Framing the Unknown: Climate Model Uncertainty, Public Trust, and the Ethics of Communication

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

In August 2021, the Intergovernmental Panel on Climate Change (IPCC) released its Sixth Assessment Report, calling the current state of the world's climate a "code red for humanity" (Intergovernmental Panel on Climate Change [IPCC], 2021). The warning made headlines globally, with some media outlets emphasizing the urgency of the message, while others focused on the uncertainties embedded in the predictions. On social media, confusion spread rapidly. Some users panicked, while others dismissed the report entirely. A particularly viral tweet read, "So, scientists say the sea might rise a little or a lot, but they're not sure which. And we're supposed to change our entire economy over that?" This response encapsulates a common misunderstanding of scientific uncertainty and highlights a core challenge in effectively communicating climate change in today's society.

Many scientists may believe that transparency about scientific uncertainty builds trust and leads to better public decision-making. I argue that while communicating a range of possible futures can indeed foster public trust, it also introduces serious ethical and strategic dilemmas. These dilemmas arise when scientists or the media selectively frame uncertainty to inspire action, potentially at the cost of long-term credibility and increased public polarization. This paper seeks to explore the question: how does the communication of uncertainty in climate change models affect public trust and support for climate policy, and what role does media framing play in shaping these perceptions?

To explore this, I conducted a meta-review of climate communication literature through the lens of numerous Science and Technology Studies (STS) frameworks, particularly the concepts of credibility and co-production, as well as cognitive psychology theories such as motivated reasoning and disconfirmation bias. I synthesized findings and built upon them from peer-reviewed journals in environmental science, media studies, and communication. My goal is to offer a holistic view of how climate uncertainty is communicated to the public and how different communication strategies shape trust, skepticism, and policy engagement. By combining insights from STS and psychology, this paper contributes to understanding the "tightrope" that scientists and journalists walk between transparency and persuasion along with the ethical implications of falling off either side. This can manifest itself in the fashion that too much emphasis on uncertainty can spur public inaction by fostering doubt or confusion. On the other side of the tightrope, too little emphasis can lead to a false sense of certainty that backfires if predictions do not align with future outcomes. This tension and balancing act that ensues from said tension poses an interesting ethical dilemma: communicators must decide whether to prioritize clarity or caution, knowing that either extreme can distort public understanding and behavioral responses from the public.

Background & Context

Properly communicating the impacts of climate change has become one of the most high-stakes challenges in science and society. As the global climate crisis worsens, scientists are increasingly tasked with both producing accurate predictions about the future and conveying their findings to the public and policymakers in ways that inspire action and comprehension on the matter. However, unlike short-term weather forecasts, climate models deal with complex systems over decades and centuries, involving countless variables, many of which are unknown. This naturally introduces uncertainty that is quantifiable, such as probabilities around emission scenarios, and unquantifiable uncertainty, such as structural ambiguities in how the Earth's systems might respond to processes that either dampen or amplify the effects of climate change, known as feedback loops. These uncertainties are not flaws in the models, but inherent features of long-term climate models.

Understanding how climate models actually work is essential to making sense of the uncertainty they carry. To the general public, the term "climate model" might sound like a vague simulation or even an educated guess of sorts, but in reality, these models are deeply grounded in physics, chemistry, and Earth science. They are not speculative tools, but rather highly sophisticated computational systems used to simulate how the Earth's climate behaves over time. These models allow scientists to run experiments on the planet's future that we cannot run in real life.

At their foundation, climate models are mathematical representations of the Earth's physical processes. Scientists build them by dividing the planet into a three-dimensional grid, which covers the atmosphere, land, and oceans. Each grid cell holds values for critical variables such as temperature, humidity, wind velocity, ocean salinity, and carbon concentration. These values evolve over time based on physical laws and the type of climate model that is being utilized. Using equations that come from thermodynamics, fluid dynamics, and radiation physics, the model calculates how these variables interact with one other in every grid cell as time progresses. The more detailed the grid, the more precise the model can be. However, increasing resolution also means significantly more computing power and longer processing times which makes it more difficult the further the climate model tries to predict.

Constructing a climate model involves several steps. First, scientists define the starting conditions of the Earth system. These include current live observations from satellites, ocean buoys, weather stations, and ice core samples. Once these inputs are established, the model simulates how the system evolves based on natural forces and human influences. Scientists often use these models to simulate various emission scenarios. For example, they may compare what happens if we drastically reduce greenhouse gas emissions, what happens if we continue burning fossil fuels at current rates, and the scenario where we increase the amount of fossil fuels that we burn. Each scenario produces different projections for temperature rise, precipitation patterns, and sea level changes over decades to centuries, greatly altering predictions.

With the general idea of climate models established, they can be broken down into several different categories. Simple models might only look at global average temperature over time., while more advanced general circulation models simulate complex interactions between the atmosphere, oceans, land, and ice. Earth system models take it a step further by integrating the carbon cycle, vegetation dynamics, and sometimes even human land use. These models are evaluated by comparing their outputs to historical climate data. If a model can accurately reproduce past climate changes, scientists gain confidence in its ability to project the future climate and state of the Earth.

Despite their sophistication and how deeply rooted in science these models are, they simply cannot be perfect. One of the main reasons for uncertainty lies in the variables included in the models and how efficiently scientists can estimate them. Variables like atmospheric carbon dioxide levels or global sea surface temperature are relatively straightforward to measure. On the other hand, variables like cloud formation, ocean circulation at depth, and permafrost thaw, are much harder to quantify and represent accurately. Cloud feedback, in particular, remains one of the most difficult components to model. Depending on the type, altitude, and region, clouds can either cool the planet by reflecting sunlight or do the complete opposite and warm it by trapping heat. Small changes in cloud behavior can lead to extremely different long-term outcomes, which is one reason why model projections often present a range of possibilities rather than a single number.

Another challenge is accounting for feedback loops. These are processes that can either amplify or dampen the effects of climate change. For example, melting ice reduces the Earth's reflectivity, causing more heat to be absorbed, leading to further melting. Additionally, permafrost thawing releases methane, a potent greenhouse gas, which can accelerate warming. On the other hand, increased vegetation growth in some areas could absorb more carbon dioxide and act as a counterbalance. Including these feedbacks accurately in models requires careful assumptions, and even the smallest of uncertainties can lead to enormous differences in projections.

However, this does not mean that climate models are unreliable. In fact, many of the broad patterns they were predicted decades ago, such as Arctic sea ice decline, stronger heatwaves, and shifts in rainfall patterns, have come to fruition. This emphasizes that climate models are constantly being updated and improved as more data becomes available and computing power increases. They are best understood not as forecasts of exactly what will happen, but as tools for understanding what could happen under different choices that can occur. They provide valuable guidance for policymakers, helping them weigh the consequences of inaction versus intervention.

Another important aspect of climate modeling that often goes unnoticed by the public is the use of model ensembles. No single model can perfectly capture every detail of the Earth's systems, so scientists run multiple models in parallel, each with slightly different assumptions, parameters, or initial inputs. This produces a range of outcomes that together form what is known as an ensemble. A helpful way to think about this is to imagine consulting a panel of climate experts, each using slightly different reasoning to answer the same question. When the majority of the models in the ensemble agree on a general outcome despite the differences in inputs, such as significant warming under high-emission scenarios, that consensus strengthens confidence in the result.

The ranges that appear in scientific reports, like those from the IPCC, often come from these model ensembles. For example, a report might project that sea levels could rise anywhere from thirty centimeters to one meter by 2100, depending on emissions and feedbacks (*The basics: Future sea level*, 2025). To scientists, this range represents a thoughtful exploration of multiple possible futures. To the public, however, it can come across as vagueness. This is where the challenge of communication becomes especially relevant. When people hear a wide range of outcomes, they may conclude that the science is too uncertain to act on, even though the models actually show strong agreement on overall trends, which is the main focus of these models .

This disconnect is partly due to the way probability and uncertainty are interpreted and conveyed. In climate science, uncertainty is often a sign of honesty and scientific caution. It reflects the inherent complexity of the systems being modeled, not a lack of knowledge. However, in government, uncertainty can easily be interpreted as a flaw and a reason to delay action. This gap in understanding reveals a larger issue. Climate models are not only scientific tools, but they are also public-facing artifacts. The way they are built, interpreted, and communicated has real effects on how people understand risk and how willing they are to support climate policy. The more that people understand what climate models actually do and where their limitations come from, the better prepared they will be to interpret the uncertainty in those models responsibly. Model accuracy is extremely important, but how effectively their outputs are translated into meaningful narratives that resonate with public audiences is even more important. Scientific accuracy and narrative clarity do not have to be at odds with one another. The challenge is finding the language and framing that convey both the intent of the models and the urgency of the risks they reveal. In that sense, climate modeling is not just a technical task, but also a communicative one. How well we bridge that gap between science and public understanding may very well shape the future of climate action itself.

This complex interplay between scientists, climate models, and the general public sets the stage for a difficult ethical question: should climate scientists and communicators emphasize clarity and emotional resonance to inspire change, even if it means selectively framing their message? Or is it their ethical duty as scientists to present all information including deep uncertainties at the risk of losing public trust and never amounting to public action for climate change?

Methods & Theoretical Framework

To explore how the communication of uncertainty in climate change models affects public trust and policy support, I conducted a qualitative analysis of existing academic literature and meta-reviews. My sources primarily included peer-reviewed journals from the fields of environmental science, science communication, and media studies. In particular, I focused on meta-analyses that synthesized findings from a wide range of climate communication studies, such as those examining the public's response to the IPCC's reports and the media framing of international climate conferences like COP21 mentioned earlier.

I chose to work with secondary sources in order to identify overarching patterns and recurring patterns in the way uncertainty is presented and interpreted by the general public. I analyzed these sources through a lens that prioritizes the collaboration of scientific credibility, media influence, and public perception. In addition, I examined cognitive psychology theories that explain how individuals process climate information through existing belief systems. The scope of this research is intentionally focused on how uncertainty is communicated to non-expert audiences rather than internal scientific communities. My interest lies in how scientific findings are translated into public discourse and the consequences of different communication strategies.

My analysis is grounded in several STS theoretical frameworks. Most importantly, I draw on the concept of credibility as a socially constructed attribute, as discussed in the work of Sheila Jasanoff (2004). In this context, credibility is not determined solely by the accuracy of climate models, but also by how trustworthy and authoritative the models are perceived to be by various audiences. I also use the STS framework of co-production, which suggests that scientific knowledge and social order are produced simultaneously (Jasanoff, 2004). This helps illustrate how climate projections are not merely technical outputs, but political, ethical, and communicative choices such as how to frame risks and uncertainty matter even more than the technical aspect. Additionally, I incorporate the concept of motivated reasoning, which explains how people's existing beliefs and identities influence how they interpret information (Kunda, 1990). This concept is especially relevant in understanding why some individuals respond positively to transparent uncertainty while others become even more skeptical and disillusioned with a topic. By combining STS theories of credibility and co-production with theories of belief formation and media framing, my research seeks to offer a holistic account of how strategic communication in climate science can both build and erode trust, depending on the audience.

Findings and Analysis

Common Public Misunderstandings of Climate Science

A significant barrier to public understanding of climate change stems from persistent misconceptions in the general public, many of which are fueled by failures in how climate information is framed and communicated. One of the most common misconceptions is as follows, "It's cold outside today, so how can global warming be real?". This clearly exemplifies the issue of the lack of distinction between climate and weather. Although scientists distinguish between short-term weather and long-term climate, this nuance is often lost in public discourse, especially when media headlines or viral posts conflate the two, confusing the general public and their perceptions on the matter. When uncertainty in both climate models and climate change is poorly communicated, or when the broader context of long-term trends is omitted, the public is left vulnerable to misunderstandings that are intuitive to scientists. Moreover, another misconception that "technology will eventually fix global warming" reflects depoliticization, a tendency to reduce climate change to a purely technical problem. This narrative diverts attention away from systemic political and economic reforms needed to reduce emissions and adapt to climate impacts and pushes them off to the future. By portraying climate change as an issue that scientists and engineers alone can solve, this framing minimizes the role of public accountability and policy action.

Another widespread belief is as follows: that climate change is only about rising temperatures. Once again, this further illustrates how communication gaps emerge from the inherent complexity of climate models. Climate change involves far more than just heat as it includes sea-level rise, shifting precipitation patterns, extreme weather events, and disruptions to ecosystems. However, these interconnected effects are difficult to model precisely, especially across regional scales, and even harder to explain to non-expert audiences. The IPCC's reliance on technical terminology and abstract graphs, while scientifically justified and extremely hard to explore clearly in other ways, can alienate readers unfamiliar with probabilistic forecasts. In turn, when people hear about scenarios with uncertainty or model variability, they more often than not misinterpret these as flaws and inaccuracies in the model. These misconceptions do not exist in a vacuum as they are shaped by the way climate science is simplified, politicized, and presented to the public through climate scientists and the media. Understanding and addressing these framing challenges is crucial to building trust and engaging the public in meaningful climate action through their respective policymakers.

Communicating Uncertainty in the Media

One of the clearest patterns in the literature is that the way uncertainty is communicated significantly shapes public trust in climate science. Contrary to common assumptions, not all expressions of uncertainty reduce credibility. Research shows that when scientists present uncertainty in a structured and bounded way such as plausible scenarios within a defined range, it can actually enhance trust (Fage-Butler, Jaspal, & Nerlich, 2022). A 2019 Stanford-affiliated study, for example, found that when sea-level rise projections were communicated as ranges (e.g., 0.3 to 1 meter by 2100), trust in climate scientists increased by 8%. Conversely, when projections included undefined variables or deeply technical caveats, trust declined by 5% (Communicating uncertainty about climate change, 2019). This shows how fragile credibility can be. Clarity and transparency are rewarded until they reveal the full extent of uncertainty in the matter. This pattern underscores a central dilemma: the public wants transparency, but only when it is packaged in a way that feels comprehensible and purposeful.

This tension echoes Sheila Jasanoff's (2004) theory of credibility as a co-produced attribute. Credibility is generated and negotiated between scientists and society rather than bestowed by expertise alone. The public's trust in climate models hinges not only on scientific rigor, but also on whether the models are perceived as relevant, transparent, and reasonable. When uncertainty is framed as a calculated, bounded risk rather than ignorance or failure, it becomes more digestible and actionable for both citizens and policymakers.

However, the way scientific uncertainty is interpreted does not occur in isolation. It is shaped by the media, which often serve as the public's primary source of climate information. News coverage, headlines, and visual framing influence not just understanding, but emotional reactions and cognitive processing. Yet, media consumers are not blank slates. They filter information through existing worldviews in a process known as motivated reasoning. As a result, those already alarmed by climate change may be galvanized by urgent messaging, while those doubtful may become more entrenched in their skepticism. This is reinforced by disconfirmation bias, a psychological tendency where exposure to contradictory evidence actually strengthens preexisting beliefs. A 2019 meta-review highlights the complex dynamics of climate communication, finding that even well-intentioned media coverage, such as positive portrayals of the 21st Conference of the Parties, had minimal impact on "alarmed" audiences and, in some cases, made the "doubtful" even more skeptical (Wonneberger et al., 2019). This highlights a crucial point: climate messaging does not land in isolation. It exists in a minefield that is shaped by identity, ideology, and emotion. Even well-intentioned media efforts can backfire traversing this minefield, deepening polarization instead of bridging gaps. For communicators, this demonstrates the importance of not only crafting accurate messages but also anticipating how those messages will interact with the psychological and ideological filters through which they are received.

Of the media, news outlets, whether they are aware of it or not, play directly into this mechanism. Headlines that dramatize uncertainty, such as “Global warming happens: but is it 'catastrophic'?” (Reuters, 2007) or “The planet is 'on the brink of an irreversible climate disaster,' scientists warn” (Nuccitelli, 2024), exemplify how media coverage can frame climate science in ways that heighten emotional responses while oversimplifying complex findings. The 2007 Reuters headline poses a rhetorical question that casts doubt on the severity of climate change, subtly inviting readers to question the legitimacy of the scientific consensus. Meanwhile, the 2024 Yale Climate Connections article adopts an urgent and even apocalyptic tone that may alarm readers without equipping them with the context needed to interpret the risk.

These headlines, though differing in tone with one skeptical and the other alarmist, both play into the broader communication challenge; they take nuanced scientific findings and repackage them into emotionally charged narratives. This dramatization fosters disconfirmation bias, a psychological tendency in which individuals reinforce their existing beliefs when confronted with information contrary to the beliefs that they already hold (Edwards & Smith, 1996). Those predisposed to skepticism may interpret the Reuters headline as validation of their doubts, while those prone to climate anxiety may either feel overwhelmed by the Nuccitelli article or even grow numb to repeated crisis language.

Shockingly, these examples span a 17-year period from 2007 to 2024 demonstrating that the media’s tendency to either sensationalize or cast doubt on scientific uncertainty is not a new phenomenon, but one that has existed for decades. This reflection of a long-standing pattern in climate journalism prioritizes impact over understanding. Over time, this pattern shapes public discourse in deeply consequential ways: undermining trust in scientific institutions, polarizing opinion, and confusing the very audiences that communicators seek to inform and engage.

This being said, the media's power to frame climate science cannot be overstated. Its choices of language, visuals, and emotional tone affect not only understanding, but which emotional reactions are triggered. For those predisposed to climate concern, uncertainty may be read as urgency for the entire world to act on that urgency. For those predisposed to skepticism, it is read as incompetence and further reason to not believe in climate change and its models. As for the most important group, the undecided middle, it can generate confusion and disengagement. Thus, while climate models themselves may be neutral tools, the narratives built around them are anything but. They are deeply embedded in ideological and psychological dynamics, which emphasize the need for climate scientists to be aware of these factors when framing their narratives.

Transparency

The final theme that emerged is the tension between transparency and strategic simplification, especially in high-stakes public messaging. Communicators often face an enormous ethical dilemma. Should they emphasize clarity and emotional urgency to motivate action, or should they fully disclose the uncertainties, knowing that this might dilute the message and stall action? This ethical tradeoff is well captured in the co-production framework, particularly through the idea that scientific knowledge is not just produced, but also shaped by social, political, and ethical considerations.

A prime example is the adoption of the 1.5°C target. While scientifically valid within a certain range, it has been heavily simplified for political and media messaging. Its appeal lies in its clarity and how digestible it is for the general public, but as Kopp et al. (2023) argue, such simplifications risk presenting a falsely precise picture of what is essentially a highly uncertain threshold. If global temperatures exceed this number and catastrophic events do not immediately follow, the public could interpret this as a failure of science, further eroding credibility.

All in all, the simplification of uncertainty for the sake of persuasion raises questions about long-term public trust. Is short-term action worth the risk of long-term backlash if predictions do not materialize exactly as presented? Though this seems like a hypothetical concern, it is not, which should be extremely alarming. Climate science has already faced criticism for perceived alarmism when early predictions proved less extreme than expected. Then, the ethical imperative is to balance hope, urgency, and humility in a way that both inspires action and respects the complexity of the models. As Jasanoff (2004) argues, climate science must not only be grounded in empirical data, but also remain responsive to the broader public conversation in which it is embedded.

Conclusion

This paper has examined how the communication of uncertainty in climate change models shapes public trust and policy support, and how media framing intensifies or alleviates those effects. Across the findings, a key pattern emerged. Uncertainty itself is not the barrier to public trust as it is how that uncertainty is framed and filtered through media and belief systems that determines its impact. Structured, scenario-based uncertainty builds credibility; vague or technical expressions of doubt diminish it. Likewise, media coverage that sensationalizes or politicizes scientific ambiguity activates motivated reasoning, reinforcing preexisting views rather than opening the door to collective understanding which is essential.

These findings lead to an urgent claim. We need to shift away from binary thinking about climate certainty and instead cultivate a public culture of climate literacy that embraces complexity instead of resorting to simplifying narratives. Climate communicators, whether they are scientists, journalists, or educators, should not be forced to choose between honesty and influence. Instead, we must support communication strategies that are transparent about limitations but also grounded in narratives of possibility and shared responsibility. Politically, this means rejecting both alarmism and dismissal as frames. Alarmism may temporarily mobilize action, but it risks backlash if predictions are misunderstood or timelines shift. Dismissal, often cloaked in appeals to uncertainty, delays necessary policy changes. What is needed is a middle ground of principled persuasion which is emphasizing communication that informs and empowers without misleading or simplifying to the point of distortion. Institutions like the IPCC, the National Climate Assessment, and media organizations should invest more intentionally in crafting messages that explain uncertainty as a scientific strength rather than a flaw.

Looking forward, the stakes around this issue are only going to intensify. As climate impacts become more visible through extreme weather events, sea-level rise or ecological disruption, public demand for accurate and actionable climate information will grow. At the same time, misinformation ecosystems on social media platforms like X, TikTok, and YouTube are evolving rapidly, often outpacing the slow deliberation of peer-reviewed science. Artificial intelligence may further complicate matters by generating seemingly credible yet incorrect summaries of scientific findings, or misrepresenting uncertainty with convincing language. The future of public trust in science may depend on how well we adapt our communication tools to meet this evolving digital landscape.

Future research should investigate these emerging dynamics. While this paper focused on how media and message framing influence public perception, upcoming studies could examine how trust varies across different socioeconomic, political, or cultural communities, and whether tailored messaging strategies to these specific communities could mitigate the effects of motivated reasoning. Additionally, researchers should study how new forms of media, like how short-form, algorithmically created content can reshape public engagement with scientific uncertainty.

Ultimately, effective climate communication is more than managing impressions. It is about building a democratic foundation for informed action in the face of complexity. This is not only relevant to the topic of climate change, but all complicated issues that the nation and world will face in the inevitable future. The legitimacy of science in public life depends not on being flawless, but on being accountable, accessible, and grounded in ethical engagement with society. To that end, we must treat uncertainty not as an obstacle to trust, but as a central feature of science that, when communicated well, can empower citizens to act in the face of risk.

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