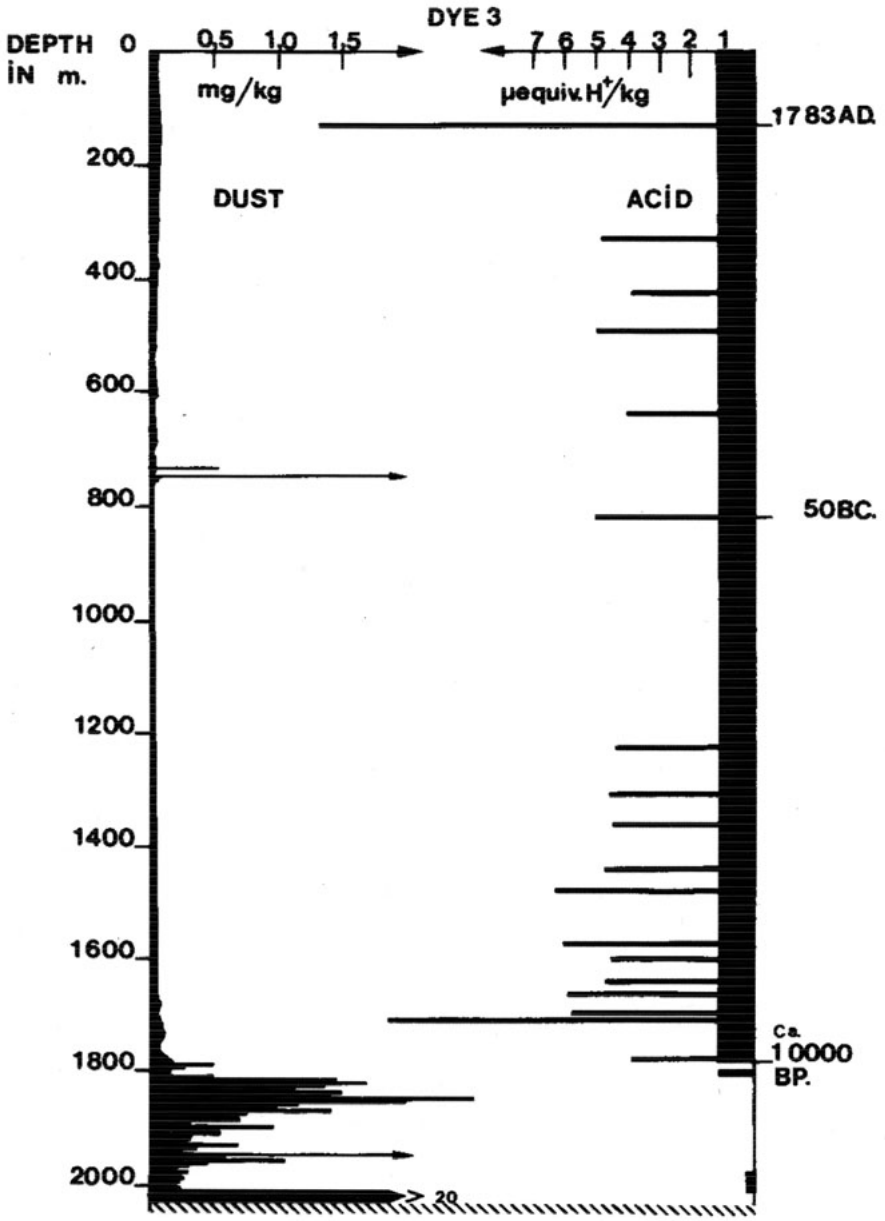
12.740 Paleoceanography
Spring 2008

Ice Core Paleoclimatology II: solutes and particulates

12.740 Topic 6 Spring 2008



Dust concentrations and acidity along the 2037 m long deep ice core from Dye 3, South Greenland, 65° 11′N, 43° 49′ W. The high acidity peaks are annual average values exceeding approximately 3.5 μ equivalent H^+/kg of ice; probably all due to major past volcanic eruptions.

Acidity and dust in Dye-3 (SE Greenland) Ice Core

Background acidity from ocean DMS emissions

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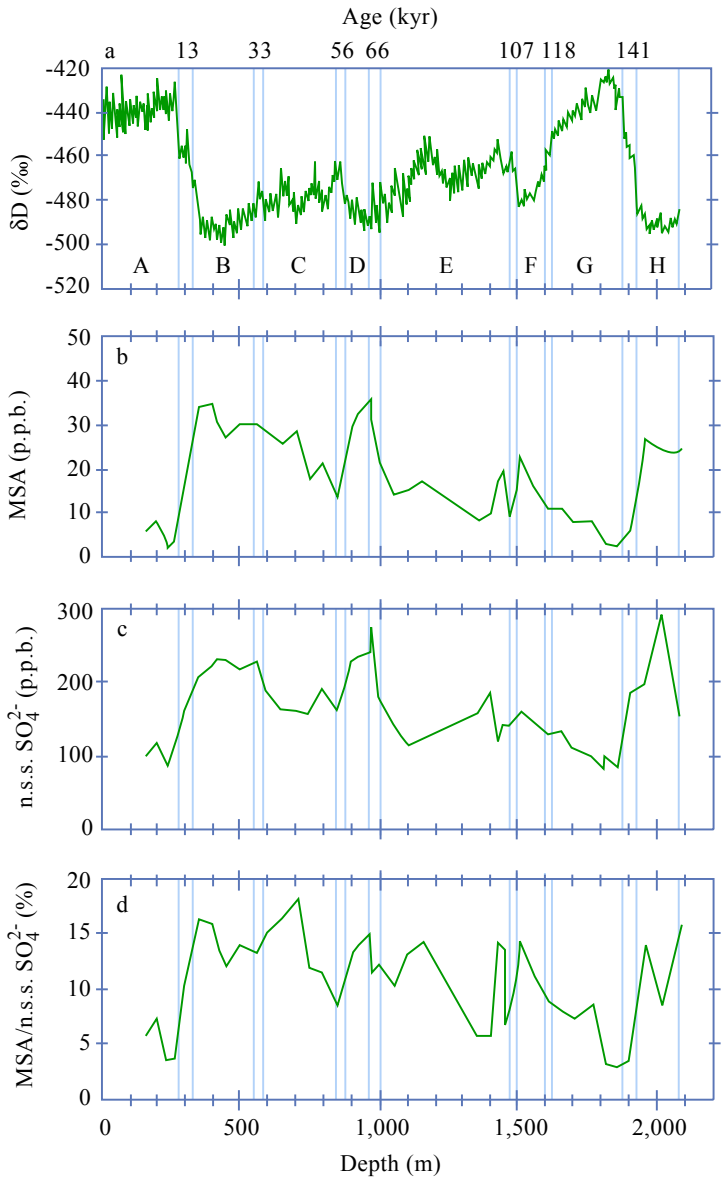


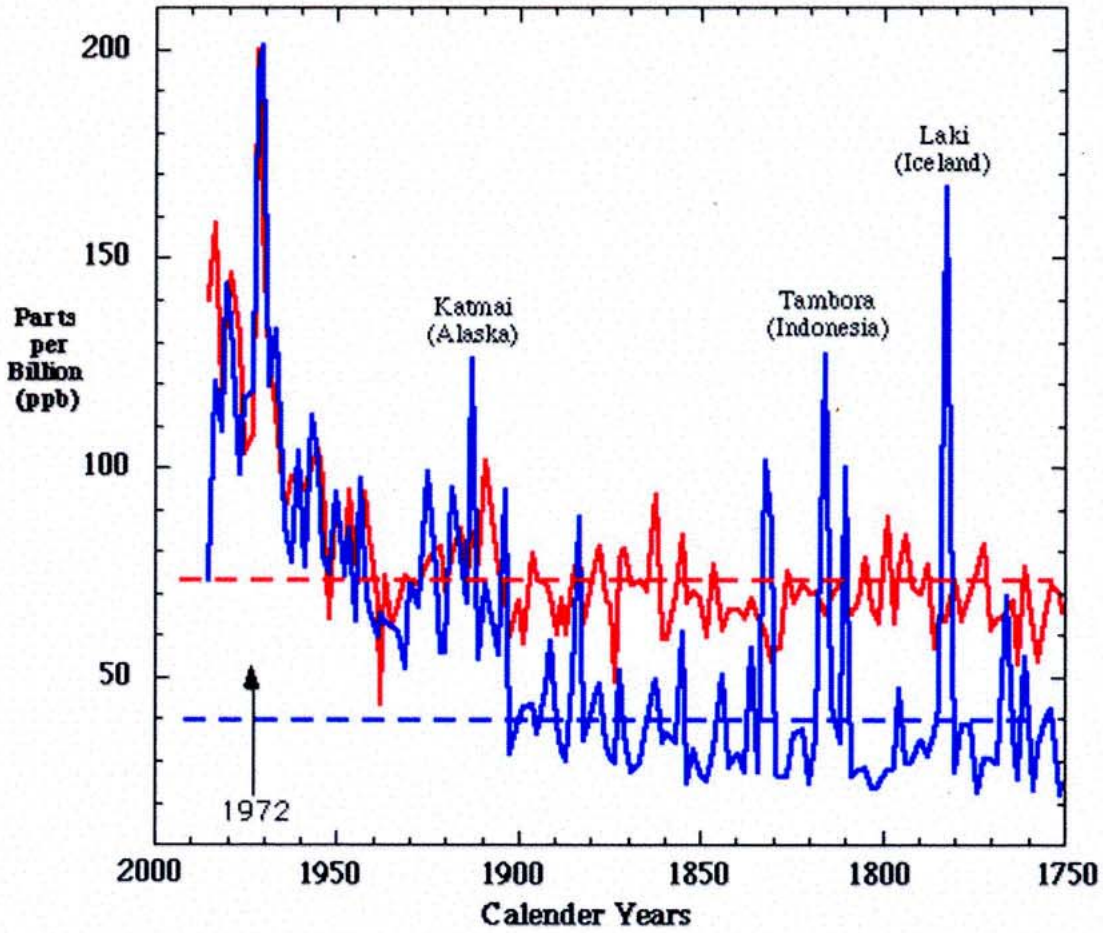
Depth profiles of a, δD, b, MSA, c, non-seasalt sulphate and d, the ratio of MSA to non-seasalt sulphate in the Vostok ice core. Upper and lower stage boundaries are marked by vertical lines. (δD is deuterium isotope profile)

Figure by MIT OpenCourseWare based on Legrand et al., 1991.

MSA and nss $SO_4^=$ in the Vostok Ice Core

? Increased DMS production or more efficient atmospheric transport?

Sulfate and nitrate in GISP 2, 1750-2000 AD



Concentrations of sulfate (blue line) and nitrate (red line) measured in the GISP2 Ice Core. Dashed lines represents the 2000 year average for each chemical measurement. Increase in sulfate starting just after 1900 is attributed to the increase in coal combustion during the Industrial Revolution. Increase in nitrate start later in the centrury and is attributed to increased burning of petroleum products. Most notable is the decrease in Sulfate concentrations since the early 1970's. This is attributed to the Clean Air Act established in the United States in 1972. Peaks in Sulfate are noted that correspond to volcanic eruptions.

(Data from Mauewski, et al., *Nature* 1990 and Zielinski, et al., *Science* 1994)

Dust and alkaline conductivity in Dye 3 (SE Greenland) Ice Core

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Toba eruption in GISP2 ice core?

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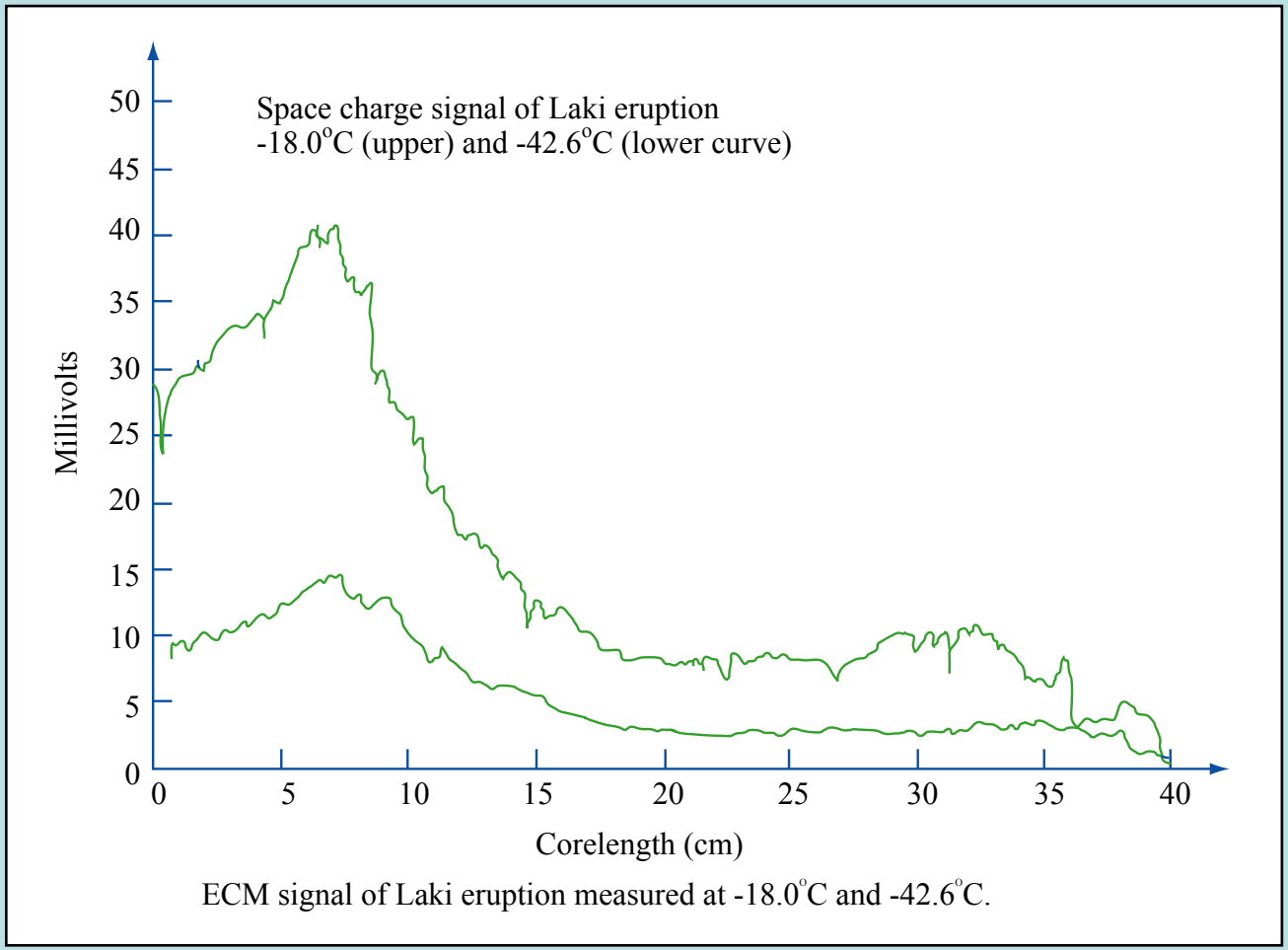
Figure 1. Time series of (A) SO_4^{2-} and Ca^{2+} concentrations, (B) electrical conductivity (ECM), and (C) $\delta^{18}O$ from the GISP2 ice core for the period between 60,000 and 80,000 years ago. Arrows show timing of Toba aerosols as related to non-volcanic Ca^{2+} and $\delta^{18}O$ records. Interstadial events 19 and 20 in (C) from *Dansgaard et al.* [1993].

Electrical conductivity of ice and volcanic acids



ECM signal of Laki eruption measured at -18.0°C and -42.6°C.

Figure by MIT OpenCourseWare.

So: volcanic acid peaks can be easily located by electrical conductivity.

However, in dusty ice, the conductivity is suppressed by neutralization of acid. ECM then becomes and indicator of the presence or absence of significant amounts of dust.

ECM for all of GISP2 and GRIP, compared to GRIP O18

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GISP2 Younger Dryas / Bolling-Allerod ECM

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Nature Vol. 361, 4 February 1993.

Expanded GISP2 Younger Dryas/ Bolling/Allerod ECM

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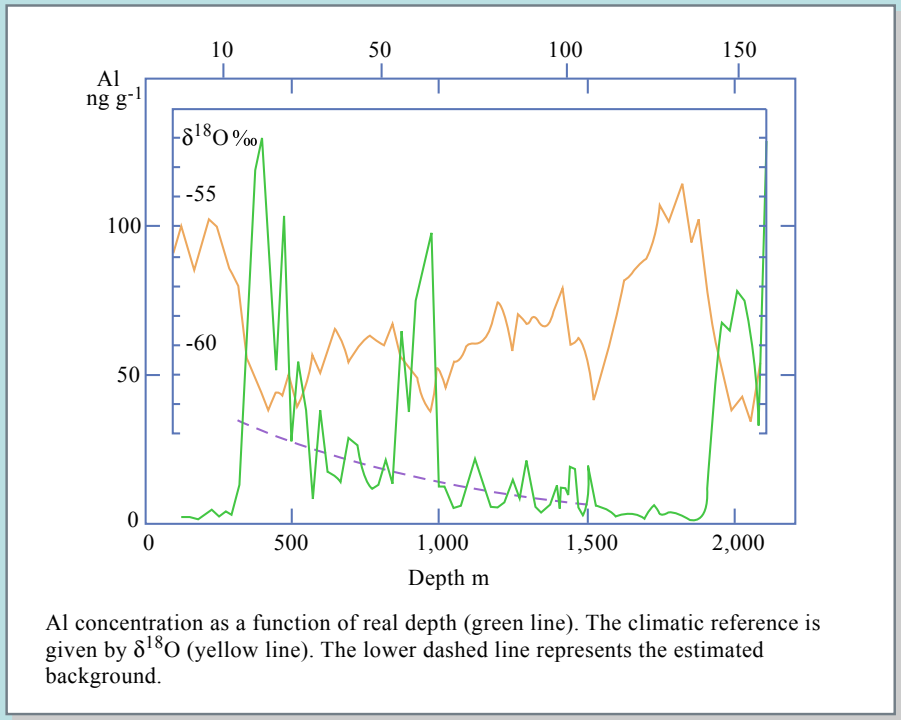
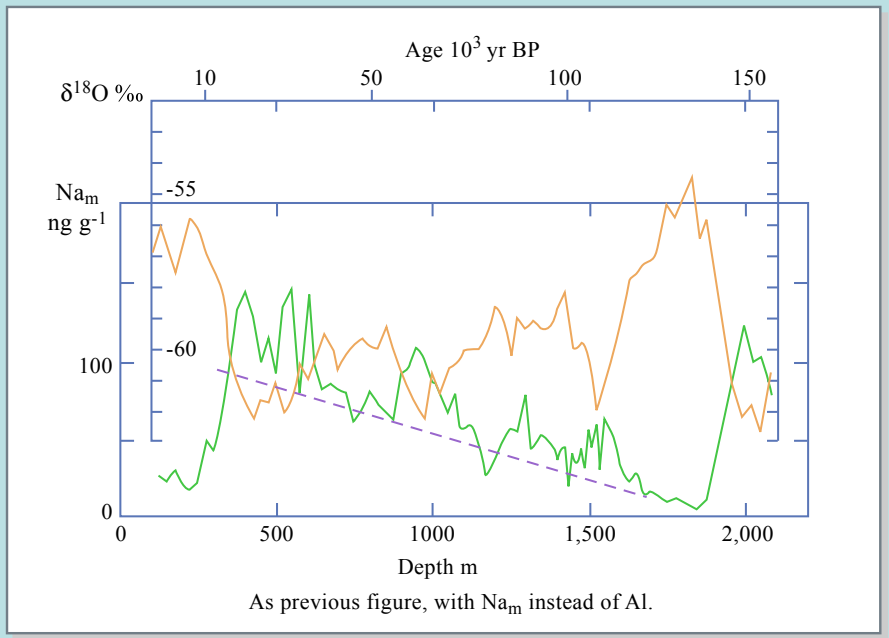
Nature Vol. 361, 4 February 1993.

Al and Na in the Vostok Ice Core



Al concentration as a function of real depth (green line). The climatic reference is given by $\delta^{18}O$ (yellow line). The lower dashed line represents the estimated background.

Figures by MIT OpenCourseWare. Adapted from de Angelis et al. (1987).



As previous figure, with Na_m instead of Al.

Reading (1)

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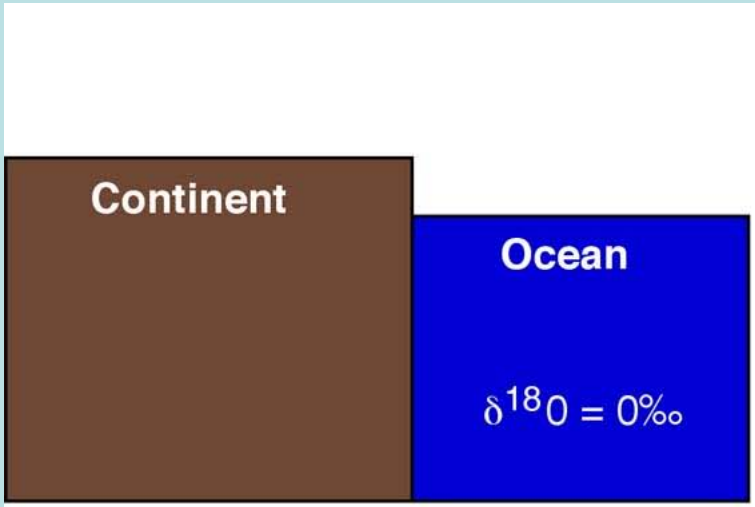
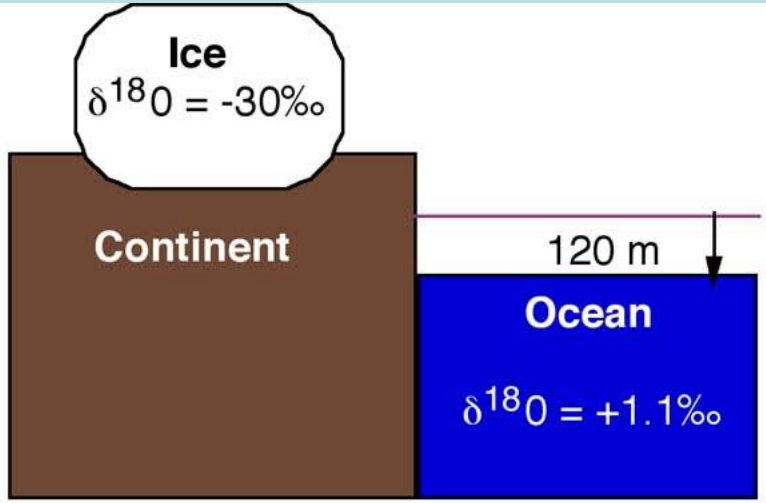
Also note: a volume of joint GISP2/GRIP results were published in JGR vol. 102 (1997, #C12 pp. 26315-26886). Many worthwhile results and summaries are contained within.

Effect of glaciation on the oxygen isotope composition of the ocean



Modern Ocean



Last Glacial Maximum
(18,000 years Before Present)

Isotope Mass Balance Equation:

$$M_o\delta_o + M_i\delta_i = M_t\delta_t$$

“Heinrich Events”: sudden invasions of the North Atlantic by dirty icebergs

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GRIP/Byrd CH_4 comparison