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Potential and methodology of satellite based SAR for hazard mapping

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Abstract - SAR and InSAR data have a high potential for change detection due to their "all weather" capability and the day/night access of the sensors. Here we investigate the potential and methodology for forest storm, flood, and avalanche mapping with ERS1/2 data. In our methodology process models are used to describe the targets before, during and/or after the hazard event. Very important are the good relative calibration and accurate coregistration of the different information layers. The presented results demonstrate the good potential of multitemporal SAR and InSAR data for hazard mapping.

INTRODUCTION

In recent years an increasing number of hazard events occurred. In Switzerland, for example, immense damage caused by a series of avalanches in February 1999, was followed by flooding in spring and heavy storms in late December. The assessment of the damage is not only important for the evaluation of the event but serves also as input to the characterization of the risk and for the planning of protection measures. Satellite-based remote-sensing data have a high potential for the assessment of damages after such catastrophes. Data acquisitions during or after the hazard event combined with archived data (representing the condition before the event) allow in many cases to map the change which occurred. SAR and InSAR data are particular useful for this purpose because of the very high potential for change detection, the large area coverage, the "all-weather" capability, and the day/night access of the radar sensors.

In hazard mapping the interest is mainly pointed to the assessment of the spatial extent and the level of the damage (although in many cases the level of the damage only includes damaged versus intact areas).

In a first step we define process models to describe changes of the target due to the hazard. In a second step a forward model is defined describing the effect on the information layers. Finally, results are presented and discussed.

CHANGE DETECTION

Typical SAR parameters appropriate for change detection are multi-temporal backscattering-coefficients and coherence estimates. These parameters estimated from SAR images acquired during or after the event are compared to reference data without damage. Appropriate estimation schemes are essential for the successful application of the methodology and include good relative and absolute calibration, accurate coregistration of the information layers, filtering and classification. Precise geocoding is necessary for multi-sensor data fusion and also for an adequate presentation of the data particularly to non-specialist users. The processing chain was set up using GAMMA Software [1].

PROCESS MODEL

In order to identify SAR and InSAR parameters well suited for the hazard mapping, it is first necessary to assess the effect of the hazard event on the target as described in Table 1.

Table 1:

Before hazard	During/After hazard
Forest storm damage	
1) intact forest	partially broken trees partially uprooted trees decreased canopy height exposed lying trunks ground visibility changed
Flood	
2) forest 3) farmland 4) urban area	trees in water shallow water surface buildings, obstacles in water
Avalanche	
5) snow covered area	snow piles with rocks, trees, soil

Fig. 1. Forest after storm near Lyss.

FORWARD MODEL

For the definition of the forward models, the effect of the change (Table 1) on the information layers backscattering coefficient σ^0, coherence γ must be understood. This can be investigated using models or reference datasets. For the investigated cases even simple signature based rules were sufficient (Table 2):

Forest can be discriminated from non-forest by its low coherence [2]. Storm damaged forest has more stable scatterers and less volume scattering, therefore the coherence is higher than for the intact forest [3].

Calm open water is characterized by very low σ^0 and γ. Flooding therefore typically causes a strong decrease in these two information layers. However, if the water is rough, σ^0 may also increase. For not very dense forest stands and also for urban areas increasing double-bounce scattering results in higher σ^0.

Compacted rough snow of an avalanche cone has a very high σ^0, even if the snow is wet [3]. Thus it can be discriminated from homogenous snow cover.

Table 2

	Change
Forest storm damage	
1) intact forest	γ increase, σ^0 uncertain
Flood	
2) forest 3) farmland 4) urban area	σ^0 increase σ^0 decrease, γ decrease σ^0 increase
Avalanche cone	
5) snow covered area	σ^0 increase

RESULTS

Forest storm damage

For the test site Treiten, Switzerland, ERS Tandem data of 26/27 Nov 1995 (before the storm) and 9/10 Jan 2000 (after) were used. Figure 2 shows a Dynamic Coherence Product, increasing coherence is shown in the red channel, the averaged backscattering coefficient before the storm in green, and the coherence before the storm in blue. In this representation intact forests appear in green, agricultural fields in blue, and forest damage in orange. Some orange spots can also be found in non-forested areas. But this is not a problem as usually it is known from an available conventional forest map or a remote sensing based landuse map where the forest stands are. The Dynamic Coherence Product clearly shows the heavy damage of the forest, which is confirmed by the air photo of the forest after the storm (Figure 3). Figure 4 shows the ERS interferometry based forest damage map of Treiten. The damage classification is based on the coherence increase. A quality assessment of different remote sensing methods for similar examples was done in France. The dynamic coherence method turned out to be the most accurate classification approach. The accuracy was 89% [3] validated with damage maps determined from air photos.

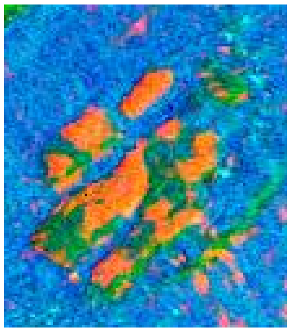

Fig. 2 (left) 3 (right). Dynamic coherence Product (left) and air photo (right) of storm damaged forest in Treiten.

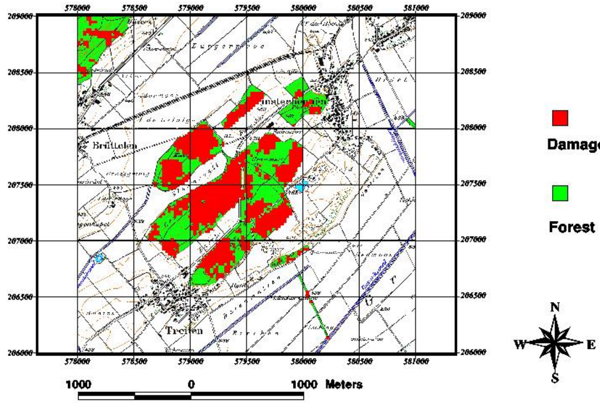

Fig. 4. ERS interferometry based forest damage map of Treiten.

Flooding

Bern Airport Switzerland is situated between the river Aare and the river Gürbe. In spring 1999 heavy rains combined with snowmelt runoff from the century-high snowfalls of the winter 1998/1999 lead to heavy floods in parts of Switzerland. On May 15 the airport Bern-Belpmoos had to be closed. It remained closed until May 25. In Figure 5 a SAR RGB composite (red: 21 Apr 1999, green: 26 Mai 1999, blue: 26 Mai 1999) is shown. The red channel represents the situation before the flood, while the blue and green channel show the situation at the end of the flood. Figure 6 shows the flood map of the authorities. The colors indicate the maximum water depth (yellow < 20cm, blue 20-50 cm, orange 50-100 cm, brown 100-200 cm, black > 200 cm). The red areas in the RGB correspond well to areas that were flooded. It is shown that the areas close to the airport are not flooded anymore. The flooded area in the knee of the river is not indicated in the RGB. This area is forested.

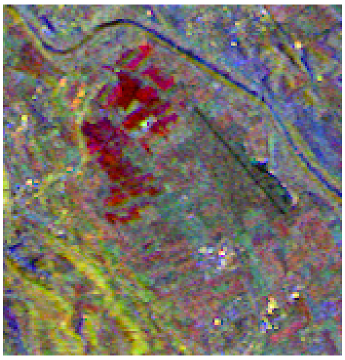
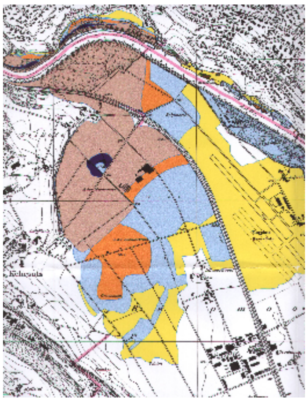

Fig. 5 (left) 6 (right). RGB composite (left) and flood map (right) of the airport of Bern. The flood map is provided by the Tiefbauamt of the Canton of Bern, Switzerland.

Avalanches

In February 1999 a high number of avalanches occurred in Switzerland due to the large amount of new snow. Figure 7 shows a RGB composite (red: 22 Jan 1999, green: 26 Feb 1999, blue: 24 Sep 1999) of the backscattering coefficient of the Ulrichen area, Switzerland. From the forward model we expect high backscattering of the avalanches. In the RGB they should show up in green. Indeed, several avalanche cones can well be identified in the RGB. Figure 8 shows an air photo of the encircled avalanche in Figure 7. Even the fine structures of the cone are visible in the RGB. At the Swiss Federal Institute for Snow and Avalanche Research (SLF) the avalanche cones were mapped. Figure 8 shows the map of this avalanche. The SAR product is also in very good agreement with this map.

CONCLUSIONS

In this paper we have shown that SAR and InSAR are powerful tools to map risk and hazard damages. The temporal behavior of the backscattering coefficient and the coherence turned out to be valuable information layers.

For the investigated events, the methodology proved to be robust and reliable. It is our expectation that it is also applicable for other risk and hazard types.

The quality of the product depends on the quality of the calibration, the coregistration of the information channels and the geolocalisation.

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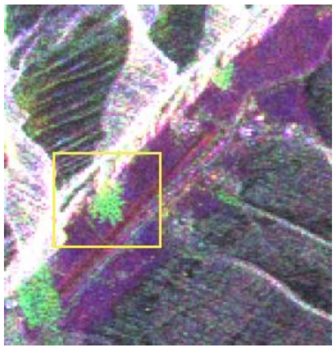


Fig. 7 (left) 8 (right). RGB composite of Ulrichen (left) and air photo of the Ulrichen Avalanche (right). The air photo is property of the SLF.

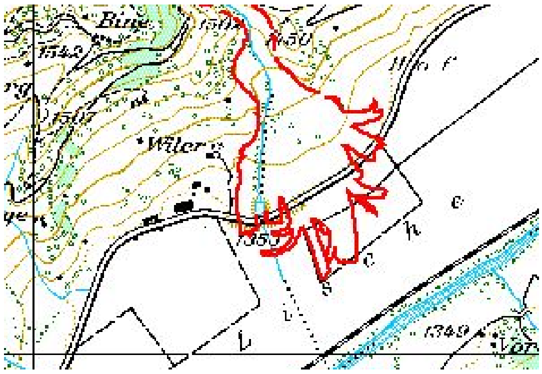

Fig. 9. Avalanche map of the Ulrichen Avalanche. Property of SLF.

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