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Evaluating effective public engagement: local stories from a global network of IPCC scientists

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Abstract
An integral part of the communications strategy for Working Group I (WGI) of the Intergovernmental Panel on Climate Change (IPCC) is to support its authors, in all geographical regions, to engage a diverse range of audiences with climate change. Building upon a Communications Handbook for IPCC authors and a bespoke photo library, both produced by Climate Outreach for WGI in 2018 ahead of the Special Report on Global Warming of 1.5C, this paper describes the findings of a global survey that gathered practical examples of efforts by WGI authors to engage non-specialist audiences around the world with climate change. A total of 107 survey responses from 44 countries were evaluated against a theoretical framework outlining key principles of effective public engagement drawn from the social science literature. Ideas for how climate scientists can enhance their communication efforts are discussed, illustrated with case studies drawn from the survey responses showing WGI authors using creative techniques to engage people with climate change, including in Senegal, Argentina, India, the Bahamas and Indonesia. This is followed by guidance for the IPCC on developing communications strategies in a way that gives climate scientists confidence to communicate their work and promotes evidence-based techniques. By critically reflecting on the communication practices within the IPCC's global author network, the paper provides insights and recommendations on how to continue to strengthen the connection between the theory and practice of climate science communication.

Keywords Public engagement · Climate change · IPCC · Storytelling · Science communication

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1 Introduction

1.1 Scientist-led public engagement

An engaged public is a prerequisite for responding effectively to climate change (Spence et al. 2012; Committee on Climate Change 2019). This is true at an individual level, with around two-thirds of global greenhouse gas emissions linked to household consumption and lifestyles (UNEP 2020). This is also true at a collective level, since the systemic changes needed to tackle climate change fairly and equitably also require broad-scale public buy-in: a social mandate (Clarke et al. 2020). Increasingly, climate science communicators are embracing evidence drawn from other disciplines in the pursuit of 'best practice' approaches for engaging non-specialist audiences with climate change (Shuckburgh et al. 2012; National Academies of Sciences, Engineering and Medicine 2017). One key insight is that values, worldviews and ideologies are far more powerful predictors of attitudes towards climate change than simple scientific literacy (Corner et al. 2014; Hornsey et al. 2016; Maio 2016; Corner and Clarke 2016). People are influenced by stories that 'feel right' — narratives that resonate with their values and identity, presented by people they trust, and made acceptable by the social norms around them (Clarke et al. 2020).

Within this context, a large literature has developed regarding scientists' role in engaging the public with climate change (Kahan 2010; Meyer et al. 2010). The traditional view of a scientist as a dispassionate observer is, arguably, shifting, alongside the recognition that scientists are highly trusted by the public to 'tell the truth' (Curtice et al. 2019; Skinner and Clemence 2020) and 'act in the public interest' (Curtice. et al. 2019). However, there is little consensus within the climate science community on *how* to engage: it may be largely up to the individual to identify their 'goal' in communicating outside of their scientific discipline (Donner 2014). Within those wide parameters, however, scientists looking to communicate their findings more widely can elect to do so in an evidence-based way, regardless of the specific context. In this sense, the social science evidence base presents an opportunity to support climate scientists to move away from the largely discredited 'deficit' model of one-directional science communication (Sturgis and Allum 2004; Shi et al. 2016) to more effective, values-based public engagement (Shuckburgh et al. 2012). There are, however, complex and nuanced issues for scientists to navigate in order to move beyond a simple representation of science. These include fears of being misinterpreted, misquoted or misunderstood; the subject of a deliberate attempt to misinform; asked to speculate or comment on areas outside their expertise; and perceived to be slipping into 'advocacy' or policy prescriptiveness and the erosion of scientific credibility that is often assumed to result (Messling 2020). For many scientists, practical barriers to communicating their work include lack of time; access to appropriately tailored training (Trench and Miller 2012); opportunities to practice in 'low-stakes' or peer-to-peer situations; and academic incentive or reward (Burchell et al. 2017).

1.2 A public engagement handbook for IPCC scientists

The Intergovernmental Panel on Climate Change (IPCC) is the world's foremost scientific authority on the causes and consequences of climate change, as well as methods to reduce the greenhouse gas emissions that drive it. Within that wide scope, Working

Group I (WGI) focuses on assessing the physical science underpinning past, present and future climate change. As such, the academics selected to be authors and review editors for the WGI reports (hereafter referred to as 'authors') tend to be primarily from a natural or physical science background — approx. 233 for the main report of the Sixth Assessment cycle, AR6.

An integral part of the WGI strategy for the AR6 cycle, which also includes three Special Reports, is to support its authors to effectively communicate IPCC findings to a global audience that includes policymakers at all levels, industry, business, educators, journalists and the public. In 2018, the IPCC WGI Technical Support Unit (TSU) commissioned Climate Outreach to produce an evidence-based, practical guide to support its authors to engage non-specialists with the Special Report on 1.5C. The resulting six principles, and associated guidance to IPCC scientists for overcoming the issues therein, are summarised in Table 1 and described in the resource, 'Principles for effective communication and public engagement on climate change: A Handbook for IPCC authors' (Corner et al. 2018). The resource is hereafter referred to as the 'Handbook'. Similarly to how the Summary for Policymakers of IPCC reports distils the most policy-relevant findings, the Handbook synthesised just the most critical elements of best practice public engagement from the available social sciences literature, in a format that served as a practical resource for time-poor communicators who are not necessarily able to engage with the primary literature themselves. In that sense, while the Handbook is grounded in established literature, it is not intended as an exhaustive summary of the factors determining effective climate science communication or how to measure it. For more extensive discussions of what constitutes 'effective' public engagement, see, for example, Moser (2010).

1.3 The current study

This paper presents the findings of a follow-up project to the Handbook, commissioned by the WGI TSU and carried out by Climate Outreach in spring and summer of 2020. Given the IPCC's global scope and the regional diversity of its authors, a major motivation was to address the fact that the evidence base on which public engagement best practice is based and, on which the Handbook drew, is predominantly from the UK, Europe and the United States. For the first time in the IPCC's history, a global survey was designed to collect information about how WGI authors around the world are engaging non-specialists with climate change (Section 2).

The survey responses were then evaluated in the context of the best practice principles for effective public engagement, as summarised in the Handbook, resulting in additional practical suggestions for how individual scientists can follow best practice techniques (Section 3). Some aspects of the field of science communication and the climate change discourse have, however, shifted since the Handbook was published in 2018. We, therefore, present a critique of the original principles as part of our analysis, where appropriate. Recommendations are discussed for how WGI, and the IPCC more broadly, can use the survey insights and analysis to develop an evidence-based and people-centred communications strategy that facilitates best practice public engagement (Section 4). Future research questions are also explored (Section 5) before a summary of learnings concludes the discussion (Section 6).

Table 1 Principles from the Handbook

Principle 1: Be a confident communicator	
Issue: Scientist communicators often seek to keep their language balanced and unemotional when describing research findings and summarising data (Weber and Schell Word 2001), which may be perceived as cold and unsatisfying	Guidance: While scientists are generally perceived as credible (Curtice et al. 2019; Skinner and Clemence 2020), they may not be seen to be trustworthy by default (Fiske and Dupree 2014). 'Trustworthiness' is earned by the extent to which a communicator is perceived by their audience to be warm and genuine, and drawing on their own experiences and perspectives and motivated by positive intent (Fiske and Dupree 2014). Combining objective expertise with subjective human concerns will enhance the scientists' credibility (Fiske and Dupree 2014) and the effectiveness of their communication (Schmidt and Donner 2017). In such a politicised field as climate change there is no neutral position from which to speak (ibid)
Principle 2: Talk about the real world, not abstract ideas	
Issue: Technical language used by climate scientists to explain climate change is not likely to be seen as psychologically close, personally relevant, and may not be engaging	Guidance: Complex topics may be made accessible by using everyday, jargon-free language or metaphors and analogies to frame climate change in a familiar way (Shaw and Nerlich, 2015; National Academies of Sciences, Engineering and Medicine, 2017)
Principle 3: Connect with what matters to your audience	
Issue: Knowledge about climate change does not relate to public opinion in a straightforward manner (Sturgis and Allum 2004; Kahan et al. 2012; Shi et al. 2016). This means that providing accurate information is necessary, but not sufficient to ensure that the public is engaged with climate change	Guidance: A considerable body of research has focused on value-based engagement on climate change (Nisbet 2009; Corner et al. 2014; Maio 2016; Corner and Clarke 2016), and the importance of speaking to 'core values' as well as group identities such as nationality
Principle 4: Tell a human story	
Issue: People intuitively make sense of the world through anecdotes and stories, rather than facts and lists (Smith et al. 2014)	Guidance: Narratives help people understand complex and abstract scientific topics (Nisbet and Markowitz 2016), and make information easier to process and recall, compared to traditional forms of scientific communication (Dahlstrom 2014). Communicating science in a narrative form is most effective when those narratives use language that reflects the values and concerns of the audience (see also Principle 3: Connect with what matters to your audience)
Principle 5: Lead with what you know	
Issue: Scientific focus tends to hone in on what is not known, but in public engagement, this can be misinterpreted as ignorance or disagreement among scientists	Guidance: Lead with what is known, and with the level of consensus. While stating that there is consensus is not on its own enough to overcome strong disengagement and scepticism, it can be a useful communication tool nonetheless (van der Linden et al. 2015; Hornsey et al. 2016)

Table 1 (continued)

Principle 6: Use effective visual communication	
Issue: For climate scientists, scientific graphs are a key component of their work and of public engagement, but these are often not accessible or engaging for the public. The overreliance on particular types of climate imagery—smokestacks, fractured sea ice and polar bears—has resulted in a narrow set of ways of visualising climate change (O'Neill and Smith 2014)	Guidance: The Climate Visuals project conducted research in three countries (the UK, Germany and the US) to examine public perceptions of climate change imagery (Chapman et al. 2016). The project produced specific evidence-based guidance for using visual imagery (www.climatevisuals.org). The five principles most relevant to IPCC authors' activities are summarised below: 1. Show real people, not staged photo ops 2. Tell new stories about climate change 3. Climate impacts are emotionally powerful, especially coupled with concrete behavioural 'actions' 4. Show local climate impacts 5. Understand your audience

2 Methods

2.1 Data collection and processing

2.1.1 Survey design

An online form was developed to collect WGI authors' accounts of engaging non-specialist audiences. The survey design was informed by 16 semi-structured, face-to-face interviews with purposively selected representatives of the elected IPCC scientific and technical leadership (IPCC Vice-Chairs and Working Group Bureau Members) from across all six of the IPCC regions (which reflect World Meteorological Organization regions — Africa; Asia; Europe; North America, Central America and the Caribbean; South America; and South-West Pacific). The survey was piloted with the author team of one chapter of the WGI AR6 and the wording of some questions amended accordingly based on their responses ($n = 7$).

The survey was produced in Google Forms and included 13, mainly open text, qualitative and quantitative questions. Respondents were asked what types of public engagement they do and to recall a particular example they had undertaken that they thought had achieved the most impact with the audience. This was to encourage tangible evidence of best practice principles in action in real public engagement examples, rather than descriptions of a generalised approach. Subsequent questions asked respondents to outline what they told the audience about in their chosen example and how, and what they did to make the content engaging for that particular audience — for example, if it was a general science talk or on a topic within their specific area of expertise and if they used visual prompts (such as PowerPoint) or used different learning and conversation formats (such as stories, interactive games or comic strips). Respondents were able to provide links to associated material available online. Respondents were also asked how they found the experience themselves; their 'top tip' for other scientists doing public engagement; and which, if any, IPCC resources they used and why. Additional text under each question gave a brief explanation or some examples, such that its meaning could be fully understood. The complete survey text can be found in Online Resource 1.

2.1.2 Adaptations to enhance geographical coverage of responses

To promote as broad a participation in the study as possible, two alternative formats were also produced: a fillable pdf for those unable to access Google, and a video call format, designed to promote participation by those for whom a discursive and/or group setting may have been preferable to written and/or individual responses. A semi-structured interview schedule was adapted from the original face-to-face interview format, covering similar themes to the survey, to collect information via a 20-min Zoom video call with groups of three to four scientists. This option was offered to all; only two WGI authors requested to contribute via this modality, however, and these were conducted as two individual interviews.

2.1.3 Sampling

The survey was available online over a period of 4 weeks during March–April 2020. An invitation to participate was emailed to all current WGI authors (also including those involved in the three AR6 Special Reports) and the members of the elected WGI Bureau who oversee and advise the report preparation. The response rate from within each region was reviewed on a weekly basis to assess representativeness. Alongside self-selecting, some participants were directly invited to contribute via a purposive sampling approach to encourage responses from under-represented regions. Specific requests were sent via email to IPCC authors known to be involved in public engagement in different geographical regions. The sampling frame was also expanded during this period to include WGI authors from the Fifth Assessment Report (AR5).

2.2 Analysis of survey responses and selection of case studies

Based on the information respondents gave in the survey and the semi-structured interviews, the approaches that WGI authors use to engage non-specialist audiences with climate change were evaluated against best practice principles for effective public engagement drawn from the social science literature, as outlined in the Handbook. One Climate Outreach team member working across the 107 survey responses flagged content that demonstrated any aspect of the six principles. It is worth noting that the survey was intended to crowd-source practical examples of public engagement by WGI authors around the world, rather than to test awareness of the Handbook principles per se or the extent to which authors were deploying them. As such, the survey questions were designed to allow authors to highlight, without reference to best practice or the principles in the handbook, the techniques they used to engage audiences, rather than to return any particular metric.

The Climate Outreach team member then used the Handbook principles as a theoretical framework to analyse how often the best-practice techniques came up organically and without prompting within the authors' own descriptions of their chosen approach. These respondents were contacted to collect more details and, in some cases, to clarify the information already given. Where a single survey respondent exhibited multiple examples of best-practice public engagement covering more than one principle, this was flagged under each of the relevant principles (i.e. each respondent can represent more than one instance of best-practice public engagement). It should also be noted that absence of evidence of authors using the approaches outlined in the Handbook does not necessarily correspond to

evidence of absence (i.e. authors may have used the technique, deliberately or otherwise, in their activities but not mentioned it in their survey responses). This suggests that the survey analysis that follows, while informative about public engagement practices among WGI authors and useful for directing future resources, should be recognised as an exploration of WGI authors' perception of what constitutes effective public engagement via their own accounts of their activities, not as an objective data collection or evaluation exercise.

From the survey responses, a subset of 11 case studies from around the world was selected to showcase the IPCC global survey project on the Climate Outreach website (https://climateoutreach.org/case-studies-from-ipcc-authors/). The criteria for selecting these were that the WGI author used a particularly creative, novel or inspiring approach to public engagement that their description demonstrated evidence-based techniques in action and that, as a full set, the case studies achieved balanced global representation with a range of different audiences. Once candidates for the case studies were shortlisted, a follow-up conversation with the WGI author enabled more detailed information to be collected and a final selection to be made.

3 Results and analysis

This section is divided as follows: descriptive statistics regarding regional representation and degree of experience with IPCC report activities among survey respondents; general insights obtained from the survey responses about the types of communication approaches WGI authors use; and an analysis of the responses in the context of the six principles for effective public engagement outlined in the Handbook.

3.1 Descriptive statistics

The survey and video interviews resulted in 107 responses from WGI authors. The respondents spanned 44 countries from across all six of the IPCC's regions (Fig. 1). Just under half (48%) of the respondents were located outside the regions of Europe and North America, Central America and the Caribbean — reflecting the corresponding proportion in WGI for AR6 (46%). Eighty percent of respondents were involved in a report produced during the Sixth Assessment Cycle, with the rest contributing to earlier assessment cycles. Fifty-seven percent had been involved in more than one IPCC report.

3.2 Communication methods

A number of survey responses ($n = 14$, 13%) revealed WGI authors using novel and creative approaches to engage different audiences around the world with climate change. These included hands-on children's games at museum open days; pub quizzes; climate-related comic-book characters; colour-coded embroidery and other visual art to show rising temperatures; songs and music videos; time-lapse photography footage of retreating glaciers; and climate modelling of famous fictional worlds. The most common type of public engagement involved some form of presentation; however, 89% said they did public lectures and 68% school talks. Fifty-one percent had produced written outputs (e.g. blogging, magazine articles and popular science books) and 33% had engaged in online discussions (via Twitter, Facebook, etc.). Thirty-nine percent indicated having engaged with the media (e.g. TV and radio interviews, providing quotes and involvement in films). Twenty-five percent had engaged through town hall debates and 22% via various fora with policymakers.

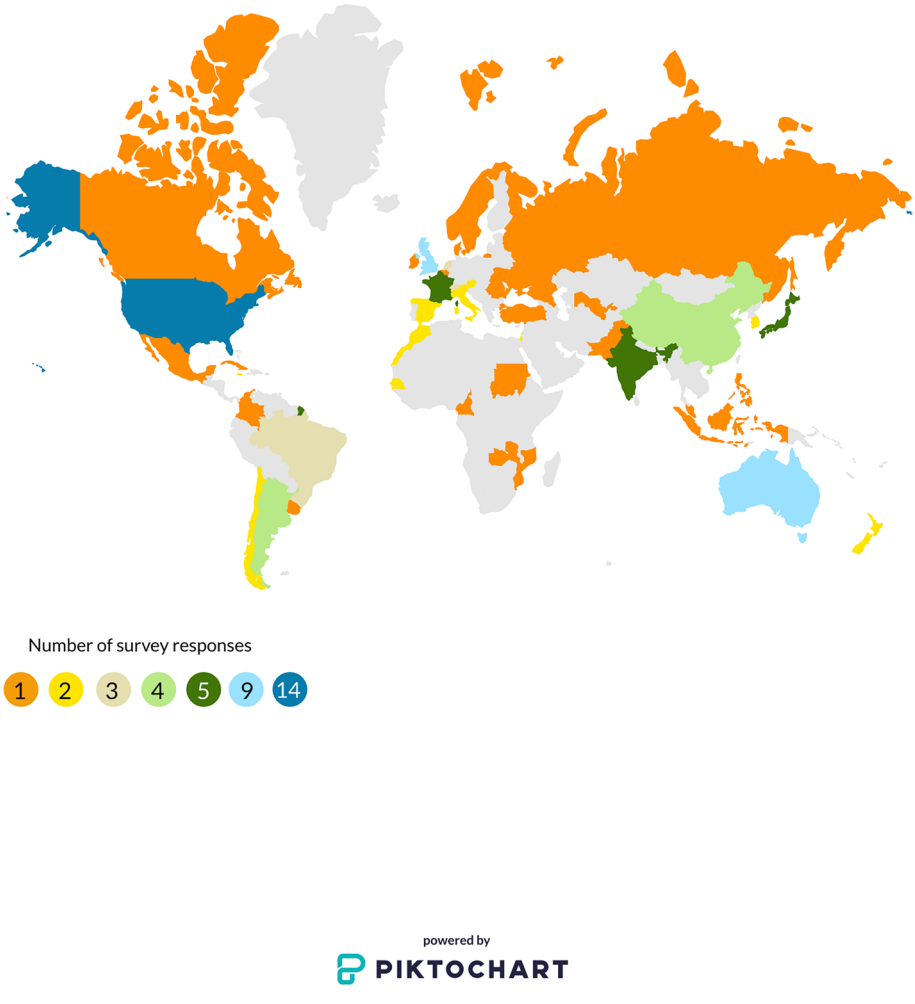

Fig. 1 Geographic distribution of survey responses. The survey generated 107 responses in 44 countries across all six of the IPCC regions. The colours represent the number of respondents from that country (refer to key)

There did not appear to be any regional differences in the prevalence of presentations as a format for public engagement. Where these were discussed, the vast majority said they used PowerPoint as a visual aid (mentioned by 48% of respondents overall, $n = 51$), with this being used widely in all regions. There were notable exceptions to this generalisation, however. Among them, Dr Aïda Diongue Niang, from Météo Sénégal/ANACIM and author for WGI AR6, described how she abandoned PowerPoint in favour of a 'normal conversation' with local farming and fishing communities on the beach (Read Aida's full story: https://climateoutreach.org/case-studies-from-ipcc-authors/senegal/). Dr Masao Ishii, Japanese Meteorological Agency and WGI AR6 author, discussed giving a PowerPoint lecture on YouTube and receiving questions from listeners through Slido (an online audience participation platform) (Read Ishii's full story: https://climateoutreach.org/case-studies-from-ipcc-authors/japan/). Prof. Michael Taylor, from the University of the West

Indies and author for the Special Report on Global Warming of 1.5 °C, explained how he uses interactive games and role play alongside presentation slides to contextualise the science so that participants can relate to it (Read Michael's full story: https://climateoutreach.org/case-studies-from-ipcc-authors/jamaica/).

3.3 Analysis of survey responses in the context of best practice public engagement

This analysis is divided into six subsections, corresponding to the six principles for best practice public engagement outlined in the Handbook.

3.3.1 Principle 1: Be a confident communicator

A few respondents mentioned including their personal perspective or personal content of some kind as a means of engaging their audience ($n=14$, 13%). One such example is Dr Lucas Ruiz from the Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales and WGI AR6 author, who described how he always introduces himself as a 'regular person': 'Of course, the audience is there to listen to you because you are an expert in climate, but that can create a distance with the audience. It's better to introduce yourself, what your motivations are for doing your science, and why you care about it' (Read Lucas' full story here: https://climateoutreach.org/case-studies-from-ipcc-authors/argentina/). Where respondents incorporated their own perspective, more people talked about their science or the experience of participating in an IPCC report ($n=9$, 8%) than their personal experience of climate change or factors that shaped their own views and values ($n=5$, 5%). One participant included photographs of themselves and scientific colleagues. These personal stories of scientists — why they do the work they do, what inspires and motivates them, what they care about and are fearful of — are a valuable resource for gaining an audience's trust (Fiske and Dupree 2014). A few participants mentioned trying to be personable in a general sense, for example, by taking a conversational tone or injecting humour ($n=12$, 11%). Several talked unprompted about wishing to show the human face behind their science ($n=6$, 6%).

While some respondents gave examples of giving talks about their specific field of expertise ($n=37$, 35%), most presentations to non-specialist audiences were about general climate science ($n=50$, 47%). Just over a third of respondents mentioned talking about potential responses to climate change — either on a personal or collective level ($n=33$, 31%), which perhaps implies that the majority do not readily do so in their public engagement activities. Research suggests the fear of being perceived as an 'advocate' can often underlie scientists' reticence to discuss societal responses to climate change (Fischhoff 2007). This is despite there being no simple definition of 'advocacy' (Nelson and Vucetich 2009; Donner 2014) or clear evidence that being perceived as an advocate damages audiences' trust in scientists (Schmidt and Donner 2017), which suggests the perception of advocacy can often be more limiting than the reality. Navigating the 'double ethical bind' of how to be both 'honest' and 'effective' when communicating to the media rests on individuals finding their own personal balance (Schneider 1988), and their place on the 'science-advocacy continuum' (Donner 2014). Rapley and De Meyer, following Pielke Jr, outline different kinds of roles in the interface between climate science and public engagement from, 'pure scientist', to 'science communicator', 'science arbiter', 'issue advocate' and 'honest broker of policy alternatives' (Rapley and De Meyer 2014).

In general, being clear about whether a communicator is representing their personal views, those of their institution or of the IPCC will help an audience interpret the information they are given. And in many cases, it may be better for a communicator with expertise to represent their view, than to let a less-qualified voice fill the void.

The survey also revealed practical factors relevant to being a confident communicator in an international organisation such as the IPCC — robust translation, for example. The exact wording of IPCC Summaries for Policymakers is approved line-by-line by all member states and produced in the six UN languages (Arabic, Chinese, English, French, Russian and Spanish). Two respondents commented on how explaining IPCC content in other languages can be very difficult. Direct translation can take on different meanings, or may not exist — one survey respondent noted, for example, that there is no word for 'resilience' in Japanese.

3.3.2 Principle 2: Talk about the real world, not abstract ideas

The survey showed widespread efforts among participants to 'simplify' the science ($n=37$, 35%), with many specific mentions of using everyday language and metaphors instead of technical scientific terms or jargon ($n=21$, 20%). Some respondents noted a tension in this simplification — a wish to neither be condescending to the audience, nor redact or reduce important complexities.

Metaphors and analogies allow communicators to use knowledge from a familiar domain of experience to explain another, unfamiliar domain (Lakoff and Johnson 1983; Shaw and Nerlich 2015; National Academies of Sciences, Engineering and Medicine 2017). Some common climate change metaphors are 'loaded dice' to describe the increased frequency of extreme weather (Hansen et al. 2012) or filling a bathtub to explain the accumulation of carbon dioxide in the atmosphere (Guy et al. 2013). While some respondents provided examples of the metaphors they use to explain the science in non-specialist terms ($n=7$, 7%), there were only a few cases that explicitly described choosing a metaphor based on the audience ($n=4$, 4%). For example, when talking to residents of downtown New York, Dr Alex C. Ruane, from NASA Goddard Institute for Space Studies and WGI AR6 author, likened the effect of sea level rise on flooding to raising the floor of a basketball court, making it more likely players will score (Read Alex's full story here: https://climateoutreach.org/case-studies-from-ipcc-authors/usa/). In most cases, the choice of metaphor appeared to be a decision about how far to 'simplify' the science, rather than what they thought the audience might personally relate to.

Similarly, while the survey responses included examples of adapting the level of scientific detail for non-specialist audiences ($n=19$, 18%), there was limited evidence that the lens through which the information is presented — or framed — was a key consideration in how respondents approached presentations ($n=8$, 7%). 'Framing' is the practice of positioning information in a way that is relatable for the audience. For example, the growing use of solar panels could be framed *economically* (in terms of rapidly falling costs) or *environmentally* (in terms of reduced carbon emissions). A considerable research effort has been dedicated to documenting the effects of different frames on public engagement with climate change (Nisbet 2009; Spence and Pidgeon 2010; Myers et al. 2012; Corner et al. 2014). (See also Principle 3: Connect with what matters to your audience.)

The tension expressed around achieving simplicity at the expense of scientific detail can be partly eased with an understanding of best practice for communicating uncertainty (see also Principle 5: Lead with what you know). But making scientific information relatable is as much about *relevance* as it is about *simplicity* — so it is worth considering both when thinking how to adapt content for a given audience. By extension, choice of framing for a public engagement event could (and should) change depending on the audience.

One respondent, Dr Intan Suci Nurhati, from the Research Center for Oceanography of the Indonesian Institute of Sciences and WGI AR6 author, described how she adapts her language, focus and analogies in different ways for different audiences: 'When I was at a forum with CEOs…I used their language to explain how paleoclimatology is similar to the stock market—projecting future climate using paleoclimate is no different from choosing good stocks by understanding patterns in past market performance' (Read Intan's full story here: https://climateoutreach.org/case-studies-from-ipcc-authors/indonesia/).

A foreshortening of the temporal scale — i.e. discussing climate change impacts as already happening, rather than risks that will not be manifested until 2050 — is another way of bringing climate change into the 'here and now'. People are not inclined to take inconvenient action now in the hope of reducing a temporally distant risk and so building a shared understanding of the impacts as a real and present risk may be more effective in building engagement with climate action (Spence et al. 2012).

3.3.3 Principle 3: Connect with what matters to your audience

Values — that is, guiding principles or ideals that an individual considers important, such as freedom, tradition or peace (Maio 2016) — and political ideology (McCright and Dunlap 2011; Hart and Nisbet 2012; Forchtner 2019; Czarnek et al. 2020) are strong predictors of attitudes to climate change. A considerable research effort has been dedicated to documenting the effects of values-based engagement with specific audiences (Nisbet 2009; Corner et al. 2014; Maio 2016; Corner and Clarke 2016). For example, frames about avoiding wastefulness have been found to resonate well with UK centre-right audiences (Whitmarsh and Corner 2017). Climate change as a symptom of a system being 'out of balance' speaks to the core value of environmental stewardship held by many faith communities (Marshall et al. 2016; Goldberg et al. 2019).

Values can be a double-edged sword for climate science communication. On the one hand, people tend to 'filter' information according to whether it fits their values, which can contribute to political polarisation on climate change in some countries (Campbell and Kay 2014; Guilbeault et al. 2018). On the other hand, a message that builds on people's core values and concerns is more likely to resonate with the intended audience and is a powerful starting point for any climate change communicator (rather than leading with the science). While it is possible to separate society into segments based on core values — and doing so is likely to be more informative than demographics alone — framing public engagement efforts primarily around widely held societal values has the power to unite society around climate change (Clarke et al. 2020). For example, recent research has shown that frames linked to protecting future generations, creating a healthier society and preserving the countryside in ways that end a 'throw away' culture resonate almost universally across all segments of British society (Wang et al. 2020). Where the shared values of an audience are not obvious in advance — as they might be for a special interest group, professional organisation or political gathering — linking to widely held societal values can help scientists communicate in a way that is sensitive to public sentiment. In addition, and as a number of survey respondents mentioned ($n=36$, 34%), choosing a communication method that facilitates a dialogue with the audience — for example, asking about changes they have noticed or what climate change means to them — can help to tailor the content and engage more meaningfully.

The survey revealed many examples of scientists adapting their communication style for their audience *in a general sense*, i.e. speaking at the level of audience understanding ($n=38$, 36%). There was little evidence, however, that respondents considered their *specific* audience beyond being non-specialist general public. For example, only a few ($n=4$, 4%) explicitly mentioned

knowing or researching the audience's values or concerns, beyond what was implied from the event's description (e.g. tailoring language for a school talk to suit school-age children).

Evidence of tailoring in the survey responses was primarily focused on the local area in which respondents were presenting and the impacts of climate change that the audience might experience ($n=35$, 33%). Connecting with points of local interest in this way — known as 'place-based' communication — is widely recognised as a powerful way of making climate change relevant at local and individual scales (Feitelson 1991; Weber 2006; Scannell and Gifford 2013; Devine-Wright 2013). For example, there was evidence of respondents taking global projected impacts and describing them at a local level ($n=15$, 14%). Some respondents described how impacts, in a general sense, may affect livelihoods ($n=16$, 15%), as a means of helping the audience to understand climate change in the context of their own daily lives and experiences. Research shows that without a clear indication of how people can respond, climate change can feel overwhelming (Chapman et al. 2016). A few survey respondents ($n=4$, 4%) mention, for example, wishing to 'empower' or 'provide hope to' the audience such that they feel better able to cope with the problem of climate change.

For example, Dr Roxy Mathew Koll, from the Indian Institute of Tropical Meteorology and author for the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, describes how he makes his content relevant for his audience: 'Starting with a global perspective and then zooming into regional aspects, moving from national to state, and then district and village levels helps the audience to realise that climate change is at their doorsteps and inside their house' (Read Roxy's full story here: https://climateoutreach.org/case-studies-from-ipcc-authors/india/).

3.3.4 Principle 4: Tell a human story

Using the narrative structure of a story has become an increasingly common approach among science communicators (Smith et al. 2014). A narrative approach can even enhance scientific impact: a recent analysis of 732 scientific abstracts drawn from the climate change literature suggests that writing in a more narrative style increases the uptake and influence of articles (Hillier et al. 2016). A number of respondents mentioned incorporating stories as a key part of their approach ($n=18$, 17%), although there was no reference to any specific narrative techniques to explain scientific concepts or engage the audience.

For scientists looking to use a storyline approach to enhance their own public engagement activities, there are various examples. One such example is the ABT (And, But, Therefore) storytelling template, developed by marine biologist Randy Olson (Olson 2015). The 'And' represents the exposition, setting the context and main purpose of the story; the 'But' part brings in the conflict or problem statement; and the 'Therefore' provides the resolution. There is considerable potential, for example, in using a storyline approach to 'walk' readers through past events or different plausible futures (Shepherd et al. 2018; Ansari and Holz 2019). Shepherd et al. (2018) suggest that storylines allow an exploration of societally relevant questions — such as the effect of different adaptation measures — across a range of plausible futures, rather than trying to predict 'what will happen'.

3.3.5 Principle 5: Lead with what you know

Historically, it has proved difficult to communicate uncertainty (Patt and Schrag 2003; Budescu et al. 2012; Harris et al. 2013) with research showing that the public only

experience science as a series of facts and figures (Rabinovich and Morton 2012). However, more recently, there appears to have been a shift towards greater public understanding of scientific uncertainty, with some studies indicating that people understand that uncertainties are a natural and necessary part of scientific inquiry and that discussing uncertainty does not, on its own, result in a loss of trust in the information presented (Hendriks and Jucks 2020; Gustafson and Rice 2020). While it was clear from the survey that respondents discussed future climate impacts in their public engagement activities ($n = 44$, 41%), there was limited evidence for how they explained uncertainty and/or consensus around these impacts. Uncertainty is a feature of climate science — and any scientific discipline — that should not be sidelined in the public conversation (Groves 2019). Relevant to the IPCC in particular is the suggestion that taking a 'storyline' approach can help avoid being 'strait jacketed' by the uncertainty language that accompanies IPCC findings and move the conversation from prediction to decision-making (Shepherd 2019). As well as thinking about *how* uncertainty is discussed, focusing on what is known (even if it feels self-evident or commonly known) before what is unknown can ensure that talking about uncertainty enhances conversations, rather than derails them.

3.3.6 Principle 6: Use effective visual communication

Visual imagery can be a powerful way to make otherwise distant and intangible concepts more relevant to everyday lives and experiences. Many survey respondents reported making use of IPCC figures ($n = 37$, 35%) and 23 (21%) mentioned scientific data-driven figures as a key feature in their public engagement. Some talked about the need to 'simplify' graphics ($n = 13$, 12%), for example, by changing axis labels and breaking them down into 'layers'. In fact, IPCC authors have been shown to have a good awareness of the kinds of graphs and figures that non-specialists struggle to understand (Harold et al. 2020). A number of respondents mentioned including photography in their presentations ($n = 10$, 9%) or other non-data-driven imagery such as comic strips ($n = 8$, 7%). Others described using videos, animations and time-lapses to demonstrate changes over time ($n = 13$, 12%).

In 2018, the WGI TSU commissioned Climate Outreach to produce a bespoke photo library underpinned by the Climate Visuals principles to support IPCC authors and staff in communicating the Special Report on 1.5C (https://www.ipcc.ch/sr15/mulitimedia/photo-library/. The library was widely used in IPCC communication materials, including the press conference to launch the Special Report and on the dedicated website. The wider Climate Visuals photo library is publicly available, with many images available to download for free under Creative Commons licences. Each image is linked to its original source and captioned with an explanation of how it fits with the Climate Visuals principles.

Since the Handbook was released, there have been notable changes to some areas of the visual landscape, particularly with the way climate change is depicted in news media[1] and by global photographic agencies.[2] But the climate change movement itself has also changed, with the dominance of global grassroots and atypical protests such as Fridays for Future. Fridays for Future has altered the visualisation of climate protests, changing the images and icons of climate change solutions. Greta Thunberg, one of the leaders of

[1] Shields, F. (2019, Oct 18). "Why we're rethinking the images we use for our climate journalism". The Guardian https://www.theguardian.com/environment/2019/oct/18/guardian-climate-pledge-2019-images-pictures-guidelines

[2] Getty images, Visual GPS https://marketing-workbench-assets.s3-us-west-2.amazonaws.com/pdfs/VisualGPS-Sustainability-MiniMag.pdf

the Fridays for Future movement, now has a prominent platform on social media (Jung et al. 2020) and engages regularly with climate scientists and climate science outputs, for instance, responding publicly to scientific reports such as the UNEP Emissions Gap report. Arguably, this has led to an evolution of science communication, with a greater connection between climate scientists and the platforms of advocates.

4 Recommendations for enhancing the WGI communications strategy

This section discusses recommendations for how WGI and the IPCC more broadly can best support authors' public engagement, based on analysis of the survey findings in the context of best practice principles. These are not intended as an exhaustive list, but rather are suggestions that (i) are likely to be straightforward to implement within the existing IPCC framework and (ii) offer high returns in terms of deepening and widening authors' public engagement skills.

Promote awareness of best practice public engagement principles While there was a broad, shared understanding and implementation of some best practice elements (e.g. tailoring talks to the local area and avoiding jargon), for others, there was limited evidence of practice (e.g. taking into account audience values). There is clearly scope for making best practice public engagement principles, such as those outlined in the Handbook, more visible to IPCC authors and for developing complementary training resources in appropriate formats to facilitate their implementation. This can complement initiatives the IPCC is already considering, such as taking a storyline approach to communicating future climate projections and their associated uncertainty. Current and future IPCC authors can also be directed to the case studies online (Fig. 2), to read the personal stories of WGI authors doing public engagement around the world and find links to the Handbook and

Fig. 2 Case studies drawn from the survey responses are showcased online, in which WGI authors use creative and evidence-based techniques to engage audiences with climate change. Covering Senegal, Indonesia, Ukraine, Colombia, Japan, Mozambique, the Caribbean, India, Argentina, USA and France, these can be viewed at https://climateoutreach.org/case-studies-from-ipcc-authors/

accompanying webinar. There is also scope for the IPCC to consider commissioning an update to the Handbook principles to account for recent literature and changes in the public discourse about climate change since the Handbook was published, as well as to identify any cross-cutting themes or potential reorganisation of the principles that would aid their practical application. For example, aligning future guidance with developments in communicating uncertainty in an IPCC context (see Section 3.3.5) and changes in the visual landscape (Section 3.3.6).

Connect scientists with confident and skilled peers who can act as mentors While there is scope to improve public engagement practice among IPCC authors, it is clear that some are already doing this very effectively. These individuals could provide support to others within their cohort (through direct contact and/or, recognising the voluntary nature of IPCC work and consequent time constraints on authors, capturing their experiences and expertise in training materials) and also act as mentors to scientists contributing to the next IPCC report. This would help mitigate loss of collective learning by bridging the gap between one assessment cycle and the next.

Provide training in constructing engaging narratives around audience values Comprehensive training tailored to the specific opportunities and challenges of being a scientist communicator (and a representative of the IPCC), alongside dedicated time and appropriate academic recognition for doing so, would offer a solid entry point for authors into the evidence base around public engagement and how to put it into practice. Training by a specialist communications organisation in values-based engagement would be a cost-effective capacity building measure — compared to providing bespoke narratives for specific contexts — as it would equip authors with the tools to create bespoke narratives themselves for any potential engagement. Training should be accompanied by opportunities for practice within a low-stakes environment to build confidence.

Curate a set of evidence-based photographic images for scientists to use on demand Through the recent publication of a Visual Style Guide (Gomis and Pidcock 2018), the IPCC is already supporting its scientists to create engaging and accessible data visuals tailored to policymaker audiences and underpinned by cognitive science and psychology insights (Harold et al. 2017). A library of photographic images related to climate change — solutions as well as causes and impacts — could provide a complementary resource by supporting IPCC authors to tell a human story and build an engaging narrative with non-specialist audiences. Such a library could take into account changes in the depiction of climate change solutions since the publication of the Handbook, as discussed in Section 3.3.6.

5 Future research needs

This section discusses potential avenues for further research that could facilitate the recommendations in Section 4 and extend the evidence base beyond the scope of the present study.

Different contexts for public engagement While the survey responses demonstrated a large number of formal presentations to a general public audience, it may be that WGI

scientists are taking part in less conventional communication activities and that the survey questions were not phrased in a way to gather detailed information on this. For example, responses to the question asking participants to recall a specific event may have been influenced by a limited interpretation of what constitutes 'impactful public engagement', both in the sense of what counts as 'impactful' and as 'engagement'. The development of a comprehensive WGI communications strategy would benefit from a deeper exploration of the range of contexts in which scientists talk about climate change outside of their specific work environment. Furthermore, the self-reported nature of the data collected here means that the audience experience of participating in these engagement events was not assessed.

Public engagement barriers that scientists face There is inevitably a bias within this self-selected sample of survey respondents towards scientists who were sufficiently available and confident to present their engagement work in this way, and in English (see also translation support below). The findings and recommendations are thus likely skewed towards better supporting those scientists who are already active in public engagement to some extent, rather than facilitating and supporting engagement by those who (i) may be potentially motivated to undertake engagement but who are not currently doing so, (ii) are undertaking it but may be less confident in their practices or (iii) are undertaking activities but were unavailable to participate.

To develop a comprehensive and inclusive communications strategy that can broaden as well as deepen public engagement by IPCC scientists, it will be important to also consider the needs of those who are not currently active — and to identify barriers to their involvement. For example, the identity and background of the speaker may affect how they are perceived when speaking about climate change. Swim et al. (2018) showed that in the US context, climate communication is gendered, with women who spoke about science-business frames for climate action (seen as more masculine) and men who spoke about ethical and justice frames (evaluated as more feminine) being evaluated more negatively than gender-conforming patterns (Swim et al. 2018). In a study of South African scientists, Black and female scientists reported facing race- and gender-based barriers in the public arena and in the international context, and scientists reported facing different barriers to public engagement depending on whether audiences shared their racial identity (Joubert 2018). Another example from Switzerland suggests that men, older academics and those with higher-level job titles are given more opportunities for public engagement than women (Crettaz von Roten 2011). Examples such as these suggest that there may be implications for who is 'allowed' to speak in certain ways, on certain values, in different cultural contexts and for other demographic characteristics.

Scientists' requirement for practical on-demand resources The survey responses highlighted a number of practical resources that could help reduce demands on scientists' time in preparing for engagement events and provide a degree of quality assurance. For example, a collection of metaphors combined with guidance on which audiences they are likely to resonate best with could help scientists to communicate complex scientific ideas in a relatable way for a given audience. Given the dominance of PowerPoint in presentations, a freely accessible slide deck of IPCC key findings and graphs tailored to different sectors, policy areas or levels of technical competence could be an extremely popular resource. Further exploration of the types of resources that would best suit IPCC scientists' public engagement needs and the most useful formats for accessing that information 'on demand'

would be extremely informative for developing a communications strategy that is inclusive for all.

Coordinated translation support for scientists to communicate in their local languages IPCC authors needing to translate IPCC findings into languages other than the six official UN ones may face an additional practical challenge in retaining the agreed meaning. Some respondents to the survey expressed a desire for translation support from the TSU, e.g. template slides in different languages. While recognising that securing agreement on precise terms is a key element of the IPCC process, it is clear that this is a very real, practical barrier that authors face in undertaking public engagement. It may be useful for authors to connect in translation networks (including, potentially, government representatives involved in the IPCC process), which can collectively review translations against the IPCC Glossary definitions. In addition, groups of authors using the same translation may also help build local and national conversations about climate change. Further research to fully understand if there are region-specific public engagement needs, beyond translation, could also be an integral part of an inclusive IPCC communications strategy.

6 Summary

The current study has generated insights about how IPCC authors are engaging different audiences with climate change around the world. A global survey in which 107 WGI authors responded to questions about their public engagement activities captured, for the first time, a snapshot of the different approaches to engaging non-scientists with climate change in different parts of the world. As well as highlighting some of the more creative methods being employed by some individuals — from simulations of fictional worlds to song-writing and pub quizzes — the responses indicated that, in general, WGI scientists in all regions appear to take a fairly similar approach, speak to similar audiences, give similar presentations and experience similar concerns. The most common reported engagement activities are PowerPoint presentations about general climate science to a public audience. There are certainly widespread efforts to use relatable language and everyday metaphors to explain scientific concepts but there is a strong reliance on data-heavy graphics and quoting IPCC reports for an authoritative 'sound bite', rather than using effective visual communication and telling a more human story. Tailoring content to audiences is largely limited to identifying local impacts and simplifying complex ideas, rather than a careful consideration of unifying characteristics, communal values or concerns.

The purpose of this research — grounded in the social science evidence on communication and wider analyses of how and why scientists engage with society — is to provide a practical but robust example of how to build a bridge between research and practice of public engagement. While there is, on the whole, wide scope to enhance the effectiveness of IPCC authors' efforts to engage the public with climate change, there is also plenty to celebrate. There are clearly a number of individuals — past and present — who are skilled and confident communicators. Facilitating those authors to act as mentors for younger or less experienced colleagues, or those in the same part of the world, would have rapid and long lasting benefits that extend beyond the current assessment cycle. Supplementing peer-to-peer mentorship with dedicated training, frequent practice in a 'low-stakes' environment and tailored on-demand resources, including a free-to-access photo library covering a

comprehensive range of climate change-related themes, would ensure IPCC scientists can engage audiences with climate change — verbally and visually — in the most evidence-based way possible.

The principles for effective public engagement summarised here — and in the IPCC Handbook — are not restricted to a particular context or audience. Nor are they a definitive rulebook. The purpose of distilling these key principles is to provide scientist-communicators with the tools to adapt their public engagement activities to better meet their audience's needs and expectations. With people at the heart of the changes that need to happen to tackle climate change — at an individual and collective level — it has never been more important to ensure that all segments of society have access to 'trusted messengers' who can connect the dots between the scientific facts of climate change, their values and the things they care about. The potential role that scientists play in this goal of deepening public engagement with climate change is largely undefined. Ultimately, it rests on the individual scientist to decide. But there remains an opportunity and an obligation on all of us who seek to communicate climate change to do so in a way that respects the decades of expertise and experience that comes from psychology, behavioural science, cognitive science and other social science disciplines. Developing IPCC communications and engagement strategies that are based on academic rigour and dedication to the evidence base provides the best foundation for advancing not only global climate literacy but also action.

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Ethics approval This research was handled with due diligence by Climate Outreach with respect to consideration of ethical standards and GDPR.

Consent to participate All participants were provided with full information regarding the survey and required to indicate their consent to participate on this basis prior to submitting their responses — as per the statements included below.

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