CLIMATE CHANGE EDUCATION THROUGH TV WEATHERCASTS

Results of a Field Experiment

by Xiaoquan Zhao, Edward Maibach, Jim Gandy, Joe Witte, Heidi Cullen, Barry A. Klinger, Katherine E. Rowan, James Witte, and Andrew Pyle

A field study shows that on-air and online education provided by a TV meteorologist over the course of one year improved viewers' understanding of climate change.

The nation's TV meteorologists and weathercasters[1] (more about the distinction can be found at www.ametsoc.org/policy/guidline_term_meteorologist.html)—the vast majority of whom work in local TV—are a potentially important source of informal science education about climate change for a wide cross section of the U.S. population. Even though digital news consumption has been steadily increasing, particularly among young people (Pew Research Center 2013a), many American adults ages 18 and older still regularly watch local TV news and network TV news (Miller et al. 2006; Pew Research Center 2013b); and the daily weather segment is a perennial favorite among them (Pew Research Center 2013b; Silcock et al. 2006). Furthermore, TV weather reporters are seen as a trusted source of information about climate change by a solid majority (60%) of adult Americans (Leiserowitz et al. 2012). Indeed, TV weather reports are arguably one of the most common voluntarily sought forms of science education in the daily lives of most adult Americans (Wilson 2008). Previous research suggests that weathercasts can be an important and effective venue for informal science education on a wide range of topics such as geography (Earl and Pasternack 1991), public health (Johnson 2009), and hurricane risk (Demuth et al. 2012).

AFFILIATIONS: Zhao, Maibach, Jo. Witte, Klinger, Rowan, Ja. Witte, and Pyle—George Mason University, Fairfax, Virginia; Gandy—WLTX, Columbia, South Carolina; Cullen—Climate Central, Princeton, New Jersey
CORRESPONDING AUTHOR: Xiaoquan Zhao, Department of Communication, Center for Climate Change Communication, George Mason University, 4400 University Drive, MS 3D6, Fairfax, VA 22030
E-mail: xzhao3@gmu.edu

The abstract for this article can be found in this issue, following the table of contents.
DOI:10.1175/BAMS-D-12-00144.1

In final form 23 April 2013

[1] According to the American Meteorological Society, "a meteorologist is an individual with specialized education who uses scientific principles to observe, understand, explain, or forecast phenomena in Earth's atmosphere and/or how the atmosphere affects Earth and life on the planet." Individuals who lack formal education in the atmospheric sciences but disseminate weather information and forecasts prepared by others are designated weathercasters. In this article, we use the terms "meteorologists" and "weathercasters" loosely to include both in our discussion of using TV weathercasts as a conduit for informal science education on climate change.

In this article, we describe an informal climate science education initiative conducted by the chief meteorologist at one local TV station in Columbia, South Carolina (SC). Branded under the name "Climate Matters," this initiative intermittently produced and aired (during the weather segment, with reposting to station's website) brief educational segments using current weather events to educate viewers about the local relevance of climate change. To evaluate the impact of the first year of this programming, we conducted viewer surveys in the Columbia media market before the educational programming started and again one year later. The primary outcomes of the evaluation were perceptions, feelings, and knowledge about climate change, which we broadly refer to in this article as climate change beliefs.

BACKGROUND AND RATIONALE. *The problem.* Although a solid majority of Americans agree that "global warming is happening" (70% in September 2012; Leiserowitz et al. 2012), public understanding of climate change is more limited. For example, in fall 2012 only half of the American adult population (54%) understood that the current global warming is caused primarily by human activities and only one-third (44%) understood that most scientists are convinced that global warming is real.

The most current U.S. National Climate Assessment (United States Global Change Research Program 2009) found that a variety of climate impacts, including rising temperatures and sea level, changes in precipitation and seasons, and harms to human and animal health, are already taking place in every region of the nation. Yet, most Americans see climate change as distant in both space (i.e., not in the United States) and time (i.e., not now; Leiserowitz 2005). For example, in September 2012 only 48% of adult Americans believed that global warming would harm people in their community "a moderate amount" or more and only 36% believed that people in the United States were being harmed currently (Leiserowitz et al. 2012).

Media-based climate change education. These low levels of climate knowledge have motivated various efforts to improve understanding. Some government agencies, such as the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), have contributed broadly to climate change education over the years. But, for the most part, media-based education efforts have been limited in scale and systematic evaluation of their impact has been lacking (Akerlof and Maibach 2008). Although the evidence is sparse and mixed (e.g., Staats et al. 1996), at least some large-scale campaigns do appear to have had some influence on climate change–related beliefs, attitudes, and behaviors (Akerlof and Maibach 2008; Cugelman and Otero 2010; Tremblay et al. 2013).

News media coverage is another way that the public can learn about climate change (Brulle et al. 2012; Russell 2008). Several studies have examined the relationship between news consumption and people's understanding of climate change. A study using data from 74 separate surveys over a 9-yr period found that media coverage is an important influence on public concern over climate change (Brulle et al. 2012). Another study showed that the news coverage of climate science—even when satirized—can help members of the public develop a more science-based understanding of the issue (Feldman et al. 2011). Research focusing on learning from digital news sources is lacking. But one study did find that Internet use in general contributed to perceived knowledge and concern over global warming (Zhao 2009). These positive findings make the paucity of research on media campaigns and news coverage of climate change both conspicuous and problematic (Maibach et al. 2008).

The potential of news media–based climate change education. Many professional communities routinely study and use strategic communication as an asset in their public education efforts (Abroms and Maibach 2008). Most notably in the public health community, campaigns have been shown to contribute to important improvements in public health outcomes (Hornik 2002a). A brief review of what has been learned in other fields provides a useful context as to why TV meteorologists have considerable potential as climate educators.

In any form of public communication, exposure is a prerequisite for the intended effects (McGuire 2012). A meta-analysis of public health communication campaigns found a strong positive correlation ($r = 0.47$) between reach—the percentage of the audience exposed to campaign messages at least once—and campaign effects (Snyder and Hamilton 2002). Yet, adequate exposure is often difficult to achieve in media-based education efforts because media campaign resources are often limited and campaign messages have to compete with myriad inconsistent and irrelevant messages in a cluttered information environment (Hornik 2002b; Randolph and Viswanath 2004). The nation's broadcast meteorologists, however, are exceptionally well positioned to generate effective exposure locally and nationally. Although an increasing number of Americans, particularly young people, are turning to the Internet and mobile devices for their news, television remains a dominant source of local information (Pew Research Center 2013a,b). Approximately 70% of American adults ages 18 and older watch local TV news at least once a week (Miller et al. 2006; Pew Research Center 2013b) and their primary reason for doing so is to learn about the weather (Pew Research Center 2013b; Silcock et al. 2006; Smith 2007).

Apart from limited exposure, media-based education campaigns may also face the problem of limited public trust in the communicator (i.e., the information source). A long tradition in communication research shows that trust in the source is a critical factor in message effectiveness (Hovland and Weiss 1951). Recent research in the specific context of climate change also attests to the importance of trust in improving public understanding of the climate change science (Malka et al. 2009). It should be noted, however, that climate change is one of the most controversial issues in public discourse in the United States today (Hulme 2009). In issue contexts teeming with contradictory messages and political strategizing, cynicism and distrust in sources are likely to arise (Cappella and Jamieson 1997; Herreros and Criado 2008). While scientists are the professional community that the public trusts most about climate change (Leiserowitz et al. 2012), there are several important limitations on scientists' potential as climate educators. Public trust in scientists has shown a general decline over the past few decades, particularly among conservatives (Gauchat 2012). Perhaps more importantly, scientists have relatively limited access to the public—few members of the public can even name a single living scientist (Research!America 2013). TV weathercasters, on the other hand, have excellent access to a broad cross section of the public on a regular basis (as documented above). They also have outstanding credibility—they are second only to research scientists and government science agencies as trusted sources of information about climate change (Leiserowitz et al. 2012).

Harnessing opportunities for experiential learning. Cognitive science research has identified two parallel interacting modes of information processing, one of which is "slow" and effort based and the other is "fast" and effortless (Kahneman 2011). The slow effortful processing system is analytical, logical, and deliberative, and it encodes reality in abstract symbols, words, and numbers (such as the abstractions and statistics of climate science). By contrast, the fast effortless processing system is holistic, affective, and intuitive, and it encodes reality in concrete images, metaphors, and narratives linked in associative networks, often derived from repeated patterns of direct experience. "Experientially derived knowledge is often more compelling and more likely to influence behavior than is abstract knowledge" (Epstein 1994, p. 711). Likewise, vivid, concrete information has a greater influence on perceptions and inferences than does "pallid" (e.g., abstract and technical) information (Nisbett and Ross 1980). Recent research has shown that people who learn about climate change through personal experience are much more likely to engage with the issue (and seek more information) than people who learn about it merely through exposure to analytical (didactic) information (Leiserowitz 2006; Marx et al. 2007; Spence et al. 2011; Weber 2006, 2010).

Local TV weather reports provide a context and conduit for experientially based climate change education that offers distinctive advantages over traditional media campaigns. As discussed earlier, climate change education embedded in local weather reports is likely to reach large audiences both efficiently and effectively. Local television meteorologists are also a trusted source of global warming information for many viewers. Severe weather provides powerful experience-based opportunities for meteorologists to educate their viewers about the relationship between weather (e.g., extreme precipitation) and climatic events (e.g., droughts) and climate change. While the nature and extent of this relationship have been a subject of ongoing investigation, there is evidence that heat waves, droughts, hurricanes, and other extremes have intensified and will intensify farther in the future (Trenberth et al. 2007; United States Global Change Research Program 2009; Knutson et al. 2010). Such phenomena provide opportunities to help the public understand the difference between weather and climate; how climate change affects extreme weather events; how an individual extreme weather event can never be wholly attributed to climate change, yet can be consistent with climate trends and projections; and how a series of extreme weather events in a wider geographic context or longer temporal scale provides evidence of global climate change (Friedman et al. 1999; Dessai et al. 2004; Doherty and Barnhurst 2009). Moreover, from a learning perspective, many people rely upon broadcast meteorologists to interpret and respond to extreme weather events (Henson 2010), which often generate strong emotional reactions and which in turn can focus attention and support new learning (e.g., Slovic et al. 2004).

Large numbers of TV meteorologists are willing and eager to adopt the role of climate educator (Maibach 2012). This is consistent with an expanded professional role (and identity) that has been developed and promoted by the American Meteorological Society over the past several years: that of weathercaster as "station scientist" (Posegate 2008; Wilson 2009). It should be noted, however, that TV meteorologists do not hold uniform positions on climate change. Although a large majority of them (82%) believe that global warming is happening, many (63%) have doubts whether global warming is primarily human caused (Maibach et al. 2011). How to improve science-based understanding in the meteorologist population at large thus is in itself an important challenge (Nese et al. 2012).

DESIGN AND DELIVERY OF CLIMATE MATTERS.

Education materials. In its first year, twelve educational segments were produced and aired. The core content for each segment consisted of a script and supporting graphical materials. These were developed by broadcast meteorologists, climate scientists, communication scientists, writers, and graphic designers from a number of collaborating institutions, including George Mason University, Climate Central, and WLTX TV in Columbia, SC. Scientific journals and government websites [such as http://climate.nasa.gov (NASA) and www.climate.gov (NOAA)] were utilized as sources of climate science research and education materials. The chief meteorologist at WLTX produced each segment on the day it aired. Segments typically ran about a minute and a half, including brief introductory comments. Each segment was self-contained, focused on one or two related points, and connected as much as possible to the experience of the viewers.

Seven of the segments addressed extreme weather (and were intended for airing during or just after the relevant extreme weather or climatic event) and five addressed "evergreen" topics (and could be aired anytime). The specific focus of each segment is presented in Table 1. Most of the segments explained probable impacts of climate change on the weather, environment, and people of the specific Columbia area or South Carolina more generally. The goal was for viewers to see that climate change was a real phenomenon that could have real and noticeable effects on matters they care about.

The extreme weather segments included variations on the relationship between global warming

Table 1. Climate Matters timeline and educational segments. Segment length is given in minutes and seconds.

Date	Activity	
11 May–15 Jul 2010	Baseline survey of panel sample	
2 Aug 2010	Campaign began	
	Segment name	***Description (length)***
2 Aug 2010 (again 8 Sep 2010)	High temperatures	Increasing number of ≥95°F days as GHG emissions increase—separate segment for each summer month (1:18).
12 Aug 2010	Extreme heat	Increasing likelihood of ≥101°F days for today, 2040s, and 2070s (1:16).
25 Aug 2010	Climate	Baseball statistics analogy explains difference between weather and climate (1:54).
16 Sep 2010	Hurricanes	Climate change may make hurricanes less frequent but more intense (1:30).
1 Oct 2010	Intense storms	Climate change may be making intense rainfall more intense in the United States (1:55).
12 Nov 2010	Sea level rise	Rate of sea level rise along South Carolina coast may triple (1:54).
9 Mar 2011	Poison ivy	More CO_2 may make some plant pests like poison ivy grow better (1:31).
22 Apr 2011	Human cause	How we know greenhouse gas (GHG) increase is due to people (1:20).
12 May 2011	Air quality	Connection between warmer temperature and code red smog days (1:07).
31 May 2011	Heat and human health	Heat is already the top weather-related killer in the United States, and GHGs will likely increase heat index in the Southeast (1:23).
9 Jun 2011	Drought	Drought outlook to explain risk for increased drought in a warmer world (2:23).
12 Jun 2011	Global weirding	Global warming can cause opposite weather extremes (1:26).
10 Jul–30 Aug 2011	Follow-up survey of panel sample; survey of new cross-sectional sample.	

and heat waves and the connection of heat waves to air pollution and heat-related fatalities. Other segments focused on drought, extreme precipitation events, and hurricanes. Three of the evergreen segments also focused on impacts including sea level rise, extreme weather events (of various kinds), and increased potency of poison ivy. The other evergreen segments focused on fundamental—and therefore more abstract—explanations of climate and global warming. (All of these segments can be viewed online at www.wltx.com/weather/climate/default.aspx.)

Intervention delivery. The Climate Matters segments began airing in evening newscasts in early August 2010, in response to current weather events. Columbia experienced its hottest summer to date in 2010, and many of the heat-related segments were aired then; others were aired at appropriate times throughout the year. Typically, but not in all cases, the segments immediately preceded the weather forecast and were set up by a news anchor creating a segue (such as a question, or statement, about climate change) responded to by the chief meteorologist. The segments were never advertised or used in teasers.

A Climate Matters section was created for the TV station's website. The website included climate-related news stories, climate-related information from the National Weather Service, a blog written by the station's chief meteorologist, and (after each educational segment was produced and aired) the Climate Matters educational videos. The blog was mostly related to the videos but occasionally also addressed other important issues and research related to climate change. The blog was updated intermittently, depending on availability of time and materials for the chief meteorologist.

EVALUATION METHOD. *Overview.* The impact of Climate Matters was evaluated using a quasi-experimental design employing both panel and cross-sectional surveys (see Table 1 for timeline). The target population was adult local TV viewers 18 and older in the Columbia media market. Because no prior research of this kind was available to guide our power calculation, we determined sample sizes based on the general assumption of a small learning effect. This assumption is consistent with the typical effect size observed in public communication campaigns in other domains (Snyder and Hamilton 2002). Availability of resources was also considered in the determination of sample sizes. The target sample size for the baseline survey of the panel was 1,000, anticipating a 50%–60% retention rate at follow-up. The target sample size for the cross-sectional survey was 800.

To establish baseline measures, prior to the intervention we conducted a telephone survey of adult TV news viewers in the Columbia media market using random digit dialing (RDD; $N = 1,068$). We screened respondents based on the local news station they watched most frequently to create a final sample with similar numbers of WLTX viewers and viewers of competing stations. Approximately one year later, we resurveyed all available members of the baseline cohort ($n = 502$), and we surveyed a new independent sample of randomly selected residents ($N = 910$). Each survey assessed a range of beliefs about global warming. The follow-up surveys also assessed exposure to Climate Matters. Learning effects were investigated by examining the association between exposure to Climate Matters and beliefs about climate change in both the panel data and in the additional cross-sectional data. Sample characteristics are summarized in Table 2.

Survey administration. All surveys were conducted using computer assisted telephone interviewing (CATI) facilities. After training the interview staff and pretesting the survey instrument with trial calls, the baseline telephone interviews began 11 May 2010 and continued through 15 July 2010. The response rate for the survey was 9.2% based on the American Association of Public Opinion Research (AAPOR 2011) standard definitions (response rate 4). The relatively low response rate is likely due to both general and specific factors. In general, telephone survey response rates have been declining for many years (Curtin et al. 2005; Holbrook et al. 2007). Specific to our survey, the interview was relatively long (approximately 25 min) and, as the baseline of a longitudinal study, respondents were informed that the research would involve a follow-up survey a year later. The screening questions based on TV viewing habits (see below) also led some potential respondents to mistake our study for a marketing survey and refuse to participate.

The follow-up interviews began in early July 2011. Just under half (47%) of the respondents to the baseline interviews completed a follow-up interview. Another independent cross-sectional survey was also conducted at the same time. Response rate for the cross-sectional survey was 8.0% (AAPOR response rate 4).

Questionnaire. The questionnaire used in the baseline, follow-up, and post-only surveys began with screening questions to identify viewers of WLTX versus other local stations. Those reporting watching news on WLTX at least once a week and not watching news on any of the competing stations were designated as WLTX viewers in our analysis. Those reporting watching news only on non-WLTX stations were labeled non-WLTX viewers.

The questionnaire then asked a series of questions to assess beliefs and attitudes about global warming. We chose to focus on global warming because it is a familiar concept to the public and a central phenomenon in global climate change. Global warming was also the underlying theme for most of the educational segments used in Climate Matters. We assessed beliefs about the certainty, human cause, and harms of global warming as the primary outcomes of the evaluation. Secondary outcomes included a number of additional beliefs that could also be influenced by the intervention even though they were not directly targeted. These included worry, perceived importance, priority of the issue for the president/congress, timing of harm, injunctive norm, and perceived scientific agreement. Measurement details on these outcomes are provided in Table 3. Response scales varied for these measures in accordance with the nature of the questions as well as the preference to use verbal response options in a telephone survey.

Exploratory factor analysis of the secondary outcomes (not including perceived scientific agreement) showed that these variables all loaded on a single underlying factor. This factor was able to account for 61% of the variance among the variables in the panel baseline data, 69% in the panel follow-up data, and 62% in the cross-sectional data. These variables were converted to standardized scores and averaged into a general measure of concern over global warming.

Table 2. Sample characteristics. Note that percentages do not always add up to 100% because of missing data (as a result of refusal, no applicable answers, and/or recording error).

	Panel sample (*N* = 502)		Cross-sectional sample (*N* = 910)	
	Unweighted percentage	Weighted percentage	Unweighted percentage	Weighted percentage
Gender				
Male	31.9	47.3	34	47
Female	67.7	52.3	66	53
Race				
White	62.7	55.1	60.2	59
Black	30.7	39.6	33.7	37
Other	4.8	3.5	5	3.2
Age				
18–34	9.8	33.9	14.8	32.5
35–44	10.8	19.4	14.2	20.9
45–64	47.6	29.9	43.6	29.2
65 and above	30.9	15.8	26	16.2
Education				
Less than high school	11.6	19	8.2	18.1
High school graduate	20.9	26.2	21.9	28.7
Some college	28.3	26.8	29.2	28.3
Bachelor's degree	18.5	18.8	21.5	16.7
Graduate or professional degree	19.3	7.7	18.5	7.8
Political Party				
Republican	28.5	25.4	24.1	25.7
Democrat	33.3	36.6	34.7	31.2
Independent	20.5	17.7	21	18.5
Other	12.8	16.2	16.5	19.9

In the follow-up and independent cross-sectional surveys, exposure to Climate Matters was measured. Respondents were asked whether in the past year they had seen any special segments during the local weather forecast that focused on global warming or climate change. Response to this question (yes vs no and not sure) was taken as a measure of general campaign awareness. Respondents were also presented with brief descriptions of four educational segments and asked to indicate whether they remembered seeing each of them on TV. These four segments were randomly selected from the twelve that aired. The number of affirmative answers was treated as a measure of recognition.

Background information on the respondents was gathered at the end of the questionnaire. In addition to basic demographics (gender, race, age, and education), we also asked questions about political party (Republican, Democrat, or Independent/other) and political ideology [1 (very liberal) to 5 (very conservative)].

Analysis strategy. With a series of regression analyses, we tested two hypotheses.

- H1: WLTX viewers will demonstrate greater learning gains than will viewers of other stations.
- H2: Regardless of initial station preference, viewers with more exposure to Climate Matters will demonstrate greater learning gains than viewers with less exposure.

WLTX viewership was used as the independent variable to test H1, and Climate Matters awareness and recognition were used as independent variables to test H2. Global warming beliefs served as the dependent variables.

These analyses were conducted on both the panel sample and the post-only cross-sectional sample. In all analyses, we controlled for a range of demographic and political background variables, including gender, age, race, and education, as well as political party and

Table 3. Key outcome questions in the evaluation surveys.

	Questions	Coded responses
Primary outcomes		
Certainty	Do you think that global warming is happening? How sure are you that global warming is (is not) happening?	–4 (complete certainty that global warming is not occurring) to 0 (not certain/do not know) to 4 (complete certainty that global warming is occurring)
Human causation	Assuming global warming is happening, do you think it is . . .	0 (not happening or caused mostly by natural changes in the environment) to 1 (caused mostly by human activities)
Harm extent	How much do you think global warming will harm you personally/future generations of people (two items, α_{panel} = 0.84 and $\alpha_{x\text{-sectional}}$ = 0.75)	1 (not at all) to 4 (a great deal)
Secondary outcomes		
Concern	Average of worry, importance, priority, harm timing, and injunctive norm after converting each to *Z* scores ($\alpha_{panel\ baseline}$ = 0.81, $\alpha_{panel\ follow\text{-}up}$ = 0.87, and $\alpha_{x\text{-sectional}}$ = 0.82)	
Worry	How worried are you about global warming?	1 (not at all worried) to 4 (very worried)
Importance	How important is the issue of global warming to you personally?	1 (not at all important) to 5 (extremely important)
Priority	Do you think global warming should be a low, medium, high, or very high priority for the president and congress?	1 (low) to 4 (very high)
Harm timing	When do you think global warming will start to harm people in the United States?	1 (never) to 6 (now)
Injunctive norm	Do you think citizens themselves should be doing more or less to address global warming?	1 (much less) to 5 (much more)
Perceived scientific agreement	Which comes closer to your own view?	0 [consensus not understood (a lot of disagreement among scientific or most scientists think global warming is not happening, or do not know enough to say)] to 1 [consensus understood (most scientists think global warming is happening)]

ideology. In the panel analysis, we also controlled for the outcome belief at baseline. The panel analysis essentially assessed the change in the outcome variable over time as a function of campaign exposure and other control variables. The cross-sectional analysis, on the other hand, examined the contemporaneous relationship between the current outcome and campaign exposure. For both analyses, statistical significance was set at $p < 0.05$ (i.e., when the probability of observing an effect by chance is less than 5%). When the outcome variable was continuous (or treated as such, e.g., certainty), we used multiple linear regression. When the outcome variable was dichotomous (e.g., human causation), we used logistic regression.

To facilitate understanding, we report predicted values (for multiple linear regression) and predicted probabilities (for logistic regression) instead of regular regression coefficients. These results are presented with respect to specific groups (e.g., WLTX viewers versus non-WLTX viewers) and can be compared to see how the intervention did (or did not) influence the outcomes, while assuming no group differences on the control variables.

RESULTS. *Longitudinal analysis.* Before conducting the final analysis, we examined the comparability of panel sample participants who completed the follow-up survey to those who did not. The two groups were not significantly different with regard to race ($p = 0.26$), political party membership ($p = 0.10$), education ($p = 0.87$), income ($p = 0.80$), or WLTX viewership ($p = 0.42$), although there were between-group differences on gender ($p = 0.04$) and age ($p < 0.001$). Men (57.8%) were slightly more likely than women (51.1%) to drop out of the study, and participants younger than 45 (64.5%) were more likely than those 45 and older (49.2%) to drop out. While these differences deserve attention, they do not appear to suggest a strong confounding factor for intervention effects because gender and age were not strongly correlated with the outcome variables (most correlations were around 0.10). At the same time, the fact that the other variables, particularly WLTX viewership and party membership, did not vary significantly between retained and lost cases further alleviates concerns that attrition might work to bias evaluation results.

Other preliminary analysis revealed that news station viewership in the Columbia media market was not stable during the study period. Notably, among those who reported never watching WLTX for local news at baseline, more than half (59.6%) reported watching WLTX at least once a week for local news at follow-up. On the other hand, only 7.3% of WLTX viewers at baseline reported never watching WLTX at follow-up. To account for the significant shift of viewership, particularly from non-WLTX viewers to WLTX viewers, we created a new viewership variable with three categories: persistent WLTX viewers ($n = 231$), new WLTX viewers ($n = 146$), and persistent non-WLTX viewers ($n = 99$).[2] This new viewership variable was used in all subsequent analysis.

Results of the final regression analyses with panel data are summarized in Table 4. The panel data show some—but not full—support for the two hypotheses among the primary outcome variables. All else controlled to be equal (including the baseline values of the outcome measures), new WLTX viewers were more likely to believe at follow-up that global warming was primarily human caused than non-WLTX viewers (53% vs 41%, $p < 0.05$); those who recognized more stories from Climate Matters were more certain that global warming was happening compared to those who recognized fewer (2.01 for four stories vs 1.39 for zero stories, $p < 0.05$); and those who remembered seeing Climate Matters in local news saw greater harm of global warming than those who did not (3.04 vs 2.74, $p < 0.01$). No other relationships between campaign exposure and the primary outcomes were significant.

There is also some support for both hypotheses among the secondary outcome beliefs (presented in the bottom half of Table 4). All else being equal, those who were aware of Climate Matters were more concerned about global warming at follow-up than those who were not (0.09 vs −0.04, $p < 0.05$). Those recognizing more Climate Matters stories were more concerned (0.16 for four stories vs −0.08 for zero stories, $p < 0.05$) and more likely to believe that scientists are in agreement regarding the reality of global warming (55% vs 22%, $p < 0.01$) than those recognizing none. Persistent WLTX viewers were also more concerned about global warming than non-WLTX viewers (0.02 vs −0.10), but this difference did not reach statistical significance ($p < 0.10$). No other relationships in the regressions were significant.

Cross-sectional analysis. With two differences—WLTX viewership only having two categories (WLTX viewers vs non-WLTX viewers) and no control for

[2] WLTX viewers at baseline who reported not watching WLTX at all at follow-up were excluded from data analysis for their small number ($n = 18$).

baseline—all of the analyses described above were replicated with the cross-sectional (post only) data. Results from these analyses are summarized in Table 5.

These analyses show more consistent support for the hypotheses. After holding potential confounders constant, WLTX viewers were more certain about the occurrence of global warming (1.73 vs 1.35, $p < 0.05$) and perceived greater harm from it (2.84 vs 2.63, $p < 0.01$) than non-WLTX viewers, but the two groups did not differ on the belief about the human cause of global warming. As far as exposure is concerned, compared to those who did not remember seeing Climate Matters, those who did were more certain that global warming was happening (1.96 vs 1.45, $p < 0.01$), more likely to believe that global warming was primarily human caused (45% vs 36%, $p < 0.05$), and perceived greater harm of global warming (2.93 vs 2.67, $p < 0.01$). Compared to those recognizing fewer stories from Climate Matters, those recognizing

Table 4. Panel analysis results—predicted values or probabilities.[a]

	Viewership				Campaign exposure				
					Awareness		Recognition		
	Non-WLTX	Persistent WLTX	New WLTX	$\Delta R^2/R^2$	No	Yes	Zero stories	Four stories	$\Delta R^2/R^2$
Primary outcomes									
Certainty[b]	1.47	1.70	1.46	0.002/0.54	1.46	1.85*	1.39	2.01*	0.01/0.55
Human causation[c]	41%	45%	53%*	0.01/0.38	38%	26%	35%	38%	0.01/0.37
Harm extent[b]	2.80	2.76	2.84	0.001/0.51	2.74	3.04**	2.75	2.94	0.02/0.53
Secondary outcomes									
Concern[b]	–0.10	0.02#	–0.01	0.001/0.70	–0.04	0.09*	–0.08	0.16*	0.01/0.70
Perceived scientific agreement[c]	33%	36%	35%	0.00/0.21	29%	24%	22%	55%**	0.02/0.23

[a] Note that # $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. All analysis is controlled for gender, age, race, education, political party, ideology, and baseline outcome. ΔR^2 represents additional variance explained by the independent variables after control variables are already entered into the regression model.

[b] Numbers are predicted values of the outcome variable. The R^2 values are adjusted R^2 values from multiple linear regression.

[c] Numbers are predicted probability of answering yes to the outcome question. The R^2 values are Nagelkerke R^2 values from logistic regression.

Table 5. Cross-sectional analysis results—predicted values and probabilities.[a]

	Viewership			Campaign exposure				
				Awareness		Recognition		
	Non-WLTX	WLTX	$\Delta R^2/R^2$	No	Yes	Zero stories	Four stories	$\Delta R^2/R^2$
Primary outcomes								
Certainty[b]	1.35	1.73*	0.01/0.15	1.45	1.96**	1.14	2.83***	0.05/0.20
Human causation[c]	38%	38%	0.00/0.07	36%	45%*	37%	40%	0.01/0.08
Harm extent[b]	2.63	2.84**	0.01/0.15	2.67	2.93**	2.61	3.07***	0.03/0.16
Secondary outcomes								
Concern[b]	–0.11	0.03**	0.01/0.18	–0.10	0.21***	–0.18	0.43***	0.07/0.24
Perceived scientific agreement[c]	26%	43%***	0.03/0.10	31%	43%**	27%	58%***	0.05/0.11

[a] Note that * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. All analysis is controlled for gender, age, race, education, political party, and ideology. ΔR^2 represents additional variance explained by the independent variables after control variables are already entered into the regression model.

[b] Numbers are predicted values of the outcome variable. The R^2 values are adjusted R^2 values from multiple linear regression.

[c] Numbers are predicted probability of answering yes to the outcome question. The R^2 values are Nagelkerke R^2 values from logistic regression.

more stories were more certain about global warming (2.83 for four stories vs 1.14 for zero stories, $p < 0.01$), and saw greater harm from it (3.07 for four stories vs 2.61 for zero stories, $p < 0.001$), but they did not differ on their perceptions about human cause.

Full support of the hypotheses was obtained with the secondary outcomes. WLTX viewers were more concerned about global warming (0.03 vs −0.11, $p < 0.01$) and more likely to perceive scientific agreement (43% vs 26%, $p < 0.001$) than non-WLTX viewers. Those aware of Climate Matters were more concerned (0.21 vs −0.10, $p < 0.001$) and more likely to think scientists were in agreement (43% vs 31%, $p < 0.01$) than those who were not. Similarly, those who recognized more stories from Climate Matters were more concerned (0.43 for four stories vs −0.18 for zero stories, $p < 0.001$) and more likely to report scientific agreement (58% for four stories vs 27% for zero stories, $p < 0.001$) than those who recognized fewer stories.

DISCUSSION. *Overall assessment.* Our evaluation of Climate Matters showed supportive evidence of educational effectiveness, although the results did not fully support our two hypotheses. For this reason, the findings of this study should be read with care, and the impact of the tested intervention strategy should not be overstated. But still, the general results of this study were consistent with our expectations. Compared to non-WLTX viewers, WLTX viewers—both loyal followers and recent converts—tended to hold beliefs that were more consistent with the climate science. Furthermore, regardless of their station preference, viewers who reported exposure to and recall of Climate Matters were also more likely to report science-based beliefs and concern over global warming. This pattern of findings—which are consistent with experiential learning theory—was observed in both the panel data and the independent cross-sectional data. The panel analysis controlled for baseline values of the outcome measures, which strengthens the case that the intervention produced the changes in the outcome measures that were documented. The cross-sectional analysis does not allow for causal interpretation. But to the extent that it showed the same pattern of associations as the panel analysis, we consider its findings further evidence that the intervention had produced the intended, favorable impact on its target audience.

In total, this evidence suggests that Climate Matters was a successful informal climate change education effort. Through Climate Matters, we sought to explain a problem that is normally considered remote, complex, and confusing in a form (in terms of both content and medium) that is proximate, concrete, and trustworthy. By connecting local weather patterns, particularly extreme local weather events, to global climate change through local TV weathercasts, our intervention appears to have helped viewers in Columbia, SC, better understand the causes, processes, and impacts of climate change.

Limitations of evaluation study and evidence. Before reflecting on the Climate Matters experience any further, it is important to note some of the limitations of the evaluation. Most important, perhaps, is the fact that TV viewership in Columbia, SC, turned out to be much more fluid than we expected. More than half of the non-WLTX viewers identified at baseline reported watching WLTX at least once a week in the follow-up survey. This indicates considerable cross-contamination between the intervention and comparison groups in our study design. Although we took this into account in our data analysis, the ability of our tests to detect differences between the intervention and comparison groups was still lower than planned because of the contamination and loss of sample size in the comparison group. Whether such fluidity in viewership is unique to Columbia, SC, or reflective of a broad market phenomenon is not clear. Audience tracking data from a variety of different markets, if available, might help to ascertain the generality of the problem. Second, and related to the point above, because this study was the first to test our informal science education approach in a local media market, the extent to which the findings of this study might also apply to other markets in the United States is not clear. Third, our surveys had fairly low response rates, which carried increased risk of sample biases. Higher response rates would enhance confidence in the accuracy of our findings.

Moreover, our findings did not fully support our hypotheses. First, not every outcome variable showed a statistically significant effect—particularly in the panel analysis. Second, the amount of variance explained by the independent variables was generally small. It is possible that other important and more sensitive outcome variables might have been left out in our evaluation. For these reasons, it is inadvisable to overstate the impact of the intervention. But at the same time, it should be noted that almost all of the relationships observed in our analyses, significant or not, were in a direction that indicated positive learning effects. Furthermore, to remove the influence of many potential confounders, we controlled for a large number of variables in the data analysis that limited the amount of variance available for the intervention variables to explain.[3] This was particularly the case in the panel analysis, where we controlled for the baseline levels of the outcome measures; those measures alone would account for the majority of the variance in the outcomes at follow-up. Given this level of control, it is indeed impressive that the intervention variables were able to consistently explain additional variance in the outcome variables.

Recognition of the limits of the evaluation and the strengths of the evidence obtained helps put the appraisal of Climate Matters in a proper perspective. Despite the issues discussed above, the evidence overall is clear and strong enough to warrant the conclusion that Climate Matters was a successful intervention. In what follows, we discuss lessons learned in this intervention, both in terms of what was done well and what could have been improved. Our hope is that future efforts using this approach to climate education can be strengthened by learning from the current case.

Lessons learned. By using a local meteorologist as its message source and local weather reports as the conduit for message delivery, Climate Matters was able to reach its target audience with both efficiency and effectiveness. This laid the important foundation for the intervention to achieve its goals of enhancing knowledge and changing attitudes and beliefs related to climate change. Noted, however, that digital news consumption has been increasing, particularly among young people (Pew Research Center 2013a), Climate Matters tried to reach digital news consumers through web posting of videos, blogs, Facebook, and Twitter. But these efforts were of a supplemental nature and the extent of their independent impact was uncertain.

One major obstacle to weathercasters reporting on the climate science is the lack of time for field producing (Maibach et al. 2010). Field producing is a full time job and the weathercaster's days are already filled with myriad duties in addition to broadcasts including web positing, blogging, tweeting, and community visits. Moreover, there are few rewards for the extra time required to become a competent science reporter or climate educator. The team-based approach we used to research and produce stories for Climate Matters can take the burden off the shoulders of local TV meteorologists. This type of support can make it more feasible for weathercasters to embrace the role of climate educator, should they wish to.

Time on air is a second major obstacle to reporting on climate change. We encountered this obstacle directly and in a variety of ways in Climate Matters (including the fact that morning broadcasts—in which weathercasts are more compressed—proved not to fit the approach we developed). The development of shorter length materials—that can be productively used in 10–20 seconds—may result in more time on air for climate education throughout the day.

Climate Matters also had other challenges during implementation. The station switched to a new weather graphics system immediately prior to the launch of Climate Matters and to high definition TV at the end of 2010, both of which caused temporary interruptions in the ability to produce and air Climate Matters segments. Breaking news events—including some weather-related news events—precluded airing several segments on their originally scheduled dates. And renovations to the station's website took the meteorologist's blog offline for nine weeks, although the Climate Matters page remained up and active. In short, broadcast news is a dynamic and changing environment where even the best laid plans will be challenged. Indeed, most of the challenges we experienced in Climate Matters were unanticipated. Hopefully, the experience of climate education "early adopters" can be leveraged to help anticipate and identify solutions to these challenges.

Finally, the evaluation of Climate Matters exemplified the many difficulties one might encounter in conducting such a large-scale field study. Although considerable care was exercised in designing the study and data collection, the quality of our data was still compromised by an unexpected shift in viewership and low survey response rates. As a result, our findings should be considered strongly suggestive but not definitive; additional research in other markets and populations is warranted. Future evaluation research should be aware of the limitations of this study and find creative ways to overcome them.

One method to strengthen the current design is to conduct the experiment across several comparable media markets, with the meteorologist-led education campaign launched in some markets but not others. The two groups of markets will be compared both at baseline and again at a follow-up point. Increased understanding and concern about climate change over

[3] It should be noted that the control variables included in our analysis are mostly demographic variables. Obviously, what viewers learned from Climate Matters was not the only knowledge they possessed. How viewers' existing knowledge and attitudes might influence their reception of climate change education messages is an interesting topic for future research.

time in the treatment markets relative to the control markets will provide strong evidence for the effectiveness of the educational intervention. This design will also effectively get around the problem of viewership shift within individual markets that was the cause of some ambiguity in the current data. In addition to replicate this study with more rigorous designs, researchers should also complement large-scale quantitative testing with small-scale highly contextualized qualitative research. By conducting ethnographic observations, in-depth interviews, focus groups, and so forth, a more nuanced understanding of how the current educational approach might work among the local TV audience can be obtained, which will, in turn, inform further implementation of this education method in other and broader contexts.

CONCLUSIONS. Using an experiential learning approach, Climate Matters was an innovative educational initiative that tried to leverage both the proximity of local weather events and the credibility of local TV meteorologists to educate the public about the relationships among weather, climate, and climate change. Our evaluation found some evidence for the effectiveness of this new climate education model. Further research and development of this educational method appears to be warranted.

REFERENCES

AAPOR, 2011: Standard definitions: Final dispositions of case codes and outcome rates for surveys. American Association for Public Opinion Research Rep., 61 pp.

Abroms, L. C., and E. W. Maibach, 2008: The effectiveness of mass communication to change public behavior. *Annu. Rev. Public Health,* **29,** 219–234.

Akerlof, K., and E. W. Maibach, 2008: "Sermons" as a climate change policy tool: Do they work? Evidence from the international community. *Global Stud. Rev.,* **4,** 4–6.

Brulle, R. J., J. Carmichael, and J. C. Jenkins, 2012: Shifting public opinion on climate change: An empirical assessment of factors influencing concern over climate change in the U.S., 2002–2010. *Climatic Change,* **114,** 169–188, doi:10.1007/s10584-012-0403-y.

Cappella, J. N., and K. H. Jamieson, 1997: *Spiral of Cynicism: The Press and the Public Good.* Oxford University Press, 336 pp.

Cugelman, B., and E. Otero, 2010: Evaluation of Oxfam GB's climate change campaign. Oxfam Rep., 60 pp. [Available online at http://policy-practice.oxfam.org.uk/publications/evaluation-of-oxfam-gbs-climate-change-campaign-119438.]

Curtin, R., S. Presser, and E. Singer, 2005: Changes in telephone survey nonresponse over the past quarter century. *Public Opin. Q.,* **69,** 87–98, doi:10.1093/poq/nfi002.

Demuth, J. L., R. E. Morss, B. H. Morrow, and J. K. Lazo, 2012: Creation and communication of hurricane risk information. *Bull. Amer. Meteor. Soc.,* **93,** 1133–1145.

Dessai, S., W. N. Adger, M. Hulme, J. Turnpenny, J. Köhler, and R. Warren, 2004: Defining and experiencing dangerous climate change. *Climatic Change,* **64,** 11–25.

Doherty, R., and K. G. Barnhurst, 2009: Controlling nature: Weathercasts on local television news. *J. Broadcast. Electron. Media,* **53,** 211–226.

Earl, R. A., and S. Pasternack, 1991: Television weathercasts and their role in geographic education. *J. Geogr.,* **90,** 113–117, doi:10.1080/00221349108979249.

Epstein, S., 1994: Integration of the cognitive and the psychodynamic unconscious. *Amer. Psychol.,* **49,** 709–724, doi:10.1037/0003-066X.49.8.709.

Feldman, L., A. A. Leiserowitz, and E. W. Maibach, 2011: The science of satire: The Daily Show and The Colbert Report as sources of public attention to science and the environment. *The Stewart/Colbert Effect: Essays on the Real Impacts of Fake News,* A. Amarasingam, Ed., McFarland, 25–46.

Friedman, S. M., S. Dunwoody, and C. L. Rogers, Eds., 1999: *Communicating Uncertainty: Media Coverage of New and Controversial Science.* Lawrence Erlbaum Associates, 277 pp.

Gauchat, G., 2012: Politicization of science in the public sphere: A study of public trust in the United States, 1974 to 2010. *Amer. Sociol. Rev.,* **77,** 167–187, doi:10.1177/0003122412438225.

Henson, R., 2010: *Weather on the Air: A History of Broadcast Meteorology.* Amer. Meteor. Soc., 241 pp.

Herreros, F., and H. Criado, 2008: The state and the development of social trust. *Int. Polit. Sci. Rev.,* **29,** 53–71, doi:10.1177/0192512107083447.

Holbrook, A. L., J. A. Krosnick, and A. Pfent, 2007: The causes and consequences of response rates in surveys by the news media and government contractor survey research firms. *Advances in Telephone Survey Methodology,* J. M. Lepkowski et al., Eds., John Wiley and Sons, 499–528.

Hornik, R. C., Ed., 2002a: *Public Health Communication: Evidence for Behavior Change.* Lawrence Erlbaum Associates, 456 pp.

——, 2002b: Public health communication: Making sense of contradictory evidence. *Public Health Communication: Evidence for Behavior Change,* R. C. Hornik, Ed., Lawrence Erlbaum Associates, 1–22.

Hovland, C. I., and W. Weiss, 1951: The influence of source credibility on communication effectiveness. *Public Opin. Q.,* **15,** 635–650.

Hulme, M., 2009: *Why We Disagree about Climate Change: Understanding Controversy, Inaction and Opportunity.* Cambridge University Press, 392 pp.

Johnson, T. D., 2009: Meteorologists making links between weather, public health: Today's weather forecast calls for health. *Nations Health,* **39,** 1–16.

Kahneman, D., 2011: *Thinking, Fast and Slow.* 1st ed. Farrar, Straus and Giroux, 512 pp.

Knutson, T. R., and Coauthors, 2010: Tropical cyclones and climate change. *Nat. Geosci.,* **3,** 157–163.

Leiserowitz, A. A., 2005: American risk perceptions: Is climate change dangerous? *Risk Anal.,* **25,** 1433–1442, doi:10.1111/j.1540-6261.2005.00690.x.

——, 2006: Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change,* **77,** 45–72.

——, E. W. Maibach, C. Roser-Renouf, G. Feinberg, and P. Howe, 2012: Climate change in the American mind: Americans' global warming beliefs and attitudes in September 2012. Yale Project on Climate Change Communication Rep., 31 pp. [Available online at http://climatechangecommunication.org/sites/default/files/reports/Climate-Beliefs-September-2012.pdf.]

Maibach, E. W., 2012: Knowing our options for setting the record straight, when doing so is particularly important. *Psychol. Sci. Public Interest,* **13,** 105–105.

——, C. Roser-Renouf, and A. A. Leiserowitz, 2008: Communication and marketing as climate change–intervention assets. *Amer. J. Prev. Med.,* **35,** 488–500, doi:10.1016/j.amepre.2008.08.016.

——, K. Wilson, and J. Witte, 2010: A national survey of television meteorologists about climate change: Preliminary findings. George Mason University Center for Climate Change Communication Rep., 24 pp. [Available online at www.klimaskeptiker.info/download/tv_meteorologists_survey_findings_march_2010.pdf.]

——, and Coauthors, 2011: A national survey of television meteorologists about climate change education. George Mason University Center for Climate Change Communication Rep., 53 pp. [Available online at www.climatechangecommunication.org/images/files/2011_Mason_AMS_NWA_Weathercaster_Survey_Report_NA_doc_pdf%281%29.pdf.]

Malka, A., J. A. Krosnick, and G. Langer, 2009: The association of knowledge with concern about global warming: Trusted information sources shape public thinking. *Risk Anal.,* **29,** 633–647, doi:10.1111/j.1539-6924.2009.01220.x.

Marx, S. M., E. U. Weber, B. S. Orlove, A. A. Leiserowitz, D. H. Krantz, C. Roncoli, and J. Phillips, 2007: Communication and mental processes: Experiential and analytic processing of uncertain climate information. *Global Environ. Change,* **17,** 47–58.

McGuire, W. J., 2012: McGuire's classic input-output framework for constructing persuasive messages. *Public Communication Campaigns,* R. E. Rice and C. K. Atkin, Eds., Sage, 133–145.

Miller, J. D., E. Augenbraun, J. Schulhof, and L. G. Kimmel, 2006: Adult science learning from local television newscasts. *Sci. Commun.,* **28,** 216–242, doi:10.1177/1075547006294461.

Nese, J. M., R. G. Najjar, and J. G. Murgo, 2012: Climate science and the broadcast meteorologist. *Bull. Amer. Meteor. Soc.,* **93,** 1913–1916.

Nisbett, R. E., and L. Ross, 1980: *Human Inference: Strategies and Shortcomings in Social Judgement.* Prentice Hall, 352 pp.

Pew Research Center, cited 2013a: In changing news landscape, even television is vulnerable. [Available online at www.people-press.org/2012/09/27/in-changing-news-landscape-even-television-is-vulnerable/.]

——, cited 2013b: 72% of Americans follow local news closely. [Available online at www.pewinternet.org/~/media//Files/Reports/2012/PIP_PEJ_Local_News_Enthusiasts_041212.pdf.]

Posegate, A., 2008: Station scientists: Beyond the daily forecast. *Weatherwise,* **61,** 20–25.

Randolph, W., and K. Viswanath, 2004: Lessons learned from public health mass media campaigns: Marketing health in a crowded media world. *Annu. Rev. Public Health,* **25,** 419–437, doi:10.1146/annurev.publhealth.25.101802.123046.

Research!America, cited 2013: Your Congress/Your Health Survey. [Available online at www.researchamerica.org/uploads/YourCongress2009.pdf.]

Russell, C., 2008: Climate change: Now what? *Columbia Journalism Rev.,* **47,** 45–49.

Silcock, B. W., D. Heider, and M. T. Rogus, 2006: *Managing Television News: A Handbook for Ethical and Effective Producing.* Lawrence Erlbaum Associates, 272 pp.

Slovic, P., M. L. Finucane, E. Peters, and D. G. MacGregor, 2004: Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality. *Risk Anal.,* **24,** 311–322, doi:10.1111/j.0272-4332.2004.00433.x.

Smith, D. C., 2007: *Power Producer: A Practical Guide to TV News Producing.* 4th ed. RTNDA/RTNDF, 171 pp.

Snyder, L. B., and M. A. Hamilton, 2002: A meta-analysis of U.S. health campaign effects on behavior:

Emphasize enforcement, exposure, and new information, and beware the secular trend. *Public Health Communication: Evidence for Behavior Change,* R. C. Hornik, Ed., Lawrence Erlbaum Associates, 357–385.

Spence, A., W. Poortinga, C. Butler, and N. F. Pidgeon, 2011: Perceptions of climate change and willingness to save energy related to flood experience. *Nat. Climate Change,* **1,** 46–49, doi:10.1038/nclimate1059.

Staats, H. J., A. P. Wit, and C. Y. H. Midden, 1996: Communicating the greenhouse effect to the public: Evaluation of a mass media campaign from a social dilemma perspective. *J. Environ. Manage.,* **46,** 189–203.

Tremblay, M.-C., S. Tice, R. Tkaczyk, and M. Bennett, cited 2013: Evaluation of the one-tonne challenge program. Environment Canada. [Available online at http://publications.gc.ca/site/eng/445787/publication.html.]

Trenberth, K. E., and Coauthors, 2007: Observations: Surface and atmospheric climate change. *Climate Change 2007: The Physical Science Basis,* S. Solomon et al., Eds., Cambridge University Press, 235–336.

United States Global Change Research Program, cited 2013: Global climate change impacts in the United States: 2009 report. U.S. Global Change Research Program. [Available online at www.globalchange.gov/usimpacts.]

Weber, E. U., 2006: Experience-based and description-based perceptions of long-term risk: Why global warming does not scare us (yet). *Climatic Change,* **77,** 103–120.

——, 2010: What shapes perceptions of climate change? *Wiley Interdiscip. Rev.: Climate Change,* **1,** 332–342, doi:10.1002/wcc.41.

Wilson, K. M., 2008: Television weathercasters as potentially prominent science communicators. *Public Understanding Sci.,* **17,** 73–87, doi:10.1177/0963662506065557.

——, 2009: Opportunities and obstacles for television weathercasters to report on climate change. *Bull. Amer. Meteor. Soc.,* **90,** 1457–1465.

Zhao, X., 2009: Media use and global warming perceptions: A snapshot of the reinforcing spirals. *Commun. Res.,* **36,** 698–723, doi:10.1177/0093650209338911.