

Tradeoff between climate and thickness histories at Siple Dome during the past 25 ka

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The WAISCORES project comprises 2 cores, one at Siple Dome, and one inland, on the Ross-Amundsen divide. The Siple Dome core has sometimes been called the “ice dynamics” core, because greater dynamic changes in the ice sheet are expected there, and such changes would have a measurable impact on the ice-core stratigraphy and geochemical records. In particular, dramatic post-glacial thinning of Siple Dome would impact the observed layer-thickness pattern in the core.

The thickness of a layer spanning a known time interval in an ice core is influenced by both the accumulation rate at the time of deposition (i.e. its initial thickness), and the total vertical strain experienced since deposition as a particle moves along its trajectory. The vertical strain rate scales with the magnitude of the vertical velocity (which tends to scale with accumulation rate). Strain rate is also influenced by divide proximity, and by ice-cap thinning rate. Therefore, the total vertical strain is a function of the ice-divide migration history, the accumulation-rate history, and the thinning history of the ice cap. As a result, thickness and accumulation-rate histories are coupled; if we accept a particular thickness history, then the ice-core depth-age scale forces us to also accept the paired accumulation-rate history, and vice versa.

First, we specified 2 different ice-divide migration histories. In the first, the divide moved across the ice-core site during the past 4 ka, and was more than 1 ice thickness away at earlier times. In the second, the ice divide was always nearby. Then, we specified a range of ice-thickness histories, ranging from no thickness changes, through thinning of 1200 m between 16 ka and 2 ka. We used velocities from a steady-state finite-element momentum-balance profile model of Siple Dome to parameterize ice dynamics in a transient 1-D ice-flow model. We then used the 1-D transient model to find the accumulation history required by each thickness history, in order to reproduce the observed depth-age relation and layer-thickness pattern in the Siple Dome ice core.

We selected the most reasonable solution pairs by comparisons with stable isotopes, accumulation trends, and inferred thickness changes at Byrd Station and Taylor Dome. We conclude that Siple Dome was thicker by at most 500 meters, and possibly significantly less, during the last glacial maximum (LGM). Although the ice divide migrated across the ice-core site over the past 4 ka, the layers in the core were probably not in a near-divide region at prior times.

A low-profile ice sheet in the central Ross Sea sector does not preclude substantially thicker ice in the western and eastern sectors, but it does imply that the Ross ice streams remained active during the last glacial cycle, and has consequences for the contribution of West Antarctica to sea-level lowering during the LGM.

While our simple kinematic 1-D model captures the general features of ice-cap flow, it does not explicitly account for horizontal advection of ice layers, or for transient thermal impacts on ice deformation. In addition, our parameterized treatment of the special divide strain-rate pattern is relatively crude. We have deliberately not incorporated any accumulation-rate data from Siple Dome. The presentation by S. Price et al. confirms that the general features of our thickness history are reproduced in a thermomechanical ice-flow model, and provides an independent test of our preferred divide-migration history.