How to Communicate Scientific Uncertainty

Summary

Scientific uncertainty is a component of many environmental and public health issues, such as climate change or the use of biotechnology. While some uncertainty is inevitable, the ways in which various professions communicate uncertainty also shape those debates, from the interpretation of scientific data to its dissemination for a mass audience to its use in advocacy and policymaking. Scientists, lawyers, and journalists all play different roles in addressing scientific uncertainty, in part due to differing professional norms and ethical standards. On April 15, 2016, the Environmental Law Institute convened a webinar featuring experts from each of these professions, who provided their perspectives on effectively communicating scientific information, practicing climate and weather journalism in a shifting media environment, and translating uncertainty into policy. Below we present a transcript of the discussion, which has been edited for style, clarity, and space considerations.

Jay Austin (moderator) is a senior attorney at ELI and Editor-in-Chief of the *Environmental Law Reporter*.
Dr. Sunshine Menezes is Executive Director of the Metcalf Institute for Marine & Environmental Reporting at the University of Rhode Island.
Jason Samenow is weather editor for the *Washington Post* and founder of the Capital Weather Gang.
Margaret Davidson is the senior leader for Coastal Inundation and Resilience Science and Services at NOAA's National Ocean Service.

Jay Austin: Today's Dialogue on issues in communicating scientific uncertainty is the second time we've addressed this topic in the past couple of years.[1] As we all know, scientific uncertainty is an aspect of almost every environmental and public health issue today, and at almost every stage of the process. It's there from the time scientists make their initial observations and measurements, through their analysis, all the way up to their published conclusions. In those conclusions, scientific uncertainty is often formally expressed and quantified.

Journalists and other communication specialists then have to grapple with how to translate those findings and the accompanying uncertainty for a larger audience; with how to stay faithful to what the science is trying to tell us (or, equally important, not tell us), while still holding their readers' or listeners' attention in an era when there's ever-increasing competition for people's attention.

We lawyers tend to invoke certainty and uncertainty in a variety of ways and in a variety of contexts. We use it as a reason for taking action where the evidence shows that something is "more likely than not." We use it as a reason for abstaining from legal action and instead deferring to an agency's scientific expertise under a much higher standard of proof, or use it as a reason for acquitting someone when there's even so much as a "reasonable doubt." Finally, policymakers and tribunals somehow have to make sense of all this and weigh the scientific evidence, the advocates' arguments, and even some degree of popular opinion when they issue their rules and decisions.

Our goal today is fairly modest: to illustrate some of the challenges and show how each of these professions addresses and communicates scientific uncertainty, and in particular how their professional culture and ethical standards might shape the way that they do that. First, we'll hear from Dr. Sunshine Menezes, executive director of the Metcalf Institute for Marine & Environmental Reporting at the University of Rhode Island and an expert in science communication. Next up will be Jason Samenow, weather editor for the *Washington Post*, founder of the much-consulted Capital Weather Gang, and a real pioneer in how to communicate very complex atmospheric science online and for a mass audience. Finally, we'll hear from Margaret Davidson, senior leader for Coastal Inundation and Resilience at the National Oceanic and Atmospheric Administration's (NOAA's) National Ocean Service. Like me, Margaret is a lawyer; unlike me, she's an experienced policymaker.

Sunshine Menezes: To start, I'd like to sum up what was discussed in the 2014 dialogue on scientific uncertainty,

1. Jay Austin et al., *Ethics of Communicating Scientific Uncertainty*, 45 ELR 10105 (Feb. 2015); *see also* ELI, Communicating Scientific Uncertainty: 2014 Workshop (Sept. 22-23, 2014), http://www.eli.org/scientific-uncertainty/communicating-scientific-uncertainty-2014-workshop. Materials from the April 2016 webinar, including an audio recording of the event, can be found at ELI, Issues in Communicating Scientific Certainty, http://www.eli.org/events/issues-communicating-scientific-uncertainty.

Figure 1: Which Profession Says What?

Profession	Norms	Challenge	Outcome
Science (per George Gray)	Accuracy and Disclosure	Hard to communicate clearly	"uncertainty equated with incompetence"
Law (per Jim Hilbert)	Preponderance of evidence; Testimony from qualified experts	Court's ability to evaluate validity and reliability of expert	"trial judge is gatekeeper of scientific information"
Journalism (per Dave Poulson)	Fairness, Accuracy, Engagement	Producing stories that engage news audiences	"dead rat" journalism

just to bring us all up to speed. The way I frame the issue is: "What does the lawyer say? What does the journalist say? What does the scientist say?" Here's a simplified table of what the scientist, lawyer, and journalist say, based on the 2014 dialogue.

As scientist George Gray puts it, the norms for the scientist with regard to uncertainty are about accuracy and disclosure, but the challenge is that it's very hard to communicate technical details clearly. The outcome, unfortunately, is often that when scientists talk about uncertainty, their uncertainty is interpreted by the general public as an admission that those scientists don't know what they're talking about.

Meanwhile, the lawyers are looking at uncertainty with regard to the familiar preponderance of the evidence standard used in civil trials, and they turn to qualified experts to gain insights on uncertainty. The challenge there is the court's ability to evaluate the expertise. As lawyer Jim Hilbert puts it, the trial judge ultimately becomes the gatekeeper of scientific information. In view of some of the data that he presented showing that many judges really don't understand scientific uncertainty, that's a big problem.

Finally, the journalist, per Dave Poulson's take on this, is looking at fairness and accuracy and engagement, with engagement being the real stickler because it's hard to talk about uncertainty in a way that's interesting and not technically difficult for a wide variety of people. This can result in what Dave has referred to as "dead rat" journalism—meaning, there's a dead rodent on my doorstep, I have no idea how it got there, I have no context and, therefore, I don't really know what to do with that bit of information.

A joint project by the Yale Program on Climate Change Communication and the George Mason University Center for Climate Change Communication published their study in the October 2015 *Climate Change in the American Mind* report.[2] What it shows is that, according to their surveys, only 12% of Americans realize that more than 90% of scientists concur on the climate consensus. This gap is a big problem because research has shown that understanding of scientific consensus is a so-called gateway belief that affects attitudes about other aspects of climate change science and mitigation efforts.

It's no surprise that so many people are confused about scientific uncertainty writ large when you look at the data on American numeracy. Data from a 2012 study by an international organization, the Programme for the International Assessment of Adult Competencies,[3] looking at the literacy and numeracy of different people found that in the United States, about 30% of the adult population lacks basic math skills. That is a real hurdle to people being comfortable with scientific uncertainty when it's discussed in the context of quantitative probabilities.

Figure 2: Public Understanding of Science

Question	1999	2001	2004	2006	2008	2010	2012	2014
Understanding of scientific inquiry scale	32	40	39	41	35	42	33	46
Components of understanding scientific inquiry scale:								
Understanding of probability	64	67	64	69	64	66	65	66
Understanding of experiment	34	40	46	42	38	51	34	53
Understanding of scientific study	21	26	23	25	23	18	20	26

NSF. Science & Engineering Indicators 2016. Table 7-4

Another way to look at this is from this table that I took from a 2016 National Science Foundation (NSF) *Science and Engineering Indicators* report.[4]

It shows minor changes over time on how Americans understand scientific inquiry. The top line, the understanding of scientific inquiry scale, is a combination of the responses to other issues all noted below.

Data on the understanding of probability pretty much matches with those found in the international study, that only about two-thirds of Americans have an understanding of basic probabilities. In addition, very few Americans have a strong understanding of what it means to do experimentation and, further, what actually qualifies as a scientific study. The understanding of scientific inquiry scale on this graphic shows, again, that about one-third of Americans lack the math skills and the understanding of probabilities

2. Anthony Leiserowitz et al., Climate Change in the American Mind: October 2015, at 9 (Yale University and George Mason University 2015), *available at* http://www.climatechangecommunication.org/all/october-2015-climate-change-american-mind/).

3. Available from the American Institutes for Research, www.air.org.

4. National Science Board, Science & Engineering Indicators 2016, https://www.nsf.gov/statistics/2016/nsb20161/#/.

to feel comfortable and confident understanding scientific uncertainty. No wonder it's so hard to explain this!

What does this mean in terms of actually talking with public audiences about scientific uncertainty? Well, the first thing to note is that there is no such thing as "the public." Social science research is helping us to understand that public audiences are very different. Their contexts are dependent upon their demographics, values, biases, experiences, et cetera. So, when you look at the goal of building public understanding of science via knowledge, attitudes, and trust, it's important to recognize that the link between knowledge and attitudes is mediated by that multi-variant context.

Likewise, it turns out that knowledge itself is mediated by trust—meaning, do we trust the source of the information that we're getting, whether it's a scientist, journalist, politician, or whomever? Researchers[5] are looking at the issue of trust mediating knowledge in terms of how expertise (for example, of scientists or journalists) and platforms of different media types (for example, television and the Internet) affect how people trust sources and build knowledge.

In the medical sciences, too, we see examples of how trust mediates knowledge. There's a recent paper from *Medical Anthropology* in which the authors were looking at how parents make decisions about whether or not to vaccinate their kids.[6] What the researchers found is that people are curating information themselves now in much the same way you would curate your own Pinterest board—meaning, pulling together bits and pieces of information from different places that are not necessarily in a linear progression of thought and could even be conflicting bits of information from different places. People are pooling all of this together to make their own decisions about vaccinating their kids.

We know now that whether it's through personal content curation, as discussed in this medical paper, or other means, people struggle with scientific inquiry. We also know that trust can be a critical mediator of knowledge and understanding. This is where the Metcalf Institute, of which I am executive director, comes in. I'm a scientist by training. I've never been a journalist. But I've been working in the field of science communication for about 10 years. What we do at Metcalf is try to build trust in a few ways. One way is by building connections between scientists and journalists. Another way is by giving each of these groups, the scientists and the journalists, the skills and resources and confidence to become trustworthy for the benefit of the public understanding of science.

One of the ways that we address this is by talking with both scientists and journalists about the various types of uncertainties. As you can see in the next graphic from the Intergovernmental Panel on Climate Change (IPCC), their language offers a prime example of the challenge for scientists to integrate their norms of accuracy and disclosure with clear communication.

Figure 3: IPCC's Language of Uncertainty

Type of Uncertainty	Descriptors
Questionable probabilities	Very unlikely to very likely
Evidence	Limited, medium, robust
Degree of agreement	Low, medium high
Degree of confidence (evidence + agreement)	Very low to very high

"I have a lot of sympathy with the efforts of the IPCC at assessing and communicating both quantifiable probabilities (when appropriate) and 'confidence' in the underlying evidence" ~ David Spiegelhalter

Spiegelhalter quote: http://www.futureearth.org/blog/2014-mar-31/medium-confusion-ipccs-approach-communicating-uncertainty

At the IPCC, there are all sorts of different types of information that are being parsed. There are those quantifiable probabilities that they're now using, both probabilistic terms from "very unlikely" to "very likely," and numbers, which is good. That helps people understand.

In addition to those quantifiable probabilities, there are the other types of uncertainty, such as how confident are we in the evidence we have to draw these scientific conclusions. Then, in addition to that, there is how much do we agree—we, the scientists working on this document—on the evidence for all these different things. All of those are combined in the bottom row on the graphic to create the so-called degree of confidence in the finding.

This is a very difficult and confusing suite of uncertainties to try to communicate to nontechnical audiences. There was a meeting convened by the IPCC in February 2016 of experts on communication, because they're continuously trying to improve the way they talk about these issues. One of the advanced papers in that meeting was from David Budescu, who said the effectiveness of communication of uncertainty can be improved by revising our definitions of probabilistic terms. The definitions that the IPCC uses for these terms are not necessarily in line with people's natural intuitive understanding of the phrases. For instance, his research has shown that the IPCC's ranges for the terms "very unlikely" and "very likely" are far too narrow. They are far too extreme in comparison with survey respondents' intuitive interpretations of those terms.

When we are working with scientists, we talk a lot about communicating uncertainty. There's a long list of best practices available from numerous sources about that. Knowing your audience and the context is important. Words and numbers are important. It's also important to frame uncertainty within a broader context and, very importantly, to stress areas of consensus. Scientists tend to focus on areas of debate because that's what is interesting to a scientist. We want to know where the uncertainties are and how we can move forward in those areas of inquiry.

5. *See, e.g.*, Bruno Takahashi & Edson C. Tandoc Jr., *Media Sources, Credibility and Perceptions of Science: Learning About How People Learn About Science* (Mar. 18, 2015), *available at* http://pus.sagepub.com/content/early/2015/03/18/0963662515574986.abstract.
6. Elisa J. Sobo et al., *Information Curation Among Vaccine Cautious Parents*, Med. Anthropology (Jan. 26, 2016), *available at* http://www.ncbi.nlm.nih.gov/pubmed/26814029.

But from an outside perspective, when scientists only talk about debate all the time rather than about consensus, it undermines the effort to help people understand the goal of narrowing our uncertainties.

Another issue is clarifying the difference between a scientific uncertainty and being certain enough in our understanding of something to make a choice to act in response to that potential problem. Presenting clear alternatives for people to choose from is really important, rather than asking them to evaluate something very abstract, such as ocean health or ecosystem services. Those terms don't mean anything to most people. These are some of the things that we work on with scientists to improve their communication of uncertainty.

On the other end, journalists face the "dead rat" problem. But we also have to face the fact that not every journalist is a great science and environment reporter such as Jason Samenow or Seth Borenstein. Many journalists who are covering science, whether it's medical science or environmental science, don't have any expertise in it. They have to cover a wide variety of topics, going from foreign affairs, to county fairs, to oil, to vinegar, from one day to the next. So, it's very hard for us to ask these journalists to clearly explain scientific uncertainty when they're having a hard enough time getting the story right in the bigger scheme of things.

One of the ways that we at Metcalf Institute have addressed this particular issue is through an exercise, or really a suite of exercises, that we call science translation. This involves giving journalists the opportunity to better understand the choices that researchers make in displaying their data. We also introduce them to probabilities, and talk about the limitations and the assumptions you can make when you're dealing with probabilities.

The real capstone to this is helping journalists figure out how to interpret and translate science journal articles more effectively. Again, this is all about building relationships between scientists and journalists and giving them an opportunity to learn from one another about their own norms, and ethics, and limitations in terms of communicating uncertainty.

Our workshop fellows have found this to be a really effective approach. They tell us that our annual Science Immersion Workshop, an informal off-deadline exchange and trust-building between journalists and scientists, is a very effective way to help journalists figure out how to better translate uncertainty. We're doing a small project now with a collaborator looking at a content analysis of our annual workshop alumni. Content analysis shows that, when comparing alumni reporting before they attended this workshop and their writing afterwards, there's a significant increase in their use of context, a broader scientific context, in covering environmental issues after attending the workshop. Also, they're talking about scientific uncertainty in those post-workshop stories in a much more sophisticated way. I'm really pleased to see that, lo and behold, the method truly is working.

I'll conclude with a reminder that, regardless of the issue, we need to help people think about scientific inquiry in a more sophisticated way so we can avoid the "back and forthing" sometimes seen in the press about specific topics (e.g., wine causes cancer, wine prevents cancer) that results from our insufficient explanations of scientific uncertainty.

Jason Samenow: I'm going to be discussing some of the challenges and lessons learned in communicating weather and climate uncertainty. I'm the *Washington Post*'s weather editor and its chief meteorologist. I am not a journalist by training; I'm a scientist by training. I have a master's degree in atmospheric science and started my career by working as a climate change scientist at the U.S. Environmental Protection Agency (EPA). So, I spent about the first decade of my career working on climate change and science communication challenges.

But ever since I was 10 years old, I've been a weather geek. While I was working at EPA, I started a weather website on the side, which was called capitalweather.com. Over time, it grew and the *Post* became interested and eventually we entered into a partnership. I was doing this as a side venture, but it ended up becoming my full-time job. I was offered a position in the newsroom, so I left EPA.

For the last five years, I've been working at the *Post*. I run a blog known as the Capital Weather Gang, which is the *Post*'s weather team. We have one full-time managing editor, that's myself, and a deputy editor, Angela Fritz, who is not a journalist but an atmospheric scientist. I think we're probably the only two scientists in the entire newsroom at the *Post*, but we write. We're science writers or science communicators. We've learned a lot about journalism just by doing and by practicing it. Neither of us had formal journalism training.

In addition, we have a bunch of freelance contributors. Some of them are science communicators, some are meteorologists. They all have other full-time day jobs, or they're retired, but they help us. With our broad mix of content, at the heart of what we do is provide a local forecast and commentary for the D.C. area. But we also cover national and international weather stories. We cover a wide mix of topics including climate change, weather policies, space weather astronomy, sort of a weather-adjacent topic our blog will cover because frankly D.C. weather isn't interesting all the time. The *Post* is increasingly trying to turn itself into more of a national and an international brand. And weather coverage is an important topic pretty much everywhere, so we cover that.

In addition to being a blog, you see our content in print and on mobile devices, and we are also the local forecast voice for our NPR affiliate in D.C.—WAMU 88.5. We do forecasts for the morning and afternoon commutes, do some video as well as TV appearances. But fundamentally, just in terms of our emphasis, ever since we started this as an independent blog back in 2004, we put a real emphasis on communicating uncertainty to help people make better weather-based decisions. We've also put a real empha-

sis on engagement and a two-way conversation about the weather. So, it's not just we the experts, providing information to the user. It's also about getting feedback from the user and helping to improve and sharpen the way we communicate weather information.

Just to step back and think about what I've learned, here are some of the fundamental qualities of successful science communication. I'm borrowing three of these from William Clark, a professor at Harvard University's Kennedy School who has studied the qualities of successful scientific assessments. He's looked at the IPCC's work. He's looked at assessments from the U.S. Global Change Research Program. He's found three qualities that successful scientific assessments must have: First, credibility—that is, the information contained within them is trustworthy. Second, legitimacy—that is, that the full range of credible perspectives are provided, that you're being fair to all the various players that might be involved in a given issue. Third, salience—that the information provided is relevant in terms of people's decisionmaking. A fourth quality, which I've added, is good storytelling.

So, fundamentally, the qualities that make up a good scientific assessment are the same qualities that I think are important for good science writing for the general public. But you'd want to add on top of that a layer of having a component of storytelling. Storytelling ability is something that some people are born with but others have to learn and practice. As a scientist, naturally, I may be not the best storyteller. I have to work on that craft over time and learn from people in the newsroom who are journalists and were born to do that.

One of the biggest challenges we have as science communicators is capturing readers' attention. Sunshine and Jay both talked about the public's limited attention span. They're being thrown so much information right now. But the first thing that people will see—and if you don't get this right, you're not going to engage people—is the headline, and it has to be your strongest and most compelling material. It has to grab people. It has to reach people. Joe Romm, in his book *Language Intelligence*,[7] noted that newspaper readers read over half the headlines but only about 13% of the stories. If your headline isn't good, you're not going to engage those people. If your story has a boring headline, it becomes irrelevant, people would not read it. And you can't include nuance in headlines because, number one, it doesn't sell; and number two, there are not enough characters for it. You're limited on how long you could make your headline. The same holds true for Twitter. Capital Weather Gang has almost 250,000 followers on Twitter. You have to be able to communicate your messages in short sound bites.

That's a challenge when you're dealing with complex scientific issues that have layers of uncertainty embedded within. The problem you face is that if you don't include that uncertainty, if you strip it out of the article or blog post, it can be perceived as click bait or sensationalism and you lose trust with your readers. The objective is to strike the right balance so you're not boring, but you're also responsibly communicating information. You're always struggling with that.

Here are some examples of Capital Weather Gang headlines that I think were not effective because they did sensationalize a bit. The top one here: "The most intense El Niño ever observed is already a worldwide disaster." That was written in autumn 2015. However, number one, the El Niño this year was not the most intense on record. It was among the most intense. It ranks among the top three in the United States and to NOAA. So, that headline was an overstatement. "And already a worldwide disaster." El Niño actually has a mix of impacts. There are positive and negative impacts. It doesn't affect the entire world. It only affects certain regions. So, this was a case where I think the headline was not conveying the right amount of nuance. It was overstating what we know about El Niño and its impacts.

The Weather Channel, weather.com, they have in the past been an offender in terms of overhyping weather stories. I called them out for it and they've actually gotten better. Hopefully, some of the criticism they've received has helped. Here's a Weather Channel headline from, I think, autumn 2013: "Northeaster to threaten millions." That was a relatively weak storm. It may have produced 20- to 30-mile-per-hour winds. Southern New England was in a drought at that time, so the rain that New England was going to get would have been beneficial, if anything. Here, the Weather Channel, in order to get people to click, was telling people they're going to be threatened by what actually was a benign storm that would have more beneficial impacts than anything.

Another Weather Channel headline: "NOAA report hurricane forecast may shock you." NOAA at the time was forecasting a below-normal hurricane season. So, telling the public that the forecast may shock them, when it was calling for a less active than normal hurricane season, was a bit over the top. This is a problem with weather communications. It's actually worse in the United Kingdom than it is here in the United States. You see some incredibly sensational weather headlines in Europe.

Let me talk about what I think are some of the key characteristics of effective weather communications. We like to include confidence levels in our forecasts, in every single one. When we're dealing with a complex event, we like to communicate different scenarios so people understand the full range of possibilities. We like to use compelling visuals to illustrate those scenarios. As we get into a situation where we have more confidence in forecast specifics, on timing and location, that's really important to help people make decisions. But you can only do that when you have a certain degree of confidence in the forecast.

Accountability is important. When you have a poor forecast, it's important to explain why the forecast was wrong and what you might do in the future to address some of the problems you had in communicating that fore-

7. Joseph J. Romm, Language Intelligence: Lessons on Persuasion From Jesus, Shakespeare, Lincoln, and Lady Gaga (2012).

cast. Learning by doing and seeking feedback from your audience is an important quality. So, in every forecast we provide on the Capital Weather Gang we include confidence levels, much like the IPCC does for its findings in its assessment reports. But we do this for weather forecasting: from high confidence (meaning bank on it) to low confidence (meaning it's a crapshoot, we really don't know). And then there's every degree of confidence in between. We do that every day in our forecasting.

Let me walk you through a case where we did not communicate effectively, and what we tried to do to improve based on that poor forecast and frankly poor forecast communication. There was a snowstorm in March 2013. It actually shut down the federal government because the forecasts were for heavy snow. I've got a picture of Jim Cantore in front of the Capitol with bare ground, in the afternoon after D.C. was supposed to be paralyzed by 6-10 inches of snow. There was nothing. It was basically a rainstorm in the city.

Let me describe the forecast we issued. The graphic showed 5-10 inches along and east of the I-95 corner, and something like 14 inches just to the west. Now we compare the forecast snowfall with how much actually fell: basically no snow in the city and points east. Maybe it entered a few of D.C.'s immediate suburbs. That was a really dark day for local weather forecasters. We at the Capital Weather Gang weren't the only ones who did a poor forecast. The National Weather Service and the other media outlets also were calling for a lot of snow.

A bad forecast for a high-impact storm can be devastating for consumer trust. I don't think I've ever had more expletives directed at me from readers in any given day than I got on March 6, 2013, when our forecast was so miserable. That took some time for us to recover from.

The next day I wrote a postmortem, which we do. Again, it's an accountability thing. After any major event, we write an assessment of how our forecast performed and what we did right, what we did wrong. In this case, we did a lot wrong. My lead for this particular postmortem assessment was that the best forecast for the storm was one we cannot issue with a straight face and one most Washingtonians would have ridiculed: "Rain, sleet and/or snow likely, heavy at times, with snow accumulations of 0-14 inches."

Interestingly, our readers in the comment area basically said, well, that's the reality. Just be straight up with us. Say what it is. Give us your probabilities. Try to be sorry rather than entertainers. Don't worry about trying to get it perfect, but explain to us what the range of possibilities is.

So, based on this experience, the next year (the botched forecast was for the last winter storm throughout that particular season), we started to include in every snowfall forecast what we would call our boom and bust scenarios. A boom scenario is the probability that the snowfall will be more than what we think the most likely amount is. A bust scenario is the probability that the amount of snow will be less than our most likely forecast. We also would include a confidence interval for every snowfall zone. We still are assigning our most likely forecast, but we're also sort of setting up a goalpost so that people understand what the full range of possibilities is. This has been met with very good feedback from our readers. We've used it for the last three winters and it's worked well for us.

Communicating uncertainty through the use of scenarios is something we do for other events than snow storms, especially for high-impact complex events. We did this during Hurricane Sandy in 2012. Weather forecasts are not terribly reliable past about five to seven days out. But once in a great while, when you have an extreme event, it does show up at long-range times in the computer models. It's sort of a skill or an art to be able to identify when there might be a credible long-term threat.

When we saw Sandy on some of the computer models, eight days out on Facebook, we just posted an image and we said, look, we may have a big storm in about one week. A number of computer models are hinting at it. But we included qualifiers that eight days is an eternity in storm forecasting, so there's plenty of time to watch this. Consider it as an early heads-up, and other details of what to expect will become clearer and will manifest themselves in the coming days.

So, we provided the initial heads-up. No specifics. Just giving people a general idea that there might be something to watch in the coming week. Then, five to seven days before the storm, again, we're providing more generalities and not too much specifics. We're mentioning that a historic storm is a possibility, but it could be just a glancing blow. Where it heads is not clear. We're telling our audience who should be most concerned about it, and we provide some historical context for that.

Then, once we get inside about five days, that's when we can really start to break down scenarios and talk about, okay, what are the probabilities that different areas are going to get hit. So, four days out, we had four scenarios. Three days out, we broke it down to three scenarios. And then, two days out—with weather forecasts for extreme events, usually you're able to really hammer out some of the details within about 48 hours. Even 72 hours is sometimes too much time. The specifics are still not black and white yet. But once you're within 48 hours, that's when you can really start to nail things down a bit.

So, a few days out, we said there are two scenarios, one much more likely than the other. Hence, one turned out to be correct. The storm made landfall near Atlantic City. The day before, we provided more of a deterministic forecast for the D.C. area. Obviously, conditions were worse to the Northeast, but we were able to fairly accurately give a forecast of what the type of winds and rain would be in the D.C. area. So, that's the way we like to handle complex events. Start with the heads-up, and then develop scenarios, develop local scenarios early on, and then try to over time narrow it down.

There are some challenges that we deal with in communicating uncertainty in the meteorological community.

We have a problem of what we call armchair meteorologists. Social media give everyone a voice now irrespective of credentials. And weather information, model information, anyone can get it and they can misinterpret it. Sometimes, you get really enthusiastic people taking a computer model eight days into the future when they're not very reliable and putting them out on Facebook, and they get shared hundreds or thousands of times, and that can mislead. It can convey more confidence in an outcome than actually exists. So, we professionals who understand what the limits of predictability are saying, we have to deal with that. We have to think about what we can do. Do we confront these bad forecasts? Do we ignore them? Do we engage constructively?

In what I've written, and where I think the community is on this issue, is that it's pointless to expose and shame. A lot of the people posting the information have the best intentions. They just don't understand the information. It's a never-ending and unwinnable game of whack-a-mole. Instead, we focus on educating our audiences on the limits of weather forecasts.

The National Hurricane Center has struggled with this issue because there are people putting hurricane forecasts out seven or eight days away, but skill in knowing where a hurricane is going to develop, where it's going to go, is really only decent within about three or four days. They are putting out statements where there is no reliable science to forecast potential impacts to specific locations that will be more than one week away. So, we're all dealing with this. I think education continually has to beat this drum about the limits of predictability, and that's what we have to do.

Having said that, I mentioned armchair meteorologists who are putting out irresponsible forecasts and who are not professionals, but we also have some corporations, and fairly well-known ones in our industry, that are putting out forecasts into the future when there is no skill. The American Meteorological Society (AMS) put out a position statement on weather forecast predictability in the spring of 2015. They said presently forecasts of daily or specific weather conditions do not exhibit useful skill beyond eight days, meaning that their accuracy is low. Yet, you have companies in the weather industry putting out specific forecasts for specific locations 90 days into the future, with no uncertainty information and with no qualifiers. They're basically selling the public a bill of goods and unreliable information.

So, it becomes very difficult to educate the public about the limits of predictability when you have very well-known companies doing this. It's a dilemma for the AMS because some of their supporting members, who give money to help sustain the organization, are doing things that the AMS' professional statements say can't be done. This is an ethical issue, in my view, and I don't know how we solve it.

I'm going to touch on climate change communication because we do it at the Capital Weather Gang. Weather and climate change are integrally linked. I don't think you can responsibly be a weather forecaster and not talk about climate change in this day. And again, I did climate change communication for 10 years at EPA. So, here are some key bullet points that I try to employ in my communication of this issue.

Don't cherry-pick and hype. Discuss the full range of results and credible viewpoints. I do find that nuance builds credibility, but you still have to deal with how do you convey a message in the headline when you can't convey that nuance. You have to think through that carefully.

It's really important that we avoid name-calling in climate change communication. I think the issue has become very polarized unnecessarily, so we always avoid labels like deniers, alarmists, warmists. Instead, I'll talk about people who may be convinced that climate change is a serious problem or unconvinced that climate change is a serious problem. You can use terms like doubters or skeptics, but you have to be careful, depending on the context, because all scientists should be skeptics. If you're talking about a skeptic, you need to be specific as to what they're skeptical about.

It's important to consider alternative views, but only if they're legitimate alternative views. We talked about this at our last workshop a couple of years ago, the problem of false balance in giving equal time to viewpoints that may not be supported by the balance of the scientific community. It's always important to keep that in mind.

It's also important that we don't demonize certain perspectives or people. You see that in climate change communications sometimes, where some people are characterized as villains. Climate change is a very complex issue. There are a lot of lenses through which you can view it. It's more responsible to try to be fair to all, bearing in mind that they may not see the issue through the same lens that you do. And as Sunshine mentioned, do discuss where there is common ground.

Jay Austin: I've got one audience question that I'm going to throw in the mix now before we turn the corner to policymaking. This is from Sara Peach, a freelance journalist in North Carolina. She says/asks: I love the boom-bust probabilities for your snow forecast, yet Sunshine just told us that up to 30% of Americans do not have a great understanding of probability. What are your thoughts on how to help that audience better understand weather predictions?

Jason Samenow: That's a challenge. In the D.C. area, where the Capital Weather Gang is based, we have a very informed and educated audience, so I haven't found people experiencing a lot of difficulty understanding our boom and bust. Having said that, I understand there are some folks who are mathematically challenged. I think the only way to deal with that is through audience engagement, and we try to make ourselves available on our social media feeds and in the blog comments. We put a real emphasis on that from the very beginning. That's the only way you can do it. I can't re-teach everyone grade-school math, but we can be available to people if they have difficulty understanding.

Jay Austin: I'd like to take that one step further with a follow-up question. This addresses the shift from your weather coverage to the component you do of climate change coverage. How does that same problem and the understanding of probabilities play out when you're talking about climate change? It's one thing to get across to people that there's a 70% chance of rain tomorrow, or to explain why that didn't quite pan out. But when you deal with climate, to what extent are you trying to explain to your readers what it means that there's a 95% certainty of a small, yet tangible and growing, risk of consequences that range anywhere from extremely mild—I may not be able to get my pinot noir next year—to unthinkable disasters? Does your scope reach some of that aspect of climate change? If so, what kind of tools do you use for trying to communicate some of the IPCC or other probabilistic results?

Jason Samenow: In some of these, I'm harking back to my EPA days. But for starters, on Capital Weather Gang, a lot of what we focus on is observational evidence rather than projections, because we're usually trying to put the current weather in the climate context. So, we're discussing whether the past month was the warmest on record or the third-warmest on record. We don't do a lot of projection on our blog. Sometimes, if there are studies about future heat waves increasing in duration, frequency, intensity, we will discuss those results. There are different ways you can do it in terms of helping people understand the uncertainty.

I'm struggling with this question a bit because we don't do it that much. But if I think back to my EPA days, one of the things that I think worked really well, one of the most effective ways of explaining, for example, the benefits of climate change mitigation was that they have these roulette wheels called the Greenhouse Gamble, in which they showed the probability of certain amounts of warming for no mitigation versus mitigation scenarios. In different roulette wheels, they showed how the probabilities of getting unacceptable amounts of warming were higher for the business-as-usual scenario, whereas in the policy scenario, the probabilities of less warming were more likely.

So, there are visuals I found really effective. In the same way, when we're trying to discuss probabilities about climate change in the Capital Weather Gang, using visuals that we find are illustrative and help people through use of metaphors to understand it, that can be constructive.

Margaret Davidson: The challenge and the opportunity of coming after Sunshine and Jason is it is both easier because they've already covered a lot of points that I wanted to cover, and harder because they've already covered a lot of points that I thought I would cover. Like them, I want to offer a little disclaimer. I'm not a scientist, although I often joke that I have spent most of the last 30 years hanging around them; I am actually a recovering lawyer.

My focus today is on the ethics of communicating scientific uncertainty and how that relates to public policy. I bring two different perspectives to that. As a lawyer, in order to complete law school, you have to take ethics courses, and most journalists also take a course on ethics as part of their curriculum. But I don't know of any scientist who was required to take a course on ethics in order to get their Ph.D., though they may be able to find a course on ethics in their school or university. So, I'm going to be talking about ethics in a formal sense as a code of conduct that lawyers and journalists follow, but also as a much more popularly understood moral perspective.

My context is to talk about the ethics of communicating scientific uncertainty, and how we do that, and how that relates to the ways in which we could take action versus the opportunities to understand more about these issues. In the context of climate, the issue of scientific uncertainty is even more important. The ethics of scientific uncertainty and policy revolve around understanding and communicating causes, likelihoods, actions, and consequences. As Sunshine indicated, we've gone through a great deal of effort to define specifically what we mean by different terminologies and the percentage of certainty/uncertainty that we have with regard to those sorts of things. Even when we're virtually certain, it's only a 99% probability.

The other thing I want to remind everyone, and as all the scientists in the room know, is that the terms "certainty" and "uncertainty" are very precious to scientists. They're also important to us in the policy domain. They often have a totally different context for non-scientists or lay people. In our attempts to be more precise, more specific about articulating uncertainty, we often wind up just being more confusing because most people revert to their own personal knowledge about these kinds of issues. Jason showed that to us—how people talking about meteorology think about and present on these issues. But we also fold other notions into that question of uncertainty. Some of us think about things like fairness, and justice, and engagement, and disclosure. So, I'm going to take off from that perspective.

Our biggest challenge in ethics and scientific uncertainty is communication. Sunshine talked about that. What are we communicating? To whom? When? Why? Communicating about uncertainty depends on being comfortable with the base information that we have, as well as understanding our audience. We need to increasingly understand our audience so that we can do a better job of explaining what uncertainty might mean in that context.

Recently, we wrestled down this issue with the last IPCC and in the National Climate Assessment (and we published what we meant about uncertainty in different levels), but also trying to set the context for conversation about uncertainty across a variety of geographical perspectives and time scales. What do I mean by that? Most of us participating in this Dialogue understand that a good bit of the science of climate change is settled, in that we have peer-reviewed science. The great majority of climate scientists are in fair agreement with one another even if they disagree a bit on the edges. But when we talk about how we take that level of consensus in the scientific community and translate that into immediate actions for climate adaptation and mitigation, then that becomes our challenge.

It really also depends upon which of the issues we're trying to talk about. Are we trying to talk about our not well-refined understanding and the weak signals about catastrophic tipping points (which I think is going to become even more important as we look at some of the current field data coming in from West Antarctica)? Or what do we know and how do we communicate about the highly unequal distribution of impacts, which in turn leads us to questions of equity, social justice, those sorts of things? Or what are the implications of ocean acidification for stabilization targets?

We have just begun to learn both the extent and the shortcomings of our knowledge about carbon sinks. The ocean is a carbon sink. How much can it absorb? Where is that in the carbon balance? And we're now just beginning to wrap our arms around understanding water mass balance within the cryosphere. Our science is advancing for those of us who work with people on the ground, for instance people at the local level who are beginning to think about planning for critical infrastructure—both the retrofit of existing infrastructures and the design and placement of infrastructure over the next 5-10 years. There are also other questions that we're not going to answer here, but I'll throw out a couple of them: First, the ethics of geoengineering, which is kind of our world, our community, risk migration. Second, as both Sunshine and Jason discussed, we really need to get much better at communicating risk and uncertainty.

I talk a good bit about where our notions of risk and how we think about communicating risk come from. I started out in the high-level radioactive and hazardous waste business, where the whole issue of understanding, quantifying, and communicating risk is a little more refined. We have about 30 years under our belts on that one now as opposed to in the science community.

So, from a global perspective, we are beginning to address scientific uncertainty and enabling it down. That's part of what's driven a great deal of our collaboration, of partnerships both at national and international scales, and that's been really phenomenal. Although we often say this, we rarely understood that regardless of what our uncertainty is, we do all have to figure out how this works. The migrations that we're seeing in Europe right now are just a harbinger of some of the challenges that we're going to face, frankly much sooner rather than later.

With respect to the issues that I work on—coastal inundation and sea-level rise—I think the next time we come around with IPCC and the National Climate Assessment we won't be talking about one to one-and-a-half meters in another 60 years. We'll be talking about a number higher than that in the next 30-40 years. That has a great implication for people who are right now thinking about water, sewer, and roads.

When we get down to our regional and national perspective, I think our own current political environment has made life very difficult. Just 10 years ago, there was an effort across all the federal agencies to come together to talk about climate issues. In our very first sets of meetings, there were so many people on the conference call, perhaps 4-5 dozen participants, that it was actually hard to run the call. Then, some people in the U.S. House of Representatives started speaking up and hammering down, and it was amazing. In March, we had 48 people on a conference call, but by the end of May, we only had about eight people on a call. So, it's been a bit of a challenge.

I'm sure you all have read the news about how the chairman of the House Science Committee feels about scientific uncertainty himself. This presents a lot of challenges for my agency, NOAA, when we think about how we accomplish policy. Personally, I've more or less temporarily abandoned the idea of national policy effects and instead have begun to focus on the local-to-sub-regional effects, particularly since land use and zoning are in fact the province of local governments.

A scientist needs to continue to work hard to narrow the uncertainty gap at all geographic and time scales. But those of us who have positions have to figure out how we bridge these gaps in a way that makes it more meaningful for folks who have to make actual financial decisions in the very short run. We have to really talk about our local community perspective because that's where you find so much bonding, financing of infrastructure, the letting of permits, deciding what the footprint on the landscape is going to look like and how that's going to affect revenues in local capacities.

We can do a better job trying to explain in a very defensible manner what scientific uncertainty is. But I've stopped talking about scientific uncertainty. I leave that to my Ph.D. friends. Instead, I try and talk about things like return on investment and cost-benefit analysis. For instance, for coastal inundation, drought and wildfire, it really doesn't matter what the causes are that we're talking about. Everything that we would like for society to do in terms of anticipating, hardening, elevating, relocating is exactly the same. So, the issue of scientific uncertainty is not really all that germane to decisions right now that pertain to more strategic infrastructure placement.

The issue that we always come down to, unfortunately, is that from an individual perspective, it kind of depends on where we're coming from. The cognitive dissonance that exists around even the understanding of science, let alone scientific uncertainty, is pretty significant in this country. But I do like to remind people that we are inherently anti-intellectual and anti-scientific in our roots. The Puritans may have come here for religious freedom, but it was actually only their religious freedom. They tended to banish or execute any member of the community whose views were different from the prescribed views. The colony of Rhode Island was established by people who were trying to get away from the Puritans. So, the notion of not being open to different viewpoints is actually inherent in our nature in this country.

In my community, we've spent a long time trying to persuade people that they want to do the right thing.

From a policy perspective, "Think of the grandchildren." Except we found out that thinking of the grandchildren is sort of like another notion in natural resources management called willingness to pay. If you ask someone how much they would be willing to pay to maintain Yosemite National Park, in a survey, they reported a very high value. But if you press harder and ask them to cough up money, it's amazing how miserly they get. So, while people talk a lot about their grandchildren in planning and zoning board meetings, when they're thinking about permits or impact development fees, maybe not so much do the grandchildren count.

A couple of years ago at the beginning of an AMS annual conference, I asked how many folks in the room understood psychographics. Very few people who were members of the AMS even knew that word. Yet, if we were in the for-profit community, we would understand everything about how we represent data. How we represent whatever we're trying to sell is really important to understanding psychology and even neurology.

So, I think there needs to be a greater marriage between not only journalists and scientists and policymakers, but I would submit also psychologists and people who are in the commercial design business, because we haven't been very effective in communicating the extent of our knowledge, how important it is that you could get so many people around the globe to basically agree on some very fundamental issues—and that is really big. We haven't been able to communicate in many ways the urgency, as well as the opportunities, associated with these issues.

We can think about these things from a global perspective. We can model it. We can attempt it for global policy. We can begin to downscale and have national and regional to sub-regional finesse in our model output, and we can begin to think about it from a policy perspective. But until we begin to understand how to sell this at a local and individual scale, I'm not sure personally that we're going to be much further now than we have gotten over the past 10-15 years. In fact, if we were to do a calculation of how much money we've spent on climate science over the last 40 years, as compared to how many of the American public actually think it's a real issue that we need to tackle right now, the one thing I'm pretty clear about is that it's a relatively poor return on investment at this moment.

However you want to think about these issues, you need to look at them from all these different perspectives. As journalists, most of you are very good at telescoping in and as well as telescoping out, but, at the end of the day, who's the audience? How can we best communicate with them? It may require not only that we understand how to adapt to our environment and our landscape, but how we ourselves adapt to our communications or with the people with whom we're trying to work.

I try to emphasize how remarkable it is, the percentage that is scientifically certain. Then, because I am neither a scientist nor a journalist, I don't linger on that question at all. I think it's too much of a confounding variable for people who are already too confused by the complexity of life. I do work in the sausage factory in a variety of geographical scales. I've been doing this for a long time and this is the space that I've come to. I'm afraid that I have begun to move away from the formal ethics, and more toward the pragmatic ethics of figuring out how do we communicate the issue in such a way that people are moved to act upon it.

Jay Austin: I have another comment/question from the audience: "My impression is that privately many scientists think that the impacts, on many measures, will be really bad by the end of the century, though few, apart from such as James Hansen, are very explicit about this. I'm curious what the speakers think about how journalists can communicate catastrophic consequences, such as sea-level rise that could substantially disrupt cities or widespread death of wildlife. If those consequences are far off in the future, there's no way to be able to compare predictions to the results, as with weather reports. It's hard to keep saying that the sky is falling when it hasn't. Even if that is likely, downer stories are depressing and people would rather avert their eyes than read on. I think there's a temptation about having an upbeat way to report on these things, to find some sort of silver lining and that may unintentionally cause public complacency."

Sunshine Menezes: That's the $60,000 question right there. One of the things that we've been doing to try to get at that is organizing programs around the country for journalists looking at regional impacts of climate change. This is a mix of things we're seeing right now that are likely attributable to climate change and projections for the near and more distant future.

Going back to my comments about the fact that there are so many reporters who are general assignment or business or politics reporters, for example, but are now covering environment stories without any background—it means that they're really struggling to tell these stories within a context that is relevant to their audiences. That's why we've been taking this regional approach, because at the very least, we can take this from "the sky is falling, the whole world is going to cave in upon itself" kind of catastrophic messaging to something that's more local/regional. At least it's then a story, a kind of more bite-sized story that can be told and be more engaging for audiences.

In terms of trying not to be too rosy about it, obviously that's a fine line between one extreme and the other. I think that this focus on more local and regional impacts depends upon the news outlet. If we're talking about a national news outlet, that's not the right way to go. But if we are talking about smaller news outlets, this is a helpful approach.

Jason Samenow: So, the question as to whether the most alarming messages about climate change are being heard, I think we do have folks who are fairly outspoken and whom

the media covers pretty well, such as Mike Mann and Hansen. They've been fairly emphatic that climate change poses a lot of risks, so much to be severe.

But on the other hand, while it is true that the overwhelming majority, whether it's 97% or 99%, of scientists believe that climate change is man-made, the degree of severity is a bit more subjective. I don't think every scientist out there believes it's the end of the world now. I think every credible scientist believes climate change creates risks. There's a general understanding that the more the climate changes, the more quickly the climate changes, the bigger the risks are; and that the more we do to reduce greenhouse gas emissions, the more we lower the risks of those unwelcome changes.

Those are the messages I'd like to try to convey, that there is a range of perspectives as to how severe climate change will be—whether it will be a major problem, or a catastrophic problem, or maybe a problem that we're able to adapt to. But irrespective of where we stand on that spectrum, climate policy and actions we take to reduce emissions will lower the risks and lower the likelihood of the worst consequences. That's the way I'd like to frame it, because I think there is a legitimate range of perspectives as to how severe the problem is.

It may be true that there are some scientists who are reticent to get out there and preach doom and gloom, but there are other scientists who are a bit more cautious and who do recognize uncertainties as to how sensitive the climate is, and are thinking about interference or how quickly emissions will increase and so forth.

It's a very complex problem. I don't think we can make it black and white and say, oh, my gosh, we're all going to die and this is necessarily a catastrophic environment. Furthermore, climate change doesn't affect everyone the same. There are regions that may benefit. So, I think we need to be a bit careful about the total disaster declarations because there's more nuance, there's a greater range of outcomes that that would convey.

Margaret Davidson: I think both Sunshine and Jason make great points. I personally have found Hansen not only to be outspoken, but also to be incredibly prophetic. But regardless, I do know why one may be able to talk with fairly sophisticated audiences about some of the newer model projections, for instance. If we're talking about a more lay audience or a less well-informed audience, as Sunshine could also tell us, it is all about doom and gloom and you're not going to get any movement at all.

Regardless of a scientific certainty or uncertainty, we need to tell the story. There needs to be a story and we need to tell the story in a way so that people understand that there are options and actions that they could take as individuals and as communities, because fear in and of itself can be paralyzing. So, even if those of us who are more into these issues recognize that data coming out of West Antarctica right now inspires an "Oh my God" kind of moment, I think that as we talk about this to larger audiences, we really need to emphasize what it is that we can do in the next 5-10 years that helps to reduce our vulnerabilities and risk over the next 50 years.

Jay Austin: I have a question, perhaps best addressed to Margaret. We've talked quite a bit about the use of metaphor, and also about how to communicate probabilistic evidence or risk or how to talk about risk allocation, and one metaphor that comes to mind is that of insurance. You see this discussed quite literally in the case of floodplain insurance: Should the government, as a matter of policy, continue to help people rebuild their homes when they're living in vulnerable areas?

But there's also a higher level of metaphor. You hear Al Gore and others talk about how we need to have an "insurance policy." Even if some of these most catastrophic consequences are low-probability, still the smart business thing to do is buy the insurance policy. Do you find, Margaret, that that has any resonance in government decisionmaking or in trying to shape policy or convince people that action should be taken?

Margaret Davidson: Absolutely. At least at the federal level, we've spent a lot of effort in recent years working with the reinsurance community, which gets all this stuff, as well as the insurance underwriting community because they are in an important position to help communicate information. The problem though is that not all insurance is created equal. Federal flood insurance, for example, is not actuarially sound; it's not tied to actual risk. Most private insurance is, but federal flood insurance is not, which creates a problem because people have a distorted sense of their risk and choose to live in risky places that would not be, and often are not, covered by private insurance.

But the fact is that insurance is actually a regulated utility. In most states, insurance rates and pricing are regulated by an insurance commission whose members are either elected themselves or are appointed by elected officials. So, more recently, we began to shift toward a greater focus on working with the financial services community. They have a little more flexibility. If we can begin to help them understand how they do a better job of pricing mortgages, for instance, then you can send another kind of signal without having to have regulation. I think we're going to be getting there in the next year or so. There's nothing that communicates to people better than their pocketbook. We will be revisiting flood insurance reform in 2017, and we should all be ready for that challenge and opportunity.

Jay Austin: I have one last written comment/question from our audience, seconding the approval of Jason's boom-and-bust approach, and pointing out that it embodies the technique that Sunshine mentioned about using words as well as numbers. The question is, whether there are emoji or other graphics that could add another dimension for the mathematically challenged public? We touched on that with the roulette wheel.

Jason Samenow: I recommend using words, numbers, and graphics—all three together. We also do a school forecast, and use varying numbers of apples to convey the likelihood that schools are going to be open or closed. It's a popular Capital Weather Gang gimmick that employs probabilities.

Jay Austin: We've reached the end of our time. Many thanks to our panelists and audience members, and to the National Science Foundation's Paleoclimate Program for providing funding.