THE MULTI-HAZARD ASSESSMENT AT MUNICIPALITY SCALE: THE CASE STUDY OF ISCHIA ISLAND (SOUTHERN ITALY)

Alberico Ines (1), Petrosino Paola (2)
Istituto per l'Ambiente Marino Costiero, CNR, Calata Porta di Massa, 80133 Napoli, Italy. e_mail : ines.alberico@iamc.cnr.it
Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse - Università degli Studi di Napoli Federico II, L.go S. Marcellino 10, 80138 Napoli. e_mail : paola.petrosino@unina.it

The best knowledge of potentially hazardous natural events and the precise mapping of the zones that they could involve are essential to plan the actions aimed at reducing the territorial vulnerability and promoting the development of a resilient community. The Act 100/2012 of Italian Civil Protection amends the art.15 of law 225/92 and introduces the term of ninety days from its entry into force to define a draft for the municipal Civil Protection plan. The Campania Regional Territorial Plan (2008), consistent with the L.R. n.65 2004, points out the importance of developing a multi-risk territorial planning as a tool to establish preventive rules, correct land use and chose appropriate locations of strategic infrastructures for the risk mitigation. At present, only 20% of municipalities in Campania provided themselves with a municipal civil protection plan.

In this framework, in accordance with the guidelines of the Department of Civil Protection and the Regional planning tools, we propose a method to assess the multi-hazard at a municipality scale for the regions where several parameters as the probability of occurrence of the events as well as the probability that some natural events (i.e. earthquake) could trigger another one (i.e. landslide) are not yet available.
Taking into account the different recurrence times of natural events, two multi-hazard indexes were quantified: the total multi-hazard index, which illustrates the hazard status of the territory considering all the natural events and the partial-hazard index, which only takes into account those events possibly occurring monthly to yearly. These indexes, depicted into simple maps, and detailed into the single hazard rate matrix for each municipality, make it possible to communicate to the local stakeholders which municipality and what natural event require a priority intervention to reduce the risk. In the light of past urban expansion experienced by most municipalities of Campania, insensitive to the impending natural hazards, the maps also permit to identify the areas where it is urgent to prevent future urban developing and to hypothesize a type of land use that takes into account the possible occurrence of a hazardous phenomenon.
The method was applied to the case study of Ischia island (Napoli bay, southern Italy), indeed, its exposure to many natural hazards (seismic, volcanic, landslide, coastal erosion and marine inundation), coupled with the intense urbanization, makes it a good test area to validate the methodology here proposed. Through completely focusing the inadequate and often unmanaged urban expansion at Ischia in last century, our work offers a basic tool for the assessment of social vulnerability and the identification of the factors that could strengthen the resilience of the island in face of natural hazards and related consequences.

PHYSICAL VULNERABILITY OF THE TERRITORY EXPOSED TO AN EXPLOSIVE ERUPTION ORIGINATINGAT THE CAMPI FLEGREI VOLCANIC FIELDS

Alberico Ines (1), Petrosino Paola (2)

Istituto per l'Ambiente Marino Costiero, CNR, Calata Porta di Massa, 80133 Napoli, Italy. e_mail : ines.alberico@iamc.cnr.it
Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse - Università degli Studi di Napoli Federico II, L.go S. Marcellino 10, 80138 Napoli. e_mail : paola.petrosino@unina.it

A way to reduce natural risk is to control the vulnerability of the exposure, based on a detailed asset inventory (construction type, year built, reinstatement value, population density) of areas potentially exposed to hazardous natural events. A knowledge of type and severity of natural events and the fragility of assets, make it possible to state how to intervene on exposure with the aim of improving the resilience.
In this work the vulnerability Province of Naples (Southern Italy) to a possible future explosive eruption originating at the Campi Flegrei volcanic field was assessed. We evaluated the vulnerability of property to the pyroclastic fallout of eruptions with medium magnitude, assuming the population was already moved to safety before a new eruption started.

The scientific literature indicates that the products of the two main eruptions which occurred in the last 15 ka (Pomici Principali, ca 12 ka; and Agnano-Monte Spina, ca 4.2 ka), blanketed the whole Campi Flegrei region reaching the pre-Apennines area. The fall deposits of eruptions with lower magnitude were emplaced close to the eruptive centres and hence confined to inside the Neapolitan Yellow Tuff caldera.
The distribution of Agnano-Monte Spina pyroclastic fall products was here considered as the scenario to define the extent of the area that could be involved in the future. Fall products distributed eastward from the eruptive centre, would blanket most of Naples city, together with the north-eastern and southern-western sectors of Somma-Vesuvio volcano. For the entire area, the effects of pyroclastic fall deposition on land cover were evaluated while the vulnerability of urban environment for the sole Marigliano municipality test area was defined as well.

According to USGS protocols (http://volcanoes.usgs.gov/ash/agric/index.php), we grouped the land-cover into three main classes and for each we defined the effects of different thicknesses of pyroclastic fall products. The results of this analysis in conjunction with the recovery time for each vegetation type were used to assess a vulnerability index.

For the Marigliano municipality test area, located ca 30 kilometers from the Campi Flegrei caldera, the vulnerability of urban environment was defined as a function of the year of construction of the buildings. The urban development older than 1945 was considered to display the highest vulnerability since it is mainly characterized by traditional brick buildings and poor conservation status, with respect to the younger RC engineered buildings.

Thematic maps depicting the degrees of vulnerability of the territory in the case of an explosive event at Campi Flegrei, emplacing pyroclastic fall deposits, are the output of the present research. In the current phase of volcanic quiescence, those maps can be used as a basic tool to prioritize intervention aimed at reducing volcanic risk through the correct territorial management and planning.

EMPIRICAL RELATIONSHIPS BETWEEN EMS INTENSITY AND INSTRUMENTAL GROUND-MOTION PARAMETERS FOR THE EURO-MEDITERRANEAN AREA.

G. **Alguacil**, F. Vidal, and L. Aramburu
Instituto Andaluz de Geofísica, University of Granada, 18071, Granada (Spain)

fvidal@ugr.es; alguacil@ugr.es ;

We analyzed 183 accelerograms, corresponding to 75 events recorded in 105 stations, from the *European Strong-Motion Database* (ESMD) and the *Italian Accelerometric Archive* (ITACA) with assigned macroseismic intensities for the recording sites from IV to IX (EMS).

For each processed accelerogram, the following strong ground motion parameters (*sgmp*) were calculated: peak ground acceleration *PGA*, and velocity *PGV* (vector module for both), Arias intensity *AI* and spectral intensity (Housner) *SI*. This latter is defined as the average value of the velocity response spectrum for periods between 0.1 to 2.5 s, with a damping coefficient of 0.2. Since the response spectrum is defined for each axis, we rotated the accelerogram and calculated the *SI* for 8 horizontal directions covering 180^0, taking the maximum *SI* as its representative value, since the structure or building affected may have any orientation.

For each intensity degree, the *sgmp* values have a large range of variation, similar to the results found by other authors, with a distribution tending to log-normal. Therefore, we used the logarithmic mean for each intensity degree as the most probable value of the log of each *sgmp* for that intensity. All *sgmp* were expressed in c.g.s. units. The empirical relations of intensity-log (sgmp) are clear and are best fitted by quadratic laws. For *PGA* and *PGV*, the intensity (EMS) estimated is $I_{ePGA} = -3.27\ (\log PGA)^2 + 18.30 \log PGA - 16.63$ and $I_{ePGV} = -2.60\ (\log PGV)^2 + 8.63 \log PGV + 1.86$, with quadratic mean residuals *r* of 0.40 and 0.21 intensity degrees, respectively. The best mono-parametric estimation obtained in terms of residuals corresponds to *SI* parameter, $I_{eSI}=-2.40\ (\log SI)^2 + 8.27 \log SI + 1.90$, with $r=0.09$.

For all the *sgmp* a light change of trend is systematically observed from intensity VI to VII, less marked for *SI*. So that, in order to compare with the results of other authors, truncated laws with two linear fits for the ranges IV-VI and VII-IX have been obtained, but the residuals do not improve relative to the quadratic fits.

It is also clear the statistical correlation between the different *sgmp* calculated. So we tried to find new variables as linear combinations of their logarithms that explain the most of their variance. With the principal component analysis (PCA), we obtained two new variables, *x* as a combination of *PGA* and *PGV* and *y* with the four *sgmp* used. The multiparametric relationships obtained of the intensity with them are: $I_{ePGA\text{-}PGV} = -1.44\ x^2 + 8.98\ x - 4.97$, with $x = 0.74 \log PGV + 0.66 \log PGA$ and $I_{ePGA\text{-}PGV\text{-}AI\text{-}SI} = -0.36\ y^2 + 3.25\ y + 1.57$, with $y = 0.75 \log AI + 0.41 \log SI + 0.40 \log PGV + 0.34 \log PGA$. The quadratic mean residuals are 0.28 and 0.21 intensity degrees, respectively.

The relationships obtained in this study may be useful for estimating the intensity from recorded accelerograms. Conversely, the estimation of the most probable *sgmp* values where only the macroseismic intensity degree is available is also possible.

ANALYSIS OF GEOTECHNICAL, AMBIENT NOISE AND ACCELERATION DATA FOR SEISMIC MICROZONING OF VIÑA DEL MAR CITY (CHILE)

Aranda, C.(1), Vidal F.(1), Alguacil G.(1), Valverde-Palacios I.(2), Navarro, M.(3) y Feriche, M.(1)

(1) Instituto Andaluz de Geofísica. University of Granada, 18071, Granada (Spain). **caranda@ugr.es** ; **fvidal@ugr.es**; **alguacil@ugr.es**; **feriche@ugr.es**

(2) Dep. of Architectonic Buildings. University of Granada. 18071. Granada (Spain). nachoval@ugr.es

(3) Dpt.. of Applied Physics, University of de Almería, La Cañada, 04120, Almería

(Spain). mnavarro@ual.es

The evaluation of the local site conditions and the estimation of their influence on earthquake ground motion is the main purpose of a seismic microzoning. This paper analyzes the surface geotechnical characteristics, the ambient noise and local strong motion records in order to characterize the local amplifications. The geological and geotechnical data obtained from soil mechanics show that the hill zones consists of rocks and the plain zone is formed by sedimentary deposits of sands and silty sands, that reach more than 100 m depth. Vs velocities estimated from N_{SPT} data are very low (Vs ≤ 200 m/s) for depth ≤ 5 m, growing from 5 to 15 m, and being generally Vs > 300 m/s for deeper layers. The coast and the Marga-Marga river shores present V_{S30} < 300 m/s and generally higher in the rest. The water table depth generally varies between 2.7 and 6-7 m. We performed city maps of lithological units,V_{S10}, V_{S30}, and basement and water table depth. The soil conditions had a clear influence in the spatial macroseismic intensity distribution in the city. The observed intensities were one degree lower at hills than in the plain area in the 2010 earthquake and previous ones. We obtained a map of the ground predominant periods, Tp, from ambient noise measurements at 89 points regularly spaced (Δ ~200 m), most of them sited on the plain zone. Our results show a heterogeneous behavior of the ground: Tp < 0.2 s at the hills, 0.2- 0.4 s at close hill zones, and 0.4-1.2 s at the plain city area (on Quaternary sediments), being the highest values (Tp > 0.8 s) on zones nearby the Marga Marga fault trace. These results are relevant information to analyze the resonance soil- building structures.

To obtain the characteristics of the ground transfer function in Viña del Mar we used two empirical known methods: The standard spectral ratio (SSR) and the H/V spectral ratio (HVSR) methods. To obtain the period range of ground motion amplification at four station sites, we used earthquake acceleration records of the 2010 earthquakes. Two strong motion stations installed on soils in Viña del Mar (CEVM and MMVM) and other two nearby stations in Valparaiso, one installed on sandy soils (El Almendral, EALM), and other on bedrock (UTFSM, that was used as reference station) were used. SSR and HVSR methods show small differences in site amplification values for Viña del Mar stations. The spectral amplification is above a factor of 4 for periods of 0.4-1.2 s (CEVM) and 0.35-1.6 s (MMVM). Other authors found similar significant ground amplification in 4 sites of the city (one of them was CEVM station) applying HVSR method to several 2010 aftershocks.

Finally, we also calculated engineering ground motion frequency-dependent parameters (response spectra, SA, SV, and input energy spectra, IES) of the mainshock to test the frequency-amplification obtained with the methods mentioned above. The results show amplification for the same range of frequencies previously obtained.

TREND ANALYSIS AND OUTLIER DETECTION IN MULTIDIMENSIONAL INSAR AND GPS TIME SERIES OVER VIRUNGA VOLCANIC PROVINCE.

Alicia **Arjona**
European Center for Geodynamics and Seismology, Gran-Duchy of Luxembourg.
E-mail: alicia.arjona@ecgs.lu

The detection of outliers and trend changes from time series is an important part of geodetic and geodynamic studies to understanding the anomalous behavior in volcanic areas. We develop and test a tool consisting on a unifying framework for analyzing ground deformation associated to volcanic activity in Virunga Volcanic Province. We

estimate trend changes using weighted moving average filter, locally weighted scatterplot smoothers and smoothing splines. Significance of detected trend changes is estimated using parametric and non-parametric statistical tests such as Mann-Kendall, Spearmans Rho and Pearson correlation methods. Further outliers are detected using both standardized residuals from best-fit model and Chebyshev's inequality. When multiple components of displacements are available (such as vertical, North-South and East-West GPS time series), the outliers detection is performed on each component separately, then jointly. We apply this tool to data recorded by the permanent GNSS volcano monitoring network in Goma as well as the extensive amount of MSBAS Multidimensional InSAR time series (Samsonov and dOreye, 2012) recorded in the Virunga during 2003-2013 time period. We identify long-term deformation of Mt.Nyamulagira and deformations associated to its most recent eruptions.

VOLCANIC HAZARD ASSESSMENT IN MONOGENETIC VOLCANIC FIELDS

Stefania **Bartolini**1, Rosa Sobradelo2, Annalisa Cappello3, Laura Becerril1, Joan Martí1
1Institute of Earth Sciences Jaume Almera, ICTJA-CSIC, Group of Volcanology, SIMGEO (UB-CSIC), Lluís Solé i Sabarís s/n, 08028 Barcelona, Spain
2 Aon Benfield UCL Hazard Centre, Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, UK
3 Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania, Osservatorio Etneo, Catania, Italy

One of the most important tasks of modern volcanology, which represents a significant socio-economic implication, is to conduct hazard assessment in active volcanic systems. These volcanological studies are aimed at hazard that allows to constructing hazard maps and simulating different eruptive scenarios, and are mainly addressed to contribute to territorial planning, definition of emergency plans or managing volcanic crisis. The impact of a natural event, as a volcanic eruption, can significantly affect human life, property, infrastructures, and the environment. Long periods of quiescence are quite common in many volcanic areas and this often leads to a fall in the alert. The consequence is lack of preparation to deal with a volcanic crisis.

The present work is focused on the development and application of different tools for the spatial and temporal analyses to assess volcanic hazard in monogenetic volcanic fields. Monogenetic volcanic fields are commonly not regarded as potentially dangerous and only a few studies concerning hazard assessment have been conducted in such environments. In the long-term hazard assessment, we assume that the future eruptive behaviour in the volcanic field could be similar to the last eruptive activity. First, we have developed a new tool, QVAST, designed to carry out the spatial analysis. This tool allows to calculate the volcanic susceptibility of the area, i.e. the probability of new vent opening, using direct and indirect structural data. Second, we have developed a new tool, HASSET, to conduct temporal analysis. Combining both tools and the previous one, VORIS 2.0.1, that uses simulation models to predict the most probable eruptive scenarios and which areas could be affected by a future eruptive event, we can evaluate in a probabilistic way long-term hazard represented by a qualitative hazard map that allows us to identify different levels of hazard in the study area.

Finally, considering the importance of both quantity and quality of the available volcanic data and an optimum storage mechanism and as complement to the e-tools we have developed, we describe the design of a new spatial database structure, VERDI,

which allows different types of data to be manipulated, organized, and managed, avoiding any duplication of information.

The methodologies described in this work establish the general guidelines of a procedure that facilitates undertaking volcanic hazard assessment in a systematic way, which can be easily applied to any volcanic area or system, and in particular to any monogenetic volcanic field.

COLLABORATIVE MONITORING IN SOUTHERN ICELAND: A TECHNICAL VOLCANIC ENVIRONMENT

Daniel **Beech,**
Aberystwyth University**,** dib8@aber.ac.uk

Monitoring of natural hazards is reforming/evolving as a result of developments in information technology. Advances in Global Positioning Systems and Geographical Information Systems have led to an unprecedented use of new and innovative technical devices. Monitoring practices, particularly across Europe and North America, have become more varied and are no longer based solely upon readings from a seismograph located at a given distance from a geophysical hazard. Instead, the networked scope of monitoring systems is focussed upon the transformation of data that is collaborated between institutions and actors.

Technology has transformed the prevention and response of geophysical hazards, in doing so, developing advanced and complex networks, such as those monitoring volcanoes across southern Iceland. Networked visions of monitoring systems are strategically designed to enable hazard information to become both accessible and transparent. The real-time aspect of monitoring merges volcanic experts and lay publics from across Southern Iceland, largely through the use of technical devices that develop new virtual data-scapes. Hazard information has become increasingly mobile and participatory, furthering the scope of the network and eradicating boundaries between monitoring institutes and citizens.

Research conducted in Iceland questions the positionality of technology within hazard management. The observation of monitoring exercises carried out jointly by leading institutions, and an extensive array of semi-structured interviews, has allowed for the identification of both the expert and non-expert stakeholders within Southern Iceland's monitoring network. The research illustrates how Iceland's relatively small population, active tectonic environment and appetite for technology has constructed a suitable platform on which to develop a sophisticated monitoring approach. The 2010/2011 eruption of Iceland's Eyjafjallajökull volcano, and the 2014 activity at Bárðarbunga, have illustrated the importance of having a technically advanced network, due to the potential impacts upon the aviation industry, not just within, but beyond Iceland.

The research illustrated how, and to what effect, leading institutions have collaborated through monitoring exercises such as VOLCEX and VOLCICE, where the use of technological instruments reduces the distance between scientific institutes such as the Icelandic Met Office, and end-user's such as ISAVIA. Project's such as FUTUREVOLC have enhanced technologies' position within monitoring networks, in doing so, creating new methods through which to convey knowledge to institutional partners across Europe. UK based monitoring institutes such as the London VAAC, also increase the scale of the network through the capability to geo-visualise volcanic environments. In the case of Southern Iceland, technology has become a reliable

mediator through which to integrate institutes that identify, represent and respond to hazardous volcanic activity.

A NETWORKED APPROACH TO SEISMIC ACTIVITY: THE NEED FOR COMMUNICATION AND COHESION

Daniel **Beech**
Aberystwyth University, dib8@aber.ac.uk

The management and mitigation of seismic hazards requires a significant investment of cohesion, trust and togetherness. Interaction between hazard management agencies, academic institutes, communities and governments often constructs effective channels of communication through which information can be transported. Channels of communication encapsulate the complex spatiality in which hazard management can be framed, observed and utilised; this approach is applicable to the management of Icelandic volcanoes, as hazard communication channels extend to the UK. Icelandic and UK based institutes require trustworthy, shared communication protocols in order to be of significant value to hazard identification and response. The 2010/2011 aviation crises resulting from volcanic activity in Iceland illustrates why a cohesive approach is required for the minimisation of future social and economic impacts.

Whilst academic research has previously tended to focus upon breakdowns in communication between science and society, and the resulting impacts of seismic hazards, an interdisciplinary perspective provides sufficient scope for research into how science, culture, technology and politics can become integral considerations in approaches to volcanic monitoring in Iceland. This research specifically explores the case of Iceland as the geographical location, demography and socio-economic position ideally lends itself to seamless collaboration with overseas communities in Europe and North America.

Redesigning hazard management through the implementation of new technical protocols has led to increased interest in how channels of communication are formed, and how they function and evolve. European wide project's such as FUTUREVOLC and COSMIC thrive on newfound bridges between science and wider publics, and are often a means through which to distribute information and broaden awareness. The generation of data hubs epitomise the co-production of data, stretching disciplinary boundaries and furthering networked geographies through the symbiosis of hazard management.

Through observations of Icelandic and UK based seismic exercises and semi-structured interviews, communicative practises have been identified and critiqued. The research conducted has led to an envisioning of a hazard management network without boundaries, a fluid entity that changes shape, scale and configuration to create efficient communication channels. Findings have outlined the participatory characteristics of Iceland's network; for example, social media has provided new communication protocols through which those monitoring seismic hazards, and those affected by them, can share dialogue openly. Smartphone applications and tablets have enabled hazard information to become flexible in format, particularly with new methods of representation in virtual environments. In addition, citizen science and the growth of open source data appears to have led to increased trust from communities to scientific experts, further enhancing the network's cohesive and collaborative abilities.

FACILITATING A PARADIGM SHIFT IN STRATEGIC SCIENCE FOR EXTREME GEOHAZARD POLICIES AND DECISIONS

Deborah **Brosnan**,
University of California, Davis California USA and Brosnan Center.
Brosnan@deborahbrosnan.com

Extreme geohazards can cause disasters on a global scale. Fortunately, modern civilization has not experienced such extreme hazards yet. However, recent events such as the Iceland volcanic eruptions point to the severity and far reaching consequences they will have. In today's world, the largest volcanic eruptions that occurred during the Holocene could impact societal infrastructure, human health, and supply of resources, transportation, and food and water security on global scale. Their potential impact on civilization is comparable to other possible mega disasters from extreme droughts, floods, pandemics, and asteroid impacts. But experience of these events is lacking and appropriate preparation is poor.

Disaster management and risk reduction for extreme geohazards, that will occur, requires a paradigm shift in scientific monitoring, science-communication to stakeholders, and in ability to respond to real threats. Scientific information can help guide decision-making but key challenges are in regularly generating that information and identifying entities that can receive and act effectively on that scientific. The audience for science is diverse. Governments must make decisions that will affect citizens, environment, and trade. Private sector has a limited timeframe before they run short and will be concerned about return to operations. For multi-national entities the challenges are even more complex.

Decision-makers frequently turn to science only when a crisis is perceived as imminent. Consequently critical decisions must be made with little time to evaluate scenarios, when the uncertainties are high and the consequences great. We need a strategic science framework and approach that will help decision makers and the public-understand and plan for extreme geohazards. This framework should also incorporate a tactical science approach that allows for the kinds of rapid decisions that must be made when events are occurring. An international science framework liking scientists to national and international decision-making levels could increase resilience and decrease the severity of the event and time spent in recovery.

Currently there is no framework for such an international science advising and reporting that integrates into decision-making for extreme geohazards. To help envision and facilitate such thinking, scenario planning can be powerful approach. Used in other situations e.g. tsunami planning it helps stakeholders to better appreciate risks and formulate innovative solutions.

GEOHAZARDS, MONITORING NETWORKS AND SYNERGIES

Paola **Campus**, European Science Foundation (ESF), 1 quai Lezay-Marnésia, BP 90015, 67080 Strasbourg cedex, France

The recursive occurrence of geohazards (among which volcanic eruptions, earthquakes, tsunamis, bolides) on our Planet throughout the last few millennia has often impacted human settlements on local and regional scales, causing significant deaths and losses of goods and structures. In some extreme cases such events have so dramatically impacted the environment on global scale to inflict catastrophic losses to populations.

The current status of our Planet, characterized by societies progressively clustering around megacities, often located in hazardous areas and heavily depending from fast and efficient transfer of information and persons faces the crucial challenge of developing an effective resilience program to geohazards and, in particular, to extreme geohazards.

Most of the decision-making and emergency centres are located in large settlements or megacities, making it thus crucial to assure a constant and efficient level of sustainability of such structures in order to enable timely decisions and support actions at local, regional and global level even under the worse environmental conditions.

The development of an effective Disaster Risk Reduction program and of a consequent robust resilience program needs to be based on a holistic approach, addressing scientific, technical, logistic, social and policy aspects related to hazards and involving all the principal stakeholders facing this challenge: scientific experts of geohazards, social sciences experts, government officials and policy makers.

The main tool supporting such holistic approach should be a Global Network of Monitoring Systems, based on synergetic technologies capable of acquiring and sharing in real-time (or near-real time) high quality data recorded on a global scale: the systematic and comprehensive analysis of such data would allow the development of a deeper understanding of the phaenomena associated to geohazards and would enable the principal stakeholders involved in Disaster Risk Reduction and Resilience to issue early warnings to populations.

Some examples of events and of the contribution to their monitoring through existing global networks will be provided.

MAPPING THE RISK OF LAVA FLOW INUNDATION: THE CASE OF ETNA VOLCANO, ITALY

Annalisa **Cappello**1, Giuseppe Bilotta1, Gaetana Ganci1, Alexis Hérault1,2, Ciro Del Negro1

1Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania, Osservatorio Etneo, Italy, 2Conservatoire des Arts et Métiers, Département Ingénierie Mathématique, Paris, France.

{annalisa.cappello, alexis.herault, giuseppe.bilotta, gaetana.ganci, ciro.delnegro}@ingv.it

Almost one million people live close enough to the Mount Etna (Sicily, Italy), the most active volcano in Europe, to have their lives and properties threatened when an eruption does occur. All eruption typologies at Mt Etna can give rise to lava flows, which are the greatest hazard presented by the volcano to inhabited and cultivated areas. Over the last 400 years, lava flows, while usually not life-threatening, have been very destructive, bulldozing and burying whole villages and sometimes setting on fire. Moreover, growing population pressure on the flanks of Mount Etna is increasing our vulnerability to volcanic hazards. Recently, we quantified the lava flow hazards at Mt. Etna combining numerical simulations of lava flow paths, spatiotemporal probability of future vent opening, and event probabilities associated with classes of expected eruptions. Here we derive the risk using the lava flow hazard map and the exposed value. The exposed value, i.e. the value of each of the elements at risk in a given area, is evaluated as the average of three kinds of information: the socio-economic index, the anthropogenic index, and the land use index. The socio-economic index takes into

account various factors, such as population, buildings, businesses, institutions, local units and employees by municipality. The anthropogenic index indicates the presence of buildings and/or infrastructures, such as roads, highways, railways and underground lines. The land use index reclassifies the area into land-cover types, e.g. rocks, wooded areas, agricultural enterprises, industrial areas, general infrastructure and urban areas. Finally, we built up the risk map of Etna volcano (Italy), showing the areas in which there would be the greatest amount of losses in case of a flank eruption. Such map is an indispensable guide in managing volcanic emergencies in terms of planning, mitigation of potential effects, relief efforts and assessing potential loss and replacement costs. Although this study was conducted on Mt. Etna, the approach used is designed to be applicable to other volcanic areas.

VOLCANO DEFORMATION PREDICTIONS THROUGH NUMERICAL MODELING. APPLICATION TO TEIDE VOLCANO (CANARY ISLANDS)

María **Charco**(1) and Pedro Galán del Sastre(2)
(1) Instituto de Geociencias (CSIC, UCM). Facultad de Ciencias Matemáticas, Plaza de Ciencias, 3. 28040 Madrid. m.charco@igeo.ucm-csic.es
(2) Departamento de Matemática Aplicada, ETS de Arquitectura (UPM), Avda Juan de Herrera, 4. 28040 Madrid. Pedro.galan@upm.esç

Changes within magma system at active volcanoes can produce a deformation signature on the Earth surface measurable by geodetic techniques. Geodetic monitoring involves the interpretation of mapped deformation to provide the link between deformation and the inaccesible sources of such effects. In doing so, the interpretation of geodetic data requires both modelling techniques to simulate deformation signals and inversion approaches to characterize processes (pressure changes), geometries and location at depth of such sources. The reliability of the model parameters obtained by solving the inverse problem depends, apart from the robustness and efficiency of the inversion technique, on how well model assumptions can approximate the mechanical and rheological properties of the Earth crust. Volcanoes such as Teide (Canary Islands, Spain) are mainly classified as stratovolcanoes. They have steep slopes and are composed of different types of strata involving the deposition of varios materials. In such a way, numerical techniques as such as Finite Element

Method (FEM) allow the inclusion of features such as topography and mechanical heterogeneities for the interpretation of volcanic deformation. However, models based on these numerical techniques usually are not suitable to be included in source parameters estimations based on explorative inversion schemes because they are so time consuming. In this work, we address the implications for misleading assumptions about homogeneity and topography that are inherent to classical deformation models. The strategy is to perform and compare some quantitative interpretations at Teide volcano based on a procedure to combine Finite Element (FE) models with explorative inversion schemes that provides FE inversions in a single step. Finally, we show that the efficiency of the procedure in terms of parallelization scalability made it very suitable to be considered for quatitative interpretations of volcanic deformation with heterogeneous models.

PITFALLS AND REALITY IN GLOBAL AND REGIONAL HAZARD AND DISASTER RISK ASSESSMENTS

Tamaz **Chelidze**
M. Nodia Institute of Geophysics of I. Javakishvili Tbilisi State University; 1 Aleksidze str., Tbilisi, Georgia; e-mail: tamaz.chelidze@gmail.com

Last years natural disasters brought enormous economical losses and caused hundreds of thousand deaths, which make the problem of disaster risk reduction (DRR) one of priorities for all countries and nations. The results of such investigations are very important as they distinguish the "hot spots", i.e. the most vulnerable areas and the most dangerous phenomena, characteristic for specific areas. Unfortunately these efforts sometimes lead to erroneous conclusions, which can be explained by using imperfect or just erroneous local inventories on disasters. In the present paper authors try to analyze some of pitfalls in Global and National Disaster Risk Assessments and in particular those related to South Caucasus region and Georgia. I conclude that: i. Different Global Hazard Maps give different assessments of hazards and risks for the same region. It is necessary to develop a standardized accounting of hazard events and losses for the nation; ii. Information on economic losses and mortality global and regional hazard/risk maps is often misleading due to erroneous input information, used for compilation of such maps. One example illustrating such discrepancies is Caucasus, where the World Hotspot Map predicts mainly hydrogeological risks, which is wrong. That means that information on local losses and mortality should be thoroughly checked by realizing close (direct) contact with local scientists, involved in hazard/risk estimation; iii. A vivid example of significant errors in regional/national risk assessments is underestimation of losses caused by a strongest in Caucasus Racha earthquake (M 6.9-7) due to ignoring of local information, collected by local seismologists and earthquake engineers immediately after event and wrong information of UNDP on losses placed on internet, which become widespread in the world; iv. Re-assessment of economic losses has been done for Georgia using well grounded local data. These recalculations show that the largest economic losses come from geological hazard, despite the fact that the frequency of meteorological and hydro hazards is much higher.

NON-LINEAR ELASTICITY AND NONLINEAR DYNAMICS FOR NEAR REAL-TIME ANALYSIS OF DAM STABILITY

T . **CHELIDZE**a,b*, T. MATCHARASHVILIa,b, V. ABASHIDZEa,b, M. KALABEGISHVILIc, N. ZHUKOVAa
a M. Nodia Institute of Geophysics, Ivane Javakhishvili Tbilisi State University, Tbilisi 0218, Georgia
b European Centre on Geodynamical Hazards of High Dams, 1 Alexidze str., Tbilisi 0171, Georgia
c Georgian Technical University, Tbilisi 0171, Georgia

Large dams are complex structures with nonlinear dynamic behavior. Engineers often are forced to assess dam safety based on the available incomplete data obtained at low sampling rate, which is extremely difficult. This important problem can be solved with near real-time monitoring systems supported by the modern theory of complex systems.

By means of high quality continuous records of some geotechnical

characteristic(s) of a dam and modern methods of time series linear/nonlinear analysis the main dynamical features of the entire, unknown process (here- dam deformation) can be analyzed.

We created the cost-effective Monitoring Telemetric System for Dam Diagnostics (DAMWATCH), which consists of sensors (tiltmeters), terminal and central controllers connected by the GSM/GPRS Modem to the diagnostic center. The tilt data recorded for varying reservoir level are compared with static design model of dam deformations computed by a finite element method (FEM) for the dam-reservoir-foundation system. Besides, recently developed linear/nonlinear data analysis and prediction schemes may help to quantify fine dynamical features of the dam behavior. The software package DAMTOOL has been developed for this purpose.

The differences between measured and theoretically predicted response parameters of the dam may signal abnormal behavior of the object. The data obtained already by testing of the DAMWATCH/DAMTOOL system during operation of the high Enguri arc dam (Georgia) show interesting long-term and short-term patterns of tilts in the dam body, which can be used for dam diagnostics. The proposed complex of real-time telemetric monitoring (DAMWATCH) and linear/nonlinear dynamical analysis system (DAMTOOL) are unique as they allow operative fixation of deflections from the dam stable dynamical characteristics (using low-frequency vibration data.

THE POTENTIAL OF GRAVITY MEASUREMENTS FOR EARTHQUAKE MONITORING IN CHINA

Shen **Chongyang**, Xuan Songbai, Li Hui and Tan Hongbo
Institute of Seismology, Chinese Earthquake Administration, Wuhan 430071, China
Email addresses: scy907@163.com; song_bai_whu@163.com; lihui@163.com; thbhong@163.com

The earthquake is one of the major geophysical hazards in the world today. Earthquake prediction is also a great scientific challenge. For frequently earthquakes and heavy disasters, the earthquake monitoring and forecasting system with a variety of geophysical means, such as seismometry and gravity network, was established supported by the government in China. We hope that it can provide some advice for the long-, medium-, short-term and impending prediction of strong earthquakes.

The gravity measurements for earthquakes monitoring started in the 1960s in China. Right now, the gravity network is composed of 100 absolute gravity stations, more than 3,000 relative gravity stations and more than 70 continuously operated gravity stations. The long practice of gravity measurements indicates that the figures of gravity change can show the relevant information of strong earthquakes (M≥6). Take the 1976 *M*s 7.8 Tangshang earthquake for example, the accumulate change of 5 years at the station near Tangshan is more than 100 microGal before the earthquake. Moreover, before the 12 May 2008, *M*s 8.0 Wenchuan earthquake, Sichuan, China, the positive gravity change lasted for years at the southwest area of the epicenter, and the large-scale gradient zone of gravity change was consistent with the seismogenic structures of Longmen Shan. And then, take the 9 July, 2009, *M*s 6.0 Yaoan earthquake for example, the gradient zone of positive and negative gravity change with north and south direction through the epicenter formed two years before the earthquake, and the gravity change displayed four-quadrant pattern centered on epicenter area about half a year before the earthquake. The absolute gravity change of Yushu station, 2 kilometers away from the fracture zone, is +27.2 microGal before and after the 14 April, 2010, *M*s

7.1 Yushu earthquake. We can say it was the coseismic gravity change. About the 20 April, 2013, *M*s 7.0 Lushan earthquake, the change tendency of gravitational tide presented four-quadrant pattern centered on epicenter area. In addition, the occurrence of strong earthquake is closely related to the gradient zone of Bouguer gravity anomaly and Moho discontinuity.

From mentioned above, the gravity measurements have great application potential for earthquake monitoring.

TOPO-EUROPE: AN INTEGRATED SOLID EARTH APPROACH TO CONTINENTAL TOPOGRAPHY AND DEEP EARTH – SURFACE PROCESSES IN 4D

Sierd **Cloetingh**
Netherlands Research Centre for Integrated Solid Earth Science (ISES), Utrecht University, Budapestlaan 4, 3584 CD Utrecht, The Netherlands.

Topography influences various aspects of society, not only in terms of the slow process of landscape evolution but also through climate (e.g. mountain building). Topographic evolution (changes in land, water and sea level) can seriously affect human life, as well as terrestrial geo-ecosystems. To quantify topography evolution in space and time, understanding of the coupled deep Earth and surface processes is a requisite.
The TOPO-EUROPE initiative of the International Lithophere Program (ILP) addresses the 4-D topography of the orogens and intra-plate regions of Europe through a multidisciplinary approach. TOPO-EUROPE initiates a number of novel studies on the quantification of rates of vertical motions, related tectonically controlled river evolution and land subsidence in carefully selected natural laboratories in Europe. From orogen through platform to continental margin, these natural laboratories include the Alps/Carpathians-Pannonian Basin System, the West and Central European Platform, the Apennines-Tyrrhenian-Maghrebian and the Aegean-Anatolian regions, the Iberian Peninsula and the Scandinavian Continental Margin. TOPO-EUROPE integrates European research facilities (e.g. EPOS) and know-how essential to advance the understanding of the role of topography in Earth System Dynamics. The principal objective of the network is twofold. Namely, to integrate national research programs into a common European network and, furthermore, to integrate activities among TOPO-EUROPE institutes and participants. Key objectives are to provide an interdisciplinary forum to share knowledge and information in the field of the neotectonic and topographic evolution of Europe, to promote and encourage multidisciplinary research on a truly European scale, to increase mobility of scientists and to train young scientists.

IH-DSS FLOODING - DECISION SUPPORT SYSTEM FOR PLANNING COASTAL RISK AND MITIGATION

Felipe **Fernández** [1] (fernandezf@unican.es), Víctor Velarde [1] ,Mirian Jiménez [1] , Damien Pham Van Bang [2] ,Vanessya Laborie [3] , Eduardo García [1] , Fernando Méndez [1] ,Iñigo Losada [1], Raúl Medina [1]
[1] Environmental Hydraulics Institute "IH Cantabria", University of Cantabria, Santander, Spain.
[2] Ministry of Ecology, Sustainable development and Energy, Institute for Maritime and Inland Waterways, Saint Venant Laboratory for Hydraulics, France

[3] Centre for expertise and engineering on risks, urban and country planning, environment and mobility, Saint-Venant Hydraulic laboratory, Margny Les Compiegne, France

IH-DSS flooding is a Web based Decision Support System that provides verified methods and an integrated set of calibrated tools that can be used along any coast by stakeholders and end users for planning coastal risk assessment and mitigation.

The software has been developed to be implemented at any area of study, under different configurations but with the same methodological framework: Source - Pathway - Receptor - Consequences (SPRC). Each site of study has its own characteristics and its environmental topology, which are described and model with the SPRC methodology; the Source is the origin of the flood (e.g. waves, rainfalls, rivers,..), the Pathway is the way in which the sources and flood are transmitted (e.g. jetty, beaches,..), the Receptor is what is affected by the flooding (properties, people, habitats,..). Finally, the physical processes (e.g. flooding, higher sea levels, higher water velocities,..) will have Consequences for the Receptor in dependence on the intensity of exposure and the vulnerability of the Receptor.

Under the Interreg Med Coastgap European Project (Coastal Governance and Adaptation Policies in the Mediterranean 2013-2014), the IH-DSS flooding has been successfully implemented at the Delta De´L Orb Site (France) in order to identify the best practices in terms of Coastal Zone Management and dissemination, see figure 1.

Figure 1. IH-DSS flooding at the Delta De L'Orb – Source parameters selection

The SPRC model has been implemented in the IH-DSS flooding software as a network of functions or light models and a large amount of data sets that describe the Delta De L'Orb Site: climate, socio-economic and ecological scenarios. End user execution is divided in three phases, see figure 2: firstly, the exterior model is executed to bring the offshore conditions to the coastline, secondly Total Water Levels (TWL) at coastline provide the inputs to execute the inland model, which makes available the flooding extent, depths and velocities, finally the Consequences execution could be launched to obtain the final damages (Euros, Lives and Environmental Vulnerability Index -EVI).

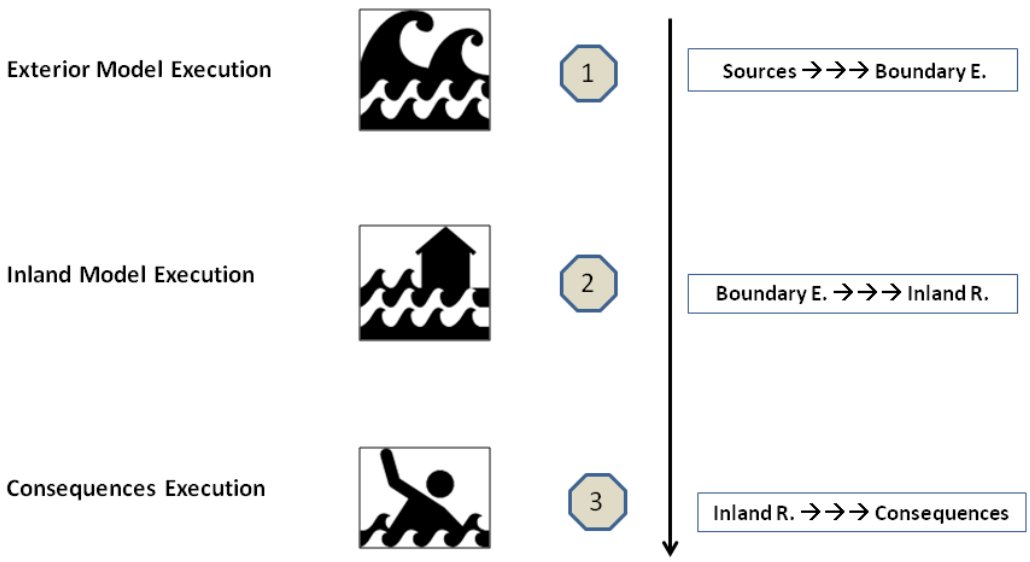

Figure 2. IH-DSS flooding Models Execution

In addition, the IH-DSS flooding has been designed to include future climate scenarios and mitigation options (infrastructure, socio-economic and environmental mitigations), which allows end users to set up user defined scenarios and dynamically calculates the new reduced damages.

In conclusion, a modular Web based Decision Support System for coastal planning and risk assessment has been developed to be applied at any site under SPRC methodology, providing a simulation tool that could be applied to different purposes, from education to decision support for coastal managers.

ESTIMATION OF BUILDING SEISMIC VULNERABILITY ADAPTED TO SMALL–TO-MEDIUM SIZE CITIES. APPLICATION TO LORCA AND GRANADA (SE SPAIN)

M. **Feriche**[1], F. Vidal[1, 2], G. Alguacil[1,2], M. Navarro[3], C. Aranda[1]
[1] Instituto Andaluz de Geofísica. University of Granada. *feriche@iag.ugr.es;*
[2] Dpto. de Física Teórica y el Cosmos. University of Granada *fvidal@ugr.es*; *alguacil@ugr.es; caranda@ugr.es*
[3] Dpto. de Física Aplicada. Universidad de Almería. *mnavarro@ual.es*

The vulnerability assessment of existing buildings for estimating Earthquake Damage Scenarios (EDS) presents problems currently applied to small or medium-sized cities, due to the large number of structures to be evaluated with a limited technical infrastructure. The application of simple methods calibrated for the study region with actual observations of post-earthquake damage greatly reduces the problem. A modification of the Vulnerability Index Method (VIM) (level-1 of Risk-UE) has been applied to Lorca and Granada (SE Spain) cities (around 90,000 and 260,000 inhabitants, respectively), both with low-to-moderate seismic hazard. This method considers the seismic action in terms of the macroseismic intensity and the building influence through a vulnerability index Iv and it provides a satisfactory prediction of the damage level for different earthquake intensities. The vulnerability index depends on the characteristics of the building connected to the structural seismic behavior (typology, quality of

materials, number of floors, state of maintenance, transformations and interventions). The first step of this work was to study in both cities distinctive features of existing buildings and classify them into typologies according to structural types and material of construction. The building types identified were 7 in Lorca (3 of masonry-, 3 of reinforced concrete- and 1 mixed-ones) and 15 in Granada (4 RC types– the most prevalent, 7 of masonry-, 3 of steel- and 1 wood-ones) and a typological vulnerability index (Iv*) was assigned to each structure according to the Building Typology Matrix. Damage field observations during the May 2011 Lorca earthquake (5.2 Mw magnitude) have allowed us to calibrate the method. The initial Iv* of each building class was modified taking into account behavior-modifier factors. The total vulnerability index Iv was calculated summing all the modifiers scores to Iv*. The scores corresponding to vertical irregularity, short-column, soft-story and slope modifiers were adapted according to observed damage. The Iv* values obtained for Lorca range from 0.40 to 0.74 and the total Iv from 0.36 to 0.84. The average expected damage was estimated from the Iv and the observed EMS intensity by semiempirical functions. The results are consistent with the observed damage: 80% of the buildings affected, 1,164 of them had severe damage and 329 had to be demolished. In Granada, we performed a sampling of 500 buildings to establish building classes and for the detailed assessment of the vulnerability. The vulnerability analysis was extended to the full buildings stock by incorporating the results of analysis of the Lorca vulnerability assessment. The average Iv estimated for the masonry buildings is 0.84, being 0.54 and 1.04 the Iv extreme values. The average Iv of the RC structures is 0.62, ranging between 0.30 and 1.07. In the steel structures, the average Iv value is 0.49 and ranges from 0.22 and 0.60. The buildings and vulnerability data have been included in a Geographic Information System (GIS), allowing the management, update and changes in any data or parameters used to estimate the final vulnerability. GIS has allowed us to map vulnerability characteristics in both studied cities.

DEVELOPMENT AND ASSESSMENT OF A RAINFALL-RUNOFF MODEL FOR OUÉMÉ RIVER BASIN (BENIN), WEST AFRICA

Charlène **Gaba**,
Laboratory of Applied Hydrology, Faculty of Science and Techniques, University of Abomey-Calavi, BENIN
imeyb@yahoo.fr

Assessing water resources has become more crucial especially in this context of climatic changes. That is why in complement to existing tools, scientists are still investigating new approaches. Our research takes place in such a framework. A new method to pass from local to large scale is proposed. The model based on the physics Principle of Least Action, in its deterministic version has already given very good results on one catchment, the Bétérou catchment in Ouémé basin in Benin (Alamou, 2011). The paper presents the new hypotheses made in order to go further in the model development (through the improvement of the numerical resolution of equations) with a view to widen its application. Then this daily lumped model has been applied to seventeen (17) subcatchments of the Ouémé basin at the outlet of Savè and its performance has been analyzed. The data time series start from the year 1998 to 2005. The main results are, one the one hand, that the model performs well for subcatchements greater than 600 km2. The Nash coefficient values vary between 0.71 and 0.97 but there are some errors in the timing. On the other hand, poorer performance is achieved on smaller subcatchments. This observation suggests that there may be a

relationship between the model performance and catchment scale. But this may be explained by the fact that a daily time step is too long for catchments with a time of concentration shorter than one day. The short length and quality of the data series are also a big constraint. Further work will focus on improving the modelling of smaller subcatchments and the model performance related to the timing.

MANAGING CRISIS COMMUNICATION: COORDINATING SCIENTISTS AND COMMUNICATION DEPARTMENTS AND GOING BEYOND THE TRADITIONAL CHANNELS OF INFORMATION

Marta **García,** Alda Ólafsson, CSIC Communications Department, Madrid,
marta.garcia@csic.es; alda.olafsson@csic.es

The consequences of a disaster can be mitigated with appropriate risk and crisis communication strategies. In this session we will talk about how information is managed when a natural disaster occurs. We will briefly outline the steps we take at CSIC Communications Department in these cases and how we interact with scientists in order to deliver a scientific and rigorous point of view to the general public. We will analyze two real communication cases: the 2011 Fukushima nuclear accident and the El Hierro submarine volcanic eruption. Even silence conveys a message, as we have seen in the management of a crisis like the first confirmed infection of Ebola in Spain. We will give recommendations on how to connect scientists and media and we will also go into detail about the usefulness of social media tools such as Twitter or Facebook for risk and crisis communication.

MITIGATION OF ROCKFALL HAZARD ALONG HIGHWAYS BY USING CATCHMENT AREA DESIGN CHARTS, OBTAINED FROM NUMERICAL SIMULATION

Cándida **García-González**, Miguel A. Franesqui, Jorge Yepes
Escuela de Ingenierías Industriales y Civiles (EIIC), Universidad de Las Palmas de Gran Canaria (ULPGC), Spain,
candida.garcia101@alu.ulpgc.es , miguel.franesqui@ulpgc.es , jorge.yepes@ulpgc.es

Rockfalls along roadways are a serious hazard to their users. Plenty of resources are invested on rock slope maintenance and on measures of stabilization and protection to mitigate the risk.

Catchment areas (ditches) to contain and restrict rockfall from roadways are one of the best and most effective protective measures. Its effectiveness depends directly on the design criteria. Previous works are limited and based on empirical studies. Ritchie (1963) elaborated the first design charts and tables, establishing the impact distance of a rockfall as a function of the slope height and steepness. Though his work is still accepted, it shows some significant limitations: his design relies on such a deep, steeply sloped ditch that it reduces the road safety, restricts the slope geometry and complicates the maintenance of these catchment areas. Pierson et al. (2001) created new graphic charts based on rockfall real tests carried out in different slope-ditch configurations.

Their research presents certain drawbacks: the examined situations are limited to a specific type of material, shape and possible rock size; the proposed dimensions to obtain certain percentages of rockfall retention are very wide and their cost unreasonably high.

The current work complements the previous studies by using a computer simulation model *CRSP 3D* (Colorado DoT, USA) and analyzing a wider number of slope-ditch configurations and input parameters: (A) 5 talus heights, 5 slope gradients and V-ditches with 3 foreslopes. The highest slopes (≥18m) have an intermediate 1 m bench at 12 m height. (B) Different kinds of materials are handled: 4 bedrock lithologies, two of them for the slope (hard rock and soft rock), one for the ditch (concrete) and the other for the road pavement (asphalt). The properties of these materials (density, elasticity, roughness) have been established according to the *CRSP 3D* methodology and adapted to previous empirical knowledge of each material. (C) A wide array of blocks was studied considering various possible combinations of geometries (cube, cylinder, sphere) and sizes (0.31, 0.62 and 0.94 m). A total number of 270 different cases for hard rock and 180 for soft rock have been evaluated. (D) Rocks are detached randomly (throughout the whole slope) and the initial velocity is zero.

As a result of the numerical analysis, a set of practitioner-friendly charts were elaborated, not only for infrastructures planning and design tasks but also to evaluate existing catchment area effectiveness and to reduce rockfall hazard. The proposed design charts offer an estimation of the ditch required dimensions, depending on the relation between the optimal stop distance and the cumulative percentage retained along the trajectory, satisfying specific retention requirements (95%).

ANALYSIS OF THE FACTORS AFFECTING ROCKFALL STOP-DISTANCE TO REDUCE IMPACT RISK ONROADS

Cándida **García-González**, Jorge Yepes, Miguel A. Franesqui,
Escuela de Ingenierías Industriales y Civiles (EIIC), Universidad de Las Palmas de Gran Canaria (ULPGC), Spain,
candida.garcia101@alu.ulpgc.es, jorge.yepes@ulpgc.es , miguel.franesqui@ulpgc.es

Costs associated with rockfall risk are high. Plenty of resources are invested on rock slope maintenance and stabilization and protection measures to reduce rockfall hazards on transport infrastructures. However, limited studies are focused to evaluate the relative influence of the different factors (geometrical and material properties) affecting falling rock trajectories and the efficiency (retention capacity) of catchment areas.

There are numerous factors that influence not only the characteristics of rockfall motion but also their impact and stop-distance. The Ritchie empirical research (1963) was the first to identify these characteristics and determine the expected impact distance of rockfalls according to the slope geometry. Later works (Pierson et al., 1994) have proved that Ritchie results were not as conservative as previously thought, and also is difficult to apply his ditches on roadways due to the excessive depth (dangerous for vehicles) and width (expensive construction and maintenance). For this reason, the Ritchie ditch has been improved by using computer simulation programs, proposing concrete walls or fences at the edge of the road (Pantelidis, 2010).

To optimize the catchment area geometry with more simple and reduced depth, it is necessary a systematic and quantitative analysis about the effect of each factor over the rock stop-distance, applying a simulation model. With this aim, this work applies a computer simulation model *CRSP 3D* (Colorado DoT, USA) considering 75 different configurations of slope-ditch geometries, 4 types of materials and 9 size and shape combinations of the falling rocks. A total number of 270 different cases for hard rock and 180 for soft rock have been examined. A statistical analysis was performed with the

simulated rock stop-distances to assess the different variables affecting rockfall motion.

Results show that: (A) lithology is a significant factor of the maximum stop-distance: in soft rock it tends to be a unimodal probability distribution; however in hard rock it seems to have a bimodal distribution. (B) These differences are related to the material properties: elasticity and density. Higher elasticity is related to lower energy loss in bounces, thus the stop-distance is larger. Greater density generates a higher mechanical work due to higher initial potential energy. The combination of both properties implies an amplification of this effect. Finally, increments of the ditch foreslop gradient reduce in a significant way the maximum reach distance of the falling rocks.

THE COPERNICUS EMERGENCY MANAGEMENT SERVICE IN NON-RUSH MODE (EMSN): PREPAREDNESS FOR FUTURE EARTHQUAKE EVENT IN NEPAL.

Antonio **Garzón**, Julia Pecci, Antonio San José, Elena Mazón, Iris Iruela, Cibeles Redondo, Daniel Emilio Carrasco (*)
(*) agarzon@indra.es , jpecci@indra.es; asanjosea@indra.es; emazon@indra.es; iiruela@indra.es. Indra Sistemas S.A.,. C/ Mar Egeo, 4. 28830 San Fernando de Henares - Madrid (Spain).

The European Earth Observation monitoring program Copernicus entered into its full operational phase following the adoption of the Copernicus Regulation from the European Commission. The Emergency Management Service (EMS) is operational since April 2012 and it ensures immediate availability of maps to respond to humanitarian crises or disasters, creating maps containing information to evaluate risks and to plan the area's recovery. The Copernicus EMS provides information in relation to different types of disasters (meteorological, geophysical, deliberate and accidental man-made disasters and other humanitarian disasters), as well as prevention, preparedness, response and recovery activities. EMS will be implemented since 2014 as four separate service modules: Rapid Mapping, Risk and Recovery Mapping, Emergency Mapping Validation and EMS Early warning.

This paper presents the results of the EMSN-012 activation for the "Preparedness, disaster risk assessment and disaster risk reduction covering districts of: Kathmandu, Bhaktapur, Dhanusa, Siraha and Mahottari, in Nepal". The districts involved are located in one of the world's most seismically active zones. For that reason, this activation acts in support to the Nepal Risk Reduction Consortium (NRRC)-Flagship II which aim is to enhance the Government of Nepal's ability to effectively respond to natural disasters at different scales of work.

The project has been leaded and developed by Indra (Spain) and has counted also with the participation of GISAT (Czech Republic). The activities have had a duration of 3 months, involving the definition and generation of 15 line of products for each of the districts (scale 1:10,000, 1:25,000 or 1:60,000). These products have resulted in a set of 326 unique maps, produced in 3 formats and 3 different dpi´s (2.924 maps products).

These mentioned products have been aggregated in 3 groups:

- Reference Geodatabase (GDB): basic cartography at 1:10.000, 1:25.000 and 1:60.000 scale, organized in GDB and containing: hydrology, transport, points of interest, toponyms, urban areas, contour lines (derived from generated DSM and DEM, 5m grid), building footprints (including buildings attributes) and estimation of

population per building.

- Pre-disaster GDB: exposure, vulnerability and risks geodatabase for earthquake, landslides (associated to earthquakes) and flooding (only for some basins). It has been made at 1:10,000 or 1:25,000 according with the available ancillary information.

This group also includes contingency end evacuation scenarios.

- Urban Sprawl GDB: analñyzing the expansion of the main cities in involved districts: metropolitan areas of Kathmandu, Bhaktapur, Lahan, Jaleshwor and Janakpur.

Additionally, some 3D flight videos have been also developed as example of utilization of the data generated in pre-disaster activities.

Satellite images have been utilized as main inputs for all the products: Pleiades (mono and stereo), WorldView-2 stereo, SPOT-6 (mono and stereo) and Landsat. Previously existing thematic cartography has been utilized as ancillary data. One of the main ancillary pieces of information have been the results of the project "Nepal Hazard Risk assessment" developed, between others, by the Asian Disaster Preparedness Center (ADPC).

The products derived of this project represent only a part of potential products that can be obtained from the geodatabases generated in this project. It constitutes a powerful tool for pre-disaster management activities.

THE NATIONAL GEOGRAPHIC INSTITUTE OF SPAIN (IGN): MONITORING, EARLY WARNING AND ALERT SYSTEMS FOR GEOHAZARDS

J. **Gómez**; E. Herrero; C. López; M. J. Blanco; J.A. López
Instituto Geográfico Nacional, Spain, jggonzalez@fomento.es

The National Geographic Institute (IGN) is the Spanish institution with longest tradition in Earth Sciences (more than 130 years). Since its creation in 1870 its primary mission has been the measure of the earth's surface and the study and quantification of the physical phenomena that can affect its shape, including all the geological and geophysical processes that govern the Earth over time periods that range from seconds (earthquakes, tsunamis) to hours, months or years (volcanic eruptions, ocean tides, geodynamics changes,...).

In the field of geohazards, IGN is the official agency in charge of the: 1. - Volcano Monitoring, volcanic alerts and associated risks assessment (since 2004); 2.- Tsunami Monitoring, including early warning capabilities (since 2013); 3.- Installation, maintenance and data analysis of the National Seismic Network (since 1909), as well as the drafting and updating of the Earthquake Resistant Building Design Code; 4.- Installation, maintenance and operation of the National Geodetic Network from its very beginning.

To fulfill these tasks and throughout its whole history, IGN has installed all around the country geophysical, geodetic and geochemical instrumentation, and trained highly specialized team. At present, its capabilities include the design and manufacture of instrumentation, the design, installation and maintenance of instrumental networks, real-time analysis, interpretation, forecasting and warning of registered phenomena and the alert and communication to Civil Protection and other institutions responsible for the emergencies management, as well as to the society in general.

Focusing on volcanic risk, IGN has been the main public scientific institution in charge of the surveillance of the eruptive submarine process that took place in the island of El

Hierro in October 2011.

TSUNAMIS OF THE XXIST CENTURY: TEMPORAL AND SPATIAL OCCURRENCE AND SOCIAL IMPLICATION

Viacheslav K.**Gusiakov**
Institute of Computational Mathematics and Mathematical Geophysics SD RAS, Novosibitsk, Russia, gvk@sscc.ru

Due to a continuous enhancement of the sea-level recording systems the statistics of tsunami observations significantly improved during the last two decades in many areas of the World Ocean, first of all, in the Pacific and in the Indian oceans. Now we can record very weak events with amplitudes of only few centimeters (in deep-water) resulted from submarine earthquakes, volcanic eruptions or subaerial landslides. All significant tsunamis producing any damaging effect are the subject for the post-event field surveys that result in precise measurements of the coastal run-up heights and inundation depths. A wealth of data available for recent tsunamis gives an opportunity to evaluate their parameters (energy, intensity, run-up distribution) with the degree of accuracy inaccessible for earlier historical events.

160 tsunamigenic events were recorded in the World Ocean during the last 15 years with 125 of them occurred in the Pacific, 21 in the Indian Ocean, 9 in the Atlantic and 5 in the Mediterranean region. Of them, 138 had a seismogenic origin, 5 events resulted from volcanic eruptions and associated failures of volcanic slopes, 10 were generated by submarine or coastal landslides and the rest (about 10) had a non-tectonic origin (meteotsunamis or freak waves, their total number can be actually much greater).

A question of great importance is how these tsunamigenic events are distributed over their overall intensity (measured on the Soloviev-Imamura scale) and the spatial extent of their coastal impact. From the total 160 recent tsunamis, the vast majority (115) were weak local or regional events, producing small level oscillations detectable only on the instrumental records. 45 events were potentially damaging (maximum wave amplitude (Amax) or run-up height (Hmax) was greater than 0.5 m). Really destructive (Hmax >5 m) were18 tsunamis and 15 of them were accompanied by human fatalities.

The total number of tsunami fatalities in XXI century is nearly 250,000, and 90% of them were resulted from only two events: the December 26, 2004 Indian Ocean tsunami (226,800 fatalities) and the March 11, 2011 Tohoku tsunami (18,506 fatalities). Both were transoceanic tsunamis generated by M9 class mega-earthquakes occurred in the nearest section of a subduction zone. From the remaining 13 deadly tsunamis, the most fatal were the August 15, 2007 Mw=8.0 Peru tsunami (508 deaths), the July 17, 2006 Mw=7.7 Java tsunami (390 deaths) and the June 23, 2001 Mw=8.4 Peru tsunami (100 deaths). Thus the statistics for the beginning of the XXIs century confirms the conclusion made on the basis of the tsunami history for XX century - the major input in the total tsunami mortality comes from rare but destructive trans-oceanic events generated by the M9 class mega-earthquakes.

CHANGE IN EXTREME RAINFALL OVER OUÉMÉ BASIN, BENIN, WEST AFRICA

J. **Hounkpe**1,3, B. Diekkrüger2, A. Afouda3,
1 West Africa Science Service Centre on Climate change and Adapted Land Use/ /University of Abomey-Calavi, Benin. Phone: (00229) 967 546 83, Email: jeanhounkpe@gmail.com

2 Department of geography, University of Bonn, Germany
3Laboratory of Applied Hydrology, University of Abomey-Calavi, Benin

Changing climate and weather patterns will have severe negative impacts on natural resources and consequently on food production and food security in developing countries. Likely accentuated by climate change, flooding is one of the disasters which affects people and destroy agricultural land and products. At different governance levels and scales, appropriate responses are needed. A methodology for testing for change was applied to high daily rainfall of 34 stations across the Ouémé basin in order to assess the environmental change impact on extreme rainfall. The influence of homogeneity in the study period on the change was also assessed.

For all studied return periods, 82% of the stations show statistically significant change among which 57% exhibit a positive change and 43% negative change. A positive change is associated to an increasing high rainfall over the area of concerned. An analysis of change in 10 year return period of high rainfall reveals an east-west gradient from negative to positive along the lower Ouémé basin following the same gradient of the annual rainfall across the river with the isohyets oriented west-southward. From the middle to upper Ouémé, the decreasing tendency of high rainfall is dominant.

This result of mixed pattern of change is of great interest since it can help the decision makers to anticipate the negative aspect this fact could produce and develop consequently adaptation measures.

PREHISTORICAL CATASTROPHES CAUSED BY EARTHQUAKE AND DEBRIS FLOWS AT THE NORTHEAST FOOT OF THE TIBETAN PLATEAU

Chun Chang **Huang**
Department of Geography, Shaanxi Normal University, Xi'an, Shaanxi 710119, P.R. China (E-mail: cchuang@snnu.edu.cn)

Geophysical hazards including earthquake, landslides, landslips and debris flows have caused immense damages to society and human life over the mountainous regions along the east foot of the Tibetan Plateau in the recent years. An investigation of the long-term changes in natural hazards in relation to environmental change and human impact was carried out in the Guanting Basin along the upper Yellow River at the northeast foot of the Tibetan Plateau. Archaeological excavations have exposed grouped human skeletons resting on the dwelling floors of the late Neolithic village of the Qijia Culture (4200–3950a BP) named the Lajia Ruins on the Yellow River banks. They show a shocking picture of the mortal struggle of human being during major catastrophes. Geophysical study indicated that the ground over the ruins was broken by two groups of earthquake fissures with a width of 10-60 cm and extending vertically along NW45º and NE45º, respectively. A layer of conglomerated red clay, with a thickness of 1.0-4.0 m and waving structure, have blanketed the human skeletons, the dwelling floors and the ground over the Lajia Ruins and filled in these earthquake fissures. Detailed sedimentological studies indicates that, immediately followed a major earthquake, the settlement was overtaken by immense mudflows coming along the tributary gullies from the hillsides behind. The Guanting Basin has been occupied by arable farmer since ca. 6000a BP. During the climate event of 4200-4000a BP, enhanced human activities increased the vulnerability of the communities to detrimental environmental change and catastrophe. These results are of important implications in understanding human impact

and the long-term change of natural hazards over the environmentally sensitive zones of the world.

References:

1. Huang, C.C., Pang, J.L., Zhou, Y.L, Su, H.X., Zhang, Y.Z., Wang, L.S., 2013. Palaeoenvironmental implications of the prehistorical catastrophes in relation to the Lajia Ruins within the Guanting Basin along the Upper Yellow River, China. Holocene, 23(11), 1584-1595.я
2. Zhang, Y.Z., Huang, C.C., Pang, J.L., Zhou, Y.L., Zha, X.C., Wang, L.S., Zhou, L., Guo, Y.Q., Wang, L.B. 2014. A luminescence dating study of the sediment stratigraphy of the Lajia Ruins in the upper Yellow River valley, China. Journal of Asian Earth Sciences, 87C, 157-164.
3. Huang, C.C., Pang J.L., Zha X.C., Zhou, Y.L., Yin, S.Y., Su, H.X., Zhou, L., Yang, J.C., 2013. Extraordinary hydro-climatic events during the period AD 200-300 recorded by slackwater deposits in the upper Hanjiang River valley, China. Palaeogeography Palaeoclimatoplogy Palaeoecology, 374, 274-283.
4. Huang, C.C., Pang, J.L., Zha, X.C., Su, H.X., Jia, Y.F., 2011. Extraordinary floods related to the climatic event at 4200 a BP on the Qishuihe River, middle reaches of the Yellow River, China. Quaternary Science Reviews, 30, 460-468.

SCIENCE-DRIVEN APPROACH TO DISASTER RISK REDUCTION

Alik **Ismail-Zadeh**
AGW, Karlsruhe Institute of Technology, Karlsruhe, Germany
IEPTMG, Russian Academy of Sciences, Moscow, Russia

Disasters due to natural extreme events continue to grow in number and intensity. Disaster risk and crisis management requires long-term planning, and to undertake that planning, a science-driven approach is needed to understand and assess disaster risks and to help in impact assessment and in recovery processes after a disaster. Science is used in assessments and rapid modeling of the disaster impact, in forecasting triggered hazards and risk (e.g., a tsunami or a landslide after a large earthquake or volcano eruption), in contacts with and medical treatment of the affected population, and in some other actions. At the stage of response to disaster, science helps to analyze routinely the disaster happened (e.g., the physical processes led to this extreme event; hidden vulnerabilities; etc.) At the stage of recovery, natural scientists improve the existing regional hazard assessments; engineers try to use new science to produce new materials and technologies to make safer houses and infrastructure. At the stage of disaster risk mitigation new scientific methods and approaches are being developed to study natural extreme events; vulnerability of society is periodically investigated, and the measures for increasing the resilience of society to extremes are developed; existing disaster management regulations are improved. At the stage of preparedness, integrated research on disaster risks should be developed to understand the roots of potential disasters. Enhanced forecasting and early warning systems are to be developed reducing predictive uncertainties, and comprehensive disaster risk assessment is to be undertaken at local, regional, national and global levels. Science education should be improved by introducing trans-disciplinary approach to disaster risks. Science can help society by improving awareness about extreme events, enhancing risk communication with policy makers, media and society, and assisting

disaster risk management authorities in organization of local and regional training and exercises.

DEVELOPMENT OF REALTIME EARLY WARNING SYSTEM COMBINING UM MODEL AND FALL3D AGAINST VOLCANIC ASH OF MT. BAEKDU

Eun-Suk **Jang**, Sang-Heon Lee
Hanzhong University, Republic of Korea

Mt. Baekdu has been known as a volcano whose volcanism stopped in the meantime, but recently experts suggest that the Mt. Baekdu is an active volcano on volcanism. In case Mt. Baekdu which shows various omens of eruption erupts, necessity of offer of information on its influence on the Korean Peninsula and early offer of information on the volcano for prompt response to possibility of dispersion of volcanic ash is increasing.

If Mt. Baekdu erupts, large amount of lava and ejecta that erupt with strong explosive power by high pressure, and about 2 billion tons of water contained in Cheonji caldera lake, which is on the summit of Mt. Baekdu cause disaster owing to large-scale flood and pyroclast to the broad area including the vicinity of the mountain. Eruptive gas that rises to stratosphere and eruptive gas and volcanic ash that will disperse vertically and horizontally must be a great variable to the change of climate and global warming that is the biggest global issue in the 21st century.

In this study in order to assume the moving path of volcanic ash, tephra ground load/thickness, and airbone ash concentration in case Mt. Baekdu erupts, we developed volcanic ash dispersion early warning system that uses meteorological elements produced in UM model that Korea Meteorological Administration presently uses as Numerical Weather Prediction Mode to predict weather of every day as realtime input data in Fall3D model. In addition, in order to apply this to future eruption of Mt. Baekdu we analyzed path of dispersion and concentration of volcanic ash and other related variables according to Volcanic explosive Index on the representative example day by numerical simulation.

Acknowledgement: This research was supported by a grant [NEMA-Baegdusan-2012-1-1] from the Volcanic Disaster Preparedness Research Center supported by National Emergency Management Agency of Korea.

NEW CONCEPTS OF RESTORATION AND RECONSTRUCTION AFTER NATURAL AND TECHNOLOGICAL DISASTERS AND POST-TSUNAMI HAZARDS

Yevgeniy A. **Kontar**, College of Sciences, The University of Findlay, Minneapolis, USA. e_kontar@hotmail.com

The presentation is concentrated on post- tsunami hazard reconstruction and restoration issues covering topics such as coastal engineering and planning including risk and vulnerability, early warning systems improvement, coastal settlements and resilience as well as socio-economic redevelopment, natural and induced coastal ecosystems recovery, restoration of affected agricultural lands, and coastal development amongst others. During the presentation we will bring specific examples from a variety of countries hit by tsunami events such as the 2010 Chilean tsunami, Indian Ocean Tsunami 2004 and the Japan Great East Earthquake and Tsunami of March 2011. The presentation participants can expect to benefit from the experiences, lessons learned and

proposed measures aiming at increasing safety and resilience reduce and or ameliorate tsunami hazards in vulnerable coastal areas. This presentation aims at scientist and scholars, decision makers, students and practitioners as well as authorities interested and involved in tsunami hazards, reconstruction and restoration.

SEISCOMP-ALERTES: AN EARLY WARNING SYSTEM PROTOTYPE BASED ON THE SEISCOMP3 SOFTWARE FOR SW IBERIAN PENINSULA.

M. **López Mesa**[(1)],J. Gallego Carrasco[(1)] , A. Pazos García[(1)], J. Martín Dávila[(1)], C. Rioja del Río[(2)], W. Hanka [(3)], M. Carranza [(4)], X. Goula [(5)]
[(1)] Real Instituto y Observatorio de la Armada en San Fernando, Cádiz, España, mireya@roa.es
[(2)] Universidad de Cádiz, España, carlos.rioja@uca.es
[(3)] GeoforschungsZentrum, Potsdam, Germany, hanka@gfz-potsdam.de
[(4)] Universidad Complutense de Madrid, macarran@ucm.es
[(5)] Servei Geológic Cataluña, xgoula@igc.cat

In recent years there has been Earthquake Early Warning Systems (EEWS) developed for different parts of the world based on the following hypothesis: earthquake characteristics can be derived from the analysis of the low energy P-wave prior to the arrival of more energetic S-waves and later phases. Thereby a time ("lead time") is available to evaluate a warning and perform automatic or semi -automatic actions on certain systems and deliver and alert to the authorities involved in emergency.

The area between SW Cape St. Vicente and the Strait of Gibraltar is one of the most seismically active zones in the Ibero-Maghreb region, with predominantly moderate and superficial seismicity. The main goal of the ALERT-ES project (2011-2014) was to study the feasibility of an EEWS for SW Iberia and develop a prototype based on "SeisComP3" and Earthworm. Now a days, a new project ALERTES-RIM, focused to improve the scaling laws and relations to predict the expected PGV (peak ground velocity) and Pd (peak displacement), but also to obtain an operational system.improve the prototype for a real time operational system, are ongoing.

The SeisComP3-ALERTES system is largely based on algorithms derived from the analysis of the first three seconds of the P wave records. Calculation of several parameters are carried out, mainly the characteristic period (τ_c), Peak displacement and velocity (Pd, Pv) and maximum period ($\tau_P^{máx}$), among others, from which correlations with corresponding earthquake magnitude, peak ground velocities , etc. are derived. Decision tables have been developed in order to deliver warnings (Buforn et al, 2012). The algorithms have been implemented by the Real Observatorio de la Armada (ROA) in the seismic data system SeisComP3, in order to provide earthquake estimations in a time window of a few seconds. And this first prototype SeisComP3-ALERTES is currently available running in real time, on a test phase, on a network of stations of WM (Western Mediterranean), IGN and IP (Portugal) broad band seismic nets.

From the above described characteristics, such as suitability of the available algorithms, software and hardware requirement, processing time required, lead times, etc., the prototype is presented as EEWS system available for earthquakes of Cape San Vicente and Gulf of Cadiz areas. In this paper we present the current state of development of the SeisComP3-ALERTES EEWS prototype.

CASCADING EFFECTS OF EXTREME HAZARDS: ARE WE PREPARED TO FACE THEM?

Joan Martí and Adelina Geyer, Institute of Earth Sciences Jaume Almera, CSIC, Barcelona, Spain
joan.martí@ictja.csic.es; ageyer@ictja.csic.es

Cascading effects of extreme hazards may have catastrophic consequences at a global scale due to their difficulty in being predicted and managed. Recent events such as the high magnitude earthquake-related tsunamis of Indonesia (2004) and Japan (2011) or the eruption of the Eyjafjallajökull volcano in Iceland (2010) offer good examples of how large magnitude, but also low magnitude, events may impact today on our globalised and technological society, causing considerable disturbance and significant socio-economic impacts. The geological record offers good evidence of past catastrophic events that in case of occurring today would cause much larger impacts on society and the environment. Tenerife exposes one of the best cases of cascading extreme hazards that repeated several times in the past and could occur again in the future. A cascading sequence involving a caldera-forming eruption, high magnitude seismicity, a megalandslide and a tsunami has occurred at least two times during the formation of the central and eastern sectors of Las Cañadas caldera, and the formation of La Orotava and Icod valleys, respectively. Each of these processes involved the eruption of up to 20 km3 of magma, high magnitude seismicity, the removal of tens of cubic km of rock from the slopes of the island and the formation of high magnitude tsunamis. Except for climate change, which despite being considered of global influence does not cause immediate impacts, no other natural catastrophes with potential regional or global consequences have been seriously considered till present, although individual large magnitude eruptions, earthquakes, landslides, or tsunamis have occurred in historical times. How, then, could we face the impact of such phenomena occurring all at the same time?. Should we forget about such phenomena due to their apparent unpredictability and impossibility of managing? or should we analyse their potentiality of occurrence and apply forecasting and mitigation measures far as our capacity allows us?. This is an important question that deserves to be addressed in the same way that we all are convinced about taking global measures to face climate change.

THE MASW AND SPAC METHODS AS MAIN TOOLS TO PROVIDE UNDERSTANDINGS IN EARTHQUAKE DAMAGE DISTRIBUTION. A STUDY CASE IN ADRA TOWN (SE SPAIN)

Pedro **MARTÍNEZ-PAGÁN**[1]*, Manuel NAVARRO[2,3], Jaruselsky PÉREZ-CUEVAS[1], Antonio GARCÍA-JEREZ[3], Francisco VIDAL[3], and Francisco J. ALCALÁ[4]
[1] Universidad Politécnica de Cartagena (Spain), p.martinez@upct.es; jaruselskyperezc@gmail.com
[2] University of Almería (Spain), mnavarro@ual.es
[3] Instituto Andaluz de Geofísica, University of Granada (Spain), agjerez@ugr.es; fvidal@ugr.es
[4] Instituto Superior Técnico, University of Lisbon (Portugal), francisco.alcala@tecnico.ulisboa.pt

Southeastern Spain is the zone with the highest seismic hazard in the Iberian Peninsula. In fact, in Adra town most of buildings were completely destroyed during the 1522 earthquake. During 1993 and 1994 small earthquakes (magnitude Mw ~ 5.0) several buildings suffered damage grade of 3 and many grade 2 (EMS scale), mainly those sited in the southeastern zone of the town. In regard to that, it is highly mandatory

to identify the factors influencing both the sort of building damage and their distribution since new urbanizing areas are planned to grow to that part of the town.

With respect to this framework, our aim was to obtain a shallow shear-wave velocity Vs structure of Adra town because Vs is a key parameter to evaluate and characterize the soil condition and its dynamic behavior that is currently applied to seismic hazard assessment. In this context, two different seismic methods were used to provide, by means of inversion of Rayleigh wave dispersion data, the Vs structure and the Vs30 parameter, where Vs30 is defined as the average shear-wave velocity value down to 30 meters depth. These seismic methods were the multichannel analysis of surface waves (MASW), and the spatial autocorrelation (SPAC). The SPAC measurements were carried out at four open spaces providing a 1-D shear-wave velocity model at each site. The MASW method was conducted through the streets of Adra town with a total of 3.5 kilometers of seismic profiles which enabled to obtain 2-D shear-wave velocity sections from the main geological structures of the town. A detailed geological survey was of assistance for accurate 2-D interpretations and soils classifications.

Results obtained from close SPAC and MASW measurements sites reflect a high similarity in the Vs30 models. As a result, both seismic methods consistently classify each geological formation in the same Eurocode 8 (EC8) soil class. The south-eastern part of the town was classified as C1 class site which is prone to generate moderate-high seismic amplifications and relatively large predominant periods. SPAC and MASW results showed the influence of the hardest rocks (EC8 A class zone), which are locate at the north of the town, where not damage by the 1993-1994 series was reported. It is worth noting that the area of the town, from which most of the building damages were reported, is composed by alluvial fans. That area falls into a transition zone classified as EC8 B2 and C sites. It should be borne in mind that area with soils classified as C is to where the town is planned to grow.

Finally, this study demonstrates the usefulness of the combination of two seismic techniques for gathering a huge amount of seismic data down to 30 m depth. As consequence, a detailed microzonation map of ground conditions of Adra town has been obtained whose results will be applicable to seismic risk management and urban use planning of the town.

KAZAN: WILL YOU SURVIVE THE NEXT DISASTER? - AN EDUCATIONAL GAME TO RAISE AWARENESS ABOUT GEOHAZARDS AND DISASTER RISK REDUCTION

S. **Mossoux**, A. Delcamp, S. Poppe, F. Canters, M. Kervyn
Department of Geography, Vrije Universiteit Brussel, Brussels, Belgium

Mostly, geological hazards are not frequently impacting a given population and those hazards might not be their first concern in life. Nevertheless, solutions have to be found to establish a continuous communication between population and scientists in order to raise awareness about the need to include basic risk reduction strategy into their daily life.

KAZAN is an educational game that raises awareness about geohazards to reduce the risk. This board game has been developed to gather population such as students, citizens and stakeholders together to let them discover the information they need to know about hazards and their spatial variability; to make them realize what the impacts of those hazards can be regarding different intensities and the importance of resources

accessibility; and to let them experience the different risk reduction strategies to be implemented before, during and after a hazard.

All the players embody during the game a character living on the KAZAN island. Each year, they receive their salary to be used to meet the basic needs of their character, but also to develop their community on the island. Huts, houses and roads can be constructed but because KAZAN island is at random times threatened by earthquakes, tsunamis, lava flows or ash falls, players can also invest in protection, adaptation and preparedness measures. In this context, players virtually experience the impacts of the hazards through their character and they are directly confronted with the implication of decisions taken during the game.

After playing KAZAN, players have a better understanding of the hazards: they can easily understand that what they lived in the game reflects situations they might experience in real life and that prevention and mitigation measures are important to take at a personal and at a community level.

In this contribution, we will present the game board and will analyse the game strategy and the players' opinion about the usefulness of the game. The KAZAN game was tested on different groups of students, geologists and hazard managers in Belgium, Tanzania and the Comoros Islands.

Q-LAVHA: A QUANTUM GIS PLUGIN TO SIMULATE LAVA FLOWS

S. **Mossoux**, A. Feltz, S. Poppe, F. Canters, M. Kervyn
Department of Geography, Vrije Universiteit Brussel, Brussels, Belgium

Q-LavHA (Quantum-Lava Hazard Assessment) is a Quantum GIS plugin which simulates lava flow propagation from one or multiple regularly distributed eruptive vents on a Digital Elevation Model (DEM). It combines existing probabilistic and 1D thermo-rheological deterministic (FLOWGO) models and proposes improvements in order to refine the probability of lava flow spatial spread and terminal length. The spatial spread is constrained by the steepest slope following the probabilistic approach of Felpeto et al. (2001). The corrective height factor which is included allows the lava flow simulation to overcome small topographical obstacles and to fill pits. The terminal length of the lava flow simulation can be determined based on a fixed length value, a Gaussian probability density function, or it can be calculated based on the thermo-rheological properties of a cooling open-channel lava flow following the approach of the FLOWGO model (Harris and Rowland, 2001).

Q-LavHA is designed for scientists and stakeholders confronted with imminent or long term lava flow hazard from basaltic volcanoes. Q-LavHA can improve their understanding of the spatial distribution of lava flow hazard, influence their land use decisions and support evacuation planning during a volcanic crisis. Because of the diversity of its uses, Q-LavHA has been developed in Python in order to allow users to adapt the code to their needs. Its availability as a Quantum GIS plugin with a user friendly interface facilitates its distribution and its use by the community.

To determine the ideal parameters for lava flow simulation, we calibrated Q-LavHA based on recent lava flows of the volcanoes Karthala (Comoros islands) and Nyamuragira (Democratic Republic of the Congo), both with an overall mafic and low-viscosity lava composition. The influence of the different input parameters on the quality of the simulations is discussed. Additionally, we discuss the influence of DEM resolutions used to realize the simulations.

REFERENCES:

Felpeto et al. (2001), Assessment and modelling of lava flow hazard on Lanzarote (Canary Islands), Nat. Hazards, 23, 247-257.
Harris and Rowland (2001), FLOWGO: a kinematic thermo-rheological model for lava flowing in a channel, Bull. Volcanol., 63, 20-44.

ANALYSIS OF SOCIAL VULNERABILITY APPLIED TO DISASTER MANAGEMENT: THE CASE OF ALMERÍA CITY (SE SPAIN)

Daniel **Navarro Cueto**[1], Manuel Navarro Bernal[2,3], Francisco Vidal Sánchez[3], Ismael Vallejo Villalta[1]
[1] University of Seville, dnavarrocueto@gmail.com, ivallejo@us.es
[2] University of Almeria, mnavarro@ual.es
[3] Andalusian Institute of Geophysics, University of Granada, Granada, Spain, fvidal@iag.ugr.es

The locations and the vulnerability of the population vary over time depending on social and economic dynamics which should be analyzed. In this study we have performed an analysis of social vulnerability applied to disasters management in the city of Almeria. The disaster is understood not as an event but as a process that develops over time as a result of economic, social and political factors. Social vulnerability is the inability of people to anticipate, survive, resist and recover from a disaster. This is explained by characteristics such as age, ethnicity, socioeconomic status, gender and level of organization and participation of the population, among others. Therefore, the social vulnerability is the result of multiple variables in a relationship of interdependence, which requires a particular type of analysis.

The methodology applied to Almeria city has two stages. In the first, quantitative and synchronous, multivariate statistical techniques have been used to identify areas of the city where the most vulnerable population live. In the second, qualitative and diachronic, the most vulnerable neighborhoods are characterized, allowing us to understand the causes of vulnerability.

In the first stage, using factor analysis, the initial 46 variables have been reduced to 4 factors: Medium-high socioeconomic status, low socioeconomic status, African population and low quality buildings and central zones. These four factors explain 85% of the total variance. Then, through the cluster analysis, the 106 census tracts are classified into 5 groups of vulnerability ranging from very low to very high. In Almeria city, the high social vulnerability is due to the *low socioeconomic status* factor and the confluence of the said factor with the *African population with more buildings in poor condition* factor.

In the second stage, we have identified the most vulnerable neighborhoods. One of them, El Puche, shows very high vulnerability and other three (La Chanca, El Quemadero and Los Almendros) have high vulnerability. La Chanca and El Puche neighborhoods have been characterized by analysing their history, urban morphology, dynamic pressures and social problems. The most vulnerable neighborhoods are located in peripheral areas of the city and the population suffers problems of social exclusion.

The research has been built on the results of local seismic hazard and physical vulnerability of buildings. The four most socially vulnerable neighborhoods show also high physical vulnerability of buildings. The local seismic risk is medium in neighborhoods with high social vulnerability, while it is very high in the district with very high social vulnerability (El Puche) due to hazardous conditions caused by effect site.

Finally, we conclude that social vulnerability is not evenly distributed in the city of Almeria, identifying most vulnerable neighborhoods than others.

RE/INSURANCE IN CATASTROPHE RISK MANAGEMENT

Delioma **Oramas Dorta**,
Guy Carpenter & Co., LLC, Delioma.Oramas-Dorta@guycarp.com

Economic losses arising from natural catastrophes have been rising steadily over the past few decades owing to interplay of factors such as increasing value and concentration of exposed assets, growing hazard levels associated with climate change, and dynamics such as the globalization of the economy.

Despite prevention and mitigation efforts, no country (or individual, or enterprise) can fully insulate itself against losses from major natural disasters; therefore disaster risk management strategies ought to include a disaster risk financing component that provides financial protection against such losses. Insurance and reinsurance are financial instruments that provide such protection, and entail the transfer or cession of risk to a third party on payment of a premium. Insurance and reinsurance protect from frequent or severe losses and spread (diversify) the risk.

At the core of any risk management strategy there is risk assessment, which in the context of catastrophe insurance usually takes the form of catastrophe risk models. These models quantitatively assess catastrophe risk in terms of probability of monetary losses, and therefore guide the design and implementation of risk management strategies, which may include the transfer of risk in the form of re/insurance programs. Development of catastrophe risk models presents various challenges, often related to the fact they aim at representing events that are relatively rare by definition.

Therefore, uncertainty in modelled processes is still a large factor in risk modelling and assessment, and is included explicitly in catastrophe model results. Availability of data (relating to hazard, the built environment, engineering and insurance) also represents a major challenge, particularly in an emerging market context. From this point of view, collaboration with the scientific community and other relevant stakeholders becomes crucial to be able to develop and fine-tune catastrophe risk models.

INVESTIGATION OF LOCAL SITE EFFECTS FROM SSR AND HVSR TECHNIQUES IN IZMIR, TURKEY

Caglar **Ozer**[1], Elcin Gok[2], Ulubey Ceken[3], Orhan Polat[1]

1 Dokuz Eylul University (DEU), Engineering Faculty, Department of Geophysics, Izmir, Turkey
2 DEU Earthquake Research and Implementation Center (DAUM), Izmir, Turkey
3 Disaster and Emergency Management Presidency (AFAD), Earthquake Department, Ankara, Turkey

Izmir where is located at the western part of Turkey, is the third biggest country in terms of population (with more than 4 million inhabitants) and industrial densities. Standard spectral ratio from earthquake recordings (SSR) and Horizontal to Vertical Spectral Ratio (HVSR) are considered to investigate site effects as a function of frequency. The SSR is applied to a reference station located on rock, while the HVSR is

applied to earthquake records (entire S-waves record length). In the framework of a bi-lateral cooperation between Dokuz Eylul University (DEU) and the Earthquake Department of Disaster and Emergency Management Presidency (AFAD) which gives direct answer to Prime Ministry of Turkish Republic, a local dense acceleration network (IzmirNet; Polat et al. 2009) has been installed around Izmir city, Aegean region of Turkey. This array now comprises 25 strong-motion recorders which is in operating as real-time continuous network. In the present study we illustrated our estimations about local site conditions on seismic ground motion from SSR and HVSR at several sites. The data allowed 5 well recorded earthquake events with good S/N ratio. SSR evaluation has been analyzed by a weighted average at each other sites. The results from two methods are compared in terms of resonant frequencies and amplification levels. The peak fundamental resonant frequencies (which lie between 0.5-1.5 Hz) are mostly identified by HVSR technique while the average amplification levels (reveal from 5 to 10) generally exhibits reasonable values comparing with local geology. The site response values at each strong-motion sites were observed to be associated with the Neogene and Quaternary aged formations. The maximum site amplification at 0.7 Hz is detected as 10 MVS and BYN station sites over thick alluvial deposits at the eastern part of the Izmir Bay. It is apparent that peak frequencies and high amplification values presence the effect of geological contacts and sediment thicknesses which control site responses in the study area.

NOISE AND PARAMETERS ESTIMATION IN EARTHQUAKE EARLY WARNING SYSTEMS (EEWS).

Pazos, A.(1); Davila, J.M.(1); Buforn, E.(2); Carranza,M.(2); Zollo, A.(3); Carrilho, F. (4)
(1) Dpto. de Geofísica, Real Instituto y Observatorio de la Armada, 11.100 San Fernando, Spain: pazos@roa.es and mdavila@roa.es
(2) Dpto. de Física de la Tierra, Facultad de Ciencias Físicas, Univ. Complutense de Madrid, 28.040 Madrid, Spain: ebufornp@fis.ucm.es
(3) Department of Physics University of Naples "Federico II", Complesso universitario di Monte S.Angelo, via Cinthia, 80124 Napoli, Italy: aldo.zollo@unina.it
(4) Divisão de Geofísica, Instituto Português do Mar e da Atmosfera, Rua C do Aeroporto, 1749-077 Lisboa, Portugal: fernando.carrilho@ipma.pt

The goal of an Earthquake Early Warning System (EEWS) is to warn about the more severe shaking caused for the S-wave train posterior to the arrival of the first P-wave train. The earthquake parameters must be obtained from the initial portion, said a few seconds, of the P-wave with the enough time prior to the S-wave arrival. The magnitude of an event is estimated using the scaling laws (previously estimated) relating the moment magnitude (Mw) and the estimated parameters of the P-wave window. Parameters such as the characteristic period (τc) (Wu et al. (2007, 2008) or Kanamori (2005) among others), the maximum predominant period ($\tau pmax$) (Allen and Kanamori (2003), Shieh et al. (2008) or Wurman et al. (2007)) or the damped predominant period (τpd) (Hildyard and Rietbrock (2010)) are independent of the epicentral distance, meanwhile other parameters, such as the peak of the displacement (Pd), the peak of the velocity (Pv) or the acceleration peak (Pa) need the epicentral distance to estimate the magnitude; these parameters are described in Satriano et al. (2010), Lancieri et al. (2011), Wurman et al. (2007) among others. The noise, always buried in signals, can take a large effect in the parameters and therefore in the

magnitude estimation. In this work we analyze the influence of the noise over several parameters and also the errors in the scaling laws for magnitude estimation.

EXTREME GEOHAZARDS: REDUCING THE DISASTER RISK ASSOCIATED WITH LOW-PROBABILITY, HIGH-IMPACT EVENTS

Hans-Peter **Plag**[1], Sean Brocklebank[2], Deborah Brosnan[3], Paola Campus[4], Shelley Jules-Plag[5], Seth Stein[6]
1) Mitigation and Adaptation Research Institute, Old Dominion University, Norfolk, VA, USA
2) School of Economics, University of Edinburgh, U.K.
3) Brosnan Center, University of California, Davis, CA, USA
4) European Science Foundation, Strasbourg, France
5) Tiwah UG, Rossbach, Germany
6) Department of Earth & Planetary Sciences, Northwestern University, Evanston, IL, USA

Humanity is challenged by low-probability, high-impact hazards that could cause global catastrophes. These events have in common that their probability is not well known and that direct experience is lacking. Although extreme geohazards have occurred in the past, the associated disasters were rare and generally less severe because human exposure was much lower. Luckily, modern civilization has not experienced the most extreme events so far. Recent large earthquakes illustrated the destruction they can inflict. Those relatively frequent hazards with major impacts are on our radar screen. The more we can handle events that occur frequently, the less we are worried about the less frequent events, so threats from low-frequency, high impact events are largely underestimated in disaster risk reduction (DRR). This applies in particular to the threats deriving from volcanic eruptions: under today's circumstances, the largest volcanic eruptions that occurred during the Holocene could impact societal infrastructure, human health, supply of resources, transportation, and food and water security on global scale. Their potential impact on civilization is comparable to other possible mega disasters from extreme droughts, floods, pandemics, and asteroid impacts.

Supported by the European Science Foundation, the Geohazards Community of Practice of the Group on Earth Observations prepared a white paper reviewing the risk associated with extreme geohazards. A global volcano monitoring system is essential to achieve an in-depth understanding of all the phenomena preceding a volcanic eruption: the systematic monitoring of all the parameters associated to a volcanic eruption sets the ground for implementing an early warning system (EWS) and mitigating the risk of occurrence of disasters. Consolidated synergies among all the existing monitoring networks are a key to success in global monitoring of hazardous events. In general, DRR for extreme events requires a paradigm shift from specified to general preparedness on regional to global scales. Similarly, while it is important to understand and detect the hazards (the contribution of geosciences), it is equally important to understand the processes that can lead to, or prevent, failure (the contribution of social sciences and engineering). A joint interdisciplinary effort and a revised science-policy relationship are required to achieve DRR through increased general community resilience and reduced fragility. A transition to co-design and co-creation of knowledge involving a broad stakeholder base is necessary, particularly for extreme events. Efficient DRR will require reducing vulnerability of infrastructure, increase economic

and social resilience, and developing adaptive capabilities to potentially large long-term changes in environmental conditions. We suggest a paradigm shift toward integrated DRR and Resilience (D3R) programs that more aggressively facilitate the public trust, cooperation, and communication needed to adequately prepare for and recover from both expected and Black Swan disasters. In D3R, science's primary goal is less to reduce uncertainties and prediction errors for hazards, but rather to develop antifragile processes and strengthen resilience through increased social capital. An international process is needed to regularly assess the risk associated with extreme geohazards and our preparedness to cope with these high-impact events. This process could be an amalgam of those used by the IPCC and the Quadrennial Defense Review (QDR) carried out by the Department of Defense of the USA.

A JOINT SEISMIC AND GEODETIC RUPTURE MODEL FOR THE 2012 HAIDA GWAII EARTHQUAKE

Polet, J., Cal Poly Pomona, Pasadena, CA, USA, jpolet@csupomona.edu; Simons, M., Seismological Laboratory, Caltech, Pasadena, CA, USA, simons@gps.caltech.edu; Fielding, E. J., Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, eric.j.fielding@jpl.nasa.gov; Samsonov, S. V., Canada Centre for Remote Sensing, Natural Resources Canada, Ottawa, ON, Canada, sergey.samsonov@nrcan-rncan.gc.ca

The October 28th, 2012, M_w7.8 Haida Gwaii earthquake occurred off the coast of northern British Columbia, in the transition region between subduction of the Juan de Fuca plate beneath the North American plate to a transform fault between the Pacific plate and North American plate: the Queen Charlotte fault system. In the immediate vicinity of the Haida Gwaii earthquake rupture, relative motion between the North American and Pacific plates is more transpressional in nature than to the North, where the Queen Charlotte Fault System has produced several large (M8+) strike-slip earthquakes. The mechanism of the October 28th, 2012, earthquake is indicative of Pacific plate underthrusting beneath Haida Gwaii, showing slightly oblique thrust faulting on a shallowly dipping plane with a strike parallel to the Queen Charlotte Fault. The Haida Gwaii earthquake was followed by a sizable tsunami and most of its larger aftershocks are tensional events in the outer rise. Both of these characteristics are indicative of the presence of significant shallow slip on the subduction interface.

We will present the results from a joint kinematic rupture inversion using teleseismic body and surface wave data, and InSAR data. We incorporate one RADARSAT-2 differential interferogram calculated from Wide Swath beam images from a right-looking operation on ascending orbital tracks with a time interval of 10 months. We find that both datasets can be fit well in a combined inversion that produces a slip model with a maximum slip of 12 m, with most slip located at a depth of about 6 km. However, our preliminary results also suggest that the surface displacements of this interferogram require additional slip on the interface at greater depth, to the East of the Queen Charlotte Fault. We are in the process of including DART waveforms in our inversion, which will further improve our resolution at shallow depth.

As satellite, high-rate GPS, tsunami and additional data become more readily available after the occurrence of earthquakes and other disasters, joint inversions similar to our modeling of the Haida Gwaii earthquake have the potential to improve the situational awareness following disasters.

EARLY WARNING SYSTEMS IN CIVIL PROTECTION AND PLANNING.

Luis **Sáenz** de San Pedro Alba
Dirección General de Protección Civil y Emergencias. Ministerio del Interior, Spain

The Spanish Civil Protection is a public service which the organization, the functioning and the implementation is carried out by the different public administrations as well as by many other actors who are involved in the risk management. The Directorate General of Civil Protection and Emergencies (Ministry of Interior) acts on the various fields of civil protection and its activities and services.

Activities related to prevention, planning, intervention, training, and research and, perhaps, the one that is the compendium of all: the coordination of each administration and sectors involved in national civil protection system.

Although the large systems and early warning detection devices for natural phenomena capable of causing disasters in our country, it is necessary to provide them with a major coordination in their operation to constitute a real National Warning Network considering natural phenomena, potentially catastrophic that facilitate:

• The knowledge of the physical processes that cause them and therefore an uncertainties reduction in the occurrence probability for each territorial unit.
• The early plans activation and operational services that improve the intervention effectiveness
• To serve as dissemination tools of risks knowledge that potentially affect the population who live in a certain territory.

Civil Protection is a Public Service and citizens are going to ask for more efficiency in disaster management and to get it, it is needed a good link between Early Warning Systems, Planning and Citizens.

A GIS-BASED METHODOLOGY FOR THE EXTIMATION OF POTENTIAL VOLCANIC DAMAGE AND ITS APPLICATION TO TENERIFE ISLAND, SPAIN

C. **Scaini**(1), A. Felpeto(2), J. Martí(3), R. Carniel(4)
(1) Computer Application for Science and Engineering (CASE) Department, Barcelona Supercomputing Center (BSC-CNS), C. Gran Capità 2-4, 08034 Barcelona, Spain
(2) Observatorio Geofisico Central, Instituto Geográfico Nacional (IGN), C. Alfonso XII 3, 28014 Madrid. Spain (3) Instituto de Ciencias de la Tierra ”Jaume Almera” (IJA-CSIC), C. Luís Solé i Sabarís s/n, 08034 Barcelona, Spain
(4) Laboratorio di Misure e Trattamento dei Segnali, DICA – Università di Udine, Via delle Scienze, 206 - 33100 Udine, Friuli, Italy

We propose a GIS-based methodology for the estimation of expected damages produced by volcanic eruptions. The methodology is constituted by four parts: definition and simulation of eruptive scenarios, exposure analysis, vulnerability assessment and estimation of expected damages. Multi-hazard eruptive scenarios are defined for the Teide-Pico viejo active volcanic complex, and simulated through the VORIS tool (Felpeto et al., 2007). The vulnerability analysis is based on previous studies (Spence et al., 2005a,b; Martí et al, 2008) and complemented with the analysis of transportation and urban infrastructures. Damage assessment is performed though damage tables that associate a qualitative damage rating to each combination of hazard and vulnerability. This operation consists in a GIS-based overlap, performed for each

hazardous phenomenon considered and for each element. The methodology is then automated into a GIS-based tool using ArcGIS® program. Given the eruptive scenarios and the characteristics of the exposed elements, the tool produces expected damage maps. The tool is applied to the Icod Valley (North of Tenerife Island) which is likely to be affected by volcanic phenomena in case of eruption from the active complex Teide-Pico Viejo. Results are thematic maps of vulnerability and damage that can be displayed at different level of detail, depending on the user preferences. The aim of the tool is to facilitate territorial planning and risk management in active volcanic areas.

ANOMALOUS CHANGES IN WATER LEVEL AND CARBON MONOXIDE ASSOCIATED WITH EARTHQUAKES IN THE MID AND EASTERN PARTS OF US

Ramesh P. **Singh** and Qing Ye
School of Earth and Environmental Sciences, Schmid College of Science and Technology, Chapman University, One University Drive, Orange, California 92866, USA E-mail rsingh@chapman.edu

Major earthquake events are rare in the Mid US and in the eastern parts of US, since the areas are far from the plate boundaries. In the Mid and in the Eastern parts of US, few earthquakes greater than 5.0 have occurred. We present here, an analysis of water level routinely measured and satellite observed Carbon Monoxide data over the region earthquakes are being observed. The day to day analysis of water well and satellite observed CO data are complimentary in nature with the observed seismicity in the Mid and Eastern parts of US. Pronounced changes in water level and corresponding CO concentrations in the wells surrounding the epicentral region of Virginia earthquake of 23 August 2011 show that the hydrological fluctuations may have played a critical role in triggering earthquake mechanism in Virginia and Mid US. The anomalous changes in CO concentrations corresponding to the anomalous changes in water level confirms a strong coupling between the earthquake process, hydrological fluctuations and CO concentrations. This coupling phenomena needs to be understood to evaluate the triggering mechanism and corresponding water fluctuations and satellite observed CO so that an early warning of an impending earthquake is issued.

GLOBAL RISK ASSESSMENT AS A COLLECTION OF NATIONAL RISK ASSESSMENT

Kuniyoshi **Takeuchi**
ICHARM, PWRI, Japan

There is no global assessment without national assessments and quality of global assessment depends on quality of national assessments. This simple reality cannot be over emphasized in pursuing risk assessment for global policy making in disaster risk reduction. Contribution of science and technology is as well.

The available databases of disaster events, casualties and economic losses that cover the globe are very limited. Among them, the EM-DAT is the most comprehensive and widely used global disaster database. Thanks to it, the global trend is identifiable and has been extensively used in policy discussion.

Nevertheless, it should be noted that the disaster data of some catastrophic events of several nations such as floods in China, droughts in India, Ethiopia, Sudan etc.

control the global trend when it was presented in a chronological form. The decreasing trend of casualties is an example often used as an evidence of a so-called success story of disaster management but the accuracy of catastrophic events are highly questionable.

The loss data need to be collected by each nation, city, district or village where many people such as police officers, firemen, accountants, land use and infrastructure administrators etc. are involved and their collective work determine the quality of data. It is not a simple thing especially in the least developed nations but without improving local efforts, there is no improvement in national and, of course, global levels.

Post Hyogo Framework for Action is expected to prioritize promoting the national mechanism of making science and technology an integral part of DRR policy making. Quality data and reliable risk assessment are fundamental to knowledge and evidence based decision making.

PROBABILISTIC TSUNAMI HAZARD MAPPING

Hong Kie **Thio**[1] (hong.kie.thio@urs.com), Wenwen Li[1], Paul Somerville[1], Jascha Polet[2], Rick Wilson[3]
[1]URS Corporation, 915 Wilshire Blvd, Los Angeles, CA 90017, United States
[2]Department of geological Sciences, California State Polytechnic University, Pomona, CA, United States
[3]California Geological Survey, Sacramento, CA, United States

Tsunami hazard analysis has evolved in recent years due to several devastating events such as the 2004 Sumatra and 2011 Tohoku events. In the US, several tsunami hazard mapping initiatives are under way and we will give an overview of two of these, the probabilistic tsunami inundation maps for the State of California, and the tsunami design maps to be included in the new chapter on tsunami loads and effects in the ASCE-7 "Minimum Design Loads for Buildings and Other Structures", which is the basis for many building codes in the US and Internationally.

For the ASCE-7 study, we have developed maps of offshore exceedance amplitudes for the five US Pacific states based on a comprehensive recurrence model for tsunami sources around the Pacific. We use a Green's function summation approach, which enables us to efficiently compute the offshore waveheights for thousands of scenarios. The amplitudes are calculated for a return period of 2500 years, as prescribed by the new ASCE-7 standards. These maps will be used by others to compute inundation zones and runup lines that will also become part of this standard and can be used to computed tsunami loads within the inundation zone.

As example, we will present probabilistic inundation maps for California that are based on offshore amplitudes. Potential uses for these maps are land-use planning, building codes, evacuation planning and more. These maps are generated by dis-aggregating the offshore hazard and performing detailed, high-resolution (10 m horizontal resolution) inundation calculations that match the offshore amplitudes for particular return periods. To this end, we are using a Clawpack-based code that is very accurate, even in the case of bore formation. An important factor in these calculations, in particular for risk-based analysis, is the proper application of epistemic uncertainties and aleatory variability. We will discuss these issues in some detail, as well as plans for improving the methodology and maps further.

ASSESSMENT OF LIQUEFACTION AND SETTLEMENTS EARTHQUAKE-

INDUCED HAZARDS IN THE GRANADA METROPOLITAN AREA (SPAIN).

Valverde-Palacios, I. [(1)]; Vidal, F. [(2)]; Valverde-Espinosa, I. [(1)]; Martín-Morales, M. [(1)]; Aranda, C. [(2)]

[(1)] Departamento de Construcciones Arquitectónicas. Universidad de Granada. Campus de Fuentenueva s/n. 18071. Granada, España. nachoval@ugr.es; valverde@ugr.es; mariam@ugr.es

[(2)]Instituto Andaluz de Geofísica. Universidad de Granada. C/ Profesor Clavera Nº12, Campus Universitario de Cartuja, C.P. 18071 Granada, España. fvidal@ugr.es; caranda@ugr.es

The Metropolitan Area of Granada (MAG) is a predominantly Quaternary plain located in the north-eastern section of the Granada basin. 47 villages and towns, including Granada city, are sited on this area. The land beneath the urbanized areas of the MAG is located on alluvial, colluvial, silt and clay deposits with different thicknesses of granular soils and varying water table depths. The MAG is acknowledged to be the most seismically active zone in Spain and seismically-induced phenomena such as liquefaction and ground settlement were reported in specific zones during moderate (1806) and strong (1431) historical local earthquakes. In the last twenty years, the population of the MAG has doubled and the built-up land increased a 30%, mainly on sedimentary deposits. Accordingly, the assessment of these earthquake-induced hazards is necessary.

We have estimated liquefaction potential index (*LPI*) at 104 sites on the basis of $(N_1)_{60}$ values, fines content, water table depth, for two reference earthquakes of magnitude Mw 6.5 and 7.0. All soil and geotechnical parameters joint to LPI values have been implemented in a GIS and mapped. The results show that the eastern part of the MAG has predominantly very low *LPI* values (not liquefiable) whereas in the western one there are two large zones with moderate and high *LPI* values. On the other hand, most of the commonly used existing empirical methods to predict earthquake-induced settlement (*S*) in sandy soils require numerous iterations or the use of charts, tables and diagrams. In general, these methods estimate the one-dimensional settlement of dry sandy soil on level ground by using a well-known step by step procedure based on Standard Penetration Test (SPT) values, which is particularly effective for practical applications. A review of the state-of-the-art methods shows that seismic settlement in all cases increases as the layer thickness (*h*) of sandy soils increases and corrected SPT blow count $(N_1)_{60}$ decreases. With that in mind, we apply to MAG a novel simple way to estimate maximum vertical displacement *S* based on the $h/(N_1)_{60}$ ratio for two reference earthquakes of magnitude Mw 6.5 and 7.0. V_s values have been estimated from $(N_1)_{60}$ data using methods proposed in the literature and tested with V_s local data from SPAC and refraction profiles. The results show predictable settlement ranging from 0.1 to 21.4 cm and up to 24.7 cm for the 6.5 and 7.0 earthquakes, respectively. The densification settlement map shows that greater expected settlements (S >2.0 cm) are in the north-central and north-western sectors of the study area, especially in small zones (nearby Atarfe and Pinos Puente towns) where *S* reach values ranging between 4 and 24.7 cm. The spatial distribution of liquefaction and settlements here obtained for the Metropolitan Area of Granada are relevant results for risk prevention.

EXPECTATIONS FOR MONITORING SEISMIC EVENTS AND WATER POLLUTION IN POPULATED AREAS WITH HIGH HYDROCARBON POTENTIAL

Carlos A. **Vargas**[1] and Alexander Caneva[2]
[1]Departamento de Geociencias, Universidad Nacional de Colombia, Bogotá
[2]Universidad Antonio Nariño, Bogotá

Since 2004, Colombia has seen a transformation of its oil industry due to an aggressive promotional strategy and a highly competitive oil contract. As result of this evolution, the daily oil production increased from 528.5 KBDE in 2004 to 1.002.1 KBDE in 2013. For maintaining these production levels and incorporating new reserves, nowadays is been experimented recovery techniques for conventional resources and planned E&P exercises in unconventional hydrocarbon resources.

The need for sustaining a production around one MBOE has motivated the implementation of secondary recovery programs based on thermal stimulation in the Eastern Llanos basin, and an extensive exploration activity are planned for testing non-conventional plays resources in the Middle Magdalena Valley, Eastern Cordillera and Catatumbo basins.

In the vicinity of the Rubiales and Quifa heavy oil fields of the Eastern Llanos basin, began an intense earthquake activity with events ranging from $1.5 < m_L < 4.5$, just in the area of the thermal stimulation pilot program with a temporal correspondence between each other phenomena. The company responsible for this operation emphatically denies that such stimulation is generating seismicity, but has not reported what sort of source is generating these events, and leaving to the public a range of possible interpretation, ranging from fault reactivation by water disposal wells, to the destabilization of the zone by subsidence in the area of exploitation. Although the nearest town is about 30 km from the earthquake nest, perception of vulnerability regarding this kind of phenomenon has grown substantially.

About 500 km west of the new anthropogenic seismic nest, in the Middle Magdalena Valley basin, has been planned an extensive program of fracking for extracting hydrocarbons from shales located in a source rock of Cretaceous age. Given the pressure of the media by the seismic destabilization and water contamination in fracking operations, the Colombian government issued a demanding regulation for E&P of these resources.

In the first zone, is appreciated a poor control and sparse knowledge of the situation by the State, allowing that the operating company interprets the phenomenon and approach to the community at its discretion. In the second zone, has been planned a seismological baseline with a dense network of permanent instruments and installed before starting the extensive process of fracking in order to alert possible scenarios of instability. The government is expecting that companies and the State will start an exercise of seismic and water monitoring in a partnership frame. In this work, we discuss and propose that independent institutions should conduct this sort of monitoring in order to ensure greater objectivity to analyze the seismic event and the behavior of water resources, and communicate results in a respectful approach with the community.

EXPECTED GROUND MOTION CHARACTERISTICS IN THE CITY OF GRANADA (SPAIN) BASED ON EMPIRICAL AND SEMI-EMPIRICAL SIMULATIONS.

F. **Vidal** (1), G. Alguacil (1), M. Navarro (1, 2), I. Valverde-Palacios (3) y T. Enomoto (4)
(1) Instituto Andaluz de Geofísica, University of Granada, 18071, Granada (Spain) fvidal@ugr.es; alguacil@ugr.es
(2) Dep. of Applied Physics, University of de Almería, La Cañada, 04120, Almería

(Spain) mnavarro@ual.es;
(3) Dep. of Architectonic Buildings. University of Granada. 18071. Granada (Spain). nachoval@ugr.es
(4) Dep. of Building Engineering, University of Kanagawa, Yokohama (Japan). *enomot01@kanagawa-u.ac.jp*

Local soil conditions modify significantly the characteristics of earthquake ground motion (egm). Wave amplification of soil deposits is controlled by shear wave velocity structure at the site. Shaking is stronger where the shear wave velocity is lower and can cause there more damage to man-made structures**.** The surface ground structure in the city of Granada varies from place to place so differences in the seismic intensity are expected in future earthquakes. To assess these differences we have analysed the egm simulated from small and moderate earthquakes using different methods.

Geological sections, boreholes and geotechnical data were used to characterise the shallowest geological structure. The VS15 characteristics in the urban area were estimated from 24 short refraction seismic profiles and the VS30, ground predominant period , Tp, and thickness of deposits, Z800, by joint inversion of dispersion curves (using SPAC method) and H / V curves of microtremor obtained at 10 sites. There, 1D simulations have been made with the Thomson- Haskell method using basement records of three local (Mw ~ 4.0) and two Italian (Mw 5.3 and 6.3) recent earthquakes. The acceleration response and the input energy spectra for soil sites show an amplification of more than twice the input value mainly between 0.1 to 1.2 s, with higher peaks for site-dependent periods.

Additionally, synthetic accelerograms were obtained applying two semi-empirical simulation methods: the stochastic and the kinematic methods based on the proposal of Ordaz et al. (OSA) and Irikura et al., respectively. The records used as Empirical Green Function (EGF) corresponding to the 1997 Agrón (Mw = 4.3) and the 2007 Sierra Elvira (Mw = 3.7) earthquakes recorded at accelerograph stations in and around Granada city. The magnitudes chosen for the target events were Mw 5.5, 6.0, and 6.5, similar to those of historical earthquakes. These simulations show amplification in soils and in some cases atypical higher values, which might be associated with directivity phenomena in the EGF event used. The OSA method is easier and faster than Irikura one, but OSA simulations don't show clear differences between the two horizontal components, while Irikura method does. The results obtained in this work are complementary and congruent among them.

TOWARDS A COMPREHENSIVE AND HOMOGENEOUS CATALOG OF GLOBAL INSTRUMENTAL SEISMICITY

A. **Villaseñor**[1], D.A. Storchak[2], D. Di Giacomo[2], I. Bondár[2], E.R. Engdahl[3], and J. Harris[2]
[1]Institute of Earth Sciences Jaume Almera, ICTJA-CSIC, Barcelona, Spain
[2]International Seismological Centre, Thatcham, Berkshire, UK
[3]University of Colorado at Boulder, USA

The ISC-GEM Global Instrumental Earthquake Catalog represents the current stage of a series of projects aimed at obtaining a homogeneous and comprehensive catalog of global instrumental seismicity. The catalog is available at the ISC website (www.isc.ac.uk/iscgem) and consists of approximately 20,000 instrumentally recorded moderate to large earthquakes that occurred during the 110-year period between 1900 and 2009.

We made every effort to guarantee the homogeneity of the earthquake hypocentre and

magnitude parameters. All hypocentres after 1903 have been relocated using the two-stage procedure that includes the EHB technique to constrain event depths and the new ISC location algorithm and ak135 velocity model to recalculate the epicentre locations. Each event in the ISC-GEM Catalog is characterised by a magnitude expressed in *Mw* scale with an uncertainty. Where possible, we used *Mw* based on a reliable determination of seismic moment either from the GCMT catalog (1976-2009) or an individual scientific article (1900-1979). Proxy *Mw* were used in all other cases (the majority), based on the newly developed empirical relationships with M_S and m_b. All M_S and m_b were re-computed using the modern IASPEI procedures and the vast number of additional amplitude and period measurements that were manually entered into the ISC database from historical seismic bulletins.

The ISC-GEM Catalog will have a multidisciplinary use in a wide range of studies such as earthquake seismic hazard and risk, global seismicity, inner structure of the Earth, tectonics, nuclear monitoring research etc. It may also serve as a reference to be used for calibration purposes by those compiling regional seismicity catalogs.

VOLCANIC VULNERABILITY IN RISK ASSESSMENT AT TERRITORIAL SCALE

G. **Zuccaro**
PLINIVS Study Centre, University of NAPLES, ITALY

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 the 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, ash fall and pyroclastic flows. 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.

All these vulnerability curves have been included into a GIS probabilistic model developed to assess the impact on urban settlements due to possible volcanic eruptions at Vesuvius and Campi Flegrei Caldera, in case of single phenomenon (earthquake, ash fall an pyroclastic flows) or possible cascading effects, taking into account the cumulative effects given by probable hazards which can occur according to a time space distributions. Impact scenarios for Vesuvius and Campi Flegrei Caldera are reported. Moreover economic impact evaluation and possible cost-benefit analyses for alternative mitigation policies are shown.