DIFFERENTIAL INTERFEROMETRIC APPLICATIONS IN ALPINE REGIONS

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1 INTRODUCTION

The high-mountain mass-transport systems are the results of steady mass shifts and catastrophic mass-movement events. The equilibrium of these systems is markedly influenced by ice occurrence, which makes high mountains especially sensitive to climate impacts [1]. The creeping and thawing of frozen debris, often found as permafrost, is a significant factor for the disposition of periglacial debris flows and related slope instabilities [2]. Not only instabilities of debris slopes but also instabilities of rock slopes can be connected to glacial and permafrost processes [3]. Glacier retreats, for instance, affect the stability of valley flanks, or varying ice content affects the rock hydrology. Such system interactions clearly show the urgent need of integral hazard assessments accounting for a variety of relevant processes in high mountains, also considering that a variety of natural hazards in high mountain regions are affecting human activities. Taking into account the wide-area coverage, remote-sensing techniques represent suitable tools for an integral hazard mapping and monitoring in high mountains, regions that are typically difficult to assess [4].

The focus of this contribution is on the potential and limitations of differential SAR interferometry [5,6] for the detection and monitoring of unstable high-mountain slopes [7-11]. SAR data of the ERS and JERS satellites for the Swiss Alps have been analyzed with short baseline interferometry and point target interferometry [12.13]. Significant results for permafrost creeping are presented. The work presented here is part of the ongoing SLAM (Services for Landslide Monitoring) project supported by the European Space Agency [14].

2 RESULTS

Differential SAR interferometry has the potential to map displacements in the cm to dm range at cm or even sub-cm accuracy [5,6]. However, important limiting factors in mountainous terrain arise from temporal decorrelation and the SAR image geometry, both leading to incomplete spatial coverage [15].

High coherence is regularly observed only during the snow free period between early summer and mid fall in the zone above the tree line where dense vegetation is no longer present. Over forest, 35-day or longer term coherence at C-band is very low because of the importance of the less stable scatterers in the crowns (small twigs, leaves, needles) and of the geometric aspects related to the volume type scattering of the forest with a quite large vertical dimension (forest height) of the target. The scattering behavior of snow changes significantly with snow moisture and also with the presence of density heterogeneities (layering, ice-lenses, etc.). Also large and incoherent displacements of adjacent scatterers may cause decorrelation. Coherence maps may therefore also support the detection of displacements.

The very rugged topography of alpine regions is another important limiting factor of the technique. Apart from layover and shadowing which cause incomplete coverage, there is a privileged slope direction, namely that facing away from the SAR look vector, where the technique is better suited for detection and monitoring of displacements because of the high sensitivity of the interferometric phase to deformation along the terrain surface gradient. The use of both ascending and descending orbits permits to reduce these limitations.

A series of differential interferograms, with the topographic related phase removed by use of an external DEM with posting of 25 m (DHM25 © 2003 swisstopo), for the Grubengletscher region, Switzerland (see Figure 1), illustrates the coherence and viewing geometry issues on a typical alpine area. Phase signals related to the displacements of glaciers in one day [16] are visible in winter ERS Tandem interferograms (Figure 2). For summer ERS Tandem interferograms (Figure 3) coherence is loss over glaciated area and also forests are generally more decorrelated than in winter. For larger time intervals (35 to 1 year) ERS SAR interferograms acquired during the snow-free period are able to highlight displacements of rockglaciers [17] and other instabilities on high alpine areas (see Figures 4 , 5 and 7). Long-time

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winter ERS SAR interferograms (Figure 6) are completely decorrelated because of the presence of snow. Summer JERS interferograms with acquisition time intervals of 88 and 1144 days (see Figures 8 and 9, respectively) are also useful for the identification of displacements in alpine areas [18].

3 OUTLOOK

Future work on the short baseline interferograms over the alpine permafrost regions will concentrate on the geomorphological interpretation of the phase signals. The objective is to derive an inventory map of displacements on regional scale. Similarly to rockglaciers, also signals related to rockslides after glacier retreat (identified on a number of interferometric pairs but not presented here) will be interpreted from a geomorphological point of view. Analysis of point target interferograms [12,13] on built-up areas, where coherence is preserved over long time, was performed for some areas in Switzerland. Preliminary results are very promising for the identification of slow displacements in built-up areas. Analysis and interpretation of these results will continue.

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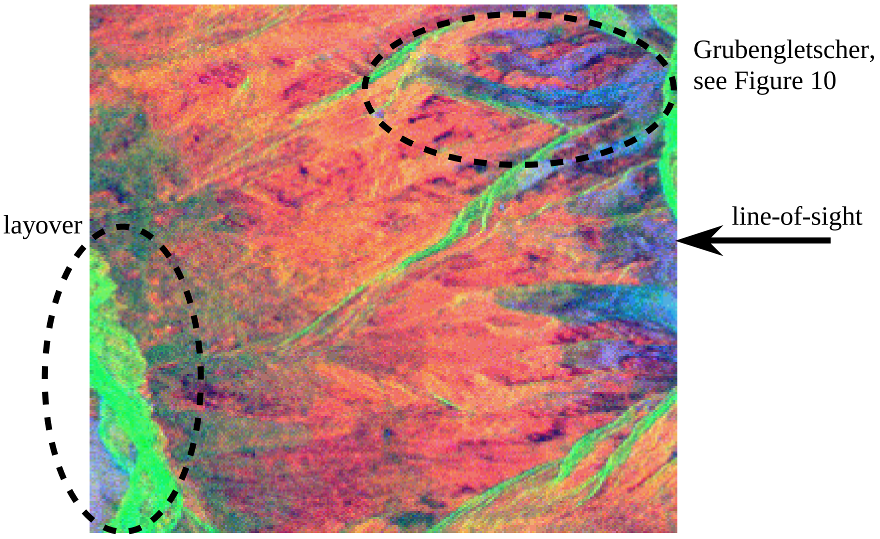

Figure 1. Grubengletscher: color composite of ERS Tandem coherence (red), backscattering coefficient (green) and temporal variability of backscattering coefficient (blue), where blue is generally water and glaciers, bright green generally layover, green generally forest, and red-orange generally alpine meadows and rocks (ERS SAR data courtesy AO3-178, © ESA, processing GAMMA).

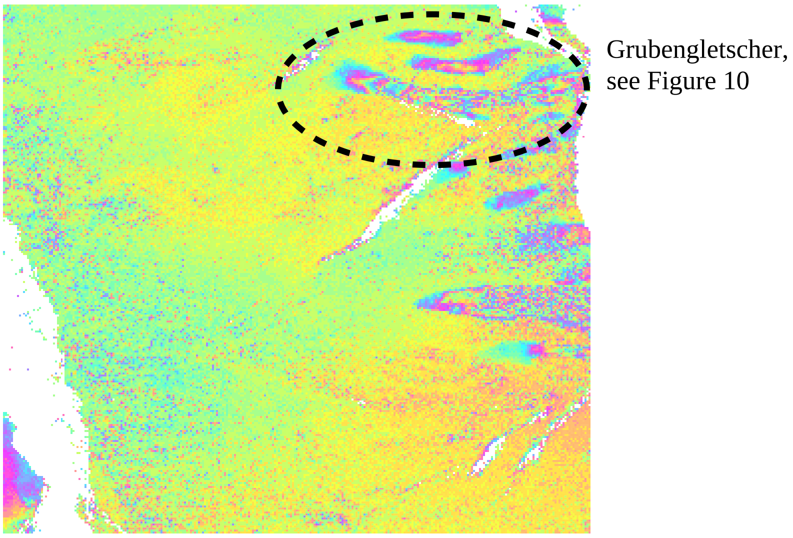

Figure 2. ERS SAR Tandem interferogram of 7 and 8 March 1996, with 1 day acquisition time interval and 34 m perpendicular baseline (ERS SAR data courtesy AO3-178, © ESA, processing GAMMA).

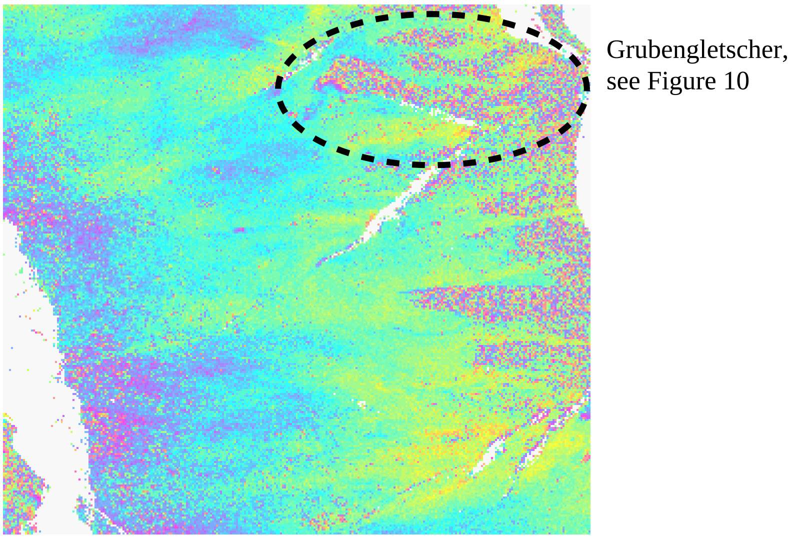

Figure 3. ERS SAR Tandem interferogram of 10 and 11 August 1995, with 1 day acquisition time interval and -54 m perpendicular baseline (ERS SAR data courtesy AO3-178, © ESA, processing GAMMA).

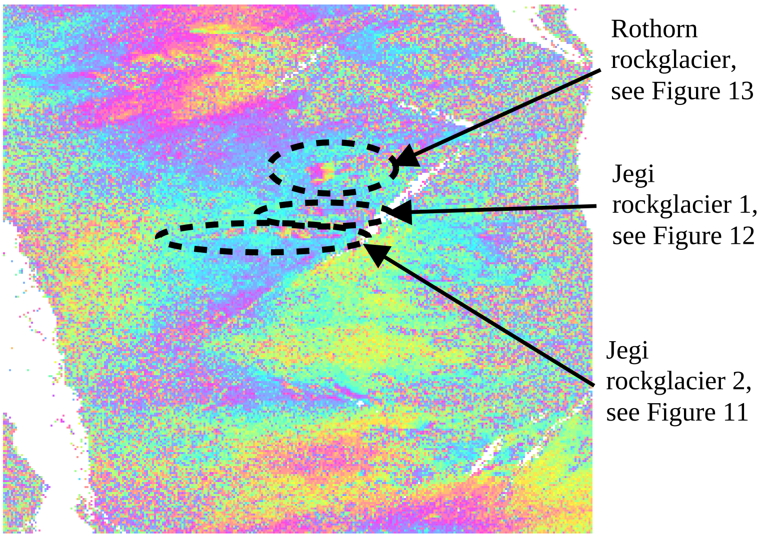

Figure 4. ERS SAR interferogram of 31 July and 9 August 1998, with 35 days acquisition time interval and 106 m perpendicular baseline (ERS SAR data courtesy AO3-178, © ESA, processing GAMMA).

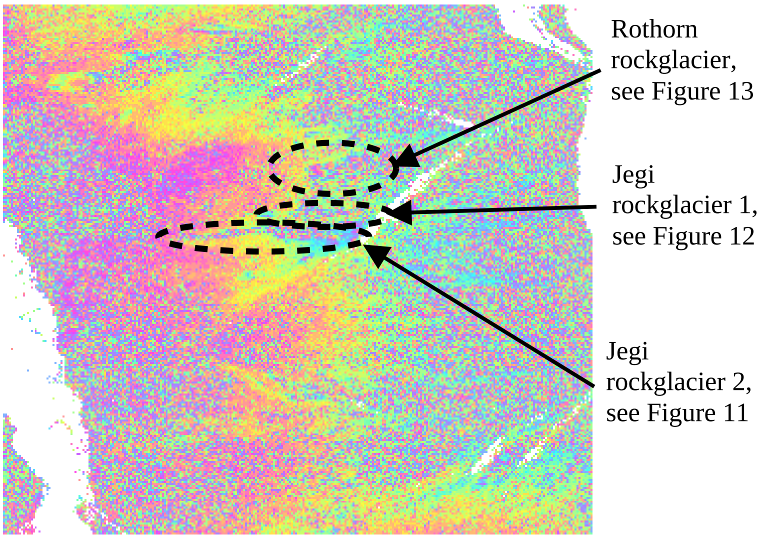

Figure 5. ERS SAR interferogram of 16 July and 29 October 1999, with 105 days acquisition time interval and 5 m perpendicular baseline (ERS SAR data courtesy AO3-178, © ESA, processing GAMMA).

Figure 6. ERS SAR interferogram of 28 December 1995 and 7 March 1996, with 70 days acquisition time interval and 26 m perpendicular baseline (ERS SAR data courtesy AO3-178, © ESA, processing GAMMA).

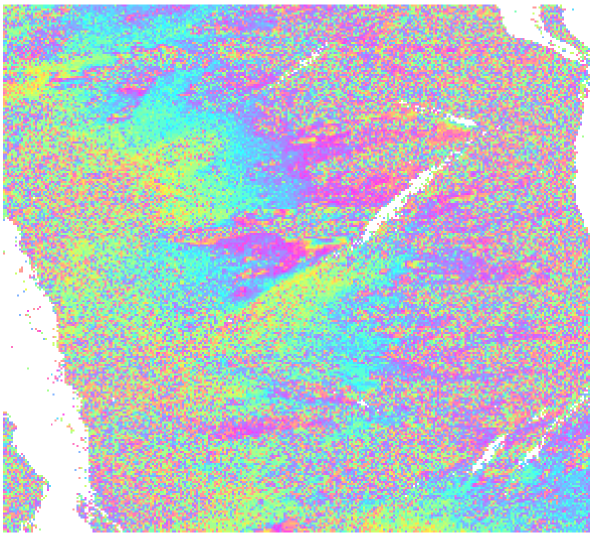

Figure 7. ERS SAR interferogram of 10 August 1995 and 26 July 1996, with 351 days acquisition time interval and 69 m perpendicular baseline (ERS SAR data courtesy AO3-178, © ESA, processing GAMMA).

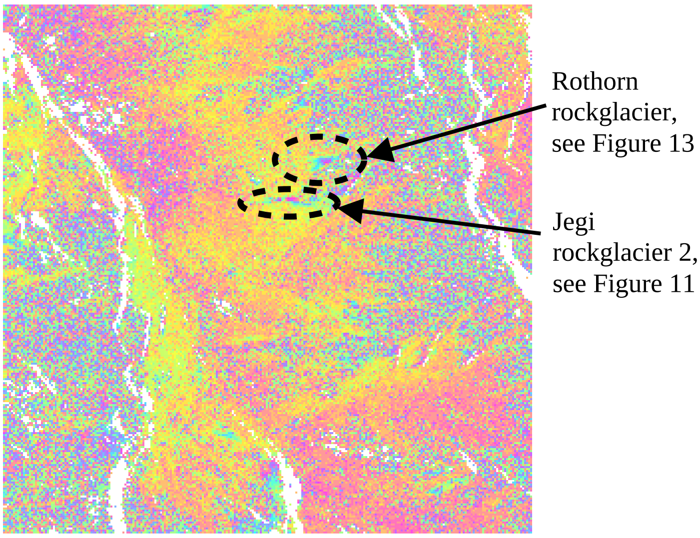

Figure 8. JERS SAR interferogram of 21 June and 17 September 1996, with 88 days acquisition time interval and -65 m perpendicular baseline (JERS SAR data courtesy J-2RI-001, © NASDA, processing GAMMA).

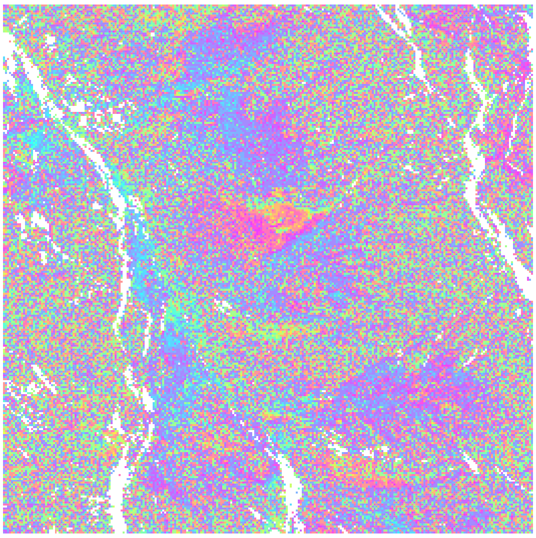

Figure 9. JERS SAR interferogram of 17 June 1993 and 4 August 1996, with 1144 days acquisition time interval and 45 m perpendicular baseline (JERS SAR data courtesy J-2RI-001, © NASDA, processing GAMMA).

Figure 10. Grubengletscher.

Figure 11. Jegi rockglacier 2.

Figure 12. Jegi rockglacier 1.

Figure 13. Front of the Rothorn rockglacier.