Annually resolved *d*-excess record from a shallow ice core (DFS10) near Dome Fuji station, East Antarctica

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Ice cores are well preserved and utilized as proxies for past climates and temperature reconstruction. A second-order equation given by the deuterium excess[1)] (referred to as *d*-excess), $d = \delta D - 8 \times \delta^{18}O$, is defined from the Meteoric Water Line. Here, δD and $\delta^{18}O$ are the isotopic water compositions given by δD or $\delta^{18}O$ (‰) $= (R_{measured} - R_{VSMOW})/R_{VSMOW}$, where R is the ratio $^2H/^1H$ or $^{18}O/^{16}O$, R_{VSMOW} is the reference standard, Vienna Standard Mean Ocean Water, and $R_{measured}$ is the measured ratio of a sample.

The *d*-excess is primarily related to physical parameters such as relative humidity, air temperature, sea surface temperature of the oceanic source or precipitation at the site, and the trajectory of moisture source.[2)] On a global scale, an annual average value of d is relatively constant around 10.

Vimeux *et al.*[3)] demonstrated the *d*-excess changes during transition from the glacial and interglacial periods of Vostok deep ice core data; the changes were well characterized in the plot of *d*-excess versus δD, implicating changes in oceanic moisture sources as a result of changes in Earth's orbital obliquity. The *d*-excess records for the Dome Fuji site have been studied with daily snow precipitation[4,5)] and a deep ice core spanning the past 360,000 years.[6)] So far, moisture sources and climate changes have been studied for deep ice cores in Antarctica which span a long period; however, is it possible to determine the same tendency on short scales with annually-resolved *d*-excess data from shallow ice cores? Here, we briefly report the correlation of *d*-excess with $\delta^{18}O$ in a shallow ice core.

The shallow ice core (DFS10) was drilled in 2010 from the site at 10 km south of Dome Fuji station, East Antarctica. The DFS10 site is located (77°40'S, 39°62'E) at 3,800 m above sea level. The ice core drilling project was conducted by Japanese Antarctic Research Expedition. The analyzed samples represent a temporal resolution of about one year ranging from 2 m to 60 m in depth (∼1300 years). All samples were analyzed using Liquid Water Isotope Analyzer (Los Gatos Research, Inc.) at RIKEN.

A linear relation between δD and $\delta^{18}O$, with a slope of 7.77, $R^2 = 0.987$ for DFS10 was determined. This is close to the local meteoric water line. The *d*-excess shows no correlation with $\delta^{18}O$ (δD) on an annual or short scale; however, simulation studies established a correlation on longer scales with other ice cores drilled in Antarctica. Fig. 1a shows a smoothed 50 data points running average of *d*-excess plotted against smoothed $\delta^{18}O$, and clusters into groups are evident. This case shows hierarchal structures: For groups of ∼500 years, a general decrease in *d*-excess with time is observed, suggesting that the moisture source could have systematically changed through the years. Each group subdivided into shorter time scales (∼50 years) reveals smaller clusters of *d*-excess pattern changing with time (Fig. 1b). As seen here, the *d*-excess/$\delta^{18}O$ small clusters follow a pattern with time. This pattern is not observed in a similar plot with the raw data ($R^2 = 0.04$, Pearson's $R = -0.19$).

The *d*-excess variation depends on a number of factors and intensive simulation or modeling studies are necessary to provide an insight into climate change on a shorter scale, which needs to be assessed using shallow ice cores.

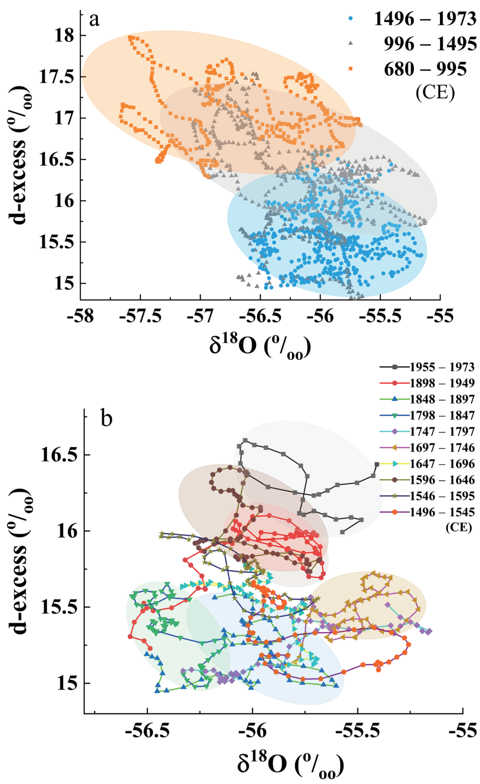

Fig. 1. (a) Deuterium excess versus $\delta^{18}O$; the data are smoothed using 50 data points running average. The color highlights the bunched ∼500 years period to show the changes in *d*-excess. (b) The same, but for data points from 1496 to 1973 CE (blue highlight from a) are subdivided into ∼50 years period.

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