Application of differential SAR interferometry for studying eruptive event of 22 July 1998 at Mt. Etna

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Abstract

One of the main objectives of the project "Development and application of remote sensing methods for the monitoring of active Italian volcanoes" is directed to an operational use of differential interferometry as a tool for volcano monitoring. A first step to achieve this goal is to test commercial software in order to evaluate the most suitable for the project purposes. For testing software, SAR images collected by ERS2 from May 98 to August 98, before and after the strong eruptive event occurred on 22 July 98 at Voragine crater of Etna, have been selected. The explosive event was classified sub-plinian producing a 12 km high eruptive column and lapilli fell on land as far as 70 km south-eastward along the dispersal axis. Pre, post and across event image pairs have been processed. In particular the pair 13 May 98-22 July 98, 22 July 98-26 August 98, 13 May 98-26 August 98 are used for testing respectively pre, post and across event. In first analysis, the fringes in the differential products show a positive elevation trend in the summit area of the volcano. In particular, an increased of about 1,5 fringes in the period pre-event, and a decrement of 1 fringe in the period post-event is observed. This result is agreement whit field of deformation expected in such kind of event, confirming that the interferometric processing tool used id suitable for the purpose of the project.

Introduction

A vigorous explosive eruption was produced by Voragine Crater of Etna on 22 July 1998. A 10 km high eruptive column above the crater rim formed at the eruptive climax between 16.48 and 17.14 GMT (Fig.1) [Aloisi et al., 2002] and the ash cloud expanded radial

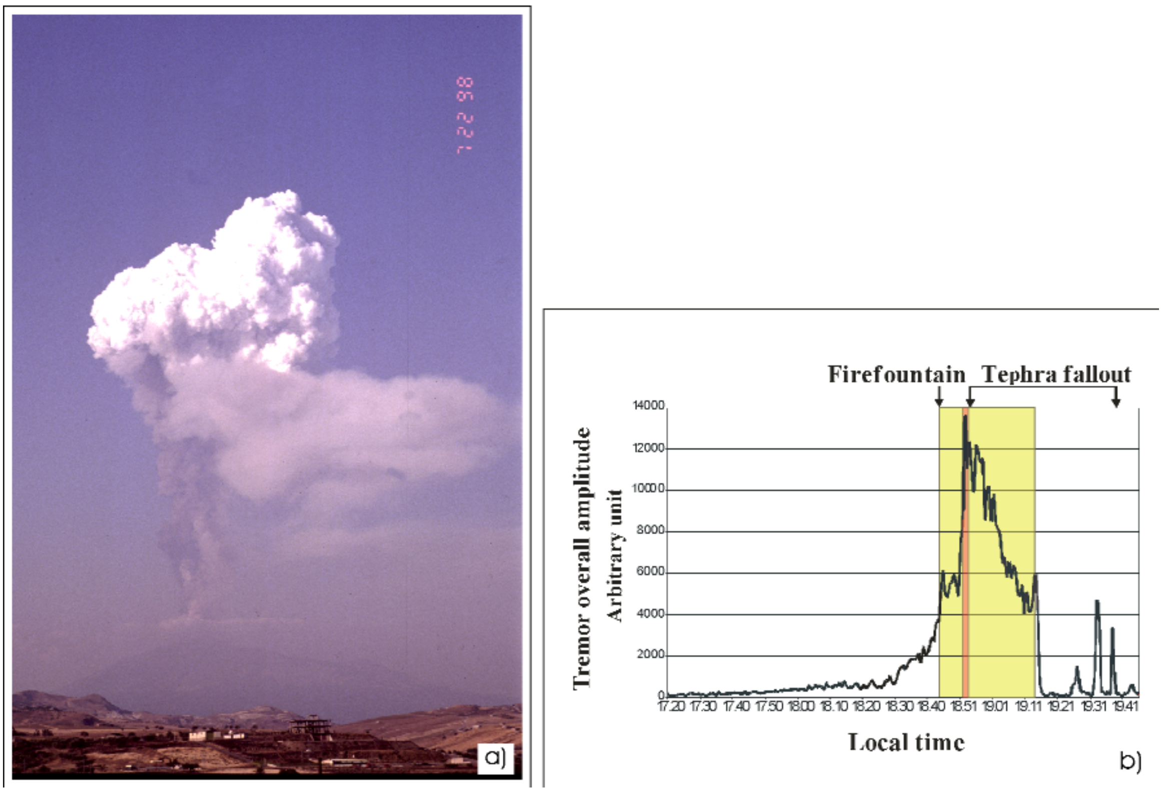

Figure 1 Photograph of the 22 July 1998 paroxysmal event at Voragine crater, and plot of tremor amplitude.

because of the low speed wind. Lapilli fell as far as 12 km south-eastward along the dispersal axis.

Coarse ash fell in the distal zone after about 2 hours from the beginning of the eruption, in a wide area along the coastline comprises between Giarre to the north and Siracusa at about 100 km from the vent to the south (Fig.2).

The huge quantity of juvenile molten material fallen inside the crater caused its complete filling, followed by a large overflow which formed a 1 km long rootless lava flow running in the valley between NEC and BN.

Fieldwork measurements, grainsize analyses and calculation of the physical parameters allowed to characterize the eruption that result subplinian in magnitude in spite of the low volume of material erupted (about 1 x 10^6 m^3 the fallout + 2 x 10^6 m^3 the proximal deposit) [Andronico et al., in prep].

SAR Interferometry Processing

The selection of the images was performed by inspecting the ERS archives with the DESCW software. In table 1 are listed all the image that were scheduled to be acquired over the Etna area. It is noteworthy that the 22 July 98 pass occurred at 21.16, thus few hours after the end of the eruptive event (see Fig.1).

These images were coupled forming the three interferometric pairs (IP1, IP2, IP3) listed in Table 2 with the associated values for the temporal baseline, perpendicular baseline and height of ambiguity. Table1

Pre, post and across event image pairs have been processed. In particular the pair 13 May 98-22 July 98, 22 July 98-26 August 98, 13 May 98-26 August 98 are used for testing respectively pre, post and across event.

The data processing was performed using the Image processing tools developed by Atlantis (EarthView InSar v. 1.2). The procedure used for the generation of interferometric products relevant to the selected image pairs is called two pass interferometry, this approach seeks to exploit all the external information available for a site, in particular, the topography through a digital elevation model.

As source of the topographic information, a photogrammetric DEM, whith a measured accuracy in the order of 10 m has been considered.

This philosophy comes into play at four steps of the processing:

1. The two radar images must be coregistered with a precision of a fraction of a pixel. The

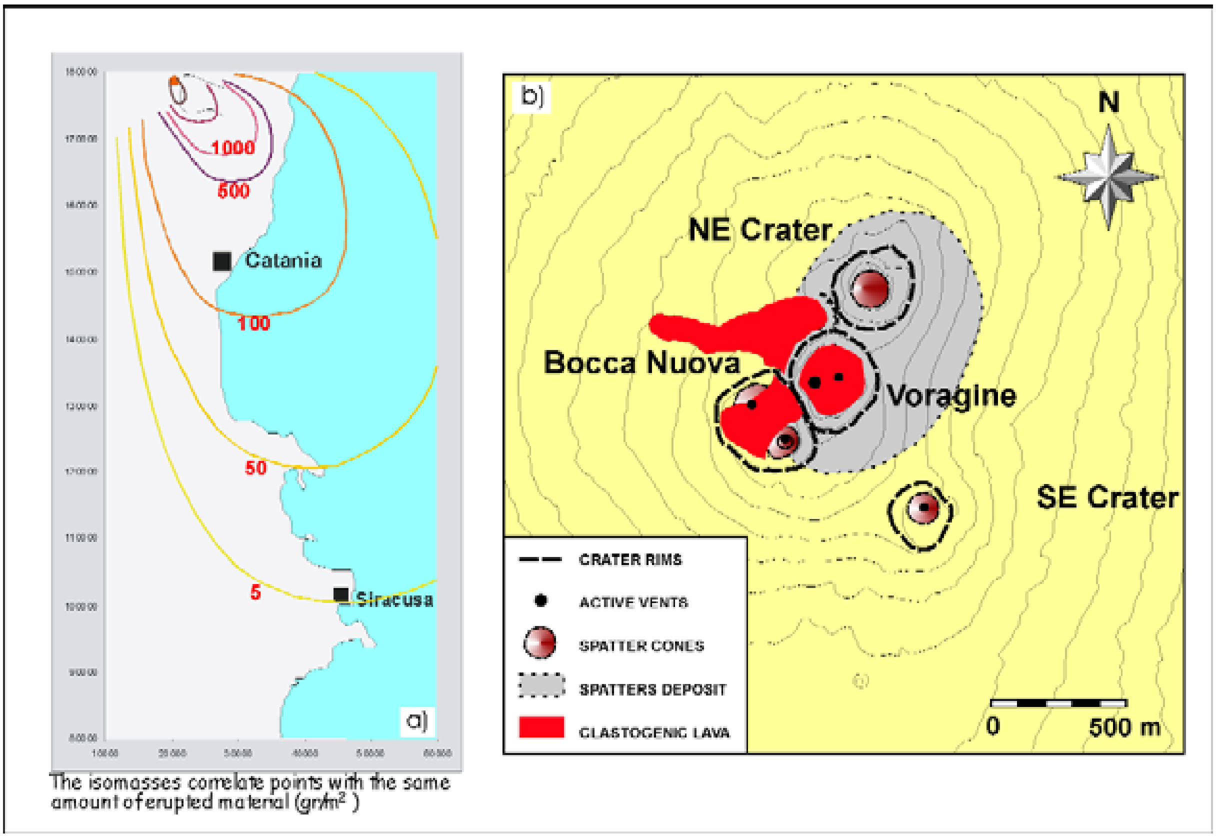

Figure 2 Distal (a) and proximal (b) pyroclastic deposits of the 22 July 1998 eruptive event.

Date of acquisition	13/05/98	22/07/98	26/08/98
Sensor	ERS2	ERS2	ERS2
Orbit	16015	17017	17518
Trak	129	129	129
Frame	747	747	747

Table 1

Image Pair	IP1	IP2	IP3
Date	13/05/98-22/07/98	22/07/98-26/08/98	13/05/98-26/08/98
Temporal baseline	70 days	35 days	105 days
Perpendicular Baseline length (m)	-310	78	-232
Height of ambiguity (m/cy)	30	136	38

Table 2

DEM and the orbits predict a deformation grid, which is compared with a sparse grid obtained from local correlations on actual images.

2. One of the radar images must be registered in absolute geographic coordinates. A radar image is simulated whose amplitude depends on the local topographic slope, which is then correlated with the observed image.
3. the topographic contribution is eliminate by subtracting the fringe pattern calculated from the DEM. The advantage of this approach is that it removes many unwanted fringes, leaving only those related to the signal of interest and/or errors in the DEM .
4. the interferogram is projected into an orthogonal geographic coordinate system, so that users need not work in the distorted radar geometry. The software developed according to these principles runs automatically in most cases, starting from the SLC radar data and the DEM.

Comparison of Results and Discussion

A preliminary rough analysis, of the interferograms has been performed. A positive elevation trend in the summit area of the volcano results this analysis. In particular, an increase of about 3 fringes in the period pre-event, a decrement of 1.5 fringe in the short period post-event (Fig.6), and a general uplift in the long period (13/05/98-26/08/98) is observed.

The existence of three GPS benchmarks around the summit crater area, belonging to the Mt. Etna GPS network, permits to consider data for validating the SAR measurements. Unfortunately, these GPS stations were not continuously running at this epoch, because the set up of the permanent GPS network on Mt. Etna was not finished, but the estimation of the strain tensor around the Summit Crater area for a time interval crossing the paroxysmal event it is allowed.

The principal ellipse strain axis, reported in Fig. 7, show an agreement with a strain pat-

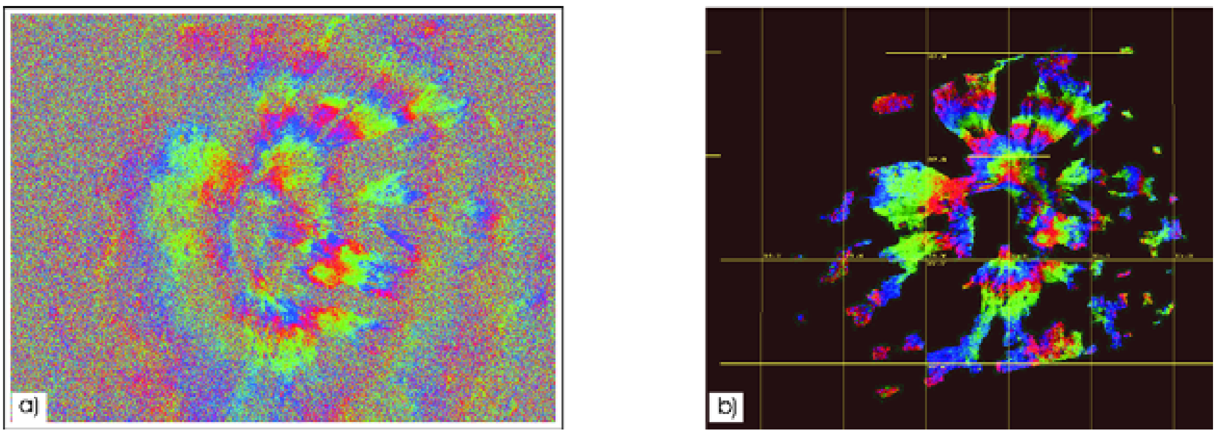

Figure 3 (a) Iterferometric pair 13 May 98-22 July 98; an increase of about 3 fringes in the period pre-event is observed. (b) The interferogram pair georeferenced. In this display the low coherence zone is masked out.

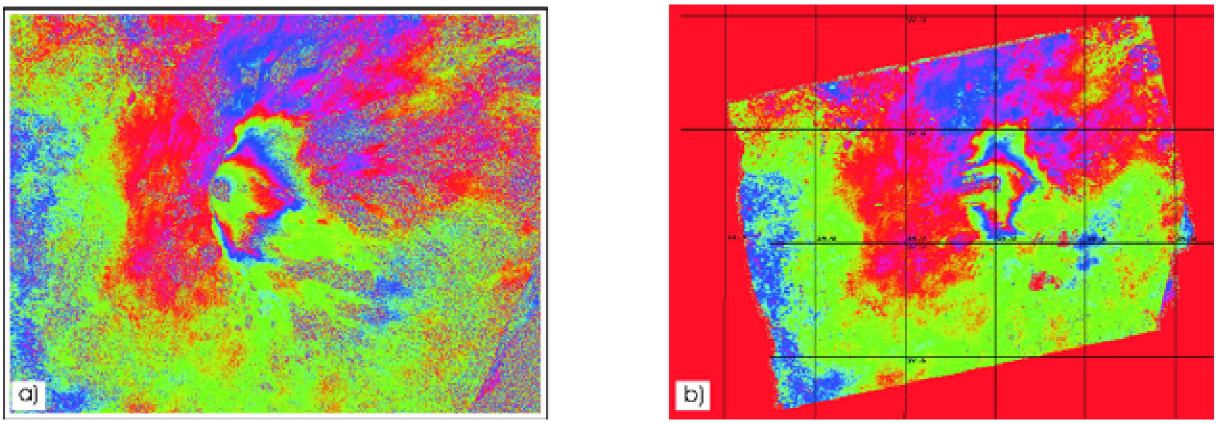

Figure 4 (a) Iterferometric pair 22 July 98-26 August 98; a decrement of 1.5 fringe in the short period post-event is observed. (b) The interferogram pair georeferenced. In this display the low coherence zone is masked out.

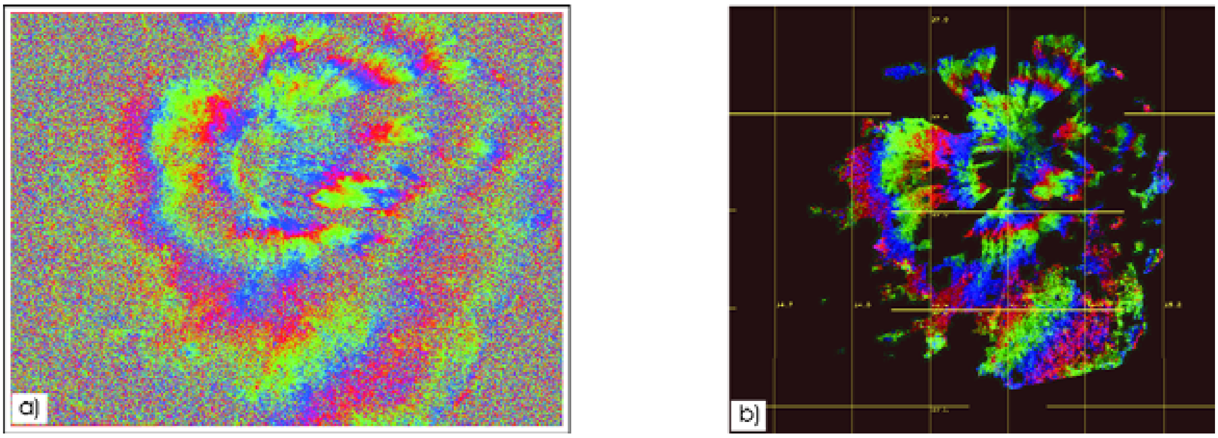

Figure 5 (a) Iterferometric pair 13 May 98-26 August 98; a general uplift in the long period is observed. (b) The interferogram pair georeferenced. In this display the low coherence zone is masked out.

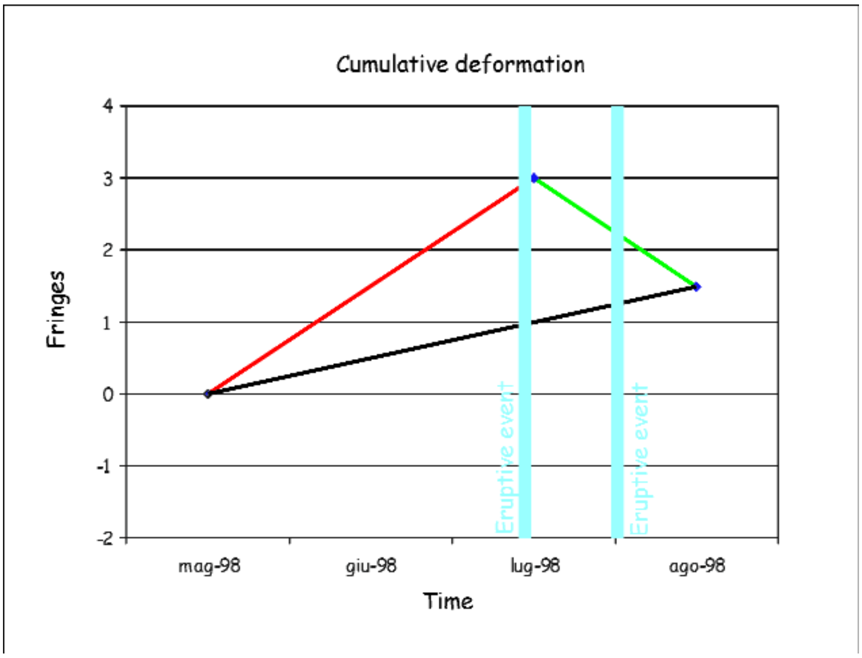

Figure 6 Cumulative deformation plot.

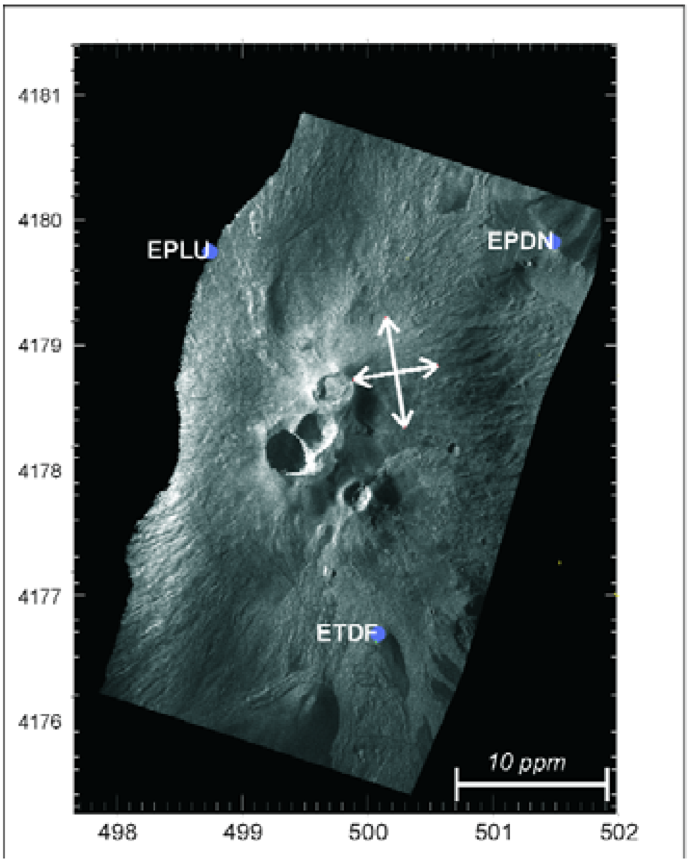

Figure 7 Ellipse strain axes from GPS data.

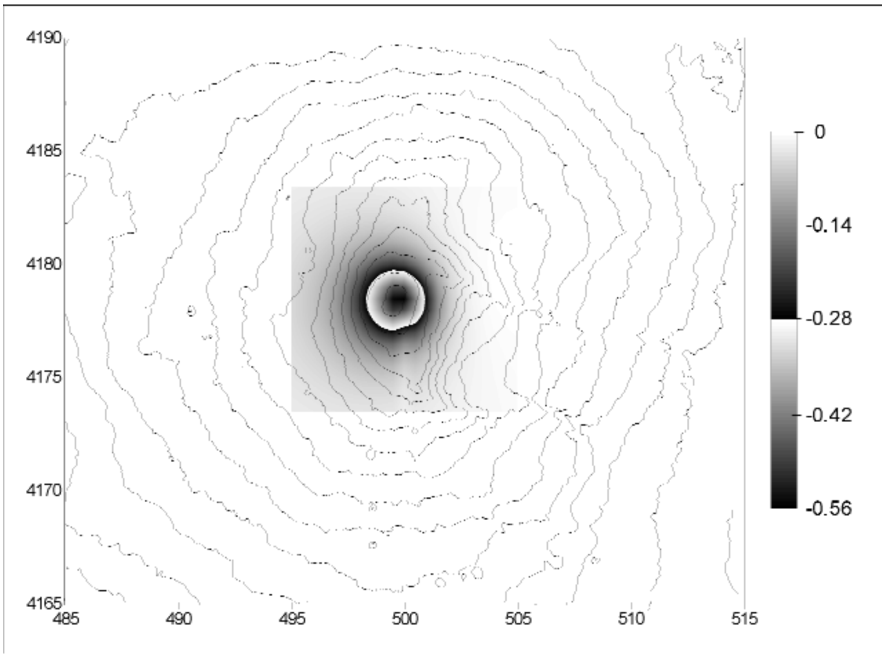

Figure 8 Synthetic displacement field.

tern produced by an axis-symmetric pressure source, centered beneath the summit craters [Bonaccorso and Davis, 1999].

By assuming the existence of a magmatic source at depth of about 1.5 km from a reference level located of about 2500 m a.s.l., it is possible to produce the synthetic displacement field reported in Fig. 8.

The corresponding magma withdrawal is estimated in the order of 0.5 10^6 m^3.

Remarks and Plans for Future Works

• The study the deformation pattern associated to the Mt. Etna paroxysmal event of 22 July 1998, shows a positive elevation trend in the summit area of the volcano. In particular, an increase in the period pre-event, a decrement in the short period post-event, and a general uplift in the long period is observed.

- The computed SAR image for this model reproduces the main characteristic features of real SAR interferogram
- Using an SAR interferogram, is possible to construct detailed models otherwise impossible using only conventional spatially sparse geodetic data
- A method for the non-linear inversion of ground deformation data using Simulated Annealing techniques and SAR images have been proposed (co-operation whit RU-UNICT)

References

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