

Climatologists' Communication of Climate Science to the Agricultural Sector

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Abstract

Farming is a risky business. Climate science information can assist agriculture in formulating management decisions that hedge against uncertainty and risks. Climatologists are key actors in communicating historical trends and forecast information. Interviews and surveys of climatologists in the North Central Region reveal that they are providing accurate and objective information but are likely to let the science speak for itself. This suggests missed opportunities to communicate climate science in ways that make science relevant to decision maker beliefs, values, and practical applications. Furthermore, more active engagement with agriculture could increase colearning necessary for effective adaptive management under increasingly variable climate conditions.

Keywords

climatologists, climate, agriculture, risk, engagement

Farmers and the agricultural value chain are confronted on a daily basis with ever-changing growing conditions, along with markets that make their occupation risky business (Harwood, Heifner, Coble, Perry, & Somwaru, 1999).

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One of the biggest risks to U.S. agriculture and its production of nearly \$330 billion in annual commodities is the uncertainty and risks associated with highly variable weather and climate, according to the Third National Climate Assessment (Melillo, Richmond, & Yohe, 2014). The potentially negative impacts of extreme events and variable climate patterns have been pointed to for many years (e.g., Adams et al., 1990), and scientists are working to provide information to assist the agricultural sector in adapting to and mitigating these effects (Cuomou & Rahmstorf, 2012; Jones, Hansen, Royce, & Messina, 2000; Walthall et al., 2012). If the agricultural sector is to continuously adapt to a changing climate, it will need climate science information that provides farmers and their advisors with decision support to guide management decisions (Howden et al., 2007; Mase & Prokopy, 2014; Melillo et al., 2014).

The U.S. Department of Agriculture (USDA) and other federal agencies are making a concerted effort to assist agricultural producers in adapting to and helping mitigate increasing variable climate patterns and extreme weather events by implementing resilient production management practices. Climatologists are key actors in communicating historical trends and forecast information to the public, including the agricultural sector, and can bridge scientific information to help inform management decisions. As publicly supported scientists tasked with collecting and making climate data available to the constituents of their states and regions, climatologists are in a unique position to provide information that is relevant and useful to the agricultural sector (Wilke & Morton, 2015).

Climatologists have the ability to access, interpret, and translate complex scientific information and tailor it to the needs of the data user. However, little is known about how climatologists, as scientists, view their role in communicating their science to farmers. Climatologists have the potential to communicate science in ways that reduce complexity of agricultural management decisions, but their engagement with their audiences may be constrained by social norms and farmers' perceptions, attitudes, and behaviors (Poliakoff & Webb, 2007) and their own uncertainty about what decision makers need to know (Fischhoff, 2012). By understanding how climatologists currently perceive their roles in communicating scientific information to the agricultural sector, we may begin to understand potential barriers and opportunities for more effective communication that bridges scientific knowledge and beliefs about climate change in support of more effective agricultural decision making.

There are many challenges associated with communicating the science of climate change (Weber, 2010; Weber & Stern, 2011), and this is particularly evident in the agricultural sector (Rejesus, Mutuc-Hensley, Mitchell, Coble, & Knight, 2013). Previous research suggests that farmer perspectives on

adapting to climate change are influenced by trust in sources of information, beliefs, personal experiences, and perceived risks (Arbuckle, Morton, & Hobbs, 2013). As a result, climate science needs to be thoughtfully communicated in order to ensure that the agricultural sector recognizes the value of effectively adapting and mitigating the uncertain risks associated with a changing climate (Moser, 2010; Nisbet, 2009).

A variety of social and cultural factors influence individual beliefs about climate change and willingness to utilize climate science in decision making (Hoffman, 2011; Nisbet, 2009). For instance, only 8% of farmers surveyed in the North Central Region (NCR) believe that climate change is occurring and is caused mostly by human activities, while 53% of climatologists surveyed in the NCR believe that to be true (Prokopy, Morton, Arbuckle, Mase, & Wilke, 2015). This discrepancy in belief about climate science is evident between not only farmers and scientists but also agricultural advisors (12.3%) and extension educators (19.2%; Prokopy et al., 2015). While there may be various factors influencing the discrepancy of climate change beliefs, including social and cultural references (Kahan, Jenkins-Smith, & Braman, 2011), individual experiences and beliefs (Weber, 2006, 2010), and mass media (Carvalho, 2007), climatologists have an important role of bridging the gap between what climate science understands and what the agricultural sector believes (Wilke & Morton, 2015).

In this article, we utilize the lens of science communication to develop a framework for investigating how climatologists perceive their roles in communicating climate science to the agricultural sector. First, climate, uncertain risk, and agriculture are presented to set the social context of climate science communication. Then an analytic framework is built on an adaptation of Fischhoff's (1995) stages of uncertain risk communication with a focus on facts, relevance, and engagement as key elements of communicating science. Of interest is how climatologists integrate (or not) facts with their audiences' values to construct information relevant to decision makers (Dietz, 2013) and the extent to which engagement (Bartels et al., 2012; Haden, Niles, Lubell, Perlman, & Jackson, 2012) is used to address how uncertainty and risks are conveyed to farmers and their advisors. To answer the question—how do climatologists communicate to agricultural audiences?—data from in-person interviews and surveys conducted in 2012 with climatologists are examined. After presenting results, we close the article with a discussion of the findings and implications for building trusted relationships and communicating climate science to farmers and agricultural policy makers so that they can most effectively access and process information that could improve their adaptation strategies.

Communicating Climate Science to Agriculture: Risk and Uncertainty

Climatologists are tasked with investigating and communicating the complex relationships among a changing climate and the potential risks and uncertainties it presents to agriculture. Climate science may be thought of as the state of scientific knowledge available on the subjects of climate change and variability and assessing long-term projections involving the interaction of earth's terrestrial surface and atmosphere. The extent to which climate has changed and will continue to become more variable and unpredictable in the future is currently subject to many scientific inquiries, social debates, and political controversies (Nisbet, 2009). Thus, to distinguish between scientific assessments and individual opinions, it is useful to understand that each is grounded in different types of data and can lead to differing interpretation and meanings.

Social scientists find that public perceptions of climate change are influenced by values, beliefs, opinions, and personal experience (Leiserowitz, 2006; Myers, Maibach, Roser-Renouf, Akerlof, & Leiserowitz, 2012), rather than only scientific fact. The ways in which scientific facts are linked to values, beliefs, and experience influence the discourse surrounding environmental consequences and assessments of personal and collective risk (Beck, 1992). Perceptions of risk help individuals "understand and cope with the danger and uncertainties of life" (Slovic, 1999, p. 690). There are a whole range of potential environmental risks investigated by climate science, particularly since all terrestrial-atmospheric interactions may directly or indirectly influence (or be influenced by) human activities such as cultivation practices associated with agricultural production (Howden et al., 2007; Melillo et al., 2014).

Uncertainty is a term employed by the climate science community to describe current scientific understanding involving potential environmental risks associated with extreme weather and an increasingly variable climate. Uncertainty in scientific knowledge is often highlighted by scientists to demonstrate gaps in literature (Lewenstein, 1992) and to justify the need for additional scientific research (Zehr, 2000). In the meteorological and climate sciences, uncertainties are particularly important to illustrate variance and statistical error potential of forecasting. Because of this, uncertainty is a term often utilized in climate science to represent probabilities, the levels of scientific confidence based on advanced statistical analysis. However, substantive evidence supports the public's misinterpretation of uncertainty, which may influence their ability to understand the advances and importance of climate science in addressing environmental risks (Delicado, 2012; McBean &

Hengeveld, 2000; Rabinovich & Morton, 2012; Zehr, 2000). The gap in scientific and lay public assessments of risk and uncertainty suggests high potential for miscommunication that can lead to misunderstanding of climate science and how to utilize it in decision making.

A 2011 survey of farmers in the NCR of the United States found that beliefs about climate change are directly correlated to concerns of environmental risks, personal experiences with drought and flooding, and attitudes toward adaptation and mitigation (Arbuckle et al., 2013). Farmers who do not believe that climate change is occurring were much less likely to support action to protect land from increased weather variability (Arbuckle et al., 2013). This suggests that perception of climate risks is a crucial component of an individual's actions in response to changes. Climatologists can greatly assist the agricultural sector in predicting and preparing for climate change by clarifying the complexities of uncertain risks and communicating scientific information in ways congruent with their values, beliefs, and experiences.

Analytic Framework

Some scholars claim that the public's doubts surrounding scientific consensus result from ignorance of the science itself (Layton, Jenkins, McGill, & Davey, 1993) and may be remedied by simply providing more information to them (Sturgis & Allum, 2004). Since only about 20% of the American public are scientifically literate (Miller, 2004), and the majority have limited climate literacy (Leiserowitz, Smith, & Marlon, 2010), the public understanding of science may appear to be a pinnacle barrier in climate science communication. However, strong evidence indicates that the deficit model may not be the most appropriate framework to understand the public's inability to understand science (Gross, 1994; Wynne, 2006). Other experiential factors, such as affect, (Leiserowitz, 2006), trust in information source (Arbuckle et al., 2013), and socially referenced value systems (Kahan & Braman, 2006) seem to have substantive influence in how people perceive and respond to scientific consensus.

To address this shortcoming, the public engagement in science and technology model has been proposed as a framework useful for more effectively transmitting scientific information to different publics (Wynne, 2006). Although science is central to solving many of the important problems faced by society, simply educating about science-based issues has not positively influenced the public's skepticism about science (Leshner, 2003). Bartels et al. (2012) claim that the complexity of the uncertainty associated with future climate conditions suggests that scientific or technical information alone may be insufficient to achieve place-based solutions. There is a need to actively

Table 1. Seven Stages of Uncertain Risk Communication.

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1. All we have to do is get the numbers right.
 2. All we have to do is tell them the numbers.
 3. All we have to do is explain what we mean by the numbers.
 4. All we have to do is show them that they've accepted similar risks in the past.
 5. All we have to do is to show them that it's a good deal for them
 6. All we have to do is treat them nice.
 7. All we have to do is make them partners.
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Source: Fischhoff (1995).

engage the public in iterative, bidirectional dialogues about scientific initiatives in order to increase trust in science, knowledge sharing, and learning that can lead to adaptation (Bartels et al., 2012; Wynne, 2006). Furthermore, the scientific community has an obligation to better communicate risk and uncertainty so as to assist in helping the general population understand positive and negative implications, improve decision making, and recognize the limits to science and technology (Fischhoff, 2012; Leshner, 2003; Poliakoff & Webb, 2007; Wilsdon & Willis, 2004).

Fischhoff (1995) has outlined seven progressive stages (see Table 1) of communicating uncertain risks that can help us understand how potential environmental impacts associated with climate change are communicated to the public. Fischhoff argues that risk communication is sensitive and that any doubts cast on the audience by the communicator may be irreversible. He presents the communication process as stages in an evolving dialogue, with each step uniquely representing a certain technique and building on its predecessors but not replacing them (Fischhoff, 1995).

Since climate change is an environmental risk subject to a great deal of skepticism in the eyes of much of the American public (Weber & Stern, 2011), it is necessary to thoughtfully approach the communication of climate science (Dunlap & Saad, 2001; Pew Research Center, 2009). Fischhoff's (1995) typology of uncertain risk communication is a valuable foundation for analyzing how climatologists communicate with various agricultural audiences. In this article, Fischhoff's stages of uncertain risk communication are collapsed into a more parsimonious framework of facts, relevance, and engagement (Table 2). His first three statements (getting the numbers right, telling the audience the numbers, and explaining what the numbers mean) are centered on facts. Stages 4 and 5 (show them they've accepted similar risks in the past and that the information is a good deal) are focused on identifying some useful application that makes the facts relevant. And Fischhoff's last

Table 2. Elements of Climate Science Communication.**Element 1. Facts**

Focus of communication relies on completely nonbias presentation of the message, or letting the facts and science speak for themselves. In this stage, the audience is tasked with interpreting the relevance of scientific information to real-world risk management situations. When not combined with other communication strategies, the agricultural sector must draw their own conclusions and employ their own methods to relate the science to particular impacts and outcomes.

Element 2. Relevance

Focus of communication relies on presenting information in ways that are relevant and important to a selected audience. In many cases, the science is presented in a manner that frames the most important or necessary components of the science for the audience to apply to their own circumstances. Science that is presented as relevant to the agricultural sector is most often framed to emphasize productivity, resilience, risk management, or other certain management techniques that directly affect decisions.

Element 3. Engagement

Focus of communication recognizes the importance of social capital in the transfer of scientific information. For instance, scientists take extra measures to ensure that they are perceived as a trusted source for information. Furthermore, scientists actively engage the audience in participatory activities to obtain precise and locally specific information that can be connected to the science. Members of the agricultural sector are encouraged to contribute weather observation data that can feed into local forecast and climate outlooks.

two steps (treat them nice and make them partners) are about engaging the audience in ways that makes them feel like valued partners in making sense of and applying the information communicated.

Facts

Facts are the scientific, expert knowledge constructed about climate. As the first element of uncertain risk communication in Table 2, facts are considered by the scientist to be value and belief neutral. In communicating facts, the goal is to provide clear, understandable, but as nonbiased as possible information. "Facts only" means that the scientist is careful to avoid overinterpretation, and allows the audience to match and interpret the facts themselves to their own need in a specific situation. In this research, we examine how climatologists represent their science and its meaning to agricultural audiences. While public employees, climatologists are scientists first and communicating information is a by-product of their profession; most have little training in communication. Thus, as scientists their communication focuses primarily

on accuracy and objectivity, and they are likely to believe that the science speaks for itself and needs little interpretation (Nielsen, 2001).

In *Knowledge and Public Policy*, Judith Innes (1994) offers several striking examples in which scientists are most respected and effective if they “stick to the ‘facts,’ and keep out of politics” (p. 75). Objectivity in the process of producing facts can ensure public confidence and reception of scientific findings (Innes, 1994). There may also be professional norms and perceptions of public roles that prevent scientists, including climatologists, from communicating knowledge beyond objective facts (Poliakoff & Webb, 2007).

Relevance

Dietz (2013) asserts that good decisions must not only be factually competent but also be value-competent. The values brought to scientific facts affect whether the information is relevant or of any value or useful (or not) to the decision maker. Relevant communication patterns acknowledge the necessity of some level of translation of the science “facts” in order for the audience to relate to the information and perceive those facts as applicable to their own situations. Framing information as relevant and important is necessary to acknowledge individual value judgments and convey information in a way in which the audience recognizes real-world connections to scientific knowledge (Kahneman, 2003).

Nisbet and Scheufele (2009) argue that “science communication efforts need to be based on a systematic empirical understanding of an intended audience’s existing values, knowledge, and attitudes, their interpersonal and social contexts, and their preferred media sources and communication channels” (p. 1767). Acknowledging values can help scientists make arguments about the relevance of their information and what should be done, especially when they “make clear that their views are grounded in both their understanding of the facts and their values” (Dietz, 2013, p. 14086). The tailoring of messages to a specific audience and using examples that trigger values can make scientific facts relevant and “break through the communication barriers of human nature, partisan identity, and media fragmentation” (Nisbet, 2009, p. 15).

Engagement

Identifying the relevance of scientific facts and hoping the information is useful are not enough to ensure it will actually be used (Dilling & Lemos, 2011). Bartels et al. (2012) call for iterative, hybrid forms of knowledge coproduced

through two-way communication between the scientist and audience so that nonscientists are not treated as passive recipients of information. This engagement can strengthen trust (Coleman, 1990) and shape thinking and opinion, particularly with regard to concern about climate change (Arbuckle et al., 2013; Malka, Krosnick, & Langer, 2009).

Jones et al. (2000) find that engagement and trust building are needed to help farmers understand and contend regularly with the uncertain nature of the climate. They recommend that “researchers need to work with farmers to develop a common language for communicating probabilistic climate information” and further suggest that “effective communication of climatic or any other new information is best accomplished through providers of information and advice that farmers already know and trust” (p. 180).

These three elements (facts, relevance, and engagement) of communicating science provide a framework for analyzing how climatologists perceive their roles and the strategies they use to interact with their agricultural audiences and communicate climate information. Specifically, we ask the following questions, and test them to see if there is support for this framework: (1) How is climate science information currently communicated to agricultural audiences in the NCR of the United States? (2) How do climatologists view their communication techniques and effectiveness of communication with farmer audiences?

Method

Climatologists were selected from a purposeful sample to represent the universe of main outlets of publicly available and location-specific climate information in 11 states of the NCR of the United States, or the “Corn Belt.”¹ The sample includes 16 male and 3 female climatologists, representing climatologists at state climate offices, public land grant universities, regional climate centers, and the National Oceanic and Atmospheric Administration central region. Climatologists were initially contacted by e-mail and given details about the research and also contacted via follow-up telephone calls as necessary. All contacted climatologists agreed to participate in the study and signed informed consent documentation. Purposeful sampling in qualitative research allows for the selection of key data sources, in this case climatologists who work with agriculture in the NCR, to reach a saturation of information relative to the purpose of the study (Neuman, 1994).

Prior to the interview, participants were asked to complete a minisurvey of 16 closed-ended questions. Following the minisurvey, a personal audio-recorded interview occurred, taking on average about 45 minutes and allowing the climatologists to elaborate on the survey questions. The research

design, interview and survey instruments, study protocols, and informed consent documentation were approved prior to administration by Iowa State University Institutional Review Board No. 12-022. For this article, the results of 19 minisurveys and 13 interviews were analyzed.

Climatologist survey questions were selected from a lengthier producer survey distributed to a random sample of farmers in the NCR ($N = 4,778$; Arbuckle et al., 2013). The geography of this survey corresponded with the 11 states represented by the climatologists. The climatologist survey included questions regarding beliefs about climate change, perceptions of the influence of forecasts in farmer's decisions, other influences on decisions, and knowledge of seasonal timing of common management practices. Differential and descriptive statistics were computed and analyzed.

We apply a mixed-methods research design incorporating qualitative and quantitative methodologies (Neuman, 1994). Quantitative survey methods offer numerical summaries across subjects (Dillman, Smyth, & Christian, 2009), while qualitative interviews allow for a more deep understanding into the pathways of how climatologists relate to and communicate with farmers (Prokopy, 2011). Both quantitative survey questions and qualitative interview questions were developed collectively by a committee of scientists involved in two USDA-NIFA (National Institute of Food and Agriculture) projects related to climate and agriculture: Climate and Corn-Based Cropping Systems Coordinated Agriculture Project and Useful to Useable: Transforming Climate Variability and Change Information. Specifically, three climate scientists (two state climatologists), two professors of sociology, a sociology graduate student, and a project manager formed the committee to develop the research design and protocols. Both instruments were pilot tested by two climate scientists to further ensure validity prior to implementation.

Interview questions and prompts focused on climatologists' roles and responsibilities, relationships with other climatologists and farmers, communicating climate information, and agriculture decision making, including influence of climate information advisors and other sources of information. Audio-recorded interviews were transcribed and analyzed line by line independently by the authors and assessed for interrater reliability. NVivo Qualitative Data Analysis Software (QSR International, 2010) was used to assist in the detection and frequency of emergent themes. All themes were first detected and then analyzed and mapped to understand their relative importance. A qualitative analysis codebook was developed and used to guide the analysis. This codebook was used to assess frequency of word and phrase references and identify topic themes for further qualitative investigation by the researchers to further analyze and parse concepts. Cohen's kappa was computed (Cohen, 1960, 1968) to ensure interrater reliability among coders, with all values greater than .866.

Results

Roles and Responsibilities

Climatologists reported that connecting scientific research relating to weather and climate to various public data users and other stakeholders was a key responsibility. Furthermore, this role encompassed providing public service to the constituents of their states. In the NCR of the United States, where agriculture is a dominant economic driver, this often included farmers and other stakeholders of the agricultural sector.

Several climatologists noted that they maintain their states' Mesonet services, which are automated networks of weather stations. They are also active in the documentation and compilation of weather and climate information collected from weather stations. In this regard, climatologists often remarked that they provide services related to "archiving" and "retrieving" climate-related information. "Mostly what I do is document the weather, what's going on climate-wise, so it's mostly recordkeeping," one climatologist noted (No. 1).

Some climatologists, often in an extension role, mentioned a responsibility to travel to talk with different stakeholder groups. Groups that requested their services ranged from storm water managers of municipalities to farm commodity organizations such as the Soybean Association. Many reported efforts to provide information that is tailored to the group in which they are presenting. For instance, a municipality would be presented with urban-specific precipitation information, while agricultural audiences would receive information related to soil moisture, growing degree days, and other agriculture-relevant information.

Climatologists are also scientists and researchers, which involves "trying to understand temporal and spatial trends of climate within the state and . . . also projected climate in the future" (No. 2). Many climatologists mentioned projects that they are working on with different departments and universities and efforts to provide climate-related information for various applications such as storm water management, highway transportation, or agricultural engineering.

Climate Beliefs

In response to the survey question about their beliefs regarding climate change, none of the climatologists indicated that the climate is not changing. This is congruent with the Intergovernmental Panel on Climate Change (IPCC) definition that climate is dynamic and in a constant state of change. During the qualitative interviews, five (26%) of the climatologists directly addressed the issue of belief in climate change, stating that survey questions

Table 3. Climatologists' Beliefs About Climate Change.

There is increasing discussion about climate change and its potential impacts. Please select the statement that best reflects your beliefs about climate change. (Please circle one number.)	Climatologists (N = 19), %
a. Climate change is occurring, and it is caused mostly by natural changes in the environment.	5
b. Climate change is occurring, and it is caused mostly by human activities.	53
c. Climate change is occurring, and it is caused more or less equally by natural changes in the environment and human activities.	37
d. Climate change is not occurring.	0
e. There is not sufficient evidence to know with certainty whether climate change is occurring or not.	5

about climate beliefs were irrelevant, since climate change is not a belief, it is a scientific fact. "It's not a belief," one climatologist declared. "It's not like believing in God or believing in ghosts or believing in Santa Claus. There's evidence, and you can ignore the evidence or not" (No. 3).

Table 3 summarizes climatologists' responses to the survey prompt, "There is increasing discussion about climate change and its potential impacts. Please select the statement that best reflects your beliefs about climate change." As the table shows, 95% of climatologists agreed climate change is occurring; with more than half of the climatologists (53%) selecting *climate change is occurring, and it is caused mostly by human activities*. A little more than one third agreed climate change is *caused more or less equally by natural changes in the environment and human activities*. Only one climatologist (5%) indicated that *there is not sufficient evidence to know with certainty whether climate change is occurring or not*.

Effective Climate Science Communication

During the interviews, climatologists acknowledged the need for more effective communication of climate science to the public. "The information, even if it is researched," one state climatologists remarked, "it has to be disseminated to the public, and that's always a challenge" (No. 4). Climatologists also recognized the challenges inherent in communicating science to different and diverse stakeholder groups. Effective communication to agricultural

audiences is perceived to be greatly influenced by political atmosphere, market economy, and other complex social factors.

Climatologists also emphasized their presence and availability, or lack thereof, to agricultural audiences. Several references were made indicating that the average public is not aware of their position and roles and as a result are unsure of whom to contact in order to inquire about climate information. This could potentially be an artifact of the privatization of agricultural weather services more than 15 years ago, since many farmers now receive weather and climate information through private sources. Also, the public is more familiar with the media broadcast meteorologist as a source of information. Increasingly, weather and climate data users are able to access information through the Internet. Because of these reasons, state climatologists may not be contacted to provide specific information. If farmers are generally not requesting information from climatologists, this may escalate the disconnection between what information is available and what information is desired and useful.

Climatologists recognize that climate science data can help people with long-term planning. Particularly in the agricultural sector, this help involves reducing potential risk. "That's something that people in agriculture typically have to do—they have to manage risk" (No. 4), one climatologist remarked. Another climatologist noted,

Many of the things that we can do to help people make decisions based on data, based on outlooks, based on probabilities, are noncontroversial. But they are the basics of longer-term planning—how do you make a decision or plan for some uncertainties to reduce your risks? (No. 5)

Climatologists discussed that they were careful in their education of non-expert publics to separate scientific data and processes from political positions and reinforce the dynamic changing nature of what science knows. One climatologist elaborated,

Climate is dynamic. That's one of the most important lessons I think that we can teach our clientele and those that we're trying to educate—it has changed in the past, it will in the future, regardless of human activity. (No. 2)

Another state climatologist reaffirmed this theme,

One point I always try to make is that climate is always changing, always changing, whether caused by humans or not. If you took humans out of the picture, there is still going to be change in climate. But I mean people should just take that as a matter of fact—you're going to have to deal with change

because things aren't going to be the same. And I think a lot of people just don't realize that. They think of nature itself as just kind of static, as kind of this museum piece that doesn't change. And yet it's always changing. (No. 6)

And another climatologist from a third state was more explicit about the dynamic nature of science,

Politicians get up there and say, "The science is settled. Global climate change is here" . . . Any scientist worth a grain of salt would never agree to that statement. The science is never settled. What we're trying to do when we question information into the future is not that we disagree with it—in some instances I do agree with it, in other instances I don't agree with it—what we're trying to do is ensure that we've got the analysis done right. Because the ultimate fear of a meteorologist or a climatologist should be that, if you can't get an accurate assessment of the future, how do you expect the public, as you go forward in time, to believe the information you're trying to present? (No. 7).

Facts. Although the structure of State Climate Offices varies by state, the vast majority of climatologists interviewed in the NCR reported direct connections with state land grant universities. With the exception of one state climatologist who is housed in a state department of agriculture, all climatologists made reference to their connections and roles within the land grant institution. State land grant universities were established by the Morrill Acts of 1862 and 1890 and have three mandated missions: teaching, research, and extension. Extension and outreach are essential components of the land grant mission extending research findings and scientific information to the communities and general public of the state, including agricultural stakeholders. As a result, several climatologists referred to themselves as public servants and considered climate data users within their state as constituents.

Perhaps because of their primary role as employees of public land-grant institutions, the majority of climatologists adamantly declared their communication techniques to always be neutral and objective. Furthermore, climatologists stressed their responsibility to communicate only scientifically accurate information. Accuracy and objective science were reoccurring and dominant themes that emerged throughout the interviews. True to the land grant mission, one climatologist remarked, "We want to be always seen as an impartial deliverer of climate data, data that people can trust, and know it was not provided by somebody with an agenda" (No. 8). Although accuracy and objectivity were not specifically referenced in this statement, undertones strongly suggest the need to remain unbiased and neutral when communicating scientific climate information. Another climatologist stated, "I'm just

presenting information that's impartial, it's nonbiased, there's no agenda with it" (No. 9).

The complex political atmosphere was also mentioned in reference to the need to remain objective. "I try to make it as apolitical as possible," one climatologists remarked, "and just show the facts, the data, the information and let folks come up with their own decision or assessment on what they think might be happening" (No. 9). In this case, the climatologist references the first communication strategy in elements of climate science communication (Table 2) by focusing only on the facts and letting the audience decide how to interpret the information. Fischhoff's (1995) third stage of uncertain risk communication, explaining what is meant by the numbers, is the transition point between facts and relevance. For climatologists, "All we have to do is explain what we mean by the numbers" is about translating their complex statistical models, for example, by explaining how the confidence of precipitation data can be used to compute probability of precipitation. However, talking about what the numbers mean does not necessarily equate with these numbers being useful or relevant to a particular clientele.

Relevance. The extension climatologists are employees of land grant institutions and are generally much more proactive in employing communication techniques in accordance with climate science communication Element 2, Relevance. In other words, they recognized the need to not only objectively convey accurate information and let the audience decide how to interpret it but also frame the information in a way in which it is perceived as relevant and important to the intended audience.

For instance, one extension climatologist discussed employing communication techniques to engage the audience, stating, "I usually try and relate it to something they're familiar with" (No. 3). By making the information relevant to the real-world impacts of the agricultural operation, the extension climatologist recognizes that science communication may be more efficient and productive. A few references were made indicating that abstract climate science concepts must be grounded in real-world situation. For instance, climatologists often utilize the El-Nino Southern Oscillation (ENSO) as a tool to predict climate patterns out for a growing season or more. However, many farmers are not aware of ENSO and thus are unable to relate why that science would be important to their operation. As a result, it is important to relate the science necessary for climate model forecasting to real-world risk impacts. "We look at the most relevant models, whether they're ENSO-based, atmospheric patterns," one climatologists stated, "We try to identify what's going on and try to project that type of pattern as we move to the growing season to give the producers a risk assessment" (No. 10). By providing a risk

assessment, the climatologist has more effectively gained the attention of the agricultural audience for which the message is intended.

Relevance may also be an important tool for avoiding controversies and political connotations associated with climate change. For instance, one climatologist acknowledges, “When you talk about risk management . . . that’s not a controversial topic. Risk management, trying to reduce risk, trying to maximize economic profitability . . . people are all on board with that . . .” (No. 1). In this regard, connecting available climate science information to relevant risk management concerns may be an effective way of communicating the science of climate to agriculture.

Engagement. Although the majority of references to the three elements of climate science communication themes revolved around remaining accurate and objective, and a few mentioned relevance and importance, there were also some references to Element 3, Engagement. Climatologists who acknowledged this stage recognized the importance of the agricultural audience’s local and indigenous knowledge. As one climatologist remarked, “A couple of things you need to understand about farmers: First, there aren’t any dumb ones. If there was ever such a thing as the old dumb farmer, they’ve been out of business now for decades” (No. 5).

The Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS) is a public weather observation program that engages local people in collecting data as citizen-scientists. Through CoCoRaHS, the public enter their local weather observations (precipitation, temperature, wind, etc.) into the system, which then feeds back into NWS (National Weather Service) forecasts, the Drought Monitor, and other agriculturally relevant weather and climate information. Since the majority of weather stations are located near airports or universities, and not necessarily in the fields of the farmers who are hoping to retrieve site-specific information, this network is a tool for scientists to assist in precision and localization of forecasts. Almost all the acknowledgments that climatologists made in reference to engaging and gaining trust from the agricultural audience were in reference to this citizen-science network.

One climatologist remarked,

Many of our observers are farmers, and so they provide us not only with the climate measurement, like the low temperature for the night, but they also provide us with field assessments of whether or not there was any damage. (No. 11)

The CoCoRaHS network is important for alerting climate scientists to weather-related risks and impacts. This greatly assists the climate science

community in more adequately adjusting their forecasts to meet the needs of farmers. Furthermore, the increased density of data points, particularly in rural areas, increases the certainty of weather and climate forecasting.

To most effectively communicate climate science to the agricultural community, it may be necessary to engage them and build trust to mutually assist the development and practical implementation of the science to real-world impacts. "I think the real approach to get farmers to adapt and change their practices so that their family farm is sustainable and can keep going economically is to approach them as a team of educators," remarked one extension climatologist (No. 11). In doing so, climatologists and farmers would benefit in increased access to site-specific climate forecasts, as well as advanced knowledge of potential risks associated with such forecasts.

Discussion and Implications

Climatologists face a daunting task in communicating phenomena that may not be directly experienced in a human lifetime (Weber, 2006). While weather and climate patterns are observed by humans where they live, greenhouse gas measurements and global warming are characteristics of global earth system cycles with complex indirect local impacts (Romero-Lankao et al., 2014). The scale at which climate science knowledge is based far exceeds human scale and the cognitive processes that evolved to address practical interactions with the surrounding environment (Dahlstrom, 2014). Climatologists as scientists play a bridge role in presenting climate science and providing information to public data users and interacting with various stakeholders. They are focused primarily on providing factual information that is objective and accurate. As employees of public land grant institutions with high-profile and often politically sensitive positions, this reliance on objectivity is highly valued. Our data suggest that some climatologists actively embrace their roles involving public service and engagement. Climatologists also discussed the necessity of making the information relevant to various stakeholder audiences so as to make it understood and useable. Some climatologists recognized the need to provide information in a way that it is trusted and avoids political agendas. And the citizen weather observation program was especially viewed as a stakeholder participatory process that builds scientific literacy and engages the public in scientific learning.

While 95% of the interviewed climatologists agree that climate change is happening, a little more than half of the climatologists agreed it is caused mostly by human activities with a third claiming both human and natural causality. This is at odds with the scientific consensus claim that 97% of climate scientists agree that "most" of the warming of the Earth's average global

temperature is caused by anthropogenic greenhouse gases (Anderegg, Prall, Harold, & Schneider, 2010). What might account for this difference?

First, it is useful to take a closer look at the methodology of Anderegg et al. (2010) and their sample of climate scientists that leads to the 97% consensus suggestion. The authors are careful to note that their list of research climate scientists was “. . . not comprehensive nor designed to be representative of the entire climate science community” (p. 12107) but rather to identify only the most credentialed, high-profile experts within this discipline. Their findings are derived from a database of climate scientists using two metrics for expertise and prominence: authorship of a minimum of 20 climate publications (344 was the median) and each researcher’s four highest cited papers. This database of climate scientists consisted of 1,372 climate researchers, including 903 researchers involved in the IPCC Fourth Assessment Report working group and 472 high-profile researchers criticizing IPCC conclusions. These are scientists examining global climate phenomena at scales and abstractness far removed from the scale at which our sample of climatologists work.

State and extension climatologists are region-specific in their science and expertise. As a result, global climate models, which appear to indicate anthropogenic atmospheric warming, are only one data point for this group of climatologists to consider. For example, while the global climate system is well-studied, “literature using place-based or integrated approaches to these complexities is limited” (Romero-Lankao et al., 2014, p. 46). Furthermore, this macro view gives insufficient detail on context specific local impacts and risks, missing the on-the-ground reality that the effects of climate change are and will be experienced at much smaller scales (Romero-Lankao et al., 2014). State and extension climatologists are not primarily research focused scientists but rather, as our data support, have roles and responsibilities that involve gathering real-time data, archiving and developing past climate trends, and responding to stakeholder requests for information. Thus, they are not researching and producing peer reviewed science on the global climate system as are the 97% of climate scientists reported in the Anderegg et al. (2010) study.

As applied scientists, climatologists must find ways to effectively bridge pure climate science “truth” and the nonexpert disconnect with what climate change is and means on a practical level. Thus, their interactions with farmers and nonexpert public are characterized by (1) distancing their message from political agendas so as to build trust, (2) presenting and interpreting the facts about local climate data in ways that are relevant to their stakeholders, and (3) reminding their clientele that climate science, like all kinds of science, is not fixed but is continually changing as new knowledge is discovered and past knowledge refined.

Conclusion

Science is a critical foundation necessary to effectively address issues facing modern society, and there is “an obligation on the scientific community to develop different and closer links with the general population” (Leshner, 2003, p. 977). Climatologists have an expertise that can benefit farmers and the agricultural sector by providing weather and climate information that will assist in developing long-term agricultural management portfolios (Wilke & Morton, 2015). This knowledge can help farmers remain resilient and profitable, while adapting to and mitigating uncertain environmental risks and hazards. While logical-scientific communication as found in scientific journals is often abstract and context-free and deals with facts that retain meaning independent of the surrounding units of information (Dahlstrom, 2014), there is a need for context-dependent communication that has practical applications of value to stakeholders. Climatologists are climate scientists who understand that they must make their science relevant to their stakeholders but are challenged to find strategies to communicate the facts and how to interpret them in a practical way while managing the controversy associated with climate causality.

Communication scientists have highlighted that facts rarely “speak for themselves” and must be translated or framed as meaningful for society (Nisbet, 2009; Nisbet & Scheufele, 2007; Pidgeon & Fischhoff, 2011). Dahlstrom (2014) suggests that narrative formats of communication may offer increased comprehension and engagement. “Climate change,” he acknowledges, “provides an obvious context where conflicting narratives are present, including disjointed narratives of problem versus solution” (p. 13618). Other researchers find that “farmers use narrative to interpret and give meaning” and recommend “. . . listening to their word choices and the language of these narratives can provide guidance to gaining their attention and effective communication” (Arbuckle et al., 2014, pp. 514-515).

Dahlstrom (2014) identifies trust in the person delivering the science as essential for successful science communication. In 2011, most of the farm community that climatologists serve clearly did not believe climate change is human-caused (8%); however, more than two thirds accepted that climate change is happening (Prokopy et al., 2015). This suggests that the entry for building trust is to focus on responding and adapting to changing conditions rather than focusing on causality. This does not mean climatologists do not discuss the sources of climate change with their stakeholders but rather indicates that they build interpersonal trust in conjunction with engaging in adaptation and mitigation dialogues. Assessment of various agricultural stakeholder groups, including scientists, indicates that to effectively connect

climate science to agricultural decision support, efforts should focus on management of risks associated with climate, or solutions (Prokopy et al., 2015). In the communication of climate science, weather and climate data may act catalysts to discussions about changing farm management systems, and potential dual outcomes of decisions may result as agricultural stakeholders seek to minimize on farm risks (adaptation) while simultaneously reducing off-farm externalities that contribute to changes in climate (mitigation).

Society obtains information in many ways and increasingly scientific information is distorted by the media environment and the cognitive interpretations of the receiver (Dahlstrom, 2014). Scientists have a unique role and responsibility to reacquaint science with reality, by making connections to real-world problems (Rockstrom, 2012). Communications intended for an agricultural audience must relate to direct impacts of climate on agricultural management systems if the information is to be relevant and useful. Furthermore, information needs to be location- and operation-specific. Utilizing the climate-is-always-changing by definition, climatologists may overcome social, cultural, and political influences that negatively affect farmers' reception of scientific information by communicating long-term projections in terms of *climate*, or *climate science*, as opposed to the politically charged phrase *climate change*. This may assist scientists in focusing on communicating beneficial climate science information for adaptive solutions, while increasing engagement and trust, and ultimately reception of scientific information.

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Note

1. States include Ohio, Indiana, Illinois, Wisconsin, Michigan, Minnesota, Iowa, Missouri, Kansas, Nebraska, and South Dakota.

References

- Adams, R., Rosenzweig, C., Peart, R., Ritchie, J., McCarl, B., Glycer, J., . . . Allen, H. (1990). Global climate change and US agriculture. *Nature*, *345*, 219-224.
- Anderegg, W. R. L., Prall, J. W., Harold, J., & Schneider, S. H. (2010). Expert credibility in climate change. *Proceedings of the National Academy of Sciences of the United States of America*, *107*, 12107-12109.
- Arbuckle, J. G., Hobbs, J., Loy, A., Morton, L. W., Prokopy, L. S., & Tyndall, J. (2014). Understanding Corn Belt farmer perspectives on climate change to inform engagement strategies for adaptation and mitigation. *Journal of Soil and Water Conservation*, *69*, 505-516.
- Arbuckle, J. G. J., Morton, L. W., & Hobbs, J. (2013). Understanding farmer perspectives on climate change adaptation and mitigation: The roles of trust in sources of climate information, climate change beliefs, and perceived risk. *Environment & Behavior*, *42*, 205-234. doi:10.1177/0013916513503832
- Bartels, W.-L., Furman, C. A., Diehl, D. C., Royce, F. S., Dourte, D. R., Ortiz, B. V., . . . Jones, J. W. (2012). Warming up to climate change: A participatory approach to engaging with agricultural stakeholders in the Southeast US. *Regional Environmental Change*, *13*(Suppl. 1), S45-S55. doi:10.1007/s10113-012-0371-9
- Beck, U. (1992). *Risk society: Towards a new modernity*. London, England: Sage.
- Carvalho, A. (2007). Ideological cultures and media discourses on scientific knowledge: Re-reading news on climate change. *Public Understanding of Science*, *16*, 223-224.
- Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, *20*, 37-46.
- Cohen, J. (1968). Weighted kappa: Nominal scale agreement with provision for scaled disagreement or partial credit. *Psychological Bulletin*, *70*, 213-220.
- Coleman, J. (1990). *Foundations of social theory*. Cambridge, MA: Belknap Press.
- Cuomou, D., & Rahmstorf, S. (2012). A decade of weather extremes. *Nature Climate Change*, *2*, 491-496.
- Dahlstrom, M. F. (2014). Using narratives and storytelling to communicate science with nonexpert audiences. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(Suppl. 4), 13614-13620.
- Delicado, A. (2012). *Climate scientists and the public: Interactions and knowledge exchanges*. Retrieved from <http://www.pantaneto.co.uk/issue47/delicado.htm>
- Dietz, T. (2013). Bring values and deliberation to science communication. *Proceedings of the National Academy of Sciences of the United States of America*, *110*, 14081-14087.
- Dilling, L., & Lemos, M. C. (2011). Creating useable science: Opportunities and constraints for climate knowledge use and their implications for policy. *Global Environmental Change*, *21*, 680-689.
- Dillman, D., Smyth, J., & Christian, L. (2009). *Internet, mail and mixed-mode surveys: The tailored design method*. Hoboken, NJ: Wiley.
- Dunlap, R. E., & Saad, L. (2001, April 16). Only one in four Americans are anxious about the environment. *Gallup News Service*. Retrieved from <http://www>.

- gallup.com/poll/1801/Only-One-Four-Americans-Anxious-About-Environment.aspx?utm_source=Only%20one%20in%20four%20Americans%20are%20anxious%20about%20the%20e&utm_medium=search&utm_campaign=tiles
- Fischhoff, B. (1995). Risk perception and communication unplugged: Twenty years of progress. *Risk Analysis*, *15*, 137-145.
- Fischhoff, B. (2012). Communicating uncertainty: Fulfilling the duty to inform. *Issues in Science and Technology*, *Summer*, 63-70.
- Gross, A. G. (1994). The roles of rhetoric in the public understanding of science. *Public Understanding of Science*, *3*, 3-23.
- Haden, V. R., Niles, M. T., Lubell, M., Perlman, J., & Jackson, L. (2012). Global and local concerns: What attitudes motivate farmers to mitigate and adapt to climate change. *PLoS ONE*, *7*, e52882.
- Harwood, J., Heifner, R., Coble, K., Perry, J., & Somwaru, A. (1999). *Managing risk in farming: Concepts, research and analysis* (Report No. 774). Washington, DC: Market and Trade Economics Division and Resource Economics Division, Economic Research Service, U.S. Department of Agriculture Economic.
- Hoffman, A. (2011). Talking past each other? Cultural framing of skeptical and convinced logics in the climate change debate. *Organization & Environment*, *24*, 3-33
- Howden, S. M., Soussana, J.-F., Tubiello, F. N., Chhetri, N., Dunlop, M., & Meinke, H. (2007). Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences of the United States of America*, *104*, 19691-19696.
- Innes, J. W. (1994). *Knowledge and public policy: The search for meaningful indicators*. New Brunswick, NJ: Transaction.
- Jones, J., Hansen, J., Royce, F., & Messina, C. (2000). Potential benefits of climate forecasting to agriculture. *Agriculture, Ecosystems & Environment*, *82*, 169-184.
- Kahan, D. M., & Braman, D. (2006). Cultural cognition and public policy. *Yale Law Policy Review*, *24*, 149-172.
- Kahan, D. M., Jenkins-Smith, H., & Braman, D. (2011). Cultural cognition of scientific consensus. *Journal of Risk Research*, *14*, 147-174.
- Layton, D., Jenkins, E. W., McGill, S., & Davey, A. (1993). *Inarticulate science? Perspectives on the public understanding of science and some implications for science education*. East Yorkshire, England: Studies in Education.
- Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change*, *77*(1-2), 45-72.
- Leiserowitz, A., Smith, N., & Marlon, J. (2010). *Americans' knowledge of climate change*. New Haven, CT: Yale Project on Climate Change Communication, Yale University. Retrieved from environment.yale.edu/climate/files/ClimateChangeKnowledge2010.pdf
- Leshner, A. I. (2003). Public engagement with science. *Science*, *299*, 977.
- Lewenstein, B. V. (1992). The meaning of "public understanding of science" in the United States after World War II. *Public Understanding of Science*, *1*, 45-68.
- Malka, A., Krosnick, J. A., & Langer, G. (2009). The association of knowledge with concern about global warming: Trusted information sources shape public thinking. *Risk Analysis*, *29*, 633-647.

- Mase, A. S., & Prokopy, L. S. (2014). Unrealized potential: A review of perceptions and use of weather and climate information in agricultural decision making. *Weather, Climate, and Society*, 6, 47-61.
- McBean, G. A., & Hengeveld, H. G. (2000). Communicating the science of climate change: A mutual challenge for scientists and educators. *Canadian Journal of Environmental Education*, 5, 9-25.
- Melillo, J. M., Richmond, T. C., & Yohe, G. W. (Eds.). (2014). *Climate change impacts in the United States: The third national climate assessment* (U.S. Global Change Research Program). Retrieved from <http://nca2014.globalchange.gov/>
- Miller, J. D. (2004). Public understanding of, and attitudes toward, scientific research: What we know and what we need to know. *Public Understanding of Science*, 13, 273-294.
- Moser, S. C. (2010). Communicating climate change: History, challenges, process and future directions. *WIREs Climate Change*, 1, 1-27.
- Myers, T., Maibach, E., Roser-Renouf, C., Akerlof, K., & Leiserowitz, A. (2012). The relationship between person experience and belief in the reality of global warming. *Nature Climate Change*, 1-5. doi:10.1038/nclimate1754
- Neuman, W. L. (1994). *Social research methods: Qualitative and quantitative approaches* (2nd ed.). Needham Heights, MA: Allyn & Bacon.
- Nielsen, L. A. (2001). Science and advocacy are different—and we need to keep them that way. *Human Dimensions of Wildlife*, 6, 39-47.
- Nisbet, M. (2009). Communicating climate change: Why frames matter for public engagement. *Environment: Science and Policy for Sustainable Development*, 51(2), 12-23.
- Nisbet, M., & Scheufele, D. (2007). The future of public engagement. *The Scientist*, 21(20), 38-46.
- Nisbet, M., & Scheufele, D. (2009). What's next for science communication? Promising directions and lingering distractions. *American Journal of Botany*, 96, 1769-1778.
- Pidgeon, N., & Fischhoff, B. (2011). The role of social and decision sciences in communicating uncertain climate risks. *Nature Climate Change*, 1, 35-41.
- Poliakoff, E., & Webb, T. L. (2007). What factors predict scientists' intentions to participate in public engagement of science activities? *Science Communication*, 29, 242-263.
- Prokopy, L. S. (2011). Agricultural human dimensions research: The role of qualitative research methods. *Journal of Soil and Water Conservation*, 66, 9A-12A.
- Prokopy, L. S., Morton, L. W., Arbuckle, J. D., Jr., Mase, A. S., & Wilke, A. K. (2015). Agricultural stakeholder views on climate change: Implications for conducting research and outreach. *Bulletin of the American Meteorological Society*, February, 1-9. doi:10.1175/BAMS-D-13-00172.1
- QSR International. (2010). *NVivo qualitative data analysis software* (Version 9) [Computer software]. Burlington, MA: Author.
- Rabinovich, A., & Morton, T. A. (2012). Unquestioned answers or unanswered questions: Beliefs about science guide responses to uncertainty in climate change risk communication. *Risk Analysis*, 32, 992-1002.

- Rejesus, R. M., Mutuc-Hensley, M., Mitchell, P. D., Coble, C. H., & Knight, T. O. (2013). U.S. Agricultural producer perceptions of climate change. *Journal of Agricultural and Applied Economics*, 45, 701-718.
- Rockstrom, J. (2012). Science's role and responsibility. In A. Wijkman & J. Rockstrom (Eds.), *Bankrupting nature: Denying our planetary boundaries* (pp. 19-28). New York, NY: Routledge.
- Romero-Lankao, P., Smith, J. B., Davidson, D., Diffenbaugh, N., Kinney, P., Kirshen, P., . . . Villers Ruiz, L. (2014). North America. In V. R. Barros, Field, C. B., Dokken, D. J., Mastrandrea, M. D., Mach, K. J., Bilir, T. E., . . . White, L. L. (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contributions of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1439-1498). Cambridge, England: Cambridge University Press.
- Slovic, P. (1999). Trust, emotion, sex, politics, and science: Surveying the risk-assessment battlefield. *Risk Analysis*, 19, 689-701.
- Walthall, C. L., Hatfield, J., Backlund, P., Lengnick, L., Marshall, E., Walsh, M., . . . Ziska, L. H. (2012). *Climate change and agriculture in the United States: Effects and adaptation* (USDA Technical Bulletin No. 1935). Washington, DC: U.S. Department of Agriculture.
- 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.
- Weber, E. U. (2010). What shapes perceptions of climate change? *Wiley Interdisciplinary Reviews Climate Change*, 1, 332-342.
- Weber, E. U., & Stern, P. C. (2011). Public understanding of climate change in the United States. *The American Psychologist*, 66, 315-328.
- Wilke, A. K., & Morton, L. W. (2015). Climatologists' patterns of conveying climate science to the agricultural community. *Agriculture and Human Values*, 32, 99-110.
- Wilsdon, J., & Willis, R. (2004). *See-through science: Why public engagement needs to move upstream*. London, England: Demos.
- Wynne, B. (2006). Public engagement as a means of restoring public trust in science: Hitting the notes, but missing the music? *Community Genetics*, 9, 211-220.
- Zehr, S. C. (2000). Public representations of scientific uncertainty about global climate change. *Public Understanding of Science*, 9, 85-103.

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