Tracing nitrogen and sulfur emissions in the Athabasca Oil Sands Region, Alberta, Canada, using stable isotope techniques
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Abstract
The Athabasca Oil Sands Region (AOSR) in north-eastern Alberta, Canada, contains the world’s largest bitumen reservoir and constitutes an enormous new energy source. However, the processing of bitumen is accompanied by significant nitrogen (N) and sulfur (S) emissions. The oxidation of N and S compounds in the atmosphere results in elevated nitrate and sulfate loads and there is increasing concern about the potential impact of elevated nitrate and sulfate deposition rates on the environment in the vicinity of the emission sources. Traditional stable isotope ratios of nitrate (δ¹⁵N and δ¹⁸O) and sulfate (δ³⁴S and δ¹⁸O) have been previously used to identify nitrate and sulfate sources in various studies. In this ongoing study, we test whether we can use stable isotope techniques to determine the source and fate of anthropogenic N and S emissions in the vicinity of industrial emitters.

Nitrate (NO₃⁻) and sulfate (SO₄²⁻) in bulk precipitation and throughfall have been collected in the AOSR since 2007 and samples were taken at various distances from the main emission stacks near Fort McMurray (57.0479875 °N, 111.615502 °W), ca 450 km NE of Edmonton, Alberta, Canada. At each site, several ion exchange resin (IER) throughfall and open field samplers were installed. Throughfall samplers were mounted on tree branches, whereas open field samplers collected bulk precipitation. The resins were exposed from April 2007 to September 2007 (“summer 2007”) and from October 2007 to May 2008 (“winter 2007/2008”) at four different sites, and between May and October 2008 (“summer 2008”) at 13 different sites.

δ¹⁵N and δ¹⁸O analyses of nitrate have shown differences in ¹⁵N/¹⁴N and ¹⁸O/¹⁶O ratios of atmospheric nitrate between summer and winter samples, and between throughfall and bulk precipitation. Winter samples had higher mean δ¹⁵N_NO₃ and δ¹⁸O_NO₃ values with 0.6±1.7‰ and 74.8±5.3‰ (n=41), respectively, than summer samples with mean δ¹⁵N_NO₃ and δ¹⁸O_NO₃ values of -3.2±1.1‰ and 66.9±5.3‰ (n=103). For both summer and winter, mean δ¹⁵N_NO₃ values were higher in throughfall samples (-1.3±2.4‰) than in bulk precipitation samples (-3.0±1.8‰), indicating that throughfall contains dry deposited N from the tree canopy, likely with elevated δ¹⁵N values. In contrast, δ¹⁸O_NO₃ values collected in summer 2008 were lower in all throughfall samples compared to bulk precipitation samples.

Throughfall also had higher δ³⁴S_SO₄ values (5.1±0.1‰, n=16) than bulk precipitation (3.4±1.2‰, n=18) and is similar to the δ³⁴S value of elemental sulfur (5.3 ± 0.5 ‰, n=10) from a large industrial sulfur block implying that anthropogenic S emissions may affect the isotopic composition of sulfate in throughfall in the vicinity of industrial emitters.