A Quantitative Analysis of the SBAS Algorithm Performance

Berardino P., Casu F., Fornaro G., Lanari R., Manunta M., Manzo M., Sansosti E.

Istituto per il Rilevamento Elettromagnetico dell’Ambiente
IREA, National Research Council of Italy (CNR)
Via Diocleziano 328, 80124 Napoli, Italy
e-mail: {berardino.p, casu.f, fornaro.g, lanari.r, manunta.m, manzo.mr, sansosti.e}@irea.cnr.it

Abstract—The Small Baseline Subset (SBAS) approach is a Differential Synthetic Aperture Radar Interferometry (DIFSAR) technique that allows analyzing deformation phenomena affecting both extended area and localized structures, by exploiting the phase difference of SAR image pairs characterized by small baselines. In this work we process a large set of ERS-1/2 data, acquired from ascending and descending orbits, at both small and large scale resolution and extend the obtained time series with available ENVISAT acquisitions. The results, relevant to the Napoli Bay area (Italy), are compared with geodetic and GPS data in order to achieve a quantitative analysis of the SABS algorithm performances.

Keywords: Ground deformations, Differential SAR Interferometry, ERS-ENVISAT integration.

I. INTRODUCTION

Differential Synthetic Aperture Radar Interferometry (DIFSAR) is a remote sensing technique that allows us to analyze deformation phenomena affecting both extended areas and localized structures, by exploiting the phase difference of SAR image pairs relevant to the area under study. In this context, several approaches aimed at detecting and following the temporal evolution of the displacements have been already proposed. Among these algorithms, we consider the technique referred to as Small Baseline Subset (SBAS) approach, whose capability to analyze deformations at low and high spatial resolution has been already shown [1], [2].

The key idea of this work is to carry out a full assessment of the SBAS procedure performances by processing a large data set relevant to a test area. In particular, the data processing operation leads to the generation of deformation time-series produced from ascending and descending tracks of the ERS-1 and ERS-2 sensors, spanning the time interval 1992-2003. The availability of these data allows us to analyze the temporal behavior of the detected deformations and, at the same time, to discriminate vertical and East-West displacement components. Moreover, we also apply the two-scale resolution approach discussed in [2] that allows us to focus the analysis on selected zones, highlighting localized displacements of single structures or buildings. Finally, we implement the integration of the available ERS data with a set of ENVISAT acquisitions, in order to demonstrate the capability of the implemented SBAS procedure to easily integrate multisensor data [3].

II. RESULTS

The test site is the Napoli Bay area which includes two volcanoes (the Campi Flegrei caldera and the Somma-Vesuvio volcanic complex), a highly urbanized zone (the city of Napoli and surroundings), the Ischia island and several areas characterized by geo-hydrological risks. A quantitative assessment of the SBAS approach performance has been carried out by comparing the DIFSAR measurements with those available from the geodetic network located in the area covering nearly 3000 km² and including more than 200 leveling benchmarks.

In order to provide an overall picture of the detected deformation, we present in figs. 1-2 the false color map of the mean deformation velocity for the descending and ascending ERS data set superimposed on the SAR image amplitude. Note that this representation is visually effective and allows us to provide a cumulative information (with respect to time) of the detected deformation; note also that areas where the deformation measurement accuracy is affected by decorrelation noise have been excluded from the false color map. Figs. 1-2 clearly show that a significant deformation pattern is present in many areas which can be easily identified: the Campi Flegrei caldera, on the left hand side; the Vomero zone, a densely populated quarter within the city of Napoli in the center; many others are in the Vesuvio zone on the right hand side of the images.
network of the Campi Flegrei caldera managed by the Osservatorio Vesuviano (OV). A comparison between SAR and geodetic data acquired projected into the radar Line Of Sight (LOS) during the deformation event has shown an excellent agreement between the different data set. Note that in this case it has been easy to compare the two different measurements because it is well known that the deformation relevant to the chosen point is essentially vertical.

On the other hand, the availability of both ascending and descending data set allows us to detect the ground deformations in the corresponding radar line of sight and, at the same time, to discriminate vertical and East-West components of the displacements. To achieve this task we have exploited, in the common coherent pixels, the sum and the difference of the two mean deformation velocities (see figs. 4-5, respectively). In particular, fig. 4 shows a dominantly vertical motion relevant to the Campi Flegrei, the Vomero area and some others in Vesuvio zone, while fig. 5 clearly shows two main effects: the radial deformation of the Campi Flegrei caldera, where the area of maximum subsidence/uplift is characterized by a vertical displacement only, and a peculiar deformation pattern that involves the Eastern flank of the Vesuvio.

In order to demonstrate the capability of the proposed approach to follow the temporal evolution of the detected deformation, an example is provided in the following. In particular, fig. 3 presents the time-series of the computed deformations, achieved by combining ERS and ENVISAT data, for a point located in the area of maximum displacement of the Campi Flegrei caldera. Note that the observed deformation is characterized by a rather continuous subsidence phenomenon from 1992 until the beginning of 2000, when a change of the deformation trend occurs resulting in an uplift phase. This phenomenon has been also detected by the geodetic surveillance.
By following the previous rationale, we have investigated the Ischia island area, not included in the previous figures. The mean vertical deformation velocity, estimated by the ERS SAR data is shown in fig. 6; in particular, we note two zones characterized by a significant vertical displacement in the South and North-West sectors. For a pixel located in the latter zone, we have compared time-series of the computed deformation to the available geodetic data projected into the radar LOS (fig. 7).

In order to achieve a quantitative analysis of the SBAS algorithm performances, we have compared the obtained results to the available leveling data. Fig. 8 shows a part of the leveling network located in the area. For each leveling benchmark we have compared the mean vertical deformation velocity obtained by using SAR data to that obtained from leveling data (the latter spanning the time interval 1990-2003) and evaluated the standard deviation of their difference, which spans from 0.05 cm/year (cyan line) to 0.25 cm/years (red line).

In fig. 9 a comparison between the two mean velocity measures (SAR: red triangles, leveling: black stars) along the leveling lines is shown. The good agreement is evident.

Finally, we show the results obtained by applying the two scale approach to the ERS descending data set to study deformation phenomena at single look spatial resolution. In particular, we have focused our analysis on the Vomero and Campi Flegrei areas. Fig. 10 provides information about the mean deformation velocity of the investigated targets in the Vomero zone. It is evident that the deformations of several structures...
and buildings can be investigated. In particular, we have considered the coherent pixel highlighted in fig. 10, which is relevant to a building where a leveling benchmark is located. The result of the comparison between DIFSAR and geodetic displacement is shown in the plot of fig. 10, wherein the leveling data have been projected on the radar line of sight. The good agreement between the SAR (triangles) and the leveling (stars) data is evident; indeed, the standard deviation of the difference between the two measurements is less than 0.5 cm.

Fig. 11 represents the map of the detected coherent pixels, overlaid to an optical image of the Campi Flegrei area. Also in this case a quantitative experiment has been performed. In particular, we have compared the SAR displacements with the continuous GPS measurements carried out, during 2000, at a site located in the highlighted zone of fig. 11; again the good agreement between the DIFSAR and the LOS projected GPS deformations is evident, in this case the difference presents a standard deviation of about 0.6 cm.

**III. CONCLUSION**

The comparative analysis between classical geodetic and DIFSAR data has shown a clear agreement between the different methodologies in both space and time. This comparison has been performed by making a joint exploitation of ascending and descending ERS-1/2 SAR and ENVISAT data.

Moreover, measurements obtained by the extended SBAS method, aimed at analyzing localized displacements that may affect small areas or single buildings, have been also validated via a comparison with GPS and leveling data.

Finally, the extension of the original SBAS technique combining ERS and ASAR ENVISAT data allows us to significantly improve the temporal analysis of the detected deformations by benefiting of the future availability of ASAR data.

The presented results obtained by applying the SBAS technique to the Napoli Bay area demonstrate the capability of the approach of monitoring ground deformation phenomena.

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**REFERENCES**

