Supplement of Clim. Past, 14, 21–37, 2018
https://doi.org/10.5194/cp-14-21-2018-supplement

Supplement of

Temperature and mineral dust variability recorded in two low-accumulation Alpine ice cores over the last millennium

Pascal Bohleber et al.

Correspondence to: Pascal Bohleber (pascal.bohleber@iup.uni-heidelberg.de)

A semi-quantitative treatment of the snow deposition influence on average Ca^{2+}-concentrations and a possible coupling to atmospheric temperature

We attempt to semi-quantitatively explore the imprint of snow preservation on the long-term variability in Ca^{2+}, using the conceptual model by Wagenbach et al. (2012) and considering $\delta^{18}O$ as a reference. The model assumes sinusoidal cycles for the precipitation-borne signal $S(t)$ and the surface accumulation pattern $A(t)$, and a phase-lag t_ϕ between $S(t)$ and $A(t)$. The deviation Δ of the mean signal recorded in the firn at CG ($\bar{S}_{\mathrm{firn}}$) with respect to the overall mean signal (S_0) in the precipitation then becomes (corresponding to equation (5) in Wagenbach et al. (2012)):

$$S(t) = S_0(1 + s_r\, sin\omega(t + t_\phi)) \qquad A(t) = A_0(1 + a_r\, sin\omega t) \qquad \Delta = \bar{S}_{\mathrm{firn}} - S_0 = S_0\, s_r\, a_r\, cos\omega t_\phi \tag{1}$$

with a_r and s_r denoting the relative signal amplitudes, t_ϕ the temporal phase shift between the two cycles and ω the cycle frequency equal to 2π/T (period T = 1 yr). We reproduced here the calculation for $\delta^{18}O$ by Wagenbach et al. (2012) with typical seasonality parameters at Colle Gnifetti (e.g. $a_r = 0.8$). To estimate Δ for Ca^{2+}, we used values reported by Preunkert et al. (2000) for CG, i.e. taking $S_0 = 112$ ppb (the average of typical summer and winter concentrations) as well as $s_r = 0.64 \pm 0.26$. Notably, this value of s_r for Ca^{2+} is close to the absolute value of $s_r = 0.5$ obtained for $\delta^{18}O$ by Wagenbach et al. (2012). Estimating the radiation-induced control of snow consolidation on the seasonal net accumulation cycle at CG is consistent with a phase shift of $t_\phi = 1.5$ months (broadly equal to the delay of the isotope/aerosol peak with respect to insolation (Wagenbach et al., 2012)). Figure 2 shows the deviation Δ for Ca^{2+} and $\delta^{18}O$ as a function of phase shift t_ϕ and a_r.
The framework of the conceptual model allows us to semi-quantitatively explore a potential coupling of the long-term Ca^{2+} signal to atmospheric temperature via snow preservation effects. For instance, the effect of warmer atmospheric summer temperatures on snow preservation is envisaged as increased summer snow deposition, corresponding to an according change in a_r and, an additional possibility, a change in phase-shift t_ϕ. In the model, a more efficient snow-preservation for dust-rich layers would correspond to a decrease in phase-shift t_ϕ. We follow Wagenbach et al. (2012) and highlight the sensitivity in the deviation corresponding to an arbitrarily chosen variability of a_r of $\pm 10\%$ and $t_\phi = 1.5 \pm 0.5$ months. This already shifts the mean Ca^{2+} level by about 15 ppb, which is in the same order of magnitude as the long-term trends of around ± 50 ppb found in previous studies (Wagenbach et al., 1996) and also in the core investigated here. The potential variability in the Ca^{2+}-seasonality due to the episodic input of Saharan dust can add a substantial contribution to the deviation (cf. dashed lines in Figure 2). However, the influence of a single Saharan dust event is rather short-term in comparison to the envisaged systematic shifts to a_r and t_ϕ imposed by atmospheric temperature change.

Table 1. Absolute age horizons used in datings of KCC and KCI

Horizon	Year AD	Depth KCC [m WE]	Depth KCI [m WE]
Dust	1977	8.8	4.7
Tritium	1963	11.2	5.8
Dust	1947	15.3	7.7
Dust	1901/02	22.2	11.5

Table 2. Radiocarbon ages used in datings of KCC and KCI

Core	Depth] [m WE]	^{14}C cal [yr b1950]	^{14}C cal sigma [yrs]
KCC	38.5	736	349
	39.2	899	695
	40.9	555	179
	41.3	1007	167
	42.6	1395	300
	43.1	1405	27
KCI	26	365	200
	28.4	1217	336
	30	354	214
	33.9	647	242
	36.2	850	276
	38.5	1178	179

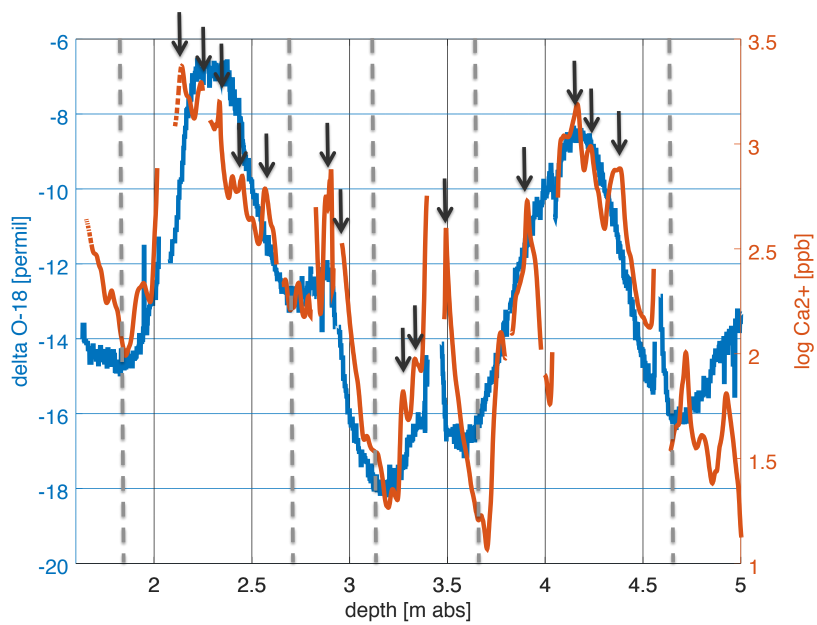

Figure 1. KCC δ^{18}O and Ca^{2+} data shown for the uppermost core section (the first 1.6 m were excavated by a snow trench for drilling). The vertical grey dashed lines indicate individual annual layers determined based on the NH_4^+ profile. Black arrows show multiple sub-seasonal local maxima in the Ca^{2+} concentration, supporting the notion of "grouped peaks" revealed by the high resolution LA-ICP-MS Ca profile at greater depths.

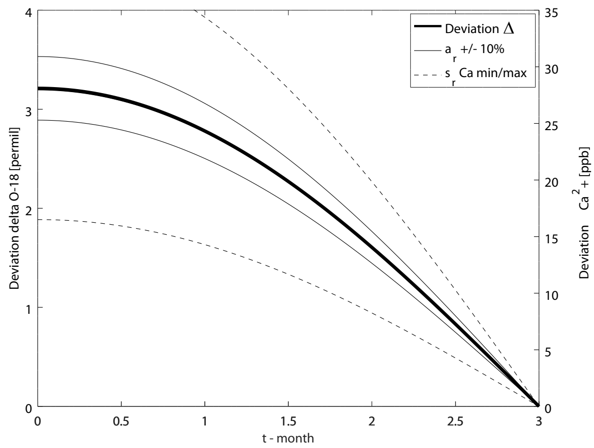

Figure 2. Sensitivity of the average Ca^{2+} signal to snow preservation effects, in comparison to δ^{18}O. The plot shows the deviation of the mean annual ice core signal from the respective precipitation mean as a function of phase shift t between the seasonal cycles of the signal and the accumulation rate. The thick solid black line shows the deviation for δ^{18}O (from Wagenbach et al. (2012)) and Ca^{2+}, plotted on the y-axes on the left and right axis, respectively, and using typical seasonality parameters at Colle Gnifetti (see text). Indicated as thin lines are ranges corresponding to a variability of the relative seasonal amplitude a_r of 10% (arbitarily chosen), and using the estimated maximum uncertainty range of s_r for Ca^{2+} (solid and dashed lines, respectively).

References

Preunkert, S., Wagenbach, D., Legrand, L., and Vincent, C.: Col du Dôme (Mt Blanc Massif, French Alps) suitability for ice-core studies in relation with past atmospheric chemistry over Europe, Tellus, 52B, 993–1012, 2000.

Wagenbach, D., Preunkert, S., Schäfer, J., Jung, W., and Tomadin, L.: Northward transport of Saharan dust recorded in a deep Alpine ice core, in: The impact of desert dust across the Mediterranean, pp. 291–300, Springer, 1996.

Wagenbach, D., Bohleber, P., and Preunkert, S.: Cold alpine ice bodies revisited: What may we learn from their isotope and impurity content?, Geografiska Annaler: Series A, Physical Geography, 94, 245–263, 2012.