore how people know climate in the following 6 chapters. The introduction (Chapter 1) continues with a discussion of the case study and gives context to the research. The literature review (Chapter 2) provides theoretical frameworks and explores multiple bodies of scholarship, including local knowledge and climate science, and is drawn upon in as a foundation of this research. The methods section (Chapter 3) discusses the methodology and outlines the research design, data
collection and data analysis. The next three chapters each address a research question. I first explore the political ecology of climate knowledge (Chapter 4), focusing on the tensions over mode of production, actors and circulation. I then focus on the composition of the knowledge itself to focus on the structure and content of experienced climate knowledge (Chapter 5) as well as the specific climate information needs of the stakeholders (Chapter 6). Lastly, I discuss future research directions and lessons learned in this research (Chapter 7).

**Case Study: The Gunnison Basin**

The Gunnison Basin in Colorado is a particularly good place to study climate knowledges and information needs. The basin has a unique and complex physical geography that extends almost 7,000 feet in elevation, creating numerous distinct ecosystems and resource niches. More than half the basin is public land is minimally developed, providing intact ecosystems with significant natural resources. The economy is closely tied to its natural resources, and follows typical demographic trends of the mountain towns in the American West of growing populations and an increasing number of second-home owners. The dual complexity of the human and physical geography, as well as the mirroring of larger regional trends, makes this a dynamic, but semi-representative case study to research climate knowledges.

**Physical Geography**

Located in the Rocky Mountains of central Colorado, the Gunnison Basin is part of the upper watershed of the Colorado River (see Figure 1 below). The Gunnison Basin is an interesting case study due to its diverse physical geography, which is attributed to its
large range in terrain. The City of Gunnison sits at 7,500 feet in the lowest portion of the Basin, which rises to over 14,000 feet at the continental divide. In its 3,508 square miles, the Basin encompasses several ecological zones and niches: sagebrush, montane, sub-alpine and alpine ecosystems (Neely et al., 2011). Basin weather is typical of mid-continental, montane patterns that have a high level of fluctuation, often in a short time scale. Temperatures in the winter drop well below 0 degrees Fahrenheit, sometimes down to -40 ° F, and climb to over 80 ° F, even into the 90s in the summer (Gunnison 1 N Colorado, 2006 b). As for precipitation, the city of Gunnison averages 11 inches annually while the surrounding mountains and upper basin receive up to 4 times that amount. Depending on elevation and terrain, the surrounding areas receive 14-40 inches annually (Gunnison 1 N Colorado, 2006 a). Much of this precipitation is in the form of snow, and the runoff from snowpack feeds the valley throughout the spring and into the summer. Additionally, summer monsoonal rains, in the form of afternoon thunderstorms, contribute to the water resources in the Basin. Numerous rivers and freshwater springs throughout the Basin are dependent on precipitation, primarily the winter snowpack; these run into a series of reservoirs on the main stem of the Gunnison River, which eventually joins the Colorado. Informally, the Blue Mesa Reservoir bounds the lower end of the Basin.
Figure 1: Map of the Gunnison Basin. The outline shown in yellow was drawn by TNC and the Climate Working Group. This map depicts the complex terrain and landscape with a variety of different public lands sharp topography (Neely et al., 2011).
History

The Basin was originally home to the Ute Indians, but western exploration and expansion drove them out and replaced them with ranchers and miners. Crested Butte, Gunnison, and Gothic were all established in the 1870s due to nearby mineral deposits (see Figure 2 for map of Basin communities). Gunnison and Crested Butte were settled by ranchers and miners, and when the railroad reached the Basin in 1882, it reduced their isolation and aided their mining economies (History of Crested Butte, n.d). Crested Butte's economy was primarily focused on the “Big Mine” with supplemental ranching and services. Gunnison’s was more diverse with a greater ranching economy, some farming, and employment opportunities created when Western State Colorado University (WSCU) (albeit under a different name) was established in 1909 (History of Crested Butte, n.d). When the “Big Mine” closed down and the railroad pulled out in the early 1950s, Crested Butte’s economy suffered a more serve decline than neighboring Gunnison. A decade later, however, Crested Butte opened the ski area and began the economic transition from mineral extraction to tourism, a transition that is still occurring. Gunnison and Crested Butte both still rely on resource use for their economy, but a greater portion now is produced through recreation and non-extractive uses.
Figure 2: Basin communities map. This shows a locator map for Colorado, the Gunnison, and the 5 communities in the Basin (including RMBL). Starting from the north, the is Gothic, Mt. Crested Butte, Crested Butte, Almont and Gunnison. Source: (Digital RMBL, n.d)

Gothic City had a different fate. Unlike its two neighbors, the high elevation town perched above much of the Basin never rebounded or recovered from the mining decline. At 9,500 feet, Gothic was originally settled for silver mining, and in its peak, the bustling “city” had numerous mining cabins, two hotels, three restaurants, a mill, two general stores, saloons, a post office, a school, a law firm, a medical office, a bank and its own newspaper. Despite its quick growth and amenities, the town only lasted 2 years before people began abandoning it due to low silver yields. By 1890, it was almost
entirely deserted, expect for a few characters. Dr. John Johnson, a successful biology professor and dean at Western State Colorado College (WSCU), was an early champion of experiential education and fieldwork, and recognized the unique environment of Gothic due to its elevation and ecological niches. In 1928, he established the Rocky Mountain Biological Laboratory (RMBL) in the old dilapidated buildings of the former Gothic City (Johnson, 2002).

In the past decades RBML has continued to grow and each summer attracts scientists from around the country and globe. More than 300 field stations are scattered across North America, but this is the largest independent field station not affiliated with a museum or university. RMBL severed ties from WSCU and is now funded through research fees from scientists and private donations (Johnson, 2002). Notable research from the field station consists of numerous long-term datasets including Dr. David Innoye’s research on climate change impacts due to changing phenology, and Dr. John Hart’s research on climate change through the experimental warming meadow. A local resident, billy barr\(^1\), is one of the few who stays Gothic cabins over winter, which until recently were without electricity or running water. Spurred by boredom from the long frigid winters, he began taking daily weather measurements, which now are some of the longest, and only, data sets for the area. billy barr has become a local icon. He never formally became a scientist or received his doctorate, but published scholarly articles with RMBL scientists interested in his observational data. He continues to take daily measurements, as well as leading weekly cricket games for students over the summer,

\(^1\) who prefers his name left uncapitalized
and makes this information public on the RMBL website and at the local crowd-sourced climate and weather tracking website iseechange.com.

**Human Geography: Demographics, economics, and land use**

The basin is typical of many rural communities in the West because it is dependent on natural resources and the majority (85%) of land is publicly owned by various government agencies. It is split between three counties, containing almost all of Gunnison county and parts of adjacent Hinsdale and Saguache counties, which are shaped by great amounts of public lands [Gunnison: 78%, Hinsdale: 94%, Saguache: 70%] (Cheng, 2006). Despite the large percentage of publicly owned lands, there is still a complex mosaic of land ownership in the Basin. About 51% of the land (1,280,000 acres) is managed by the U.S. Forest Service, 24% (585,000 acres) managed by the Bureau of Land Management, 2% (40,000 acres) managed by the National Park Service, and 8% (160,000 acres) managed by state or municipal agencies. The remaining 15% (300,000 acres) of privately owned land is split between smaller holdings such as residential units, and larger holdings such as ranches (Gunnison Basin Habitat Partnership Program Committee, 2011). The public lands play a very important role in the local economy.

The basin has a complex human geography and is home to more than 22,000 residents [Gunnison: 15,434, Hinsdale: 788, Saguache: 6,389] (Department of Local Affairs, 2012 a and b). The U.S. Forest Service, which manages approximately half the Basin’s land, provides 12% of all jobs in Gunnison and Hinsdale Counties (Cheng, 2006). Agriculture- largely ranching- only accounts for 10% of the jobs in the three counties, yet it occurs on 96% of private lands and 89% of US Forest Service lands (Cheng, 2006).
This is partially because of the grazing permits for cattle, which are connected to 27% of private lands in the basin (Ferriday, 2004). Ranching is not only influential to the economy and the landscape, but it remains an important part of the culture of the basin, and a distinct part of the local heritage. Efforts to protect this traditional economy, as part of the cultural identity of the landscape, have included conservation easements to buy development rights and preserve the working landscape as well as preventing subdivisions and sprawled development that many Western communities experience.

The Basin values its historic roots and identity, but simultaneously is undergoing rapid changes in its demographics and economics, following trends of the larger American West. Like many other places with ample public lands and natural resources, amenity migrants are arriving with hopes of a higher quality of life. Gunnison County has seen dramatic changes; it grew by 47% in just 25 years, from 1990 to 2005 (Cheng, 2006). The demographic makeup is also shifting with a shrinking population of school-aged children and a growing retired community, expected to double by 2020 (Cheng, 2006). This is shifting the economy; for example, it’s demanding greater number of elderly services, with less of the economy geared towards families. Crested Butte, like many other small mountain towns, is becoming a sought after location for second home development. This expands the footprint of the town, and elevates the price of real estate, making it less affordable to many of the working class residents.

The Basin has a new resource economy that focuses largely on recreation and tourism. While traditional economic activities still dominate the three county region, making up 25% of the jobs, they are closely followed by tourism at 23%, and retirees at 11%. (Department of Local Affairs, 2010 a and b). Government remains the largest
employer overall in the basin, which includes state and municipal offices, federal land
management agencies, and Western State Colorado University. These changes are likely
to continue with a greater focus on the tourism economy. In 2011, local business owners
were surveyed, and reported that quality of life, recreation, and geography were the top
three reasons they lived in the Basin, and that they expected tourism/recreation to exhibit
the greatest economic growth in the coming years (Gunnison County, 2011). This
tourism is focused on the natural resources in the Basin such as the rivers, steep terrain,
flora and fauna.

Climate Change in the Basin

The Gunnison Basin is a unique focal landscape for this study because, aside from its geographic and demographic qualities, the community is already engaged in a
participatory process planning for climate change impacts. The American Southwest will
see a marked increase in aridity that will affect the already over-allocated water systems
and alter natural resources (Seager et al., 2007). It is projected in the next 50 years that
the Gunnison Basin will likely experience increases in temperatures and changes to the
type and timing of precipitation (see projected changes in the hydrograph in Figure 3)
(Barsugli & Mearns, 2010). Warmer temperatures will make drought impacts more
severe, depleting soil moisture and adding stress to ecosystems. Linked with changes in
precipitation, warmer temperatures could change the form of precipitation and increase
rain-on-snow events (Neely et al., 2011).
Figure 3: Projected changes to the hydrograph from runoff, above the Blue Mesa Reservoir. The blue line shows a historic 30-year average for the hydrograph peak, and the black line shows a projected 30-year trend for future hydrographs starting in 2040. The red lines show outputs of different models (Neely et al., 2011).

The Gunnison Climate Working Group was founded in 2010 as a partnership of public and private stakeholders working to build resiliency for species and ecosystems so that they provide sustainable livelihoods for the human communities in the Basin (Gunnison Basin Climate Change Vulnerability Report, 2011). Their goals are to: 1) understand climate vulnerabilities; 2) create strategies for climate adaptation; and 3) collectively promote those strategies (Neely et al., 2011). The working group collaborates with The Nature Conservancy’s Southwest Climate Change Initiative (SWCCI) (McCarthy, 2012; Cross et al., 2013) and they produced a vulnerability report in 2011 to enhance natural resource decision-making by assessing risk of climate impacts (Neely et
The report identified 13 ecosystems as highly vulnerable to climate change with many others rated as moderate or low (Neely et al., 2011). In addition, other academic researchers have studied climate and resources in the Basin. Knapp (2011), worked with TNC to create a social reliance and vulnerability assessment to aid the Gunnison Climate Working Group in analyzing the basin as a socio-ecological system and to factor in both humans and the environment into the report. She focused on land managers, recreationalists and ranchers. Knapp returned to the Basin to study the Gunnison Sage Grouse, a threatened species under consideration for endangered species listing, and looked at local knowledge and decision-making (Knapp et al., 2013). The GCWG and TNC put on workshops using the “ACT framework” (Cross et al., 2012) to engage stakeholders in identifying conservation targets, and then shared climate information produced by NOAA climate scientists.

This research was designed in collaboration with TNC, in an effort to build upon previous research. I intentionally am using the same three stakeholder groups as Knapp, adding RMBL scientists, and interviewed many members of the GCWG.
Chapter 2: Literature Review

Climate knowledge engages a number of diverse bodies of literature because it straddles studies of both the physical and human geography. My research is situated at the intersection of several spheres of research and draws from multiple sources and theoretical frameworks. This research relied on five intersecting subfields within the field of human-environment geography including: social dimensions of climate, environmental perception, political ecology, and critical studies of knowledges. All of these subfields, and the dynamic relationships and processes at the heart of them, are contextualized in the greater region of the American West, which itself has evoked a large regional studies literature.

Climate and Scale

Scholars and practitioners alike both struggle with the topic of scale as it applies to climate change. Climate change research needs to give attention to the issue of scale, recognizing the limitations and tradeoffs of different scales as well as the linkages between multiple scales. A number of questions arise: at what scale should we analyze climate, measure its impacts, produce information, and govern our responses?

Climate, and climate change, has historically been studied and acted on at a global scale. Atmospheric modeling of the physical processes (gas exchanges, ocean circulation, and radiative forcing) were understood and framed globally, and governance attempts were primarily made through international conventions and treaties, such as Kyoto. Even climate change’s various appellations (global climate change, global warming, global environmental change) imply scale. Climate change is a global issue of
dynamic atmospheric process and driven by the aggregate actions of people internationally. But the impacts are felt personally, and individual decision-makers engage with climate on a local scale and need information to match that scale. This brief discussion of scale does not delve into its complexities, but there are many as scale is socially constructed (Marston, 2000) and can be problematic as there are not clear distinctions between scales (Clark, 1987; Sayer, 1991).

The recognition that there are multiple scales of climate change has led to research focusing on the local scale, as well as multiple interacting scales. Cash & Moser (2000) distill the multiple challenges that arise when studying climate into three scalar problems. These problems include institutional fit (a mismatch between management and environmental processes), scale discordance (a disconnect between scientists and information users), and cross-scale dynamics (including interactions between scales). Scale discordance, and the challenges of producing useful information at the appropriate scale, is at the heart of this research in the Gunnison. A global lens can obscure important elements of climate change, especially localized impacts (Wilbanks & Kates, 1999). Attempts to address scale discordance often overlook the important linkages between scales where processes, or actions, at one scale, shape another scale (Cash & Moser, 2000; Wilbanks & Kates, 1999). This suggests that scale must match the purpose of the research or decision (Sovacool & Brown, 2009). Local impacts and processes are influenced by global processes, and global processes are essentially built on aggregate local processes.

Increasing focus is placed on producing local scale climate information to aid in local decision-making (Cozzetto et al., 2011; Rasmussen et al., 2011). However,
technology has not kept pace with this demand and been able to provide the type of high-resolution information requested (Kattenberg et al., 1996; Easterling, 1997; Houghton & Harvey, 1997; Shackley et al., 1998). This is due to the large uncertainties that already exist at the global scale. Climate scientists are improving the models, using techniques such as creating ensembles (combinations of different models) to improve accuracy, and making progress on increasing the resolution of data through downscaling. Climate models are built with grid cells that express the same characteristics throughout, and the downscaling process can increase the quantity of grid cells by 20-40 times (Rasmussen et al., 2011). While downscaling offers more details for analysis, landscape scale scenarios are challenging to produce because of a lack of fine scale data – needed to increase grid cell resolution-- and difficulty in modeling specific microclimates (Rasmussen et al., 2011).

Many uncertainties are created through downscaling climate models. Downscaled models retain the uncertainty of the original Global Climate Models (GCMs) -due to the process of downscaling that renders course, fuzzy, and often incomplete data- and because they depend on the same predications of emission scenarios that are impacted by unknown future socioeconomics and policies (Daniels et al., 2012). Additionally, the design of the model creates added uncertainties. Two types of models exist for downscaling (statistical and dynamic), and each will render different results, so the appropriate method must be chosen based on the landscape and the decision-maker’s needs (Cozzetto et al., 2011). Challenging decisions must be made regarding the scope, scale, and boundaries (ecosystem, watershed, regional) as well as what timescale will make information useful and digestible (Daniels et al., 2012). The types of inputs,
ecosystem processes, and outputs all are programmed by the climate modeler and will shape model outputs differently (Rasmussen et al., 2011).

It is especially challenging to model climate in mountainous terrain because of scarce data and limitations of GCMs. Historically, mountains, along with arctic and other remote areas, lacked reliable instrument data—temporal and spatial—for long-term climate measurements (Barry 1992; Changnon and Kunkel 2006). Mountainous regions could greatly benefit from downscaling attempts because low-resolution GCMs smooth complex terrain. For example, GCMs cut the elevation of the Rocky Mountains in half, modeling them as an elevated 7,000-foot plateau (Cozzetto et al. 2011; Rasmussen et al. 2011). This is problematic for modeling climate and creating projections because one the most terrain-dependent climate processes is precipitation and because elevation influences snowpack, albedo effect, orographic precipitation (rainshadow effect), monsoon variability, snowmelt and runoff (Rasmussen et al. 2011). Some scholars are questioning whether this predicament might create an important opportunity for local climate knowledges to make contributions (Dickson, 1999; Wilbanks and Kates, 1999).

**Climate Perception**

A single landscape, element or process can be perceived differently by people because of social and cultural situations and dynamics. Perceptions of the environment shape behaviors and beliefs towards the natural environment, and understanding perception was an early and foundational question in the study of human and environment interactions. Scholars questioned how people understand wild areas, the
built environment, their neighborhood, wildlife, and atmospheric processes, and examined what caused differences in perceptions. With attention to climate change growing, researchers have begun asking questions about climate perception. Most of this research focuses on attitudes towards climate change and mitigation, to understand why people hold beliefs and what influences them (Bord et al. 1998; Lorenzoni et al. 2006; Lorenzoni & Pidgeon, 2006). Research has examined why attitudes toward climate change are polarized and how people perceive the risks generated through climate change (Leiserowitz 2005). However, most of this research has focused on climate change, and overlooked the more foundational question of how people understand climate itself. This represents a demonstrated gap in perception literature, and a new focus may provide novel insight into previous studies on perception of climate change.

Environmental perception was an early area of human-environment geography and “assume[s] that an understanding of space and place is fundamental to how individuals and groups perceive and experience their particular environment, and the resulting behaviors in which they engage [are] a product of this understanding” (Denny 2006, 136). Lynch (1960), who explored mental maps of urban landscapes in one of the cannons in environmental perception (The Image of the City), asserted that individual perception of a place is directly related to their functional relationship with the place. Ittelson (1973) expanded this notion by discussing the different scales of environment to which people relate and argued that people do not merely build perception through observation, but instead through interaction. Saarinen (1976), who spent most of his career on environmental perception, argues that perception is influenced by social and cultural factors of the present, but also past memories, values and experiences. He
claimed that perception scholarship is the link between behavior and the environment and has important implications for policy and planning. One of his key works studied perception of drought and climatic events. Saarinen (1966) interviewed nearly 100 Great Plains farmers to study perceptions and found that farmers underestimated past drought severity, and simultaneously overestimated the frequencies of good seasons, suggesting that people cognize good outcomes as the norms, a finding in keeping with later studies of risk perception and decision heuristics (see Kahneman, 2011).

This body of research continued to expand past its early scholarship with theoretical applications of environmental perception to natural hazards (Burton et al. 1993), risk (Slovic, 2000), climate change (Whyte, 1985), and climate risk (Leiserowitz 2005). Whyte and Harrison (1981) was one of the earliest attempts to study perception of climate change. They used telephone-administered surveys to explore how people interpreted past weather, predicted future weather and understood climate trends. Three groups of participants were chosen to represent a range of hypothesized climate sensitivities; snowplow operators were hypothesized to be very sensitive to weather and climate, followed by rural residents, and urbanites at the low end of the spectrum. A similar hypothesis was used to select participants in this research except I focused only on people I expected to have high sensitivity to climate. 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. Environmental perception has focused less attention to how climate – not just climate change – is perceived, despite its importance to planning and decision-making. Other
research has attempted to validate and test the accuracy of climate knowledge (West & Vásquez-Léon, 2013; Mamberg 2014) but not to understand its formation and content.

Perception research has recently focused on climate change largely in an attempt to understand why lay communities are skeptical of climate change. A number studies have used large scale surveys to study climate change perception that include exploring skepticism and correlating demographics (Poortinga et al. 2011), influence of place and spatial risk in perception (Brody, Zahran, and Vedlitz 2007), accuracy of educated populations’ knowledge on climate change (Reynolds et al., 2010), and comparisons between countries (Lorenzoni et al., 2006). These surveys have produced generalized information that helps explain attitudes about climate change of large populations, but speaks less to the nuances of how people understand climate change.

Connor and Higginbotham (2013) used interviews to ask how people understand their climate- albeit climate change- and discovered 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 stable process that showed resiliency, in contrast to fragility, of climate. They found there were two competing narratives of that explain climate; the “scientific narrative” explained climate change as anthropogenic and based on models and climate research, while the “natural cycles” explanation suggested an underlying balance and was built through personal experiences and monitoring. This research suggests 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 that read it as skepticism. Their research offers clues as to how people understand their climate, but further research is needed to tease apart perceptions of climate change and climate.

**Political Ecology**

Political ecology is a subfield within environment and society geography that emerged around the argument that human environment relationships “demonstrate the way that politics is inevitably ecological and that ecology is inherently political” (Robbins, 2012, p. 3). Exposing power relations and “the political,” aids in understanding interactions regarding natural resources and the marginalization of some communities that can accompany resource decision-making. Political ecology grew out of a response to the positivist view of apolitical ecology and science, and was a reaction to argue that all data from environmental science, and the decisions this data influences, are inherently political (Robbins, 2012). Greenberg and Park (1994) assert that political ecology analyzes the “political economy, with its insistence on the need to link the distribution of power with the productive activity and ecological analysis, with its broader vision of bio-environmental relationships” (p. 1). Political ecology goes beyond a mere survey of the politics of resource use and environmental conflict, or investigations of these issues from the scientific realm; it attempts to merge the two areas of study into one holistic field that offers a greater understanding of environmental issues.

Walker (2005; 2006) examines the composition of political ecology and argues it should be a balance between the political and ecological sciences. In his first essay regarding the role of ecology, he critiques the lack of ecological processes incorporated in
the field and the over emphasis on social aspects and power dynamics. He argues that if political ecology loses its partial foundation in ecology, it can no longer speak to this dynamic relationship, and this requires tensions within the field be resolved (Walker, 2005; Walker, 2006). Conversely, he also critiques the absence of policy relevant research and asks why the field has divorced itself from the policy world that makes decisions about the phenomena they are studying. He explains this divide, with specific causes, including the focus on critical theory that makes it challenging for policy-makers to digest and the question of scale, which is whether a solely local approach with local consequences is studied or if it can be broadened and applicable to policy. Political ecology is largely focused on critiquing powers and current policy, but for relevancy’s sake, it must also offer counter-narratives and give a path forward (Walker, 2006).

Historically, political ecology focused on the relationships between humans and their environment solely in the context of the third world. However, in the past decade, political ecology has grown in a first world context, and pioneers in the field are advocating its presence more widely in first world contexts, particularly the American West (McCarthy, 2002; Walker, 2003; Schroeder, 2005; Robbins, 2002; Castree, 2007; Phadke, 2011). It is important to note the large overlap between first world political ecology and scholars on the American West, and a significant intersection and blurring between the two fields. McCarthy (2002) applied political ecology to the first world, which ignited an outpouring of discourse on whether political ecology applies to first world contexts. The reactions led to the Journal of Environment and Planning A to publish a themed issue on the topic in 2005, where a significant amount of literature I used was published (McCarthy, 2005).
In this pivotal piece, McCarthy (2002) applies a political ecology framework to the Wise Use political movement in the American West. He argues that the rural West has the same resource conflicts and problems of environmental governance as communities in the third world and that we just contextualize these relationships with power structures differently (McCarthy, 2002). Our views of rural, western communities are much less sympathetic, and he discusses the “geography of motivations,” or the concept that first and third world communities have different motivations for their claims to land, with the former focused on aesthetic uses, and the latter on subsistence. However, across the rural west there are complex relationships that mirror themes of the third world, including poverty, lack of power, and subsistence on local resources (McCarthy, 2002). These communities are marginalized and confront the same blurred boundaries and identities as they relate to the adjacent public lands, so a politically ecology lens is very applicable and allows us to see old environmental conflicts in a new light.

McCarthy’s article led to a number of well-known political ecologists weighing in on this new application and outlining the benefits of this new approach. Many of the marginalized and impoverished rural communities of the first world are experiencing profound changes with the emergence of gentrification and political ecology is well equipped to study this process (Schroeder, 2005). Additionally, a binary between first and third world countries at the heart of this debate is problematic because it assumes that all of the first world functions in capitalist systems, while in reality, there are communities within first world nations that operate outside of the capitalist framework (Martin, 2005; Emery & Pierce, 2005). Political ecology can contribute new methodology, moving from
quantitative to qualitative by employing ethnographies and case studies at community level scales (Robbins, 2002; McCarthy, 2005). With this new methodology, political ecology can offer a more profound insight into resource conflicts because it asks different questions than previous research, and reduces the distance between the researcher and the researched, providing an opportunity for critical self-reflection (McCarthy, 2005). The new focus is not without critiques, with well-established political ecologists rejecting the notion of a global political ecology that is applicable outside of the third world (Bryant & Bailey, 1997).

Much of the discussion regarding the new application of political ecology is about scale. Focusing on how the global and local relate can be dangerous if it sacrifices the importance of place and social differences (McCarthy, 2005), but these comparisons also allow a chance to look “upwards” and move beyond national governance to examine transnational influences (Robbins, 2005). While political ecology usually investigates relationships on a community level, Walker (2003) suggests a move to “regional political ecologies” that transcend the binaries between first and third world. The concept of regional political ecologies “retain[s] the greatest strengths of recent political ecology in revealing the importance of local-scale social dynamics while situating these dynamics within broader scales of regional (and global) processes,” (Walker 2003, 7).

**Local Knowledge**

Situated knowledge has emerged from feminist critiques of science and its claim of objectivity (Haraway, 1988; Harding, 1986). Scholars argue that every knowledge, whether produced in a laboratory or in a backyard is “socially situated” and influenced by
who is producing it and for what purpose (Harding, 1986, p. 50). Regardless of how much intention is placed on objectivity, people’s perceptions will always pervade the production of knowledge; how they approach the investigation, and the prior assumptions they have made, are based on their personal experience. Personal experience impacts how research is conducted, which questions are selected, what topics are studied, and what frameworks and approaches are utilized (Evely et al., 2008). This means there is not one single way of knowing, but multiple, and each reflects a partial or limited view rather than an all encompassing one (Hawaway, 1988). No partial view can capture an entire truth, so “knowledge is not something an individual has ‘more’ or ‘less’ of, but rather reflects the specific forms of practice undertaken in daily life; thick in some areas and thin in others, knowledge is embedded in daily political and environmental activity” (Robbins, 2006, p. 191). Understanding the situated nature of knowledge opens up space for new knowledge to gain legitimacy and for multiple, and sometimes conflicting, knowledges to combine. The goal of including many different types of knowledge in the production of science, and in environmental decision-making, raises a number of questions: what type of knowledge should be used; who has it; how to describe it; and how to engage and collaborate with multiple types of knowledges. Knowledges have their own strengths and weaknesses, all should be respectfully engaged to explore commonalities and divergence (Nadasdy 1999; Goldman 2007). This research recognizes the situated nature of knowledges and is careful not to compare or evaluate knowledges against each other.

I do not discuss my choice in terminology for knowledges, but that is not an attempt to disregard the politics of language. I refer to empirical knowledges as scientific
and I refer to climate knowledges produced through daily experiences as “experienced knowledges.” I understand that these divisions are problematic, and often paint them as separate rather than hybrid, but for the clarity of this thesis, I used set terms to describe the knowledges.

Scenarios, Climate knowledge and the Gunnison Basin

Climate scenarios are increasingly integrated into adaptation policy and decision-making. Forecasts describe possible future climates and impacts that can aid in environmental management and protecting livelihoods. Climate change can differ from other localized environmental problems because its processes, causes, and outcomes are usually framed globally, and there is inherent power and politics in a global scale (Jasanoff, 2004). The framing of climate as a global problem dictates who can be involved; a great amount of power is needed to engage with global institutions and in global politics, excluding many people who will be most impacted by climatic changes (Miller, 2004).

The politics of climate knowledge can be obscured and disregarded when science is assumed to be apolitical process. This alleviates pressures to address the production of science, the politics of who uses the science and how, and the relationships and accountability between parties engaging climate knowledge. One way that climate science is framed is through “Instrumentalism,” which uses science and technology to depoliticize inherently political decisions regarding social problems and policies (Ezrahi, 1990). In terms of climate scenarios, Instrumentalism translates subjective knowledge into “objective” data that allows decisions to be made without acknowledging their political dimensions. Traditional climate modeling practices act in a top-down
dissemination of science and can be disconnected from the people who use or are impacted by their forecasts. New approaches to climate modeling are tested, but the scientists are often still separated from users (Andersson et al., 2008; Holman et al., 2008; van Aalst et al., 2008). Most novel approaches are changing the scale of the scenarios through downscaling rather than changing how users are involved in the engagement in, and production of, the science (Miller, 2004).

This breakdown also occurs in the consumption of knowledge. Climate scenarios have a high level of uncertainty, both in modeling the physical processes and in predicting the social inputs to the model (Daniels et al., 2012). Miller (2004) argues that the climate information process lacks accountability because climate modelers do not communicate the uncertainty of information well to its users who can make important decisions based on this information. He uses the example of the Institutional Research Institute for Climate Prediction (IRI) that went into communities, primarily developing communities, around the globe to present them with ENSO projections. Unfortunately this backfired in many of the cases leading to new policies that harmed local fishermen in Peru, and new approaches to agriculture that decreased yields for subsistence farmers who have little resilience. Appropriate communication about the uncertainty of scenarios and their subjective nature is needed because scenarios can lead to decisions that impact livelihoods of local users without climate modelers held accountable for the scenarios they produce (Miller, 2004). This notion of accountability can be taken too far as well; seven seismologists in Italy were convicted of manslaughter for failing to predict a large earthquake in 2009, despite the impossible nature of this task (Povoledo, 2012).
To make models, the climate modelers must simplify and quantify complex atmospheric processes. Even the most complicated climate models require simplifications that distort the models. It is important to recognize the human element in the creation of this partial knowledge. Climate modelers choose characteristics, all of which greatly impact the outputs, including scale, timesteps, radiative forcing levels, and projections about human influences such as population and emission levels (Liu et al. 2007). The size of future populations and greenhouse gas emission levels are steeped in uncertainty. Modelers must make predictions, and often multiple predictions, as to human interactions in the distant future that rely on complicated choices involving politics and regulation as well as personal values. Many modelers make these decisions with great care, doing their best to select ranges and the most likely future scenarios. Regardless of intentions, the tinkering and assumptions are important to highlight, and it is important to recognize models as just one more partial knowledge (Demeritt 2001), so that people understand their uncertainty.

Knowledge(s), Circulation, and Power: Finding the power within production and categorization of knowledges

A robust study of knowledge incorporates its production, circulation, and use as well as acknowledging the deeply ingrained power (and lack of power) that controls and shapes it. This power determines what knowledge is accepted and legitimized, and what knowledge is disregarded and cast aside. Agrawal (1995) reminds us that this power moves in both directions; power simultaneously produces knowledge and knowledge itself is power. By utilizing and legitimizing some knowledges, we are effectively legitimizing the producers of that knowledge including the people and culture at its
origin. Knowledge, and particularly “science,” is often discussed without acknowledgement of its link to power, and this divorcing of knowledge from its production blackboxes it, obscuring its political nature.

The way knowledge is defined and the very terms used, empowers some and disempowers others by constructing hierarchies of knowledge(s). While creating a separate entity for local knowledge can empower it, the act of naming and separating can similarly undermine knowledge and raise questions of its accuracy in comparison to “science.” The power imbalances and inequalities between “science” and “local knowledge” are studied in remote regions of the globe in the context of histories of colonialism and indigenous communities (Harding, 2011; Phadke, 2011; Vandergeest & Peluso, 2011). This is well documented and worthy of scholarship, but the focus on and fascination with “far away” indigenous communities often obscures the very same relations at home.

First world political ecology emerged at the end of the 1990’s when scholars suggested that the same themes and political inequalities embedded in environmental management and knowledge were rampant domestically (McCarthy, 1998; St. Martin, 2001; McCarthy, 2002). Why is it that the same type of local environmental knowledge is overlooked when it originates from people of European descent embedded within rural, western communities? Critics argue that this population is overlooked because “social scientists sometimes find it easier to study, recognize and valorize only the environmental knowledges and practices of third world people,” rather than focus on the systems and communities they are part of (Robbins, 2006, p. 186). It is easier to look from outside because challenges arise from situating yourself while studying your own community.
The omission of local knowledge is often defended because of the values associated with it. It is deemed unworthy or impure because of an assumed “geography of motivations,” that wrongly perceives the rural poor in the first world to be motivated by money rather than survival or culture (McCarthy, 2002), or the political affiliation of individuals, that is believed to alter the integrity of their knowledge (Robbins, 2006). The socioeconomic status, political affiliation, and class of rural residents obscures, but does not remove, resource conflicts, power imbalances, rural marginalization, and livelihood needs that represent the foundation of the political ecology framework. Understanding what value judgments and assertions are placed on local knowledge helps explain the “complex ways that some knowledges are celebrated while others are denigrated,” and which stakeholders are incorporated into decisions and science, and, equally important, which ones are not (Robbins, 2006, p.186). I will specifically focus on this type of local knowledge and stretch traditional boundaries of local and indigenous in this discussion to encompass place-based knowledge of rural populations in the American West.

(Un)Divided knowledge: the Local and the Scientific

The divide between local and scientific knowledges is often looked at as a concrete division of two separate entities, and this dichotomy is deeply rooted in politics. Originally this division was made as a way to draw attention to local knowledge and create space for knowledge outside the dominant, scientific knowledge by establishing it as different and separate. Identifying local knowledge was a way to “empower” disenfranchised people through the very act of naming and therefore legitimizing their knowledge (Hoppers, 2002). This attempt to create space for different ways of knowing by juxtaposing local and scientific knowledge also had the effect of creating rigid
boundaries and dichotomies. If knowledge is local, then knowledge is not science and vice versa. Elevating and identifying local knowledge has dug a deep rift between local knowledge and science, but this separation can be problematic.

The dichotomy creates science and local knowledges as separate, but are they also equal? History has shown examples that the act of separation often carries values and forms hierarchies that disparage one entity and empowers another (Goldman, 2003). This is the case with local knowledge. This hierarchy plays out in the integration of environmental knowledges when local knowledge is used to supplement science and to contextualize it to the local scale and culture, but not have equal control in the knowledge production process (Raymond et al., 2010). This artificial division allows for artificial distinctions including objectivity and the open or closed nature of a knowledge system (Agrawal, 1995). Problematizing the divide helps unearth the power and hierarchy rooted in the boundaries between local and scientific knowledges.

Challenging divisions allows for the possibility of a complex terrain of knowledges that are fluid and situated and interact with each other in new ways. It raises a number of questions about our assumptions of divisions between local and scientific knowledge: Is local knowledge different from scientific knowledge? Can one knowledge be a combination, a “hybrid,” or both the local and scientific? If so, what does this do to the boundaries and identities of local and scientific knowledge?

Questions of knowing and partial knowledges relates to this research in the Gunnison Basin because it engages many different climate knowledges. The climate scenarios built from models include one knowledge that makes assumptions and suggestions of future climate and starts at the global scale. RMBL scientists have another
knowledge built on daily observations through fieldwork over the years and how climate interacts on a very small scale. Ranchers and recreationalists have a knowledge built on years of experience in patches of the landscape they use on a regular basis (grazing permits or guided rivers). All of these knowledges represent partial knowledges, and none of these knowledges is independent of each other because as they interact, they mutually coevolve and inform each other’s growth. This is especially true of the RMBL scientists who build their knowledge through empirical research and formal education, but also have a tacit knowledge of the landscape through months of field research.

**Hybridity**

Hybridity emerges at the intersection of local and scientific knowledge and asks us to question the boundaries and to focus on where they blur. Phadke (2011) explains that boundaries between knowledges dissipate since “hybridity refers to knowledge systems that are built on both local experience and expert science” (246). While the outcomes of multiple knowledges can be considered a hybrid, knowledge itself can be a mix created through the process of “dynamic co-evolution” (Forsythe, 2003, p. 105). Categorizing all knowledges as hybrid is a way that some scholars have attempted to remove hierarchies, and not privilege one over the other (Thomas & Twyman, 2004). Beyond recognizing hybridity, is important to question how knowledges blend unevenly in practice and in discourse based on scale, production, origin and culture.

Gupta (1998) studies Indian farmers and uses agricultural knowledge and practices to interrogate the concept of hybridity. He recognizes the challenge of studying amorphous, hybrid knowledges and asks the research community “how does one theorize a condition in which disparate epistemologies and practices coexist and
interpenetrate with such disarming ease?” (156). Over time the farmers incorporated outside knowledge into their daily work at a level that it became difficult to ascertain what was indigenous or local rather than scientific or global. The agricultural practices and knowledge of the Indian farmers can no be categorized solely one type of knowledge, but instead are hybrids. Understandings of climate processes are often syntheses of both empirical science and community narratives (Ryghaug et al., 2010), making it challenging to extract local and scientific knowledge from their hybrid combination.

All the knowledges in this research are hybrids. None of the stakeholders, despite their education and livelihood, have a “pure” uninfluenced knowledge, and instead each way of knowing is made up of experiences from different knowledge spheres. The knowledge of the RMBL scientists is an excellent example of hybridity. While I argue they have a wealth of experienced knowledge from yearly fieldwork spanning decades, this is not compartmentalized from their professional research, but instead is constantly influenced and blending with their formal, scientific knowledge. Similarly, The Gunnison ranchers have hybrid knowledges because they are incorporating multigenerational and tacit knowledge, but utilize scientific information and technologies, such as technical machinery or weather forecasts.

**Regional Focus: The American West**

Place matters in the discipline of geography, and the regional context uniquely shapes my research on the intertwined nature of climate and society and political ecology. Across disciplines, ample regional scholarship on the American West, investigating its
historic influences as well as the dynamic processes currently transforming the region, provides a context for this study (Travis, 2007; Robbins et al., 2009; Limerick, 2000). I argue that contextualizing my work in the themes and scholarship of the American West is critical to my research in the Gunnison Basin because of many aspects. The extensive amount of public lands is the most significant reason that a regional context important for this research.

These complex influences and processes have led to a blurring boundary of this ever-changing region. The task of defining the American West is just as complicated as many of the complex relationships that dominate this region. The Atlas of the New West, which illustrates the changing nature of the region and depicts regional qualities through maps and graphic representation, asserts “the `West' keeps moving around in time and space,” making boundaries particularly hard to define (Riebsame et al., 1997, p. 46).

Much of what defines the West beyond physical boundaries is the underlying mythology of the West and the identities it shapes. In the mythic West of the frontier, conquest and an imagined pastoral identity continues to shape place politics and conceptualizations of rural landscape identities (Phadke 2011). Iconic images of working lands and wilderness are part of this mythology and part of what Cronin (1992) called American Nationalism. Even as the West changes and diversifies, no longer fitting the overarching generalities informed by mythology, the identities of the past still remain remarkably intact and shape the culture and behavior of residents in the rural West. Leo Marx’s concept of “Middle Landscape” was used to explain this clash between current and historic identities. “Middle Landscapes” refers to the glaring contradiction between the American pastoral ideal and its conflicting relationship with nature (2000). On one
hand it values the wild quality of nature, while also insisting on the simultaneous importance of industrial and commercial economies for rural landscapes. This conflicting relationship highlights the growing tensions between contemporary and historic visions for the American West (Travis, 2007; Riebsame et al., 1997; Gosnell & Abrams, 2009; Sheridan, 2007; Hines, 2010; Limerick, Cowell, & Collinge, 2009; Bryson & Wyckoff, 2010; Abrams & Gosnell, 2012).

Scholars have argued that the West has changed so greatly from its frontier roots that it should be divided into an “Old West” and a “New West” (Travis, 2007; Riebsame et al., 1997; Robbins et al., 2009; Bryson & Wyckoff, 2010; Nelson, 2002; Long, 2008). While many of the same trends occurred since settlement of the West, the speed and types of changes differ as do the population and identity of Westerners. “The main story in the West is rapid development… it creates tensions between the newcomers and the longtime residents: and it raises many of the enduring debates about access to land and resources” (Riebsame, 2000, p. 47).

Resource conflicts are growing in number and intensity as greater populations migrate to the region. The West is still reliant on its natural resources, but now instead of an economy that relies mostly on the extraction and commodification of resources, a new commodification is taking place. Now, the region is also reliant on resources for the quality of life they offer and the recreational opportunities they create, and this change is shaping the culture and rural identity of the region. Natural amenities have offered Western communities an edge in recruiting new investment and highly skilled residents (Rasker & Hansen, 2000).

While the West historically had a cycle of booms and temporary busts, the nature
of this trend is changing (Travis, 2007). In the New West, booms are different with mature and diverse development that moves beyond extractive industry to embrace new economies in technology, entrepreneurship and recreation (Riebsame, 2000). The New West is broadening its economy and moving towards a more developed service economy that creates new jobs (Rasker & Hansen, 2000). The concept of the New West does draw critiques from those that argue that the Old West has not died, and that many of these dynamic processes have occurred throughout time, making the New West less new and novel (Hyde, 2011; Taylor, 2004).

Increased migration to the West because of its abundant open space, access to natural resources, and its assumed high quality of life, is part of a major demographic change and defines an “amenity migration.” This influx of new populations, that are often more affluent and educated than traditional rural populations, is not only transforming the region as a driver of the New West, but also creates conflicts rooted in class and competing resource use (Gosnell & Abrams, 2009; Abrams & Gosnell, 2012; Travis, 2007; Walker, Marvin, & Fortmann, 2008; Robbins et al., 2009; Nelson, 2001; Nelson, Oberg, & Nelson, 2010; Rasker & Hansen, 2000; Kondo, Rivera, & Rullman, 2012). Gosnell and Abrams (2009) assert that amenity migrations are “both driver and outcome of this transition, resulting in significant changes in the ownership, use, and governance of rural lands, as well as in the composition and socioeconomic dynamics of rural communities,” (p. 304). The American West is one of the best examples of the amenity migration phenomenon, specifically with the move from urban to rural, which is part of a larger trend of “rural restructuring” (Gosnell & Abrams, 2009). The inflow of urban, educated population into rural areas is significantly impacting gentrification and even
“greentrification.” Greentrification is the concept that migration for natural resources is spurred by the ideals of nature and that rural and “wild” spaces have become commodities themselves (Smith, 1998). Technology has also played a role in the push and pull factors of this migration. Urbanites are leaving cities because the cities lack nature and in reaction to the high-tech development and speed of urban and suburban lifestyles. Ironically, their migration to rural areas is facilitated by technological advancements that allow flexible locations (Rasker, 2006; Gosnell & Abrams, 2009).

Publicly-owned lands are a major driver of amenity migration in the West because of their scenic nature (Frentz et al., 2012). Wilderness areas have an especially strong draw for amenity migrants coming to the American West (Rudzitis & Johnson, 2000). New migrants and long time rural community members often envision the role of public lands very differently. This not only creates conflict, but as migrants engage in politics, community decision-making, investment, and land ownership, new ideas in rural communities become new realities (Robbins et al., 2009). The imposition of new populations and new constructions of rurality can have great implications on receiving communities both socially and ecologically by transitioning parcels from working land to fallow or subdivisions (Gosnell & Abrams, 2009).

Both Robbins et al (2009) and Gosnell and Abrams (2009) outline future research questions for the New West, including studies of economic transitions, how new and old economies coexist, and what impact these changing economies have on the production of culture. Additionally, research gaps were identified in the impact of changing development and land tenure on biodiversity, as well as diversity of governance across diverse landscapes, with comparisons to other postindustrial, rural communities abroad,
or exurban development in other regions of the United States (Robbins et al., 2009). To better understand amenity migration, cross-fertilization is needed between regions and disciplines through interdisciplinary collaboration and comparisons of local and global trends. In addition, future work should focus on how amenity migration intersects with social and physical landscape diversity, and what role migrants have in environmental governance, collaborative conservation, and alliances within the community (Gosnell & Abrams, 2009).
Chapter 3: Methods

3.1 Methodology

Questions of climate impacts and adaptation can be explored using multiple research designs, different frameworks and various methods, but qualitative research offers one avenue to understand climate knowledges. Qualitative research allows “exploring and understanding the meaning individuals or groups ascribe to a social or human problem,” (Creswell 2009, 4). Methods of qualitative research were developed in the social sciences to allow the study of social and cultural phenomena (Myers 1997). Extensive research is focused on widespread understanding, while intensive research delves into a subject for a deep understanding. Messy, real world, social research can benefit from a qualitative, intensive design. The open-ended nature can offer a much better methodology for these types of research questions because it maintains flexibility and offers avenues for unanticipated information to be included.

Creswell (2009) identifies a number of attributes that are often found in qualitative research and separate it from quantitative research including: data collection in the “field;” information gathered personally by the researcher; research grows from the bottom up; the focus is on understanding and meaning of individuals; interpretation of multiple senses; and development of a complex view. My research design relied on qualitative methodologies to structure this thesis.

Ethics

This research used human subjects and therefore required special ethical attention to protect all participants from harm. In compliance with university and department regulations, and standard research procedures, I submitted my research proposal to the
Institutional Review Board (IRB) at the University of Colorado at Boulder. The research and line of questioning did not present a risk to participants and I received IRB approval for my research design. All interviewees were asked to give verbal consent at the beginning of the interview. They were assured that their identities would be protected and informed of the measures taken to protect their anonymity. Participants were involved in this research on a voluntary basis and were not compensated in any fashion. There was no promise of future benefits to participants, but these research findings will hopefully aid in providing better climate information.

3.2 Methods

To examine local climate knowledge in the Gunnison Basin, I used a single case study research design relying primarily on in-depth interviews as well as direct observations and fieldnotes over a two-month field season.

3.2.1 Case Study

Case studies are best suited to understand a complex, social, contemporary, real world phenomena where place and context matter (Yin 2014). Yin (2014) explains that three factors determine if case studies are an appropriate design for a research project: the research questions are driven to understand why and how something works rather than what or how many of something occur; the researcher needs no control over the variables in contrast to empirical research; and the focus is a contemporary issue or phenomenon. Each researcher shapes their case study to answer their research questions and cases are usually bounded by time, activity, or geography (Stake 1995). Case studies are used to
understand a complex issue with multiple variables that cannot easily be distilled, or untangled, and that require in-depth explanations.

This research design is a single case ---the Gunnison Basin--- with embedded units of analysis ---each stakeholder group--- that were compared within the case (See Figure 4 below). The four stakeholder groups were founded in key elements of the economy, the need to study outdoor livelihoods, and previous research.

![Figure 4: Basic Types of Designs for Case Studies (Yin 2011)](image)

The Basin 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 the culture is still very linked to its western roots. It is unique, falling in the “unusual case” category (Yin 2014), as a

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2 Knapp (2011) focused on three of the four stakeholder groups in the social-ecological vulnerability in the basin.
noteworthy example to study and to focus in-depth. This is because of the current adaption planning efforts in the Basin and because of its diversity in its 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 this effort and an important case to learn from for exploratory uses. Selecting one case study, rather than multiple, was the best option because the planning process involved is very unique and because a single case allows for greater depth. The four embedded units of analysis --- the stakeholder groups --- did allow diversity and comparison within the single case study. Additionally, the range of vegetation zones and complex demographics in the community also make it more rich and diverse than many rural communities. These reasons made the basin an interesting and opportune case study to investigate local climate knowledge and climate information needs.

*Fieldwork*

This research centered on two months of fieldwork in the Gunnison Basin of Colorado, from June to August during the 2013 summer. I lived in Gothic, the former ghost town and mining settlement revamped into a field research center, the Rocky Mountain Biological Laboratory. While this research was not intentionally designed as a deep ethnography with a major component of the data gained through the experience and observation of the researcher, my observations were recorded in fieldnotes throughout the field season and included an ingredient of personal experience and short-term embeddedness. For example, observations were made of social interactions in public settings such as community lectures by scientists at RMBL to conversations overheard in
bars and coffee shops in town, and discussions with local community members at city events in town.

3.22 Interviews

Interviews are an important method in qualitative research to gain understanding and insight from people within a case study. Interviews usually take place between two people, the interviewee and the interviewer, and are directly focused on the research topic (Rubin & Rubin 2011). They are a critical piece of evidence that helps the research gain perspective, understand the history, culture and identity of a person and place, and direct the researcher to other resources (Yin 2014). The research philosophy, research goal, and data analysis approach will shape what type of interview is implemented, ranging from a structured, formal interview that uses the same questions, wording, and ordering across all interviews to an informal, unstructured interview that often does not include specific questions. Thus unstructured interviews are unique from each other. This research used semi-structured interviews, which utilizes the benefits of both types of interviews. Semi-structured interviews maintain a consistent line of questions and cover the same themes, but they can be more fluid than structured interviews to achieve the desired outcome (Rubin & Rubin 2011) With some specific questions asked and themes covered in all interviewees, data is comparable across interviewees. However, the flexibility to delve deeper into a new topic, to change the order of the questions for a more natural flow, can yield richer, more in-depth interviews. Additionally, the casual feeling of a semi-structured interview creates a more relaxed atmosphere for the interviewee.

3.23 Sampling and Selection
The primary method utilized in this research was in-depth, semi-structured interviews with permanent residents of the Gunnison Basin. Four stakeholder groups were selected for the interviews to allow focus but also comparison among groups; these were:

- **recreationalists**- defined as people who generated their income from a recreation-based business such as guiding or outfitting; (n=6)

- **public land managers**- this included state and federal agency employees that managed a specific publicly owned landscape, but some, namely NRCS, were federal employees without a focal landscape; (n=6)

- **ranchers**- defined as individuals who are part of the ranching community with most operating a ranching outfit. It was the primary income for all except for one interviewee who had a second job and another who was a ranching consultant and worked for and with ranchers, but did not own a ranch; (n=7)

- **scientists**- defined as scientists and employees of the Rocky Mountain Biological Laboratory in Gothic, Colorado; (n=7)

These four stakeholder groups were chosen because they were representative of the community, because they were used in previous, related research, and because of their unique knowledge and experience with climate. In a basin dominated by public lands and a natural resource economy, the first three groups represent a significant sector of society. This selection allowed me to gain insight from different subsets of the community (ranchers vs. recreationalists); they were chosen because of how representative they were of the Gunnison community, but also the larger American West.

This research was conducted and designed collaboratively with The Nature Conservancy, who was guiding the adaptation planning process, and was built upon previous research conducted by a TNC-affiliated scholar. The previous research, and the adaptation planning process, both identified recreationalists, public land managers, and ranchers as key stakeholders, so selecting those same groups allows comparison of research findings.
The most significant reason these stakeholder groups were selected was because they represented communities who relied on natural resources (and climate) for their livelihoods and interacted with their natural environment on a daily basis. This was hypothesized to be an important factor of local knowledge and to offer a rich dataset of experienced climate.

Because the research objective was to understand local knowledge of climate among these four stakeholder groups, criteria were established to identify, and exclude, candidates for the study. First, interviewees would have a minimum residency in the area of five years, with a goal of over 10 years when possible. This is because climate, unlike weather, infers a long time period to develop a knowledge about climate. Five years was set as an absolute minimum to ensure that participants had a longer internal dataset, and most (all but two) had lived in the basin for 10 years or more\(^3\). The shortest residency of the year-round interviewees was 8 years in the basin with the longest being over 70 years.

The second criteria was that interviewees live in the basin year round, or, since this is a community with “off seasons” allowing for seasonal travel, that they spend the majority of their time in the basin. The exception to this criteria was that RMBL scientists primarily only come to the basin during the summer, so this stakeholder group provided information just about summer climate and seasonality. A few in the scientist group were year round staff and they did meet the second criteria.

The third and most important criteria, which was supported through the selection of stakeholder groups, was a strong connection to the physical landscape through daily activities. I selected people whose work was engaged in the outdoors, with the physical

\(^3\) This excludes RMBL scientists who had all spent ten summers, but not ten fully years in the Basin.
landscape, and whose livelihoods were directly tied to natural resources, and, therefore, to their understanding of the natural system. This criterion meant that for my research subjects place, weather, and ecology mattered to their livelihood. The assumption was that climate would also be both important and an environmental factor that they noticed, tracked and acted on for the success of their livelihood.

**Sampling**

This research was not designed to obtain a representative, or statistically significant sample to be able to generalize to the larger population. Stakeholder groups were chosen to include key populations, but this was an exploratory study aimed at revealing how these participants understand climate. This gives us a glimpse into how others might also understand climate, but a much larger sample would be needed to scale-up this information.

Since statistically sampling was not the goal, participants were chosen using a snowball sampling method, starting with key figures and leaders in the community. Snowball sampling is where the researcher starts with an initial set of contacts and then uses those contacts to aid in finding other participants and new connections so their sample grows with each person’s recommendation (Goodman 1961, Atkinson & Flint, 2004). This sampling method is useful when the objective is to talk with leaders and “experts” because experts within a field usually know others with similar experience. This method is criticized for being biased and is not the best sampling approach to designing a statistically representative sample because it will likely only produce a small, interconnected and often similarly-opinioned group or one with homogenous backgrounds (Biernacki & Waldorf, 1981). Since the objective of this research was not
to understand how all people in the Gunnison understand climate, but explore the local knowledge of “experts” who met specific criteria, this was a well-matched method. Additionally, the cultural aspect of rural western communities that is untrusting of outsiders made snowball sampling a very successful method. This community, and especially the ranchers, was wary of outsiders coming into the community and questioned their motives. Therefore, engaging initial contacts to recommend others was helpful in identifying who to target and in convincing them that my motives were research not advocacy.

The original contacts all came from The Nature Conservancy and people involved in the Gunnison Climate Working Group. These were primarily public land managers. The participants from RMBL were almost entirely enlisted during the two-month field season and via contacts made through living in the community. The recreation community was mostly enlisted through cold calls and going into shops and guiding outfitters in the community. Almost all the ranchers I interviewed were introduced through one very helpful research contact. Beyond that, all other interviewees were through snowball sampling via recommendations of other interviewees.

Demographics

The participants in this research were primarily white and male which is likely due to the four stakeholder groups selected, which all are historically dominated by male and white participants. The 6 women (21%) in the interview sample may actually represent the community make up in their stakeholder groups. Women were interviewed in all sectors except for recreation and this is not representative. Women do work in this industry, but I discovered that many of those women worked in administrative capacities
or were not the owners or operators. Of all the guiding operations and outfitters, only male guides and supervisors spoke with me. The ages of interviewees ranged from 27 to late 70s with most participants between 30 and 50. Residency in the basin ranged widely, but with all but two having more than 10 years in the basin. Interestingly, in a place obsessed with “localness,” this residency did not make a local. It seemed to require childhood in the area, or for some, becoming a notorious local character. Three of the participants were bonafide locals who were born and spent their entire lives in the basin. All of these were ranchers whose families had lived in the area for multiple generations. All other participants ranged from approximately 10–45 years in the basin. A number of people had come to the basin through Western State Colorado University (WSCU) and stayed for the physical landscape and the lifestyle it afforded.

3.3 Procedure

I conducted 28 in-person, in-depth, semi-structured interviews among four stakeholder groups (ranchers, recreationalists, public land managers, and RMBL scientists). The semi-structured format allowed flexibility across interviews, but a uniformity for analysis and comparison was maintained through a general interview structure and specific topics addressed in all interviews. Interview questions were assigned to six themes. While different questions were asked in varying orders throughout the interviews, all interviews covered the six themed areas:

1. background and demographic information
2. seasonality and local climate
3. climate decisions
4. adverse climate
5. reference events and thresholds

6. climate information needs

(see Appendix 1 for a list of interview questions).

Interview locations were decided by the interviewee and researcher to be convenient for participants. Some interviews took place at the homes of the interviewees (almost all the ranchers and research scientists invited me to their homes), at coffee shops or bars, local businesses, or outdoors near their focal landscapes. This allowed participants to choose a place they would be comfortable and have control over the situation. In some cases, locations were places that allowed them to “show” what they were talking about during the interview.

At the beginning of the interview, I would arrive at the meeting place early to set up, and when meeting the participant I would engage in casual conversation. This lasted from 5 to about 30 minutes on topics ranging from the weather, outdoor activities and sports, being new to the basin, or the food or drink at the restaurant. The purpose of this relaxed initial interaction was to establish a rapport between the interviewee and researcher and make them comfortable. The researcher waited for cues from the participant as to when they wanted to start the formal interview process.

To start the interview, I explained the purpose of the study and the confidentiality measures taken to protect participants, and then asked to record the rest of the interaction. All participants agreed to be audio recorded. All interviews started with background information questions, but from there departed from a strict format to a more flexible semi-structured format.
Interviews ranged in length from 25 minutes to over three hours. The majority of interviews ranged between 45 and 75 minutes. During and after each interview, I kept fieldnotes on reactions and themes that came up during the interview.

3.4 Analysis

Twenty-six of the 28 interviews were transcribed in their entirety. I transcribed them using “intelligent verbatim” protocol to maintain the full, rich quality of each interview and correctly capture participants opinions and insights, while dispensing with non-essential words. These documents ranged from 1297 to 4310 words per interview transcript.

All transcribed interviews were entered into the qualitative coding software, NVivo (Bazeley & Jackson, 2013). Before qualitative codes were assigned to the transcripts, I created a priori codes based on hypotheses, interview topics and assumed themes. The a priori codes were built around the hypothesized structure of features, benchmarks and processes, that I expected interviewees to use when explaining experienced climate. Then, I went through all 26 transcripts sentence by sentence assigning qualitative codes. Codes were assigned for concrete and specific topics such as environmental features (e.g. snow, rain), processes (e.g snowmelt), places (e.g. high country), climate information needs (e.g. hydrograph timing), and reference events (e.g. extreme events, drought years), but also for abstract, qualitative codes such as attitude (e.g. positive, negative), knowledge (e.g. certainty, tensions between knowledges), normality (e.g. normal, abnormal), and mental concepts (e.g. system balance, change). Both concrete and abstract codes help show themes that correlated with hypotheses and
led to new research findings (see Table 1 for abbreviated set of codes). As the coding process continued, new codes emerged in an iterative process of coding and recoding transcripts with new codes. This framework created nested codes within each structure and helped cluster similar codes. Once broad codes were assigned to all transcripts, they were reviewed again and subcoded for nuanced and subtle arguments or different clustering within a topic. For example, I originally coded content discussing what people wanted from scenarios into one code, “climate information needs.” After completely coding of all the transcripts, I returned to the original code and then sub-coded within it for different types of information needs (ie shorter timeframe, hydrologic information, scale).

<table>
<thead>
<tr>
<th>Abbreviated Coding Chart</th>
<th>(First order codes only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>Attributes</td>
<td>Descriptions given to different event, features, processes, both concrete (quantity, wet) and evaluative (negative, normal, etc.).</td>
</tr>
<tr>
<td>Benchmarks</td>
<td>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.</td>
</tr>
<tr>
<td>Change</td>
<td>Discussions of trends, trajectory or changes. This is primarily climate related, but also could include other processes (social, economic, etc.).</td>
</tr>
<tr>
<td>Climate Info Need</td>
<td>Any case in which an interviewee talked about what they wanted to know about climate or about reactions to past experiences with climate information</td>
</tr>
<tr>
<td>Features</td>
<td>Elements and components used to construct climate knowledge, the building blocks or structures, typically atmospheric, ecological, or hydrological.</td>
</tr>
<tr>
<td>Knowability</td>
<td>People talking about how they know something, their certainty, and tensions among knowledges.</td>
</tr>
<tr>
<td>Place</td>
<td>Specific geographies discussed, or when climate was anchored to a certain part of the landscape. Not abstract or generalized.</td>
</tr>
</tbody>
</table>
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.

Table 1: Abbreviated first order codes and descriptions. This excludes second and third order codes that were used in NVivo. See Table 2 for complete set of codes.

3.5 Limitations and Assumptions

Despite best attempts to create a robust research design, methodological limitations of this research remain and assumptions made in the process may prove to be unreliable. The sample size yielded deep insight into the local knowledge of a few rather than larger, and generalizable conclusions. Additionally, the summer fieldwork schedule enlisted locals while they were not gone during the “off season,” but this was also their most busy work season, which made it harder to get ahold of some people and probably limited the number of interviews I was able to schedule. The sampling method used might have selected only for those most supportive and open to climate decision-making since it was a voluntary study. I have to assume that people who were politically against outsiders or environmental researchers would not have answered my request for an interview. Therefore, I assume that my population was slightly more politically left than the general populace. Another assumption I made while analyzing my interview data was
that the people I talked with from each stakeholder group, generally represent others
within that same identity.
Chapter 4: The Political Ecology of Knowing Climate: Examining knowledge tensions among stakeholders in the Gunnison Basin

“If you are connected to the land, you are an ecologist. That is basically the case even if you don’t use the same technical terms.”
- RMBL scientist

This research of how people understand their climate, and its impact on the natural environment, engages with many knowledges, from scientifically-produced information to experienced understandings of community members. It foremost asks how people perceive and understand their climate and what structures and features exist in that knowledge, but is incomplete without addressing discourse on knowledge. A critical examination of knowledge, and multiple knowledges, is embedded within this research and this chapter explores different ways of knowing climate and various climate data.

The purpose of this section is to examine the climate knowledges, to unpack the power relations at play in engaging these knowledges, and to present the research findings that relate to multiple climate knowledges. First, I will contextualize how the discourse of local and scientific knowledge fits within my case study of local climate knowledge and scenarios for the Gunnison Basin, and expose the underlying power relations and imbalances embedded in knowledges. Next, I discuss four findings about the political ecology of knowledges, rather than the content of knowledges themselves. I found the mode of production and social characteristics of the producers imbue knowledge with tensions that impact their circulation through the Basin. In this chapter I use the terminology of “experienced knowledge” to describe the local knowledges in
the Basin, which is not an attempt to disregard the politics of language, but just the opposite. I acknowledge the problems and power within all the different categorizations of knowledge explicitly and choose what term will be represented in my research.

Local climate knowledge is personal, learned, everyday, and situated. It is not only based on middle school science lessons or formal education, but instead, people make decisions supported by an understanding of local climate and how it shapes the natural environment. It is not a homogenous knowledge, but each individual (or each community) has an understanding of climate unique to their experiences, their objectives, and their natural environment. Each person has his or her own situated knowledge.

**Knowledge in the Gunnison Landscape**

A case study of the Gunnison Basin in Colorado is used to explore multiple climate knowledges. The Gunnison Basin is located in the west central region of the Rocky Mountains and is a landscape with complex biology (ecosystem, species, topography) and politics (land use, land ownership, socioeconomics). The vast majority of land in the Basin is publicly owned by federal and state agencies. Natural resources are central to rural livelihoods in the Basin, and this is representative of many of larger trends in the rural American West, making it a good case study for the region.

The basin has diversity in its residents and cultures with a divide between the affluent amenity migrants and university scientists in the upper basin, which has the resort and mountain town of Crested Butte, and the lower basin, which is dominated by traditional and more conservative populations. There are long rooted tensions between how these different communities view their natural environment that are representative of larger demographic and cultural trends in the region. Amenity migration has led to new
people moving to the upper basin who value the landscape for its recreational opportunities and its natural, “untouched” beauty. The lower basin is a mix of long-term community members whose family has been in the Basin for generations (largely the ranchers) and newer arrivals. This is in contrast to their upper basin counterparts; the newer lower basin residents were attracted to the area’s traditional roots in ranching and are more likely to value a “working landscape.” Additionally, cost of living and property values are much higher in the upper basin leading to a divide in socioeconomic statuses. This creates tensions seen in many rural, mountain communities of the west (Gosnell & Abrams 2009), and complicates decision-making for the Basin’s shared resources.

In addition to differing environmental land use values, socioeconomic divisions, and cultural divide between Crested Butte and Gunnison, the social landscape gets more complicated with the addition of a third community: the Rocky Mountain Biological Laboratory (RMBL) in Gothic. World-class ecologists travel from around the country and the globe to spend summers in this retrofitted mining town to conduct their field research. The result is a rustic academic institution perched above the rest of the basin, and this spatial and educational difference has led to bizarre interactions. With transitions of directors and scientists at the research lab, there has been an ebb and flow of changing relations between the laboratory and the rest of the Basin. At some points there have been very tense relationships between RMBL and the rest of the community, primarily the ranching community, because of competing claims to shared public lands. For many decades, the laboratory could not afford to fence their land from the adjacent public and private lands used for grazing. This led to disputes because of impacts experienced on both sides. Cattle compromised research plots of scientists making it challenging to find
undisturbed research sites, and some of the research practices endangered cattle. During the summer of 2013, a rancher who had given access to RMBL scientists found discarded rebar on his land that could have injured his cattle. The RMBL administration took this charge very seriously because of the large effort it had already taken to overcome past conflicts and allow the informal sharing of land.

All of these populations will have unique climate knowledges, uniquely influenced by culture and education (informal and formal). I specifically engaged four sets of stakeholders to understand their experienced climate knowledges derived from long term experience in the Basin: ranchers, recreationalists, land managers, and Rocky Mountain Biological Laboratory (RMBL) scientists (focusing on their lived experience of climate rather than their research). All of these communities are experts of their local climate through their daily experience. Experienced knowledge was gathered primarily through in-depth interviews, but also direct observations. All interviewees lived in the Basin for a minimum time period of 5 years to ensure notions of climate rather than just weather.

**Findings**

None of the interview questions were specifically created to probe the tensions among knowledges or their circulation, but throughout the study, similar themes emerged. People spoke to how they produce their knowledge, how it circulated, what tensions existed among knowledges, and what type of knowledge they used to make decisions. Through qualitative coding, four findings emerged that go beyond the structure of knowledge and explain the political nature of knowledge. These explain not
just *how* the experienced knowledge was created and used in the Basin, but *why* it had evolved into the current knowledge landscape.

**Finding 1:** Tensions exist between and among climate knowledges based on the mode of production of the knowledge.

Interviewees were careful to express *how* their climate knowledge was produced and this often had as much emphasis as the knowledge itself because of values associated with production. This tension between modes of production of climate knowledges focused primarily on whether knowledges were derived from formal education, or informal, and experienced-based. These tensions were about the basic question of what constitutes knowledge. People asserted this qualifier to their knowledge, at times at the detriment of other knowledges. This research revealed divisions along employment lines with the four stakeholder groups. The ranching and recreational communities valued experienced climate knowledge and its ability to understand climate processes, while the land managers and the RMBL scientists, somewhat, were more skeptical of its subjective nature and accuracy.

People who had built their knowledge through experience were quick to defend its legitimacy and that they understood their microclimate and its impacts. They argued that they understood it because they “experienced it” and dealt with it on a daily basis. One rancher spoke to the knowledge of weather and climate that the ranching community gained through daily experiences. He argued that they were experts and very aware of the trends because they lived on the frontlines.

“You are talking about people who every day they walk out the door and it’s a battle with the weather. Everyday.”
While unspoken, there was a sense that some felt that their knowledge was devalued or disregarded by others because it lacked formality. Experienced knowledge was passed down by generations, sometime based on observed measurements such as recorded weather journals, but also felt and lived. Producers of experienced climate knowledge were skeptical of climate scenarios and felt like they were partial knowledge because of scale and uncertainty, but did not disregard them entirely. Localness is very highly valued and hard to obtain in this basin. Some spoke of needing to have grown up in the Basin to know it, and this was a way they categorized their community’s knowledge. This localness, and the long-term and often multi-generational experiences, created a privileged knowledge that also separated them, similar to the distinguishing higher education, from experienced knowledge.

Interviewees with more formally trained backgrounds (RMBL scientists and land managers) were more likely to look negatively at experienced knowledge (although not all- some were very supportive of its value) and want to clarify that their knowledge claims came from “data” and “science.” While many did not explicitly say so, they communicated that experienced knowledge was more subjective and were skeptical of how well people could really understand climate on a personal level. They were critical of how well people could remember weather and climate accurately, and its usefulness. Overall, most emphasized how different their knowledge was due to its production. A land manager found it very challenging to answer questions that targeted his experienced knowledge rather than what he had been taught. This was expressed in the following quotation:
“For me. I know there will be some people who will be like ‘oh it was like this...’ It’s like hmmm... Don’t put me in that category.”

While tensions among modes of production existed, I also found attempts at cordiality and some interviewees had genuine respect for other knowledges. They might not want their knowledge to be associated with the other type, but they were quick to mention that other forms of knowledge were not without value. It was challenging to assess how genuine these sentiments were when they focused so intently on distinguishing their own knowledge. Community members struggled for balance between wanting to clearly distinguish and promote their knowledge, but also did not want to fully, or publicly, discount other forms. Despite tensions and values associated with a knowledge’s “localness” or empirical nature, there were attempts to be open to other knowledges and acknowledge some value. This depended more on the individual rather than the group they belonged to.

The following two quotations show how varied the responses were about experienced knowledge. The first quotation came from a RMBL scientist in response to my description of experience knowledge and was specifically aimed at ranchers.

“If you are connected to the land, you are an ecologist. That is basically the case even if you don’t use the same technical terms.”

This quotation shows a respect of different knowledges regardless of their mode of production. The scientist was very interested in the idea of experienced knowledge and tried to speak from his personal experiences during the interview. The second quotation was from the same land manager above when he was pressed if the anecdotal evidence he shared was indicative of change. This quotation expresses a desire to show respect for other knowledge and hesitancy to trust it.
“I hesitate to be one who says ‘oh I remember the day when such and such.’ I put stock in that. I think there is value in that. But at the same time I am hesitant to go out on a limb without... I am more of a scientist. I would prefer to back everything I just said up with data.”

One possible explanation for the disparate values about the mode of knowledge production is education level. Almost all interviewees had at least a bachelors degree. The ranchers and recreationalists, in general, had lower levels of education with most having a college degree, while the land managers were a mix between bachelors and masters degrees, and the RMBL scientists were primarily doctorates. Interviewees with higher formal education tended to couch their observation with more uncertainty and were less definitive in their ability to make statement from their experiences. Higher levels of formal education not only changed knowledge, but also changed the perception to what is valuable knowledge. In the recreation and ranching community, experienced knowledge was used and swapped regularly, and they were comfortable using it as evidence to support their ideas about climate. People with higher formal training were less likely to use experienced knowledge and more likely to question its validity.

Another explanation for different attitudes about experienced knowledge might be due to the type of information people use in their profession. The land managers are tasked by their agencies with using the “best available science” and often struggle how to define it. As part of their job, they will make unpopular management calls, have decisions scrutinized by outsiders, and often face litigation. This might lead them to emphasize empirical knowledge that has a concrete mode of production and is often less controversial. Both land managers and RMBL scientists have to regularly justify their data, and its production, to outside bodies through the peer review process of academic journals and the public comment process for natural resource decisions. Using data that
claims objectivity, is not personal, and has been produced elsewhere, might be a safer choice.

**Finding 2:** Deeply ingrained tensions (and assumed motivations) between community members and stakeholder groups politicize and polarize competing climate knowledges.

Interviewees identified with their profession, aligning their knowledge with others within their sub-community, and the circulation and interaction between knowledges was largely dictated by the ingrained local politics of the knowledge producers. Knowledges passed easily among stakeholder groups through community interactions. Ranchers shared stories with their neighbors or at ranching association meetings, recreationalists talked with each other out in the field, and land managers of different agencies often met to discuss larger conservation projects. All of these interactions lubricated the flow of climate knowledges within subgroups allowing people to easily recall and quote the climate knowledges of their subgroup. This was not the case between communities.

Some interviewees expressed fears about the motivations behind other people’s knowledges. Without trust in the people producing the knowledge, there was little trust in the knowledge itself. Each community group had its own agenda (maintaining grazing rights to public land, protecting the endangered Sage Grouse), and outsiders assumed these motivations politicized knowledge. The assignment of assumed motivations to outside knowledge and actions is a major tenant of first world political ecology (McCarthy 2002). Political difference was an easy scapegoat that allowed quick dismissal of outside knowledge and constructed large barriers between groups,
obstructing knowledge circulation. The divisions most significant in this basin were between the ranchers and the RMBL scientists, and between the upper and lower basins.

**RMBL and Ranching**

A divide, both physically and culturally, exists between the RMBL scientist community in Gothic, and the ranching community, based primarily out of Gunnison. This schism has evolved out of competing claims to land in the sub-alpine zone near the laboratory where scientists conduct research and ranchers graze their cattle; it also stems from large cultural differences. Until the 1980s, the RMBL community had no fences around their property due to limited funding, so cattle on adjacent public lands regularly interacted with field experiments and caused the two communities to collide. Beyond the resource allocation, these communities greatly differed in culture. RMBL is physically isolated nine miles above the upper basin town of Crested Butte without cell phone service and only accessible on a rough dirt road; this builds a tight-knit community that is largely separated from the upper basin and even more from the lower basin. This, and the nature of the work at RMBL, cultivates a very specific culture among the RMBL community who report finding their identity in their “nerdiness” and “quirkiness.” Cultural differences were expressed in town activities when RMBL students went to Crested Butte bars in cross-dressed costumes, and at the 4th of July parade in costumes made of veratrum, a leafy native plant chanting “what do we do? Science!” and “where do we do it? Over there!” In Crested Butte, which prides itself on its character and eccentricity, this is met with mixed reactions, but there is a general appreciation for the odd behavior and outlandish costumes. This appreciation of quirk does not travel down to the lower basin. While these activities bond the RMBL community, and even work to
build a presence in Crested Butte, they simultaneously work to separate RMBL from the traditional, and more conservative, ranching community in Gunnison. Furthermore, the disconnect between many of the long-term locals and the RMBL community sprouts from the transient nature of most of the visitors who only come for one summer, or at most, multiple summers.

Both the ranchers and RMBL scientists spoke to the importance of RMBL leadership in establishing relationships between the two communities and remarked on great swings in their relations over the tenure of different RMBL directors. One director placed a very high importance on building ties with the ranching community, but others have put little effort into outreach, which unraveled the earlier progress. The current director is attempting to rebuild ties between the two communities, but legacies of former directors still imbue relations with lasting animosity.

Many of the ranchers were skeptical of the applicability of RMBL science. They questioned the point of what they saw as myopic research. The research, and the researchers, was esoteric and not applicable to their daily lives of managing a landscape. This assumption obstructed climate knowledge from passing between the communities with ease as it does within communities. A rancher, whose community still deemed him as “new” after two decades in the Basin, described how people felt about RMBL.

“There just hasn’t been a lot of outreach. Honestly most of the ranching community they see that as a bunch of strange scientists up there following ants around with little paint dots on them, and that’s true.”

Some ranchers did see value in some of the research conducted at RMBL, but felt there was a problem circulating this knowledge and translating it to the ranching community. This sentiment was echoed by in the RMBL community as well. The
growing research on climate change, phenology, and a unlinking of different climate elements (i.e. precipitation and temperature) driven by changing climate were seen as very relevant to ranching. Both the ranchers and the RMBL scientists spoke to current attempts to promote communication and its importance, but noted a continued disconnect between the two communities. Both thought that they could learn important ecological information from the other. The obstacle that they cited, beyond trust, was that different language made communication challenging. How knowledge was articulated and presented blocked its circulation between community members. This was in part shaped by the dueling perceptions and prior conceived characteristics of the other groups.

Interviewees expressed hope that bonds would continue to grow and that knowledge could be shared in both directions to build a stronger ecological and climatic knowledge for the Basin. The rancher who previously criticized the divide, slightly recanted later in the interview expressing that RMBL science could be useful to the larger community and that both the ranchers and scientists were responsible for the division.

“That there is a connection and I think there is good information. It’s just how to put it in a form that literally a cowboy can understand, or that he is willing to accept. There hasn’t been a lot of outreach either way.”

This quotation shows that the challenge might be in the communication and translation of the science, rather than obscurity as he earlier criticized, and that he assigns blame to both parties, rather than his original one-sided assessment earlier in the interview. This challenge of sharing knowledges, might not only be a communication issue as he suggests, but also an issue of knowledge circulation and the actors involved in its circulation.
Upper and Lower Basin

The division between the upper and lower basin is similar to the relationships between ranchers and RMBL, but basin divisions were largely based on socioeconomic status and cultural differences. The upper basin evinces a funkiness expressed through costume events, local parades, and self-professed eccentricities often in contrast to the lower basin that has a lower socioeconomic status and a much more traditional culture. This obstructed knowledge flow between the upper and lower basin was also present because of the tensions between the communities, as well as the underlying dependencies. A person who married into a multigenerational ranching community explained how she, as newcomer to the basin, understood the division.

“The deal between Crested Butte and Gunnison probably took years to develop, the things that divide them. And there is so much common ground that could bring us all together, but it’s all about treating each other with respect. I think. And that doesn’t always happen, from both sides. So the tension builds.

She was frustrated with the upper basin community, which she stereotyped as tourists driving crazily to get up to mountain bike trails. Despite this, their ranching business needed the more affluent customers who are willing to pay more for grass fed or organic beef, which is not the case in the lower basin. These obstructions between communities were in part intentional; people did not fully trust each other, but these obstructions were also due to community activities and how knowledge is shared. Experienced climate knowledge is informal and the avenues it travels are built around informal pathways that are at the neighborhood pub or on the ski resort chairlift.

Cultural barriers to knowledge flow suggest that there might not be a climate knowledge deficit in the Basin, but instead an issue of circulation and translation.
Scholars and planners called for scientists to provide robust and useful climate information to aid in community planning (NERC 2007; Cozzetto et al. 2011; Rasmussen et al. 2011) and while this could be useful in the form of climate scenarios, increasing interaction between climate knowledges might also work to remedy this. An emphasis on educating lay people and bringing in scenarios might also need to include creating cross dialogue and knowledge sharing in the Basin. This finding begs the question of whether solely new knowledge is needed, or if sharing of existing knowledge is also needed to support climate adaptation planning. Additionally, when climate scenarios are built for communities, this finding suggests that the selection of who does outreach might impact where knowledges trickles down to. Assuming that climate information would spread to various subgroups, rather than within subgroups, might be an unrealistic expectation.

**Finding 3:** People with less formal education had greater confidence in their experienced knowledge of climate.

This research asked all participants to comment on their experienced-based knowledge of climate, regardless of how they usually engage with climate. This means that even the RMBL scientists with doctorates in ecology were ask to speak from personal experience rather than from research findings. There were strong divisions of interviewees’ certainty in experienced knowledge and comfort in using it as evidence to support their opinions. Recreationalists and ranchers spoke with the most certainty. None of the land managers spoke with certainty when pushed to talk from informal experience. The RMBL participants were mixed. Some RMBL interviewees were very
committed to participating in the spirit of this research, and as an exercise prompted by this research, only spoke from their experience. Others found it more difficult making claims built on their experiences with a place without using scientific measurements.

When I asked land managers to describe something from experience or interpret their landscape, almost all of them prefaced or finished their answer saying “I don’t know…” by specifying they did not have data, or that their answer was only speculation. I followed up on a land manager’s description of a normal monsoon, asking if she thought the intensity of rain mattered. Her response shows strong hesitation to speak from experience on the landscape without expertise or formal training in the area.

“I don’t know. I don’t know.... I don’t know. This is all observational. I have no science. And I have absolutely no real education behind it. It’s just purely observational. I don’t know if that would matter or not.”

A rancher and I discussed his views on the hyper-political nature of climate change. He felt that it had gotten so political that he could not distinguish what was true or not true and what different peoples’ motivations were.

“Regardless of all of that, I think things are changing because I can see it here. So I believe that.”

He was frustrated that his neighbors became engaged in these politics either rejected climate change or mistaking natural variation or singular events as evidence of climate change. He recognized the difference between weather fluctuations or extreme events and changes to the long-term climate. He had witnessed changes in the timing of peak runoff to earlier in the season, which he understood as climate change rather than weather.
This research implies that people approach knowledge claims about climate (trends and averages) similarly; they use data to support these claims. The difference between groups was what types of knowledge they were comfortable using as data. Tensions in interviews showed that some people were uncomfortable with using their experiences as data and evidence and wanted different information to support their claims. They narrowly defined data as empirically produced and numeric. Ironically, champions of experienced climate knowledge structured their arguments the same way as those using empirical knowledge. They used data and evidence to support their claims, but just had a broader definition of what constituted data, and used personal experiences as evidence to support their climate knowledge. Understanding that the differences lie in what constitutes data, helps expose similarities between how people approach making claims or share opinions about climate.

This finding suggests that certainty of a knowledge claim produced through experience will differ based on the training and culture of the individual rather than purely on the experience itself. Studies of knowledges over a large landscape should recognize that those with advanced degrees might signal lower confidence for the same observation. This could be used to aid in interpreting or calibrating broad climate knowledge of diverse groups of people. Someone who is only tentatively sure of their experienced knowledge might be more an indicator of its mode of production rather than the content of a knowledge claim.

**Finding 4:** Most of the climate knowledge was not purely experience based or scientifically informed, but a blending of the two into hybrid knowledge.
While I have discussed “experienced climate knowledge” as a pure entity and in contrast to empirical knowledge, this was not the case for most of the interviewees. Understandings of climate were hybrid knowledges, shaped both by what they had personally experienced and also through information provided in climate and weather forecasts and research. All of the participants said that they monitored weather (temperature and precipitation) as well as ecological processes (river flows) regularly and that this information was used to make decisions. Many said that they could also come to the same finding through observations in a place. For example, fishing guides spoke of being able to go to familiar rivers and knowing what the river flow (CFS) was just by floating it and observing how far certain rocks were submerged. Ranchers spoke of watching for key ecological indicators (flowers blooming) as indicators of larger ecological changes. RMBL scientists discussed watching for phenological cues of when different species would arrive to Gothic to inform their rubrics (built off of years of fieldwork) and decide when to plan fieldwork.

However, when discussing decision-making, interviewees were often using personal observation and forecasts in tandem to inform each other and to offer more robust decision rubrics. It oversimplifies climate knowledges, and the individuals who produce it, to characterize a knowledge as purely experiential or purely empirical, and it obscures the creative nature that these people employ in building their knowledge. A number of the guiding operations were making short-term decisions on what type of excursion to provide for a client, but they occasionally needed to make decisions further out. When planning for specific courses, a mountain guide explained they needed to start booking them months before the weather was knowable. He would try to plan courses
during the “heart” of a season based on his knowledge of climate, but he also used NOAA data to aid in the decision.

“On a day to day basis we’re looking at weather models through NOAA or wherever we are, kind of being our own weather forecasters –as well as reading the forecast. We’re pretty in tune with that but that’s more on a day to day model.”

A fly fisherman discussed a similar strategy when I asked where he gets his information about climate.

“I’ll check NOAA’s weather forecast. I will check the avalanche centers snowpack and stuff like that. And I will check the river flows on the geological survey. Stuff like that. But a lot of it you can kinda tell what’s going to happen after a certain amount of time around.”

He was very confident in his ability to read the landscape for cues after 20 years in the Basin, but still tracked weather forecasts. The quotation shows that while he uses NOAA weather forecasts, he does not view them as necessary due to his experienced climate knowledge. Another example of this was that many of the ranching community members spoke about the state climatologist by name, Nolan Doesken, and commented on his forecasts and climate information suggesting that they also created hybrid knowledges from various sources.

Viewing climate knowledge as a hydrid and acknowledging the multiple sources, might explain commonalities and differences between experienced and empirical knowledges. Hybridity also helps in understanding what information factors into individuals’ own forecasts and decision tools.

**Conclusion**

The Gunnison Basin represents a community with rich experienced climate knowledge as most of the residents rely on and interact with the physical environment on
a daily basis. Through this engagement they have built complex understandings through both informal and formal experiences.

This chapter looked deeper into the production, circulation, and politics of climate knowledge. Literature aided in critically examining what constitutes experienced knowledge, how it is both different and similar to empirical knowledge, and how climate scenarios interact with various knowledges. This study found that the mode of production as well as the producer of the knowledge influenced the politics of that knowledge. These politics and tensions caused some knowledge to be valued and others to be devalued, and determined whose knowledges interacted. Beyond the tensions between knowledges, different subgroups expressed very different levels of confidence in their own experienced climate knowledge, suggesting that while all participants have experienced climate knowledge, some were seen as better sources of information for decision-making. This research pushed beyond the dichotomy of how local versus scientific knowledge informs peoples’ understanding climate, and found that many sources build experienced climate knowledge and that each is a hybrid of both empirical and lived knowledge.

These insights help us understand how rural communities understand climate, the politics of climate knowledge, and how to engage with climate knowledge. Climate adaptation is increasing suggested at the local level, and these research findings show that not only looking at the knowledge, but the knowledge interactions and characteristics, is important when engaging experienced climate knowledge. Probing further to understand the knowledge landscape can help inform how to engage different knowledges and lead to more successful adaptation planning processes.
Chapter 5: The Anatomy of Experienced Climate Knowledge: Dissecting Structure, Characteristics and Emerging Themes

“It seems like this place is pretty blessed, with just kind of the weather obviously tweaking here and there, but it seems pretty blessed. It doesn’t seem like it’s really radical to me. We always seem to luck out and get our rain. We seem to luck out and get our snow... “

-Recreationalist

People interact with climate on a daily basis, and a growing body of literature studies climate in terms vulnerability, risk, adaptation, and human perception and beliefs. The study of climate perception has almost entirely been eclipsed recently by the study of attitudes towards and beliefs about climate change per se (Lorenzoni et al., 2006; Leiserowitz 2005; Kellstedt, Zahr, & Vedlitz, 2008). Much less attention is given to questions that push beyond beliefs about climate change to focus on how people understand their climate in its multifarious nature. Yet, experienced climate knowledge is at the foundation of social dimensions of climate research and permeates into other studies of attitudes and actions. Without understanding the character of climate knowledge, only superficial conclusions can be offered about why people hold particular beliefs and take certain actions.

This research was motivated to tease apart how people build their understanding of climate knowledge, and to examine the critical components and experiences that comprise this knowledge. Stakeholders were specifically chosen based on livelihoods connected to natural resources, which I argued made them “experts” of climate due to deep experiences. Because of this selection, I would expect these stakeholders to have a much more finely tuned cognitive climate (that
is, a mental model of climate) than the average person, making them especially helpful to build theories focusing on climate knowledge and sorting out usefulness of climate information. These stakeholders may have a stronger connection to their climate, but I believe that the findings still can provide insight into the knowledges of other populations.

A priori ideas of structure and characteristics were established before conducting interviews to provide a framework to understand and analyze local knowledge. This was based on initial exposure to community members and built from previous work and the limited literature on climate perception. I hypothesized that mental models of climate are built on three components: features, processes, and benchmarks.

1) *Features* capture the different climate elements and components that people used to construct their climate knowledge. This is the most basic structure, the building blocks that shape all the 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. Features can offer a common ground between modeled and cognized climate and can help in the circulation of knowledge. Features include static elements that might be the product or driver of a process, but that are one entity. Interviews provided a range of features to examine including: dust, snow, drought, storms, water etc.
2) *Processes* help explain “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 between features. 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, to which people bind their climate knowledge. People use benchmarks as temporal structure to help order the messy climate around them, and help them read the climate for 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.

I expected to find these three components elaborated in various ways, yet still providing the skeleton for structuring experienced climate knowledges. I do recognize a few dimensions of experienced climate knowledges that transcended
This three-part structure, as described below. Table 2 shows the codes used in qualitative analysis.

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<td>Snow/Snowpack</td>
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Table 2: Codes and subcodes used in NVivo analysis. This includes a combination of *a priori* and emergent codes. See Table 1 for description of codes.

The hypothetical structures proved to be important characteristics in experienced climate knowledge. As critical components of the anatomy of climate knowledge, these structures were present across interviews and provided a useful framework to examine this knowledge. However, the outcomes complexified and the elements became rearranged across the multiple interviews. This led to a
number of new findings that went beyond structure, to explain the nature of experienced climate knowledge. The most surprising of these results was how social knowledge, ecological knowledge, and atmospheric knowledge were blended and blurred into complex and dynamic climate knowledges. This finding is at the foundation of my research. After addressing the complex nature of climate knowledges, I organize findings under the social, ecological and atmospheric dimensions of climate. Each category has findings that complexify notions of climate knowledge and add insight into how people come to their individual understandings of climate.

Finding 1: Climate is a social-ecological-atmospheric construct. Climate processes are imbricated with ecological and human processes.

Interviewees were asked a range of questions about climate, and surprisingly a lot of their answers were not just about atmospheric processes that are typically considered climate. Instead, answers about “climate” included ecological impacts, climate processes, and social dimensions. Throughout interviews, when people discussed climate they talked about the social pressures relating to climate and about ecology as part of climate. They also looked at the impacts of climate as tied to the human management decisions, rather than keeping them apart in different categories. In short, people refused to compartmentalize climate, and instead offered hybrid knowledges of socio-climate impacts.

For example, interviewees were asked to describe an “adverse climate” that would evoke feelings of risk or be detrimental to their livelihoods. Many answered this question with how human elements of change, and specifically changing demographics in the
future, would cause impacts. A deep-seeded tension exists within the community between both the tourism economy with an increasing number of second homeowners and the communities that identified with the traditional and historic economies in the Basin. Specifically, people discussed increased migration and vacationing (tourism) as a likely part of climate change. Crested Butte visitors travel from around the country and globe, but the majority of them are from Texas and Oklahoma. Most of the second homeowners and regular seasonal visitors flee to the high-elevation mountains of Crested Butte to escape the suffocating summer heat in Texas and Oklahoma. People saw this seasonal migration of Texans and Oklahomans as inextricably linked to climate and part of a growing social pressure that previous generations did not encounter or need to negotiate on a daily basis.

One rancher in particular, deeply felt human changes to the landscape and he linked them to climate. He was approaching retirement after more than seven decades in the Basin and had witnessed large changes due to demographics and increasing recreational pressures. Both his father and grandfather had spent their lives ranching the very same land, using the same practices. He explained how different ranching was for him and for his father:

“We have a whole different set of circumstances today that he didn’t have to deal with. He didn’t have to deal with all the mountain lions. He didn’t have to deal with all the tourism and all the recreation. He didn’t have to deal with too many elk. All those kind of things are new today compared to what he had to deal with 60 or 70 years ago.”

He claimed that growing recreation pressure, and mountain biking in particular, was completely altering how he ranched. The growing recreation pressures were not only encroaching on his land and the federal lands he held permits for, but also influencing the
wildlife populations. He felt that changes in elk movements were due to changes in human behavior, in part linked to climate. More people were biking in the Basin and they were expanding more deeply into wildlands, disrupting and haz ing elk herds so that the herds moved onto his grazing land before his cattle did. He saw increased interactions and conflicts with elk and mountain lions as a product of increased recreation pressures. Peoples’ movement was driven by climate and was part of a changing climate according to my interviewees. Many did not distinguish between climate and social processes when discussing migration because they viewed them as connected and both parts of a larger system.

Additionally, other ranchers interviewed specifically talked about the challenges faced by this older rancher due to his land’s geography and adjacent recreation areas, unlike many of the other ranchers with landholdings in the lower basin. A husband and wife who ranch in the lower basin where recreation is less of an issue, corroborated the challenges faced by the older rancher. The wife explains, ”[the rancher] deals with a whole different set of issues than we deal with.“ Her husband added that he did not think he could ranch with those types of pressures and be successful the way the older rancher has. He added that “he’s been through a lot… you wouldn’t want to ranch there.“ The older rancher and his community members felt that recreation pressures and increased populations were the biggest threat to ranching in the upper Basin. Both of these pressures will likely continue to increase and be driven by a changing climate. The older rancher explains that the biggest impact of climate change for the ranching community will not be climatic changes in Gunnison; it will be the warming of other localities linked to the Basin.
“They say if it continues to get warmer, tourism is going to increase because the Southwest is going to be unbearable. So that is going to mean more people come, more people want to live here. The more people, the harder it is on our business. It doesn’t matter whether it is winter or summer. So, to me that is the biggest challenge.”

This discussion on migration due to climate change echoed through many interviews, to the delight of the recreation community and the dread of the ranching community. Many different ranchers focused on recreation as a major threat. It is unclear whether this strengthens and validates the argument that many of them actually experienced recreation pressures, or if it shows the circulation and communication of a common narrative within the community.

A younger rancher, who was member of a prominent a fifth generation family in the Basin, viewed recreation and climate pressures separately. He differed from his older counterparts due to his age and education. He studied agricultural sciences at graduate school and was very familiar with climate and climate change forecasts. He suggested that it was the nature of the human changes, which were felt so acutely and in such a short timeframe, that caused his community to focus more on human than atmospheric dimensions of climate.

“The climate issue is more like a frog in a boiling pot where the tourist influx is very abrupt even if it’s just seasonal. It’s abrupt and it’s more, it can be more challenging. But I’d say, on my timeframe, its probably the more predominant, I can work on PR and communicate to people and actually... the tourist thing, I can work with that. But, what falls out of the sky is the real constraint.”

He thought that, as a young rancher planning a long future, that atmospheric climate would be a much more important risk than tourism. Indeed, he was contemplating leaving his family land for places up in Montana or the Pacific Northwest. Finding a ranch that would support him throughout his working life and have a stable water supply despite a
changing climate was very important. He thought that tourism and increased migration of
visitors, in contrast, was what the older ranchers felt most intensely in the few remaining
years of their career because the changes in climate were likely not to impact them
immediately.

Another component of an integrated social-ecological-atmospheric climate, was
how land management decisions were part of the climate impacts people felt. Impacts
were a hybrid of climate drivers and human drivers. These 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 are paired with a changing climate.

A fly fisherman 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.”

Later in the interview when asked what information he wanted in climate scenarios, his request was for something akin to integrated models that include humans 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, in terms of information needs, risk, adverse climate, or decisions, they often responded by bringing in the human elements of change. This suggests that people 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.

**Social Dimensions of Climate**

*Finding 2: Climate knowledge is shaped by, and a product of, livelihoods that:*

2. a)- focus on specific times of year
2. b)- focus on a specific sub-set of climate features, events and processes
2. c)- shape climate rubrics that aid in interpretation and anticipation of climate.

Experienced climate knowledges are tailored to their producer and shaped through their daily actions and experiences. Fly fishermen 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 enshrined through the repetition of certain actions. 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.

*2. a)- Climate knowledge is shaped by, and a product of, livelihoods that focus on specific times of year*

Natural resource livelihoods are balanced on different elements of climate that key to distinct times in the 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 incredibly 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 struggled to find the "sweet spot," which is only made more challenging by the logistics of having to schedule semi-trucks in advance to come move cattle off pastures with blooming larkspur because the trucks book up. 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 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 the monsoon season, or summer afternoon rains. They offered specific days on which they
would expect the rains to start whereas other groups only discussed their presence in a broad, seasonal manner. This attention was due to how summer rains disrupt haying season, and therefore are carefully watched. Multiple ranchers retold the same joke that the rains only seem to come right when it is haying season. 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 is highly variable and challenging to predict, this quotation 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, others outside the ranching community shared it with me. “Monsoon [occurs] in July, early to mid July on through hay making season,” a land manager shared with me laughingly. Numerous other ranchers spoke in great detail regarding the monsoon start.

For the RMBL community, seasonal changes were key because they triggered the mass arrival and departure of ecologists to and from Gothic. These academics’ field season is 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; timing this proves to be very difficult. Many spoke of rubrics they used to help predict this, and of attentive monitoring of the local weather 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 the strict university schedule. 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 have such a high resolution among the RMBL researchers. Livelihood practices that lead to seasonal climate focuses, also lead to specific focuses on features and processes.

2. b)- focus on a specific sub-set 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 the type of work. For example, every person I talked to discussed snow in winter as a key element of climate, but the ski guide was able to elaborate in much greater depth and differentiated between different snows 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 I interviewed had a very deep notion of climate change that he experienced through his years of guiding and seeing tangible changes in the glacial 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.

This guide was one of only two people who spoke about corn skiing and corn snow. Because others did not require this for their livelihood, it was excluded from key features of climate. Furthermore, this guide 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 shoulder seasons, are not as salient to his recreation
business, and tourism seasons. 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.

Only one segment of one group mentioned water temperature: fly fishermen. As they responded to my question asking seasonal change in a typical climate, the three fly fishermen I 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 fishermen came back to the feature of water temperature throughout the interviews. The fly fisherman 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 fisherman 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 quotation 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 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 USFW, but most of the fisherman 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 their competitors continued to fish these areas. The actions of the guides are in direct conflict with many of the theories of shared resources that result in a “tragedy of the commons” (Hardin, 1968), or incentives of freeriding with public goods (Olson, 1965).

Water temperature was a focus throughout the guiding season, and along with water levels, was tracked for key thresholds. The guides expressed specific thresholds of temperatures that were detrimental to the fish. Another guide shared an absolute threshold that he tracked conditions for:

“The only time that you don’t want to fish is the real hot low water. 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 ecological system. The guides were very certain of their riparian system knowledge and of the thresholds that existed within the system. This shows how highly developed experienced climate knowledge of key features of a system when they are connected to livelihoods.

2. c) Shape climate 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, multigenerational guidance passed down, 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 away from the rest of the month 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.”

Locals whose family had lived in the basin for generations – primarily ranchers- had rubrics that were formed and tweaked and handed down along with family 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 cattlemen 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 variously-located pastures, and this scheduling must be done days in advance. To help him decide when to move the cattle, he recalls a landscape clue- 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 whose family had lived in the area, created a new climate rubric based on new benchmarks. In my 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 gage managed by NOAA and the NRCS) 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 feet, 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, it’s 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.’”

In addition to families having developed rubrics specific to managing their landscape, different sub-communities shared benchmarks that acted as rubrics for decision-making. For the RMBL community, their main benchmark was if 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 of research design and implementation, as well as field season 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 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 of Climate

Finding 3: 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. I spoke with one scientist who
researched this mismatch, and had been coming to the laboratory for more than four
decades to study the timing of plants and pollinators. He 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 previous (2012) summer.

“What happened last 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 so extremely early, snowmelt. The key difference was that early snowmelt was not followed by 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.

If temperature and precipitation continue to become unlinked and to redefine the seasons, new threats and challenges will emerge in the local ecology. I 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, and how neither of them know what to expect from these changes for their research.

“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, it’s 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 these 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.

I expected to hear a significant amount about this in my 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 this 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 fishermen, ski guide), did not mention this 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 a 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 between 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.

**Atmospheric Dimensions of Climate**

The Gunnison Basin experiences a highly variable climatology with temperatures changes of over 130 degrees Fahrenheit through the year. In summer temperatures creep into the high 80s and in extreme cases approach three digits. In winter, temperature regularly drops below zero and even down to 45 degrees F. below zero (Gunnison 1 N Colorado, 2006 b). Precipitation can be mixed as well with a single month experiencing several feet of snow and another one being “bone dry.” Additionally, climate variability exists inter-annually in the basin 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” and springs that come too soon. Residents 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. Even within a single day, weather can widely fluctuate, as a young fly fisherman alludes to in his joke.

“In this state, the hardest job is to be the weather man in Colorado. It’s difficult to get a breakdown of seasons here because the people, you will see every season, even in one day, sunshine, snow, rain.”

While sunshine and rain are not examples of seasons, this was a sentiment repeated by numerous interviewees; they could have drastic changes in weather within one day of work. For those who were interviewed and believed that climate was changing, they 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, and again specifically focusing on variable precipitation, using reference years as evidence to support his claim. The following quotation also depicts the high resolution of climate memory.

“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.
Finding 4: 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 rancher who had lived in the Basin for more than 7 decades described how quickly the weather changes, impacting daily decisions.

“One week you have 4 or 5 days that are really nice, you will shed your coats, and the next week you are finding all your winter clothes again.”

He spoke about this with a chuckle, but explained how this can be an inconvenience. This inconvenience, similar to experiences of risk, forms memories. The climate and its daily weather were discussed as challenges that people had to overcome and therefore required attention. 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 in her early thirties explained how challenging this variability made planning her wedding. She had just moved to the Basin with her fiancé and was polling her neighbors about when to plan an outdoor wedding, a risky endeavor in this climate. She selected August after a number of discussions because most agreed that it was the safest and most predictable month. Despite her best efforts, they 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... 2004... So yeah, August 2004, hail. In the afternoon for like an hour.”

Assessing the weather for her wedding required much greater research and detail than it would likely require in moderate locations, and the personal benchmark (her wedding) helped her remember specific weather details for more than a decade. While people give greater attention and focus to variation, this range and constant unpredictability make it challenging for them to see overarching trends.

**Finding 5:** Noise generated from climate variability obscures trends and makes it difficult to recognize patterns

All the interviewees recognize that their climate is extremely variable, but detecting a trend is much more challenging. Even attempting to pinpoint a “normal” or “typical” climate was very challenging for locals. This was the sentiment regardless of how much time they had spent in the Basin. When I asked what a typical or normal climate was, many of the participants simply baulked at the question because typical was so hard to determine for this place. The general sense was that it was hard to identify normal, and that variability is the only thing that you can expect from the climate. One land manager interviewee refused to even discuss 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, [if he] hasn’t ever seen one, then I am not going to...”

This is a place that even 70 years of experience cannot calibrate a “normal” or trend. The interviewee continued by explaining how variable the system is and how he thinks it 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. He claimed to detect changes in climate, but found it harder to cohesively characterize what was happening. He explained this was the case for others in the community.

“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.”

**Conclusion**

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 processes.

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.
Chapter 6: Actor Driven Climate Scenarios: Understanding climate needs to better shape climate information

“The weather is weird. It seems like it's getting weirder. For us, we're kind of like climate farmers. We're based on whatever the environment is doing. It affects the business here.”

- Mountain Guide

Globally, people will increasingly be facing decisions about living in a changing climate. This is especially true for people whose livelihoods are directly tied to natural resources. The Gunnison stakeholders in this research all have livelihoods that rely on their natural environment. They built an experienced knowledge of their climate to aid them in interacting with it, and to guide their climate-sensitive decisions. With growing scientific evidence that the near future climate will be different from the recent past, and as this change ripples across ecosystems on which they depend, stakeholders may value new scientific information about the climate that they can use in tandem with their experienced knowledge.

The political ecology and the cognized structure of climate as it is construed in the Gunnison Basin, analyzed in previous chapters, provide a framework for addressing the instrumentalities of climate information, and the apparatus of climate models and projections. The construction of these knowledges was first examined through its structural components and then through an examination of how people understand their localized climate. Together, these two research questions can illuminate the climate knowledge landscape and this foundation can be used to inform the climate information needs of stakeholders. This chapter focuses on what information stakeholders desire and
need, if it’s perceived as useful, and the challenges in making that information digestible for stakeholders.

Interviews and observations in the basin indicate that there is no lack of climate information, but instead, that this information is not always compatible with stakeholders’ cognized, experienced climate knowledges. The stakeholders in this research are actually a bit unusual for the amount of high quality climate information that has been made available to them. NOAA scientists created custom downscaled climate information for the Gunnison Climate Working Group stakeholders, and the group has regular access to a climate scientist familiar with their multiple goals for planning, assessment, conference calls, public meetings, and other venues. But the effort has proved of limited efficacy for a variety of reasons, some of which came out in the interviews, and other aspects of which can be discerned from reports of the group. Many of the now well-known barriers to useable climate information (Moser & Eckstrom, 2010) are present, including a persistent uncertainty in projections that, in this particular region, have the awkward quality that model, nor dynamical reasoning, can pin down the sign (plus or minus) of future precipitation trends. But a more subtle barrier also exists: disconnects and incompatibilities between the stakeholders’ climate knowledges and the climate scenarios. This chapter explores these problems, and makes recommendations about how more effective information might be developed.

Finding 1: Needs are socially-constructed

Just as this thesis has discussed the social construction of climate processes and features, it also acknowledges the socially constructed nature of information
needs, needs that are imbued by the local culture. The Gunnison Basin’s culture, geography, and prior experiences all mold information needs and usability.

1.1 Livelihoods determine information needs

Livelihoods and daily practices shape information needs similarly to how they sculpt knowledge. Critical elements and aspects of timing and specificity of information are based on how stakeholders engaged with climate. While some commonalities exist among stakeholder groups in areas such as runoff timing and snowpack accumulation, individual communities require different information for decision-making related to their livelihoods.

A rancher explains that for his community, the timing of monsoons is critical, although for different reasons within his community.

“Monsoons, if monsoon timing were to change over time, if it got later or earlier that would impact ranching. Depends on if you are trying to put up hay or not. If [the monsoon] were later and runoff were to stay the same, it might mean that more people would get up more hay. That’s the hay part of it. If you are looking at rangeland and grazing, if summer grazing and the monsoons didn’t come until later, then that would not be good. For two reasons: one is the grazing, and the second is stock water.”

Other communities were concerned with monsoons, but for different reasons. The scientists worried about timing, but because it might create phenological mismatches. Land managers cared about the quantity of precipitation, and measured it in their systems, but were less attentive to start and end times. Recreationalists’ concern about monsoons was mixed; the fly fishers and river guides relied on additional water inputs during midsummer, and paid close attention to the summer rains. But a guide who only
offers excursions in the terrestrial environment cared less about the monsoon, and instead was concerned about the timing and quality of the “shoulder seasons.” His guiding operations were simple to plan during the heart of the main season, but he tried to tailor specific activities to the shoulder season- the transitions between winter and summer.

“If you could say we are going to have predictable snowfall starting in November or December, and it’s going to go through March or it’s going to go through May, that would be super-helpful because then we can plan. [Seasonal timing is hard to figure out]…because that shoulder kind of stuff is up in the air.”

He needed to be able to plan guided trips months ahead of time, but felt that outside of the heart of seasons, predicting seasonal timing was challenging. The “shoulder seasons” were moveable, and certainly not tied to the typical climatic seasons by which most climate data, and model output, is organized.

1.2 Place determines information needs: the case of dust

Stark cultural divisions exist between the upper and lower communities in the Gunnison Basin. They operate in different physical and social landscapes, which shape identities and create different places with differing economies, politics, and cultures. Different ideas about climate emerge in each place. As Chapter 5 argues, climate is not isolated to atmospheric processes. Questions about information needs elicited social and ecological responses that differed due to place. The upper and lower basin communities both expressed concerns about two elements that fall outside the traditional notions of climate: dust and sage grouse. Dust is an abiotic factor that is now seen as integral to the snow climatology of the basin via its role in hastening snowmelt processes, and sage grouse is a biotic feature that also grew in salience in recent years as the U.S. Fish and
Wildlife Service proposed to list it as endangered. They both bring a notion of fear and threat; sage grouse threatens the traditional way of life – ranching – in the lower basin and dust endangers the modern economy and quality of life in the upper basin. These two issues are entangled in climate in complex ways; sage grouse become part of the climate via their obligation to certain climate-controlled ecological niches, like sagebrush slopes and the few wetland sites that perforate sagebrush slopes, and dust became part of climate as it traveled in storms and changed precipitation on the landscape.

Dust was an unanticipated element that emerged numerous times in interviews. Specifically the issue of dust-on-snow was described, which results from dust storms from the Colorado Plateau traveling into the Rockies and depositing reddish dust on the snowpack. This is not a completely new phenomenon, but many who observed it argue that it is increasing in intensity and frequency, and it has received increased researcher and media attention recently (Neff et al. 2005; Painter et al. 2010; Reaman, 2014). A variety of impacts from dust-on-snow are felt in the Basin, but the main one is that it causes the snowpack to melt faster and sooner. A mountain guide, who does extensive winter recreation guiding – primarily skiing – described this trend and the risk associated with it.

“The dust layers that have been happening here in the spring have been a huge problem. We’ve seen more and more of that happen, and then it shuts down the end of the ski season. Because the dust sits on top and then ruins the spring skiing, and then snow melt happens way faster, so that’s been a huge concern.”

This fear was echoed by others because of how important the ski industry is to the economy of the upper basin, but also the impact to water supply, a perennial natural resource and political worry in a basin intricately entangled in the management rules, legal mandates, and exacting regulations of Colorado River water.
With a less dependable snowpack, some locals have suggested that the upper basin transition to focusing on summer recreation. Residents believed that dust events were a significant driver of what they saw an increasingly unreliable snow conditions. A fly fisherman, who first came to the Basin 20 years earlier for the skiing, explained how the dust makes “skiing kinda funky” which will have substantial impacts for the economy. He concluded that “the dirt’s a big thing.”

The rapid runoff is detrimental to a community built around a ski area, but also has impacts felt beyond the recreation community. Another guide independently brought up dust in the interview and seconded the fears surrounding it. He described how “one of the biggest influences in snowcover has been the dust events” and spoke in some detail of how the change in albedo altered the hydrologic cycle critical to the ecology and social dynamics of the Basin. He continued by discussing how dust will amplify existing climate impacts, particularly contributing to the climatic-ecological “mismatch,” which has become something of a basin-wide climate narrative. Specifically, dust will impact the ecology due to early snowmelts from dust deposition “because you have got plants emerging potentially two months early, and yet the pollinators aren’t here yet.”

The residents who discussed dust had a very high understanding of the physical concepts linked to the process. While not all of them used terms like “albedo” or “deposition,” they all explained to me the airborne transport of the dust, or dirt, from the Colorado Plateau, and explained in one way or another the radiation balance of the snowpack. This attention and focus on dust indicates the weight that is placed on it locally, and the amount of time the community discusses it. People who live and work in the lower basin did not discuss dust generally, and those who did felt less vulnerable to it.
The one exception was that it came up in interviews with land managers who primarily live in Gunnison. This is likely because much of the land they manage is in the upper basin, and as a result they are more aware of the issues of the upper basin.

1.3 Past experiences with climate information determine information needs

Many interviewees were unique from other rural westerners because they had previous experience with climate models and scenarios. The Nature Conservancy (TNC) provided stakeholders with climate information as part of their Gunnison Climate Working Group (GCWG); this was an attempt to bring climate information to diverse users and lay people. Other university researchers also interviewed stakeholders about climate.\(^4\) The information needs they shared with me were a product of their previous experiences with climate scenarios. For many locals, the GCWG was their first experience with climate information and scenarios, and it directly shaped how they thought about future information from models, specifically in terms of whether useful information could be provided.

Common complaints about the scenarios were how hard it was to understand them, and doubts as to whether they even offered actionable information. An opinionated part-time rancher had a strong reaction to the original scenarios produced by TNC and NOAA partners:

“The climate change modeling was so broad and so esoteric that you look at it and you say yeah right, you know?”

He continued to explain that the information is simply not compatible with resource management decisions. This previous experience made him skeptical of how useful

\(^4\) (Knapp, 2011; Knapp et al. 2013)
additional climate information would be. Another land manager who participated in TNC workshops where climate information offered a milder response, but still was skeptical of how usable the information would be. She responded that in the years since the information was given to her, she still had not incorporated the information into her management decisions.

“I am not sure I buy into the models 110%, especially since I think there was one out there that said that things were actually going to get colder and wetter. So I was, I came to a couple meetings in the very beginning and ... But its still, so I have to say. I looked at the models and I was kinda like ‘aaah I don’t know if I buy into this,’ but anything to improve water holding capacity and ecosystem function, that’s got to be a good project.”

This quotation shows a hesitation towards the accuracy of the climate information and she explained that a lot of her hesitancy came from not being sure how certain the information was. Error bars and other indicators of certainty would be very helpful for her interpretation. Uncertainty in the models was a struggle for many of the people interpreting them; many also expressed skepticism about whether climate was changing for the long-term or whether recent trends, if any were noted at all, were just part of a cycle. One rancher who was active in water management shared that a colleague and friend had told him that the models predicted temperature well, but were not able to predict precipitation well, so he would be very skeptical of those projections. This anecdote shows how not only direct experience with climate information, but also the experience of others, will impact interpretation, interest and trust in the information.

**Assessing climate needs**

The second part of this chapter focuses specifically on feedback from stakeholders about previous experiences with climate scenarios, and on their current
information needs. Previous attempts to disseminate climate information in this basin yielded mixed results, and these findings might help improve the success of future efforts.

Interviewees were specifically asked to describe the type of information about a future climate that would be useful for decision-making. They were prompted to explain not only the content of this information, but also how the information could be presented in a format they would find useful. The answers to these questions clearly showed that: there was a demonstrated interest in climate information, people prioritize information about certain climate elements over others (such as temperature and water), and the scale of information matters.

Some interviewees said that the information they were given might be reliable, but that it did not address the questions they needed answered. The two groups—climate scientists and climate information users—were not connecting. This disconnect created a hurdle and often led to frustration on both sides. Why were these people not acknowledging the useful and important information they were given? Why was the information so esoteric and not able to be used by everyday people?

Gunnison Basin residents were excited about the insights this study could provide to climate modelers and how it could better shape climate information to meet their needs. Excitement about climate information, and revised information, shows that this community does value climate information and has unmet information needs. A young rancher I spoke with who was already familiar with general climate projections, was thrilled by the idea of localized climate information.

“I’d love some applicable models! To know what to plan for, because a lot of these guys aren’t on the time horizon I am at. I am thinking like [the case of an
older rancher], 20 years probably at the most and I am looking at the next 50. And our inaction on things, I would suspect that I am going to see dramatically more impacts on the ground then those guys are.”

This young rancher was one of the most worried about climate change and had just returned from graduate school studying agriculture to take over the family ranch; he was nervous about climate impacts. He also brought up how his interests in climate were different than most of the ranchers in the Basin due to his young age and long horizon for ranching. I spoke with a rancher who also articulated quite clearly and forcefully how important it was that climate information was made more usable. She explained that they rarely talk with scientists and researchers, but felt that this research was important.

“We get a lot of people who want to come talk to us and when [my husband] said he had said yes, I’m like another student. Then he said nah, nah, she is doing really... she is turning the climate change discussion... she is trying to bring it down to what would be useful for regular people. “

These two quotations show a genuine interest in climate information among the stakeholders and that previous information has not fulfilled their information needs. Many voiced frustrations that they were given answers to questions they never had, and instead they wanted specific climate questions answered. There was a range of how vulnerable people felt to climate change, and some said they were not even sure if they could use additional climate data because many of their decisions were reactions to weather rather than climate due to timeframe. But the people who did feel vulnerable to climate, were interested in additional information, as long as the information was more usable.

Finding 2: Temperature does not capture the whole story
Temperature is the most frequently cited measure of climate change, especially in reference to anthropogenic global warming and is discussed regularly in scientific and policy communities. Stakeholders reacted differently to projections of future temperature, but most felt that even though it was often the first climate information they were given, temperature was not the most critical to their daily lives. Stakeholders were not vulnerable to changes in temperature like they were to other climate elements. In fact, a number of people jokingly told me that temperature increases might be a good thing in a Basin that regularly experiences winter lows of -40 degrees Fahrenheit and below. A rancher who had participated in the original working group meetings where climate scenarios were presented felt strongly that temperature was not a metric that was useful to most of his decision-making nor that it illuminated important aspects of change in the Basin.

“One degree of temperature change is absolutely meaningless. They absolutely are meaningless. They mean nothing. There is a huge disconnect between climate science and climate scientists and people on the ground.”

He attributed this incorrect focus on temperature to a lack of communication between the scientists and the stakeholders that could have shaped the information. Another rancher had similar opinions about temperature projections.

“I don’t give a damn about temperature. I want to know snow! I don’t care about precipitation either. I want to how much we are going to get in November, December, January, February, March, April and May”

He used climate rubrics based on snow depth at SNOTEL sites to understand the seasons and make seasonal forecasts, so he required information about future snow conditions to use his rubric to translate projections to others aspects of a future climate. Many others
did not describe it as “meaningless” or express intense frustration, but did prioritize other aspects over temperature.

A number of interviewees did want information about temperature, often secondary to issues of water. Many of those who wanted to know about future temperatures explained that it was not just about the temperatures, but how they would affect other parts of the environment. A long timer RMBL scientist reflected the same low prioritization of temperature as many of the stakeholders:

“I think the temperature itself is not a big deal here. Its how temperature affects winter snowpack and summer rainfall. Moisture.”

He is able to interpret what temperature means to other elements of climate that he is concerned with, and this makes temperature useful. The impact of temperature on water resources was why most cited it as useful. The ability of people to translate temperature into other landscape impacts influenced how important they thought it was. The first frustrated rancher quoted above placed the onus on the climate scientists to translate temperature into meaningful climate impacts, rather than rely on lay people to be able to make conversions.

“To get their attention you have to talk about if there is going to be an increase in temperature it is going to mean earlier run off. They understand that.”

This shows that while he dismissed temperature information per se, he actually does see value in it, but does not want it to be the main information focus. Instead, he views temperature as one element of climate and a puzzle piece to compare with a larger picture to illuminate changes in critical elements.

It is important to note that temperature can be interpreted into landscape effects by some, but that its impacts on the rest of the environment might not be explicit to all
stakeholders, rendering it less useful. People want integrated information that does not distill climate from other processes. In essence, people think like an integrated “Earth System Model” and they want information that would come from such models instead of from pure climate models. They may not know that is how their climate knowledge and needs are constructed, but the interviews certainly point in that direction and have profound implications for the future of climate modeling, projections, and user applications. Incorporating integrated models that attempt to capture many processes would be an avenue to address this need. Another avenue would be for climate model outputs to be synthesized by scientists (social and ecological) to extrapolate impacts not captured in atmospheric models.

**Finding 3: The Basin is Hydrocentric**

The single most common climate information need expressed by interviewees was water resources. It quickly became clear that people viewed water as a critical element in the Basin, and a highly constrained, critical element. They felt that while the Basin could easily absorb changes in temperature and not experience drastic impacts, that there was much less flexibility for water resources. Everyone needed water for their work: the ski area, the pastures, or in the steams for recreation. A fly fisherman discussed how important water was to his livelihood and to the Basin.

“I mean its everything. It's all the downstream agriculture, its not just us, it's the white water runners, its everything. The rivers [are] the lifeblood of the valley. From the ranching to the recreational to everything. Even for the mines back in the day, they needed the water to run...too.”

This was the only climate information need that was universal across stakeholders and livelihood. People in all stakeholder groups were concerned with water and felt that
the success of their work, and the social and ecological community as a whole, relied on water resources. A ranching consultant and former government employee suggested that all stakeholders would benefit from information about what many people simply call “the hydrograph,” and that it should be the central information feed.

“Just knowing what the rivers and streams are going to do as far as water production, is key to just about everything in this basin.”

A long time RMBL scientist and employee attested that knowing how water resources could change was as critical to many stakeholders in the Basin as was the ecology that she and her colleagues studied. She criticized the emphasis on future temperature, and urged that water be studied as well.

“Not just temperature, but adding the water, cause that affects all the people who live off the land, like ranchers, fisherman.”

Stakeholders wanted information about both the timing and the quantity of future water resources. Changes in either could alter the hydrologic system enough to create adverse impacts. The majority of the water in the Basin comes from snowmelt, so whether there would be a sufficient snowpack was highlighted by many as a vital climate change question. Additionally, the timing of the hydrology—captured by the concept of the hydrograph--- of either runoff or summer monsoon precipitation, could either ameliorate risky conditions or exacerbate them. A land manager, tasked with advising ranchers and private land managers, expressed this:

“I think it would be really interesting to see what the predicted precipitation would be, and timing of that precipitation. And maybe even form. When and how much rain are you going to get during the summer, and when and how much snow are going to get throughout the winter.”

This quotation shows that some observers recognize water as a complex system that includes timing and quantity, and as this interviewee discusses, form. People discussed
form because rain is much harder to store in the Basin than snow, which naturally collects on the landscape. When I pushed to see if there was a most important aspect of precipitation, people differed in their responses, with some saying quantity, some saying timing, but most acknowledging that both were important and part of understanding the whole hydrologic picture.

A state biologist who focused on endangered species in the Basin thought that this detailed level of information would aid him in management decisions and planning for species that have very little resilience. However, he struggled with balancing one aspect over another.

"Both are, I don’t want to say equal value, but I just don’t know. I am going to put them at equal value. Yes, you need certain levels [of precipitation], but if you don’t get it at the right time, then all the other ecological responses aren’t going to occur naturally. Or how they should. Or what we have seen."

Many people felt that if snowmelt continued to occur earlier and the monsoon timing either stayed the same or got later, that a marked dry season would become common in the basin. Interviewees thought that many natural resource systems were stretched during the time between peak runoff and monsoons, and that there was not much buffer in the system. Uncertainty about future water resources elicited a range of different questions from stakeholders. People asked about the future of the monsoon rains, how the hydrograph peaks would change, and for information about specific times of year, like the shoulder seasons. People understood their climate/environment to be hydrocentric, dependent on and driven by the water resources.

This finding of hydrocentrism is important regardless of whether climate scientists agree with interviewee’s assertion. One way of addressing this issue is to question where the observations of locals are accurate (Malmberg 2014; Marin, 2010;
Kempton, Boster, Hartley, 1996). Attempts to determine the accuracy climate knowledges exist, but this line of inquiry dismisses the importance of perception. How people perceive their environment shapes what they value and find useful, as well as how they make their decisions. Perceptions will continue to shape how people interact with their environment whether or not it’s “scientifically accurate” according to formally trained scientists. An understanding of cognized climate and its structure is important and useful information in its own right, for climate scientists, regardless of its resemblance of their models of climate. Cognized climate reveals where information could be influential, which elements stakeholders prioritize, and why stakeholders are more receptive to certain types of information.

**Finding 4: Scale matters**

The scale of climate information matters; this is not a novel finding for research on climate information. Experience shows that one of the disconnects that renders climate information less useful is scale (Cash & Moser, 2000) and that climate change impacts are felt locally as opposed to globally (Wilbanks & Kates, 1999). People’s experienced climate knowledges are at a much higher resolution than the global models and it is challenging to convert and reconfigure knowledges to reconcile the two. Information needs to be at a higher resolution to fit into established climate rubrics, address information needs, and explain a future climate. This is the case in terms of both geographic scale and temporal scale.
4.1 Geographic Scale

A finer geographic scale of climate information was desired by most interviewees. They had experience with global, national, and regional climate information, but wanted more than broad trends. Many also spoke to how different the Gunnison Basin is from the rest of the state and region, and this made them question the validity of regional data being applied to their Basin. Almost all participants said that selecting large landscapes made the information less useful, as one land manager clearly reports.

“National is completely un-useful. Even regional un-useful.”

Another land manager who participated in the workshops with TNC agreed, and went further to say that even scaling to the “Western Slope” of Colorado was problematic because of how diverse it was. He explained that at the workshops, climate scientists would “even make a comment every so often, well we know at higher elevation this may not even apply. And then, why are we worried about it here in Gunnison?” This anecdote shows how the larger scales decrease confidence in the outcome for users, and this land manager specifically wanted information scaled to the Gunnison Basin. Responses were mixed on this issue, with some people wanting just the Basin, and others appreciating knowing about the entire Western Slope. This was often dictated by the landscape they managed and whether it was wholly contained in the Basin. People understood that there were constraints to resolution in models, and many emphasized they only wanted scale changes if confidence in the findings remained.

4.2 Temporal Scale
Stakeholders wanted climate information on shorter timescales than they had previously seen. There were very high levels of agreement about timescale compared to other topics in interviews. They reacted to prior experiences where they had been given information on a timescale that pushed past their lifetime and maybe even that of their children. It was hard to even know how to interpret this information or use it in their daily decisions. A wildlife biologist who is active in the Gunnison Climate Working Group captured how he and land managers felt about long timescales.

“Yeah, it seems like most of the projections are like 50 years or 100. And obviously, we want to know what is going to happen in the short term.”

Interviewees agreed that information that went a century out was less useful, but the shorter timeframe requested often reflected institutional schedules. This was especially the case for land managers, but was expressed by the other stakeholder groups as well. Each agency has management plans at different timescales, with different frequencies of reviews. Understanding a future climate at a timeframe that is comparable to management planning schedules would facilitate integrating climate information into them. Most plans or goals were evaluated on 5, 10, or 20-year timeframes, so longer timeframes than that were challenging to incorporate. In addition to the agency planning schedules, interviewees talked about larger institutions. A rancher discussed wanting a 10-year timeframe because that was what was used for the running average for the Colorado River Compact. She wanted climate information that she could readily combine with the social information - and constraints - to imagine a more holistic climate.

Besides institutional influences, stakeholders complained that it was too hard to relate to longer time scale information. This was especially true of timeframes that fell
outside the anticipated lifetime of stakeholders. Older ranchers spoke to how they only had a few years left ranching, 5-10 at most, and then only a handful more that they expected to live, so 100-year forecasts were laughable. Even those early in their careers felt that 100-year timeframes were daunting. A land manager, in her mid-thirties and early in her career, had the same reaction as her older counterparts towards a climate formation in the next century.

“I think there would greater gravity or understanding if you could reduce the time. You know going from that 100 years down to 50, 25, 10 years. Like a manageable, something where we could be like ‘well our goal, we can make for the next 10 years. I can see that it might change half a degree in the next 10 years.’ Something like that. Something that people can digest, something bite size. Because when they hear, when I hear, ‘50 years from now,’ I am thinking ‘oh god, I hope I am retired by then.’ 100 years, might as well not do anything!’ You know? They can deal with it later, you know?”

One request that could be paired with a shorter timeframe was to offer climate odds. These would be basic trends that were brought to the decade level. Many people wanted to know an estimate of how often different climate events would occur in a standard decade. These estimates could help stakeholders understand longer timeframe data and make it useful to short-term decisions in the lifespans of stakeholders. Odds could also be paired with short-term climate projections to explain the inter-annual variability. A range specialist working for the NRCS, wanted 10-year timeframe scenarios because she supervises monitoring on a three to five year scale and their long term monitoring is on a 10-year scale. From that monitoring, they make conservation goals with landowners and she specifically asked for information about the ranges and extremes in climate.

“If you can show... you can count one of the 10 years to be a wet year. Two to be dry years. And seven to be normal.”
A rancher also asked for a similar type of information because it would help him in planning for a climate that is likely to contain more extremes and he felt that odds translated climate information into meaningful metrics. Such information made it easier for him to identify risk and vulnerability rather than general trends and average changes because climate extremes are likely to have larger impacts.

“5-10 years would even be more practical. Because if you know there is a pretty high percentage that you are going to be in a drought like last year, 7 outta 10 years, boy, and that is going to be the norm, that is not going to work.”

This type of information captures climate variability unlike scenarios, which often describe a stagnant climate rather than one in motion. Incorporating this into climate information can help prepare decision-makers for uncertainty and variability rather than just a singular future climate. This method might also decrease issues where climate information is taken as a predication rather than a projection because it shows the dynamic nature of climate change.

Conclusion

People ask climate scientists for “better” information, but this does not necessarily mean they want better climate models. Their perceptions, experienced climate knowledges, and decision needs all shape what information is deemed useful. To make “better” information, attention needs to be given to how people understand climate and their climate decisions, not just improving climate models. A greater understanding of cognized climate, in comparison to computer models, helps expose similarities and differences between models and has the capacity to shape information.
Our findings focused on how people ingested outside climate information and what factors were important. Past experiences, and frustrations with climate scenarios influenced stakeholders’ reception of new information, but a general interest in usable information existed. In the Gunnison, stakeholders wanted high-resolution information – both geographically and temporally – that focused on the Basin and short timeframes, which reflects the type of decisions being made. Temperature was not a useful metric on its own, but was helpful when translated into other impacts or paired with other elements such as water. Residents viewed the Basin as hydrocentric, and therefore valued hydrologic information above other types.

These general findings held true across stakeholder groups, but groups and individuals also had very specific questions about climate that could be further explored. People wanted answers to specific questions from about a future climate rather than just broad information about trends. The types of questions people asked show how they experience and understand climate. Some of the specific questions were atmospheric and regarded changes to the jet stream, dust storms, timing of shoulder seasons, and extreme events. Other questions encompassed the socio-ecological aspect of climate and included concerns about soil moisture, the growing season, beetle infestation, and vector-borne disease outbreaks.

Insights into how climate models and people might differently bound “climate” explains disconnects that can emerge between the models and the users. Findings from previous chapters combined with identified information needs highlight possible avenues for working with stakeholders and climate scenarios.
Chapter 7: Conclusion

This research explores how people understand climate and specifically examines the climate knowledges of a rural community in the American West. The main goals of this research were to explain how people understand climate, to address how political ecologies flavor climate knowledges, and to ask how understanding climate cognition can illuminate the way people interpret outside knowledge. My research produced findings and insights about climate knowledges and worked as a theory building rather than theory testing inquiry.

In-depth interviews were conducted among four stakeholder groups in two months of fieldwork. The stakeholders were selected based on an assumed climate expertise built through their natural resource-based livelihoods and their daily experiences. Cognized climate was analyzed in terms of benchmarks, features and processes; the politics of such climate knowledges, along with the structure and content of climate knowledges, helped to clarify how cognized climate shapes engagement with outside information from climate models.

I explore the political ecology of climate knowledge specifically addressing mode of production, actors, and hybridity, all of which greatly influenced how knowledges were shaped. All of the knowledges engaged in this research were situated in a social and ecological context, all were partial, and all were shaped by the social dynamics and political ecology in the Gunnison Basin. For example, over almost a century rancher and RMBL scientist relationships have degraded due to tensions over land tenure, concepts of ecologically “correct” land use, and competing claims to land, all of which are especially hard to resolve in landscapes dominated by public lands. Interviews suggest that these
tensions run deeper than land claims, and also influence climate knowledges. The political ecology of the basin explains why knowledges in one community are not circulated to others—whether they are unable to cross divides or if they are dismissed by new communities because of prejudice—and the political nature of competing ways of knowing climate.

After examining the political ecology and situated nature of climate knowledges, I focused on their structure and content. My analysis revealed findings about how people know climate; the most salient being that people conceive of and express climate as a social-ecological-atmospheric process. This differs from how most climate models, and therefore model outputs, understand and bound climate. This finding supports scholarship arguing that climate needs to be understood as a “physical transformation and cultural object, as a mutating hybrid entity in which the strained lines between natural and cultural are dissolving” (Hulme, 2007, p. 5), and incorporate new epistemologies to understanding of the structure of climate knowledge (Petts et al, 2007). This finding provides a foundation for interpreting other outcomes of this research.

People used rubrics to sort and organize a messy, disordered climate. They made sense of their climate through rubrics, which helped them make decisions and interact with climate processes, which they see as an amalgam of ecological, atmospheric and social processes. People regularly manage their environment; in urban areas, for example, people attentively manage their lawns using rubrics and indicators that trigger decisions. Rural communities—with rural livelihoods—have larger environments to manage, and respond by producing more, and increasingly complex, rubrics. Some rubrics are formed over generations, they are place-specific, and are produced through an
iterative processes of tinkering to calibrate them to fit climate decisions. For example, a rancher may use a certain sign of spring to know when to move cattle, and recognizes that the timing changes due to current and recent climate conditions. Rubrics explain how people act on a cognized climate, and what elements they use as indicators or benchmarks.

The timing of climate events, individually and in combinations, was important to people; they especially felt vulnerable to climate events and processes delinking from each other, thus changing the sequencing of seasonal patterns or even creating new seasonal features. This “mismatch” can occur as the relationship between two ecological processes unravels, but also as social and ecological processes delink. Similar findings have appeared in other cases. For example, the changing arctic climate is complicating traditions, rules and regulations for hunting in native communities (McNeeley, 2009), and changes in runoff timing are impacting calendar-dependent water rights in the Colorado River Basin (Kenney et al. 2008). In the Gunnison, mismatches are seen in disrupted timing for pollinators (CaraDonna, Iler & Innoye, 2014; Innoye et al, 2000), early snowmelt exposing plants to frost damage, inappropriate grazing times, and changes to the tourist season fixed by school schedules but inappropriate to shifting seasonal conditions. Livelihoods built around assumed climate links become disrupted, and people expressed concerned for how the ecologic and human communities would respond to growing mismatches.

This study of how people understand climate differs from most previous scholarship in environmental perception that focuses on attitudes towards climate change. Peoples’ narratives explained climate differently, and reveal a hybrid of experienced
climate knowledges and formally produced climate information. Ideas of balance and natural cycles emerged, along with how people understood trends in conjunction with variation. My research supports the findings of Connor and Higginbotham (2013) that suggest previous studies surveying attitudes about climate change oversimplify their findings. Instead of denial, survey findings might indicate differences in how people understand climate, not just climate change.

Findings regarding the political ecology, structure, and content of climate knowledges offered context to explain of how perception shapes climate needs and relationships with outside climate information. I found that past experiences with climate information, elements selected as indicators, stakeholders’ livelihoods, and scale (temporal and geographic) all shaped information needs and how outside information was digested. Climate information at the wrong scale can decrease use in decision-making and also cause stakeholders to lose confidence in climate science, and climate information generally (Cash & Moser, 2000). My findings support this, but also suggest it applies not only to scale, but also to which elements are perceived as indicators of change. Stakeholders prioritized water-related features (precipitation, monsoons, runoff and snowmelt) as key elements, and were apathetic to, and even frustrated by, information about changes in temperature. Unfortunately, climate scientists are most confident in their predictions of future temperature trends, especially in the high-resolution models. Insights into priorities can improve the usefulness of climate information, but the political ecologies of climate knowledge complicate the simple model of information needs and delivery. My findings are consistent with previous work showing disconnects between climate information and its use driven through scale
discordance (Cash & Moser 2000) between information and decision needs. Problems emerge in “the fit” (Lemos et al., 2012) of how users perceive information needs and their ability to use knowledge. Kirchhoff et al. (2013) advocate for producing climate information tailored to specific stakeholder groups with similar climate information needs, but even this framing of “user needs”, which is sensitive to stakeholder groups, is simplistic in light of the political ecologies of climate knowledge’s discovered here.

The limitations of this research study were primarily in the constraint of the research design. The use of a case study provided in-depth data, and allowed me to analyze in detail the context of climate knowledge, but limited how much I can generalize the findings. This is true with all case study research, but the design is useful for theory building, and necessary for the context-specific study of political ecology. The Gunnison Basin is an especially instructive case: a climate planning process sponsored by The Nature Conservancy is already underway in the basin. Stakeholders were already identified and organized, and had set an agenda for evaluating their climate sensitivities and options. This work was able to draw on, and build on, that effort while still developing its own research focus and questions (e.g., focused on climate knowledge rather than concerns about climate change). Still, the resources and time frame of a masters thesis limited the ability to conduct follow-up interviews or to explore emerging issues (e.g., dust on snow) more fully, and opportunities for follow-on research on cognized climate abound in the Gunnison Basin.

Future research is need to further tease apart how people know climate, its politics, and how this shapes people’s reception of outside information. This research has a broad scope, and worked to build theories and findings about climate knowledges in
general, but could benefit from future research focusing on specific elements. I was surprised when dust emerged as a climate feature to which people felt vulnerable and about which they wanted more information. This is not a focus of most climate models, and is not a new phenomenon, but one receiving increasing attention, especially in the realm of water resources; it comes with significant social and ecological components. Future research should explore how dust relates to climate, how it is different than other climate features, what impacts it has on the landscape and personal scale, and the political ecology of dust narratives, specifically focusing on hints of villains and heroes that showed up in the interviews.

The issue of climate processes delinking deserves future attention. This phenomenon has garnered attention from the ecological community, but scholars need to ask how mismatches are perceived by and cascade into the human communities. Attention is also needed on how the climate models capture or neglect the potential delinking of seasonal patterns, or the emergence of wholly new seasonal features. There needs to be attention to multiple types of climate driven mismatches: delinking ecologies; unraveling social and ecological relationships; and webs of multiple social and ecological actors severing ties. The political ecology and study of the knowledges of mismatch is important. This was one of the only areas of RMBL science that permeated throughout different communities, hybridized with new knowledges, and was integrated into the climate narratives of different stakeholders. Why did this RMBL knowledge circulate and interact with other basin knowledges when others did not?

Research on the structure of climate cognition illuminated cognitive and decision frameworks that people used to interpret their own and outside climate knowledges.
They used rubrics and interpreted climate variability as “odds” (as in statistical odds, or gambling odds) of events, to sort and manage a chaotic climate. Research needs to examine rubrics further, and explore how or if they transform when climate changes. Similarly, climate odds are important to how people understand variability and could have impacts on the design of climate information.

This research assumed, but did not test, the hypothesis that rural people with resource based livelihoods had an express expertise in climate. However, scholars could create a counterfactual per se by changing the geography of the case. How are knowledges different in very predictable and moderate climates, places without as large variation or defined seasons? How does this shape rubrics and decisions? Or, are the climate knowledges different for people who work in office jobs or in places with cultivated landscapes (e.g., the Corn belt)?

This research engaged multiple climate knowledges and was careful not to evaluate or try to validate them, but further research comparing local and climate model knowledges could show where they converge and diverge. Scholars should explore how people and computers “model” climate differently and similarly, and study how different models define climate. People respond to questions about climate with elements that fall outside what tradition computer models incorporate, but further comparison is needed of different types of models, such as integrated models that try to incorporate ecological systems. Future research should focus on “how climate works,” to explain the connections and relationships in the cognized climate. Additionally, attention should be given to where boundary objects, the same concept or term given distinct meanings in different communities (Star & Griesemer, 1989), appear.
References


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Appendices

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 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?