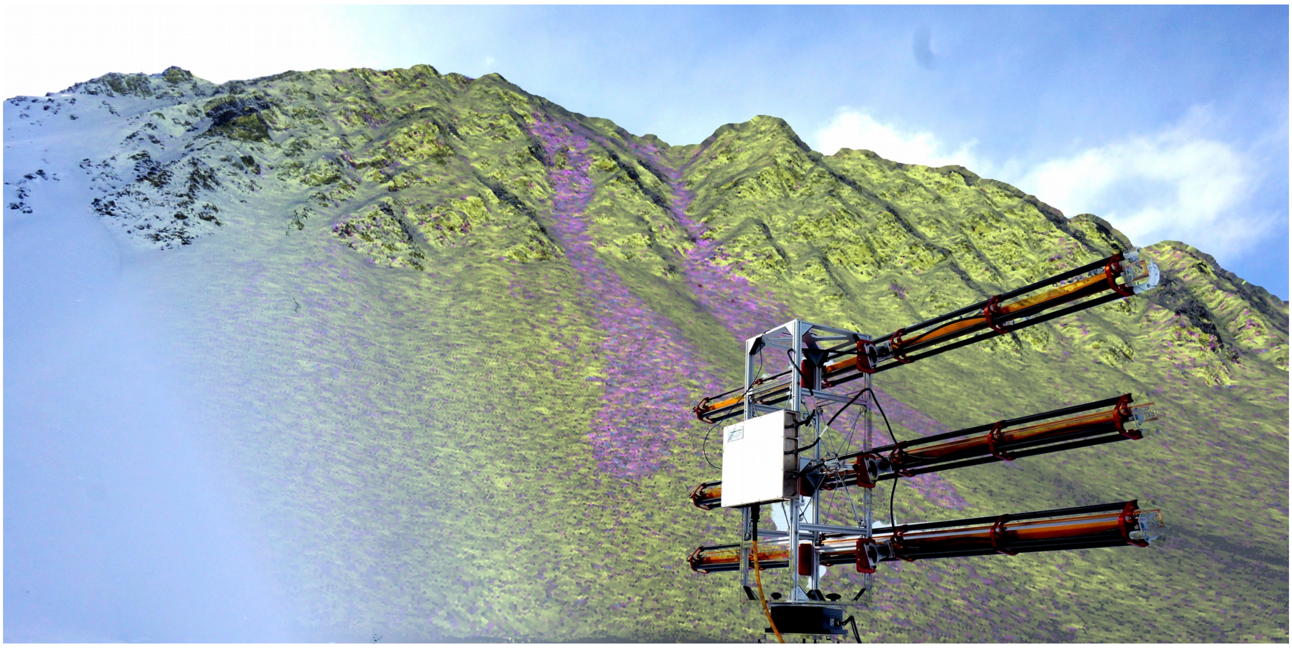
GAMMA REMOTE SENSING

GPRI Measurement Experiments during artificial Snow Avalanche Release – Decorrelation Signatures and Avalanche Velocity Profiling

Short Report on Flüelapass Campaigns of 23. January 2013 and 31. January 2014



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Introduction

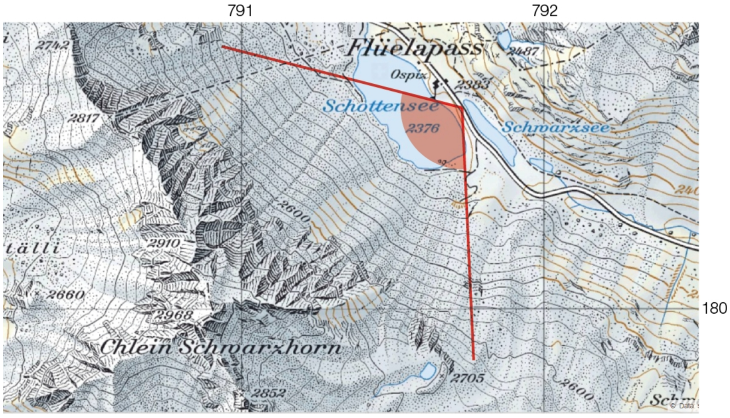
In this report, results of the observation using the Gamma Portable Radar Interferometer (GPRI) of controlled avalanche releases are shown. Two avalanche experiments took place on 23rd of January 2013 and 31st of January 2014. The campaign was led by the WSL Institute for Snow and Avalanche Research SLF.

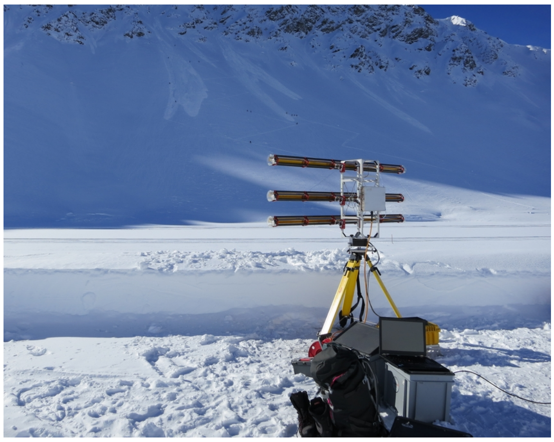
This report describes the instrument setup and campaign mode. The focus is on the main results gained during the two campaign. The campaign goals were to:

- Map the post-avalanche extent in the spatial domain.
- Measure the avalanche velocities with fixed observation angles of the radar but with high temporal sampling frequency.

Mapping of avalanche extent was possible using the interferometric decorrelation in both campaigns. Velocity estimation of an avalanche release could be performed for the first time in 2014.

Instrument Setup





PK 25 – www.map.admin.ch (c) swisstopo

	2013-01-23	***2014-01-31***
Setup Coordinates (CH1903)	791702 / 180689 / 2388	791723 / 180658 / 2385
First Acquisition [UTC]	07:48:34	11:16:02
Last Acquisition [UTC]	12:45:03	13:00:01
Number of Scans	67	87
ATI-Mode Acquisitions	No (Disk I/O Failure)	Yes (3 Profiles)
Weather Data (IMIS-Flüelapass)		
Air Temperature [°C]	-10.1 to -9.1	-3.1 to -2.6
Snow Surface Temperature [°C]	-16.4 to -13	-3.8 to -3.0
Max. Wind Gust [km/h]	34	62
Instrument Data		
Instrument	Gamma Portable Radar Interferometer (GPRI)	Gamma Portable Radar Interferometer (GPRI)
Serial	GPRI-II-1	GPRI-II-1
Center Frequency [GHz]	17.2	17.2
Chirp Bandwidth [MHz]	200	200
Chirp Duration [ms]	2	2
ATI-Mode Sampling Frequency [Hz]	-	500 (2ms chirp)
Operators	Tazio Strozzi, Jessica Papke	Rafael Caduff, Tazio Strozzi

Figure 1 Instrument setup map location and photo of the situation on January 23rd 2013 on top. Table with parameter description of the two individual campaigns below.

Results

Selected results of the acquisitions are shown in this section. Coherence maps of scan-acquisitions are displayed onto calibrated terrestrial images of the corresponding dates (Figure 2 and Figure 3). Results from the continuous sampling mode at a fixed angle are shown in range-time domain (Figure 4). Finally, Table 1 shows the measured line-of-sight (LOS) velocities of selected avalanche onsets together with the estimated maximum velocity in the 3d-direction of travel of the avalanche. For calculations of the latter, the direction of travel of the avalanches was determined using the absolute location center flow line of the avalanche determined in the corresponding decorrelation map (Figure 4e).

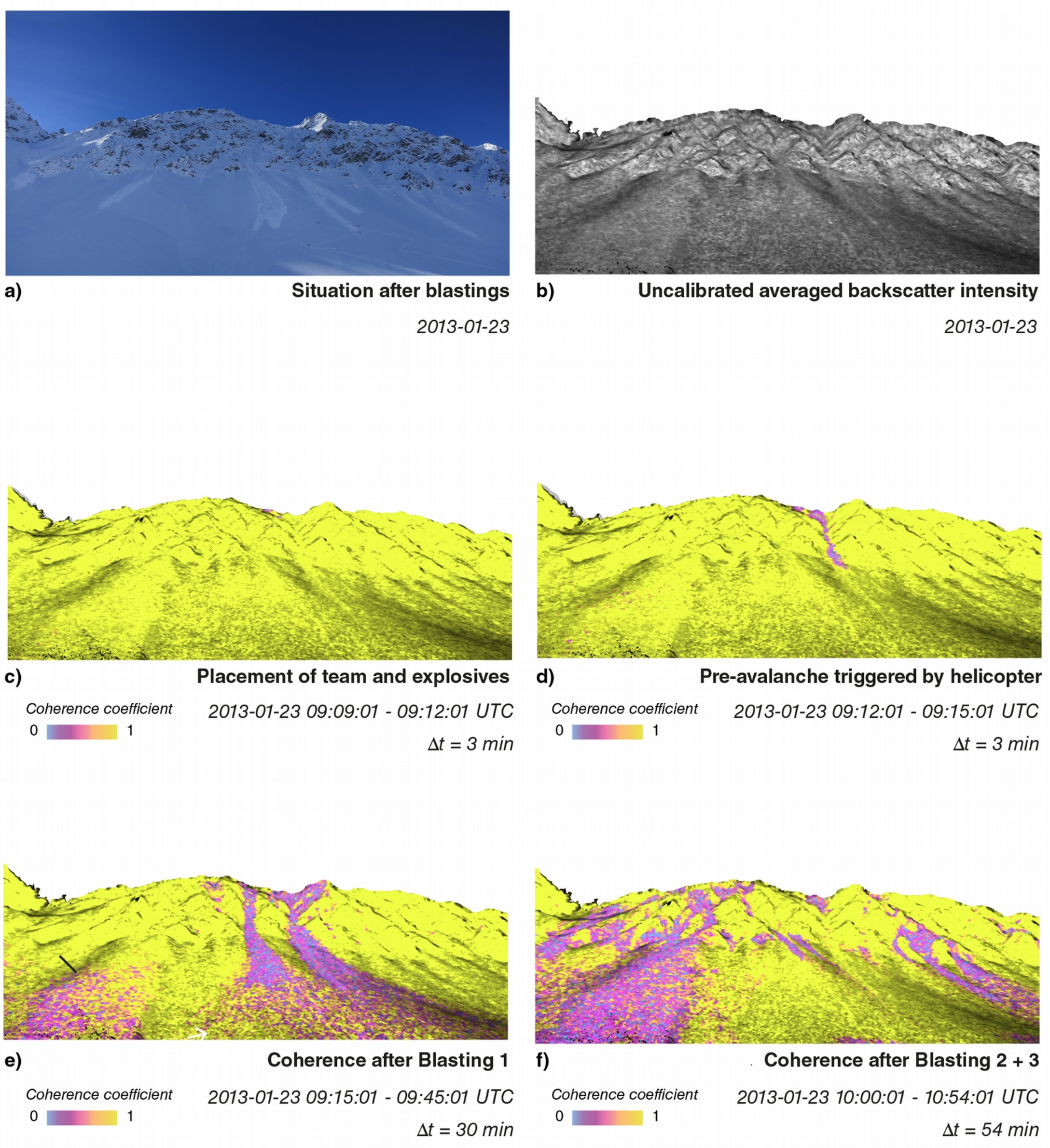


Figure 2 Situation and coherence maps of the 2013 campaign.

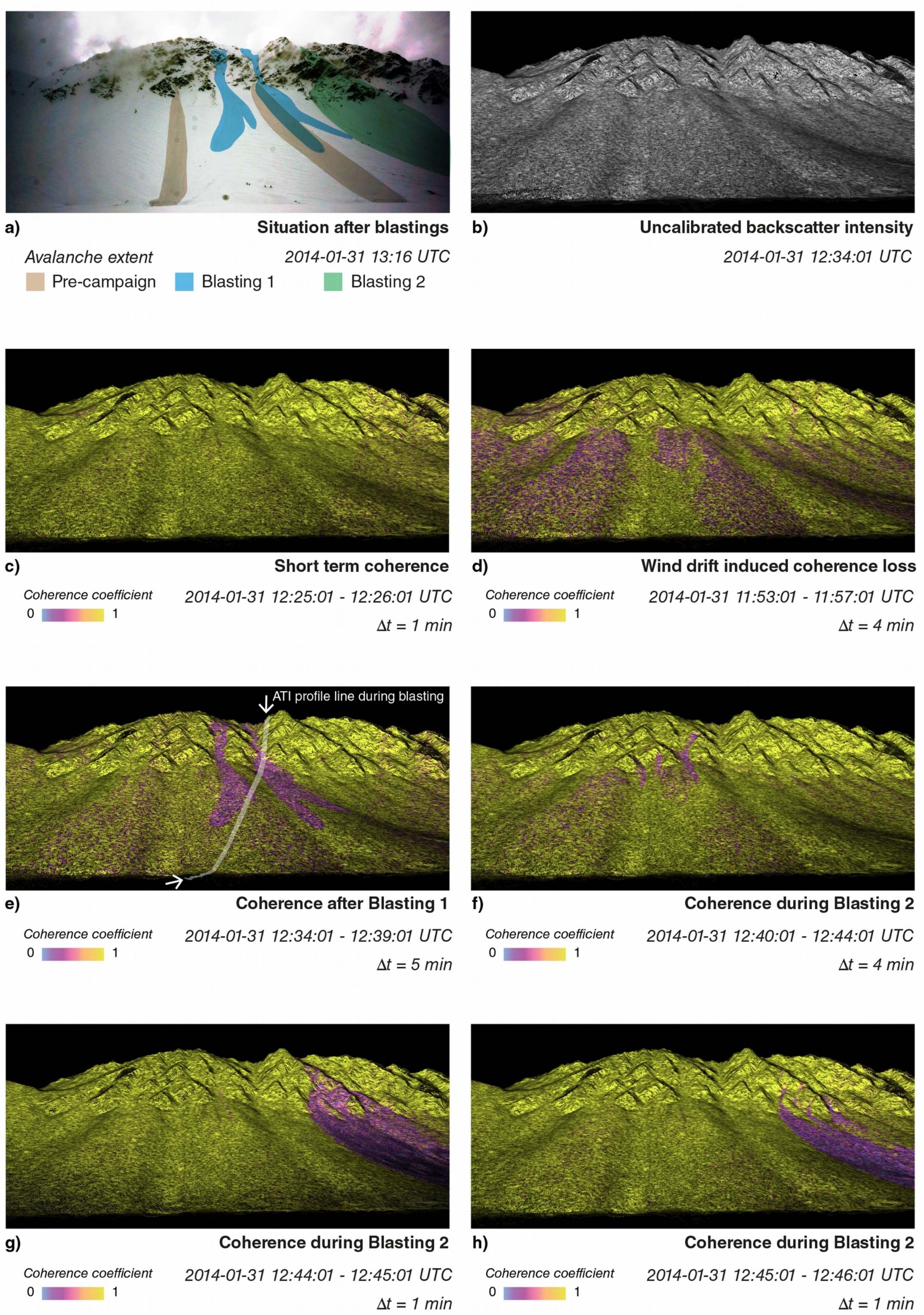


Figure 3 Situation and coherence maps of the 2014 campaign.

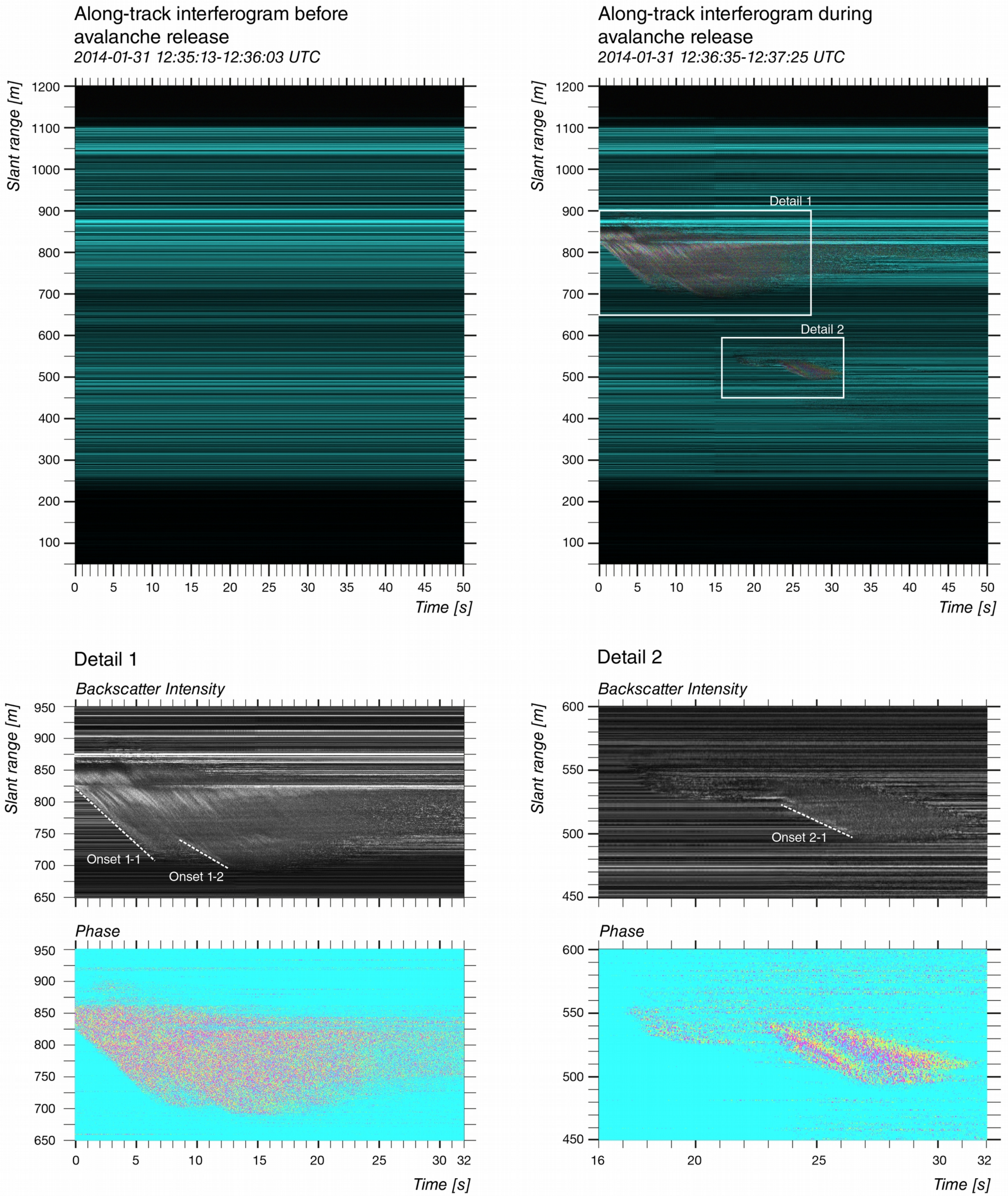


Figure 4 Results of the continuous sampling mode at 500 Hz sampling rate at a fixed angle (Profile line indicated in Figure 3e). Top left: Situation before avalanche release shows no decorrelation or phase shifts. The top right graph shows the avalache impact in intensity and phase. The blasting and the initial phase were missed in the acquisition. Details on the transitional phase and the onsets of the frontal part of the avalanche are shown in Details 1 and 2. Estimations of frontal velocities on the three different onsets are shown in Table 1. Interferometric phase information is calculated with along-track interferometry.

	Onset 1-1	*Onset 1-2*	*Onset 2-1*
vLOS [m/s]	17.06	11.6	8.7
vLOS [km/h]	61.4	41.8	31.4
*Direction of travel: Avalanche (**n**)*	$\begin{pmatrix} -0.507 \\ -0.642 \\ 0.575 \end{pmatrix}$		$\begin{pmatrix} 0.548 \\ 0.672 \\ -0.498 \end{pmatrix}$
*LOS direction **(n)***	$\begin{pmatrix} 0.877 \\ 0.390 \\ 0.280 \end{pmatrix}$		$\begin{pmatrix} -0.861 \\ -0.450 \\ 0.239 \end{pmatrix}$
LOS-fraction [%]	86		89
v3D (est) [m/s]	**19.84**	**13.49**	**9.78**
v3D (est.) [km/h]	**71.4**	**48.6**	**35.28**

Table 1: Velocity calculations from continuous sampling mode on the avalanche onsets marked in Figure 4. The normalized vectors of the avalanche travel directions were estimated using the coherence maps of the corresponding scenes, overlaid on the 2 m-resolution dem of the area (obtained from SLF).

Discussion

The presented results show that the mapping of avalanche releases using the decorrelation signature of an interferometric pair as seen in Figures 2 and 3 is straightforward. The results from 2013 show that the avalanche extent tends to be over-estimated in the frontal part of the avalanche lobe. This is caused by the disturbed snowpack due to avalanche caused snow-spreading.

In the 2014 campaing weather conditions were more difficult. Heavy wind gust of more than 62 km/h were observed. On the one hand, this triggers wind induced snow-drift that reduces the coherence as shown in the Figure 3e. However, the effect is very small for short observation intervals of 1 minute (Figure 3c). In Figure 3e, it is also visible, that the wind-induced decorrelation is smaller in areas of previously triggered avalanche lobes as indicated in Figure 3a due to surface snow compaction. Those areas show a higher backscattering coefficient.

Another effect of wind-gust induced decorrelation is shown in Figure 3c. The right quarter of the image shows slightly higher decorrelation. Here, a wind-gust caused a decelleration of the antenna rotation which lead to image line jumps in azimuth direction. If those disturbances are not corrected prior to interferometric processing, this leads to sometimes massive decorrelation. Wind sheltering of the instrument would prevent such effects.

For the first time, continuous sampling of an avalanche release along a fixed profile could be acquired (Figure 4). The avalanche triggered by the blasting of explosives as well as the initial part was missed. Nevertheless the measured signature captures the main avalanche release (Detail 1) as well as a secondary lobe (Detail 2). The frontal velocities were calculated using the way-time signature of the onsets. The range resolution of the GPRI is 0.75cm per pixel and the temporal sampling is 500Hz. LOS-velocities were corrected using estimated vectors of travel of the sampled lobes. Results will need to be further investigated and cross-validated.

Line-to-line decorrelation is induced to the fast velocities regarding the sampling frequency (500 Hz) and the used microwave frequency (17.2 Ghz / 1.74 cm wavelength). For a LOS velocity of 17.06 m/s as measured for Onset 1-1, a shift of 3.4 cm per sample results, which is double the radar-wavelength. To obtain high coherence, shifts should not exceed 1/2 radar-wavelenght (two-way-travel).

Coherence remains (at least partly) high in the signature of Onset 2-1. Here the measured velocity matches exactly the radar-wavelength. This is shown in the interferometric „fringes“ in the along track interferogram in Detail 2.

However, information on the internal structure can be gathered as well by interpretation of only the backscatter intensity. As visible in Detail 1 of Figure 4, an internal structure is clearly visible that matches the slope of onset 1-1. The cause for this pulsed and consistent alteration of the backscatter intensity cannot be determined yet.

Conclusively, it can be said that terrestrial radar-interferometry is an all-weather (if protective measures are taken) method for mapping avalanche signatures using the interferometric decorrelation. Additionally, it could be shown, that continuous sampling at high frequency led to avalanche velocity measuring. However, improvements on trigger timing and especially in the sampling frequency may lead to enhancement of the observations by keeping the along-track coherence high. As a result, the phase information can be used as measure of velocity as well.