Research Interests – Mariel Dirscherl

With accelerating global climate change, the Antarctic Ice Sheet (AIS) is exposed to increasing environmental pressure. During 1992–2017, Antarctica lost tremendous amounts of ice and contributed ~7.6 mm to global sea-level-rise (SLR). Apart from enhanced ocean melting of floating ice shelves that fringe and stabilise the AIS, one major contributor to past and present-day Antarctic ice mass loss is atmospheric warming leading to the formation of supraglacial meltwater lakes on the ice sheet and surrounding ice shelves. Supraglacial lakes can trigger sustained glacier acceleration and increased ice discharge due to their ability to penetrate the full ice sheet or ice shelf thickness leading to basal sliding or the collapse and disintegration of entire ice shelves. As global warming continues, these processes will intensify and Antarctica's contribution to SLR could increase significantly. At the same time, future climate scenarios suggest that atmospheric warming and the formation of supraglacial lakes will soon become a dominant driver of Antarctic ice mass loss. Given that the AIS holds ~57 m of sea-level-equivalent, research on Antarctic supraglacial lakes and their potential contribution to future SLR is of paramount societal importance and relevance. Even though the understanding of Antarctic supraglacial lakes has improved during recent years, their past and present distribution as well as underlying control mechanisms and impacts remain poorly constrained, mainly due to the lack of an automated mapping technique for supraglacial lake delineation in Earth Observation (EO) data. In fact, EO provides a wealth of high-resolution satellite data over Antarctica where ground-based monitoring efforts are difficult to perform.

Considering the pressing need for an advanced understanding of past and present-day Antarctic surface hydrology using EO data, my main research focus and interest is on the use of spaceborne remote sensing for the monitoring of intra-annual and inter-annual supraglacial lake dynamics in Antarctica. To this end, an overarching goal of my research is to develop novel methodological frameworks for automated supraglacial lake identification in large volumes of Sentinel-1 Synthetic Aperture Radar (SAR) and optical Sentinel-2 satellite data of the European Copernicus programme. In particular, innovative methods from artificial intelligence and big data processing are exploited due to their superior performance compared to conventional image classification techniques, especially considering the required spatio-temporal transferability of methods. To provide more detail, a workflow for fully automated supraglacial lake identification in Sentinel-1 and Sentinel-2 satellite imagery over Antarctica has been developed as part of my dissertation. For radar-based Sentinel-1 imagery, a deep convolutional neural network based on residual U-Net (ResU-Net) was trained enabling the semantic segmentation of independent Sentinel-1 acquisitions through consideration of the spatial image context. The developed method is the first to permit a fully automated identification of Antarctic supraglacial lakes in SAR imagery. Similarly, a pixel-based machine learning classifier based on Random Forest was trained with multiple spectral bands and indices, allowing for the automated classification of Sentinel-2 data over Antarctica. Both methods were implemented as part of the High-Performance Computing infrastructure of the German Aerospace Center (DLR) facilitating the large-scale processing of large volumes of satellite data. For the first time, the established workflow enabled the monitoring of seasonal supraglacial lake dynamics across six major Antarctic ice shelves at unprecedented 10 m spatial resolution and bi-weekly temporal scale. For this purpose, the full archive of Sentinel-1 and Sentinel-2 acquisitions during the summer melting seasons 2015–2021 was exploited. For example, the results show that supraglacial lakes were particularly widespread on Antarctic Peninsula ice shelves during the last two melting seasons, posing a major threat to their stability. During ongoing and future work, the implemented framework will be further refined in order to obtain even higher performance metrics and to apply it to data over the Greenland Ice Sheet. Subsequently, the whole ice sheet regions will be analysed and supraglacial lake dynamics will be linked to underlying controls and impacts.

In agreement with this, another focus of my research is to establish links between supraglacial lake formation and environmental control factors. For instance, the application of multi-temporal statistical correlation analyses revealed that the complex interplay between the local glaciological setting, the regional near-surface climate as well as large-scale atmospheric modes and teleconnections with the tropics determined the spatio-temporal distribution of Antarctic supraglacial lakes in 2015–2021. Additionally, the detected patterns and control mechanisms suggest that Antarctic supraglacial lakes will be far more widespread in the light of global climate change and are very likely to affect further regions that are vulnerable to ice shelf collapse. In this context, another future research focus will be on the analysis of future supraglacial lake evolution. For this purpose, time series on supraglacial lakes will be exploited together with climate data and state-of-the-art prediction methods to enable the projection of future lake evolution and thus a better understanding of climate change impacts in polar regions.