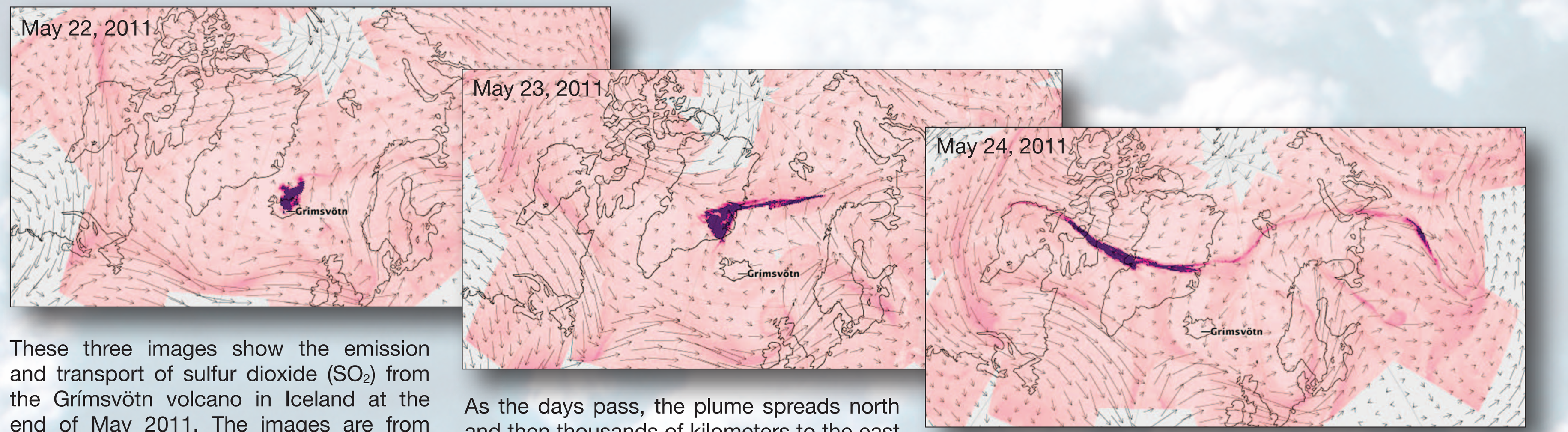
Sulfur Dioxide

National Aeronautics and Space Administration

Sulfur dioxide (SO_2)—a colorless, toxic gas with a sharp odor—is a very water soluble, acidic gas. SO_2 irritates the eyes, nose, and lungs. High concentrations of SO_2 can result in temporary breathing impairment. It is both human-generated and naturally occurring.

SO_2 is a precursor to sulfuric acid, a major constituent of acid rain. It is produced by the combustion of coal, fuel oil, and gasoline (since these fuels contain sulfur), and in the oxidation of naturally occurring sulfur gases, as in volcanic eruptions. Volcanic plumes, rich in ash and SO_2, are a hazard to aviation. SO_2 can be transformed into tiny sulfate particles, called aerosols that can alter the brightness of clouds and precipitation. Some very explosive volcanoes send SO_2 into the stratosphere, where it can form sulfate aerosols that persist for long periods of time and can contribute to climate change.

Instruments like the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite, track SO_2 in the atmosphere allowing scientists to compare SO_2 emissions around the world from both natural sources and man-made emissions. These measurements are recorded in Dobson units—a unit of measurement of atmospheric columnar density. Just imagine if you could compress all of the SO_2 in a column of the atmosphere into a single layer at the Earth's surface at a temperature of zero degrees Celsius, one Dobson Unit would be 0.01 millimeters thick. While this may seem small compared to the amount released during some volcanic eruptions, emissions from power plants and other human sources are an "all day, every day" occurrence. Even with SO_2 emissions from continuously erupting volcanoes, such as those in Hawaii, human sources of SO_2 far exceed natural sources.



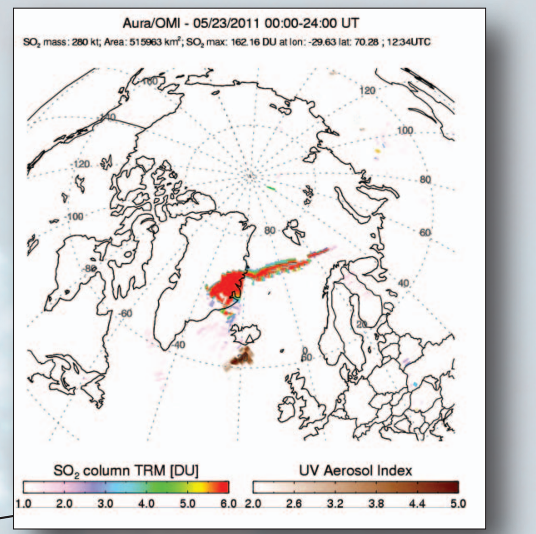
These three images show the emission and transport of sulfur dioxide (SO_2) from the Grímsvötn volcano in Iceland at the end of May 2011. The images are from measurements from the Atmospheric Infrared Sounder (AIRS) on NASA's Aqua spacecraft. The concentration of SO_2 is represented here in purple, with small arrows depicting dominant wind direction.

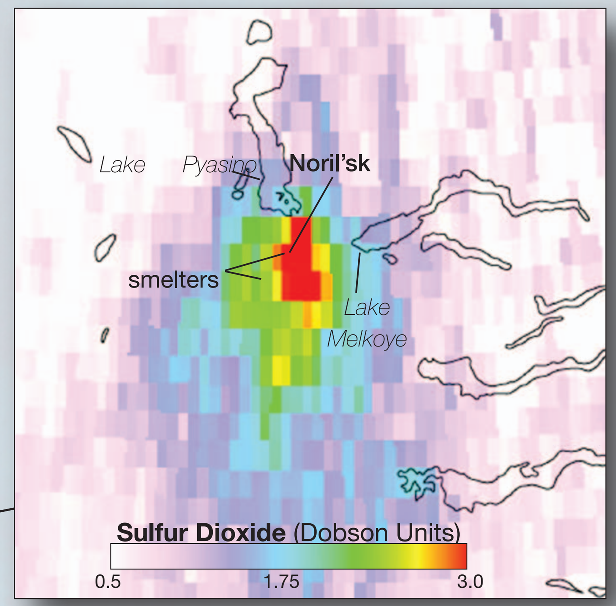
As the days pass, the plume spreads north and then thousands of kilometers to the east and west, carried by winds.

SO_2 near the surface of Earth can be harmful to breathe, particularly for people with asthma. It also dissolves in water in the atmosphere to produce acid rain and volcanic smog, or vog.

While SO_2 aerosols at higher altitudes after an eruption do not necessarily pose an immediate hazard to aircraft operations, it can corrode and damage aircraft windows.

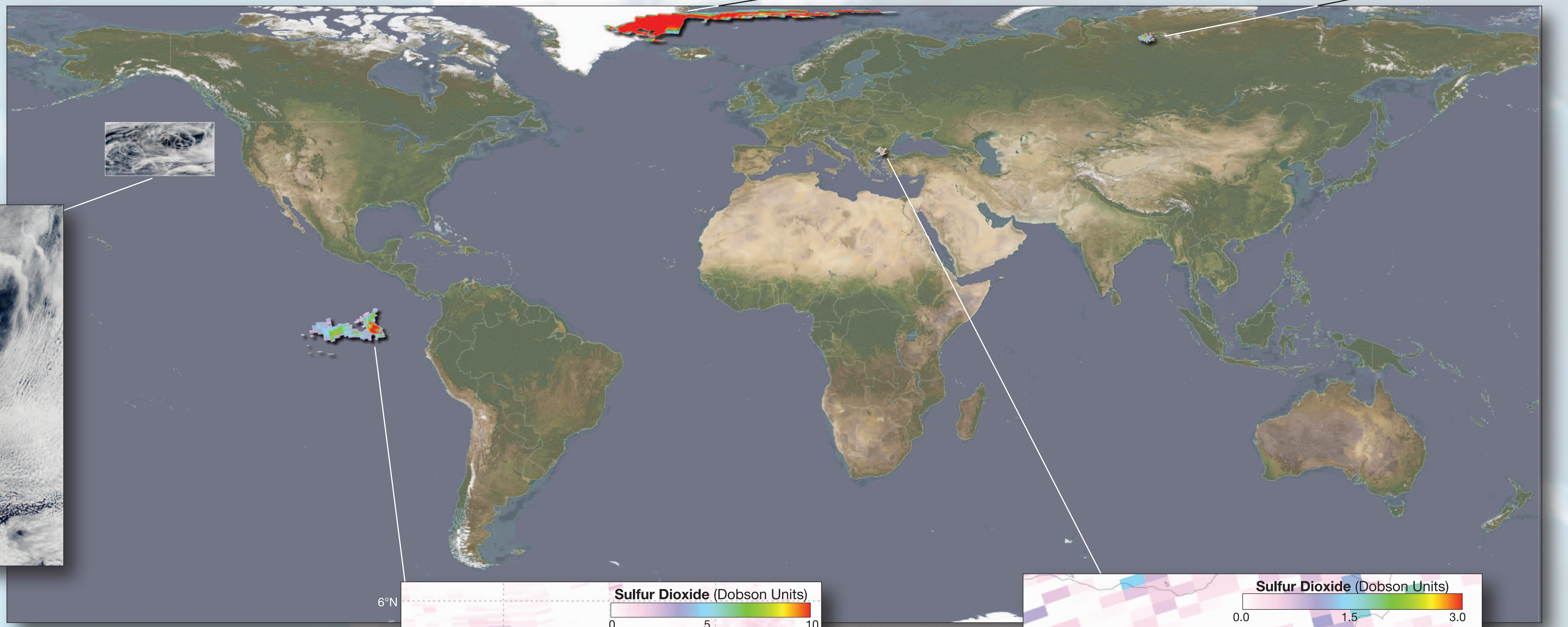
The image below of the Grímsvötn volcanic eruption was captured on May 23, 2011—the same day as the middle image from the image series shown on the left. This image however, reveals data collected by a different satellite instrument, OMI. Both images reveal similar patterns of SO_2 in the atmosphere. Their striking similarities provide evidence that the instruments, detecting SO_2 in our atmosphere, are in good agreement with one another, providing consistent datasets for scientists to use.

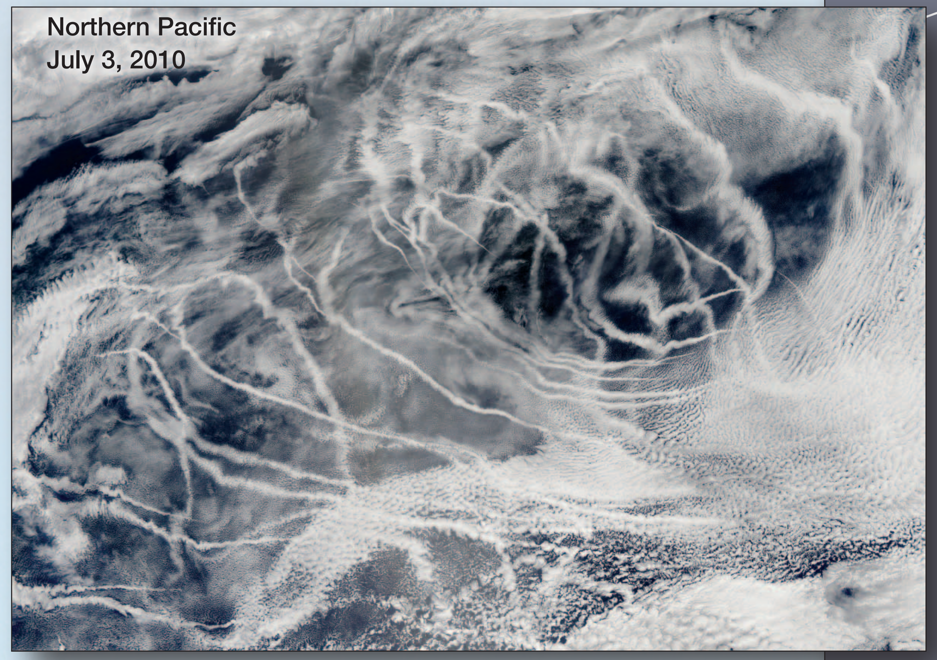




Stainless steel producers rely on nickel to give their products a subtle sheen. Automobile manufacturers rely on palladium to make catalytic converters. Significant amounts of these metals, along with copper, come from one place: Siberia's Noril'sk smelting facility. The mining facility supports a population of roughly 200,000 people, yet it has also created some of the world's worst air pollution. Miners must extract the metals from sulfide ore, and the process produces 1.9 million tons of sulfur dioxide each year—more than the entire sulfur dioxide (SO_2) output of France.

The image above shows concentrations of SO_2 from the Noril'sk facility, measured by OMI. The measurements shown in this image are averaged data for the months of June-August from 2005-2007.

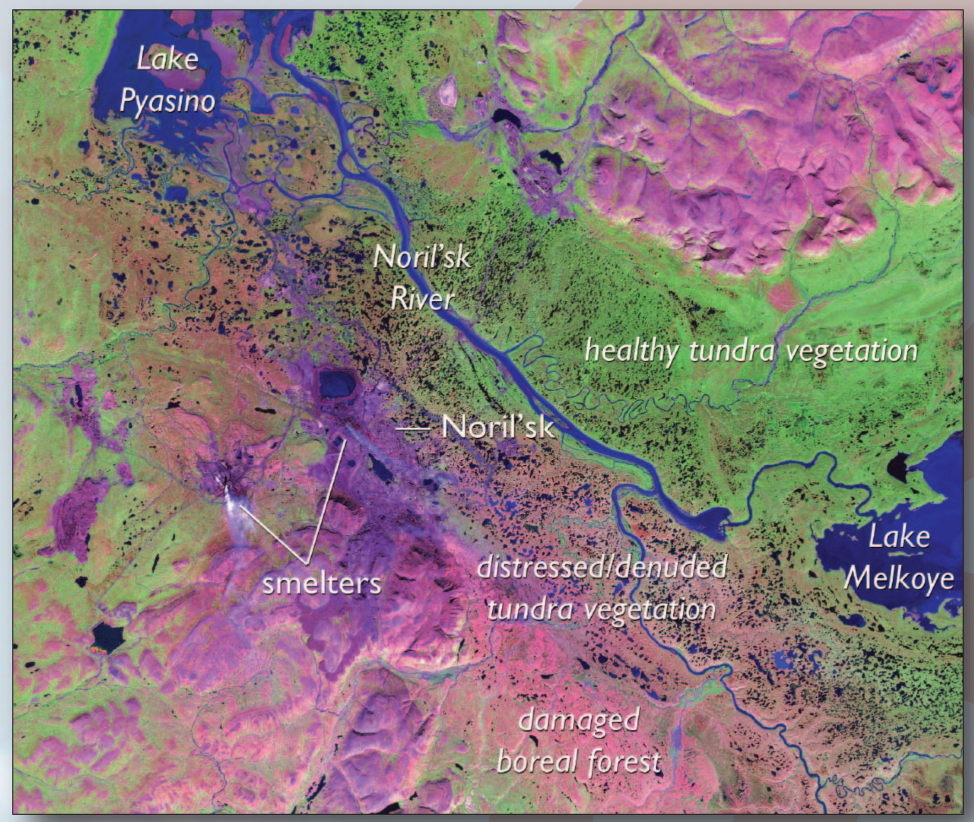




This image, made with data from the Aqua satellite, shows "ship tracks"—clouds formed by water vapor condensing on the aerosols coming from large ships—as they appeared from Earth orbit over the Northern Pacific Ocean on July 3, 2010.

Researchers from NASA's Goddard Space Flight Center and a number of universities around the country have turned to studying ship tracks. Not significant sources of pollution themselves, ships release their exhaust into the relatively clean and still marine air, where scientists have an easier time measuring the effects of fossil fuel emissions on cloud formation.

What they have found is that the sulfur dioxide (SO_2) released from ships' smokestacks could be forming sulfate aerosol particles in the atmosphere, which cause clouds to be more reflective, carry more water, and possibly stop precipitating. This is proof that humans have been creating and modifying clouds for generations through the burning of fossil fuels.

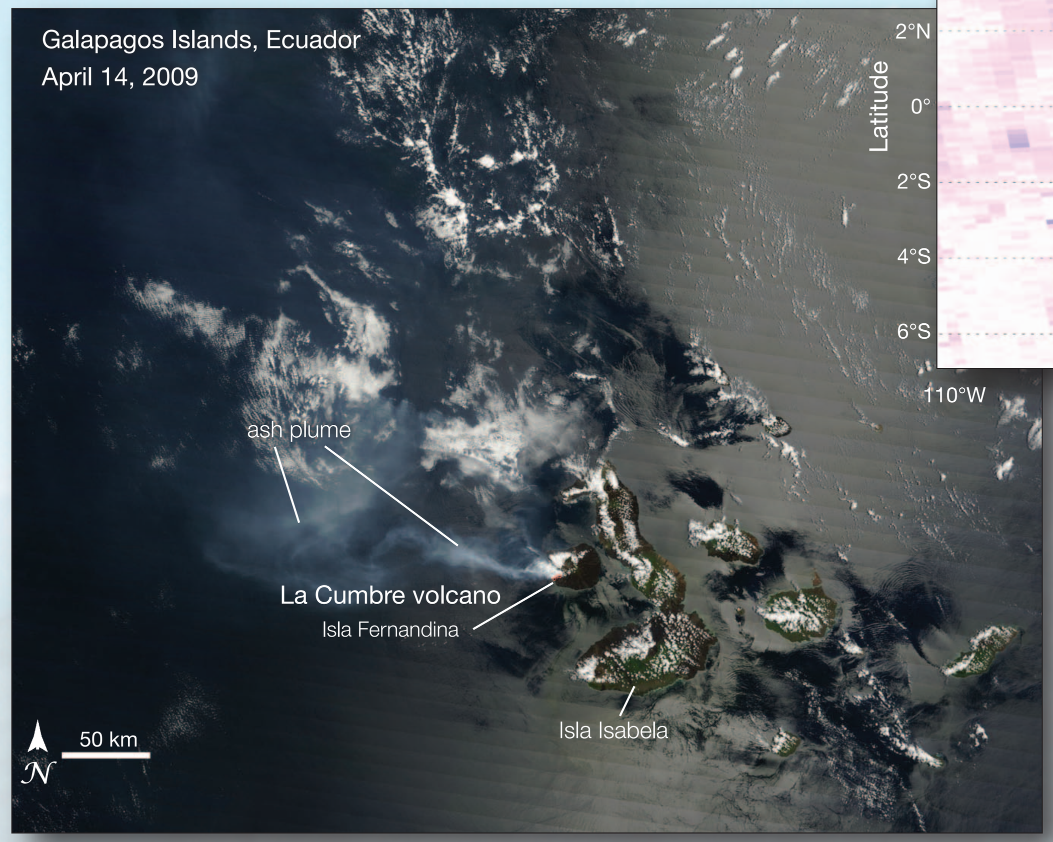


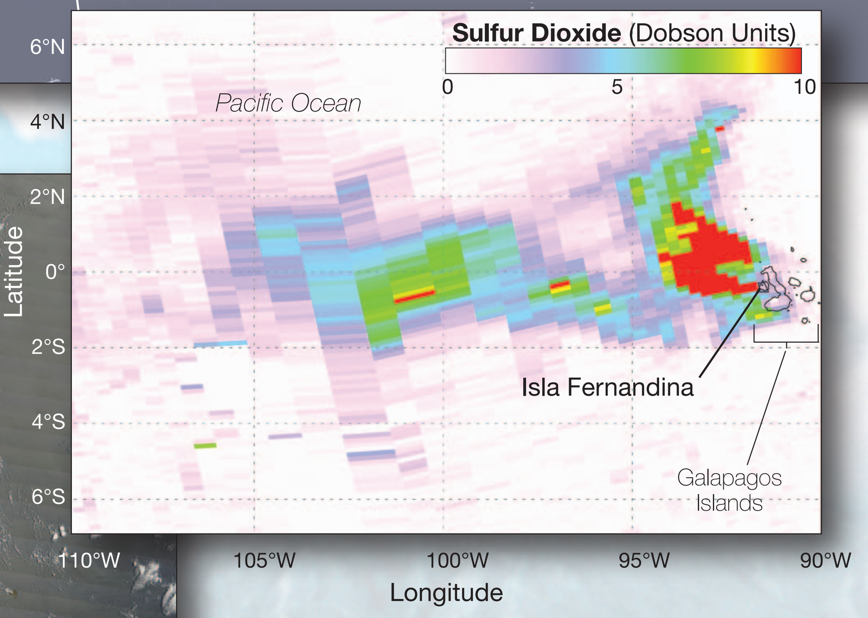
Large amounts of SO_2 can cause acid rain and affect the local environment. The above image shows the area around the Noril'sk mining facility captured by NASA's Landsat 7 satellite. Expanses of dead forest (revealed in pink and purple colors) testify to the acid rain's impact downwind of the smelters. Starting in 1968, tree death increased steadily each year. By 2007, at least 1.2 million acres (4,850 square kilometers) of trees had died. A 2003 study found that the trees with the highest concentration of sulfur in their needles occurred in the most heavily damaged parts of the forest—closest to the smelting facility. The image above shows the area around Noril'sk on April 9, 2006.

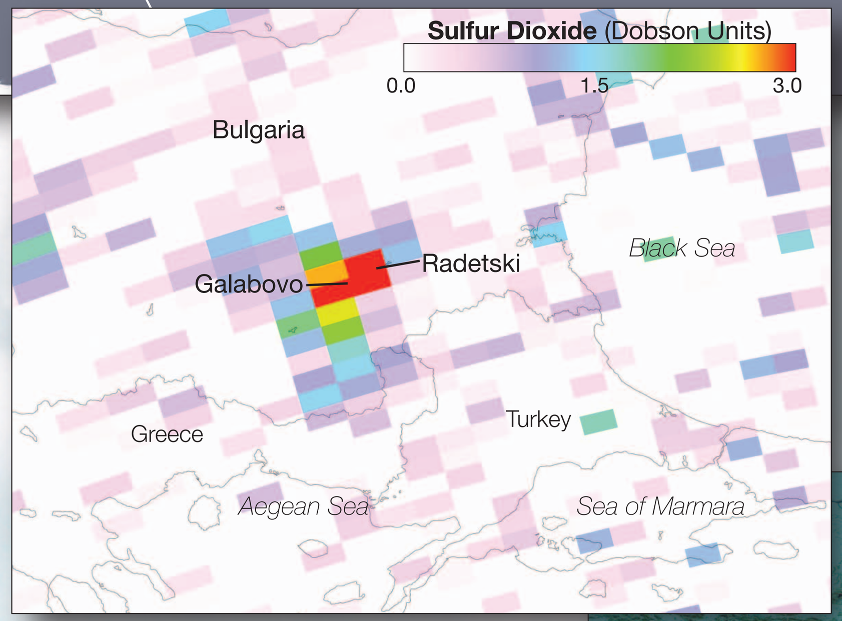
In early April 2009, La Cumbre Volcano on Isla Fernandina in the Galapagos Islands erupted, producing an ash plume and lava flows. The eruption also produced a substantial plume of sulfur dioxide (SO_2) that extended far west of the islands, over the Pacific Ocean.

The image (right) was made from data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite April 14, 2009. In this image, the volcano plume can be seen drifting westward as it expands and mingles with clouds. Although faint, the plume perseveres far northwest of the volcano. Opaque white puffs near the volcanic summit may be part of the plume, or may be clouds collected over the volcano. Compared to the nearby clouds, the volcanic plume is blue-gray, with less distinct margins.

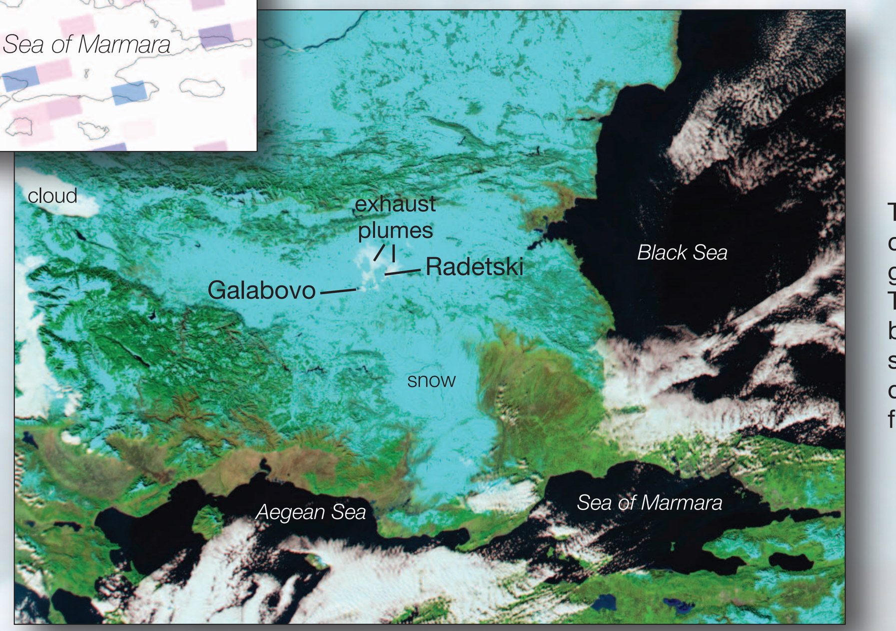
OMI onboard the Aura satellite was able to measure concentrations of SO_2 from the La Cumbre Volcano on the same day (image far right). The greatest concentrations of SO_2 appear in red, and the smallest concentrations appear in lavender. As the SO_2 plume moved away from the volcano, its intensity dissipated, evidenced by the red hues near the summit, and blues, greens, and lavenders farther away.







The image above shows measurements of sulfur dioxide (SO_2) in the air over one of the largest power plants in Eastern Europe, the Maritsa Iztok Complex in Bulgaria, on January 12, 2009. The highest SO_2 concentrations detected by OMI appear in the air directly over two of the complex's large coal-burning power plants, one near the town of Galabovo and one near the village of Radetski. SO_2 in three "blocks"—or pixels—of the image (each block is about 24 by 13 kilometers) reached values of 3 Dobson Units (red).



The image at left reveals exhaust plumes coming from the power plant. SO_2 and other gases continually fill the air surrounding the site. This false-color image is from data collected by MODIS on NASA's Aqua satellite on that same day. It uses visible and infrared light to distinguish clouds and exhaust plumes (white) from snow on the ground (bright blue).