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Analysis of the vertical dispersion of pollution layers in the urban Arctic during the ALPACA 2022 field campaign

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The Alaskan Layered Pollution and Chemical Analysis (ALPACA) field campaign was conducted during the winter months of January and February 2022 to examine urban pollution sources and transformations in Fairbanks, Alaska. Several data collection sites were set up throughout the city to investigate the less-explored dynamic, physical, and chemical mechanisms governing air pollution events during the cold and dark winter.

The vertical dispersion of pollutants was investigated from an observation site in the suburban area just outside downtown Fairbanks. It featured ground-based measurements, a ten-meter mast for eddy covariance measurements, and a tethered balloon for vertical profiling of the atmosphere. Sampling included measurements of aerosol microphysical characteristics and trace gases (CO, CO_2, O_3, NO_x). Meteorological parameters were also continuously measured at 2m and 10m from the mast, and also during the balloon flights. The tethered balloon was deployed to assess the vertical mixing of pollutants under stable atmospheric conditions from sources located at the surface but also at higher elevations, such as emissions from high power plant stacks.

A total of 148 individual profiles (up to a maximum altitude of 350 m above ground level) from 24 flights were collected between January 26 and February 25, 2022. The atmospheric conditions featured surface-based temperature inversions (SBI) in 86% of the cases due to the upwelling longwave radiation dominating the surface energy budget. Interestingly, eight flights captured elevated pollution plumes from power plants located downtown.

The analysis of profiles reveals that the atmospheric stability and mixing of the surface layer was affected by two mechanisms. On one hand, radiative cooling promoted strong SBI locally,

suppressing turbulence. On the other hand, a drainage flow at the surface from a nearby valley increased the shear stress at the surface, promoting mechanical turbulence near the surface. The measurements show how these two competing mechanisms affect the mixing of the surface layer.

The second part of the study focuses on the vertical dispersion of elevated plumes. The vertical mixing of pollutant plumes and their potential to contribute to surface pollution are investigated using the chemical and physical signature of the plumes and their vertical extents.

Together, the results of this study contribute to improving our understanding of pollution mixing under the very stable conditions typical of the Arctic winter and can help to design pollution mitigation strategies by identifying the conditions and mechanisms leading to high pollution events.