Diagnose oscillation properties observed in an annual ice-core oxygen isotope record obtained from Dronning Maud Land, Antarctica

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Ice cores are time capsules that consist of snow accumulated in layers over a range of years; the deeper an ice core is, the older the age of it is. Analysing water isotopes in ice cores is one of the ways to understand climate change in the past. In particular, the oxygen isotope ratio δ^{18}O in water, H_2O, has been established as the temperature proxy in glaciology[1]. Here, δ^{18}O is defined as

$$\delta^{18}\mathrm{O} = \left\{ \frac{(^{18}\mathrm{O}/^{16}\mathrm{O})_{\mathrm{Ice\ core}}}{(^{18}\mathrm{O}/^{16}\mathrm{O})_{\mathrm{SMOW}}} - 1 \right\} \times 1000\ [‰], \qquad (1)$$

where SMOW (Standard Mean Ocean Water) indicates an international standard of the water isotope ratio. The objective of this work is to investigate the relationship between the temperature and solar activity by analyzing the oscillation properties of the δ^{18}O data.

Figure 1 shows the δ^{18}O time-series record from AD 1025 to 1997. These data were obtained from ice cores drilled in Dronning Maud Land (DML), East Antarctica[2]. The temporal resolution of the record is annual. In Fig. 1, the DML δ^{18}O data are translated into the temperature deviation from the mean using the commonly-accepted proportional relationship[1].

Figures 2 and 3 show the results of our time series analysis using Fourier analysis (FT) and auto-regressive model (AR)[3]. Here, the AR method has higher resolution than FT. As the first step, we analysed the data from AD 1825 to 1997. This is because the dating of this portion of the ice core is considered to be relatively precise. As shown in Fig. 2, we obtained a clear signal of a 21-year periodicity using the AR. This peak almost corresponds to the peak of FT within the range of the FT's step size. Next, we analysed the overall data from AD 1025 to 1997. As shown in Fig. 3, we obtained signals of periodicity around 102, 126, and 194 years using the AR.

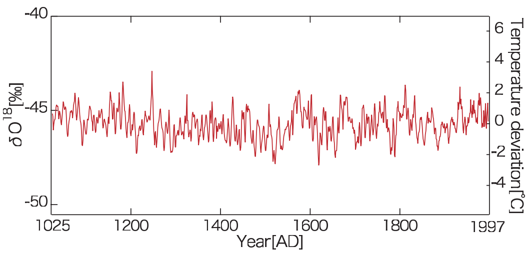

Fig. 1. Oxygen isotope ratio (δ^{18}O) time series record (left vertical axis) in DML[2] and corresponding temperature deviation (right vertical axis) are shown.

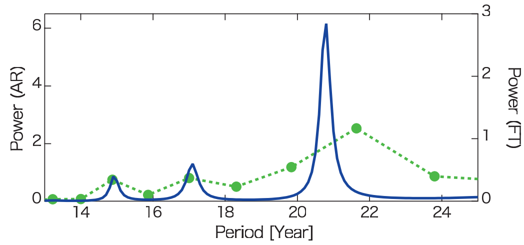

Fig. 2. Power spectra obtained from analysing the δ^{18}O record from AD 1825 to 1997. The solid blue line and green circles represent the results obtained using the auto-regressive model (AR) and by Fourier analysis (FT), respectively.

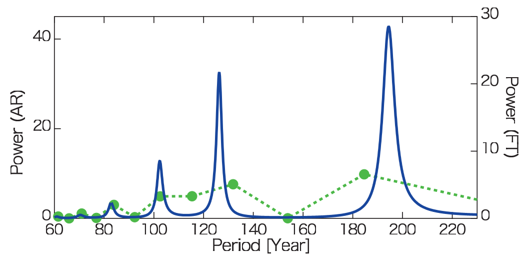

Fig. 3. Power spectra for the data from AD 1025 to 1997.

Furthermore, we also analyzed the measured surface temperature record in the southern hemisphere from AD 1850 to 2015 (HadCRUT4)[4]. We then confirmed that these observed surface temperatures have a 21-year oscillation periodicity. This result is the same as that of DML (Fig.2). It is thus confirmed that the DML δ^{18}O data actually reflected temperature history.

From the observed sunspot numbers and ^{14}C content in tree rings, ∼11, ∼22, ∼90, and ∼200 years are known to be solar activity cycles. In our analysis, nearly 22 and 200 year cycles were obtained. Therefore, the temperature modulation in the DML ice core record is suggested to be related with the solar activity cycles. The significance analysis for the obtained signals is in progress.

References

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