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Local temperature anomalies increase climate policy interest and support: Analysis of internet searches and US congressional vote shares

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ABSTRACT

Two studies examine the effects of temperature anomalies (relative to ten-year averages) on interest in and support for climate policies. Study 1 analyzes the impacts of local temperature anomalies on information acquisition, namely Google searches, about climate change and climate policies. We find strong evidence that temperature anomalies are associated with increased climate change information acquisition. Our results show that deviations from seasonal norms in both directions (i.e., temperatures higher or lower than expected) predict increased interest. Study 2 analyzes voting for Republican candidates, who in the timeframe of our data were not likely to support climate policies. Analysis of voting records from ten US midterm elections from 2002 to 2020 shows that greater local temperature anomalies are significantly associated with lower vote shares for Republican candidates.

1. Introduction

Understanding how anomalous weather events affect climate policy support can help communicators to strategically leverage weather events to promote citizens' attention to and support for climate change policies. Notable weather events may help open policy windows that can be anticipated. Knowledge of how weather experiences affect climate attitudes and behaviors also aids us in generating long-term predictions about how climate policy support will evolve over time in response to changes in weather patterns brought about by climate change (Moore et al., 2019; Ricke and Caldeira, 2014).

Climate policy support is an important pro-environmental behavior because enacting climate policies is likely necessary to mitigate climate change (Pachauri et al., 2014). To date, much research has examined the effects of local weather events (WE) on climate attitudes, but fewer studies have examined their effects on climate behaviors or on climate policy support (Sisco, 2021). In the current study, we address this gap by presenting two studies that analyze how WE impact climate policy interest and support in the public.

Climate attitudes. Past research on the effects of WE on climate attitudes has delivered mixed results (see Howe, 2021; Howe et al., 2019; Sisco, 2021 for reviews). A meta-analysis (of 171 academic studies and 25 polls) that compares predictors of belief in climate change finds that self-reported experience with local changes in weather is one of the strongest predictors of belief in climate change (Hornsey et al., 2016). The effect is similar in size to effects of variables such as trust in scientists and perceived scientific consensus. Citizens have some metacognitive insight about this influence on their climate beliefs. In a representative survey of US citizens conducted in 2018, participants were asked how much different factors affected their views on climate science (EPIC/AP-NORC, 2018). Out of seven potential influences including sources of information like news stories and views of political leaders, participants most commonly reported recent extreme weather events and personal observations of weather in their local areas as their top influences.

Beyond meta-analyses and polls, several studies have sought to examine the effects of WE more directly by examining the associations between objectively measured weather and climate attitudes. When people experience temperatures that are warmer than usual, and perceive them as such, they are more likely to report concern about global warming (Li et al., 2011), a result known as the local warming effect (Zaval et al., 2014). Numerous other studies find that local temperature anomalies increase people's concerns about climate change and attention to it, at least temporarily (Egan and Mullin, 2012; Hamilton and Stampone, 2013; Joireman et al., 2010; Kirilenko et al., 2015; Lang, 2014; Myers et al., 2013; Sisco et al., 2017). A re-analysis of about

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400,000 responses across 170 polls finds that self-reported climate attitudes are modestly responsive to changes in state-level annual temperatures (Bergquist and Warshaw, 2019). Approaching this question with a laboratory experiment, Joireman et al. (2010) demonstrated that experimentally priming participants with heat-related cognitions increased beliefs in climate change.

Climate behaviors. A small but growing literature examines the effects of WE by observing behavioral outcomes instead of relying of self-reports of behaviors or behavioral intentions which can be prone to bias. Zaval et al. (2014) show that abnormal weather affected real monetary donations to climate charities in an online experiment. These results are suggestive, but bear the limitation that these behaviors were observed within a controlled experimental setting with generalizability to real-world settings somewhat unclear.

Some researchers have reported effects of WE on social media messages about climate change (Kirilenko et al., 2015; Mumenthaler et al., 2021; Sisco et al., 2017). Citizens' online posts about climate change are observable behavioral outcomes, however, these behaviors may have minimal impacts on climate action. This is in part due to the presence of echo chambers in social media networks which can limit the audience of positive messages about climate change to those who already endorse them (Pearce et al., 2014).

Other papers have analyzed searches about climate change on the internet as observed behaviors (Choi et al., 2020; Lang, 2014; Sisco et al., 2021). Herrnstadt and Muehlegger report that climate-related searches increase with extreme temperatures (Herrnstadt and Muehlegger, 2014). Lang (2014) finds that monthly temperature fluctuations predicted US searches about "climate change" and "global warming" from 2004 through 2013. Lang observed that monthly search activity increased with extreme summer heat, but also with colder winter and spring temperatures. Choi et al. (2020) examined monthly search activity in 72 international cities. Choi et al. report that searches about "global warming" increased when local temperatures were abnormally high. In the current paper we attempt to replicate these results. We also extend them by examining whether WE influence searches beyond the keywords "climate change" and "global warming" to searches that are more specific to climate change policies. We use a high temporal resolution of weekly averages. In Table 1 we present a comparison of our internet search study and past studies on the effects of temperature on internet searches.

Others studies have not detected evidence of WE's impacts on climate change attitudes and behaviors (for example, Brulle et al., 2012; Shum, 2012). Scholars have reasoned that the mixed results may be due to the wide heterogeneity of operational definitions of WE, heterogenous outcome variables, and varied methodological approaches that have been employed as well as varying amounts of media and public attention to the different weather phenomena studied (Howe, 2021; Howe et al., 2019; Sisco, 2021).

Climate policy support. While there has been much past research on the effects of WE on climate attitudes and to some extent behaviors, only a small subset of work has examined WE's effects on climate policy support. Rudman et al. (2013) examined the impacts of Hurricane Irene and Hurricane Sandy on attitudes toward a (real) green politician. They report that, before experiencing the hurricanes, New Jersey residents had negative implicit attitudes toward the green politician. After experiencing the hurricanes, residents showed more positive implicit preferences for the candidate. Bergquist et al. (2019) find that participants living in Florida reported more willingness to pay higher taxes to protect the environment after Hurricane Irma compared to directly before. Similarly, Demski et al. (2017) report that flood experiences increased reported support for climate mitigation policies in a sample of UK residents.

One highly consequential behavior that is a direct measurement of climate policy support is voting behavior. Hoffmann et al. (2022) show a significant effect of temperature anomalies on votes for Green parties in Europe. Hazlett and Mildenberger (2020) examine the impacts of experiences with wildfires on votes for climate policy measures. They find that proximity to wildfires bolstered support by five to six percent for those living in Democratic-voting areas, with the effect diminished to near zero in areas farther than 15 km away from the fires. Gagliarducci et al. (2019) report positive impacts of local hurricane disasters from 1989 through 2014 on US congress members' support for environmental policies. Similarly, Herrnstadt and Muehlegger (2014) find that congressional members are more likely to cast pro-environmental votes after their home states experienced abnormal weather. Relatedly, Liao and Junco (2021) find that financial contributions to the Democratic Party increase in response to higher weekly temperatures.

Theoretical mechanisms. Some past work has postulated possible mechanisms by which WE can affect attitudes and behaviors (Giordono, Gard-Murray and Boudet, 2021). Sisco (2021) used a literature review to identify three theoretical mechanisms: affect activation, issue salience, and psychological distance. That is, WE may affect climate attitudes/behaviors by evoking strong emotional responses, by increasing the salience of climate change as a threat, and by decreasing the felt psychological distance from the risks of climate change (Zanocco et al., 2019). Brügger et al. (2021) introduced a conceptual framework organizing relevant psychological theories into three clusters of processes by which WE can influence climate attitudes/behaviors: noticing and remembering a WE, mental representations of the WE and its connection to climate change, and effects of a WE on risk perceptions and decision-making (Brügger et al., 2021).

Overview of the current work. We examine the effects of WE, specifically temperature anomalies, on behavioral measures of interest and support for climate policies. Climate policy support is arguably-one of the most important climate mitigation behaviors in part because it allows one individual to affect the behaviors of others. For example, if a slim majority votes to enact a mandatory recycling policy, then all citizens are required to recycle. A challenge with many personal green behaviors, such as recycling or using public transportation, is that they need to be performed repeatedly over time. In contrast, supporting a

Table 1
Comparison of internet search studies on climate change attention.

Study	Keywords	Geographies	Time interval	Dates of Observations	Results
Herrnstadt and Muehlegger (2014)	global warming, climate change	US states	weekly	2004–2011	Climate-related searches increase with extreme temperatures
Lang (2014)	global warming, climate change, drought, flood, weather	USA Designated Market Areas (DMA)	monthly	2004–2013	Search activity increased with extreme summer heat, but also with colder winter and spring temperatures
Choi et al. (2020)	global warming	International cities, countries	monthly	2004–2017	Searches increase when local temperatures are abnormally high
The current study	climate change, global warming, cap and trade, renewable energy, carbon tax	USA Designated Market Areas (DMA)	weekly	2016–2020	Climate change and renewable energy searches increase with temp. abnormalities in both directions

climate policy or a candidate committed to climate policies can be done with a highly consequential one-time action of casting a vote.

There are many different manifestations of WE such as temperature anomalies, droughts, hurricanes, flooding, and so on. In the current paper we focus on anomalous temperatures for several reasons. As described above, temperature anomalies have been shown to affect climate attitudes and behaviors in a variety of past studies. Moreover, changes in temperature are some of the most direct consequences of climate change. Given that climate change is sometimes referred to as global warming, increases in temperature are likely still strongly associated with climate change in the public mind (Schuldt et al., 2011).

In the current work, we investigate whether local anomalous temperatures lead to increased climate policy interest and support. We report on two studies that approach this research question with different datasets, levels of analysis, and outcome variables. Study 1 analyzes information acquisition, showing that abnormal temperatures predict increased Google searches about climate change as well as search terms more directly related to climate policies (e.g., "renewable energy"). Study 1 lays the foundation for Study 2 by showing that temperature anomalies are associated with increased attention to climate change and climate policies which is arguably prerequisite for WE to affect voting behavior (Brügger et al., 2021; Sisco, 2021). Study 2 examines the more consequential behavior of voting for political candidates who are likely to support climate policies. We find a significant negative association between local anomalous temperatures and votes cast for Republican US congressional candidates.

2. Study 1: Do temperature anomalies increase climate information acquisition?

2.1. Methods

In Study 1, we analyze the effects of local temperature anomalies on climate information acquisition operationalized as internet searches about climate change.

Temperature measurements. We calculate temperature anomaly by comparing present temperatures to ten-year averages. To calculate temperature anomalies we use temperature observations from the NOAA Climate Prediction Center (CPC) Global Daily Maximum Temperature 0.5 × 0.5 degree gridded datasets (NOAA/CPC, 2018). We process these data to calculate the average population-weighted positive and negative temperature anomalies for each week (w), year (y), and location (l). Since the raw NOAA CPC data are aggregated at a daily temporal resolution and 0.5 × 0.5 degree geographic cells, we first generate ten-year historical temperature averages, $\widehat{T}_{dyc}$, (which can be thought of as predictions for the current year, hence the hat notation) for each day (d), year (y), and geographic cell (c) by averaging temperature values in each cell and calendar day over the past 10 years:

$$\widehat{T}_{dyc} = \sum_{i=1}^{10} \frac{T_{d,y-i,c}}{10}$$

We then calculate the temperature anomaly, A_{dyc}, for each day and year in each cell by subtracting the observed daily values from the historical averages:

$$A_{dyc} = T_{dyc} - \widehat{T}_{dyc}$$

To calculate the population-weighted average temperature anomaly, $\overline{A}_{dyl}$, in day d of year y in each location (i.e., metropolitan area) l, we calculate the weighted mean of the temperature anomaly values of all the cells (where N cells varies based on the size of each location's boundaries) falling within the boundaries of each location, using the 2020 population values, P, of the cells as weights:

$$\overline{A}_{dyl} = \frac{\sum_{c=1}^{N} A_{dyc} P_c}{\sum_{c=1}^{N} P_c}$$

Finally, to arrive at both positive and negative weekly aggregated temperature anomaly values,A^+_{wyl} and A^-_{wyl}, for week w, year y, and location l, we take the maximum and minimum values over the daily temperature anomaly values for the days, D, in each week:

$$A^+_{wyl} = \max_{d \in D}\left(\overline{A}_{dyl}\right)$$

$$A^-_{wyl} = \min_{d \in D}\left(\overline{A}_{dyl}\right)$$

We measure both the maximum and minimum temperature anomaly from each week to account for the possibility that anomalies in each direction (positive and negative) may be uniquely predictive of increased climate policy support (as has been seen in past work, e.g., Pianta and Sisco, 2020). In Supplementary Material 1 we show regression results with alternative quantifications of temperature (i.e., weekly means) demonstrating the robustness of our results to different anomaly quantifications.

Search frequency measurements. We extracted weekly search frequencies for the terms "climate change", "global warming", "cap and trade", "renewable energy", and "carbon tax" from the Google Trends data service using the R package gtrendsR. These keywords were selected to measure a general interest in climate change with the keywords "climate change" and "global warming" and to measure searches more directly related to climate policies using the other keywords. We collected weekly search frequencies of the keywords from January 2016 through December 2020.

Raw Google Trends data represent the magnitude of searches for a given keyword over time, quantified as the proportion of all searches within a target area and timeframe. These proportions are rescaled so that the maximum value observed in a target area over the time range of the requested data equals 100.

The geographic aggregation of our search data is at the level of US Designated Market Areas (DMAs) which roughly correspond to metropolitan areas. We collected observations for 207 DMAs over five years which amounts to 261 (weekly) observations per DMA, per keyword. We excluded three DMAs entirely that had too little search activity on any of our keywords to be reported on by Google Trends. Our geographic coverage of the US is comprehensive as we include in our sample 99% of US DMAs. In total we analyze 53,820 observations with each model. The averages and standard deviations of search frequencies for each keyword are $\bar{s}_{climatechange} = 14.3, \widehat{\sigma}_{climatechange} = 18.9$; $\bar{s}_{globalwarming} = 9.2$, $\widehat{\sigma}_{globalwarming} = 14.2$; $\bar{s}_{capandtrade} = 0.24, \widehat{\sigma}_{capandtrade} = 2$; $\bar{s}_{renewableenergy} = 4.5$, $\widehat{\sigma}_{renewablenergy} = 9.3$; $\bar{s}_{carbontax} = 0.2, \widehat{\sigma}_{carbontax} = 1.3$. Visualizations of the time series for "climate change" searches can be found in Supplementary Material 2.

Regression specification. We analyze search frequencies for each keyword individually. We analyze the effects of temperature deviations on search frequencies using a time series regression model. Specifically, we regress changes in search frequencies for each location l and week w, Δs_{lw}, on changes in maximum and minimum temperature anomaly, $\Delta a^+_{lw}, \Delta a^-_{lw}$ (each week differenced from the week prior). We also control for time (week) and w-1 lags of search frequency, maximum temperature anomaly, and minimum temperature anomaly. Thus, our full regression specification is:

$$\Delta s_{lw} = \beta_0 + \beta_1 \Delta a^+_{lw} + \beta_2 \Delta a^-_{lw} + \beta_3 a^+_{lw-1} + \beta_4 a^-_{lw-1} + \beta_5 s_{lw-1} + \beta_6 w + \varepsilon_{lw}$$

More details on this specification and its assumptions can be found in Supplementary Material 3. To account for observations being nested within locations and weeks (and therefore potentially having correlated errors), we compute standard errors that are clustered on location and week. We ran placebo tests regressing search frequencies on future temperature patterns to check that our specification is not prone to excess false positives (see Supplementary Material 4).

2.2. Results

Table 2 shows the results from these models. We find that weekly temperature anomalies have statistically significant associations with search frequencies for most of the keywords analyzed. Generally, we see that the maximum temperature anomalies are positively predictive of online searches, and the minimum temperature anomalies are negatively predictive. In other words, our results show that the more abnormal temperatures are in either direction (positive or negative) the more interest in climate change is generated, though positive anomalies are more consistently predictive than negative anomalies.

In Model 1, the estimated beta coefficient of 0.104 for maximum temperature anomaly suggests that a 1-degree Celsius difference in weekly temperature anomaly is associated with searches about climate change increasing by about 0.1% of the maximum search intensity in each area in the timeframe of our data. Several degree temperature deviations are a common occurrence, so a sizable annual impact of temperature anomalies on Google searches can result over time from the aggregate of many minor impacts.

We find these to be impressive results, but note the limitation that internet searches are not necessarily highly consequential behaviors. This leads to Study 2, wherein we examine effects of abnormal temperatures on the high-impact behavior of voting for climate policy advocates.

3. Study 2: Do temperature anomalies predict vote shares?

3.1. Methods

In Study 2 we examine if local temperature anomalies affect votes for candidates who were less likely to support climate policy initiatives, that is, Republican candidates. We analyze election results from ten congressional elections spanning from 2002 through 2020.

We use political party affiliation as a proxy for climate advocacy. This assumes the public perceived Democratic candidates as generally supportive of climate policies, and the opposite for Republican candidates. To check the validity of this premise, on the day of the 2018 congressional election we downloaded the public websites of congressional candidates and coded them for expressing climate policy support, no stated position, or opposition to climate policies.[1] As expected, we find a strong relationship between party affiliation and explicit climate policy support, with 94% of the candidates who expressed advocacy for climate policies on their websites being Democratic candidates. This is consistent with analyses of partisan positions on climate change in prior years (McCright and Dunlap, 2010).

Weather measurements. We quantify the temperature anomalies experienced over the year leading up to each election in the area of each congressional district with a similar approach as used in Study 1. As in Study 1, we analyze temperature records obtained from the NOAA CPC 0.5 × 0.5 degree gridded datasets. We followed the steps described in Study 1 to calculate the maximum and minimum temperature anomalies experienced in each area, except in Study 2 we now use congressional districts (instead of DMAs) as our locations of interest and we use the year leading up to each election day (Jan 1st through Nov 2nd) for the time periods we aggregate over (instead of week). In Fig. 1 (top panel) we show the maximum temperature anomalies, our main temperature variable of interest, experienced in each congressional district in each election year in our study.

Congressional election data. We analyze vote shares for candidates for the US House of Representatives in congressional elections from 2002 through 2020. In order to minimize statistical dependence across our observations, we only analyze US House results and do not examine contemporaneous races such as US Senate elections. We obtained official vote share information for the candidates from the MIT Election Data and Science Lab records (MIT EDSL, 2021). We do not analyze candidates in seats that were uncontested. Similarly, we do not analyze candidates who had final vote shares of less than 10% or more than 90% in order to focus on congressional races that were competitive.[2] In total, we analyze 3,389 congressional races. In Fig. 1 (bottom panel) we visualize vote shares across US Congressional districts in every year analyzed in the current study.

3.2. Results

Fig. 2 shows visually that temperature anomalies are negatively associated with the vote shares obtained by Republican candidates while positively associated with the vote shares of Democratic and other candidates. This pattern is interesting, but is limited in that it visualizes bivariate relationships without controlling for any potentially confounding variables. To address this, we conduct regression analyses to estimate the effects of anomalous temperatures on vote shares.

Regression specification. Since Democratic and Republican vote shares within each district are highly negatively correlated, we only analyze one party per district and race in our regression model. For simplicity we use the Republican vote share per district as the main outcome variable, represented as the percent of total votes ranging from 0 to 100. Using Republican vote share as the main outcome is also sensible because votes shifted away from Republicans due to citizens' increased climate support may shift to Democratic or independent candidates.

We analyze the effects of temperature anomalies on vote shares using a time series regression model. Specifically, we regress changes in vote shares, Δv_{lt}, in each location l and election time t on changes in maximum and minimum temperature anomaly, $\Delta a_{lt}^{+}, \Delta a_{lt}^{-}$ (in all cases values from each current election are differenced from those from the last occurring in that district). As described above, we calculated the maximum and minimum temperature anomalies experienced in each

Table 2
Searches about climate change regressed on temperature deviations.

	Climate Change	Global Warming	Cap and Trade	Renewable Energy	Carbon Tax
	1	2	2	4	5
Max temp. anomaly change	0.104* (0.051)	0.126** (0.041)	-0.001 (0.003)	0.051** (0.019)	0.001 (0.002)
Min temp. anomaly change	-0.080 (0.051)	-0.172*** (0.041)	0.006* (0.002)	-0.042* (0.018)	0.002 (0.002)
Max temp. anomaly lag	0.182** (0.070)	0.167** (0.055)	0.000 (0.003)	0.109*** (0.025)	0.002 (0.003)
Min temp. anomaly lag	-0.100 (0.075)	-0.192** (0.059)	0.003 (0.003)	-0.093*** (0.025)	0.004 (0.003)
Search volume lag	-0.726*** (0.019)	-0.832*** (0.013)	-0.829*** (0.066)	-0.900*** (0.011)	-0.861*** (0.024)
Week	0.001 (0.001)	-0.002*** (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000* (0.000)
Constant	−12.078 (11.358)	49.762*** (6.455)	0.798 (0.642)	3.960 (2.843)	0.874** (0.318)
Observations	53,820	53,820	53,820	53,820	53,820
Adjusted R^2	0.363	0.417	0.416	0.451	0.431
Residual Std. Error	18.107	14.039	1.951	9.206	1.324

Notes: *P <.05; **P <.01; ***P <.001.

[1] We obtained information on the official congressional candidates and their campaign websites at the time of the election from the ProPublica database..

[2] To ensure our results do not depend on examining only competitive races, we ran a robustness check with the same regression specification as in the main analysis but without excluding candidates with vote shares less than 10% or more than 90%. We find a virtually identical pattern of results. These results are shown in Supplementary Material 7.

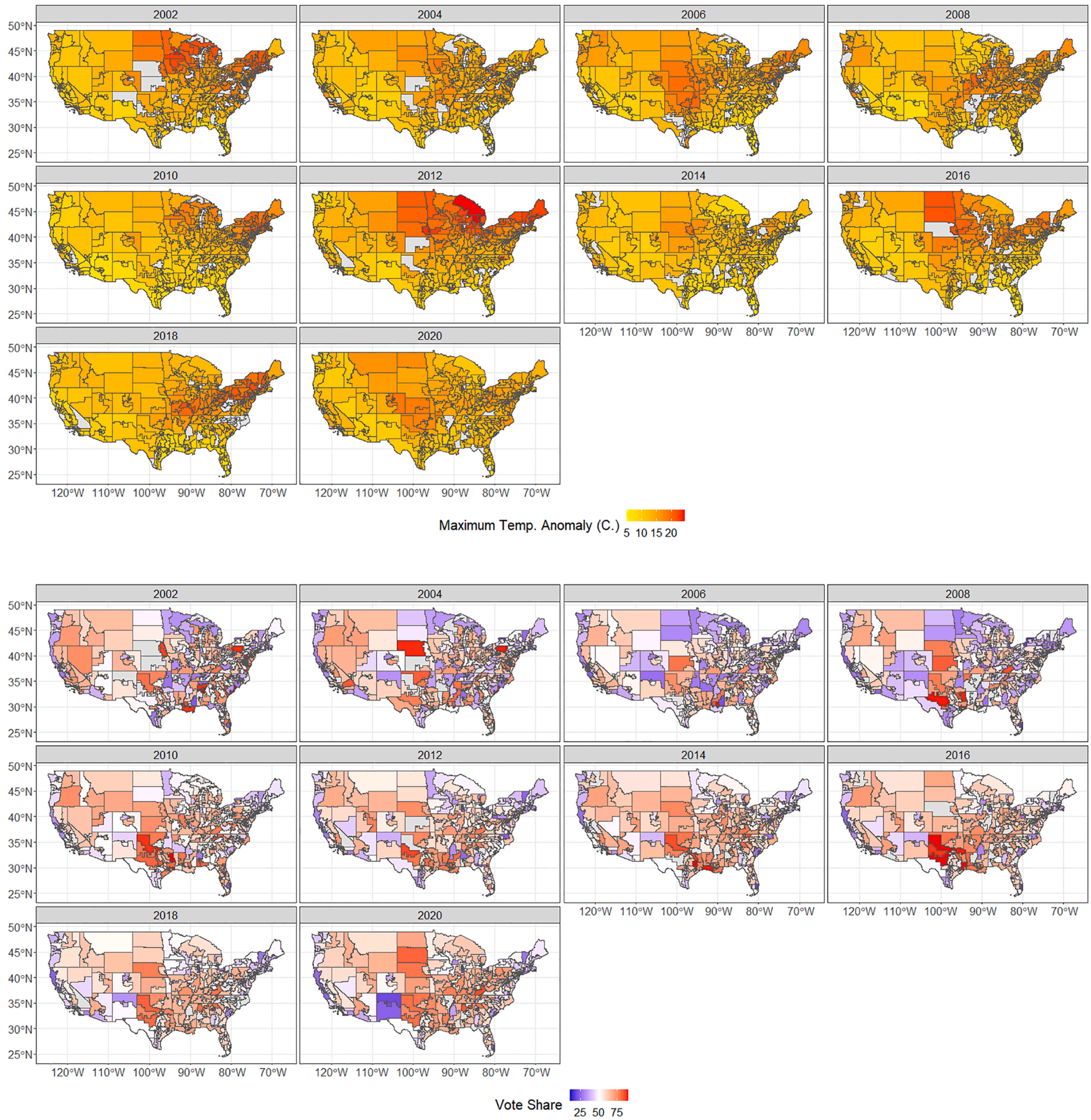

Fig. 1. Top panel: Maximum Temperature Anomaly (degrees C) in continental US Congressional Districts from 2002 through 2020. Bottom panel: Republican Vote Share in continental US Congressional districts from 2002 through 2020. These variables are used in the regression models shown in Table 3.

geographic area over the calendar year prior to each election. We also control for time (year, y, transformed so that year 2002 is coded as year 0) and t-1 lags of vote share, maximum temperature anomaly, and minimum temperature anomaly. Since we analyze change scores and lags, the first election in each district is not included directly in the analysis but is used to calculate the change score and lag for the second election. Thus, our full regression specification is:

$$\Delta v_{lt} = \beta_0 + \beta_1 \Delta a^+_{lt} + \beta_2 \Delta a^-_{lt} + \beta_3 a^+_{lt-1} + \beta_4 a^-_{lt-1} + \beta_5 v_{lt-1} + \beta_6 y + \varepsilon_{lt}$$

We differenced the weather anomaly variables and the vote shares to factor out the time invariant voting tendency of each congressional district and to minimize autocorrelation. This precludes the need to control for district-level effects. To account for nestedness within locations and years, we compute standard errors that are clustered on congressional district and year. Supplementary Material 3 contains more details on our regression specification and assumptions. To ensure that our regression approach is appropriately robust to false positives, we conducted placebo tests fitting the same regression model to permutated data which are shown in Supplementary Material 5 and find confirmatory results.

Table 3 shows the results of our regressions. Column 1 in Table 3 shows the results across all congressional districts, and columns 2–4 show the results for subsets of the data that represent Democratic leaning districts, center districts, and Republican leaning districts, respectively. We classified districts as Democratic or Republican leaning if their average vote share across all of our data was 60% or more for one party. Districts that fell into neither category were classified as center.

The results show that higher temperature anomalies are associated with lower Republican vote shares. The estimated beta coefficient of -0.32 for positive temperature anomaly suggests that a 1-degree (Celsius) change in maximum temperature anomaly is associated on average with a -0.32% ($\beta = -0.32$; $SE = 0.07$; $p < 0.001$; 95%CI = 0.19%, 0.45%) change in Republican vote share. This effect is statistically significant and significant in real-world terms. To put this effect in

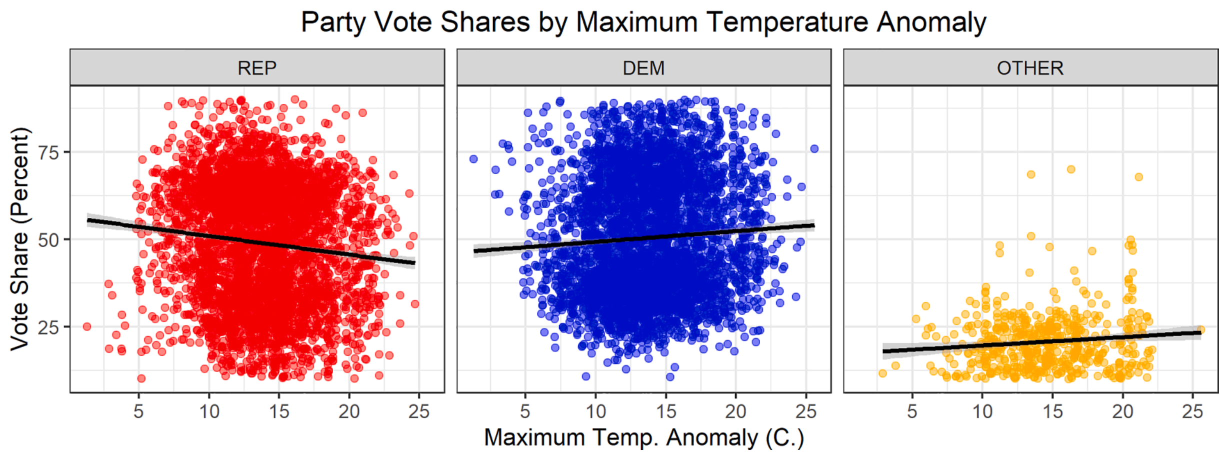

Fig. 2. Scatterplots of local temperature anomaly (maximum) and vote shares for Democratic, Republican, and other candidates. OLS bivariate regression lines are shown with 95% confidence intervals shaded.

Table 3
Change in Republican vote share regressed on changes in temp. anomaly.

	All observations	Democratic Leaning Districts	Center Districts	Republican Leaning Districts
	1	2	3	4
Max temp. anomaly change	-0.32***	-0.03	-0.29***	-0.61***
	(0.07)	(0.10)	(0.08)	(0.11)
Min temp. anomaly change	-0.29*	-0.19	-0.25	-0.25*
	(0.14)	(0.13)	(0.20)	(0.10)
Max temp. anomaly lag	-0.24**	-0.02	-0.25**	-0.33**
	(0.08)	(0.06)	(0.08)	(0.10)
Min temp. anomaly lag	-0.47***	-0.09	-0.45**	-0.62***
	(0.11)	(0.10)	(0.15)	(0.12)
Vote share lag	-0.15***	-0.29***	-0.32***	-0.51***
	(0.03)	(0.07)	(0.08)	(0.07)
Year	0.07	0.13	0.09	-0.03
	(0.16)	(0.11)	(0.19)	(0.14)
Constant	3.33	6.53*	12.41*	28.72***
	(3.03)	(2.57)	(5.50)	(5.70)
Observations	3,389	1,003	1,439	947
Adjusted R^2	0.11	0.15	0.19	0.31
Residual Std. Error	7.76	6.63	7.94	6.87

Notes: *P <.05; **P <.01; ***P <.001.

perspective, consider that the third quartile of maximum temperature deviation in our sample is 2.2 degrees. Our results predict 0.7% less Republican vote share in a district with this level of temperature anomaly. This is large enough of an effect to change the outcome of about 1.1% of the races in our data. Regarding the effects of negative temperature anomalies, we see a marginally statistically significant effect on average ($\beta = -0.29;\ SE = 0.14;\ p < 0.05;\ 95\%\mathrm{CI} =\ -0.001, -0.57$).

We implemented an alternative temperature aggregation approach with mean positive and negative temperatures instead of maximums and minimums (see Supplementary Material 6) wherein we find a similar pattern of results but find less strong results than we do in the main analysis. This could indicate that the public's memory of past weather events is dominated by outliers, which political campaigns may have focused on.

Turning to the models fitted to subsamples of the data (Table 3, Models 2–4), we observe that the negative effects of maximum and minimum temperature anomalies are strongest in Republican learning districts and center districts. The estimated effects of positive and negative temperature anomalies are not statistically significant in Democratic leaning districts. In contrast to what was seen in Study 1, we find that the maximum and minimum temperature anomalies are estimated to have the same sign of effects. Extreme cold temperatures may incline the public to seek out more about climate change, but they do not seem to incline the public to increase their climate policy support.

4. Discussion

In the current paper we report on two studies that examine the effects of local temperature anomalies on interest in and support for climate policies. Study 1 examines the behavior of searches about climate change and climate policies on the internet and finds that temperature anomalies are associated with increased information acquisition by citizens. Study 1 shows that temperature anomalies in either direction (positive or negative) are associated with higher internet searches about climate change and climate policies. This relatively short time span (within the same week) between experienced anomaly and measured impact is similar to studies that have found evidence of the local warming effect (e.g., Li et al., 2011; Zaval et al., 2014). Interestingly, we find a stronger association between temperature anomalies and the keyword "global warming" than with the keyword "climate change." Past research has found that conservatives tend to use the phrasing "global warming," thus these results may indicate a stronger influence on conservative citizens (Schuldt et al., 2011).

Study 2 analyzes a highly consequential behavior, namely voting for Republican candidates who were unlikely to support climate policies. We find that local temperature anomalies are associated with less Republican vote share in the time frame of our analysis. In line with the pattern of results in Study 1, we find the strongest effects in Republican leaning districts. Study 2 documents effects of temperature anomalies experienced over a longer time span, namely the calendar year leading up to each election. Mechanisms posited to underlie the local warming effect, such as attribute substitution or visceral reactions to extreme experiences, explain short-term effects of temperature anomalies but do not clearly account for long-term effects. With memories of extreme events appearing to linger longer to increase citizens' support for climate policies, additional mechanisms should be considered (Brügger et al., 2021).

It remains to be examined what mechanisms drive these effects (Brügger et al., 2021; Sisco, 2021). One plausible mediating variable is increased news media attention to climate change in response to weather extremes (Pianta and Sisco, 2020). Without this, many citizens may not make the connection to climate change (Boudet et al., 2020). Using the current data, we cannot strongly ascertain to what extent the effects on vote share are due to changes in voter turnout or changes in voter preferences. As described above, psychological mechanisms are likely also at work (Brügger et al., 2021; Sisco, 2021) but cannot be examined with the current data.

Public attention to climate change continues to evolve and thus the effects of anomalous weather experiences on climate attitudes and behaviors may evolve over time. It is possible that eventually citizens can become accustomed to weather anomalies and their effects on climate attitudes and behaviors will diminish. Nonetheless, the evidence we present of consequential impacts of anomalous weather experiences on climate policy support over two decades suggests that local weather anomalies can have significant impacts on climate policy support.

5. Conclusion

The results presented in this paper add to the growing body of evidence that local anomalous weather events can affect individuals' attitudes, beliefs, and behaviors concerning climate change. The current paper reports evidence that local temperature anomalies predict consequential behaviors related to climate change interest and policy support.

The predictability of weather makes these findings especially actionable. Organizations and individuals seeking to communicate about climate change or to solicit support from citizens may benefit from coordinating their efforts around predictable anomalous weather events. To inform this, future research should examine the decay rate of the effects on citizens' attention to climate change to shed light on how long they can be leveraged after the events have occurred. Our results and similar past findings suggest that anomalous weather events may increase climate policy support and thereby open policy windows (Gagliarducci et al., 2019; Hazlett and Mildenberger, 2020; Herrnstadt and Muehlegger, 2014) that can be leveraged to advance climate change policies.

CRediT authorship contribution statement

Matthew R. Sisco: Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – original draft, Visualization. **Elke U. Weber:** Conceptualization, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloenvcha.2022.102572.

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