Joint EMSEV*-PHIVOLCS** campaign on Taal volcano (The Philippines)

February 27 to March 15, 2013

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* **IUGG Inter-Association Working Group on ElectroMagnetic Studies of Earthquakes and Volcanoes (http://www.emsev-iugg.org/emsev/)**

** **Philippines Institute of Volcanology and Seismology, PHIVOLCS-EMSEV team (http://www.phivolcs.dost.gov.ph/)**

1. Objectives

Four main objectives were targeted during the February-March 2013 campaign:
- Repairing and upgrading the three EMSEV stations located inside the crater (MCL) and on the outer northern flank of the volcano (DAK, PAN),
- Integration of three borehole tiltmeters in the EMSEV multi-parameters monitoring network,
- Completion of the fourth station CUS dedicated to continuous resistivity soundings and tilt monitoring, the infrastructure of which was built in December 2012,
- Resurveys of magnetic and electric fields, as well as ground temperature on characteristics benchmarks and along specific profiles,
- Ground magnetic and superficial resistivity surveys along major paths located on the volcano,

To review this campaign, achievements, problems and future plans, an EMSEV-PHIVOLCS meeting was held at PHIVOLCS Volcano Department on March 15.

2. Participants

2.1. PHIVOLCS participants

- Buco Observatory

A. Loza-Oic, L. Aron-Pogi, Eric, Rick

- EM PHIVOLS team

E.U. Villacorte, P. Reniva, C.J. M. Clarito, Ronald Pigtain, A. Alanis, J. M. Gordon Jr, W. Reyes, Kimberiey M. Vitto

2.2. EMSEV participants

- Japanese team

Y. Sasai, T. Nagao, A. Takeuchi

- French Team

J. Zlotnicki, F. Fauquet

- US team

M.J.S. Johnston

3. Upgrading MCL, PAN and DAK real-time monitoring stations

3.1. MCL site

The MCL site is located near, and just to the North-East of the main Crater Lake (Figure 1). Data types collected at this site include magnetic field, electric field, temperature, and RMS seismic data.

- Total magnetic field data are measured with an automated proton magnetometer with synchronized timing controlled by GPS time-code receiver. The magnetic field data are recorded every minute.
- Telluric electric fields are measured along two orthogonal lines oriented NS and EW, with lengths of 81 and 87 m, respectively.
- Horizontal components of magnetic field are measured along the same directions with a fluxgate magnetometer.
- Ground temperature is measured at the spot of the electrodes of the telluric lines,

These data 8-channels of data are sampled at a 2-seconds sampling interval and are radio-transmitted to Buco Local Observatory through a radio-relay located on the northern crater rim. Description of this system can be found at http://www.emsev-iugg.org/emsev/page005.html.

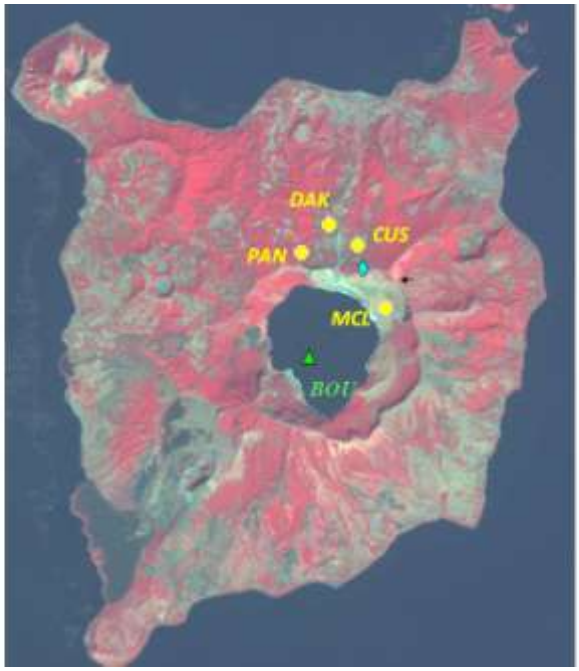

Figure 1. Location of the 4 multi-parameter stations (yellow diamonds). MCL, PAN, and DAK are telemeter stations. Blue diamond shows location of the relay radio-transmitter.

3.2. PAN site

This station (see location in Figure 1) now collects:

- Total magnetic field, as at MCL site. The station is powered by a 65Ah battery recharged by a 40W solar panel.
- Horizontal telluric field in NS and EW directions,
- Two horizontal components of ground tilt in a NS and EW direction with the following sign convention - tilt down to the N and E, respectively, is positive. The tiltmeter is powered by a 120Ah battery and a 80W solar panel bought by the Japanese team.

The borehole tiltmeter, provided by the USGS, was installed by M.J.S. Johnston in March 2013, at a depth of about 2 m.
- The ground temperatures at the location of the telluric field electrodes.

The magnetic data are sampled by one logger while the second 8-channel logger samples all other data every 2 seconds. The 8-channels data logger is powered by a 65 Ah battery connected to a 60W solar panel.
The 8-channels data sets are directly transmitted to Buco Observatory.

In summary, the budget required for the purchase, installation and operation of this station is as follows:

Origin	Equipment	Investment
PHIVOLCS	1x65Ah battery, 1x60W solar panel, workers	1 200 €
USGS, US	Tiltmeter, regulator	6 000 €
CNRS, France	0.5 km of cables, PVC protection, 1 data loggers, sensors, telemetry.	6 500 €
Tokai Univ., Japan	1x120Ah battery, 1x80 W solar panel, workers, boat and horse rental Proton magnetometer, GPS, data logger, 1x65Ah battery, 1x40 W solar panel	3 600 €
EMSEV, IUGG	Shelter, infrastructure	1400 €
Approximate cost		***19 700 €***

In addition, PHIVOLCS provides maintenance of the equipment and retrieval of data every month of magnetic data from one logger and every 2-3 months for all other data from the second logger

3.3. DAK site

This station (see location in Figure 1) now collects:
- Total magnetic field, as at MCL and PAN sites with GPS timing for synchronization. The total magnetic field is recorded every minute. The magnetometer is powered by a 65Ah battery recharged by a 40W solar panel.
- Horizontal telluric field in NS and EW directions,
- Two horizontal components of ground tilt in a NS and EW direction with the following sign convention - tilt down to the N and E, respectively, is positive. The borehole tiltmeter, provided by the USGS, was installed by M.J.S. Johnston originally in March 2010 and reinstalled in March 2012, at a depth of about 2 m. The automatic re-zeroing capability was turned off in 2012. This was turned back on in 2013.
- The ground temperatures at the location of the telluric electrodes,
- RMS Seismic values.

Two data loggers collect the data. One logger collects the magnetic field data. All other data (horizontal components of the tiltmeter, the horizontal components of the telluric field, the ground temperatures, and RMS seismic noise) are recorded on a 8-channels logger and are transmitted by radio telemetry to the Buco Observatory at a sample rate of 2 seconds. Two 65 Ah batteries connected to three solar panels totaling 140W are used to power the data logger.

3.4. Data reception at Buco Observatory

At the observatory, a dedicated PC computer collects the 2 seconds sampled data from MCL, DAK and PAN stations. The system is currently setup and ready to receive data from the fourth station CUS.

Daily, files are sent to the PHIVOLCS headquarters, the EMSEV server and to the VEML server.

At the Observatory, observers daily check data, integrate them in an excel file, and retrieve the graphs at their convenience.

4. Installation and running the fourth monitoring station CUS

4.1. Objective

The goal of this new station is to monitor the hydrothermal activity to the East of the geothermal field related to Dang Kastila area (DAK), and to complete the network of continuous USGS tiltmeters (PAN and DAK) with a third station in order to locate the source(s) of large-scale ground deformation (Figure1 and 2).

4.2. Parameters

Resistivity monitoring

The 2010 electrical resistivity tomography (Fikos et al., 2012), as well as an experiment completed in March 2012, have shown that it was possible to measure the electrical resistivity up to some hundred meters of depth. At present, the objective is to record the resistivity changes of the subsurface locally and at the three telemetered stations. To achieve this goal, a fourth shelter was built in December 2012 and March 2013.

Figure 2. Installation of a continuous resistivitymeter in a Shlumberger configuration (CNRS, France) and one borehole tiltmeter (USGS, US) during March 2013 campaign.

- Two current orthogonal lines of 300 m length have been buried along NS and EW directions. Two short length lines (75 m length) have been installed together with the longer lines for the local measurement of the resistivity at the station (Figure 3).

Automatic injections of current are now performed 4 times a day (this timing can be adapted in case of renew of activity). At present, the characteristics of the current system is about (260 Volts, 1 A).
Later on, these parameters will be adapted into a more powerful system.
- In parallel, the telluric field is continuously recorded along the two short orthogonal lines, as at the PAN station.

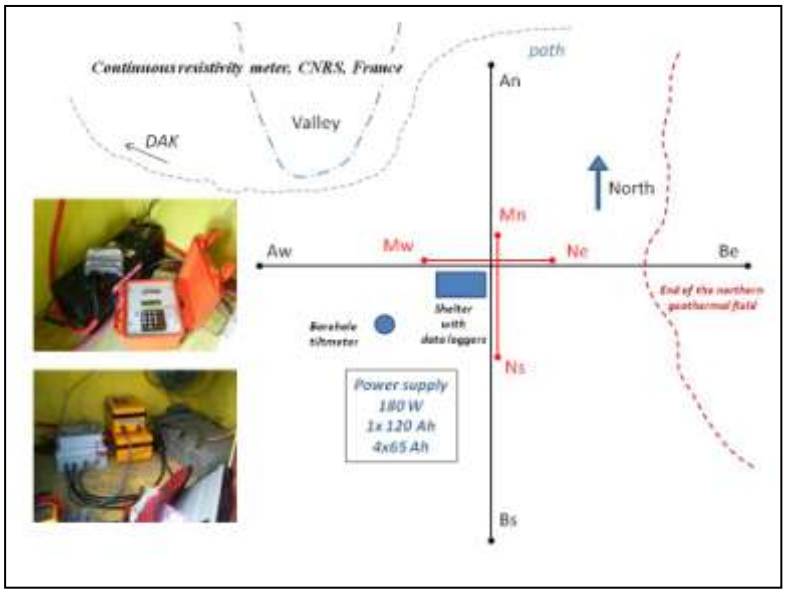

Figure 3. Schematic installation of CUS station.

Borehole tiltmeter
A third borehole USGS tiltmeter was installed nearby the EMSEV shelter at about 2 m depth. This tiltmeter is now recording the tilt in the two horizontal NS and EW directions (Figure 4).

Figure 4. Borehole instrumentation (from M.J.S. Johnston)

4.3. Installation

The construction of the infrastructure started in December 2012. In March 2013. The telluric lines, the borehole tiltmeter, and the data loggers were installed.
The installation represents a huge financial effort made by all the participants to the project, and it is noteworthy to detail it.

Origin	Equipment	Investment
PHIVOLCS	4 batteries 65Ah, solar panels workers	2 000 €
USGS, US	Tiltmeter, regulator	6 000 €
CNRS, France	Resistivity-meter, 1.5 km of cables, PVC protection, 2 data loggers, etc.	10 000 €
Tokai Univ., Japan Dec. 2012, Mar. 13	1x120 Ah battery, workers, boat and horse rental	1 300 €
EMSEV, IUGG Dec. 2012, Mar. 13	Shelter, infrastructure	1800 €
Approximate cost		***21 100 €***

In addition, PHIVOLCS takes care of the maintenance of the equipment and the retrieval of data every 2 months.

4.4. Prospective

For this first step focused primarily on the installation of the equipment, it was not possible to integrate all the measured parameters onto the same data logger and to install the telemetry system at the station. Therefore, we have put two separate data loggers into operation. These will be combined in the EMSEV radio-transmission system during the next campaign. It will secure the homogeneity of the data on the same informatics support and the same reading format.
Furthermore, the station will have the possibility to host other new parameters such as ground temperature sensors, 3 components magnetometer, and RMS seismometer.

5. Surveys

Several surveys were performed during the March 2013 campaign in order to monitor the long term variation of the volcanic activity.

5.1. Self-potential survey along the northern slope of the volcano

This survey was operated by measuring the ground voltage from a reference benchmark positioned down slope, and the ground temperature.

Figure 5 shows the data measured during the December 2012 and March 2013 surveys.

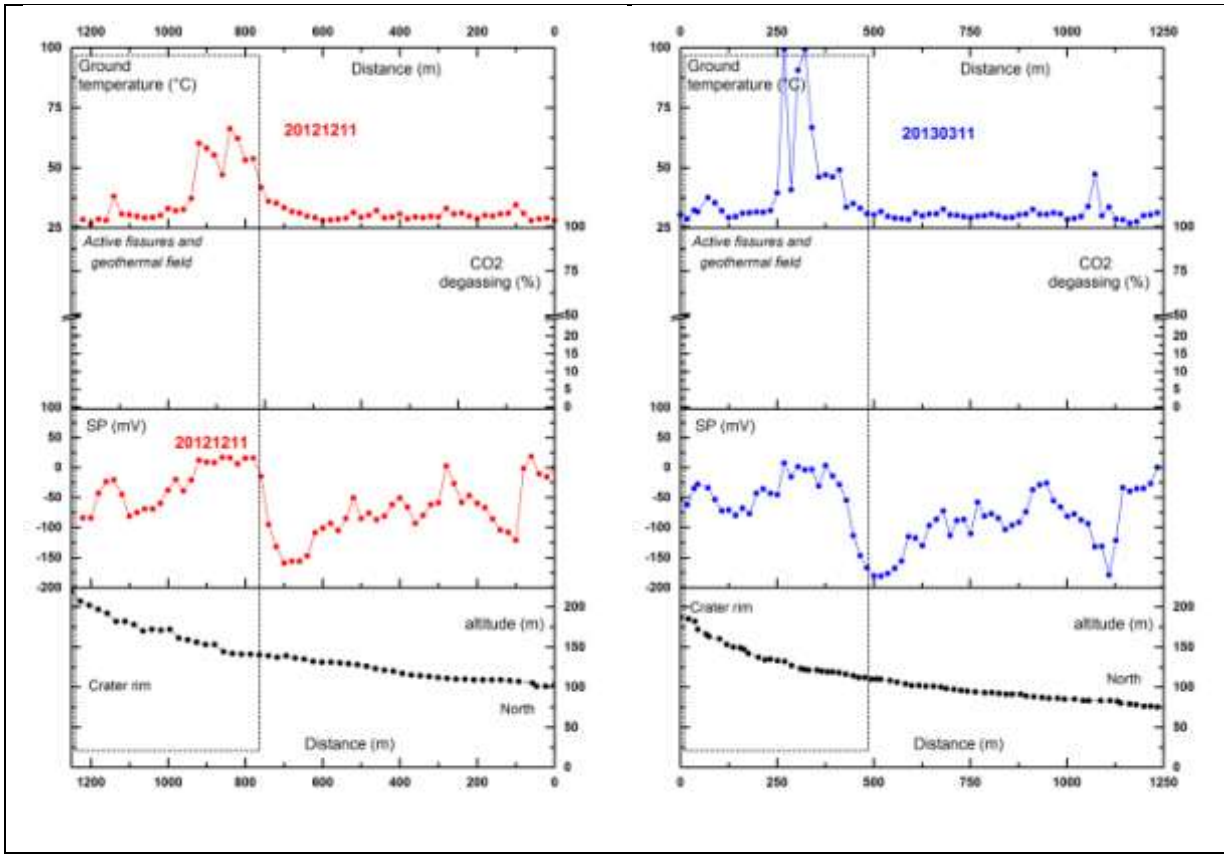

Figure 5. SP surveys along the northern slope of the volcano. Left: December 2012. Right: March 2013

5.2. Maintenance of magnetometers and repeat magnetic survey

Maintenance of continuously-recording magnetometers at DAK, PAN and MCE was done by the magnetic team. In particular, the sensor at MCE was replaced with a new one (Figure 6). The geothermal area on the eastern coast of MCL was carefully inspected by the team if any anomalous feature might appear, but none (middle). Repeat magnetic survey of TMF was conducted by PHIVOLCS magnetic team using a new Overhauser magnetometer (right). It turned out that the tripod used is magnetized, which implies that we had to discard the results obtained during March 2013 and last November 2012 campaigns. We will summarize the results of continuous measurements at DAK, PAN and MCE, together with those in last November survey soon later.

Figure 6. Left: Proton magnetometer at MCL; Middle: Eastern geothermal field in MC; Right: TMF survey.

A new sensor of the proton magnetometer was installed at MCE (left). No anomalous feature of geothermal activity was noticed on the eastern shore of MCL (middle: viewed from north cliff of MC). Red circle indicates MCE site. Repeat magnetic survey using a new OH magnetometer (right). The tripod was found to be magnetized.

5.3. Ground reconnaissance survey of TMF and superficial resistivity survey

Ground reconnaissance survey of TMF and superficial resistivity was conducted by Paul Alanis and Akihiro Takeuchi. The instruments are shown in the picture below on the left, while the survey routes are shown in the map below on the right. The survey on the southern slope of the main crater (Plang Bato site) was extremely difficult owing to thick vegetation on the slope and deep gullies across which we traversed.

Figure 7. Equipments used during surveys.

A near-surface resistivity sounder GEM2 (right) and an Oberhauser (OH) magnetometer (middle) on the shore of Plang Bato.

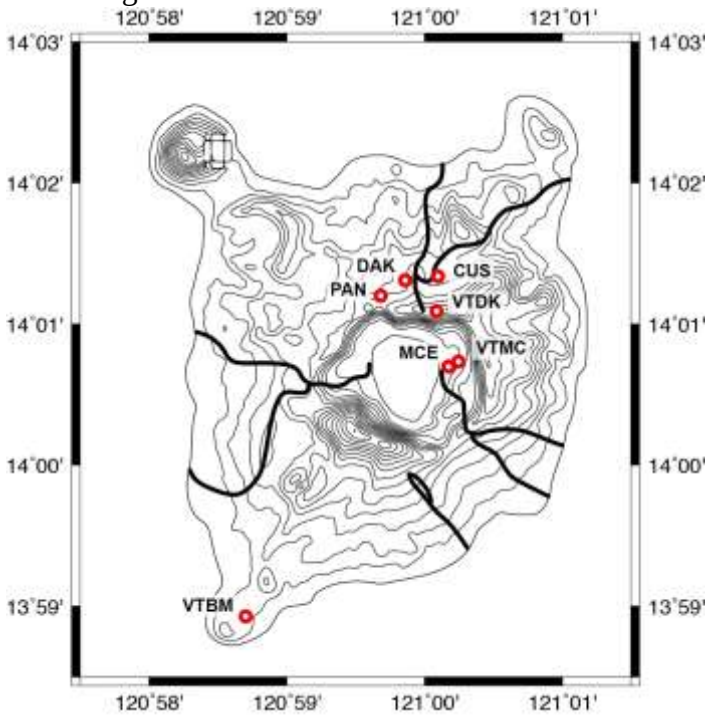

Figure 8. Map of Volcano island, showing the routes (solid lines) of GEM2 and OH surveys, together with the EM observation sites by EMSEV (DAK, PAN, CUS, MCE) and by JICA-SATREPS project (VTDK, VTMC, VTBM).

6. EMSEV-PHIVOLCS Meeting and further developments

6.1. EMSEV-PHIVOLCS meeting

On March 15, 2013, a meeting was held at the volcano Department with Ma. M. Bornas, Director of the volcano group.
T. Nagao, Y. Sasai, H. Takeuchi, and J. Zlotnicki represented EMSEV Working Group. The next points are in agreement with M.J.S. Johnston proposals who had to leave before the meeting.

EMSEV warmly thanks all the PHIVOLCS members who have contributed to the success of this almost three weeks campaign.

1. For EMSEV-TVO(PHIVOLCS): Together with regular bimonthly remanding of seismic data to French partners and replacement of CF cards in MCL, PAN, DAK and CUS stations. The PHIVOLCS team is expected to check synchronicity with GPS time at the stations.
Note that the data format is DAY-MONTH-YEAR, DD-MM-YYYY. As per advice of Dr. Zlotnicki, there have been some cases in the past when the reset time was in the format MM-DD-YYYY. Please be conscious that this error produces an enormous obstruction to the accurate computation of observation data, so let's NOT repeat this mistake next time.

Be aware that there are now 4 sites where data should be collected:
MCL: Two data loggers (8Go card for the 20 Hz data, 1Go for the 2 sec sampling)
There is also a proton magnetometer working there (J. M. Gordon Jr knows)
PAN: One data logger (1Go for the 2 sec sampling)
There is also a proton magnetometer working there (J. M. Gordon Jr knows)
DAK : Two data loggers (8Go card for the 20 Hz data, 1Go for the 2 sec sampling)
There is also a proton magnetometer working there (J. M. Gordon Jr knows)
CUS : Two data loggers (1Go card for both at 2 sec sampling)

2 seconds data are telemetered to Buco Observatory for MCL, PAN, DAK. CUS will be telemetered next time by the EMSEV system. Files are saved on Buco EMSEV-French computer and then sent by Internet to PHIVOLCS and VEML
English version of the notice of the stations has been sent to Paolo during the campaign.
Tilt data from CUS will be sent back on PHIVOLCS server by internet when French team will get the data every two months

2. For TVO information: the EMSEV team has set-up current injection of 1A-260V every 6 hrs at the CUS station. Let's put up a crude sign for the meantime at CUS for passerby to avoid a 25 m-radius area from the CUS to avoid static electricity.
Mainly, please be aware that the station will inject current in the ground at : 00:01, 06:01, 12:01, 18:01 UT time.
There is no danger at the station even during injection, except if water floods the floor of the shelter. In such a case, stop the station between injections. The location of the injection current is done at about 120-150 m from the shelter, so there is also no risk, except if the cable is cut.
So, the only danger could come within a radius of 10 m around the injection electrodes when the ground is highly wet and during the 1 minute sequences of injection).
At CUS, EMSEV will complete the station during the next field work effort and will add new sensors.

The functioning of the CUS resistivity monitoring may disturb other devices that might be installed in the vicinity of the station.

3. For EMSEV Group: A gentle reminder that the team needs to write up and formalize documentation of all EMSEV station layout and instrumentation, instrument specifications and network map/diagram. We hope to finalize this document in the course of this year, so that PHIVOLCS can incorporate this into our Manual of Standard Operating Procedures this year.

4. CO_2 and geochemical studies made by A. Bernard (Belgium).
The experiments made by A. Bernard and his team on Taal in cooperation with PHIVOLCS are done under the behalf of EMSEV. The general rules applied in the cooperation between EMSEV and PHIVOLCS are applied.
The skill of A. Bernard will greatly contribute to the understanding of the volcano dynamism and will allow a better monitoring soil and lake degassing.

6.2. EMSEV-PHIVOLCS Monograph on Taal

EMSEV has PHIVOLCS Director's imprimatur to commit to an IUGG 2015 Monograph on Taal, which is planned to feature 15-20 papers.
So, EMSEV would like to ask to the following key persons to be involved in the elaboration of Monograph content:

Jacques Zlotnicki, EMSEV	Ma Mariton Bornas Volcanology
Yoichi Sasai, EMSEV	Ma Mylene Villegas Geologic disaster awareness preparedness division
and	
Malcolm Johnston, EMSEV	PHIVOLCS has to define some key person: Maybe in Geology, or in Geophysics research and development division

J. Zlotnicki will contact IUGG for the realization of this Monograph.

6.3. EMSEV-PHIVOLCS 2014 meeting

The second EMSEV-Agreement entitled *" THE UNDERSTANDING OF THE GEOTECTONICS, SEISMICITY AND VOLCANISM OF THE SOUTHERN LUZON REGION"* needs to be renewed in 2014 for a new 4-years period.
Because, the next Asian Seismological Commission (International Association of Seismology and Physics of the Earth's Interior (IASPEI)) will held its 2014 meeting in Manila under the responsibility of PHIVOLCS. It will be more efficient to include a special session on Volcano-seismology managed by EMSEV and PHIVOLCS than to have a separate EMSEV-PHIVOLCS meeting http://www.iaspei.org/meetings/forthcoming.html#asc2014).

PHIVOLCS will take care to include this session in this Asian Seismological meeting. PHIVOLCS will maintain information with T. Nagao and J. zlotnicki.