DINSAR APPLICATIONS FOR DEFORMATION MONITORING

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ABSTRACT

The differential interferometric SAR (DINSAR) was successfully applied to monitor a number of different sites like urban, glaciers and landslides.
For the urban site (Bucharest, Romania), a data set of 43 ERS images was used for interferogram stacking. An average deformation map was derived.
For the glacial site (Himalayan glaciers), two Envisat images were processed to form a differential interferogram, in which we distinguish three different zones (stable slopes, moving glaciers and melted ice).
For the landslides site (Siriu, Romania), the region around the waterdam Siriu and the slope stability of both sides of the waterdam is monitored.

1. URBAN SITE: BUCHAREST, ROMANIA

We acquired a set of 43 ERS-1/2 data from descending pass covering the area of Bucharest between 1992 and 1999 in order to detect ground deformation. The European Remote Sensing (ERS-1/2) satellites, operating from an altitude of roughly 800 km and at a wavelength of 5.67 cm, observe the Earth from a direction of 23 degrees from vertical, being thus more sensitive to vertical than to horizontal displacements of the surface.

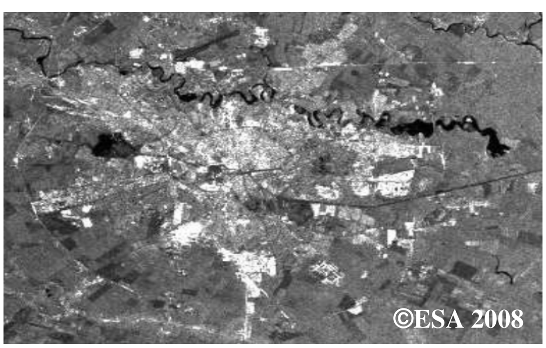

Figure 1 ERS-1 image of Bucharest

The data was received in single look complex format, and the interferometric processing was performed using the DORIS software package [9].
These images were used to create 9 interferograms with different master images and with perpendicular baselines smaller than 10 m. We chose only interferograms with small baselines in order to optimize the coregistration process and to reduce the topography induced phase contribution. Small baselines interferograms are used e.g. also in [2]. The topographic component has been removed using an SRTM3 DEM, which has the height accuracy of about 16 m [1], and the ERS precise orbits computed by Delft University of Technology were used for flat earth removal [5].
Then the interferograms are filtered in phase using the adaptive algorithm of Goldstein. Since the measured phases in the interferograms are wrapped in modulo of 2π, the surface displacement map can be derived by phase unwrapping. To unwrap we are using the freely available software SNAPHU [4]. Once unwrapping has been performed, phase values are converted to displacement values by multiplying with $\lambda / 4\pi$. Finally, applying a stacking method on the unwrapped interferograms, we obtain the deformation map from Fig. 2.

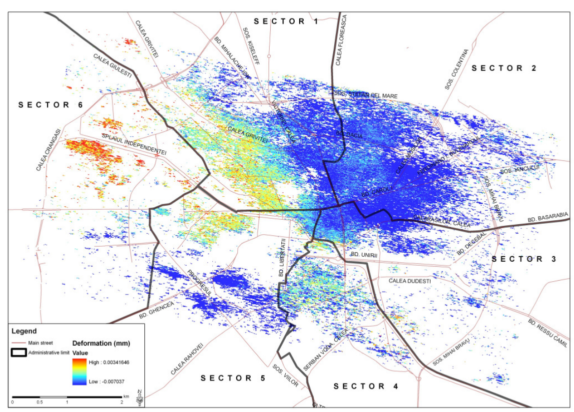

Figure 2 Deformation map of Bucharest showing subsidence areas detected with up to 7 mm/year over 7 years

The height of ambiguity is defined as the altitude difference that generates an interferometric phase change of 2π after interferogram flattening [7] and is given by:

$$h_{\text{amb}} = -\frac{\lambda \cdot R \cdot \sin(\theta)}{2 \cdot B_{perp}} \quad (2)$$

where λ represents the wavelength of the carrier wave, R the range to the target, θ the look angle and B_{perp} the perpendicular baseline. From this formula, for a baseline of 10 m, we obtain $h_{amb} = 970m$..

Having only a low resolution SRTM DEM, a few GPS measurements with accuracies of 1 m each were taken at selected points in the area of deformation and around it, to make sure that the phase variation we measured is not an effect of variable topography. It was found that the surface altitude variation is less than 3-4 meters; therefore, the only relevant source of topographic phase in the interferograms could come from differences between the surface elevation and the top of the buildings (an average of 20 m). Now knowing that the height of ambiguity corresponds to 2π, we find that the possible topographic error of 20 m corresponds to 7 degrees phase error, further corresponding to 0.056 mm possible deformation error. Thus we may say that the obtained results are reliable.

2. GLACIAL SITE: IMJA LAKE, HIMALAYA

The region of interest is around the 2km long glacial lake of Imja at 5000 m altitude which is a potential danger for people, animals and infrastructure down-valley, as the lake could produce a catastrophic flash flood. The steep side moraines (see Fig.3) are unstable and with an earthquake may collapse and trigger a tsunami.

Figure 3 Imja lake and surrounding moraines

From two ENVISAT images acquired at 10th of January 2009 and at 14th of February 2009 (ESA Cat-1 project) we compute a differential interferogram (see Fig. 4), using a 30 m resolution DEM supplied by ICIMOD, Kathmandu/Nepal.

Over the lake and along the glaciers the coherence is almost completely lost, maybe because of the 35 days temporal baseline of the acquisitions, which is too big in this case and temporal decorrelation appears. But at the western end of the lake (see Fig. 5), in the south part of the lake, and along a valley in the west of the lake we could measure deformations up to 2 cm in 35 days.

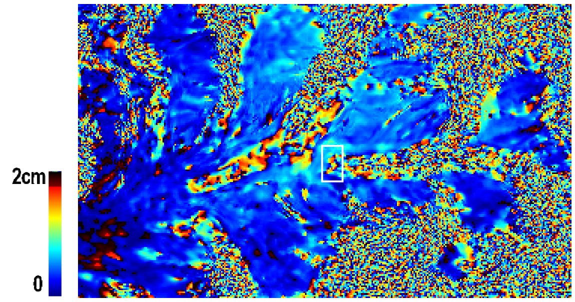

Figure 4 Differential interferogram over the Himalayan glaciers around the Imja lake, showing deformation rates up to 2 cm in 35 days

Figure 5 Ice covered by ground moraines at the western end of the lake. This part also shows a movement in the interferogram probably due to the melting process. It could result in a lowering of the terrain and hence a rapid lowering of the lake level.

3. LANDSLIDE SITE: WATERDAM SIRIU, ROMANIA

The monitored region is around the lake and the waterdam Siriu, Romania. The waterdam construction triggered slopes instability that led to one major landslide blocking the lake (Fig. 7) and other landslides affecting the main roads (Fig. 11) and the waterdam infrastructure (Fig. 9).

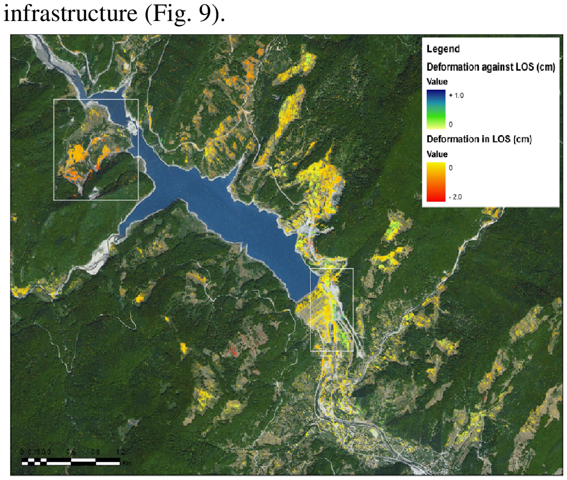

Figure 6 Geocoded deformation map of Siriu area displayed over an optical image

Two TerraSAR-X High Resolution Spotlight images at 11 days temporal distance from September-October 2009 were supplied by Infoterra GmbH, Germany. With DInSAR a number of instable sites were detected (see Figures 6-12). It was shown that the major landslide is still active (Fig. 8), the road is moving in two main regions due to slopes activities (Fig. 12) and the waterdam infrastructure is also affected by yet another slope movement (Fig. 10).

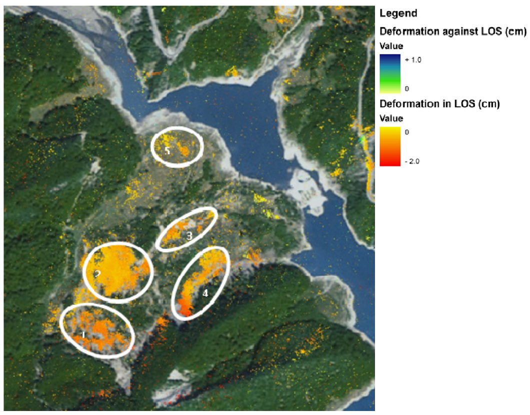

Figure 7 Deformation map and identified deformation zones with different deformation rates

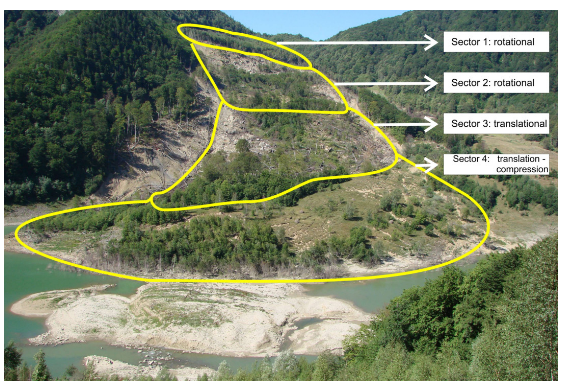

Figure 8 Morphodynamical sectors of the landslide

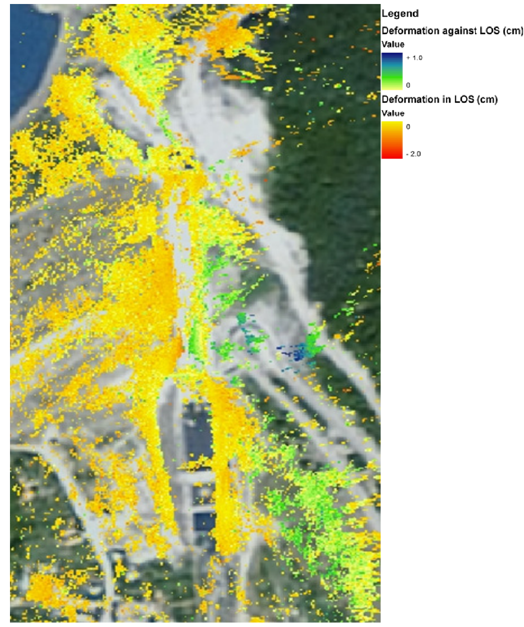

Figure 9 Enlarged display of the deformation map around the spillway channel near the dam

Figure 10 Deformation of the waterdam infrastructure due to the slopes instability

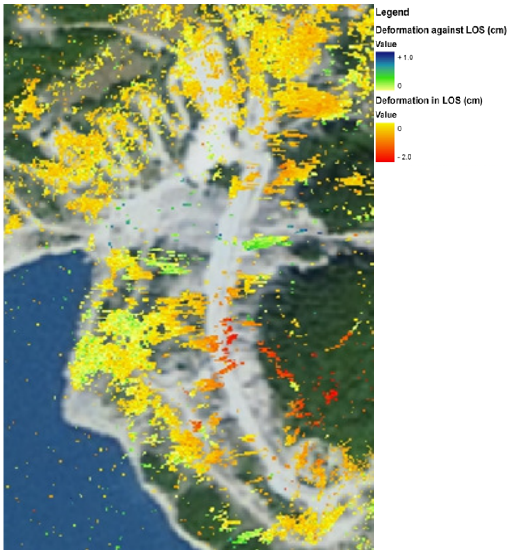

Figure 11 Zoom of the deformation map around the road affected by a landslide from Fig. 12

Figure 12 Road affected by a landslide. It can be seen as coherent on the deformation map (see Fig. 11) except the two new landslides (gray) that occurred in between the acquisition dates. According with the DInSAR measurements, the left side if the landslide is stable, the middle part (between the new flow) is moving slightly, while the right side is very instable, moving with 2 cm in 11 days.

4. Conclusions

The InSAR technique was successfully applied to monitor ground deformation processes at different scales. Medium to large scale deformation processes (urban site of Bucharest) can be properly detected using ERS/ASAR data and small scale (meters level) deformation processes can be detected using High Resolution Terra-SAR X data.

5. Acknowledgements

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Envisat data were also supplied by ESA under a Category 1 Project.
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