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WORKSHOP ON DUAL-BAND ALTIMETRY OF THE CRYOSPHERE

Time varying surface penetration bias generated from coincident ICESat-2 and CryoSat-2 observations for Greenland and Antarctica

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Introduction

Radar altimetry has since the early 1990s provided the scientific community with key observations about the changes of the Earth's ice sheets and glaciers. This long-term record is of vital importance for understanding current and future trends in ice loss, and the processes governing the ice sheets contribution to global sea-level rise.

Though modern radar altimetry allows for detailed mapping of the changes in mass of the ice sheets, this measurement is still affected by changes at the snow-air interface, manifested by penetration of the radar signal into the firn column. These changes can introduce large biases in the retrieved elevation change signal, which to date is one of the major error sources. This error source is difficult to quantify due to lack of an adequate model for correcting changes in the scattering regime and lack of a large-scale validation datasets.

With the launch of ICESat-2 in September, 2018, we have the opportunity for the first time to compare unbiased laser measurements with overlapping radar data from CryoSat-2. This will allow us to investigate spatial and temporal changes in the penetration bias and how they are affected by changes in snow properties.

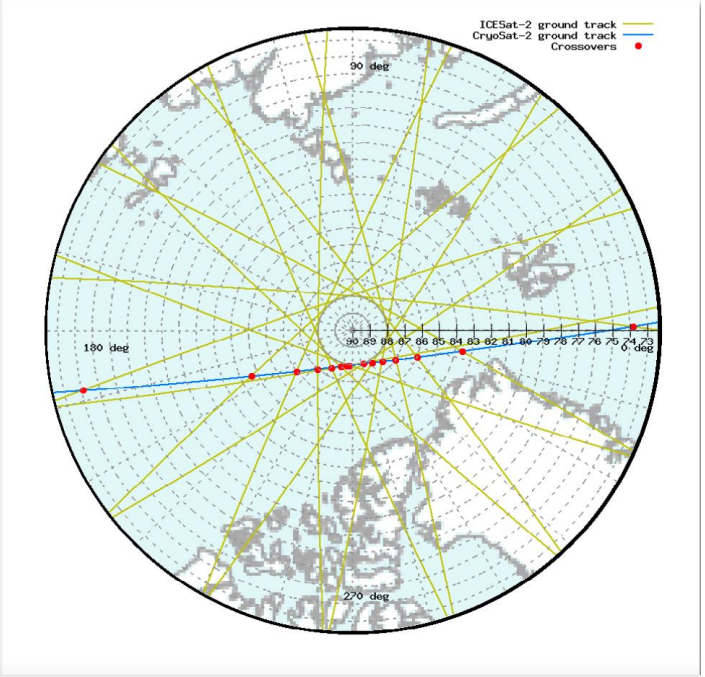
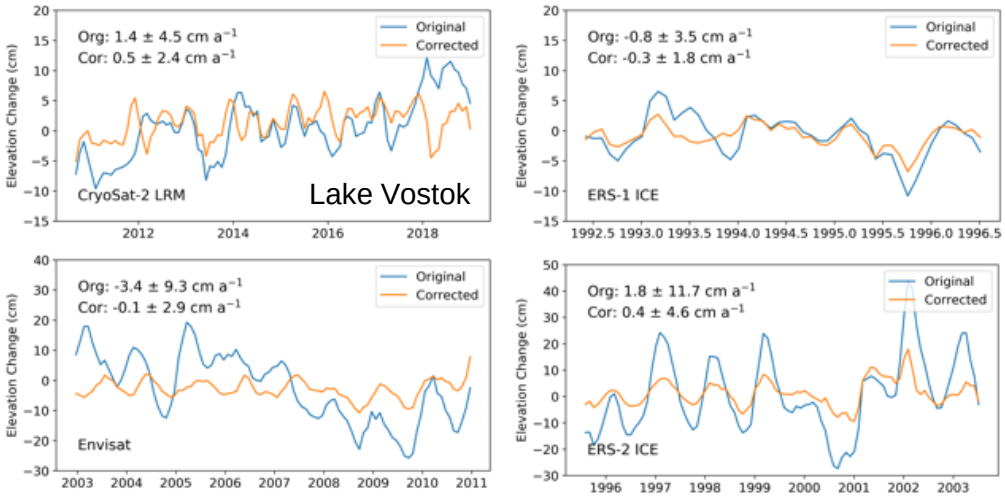
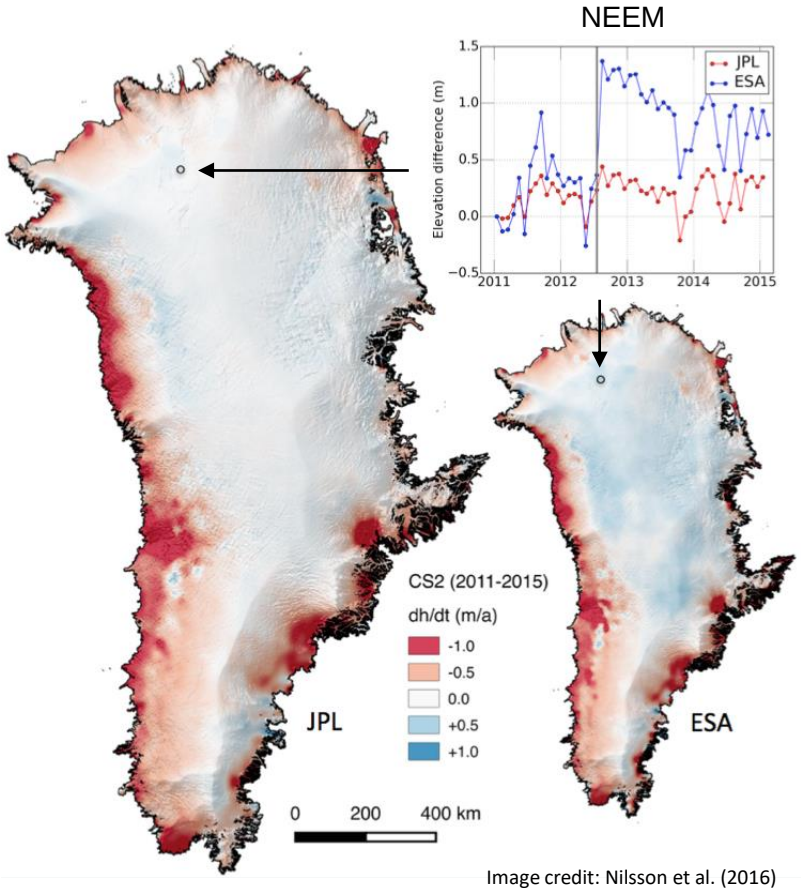


Image credit: ESA

Problem Description





Context: Radar altimetry has the longest record of measurements to observe the mass balance of the worlds ice sheets. However, the measurement it affected by the changes in the surface scattering regime creating a spatial and time variable penetration bias. This bias creates both artificial trends and seasonality in the long-term record. Quantifying and removing these effects are essential for the accurate reconstruction of mass balance trends to improve long-term sea-level rise predictions. With the launch of ICESat-2, a laser altimeter, we have for the first time both high-fidelity and dense spatial sampling of overlapping radar-laser measurements to investigate the radar penetration bias.

Image credit: Nilsson et al. (2016)

Methodology

- **Formulation of study:** We use elevations from both the CryoSat-2 (LRM-mode) and ICESat-2 to generate elevation difference to produce ice sheet wide penetration bias estimates. For CryoSat-2 generate elevations from several different retracking threshold form the radar waveform as these are directly proportional to penetration depth. Further, to quantify or to judge the sensitivity of these different threshold to change in surface properties we extract parameters describing the shape of the waveform (Bs, LeW and TeS). These parameters are directly linked to changes in surface conditions and can be used as a proxy to describe surface properties. To extract differences we used crossover analysis.

- **Possible Innovation:** Previously in radar altimetry the volume component has been minimized by removing the correlation between the change in the elevation to change in shape of the waveform. However, approach has limitation as reference surface is lacking. Here, we have for the first time the ability to study time variable changes in penetration depth and its major components. It will allow us to track the seasonal evolution of snow-depth of the polar ice sheets, and it will allow us to improve our understanding of the interaction between snow/firn/ice on altimetry signals. Further, it will allow us to improve our which can help improve firn-models understanding of ice sheet climatology such as long-term snow accumulation, necessary for converting ice sheet volume to mass. In the end this knowledge can be leveraged to improve our corrections of the historical radar altimetry record and in the end sea-level rise projections.

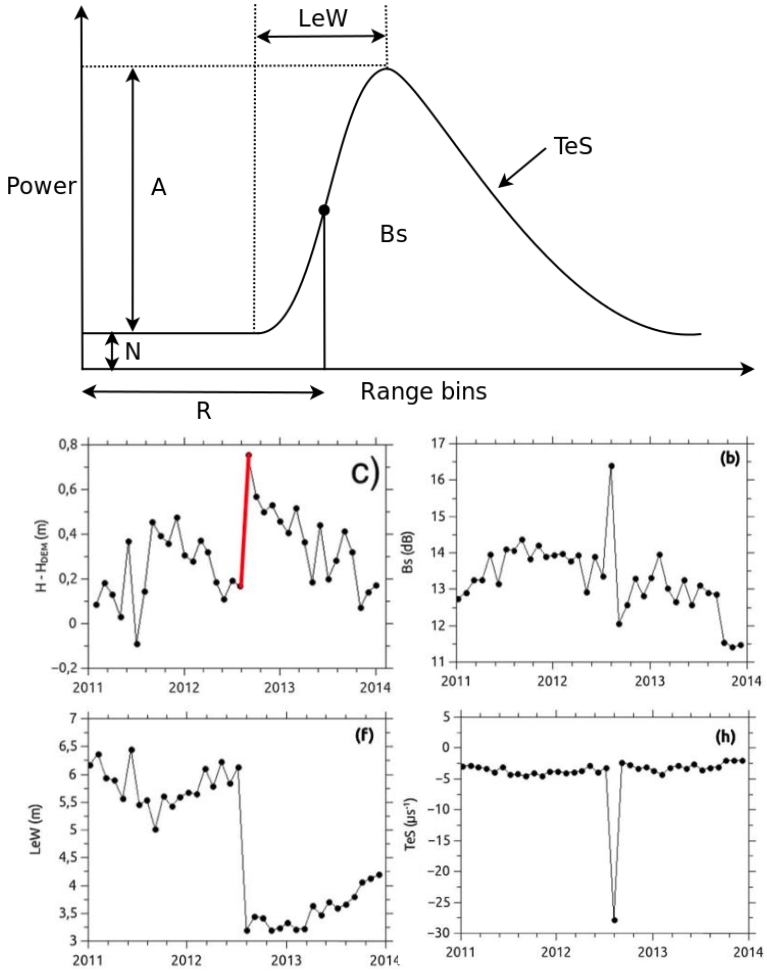
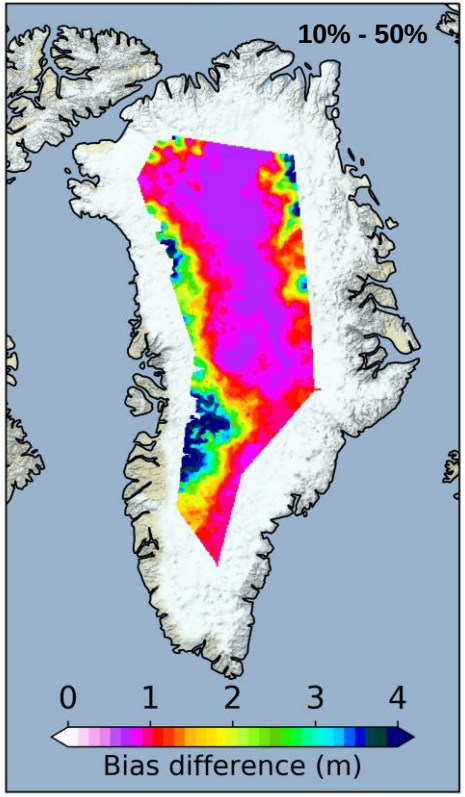
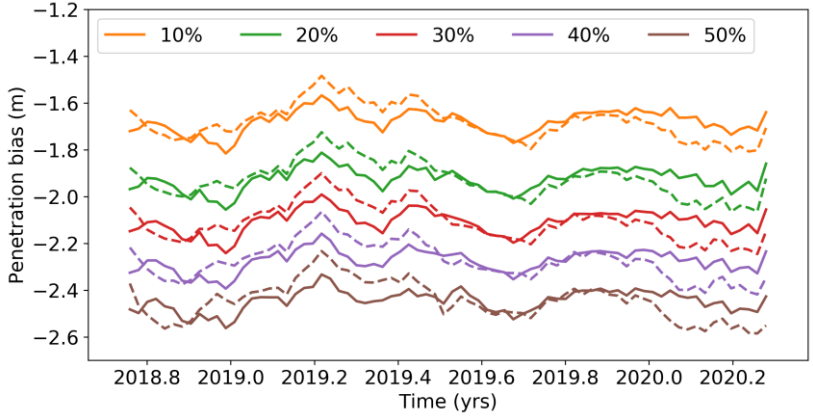
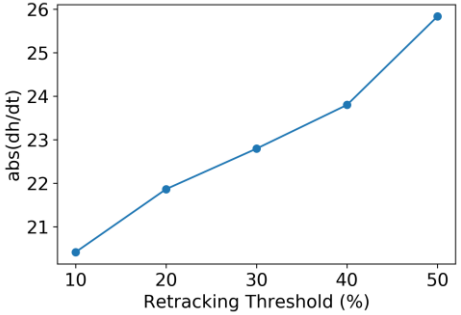


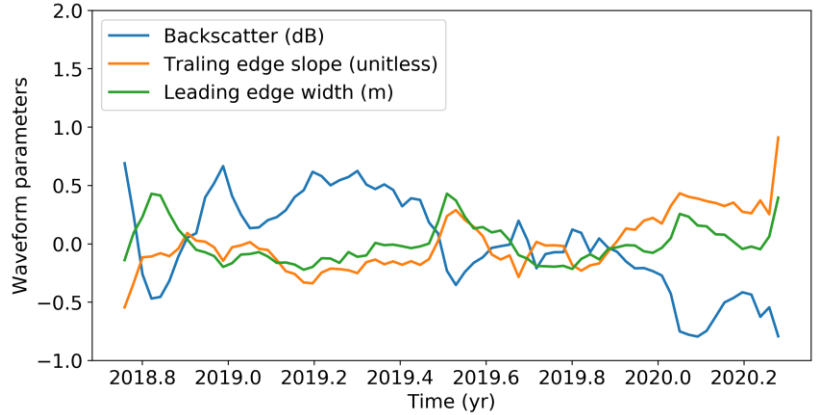
Image credit: Nilsson et al. (2015)

Results - Greenland

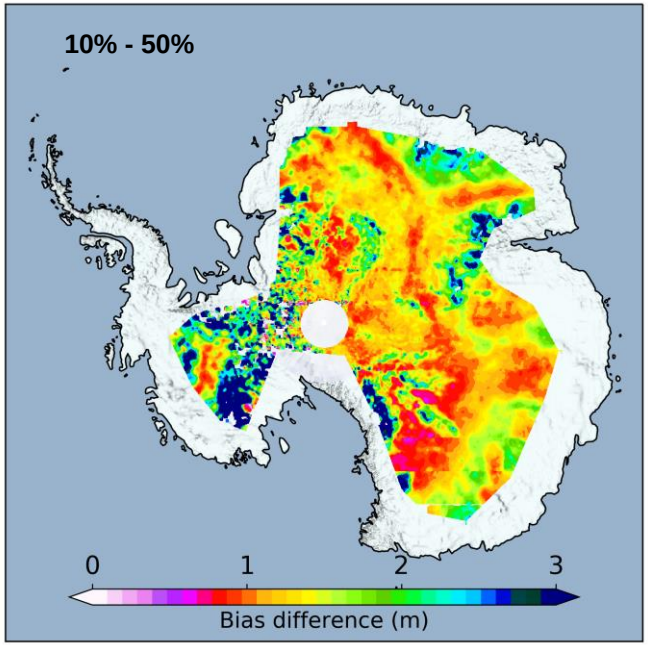


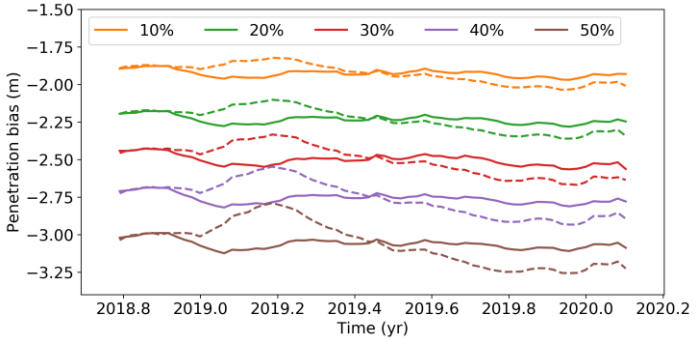


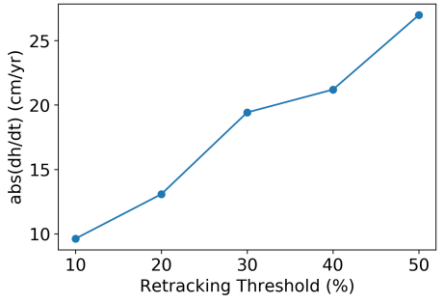


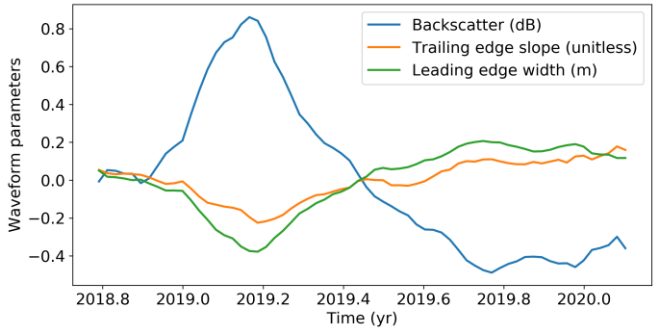


Results - Antarctica

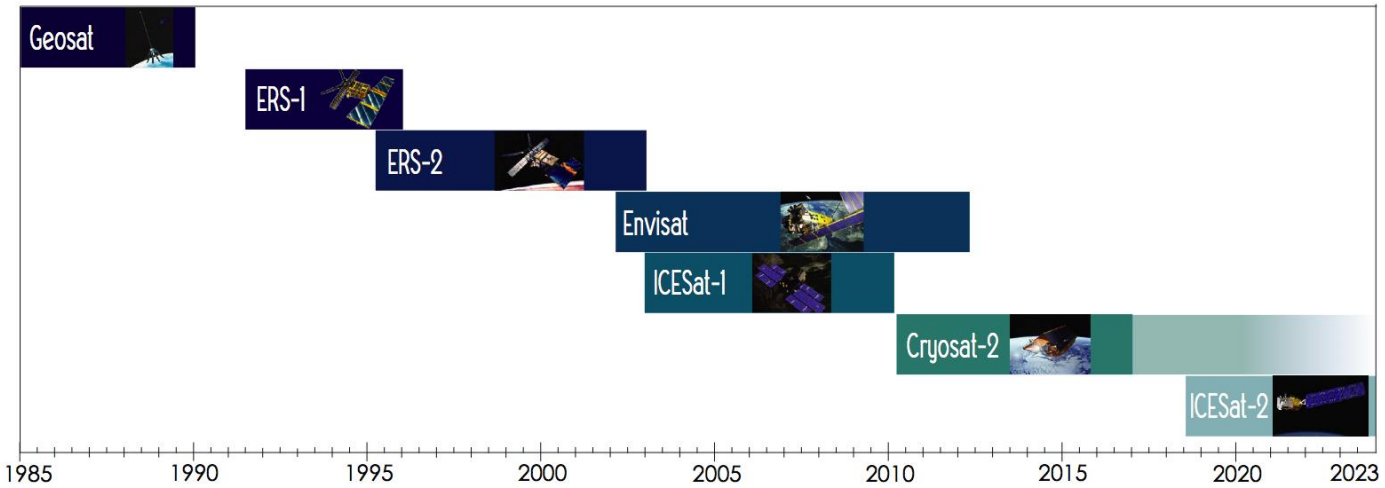








Discussion Questions



- How can we use dual-frequency altimetry to correct the long-term radar altimetry record?
- What near surface processes can we measure using dual-frequency and at what accuracy?
- What are the main technical challenges and/or improvements needed to obtain these goals?