



Central Arctic Atmospheric SO₂ pollution from smelters: Airborne detection and Arctic Haze formation

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Arctic Haze represents a dramatic manifestation of anthropogenic pollution of a remote and previously pristine atmospheric environment, which presently experiences faster climate warming than any other region on the planet. Arctic haze influences visibility, ecosystems, and may contribute to Arctic climate warming. In spring, Arctic Haze occupies large parts of the Arctic lower troposphere, the so called Arctic Dome. The most abundant Arctic Haze component is sulphate, which was previously thought to stem preferably from Extra-Arctic anthropogenic pollution sources. However, recent model simulations suggest that sulphate particle transport into the Arctic Dome is severely hindered. During the recent POLAR YEAR 2007/2008, in 2007, we have made the first Central Arctic SO₂ measurements with high vertical and horizontal resolution and detected SO₂ rich pollution plumes in the entire troposphere height range up to 9000 m. Below 2000 m, inside the Arctic Dome, these plumes were most pronounced and stemmed preferably from a giant Ni-Cu smelter complex, located in the Siberian sector of the Arctic Dome, near the city Norilsk, at a distance of 2100 km from our measurement region. Our measurements and accompanying model simulations indicate that SO₂ emitted by that smelter complex represents a major if not the dominant precursor of Arctic Dome cloud condensation nuclei and haze particles.

Along with SO₂, we measured aerosol particles and additional trace gases including also gas-phase NO_y (sum of reactive nitrogen gases). Importantly, the abundance ratio $R = \text{SO}_2/\text{NO}_y$ is quite different for different SO₂ source types (about 1-2 for fossil fuel combustion, <0.1 for bio mass burning, and about 40 for Ni/Cu smelting) and therefore serves as an SO₂-source marker. In addition to our air craft measurements, we have made accompanying model simulations of pollutant transport and aerosol formation and growth.

Our air craft measurements were part of the ASTAR 2007 (ASTAR=Arctic Study of Tropospheric Aerosols, Clouds, and Radiation) campaign and took place in March/April 2007 (during the recent "International Polar Research Year") aboard the German research air craft FALCON, mostly in the vicinity of Spitsbergen about 2100 km away from Norilsk. Atmospheric SO₂ was measured on 7 Central Arctic FALCON flights at altitudes up to 10000 m in the geographic region between approximately 74-83 degrees North and 10-20 degrees East.

On the FALCON flights, Arctic Haze was often observed as a dark coloured band against the horizon. During each of the 7 Central Arctic FALCON flights, stratified SO₂ rich pollution plumes, with elevated SO₂ mole fractions of 300-6000 ppt, have been detected below 2000 m. In comparison, measured atmospheric background SO₂ mole fractions were usually below about 40 ppt. In addition, numerous SO₂ rich pollution plumes were detected in almost the entire altitude range covered.