Changing the Paradigm for Risk Communication: Integrating Sciences to Understand Cultures

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Abstract

This paper uses case studies from around the world to examine the integration of social and physical sciences in service of risk communication. It argues for a holistic view of risk from assessment to communication, suggesting that post-normal science as applied in risk assessment works best when both physical and social sciences are involved throughout. The involvement of social sciences in risk assessment can significantly improve the communication of risk both to stakeholders and to wider communities. This is in part because science itself has cultures and it approaches risk in different ways according to those cultures: some scientists prefer deterministic approaches and others argue for probabilistic ones, for example. These scientific debates have implications for risk communication – shown dramatically in the L'Aquila court case, for example. The paper considers case studies from the Caribbean, Latin America, East Asia, India and others to propose a framework for the provision of expert advice to governments and the subsequent communication of risk to populations. It also considers cultural aspects that differ between regions, as communication of risk may be diverse even in neighbouring countries affected by the same hazard event but who assess and respond to risk differently. Complex and systemic risks, such as those considered by the Sendai Framework, require consideration of the effect of international borders on public receipt of risk messages: risk communication is not one-size-fits-all. Furthermore, research has shown that risk perception is not clearly linked to people taking action (the "risk perception paradox"). Empowering or motivating people to act is thus also a function of the risk communication process, and greater attention is needed to the cross-scale social, political and institutional factors that support or inhibit the relative agency of risk management stakeholders (including the public) to respond to known risks and the relative prioritisation of one risk over another. Thus, the paper argues for a paradigm shift away from the old model of risk communication as a bolt-on to risk assessment and decision-making, towards an integrated and holistic approach to risk communication.

Introduction

This paper uses case studies from several recent research projects to understand the processes of risk communication from the identification of hazards through to decision-making and community response. It does so drawing on literature from disaster research, science studies and human geography, to provide a framework for holistic risk communication across disciplines. In an era of post-normal science, where the questions that science is increasingly required to answer force it to move beyond its traditional remits, there is an increased pressure on scientists to communicate uncertain and sometimes contested results. Post-normal science (Funtowicz and Ravetz, 1993) involves so-called "wicked problems": those that are highly complex and uncertain. Many of the disciplines involved in disaster risk research for early warning encounter these problems regularly: this is "mode-2" science - science that is primarily aimed at responding to questions from society, rather than following the precepts of "blue-skies research" (Gibbons et al, 1994). Funtowicz and Ravetz (1993) suggest that post-normal science requires an extended peer community in order to ensure that the social dimensions of risk are managed effectively. This is consistent with the arguments of scholars in Science Studies and Environmental Social Science (e.g. Stirling, 2008; Pidgeon and Fischoff, 2011).

The recent court case in Italy following the L'Aquila earthquake of 2009 has demonstrated the importance and the political and cultural complexity of risk communication (Alexander, 2014; Scolobig et al., 2014; Donovan and Oppenheimer, 2015; Benessia and De Marchi, 2017). Six seismologists and a local official from civil protection were charged with negligent manslaughter after the earthquake. Analysis of the court documents and media reports at the time demonstrates the challenges that arise when non-scientists explain scientific advice in complex political, institutional and cultural contexts, and when authorities anticipate popular responses to advice and uncertainty, and shut down rather than being transparent (Benessia and De Marchi, 2017). Post-normal science, operating under high uncertainty and concerning "wicked" problems, requires a broader expert community to be involved.

One of the often-cited challenges for risk communication is the diversity of approaches towards it. If social scientists are consulted at all, they tend to be involved in the latter stages – taking the scientific information and/or a decision and conveying it to citizens. Many risk communication studies focus on risk perception, helping to understand the diverse ways in which people make sense of risk. However, this has repeatedly been shown to be inadequate in motivating people to take action (Wachinger et al., 2013) – perhaps because this approach has tended

to assume that risk perception can be "corrected", rather than using the information to enhance inclusive decision-making. Furthermore, scientific reports and hazard maps are often created without engagement with local cultural experiences of the environment – they are derived rather from macroscale scientific cultures that show regional variations but remain removed from local contexts (Haynes et al., 2007a). Building on work in science studies in particular, we argue that these conclusions suggest that integrated social and physical sciences should be involved in every aspect of the risk management chain, from risk assessment to mitigation, to ensure effective risk communication. Ultimately this change of paradigm provides an entry point towards more sustainable pathways, consistent with the Sustainable Development Goals (2015-2030).

Background

There are numerous approaches to risk communication, many of which are drawn from social psychology and quantitative social science. Risk communication has been shown to be affected by format of information, by demographics of the "readership", by the assumptions of the originators and many other factors (Slovic, 2000; Slovic, 2016; Slovic et al., 2004; Eiser et al., 2012). Much research in the effectiveness of risk communication is quantitative. This can allow the measurement of many views, but, as noted by many authors, also limits the scope for (i) detailed explanation of those views and (ii) cultural diversity that may not be readily measured in a survey (Pidgeon et al., 2003; Slovic, 2016) and (iii) awareness of the political context and environment. We therefore caution against an approach to risk communication that is *purely* based on behavioural science, for reasons that will become clear in the next few sections of the review.

A very influential and significant approach to risk communication is the "mental models" approach (Morgan et al., 2002). This approach involves interviews and participatory research to understand the ways in which risk is understood as a "mental model" or map in the minds of people. Within this view, risk communication seeks to "correct" those models. An issue with the approach is that it suggests that expert perceptions of risk may be more "accurate" than lay perceptions, implying that there is a "correct" perception of risk, which is disputed by those who emphasise that even with a high perception of a risk, action is not guaranteed, and that actually context is more important in risk communication (Gaillard, 2008; Lindell, 2013).

This paper argues, drawing on examples from disaster studies and STS, that risk communication should be transdisciplinary and deliberative: it is not linear but rather should be informed by and through engagement

between authorities and audience. Understanding the vulnerabilities, values and culture of the audience is critical – not least because these factors will affect how advice and warnings are interpreted, and whether or not they are acted upon.

This section of the paper seeks to contextualise the subsequent case studies in the academic literatures that pertain to risk communication. Initially, it outlines a metaphor of reading that is used throughout the paper for clarity and also for illustration. It then discusses a range of pertinent topics in the formulation of messages for risk communication, from the production of knowledge about risk to its communication and perception.

Authors and readers in dialogue

Risk communication can be thought of as a reading process: the authors devise a message (which may be translated by an intermediary) and it is interpreted by the reader. In this paper, we will consider both elements of this process – both the work that goes into the creation of a message (how the authorship/translation is assembled), and how the reader interprets the message and acts (or not) on it. Thinking of risk communication in this way is useful because it highlights the diversity of roles, but also that work is done on both sides – the reader interprets the message in their own cultural, individual context, and has to do some imaginative work to turn words or maps into a mental conceit of how the disaster might unfold or affect them. They may also feed back to the author that the message is unclear, either by directly challenging it, or by ignoring it: they participate in the formulation of the message directly and indirectly. How authors imagine their readership is also important: writing a paper for a scientific audience differs from writing a children's science book. The mental world – and the cultural, social and political contexts – of the authors are also important in determining what goes into the book. We will not consider translation in detail – but we note here that the involvement of intermediaries as translators is inevitably and invariably problematic, because very few if any languages translate perfectly word-for-word: translation changes meaning, even subtly. This was part of the problem at L'Aquila.

The reason for adopting this metaphor is that it is more flexible than thinking of risk communication as top-down or bottom-up – it has no fixed direction. Risk communication involves multiple flows of meaning-making, interpretation and re-interpretation. The metaphor of authors and readers also recognizes that there is much to learn about risk communication from literary studies of how people understand and translate texts – something that is largely absent from the risk communication literature. In literary studies, there is a spectrum between

theories that focus entirely on the author – arguing that the "true" meaning of the text is what the author intended – and studies that focus instead on "reader response", arguing in the most extreme cases that the author is irrelevant (Barthes, 1994). This spectrum is useful in understanding the literature on risk communication because it opens up the process to the worlds around the various actors – the factors that affect how readers respond and how authors "intend" a message to be understood (Foucault, 2001; Livingstone, 2005) – and it also emphasizes the active role of people in the process (Scolobig et al., 2015).

An example of the significance of reading is provided in the literature on the reception of IPCC reports: while some literature focuses on the ways in which the IPCC manages uncertainties (Patt, 2007), others have studied the communication techniques that the IPCC uses (Mahony, 2015; Schenk and Lensink, 2007), and the ways in which reports are interpreted (Ha-Duong et al, 2007; Nerlich et al, 2010): the communication of scientific information that is uncertain is highly complex. Furthermore, the ways in which people interpret information can differ significantly depending on context. Taking another example, Livingstone (2005) shows how Darwin's theory of evolution was interpreted differently across different scientific communities ("readers") of the US, New Zealand and Russia therefore demonstrating the significance of local context to people's understanding of (scientific) meanings.

In the context of disaster reduction, the "authors" are typically scientists and/or decision-makers, who may be working together or separately. For example, a volcano observatory may submit a report to the civil protection, who then assess, based on their understanding of the report, whether or not an action is needed. If it is, they may, for example, raise an alert level and order an evacuation. Alternatively, the volcano observatory may raise the alert level themselves – the responsibility for this practice varies geographically (Fearnley and Beaven, 2018). In interpreting the warning, whatever its format, residents are likely to want to know why it is being raised – evacuating is very inconvenient and costly – and so they are likely to question the science and the motives of the civil protection, scientists and others involved (Donovan and Oppenheimer, 2014). The authors may anticipate this in their formulation of both scientific advice and warnings – and how these are communicated and by whom varies with context. Furthermore, social vulnerabilities and values may have significant impacts on how messages are received and whether or not they can be acted upon. Already, the complex circularity of flows of knowledge and warnings is becoming clear. In the next section, we discuss this in relation to science studies work on scientific advice to policymakers – an important part of risk communication – before moving on to look at communication with the public and across the population.

Authors: Risk communication in scientific advice to policymakers

The linear model

The linear, or technical-rational, model for scientific advice basically suggests that scientists do the modelling of the hazard, policy makers make decisions and the public acts in response (Owens, 2015). The quality and form of risk communication is likely to depend on the motivations of risk managers and decision-makers. Wardman (2008; building on Fiorino 1990 and others) distinguishes three common imperatives: the normative imperative (the view there is inherent good in publics being aware of risks affecting them, and an argument for deliberative and democratic decision-making); the instrumental imperative (that planned risk communication strategies can help decision-makers manage public responses to known risks); and the substantive imperative (that the quality of decision-making is improved through better availability of knowledge). The relative influence of these imperatives has important implications for the balance of power and knowledge that are held respectively by the writers and the readers of risk messaging – and who those writers and readers are. This varies between contexts, and may be culturally mediated. It may also be affected by level of development and the available resources for science and decision-making: remits and responsibilities vary significantly with geography.

The linear model is a heavily idealized vision of what happens in reality (see Beck, 2011) – rather, knowledge travels. The scientific knowledges (or estimates/probabilities) that are produced by scientists have to be dealt with and understood by both of the other groups (who are in reality made up of multiple stakeholders with multiple interests). This typically results in misunderstandings, biases and complications in how scientific knowledge is deployed – and thus scientists often find themselves and their work heavily politicized (as was the case in L'Aquila and elsewhere). The road-map of Gaillard and Mercer (2012) is useful but oversimplifies the knowledge processes – questioning and re-interpretation occurs between, across and within knowledge, dialogue and action, producing a *landscape* of complex interactions and interpretations (we would add diagonal and feedback arrows to the road map!). The impact of context on how knowledge is interpreted within dialogue (and therefore whether it is acted upon) is critical in this, and produces considerably complexity. Indeed, as Gaillard and Mercer (2012) note, there may be latent power dynamics within the communication process that have to be managed, and there are also particular institutional knowledges that communicators are not always conscious of, but can undermine effective transmission of messages. It is thus important to integrate different kinds of knowledge whilst also allowing updates to that knowledge through dialogue and learning from past events. As DRR moves to

focus more and more on early warning systems and technology, these issues will increase. It is critical that DRR learns from the wider literature on scientific advisory practice and policy making – and also that social scientists in DRR, who have considerable experience in integrating diverse knowledges (e.g. Mercer et al., 2010; Cadag and Gaillard, 2012; Naess, 2013), work closely with physical scientists who are involved in warnings.

A note on geographies and genealogies of science

The practice of science in meteorological offices, geophysical observatories and geological surveys differs geographically (Donovan and Oppenheimer, 2015b; Powell, 2007), and serves different purposes. Institutional responsibilities vary, as do resources and expertise. This means that it is important to understand the institutional and intra-science culture (e.g. Hulme et al 2018) as well as the cultural assumptions of readers. These dynamics tend to be historically derived – they emerge from institutional histories that may be linked closely to political histories. For example, geological surveys may be part of home ministries or defence ministries, and may be limited in their ability to share data as a result of past concerns. This can lead to major curtailments in resources for collaboration with geological surveys across a national border, or with other institutions that would increase capacity. The landscape of scientific advice is itself highly complex, even before it encounters government agencies and their variability, and this complexity can affect communication within and beyond science.

Readers: Risk communication research challenges

Geographies of risk communication studies

Risk communication studies have been shockingly Western-centric, with an increasing focus on hurricane risk in the USA in recent years (especially since Katrina in 2005). Some of the most influential early risk communication scholarship (e.g. Slovic 1987; Kasperson and Kasperson 1996) focused on anthropogenic techno- or bio-centred hazards such as nuclear power, genetic modification and environmental contamination – all hazards that (until recently) have been viewed as more relevant in developed contexts (though they affect developing contexts just as much, if not more). The focus in Western-centred risk communication scholarship has tended to be on understanding, predicting and using communicative strategies to manage “irrational” public responses to perceived hazards (the public are assumed to have access to knowledge, and there is a focus on the technologies

of knowledge transfer). Furthermore, such studies often assume a realist ontology – that there is a "real" value for risk and that risk perception can somehow be corrected. Despite the growing interest in the role of emotion or "affect" in shaping how publics receive information (e.g. Slovic and Peters 2006), the focus often remains on how to best package a known and quantifiable risk.

Disaster risk reduction (DRR) scholarship and practice, in contrast, came more from international development – focusing more on reducing risk through alleviating poverty but also through assessment of different (non-technological, natural) hazards. A knowledge-transfer model has also often dominated in DRR (e.g. Cutter et al., 2015; Gaillard and Mercer, 2012), but with a different rationale: that many members of the public in low-income countries are illiterate or lack formal education, don't have access to scientific knowledge, and/or prioritise traditional forms of knowledge in their decision-making. In other cases, the model advocated is entirely linear, with physical scientists seeing their role as purely to inform policymakers, without taking care to work with communities (e.g. Marzocchi et al. , 2012). Risk communication in DRR has often been rolled into the broader developmental focus on educating and informing, via expert-led awareness-raising programmes. However,there has been a consistent push in recent years towards integrated approaches to technical and local knowledges, seeking to overturn the assumption that Western forms of knowledge and understanding are inherently superior (Mercer et al. 2010, Gaillard and Mercer 2012). Scholars have also called for the recognition of everyday risks (Ziervogel et al 2017; Bull-Kamanga et al 2003) and underlined the importance of considering the social effects of DRR, such as in the case of informal settlements (Fraser 2017).

The role of communication in the production of risk – as well as being a solution to risk – has also been neglected in DRR. This is because whilst poverty is known to be the most fundamental driver of risk (Wisner et al. 2004), it is also linked to poor communication. Exclusion from formal risk communication channels is common where investment in communications infrastructure has not been forthcoming, and/or the upkeep of these is lacking – common for example in informal settlements or isolated agricultural communities. Poverty also undermines access to risk information where communications rely on private television, radio or mobile phone ownership. Intersecting with these issues, social-political structures can serve to disproportionately preclude socially, economically or otherwise marginalised households from access to (or ability to act upon) risk information, depending on their status and agency within society. In sum, poor communication typically impacts the more remote, vulnerable and isolated individuals and communities the most, and thereby exacerbates their vulnerability. Poor access to risk communication infrastructure (e.g. early-warning systems) may equally be the

result of poor governance, of active discrimination against certain groups, or of poor or unequal investment in infrastructure.

Hurricane Katrina stimulated a gear-shift in both viewpoints (i.e. those focusing on both developed and developing contexts). In Western-oriented risk communication, it stimulated a shift toward greater focus on socio-political drivers of risk, because it was the first time poverty was clearly seen as a driver of risk in a developed country context (the USA); in DRR, it prompted a realisation that it is not only developing countries where vulnerability exists. Nevertheless, issues around poverty and governance are still not fully addressed in studies of risk communication, because such studies are still dominantly based in the developed world. One of the major issues with this is that risk communication studies, being so geographically focused on the developed world, also frequently fail to take into account cultural differences in the interpretation of messages.

Timescales of risk communication

There are essentially two types of risk communication – that which takes place over time (for example, because an area is at high risk of flooding) and that which takes place in a crisis (when flooding is imminent). Both of these are relevant in DRR – particularly as scientific ability to map and assess hazards is improving rapidly. However, their outcomes are very different – long-term risk communication is focused on empowering people to mitigate hazards by reducing their vulnerability through land-use decisions, building codes, insurance cover, planning and design. It can also include ensuring that people are aware of the plans for crisis management – such as knowing what the alert levels for a weather event actually mean. Crisis communication often takes place through boundary objects (Star and Griesemer 1989) – alert level systems or weather maps that enable the rapid communication of complex knowledge, sometimes tied into particular decisions. It may also be the communication of a political decision, such as an evacuation order or curfew. Boundary objects are useful in allowing multiple interpretations to co-exist, therefore allowing collaboration, but can also erase conflicting meanings and values, rendering invisible the politics of risk communication.

Politics of risk communication

A key reason why a linear, positivist model of risk communication fails to explain risk behaviour is that it assumes knowledge production and dissemination occurs in a political vacuum. In reality, political questions arise

at every stage: in the authorship (what forms of risk are known and by whom; which hazards receive more/less funding for research; which universities, labs, scholars have closer governmental connections and are better able to influence decision-makers; and in whose interest is it to accentuate or attenuate particular forms or levels of risk, who is included or excluded?), circulation (how interested is the mass media currently in any particular form of risk; who has access to what forms of knowledge; what forms of translation may be involved, and who influences them?) and reading (are publics capable or motivated to hold responsible stakeholders to account?) of risk information/messaging.

Unfortunately, when funds and capacities are finite, difficult decisions have to be made between competing interests, priorities and values (e.g. Pelling, 2011a). Whose voices have priority or have greater influence in risk-related decision-making is in all cases a function of politics (both small 'p' and big 'P'). The capacity for risk communication strategies to reflect and reproduce underlying politics was emphasised, for example, in the case of Hurricane Katrina, where politicians were criticised for not having prioritised upgrades to key flood defense infrastructure in low-lying areas, and the inadequate post-disaster communication and emergency response in certain parts of the city was attributed to those communities' relatively low socio-economic status (Squires and Hartman 2006; Klein 2008). By assuming a values-neutral line of decision-making, a positivist ontology may mask politically-motivated action, and fail to explain why particular risk decisions are made or understand how publics respond to them.

Formats in risk communication

This section briefly outlines some of the boundary objects that are used to facilitate risk communication. Its purpose is to demonstrate that there are many tools available, but that they remain contentious – each has limitations and has to be used with care. Ultimately what is regarded as a relevant format of risk communication also depends on the timescale that is considered, for example for longer timescales one could also include planning strategies or building codes. The examples listed here are therefore indicative of a wider range of possibilities.

Alert level systems

Alert level systems are used in many hazards communities as a way of communicating between elites (scientists, policymakers) and the public. They can take many forms, and may be adapted to the particular communities that use them – but they are also challenging to use effectively (Fearnley and Beaven, 2018; Winson et

al., 2014). Increasingly, alert levels are impact-focussed, as is the case with the UK Met Office's alert levels, for example (e.g. Stephens et al., 2012), which combines likelihood and impact in deciding a level. This is important in low-probability but high impact events. In general, alert levels are a rapid means of communicating a risk in formats that are generally well understood (Donovan et al., 2018), but they are often challenging to set and they are not "one-size-fits-all": colours, for example, have to be used carefully in diverse cultural contexts, and some hazards are more suitable for alert levels than others (Sorensen, 2000; Garcia and Fearnley 2012).

Probabilities

The use of probabilities in risk communication has been advocated by many scientists (Aspinall, 2011; Papale, 2017; Sparks and Aspinall, 2004). Probability has the benefit that unless it is 0 or 1, it cannot be falsified, so it provides some "cover" for scientists (Aspinall, 2011). It is also possible to use probability distributions to approximate scientific uncertainty (though not social uncertainty). However, there is also widespread evidence that scientists, decision-makers and the public do not understand probability very well (Donovan et al., 2015; Gigerenzer et al., 2005; Gigerenzer, 2007; Hoffrage et al., 2000). This has led to various approaches to visualization of uncertain information – and this is a rapidly growing area of research (Spiegelhalter et al., 2011). Another issue with probability is cultural context: while probability and probabilistic language is used frequently in the Anglophone West, it is much less common in other parts of the world - and while there is a perception among scientists that probabilities are desired by governments (e.g. Papale, 2017), this is rarely the case in practice outside of the West.

Hazard maps

The use of hazard maps to communicate risk and hazard is another rapidly expanding area of research in the disaster science community. While there is evidence that people struggle to interpret them (e.g. Haynes et al., 2007a), there is ongoing research into the best methods for producing hazard maps that people can understand (e.g. Thompson et al., 2015). Many populations are accustomed to weather maps, for example, and so can interpret some level of map-based warning. However, hazard maps can only be communicated on visual media, which can limit their usefulness. Moreover, although often pictured as neutral and objective, maps are always embedded into wider socio-political processes and can be highly contested (Peluso 1995; Leuenberger & Schnell 2010; Kitchin 2012). Linear models of risk communication, assuming that if things are explained clearly then people will understand and adopt "the truth", cannot appropriately explain such contestation and miss out on the wider range

of reasons that trigger these contestations in the first place. Like books, maps can be written and read in many different ways.

Social media

There has been an explosion in the use of social media for risk communication – for example, to collect 'real-time' data on risk exposure, or enabling users to share updates on preparedness or emergency response procedures. Social media can expand the reach of risk communication to marginalised communities and provide new data via open source (Sen, 2018). This can be very effective provided that connectivity is not significantly affected by the hazard itself (e.g. Veil et al., 2011). A significant issue with social media is risk amplification or attenuation (Pidgeon et al., 2003): the reaction of "friends" or other trusted groups can affect people's interpretation of information. This is also true of news reporting. The pervasive power of social media in risk communication is currently the subject of much research; for example regarding the ways in which alerts given by actors on social media interact with formal institutional channels.

Bulletins

Bulletins may be issued on the radio, television, by SMS or online, and range from a few lines to complex weather reports. They play a key role in regular reporting from scientific institutions both to the public and to decision-makers. In some contexts, sirens are also used to alert populations to imminent hazards. In this case, it is essential that people know what to do when the siren is sounded.

The context of communication

In the final section of the literature review, we briefly expand on some of the key contextual factors that affect readers.

Institutions and trust

Trust in institutions and groups can be a major factor in risk communication. There have been extensive studies on the trust in different groups and how this affects risk perception and communication (e.g. White et al., 2003; Eiser et al., 2009, 2012). In particular, there is strong evidence that scientists are well trusted, while trust in governments is highly variable (Haynes et al., 2007b, 2008; Donovan et al., 2018; Eiser et al., 2015). Interestingly, people tend to gain information from the news media, but report their levels of trust in it as low (e.g. Donovan et al., 2018).

The basis of trust is variable, but often relates to perceived motivation as well as to knowledge and expertise (Eiser et al., 2009; Donovan et al., 2018): people who are viewed as having financial or political motives are less trusted. Qualitative studies have demonstrated that how knowledge claims are tested also differs depending on cultural context: Sheila Jasanoff, for example, has shown very different approaches to knowledge testing across Europe and the USA (Jasanoff, 2005). She refers to this knowledge-testing by citizens as "civic epistemology", and demonstrates its complexity: people vary in what they value in those who produce and mediate knowledge, and in how those values inform their assessment of the knowledge itself.

Institutions can also play an important role in the mediation of information. The transparency of institutions – particularly those directly linked to government – is highly variable, and a lack of transparency can also affect trust in information: if people suspect that information is being withheld in an institution, trust breaks down. Again, this was relevant in the L'Aquila case and its aftermath (Benessia and De Marchi, 2017; Donovan and Oppenheimer, 2015a).

Whether risk information is trusted or not is not static, but a function of dynamic social relationships (meaning, I may not inherently distrust the government but this belief is likely to be formed over time as a result of my particular interactions with government agencies). Trust is therefore likely to change over time and differentially between groups. This can be understood as a function of the implicit "social contracts" that exist between social actors (including, but not limited to, state and society) – these describe the distribution of rights and responsibilities that is expected, claimed or legislated, and by whom (Pelling, 2011b; Blackburn and Pelling 2018). If a government fails to protect its citizens from a known hazard, or to a level or in a way considered legitimate by the public, then the social contract is broken and citizens are likely to seek protection through other channels.

In most cases there are multiple social contracts at work – all in tension with other another (Blackburn and Pelling, 2018). In Jamaica, for example, politicians are historically not well-trusted by the public, and many people (particularly the urban poor) rely instead on community networks (even local gang-leaders) to provide stable governance and security. The perception of politicians as clientelistic and self-interested results in low public participation in government-funded risk management activities, e.g. preparedness drills and meetings (Blackburn 2014). This serves to undermine risk management during a flood event, since many people are not familiar with formal risk management procedures. Greater understanding of the distance between people's expectations of what risk management systems are needed (imagined social contracts) and the extent to which these are being met (practised social contracts), could help governments better understand the conditions under which trust will be

broken (Blackburn and Pelling, 2018). This could help them design better risk communication strategies that hold public attention and trust.

Cultures

Culture and world view are major factors in understanding risk – indeed, the idea of "risk" is not compatible with all belief systems. For example, many monotheistic religions believe that God is ultimately in control – they do not experience ontological risk, but can be persuaded to act on epistemological risk (the fact that while God knows the future, they do not know it themselves, and can take action with free will under God to avoid harm). Cultural studies of risk perception have demonstrated the importance of understanding culture and ideology as key features of risk perception (Douglas and Wildavsky, 1982; Kahan et al., 2009). While many of these studies are quantitative, work in science studies (e.g. Jasanoff, 2005), the anthropology of disaster (e.g. Hoffman and Oliver-Smith 2002,) and DRR (e.g. Kruger et al. 2015) also increasingly demonstrate the central significance of culture in the social construction of risk.

Trust is also important here: science itself has cultures and cultural attributes, and scientists sometimes struggle to trust the public, just as the public may not trust institutions (Donovan et al., 2014). Assumptions made by the scientific community can generate a mismatch between the belief systems of authors and readers, especially when it is across cultures. When messaging does not resonate with local priorities, values, everyday norms and practices, this adversely affects risk communication. It can even exacerbate risk, for example where a felt mismatch between author-reader belief systems magnifies or legitimizes an existing distrust in authority. Hence, it is important that risk communicators understand indigenous belief systems and take them seriously (e.g. Borie & Hulme, 2015; Mei and Lavigne, 2013).

Demographics

Many studies have found demographic patterns in understanding risk perception and communication and acting on it. This ranges from societies where women generally cannot read an SMS and are therefore more vulnerable, to societies where the elderly are more vulnerable because they lack access to social media, to cases where men tend to be more confident in their ability to take action than women. Factors such as education level, job type and social caste can also affect risk perception and access to information – but there are considerable geographical variations. For example, in India, the fact that more women died in the Indian Ocean tsunami was

attributed partly to the fact they had not attended public disaster preparedness meetings and/or felt fearful to evacuate their houses when the warnings came since the male head of household was at work (pers. communication, 2018 [S. Blackburn fieldwork in Tamil Nadu]).

Risk ranking

Another key concept in mobilizing action in response to risk communication is risk ranking (Fischhoff and Morgan, 2009). People who are struggling to find food to live on will naturally be less concerned about low-probability tsunami events, for example. Furthermore, those whose children are in school when a tsunami warning is issued may choose to take the risk of going to the school to get the children because they regard the risk of losing their children as more significant than the risk from the tsunami. Risks may be ranked because of need and vulnerability, or because of personal values and beliefs.

Civic agency

People's felt agency (capacity to influence, self-efficacy) also plays a very significant role in determining risk behaviours. This is about more than knowledge: if individuals feel they lack the capacity, knowledge or social networks to support them in (for example) evacuating their home, then they are less likely to take action. Studies have shown that the relationship between citizens and the government (and other emergency response or disaster management agencies) during normal times plays a major role in shaping self-efficacy in disaster scenarios (Blackburn, 2014). This is because those relationships affect how much choice and agency people feel they have to determine their exit from risky situations or behaviours. If people feel marginalised or not prioritised – which can be the effect when they are not given a voice in decision-making, or they feel their voices are ignored – they are likely to disengage from formal processes and are less likely to respond positively to risk communications coming via formal channels (Blackburn 2014, 2018b). This is a strong argument for bottom-up community participation and consultation to be normalised as part of pre-disaster risk communication activities.

Literature review: conclusions

The literature discussed briefly in this section demonstrates the complexity and breadth of risk communication: it is not merely the last part of a process, but occurs throughout risk assessment, management and dissemination – with each of these processes drawing on the same original knowledge base. The fact that the knowledge travels, and is read differently across diverse audiences, strongly suggests that robust risk

communication that can withstand social questioning must be built on protocols that are derived with the knowledge itself, paying attention to relations between authors and readers. Involving citizens and social scientists in planning and in knowledge production – genuine co-production – can facilitate this (Lane et al., 2011). Ultimately, reducing the risk from disasters requires the effective communication of warnings that are useful and useable for populations, and that meet them in their context. If people receive a warning but have no power to act on it (e.g. because they lack transport, or are not also given advice on what to do), then the warning will be ineffective. If they lack trust in the source of the warning, or cannot understand it, then similar problems arise. This also applies to advice about mitigation of disasters in the preparatory phase – people need to have capacity to act, and the formulation of warnings and advice should therefore be collaborative with populations.

Case study evidence

This paper draws on five case studies to inform its argument. Much of this research was conducted by the authors, but we also draw on the wider published literature to contextualize the case studies.

India: a case of social-technical disconnect

These findings draw on unpublished data collected by S. Blackburn in 2014 and 2018, drawing on interviews with disaster management officials and residents in tsunami-affected villages in South India (Blackburn, 2018b).

The Government of India's investment in disaster management has increased dramatically over the past two decades, stimulated by three large-scale disasters: the Orissa "super-cyclone" in 1999, the Gujarat earthquake in 2001, and the Indian Ocean tsunami in 2004. The tsunami was particularly influential owing to its vast magnitude and spread. It occurred early-morning on 26th December 2004, generated by two major submarine earthquakes off the coast of northern Sumatra. The waves affected more than 2250 km of coastline in India, crossing Tamil Nadu, Kerala, Andhra Pradesh, Pondicherry, and the Andaman and Nicobar Islands (ANI) (Srinivasan and Nagaraj 2006; UNTRS 2007). Over 12,400 died and displacement was highest of any tsunami-affected country (estimated 647,599) (UNTRS 2007).

The high mortality was attributed to the fact very few people (including government agencies) had heard of a tsunami before, and there was no emergency warning procedure in place. Nevertheless the effects were not uniform: social norms and the availability of information played major roles in determining uneven geographies of

impact. Tsunami impact was not only a function of differentiated access to information, but also differential felt capacity to act upon it.

Key findings include:

- Mortality was highly gendered, with women affected far more badly than men (as outlined in the literature review, under Demographics).
- In the Andaman and Nicobar Islands there were reports that a group of indigenous tribespeople in the Andaman and Nicobar Islands survived the tsunami because their ancestral storytelling had preserved the knowledge that when the ocean recedes unusually far, a large and dangerous wave will shortly follow (Misra 2005; Lauer 2012). The community survived by climbing trees; however many non-tribal people sadly did not since they had not been educated about tsunami risk in their formal education, and followed the ocean out when it receded.
- Alternative – informal, traditional – forms of governance played an important mediating role in the management of the tsunami aftermath. In many traditional fishing communities in Tamil Nadu and Pondicherry, village-level governing bodies called *panchayats* have much higher levels of trust and engagement locally than the formal government does. Post-tsunami, the *panchayats* acted as a go-between the formal government and the local people, e.g. distributing government-provided materials, coordinating the allocation of shelters, negotiating with the government and taking decisions on behalf of their village.
- After the tsunami the Government of India enacted the Disaster Management Act and established a national-level body called the National Disaster Management Authority (NDMA). There has been massive investment in early-warning technologies (e.g. INCOIS) and sophisticated communication networks established around disaster control centres. However, these are not always well-connected to communities. For example, in coastal villages in Tamil Nadu and Karaikal, the loudspeakers installed to disseminate risk warnings were observed to malfunction regularly in the field: during one interview when they went off, local people remarked, “that happens often, they make noise, we just ignore it now”.

The Indian case shows the importance of political context, social norms and culture in shaping risk behaviours, and highlights the need for disaster governance to be sensitive to these. It is the government (and scientists’) responsibility to reach out to all groups and communities, to actively seek to understand their needs,

knowledges and priorities, take these into account and design risk communication accordingly. Ignoring differential needs and risk behaviours will lead to risk management strategies that not only fail to adequately predict public responses, but also reproduce the marginalisation of vulnerable groups. Technological innovation and government investment is not sufficient if messaging does not reach vulnerable people, and if procedures or relief operations do not recognise and work with existing social norms.

Montserrat: a colonial crisis

The volcanic crisis on Montserrat commenced in 1995 and continues to the present day, although no juvenile lava has erupted since February 2010 (there is still substantial gas emission). The eruption has inspired a vast amount of research, and a summary is given here, focusing particularly on risk communication. The research cited was based on surveys, interviews and participant observation (Donovan et al., 2013; Donovan and Oppenheimer, 2014; Donovan et al., 2012; Donovan and Oppenheimer, 2015b,c).

Montserrat is a UK Overseas Territory in the Caribbean, and so is subject to UK sovereignty. It has a British governor and a small locally elected government. The Governor is responsible for foreign policy, internal security and safety, and the local government deals with health, education, tourism and other internal practical matters including disaster management, though the Governor makes emergency decisions in consultation with key stakeholders (Donovan et al., 2013).

Key results include:

- A breakthrough was made when scientists began to speak directly to the public, without “translators”.
- Technical scientific reports (including probabilities) were not comprehensible to the authorities or the public – many knew only enough to see if “numbers went up or down” rather than understanding what the numbers meant. They did not understand technical reporting or the uncertainties on the probabilities (and these uncertainties were often extremely substantial).
- Alert level systems evolved considerably in the early years of the eruption and until 2008 were ineffective and heavily contested, partly because of the perception that they were being rewritten to match the volcanic activity. After 2008, a new system was developed that managed the land reflexively and was malleable enough to allow for the complex hazards and rapidly evolving situation.

- Major issues arose because of the particular institutional, social and cultural context of a UK Overseas Territory in the Caribbean – perceptions of scientists and science were affected by a much wider set of discourses that had very little to do with the volcanic risk itself.

The communication of volcanic risk was only a small part of eruption management. It was undermined by high scientific uncertainty, and also by the reluctance of the British government to fund the island's recovery (or the science) adequately. The main conclusions from this case study are:

- The science itself is a relatively small part of the risk management process, and social scientists could beneficially have been involved from the start in understanding the institutional and cultural context of the new volcano observatory – particularly given the colonial context.
- The pioneering of belief-based probabilistic methods for risk assessment (driven by the culture of Whitehall/the UK) led to some very useful information for scientists and potentially for government, but many local actors did not find the formats useful or intuitive.
- The hazard level system used since 2008 has been a successful communication tool. It is difficult to judge how much its success is also amplified by the experience of the islanders with the volcano and the new institutional structure running the volcano observatory (since 2008 run by Caribbean institutions, in collaboration with French institutions until 2013).
- Science has cultures – this is widely acknowledged in the STS literature, but often not in hazards geography. The ways in which risk is perceived and assessed by scientists depends on their own backgrounds. It is approached very differently in different contexts and, on Montserrat, by the two different governments involved.
- Interviews with residents and with church leaders suggested that greater engagement with and respect for the churches and the strength of the Christian community on Montserrat would have significantly improved communication in the early stages of the eruption. The churches generally asked their congregations to support the advice given by authorities.

Experiences on Montserrat also speak into the different timescales of risk communication. The volcanic risk was known prior to the eruptions (Wadge and Isaacs, 1988), but was not communicated effectively to the government – one interviewee noting that this was because it was communicated in scientific language that local politicians could not understand. This highlights the importance of the parts of risk communication that take place within the risk assessment–risk management nexus, even before the public are told. Indeed, the discussions that

scientists have within observatories or meteorological institutions about how to manage risk and what text to use in a report or a warning to authorities are also a critical part of risk communication – and are affected by many of the same factors that affect risk communication and perception more broadly. Again, this emphasises the need for a reflexive and holistic approach.

Volcanic risk perceptions and risk communication in multiple contexts

A recent review of volcanic risk perception research drew out some important themes in risk communication in volcanic contexts (Favereau et al., 2018). It also demonstrates that these themes vary geographically. While once again the focus is mainly in the developed world, the study emphasizes the importance of trust in decision-makers and scientists, the significance of past experiences, place attachment and knowledge. However, it struggles to compare studies because their methodologies differ significantly. In this section, we review three studies that used a similar questionnaire format in Mexico, Iceland, the UK and Japan (Donovan et al., 2018; Donovan et al., 2017; Eiser et al., 2015). These studies were designed to analyse the experiences of populations (and in Japan, businesses) in volcanic crises, focusing particularly on their risk perception and trust. It should be noted that the samples for these studies were selected in different ways and that the crises they dealt with differed in important aspects, so the results are not nationally representative. They do however suggest useful patterns between the groups of people sampled.

Key results include:

- Trust in different groups was variable both in terms of its predictors and its distribution.
- Scientists were generally well trusted; governments less so; trust in family and friends was variable by location.
- The news media were not well trusted – but most people did get their information from this source.
- Knowledge is not necessarily the most important predictor of trust; perceived motive is also important.
- In Japan, there was a strong feeling that rumours about the volcanic crisis and a lack of official information, beyond the issuing of exclusion orders and alerts, were very destructive to local business.
- Trust in evacuation and warning plans was poor in general and many were not aware that they existed (if indeed they did).

This work suggests that there are local complexities in risk perception, trust and also cultural and socio-economic factors that affect the uptake of risk information. Many of these confirm the literature review above – that format is important, and that people are often completely unaware of plans in place (where there are any – in the case of the UK ash crisis, there were not). In each case, though, there are particular, event-specific issues that were significant. These involve governance issues, knowledge gaps, top-down decision-making that is not people-centred and economic interests.

Unpublished data (survey and interviews) from a similar study in Argentina backs up these results – people in Argentina did not trust their own government, but trusted the Chilean government more during the eruptions of Puyehue Cordon Caulle 2011-2012. They felt that Argentina was not prepared and that no one had warned them about the volcanic eruption until it was already underway. The impacts of the eruption close to the volcano on the Argentinian side were very significant (Elissondo et al., 2015; Wilson et al., 2013). The reason for failures in communication were partly lack of knowledge, resources and preparation, but also attempts to deny the seriousness of the impacts to preserve the ski industry. These were compounded by turbulent political and economic issues across state jurisdictional boundaries. In this case, the lack of transborder communication between Chile and Argentina was a complicating factor, and one that is highly relevant for many environmental hazards. Risk communication is clearly not just the last element of risk management – it must be engaged with throughout the handling of a risk, with awareness of social, political and economic influences.

Risk communication around weather forecasting in the Caribbean region: Hurricanes and beyond

There is a heterogeneity of situations among Caribbean islands when it comes to weather services in terms of knowledge, technical infrastructure, and capacity (e.g. Foley 2017). This is largely related to the history of the region which encompasses both sovereign islands (Cuba, Jamaica, the Dominican Republic) and overseas territories (Montserrat, Guadeloupe, US Virgin Islands) (see Mahony & Endfield 2017; Duverge 1995; Frayssinet 1993). For example, for Saint Martin, which is an oversea French territory, weather services are based in Guadeloupe, where there is an antenna of the French national meteorological centre. In contrast other islands have their own, locally based, weather services (e.g. Antigua, Cuba), some with forecasting capacity and some without (Dominica). Yet others depend on the meteorological bulletins of neighbouring islands (e.g. Anguilla depends on Barbuda); Saba and Sint Eustatius depends on Dutch weather services. Some islands are equipped with radars (e.g. Cuba, Puerto Rico, Martinique), providing a view different from the satellite one and improving the accuracy of

predictions locally, while others are in project (e.g. in the Lesser Islands). Despite these differences, several local and regional scientific cooperation efforts exist (e.g. Taylor et al 2013).

At the institutional level, the World Meteorological Organization (WMO) committee for region IV (aka hurricane committee)[1] plays a key role in harmonizing processes around weather forecasting and warning in the region while providing a space for multiple concerns to be addressed (e.g. WMO 2018). With regards to hurricanes, the National Hurricane Centre (NHC), based in Miami, has been given key responsibilities by the WMO. Hurricane prediction, and risk communication associated with it, is affected by many factors. In the Lesser islands, Hurricane Irma (Sept 2017) was predicted two weeks in advance. In contrast, Hurricane Gonzalo (2014) was formed on a Sunday, the day before, and there was barely any time to warn the population - it was a lot worse than anticipated. Historically more efforts have also been put into the detection of extreme weather events, as opposed to other weather events (e.g. Pietruska 2016). However beyond extreme weather events such as hurricanes, meteorological events, which do not necessarily trigger a warning, routinely have harmful impacts in the region. Hurricanes with unexpected trajectories (e.g. Lenny in 1999) or whose trajectories do not directly go through these islands can trigger significant amount of wind and rain frequently leading to floods and/or landslides (e.g. heavy rains in Santa Lucia in 2013). In the context of the WMO, a pilot project has recently been adopted to address this gap: the Serious Weather Forecasting Demonstration project[2].

Key results:

- Political and economic reasons also explain why alerts are sometimes given at different times in two places. Alerts can be delayed to allow for the entry of a cruise boat or a plane. Some systems of 'Watch Out and Warning' are tighter than others. For example, on the binational island of Saint Martin (France)/Sint Maarten (Dutch), the French meteorological system uses a color code whereas the Dutch does not. It used to be the case but the colors did not mean the same in the French and Dutch systems

[1] http://www.wmo.int/pages/prog/www/tcp/HC-40.html (last accessed 06/08/2018).
[2] http://www.wmo.int/pages/prog/www/swfdp/ or http://www.cmo.org.tt/project.html (Last accessed 6/08/2018).I am particularly grateful to Jean-Noel Degrace (Meteorologist, Meteo France Guadeloupe) and Isaac Joseph (Meteorologist, Sint Maarten) for sharing their knowledge and insights on hurricane prediction and warning in the Caribbean region and on the WMO.

so Sint Maarten suppressed it. Coordination efforts are important to ensure that the information provided is consistent across places

- Attending to linguistic differences is particularly important in the Caribbean where multiple languages are spoken. Some islands (e.g. Anguilla) are already providing information is the three main languages (English, Spanish, French) but this is not the case everywhere. Communication between English and non-English speaking countries (e.g. Haiti, Dominican Republic) remains challenging. Semantic differences also need closer consideration.
- Communicating risk using probabilities & uncertainties to policy and decision-makers (e.g. 'there is a 20% chance of rain') is received differently across places. For example, French policy makers and operational are frequently uneasy with probabilities, and how to interpret them (Does it mean 20% chances of rain during the day? in a particular place? etc.). This explains partly why some vigilance systems can take several years before being implemented, generally in a reactive manner, after a disaster, more than an anticipatory one (e.g. on marine submersion). False alarms are badly perceived but normal when adopting a precautionary approach.
- There is insufficient warning system for these events which are not in the mandate of the NHC, and these are often harder to predict. It is important to realize that there are lots of different meteorological event. Floods, for example, are often overlooked and need to be better anticipated.

While scientific and technological investments help downscale and improve the accuracy of predictions locally (e.g. Cantet et al 2014; Giorgi et al 2009), a more holistic approach is needed. One starting point is to change the paradigm of weather prediction to develop impact-based forecasts and develop links with operational services. This requires a transversal institutional approach: for example, meteorological services would need to collaborate more with hydrological services. This also entails taking a step back from weather forecasting towards a more holistic and integrated approach, requiring multidisciplinary expertise (see also Duvat et al., 2017). In Saint Martin, Irma, which was well anticipated, recently made salient the lack of implementation of building codes and the need for a real planning strategy (PEARL 2018). This change of approach entails the study of governance systems to understand existing DRR practices and institutional deadlocks.

The power of Geohazard maps: Risk perception and socio-spatial exclusion in the Philippines

Situated on the 'Ring of Fire' and on the typhoon belt, the Philippines are particularly vulnerable to natural hazards including typhoons, tsunamis and earthquakes. In 2010 a National Disaster Risk Reduction and Management Plan (NDRRMP), organized around four pillars (Prevention and Mitigation; Preparedness; Response; Rehabilitation and Recovery), was adopted (Shaw et al 2017). In this context, risk communication has focused predominantly on natural hazards, also placing much emphasis on the predictive sciences and geophysical expertise. Detailed geohazard maps – e.g. liquefaction, storm surge, tsunamis – have been provided and largely circulated among institutional actors. Local authorities such as Manila City Hall, have invested in technological equipment to monitor disasters and individuals are encouraged to invest in survival kits[3]. Although the national regulatory framework on DRR recognizes the key role of local communities for risk reduction, there is a disconnect between the formalized institutional approach and local perspectives (e.g. Porio 2016; Kim 2015).

While geohazard maps account for geophysical risks, different approaches to defining risk exist and the perceptions and knowledges of low-income households living in risk areas are often overlooked (e.g. Haughton & White 2017; McEwen et al 2017). These communities may choose to live with risk, for different reasons including concerns over proximity of livelihoods and social networks (Morin et al 2016; Kim 2015). While often presented as neutral and objective, maps are inevitably associated with power and render visible some connections and concerns while making invisible others (e.g. Borie et al., forthcoming; Dovey & Ristic 2017; Harley 2009). Geohazard maps, for example, are frequently used to justify relocation. Yet, how people make sense of and experience risk in these areas is not easily understood via conventional risk assessment methods including geohazard maps. Alternative methods, including qualitative GIS or art-based methods, can usefully help capture and convey alternative understandings of risk, being complementary to conventional ones (Brown et al 2017; Heras & Tabaras 2014; 2016). The value of these methods is that they can open-up conversations between different actors and enrich possible interpretations of risks, hence making possible a more deliberative approach.

[3] http://cnnphilippines.com/lifestyle/2015/06/05/what-to-pack-in-a-survival-kit.html (Last accessed 6/08/2018)

Key results:

- Science and scientific methods are multifaceted and can both open up and close down governance options (see Stirling 2008). Using tools and methods (e.g. participatory mapping) that brings together different stakeholders help enhance conversations and governance options which have implications for the vulnerability and exposure of affected populations
- The focus on geo-hazards and the technical framing of risk management can exclude alternative understandings of risks and take priority over concerns such as poverty reduction and the well-being of marginalized communities. Such focus also sidelines the need for longer term planning (Borie et al., forthcoming; see also Shatkin 2004)
- Local knowledge (e.g. of flood risk) held by people experiencing such events is more extensive and accurate than initially assumed by experts and institutions. The importance of everyday risk, for people living in informal settlement in particular, is insufficiently recognized. There is a disjunction between the preoccupations of people living informal settlements, what they actually experience and how they are perceived and represented by institutions.

To capture and understand different perspectives on what risk means, diverse approaches combining both quantitative and qualitative knowledges are useful (e.g. McEwen et al 2017; Lane et al 2011). Some applications of science and technology can reinforce existing inequalities and marginalize communities. With appropriate institutional support, community-responsive adaptation, for example, can provide an opportunity to address the challenges of knowledge integration as well as social exclusion. Processes matter and deliberative spaces are key for inclusive and transparent risk governance. These allow revealing a wider array of perspectives, across different scales, while making possible different policy options and solutions.

Emerging patterns

Where does communication falter?

The UNISDR outlines four elements of early warning: disaster risk knowledge, monitoring and warning, communication and dissemination, and response capacity. We argue that good risk communication is a necessary part of all of these elements, and speaks across them. Disaster risk knowledge ideally comes before an event – it is the longer timescale – but it involves effective collaboration between scientists, decision-makers and populations

over long periods of time to build up trust and establish relationships that become critical in a crisis. The monitoring and warning element also involves significant communication, particularly between scientists and officials as decisions are made about any necessary action. The communication and dissemination of warnings is clearly central in this paper, but it is dependent on both of the previous two elements and on some understanding of likely response capacity as well.

Communication can therefore falter at any point in the early warning cycle. It depends on institutional and political cohesion, clear messaging, effective wider management of vulnerable populations and on trusted relationships. These are not trivial to accomplish.

Transborder issues

In several of the cases above, transborder events have been discussed (the volcanic ash crisis in Northern Europe, the eruption of Puyehue Cordon Caulle in Chile, hurricane warning in the Caribbean). This adds another layer of complexity to risk communication, because multiple nation-states are involved. Even within a country, however, a hazard event may involve multiple jurisdictions, such as state boundaries, and this can mean that different political systems and expectations are involved. Immigration and tourism can create additional challenges. The results in this paper provide some insights into the complexity of this problem, and a holistic consideration of risk communication for disaster risk reduction should acknowledge this challenge.

Solutions

How might we integrate some of the results in this paper into a framework for more effective risk communication? To break this down, we first summarise the results under “authors” and “readers”, before suggesting ways forward.

Authorship issues

It is clear from the evidence here and elsewhere that the production of risk information is not a linear one, nor is it straightforward: there is no one key approach that serves all circumstances. The most important result in this study is the need for listening: authors need to understand their readership in order to communicate – and this includes scientists understanding government decision-makers, as well as both of these groups having insights into

the publics that they serve. The need for community participation in decision-making is already well established in DRR literature (e.g. Ahrens and Rudolph 2006, Allen 2006). Lane et al (2011), for example, provide an innovative approach to risk management, involving the consultation of local people in the development of plans for flood risk mitigation in Pickering, Yorkshire (UK). It is clear from their study that the involvement of local people significantly enhanced the knowledges that were involved in risk assessment as well as allowing the inclusion of local values in the mitigation measures proposed. This holistic approach to risk communication is resource-intensive, however, and the challenges of participatory work are already established in the DRR (e.g. Cannon 2008), development (e.g. Cooke and Kothari 2001) and community-based resource management literatures (e.g. Blaikie 2006). It also relies on pre-existing local awareness and trust in formal deliberative spaces. Evidence from the Andaman Islands (South India) indicates that in contexts where communities are disengaged or otherwise cut off from formal lines of communication (or where democratic channels are dysfunctional or even absent), simultaneous efforts are needed to transform cross-scale communication channels in ways that foster more productive local participation in decision-making (Blackburn 2018a).

Monitoring institutions and civil protection agencies are frequently working under pressure in a disaster – many of the suggestions in this paper require input *prior* to disaster to ensure that communication is effective. Involving wider communities of experts, particularly from the social sciences, in the risk assessment process – so that social scientists are aware of the uncertainties inherent in the science, and also have time to work with populations on messaging – would facilitate communication. Scholars in science studies have advocated deliberative approaches to risk communication involving the presence of laypeople on committees, for example – but a less resource-intensive way of managing this would be the involvement of experts from other disciplines as laypeople, for example.

Another issue with the authorship of messages relates to narrow perceptions of what risk really is. The reduction of risk to a technical scientific issue that can be represented "accurately" by a probability can preclude effective communication because it does not take into account the values and beliefs of local people concerning not only the risk, but its likely impacts. It also fails to consider their ability to deal with the risk. Risk messaging has to include mitigation actions – there is no point in telling people that the river is going to flood if they do not know what to do in this eventuality, or if the proposed solution is not acceptable to them, reinforcing, for example, their

social exclusion . Again, this calls for a wider disciplinary scope throughout the risk assessment and management process.

Readership issues

Scientists often claim that people do not understand uncertainty. This may be true of technical uncertainties such as scientific error expressed as a distribution, but in the broader context, people deal with uncertainty on a daily basis – when crossing the road, applying for jobs, hoping that supplies will arrive on time. People do understand uncertainty, even if many do not like it very much. Careful explanation from a trusted group can ensure that risk is communicated effectively. Misunderstanding the readership and falsely anticipated their needs can be hugely problematic. Information campaigns that tell people what to include in an emergency bag can be effective – but long-term relationships that build trust are also important. Sometimes, the messenger needs to be someone perceived as impartial (like a scientist) rather than a political official: this depends on political and institutional contexts as well as on the local culture.

A further issue with readerships is the differential management of different hazards in different places – and the differential vulnerabilities involved. The US NHC, for example, is dominantly focussed on protecting the USA, but is also depended upon in the Caribbean for extreme weather warnings. Volcanic hazards in the Caribbean are dealt with separately. While civil protection agencies are generally responsible for all hazards, the rarer events tend to receive much less preparation and planning – as was the case prior to the eruptions on Montserrat, for example. As work in the Philippines and elsewhere shows, alternative approaches that involve the perspectives of community members in planning and are more holistic can be extremely useful for risk communication. Moreover, in addition to or in combination with participatory methods, using techniques that allow surfacing social concerns and perceptions of risk (e.g. via qualitative GIS or art-based methods) enriches conventional approaches.

Summary and ways forward

Authors and readers need to understand each other and themselves, not only in terms of the words but also what they imply about action. An important paradigm-shift has been taking place in risk communication towards participatory processes – but these are often challenging to manage in practice. We argue that involving social scientists throughout the risk assessment–management process can provide critical insights into a wide

range of challenges that arise in risk communication. Risk communication cannot be viewed as a bolt-on to risk assessment and decision-making: it is formulated within the risk assessment process, and that process must itself be reflexive – as emphasized in other fields (Jasanoff, 2003; Jasanoff, 2005; Stirling, 2006; Stirling, 2008; Stirling, 2010). To expand on the author/reader metaphor, this does not mean that multiple authorship is always better, but implies being explicit about who can hold the pen and why; diverse authors can write in different styles which makes them attractive to a wider range of readers. In some cases, authors and readers may overlap. However, knowledge travels beyond those assessing the risk, and is likely to be questioned by populations who are anxious about the responses they are being asked to make to the risk: if people are asked to move to uncomfortable shelters, they want good reasons for this. Ultimately, the involvement of a wider disciplinary community in risk assessment, management and mitigation would improve risk literacy, benefiting both authors and readers, therefore ensuring that risk communication is more effective, and that people's questions about knowledge under uncertainty are addressed.

The Sendai Framework for DRR requires countries to reduce the risk from disasters at multiple scales, taking a multi-hazard approach and increasing public awareness of risk. Communication is a substantial part of this process – not only in public education, but also in scientific assessment and government planning. Understanding disaster risk holistically requires engagement with populations from the start of the process – and also requires some acknowledgement of the risk perceptions and heuristics of physical and social scientists (e.g. Donovan et al., 2014): risk is dynamic both objectively and subjectively. Understanding risk and enhancing preparedness involve significant interdisciplinary thinking – beyond and between the social and physical sciences, and involving engagement with communities and institutions. The requirements of the SFDRR are extensive and ambitious – incorporating multiple knowledges, all hazards, all dimensions of vulnerability and capacity – which requires a truly transdisciplinary and reflexive community of practice with an understanding of the complexity and dynamism of disaster risk.

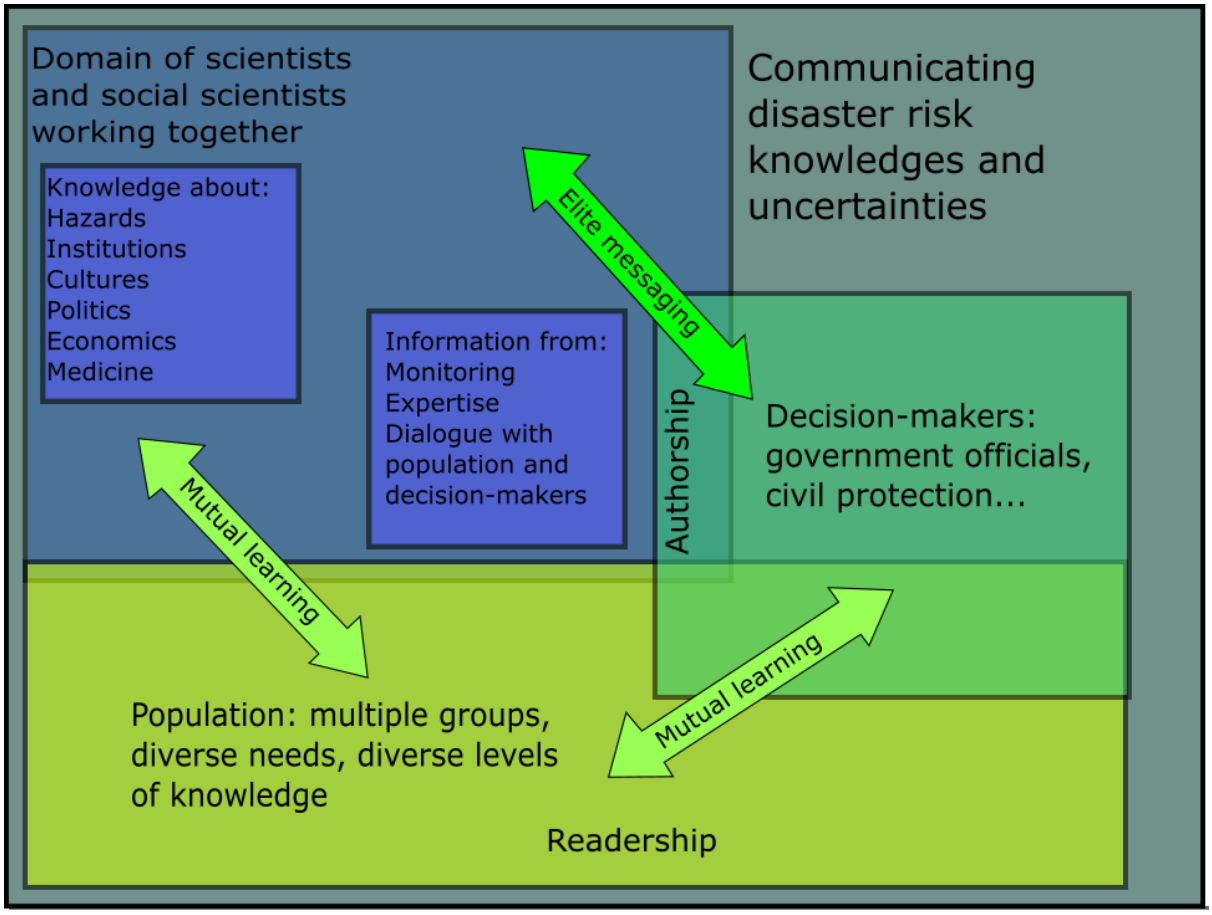

Figure 1. Summary of the argument in this paper.

References

Ahrens, J. and Rudolph, P. (2006) “The Importance of Governance in Risk Reduction and Disaster Management”, *Journal of Contingencies and Crisis Management*, 14 (4), pp.207-220.

Alexander, D.E., 2014. Communicating earthquake risk to the public: the trial of the “L’Aquila Seven”. *Natural Hazards*, 72(2), pp.1159-1173.

Allen, K. (2006) “Community-based disaster preparedness and climate adaptation: local capacity-building in the Philippines”, *Disasters*, 30 (1), pp.81-101

Aspinall, W., 2011. Check your legal position before advising others. *Nature*, 477: 251.

Barthes, R., 1994. 11 The Death of the Author. *Media Texts, Authors and Readers: A Reader*: 166.

Beck, S., 2011. Moving beyond the linear model of expertise? IPCC and the test of adaptation. *Regional Environmental Change*, 11(2), pp.297-306.

Benessia, A. and De Marchi, B., 2017. When the earth shakes… and science with it. The management and communication of uncertainty in the L’Aquila earthquake. *Futures,* 91, pp.35-45.

Blackburn, S. 2014. The politics of scale and disaster risk governance: Barriers to Decentralisation in Portland, Jamaica”. *Geoforum*, 52, pp.101–112.

Blackburn, S. and Pelling, M. (2018) “The political impacts of adaptation actions: social contracts, a research agenda”, *WIRES: Climate Change*, 9(6). DOI: https://doi.org/10.1002/wcc.549. IF: 5.124.

Blackburn, S. (2018a) "What does transformation look like? Post-disaster recovery politics and the case for progressive rehabilitation", *Sustainability*, 10(7). Special Issue: Transforming Development and Disaster Risk (eds. F. Thomalla and J. Ensor). DOI: 10.3390/su10072317. IF: 1.343.

Blackburn, S. (2018b) [unpublished PhD thesis] *(Re)negotiating social contracts in the post-disaster space: pathways of citizenship formation in the Andaman Islands.* Submitted August 2017 [conferred February 2018], King's College London.

Blaikie, P. (2006) "Is Small Really Beautiful? Community-based natural resource management in Malawi and Botswana", *World Development*, 34 (11), pp.1942-1957

Borie, M., & Hulme, M. 2015. Framing global biodiversity: IPBES between mother earth and ecosystem services. *Environmental Science & Policy*, *54*, 487-496.

Borie, M., Ziervogel, G., Taylor, F., Millington, J., Sitas, R, and Pelling, M. [Forthcoming] Opening-up urban resilience? Maps and mapping practices as an opportunity to integrate data from the local and city perspective. *Environmental Science and Policy*

Borie, M., Pelling, M., Ziervogel, G., Hyams, K. [Forthcoming] Mapping narratives of resilience in the Global South. *Global Environmental Change*

Brown, K., Eernstman, N., Huke, A. R., & Reding, N. 2017. The drama of resilience: learning, doing, and sharing for sustainability. *Ecology and Society*, 22(2).

Cadag, J.R.D. and Gaillard, J.C., 2012. Integrating knowledge and actions in disaster risk reduction: the contribution of participatory mapping. *Area*, 44(1), pp.100-109.

Cantet, Philippe; Michel Déqué, Philippe Palany & Jean-Louis Maridet, 2014. The importance of using a high-resolution model to study the climate change on small islands: the Lesser Antilles case *Tellus A: Dynamic Meteorology and Oceanography* Vol. 66, Iss. 1.

Cutter, S.L., Ismail-Zadeh, A., Alcantara-Ayala, I., Altan, O., Baker, D.N., Briceno, S., Gupta, H., Holloway, A., Johnston, D., McBean, G.A. and Ogawa, Y., 2015. Global risks: Pool knowledge to stem losses from disasters. *Nature*, *522*(7556).

Bull-Kamanga, L., Diagne, K., Lavell, A., Leon, E., Lerise, F., MacGregor, H., Maskrey, A., Meshack, M., Pelling, M., Reid, H. and Satterthwaite, D., 2003. From everyday hazards to disasters: the accumulation of risk in urban areas. *Environment and Urbanization*, 15(1), pp.193-204.

Cannon, T. (2008) "Reducing people's vulnerability to natural hazards: Communities and resilience", UNU-WIDER Research Paper No.2008/34.

Cooke, B. and Kothari, U. (eds.) (2001) *Participation: The new tyranny?* London: Zed Books.

Donovan, A., Ayala, I.A., Eiser, J. and Sparks, R., 2018. Risk perception at a persistently active volcano: warnings and trust at Popocatépetl volcano in Mexico, 2012–2014. *Bulletin of Volcanology,* 80(5): 47.

Donovan, A., Bravo, M. and Oppenheimer, C., 2013. Co-production of an institution: Montserrat Volcano Observatory and the social dependence on science. *Science and Public Policy*.

Donovan, A., Eiser, J.R. and Sparks, R.S.J., 2015. Expert opinion and probabilistic volcanic risk assessment. *Journal of Risk Research*: 1-18.

Donovan, A. and Oppenheimer, C., 2014. Science, policy and place in volcanic disasters: Insights from Montserrat. *Environmental Science & Policy*, 39: 150-161.

Donovan, A. and Oppenheimer, C., 2015a. Resilient science: The civic epistemology of disaster risk reduction. *Science and Public Policy*, 43(3), pp.363-374.

Donovan, A. and Oppenheimer, C., 2015b. At the mercy of the mountain? Field stations and the culture of volcanology. *Environment and Planning A*, 47(1): 156-171.

Donovan, A., Oppenheimer, C. and Bravo, M., 2012. Contested boundaries: delineating the "safe zone" on Montserrat. *Applied Geography*.

Donovan, A., Suppasri, A., Kuri, M. and Torayashiki, T., 2017. The complex consequences of volcanic warnings: Trust, risk perception and experiences of businesses near Mount Zao following the 2015 unrest period. *International Journal of Disaster Risk Reduction*.

Donovan, A.R. and Oppenheimer, C., 2015c. Modelling risk and risking models: The diffusive boundary between science and policy in volcanic risk management. *Geoforum*, 58: 153-165.

Donovan, A., Eiser, J.R. and Sparks, R.S.J., 2014. Scientists' views about lay perceptions of volcanic hazard and risk. *Journal of Applied Volcanology*, *3*(1), p.15.

Douglas, M. and Wildavsky, A., 1982. *Risk and culture: An essay on the selection of technological and environmental dangers*. Univ of California Press.

Dovey, Kim, and Mirjana Ristic 2017. Mapping urban assemblages: the production of spatial knowledge. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability* 10.1: 15-28.

Duvat, V. K., Magnan, A. K., Wise, R. M., Hay, J. E., Fazey, I., Hinkel, J., ... & Ballu, V. (2017). Trajectories of exposure and vulnerability of small islands to climate change. *Wiley Interdisciplinary Reviews: Climate Change,* 8(6), e478.

Duvergé, P. 1995. Le service météorologique colonial. Rubrique: Histoire. http://documents.irevues.inist.fr/bitstream/handle/2042/52025/meteo_1995_SP_46.pdf

Eiser, J.R., Donovan, A. and Sparks, R.S.J., 2015. Risk perceptions and trust following the 2010 and 2011 Icelandic Volcanic Ash Crises. *Risk Analysis*, 35(2): 332-343.

Eiser, J.R., Stafford, T., Henneberry, J. and Catney, P., 2009. "Trust me, I'm a scientist (not a developer)": Perceived expertise and motives as predictors of trust in assessment of risk from contaminated land. *Risk Analysis,* 29(2), pp.288-297.

Eiser, J.R., Bostrom, A., Burton, I., Johnston, D.M., McClure, J., Paton, D., Van Der Pligt, J. and White, M.P., 2012. Risk interpretation and action: A conceptual framework for responses to natural hazards. *International Journal of Disaster Risk Reduction*, *1*, pp.5-16.

Elissondo, M., Baumann, V., Herrero, J., Gonzalez, R., Bonadonna, C., Biass, S., Pistolesi, M., Cioni, R. and Bertagnini, A., 2015. Chronology and impact of the 2011 Puyehue-Cordón Caulle eruption, Chile. *Natural Hazards & Earth System Sciences Discussions*, 3(9).

Favereau, M., Robledo, L.F. and Bull, M.T., 2018. Analysis of risk assessment factors of individuals in volcanic hazards: Review of the last decade. *Journal of Volcanology and Geothermal Research*, 357: 254-260.

Fearnley, C.J. and Beaven, S., 2018. Volcano Alert Level Systems: Managing the Challenges of Effective Volcanic Crisis Communication. *Bulletin of Volcanology*.

Fiorino, D.J., 1990. Citizen participation and environmental risk: A survey of institutional mechanisms. *Science, Technology, & Human Values*, 15(2), pp.226-243.

Fischhoff, B. and Morgan, G., 2009. The science and practice of risk ranking. *Horizons*, 10(3): 40-47.

Foley, A. M. 2017. Climate impact assessment and “islandness” Challenges and opportunities of knowledge production and decision-making for Small Island Developing States. *International Journal of Climate Change Strategies and Management.*

Foucault, M., 2001. What is an Author? *Contributions in Philosophy*, 83: 9-22.

Fraser, A. (2017). The missing politics of urban vulnerability: The state and the co-production of climate risk. *Environment and Planning A*, 49(12), 2835-2852.

Frayssinet, P. 1993. Historique du service météorologique interrégional Antilles-Guyane. Rubrique: Dossier. http://documents.irevues.inist.fr/bitstream/handle/2042/53357/METEO_1993_3_52.pdf

Funtowicz, S.O. and Ravetz, J.R., 1993. Science for the post-normal age. *Futures*, *25*(7), pp.739-755.

Gaillard, J.-C., 2008. Alternative paradigms of volcanic risk perception: The case of Mt. Pinatubo in the Philippines. *Journal of Volcanology and Geothermal Research*, 172(3-4): 315.

Gaillard, J.C. and Mercer, J., 2013. From knowledge to action: Bridging gaps in disaster risk reduction. *Progress in human geography*, 37(1), pp.93-114.

Garcia, C. and Fearnley, C.J., 2012. Evaluating critical links in early warning systems for natural hazards. *Environmental Hazards*, 11(2), pp.123-137.

Gibbons M, Limoges C, Nowotny H, Schwartzman S, Scott P, Trow M 1994 *The new production of knowledge: The dynamics of science and research in contemporary societies*. Sage, London

Gigerenzer, G., Hertwig, R., Broek, E.V.D., Fasolo, B. and Katsikopoulos, K.V., 2005. 'A 30% chance of rain tomorrow': How does the public understand probabilistic weather forecasts? *Risk Analysis*, 25(3): 623-629.

Gigerenzer, G., W. Gaissmaier, E. Kurz-milcke, L.M. Schwartz, S. Woloshin, 2007. Helping doctors and patients make sense of health statistics. *Psychological Science in the Public Interest*, 8(2): 53-96.

Giorgi F. , Jones C. , Asrar G. R . 2009. Addressing climate information needs at the regional level: the CORDEX framework. *World Meteorol. Organ. Bull.* 58(3): 175

Ha-Duong M, Swart R, Petersen A, et al. 2007. Uncertainty management in the IPCC: agreeing to disagree. *Global Environmental Change* 17(1): 8–11.

Harley, J. B. 2009. Maps, knowledge, and power. *Geographic thought: a praxis perspective*, 129-148.

Haughton, G. and White, I. 2017, Risky spaces: creating, contesting and communicating lines on environmental hazard maps. *Trans Inst Br Geogr.* doi:10.1111/tran.12227]

Haynes, K., Barclay, J. and Pidgeon, N., 2007a. Volcanic hazard communication using maps: An evaluation of their effectiveness. *Bulletin of Volcanology,* 70(2): 123-138.

Haynes, K., Barclay, J. and Pidgeon, N., 2007b. The issue of trust and its influence on risk communication during a volcanic crisis. *Bulletin of Volcanology*, 70(5), pp.605-621.

Haynes, K., Barclay, J. and Pidgeon, N., 2008. Whose reality counts? Factors affecting the perception of volcanic risk. *Journal of Volcanology and Geothermal Research*, 172(3-4), pp.259-272.

Heras, M., & Tàbara, J. D. 2014. Let's play transformations! Performative methods for sustainability. *Sustainability Science*, 9(3), 379-398.

Heras, M., & Tàbara, J. D. 2016. Conservation theatre: mirroring experiences and performing stories in community management of natural resources. *Society & Natural Resources*, 29(8), 948-964.

Hoffman, S. and A. Oliver-Smith (2002) *Catastrophe and Culture: the anthropology of disaster*, School of American Research Press: US.

Hoffrage, U., Lindsey, S., Hertwig, R. and Gigerenzer, G., 2000. Communicating Statistical Information. *Science*, 290(5500): 2261-2262.

Hulme, M., Obermeister, N., Randalls, S., & Borie, M. 2018. Framing the challenge of climate change in Nature and Science editorials. *Nature Climate Change*, 1.

Jasanoff, S., 2003. Technologies of humility: Citizen participation in governing science. *Minerva*, 41: 223-244.

Jasanoff, S., 2005. *Designs on Nature: Science and democracy in Europe and the United States*. Princeton University Press, Princeton.

Kahan, D.M., Braman, D., Slovic, P., Gastil, J. and Cohen, G., 2009. Cultural cognition of the risks and benefits of nanotechnology. *Nature nanotechnology*, 4(2), p.87.

Kasperson, R.E. and Kasperson, J.X., 1996. The social amplification and attenuation of risk. *The Annals of the American Academy of Political and Social Science*, 545(1), pp.95-105.

Kim, S. J. 2015. Exploring the ambiguity of community in disaster risk reduction: A case study of Metro Manila (Doctoral dissertation, UCL (University College London)).

Kitchin, R., J. Gleeson, M. Dodge Unfolding mapping practices: a new epistemology for cartography *Transactions of the Institute of British Geographers*, 38 (3) (2012), pp. 480-496

Klein, N. 2008. *The Shock Doctrine: the rise of disaster capitalism*, Penguin: London.

Kruger, F., Bankoff, G., Cannon, T., Orlowski, B. and Schipper, L. (eds) (2015) *Cultures and Disaster: understanding cultural framings in disaster risk reduction*, Routledge studies in Hazards, Disaster Risk and Climate Change, Routledge: Abingdon, Oxon.

Lane, S.N., Odoni, N., Landström, C., Whatmore, S.J., Ward, N. and Bradley, S., 2011. Doing flood risk science differently: an experiment in radical scientific method. *Transactions of the Institute of British Geographers*, 36(1): 15-36.

Lauer, M. 2012. Oral Traditions or Situated Practices? Understanding How Indigenous Communities Respond to Environmental Disasters, *Human Organization*, 71(2), pp.176-187.

Leuenberger, C., & Schnell, I. 2010. The politics of maps: Constructing national territories in Israel. *Social Studies of Science*, *40*(6), 803-842.

Lindell, M., 2013. North American cities at risk: Household responses to environmental hazards, *Cities at Risk*. Springer, pp. 109-130.

Livingstone, D. N. 2005. Science, text and space: thoughts on the geography of reading. *Transactions of the institute of British geographers*, 30(4), 391-401.

Loewenstein, G., Weber, E., Hsee, C. and Welch, N. 2001 “Risk as Feelings”, *Psychological Bulletin*, 127 (2), pp. 267-286

Mahony, M. 2015. Climate change and the geographies of objectivity: the case of the IPCC's burning embers diagram. *Transactions of the Institute of British Geographers,* 40(2), 153-167.

Mahony, M., & Endfield, G. 2017. Climate and colonialism. *Wiley Interdisciplinary Reviews: Climate Change.*

Marzocchi, W., Newhall, C. and Woo, G., 2012. The scientific management of volcanic crises. *Journal of Volcanology and Geothermal Research*, 247, pp.181-189.

McEwen, L., Garde-Hansen, J., Holmes, A., Jones, O. and Krause, F. 2017. Sustainable flood memories, lay knowledges and the development of community resilience to future flood risk. *Transactions of the Institute of British Geographers*, 42: 14–28. doi:10.1111/tran.12149

Mei, E.T.W. and Lavigne, F., 2013. Mass evacuation of the 2010 Merapi eruption. *International Journal of Emergency Management*, 9(4), pp.298-311.

Mercer, J., Kelman, I., Taranis, L. and Suchet-Pearson, S., 2010. Framework for integrating indigenous and scientific knowledge for disaster risk reduction. *Disasters*, 34(1), pp.214-239.

Misra, N. 2005. Stone Age cultures survive tsunami wave, NBC News [Associated Press], 4th January 2005. URL: www.nbcnews.com/id/6786476/ns/world_news-tsunami_a_year_later/t/stone-age-cultures-survive-tsunami-waves/#.W3Juf-gzY2x [accessed 14.08.18].

Morgan, M.G., Fischoff, B., Bostrom, A. and Atman, C.J., 2002. *Risk communication: A mental models approach*. Cambridge University Press, Cambridge.

Morin, V. M., Ahmad, M. M., & Warnitchai, P. 2016. Vulnerability to typhoon hazards in the coastal informal settlements of Metro Manila, the Philippines. *Disasters*, 40(4), 693-719.

Naess, L.O., 2013. The role of local knowledge in adaptation to climate change. *Wiley Interdisciplinary Reviews: Climate Change,* 4(2), pp.99-106.

Nerlich B, Koteyko N, and Brown B 2010. Theory and language of climate change communication. *WIREs Climate Change* 1(1): 97–110.

Owens, S., 2015. *Knowledge, policy, and expertise: the UK royal commission on environmental pollution 1970-2011*. OUP Oxford.

Papale, P., 2017. Rational volcanic hazard forecasts and the use of volcanic alert levels. *Journal of Applied Volcanology*, 6(1): 13.

Patt A 2007. Assessing model-based and conflict-based uncertainty. *Global Environmental Change* 17(1): 37–46.

PEARL 2018. Hurricane Irma Special Report: From resilience to reconstruction to Extreme Events. Report for the EU-funded PEARL Project on Preparing for Extreme and Rare events in coastAL areas: http://www.pearl-fp7.eu/.

Pelling, M. (2011a) *Adaptation to climate change: from resilience to transformation*, Routledge: London.

Pelling, M. (2011b). Urban governance and disaster risk reduction in the Caribbean: the experiences of Oxfam GB. *Environment and Urbanization* 23(2), 383-40

Peluso, N. L. 1995. Whose woods are these? Counter-mapping forest territories in Kalimantan, Indonesia. *Antipode*, *27*(4), 383-406.

Pietruska, J. L. 2016. Hurricanes, crops and capital: The meteorological infrastructure o fht American empire in the West Indies 1. *The Journal of the Gilded Age and Progressive Era*, 15(4), 418-445.

Pidgeon, N., Kasperson, R.E. and Slovic, P., 2003. *The social amplification of risk*. Cambridge University Press, Cambridge.

Pidgeon, N. and Fischhoff, B., 2011. The role of social and decision sciences in communicating uncertain climate risks. *Nature Climate Change*, 1(1), p.35.

Porio, E. 2016. Prosperity and Inequality in Metro Manila: Reflections on Housing the Poor, Climate Risk, and Governance of Cities. *In Globalization and Democracy in Southeast Asia* (pp. 177-197). Palgrave Macmillan, London.

Powell, R.C., 2007. Geographies of science: histories, localities, practices, futures. *Progress in Human Geography*, 31(3): 309-329.

Schenk N, Lensink S 2007. Communicating uncertainty in the IPCC greenhouse gas emissions scenarios. *Climatic Change* 82(3): 293–308.

Scolobig, A., Mechler, R., Komendantova, N., Liu, W., Schröter, D. and Patt, A., 2014. The co-production of scientific advice and decision making under uncertainty: lessons from the 2009 L'Aquila earthquake, Italy. *Planet@ risk*, 2(2), pp.71-76.

Scolobig, A., Prior, T., Schröter, D., Jörin, J. and Patt, A., 2015. Towards people-centred approaches for effective disaster risk management: Balancing rhetoric with reality. *International Journal of Disaster Risk Reduction*, 12: 202-212.

Sen, S. 2018 "#Chennaifloods: Use of Social Media and Collective Intelligence in Disasters", *Contested Development Working Paper Series*, 79, King's College London.

Shatkin, G. 2004. Planning to forget: Informal settlements as' forgotten places' in globalising Metro Manila. *Urban studies*, *41*(12), 2469-2484.

Shaw R., Lu L., Lian F. 2017. *Science Technology Plan for Disaster Risk Reduction: Asian and Pacific Perspectives*, ICSU and IRDR, Beijing, China.

Slovic, P., 1987. Perception of risk. *Science*, 236(4799), pp.280-285.

Slovic, P., 2000. *The perception of risk.* Earthscan, London.

Slovic, P., 2016. Understanding Perceived Risk: 1978–2015. *Environment: Science and Policy for Sustainable Development*, 58(1): 25-29.

Slovic, P. and Peters, E. 2006 "Risk Perception and Affect", *Current Directions in Psychological Science,* 15 (6), pp.322-325

Slovic, P., Finucane, M.L., Peters, E. and MacGregor, D.G., 2004. Risk as Analysis and Risk as Feelings: Some Thoughts about Affect, Reason, Risk, and Rationality. *Risk Analysis*, 24(2): 311.

Sorensen, J.H., 2000. Hazard warning systems: Review of 20 years of progress. *Natural Hazards Review*, 1(2), pp.119-125.

Sparks, R.S.J. and Aspinall, W., 2004. Volcanic activity: Frontiers and challenges in forecasting, prediction and risk assessment, *The State of the Planet: Frontiers and challenges in Geophysics.* Geophysical Monograph 150; IUGG Volume 19.

Spiegelhalter, D., Pearson, M. and Short, I., 2011. Visualizing uncertainty about the future. *Science*, 333(6048): 1393-1400.

Squires, G. and Hartman,G. 2006. *There is no such thing as a natural disaster: Race, class and Hurricane Katrina,* Routledge: New York.

Srinivasan, K. and Nagaraj, V.K. 2006. "The state and civil society in disaster response: post-tsunami experiences in Tamil Nadu", *Journal of Social Work in Disability and Rehabilitation*, 5(3/4), pp.57-80.

Star, S. L., & Griesemer, J. R. 1989. Institutional ecology,translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social studies of science*, *19*(3), 387-420.

Stephens, E.M., Edwards, T.L. and Demeritt, D., 2012. Communicating probabilistic information from climate model ensembles—lessons from numerical weather prediction. *Wiley interdisciplinary reviews: climate change,* 3(5), pp.409-426.

Stirling, A., 2006. Precaution, foresight and sustainability: Reflection and reflexivity in the governance of science and technology. In: J.-P. Voss, Dierk Bauknechy, Rene Kemp (Editor), *Reflexive governance for sustainable development*. Edward Elgar Publishing, Cheltenham.

Stirling, A., 2008. Opening Up and Closing Down. *Science, Technology & Human Values*, 33(2): 262-294.

Stirling, A., 2010. Keep it complex. *Nature*, 468(7327): 1029-1031.

Taylor M. A. , Centella A. , Charlery J. , Bezanilla A. , Campbell J. , 2013 The PRECIS-Caribbean story: lessons and legacies. *Bull. Am. Meteorol. Soc.*; 94(7): 1065–1073.

Thompson, M.A., Lindsay, J.M. and Gaillard, J.C., 2015. The influence of probabilistic volcanic hazard map properties on hazard communication. *Journal of Applied Volcanology*, 4(1), p.6.

UNTRS 2007 "Tsunami, India – Three years after", Chennai: United Nations Team for Tsunami Recovery Support. Available at: http://reliefweb.int/report/india/tsunami-india-three-years-after [accessed 02.08.17].

Veil, S.R., Buehner, T. and Palenchar, M.J., 2011. A work-in-process literature review: Incorporating social media in risk and crisis communication. *Journal of contingencies and crisis management*, *19*(2), pp.110-122.

Wachinger, G., Renn, O., Begg, C. and Kuhlicke, C., 2013. The risk perception paradox—implications for governance and communication of natural hazards. *Risk Analysis*, 33(6): 1049-1065.

Wadge, G. and Isaacs, M., 1988. Mapping the volcanic hazards from the Soufriere Hills Volcano, Montserrat, West Indies, using an image processor. *Journal of the Geological Society, London*, 145: 541-551.

Wardman, J.K., 2008. The constitution of risk communication in advanced liberal societies. *Risk Analysis*, 28(6), pp.1619-1637.

White, M.P., Pahl, S., Buehner, M. and Haye, A., 2003. Trust in risky messages: The role of prior attitudes. *Risk Analysis: An International Journal*, *23*(4), pp.717-726.

Wilson, T.M., Stewart, C.A., Bickerton, H., Baxter, P.J., Outes, V., Villarosa, G. and Rovere, E., 2013. Impacts of the June 2011 Puyehue-Cordón Caulle volcanic complex eruption on urban infrastructure, agriculture and public health. GNS Science.

Winson, A.E., Costa, F., Newhall, C.G. and Woo, G., 2014. An analysis of the issuance of volcanic alert levels during volcanic crises. *Journal of Applied Volcanology*, 3(1): 14.

Wisner, B., P. Blaikie, T. Cannon, I. Davis (2004) *At Risk: natural hazards, people's vulnerability and disasters*. London: Routledge.

WMO RA IV Hurricane Committee. Coordination within the WMO tropical cyclone programme RA Information document IV/HC-40/Doc. 4 (14.III.2018). 2018, 7pp.

Ziervogel, G., Pelling, M., Cartwright, A., Chu, E., Deshpande, T., Harris, L., Hyams, K., Kaunda, J., Klaus, B., Michael, K. and Pasquini, L., 2017. Inserting rights and justice into urban resilience: a focus on everyday risk. *Environment and Urbanization*, 29(1), pp.123-138.