Geophysical Research Abstracts
Vol. 21, EGU2019-9756, 2019
EGU General Assembly 2019

Potential of Sentinel-1 for assessing meltwater dynamics on Antarctic ice shelves in Antarctica

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Meltwater ponds and channels have been spotted on multiple Antarctic ice shelves by optical remote sensing and in-situ studies in recent years. Since these meltwater features potentially make these ice shelves vulnerable to hydrofracturing, it is key to monitor the meltwater dynamics of these ponds and channels in order to improve the understanding of ice-shelf stability. Yet, a remote sensing approach to assess these meltwater dynamics over Antarctic ice shelves is currently lacking as all previous studies were focused on optical remote sensing which cannot reveal the highly variable meltwater dynamics over frequently cloud covered areas.

In this study we illustrate the potential of Sentinel-1 to monitor the spatial and temporal dynamics of meltwater features on Antarctic ice shelves. By combining SAR backscatter to discriminate between ice, water and snow with repeat-pass InSAR to detect elevation changes related to lake collapse and refreezing, we show the potential of Sentinel-1 to assess the occurrence and temporal evolution of meltwater features.

To assess the potential of Sentinel-1 for assessing meltwater dynamics, we combined i) spatial and ii) temporal variations of SAR backscatter with iii) InSAR coherence and iv) interferogram patterns over both the Roi Baudouin ice shelf (RBIS) and the Amery ice shelf (AIS) in the period 2017-2018, where multiple meltwater features were detected by previous studies.

The results of our analyses highlight both the potential and limitations of SAR and InSAR for detecting meltwater dynamics. The spatial analysis of SAR backscatter shows the clear appearance of meltwater features contrasting to their surroundings without meltwater. The results of the time series analysis show that the temporal backscatter variation of meltwater features depends on the location of the features (e.g. on blue ice or in firn covered area), the size of the features and whether they refreeze in winter. Therefore, it is not trivial to summarise a pattern of the meltwater features purely from backscatter images. The results of InSAR coherence approach on the other hand show that coherence images are more adequate to detect changes in meltwater features as they detect the change of scattering within the time series. This improved detection is more apparent over the AIS than over the RBIS. This regional difference can be explained by a better data availability and an overall higher coherence over the AIS, which indicates that the AIS ice shelf surface was more consistent in the InSAR time series. Finally, the InSAR interferograms show that both refreezing processes and lake collapse events can be detected by analysing InSAR fringe patterns. The quality of this detection however depends strongly on the quality of the phase unwrapping preprocessing step, which can be complicated over ice shelves.

Consequently, our results highlight the potential of Sentinel-1 SAR and InSAR approaches to assess both gradual meltwater processes such as refreezing and instant prcoesses such as drainage and collapse over Antarctic ice shelves. As such it highlights the importance of future dedicated meltwater products from Sentinel-1 to facilitate the study over Antarctic ice shelves in a changing climate.