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Combined GNSS Reflectometry/Refractometry for Continuous In Situ Surface Mass Balance Estimation on an Antarctic Ice Shelf

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We developed a methodology for deriving automated and continuous specific surface mass balance time series for fast moving parts of ice sheets and shelves (>10m/a) by an accurate and simultaneous estimation of continuous in-situ snow density, snow water equivalent (SWE), and snow deposition and erosion, averaged over an area of several square meters and independent on weather conditions. Reliable in-situ surface mass balance estimates are scarce due to limited spatial and temporal data availability. While surface accumulation can be obtained in various ways, conversion to mass requires knowledge of the snow density, which is more difficult to obtain.

A combined Global Navigation Satellite Systems reflectometry and refractometry (GNSS-RR) approach based on in-situ refracted and reflected GNSS signals is developed. The individual GNSS-RR methods have already been successfully applied on stationary grounds and seasonal snowpacks and are now combined and transferred to moving surfaces like ice sheets. We installed a combined GNSS-RR system in November 2021 on the fast moving (~150m/d), high latitude Ekström ice shelf in the vicinity of the Neumayer III station in Antarctica. Continuous snow accumulation reference data is provided by a laser distance sensor at the same test site and manual density observations. Refracted and reflected GNSS observations from site are post-processed for SWE, snow accumulation, and snow density estimation with a sub-daily temporal resolution. Preliminary results of the first year of data show a high level of agreement with reference observations, calculated from snow accumulation data collected by the laser distance sensor and linearly interpolated monthly snow density observations of the uppermost layer equivalent to the height of snow above the buried antenna.

The deployed devices are geared towards prototype applications for reliable low-cost applications, which will allow large-scale retrieval of surface mass balance for general cryospheric applications, not only on ice sheets or shelves, but also sea ice. Regional climate models, snow modelling, and extensive remote sensing data products will profit from calibration and validation based on the derived field measurements, once such sensors can be deployed on larger scales.