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Triggering Multi-Actor Change Cascades: Non-Representational Theory and Deep DRM Co-production

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1. Introduction: DRM Co-production and Social Change

Climate change and the related challenges of global poverty, inequality and disaster vulnerability require deep changes to current economic and political structures, values and lifestyles. Incremental solutions that leave existing ways of doing things largely untouched are not enough. Deep transformative change is needed, to re-orientate systems and values in ways that transcend current structures and behaviours (Lonsdale, Pringle & Turner 2015, Kates, Travis & Wilbanks 2012, Park et al 2012). Disaster risk management (DRM) is an important part of these multi-dimensional transformative efforts to reduce risk and poverty and enhance adaption (O'Brien et al 2008).

Co-production is a common component of DRM solutions. Broadly defined, it is a process by which established, often hierarchical, power relationships between expert and lay communities, and service providers and users are broken down, so that citizens, experts and decision makers are more equal partners in co-producing programming and policy (Bremer & Meisch 2017). However, the root causes of poverty, risk vulnerability and climate change lie in the power, wealth, energy and information that flow through current global, socio-ecological and technical systems and 'traditional' approaches to DRM co-production are too 'shallow' to tackle these deep structural causes. They focus on the knowledge, values and decisions of individuals rather system level processes and are wedded to the notion that changes in personal and cultural values (through social learning and critical reflection or providing new knowledge and information), inevitably lead to transformations in material practices and structures. As sustainable consumption research repeatedly shows for example, there is a persistent gap between values and action, and current systems of production, consumption and energy use are 'locked in' by structures of power, vested interests, habit and inertia and are extremely difficult to change (Geels et al 2015).

In this paper we use non-representational theory to derive an alternative 'deep' approach to DRM co-production. Non-representational theory takes underlying socio-ecological-technical systems and assemblages as its starting point and gives the knowledge and values of human subjects a more modest role in the process of social change. Human actors are not directing change from outside or above but are embedded within these assemblages. There is less of a role for human values and rationality in driving change, and more for chance, accidents, the transformative power of science and technology, and other sources of non-human agency (including non-human actors such as climate change and earthquakes). More specifically we do two things. Firstly, we introduce non-representational theory and build a hybrid theoretical framework to throw light on how change is coproduced in DRM. Secondly, we use this framework to analyse a case study of science-humanitarian DRM co-production (the AFTER Project). This project developed an aftershock forecasting tool to aid humanitarian decision making that was used during the emergency response to the April 2015 earthquake in Nepal. We analyse the case study using the concepts of assemblage, event and fidelity to reveal how change occurred in this instance, and pave the way for a more effective, deep approach to DRM co-production as 'a practical means of going on' (Thrift 1999). We finish with five precepts to guide transformational DRM based on the concept of multi-actor change cascades.

2. Beyond Shallow DRM Co-production: Non-Representational Theory and Social Change

2.1 Shallow Co-production and Incremental Change

The scale and gravity of climate change, deep poverty and hazard vulnerability demands profound transformation of existing technical, governance, economic and socio-ecological systems (Chatterton & Pusey 2019). Climate change adaption for example, can't be achieved through incremental shifts in individual values and patterns of behaviour. Fundamental and deep-rooted transformation of the economic, transport, energy and agro-food systems that underpin these lifestyles is required (Termeer et al 2017). As Urry states, it is

> *Not a question of changing what individuals do or not do but changing whole systems of economic, technological and social practice. Systems are crucial here and not individual behaviour (Urry 2010, p3)*

The theory and practice of co-production is an increasingly important element in these adaption processes and related poverty reduction and DRM policy and theory (Cvitanovic et al 2015, Dilling & Lemos 2010). Co-production is defined as *the deliberate collaboration of different people to achieve a common goal* (Bremer & Meisch 2017). It is used in a wide variety of contexts ranging from the co-design of policy and services (Otsuki 2016), as a framework for knowledge exchange, (Fazey et al 2014), and in the co-production of useful science (Shaw et al 2017, Van der Hel 2016, Dilling & Lemos 2010, Lemos & Moorhouse 2005). Bremer & Meisch (2017) in their review of co-production in climate change adaption, describe a wide range of applications. These include, enhanced science-user iteration to produce more effective climate knowledge; integrating non-science perspectives into the science process; enabling an active role for citizens in the production of social policy and public services; as a process to improve institutional capacity for social learning and critical thinking around climate change, and empowering traditional environmental knowledge users in environmental management and governance processes (Bremer & Meisch 2017).

This approach to co-production can make useful incremental contributions to adaption, poverty reduction and DRM. However, we contend that it struggles to theorise and deliver the deep change to systems and practices that is required because it focuses on changing the behaviours and mind sets of individuals rather than the underlying socio-technical systems and power relations within which human actors are embedded. This ignores the ways in which human behaviours are governed by habit, routines and roles that are locked-in by deep socio-political structures. As Geels et al (2015) put it these,

> *Socio-technical systems are hard to change because of various 'lock-in' mechanisms. For example, taken for granted rules and institutions, sunk investments, policies that create a non-level playing field, and active resistance by incumbent actors using power and politics to stabilise existing systems (Geels et al 2015, p6)*

Social change is not a reflection of mind sets, knowledge and intentions but the consequence of shifts, transitions and tipping points in complex, emergent and co-evolving assemblages of human and non-human actors (including ecosystems, information and knowledge networks and technological, transport, communication and market infrastructures). These changes are often unpredictable, outside of human control, and driven by alterations in the non-human elements of systems. These are the deep structures that underpin climate change, deep poverty and hazard vulnerability and we contend that an equally 'deep' approach to co-production is required to comprehend and enable their transformation. Non-representational theory is a good place to start developing this alternative view and we explore this approach in the next section.

2.2. Non-Representational Theory & Deep Co-production

For non-representational theory, shallow co-production's over emphasis on human subjectivity is an example of a more general problem with Western thought. This is exemplified by Descartes's 'I think therefore I am', where all we are certain of is that we exist as an isolated bubble of human consciousness. Much of Western philosophy since has been an attempt to prove that the world beyond the self is really there!

Non-representational thinking begins instead with the human subject embedded in the world rather than observing it from a distance. As Thrift puts it, we are not separate from the world and reflecting upon it but

> *Slap bang in the middle of it, co-constructing it with numerous human and non-human others (Thrift 1999, pp296-297)*

This is an 'horizontal' ontology, rather than the vertical, hierarchal one of the Cartesian subject in a world of inanimate objects. This is an ontology that works *through things rather than impose itself upon them from above* (Thrift 1999, p302). Human subjects are elements in these complex networks of human and non-human actors (objects, things, technology, creatures) and actions and outcomes are the consequence of these relations rather than driven solely by human subjects. Knowledge too is embedded and co-produced in these networks and assemblages and is a tool to guide action for particular practical ends rather than detached contemplation for its own sake. As Thrift puts it, knowledge is

> *A practical means of going on rather than something concerned with enabling us to see, contemplatively the supposedly true nature of what something is (Thrift 1999, p304)*

Various perspectives have developed within this general non-representational position. We introduce three below that are of particular use to DRM.

2.2a. Power-Knowledge The work of Michel Foucault is an influential precursor to non-representational theory (Murdoch 2006). For Foucault knowledge is always situated and embedded within particular historical contexts and distributions of power (Foucault 1980). Foucault's work displaces the primacy of the human subject and instead treats 'discursive formations', (arrangements of power-knowledge and associated technologies and techniques) as the agents of social change (Foucault 1998). For example, in *Discipline and Punish*, his study of the birth of the modern prison, discourses and techniques of surveillance and self-improvement initially developed to reform inmates, rapidly spread to other institutional environments (schools, hospitals, factories) and then across the social fabric in unexpected and accidental ways, seemingly beyond the control of human subjects (Foucault 1991).

Foucault also gives insight into the role of the intellectual in non-representational change (Patton 1985). Given that knowledge is embedded and produced in particular social contexts, we should give up the idea of the 'universal intellectual' that can access values and truths that speak for 'all of humanity'. We should avoid the perspective of the totality, for it is always the standpoint of some masquerading as the truth for all. Instead we should adopt the role of the 'specific intellectual', and engage in a strategic way, in specific situations, to solve particular problems, for limited socio-political goals. Knowledge shouldn't be judged on its universality but on its practical usefulness. Its capacity to trigger cascading lines of productive, transformative change.

These ideas have been taken in a number of interesting directions. For example, Jasanoff has explored how knowledge is institutionally embedded through studies of science and politics in modern democratic societies (Jasanoff 2004). She focuses on diverse 'civic epistemologies' (the decision-making routines, conventions around what counts as evidence, guidelines pertaining to the role of experts in policy making) embedded in political and legal institutions and tracks how these frame policy co-production (Jasanoff 2004). A related emphasis is found in work on governmentality**.** Here the focus is on technologies and strategies of modern government developed to produce healthy and productive citizens, that have in so doing, fashioned identity categories such as normal/abnormal, sane/insane, productive/unproductive (Fraser 2017).

2.2b. Actor-Network Theory (ANT) ANT is a theoretical and methodological approach that builds on Foucault's concepts of discursive formations and power-knowledge (Murdoch 2006). It is frequently used to analyse the relationship between science, technology and innovation (Latour & Woogar 1986, Callon 1986, Latour 1983, Callon & Latour 1981). Central to ANT is the view that reality is composed of complex networks of human and non-human actors. Social change is the consequence of interactions between agents that are both human (e.g. scientists, technicians and wider publics), and non-human (e.g. the microbes, electro-magnetic fields or tectonic processes that science aims to understand and control, as well as the laboratories, technology, computer code and specialised ways of writing and representation that enable this). There is a symmetry to actor-networks. Non-human actors (as well as human actors) have agency, as without them the actor-network would not function. Natural hazards and processes are not the passive backdrop to human action, but agents, and events that disrupt and reorder settled social realities and frameworks.

Science is embedded in these networks and has a key role in driving new forms of social change. For Bruno Latour science has a special status because of the sophisticated institutional architecture that makes it our deepest and most powerful knowledge of how nature works. This is the institutional architecture of *large numbers of researchers…complex systems of verifying data, the articles and reports, the principle of peer evaluation, the vast networks of (data collection) stations…satellites and computers that ensure the flow of information* (Kofman 2018, p11). It is because of these underlying cultural practices that science thrives and is our most robust, sophisticated and convincing knowledge of nature.

For Latour science is 'special' in a second sense. It can be a source of fresh power and fresh politics. Latour's target is 'the Sociology of Science' which treats science as an epiphenomenon of underlying social processes and interests. For Latour science is a transformative force precisely because it is the source of new knowledge that, initially at least, is outside of society and politics. In the early stages of science development, the full implications of the science and related technology are yet to be imagined and realised. As Latour puts it

> *The congenital weakness of the Sociology of Science is it propensity to look for obvious stated political motives and interests in one of the only places, the laboratories, where sources of fresh politics, as yet unrecognised as such are emerging (Latour 1983, p157)*

ANT provides several conceptual tools to analyse and understand the process of actor-network building and stabilisation. We focus on two, enrolment and translation. Transformative change happens by enrolling actor-networks. This process of producing and transforming the wider social world begins by enlisting social actors in a shared project of change. This proceeds firstly by enrolling participants through displays of institutional architecture and (potential) science power. Latour gives the example of Louis Pasteur's demonstration of the power of his new anthrax vaccine at the Puilly le Fort field trials in May 1881 to an invited audience of politicians, farming leaders, scientists and other key actors (Latour 1983). The elaborate display of the vaccine's effectiveness produced a coordinated actor-network that eradicated anthrax across France (Latour 1983).

Once wider publics are enrolled, actor-networks are built through 'translation'. Science and non-science groups spend time sharing perspectives so the science is tailored and relevant to user needs, and users have an accurate and realistic understanding of what science can do for them. Translation occurs when some of the features of the laboratory are translated into the wider world through training (Latour 1983). For the science to be transformative, the skills, knowledge and behaviours of 'the laboratory' (e.g. accurate data interpretation, measuring and monitoring), must become routine to wider publics. These translation processes are dependent on effective science communication, education and training.

2.2c. Assemblage Thinking Our third perspective, like ANT, sees reality as composed of networks of multiple diverse actors, but stresses the fluidity, uncertainty and emergent qualities of these assemblages, over processes of ordering and stabilisation (Muller 2015). For Deleuze & Parnet an assemblage is

> *A multiplicity which is made up of many heterogeneous terms and which establish liaisons, relations between them across ages, sexes and reigns-different natures. Thus the assemblage's only unity is that of co-functioning: it is a symbiosis, a sympathy. It is never filiations which are important but alliances, alloys, these are not successions, lines of decent, but contagions, epidemics, the wind (Deleuze & Parnet 1987, p69, cited in Muller & Schurr 2016, p219).*

This difference of emphasis leads to an interest in forces, processes and pressures that crowd in from beyond the immediate actor-network that can intrude, disrupt and provide new opportunities for change. For Muller & Schurr this is the realm of 'the virtual'. These are

> *Relations of exteriority…entities in relation are not fully determined by these relations, but always exhibit a surplus that is something outside reality… (For example) the very possibility of unpredictable events in the future (for example a forecasted natural hazard) shapes the forms of the networks in the present (Muller & Schurr 2016, p 220)*

Both ANT and assemblage thinking decentre the human subject in social change, but in different ways. In ANT social change is built though science power and resulting ordering processes of enrolment and translation, however assemblage approaches emphasise surprising ruptures that are beyond the control and understanding of human agents. These are 'events'. Events are dislocations that open potentialities for change. They are the continuous effects of shifting fields of human and non-human actors that Anderson & Harrison describe as *the escaping edge of any systemisation or economisation; the effects or affects of any light of flight* (Anderson & Harrison 2010, p20). Assemblages are inherently volatile and always threaten to spin off into new configurations. Considerable effort is needed to hold things together. 'Events' can also be shocking surprise ruptures that violently overturn and shatter existing frames of meaning and stable patterns of order (Anderson & Harrison 2010, pp21-22). For Zizek, this type of event is

> *Something shocking, out of joint, that appears to happen all of a sudden and interrupts the usual flow of things… (Zizek 2014, p2) … An event is not something that occurs within the (existing) world, but is a change of the very frame through which we perceive the world and engage in it (Zizek 2014, p 10)*

Once a space for change has been opened, fidelity is a force that influences the direction in which things then move. As Badiou puts it, it is a matter of extracting

> *Something else from what was mere chance. I'm going to extract something that will endure, something that will persist, a commitment, a fidelity…that transitions*

> *from a random encounter to a construction that is resilient, as if it had been a necessity (Badiou 2009, p 44)*

It is about finding the good in the new situation and, through fidelity, growing and amplifying it into a positive cascade of social change. For Badiou, there is also the sense that fidelity can create (not just react to) events. Fidelity to a specific political cause can constitute the initial event that challenges existing structures. Continued fidelity to the cause can reaffirm and amplifying it into a larger political movement until it is a line of flight, rippling across the fabric of the assemblage, triggering other events and cascades of change. Both fidelity as reaction and catalyst occur together, overlapping and mutually reinforcing.

2.3. Cross-Fertilising Non-Representational Theory for Deep DRM Co-production

Non-representational theory has been taken in two directions by researchers in disasters and DRM**.**

2.3a. Disasters as Events: Disasters have been analysed as assemblages of human and non-human actors. For example, for Donovan (2017)

> *A (volcanic disaster is) an assemblage of human-nature constituents, including the livelihoods, identities, cultures and imagination of populations, alongside the physical movement of magma in the earth and the scientific interpretation of the signals it produces (Donovan 2017, p49)*

In a manner that echoes the definition of 'event' as 'absolute surprise', Donovan also conceives of the natural hazard as an 'actor' within this actor-network that disrupts and transforms existing patterns of social order. Donovan gives the example of the Eyjafjallajokull volcanic eruption in 2010.

> *(This) was not a surprise to volcanologists, but it sent shockwaves across governments and industry in Northern Europe. It neatly demonstrates the intersection of knowledge networks, the aviation industry, policy makers and the earth system. The volcano triggered a response that rapidly spread around the globe, flights were cancelled, and economic impacts were felt by governments, the aviation industry, travellers and insurers-and Icelandic farmers (Donovan, 2017, p50)…Ultimately, the volcano itself has agency within the human-physical environment to transform such links and to continue transforming them long after the physical eruption has ended (Donovan 2017, p50)*

For Pelling & Dill (2010) events like these can be tipping points. These are

> *Temporary breaks in dominant political and social systems that post disaster can open space for alternative social and political organisation to emerge (Pelling & Dill 2010, p25)*

Disasters can puncture the existing social fabric and open unforeseen opportunities for social transformation and experimentation (Dickinson 2018).

2.3b *Governmentality and Civic Epistemologies:* Foucault's concept of governmentality has been used in DRM research to explore how governments and related agencies produce social order through the techniques, rationalities and strategies they routinely deploy (Fraser 2017, Aggarwal 2016, Rebotier 2012, Mustafa 2005). Fraser, for example, has used this idea to explore how the field of 'urban vulnerability' to climate risk has been constituted *as a new problematic of urban governance, creating new technologies and* *subjects* (Fraser 2017, p2836). In a similar way Boyd et al (2014) used a case study of Maputo municipality in Mozambique to explore how governmentality processes produced new political and environmental identities. Here the state, through its risk assessment processes, defined some sectors of the population as responsible citizens and others, who were building on flood plains, as illegally settled. The latter were 'produced' by these risk assessments as a cause of flood risk. Finally, Scolobig and Pelling (2016) in their study of the co-production of technical solutions to landslide risk in Italy, use Jasanoff's concept of 'civic epistemologies' to analyse how differences in institutional context impacted on the effectiveness of these interventions.

Current approaches in DRM draw usefully but selectively from non-representational theory (Figure 1 in bold). To build on this we propose a fuller cross-fertilisation of non-representational approaches (Figure 1 in italics). From ANT we add Latour's emphasis on 'science-power' as a non-human catalyst for change, and the role of enrolment and translation processes in re-ordering and transformation. We include Foucault's concept of the 'specific intellectual' to clarify the role of the human subject in non-representational change and from Assemblage Thinking we incorporate the importance of 'fidelity' to the event and the role 'the virtual' plays in these processes. Including these elements, we contend, gives a deeper understanding of transformative social change and the role of DRM co-production within it.

In Section 4 we use this cross-fertilised framework to analyse an example of deep DRM co-production from Nepal, (the AFTER project). In this analysis, we use the concepts of assemblage, event and fidelity discussed above, to show how deep co-production, rather than shallow perspectives, gives the most convincing account of this case study of social change. We conclude in Section 5 with some of the real-world implications of this analysis and derive five precepts for deep DRM co-production in practice. Before all of this, in Section 3, we introduce the fundamentals of aftershock science, some key features of natural hazard risk and DRM in Nepal, and the AFTER Project.

<table>
<tr><td>Actor-Network Theory

Latour</td><td>Assemblage Thinking

Deleuze & Parnet
Badiou
Zizek</td><td>Power-Knowledge

Foucault</td></tr>
<tr><td colspan="2">Disasters as assemblages/networks of human and Non-human actors
(e.g. Donovan 2017)</td><td rowspan="2">Governmentality
(e.g. Fraser 2017, Boyd et al 2014, Reboitier 2010, Mustafa 2005)

Civic Epistemologies
(e.g. Scolobig & Pelling 2016)

The Specific Intellectual</td></tr>
<tr><td>Science Power

ANT Tools
• Enrolment
• Translation</td><td>Disaster as Event
(e.g. Donovan 2017)

Disasters as Tipping Points (e.g. Pelling & Dill 2010)

Fidelity to the Event

The Virtual</td></tr>
</table>

Figure 1: Cross Fertilising Non Representational Theory for Deep DRM Coproduction
Existing applications of non-representational theory to disasters and DRM are in bold. New elements included in the hybrid approach are in italics

3. The AFTER Project

3.1 The Science of Aftershock Forecasting

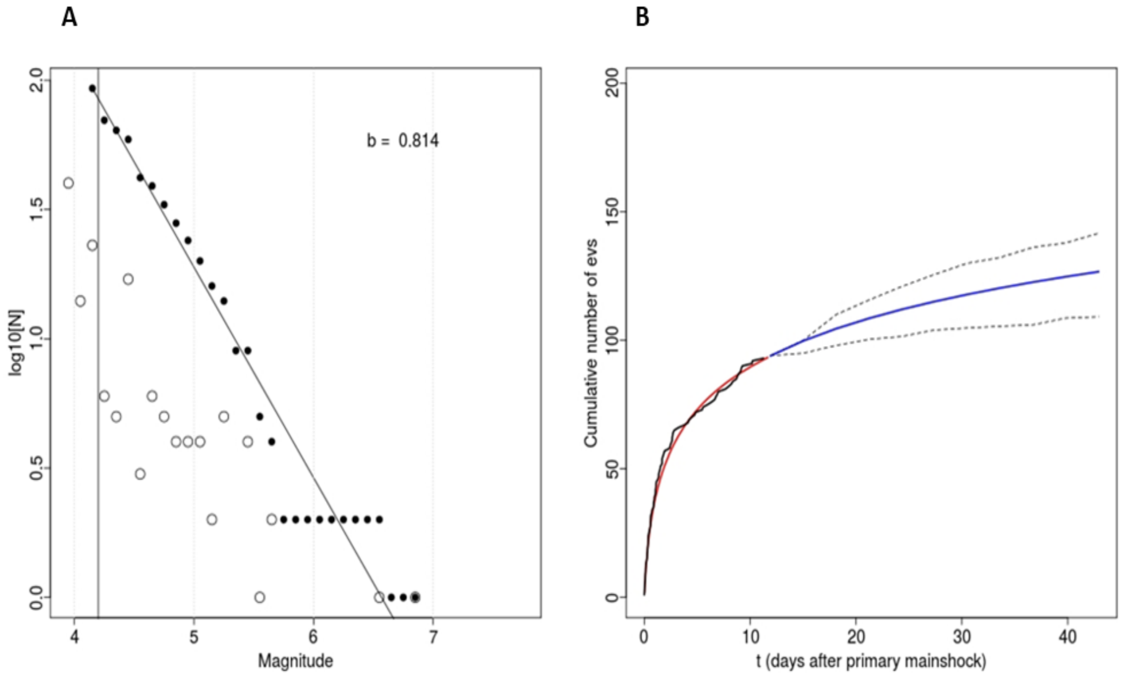

Figure 2: A) The Earthquake Frequency Magnitude Distribution and B) The Cumulative Aftershock Decay Curve during the Early Aftershock Phase of the 2015 Nepal Earthquake

Seismic networks detect and record earthquakes worldwide (e.g. USGS n.d.), reliably down to magnitude M=5, even for events which are very distant from the nearest seismic stations. The location and size of events can be calculated automatically; they are recorded in earthquake catalogues, which are published in near-real time in online repositories. Good quality earthquake catalogues allow scientists to examine the evolution of aftershock behaviour in near-real time following a large earthquake. By observing the behaviour of the abundant smaller earthquakes in the aftershock period, we can make forecasts about the probability of a rare, damaging large aftershock.

Aftershock behaviour is characterised by two statistical laws: the Omori-Utsu law describes how the total aftershock activity decays with time after the mainshock and the Gutenberg-Richter law describes how their magnitudes are distributed. These are the strongest relations in earthquake statistics. All modern aftershock forecasting relies on the premise that, if we can condition these two models on early aftershock data, the statistical behaviour will hold reliably into the near-future. Figure 2 shows A) the earthquake frequency magnitude distribution and B) the cumulative aftershock decay curve during the early aftershock phase of the 2015 Nepal earthquake, including all aftershocks above the (network dependent) magnitude detection threshold Mc for the Nepal agency catalogue. The best fit models are shown, along with the forecast for the total cumulative number of aftershocks expected above Mc during the forecast period of 30 days.

The Omori-Utsu and Gutenberg-Richter laws are combined to give a forecast for the expected number of events above a given magnitude threshold during the forecasting period. An example of the type of forecast that humanitarian participants used during the Nepal earthquake response is shown in Table 1. The clear message from these data is that in the aftermath of the Nepal mainshock, large damaging events of M5-6 were almost certain, and there was an extremely large probability (possibly as large as 25%) of an aftershock greater than M7.

M	5.0	5.5	6.0	6.5	7.0	7.5	8.0
<p>	0.99	0.87	0.58	0.29	0.13	0.06	0.02
p(90%)	1.00	0.98	0.80	0.49	0.25	0.11	0.05

Table 1: Example of forecast made on the 10/05/2015 for 30 days of future aftershocks in Nepal
Results for the probability forecast are shown for a series of magnitude thresholds. The middle row shows the expected probability that there will be one or more event with magnitude above threshold M. The bottom row shows an upper bound on the probability, such that there is a 90% chance that the "true" probability does not exceed this value

Further information on the spatial distribution of aftershocks was available. Humanitarian participants were provided with maps of aftershock activity (Figure 3) that had already occurred; these were presumed also to be the most dangerous regions for future aftershock activity.

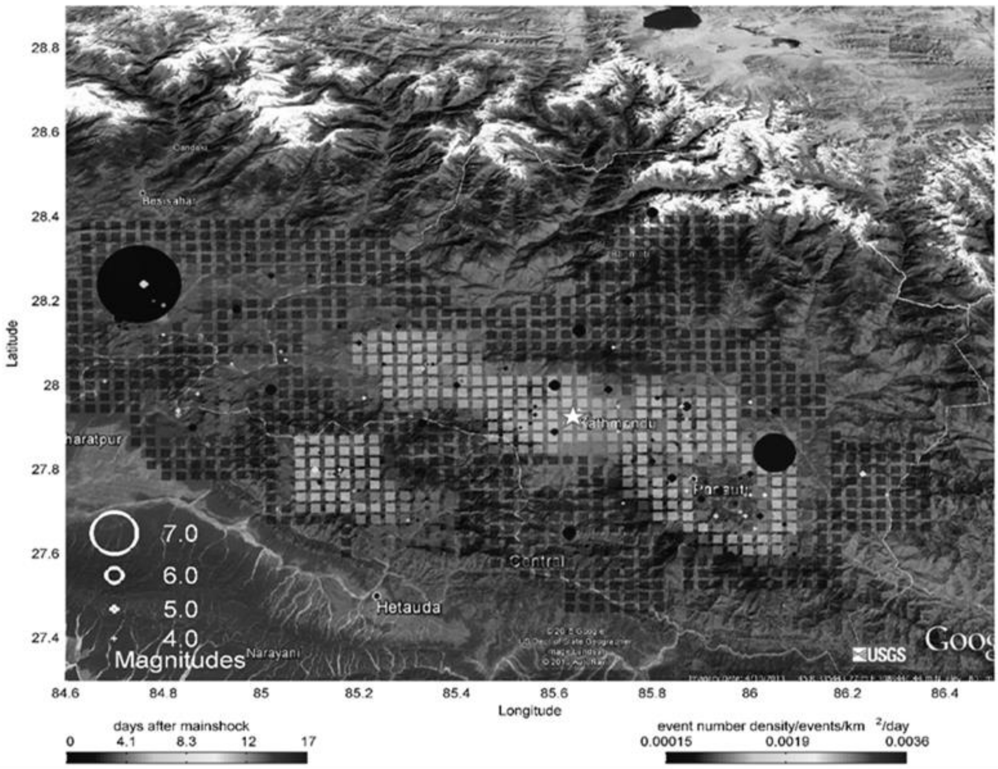

Figure 3: Aftershock Map as used by Concern in Nepal 2015 Emergency
Lighter regions have highest density of aftershocks. Kathmandu is starred

3.2 Natural Hazards and DRM in Nepal

Nepal is located at the interface of the Indian and Eurasian tectonic plates and has a long history of destructive earthquakes (MoHA 2018b). The April 2015 earthquake (M7.8) was the largest for over eighty years and triggered over 553 aftershocks of M4 or greater within 45 days of the initial event (MoHA 2016, Adhikari 2015). Four of these aftershocks were bigger than M6, the largest being an M7.3 on May 12th 2015. With mountainous terrain, steep topography and subject to the SW (summer) monsoon in South Asia, Nepal is vulnerable not only to earthquakes, but to a wide range of other hazards (Nepal et al 2018, Petley et al 2007). The Nepal Ministry of Home Affairs estimate that between 1971 and 2015 there were 40,264 natural hazard fatalities, largely as the result of epidemics, earthquakes, landslides and floods (MoHA 2016). These hazards interact in complex ways and primary hazards, such as earthquakes, can trigger cascades of secondary events (Goda et al 2018, Gill & Malamud 2016). For example, it is estimated that the 2015 Nepal earthquake generated at least 2780 landslides, many resulting in fatalities (MoHA 2018a).

A quarter of Nepal's population is poor, and the 2015 earthquake pushed a further 2.5-3.5% into poverty (World Bank 2018). This vulnerability is exacerbated by political instability, and caste, religious and ethnic divisions (De Juan & Pierskalla 2014, Askvik, Jamil & Dhakal 2010). This and rapid unregulated urbanisation mean that natural hazard vulnerability in Nepal continues to rise (MoHA 2018b, DFID 2012). The introduction of a new political constitution in 2015 established a federal structure that has paved the way for a multi-level approach to disaster risk management (Nepal et al 2018). This gives primary responsibility for DRR to local governments, supported by provincial and federal structures (MoHA 2018a). Key developments include the National Disaster Risk Reduction National Policy (2018) and Disaster Risk Reduction Strategic Action Plan for Nepal (2018-2030). These demonstrate a shift in policy from emergency response to preparedness and disaster risk reduction, and greater alignment with global initiatives such as the Sendai Framework for Disaster Risk reduction (SFDRR) and the Sustainable Development Goals (SDGs) (Nepal et al 2018).

3.3 The AFTER Project

AFTER was a UK research council funded project that ran from December 2013 to July 2016, based on a collaboration between the University of Edinburgh School of Geosciences and Concern Worldwide. Concern Worldwide are a Dublin based international humanitarian organisation. Founded in 1968 their mission is to reduce extreme poverty and hunger. They have 35000 staff worldwide and focus their work in countries where people are living on less than $2 a day. They are involved in emergency response programming and disaster risk reduction, and have particular expertise in health and nutrition, education, livelihoods and gender equality (Concern n.d.). Concern frequently work in earthquake prone countries (Haiti, Nepal) and the aim of the project was to develop the aftershock science described above into an approach to inform their decision-making during an earthquake emergency.

There were seven core members of the AFTER team (three geoscientists, two humanitarian participants and two social scientists). This expanded to thirteen during and after the Nepal 2015 earthquake. The science group was led by a professor of geoscience and the humanitarian group by Concern's Emergency Director. Concern's Emergency Response Coordinator during the Nepal emergency was a full participant in the project.

The project had two phases. From December 2013 to May 2014 and from January 2015 to June 2016. The first phase consisted of five workshops that introduced participants to earthquake and aftershock science fundamentals and the key principles and practice of humanitarian work. This included skills development training (e.g. plotting Omori-Utsu curves (Figure 2) by hand and interpreting tables of probability forecasts (Table 1). Scenario planning activities using fictional earthquake catalogues and emergency situations gave insight into the potential use of aftershock warnings in health and safety planning and logistical and programming decision-making, and the most useful and accessible ways in which to report and present this information. The April 2015 M7.8 Nepal earthquake occurred at the beginning of the second phase of the project (Hope et al 2016). Concern staff, including participants in the AFTER project, were part of the humanitarian response. The science team produced a series of real-time aftershock forecasts using the real world earthquake catalogues available immediately after the earthquake and emailed these forecasts to Concern staff in Nepal. In the weeks after the emergency four workshops were run to reflect on and learn from the Nepal event.

The AFTER project was planned as a case study of science-humanitarian co-production from the beginning. Two social scientists were an integral part of the project team. Qualitative research was built into both phases of the project and all workshops were recorded and transcribed. Qualitative data was collected by participant observation, and informal interviews and discussions with workshop participants. Over twenty five formal interviews were conducted with participants over the course of the two projects. Opportunities for reflection on the co-production process and the results of the qualitative analysis were built into workshops.

In the next section we examine the AFTER case study through the lens of non-representational theory. We demonstrate the relationship between DRM, co-production and social change by emphasising three themes: assemblage, event and fidelity. It wasn't the shallow co-production processes of knowledge exchange or critical reflection that drove transformation, but deeper, often unexpected shifts in networks of human, non-human, virtual and real actors. We use the case study to develop an alternative, deeper version of co-production (as a 'practical means of going on') and derive five precepts to guide DRM co-production using the concept of multi-actor change cascades.

Section 4: Assemblage, Event & Fidelity: Aftershock Forecasting and Social Change in the Nepal 2015 Earthquake

Section 4.1: Assemblage

The constant risk of serious damaging earthquakes underpinned the development of the DRM assemblage in place in Nepal prior to the April 2015 event. Key actors included the Government of Nepal (GoN) which introduced the Nepal National Strategy for DRM in 2009 and launched the Nepal Risk Reduction Consortium in 2011 (GoN n.d.). Many international humanitarian agencies were working in Nepal prior to the 2015 event (Barcia 2015), (including Concern since 2010), and the Department of Mines and Geology (DMC) within the GoN was a central, (if underfunded), source of scientific expertise in seismology (Oven et al 2016). The pre-2015 DRM assemblage was dynamic as shifts in components generated change elsewhere in the network. For example, alterations in global hazard governance such as the implementation of the Sendai Framework for DRR had consequences for the restructuring of DRM in Nepal (GoN 2017). 'Virtual' actors had a part in these re-orderings. The core humanitarian principles of humanity, impartiality and neutrality were a virtual pressure that motivated the humanitarian actors within the assemblage (Barcia 2015), and the risk of future earthquakes was a constant possibility that crowded in on the present (Anderson 2010). Power and resources flow through assemblages, enhancing the agency of some and reducing it for others, and Nepal has been for many years amongst the poorest countries in the world with persistent social inequalities and political uncertainty (Titz & Kruger 2015). This meant that the April 2015 earthquake when it came, *was an extreme event that people…had been expecting for a long time, yet no one was adequately prepared for it* (Titz & Kruger 2015).

The AFTER project was catalysed in 2013 by the convergence of two virtual pressures. Firstly, as with the sector in general, humanitarian principles were a crucial motivating force. As Concerns emergency director put it

> *Our particular mission is to address the root causes of extreme poverty, and to do so in a way that respects the dignity of all human beings. This is fundamentally what our Nepal programming was trying to achieve*

Secondly the possibility that science could forecast and anticipate damaging aftershocks before they occurred, was a stimulus for assemblage building. One Concern member of staff said

> *Because we were working in this earthquake prone area, and others such as Haiti, but we really didn't know that much about earthquakes, we started to reach out to the science community to build these sorts of collaborations. We really needed to know if there were things, they could do for us that could reduce the threats we were exposed to*

Initially it was science's underlying 'institutional architecture' that propelled the enrolment process (Latour 1983). Results of previously successful research projects run by the science team were presented to Concern staff to convince them of the soundness of the collaboration. One Concern staff member said

> *We knew the science team was top notch. They have a great track record. And they told us about it. Repeatedly (ha ha). But at that point none of us were sure about what could be done. We knew we were working with the right people but we still had to find out if there were useful things that they could help us with*

The strong academic reputation of the science group underpinned efforts to 'translate' geoscience skills and knowledge for humanitarian participants and vice versa. The workshop programme for Concern staff and scenario planning activities (Section 3.2) transported features of 'the laboratory' out into the wider humanitarian community (Latour 1983).

Over time these methodologies and technologies coalesced around, and 'produced' aftershock risk as a new territory for DRM (Fraser 2017). Once Concern participant said

> *We had to work at it for quite a while, but it became clear that something could be done with aftershock forecasts. Maybe aftershock hazard was something that for the first time we could actually do something about*

Section 4.2: Event

The 25th April Gorkha earthquake caused significant loss of life, injury and damage to property (Hope et al 2016). The earthquake reverberated through the pre-existing DRM assemblage in Nepal causing considerable restructuring and change (Donovan, Bruno & Oppenheimer 2013). The assemblage rapidly expanded to include the thousands of Nepalese and the local NGOs who were first responders. The GoN and the UN coordinated the efforts of 450 humanitarian agencies and 3.7 million people were the recipients of humanitarian aid (Oveson & Heiselberg 2016).

The April 2015 event also resonated through the AFTER actor-network stimulating new processes of enrolment, translation and reordering. An expanded Concern team were deployed in Nepal as part of the humanitarian response, linking up with the staff of two Nepali NGOs and people in local disaster affected communities. The 25Th April earthquake was a catalyst for innovation as the science team began producing aftershock forecasts in real-time using online global earthquake catalogues and the statistical laws outlined in Section 3.1. It spurred the development of fresh ways of translating this science for the humanitarian partners including new tables and maps (e.g. Table 1 & Figure 3) and reporting formats.

On the 7th May the science team forecast up to a 25% possibility of a M7 aftershock where Concern were working (Table 1). This introduced a new 'anticipatory' dimension into Concern aftershock risk decision making (Anderson 2010). As one staff member put it

> *When AFTER sent the probabilities…I was able to say to my staff 'look what this is saying is that we are in the most active area and we have this ridiculously high chance of getting very damaging aftershocks. What are we going to do about it?*

Forecasts used real world data rather than the fictional data sets of the earlier stage of the project, giving the virtual science power added authority. Concern's emergency response coordinator in Nepal explained

> *I was able to say things with a level credibility…I could show them the aftershock sequence. It gave my decisions scientific credibility…It wasn't like before when I was saying 'if you are scared it may help you to follow these safety guidelines'. It became 'these are absolute rules…you will not bend them.' The science meant they were absolute obligations to follow. I could say 'If you are going to work for us, then you have to read them and follow them'*

The earthquake catalysed a range of fresh translation activities including new health and safety guidelines and staff briefings incorporating the AFTER advice and forecasts (Hope et al 2016). This urged on Concern managers to develop this hazard advice into more formal plans and protocols.

As one worker said

> *The tool gave us an early warning in the response phase. We had an idea of when the (aftershocks) were going to happen and an early indication of where they are. So, we could do things to keep us safe while we were doing our job*

Section 4.3: Fidelity

The destructive agency of the aftershock sequence was felt again on 12th May 2015 when there was a M7.3 aftershock in Dolakha District (Section 3.1). There was significant additional loss of life, injury and damage to property (Hope et al 2016). The 25% risk of a M7 aftershock forecast by AFTER on the 7th May was now an actual rather than virtual agent in the assemblage. The accuracy of the forecast was a fresh demonstration of science power and enrolled further actors into the AFTER assemblage. These included humanitarian workers from different organisations who shared a hotel with Concern staff. They had had previously been sceptical of the forecasts, but now began to follow Concern's health and safety guidance and were included in risk communications.

Reports of the chance of a 'second earthquake' had circulated amongst Nepali and international geoscientists since April 25th and on the 5th of May the United Nations Office for Humanitarian Affairs (UNOCHA) sent an email to all humanitarian organisations working in Nepal regarding the risk of a second large earthquake to the west of Kathmandu (Hope et al 2016). For some within the science and policy communities, the May 12th aftershock was this event and they began to reduce their alert levels. For the AFTER team the aftershock stimulated a further round of science innovation including fresh methodologies to explain the new sequence. The May 12th event overlaid the originally Omori distribution with a new sequence of aftershocks with its own pattern of decay over time (Figure 4). Filling the Omori curve from the 25th April event onwards no longer described the sequence accurately but filling a second Omori curve from 12th May produced an accurate fit between the forecast and overall pattern of aftershocks and showed that the probabilities were as nearly as high after the second event as they were after the first. This 'Double Omori' method revealed the 12th May aftershock as an event in an ongoing aftershock sequence rather than a separate, 'second earthquake'. It was one of many aftershocks linked to the April 25th earthquake, rather than a separate event and this increased the risk of a future large event rather than reducing it. The second earthquake' is still to come (Hope et al 2016). The AFTER team maintained fidelity to the fidelity of the science. A Concern manager put it like this

> *I suspect that many people involved in the Nepal response may still believe that the big aftershock was indeed the 'second earthquake' that had been forecast and which UNOCHA briefed agencies on. That the big earthquake may still come is a very important point and has implications for all our future programming in Nepal*

These forecasts drove further expansion of the actor-network as AFTER representatives were invited to participate in the work of the UK Scientific Advisory Group for Emergencies (SAGE) on the Nepal earthquake, as well as share these findings with the UK Government Office for Science. Further science has confirmed that the May 2015 event was an aftershock rather than a separate 'second earthquake' (Bilham 2015, Collins & Jibson 2015).

This is where the cascade of change came to rest. Subsequent efforts to scale the project with UN and national level DRM actors have still to come to fruition (Hope et al 2018). The threat of 'the second earthquake' remains a key ingredient of the Nepal DRM assemblage.

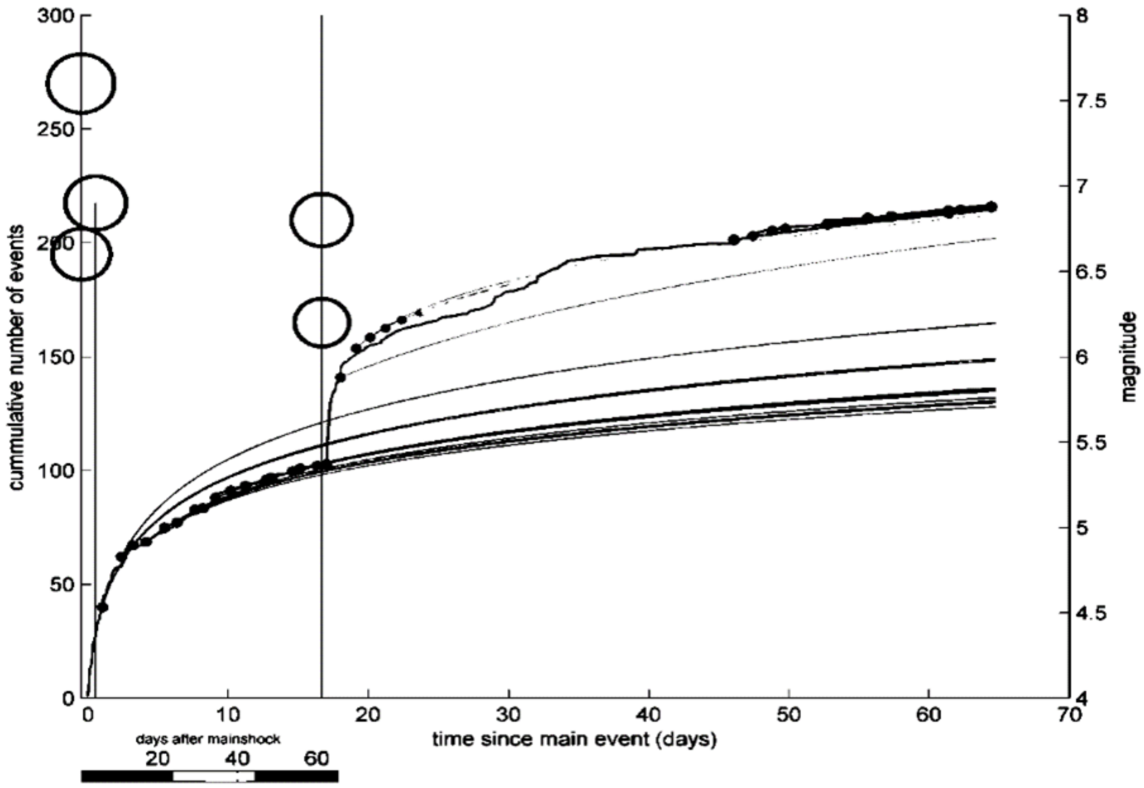

Figure 4: Double Omori Forecast of the Nepal 2015 Earthquake Sequence The May 12th event overlaid the originally Omori distribution with a new sequence of aftershocks with its own pattern of decay over time. This produced an accurate fit between the forecast and overall pattern of aftershocks and confirmed the 12th May aftershock as an event in an ongoing aftershock sequence rather than a separate, 'second earthquake'

5. Conclusion: Triggering Multi-Actor Change Cascades

This paper has developed a cross-fertilised non-representational framework and used it to analyse the AFTER example as deep co-production. In the AFTER example transformative change was a chain reaction of events linking tectonic processes and the virtual pressures of earthquake risk and humanitarian ideals, to fresh science power. Human agents didn't lead these processes but were spurred on by them, producing innovations in science and humanitarian practice that enrolled and expanded networks of diverse actors. Human actors worked with the flow of events and maintained fidelity to the change cascade as it unfolded. This analysis requires us to rethink and deepen the concept of co-production. We should move beyond shallow conceptions of knowledge exchange and policy co-design and reserve the term instead for the distinctive 'practical means of going on', we have described in this paper. This comprises a clear eyed acceptance of our embeddedness in actor-networks and our important, but modest role in shaping change. It also contains a sense of actively 'working with' the diverse human and non-human others in the assemblages that carry us along. To trigger change in ways that make a difference; to bear witness, respect, and aid mutual flourishing.

To conclude we consider some of the real-world implication of this perspective. To do this we build upon synergies between the deep co-production standpoint and the concept of multi-hazard cascades which is an important component of current natural hazards science (Goda et al 2018, Gill & Malamud 2016). Natural hazards science, as Latour shows, is routinely concerned with the workings and behaviour of non-human actors, and it is increasingly common for these processes to be framed in actor-network terms. For example, the concept of multi-hazard cascades, where primary hazard events trigger cascades of secondary hazards that amplify and multiply initial impacts and risk, is an important emerging element in DRM policy (UNISDR 2017). Here, alterations in one human or non-human actor trigger transformations in others that unfold in complex cascades of risk (Goda et al 2018). A useful way of working through the practical consequences of non-representational theory for DRM is to extend existing cascade thinking in DRM to include human actors and processes, and to embrace the full implications of this for human agency, (namely a limited role for human subjectivity, values and knowledge in directing change). We build on this suggestion to derive five practical precepts for deep DRM coproduction.

1. Trigger cascades of change: Change cascades are a key point of connection between DRM practice and non-representational change. Disaster risk managers are used to working with multi-hazard cascades of non-human agents (Gill and Malamud 2016). Natural hazards and their impacts can have complex inter-relationships. A primary hazard can trigger secondary hazards that in turn trigger other hazards in a multi-hazard cascade. An earthquake for example can trigger landslides that trigger flooding. Secondary and tertiary effects can amplify and exacerbate the impact of the initial hazards (Gill and Malamud 2016). A significant implication of non-representational theory for DRM is that risk managers extend their cascade thinking to include human and virtual agents. How can we think creatively about triggering then amplifying the cascades of transformative change emerging through the inter relationships of human and non-human actors? In the AFTER example, the virtual and real agency of the earthquake hazard led to a cascade of innovation in science and humanitarian practice until halted by various barriers to the scaling of the approach. Imagine an alternative scenario where the chain reaction continued. Where the successful use of the AFTER approach in Nepal led to the development of a mobile phone app which local citizens successfully used to gather real-time 'shake data' that greatly improved the accuracy and usefulness of the aftershock forecasts (e.g. Reilly 2013). Where an unexpected consequence of this was that local women embraced the mobile phone app project and citizen-science process, and this cascaded into a range of other citizen-science projects around health and education (e.g. Jennings & Gagliandi 2013, Chib 2010). That this, in turn catalysed activism and community pressure for greater participation in local governance structures, initially around DRM, health and education, but then more widely and deeply (e.g. Hellstrom 2015, Mitlin 2008). Our first precept to guide deep DRM co-production therefore, is for disaster risk managers to include human and virtual actors in their cascade thinking and to look to identify and trigger transformation cascades that as Zizek (2014) suggests, can emerge in unexpected, accidental ways through the amplifications and inter-relationships of human and non-human actors.

2. Fidelity to the event: Once the line of flight has been triggered, our second precept is to sustain fidelity to the change cascade wherever it goes; until it has run its course (Badiou 2009). This is a continual challenge. While the AFTER team, as we have seen, maintained fidelity to the implications of their forecasts for DRM programming in Nepal, the change cascade stalled because that fidelity was not matched by government and global level DRM actors (Hope et al 2018). In the mobile app scenario above, fidelity means finding the funding and flexibility to follow and support each unexpected twist and turn in the transformative cascade of change.

3. Be linear & specific. Change cascades are specific interventions focused on particular issues that unfold and expand in an often unplanned linear sequence. They are pathways of deep change that disrupt and cut through existing surfaces and territories and challenge established ways of doing things. The AFTER project initially coalesced around specific problems Concern faced when working in earthquake prone areas, but quickly became part of a chain of events that grew the assemblage in unforeseen transformative ways. Our third precept for deep DRM co-production is to embrace this linear and specific approach to change (Foucault 1988). To give up dreams of whole system solutions and instead build multiple lines of transformation, that cascade and intersect, sometimes combining and amplifying. So that change emerges out of working with events rather than as if imposed from the outside.

4. Cultivate science as a source of fresh politics: Non-representational theory shows science to be a uniquely important source of fresh politics and power, and trigger of change cascades. For Latour (2018), the socio-political consequences of science innovation are often unknown at the point of discovery. In the AFTER example, it took some time before aftershock forecasting materialised as the earthquake science most useful to humanitarian workers. But when it did it precipitated a chain reaction of transformative change. Our fourth precept for deep DRM co-production is to make science power building a key priority, and cultivate the often accidental, unintended and unexpected opportunities for transformative cascades it triggers.

5. Become skilled in enrolment and translation: Change cascades are built by processes of enrolment and translation (Latour 1983). In the AFTER example, the actor-network expanded in Nepal because humanitarian workers were already convinced of the validity of the science and the science team, and the science had been translated into terms that were meaningful to them. In the mobile app scenario above, effective enrolment and translation processes are crucial in linking each moment of change to the next, and to ensuring events are followed to their conclusion. For example, enrolment and translation are central to attracting the funding to finance the development of the mobile app, to ensure the participation of local women in the citizen-science projects and to build the activism and transformation of wider governance structures. Our fifth precept for deep DRM is to make enrolment and translation processes an integral part of programming and decision making rather than an 'add on'.

In some ways our approach might seem pessimistic about the possibility of transformative change. After all, we have displaced the power of human agency and emphasised how social change is driven by random disruptions and non-human, virtual and real actors. However, we contend that ours is a more realistic view of how change occurs in DRM than that underpinning shallow co-production and is a valid alternative to the powerlessness sometimes felt when faced with system scale risks, such as climate change (Aitken, Chapman & McClure 2011). Even small projects can contribute to deep change and this is empowering. AFTER, for example, was more than a knowledge exchange project. It was part of a cascade of social change. The underpinning earthquake science was a source of 'fresh power' around which new social structures were built. These actor-networks were enrolled and extended by displays of institutional architecture and potential science power, and aspects of the wider world changed by processes of translation. The development of the new forecasting technique opened up aftershock risk as a new territory for governance and intervention where previously this had not been the case. Non-human actors within the assemblage were a catalyst for further network expansion and innovation in science. These *challenged the existing stable scheme* (Zizek 2014, p6) in ways that continue to have implications for ongoing DRM, political actors and wider populations in Nepal (Hope et al 2016). This reading of deep co-production is a spur to coproduce events that cascade across fields of diverse actors, bypassing established channels in unexpected ways, reframing existing meanings and opening a space for deep change.

Bibliography

Adhikari LB, Guatam UP, Koirala BP, Bhattarai M, Kandel T, Gupta RM, Timsina C, Maharjan N, Maharjan K, Dahal T, Hoste-Colomer R, Cano Y, Dandine M, Guilhem A, Merrer S, Roudil P and Bollinger L (2015) The Aftershock Sequence of the 2015 April 25 Gorkha-Nepal Earthquake, *Geophysical Journal International*, Vol 203, pp2119-2124

Aggarwal A (2016) Exposure, Hazard and Risk Mapping during a Flood Event Using Open Source Geospatial Technology, *Geomatics, Natural Hazards and Risk*, Vol 7(4), pp1426-1441

Aitken C, Chapman R and McClure J (2011) Climate Change, Powerlessness and the Commons Dilemma: Assessing New Zealanders Preparedness to Act, *Global Environmental Change*, Vol 21, pp752-760

Anderson B (2010) Preemption, Precaution, Preparedness: Anticipatory Action and Future Geographies, *Progress in Human Geography*, Vol 34(6), pp777-798

Anderson B and Harrison P (2010) The Promise of Non-Representational Theories, Chapter 1 in Anderson B and Harrison P (Eds) *Taking Place: Non-representational Theories and Geography*, Farnham, Ashgate

Askvik S, Jamil I and Dhakal TN (2010) Citizens Trust in Public and Private Institutions in Nepal, *International Political Science Review*, Vol 32(4), pp417-437

Badiou A (2009) *In Praise of Love*, London, Profile Books

Barcia L (2015) *Global NGOs Supporting Earthquake Relief Efforts in Nepal* [Online]. Available from: https://www.devex.com/news/global-ngos-supporting-earthquake-relief-efforts-in-Nepla-86102 [Accessed 18th August 2019]

Bilham R (2015) Raising Kathmandu*, Nature Geoscience,* Vol 8, pp582-584

Boyd E, Ensor J, Broto VC, Juholo S (2014) Environmentalities of Urban Climate Governance in Maputo, Mozambique, *Global Environmental Change*, Vol 26, pp140-151

Bremer S and Meisch S (2017) Co-Production in Climate Research: Reviewing Different Perspectives, *WIREs Climate Change*, Vol 8, pp1-22

Callon M (1986) Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St Brieuc Bay, in Law J (Ed*) Power, Action and Belief: A New Sociology of Knowledge?* London, Routledge, pp196-223

Callon M and Latour B (1981) Unscrewing the Big Leviathan: How Actors Macro Structure Reality and How Sociologists help them to do so, in Knorr-Cetina K and Cicourel A (Eds) *Advances in Social Theory: Towards an Integration of Micro-Macro Sociologies*, London, Routledge, pp277-303

Chatterton P and Pusey A (2019) Beyond Capitalist Enclosure, Commodification and Alienation: Postcapitalist Praxis as Commons, Social Production and Useful Doing, *Progress in Human Geography*, pp1-22

Chib A (2010] The Aceh Besar Midwives with Mobile Phones Project: Design and Evaluation Perspectives Using the Information and Communities Technologies for Healthier Development Model, *Journal of Computer-Mediated Communication*, Vol 15, pp500–525

Collins BD and Jibson, RW (2015) *Assessment of Existing and Potential Landslide Hazards Resulting from the April 25, 2015 Gorkha, Nepal Earthquake Sequence*, U.S. Geological Survey Open-File Report 2015–1142, 50 p http://dx.doi.org/10.3133/ofr20151142.

Concern (n.d,) Concern Worldwide [Online]. Available from: https://www.Concern.org.uk [Accessed 18th August 2019]

Cvitanovic C, Hobday AJ, Van Kerkhoff L, Wilson SK, Dobbs K and Marshall NA (2015) Improving Knowledge Exchange Among Scientists and Decision-Makers to Facilitate the Adaptive Governance of Marine Resources: A Review of Knowledge and Research Needs, *Ocean and Coastal Management*, Vol 112, pp25-35

Deleuze G and Parnet C (1987) *Dialogues II,* New York NY, Columbia University Press

De Juan A and Pierskalla JH (2014) Civil War Violence and Political Trust: Microlevel Evidence from Nepal, *Conflict Management and Peace Studies,* Vol 33(1), pp 67-88

DFID (2012) *Building Resilience in Nepal: A Multi-Hazard Approach*, [Online]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/191922/Approach_to_disaster_resilience_-_Nepal_case_study.pdf [Accessed 17th November 2019]

Dickinson S (2018) Spaces of Post-Disaster Experimentation: Agile Entrepreneurship and Geological Agency in Emerging Disaster Counter Cartographies, *Environment and Planning E: Nature and Space*, Vol 0(0), pp1-20

Dilling L and Lemos MC (2010) Creating Usable Science: Opportunities and Constraints for Climate Knowledge Use and their Implications for Science Policy, *Global Environmental Change*, Vol 21, pp680-689

Donovan A (2017) Geopower: Reflections on the Critical Geography of Disasters, *Progress in Human Geography*, Vol 41(1), pp44-67

Donovan A, Bravo M & Oppenheimer C (2013) Co-production of an Institution: Montserrat Volcano Observatory and Social Dependence on Science, *Science and Public Policy*, Vol 40, pp171-186

Fazey I, Bunse L, Msika J, Pinke M, Preedy K, Evely AC, Lambert E, Hastings E, Morris S and Reed MS 2014) Evaluating Knowledge Exchange in Interdisciplinary and Multi-Stakeholder Research, *Global Environmental Change*, pp204-220

Foucault M (1998) *The History of Sexuality: The Will to Knowledge*, London, Penguin

Foucault M (1991) *Discipline and Punish: The Birth of the Prison*, London, Penguin

Foucault M (1988) *Michel Foucault Politics Philosophy Culture, Interviews and Other Writings 1977-1984*, Kritzman LD (Ed), New York, Routledge

Foucault M (1980) *Power/Knowledge: Selected Interviews and Other Writings 1972-1977*, Brighton, The Harvester Press

Fraser A (2017) The Missing Politics of Urban Vulnerability: The State and the Co-Production of Climate Risk, *Environment and Planning A*, Vol 49(12), pp2835-2852

Geels FW, McMeekin A, Mylan J and Southerton (2015) A Critical Appraisal of Sustainable Consumption and Production Research: The Reformist, Revolutionary and Reconfiguration Positions, *Global Environmental Change*, Vol 34, pp1-12

Gill JC and Malamud BD (2016) Hazard Interaction and Interaction Networks (Cascades) Within Multi-Hazard Methodologies, *Earth System Dynamics*, Vol 7, pp 659-679

Goda K, Rossetto T, Mori N and Tesfamariam S (2018) Editorial: Mega Quakes: Cascading Earthquake hazard and Compounding Risks. Front. *Built Environment*, Vol 4, no 8, pp5-7

GoN (2017) *Nepal Disaster Report 2017*, Government of Nepal, Ministry of Home Affairs [Online]. Available from: https://www.drrportal.gov.np [Accessed 18th August 2019]

Hellstrom J (2015) Crowdsourcing as a Tool for Political Participation: The Case of Ugandawatch. *International Journal of Public Information Systems*, Vol 1, pp1–19

Hope M, McCloskey J, Hunt D, Crowley D and NicBhloscaidh M (2018) Innovation Pathways to Adaption for Humanitarian and Development Goals: A Case Study of Aftershock Forecasting for Disaster Risk Management, *Journal of Extreme Events*, Vol 4 2(3), pp1-28

Hope, M, McCloskey J, Hunt D and Crowley D (2016) Integrating Aftershock Forecasting into Humanitarian Decision-Making: Lessons from Nepal. *Humanitarian Exchange*, [May 28, 2018]

Jasanoff S (2004) The Idiom of Co-Production, Chapter 1 in Jasanoff S (Ed) *States of Knowledge: The Co-production of Science and Social Order*, Abingdon, Routledge

Jennings L and Gagliandi L [2013] Influence of mhealth Interventions on Gender Relations in Developing Countries, *International Journal for Equity in Health*, Vol 12, p85

Kates RW, Travis WR and Wilbanks TJ (2012) Transformational Adaption When Incremental Adaptions to Climate Change are Insufficient*, Proceedings of the National Academy of Sciences of the United States of America*, Vol 109(19): 7156–7161

Kofman A (2018) Bruno Latour, the Post-Truth Philosopher, Mounts a Defence of Science, *The New York Times*, 26/10/2018

Latour B (2018) *Down to Earth: Politics in the New Climatic Regime*, Cambridge, Polity Press

Latour B (1983) Give me a Laboratory and I Will Raise the World, in Knorr-Cetina K and Mulkay M (Eds) *Science Observed,* London, Sage

Latour B and Woogar S (1986) *Laboratory Life: The Construction of Scientific Facts,* Princeton, Princeton University Press

Lemos MC and Morehouse BJ (2005) The Co-production of Science and Policy in Integrated Climate Assessments, *Global Environmental Change*, Vol 15, pp 57-68

Lonsdale, K, Pringle P and Turner B (2015) *Transformational Adaption: What it is, Why it Matters and What is Needed, UK Climate Impacts Programme*, University of Oxford, Oxford, UK

Mitlin D (2008) With and Beyond the State: Co-production as a Route to Political Influence, Power and Transformation for Grassroots Organisations, *Environment and Urbanisation*, Vol 20 (2), pp 339-360

MoHA (2018a) *Nepal Disaster Report 2017: The Road to Sendai,* Kathmandu, Government of Nepal

MoHA (2018b) *Disaster Risk Reduction and Management in Nepal*, National Position Paper for the AMCDRR 2018, 3-6 July, Ulaanbaatar, Mongolia, Ministry of Home Affairs

MoHA (2016) *Disaster Risk Reduction in Nepal: Achievements, Challenges and Ways Forward*, National Position Paper for the AMCDRR 2016, 2-5 November, New Delhi, India, Kathmandu, Ministry of Home Affairs

Muller M (2015) Assemblages and Actor-Networks: Rethinking Socio-Material Power, Politics and Space, *Geography Compass*, Vol 9(1), pp27-41

Muller M and Schurr C (2016) Assemblage Thinking and Actor-Network Theory: Conjunctions, Disjunctions, Cross-Fertilisations, *Transactions of the Institute of British Geographers*, Vol 41, pp217-229

Murdoch J (2006) *Post-Structuralist Geography: A Guide to Relational Space*, London, Sage

Mustafa D (2005) The Production of an Urban Hazardscape in Pakistan: Modernity, Vulnerability and the Range of Choice, *Annals of the Association of American Geographers*, 95(3), pp 566-586

Nepal P, Raj Khanal N, Prasad B and Sharma P (2018) Policies and Institutions for Disaster Risk Management in Nepal: A Review, *The Geographical Journal of Nepal,* Vol 11, pp1-24

O'Brien, K, Sygna L, Leichenko R, Adger WN, Barnett J, Mitchell T, Schipper L, Tanner T, Vogel C and Montreux C (2008) *Disaster Risk Reduction, Climate Change Adaption and Human Security*, Report Prepared for the Royal Norwegian Ministry of Foreign Affairs by the Global Environmental Change and Human Security (GECHS) Project, GECHS Report 2008:3

Otsuki K (2016) Infrastucture in Informal settlements: Co-production of Public Service for Inclusive Governance, *Local Environment,* Vol 21(12), pp1557-1572

Oven K, Milledge D, Densmore A, Jones H, Sargeant S and Datta J (2016) *Earthquake Science in DRR Policy and Practice in Nepal*, London, ODT

Ovesen P and Heiselberg S (2016) The Humanitarian Response to the 205 Nepal Earthquake, *UN Chronicle*, Vol LIII (1)

Park SE, Marshall NA, Jakku E, Dowd AM, Howden SM, Mendham E and Fleming A (2012) Informing Adaption Responses to Climate Change Through Theories of Transformation, *Global Environmental Change*, Vol 22, pp115–126

Patton P (1985) Michel Foucault: The Ethics of an Intellectual, *Thesis Eleven,* Vol 10/11, pp71-79

Pelling M and Dill K (2010) Disaster Politics: Tipping Points for Change in the Adaption of Socio-Political Regimes, *Progress in Human Geography*, Vol 34(1), pp21-37

Petley DN, Hearn GJ, Hart A, Rosser NJ, Dunning SA, Oven K and Mitchell WA (2007) Trends in Landslide Occurrence in Nepal, *Natural Hazards*, Vol 43(1), pp23-44

Rebotier J (2012) Vulnerability Conditions and Risk Representations in Latin America: Framing the Territorializing Urban Risk, *Global Environmental Change*, Vol 22, pp391-398

Reilly J, Dashti S, Ervasti M, Bray JD, Glaser SD and Bagen AM (2013) *Mobile Phones as Seismologic Sensors: Automating Data Extraction for the iShake System*, IEE Transactions on Automation Science and Engineering, Vol 10(2), pp242-251

Scolobig A & Pelling M (2015) The Co-production of Risk from a Natural Hazards Perspective: Science and Policy Interaction for Landslide Risk Management in Italy, *Natural Hazards*, Vol 81(1), pp7-25

Shaw R, Chan E, Lain F, Lu L, Shi P, Yang S, Chan G and Wong J (2017) *Co-Designing DRR Solutions: Towards Participatory Action and Communication in Science, Technology and Academia*, ASTAAG, IRDR and CCOUC, Honk Kong, China, 98 Pages

Termeer CJAM, Dewulf A and Biesbroke R (2017) Transformational Change: Governance Interventions for Climate Change Adaption form a Continuous Change Perspective, *Journal of Environmental Planning and Management*, Vol 60(4), pp558-576

Thrift N (1999) Steps to an Ecology of Place, in Massey DB, Allen J and Sarre P (Eds*) Human Geography Today*, Cambridge, Polity Press

Titz A and Kruger F (2015) *Why Was Nepal Badly Prepared for the Earthquake on 25 April 2015* [Online]. Available from: https://www.fav.eu [Accessed 18th August 2019]

UNISDR (2017) *UNISDR Terminology* [Online]. Available from: https://www.unisdr.org/we/inform/terminology [Accessed 18th August 2019]

Urry J (2010) Sociology Facing Climate Change, *Sociological Research Online*, Vol 15(3)

USGS (n.d.) Earthquakes Hazards Programme [Online]. Available from: https://earthquake.usgs.gov/data/shakemap [Accessed 18th August 2019]

Van der Hel S (2016) New Science for Global Sustainability? The Institutionalisation of Knowledge Co-production in Future Earth, *Environmental Science and Policy*, Vol 61, pp165-175

World Bank (2018) *Adaptive Social Protection for Effective Disaster Risk Management*, Washington, D.C., World Bank Group, [Online]. Available from: http://documents.worldbank.org/curated/en/555751539350285844/Adaptive-Social-Protection-for-Effective-Disaster-Risk-Management [Accessed 17th November 2019]

Zizek S (2014) *Event*, London, Penguin