9

DISASTERS, HUMANITARIANISM AND EMERGENCIES

A politics of uncertainty

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Introduction

A central tenet of disaster risk management is reducing uncertainties to manageable risks, such that, where possible, probabilities of outcomes are known or at least predictable. Thus, the starting points for research and policy are to reduce uncertainty through improved knowledge of hazard processes to enable better event forecasting, but also to understand better how information on risk is communicated and accessed, and the social and political processes that constrain what individuals and organisations can do with such information – since early warning needs early and inclusive action. This approach has delivered considerable gains in regions exposed to weather extremes, including coastal lands and rainfall-dependent agricultural communities.

One of the greatest global achievements for this style of risk-based science has been the reduction in the number of people killed and harmed by flood events since records began in the 1980s (UNISDR 2019). Global loss data are available from the 1980s to present, allowing long-term trend analysis over this period. This shows declining mortality even when the number of flood events has increased. Losses to property and people affected have increased over this period, indicating the further challenge of reducing risk that goes beyond effective evacuation. This success is as a direct outcome of reduced uncertainty across all aspects of flood warning and response drawing together inputs from natural and social sciences. This gain is especially impressive when seen alongside the increased number of reported flood events from all causes, and the increasing number of people made homeless and suffering property damage. Flood risk is increasing as more people and property are exposed to flood hazard, with climate change acting as a hazard multiplier, but reduced uncertainty in knowledge about the likelihood of outcomes and how to act on early warning has enabled more people to make decisions to avoid personal harm.

The success of this type of approach to reduce flood risk is important because it highlights the multiple factors required for success. Yet uncertainties are present in all areas of knowledge production and decision-making in the knowledge chain that underpins such early warnings. One of the key lessons from the success referred to is that reducing uncertainty in ways that can allow individuals to make decisions and avoid harm is best achieved through interdisciplinary knowledge production coupled with cross-sectoral policy action. The length of the knowledge production chain is captured well by the World Meteorological Organisation HiWeather project (http://hiweather.net) (Figure 9.1). This identifies six specific stages of technical expertise as components of a knowledge chain. At each step, different combinations of science are needed to address specific technical challenges, and so to better articulate knowledge and identify knowledge gaps to describe the significance of remaining known uncertainties. Each of these stages helps describe known uncertainty brought about by incomplete data, modelling and theoretical assumptions and biases in understanding and communication. Because knowledge to reduce risk is produced across multiple stages, additional uncertainty is introduced through the transfer or exchange of data, understanding and information from one site of expertise to another. Such exchanges often require data transformation, for example where model output and input work at different spatial scales or where additional variables have to be interpolated to allow analysis. Although uncertainties may of course not be reduced through such a knowledge chain, the hoped-for result is not a compounding of but a reduction in uncertainty in understanding for the end-user: the citizen at risk contemplating evacuation. It is worth noting the origin of Figure 9.1, which reflects the ambition of weather forecasters to make their work as relevant as possible to end-users. The result in this figure is a representation of a knowledge chain that is linear and emphasises formal scientific knowledge. This allows a clear delimitation of opportunities to improve the quality of early warnings – through each stage and bridges between them. It also prompts the question 'How would other actors view knowledge production?' from a more bottom-up viewpoint. For example, it might be that these stages are compressed into compound acts of assessment, often including informal or local knowledge based on experience. It is likely, from this perspective, that the final decision stage might be more central.

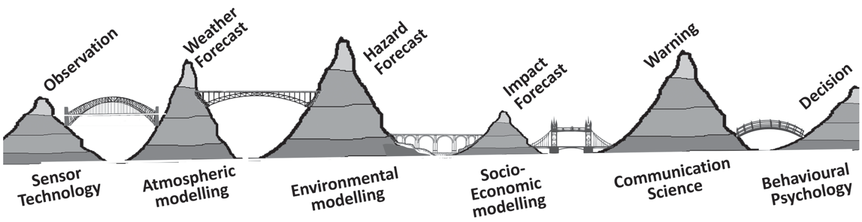

FIGURE 9.1 The knowledge chain for flood early warning
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The historical progression in disaster studies from a hazard to a people-centred approach, and more recently to an integrative and multidisciplinary framing where a range of epistemic logics has been recognised (including local knowledge), has increased awareness of uncertainties and the ambiguities buried deep in multiple knowledge production and communication efforts. More than this, the extension of disaster studies into interdisciplinary analysis (where physical and social science approaches are blended or synthesised) – for example in risk analysis that combines hazard likelihood with the susceptibility, coping and adaptation of people and their asset systems – has brought to the surface the political nature of knowledge. Science does not have a unique claim on legitimacy for knowledge production, even where its methods are more transparent and defendable. Local knowledge based on personal experience and indigenous knowledge rooted in cultural identity are increasingly recognised as being part of the conversation out of which knowledge becomes relevant to specific decision-makers' needs. Here the robustness and transparency of the scientific method is also key in bringing accountability to decision-making and confidence to action. The scientific method, with its roots in replicability and falsification of analysis, brings clarity to linear questions of cause and effect – as exemplified in Figure 9.1. Recent innovations in disaster science have pushed at the boundaries of complexity theory, where cause and effect are less clearly connected – with multiple intervening and dynamic variables. This makes scientific work less transparent to non-experts. A central dilemma facing disaster studies is how expert analysis interacts with other knowledge traditions in developing more integrated understandings.

Where different knowledge traditions are clear about embedded uncertainties and open to a reinterpretation of positions, together with evidence-based science, there is scope for a nuanced confrontation of uncertainty. Where science or other knowledge traditions reject each other's assumptions, value positions and findings, uncertainty is likely to be ignored and improved outcomes are more difficult to anticipate.

Uncertainty has become more visible as research has expanded its knowledge base through interdisciplinary and multidisciplinary work and the increasing inclusion of local/traditional knowledge. There is much debate on how to best do this, from weather forecasting in a daily news bulletin to flagging future climate scenarios integrated with specific economic futures. The latter places less emphasis on describing uncertainty as a qualifier on analysis and rather works in a constant state of contestation where few complex concepts like poverty, vulnerability, resilience or development have a concrete meaning or material expression.

The remainder of this chapter explores these two traditions from particular viewpoints, reflected in the authorship of this chapter. The next section, emerging from a social science perspective, examines the social construction of uncertainty and certitude within studies of social vulnerability and resilience in Africa, while the following section, taking a more physical science perspective, takes us from weather and climate science to an exploration of risk and uncertainty and the implications for earthquake science and modelling. Both sections reflect on a common set of themes outlined in Box 9.1, to which we return again in conclusion to tease out similarities and differences between these two traditions of disaster risk research.

BOX 9.1 FOUR AREAS OF QUESTIONING TO EXPLORE THE POSITION OF UNCERTAINTY IN DIFFERENT KNOWLEDGE PRODUCTION CONTEXTS

Knowledge: Where does uncertainty or ambiguity sit? Is it inherent within the methodologies deployed, inherited from external inputs or consequential through the use others make of knowledge and data that have been produced?

Communication: How, if at all, is uncertainty communicated? Is this a major or minor aspect? Is the balance right or are disciplinary norms and expectations for the communication of uncertainty in need of revision?

Response: If we accept that uncertainties are always present in science and decision-making then are there progressive or productive uses to which uncertainty can be put? What kinds of actors or discourses tend to dominate when the level of uncertainty is high? Can such actors be enabled to open space for more inclusive processes of knowledge production and progressive outcomes for knowledge application in decision-making?

Ethics: What are the ethical implications for researchers in managing uncertainty and its communication? Is the existing ethical approach right for the complexities we face in integrating physical and social science with local or indigenous knowledge?

A social science perspective: uncertainty as a challenge for disaster risk management in Africa

Uncertainty presents a serious challenge for disaster risk management because it impedes pre-emption. As a consequence, precaution becomes imperative but difficult to achieve. Disaster prevention and management require the reduction of uncertainty – or, more precisely, the translation of forms of uncertainty and ignorance into calculable probabilities (i.e. risk). But what if this is not possible? What if disaster risk management cannot avoid knowledge gaps and unpredictable events? Embracing uncertainty first and foremost requires an understanding of its causes and consequences. Situations characterised by uncertainty may originate from lack of knowledge and experience, unprecedented events or new and unpredictable conditions. Climate change is a major driver of newly emerging uncertainties, especially in poor countries. This section of the chapter focuses on the social construction of uncertainty in the context of climate change and natural disasters in Africa. The African continent is often portrayed as the continent that is most seriously affected by climate change due to its exposure to extreme events, high vulnerability and limited coping capacities (IPCC AR-5 2014). This raises a number of questions: How is uncertainty socially constructed and communicated? In which way are real and constructed uncertainties related? And how does this matter for disaster risk management? These themes are explored in the four sub-sections below, linking to the questions posed in Box 9.1.

Uncertainty, just like risk, can be viewed from a realist and from a constructivist perspective. The realist perspective claims to build upon scientifically produced 'facts'. It acknowledges that some aspects of the future are simply not predictable, such as events related to tipping points, complex human–environment relations and unforeseeable system changes. The constructivist perspective, on the other hand, embraces people´s perceptions, imaginations and feelings of unknown futures (Cooper and Pratten 2015). It refers to the ways in which individuals or societies live with uncertainty, how they get along with insufficient knowledge and how they navigate their future without a clear vision of what to expect. From a constructivist view, the shapes and contents of both knowledge and uncertainty are partly constituted not just by 'the facts' (as highlighted in the realist view), but by social orders acting on the processes of knowledge production. In other words: to a realist, knowledge (and uncertainty) are effectively shaped solely by the conditions of the focal objects; to a constructivist they are also shaped by the conditions of the subjects of knowledge.

The distinction between realist and constructivist concepts is important because human behaviour does not so much respond to the world as it is, but rather as it is perceived. In practice, however, 'real' and 'socially constructed' uncertainties are difficult to differentiate, as can be seen in the context of climate change.

Climate-related uncertainties in Africa can be traced back to diverse origins (IPCC AR-5 2014; Niang *et al.* 2014). First, the future effects of climate change on the continent are expected to be highly heterogeneous in space. As a consequence, place-specific predictions are often quite inaccurate. While most of the continent is likely to receive less rainfall, eastern Africa will probably receive more – but highly erratic – rains. Second, model-based forecasts of future climate change in Africa are less refined than in other parts of the world due to a relatively weak data base and short time of observation. Third, environmental change is caused not by climate alone but by complex human–environment interactions that cannot be predicted. Fourth, societal transformations play an essential role in future disaster risks and coping capacities in Africa, but they are not predictable. And, finally, cross-scalar influences and power relations are decisive for local agency and the struggle for control.

A recent IPCC special report mentions the impact of climate change on growing disparities and social disintegration in Africa (IPCC 2019). It leaves no doubt that there has been an increased frequency of droughts in African drylands over the past few decades, which, together with population pressure, exacerbates land degradation. This is affecting the productivity of land use systems in large parts of the continent, leading to a deterioration of food security and local livelihoods. The report, in turn, draws attention to regional heterogeneity, cascading risks, telecoupling[1] and socially differentiated effects on women, the elderly and the poor (IPCC 2019: 17).

To give an example, the Afar pastoralists in Ethiopia have a long experience of living with multiple risks, including highly variable rainfall, recurring droughts and famines, sudden outbursts of violent clashes and disruptions of trade connections and markets due to changing international relations between Ethiopia, Eritrea, Djibouti and Somalia (Müller-Mahn *et al.* 2010). The overlapping livelihood challenges are today further enhanced by newly emerging uncertainties. Rainfall anomalies are occurring more frequently. The expansion of irrigated farms and new infrastructure reduces access to pasture lands, while the uncontrollable invasion of alien species undermines rangeland quality. Under these conditions, the Afar feel that they are surrounded by enemies. They experience uncertainty not only in terms of unpredictability, but – worse than that – as a situation in which they are losing control over what is happening, and the capacity to cope.

The social construction of uncertainty is based on communication among actors about shared future visions. In situations where the outcome of ongoing processes cannot be foreseen, and where future conditions remain concealed, decision-making lacks clear reference points. People are therefore searching for collective orientations. They rely on each other in order to obtain clues for decision-making. Communication over uncertainties may lead to 'fictional expectations' (Beckert 2016): in other words, shared imaginations regarding what is going to happen in the future. These joint expectations are essential for making people act collectively. By sharing visions of the future, people come to an understanding about what may be expected, or feared, and how to prepare for it.

Experts and lay people frame uncertainty differently, which has consequences for how uncertainties are responded to. While experts encounter uncertainty as a limitation of scientific methods, forecasts and planning, others instead view it as a quotidian experience, something they cannot influence – and thus have to take for granted. Against this backdrop, communication among and between experts and lay people becomes important in order to find common understandings and orientations.

To give another example, a case study in Côte d'Ivoire revealed how farming communities respond to climate-related uncertainties that go beyond the 'normal' rainfall variability of previous years (Müller-Mahn *et al.* 2020). Over the past two decades many farmers adopted new crop varieties that are more resilient to dry spells, or they shifted cultivation to areas with better water supplies. But today the increasingly unpredictable onset of the rainy season makes it extremely difficult for farmers to decide when to start cultivation. They cannot fully rely on traditional experience, nor do they trust the weather forecasts. While people are waiting for the beginning of the rainy season, the feeling of uncertainty among community members passes through stages of unrest, hope and despair. People communicate intensively over their assessment of the situation, with the effect that some simply follow the practices they know, while others feel more inclined towards new strategies to secure household incomes outside of agriculture.

How can the uncertainties of drought and famine be responded to in practice? Development cooperation and humanitarian assistance have developed a number of instruments for that purpose, which aim at strengthening local resilience against drought, or improving external assistance to alleviate its consequences. An example of a resilience-building approach is the drought cycle management model. It provides a disaster risk management strategy that uses the periods between droughts to prepare for the next one by better linking activities of development, relief and rehabilitation. The approach is based on an analysis of the underlying causes of vulnerability at household levels and the dynamic pressures that enhance vulnerability further, and an assessment of coping capacities and disaster preparedness (Brüntrup and Tsegai 2017).

An example of improved external assistance is the Famine Early Warning Systems Network that is used for the organisation of famine relief. FEWSNET is an information platform that provides data on current and expected food insecurities at country and regional levels for most parts of the world, including all of Africa (see: https://fews.net/). It was established by the US Agency for International Development in 1985, and it has since helped to manage food crises more effectively by analysing data on rainfalls, yields, markets, prices and regional food stocks. These data are combined with observations on local livelihoods, trade and the political environment. FEWSNET publishes monthly bulletins that classify the observed state of food insecurity, from stress to emergency and famine. Such early warning systems use scenarios that link the observation of present food security assessments with informed assumptions about future events. Based on these assumptions and future scenarios, it is possible to prepare for emerging crises, for example by concentrating food stocks in regions that are expected to be most seriously affected.

However, critical voices point out that the combination of drought cycle management and famine early warning is insufficient to overcome the challenges of uncertainty. Managing the uncertainties of drought and famine in Africa more effectively would require a better integration between short-term humanitarian assistance, long-term development and political activities to support peace and human security. This is often lacking, especially in areas affected by violent conflicts, such as Somalia (Medinilla *et al.* 2019).

In designing responses to climate uncertainty, ethical implications arise concerning the acknowledgement of local knowledge, felt needs and local perspectives. Uncertainty does not only present a challenge for the future, it also represents an opportunity: can uncertainty open up new spaces for alternative developments, innovation and desirable futures?

Uncertainty in Africa, like anywhere else, may concern all aspects of life, with negative as well as positive connotations (Cooper and Pratten 2015). This raises the question whether there is anything special about uncertainty in Africa. The understanding of uncertainty in Africa is embedded in the historical relations between the global North and South. This relationship has stimulated controversial debates about the dynamics of contemporary world society, and about uncertainty as a distinguishing characteristic of societies in the global North and South. Current debates on the concepts of 'risk society' (Beck 1992) and 'imagined futures' (Beckert 2016) are informed by the historical experience of the industrialised North, where technological risks are seen as unavoidable side-effects of modernity. It would, however, be misleading to view the global South simply in juxtaposition to this, as the realm of uncertainty, where future changes in nature and society cannot be properly predicted and managed (Bloemertz *et al.* 2012).

A physical science perspective: the challenges of forecasting earthquakes

On 28 March 2005 the magnitude 8.7 Nias earthquake ruptured the Sunda megathrust fault where the Indo-Australian plate is being forced under the Eurasian plate. The earthquake, at the time the fourth biggest ever instrumentally recorded, produced strong shaking in the islands of the Sumatran forearc and along the densely populated west Sumatran coastline, causing significant damage and more than 1,000 deaths (Hsu *et al.* 2005). While the impact of such a large earthquake was not surprising, and perhaps less severe than might have been expected, this earthquake was unique in that its approximate location and energy release had been forecast in a paper that was published in an international peer-reviewed science journal only 11 days previously (McCloskey *et al.* 2008). On the one hand, this forecast could be viewed as a confirmation of the physical understanding of crustal physics that enabled it, but, on the other, for many – including its authors – it confirmed the fundamental intractability of earthquake prediction: a step change in precision from forecasting where, when and how big future events might be.

Earthquakes communicate by stress transfer. A large earthquake deforms the earth's crust around it, changing the stress field on neighbouring earthquake faults (Stein 1999; King *et al.* 1994), bringing some closer to failure and triggering aftershocks, some of which can be very large. In the decade before the Nias event, physical scientists had developed techniques for calculating this so-called Coulomb stress and identifying particular faults that were made more dangerous by the occurrence of any large earthquake (Hubert-Ferrari *et al.* 2000; Nalbant *et al.* 1998). Statistical assessments of aftershock sequences had repeatedly demonstrated that these calculations had the ability to explain the distributions of triggered events (e.g. Toda *et al.* 2011). Estimation of the Coulomb stress from the great Sumatra-Andaman earthquake, which produced the Indian Ocean tsunami, resolved onto neighbouring active fault segments, combined with considerations of their seismic history, allowed researchers to suggest an increased risk that was confirmed by the Nias event.

Remarkably, the causative stress change was less than 0.1 megaPascal (Nalbant *et al.* 2005), which is less than the stress caused by a handshake. The precise mechanism whereby this geologically imperceptible perturbation broke the grip holding some small part of the opposing sides of the fault together is not properly understood, but the resulting non-linear amplification of the rupture process eventually broke an area of 50,000km^2, displacing the fault by as much as 15 metres and releasing energy equivalent to 1,000 times the bomb dropped by the US on Hiroshima. This avalanche of energy release was probably initiated 20km below the seafloor. The following paragraphs draw on this case, and other earthquake events, to explore the set of questions outlined earlier, from a physical science perspective.

Geophysical scientists frequently distinguish two sources of uncertainty. Aleatory, or statistical, uncertainty results from lack of knowledge of the time-varying state of a system – here, the precise distribution of the stress on, and the strength of, the Nias fault segment, the precise distribution of slip on the Sumatran-Andaman earthquake, and the precise history of tectonic stress accumulation on the plate interface. Epistemic – or systematic – uncertainty, by contrast, emerges from an insufficient understanding of the physical processes that govern the earthquake event. In this case, tectonic convergence of the plates increases their mutual stress for hundreds of years and interactions with neighbouring earthquakes increase it rapidly and locally. Thus, the forecast of the Nias event was successful because the epistemic uncertainty in the problem was relatively small, the seismic and tectonic history were reasonably well understood, and the physical link between cause (the Sumatra-Andaman earthquake) and effect (the Nias earthquake) was well enough described by the equations governing the Coulomb stress calculations.

Perhaps more importantly, the problem was sufficiently well posed to promote the epistemic clarity of the physical process above the aleatory uncertainty in the initial conditions. While uncertainty in the precise initial conditions precluded specification of the exact hypocentral location, and lack of knowledge of the loading history precluded specification of the event origin time, the large area of interaction identified, and the lack of specificity in the forecast, cast the net wide enough that many different futures were consistent with a successful forecast. This does not imply any duplicity. Rather, it reflects a careful consideration of the physical process (through accurate calculation of the Coulomb stress resolved on large areas of appropriate active structures with a known seismic and tectonic history) maximising the chances of an accurate forecast over an unspecified time into the future.

While the location and size of a magnitude 8.7 earthquake being deterministically forecast 11 days before it happened might be considered a success of physical science, this success came at a very high price. Firstly, this case demonstrates that large earthquakes can be triggered by almost infinitesimally small perturbations, and that, despite the underpinning determinism of the process, this – paradoxically – probably precludes deterministic forecasting of particular events. The precision with which the initial conditions are required to be known 20km below the ocean floor makes such prediction of this, or any other, rupture initiation an impossibility. Secondly, the non-linear amplification of the initial rupture required to produce a massive failure is controlled by the detail of the stress on the Nias fault segment and recent observations expose the fractal complexity of earthquake slip, and suggest that slip, even after rupture initiation, is also inherently unpredictable. The earthquake is one possible outcome of a game of tectonic bagatelle and successive events on the same fault are completely different (Lindsay *et al.* 2016; Nic Bhloscaidh *et al.* 2015; Philibosian *et al.* 2014).

This – now rarely disputed – observation provides the final blow to hopes of useful deterministic earthquake forecasting. If it were possible to identify segments of active faults with a high likelihood of rupture in the near future, and if, as in the Nias case, previous history made it possible to estimate the likely magnitude of the impending earthquake, even then we would be unlikely to make useful forecasts. Consider, for example, how tsunamis are generated by megathrust earthquakes. Strain, accumulated over hundreds of years, depresses the near-shore sea floor by metres and large earthquakes rupture the plate interface, allowing this century-scale strain energy to be released in seconds, forcing the seafloor upward over a vast area and producing a 10 billion tonne bulge in the sea surface. The collapse of this bulge generates a tsunami, the impact of which might be expected to be related simply to the earthquake magnitude. However, several studies (McCloskey *et al.* 2008; Geist 2002) have shown that this is not the case. Again, the non-linear amplification, this time of small differences in the relationship between water depth and earthquake slip, result in very different impacts when viewed, for example, from the coastal city of Padang in western Sumatra. Almost identical earthquakes on the same segment of the off-shore fault might produce a 50cm wave for the city or a 5m wave – killing no one or possibly hundreds of thousands (Borrero *et al.* 2006). Similar numerical experiments examining the shaking produced by possible earthquake scenarios for Istanbul show similar divergence, both in wave amplitude measured at particular places and in estimated fatalities.

These observations have important philosophical as well as practical implications for the application of physical science to earthquake risk management. Despite undeniable advances in the understanding of the physical processes underlying large earthquakes, several seismic butterfly effects ensure that the outcome will always be a surprise (cf. Lay 2012). Consider a world in which earthquake physics was completely known and where Laplacian determinism[2] would only require accurate assessment of the initial conditions fully to constrain the future (and the past). Even then, the hope that these initial conditions might be estimated with sufficient accuracy to yield actionable forecasts by the techniques of geology and geophysics are dashed by Lorenzian exponential[3] (or even super-exponential) divergence of dynamical trajectories. The immutable aleatory uncertainty in our observations, no matter how good our epistemic understanding, forbids useful prediction of the outcome. In this world, conservative estimates of impact might wildly underestimate the consequences of particular decisions and unfulfilled forecasts of the worst impacts would leave physical scientists exposed to accusations of crying wolf, fundamentally undermining their collective credibility.

What are the implications of this perspective for physical science in earthquake risk management? Many physical scientists now recoil from traditional pronouncements made with certainty and clarity that effectively made science and engineering the decision-makers in many development environments (cf. Chiarabba *et al.* 2009). For some, this is a cause for celebration but, spurious as this over-confidence might have been, the potential vacuum thus created is unlikely to be filled by better assessments of risk. Allowing this, the challenge becomes a reassessment of what can be learned by scientific risk estimation, and finding a more nuanced, and perhaps a more modest, role for its insights.

In the Global Challenges Research Fund Urban Disaster Risk Hub (www.tomorrowscities.org), attempts are being made to use the enduring convening power of physical science simulation, rather than its certainty. In this approach, simulations of the consequences of particular development choices are used to convene multidisciplinary teams of decision-makers who provide multiple perspectives to illuminate complex development decisions. Rather than usurping decision authority, science now becomes a tool for decision support. Rather than scientists providing definitive forecasts, they relegate the consequences of immutable aleatory uncertainty and promote the epistemic certainty of well-constrained physical principles to a supporting role in a multidisciplinary process. Time will tell if this is a more effective, sustainable role for geophysical science.

Conclusion

Responding to the questions posed in Box 9.1, the accounts of uncertainty presented here, from quite different perspectives and in very different contexts, agree on four fundamental properties of knowledge production in the context of disaster risk management and international development:

Uncertainty is prevalent throughout disaster research. Uncertainty is a product of the complexities of physical and social processes and their interactions. There are some areas that are more predictable than others: flood risk as a consequence of upstream river catchment rainfall and river level rise is highly predictable when all catchment characteristics are known in detail. However, anticipating the probabilities of outcomes becomes difficult where non-linear physical or social processes distance observable phenomena from potential outcomes – in time, space and scale. It is much harder to predict flooding accurately in urban catchments due to the complexity and dynamism of land use, or to predict earthquakes based on observable changes in crustal stress.

As knowledge has grown, so has awareness of the uncertainties that constrain this knowledge. Researchers have been very successful in their mission to resolve knowledge gaps in the understanding and predictability of social and physical systems behaviour. However, the history of disaster studies shows that greater depth of knowledge, while offering specific insights, tends then to reveal further the complexity, context-specificity and ambiguity of revealed knowledge.

Uncertainties are likely to continue into the future and so must be embraced. Research that seeks to push forward the frontiers of knowledge is key to scientific endeavour and its social contribution. It is tempting for researchers to claim to have reduced uncertainty through their work. For research findings to be useful to society it is important also to recognise that uncertainties remain even as knowledge grows. The pressures on academics to publish results that emphasise comprehensiveness and certainty does not allow broader uncertainties embedded in question framing, methodology and interpretation to be fully expressed. This is compounded in aggregate reviews and integrated assessments, where uncertainties may be systematically overlooked. This challenge is especially important for disaster risk studies, which are often interdisciplinary or multidisciplinary. With knowledge crossing domains of expertise it becomes more difficult for researchers to bring expert judgement to questions of uncertainty embedded in research processes and yet not made explicit through publication or other formal reporting.

Managing the presentation of uncertainty is a challenge for scientists working with policy-makers and the public, who look to science to reduce uncertainty. The case of L'Aquila in Italy, where seven public officials were tried for having allegedly given out misleading and incorrect information to the public before the 6 April 2009 earthquake, has highlighted how exposed scientific comment (and scientists) can be when knowledge is taken into politicised and emotive contexts (Alexander 2014). There remains a popular assumption that the role of science is to make the world more understandable, not to reveal its uncertainties. Indeed, the public legitimacy of scientists as 'speakers of truth through evidence' rests on this. As science moves more deeply into researching the behaviour of non-linear systems and processes of production of risks and uncertainties, so the gap between popular (and political) expectations of science, and the actual practice of science, grows.

These four fundamentals of uncertainty within the context of disaster studies reveal an increasing tendency for science to move from providing society with increased certainty and having its legitimacy built on bringing clarity, towards a situation where natural, physical and social science is one arbiter among other arbiters of diverse knowledges that are always partial and contingent. This challenge matches the movement of science from providing linear to providing non-linear conceptualisations of nature and society. The value of natural and physical science in offering a transparent and robust way into the uncertainty of non-linear systems, and a key challenge for the future, is to continue to communicate the value of the contribution of a broader interdisciplinary science. This does not mean that only the formal natural-physical scientific methodology is legitimate – but it does emphasise the importance of a particular type of quantitative rigour in the presentation of underlying conceptual and methodological frameworks, and the ability to communicate these in non-specialist language to allow such contributions to grow into the interdisciplinary spaces demanded of complex and non-linear phenomena.

At the same time, there is a danger that the technical expertise needed to understand such cutting-edge research could push this type of science into elite spaces – with only experts being seen as having the analytical tools to make sense of uncertainty; or that the burden for decision-making under uncertainty is unreasonably placed into the hands of local actors with constrained access to appropriate interpretive tools. Instead, researchers have a responsibility to work with uncertainty in disaster management as a mechanism for the levelling of formal expertise. Realising this opportunity is perhaps the greatest challenge facing contemporary research that aims to make a difference in the world.

Notes

1 Telecoupling refers to interactions between distant social-ecological systems (Hull and Liu 2018).

2 The mathematician Pierre Simon Laplace argued, in 1814, that if we knew the precise location and momentum of every atom in the universe, the entire past and future could be calculated from the laws of classical mechanics. Thus, if we knew the physical law perfectly (no epistemic uncertainty), knowledge of the precise state of the fault would allow the perfect description of all past and future events.

3 Ed Lorenz was the meteorologist who, in his paper of 1963, first described the butterfly effect. Tiny changes in initial conditions are amplified through dynamics to render the future extremely unpredictable.

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