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Firn air-content of Larsen C Ice Shelf, Antarctic Peninsula, from seismic velocities, borehole surveys and firn modelling

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The rising surface temperature of Antarctic Peninsula ice shelves is strongly implicated in ice shelf disintegration, by exacerbating the compaction of firn layers. Firn compaction is expected to warm the ice column and, given sufficiently wet and compacted layers, to allow meltwater to penetrate into surface crevasses and thus enhance hydrofracture potential. Integrating seismic refraction surveys with borehole neutron and firn core density logging, we reveal vertical and horizontal changes in firn properties across Larsen C Ice Shelf. Patterns of firn air-content derived from seismic surveys are broadly similar to those estimated previously from airborne radar and satellite data. Specifically, these estimates show greater firn compaction in the north and landward inlets compared to the south, although spatial gradients in seismic-derived air-contents are less pronounced than those previously inferred. Firn thickness is less than 10 m in the extreme northwest of Larsen C, in Cabinet Inlet, yet exceeds 40 m in the southeast, suggesting that the inlet is a focus of firn compaction; indeed, buried layers of massive refrozen ice were observed in 200 MHz GPR data in Cabinet and Whirlwind Inlets during a field campaign in the 2014-15 austral summer. Depth profiles of firn density provide a reasonable fit with those derived from closely-located firn cores and neutron probe data.

Our model of firn structure is driven by RACMO and includes a ‘bucket’-type hydrological implementation, and simulates the depth-density profiles in the inlets well. Discrepancies between measured and modelled depth-density profiles become progressively greater towards the ice-shelf front. RACMO incorrectly simulates the particular leeward (sea-ice-influenced) microclimate of the shallow boundary layer, leading to excess melt and/or lack of snowfall.

The spatial sampling density of our seismic observations will be augmented following a further field campaign in the 2016-17 austral summer, allowing quantitative comparison of our firn air-content estimates (and their hydrostatic implications) versus those derived from airborne radar data. We suggest that our seismic data may provide more realistic profiles of firn density and air-content in the southeastern sector of Larsen C, where the ice shelf is heavily fractured.