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Dielectric sea-ice properties examined by GNSS reflectometry: Findings of the MOSAiC expedition

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The dielectric properties of sea ice differ significantly from the open-water surface when we consider the L-band frequency range of GNSS signals. In contrast to water, the signal's penetration into sea ice can reach several decimeters depending on properties like salinity, temperature and thickness. Exploiting these different dielectric properties is a key to use GNSS for sea-ice remote sensing. For this purpose, GNSS reflectometry measurements have been conducted over the Arctic Ocean during the MOSAiC expedition (Multidisciplinary drifting Observatory for the Study of Arctic Climate). A combined receiver setup was used that allows the here described reflectometry study and another study for atmosphere sounding. The setup was mounted, in close cooperation with the Alfred-Wegener-Institute (AWI), on the German research icebreaker Polarstern that drifted during nine months of the expedition with the Arctic sea ice.

Here, an initial study is presented that focuses on the expedition's first leg in autumn 2019 when the ship started drifting at about 85°N to 87°N in the Siberian Sector of the Arctic. Profiles of sea-ice reflectivity are derived with daily resolution considering reflection data recorded at left-handed (LH) and right-handed (RH) circular polarization. Respective model predictions of reflectivity are assuming a sea-ice bulk medium or a sea-ice slab. The later allows to include the effect of signal penetration down to the underlying water. Results of comparison between LH profiles and bulk model confirm the reflectivity contrast (about 10 dB) between sea ice and water. The particularly low level of LH reflectivity in the late observation period (December 2019) indicates the presence of low-saline multiyear (MY) ice. A bias due to snow accumulating on the ice surface may occur. A snow-extended reflection model, driven by additional snow data, can help in future for clarification.

Anomalies of observed reflectivity with respect to bulk model predictions are especially obvious at lowest elevation angles. According to the model, the slope of profiles at low elevations is about 1.0 to 1.2 dB/°. The observation shows significantly lower values (< 0.5 dB/°) including negative slopes. A comparison of LH results with the ice slab model provides clarification. The anomalies are induced by signal penetration leading to interference pattern of reflections from the ice's surface and bottom. Slope retrievals quantify the anomaly and allow a coarse estimation of the mean sea-ice temperature (about -10°C in December 2019) based on the slab model predictions. Further investigations are needed to better understand sea-ice reflectivity at RH polarization. RH profiles show a response to sea ice and features at low elevation angles that cannot be explained by current reflection models.

As a conclusion, GNSS reflectometry is sensitive to dielectric sea-ice properties. Estimates of ice type/salinity and temperature are reported based on LH observation data. These findings will be exploited to further strengthen the application of GNSS signals for sea-ice remote sensing. Future studies on GNSS observations from ships and satellites are anticipated.