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Editorial: Remote sensing of the cryosphere

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Editorial on the Research Topic
Remote sensing of the cryosphere

The understanding of key environmental parameters operating within the cryosphere is of importance for climate change and sea level rise studies, and also for the assessment and characterization of snowmelt and snow pollution episodes. It is known that the year 2024 was the warmest year on the observational record. If the trend established since industrialisation continues for the next decade, the multiple climate tipping points may be triggered and humankind will face a multidimensional global crisis not seen before. Currently, the world is heading toward 2°C–3°C of global warming by 2100. The observed global warming leads to the increased speed of snow melting, the decrease in snow-covered area and snow duration, disappearance of glaciers, decrease in sea ice extent (https://seaice.uni-bremen.de/sea-ice-concentration/amsre-amsr2/time-series/), change in the precipitation patterns, sea level rise, the degradation of the permafrost, catalyse widespread temporal turnover in biodiversity and intensification of various nonlinear feedbacks in the climate system including surface - atmosphere interactions and change in precipitation patterns and increase of hazard probabilities. Therefore, the spaceborne monitoring of the key parameters of the terrestrial cryosphere is of great significance. The papers presented in this Research Topic can be grouped in three categories. The largest category contains four papers (Chen et al.; Kokhanovsky et al.; Kokhanovsky et al.; Wilder et al.) aimed at the presentation of algorithms to retrieve snow characteristics (e.g., snow grain size and albedo) from spaceborne multispectral measurements over Greenland (Chen et al.), spaceborne hyperspectral measurements over Antarctica (Kokhanovsky et al.; Kokhanovsky et al.); and airborne lidar measurements in steep forested terrain in United States (Wilder et al.). While Chen et al. concentrate on the validation of their snow property retrieval algorithm, Kokhanovsky et al., Kokhanovsky et al. show the benefits of hyperspectral observations (PRISMA, EnMAP) for snow monitoring including the detection of sizes of ice grains in the snow surface layer and also at some distance from the snow surface. Wilder et al. introduces fast and simple technique to retrieve the snow grain size in steep forested terrain using airborne lidar measurements at the single wavelength (1,064 nm). The presence of liquid water is a strict limitation on their method, preventing reliable results during the melt period. In particular, mixed ice grains and liquid water manifests into the respective ice absorption feature widening and shifting towards shorter wavelengths.

The second group of papers (Gascoin et al.; Gu et al.; Meyer et al.) is aimed at studies of snow cover in mountainous regions of our planet. In particular, the spatial and temporal changes of snow cover area, and derivation of snow depth and snow volume and also other snow properties are discussed in depth. For example, Gu et al. has found that from 2010 to 2019, the spatial fragmentation of snow cover in Northeast China increased by 50% compared to the 1980–1989 period. This paper suggests that the increase in temperature is the major factor leading to the fragmentation of snow cover in the studies area. Clearly, similar trends exist in other mountainous areas. It is pointed out by Meyer et al. that time series mapping of snow volume (governed by snow cover area and snow depth) in the mountains at global scales and at resolutions needed for water resource management is an unsolved challenge to date. The authors of this paper underline that digital surface models from multi-view Structure from Motion (SfM) photogrammetry can map snow depth up to alpine catchments size. They compared snow depth mapped from multi-view Structure from Motion photogrammetry to that mapped by lidar at multiple resolutions over an entire mountain basin (300 km^2). SfM had lower snow-covered area (~27%) and snow volume (~16%) compared to lidar. The derived results indicate that photogrammetry from aerial images can be applied in the mountains but would perform best for deeper snowpacks above tree line. Finally, Gascoin et al. discuses challenges in remote sensing of mountain snow from space and give recommendations for the improvement of relevant algorithms and observation capabilities. The paper has resulted from the 2-day WMO Mountain Snow Workshop at EUMETSAT (Darmstadt, Germany, 27–28 March, 2023). In particular, the authors advocate the establishment of geostationary orbit satellite constellation with relatively high temporal and spatial resolution. They call for the strengthening of the coordinated observations of daily changes of snow cover in unstable and highly sensitive to climate change mountain areas.

The third group of papers (Pukanská et al.; Temuujin et al.) is aimed at studies of particular regions of the cryosphere (Dobšiná Ice Cave in Slovakia and Khenti Mountain in the permafrost zone of central Mongolia). Temuujin et al. presents the analysis of 2 years of measurements of spatially distributed near-surface ground temperatures from a 6 km^2 large study area in the southern part of the Khenti Mountain, which features a range of different elevations, expositions, and ecosystem types. Sites in forests show generally colder near-surface temperatures in spring, summer and fall compared to grassland sites, but they are warmer during the winter season. The study shows that sites with higher snow depths are characterized by warmer winter temperatures, as expected from the insulating properties of snow. The comprehensive study performed by Pukanská et al. demonstrates that various geodetic (digital tacheometry, laser scanning, digital photogrammetry) and geophysical (microgravimetry, GPR) methods are necessary for a comprehensive study of ice filling dynamics in an ice cave, especially in terms of long-time monitoring.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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