Sensing Snow Depth Over Arctic Sea Ice Using GPS Reflectometry
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Abstract
In the Arctic Ocean, sea ice processes are partly regulated by the thickness of the snow layer above it. Therefore, it is important to obtain reliable estimates of snow depth over sea ice to understand ongoing changes in the Arctic Ocean. Here, we explore the feasibility of snow depth estimation using Global Navigation Satellite System-Interferometric Reflectometry (GNSS-IR). This remote sensing technique uses the interferometric pattern in the GNSS Signal-to-Noise Ratio (SNR) observable, which results from the direct and reflected GNSS signal interference, to estimate the reflector height. In the case of Arctic sea ice, the reflector is snow, and vertical distance changes are due to snow accumulation or melt. The cm-level precision of the GNSS-IR technique has previously been demonstrated using stationary GNSS antennas. Here, data from the Sea Ice Dynamic Experiment (SIDEx) is used to investigate the precision of dynamic GNSS antennas anchored to an ice floe, drifting with the Arctic Ocean ice pack. We have processed approximately one month of GNSS data from 12 identical GNSS systems deployed during the March 2021 SIDEx campaign, forming a small-scale network of ~5 km. There are noticeable differences between systems’ reflector heights, possibly attributed to the quality of the reflecting environment.

Time Series Analysis
Time series of the SIDEx \( h_R \) calculations demonstrate the overall precision of GNSS-IR, in addition to sea ice characteristics in relation to the stations. The station deployed on an ice ridge (Fig. 3) can be identified as SX20. Its \( h_R \) values vary between 4 - 6 m, which can be attributed to reflections from different locations on the ice ridge.

The bimodal distribution of SX19 \( h_R \) values (Fig. 5) may be attributed to differences in the reflecting surface surrounding the station, such as the station being in proximity to a lead. The time series allow us to identify different characteristics of the stations, including differences between the physical surroundings at different stations and azimuths.

Future Research
- Sensitivity analysis for the effect of station coordinate error on the calculated \( h_R \).
- Examine additional SIDEx observations beyond March 2021.
- Extract sea ice thickness and/or snow depths from SIDEx observations.
- Use SIDEx snow depths to validate ICESat-2 and CryoSat-2 snow depths.

References