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Shifting public opinion on climate change: an empirical assessment of factors influencing concern over climate change in the U.S., 2002–2010

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Abstract This paper conducts an empirical analysis of the factors affecting U.S. public concern about the threat of climate change between January 2002 and December 2010. Utilizing Stimson's method of constructing aggregate opinion measures, data from 74 separate surveys over a 9-year period are used to construct quarterly measures of public concern over global climate change. We examine five factors that should account for changes in levels of concern: 1) extreme weather events, 2) public access to accurate scientific information, 3) media coverage, 4) elite cues, and 5) movement/countermovement advocacy. A time-series analysis indicates that elite cues and structural economic factors have the largest effect on the level of public concern about climate change. While media coverage exerts an important influence, this coverage is itself largely a function of elite cues and economic factors. Weather extremes have no effect on aggregate public opinion. Promulgation of scientific information to the public on climate change has a minimal effect. The implication would seem to be that information-based science advocacy has had only a minor effect on public concern, while political mobilization by elites and advocacy groups is critical in influencing climate change concern.

One of the earliest U.S. public opinion polls on global climate change was taken in July 1986, when the Cambridge Reports National Omnibus Survey asked individuals if they

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considered global warming a serious problem. Since then, nearly 300 different surveys have been performed on this topic, making opinions about the threat of climate change an expanding area of intense political (Pooley 2010) and academic (Krosnick et al. 2008; Kellstedt et al. 2008) interest. Along with this attention have come repeated calls for the creation of "political will," based on the assumption that a shift in perception of this risk is the key to meaningful governmental and private action on climate change.

Existing research on public opinion about global warming uses approaches derived from communications and social psychology that seek to determine which factors influence individual beliefs, knowledge, and action regarding climate change (Marquart-Pyatt et al. 2011). While useful, this approach neglects the larger cultural and political context that informs aggregate patterns of public opinion (Hindman 2009). When elected officials formulate their policy agenda, the aggregate distribution of public concern on various issues is a key consideration. Unless an issue is widely perceived as a major threat and/or a priority, it is unlikely to be on the agenda.

Public concern about climate change has varied widely over the past few decades. For example, Gallup has been polling individuals about how much they personally worry about climate change. In 2004, 26% of the respondents stated that they worried "a great deal." By 2007, this proportion had risen to 41%. But by 2010, this fraction dropped to 28%. Why? While this shift may be partially explained as individual attitude change, it seems more likely that broader climatic, cultural and political developments are responsible. We need to be able to consider such questions, including: Did media coverage, exposure to extreme weather, or scientific information at certain points in time contribute to greater or lesser concern? What about the mobilizing efforts of advocacy groups and elites, whose influence is often central to public perceptions of threat? An aggregate-level analysis is needed that can identify the informational, cultural and political processes that influence public concern about climate change.

We begin our analysis with a discussion of how to measure aggregate public opinion, advocating Stimson's (1999) method. Using all available national public opinion polls on climate change, we chart the quarterly changes in concern about climate change from 2002 through 2010. We then use time-series analysis to evaluate five explanations of climate change concern and conclude with a discussion about the implications for future efforts to influence public concern about the threat of global climate change.

1 Public opinion on climate change

In the United States, climate change and environmental issues have consistently ranked at the bottom of public concerns as measured by polls. The most frequently used measure is the "Most Important Problem" question administered by the Gallup organization. Over the past 40 years during which environmental issues have been included in this scale, the overall response rate rarely exceeds 3%. Within subcategories of environmental concerns, global warming or global climate change is usually at the bottom. For example, in the March 2011 Gallup poll, environmental concerns were mentioned by only 1% of respondents as the most important problem facing the nation, and ranked 22nd overall. Among those mentioning environmental concerns, 79% worried a "great deal" or "fair amount" about toxic waste and water pollution. Out of nine environmental issues, global warming was ranked last, with only 51% of the public worried a great deal or a fair amount about this issue.

An issue with a level of salience this low raises a question: Is the topic an actual concern of those polled, or simply a response constructed to conform to the options the survey offers? According to the Receive Accept Sample (RAS) model (Zaller 1992), individuals do not possess integrated true attitudes on most issues that are relatively peripheral to their

everyday concerns. Instead, they tend to respond to survey questions based on the most recent information that they have been presented on that issue. Thus, cues from political elites play an important role in these responses. Zaller's research has shown that the higher the individuals' level of education, the more aware they are of elite cues and the more likely it is that individuals will respond in accordance with those cues. The RAS model has compiled an impressive body of evidence showing that opinions vary widely within the same individuals over time, and that they are usually based on the latest media presentations on an issue, as well as on ideological cues.

A second perspective focuses on aggregate trends in public opinion. In his research, Stimson (1999; also Erikson et al. 2002) has shown that each major issue area can be characterized by a "policy mood" reflecting a general disposition towards government action. Specific 'policy moods' can be measured over time by analyzing multiple cross-sections of public opinion polls. This research shows that these aggregate policy moods change slowly over time. Kellstedt (2003) applies this approach to trace changes in American racial attitudes. Invoking the idea of parallel publics, he shows that, despite that different groups have distinctive racial attitudes, aggregate opinion about race moves in the same direction across all of these populations in parallel (Kellstedt 2003: 71–75, Enns and Kellstedt 2008). A significant segment of the American public has fixed beliefs, either because they are not politically engaged, or because they hold strong beliefs that are unlikely to change. But another segment, the "scorekeepers," are attentive and change their views in response to events, elite cues, and the like, creating aggregate opinion change that influences aggregate trends in policy adoption (Stimson 2004; Erikson et al. 2002).

In a similar fashion, opinion on climate change is, for some portion of the public, stable and largely fixed by ideological and social identities; among other population segments, media coverage, elite cues and other real-world events lead to opinion change. A careful aggregate-level analysis can help clarify the contextual factors that influence these opinion movements in parallel.

As noted, since the first survey on the threat of climate change was taken in 1986, there have been nearly 300 such polls on the topic. But a valid trend has not yet been constructed, in part because existing surveys use slightly different question wordings and occur at irregular intervals. This inconsistency results in discontinuous time-series, with jumps of several years between the administrations of identical polls. When trend interpretations are provided, they are usually based on a single polling series, with the extrapolation of missing data based on polls taken several years apart. This method can result in differing interpretations of the polling results.[1] What remains unaddressed is whether the yearly fluctuations are simply random variations within a normal range of a multiple-year trend or are actually substantial and significant shifts that exceed the sampling errors of the survey.

The inadequacies of polling on climate change, as described above, are well recognized and have resulted in the initiation of several more-robust periodic surveys of public opinion on the topic.[2] However, it will take several years to collect sufficient time-series data to provide reliable and valid measures of shifts in public opinion, and to conduct empirical analyses of the drivers of changes in public opinion.

[1] For example, see the debate between Jon Krosnick based on his NY Times Op-Ed (NY Times June 8, 2010) and the critique provided by the Editor in Chief of Gallup, Frank Newport, in the blog posting of June 10, 2010 (online at http://pollingmatters.gallup.com/2010/06/reflections-on-jon-krosnicks-global.html—accessed 4/19/2011.

[2] See the work of Krosnick (http://woods.stanford.edu/research/surveys.html) and the Six Americas Project at the George Mason University Center for Climate Change Communication: http://www.climatechangecommunication.org/images/files/Six_Americas_June_2010percent281percent29.pdf

The situation encountered in polling over the issue of climate change is encountered regularly in social research on public opinion. One technique that has been developed specifically to analyze existing survey research is Stimson's (1999) "Policy Mood" analysis. The basic idea is to utilize all existing relevant survey data to construct a time-series measure of public opinion on a specific topic, which can then be used to gauge the level of societal concern or "public mood" about a given topic over time.

The first step in such an analysis is to compile survey marginals from all relevant questions. Survey marginals are the percentage of respondents choosing a particular response, e.g., the percentage that sees global climate change as a "serious problem" or a "major threat." Each nationwide survey is treated as a single data point that can be analyzed over time. This form of analysis is quite common—it is used, for example, to compare the latest poll results with those of earlier polls. However, this type of analysis usually results in only a few responses to a particular survey question, administered irregularly over a several year time-period.

To move beyond this limitation, Stimson (1999) uses a complex algorithm that utilizes the relationships between survey marginals to develop a measure of the central tendency across a number of different surveys over time. The approach calculates a comparable metric for each survey question, and then uses the variation in the metric to measure the underlying policy mood. Importantly, this approach allows for the calculation of missing data based on the existing data of other survey responses. By processing a large number of survey marginals among several different surveys, this approach can develop robust and reliable measures of public opinion on a specific topic. It has already been widely used in political science and sociology (Kellstedt 2003, Erikson et al. 2002; Stimson 2004). While this approach has been criticized for being based on mixing a large number of issues (Best 1999), in the present analysis, we are focusing on a single issue area, and so this critique is not relevant. Additionally, recent research on policy mood has moved toward the development of policy-specific mood measures, which is the focus of this paper (Atkinson et al. 2011).

We constructed a time-series measure of public opinion on climate change by applying the Stimson algorithm to polling on climate change using the iPoll database maintained by the Roper Center. The data were searched for poll questions containing the words "climate change," "global warming," or "greenhouse." From these questions we selected those that asked respondents to gauge the level of threat they attributed to climate change. Such questions are tapping into the specific issue salience of global climate change, as well as its perceived seriousness. Accordingly, we label this measure the Climate Change Threat Index (CCTI). Our search identified 14 different questions from 6 different polling organizations in 74 surveys, which were administered to 84,086 respondents between 2002 and 2010. These survey questions thus provide a robust sample of all climate change surveys conducted in the United States[3]

For each question, the marginal score was obtained. For example, consider the response to Q12 (see Supplementary Material) in the Gallup Survey conducted in March 2004: "I'm going to read you a list of environmental problems. As I read each one, please tell me if you personally worry about this problem a great deal, a fair amount, only a little, or not at all. First, how much do you personally worry about…the greenhouse effect' or global warming?" Here, 26% of the respondents said they worried "a great deal." In March 2007, 41% of

[3] The specific questions used in the analysis, dates administered, and surveying organization, and the data used in the analysis are provided in Supplementary Material online. All of the surveys utilized in the calculation of the CCTI were national samples.

the respondents were worried "a great deal." This percentage then declined to only 28% of respondents in 2010. These three survey marginal values (26, 41, and 28), along with the date of the survey and the sample size, were entered into the calculation procedure. A total of 74 different survey marginals were used to construct the CCTI.[4]

The survey marginal scores were processed using the WCALC program, [5] and the Climate Change Threat Index (CCTI) was then calculated. The Threat Index loadings and the number of time periods covered for each question are shown in Table 1, below. As this table shows, the question with the highest loading was the long running question regarding the level of concern over global warming by the Gallup Poll organization (Q12). Not surprisingly, Q47 and Q47A load negatively, as they have a reverse scale of severity of threat (1 being the highest). Overall, the index explains more than 81% of the variance in all of the survey responses.

The results of the changes shown in the CCTI are shown in Fig. 1, below. The vertical axis represents the level of public concern over the threat posed by climate change. As this graph illustrates, public opinion on this topic was relatively unchanged throughout the period 2002 to 2005. None of the shifts in the CCTI during this time exceeded one standard deviation. In essence, the CCTI was stable from 2002 to 2005.

Beginning in the first quarter of 2006, and continuing until the third quarter of 2007 however, there was a steady and persistent increase in the CCTI. The CCTI peaked in the third quarter of 2007 at 53.2. This represents an increase of more than 10 points from where the index had stood during the third quarter of 2005—more than three standard deviations. The peak in the CCTI during the third quarter of 2007 was followed by a rapid decline. By the third quarter of 2009, the CCTI index had fallen 9.2 points, to 44.0. This was a decrease of 2.89 standard deviations. After an increase of 5.4 points in the second quarter of 2009, the index subsequently declined to the levels of the 2002 to 2005 period, and remained at this level through 2010.

As demonstrated, this approach allows researchers to move past the limitations of a single survey instrument and hence permits the analysis of longer time series in public opinion. Because it uses all of the publically available polling data, it maximizes the reliability and validity of the measurement of public concern regarding climate change that can be achieved using available historical polling data. Moreover, this measure now permits an empirical analysis of the factors that drive shifts in public concern over climate change.

2 Drivers of public concern over climate change

The key question is, What drove this change? While there has been a great deal of speculation and analysis of individual level correlates of climate change concern, the relative efficacy of these different factors has not been tested regarding shifts in public opinion at the national level. A review of the existing literature shows that five major categories of explanation have been invoked to explain public opinion about threat of climate change.

One popular idea is that *extreme weather events* are leading to increased recognition of and concern over the threat of climate change (Weber 2011). This approach theorizes that perceptions of the seriousness of climate change are related to individual's personal experiences. Those individuals experiencing the adverse effects of climate change would be more

[4] A complete listing of the survey marginal scores, date of administration, and sample size are provided in the Supplementary Material, Table S1.
[5] The WCALC program is available online at http://www.unc.edu/~jstimson/ .

Table 1 Climate change threat index loadings by variable

Variable	Number of time obsertaons	Correlation with threat index	Mean	Std deviation
Q12	8	0.94	32.50	5.07
Q13	4	0.74	38.50	3.28
Q2	3	0.96	67.00	2.45
Q34	4	1.00	65.50	4.03
Q35	6	0.95	44.07	5.59
Q38	5	0.86	35.60	3.01
Q46	4	0.97	48.50	2.60
Q47	2	−1.00	52.00	1.00
Q47A	3	−0.96	11.33	1.70
Q53	9	0.96	40.89	4.89
Q58	2	1.00	39.00	1.00
Q64	9	0.51	60.67	4.97
Q71	9	0.98	54.50	3.79
Q9	3	0.99	44.00	2.94

Eigen estimate 1.6 of possible 1.97, variance explained: 81.34%, mean: 44.99 St. Dev: 3.19

likely to show higher levels of concern. Several studies show that increasing temperatures (Krosnick et al. 2008), floods (Spence et al. 2011), and other extreme events such as hurricanes and droughts (Borick and Rabe 2010) are associated with individual recognition of climate change and increased salience of the issue. The question is whether this trend also operates at the aggregate level.

A second explanation is lack of *exposure to and understanding of scientific information* about climate change (Bord et al. 2000; Bauer et al. 2007). This approach can be summarized under the Information-Deficit Model. Under this model, the failure of the public to

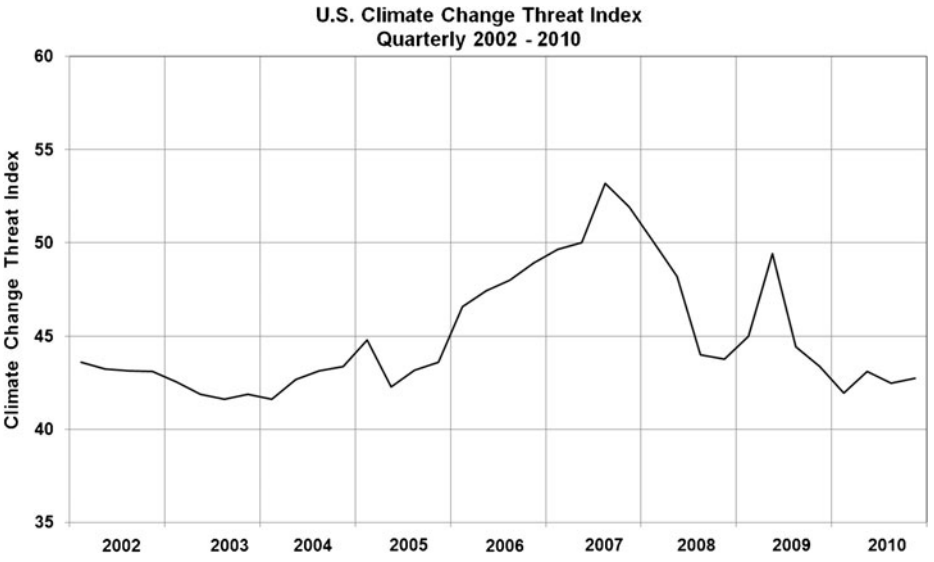

Fig. 1 U.S. climate change threat index, quarterly, 2002–2010

possess a clear understanding of climate science leads to a fundamental misunderstanding of the topic, and underlies the difference between the scientific and public understanding of it. Several factors, including the inherent difficulty of understanding climate change, the limitations of personal experience, and inappropriate mental models all combined to limit individual understanding (Weber and Stern 2011). The logical implication of this view is that culturally and socially appropriate messages that properly convey this information will result in a shift in public opinion about the threat of climate change (Pidgeon and Fischoff 2011; Reynolds et al. 2010; Sterman 2011). However, Reynolds et al. (2010) show that in recent years, there has been a significant increase in information available to the public about the topic. Zhao et al. (2011) found that attention to science-based news has a positive effect on individual concern and knowledge about climate change. Does this process also work on the aggregate level?

A third idea is that *media coverage* influences public concern over climate change. The Agenda-Setting Hypothesis (McCombs 2004; Dumitrescu and Mughan 2010) states that public opinion is a reflection of the extent and prominence of media coverage. According to the Quantity of Coverage Theory (Mazur and Lee 1993; Mazur 1998; Mazur 2009), the major impact of news media coverage is heightened issue salience. The frequency and prominence of a story in media coverage conveys a message to the individual about the relevance of news. Headlines or lead stories further convey the impression that a given issue is important, worthy of an individual's attention. Repeated stories also convey importance. In fact, the frequency of coverage and a story's placement within newspapers matters more than the actual content of reporting in conveying the importance of the issue (Andrews and Caren 2010: 843). As public interest in a given issue is driven to higher levels by media coverage, individuals will then tend to seek out further media coverage of the issue, expanding the level of issue salience (Zhao 2009). The question remains whether shifts in the prominence and quantity of media coverage of climate change has an impact upon aggregate levels of public concern over this issue.

As with any political issue area, the major *advocacy groups* expend considerable effort and funds to mold beliefs and increase salience in favor of their positions. Corporations, industry trade associations, and social movement /countermovement organizations attempt to garner favorable media attention through a variety of means (Gamson et al. 1992; Agnone 2007, Andrews and Caren 2010, Brick and McGreggor Cawley 2008). Climate change is a contentious arena in which multiple organizations compete for media access (Koopmans 2004). A commonly mentioned reason for the recent downward shift in public concern over this topic has been the efforts of the "climate skeptic" or "denier" movement (Weber and Stern 2011; McCright and Dunlap 2011). Several studies document the tactics of these corporate front groups and countermovement organizations to create uncertainty and doubt about the scientific consensus on climate change and the need to take actions to address the issue (Greenberg et al. 2011; Oreskes and Conway 2010; Pfau et al. 2007; Smith 2010).

At the same time, advocates of action on climate change also prominently promote their cause, with perhaps the best known example being Vice President Al Gore's documentary *An Inconvenient Truth*, released in May 2006. The wide release of this movie, and the subsequent Academy Award and Nobel Prize awarded to Vice President Gore, should be expected to confer legitimacy on the seriousness of the issue of climate change to the public and thereby increase aggregate issue salience (Gamson and Wolfsfeld 1993; Andrews and Caren 2010). Beyond this, numerous topical blogs, websites and media projects have been developed to influence media attention and public opinion on climate (Greenberg et al. 2011). Yet there has been no systematic empirical analysis of their impact on public beliefs or the threat associated with climate change as a result of these efforts.

A fifth idea focuses on *elite cues*, specifically those generated by elite conflicts over climate change. Over the past four decades, the major political parties have gone from consensus to polarization on environmental issues (Lowry 2008; Shipan and Lowry 2001). In this school of thought, individuals use media coverage to gauge the positions of elites and interpret the news based on their party and ideological identification (Lenz 2009). Kellstedt (2003) finds that elite cues interact with media coverage to shape aggregate changes in racial attitudes. Is science information different? Darmofal (2009: 392) concludes that science is often superseded by ideological considerations: "When political elites offered dubious policy cues, many citizens followed these cues rather than rejecting them in favor of more valid cues from opposition elites." Yin (1999) found that elite cues and media diffusion influenced public concern about environmental issues. In this vein, several studies have found that more educated individuals are better able to discern rival partisan positions; hence, their individual attitudes about climate change are more closely synchronized with those of their party leadership (Kellstedt et al. 2008; Malka et al. 2009; Borick and Rabe 2010; Hamilton 2010; Brewer and Pease 2008). But this phenomenon has not been examined at the aggregate level (Gamson and Wolfsfeld 1993; Andrews and Caren 2010).

Finally, it is well known that major *economic and political factors* exert an important influence on public opinion. In a recent analysis, Kahn and Kotchen (2010) found that the business cycle influenced levels of environmental concern. Increases in unemployment and lower levels of income both had a negative impact on measures of public concern regarding the environment. Gelpi et al. (2009) show that increased war casualties shift public opinion toward foreign policy concerns. Finally, Bolsen and Cook (2008) show that energy prices have a significant negative impact regarding public acceptance of alternative energy sources over conventional, carbon-based energy sources.

In order to examine the effects of the other independent variables on public opinion regarding climate change, it is necessary to include these four macro level socioeconomic control variables in our analysis.

3 Data and methods

To test the influence of these five factors and the control variables, we developed a series of measures of the independent variables, as described below.[6] There are six different categories of variables.

1. *Extreme Weather Events*. To capture weather extremes, we use four measures of weather variability from the NOAA Climate Extremes Index (Gleason et al. 2008).[7]

    - Overall Climate Extremes Index
    - Extremes in Maximum Temperature—percentage of United States with maximum temperatures much above normal
    - Extremes in 1-Day Precipitation—Twice the value of the percentage of the United States experiencing extreme (more than two inches) one-day precipitation events
    - Drought Levels—percent of U.S. in severe drought based on the PDSI

[6] Specific details about the variables, key words used in searches, specific magazines used in different categories, and the full data used in the analysis is provided in the Supplementary Material.

[7] We also constructed a measure of major landfalling hurricanes in the U.S. based on data from the Center for Research on the Epidemiology of Disasters (CRED) data set (www.credd.be/). However, it produced negative effects and was collinear with the other weather extremes measures, so we do not show it.

2. *Scientific Information*. We used three measures to capture the dissemination of scientific information about climate change:

    - The number of articles about climate change in the refereed journal *Science*
    - Popular scientific magazine coverage of climate change—the number of stories on climate change in 15 major popular scientific magazines
    - Release of major scientific assessments of climate change

3. *Mass Media Coverage*. We constructed a mass media index based on an additive index of three measures:

    - Number of stories on climate change on the nightly news shows of the major broadcast TV networks (NBC, CBS, ABC)
    - Number of stories on climate change in *The New York Times*
    - Number of stories on climate change in *Newsweek*, *Time*, and *U.S. News and World Report*

4. *Media Advocacy*. To capture media advocacy efforts, we utilized three measures:

    - Number of stories on climate change in 12 major environmental magazines
    - Number of stories on climate change in 6 conservative magazines
    - Number of *New York Times* mentions of *An Inconvenient Truth*

5. *Elite Cues*. To capture elite cues, we include three measures?

    - Congressional press release statements on climate change issued by Republicans and Democrats
    - Senate and House roll call votes on climate-change bills identified in the League of Conservation Voters (LCV) National Environmental Scorecard
    - Number of Congressional hearings on climate

6. *Control Variables*. We added four control variables that have been hypothesized to influence public concern about the environment:

    - Unemployment rate
    - Gross Domestic Product
    - War deaths in Iraq and Afghanistan
    - Price of oil

3.1 Data analysis

In this analysis, we assume independent effects between quarters, i.e., that the previous quarter's independent variables do not influence public opinion in the following quarter. This assumption is in line with the media-effects literature, where the time decay effect of media messages on public opinion are well established, and virtually never exceed a month, much less a quarter. In a comprehensive review of media effects decay, Wanta and Hu (1994) found a rapid decline of effects of news stories on public opinion. For example, the effect of national television news on public opinion disappeared in as few as 8 weeks. Integrating a large number of studies of media effects on a variety of attitudes, McCombs (2004: 46) concludes that press coverage has the greatest effect during the first week and then decays logarithmically. Examining environmental and energy issues, MacKuen (1981) found that the effect of news coverage of energy issues on public opinion decayed in a month. Watt et

al. (1993) found that news coverage of environmental degradation had a short-term impact of around 60 days. Finally, Sampei and Aoyagi-Usus (2008: 210) specifically tested the impact of television coverage of climate change on public opinion. They found that this impact "did not last for more than a month." This literature supports our assumption of independence effects between quarters. Thus to appropriately test for media effects and public opinion, an assumption of independence of the effects of the independent variables is theoretically justified, and necessary to ensure fidelity to previous research. As the previous discussion of the CCTI Index shows, public opinion regarding the threat posed by climate change is extremely volatile. In the year from the third quarter of 2007 to 2008, for example, the CCTI dropped nearly three standard deviations. This type of volatility lends credence to the independence of media effects across quarters.[8]

To estimate changes in the CCTI, we used time-series regression with robust standard errors corrected for unspecified heteroskedasticity using White's (1981) correction in Stata 12. Given the limited number of cases (N=36), we can test no more than six independent variables at a time. Durbin Watson statistic suggests no autocorrelation in our models. Tests for multicollinearity with the Variance Inflation Factor (VIF) indicated that the media index is the only variable with even moderate mulitcollinearity (VIF=5.91). Descriptive statistics for all variables are provided in the Supplementary Material. Table 2 shows the results of our time- series regression analysis of the quarterly levels of the CCTI from 2002 to 2010.

4 Results and discussion

The first two models test our first hypothesis, that extreme weather conditions influence public concern about climate change. We use two specifications. Model 1a tests the influence of high temperature, precipitation and drought. Model 1b uses the Climatic Extremes Index developed by NOAA, which includes six indicators of weather extremes. Two separate models were run because the Climate Extreme Index is a composite index that includes the three variables in model 1a. Neither specification was statistically significant, suggesting that weather events, in themselves, do not influence the overall level of public concern regarding climate change. That is not to say that individuals who experience disruptive weather events do not change their opinions regarding the threat posed by climate change. However, the extent of these changes has not reached a level where these shifts can be measured in nationwide polls at the aggregate level. This result may change over time if weather disruptions attributable to climate change increase.

Model 2 tests the hypothesis that the availability of scientific information will lead to an increase in public concern. The model controls for the number of climate change articles in *Science*, popular scientific magazines, and the release of major climate change scientific assessment reports. We found that the number of articles in the journal *Science* does not have

[8] In order to test for the possibility of effects carrying over from one quarter to another, we ran our regression results including the lagged CCTI as an independent variable. In all cases, this procedure resulted in non-significance for all of the independent variables. This is in line with the analysis conducted by Achen (2001). He argues that the addition of a lagged dependent variable (LDV) can inaccurately degrade the effects of the other variables when serial correlation and trending exist in the exogenous variable (as is the case here). Keele and Kelly (2005) further note that if the process is considered to be stationary, the addition of the LDV will bias the analyses. Both the Phillips-Perron and Dickey-Fuller unit root tests showed that the dependent variable is stationary. Since the statistical literature argues against the inclusion of a LDV when the underlying data is stationary and serial correlation is present we only show models without the LDV as they will provide the most statistically accurate estimates.

Table 2 Time-series regression estimates of climate change threat index in the U.S., quarterly, 2002–2010[a]

	Model 1a	Model 1b	Model 2	Model 3	Model 4	Model 5a	Model 5b	Model 6	Model 7
Extreme weather variables									
High temperature	3.127 (7.700)	–	–	–	–	–	–	–	–
High rain	48.104 (32.781)	–	–	–	–	–	–	–	–
Drought	8.290 (6.654)	–	–	–	–	–	–	–	–
Climate extreme index	–	−.004 (.173)	–	–	–	–	–	–	–
Scientific information									
Science magazine (refereed journal)	–	–	−.021 (.063)	–	–	–	–	–	–
Popular scientific magazines	–	–	.195** (.059)	–	–	–	–	–	–
Major climate change assessment reports	–	–	2.533^{+} (1.435)	–	–	–	–	–	–
Media coverage									
Media index	–	–	–	.041*** (.011)	–	–	–	–	−.009 (.009)
Media advocacy									
Environmental magazines	–	–	–	–	.080 (.056)	–	–	–	–
Conservative magazines	–	–	–	–	−.027 (.068)	–	–	–	–
Inconvenient truth *NYT* mentions	–	–	–	–	.176*** (.046)	–	–	–	.066^{+} (.039)
Elite cues									
Pro CC action statements by democrats[b]	–	–	–	–	–	.252*** (.049)	–	–	.112* (.055)
Anti–CC action statement by republicans	–	–	–	–	–	−.166** (.064)	–	–	–
House hearings on CC	–	–	–	–	–	–	−.051 (.159)	–	–
Senate hearings on CC	–	–	–	–	–	–	.209 (.242)	–	–
	–	–	–	–	–	–		–	−.257^{+} (.140)

Table 2 (continued)

	Model 1a	Model 1b	Model 2	Model 3	Model 4	Model 5a	Model 5b	Model 6	Model 7
Anti-environment voting republicans							−.552*** (.141)		
Pro-environment voting democrats	–	–	–	–	–	–	.075 (.111)	–	–
Additional controls									
Unemployment rate	–	–	–	–	–	–	–	−1.146*** (.263)	−.509* (.205)
Gross domestic product	–	–	–	–	–	–	–	.006*** (.002)	.001* (.001)
War deaths	–	–	–	–	–	–	–	−.012* (.006)	–
Price of oil	–	–	–	–	–	–	–	−.051 (.032)	–
Constant	39.91*** (2.18)	44.92*** (3.33)	41.32*** (1.35)	41.96*** (.66)	42.12*** (.70)	42.83*** (.51)	85.38*** (9.33)	−20.95 (16.94)	53.02*** (8.96)
# of Quarters	36	36	36	36	36	36	36	36	36
R^2	.124	.000	.273	.432	.557	.478	.660	.600	.788

+ $P \leq .1$; * $P \leq .05$; ** $P \leq .01$; *** $P \leq .001$. Standard errors are in parentheses. Significance based on two-tailed tests. [a] All Models corrected for unspecified heteroskedasticity using White's (1981) correction. [B] *CC* refers to Climate Change

a significant direct effect on public concern. Because *Science* articles are generally not read by the general public, it is not surprising that they have no discernible direct effect. The release of major scientific assessment reports is marginally statistically significant ($P \leq .1$). The release of these reports produces an increase in the CCTI of 2.5 points. Articles in popular scientific magazines do reach significance ($P \leq .01$). The publication of an individual magazine article in this forum increases the CCTI by .2 points.

Model 3 examines the impact of the media on public attitudes. The media index includes coverage of climate change in *The New York Times*, major broadcast television nightly news coverage, and weekly magazine coverage. As predicted by the media effects literature, media coverage has a significant ($P \leq .001$) impact on public concern over climate change.

The media are also used by advocacy organizations to promote their positions on the environment. Model 4 examines these advocacy efforts using three different measures: the number of climate change articles in environmental and conservative magazines, and *New York Times* mentions of the film *An Inconvenient Truth*. Neither type of magazine article had any significant impact on public concern over climate change. Given the limited circulation and specialized audiences for these outlets, this result is not surprising. However, *New York Times* mentions of *An Inconvenient Truth* significantly boosted the public's perception of the urgency of climate change ($P \leq .001$). The number of mentions in the *New York Times* is a proxy for the extent of overall media attention to this film. The release of this movie, and the subsequent Academy Award, generated an enormous level of public attention regarding the threat posed by climate change. This attention translated into an increase in the CCTI. For every mention of this movie in the *Times*, the CCTI increased by .18 points.

Models 5a tests the effect of elite cues on public opinion by examining the impact of public statements made by members of Congress about climate change. When Democrats released public statements promoting action to address climate change, the CCTI increased significantly ($P \leq .001$). For each statement, the CCTI increased .25 points. Similarly, when Congressional Republicans released public statements opposing climate change action, the CCTI index declined significantly ($P \leq .05$). Each Republican statement drove the index down .17 points.

Model 5b estimates the influence of four additional elite cues that may alter public concern. Here we examined the effect of the number of House and Senate hearings and their effect of environmental voting behavior by members of Congress. Neither of the hearings measures had a statistically significant impact on the CCTI, but the results for public statements made by politicians were more nuanced. Based on the League of Conservation Voters (LCV) Index, we found that when Democrats voted for environmental bills, it had no significant effect on public concern. Since the LCV score of Democrats is very high and does not vary much over the time frame of this study, this result is also not surprising. However, the environmental voting record of Republicans exerted a significant effect on the CCTI ($P \leq .001$). A change of 1 point in the overall Republican LCV score resulted in a change of .5 points in the CCTI. This result shows that the message sent to the public by the Republican voting record on environmental bills is very influential. When the Republican LCV score decreases, so too does the CCTI. Conversely, when the LCV score of Republicans increases, the CCTI also increases. This result provides strong confirmation of the role of elite cues and their influence on public concern about climate change. In an extremely partisan environment, Republican votes against environmental bills legitimate public opinion opposed to action on climate change. When the Republicans increase voting support for environmental bills, it reduces partisanship and increases public support for actions to address climate change.

Model 6 tests controls for a number of additional factors that may influence public attitudes on climate change. Of these controls, only the price of oil fails to reach significance. Consistent with our expectations, economic factors play a major role in the CCTI level ($P \leq .001$). An increase in the unemployment rate significantly decreases the CCTI, and conversely, an increase in GDP significantly increases the CCTI. The number of U.S. war deaths in Iraq and Afghanistan significantly decreases public concern about climate change ($P \leq .05$). These findings suggest that when there is a shock to the economy or intensification in the wars, the general public may reduce their level of concern about climate change.

Model 7 is a combined model that includes only those variables about which we were most confident regarding their effect on the CCTI. Given the limited number of cases in the study, we estimate a combined model using only those variables that attained statistical significance at the .001 level. These are 1) Media Index, 2) *New York Times* coverage of *An Inconvenient Truth*, 3) Pro-climate change action statements by Democrats, 4) Anti-environmental voting by Republicans, 5) Unemployment rate, and 6) GDP. The results of this combined model show that all variables remain statistically significant predictors of the CCTI except the media index. The overall explanatory power of the model increases. This combined model explains nearly 80% of the variance in the CCTI ($R^2 = .79$). The characteristics of this model are shown in Table 3, below.

An examination of the normalized or beta coefficients allow for a comparison regarding the relative influence of each factor upon the CCTI. We see from these coefficients that public statements in support of climate change action by Democrats are the strongest positive predictor of change in the CCTI (Beta=.408), followed by increases in GDP (Beta=.238) and then *New York Times* mentions of *An Inconvenient Truth* (Beta=.223). The strongest negative predictor is the level of LCV anti-environmental Republican voting patterns (Beta=−.322), and the unemployment level (Beta=−.29).

The failure of the Media Index to have a significant effect on the CCTI is at first glance perplexing. But when the other five factors are taken into account, the effect of media is accounted for. To test this assumption, we ran a regression using the Media Index as the dependent variable, and the other five factors in the model as independent variables. The results showed that 83% of the variation in the Media Index is accounted for by the variables in Model 7. This is not to say that the media do not influence our outcome measure. Rather, the Media Index does not reach significance because its effect is accounted for by the factors already in the model.

Overall, our results show a dynamic in which media coverage of climate change and elite cues from politicians and advocacy groups are among the most prominent drivers of the public perception of the threat associated with climate change. We see that, after controlling for macroeconomic conditions and war deaths, when Congressional Democrats speak publically about the need for action on climate change, the public increases its perception

Table 3 Model seven characteristics

Model input	Model coefficient	Beta coefficient
Dem statements pro CC action	0.112	0.408
LCV rep anti-env	−0.257	−0.322
Unemployment	−0.509	−0.290
GDP	0.001	0.238
NY times mentions	0.066	0.223
Constant	53.020	

Total R^2 value=.778, root mean square error=1.6325 95% confidence interval±3.265

of the seriousness of the issue. Yet, when Congressional Republicans vote against key pieces of environmental legislation, the public adjusts perceptions of the threat of climate change downward. Our results also show that advocacy efforts produce substantial changes in public perceptions related to climate change. Specifically, the film *An Inconvenient Truth* and the publicity surrounding its release produced a significant positive jump in the CCTI.

To illustrate the overall coverage of Model 7, the Model Coefficients (provided in Table 3) were utilized with the empirical data measures of the independent variables to calculate the predicted values of the CCTI. These values of the calculated CCTI, along with the 95% confidence interval (in light red) are shown in Fig. 2. In addition, the actual values of the CCTI are shown in black. This graph shows the extent of the fit provided by this model. There are only two brief periods when the actual values of the CCTI lie outside of the 95% confidence interval. Thus, this model shows a robust capacity to predict the actual CCTI.

This empirical investigation allows for the construction of a narrative regarding the shifts in the CCTI and enables us to answer the question as to why concern over climate change first increased in 2006 and 2007 and declined thereafter. As discussed earlier, until the end of 2005 the CCTI was relatively stable. Beginning in the first quarter of 2006, and continuing until the third quarter of 2007, there was a steady and persistent increase in the CCTI. During this same period, the LCV score of Republican anti-environmental voting decreased and Democratic statements in favor of action on climate change increased. Prominent Republican Senators such as John McCain were openly advocating for climate change legislation and working with Democratic Senators to pass it. Congressman Newt Gingrich appeared in commercials with Speaker of the House Nancy Pelosi to support government action to address climate change. Clearly, partisanship over the issue of climate change declined in 2006 and 2007. Taken together, these elite cues worked to increase concern about this topic. This congressional unity was coupled with the release of *An Inconvenient Truth*, and its subsequent receipt of an Academy Award, which greatly increased public concern about climate change. The subsequent release of the IPCC report in 2007 further facilitated

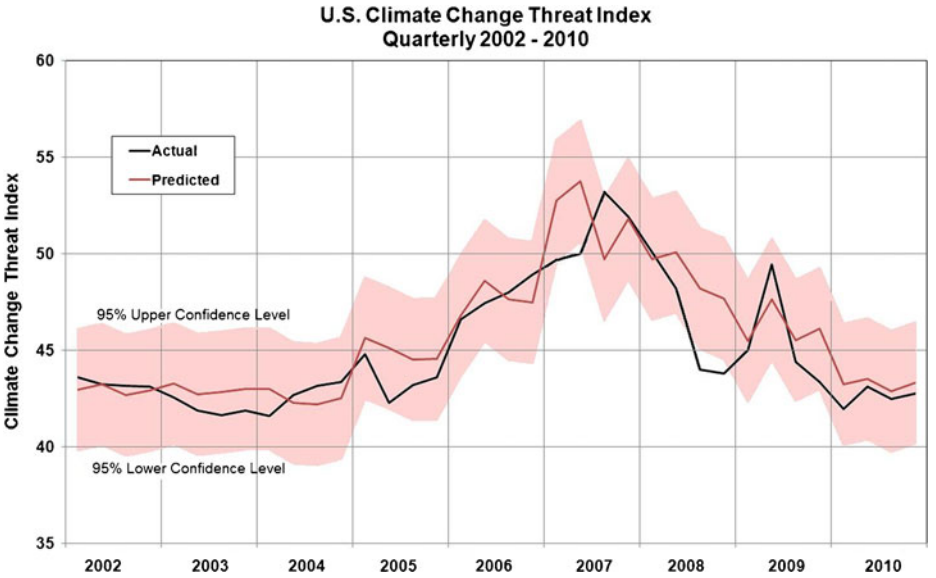

Fig. 2 U.S. climate change threat index model, quarterly, 2002–2010

increases in the CCTI. During this period, GDP was increasing, and unemployment remained low and stable.

Then, beginning in 2008, the level of Republican anti-environmental voting increased progressively, reaching the highest level ever recorded in 2010. Whatever remained of the cooperation between Republicans and Democrats on environmental issues, and the subsequent elite cues provided by the Republican voting record, drove down climate change concern. The media coverage of *An Inconvenient Truth* faded, and the influence of this factor declined. Additionally, unemployment increased, and GDP declined, following the 2008 financial collapse. These economic trends also contributed to a decline in the CCTI. There was one final increase in the CCTI during the second quarter of 2009, when a number of Democratic congressional statements were released, urging action to address climate change. These statements coincided with the House debate and vote on *H.R. 2454: American Clean Energy and Security Act of 2009* (commonly referred to as the Waxman –Markey Bill) in June of 2009. Subsequently, the CCTI declined to the level of the 2002 to 2005 period, and remained at this level through 2010.

As this analysis has shown, Stimson's (1999) algorithm can be used to develop valid and reliable methods to examine public concern on climate change. The calculation of a Climate Change Threat Index allows research to move past the limitations of a single-survey instrument and permits longer time-series analyses to evaluate empirical explanations of the factors that drive public concern about climate change. It also compliments the existing research based on individual-level analyses by evaluating which aggregate factors influence aggregate changes in public concern over time. We need no longer rely on conjecture regarding the factors that drive changes in aggregate public concern over climate change.

This analysis opens the door to future research regarding these driving factors, which will need to address the limitations imposed by the availability of time-series polling data on climate change. Due to the uneven scheduling of polls on this topic, it is very difficult to construct a monthly-level measure of concern over climate change. This problem precludes analysis of short-lived factors that influence climate-change concern. The consistent and empirically robust collection of public opinion on climate change is a necessary prerequisite to furthering this form of analysis. Additionally, there is a need to expand the range of variables to include climate movement and countermovement activities (such as demonstrations, book publication, or public meetings), advertising expenditures by proponents and opponents of action on climate change, coverage of climate change on cable news shows (such as CNN, FOX, and MSNBC), as well as the effect of talk radio and comedy news broadcasts (such as The Colbert Report and The Daily Show).

One final but critical area ripe for additional research involves second-order media effects, i.e. does the framing employed in mass-media coverage of climate change influence public-concern levels? This analysis is restricted to examining only first-order effects by measuring quantity of coverage. A number of studies examine media framing of climate change. From this research has come conjecture about how these different framings impact aggregate public concern, but to date these ideas have not been assessed empirically.

5 Conclusions

In this analysis, we set out to test a number of hypotheses regarding the factors that drive levels of public concern over climate change. Overall, the analysis explains nearly 80% of the variance in U.S. Public concern over climate change. Specifically, we found that weather events, in themselves, do not influence the overall level of public concern (so far). The

promulgation of scientific information about climate change has a small but significant effect. Science articles, generally not read by the public, have no discernible effect, while major assessment reports and articles on climate change in popular science magazines do affect public concern. The implication would seem to be that science-based information is limited in shaping public concern about the climate change threat. Other, more directly political communications appear to be more important.

The major factors that affect levels of public concern about climate change can be grouped into three areas. First, media coverage of climate change directly affects the level of public concern. The greater the quantity of media coverage of climate change, the greater the level of public concern. This is in line with the Quantity of Coverage theory of media effects, and existing individual level research on the impact of television coverage on climate-change concern. The importance the media assigns to coverage of climate change translates into the importance the public attaches to this issue. Second, in a society with a limited amount of "issue space," unemployment, economic prosperity, and involvement in wars all compete with climate change for public concern.

The most important factor in influencing public opinion on climate change, however, is the elite partisan battle over the issue. The two strongest effects on public concern are Democratic Congressional action statements and Republican roll-call votes, which increase and diminish public concern, respectively. This finding points to the effect of polarized political elite that is emitting contrary cues, with resulting (seemingly) contrary levels of public concern. As noted by McDonald (2009: 52) "When elites have consensus, the public follows suit and the issue becomes mainstreamed. When elites disagree, polarization occurs, and citizens rely on other indicators, such as political party or source credibility, to make up their minds." This appears to be the case with climate change.

The implication would seem to be that a mass communications effort to alter the salience of the climate change issue is unlikely to have much impact. A great deal of focus has been devoted to the analysis and development of various communication techniques to better convey an understanding of climate change to individual members of the public. However, this analysis shows that these efforts have a minor influence, and are dwarfed by the effect of the divide on environmental issues in the political elite. Additionally, the analysis has shown that, in line with the media effects literature, the effects of communication on public opinion regarding climate change are short lived. A high level of public concern over climate change was seen only during a period of both high levels of media coverage and active statements about the issue's seriousness from political elites. It rapidly declined when these two factors declined. Thus, if public concern is to be sustained under the present circumstances, there is a need for continuous public communications efforts to maintain public support for climate change action in the face of opposing messaging campaigns (Habermas 1989: 141).

The more important factor at the aggregate level is the polarized positions taken by Democrats and Republicans. This polarization over environmental issues is long standing, and has extended to the climate- change arena, making it a highly partisan issue. Given the vested economic interests reflected in this polarization, it seems doubtful that any communication process focused on persuading individuals will have much impact. As Orr (2005) has noted, the barriers to action on climate change are based in the distribution of social power in the economic, political, and cultural spheres. Introducing new messages or information into an otherwise unchanged socioeconomic system will accomplish little (Luke 2005). Observing the limits of communication to resolve conflicts of this nature, Strömbäch and Kiousis (2011: 6) note that "some conflicts and questions of power are rooted in enduring and incompatible differences between positions or interests, and cannot be resolved through communication." Therefore, any communications strategy that holds

out the promise of effectiveness must be linked to a broader political strategy. Political conflicts are ultimately resolved through political mobilization and activism. Further efforts to address the issue of climate change need to take this into account.

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