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Antarctic ice shelf thickness from CryoSat-2 radar altimetry

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The Antarctic ice shelves provide buttressing to the inland grounded ice sheet, and therefore play a controlling role in regulating ice dynamics and mass imbalance. Accurate knowledge of ice shelf thickness is essential for input-output method mass balance calculations, sub-ice shelf ocean models and buttressing parameterisations in ice sheet models. Ice shelf thickness has previously been inferred from satellite altimetry elevation measurements using the assumption of hydrostatic equilibrium, as direct measurements of ice thickness do not provide the spatial coverage necessary for these applications. The sensor limitations of previous radar altimeters have led to poor data coverage and a lack of accuracy, particularly the grounding zone where a break in slope exists.

We present a new ice shelf thickness dataset using four years (2011-2014) of CryoSat-2 elevation measurements, with its SARIn dual antennae mode of operation alleviating the issues affecting previous sensors. These improvements and the dense across track spacing of the satellite has resulted in ~92% coverage of the ice shelves, with substantial improvements, for example, of over 50% across the Venable and Totten Ice Shelves in comparison to the previous dataset. Significant improvements in coverage and accuracy are also seen south of 81.5° for the Ross and Filchner-Ronne Ice Shelves.

Validation of the surface elevation measurements, used to derive ice thickness, against NASA ICESat laser altimetry data shows a mean bias of less than 1 m (equivalent to less than 9 m in ice thickness) and a fourfold decrease in standard deviation in comparison to the previous continental dataset. Importantly, the most substantial improvements are found in the grounding zone. Validation of the derived thickness data has been carried out using multiple Radio Echo Sounding (RES) campaigns across the continent. Over the Amery ice shelf, where extensive RES measurements exist, the mean difference between the datasets is 3.3% and 4.7% across the whole shelf and within 10 km of the grounding line, respectively. These represent a two to three fold improvement in accuracy when compared to the previous data product.

The impact of these improvements on Input-Output estimates of mass balance is illustrated for the Abbot Ice Shelf. Our new product shows a mean reduction of 29% in thickness at the grounding line when compared to the previous dataset as well as the elimination of non-physical 'data spikes' that were prevalent in the previous product in areas of complex terrain. The reduction in grounding line thickness equates to a change in mass balance for the areas from -14±9 GTyr^{-1}to -4±9 GTyr^{-1}. We show examples from other sectors including the Getz and George VI ice shelves. The updated estimate is more consistent with the positive surface elevation rate in this region obtained from satellite altimetry. The new thickness dataset will greatly reduce the uncertainty in Input-Output estimates of mass balance for the ~30% of the grounding line of Antarctica where direct ice thickness measurements do not exist.