Workshop of the Cost Action IS1304
"*Expert Judgment Network: Bridging the Gap Between Scientific Uncertainty and Evidence-Based Decision Making*"

Science, uncertainty and decision making in the mitigation of natural risks

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Abstracts

The workshop is part of the COST Action "Expert Judgment Network: Bridging the Gap Between Scientific Uncertainty and Evidence-Based Decision Making" and is organized by the University of Strathclyde and the Istituto Nazionale di Geofisica e Vulcanologia in cooperation with the Dipartimento della Protezione Civile.

The COST Expert Judgment Network and its goals

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Governments and businesses have to make decisions in the face of risks and uncertainties, but time pressures too often hamper the collection of large-scale datasets that might help reduce those uncertainties. Structured Expert Judgement aims to provide a proper evidence base that enables decision makers to obtain reasonable uncertainty assessments in a timely and defensible way. The best methods of Structured Expert Judgement ensure that expert data is collected in a way that minimizes potential biases and, crucially, tests expert performance. Decision makers can and should demand that expert judgement procedures provide for the most unbiased possible forms of judgement. In this talk we will take a broad look at the challenges and demands for uncertainty assessment that make this COST Action so important.

Experts in emergency

Roger M. Cooke
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In Structured Expert Judgment (SEJ) experts quantify their subjective uncertainty according to a fixed protocol and expert uncertainties are treated as scientific data. We now have a wealth of data and experience, and we have learned quite a lot along the way, including:

- How expert subjective uncertainties can be evaluated and validated
- How the quality of expert subjective assessments varies
- What pitfalls can cause inferior uncertainty assessments
- What problems arise in communicating uncertainty to decision makers
- What errors exist when in reasoning under uncertainty

When transferring these insights into the context of real time decision support in crises, two main lessons emerge:

- *Uncertainty communicators must themselves understand uncertainty.* In general they do not. Examples are legio. Do not leave uncertainty communication in the hands of people who are untrained for this. Decision makers are paid to make decisions under uncertainty, yet often they try to off-load that problem onto scientific advisors by refusing to receive the uncertainty message. Communicators must overcome this.

- *The process of uncertainty assessment - communication - reception should be documented and traceable.* Of course in the heat of a crisis there is no time for formal elicitation, nonetheless the creation and preservation of an accounting trail 'who said what to whom and why' could be of great value.

From science to action: the risk analyst intermediary

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Progress in the basic understanding of natural hazards is the achievement of scientists specializing in volcanology, seismology, hydrology, meteorology etc.. Each of these domains of hazard science encompasses observational, experimental, theoretical and computational research fully occupying the time and attention of scientists. For any natural hazard in a populated region, there are stakeholders with diverse interests in the outcome of scientific studies, and there are civil protection authorities with responsibility for all the stakeholders, some of whom may wish to participate actively in the decision making process.

To facilitate the participatory decision making process, where optimal decisions are made for individual stakeholders, mediation is required by risk analysts who are both knowledgeable about the underlying hazard science as well cognizant of the respective costs and benefits of any action that a stakeholder may take. Scientists may output hazard probabilities, but these may be as ineffective means of public communication as a programming manual would be to the new user of a tablet computer. A cadre of stakeholder-focused risk analysts is required to tailor scientific output in a practical and meaningful way to the varying needs of individual stakeholders – the elderly, the infirm, farmers, ranchers, tourists etc.. The role of expert judgement exercised by these intermediaries will be discussed.

Forecasting and management of flood risk

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This paper reviews approaches to the forecasting and management of flood risk, and the typical data sets and model cascades used to create hazard and risk information. In particular, it focuses on the use of numerical hydraulic models at a variety of different scales from street to global, and recent developments to improve the computational efficiency of these models to enable wide area, high resolution simulations. It reviews typical approaches to risk decision making and management and in particular addresses the question of uncertainty.

Assessing uncertainty in sea level rise due to ice sheet melting under global warming – using expert elicitation to characterize variable dependences and tail correlations

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The effect of global warming on the three major ice-sheets (Greenland; West Antarctica and East Antarctica) could engender significant contributions to sea level rise (SLR) if ice-loss rates continue to increase, with important risk implications. Current numerical models are not capable of producing dependable projections over timescales of decades to a century, or longer. Two groups of experts, one in the EU the other in the US, have been elicited on the influences of fundamental ice gain/loss processes at each ice-sheet under various plausible long-term global temperature rise scenarios. The experts' judgements on these variables have been aggregated with Classical Model weightings to provide expectations of SLR by 2100 CE and 2200 CE, with quantified uncertainties on estimates derived from the elicitations. Here we report an extension of the basic elicitation to enlist experts' judgements about dependences between variables and possible tail correlations – ignoring such dependences, if they exist in real world processes, could result in unreliable analyses, not just for ice-sheet melting but also when assessing other natural hazards. We give a brief outline of an approach to this problem by determining dependences and correlations from a few simple elicitation questions, using these judgements to enumerate a probability scheme for inducing multivariate conditional dependence dynamically across the complete processes model through vine decomposition; we illustrate this with the ice-sheet melting projections.

Communicating hurricane risks to local officials for protective action decision making

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Research and operational practice for hurricane evacuations in the United States have led to the development of planning concepts for local officials to use when deciding what protective actions to take when their jurisdictions are threatened by approaching hurricanes. Hurricane evacuation decisions require meteorologists to provide assessments of the current state of a hurricane (especially its center location, intensity, size, track, and forward movement speed), forecasts of these parameters at six-hour intervals over a five-day period, and projections of a hurricane's expected impacts (point of landfall, wind speed, surge height, rainfall, and tornadoes). These storm data need to be considered in the context of transportation analysts' estimates of the time required to evacuate different geographical areas (barrier islands, open coast, bays and rivers, inland areas) and population segments (e.g., households with vehicles, transit-dependent travelers, hospital/nursing home patients, prisoners). Most local officials access hurricane information using HURREVAC, which displays current and forecast hurricane parameters, especially the hurricane track and wind swath on maps of the US Atlantic Ocean and Gulf of Mexico basins. One particularly challenging aspect of communicating hurricane risk to local officials is the communication of uncertainties about hurricane parameters and evacuation time estimates (ETEs). Currently, meteorologists communicate uncertainties for only a few storm parameters and transportation analysts mostly ignore uncertainties in their ETEs. Although there is a substantial literature on communication of uncertainty about health risks, hurricane researchers have only recently begun to examine people's interpretations of the most common hurricane uncertainty display. This is the forecast track *uncertainty cone*, which encompasses the 66.7% probability interval. Contrary to some researchers' concerns, participants in one recent experiment judged areas outside the uncertainty cone to have a significant probability of being struck. Surprisingly, there were no appreciable differences in the patterns of strike probability judgments for hurricane tracks represented by a forecast track only, an uncertainty cone only, or forecast track with an uncertainty cone. Overall, these results suggest that people are able to correctly process basic information about hurricane tracks but they do make some errors. This research on hurricane information displays is relevant to volcano evacuation decision making because uncertainty cones can be used to display uncertainty about a temporal trend in volcanic activity that is analogous to uncertainty about the spatial trend of a hurricane track. This conceptual similarity suggests the possibility of fruitful interchanges between scientists studying risk communication for hurricane and volcanic threats.

The Italian Civil Protection and scientific advice system

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The Italian civil protection system is based on the concept stated in its constitutional law (L. 225/1992), which foresees that civil protection is a service provided to the citizens by a number of actors, belonging either to the public institutions or to the private organisations, that concur to the different activities in the field of civil protection. This means that prevention, preparedness, relief and post disaster activities are carried on, in Italy, under the general coordination of the national department of civil protection that has the specific mandate to guarantee the appropriate functioning of the abovementioned system providing guidelines, defining common objective and coherent strategies. In line with the approach described so far the scientific community is asked to provide its support to the system when it comes, normally, to develop prevention activities. Of course if needed and when appropriate the scientific community, in its advisory role, is called to provide support in all the phases of the risk management cycle. The ways the scientific communities participate to this are several and certainty one of the most important is the 'National Committee for the Prevention and Preparedness of the Major Risks' which is composed by more than 80 experts divided in different sectors reflecting the risks that affect our country (seismic, hydrogeological, volcanic, transports, etc...). The Committee is generally convened by the Head of the department of civil protection in order to advice him on the different ongoing emergency situations or to provide recommendations in the field of risk management.

Scientists advising decision-makers – experiences from Mount St. Helens and Mount Pinatubo

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Some scientific help to decision-makers is based on classic science, and is quantitative, evidence-based, and impersonal. Most scientists understand that they must produce good data and forecasts of what the volcano can produce and, increasingly, probabilities of each scenario and associated uncertainties. These are indeed very helpful -- ***but insufficient***. What else is needed?

1) Crystal clear, two-way communication, honed by practice. Only a relatively few scientist-teachers truly excel in working with lay audiences, striving to understand each audience and tailor communications accordingly. Our community should thank and treasure these talented colleagues! At Mount St. Helens (MSH), among the best communicators were a geographer who later studied film-making and a future world-leading volcanologist. At Pinatubo, the best educators were Ray Punongbayan and the Krafft/IAVCEI video. Some extra help is needed re: how to use probabilities. A few groups, especially engineers and military officials, understand probabilities well. Military commanders at Pinatubo understood that a 3% chance of mass death was high and unacceptable; most end users, though, would not. Societal P-N diagrams help, but more effective are estimates of individual risk of death, accompanied by a table of comparable risks.

2) Trust between scientists and decision-makers. Scientists need to trust decision-makers to know and tell them what information is needed. Decision-makers need to trust that scientists are professionally competent and are working for them and the public good rather than for selfish research purposes. Trust takes time to build, so start now, long before crises, and nurture that trust frequently. At MSH, it was built over years before 1980 by years of interaction during fieldwork, and during the crisis by having a liaison scientist co-located with the decision-makers. At Pinatubo, serious scepticism or even distrust had to be converted into trust. Some sceptics responded best to hard data; others were swayed more by interpersonal openness, honesty, and a balance between modesty and speaking authoritatively.

3) Scientists being willing and able to share their own personal sense of risk, in non-scientific terms. At MSH, scientists were prohibited by law from recommending for or against any mitigation measure (we were required to "stick to the science"), but when it became obvious that decision-makers needed some help in understanding our messages, we devised "body language" and personal queries that made our messages clearer (e.g., "Would you let your own family stay there?"). At Mount Pinatubo scientists were sufficiently worried about pyroclastic flow hazard on Clark AB that they moved their observatory from the center of Clark to the farthest fringe. This put very personal meaning to the numbers. Actions speak.

4) Offering help as needed even on matters beyond science, e.g.,

- Volcanologists sharing what they know about how similar hazards and risks were managed elsewhere. In general, scientists stay in their positions for decades while many decision-makers come and go with alarming frequency. Volcanologists carry important "institutional memory" of social issues and decisions made elsewhere, and of potential resource persons.

- Helping decision-makers work with their own constituents and bosses. At MSH, land managers were tugged between business interests (logging, tourism) and generally low risk tolerance among citizens (and their lawyers!). Privately, scientists provided pro- and con- comments on mitigation options that were being considered. Publicly, we carefully avoided comment on mitigation decisions. At Pinatubo, there were pockets of resistance to evacuation (indigenous Aeta people who lived high on the volcano, and US military at its foot). For the Aetas, we worked with the nuns and pastors they trusted, and even with Marxist guerrillas. For the military, scientists had to convince top-level commanders to give local commanders a green light to evacuate as needed.
- Economic and social costs of mitigation vs. non-mitigation. Volcanologists cannot estimate these by themselves, but we can provide volcanological data for the calculation. I'm not aware of any formal cost-benefit analyses prior to evacuation decisions at MSH or Pinatubo; rather, the decisions were based on gut-level assessments of tolerable risk. But elsewhere, cost-benefit studies may be needed, can be done in advance of crises, and volcanologists can help.

Failed magmatic eruptions, uncertain precursors and false alarms: lessons learned from the 1976-77 La Soufrière of Guadeloupe volcano (French Antilles) crisis

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Mild but persistent seismic and fumarolic unrest since 1992 at La Soufriere volcano has prompted renewed interest in geologic studies, monitoring, risk modeling, and crisis response planning. Increasing intense seismicity was recorded and felt at La Soufrière 1 year prior the eruption which began with an unexpected explosion on 8 July 1976. The 9-month long period of explosive and ash-venting activity produced ca. 1 x 10^6 m^3 of non-juvenile tephra (Feuillard et al. 1983). Syn-eruptive degassing (H_2O, minor CO_2, H_2S, SO_2) with acid condensates (HCl, HF, Br) led to moderate environmental impact with short-term public health implications. Given evidence of continued escalating pressurisation and the uncertain transition to a devastating magmatic eruption, authorities declared a 6-month evacuation of ca. 70000 people on August 15 that engendered severe socio-economical consequences for months to years thereafter. This evacuation is still perceived as unnecessary and reflecting an exagerated use of the "principle of precaution". The erroneous interpretation of «fresh glass» in the ejecta, as evidence of a juvenile magmatic component, led to a major controversy among scientists that was widely echoed in the media. Lack of a comprehensive monitoring network prior the crisis, limited knowledge of the eruptive history, and memory of past devastating Caribbean eruptions all contributed to a high degree of scientific uncertainty and a publically-expressed lack of consensus and trust in available expertise. Hence analysis, forecast, and crisis response were highly challenging for scientists and authorities in the context of escalating and fluctuating activity and societal pressure. The high uncertainty about a so-called "unequivocal" impending disaster fostered a binary manichean, thus messianic, approach in the scientific discourse. The public debate thus became polarized on issues of opposing "truths" served by contrasted scientific expertise rather than on how science could help constrain epistemic and aleatory uncertainty and foster improved decision-making in the context of uncertainty. This situation acted as an ideal crucible to fuel a media-hyped controversy on the crisis and its management. A recent retrospective Bayesian Belief Network analysis of this crisis (Hincks et al., 2014) demonstrates that a formal evidential case could have been made to support the authorities' concerns about public safety and decision to evacuate in 1976. Development of such novel probabilistic formalism for decision-making could help reduce scientific uncertainty and better assist public officials in making urgent evacuation decisions and policy choices should the current and ongoing unrest lead to renewed eruptive activity.

The 1995-2013 eruption of Soufrière Hills volcano (Montserrat, West Indies): lessons from 18 years of application of EJ techniques to an erupting volcano

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Volcanic hazard and risk at Soufrière Hills volcano has been assessed in a quantitative and consistent manner for sixteen years (1997 – 2013) of the eighteen-year eruption. This is the longest continuous series of quantitative volcanic risk assessments in the world. Highly variable eruptive activity involving andesitic lava dome growth placed serious constraints on Montserratian society and justified continuous effort. This work has been carried out by a Scientific Advisory Committee (SAC) and its precursor, funded by the UK government in collaboration with the Montserrat Volcano Observatory. We describe the organisational context of the assessments, the types of hazards and the methods used to analyse them. Knowledge elicitation using hazard scenarios and analysis by the Cooke method was employed to forecast the probabilities of future hazardous events over the next year and the risks to individuals and Montserrat society generally. The accuracy of the forecasts were tested using Brier Skill Scores. For events that were critical to life the forecasts were 83% "correct" as measured by this method. We discuss how the internal working practice of expert judgement evolved within the SAC. We also describe how Government responded to our methods and acted upon our assessments.

Hazard early-warning system as a tool for forecasting volcanic eruptions: the case of Sinabung's 2013 eruption

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Sinabung volcano first erupted on 27 August 2010 after being dormant for more than 1200 years. A notable lava collapse and resulting pyroclastic flow and surge on 1 February 2014, killed 17 persons who had entered the restricted hazard zone without approval while the highest alert (Level 4) was in effect. CVGHM has not been judged as responsible for these victims. This is because the Indonesian Hazard Early Warning System had been used correctly to: 1) monitor the volcanic unrest, 2) provide socialization and education about the hazards to the people who live in the area surrounding this newly active volcano, 3) produce a volcanic hazard map and 4) issue appropriate warnings and alerts, which resulted in the restricted hazard zone where the people were killed.
CVGHM uses a warning system with 4 Alert Levels to communicate hazards. Actions of CVGHM and emergency managers are linked to these levels. When an alert is issued socialization and quick response teams are sent to the hazardous areas. These teams conduct socialization and education programs about volcano hazards with communities and help them develop contingency plans. They evaluate the unrest, forecast future activity and prepare (or update) hazard maps, and recommend areas to be evacuated. They also change the Alert Levels according to the degree of unrest and risk to the people.
The 2013 eruptions began on 15 September 2013 and triggered waves of public panic and anger. Upon this occurrence of renewed eruptions CVGHM increased the alert from Level II to III. Subsequently, explosive eruption frequency and seismicity decreased, prompting a decrease back to Level II. The Alert Level was raised again on 3 November 2013 to level III, prompted by in an increase in SO_2 emissions and an increase in eruption column heights. CVHGM then recommended a 3 km exclusion zone around the crater, prompting evacuation of 4 villages inside this hazard zone. On 24 November after further increases in seismicity and occurrence of pyroclastic flows, CVGHM raised the Alert Level from Level III to Level IV (the highest level) and recommended an exclusion zone of 5 Km radius from summit. Evacuation of residents within this zone was managed by local Government officials.
Even though the timing and the certainty of pyroclastic flows and other dangerous phenomena was uncertain, CVGHM used lesson learned from previous eruptions at other volcanoes, the geologic map and eruptive history of Sinabung volcano, and measurable changes in seismicity, ground deformation and other physical or chemical parameters to conduct probabilistic event-tree forecasts. Based on the level of unrest and these forecasts and on the experience of senior staff, Alert Levels were issued. This allowed eruptive activity to be anticipated and communities at risk to be forewarned with reliable information in sufficient time to implement response plans and mitigation measures. The eruption continues to the current time (late September 2014). Such a long-duration eruption poses challenges for the local people and for the scientists and emergency managers responsible for their safety.

Use of Bayesian Event Trees in forecasting outcomes of volcanic unrest

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For the past 3 decades the Volcano Disaster Assistance Program (VDAP) has used Bayesian Event Trees (BET) as a means to elicit opinions, reach consensus among scientists, and issue semi-quantitative probabilistic forecasts regarding the outcomes of episodes of volcanic unrest. The value of BET analysis is evident in a number of ways: 1) eliciting effective communication and constructive debate among volcano scientists with expertise in different disciplines, 2) providing a structure to logically combine and weigh the meaning and predictive value of geophysical monitoring data streams and historical/geological records, 3) reaching a consensus opinion from a diverse team with varied expertise, 4) serving as a means to document and communicate forecasts (either directly as numerical probabilities, or in more general terms; e.g., "one out of three chance"), and 5) enabling an evaluation of uncertainty (where uncertainty incorporates variance in opinion and variance in model outcomes).
VDAP applications of BET combine conceptual models of volcanic processes with current monitoring data and patterns of prior occurrence to reach a team consensus of the probability (or range in probabilities) for each node in an event tree. Accordingly, this method is a "hybrid" that combines deterministic and subjective models with objective statistical data. The rationale for the assignment of probabilities in the VDAP method is given in a written document that is linked to the tree and serves as a permanent record. Examples of this use of BET analysis from crises in Latin America and the Asia-Pacific region illustrate the strengths and weaknesses of the method. We anticipate that future improvement of the VDAP hybrid method will focus on improving the global database (i.e., WOVOdat), on determining predictive monitoring data thresholds and on the relative weighing of different monitoring data types and patterns, in order to better quantify probabilities *and* uncertainties.

Assessing vulnerability curves for natural risks

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Vulnerability constitutes the damage measurement of an exposed element (people, buildings, infrastructures, etc.) under effect of natural hazards. Today, vulnerability assessment is often conducted through use of vulnerability curves. They represent the probability that a specific vulnerability class of exposed elements reaches a certain level of damage (D0:No damage, D1: Slight damage, D2: Moderate damage; D3: Heavy damage, D4: Very heavy damage, D5: Destruction) in function of hazard magnitude.
Methodologies to assess vulnerability curves can be grouped in three typologies: analytical, empirical and hybrid. The first approach identifies vulnerability curves through analytical studies of samples of exposed elements, obtained generated by statistical procedures (i. e., Montecarlo simulation). The second approach identifies vulnerability curves through the statistical examination of damage observed after past critical events. The third approach is intermediate to the other two. It identify vulnerability curves through both analytical studies that observation of damage occurring.
In this presentation, the author aims to illustrate an overview of methodologies for vulnerability assessment and show the results obtained from his research with reference to buildings behaviour under effect of three natural hazards: earthquakes, volcanic eruptions (ash fall and pyroclastic flows) and landslides.
For seismic events, vulnerability curves have been obtained by empirical approach, observing damage due to past Italian earthquakes. For ash fall, vulnerability curves have been obtained by hybrid approach, combining mechanical analysis and experimental tests. For pyroclastic flows and landslides, vulnerability curves have been obtained by analytical approach.

The emergency planning for volcanic risk at Vesuvio and Campi Flegrei

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The Italian Civil Protection Service is a complex system that includes all national and local components and operational structures in charge of civil protection activities (forecasting, prevention, relief, contrast and emergency overcome).
According to the Italian legislation, the President of the Council of Ministers is responsible for the orientation, promotion and coordination of the entire Service. The Civil Protection Department, which is a branch of the Presidency of the Council of Ministers, is the focal point of the National Civil Protection Service, especially for the management of emergencies at national level.
The Italian territory is subject to several natural and anthropic risks. In particular, volcanic risk directly affects 2 million people, about 1 million of them lives in Campania Region.
The first national emergency plan for volcanic risk was elaborated in 1984 after the bradyseism of Campi Flegrei, and in early 90s for Vesuvio.
The elaboration of such emergency plans requires a constant interaction with the scientific community for the definition of the eruptive scenario and the alert levels, and with local authorities and operational structures for the definition of strategies and operational measures to be adopted in order to face a possible eruption. Furthermore, the planning process foresees an information process to the population in order to increase the awareness on volcanic risk and the adoption of protective measures to be taken in case of eruption.
Vesuvio and Campi Flegrei are located in a zone of the Campania Region with a very high population density. Although the past 30 years have seen a demographic decrease, the spatial growth still continued.
Nowadays the Vesuvio Emergency Plan is being reviewed and updated with the enlargement of the Red Zone, which is composed by 25 municipalities and about 700,000 people exposed to the pyroclastic flows and the high risk of buildings collapse caused by the ash deposit. In case of an eruptive event, the population living in the Red Zone should be evacuated before the eruption's onset; in addition to that, hundreds of thousands of people would be exposed to the severe ash fallout and lahar hazards (Yellow and Blue Zones). The eruptive scenario has been thoroughly revised as a consequence of the results of the research carried out in the past few years.
Currently the Civil Protection Department, in accordance with Campania Region, is reviewing the Red Zone that, in this case, is the area exposed to the pyroclastic flows, and that involves 7 municipality, including neighborhoods of Naples. In case of an eruptive event, also the population living in the Campi Flegrei Red Zone should be evacuated before the eruption's onset.
While elaborating an emergency plan, or managing an emergency several problems arising from the decision making process need to be taken into consideration; the uncertainty of the event prediction is one of them considering the possibility of false alarm. The consequence of false alarm can result in a consequent lack of reliability of the warning system also towards the population and economic loss caused by the actions undertaken to respond to.

The role and responsibility of scientists in the Italian Civil Protection: possible mitigation actions

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A study carried out by an Italian research institute (CIMA Research Foundation) highlighted the existence of a significant number of judicial investigations concerning Civil Protection in Italy (Figure 1). The interest in this series of trials lies in the fact that such enquiries are extended into the domain scientific consultancies connected to the prediction of natural events and, eventually, into the formulation of risk scenarios.
The said judicial control has resulted - in some cases – into the indictments of scientists (as in the case of the L'Aquila earthquake trial), or of public servants, experts in specific scientific topics (geologists, meteorologists and / or hydraulic engineers) whom, for duty, provide support to decision makers. In addition to the trial of the scientists belonging to the National Commission for High Risks[1] two other significant cases were outlined in the workshop.

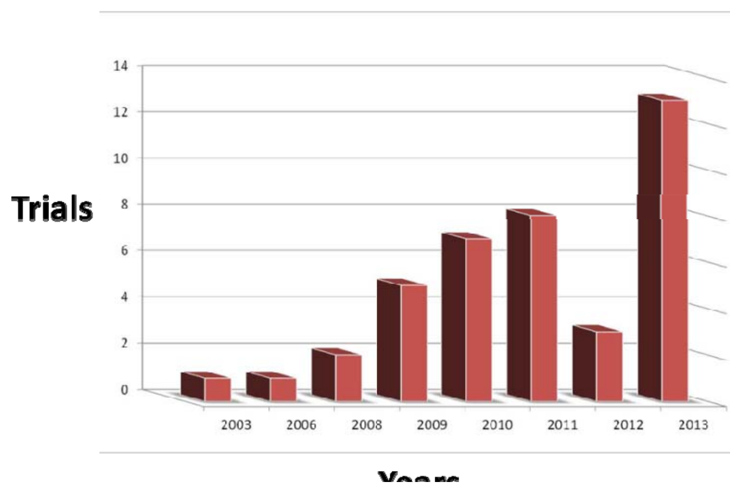

Figure 1 Number of trials per year, against Civil Protection operators, since 2003

1) The first case involved the prosecution of the vice Director of Civil Protection Department (at the time of the trial also in charge of the Italian service of forecast and alerting) for failing to provide the correct evaluation of a meteorological phenomenon which resulted in vast damages and four fatalities.
2) The second case involved a geologist whom, after a 10 years trial, was held responsible for underestimating the impacts of an ongoing storm. The natural event triggered a landslide that was being monitored, the geologist was the responsible person on shift, as provided by the specific Emergency Plan.

According to researchers at CIMA Foundation, authors of the study, the effects of such trials represents a setback for scientific advice necessary for Civil Protection activities. The following are the critical vulnerabilities identified:

- Judgments suffer from the "*hindsight bias*". Unpredictable events are considered predictable due to the fact that they have occurred. The same event however, before its occurrence, would have been considered unpredictable;

[1] All defendants where condemned by the court of l'Aquila (sentence issued on October 22^{nd},2012), to jail and to refund damages, for having made an incorrect assessment of the seismic risk and having miscommunicated the real levels of risk

- Judges usually contest the violation of the rule of precaution. This however flees from the criteria of stringency, determination and the preventive knowledge of the warranty obligations that operators and experts are called to fulfill. The liability for negligence is affirmed throughout the trial by constructing, *ex post* – an hypothetic virtuous behavior that the operator/expert should have followed.

The study, finally, considered some of the effects enacted with the affirmation of the phenomenon of "Defensive Civil Protection" (having the same conceptual basis of "Defensive Medicine"). Operators / experts , for defense purposes and to avoid a possible indictment ask for procedures and stringent protocols leading the way to the affirmation of automation. By so doing, risk scenarios are increasingly overestimated and more rigorous measures and invasive precautionary measures are enacted.

Moreover, it was observed that there are regions in Italy that operate very well in the field of prediction of hydrometeorological disasters, yet they are much more exposed to criminal liability with respect to regions that operate less well. This phenomena has been defined *"performance paradox"*. This paradox is likely to reduce the scientific contribution in the field of Civil Protection and relegate it to a mere relief and response system taking a giant leap back into time of at least 30 years.

Stemming from this study, a set of possible solutions will be presented that, if implemented, could reduce the detrimental impact of such a paradoxical control and, simultaneously, increase the efficiency of the entire Civil Protection System.

The Role of Science within the Rule of Law

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Discourses about recent court cases involving natural hazards have overlooked the many different roles that laws (both national and international) play within the governance of risks. For societal risk governance, laws not only create the stakeholders (infrastructures, duty holders and beneficiaries) and the stakes (duties and rights) but also dictate the ultimate rewards (acceptable standards of safety and wellbeing).

In both theory and practice, risk involves characterisations of the uncertainties of the future with the object of attempting their management. This permits (and perhaps encourages) accountability, blame and legal liability (after a rigorous comparison of achieved standards with those required in law). Legal liability (criminal and civil) plays a fundamental regulatory function. The allocation of liability not only makes possible post-facto criminal law sanctions and civil law remedies (reparation for injury and distributive justice to rebalance the effect of risk outcomes) to penalise inadequate risk management but also provides an ex-ante indirect incentive for good risk management[2].

Scientists are best placed to characterise the spatial, physical and temporal characteristics of natural hazards. Accordingly, they are required to produce and thereafter communicate to a wide range of governance stakeholders (including but not limited to risk managers and at-risk communities) timely, evidence-based, user- and use-focussed deliverables.

What is the mischief? Although laws may particularise the stakeholders, stakes and rewards of governance, they will rarely, if ever, set out the dynamic processes by which duties of care can be fulfilled. In the absence of commonly agreed and practical principles/methodologies by which compliance can be measured ("standard-unequivocality"), process compliance is difficult to monitor and process non-compliance is difficult to enforce[3].

The devil (the risk of accountability and blame – institutional/professional risk) therefore lies in the dynamic detail of what represents current "acceptable practice" – the ways and means by which legal duties can actually be achieved to the required legal standard. This devil ignited and continues to fuel the current debate about the merits of initiatives to identify and record scientific "best practice".

Two obvious reactions to increasing institutional risk are "Get smarter" and "Get a lawyer"[4]. It will be suggested that scientific communities should concentrate on the former to ensure that future science deliverables maintain their traditional hallmarks of excellence, objectivity, independence, balance and value-free neutrality.

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Scientific advice for policy-making: lessons learned from recent crises

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The OECD Global Science Forum initiated an activity related to scientific advice late 2012, following a discussion that was triggered by the conviction of scientists in connection with the L'Aquila earthquake. This activity comprised an analysis of the various organizational (and procedural) models that are in use or advocated to raise or optimize the quality of scientific advice, including during emergency crises, a study of the responsibility and/or liability of scientists who provide advice to governments, and relevant communication issues, and the identification of emerging issues related to scientific advice.

Scientific advice can play an invaluable role in short- and long-term risk assessment for unexpected crisis situations. It can also be essential in informing effective risk management strategies during such crises. When a rare crisis event occurs, which may have impact at regional or global scale, emergency response systems, science advisory structures and policy makers can be confronted with novel complex and rapidly changing challenges. In such circumstances, existing advisory processes are usually neither entirely appropriate nor entirely adequate. The pressure on scientists to come up with swift and clear answers for policy-makers can be unbearable, in particular in those emergency situations. In recent years we have seen the consequences of performing under this pressure in Italy (L'Aquila earthquake of 2009) and in Japan (Fukushima nuclear disaster in 2011).

Based on experience with recent trans-national crises, a number of governments and independent advisory bodies have introduced new processes to provide scientific advice in crisis situations. A few basic principles are emerging which will be presented during the session, including elements which can help reduce the likelihood of litigation.

Monitoring, hazard assessment and decision-making during the on-going crisis at Bárðarbunga volcano (Iceland)

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On the 16th of August, Bárðarbunga volcano entered in a new phase of unrest. Since that day, the elevated seismicity in the area generated thousands of earthquakes per day, in conjunction with a significant deformation rate observed NE of the Bárðarbunga caldera. In this area a dike intrusion has been then monitored for almost two weeks, until when a small and short-lived effusive eruption started on the 28th in Holuhraun. After few days a second, more intense, fissural eruption took place and it is still ongoing.
Bárðarbunga volcano is part of a large volcanic system that erupted last time in 1910. This system is partially covered by ice within the Vatnajökull glacier and it extends further to the NNE as well as to SW. Based on historical data, its eruptive activity has been predominantly characterized by explosive eruptions, originated beneath the glacier, and important effusive eruptions in the ice-free part of the system itself. The largest explosive eruptions took place in the southern side of the fissure system and the Veidivötn eruption (1477 AD) produced abundant ash that reached and spread all over European countries.
Due to the extension and location of this volcanic system, the range of eruptive scenarios and associated hazards is quite wide. Indeed, the possible hazards include: inundation, due to glacial outburst; tephra fallout , due to rich-ash plume generated by magma-water interaction; abundant volcanic gases release; lava flows. In addition, the temporal and spatial evolution of the geophysical monitoring signals (the seismicity, the deformation, the hydrology) created a very dynamic picture of the ongoing events. For these reasons the scientists have been asked for rapid re-evaluation of potential outcomes and hazard assessment on a daily basis.
The Icelandic Meteorological Office is in charge of monitoring all kind of natural phenomena in Iceland, evaluating their related hazards, and issuing warning to the public, as well as providing information regarding volcanic eruption of concerns for the aviation. It is monitoring the Bárðarbunga unrest phase since its beginning and, in collaboration with the University of Iceland, is providing scientific support and interpretation of the ongoing phenomena to the Icelandic Civil Protection. Each day all these institutions joined a common round table for discussing scientific data, their analysis and observations; further the scenarios towards which the current situation could evolve is drawn and communicated to the public as well as to Administrative and Governmental Institutions. Based on these information and advices, the Civil Protection is taking decisions for what concerns precautionary measures like for example the limitation of accessibility to the eruption site, the evacuation of exposed areas, and the issuing of warnings and information for mitigating discomforts to inhabitants and tourists.

Evidence-based volcanology in a rare eruption scenario: a future Laki- style, Icelandic eruption and predicting its impact on mortality and morbidity in the UK

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In 2010 the Eyjafjallajökull volcano erupted into a Europe unprepared for the grounding of aircraft and the spectre of fine volcanic ash as respirable particulate matter (PM 2.5) falling over the continent. Afterwards, the UK government included in its risk register a 'precautionary worst case' scenario of an extreme effusive eruption that has happened twice in the last 1000 years – the last occasion in 1783 at the Laki fissure – whose emissions were mainly sulphur dioxide gas and sulphate aerosol polluting the atmosphere for many months. This presentation will outline the methods used so far in Cabinet Office study H55 to derive eruption source terms – from Monte Carlo simulation informed by uncertainty ranges obtained by elicitation – that are then used then as inputs to a dispersion model to provide estimates of flight level plume and ground concentrations in the UK for the risk register scenario. The principal impacts of concern are on human health, but these are also shrouded in uncertainty and are critically dependent on a very narrow window of predicted ground concentrations and loosely applicable – and also uncertain – exposure-response coefficients. It is not clear that such model results can be used for operational forecasting or for urgent decision-taking. This meeting is taking place a month after the latest Icelandic fissure eruption (at Bardabunga) has begun.

Assessing volcanic hazard at Campi Flegrei caldera (Italy) with uncertainty quantification

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Campi Flegrei (CF) is an example of an active, densely populated, caldera with very high risks associated with the occurrence of explosive eruptions. In particular, mapping of pyroclastic density currents (PDCs) hazard is challenging due to the large uncertainty on future vent location and eruption scale as well as the complex dynamics of flows over caldera topography. In this presentation we show how volcanological datasets of different type, mathematical modelling and expert elicitation techniques have been used to produce base-rate probabilistic vent opening and PDC inundation maps. The analysis particularly focused on the reconstruction of the location of past eruptive vents and it allowed the incorporation of additional volcanological datasets, such as the distribution of faults and surface fractures assumed to be representative of areas of crustal weaknesses in the caldera. One key objective was to directly incorporate some of the main sources of epistemic uncertainty relating to an understanding of the volcanic system. We used a formal and structured expert elicitation procedure to quantify uncertainties for the main parameters and evaluate the outcomes through different expert weighting models. A set of probabilistic PDC inundation hazard maps were then produced by the Monte Carlo approach based on a simplified inundation model and incorporating uncertainties on future vent location and event scale.

Expert elicitation in natural hazard and risk assessment in New Zealand

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We present two examples how expert elicitation contributes to hazard and risk assessment of natural phenomena in New Zealand.
The Canterbury earthquake sequence is an on-going earthquake sequence, which started with the September 2010 M7.1 Darfield earthquake. The three M≥6.0 aftershocks included the devastating M6.3 Christchurch earthquake on 22 February 2011, which resulted in 185 deaths and extensive damage. As a consequence of the earthquake sequence the New Zealand National Seismic Hazard model was expected to underestimate the level of ground shaking for the Canterbury region for the coming decades due to on-going aftershock activity and the possibility of other triggered moderate to large earthquakes. Therefore a new time varying earthquake hazard model was developed. The development of the model included two structured expert elicitations, one for the seismicity model, and the other for the ground-motion model. The model has been used for revision of building design standards and for planning of the city rebuild.
White Island volcano off the east coast of the North Island has been in a state of volcanic unrest since August 2012. Level for the annualised risk of dying while visiting the volcano have been set, and govern if and for how long volcanologists are allowed to visit the island for monitoring and data sampling. We are exploring the use of Bayesian Belief networks (BBN) as decision support tool for estimating volcanic hazard and risk. So far we have developed a BBN structure to estimate the probability of a magmatic eruption on White Island volcano and we are planning an expert elicitation to quantify the BBN in the near future.

Using expert elicitation to characterize long-term tectonic risks to radioactive waste repositories in Japan

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Siting and designing technological facilities that need to be located in regions susceptible to major tectonic events requires evaluation of the full range of knowledge and appraisal of plausible alternative models and interpretations, all within a probabilistic framework. This challenge has been clearly demonstrated by the extreme effects of the March 2011 Tohoku earthquake in Japan and is nowhere more problematic than in siting facilities with hazard potentials that last for thousands of years, such as geological repositories for radioactive waste. The use of formalized expert elicitation to help derive credible impact scenarios for volcanism, faulting, deformation and other tectonic events, together with their likelihoods of occurrence, is being trialled for the first time in the Japanese geological disposal programme. We look at the methodology for eliciting expert judgement under uncertainty, and explore the broader possibilities of this approach for tectonic hazard forecasting.