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Grounding zone ice thickness from InSAR: Inverse modelling of tidal elastic bending

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Ice thickness measurements in Antarctic ice-shelf grounding zones are necessary for calculating the mass balance of individual catchments but remain poorly constrained for most of the continent. We describe a new satellite-based approach to estimating ice thickness in the grounding zone of outlet glaciers and ice shelves using spatial patterns of tide-induced flexure derived from differential interferometric synthetic aperture radar (InSAR). Vertical motion of the ice in response to tides varies spatially across the grounding zone region where the ice shelves are partially supported by the land. This displacement pattern is a function of the flexural rigidity, determined by thickness and internal ice properties, and can be observed at high precision using InSAR. We demonstrate that an inverse formulation of the simple elastic-plate equations for bending can be applied to estimate flexural rigidity from vertical motion. In 1D, the model recreates smooth, synthesized profiles of ice thickness from flexure information to within 1-2%. We also test the method in 2D and validate it in the grounding zone of the Beardmore Glacier, a major outlet glacier in the Transantarctic Mountains, using interferograms created from TerraSAR-X satellite imagery acquired in 2012. We compare our results with historic and modern ice thickness data (radio-echo sounding from 1967 and ground penetrating radar from 2010). Modelled thicknesses match both longitudinal and transverse radar transects to within 50 m RMSE using an effective Young's Modulus of 1.4 GPa. The highest accuracy is achieved close to the grounded ice boundary, where current estimates of thickness based on surface elevation measurements contain a systematic bias towards thicker ice.