

Turning Personal Experience into Political Attitudes: The Effect of Local Weather on Americans' Perceptions about Global Warming

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How do people translate their personal experiences into political attitudes? It has been difficult to explore this question using observational data, because individuals are typically exposed to experiences in a selective fashion, and self-reports of exposure may be biased and unreliable. In this study, we identify one experience to which Americans are exposed nearly at random—their local weather—and show that weather patterns have a significant effect on people's beliefs about the evidence for global warming.

Daily life includes many personal experiences that are, on their face, directly relevant to the development of political attitudes.¹ On issues such as crime, the economy, education, health care, public infrastructure, and taxation, large shares of the public are exposed to experiences that could logically be linked to attitude formation. But findings from research examining how these experiences affect opinion have been mixed. Although direct experience—whether it be as a victim of crime, a worker who has lost a job or health insurance, or a parent with children in public schools—can influence attitudes, the impact of these experiences tends to be weak or nonexistent after accounting for typical predictors such as party identification and liberal-conservative ideology (Citrin and Green 1990; Lau and Heldman 2009; Sears and Funk 1991).

However, research about the effects of personal experience on attitude formation almost always suffers from two threats to inference. First, individuals are usually exposed to experiences—or in fact may select into these experiences—in nonrandom ways that are correlated with the attitudes hypothesized to be dependent on the experiences. Second, most research relies on self-reports of experience. These reports are not only unreliable; they may also be the consequences

of specific attitudes about politics and public affairs, rather than bias-free measures of their causes.

In this article, we explore how Americans translate their personal experiences into political attitudes with a research design that avoids both threats to inference. The experience we analyze is fluctuation in local temperatures across the United States. The attitude it affects is Americans' beliefs in the existence of global warming. Our research strategy is straightforward: we merge local weather records with geocoded data collected from five nationally representative sample surveys. Our approach avoids the first threat to inference because, as we show, weather patterns fluctuate in ways that are independent of individual-level covariates. We avoid the second threat to inference by using weather data recorded by scientific weather authorities rather than self-reports. In short, we exploit the fact that changes in local temperature assign individuals nearly at random to experiences that they may choose to interpret as evidence for or against global climate change.

With this powerful design, we find that experience can affect attitudes in a significant and sizable fashion. For each 3.1° Fahrenheit that local temperatures in the past week have risen above normal, Americans become one percentage point more likely to agree that there is

¹An online appendix with supplementary material for this article is available at <http://journals.cambridge.org/jop>. Data and code necessary to replicate this analysis will be made available at politics.as.nyu.edu/object/patrickegan.html upon publication.

“solid evidence” that the earth is getting warmer. Our data allow us to explore this effect’s size, its duration, and its variation across groups in the national population. The size of the effect is substantial, comparable to the *ceteris paribus* differences in global warming beliefs by race, age, or education, and the effect increases in magnitude after longer periods of abnormal temperatures. The impact is short-lived, however, and therefore does not induce long-term attitude change. The effects of weather vary across individuals: effects are most pronounced among the least educated and those who “lean” Republican or Democratic with regard to party identification, suggesting that cognition and political engagement may be important moderators. Overall, the study confirms that individuals rely on personal experiences in forming attitudes, and our design allows us to gain new insight about the duration and variability of the effects of experience on attitudes.

Personal Experience, Political Attitudes, and Threats to Inference

On its face, personal experience would appear to be an important factor shaping political attitudes. After all, such experience is directly accessible and requires little in the way of information search. In the realm of economic voting, this reasoning formed the basis for conjectures that the less politically aware should “vote their pocketbooks”—that is, render a retrospective judgment on the incumbent party on the basis of their own financial situations (e.g., Campbell et al. 1960; Fiorina 1981). Scholars have looked for other links between individuals’ political attitudes and their personal experiences, including such as experiences as losing a job (Sears et al. 1980), having close friends or family serving in Vietnam (Lau, Brown and Sears 1978), having children in public schools (Kinder and Sears 1981), or lacking health insurance (Lau and Heldman 2009).

But research on the relationship between personal experience and political attitudes has determined that the effect of experience is either weak or nonexistent (Citrin and Green 1990; Lau and Heldman 2009; Sears and Funk 1991; Sears et al. 1980). For example, Americans seem to cast their votes more on the basis of their assessment of the national economy than on their personal financial circumstances (Kinder and Kiewit 1979), and self-interest rarely plays a substantial role in attitude formation except when the stakes are large and well-defined (Sears and Citrin 1985). Two noteworthy exceptions to this pattern are the experience of being victim of a crime, which contributes to perceptions about crime as a problem

and support for law-and-order policies (Marshall 2004; Sears et al. 1980), and the experience of vulnerability to being drafted into the military, which has enduring effects on party affiliation and political attitudes (Erikson and Stoker 2011).

By necessity, studies of the effect of individual experience on political attitudes have relied on observational data drawn from sample surveys. This typically causes two problems that make it difficult to identify cleanly any effect of experience on attitudes. First, the use of observational, rather than experimental, data means that individuals are exposed to personal experiences in nonrandom ways.² Experiences such as losing a job, being the victim of a crime, or a change in one’s personal financial situation are distributed among the population in ways that are inevitably correlated with unobservable personal characteristics that themselves determine attitudes. Including controls for variables in the analysis is an imperfect solution (e.g., Achen 1987), and strong exogenous instruments for the experiences are often unavailable. Estimates of the effects of personal experience can thus be biased, often in an indeterminate direction.

Second, reliance on sample surveys requires use of survey respondents’ often inaccurate self-reports of the experience. Self-reports are subject not only to random measurement error, but in many cases to bias as well. Americans’ perceptions about the state of public affairs tend to be slanted in their party’s favor (Bartels 2002; Gerber and Huber 2009; Shapiro and Bloch-Elkon 2008), particularly among the politically sophisticated (Shani 2009). Reports of politically relevant personal experiences may also be biased. Even a phenomenon as minor as survey item order can affect self-reports of experience. For example, priming attention to politics can “politicize” personal experience by prompting respondents to report their experiences in a manner that rationalizes positions already stated (Lau, Sears, and Jessor 1990; Sears and Lau 1983). Evidence from survey experiments confirms that question order has a strong effect on retrospective personal financial assessments (Palmer and Duch 2000). Question wording also might influence how respondents characterize their experience. For example, much of the literature examining “pocketbook” voting relies upon the following survey item, which has been included on the American National Election Studies time-series study since 1962: “Would you say that you and your family living here are better

²A few exceptions take advantage of experiences that are truly assigned at random, such as the Vietnam draft lottery (Bergan 2009; Erikson and Stoker 2011).

off or worse off financially than you were a year ago?" Given that this is precisely the sort of language used by political candidates in their campaigns, perceptions of one's own economic circumstances can be more strongly influenced by partisanship than the reverse (Evans and Andersen 2006).

Thus the literature on the effect of personal experience on political attitudes leaves on the table the question of what such an effect might look like, if it could be analyzed in a context free of selection effects and without the bias and errors arising from self-reports of the experience. The present study allows us to answer this question in a more satisfactory way than permitted by previous work.

Public Opinion on the Existence of Global Warming

Studies that have examined opinion about the existence of global warming suggest that people's values and political predispositions have a bigger impact than factual information on judgments about the nature and extent of the problem. Age, liberal ideology, pro-environment attitudes, and being nonreligious are associated with existence beliefs, while the effect of scientific knowledge about the causes and consequences of climate change is weak and inconsistent (Bord, O'Connor, and Fisher 2000; Kellstedt, Zahran, and Vedlitz 2008; but see Curry, Ansolabehere, and Herzog 2007).³ People's perceptions of the threat posed by global warming appear to be guided more by the polarized discourse of political elites than by the scientific consensus affirming that climate change is taking place.

We hypothesize that an additional factor—the personal experience of local temperature variation—has an independent effect on attitudes about the existence of global warming. Of course, local short-term weather variation is a rather low-quality signal about whether global warming is taking place. But the same could be said for other personal experiences studied by political scientists, such as job loss or being victimized by crime, that also lead individuals to update their assessments of national conditions. Only a handful of studies have examined this relationship, and none have done so with the comprehensive and rigorous approach undertaken here. In lab experiments, the experience of heat, regardless of whether it takes place indoors or outside, has been

shown to make people more likely to say that global warming is a proven fact (Joireman, Truelove, and Duell 2010; Risen and Critcher 2011). Using evidence from a national telephone survey, Krosnick et al. (2006) find that respondents who perceive that local temperature has increased in recent years are more likely to believe that global warming will occur in the future if nothing is done to stop it. But without an objective measure of temperature conditions, the authors could not rule out the possibility that their results were attributable to projection, and that people who already believe that a global warming threat exists may perceive associated changes in weather.

Two studies use geocoded location data to measure the effect of temperature on climate change attitudes, but they have a different emphasis from this research. Brody et al. (2007) test whether a 57-year trend of rising temperatures in a respondent's region influences perceptions of how climate change will affect the respondent's health, financial situation, and local environment. They found that vulnerability to floods, sea level rise, and other natural hazards had an effect on risk perceptions, but long-term temperature did not. Given the modest long-term change in temperatures experienced thus far in the United States and the modest cross-sectional variation in that change, we would not expect to see a measurable impact on Americans' attitudes. We look instead at the much more dramatic short-term fluctuations in temperature that individuals experience as part of their daily weather and ask whether that immediate experience affects how individuals report their beliefs about the global problem. Li, Johnson, and Zaval's (2011) recent study uses a nonrepresentative sample at a single point in time and focuses on how individuals' perceptions of temperature affect global warming beliefs; the study does not directly estimate the effect of outdoor temperature. Our approach represents a substantial advancement over previous work in that we use surveys of nationally representative samples of Americans conducted at multiple points in time across a variety of weather conditions, and we employ official weather records instead of self-reports of weather. These features of our study allow us to generate population-level estimates of how the exogenous experience of local weather affects assessments of the climate change problem, as well as the size, duration, and heterogeneity of this effect.

Data

Opinion on climate change. Our data on Americans' attitudes about climate change come from

³Inconsistent results about the effects of scientific knowledge may be attributable to research design, as these studies rely on either self-reports about a respondent's level of knowledge or performance on factual information items, both of which may be effects, rather than causes, of interest in and attitudes about the climate change problem.

five national surveys sponsored by the Pew Research Center in June, July, and August 2006, January 2007, and April 2008. The surveys were conducted by telephone with a representative national sample of American adults living in the contiguous 48 states. In each survey, respondents were asked the following question: “From what you’ve read and heard, is there solid evidence that the average temperature on earth has been getting warmer over the past few decades, or not?” Americans’ responses to this question were largely in the affirmative: on average over the five surveys, 73% of respondents agreed that the earth is getting warmer. Summary statistics and distributions for all variables appear in Table A2 in the online appendix.

Local weather. Our goal was to measure the short-term weather conditions that respondents might call to mind when asked whether evidence supports the existence of global warming. The variable we used to capture these conditions is the departure from normal daily average local temperature, measured in degrees Fahrenheit. In our main analyses, departures from normal are averaged over the week prior to the date on which the respondent was interviewed by Pew. That is, we calculated

$$ddt_week_{it} = \frac{1}{7} \sum_{d=t-7}^{t-1} temp_{id} - normaltemp_{id},$$

where ddt_week_{it} is the local temperature variation experienced by respondent i in the week prior to being interviewed on day t , $temp_{id}$ is respondent i ’s local temperature (the average of the minimum and maximum temperature recorded that day) on the day occurring d days before interview, and $normaltemp_{id}$ is the normal local temperature for that date (calculated over the period 1971–2000). Data on local weather conditions (both past and present) come from the National Climatic Data Center (NCDC), part of the National Oceanic and Atmospheric Administration in the U.S. Department of Commerce. The NCDC compiles meteorological data over time from weather stations worldwide in order to produce climatic profiles of locations or regions. Zip-code information in the Pew dataset allowed us to attach weather data to individual respondents. Details on merging weather and zip-code data appear in the online appendix.

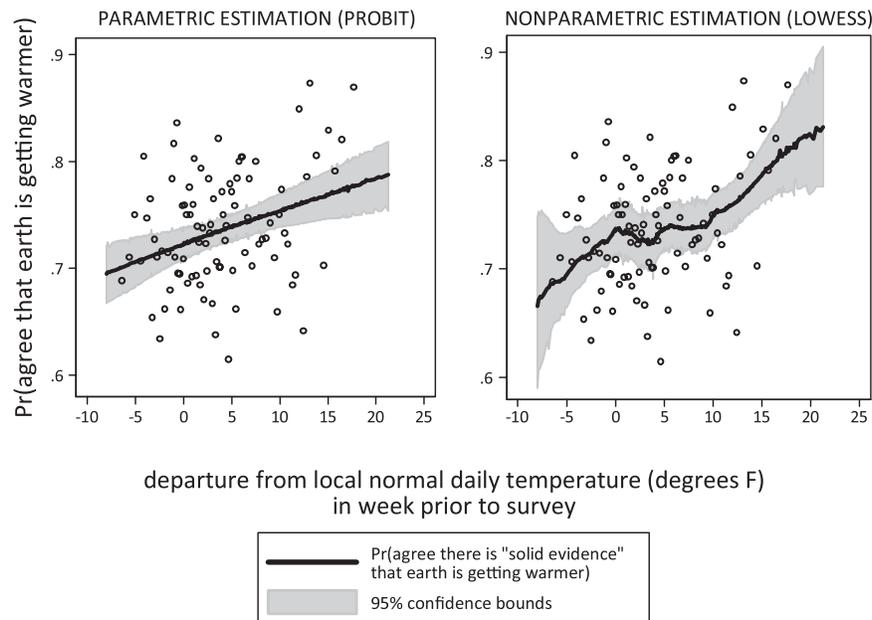
The temperature departure measure captures variation in local weather conditions both cross-sectionally and over time. Weather patterns exhibited a fair amount of variation while Pew’s surveys were in the field. The mean value of ddt_week for respondents in our dataset was 3.8°F; its standard deviation was 5.9°. The 5th and 95th percentiles of this variable were –4.3° and 14.7°, respectively.

The exogeneity of local weather to political attitudes. Weather can have substantial political consequences but is itself exogenous to most social processes, drawing the attention of scholars interested in weather’s effects on phenomena such as voter turnout (Fraga and Hersh 2010; Gomez, Hansford, and Krause 2007), the public’s assessments of political leaders (Achen and Bartels 2004; Malhotra 2008), and the prevalence of civil conflict (Hsiang, Meng, and Cane 2011). In addition, weather’s exogeneity makes it a valuable instrument for endogenous causal variables including voter turnout (Hansford and Gomez 2010) and economic growth (Miguel, Satyanath, and Sergenti 2004; Hidalgo et al. 2010). Two types of tests provide confidence that weather is exogeneous to global warming attitudes and therefore that our estimates of weather’s effect are unbiased by the omission of unobserved confounders. First, no discernable relationship exists between weather and observable covariates that previous research has determined to be associated with attitudes on global warming (age, gender, race or ethnicity, attendance of religious services, education, party identification, and ideology) after accounting for geography and time.⁴ Second, if the observed relationship between weather and global warming beliefs were spurious and attributable to unobserved covariates, we would expect to see relationships hold in a consistent ideological direction between weather and other political attitudes. We do not: placebo test estimates of the association between local weather patterns and (1) respondents’ assessments of the decision to invade Iraq and (2) their approval of George W. Bush’s job as president confirmed that the relationships between local weather and these variables did not operate in any ideologically consistent fashion.⁵

⁴A Wald test (shown in Table A3 in the online appendix) comparing a model including only weather station and date-of-interview fixed effects with a model that also incorporated the individual covariates failed to reject the null that the covariates were jointly insignificant predictors of ddt_week .

⁵Table A4 in the appendix shows that in models with the same specifications as those used throughout this article, warmer weather was associated with slightly negative attitudes regarding the Iraq War ($p = .81$) but with positive attitudes about George W. Bush’s performance as president ($p = .09$). Although the latter effect is notable, it actually increases our confidence that weather is exogenous to global warming attitudes. If the test were an indication of locational sorting by ideology, we would expect higher temperatures to be associated with depressed approval of a conservative Republican president. Instead, we find the opposite. We speculate that the result may be attributable to unexpectedly warm weather improving people’s moods and suspect that temperature may have a similar effect on approval ratings for politicians from across the ideological spectrum.

FIGURE 1 Americans' Beliefs about the Evidence for Global Warming, by Departure of Local Weather from Normal Temperature in Week Prior to Survey



Source: National Climate Data Center; Pew Research Center.

Note: Points indicate mean proportion agreeing that the earth is getting warmer within each of 100 temperature centiles. Each point represents approximately 70 survey respondents.

The Effect of Local Weather on Beliefs about Global Warming

The plots in Figure 1 display the simple bivariate relationship between temperature and beliefs about the evidence for global warming. To construct the figure, we divided the cases in our dataset into 100 centiles on the basis of the *ddt_week* variable and calculated the percentage of respondents in each centile who agreed that there is solid evidence for global warming. In the figure, the mean of *ddt_week* within each of the centiles is plotted on the *x*-axis and the percent of respondents in the centile believing in global warming's existence is plotted on the *y*-axis. We summarize the relationship both parametrically and nonparametrically. The left-hand plot includes a line that traces the predicted values of opinion obtained from a bivariate probit estimation on the individual-level data. The right-hand plot traces the aggregate relationship with a nonparametric lowess smoother. Both plots include 95% confidence bounds constructed using bootstrapped resamples of the data. The figure shows a significant and substantial relationship between

the two variables: as local temperatures rise above normal, so does the percentage of Americans believing that global warming is a reality. The smoother indicates that the relationship between weather and global warming opinion is stronger in extreme weather and holds for both unusually hot and cold temperatures.

To rule out the possibility of a spurious relationship, we control for variables that may be correlated with both opinion and geography (and thus weather) with a series of ordered probit regressions in which respondents' assessments of the evidence for global warming are the dependent variable.⁶ In Table 1, we model the simple bivariate relationship between weather and attitudes, then add fixed effects for date of interview, state of residence, and weather station, and then in the third column estimate a fully saturated model that includes a block of demographic and political covariates. In all models, standard errors are clustered on weather station, as it is the level at which the "treatment" of temperature variation is

⁶The dependent variable is scored 1 for "no" responses, 2 if the respondent volunteers that the evidence is mixed or they don't know, and 3 for "yes."

TABLE 1 The Structure of Beliefs about Global Warming

	I	II	III
Departure from normal local temperature (°F) in week prior to survey	.010* (.003)	.013* (.005)	.011* (.006)
Gender: Male			-.234* (.040)
Race/Ethnicity: Black			.023 (.070)
Race/Ethnicity: Hispanic			.207* (.092)
Race/Ethnicity: Not White Black or Hispanic			.083 (.095)
Age: 18-24			-.087 (.089)
Age: 25-34			-.132 (.071)
Age: 35-44			-.118 (.063)
Age: 55-64			.013 (.058)
Age: 65 plus			-.029 (.061)
Education: High school or less			.088 (.050)
Education: College grad			.061 (.055)
Education: Post grad			.123* (.057)
Party ID: Republican			-.383* (.067)
Party ID: Lean Republican			-.150 (.078)
Party ID: Lean Democrat			.325* (.074)
Party ID: Democrat			.394* (.064)
Ideology: Very conservative			-.451* (.071)
Ideology: Conservative			-.204* (.045)
Ideology: Liberal			.194* (.068)
Ideology: Very liberal			.158 (.105)
Attend services: Never			.091 (.081)
Attend services: Seldom			-.111 (.079)
Attend services: Few times/year			-.064 (.068)
Attend services: Weekly			-.084 (.063)
Attend services: More than weekly			-.168* (.073)
Fixed effects for date of interview, state of residence, and weather station	No	Yes	Yes
Number of observations	6,726	6,500	6,492
Goodness-of-fit statistics:			
Expected % correctly predicted	58.19	59.72	63.07
Expected proportional reduction in error	.14	5.70	13.60

Note: Ordered probit. DV: Opinion on whether there is “solid evidence” for global warming (scored “no” = 1; “mixed”/“some”/DK/ref = 2; “yes” = 3). Coefficients significantly different from zero at $*p < .05$ (two-tailed tests, robust standard errors clustered on weather station). *N*'s vary across specifications due to the omission of cases perfectly predicted by models. Excluded categories are the medians or modes of each variable: female, white, between 45 and 55 years old, some college, Independent, moderate, attends services a few times per month.

Included in the analyses, but not shown, are estimates of cutpoints and (in Model III) coefficients estimated for each variable for those who responded “don't know” or did not provide a response. Throughout this article, goodness-of-fit statistics (expected percent correctly predicted and expected proportional reduction in error) are calculated as proposed by Herron (1999) and implemented by the *epcp* routine in Stata (Lawrence 2009).

applied. The estimated effect of weather on beliefs about climate change is statistically significant across all specifications, and its size remains essentially unchanged with the introduction of controls.⁷ We rely on the fully saturated specification in Model III for the remainder of this article.

⁷Throughout this article, *N*'s vary across specifications where we were required to drop cases perfectly predicted by models.

In Table 2, we conduct a series of checks to confirm that our findings are robust to different specifications and measures. The first two columns of Table 2 show that results are robust to estimating the model using OLS rather than maximum likelihood ($p = .10$) and to treating the dependent variable as dichotomous in a probit model. The final column shows the effect of temperature when it is normalized for local weather variation. This specification is motivated by the possibility that rather than being

TABLE 2 Robustness of Findings to Choices of Measures and Specifications

	OLS	Probit	Ordered Probit
Departure from normal local temperature (°F) in week prior to survey	.005 (.003)	.013* (.006)	
Departure from normal local temperature (°F) in week prior to survey, normalized for local temperature volatility			.020 (.013)
Number of observations	6,726	6,486	6,493
Goodness of fit statistics:			
Adjusted R-squared	.12		
Expected % correctly predicted		66.95	63.06
Expected proportional reduction in error		16.60	13.57

Note: Dependent variable: Opinion on whether there is “solid evidence” for global warming (scored “no” = 1, “mixed”/“some”/DK/ref = 2, “yes” = 3 in OLS and ordered probit analyses; scored “no”/“mixed”/“some”/DK/ref = 0, “yes” = 1 in probit analysis). Coefficients are significantly different from zero at $*p < .05$ (two-tailed tests; robust standard errors clustered on weather station). N 's vary across specifications due to the omission of cases perfectly predicted by models. Analyses include all control variables included in Table 1, Model III.

affected by absolute deviations in local temperature, individuals might instead respond to change relative to the typical amount of volatility in their local weather.⁸ Unfortunately, data availability limits us to a measure of volatility that is subject to error.⁹ Nevertheless, according to this measure, weather adjusted for local temperature volatility has a positive and nearly significant ($p = .14$) effect on global warming beliefs.

Effect size. Our estimates from the fully saturated model indicate that a shift in local temperature of two standard deviations centered on the mean (from -2.1° F below normal to 9.7° above normal) increases the probability of believing there is solid evidence for global warming by 3.8 percentage points,

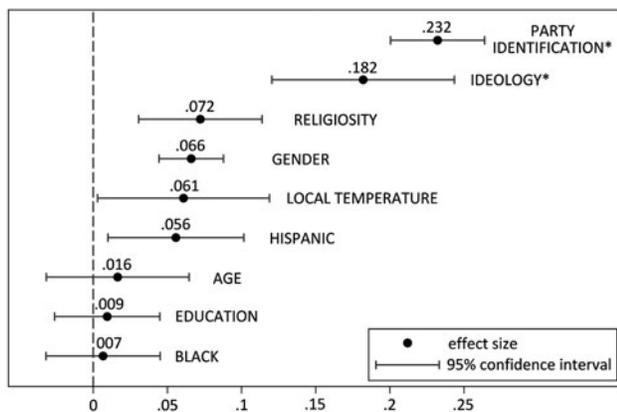
an effect that is significantly different from zero at $p < .05$.¹⁰ The size of temperature's effect is substantial, both when considered alongside the effects of other covariates and when compared to other effects found in the literature on attitude formation. Figure 2 provides the relative size of the effects of local temperature compared to those associated with individual demographic, political and other variables that have been shown to be strong predictors of opinion on climate change. Because none of these covariates is measured at the interval level, a comparison of their effects in terms of standard-deviation shifts is impossible. Instead, we calculate the change in probability associated with a shift from the minimum to maximum value of each variable using the estimates in Table 1, Model III. For a comparable effect of temperature, we generate the change in opinion accompanying a shift in local temperature from the 5th to 95th percentile in our dataset (from 4.3° below normal to 14.7° above normal). This shift causes the share of Americans who believe there is solid evidence for global warming

⁸We thought it possible, for example, that respondents who live in the upper Midwest, where temperature variability is highest, would be less responsive to a given level of departure from normal temperature than respondents who live in climates with more predictable weather patterns. In other words, a five-degree departure from normal on a January day may be more noticeable in Arizona than in Minnesota.

⁹Data on the standard deviation of average temperatures are available only on a monthly, not weekly, basis; furthermore, these data are available only from 344 NCDC “climate divisions,” rather than the 448 NCDC weather stations. (Climate divisions are geographic entities developed by the NCDC that represent areas with fairly uniform climate conditions; we assigned each ZCTA to the climate division in which a majority of its land area lay.) Dividing *ddt_week* by the respondent's assigned monthly local standard deviation measure produced an indicator of temperature departure normalized for local weather volatility.

¹⁰Throughout this article, we estimate effects of variables with a statistic called the “average predictive comparison.” This statistic is calculated by generating predicted probabilities for each observation in the dataset at two values of the variable of interest while holding all other variables and their effects constant at their actual values. The difference in these two predicted probabilities is known as the “predictive difference” for any given observation, and the statistic reported is the average predictive difference across all observations. Because average predictive comparisons take into account how all variables in the model actually covary in a dataset, they are more representative estimates of the size of a variable's effect than those generated by the approach of holding all variables constant at their medians or other values (Gelman and Hill 2007, 101–103).

FIGURE 2 Effects of Variables on Americans' Beliefs about the Evidence for Global Warming



Note: *Only these variables' effects are significantly different ($p < .05$) from that of local temperature.

Graph plots average effect of variable on beliefs about global warming. Effects are the average predictive differences generated by Table 1, Model III in the probability of agreeing there is evidence for global warming accompanying shifts in variables as follows. Party identification: Republican to Democrat; ideology: very conservative to very liberal; religiosity: attend services more than weekly to never attend services; gender: male to female; local temperature: 5th to 95th percentile (-4.3°F to 14.7°F); Hispanic: compared to white, not Hispanic; black: compared to white, not Hispanic; education: HS or less to postgraduate; age: 18–24 to 65 or over. For additional details, see Note to Table 1.

to increase by an estimated 6.1 percentage points. The figure shows that the effect of temperature is substantial compared to other variables typically considered important in shaping Americans' attitudes on the environment. The effect is substantially larger than the ceteris paribus differences in opinion between whites and blacks, between those belonging to the youngest and oldest age groups, and between the least and most educated.

Furthermore, the estimated effect of weather variation on opinion (a 3.8-percentage point difference for a two-standard deviation shift in temperature, or a 6.1-point difference for shifting from the 5th to the 95th percentile) is sizable compared to other effects on attitudes that have been found noteworthy by political scientists, including the change in vote intention associated with a sharp boost in campaign advertising (Gerber et al. 2011; Shaw 1999); the increase in Americans' approval of the president's handling of the economy in the wake of a burst of positive economic news coverage (DeBoef and Kellstedt 2004); and shifts in opinion on public affairs following

broadcasts of relevant TV news stories (Page, Shapiro, and Dempsey 1987).

Effect duration. Under normal circumstances, the constant fluctuation of temperatures produces rapid shifts in the stream of information that can influence an individual's attitudes on global warming in either direction. The result is that attitudes on global warming shift as rapidly as the weather: isolated days of abnormally high or low temperatures leave no permanent trace on public opinion as they recede into the past. Although beliefs about global warming are affected by the weather in the week prior to interview, attitudes are typically unaffected by weather patterns occurring any earlier than that. Specifically, a search over finite distributed lag model specifications found that predictions of attitudes were not improved by adding lagged values of *ddt_week* to the model, as indicated by the models' Akaike and Bayes' Information Criterion statistics. If we use more granular data by employing daily (rather than weekly) departures from normal temperatures as regressors, predictive accuracy is optimized when just one lagged value of daily temperature is included in the model. (See Table A5 in the online appendix.) The rapid decay of weather's relatively large effects echoes recent work showing that campaign television advertising has strong, but short-lived, effects on vote intention (Gerber et al. 2011; Hill et al. 2011).

Thus weather's effect on opinion is fleeting under the circumstances of normal temperature variation. However, such variation is not always the case: from time to time, everyone experiences longer spells of higher or lower temperatures than usual. Because these spells can linger in memory, they provide the opportunity to gain additional insight about how attitudes respond to weather. For illustrative purposes, we focus here on the effects of a heat wave, which we define as seven consecutive days of temperatures at least 10 degrees above normal. Thus defined, a heat wave is an unusual, but by no means rare, occurrence: 9.5% of the individuals in our dataset had experienced a heat wave at some point in just the three weeks prior to interview.

An appropriate counterfactual for considering the effect of a heat wave on opinion is to compare respondents exposed to a heat wave prior to interview with those experiencing the same number of days of high temperatures nonconsecutively. We do this in Table 3. The table displays estimated opinion for those experiencing at least seven days of temperatures of 10° or more above normal in the three weeks prior to interview, with estimates generated for those who

TABLE 3 The Effects of a Heat Wave on Beliefs about Global Warming

	Means	Estimates after Controls	
		I	II
Exposed to a heat wave (7 consecutive days of weather 10° above normal) in three weeks prior to interview	79.2	78.4	74.9
Exposed to 7 days of weather 10° above normal, but <i>not</i> to a heat wave	74.2	72.4	69.6
Difference (estimated effect of heat wave) (standard error)	5.0* (2.2)	5.9* (2.5)	5.2 (3.0)
Controls included in generating estimates:			
Controls for temperatures over the past three weeks: <i>ddt_week</i> and two lags; # of days of temperatures 10° above normal in three weeks prior to interview		x	x
All controls included in Table 1, Model III			x

Note: Cells contain percentages of respondents agreeing there is “solid evidence” for global warming. Estimated effects are significantly different from zero at $*p < .05$ (two-tailed tests; robust standard errors clustered on weather station in columns I and II). Estimates in columns I and II were generated by models I and II in Table A6 in the online appendix.

experienced these days consecutively (and thus were exposed to a heat wave) and those who did not. The first column of the table displays a simple difference in means between these two groups. The remaining columns display estimates that control for potential confounds. These estimates were generated by ordered probit regressions (shown in Table A6 in the online appendix) in which attitudes were regressed on a heat-wave indicator variable, an indicator for whether the respondent had experienced at least seven days of temperatures of 10° above normal in those three weeks, and controls for temperatures over the past three weeks (*ddt_week* as well as two of its lagged values, as well as a count of the number of days exceeding 10° above normal). The final specification also incorporates all fixed effects and all demographic and political covariates included in our basic model. The estimates show that the effect of a heat wave on opinion is substantial, increasing the share of Americans believing in global warming by 5.0 to 5.9 percentage points depending upon the specification. These effects are all statistically significant at the .10 level (two-tailed tests), which is impressive given that the power of the significance tests in the models is reduced by high degree of multicollinearity between the heat wave indicator and the other weather regressors and fixed effects.¹¹

Concentrated spells of hot weather thus change opinion in a substantial fashion, even after accounting for the effects of concurrent temperature variation. To determine how long these effects last, we

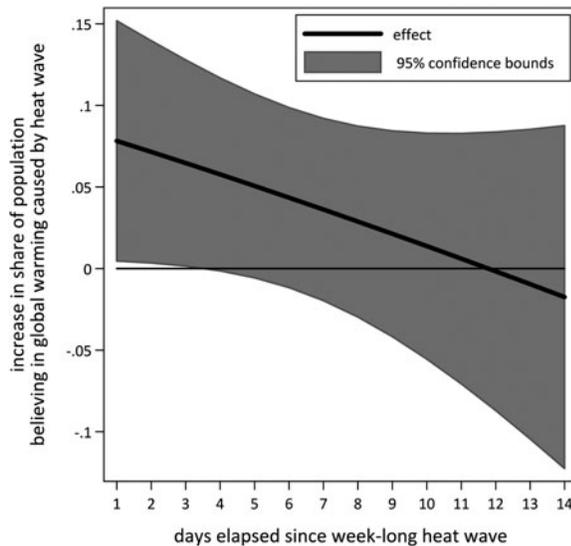
modified our specification to permit the effect of a heat wave to decay over time. As shown in Table A6 in the online appendix, this was done by adding an additional term to the equation generating the estimates in Table 3, Model II, and setting this term to the number of days that had elapsed between the day of interview and the last day of the heat wave to which the respondent was exposed. (The term was set to zero for respondents who did not experience a heat wave.) We again generated estimates of the effect of a heat wave by comparing respondents exposed to a heat wave prior to interview (now accounting for the decay of this effect over time) with those experiencing the same number of days of high temperatures non-consecutively in the three weeks prior to interview. Figure 3 is a graph of these estimated effects, and it shows that they are of relatively long duration. Once a heat wave has concluded, its effect on opinion is significant at $p < .05$ for three days and is estimated to take 12 days to decay completely to zero.

In sum, under typical circumstances, the effects of temperature fluctuations on opinion are swiftly wiped out by new weather patterns. More sustained periods of unusual weather cause attitudes to change both to a greater extent and for a longer period of time. However, even these effects eventually decay, leaving no long-term impact of weather on public opinion.

Effect heterogeneity. The effect of weather can vary widely across different groups in the U.S. population. To assess the extent to which the effects of temperature are heterogeneous, we estimated the fully saturated model (Table 1, Model III) with additional terms interacting *ddt_week* with each of the model’s demographic and political covariates.

¹¹A regression of the heat wave indicator on the weather regressors and fixed effects has an R-squared statistic of .64.

FIGURE 3 The Decay of a Heat Wave's Effects on Opinion



Note: Effects are the average predicted differences (generated by Table A6, Model III in the online appendix) in the probability of agreeing there is evidence for global warming accompanying exposure to a week-long heat wave, by the number of days elapsed between the heat wave's conclusion and the day of interview.

(See Table A7 in the online appendix.) We then used this model to generate estimates of temperature's effects on beliefs for each category. These results come with an important caveat: because we do not have data on all the possible attitudinal and behavioral characteristics that might account for heterogeneous effects across individuals, we cannot assert causal relationships or test mechanisms by which the effect of temperature on beliefs varies across different groups.

The results are depicted in Figure 4. In this graph, each of the covariate categories is plotted according to how the group's attitudes change in response to a shift in local temperatures from the 5th to 95th percentile, holding all other covariates constant at their actual values. As shown in the figure, the effect of weather on beliefs varies in a statistically significant fashion by education and party identification. Those with a high school education or less are strongly affected by temperatures, while those with a postgraduate degree hold beliefs about global warming that are essentially unaffected by weather variation. Although we cannot test the mechanism, we attribute this result to differences in information processing. Given that educational attainment is correlated with the cognitive ability to evaluate evidence rather

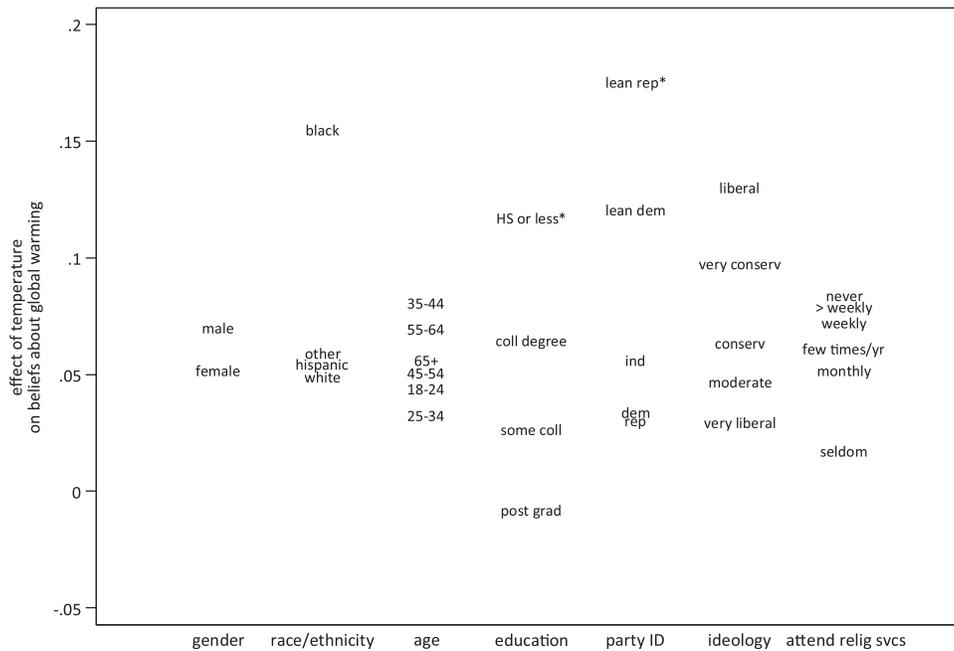
than rely upon heuristics (Chaiken 1980; Petty and Cacioppo 1986)—and that short-term local weather is a rather poor piece of evidence for the existence of global climate change—it appears that the less educated are most likely to find weather appealing as a heuristic in this context.

The high degree of heterogeneity of effects by party identification—where weather's effects are substantially greater among “leaning” Democrats and (significantly so) among “leaning” Republicans than among strong partisans or independents—has a less clear-cut explanation.¹² Political engagement and information rises with the strength of partisanship, and thus leaning partisans are likely to be in the middle of the political awareness spectrum between partisans and independents (Bennett 1994; Bennett and Bennett 1993; Campbell et al. 1960; Converse 1964; Miller and Shanks 1996).¹³ The fact that weather's effects are significantly more pronounced among leaning partisans thus corresponds to expectations from the “two-step model,” which holds that many political stimuli should have their greatest impact on those in the middle of the political awareness spectrum (Converse 1962; MacKuen 1984; McGuire 1968; Zaller 1987). Unfortunately, efforts to investigate this idea further were hindered by the fact that Pew did not ask factual information questions of the kind favored by political scientists as measures of political awareness. Nevertheless, these results confirm that the effects of temperature on global warming beliefs cannot be entirely explained by respondents' lack of political sophistication. If that were the case, we would expect temperature to have a sizeable effect on independents, who instead—like strong partisans—seem not to incorporate consideration of recent temperature into their attitudes about climate change.

¹²Pew measures party identification with a standard branching format question in which respondents are first asked whether they are a Republican, Democrat, or Independent. Those who respond “Independent” or volunteer another party, no preference, or don't know and those who refuse to answer the question altogether are then asked, “As of today do you lean more to the Republican Party or the Democratic Party?” Those who answer the second question by continuing to refuse to claim a party identification (a volunteered response, because participants are not explicitly offered this choice) are categorized as independents. When this variable is collapsed into three categories of partisans, leaning partisans, and independents, the effect of temperature on attitudes is strongest among leaning partisans to a statistically significant degree ($p = .03$).

¹³In the Pew dataset, partisans were significantly more likely to say they were following specific news stories about politics and current affairs than leaning partisans, who were in turn significantly more likely to report following the news than independents.

FIGURE 4 The Heterogeneous Effects of Temperature on Beliefs



Note: *Effects are significantly larger ($p < .05$) compared to that associated with the covariate category with the smallest effect.

Effect is the average predictive differences (generated by model in Table A7 in the online appendix) in each group's probability of agreeing there is evidence for global warming accompanying a shift in local temperature from the 5th to 95th percentile (-4.3°F to 14.7°F).

Conclusion

This article presents results that offer both topical relevance and methodological advance. Global climate change is one of the most important public policy challenges of our time, but it is a complex issue of low salience with which Americans have little direct experience. As they try to make sense of this difficult issue, many people—particularly the less educated and those with weak attachments to the political parties—use fluctuations in local temperature to reassess their beliefs about the existence of global warming. The effect of weather on beliefs is significant and substantively large, even more so after longer periods of unusually hot or cold weather. This is an interesting and important finding in itself and a discovery that should trouble anyone interested in engaging the public in a thoughtful debate about global warming. A possible source of comfort in our findings is that the effect decays rather quickly and therefore is unlikely to induce permanent attitude change. The approach here also represents an advance over most other attempts to measure the effect of personal experiences on political attitudes, because

the exogenous variation in experience with weather allows clean identification of its effects.

A question raised by our research is whether it is rational for individuals to form beliefs about the existence of global warming from short-term local temperature variation. Without a doubt, short-term weather variation provides little information about broad climatic trends. However, in expectation, a relationship exists between climate change and local weather patterns. Scientists agree that one of the primary manifestations of climate change—both now and in the future—is a rise in global surface temperatures, with an increase in the probability of milder winters and more frequent, intense, and long-lasting heat waves. Thus the key question is not whether one should update beliefs due to fluctuations in local temperature, but how much weight should be assigned to this information. Indeed, the information contained in a particular weather pattern about the overall existence of global warming is slight—but arguably the same is true for the relationship between personal experience and many of the other societal conditions political scientists typically study. For

example, one's probability of losing a job or being a victim of crime rises only slightly to the extent that unemployment or lawlessness has become a national problem. Thus in all of these contexts, individuals who draw inferences about society's problems from their personal experiences generally put too much weight on those personal experiences in forming their beliefs about the state of the world.

In the current example, the short-lived nature of the effect we identify suggests that temperature may influence mass beliefs about climate change by priming people to consider their immediate experiences with weather when responding to survey questions about global warming. Our findings are consistent with recent work in psychology suggesting that temperature affects people's visceral state, allowing them to imagine more easily experiencing similar states in the future (Risen and Critcher 2011). Our results do not support an online processing model of attitude formation, by which temperature would produce more lasting effects on beliefs. Instead, we find evidence of memory-based processing in which short-term fluctuations in the weather affect attitudes about global warming. Furthermore, in analyses presented in the online appendix (Table A8), we found no evidence of a motivated reasoning account in which directional goals bias the integration of personal experience with temperature. Liberals' attitudes did not change more in unusually hot weather, and conservatives were not more likely to be affected by unusually cold weather. By priming attention to one's personal experience rather than providing new information that has an enduring effect on beliefs, temperature's impact seems similar to that of campaign television advertising (Gerber et al. 2011; Hill et al. 2011).

This leads us to the final conclusion to be drawn from our study, which is that further research on political attitude change is needed that takes advantage of sources of exogenous variation in personal experiences and other politically relevant stimuli. It is difficult to predict how our results might extend to other types of personal experience. On the one hand, we might expect other experiences to have similarly large, but transitory, impacts on opinion. On the other hand, although the effect of temperature appears to be short-lived, it is stronger if a spell of abnormal weather is more prolonged, which may suggest that a more consequential personal experience would have attitudinal effects that are larger and more enduring. Either way, our research suggests that personal experience has substantial effects on political attitudes and that rich discoveries await those who can explore these

questions in ways that permit clean identification of these effects.

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