MONITORING ACTIVE VOLCANOES BY ELECTROMAGNETIC AND OTHER GEOPHYSICAL METHODS

Application to Asian Volcanoes

25-27 February 2010
PHIVOLCS Auditorium
C.P. Garcia Avenue, U.P. Campus,
Diliman, Quezon City, Philippines

DOST PHIVOLCS

EMSEV IUGG Inter Association

International Union of Geodesy and Geophysics

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EMSEV[1]-PHIVOLCS[2] Workshop

[1] : http://www.emsev-iugg.org/emsev/
[2] : http://www.phivolcs.dost.gov.ph/

25-27 February 2010

PHIVOLCS Auditorium,
C.P. Garcia Avenue, U.P. Campus Diliman,
Quezon City, Philippines

In cooperation with:

The Philippine Institute of Volcanology and Seismology, Department of Science and Technology (PHIVOLCS-DOST)

The Electromagnetic Studies of Earthquakes and Volcanoes Working Group (EMSEV)

The International Union of Geodesy and Geophsyics (IUGG)

The French Embassy in Manila, Philippines

The International Association of Geomagnetism and Aeronomy (IAGA)

The International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI)

The International Association of Seismology and Physics of the Earth's Interior (IASPEI)

Tokai University

KLM Royal Dutch Airlines

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Scope:

Following the first Workshop held in 2003 for initiating Seismic and Electromagnetic Monitoring in Asian Countries, this second workshop will highlight techniques and methodologies for monitoring active volcanoes with the application to Philippines and other Asian volcanoes. Topics will focus on advanced multi-methodological methods based on electromagnetic and other geophysical methods for understanding volcanic structures and monitoring awaking volcanoes and hydrothermal/magmatic unrests. A particular attention will be paid to volcanic hazards, public information and risk management in highly populated volcanic areas. The five years cooperation between EMSEV and PHIVOLCS on Taal volcano will be exploited for educating young scientists to field work.

Organization contact:

EMSEV:

Jacques Zlotnicki: jacques.zlotnicki@wanadoo.fr
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Angela Montes: angelofthemountains@yahoo.fr
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Ma. Mylene Villegas: mylene_villegas@yahoo.com

Taal Field Excursion

Taal Excursion is organized on 27 February 2010.

WORKSHOP PROGRAM

25 February 2010	**Registration**

08:30-09:00 Registration

25 February 2010	**Opening Ceremony**

09:00-09:45 Opening Ceremony
Philippine National Anthem

Welcome address:
Dr. Renato U. Solidum, Jr. *, Director, PHIVOLCS-DOST*

Message:
Mr. Christian Merer*, Counselor for Cooperation and Cultural Affairs, Embassy of France in the Philippines*
Represented by: ***Ms. Marie Aurousseau****, Attachée for Higher Education and Academic Exchange*

Message
Dr. Estrella F. Alabastro*, Secretary, Department of Science and Technology, Republic of the Philippines*

Background of EMSEV
Dr. Seiya Uyeda*, Member, Japan Academy, Japan*

09:45-10:15 Group photo session and coffee/ tea break

25 February 2010	**Session 1: Volcanic Risks and Preparedness Activities in Asian Countries** ***Moderators: Dr. Teresito Bacolcol and Dr. Malcolm J.S. Johnston***

10:15-10:35 Active Fault Systems and Volcanoes in the Philippines
Dir. Renato U. Solidum, Jr.*, PHIVOLCS, Philippines*

10:35-10:55 The “magma marathon” View of Eruptions
Dr. Christopher Newhall*, Nanyang Technological University, Singapore*

10:55-11:10 EMSEV Project and Its Activities
Dr. Jacques Zlotnicki*, EMSEV*

11:10-11:25	Detailed EM Monitoring Plan under the Japanese JICA/JST Project 2010-2014 ***Prof. Toshiyasu Nagao****, Director, Earthquake Prediction Research Center, Tokai University, Japan*
11:25-11:45	Volcano Disaster Awareness and Preparedness Programme in the Philippines ***Ms. Ma. Mylene L. Martinez-Villegas****, PHIVOLCS, Philippines*
11:45-13:00	Lunch

25 February 2010	**Session 2: Methodologies for Imaging and Monitoring Volcanoes;** **Case Studies** ***Moderators: Dr. Toshiyasu Nagao and Dr. Christopher Newhall***

Self-potential, Magnetic, Electric and Magnetotelluric Methods

13:00-13:20	Electromagnetic (EM) Fields and Deformation Accompanying Volcanic Activity: Case studies from Mount St. Helens, Long Valley Caldera and other Volcanoes ***Dr. Malcolm J.S. Johnston****, USGS, USA*
13:20-13:40	EM Observations of Izu-Oshima Volcano, Central Japan, in its 1950 and 1986 Eruptions ***Dr. Yoichi Sasai****, The Disaster Prevention Division (Tokyo), Japan*
13:40-14:00	Electromagnetic Observations on La Fournaise volcano (Réunion Island) ***Dr. Jacques Zlotnicki****, CNRS-OPGC-UMR6524-UBP, France*
14:00-14:20	Airbone EM Survey ***Prof. Toru Mogi****, Hokkaido University, Japan*
14:20-14:40	Investigation of the Near Surface Tectonic Structure in Volcanoes using VLF Electromagnetic Method ***Dr. George Vargemezis****, Aristotle University of Thessaloniki, Greece*
14:40-15:00	Deep ERT Measurements Using Remote Current and Voltage Electrodes ***Dr. Ilias Fikos****, Aristotle University of Thessaloniki, Greece*
15:00-15:20	Resistivity Imaging by Magnetotelluric Method at Active Volcanoes –Some Cases in Japan ***Dr. Yusuke Yamaya****, Hokkaido University, Japan*

15:20-15:35	Break

Geochemical and Soil/Water Degassing Methods, Sources

15:35-15:55	Testing the Use of Analogues in Eruption Forecasting: Do Volcanoes with Similar Eruptions Exhibit Similar Eruption Precursors ***Dr. Christopher Newhall***, *Nanyang Technological University, Singapore*
15:55-16:15	Soil Degassing and Thermal Transfers at Active Volcanoes ***Dr. Jean-Paul Toutain***, *Observatoire Midi-Pyrénées, France*

Volcano Seismology

16:15-16:35	Broadband Seismic Monitoring of Active Volcanoes Using Deterministic and Stochastic Approaches ***Dr. Hiroyuki Kumagai***, *National Research Institute for Earth Science and Disaster Prevention, Japan*
16:35-16:55	Seismic Precursors of the 1991 Pinatubo Volcano Eruption ***Dr. Bartolome C. Bautista***, *PHIVOLCS, Philippines*

Dinner /Reception - 18:30

26 February 2010	**Session 2 continued: Methodologies for Imaging and Monitoring Volcanoes; Case Studies** ***Moderator: Prof. Toru Mogi and Dr. Jacques Zlotnicki***

Geodesy: Borehole Tiltmetry, Levelling, GPS and Satellite Interferometry

08:30-08:50	GPS Studies around Mayon Volcano ***Dr. Teresito C. Bacolcol***, *DOST- PHIVOLCS, Philippines*
08:50-09:10	Mechanics of Volcanic Activity in Long Valley and Kilauea/Mauna Loa. Volcanic Areas from Multi-parameter Borehole and Local Magnetic Field Measurements ***Dr. Malcolm J.S. Johnston***, *USGS, USA*

Real-time Data Monitoring, Data Processing and Analysis, Modelling

09:10-09:30	Kelud Volcano: Its Monitoring, 2007 Crisis and Risk Analysis ***Dr. P. Surono***, *DVGHM, Indonesia*

09:30-09:50	Mayon Volcano Real-time Data Monitoring, Data Processing, Analysis and Modeling ***Mr. Eduardo Laguerta**, PHIVOLCS, Philippines*
09:50-10:05	Break

26 February 2010	Session 3: Taal Volcano History and Land Use *Moderator: Dr. Ma. Hannah T. Mirabueno and Dr. P. Suruno*

Regional Tectonic Setting

10:05-10:25	Indicators of Rifting in Macolod Corridor Through Crustal Deformation ***Dr. Teresito C. Bacolcol**, DOST-PHIVOLCS, Philippines*

Historical Eruptions: Impacts and Precursory Phenomena

10:25-10:45	Historical Eruptions of Taal Volcano: Impacts and Precursory Phenomena ***Ms. Esfeca T. Del Mundo**, PHIVOLCS, Philippines*

Population Settlement and Economical Growth

10:45-11:05	Population Settlement and Population Growth on Taal Island and its Surrounding Communities ***Dr Amante Moog**, Provincial Planning and Development Office, Province of Batangas, Philippines*

Information and Education

11:05-11:25	Seminar-workshops in the Community-Level Around Taal Volcano ***Ms. Angela G. Montes**, PHIVOLCS, Philippines*

The Usefulness of GIS in Mapping Volcanic Hazards

11:25-11:45	Current Applications and Challenges of GIS/RS Tools to Volcanic Hazards Analysis and Monitoring ***Ms. Ma. Antonia V. Bornas**, PHIVOLCS, Philippines/Nanyang Technological University, Singapore*
12:00-13:00	Lunch Break

26 February 2010	**Session 4: Understanding and Monitoring Taal Volcano** ***Moderators: Dr. Yoichi Sasai and Dr. J.P. Toutain***

Taal Activity from the 1965-77 Eruption to Present

13:00-13:20	Revisiting the 1965 Taal Volcano Eruption: Lessons Learned from Survivors' and Eyewitness' Accounts ***Ms. Ma. Mylene L. Martinez-Villegas***, *PHIVOLCS, Philippines*
13:20-13:40	Taal Volcano: Observations on Recent Activity and Previous Unrests ***Mr. Julio P. Sabit***, *PHIVOLCS, Philippines*

Imaging the Hydrothermal System, Heat, Gas and Fluid Transfers

13:40-14:00	Electromagnetic, geochemical and thermal investigations of Taal volcano ***Dr. Jacques Zlotnicki***, *CNRS-OPGC-UMR6524-UBP, France*
14:00-14:20	Magnetic Observations on Taal Volcano (Philippines) in Combination with Other Geophysical and Geochemical Methods from 2005 to Present ***Mr. Paul Karson B. Alanis***, *PHIVOLCS, Philippines*
14:20-14:40	Soil degassing and thermal transfers at Taal volcano (Philippines) ***Dr. Jean-Paul Toutain***, *Observatoire Midi-Pyrénées, France*
14:40-15:00	The 2009 Resistivity Survey at Taal Volcano ***Mr. Agnes Aguilar***, *PHIVOLCS, Philippines*
15:00-15:20	Diffuse CO2 emissions from Taal Volcano Main Crater, 2008-2009 surveys ***Ms. Ma. Carmencita Arpa***, *PHIVOLCS, Philippines*
15:20-15:35	Break

Taal Monitoring: Seismicity, Deformation and Hydrothermal Activity

15:35-15:55	Monitoring Taal Volcano: An Overview ***Mr. Jaime Sincioco***, *PHIVOLCS, Philippines*
15:55-16:15	Self Potential, Ground Temperature and Geochemical Measurements on Taal: From Repeated Surveys Toward Volcano Monitoring by Telemetry ***Mr. Edgardo U. Villacorte***, *PHIVOLCS, Philippines*
16:15-16:35	1991 to 2010 Ground Deformation Monitoring of Taal Volcano ***Mr. Teodorico A. Sandoval***, *PHIVOLCS, Philippines*

16:35-17:00 Table Discussion

- Needs for monitoring more accurately Taal Volcano
- Real time monitoring, analysis and predictability
- Risk assessment
- Prospective, Education, further cooperation

26 February 2010	Closing Ceremony

27 February 2010	Field Excursion to Taal volcano - 5:00 AM to 6:00 PM

Posters - 2F PHIVOLCS Auditorium Lobby

Determination of the three-dimensional seismic velocity structure beneath Southern Kysuhu, Japan, by tomography of travel times derived from local earthquake data
Paul Karson B. ALANIS and Hiroki Miyamachi

A Proposal for the STAR Program: SeismoSTAR and New Satellite Constellation: ELMOS
Tetsuya Kodama, Koh-Ichiro Oyama, Jann-Yenq Liu, Makoto Suzuki

Magnetic observations on Taal Volcano (Philippines): Reconnaissance, Repeat Surveys and Continuous Measurements
J.M. Cordon Jr., J.P. Sabit, M. Harada, Y. Sasai, P.K.B. Alanis, W. Reyes, J. Zlotnicki, E.U. Villacorte, H. Hase, J.T. Punongbayan, T. Nagao, J.S. Sincioco and R.U. Solidum Jr.

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MESSAGES

International and interdisciplinary cooperation for Disaster Risk Reduction

Isabelle Epaillard[1], Christian Merer[1]

[1] *Service de Coopération et d'Action Culturelle, Ambassade de France aux Philippines.*

Christian Mérer

Counselor for Cooperation and Cultural Affairs, Embassy of France to the Philippines. Mr. Mérer took up his post as Counselor for Cooperation and Cultural Affairs on September 1, 2009. He holds degrees in philosophy and letters. He joined the Foreign Ministry in 1995 and his previous postings were in the areas of culture, French education and cooperation.

ABSTRACT

The Philippines are one of the most vulnerable countries in terms of natural hazards, due to geophysical and meteorological conditions, but also due to human and social aspects: the EVI, Environmental Vulnerability Index, of the country is one of the highest. Few countries only beat its score of 402, as the French Guadeloupe in the Caribbean's (score of 412). Like the Philippines, France is vulnerable to typhoon and flash floods and has active volcanoes: la Soufrière in Guadeloupe, la Montagne Pelée in Martinique, le Piton de la Fournaise in La Réunion.

Regarding natural hazards and risk mitigation, the Embassy of France to the Philippines promotes international research and interdisciplinary cooperation. The variety of cases, of suitable technologies, the economical and human resources available worldwide are advantages that have to be taken at most. Natural science outputs and the results from the human and social sciences studies have to be used mutually by the decision makers and stakeholders in their policy and programs for preparedness, response and rehabilitation in the occurrence of natural disasters. Effects of natural risks can be reduced if local communities are involved in implementing policies enacted on the national level. Some of our projects and objectives will be presented.

Background Information on EMSEV and its Activities

Seiya Uyeda

Professor Emeritus, University of Tokyo, Japan

Seiya Uyeda

Prof. Univ. Tokyo (1969-1990) and Tokai Univ. (1990-2008). During this period, British Council Scholar at Cambridge and Oxford Univ., Visiting Prof. at Stanford, California (UCSD), Columbia (LDGO), Paris 6 (UPMC),Texas A&M Univ., MIT and Caltech. Member: Japan Acad., US Nat. Acad. Sci. and Russian Acad. Sci. EMSEV Founding Chair (2002-2008). Now, Prof. Emeritus, Univ. Tokyo.

ABSTRACT

"Electro-Magnetic Studies on Earthquakes and Volcanoes (EMSEV)" is an IUGG Working Group established in 2001 to promote inter-disciplinary and international cooperation. It is supported by three IUGG associations, IASPEI, IAGA and IAVCEI because recent EM studies are making rapid and epoch-making progress, but the researchers in this new science are widely scattered both in discipline and geography so that mutual interaction is of vital importance. EMSEV in particular puts emphasis on helping promotion of this new science in seismic and volcanic hazard prone developing countries. Actually, an EMSEV-PHIVOLCS Workshop entitled "Initiating Seismic/Volcanic Monitoring in Asian Countries" was held in 2003 here in this PHIVOLCS building. History of EMSEV activity and recent progress in EM studies will be briefly reviewed.

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ABSTRACTS

Session 1

Volcanic Risks and Preparedness Activities in Asian Countries

The "Magma Marathon" View of Eruptions

Christopher Newhall

Earth Observatory, Nanyang Technological University, Singapore

Christopher Newhall

Chris studies eruptive histories (historical and geologic data of eruptions), and volcanic unrest (geophysical and geochemical changes, whether they lead to eruptions or not). The goal is good forecasting. Chris is Volcano Group leader at the new Earth Observatory of Singapore, Nanyang Technological University

ABSTRACT

Most descriptions of eruptions are based on the character of the eruption itself. But if one emphasizes uncertainties of preeruption unrest, the view is quite different! Slightly tongue-in-cheek but with a serious purpose to guide discussion during preeruption crises, I propose the following a "magma marathon" view of eruptions in which magma is the runner and the finish line is the earth's surface and eruption:

- **Strong finish**, e.g., vigorous magmatic explosions, lava fountaining, or lava flows.
- **Hairline finish**, e.g., eruptions of sluggish, viscous magma that just barely extrudes onto the earth's surface, forming a lava dome. Let's include cryptodomes here.
- **"Close but not quite" finish**, e.g., magma that "almost" or "nearly" erupts but freezes short of the surface. At well-monitored volcanoes in populated areas, alert levels might be raised and evacuations considered; and
- **False starts**, e.g., magma that starts the race too soon or without adequate preparation and must soon drop out, e.g., cases of small increments of deep recharge or small disturbances of magma reservoirs that don't catch a second wind and progress to or trigger further upward intrusion.

The main drivers of magma ascent are:

- buoyancy in a ductile country rock,
- tectonic or lithostatic pressure (squeezing), or
- buoyancy of one magma within another. A special case of the last is gravity-driven sinking of dense, degassed magma into less dense, gas-rich magma, displacing the gas-rich magma upward.

Magma can approach the finish line, i.e., come close to erupting, by

- intrusion through all but a thin cap of country rock,
- by intrusion into an existing, magma-filled conduit that already reaches close to the surface, or
- other disturbance of a shallow magma body, e.g. by decompression by an overlying phreatic explosion.

However, in many (indeed, most) cases, magma stops before eruption by:

- loss of driving force, generally by loss of volatiles ("running out of gas")
- increased viscosity of the magma, closely related to volatile loss
- encounters with groundwater that chill and solidify a carapace on the magma
- encounters with density or structural barriers, or with chances to flow laterally more easily than upward.

(Newhall, Magma Marathon, continued)

It is not easy to tell the final outcome during a crisis, and, indeed, those who have the job to warn of eruptions know uncertainty, anxiety, and "sweaty palms" as magma rises Fortunately, there are some geophysical and geochemical signs that can help. During most of its ascent, magma is likely to erupt if it is ascending rapidly and even more likely if it is accelerating upward. Rapid ascent reflects relatively low viscosity and a healthy initial gas content, and it minimizes the time for magma to leak gas enroute to the surface. Accelerating deformation rates are especially diagnostic (Nishimura, GRL, 2006).

High levels of seismicity by themselves are not diagnostic. Sometimes, magma that is very viscous and might or might not reach the surface causes a lot of seismicity if it is opening up a broad new passageway, or even generating earthquakes within itself by shear along the viscous margins. Sometimes, too, hydrothermal or pressurization beneath a volcano will exert a compressive stress on faults up to 10-15 km away from the volcano, triggering distal volcano tectonic earthquakes (DVT's) (White and Power, Fall AGU 2001; White COV4; Roman, GRL 2005). These say nothing about whether the magma will erupt.

High gas emissions favor eruption, especially if accelerating, but high flux rate is a double-edged sword because it also reflects degassing that can slow the magma. Low SO_2 emissions tell us almost nothing, because SO_2 and other acidic gases will get absorbed into and masked by groundwater. Where magma already fills a conduit close to the surface, increasing SO_2 emissions may be the most diagnostic indicator, because there is little pressure buildup and fresh fracturing to cause seismicity and deformation.

Finally, a sudden cessation or reversal of seismicity, deformation, or gas emission is often an indicator that magma is close to eruption. One origin of sudden seismic quiescence is when magma has reached so close to the surface that no further fracturing is needed. Another is when quenching of rising magma and/or rapid degassing causes such a sharp increase in magma viscosity that magma ascent is briefly halted. Very shallow deformation might continue. Inflation measured at stations on the slopes of a volcano generally doesn't reverse itself to deflation until an eruption has begun, but uplift measured close to the expected vent will reverse to subsidence when the magma is very near the surface. Gas emission can halt suddenly when magma viscosity sharply increases, or if deformation clamps gas pathways shut, or conversely, opens pathways for groundwater that floods a previously dry gas chimney.

If seismicity and deformation are constant or slowly decelerating, or if gas is slowly diminishing, forces that slow the intrusion are likely to prevent the magma from finishing the marathon.

Chances that magma will reach the finish line depend critically on having enough initial gas, having continued gas and magma supply or at least not losing too much gas before reaching the finish line, and not encountering major obstacles enroute.

The rest of the paper will present an example or two of each variant of marathon finish.

EMSEV Project and Its Activities (http://www.emsev-iugg.org/emsev/)

Jacques Zlotnicki[1], and EMSEV bureau[2]

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M.JS. Johnston, Vice Chairperson, USA
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Jacques Zlotnicki

President of the IUGG inter-association Electromagnetic studies of Earthquakes and Volcanoes EMSEV

ABSTRACT

The Inter-Association Working Group of Electromagnetic Studies on Earthquakes and Volcanoes (EMSEV) focuses on the physics and the monitoring of electromagnetic (EM) effects of earthquakes and volcanic eruptions (http://www.emsev-iugg.org/emsev/).
The main objectives are:

- To promote magnetic and electric studies of earthquakes, tsunamis and volcanoes from the source to the ionosphere, through national and international collaborations,
- To integrate multi-disciplinary techniques in order to better analyze the physical mechanisms,
- To organize international and regional meetings, and to disseminate relevant data and research results,
- To contribute to develop EM studies in developing countries and to assist to develop integrated EM monitoring systems and data analyses.

After a joint EMSEV-PHIVOLCS meeting held in 2003 in Manila, it was commonly decided to focus on the understanding of Taal activity and the volcanic hydrothermal system, and on the development of electromagnetic (EM) and other geophysical monitoring systems. In 2004, an PHIVOLCS-EMSEV agreement was signed in which teaching of new PHIVOLCS scientists to EM methods was included.

Taal volcano exhibits signs of unrest since 1992. The surrounding population exceeds some hundreds thousands of local inhabitants. Recent catastrophic eruptions with surges, pyroclastic flows and phreatic explosions, the weak knowledge of the volcanic structure topped by an acidic hot Crater Lake, and the monitoring capability led to the initiation of a multi-disciplinary program.

In 2005, an international EM team composed of Japanese, French, and Filipinos scientists began common field works. 5 to 10 PHIVOLCS including scientists, engineers and technicians constitute the core of the PHIVOCS EM team. Since then, one to two joint campaigns are done each year including magnetic, electric, and soil degassing surveys, ground and water temperature of Main Crater Lake, and installation of continuous EM stations associated with other geophysical parameters (Radon, temperature, seismicity, seismic noise RMS, magnetism) (see 2005, 2006, 2007, 2008, 2009 EMSEV annual reports; http://www.emsev-iugg.org/emsev/).

Targets are:

- Characterization of the volcano structure, the geological and regional settings,
- 2- and 3-D Mapping, of the hydrothermal system and of its connection with magmatic sources; using satellite and ground observations,
- Bathymetric survey of the Main Crater Lake, and the monitoring of this water level and temperature changes,
- Assessment of fluids transfer through the lakes and the volcano. Computation of the volatile and heat budgets,
- Evaluation of the scenarios of future activity (i.e. collapse of crater rims, sudden phreatic explosions),
- Development of continuous monitoring multi-parametric stations with real time data acquisition systems and processing at the local observatory and PHIVOLCS headquarters,
- Implementation of on-line data processing, and development of coherent models of the volcanic activity,
- Training program, invitations to young researchers for short stays in France and Japan,

EM and geochemical mappings have already highlighted a key issue. Every day, some hundreds of tourists climb the volcano along a trail crossing the northern active fissures opened during the 1992-1994 seismic crises. But, the sector located between these fissures and the view point located along the crater rim may collapse in case of large eruptive activity. Now, PHIVOLCS has advised Local Authorities of this possible scenario.

Another issue is the thermodynamical equilibrium of the hydrothermal/volcanic system which can be rapidly annihilated giving rise to an eruptive event following a process as: 1) an increase of magmatic fluids and heat in the hydrothermal system, 2) a collapse of the hydrothermalized northern crater rim of MC, 3) a seismically-induced response of the hydrothermal system, and 4) self-sealing processes leading to a closing system with subsequent pressure built-up.

During the past years, cycles of activity have been observed, with inflation and deflation of the ground surface, seismic swarms, local geysering activity, and transient changes in the hydrothermal activity (fumaroles, bubbling in MCL, thermal activity, etc.). These events can start within a few days or less. Because of the proximity of the magma below the crater, the presence of the 45 M^3 of water of MCL, the activity could give rise to sudden violent phreatic to phreatomagmatic explosions followed by a possible larger activity. This scenario is the most difficult activity to monitor and to predict.

Detailed EM Monitoring plan under the Japanese JICA/JST project 2010-2014.

Toshiyasu Nagao

Earthquake Research Institute, University of Tokyo, Japan

Toshiyasu Nagao

1987 - Doctor of Science, The University of Tokyo
2001- Professor of Geophysics, Earthquake Prediction Research Center, Tokai University
2006-2007 Visiting Professor, Earthquake Research Institute, the University of Tokyo
2003- Secretary of EMSEV

Abstract

In FY2008, Japanese Government started the new program entitled "Countermeasures towards Global Issues through Science and Technology Research Partnership". Our group proposed the following project entitled “Enhancement of Earthquake and Volcano Monitoring and Effective Utilization of Disaster Mitigation Information in the Philippines” (Chief investigator: Dr. H. Inoue of National Research Institute for Science and Disaster Prevention; NIED). This five years’ project is adopted in FY2009. In the project, we upgrade the earthquake and volcano monitoring systems of the Philippines. We install broadband seismometers together with an automatic analysis system, and develop an online intensity meter network for rapid and accurate estimation of earthquake location, magnitude, ground shaking and damage, and local tsunamis. We also estimate the largest potential earthquakes and their recurrence times by GPS observations and paleo-earthquake records, and predict surface ground motions caused by the scenario earthquakes. Concerning the volcanic monitoring, we install integrated real time volcano monitoring systems on Taal and Mayon volcanoes to enable estimations of magma accumulation and migration. In the program, electromagnetic monitoring concentrates to the Taal volcano. We are going to install three total intensity magnetometers and one ULF-MT device on the Taal volcanic island. All data are transmitted to the PHIVOLCS main office. Furthermore, to know the three-dimensional electromagnetic structure of the volcano, we have a plan to make a magneto-telluric survey in FY2010. We also measure the physical properties such as magnetic susceptibility and Curie temperature of the rock samples. In the presentation we are going to introduce the detailed monitoring plan next five years.

Volcano Disaster Awareness and Preparedness Programme in the Philippines

Ma. Mylene Martinez-Villegas and Renato U. Solidum, Jr.

Philippine Institute of Volcanology and Seismology, Quezon City

Ma. Mylene Martinez-Villegas

Ma. Mylene Martinez-Villegas is currently Chief Science Research Specialist of the Geologic Disaster Awareness and Preparedness Division (GDAPD) of PHIVOLCS since 2001. She obtained her BS Geology from the University of the Philippines (1990) and MS in Geology (1998) from Arizona State University, USA. Her current research interests include hazards and risks perceptions and disaster education.

ABSTRACT

The Philippine Institute of Volcanology and Seismology (PHIVOLCS) is the agency responsible for implementing programs on geologic disaster awareness and preparedness specifically those related to volcanic eruptions and earthquakes. In accordance with its mandates to mitigate disasters arising from major volcanic eruptions and to take steps to increase awareness and preparedness of the public regarding the hazards from volcanic eruptions, various programs have been implemented since the institute was reorganized in 1984 and more emphasis was put on preparedness and mitigation. As a strategy, different sectors- from policy makers, local government officials, planners and developers, barangay officials, teachers, students and members of the tri-media were included in the awareness efforts. To be more effective, results of volcano studies such as hazards zonation maps and Alert Level Schemes are distributed to the local government units concerned. General information on specific volcanoes (historical activities, hazards) were packaged into more popular forms and various types of materials from print (posters, flyers, brochures) to video were developed. These were presented and disseminated during various organized meetings, workshops, conferences, fora and the like. The focus of the activities and materials is not only volcano hazards awareness but also on preparedness and mitigation measures, to emphasize what is being done, and should be done to avoid and reduce the impact of volcanic eruptions. The importance of strengthening capacities through community-based activities is also highlighted.

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ABSTRACTS

Session 2

Methodologies for Imaging and Monitoring Volcanoes; Case Studies

Electromagnetic (EM) Fields and Deformation Accompanying Volcanic Activity: Case studies from Mount St. Helens, Long Valley Caldera and other Volcanoes

M.J.S. Johnston

U.S. Geological Survey, USA

M.J.S. Johnston

B.Sc. (1965), Phys., B.Sc. (Hons) (1967), Phys./Geophys., Ph.D. (1970). Geophys./Phys., University of Queensland, Australia.
1970-1972: *Res. Assoc./Assistant Professor*, Dept. Geology and Mineralogy, University of Michigan
1991-1996: *Consulting Professor*, Dept. of Geophysics, Stanford University.
1972-1999: *Project Chief.* U.S. Geological Survey
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ABSTRACT

Continuous ground-surface observations of local magnetic and electric fields have been obtained in the near field of numerous volcanoes during the past 50 years. These observations provide a multi-faceted reference data set documenting the form and amplitudes of these fields during this activity. Contributions from different physical processes can be identified during the various eruption stages. Slow processes (weeks to months) include 1) near-surface thermal demagnetization/remagnetization effects, 2) piezomagnetic effects from stress changes on magnetic rocks in the volcano, 3) electrokinetic effects from thermally driven fluid flow within the volcano, 4) electric fields from fluid vaporization, and 5) rotation/displacement of magnetized material. Rapid processes (seconds to days) include: 1) piezomagnetic effects from instantaneous stress redistribution with "explosive" eruptions and earthquake rupture, 2) electrokinetic effects from rupture of high-fluid pressure compartments commonly encountered in volcanic regions, 3) rapid changes from mass removal/redistribution, and 4) propagating EM disturbances from coupled explosion-generated EM fields and trapped acoustic waves in the atmosphere. Separating these different physical processes and their contributions during different eruption scenarios requires EM monitoring, together with high-resolution seismic, geodetic, deformation and geochemical monitoring. This is particularly necessary where poroelastic processes from highly compressible magmas and fluid movement lead to misleading estimates of eruption volumes and misidentification of eruption processes. Examples of different processes are demonstrated using data from Mount St. Helens, Washington, Long Valley, California, and Kilauea volcano, Hawaii.

EM Observations of Izu-Oshima Volcano, Central Japan, in its 1950 and 1986 Eruptions

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ABSTRACT

Izu-Oshima volcano is a basaltic volcano island, about 120 km south from Tokyo, which belongs to Izu-Bonin Arc. It is one of the most active volcanoes in Japan: the latest eruption took place in 1986, which started with the summit eruption from the central cone within the main caldera and was followed by flank fissure eruption. The former eruption cycle before the 1986 activity started from 1950, and continued intermittently until 1974. At the initial stage of the 1950 activity, enormous changes in the geomagnetic dip were observed by Rikitake (1951). Magnetic changes had been observed in association with the moderate activities at the summit crater of the central cone during the 1950's (Yokoyama, 1969). Continuous magnetic and resistivity measurements had been intensively made before, during and after the 1986 eruption, which contributed to clarify the eruption mechanism of Izu-Oshima volcano. The long-term, medium-term and short-term precursory magnetic changes were ascribed to the thermal magnetic and the piezomagnetic effect (Sasai et al., 1990). The most outstanding were the apparent resistivity changes of the central cone (Yukutake, 1987), which turned out that the resistivity observation can detect the silently uprising magma without any ground deformation or earthquakes. A more quantitative modelling of resistivity changes revealed the position, the amount and the speed of uprising magma, which was completely masked beneath the volcano edifice (Utada, 2003). Repeat SP surveys were introduced into the volcano after the 1986 eruption (Ishido et al., 1997). The SP anomaly inside the caldera shows a typical W-shaped positive anomaly, which was interpreted as due to the hydrothermal circulation beneath the central cone and the caldera via the electrokinetic effect. The computer simulation was performed for the multi-phase, multi-component, unsteady geothermal reservoir. The phase II activity (fissure eruptions) of the 1986 eruption was caused by a more differentiated andesite magma, which should have been intruded into a shallow depth in the past (Aramaki and Fujii, 1988). No evidence exists for such an intrusive event. We suspect if the large dip changes observed in the 1950 activity could be an indication of such an event. Rikitake's (1951) data were reexamined to obtain a more reasonable source, and a triaxial ellipsoid model was presented with the aid of genetic

algorithm (GA). This model suggests that there exists a large vacant space filled with highly magnetized coarse scoria, which may be closely related to the past activities of the volcano. Izu-Oshima volcano is one of the best test-field sites for the volcano-electromagnetics.

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Electromagnetic Observations on La Fournaise Volcano (Réunion Island)

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ABSTRACT

Magma intrusion, stress field change, ground water or gas flow, and thermal perturbations can drastically change physical characteristics of a volcano, for example fluid flow-matrix rock interaction, can give rise to large volcano-magnetic, -electric or -electromagnetic (EM) signals. Magnetic signals of a few nano-Teslas (nT) can appear several years before an eruptive event. Most often the mechanism is due either to a change in the magnetization of rocks due to an applied stress field (piezomagnetism effect), or to a slow modification of the thermal state (thermomagnetism effect) or to a slow alteration of the hydrothermal system (electrokinetic effect). In addition these slow processes can modify the permeability and the pore pressure of rocks and induce electrical resistivity changes in volcanoes.

We will base the discussion on electric, magnetic and resistivity changes that have been observed on La Fournaise volcano (Réunion Island). La Fournaise is a very active, 2634 m high, basaltic volcano which erupts once or two times a year in average.

- Large scale Self potential anomalies cover the inner caldera of Enclos Fouqué, which is submitted to a large hydrothermal activity,
- The amplitude and the location of the large scale SP anomalies change with the successive eruptions,

- Magnetic signals, a few nT in amplitude, may appear some weeks before the eruptions. Signals are emphasised the day of the outburst, when the magma has migrated towards the ground surface.
- Telluric signals are recorded at different spots of the volcano. Some signals appear with a phase delay, depending on the location of the station compared to the emplacement of the activity. Signals may be as large as 2 V/km,
- Resistivity changes have also been evidenced during the large 1998 eruption which has occurred after several years of rest.

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Airborne EM Survey in Volcanoes

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ABSTRACT

Airborne electromagnetics (AEM) is a useful tool for investigating subsurface structures because it can survey large areas involving inaccessible areas. Disadvantages include lower accuracy and limited depth of investigation. AEM has been widely used in mineral exploration in frontier areas, and new applications of AEM have been appearing in the engineering and environmental fields, particularly in studies involving active volcanoes. AEM systems typically comprise a transmitter and a receiver on an aircraft or in a towed bird, and although effective for surveying large areas, their penetration depth is limited because the distance between the transmitter and receiver is small and higher-frequency signals are used. To explore deeper structures using AEM, a semi-airborne system called GRounded Electrical source Airborne Transient ElectroMagnetics (GREATEM) has been developed. The system uses a grounded-electrical-dipole as the transmitter and generates horizontal electric fields. The GREATEM technology, first proposed by Mogi et al. (1998), has recently been improved and used in practical surveys. The GREATEM survey system was developed to increase the depth of investigation possible using AEM. The method was tested in some volcanoes at 2004-2005. Survey results were verified by comparing the GREATEM data with other geophysical surveys and LOTEM data for the same location based on the transient response and resistivity structure. The resistivity structures obtained from both systems were almost identical. Here I will talk about some results of typical AEM survey and GREATEM survey in some volcanoes.

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Investigation of the Near Surface Tectonic Structure in Volcanoes Using VLF Electromagnetic Method

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ABSTRACT

Volcanoes are probably the most 'living' and real time changing geological formations. Any activation which took place in the past had as a result the re-formation of a volcano, which led to changes –among others- to the tectonic state of the area. These tectonics changes, in a volcanic area, may be take place in shallow depths or even at the surface. Therefore, as a result, conditions concerning infiltration and underground water flow may change, even in a 'calm' period that means a period between two volcanic eruptions.

From all the above, stands to reason that study of the near surface tectonic state is of a very high importance. Hydrothermal state in volcanoes is continuously changing since sealing of fractures may be in progress and new underground water flows may be creating.

A very important parameter that can be very useful to the detection of any changes in the state of a faulting system is the resistivity. After an explosion of a volcano new opened fractures may be created. Underground water (fresh infiltrated or geothermal) can use these fractures as a channel to flow. That means a sudden increase of the resistivity at the beginning and a decrease of the resistivity afterwards. Then, procedures of slow mineralization, or salts or clay deposition can also result to the increase or decrease of the resistivity according to the case.

This resistivity changes can be measured form the surface and thus, a special geophysical method can be a very useful tool as a part to the monitoring procedures on a volcano.
Among a variety of geophysical methods that can study the resistivity distribution in a near surface environment, the most prominent ones, are the electrical resistivity tomography and VLF electromagnetic method. These are two very different methods but in case of inclined conductors they can lead to comparable results, as concerns the location and the dipping of the conductors (i.e. case of faulting zones).

Volcanoes in general are not very friendly field for geophysical measurements especially for installing complicated and heavy material. Geophysical methods which are combining easiness on the field and confidence in the data are very important especially in volcanoes.
VLF method is an electromagnetic method which satisfies these two demands for the specific target in volcanic fields, since only one operator is needed using a relatively light equipment.

With only dependence on the radio stations emitting the signal which is considered to be the primary field, VLF measurements along profiles can measure the secondary field which will be produced in the case of a conductor within the underground.

Depending on the characteristics of the resulting component interpretation results can lead to the characterization of the inclined zone regarding the conductivity of it.

Seasonal changes of the conductivity can be used as an indication of dynamic changes to the hydrothermal state of the volcano and detect any new fracture systems that could be possible pipes for any imminent phreatic explosions.

Application of VLF method in La Soufriere volcano showed very well correlation with SP measurements. Comparative interpretation of both methods can contribute to the study of underground water flow. Fast and accurate detection of fracture zones can also be a very useful tool to the planning of further geophysical survey like electrical resistivity tomography.

Deep ERT measurements using remote current and voltage electrodes

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ABSTRACT

The application of geophysical methods is well known approach helping in better understanding the geological regime and in this sense it's very useful in monitoring active volcanoes. The resistivity methods provide a useful tool for mapping the different geological formations with adequate precision even in few hundreds meters depth.

The resistivity method involves the introduction of direct electrical current into the ground; the resultant measured potential differences at the surface give an indication of the subsurface electrical resistivity (ρ) distribution. The most efficient resistivity method applied in shallow surveys is 2D or 3D geoelectrical tomography known as ERT. In the last decade the resistivity meters have become very sophisticated using multichannel measurements thus making it possible for the geophysicist to combine more than one electrode array. A vast variety of state of the art equipment provides the capability for acquiring large datasets in relatively short time.

For all resistivity methods the depth of investigation depends on the electrode distance. In the case of multi-electrode resistivity imaging the most common used arrays are Dipole – Dipole, Wenner and Schlumberger. The maximum depth of investigation is of the order of 0.2 times the total length of cables, for instance 50m for 48 electrodes spaced at 5m (total length: 235m).

In practical point of view the multichannel arrays are subject to the total length of cables available. Longer cables increase the depth of investigation but also require more free space and greatly increase the effort required for setting up the array.

In order to develop a system for ERT measurements in difficult terrain conditions and avoid using long multichannel cables we decided to use separate current source and voltmeter. We used National Intruments CompactDAQ chassis and NI 9206 data acquisition card to read voltage and an IRIS instrument (Syscal Pro) as current source. We developed a simple application using the National Instruments LABVIEW environment in order to acquire 3 differential voltage inputs and save it in binary form. Next we used MATLAB environment to read these records and calculate the desired voltage difference for each dipole. Tests proved that in real conditions voltages in the order of 10^{-4} Volts can be measured.

Using the above hardware, a large scale survey was carried out in a river basin near Thessaloniki city, in Greece. Five parallel ERT lines of 3000 meters length each were measured using dipole – dipole array with 200 meters dipole separation. The inverted results followed the bedrock to a depth of 500 meters under sediments deposits revealing significant fault lines and providing a better understanding of the deep geological structure for 3000 by 1500 square meters area.

Although much slower than measuring ERT using standard instruments with multichannel arrays the above mentioned approach provides the capability of measuring ERT in conditions were laying out long cables is not possible. Based on the target's characteristics, it is possible to design irregularly spaced arrays. Moreover the depth of investigation is only subject to the available current source and therefore can 'see' deeper than any multichannel array.

Resistivity Imaging by Magnetotelluric Method at Active Volcanoes – Some Cases in Japan

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ABSTRACT

Electrical resistivity surveys using the magnetotelluric (MT) method have been applied to clarify subsurface structure of active volcanoes. Since the resistivity of rocks depends on the physical or chemical conditions by several orders, the specific structures of volcanoes such as a magma, hydrothermal water and clay minerals can be found as resistivity anomalies. For example, distribution of aquifer imaged by the resistivity investigation can be one of the most important information as a preparation for a possible phreatmagmatic eruption in future. I will present some recent case studies of the resistivity structure beneath active volcanoes in Japan using the MT method. (1) The 2000 eruption of Usu volcano, located in NE Japan, was the phreatmagmatic explosion with significant ground deformation. The magma intrusion is considered to reach the shallow subsurface. A magnetotelluric survey was conducted to prospect the intruded magma (Hashimoto et al., 2009). A relatively resistive zone beneath the main crater was found at the middle part of the conductive layer. This resistive zone can be corresponding to a part of the intruded magma, which contains a partial melt. The conductive layer is considered as an aquifer saturated by hot water containing some soluble components. (2) Tarumai volcano has not experienced any magmatic eruption for a hundred year, while fumarolic activities have continued at and around the lava dome at the summit area. The AMT survey with a denser arrangement of the stations were carried out around the lava dome, and then a three dimensional structure was suspected by a forward modeling (Yamaya et al., 2009). A bowl-shaped conductor corresponding to the past crater was found beneath the dome. This conductor is considered as a shallower aquifer, which can act as a buried crater lake. It is likely that the fumarolic activities are controlled by the contact by volcanic gasses with this aquifer. (3) Hachijo-Nishiyama volcano is located in Hachijo island, 300 km south of Tokyo, Japan. While eruptions and magmatic activities at this volcano had not been realized for 200 years, a seismic swam and geodetic deformation was observed near the island in 2002. Evidence of the phreatmagmatic explosion is recognized at the side of the volcano, and the next eruption will take this type activity. We investigated a distribution of the aquifer, applying the AMT survey. The resistivity structure is characterized by two layers: resistive volcanic edifice and conductive layer below the sea level. The salinity concentration estimated from the

conductive layer below the sea level suggests that the seawater can penetrate into the whole subsurface of the volcano.

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Testing the Use of Analogues in Eruption Forecasting: Do Volcanoes with Similar Eruptions Exhibit Similar Eruption Precursors?

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ABSTRACT

One of the difficulties in forecasting the outcome of unrest at a volcano that erupts infrequently is that there are few historical data on eruption precursors. One way to expand the dataset is to also consider data from analogous volcanoes, soon to be easier using WOVOdat, but skeptics will ask whether data from analogues should be applied to the specific volcano in question.

I will propose a test comparison between key geophysical and geochemical precursors of volcanoes in two separate groups of volcanoes. Group A volcanoes are basaltic to andesitic and have small- to moderate eruptions every few years with no recent repose longer than about a decade. Group B volcanoes are basaltic to dacitic and produce small- to large eruptions with repose periods generally longer than a decade.

The test will compare the following parameters:

- Pre-eruption seismicity -- M_{max}, seismic energy release (in ergs), temporal pattern of seismicity (eq counts or E release) from the end of one eruption to the start of the next; and relative abundance of VT earthquakes with hypocenters several km away from the vent (distal VT's) relative to those under the vent.
- Pre-eruption deformation – Maximum magnitude of deformation (in microstrain or microradians of tilt) at a distance of ~3 km from a vent; temporal pattern of deformation from the end of one eruption to the start of the next; depth(s) of pressure sources inferred from Mogi models.
- Poroelastic response of groundwater to intrusions

- Pre-eruption gas fluxes -- CO_2 vs. time; SO_2 vs. time; correlation (or anticorrelation) of SO_2 flux with seismicity and deformation.
- Pre-eruption electromagnetic changes
- Ability of a lake to form and persist in small craters (unless the crater walls are exceptionally permeable, persistence would imply sufficiently low heat flux that collected rainwater and groundwater doesn't boil away).

I'll present a sample comparison. Beyond this, we should assess if there are statistically different precursor patterns in the two groups. Next, we should judge which parameters are the most diagnostic predictor of volcano type or group, and thus the best basis for selection of analogues. A third, we should ask if the differences observed between the groups are consistent with what we might predict based on conceptual models of how representatives of these two groups of volcanoes "work."

Soil Degassing and Thermal Transfers at Active Volcanoes

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ABSTRACT

Active volcanoes result from the interaction between a magma supply and more or less-developped hydrothermal fluids. At such volcanoes, studying fluid and heat transfers, their spatial distribution and their change in time is a need for assessing the potentiality of a magmatic/hydrothermal system to be destabilized. It is a fundamental request for forcecasting eruptions and risk mitigation in such areas. With this aim, soil temperature and gas are investigated for the precise imaging of active areas and the assessment of volatile budgets.

We describe here briefly the methods used (CO_2 concentration and flux measurements) and discuss the use of these methods at 2 volcanoes : Vulcano (Aeolian Islands and Merapi, Indonesia).

At Vulcano, we demonstrate that lateral soil gases display the same chemical and isotopic signature that deep fumarolic fluids and show that the chemistry of soil gases follows the general increase of volatile flux at this volcano.

At Merapi, soil degassing is controlled by structures identified as concentric historical caldera rims, which have undergone severe hydrothermal self-sealing processes that dramatically lower the permeability and porosity of soils. Temperature and CO_2 flux measurements near the dome suggest the summit to be made of isolated and mobile blocks. Self-sealing both prevents long-distance soil degassing and controls heat and volatile transfers near the dome. An estimate of the CO_2 output through soils near the dome is 200-230 T/day, i. e. 50% of the estimated total gas output in quiescent periods.

Sub-surface soil permeability therefore appears as the key parameter that controls the transfer of heat and volatiles within volcanoes, allowing their major tectonic architecture to be revealed by soil gas and soil temperature surveys.

Broadband Seismic Monitoring of Active Volcanoes Using Deterministic and Stochastic Approaches

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ABSTRACT

Broadband seismic instruments introduced to observe active volcanoes in the early 1990s have led to innovative approaches in the study of active volcanism. Quantitative analyses of very-long-period (VLP) signals based on waveform inversions have been successfully used to investigate dynamic magmatic and hydrothermal processes. The deterministic approach of the waveform inversion is, however, basically applicable to VLP signals with periods longer than a few seconds. We demonstrate that a source location method using high-frequency seismic amplitudes is useful to locate various seismic signals such as long-period (LP) event, explosion event, and tremor associated with lahars and pyroclastic flows. The source location method uses seismic amplitudes corrected for site amplifications and assumes isotropic radiation of S waves. The isotropic radiation assumption may be valid in a high frequency range in which the path effect caused by the scattering of seismic waves results in an isotropic radiation pattern of S waves. The source location method may be categorized as a stochastic approach based on the nature of scattered waves. A systematic use of the deterministic and stochastic approaches provides a way to better utilize broadband seismic signals for improved monitoring of active volcanoes.

Mechanics of Volcanic Activity in Long Valley and Kilauea/Mauna Loa Volcanic Areas from Multi-parameter Borehole and Local Magnetic Field Measurements

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ABSTRACT

Multi-parameter borehole instrumentation (high-precision strain, seismic, pore pressure, tilt sensors, etc) together with precise magnetic measurements allow exciting new insights into the mechanics of volcanic activity. The new data include real-time observations of 1) subsurface intrusions leading to seismic activity and surface deformation, 2) intrusions and swarm activity triggered by distant earthquakes, 3) deformation preceding and following very long-period (VLP) earthquakes, and 4) unusual deformation sometimes associated with "normal" volcanic earthquakes. Many intrusive episodes have been observed in their early and final eruptive stages on borehole strain and tilt instruments, EM and GPS in Long Valley Caldera. and on borehole instruments and GPS on Kilauea and Mauna Loa in Hawaii. Prior to the recent eruptions on Kilauea, large intrusive events were observed out to a distance of 58 km from their source. These can be modeled with a propagating dike feeding into the east rift system. The 2002 M7.9 Denali earthquake, the 1999, M7.1 Hector Mine, California, earthquake and the previous 1992, M7.3 Landers earthquake all triggered deformational transients and seismicity in the Long Valley Caldera. The deformation was triggered by the passage of large-amplitude surface waves (~3.2 bars) through the region. For the Landers earthquake, diffusive seismicity throughout the south moat occurred simultaneous with the deformation and has been explained as either triggered dike intrusion or diffusion of hydrothermal fluids, triggered bubble release from magma, or triggered dike intrusion. For the Hector Mine earthquake the seismicity was localized under the north side of Mammoth Mountain and followed the onset of deformation by 20-30 minutes. Triggered slip and perhaps intrusive opening on a north-striking normal fault at a depth of 6 km beneath the triggered seismicity can explain these data. Total moment release was 3X10E15 Nm, equivalent to about a M4.3 earthquake while that of the associated seismic moment release

was three orders of magnitude smaller. Decay of strain and seismicity occurred over the next five days. Volcanic VLP events occurring beneath the strainmeter at Devil's Postpile (POPA) are preceded by increasing extensional strain in the minute before the event followed by relaxation and, in one case, a net offset of about 0.3 nanostrain after the event. High frequency radiation occurs also with these events. This is consistent with models of these events as pressure driven opening of a crack with fluid oscillation as proposed by Chouet (1996) and suggests that pressure opening of cracks can generate radiation with both brittle failure and oscillatory low-frequency behavior.

Kelud Volcano: Its Monitoring, 2007 Crisis and Risk Analysis

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ABSTRACT

Kelud volcano in East Java is one of the most active and dangerous volcanoes in Indonesia. The summit elevation of this stratovolcano is 1731 m and a large lake occupies the summit crater. In 2007 the volume of crater lake was about 2.5 km^3.

From the historical eruption, the interval of eruption can be divided into two: the long interval (about 30 years) and the short (15 – 17 years) one. Historical eruptions also noted that number of victims related to volume of the crater lake. The higher volume of crater lake the more number of victims were reported.

The eruptions of the volcano were characterized by initial phreatomagmatic followed by the explosive eruptions which produced pyroclastic flows, ash-fall and lapilli. The explosive eruptions of Kelud volcano usually take place in a short time.

In 2007, Center for Volcanology and Geological Hazard Mitigation (CVGHM) has monitored Kelud volcano continuously using 5 seismic stations, 2 tiltmeters, and temperature of crater lake at surface, 10 m depth and 15 m depth. Measurement of Electronic Distance Measurement (EDM) and flux CO2 was carried out episodically.

During normal state of activity (Level I) occurrence of VT earthquake is usually less than 5 events a month, meanwhile B-type and other type of volcanic earthquakes were very rarely recorded. However, starting on September 8, 2007 some VT earthquakes and on September 10, the number of those VT reached 15 events within 5 hours. Meanwhile, tiltmeter noted both radial and tangential deformation. So, on September 11, the state of activity was raised to Level II.

The occurrence of VT earthquakes continued in average one event a day. On September 26 and 27, number of VT's reached remarkable number of 22 and 26 events, respectively. Field observations at the summit found that the color of crater lake had changed to whitish blue. On September 29, when the first tremor was recorded the state of activity was upgraded to Level III. In addition, deformation measured by tiltmeter detected deflation and the lake

temperature measurements were continuing to increase gradually. At Level III, the area within radius 5 km from the crater was prohibited for any activities. During Level III, the flux CO2 reached 515 ton/day while on normal state is about 40 ton/day. Also, occurrence of volcanic earthquakes still continued, lake temperature increased with in average 0.2 – 0.4^{o}C/day, radial component of tilmeter showed inflation.

On October 16, swarm of 306 of B-type events occurred within 7 hours (10:00 -17:00 local time). Later, number of B-types earthquakes sharply decreased, until October 21st there were only 4 events recorded. After 2 days in quiescence, on October 24th VT earthquakes occurred about 10 events. The occurrence was then followed by B-type earthquakes.

Crater lake temperature becomes 37.8^{0} C, volcanic tremors are recorded occasionally, then on October 16, 2007, at 17:25 (Local Time), Kelut volcano upgraded its status from Level III to level IV (Highest Level). On this level, CVGHM make a recommendation to evacuate people out of the areas within a radius 10 km from the active crater. More than 13.000 peoples evacuate from III hazard prone areas (within a radius 10 km from the active crater).

In November 3rd, 2007, Kelut volcano record a new history, effusive eruption occur (in the 100 years history eruption always erupt in explosive type).

To minimize the risk of volcano hazards threat, CVGHM conduct a risk analysis. Volcanic hazards maps became the basic data in analysing the risks, overlayed with residential and land use (a place of community activities).

Risk Analysis results directly socialized to communities and local government around Kelut volcano. When the Status of Kelut Volcano in level IV, priority of evacuation is for people who live and had a n activity in III hazard prone areas, which has a high risk towards Kelut Volcano eruption threat.

Mayon Volcano Real-Time Data Monitoring, Data Processing, Analysis and Modelling

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ABSTRACT

Monitoring active volcanoes using different methods and associated instruments help in understanding the various processes prior to the onset of volcanic activity.

The current data acquisition at Mayon Volcano is divided into instrumentally derived data and visually acquired data. The instrumentally derived data is further divided into real-time and those that are periodically acquired through field surveys.

The real to near real time data acquisition are telemetered digital seismic and electronic tilt. Periodically acquired data are gathered during scheduled field survey such as those from flyspec, pHMeter, Electronic Distance Meter (EDM), Digital Precise Leveling and Global Positioning System (GPS).

The seismograph is still considered the most vital geophysical monitoring instrument to date for volcano eruption forecast. Various volcano earthquake type best indicate varied processes as magma pushes its way up to the surface. Sulfur Dioxide gas discharge measured from steam and pH values from wells and springs contributes in understanding the behavior of Mayon Volcano. In addition, edifice deformation is being monitored using geodetic instruments like GPS, EDM and Precise Level.

The geophysical, geochemical and geodetic data are being processed, analyzed and interpreted using special processing software like SEISAN and supplementary MapInfo , GPS software, spreadsheets and other instrument built-in software. Geodetic data are also used as input to the Mogi's model.

MONITORING ACTIVE VOLCANOES
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Session 3

Taal Volcano History and Land Use

Historical Eruptions of Taal Volcano: Impacts and Precursory Phenomena

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Esfeca T. Del Mundo

Ms. Del Mundo's study on Taal Volcano began almost 20 years ago. As a chemist, she was formerly a member of the Geochemical Laboratory, which monitors and evaluates the chemical composition of Main Crater and Taal lakes. In 1995, she attended A 6-month training on Geological Data Management and since then her work involves not only monitoring volcanoes but also managing daily data coming from field observatories. Currently, she leads a team which handles and maintains the databank on volcanoes and monitoring parameters. She is also involved in information campaign around Taal Volcano Island in order for the population to be aware of the volcanic activities and the hazards the volcano poses to life and properties.

ABSTRACT

Taal Volcano is the second most active volcano in the Philippines, with 33 known eruptions. Out of these eruptions, those of 1749, 1754, 1911 and 1965 are classified as violent with volcanic explosivity index of 3-4.

Most of Taal's eruptions have been phreatic or phreatomagmatic in nature mainly because of the access to great body of water. The 1911 eruption was classified as phreatic while that of 1965 was classified as phreatomagmatic. Those of phreatomagmatic eruptions in Taal have been the most violent and destructive activities. The 1968 and 1969 eruptions, however, were of Strombolian type. Although the 1754 eruption was predominantly phreatomagmatic in nature, it commenced with a sub-Plinian phase, which later developed into a Plinian phase.

The eruptions of Taal Volcano occurred in four eruption series. This categorization was based on the center of activity and on the repose periods in between these eruptions. Eruption Series A and C were centered at the Main Crater Lake; Eruption Series B at the flank craters of the volcano and Eruption Series D at Mt. Tabaro. Series A and B were separated by a 62-year repose period; series B and C by 18 years and series C and D by 54 years.

Since the establishment of Commission of Volcanology (COMVOL) in 1952, the 1965 eruption of Taal Volcano and the succeeding eruptions were instrumentally as well as visually monitored. The abnormal increase in the temperature and lowering of water level of Main Crater Lake alerted COMVOL of the growing unrest of Taal Volcano. Several months prior to the August 1967 eruption, steaming at the thermal area inside the Main Crater varied from

weak to intense. Intensive bubbling activity at the Crater Lake was also observed. A tremendous change was also noted at the 1965-1966 eruption site such as enlargement of the steaming/thermal area, intense steaming and bubbling. The most notable precursory sign before the 1969 eruption was the occurrence of local perceptible quakes which was invariably accompanied by rumbling sounds. Appearance of harmonic tremors a few hours before the start of the 1967 and 1968 eruptions enabled COMVOL to issue warnings.

Based on the accounts or early inhabitants at the shoreline areas surrounding the Volcano Island several phenomena were observed prior to the events. Residents experienced felt quakes, some accompanied by rumbling sounds. Ground swells and fissuring were noted not only in the island but as well as at the nearby towns and villages located at the mainland. The most destructive known eruptions brought so much damage that several towns around the Volcano Island were relocated. The population fled their homes and settled in areas away from their former villages. This devastation was due to heavy ash fall, base surge and seiche/flooding.

Population Settlement and Economic Growth in Taal Volcano Island and Its Surrounding Communities

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1964 – 2000 College Professor, Western Philippine Colleges, (presently University of Batangas), Batangas City
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1989 – 1992 Executive Assistant – Office of the Governor, Batangas
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OUTLINE

CONTENTS OF THE PROVINCIAL PLANNING AND DEVELOPMENT OFFICE (PPDO) BATANGAS BRIEFING

I. HISTORICAL PROFILE OF TAAL VOLCANO ISLAND

- Land Area
- LGUs with control over the six community groupings in the Island
- Volcano-geomorphic features
- Taal Volcano Island as “No man’s Land and a National Park” under PP 235 s. July 22, 1967
- Hazards brought by the eruption of Taal Volcano during the 1754, 1911 and 1965 eruptions.

II. POPULATION SETTLEMENTS OF TAAL VOLCANO ISLAND AND ITS SURROUNDINGS COMMUNITIES

1. SORROUNDING COMMUNITIES (ELEVEN LAKESHORE MUNICIPALITIES/CITIES NAMELY: AGONCILLO, ALITAGTAG, BALETE, CUENCA, LAUREL , MATAAS NA KAHOY, SAN NICOLAS, STA. TERESITA, TALISAY, LIPA CITY AND TANAUAN CITY)

2. SIX (6) COMMUNITY GROUPINGS IN THE ISLAND WITHIN THE JURISDICTION OF THE FOLLOWING LOCAL GOVERNMENT UNITS (LGUs)

   a. TALISAY (Sitios Tabla, San Isidro and Sitio Balantoc)
   b. BALETE (Sitio Calauit)
   c. SAN NICOLAS (Sitios Pulang Bato and Sitio Alas-as)

III. ECONOMIC ACTIVITIES AND GROWTH IN THE TAAL VOLCANO ISLAND AND SURROUNDING COMMUNITIES

1. AGRICULTURE
   a. Farming
   b. Aqua-culture
   c. Livestock
   d. Fishing

2. TOURISM
   a. Resorts
   b. Volcano Trekking

IV. PROGRAM/PROJECT INITIATED BY THE PROVINCIAL GOVERNMENT IN THE CONTEXT OF RELOCATION SITE (Brgy. Ma. Paz, Tanauan City, Brgy. Nazi, Rosario, Batangas and Brgy. Balete in Batangas City)

V. ISSUES AFFECTING GOVERNANCE AND THE SAFETY OF TAAL VOLCANO ISLANDERS

1. Increasing population and economic activity despite of PP 235 dated July 22, 1967
2. Political will LGUs concerned regarding enforcement of PP 235 and implementation of Relocation Plan
3. Defiance/Arrogance of Settlers despite advices to vacate the Island
4. Titled Land being claimed by some alleged landowners and residents of the Island
5. Concerned LGUs and implementing agencies not providing evacuation drills if and when Taal Volcano erupts

Seminar-workshops in the Community-Level Around Taal Volcano

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ABSTRACT

Taal Volcano Island and the Municipalities of Laurel and Agoncillo in the Province of Batangas were badly hit by the volcano's worst eruptions in 1911 and 1965 which caused loss of thousand of lives and millions in pesos in damages to properties. Despite those events, people continued to return and live in the areas around Taal Volcano, claiming that it is where their source of livelihood is.

In November-December 2005, seminar-workshops were held in Taal Volcano Island for the community residents of 1) Sitio Pira-piraso, Talisay, 2) Barangay Calauit, Balete and 3) Barangay Alas-as, San Nicolas. By October 2008, another series of seminar-workshops was conducted in the Municipality of Laurel and Agoncillo as part of PHIVOLCS program on dissemination of information on volcanoes. Participants in the 2008 workshops were representatives from the Batangas Provincial Disaster Coordinating Council (PDCC), municipal disaster coordinating councils, barangay leaders and community residents.

The workshops aimed to share technical information about the hazards of living near a volcano, historical and current status of the volcano and enhance the capacity of communities into making concrete actions to prepare them should an eruption occur. A learning workshop on understanding the Taal Volcano Hazard Maps was done in all the 2008 workshops.

Most important activity was the small-group discussions where the participants were asked about their ideas about future activities in preparation for a volcanic eruption.

Current Applications and Challenges of GIS/RS Tools to Volcanic Hazards Analysis and Monitoring

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ABSTRACT

In the past two decades, the tandem of GIS and RS has produced significant advancements in monitoring and analysis of volcanic activity and associated hazards and risk. From basic functions of geospatial databasing and visualization, GIS/RS tools have evolved into detection, mapping and quantification of volcano features and processes on the ground and in the atmosphere. Some of the current land-based applications in volcanology include the production of digital elevation models (DEMs) and the simulation of volcanic mass flow/inundation on DEMs for hazards modelling, near real-time eruption monitoring and mapping of eruptive products, and thermal and deformation monitoring. High-resolution RS imagery has enabled detailed mapping of risk elements and land-use which can be integrated with volcanologic data in GIS for risk, vulnerability and loss estimation. Low- resolution RS data and tools for measuring ash emission, altitudes and dispersion, as well as magmatic gas output in active or passive volcanic plumes, are in robust use worldwide for eruption and aviation monitoring. GIS/RS applications to volcanology are facing practical concerns of access and sustainability for developing nations, data quality/homogeneity and the increasing demand for accurate, high-resolution data. GIS/RS visualization tools are anticipated to ease into public domain emerging worldwide volcano databases that will soon become indispensable tools for successful prognostication of volcanic activity.

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Session 4

Understanding and Monitoring Taal Volcano

Revisiting the 1965 Taal Volcano Eruption: Lessons Learned from Survivors' and Eyewitnesses' Accounts

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ABSTRACT

Revisiting the 1965 Taal Volcano eruption by video documenting eyewitnesses and survivors is a valuable tool for reconstructing the event. Potential future use of these materials for community-based capacity building is also seen. PHIVOLCS was able to find 17 resource persons with ages ranging from 55 to 88 at the time of the interview in June 2009. They were interviewed to record important information of their experiences- from what they felt, heard and saw which confirms certain aspects that we already know about the 1965 event and gives new light to some details of the eruption as well. The description in their stories tells much about the eruption as observed from inside ground zero. To some, remembering practical advises from parents and grandparents who experienced the 1911 eruption also clearly demonstrated the importance of passing on historical information even just within the family as these helped them respond to the 1965 event. The valuable lessons learned from the experience of individuals would certainly benefit the generations to come. Some of these include the importance of planning, communication, what to do during an eruption such as having a sense of direction as to where to go, by observing the wind direction and going against or away from it.

Taal Volcano: Observations on Recent Activity and Previous Unrests

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ABSTRACT

Episodes of seismic crisis occurred at Taal Volcano in 1987, 1989, 1990, 1992, 1994 and 2000. The recurrent seismic swarms were associated with ground deformations and geothermal activities. At the peak of the 1992 and 1994 seismic crisis, the north and southeast sectors of Volcano Island were significantly uplifted and ground fissures occurred on its northern flank. On 23 September 2004, Taal Volcano's seismic activity began to intensify again.

In 2005, seismic and geothermal activities further increased from January to February. Felt earthquakes accompanied by audible rumblings occurred causing inhabitants of Volcano Island to evacuate temporarily to the mainland. Seismic activity declined between March and September but increased again in October that year. In November, felt earthquakes occurred at the northern and eastern flanks of the volcano. During the seismic crisis, enhanced geothermal activities were observed at Daang Kastila and Main Crater Lake. In 2006, a few felt earthquakes occurred in August and September. Again, in 2007, seismic activity briefly intensified on 24 June with the occurrence of a few felt earthquakes. During the peak of the seismic crisis, the Main Crater Lake's pH, temperature and chemistry slightly increased.

Seismicity and ground deformation continued to occur in the same geothermal areas located inside and at the northern flank of the Main Crater Lake. Hypocenters ranged from 1 to 6 km. but no trend or pattern such as increasing trace amplitude, clustering of epicenters and shifting of hypocenters to shallow depths were observed. However, the recurrent earthquake swarms and enhanced geothermal activities inside the Main Crater and at its northern flank signifies increasing volcanic activity. In addition, the presence of ground fissures at its northern flank is subjecting this sector to collapse or flank failures.

Electromagnetic, Geochemical and Thermal Investigations of Taal volcano

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Since 2007, President of the IUGG inter-association Electromagnetic studies of Earthquakes and Volcanoes EMSEV ((http://www.emsev-iugg.org/emsev/)
Past President of the Volconological section in France
Long experience in volcano monitoring and imaging by electromagnetic methods
Research on Electromagnetic phenomena related to earthquakes

ABSTRACT

On volcanoes which display hydrothermal/magmatic unrests, EM methods can be combined with geochemical (GC) methods. The integration of these methods allows to image in detail hydrothermal systems, to find out possible scenarios of volcanic unrest, and to monitor the on-going activity with some knowledge on the sources of heat, gas and fluid transfers. The objective followed on Taal is to highlight the complementarities between EM and GC methods when these methods are jointly applied on volcanic/hydrothermal systems.

Since 1992, Taal volcano in Philippines suffers sporadic, but sometimes intense, seismic crises since 1992. A strong and large scale hydrothermal system stands on the volcano and is periodically re-activated. In the frame of an EMSEV-PHIVOLCS agreement, combined EM and GC methods are applied after 2005. They give an accurate description of the hydrothermal activity and heat discharge. EM methods, as self-potential and magnetic surveys, audiomagnetotelluric soundings map the hydrothermal system and locate the source of thermal and fluid transfers at depth, while soil degassing

and thermal imageries clearly point out the location of the most active areas where thermal discharges take place.
GC methods also specify the origin of the gas and fluids escaping from faults, fumaroles, and geothermal areas. Between 2005 and 2007, no large change in the hydrothermal activity took place, in spite of sporadic seismic swarms and surface activities which could lead to sudden phreatic explosions which may induce landslides or collapses of some parts of the crater rim.

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"Magnetic observations on Taal Volcano (Philippines) in combination with other geophysical and geochemical methods from 2005 to present" (oral)

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ABSTRACT

Taal Volcano is one of the most active volcanoes in the Philippines. Its first recorded eruption was in 1573. It has since erupted 33 times resulting in hundreds of casualties and large damages to property. In 1995, it was declared one of the 15 Decade Volcanoes. Beginning in the early 1990s it has experienced several phases of abnormal activity, including seismic swarms, episodes of ground deformation, ground fissuring and hydrothermal activities. In January 2005, several felt earthquakes drove inhabitants living near the volcano to evacuate.

Joint total magnetic field (TMF), self-potential (SP), ground temperature, and carbon dioxide (CO_2) soil degassing surveys along with satellite thermal imaging were begun in Taal Volcano in 2005, which aims to study the geothermal activity occurring in the volcano. This project is done in the behalf of PHIVOLCS-EMSEV agreement (http://www.emsev-iugg.org/emsev/). These surveys are repeated regularly and several permanent and continuous TMF and multi-parametric (SP, ground temperature, Rn, etc.) stations have been established on the northern part of the volcano, as well as on the northeastern shore of the Main Crater Lake (MCL).

Here we present the results of the continuous total magnetic field measurement studies:

1. Active geothermal areas show strong positive TMF anomalies. These areas are found in the northern flank of the Volcano Island and at the eastern shore of the Main Crater Lake.

2. There is a demagnetized body 150m wide underneath the Daang Kastila horsetrail at the northern flank of Volcano Island.

3. A 40m mound was found representing a clear bathymetric change in the Main Crater Lake between 1986 and 2008 bathymetric surveys. This mound is non-magnetic.

4. Recent magnetic measurements from continous magnetic measurement points indicate a gradual remagnetization of rocks beneath the Main Crater Lake. This could be due to recent heavy rains and an increasing lake water level.

Soil Degassing and Thermal Transfers at Taal Volcano (Philippines)

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ABSTRACT

Here we assess the current fluid and heat tranfers at Taal volcano using soil carbon dioxide (concentrations) and temperature gradients.

Methods. 360 soil CO_2 concentration and temperatures at 10 cm depth [T_{10}] are measured along 17 traverses intersecting the main structural features for mapping. Vertical thermal gradients (ΔT) are calculated using 4 to 8 measurements from 0.02 to 0.4 m depth at 21 sites.
CO_2 concentrations and [T_{10}] mapping. The highest temperatures (up to 100°C) are measured along the northern MCL shoreline and the northernmost active 1992–1994 fissures. Lower GTs are measured between these areas. The CO_2 map reveals the close relationship between degassing and the main structural features. A main spot of volcanic/hydrothermal gas is located within the crater on the northern shoreline of MCL, and a smaller spot is associated with the active fissures outside the crater on the northern flank, in agreement with the GT measurements.

Heat loss conditions Temperature gradients ΔT values are very low (14°C m^{-1}) to very high (1225 °C m^{-1}). Conductive heat transfer takes place in a first thin near-surface soil layer of tens of centimetres. Sites with medium [T_{10}] (< 50 °C) and linear ΔT are related to pure conductive transport, whereas sites with high [T_{10}] (> 80 °C) display nearly vertical profiles as temperature reaches the boiling point. Convective transport dominates at depth, but conductive transport remains the heat transfer mode in the surface layer. ΔT can be scaled to [T_{10}] : it increases exponentially with [T_{10}], and can be regressed as a function of temperature at 10 cm depth as follows : $\Delta T = 1\times10^{-5}\, T_{10}^{4.0343}$

Estimating total heat flux. Both aerial degassing areas (Dang Kastila and Main Crater lake) can be devided in 6 thermally homogeneous areas with [T_{10}] in the range of 40-50, 50-60, 60-70, 70-80 and 90-100 °C. Subaerial degassing areas are $24.1x10^4$ and $8.9x10^4$ m^2 for MCL and Dang Kastila areas, respectively. For each of these zones, corresponding ΔT are calculated
using the above equation. Considering that heat is mainly released by conduction, even in high heat flow zones, a rough estimation of heat flows at Dang Kastila and MCL areas gives 28.1 and 7.2 MW, respectively, using a mean soil thermal conductivity value of k = 1.0 $W°C^{-1}m^{-1}$. Assuming that degassing operates similarly beneath MCL, the total energy released by Taal is 63 MW. Scaling this value with a total degassing surface of 57.10^4 m^2 allows to compute a total heat flux of 110 W m^{-2}.

The 2009 Resistivity Survey at Taal Volcano

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Abstract

Two (2) resistivity surveys were conducted for the year 2009. The initial sites selected for the survey are Barangay Calauit at the eastern side of the volcano island and the Main Crater floor (Calauit side).

For Barangay Calauit area, some significant volcanic events were observed in the recent past. In 1994, an intense seismic activity occurred in this area resulting to two (2) steaming fractures. During this period, the area was observed to be uplifted by as much as 9.8 centimeters. These geological events lead the survey team to consider this area for future resistivity monitoring.

The choice for Main Crater Floor (Calauit side) for monitoring consider the variation of the resistivity values brought about by the decreasing or increasing acidity and temperature of the crater lake water. Migration of volcanic fluids at depth towards the surface through cracks and fractures and location of possible structures can also be of great help in the evaluation of Taal Volcano's activity. It is worth mentioning here that the catastrophic eruption of Taal Volcano in 1911 occurred in the Main Crater.

A newly acquired GEOTRADE GTR-3 resistivity meter was used in the survey employing Pole–pole resistivity array with a constant electrode distance of 10 m. The Pole-pole array was employed primarily for the following considerations: 1) Strong signal, 2) Effective depth of penetration, 3) Less personnel involved and 4) Less laborious as compared to other methods as only two (2) electrodes are moving.

Data processing using RES2DINV showed a high resistivity formation about 45 meters below the southern half of the Barangay Calauit resistivity line with a horizontal extent of 150 m and at the Main Crater Floor, two resistivity lows were detected positioned near the northern and southern end of the resistivity line. The interesting features observed at Barangay Calauit and the Main Crater Floor showed that resistivity survey can be a valuable tool in volcano surveillance activities.

Diffuse CO_2 Emissions From Taal Volcano Main Crater, 2008-2009 Surveys

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ABSTRACT

Measurements for diffuse CO_2 emissions done in 2008 and 2009 in Taal Main Crater Lake and soil give the estimate of total flux from the lake and show areas with high CO_2 flux. CO_2 fluxes were measured by accumulation chamber method on March-April 2008 and February 2009. Taal Main Crater Lake is a 1.3 km wide lake inside the largest crater (Main Crater) at the center of Taal Volcano Island. Volcano Island is composed of around 47 cones and craters that largely follow northeast-southwest and northwest-southeast trends and reflect the dominant structures in the area. In 2008, areas with high CO_2 flux anomalies, with highest value 1,831 g m^{-2} d^{-1}, were found on the northern part of the lake. In 2009, the same high anomaly area was observed but with additional areas on the south and east of the lake following a northeast trend near the shore. Projection of this trend in anomalies to the southwest of the island connects it with northeast trending fissures in the area. Highest flux value on the lake from the 2009 survey was 2,457 g m^{-2} d^{-1} near the southwest shore. Total CO_2 flux for the Main Crater Lake at the time of the measurements also increased from 506 ± 15 t/d in 2008 to 947 ± 22 t/d in 2009. Subsequent measurements should see if this is within seasonal variation or a significant change in the volcano's activity. Measurements of soil CO_2 degassing in the northeast thermal area in the Main Crater show a decrease in areas with high anomalies from 2008 to 2009. High thermal anomalies on the lake were found near the northeast and southwest shores, reflecting thermal areas within the Main Crater.

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Monitoring Taal Volcano: An Overview

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He started his career in geothermy at the University of Auckland (New Zealand), then at the Kyushu University in Japan, where he completed a post graduate diploma course in geothermal engineering in 1977. He was the Officer-In-Charge of the Geothermal Division in 1982 and then Overall Program Coordinator of Non-Active Volcanoes and Volcanic Terranes Program in 1983. He was then resident volcanologist of the Kanlaon Volcano (1984 to 1991) and Pinatubo Volcano (1992 to 2004). He underwent training on the General Operation of USGS Volcano Observatories and the Applicability of Methods and Approaches to the Pinatubo Volcano Monitoring in United States. Since 2006, he is the Officer-In-Charge of the Volcano Monitoring and Eruption Prediction Division.

ABSTRACT

Taal Volcano's last eruption was in 1977. Since then, five major episodes of volcanic unrests occurred in June to October 1989, March to July 1991, February 1992, March to May 1994 and 1999 to 2000 indicating its restive condition. The 1992 and 1994 seismic swarm resulted to opening of ground fissures on its northern flank and upliftment of the north and southeast sectors of the volcano island. This provides a good opportunity to work and find reliable prediction methods for volcanic eruption. Taal research activities are directed toward understanding of volcanic processes and products, evaluation of the ongoing hazards posed by Taal and delivery of warnings to the public and concerned authorities regarding these hazards.

Monitoring of Taal Volcano involves establishment and operation of observation systems of the various monitoring networks. This covers operations of Taal Volcano Observatory and monitoring system to gather high quality data on a near real-time to real- time basis. To date, the prognostic parameters that are used in predicting its activity are those that are caused by pressure (seismicity, ground deformation, rumblings and landslide slumps), temperature changes (crater lake, ground probe holes, fumaroles, steaming activity, drying of vegetation and electro-magnetic values), chemical changes (crater lake water composition and fumarolic gases evolved) and others (mass dying of lake fishes, bubbling activity in the lake and animal uneasiness). Ground deformations are detected generally by precise leveling, electronic distance measurement (EDM), global positioning system (GPS) and tilt to determine vertical and horizontal displacement of the ground surface caused by volcanic forces acting underneath Taal Volcano. The data gathered are then processed and evaluated.

Seismic monitoring remains the main tool for predicting the eruption of Taal Volcano by providing the earliest warning of volcanic unrest. The rising magma and gas can generate ground vibrations and cause earthquakes. Seismic monitoring relies on an array of short period seismometers to detect earthquakes. Seismic signals are transmitted by radio wave from remote station and are received at Taal Volcano Observatory for processing, analysis and storage. Use of digital telemetered seismic network was established in Taal under JICA-PHIVOLCS Phase I and II Projects.

Together with the seismic array, a network of geodetic stations forms the backbone of Taal Volcano monitoring. The network was set to monitor ground deformation caused by the pressure of magma moving beneath the earth surface. Techniques commonly used include precise leveling to measure vertical elevation changes relative to a reference benchmark; horizontal distance changes are measured using Electronic Distance Measurement instrument, which uses a laser beam aimed at a reflector station to measure minute changes in horizontal distances; and use of Global Positioning System to obtain real time records of ground movement. Changes in earth's surface local electrical conductivity and magnetic field of strength properties are pursued through magnetic and resistivity measurements to trace magma movement.

Geochemical studies for surveillance and prediction Taal's activity consists of sampling and analyses of collected water samples from Taal and Main Crater lakes. These are conducted on a regular basis to detect any change in their physical and chemical properties that would be used in evaluating their role in eruption prediction.

As part of the national disaster mitigation system, monitoring of Taal also involves other entities – the general public, media and government. The information exchange between volcanologists and other disaster government agencies is very essential for implementation of timely warning and evacuation schemes during volcanic crises. Delineation of appropriate danger/hazard zones and information campaign provide early precautionary measures. The Provincial Government of Batangas, which has the jurisdiction over the communities around the Volcano Island, supports PHIVOLCS in the implementation of policies established by the disaster mitigation system. The media helps in information dissemination regarding volcanic activities. The system also encourages the local population living around the volcano island to become involved in reporting unusual phenomena which may help in volcano monitoring.

Self Potential, Ground Temperature and Geochemical Measurements on Taal: From Repeated Surveys Toward Volcano Monitoring by Telemetry

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ABSTRACT

In January 2005, self-potential (SP) measurements combined with geochemical method of monitoring volcanic activity in Taal Volcano was introduced as a collaborative project between PHIVOLCS and EMSEV/IUGG, in combination with magnetic methods. Self-potential is closely related to heat triggered phenomena such as thermoelectric and electrokinetic effects due to hydrothermal circulations and therefore can be an effective method in tracking thermal changes and the evolution of hydrothermal activity. The existence of a large hydrothermal system in Taal volcano makes it very amenable to SP measurements.

Initial surveys in 2005 have revealed self-potential anomalies along the Daang Kastila fissure zones and above fumarolic areas in the main crater. Repeated surveys have also been conducted between 2005 and 2009 and no large change in the spatial extent of hydrothermal activity took place in spite of occasional seismic swarms that could have led to phreatic eruptions.

A telemetry system transmitting SP, magnetic, ground temperature seismic data at 2 seconds intervals from the main crater and Daang Kastila fissures was also installed. Time varying parameters reveal the dynamic aspects of volcanic activity.

1991 to 2010 Ground Deformation Monitoring of Taal Volcano

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Started his career in PHIVOLCS as Science Research Specialist I in 1994 and completed a postgraduate diploma course in Assessing Volcanic Hazards and Monitoring Active Volcanoes at Center for the Study of Active Volcanoes, Hilo Hawaii. In 2002, he underwent training on Volcanology and Sabo Engineering at Institute of Seismology and Volcanology, Graduate School of Science Hokkaido University, Sabo Department, River Bureau, Ministry of Land Infrastructure and Transport, Japan. In 2006, he graduated with a degree of Master of Science in Geology at National Institute of Geological Sciences, University of the Philippines, Diliman.

ABSTRACT

Since the last eruption of Taal Volcano in 1977, at least eight episodes of volcanic unrest happened on the span of 31 years. The 1987 Bilibinguang seismic crisis was attributed to the occurrence of volcano-tectonic type earthquakes. The 1989 swarm of high frequency volcanic earthquakes is located at the south and southeast of the volcano island. The 1991 activity was characterized by occurrence of high frequency type volcanic earthquakes with an average of forty- five events per day that lasted for five months. The 1992 seismic swarm resulted to the formation of steaming fissure cutting through the Daang Kastila trail. The 1994 episode of seismic crisis occurred at Calauit area produced steaming vents. The 1996-1999 steam and mud geysering activities occurred at the Main Crater floor and significant seismic events was also observed from 2000- 2001 and 2004-2005.

It is well known that the surface of active volcanoes deformed to some measurable amounts, apparently because of changes in the pressure exerted by underlying or intruding magma. Crustal deformation observations at Taal volcano was by geodetic method such as Precise Leveling, Electronic Distance Measurement, and Global Positioning Survey. Four Precise leveling lines were established since 1991 at the volcano's quadrant.

The depth and changes in volume of pressure source during the 1992, 1994, and recent unrest of Taal volcano were determined using the principle of point source modeling developed by Kiyoo Mogi (1956). The method had been adapted and applied to the precise leveling data. The estimated depth of pressure source beneath the volcano island during the 1992 and 1994 unrest is about 3.0 to 4.5 km. with volume changed of 5 to 6 x 10^6 m^3. The estimated depth of pressure source for 2007 and 2009 is about 4.0 to 4.5 km. with volume changed of 5 to 7.5 x 10^6 m^3.

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POSTERS

"Determination Of The Three-Dimensional Seismic Velocity Structure Beneath Southern Kysuhu, Japan, By Tomography Of Travel Times Derived From Local Earthquake Data" (Poster)

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ABSTRACT

The Japanese island of Kyushu is a geologically active area. It is bounded to the east by the northwest trending Nankai Trough formed by the subduction of the relatively young Philippine Sea Plate as it slips underneath the Eurasian Plate. A product of this subduction is the chain of Quaternary volcanoes that run along the middle of the island trending roughly north-south. The Median tectonic Line on the other hand runs across the island diagonally northeast to southwest, almost cutting the island in two halves.

In order to obtain a velocity structure of southern Kyushu, we applied the tomography method to P and S wave arrival times of 829 local earthquakes observed at 101 stations. We were then able to distinguish subsurface geological features from the interpretation of P and S wave arrival time delays and corrections. We found that areas comprising of loosely consolidated sedimentary rocks will generally have a negative P and S correction. We deduced the approximate depth of the Mohorovicic Discontinuity based on the assumption that the P-wave velocity of the upper-most part of the upper mantle is 7.4km/s. This then revealed variations in the crust based on velocity distributions such as its increasing thickness going towards east and towards the north. In the subducting slab we found that there is a relationship wherein earthquakes concentrate in areas of relatively high P and S wave velocities (Vp greater than 8.0km/s and Vs greater than 4.5km/s) and low Poisson's ratio (less than 0.25). In the crust, there appears to be no discernible relationship between velocity and earthquake occurrence, but based on Poisson's ratio distributions, the earthquakes will tend to occur in areas of low Poisson's ratio (<0.25). High Poisson's ratio zones on the other hand such as the mantle wedge, where seismicity is usually low could be indicative of fluid saturation.

A Proposal for the STAR Program: SeismoSTAR and New Satellite Constellation: ELMOS

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The Japan Aerospace Exploration Agency (JAXA) is inviting members from six space agencies in the Asia-Pacific Region to participate in the Satellite Technology for the Asia-Pacific Region (STAR) Program, which JAXA introduced at the Asia-Pacific Regional Space Agency Forum (APRSAF) held in 2007.

The STAR Program is an international project team consisting of JAXA and the invited participants. The program soon initiates a three-year study of the EO-STAR (300 to 500kg) system and starts developing Micro-STAR (50 to 100kg).

We proposed SeismoSTAR (Seismo-Electromagnetic IonoSphere MOnitor for STAR program). Its mission objectives are as follows;

- Contribution for Ionospheric/Atmospheric Science and Engineering Applications
- Establishing Proof of Pre-seismic Ionospheric Precursors (electron temperature decrease around 600km altitude and electron density decrease in F-layer) based on the Reliable Ionospheric Model

All the mission instruments of the SeismoSTAR are simple, hi-precision, reliable and space-proven.

- Electron Temperature Probe and Impedance Probe (ex. Astro-A: Hinotori)
- GPS Occultation Receiver (ex. Formosat-3/COSMIC)

If the SeismoSTAR constellation will be realized, it will be the first space mission for comprehensive monitoring from the atmosphere to the ionosphere with its time and space variability. Particularly ionospheric/atmospheric data provided by GPS occultation will be expected to understand ionosphere-atmosphere coupling with its ionospheric temperature/density data.

It is clear that the SeismoSTAR will contribute various scientific research and engineering applications without seismo-related research, therefore, the International Reference Ionosphere (IRI) task group has released a "Letter of Support for SeismoSTAR" as of November 29, 2009. (see the website below)

http://space.geocities.jp/seismostar

ELMOS (ELectric and Magnetic field Observation Satellite) is a mission candidate for small scientific satellite of ISAS/JAXA. As ever, ELMOS was a single satellite like a DEMETER but it is impossible to observe daily variation of the ionosphere by fixed local time satellite.

New ELMOS satellite constellation is composed by one small satellite (200kg～) and 4 microsatellites (50kg～). All the satellites carry electron temperature probe, impedance probe and GPS occultation receiver.

The ELMOS satellite constellation will be launched around 500～600km altitude with inclination 30～40degree.

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Magnetic Observations on Taal Volcano (Philippines): Reconnaissance, Repeat Surveys and Continuous Measurements (poster)

Speaker: J.M. Cordon Jr., J.P. Sabit, M. Harada, Y. Sasai, P.K.B. Alanis, W. Reyes, J. Zlotnicki, E.U. Villacorte, H. Hase, J.T. Punongbayan, T. Nagao, J.S. Sincioco and R.U. Solidum Jr.

ABSTRACT

This is a report supplementary to Alanis et al. "Magnetic observations on Taal Volcano (Philippines) in combination with other geophysical and geochemical methods from 2005 to present". We have conducted reconnaissance magnetic surveys over Volcano Island, in particular on the northern slope of the volcano, i.e. Daang Kastila, as well as in the eastern and western coast of the Main Crater Lake (MCL). Moreover, we extended our magnetic survey on the surface of MCL, where we used a small banka to measure TMF, the lake bottom topography and surface water temperature simultaneously. CO2 concentration was also measured separately by Toutain et al. A new mound, which appeared between the years 1986 and 2008, was found near the NNE coast of MCL. The mound (a topographic high at a depth of 40 m) is non-magnetic and coincides with the position of thermal anomaly emerged during the volcanic crisis in the early 2005. This area could be the outlet of magmatic fluids, which is connected to the vent from the magma reservoir at depth. Repeat magnetic surveys have been carried out since the beginning of 2005. In order to reoccupy the same survey point at each survey, we installed a concrete benchmark at each repeat survey point. Nevertheless, we sometimes lost the point owing to thick vegetation, which grows rapidly during the repeat survey interval of a few months. Another difficulty we met is the heavy tropical rainfall, which sometimes alters the surface topography around the survey point. This caused some apparent changes in TMF, which had nothing to do with the volcanic activity. These problems peculiar to the tropical zones are presented for your information.

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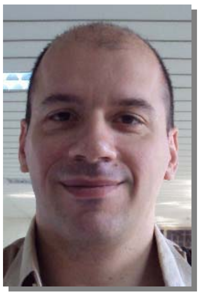
DR. ILIAS FIKOS 	Permanent Staff-Researcher Aristotle University of Thessaloniki University Campus – School of Geology Greece Tel: +0030-2310-991420 Fax: +0030-2310-991403 E-mail: ifikos@geo.auth.gr
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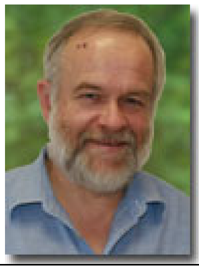
DR. CHRISTOPHER NEWHALL 	Volcano Group Leader Earth Observatory of Singapore Nanyang Technological University N2-01a-10, Singapore 639798 Telephone: +65 9621-9140 Fax: +65 6790-1585 E-mail: cnewhall@ntu.edu.sg
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