Investigation of bistatic scattering properties of snow using Ku-band radar

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1. Project description

The goal of the project is to investigate the potential of Ku-band bistatic radar for monitoring and parameter estimation of snow cover, as well as an investigation of the dynamics of the Great Aletsch Glacier using monostatic and bistatic radar interferometry.

The experiments at HFSJG are carried out with the Ku-band Advanced Polarimetric Radar Interferometer (KAPRI), a ground-based portable radar instrument based on the GAMMA GPRI-II. The KAPRI instrument allows deployment of following radar imaging techniques: 1) Polarimetry: By observing the difference between scattering of horizontally and vertically polarized radio waves, information about the scattering processes occurring within the observed scene can be inferred. 2) Interferometry: By analyzing the phase of the scattered radio waves, small movements on the order of millimeters (e.g., glacier motion) can be detected. 3) Bistatic radar: By deploying an additional receiver in a location different from the transmitter's location, we can analyze the scattering of radio waves under a non-zero bistatic angle (i.e., the separation angle between the transmitter and the receiver from the point of view of the target).

2. Measurements of coherent backscatter enhancement in snow

In 2023, the focus of our activities at HFSJG was development of a novel experimental method of measurement of the coherent backscatter opposition effect (CBOE) occurring in snow cover on top of the glacier. The CBOE causes a sharp change of backscatter intensity of radio waves when the distance between the transmitter and receiver is varied. The exact manner in which the backscatter intensity changes depends on the structure of the scattering medium (i.e. the structure of the snow cover), which is why the CBOE is of interest due to its potential applications for property estimation of snow cover using spaceborne bistatic radar systems. In order to observe the effect, radar measurements with a very specific geometric configuration must be carried out. Specifically, it requires measurements of radar backscatter intensity where the separation angle between the transmitter and the receiver from the point of view of the target (also known as the bistatic angle) is varied between 0 degrees and approximately 1.5 degrees. To achieve these configurations in a repeatable, stable, and automated manner, a novel rail-based experimental setup was developed. This setup is shown in Figure 1, and allows automated variation of the spatial separation of the transmitting and receiving antennas.

Figure 1. First tests of the rail-based experimental setup of KAPRI for measurements of the coherent backscatter opposition effect (CBOE) at the terrace of HFSJG in March 2023.

Due to the complex acquisition geometry of the experimental setup shown in Figure 1, data interpretation is not trivial. To help better understand and interpret the acquired data, a hybrid tower-rail setup was developed and tested. This setup combines the possibility of separation of transmitting and receiving antennas, while preserving a more "traditional" radar observation geometry and is thus easier to interpret – this setup is shown in Figure 2. This setup exhibits several drawbacks of its own, however it can help validate the novel rail-based setup's measurements.

Figure 2. Deployment of the hybrid tower-rail experimental setup in December 2023.

Several acquisition campaigns aiming to gather data on CBOE's properties are planned for the 2023/2024 winter season. The first week-long campaign was carried out between 3rd and 8th December 2023. In addition to deployment of the two experimental setups shown above, in-situ data of snow properties on top of the glacier was acquired (Figure 3).

Figure 3. In situ measurements of snow cover properties in the Jungfraufirn area in December 2023. Photo credit: Michael Arnold, Philipp Bernhard

Analysis of acquired data is ongoing. Preliminary results (Figure 4) indicate successful detection of the coherent backscatter opposition effect in snow cover using the novel experimental setup.

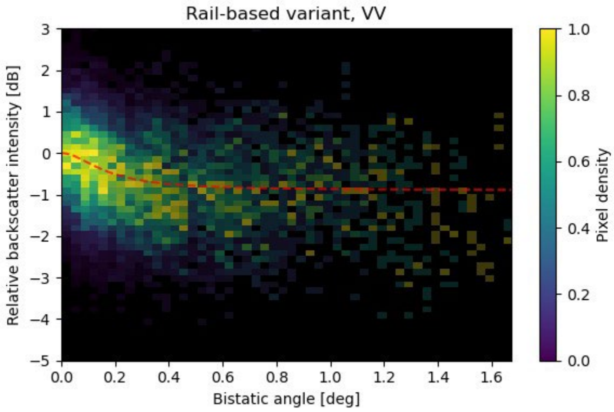

Figure 4. Preliminary results of measurements of backscatter intensity with the novel rail-based KAPRI experimental setup. An increase of backscatter intensity of approximately 1dB is observed when bistatic angle reduces from 1 degree to 0 degrees. This behavior is in alignment with occurrence of CBOE in the observed snow cover.

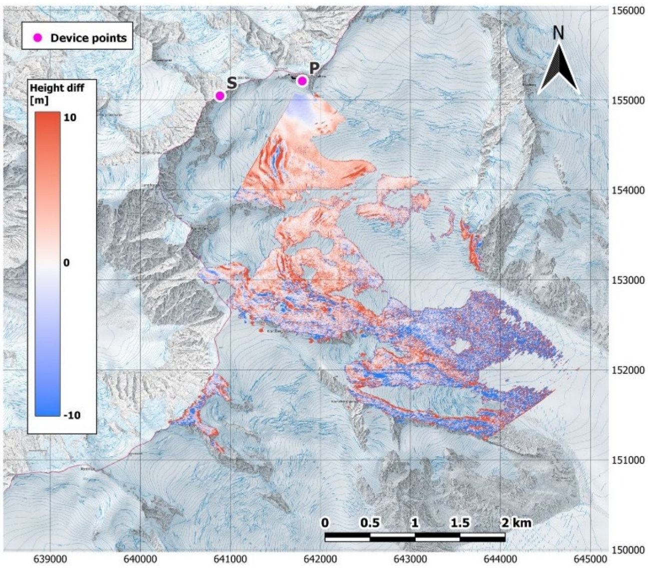

Figure 5. Differential Digital Elevation Model (DEM) created by comparing heights retrieved by KAPRI in winter of 2022 to the swissalti3D reference DEM.

3. Exploration of the topography and dynamics of the Great Aletsch Glacier at Ku-band with KAPRI

Work is continuing on further exploitation of previous as well as new datasets acquired with the tower-based configuration of KAPRI. The interferometric data from years 2021 and 2022 was analysed to generate digital elevation models (DEMs) of the surrounding area, as well as to estimate glacier drift. Figure 5 shows a preliminary comparison of height data retrieved by KAPRI to a reference DEM, highlighting temporal changes.

Furthermore, in December 2023, first preliminary measurements aiming to explore the potential of KAPRI for tomographic acquisitions were performed and data analysis is ongoing.

References

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Collaborating partners / networks

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Scientific publications and public outreach 2023

Conference Papers

Stefko, M., P. Bernhard, S. Leinss, O. Frey, and I. Hajnsek, Bistatic Radar Measurements of Terrestrial Snow at Ku-band - Phenomena, Models, and Opportunities, IGARSS 2023 - 2023 IEEE International Geoscience and Remote Sensing Symposium, Pasadena, CA, USA, July 16-21, 2023, pp. 658-661, doi: 10.1109/IGARSS52108.2023.10282423.

Theses

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