Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.36991

Linking the Atmospheric Water Cycle to Trace Element Speciation in Arctic Aerosols

ESTHER S BREUNINGER[1,2,3], IRIS THURNHERR[1], JULIE TOLU[1,3], FRANZISKA AEMISEGGER[1,4], HEINI WERNLI[1] AND **LENNY H.E. WINKEL**[1,3]

[1]ETH, Swiss Federal Institute of Technology
[2]Centre for Microbiology and Environmental System Science, University of Vienna
[3]Eawag, Swiss Federal Institute of Aquatic Science and Technology
[4]University of Bern

The atmosphere is an important pathway for the essential elements sulfur (S) and selenium (Se), as well as the toxic element arsenic (As), connecting marine biological emissions to both marine and terrestrial ecosystems through atmospheric transport and deposition. The bioavailability and toxicity of these elements upon deposition depend on their chemical speciation. However, the factors controlling chemical speciation, particularly the relative roles of emission source characteristics versus atmospheric transformation during transport, remain poorly understood, partly due to the lack of independent tracers of atmospheric processing history.

Here, we present observations of S, As, and Se speciation of aerosols alongside water vapor isotopic composition ($\delta^{18}O$, $\delta^{2}H$, *d*-excess) from the Arctic Century expedition (Barents, Kara, and Laptev Seas; August–September 2021). Twelve-hour aerosol samples (n=44) were analyzed for chemical speciation of water-soluble fractions, including the S species methanesulfonic acid (MSA) and dimethylsulfoxide (DMSO), the methylated As species trimethylarsine oxide (TMAO) and dimethylarsinic acid (DMA), and organic Se. These species are derived from marine biogenic volatile emissions and represent various degrees of atmospheric oxidation and transformation. These analyses were combined with continuous ship-based water vapor isotope measurements, air parcel backward trajectory analysis, and Lagrangian moisture source fingerprints using three-dimensional wind data from the ERA5 reanalysis.

Moisture processing indicators (*d*-excess, $\delta^{18}O$, and specific humidity) define two distinct moisture source fingerprints, each associated with characteristic trace element speciation patterns. Air masses with extended oceanic transport and sustained high humidity showed the highest proportions of oxidized species (MSA, TMAO, DMA), while air masses from nearby ice-margin regions showed elevated early-stage species (DMSO, organic Se), linked to recent biological exposure at productive ice-margin phytoplankton blooms. These contrasting patterns indicate that both proximity to emission sources and atmospheric transport conditions exert strong controls on aerosol speciation.

These results demonstrate that water cycle indicators can serve as tracers of atmospheric transformation pathways for S, As, and Se. The bioavailability and toxicity of these elements to Arctic ecosystems upon deposition depends on their chemical speciation, which is strongly driven by atmospheric transport and processing conditions. Understanding these controls has implications for predicting elemental deposition fluxes under variable Arctic sea ice conditions.