Can a global chemistry climate model reproduce interannual variabilities and trends of depositions of sulfate, nitrate, and ammonium preserved in the Southeastern Greenland Dome ice core?

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Inorganic compounds like sulfur and nitrogen oxides (SOx/NOx) are mainly emitted from fossil fuel combustion or high-temperature air combustion associated with anthropogenic activities. Those components are chemically oxidized in the atmosphere to form sulfate and nitrate which cause air pollution and acid rain. Aerosols like sulfate and nitrate are also involved in the global climate change, inducing negative radiative forcing by scattering solar incident and changing clouds. For accurate evaluation and future projection of global changes in atmospheric environment and climate, it is vital to quantitatively validate a chemistry climate model that simulates global distributions of aerosols including sulfate and nitrate making maximal use of available observations. In this study, we evaluate global simulation by a chemistry climate model (CHASER) using a long-term (60 years) record of aerosol depositions preserved in the High-Accumulation Dome ice core in Southeast Greenland (SE-Dome) and investigate controlling factors of interannual variation and trends in inorganic ions of sulfate (SO_4^{2-}), nitrate (NO_3^-), and ammonium (NH_4^+).

It is found that our model simulation basically well captures both seasonal cycles and interannual variabilities in the flux of each component as seen in the ice core record for 1970s to 2010. The model calculations suggest that the long-term SO_4^{2-} trend seen in the ice core (-0.15 μmol L^{-1} d^{-1}) is mostly from SO_2 emission changes in the source areas like Europe, U.S. , and Asia over the decades. In contrast, long-term trends for NO_3^- and NH_4^+ (-0.06 and 0.01 μmol L^{-1} d^{-1}, respectively) appear to be affected largely by changes in natural sources and meteorological conditions in addition to the anthropogenic emissions of NOx and NH_3.

Interestingly the model simulation replicates the spiky peaks (positive anomalies) in concentrations (particularly for SO_4^{2-}) recorded in May 1992. The peaks were tentatively attributed to the 1991 eruption of Mt. Pinatubo in the previous studies. Our model simulation, however, nicely reproduces the concentration peaks even without any direct injection from the Mt. Pinatubo to the atmosphere, implying that anomalous changes in meteorological fields (most probably for transport and precipitation) are the dominant factors of the peaks in May 1992. Actually, the model simulation suggests that there were anomalously enhanced transport pathways from Europe and North America toward Greenland and the SE-Dome site for both of SOx, NOx, and NHx.

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