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A machine learning approach for Greenland ice sheet altimetric mass balance

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Satellite altimeters have monitored the surface elevation change of the Greenland ice sheet since 1978 and with an ice-sheet wide coverage since 1991. The satellite altimeters of interest for Greenland mass balance studies operate at different wavelengths; Ku-band radar, Ka-band radar, infrared laser, and visible laser. Some of the applied wavelengths can penetrate the surface in snow-covered regions and map the elevation change of subsurface layers. Especially the longer radar wavelength can penetrate the upper meters of the snow cover, whereas the infrared laser measurements from ICESat observes the snow-air interface of ice sheets. The pure surface elevation change derived from ICESat has been widely used in mass balance studies and may provide a benchmark for altimetric mass balance estimates after being corrected for changes in the firn-air content. The Ku-band radar observation provides the longest time series of ice sheet volume change, but the record is more difficult to convert into mass balance due to climate-induced variations in the surface penetration.

Here, we apply machine learning to build an empirical calibration method for converting the observed radar-derived volume change into mass balance. We train the machine learning model during the limited period of coinciding laser and radar satellite altimetry data (2003-2009). The radar and laser datasets are not sufficient to guide the empirical calibration alone. Hence, additional datasets are used to help build a stable predictor needed for radar calibration, such as ice velocity.

We focus on the lessons learned from this machine learning approach but also highlight results from the resulting 28-yearlong time series of Greenland ice sheet mass balance. For example, the Greenland Ice Sheet contribution to global sea-level rise has been 12.1±2.3 mm since 1992, with more than 80% of this originating after 2003.