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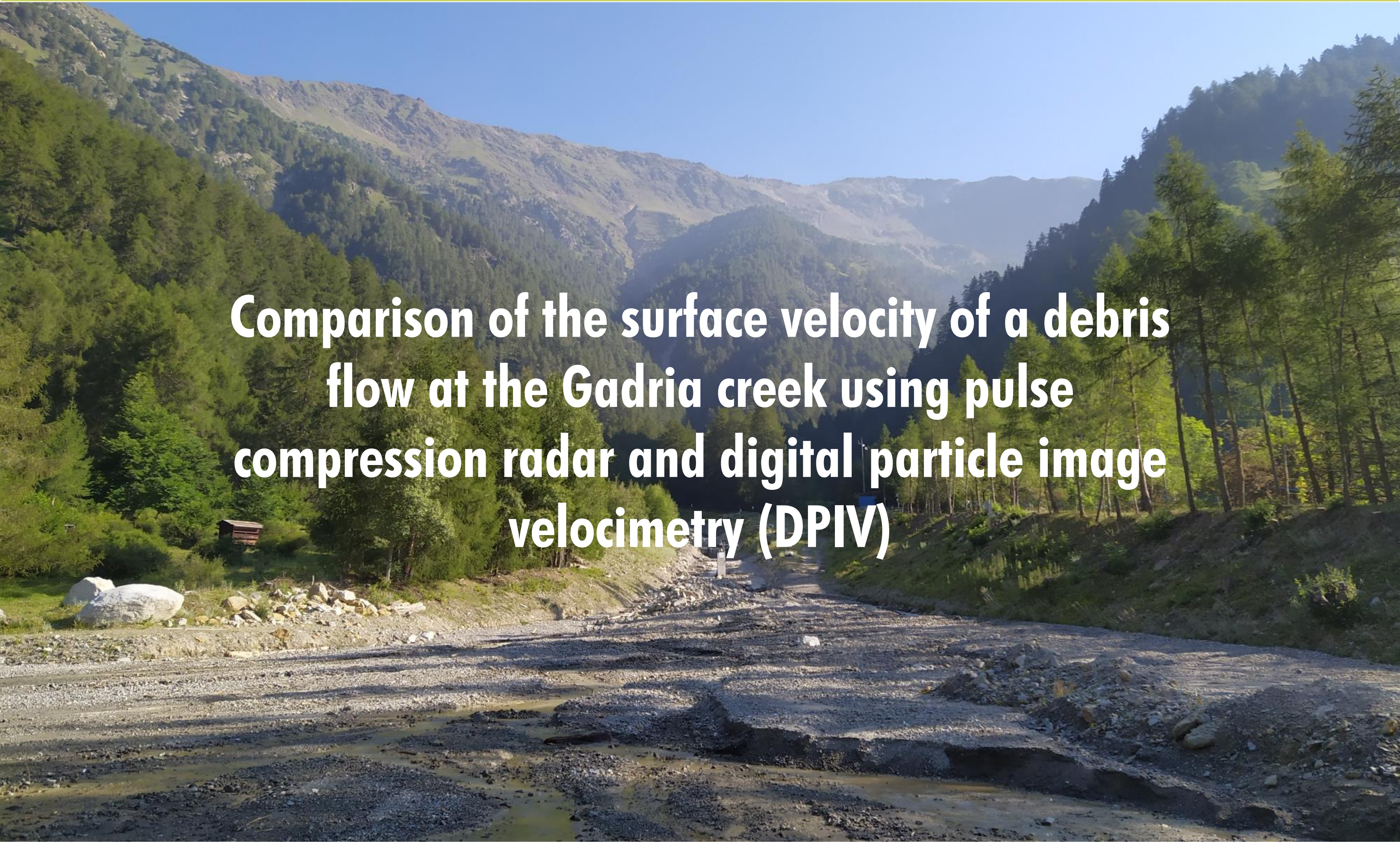
Comparison of the surface velocity of a debris flow at the Gadria creek using pulse compression radar and digital particle image velocimetry (DPIV)



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Abstract

A central aspect of protection against debris flows is the understanding of the process. The flow velocity is an important parameter which is used, for example, in the dimensioning of protective structures, for technical building protection and for early warning systems. The measurement of the surface velocity which is regarded as the maximum velocity occurring within a debris flow, is therefore an essential link in the chain of fundamental process research and applied protection against natural hazards.

Due to the further development of various technologies such as video technology and high-frequency radar technology, the non-contact measurement of the surface speed of a debris flow has improved significantly in recent years. Radar technology provides a wide aspect of applications in alpine mass movements such as debris flows, avalanches and rockfall and is able to detect such processes up to a range of 2500 meters in distance. An additional beneficial feature is the possibility of non-contact measurement of the surface velocity. In the catchment area of the Gadria basin (South Tyrol, Italy), the measuring station, which has been in operation since 2016, has been extended by a pulse compression radar and a new HD video camera. On July 26, 2019 a debris flow consisting of several surges was recorded with both the radar and the HD video camera. To obtain surface velocity data from the video material, the material was analyzed and evaluated using digital particle image velocimetry by making use of the MATLAB software and its freely accessible Add-On *PIVlab*.

The results of the compared surface velocity data showed a value of up to 0.74 according to the statistical mean of the coefficient of determination. The results demonstrate the high effectiveness of the pulse compression radar and the DPIV analysis in a wide range of the assessment of surface velocity of natural debris flows. There is great potential in both measuring systems and the chosen comparative analysis provides a blueprint for future recorded debris flows.

Pulse Compression Radar

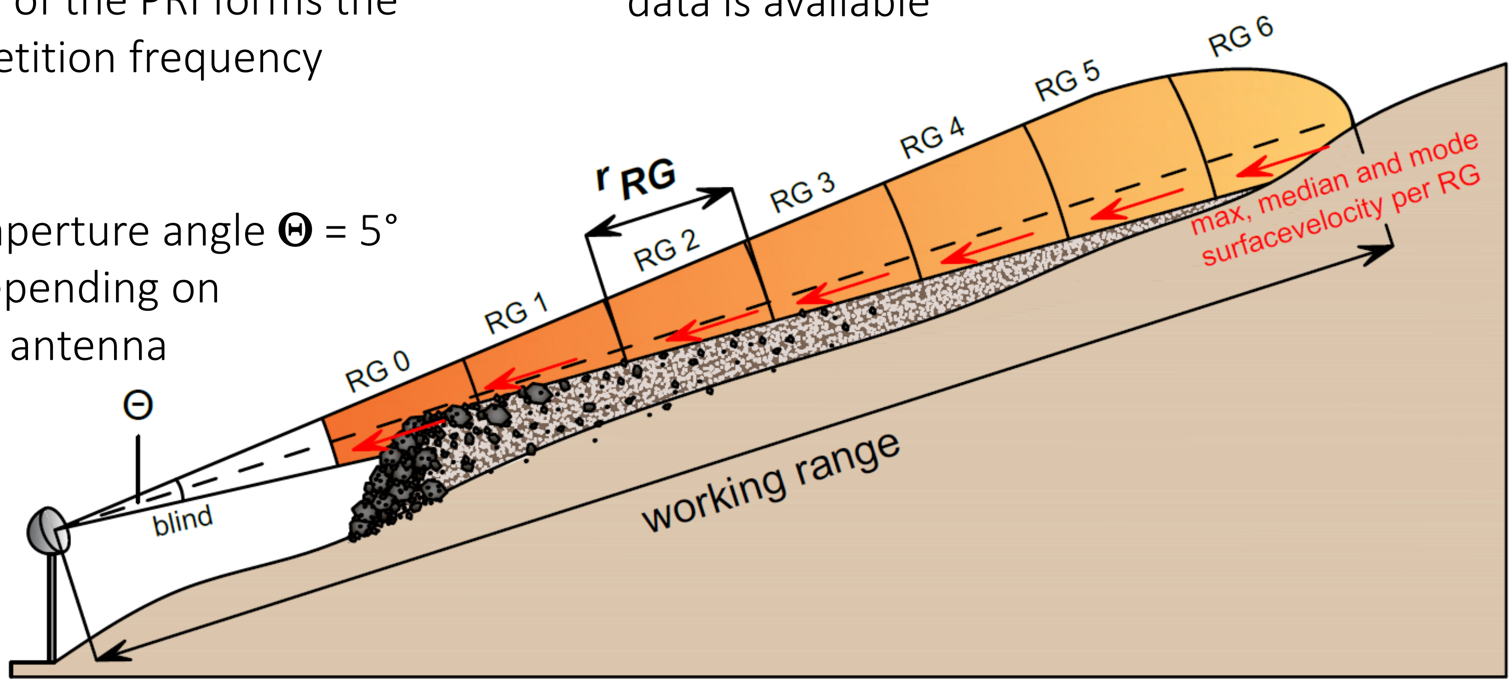
- range gate width $\boldsymbol{r_{RG}} = c\tau$ [m]
  $\boldsymbol{c}$ … speed of light [m/s]
  $\boldsymbol{\tau}$ … pulse duration [s]

- pulses are sent within a pulse repetition interval (**PRI**) [s], the reciprocal of the PRI forms the pulse repetition frequency (**PRF**) [hz]

- antenna aperture angle **Θ** = 5° or 10°; depending on operating antenna

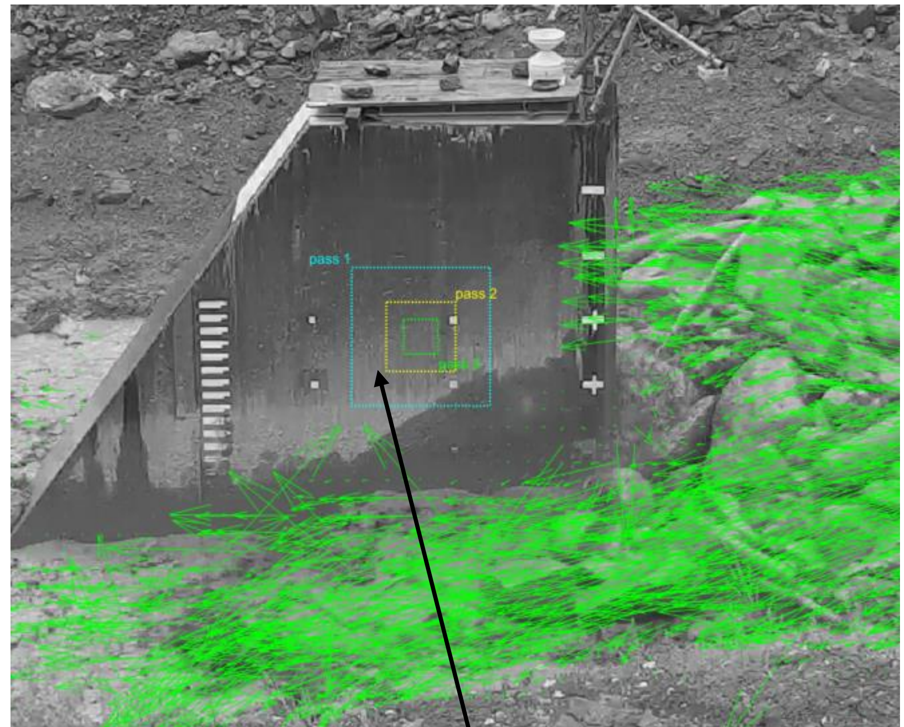
- Transmission procedures can be: **single pulse** or **pulse modulated**

- for each RG **max**, **median** and **mode** surface velocity data is available



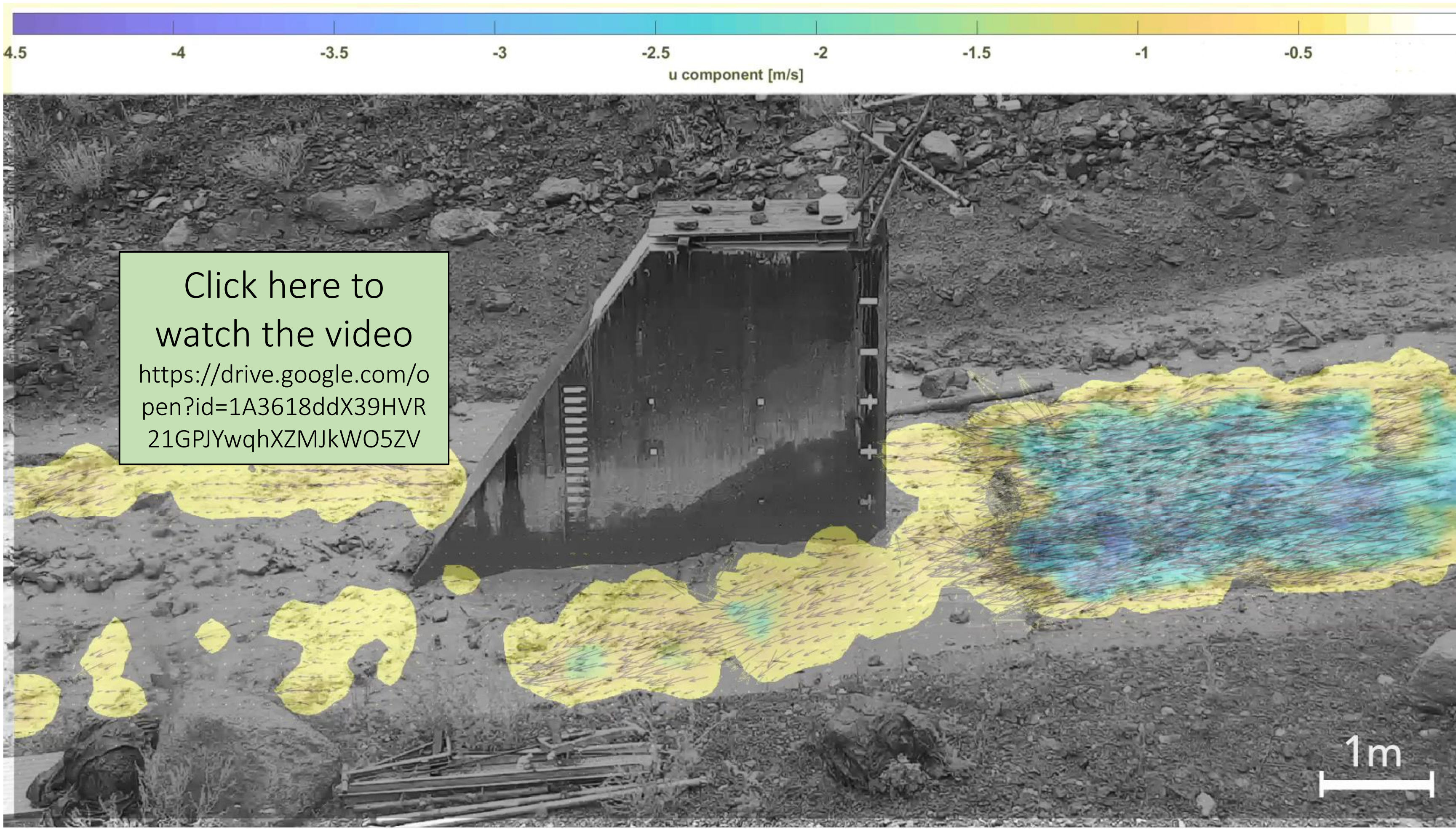
Digital Particle Image Velocimetry (DPIV)

- The surfacevelocity is calculated by tracer particles which are tracked within **interrogation areas**
- Therefore the videomaterial has to be dismantled to single frames (pictures)
- **Crosscorrelation** is used to find the particle pattern from the interrogation area of picture A in the interrogation area of picture B
- For **orthogonal rectification**, an open source software was used (RIVeR)
- Multiple analyzes were carried out

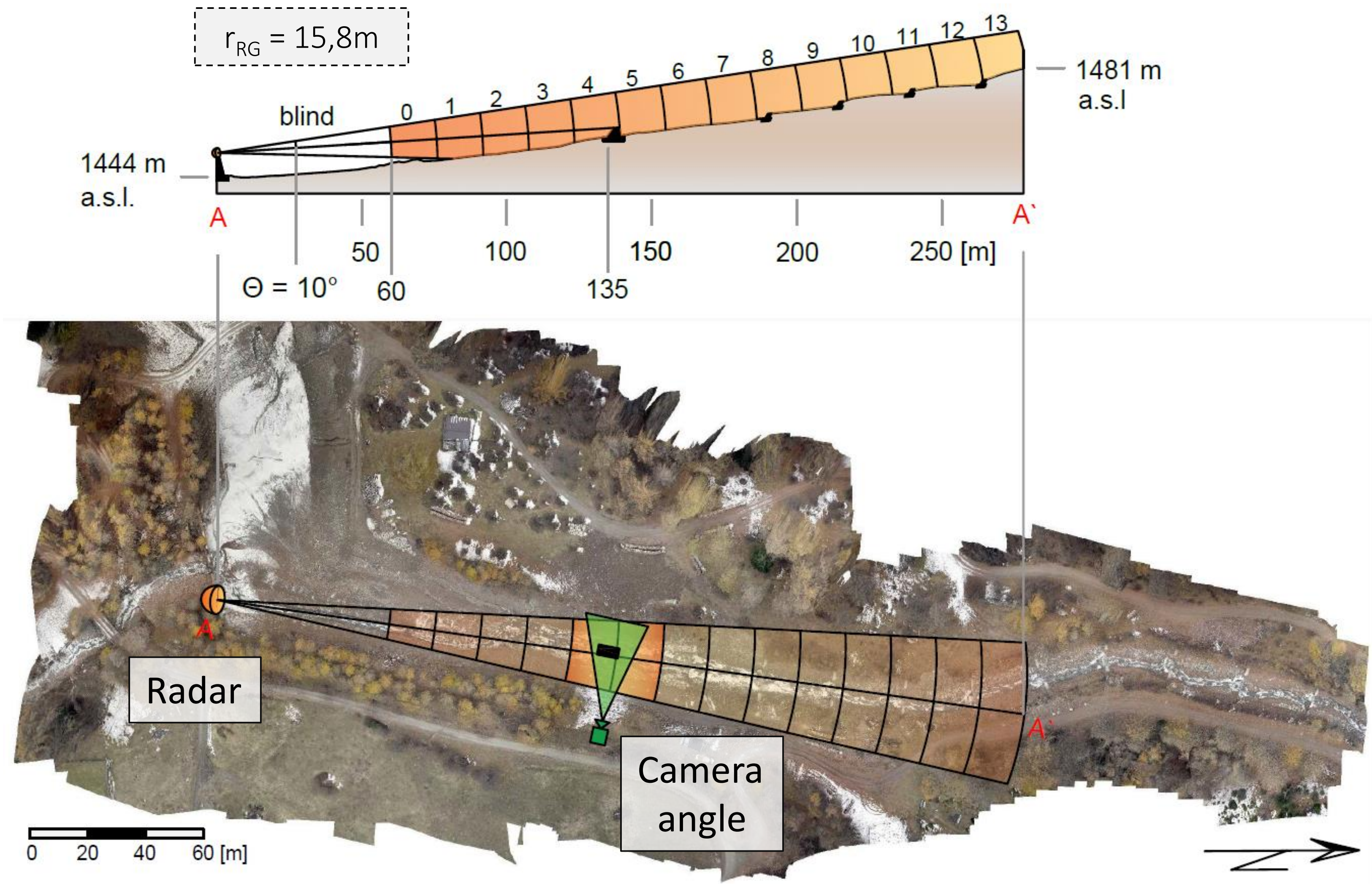


Interrogation areas

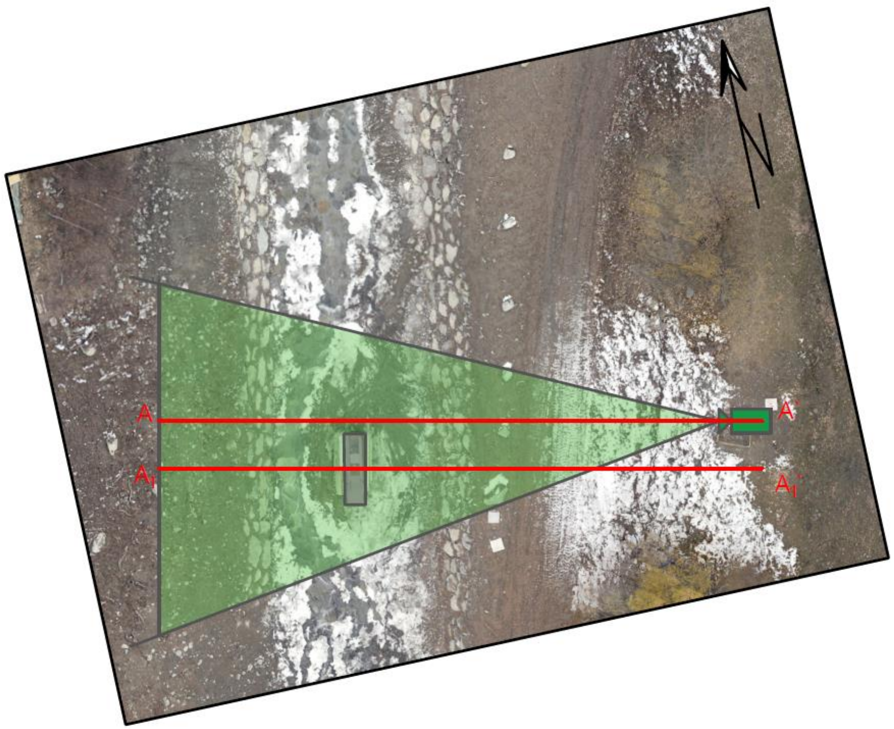
DPIV example of the analyzed debris flow front

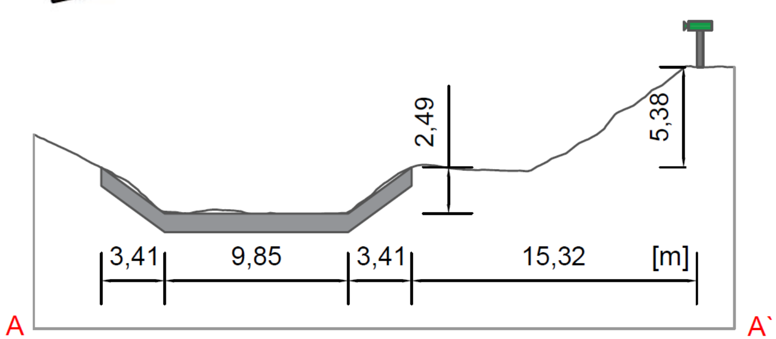


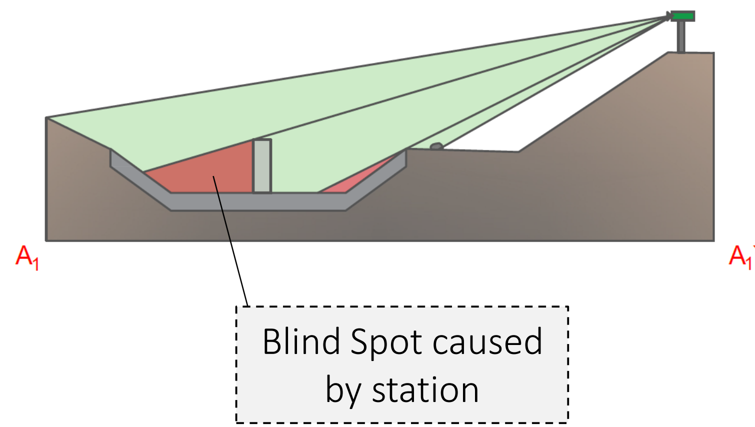
Testside overview

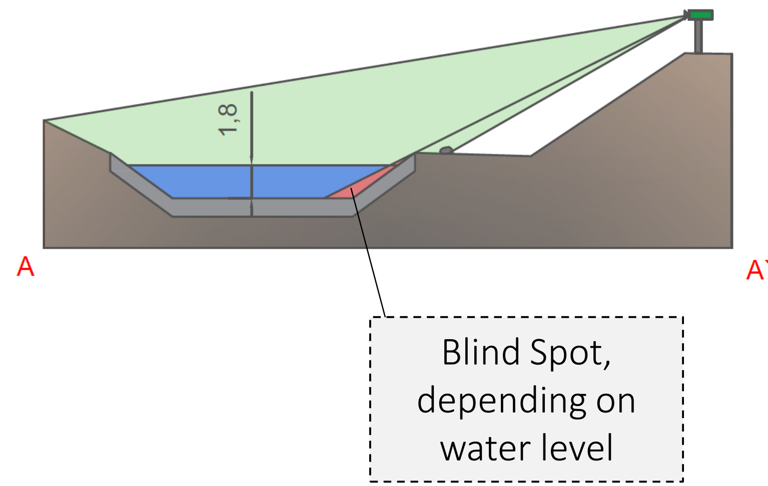


Camera perspective







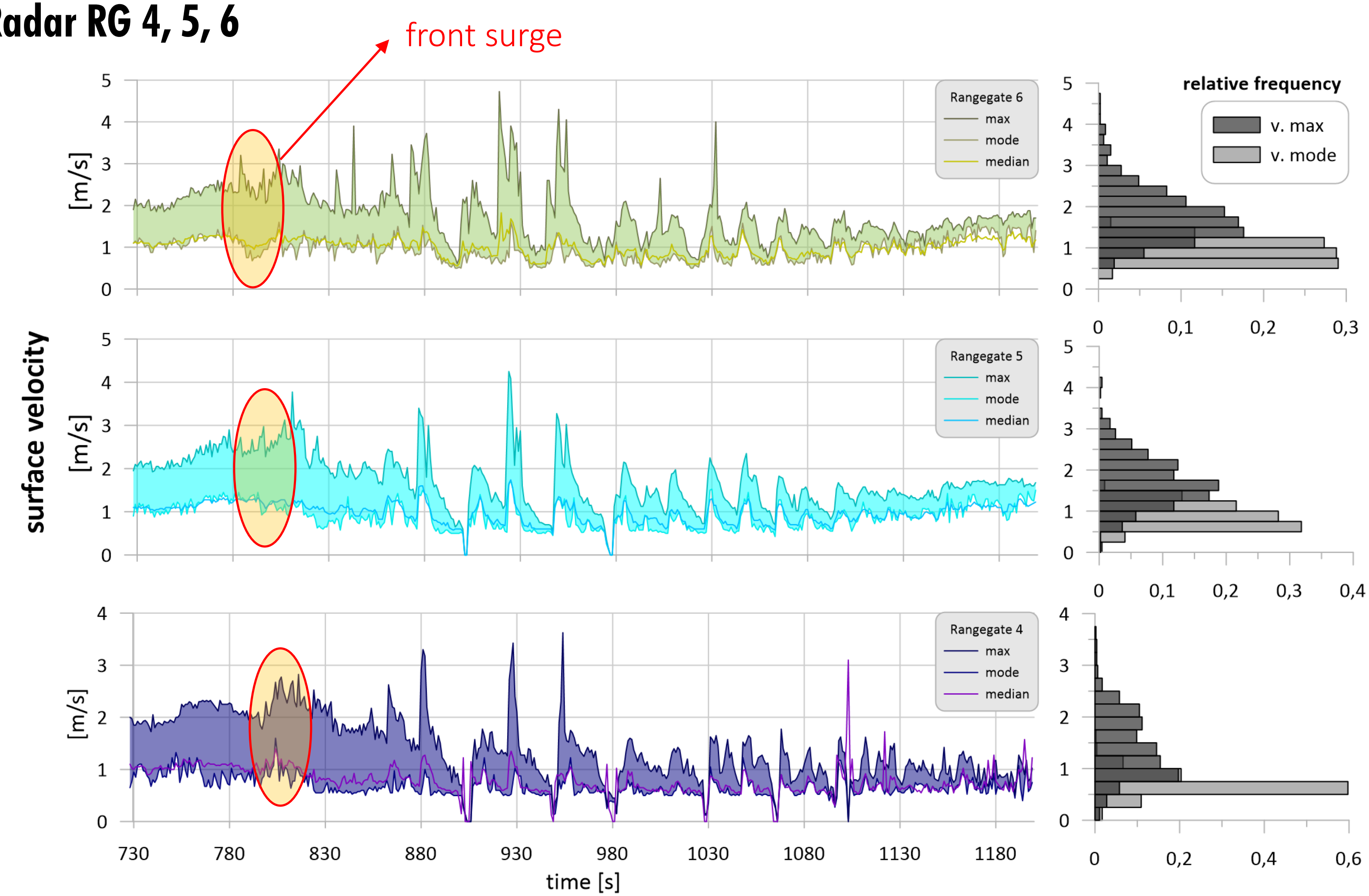


Results

- After binning the data to one value per second, visualization in form of **velocity-time graphs** was carried out
- A first comparison between the radar and PIV data showed, that RG 4 had to be shifted +1 and RG 5 +5 seconds in order to overlap with the curves gained from water level and DPIV data
- As can be seen the following statistical methods were used to analyze and compare the data:
  - standard deviation σ
  - relative frequency
  - coefficient of determination R^2

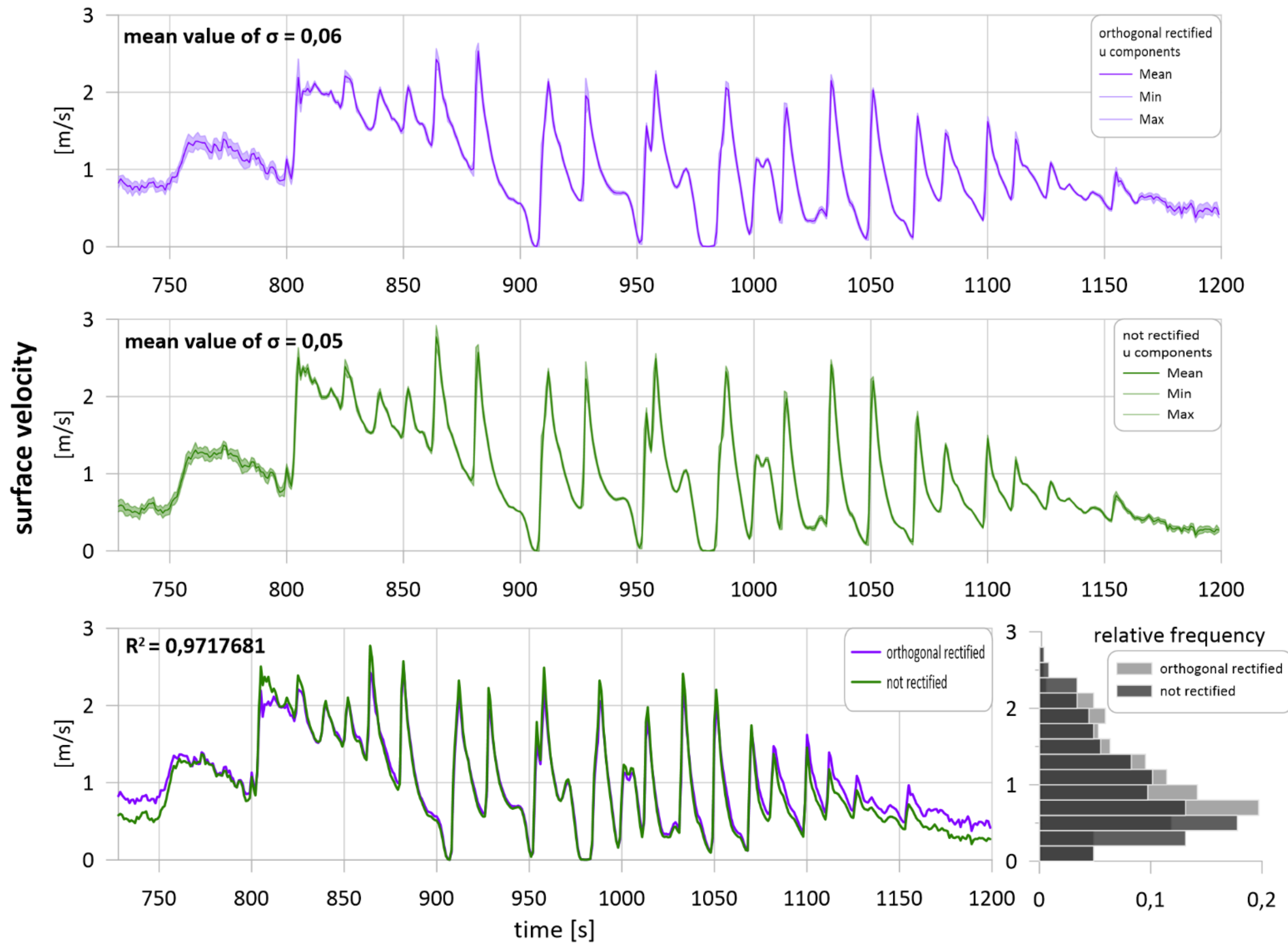
Results

Radar RG 4, 5, 6



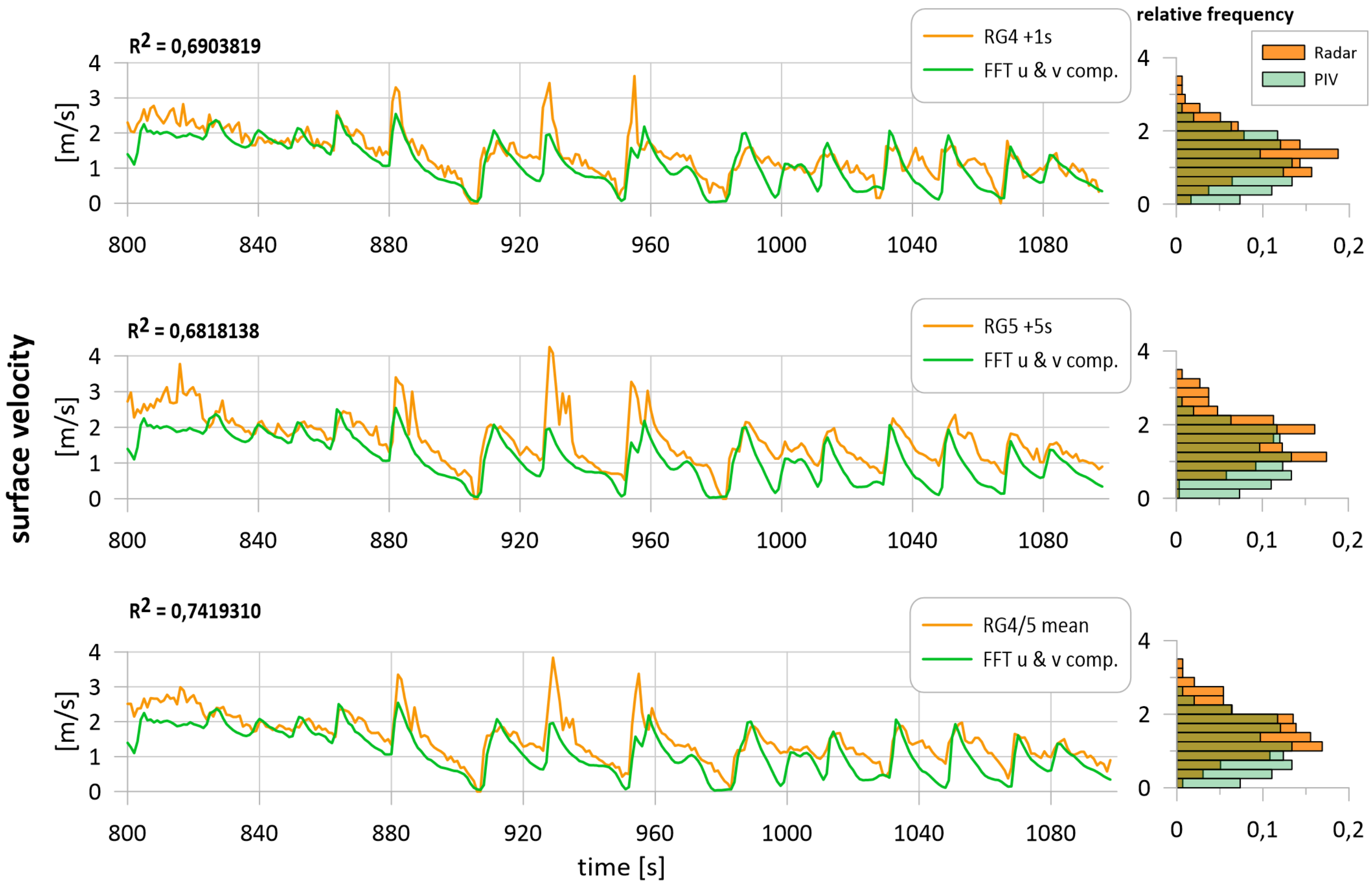
Results

DPIV comparison between rectified and original images



Results

Comparison between PIV and radar data



Discussion

- For future measurements, **validation** for both systems in various forms is possible:
  - The accuracy of the radar data can be improved by changing the transmission form from modulated (compressed) to **single pulse**
  - To avoid **blind spots** on the video, the camera could be installed hovering over the stream bed
  - To improve the **rectification process**, measured out markers along the monitored view of the camera should be installed

- For **discharge** calculations and comparison, further analysis of the velocity spectrum is necessary