MONITORING OF LUMNEZ LANDSLIDE WITH ERS AND ENVISAT SAR DATA

H. Raetzo(1), U. Wegmüller(2), T. Strozzi(2), F. Marks(3), P. Farina(3)

(1) Federal Office for the Environment, Risk Prevention Division, Worblentalstrasse 68, CH-3063 Ittigen, Switzerland, Hugo.Raetzo@bafu.admin.ch
(2) Gamma Remote Sensing AG, Worbstrasse 223, CH-3073 Gämlikigen, Switzerland, wegmuller@gamma-rs.ch
(3) Universita' degli Studi di Firenze, Dipartimento di Scienze della Terra, Via G. La Pira 4, I-50121 Firenze, Italy, paolo.farina@unifi.it

ABSTRACT

As part of the ESA Terrafirma Project an interferometric point target analysis (IPTA) was conducted to monitor the LUMNEZ landslide. The main interferometric result consists of the average line-of-sight deformation rates and the deformation histories for the selected points. The observed deformation rates reach values up to several centimeters per year. The interferometric result was delivered to the Swiss Federal Office for Environment and to the University of Florence where it was further interpreted. Combining IPTA results with the use of digital terrain data, aerial imagery and in-situ data a geomorphologic and geological interpretation of the Lumnez landslide was carried out. DTM data and aerial imagery allowed a geomorphologic zonation of the unstable slope taking into account derivates of the DTM as shaded relief, slope and aspect map. A field survey enabled the assessment of findings from the satellite monitoring, with the identification of damaged buildings and morphologic evidences connected to the slope movements.

1 INTRODUCTION

The Northern-Western slope of the Val Lumnez is one of the most active landslides in urbanized areas of the Swiss territory. The Swiss Federal Office for Environment and the Canton Graubünden spent many investigations on this landslide affecting some 18 km2. On the toe of the landslide the river Glenner is eroding frontal parts. Many debris flows were initiated by this landslide activity and the damage downstream is considerable. For these reasons several projects of countermeasures have been realized since the 19th century. Inside the unstable area seven villages are affected by the displacements and open cracks in houses and walls are frequent. In the 20th century the Cantonal Authority planned to relocate the village of Peiden, because the movements were very fast, sometimes reaching several decimeters per year. Efforts undertaken to improve the drainage of the entire slope were partially successful in reducing the movement rates.

As part of the ESA Terrafirma Project Gamma Remote Sensing conducted an interferometric point target analysis (IPTA) to monitor the LUMNEZ landslide. ERS and ENVISAT ASAR images were used for the monitoring. The main interferometric result, consisting of the average line-of-sight deformation rates and the deformation histories for the selected points, was delivered to the Swiss Federal Office for Environment and to the University of Florence where it was further interpreted and validated.

In the following the processing done is summarized, followed by a discussion of the result and the integration and validation work done.

2. THE IPTA TECHNIQUE

Interferometric Point Target Analysis (IPTA) is a method to exploit the temporal and spatial characteristics of interferometric signatures collected from point targets to accurately map surface deformation histories, terrain heights, and relative atmospheric path delays.

The use of targets with point like scatter characteristics has the advantage that there is much less geometric decorrelation. This permits phase interpretation even for large baselines above the critical one. Consequently, more image pairs may be included in the analysis. Important advantages are the potential to find scatterers in low-coherence areas and that interferometric image pairs with large baselines may be included in the analysis. Finding usable points in low-coherence regions fills spatial gaps in the deformation maps while the ability to use large baselines improves the temporal sampling. For a more detailed discussion of the point target based interferometric technique used see [1].

The most straightforward application of IPTA is the monitoring of slow and temporally uniform deformation. In this case the temporal and spatial
sampling of the signal is very good. In the case of higher deformation rates the capability of the point target based interferometric technique to use pairs with large baselines has the advantages that high phase gradients can be reduced if shorter observation intervals become available. In addition, large scale corrections such as baseline errors and the large scale component of the atmospheric distortions can be estimated independently of the areas with high deformation gradients and interpolated or extrapolated to get relatively accurate corrections for the entire area. The spatial separation of the available point-like scatterers is of course an important factor. Larger distances, i.e. lower spatial sampling, strongly reduces the potential to resolve high phase gradients. In the case of temporally strongly varying deformation rates spatial unwrapping of the point phases is necessary.

In the present analysis the main area of interest was the Northern-Western slope of the Val Lumnez. Relatively high deformation rates of several cm/year were expected. In spite of the several villages present, the spatial point densities were likely to be low for this site. Furthermore, in this Alpine site significant topographic differences within the area of interest and periods with snow cover need to be considered. Overall very challenging conditions.

For the area processed an image of the average line-of-sight deformation rates is shown in Figure 1 overlaid to a shaded relief. Figure 2 shows a more detailed view of the result for the primary area of interest, this time overlaid to a topographic map and using a different color scale to display the deformation rates. In both cases the line-of-sight component of the deformation is shown. This can be converted to the full deformation value if the 3D direction of the movement is known.
3. DISCUSSION OF THE RESULTS

Combining IPTA results with field mapping and the use of digital terrain data, aerial images and in-situ data a geomorphologic and geological interpretation of Lumnez landslide was carried out.

The geological mapping in the field focused on the activity of the landslide and the different mechanisms. DTM and aerial images were helpful in the zonation taking into account derivates of the DTM as shaded relief and slope maps. Following the landslide classification employed currently in Switzerland based on the long term mean velocity of the movements [4] the IPTA measurements projected along the slope direction have been re-classified into three groups: sub-stabilized (average velocity < 2 cm/year), slow (average velocity 2 – 10 cm/year) and active (average velocity > 10 cm/year). In Fig.4 such a classification of the IPTA average displacement rates is reported.

Considering the relatively high concentration of IPTA-points inside the villages, the zonation of different activities was detailed. This mapping was validated by damage inventories and geomorphologic interpretation. Field surveys were carried out during summer 2006 in order to identify morphological evidence of the landslide activity and to detect damage on buildings and man-made structure (Fig.5).

In rural areas the low density of reflectors makes problems in the interpretation. For several active landslide bodies an interpretation is impossible due to the missing IPTA reflectors. Some interferograms with short baselines could be an option for additional satellite information. Considering the limits of C-band, additional interferograms based on L-band InSAR are probably helpful (see also [3]).

For the validation of IPTA results geodetic measurements spanning the time period 1887-1992 were available. The comparison of the spatial distribution of
movements has shown that from a general point of view the same pattern of displacements is recognisable from the geodetic measurements as from the IPTA analysis. Highest displacement rates are observed in the area of Vignogn and Peiden, whereas the marginal part of the slope in the N of Cumbe and Morissen remains quite stable. The line-of-sight component of the deformation is lower than the real 3D displacement. By projecting the IPTA l.o.s. measurements along the local slope direction it has been possible to improve the comparison with the available in situ data (Fig.6 and Fig.7).

**Figure 6:** Ground displacement rates projected along the slope direction determined from ERS/ASAR data between 1992 and 2006 compared to the in-situ measurements.

**Figure 7:** Comparison between IPTA deformation rates (1992-2005) and in-situ measurements (1887-1992).

Displacements rates measured by the topographic network appear to be higher than the IPTA analysis. This observation could be related to the temporal evolution of the movements, because the displacement rates were decreasing from the beginning of the '50 (as evident from Noverraz et al. (1998) [5]). Since the geodetic measurements do not account for single time periods, but provide only a mean value for the entire time period of 1887 – 1992, these displacement rates may have been higher than measurements from the last decades ('80 or '90). We assume that the velocity of Lumnez landslide decreased since 1940 according to the drainage systems built. Furthermore recent GPS measurements should confirm the lower activities in the last decade.

**4. CONCLUSIONS**

The IPTA analysis of Lumnez landslide gives very interesting results about the activity and the spatial distribution. A high correlation between in-situ data and satellite data underlines the potential of this method in managing landslide hazards.

Considering the high costs related to the landslide activity and the difficulties in the detection of the active, slow, and dormant parts of the landslide, especially over urban areas, the use of an InSAR approach can positively impact on the current hazard mitigation activities of the local authorities. As a next step the monitoring of the actual movements using InSAR techniques could be implemented in the risk management.

A variation of the landslide activity is expected according to the climate change in the Alps, especially in permafrost environment. Mountain areas are not very well controlled by the different monitoring systems due to the high costs. The satellite data and especially InSAR are an important option for the monitoring in the future. A combination of in-situ data, C- and L-band analysis would help the local risk managers dealing with landslide hazards.

**5. REFERENCES**


6. ACKNOWLEDGEMENTS

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