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Arctic haze over the North Slope, Brooks Range, Alaska.
Arctic Haze is a winter- and spring-time build-up of anthropogenic atmospheric pollution in the Arctic atmosphere that can persist for weeks.

PHOTOGRAPH BY CAMERON S. MCNAUGHTON

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Analyzing Pollution in the Arctic Atmosphere

GEOS-Chem model helps quantify atmospheric composition

BY JENNY FISHER, FOURTH-YEAR GRADUATE STUDENT

F*or centuries,* the remote, sparsely-populated Arctic has been considered one of the most pristine and unpolluted environments on Earth. Yet despite its distance from the world's major population centers, the region is adversely affected by a by-product of human activity: air pollution. Large amounts of soot, ozone, mercury, and other pollutants accumulate over the pole every winter and spring, when constant darkness and cold temperatures slow the atmosphere's natural removal processes. The resultant hazy Arctic skies have far-reaching implications for air quality, atmospheric chemistry, polar ecology, and global climate.

Quantifying the sources of Arctic pollution has been a problem of long-standing interest to the scientific community. While some pollutants are undoubtedly local (such as the oil fields of Alaska and the copper smelters of Russia), the scale of the pollution influence points to emissions transported from much larger sources in the industrialized countries of the northern mid-latitudes. Early studies in the 1970s and 1980s blamed industrial activity in Europe and the former USSR. Over the past 20 years, however, the global distribution of pollutants has changed dramatically, and more recent studies disagree as to which sources are responsible for the pollution.

A variety of data are available to study the Arctic atmosphere, CONTINUED ON PAGE 3

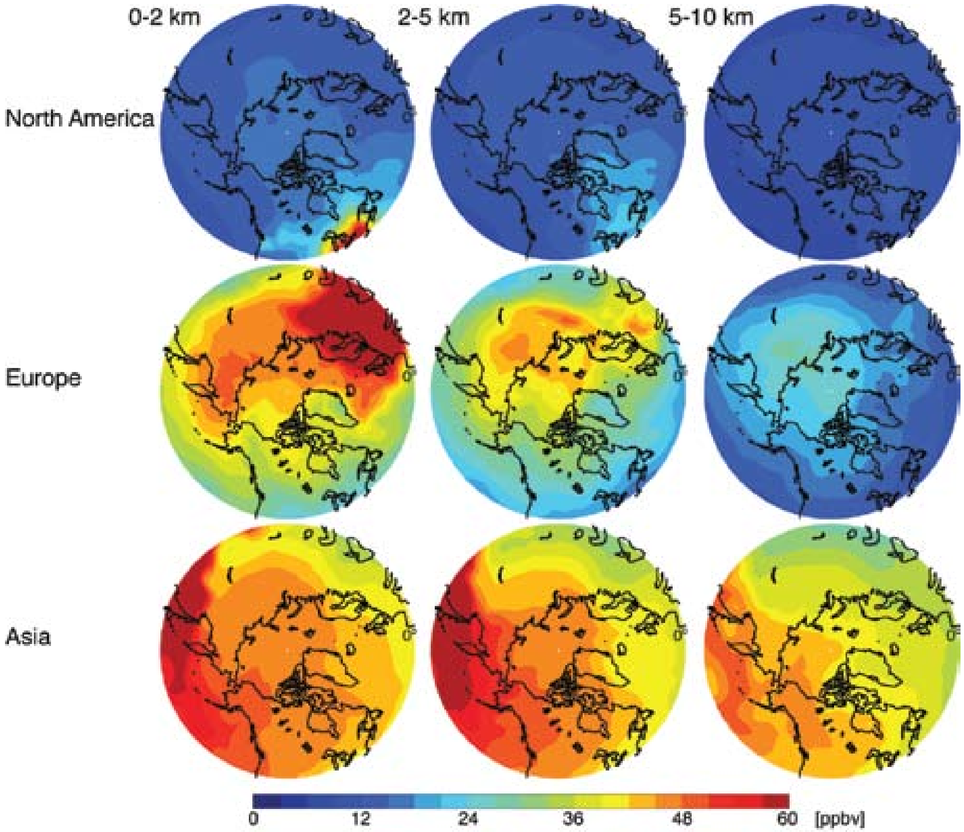

CHART COURTESY OF JENNY FISHER

Figure 1. Mean CO concentrations in different altitude bands for emissions from different regions as simulated by the GEOS-Chem model.

> *"Plumes of pollution aren't impossible to track if you know how to look for them."* ~*Jenny Fisher*

CONTINUED FROM PAGE 1 each with distinct advantages and disadvantages. Surface-based measurements provide long-term records but are limited to a few sites and to the lowest levels of the atmosphere. Aircraft campaigns provide enhanced vertical coverage but occur infrequently (every 5-10 years) and cover a limited spatial region. Satellites provide daily coverage of the polar region but the data are difficult to interpret and have yet to be tested in the Arctic. Individually these data provide only sparse snapshots of the polar region, but combined they form a more comprehensive picture. Unfortunately, they can't be compared directly due to differences in resolution, sampling location, and sampling frequency. In the Atmospheric Chemistry Modeling Group, we use a global three-dimensional chemical transport model (GEOS-Chem) to combine the complementary information available in these different datasets in order to provide quantitative constraints on the sources of Arctic pollution.

Plumes of pollution aren't impossible to track if you know how to look for them. We use carbon monoxide (CO) as an indicator of atmospheric pollution. CO is emitted by incomplete combustion—fossil fuel and biomass burning—and stays in the atmosphere for several months. This is long enough for a plume of CO to be tracked from a mid-latitude source to the Arctic but short enough that it doesn't get mixed into the background. Perhaps most importantly, CO is one of only a few pollutants that is measurable from space.

Last April, as part of the 4th International Polar Year, NASA and NOAA sponsored extensive aircraft campaigns, covering a swath from Alaska to Greenland to the North Pole and providing enough CO observations to perform a comparison with the CO modeled by GEOS-Chem. The data show that CO in the GEOS-Chem model is consistently lower than observations, indicating that our state-of-the-science estimates of CO emissions from fossil fuel burning are underestimated, particularly over Europe and Asia.

With improved estimates of CO emissions, we used the model to quantify the sources affecting Arctic pollution during spring 2008. Figure 1 shows the impact of fossil fuel burning in three regions (North America, Europe, and Asia) on CO pollution in the Arctic. Asian pollution is clearly dominant at all altitudes, although European pollution has some influence near the surface. In contrast, North American pollution has virtually no impact on the Arctic.

Satellite observations offer a longer-term perspective, providing context for the 2008 results. Data from NASA's Atmospheric InfraRed Sounder (AIRS) satellite instrument show that CO over Alaska in April 2008 was lower than average. We have found that AIRS observations of CO over Alaska are strongly correlated with the Ocean Niño Index, a measure of the strength of El Niño. Meteorological changes associated with El Niño enhance transport of Asian pollution to Alaska, while conditions associated with La Niña reduce this transport. This result suggests that the impact of Asian pollution on the Arctic, already dominant, could be even greater during a strong El Niño event.

Our work thus far has provided important constraints to understanding Arctic pollution—namely, the underestimation of fossil fuel sources, the dominance of Asian emissions and the importance of El Niño—but the picture is far from complete. While CO serves as a good indicator of overall pollution, other environmentally-important species are affected by different source distributions and atmospheric processes. Current research in our group is expanding on this work to better understand the sources and impacts of a variety of Arctic contaminants, including environmental toxins like mercury and climate-forcing pollutants like ozone, soot, and sulfate.

RYAN PETTERSON

Jenny's interest in air pollution developed while she was living in Pasadena, CA, where pollution haze was often thick enough to completely block the nearby San Gabriel mountains from sight.

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