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Time-evolving mass changes of Jakobshavn Isbrae, Greenland, derived from satellite altimetry

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Changes in mass of the Greenland and Antarctic ice sheets can be estimated from elevation changes as measured by airborne or spaceborne altimeters. Such measurements are limited by their spatial and temporal resolution and coverage, and to get a basin-integrated value they need to be interpolated. A widely used approach to do this is ordinary kriging, in which the value in an unsampled location is calculated using a weighted average of neighbouring samples. The largest elevation changes, however, typically occur in relatively narrow outlet glaciers, over which slopes are generally too steep to get accurate measurements from satellite altimetry. It is therefore unlikely that ordinary kriging yields a realistic pattern of elevation changes in such areas.

To interpolate elevation change estimates from ICESat, Envisat and ERS-2, we use kriging with external drift. This is an alternative form of kriging, where ice velocity is provided as a secondary variable. We thus make use of the relationship between flux divergence (the spatial gradient of ice velocity) and dynamically induced elevation changes as described by the continuity equation. In addition, we take into account the temporal component of variability by fitting a space-time semi-variogram to the data and interpolate in both space and time.

As a case study we focus on Jakobshavn Isbrae, one of the largest outlet glaciers in Greenland, for which a wealth of accurate airborne laser altimetry data (ATM) is available to validate our approach. Interpolation including the velocity pattern yields a more realistic spatial pattern of elevation changes, and generally smaller errors with respect to ATM data. Conversion of the obtained elevation changes to mass requires the surface layer density, and a correction for elevation changes due to firn compaction which is unrelated to ice mass. Both are obtained from a simple, empirical model based on regional climate model output. As an additional, independent validation of our interpolation method, the obtained mass changes from all kriging types are compared with results from the mass budget approach.