Impact of density and microstructure on bubble close-off in layered firn at a new site near Dome Fuji, East Antarctica

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Knowledge of firn densification, layering and bubble trapping processes is crucial for better understanding of ice-core signals in terms of chronology and past climatic changes. Recent studies have found that not only density but also microstructure of firn such as open pore structure (Gregory et al., 2014) controls bubble close-off at firn-ice transition. However, because the relationship between microstructure and bubble close-off is poorly understood due in part to the lack of continuous high-resolution data on microstructure, typical firn densification models only include density for parameterizing the bubble close-off (e.g., Mitchell et al., 2015). Thus, it is nesessary to further investigate the relationship between microstructure and bubble close-off with fine measurement intervals along firn cores.

We investigated the evolution of centimeter-scale layerings of density and microstructure, and their relationships to bubble close-off, in a 152-m firn core collected at a site about 54 km south of Dome Fuji station (77°47’18S, 39°3’15E, 3763 m a.s.l.). This site is tentatively named as NDF. We obtained high-resolution and continuous profiles of multiple physical properties along the ice core. The properties include (i) microwave permittivity ε and (ii) dielectric anisotropy $\Delta\varepsilon$ as proxies for density and geometric anisotropy of pore spaces, respectively (e.g., Fujita et al., 2009), (iii) reflectance R for near-infrared light as a proxy for specific surface area, and (iv) qualitative permeability by an air-sucking system (Langway et al., 1993).

We found significant positive correlation between $\Delta\varepsilon$ and R, calculated within 50-cm segments, from about 2 m below surface down to the bottom of firn. The positive correlation suggests that the layers with vertically elongated pores have relatively large specific surface area. Moreover, the correlation down to the bottom of firn suggests that these microstructural features are preserved until pores are closed off. In the bubble close-off region (~ 80 – 102 m), in addition to the general tendency of increasing impermeable layers with increasing bulk density, we found impermeable layers with relatively low density. This observation suggests that bubble close-off is not established at a fixed density. We also found that such low-density impermeable layers have relatively large $\Delta\varepsilon$ and small R. Based on these relationships between density, microstructure and bubble close-off, we hypothesize that the layers with vertically elongated pores are closed off in relatively low density, with specific surface area reduced by pore closure. To confirm this hypothesis, we are advancing the investigations with (v) higher-resolution density measurements, (vi) X-ray computed tomography for documenting microstructure, and (vii) closed porosity measurements, on selected depth intervals such as the low-density impermeable layers.

References

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