Reflections on Climate Change Communication Research and Practice in the Second Decade of the 21st Century: What More Is There to Say?

Susanne C. Moser, Susanne Moser Research & Consulting, Santa Cruz, CA and Woods Institute for the Environment, Stanford University, Palo Alto, CA, USA; email: promundi [at] susannemoser.com

The author has declared no conflicts of interest for this article

Abstract

Appreciable advances have been made in recent years in raising climate change awareness and enhancing support for climate and energy policies. There also has been considerable progress in understanding of how to effectively communicate climate change. This progress raises questions about the future directions of communication research and practice. What more is there to say? Through a selective literature review, focused on contributions since a similar stock-taking exercise in 2010[1], the paper delineates significant advances, emerging trends and topics, and tries to chart critical needs and opportunities going forward. It describes the climate communication landscape midway through the second decade of the 21st century to contextualize the challenges faced by climate change communication as a scientific field. Despite the important progress made on key scientific challenges laid out in 2010, persistent challenges remain (superficial public understanding of climate change, transitioning from awareness and concern to action, communicating in deeply politicized and polarized environments, and dealing with the growing sense of overwhelm and hopelessness). In addition, new challenges and topics have emerged that communication researchers and practitioners now face. The paper reflects on the crucial need to improve the interaction between climate communication research and practice, and calls for dedicated science-practice boundary work focused on climate change communication. A set of new charges to climate communicators and researchers are offered in hopes to move climate change communication to a new place – at once more humble yet also more ambitious than ever before, befitting to the crucial role it could play in the cultural work humanity faces with climate change.

Keywords

Communication science/research, communication practice, progress since 2010, boundary work, role of communication in societal transformation

Introduction

Climate change communication in the second decade of the 21st century is no longer the largely uncharted "wilderness" (or metaphorical "wild West") of 20 years, or even just 10 years, ago. Both the science and practice of communicating the most profound environmental change in human history have progressed considerably in recent years. This change has been brought about by a confluence of forces originating in the climate itself, in climate science, and climate policy and actions, as well as in climate communication science (a shorthand used here to describe the multi-disciplinary research activities underway that contribute to a better social-scientific understanding of the climate communication process) and communication practice, including its supporting communication technologies. From the first three emanate foreboding along with urgency, unrest and upset; from the latter a growing sense of proficiency yet also diversity, dispersion and discontent.

In the aftermath of the 21st Conference of the Parties to the UN Framework Convention on Climate Change in Paris in December 2015 (COP21), this is an opportune time to consider the progress made, and the challenges ahead for communicating climate change. Clearly, since a similar stock-taking review during *WIREs-Climate Change*'s first year of existence[1], much has happened in our field. Appreciable advancements in climate change awareness and majority support for climate and clean energy policies, as well as appreciable advances in our understanding of how best to communicate climate change, may make one wonder what more there is to say about climate change, including about how to communicate it. Is it not simply time for action now? This paper considers these questions not through an all-encompassing literature review, but through a delineation of trends, a critical sifting of claims, and a prospective outlook so as to offer another road marker and to chart priority needs and opportunities going forward.

If metaphorically climate change communication has left behind the "wild West" stage of its early beginnings, one might view its current state more like a "working landscape," bearing the clear signs of domestication. It is this metaphorical comparison that guides the structure of this paper. The section immediately below launches from a description of the "landscape" midway through the second decade of the 21st century in which climate communication occurs. This sets the context for the challenges faced by climate change communication as a "field." I will discuss the progress made on key scientific challenges laid out in my 2010 review paper [1], but also offer a critical assessment of persistent and newly emerging communication challenges that both researchers and practitioners now face. The paper then turns to a challenge not addressed in 2010, namely the need for improved bi-directional flow of insights and influence between communication science and practice, i.e. better interactions across the science/practice interface (the metaphorical "fence" or, rather, fences). The paper concludes with a set of new charges to climate communicators and researchers, proposing areas of "work" that could move climate change communication to a new place – at once more humble yet also more ambitious than ever before, befitting to the crucial role it could play in the cultural work humanity faces with climate change.

The Landscape

Over the past five years, critical opportunities to communicate climate change have abounded. These opportunities have emerged from a landscape, which is shaped by profoundly influential forces, some incremental, others extreme and novel. One may group these defining forces into six categories.

First, there is the climate itself, regularly giving opportunity to talk about climate disruption and climate change. The last few years have given us repeatedly notable climatic extremes such as Superstorm Sandy (2012) or Typhoon Haiyan (2013), and the extreme-heat events in India (2015), each contributing to crop failures, extensive infrastructure damage and tragic loss of life. In some instances it was the unprecedented nature of these extremes that stood out; in others it was the crossing of (anticipated and arbitrary, albeit symbolic) thresholds in the context of accelerating trends that mattered: passing the 400 ppm CO_2 concentration threshold, 2015 being the sad "winner" to date in the long sequence of annual average temperature records yet to come, the collapse of significant segments of Greenland and Antarctic ice sheets, or the crossing of the half-way point on our seemingly inexorable path to the much debated 2°C warming threshold.

Closely related, of course, is the second category of forces shaping the climate communication landscape, made up of regular incremental scientific advances, notable discoveries, as well as landmark climate change assessments. Over the past few years, the Intergovernmental Panel on Climate Change (IPCC) released its fifth comprehensive assessment[2], and the US released its third in 2014[3] with extensive

outreach efforts and media coverage[4]. Astonishingly, much less press fanfare followed the 2015 update to the "planetary boundaries" paper[5], testifying that the world had crossed four planetary boundaries and moved into the high-risk zone for three of the nine boundaries that shape humanity's "safe operating space." Not surprisingly, scientists are now asking, how to communicate the increasingly urgent, "bad" and "unwelcome" messages to a seemingly indifferent public[6].

Thirdly, climate policies and actions have exerted and demanded their own influence on climate communication. Events such as the annual international meetings of policy-makers to work toward and now beyond the critical COP21 meeting. While news coverage of COP21 was more extensive in Europe than in the US, bilateral agreements as well as unilateral, voluntary commitments by industry, investors, municipal and state governments to significantly reduce emissions gave more localized attention, yet played influential roles in the lead-up to Paris. The concurrent growth of an increasingly unified and visible climate protection movement, frequently wedded to the call for climate justice, with coordinated events and direct actions around the globe and key victories such as the defeat of the Keystone XL pipeline under pressure from Canadian and US activists and the growing divestment from fossil fuel garnered widespread public attention.

For climate communicators and the practitioners who support them, collectively constituting the fourth set of influences on the climate communication landscape, these events and processes were occasion to practice an effective craft, trying on different frames, venues and tools, using not just traditional but increasingly social media, directing their attention to different audiences while relying on a wider range of messengers to move the needle on public opinion. Maybe the most incisive communication moment occurred in 2015, when Pope Francis released his much anticipated encyclical on the human-Earth relationship with its particular focus on climate change[7], accentuating the cultural and moral turn in communication practice witnessed over the past five years. All these occasions provided ample opportunities around the world for people to learn more (or maybe for the first time) about climate change and as a result form, change, or reinforce their views and attitudes towards it.

An influential fifth force in the landscape is climate communication science as a multidisciplinary branch of academic research in its own right. While the next section will go into greater detail on its advances over the past few years, suffice it to say here that it has used the rich palette of opportunities presented above to study publics, messengers, and communication practices. The shear growth of the number of studies over the last 10 years, and particularly over the past five (Figure 1), as well as the establishment of dedicated research clusters, and the spread of climate communication research to previously neglected regions and countries of the world (e.g., Refs. 8-11 are indicative of the growth of the field). As a result there are now longitudinal and comparative studies of changes in public perceptions, understanding and opinions (e.g., Refs. 12-14); and a deepening understanding of different audiences (e.g., Refs. 15-17) and subtopics (e.g., the use of visual imagery, emotional responses to climate change, the role of particular types of media or messengers, all discussed in more detail below). Given this plentitude of climate communication research, a growing number of review articles on communication topics have appeared (with review journals like *WIREs-Climate Change* being a leading source, as well as encyclopedic academic volumes[18-20] and more widely accessible, integrative books[21, 22]. Methodologically, the field has become more diverse and theoretically more contested (e.g., Refs. 23-27), all together marking the firm academic establishment, increasing sophistication and professionalization of climate communication research.

[insert Figure 1 about here]

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The final set of influential factors on climate communication – as is the case for any topic – is comprised of those things which one might consider contextual, foundational, often unrelated, or distracting. Some are unique to the past few years, some are enduring, such as the political culture of a nation (e.g., public sentiment vis-à-vis the role of science or government, the degree of democratic culture, social norms); electoral turn-over (as recently occurred in Australia or Canada opening the door to climate action) or political destabilizations; politically or publicly consuming events such as heightened terrorism fears, pandemics (e.g., Ebola), or the ongoing refugee crisis in the Middle East and Europe; as well as larger economic, technological or cultural shifts and events in specific industries, nations, or regions of the world. Together, these interactive factors have created at times more or less hospitable environments for climate communication, variably succeeding in penetrating the perpetual news buzz and limited attention spans of early 21st century audiences[28].

The reason for describing this landscape at some length is, firstly, to contextualize and recall the *opportunities for* climate communication. This is not to simply itemize events, but to bring into consciousness the momentousness of what is actually occurring (but which we may not realize due to being immersed in and acclimatized to it): the crossing of symbolic thresholds and real-world tipping points, the unprecedented political feat of bringing nearly 200 nations together in an agreement to act on climate change while simultaneously acknowledging that agreement's inadequate ambition, notable omissions, and unconscionable evasions of responsibility. A second reason for painting this picture is to recognize that this landscape is an arena of interactions among forceful *influences on* climate communication. And a final, challenging reason is to ask: what evidence is there to say whether, how much, and precisely *in what ways climate communication itself has influenced and shaped this landscape*? This points to an oft-demanded, and rarely fulfilled request to evaluate communication's impact on an observed social or policy changes (in recent years, see, e.g., Refs. 29, 30). Answering this call – however challenging in any multi-factorial complex situation – constitutes one of the most important prospects for growth and advancement, and – if not met – may be the single most significant missed opportunity for climate communication research.

The Field

Let us turn our attention then to climate communication as a field of study. In 2010, I described the status of that field as follows: "Climate change communication—after years of practice without a solid foundation of research—is now of keen interest to those interested in increasing public engagement, and is emerging as a field of research in its own right" (Ref. 1, p.43). At the time, opinion polling and tracking of climate media coverage was already well established, while detailed insights into other aspects of the communication process, its elements, and impacts on different audiences were far less well developed. Hypotheses and untested assumptions abounded and often borrowed from other areas of science and risk communication. Five years hence, how has that situation changed? Have researchers advanced our understanding of the particular challenges put forth in that review?

Characterizing the Current Field

As Figure 1 above illustrates, the shear productivity of the field has increased dramatically, reflecting that climate communication no longer has to rely on relevant but untested work from neighboring fields, but has its own and growing cadre of experts now researching the vexing challenges of effective climate communication. A closer look at the data underlying Figure 1 reveals that this research is reported in a large number of journals. Table 1 lists the top peer-reviewed outlets for climate communication research over the 2005-15 period, suggesting at least three important observations:

(1) Climate communication research is *highly distributed across sectors and disciplines*: the top five outlets for climate communication research capture not even 20% of all published research, while the

top 18 represent not quite 35%, with the far greater majority of articles appearing in widely spread academic outlets (in all, in more than 400 journals!);

(2) Climate communication research *varies in academic visibility*, appearing in low- to high-impact journals: 11 out of the 18 top outlets have impact factors (in 2014/15) <3.000 (relatively speaking, a lower impact factor), but four have impact factors >3.000 (medium) and three >5.000 (high impact); and

(3) Climate communication research is *highly interdisciplinary*: it cannot be solely characterized as a subfield of communication (only three of the top 18 outlets are principally communication journals); nor is it merely a subfield of climate change research although several of the leading outlets are interdisciplinary climate journals (e.g., *Climatic Change, WIREs-Climate Change and Nature Climate Change*).

[insert Table 1 near here]

Arguably, this is as it should be. Because climate change affects everything and everyone everywhere, effective communication about it should involve and reach across disciplinary, sectoral and geographic boundaries, aiming to reach colleagues wherever they work. Speaking to those diverse interests and spheres of application may be more influential on choice of outlets than academic impact; and as an integrative human activity in a highly contested communications milieu, climate communication simply defies traditional, albeit artificial disciplinary divisions.

As a result, no one "owns" climate communication research," or maybe more accurately, everyone does, which entails both dangers and benefits. Everyone needs it, everyone contributes to it, yet it is difficult to gain disciplinary prestige with it and nearly impossible to keep up with the often highly relevant but impossibly wide distribution of scholarship. This situation makes review journals like *WIREs-Climate Change* indispensable to keep track of any number of subtopics, but even those reviews are so plentiful now that even "renaissance scholars" would find it difficult to keep up with and integrate across them. Not surprisingly, innovative approaches are now emerging to organize and make relevant scholarship more accessible (see The Climate Web at: http://climatographer.com/climate-web/).

Progress on Core Climate Change Communication Concerns since 2010
Beyond this broad characterization, what substantive advances have climate communication researchers made since 2010? Below, I highlight contributions in the six challenge areas outlined in that review article (Ref. 1, pp.43-44).

Key elements of the communication process
Effective communication requires detailed understanding of one's audience, and researchers have spent considerable time better understanding different audience types and segments within and across national, sectoral, and age samples. Some of this work has been experimental (e.g., exploring changes in perceptions, understanding and attitudes upon a controlled intervention), while other studies have used (singularly or in combination) the more common survey, interview or focus group approaches[12, 13, 31-41].

Out of this context, the role of values, beliefs, worldviews, identity and meaning-making has become one of the most prominent occupations of climate communication researchers[24, 42-47]. Among the critical takeaways from this body of work is that, first, we all hear, perceive, make sense of and judge incoming information (be it spoken, written, visual or sensory) through the filters of culturally transmitted values and *no one* can escape this influence although we can become conscious of this influence and actively probe it, if we are willing. Second, the values we hold affect not only our perceptions and interpretations

of the climate and our acceptability of climate science, but – crucially, and often more prominently – the acceptability of anticipated or proposed behavioral changes, technological solutions or climate policies. Third, and logically following, climate communication meets acceptance or resistance and thus can be made more resonant for different audiences by approaching it through value frames[48-52]. Not surprisingly, this focus on values has spawned considerable attention to framing, messaging and language[53-70], and as part of framing and messaging, the question of effectiveness of different messengers[66, 71-74].

Beyond the written or spoken word itself, climate communication researchers have concerned themselves increasingly with a wide range of communication aids. Given the difficulty of seeing and representing the causes of climate change, as well as the climate itself and changes in it, the role of visualizations and the use of imagery have become prominent topics of exploration[75-87]. Integrating insights on the difficulties of understanding climate change, on language, imagery, and the imaginal, communication experts now point increasingly to the importance of story-telling and using narrative formats to convey climate change[88-94]. Others have investigated gaming and other interactive tools to make climate change and an otherwise abstract and difficult to imagine future more accessible both for lay audiences of all ages as well as in professional planning and decision-making contexts[80, 95-97].

These various lines of research have come together in, and inevitably brought greater attention to, the role of emotions in climate change communication. This greater focus on the affective and emotional (as opposed to just the cognitive) side of climate change is partly driven by the irrational-seeming lack of concern about the problem and persistent psychological distancing[98-103], partly by the often intense emotional reactance to climate change (and its messengers) by those who do not "believe" in climate change[104, 105], and partly by the increasingly observed sense of despair and hopelessness among those who understand the science and experience early impacts and/or the lack of commensurate action[59, 106-108]. Some researchers emphasize that emotions play a critical role in decision-making[109], while others recognize their importance in issue acceptance, motivation or resistance to action and policy-support or opposition[27, 110-115], and in health and well-being[116-120]. Maybe not yet as fully appreciated as it might be, this growing body of research illustrates the mutually constitutive nature of the psychic, social and cultural realms[110, 121, 122].

Communication channels and forms
On the second set of research challenges posed in 2010, a steady flow of studies has emerged on the question of communication channels and forms. This reflects, of course, their crucial importance for the communication process itself, but also because of the paramount importance of the media in conveying, translating, interpreting and giving meaning and importance – or not – to the complex scientific and policy aspects of climate change. At the same time, the media landscape is itself undergoing profound changes, both political-economically and technologically, thus affecting what, how, how often, and at what level of proficiency climate news is being reported and discussed [123-127].

The growing proliferation of studies empirically and critically examining media coverage of climate change, new scientific discoveries or specific policy events, as well as climate-related topics (such as energy supplies) in traditionally well-studied countries clearly has continued since 2010 (e.g., Refs. 128, 129). What is new, refreshing and beginning to fill a significant gap in the literature, are media studies for heretofore neglected areas of the world (e.g., Refs 130-134) as well as cross-national, comparative studies[83, 135-137]. What is maybe as significant as this broader survey of world climate news coverage is the implied fact that such coverage now actually exists.

A number of researchers have offered reviews and in-depth examinations of the role of traditional and/vs. newer social media[138-144], illustrating clearly how the communication landscape – not just for climate change – is in flux and being transformed. This suggests that traditional, single-media focused communication approaches are, if not necessarily a thing of the past, clearly losing their dependable impact on public audiences, given the far more fragmented, but also more diverse set of communication channels available. The tension between climate change as a scientifically, politically, socioeconomically and culturally complex phenomenon often requiring expert communication and interpretation on the one hand and a media landscape that is in the hands of the variably educated, motivated and ideologically leaning many on the other, however, could not be starker[145]. The situation poses extraordinary challenges for those wishing to communicate, as well as for those who must discern which communication channels to trust and which to pay attention to[146]. It also poses new challenges to communication research in that the once heuristically defensible approach to understanding shifts in public opinion by studying news media coverage with its assumed opinion-shaping influence is now proving insufficient. Clearly, there has been a shift from viewing media mainly as news sources, leading influencers, and crucial fora for public debate toward seeing them increasingly as political actors in their own right, as public extensions of deep social divisions, and as echo chambers for opinions in a profoundly political, politicized, and polarized debate[147-149]. Nonetheless, some researchers see positive opportunities afforded by the range of media channels, taking them as imperative to make more effective use and to integrate media research into transdisciplinary climate research[150].

Another body of relevant climate communication research here is focused on specialized forms of communication, ranging from critical reviews of how major reports such as the IPCC assessments serve communication[69, 132, 151-154], to examinations of climate change in films[155, 156], to explorations of the relatively new sub-genre of sci-fi embellishing predominately dystopian climate futures ("cli-fi")[139]. Similar reviews and critical examinations of the impact of such cultural expressions as climate change music, poetry, photography, fiction, cartoons, sculpture, and theater are only beginning to emerge (exemplary contributions are found in Ref. 19).

Communicating mitigation and adaptation
If early climate communication was largely focused on awareness raising and explaining the science of climate change (assuming that knowledge alone would suffice to move people to action), the challenge that has become apparent long since is how best to move audiences to action. This has resulted in considerable research into human motivation and capacities[43, 113, 157, 158], and also in what distracts from it[159, 160], with a persistent focus on uncertainty, and whether, when, and how best to communicate it[30, 35, 97, 151, 152, 161-164].

What has surfaced clearly from this body of work, is that the need for explaining and educating has not diminished[165], but that knowledge itself is insufficiently motivating to take action, and that it is far from clear to even the most motivated people what actions to take[166]. Thus, a shift toward enabling and empowering action has followed[73, 113, 167, 168]. It is now widely recognized that actions and practical support must be a central part of all climate communication, not necessarily in a prescriptive fashion, but options should be discussed and audiences must see and feel empowered to choose viable options.

Along with this recognition has come a growing focus in practice and research on how best to communicate mitigation and adaptation. Where and how much to focus one's communication, however, and how soon to pivot from science to policy, from impacts to responses, from urgency to action, from explaining to mobilizing remain critical concerns. Along with these has come the question how best to balance talk about mitigation versus adaptation, as many have argued that raising the specter of

adaptation is all but an admission of failure on mitigation (for a review of pertinent literature and a refute of that argument, see Ref. 169 and newer work in Ref. 170).

From a communication research perspective, the novelty since 2010 is that there is a body of research at all that examines the communication of specific mitigation options[159, 171-173] and another researching the communication of adaptation[169, 174, 175].

Mass mobilization
The role of communication specifically in mass mobilization and the climate movement has remained relatively neglected over the past five years. Of course, communication research into motivation and mobilization of individuals or groups of individuals has progressed (as discussed above), as has a separate body of work on the strengthening climate movement, but the link between these two has been weak.

The most directly applicable work is that on framing and the multitude of values that can motivate people to action (cited above), the extensive work – overlapping with behavior change research – on social marketing (e.g., Refs. 176, 177), and the recognition that the climate movement – if it is to become a bigger, more powerful movement – must reach beyond the narrowly defined "environmental," connect to other social movements, and embrace, integrate and collaborate (not subsume!) those whose work focuses on sustainability more broadly, but also the many others who work on social justice (regarding race, gender, North-South relations, etc.), labor rights, economic opportunities and justice, and re-enfranchisement of those long excluded from the political process[64, 178-181].

Maybe driven by the persistent obfuscation of climate policy and action in conservative corners of the US, and in particular in the US Congress, far greater energy has been focused on the climate counter-movement, including the politicized environment for climate science communication, and particularly the – by now – entrenched polarization around climate change (in the US more than in any other country). In many instances this polarization has hindered progress on climate action even though climate disruptions are increasingly prevalent[104, 182-186]. In addition to better understanding underlying drivers, political economies and structural underpinnings, maybe the most important and encouraging insight gained from this work is that it is far from impossible to connect across deep cultural and ideological differences[158, 182, 187,188], though the communication needed to achieve it will not come via the more common, traditional messages, forms, channels and messengers. Thoughtful, respectful, and deliberative communication practices must be fostered[189].

Dialogic forms of communication
Pearce and colleagues[138], in a review of the recent literature, discerned a crucial shift from deficit-model driven unidirectional communication to dialogic communication over the past five years. Given the observed superficial understanding of climate change, lack of apparent concern and pro-environmental engagement, and paralyzing polarization, this is maybe more important on climate change than any other contemporary risk, but prevalent political cultures may be more or less receptive to dialogue and deliberation.

A growing number of studies is available illustrating how dialogic, deliberative processes can open minds, deepen understanding, foster empathy, change attitudes, and increase receptivity to policy alternatives whereas not nearly as much impact could be achieved by simply transmitting information[187,188,190-192]. Review papers of a broader set of studies (not all from the climate change context) give reason for optimism[25, 178, 189], but much remains to be learned, e.g., exactly which social, psychological and cognitive processes are involved and how they interact, in causing the observed shifts in dialogue.

Long-term and deeper engagement

Despite a clear recognition in the scientific community how far-reaching and long-lasting human-driven climate change will be, despite the emerging literature on communicating climate adaptation, and the observation – and sometimes lament – of climate change issue fatigue, few have begun to grapple seriously with what it means to communicate, deal with, and engage publics around an issue – practically – forever. A Special Issue of *Ecopsychology* (December 2015, Vol. 7, Iss. 4), entitled after Howard Kunstler's "The Long Emergency" stands as the exception to this more common observation. Similarly, a Special Issue of the *Journal for Sustainability Education* (November 2015, Vol. 10) on "Hope and Agency in Sustainability Education" speaks loudly to the call for help with sustained engagement on complex and often depressing issues like climate change, especially with youth.

Most of the papers included in these collections issue passionate calls for long-term and deeper engagement. Very little well-established scientific support is available as yet, however, on how to sustain lengthy engagement or reinvigorate it after lapsing, and how to deepen it (beyond the use of dialogic formats). Little is known about how the increasing use of war metaphors (*combating* climate change, *fighting* for climate justice, engaging in culture *wars*), apocalyptic imagery and narratives, and the pervasive negative labeling of one another help or hinder long-term communication[104, 178, 193-196]. It is notable, however, that researchers are increasingly interested in the role of hope, optimism and positive emotions in climate communication[17, 27, 113, 197, 198].

Clearly, there are many areas in which our understanding could be advanced, which will pragmatically, require that we employ not only the commonly used research methodologies (survey snapshots, one-time focus groups, or interviews), but also longitudinal studies of cohorts engaged repeatedly over many years, and comparative work with long-term non-climate struggles. More fundamentally, however, climate communication practice and research must grapple with the question what communication for the very long-haul entails, and what its function might be. A first attempt of grappling with this question was offered in Ref. 118, but more intensive, deliberate engagement with the humanities and arts, and with the broader literature on social transformations offer yet-to-be-explored opportunities to redefine the role and purpose of climate communication in the future[199-203].

Emerging Trends, New Topics and Persistent Challenges in Climate Change Communication

Given the richness of climate communication research on so many aspects, it is difficult to discern clear trajectories for the field as a whole. While several distinct research gaps have already been mentioned above, my suggestions here are as much influenced by personal interests as by the US context in which I work.

Looking across the landscape and advances in our field, five cross-cutting, welcome and fruitful trends stand out. Firstly, climate communication research has benefited greatly from greater interdisciplinarity and integrative research evident in many of the studies and review papers cited so far. Secondly, many of the advances observed have come about from the increasing methodological sophistication and diversification in recent years, including the growing recognition of the importance and value of participatory and in-depth qualitative research. Thirdly, the emphasis on values, belief systems, and worldviews has helped bring culture back from its exiled relevance supposedly only to marginalized "traditional cultures" to its irrefutable centrality in all societies. This was aided, fourthly, by the growing number of studies emerging from Western/Westernized countries previously less well studied, and from non-Western/Global South countries, where climate communication research is still new. Finally, and not unrelated to these trends, is the growing attention now given – in practice and research – to insights

from the humanities and the role of the arts in communicating and engaging the public on climate change.

Along the way, new topics and needs have been emerging, and they will continue to occupy researchers for years to come, including the needs and ways of communicating different types of climate mitigation/energy solutions (e.g., renewables, carbon capture and storage, nuclear energy) [173, 204, 205], adaptation options in different sectors [169, 206], as well as the specter of the yet more complex and challenging issue of geoengineering [207-214].

Meanwhile, persistent challenges plague practitioners and provide ample opportunity for further advancement. Most likely, they can only be achieved through integrative science and connecting insights across each of the issue areas listed above. For example, further work is needed on the stubborn superficiality of climate change understanding in the general public, on how to move publics from mere awareness, concern and understanding to active engagement, on how to communicate effectively in a deeply politicized and polarized environment, and on how to deal with the growing sense of overwhelm and hopelessness observed among many audiences.

First attempts at such science-based, practice-oriented integration have recently been offered, and they deserve widespread attention[21, 22]. Their contributions are many, but among the most important may be that they lay bare the intra-psychic, inter-personal, social, cultural and political-economic dynamics that shape people's responses to climate change. In so doing, these authors have brought crucial attention to the ways in which social norms and psychological defenses perpetuate a remarkable "climate silence" in society. But they also help counter the demonization of just one particularly obstinate segment of humanity – the "deniers" and "contrarians." Outright efforts in public deception aside, they show instead how we all, even the constructively engaged, have various defenses against a threat that is existential to some, deeply disturbing to emotional equanimity in others, and profoundly challenging to the identities of many more. Table 2 is an attempt to synthesize (in even more compressed form) what is scientifically known about the defenses climate communicators have to contend with, and in fact often inadvertently trigger. The naming of the defenses listed here is based on Ref. 22, but their explanation, how they are triggered, and how they might be overcome also draws heavily on Refs. 21, 215.

[Insert Table 2 about here]

Given the proliferation of research across many disciplines, outlets, and research centers, such integrative syntheses are extremely helpful to meet the growing and changing needs of communicators. Yet there is a significant challenge in conducting thorough reviews and integrating – often seemingly contradictory or partial – insights from various subfields while not succumbing to offering simplistic guidance. If climate communication research wants to be more than an academic field of study, it must take on the lessons from its own research (and from its close neighbors in STS studies) and engage with communication practitioners more effectively than is currently practiced.

The Fence

The Communication Science–Practice Gap
Of course, the world of climate communication practice is not sharply separated from the world of climate communication research. Many of the researchers cited here also engage the public on climate change, be it via op-eds, blogs, social media platforms like Facebook and Twitter, public speeches,

dialogue events, or otherwise. Many focus on communicating climate change, and some serve as models for how to do so effectively; fewer, however, seem to be engaged in sharing with practitioners their social scientific insights on how to communicate climate change most effectively.

Granted, there exists to my knowledge no systematic study that has surveyed how many and how often climate communication researchers share their insights with those who spend their days practicing the trade. Thus, the science-practice gap in climate communication and the many different shapes it takes ("fences" rather than a single "fence") is somewhat speculative, may vary across nations, and constitutes an area ripe for study itself. There are reasons to believe, however, that relatively few communication researchers – some prominent individuals excepted –actively, frequently, or on a sustained basis interact with those who do the lion share of climate communication. Academics typically are not rewarded for such outreach, i.e., for sharing their findings in non-academic outlets; it is time-consuming to do; researchers are not trained to do so effectively, and given the often polarized atmosphere around climate change, many shy away from it. Clearly, there are some encouraging signs – such as research programs encouraging engagement with societal partners (not just as research subjects, but as co-designers and co-producers of research) and funding requirements to demonstrate "societal benefit." However, the landscape of incentives and capacity building efforts to assist researchers to engage beyond academia is highly varied and far from what it might be.

Meanwhile few practitioners have the time, inclination or access to read social science journals and keep up with the ever increasing output from researchers in climate communication. This is even more difficult in an interdisciplinary field such as climate communication, where research is presented across a wide spread of disciplinary social science or interdisciplinary journals and books (see Table 1). The still dominant, narrow disciplinary studies reinforce partial and disjointed treatment of what is in reality a holistic communication challenge. Non-experts may not find it easy to put the latest findings into a larger, integrative picture of communication. Moreover, academic publications are typically jargon-laden, and frequently do not offer recommendations for how to use the findings in practice. And even if some are offered, they are often too general for application in specific contexts. Thus, it is not surprising (if only anecdotal at this time), when communicators admit that they hear about and are interested in relevant social science research (in particular polling data) but don't know "what it means" or "how to translate these scientific insights into real-world communication strategies." Kahan's (2014) provocative essay [216], "Making climate-science communication evidence-based," should be read against that backdrop. He states: "mere familiarity with the science of science communication is not sufficient. For genuine progress to be made, it is necessary for [scientists, government officials and advocacy groups] to proceed scientifically in making *use* of such knowledge" (pp.203-204).

This challenge is far from unique to communication science, but it is singled out here as a challenge to our field, which is in large part motivated by the claim that "perception, behavior, and communication are central to addressing climate change" (Ref. 217, p.703). If communication researchers want climate communication to be as effective and impactful as it could be, their work must connect more effectively with those who do most of the talking (climate scientists, policy-makers, advocates in all sectors of society, journalists, editors, public intellectuals). Differently put, simply putting social science findings "out there" and assuming they will find their way into practice, is as ineffective in communication science as it is in climate science[218]. In fact, drawing on insights from experts in transdisciplinarity and STS, communication researchers have to actively help make that connection happen[219].

Boundary Crossings: Examples of Communication Science–Practice Interaction

Do we see such active engagement between communication researchers and practitioners? The science-practice gap just described notwithstanding, the reality is not entirely bleak. Traditional forms of interaction via "science translators" and more recently emerging, innovative instances of exchange between communication researchers and practitioners exist. The latter – as a newer facet of the climate communication landscape – is promising indeed, though is not yet at scale.

Traditional links between communication expertise and those who want it
Advocates more than any other group of climate communicators have traditionally relied on communication consultants and media firms to help with their outreach and campaigns. Such work has assisted strategic communication and involved opinion surveys, message testing, targeted framing research, etc. Often, such applied work-for-hire is not accompanied by a comprehensive review of the latest relevant communication science, and typically is proprietary, thus not widely available or broadly shared. But due to the rapid turn-around, context-specificity, and strategic orientation, such work can be more responsive than academic research to practitioner needs.

Another traditional form of improving climate communication has been to "outsource" that task from researchers to professional science communicators or translators, e.g., extension agents, outreach specialists, educators, professional editors, or journalists. While this approach has the potential to improve the communication of climate science, no systematic study to my knowledge has tested whether such intermediaries actually put the latest insights from climate communication research to use. Based on more than a dozen communication trainings personally offered to professional communicators who had basic training in science education or science communication, but no specific training in climate change communication, even this group makes little use of the existing social scientific literature. Thus, there is a cohort of willing and well-positioned professionals whose effectiveness may be significantly enhanced through dedicated training or professional development.

Novel climate communication resources
An important development over the past five or so years is the emergence of climate communication resources intended to better equip communicators with requisite background and guidelines. Most of these are online and freely available. Table 3 lists these, suggesting that most are either resource hubs or research-based entities that make their findings more widely available. Fewer provide hands-on trainings in communication, and even fewer are true collaboratives in which researchers and practitioners interact directly (the Climate Advocacy Lab may be one of the best examples for that).

[Insert Table 3 about here]

Only English-language resources are included in Table 3 because of linguistic limitations of the author (no comparable resources were found in French or German), thus the listing includes predominantly European and American sites. That limitation notwithstanding, it may be telling that such resources dominate in the Anglo-Saxon world, where resistance to climate action, politicization of climate science, and polarization have been stronger than elsewhere. Recent findings on the widespread lack of awareness and understanding of climate change, and frequently religious explanations of observed changes in large portions of the world[12, 14, 34, 220], however, point to the need to strengthen climate change communication everywhere, albeit heeding unique needs in different contexts.

Meeting the Communication Science-Practice Interaction Needs
As Corner and colleagues argue[221], in order to advance improved climate communication, more than better communication practice, more than interdisciplinary research, resource hubs and dedicated

research centers offering their wares in a "loading dock" fashion are needed[222]. They call for novel institutions that can accommodate the normative tensions between science and action, between scientific practice and the inherently political nature of deliberating climate change in the public sphere. In parallel there are calls for the establishment of boundary organizations in any number of spheres that can improve the link between science and practice (e.g., Refs. 222-224). In linking these two strands of thought, I would argue for boundary institutions dedicated to the improved exchange between climate communication researchers and communication practitioners, and in many instances involving a third party: the intended audiences.

The purpose of such entities would be to increase mutual understanding of communication needs, situations, and complexities on the one hand, and multi-disciplinary research, methods, and approaches on the other; to improve the translation of social science research findings and provide fora for jointly exploring the meanings and implications of those findings. Such boundary organizations for climate communication should also offer trainings so as to help meet the growing capacity needs for effective communication and engagement[206]. This will aid in the accelerated uptake of communication research in communication practice and help researchers realize just how large the distance is between their findings and real-world application, fostering more relevant, integrative communication science in turn.

As in any other context, there are few institutionalized incentives and resources for academics and practitioners to engage directly with each other, much less to do so on a sustained basis (the emerging signs of a changing landscape of incentives notwithstanding). On the rising wave of calls for greater transdisciplinarity, the growing need for more, different and more effective communication, and for demonstrating such effectiveness to funders, however, boundary entities dedicated to climate communication would enable sustained interaction and constitute a mechanism – proven in many other contexts – to positively affect both the climate communication field and the broader landscape in desirable ways in the years to come.

The Work

The review of the climate communication landscape, field, and the "fences" (interfaces) between communication research and practice offered here leads to one clear answer: despite appreciable progress made, there is, indeed, more to say. The security implied in this affirmation should not, however, bestow on us a sense that what more is needed is more of the same. Far from it. Rather, the challenges for communication researchers and practitioners going forward are more difficult in a landscape already and continuously shaped and modified by powerful forces, in a field of study that has been plowed and sowed in this direction and that, and where careful work is needed now to harvest that which is fruitful, and to thresh the seed from the chaff. In the meantime, the fences between worldviews and ideologies, between disciplines and subfields, between research and practice, need deliberate and careful tending, maybe to better understand them, to bring them down entirely, or to exchange and interact more effectively across them. Much of this work goes against social instincts, ideological preferences, professional norms, institutional incentives, time and the tide of proliferating information that threaten to overwhelm us all.

The challenges before us then may be grouped into four rubrics:
- *What topics and questions should we focus on?* – This review identified a range of opportunities for topical advances over the next 5-10 years. Among the questions calling for intensified research and practical experimentation are: how to communicate in a much more diverse and fragmented media landscape and in highly polarized environments; what roles varied cultural expressions such as music, poetry, and theater play in communication and engagement around

climate change; how to move publics from mere awareness, concern and understanding to action; how the social, psychological and cognitive processes involved in dialogue interact to cause observed shifts in attitudes and opinion; how to sustain long-term communication and engagement; how to communicate climate mitigation, adaptation, and geoengineering; and how to deal with overwhelm and hopelessness as climate change accelerates, causing increasingly severe disruptions and destabilization.

- *How should we work together?* – Building on the growing interdisciplinarity and methodological and theoretical diversity, maybe the most challenging, yet more fruitful avenue going forward lies in greater transdisciplinarity. Particularly for a field aiming to have practical relevance, engaging across the communication science/practice interface in informal and formal (boundary organization-based) ways, holds great promise for greater relevance and applicability of our research and for accelerated uptake of findings in practice.

- *How will we know and demonstrate our impact?* – Both climate communication research and practice have failed to date to routinely track, critically evaluate, and thus demonstrate their impact on the broader communication landscape. This is clearly not easy to do, but it misses a critical strategic opportunity to focus research and to improve practice more quickly and deliberately. Maybe instead of focusing so much on how deep-pocketed interests have succeeded in achieving public confusion, apathy and political stalemate, it is now time to focus on showing how our field's many valuable insights can be employed systematically and fruitfully in loosening entrenched positions, mobilizing people across the political spectrum, and engage them productively in building a livable future.

- *What role could or should communication play in a profoundly, rapidly changing world?* – The question of impact raises the far more foundational issue of what function climate communication could or should serve in a world that will rapidly, profoundly, often tragically, and sometimes surprisingly change in the years and decades ahead. Climate communication research has never been motivated merely by being a distant and disinterested observer, or trying to understand and explain a complex societal phenomenon. As a field it has covered the waterfront from the most basic to use-inspired fundamental to applied research. But does the desire to be useful and impactful in the broader climate communication landscape not push us even further? Does our own research not tell us that science alone, climate alone, policy alone will not address the deep human needs in the unfolding Anthropocene? Does the magnitude of change underway not demand more? Far beyond the descriptive, prospective, retrospective/reflective, and prescriptive, climate communication is increasingly asked to be narrative, interpretive, and even contemplative[117, 225]. Enabling, mirroring, and facilitating what may be the largest social transformation in human history would seem far more demanding a role than we have been willing to take on to date. Doing so would change our topics, foci, approaches and partners in both research and practice. It is time to contemplate these deeper questions now, and challenge ourselves to consider what that transformational journey may ask of us in terms of competencies, resources, institutional support, and interaction with each other.

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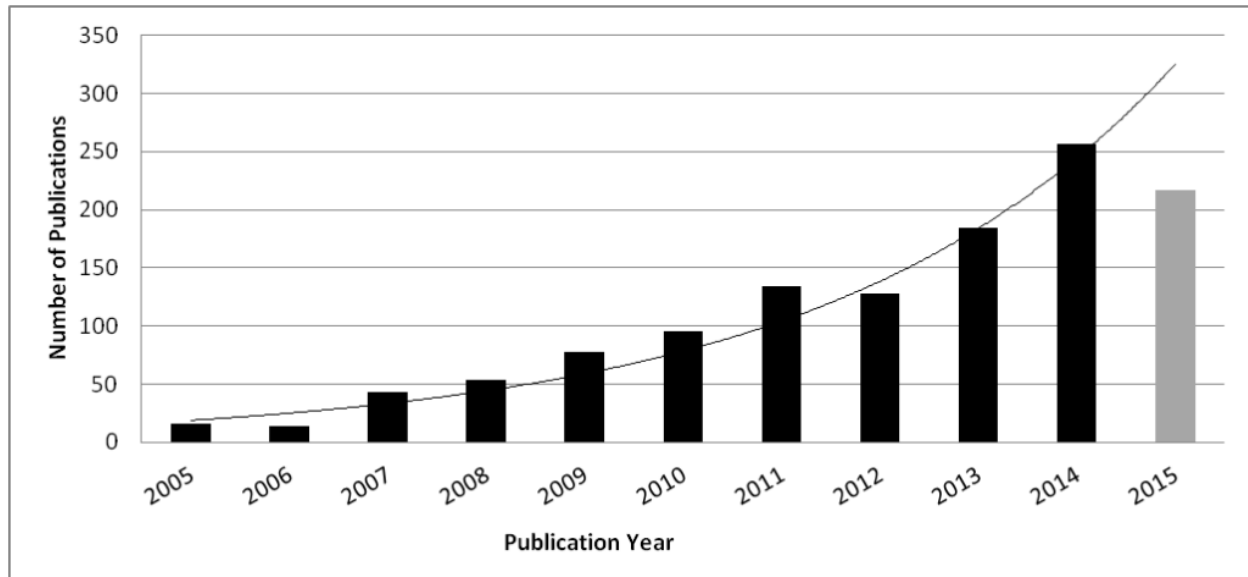
Figure

Figure 1: The Steady Rise in the Number of Publications on Climate Change Communication from 2005 to 2015, based on a Web of Science Search*
* See Supplementary Material 1 for methodological details. Data for 2015 (in grey) are incomplete.

Tables

Table 1: Leading Publication Outlets for Climate Change Communication

Rank (by # of papers)	Journal	Impact factor† (2014/15)	# of Papers on climate communication (2005-15)*	
			Total‡	% of N
1	Climatic Change	3.430	60	4.9
2	Environmental Communication	0.817	51	4.2
3	Global Environmental Change	5.089	47	3.9
4	Science Communication	1.517	35	2.9
5	WIREs-Climate Change	3.415	33	2.7
6	Risk Analysis	2.502	27	2.2
7	Public Understanding of Science	1.766	26	2.1
8	Journal of Risk Research	0.935	18	1.5
9	Energy Policy	2.575	17	1.4
10	Environmental Science & Policy	3.018	16	1.3
11	Journal of Environmental Psychology	2.640	15	1.2
12	PNAS	9.674	14	1.1
13	Regional Environmental Change	2.628	13	1.1
14	Weather, Climate & Society	1.696	13	1.1
15	Ecological Economics	2.720	11	0.9
16	Nature Climate Change	14.547	11	0.9
17	Bulletin of The Atomic Scientist	0.690	11	0.9
18	PLOS One	3.234	10	0.8

N=1,220

* - While all available data were included for 2005-2015 (see text), there is a delay in records being entered into Web of Science, thus the reported total for 2015 that is likely too small, and the total N likely larger for the 10-year range.

† - Impact factors collected from http://www.bioxbio.com/if/

‡ - Only those journals are listed which had at least 10 articles (on average 1/year) over the 10 year period examined.

Table 2: Psychological defenses and how communication can trigger or help overcome them

Defenses	Activation through pro-climate science/action communication	Activation through anti-climate science/action communication	Improved communication approaches
#1 DEFENSE – DISTANCE: DEFENSE AGAINST THINKING, FEELING AND KNOWING ABOUT CLIMATE CHANGE. Maintaining psychological distance to the issue (spatial; temporal; ecological/social; conceptual/ perceptual) through issue avoidance, narrow focus on the here/now, seeking distractions, optimism bias, etc.	Emphasis of climate change as a science issue Use of abstract scientific graphs or language Lack of specificity Talk about climate change as a future threat "in 100 years from now", or in 2050 or 2100; Emphasis on slow, gradual, long-term change Emphasis of the ecological/ environmental aspects Use of images of polar bears, events in distant places, decaying ice sheets	<u>Not</u> talking about or limiting news on the issue (perpetuating silence) Emphasis of the naturalness of climate variability and change; avoidance of "global warming" Why worry now? There are more urgent matters to focus on It won't happen here We can cope, we'll be fine	Make the issue feel near, human, personal and urgent; climate change is happening "here and now" Speak of people, places and entities where you are Use emotion and stories for meaning-making Include some link to personal behavior Point to tangible locus of control Use witnesses to change as messengers Use citizen science opportunities to engage people directly in tracking change Focus on human health Stories of well-being and community (personal, concrete, vivid, extraordinary, show-don't-tell, humorous, witty, strong plot) Signal progress with concrete examples of change in local or direct experience

#2 DEFENSE – DOOM: DEFENSE AGAINST THINKING ABOUT OR FEELING THE LOSS ASSOCIATED WITH CLIMATE CHANGE (OR ACTION). Loss aversion/sense of doom/fear/catastrophism lead to issue avoidance, rationalization of inaction, transfer of responsibility to others/to future (e.g. technological fixes, government, future generations)	Use of loss and cost frames Use of catastrophe frames, disaster imagery, apocalyptic imagery or stories (climate hell) "weapon of mass destruction" metaphor Use of sacrifice frame Not linking risks to action	Spin – euphemisms, reframing negative as positive Emphasis on disasters (natural causes, Acts of God) Playing to fear of solutions, rather than fear of problem Highlighting how costly it would be to change from the status quo (economic ruin) It is unpatriotic to acknowledge anything negative, to hint at the end of growth, or to mention despair, fear, failure	Focus on past loss and restoration of what has been lost Focus on near-term benefits and opportunities to avoid future losses or costs "A crisis we can't afford to ignore" Use of engaging, reasonable frames (e.g., insurance, preparedness, doing what is right, security) Focus on improvement of health and quality of life (people, love, family, community) Focus on positive emotions Stories of people who act out of determination, joy, vision; heroic stories of overcoming adversity Validate all emotional responses; be witness to suffering; make it safe to publicly display and explore emotional responses (grief, fear etc.)
#3 DEFENSE – DISSONANCE: DEFENSE AGAINST GUILT; MANAGING THE KNOWLEDGE-ACTION DISCONNECT. Dealing with cognitive dissonance through doubt of science, confirmation bias/motivated reasoning, downplaying of problem, diminishment of solutions, avoidance of issue, rationalization of inaction, transfer of responsibility to others (e.g. technological fixes, government), apathy	Use of explicit or implicit guilt appeals Leading with uncertainty or overstating the state of science (avoiding uncertainty altogether)	Playing up scientific uncertainty as justification for inaction Emphasis on "independent" science, opinion; "underdog" stories Cherry-picking scientific results Scientists "can't even predict tomorrow's weather" Questioning scientists' integrity Actively confusing people (e.g., CO_2 is a natural substance needed for life, how can it be bad?)	Emphasis on the high degree of scientific consensus Justify action because of uncertainty Better safe than sorry Emphasize the moral case for climate action Common sense course of action Building resilience Illustrate solutions in positive, desirable ways Provide opportunities for clear, consistent, visible action Make actions easy, convenient Make the right action the default choice Stories of discovery and opportunity, stories of green growth

#4 DEFENSE – DENIAL: DEFENSE AGAINST LOSS OF ONE'S SOCIAL TIES OR STANDING. Dealing with social dissonance through active denial, self-defense, playing to in-group/out-group dynamics, and attack on others	Unnecessary polarization, demonization Trigger fear, guilt and self-protective impulses through frames (language, imagery) Climate deniers = Holocaust deniers Complicit avoidance of potentially divisive, disturbing topics	Death threats, ad hominem attacks on scientists Active politicization of science Active polarization through name-calling, demonization of politicians, activists, scientists Use of enemy narratives Activists and scientists are heavy CO_2 emitters "There has been no warming" claims "Fossil fuel energy is essential or else..." claims	Use face-to-face interactions wherever possible (dialogues, joint action, clubs) Use peer messengers Use the power of social networks Tap competition, desire to be better, recognized as good/better Tap desire to work/be together Stories of reconciliation, coming together, cooperation, resilience (not necessarily unity of opinion) Provide positive feedback as signals of valuable change
#5 DEFENSE – iDENTITY: DEFENSE AGAINST IDENTITY CHANGE. Resistance to change who we are, how we see ourselves through avoidance, denial, helplessness, reinforcement of existing identity, or attack on others	Insisting on actions, policies, solutions that are unacceptable to opponents (e.g., government intervention) Unnecessary polarization, demonization Using messengers that are not trusted by/similar to the intended audience The threat to mobilize around is climate change, at all costs Offering no vision of a positive future	Unnecessary polarization, demonization "The American way of life is not up for debate..." proclamations The threat to mobilize around is what "they" propose as solutions to climate change Fostering anti-science and anti-government sentiments Emphasis on freedom from government, individual freedom, free market economics	Inspiration (to become better humans, to have a better life) Appeal to deeply held values (e.g., responsibility, stewardship, family, community) Illustrate new social/cultural norms Open up space to discuss a wide variety of policies/responses Use the power of stories to make meaning Stories of positive transformation (a better life is possible) (quest, overcoming a huge challenge, hero's journey) Stories of commitment, conviction (and change in conviction) Create a sense of the collective Tap into local sense of place/ patriotism/community/pride Tap into status as respected, compassionate, leading, innovative community member

Sources: See text.

Table 3: Selected climate communication resources: Think tanks, service providers, collaboratives and resource hubs

Name of resource (alphabetic order)	Type[1]				Web access
	Think tank, forum or research org.	Service provider (e.g. trainings)	Resource hub	Collaborative	
American Association for the Advancement of Science (AAAS) Center for Public Engagement with Science & Technology		X			http://www.aaas.org/pes/communicating-science-workshops/
Center for Research on Environmental Decisions (CRED)	X				http://guide.cred.columbia.edu/
Climate Access	X	X	X		http://www.climateaccess.org
Climate Advocacy Lab			X	X	http://www.climateadvocacylab.org/ (special access to resources for members)
Climate Change Media Partnership				X	http://www.climatemediapartnership.org/ (for members)
Climate Communication		X			https://www.climatecommunication.org/
Climate Nexus		X	X		http://climatenexus.org/
Climate Outreach	X	X	X		http://www.climateoutreach.org.uk/
Climate Shift	X				http://climateshiftproject.org/
Climate Voices			X	X	http://climatevoices.org/
CoClimate	X	X			http://www.coclimate.com/
Common Cause	X	X	X		http://valuesandframes.org/
Connecting on Climate[2]			X		http://www.connectingonclimate.org/
ecoAmerica	X		X		http://ecoamerica.org/
George Mason University Center for Climate Change Communication	X				http://www.climatechangecommunication.org/
International Environmental Communication Association (IECA)[3]	X	X	X		https://theieca.org/
MeCCSA Climate Change	X		X	X	http://www.meccsa.org.uk/networks/climate-

Name of resource (alphabetic order)	Type[1]				Web access
	Think tank, forum or research org.	Service provider (e.g. trainings)	Resource hub	Collaborative	
Network[4]					change-network/
Metcalf Institute for Marine and Environmental Reporting			X		http://metcalfinstitute.org/resources/communicating-on-climate-change/
MomentUs[5]	X			X	http://ecoamerica.org/momentus/
National Network for Ocean and Climate Change Interpretation (NNOCCI)[6]		X	X	X	http://www.nnocci.org/
Science and Environment Communication Section of the European Communication Research and Education Association (ECREA)	X		X		http://www.ecrea.eu/divisions/section/id/16
Susanne Moser Research & Consulting	X	X			http://www.susannemoser.com/
Talking Climate[7]	X		X		http://talkingclimate.org/
Union of Concerned Scientists[8]		X			http://www.ucsusa.org/action/science_network/science-network-workshop-series.html
Yale Project on Climate change Communication	X				http://environment.yale.edu/climate-communication/
Yale Climate Connections			X		http://www.yaleclimateconnections.org/
Yale Forum on Climate Change and the Media	X		X		http://www.yaleclimatemediaforum.org/
TOTALS	**16**	**11**	**16**	**6**	

Notes:

1   The resources listed can be broadly categorized, but many transcend the listed categories and offer more than one type of resource for those interested in improving their climate communication. Dominant characteristics for each resource are marked (x). Traditional consulting firms, academic communications programs, general communication-focused professional societies, and general environmental communications centers have been excluded from this listing.

2   This resource is a joint product of CRED and ecoAmerica.

3   While a broader professional association, IECA has a strong climate change focus in publications, trainings, resources .

4   MeCCSA - Media, Communication and Cultural Studies Association.

5   A project of ecoAmerica and other partners.

6   NNOCCI is mostly focused on the intersection of climate change and ocean impacts; the collaborative has multiple partners, including a research and service-oriented organization which has a long-standing emphasis on climate communication, the Frameworks Institute (http://frameworksinstitute.org/).

7   A project of Climate Outreach, http://www.climateoutreach.org.uk/.

8   The Union of Concerned Scientists offers workshops for its scientist members to build capacity in more effective science communication with the public, the media and policy-makers, frequently focused on climate change.

Supplementary Material 1: Web of Science Search

In order to get an approximate sense of the growth of the field of climate communication science, a Web of Science search was conducted as follows:

The search for relevant entries used the thematic search term: TS=(climat* NEAR chang* AND communicat*). Thematic searches are broader than title or keyword searches. The truncated terms allowed for variations in use of the search terms (e.g., climate/climatic; or change/changing/changed; or communication/communicate/communicated/communicating/communicative).

The search returned N=2,294 entries for the search period from 1/1/2005 to 12/31/2015.

These entries were manually reviewed to ascertain relevance. Retained were all articles addressing topics related to climate change communication, including perception, attitude and opinion polls, studies on the change in understanding and knowledge about climate change, word and framing choices, the use of tools for climate change communication (scenarios, story-telling, visualizations, interactive tools), participatory approaches to communication and engagement, the value and integration of different types of knowledge, the importance of values, belief systems, worldviews, as well as cognitive and affective responses, and studies on closely related, yet specialized topical areas, such as communication about energy choices, and other mitigation, adaptation and geoengineering options. By contrast, excluded from the search were all entries that referred to the "climate for communication" in non-climate change contexts (e.g., in schools, medical facilities, or business environments), communication primarily about non-climate topics (e.g., volcanic hazards or HIV/AIDS) which only pointed to the general applicability of findings to climate change, papers on generic climate information needs, and articles primarily about climate change impacts, vulnerability, adaptation, or mitigation topics (with tangential mention of the need for effective communication).

After this screening, n=1,220 (or 53.2% of N) relevant entries remained. This number is significantly larger than the 311 articles found in another recent *WIREs-Climate Change* review by Pearce et al. (2015). Their search focused on only the 2010 to mid-2015 period, was conducted with the (smaller) Scopus database, and used a simpler search term. (The more closely comparable number from this search for this shorter period from 2010-2015 is 998 articles.)

Yet, even the more comprehensive search results presented here should be considered indicative rather than definitive or complete. Given the simple topical search, the strict criteria for inclusion/exclusion, the likely incompleteness of data for 2015 (due to delay of entry of records into the Web of Science database), and the basic limitation of Web of Science which does not include highly relevant "grey" literature, the resulting number of articles must be viewed as a conservative estimate of the productivity in the climate change communication field.

Reference:
1.   Pearce W, Brown B, Nerlich B, Koteyko N. Communicating climate change: Conduits, content, and consensus. *Wiley Interdisciplinary Reviews: Climate Change* 2015, 6:613-626.

Further Reading/Resources

Hansen A. and Cox R. *The Routledge Handbook of Environment and Communication*. Routledge: Oxon, UK and New York, 2015.

Related Articles

DOI	Article title
DOI:10.1002/wcc.366	Communicating climate change: Conduits, content, and consensus.
DOI:10.1002/wcc.353	How do young people engage with climate change? The role of knowledge, values, message framing, and trusted communicators.
DOI:10.1002/wcc.276	Communicating adaptation to climate change: The art and science of public engagement when climate change comes home.