Formation of layered firn within near-surface depths around Dome Fuji, East Antarctica from physical and chemical analyses of multiple firn cores

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The physical and chemical properties of polar firn and their layerings initially formed or developed in the near-surface snow and affect the densification and bubble close-off process of firn (e.g., Hörhold and others, 2012; Fujita and others, 2016). Thus, it is important to better understand the formation of layered physical and chemical properties in near-surface firn. However, at low accumulation (< ~30 mm w.e. yr^{-1}) sites where deep coring is performed, there are little continuous and multi-property data (e.g., density, microstructure, water isotopes and impurities) from the same sample, partly because near-surface firn (at ~0–5 m) is often too fragile to collect in high quality. Hence, it is not well understood how density, microstructure, and their layering evolve with depth through temperature gradient metamorphism and how the layering of density and microstructure relates to the layering of chemical components. To solve these questions, we performed continuous and high-resolution (2.5–20-mm increment) analyses of multiple physical and chemical properties of firn cores and snow pit samples from seven sites around Dome Fuji (Table 1 and Figure 1). The properties include (1) density measured by a gamma-ray absorption method, (2) microwave permittivity ε as a proxy for density, (3) dielectric anisotropy Δε as a proxy for vertical elongation of ice and pore spaces, (4) near-infrared reflectance R as a proxy for specific surface area, and (5) $\delta^{18}O$, (6) Na concentration (5 and 6 are measured by a continuous flow analysis system). Here, we mainly focus on the top few meters of the samples. We found that, within the top ~3 m for all the measured samples, density increase tends to be smaller than that at deeper depths, Δε increases (more at lower accumulation sites), and SSA rapidly decreases. We also suggest that Δε increases preferentially in higher-density layers and the contrast between higher-density and lower-density layers is enhanced through temperature gradient metamorphism. In addition, we identified layers considering density, microstructure and chemical components together: (1) winter-spring layer preserving higher Na and lower $\delta^{18}O$ around Sep. – Nov., (2) Hard depth hoar with higher density, Δε and SSA, and (3) Skeleton-type depth hoar with lower density, Δε and SSA.

Sample name	Year of coring	Core length (m)	10 m snow temperature (°C)
S80	Jan. 2013	30	-
NDF18	Dec. 2017	152	-56.4
NDF13	Dec. 2012	31	-
NDFN	Dec. 2018	142	-
DFSE	Dec. 2017–Jan. 2018	41	-58.1
DFS	Dec. 2010	122	-
DF pit	Dec. 2007	3	-57.3
DFNW	Jan. 2018	43	-56.2

Table 1. Information of the samples.

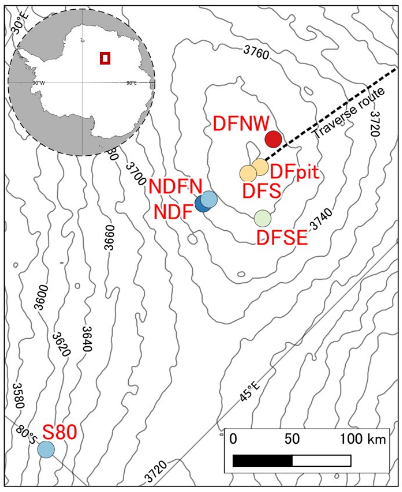

Figure 1. Locations of the sites where a firn core or snow block samples were collected.

References

Fujita S and others (2016) Densification of layered firn in the ice sheet at Dome Fuji, Antarctica. Journal of Glaciology 62(231).

Hörhold MW, Laepple T, Freitag J, Bigler M, Fischer H and Kipfstuhl S (2012) On the impact of impurities on the densification of polar firn. Earth and Planetary Science Letters 325–326, 93–99.