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Who remembers a hot summer or a cold winter? The asymmetric effect of beliefs about global warming on perceptions of local climate conditions in the U.S.

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ABSTRACT

This paper explores the phenomenon of local climate perception and the extent to which public perceptions match climate conditions as recorded in instrumental climate data. We further examine whether perceptions of changes in local climates are influenced by prior beliefs about global warming, through the process of motivated reasoning. Using national survey data collected in the United States in 2011, we find that subjective experiences of seasonal average temperature and precipitation during the previous winter and summer were related to recorded conditions during each season. Beliefs about global warming also had significant effects on subjective experiences with above-normal temperatures, particularly among those who believed that global warming is not happening. When asked about the summer of 2010, those who believed that global warming is not happening were significantly less likely to report that they had experienced a warmer-than-normal summer, even when controlling for demographics and local climate conditions. These results suggest that the subjective experience of local climate change is dependent not only on external climate conditions, but also on individual beliefs, with perceptions apparently biased by prior beliefs about global warming.

1. Introduction

Thus far, global warming has manifested gradually over many decades and at spatial scales well beyond the direct perceptual capabilities of any individual human being (e.g. the global or continental scale). Local weather conditions, on the other hand, are a readily available source of information that, when aggregated over time, may enable people to detect long-term climate trends at the local scale (Howe et al., 2013; Orlove et al., 2010). The translation of personal experience of changes in local weather conditions to perceptions of climate variability and change is an important component of individual and community adaptation (Adger et al., 2007). Research on local climate knowledge has found that people are able to detect and respond to changes in climate (Strauss and Orlove, 2003), but the characteristics of local manifestations of climate change that are perceived have been hypothesized to be dependent on a variety of individual and contextual factors. These factors include the importance of specific climatic conditions to individual livelihoods (Meze-Hausken, 2004; Osbahr et al., 2011; Roncoli et al., 2002), the spatial scale of changes (Howe et al., 2013; Ruddell et al., 2012), and the reference periods over which individuals establish representations of a normal climate (Hulme et al., 2009; Sánchez-Cortés and Chavero, 2011). Perceptions of change in local climate, as with other individual judgments, may be subject to systematic cognitive biases that favor experiential over descriptive learning (Marx et al., 2007). However, there has been little attention to the possibility of biased perceptions of climate change at the local scale due to pre-existing beliefs about climate change at the global scale. The existence of strongly held beliefs about the direction of change in the global climate may bias judgments about local climate in the direction predicted by one's prior beliefs about the global climate. Such biases in local climate perceptions, if present, may act as a barrier to accurate detection of local climate change and an impediment to effective climate change adaptation.

Recent research has shown that perceived personal experience with global warming leads to heightened global warming risk perceptions and greater certainty in the belief that global warming is happening (Akerlof et al., 2013; Myers et al., 2012; Spence et al., 2011). More specifically, perceived experience appears to lead to greater certainty that global warming is happening only among those who have weakly held beliefs about global warming, while motivated reasoning affects perceived personal experience among

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those who have strongly held beliefs about global warming (Myers et al., 2012). Motivated reasoning is the tendency to interpret information to fit pre-existing beliefs (Kunda, 1990). In this paper, we extend previous findings by exploring the effect of motivated reasoning on perceptions of local seasonal climate while controlling for actual local climate conditions. Drawing from a nationally representative survey of the U.S. population, we first characterize the relationship between instrumental climate data and perceptions of local seasonal climate. We subsequently examine the relationship between sets of beliefs about global warming and perceptions of local climate conditions.

The relationship between personal experience and beliefs about global warming is of considerable interest as changes in local weather and climate conditions continue to be consistent with scientific projections of global warming. For example, between January 2000 and September 2009 maximum temperature records were broken more than twice as frequently as minimum temperature records in the contiguous U.S. (Meehl et al., 2009), and extreme events such as the 2011 Texas heat wave and drought have become much more likely (Peterson et al., 2012). While direct attribution of any single weather event to long-term processes like global warming is not possible, the accumulation of weather events that fall outside the range of previous experience does provide evidence that the climate is changing, since local extreme events become more likely as the world warms (Hansen et al., 2012; Meehl and Tebaldi, 2004; Rahmstorf and Coumou, 2011). But can individuals, drawing upon their personal experience, accurately detect the extent to which recent conditions have changed relative to the past? It is therefore important to understand how people subjectively experience their local climate, and what factors influence their judgments about whether local climates are changing. Previous broad-scale survey research suggests that changes in local climate conditions can influence public perceptions of local warming trends (Howe et al., 2013). While there is some evidence that recent experience with short-term ambient temperatures may influence global warming beliefs (Akerlof et al., 2013; Borick and Rabe, 2010; Egan and Mullin, 2012; Goebbert et al., 2012; Hamilton and Stampone, 2013; Joireman et al., 2010; Li et al., 2011; Risen and Critcher, 2011), there has been little attention to the possibility that subjective experiences of local climate may also be influenced by pre-existing beliefs and attitudes about global warming, which could affect the ability to recognize local climate change.

2. Background

Research in communities around the world has documented many cases of people using personal experience to detect changes in their local climate; such changes include altered plant and animal phenology, new distributions of species, shorter or longer growing seasons, and the changing frequency of extreme weather events (Deressa et al., 2011; Orlove et al., 2000; Roncoli et al., 2002; Smit et al., 1997; Thomas et al., 2007; Tschakert et al., 2010; Weatherhead et al., 2010; West et al., 2008). Such research has almost exclusively been carried out at the local scale using case studies of one or a small number of communities. The communities in these studies tend to be rural, with most residents engaged in livelihoods based on agriculture, ranching, or fishing. Because their livelihoods are dependent on the weather, residents have a strong incentive to pay attention to the variability of local weather and climate, and indeed they tend to notice changes. The changes that people notice tend to be closely related to the aspects of the weather that have the most direct effect on the livelihoods in which they engage, to such an extent that residents of the same community may identify different changes depending on their occupation (Hartter et al., 2012; Meze-Hausken, 2004; Osbahr et al., 2011).

Less clear is how individuals whose lives are not as directly dependent on the weather might perceive local climate changes, and if other individual factors might influence their perception of climate. Relatively few people in the U.S. are employed in a profession that is as dependent on the vagaries of day-to-day weather as, for example, a farmer who relies on rain-fed agriculture (Meyer, 2000). Furthermore, the populations of industrialized countries like the U.S. have adopted indoor climate control technologies that insulate them in a thermal environment disconnected from their local climate for much of the day (Hitchings, 2011). These characteristics of the U.S. population may be barriers to the public perceiving long-term changes in their local climate. Despite findings from national surveys in the U.S. that majorities of the population believe that global warming is affecting local weather and making extreme weather events worse, it is not clear if the experience of such events is a causal factor in belief change (Leiserowitz et al., 2013, 2012). Existing research is mixed about the effect of short-term extreme events on beliefs and behaviors related to climate change. For instance, there is contradictory evidence that direct experience of flooding among U.K. residents relates to concern about climate change (Spence et al., 2011; Whitmarsh, 2008).

This analysis examines one facet of local climate perceptions: judgments about whether seasonal temperature or precipitation has differed from normal. Identifying abnormalities in seasonal climate involves comparing current experience to memories of past experience (Weber, 2010). If memories of past experience are uninformative or inaccurate, it is possible that current conditions may be falsely judged to be normal or abnormal, depending on the direction in which memories of past experience have been distorted (Rebetez, 1996). For example, an individual may assume a July heat wave to be normal for that time of year if she remembers previous years with hot summers, whether or not those memories are accurate representations of her experience. Thus, for personal experience with short-term climate conditions to be an effective source of information about long-term local climate change, individuals must be able to perform two processes: perceive current weather conditions, and compare their perceptions to their expectations of what is "normal." Expectations may be based on memories of personal experience or descriptive information from external sources. If perceptions of current conditions in relation to expectations are accurate, then personal experience may be able to serve as a useful source of information to motivate and guide adaptation to the specific climatic changes happening in local places.

There are, however, multiple ways by which climate perceptions and expectations can be distorted. When asked to make a rapid assessment of a complex phenomenon like the climate, people may rely on intuitive processes, which may create systematic biases in how people perceive seasonal climate. Cognitive biases such as the tendency to overweight recent experience in memory (known as the recency effect) and the tendency to disregard the prior probabilities of events (known as base rate neglect) may lead people to believe that the recent weather that they have experienced is more representative of a longer-term period than it really is. Base-rate neglect explains why people may fail to account for prior probabilities when evaluating conditional probabilities (Koehler, 1996), and may lead people to assign an inordinate weight to unusual recent weather events when evaluating the probability of long-term climate change. Indeed, some existing evidence suggests that recency effects are indeed present in farmer decision-making with respect to climate information (Hansen et al., 2004).

Another potential source of error in judgments about seasonal climate may result from motivated reasoning. Motivated reasoning is the unconscious tendency to fit information to conclusions that correspond with a preexisting belief or goal (Kunda, 1990). Motivated reasoning may lead people to selectively misremember their experiences in ways that reinforce their prior beliefs about global warming. Evidence from a study of farmers in the Midwestern U.S. supports this view, finding that farmers who believed climate change was occurring were more likely to accurately remember a local warming trend over the past five years (Weber, 1997). The increasing ideological polarization of global warming in the U.S. may provide further additional incentives for motivated reasoning in seasonal climate perceptions (McCright and Dunlap, 2011). As global warming beliefs become strongly associated with certain ideological orientations, ideologically motivated cognition gives people strong reasons to perceive their experiences in ways that support their worldview (Kahan, 2013; Kahan et al., 2011).

Motivated reasoning may not influence memories of all types of weather uniformly, however; memories of local temperatures may be more influenced by global warming beliefs than memories of local precipitation because of the intuitive association between global warming and temperature (Leiserowitz, 2006, 2005). Global climate models project a long-term rise in local average temperatures across most of the world, resulting in a rise in global mean temperature of 2–4 °C by 2100 relative to the late 20th century (Meehl et al., 2007). Projected changes in precipitation, however, are much more place-dependent and comparatively uncertain (Christensen et al., 2007). These differences imply a more intuitive association between the constructs of local temperatures and global warming. The relationship between temperature and global warming is also supported by findings that ambient air temperature significantly affects global warming beliefs and concern (Joireman et al., 2010; Li et al., 2011; Risen and Critcher, 2011) and by cognitive associations between global warming and heat (Smith and Leiserowitz, 2012; Whitmarsh, 2009). Recent research has also found that perceptions of local temperature show a greater divergence from measurements of actual local weather than do perceptions of hydrometeorological phenomena such as flooding and drought (Goebbert et al., 2012). Motivated reasoning may thus be more likely to bias perceived experience of local temperature than that of local precipitation.

Our analysis begins with an exploration of the spatial pattern of U.S. seasonal climate perceptions. We hypothesize that the spatial distribution of perceptions of local climate conditions—the conditions to which individuals are exposed in the immediate area of their household—will broadly coincide with patterns of recorded temperature and precipitation anomalies. Perceptions should thus exhibit non-random spatial patterns, with perceptions tending to be similar among individuals nearer to each other and dissimilar among individuals at greater distances, since nearby individuals would be more likely to share the same experiences. If seasonal climate perceptions do exhibit a non-random spatial distribution then we would further expect their distribution to coincide with that of measured local climate anomalies during the season of interest, under the assumption that people have generally accurate perceptions of seasonal climate as recorded in instrumental data.

Our second hypothesis relates to the role of motivated reasoning in seasonal climate perceptions due to sets of beliefs about global warming. Survey research in the U.S. has identified six segments of the American public who have relatively homogenous levels of concern, knowledge, and related beliefs about global warming (Leiserowitz et al., 2009; Maibach et al., 2011). These segments range along a spectrum from the "Alarmed," who believe climate change is occurring, perceive it to be a serious threat, and support policies and personal behavior changes to mitigate the threat, to the "Dismissive," who believe climate change is not occurring, do not perceive it to be a serious threat, and do not support mitigation policies. Also along the spectrum are the "Concerned," who like the Alarmed believe climate change is happening and a threat, but are not personally engaged with the issue; the "Cautious," who are uncertain whether climate change is occurring or not; the "Disengaged," who know little to nothing about global warming; and the "Doubtful," who tend to think global warming is not happening, but if it is, it is not human caused, and not a serious threat. We hypothesize that, if motivated reasoning does influence seasonal climate perceptions, then respondents with different sets of beliefs about global warming will exhibit different perceptions of local climate conditions, even after controlling for the conditions experienced by each respondent. For instance, those who believe in the existence, certainty, and threat of global warming (i.e. the Alarmed and the Concerned) may tend to recall above-normal seasonal temperatures regardless of actual conditions. Conversely, those who believe that global warming is not happening, uncertain, or not a threat (i.e. the Dismissive and the Doubtful) may be less likely to recall above-normal seasonal temperatures. Motivated reasoning may also have a stronger influence on perceptions of climatic variables that are intuitively associated with preexisting beliefs about global warming, such as temperature, than on climatic variables that are less associated with the construct of global warming, such as precipitation.

3. Methods

This study is based on data from a nationally representative survey of the United States in April and May 2011, conducted by Knowledge Networks using a probability-based online panel. Survey respondents were randomly sampled from a panel of over 50,000 members originally recruited using random-digit dialing and address-based sampling. To ensure that the panel is nationally representative, members without internet access receive a netbook and internet service. The survey was fielded from April 22 to May 11, 2011, with a total of 1,010 completed responses from adults aged 18 or older. The survey had a recruitment rate of 15.7% (contacted individuals who opt to join the panel), a profile rate of 60.9% (panel members who complete the profile survey), a completion rate of 66.1% (invited panel members who completed the survey), and a cumulative response rate of 6.3% (the product of the recruitment, profile, and completion rates; see Callegaro and DiSogra, 2008).

The geographic distribution of respondents roughly reflected that of the U.S. population. By state, the greatest number of respondents lived in California (12%), followed by Texas (8%), New York (8%), and Florida (7%). The global warming audience segmentation was consistent with previous U.S. representative surveys, with the majority of respondents classified as the Concerned (27%) followed by the Cautious (25%), the Doubtful (15%), the Alarmed (12%), the Disengaged (10%), and the Dismissive (10%) (Leiserowitz et al., 2011).

Four survey items are the dependent variables in this study. These items measure perceived departures from normal in average temperature and precipitation during the preceding winter (winter 2010–2011) and the preceding summer (summer 2010). The questions were presented as follows: (1) "Has this winter in your local area been warmer, colder, or no different than normal?", (2) "Has this winter in your local area brought more snow or rain, less snow or rain, or was it no different than normal?", (3) "Thinking back to last summer, in your local area was it warmer, colder, or no different than normal?" and (4) "Thinking back to last summer, in your local area, did it bring more rain, less rain, or was it no different than normal?" The text of the survey did not specify a normal period with respect to these items, since individual definitions of "normal" are likely to be subjective and dependent on individual experience.

The survey also contained a battery of items on global warming beliefs, policy preferences, issue importance, and behavior that was used to classify respondents into six like-minded global warming audience segments using a 36-variable linear discriminant function (see Leiserowitz et al., 2009; Maibach et al., 2011). The classification function was based on a latent class analysis of nationally representative survey data collected in fall 2008.

Survey respondents were geocoded based on their street addresses. To protect panel member confidentiality geocoded coordinates were randomly jittered within a radius of up to 0.15 km prior to analysis. Spatial climate data were obtained from the PRISM climate mapping system, a high resolution monthly dataset of the contiguous U.S. using a knowledge-based regression model (Daly et al., 2002; PRISM, 2004). This analysis uses grids of monthly mean temperature (derived as the average of the mean monthly maximum and minimum temperature) and total precipitation at the 2.5′ resolution (approximately 4 km between grid points). For the purposes of this analysis, such high-resolution gridded spatial climate data provide a more accurate spatial representation of climate parameters than those available from individual climate station records. These data represent a best-estimate of climate conditions in the immediate vicinity of respondents' households, since they account for fine-scale spatial variations in climate such as rain shadows, temperature inversions, and coastal effects that may not be apparent in station data or coarsely gridded data. Since this analysis addresses perceptions of the departure of local seasonal climate from long-term averages, we derived anomalies for each month of the temperature and precipitation datasets. Temperature anomalies were calculated as the difference between the current month's mean temperature and the monthly mean temperature during the 1971–2000 period. Precipitation anomalies, represented as a percentage of normal precipitation, were calculated by dividing the current month's precipitation amount by the mean precipitation amount during the period 1971–2000 and multiplying by 100. The choice of base period for this analysis does not substantively affect the results, since we examine relative anomalies between different sets of respondents. Seasonal anomalies were derived by calculating a three-month average based on winter (December–February) and summer (June–August) climatological seasons.

3.1. Spatial analysis

If seasonal climate perceptions reflect personal experience with local climate conditions, then they should exhibit spatial patterns significantly different than what would be expected by random chance. The spatial distribution of seasonal climate perceptions would also be expected to coincide with the spatial distribution of the climatic variable of interest during each respective season. To examine the spatial distribution of the seasonal climate perceptions items, we mapped relative risk surfaces depicting the relative probability density of each response. Rather than depicting the probability density of each type of point alone, relative risk maps represent the spatially varying probability of each possible response conditional on the locations of all other responses. This method accounts for the spatial inhomogeneity of the population from which survey respondents are sampled. More specifically, a relative risk surface is derived from the ratio of bivariate kernel density estimates for two sets of points (Hazelton and Davies, 2009). This ratio can then be used in hypothesis tests by calculating a tolerance surface of p-values (Kelsall and Diggle, 1995).

In the current analysis, we created relative risk maps for each of the possible responses to the seasonal climate perceptions items using the *spatstat* (Baddeley and Turner, 2005) and *sparr* (Davies et al., 2011) R packages. Kernel densities were estimated by an isotropic kernel smoother with optimal bandwidths selected by cross-validation (Baddeley and Turner, 2005; Kelsall and Diggle, 1995). The optimal smoothing bandwidth for each map ranged from 220 km to 517 km. Statistically significant positive concentrations of responses were identified by calculating asymptotic p-value surfaces based on a 50×50 grid (approximately 88 km between grid points), with positive concentrations at the 95% and 99% confidence level represented as contours superimposed on the relative risk surface (Hazelton and Davies, 2009).

3.2. Bivariate and multivariate analyses

To examine the direct relationship between local conditions and seasonal climate perceptions, we used the locations of respondents to obtain monthly temperature and precipitation data based on their household coordinates. We then summarized and compared average climate conditions among respondents who had similar seasonal climate perceptions using one-way analysis of variance.

To investigate the effects of demographics, local temperature and precipitation, and beliefs about global warming on seasonal climate perceptions, we constructed two sets of four binary logistic regression models. The dependent variable in the first set of models is a dichotomous variable indicating the perception of a positive departure from normal seasonal temperature (warmer than normal), as compared to a neutral or negative departure from normal, during summer (models A1–A2) and winter (models B1–B2). The dependent variable in the second set of models is a dichotomous variable indicating the perception of a positive departure from normal seasonal precipitation (more rain than normal or more rain and snow than normal), as compared to a neutral or negative departure, during summer (models C1–C2) and winter (models D1–D2). In each set of models, model 1 includes demographics and climate change beliefs as predictors, while model 2 adds local temperature or precipitation anomalies. Demographic variables include age (18–29, 30–44, 45–59, 60+), gender, educational attainment (less than high school, high school, some college, bachelor's degree or higher), race/ethnicity (White, non-Hispanic; Black, non-Hispanic; other races, non-Hispanic; two or more races, non-Hispanic; Hispanic), and political ideology (conservative, moderate, liberal). Climate change beliefs are represented by indicator variables classifying respondents into one of the six audience segments (Alarmed, Concerned, Cautious, Disengaged, Doubtful, Dismissive) with like-minded beliefs, risk perceptions, and policy preferences about climate change (Maibach et al., 2011).

3.3. Seasonal context

The survey was fielded in April–May 2011, following a period with multiple record-breaking extreme weather events, including tornadoes, floods, wildfires, and drought in the U.S. (NCDC, 2011a). The 751 tornadoes recorded in April 2011 set an all-time U.S. record, while extensive rainfall and fast-melting snowpack caused historic floods in the Ohio River valley and the lower Mississippi River. March and April also brought abnormally dry weather in Oklahoma, New Mexico, and Texas that caused extreme drought conditions in large areas of those states (NCDC, 2011a).

For much of the U.S., the seasons examined in this study contrast sharply with each other relative to historical averages. The unusual weather of spring 2011 followed an unusually cold winter of 2010–2011, both of which coincided with a relatively strong La Niña that began in fall 2010. The December 2010 through February 2011 period was colder than average across most of the Midwestern and eastern U.S. (Fig. 1a), particularly in the Southeast,

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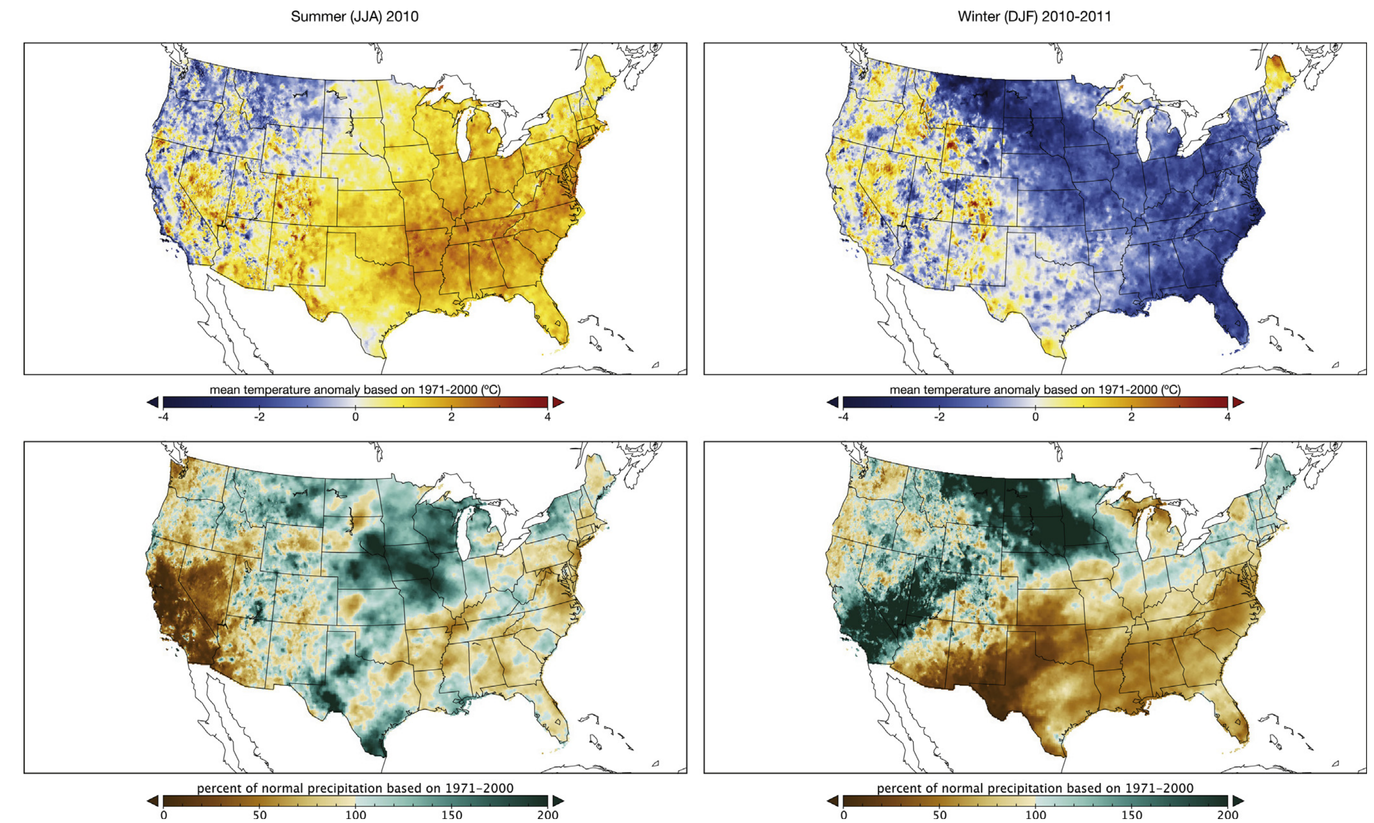

Fig. 1. Mean temperature anomaly (panels A and B, top) and percent of normal precipitation (panels C & D, bottom) during climatological winter (December–February) 2010–2011 and summer (June–August) 2010. Data derived from monthly PRISM (2004) analysis.

where Florida experienced its tenth coldest winter in the 116-year record (NCDC, 2011b). Winter 2010–2011, as in a typical La Niña year, brought above-normal precipitation to the northern Midwest, the northeastern states, and the Ohio Valley, while the Southern Plains and Southeastern states received below-normal precipitation (Fig. 1c). By contrast, summer 2010 was the fourth hottest summer on record in the U.S. as a whole, with the highest temperature extremes occurring in the Mid-Atlantic and Southeast (Fig. 1b). June through August 2010 was the hottest climatological summer on record in Rhode Island, New Jersey, Delaware, Maryland, Virginia, North Carolina, Tennessee, South Carolina, Alabama, and Georgia. California and the Pacific Northwest were not part of the pattern, experiencing normal or slightly below normal temperatures. Precipitation during summer 2010 was slightly below normal to slightly above normal across most of the U.S. (Fig. 1d), with the northern Midwest ranking among the 10th wettest summers on record (NCDC, 2010). There were also several small regions with extremely below normal summer precipitation, including southeastern Missouri and western Kentucky, the California Central Valley, and southern Mid-Atlantic region.

The contrasting conditions between each season serve as a natural quasi-experiment to examine perceptions of seasonal climate. Summer 2010 was abnormally hot for much—but not all—of the U.S., while the following winter was abnormally cold in a similar swath of the country. It is also important to note that the climatic extremes of spring 2011, when the survey was conducted, may have influenced survey responses about winter 2010–2011, particularly regarding perceptions of seasonal precipitation in the Ohio Valley and Northeast. These regions experienced persistent above-normal rainfall from March through May 2011, which may have influenced respondents' assessments of the overall average precipitation for winter 2010–2011. This may particularly be the case if an individual's understanding about what period constitutes the winter season does not correspond with the months of climatological winter (December–February). For example, astronomical winter in the northern hemisphere extends to the vernal equinox on March 20, and snowfall—associated with winter conditions—frequently occurs after that date in the northern U.S. Because of this disparity, we include temperature and precipitation data for March and April 2011 in our analysis to control for the effect of weather conditions immediately before and during the survey.

4. Results and discussion

4.1. Descriptive survey results

Between 969 and 977 respondents in the contiguous U.S. completed each of the four seasonal climate items (Table 1). The majority of respondents reported that the previous winter had been colder than normal (58%) and brought more rain and snow than normal (59%). For the previous summer, the largest portion (43%) of respondents reported that the season had been warmer than normal, while nearly as many (42%) reported that the summer had been no different from normal. A similar number (47%) reported that precipitation during the previous summer had been no different from normal.

Survey respondents experienced a wide range of local climate conditions due to the spatial variability of climate in the U.S. On average, local temperature anomalies among sampled respondents differed more dramatically between the summer and winter seasons than did local precipitation (Table 2). The average respondent experienced above-normal temperatures and slightly below normal precipitation in summer 2010, and below-normal

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Table 1
Seasonal climate perception items.

Temperature	Colder		No different than normal		Warmer	
	n	%	*n*	%	*n*	%
Winter 2010–2011[a]	603	61.8	259	26.6	113	11.6
Summer 2010[b]	136	14.0	420	43.2	417	42.9
Precipitation	Less snow or rain		No different than normal		More snow or rain	
	n	%	*n*	%	*n*	%
Winter 2010–2011[c]	128	13.2	222	22.9	619	63.9
Summer 2010[d]	266	27.2	484	49.5	227	23.2

[a] Has this winter in your local area been warmer, colder, or no different than normal?
[b] Thinking back to last summer, in your local area was it warmer, colder, or no different than normal?
[c] Has this winter in your local area brought more snow or rain, less snow or rain, or was it no different than normal?
[d] Thinking back to last summer, in your local area, did it bring more rain, less rain, or was it no different than normal?

temperatures and slightly below normal precipitation in winter 2010–2011.

4.2. Geographic patterns

The relative risk surfaces reveal substantively different spatial patterns of responses across each of the four items. When asked about the winter of 2010–2011 (Fig. 2a), respondents in the northeastern states, extending from the Mid-Atlantic to New England, were more likely to report that the previous winter was colder than normal. This cluster coincides with colder than normal conditions in the region during December 2010–February 2011. Respondents in the Northeastern U.S. also were more likely to report more rain or snow than normal during the previous winter, as did respondents in the upper Midwest and the Pacific Northwest (Fig. 2c). A further cluster of respondents in Colorado, New Mexico, and Texas reported less snow or rain than normal during the winter. Although precipitation was indeed below normal in the Southwest during December 2010 through February 2011, these assessments may have also been magnified by the drought and wildfires in the region during March and April 2011.

When asked to remember the summer of 2010, respondents in the eastern U.S. were significantly more likely to report warmer than normal conditions, particularly along the Atlantic coast from Rhode Island to North Carolina and inland to northern Georgia, Alabama, and Tennessee, which coincides with the region affected by that summer's record heat wave (Fig. 2b). Respondents along the Pacific coast, who were unaffected by the heat wave, were significantly more likely to report that the summer was colder than normal. Respondents in a band from New Mexico and Colorado to Arkansas and Mississippi were significantly more likely than others to report less rain than normal during summer 2010. Finally, respondents in the Pacific Northwest and the northern Great Plains were significantly more likely to report more rain than normal, coinciding with near record high precipitation in Iowa, Minnesota, and Wisconsin (Fig. 2d).

4.3. Bivariate analysis of seasonal climate perceptions by local temperature and precipitation anomalies

Differences in perceptions of seasonal climate conditions corresponded with relative differences in measured climate conditions, as would be expected if respondents had based their perceptions on their local conditions. One-way analyses of variance indicated significant differences in three-month temperature anomalies among respondents to the items for winter temperature, $F(2,972) = 4.82$, $p = 0.01$ (Fig. 3a). When asked about temperatures during the most recent winter, individuals who responded that the winter was warmer than normal were indeed living in places where, during the months of climatological winter (December–February), the mean temperature anomaly was higher than among those who responded that the winter was colder than normal (Tukey HSD; mean difference: 0.26 °C, $p = 0.01$).

Summer temperatures also differed significantly among respondents with different perceptions of summer temperature, $F(2,970) = 33.98$, $p < 0.001$ (Fig. 3b). The mean June–August 2010 local temperature anomaly among those who responded that the summer was warmer than normal was significantly greater than the anomaly among those who responded that the winter was colder than normal (mean difference: 0.78 °C, $p < 0.001$). The mean local temperature anomaly among those who responded that the summer was no different than normal also differed significantly from that of those who responded that the summer was colder than normal (mean difference: 0.69 °C, $p < 0.001$).

Likewise, there were significant differences in relative December 2010–February 2011 precipitation among respondents who perceived different amounts of winter precipitation, $F(2,970) = 32.45$,

Table 2
Summary statistics for temperature anomaly and percent of normal precipitation at survey respondent coordinates. Data derived from PRISM (2004), based on 1971–2000 normals.

	Mean	Median	Std. dev.	Minimum	Maximum	Percent above 1971–2000 mean
Temperature anomaly (°C)						
June–August 2010	1.2	1.4	1.0	−2.5	3.0	85.5
December 2010–February 2011	−0.9	−1.1	0.9	−3.3	2.1	16.9
March–April 2011	0.1	0.3	1.0	−3.3	3.3	62.7
Percent of normal precipitation						
June–August 2010	92.7	93.0	40.0	0.6	216.9	40.5
December 2010–February 2011	94.2	88.7	39.4	11.8	342.1	33.2
March–April 2011	106.0	109.0	48.5	0.6	273.4	57.3

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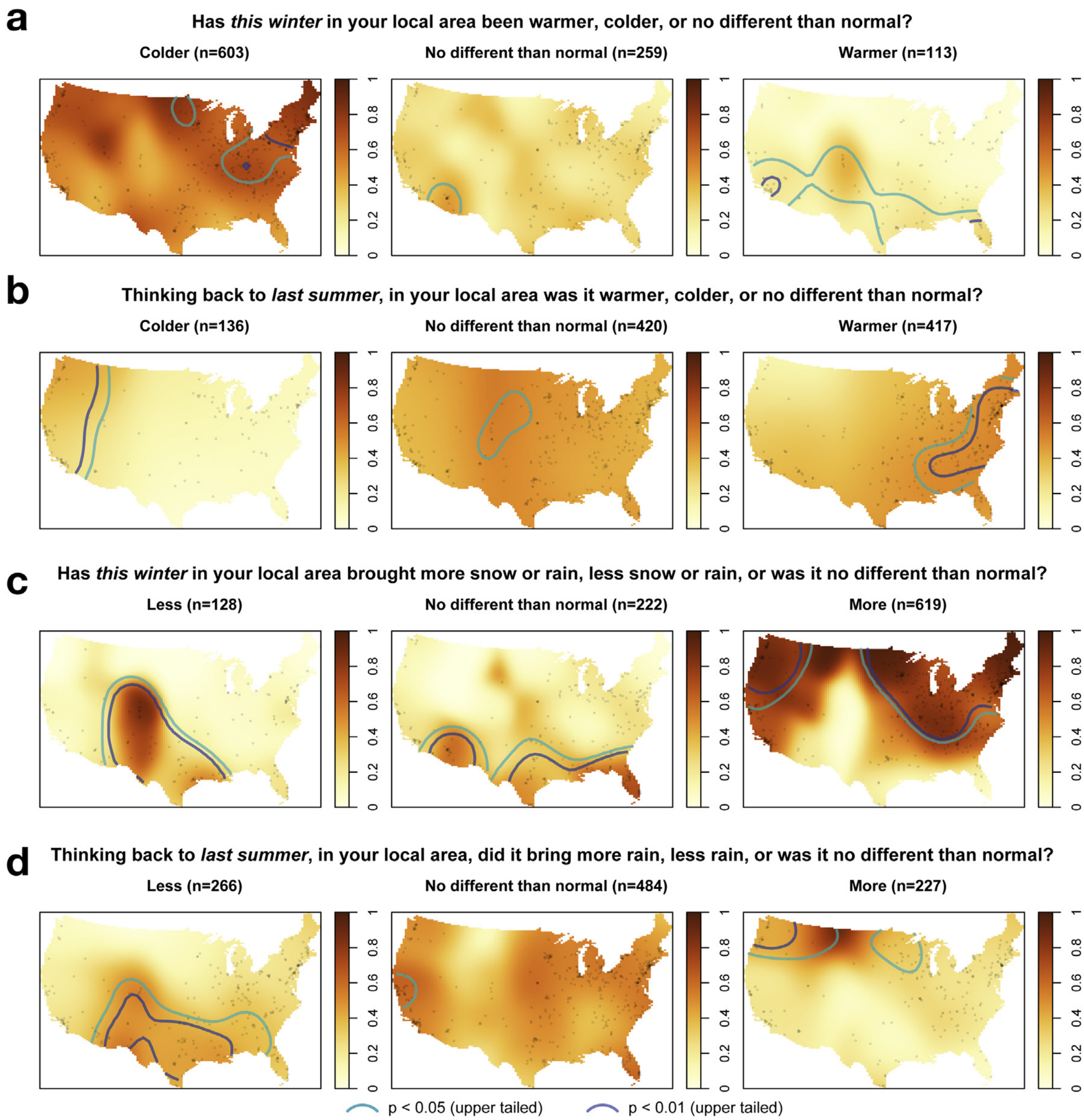

Fig. 2. Relative risk surfaces of the probability of responses to each item, conditional on the overall spatial distribution of responses. Each map depicts the ratio of two bivariate kernel density estimates, the first for case locations (respondents who responded as labeled), and the second for control locations (all remaining respondents). Darker shading indicates a higher probability of responding as labeled. Optimal kernel smoothing bandwidths were selected by cross-validation: winter temperature, 276 km; winter precipitation, 220 km; summer temperature, 517 km; summer precipitation, 294 km. Light blue contour lines indicate significantly elevated probabilities at $p < .05$ (upper tailed). Dark blue contour lines indicate significantly elevated probabilities at $p < .01$ (upper tailed). Significance contours based on asymptotic p-value surfaces (Hazelton and Davies, 2009; Kelsall and Diggle, 1995). Dots indicate approximate household locations of labeled respondents. (For interpretation of the references to color in figure legend, the reader is referred to the web version of the article.)

$p < 0.001$ (Fig. 3c). The mean December 2010–February 2011 percent of normal precipitation among those who responded that the winter had more rain and snow than normal was significantly greater than among those who responded that the winter was no different than normal (mean difference: 18.4 percentage points, $p < 0.001$), or had less snow or rain than normal (mean difference: 22.2 percentage points, $p < 0.001$). Significant but smaller differences were present in mean June–August 2010 precipitation for those who perceived different amounts of summer precipitation, $F(2,974) = 3.54$, $p = 0.03$ (Fig. 3d). The mean percent of normal precipitation was significantly greater among those who responded that the summer had more rain than normal than among those who responded that the summer was no different than normal (mean difference: 8.5 percentage points, $p = 0.02$).

4.4. Multivariate analysis

4.4.1. Effect of local climate conditions on perceptions of seasonal temperature and precipitation

Perceptions of a warmer-than-normal summer and winter were related to local climatic conditions during each season (Table 3). Despite the dramatic differences between winter 2010–2011 and summer 2010, the effect of the local three-month temperature anomaly on the perception that the season was warmer than normal was positive and significantly different from zero for both seasons. Holding all other variables constant at their medians, a shift from the 5th percentile to the 95th percentile in the December–January temperature anomaly (from −2.2 °C to 0.5 °C) increased the probability of recalling the winter as warmer than normal by

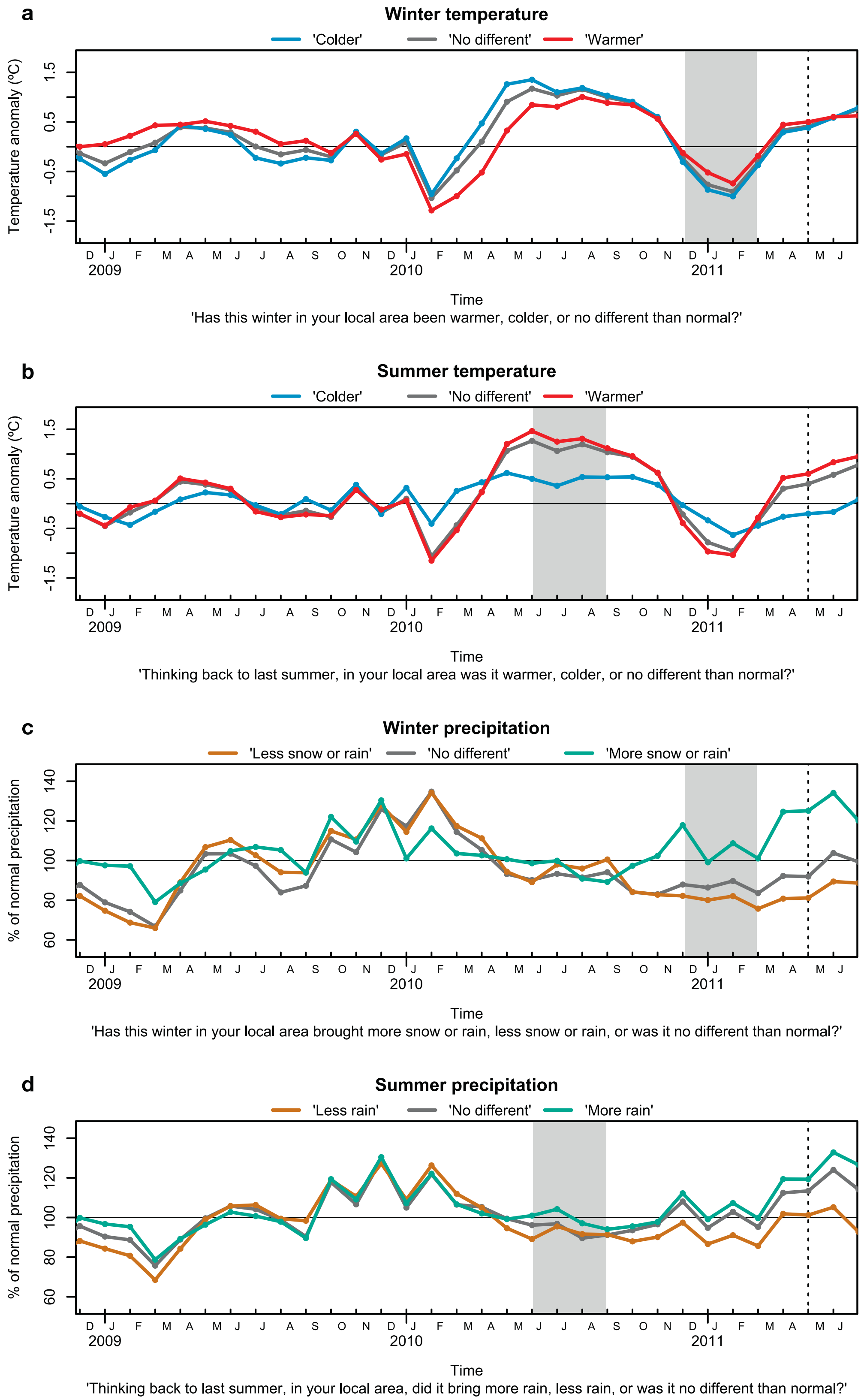

Fig. 3. Time series plots showing mean climate conditions among groups of respondents to the seasonal climate perceptions items. Values are three-month moving averages. Panels A (winter temperature) and B (summer temperature) report mean temperature anomaly (°C) by response; panel C (winter precipitation) and D (summer precipitation) report mean percent of normal precipitation by response. Shaded gray box indicates the season referenced by each item. Vertical dotted line indicates the date of the survey. Data derived from PRISM (2004).

Table 3
Logistic regression models predicting perceived positive departure from normal in seasonal temperature, including climate change belief segments and local temperature and precipitation anomalies.

Dependent variable	Winter, "warmer"		Summer, "warmer"	
Model	A1	A2	B1	B2
Intercept	−0.46 (0.45)	0.65 (0.61)	0.58 (0.35)	0.58 (0.43)
Demographics				
Gender (female)[a]	−0.28 (0.21)	−0.28 (0.21)	0.19 (0.14)	0.20 (0.14)
Age (30–44)[b]	−0.11 (0.29)	−0.14 (0.30)	−0.10 (0.22)	−0.14 (0.22)
Age (45–59)[b]	−0.27 (0.29)	−0.37 (0.29)	−0.15 (0.21)	−0.19 (0.21)
Age (60+)[b]	−1.06 (0.33)**	−1.14 (0.34)***	−0.06 (0.21)	0.03 (0.21)
Education (high school)[c]	−0.97 (0.34)**	−0.99 (0.33)**	−0.02 (0.25)	0.09 (0.25)
Education (some college)[c]	−0.67 (0.33)*	−0.78 (0.33)*	−0.14 (0.25)	−0.01 (0.26)
Education (bachelor's or higher)[c]	−0.72 (0.35)*	−0.78 (0.36)*	−0.73 (0.27)**	−0.51 (0.27)
Black, non-Hispanic[d]	0.81 (0.30)**	0.82 (0.31)**	0.20 (0.23)	0.12 (0.23)
Other races, non-Hispanic[d]	0.60 (0.50)	0.57 (0.51)	0.40 (0.39)	0.53 (0.41)
Hispanic[d]	0.35 (0.32)	−0.04 (0.35)	−0.57 (0.24)*	−0.44 (0.25)
Two or more races, non-Hispanic[d]	0.74 (0.59)	0.56 (0.61)	−0.48 (0.49)	−0.48 (0.49)
Conservative[e]	−0.05 (0.27)	−0.08 (0.27)	0.13 (0.17)	0.11 (0.17)
Liberal[e]	−0.05 (0.27)	−0.03 (0.27)	−0.08 (0.18)	−0.04 (0.18)
Climate change beliefs				
Concerned[f]	−0.68 (0.33)*	−0.57 (0.33)	−0.29 (0.23)	−0.25 (0.23)
Cautious[f]	−0.77 (0.34)*	−0.70 (0.34)*	−0.49 (0.24)*	−0.46 (0.23)
Disengaged[f]	−0.20 (0.40)	−0.14 (0.40)	−0.74 (0.29)*	−0.72 (0.29)*
Doubtful[f]	−0.90 (0.40)*	−0.86 (0.41)*	−1.20 (0.27)***	−1.16 (0.27)***
Dismissive[f]	−0.46 (0.43)	−0.39 (0.44)	−1.65 (0.32)***	−1.67 (0.32)***
Local climate				
Mean temperature anomaly, MA 2011 (°C)		−0.18 (0.14)		0.17 (0.10)
Percent normal precipitation, MA 2011 (/100)		−0.89 (0.26)***		−0.20 (0.17)
Mean temperature anomaly, DJF 2010–11 (°C)		0.24 (0.12)*		
Percent normal precipitation, DJF 2010–11 (/100)		0.12 (0.29)		
Mean temperature anomaly, JJA 2010 (°C)				0.19 (0.09)*
Percent normal precipitation, JJA 2010 (/100)				−0.25 (0.19)
n	975	975	973	973
Deviance (−2*log-likelihood)	650	633	1253	1236
AIC	688	679	1291	1276
Nagelkerke pseudo r^2	0.10	0.13	0.10	0.12
Spatial autocorrelation of residuals[g]	0.05	0.03	0.05	0.03
Change in residual spatial autocorrelation		−37.4%		−48.6%

Unstandardized regression coefficients (standard errors).
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.
[a] Reference category is "male".
[b] Reference category is "18–29".
[c] Reference category is "less than high school".
[d] Reference category is "White, non-Hispanic".
[e] Reference category is "Moderate".
[f] Reference category is "Alarmed".
[g] Univariate global Moran's I. Distance weights based on 314 km threshold.

6 percentage points. The average temperature anomaly in the two months prior to the survey, March and April 2011, did not have a significant effect on the perception that the winter had been warmer than normal. Regarding summer temperature, a shift from the 5th percentile to the 95th percentile in the June–August temperature anomaly (from −1.0 °C to 2.3 °C) increased the probability of recalling the summer as warmer than normal by 15 percentage points. The addition of local climatic variables improved the predictive ability of the models of perceived summer and winter temperature, as illustrated by the reduction in the AIC statistic and residual spatial autocorrelation in each model.

Local climate conditions were also related to perceptions of above-normal precipitation during the summer and winter seasons (Table 4). The perception that the winter had more rain and snow than normal was predicted by both temperature and precipitation anomalies during December–February, as well as by precipitation during the two months immediately preceding the survey. Holding all other variables constant, a shift from the 5th to the 95th percentile in the local December–February departure from normal precipitation (from 46.6 to 176.1% of normal) increased the probability of recalling the winter as having more snow or rain than normal by 25 percentage points. Similarly, a shift from the 5th to the 95th percentile in the March–April 2011 departure from normal precipitation (from 17.5 to 190.0% of normal) increased the probability of recalling that the winter as having more snow or rain than normal by 41 percentage points. Regarding summer precipitation, a shift from the 5th to the 95th percentile in the June–August departure from normal precipitation (from 7.8 to 152.8% of normal) increased the probability of recalling that the summer had more rain than normal by 18 percentage points. As in the models predicting perceived seasonal temperature, adding local climatic variables improved the predictive ability of the models of perceived winter and summer precipitation.

4.4.2. Effect of global warming beliefs on perceptions of temperature

This section examines evidence for motivated reasoning in seasonal climate perceptions, specifically addressing the role of

Table 4
Logistic regression models predicting perceived positive departure from normal in seasonal precipitation, including climate change belief segments and local temperature and precipitation anomalies.

Dependent variable	Winter, "more snow or rain"		Summer, "more rain"	
Model	C1	C2	D1	D2
Intercept	0.60 (0.35)	−2.06 (0.49)***	−0.73 (0.38)	−1.69 (0.52)**
Demographics				
Gender (female)[a]	0.09 (0.14)	0.11 (0.15)	0.25 (0.16)	0.23 (0.16)
Age (30–44)[b]	0.29 (0.22)	0.47 (0.24)*	0.10 (0.25)	0.15 (0.25)
Age (45–59)[b]	0.47 (0.21)*	0.70 (0.23)**	0.20 (0.23)	0.25 (0.24)
Age (60+)[b]	0.50 (0.21)*	0.69 (0.22)**	−0.13 (0.24)	−0.10 (0.24)
Education (high school)[c]	−0.11 (0.25)	−0.23 (0.28)	−0.33 (0.27)	−0.30 (0.28)
Education (some college)[c]	−0.14 (0.26)	−0.12 (0.28)	−0.37 (0.27)	−0.33 (0.28)
Education (bachelor's or higher)[c]	0.20 (0.27)	0.14 (0.29)	−0.70 (0.29)*	−0.70 (0.30)*
Black, non-Hispanic[d]	−0.38 (0.23)	−0.33 (0.25)	0.18 (0.26)	0.31 (0.26)
Other races, non-Hispanic[d]	−0.63 (0.39)	−1.05 (0.42)*	0.33 (0.42)	0.42 (0.44)
Hispanic[d]	−0.77 (0.23)***	−0.55 (0.28)*	0.13 (0.25)	0.37 (0.27)
Two or more races, non-Hispanic[d]	−0.88 (0.44)*	−0.72 (0.49)	−0.33 (0.57)	−0.26 (0.58)
Conservative[e]	−0.04 (0.17)	0.00 (0.19)	−0.05 (0.19)	−0.05 (0.20)
Liberal[e]	−0.03 (0.19)	−0.19 (0.20)	0.13 (0.20)	0.09 (0.21)
Climate change beliefs				
Concerned[f]	0.16 (0.25)	0.03 (0.27)	−0.32 (0.25)	−0.38 (0.26)
Cautious[f]	−0.26 (0.25)	−0.43 (0.27)	−0.25 (0.26)	−0.29 (0.27)
Disengaged[f]	−0.28 (0.31)	−0.32 (0.33)	−0.85 (0.36)*	−0.80 (0.36)*
Doubtful[f]	−0.52 (0.27)	−0.70 (0.29)*	−0.21 (0.29)	−0.26 (0.30)
Dismissive[f]	−0.67 (0.30)*	−0.82 (0.33)*	−0.40 (0.34)	−0.40 (0.35)
Local climate				
Mean temperature anomaly, MA 2011 (°C)		0.04 (0.11)		−0.21 (0.11)
Percent normal precipitation, MA 2011 (/100)		1.45 (0.20)***		0.34 (0.19)
Mean temperature anomaly, DJF 2010–11 (°C)		−0.20 (0.10)*		
Percent normal precipitation, DJF 2010–11 (/100)		1.08 (0.26)***		
Mean temperature anomaly, JJA 2010 (°C)				−0.09 (0.10)
Percent normal precipitation, JJA 2010 (/100)				0.69 (0.21)**
n	969	969	977	977
Deviance (−2*log-likelihood)	1216	1070	1039	1008
AIC	1254	1116	1077	1054
Nagelkerke pseudo r^2	0.07	0.25	0.03	0.08
Spatial autocorrelation of residuals[g]	0.28	0.16	0.05	0.02
Change in residual spatial autocorrelation		−44.2%		−50.8%

Unstandardized regression coefficients (standard errors).
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.
[a] Reference category is "male".
[b] Reference category is "18–29".
[c] Reference category is "less than high school".
[d] Reference category is "White, non-Hispanic".
[e] Reference category is "Moderate".
[f] Reference category is "Alarmed".
[g] Univariate global Moran's I. Distance weights based on 314 km threshold.

beliefs about global warming. The effect of global warming beliefs on seasonal climate perceptions varied with the season and climatic variable of interest, with the largest effects on perceptions of the previous summer's temperature. Even when controlling for the local summer temperature anomaly, which was positive for 86% of the sample, respondents with different sets of global warming beliefs had substantially different likelihoods of perceiving the summer as being warmer than normal. For example, holding all other variables constant at their medians, respondents in the Dismissive segment were 40% less likely than those in the Alarmed segment, and 32% less likely than those in the Concerned segment, to report experiencing a warmer-than-normal summer. The standardized effects of belonging to the Doubtful and Dismissive segments were larger than that of any included demographic variable. The size of the effect also increased steadily along the spectrum of belief certainty from those who believe global warming is happening to those who do not believe it is happening (Fig. 4). This pattern would be expected if individuals who strongly believe that global warming is not happening are more likely to bias their perceptions of their own experience toward conditions that are inconsistent with global warming, e.g. to report experiencing the summer as not being warmer than normal despite having experienced above-normal temperatures.

If the effect of global warming beliefs on perceptions of seasonal temperature is also present among those who strongly believe that global warming is happening, then we would expect that these individuals would tend to bias their perceptions of their own experience toward conditions that are consistent with global warming when faced with an experience that is superficially inconsistent with global warming. In this case, those who strongly believe that global warming is happening should report experiencing a warmer-than-normal winter despite extensive below-normal temperatures. However, when controlling for the local temperature anomaly during winter 2010–2011, which was below normal for 83% of the sample, global warming beliefs did not have a consistent effect on the perception that the winter was warmer than normal. During a season that was colder than normal for most respondents, those in the Alarmed segment were no more likely

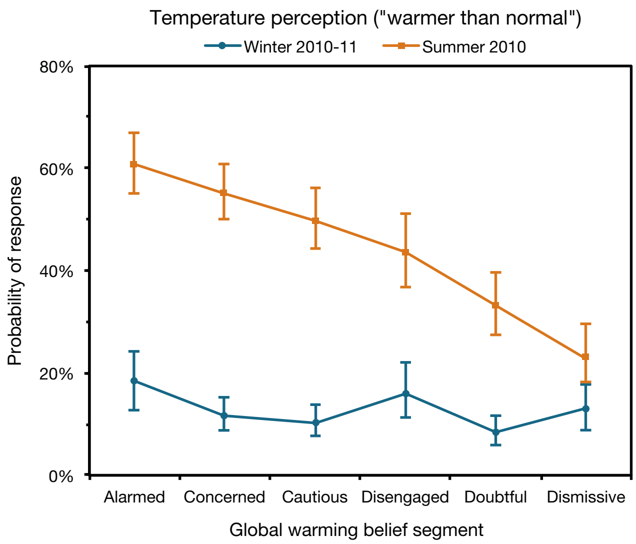

Fig. 4. Predicted probability of responding that winter 2010–2011 and summer 2010 were warmer than normal, by global warming belief segment and holding all other variables constant at their sample medians. Based on model A2 (winter 2010–2011) and model B2 (summer 2010). Error bars represent 95% confidence intervals.

than those in the Dismissive segment to perceive the winter as warmer than normal, and only slightly more likely than those in the Doubtful and Cautious segments to perceive the winter as warmer than normal. This evidence points to an asymmetric effect of global warming beliefs on perceptions of local climate conditions, with those who do not believe global warming is happening more likely to have biased perceptions of their local climate when conditions are inconsistent with their beliefs.

To further explore the asymmetric effect of beliefs on perceptions of local climate conditions, we filtered respondents into two groups based on whether they were living in places with above-normal or below-normal temperatures in summer 2010. Within each group, we then compared the proportions of respondents with different sets of global warming beliefs who rated the season as warmer than normal. The proportion of respondents who rated summer 2010 as warmer than normal differed significantly across global warming belief segments, $\chi^2(5, N = 830) = 52.0, p < .000$. Among respondents living in places with above-normal summer temperatures, those in the Alarmed, Concerned, Cautious, and Disengaged segments were significantly more likely than those in the Doubtful and Dismissive segments to rate the summer as warmer than normal ($p < .05$). Among Alarmed, Concerned, Cautious, and Disengaged respondents who experienced a warmer-than-normal summer, 53% rated the summer as warmer than normal, as opposed to 27% of Doubtful and Dismissive respondents.

If those who believe climate change is happening and a threat were to exhibit biased perceptions of seasonal climate conditions when confronted with a colder-than-normal season, then we would expect those who had experienced a colder-than-normal summer during 2010 to be more likely to rate the season as being warmer than normal. However, among those living in places with below-normal summer temperatures there were no significant differences across global warming belief segments in perceptions of summer temperature, $\chi^2(5, N = 143) = 1.7, p = 0.89$. These results provide further support to the finding of an asymmetric effect of global warming beliefs on perceptions of local climate conditions.

4.4.3. Effect of global warming beliefs on perceptions of precipitation

The effect of global warming beliefs on perceptions of local precipitation was less extreme than for perceptions of temperature, for both the winter and summer seasons. Holding winter 2010–11 precipitation and temperature anomalies constant at the sample median, respondents in the Dismissive segment were 16% less likely than those in the Alarmed segment to perceive the winter as having more snow or rain than normal, while those in the Doubtful segment were 13% less likely. Summer 2010 brought above-normal precipitation to only 33% of the sample. Holding precipitation and temperature anomalies constant at the sample median, respondents in the Disengaged segment were 15% less likely than those in the Alarmed segment to perceive the summer as having more rain than normal. The differences between the remaining segments were not significant.

5. Discussion

The results provide support for our first hypothesis that the spatial distribution of seasonal climate perceptions would coincide with the spatial distribution of temperature and precipitation anomalies. Spatial analysis of responses indicated that the distribution of seasonal climate perceptions was non-random, and analysis of local clusters found broad agreement between the patterns of seasonal climate perceptions and patterns of local climate anomalies. For instance, the extreme heat wave of summer 2010 in the eastern U.S. was visible in a map of the probability that respondents would report that the summer was warmer than normal, and the droughts of winter 2010–2011 in the Southwest were visible in a local concentration of respondents who reported that the winter was drier than normal. Furthermore, seasonal climate conditions were significantly different among groups with different perceptions of seasonal temperature and precipitation. However, the perception of a single climatic variable during a specific season was not solely dependent on that variable, particularly in regard to the perception of seasonal precipitation, which was consistently associated with both local temperature and precipitation. This finding reflects the physical relationship between temperature and the type and amount of local precipitation. For instance, a colder-than-normal winter may lead to more persistent and visible accumulations of snow.

The results also support our second hypothesis that global warming beliefs may bias recollections of seasonal climate through motivated reasoning. If global warming beliefs do affect seasonal climate perceptions, we would expect perceptions to be biased toward a state of the world that is consistent with beliefs about global warming, e.g. toward seasons that are warmer than normal for those who believe that global is happening, and seasons that are not warmer than normal for those who doubt that global warming is happening. Our results provide some evidence that global warming beliefs bias perceptions of seasonal temperature, but the effect is strongest among those who do not believe global warming is happening. Controlling for local conditions, those who believed in the existence and threat of global warming (the Alarmed and the Concerned) were indeed significantly more likely to recall the summer of 2010 as being warmer than normal than those who believed that global warming is not happening or is not a threat (the Dismissive and the Doubtful). Conversely, for the winter of 2010–2011, a season that was colder than normal for most of the population, those who believed in the existence and threat of global warming were not significantly more likely to recall the winter as being warmer than normal than those who most strongly believed that global warming is not happening and is not a threat (the Dismissive), and only somewhat more likely than those who believe global warming may be happening but is not a threat (the Doubtful). These results therefore suggest that motivated reasoning may bias individual recollections of seasonal climate, but the effect is asymmetric and more pronounced among those who most strongly believe that global warming is not happening. The results also suggest that the influence of motivated reasoning may change over time, with less of an effect on memories of more recent events that are easier to recall, such as the conditions during the winter that recently ended, than on memories of more distant events, such as the conditions of the last year's summer.

A number of recent studies have suggested that perceptions of short-term weather patterns may shape climate change beliefs (Borick and Rabe, 2010; Egan and Mullin, 2012; Goebbert et al., 2012; Joireman et al., 2010; Li et al., 2011; Risen and Critcher, 2011), particularly among those who do not already hold strong opinions about the issue (Hamilton and Stampone, 2013; Myers et al., 2012). These findings present challenges for climate change communication, since they imply that attitudes among those who have not yet made up their mind are sensitive to short-term weather conditions that are only marginally informative about long-term climate trends. Our results pose further challenges for communication, since we show that those who strongly believe that climate change is not happening are not likely to accurately recall their experiences with local weather patterns when these patterns are consistent with global climate change. In turn, they are less likely to change their beliefs when confronted with real-world experiences consistent with the existence of climate change. However, both this study and previous findings imply that extreme weather events can act as teachable moments for those who do not have strongly held beliefs about climate change. We show that—excluding those who strongly believe climate change is not happening—individuals are likely to accurately recall their experiences with seasonal climate conditions whether or not they are consistent with long-term climate change. These results suggest that many individual hold a mental model of climate change that allows for attribution of extreme weather events to long-term climate change, including both abnormally warm and abnormally cold temperatures. This is in line with recent research showing that people connect diverse extreme weather events to climate change (Leiserowitz et al., 2013).

The findings of this study are limited by the cross-sectional nature of the survey data. Because data were collected at a single point in time, we cannot definitively establish whether the differing results between winter and summer seasons were due to differences in how each season is perceived, or due to respondents having more recently experienced the winter season. In addition, we cannot rule out the possibility of reverse causality in the model of global warming beliefs affecting seasonal climate perceptions via motivated reasoning, since biased memories of seasonal climate conditions may also have influenced global warming beliefs. Finally, although respondents were exposed to a wide range of local climate conditions, exposure was not distributed normally across the population—most respondents experienced a warmer-than-normal summer and a colder-than-normal winter. Further research conducted in different seasons, and using longitudinal data, may provide additional evidence for the effects of global warming beliefs on seasonal climate perceptions identified in this study.

6. Conclusions

This study investigated how people perceive seasonal climate at the local scale and how beliefs about global warming may influence subjective experiences of local climate conditions. To address these questions, we compared judgments about two seasons in the U.S. that had opposite extremes in temperature and varying patterns of precipitation across much of the country. Although previous research shows that populations with livelihoods directly reliant on local weather are able to perceive and adapt to local climate variability and change, this study was one of the first to investigate whether the population within a large industrialized country such as the U.S. is able to detect changes in their local climate. Our findings indicate that perceptions of local seasonal climate exhibit significant non-random spatial patterns that appear to derive from place-dependent experience with local climate conditions. People generally are capable of characterizing departures from normal in temperature and precipitation during recent seasons, with several important caveats: as seasons recede into the past and become harder to remember, the recollection of whether they were warmer or colder than normal may become more dependent on preexisting beliefs about global warming, with perceptions tending to be biased in the direction consistent with one's beliefs about global warming. Moreover, this effect appears to be asymmetric, with larger biases evident among those who do not believe global warming is happening.

While people are capable of recognizing and adapting to short- and long-term climate variability and change, these processes depend, at least in part, on the changes in local climate conditions being perceived by the affected individuals, either through personal experience or description. As suggested by recent research, climate change perceptions and beliefs are—in part—dynamically constructed based on personal observations through experience (Akerlof et al., 2013; Howe et al., 2013; Myers et al., 2012). Even though personal experience with climate change may elevate risk perceptions and belief certainty, the effect of personal experience is dependent on the experience first being recognized. As we have shown, the recognition of local climate change can also depend on one's prior beliefs about global warming.

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