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Remote Sensing of Ice Motion in Antarctica – A Review and Future Requirements

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In the advent of global climate change, cryospheric research received an ever increasing attention and emerged as one of the key disciplines in climate change studies. Due to their high sensitivity to even small-scale meteorological variations, the components of the cryosphere are in fact regarded as natural indicators of climate change. One of the most alarming consequences of a changing cryosphere are melting ice masses with the potential to considerably raise global mean-sea-level and threaten low-lying coastal populations and ecosystems at all spatial scales. The Antarctic Ice Sheet (AIS) on its own holds $\sim$91% of the global ice masses, corresponding to $\sim$58.3 m of sea-level-equivalent (SLE) and making it the biggest potential contributor to global sea-level-rise. In order to draw valid conclusions about the state of the AIS or the behaviour and response of individual glaciers and ice shelves, detailed knowledge about mass changes and ice flow dynamics is required. Especially the measurement of ice motion is of fundamental interest to determine the rate of ice transport from the interior of the ice sheet to its margin and to quantify the spatial and temporal pattern of ice flow dynamics. Historical measurements of ice velocity were made with ground-based equipment but are impractical over the AIS due to its remoteness and vast size. The advent of spaceborne remote sensing revolutionised the ability to monitor ice dynamics in Antarctica at unprecedented spatial and temporal resolution, being of fundamental importance for an adequate prediction of future contributions to global sea-level-rise.

In this study, we present the state-of-the-art of currently existing ice velocity products from satellite imagery, we summarize the spatial and temporal pattern of ice flow and we identify the main challenges and research gaps associated with ice motion over the Antarctic continent. Our analysis reveals a highly dynamic and variable flow pattern in accordance with the local and regional forcing mechanisms such as ice shelf disintegration, calving events, the bedrock geometry, oceanic and atmospheric boundary conditions, pre-frontal marine conditions or ice thinning, to only name a few. At the same time, many Antarctic glaciers were found to adjust only slowly to new environmental conditions with the dominant driving mechanisms still partly unclear and calling for increased monitoring efforts over the entire AIS. Even though numerous studies investigated the dynamical flow behaviour of Antarctic glaciers and ice shelves at local to circum-antarctic scales, many glaciers, mainly the currently stable ones on the EAIS but also several on the API and the WAIS, still lack a sufficient number of studies at high temporal and spatial resolution or with homogeneous datasets. To capture the full picture of Antarctic ice sheet motion, to better understand glacier and ice shelf response to changing boundary conditions or to separate long-term velocity signals from seasonal effects, even more uniform velocity products at high temporal resolution and with continent-wide coverage would be required. The findings of our study contribute to an improved understanding of glacier dynamics in Antarctica, being of fundamental importance for climate change studies and future sea-level-rise.