Variability in marine biogenic species in the EPICA ice cores during the last 150'000 years: Effects of aerosol deposition or bio productivity?

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INTRODUCTION

The European Project for Ice Coring in Antarctica (EPICA) provided deep ice cores from two drilling sites in Antarctica. The Dronning Maud Land (DML) core at [00°04'E, 75°00'S], representing climate variability of the Southern Atlantic Ocean, and the Dome Concordia (DC) core at [123°21'E, 75°06'S], mainly reflecting changes of the Indic part of the Southern Ocean (figure 1). Both cores reach back to at least the cold stage MIS 6. Ion chemistry measurements allow conclusions on source strength and transport efficiency of sea salt, bio production compounds, dust, volcanoes etc. In the framework of the EPICA project, the aerosol chemistry is analyzed by ion chromatography (IC) in relatively high resolution at both cores. This poster will give deeper insight in the components originating from biological productivity methanesulfonate (MS) and non sea salt sulfate (nss-SO_4). As so far only for the DC core an independent depth age scale has been established, the cores were synchronized by matching conspicuous peaks and dips in the dust records. The dust record was chosen because of the identical source region (Patagonia) for both sites. The shown records are resampled to a resolution of 100 years, as this can be sustained for large parts of the cores. First comparisons show synchronous temporal evolutions of chemical components in both cores.

One of the few significant discernible differences can be seen in the MS record of both cores concerning concentration levels, variability and phasing. As MS measured in ice cores is subject to diverse influences, the interpretation of this observed deviations is challenging. For MS, those deviations could be caused by regional differences in MS production, or differences in accumulation and dust deposition, implying changing MS fluxes or postdepositional losses.

The surprisingly constant flux of nss-SO_4 at DC is in contradiction to the often mentioned iron fertilization hypothesis of the Southern Oceans (SO) biosphere. An unchanged productivity of the SO during the last Glacial would have a large imprint on existing models of the carbon cycle. However, the record of the nss-SO_4 flux from DML shows an increased during the LGM. In this poster the influence of transport and source strength of nss-SO_4 measured at DML is estimated.

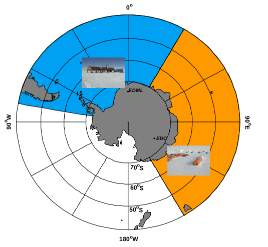

Figure 1: The drilling sites DML and DC in Antarctica with the source region of deposited aerosol marked roughly in blue (DML) and red (DC)

MS

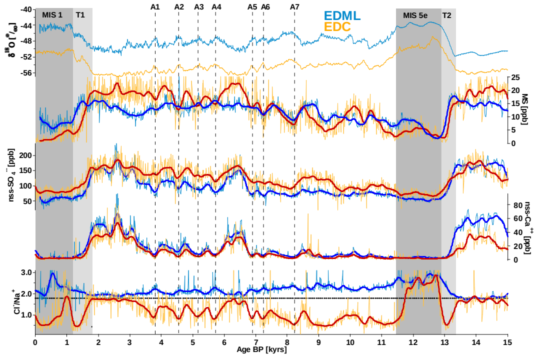

Figure 2: Oxygen Isotopic ratio, MS, nss-SO_4, and nss-Ca concentrations as well as the Cl/Na ratio from DML and DC in centennial resolution. The horizontal line shows the standard sea water ratio of Cl/Na. The dotted vertical lines roughly mark the Antarctic warm events, labeled by A1-A7. Interglacials and transitions are shaded grey, thick lines show the 2000 years low pass filtered records. Volcano events in nss-SO_4 are removed.

The MS concentration records from DML and DC (figure 2) show only few similarities. They differ in concentration level, long and short term variability and phasing. The poor correlation of both MS records suggests other processes than changes in source strength to be responsible for the observed signal. Most likely loss processes are worth to be considered.

At DC, the utilization of loss processes as main influence for the observed variation in MS is a plain sailing. This can be clearly seen when comparing the DC MS record to the Cl/Na ratio. Röthlisberger et al., 2005 have shown the dependency of the Cl/Na ratio on postdepositional loss for the past 45kyrs. This loss is especially strong in periods of low dust levels, where the risen acidity of the ice supports volatilization of HCl. In these periods, the Cl/Na ratio is far below the standard sea water ratio (SWR) of 1.79. However, during the LGM, the Holocene Optimum (9-11kyrs BP) and MIS 5.5, the Cl/Na ratio close to or above the SWR indicates no loss of HCl. The good correlation of Cl/Na and MS (figure 4) suggests the same mechanism of loss responsible for MS as well as for HCl at DC. During the warm stages, higher accumulation might prevent loss of HCl, whereas during LGM the high dust levels improve fixation of HCl. There, the correlation of MS and Cl/Na breaks down as well, and some original biogenic signal might be left over.

At DML, under present conditions, loss of MS exists as well, as shown by Weller et al., 2004. Since the Cl/Na ratio is above the SWR for the entire record, loss of MS might have been not significantly increased during low accumulation periods as well. This is also supported by the loss estimation given by Weller et al., 2004, that predicts loss of more than 100% and thus clearly can not be valid in glacial times. Further on, besides long term trends, there is no correlation of MS and the accumulation rate existing in glacial times (figure 3). The dust fixation mechanism, that works well at DC, is not possible to explain all of the MS variability in glacial times as well. At the Antarctic Warm Events A2-A5 low levels of nss-Ca can account for the observed MS levels yet dust fixation fails in explaining the high MS levels during the other A events. Here, the Cl/Na record, used as transport efficiency indicator, might give a clue. According to Weller et al., 2004, no loss of HCl is observable at DML at recent conditions. This probably holds for the Glacial as well, indicated by an Cl/Na above the SWR. The formation process of HCl described by Legrand and Delmas, 1985 thus allows to interpret a period of Cl/Na close to the SWR as time of efficient transport and vice versa (figure 4). The observed Cl/Na during A events suggest an inefficient transport and might thus explain the relatively low MS levels at A2-A5.

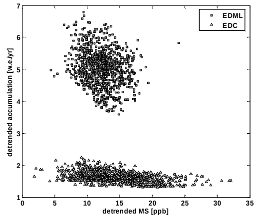

Figure 3: Scatter plot of linearly detrended accumulation rates and MS concentrations form EDC and EDML. The shown data are taken from the last Glacial only (17-115kyrs BP).

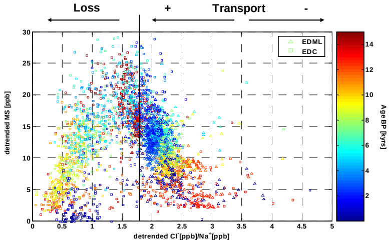

Figure 4: Scatter plot of detrended MS and Cl/Na from EDC and EDML. The colors show the actual accumulation rate. The vertical line shows the standard sea water ratio of Cl/Na.

nss-SO_4

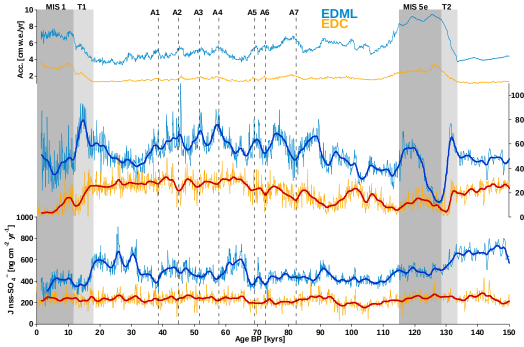

Figure 5: Accumulation rates, MS and non sea salt SO_4 fluxes from DML and DC in centennial resolution. The DML accumulation rate was estimated by thermo dynamical model based on $\delta^{18}O$. Volcano events in nss-SO_4 were removed.

Nss-SO_4 is a conservative chemical species in Antarctic ice cores. Effects of loss or diffusion are not known or of low order only. Therefore the fluxes of nss-SO_4, that are representative for concentrations in the air at low accumulation sites, can be interpreted in terms of changes in the source. Cosme et al., 2005 found at least 90% of nss-SO_4 to be derived from DMS and thus from the Southern Oceans biosphere. This makes nss-SO_4 a reliable indicator for changes in the SO bio-productivity

The DC record of the nss-SO_4 flux shows a surprisingly constant level throughout the last glacial cycle (figure 5). In DML, during the glacial maxima and between A4 and A5, the nss-SO_4 flux is increased by approximately 50% compared to the rest of the record.

The constant flux of nss-SO_4 measured at DC suggests an unchanged productivity of the Indic Ocean biosphere. A balancing effect of meridional transport efficiency and source strength appears feasible as well but not uniformly supported by atmospheric transport models.

At DML an effect of additional nutrient supply, due to the proximity to the Patagonian source of aeolian dust might be responsible for the higher LGM flux, as well as an additional effect of transport efficiency, as supported by the Cl/Na ratio. An estimate of the strength of source and transport effects at DML is performed with an simple one dimensional transport model described in the right box. To quantify the transport effect, the Cl/Na ratios found by Legrand and Delmas, 1985 on a traverse from Dumont D'Urville to DC were used (figure 6). The mean Holocene Cl/Na ratio compared to the mean LGM ratio results in a reduction of 14% of transport time from Holocene to LGM. Assuming a constant source strength of nss-SO_4 in the Holocene and in the LGM (mean fluxes were used as input parameter here), 10% of the increase of nss-SO_4 air concentration can be explained by changes in transport. As this is still below the measured nss-SO_4 flux at DML, an additional increase of source strength (40% of the Holocene level) is suggested here.

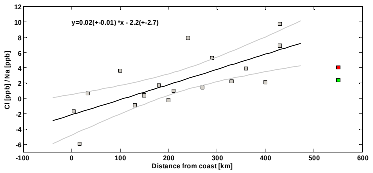

Figure 6: Cl/Na ratio with distance from coast on a traverse to DC. The used data are taken from Legrand and Delmas, 1985. The lines show the linear trend with confidence intervals (95%) for the expected Cl/Na ratio. The red square shows the composite of 12 snow pits from DML, the green square shows the mean Holocene ratio derived from the EDML core. Both are not included in the regression.

1 dimensional Transport Model

$$C_{air(t)} = C_{air0}\exp\left(-\frac{t}{\tau}\right)$$

$\tau =$ atmospheric residence time (7days)
$C_{air0} =$ atmospheric concentration at source
$C_{air(t)} =$ atmospheric concentration at time t

Input parameters (units arbitrary):

$C_{air(t)Holocene} = 400$
$C_{air0Holocene} = C_{air0LGM} = 820$

$$\left.\begin{array}{l} t_{Holocene} = 5days \\ t_{LGM} = t_{Holocene}\cdot 14\% \end{array}\right\}$$

Output:

$C_{air(t)LGM} = 440$

SUMMARY

The MS records from DML and form DC are not interpretable in terms of biogenic productivity of the SO. DC MS is clearly influenced by loss processes. The loss is especially pronounced in times of low dust and low accumulation rates.

DML MS shows an influence on dust concentrations as well, but not all variability can be explained by this. Additionally an effect of transport efficiency on MS is proposed here. This is supported by the anti-correlation of MS and the Cl/Na ratio which can be used as indicator for transport efficiency in DML.

The constant nss-SO_4 flux observed at DC is probably the result of an unchanged bio productivity during all ages in the Indic sector of the SO. At DML, where the Cl/Na ratio can be used as transport efficiency indicator, the effect of transport on the enhanced level of nss-SO_4 during the LGM is roughly estimated to account for a 10% increase. The remaining 40% increase from Holocene to LGM might be the effect of enhanced bio-productivity in the Atlantic sector of the SO. The proximity to the source of fertilizing dust, Patagonia, might be the reason why the biological source in the Atlantic shows an increase whereas the Indic biosphere does not.

References:

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