ALOS PI Symposium 2009, 9-13 Nov 2009 Hawaii

ALOS Data Nodes: ALOS RA-094 and RA-175 (JAXA)

MOTION MONITORING FOR ETNA USING ALOS PALSAR TIME SERIES

Urs Wegmüller, Charles Werner and Maurizio Santoro
Gamma Remote Sensing, CH-3073 Gümligen, Switzerland

Abstract

Since it's launch ALOS PALSAR acquired over many areas more than 10 repeat observations which can be interferometrically combined. Using such a time series over the Etna Volcano in Sicily we investigated the potential of interferometric time-series analysis for deformation monitoring. In the case of the Etna a strictly uniform motion cannot be reasonably assumed. Furthermore, height dependent atmospheric phase delays are potentially affecting the result.

At the longer L-band phase unwrapping is of reduced complexity as compared to C- or X-band. Furthermore, vegetation does not decorrelate the signal as much at this wavelength. Consequently, results were obtained for each PALSAR acquisition date and for much of the volcano area.

In our contribution we describe the processing we performed to obtain improved topographic heights and a deformation time series from the PALSAR FBS and FBD data.

1. Background

In the past SAR interferometry has shown a good potential for volcano motion monitoring. Differential SAR interferometry (DINSAR) and persistent scatterer interferometry (PSI) was used for this purpose. The main problem of DINSAR is that atmospheric path delay effects related to the spatial heterogeneity of the water vapor cause displacement errors in the cm range. This problem can be avoided to a large degree by using PSI. The problem with PSI, nevertheless is, that quite large data stacks (e.g. > 20 scenes) are required and that the presence of point like scatterers is necessary.

Since it's launch ALOS PALSAR acquired over many areas more than 10 repeat observations which can be interferometrically combined. Over the Etna volcano 13 repeat observations in FBS or FBD mode were available at the time of our investigation. Differential interferograms, show a good spatial coverage over the area. Nevertheless, the deformation signals are not very large over many sites and so the relative errors of the interferometric deformation maps are considerable.

2. Objective

Our objective was to use the 13 available PALSAR acquisitions over the Etna to derive a complete deformation time series. For this purpose we developed a "hybrid INSAR" methodology using elements of conventional DINSAR, short baseline interferometry approaches, and PSI.

In the case of the Etna a strict uniform motion cannot be reasonably assumed and height dependent atmospheric path delays potentially affect the interferometric phase. Consequently, the developed methodology needs to address these aspects.

3. Methodology

The basic idea of the methodology developed was to derive the deformation time series from a set of differential interferograms with short time intervals and short baselines.
The short temporal intervals are required to keep the level of deformation phase present low. For pairs with long intervals the deformation causes high phase gradients which may not be correctly resolved in the unwrapping. Using short spatial baselines optimizes the coherence and minimizes the topographic phase resulting from errors in the SRTM height reference which was used.

The baselines relative to the first scene are shown in Table 1. Pairs with short time intervals and short baselines nicely form a set well suited for the derivation of a time series with the exception of the interval between 1-May-2008 and 15-Jun-2008 which has a 6.6km baseline because an adjustment of the orbit. To also cover this time interval we included several pairs with a long time interval and a short spatial baseline. These pairs are important to connect the acquisitions before and after this orbit adjustment. The set of pairs used is listed in Table 2.

Table 1: Baselines and time intervals relative to the first scene

Nr	Pair	Bperp	dtime
1	20070127 20070127	0	0
2	20070127 20070614	1082	138
3	20070127 20070730	1608	184
4	20070127 20070914	1738	230
5	20070127 20071030	2303	276
6	20070127 20071215	2497	322
7	20070127 20080130	2888	368
8	20070127 20080316	3066	414
9	20070127 20080501	3733	460
10	20070127 20080616	-2877	506
11	20070127 20080916	-1341	598
12	20070127 20081101	-1017	644
13	20070127 20090201	-352	736

Table 2: Baselines and time intervals used for analysis

Nr	Pair	Bperp	dtime
0	20070127_20070614	1085	138
1	20070127_20080916	-1343	598
2	20070127_20081101	-1019	644
3	20070127_20090201	-353	736
4	20070614_20070730	525	46
5	20070614_20070914	656	92
6	20070614_20090201	-1438	598
7	20070730_20070914	130	46
8	20070730_20071030	696	92
9	20070914_20071030	565	46
10	20070914_20071215	760	92
11	20071030_20071215	194	46
12	20071030_20080130	586	92
13	20071215_20080130	391	46
14	20071215_20080316	569	92
15	20080130_20080316	178	46
16	20080130_20080501	847	92
17	20080316_20080501	669	46
18	20080616_20080916	1539	92
19	20080916_20081101	323	46
20	20080916_20090201	990	138
21	20081101_20090201	666	92

For all the selected pairs differential interferometric processing was done to derive unwrapped "deformation phases" using the following steps:

- raw data processing with range extension
- range oversampling of FBD scene to FBS sampling
- co-registration of SLCs to common geometry
- 2-pass differential interferometry using
  - oversampled SRTM as initial height reference
  - updating of height reference based on very long baseline pair with short time interval (20080501_20080616)
  - slope adaptive common band filtering
  - baseline refinement
- estimation and subtraction of a topography related atmospheric phase term
- phase unwrapping

The height dependent atmospheric phase effect was estimated over the mountains to the north of Etna and not over the Etna itself to avoid confusion between volcanic deformation and atmospheric phase.

Then, starting from the multi-reference stack of unwrapped phases we derived a single reference time series using Singular Value Decomposition (SVD) to obtain the least-squares solution for the phase time-series. A complete series is obtained for the times connected by the multi-reference pairs. Based on the 21 pairs we obtained the time series for the 13 acquisition dates. Redundancy in the differential interferogram input data reduces uncorrelated errors in the time-series. Uncorrelated errors include residual topographic phase errors and phase noise. Atmospheric phase on the other hand is not reduced by this estimation procedure. For a given acquisition date there is a well defined atmospheric phase delay pattern which is present in all the pairs including this date. The same applies for non-uniform deformation phase. Consequently, the obtained time series of unwrapped phases still includes the atmospheric phases as well as non-uniform deformation phase.

Apart from the phase time series the RMS deviation of the values from the SVD is calculated as a quality value, permitting to identify unwrapping errors which remained undetected.

Applying linear regressions to the time series we also estimated the linear deformation rates (Figure 1). Atmospheric phases as well as phases relating to non-uniform motion are part of the deviation of the time series from the linear regression. Temporal filtering was used, to separate temporally correlated (non-uniform deformation) and uncorrelated (atmospheric delay and phase noise) components.

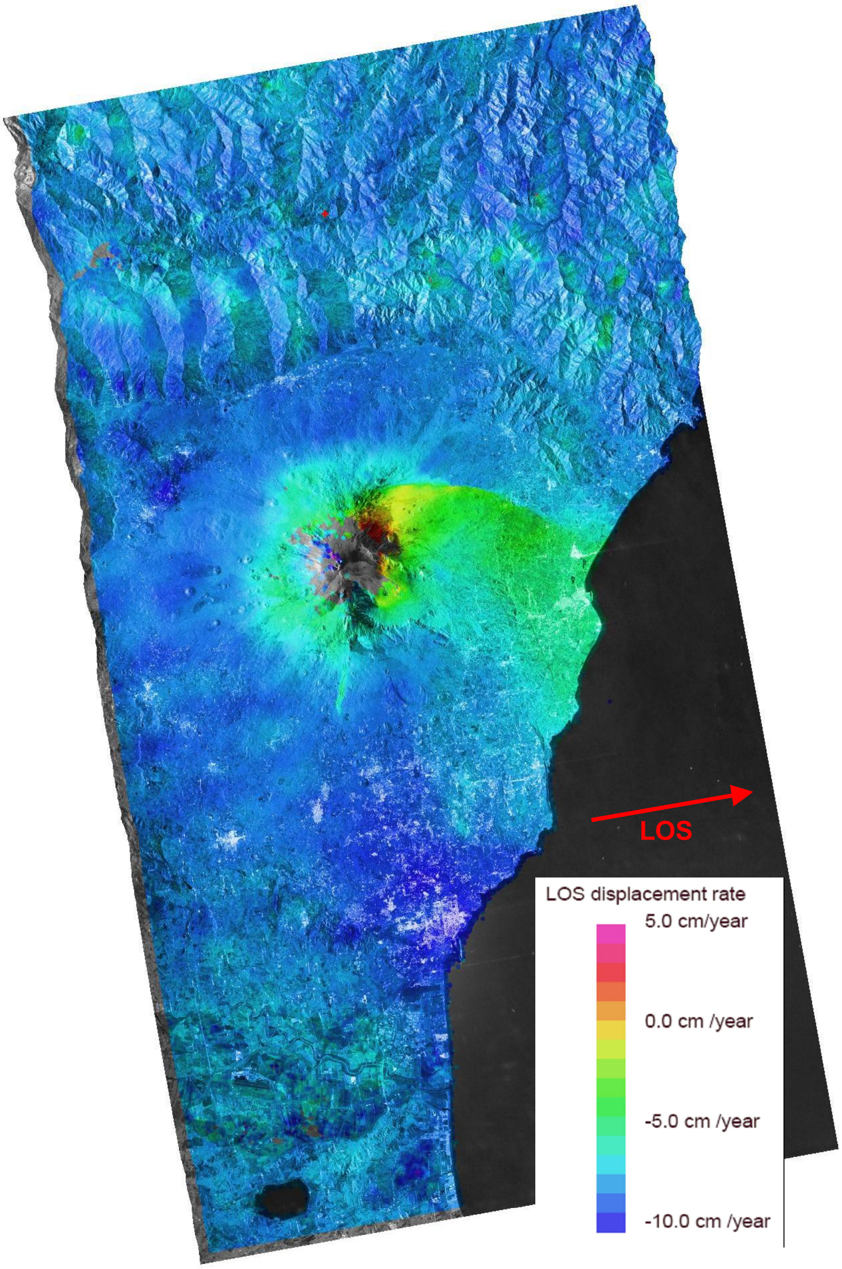

Figure 1 Average deformation rate (LOS component) determined from ALOS PALSAR data between 27-Jan-2007 and 1-Feb-2009 over the Etna Volcano.

4. Results

The deformation time series derived from the PALSAR data are shown in Figures 2 and 3. A good spatial and temporal coverage is achieved. Gaps are only present near the peak because of snow cover and over the ocean.

Looking at the time series more carefully shows that the deformations accelerate after the end of 2007 (see Figure 3).

To check the result we looked if the deviations from the non-uniform deformation model show significant correlation with the deformation pattern or with the topography. This was not the case, so we concluded that the separation of atmospheric phase and deformation signal was quite successful.

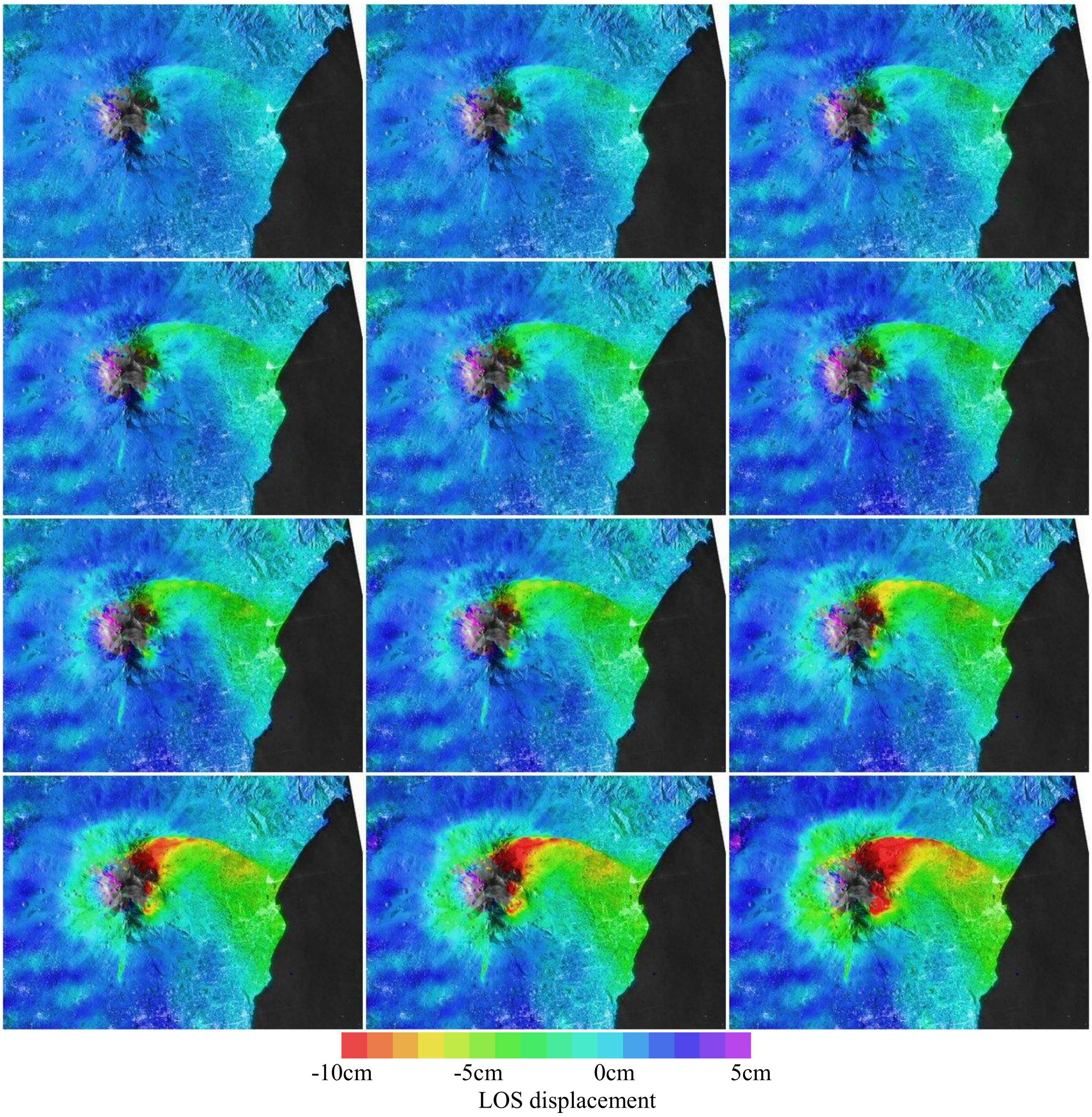

Figure 2 Deformation time series (LOS component) relative to 27-Jan-2007 estimated from ALOS PALSAR data between 27-Jan-2007 and 1-Feb-2009 over the Etna Volcano. (for dates see Table 1).

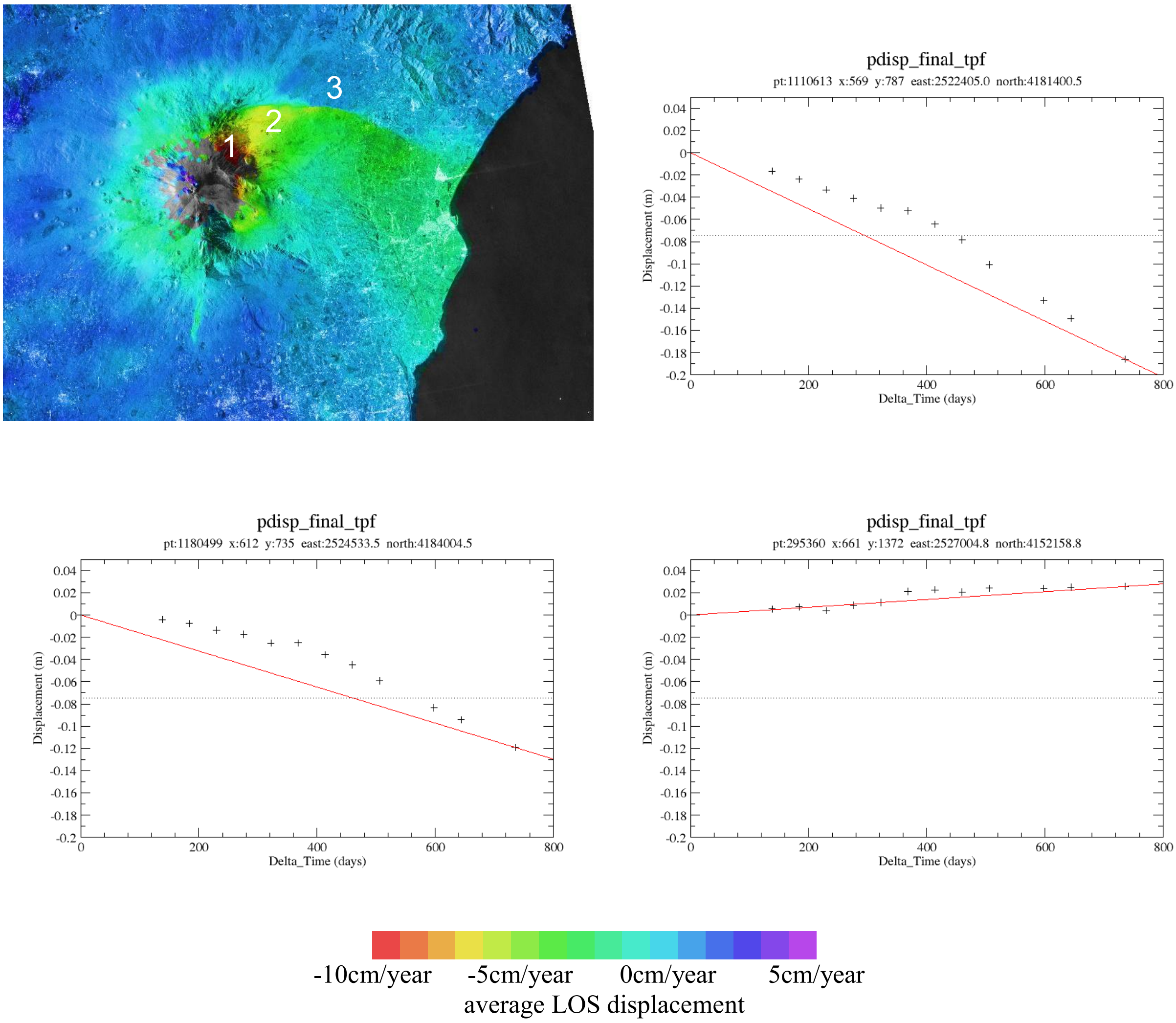

Figure 3 Deformation time series (LOS component) for 3 characteristic points (1 is top right, 2 bottom left and 3 bottom right, times are indicated in days after 27-Jan-2007

5. Conclusions

A PALSAR FBS and FBD time series was used to derive a deformation history for the Etna Volcano. In the processing methodology elements of DINSAR and PSI were combined to achieve a good spatial coverage and to effectively remove residual topographic phase and atmospheric phase effects.

The height model used could be improved using a pair with a 6.6km baseline and 46 day interval. Height dependent atmospheric delays were estimated over nearby hilly areas to avoid potential confusion with deformation phase over the volcano.

6. Acknowledgments

JAXA is acknowledged to provide the PALSAR data used through RA projects 094 and 175. This work was supported by the FP7 GMES Project SAFER.