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Self-consistent Ice-Sheet Evolution and Climate

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Accumulation history on space and time can be inferred from well-dated radar-layer stratigraphy together with an ice-flow model; however, dates for those layers often are derived from dated occluded gases, whose ages relative to the enclosing ice themselves depend on accumulation rate. To avoid this circularity, we have developed a self-consistent approach in which we determine past-climate histories while simultaneously determining the past ice-sheet evolution. Constraining the self-consistent model with data sets from 2-d radar isochrones and 1-d ice-core records and including multiple physical processes including ice-sheet flow, heat flow, grain growth and firn compaction, we can infer past climate information from polar regions and simultaneously constrain ice-sheet evolution. Inferred climate information includes accumulation rate and delta age (ice-age gas-age offset), and ice-sheet evolution includes thickness and divide position. We currently model limited domains near ice divides and ice-core sites where radar data are available. The model can be embedded in larger scale ice-sheet model in several ways.

The self-consistent model consists of modules, or subroutines, connected in an iterative loop. Subroutines include an inverse method to determine the spatial and temporal accumulation rate, firn-compaction model with grain growth, and particle tracking to determine the ice-core accumulation-rate history. The spatial 2-d radar isochrones and temporal 1-d ice-core records, together provide additional constraints on the paleoclimate histories (boundary conditions) and ice-sheet evolution. From radar isochrone patterns, it is possible to determine the past thickness and ice-divide migration. Ice-core chemistry provides excellent dating constraints where well-mixed atmospheric gases such as methane allow tie-points to other well-dated ice-core records. Here, we establish the proof of concept that the self-consistent model can recover self-consistent paleoclimate histories and ice-sheet evolution from synthetic data. This work paves the way for simultaneously reconstructing self-consistent paleoclimate and ice-sheet evolution from multiple polar data sets.