Improved elevation change records for Antarctic ice shelves from satellite radar and laser altimetry, 1992-2012

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We have been working to increase accuracy, resolution and record length of satellite radar and laser altimetry over ice shelves to provide an improved data set of elevation change for studies linking ice-shelf change to oceanic- and atmospheric-forcing variability. Here, we report our recent findings, focusing on the large Filchner-Ronne (FRIS) and Ross (RIS) ice shelves. In our satellite radar altimetry (RA) analysis we use improved procedures to integrate data from multiple satellite RA missions (ERS-1, ERS-2, and Envisat) to derive long-term (~20 years) continuous records of surface elevation changes for most of Antarctica's ice shelf area. There is considerable variability in the elevation change signal on the ice shelves both in space and time, with large interannual signals that mask the long-term trend when data from only a few years are considered. In our laser altimetry analysis, we have developed a new method that uses InSAR-based velocity fields to account for ice advection between overpasses of the ICESat laser altimeter. This allows us to monitor elevation changes in a "Lagrangian" reference frame, i.e., following specific locations on the ice shelf as they advect downstream. The Lagrangian approach reduces the noise level of the derived elevation changes and reveals clearer spatial patterns that can be transferred into basal melt/accretion rates after accounting for ice shelf strain, surface accumulation, firn air content and hydrostatic compensation. For the RIS and FRIS, we find that basal melt rates are highest around the grounding lines and near the ice shelf fronts, in agreement with oceanographic models. The maps show significant basal accretion over the central parts of FRIS, and much less basal accretion on RIS, consistent with previous studies. Although both these ice shelves are relatively stable at present, the differences in their spatial structure of basal mass balance and temporal response of dh/dt (from RA) implies that they may respond quite differently to similar large-scale changes in ocean state. We note that the spatial distribution of standard ("Eulerian") RA estimates of dh/dt from Envisat for the period 2003-2008 resembles that of the Lagrangian analysis of ICESat laser dh/dt, suggesting that over short time periods the RA dh/dt values might be biased by advection of ice elevation gradients.