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A novel approach for change detection from ICESat satellite laser altimetry – spatial and temporal pattern of Greenland Ice Sheet surface changes, 2003-2008

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The main objective of the ICESat satellite laser altimetry mission is to determine the mass balance of polar ice sheets and their contributions to current sea level changes. By measuring surface topography, ICESat also provides important boundary conditions for ice sheet and atmospheric modeling. To quantify surface elevation changes, to investigate their causes, and to improve predictive ice sheet models, accurate elevation changes on a seasonal, annual and inter-annual basis at scales of drainage basins and outlet glaciers are essential.

Determining the spatial and temporal distribution of surface changes from repeat satellite laser altimetry remains a challenging problem, mainly because the footprints of repeat missions do not precisely overlap. We have developed a new method that is based on fitting analytical functions to laser points within repeat tracks or cross-over areas for estimating the ice sheet surface topography. The mathematical model of the change detection algorithm is based on the assumption that for a small surface area, e.g. 1 km by 1 km, only the absolute elevation changes over time but not the shape of the surface patch. Therefore, laser points of all time epochs of a small surface patch contribute to the shape parameters, and the laser points of each time period determine the absolute elevation of the surface patch at that period. The least squares adjustment delivers the surface elevation changes together with statistical information that is extremely helpful in judging how significant the elevation changes and the derived volume changes are.

We demonstrate the feasibility of the proposed approach by reconstructing surface and volume changes of the Jakobshavn drainage basin in west Greenland. The accuracy of the surface change estimates derived from repeat ICESat measurements is verified by using NASA's Airborne Topographic Mapper (ATM) airborne laser altimetry. We then combine repeat ICESat and ATM laser altimetry and stereo satellite imagery (ASTER, SPOT) to determine the evolution of the surface in the Jakobshavn drainage basin since the beginning of the ICESat mission (2003). Finally, estimates of the spatial variation of annual and interannual changes of the whole Greenland Ice Sheet are presented.