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A mechanism for local insolation modulation of gas transport conditions during bubble close-off in the firn in Antarctica

Shuji Fujita[1]; Junichi Okuyama[2]; Akira Hori[3]; Takeo Hondoh[4]

[1] National Institute of Polar Research; [2] Advanced Applied Science Department, IHI Corporation; [3] KIT; [4] Low Temperature Sci,Hokkaido Univ

The evolution of the structure of a 112.59-m-long firn core recovered at Dome Fuji, East Antarctica, was investigated in order to improve understanding of firn densification and bubble formation processes, which are important for interpreting local insolation proxies used for astronomical dating of deep ice cores. We measured physical properties including: (i) the relative dielectric permittivities in both the vertical and horizontal planes, (ii) the bulk density at a resolution of millimeters, (iii) the three-dimensional geometric structure of pore space, and (iv) crystal orientation fabrics. We found that the firn at Dome Fuji contains horizontal strata with thicknesses of several centimeters. Near the surface of the ice sheet, these strata are characterized by contrasting bulk density. Earlier field studies suggest that summer insolation causes densification of surface firn. Down to ~30 m, density maxima exhibited a clear positive correlation with the strength of structural anisotropy and c-axis clustering around the vertical. In contrast, the correlation is negative in deeper firn, confirming previous findings that initially less-dense firn became denser than initially dense firn. In addition, numerous examples of textures indicating that deformation preferentially occurred in weaker layers were found. Moreover, the initially dense firn layers with larger structural anisotropy were more permeable for air near the bottom of firn. We propose a model linking firn properties with conditions for the gas transport processes near the bottom of firn. The model explains how stronger insolation can lead to bulk ice with a lower O_2/N_2 ratio and smaller total gas content.