AIRBORNE RADAR DEPTH SOUNDING OF FAST FLOWING GLACIERS

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Abstract:

Future sea-level rise will have significant impacts on populations living in costal regions, and the development of coastal infrastructure. Adaptation to these changes to minimize the negative consequences requires improved predictions of sea level. While there are several contributors to changes in sea level, future changes in the Antarctic and Greenland ice sheets is perhaps the least understood. Accurately mapping the bed topography will contribute greatly to improving predictive ice sheet models. This makes the accurate sounding of polar ice of paramount importance to predicting sea level rise. In much of the central portion of the ice sheets, where the ice is cold and slow moving, existing radar instruments and techniques are sufficient for imaging the bed. However, in regions with warm and fast moving ice, attenuation and scattering degrade signal-to-noise-ratio (SNR) at the bedrock, making accurate depth sounding difficult. In spite of said difficulties, these fast flowing glaciers are of particular interest and importance to the climate change community. The dynamic nature and influence of these outlet glaciers on the short and long term stability of the ice sheets mean that inaccurate or incomplete measurements of their ice thickness can have significant impact on the accuracy of ice sheet models using this data.

The size and remoteness of these large ice sheets requires the use of airborne or satellite sensors. At present, there are no satellites capable of imaging the bed. CReSIS has developed radar depth sounders which, for the first time, are able to accurately image the bed of fast flowing glaciers. However, these airborne radars systems are plagued by reflections between the ice surface and airplane body which cause multiples of the surface to appear at regular intervals below the actual surface of the ice. These multiples can potentially mask reflections from sub-surface layers.

Here, we describe three techniques developed to improve radar sounding of fast-flowing glaciers. We developed algorithms to reduce clutter in the cross-track direction, remove surface multiples and accurately estimate aircraft height over the surface and ice thickness. We applied these algorithms to data collected in stripmap SAR mode over a few outlet glaciers in Greenland and Antarctica. Our results show that the ice thickness is about 850 m at the calving front of the Jakobshavn glacier— one of the fastest flowing glaciers on Earth. The ice thickness increases to a maximum of about 2.7 km at about 30 km from the calving front. Similarly, the echogram of the Helheim glacier (Figure 1), a fast flowing outlet glacier on the east coast of Greenland, shows an increase in ice thickness of 400 m at the calving front up to 1.5 km thick around 25 km inland. These are the first successful soundings of these fast flowing ice glaciers. The algorithms developed in this paper improve our ability to detect and accurately measure these thicknesses as well as removing ambiguities due to multiple surface reflections and clutter near the calving front.

In this paper we will discuss radar signal processing algorithms and present results from processed data over fast flowing glaciers in Greenland and Antarctica.

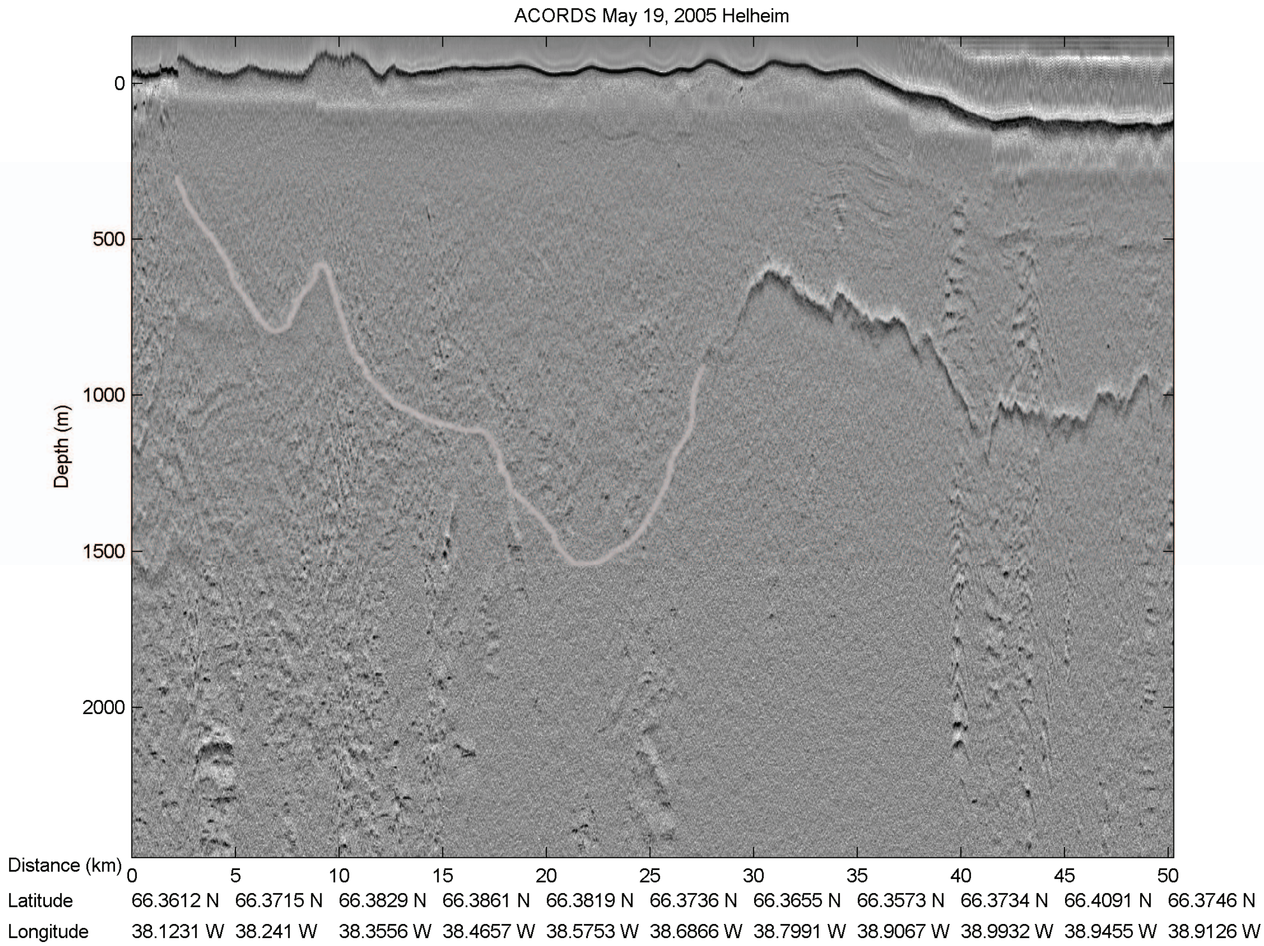

Figure 1: Echogram of Helheim glacier in eastern Greenland. The calving front can be seen on the far left side of the image around 2 km. The glacier flows from right to left. Helheim is one of the fast flowing outlet glaciers controlling the stability of the Greenland ice sheet.