

Environmental variability and change impacts on firn memory in West Antarctica

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Ice sheets of the earth are repositories of clues to past climates. It has long been recognized that cold, high accumulation sites provide the optimum conditions for preservation of the climate record in the firn. Sampling in spatial arrays across an ice sheet enables elucidation of local, regional, or global influences, yet local mean annual temperatures and accumulation rates vary across Antarctica; not all sites are high accumulation, cold sites. Snow is one of the earth's most dynamically changing naturally deposited porous media, and can experience dramatic changes in response to changing weather and climate patterns. Snow microstructure and permeability of firn act as indicators of the local climate.

Temporal changes in local climate at any given site may also occur, on many different time scales. Temporal changes in accumulation rate and temperature at a site impact the metamorphic processes in the near-surface snow and firn, and these remain recorded as changes in microstructure and permeability of the firn. Physical characteristics of firn cores gathered from the U.S. International Trans-Antarctic Science Expedition show great spatial variability across West Antarctica, as well as changing local climate at fixed locations. Patterns of change in the microstructure and permeability on interstitial transport in the top meters of firn reflect seasonal patterns and also decadal changes in local accumulation rate and temperature. Local climate and the dynamics of the snow and firn properties are closely linked, and the interaction affects both the extent of near-surface snow-air transfer processes as well as diffusion rates of interstitial gases deep in the firn.

Climate in the years immediately following deposition creates the subsequent profile of permeability in that firn. These patterns in permeability persist as those layers become buried more deeply in the firn. The variation in the microstructure and permeability profile affects gas diffusion as the layers become embedded deeper and deeper in the firn, including near pore close-off. Temporal variability in firn microstructure and permeability and their effects on diffusion in the firn column account most likely for past anomalous firn air measurements that could not be explained through traditional density-porosity measurements.