Identifying water availability in the Atacama Desert (Chile) by triple oxygen isotope analyses of sulfates

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Ca-Sulfates (Gypsum and Anhydrite) are the most common salts accumulating in the soil of the Chilean Atacama Desert. Sulfate sources include sea spray, redeposition of playa sediments, terrestrial weathering, and deposition of sulfate formed in the atmosphere (secondary atmospheric sulfate = SAS). Sulfate from sea spray, playa lakes, and terrestrial weathering have a triple oxygen isotope composition ($\Delta^{17}O_{SO_4}$) at or slightly below zero reflecting reaction with water and oxygen. Positive $\Delta^{17}O_{SO_4}$ are generally the result of atmospheric $SO_2$ oxidation by ozone or hydrogen peroxide. Sulfate oxygen is only altered with ambient water by cycling through biological activity resulting in $\Delta^{17}O_{SO_4} \approx 0‰$. Therefore, $\Delta^{17}O_{SO_4}$ aids in quantifying the relative contribution of SAS to the desert soil and in identifying bioactivity and water availability in the hyperarid Atacama Desert. The spatial quantification of different sulfate sources may serve to improve the understanding of sulfate deposition in this region.

Samples were analysed by continuous flow IRMS using the pyrolysis of Ag$_2$SO$_4$ to determine $\Delta^{17}O_{SO_4}$ from O$_2$. An optimized sample preparation to form clean silver sulfate and intra-day calibration against two in-house standards resulted in an external reproducibility of 0.12‰. An inter laboratory comparison including data derived from the laser-fluorination method confirmed the accuracy of our analyses.

We analyzed desert soil surface samples from four E-W transects in the Atacama Desert reaching from the Pacific coast across the Coastal Cordillera, the Central Depression, and up the alluvial fans protruding from the Pre-Andean Cordillera. Transects begin at Pisagua (19.5°S), Salar Grande (21.0°S), Antofagasta (24.0°S), and Paposo (25.0°S). Values of $\Delta^{17}O_{SO_4}$ vary between 0.3 and 1.1‰. The lowest $\Delta^{17}O_{SO_4}$ values were measured near Salar Grande and on the Pre-Andean alluvial fans. The highest $\Delta^{17}O_{SO_4}$ values are observed at the highest altitudes in the Coastal Cordillera - east of Paposo - well above the coastal fog zone (> 1200 m). At similar or higher altitudes on the Pre-Andean fans, $\Delta^{17}O_{SO_4}$ converge towards zero.

The spatial distribution is the result of source contributions and subsequent biological reset. Positive $\Delta^{17}O_{SO_4}$ values throughout suggest a significant contribution from SAS. We quantified sea spray contributions using Cl- concentration, which drop dramatically above the fog-zone [1]. Furthermore, salt distribution suggests minimal weathering and redistribution in recent times. The lowest contribution from such near zero $\Delta^{17}O_{SO_4}$ sulfate sources are expected in the Coastal Cordillera, which is consistent with our data. Within the Coastal Cordillera there is a north to south
\( \Delta^{17}O_{SO_4} \) trend, which is also an elevation trend. Increased water availability from fog at lower elevations facilitates more efficient resetting of \( \Delta^{17}O_{SO_4} \) via microbial activity. These observations suggest that the driest place in the Atacama Desert is situated within the Coastal Cordillera above the fog zone.