Ice Core Observations of Arctic Sulfate Aerosols: 800-year record of Anthropogenic, Volcanic, and Marine Biogenic Sulfur



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Introduction

The Arctic, which has warmed at twice the rate of the global average, is especially sensitive to changes in aerosol abundances. Sulfate is one of the most important aerosols in the Arctic, which has primarily been sourced from anthropogenic emissions during the Industrial Era (Smith et al., 2011). However, it is unclear how other sources of



Ice core concentrations of nssSO₄²⁻ and emissions inventories from source regions. (Cole-Dai et al., 2013)

atmospheric sulfate will change as the Arctic experiences physical and ecological changes due to climate change. Along with anthropogenic emissions of sulfur, sulfate aerosols in the Arctic have three natural sources: sea salt, volcanic eruptions, and biological activity. Concentration trends follow anthropogenic emissions trends, but sulfate concentrations are much lower in the present day than one would expect based on anthropogenic emissions inventories.

Time period (C.E)	Ice core nssSO ₄ ²⁻ conc. (ug g ⁻¹)	North American emissions (Tg S yr ⁻¹)	Total emissions (Tg S yr ⁻¹)
1850-1860	33.1 ± 9.6	0.5 ± 0.1	2.2 ± 0.4
2000-2005	36.8 ± 7.2	16.0 ± 0.8	33.0 ± 1.7
Absolute Difference	3.7 ± 12.0	15.4 ± 0.8	30.9 ± 1.8
Factor difference	0.11 ± 0.36	64 ± 2	14 ± 1

Table 1. Mean and standard deviation of ice core sulfate concentration and anthropogenic sulfur emissions from North America and the sum of North America, the former Soviet Union, and Europe (Total). Emissions are from Smith et al. (2011).

Research Questions

- How have biogenic, volcanic, and anthropogenic sulfate changed over the last 800 years?
- Why is the recent decline in total sulfate larger than expected based on anthropogenic emissions trends?

Methods

We measure δ^{34} S(nssSO₄²⁻) in ice core samples from Summit, Greenland from 1200-2005 at one- to two-year time resolution.



Figure 1. Summit, Greenland and an ice core.



Figure 2. Sulfate is concentrated using an anion-retaining resin and converted to barite (BaSO4)



Results



Figure 3. Sulfate is combusted to SO₂ and δ^{34} S is measured on a stable isotope mass spectrometer



Source	Typical δ^{34} S(nssSO ₄ ²⁻) value	
Sea salt	21‰	
Biogenic	16 to 20 ‰ -2.6 to 3.2 ‰	
Volcanic		
Anthropogenic	3 to 6 ‰	

References

Cole-Dai, J., Ferris, D. G., Lanciki, A. L., Savarino, J., Thiemens, M. H., and McConnell, J. R. (2013), Two likely stratospheric volcanic eruptions in the 1450s C.E. found in a bipolar, subannually dated 800 year ice core record, J. Geophys. Res. Atmos., 118, 7459-7466, doi:10.1002/jgrd.50587. Carn, S. A., L. Clarisse, and A. J. Prata (2016), Multi-decadal satellite measurements of global volcanic degassing, Journal of Volcanology and Geothermal Research, 31, 99-134, doi:10.1016/j.jvolgeores.2016.01.002. Smith, S. J., J. van Aardenne, Z. Klimont, R. J. Andres, A. Volke, and S. D. Arias (2011), Anthropogenic sulfur dioxide emissions: 1850–2005, Atm. Chem. Phys., 11, 1101-1116,



