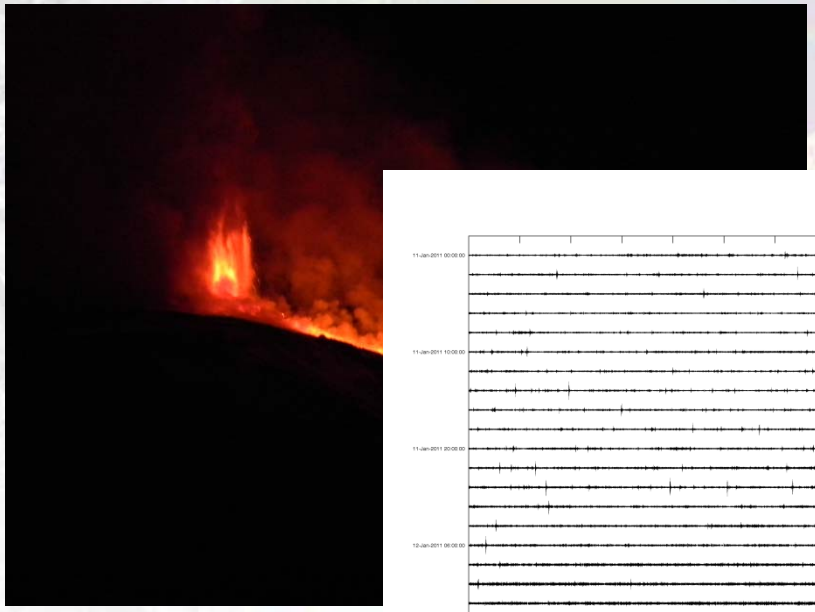
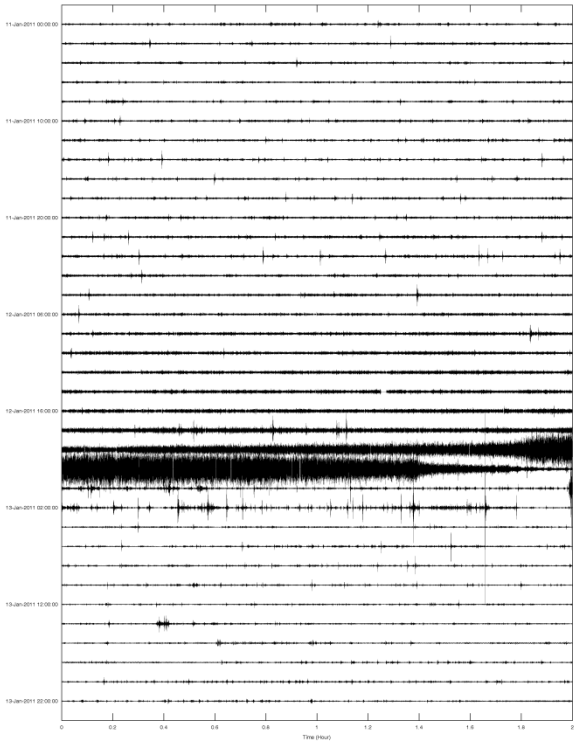
InSAR and thermal monitoring of lava fountain episodes at Mt. Etna: the case study of the ASI-SRV Pilot project during the January 2001 episode

Puglisi G. (1), Aranzulla M. (1), Behncke B. (1), Branca S. (1), Buongiorno M.F. (2), Coltelli M. (1), Casu F. (3), De Beni E. (1), Guglielmino F. (1), Musacchio M. (1), Proietti C. (1), Sansosti E. (3), Silvesti M. (2), Solaro G. (3), Spampinato L. (1), Zoffoli S. (4).

1. *Istituto Nazionale di Geofisica e Vulcanologia – Sezione di Catania, Osservatorio Etneo*
2. *Istituto Nazionale di Geofisica e Vulcanologia – Centro Nazionale Terremoti, Roma*
3. *Consiglio Nazionale delle Ricerche - Istituto per il Rilevamento elettronico dell'Ambente, Napoli*
4. *Agenzia Spaziale Italiana.*



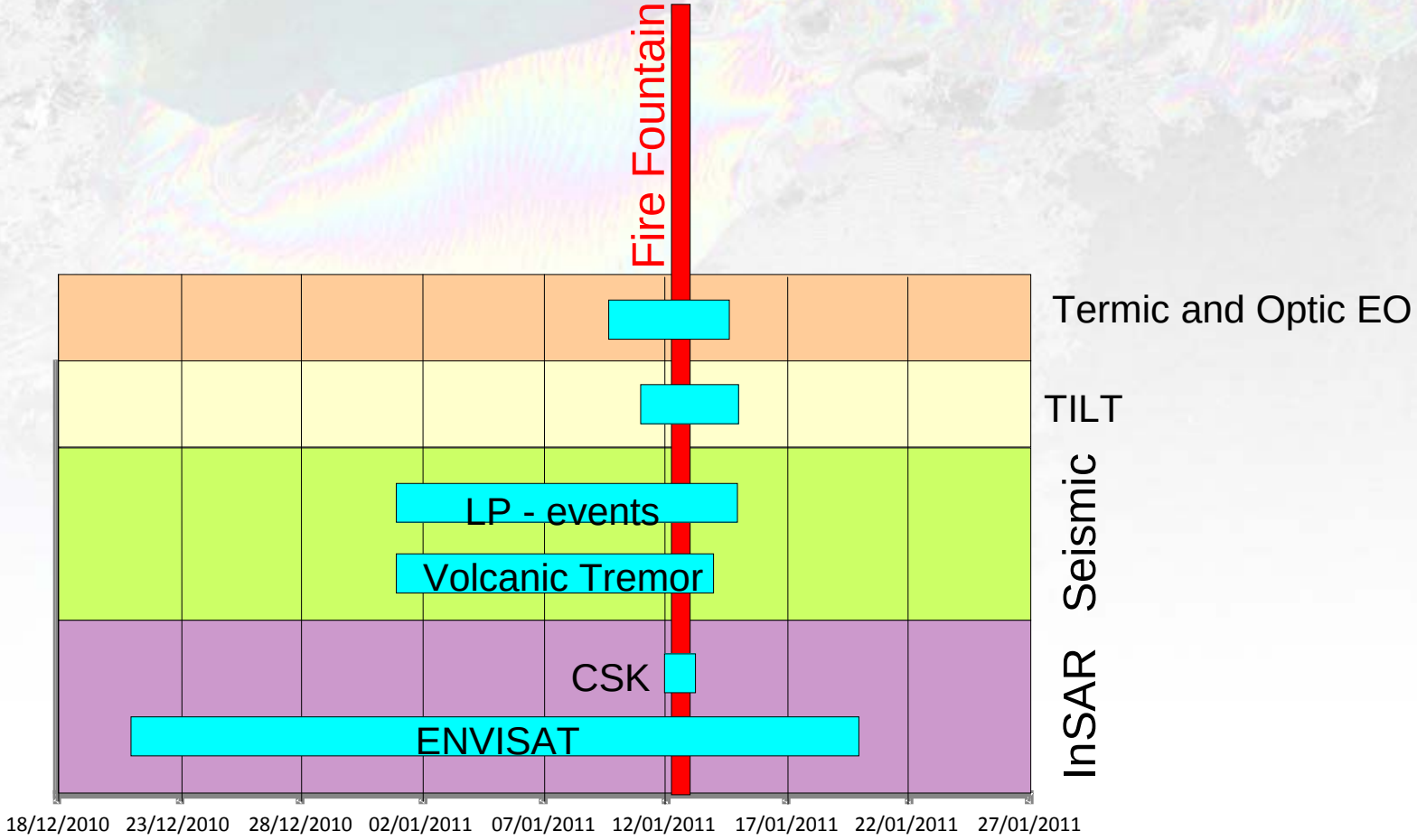


Mt. Etna is characterized by almost continuous volcanic activity at the summit craters, which ranges from quiet degassing to periodic explosions. Intensity of the explosions varies from strombolian activity to fire fountains.

Lava fountain episodes are controlled by processes that originate in the shallow part of the plumbing system and their geophysical effects may give information on the eruptive dynamics, as well as on the geometry of conduits and stocking volumes in the plumbing system.

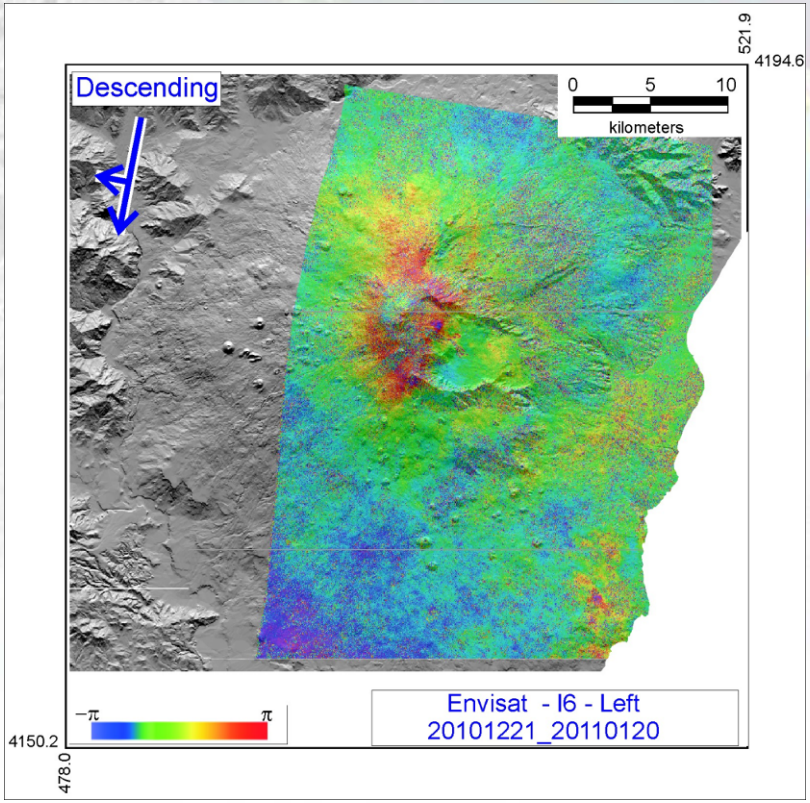
We focused our attention on the fire fountain episode occurred on 12 January at the South Eastern Crater (SEC) of Mt. Etna, which produced an eastward flowing lava flow, within the Valle del Bove area, and a large volcanic plume high several kilometers. The episode started at about 22:00 local time and ended at about 00:50 of 13 January (Behncke et al., internal report INGV-CT and seismogram of figure 2). Recent improvements in the monitoring system of Mt. Etna have allowed to collect high-quality seismic and ground deformation data during lava fountain episodes. Cross analysis of these data have been exploited to investigate the spatial-temporal evolution of the underground source processes.

DATA SET


Fire Fountain
Termic and Optic EO
TILT
Seismic
LP - events
Volcanic Tremor
InSAR
CSK
ENVISAT
18/12/2010
23/12/2010
28/12/2010
02/01/2011
07/01/2011
12/01/2011
17/01/2011
22/01/2011
27/01/2011

ENVISAT data

12 Dec 2010 – 20 Jan 2011



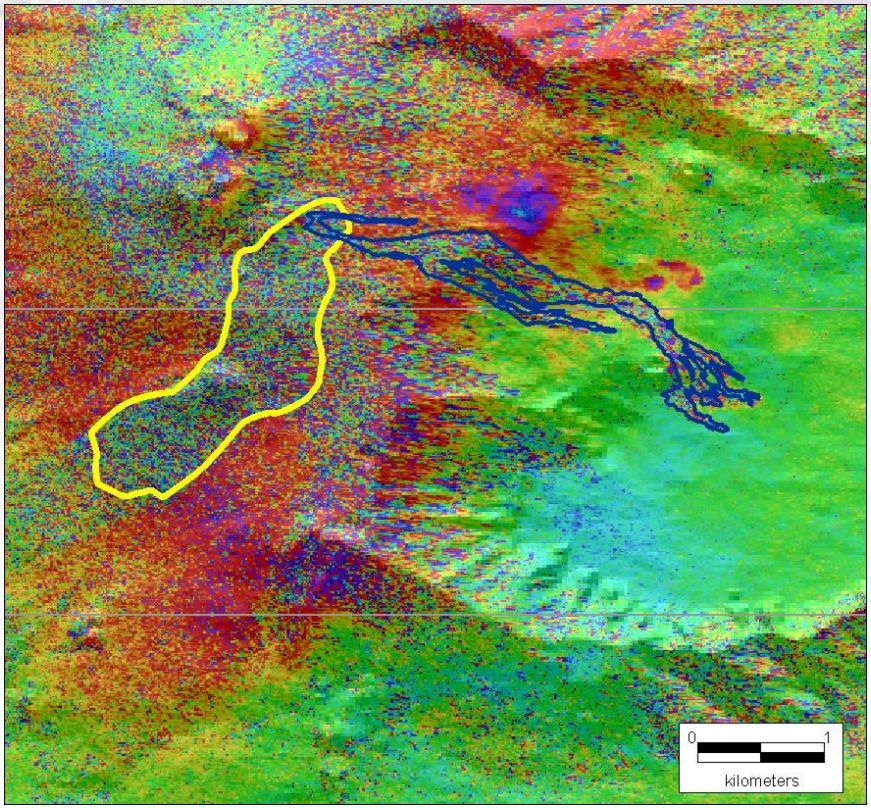
The Envisat mission extension beyond the end of 2010 allows to (a) operate the mission for anadditional 3 years (until end of 2013 or early 2014) and (b) ensure the continuity of the maximum number of Envisat applications, with the exception of ASAR Interferometry.

The change of orbit, indeed, degraded the interferometric capabilities. Nevertheless, the new orbit configuration of Envisat has been refined, in order to ensure that the InSAR baselines will be kept at a minimum value at specific latitude, around 38° North for descending passes and 38° South for ascending passes.

Etna area (latitude 37.5 °) is favored by this new orbital configuration of Envisat, and the new orbital repeat cycle of 30 days (instead of 35) will ensure more frequent acquisitions.

In the framework of the CAT-1. 5843, we produced an interferogram relevant to the 12 December 2010 – 20 January 2011 passes.

The deformations recorded in the interferogram are relatively small and limited around the summit area, at elevations above the 1500-2000 m. The interferometric fringes, suggest a deflation that might be related to the emptying of the shallow magmatic reservoir, although an atmospheric component cannot be definitively excluded.



A detailed analysis of the summit area highlights two highly decorrelated areas:

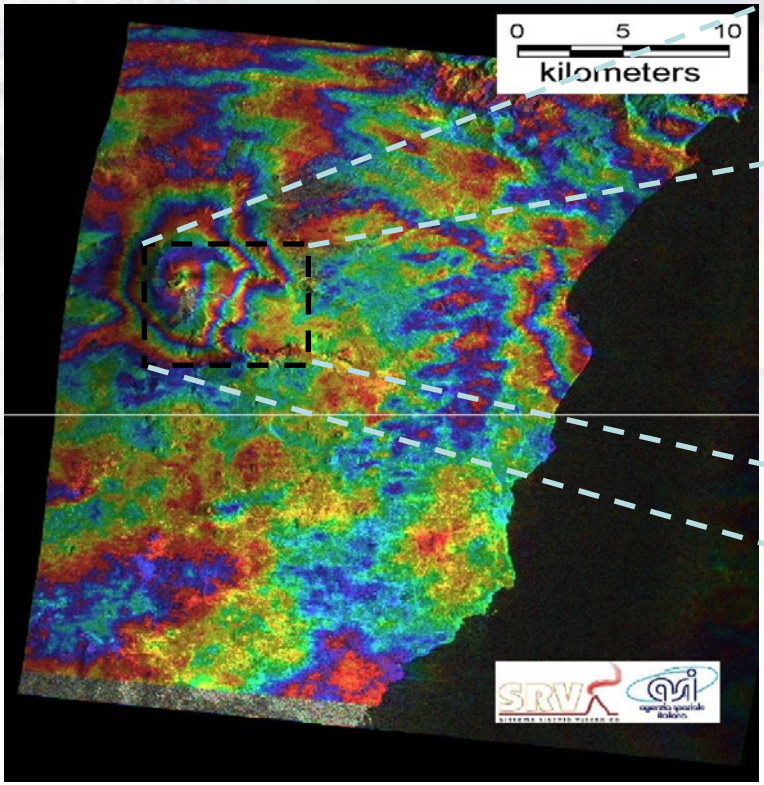
- the first, trending ESE (blue contour line in Fig) corresponds to the lava flow emplaced during the fire fountain episode

- the second, trending SSW (yellow contour line in Figure, corresponding to the fall-out deposit of the largest (> 3 cm) pyroclasts around the SEC

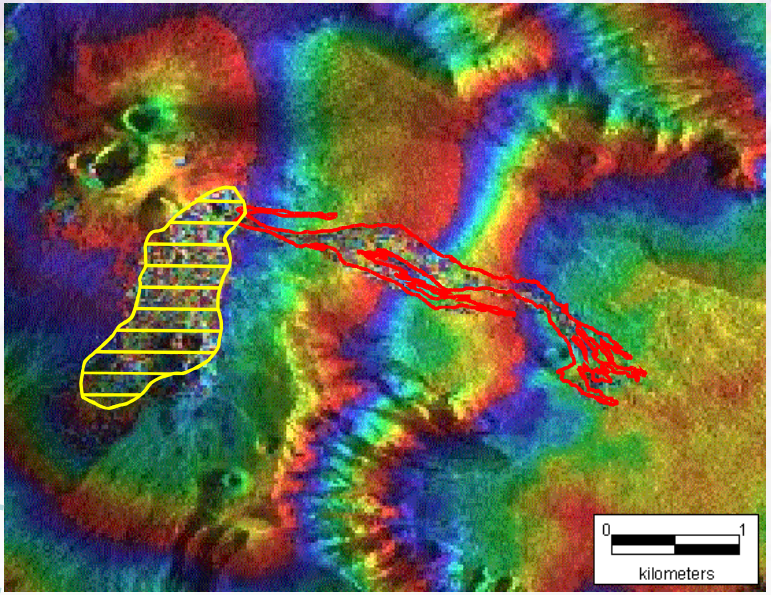
- These preliminary analyses well fit with the data acquired by the monitoring systems managed by the Section of Catania of the INGV (GPS, tilt, seismic) and field and helicopter surveys (Behncke et al., internal report INGV-CT)

Cosmo Sky

12 – 13 gennaio 2011 (processing CNR-IREA)

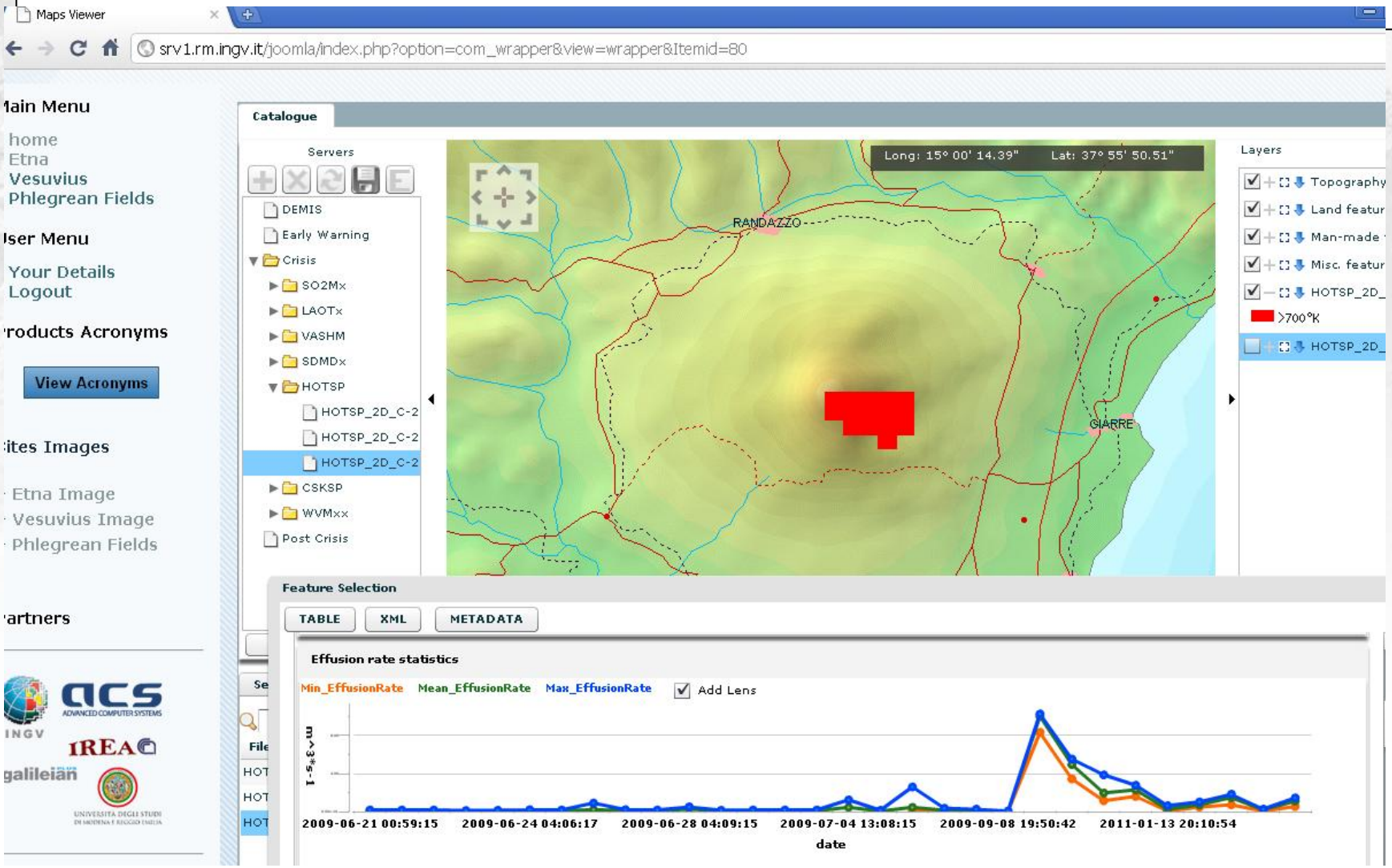


The CSK data confirm the deflation detected by ENVISAT data.



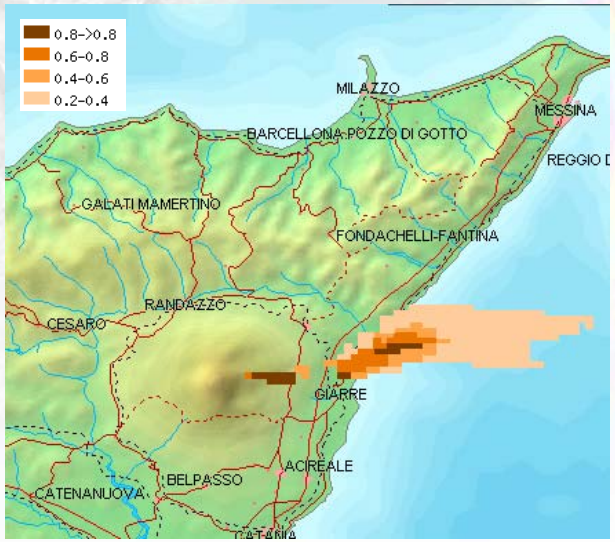
The detail show the flow emplaced (red contour line) and the area interested by fall-out deposit (yellow contour line).

AVHRR Hot-Spot temperature and lava flow effusion rate

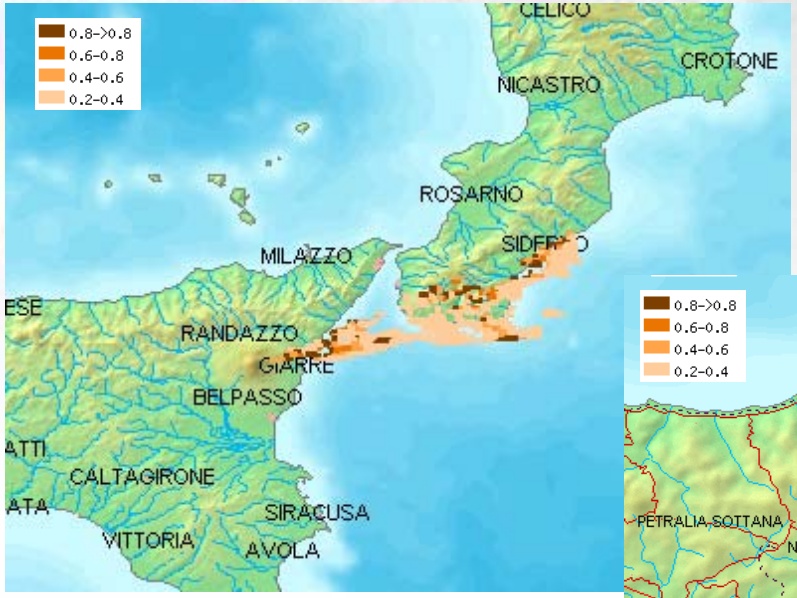


MODIS product AOT @ 550nm 1km resolution

The high values of Aerosol Optical Thickness (AOT) indicates the formation of volcanic aerosol in the Mt.Etna plume due to high degassing. Aerosol plume has been identify on 11 January using Modis data extending ENE about 100 km from the vent reaching the Calabria region south costs prior and after the event on 13 January in SW direction

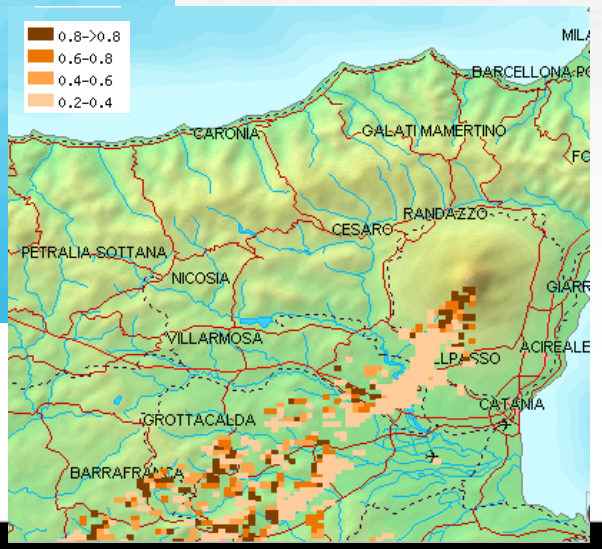


11 January 2011
9:16 UTC

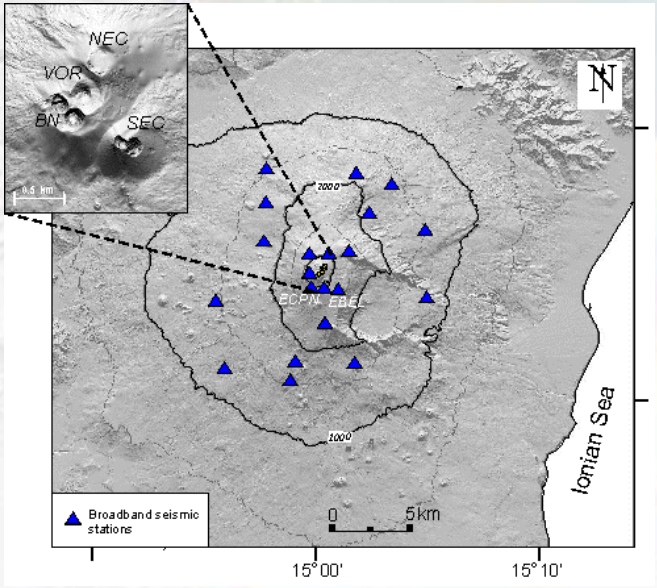


11 January 2011
12:36 UTC

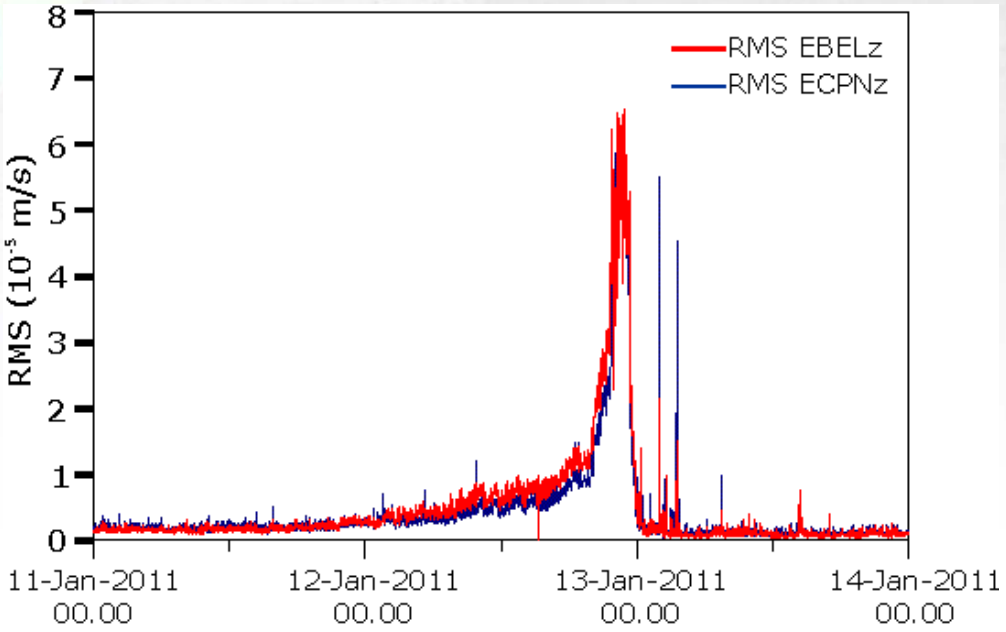
13 January 2011
12:23 UTC



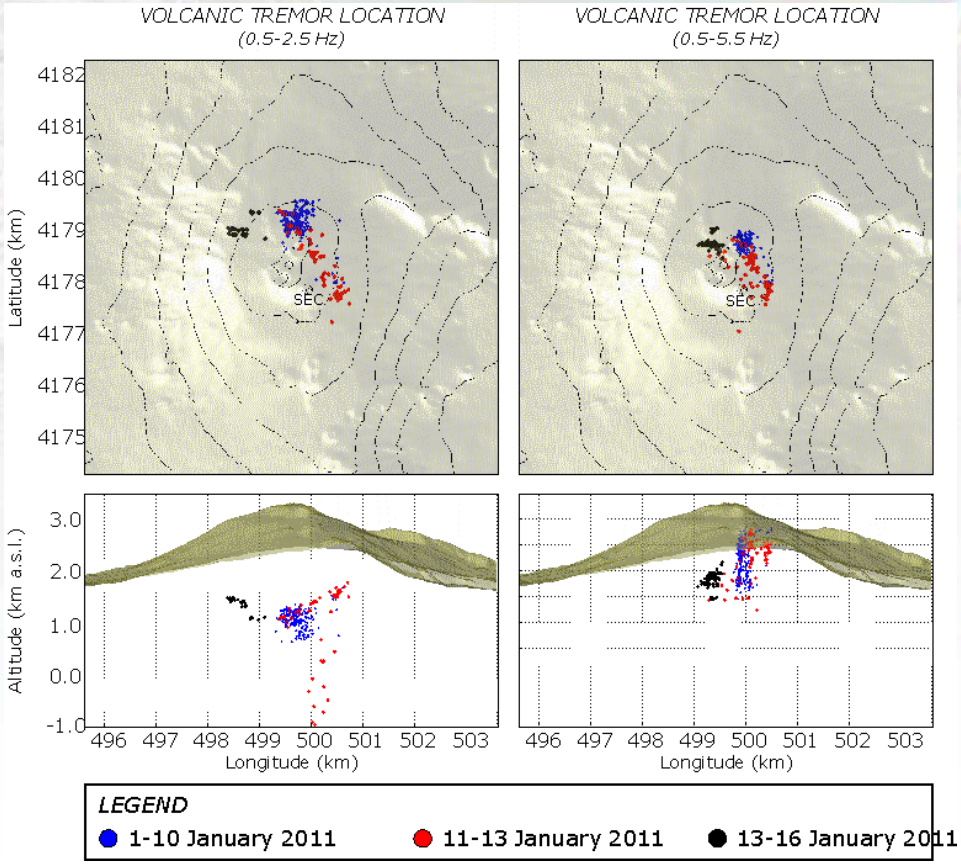
Seismic data analysis



We calculated the RMS time series of the signals recorded by ECPN and EBEL stations during 11-13 January 2011 and filtered in the frequency band 0.5-5.5 Hz



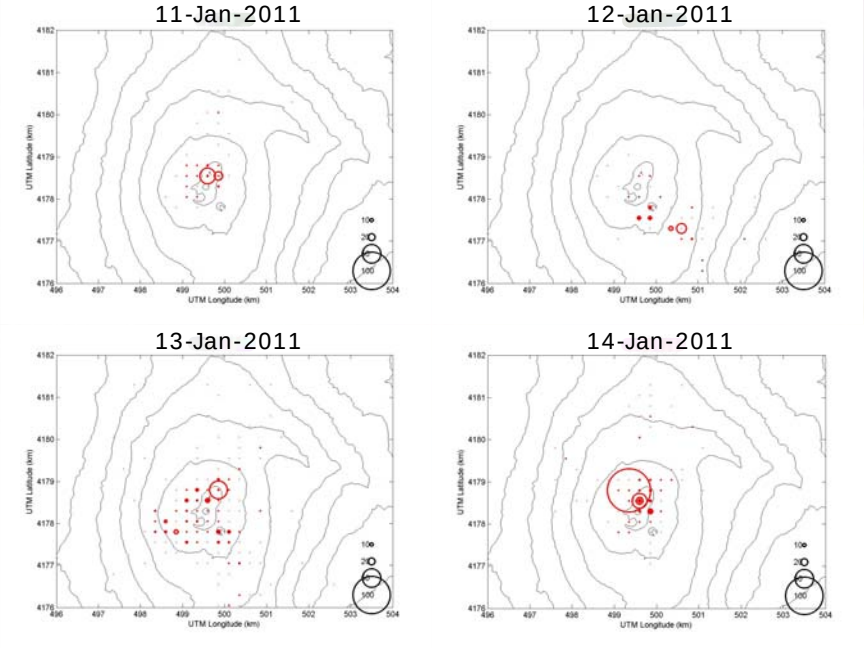
It is worth noting that the amplitude of volcanic tremor gradually increased from the end of 11 January, reaching the maximum values during 21:50-23:30 GMT at the same time as the paroxysmal activity took place at SEC. Successively, the tremor amplitude drastically reduced with some peaks related to strong LP events well evident in the ECPN RMS series.



The source locations of volcanic tremor were retrieved by a grid search method based on the amplitude decay of the seismic signals (eg. Di Grazia et al., 2009). Two different frequency bands (0.5-2.5 and 0.5-5.5 Hz) were taken into account: the former is mostly affected by deep sources, while the second is also influenced by the shallower ones.

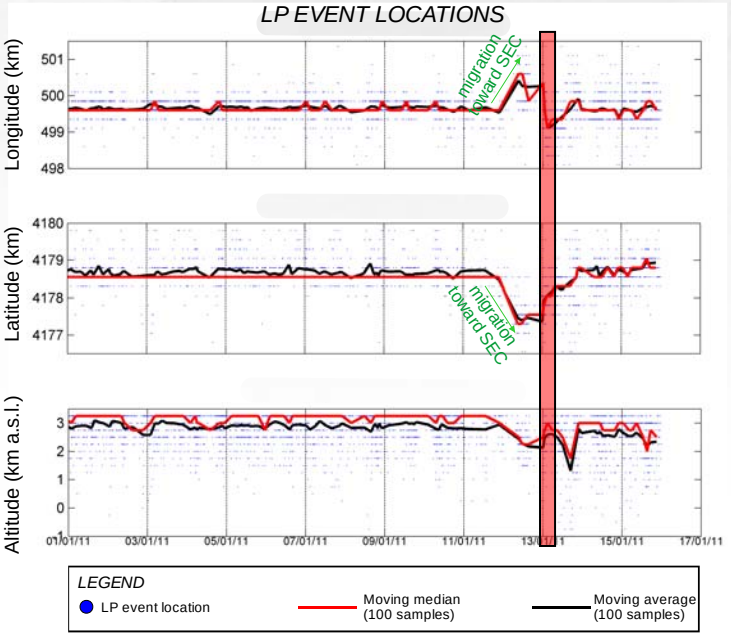
The volcanic tremor centroids migrated from NEC to SEC during the explosive activity at SEC, highlighting the strict link between tremor and volcanic activity, and again shifted north-westward after the end of the activity. Unlike before the lava fountain, from 14 January the volcanic tremor source turned out to be located slightly west of NEC..

LP EVENT LOCATION



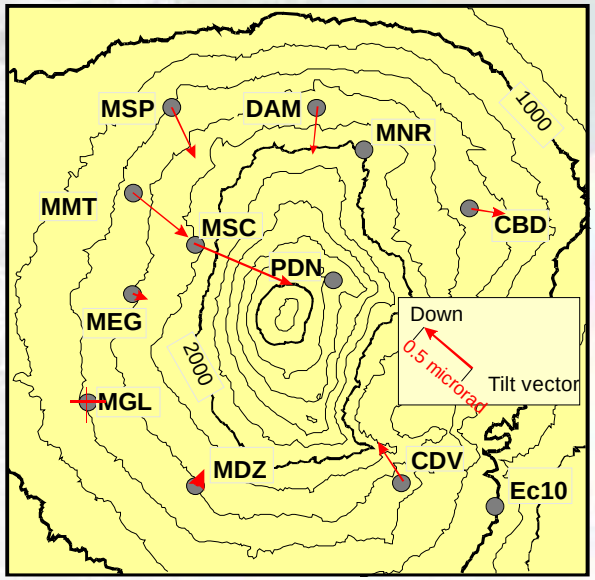
Finally, also the LP events recorded during 1-15 January 2011 were located by following a new grid-search method based on both semblance function, used to measure the similarity of multi-channel data, and amplitude decay

LP EVENT LOCATIONS



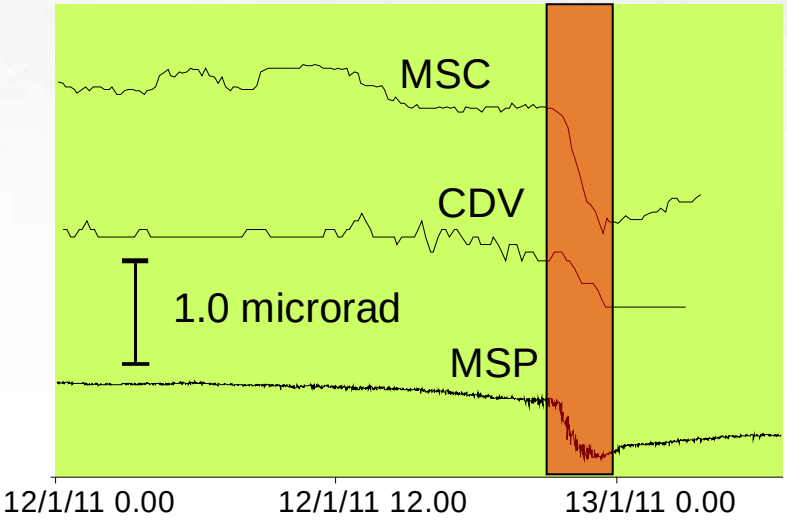
Similarly to volcanic tremor, LP event sources migrated from NEC towards SEC during the explosive activity, and again shifted toward NEC at the end of the eruption. Also in the case of the LP events, their source was located slightly west of NEC after the end of the lava fountain

Continuous TILT data



Mt. Etna permanent tilt network is composed by 14 bi-axial electronic instruments installed in shallow boreholes and one long-base instrument. The shallow borehole tiltmeters have resolution in the order of 0.1 microradians which is mainly appreciable in the rapid tilt change. For slow variation (hours to months) the precision is affected by noise due to temperature and thermoelastic effects.

- During the Jan, 11-12 paroxysm (from 21:00 GMT), almost all tilt stations recorded signal variations; MSC showed the largest changes of about 1.2 μrad; MSP showed about 0.8 μrad, while minor o no changes were detected at the other stations .
- The clearest changes are visible on the radial components showing a general deflation of the edifice during the fountain. These tilt changes recorded at the stations 5-6 km away the summit craters imply that the depth of the deflation source can not be too shallow.



Activity within the ASI-SRV project

Satellite products have been available in near real time to the end-user Italian Department of Civil Protection through the dedicated web site

http://srv1.rm.ingv.it/srv1/srv

Newsletter has been published on the Italian Space Agency website

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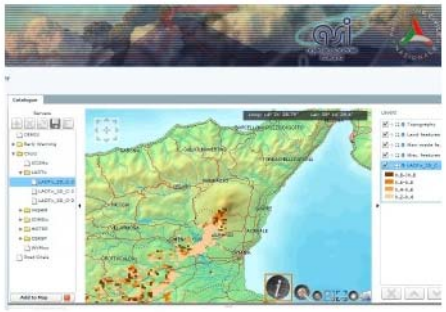
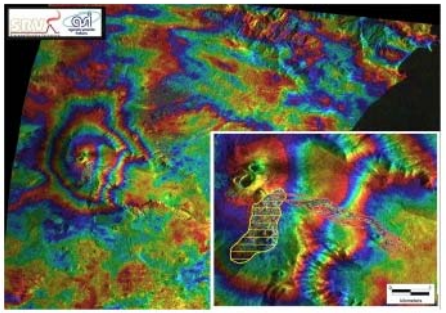
Gli occhi di ASI-SRV sull'Etna

Nuova attivazione del progetto sistema rischio vulcanico: rilevazioni del 12 e 13 gennaio



27 Gen 2011
Le recenti attività del progetto **ASI-SRV (Sistema Rischio Vulcanico)** dimostrano ancora una volta le potenzialità applicative dei dati satellitari, ed in particolare di quelli della costellazione **COSMO-SkyMed**, per il monitoraggio degli edifici vulcanici.
L'Agenzia Spaziale Italiana, in coordinamento con il **Dipartimento di Protezione Civile**, ha attivato il team del progetto ASI-SRV, guidato dall'**Istituto Nazionale di Geofisica e Vulcanologia**, in occasione dell'episodio parossistico che si è verificato sull'Etna (cratere di SE) la notte tra il 12 ed il 13 gennaio e che ha prodotto alte fontane di lava, un trabocco lavico verso est in Valle del Bove e una colonna eruttiva carica di cenere alta alcuni chilometri. I dati dei satelliti COSMO-SkyMed, acquisiti il **12 ed il 13 gennaio 2011**, sono stati processati dall'**IREA/CNR**, partner del team ASI-SRV, ed è stato generato l'interferogramma. L'interferogramma mostra una generale assenza di deformazione alle basse quote del vulcano e tre frange interferometriche intorno all'area sommitale. Queste ultime potrebbero essere il risultato dall'effetto deformativo associato alla deflazione delle parti più alte del vulcano, anche se non si può escludere completamente una parziale componente atmosferica.

La deflazione, registrata anche dalle stazioni clinometriche INGV poste ai margini dell'area deformata, si sarebbe prodotta dal rapido svuotamento delle zone di stoccaggio magmatico, prodotto dalla violenta emissione di magma nel corso dell'episodio parossistico. L'analisi di dettaglio dell'area sommitale evidenzia due aree completamente decorrelate la prima con direzione ESE (area in rosso) visibile nella figura a lato che corrisponde alla colata messa in posto durante l'evento parossistico, e la seconda con direzione SSW (area in giallo) che permette di mappare la parte più grossolana con spessore (> 3cm) dei depositi di ricaduta, come confermato dal confronto con i dati rilevati sul terreno.
Il Sistema ASI-SRV ha inoltre messo a disposizione del Dipartimento di Protezione Civile, tramite il webgis del progetto, prodotti ricavati dall'elaborazione di dati ottici AVHRR e MODIS, come la mappa di spessore ottico degli aerosol (AOT), Temperatura, Flusso Termico, Tasso di effusione e contenuto



CONCLUSIVE REMARKS

- We considered EO (SAR and thermal images) and in-situ (seismic, tilt) data sets related to the fire fountain episode occurred on 12 January at the South Eastern Crater (SEC) of Mt. Etna, which produced an eastward flowing lava flow , within the Valle del Bove area and a large volcanic plume high several kilometers.
- The volcanic tremor and LP event sources centroids migrated from North-East Crater to SEC during the explosive activity and shifted toward NEC at the end of the eruption. A deepening until to 1.0 km below sea level is shown for the source of the tremor during the lava fountain.
- Thermal data clearly identify the temporal evolution of the phenomena.
- Deformations recorded in the interferogram are relatively small and limited around the summit area, at elevations above the 1500-2000 m. Tilt changes show a general lowering of the radial components. Tilt and interferometric fringes, suggest a deflation that might be related to the emptying of a magmatic reservoir.
- Analysis of the SAR interferometric coherence is a powerful tools to identify the distribution of volcanic products even in harsh environmental conditions.
- FUTURE WORK: The inversion of this unique deformation data set (in-situ and EO) – constrained by the seismic results - will furnish new insights on the driving mechanisms of the fountain episodes on Mt. Etna.

Thanks