Inferring Transients in Ice Flow, Ice Thickness, and Accumulation Rate from Internal Layers near the WAIS Divide ice-core site

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Ice-sheet internal layers preserve information about how the ice sheet responded to past spatial and temporal changes in accumulation rate and ice dynamics, and present-day internal-layer shapes observed by radar are the most accessible remaining record of this past information. To infer transients in ice flow, ice-sheet thickness, and accumulation rate from the shapes of internal layers, we solve an inverse problem. While some details of these histories can be recovered from ice cores, ice cores represent conditions at only a single point. However, our approach is more robust in combination with ice-core data. If internal layers are dated, for example by an intersecting ice core, then radar-observed internal layers provide both spatial and temporal information. We apply our new inverse approach near the WAIS Divide ice core.

Each layer represents a past surface of a particular age that has been subsequently buried by accumulation and also modified by ice flow; the process of internal-layer formation can be described with an ice-flow forward model. Deeper layers contain information from further in the past, making them highly valuable. However, deep layers have also likely been subjected to greater spatial and temporal gradients in strain rate and accumulation, making them more difficult to decipher. Our goal in solving this inverse problem is to find the smoothest set of model parameters (e.g. accumulation-rate history) that will explain the data (e.g. internal-layer shapes). We match predictions of observable quantities made with our forward algorithm to the measured values at an expected tolerance while, in this case, finding a spatially smooth accumulation pattern and a parameter set that is consistent with physically characteristic values of the parameters.

The spatial and temporal histories of ice-sheet flow and of accumulation are necessary to recreate ice-volume and sea-level histories. In addition, understanding large-scale evolution of ice sheets over long timescales is critical in order to properly interpret ice-core chemistry and to properly date an ice core, especially in portions of the core where annual-layer counting is no longer reliable. For example, we can infer the accumulation rate at the location and time where each piece of ice in the ice core originated on the ice surface to convert chemical concentrations into fluxes from the atmosphere, or we can infer temporal changes in accumulation and ice thickness at one location on the surface to test GCM simulations of past climate. These spatial and temporal histories are necessary to properly date the ice core with occluded gases because Δage at pore closeoff depends on accumulation rate. We also examine the sensitivity of our approach to infer the individual imprint of ice-divide migration and of accumulation-rate variations on internal-layer architecture.