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Inferring ocean melting of Antarctic ice shelves from their radar stratigraphy

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The floating ice shelves surrounding the Antarctic Ice Sheet are the interface for interactions between ice and ocean. A plethora of previous studies has highlighted the role of ice shelves for stabilizing ice sheets. Quantification of melting at the ice-shelf base is imperative for quantifying ice-shelf stability, and also to test the coupling of upcoming ice-ocean models.

Today, the basal mass balance is either inferred from mass conservation or measured using phase-sensitive radars. The former has good spatial coverage, but low spatial and virtually no temporal resolution. The latter is highly resolved in time, but with limited spatial coverage. Here we investigate a third approach exploiting the geometry of observed radar isochrones (dips, synclines, anticlines) which is a function of both ice deformation and the atmospheric/oceanographic history. By comparing isochrones with modeled age fields we can disentangle the different mechanisms and unravel the melt history.

We solve the age equation on highly resolved ice-shelf geometries, and derive the required 3D velocities from surface velocities using a plug-flow approximation (and a first-order guess of basal melting from mass conservation). Validation with a full Stokes model shows that the plug-flow assumption holds well seawards of the grounding zone. We compile the radar isochrones for two Antarctic ice shelves from ground-based (i.e. Roi Baudouin Ice Self) and airborne (i.e. Ekstömisen) profiles. Our compilation includes ice-shelf channels, and we find a number of features in the isochrones geometry that indicate strong localized melting, but also anomalous snow accumulation in corresponding surface depressions. We can distinguish between both mechanisms using our age model. This study shows the potential of using radar isochrones as a unique archive for ice-ocean interactions, and serves as a precursor for setting up the full inverse problem, allowing to infer the currently unknown ocean melt history on decadal-centennial time scales.