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EXPERIENCING THE WEATHER: PUBLIC PERCEPTIONS OF CHANGES IN LOCAL WEATHER PATTERNS

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1. INTRODUCTION

In nations that rely on representative political systems, policies designed to address climate change will ultimately depend on sustained public support. By design, representative political systems punish politicians for taking costly actions that are not high priorities for their constituents, making it very difficult to align the legislative and bureaucratic processes necessary for effective policy change (Wilson, 1980; Sabatier and Jenkins-Smith 1993; Baumgartner and Jones 2004). Efforts to address climate change through reductions in greenhouse gas emissions provides a challenging case for garnering and retaining public support, because the science is complex and subject to political controversy, and solutions are potentially quite costly. How, then, does the public come to perceive climate change as a pressing issue requiring potentially costly policy responses?

In part, the answer may be that people draw inferences about changes taking place in the broader climate from observations of their own local weather patterns. Unusually hot summers and milder winters, prolonged periods of drought, or unusually frequent flooding would seem to provide the kinds of local weather "signals" to members of the public that the broader climate is changing.[1] On the other hand, is it plausible that other factors – such as individual level characteristics, political views, or more general concerns about the environment – do more to explain perceptions of weather patterns. The relative weight given to these factors by members of the public in reaching conclusions about changes in the weather are very likely to influence support for policies designed to address climate change.

This paper addresses the question of what kinds of changes members of the American public perceive to be taking place in their local weather, and tests a series of hypotheses concerning why they hold these perceptions. Using a dataset consisting of interviews with a large sample of the American public coupled with geographically specific measures of temperature and precipitation change, we are able to evaluate the relationship between perceptions of weather change and actual local weather patterns. In addition, the survey data include measures of individual level characteristics (age, education level, gender, income) as well as ideology, partisanship and environmental views. Thus the data permit testing of rival hypotheses concerning the origin of the American publics' perceptions of weather change.

The next section of the paper describes the data used in our analysis, followed by an overview of perceived weather changes and their correlation with the broader perception of global climate change. As will be evident, perceptions of local weather patterns are highly predictive of Americans' beliefs about the occurrence of, and risks posed by, global climate change. The next section presents and tests a series of hypotheses about how the survey respondents arrive at their perceptions of local temperature and precipitation changes. The final section provides discussion of the implications of our findings for the evolution of public perceptions of the weather, and for public willingness to support policies designed to address climate change.

2. DATA

The objective of this study is to assess American's perspectives on temperature and precipitation changes over the past several years. The data employed in the study are derived from three sources: (1) survey interviews with a cross-section of the American public taken in 2008, coupled with reanalysis data on geographically defined departures from (2) mean temperature and (3) precipitation patterns. The University of Oklahoma collected the survey data as part of its long-term National Energy and Environment project

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[1] For purposes of this paper, we set aside the question of whether the public *should* interpret local weather changes as evidence of climate change, and focus instead on whether the public *does* perceive real changes in local weather patterns.

(Jenkins-Smith and Herron 2008). Using both Internet and telephone survey platforms, the data provide both a regional and demographic cross-section of the adult population (ages 18 and over) of the US. The telephone survey employed a random-digit dialing protocol, and received a cooperation rate of 60.7%, as defined by the American Association of Public Opinion Research (AAPOR 2004). The Internet survey utilized the SurveySpot panel maintained by Survey Sampling, Inc. of Fairfield, CT.[2] The survey questionnaires were nearly identical in the two surveys, and the results were consistent. For purposes of the analysis shown here, the data were combined in to a single

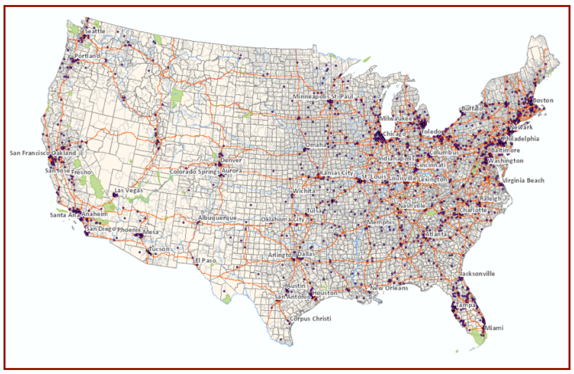

Figure 2.1 Map showing survey respondent locations.

survey dataset.[3]

In order to match local weather changes to the survey data, all survey respondents were asked for the zip code at their primary residences. In addition, for those cases in which the zip code could not be obtained, the Federal Information Processing Standards (FIPS) county code was extracted and retained from the sample listing of phone numbers. Figure 2.1 shows the regional distribution of the sample respondents.

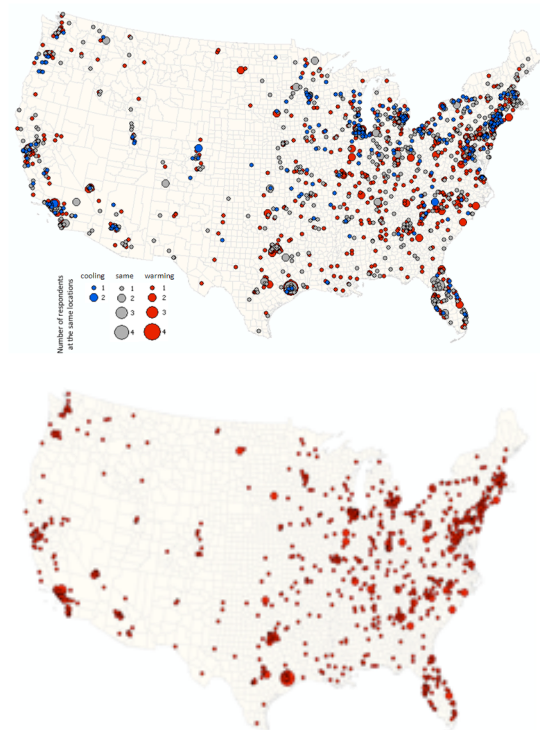

Figure 2.2 Perceived temperature changes: cooling, no change, and warming. Warming respondents (some underlying the other respondents) are well distributed across all survey areas.

In order to identify local departures from longer-term average temperature and precipitation, the National Center for Environmental Prediction – National Center for Atmospheric Research (NCEP–NCAR) reanalysis (Kalnay et al. 1996) and Global Precipitation Climatology Project (GPCP) Version 2 Combined Precipitation Data Set (Adler et al. 2003) data are used as ground validation. Respondents' locations are identified either through their zip code or Federal Information Processing (FIP) code, which are linked to latitude and longitude pairs through 2000 Census Gazetteer files.[4] The ZCTA file was used to link zip codes, and the county subdivision file was used to link FIP codes to give each respondent a latitude/longitude location. The NCEP–NCAR

[2] SSI's SurveySpot members are recruited exclusively using permission-based techniques. Unsolicited email is not employed. The membership of SurveySpot is continuously changing, but at the time of our sample, it consisted of approximately two million households with about five million household members. Only one member in each household can participate in the SurveySpot panel. SSI maintains a subpanel of approximately 400,000 members whose demographics are roughly proportioned to national census characteristics. Our sample was randomly drawn from the 400,000 census balanced subpanel.

[3] There was no effect of the mode of data collection in any of our models. For complete details of the data collection process and a full listing of the survey questions and responses, see Appendices 1 and 2 of Jenkins-Smith and Herron (2008).

[4] These are available from http://www.census.gov/geo/www/gazetteer/places2k.html

reanalysis data and the GPCP data are stored on a 2.5° latitude x 2.5° longitude grid. The ground validation used for each respondent corresponds to the closest great arc distance calculated between the reanalysis grid point to the respondents latitude/longitude location.

To assess the changes in temperature and precipitation at each respondent's location, anomalies are calculated from (1) the long-term mean, (2) the most recent 5 year mean, and (3) the most recent 3 year mean. The long-term mean for the temperature data set is calculated from the period 1968–1996, where as the long-term mean for the precipitation data is calculated from the period 1979–2000. The most recent 5-year mean is calculated from the period 2003–2007 and the most recent 3-year mean is calculated from the period 2005–2007.

In order to measure the respondents' perception of local weather changes, we asked a set of three questions:

> **Temp:** In your personal experience, over the past few years have average temperatures where you live been rising, falling, or staying about the same as previous years?
>
> **Drought:** In your personal experience, over the past few years has drought where you live been more frequent, less frequent, or stayed about the same as previous years?
>
> **Floods:** In your personal experience, over the past few years has flooding where you live been more frequent, less frequent, or stayed about the same as previous years?

For purposes of this analysis, responses were recoded to range from a value of -1 (falling or less frequent), and 0 (stay the same) to +1 (rising or more frequent). Table 2.1 shows the pattern of responses to the three questions.

	Perceived Direction of Change		
	Increased	Stayed Same	Decreased
Temperature	51.4%	36.2%	12.4%
Droughts	42.6	45.3	12.1
Floods	27.2	52.5	19.8

Table 2.1 Perceptions of Weather Changes "Where You Live".

As is evident in Table 2.1, a majority of the respondents perceived local temperatures to have been rising over the past few years. While a plurality of respondents perceived drought frequencies to have remained "about the same" as prior years, nearly 43% believed them to have increased. A majority believed flooding to have remained about the same as prior years.

Figures 2.2 - 2.4 show the regional distributions of perceived weather changes across the US. While our analyses of the geographical distributions are ongoing, these maps illustrate that there is no obvious regional clustering of perceived weather changes. Statistical tests of the differences in perceptions of changes for urban versus rural respondents are ongoing, though preliminary analyses suggest that there are no pronounced differences.

3. LOCAL WEATHER PERCEPTIONS AND VIEWS ON CLIMATE CHANGE

Before analyzing the determinants of perceived local weather, we address the relationship between perceptions of changes in local weather patterns and views on climate change. Is the perception of local weather correlated with the way members of the public understand global climate issues? To find out, we asked our respondents the following question:

> In your view, are greenhouse gasses, such as those resulting from the combustion of coal, oil, natural gas, and other materials causing average global temperatures to rise?

	Climate Change is happening through Anthropogenic Forcing…		
	Yes	No	$\chi^2(p)$
Overall	75.2%	24.8%	NA
Local Temps Rising	87.4	12.6	204.3 (p>0.000)
Drought Increasing	85.1	14.9	93.3 (p>0.000)
Floods Increasing	80.8	19.2	17.8 (p>0.000)

Table 3.1 Climate Change Beliefs by Perceived Local Weather.

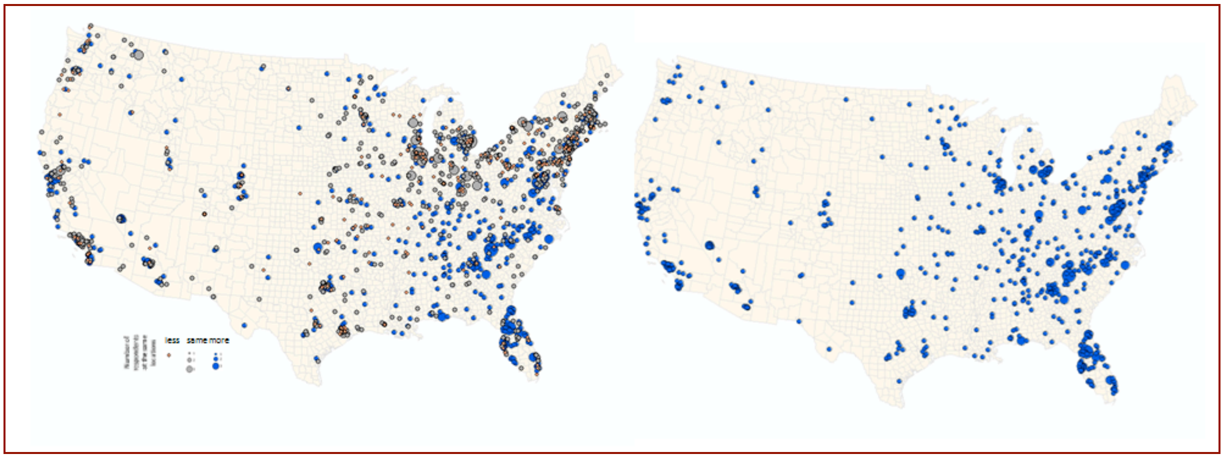

Figure 2.3 Perceived changes in drought frequencies. Most respondents indicated increases in drought frequencies.

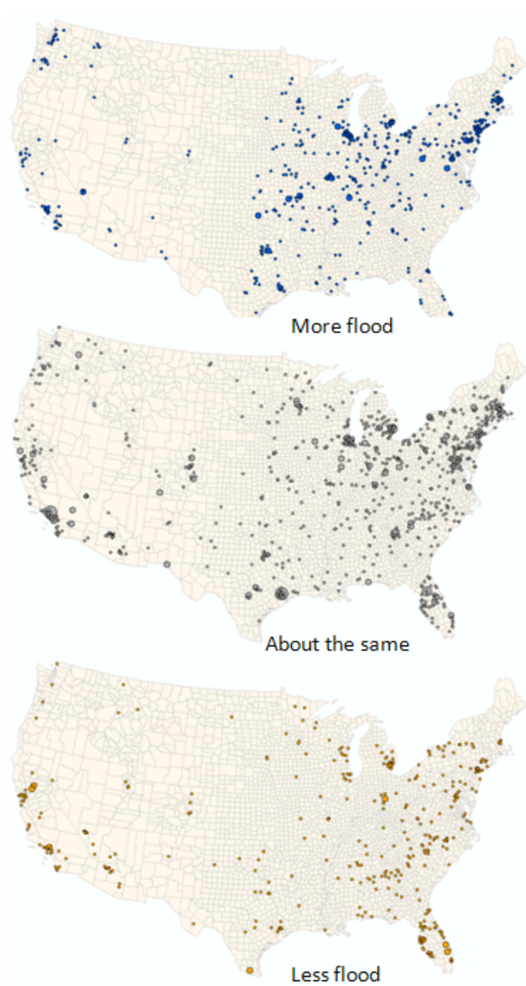

Figure 2.4 Perceived flood frequencies. Most respondents perceived no change in flood frequencies, yet mixed with respondents with more floods.

Overall, 75.2% of the respondents said they believed that greenhouse gasses are causing global temperatures to rise.

Is there a correspondence between perceptions of changes in local weather and the belief that the global climate is warming? Table 3.1 shows the percentage of the survey respondents who do (and do not) believe the global climate is changing due to anthropogenic greenhouse gas emissions for those who perceive local temperatures to have risen, and droughts and flooding to be more frequent. The fourth column shows the chi-square value for the relationship, and the statistical significance of that relationship.

As the table makes clear, the perception that local temperatures, droughts and floods are rising is positively related to the belief that the global climate is changing. The relationship is particularly pronounced for perceived temperature changes: over 87% of those who see local temperatures as having risen over the past few years believe human-caused greenhouse gas emissions are forcing global climate change.

Are perceptions of local weather change linked to the perceived risks posed by climate change? To find out, we asked the following question:

> On the scale from zero to ten, where zero means no risk and ten means extreme risk, how much risk do you think global warming poses for people and the environment?

Overall, the survey respondents placed the (mean) risk at 6.8 (std dev=2.67) on the zero to ten-point scale. The average climate change risks by perceived change in the local weather are shown in Table 3.2.

	Average Risk by Perceived Direction of Change			
	Increased	Stayed Same	Decreased	*p*-value of diff
Temperature	7.88	5.52	6.14	p>0.000
Droughts	7.67	6.12	6.28	p>0.000
Floods	7.47	6.38	7.03	p>0.000

Table 3.2 Perceived Risks of Global Climate Change by Perceived Local Weather

Across all three dimensions of local weather change, perceived increases are associated with greater perceived risks from climate change. All of these differences are statistically and substantively significant.[5]

How does perceived local weather affect support for policies to address climate change? We asked our respondents whether the US should agree to be bound by international treaties to reduce greenhouse gas emissions:

> We should agree to accept internationally established limits on US production of carbon dioxide and other greenhouse gases thought to cause global warming.

Responses were recorded on a 7-point scale, where 1 means "strongly disagree" and 7 means "strongly agree". The average response was a 4.68, leaning toward support. Table 3.3 shows support by perceived changes in local weather patterns. Among those who see temperatures rising, and droughts and floods occurring more frequently, support for US participation in international agreements to limit greenhouse gas emissions is significantly greater.

In sum, we find a consistent correspondence between perceived changes in local weather patterns and views on global climate change. The perception of rising local temperatures, longer droughts, and more frequent floods makes it more likely that one will perceive the climate to be changing due to human actions. These perceptions are also associated with elevated support for policies designed to address climate change.[6] While the effect is apparent across all three dimensions of perceived weather, it is most pronounced for perceived changes in temperature. We therefore ask: how do perceptions of local weather come to be?

4. EXPLAINING PERCEPTIONS OF LOCAL WEATHER

How might people come to perceive changes in their local weather patterns? The seemingly obvious answer is that they use their senses, perhaps augmented by attention to local weather reporting. In either case, we would expect to see a positive correlation between recorded local weather changes and those that are perceived.

A second explanation would rest on the individual-level characteristics of those perceiving the weather. It is reasonable to conjecture that education levels, age, and perhaps even gender are associated with perceptions of weather. Education might facilitate acquisition and interpretation of data; age might add experience and over-time

	Average Support for International GHG Limits			
	Increased	Stayed Same	Decreased	*p*-value of diff
Temperature	5.14	4.11	4.39	p>0.000
Droughts	5.11	4.27	4.65	p>0.000
Floods	5.08	4.46	4.67	p>0.000

Table 3.3 Support for US Agreement to International GHG Limits by Perceived Local Weather

[5] Interestingly, those who see temperatures, drought and floods to be *declining* also tend to perceive greater risks from climate change than do those who see these patterns as unchanged. Change in either direction, apparently, heightens perceived risk of climate change.

	Weather Model	Demographics	Politics	Environ. Views
Temperature Departure (3-Yr)	0.201***	0.187***	0.200***	0.197***
Gender (Male=1)	NA	-0.185*	-0.056	-0.007
Age (Years)	NA	-0.008**	-0.002	-0.002
Education Level	NA	0.114**	0.088*	0.085*
Income ($10K units)	NA	-0.013	-0.007	-0.010
Partisanship (Democrat=1)	NA	NA	0.388***	0.297**
Political Conservatism	NA	NA	-0.249***	-0.175***
Environmental Concern (0-10 scale)	NA	NA	NA	0.105***
Attention to Environment (0-10)	NA	NA	NA	0.100***
Log-Likelihood	-1792.295	-1565.427	-1479.153	-1444.48
Model χ^2	22.48***	36.04***	133.96***	197.11***
Pseudo-R^2	0.006	0.011	0.043	0.064
Sample size	1854	1629	1592	1590

Table 4.1 Predictors of Perceived Local Temperature Change Ordered Logistic Regression
Statistical Significance: ***<0.001; **<0.01; *<0.05

perspective; and gender may be associated with differential exposure of respondents to weather conditions.

A third explanation for perceptions of local weather is broadly "political" in nature. Issues that have a bearing on consequential public policies become entangled with preferences concerning the role of government in society. The belief that climate change is occurring, and that addressing it might require a substantial intervention by governments into the otherwise private affairs of individuals and businesses, raises significant ideological considerations (Rothman and Lichter 1987; Douglas and Wildavsky 1983). Thus one can reasonably conjecture that political ideology will play a part in shaping perceptions of weather changes, with conservatives perceiving climate to be stable and benign, and therefore requiring little or no government intervention. Similarly, partisanship might become entangled with perceptions of weather, such that individuals who identify with parties representing a more active role for government would be more prone to see ominous weather changes calling for government action. We therefore conjecture that those who identify with the Democratic Party will be more likely to perceived local temperatures to be rising, and to see droughts and floods to be more prevalent.

Another explanation is more directly related to views of the environment. It is plausible that those who have a greater generalized concern about (and for) the environment, and a more specific attentiveness to the climate change issue, will be more likely to attend to local information suggesting that the environment is in jeopardy. Such individuals would, therefore, be more likely to perceive temperatures as rising, and floods and drought occurring more frequently.

Each of these explanations can be tested using a simple ordinal logit model, and a nested test for the significance and explanatory power of each set of explanatory variables. The dependent variable in each of our models is respondent's perception of temperature, drought, or flooding

[6] For an analysis of American's willingness to pay to support shifts away from carbon-based energy sources, see Li et al (2009).

	Weather Model	Demographics	Politics	Environ. Views
Precipitation Departure (1-Yr)	-0.293***	-0.305***	-0.310***	-0.301***
Gender (Male=1)	NA	-0.151	-0.082	-0.068
Age (Years)	NA	-0.001	0.002	0.002
Education Level	NA	0.102**	0.075*	0.075
Income ($10K units)	NA	>-0.000	0.003	>-0.000
Partisanship (Democrat=1)	NA	NA	0.129	0.060
Political Conservatism	NA	NA	-0.145***	-0.084*
Environmental Concern (0-10 scale)	NA	NA	NA	0.063*
Attention to Environment (0-10)	NA	NA	NA	0.099***
Log-Likelihood	-1788.987	-1568.729	-1517.947	-1495.39
Model χ^2	113.95***	112.71***	139.70***	181.47***
Pseudo-R^2	0.031	0.035	0.044	0.057
Sample size	1868	1642	1603	1601

Table 4.2 Predictors of Perceived Change in Local Drought Ordered Logistic Regression
Statistical Significance: ***<0.001; **<0.01; *<0.05

change. The independent variables are introduced in a sequence of four steps. First, we introduce the measure of recorded temperature change. We hypothesize that there will be a positive and significant relationship between each type of recorded local weather changes and perceived changes. Second, we add the individual-level characteristics, testing for relationships between perceived local weather changes and age, gender, education level and household income (a proxy for socioeconomic status).[7] Third, we include the "political" variables of self-identified ideology – measured on a seven-point scale ranging from strong liberal (1) to strong conservative (7) and identification with the Democratic Party.[8] And finally we add the variables capturing environmental concern, including a measure of overall concern about environmental issues (ranging from 0 – "no concern" to 10 – "extremely concerned") and attention to the issue of climate change (0 – "no attention" to 10 "constant attention").

Table 4.1 shows the model results for the perceived change in local temperatures. The second column contains the estimated ordinal logit model coefficients for the recorded local temperatures; the third column includes the individual-level attributes; the fourth adds the political variables; and the fifth presents the full model including the environmental concerns and attention measures. Indicators of statistical significance and model fit are also included.

As shown in column 2 of Table 4.1, the recorded departures from long-term average temperatures are both positively and significantly related to perceived temperature change. Note that, while highly statistically significant ($p<0.000$), the effect is quite small – accounting for less than a percent of the variance in perceived temperatures. Adding the individual-level demographic variables improves prediction only slightly; males and older respondents appear to be slightly less likely to perceive temperatures to have risen, while those with higher education levels are more likely to see a rise.

When the political variables are added to the model we obtain a significant increase in the explained variance in perceived temperature change

[7] While we could derive competing conjectures about the directions of these effects, we use them here chiefly as control variables.

[8] This is a dummy (zero or one) variable. Also considered was a model using Republican Party identification, with similar results (but the opposite sign).

	Weather Model	Demographics	Politics	Environ. Views
Precipitation Departure (1-Yr)	0.168***	0.175***	0.174***	0.178***
Gender (Male=1)	NA	-0.108	-0.081	-0.065
Age (Years)	NA	-0.004	-0.003	-0.003
Education Level	NA	0.013	0.004	0.005
Income ($10K units)	NA	>-0.000	0.002	>0.000
Partisanship (Democrat=1)	NA	NA	0.263*	0.234*
Political Conservatism	NA	NA	-0.034	-0.011
Environmental Concern (0-10 scale)	NA	NA	NA	0.038
Attention to Environment (0-10)	NA	NA	NA	0.021
Log-Likelihood	-1879.2865	-1649.912	-1602.674	-1598.68
Model χ^2	38.36***	40.65***	50.05***	55.44***
Pseudo-R^2	0.010	0.012	0.015	0.017
Sample size	1868	1642	1603	1601

Table 4.3 Predictors of Perceived Change in Local Flooding Ordered Logistic Regression
Statistical Significance: ***<0.001; **<0.01; *<0.05

(the pseudo-R^2 increases to 0.043, and the model χ^2 jumps from 36.04 to 133.96 with the loss of two degrees of freedom). As hypothesized, identification with the Democratic Party is associated with a perceived increase in local temperatures, while political conservatism has the opposite effect.[9]

The addition of the environmental views again improves the model fit, with the pseudo R^2 rising to 0.064. Both the generalized concern about the environment, and the more specific attentiveness to the issue of global climate change, are associated with the perception of rising local temperatures. Both effects are statistically significant. The increased model χ^2 value (from 133.96 to 197.11 with the loss of two degrees of freedom) is statistically significant, indicating that environmental views and attentiveness influence perceptions of local weather independently of broader political beliefs and affiliations.

Note that the estimated effect of recorded local temperature changes remained significant and consistent across all four models of perceived local temperature change. These results indicate that Americans' perceptions of the local weather are anchored in "facts" about the weather, but these facts are filtered and refracted through personal, ideological, and issue-oriented lenses. This is consistent with the literature on public opinion formation (see, for example, Herron and Jenkins-Smith 2006; Kahan and Braman, 2004), and it suggests that public support for policies to address climate change will necessarily rely on an interactive mix of perceived facts and value-based cognitions.

Table 4.2 presents the models predicting perceived changes in the frequency of local drought. The four sequential models employ the same independent variables described for the perceived temperature change models presented in Table 4.1, with the exception of the recorded local weather variable. In this model we use the departure of local precipitation over the last year (the most recent available was the year ending in Feb-

[9] Note that, with the addition of the political variables, the estimated effects of age and gender as predictors of temperature change become statistically insignificant.

ruary 2008) from the long-term average for the area.

As shown in Table 4.2, the hypothesized effect of the record of actual precipitation change is as expected: positive departures from long-term precipitation are associated with less frequent perceived droughts. Note that the explained variation for this model is larger than it is for the comparable model of temperature change (with a pseudo-R^2 of 0.031 compared to 0.006 as shown in Table 4.1), though once again the overall precision of the model is quite modest. Nevertheless, the model demonstrates that (a) our respondent's perceptions of drought are consistent with expectations from precipitation data, and (b) the relationship is stronger for drought than it is for temperature.

The addition of the individual-level demographic variables in column 3 adds very little to the model explanation. Of these variables, only the estimated effect of education level is statistically significant: as education level rises, the perceived frequency of drought increases.

The addition of the political variables also adds very little explanatory power to the model. Partisanship has no effect on perceptions of the frequency of local drought. On the other hand, the more politically conservative the respondent is, the less likely they are to perceive local droughts to have increased in frequency.

Finally, the addition of the environmental views adds modestly to the explanatory power of the models. The greater the respondent's concern about the environment, the more likely they are to perceive local droughts to have increased in frequency. Similarly, the more attentive the respondent is to the climate change issue, the more likely they are to perceive droughts to have increased locally. The increased χ^2 value (from 139.70 to 181.47 with the loss of two degrees of freedom) is significant. Thus, as with perceived temperature changes, environmental views and attentiveness influence perceptions of local weather independently of broader political beliefs and affiliations.

Overall, the models of perceived local drought are less driven by social, political and environmental views, and more responsive to recorded weather changes. Thus compared to perceived temperatures, drought perceptions appear to be less "politicized" and less prone to social construction, and more responsive to the "facts" of local weather.

Table 4.3 shows the four models predicting perceived changes in the patterns of local flooding. The models are structured similarly to those in Table 4.2.

The estimated effect of recorded departures of local precipitation from the long-term average is as predicted: the greater the (positive) departure, the more likely the respondent is to perceive increased local flooding. This effect is highly statistically significant, and is consistent across all four models.

What stands out in the models of perceived local flooding is the relative absence of influence by social, political and environmental variables. None of the individual-level demographic variables has a significant influence, and only partisanship has a detectible effect among the political variables (Democrats are more likely to perceive flooding to have increased in frequency, holding all else constant). Neither of the environmental perceptions variables have a statistically significant effect on perceived local flooding. Perceptions of changes in local flooding stand out as the least prone to be influenced by social factors, politics, or environmental views.

5. Discussion and Conclusion

Our inquiry is motivated by the question of how public support is generated for complex, controversial, and potentially costly policies to address such problems as global climate change. We noted that, within modern representative political systems, substantial and persistent public support is necessary for sustained public policies of this kind. We conjectured that perceptions of local weather patterns would be an important ingredient, and demonstrated that these perceptions are indeed consequential: people who perceive local temperature to have risen, droughts to have become more persistent and floods more frequent are more likely to believe that the climate is changing due to human actions, that the risks of climate change are high, and that the US ought to commit to internationally set greenhouse gas emissions limits.

So where do Americans get their perceptions of local weather changes? Our most reassuring finding is that, over all three measures of change, public perceptions of weather change are positively correlated with the recorded temperature and precipitation changes taking place around them. This effect, however, is not large relative the overall variation in perceptions of local weather change. Other factors – notably political beliefs and affiliations and more general orientations toward environmental issues – significantly shape perceptions as well, and these will undoubtedly continue to compete with weather and climate "facts" for primacy in shaping public opinion.

Among the dimensions of weather change analyzed here, temperature change perceptions are the most highly "socially and politically constructed" of the dimensions of perceived weather. This makes intuitive sense, in as much as temperature change has been made most salient by the arguments back and forth about "global warming". This finding has substantial significance for those who would increase public understanding of weather and its relationship to broader climate issues. Arguments over temperature are tough, because the term has been politicized and the on-the-ground measures include enough variation to readily permit social construction. Perceptions of changes in frequency of droughts and – especially – floods appear to be less "contaminated" and therefore may offer a more dispassionate basis for communication, discussion and learning.

Substantial continuing work is required to more fully appreciate and understand geospatial patterns in perceived weather, including variations in the regional, urban-rural, and economic characteristics of the local areas in which the respondents reside. Moreover, new data will be collected for 2009, increasing the sample size and allowing for some over-time analysis. Overall, through these and other efforts, our research will continue to focus on the processes by which mass publics obtain the perceptions of weather, the linkage to understandings of larger climate issues, and the generation of public support for politically sustainable policies to address climate change.

Acknowledgements
The authors wish to acknowledge the financial support provided by the Sandia National Laboratories and the University of Oklahoma. The project would not have been possible without the intellectual contributions of Dr. Kerry Herron, and it benefited from the help of Mike Jones. Lastly, we wish to acknowledge the inspiration, insights and general harassment provided by the University of Oklahoma's MOLA group.

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