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G-EVER Global Earthquake, Tsunami & Volcanic Eruption Risk Management

National Institute of Advanced Industrial Science and Technology AIST

G-EVER Consortium and Geological Survey of Japan, AIST support the Third UN World Conference on Disaster Risk Reduction

2015 International Workshop on Earthquake and Volcanic Hazards and Risks in Asia-Pacific Region

Abstracts Volume

March 16th-17th, 2015

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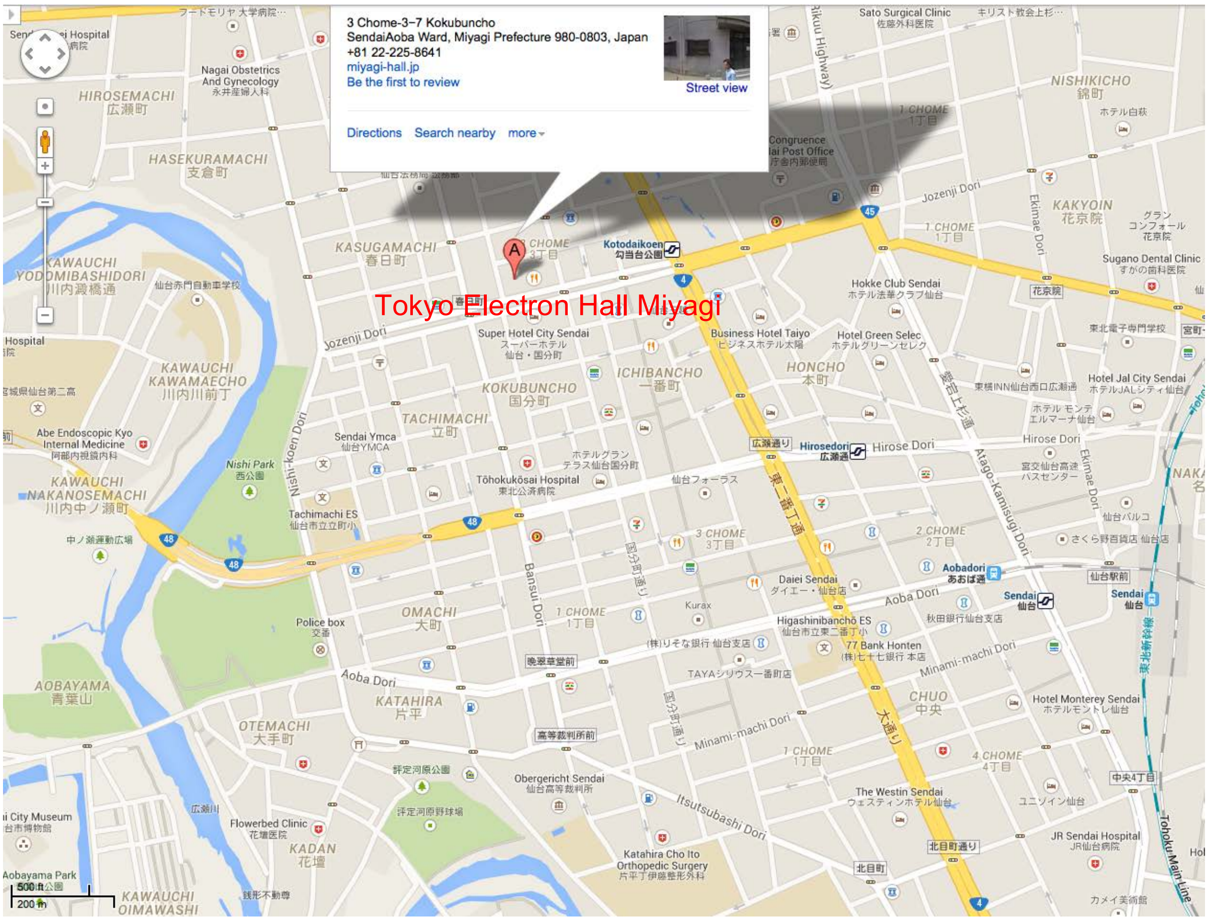

Locality map of Tokyo Electron Hall Miyagi (Room 602)

2015 International Workshop on Earthquake and Volcanic Hazards and Risks in Asia-Pacific Region

Abstracts Volume
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Preface: Continuous Efforts for G-EVER

The G-EVER Consortium and the Geological Survey of Japan jointly organize the "2015 International Workshop on Earthquake and Volcanic Hazards and Risks in Asia-Pacific Region" during the Third UN World Conference on Disaster Risk Reduction (WCDRR) from 14 to 18 March 2015 in Sendai City, Japan as one of the major public forum. The 3rd WCDRR will be held to consider and adopt the post-2015 framework for disaster risk reduction.

In February 2012, the first workshop of Asia-Pacific Region Global Earthquake and Volcanic Eruption Risk Management (G-EVER1) was held in AIST, Tsukuba, Japan, which was memorable event after the 2011 earthquake off the Pacific coast of Tohoku, Japan. The consortium's major activities were summarized as follows,

1. Establish a framework for cooperation of research institutes and organizations working on volcanic disaster prevention in the AsiaPacific region.
2. Enhance the exchange and sharing of information on seismic and volcanic disaster prevention.
3. Formulate international standards for the database, data exchange and disaster risk assessment.

The 1st G-EVER International symposium was held on March 11, 2013, the second anniversary of the devastating 2011 earthquake off the Pacific coast of Tohoku, Japan. Large number of efforts for the prevention and reduction of the risks of natural disasters have been introduced all over the world after the Tohoku earthquake,

In October 2013, the 2nd G-EVER International Symposium and the 1st IUGS & SCJ International Workshop on Natural Hazards were held in Sendai, Japan with the title of Hazard and Risk Management in Asia Pacific Region: Earthquake, Tsunami, Volcanic Eruption and Landslide in Subduction Zones, aiming to encourage extensive discussions on the present situation of natural disaster mitigation from earthquake, tsunami, volcanic eruption and landslide in the Asia and Pacific regions, including (1) important research works and priorities to make strong resilience to our society, (2) ideal hazard maps which are essential to the society and Asia-Pacific scale hazard assessment activities, and (3) importance of contributions to solid earth science. The Sendai agreement has been adopted during the symposium*.

We will continuously organize G-EVER workshop and symposiums and encourage many contributions from all over the world.

Eikichi TSUKUDA

President of G-EVER Consortium

Director General, Geological Survey of Japan

*Tsukuda, E. and G-EVER Promotion Team (2014) Report of the 2nd G-EVER International Symposium and the 1st IUGS and SCJ International Workshop on Natural Hazards and the "Sendai Agreement", Episodes Vol. 37, no. 4, 329-331.

Group photo of the 2nd G-EVER International Symposium and the 1st IUGS and SCJ Workshop on Natural Hazards at Sendai, Miyagi, Japan on Oct. 19-20, 2013.

2015 International Workshop on Earthquake and Volcanic Hazards and Risks in Asia-Pacific Region

Program

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March 17 (Tue) 9:00-16:50 — Venue: Hotel Iwanumaya (Conference room)

Invited Participants only — **Current Situation and Future Strategy of the Earthquake and Volcanic Hazards and Risk in Asia-Pacific Region**

International Geoscience Programme and Global Geoparks: Looking Towards The Future

Patrick McKeever[a]

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1. Internatational Geoscience Programme

Better understanding the Earth is essential for the diversity of life and the future of human society. The Earth Sciences hold key answers to the challenges we must overcome to preserve our environment and to develop sustainably. For over forty years, UNESCO has worked with the International Union of Geological Sciences (IUGS) to mobilize global cooperation in the Earth Sciences through the International Geoscience Programme (IGCP).This programme has provided a platform to scientists from across the world to push the frontiers of knowledge forward through concrete project arranged under five thematic areas:

- Earth Resources: Sustaining Our Society,
- Global Change: Evidence from the Geological Record
- Geohazards: Mitigating the risks
- Hydrogeology: Geoscience of the water cycle
- Geodynamics: Control of our environment.

Sida Swedish International Development Cooperation Agency

The IGCP has always built bridges between disciplines and between scientists, including young ones, with the aim of stimulating cutting-edge research and sharing scientific knowledge for the benefit of all. UNESCO is the only United Nations organisation with a mandate to support research and capacity in geology and geophysics and the IGCP is our flagship.

2. Global Geoparks

A Global Geopark is a unified area with geological heritage of international significance. Global Geoparks use that heritage to promote awareness of key issues facing society in the context of the dynamic planet we all live on. Many Global Geoparks promote awareness of geological hazards including volcanoes, earthquakes and tsunamis and many help prepare disaster mitigation strategies among local communities. Global Geoparks hold records of past climate change and are educators on current climate change as well as adopting a best practice approach to utilising renewable energy and employing the best standards of "green tourism."

Presently there are 11 Global Geoparks spread across 32 countries on 5 continents. UNESCO supports Global Geoparks on an ad-hoc basis upon requests from individual Member States. Within Japan there are presently 7 Global Geoparks with a further two new applications due to be assessed during 2015. Furthermore, during 2015 one Japanese Global Geopark (Muroto) will be subject to its first

revalidation exercise.

3. International Geoscience and Geoparks Programme

Following the success of the Global Geoparks and their growing visibility across the world, UNESCO has for the last two years been exploring ways to formalize the link between the Organisation and the Global Geoparks. At the same time, a re-organisation of Earth Science activities in UNESCO, which now formally includes activities related to Geohazard Risk Reduction, (e.g. International Platform for Reducing Earthquake Disaster - IPRED), has provide an opportunity to re-focus the IGCP. As a result, a revised international science programme is currently being drafted and will be proposed to UNESCO in April 2015. This new "International Geoscience and Geoparks Programme" will bring together the IGCP science projects and Global Geopark activities. Significantly, it will allow for, the first time, the designation of official UNESCO Global Geoparks. UNESCO global Geoparks will be the first new site designation from UNESCO since the creation of the World Heritage Site label in 1972.

Community-based Geo-hazard management in CCOP Countries

Adichat Surinkum[a]

[a]Director, Coordinating Committee for Geoscience Programmes in East and Southeast Asia

East and Southeast Asia region has been vulnerable to a wide range of natural geo-hazard processes leading to a great loss of life. Some of them create disruption of industry, agriculture and infrastructure as well as major environmental changes. People living in the region has seen dramatically increase of, so called, one-in-a-life time events, not just once but many times in the last decade. In this context, upon the need of society to have a better preparedness, CCOP as a geoscience cooperation organization focused on capacity buildings has been devoting an ever increasing effort to its geo-hazard program. The program started with sharing information how to deal with a specific geo-hazard among Member Countries who has experiences to who has difficulties to cope with people demands. Best practice and lesson-learned are parts of the training programs. Expert visits are also provided to both administrative levels and community levels.

One of the fast and quite sustainable for minimizing the loss of life is the community-based geo-hazard management program. The output of those programs are building the partnerships within the community level, both local people and administrations, and equipping them with a simple but effective tool for mitigation and preparedness activities. Since 2004, CCOP project on Tsunami Risk Mitigation Measures has been conducted by Norwegian Geotechnical Institute under the supporting of the Norwegian Ministry of Foreign Affair. This Tsunami project focused on Land-use and Rehabilitation in the beginning and then later on extended to promotion of the Disaster-resilient Communities in many CCOP countries. CCOP project on Community-based Landslide Mitigation, started in 2013, aims to establish the Landslide Watch Network by enhancing skills of locals living the prone areas. They learn how to analyze, map the risk area and create their own way of communication for an early warning from upstream to downstream. Geoscience Sharing Information on WebGIS application is the next project in CCOP. This project will provide all geoscience information not only for geoscientist but also to the rest of the world by opened-source software. The massive flooding in Thailand in 2011 is a very good example how WebGIS make information available to all stakeholders. Photos on spot from every flooding areas assigned by a location on a simple map posted regularly, told all viewers how serious is flooding on time. A simulation, or just a different color-code of flooding height, on how serious is the flood upstream today and how the effect toward downstream may provide a way to survive from the flood, even without moving to the higher land. Local administrations may also get the best preparedness activities beforehand. However, keys of success are still based on the understandings of geoscience by non-geoscientist and social science by geoscientist at a certain level, not the best techniques nor the best equipment.

By these applications, CCOP has helped the local communities to enhance their awareness on geo-hazard risk and how to minimize the impacts. By encouraging public, via an easy to understand geoscience information and effective tools of dissemination, be actively involved in the geo-hazard management, local community can prepare themselves ready to any naturally geo-hazard. They can do their own warning system, make a quick suitable response plan, have an optimum prevention and mitigation measure and, most of all, lessen the loss of life in the future.

Mitigation of Earthquake and Related Hazards for Risk Reduction in Indonesia: Challenging from Research to Policy

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Indonesia is an archipelago dense populated country that strongly influenced by Indian Ocean subduction system. It makes the country very rich on natural hazards, such as earthquake, tsunami, earthquake accompanied by tsunami, liquefaction, floods, landslides, floods and landslides, volcano eruptions, drought, and forest fire, so that the country can be drawn as a supermarket of disaster. More than 250.000 peoples are recorded as death victims of natural disasters in Indonesia in the period of 1815-2014 and the worst disaster killing many people are earthquake accompanied by tsunami and volcano eruptions. More than 155.000 people were killed by a few events of earthquake accompanied by tsunami, including the Aceh giant earthquake accompanied by tsunami in 2004, and almost 70.000 people were disappeared by volcano eruptions. Three major islands with highly disaster distribution are Sumatera, Java and Sulawesi and the three islands are also highly populated so that the potential losses on soul and property become higher too.

In term of earthquake and tsunami, Sumatera and Java are two islands experiencing the event more times than other areas in Indonesia, especially Sumatera, because they are parts of very active region tectonically in Indonesia. However, for the earthquake disasters, its hazard does not come only from the tectonic movement along the subduction system, but also from active faults on the islands. In term of volcano eruption, there are many active volcanoes that always threat their surrounding areas spreading along Indonesia Archipelago from Aceh Province in the most northern part of Sumatera in the Western Indonesia until to Banda Sea in the Eastern Indonesia. Krakatau and Tambora eruptions are two giant volcano eruptions in the ancient time where the victim of Krakatau eruption in 1883 reached more than 36.400 people, while the Tambora eruption in 1815 has destroyed three ancient empire in the region, namely Tambora, Pekat and Sanggar empires.

Mitigation of the earthquake and related hazards has been conducted in Indonesia since decades, but the efforts become more intensive and systematic since the giant earthquake and tsunami Aceh in December 2004. Indonesia Institute of Sciences (LIPI) has given high attention to the threat of earthquake on Sumatera since 1992 started with study of Sumatera Fault in Liwa (West Lampung Province) and in Bukittinggi (West Sumatera Province). The areas along the Sumatera Fault (or known also as Semangko Fault) are usually dominated by relatively flat surface and good condition for living, so that many villages and town are developed along the Fault. Therefore, the understanding of the behavior of the Fault is very important to avoid the communities from the unpredictable threads coming from the Fault movements.

Tectonic activities influencing Sumatera and threat the communities does not come only from Sumatera Fault activities but importantly coming from megathrust activities below the bottom of the Indian Ocean. Therefore the focus of study is enlarged to Mentawai Megathrust based on paleoseismology-paleogeodesy method using micro-atoll approach. The approach reveals that the cycle of megathrust causing strong earthquake and mostly accompanied by tsunami in the areas are about 200 years during the last 700 years. This information is very valuable to understand and to predict the next earthquake disaster event in this region to reduce the risks.

To get more data and comprehensive figure about what is going on in the earth surface tectonically, the study continues with installation the continue GPS since 2002 on islands along west coast of Sumatera, such as on Pagai, Sipora and Siberut islands in Mentawai Archipelago. It is known as Sumateran GPS Array or SuGAr. Currently, there are already 60 GPS stations installed and it covers also the Sumatera Fault Zone, to monitor and reveal any movements of the Fault. This study has been conducted through joint research between LIPI and Caltech University and now is continued with Earth Observatory of Singapore (EOS). Data of above studies are also used to construct the Indonesian Hazard Maps on earthquake and tsunami.

Earthquake events are almost always accompanied by liquefaction phenomenon through which the worst building and infrastructure destructions are happened. The study on liquefaction are also always conducted in the destroy areas after earthquake events and produces micro-zonation maps that are very important for space planning in redeveloping destroy areas. The studies have been conducted in Aceh, Nias, Padang, Bengkulu and also in Yogyakarta.

All above research results are analyzed and processed in term to reduce risks of the disasters, to arrange policy recommendations for the decision makers, but unfortunately most of the recommendations are rarely considered by the government, both in central and local levels. This is the main problem for researchers in Indonesia, how to bring the research results to policy level in order to reduce risks of natural disasters. This condition triggers strong spirits among the researchers and LIPI with other related agencies work together to share directly to communities the knowledge and information based on the study results. In a few area, the alert disaster schools are initiated and the knowledge to understand natural disasters are spread through meetings and printed media for risk reduction in communities level.

Building community resilience to natural hazards in Wellington, New Zealand: linking global programmes to local action

David Johnston[a], Emma E. H. Doyle[a], Bruce Pepperell[b], Dan Neely[a], Julia Becker[a]

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1. Introduction

The Integrated Research on Disaster Risk (IRDR) is a decade-old, interdisciplinary research programme sponsored by ICSU in partnership with the International Social Science Council (ISSC), and the United Nations International Strategy for Disaster Reduction (UN-ISDR). It is a global initiative seeking to address the challenges brought by natural hazard events, mitigate their impacts, and improve related policy-making mechanisms.

The IRDR Programme has three research objectives:

1) the characterisation of hazards, vulnerability and risk,
2) understanding decision-making in complex and changing risk contexts, and
3) reducing risk and curbing losses through knowledge-based actions.

To meet these objectives, IRDR has established four working groups (which bring together diverse disciplines to conceptualise new approaches to disaster risk reduction), established National Committees, and as of 2015, five international centres of excellence[i]; and running a biennial conference (Rovins et al. 2014) The four working groups are Forensic Investigations of Disasters (FORIN), Risk Interpretation and Action (RIA), Disaster Loss Data (DATA), and Assessment of Integrated Research on Disaster Risk (AIRDR). More details of the working groups can be found on the programmes website (http://www.irdrinternational.org/).

2. International Centres of Excellence

Through the IRDR Scientific Committee and the relevant National Committees, a limited number of IRDR International Centres of Excellence (ICoE) are being established to provide regional and research foci for the IRDR. Each ICoE embodies an integrated approach to disaster risk reduction that directly contributes to the IRDR Science plan (2008) and objective. As outlined in the IRDR Strategic Plan (2013-2017), "each ICoE will collaborate to provide global contributions towards achieving the IRDR legacy and, in particular, enable regional scientific activities through geographically-focused contributions based on more localised inputs and by being visible centres of research to motivate participation in the IRDR programme." As of January 2015 five IRDR International Centres of Excellence have been established:

- **IRDR ICoE-Taipei**
- Home Institution: Academy of Sciences located in Taipei, China**IRDR ICoE in Vulnerability and Resilience Metrics (IRDR ICoE-VaRM)**

  Home Institution: Hazards and Vulnerability Research Institute (HVRI), Department of Geography, College of Arts and Sciences, University of South Carolina, Columbia, South Carolina, USA
- **IRDR ICoE in Community Resilience (IRDR ICoE-CR)**

  Home Institution: Joint Centre for Disaster Research (JCDR), Massey University, Wellington, New Zealand (http://www.getprepared.org.nz/excellence/)

- **IRDR ICoE in Understanding Risk & Safety (IRDR ICoE-UR&S)**

Home Institution: Disaster Risk Management Task Force, Institute of Environmental Studies (Instituto de Estudios Ambientales – IDEA), National University of Colombia (Universidad Nacional de Colombia), Manizales City, Colombia

- **IRDR ICoE for Risk Education and Learning (IRDR ICoE-REaL)**

Home Institution: Periperi U (Partners Enhancing Resilience for People Exposed to Risks) Consortium, Research Alliance for Disaster and Risk Reduction (RADAR), Department of Geography and Environmental Studies, Stellenbosch University, South Africa

3. The International Centre of Excellence in Community Resilience

In 2014 the International Centre of Excellence in Community Resilience was launched, based in the Wellington Region. The Joint Centre for Disaster Research (Massey University/GNS Science) and the Wellington Region Emergency Management Office are coordinating this region-wide initiative to answer the question: 'How does a community make itself resilient to future disasters?' The 'IRDR International Centre of Excellence in Community Resilience', herein referred to as ICoE:CR, is composed of a number of key organisations across the Wellington region, each of which play a fundamental role in the research into, and implementation of, disaster preparedness. Through partnerships at the local, national and international level, leading research will be applied to the practice of the Wellington Region Emergency Management Office's Community Resilience Strategy. The implementation and outcomes of this strategy will in turn become a primary research focus of the ICoE:CR.

The ICoE:CR will encompass key organisations across the region to develop the science-based models, methods and metrics that provide empirically-based support for community resilience practices. The key objectives of the ICoE:CR are to:

- Provide an evidence base for the Community Resilience Strategy.
- Act as a vehicle to share international good practice in Community Resilience.
- Promote the Wellington Region as a living laboratory for research and learning.

This vision will be implemented in a number of ways. Primarily the ICoE:CR will support the IRDR objectives of characterising resilience through empirical measurements, based upon the principle that resilience affords many benefits to societies and their members. This involves understanding how mainstream community/cultural processes influence resilience (based on the premise that people's capacities derive primarily from their everyday life experiences). That is, understanding how 'everyday' community competencies and characteristics influence risk, consequences, and the choices people make about how to manage their risk. This affords opportunities to implement resilience programmes in ways that integrate risk management and community development through community engagement. This process increases the likelihood of sustained benefit as a result of its focus on developing social capital that can have benefits in everyday life, and not just when disaster strikes.

The ICoE:CR will provide some baseline support for all four of the working groups of IRDR—Risk Interpretation and Action (RIA), Assessment of Integrated Research on Disaster Risk (AIRDR), Forensic Investigators of Disasters (FORIN) and the WMO-partnered Societal and Economic Research and Applications (SERA) Working Group.

The core of the ICoE:CR is the Wellington Region Community Resilience Strategy (2012), and it is expected that all active members of the ICoE:CR will feed their outcomes and findings back to the Strategy such that we can all enhance the resilience of the Wellington Region. Wellington Region Emergency Management Office (WREMO) and the Joint Centre for Disaster Research (JCDR) thus act as the co-ordinating organisations of the ICoE:CR, through which they help facilitate engagement with the ICoE at regional, national and international level, as depicted in Figure 1.

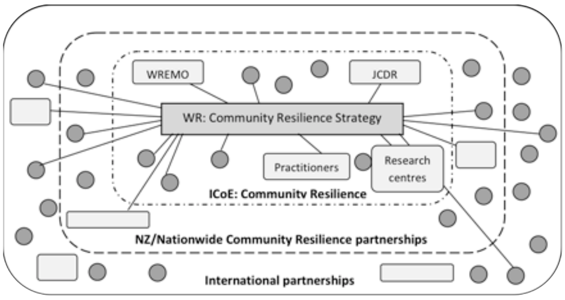

Fig. 1. Structure of the ICoR:CR

4. Guiding Principles

It is the vision of the ICoE:CR that work undertaken within this framework is built upon a strong relationship between researchers and practitioners. Thus, any research that is conducted must incorporate an active partnership with practitioners from the outset, so that practice can be enhanced through a robust evidence base.

Thus, the International Centre of Excellence in Community Resilience is underpinned by the following principles, related to the Wellington's Community Resilience Strategy (2012):

- **Listen first** – Understand and abide by the interests and needs of stakeholders before offering options that can enhance resilience.
- **Local solutions** – Communities generate innovative ideas to local and regional challenges. The ICoE:CR will encourage and support local solutions.
- **Ownership** – Facilitate activities and research that enhance resilience in a manner that is adopted and owned by the user. Individuals, organisations and communities must be responsible for their own preparedness.
- **Purposeful outcomes** – Each engagement with the community will have a clear purpose and measurable outcome. The ICoE:CR will make a point of encouraging all members to value the time and energy of individuals who make themselves available for research, or who make an effort to get themselves or their community prepared or connected through enhanced practice.
- **End-user focused** – Preparedness solutions developed from international best practice and from empirical research findings will be easy for communities to adopt and use. Messaging will be delivered to convey positive outcome expectancies.
- **Evidence Informed** –The ICoE:CR will draw upon current good practices in the implementation of research findings and either adopt or adapt these as appropriate. Where available, these good practices will be complemented by a robust suite of metrics in order to better understand cause and effect, thus aiding decision making.
- **Innovation** – Seek out and try new ideas to enhance resilience where they are well reasoned, planned and meet the needs of the community.
- **Proactive engagement** – Seek out stakeholders to work with and actively follow up on inquiries and opportunities to engage. Researchers must actively engage stakeholders from research inception to implementation and beyond.
- **Inclusiveness** – Seek the input from a cross section of the community during the engagement process of any research or practitioner initiative, and ensure people affected by outcomes have the opportunity to participate in the process.
- **Transparency** – Act as honest brokers with communities and any potential research participants or collaborators. The actions and intentions of members of the ICoE:CR

will be transparent.

- **Relationship building** – Foster relationships with community and organisational leaders with the aim of building trusting and honest partnerships between the community, practitioners, and researchers.
- **Ethics** – Researchers will act in a way that is in line with the ethical codes for research with human participants as outlined by their universities or organisations.
- **Reporting** – At six monthly intervals (early February and August), members will report to the co-ordinating organisations with a 250-500 word summary of activities that fall under the ICoE:CR. A reporting template will be set up for this purpose, and will include a list of outcomes, findings and publications. These reports will help form a research, practice and network database for the ICoE:CR. Activities will be collated into an annual report (released in March), and highlights also reported in bulletins such as the JCDR newsletter.

5. Activities since establishment

Typical activities of the ICoE:CR, since formation in March 2014, have included co-hosting the World Social Science Fellows Seminar 'Decision-making under conditions of uncertainty' in December 2013, in partnership with ISSC, ICSU, UNISDR, RIA Working Group of IRDR, ICoE Taipei and START International (WSS Fellows on RIA, 2014); the EU Community Resilience Workshop conducted in Wellington and Christchurch in April 2014; co-hosting the 7th Australasian Natural Hazards Management Conference, September 2014, Wellington, NZ; the Community Resilience Knowledge Transfer workshop, September 2014, Wellington, NZ (discussed herein); co-hosting the Massey University/GNS Science Emergency Management Summer Institute in March 2014, Wellington; and attending the International Workshop on "Post Earthquake Data" as part of the 10th U.S. National Conference on Earthquake Engineering (http://10ncee.org/).

6. Enhancing Practice

Research and practice established through the objectives of the ICoE:CR is not intended to be prescriptive and is therefore applicable to all. Rather it is intended to challenge traditional thinking by providing a smorgasbord (or diversity) of options that may be tailored to meet the needs of communities intent on building their levels of resilience. The intent is that ICoE:CR will create a knowledge bank of research, practice and metrics, and make these available to organisations that wish to participate. These participating organisations would then be free to engage to the extent that they gain value from the collaboration, taking into account the ICoE:CR guiding principles. During the initial stages of the ICoE:CR, metrics will be identified and developed to measure the enhancement of this emergency management practice through application of the research and activities of the ICoE:CR.

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Recent volcanic and earthquake hazard and risk activities at GNS Science, New Zealand, and the Cities and Volcanoes Commission of IAVCEI

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This paper presents highlights from recent volcanic and earthquake hazard and risk related activities within IAVCEI hazard commissions and connected with GNS Science in New Zealand. It is not intended to provide comprehensive coverage of the wide range of activities covered by these organisations.

1. IAVCEI hazard commissions and working groups

The International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) recently moved to coordinate its commissions under four broad liaison committees (http://iavcei.org/IAVCEI_commissions/commissions_liaisons.htm). The Mitigation of Volcanic Disasters committee now comprises seven commissions: Statistics in Volcanology, Cities and Volcanoes (CAV), World Organisation of Volcano Observatories (WOVO), International Volcanic Health Hazard Network (IVHHN), Tephra Hazard Modeling, Volcanism and the Earth's Atmosphere, and Volcanic Hazard and Risk.

Two of these commissions are particularly focused on hazard and risk:

(1) The CAV Commission (http://cav.volcano.info/) has three main activities at present:

i. selection and support of the next Cities on Volcanoes meeting, to be held in Puerto Mont, Chile in late 2016. This will be an excellent opportunity to learn from the recent impacts of the PCC and Chaiten eruptions nearby in Chile and Argentina.

ii. Launch and development of its official journal with Springer, the Journal of Applied Volcanology (http://www.appliedvolc.com/) which is focused on the application of volcanic research to society and is entirely open access. It has received wide interest with 28 published articles and another 30 in review or publication. Most publications have already been accessed thousands of times.

iii. The ongoing activities of the Volcanic Ash Impacts Working Group, which has recently produced an international 'Protocol for analysis of volcanic ash samples for assessment of hazards from leachable elements' (http://www.ivhhn.org/images/pdf/volcanic_ash_leachate_protocols.pdf) with IVHHN, and is working on an inter-laboratory comparison of results from this method on standard samples. The working group is also conducting a major update to the content and organization of the ash impacts and mitigation encyclopedia website: http://volcanoes.usgs.gov/ash/, assisted by a U.S.-New Zealand Joint Commission on Science and Technology Cooperation activity between the US Geological Survey and GNS Science

(2) The Commission on Hazards and Risk (https://vhub.org/groups/iavceicommhazrisk/) is new, and will focus on understanding, quantifying and communicating the hazards, the extent and likelihood of their occurrence, and assessing their impacts and the societal vulnerabilities they create from near to far-field. It initially includes two working groups:

i. The Communication of Hazard and Risk, and

ii. Hazard Mapping. The Hazard Mapping

working group held its first workshop as part of the Cities on Volcanoes Conference in 2014, and will focus on the development of an international IAVCEI guideline on the development of hazard maps.

2. New Zealand national hazard and risk research coordination, and link to IRDR

The Natural Hazards Research Platform is a central government-funded multi-party research platform set up in 2009 and dedicated to increasing New Zealand's resilience to Natural Hazards via high quality collaborative research. (http://www.naturalhazards.org.nz/).

The platform represents New Zealand in the Integrated Research on Disaster Risk programme (IRDR, see Johnston, this volume) and it coordinates research across five themes: geohazards, engineering, societal, weather, and risk. A substantial proportion of the volcanic and earthquake hazard research in New Zealand is conducted within the geohazards theme. Multi-hazard risk is calculated via the Riskscape programme (see 3. below) under the risk theme.
Research will be expanded and extended via the new Resilience to Nature's Challenges research area, one of 11 National Science Challenges (http://www.msi.govt.nz/p/7S) "designed to take a more strategic approach to the government's science investment by targeting a series of goals, which, if they are achieved, would have major and enduring benefits for New Zealand".

A critical aspect of the New Zealand collaborative approach to research and mitigation of natural hazard risk is the underpinned legislation. The Civil Defence Emergency Management Act 2002 (the CDEM Act) promotes co-operative planning and sustainable management of hazard risks through the "4Rs" – reduction (of risks), readiness, response and recovery. It recognises the central government's roles of national coordination, and emphasises the responsibilities of regional emergency managers, local government and communities for managing local hazard risks (Lee, 2010).

Finally, GNS Science operates the GeoNet Project, core funded by EQC (http://www.geonet.org.nz/). GeoNet builds and operates the geological hazard monitoring system in New Zealand for earthquake, volcano, tsunami and landslide hazards. The long term partnership between GNS Science and EQC in the development of GeoNet has been a major success story, with strong benefits provided by the project's provision of all data "free-to-air" – publically available directly from databases for both domestic and international research. GeoNet is currently planning for its long term goals, and director Ken Gledhill recently described potential changes as "moving from event to impact reporting, a greater emphasis on early warning and forecasting, and much more two-way communications with our community. This process has started, but has a long way to go and much of the progress will come from the research currently being carried out using GeoNet data, and as an extension to our current citizen science and social media initiatives".

3. Key New Zealand multi-agency volcano and earthquake hazard and risk research programmes:

Several multi-agency research programmes have been developed to address major earthquake and volcanic hazard issues:

(1) The It's Our Fault (IOF) programme http://www.gns.cri.nz/Home/IOF/It-s-Our-Fault is a collaboration between GNS Science, local government, the national disaster insurance fund (the Earthquake Commission, EQC), and the national accidental injury insurance fund (ACC). It coordinates research to help New Zealand's capital Wellington become a more resilient city through a comprehensive study of the likelihood of large Wellington earthquakes, the effects of

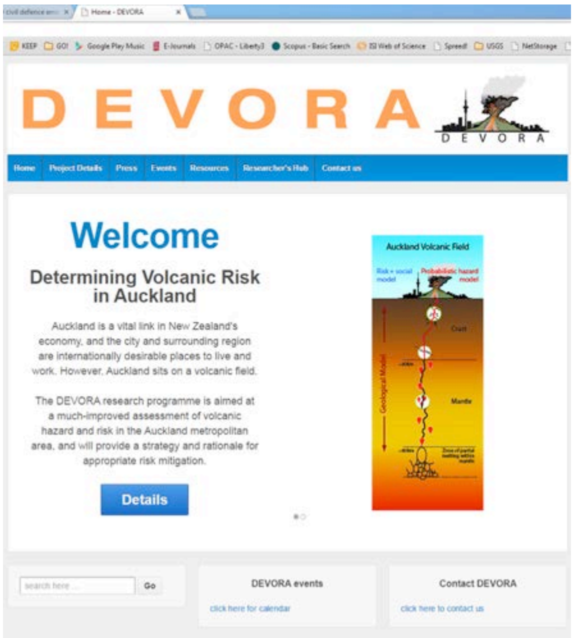

Fig. 1. DEVORA website (www.devora.org.nz)

these earthquakes, and their impacts on humans and the built environment.

(2) The Determining Volcanic Risk in Auckland (DEVORA, Fig. 1) research programme is a collaboration between Auckland Council, EQC, GNS Science and The University of Auckland aimed at a much-improved assessment of volcanic hazard and risk in the Auckland metropolitan area, and will provide a strategy and rationale for appropriate risk mitigation.

(3) The East Cost Lab (EC Lab) is a programme being set up now to coordinate existing research into the subduction zone earthquake and tsunami hazard offshore of the east coast of New Zealand, including NHRP research, local government, EQC and the research of the US NSF Geoprisms Program's New Zealand Primary Site (http://geoprisms.org/).

(4) The Riskscape programme comprises the risk theme of the NHRP, building an easy-to-use multi-hazard impact and risk assessment tool developed in partnership between GNS Science and the National Institute of Water and Atmospheric Research (NIWA). (https://riskscape.niwa.co.nz/).
Riskscape provides the volcanic risk calculation engine for the DEVORA programme, and the earthquake and tsunami risk aspects coordinated by the EC Lab programme.

4. New earthquake-related activities in New Zealand

As well as the IOF and EC Lab programmes described above, a plethora of new research has been conducted during and following the recent Canterbury Earthquake Sequence. Kelvin Berryman, the NHRP Director, recently summarised the major lessons learned from Christchurch as:

1. Land use planning is important to limit unacceptable economic losses.
2. A solution must be found to manage earthquake prone building risk.
3. Better communication is needed to explain building codes.
4. Improved communication in terms of risk not hazard is needed.
5. Engineers and scientists should talk to the public in terms of possible impacts, not the word "safe", and not earthquake magnitudes.
6. The Building Code is for life safety but a city's future depends on functionality – how do we achieve this in the code or city planning process?

From an emergency management and social impacts perspective, the Christchurch earthquakes have also highlighted the long duration, large magnitude, and complexity of the post-earthquake recovery effort.

In the last few years GNS Science has gained significant experience in various aspects of Operational Earthquake Forecasting (OEF) and in aftershock hazard and forecasting. In response to the Canterbury Earthquake Sequence, a time-dependent model that combined short-term (STEP & ETAS) and longer-term (EEPAS) clustering model components with time-independent model components was developed. This model was used to produce a forecast of the expected ground-motion for the next 50 years which has been used to revise building design standards for the region and has contributed to planning the rebuilding of Christchurch. An important contribution to this model comes from medium-term clustering. Also important is the rate to which seismicity is expected to return in 50-years. With little historical seismicity in the region, the model learning period and whether-or-not a declustered catalog is used becomes critical in estimating the long-term rate. This model uncertainty was allowed for by using forecasts from both declustered and non-declustered catalogs. With four recent moderate sequences, we have continued to refine our forecasting techniques.

An important addition has been scenarios based on the aftershock forecasts. These provide examples of how the sequence might eventuate, including the understanding of nearby faults and the Hikurangi megathrust. They have been developed with input from social scientists and have been provided to the public and government officials; they have proven useful in aiding the interpretation of the aftershock probabilities.

With several recent sequences in New Zealand we have been improving our integrated end-to-end response with emergency managers and the public, learning from each event and improving for the next.

GeoNet has also moved to rapid earthquake locations through implementation of SeisComP3 software. This allows initial automated locations and magnitude estimates within minutes, which are then refined through manual review by a duty officer or analyst.

Finally, there is a major effort underway to better understand the hazard from the Alpine Fault, the major strike-slip plate boundary fault system across the South Island. The Deep Fault Drilling Project (DFDP) is an international science project studying the Alpine Fault in western South Island. It will retrieve rock and fluid samples, make geophysical and hydraulic measurements, and establish a long term monitoring observatory inside the fault zone (http://drill.gns.cri.nz/DrillNZ/Continental-Drilling/Alpine-Fault-Project)

5. New volcano-related activities in New Zealand

As well as the DEVORA research programme described above, several initiatives are underway to further understand and prepare for the next volcanic eruption in New Zealand.

The multi-disciplinary multi-agency coordinate response to the 2012 Te Maari eruption from Tongariro Volcano was built from start to finish around stakeholder engagement with emergency managers, local government, and local indigenous communities. It has led to 18 papers in a Special Section of Volume 286 of the Journal of Volcanology and Geothermal Research (Jolly and Cronin, 2014). A critical aspect of the risk management during this crisis was the application of monitoring data to quantitative risk assessment (Jolly et al., 2014), underpinning life safety decision making within this UNESCO World Heritage Area, Tongariro National Park.

The New Zealand Volcanic Science Advisory Panel (NZVSAP) has been set up and was tested in 2012. It is comprised of scientists from all of the Universities and research agencies likely to conduct research and give advice during an eruption. The panel aims to provide authoritative, trans-disciplinary volcanic science advice (for planning and response) that is integrated across agencies, and to lead collaborative planning for multi-agency science research response during volcanic events. It supports four existing regional planning groups focused on different volcanic terrains across the North Island.

The NZVSAP will operate sub-groups focusing on specific research sectors. Two key areas already underway are:

(1) Volcanic ash and health – This subgroup is developing a national framework for the public health response to a volcanic eruption. This includes the forecasting of ashfall (with analysis of various new models), the mapping of ashfall, including citizen reporting using a modification of the US Geological Survey portal http://www.avo.alaska.edu/ashfall/ashreport.php, the standardized collection of ash including guidelines, sample coordination and splitting, the laboratory analysis of samples for petrology, leachate chemistry (see guideline under 1. above), respiratory hazard, and the communication of health hazards.

(2) Hazard mapping – A guideline for the development of volcanic hazard maps in New Zealand, aligned to the developing IAVCEI guideline (see Section 1. above). This will document a process for map development, and outline different approaches under key headings: the audience and purpose (life safety? ash disruption?); timeframe (e.g. background probabilistic vs. crisis scenario); spatial scale (regional, whole volcano, or vent?); key messages from emergency managers; hazards and zone styles to be depicted; geological, historical and/or computer modeled input data to be used; organisations and their roles; procedure for discussion and ratification. These have evolved from the recently published analysis of hazard maps produced for both the long term hazard and crisis events (most recently in 2012) in Tongariro National Park (Leonard et al., 2014).

To better underpin the zones in hazard maps, a new research project has been initiated by the University of Canterbury and GNS Science looking at the distribution of ballistics in different eruptions, and how these can be understood and modeled in terms of life safety risk for improved hazard zones on maps.

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Disaster Loss Data for Risk Assessment and Achieving Post-2015 Targets for Disaster Risk Reduction

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1. Introduction

Availability of reliable disaster loss data is the basis of assessment of disaster risk and evidence based decision making in disaster risk reduction at any levels. Disaster losses extend to human, assets, economic impacts and natural environment. They should be measured and collected both in-situ and satellites/airborne means. But the local disaster damage details indispensable to local decision making should be collected and analyzed by local people in local administrative scheme.

There are some global disaster loss datasets such as EM-DAT of CRED, Catholic University of Louvain, Belgium and NatCatSERVICE of Munich Re, Germany that have been playing crucial role in global decision making. Their information was extensively and repeatedly used by many opinion leaders and policy makers although their accuracy is questionable. Better policy needs reliable data.

2. UNISDR

UNISDR publishes Global Assessment Report on Disaster Risk Reduction (GAR) every two years since 2009 at the occasion of Global Platform. Its predecessor was Disaster Risk Reduction: 2007 Global Review. It is a major effort to monitor the progress of Hyogo Framework for Action based on societal risk management records and the risk and disaster loss data from all possible sources. But the data on many local events are difficult to collect as they totally depend on local measurements and reports.

Reflecting such a gap in needs, UNISDR recently started hosting a disaster inventory system DesInventar as a disaster information management system. It originally started in Latin American nations in the 90s and now extended to Caribbean, Africa and Asia. Using DesInventar and EM-DAT data sets, UNISDR made a major study on economic losses of disasters for GAR2013. The report states "Direct disaster losses are at least 50 percent higher than internationally reported figures: Total direct losses in 40 low and middle income countries amount to US$305 billion over the last 30 years; of these more than 30 percent were not internationally reported (Part I-Intro)." It is a result of insufficiency of reporting system of uninsured, recurrent, extensive, small scale disasters that happen many times in the world every year. This is a strong call for the need of collecting reliable local disaster loss data.

3. IRDR-Japan

IRDR was established by International Council of Science (ICSU) co-sponsored by International Social Science Council (ISSC) and UNISDR in 2008 with a science question "*Why, despite advances in the natural and social science of hazards and disasters, do losses continue to increase?*" This strongly attracted Japanese disaster management community and a national committee, IRDR-Japan was formed within Science Council of Japan in 2009 as the first national committee in IRDR in the world. The committee has been working actively such as forming a FORIN study group on Tohoku tsunami disaster, participating IRDR Conferences 2011 and 3013, and organizing research plans for research fund applications.

The major contribution to the global IRDR and DRR community was the organization of Tokyo Conference on International Study for DRR and Resilience held on 14-16 January 2015 attended by nearly 400 participants from more than 30 nations. It was a great success forming a consensus towards the post-2015 framework for DRR. It declared the Tokyo Statement which was based on a strong spirit of promoting the national and local platforms for disaster risk reduction. It emphasizes the importance of synergy of various existing efforts and strengthening local capacity to collect and analyze risk data, plan, implement and monitor actions etc. The strategy is eloquently shown in Fig. 1 below.

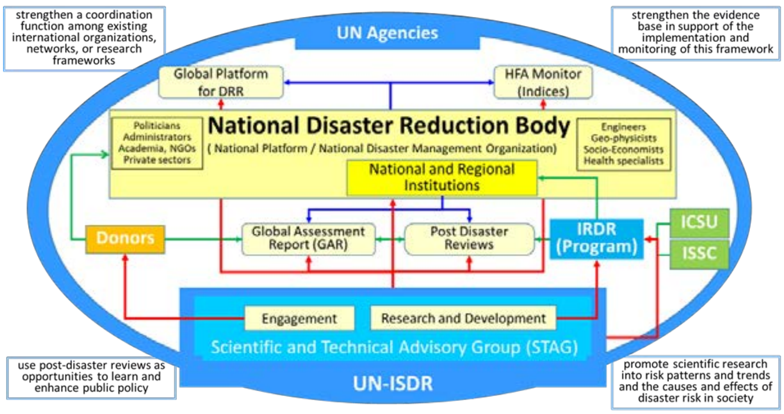

Fig. 1 New Approach to Strengthen and Support Decision-making on DRR

4. ICHARM

The International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM) was established within Public Works Research Institute (PWRI) in Tsukuba, Japan in 2006 as a Japanese contribution to UNESCO International Hydrological Program (IHP). Its mission is to serve as a Global COE for managing water-related disaster risk. The first phase emphasized flood-related disasters and now extending the focus to drought issues in arid zone. ICHARM conducts research, training and information networking: Research is on early warning and risk assessment; training is on Mater and PhD programs jointly with GRIPS (National Institute for Policy Studies) and JICA; and opinion leadership promotes science based decision making on DRR. ICHARM's challenge is "localism" to deliver best practicable knowledge to local practices. For this end, a number of local practices projects are conducted with the support of JICA, ADB, UNESCO etc. involving local people such as in Philippines, Indonesia, Pakistan etc.

ICHARM is assuming the Secretariat of International Flood Initiative organized by UNESCO, WMO, UNISDR and UNU. Current focus is IFI Flagship project "to support benchmarking flood risk reduction in global, national and local levels." It is a project to develop and provide common methodologies for benchmarking and the values of the current and targeted flood risk levels. The benchmarking requires assessing flood risk (hazards, exposure and vulnerability) and monitoring its change by risk reduction efforts. It is not an easy matter especially in developing nations where even precipitation and discharge data are not enough available and much less human and socio-economic data. To solve such a difficulty, IFI Flagship project takes a collaborative approach to integrate advanced studies with local involvement.

In the 3rd WCDRR in Sendai, one of discussion points is so-called *global targets*: reduce by [a given percentage in function of number of hazardous events] by 20[xx] disaster mortality, affected people and economic losses. Question to the geo-scientists is whether we can provide methodologies for counting such losses and monitoring progresses. Answer is in an integrated approach.

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The Global Earthquake Model: A new approach to calculate, understand, manage, and reduce seismic risk worldwide

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Most of the world's seismically vulnerable populations are unaware that they are at risk, a circumstance GEM aims to change. Launched in 2009 by the Organization of Economic Cooperation and Development (OECD), the Global Earthquake Model (GEM) creates and promotes - within a community effort - open and transparent method, tools, datasets and models for seismic risk assessment. GEM is a public-private partnership, which brings together private companies operating in the insurance market as well in engineering consulting as well as numerous public organization and associate members encompassing international organizations such as the UN International Strategy for Disaster Reduction.

One of GEM's goals is to distribute through the OpenQuake-platform a full suite of hazard and risk measures (e.g. maps, loss exceedance curves, disaggregations, uncertainties) in a transparent, and well documented, manner so that the public can interactively collect information useful to describe and understand the risk they are exposed to. Over the last five years, GEM invested considerable resources to build the global datasets without which seismic hazard assessment can neither be properly tested nor rapidly improved. These datasets had been being gathered by an international community of scientists and engineers in the countries affected by earthquakes. GEM is making a similar investment on its open source hazard and risk calculation software, the OpenQuake.engine, which is beginning to be used for different applications e.g. for national seismic hazard models and for nuclear reactor siting studies; it will soon be taught around the world.

GEM released the first version 1.0 of the OpenQuake-engine in June 2013 while its web-based portal - called the OpenQuake Platform (http://www.globalquakemodel.org/openquake/about/platform/).- which provides access to models, datasets and tools was released in January 2015.

The OpenQuake-engine hazard component: current status and new experimental features

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The OpenQuake-engine is a free and open-source software for the calculation of earthquake hazard and risk, developed by the Global Earthquake Model initiative (http://globalquakemodel.org/gem). In addition to its powerful and extensive tools for modelling seismic hazard, the software is developed following a fully transparent process with a strong commitment to testing and validation built into its construction. The open repository can be found at http://github.com/gem. The hazard component of the OpenQuake-engine (OQ-engine) currently offers four main calculation workflows – classical Probabilistic Seismic Hazard Analysis (PSHA), event-based PSHA, disaggregation of classical PSHA and scenario-based seismic hazard analysis (SHA) – which support a suite of different applications at multiple spatial scales. These range from complex site-specific hazard studies, to the calculation of losses for a portfolio of distributed assets over a city or sub-national scale, all the way to the calculation of regional, and even global-scale, PSHA models. The OQ-engine hazard component is tightly linked with the OpenQuake-platform (http://platform.openquake.org; see Figure 1), a web site offering – amongst many datasets and tools - hazard models covering several areas of the world and ready to be used with this software. In addition, two toolkits – the OpenQuake Hazard Modeller's Toolkit and the Ground Motion Toolkit – have been built upon the OQ-engine, offering a large set of methodologies commonly used for building hazard models (i.e. source models and ground motion models) and exploring the large suite of ground motion prediction equations (GMPEs) implemented within the software.

Despite its relatively short life, the OQ-engine is now one of the principal PSHA software, with increasing numbers of users across the world. With its widespread global application, however, emerges the need to implement new features to ensure the most complete compatibility with state-of-the-art seismic hazard models. The open, flexible and rigorous nature of its development greatly facilities this continual endeavour, and as such GEM is now embarking upon the creation of a new set of features that will become available to users throughout 2015 and beyond. The two most notable forthcoming features are incorporation of new directivity models, such as those included in the recent Chiou and Youngs (2014) GMPE, and a new hazard curve calculator supporting mutually exclusive sources and/or ruptures, required for a rigorous implementation of the 2012 and 2014 PSHA models developed by NIED (Fujiwara et al., 2014). In this communication we will illustrate the main features available in the hazard component of the engine and will discuss, also though examples, experimental features that will be included in the engine in the close future.

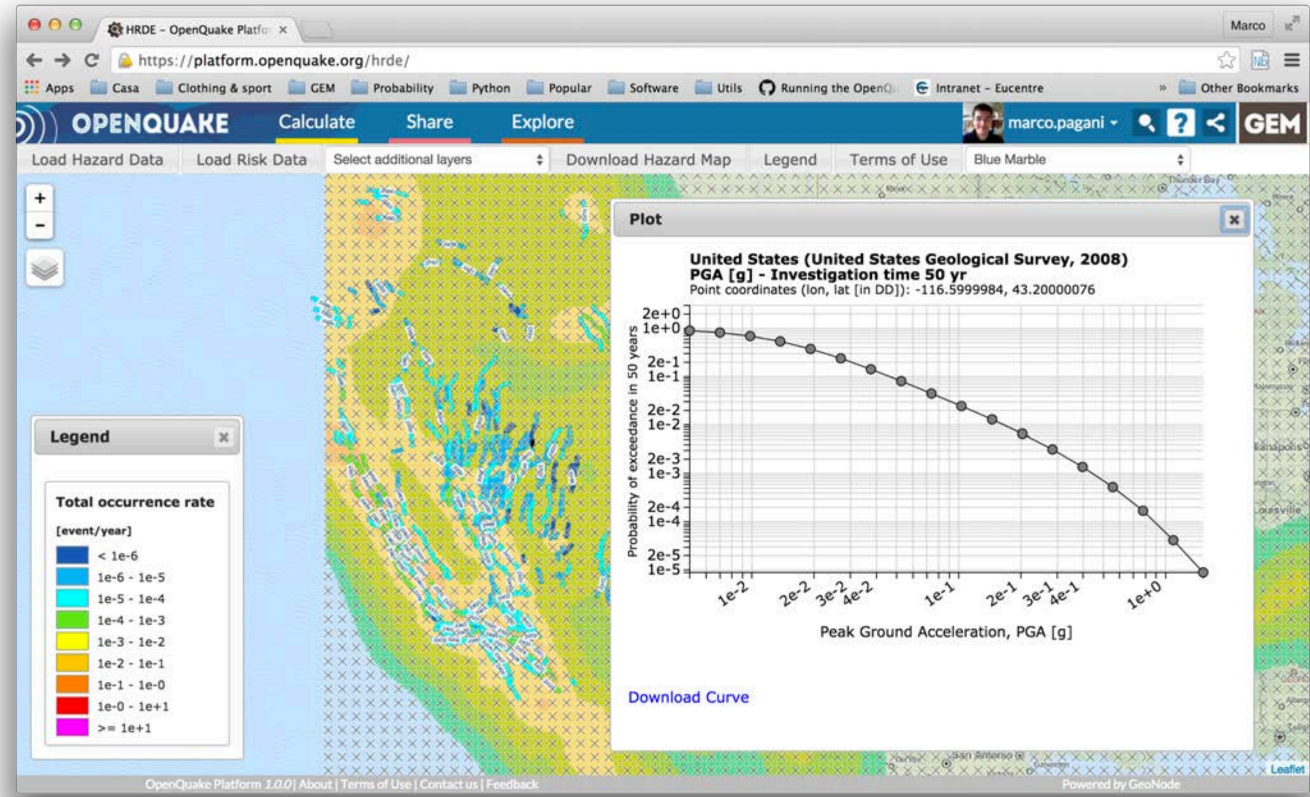

Figure 1 - A screen shot showing the hazard model explorer included in the Openquake-platform.

G-EVER Consortium activities: towards earthquake and volcanic hazards risk mitigation in Asia-Pacific region

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1. G-EVER activities and the Sendai Agreement

The Asia-Pacific Region Global Earthquake and Volcanic Eruption Risk Management (G-EVER), a consortium among the Asia-Pacific geohazard research institutes, was established in 2012 with the main objective of reducing the risk caused by earthquakes, tsunamis and volcanic eruptions worldwide. The First Workshop on Asia-Pacific Region Global Earthquake and Volcanic Eruption Risk Management (G-EVER1) was held in Tsukuba, Japan on February 22-24, 2012 to discuss measures to reduce the risks of the aforementioned hazards worldwide. There were 152 participants from 12 nations and regions and, 56 research institutes. The participants were deeply saddened by the disasters that occurred in Sumatra, Christchurch and Tohoku, but were also encouraged by successful cases of hazard mitigation and progress of various local and global risk reduction efforts. We believe that increased collaboration between geohazard institutes and organizations in the Asia-Pacific region can advance the science of natural hazards thereby contributing to the reduction risks from earthquakes, tsunamis, and volcanic eruptions. The participants approved the G-EVER1 accord during the workshop and 10 recommendations were made. The G-EVER Promotion Team of Geological Survey of Japan was formed in November 2012. The G-EVER Hub website (Fig. 1) was setup to promote the exchange of information and knowledge about volcanic and seismic hazards among the Asia-Pacific countries. Establishing standards on data sharing and analytical methods are very important to promote the sharing of data and analyses results. The major activities of G-EVER include the participation in global risk reduction efforts such as the Integrated Research on Disaster Risk (IRDR) Program, Global Earthquake Model (GEM) and Global Volcanic Model (GVM).

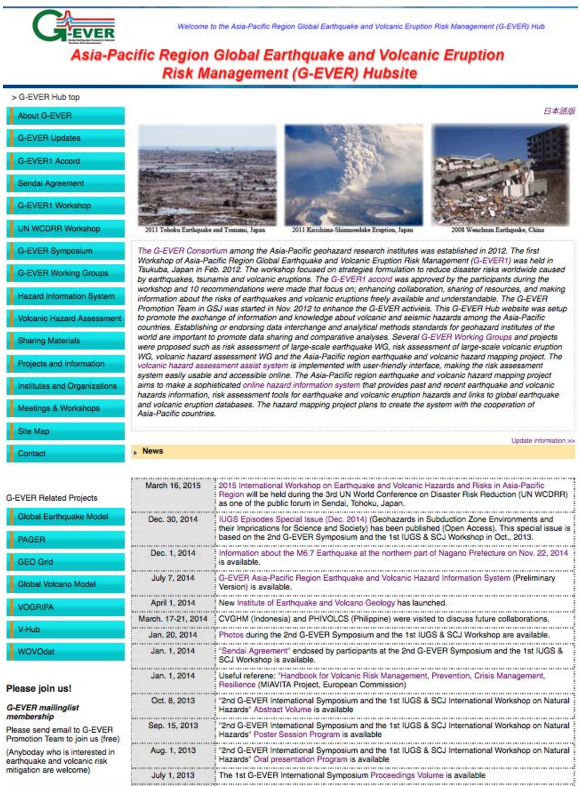

Fig. 1. G-EVER Hubsite (http://g-ever.org)

The 1st G-EVER International Symposium was held in Tsukuba, Japan on March 11, 2013, which coincided with the second anniversary of Tohoku Earthquake (Takarada, 2013). The 2nd G-EVER Symposium and IUGS & SCJ International Workshop was held in Sendai, Tohoku Japan on October 19-20, 2013 (Tsukuda and G-EVER Promotion Team, 2014). The workshop was attended by 94 individuals from 12 nations and regions and 30 national and international institutes. The participants crafted the Sendai Agreement and unanimously endorsed it. The highlights of the Sendai Agreement are the following:

・Study the processes leading to natural disasters through the support of international, broad-based, and inter-disciplinary scientific studies relevant to the entire Earth System.
・Improve the methods and contents of hazard maps for society and hazard assessment activities in Asia-Pacific region.
・ Create or help build comprehensive international databases including past disasters and hazards, and geological and geophysical features of subduction zones of the world.
・Promote scientific research on topics such as geodetic measurements, submarine landslides and predicting the maximum aftershocks from major earthquakes like the 2011 Tohoku-oki earthquake.
・ Enhance systematic mapping/dating of paleo-tsunami deposits in all regions especially those with significant populations and infrastructure.
・Promote innovative practical applications of monitoring data.
・Strive for better hazard assessments by seeking convergence of a variety of methods and disciplines, and try to understand any discrepancies.
・Improve the quantity and quality of data on past (paleo) and recent (modern analogues) events including data from monitoring sensors and precursors of future events. Better understanding and modeling of what controls the occurrence and magnitude of events
・Promote better translations from hazard to risk including damage curves, values at risk, etc.
・ Improve outreach mechanisms, including visualizations, to enhance communication with end users from early stages of research to outreach stages. Develop multidisciplinary teams and communicate uncertainty to end-users.
・ Improve methods for communicating authoritative information to underpin decision-making. Offer training to public officials and local people to reduce geohazard risks.
・Promote the optimum use of geoscientific information by public officials and other decision makers. Lessons learned and best practices are the most useful types of warning information. Gather feedback from public officials and engage in dialogue about what decisions they need to make and what information they need to make those decisions.
・Develop creative new options for mitigating impacts based on scientific, technical and socio-economic expertise, and develop effective means to have advice used in policies/decisions. Engineers, social scientists and economists should be involved.
・Play international leadership, coordination and best practices through ICSU.
・Participate in related global risk reduction efforts, such as Integrated Research on Disaster Risk (IRDR) Program, Future Earth, Global Earthquake Model (GEM), and Global Volcanic Model (GVM).

We wish our activities will help build a better future for Earth. The 3rd United Nations (UN) World Conference on Disaster Risk Reduction is held in Sendai Japan on March 14-18, 2015. We hope our efforts will be an important model for future disaster risk reduction activities in the world.

Several G-EVER Working Groups and projects were proposed such as: (1) Risk mitigation of large-scale earthquakes WG, (2) Risk mitigation of large-scale volcanic eruptions WG, (3) Volcanic hazard assessment support system WG, and (4) Asia-Pacific region earthquake and volcanic hazard mapping project.

2. G-EVER volcanic hazard assessment support system

The G-EVER volcanic assessment support system is developed based on eruption history, volcanic eruption database and numerical simulations (Takarada et al., 2014). The volcanic eruption database is developed based on past eruption results, which only represent a subset of possible future scenarios. Therefore, numerical simulations with controlled parameters are needed for more precise volcanic eruption predictions. The "best-fit" parameters of the past worldwide major eruptions have to be estimated and the simulation results database should be made. Using the volcano hazard assessment system, the time and area that would be affected by volcanic eruptions at any locations near the volcano can be predicted using numerical simulations. The system could estimate volcanic hazard risks by overlaying the distributions of volcanic deposits on major roads, houses and evacuation areas using GIS enabled systems. The G-EVER hazard assessment support system is implemented with user-friendly interface, making the risk assessment system easy to use and accessible online. The volcanic hazard assessment support system using Energy Cone and Titan2D simulations is available online (Fig. 2). The system can assess any volcano in the world

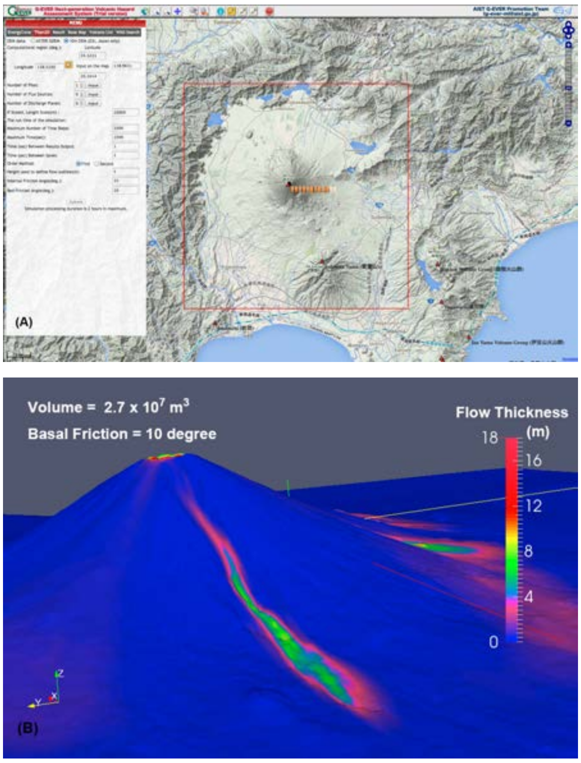

Fig. 2. Titan2D simulation result at Fuji Volcano, Japan, using G-EVER volcanic hazard assessment support system (http://volcano.g-ever1.org).

using ASTER Global DEM (10m resolution DEM is used in Japan). Links to major volcanic databases, such as Smithsonian, VOGRIPA, ASTER Satellite images, and Volcanoes of Japan are available on each volcano information popup on the map. A new fast-processing version of energy cone simulation system using elevation tiles is available (g-ever1.org/quick). The updated Titan2D simulation system could be run using DEM data uploaded by the user and download more detailed simulation results. It also provides informative and user friendly interface.

3. Asia-Pacific region earthquake and volcanic hazard mapping project

The Asia-Pacific region earthquake and volcanic hazard mapping project aims to develop an advanced online hazard information system that provides past and recent earthquake and volcanic eruption information (eg. age, location, scale, affected areas and fatalities) and list assessment tools for earthquake and volcanic eruption hazards (Fig. 3). The printed map version, Eastern Asia Earthquake and Volcanic Hazards Map, will also be published as the new version of the Eastern Asia Geological Hazard Map (Kato and Eastern Asia Natural Hazards Mapping Project, 2002) of the Commission for the Geological Map of the World (CGMW) (Fig. 4). The online hazard information system provides useful information about earthquake and volcanic hazards in an interactive and user-friendly interface. It could also be used as

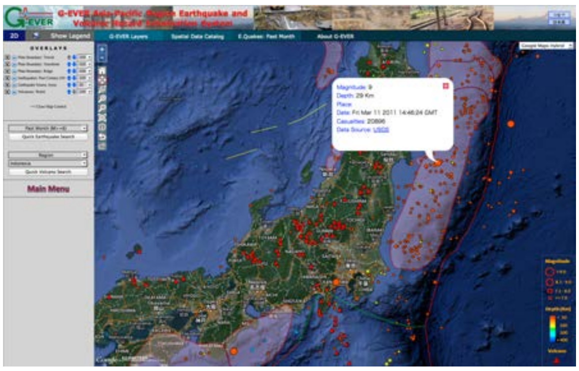

Fig. 3. Preliminary version of G-EVER Asia-Pacific Region Earthquake and Volcanic Hazard Information System (http://ccop-geoinfo.org/G-EVER).

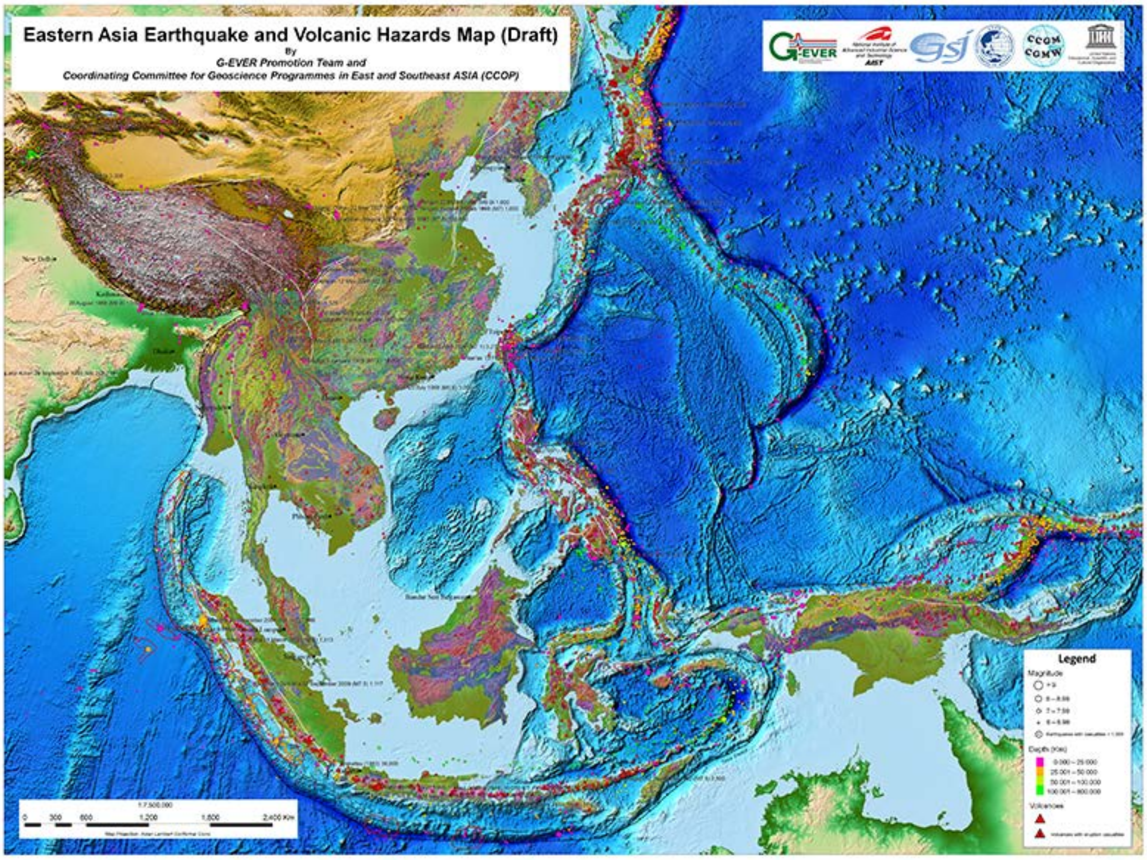

Fig. 4. Eastern Asia Earthquake and Volcanic Hazards Map (Draft).

earthquake and volcanic hazard risk assessment tool. The information system also shows tsunami inundation areas, active faults distributions and hazard maps. This project will be implemented with the cooperation of major research institutes and organizations in the Asia-Pacific region such as PHIVOLCS (Philippine), CVGHM (Indonesia), GNS Science (New Zealand), EOS (Singapore), USGS (USA) and the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP). A preliminary version

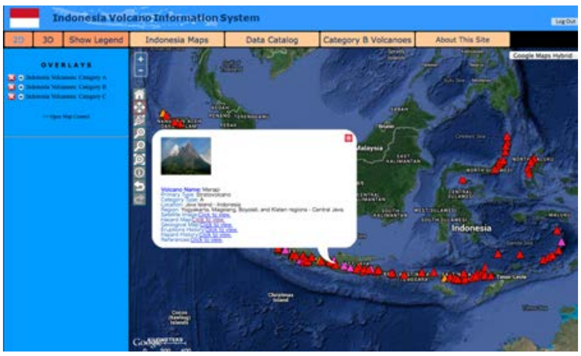

Fig. 5. Preliminary version of Indonesia Volcano Information System.

of Indonesia Volcano Information System was made in collaboration with CVGHM (Fig. 5). Volcano type, category, satellite image, hazard map, geological map, eruption history, hazard history and reference of active volcanoes can be displayed on this system.

4. CCOP Geoinformation Sharing Infrastructure for East and Southeast Asia Project

The Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP) and Geological Survey of Japan (GSJ) started the CCOP-GSJ Geoinformation Sharing Infrastructure for East and Southeast Asia (GSi) project (Fig. 6). The project aims to compile various geoscientific information in CCOP countries and develop a Web-based database and Geographic Information System (Web-GIS) using Free and Open Source Software (FOSS) and Open Geospatial Consortium (OGC) standards. This project was approved by the CCOP countries at the 63th CCOP Steering

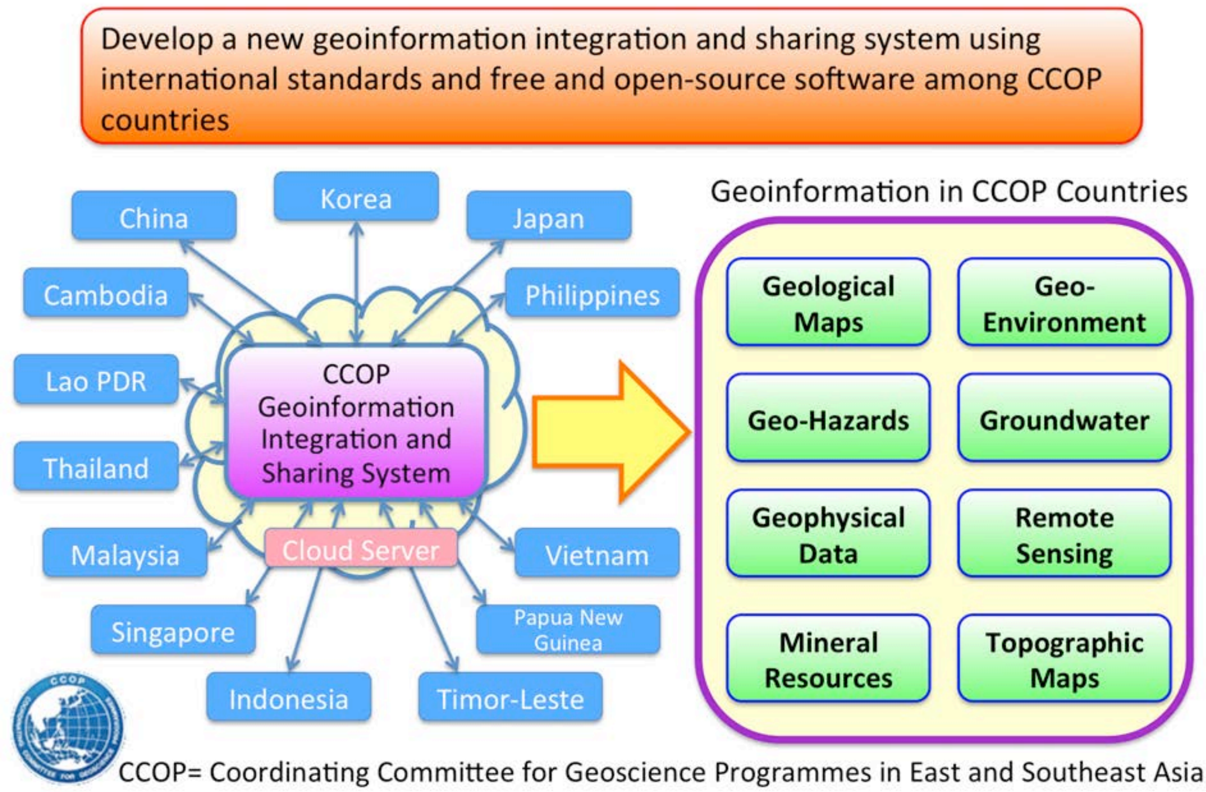

Fig. 6. Concept of the CCOP Geoinformation Sharing Infrastructure for East and Southeast Asia Project.

Committee Meeting in Kokopo, Papua New Guinea. The preliminary portal site of the project (ccop-geoinfo.org/GeoPortal) provides spatial data about geohazards, geology, geoenvironment, groundwater, mineral resources, remote sensing, geophysical and topography covering the countries in East and Southeast Asia. Development of spatial data model standard, data integration and sharing and capacity building are the major targets of this project.

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Earthquake and Volcanic Hazards and Risk Assessment Efforts in the Philippines

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The Philippine archipelago, due to its geographic and geotectonic setting, is prone to earthquakes, tsunamis and volcanic eruptions. It has been affected by about 170 eruptions from 21 active volcanoes, 90 damaging earthquakes and 40 tsunamis, near- and far-field, in the past 400 years. Significant loss of lives, and impact to properties have been caused by these events, and with the large number of population exposed to these natural hazards, the Philippines is not only considered to be among the countries in the top ten exposed to but also at risk to earthquake, tsunami and volcanic hazards.

Critical in the national efforts of reducing risks is the appreciation by the communities and the local to national government of the appropriate hazard and risk scenarios so that proper and timely responses are implemented. To achieve this, the Philippine Institute of Volcanology and Seismology (PHIVOLCS) has been conducting hazards and risk assessment activities in various areas in the country, information and education campaigns to make people aware of the hazards and risks and how to prepare for these, and development of tools and training of relevant local to national government staffs, academe and the private sector on the use and application of these tools. Several of these activities are collaborative efforts with national and local governments, non-government organizations, and international partners.

Volcanic hazards assessment has been done for the 21 active volcanoes but maps are being improved with numerical modelling. Earthquake hazards assessment has progressed with time from small scale (national) to large scale (town scale) mapping. Ground rupture, ground shaking, liquefaction, earthquake-triggered landslide and tsunami hazard maps are being produced per provinces. PHIVOLCS has developed a hazards and risk assessment software, the Rapid Earthquake Damage Assessment System (REDAS), which is being shared with disaster managers, planners and other key staffs of local government, and government organizations, academe, and the private sector. The software contains three modules – hazard assessment, exposure database and impact assessment. PHIVOLCS and other national government agencies have also been implementing since 2005 multi-hazard community-based risk reduction activities in several provinces in the Philippines, as supported by other international partners such as Australian Agency for International Development (AusAID) and United Nations Development Programme (UNDP). Activities include multi-hazards and risk assessment, the provision of and training on how to use the REDAS and how to integrate risk reduction into local development planning process. A check-list questionnaire and software was developed by PHIVOLCS, the Association of Structural Engineers of the Philippines and the National Institute of Earth Science and Disaster Prevention to help owners or occupants appreciate the safety of houses to earthquakes.

The Important of Earthquake and Volcano Hazard Mappings in Disaster Mappings in Disaster Risk Reduction and its Implementation to Spatial Planning

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Indonesia is located at collision amongst 3 active tectonic plates resulted in the country is very prone to earthquakes, tsunami, volcanic eruption and landslide. From those type of disasters, the Aceh earthquake which followed by tsunami took 227,898 casualties (USGS,2012), the highest number in the history of disasters in Indonesia. High probability of casualties from earthquake is mostly due to unpredictable time, magnitude and location of the event. Therefore, understanding the history, mechanism and distribution of earthquakes are very important for disaster mitigation.

In case of volcanic eruption, high number of casualties is due to unknown eruption history of the volcano, change of eruption style, geographic, demographic and culture. The recent Merapi eruption in 2010 took 386 casualties (National Disaster Management Agency, 2011). Even though the Merapi community has undergone experience of eruption and has high capacity. This condition is due to rapid change of magnitude and eruption style. In volcanic island, problem arises mostly

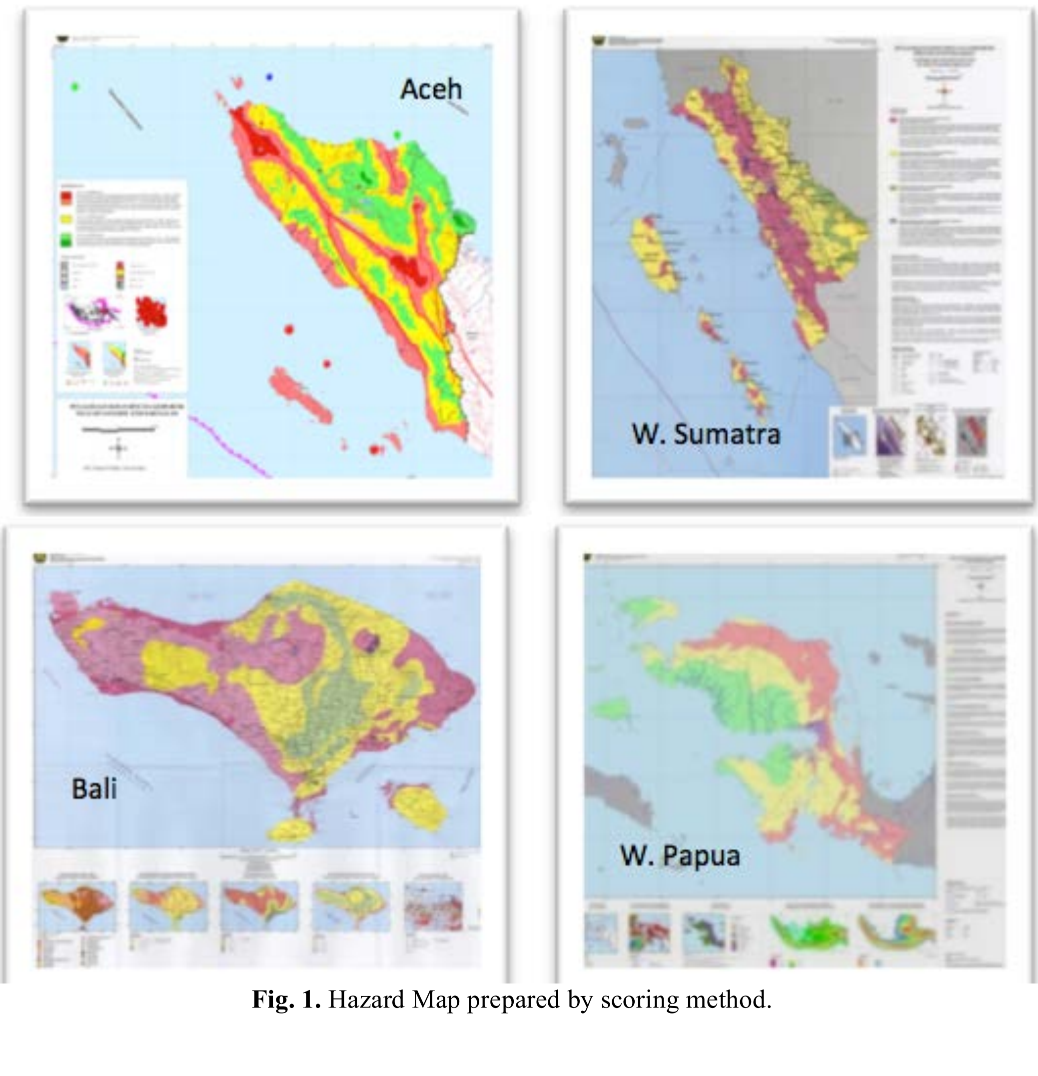

Fig. 1. Hazard Map prepared by scoring method.

due to infrastructure of evacuation, livelihood and background of culture.

Widespread risk associated with earthquake and volcano disasters influenced by high population, infrastructure and facilities, and high activities (economic, tourism, etc) of the people resulted in the community exposed even to higher risk. In areas, which have high intensity of those disasters, program of disaster mitigation become a priority.

Earthquake and volcanic hazard mappings are part of efforts to reduce disaster risk factors. Specifically, earthquake hazard map describes ground shaking estimation expected to occur in the future. Mapping of earthquake and volcanic hazards has been done for many years in Indonesia. These maps are prepared based on the history of events and characteristic of the hazards.

Previously, preparation of earthquake hazard map, scoring method was used. The method consider geological, faults, peak ground acceleration (PGA), Modified Mercalli Intensity (MMI) and microzonation data. Figure 1 shows examples of Hazard maps prepared by scoring method.

Since 2011, Probabilistic Seismic Hazard Analysis (PSHA) method has been applied. This method includes uncertainties in time, location, and magnitude of the future earthquake. Data collections were provided from study of microzonation, earthquake source, historical data, and post disaster observation. Figure 2, shows examples of hazard maps prepared by PSHA method.

Earthquake hazard map is created based on

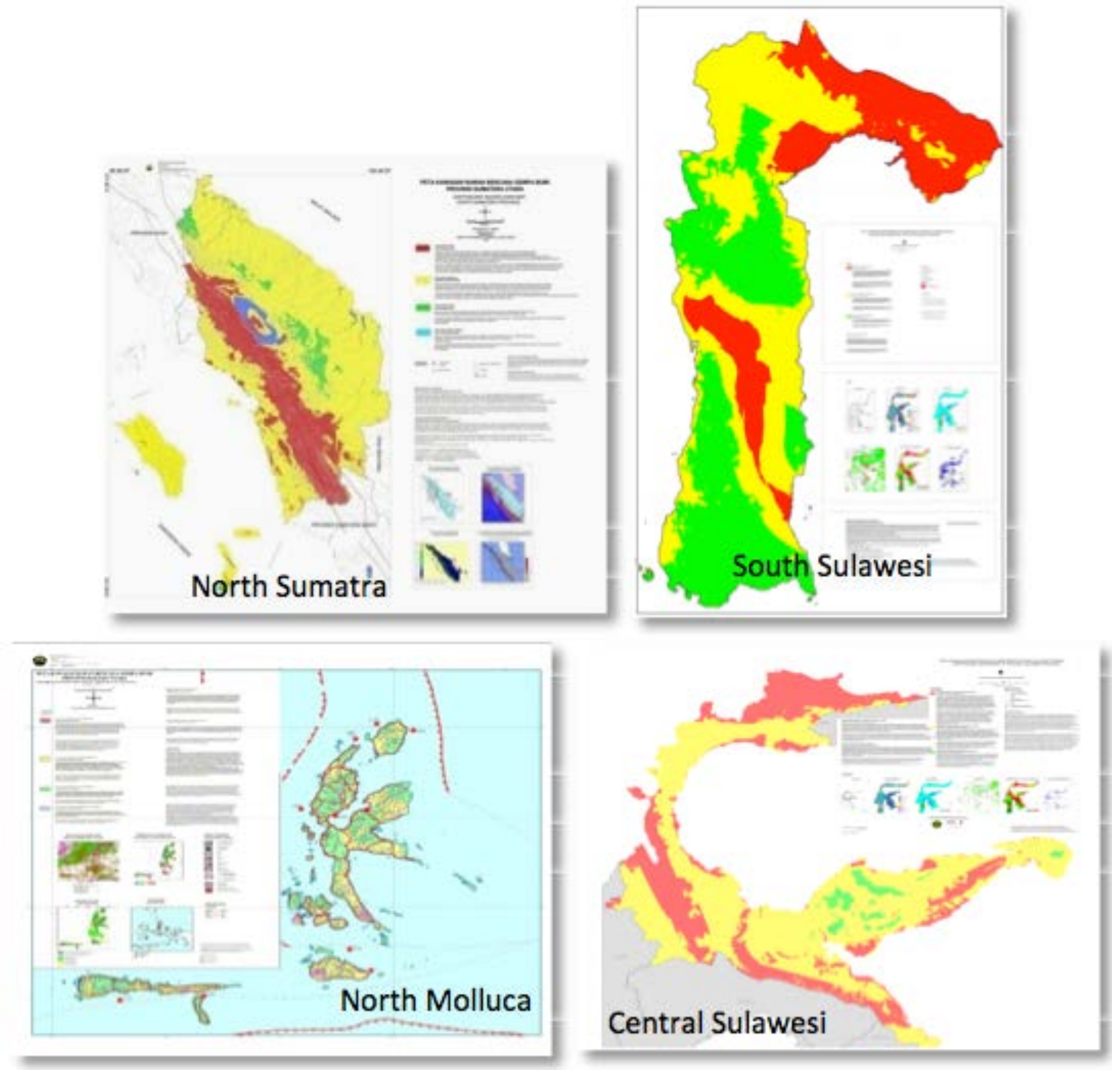

Fig. 2. Hazard Map prepared by PSHA method (collaborative work with Geoscience Australia and ANU through AIFDR)

the estimated intensity, which obtained by converting the acceleration level on a certain (0.2 - 0.33) second RSA (*Response Spectral Acceleration*). The hazard levels are classified into very low (MMI < V), low (VII > MMI ≥ V), moderate (VIII > MMI ≥ VII), and high (MMI ≥ VIII) respectively. The map is accompanied by recommendation of each level to people living within the hazard zones. The recommendation relates with type and strength of building and infrastructure permitted to be built.

On the other hand volcanic hazard map is a guidance map identifies the degree of hazard in a volcano. Volcanic Hazard map is prepared based on eruption history, distribution of product and frequency and magnitude of eruption. The map is divided into 3 degree of hazards, from the lowest, Hazard Zone (HZ) I (yellow), HZ II (light pink) and HZ III (dark pink), figure 3.

The map is also accompanied by recommendation of each alert level to people living surrounding the volcano. The recommendation is given according to their activity within hazard zones and preparedness for evacuation.

The earthquake and volcanic hazard maps produce a scientific information. Therefore, practical knowledge is nescessary to support the information in order to be understandable by stakeholders and community. Accordingly, these maps are also implemented during formulation of contingency plan and further be simulated in the form of Table Top Exercise. Regularly review on strategy and simulation of disaster mitigation plan is an important polices for disaster risk reduction.

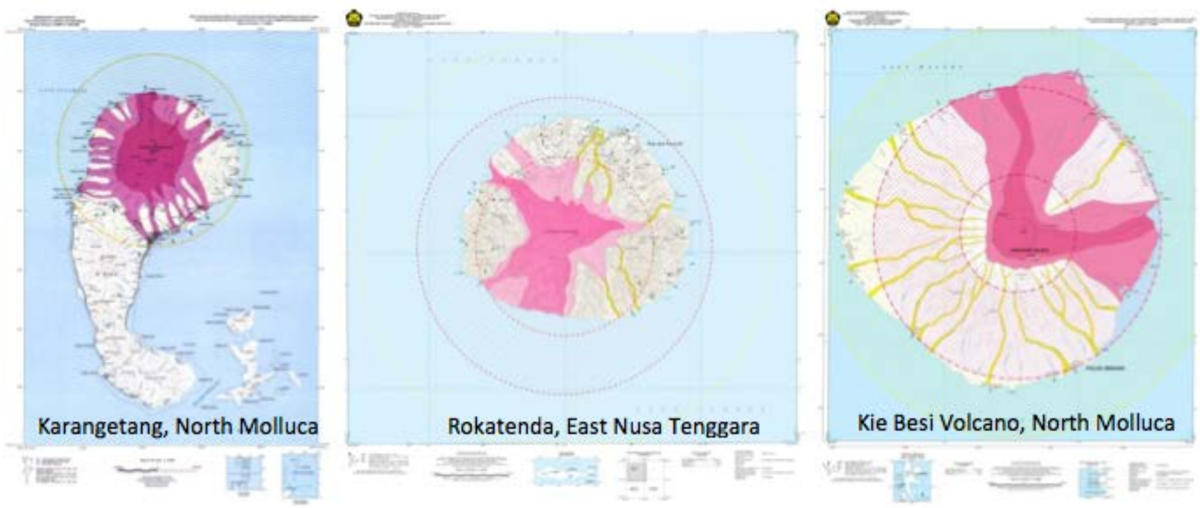

Fig. 3. Volcanic Hazard Maps show the degree of hazard zone I (yellow), hazard zone II (light pink and hazard zone III (dark pink)

Recent development of WOVOdat - The global volcano unrest database - as a resource to improve eruption forecasts

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1. Introduction

During periods of volcanic unrest, volcanologists need to interpret signs of unrest to be able to forecast whether an eruption is likely to occur (Newhall and Hoblitt, 2002; Aspinal et al., 2003). An unrest episode may include different stages or time intervals of increasing or decreasing activity, which in each stage can lead into different outcomes. The most challenging task during volcanic crisis is to interpret the monitoring data, to better anticipate the evolution of the unrest and implement timely mitigation actions (Sobradelo and Marti, 2015).

WOVOdat is the World Organization of Volcano Observatories' (WOVO) Database of worldwide volcanic unrest – an international effort to develop common standards for compiling and storing data on volcanic unrests in a centralized database and made freely web-accessible.

As a unique comprehensive global database, WOVOdat is designed to provide reference during volcanic crises and for basic research on pre-eruption processes, which also allow for comparative studies (Ratdomopurbo et al., 2010; Widiwijayanti et al, 2014). WOVOdat will be to volcanology as an epidemiological database is to medicine (Venezky and Newhall, 2007).

Since January 2009, the Earth Observatory of Singapore has hosted the WOVOdat project and is currently developing the database and its web-interface.

2. Uses of WOVOdat

Some volcanic eruptions display signs of impending eruption such as seismic activity, surface deformation, or gas emissions; but not all will display signs and not all signs are necessarily followed by an eruption (Rouwet et al., 2014). All volcanoes behave differently. Precursory signs of an eruption are sometimes very short, less than an hour, but can also last for weeks, months, or even years (Phillipson et al., 2013).

Some volcanoes are regularly active and closely monitored, while others are not. Oftentimes, the record of precursors to historical eruptions of a volcano is not enough to allow a forecast of its future activity. Therefore, volcanologists must refer to monitoring data of unrest and historical eruptions at similar volcanoes (Newhall and Dzurisin, 1988). WOVOdat provides access to that information. For example, a volcanologist responding to a crisis will usually ask, "Where has unrest like (the present) been seen before, and what happened?" Statistics of previous outcomes may also be used in constructing probabilistic event trees.

For research, volcanologists may ask, "What do the systematics of unrest between and leading up to eruptions tell us about the processes before a volcano erupts?" Or, "Are there systematic differences in the monitoring signals between intrusions that erupt and intrusions that failed to erupt?" If the unrest situation is puzzling, the researcher can use WOVOdat to look for systematics in other cases of similar unrest.

Recent advances in ground based and remote sensing volcano monitoring, data processing and analysis techniques have resulted in significantly improved ability on understanding the physics of the volcanism processes. Such that in recent unrests, these integrated time-series data proved to have resulted several successful examples of alerts being issued on impending eruptions (Winson et al., 2014).

Forecasting of hazardous volcanic phenomena is becoming more quantitative, based on the understanding of the physics behind the pre-eruptive processes (Sparks, 2003), but must also acknowledge and express the uncertainties (Newhall and Pallister, 2014). The field of eruption forecasting is progressing as a result of focused research and the application of Bayesian Event Tree (BET) analysis to reflect multiple possible scenarios and the probability of each scenario (Marzocchi et al., 2008; Aspinall et al., 2003; Lindsay et al., 2010; Sandri et al., 2012; Sobradelo and Marti, 2014; Newhall and Pallister, 2014). Such forecasts are critically dependent on comprehensive and authoritative global unrest data sets (Newhall and Pallister, 2014) – the very information currently collected in WOVOdat.

Statistical distribution obtained from WOVOdat can be then used to estimate the probabilities of each scenario after specific patterns of unrest. As database becomes more complete, Boolean search tool of WOVOdat will generate reliable results and users can get the matching data subset of returned Boolean conditions.

3. Database structure

WOVOdat stores instrumentally and visually recorded changes in seismicity, ground deformation, gas emission, and other monitoring parameters above their normal baselines. The database is created per the structure and format described in the WOVOdat 1.0 report (Venezky and Newhall, 2007), updated in WOVOdat 1.1.

The volcano table is the center point of the data structure from which all the other data can be linked. Monitoring data are generally linked from the data to the station where the data is collected, to the network of stations, and to the volcano itself.

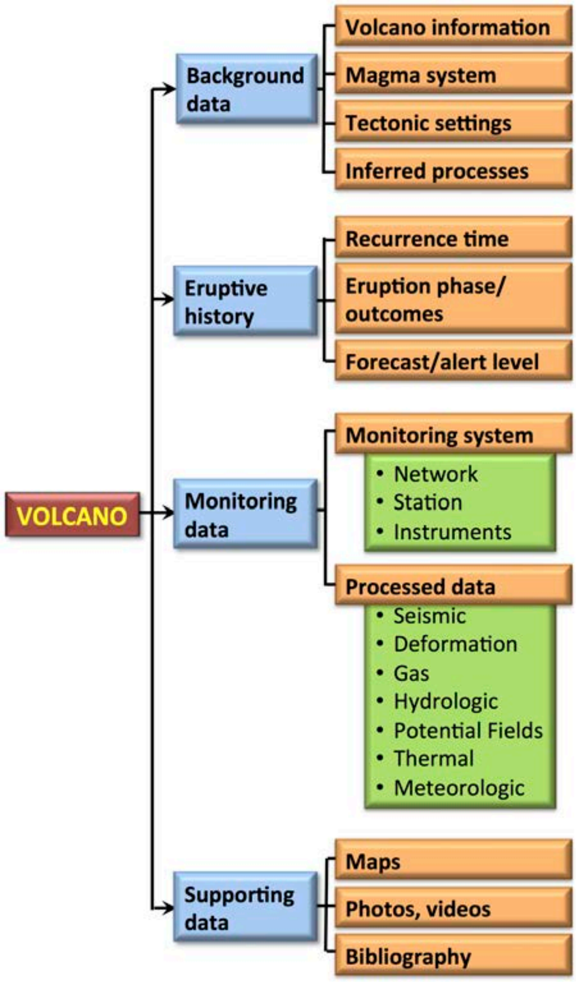

Figure 1. Simplified schema of WOVOdat, showing types of data stored in the database where volcano monitoring data will be the core.

4. Current development

We have now incorporated about 15% of worldwide unrest data into WOVOdat, covering more than 100 eruption episodes, which include: volcanic background data, eruptive histories, monitoring data (seismic, deformation, gas, hydrology, thermal, fields, and meteorology), monitoring metadata, and supporting data such as reports, images, maps and videos. Nearly all data in WOVOdat are time-stamped and georeferenced, so that they can be studied in both space and time.

Along with creating a database on volcanic unrest, WOVOdat is also developing web-tools to help users to query, visualize, and compare data, which can further be used for probabilistic eruption forecasting. Reference to WOVOdat will be especially helpful at volcanoes that have not erupted in historical or 'instrumental' time and thus for which no previous data exist.

In the current status of WOVOdat there are 3 main focus tasks:

- **Data population**, which is the main activity of WOVOdat. The objective is to include all recorded historical unrest, including but not limited to that which lead to an eruption, from reliable sources direct volcano observatories, open and partner databases, and published materials.

- **Database and Web Interface**, which is continuously being developed to support interaction between WOVOdat developers, observatories, and other partners in building the database, accessing documentations, submitting data, query and visualize data.

- **Participation in international community & outreach activities**. As part of international volcanological community, with efforts to provide information for assessment of volcanic hazard and risk, WOVOdat is a major partner in Global Volcano Model (GVM), a UN-ISDR Global Assessment Report (GAR)-15 task force.

Registered users will be able to interactively query the database and view volcano monitoring dataset.

The main visualization tool in WOVOdat enables comparisons of processed monitoring data, e.g., earthquake hypocenters, displacements, and gas flux time series from different episodes of unrest from a single volcano, or between two different but analogous volcanoes.

A Boolean search tool, which is currently in development, allows the user to query specific volcano information and retrieve available monitoring data related to a specified eruption time. These search results can then also be displayed in an interactive time-series visualization of eruption phases, alert level information, and monitoring data related to the eruption.

5. Data contribution

Our website (www.wovodat.org) supports interaction between WOVOdat developers, observatories, and other partners in building the database, e.g. accessing schematic design information and documentation, and utilities for submitting data.

Active data that are younger than a 2-year grace period are generally not available, because they may still be in use by volcano observatories and other contributors. WOVOdat welcomes any volcano monitoring data, but it respects the prerogative of those who collected the data to have first option in interpretation and publication.

Ownership of the data remains with the data contributors, and all users agree to abide by the terms of the data use agreement.

The more data in WOVOdat, the more useful it will be. We actively solicit relevant data contributions from volcano observatories, other institutions, and individual researchers. WOVOdat also welcomes visualization tools, pattern recognition tools and scripts that will optimize the Boolean search engine or data display.

Data can be submitted into the WOVOdat database at (http://www.wovodat.org/populate/home_populate.php).

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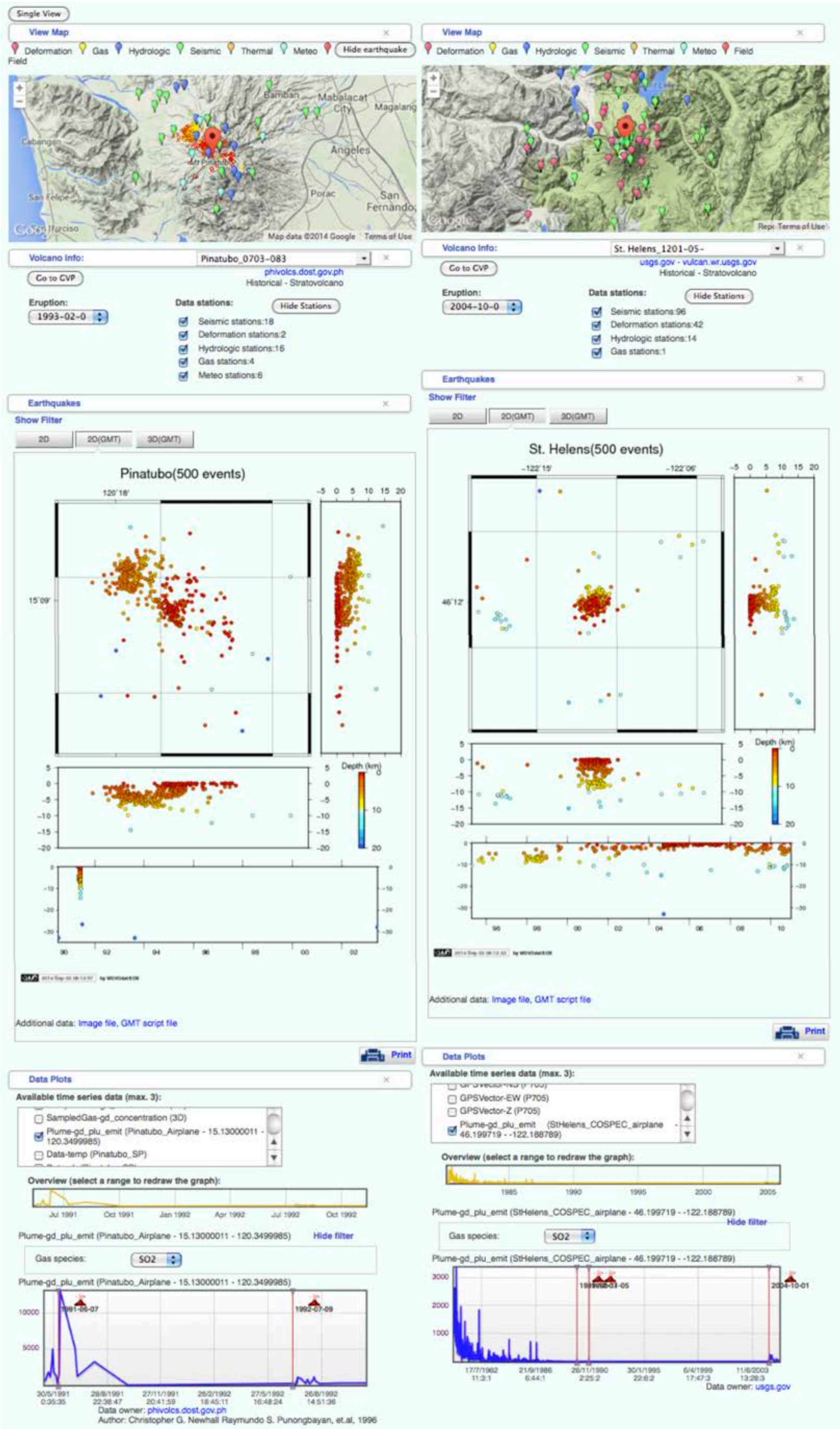

Figure 2. *Example of WOVOdat visualization tool: Data comparison between Pinatubo and St. Helens eruptions.*

Scientific products for the multi-scale seismic hazard and risk assessment in China: present status and future prospects

Zhongliang Wu[a], and the Group for the 13th Five-Year Plan (2016~2020) for Earthquake Monitoring and Forecast of the CEA[a]

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It might be interesting to review the recent activities on earthquake hazard and risk assessment within the China Earthquake Administration (CEA) at the 40th anniversary of the February 4, 1975, Haicheng earthquake. Since that marvelously successful but scientifically controversial prediction and evacuation, it has been recognized that the scientific problems associated with earthquake forecast and prediction are much more complicated than what had been thought in the 1960s. On the other hand, the role of seismic hazard and risk assessment in social sustainability had caused much attention not only in the scientific communities but also in the public. Reflection on the practice of seismic hazard and risk assessment had led to significant developments in the basic understandings of earthquake forecast and prediction as well as the reduction of earthquake disaster risk.

It has been well accepted that earthquake is a type of low-probability high-impact event. In recent years, it has been repeatedly revealed that over-simplified communication with the public regarding to earthquake forecast or prediction plays a minor role in enhancing the resilience of the society against earthquake disasters. One of the solutions to this problem is to rethink seismic hazard and risk assessment in the context of the social countermeasures for the prevention and management of earthquake disasters. For such analysis the scientific products of the CEA are good samples not only because of its official quality-control system but also due to its long-lasting, persistent, organized, and forward-forecasting-and-testing nature.

Earthquake forecast has been conducted persistently in an organized manner in China since the early 1970s. The scientific products associated with earthquake forecast in China have been systemized and developed since the 1990s, which can be (over simply) summarized as follow: 1) The century-scale seismic hazard assessment, in connection to the seismic zonation map, which plays an important role in the engineering countermeasures against seismic strong ground motion; 2) The 10 or 15 year estimation, in the form of the 'Key Regions' for enhanced monitoring and preparedness, which has shown its relatively sound scientific basis and potentials for application for the preparedness, with an example shown in Figure 1; 3) The 3 year estimation of seismic hazard (performance not yet evaluated) and the annual consultation (with hit rate about 20~30%, and statistically outperforming random forecast, with an example shown in Figure 2), which helps the local preparedness; 4) The assessment of the type of earthquake sequence and the likelihood of strong aftershocks, which has relatively sound scientific basis and has played a positive role in assisting the rescue and relief actions as well as the reconstruction; and 5) The case-based evaluation of earthquake forecast and prediction, which has contributed much to avoid the negative effects associated with the non-scientific forecast by some amateur forecasters.

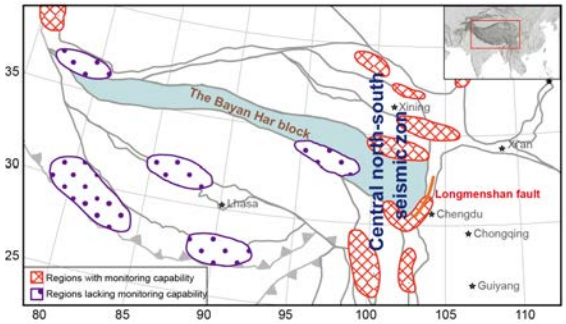

Figure 1 Key regions subject to enhanced monitoring and preparedness, which are estimated as probable for earthquakes over M_S7 in western China (west of 107°E), for the period from 2006 to 2020 (Adapted from the result of the CEA Research Group of 'Researches on Earthquake Risk Regions and Losses Prediction of China Continent from 2006 to 2020'). Gray lines indicate the boundary zones of the tectonic blocks. Note that the south-to-mid Longmenshan fault zone (near Chengdu), which accommodated the May 12, 2008 Wenchuan $M_S8.0$ earthquake, was identified as the key region. Just west to 107°E is the central north-south seismic zone. Indexing figure to the top right shows the location of the map, from which the Tibetan plateau can be clearly seen. Reproduced from: Wu, Z. L. and Ma, T. F., 2014. Chapter 23: The 2008 Wenchuan, China, earthquake. In: Ismail-Zadeh, A., Urrutia-Fucugauchi, J., Kijko, A., Takeuchi, K. and Zaliapin, I. (eds.), *Extreme Natural Hazards, Disaster Risks and Societal Implications*, Cambridge: Cambridge University Press, 301~309.

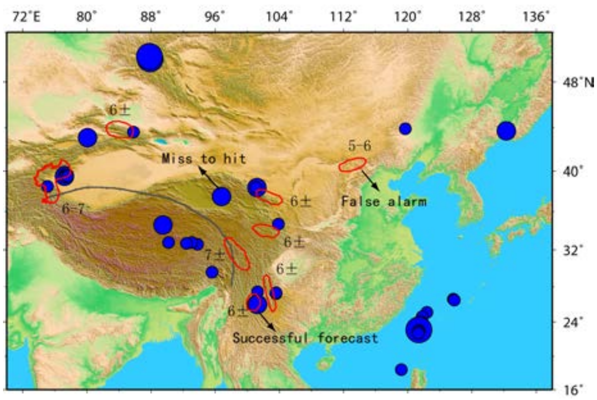

Figure 2 An example of the output of the Annual Consultation Meeting: the Annual Consultation which was held by the end of 2003, for the annual likelihood of 'significant' earthquakes ($M\geq6$ in the west and $M\geq5$ in the east - for example, 6± means that the magnitude of the 'target' earthquake is about 6) in 2004 (marked by the closed red lines, with expected magnitude of the 'target' earthquake). The 'target' earthquakes in 2004 are also shown in the figure by solid blue circles, indicating the successful forecast, the false alarm, and the miss-to-hits, respectively. The gray line around the Tibetan plateau delimitates the regionalized monitoring capability: to the southwest of this line (mainly on the Tibetan plateau) the monitoring capability is low, and the region is not considered in the Annual Consultation. Courtesy of Dr. Fuqiong Huang of the China Earthquake Networks Center (CENC).

Like other countries, earthquake forecast in China suffers from the shortcoming that forecast messages are, in the communication with the public, often directly connected to emergency management such as evacuation, which to much extent limited the functioning of the forecast practice. To move from disaster reduction (DR) to disaster risk reduction (DDR), a transform of paradigm, it is essential to explore the understanding and usage of the forecast information at different spatio-temporal scales so that corresponding countermeasures may be considered.

China has a long history of 'citizen seismology', mainly concentrating on the public participation in collecting the macro-seismic data. With the recent development of economy and society, especially with the application of new technologies associated with the time of 'big data', this field shows new horizon as per the assessment of seismic risk and the preparedness for earthquake emergency.

With the development of economy and society, system construction and capacity building for earthquake disaster resilience become new challenges to the CEA. Meeting such challenges is one of the aims of the 13th Five-Year Plan (2016~2020) of the CEA in designing the next generation of scientific products and the mechanism for these products to serve the society, as well as the system for the evaluation, quality control, upgrading, and development of such scientific products.

Seismological Evidence of Plumping System beneath the Tatun Volcano Group, Northern Taiwan

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The Tatun Volcanic Group (TVG), where is located around the border between two cities (Taipei and New Taipei) in northern Taiwan. Within distances less than few tens of kilometers from TVG, there are about 7 million residents living in the Taipei metropolitan area. Seismological observations at TVG show some interesting results associated with the plumping system in the crust.

First, some very-long-period (VLP) volcanic earthquakes have been detected in TVG. Using both particle motions and travel-time delay recorded at nearby seismic stations, the source of VLP is estimated at the shallow depth (1.5 km) beneath the Chihsinshan, which is the highest mountain and formed at the last eruption in TVG. Synthetic modeling of seismograms indicates that the VLP source was probably generated by a vertical opening crack.

Second, some pre-slip micro-earthquakes were found around 2 seconds before the felt earthquakes in TVG. Careful analyses of seismograms recorded at the dense seismic array show locations of both pre-slip and felt events are almost identical. The pre-slip event along the fracture zone might open the space for the fluid immediately. Thus, the pre-slip event might play an important role to open the door for fluid infiltration into the larger fissures and induce the felt earthquakes. infiltration into nearby larger fissure. The fluid suddenly infiltrate into the fracture or fissure will significantly reduce the friction within it, and then earthquake will be taken place.

Third, some significant travel-time delays were recorded at some seismic stations at TVG. The preliminary results from tomographic image also imply some possible low-velocity zones might exist in the crust beneath TVG.

In short, a plumping system in the crust (Fig. 1) is required for generating the VLP signals, providing fluid infiltration, low-velocity zone and other volcanic earthquakes in TVG. Combining this result with the previous studies, we conclude the TVG might not be totally extinct and some further investigations have to been carried on for improving the understanding of volcanic characteristics in the TVG.

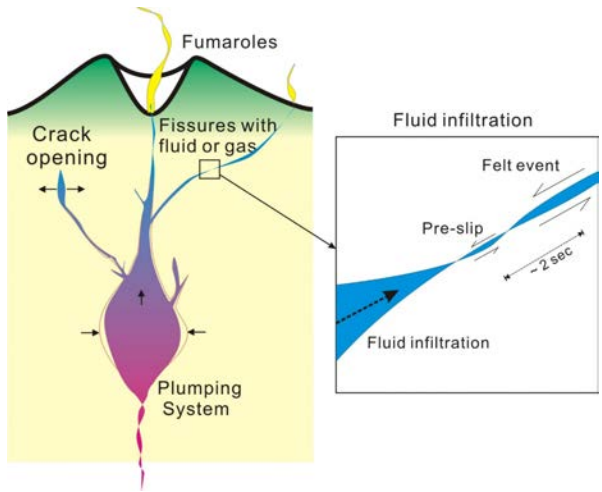

Fig. 1 Schematic plot for showing both crack opening and pre-slips caused by the pressure variation of the plumping system in the upper crust.

Updated Probabilistic Seismic Hazard Maps of Vietnam

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In this paper, the probabilistic seismic hazard maps for the territory of Vietnam and the East Vietnam Sea revised from the existing 2010 ones are presented. An earthquakes catalog updated until 2014 and most recent seismotectonic and geodynamic information of South East Asia were used for delineation of 37 seismic source zones for the whole territory of Vietnam and the East Vietnam Sea area extended to 125^0E. While the Toro et al. (1997) attenuation equation was used for the most seismic sources, the equation developed for the subduction zones by Youngs, Chiou, Silva and Humphrey (1997) was used for the Manila Trench source zone. The hazard maps show distribution of the mean peak ground acceleration (PGA) with a 10%, 5%, 2% and 0.5% probability of exceedance in 50 years. The highest hazard areas were revealed in northwestern part of the country, in Dien Bien – Lai Chau and Son La source zones, with the maximum values of PGA for the 475 – 9975

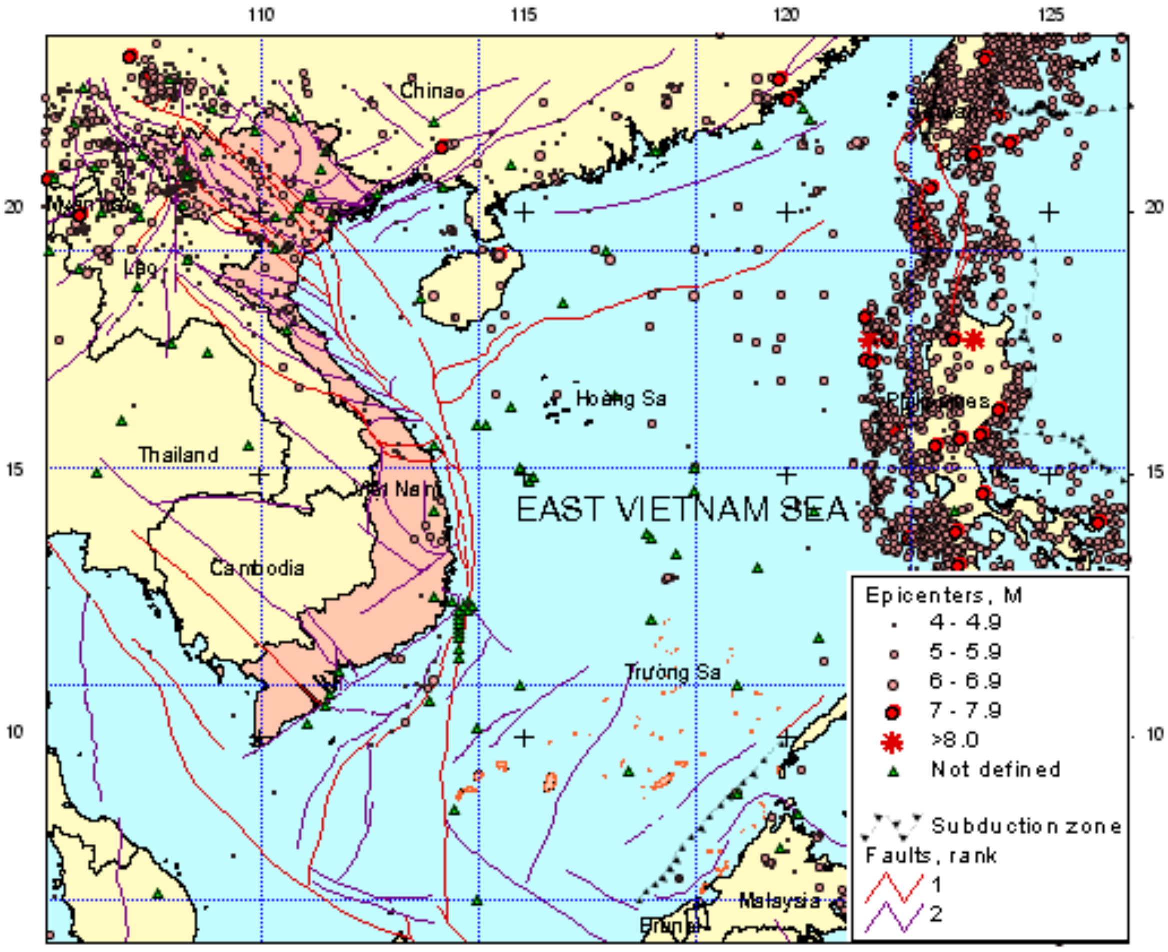

Fig. 1. Seismotectonic map of Vietnam and the East Vietnam Sea. The earthquakes catalog used includes historical events and was updated until 2014.

years periods of 180 – 272 gals; and off-shore Southern Central Vietnam coast, in the 109^0 Meridian Fault source zone, where the maximum values of PGA for the 475 – 9975 years periods are 118-285 gals. These PGA maps present both short-term and long-term forecasts of seismic hazard in Vietnam and the East Vietnam Sea and can be used as a reference for antiseismic design and many engineering applications.

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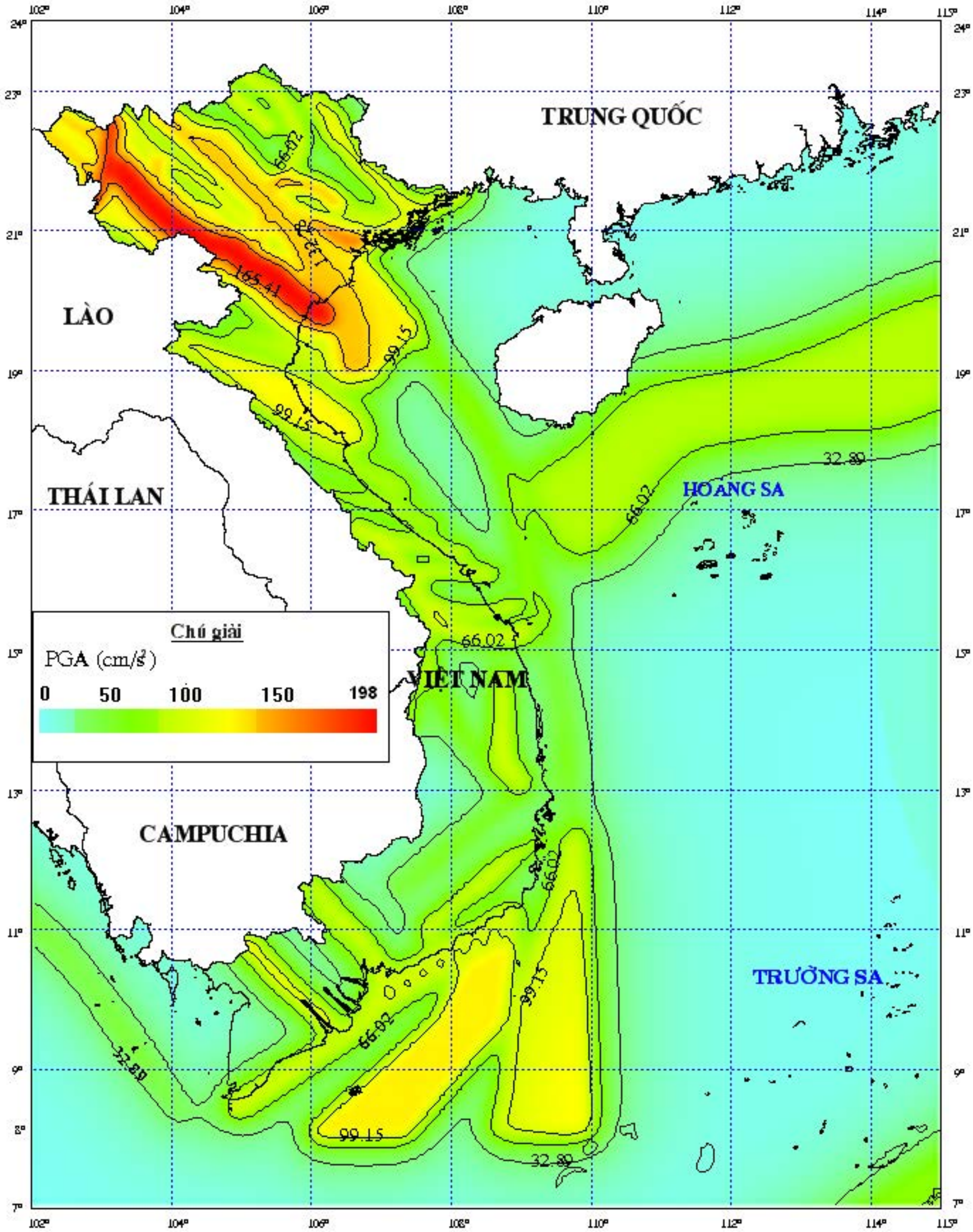

Fig. 2. PGA map of Vietnam and adjacent sea area with 10% probability of exceedance in 50 years.

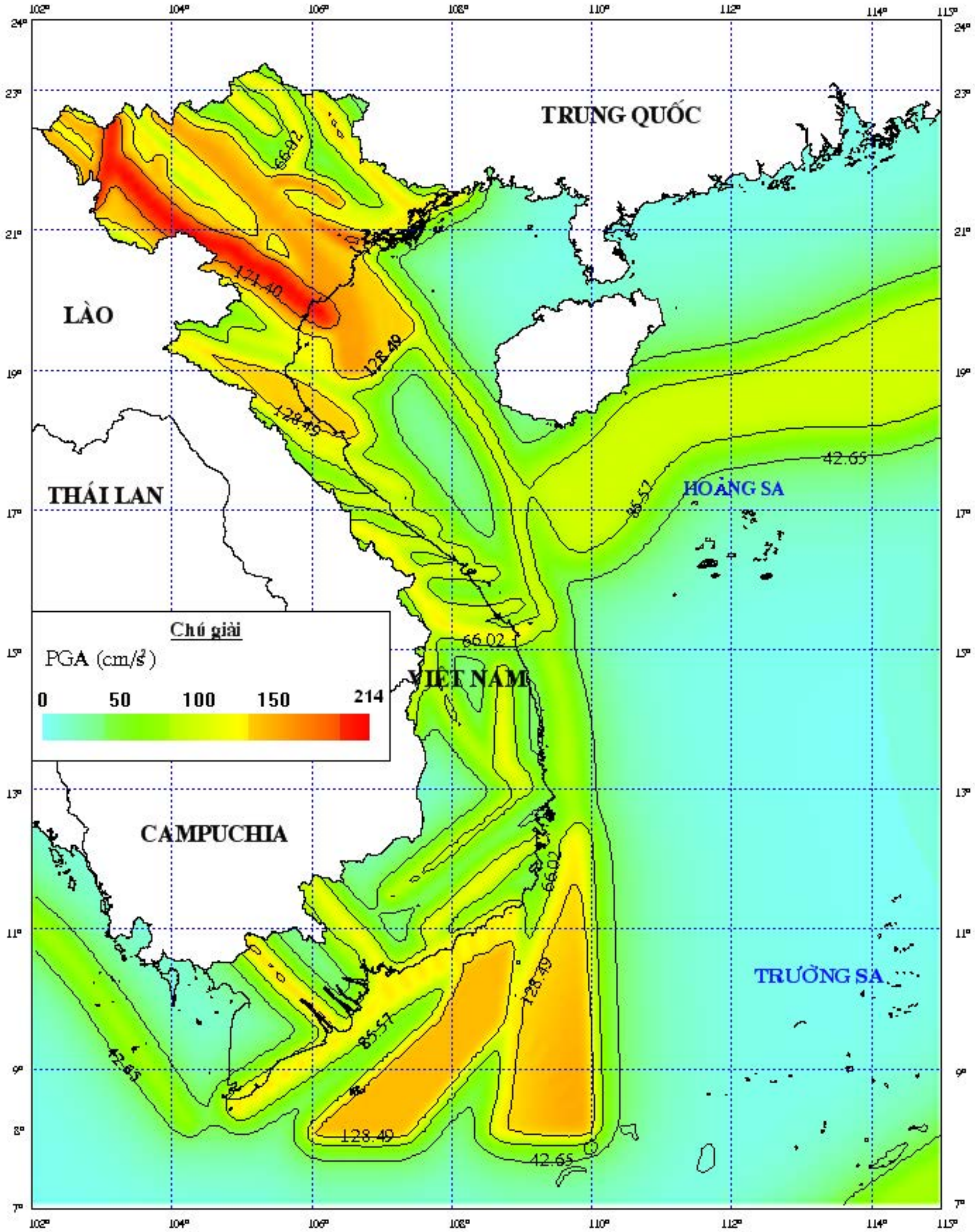

Fig. 3. PGA map of Vietnam and adjacent sea area with 5 % probability of exceedance in 50 years.

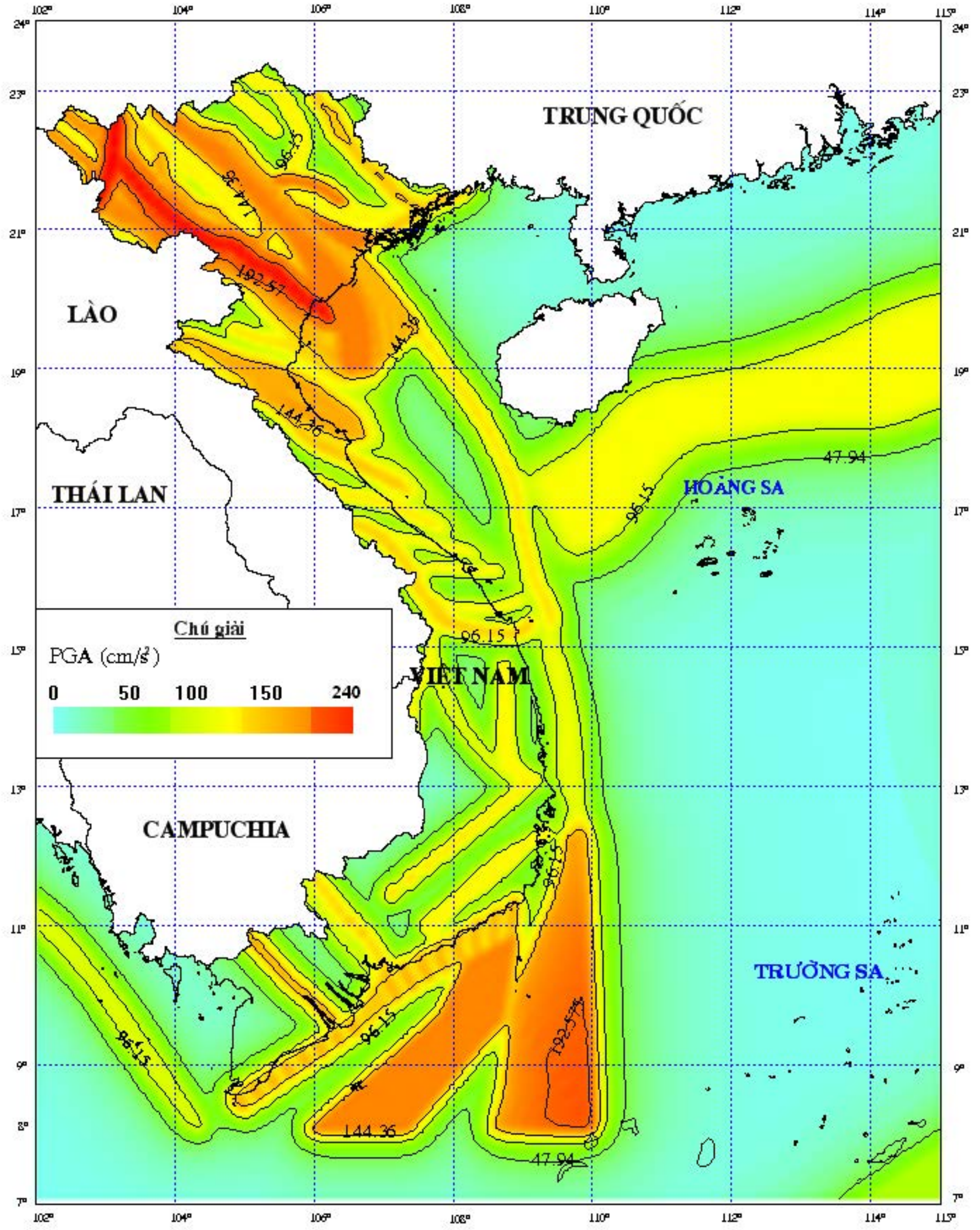

Fig. 4. PGA map of Vietnam and adjacent sea area with 2 % probability of exceedance in 50 years.

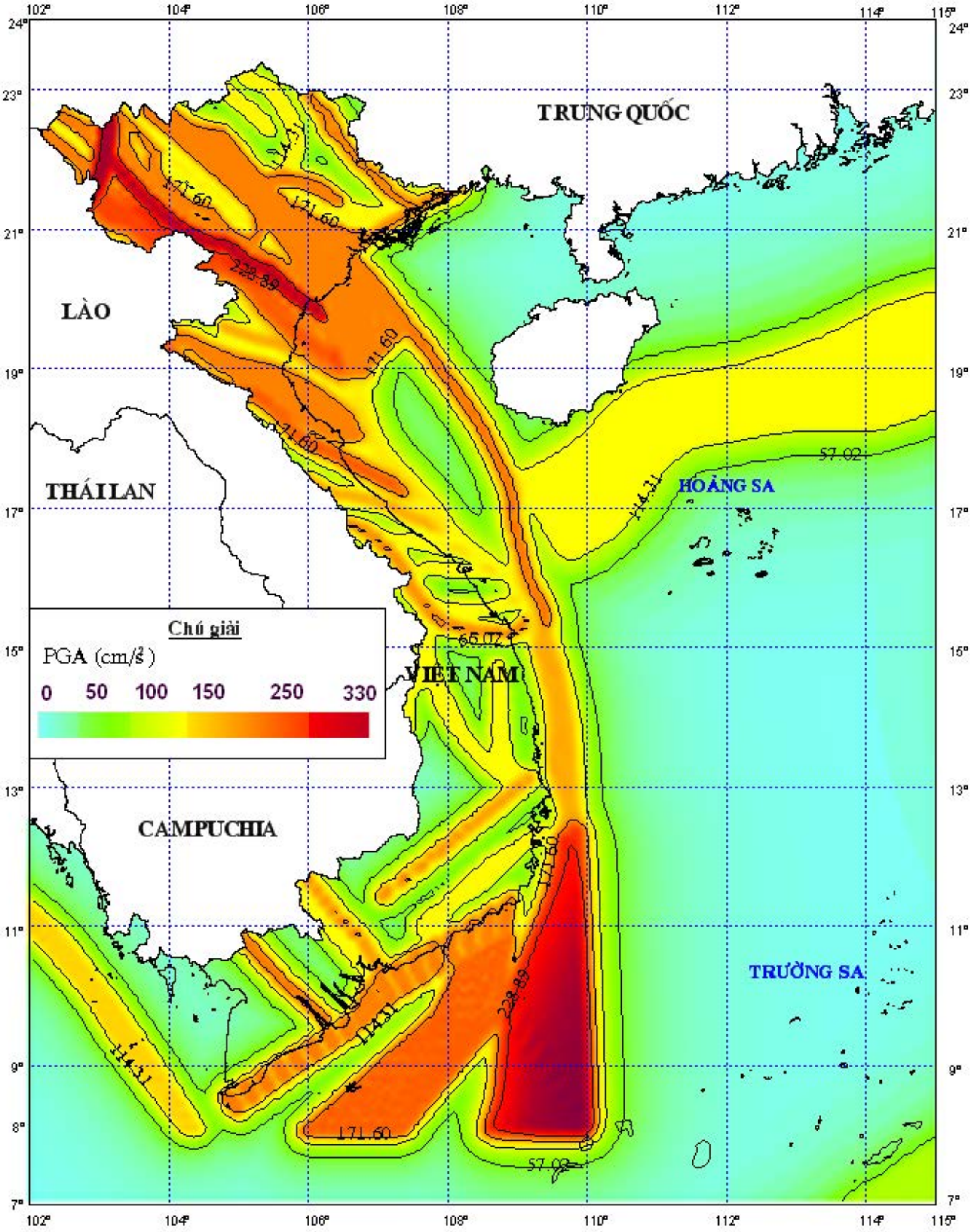

Fig. 5. PGA map of Vietnam and adjacent sea area with 0.5 % probability of exceedance in 50 years.

How can the world learn the lesson from Tohoku Earthquake? : Epistemic uncertainty aspects

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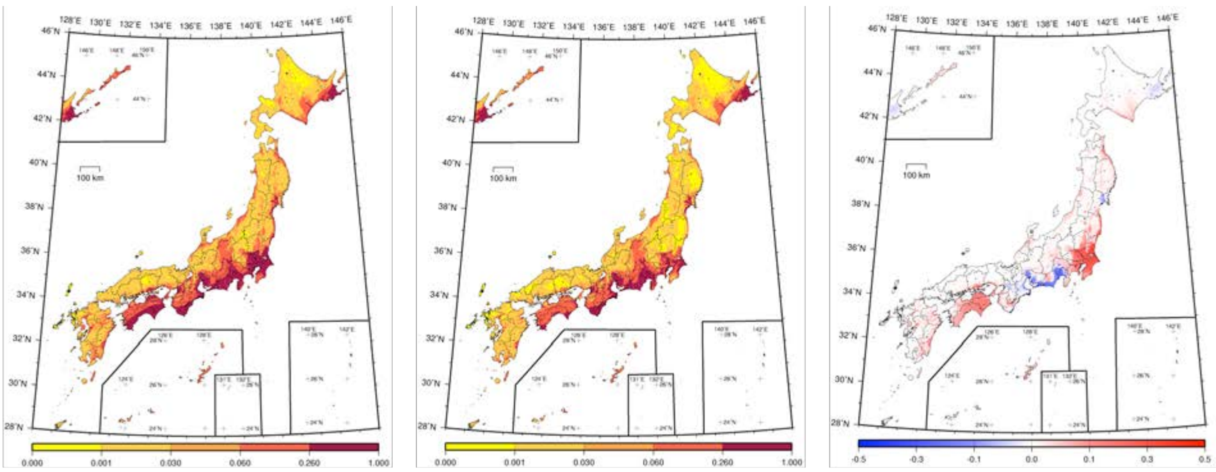
1. Introduction

An M=9 class earthquake had never been considered in the Japanese Seismic Hazard Assessment (SHA) until the 2011 Tohoku-oki M=9 occurred. Tohoku (northeastern Hoshu, Japan) was one of most investigated subduction zones in the world where many earthquake reoccurrence cycles discovered and therefore a renewal model of Brownian Passage Time (**BPT**) was applied to SHA. Seismologists became deeply aware of the SHA's complexity and uncertainty. In order to reduce epistemic uncertainties, several discussion models over three years have been carried out to enrich the epistemic for the SHA.

2. Re-examination of intensity distribution during the Tohoku earthquake

The 2011 Tohoku M 9-class earthquake devastated huge regions but its treasurable kinematic processes of strong ground-motions were first-time captured by more than 1200 K-NET and KiK-net stations. It provided an irreplaceable chance to examine the probabilistic SHA maps from the point view of strong-motion observation. The strong-motion intensities observed in Fukushima (36.6-38N, 140-141E) are larger than the predicted in a return period of 2475 years. The predicted ground motion was then the consequence of the under-estimated maximum potential earthquake magnitude. This complicated issue with epistemic uncertainties brought a challenge to seismological society not only in Japan but also in the world. An on-going long-term evaluation of seismic activity model for Japan has been modified under the authorization by ERC, HERP. By modified calculation (Fujiwara *et al.*,



(a) Modified model (start point 2014)   (b) Ver. 2010 model (start point 2010)   (c) Difference of exceedance probabilities

Fig. 1. Distribution of exceedance probability for the JMA seismic intensity 6- within 30 years, which are accounted from start point 2014 (a), 2010 (b), as well as their residuals (c), after Fujiwara *et al.*, (2014).

2014), we understood that exceedance probabilities would be higher if considered the earthquake type of the 2011 Tohoku earthquake as Ver. 2014 shown in Fig.1 (a), but the Ver. 2010 in Fig.1 (b), was absence this consideration by the epistemic uncertainty.

3. Low probability of earthquakes in long-term return periods

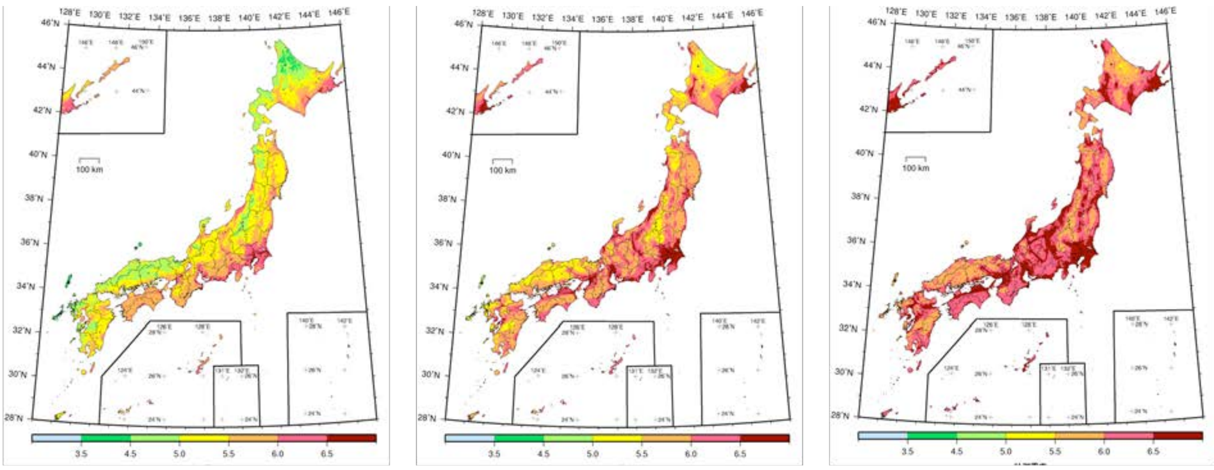
To emphasize urgency of earthquake occurrence by showing time-dependent probabilities, the BPT model was used for seismic regions where detail researches carried out with several hundreds years of historical records. However, epistemic uncertainty may increase largely since we had limited knowledge over thousands years. For earthquakes occurring both in subduction zones and in active faults, it is necessary to model seismicity that the large events can be considered in a long-term return period, say, tens thousands of years. To achieve this goal, we need to model background earthquakes that include a low probability of earthquakes by using the Gutenberg-Richter formula to compensate the long-term evaluation. Based on modeling of Poisson process with averaged occurrence intervals, we evaluated PSHA maps in JMA intensities with consideration of a long-term return period of 1,000, 10,000 and 100,000 years, as shown in Fig. 2 respectively.

The PSHA map for a 1,000-year return period indicates the degree of shaking caused dominantly by subduction zones. The 10,000-year one indicates the degree of shaking caused by not only subduction zone earthquakes but also earthquakes in major fault zones with low frequency. The 100,000-year one shows almost all regions of Japan could be possibly hit by strong shaking of seismic intensity 6- or even large (Fujiwara *et al.*, 2014).

4. Preparation of "Big Earthquake"

The lesson learnt from the under-estimation of possible maximum earthquake magnitude in the East Japan was also extended to the other conjunction subduction zone areas, such as an area of Nankai Trough earthquakes. With a set of mutual exclusive occurrence cases (15 for Nankai Trough), where each case may contain independent seismic sources, the seismic hazard was calculated. We do think what happened in Tohoku most likely occur in the other seismic zones where knowledge may be absent.

With these common motivations and missions, NIED joined Global Earthquake Model (GEM) as a representative of Japan to reinforce the public part of GEM's partnership in 2012. We call for collaborations and supports from public institutions and GEM regional programs to carry



(a) Return period of 1,000 years (b) Return period of 10,000 years (c) Return period of 100,000 years

Fig. 2. PSHA maps in JMA intensity on surface based on Poison process in long-terms, after Fujiwara *et al.*, (2014).

on working for a harmonization SHA map in the East Asia region (CJK, 2011) as well as the Asia region.

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International collaboration for mitigation of volcano hazard in Asia

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1. Collaboration study with Indonesia

Disaster Prevention Research Institute of Kyoto University has collaborated with Directorate General of Geology and Mineral Resources (Present: Geological Agency) of Republic of Indonesia for the study on eruption mechanism and tectonics in Java, Indonesia since 1993. The collaborating project started under the umbrella of IDNDR (International Decade for Natural Disaster Reduction) in 1990s. The project was composed of three operations; 1) enhancement of monitoring capability of Indonesian volcanoes, 2) exchange knowledge of Japan and Indonesia for evaluation of volcanic activity and prediction of eruptions and 3) capacity development of human resources of researching and technical staff levels.

We installed seismic stations at Guntur volcano and tiltmeters at Merapi volcano. Merapi volcano was only the volcano where hypocenter of volcanic earthquake could be determined in Indonesia at that time, the newly installed seismometer pushed up the Guntur volcano to the second upgraded volcano. The hypocenters of volcanic earthquakes were located not only beneath the summit area but also its extension to geothermal field at the western flank of the Guntur volcano. Tiltmeters at the Merapi volcano detected migration of pressure source from deep to shallow parts associated with a new lava dome formation in 1996.

During the collaboration, some younger researchers in Indonesia obtained Master and PhD degree in Japan to study volcanoes both in Japan and Indonesia. In addition, JICA (Japan International Cooperation Agency) provided an educational group training course for volcanology and sediment hazard management by inviting a lot of young staffs engaging at the fields from all over the world, especially Asia-Pacific region.

2. SATREPS projects

SATREPS (Science and Technology Research Partnership for Sustainable Development) is a new bilateral international collaboration scheme funded by both JST (Japan Science and Technology Agency) and JICA. SATREPS adopted two projects to mitigate hazards due to earthquake and volcanic eruption in Southeast Asia; "*Multi-disciplinary Hazard Reduction from Earthquakes and Volcanoes in Indonesia*" (2009-2011: Leader Prof. Kenji Satake) and "*Enhancement of Earthquake and Volcano Monitoring and Effective Utilization of Disaster Mitigation Information in the Philippines*" (2010-2014: Leader Dr. Hiroshi Inoue).

During the period of the preceding projects, the eruption at Merapi volcano in 2010 brought quite large disaster and more than 300 residents were killed by pyroclastic flow running to the distance of 17 km from the summit of Merapi volcano. This eruption was a centennial from the 1872 eruption and was much larger than previous eruptions in 20th century. Center for Volcanology and Geological Hazard Mitigation (CVGHM) upgraded the warning to level 4 one day before the first eruption on October 26 based on accelerating seismicity and ground deformation up to 3 km near the summit, and 71,000 people evacuated before the eruption occurred. However, process of volcanic activity

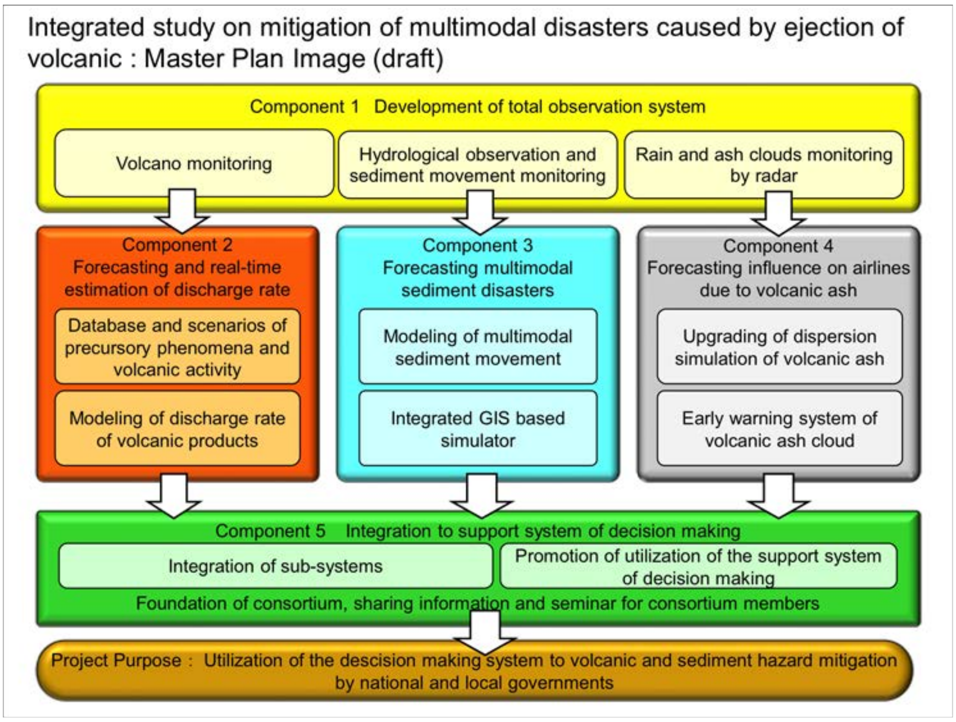

Fig. 1. Master plan of "Integrated study on mitigation of multimodal disasters caused by ejection of volcanic products" under SATREPS

was quite complicated as seen from increase in plume height from November 3, accompanying pyroclastic flow and evaluation difficulties due to loss of monitoring apparatus by the first eruption. Disasters are not only direct movement of pyroclastic flow but also dispersion of volcanic ash and lahars induced by heavy rain later.

Considering such complexity of volcanic eruption and scale dependence of volcanic disaster on volume of eruptive materials, the new project "*Integrated study on mitigation of multimodal disasters caused by ejection of volcanic products*" started formally in 2014. As archipelago country, Indonesia contains over 127 active volcanoes. Volcanic eruptions produce many kinds of material, such as volcanic ash, pyroclastic flow and lava flows. The volcanic products completely destroy their deposit area and volcanic ash is widely dispersed beyond borders of countries. In addition, deposited volcanic ash induces lahars triggered by heavy rain and the lahars cover not only neighboring of volcanoes but also distant place from the volcanoes. Furthermore, the slope of volcanoes is eroded by the lahars and multimodal sediment disaster is induced such as shallow landslide, deep landslide, flush flood and so on. Indonesia is one of the highest risk countries, which are suffered by such multimodal disasters generating by volcanic eruptions. We develop an integrated system to mitigate many kinds of disasters which are generated by volcanic eruptions and extended by rain fall and wind, based on scientific knowledge. The integrated system will be ready to be utilized by national and local governments for mitigation of volcanic and sediment disasters and countermeasure against volcanic ash for airlines. The integrated system is composed of 4 sub-systems. These are; 1) Total observation system to mitigate multimodal disasters induced by volcanic eruptions. 2) Early warning system of volcanic eruptions based on prediction and real-time estimation of discharge rate of volcanic products. 3) Early warning system of multimodal sediment disaster. The main engine of the system is an integrated GIS based simulators for multimodal sediment, 4) Early warning system of volcanic ash. Basic design of the system will be developed at Merapi, Semeru and Kelud volcanoes. The system will be extended to Galunggung and Guntur volcanoes, covering the eruptive activity of Sinabung volcano. The counterparts in Indonesia are Center for Volcanology and Geological Hazard Mitigation (CVGHM), Universitas Gadjah Mada, Ministry of Public Works and Meteorological, Climatological and Geophysical Agency. This project is conducting under collaboration not only volcanologists but also civil engineers and meteorologists.

3. Asian Consortium of Volcanology

After thirty-two years passing from the last IAVCEI (International Association of Volcanology and Chemistry Earth Interior) scientific assembly in Japan, Scientific Assembly IAVCEI 2013 was held in Kagoshima, Japan in July 2013 sponsored by Volcanological Society of Japan (VSJ), Kagoshima Prefecture, Kagoshima City and IAVCEI. A lot of volcanologists (1069) participated in the meeting. In particular, the participants from Asian countries drastically increased. This may be reflected by increase in necessity for volcanology and research for volcano hazard mitigation in Asia, in addition to geographical convenience from the Asian countries. Following the Scientific Assembly 2013 IAVCEI, CoV (Cities on Volcanoes) 8 was held in Yogyakarta, Indonesia in September 2014. CoV aims to provide a linkage between the volcanology community and emergency managers, to serve as a conduit for exchange of ideas and experience between "volcano cities", and promote multi-disciplinary applied research, involving the collaboration of physical and social scientists and city officials. Yogyakarta is the second city hosting CoV in Asian countries, after CoV5 in Shimabara in 2007 and the CoV models Kagoshima International Volcano Conference 1988, which was the first conference joined by not only volcanologists but also authorities of decision making and residents on volcanoes.

In Asian countries, especially Indonesia, Philippine and Japan, many residents live very close to presently or potentially active craters, facing violent volcanic hazard. Coexistence with volcanoes is a problem to be solved through our sustainable developments in Asia. Considering necessity of researches on volcanology and mitigation from volcano hazard in Asia, VSJ proposed foundation of “Asian Consortium of Volcanology” (ACV) to CVGHM, EOS (Earth Observatory of Singapore), PHIVOLCS (Philippine Institute of Volcanology and Seismology) and other institutes in Asia in September 2014. We agree as follows; 1) ACV shares the scientific and technological knowledge in volcanology. 2) ACV shares the experiences of volcanic disaster and strategies of hazard mitigation. 3) ACV encourages young volcanologists through the scientific lectures, trainings and projects. 4) ACV promotes collaboration with the international projects and databases. 5) ACV holds annual workshops. 6) VSJ, CVGHM, EOS and PHIVOLCS are the core-organizations of ACV, and host the activity of ACV by turns. ACV mainly focuses on the development and sharing the knowledge among young volcanologists through lectures and training courses; geophysical, geochemical and geological monitoring technique, geological data sampling, data processing, numerical simulations, database management and interpretations. ACV could be one of the most effective ways to solve a large concept of G-EVER.

The Development of Tsunami Trace Database on the Coast of Japan

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The purpose of this research is to develop the Tsunami Trace and the Source Database by collecting historical materials and the previous tsunami source models of tsunamis that arrived or attacked Japan, and concerning the reliability of the tsunami trace and the related data.

The database was designed by JNES (currently, NRA) and International Research Institute of Disaster Science (IRIDeS), Tohoku University seven years ago, 2007 fiscal year. The Database Review Committee that consists of experts in tsunami engineering, seismology, geology and history of Japan after the medieval period had collected historical materials of tsunami and tsunami source models previously.

The system is based on the analysis results and the necessary functions for utilizing the database system as a platform in order to collect and deliver tsunami trace data and fault parameter of tsunami source model. The database except for the tsunami source model has been open to public on internet since 2011. This database is expected to be used effectively for tsunami assessment and general tsunami disaster prevention, and also in the field of nuclear seismic safety.

Acknowledgment: The authors of the present study wish to express their thanks to JNES currently known as NRA for its financial support in promoting our research.

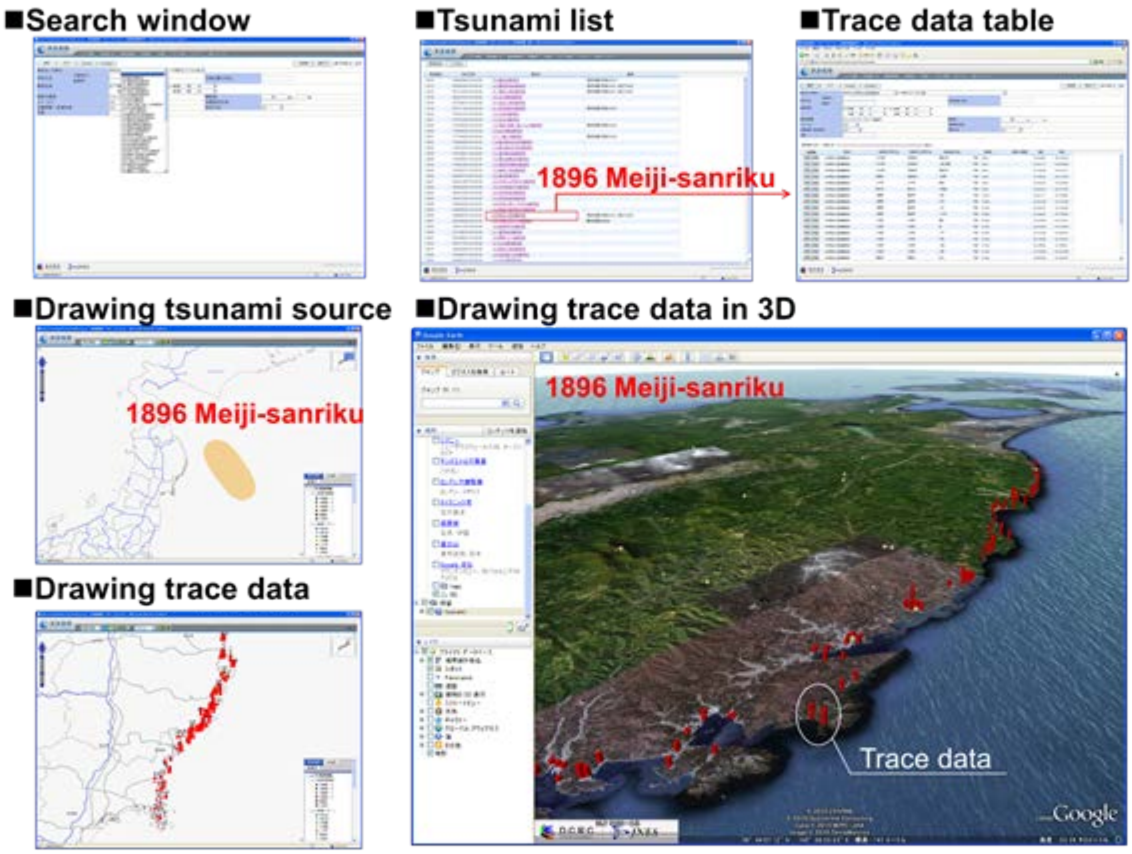

Fig.1. Schematic of the tsunami trace database.

Try to draw the volcanic eruptions and earthquake activity in the same figure: (part 1) in and around Japan

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1. Introduction

The relation between the volcanic eruption and the occurrence of large earthquakes were well known. It was the famous eruption of Mt. Fuji in 1707 in Japan. It was followed 49 days after the occurrence of M9 Hoei earthquake. The 2004 Sumatra M9 earthquake followed some eruptions, too. But 2011 off Tohoku, Japan M9 earthquake did not follow eruptions, yet. The seismicity was commonly analyzed in time and space, using several database, for example ISC and PDE catalogs. But the data of volcanic eruptions were not popular and needed to analyze the relation.

2. Data of volcanic eruptions

The data of eruptions in and around Japan was inputted in order to search the relation between eruptions of volcanoes and occurrence of large earthquakes. The database of the Global Volcanism Program by Smithsonian Institute (http://volcano.si.edu/) was adopted. The histories of volcanoes of Onkakesan, Asosan, Kuchinoerabujima, Nishinoshima, Izu-Torishima, Kikai, loto, Kirishimayama, Miyakejima, Fukutoku-Oka-no-Ba, Asamayama, Akan, Suwanosejima, Tokachidake, Kita-loto, Hokkaido-Komagatake, Toya, Niigata-Yakeyama, Akita-Yakeyama, Adatarayama, Unzendake, Minami-Hiyoshi, Kujusan, Yakedake, Izu-Oshima, Izu-Tobu, Kusatsu-Shiranesan, Myojinsho, Kaitoku Seamount, Fukujin, Shikotsu, Nikko, Azumayama, Kasuga, Izu-Torishima, Sofugan, Chokaisan, Io-Torishima, Nasudake, Kita-Fukutokutai, Aira, Nikko-Shiranesan, Kurikomayama, Nakanoshima, Akagisan(no), Shiretoko-lozan, Iwatesan, Submarine Volcano NNE of Iriomotejima, Akita-Komagatake, Maruyama, Bandaisan, Esan, Midagahara, Fujisan, Yokoate-jima, Kuttara, and (Smisujima) were checked and only 'Confirmed' eruptions were adopted.

The format of eruption data is same as the hypocenters’. The location of the volcano, not craters, is the epicenter. The height of volcano is minus depth in 10m of hypocenter, and the volcanic explosivity index (VEI) is used as the magnitude of the earthquake. The origin time is the date of the eruption and is assumed on 00:00:00 time. The eruption was assumed every day from the start of the eruption to the end. If the start date and the stop date were only known in year, Jan. 1 was assumed for the start day and Dec. 31 for the stop date. If there was no information of the stop date, only the start date was inputted. Totally more than 153,000 eruptions were inputted from AD 20 to 2014.

3. Discussion

Mixing this data and earthquake catalog, we can get some relations between eruptions and earthquake occurrences. One is that the 1922 M7.6 earthquake in Okinawa followed VEI 4 eruption near the Miyako island in 1924. The other is some large earthquakes occurred before and after the large eruptions in NE Japan in 17 century. Fig. 1 and 2 show such relations.

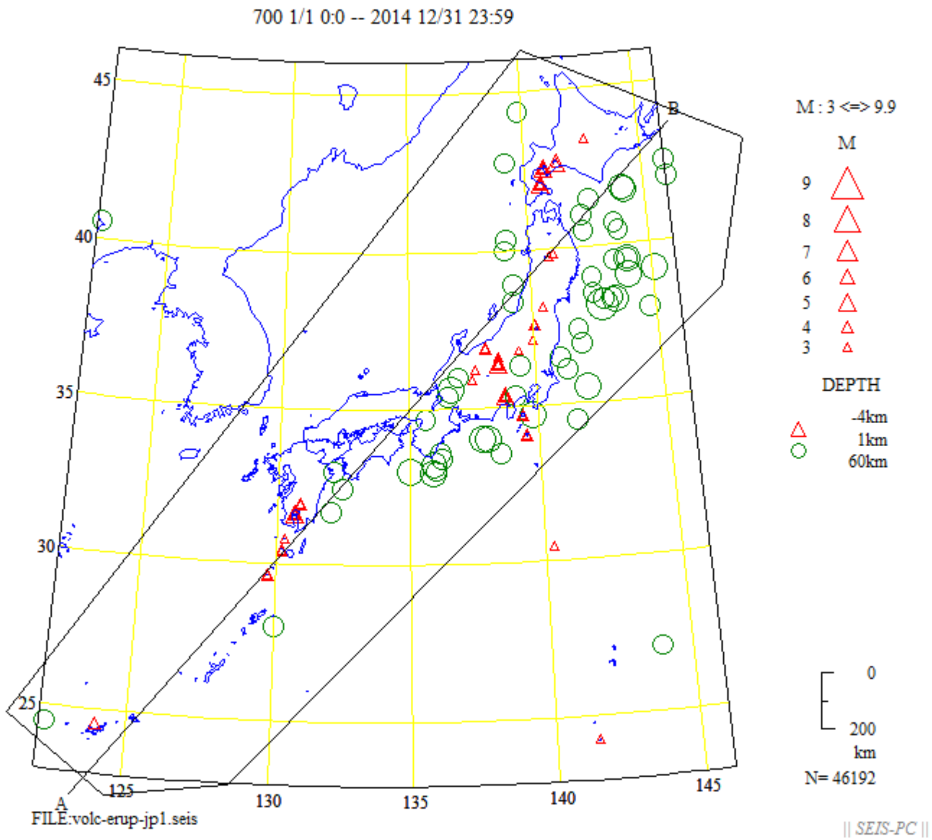

Fig. 1 Distribution of large shallow earthquakes (M>=7.5, D<=60km) and volcanoes which erupted bigger and equal to VEI 3 in this period (AD 700 -2014). Open circles show epicenters and triangles show eruptions.

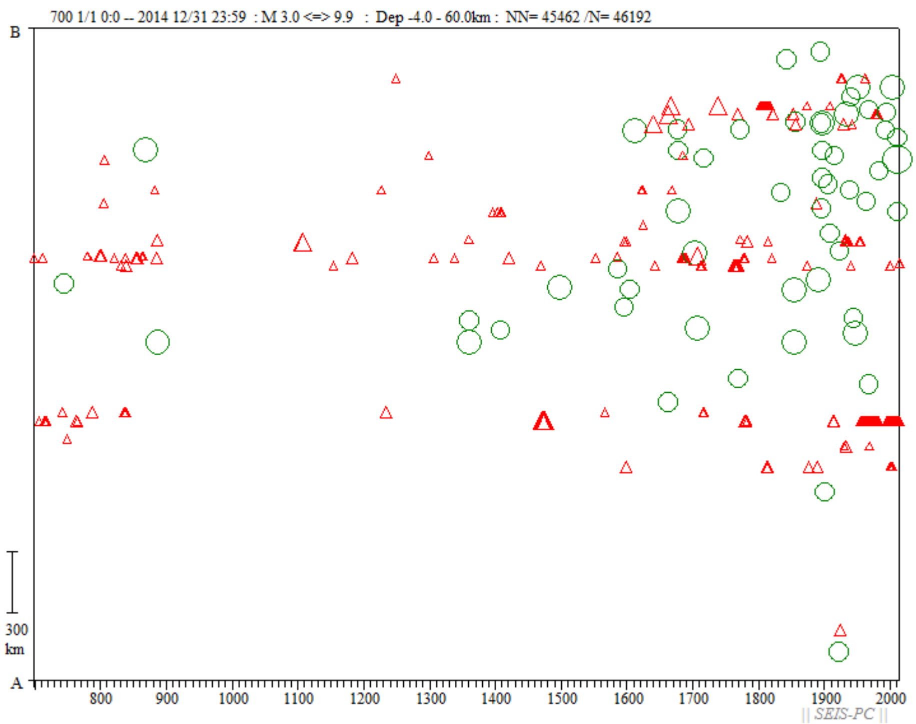

Fig. 2 Time space distribution of epicenters and volcanoes in the area in Fig.1. The horizontal axes show year (700 – 2014). Upper side is NE in Fig.1.

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Caldera forming eruptions and their characteristics of preceding activities during the last 1000 years in Sunda Arc, Indonesia

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1. Introduction

Caldera-forming eruption is the largest eruptive phenomenon in the volcanic area and can causes huge direct damages on life and earth environment by pyroclastic fall and flow with subsequent lahar, tsunami, and short-term climate change. Duration of damages are generally very long as 1-10 years for climate, ocean, food, human health (epidemic), traffic, and buildings, however 100-1000 years for land use. Risk against a large magnitude eruption also increases with the advancement of civilization and the increase of population on earth. Recent population of the earth is five times larger or more than those of 10th century which suggests increasing risk in the future.

Caldera-forming eruptions have occurred at least 5 times during last 1000years in eastern - southeastern Asia as Baitoushan 10th century (North Korea/China), Rinjani 13th century (Indonesia), Tambora AD 1815 (Indonesia), Krakatau AD1883 (Indonesia), and Pinatubo AD1991 (Philippine) while the latest caldera-forming eruption (Kikai) has occurred ca. 7000 years before in Japan. As Indonesia has suffered frequent caldera-forming eruptions and 50% of the total casualty of volcanic hazard within the last 300 years comes from caldera-forming eruptions in Indonesia.

GSJ and CVGHM have been involved from 1996 to perform cooperative volcanological research to study caldera-forming eruptions by geological method and to find evaluation and forecasting measure of large-magnitude and low-frequency hazards. We have already treated caldera volcanoes of Tambora, Rinjani, Batur, Bratan and possible area of caldera-formation in the future in the sense of geology.

2. Volcanic activity along Sunda Arc

Quaternary volcanoes of Indonesia are mostly lying on an island-arc system of 6000 km long mainly of the Sunda Arc. Active volcanoes are at least 127 and 68 are very active as A-rated. 74 volcano observatories are monitoring 24 hours a day to detect preceding anomaly of the eruption and geological hazard.

3. Caldera-forming eruption in last 1000 years

Our result of geological survey and previous studies are summarized below especially focusing on the eruptive activities before caldera-formation.

Tambora : Tambora volcano which was originally 4000 m high shield volcano composed of mafic lavas and pyroclastics have erupted enormous pyroclastic resulting caldera collapse in 1815 . Pyroclastic flows covered the half of the volcano, air fall spread westward. Four kingdoms disappeared. The total victims including starvation amount to 92,000. Geological studies revealed long-term eruption rate ranges 3-6 km^3/1000 years which remarkably decreases before caldera formation (ca. 0.05 km^3/ 1000years in last 4000 years: Takada and Yamamoto, 2008). Vent location has been confined to specific area and magma composition changed from mafic into felsic. Eruption style also changed from effusive (lava flows) to explosive (sub-plinian).

Krakatau: Volcanic islands of Krakatau were parts of caldera rim formed by older caldera-forming eruption. Extensive fumaroles had occurred in wide area inside the caldera-rim and relatively small eruption occurred from 4 months before climactic eruption and intensity of the each eruption increased (Rampino and Self, 1981). Climactic eruption is characterized by 38 km of eruption column height and tsunamis caused by pyroclastic flow resulted 36000 casualties. Enormous volume of fine ash ejected into atmosphere and strong glow of sunrise and sunset have been observed in northern hemisphere (Simkin and Fiske, 1983).

Rinjani: Caldera of 6km in diameter formed on the western foot of stratovolcano located on the Central Lombok Complex (Takada et al., 2003). Eruptive age dedicated from ice core sulfuric acid suggests the large amount of volcanic gas penetrated into atmosphere from equatorial volcano. Major element composition of glass shards have mostly identical to those of pyroclastic fall and flow deposits surrounding the caldera. Geological studies also revealed long-term eruption rate were more than 1 km^3/1000 years which remarkably decreases into 0.15 km^3/ 1000years in last 5000 years before caldera formation (Takada et al., 2003). Vent location has moved to the east and magma composition changed from mafic into felsic. Eruption style also changed from effusive (lava flows) to explosive (plinian).

4. Summary

Our geological studies allows us to conclude caldera-forming eruption has long-term precursory transitions in eruption rate, eruption style, vent location, magma composition in case of caldera formed at stratovolcano. Recently we are aware of large and inactive dormant volcanoes in central Java region. Now we are trying to clarify the long term eruptive history and characteristics of eruptives of central Java volcanoes to compare the previous caldera volcanoes in Indonesia and the world.

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Observation of groundwater and crustal deformation for forecasting the Tokai, Tonankai and Nankai earthquakes in Japan

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1.Introduction

Along the Nankai and Suruga troughs, large earthquakes about magnitude 8 (M8) or more have been occurred at intervals of 100 - 200 years. Recent events were the 1944 Tonankai (M7.9) and the 1946 Nankai (M8.0) earthquakes along the Nankai trough after 90 - 92 years from the 1854 Ansei Tokai (M 8.4) and Nankai (M 8.4) earthquakes, whereas no earthquake has occurred along the Suruga trough since 1854. This anticipated earthquake is referred to as "Tokai earthquake", and the Japanese Government has been continuing an earthquake prediction program for the anticipated Tokai earthquake since 1978. Japan Meteorological Agency (JMA) is responsible for the prediction of the Tokai earthquake. Geological Survey of Japan(GSJ), AIST has been monitoring groundwater in and around the Tokai area since the late 1970's to contribute to the prediction of the Tokai earthquake.

2.Groundwater observation and analysis for forecasting the Tokai earthquake

JMA assumes a slow slip to occur in the expected focal region just before the Tokai earthquake. It is called the pre-slip. We evaluated the detectability of inferred groundwater level/pressure changes caused by different assumed pre-slips. We confirmed that the groundwater level/pressure changes caused by some of the pre-slips can exceed the usual noise level at some of our wells prior to the Tokai earthquake. This was the first attempt to evaluate detectability of hypothetical preseismic groundwater level/pressure changes based on a plausible physical mechanism (Matsumoto et al., 2007).

3.Observation of groundwater and crustal deformation for forecasting the Tonankai and Nankai earthquakes

GSJ, AIST has also established sixteen observatories in and around the focal regions of the Nankai and Tonankai earthquakes to monitor groundwater and crustal strain since 2006. Each of the new observatories has three observation wells, typically, 30-,200- and 600-m deep. Groundwater level/pressure is observed at each of the wells, and a multi-component borehole strainmeter is deployed at the bottom of either the 600-m-deep well or the 200-m-deep well. We expect to observe changes in crustal strain and groundwater level/pressure associated not only with the pre-slips but also with the short-term slow-slip events (S-SSEs) , which are accompanied by non-volcanic tremors on the plate boundary. As those S-SSEs, which are similar to the pre-slip, occur repeatedly on the plate boundary of the Nankai trough several times per year, observation data during the S-SSEs can be easily obtained and yield information useful for understanding the plate boundary and making progress in forecasting the large earthquakes on it.

We already observed the strain changes caused by the SSEs (Itaba et al., 2010). Kitagawa and Koizumi(2013) also detected the S-SSEs-induced groundwater pressure changes for the first time in the world. It means precise observation of strain-sensitive groundwater can detect S-SSEs. This can magnify the observable area for detecting S-SSEs throughout the world because observation of groundwater is more popular than that of crustal deformation.

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Variability of slips at point on fault in each of successive surface-rupturing earthquakes: examples from paleoseismology of surface ruptures in recent inland earthquakes in Japan

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Paleoseismology provides unique on-fault rupture histories. The paleoseismological data such as timing and slip magnitude for the past surface-rupturing earthquakes has been used as basic input for the long-term evaluation of active faults. A large number of paleoseismological investigations have been conducted for the major active faults in Japan, especially after the 1995 Mw 6.9 devastating Hyogo-ken-Nanbu (Kobe) earthquake because it occurred by rupture of the previously identified Nojima active fault. However, how slip magnitudes at a given point on fault vary in each of successive surface-rupturing earthquake events, which is fundamental for understanding the long-term behavior and evaluating the capability to capture history of surface-rupturing earthquakes, is still poorly known. In the past decade, several damaging inland earthquakes accompanied by surface ruptures occurred in Japan. Since the surface ruptures that appeared in those earthquakes provide the reliable references for assessing the repeatability of slip magnitude in the successive surface-rupturing earthquakes, we have performed paleoseismic studies containing trenching and geomorphic mapping for the surface ruptures associated wit the 2004 Mw 6.6 Niigata-ken-Chuetsu (Mid-Niigata) earthquake, the 2008 Mw 6.8 Iwate-Miyagi Nairiku earthquake and the 2011 Mw 6.6 Fukushima-ken Hamadori (Iwaki) earthquake.

The 2004 Mid-Niigata earthquake, which caused severe damage in Chuetsu region, produces small and short reverse faulting surface rupture with maximum vertical offset of about 20 cm on the northern extension of the previously mapped Muikamachi-bonchi-seien fault. A trench across the 0.1-m-high surface rupture that occurred at the basal part of pre-existing 2-m-high fault scarp exposed the clear evidence for three surface-rupturing earthquake events containing the 2004 event. The 10 cm small slip of the 2004 event is clearly defined by discrete slip reaching to the present soil. Slip amount of the previous two events, which are measured by stratal offset and thickness of colluvial wedge, are one order larger than that of the 2004 event. Although several faults with small displacement were observed, compelling evidence for older events with small slip like the 2004 event was not found in the trench. However, we could not preclude the possibility of existence of missing small slip events because it is difficult to distinguish the primary slip associated with the small slip event from the subsidiary slips of large slip faulting event. If such missing small slip events that have potential to generate the moderate earthquake as similar to the 2004 event do exist, paleoseismic data might underestimate in terms of frequency of damaging earthquakes.

Similar variable rupture behavior has also been observed on the surface rupture of the 2008 Iwate-Miyagi Nairiku earthquake, which caused severe damage in infrastructures in mountain areas due to extensive earthquake-induced landslides. The earthquake produces the scattered reverse surface ruptures that extend for about 20 km, which occurred where active faults are not mapped before the earthquake. On the middle part of the surface rupture, a distinct back-thrust rupture with 0.1 to 0.2 m of vertical offset was emerged in addition to the main thrust rupture. Three trenches on the central part of the surface rupture (a trench across the main thrust rupture and two trenches across the backthrust) exposed evidence for previous events that have slipped remarkably larger than the 2008 event. Notably, we could not detect the 2008 event in the stratigraphy in one of the trenches, which implies that the small surface slip in 2008 event is partly lower than a threshold for preservation of paleoseismic evidence and thus representing that the trenching may not always capture the damaging earthquakes that accompanied by surface faulting.

The 2011 Iwaki earthquake, which was triggered by a gigantic 2011 Great Tohoku earthquake, generated distinct normal faulting surface on the sub-parallel Itozawa and Yunodake faults, both of which have been mapped as presumed active faults. The linear surface rupture with generally larger than 1 m of vertical offset (maximum vertical offset of 2.1 m) was observed on the Itozawa fault. Post earthquake geological investigations by several research groups containing paleoseismic trenching and densely spaced boreholes across the surface rupture and comparison of pre- and post-earthquake high-resolution topographic data revealed that the surface slip in the preceding event is significantly small compared to the 2011 event for the Itozawa fault. This result suggests that some active faults might rupture accompanied by larger slip than paleoseismically determined slip magnitude in the future event. Taken together, near surface rupture behavior of active fault is rather complicated spatiotemporally having the significant slip variability from event to event based on the paleoseismic investigations of the surface ruptures appeared in the recent inland earthquakes in Japan. In addition, it is obvious that the preservation of paleoseismic evidence largely depends on the many factors such as sedimentation rate, local stratigraphy, and deformation style of the fault.

For these, we should note that paleoseismic data underestimates the frequency of large- to moderate-sized earthquakes in some cases and further paleoseismic study is required to assess the completeness (or incompleteness) of paleoseismology in capturing the history of surface-rupturing earthquakes.

Data collection for estimation of surface deformation by faulting

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1. Introduction

Surface deformation of shallow earthquake can cause severe damage to our society. It deforms or collapses structures such as dam, bridges, or buildings above the fault with permanent displacement, which leads to network damage of transportation, water supply, sewage, and drainage. Large inland earthquakes of the 1999 Chu-Chu earthquake, Taiwan, and the 2008 Wenchuan earthquake, China, are remarkable examples of how surface ruptures affect structures.

As, in our country, active faults are densely distributed and a lot of important infrastructures such as highways and railroads are running on or across them, it is quite important to estimate surface deformation associated with future earthquakes in order to take effective countermeasures for resilient society.

2. Data needed to estimate surface deformation

Paleoseismological and geomorphological studies on active faults have provided large amount of data of deformation history. These include location of faults on surface or depth cross-sections, accumulated displacement during several thousand to million years, or event deformation. They have already been assembled in databases and used as fundamental resources for activity evaluation of the active faults.

In addition to those datasets, more information must be incorporated for reliable deformation estimation (including its location) of the next earthquakes. These include high-resolution digital elevation model and shallow/deep reflection data across an active fault to know precise location of the fault tip along the active fault, and mechanical property such as soil test data of the medium sediments where rupture propagates.

Medium models with soil properties have been developed for deformation study by compiling soil tests and cross-section data. Also, deformation field are to be retrieved from assembled dataset.

It is also important to obtain event data when a rupturing earthquake occurs. We have collected deformation data during three domestic inland earthquakes with apparent surface ruptures: 2008 Iwate-Miyagi inland earthquake (Mw 6.8), 2011 Iwaki earthquake (Mw 6.6) and 2013 Northern Nagano earthquake (Mw 6.2).

3. Numerical study and future efforts

Numerical simulations of faulting, rupture propagation and fault detection from surface deformation pattern are key techniques to be developed. For example, as rupture (or share band) propagation in the sediments is nonlinear phenomena, numerical codes of 2-d, 3-d discrete element method and finite element method have been applied to obtain results consistent with experimental studies on fault deformation.

Future studies will include numerical simulation of specific target using collected dataset.

G-EVER Asia-Pacific Region Earthquake and Volcanic Hazard Information System and the CCOP Geoinformation Sharing Infrastructure for East and Southeast Asia

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The G-EVER Asia-Pacific Region Earthquake and Volcanic Hazard Information System was developed to mitigate the risk caused by the occurrence of seismic and volcanic eruption hazards in the Asia-Pacific region. The system provides relevant historical, recent and near real time information about earthquake, tsunami and volcanic eruption occurrences in the region. It also provides information for risk assessment analysis. The system is designed to be highly accessible and user-friendly through the use of Web-based Geographic Information System (Web-GIS). The system uses Free and Open Source Software (FOSS) and Open Geospatial Consortium (OGC) standards. The URL of the system is http://ccop-geoinfo.org/G-EVER/. Related to the aforementioned system is the CCOP Geoinformation Sharing Infrastructure Project of East and Southeast Asia. The project aims to develops an information system that provides the framework for the sharing of geoscience information among the countries in East and Southeast Asia. The information include geology, geological hazard, ground water, mineral resources, magnetic anomaly and geophysical data, and carbon dioxide storage maps. The major components of the information system are the data upload and database entry, web services formulation and Web-GIS portal generation. The system also uses FOSS and OGC-based standards. The web services formulation component provides interface for the users to freely develop their own spatial information processing and query functions. On the other hand, Web-GIS portal generation gives users the option to develop their own customized Web-based information system to view the shared spatial data content. It also provides user interface for spatial data query and processing. The URL of the current version of the system is http://ccop-geoinfo.org/GeoPortal/.

Earthquakes, tsunamis and volcanic eruptions are the most destructive natural phenomena frequently occurring in the Asia-Pacific region. The Global Earthquake and Volcanic Eruption Risk Management (G-EVER), a consortium among the geohazard research institutes in the Asia-Pacific region, was established in 2012 with the main objective of formulating strategies to mitigate the risks caused by aforementioned hazards (Takarada et al., 2014). One of the projects of the consortium is to develop an advanced hazard information system that is highly accessible and easy to use, cost efficient and conforms to an internationally accepted standards. Specifically, the information system will be developed using Free and Open Source Software (FOSS) and Open Geospatial Consortium (OGC) standards. OGC standards are technical documents that detail interfaces or encodings that software developers use to build open interfaces and encodings into their products and services (OGC, 2012a). The use of OGC standards and FOSS makes this information system cost efficient and interoperable. The developed system is called the Asia-Pacific Region Earthquake and Volcanic Hazard Information System. It is an advanced Web-based Geographic Information System (WebGIS) using FOSS and OGC standard. The system provides information about earthquake, tsunami and

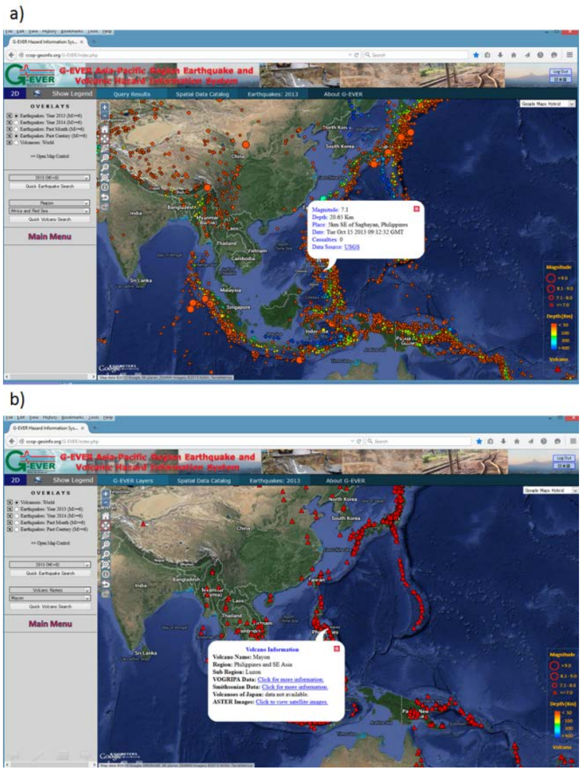

Fig. 1. The G-EVER Asia-Pacific Region Earthquake and Volcanic Hazard Information System showing (a) earthquake epicenters for the past 100 years and (b) volcano locations in the Asia-Pacific region (http://ccop-geoinfo.org/G-EVER/index.php).

volcanic eruption with an interactive and user-friendly interface. It could also be used as risk assessment tool through its Web Map Service (WMS) and Web Processing Service (WPS). Information about past and recent major earthquakes and volcanic eruptions, tsunami inundation areas and active faults distribution could be easily queried and displayed using the system (Fig. 1). Links to major earthquakes and volcanic eruptions databases are also available.

The CCOP Geoinformation Sharing Infrastructure Project of East and Southeast Asia (GSi) is a project implemented by the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP) and the Geological Survey of Japan (GSJ). The main objective of the project is to developed an information system that will encourage voluntary sharing of geoscience information among the countries in the Asia-Pacific region (Fig. 2). The developed information system will

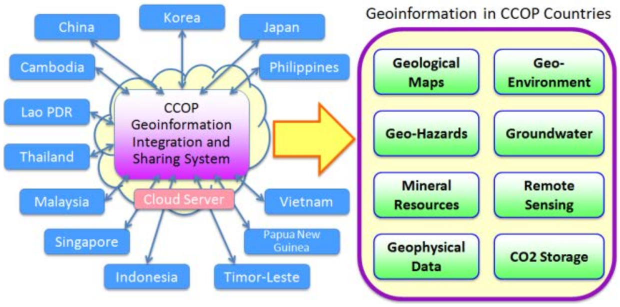

Fig. 2. The CCOP Geoinformation Sharing Infrastructure Project of East and Southeast Asia (GSi).

Fig. 3. The CCOP Geoportal. (http://ccop-geoinfo.org/GeoPortal/index.php).

also make geoscience information readily accessible in the region. It provides Web-based functions for spatial data rendering and analysis in the forms of Web Processing Service (WPS) and Web Map Service (WMS), respectively. WMS is a standard protocol that provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geospatial databases (OGC, 2012b). Fig. 3 shows the main page of the trial version

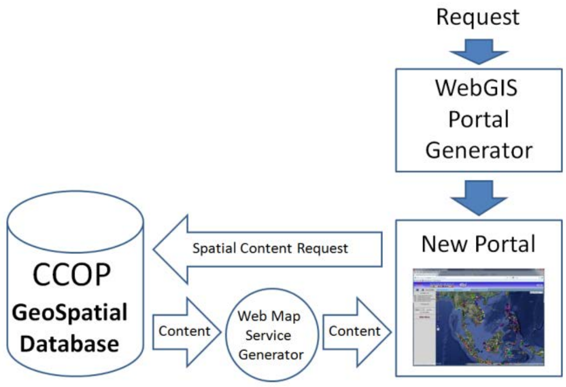

Fig. 4. The Automated WebGIS Portal Generation System.

of the information sharing system called CCOP Geoportal. It also provides a service for a customized Web-GIS portal creation which enable the users to develop their own Web-based information system for spatial data viewing and processing (Fig. 4).

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Analog experiments for outreach program to understand fundamental processes of volcanic hazard

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Analog experiments are useful for outreach program. We cannot see the inside of a volcano directly, though an eruption is caused by underground magma. We develop the see-through experiments to understand a process from magma system to eruption (Takada UTR).

1. The first experiment is to observe magma ascent to eruption through cracks (Takada, 2006). Liquid-filled cracks are injected in gelatin under the stress field (Fig. 1). We can observe crustal deformation process just before eruptions (Fig. 2).

2. The second is to observe the effect of bubble. A plastic transparent sheet is covered on a plastic transparent bottle to build an artificial volcano (Fig. 3). Bicarbonate and citric acid with detergent for kitchen (BCD liquid) are put in the bottom of the bottle. Next, just after the bottle is filled up to the middle level with colored juice (or water), the cap with a hole is closed. Eruption will occur with a 1m high explosive column, and change into effusive flow. After experimental eruption, audience can learn hazard areas controlled by the topography and eruption types, and the time sequence of typical eruption (Fig.4) (Omiya et al., 2013; Oikawa et al., 2013; Yamasaki et al., 2013a,b; Yamasaki et al., 2014).

3. The third is the mixed effect among bubbles in the host brittle material (Takada UTR).. The liquid with bubble such as BSD liquid or carbonate drink is injected into gelatin as the host material. We can cause an explosive eruption to form a funnel -shaped crater like diatreme (Fig. 5). If the liquid injection is slow, the liquid accumulate bubble in it upper part (Fig. 6). After bubble escapes like de-gassing, the liquid injects laterally like dike injection.

4. Distribution of volcanic ash with its thickness and grain size is observed by an artificial sand eruption on a map under westerlies wind caused by electronic fun (Fig. 7) (Takada UTR)..

5. Experiments of pyroclastic flow were carried out in 2008 and 2009 AIST open houses (Takarada et al., 2008).

6. Caldera collapses were demonstrated by air leaking in a balloon installed in a sand box (Namiki, 2007).

7. Sector collapse experiments were carried out vibrating a sand volcano (Fig. 9) (Takada UTR)..

8. Artificial tsunami was generated in a small pool with various coastal lines to observe wave velocity and height with the effect of topography (Fig. 10). Tsunami caused by volcano collapse is demonstrated by Furukawa and Nanayama (2006).

These experiments were carried out at elementary or junior high schools, science museums, the open house in AIST, training course for school teachers in Yamanashi Pref, and lectures of university, the international training course of JICA, APEC, and COV.

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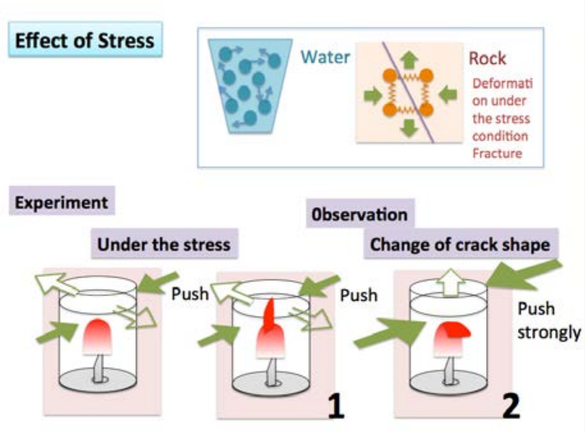

Fig.1. Effect of stress on magma transport.

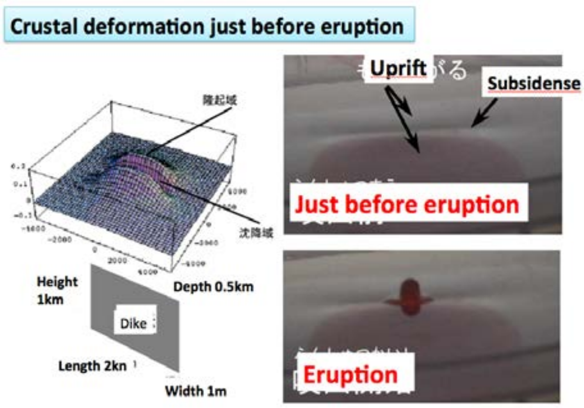

Fig.2. Crustal deformation just before an eruption from a dike.

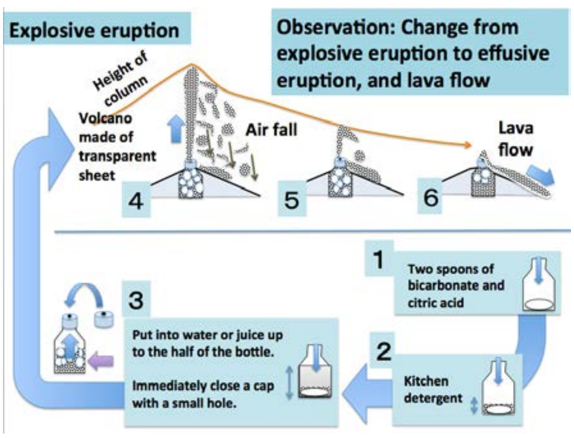

Fig.3. Experimental procedure of explosive eruption.

Fig. 4. Explosive eruption and lava flow at 2014 Open house of AIST.

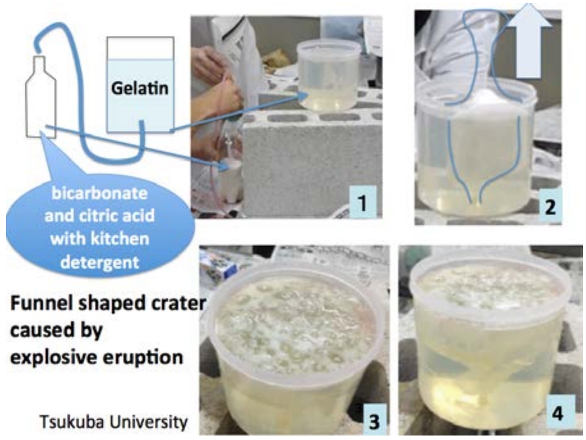

Fig. 5. Explosive eruption with forming a funnel-shaped crater in gelatin (Tsukuba Univ.).

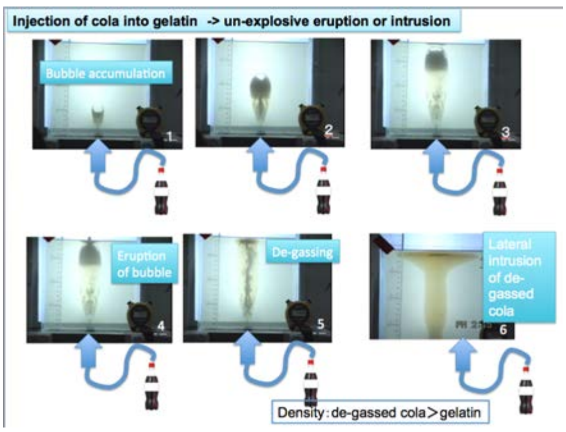

Fig. 6. Non-explosive eruption with degassing.

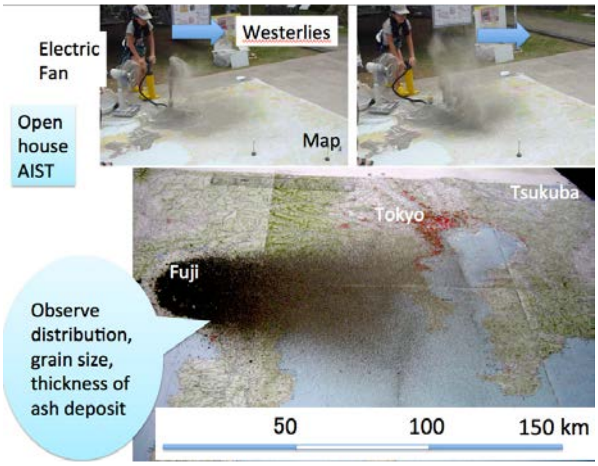

Fig.7. Artificial sand eruption from air pump on a map.

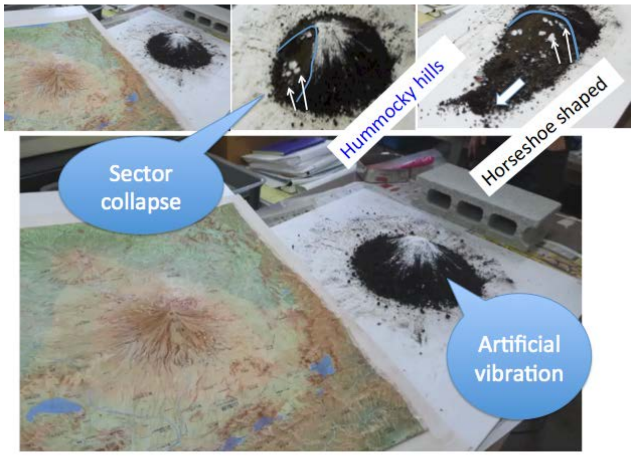

Fig.10. Sector collapse experiments caused by vibration.

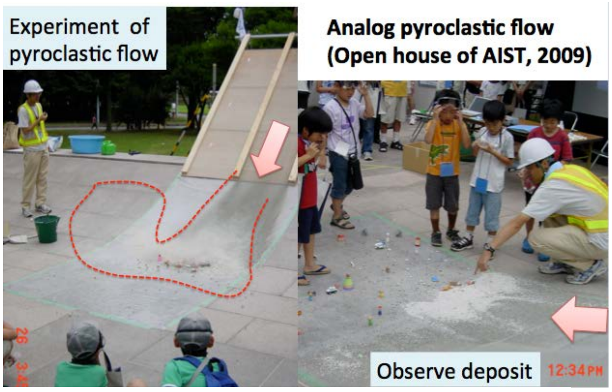

Fig.8. Experiments of pyroclastic flow in 2008 AIST open house (Takarada et al., 2008).

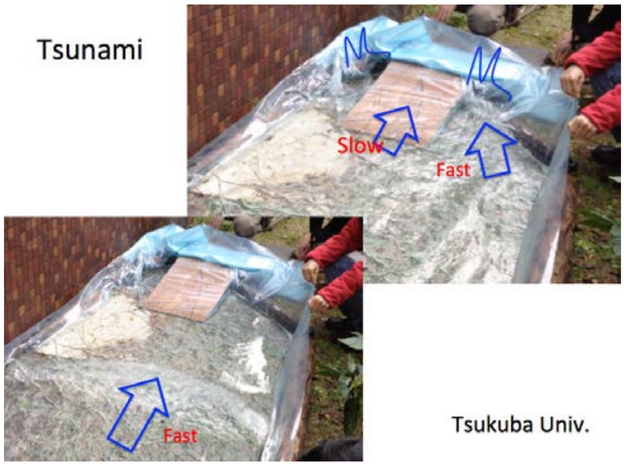

Fig.11. Artificial tsunami was generated in a small pool to observe the wave velocity and height with the effect of topography.

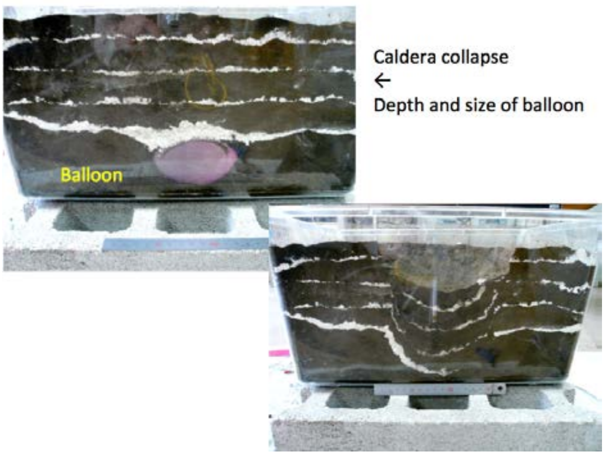

Fig.9. Caldera collapse experiments caused by a air leaking from a balloon in a soil box (Namiki, 2007).

International activity of Geological Survey of Japan, AIST

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1. Scope of the international activity

The promotion of cooperation with overseas geological survey organizations is a priority for the Geological Survey of Japan (GSJ). GSJ is engaged in two types of international activities. One is bilateral research cooperation with an overseas research organization, and the other is multilateral research cooperation conducted within the framework of an international organization or consortium.

Regarding the bilateral cooperation, GSJ has a memorandum of understanding on research collaboration with a number of overseas research organizations that are involved in earth science and geological surveys. The collaborative research includes:

- Development of innovative survey and analysis techniques applicable to the study on geological resources exploration, earthquake and tsunami, volcanology, remediation of soil contamination, CO_2 geological storage, etc.,
- Joint surveys and studies on geological mapping, mineral resources, geological hazards mitigation, etc. in the counterpart countries, and
- Capacity building on earth science in developing countries.

Through many years of human interaction and communication among the researchers, we have been building a solid relationship based on mutual trust. Based on this relationship and by at times competing with each other, we are doing our best to accelerate the research in various fields of earth science.

2. CCOP

Regarding the multilateral cooperation, GSJ is taking an active role in international organizations and consortiums including OneGeology, CGMW, ICDP/IODP, and Global Geopark Network.

Among those, GSJ's most important multilateral international cooperation is the one under the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP). CCOP is an intergovernmental organization that aims to support economic development and improvement of the living standards in the East and Southeast Asian regions through the promotion of various projects and workshops in the field of earth science.

CCOP was established in 1966 and is now consists of 13 member countries in East and Southeast Asia. There is no other international organization in the field of earth science that has such a long history in the world. Japan has continued to take a leading role in CCOP since its establishment, by providing both technical and financial supports through various joint research projects. GSJ is currently running several projects in CCOP, including 1) compilation of groundwater environment map of the major plains in Southeast Asia, 2) integrated geological assessment in delta and coastal areas, 3) publication of earthquake and volcanic hazard map of the CCOP region, and 4) Development of a web-based geo-information sharing platform for East and Southeast Asia.