



HAL
open science

Investigating processes affecting wintertime air pollution variability and estimating contributions of power plant emissions relative to the surface in the stratified Arctic boundary layer

Natalie Brett, Kathy S. Law, Stephen Arnold, Brice Barret, Elsa Dieudonné, Gilberto Fochesatto, Jean-Christophe Raut, Tatsuo Onishi, Roman Pohorsky, Andrea Baccharini, et al.

► To cite this version:

Natalie Brett, Kathy S. Law, Stephen Arnold, Brice Barret, Elsa Dieudonné, et al.. Investigating processes affecting wintertime air pollution variability and estimating contributions of power plant emissions relative to the surface in the stratified Arctic boundary layer. EGU General Assembly 2024, Apr 2024, Vienna, Austria. pp. EGU24-15899, 10.5194/egusphere-egu24-15899 . insu-04508315

HAL Id: insu-04508315

<https://insu.hal.science/insu-04508315v1>

Submitted on 31 May 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



Investigating processes affecting wintertime air pollution variability and estimating contributions of power plant emissions relative to the surface in the stratified Arctic boundary layer

Natalie Brett^{1,2}, Kathy S. Law¹, Stephen R. Arnold², Brice Barrett³, Elsa Dieudonné⁴, Gilberto J. Fochesatto⁵, Jean-Christophe Raut¹, Tatsuo Onishi¹, Roman Pohorsky⁶, Andrea Baccarini^{6,14}, Julia Schmale⁶, Joël Savarino⁷, Sarah Albertin^{7,1}, Slimane Bekki¹, Barbara D'Anna⁸, Brice Temime-Roussel⁸, William Simpson¹¹, Meeta Cesler-Maloney¹¹, Stefano Decesari⁹, Antonio Donateo¹⁰, and the ISAC, Italy, EPA-Alaska and ADEC*

¹Sorbonne University, Laboratoire Atmosphères, Milieux, Observations Spatiales, France (natalie.brett@latmos.ipsl.fr)

²Institute for Climate and Atmospheric Science, School of Earth and Environment, University of Leeds, Leeds, UK

³Laboratoire d'Aérodynamique, Université de Toulouse III Paul Sabatier / CNRS, Toulouse, France

⁴Laboratoire de Physico-Chimie de l'Atmosphère, Université du Littoral Côte d'Opale, Dunkerque, France

⁵Department of Atmospheric Sciences, University of Alaska Fairbanks, Fairbanks, Alaska, USA

⁶Extreme Environments Research Laboratory, École Polytechnique Fédérale de Lausanne Valais Wallis, Sion, Switzerland

⁷IGE, Univ. Grenoble Alpes, CNRS, IRD, Grenoble INP, 38000 Grenoble, France

⁸Aix Marseille Univ, CNRS, LCE, Marseille, France

⁹Institute of Atmospheric Sciences and Climate, National Research Council, Bologna, Italy

¹⁰Institute of Atmospheric Sciences and Climate, National Research Council, Lecce, Italy

¹¹Department of Chemistry and Biochemistry and Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA.

¹⁴Laboratory of atmospheric processes and their impacts, EPFL, Lausanne, Switzerland

*A full list of authors appears at the end of the abstract

The Arctic is warming rapidly compared to the global average. As Arctic warming continues, urbanisation and industrial activities are predicted to increase, along with complex climate and ecosystem feedbacks. Therefore, local sources of air pollutants are expected to play an increasingly significant role in Arctic environmental changes in the coming years. Poor air quality is already a growing public health issue in Arctic and sub-Arctic cities. During wintertime, stable meteorological conditions and the persistence of strong surface-based temperature inversions suppress the dispersion of pollutants, which accumulate due to enhanced emissions linked to high energy demands. Fairbanks, in central Alaska, is an example of a sub-Arctic city that suffers from acute wintertime pollution episodes. The city's topography (situated in a basin), strong stratification of the Arctic boundary layer (ABL), and high emissions, primarily from domestic heating at the surface, and power plant stacks aloft, are known to contribute to the problem. However, interactions between vertical stratification of the ABL and dispersal of pollutants from surface and elevated sources are poorly quantified due to a lack of observations and complexities of the ABL structure and dynamics. To address these uncertainties, comprehensive atmospheric composition and meteorological measurements were collected at the surface, and vertical profiles

were obtained using a tethered balloon during the international ALPACA (Alaskan Layered Pollution and Chemical Analysis) field campaign in January and February 2022.

Here, we explore the contribution of power plants and surface emission sources to pollution concentrations in the Fairbanks region. We use the FLEXPART-Weather Research and Forecasting (WRF) Lagrangian particle dispersion model, driven by meteorological fields from US Environmental Protection Agency (EPA) WRF simulations including data assimilation of meteorological observations, to simulate the evolution of selected emission tracers. Hourly power plant and sector-based surface EPA emissions at 1.3km resolution during ALPACA 2022 are included in the model runs. A novel model parameterisation of power plant plume injection heights accounts for the ABL structure, notably surface-based and elevated temperature inversions. Model results are evaluated against available observations from ALPACA 2022, and sensitivity to, for example, emissions and vertical mixing is explored. The simulation of pollution plume altitudes is significantly improved when ABL stratification is taken into account in the plume rise parameterisation since inversion layers can trap plumes. Variability in modelled surface pollutant concentrations is predominantly driven by meteorology, and the ability of the model to capture surface-based temperature inversions (as low as 10m). A cold-temperature dependence for NO_x vehicle emissions, currently missing from the EPA emission inventory, is required to reproduce the magnitude of observed NO_x surface concentrations at low temperatures below 0°C and needs to be considered in future emission inventories in the Arctic, and potentially in other wintertime environments. Finally, using the most realistic simulation, we estimate the contribution of power plant emissions to surface pollution in the Fairbanks region, addressing an important policy question. The results indicate preferential areas for downward transport of pollution from aloft and larger contributions to surface pollution under less stable meteorological conditions.

ISAC, Italy, EPA-Alaska and ADEC: ISAC, Italy: Gianluca Pappaccogli, 10, pappaccogli@le.isac.cnr.it Federico Scoto, 10, federico.scoto@unive.it EPA-Alaska and ADEC: Kathleen Fahey, 12, fahey.kathleen@epa.gov Deanna Huff, 13, deanna.huff@alaska.gov George Pouliot, 12, pouliot.george@epa.gov