INGV-DPC Project V3_5 – Vulcano

Section 2. Report from individual Research Units

INGV-DPC Project V3_5 – Vulcano

Research Unit V3-5/10

Responsible:

Iole Diliberto, INGV Sezione di Palermo

2.1 Achievement of project Deliverables

During these 2 years of activity the UR Diliberto has performed laboratory tests, spot campaigns of soil temperatures, and has set up 4 monitoring station at La Fossa cone, which supplied soil temperatures and self potential in order to study the variation of heat flux out of main fumaroles field. Moreover some transmission tests were performed in order to set up the remote control of the stations. The tested remote control is a wireless system (2.4 Ghz). The wireless system enable to transfer data or to program a remote station at the top of La Fossa crater, from any pc connected to internet, using an access points connected via radio to the nodal point sited at INGV Center of Vulcano.

The **laboratory tests** showed the optimum response of the sensors to forced physical variation of the multi-phases system, caused by bottom heating cycles. Measurement error of thermal sensors is <0.1% in the range 20-100 °C, it increases to <5% in the range 120-200 °C. This last conditions can be reached only with a dry system, unexpected in the sites selected for monitoring stations. Further laboratory tests showed the influence of pore water in the conductive heat transport through the soil. Soil sample, taken at La Fossa cone, has been heated and change of temperature and self potential have been recorded during each heating cycle. These tests have been made on a plastic (PVC) cylinder (vol 17410 cc) full of dried sand (W: 26500 g; density 1.57 gxcm^{-3}), where the heat source from the bottom is a metallic disk connected to a heating wire and to a thermocouple. The heat source drove conductive heat transfer through the soil and the thermal response of shallow levels of the dry sample was compared to that of the wet sample. The influence of water was observed putting a layer of sand saturated with water (height 600mm, density 1.98 gxcm^{-3}) in between the heat source and the thermal sensors. The thermal diffusivity of the wet sample is higher than that of the dry one for one order of magnitude. More laboratory tests, with several heating steps and various water content, will be performed in order to obtain the relationship between thermal conductivity and water content in the monitored layers. Figures 1,2 show the thermal distribution along zed axis during a heating step (heat source kept constant at 125 °C):

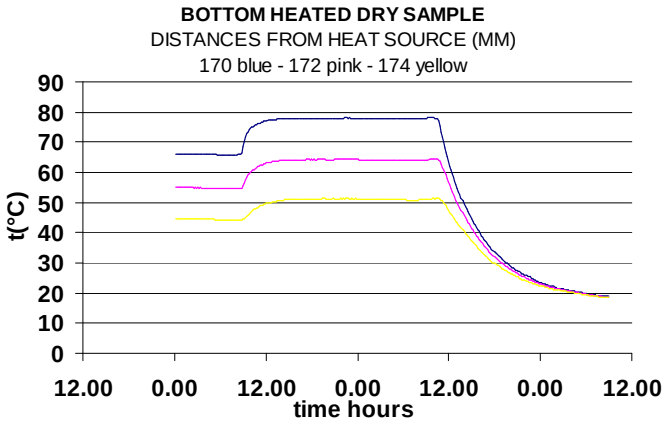
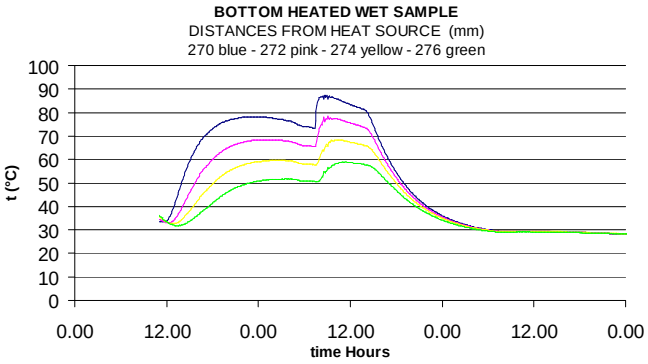


Fig 1. Test on the dry sample:
T = 373 °K was reached at distance of 0.167m from heat source after 1.20h, the maximum temperatures at the monitored depths were reached after over 9 hours when the stationary heat transfer was set (dt/dz = -4.72 °C/mm).

Fig. 2. Test on the wet sample:
T = 373 °K was reached a distance of 0.265m immediately after starting the heating phase, while the maximum temperatures were reached in the unsaturated layers after 10 hours from the starting time The wet sample didn't reach the stationary state until pore water was present below the sensors,
(max dt/dz = -4.72 °C/mm).



Spot campaigns of soil temperatures measurements were carried out using a thermocouple (resolution ±0.1 °C) with the probe directly infixed into the soil at 10 cm depth. Surface temperature higher than the atmospheric background showed that, small surface, areas receive heat from the underlying hydrothermal system, away from fumaroles. A discontinuity (defined by heat and CO_2 flux measured at the surface) exists between the high temperature fumaroles field to the North and the warm areas of the southern edge of the crater. Moreover, in times of enhanced exhaling activity (such as 1996, November 2004, October2005) minor thermal anomalies appear in the same locations, so that the surface temperature distribution showed a similar pattern over the last 10 years.

Monitoring stations 4 stations for heat flux monitoring out of main fumaroles field have been installed at the top of La Fossa cone (MN, MS, BN and BS) within June and July 2005, supplying time series of temperatures and self potential recorded hourly, with a minor gap in MN and a major gap in BN for technical failures. A station, already operating since 2004 at the base of La Fossa cone, has been considered "the cold reference" to interpret the variations of heat flux recorded at the top.

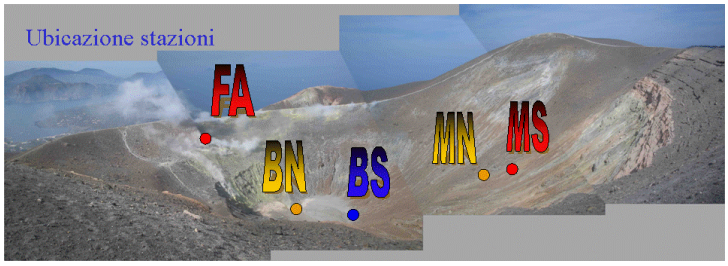
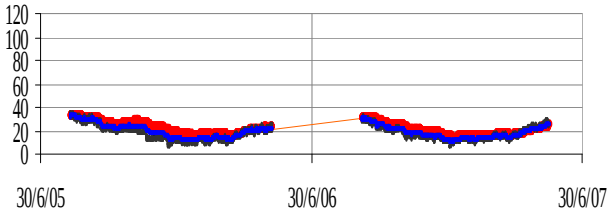
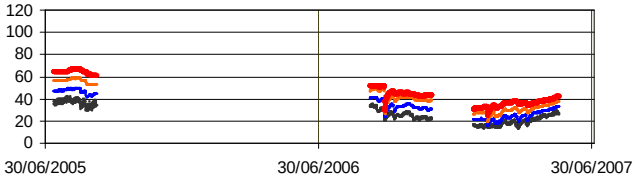


Figure 3. Westward view of the sites (BN, BS, MN, MS) for heat flux monitoring, the position of thermal sensor at high temperature fumaroles (FA) is given for reference.

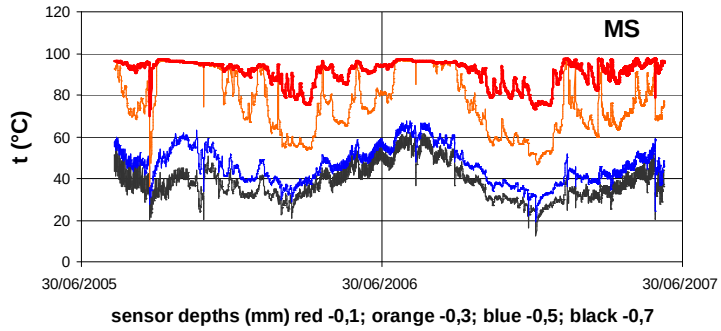
Acquired parameters were soil temperatures, along a vertical profile 70cm deep, in the unsaturated layer, and Self-Potential. Vertical gradient of temperature have been interpreted as function of the heat flux towards the surface, in accordance to the conduction rate equation (Fourier Law).



In particular in station BN and BS soil heat flux has been modulated mainly by exogenous phenomena (related to atmospheric parameters). At BS (fig. 2) change of heat flux are seasonal and also the temperature variations are equivalent to those of the cold station. BN (fig. 3) show a thermal gradient higher than the cold reference but technical failures don't allow further considerations.

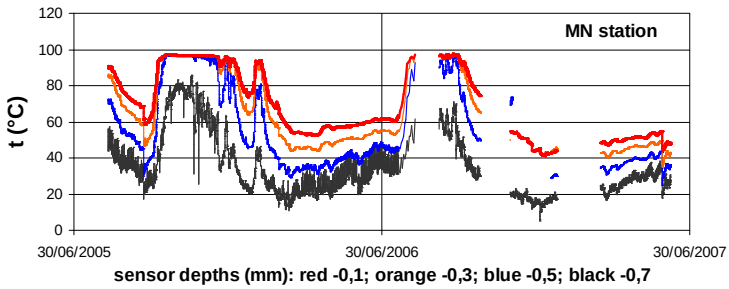


The main time-variation recorded in station MN and MS are related to change in the hydrothermal heat release and reveal periods of anomalous release of deep fluids (steam and carbon dioxide).



The first period of increased heat flux from soil occurred from October to December 2005, the second period lasted from August to September 2006, even the minor events of January 2005 and February 2007 resulted time related to anomalies other monitored parameters.

In October 2005, also, the UR Gambino observed an increased of activity through the geophysical parameters, moreover the time variation observed in the heat flux from soil are related to increase of the maximum temperatures of fumaroles release and geochemical anomalies interpreted as a new increase of the deep component in the fluid release.



Since November 2005 to January 2006 soil temperature at depth > 30cm has been buffered at the boiling point in MN and MS showing high hydrothermal heat flux, not valuable using only the conductive method. This occurred again from January to February 2007.

The self-potential monitoring has been conceived to allow evaluation of heat flux in such a case, but data analyses haven't yet produced this result because self-potential recorded in the 4 stations at depth of 10 cm has been highly variable in time as well as from site to site, and many technical failures have been recorded, caused by the presence of moisture in the junctions of the cables. This experience suggests that, in order to define the relationship with heat flux in unsaturated soil, self potential monitoring needs many accurate laboratory test. Moreover much attention has to be paid for insulating the connection of sensors to datalogger from moisture and other source of disturb present in the field.

The monitoring stations are away from fumarole fields and the measurable surface flows are related to heat transfer from lower layers and to diffuse degassing. Thus, a comparison between gas flux and heat release gives an indication of the **different quotes of surface energy release**. CO_2 flux has been measured in the monitoring stations and in the areas around them with the chamber accumulation method: the areas with higher thermal gradient correspond to areas with the highest diffuse CO_2 flux. The table shows values measured in June 2007 for the 4 monitoring stations.

Station name	Dt/Dz ($°K/m^{-1}$)	Conductive heat flux (Wm^{-2})	CO2 flux ($gm^{-2}d^{-1}$)	Heat flux by steam condensation (Wm^{-2})
BS	**0**	**0**	**0**	**0**
BN	**26**	**21**	**11**	**1**
MN	**34**	**31**	**272**	**26**
MS	**96**	**77**	**337**	**32**

Heat flux values obtained from temperature gradient and those recalculated from CO_2 flux is similar, indicating that in these monitoring station they represent the same form of energy release. The difference between column 1 and 3 may have different causes: a) difference may depend on the ratio CO2/steam, the real value should be measured at the depth of condensation for each site in this calculation it is assumed from the ratio in the high temperature fumaroles; b) the heat flow may not be unidirectional, in this case with the vertical gradient we loose the lateral heat flux c) difference may depend on the permeability of soil that influence mainly diffuse degassing.

Indeed, in stations BN and MS a surface layer of mud is present, accounting for the underestimation of heat flux calculated from measured CO_2 flux. However this situation cannot be avoided because the best sites for monitoring station are affected by intense chemical weathering and clay is the product of it .

Time-series acquired during last years by surface monitoring parameters have been compared, and the results are discussed, following a theoretical approach in a poster presentation to EGU 2007. Discussed periods are 1998 and from 2004 to 2007, when time relationship between changes of the heat flow from the ground and seismic activity, resulted worth noting. Compared parameters are fluid temperature, soil temperatures and seismic activity at La Fossa of Vulcano. In November 1998 seismic activity at La Fossa sharply increased: Five events were registered, with seismic signals of typical faulting earthquakes, triggered by mechanism of shear fracturing and focal depths ranging 1-4 km. Fumaroles temperatures, recorded by continuous monitoring system of INGV - Palermo, showed a growing trend since October to November 1998, highlighting a big increase of heat transfer during the period, and also the soil temperature, out of the fumaroles field showed a marked increase. Following a period of lower energy release, other 3 anomalous periods were observed from November 2004, either in the seismic release and in the surface heat flow, even out from fumaroles. So far, the monitored sites resulted very sensitive to minor perturbations of the system. The comparative analysis of different time-series supplies information related to perturbations of the state variables, useful to verify conceptual framework and to better define “classical” and “new” monitoring techniques for volcanic, as well as seismic surveillance

2.2 Specific problems which have delayed progress

2.3 Relevant publications which have arisen directly from this project

Abstracts/conference presentations

Aubert M., Diliberto I.S., Finizola A., Madonia P. (2005) Convective heat flux from the hydrothermal system First results of monitoring at La Fossa of Vulcano. IAVCEI 9th GAS WORKSHOP ITALY

Diliberto I.S., Alparone S., Liotta M., Madonia P. (2007) Relationship between surface temperatures and seismic activity at Vulcano, Aeolian Island (Italy). Geophysical Research Abstract, vol 9, 08553,2007 SRef-ID:1607-7962

List of deliverables

Deliverable: Report on intercalibration of thermal sensors

Description: Data files of recorded temperature during heating cycles of unsaturated soil sample. Recorded temperature ranges: 20-100 °C for the wet sample; 20-190 °C for the dry sample

	Data files of conductive heat transfer during various heating steps in unsaturated wet and dry soil samples.
Nature:	Hard-copy and data file
Contact:	Iole Diliberto, INGV-Sezione di Palermo, s.diliberto@pa.ingv.it
Availability:	Delivered to DPC as hard copy inside the Project Final Report

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Deliverable:	Acquisition of the thermal gradient in the soil out of fumarole
Description:	Data files of recorded temperature profiles on zed axis in 4 sites at the top of La Fossa crater, out from fumarole field
Nature:	Hard-copy and data files
Contact:	Iole Diliberto, INGV-Sezione di Palermo, s.diliberto@pa.ingv.it
Availability:	Delivered to DPC as hard copy inside the medium period Final Report

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Deliverable:	Report on first record of time variations of parameters acquired by the new stations (temperature and self potential)
Nature:	Hard-copy and data files
Contact:	Iole Diliberto, INGV-Sezione di Palermo, s.diliberto@pa.ingv.it
Availability:	Delivered to DPC as hard copy inside the medium period Final Report

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Deliverable:	Report of time variations of hydrothermal heat flux measured at la Fossa crater
Description:	calculated heat flux in the unsaturated zone of the monitored stations, above the level of steam condensation
Nature:	data files
Contact:	Iole Diliberto, INGV-Sezione di Palermo, s.diliberto@pa.ingv.it
Availability:	Delivered to DPC as hard copy inside the medium period Final Report

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Deliverable:	Estimation of different quotes of energy release (heat, steam and CO2 flows) in the monitored stations
Description:	table of calculated and measured value
Nature:	Hard-copy and data files

Contact:	Iole Diliberto, INGV-Sezione di Palermo, s.diliberto@pa.ingv.it
Availability:	At the reported contact

Deliverable:	Report on the results of correlations of the new data with other available geochemical and geophysical data relative to the present activity of La Fossa system
Description:	word document with binary graphs for comparisons of time variations of different parameters
Nature:	Poster presentation, Hard-copy and data files
Contact:	Iole Diliberto, INGV-Sezione di Palermo, s.diliberto@pa.ingv.it
Availability:	At the reported contact

Deliverable:	Tematic maps at the top of La fossa cone (surface temperatures)
Description:	areal distribution of temperature at depth of 0.1m around the monitoring stations
Nature:	Hard-copy and data files
Contact:	Paolo Madonia, INGV-Sezione di Palermo, Madonia@pa.ingv.it
Availability:	At the reported contact
