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Psychological Challenges in Communicating about Climate Change and Its Uncertainites

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Summary and Keywords

The overwhelming majority of the scientific community agrees that climate change (CC) is occurring and is caused by anthropogenic, or human-caused, forcing. The global populace is aware of this phenomenon but appears to be unconcerned about CC and is slow to adopt potential mitigative actions. CC is a unique and complex phenomenon affected by various kinds of uncertainty, rendering communicative efforts particularly challenging. The compound and, potentially, conflicting uncertainties inherent in CC engender public ambivalence about the issue. The treatment of uncertainty in the Intergovernmental Panel on Climate Change's (IPCC's) reports have been shown to be confusing to policymakers and the general public, further confounding public outreach efforts. Given diverse communication styles and the multifaceted nature of CC, an assortment of strategies has been recommended to maximize understanding and increase salience. In particular, using evidence-based approaches to communicate about probabilistic outcomes in CC increases communicative efficiency.

Keywords: climate change, communicative efficiency, IPCC, linguistic probability, uncertainty lexicon, science communication

Introduction

Climate change (CC) is one of the great societal challenges facing humanity in the 21st century. Doran and Zimmerman (2009) found that about 97% of climate scientists agreed that CC was caused by anthropogenic, or human-caused, forces. Public awareness of CC, at least in most developed countries, is quite high (Lee, Markowitz, Howe, Ko, & Leiserowitz, 2015; Upham et al., 2009). Yet CC is a low priority for most people, and the relative inaction of individual actions belies their stated belief in taking action against CC.

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Climate change has some unique aspects that make communications about it particularly challenging. We briefly review findings in the social psychology and the judgment and decision-making literature that offer theoretical and empirical explanations for the apparent lack of concern and action. In the second part of the paper we focus on the complex nature of uncertainty surrounding various facets of CC, and discuss the ways in which this is communicated to the public and policymakers by the Intergovernmental Panel on Climate Change (IPCC). Finally, we suggest some ways, informed by behavioral research, to improve communication about CC in order to increase the public's awareness and understanding.

What Makes Climate Change Uniquely Difficult to Communicate and Accept?

Construal and Framing

A large literature documents various mental frames through which people view their surroundings (see Geiger, Middlewood, & Swim, 2017). Only a brief review is presented here. Construal level theory (Trope & Liberman, 2010; Liberman, Trope, & Wakslak, 2007) suggests that individuals use concrete and low-level construals to mentally represent events that are "psychologically close," but abstract, high-level construals for events that are psychologically more distant. CC has all the features of psychologically distant events: It is a global phenomenon whose full effects are most likely to be fully experienced in the (not too close) future; these effects will be differential, not touching everyone in the same way, at the same time, and to the same degree, and uncertain. Thus, for most people CC is an abstract, high-level construal and, as such, lacks the affect and urgency that more concrete representations inculcate (Leiserowitz, 2006; Oppenheimer & Todorov, 2006), which Milfont (2010) argues may explain the public's relatively apathetic response.

In a large international survey, Broomell, Por, and Budescu (2015) found that one of the best predictors of willingness to change one's behavior and take action to counter the effects of climate change is (self-reported) personal experience with CC. For most people, "climate experiences" are closely correlated with, and driven by, local (rather than the global), present (rather than future) weather (rather than climate) experiences. Values and beliefs are not fixed, but rather subject to dynamic construction and updating in real time (Fischhoff, 1991; Lichtenstein & Slovic, 2006). Judgments are malleable, and behavioral research has shown that the local weather can affect perceptions of well-being (Schwarz & Clore, 1983) but, more pertinently, perceptions of the prevalence and severity of CC (Broomell, Winkles, & Kane, 2017; Guéguen, 2012; Li, Johnson, & Zaval, 2011). This suggests

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that individuals pay close attention and are highly sensitive to physical cues in their immediate environment when prompted to think about CC (see Borick & Rabe, 2017).

In the absence of strong and unambiguous feedback, the classification of an event as being associated with climate change is highly subjective, and people with different backgrounds, beliefs, and expectations may apply different classification rules. For example, in a national random representative sample of U.S. adults, Budescu, Por, and Broomell (2012) found that those who self-identified as Republicans reported significantly lower levels of perceived experience with CC, compared to their Democratic counterparts. Clearly, the two groups classify the same experiences in slightly different ways! Weber (2006) argued that this lack of adequate feedback in the environment causes miscalibration of subjective probabilities—more specifically, the underappreciation and underweighting of the risks associated with CC.

Another facet of the malleability of perceptions of CC is their sensitivity to framing and labeling. The terms “global warming” and “climate change” are often used interchangeably, but some research (Schuldt, Konrath, & Schwarz, 2011; Villar & Krosnick, 2011; Whitmarsh, 2009) suggests that “global warming” has become more emotive and more polarizing, evoking different responses from people with different political views (see Schuldt, 2017). Benjamin, Budescu, and Por (2017) showed how this framing interacts with political affiliation and ideology. They report systematic framing effects only for political Independents and those who are disengaged from climate change issues, indicating that those with moderate beliefs are more susceptible to labeling and framing effects. Thus, public perceptions of CC are fragile, transient, and highly dependent on external cues (Kause, Townsend, & Gaissmaier, 2017).

Filtered and Incomplete Information

The general public does not always have easy access to the scientific evidence and, as a rule, does not consult the evidence directly. The primary sources of scientific information for most people (Nelkin, 1995; Wilson, 1995) are the mainstream mass media and, increasingly, the social media (Gil de Zúñiga, Jung, & Valenzuela, 2012). Yet, its reports may also be lacking and in some cases may be (unintentionally) biased. Boykoff and Boykoff (2004) suggest that the structural norms of journalistic discourse have also played a considerable role in the surprising diversity of public opinion regarding the causes and effects of CC (see Guber, 2017 and McDonald, 2017). These complexities and ambiguities associated with CC have allowed some politically motivated bodies to assault and try to undermine the overwhelming scientific evidence for climate change and its dangers (Oreskes & Conway, 2010). The communicative gap between the general public and scientists is in no small part due to the confluence of human factors with the multifaceted and involved nature of climactic models.

Difficulties Dealing with the Complexities of Climatic Models

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Understanding and properly interpreting CC, especially projections of anthropogenic CC, often requires a highly specialized knowledge base (e.g., advanced graduate training in physics or meteorology). These models are often simulation-based and involve multiple interrelated and high-variance variables, which make some of their subtleties hard to grasp for laypeople.

Climate feedback processes, as defined by Hansen et al. (1984), capture the response of the climate system to an external radiative forcing (RF), or climactic elements that affect atmospheric energy balance, resulting in climate change. RFs can be used to compare the anthropogenic and natural causes of CC. Examples of RFs include greenhouse gases and water vapor. Climate scientists themselves find evaluating such predictions from global climate models difficult (Bony et al., 2006). Among the complications in interpretation are the lack of observational assessment, difficulty in causal attribution for natural processes on CC, and the many different assumptions of climate models. As if modeling the climate system is not sufficiently complex, integrated assessment models incorporate additional parameters of interest, such as economic factors (e.g., CIESEN, 1995). This confluence of such disparate specialized disciplines render a complete understanding elusive even to trained scientists, who may be used to more empirical methods.

Seeking to understand the public's views of climate change, Lorenzoni and Hulme (2009) held discussion groups in Norwich and Rome. The discussants provided their views and expectations regarding management of climate change and the long-term impact of CC. They also discussed future societal development and the effects of socioeconomic change on the climate and provided their views on climate change scenarios. The discussants were chosen to represent a wide array of views on CC, that is, Engaged, Denying, Doubtful, and Uninterested. It was evident that most discussants were aware of climate change and also acknowledged a human contribution to the change in climate, though some did so with hesitation and skepticism. Discussants also felt that it was "not their role to engage with scientific tools" that were presenting a complex reality. As expected, individuals without in-depth knowledge of climate change found it challenging to understand complex climate change information. The authors concluded that the nature of scientific work could not meet the high expectations of certainty required by less engaged individuals, and so this gap provided justification for inaction.

Benjamin and Budescu (2013) provided a striking illustration of this problem. In their experiment, subjects were asked to make predictions about a climate-related event (the rise in sea level as it can affect the operation of ports in Southern California) based on predictions from two experts. The subjects focused on, and were quite sensitive to, "surface" factors such as the precision of the experts' predictions and the degree of their agreement. However, they were totally insensitive to many relevant factors, describing deeper and more technical aspects of the modes used. In particular, they were not affected by model structural uncertainty (whether the experts used the same or different models in their projections) or by judgmental uncertainty (whether the experts used the

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same or different parameters when running the models). Overall, they displayed clear "system neglect" (Budescu & Yu, 2007; Massey & Wu, 2005).

To complicate things further, the addition of more parameters, which may add more explanatory power to the already complex climatic models, inevitably introduces more uncertainty in climate projections (Pidgeon & Fischhoff, 2011). A causal analysis may incorporate several parameters, all containing their own degree of uncertainty, and poorly specified summary estimates may inadvertently lead to a "cascade of uncertainty" (Schneider, 1983). Ostensible paradoxes such as these make proper conveyance about climate model results (and potential solutions) challenging.

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Difficulty Dealing with Deep Uncertainty in Climate Change

In the context of CC, uncertainty—an inevitable outgrowth of the research process—is extremely high because it emanates from many sources: some related to natural systems, others to socioeconomic processes and others to climate policies. Lempert, Popper, and Bankes (2003) defined deep uncertainty as the condition in which decision makers do not know, or do not agree upon, (1) the appropriate models that relate actions to consequences, (2) the probability distributions over key input parameters to those models, and (3) how to value the desirability of alternative outcomes. Drouet, Bosetti, and Tavoni (2015) called attention to distinct sources of uncertainty that are of special relevance in this context where future projections are generated by models but there is no universally accepted single/best model. These authors differentiate between “model uncertainty,” which is associated with the existence of alternative modeling paradigms that relate how variables such as mitigation costs, the dynamics of the climate system or CC economic damages might interact and respond to climate policies, and “state uncertainty,” which refers to the probabilistic response (e.g., of mitigation costs, temperature or climate damage) of the various models given a climate policy.

Clearly, such deep and complex uncertainties are hard to communicate. Wallsten and Budescu (1995) offered a three-way classification of possible sources of miscommunication of uncertainty: the nature of the event; the nature of the uncertainty; and the communication language. Each of the three can vary from being imprecise to precise: The events to which probabilities are attached can vary from ambiguous (e.g., “a sharp and abrupt change in the near future”), which can be interpreted differently by various people, to precise and unambiguous ones (e.g. “a change between 15 and 20% within the next decade”). The uncertainty can also vary in its imprecision. More broadly, Knight (1921) differentiated uncertainty from risk: uncertainty, he observed, is inherently unknowable and uncalculable, whereas risk is calculable but still unknown. Consider, for example tossing a coin. If, on the one hand, one has information that the coin is unbiased, he or she can calculate that its probability of landing on one side is one-half, but it is impossible to predict the result of any specific toss. This is a textbook example of risk. If, on the other hand, the provenance and nature of the coin are unknown and there may be doubts about its fairness, one may not be able to quantify the probability of its landing on one side, although one could venture guesses and estimates. This is an example of uncertainty. Finally, the modality of communication selected to convey uncertainty can also vary from the very precise to the overtly vague.

IPCC Treatment and Communication of Uncertainty

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Communication of Uncertainty

Uncertainty can be communicated in several distinct ways: (1) numerical point probabilities (e.g., 15%), (2) numerical interval probabilities (e.g., 15–40%), (3) verbal probability terms (e.g., unlikely), or (4) a combination of these formats. The language of uncertainty can itself be a source of confusion. Budescu and Wallsten (1987) argued that uncertainty should be communicated as precisely as possible but not more precisely than warranted by the evidence. Wallsten and Budescu articulated a "congruence principle" (1995), in the context of the three-way classification discussed previously, which suggests that the communication modality should match the nature of the target event and its uncertainty—the more ambiguous the event and the more imprecise its uncertainty, the harder it is to justify a precise communication mode. Imagine being informed that "[t]he probability of a sharp and abrupt change in the climate in the near future" is 0.2356. The overprecision of the estimate does not correspond with the knowledge available, and such language may lead to erroneous beliefs about the true state of the event. There is good empirical support for this principle (e.g., Du, Budescu, Shelly, & Omer, 2011; Olson & Budescu, 1997).

The IPCC has struggled with this difficult problem of communication of uncertainty in its assessment reports (ARs), given the unique challenges imposed by its mission.

The Intergovernmental Panel on Climate Change

The IPCC's goals are to evaluate the science related to climate change in the form of assessments meant to "provide a scientific basis for governments at all levels to develop climate-related policies" and to include the "full scientific, technical, and socio-economic assessment of climate change" (IPCC, 2013).

Three working groups (WGs) have been created, and their missions are to:

1. Assess the available scientific information on climate change (WG I)
2. Assess the environmental and socioeconomic impacts of climate change (WG II)
3. Formulate response strategies (WG III)

Each AR contains reports from each of the three WGs (each containing a Policymaker Summary targeting government officials and policymakers) and the IPCC overview and conclusions (Moss, 2011). The IPCC's stated goal, to clearly communicate heterogeneous and multidisciplinary perspectives, presents a natural challenge of how to adequately distill the full range of current scientific information into a report that must be both accurate and digestible by decision makers.

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Dealing with Uncertainty

Generating recommendations is made difficult in part by the multitude of different uncertainties underlying the evidence from the various disciplines considered by each WG. They have distinct domain-specific definitions of, and conventions related to, uncertainty. For example, Grübler and Nakicenovic (2001) argue that probabilities in natural sciences are fundamentally different from social science, since the natural sciences can lend themselves to repeated experimentation and social science often involves ingrained interdependencies that may be neither clearly estimated nor even known.

Climate science research involves additional sources of uncertainty that are not encountered in other domains, such as long time lapses between actions (e.g., increase in carbon emissions) and response (e.g., radiative forcing), inability to test causality through experimentation, and the centrality of dependent variables that have greater longevity than measurement tools. The types of uncertainty frequently encountered by authors of IPCC reports include problems with data (e.g., missing components, noise, and nonrepresentative biases), models (e.g., model parameters expected to change over time, uncertainties from approximation techniques), and other sources of uncertainty (e.g., ambiguous concepts, inappropriate assumptions; for details, refer to Moss & Schneider, 2000, Box 2, p. 38).

Because of these complexities, results do not lead neatly to objective (frequentistic) probabilities, and uncertainties cannot be quantified through repeated trials. One approach to quantifying such deep uncertainty is to elicit subjective probabilities from multiple experts and aggregate the elicited probabilities. The studies by Nordhaus (1994), Morgan and Keith (1995), and Morgan, Adams, and Keith (2006) are excellent examples of this approach. They describe carefully the expert identification and selection process, the choice of the target variables and their ranges, and the technical details of the elicitation methodologies. More than helping in the procurement of a single “collective” estimate, these studies illustrate the divergence of opinions in the field. These studies show the difficulty, and at times reluctance, of translating subjective opinions more compactly so that the opinions remain faithful to both the decision maker’s intent and full range of highly variable subjective probabilities. The next section briefly describes how the IPCC has addressed uncertainty communication in the various ARs.

Communication of Uncertainty

The first IPCC-sanctioned guidelines for dealing with uncertainty were not put in place until the Third Assessment Report (AR3). In the first three assessment reports, authors in different working groups developed their own rubrics of confidence and uncertainty language—WG I (Folland, Karl, & Vinnikov, 1990) and WG II (Table 1; Watson, Zinyowera, Moss, & Intergovernmental Panel on Climate Change, 1996, p. x). Furthermore, the

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general public and the media were not given clear guidelines on how to interpret the report, and so they drew their own conclusions. In doing so, they sometimes omitted pertinent information (Moss & Schneider, 1997). In response, the IPCC convened a nine-day summit at the Aspen Global Change Institute in the summer of 1996 to review how to convey uncertainties and confidence levels. The session revealed many challenges, among them “involving author team dynamics, heuristics that lead to over-confidence, disagreement over definitions of uncertainty, confidence, and likelihood, and lack of standardized terminology” (Meehl & Moss, 2016).

Table 1. Level of Confidence Assigned to Scientific Findings and Number of Appearances in the AR2 WG II Executive Summary. (R. T. Watson, Zinyowera, Moss, & Intergovernmental Panel on Climate Change, 1996)

Level	**Definition**	**Times present**
High Confidence	This category denotes wide agreement, based on multiple findings through multiple lines of investigation. In other words, there was a high degree of consensus among the authors based on the existence of substantial evidence in support of the conclusion.	70
Medium Confidence	This category indicates that there is a consensus, but not a strong one, in support of the conclusion. This ranking could be applied to a situation in which an hypothesis or conclusion is supported by a fair amount of information, but not a sufficient amount to convince all participating authors, or where other less plausible hypotheses cannot yet be completely ruled out.	63
Low Confidence	This category is reserved for cases when lead authors were highly uncertain about a particular conclusion. This uncertainty could reflect a lack of consensus or the existence of serious competing hypotheses, each with adherents and evidence to support their positions. Alternatively, this ranking could result from the existence of extremely limited information to support an initial plausible idea or hypothesis.	6

The result of this workshop was the first IPCC-sanctioned list of recommendations for communicating uncertainty in anticipation of the IPCC AR3. Moss and Schneider (2000) recommended explicit specification of probabilities by experts, even if there is a degree of uncertainty, rather than leaving nonexperts to draw their own conclusions. Moss and

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Schneider (2000) proposed guidelines to communicate confidence in conclusions/ projections (Table 2), extent of agreement and evidence available (Figure 1), and likelihood (i.e., probability of occurring) of events/projections (Box 1).

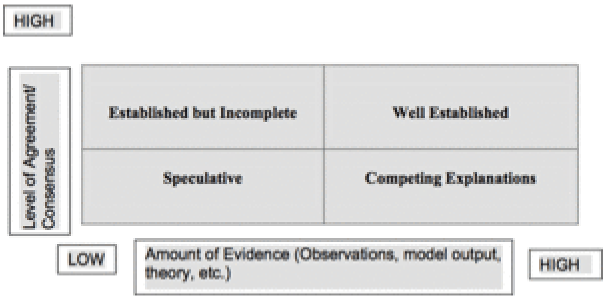

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Figure 1. AR3 Supplemental Qualitative Uncertainty Terms (Moss & Schneider, 2000).

Key to qualitative "state of knowledge" descriptors

Well-established: models incorporate known processes; observations are largely consistent with models for important variables; or multiple lines of evidence support the finding)

Established but Incomplete: models incorporate most known processes, although some parameterizations may not be well tested; observations are somewhat consistent with theoretical or model results but incomplete; current empirical estimates are well founded, but the possibility of changes in governing processes over time is considerable; or only one or a few lines of evidence support the finding

Competing Explanations: different model representations account for different aspects of observations or evidence, or incorporate different aspects of key processes, leading to competing explanations

Speculative: conceptually plausible ideas that haven't received much attention in the literature or that are laced with difficult to reduce uncertainties or have few available observational tests

Box 1. IPCC AR3 Summary for Policymakers: Confidence and likelihood description. (IPCC, 2001, p. 5)

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Confidence and likelihood statements. Where appropriate, the authors of the Third Assessment Report assigned confidence levels that represent their collective judgment in the validity of a conclusion based on observational evidence, modeling results, and theory they have examined. The following words have been used throughout the text of the Synthesis Report to the Third Assessment Report (TAR) relating to WGI findings: virtually certain (greater than 99% chance that a result is true); very likely (90–99% chance); likely (66–90% chance); medium likelihood (33–66% chance); unlikely (10–33% chance); very unlikely (1–10% chance); and exceptionally unlikely (less than 1% chance). An explicit uncertainty range (±) is a likely range. Estimates of confidence relating to WGII findings are: very high (95% or greater), high (67–95%), medium (33–67%), low (5–33%), and very low (5% or less). No confidence levels were assigned in WGIII.

Table 2. AR3 Confidence Scale Adapted from Moss and Schneider (2000)

Confidence Level	**Label**
0.95–1.00	Very High Confidence
0.67–0.95	High Confidence
0.33–0.67	Medium Confidence
0.05–0.33	Low Confidence
–0.05	Very Low Confidence

Patt and Schrag (2003) found that the guidelines were used unevenly across the WGs in AR3, in no small part because of the methods used to characterize uncertainty in different disciplines. For example, the natural scientists of WG I preferred framing uncertainty using objective probabilities, while the WG II concentrated on future impacts, resulting in estimates that were necessarily less precise, with an inclination toward subjective probabilities. A simple word count analysis by Swart et al. (2009) showed that probabilistic words like “uncertain,” “probability,” “risk,” “choice,” and “decision” were found in varying rates across the WG reports, leading them to conclude that “uncertainty dominates WG I; risk, WG II and choice, WG III.”

Even with the Moss and Schneider (2000) recommendations for communicating uncertainty, AR3 still suffered from a lack of unity in its management of uncertainty. The inescapable relationship between confidence and likelihood was manifest in the divergent application of the terms across the IPCC WG Reports, with some WGs using one or both of the phrases to simultaneously communicate the probability of a given outcome or scientific consensus.

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The IPCC attempted to resolve this terminology conflation in AR4 by creating two distinct sets of guidelines for confidence in available scientific information (Table 3) and assessed probability of outcome (Table 4). The likelihood scale devised by WG I in AR3 (Table 4) was updated to replace *medium likelihood* (between 33 and 66% chance of occurring) to *about as likely as not* (between 33 and 66% probability). Yet, while the AR4 Guidance Note discussed the implicit relationship between confidence and likelihood, it lacked actionable recommendations for how to report such results, leading to a mischaracterization of both concepts.

Table 3. Confidence Level Guidelines from IPCC AR4 Guidance Note (IPCC, 2005)

Terminology	**Degree of confidence in being correct**
Very High confidence	At least 9 out of 10 chances of being correct
High confidence	About 8 out of 10 chances
Medium confidence	About 5 out of 10 chances
Low confidence	About 2 out of 10 chances
Very Low confidence	Less than 1 out of 10 chances

Table 4. Likelihood Scale from IPCC AR4 Guidance Note (IPCC, 2005)

Terminology	**Likelihood of the occurrence/outcome**
Virtually certain	> 99% probability of occurrence
Very likely	> 90% probability
Likely	> 66% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Exceptionally unlikely	< 1% probability

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The Guidance Notes for AR5 reflected an attempt to encourage more rigor and consistency in the reporting of uncertainties. The confidence scale from AR4 (Table 3), which included quantitative information, was removed so to "prevent . . . interpretations of levels of confidence as subjective probabilities" (Figure 2; Mastrandrea et al., 2010, p. 2).

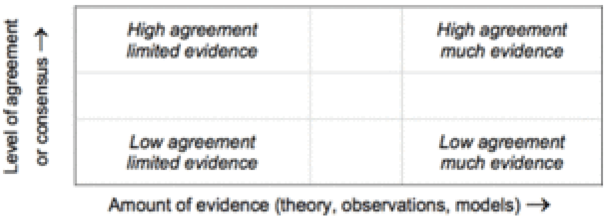

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Figure 2. Agreement and Evidence Levels of Understanding Scale in IPCC AR4 Guidance Note (IPCC, 2005).

In light of growing IPCC discussions on the inextricable link between confidence, author agreement, and amount of evidence available, the confidence scale was appended to the Evidence and Agreement scales so that confidence was explicitly correlated with agreement, and, to a lesser extent, evidence (Figure 3).

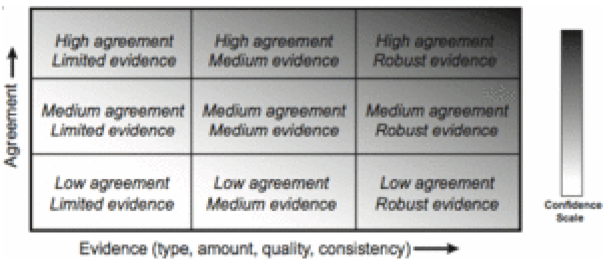

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Figure 3. Agreement and Evidence Levels of Understanding Scale in IPCC AR5 Guidance Note (Mastrandrea et al., 2010).

Additionally, the numerical ranges of the AR5 likelihood scale were amended so as to include both an upper range and a lower range for uncertainty phrases that were bounded by either 0 or 1 (Table 5 in AR5; previously, ranges that contained these quantities were left open-ended. Yet, as in prior versions, the probability ranges remained nonexclusive: if the belief about the probability of an event is around 95%, then one could use either *Likely* or *Very Likely*.

This continued problem points to the need to conduct empirical research to validate the language of uncertainty. Indeed, Kahan (2013) argues that science communication must leave the realm of "plausible conjecture" and move toward evidence-based approaches that identify empirically supported strategies of communication. We focus on one specific area where we have taken this extra step, namely, the communication of uncertainty in the IPCC reports.

Evidence-Based Approaches to Maximizing Communicative Effectiveness

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Given the high uncertainty associated with many climactic assessments and its projections, and as a way of bridging the many interdisciplinary differences, the IPCC adopted the use of a "standardized lexicon of uncertainty" in AR5 (Table 5), an approach used in other domains (e.g., intelligence and medicine). All contributors to the reports are instructed to refer to this table when making probabilistic pronouncements. The Likelihood Scale is also included in all IPCC reports to help readers make sense of the assessment.

Table 5. Likelihood Scale in IPCC AR5 Guidance Note (Mastrandrea et al., 2010)

Term	**Likelihood of the occurrence/outcome**
Virtually certain	99–100% probability of occurrence
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33 to 66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

Note:

(*) Additional terms that were used in limited circumstances in the AR4 (*extremely likely*–95–100% probability, *more likely than not*–>50–100% probability, and *extremely unlikely*–0–5% probability) may also be used in the AR5 when appropriate.

The key to effective communication in such asymmetric situations is that both sides in the process—the communicator and the audience—interpret and understand every term, recommendation, and projection in identical fashion. Thus, it is natural to ask whether the readers of the ARs interpret their probabilistic pronouncements as the authors intended it. Budescu, Por, Broomell, and Smithson (2014) conducted a large study to understand the public's interpretation of these expressions. The survey was administered in 25 countries and 17 languages and involved almost 11,000 valid responses. Participants saw eight sentences from IPCC reports (two with each of the terms *Very Unlikely*, *Unlikely*, *Likely*, and *Very Likely*) and provided their numerical estimates of the probability, as well and lower and upper bounds of the sentences' intended meaning. In all the samples, the public interpreted the probabilistic statements in the IPCC reports as less extreme—much closer to 50%—than the authors intended. Participants were

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randomly assigned to two groups: the control group and the verbal–numerical (VN) group. The control group saw the IPCC statements as they appear in the report along with its translation table. The VN group always saw the verbal terms and their numerical ranges simultaneously. For example, when the sentence "It is *very likely* that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent" was shown to respondents in the VN group, the uncertainty was described as *very likely (greater than 90%)*. Budescu et al. (2014) found that the new communication format was highly beneficial: (1) the level of correspondence between the public's interpretation of the terms and the IPCC guidelines increased significantly (actually doubled for the most extreme terms); (2) the terms were better differentiated by the readers; and (3) the range of values associated with the various terms was reduced. These qualitative patterns were remarkably stable across all samples and languages. Remarkably, the joint presentation format makes the meaning of the terms more similar across languages, facilitating international communication. Harris, Por, and Broomell (2017) showed that communication can be further improved by explicitly stating the numerical bounds implied by the expression (e.g., 66–100% for "likely" instead of "greater than 66%"). Clearly, minor changes in format greatly increased the effectiveness of the message to the public.

Another potential issue associated with the current conversion table is related to definition of the meaning of the verbal terms or, more precisely, the choice of the cutoff points that separate and differentiate between the terms. These values were chosen by fiat by a small selected committee, and, unfortunately, they do not match most people's natural and intuitive daily usage of the terms. Ho, Budescu, Dhami, and Mandel (2015) illustrated the superiority of evidence-based communication lexicons using data from the same survey. The participants in the Budescu et al. (2014) IPCC survey were also asked to indicate the numerical meanings they assign to the same four phrases in their daily use, without specifying any particular context. Ho et al. (2015) used standard statistical techniques to analyze the estimates of the U.S. sample and to derive "optimal" cutoff points, that is, values that maximize the agreement in meaning across respondents. They found that some of these cutoff points were quite different from the boundaries used in the IPCC translation table. For example, the IPCC's ranges for *very unlikely* and *very likely* are much narrower and more extreme (closer to the end points, 0 and 100) compared to the respondents' intuitive and natural interpretations of these phrases.

To compare how effectively the evidence-based lexicons and the IPCC guidelines convey information about uncertainty, Ho et al. (2015) reanalyzed evaluations of the phrases in the eight IPCC sentences, using the U.S.-sample-derived cutoff points on responses of other English-speaking samples (Australia and the United Kingdom) samples. The mean consistency rates in these samples was 26% when using the IPCC guidelines, and increased to 40% when using the evidence-based lexicons. Clearly, the effectiveness of communication can be easily improved by revising the definitions of the terms, in line with people's natural use of these phrases.

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How Can We Improve Communication?

The following short list of recommendations and suggestions, if implemented, could at least partly alleviate some of the problems described here. Given the magnitude and multifaceted nature of the problem, it is clear that no single intervention, nor single principle, nor general approach can completely overcome all the various obstacles. It is equally clear that no approach will work for everyone, everywhere. A positive development has been the increased level of involvement of psychologists and communication specialists in climate change research, coupled with the higher awareness, and openness, of physical scientists and climate modelers to the potential contribution of these experts in communicating the science to the public and policymakers (e.g., see IPCC, 2016). As a result, one can find some excellent and quite comprehensive guidelines on communication about CC (e.g., CRED, 2009; Moser, 2010).

Such guides on communication about climate change (e.g., CRED, 2009) stress the need to appeal to various social and societal identities when talking about CC. This was clearly illustrated by the noticeable impact of Pope Francis's encyclical, which framed climate change as a moral and religious issue, on the public's perceptions and especially among Catholics (e.g., Maibach et al., 2015). Similar appeals can be made in terms of national security (e.g., Busby, 2007) and biodiversity. Discussions of CC can also be framed in terms of costs and benefits from specific business perspectives (for an example in the insurance industry, see Mills, 2007) and indirect effects (e.g., establishing a clear link between climate change and price and availability of food (Worldwatch Institute, N.D.).

In all these situations, communicators and scientists need to be mindful of the language used in discussing climate science. Lewandowsky, Gignac, and Vaughan (2012) showed that people were more likely to believe that climate change was occurring primarily because of anthropogenic causes when they were presented with scientific consensus on it. A balance needs to be struck between adequately characterizing uncertainties about climactic vulnerabilities, mitigation, and adaptation, while appropriately communicating the clear agreement from effectively all scientists that anthropogenic climate change is a reality.

Finally, the empirical research on conveying and comprehending uncertainty provides strong justification for revising the way the IPCC communicates uncertainty to the public and policymakers. Ho et al. (2015) recommended continuing the use of the seven verbal categories used in AR5 (Mastrandrea et al., 2010), but with the following modifications: change the thresholds defining the bounds of the categories to reflect the general public's intuitive and natural interpretation of the seven words (as in Ho et al., 2015), and generate a partition (mutually exclusive and exhaustive categories) of the probability scale, excluding overlapping categories; use probabilistic terms in conjunction with a range of numerical values; and list the default range (subject to the changes proposed in points 1 and 2 above) for each term (i.e., in the Likelihood Table accompanying each AR).

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However, if the authors are sufficiently confident about a certain event, they should be allowed to narrow the range, as long as it is consistent with the table. For example, if by default *Likely* is mapped into the 60%–85% range, authors should have the option to use a narrower range (e.g., *Likely* (65%–75%), if the data warrant such determination). These changes would improve the effectiveness of the communication by appealing to readers who prefer different communication modes; would facilitate communication across cultural and linguistic bounds; and would allow IPCC authors more flexibility.

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