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Dating a tropical ice core by time–frequency analysis of ion concentration depth profiles

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SUPPLEMENT

1 Influence of interpolation methods on ice core chronologies

To get samples regularly distributed in depth, the raw data must be interpolated. Several interpolations can be applied. In order to evaluate the influence of the interpolation method, we compare the results of time frequency analysis (see text for the detail of the method) applied to nitrate concentration depth profile using successively linear, nearest neighbour, Hermite polynomial and spline interpolations. As detailed in text (section 4.1), concentrations in a few very high peaks considered as outliers have been preliminary thresholded.

1.1 Presentation of the results

The main comparisons used to evaluate the potential influence of each interpolation methods are summarized in four figures:

- Fig.S1: Spatial frequency as a function of depth, estimated with successively linear, nearest neighbour, Hermite polynomial and spline interpolations.
- Fig.S2: Upper panel: Chronologies deduced from nitrate concentration depth profile using the four interpolation methods. Fig.S2-lower panel: Ice-age differences of these four chronologies with the average chronology as a function of depth.
- Fig.S3: Ice age differences along the 36 upper meters (we) between the chronology of de Angelis et al. (2003) and chronologies deduced from NO_3 concentration depth profile pre-processed with linear, nearest neighbour, Hermite polynomial and spline interpolation of the raw data.
- Fig.S4: Spectra of nitrate concentration depth profile as a function of time delay estimate: raw data have been previously interpolated with successively linear, nearest neighbour, Hermite polynomial, and spline interpolation.

1.2 Analysis of the results

The chronologies presented here are based on the determination of concentration spatial frequency as a function of depth (expressed in $m\ we$). Fig.S1 shows that, despite some slight differences, the four interpolations result in very consistent spatial frequency depth profiles.

In order to evaluate the effect of these slight differences, we present in the upper panel of Fig.S2 the chronologies resulting from the four interpolations. Deviations between the different chronologies are hard to see. Thus, we have reported in the lower panel of the figure the deviation of each of the four chronology from the average chronologies as a function of depth ($m\ we$). Differences remain lower than 1 year over the upper 35 $m\ we$. Deeper, the maximum value of the difference slowly increases, reaching 2 years at 43 $m\ we$ and 4 years at the bottom of the core. A more marked increasing trend of age differences is observed a few meters above the aliasing depth, between 42 and 46 $m\ we$ due to depth window size . It must be noted that the maximum age difference at the bottom of the core (4 years) accounts for only 1% of the whole duration (400 years).

It can be observed in Fig.S3 that the four interpolations result in chronologies closely approaching the chronology deduced from the search for annual layers combining several markers (de Angelis et al., 2003). The difference maximum is lower than 1 year above 30 $m\ we$ and reaches 2 years (linear interpolation) in the deepest part of this core sequence.

Table S1. Frequency (yr^{-1}) of the main peak observed in spectrum of concentration estimate profiles reported as a function of time delay estimate (middle column), after raw data have been pre-processed with interpolation methods listed in the left column. Differences with the 1 yr-1 period expected from signal seasonality (right column).

Interpolation	Frequency yr^{-1}	Difference to 1 yr^{-1}
Linear	1.0100	0.01
Nearest neighbour	1.0180	0.018
Spline	0.999	0.001

We show in Fig.S4 spectra of the concentration estimate profile corresponding respectively to linear (Panel A), nearest neighbour (Panel B), Hermite polynomial (Panel C), and spline (Panel D) interpolation as a function of the time delay estimate. A dominant peak close to 1 yr^{-1} is observed for data pre-processed with linear, nearest neighbour, and spline interpolations. The accurate frequency of these three peaks is reported in Table 1.

Table 1 shows that the spline interpolation gives the peak frequency the closest to the objective of 1 yr^{-1}. Only Hermite polynomial interpolation does not allow to clearly identify an annual signal since it results in 2 significant peaks (Fig.S4, Panel C), the major one being centered at $1.0232\ yr^{-1}$.

1.3 Conclusion

Although the fact to interpolate raw data necessarily influences chronologies resulting from the spectral analysis of ion concentration depth profiles, this influence seems not very important for the core studied here. Considering that Hermite polynomial interpolation failed to recover the seasonal variability expected at Illimani site while the spline interpolation results in a concentration estimate spectrum whose central frequency is the closest to the objective of 1 yr^{-1}, we have decided to use the spline interpolation in the main text.

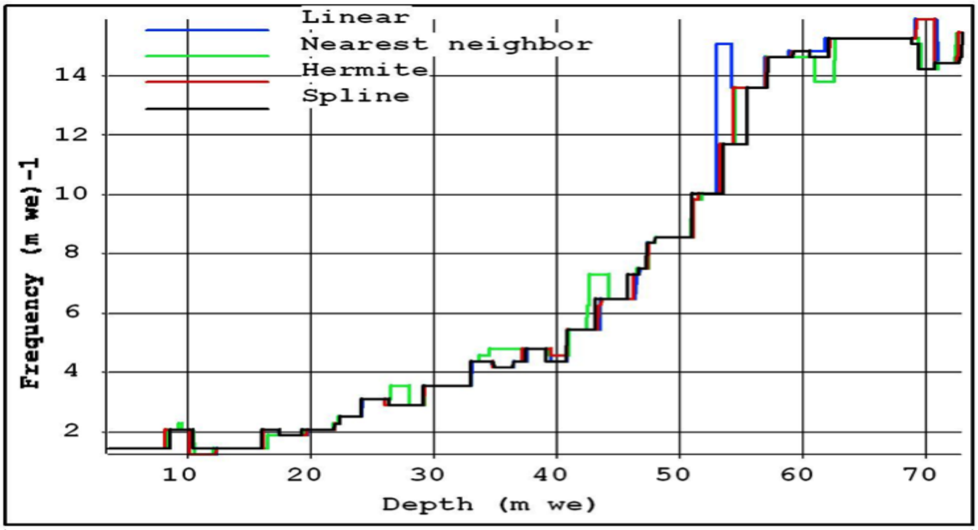

Fig. S1. : Estimate of NO_3 concentration spatial frequency as a function of depth ($m\ we$) after raw data pre-processing with linear (blue line), nearest neighbour (green line), Hermite polynomial (red line), and spline interpolation (black line).

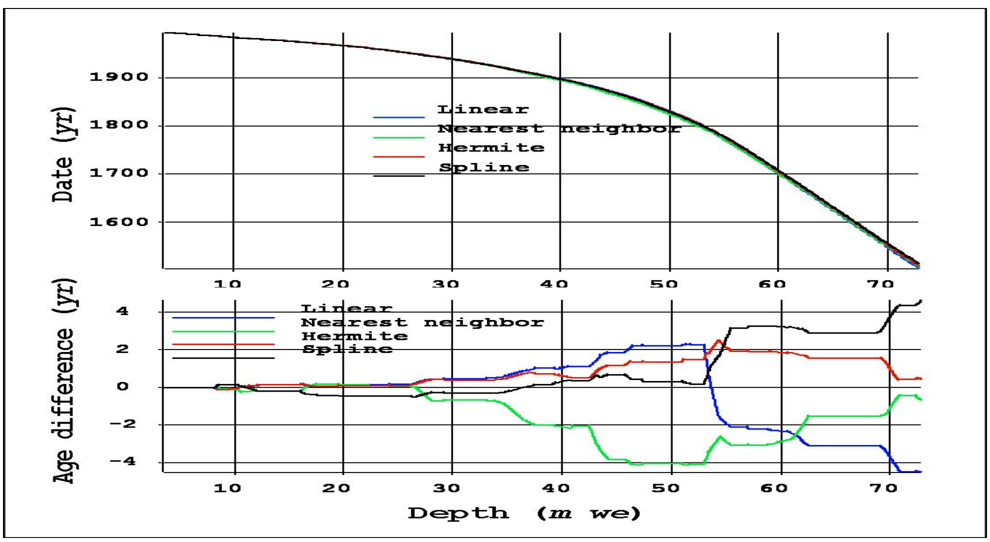

Fig. S2. : Upper panel: chronologies deduced from NO_3 concentration depth profile pre-processed with linear (blue line), nearest neighbour (green line), Hermite polynomial (red line), and spline(black line) interpolations. A2-Lower panel: Age differences (year) between each of the four chronologies (same colour code as above) and the average one as a function of depth ($m\ we$).

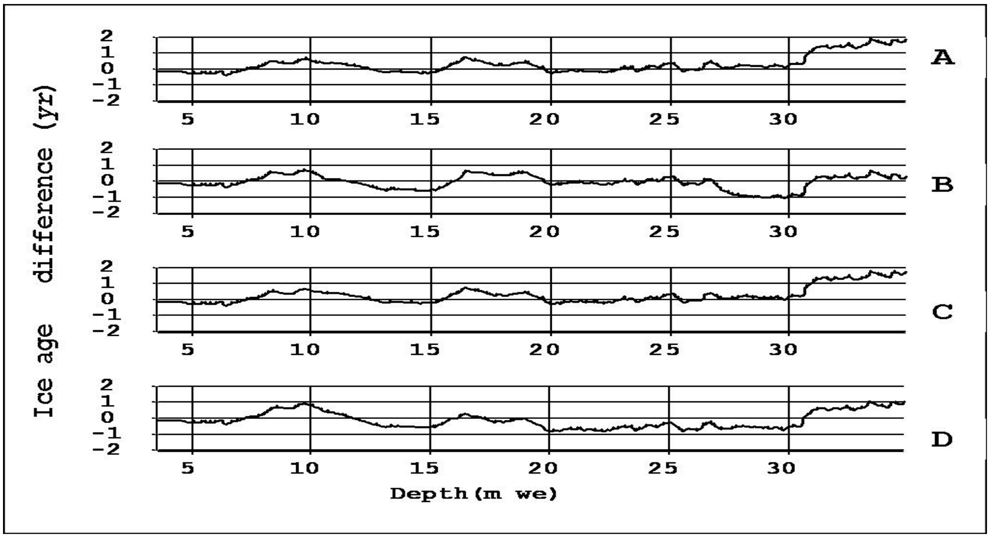

Fig. S3. : Ice age differences (year) calculated for the 36 upper meters ($m\ we$) between the chronology of de Angelis et al. (2003) and chronologies deduced from NO_3 concentration estimate after raw data pre-processing with linear (Panel A), nearest neighbour (Panel B), Hermite polynomial (Panel C), and spline interpolation (Panel D).

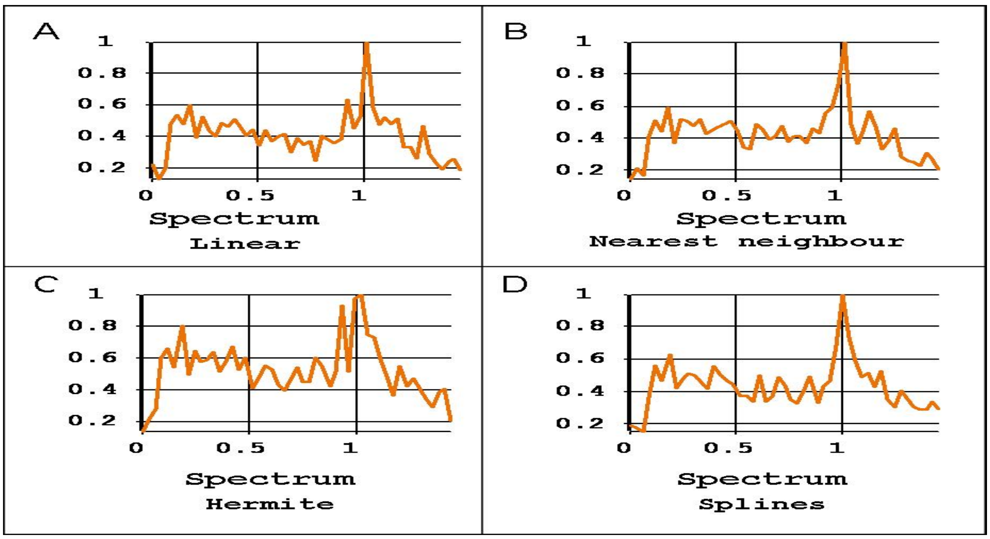

Fig. S4. : Spectra of NO_3 concentration depth profile as a function of time delay estimate, after raw data pre-processing with linear (Panel A), nearest neighbour (Panel B), Hermite polynomial (Panel C), and spline interpolation Panel D).