GEOMORPHOLOGY AND GEOMORPHOLOGICAL CHANGES AT VOLCANOES AND ACTIVE FAULTS OBSERVED WITH ALOS. FUSION WITH OTHER REMOTE SENSING AND GROUND DATA. APPLICATION TO NATURAL DISASTER MONITORING.

PI No 167

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1. ABSTRACT

We investigated the available ALOS/PALSAR data over two active areas in Europe: Etna volcano (Italy) and the western rift of Corinth (Greece). All data processing was performed at the National Observatory of Athens using the version 3.0 of ROI-PAC. At Etna the level of coherence of all interferograms is good, even for those with large baselines, in the rift of Corinth the level of coherence is in general less good than at Etna. One M=6.3 earthquake (June 8, 2008) and two M=5.3 (January 18 and 22, 2010) occurred in the western rift of Corinth during the investigated period, but no ground deformation was observed with PALSAR. In the case of the M=6.3 one the absence of ground deformation provides constraints on the depth of the fault, the two M=5.3 are too small for the L-band PALSAR-ALOS interferometry but they are visible with C-band ENVISAT-ASAR interferometry and with GPS. On Etna the sampled period was characterized by volcanic activity at the summit and shallow seismicity and creep along the Pernicana fault which is a major left-lateral strike slip structure located east-north-east of the volcano. The available C-band and L-band interferometry is combined with GPS and levelling data to model the ground deformation using. The tool used for merging the various ground deformation data is a new tool developed at INGV-Catania called SISTEM.

2. WESTERN RIFT OF CORINTH

We produced a series of PALSAR interferograms over the western rift of Corinth (Figure 1) using ROI-PAC 3.0.

Fig 3. Location of the investigated frames

The results are compared and combined with ENVISAT results, including a PS and SBAS analysis of the data [1]. They are also compared with the available GPS data from permanent and campaign networks. The investigated area includes (1) the large city of Patras where two shallow faults (or discontinuities) are observed, (2) the area of the MS=6.3, June 8, 2008 Andravida earthquake (Figure 2) where the absence of significant ground deformation helps constraining the depth of the earthquake, (3) a inland zone located between the western Corinth rift near Nafpaktos and the Trichonidas graben where 4mm/yr or more oblique extension is inferred by GPS, (4) the area of Efpalion, east of Nafpaktos where a moderate seismic swarm occurred in January 2010 (major events Mw=5.3 on January 18 and Mw= 5.2 on January 22) with 3cm vertical displacement measured at a nearby permanent GPS station.

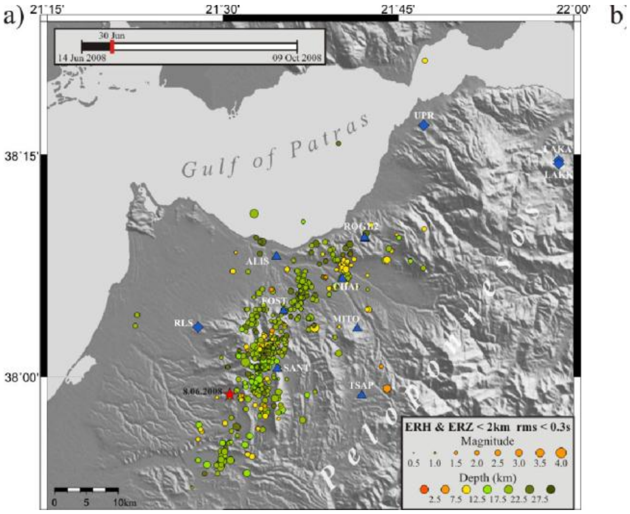

Fig 2. Area of the June 8, 2008 M=6.3 earthquake southwest of the city of Patras. From Ilieva, 2001 [2]

The interferograms can be downloaded from http://idaios.space.noa.gr/ALOS-Aigion/. Figure 3 shows the images that were processed and the interferograms that were used in our analysis for one of the three frames (that covering the northern coast of the rift). Baselines up to 2000m lead to still coherent and usable interferograms.

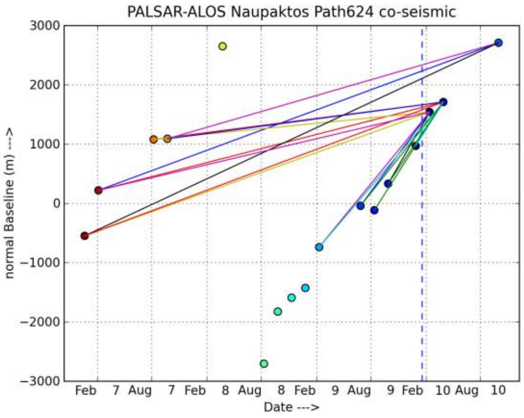

Fig 3. ALOS data analyzed in path 624 / frame 760

The analysis of the PALSAR interferograms over the Patras area (Figure 4) shows no significant deformation in the area of the M=6.3, June 8, 2008 earthquake.

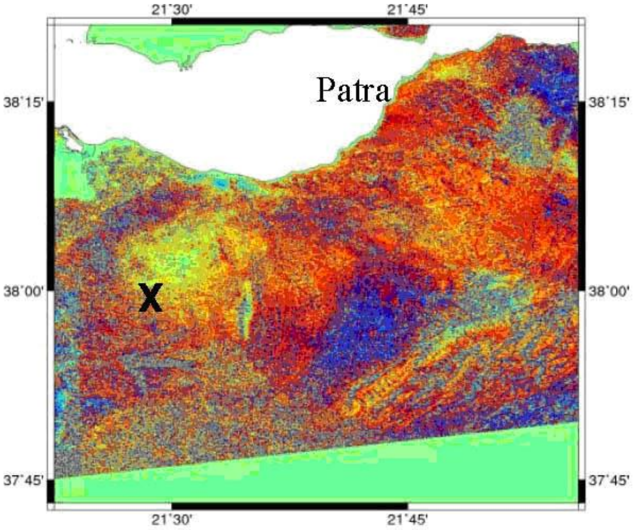

Fig 4. ALOS interferogram over the Patra area. Cross indicates the location of the June 8, 2008 earthquake (see also Figure 2)

The area located north of the rift exhibits a high level of coherence. However, the two earthquakes that occurred in January 2010 (Figure 5) are too small to be observed with PALSAR (Figure 6) while they are detected with the C-band of ENVISAT-ASAR (Figure 7).

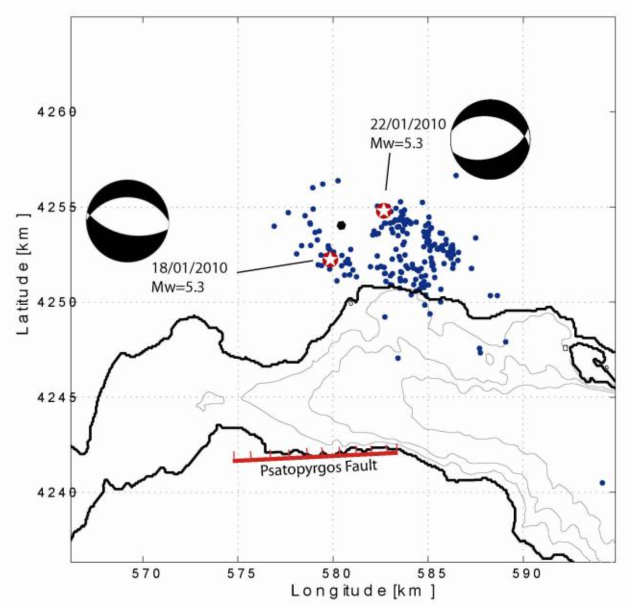

Fig 5. Location of the two earthquakes of January 18 and 22, 2010 near Nafpaktos, northern shore of the rift of Corinth

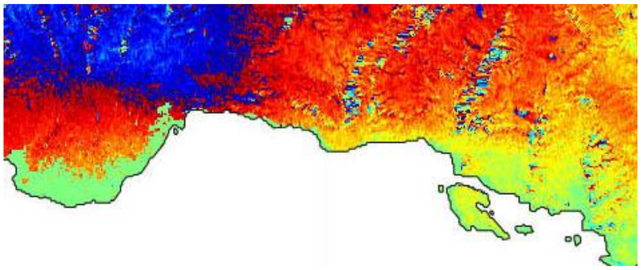

Fig 6. PALSAR-ALOS interferogram sampling the month of January 2010 over the Nafpaktos area

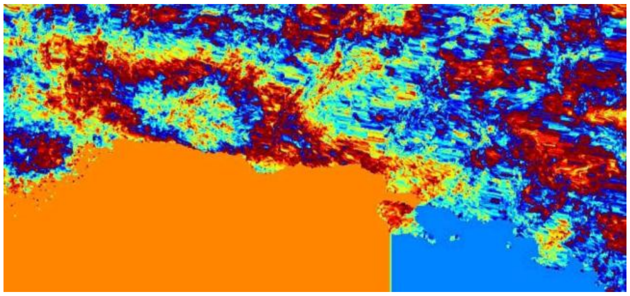

Fig 7. ASAR-ENVISAT interferogram sampling the month of January 2010 over the Nafpaktos area

The earthquakes are also seen by a GPS receiver (EYPA) located just above the hypocenter of January 18 which shows a subsidence of approximately 30mm and eastward motion of 5mm (Figure 8 and see also https://gpscope.dt.insu.cnrs.fr/chantiers/corinthe/plots/EYPAlg.gif)

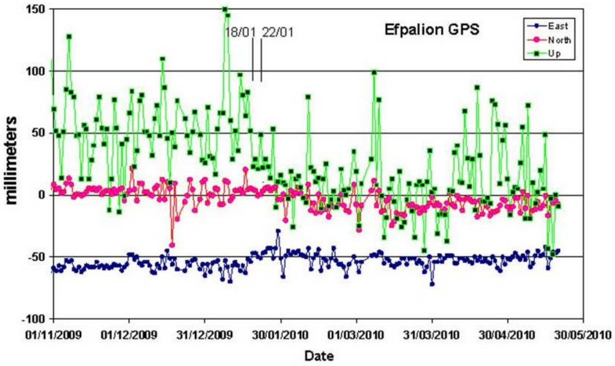

Fig 8. GPS displacement of the EYPA station located above the first main shock

3. ETNA

We produced nineteen interferograms with baselines up to 3000m. Figure 9 shows the data that were used and the interferograms that were produced. All interferograms contain information, even those with the larger baseline although they contain more noise. All interferograms are available at http://idaios.space.noa.gr/ALOS_Etna-Catania, they come along with GoogleEarth files that allow to directly drap them in GoogleEarth.

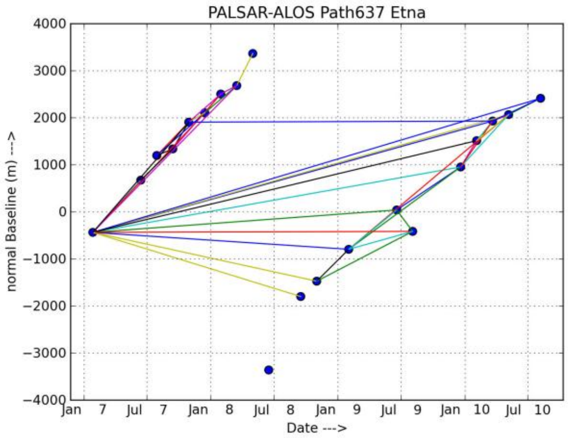

Fig 9. ALOS data used for the study of the deformations of Etna

Around Etna volcano, the coherence remains relatively high even in the interferogram sampling 14 months. Winter scenes appear to be as good as fall scenes. Around the summit of the volcano, the coherence is less good and almost lost in some places. A clear subsidence signal is visible on a recent lava flow in the Valle del Bove area, east of the summit. In and around the city of Catania, to the SE of the image, the coherence is very high in the urban areas. Creep on active faults around the base of Etna, already seen on ERS and ENVISAT interferometry [3], is visible in some places, but the time period sampled by PALSAR and the lower range resolution compared to the C-band make the signal weaker except for the Pernicana fault which is located mostly in a forest area (Figure 10) and which is observed with PALSAR much better than with ASAR (Figure 11).

Fig 10. Surface ruptures along the Pernicana fault

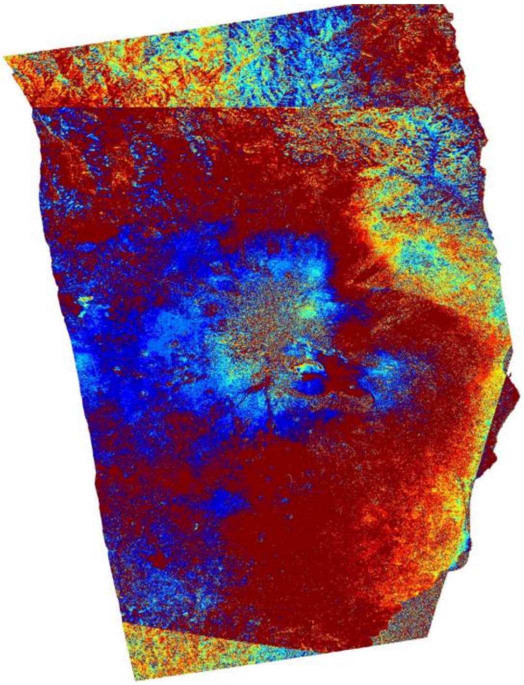

Fig 11: Interferogram of Etna volcano area for the period 30/10/07 – 16/03/08. Creep in visible on the Pernicana fault, east of the volcano

In order to define the dynamics due to the onset of the eruptions on 13 May 2008 and 8 April 2010 and analyse the movement along the Pernicana fault associated with there eruptions (see Figure 12 and Figure 13), we integrated all the available geodetic dataset (both GPS and InSAR), using a dedicated tool called SISTEM developed at INGV-Catania [4].

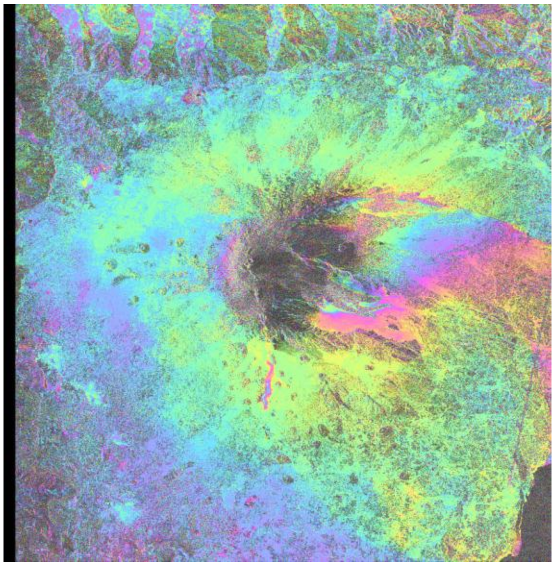

Fig 12. PALSAR interferogram (16/03/2008-22/03/2010). A large offset is visible along the Pernicana fault. Subsidence of past lava flows can also be observed

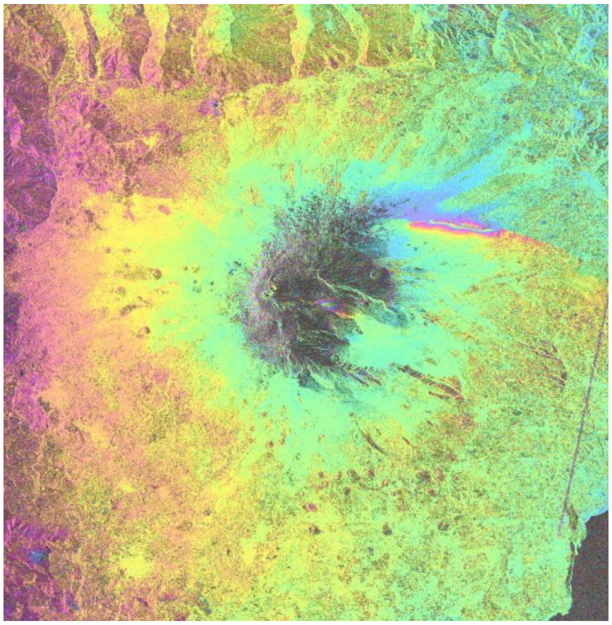

Fig 13. PALSAR interferogram (22/03/2010-7/5/2010) covering the period of the M=4.3 shallow earthquake of April 2, 2010

This tool (Figure 14) merges the available data sets to produce interpolated maps of the ground motion in 3D [4,5]. It performs an integration of GPS and InSAR data for computing displacements on each point of the studied area, using the elasticity theory, and provides the complete 3D strain and the rigid body rotation tensors in the same solution

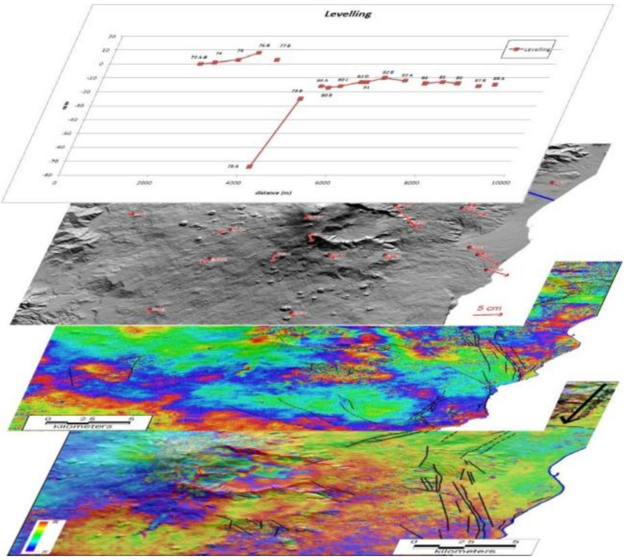

Fig 14. Principle of the INGV System (Simultaneous and Integrated Strain Tensor Estimation from geodetic and satellite deformation Measurements) tool

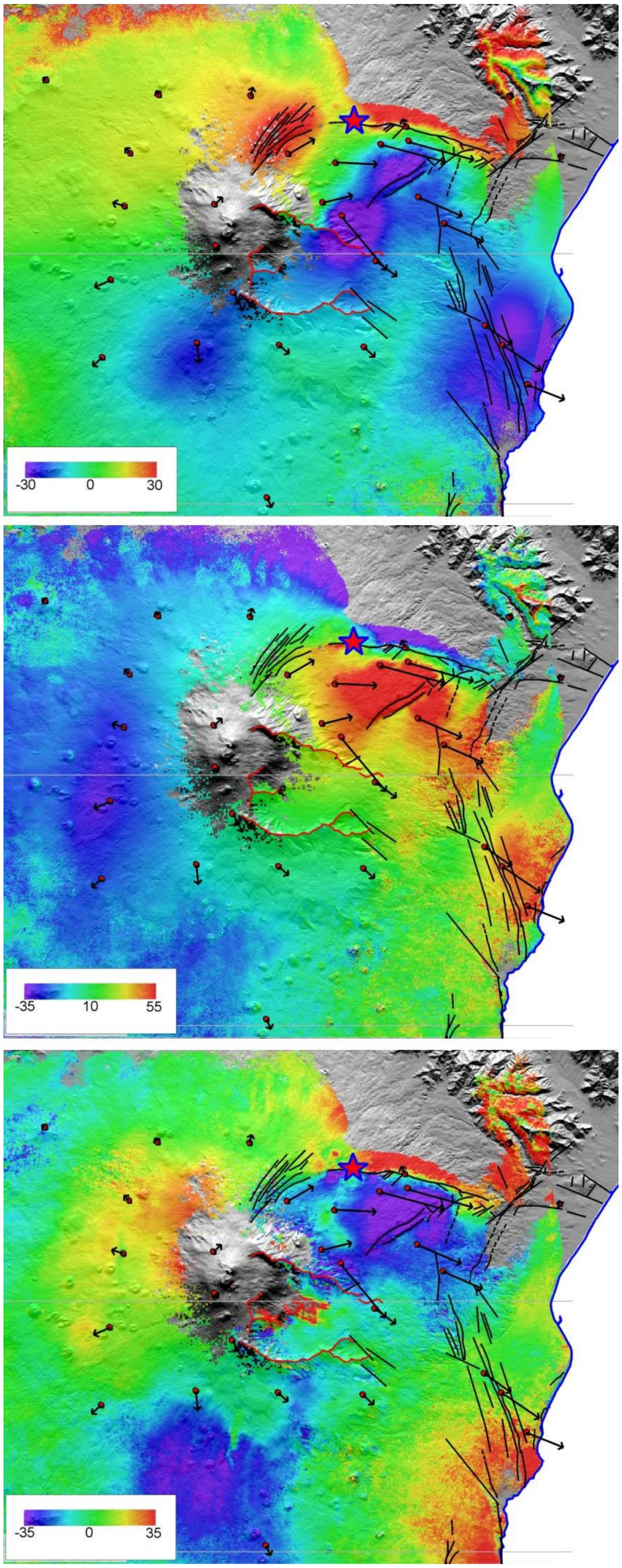

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Fig 15. Ground deformation data (North, East and Up) merged by the SISTEM tool and used for further data inversion and modelling [4]. Star indicates the location of the M=4.3 earthquake of April 2, 2010. Colour scale is in mm

In the case of the seismic and volcanic activity of April 2010, the ground deformation detected using the data acquired by ALOS and ENVISAT agree each other and clearly show (Figure 15): (i) the shallow strike slip motion across the Pernicana fault; (ii) the ground deformations due to the 2010 eruption; (iii) ground deformation (bulge) across the Ripe della Naca fault system; (iv) subsidence of some past lava flows in the Valle del Bove. The small uplift of the northern block indicates that there is elasticity in the medium even at such shallow depth and with fractured material. At the volcano scale the south-eastward motion of the eastern flank is clearly seen

4. CONCLUSIONS

In both investigated areas the ALOS PALSAR interferometry provides significant insights to constrain the displacement on active faults after earthquakes of during creep events. In the rift of Corinth the earthquakes that occurred in the ALOS data time window did not produce significant deformation, however this is also a result and allowed to constrain the depth of the fault of the June 8, 2008 earthquake. Further investigation using ALOS PALSAR data are in progress in the Patras area where a system of shallow fault has been inferred with ERS and ENVISAT data. At Etna, the SISTEM method developed for the analysis of the deformations of the volcano provides the complete 3D strain and the rigid body rotation tensors in the same solution. These results, which provide both accurate and fine spatial characterization of ground deformation, are hence promising for future studies aimed at improving the knowledge of either the structural framework of the intrusion and the dynamic of the volcano in the eruptive period.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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