Cabot Institute, University of Bristol

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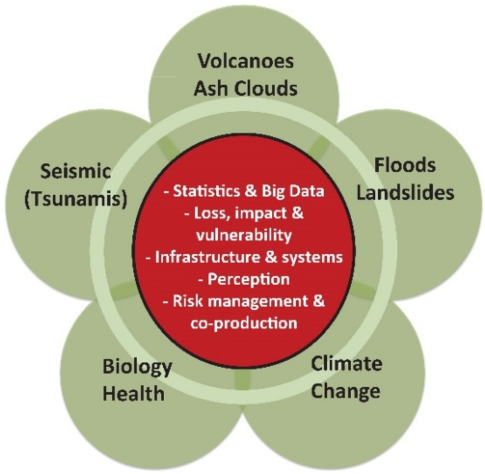
Outline

The University of Bristol has been at the forefront of natural disaster risk and mitigation research for over 20 years. With the inception of BRISK (Bristol Environmental Risk Centre) in 2009, which was subsequently folded into the Cabot Institute in 2012, the University made a commitment to supporting novel, multidisciplinary research that sought to tackle the risks and challenges of the 21st century. The Cabot Institute realises a vision for a new generation of interdisciplinary, science-to-practice focussed scholars and fosters engaged research with end-users. The core natural disaster research areas cover hazard and risk related to volcanic eruptions, earthquakes, landslides, and floods using the most advanced computational/statistical tools for assessing and communicating environmental risk. The Cabot experts advise the UK government about hazards, such as volcanic ash, and work with agencies, such as the World Bank and the UK Met Office, to reduce disaster risk. The concepts of risk, uncertainty, and resilience underpin all of research themes and remain central aspects of the Cabot vision, strategy, and expertise portfolio.

The Cabot Institute involves academics of international standing from the Schools of Earth Sciences, Geographical Sciences, Experimental Psychology, Policy Studies, Maths, Engineering Maths, Civil Engineering, Computing, and Sociology, Politics and International Studies, who undertake research in the fields of *risk & uncertainty* and *natural hazards*.



Cabot Core Research Areas

- *Volcanic risk and ash cloud* : The volcanological research group has established a high international reputation, and leads the Global Volcano Model (GVM) to create a sustainable, accessible information platform on volcanic hazard and risk. It has developed a strong relationship with the Volcanic Ash Advisory Centre (e.g. 2010-2011 Icelandic eruptions).
- *Seismic risk* : The seismic research group has focussed upon 1) effective delivery of infrastructure resilience subject to cascading multi-hazards, and 2) systems' responses to earthquake-triggered hazards. The group is also specialised in monitoring and evaluating hazard due to induced seismicity (e.g. hydraulic fracking and carbon capture and storage).
- *Hydrometeorological risk*: The flood research group has been internationally recognised for: 1) the development of an efficient hydrodynamic model for floodplain inundation simulation over complex topography (LISFLOOD-FP), and 2) the impact assessment of major flood events by taking into account various sources of uncertainty. LISFLOOD-FP is used by the European Joint Research Centre, the Environment Agency, and Defra.
- *Landslide risk*: The landslide research group has developed sophisticated numerical models of physical processes of landslides, including the Combined Hydrology And slope Stability Model (CHASM) that dynamically simulates rainfall-triggered landslides, and has applied them to practical situations (e.g. Caribbean islands) to develop a new cross-disciplinary platform for measuring the effectiveness of landslide mitigation in vulnerable urban communities.
- Other related expertise in hazard areas: climate change, including impact on meteorological phenomena and sea level rise, drought, disease and epidemics, food security including parasite outbreaks, and technology.

Research Achievements and Challenges

The University has recently achieved remarkable success in the 2014 UK Research Excellence Framework (REF) assessments, coming 1st overall in Geography, 2nd overall in Sociology, 2nd overall in Earth Sciences, 4th overall in Mathematical Sciences, and 4th overall for Computer Sciences and Informatics. A vibrant risk community resides within each of these areas, contributing world-class research in the Cabot Institute. In addition to this academic capacity, the Cabot researchers have consistently engaged with the government, industry (engineering consultancy and insurance/reinsurance), and the public to transform research into meaningful impact.

Recent Research Achievements

Method development

- *Consortium on Risk in the Environment: Diagnostics, Integration, Benchmarking, Learning and Elicitation* (***CREDIBLE***): A £2M project to: 1) introduce statistical techniques to move uncertainty out of the margin for error, 2) help modellers assess less quantifiable uncertainty, and 3) improve risk visualisation and communication. Methods are tested in various case studies for flood, windstorm, landslide, earthquake, drought, lahar, and ash dispersal.

Monitoring risk

- *Strengthening Resilience in Volcanic Areas* (***STREVA***): An adaptable risk assessment framework using satellite data for over 500 volcanoes to establish statistical evidence of their eruption potential based on deformation. This leads to a forecast system for all volcanoes, including those that are remote and inaccessible.
- *Volcanic Unrest in Europe and Latin America* (***VUELCO***): The project dissects the science of monitoring data and creates global strategies for 1) enhanced monitoring capacity and value, 2) mechanistic data interpretation, and 3) identification of reliable eruption precursors, all from geophysical, geochemical, and geodetic fingerprints of unrest episodes.
- ***RIFTVOLC***: A project in the main Ethiopian Rift improves knowledge of past activities, establishes baseline monitoring of current states of apparent unrest, and develops reliable assessments of eruptive potential.
- *First independent UK research to monitor fracking*: A programme to conduct real-time monitoring of groundwater, regional air quality, seismicity, and ground movements before, during, and after fracking. The results will support peer-reviewed science on the environmental effects of shale gas operations in the UK.

Assessing risk

- ***LISFLOOD-FP***: A computationally efficient 2D hydrodynamic model can simulate grids up to 10^6 cells for dynamic flood events utilising terrain information from remote sensing, and simulate the dynamic propagation of flood waves over fluvial, coastal, and estuarine floodplains. It has major advantages in quantifying the uncertainty of hazard/risk predictions.
- *Cascading Risk and Uncertainty assessment of earthquake Shaking and Tsunami* (***CRUST***): An integrated methodology for cascading hazards is developed by: 1) characterising earthquake slips for future mega-thrust earthquakes, 2) modelling a sequence of mainshock-aftershock records, and 3) modelling tsunami inundation and damage.
- *Seismic loss model for urban city*: A probabilistic framework is developed by incorporating: 1) seismic hazard analysis, 2) realistic spatial correlation of ground motions, 3) seismic vulnerability model, and 4) seismic loss estimation. The model outputs promote decision-making related to seismic risk management, including retrofitting and earthquake insurance.

Managing risk

- *Management of Slope Stability in Communities* (***MOSSAIC***): A flexible blueprint for landslide risk reduction is developed to understand the physical risk drivers and reduce the landslide hazard. It seeks low-cost solutions suitable for local communities, and encourages a government-community partnership for ongoing management of slope stability.
- *Managing the Risks, Impacts and Uncertainties of droughts and water Scarcity* (***MARIUS***): A £3.5M project to develop improved models and methods to mitigate the impact of drought on water quality, agriculture, biodiversity, and the economy. The local impact and the role of institutions, regulation and markets in drought management are investigated using scenario modelling, case studies at household to national scales, and stakeholder engagement.

Research Challenges

Emerging research areas

- *Bridging the hazard-risk-management gap*: The gap between hazard, risk, and risk management research is pervasive and the Cabot Institute is uniquely placed to carve a niche at the interface. Cabot plays a catalyst role to fuse natural hazard expertise (science) and impact/risk management expertise (engineering and social science) to develop an integrated, cross-disciplinary *science-into-practice* framework for dealing with catastrophic natural disasters (e.g. ***VUELCO*** and ***MOSSAIC***).
- *Disaster risk reduction*: The 2005-2015 Hyogo Framework for Action called for investments in emergency preparedness, climate change adaptation, and resilience to environmental shocks. Cabot has a significant skillset to contribute, particularly through the integration of natural and social sciences.
- *Integrated modelling of hazards*: The non-stationarity of our environment forces us to move from empirical (correlation) approaches to mechanistic models (based on process understanding). Cabot has an opportunity to pool its mechanistic modelling expertise and to lead the research for integrated empirical-mechanistic hazard assessment.
- *Psychology of evidence-based decision-making*: Public's understanding of science and why people often embrace beliefs that are sharply at odds with the scientific evidence are critical factors in avoiding misinformation and promoting the acceptance of scientific advice on natural hazards and climate change.
- *Risk, society and weather extremes*: Society has the capacity to both drive and mitigate risk to extreme weather. Collaborations across engineering, climate, behaviour and planning disciplines have potential to investigate the interaction between society and the environment.
- *Risk research at multiple decision scales*: Much risk research is conducted at a single decision *scale* and often strictly *top-down* or *bottom-up* in nature. Research with the World Bank has brokered risk approaches between scales and is now progressing with the Global Network for Disaster Reduction.
- *Risk and food supply chains*: Natural hazards and climate change pose severe risk to food supply and security. In a Defra project, Cabot's mapping, climate, natural hazard, and food security experts collaborate to explore risk to supply chains.

Research capacity building and organisational partnership

To fully exploit emerging opportunities, Cabot needs to address gaps in expertise or areas of expertise that have not been fully integrated into natural disaster risk research.

- Developing underpinning expertise in mathematical sciences and Big Data, by building close internal links to the Heilbronn Institute and the Bristol Research Initiative for the Dynamic Global Environment (***BRIDGE***).
- Developing stronger relationships with the GW4 institutions (Bristol, Bath, Cardiff, and Exeter), e.g. in the fields of experimental psychology.
- Building on existing links with the energy/insurance/reinsurance industry, government departments and agencies, the city of Bristol (2015 European Green Capital), and NGOs.
- Adding capacity/linking more closely with the international disaster management research community in Japan (Kyoto), New Zealand, the US, and Europe, in addition to developing nations.

Maximising the research impact

- Create a hazard and risk toolkit (including hazard process modelling, sensitivity analysis, uncertainty assessment, and visualisation/hazard-mapping tools; e.g. ***LISFLOOD-FP*** and ***CREDIBLE***) publicly accessible for widespread use in industry/government.
- Continue to deliver the Cabot Summer School which attracts 25-30 professional delegates annually.
- Be increasingly proactive (and responsive) to public outreach and risk communication opportunities, focussing on evidence-based dialogue, in close collaboration with the Science Media Centre and risk perception experts.
- Ensure natural hazard, risk, and uncertainty expertise is accessible to the Cabot Corporate Club.

Research Vision

Effective disaster risk reduction and management (DRR and DRM) require further research in filling current major gaps. Three critical themes are identified: 1) *from science/social science to hazard* (understanding hazards), 2) *from hazard to loss*, and 3) *from assessment to decision-making*. Theme 1 achieves better prediction of low-frequency, high-impact hazards, multi-hazards, scales and cascades of hazards, and complex interactions including climate change impact. Theme 2 aims to extend the risk assessment not only for direct and tangible loss but also for indirect and intangible loss, including social impact; Big Data can help elucidate such indirect loss. Theme 3 is focussed upon the challenging issues by addressing how risk is it perceived and culturally contingent, what are the appropriate options and what is the evidence, and how is the risk assessment conveyed and how are end-users engaged.

Gaps in our understanding of hazards: from science to hazard and mitigation

- Uncertainty is ubiquitous in environmental science, due the complexity of the Earth system, limited understanding of its components, and a paucity of observations at relevant spatial and temporal scales. Moreover, mitigating actions against natural hazards are complicated by imperfect knowledge of future changes. Thus it is crucial that physical research in such complex and changing environments is integrated with rigorous statistical analyses, both to improve knowledge and understanding of the physical processes and underlying uncertainty, but also to inform robust decision-making and policy formulation. The application areas/topics include problems at the interface between natural and social sciences: 1) multi-hazard and correlated risk, with probabilistically likely co-occurring phenomena (i.e. tidal surges, strong winds, and lightning associated with some storms), and 2) cascaded hazards through data and modelling chains (e.g. flood risk to emergency planning and decision support) that are particularly relevant to the social science issues of implementing mitigation methodologies to reduce future vulnerabilities.

Gaps between hazard and loss: assessment and uncertainty with Big Data

- Understanding the linkages and limitations between data rich (big and broad data) and data sparse environments and situations is critically important. Essential to this is translating knowledge, process understanding, and predictive capability from systems that are understood well to those that inherently have limited information and are resource limited. This will facilitate the exploration of the challenges of predicting and understanding extreme behaviour via data-extrapolation methodologies for a variety of natural hazards.
- Disasters are not only devastating as they occur and in their immediate aftermath with respect to loss of life and destruction of infrastructure. They can lead to social upheaval and disenfranchisement and disproportionately affect the poorest members of the population. Disruption of supply chains impact the global economy and disruption of food distribution networks can prolong the impact of disasters and extend their global impact. Crucially, Big Data approaches are essential to interrogating the far-flung and sometimes non-intuitive consequences of disasters.

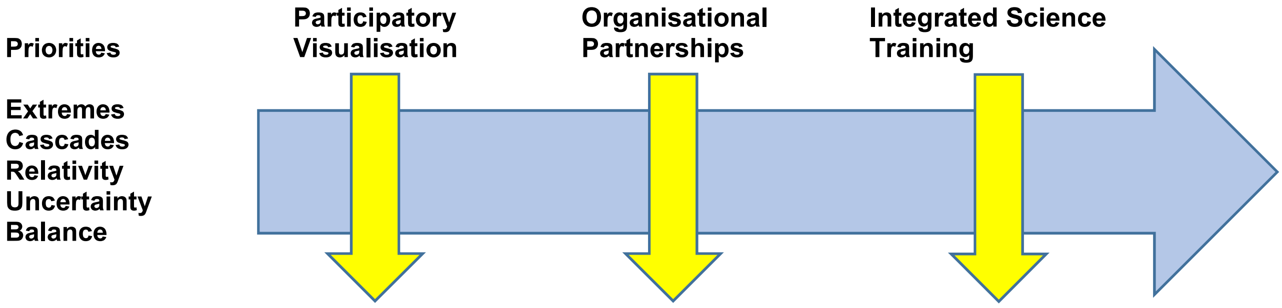
Gaps between assessment and decision-making

- Three components are missing in the delivery of DRR research and DRM practice on the ground: *science-base*, *community-base*, and *evidence-base*. Specifically required are: 1) methods for risk analysis and decision support in developing countries, and 2) focus on *action into knowledge* (finding out what works on the ground) to facilitate delivery within local knowledge in participation approaches. Policy-makers and funders require evidence for investment so that they can see what works and replicate it. Innovative science-based and community-based approaches can be powerful policy-changers.
- A critical aspect for scientists engaged in hazard assessment is to communicate the nature of hazards and their probability of occurrence in a manner that is useful and understandable for emergency managers and policy makers. The research has highlighted a need to further investigate the role of different stakeholders in emergency planning and crisis management, their mutual expectations, the social context of at-risk communities, the legal framework within which advising scientists operate, and the benefits of visualisation and participation approaches

to a range of actors. Therefore, research should be conducted in a framework that amalgamates various disciplines, such as natural/social sciences, emergency management, computer visualisation techniques, and the law.

Broader Perspectives

Bristol University and the Cabot Institute play crucial roles within the UKDC-Resilience (Bristol, Durham, King's College, and UCL), which is an alliance of the leading UK centres of excellence for disaster risk and resilience research and learning. A collective perspective of the UKDC-Resilience on future disaster science agendas is illustrated below by identifying five key research priorities and three novel mechanisms for better connecting science to policy and society. Contemporary science is called to be increasingly impact-oriented, to embrace co-design or co-production through engagement with stakeholders beyond the science community, and to be transdisciplinary.



UKCD-Resilience Research Vision

The UCKCD-Resilience calls for integrated science organised around five research and three capacity-building priorities. Research and capacity-building are envisioned to cross-cut and offer a vision of academic engagement in disaster studies that is current, grounded, and reflexive.

- ***Extremes***: Extremes exist at both ends of a frequency distribution, highlighting rare/large events and common/small events. Future research should address integrated risk management approaches that cover a range of small to large events.
- ***Cascades***: Disaster events need to be conceptualised as cascades, involving phased/concurrent multi-hazard interactions. Applied disaster research on economic impact requires empirical/theoretical work to take into account systemic and indirect disaster impact.
- ***Relativity***: Time, space, and scale are relative concepts that shape the conditions through which physical, social, and combined social-environmental systems move, and potentially cascade. Science needs to work to better understand how social-environmental systems learn and change behaviour over time, space, and scale.
- ***Uncertainty***: Uncertainty cannot be taken out of science but it can be made more transparent. This requires collaboration between modellers, social scientists, and research users in science design and implementation.
- ***Balance***: Improving decision-making to strike the best possible balance between risk reduction and risk response incrementally adjusts existing social-environmental systems (e.g. technology and culture). This is an agenda for enhancing critical reflexivity in decision-making at all scales.
- ***Participatory Visualisation***: A wide range of modelling and scenario techniques increasingly offers new opportunities for engaging stakeholders, including the public, to better understand underlying natural and social properties shaping disaster risk and loss. The next step in this agenda is to internationalise knowledge sharing.
- ***Organisational Partnerships***: The organisational level support is necessary to overcome brain drain effects of highly qualified/trained individuals of key agencies in the UK government and overseas. This is important for transdisciplinarity that calls for far more embedded and interconnected science-policy relationships.
- ***Integrated Science Training*** : Training a new generation of integrated disaster scientists requires a reorientation in support for postgraduate learning. Any initiative needs to build in not only traditional PhD but also professional training and reach out to integrate natural as well as social science into the humanitarian sector, civil defence, and development sectors.