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Grounding Line Migration at Orville Coast, Ronne Ice Shelf, West Antarctica, based on Long Interferometric Sentinel-1 Time Series

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1. INTRODUCTION

Research on ice sheets, which are a major factor in the world's climate system, has become increasingly intensive, as understanding the processes regulating their behaviour is important for assessing and predicting ongoing global climate change. One important indicator of changes in shelf glaciers is the location of the grounding line, which is defined as the line where a glacier loses contact with the bed and becomes a floating ice shelf (Weertman 1974). Determining the grounding line of an ice shelf glacier is essential for precise measurement and understanding of ice sheet mass balance and glacier dynamic (Fricker and Padman 2006).

Accurate determination of the GL position is problematic mainly due to its location beneath the glacier. Recent popular methods for monitoring the GL migration are based on remote sensing data. These data are useful because they cover extensive areas of land, and their acquisition does not require any in situ instruments. Our approach leverages Sentinel-1 synthetic aperture radar (SAR) images. The technique is based on differential interferometric synthetic aperture radar (DInSAR) (Rignot et al. 2011) and machine learning algorithms (Mohajerani et al. 2021). It allows glacier surface changes to be monitored with high resolution, even in darkness and cloudy conditions, and is thus advantageous in polar regions. The double-difference method helps minimize horizontal displacements resulting from glacier movement and expose primarily vertical displacements resulting from tidal changes (Rignot 1996). As a result, the method allows the identification of a hinge/flexure line, which is the landward limit of vertical movement. Although the flexure line is usually located slightly deeper in-land, it serves as a valid representation of the GL position (Vaughan 1994). The machine learning algorithm was adopted by Mohajerani et al. (2021) to automatically identify fringe patterns and vectorize the grounding line on images, and in effect – to significantly reduce the time needed for obtaining final results.

2. RESULTS

We employed a long time series of Sentinel-1 differential radar interferometry data from 2017 to 2021 to detect the variability in grounding line position on Orville Coast, the western region of the Ronne Ice Shelf, West Antarctica. The minimum and maximum extents of migration were identified, allowing for an estimation of the grounding zone width. In a single location, an approximate seasonality was evident, with maximum grounding line retreat typically occurring around the end of the calendar year and re-advance toward mid-year. It was then revealed that there is a high similarity in the migration extremes in different areas of the same glacier. It can be observed that they match not only in terms of timing but also in the magnitude of change. Additionally, data from separate satellite tracks showed consistency, which has also been demonstrated for the first time in the context of grounding line migration observations. It was also confirmed that the grounding zone width is several orders of magnitude larger than expected. This contradicts existing physical models, which are based on zero ice melt and a fixed grounding line position.

Irregular interactions between ice and seawater might have a significant impact on glacier evolution and projections if incorporated into physical models. The research carried out over a long period and with high frequency allowed a more detailed study of changes occurring in the grounding zone, and gave us the opportunity to detect seasonal movement in grounding line migration. We also compared it with external factors, e.g. ocean tides or topography. This might provide a better understanding of the behaviour of the ice sheet and glaciers, which are currently undergoing such rapid changes.

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