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Simultaneous measurements of ice sheet elevation change, accumulation, and firn compaction using Operation IceBridge data

Brooke Medley (1), Stefan Ligtenberg (2), Michiel van den Broeke (2), Sivaprasad Gogineni (3), and Sophie Nowicki (1)

(1) NASA Goddard Space Flight Center, Greenbelt, MD, USA (brooke.c.medley@nasa.gov), (2) Institute for Marine and Atmospheric Research, Utrecht, The Netherlands (s.r.m.ligtenberg@uu.nl), (3) Center for Remote Sensing of Ice Sheets, University of Kansas, KS, USA (Gogineni, Sivaprasad (pgogineni@ku.edu)

Altimetric methods for determination of ice sheet mass balance are extremely valuable as they typically measure large regions of the ice sheet, from basin- to continental-scale. The measured volume change is converted to mass change if the density of the lost material is known. The complication lies in the fact that the observed elevation change consists of two components of differing densities: firn and ice. Annual fluctuations in snow accumulation and firn compaction cause the firn column to vary in thickness, which is often a large component of the total elevation change in the interior since the density of firn is less than that of ice. Further complication arises from the fact that fluctuations in the firn compaction rate do not result in mass change. Therefore, to properly determine mass change, the observed elevation change must be partitioned into accumulation, firn compaction, and ice components.

Because altimetry studies are often large in scale, models are used to account for the firn processes, which are coarse in resolution (∼10s kilometers) relative to the observed elevation changes (sub-kilometer). Here, we take advantage of a unique opportunity to simultaneously measure surface elevation change, snow accumulation, and firn compaction over the Thwaites catchment in West Antarctica using two Operation IceBridge (OIB) sensors. The firn processes are observed using the Center for Remote Sensing of Ice Sheets (CReSIS) snow radar, and elevation changes are measured using the Airborne Topographic Mapper. Coincident observations such as the aforementioned allow us to not only accurately evaluate mass change over short distances, but also determine the importance of accounting for small-scale variations in firn processes in large-scale (basin-wide to continental) assessments of mass balance. Our results indicate that accumulation rates vary by more than 10% and compaction rates vary by more than 10 cm/yr over distances as little as 5 km in this region. Thus, the importance of these spatial variations on evaluating mass change using altimetry must be considered. The measurements also provide an accurate baseline for comparison with larger-scale mass balance studies. The work presented highlights the utility of NASA's OIB Mission through its multi-sensor approach.