Global Environmental Change 49 (2018) 1–9

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

# Knowing climate as a social-ecological-atmospheric construct

Katherine R. Clifford[a,b,*], William R. Travis[a,b]

[a] Western Water Assessment, University of Colorado, Campus Box 216, Boulder, CO, USA
[b] Department of Geography, University of Colorado, Campus Box 260, Boulder, CO, USA

ARTICLE INFO

*Keywords:*
Climate perception
Climate knowledge
Attitudes
Beliefs
Climate literacy
Climate knowledge

ABSTRACT

Climate perception, broadly construed, can include interpretations of experienced climate, beliefs about how climate works or changes, attitudes about climate issues such as the human role in climate change, and even climate preferences. The recent literature has stressed three main themes: attitudes and beliefs about anthropogenic climate change, climate literacy, and experienced knowledge of climate change. This study focuses on how people come to “know” climate, not just climate change, in a more fundamental way. To discern the structure of these knowledges we conducted semi-structured interviews of residents of a basin in the U.S. Rocky Mountains whose livelihoods and avocations bring them in routine contact with weather, climate, and landscape. Analysis of their climate knowledge in three categories, features, processes, and benchmarks, and placed in perspective of previous research on climate knowledges, yielded three findings. 1) People often focus on climate-related proxies that might be disregarded as tangential within narrow definitions of climate. 2) People use rubrics to structure climate knowledge, they understand climate as relational and connected. 3) Climate knowledge does not isolate individual climate elements, but accentuates the complex way that many processes together constitute climate. These findings reveal that, for our interviewees, climate is a social-ecological-atmospheric construct. This has both theoretical and methodological implications for future research on climate perception and illuminates the challenge of linking perception to effective mitigation and adaptation.

## 1. Introduction

The Pew Research Center reported that in 2016 only 48% of Americans believed that global warming was occurring due to human activity (Funk and Kennedy, 2016). This was only one example of a number of surveys meant to assess Americans’ perceptions of climate change (Borick et al., 2010; Pugliese and Ray, 2011; Kohut et al., 2011; Leiserowitz et al., 2017). The notion that roughly half of Americans do not accept the scientific consensus on global warming circulates through communities of scholars, activists, and practitioners and is discussed in research, policy, and the media (Leiserowitz, 2006; Harris, 2011; Kahan et al., 2012).

The reported disparity between scientists and the public has motivated a range of studies. Several large-scale surveys have probed variables that might influence public perception, and specifically climate change skepticism, and have found a number of different correlations ranging from livelihood (Arbuckle et al., 2013), to political affiliation (Dunlap and McCright, 2008), to gender (Sundblad et al., 2007; Israel and Sachs, 2013), to political attitudes about solutions (Leiserowitz, 2006), to distrust of science (Kahan et al., 2012). Others scholars have interpreted global warming skepticism as a *lack* of knowledge about climate processes and climate change. However, the inference from beliefs about climate change to climate illiteracy over-simplifies the idea of climate knowledges, and may distort our understanding of how people perceive climate differently and why.

Less attention is given to questions that push beyond beliefs about climate change or scientifically-accurate knowledge of climate processes to focus on how people understand their climate in its multifarious nature. Yet, climate knowledge is at the foundation of social dimensions of climate and permeates other studies of attitudes and actions. A person’s understanding of climate—how it works, what elements are important, what counts as climate—will undoubtedly shape how they understand and respond to climate change (Hulme, 2009, 2017). Understanding climate knowledge is important for understanding climate change knowledge and may not be captured in climate change belief or literacy surveys, that can fail to capture how climate and climate change are known.

The purpose of this study is to examine climate knowledges in depth to understand their content and structure. People interact with weather and climate on a daily basis (Hulme, 2017), and researchers using qualitative methods and critical theories can ask how individuals understand and know climate change as a product of their experiences

* Corresponding author at: Department of Geography, UCB 260, University of Colorado, Boulder, CO 80309-0260, USA.
*E-mail address:* Katie.clifford@colorado.edu (K.R. Clifford).

https://doi.org/10.1016/j.gloenvcha.2017.12.007
Received 28 April 2017; Received in revised form 10 November 2017; Accepted 28 December 2017
Available online 30 January 2018
0959-3780/ 

with place (Brace and Geoghegan, 2011; Rice et al., 2015). Inasmuch as our inquiry is concerned with climate change, it is about *how* people understand climate change rather than *if* they believe in it. We approach this by interviewing people with climate knowledge produced through rich experiences with local weather, climate, and their manifestations through the behavior and quality of natural resources to which their livelihoods and avocations connect.

This research can help expand the way we understand local knowledge and perceptions of climate and may challenge, or at least problematize, previous claims about climate skepticism. Better understanding the character of climate knowledge can improve conclusions about *why* people hold particular beliefs about climate. This analysis may provide further insight into previous interpretations of public perceptions of climate and highlight how local climate knowledge may fail to meet climate literacy tests, but still reflect a robust and intricate understanding of local climate. In this paper, we first describe the scholarship of different approaches to climate perception. Then we highlight three key findings from our fieldwork in Colorado's Gunnison Basin on how people know climate through everyday experience. Lastly, we explore how these findings provide alternative interpretations of the claims produced through literacy and belief surveys.

## 2. Climate perceptions: attitudes, literacy and knowledges

Climate perception, broadly construed, can include interpretations of experienced weather and climate (and, indeed, the distinction between weather and climate), beliefs about how climate works or changes, attitudes about climate issues such as the human role in climate change, and even climate preferences. We divide the study of climate perception is broadly into three approaches. First, large, regional or national-scale surveys provide longitudinal data on changing beliefs and attitudes about climate change, and examine possible influences of those beliefs on mitigation and adaptation policy. Second, in response to what many interpret as a misinformed or scientifically-illiterate public, attention is given to measuring the public's climate literacy and to devising better science communication. A third approach explores local experience and knowledge of climate at the community and individual scale. The first and third approaches have tended recently to focus on anthropogenic climate change, while the second is more agnostic and explores both climate and climate change, and in some cases the perceived connections between weather and climate. All three areas of research are important to understanding the social dimensions of climate, but each frames the problem in a different way.

### 2.1. Climate change attitudes and beliefs

The major thread of climate perception scholarship in recent research focuses on beliefs and attitudes about anthropogenic climate change, largely in an attempt to assess whether lay communities are skeptical of global warming and its proposed solutions (Capstick and Pidgeon, 2014). Large-scale surveys correlate climate change belief and skepticism with demographics (Poortinga et al., 2011), political affiliation (Saleh et al., 2012), personal experience of climate (Brody et al., 2008; Whitmarsh, 2008; Spence et al., 2011; Kaufmann et al., 2017), accuracy of educated populations' knowledge of climate change science and trends (Reynolds et al., 2010), and differences among countries (Lorenzoni et al., 2006). While such studies differ in how they explain skepticism (Whitmarsh, 2008; Capstick and Pidgeon, 2014), complicating comparison of results, they broadly find that a large portion of the general public is skeptical of anthropogenic global warming.

Many of these studies point to political affiliation as among the most important factors in determining attitudes and beliefs about anthropogenic climate change. Thus even long-term (Leiserowitz et al., 2017) studies providing longitudinal data about changes in beliefs and attitudes may reflect the political connotations of the term climate change. These studies report that Republicans (people with conservative ideology) in the United States are more skeptical of climate change than Democrats (people with liberal ideology) or Independents, at least partly because they are skeptical of the solutions posed (e.g., renewable energy systems) and the policies imposed to fix the problem. This would suggest levels of skepticism would be higher in a conservative state like Arizona, yet a study at the University of Arizona that posed a broader set of climate questions (http://www.environment.arizona.edu/climate-survey) found that a majority (74%) of the state's residents believe that world temperatures are increasing, with 78% of those respondents attributing that trend at least partially to human activity. This case shows how new dimensions emerge that move beyond clear categories of skeptic and believer when different elements of climate are incorporated, and perhaps indicate the limitation of attitude surveys to reveal climate knowledge.

### 2.2. Climate literacy

This thread of research is in part propelled by the findings of attitude and belief surveys and focuses on how well laypeople understand processes and features of climate as defined by climate science. Climate literacy is a growing theme in earth science and science education; it was the subject of a special issue of *Physical Geography* (Dupigny-Giroux, 2008). The field is still taking shape and even the definition of climate literacy has not been uniformly established with some papers describing it as knowledge of climate science (Niepold et al., 2007), and others more broadly as "understanding your influence on climate and climate's influence on you and society" ("Climate Literacy", 2009, p. 4).

While there are overlaps between climate literacy and attitudes and beliefs, key differences make literacy a distinct research and applications area. First, climate literacy studies are more often conducted by climate scientists themselves. This means that the work is less anchored in behavioral, cognitive, and social framings. Second, climate literacy is focused on processes of climate and climate change, rather than attitudes about climate change. Third, this line of research takes a normative stance. It approaches the issue of climate knowledge with the stated goal of testing and then *increasing* climate literacy, and argues that climate literacy is a "critical skill" (Dupigny-Giroux, 2010, p. 1203), and "is needed for planetary citizens" (Harrington, 2008, p. 575), with scientists describing the work as a "quest to achieve literacy" (p. 483) motivated by "fervent hope" (p. 485) that a climate-literate citizenry will better respond to the threat of global warming (Dupigny-Giroux, 2008).

Climate literacy also departs from the study of climate knowledges, even though the two bodies of literature occasionally use similar language. The study of climate literacy tests public knowledge against a "correct" scientific answer and thus casts, implicitly or explicitly, knowledge departing from science as "wrong." For example, Dupigny-Giroux (2008) differentiated somewhat confusingly between "actual knowledge" and "perceived knowledge" (p. 485), the former defined as knowledge that comported with scientific understanding of climate. In many ways, this body of scholarship looks more for an absence of knowledge than a presence of it, and embraces a hierarchical understanding of knowledge rooted in the scientific method; it is less concerned with cognition than understanding science and effective communication. While the "climate knowledge deficit" interpretation has been largely debunked by social scientists (Rudiak-Gould, 2012), it has remained current among climate scientists and science educators and continues to spur calls for better climate communication to increase "climate literacy," or scientifically accurate understanding of climate.

### 2.3. Climate knowledges

Climate knowledges scholarship seeks to understand not only *if* people understand climate as a scientific element and/or believe in climate change, but *how* they understand this subtle and pervasive element of nature and environment. This thread of inquiry is especially interested in local or experienced-based knowledges (Brace and Geoghegan, 2011; Geoghegan and Leyson, 2012; Rudiak-Gould, 2012; Solli and Ryghaug, 2014; Mahony and Hulme, 2016; Kohl and Knox, 2016; Popke, 2016; Hulme, 2017), and is often, at least partially, based on qualitative methods with open-ended questions in interviews or focus groups, though a few studies have paired these with quantitative surveys as well (Connor and Higginbotham, 2013; Capstick and Pidgeon, 2014).

Climate knowledges scholarship treats climate as not just a biophysical phenomenon but also a social and cultural one (Hulme, 2009, 2017), and seeks to learn not only "what is known about climate but how it is known, remembered, experienced, embodied, and practiced" (Geoghegan and Leyson, 2012, p. 57). Climate knowledge is place-based, culturally contingent, and built through everyday activities that engage weather and climate (Hulme, 2017, such as gardening Brace and Geoghegan, 2011), farming (Geoghegan and Leyson, 2012) or other outdoor activities. Place and culture also influence how climate change knowledge is received, circulated, and applied (Endfield and Morris, 2012). Marin and Berkes (2013) referred to this as "the detailed local anchoring of the knowledge often held by people who rely on natural resources for their livelihoods" (p. 1).

These approaches do not privilege non-scientific knowledges over scientific, but instead recognize many ways of knowing climate, and that climate may be different for different actors within cultures (Lejano et al., 2013; Israel and Sachs, 2013; Leyshon, 2014; Goldman et al., 2016) Explicitly feminist approaches have argued for engaging anti-hierarchical ways of knowing that challenge the hegemony of dominant scientific knowledge (Rice et al., 2015). This work investigates "climate (and weather) as a function of memory, experience and intergenerational transfer of 'climate knowledge'" (Hulme, 2009: 330). Finally, the study of climate knowledge is sometimes used to extract new information on climate and climate change. Studies have attempted to plumb climate change through ethnoscience, or what is variously labeled local knowledge or indigenous knowledge (Solli and Ryghaug, 2014), taking an instrumentalist approach to extracting data from narratives, for example, using stories of past ice-free waters or the changing reliability of springs and other water sources to document the impacts of climate change.

A theme in climate knowledge scholarship is the relationship between and difference of climate and weather with a debate about whether an abstract phenomenon like climate can be observed by an individual (Rudiak-Gould, 2013). Traditionally, climate is the average of weather, and thus is a statistical concept that cannot be directly experienced. Yet, as Hulme argues "experiences of weather evolve into knowledge about climate" (2017, p. 32), and people use that knowledge every day and make plans and investments based on it, especially people like farmers (Geoghegan and Leyson, 2012) and others who negotiate both weather events and seasonal swings in natural resources. Climate becomes a cultural artifact that "introduces a sense of stability and normality into what would otherwise be too chaotic and disturbing an experience of unruly and unpredictable weather" (Hulme, 2017, p. 4). Thus the abstract is made concrete and becomes imbricated with culture in a place. "All knowledge of climate should therefore be regarded as cultural: it cannot exist separately from the cultures in which it is made or through which it is expressed." (Hulme, 2017, p. 27).

The simplest hypothesis is that people "assemble" their climate from their weather. Solli and Ryghaug (2014) apply this approach to highway snow clearers in Norway who, over time, develop local knowledge of the conditions under which avalanches occur, and can apply that knowledge both to short-term road-closing decisions and to long-term climate adaptations like where to place a permanent avalanche protection berm. But the translation from weather to climate knowledge is certainly a more complicated cultural and mental process than this hypothetical "assembling" process. Lejano et al. (2013) show that climate narratives inculcate many ways of knowing climate, some derived from climate as opposed to weather artifacts, like vegetation zones and wildlife migration patterns. In this way, climate knowledge is built on both weather *and climate* cues, a process we look for in our study.

Two recent studies come closer to our approach of understanding experienced climate knowledges. Rice et al. (2015) examine local knowledge of climate change in rural Appalachia and engage with multiple types of knowledge claims produced by a range of experience and expertise. They implore climate scholars to "take seriously the experiential, embodied, and even contradictory ways that people understand the world" (Rice et al., 2015, p. 256) and to examine which knowledges are accepted and which ignored. They explore how climate change manifests in different local contexts, including family histories of changing weather and climate-driven migration. Rice et al. (2015) employ a duality of formal and informal climate expertise, obscuring the many ways that informal knowledge is also imbued by scientific knowledge and technical climate and weather information. The study conflates informal experts with lay people, and we argue that there are important differences. Participants included people who had just moved to the area and second homeowners who were never full-time residents, neither of which could be considered informal experts on the local climate. In contrast, Geoghegan and Leyson (2012) interview long-term residents in Cornwall to examine memory, place and intergenerational knowledge as an approach to understand how those residents experience climate change.

Connor and Higginbotham (2013) bridge the gap between climate knowledges and attitudes toward climate change by combining surveys with interviews to examine how people understand both. They find two narratives of climate change affecting people's cognized climate: the "scientific narrative" explains climate change as anthropogenic, with knowledge based on models and climate research, while the "natural cycles" explanation suggests variation around an underlying balance, built more on personal experiences and observation, and notions of how nature works. Key to their findings is that many lay people perceive climate as a cyclical process showing resiliency, with the climate swinging back and forth around some central tendency, in contrast to fragility or mutability. Connor and Higginbotham argue that this offered an alternative to claims that skepticism and politics dominate and shape the climate change discourse, and that attitudes research could be misinterpreting belief in "natural cycles" as skepticism. Their research begins to reconcile climate knowledge and climate change attitudes; further research is needed to tease apart perceptions of climate and climate change.

## 3. Seeking climate knowledge

Like Geoghegan and Leyson (2012) we seek to contribute to climate perception scholarship by focusing on experienced climate knowledge developed by individuals with expertise of climate, rather than a sample of the general public that might be less attuned to climate. Unlike Rice et al. (2015), we study the knowledge built by local people with a long, intimate relationship with their environment (Solli and Ryghaug, 2014), rather than a sample with different residence times. We examine this experienced knowledge through in-depth, semi-structured interviews that interrogate how people understand their climate and its processes. We recognize that knowledges are not produced in isolation from each other and that both local and scientific knowledges blur and are themselves multifarious. We also build on Connor and Higginbotham (2013) by expanding the analysis of how people understand climate change differently, to how they understand *climate* differently. Furthermore, we direct attention to the structure of climate knowledge rather than to the worldviews that influence it, a common aspect of anthropological approaches (Lejano et al., 2013).

### 3.1. Study area

The Gunnison Basin in the Rocky Mountains of south-central Colorado (Fig. 1) is representative of many communities in the rural West: public land dominates the landscape; the economy is largely dependent on natural resources, especially livestock ranching, mining, and recreational uses of the landscape; and recent amenity migration (Gosnell and Abrams, 2009) is changing the socio-economic complexion of the region. The range of climate and vegetation zones, and complex socio-demographics in the community, made the Basin an opportune case study to investigate local climate knowledge. The Basin had 8108 permanent residents in 2010 and by virtue of rural and recreational livelihoods many of them reflect a strong connection to, and sense of, place. The case study area may be somewhat unusual because of an on-going climate change planning effort sponsored by The Nature Conservancy and including collaboration by federal, state and county government as well as a range of individuals in the region (Neely et al., 2011). Indeed, the Gunnison Climate Working Group provided the basis for this study and offered access to approximately one-third of interviewees; two-thirds were recruited outside of the group. This is what drew our attention to the area, and our study was coordinated with the Working Group, and thus had ready access to residents with an interest in climate. 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 (Crabbé and Robin, 2006). This makes the Gunnison Basin at the forefront of such efforts and an important case from which to learn about the role of climate knowledge in adaptation.

### 3.2. Methods

We relied on in-depth interviews as well as direct observations, and field notes over a two-year period interacting at meetings of the Gunnison Climate Working Group. The senior author conducted 28 semi-structured interviews of long-term residents of the Gunnison Basin in four groups (ranchers, recreationalists, public land managers, and scientists). The senior author also lived at the Rocky Mountain Biological Laboratory (RMBL) for two months. While this research was not intentionally designed as ethnography, observations during this period were recorded in field notes and employed to place the interviews in better context.

Following the exposition common in the reporting interview or focus-group based qualitative analysis (for example, Jurt et al., 2015; Capstick and Pidgeon, 2014; Rice et al., 2015), we present findings supported by selected quotations in the text, and provide richer sets of quotations organized by the findings in the Supplementary material. This paper analyzes qualitative, interview-based data, which has strengths – of depth and richness—and limitations—of generalizability. We do not attempt to answer what the *community as a whole* knows about climate, but instead *how local climate knowledge is produced*, which asks us to examine knowledge in depth and in context.

### 3.3. Sampling local knowledge

We are specifically interested in experienced climate knowledge that people construct through daily practices and engagement with their landscape. Climate decisions are complex and embedded in the daily life of rural communities that rely on climate-driven natural resources for livelihoods. But, experienced climate knowledges are not all equally robust. Not all daily routines and experiences build the same depth of climate knowledge. Sharper climate knowledge is built by rural communities that regularly engage with their climate, have livelihoods dependent on climate, and make high stakes decisions based on climate. 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. So, participants were chosen based on livelihoods connected to natural resources, which makes them "experts" of climate based on deep experience. Four groups were selected for the interviews:

1) *Recreationalists:* defined as people who generated their income from a recreation-based business such as guiding or outfitting (n = 6)
2) *Public land managers:* this included state and federal agency employees that managed a specific publicly-owned landscape, but some, such as the Natural Resource Conservation Service, were federal employees with broad natural resource responsibilities without a focal landscape (n = 6)
3) *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)
4) *Scientists:* defined as scientists and employees of the Rocky Mountain Biological Laboratory (RMBL) in Gothic, Colorado (n = 7)

Previous research and the community adaptation planning process (Knapp, 2013, 2011; Neely et al., 2011) identified recreationalists, public land managers, and ranchers, to represent the main cultural groups in the Basin, so we selected those same groups to allow comparison of research findings. We added field-based scientists at RMBL to explore a wide variety of different knowledges built through experience—as field ecologists too build climate knowledge broader than just their research focus—and to not ignore an important source of climate and ecological knowledge in the Basin.

Criteria were established to identify, and exclude, candidates for the study, and to respond to critiques of the transparency of sampling procedures in qualitative methods (Nielsen and D'haen, 2014). First, interviewees have a minimum residency in the area of five years, and over 10 years when possible[1] so that interviewees would have sufficient experience of the basin's weather to develop a sense of its climate. The second criterion was that interviewees live in the Basin year-round, or, because 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 criterion was that RMBL scientists[2] primarily only come to the Basin during the summer, so this group has developed knowledge mostly about summer climate. The third and most important criterion, which was supported through the selection of community groups, was a strong connection to the landscape through daily activities. Here we accept as an initial hypothesis, common though often implicit in the literature cited earlier, that climate knowing is processed partially from the repeated experience of weather across seasonal and annual cycles. But we also expected that experience with landscape resources and features (like the obvious altitudinal zonation of vegetation in the Basin) that themselves reflect climate more than weather, could add a more direct climate knowing on top of weather-derived climate notions.

### 3.4. Analysis

Interviews were transcribed verbatim to maintain the rich quality of each. Transcribed interviews were qualitatively coded using NVivo software (Bazeley and Jackson, 2013) with both *a priori* codes based on a set of propositions and themes distilled from previous work as well as emerging codes identified during the analysis.

One of the challenges of analyzing climate knowledges—in a way that departs from attitude surveys or climate literacy testing—is

[1] 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. The shortest residency of the year-round interviewees was 8 years in the basin with the longest being over 70 years.

[2] A few in the scientist group were year-round staff and thus they met the second criteria.

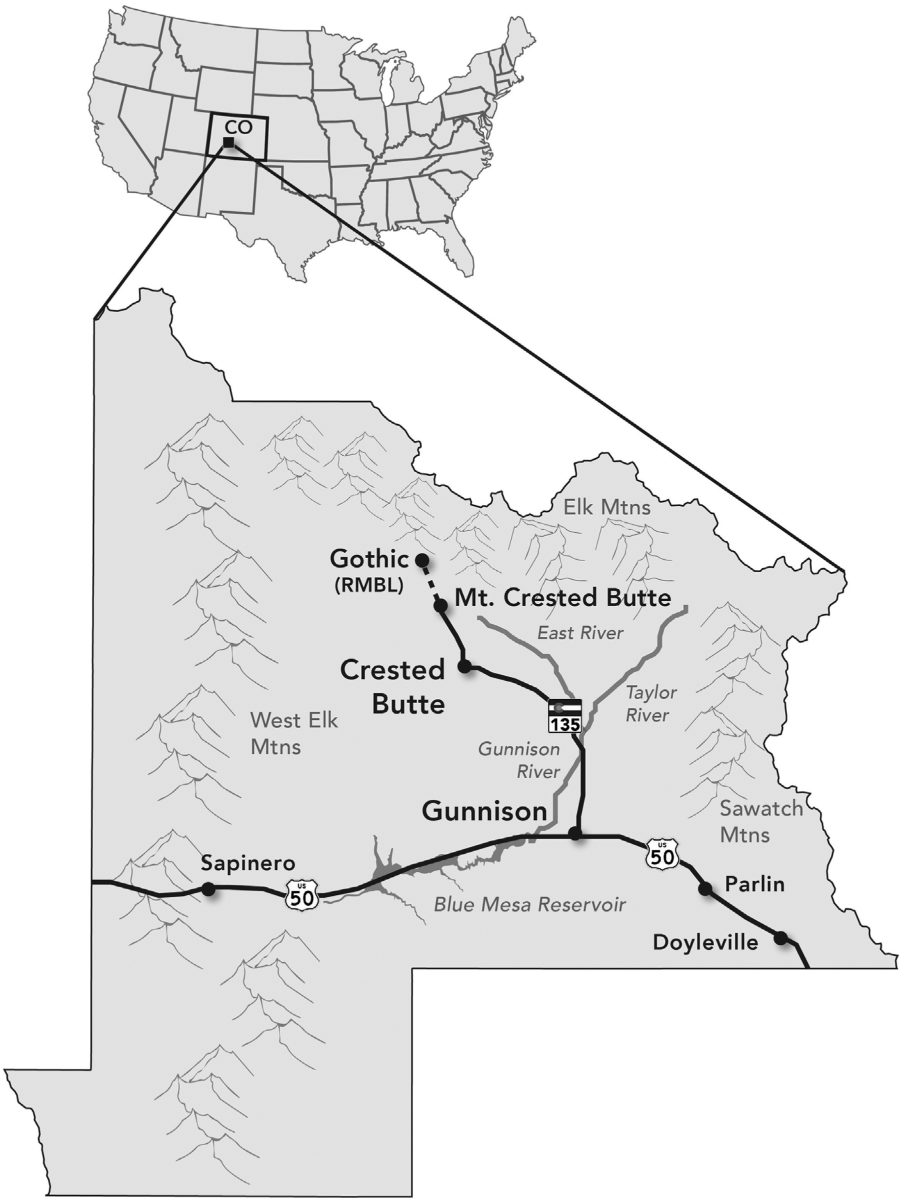


**Fig. 1.** The study area in Colorado's Gunnison Basin is a broad valley at the headwaters of the Gunnison River and its tributaries in the southern Rocky Mountains with a rural and small-town economy based on ranching, forestry, mining, recreation, education and water resources. Interviews were conducted in three Basin communities: Gunnison, Crested Butte, and Gothic (where the Rocky Mountain Biological Laboratory is located).

determining how to bound the inquiry. We did not want to narrowly define climate so that the coding only yielded scientific answers about climate (precipitation, solar radiation, atmospheric gases etc.), which would of course miss the broader ways that people know climate. At the same time, we wanted a parsimonious coding structure. We used *a priori* codes focused on three dimensions: *features, processes, and benchmarks*:

1) *Features* capture the different weather and climate elements that people use to construct climate knowledge. This is the most basic structure, the building blocks and that feed into *processes* and *benchmarks*. Features are central to the cognized climate, revealing the parts of climate that are important to people and what they understand as climate as opposed to other aspects of the natural world. Features provide a common grounding for the cognized climate and can act as markers to track the circulation of knowledge in the community. The interviews provided a range of features, such as: snowpack, drought, storms, and streamflow.
2) *Processes* reflect "how climate works" and the mechanisms driving climate. They are dynamic and engage with multiple features and were often tied to *benchmarks* in the mental models revealed in the interviews. Processes explain how features are created and relationships among features, like snowpack and runoff. These dynamic operations drive the impacts felt by interviewees and are an important part of how they make sense of an abstract, dynamic climate, and how they adjust their behavior to it. Interviews captured a number of processes including: snowmelt and runoff, human impacts, and spring green-up/plant growth.
3) *Benchmarks* are the anchors, both human and natural, with which people bind their climate knowledge. People use benchmarks as temporal structures to help order the messy climate around them, and to help them read the climate for achieving specific goals. Benchmarks are also a key way that people mediate the complicated relationship between weather and climate. Benchmarks may be imbued with instrumental and affective meaning and can inculcate processes, especially when they demark the timing of particular seasonal conditions. Benchmarks tended to be very specific to the interviewee's livelihood and included for example: condition of the road to Gothic, reference years and events like the drought of 2012, and sensory cues of seasonal changes.

Coding was open to other dimensions of climate knowledges that transcended this three-part structure by searching the transcribed interview for emergent topics that complemented our *a priori* codes. This was done following an approach that has become standard in qualitative analysis (Bazeley and Jackson, 2013; Stemler, 2001). Codes were assigned for concrete and specific topics such as environmental features (e.g. snow, rain), processes (e.g snowmelt), and reference events (e.g. storms, drought years), but also for abstractions such as attitude (e.g. positive, negative), knowledge (e.g. certainty, tensions between knowledges), normality (e.g. normal, abnormal), and system attributes (e.g. balance, change). Both concrete and abstract codes reveal themes that correlated with the initial three climate knowledge dimensions. As the coding process continued, new codes emerged in an iterative process of coding and recoding transcripts with new codes. Once broad codes were assigned to all transcripts, they were reviewed again and sub-coded for nuanced and subtle arguments or different clustering within a topic. Since we were committed to examining climate knowledge that manifested differently, this structure gave us an approach that was not so open-ended that we moved away from climate (to the many other local issues on people's minds), but that did not tend to exclude data about climate, described in unconventional terms.

## 4. Finding 1: climate is known and discussed through climate-related proxies rather than climate itself

In discussing climate, participants often described climate-related proxies rather than climate as it would be defined by climate science (e.g., via station data, climate summaries, or model output). When asked a range of questions about climate, many of the interviewees made reference to atmospheric states and processes, but simultaneously entrained ecological and social elements. Interviewees integrated the impacts of climate with land and resource management decisions, rather than sorting them into different categories: they discussed climate in terms of, for example, snowpack levels, wildfire, endangered species, human migration, and other local to regional processes and features. Climate proxies considered especially important were discussed in detail, often not explicitly tied to their underlying climate driver.

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, had or would cause impacts to livelihoods and the landscape. A deep-seated tension exists within the community between the tourism economy, marked by a growing recreational footprint and increasing number of second-home owners, and the communities that identify with the traditional and historic economies, tied to agriculture, forestry and mining. Specifically, people discussed increased migration and vacationing (tourism) as a likely part of climate change.

An older rancher felt that recreation pressures and increased populations were the greatest threat to ranching in the upper basin and that both of these pressures will likely continue to increase and be driven by a changing climate. The 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, often with a positive connotation within the recreation community and dread in the ranching community. Visitors come from around the country and globe, but the largest sources are nearby states of Texas and Oklahoma. Second-home owners and regular seasonal visitors are seen as fleeing to the mountains to escape the suffocating summer heat in Texas and Oklahoma. People saw this seasonal migration 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.

Dust, or dust storms, was another climate proxy that emerged numerous times in interviews. One specific manifestation often mentioned was "dust-on-snow," which results when dust storms that originate in the Colorado Plateau deposit reddish, easily noticeable, dust on the mountain snowpack. This is not a new phenomenon, but many who commented on it argued that it is increasing in intensity (an observation supported in the scientific literature, see Neff et al., 2008; Painter et al., 2010, though little is known about what is causing this uptick in dust events). A variety of impacts result from dust-on-snow, but the main one discussed was faster and earlier snowmelt. A mountain guide, who works in winter recreation – primarily skiing – described this trend in terms of climate risk.

> *"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 Basin's economy, but also the impact to water supply, a perennial natural resource and political worry entangled in legal mandates and exacting regulations of Colorado River water. A complex series of drivers is probably liberating this dust, including land use and climate of the southwestern states, but for Basin residents, this was an element of their climate.

Many more climate proxies were employed by Basin residents during interviews and these signaled an important element of experienced climate knowledge; these included climate effects such as: wildfire, snowmelt, bark beetle, endangered species listings, elk migration, and green-up (see Supplementary material for additional quotations). We argue that these represent not an avoidance of climate questions or a form of illiteracy, but instead rich climate knowledges. People engage with climate through proxies.

## 5. Finding 2: climate knowledge is shaped by rubrics

People use climate rubrics, based on their own, or others', experienced climate knowledge, to make sense of complex patterns. We define climate rubrics as stable evaluative linkages that people apply to determine how one feature will affect another feature, or refract through a benchmark; these linkages coevolved over time and allow people to use climate information about one feature to inform decisions about another feature or benchmark. Rubrics that people expressed took several forms, with the most frequent being: time-hacks (e.g., holidays), guidance passed down across generations (e.g., take the cows up-country along this path in snowy years), or visual cues in the landscape (e.g., blooming of certain plants used to signal grazing or other land uses).

People whose family had lived in the Basin for generations—primarily ranchers—possessed rubrics formed, tweaked and handed down over time along with land. Trial and error and experienced climate knowledges shaped these rubrics to help people anticipate processes and near-future conditions, and aid in climate-sensitive decision-making. An older rancher from a long line of cattle producers in the Basin shared a rubric that helps him decide when to move cattle to different pastures at different elevations in the narrow window between when the grass is ready for grazing and when the poisonous Larkspur blooms. Unlike his father and grandfather who herded the livestock, he schedules trucks to transport cattle to pastures, and this must be scheduled several days in advance. To help him decide when to move the cattle, he cites a phenological marker—in a climate rubric—that his father used.

> *"My dad had a saying up here, just this side of [a landmark] 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 [a local] creek.' And it's pretty damn close to always being that way."*

Another rancher created a new climate rubric based on new benchmarks. In our interview, his wife prodded him to explain how he used snow depth on a mountain pass as an indicator for the season. This snow measuring station (a SNOTEL or "Snow Telemetry" gauge that can be tracked on the web) did not even exist 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 kind of correlates that to 'Okay, if its only at 4 feet, we are in trouble, but if its at 5 ft, we'll be Okay' … he would have liked 7*

*H: I want 7. 6 Feet the first of May…*

*W: It's a good year*

*H: Even if it gets hot, and you can go back. I mean if you have 7 feet the 15th of March and then you have a hot spring, you are still going to make it. Or if you have 5.5 feet the first of May, then you are going to be OK. But, if you are 3 feet the first of May, then you are probably going to be in trouble. You can start to know you can't kid yourself that even if we get a big storm in May, but if the marker was at 2 feet, its not going to be enough. You still can't [kid yourself] because you have seen it enough years, you think 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.'"*

This discussion between husband and wife shows how a very sharp rubric was created and honed over the years to aid in predicting important climatic and terrestrial processes. He uses the benchmark of different depths of snow at a certain time to predict features like cattle forage. This informs key decisions like how much additional feed he needs to buy.

Different groups developed climate rubrics that reflected their livelihoods and the decisions they needed to make. Flyfishers would stop fishing a stretch of steam if a certain rock was exposed by a certain date. Research laboratory scientists used snow levels on their access roads to decide when to begin their experiments, start their summer fieldwork, and expect certain phenological events. Rubrics reveal how people build experienced climate knowledge, the structure of that knowledge (benchmarks and features), and how they act on that knowledge. This shows us that climate knowledge is not only about features, processes, and benchmarks (or how these structures manifest as proxies), but that climate knowledge is relational. The relationships, or linkages, among different elements of climate matter and shape how people understand it.

However, people also reported that rubrics relied on for years to generations are losing efficacy. Rubrics help connect terrestrial changes—often related to proxies—with their underlying climate processes, but they rely on the consistent order and timing of climate processes. Many residents in the Basin, from scientists to recreationalists, explained to us that they were seeing increasing climate mismatch, where longstanding processes that had coevolved together were de-tethering (this behavior is also discussed in the scientific literature, e.g.: Inouye, 2008; Miller-Rushing et al., 2010; Thomson, 2010). This made their rubrics less robust. For example, mismatch can manifest in climate in one place changing without other corresponding places similarly changing, so the snow could melt earlier in the Gunnison Basin, but pollinators would arrive at their original time, missing an important pollination window. These types of changes made people less confident about the rubrics they reported to us.

## 6. Finding 3: people did not discuss different elements of climate discretely, but instead in an integrated way

Interviewees did not always isolate specific climate variables nor discuss them discretely, but instead refused to disentangle elements from their complex relationships and contexts. People rarely talked about one climate element (e.g. temperature) removed from its connection to others, and instead explained to us how elements interacted with related processes. This highlights how experienced climate knowledge reflects an integrated system, allowing residents to understand how impacts of climate could cascade through social and ecological communities. This finding is distinct from our first finding regarding proxies because people often did not interpret climate through just one proxy alone, but instead identified how changes and proxies together worked to alter the landscape and livelihoods. We employ two proxies discussed in the first finding − human migration and dust—to show how those proxies are embedded in complex dynamics.

One longtime rancher described a series of landscape changes that he linked to both social change and climate. He was approaching retirement after more than seven decades in the Basin and had witnessed significant increasing demographics and recreational pressures. Both his father and grandfather had spent their lives ranching the same land, using the same practices. He explained how different ranching was for him than 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 altering how he ranched. Like many of the interviewees, he also emphasized the human migration proxy: more people moving into the Basin, escaping hotter conditions elsewhere. This pressure was not only encroaching on his private land and the federal lands he held permits to graze on, but also influencing wildlife populations. More people were biking in the Basin and they were expanding further into wildlands, disrupting and hazing elk herds so that the herds moved onto his grazing land before his cattle did. For the rancher, climate was driving processes that included human migration, expanding recreation, altered elk movements, and predator behavior, with all of these processes influencing each other and compounding the feeling of change.

A wildlife biologist took a similar integrated approach to explain how he expected changes in climate to ripple through the abiotic and biotic systems. He started by describing anticipated changes in precipitation timing from climate models and how he thought those would affect the greater climate system.

*"We will have rains later in the fall, and we will have… still this time period where we are going to have snow. But then we are going to have rain on snow events in the spring and we are going to start losing those little reservoirs of moisture. And that is going to have dramatic impacts on soil moisture throughout the entire system. Dust-on-snow events, and then intensive solar radiation, we are going to have… a hydrograph that peaks early at a much higher level and then drops off really fast. And that is going to change the ecology of the entire system. It's also going to change, its going to have dramatic impacts on agriculture, which those agricultural meadows are really important for [sage] grouse and a number of other species."*

He carefully described the series of changes he expects by starting with how altered precipitation temporal patterns (opposed to the more common focus on quantity), would affect the snowpack and melt rates accelerated by rain falling on snow. An earlier runoff would both drive and be driven by dust-on-snow events, one of the climate proxies that emerged in this study. He envisions a complex system of feedbacks where runoff shapes soil moisture and therefore dust, but also where dust shapes runoff. Next, he anticipates how these abiotic changes could shape the ecology of the area through plant productivity and then animal communities. This is another example of how people understood climate and its impacts in complex, relational ways that integrated a range of different processes into one system.

## 7. A social-ecological-atmospheric construct

Our aim was to better understand the content and structure of climate knowledge, to focus on what was present rather than absent in that knowledge, and to evaluate whether people were as naïve about their climate as many previous studies claimed. By taking an approach that engaged climate broadly, we were able to identify three findings about the character of this knowledge help us better conceptualize *how*, not if, people understand climate. Our first finding showed that people often keyed on climate-related proxies that might be disregarded as tangential by narrow definitions of climate. The second finding, that people use rubrics to structure climate knowledge, highlights how people do not understand climate through isolated elements, but instead as relational and connected. The third finding, that climate knowledge does not isolate individual climate elements, accentuates the complex way that many processes together constitute climate.

These findings reveal climate as a social-ecological-atmospheric construct in which climate processes are imbricated with ecological and human processes. They suggest that people do not separate humans from atmosphere in the same way that models or climate scientists do. Interviewees viewed climate with more complexity, as a socio-ecological-atmospheric system with complicated interactions among different types of processes. Marin and Berkes (2013) similarly referred to people's observations about climate that "often rely on holistic ways of knowing their environments, integrating large numbers of variables, and the relationships between these" (p. 1). This construct makes these relationships explicit and pulls in other theorizations recognizing the hybridity of climate, and that personal climate knowledge is "bound up with places, bodies and with social practices such as farming, fishing, gardening and recreation" (Hulme, 2017, p. 29).

Previous studies of climate knowledge find some of the same complexities revealed in this study. Geoghegan and Leyson (2012), who take an explicitly critical and interpretive approach, argue that it is in the "often excluded, complex and 'unquantifiable' relationships with climate and landscape that people make sense of and respond to climate change" (p. 64). Our study examined those "unquantifiable" elements of climate that cannot be as readily assessed in literacy and attitude surveys. Approaching climate as a social-ecological-atmospheric construct makes room for the hybrid ways climate forms, asks scholars to re-think how they study and ask questions about climate, and most importantly allows for local expertise and placed-based climate knowledge to *count*.

## 8. Conclusion: a more inclusive climate

Our research can provide new interpretations of results from previous research on attitudes about climate change, especially skepticism. Surveys of attitudes toward climate change fail to address the underlying question of how people understand climate, much less why and how it changes. A focus on climate skepticism assumes that climate change beliefs are based on ignorance, politics and socio-economic motivations, when differences in climate experiences, and climate knowledges, could lead to some of these differences in attitude.

Future research is needed to explore climate knowledges and compare different research approaches. Are our coding structures useful to research in other settings and with different demographics? Are other approaches missing climate knowledge? Research that engages multiple approaches (e.g. climate knowledges and climate literacy) would be useful to highlight the limitations of each. Would conclusions about climate literacy be altered if researchers administered climate literacy tests and followed up with open-ended qualitative research that recognizes that climate extends beyond atmospheric processes?

A better understanding of climate knowledge can, and should, shape how we work to mitigate and adapt to climate change. Yet, some climate perception studies may be misleading. People might "fail" climate literacy tests because of jargon or technical language while still having robust knowledge; they might respond negatively to the politics of "climate change" or "global warming" in attitude surveys despite holding personal observations that climate is changing. Resources devoted to fixing assumed illiteracy or combating assumed skepticism, may thus be wasted. Our conclusions do not negate previous findings, but highlight their limitations in understanding a complex, dynamic, and non-linear topic. By understanding more about how people know climate, we may be able to better interpret climate attitudes and beliefs, diagnose why past efforts to encourage climate adaptation and mitigation have been unsuccessful, and provide insights into limits on the effective application of climate information.

## Authors' contributions

KC and WT conceived of the study. KC conducted the fieldwork, interviews and initial analysis. KC and WT drew conclusions and co-wrote the paper.

## Declaration

The authors declare no financial/personal interest or belief that could affect their objectivity in this research. The funding agency did not participate in the design or carrying out of the work.

## Acknowledgements

We would like to thank the many residents of Gunnison, Colorado who participated in interviews. We are grateful to Sara Fall and three anonymous reviewers whose comments and feedback improved this paper. Ami Nacu-Schmidt produced the map. Research was supported by the Western Water Assessment, a project of the University of Colorado's Cooperative Institute for Research in the Environmental Sciences, funded by the U.S. National Oceanic and Atmospheric Administration under Climate Program Office grant #NA10OAR4310214.

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.gloenvcha.2017.12.007.

## References

Arbuckle, J.G., Morton, L.W., Hobbs, J., 2013. Farmer beliefs and concerns about climate change and attitudes toward adaptation and mitigation: evidence from Iowa. Clim. Change 118 (3), 551–563. http://dx.doi.org/10.1007/s10584-013-0700-0.
Bazeley, P., Jackson, K. (Eds.), 2013. Qualitative Data Analysis with NVivo. Sage Publications Limited.
Borick, C.P., Lachapelle, E., Rabe, B.G., 2010. Climate Compared: Public Opinion on Climate Change in the United States and Canada. People.
Brace, C., Geoghegan, H., 2011. Human geographies of climate change: landscape, temporality, and lay knowledges. Prog. Hum. Geogr. 35 (3), 284–302.
Brody, S.D., Zahran, S., Vedlitz, A., Grover, H., 2008. Examining the relationship between P.V. and public perception of global climate change in the United States. Environ. Behav. 40 (1), 72–95.
Capstick, S.B., Pidgeon, N.F., 2014. What is climate change scepticism? Examination of the concept using a mixed methods study of the UK public. Global Environ. Change

24, 389–401. http://dx.doi.org/10.1016/j.gloenvcha.2013.08.012.
Climate Literacy, 2009. Climate Literacy: The Essential Principles of Climate Science. United States Global Change Research Program, Washington, D.C Available at: http://cpo.noaa.gov/sites/cpo/Documents/pdf/ClimateLiteracyPoster-8_5x11_Final4-11LR.pdf.
Connor, L.H., Higginbotham, N., 2013. Natural cycles in lay understandings of climate change. Glob. Environ. Change 23 (6), 1852–1861.
Crabbé, P., Robin, M., 2006. Institutional adaptation of water resource infrastructures to climate change in Eastern Ontario. Clim. Change 78 (1), 103–133.
Dunlap, R.E., McCright, A.M., 2008. A widening gap: republican and democratic views on climate change. Environ.: Sci. Policy Sustain. Dev. 50 (5), 26–35.
Dupigny-Giroux, L.A.L., 2008. Introduction—climate science literacy: a state of the knowledge overview. Phys. Geogr. 29 (6), 483–486.
Dupigny-Giroux, L.A.L., 2010. Exploring the challenges of climate science literacy: lessons from students, teachers and lifelong learners. Geogr. Compass 4 (9), 1203–1217.
Endfield, G., Morris, C., 2012. Cultural spaces of climate. Clim. Change 113 (1), 1–4.
Funk, C., Kennedy, B., 2016. The Politics of Climate. Pew Research Center. http://www.pewinternet.org/2016/10/04/the-politics-of-climate.
Geoghegan, H., Leyson, C., 2012. On climate change and cultural geography: farming on the Lizard Peninsula, Cornwall, UK. Clim. Change 113 (1), 55–66.
Goldman, M.J., Daly, M., Lovell, E.J., 2016. Exploring multiple ontologies of drought in agro-pastoral regions of Northern Tanzania: a topological approach. Area 1, 27–33.
Gosnell, H., Abrams, J., 2009. Amenity migration: diverse conceptualizations of drivers, socioeconomic dimensions, and emerging challenges. GeoJournal 76 (4), 303–322.
Harrington, J., 2008. Misconceptions: barriers to improved climate literacy. Phys. Geogr. 29 (6), 575–584.
Harris, R., 2011. Climate Change: Public Skeptical, Scientists Sure. National Public Radio.
Hulme, M., 2009. Why we Disagree About Climate Change. Cambridge University Press, Cambridge, UK.
Hulme, M., 2017. Weathered: Cultures of Climate. Sage Publications.
Inouye, D.W., 2008. Effects of climate change on phenology, frost damage, and floral abundance of montane wildflowers. Ecology 89 (2), 353–362.
Israel, A.L., Sachs, C., 2013. A climate for feminist intervention: feminist science studies and climate change. In: Alston, M., Whittenbury, K. (Eds.), Research, Action and Policy: Addressing the Gendered Impacts of Climate Change. Springer Netherlands, Dordrecht, pp. 33–51.
Jurt, C., Burga, M., Vicuña, L., Huggel, C., Orlove, B., 2015. Local perceptions in climate change debates: insights from case studies in the Alps and the Andes. Clim. Change 133 (3), 511–523. http://dx.doi.org/10.1007/s10584-015-1529-5.
Kahan, D.M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L.L., Braman, D., Mandel, G., 2012. The polarizing impact of science literacy and numeracy on perceived climate change risks. Nat. Clim. Change 2, 732–735.
Kaufmann, R.K., Mann, M.L., Gopal, S., Liederman, J.A., Howe, P.D., Pretis, F., et al., 2017. Spatial heterogeneity of climate change as an experiential basis for skepticism. Proc. Natl. Acad. Sci. 114 (1), 67–71. http://dx.doi.org/10.1073/pnas.1607032113.
Knapp, C., 2011. Connected to the Land: Social Resilience and Vulnerability Assessment of Land-Based Livelihoods in the Gunnison Basin, Colorado. The Nature Conservancy, Gunnison.
Knapp, C.N., 2013. Engaging Local Perspectives for Improved Conservation and Climate Change Adaptation. University of Alaska, Fairbanks Doctoral dissertation. https://scholarworks.alaska.edu/handle/11122/4470.
Kohl, E., Knox, J.A., 2016. My drought is different from your drought: a case study of the policy implications of multiple ways of knowing drought. Weather Clim. Soc. 8 (4), 373–388.
Kohut, A., Doherty, C., Dimock, M., Keeter, S., 2011. Beyond Red vs. Blue: The Political Typology. The Pew Research Center for the People & the Press. http://www.people-press.org/files/legacy-pdf/Beyond-Red-vs-Blue-The-Political-Typology.pdf. (Accessed 11 April 2017).
Leiserowitz, A., Maibach, E., Roser-Renouf, C., Rosenthal, S., Culter, M., 2017. Climate Change in the American Mind: November 2016. Yale University and George Mason University and Yale Project on Climate Change Communication, New Haven, CT.
Leiserowitz, A., 2006. Climate change risk perception and policy preferences: the role of affect, imagery, and values. Clim. Change 77 (1), 45–72.
Lejano, R.P., Tavares-Reager, J., Berkes, F., 2013. Climate and narrative: environmental knowledge in everyday life. Environ. Sci. Policy 31, 61–70.
Leyshon, C., 2014. Critical issues in social science climate change research. Contemp. Soc. Sci. 9 (4), 359–373.
Lorenzoni, I., Leiserowitz, A., De Franca Doria, M., Poortinga, W., Pidgeon, N.F., 2006. Cross national comparisons of image associations with global warming and climate change among laypeople in the United States of America and Great Britain 1. J. Risk Res. 9 (03), 265–281.
Mahony, M., Hulme, M., 2016. Epistemic geographies of climate change: science, space and politics. Prog. Hum. Geogr 0309132516681485.
Marin, A., Berkes, F., 2013. Local people's accounts of climate change: to what extent are they influenced by the media? Wiley Interdiscip. Rev. Clim. Change 4 (1), 1–8. http://dx.doi.org/10.1002/wcc.199.
Miller-Rushing, A.J., Høye, T.T., Inouye, D.W., Post, E., 2010. The effects of phenological mismatches on demography. Philos. Trans. R. Soc. Lond. B: Biol. Sci. 365 (1555), 3177–3186.
Neely, B., Rondeau, R., Sanderson, J., Pague, C., Kuhn, B., Siemers, J., Grunau, L., Robertson, J., McCarthy, P., Barsugli, J., Schulz, T., Knapp, C., 2011. Gunnison Basin: Climate Change Vulnerability Assessment for the Gunnison Climate Working Group The Nature Conservancy, Colorado Natural Heritage Program, Western Water Assessment, University of Colorado, Boulder, and University of Alaska, Fairbanks. Project of the Southwest Climate Change Initiative, Boulder, CO, USA.
Neff, J.C., Ballantyne, A.P., Farmer, G.L., Mahowald, N.M., Conroy, J.L., Landry, C.C., et al., 2008. Increasing eolian dust deposition in the western United States linked to human activity. Nat. Geosci. 1 (3), 189–195.
Nielsen, J.Ø., D'haen, S.A.L., 2014. Asking about climate change: reflections on methodology in qualitative climate change research published in Global Environmental Change since 2000. Glob. Environ. Change 24, 402–409.
Niepold, F., Herring, D., McConville, D., 2007. The case for climate literacy in the 21st Century. 5th International Symposium on Digital Earth from. http://www.isde5.org.
Painter, T.H., Deems, J.S., Belnap, J., Hamlet, A.F., Landry, C.C., Udall, B., 2010. Response of Colorado River runoff to dust radiative forcing in snow. Proc. Natl. Acad. Sci. 107 (40), 17125–17130.
Poortinga, W., Spence, A., Whitmarsh, L., Capstick, S., Pidgeon, N.F., 2011. Uncertain climate: an investigation into public scepticism about anthropogenic climate change. Glob. Environ. Change 21 (3), 1015–1024.
Popke, J., 2016. Researching the hybrid geographies of climate change: reflections from the field. Area 48 (1), 2–6.
Pugliese, A., Ray, J., 2011. Fewer Americans, Europeans View Global Warming as a Threat. Gallup. http://www.gallup.com/poll/147203/fewer-americans-europeans-view-global-warming-threat.aspx. (Accessed 11 April 2017).
Reynolds, T.W., Bostrom, A., Read, D., Morgan, M.G., 2010. Now what do people know about global climate change? Survey studies of educated laypeople. Risk Anal. 30 (10), 1520–1538.
Rice, J.L., Burke, B.J., Heynen, N., 2015. Knowing climate change, embodying climate praxis: experiential knowledge in southern appalachia. Ann. Assoc. Am. Geogr. 105 (2), 253–262. http://dx.doi.org/10.1080/00045608.2014.985628.
Rudiak-Gould, P., 2012. Promiscuous corroboration and climate change translation: a case study from the Marshall Islands. Glob. Environ. Change 22 (1), 46–54.
Rudiak-Gould, P., 2013. We have seen it with our own eyes: why we disagree about climate change visibility. Weather Clim. Soc. 5 (2), 120–132.
Saleh, S.A., Smith, J.W., Liu, Z., 2012. Rural Nevada and climate change: vulnerability, beliefs, and risk perception. Risk Anal. 32 (6), 1041–1059.
Solli, J., Ryghaug, M., 2014. Assembling climate knowledge. The role of local expertise. Nord. J. Sci. Technol. Stud. 2 (2), 18–28.
Spence, A., Poortinga, W., Butler, C., Pidgeon, N.F., 2011. Perceptions of climate change and willingness to save energy related to flood experience. Nat. Clim. Change 1 (1), 46–49.
Stemler, S., 2001. An overview of content analysis. Pract. Assess. Res. Eval. 7, 137–146.
Sundblad, E.-L., Biel, A., Gärling, T., 2007. Cognitive and affective risk judgements related to climate change. J. Environ. Psychol. 27 (2), 97–106. http://dx.doi.org/10.1016/j.jenvp.2007.01.003.
Thomson, J.D., 2010. Flowering phenology, fruiting success and progressive deterioration of pollination in an early-flowering geophyte. Philos. Trans. R. Soc. Lond. B: Biol. Sci. 365 (1555), 3187–3199.
Whitmarsh, L., 2008. Are flood victims more concerned about climate change than other people? The role of direct experience in risk perception and behavioral response. J. Risk Res. 11 (3), 351–374.