# Characterization of size-segregated particles turbulent fluxes in an Arctic city (Fairbanks, Alaska)

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# PBL meteorology – atmospheric composition interaction and depositions over snow surfaces

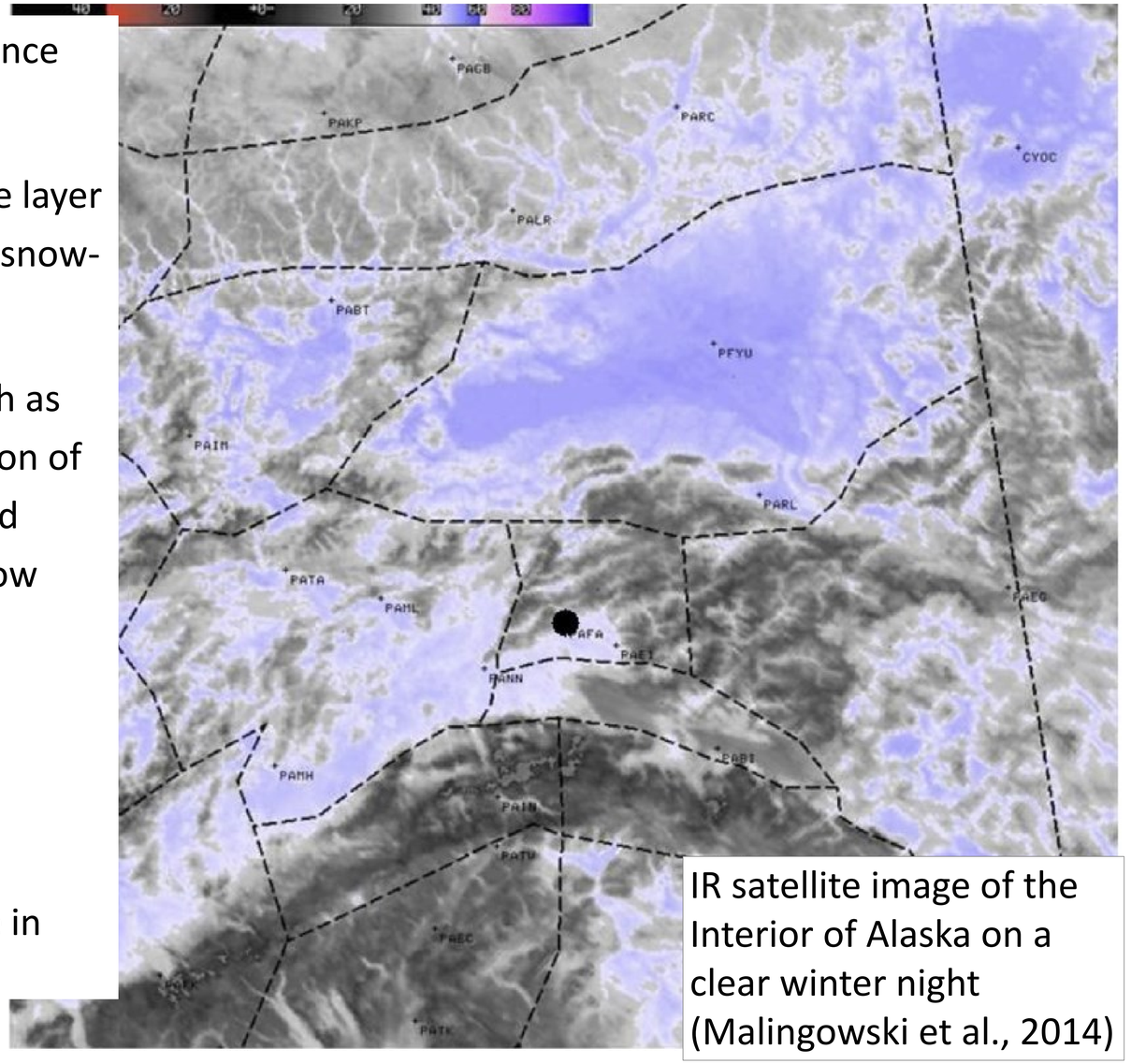
BC deposition in atmospheric models shows orders of magnitude of variance among modeled depositions over the Arctic (AMAP SLCF report 2023).

Dry depositions depend on the aerosol concentrations in the near-surface layer (with link to AQ in inhabited areas), on the characteristics of the surface (snow-covered, snow-free, «roughness») and on the PBL meteorology.

The winter Arctic PBL in inland areas exhibits peculiar characteristics, such as very stable conditions with little diurnal cycles and leading to the formation of very shallow suface-based inversions, sometimes associated with elevated inversions. The stratified PBL can be perturbed by Kelvin waves and shallow cold fronts (Fochesatto et al. 2013, 2015).

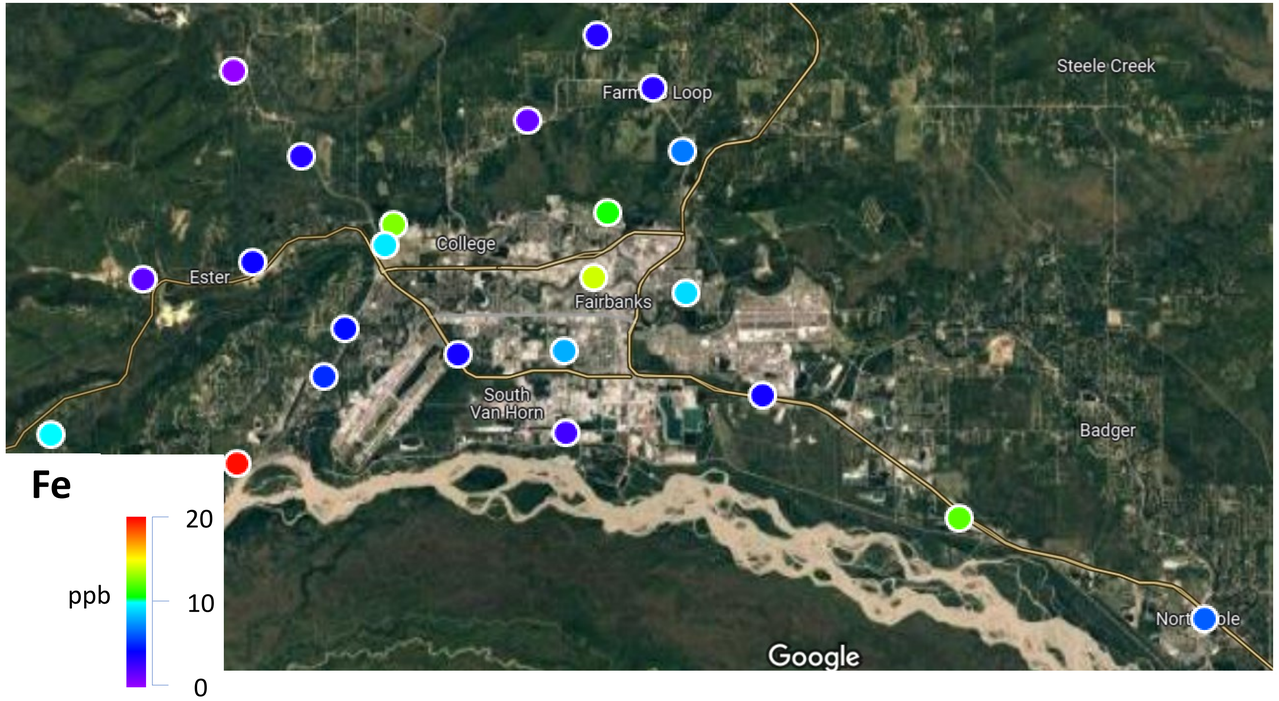
In urban areas, surface-based inversions are associated to very high PM loadings.

These are among the science topics targeted by the **ALPACA** experiment (ALaskan Pollution And Chemical Analysis). The field campaign took place in Fairbanks (Alaska) between Jan and Feb 2022.




IR satellite image of the Interior of Alaska on a clear winter night (Malingowski et al., 2014)

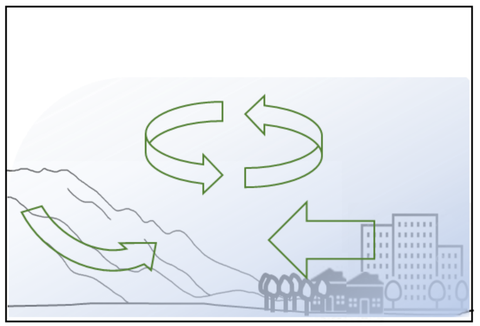
B

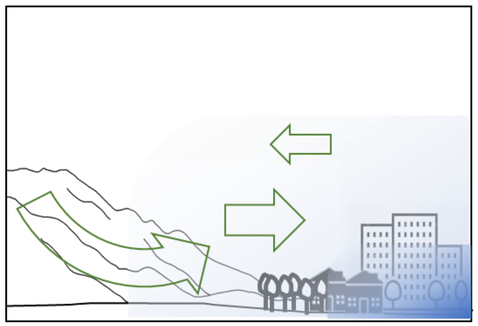


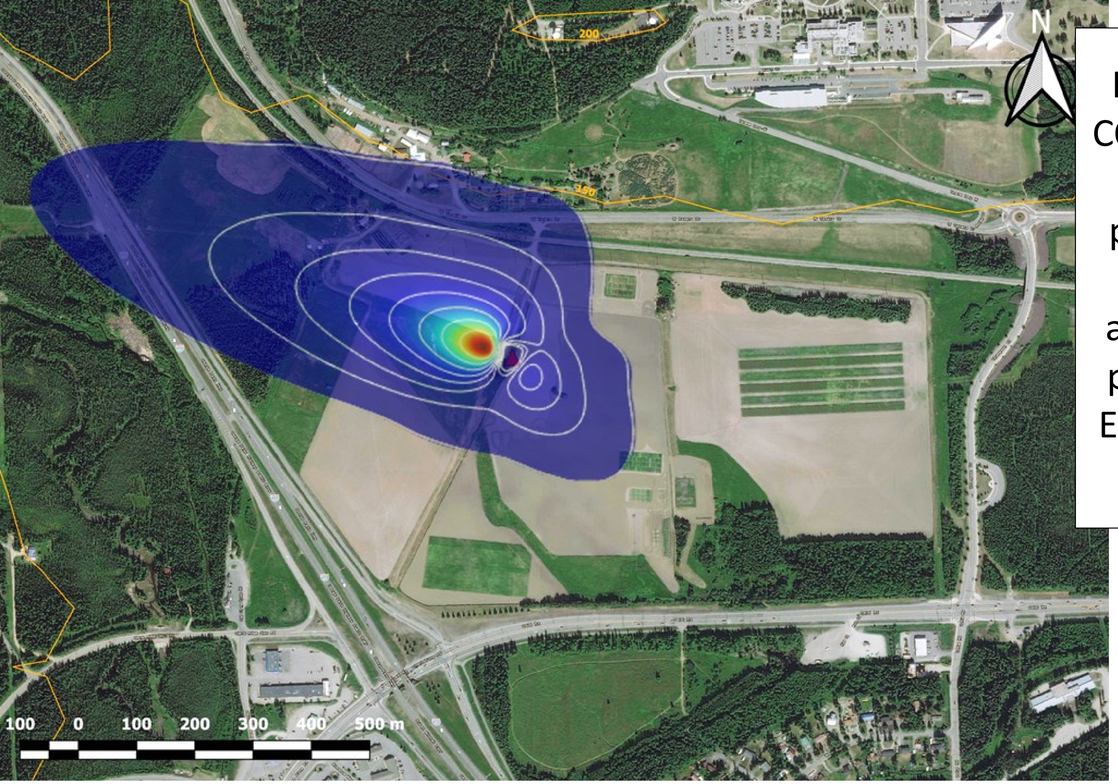

- A) the comparison between atmospheric monitoring in the city center with respect to those carried out in the suburbs, along with on-road mobile sampling showed that «Spatial variations of PM in Fairbanks are tightly connected to meteorological conditions; dramatic between-neighborhood differences exist during strong temperature inversion conditions, but are significantly reduced during weaker temperature inversions, where atmospheric conditions are more well mixed» (Robinson et al., Environ. Sci.: Atmos., 2023)

- B) Sampling of the surface snowpack at 23 sites across the Fairbanks area (on the same day, 6° Feb 2022) highlited sharp gradients in concentrations for most of the analyzed compounds (metals by ICP-MS). Elements of anthropogenic origin showed peak concentrations at hotspots and – on average – higher concentrations downtown, indicating that atmospheric depositions in the snowpack were influenced by the urban dome of pollution in the central districts. Atmospheric depositions can be responsible for fluxes of contaminants (metals, POPs) and climate-forcing agents (black carbon) into the snowpack

A

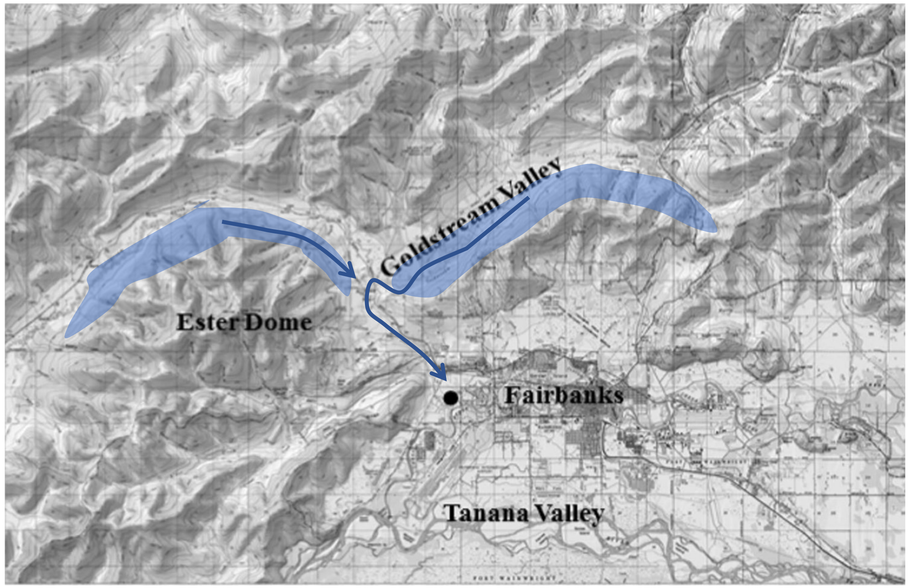




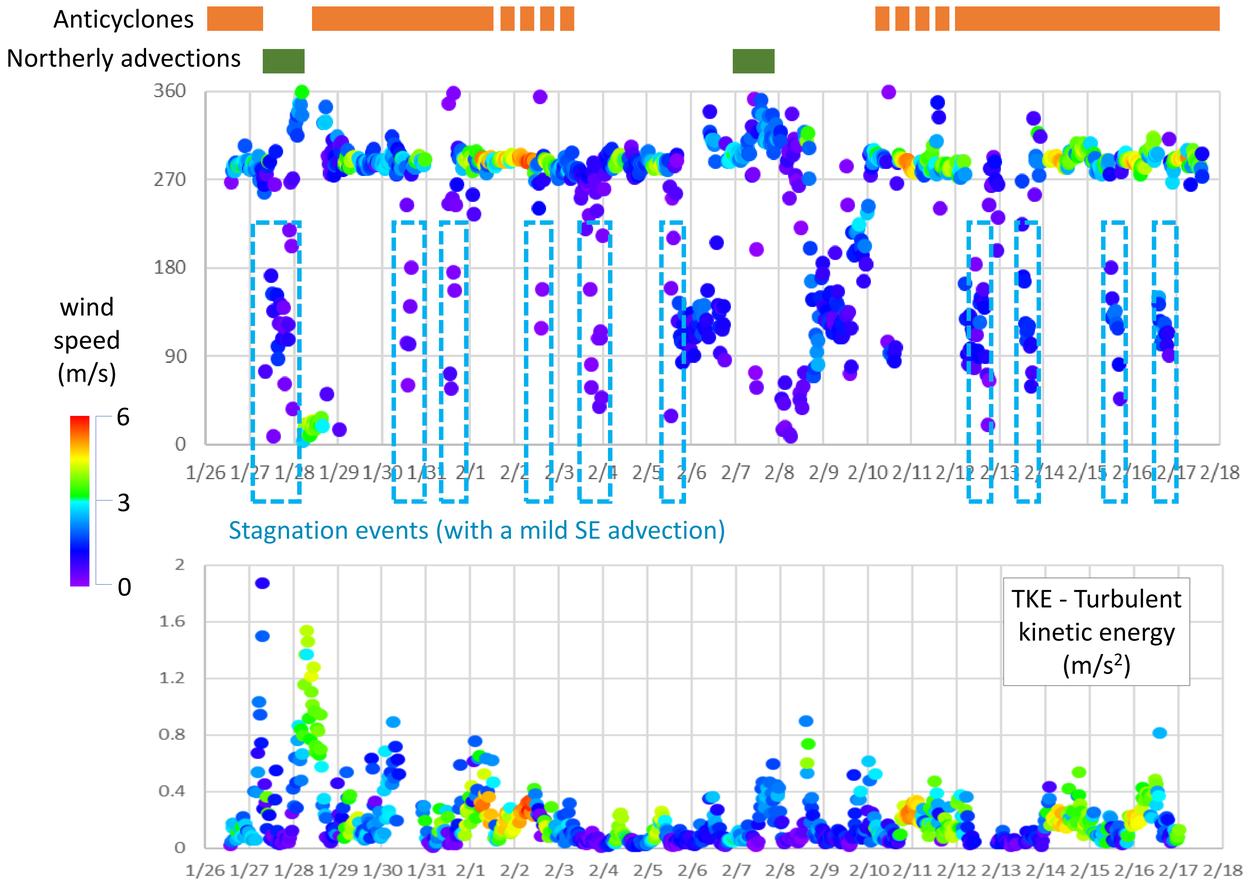



Intensive observations of the PBL structure, vertical distributions of temperature, RH, $CO_2$, trace gases and aerosols, as well as surface aerosol concentrations and fluxes were performed at the UAF Farm site in the NW outskirts of the city (Fochesatto et al., in preparation). Particle flux measurements were carried out by an eddy covariance (EC) technique. The EC system consisted of a 10 m mast, an ultrasonic anemometer (with acquisition frequency of 100 Hz), a condensation particle counter (CPC) and an optical particle counter (OPC) with 16 size channels from 0.25 to 3 µm (Donateo et al. Atmos. Environ. 2019). The footprint covered essentially a snow-covered flat terrain and it was alongated toward the prevalent wind direction from NW.

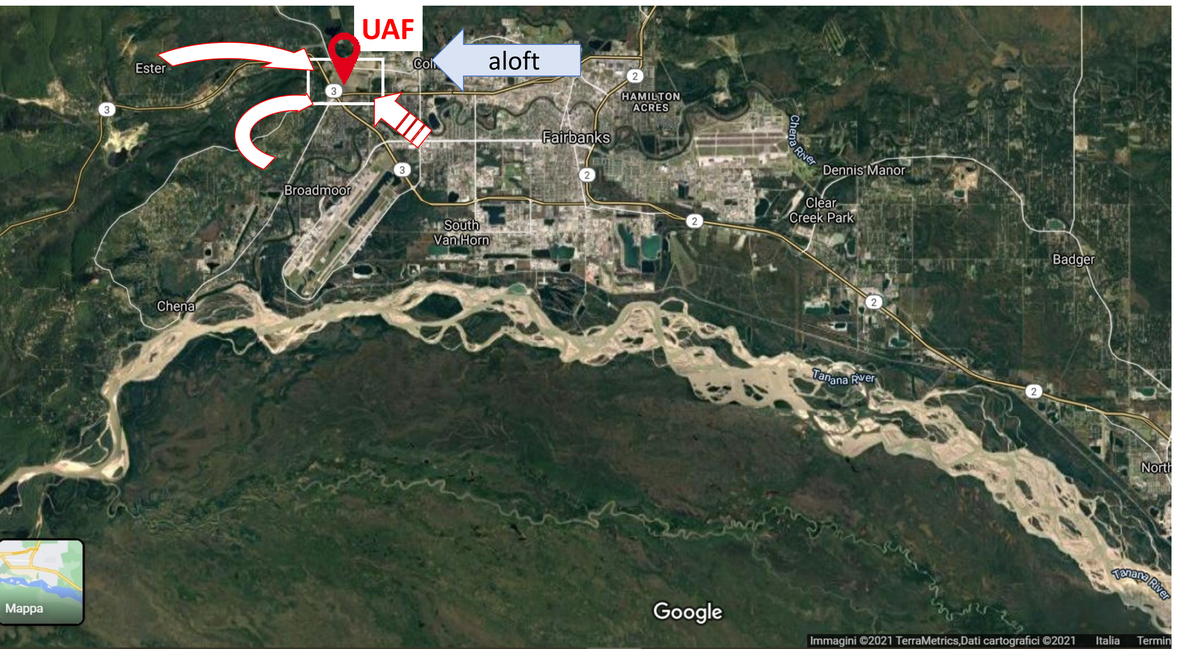

The measurement period of the EC system lasted from 26 Jan to 17 Feb 2022. The early days were characterized by a cold period (with surface temperatures as low as -35°C) which developed during anticyclonic conditions. The period was interrupted by a northerly advecation for one day (27 Jan). Starting from 3rd Feb, a cyclonic circulation brought more perturbed weather conditions with higher temperatures, clouds and precipitations (snowfalls between 6 and 7 Feb). Finally a second antyclone was established: this final phase was characterized by strong diurnal variations as a consequence of the increased daytime insulation. Winds at 10 m agl blew prevalently from WNW, often as a fable breeze, sometimes intensified by slope currents (formed by cold air pooring in the Fairbanks plain from secondary orographic basins). Cold flows and northerly advections enhanced turbulence in the PBL. Very calm conditions were associated with a very weak circulation from SE (from downtown).

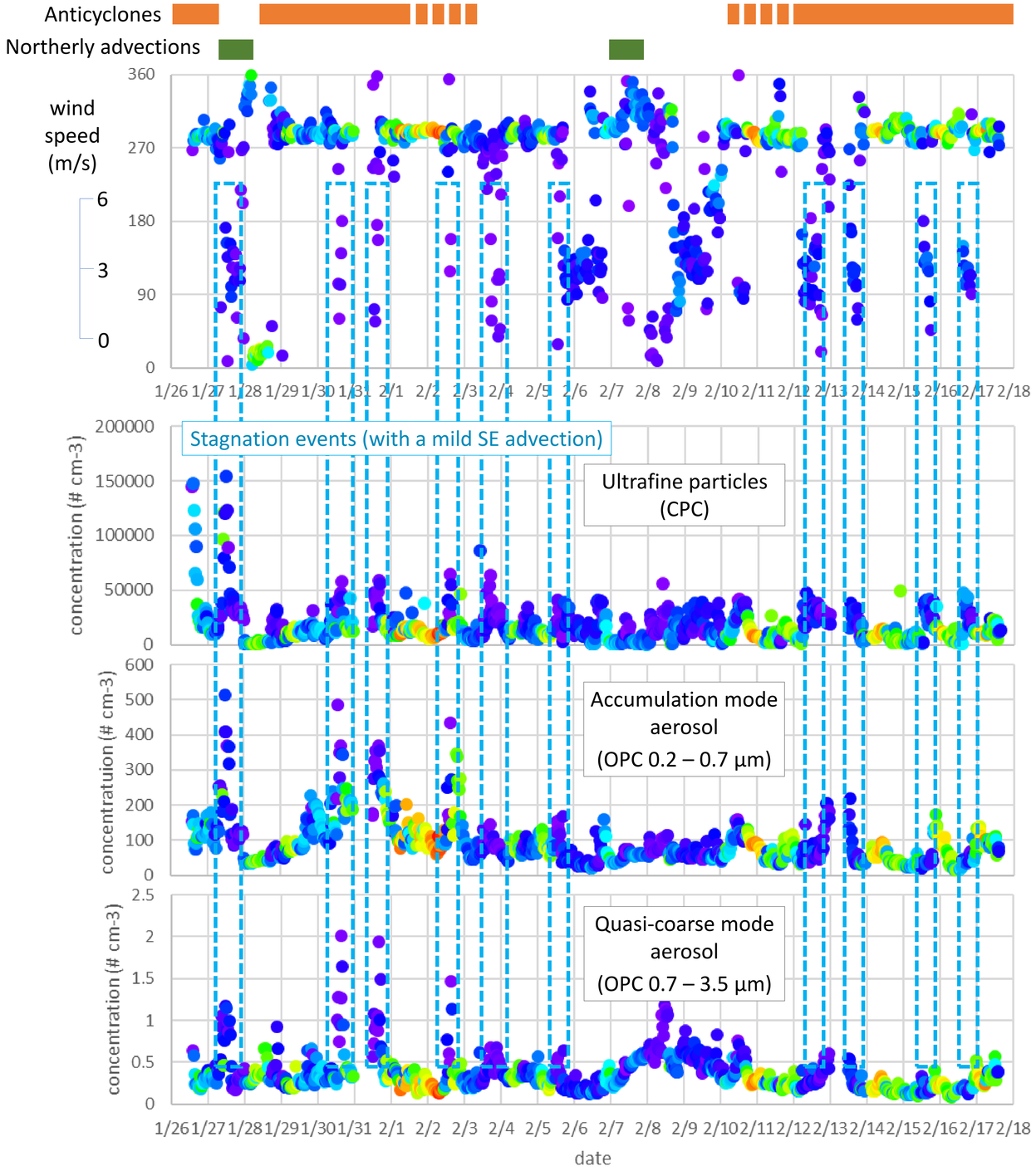


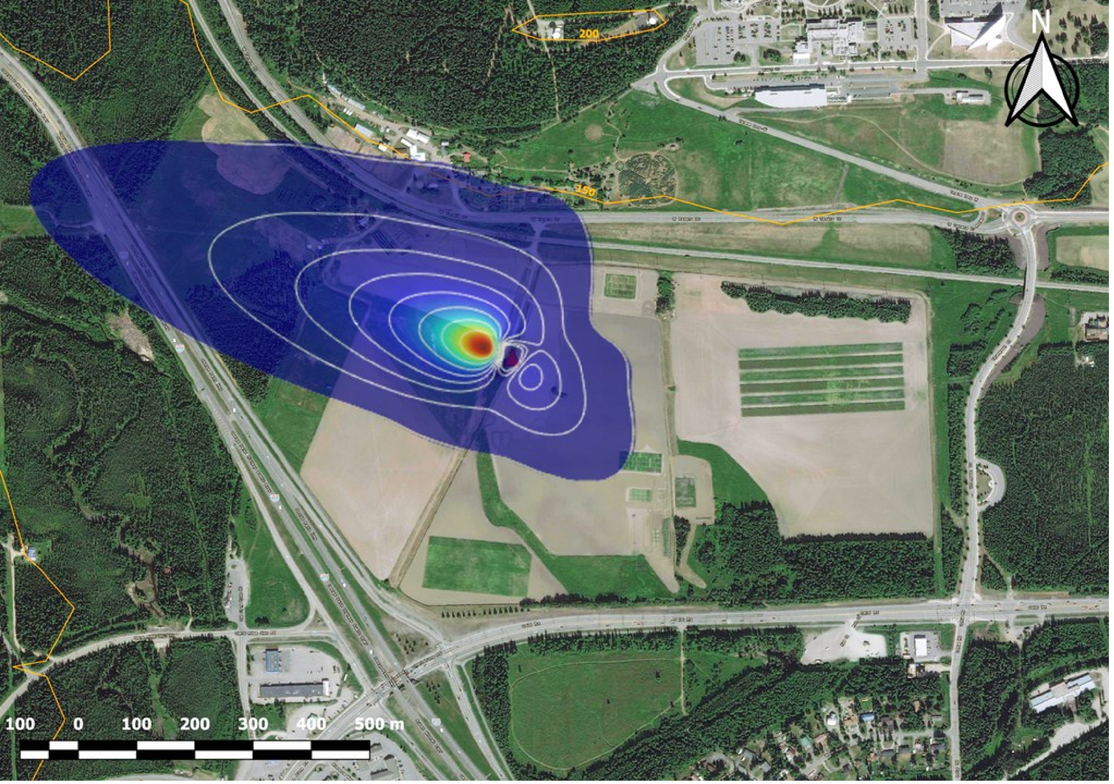

Fochesatto et al 2015



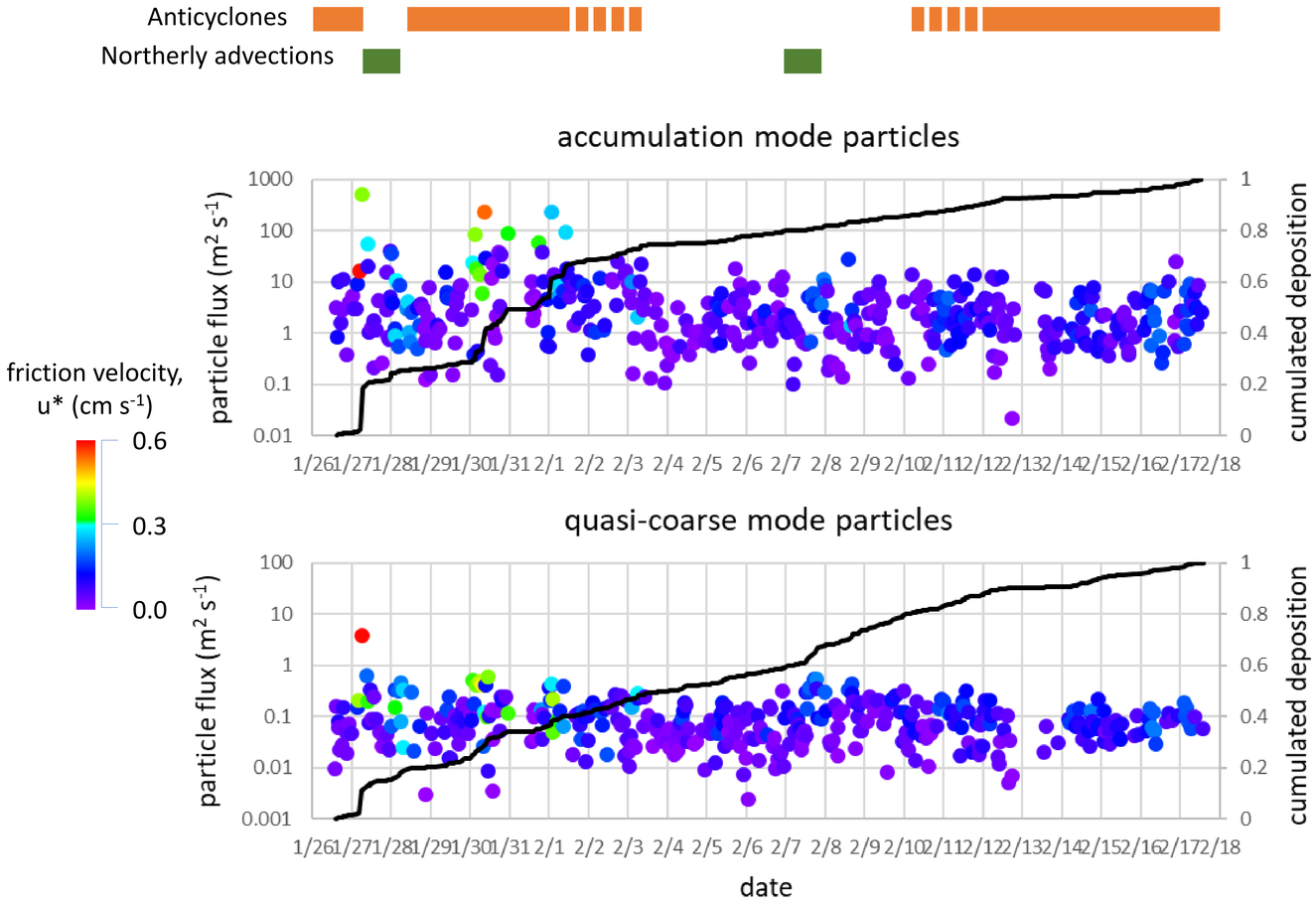
The analysis of the trends of size-segregated particle number concentrations shows that: a) peak levels are observed for all particle classes during episodes of stagnation associated with a weak SE circulation (from dowtown); b) accumulation mode particles exhibit an additional source from the prevalent wind direction (WNW) pointing to emissions from outside the Fairbanks basin or to recirculation of Fairbanks pollution during the first anticyclonic period; c) «quasi-coarse» particles (including the largest size bins of the OPC) show enhanced concentrations under cyclonic conditions (7 – 10 Feb) and a northerly wind circulation. Surface wind patterns do not account for the possible contribution of entrained polluted air transported aloft from the city.



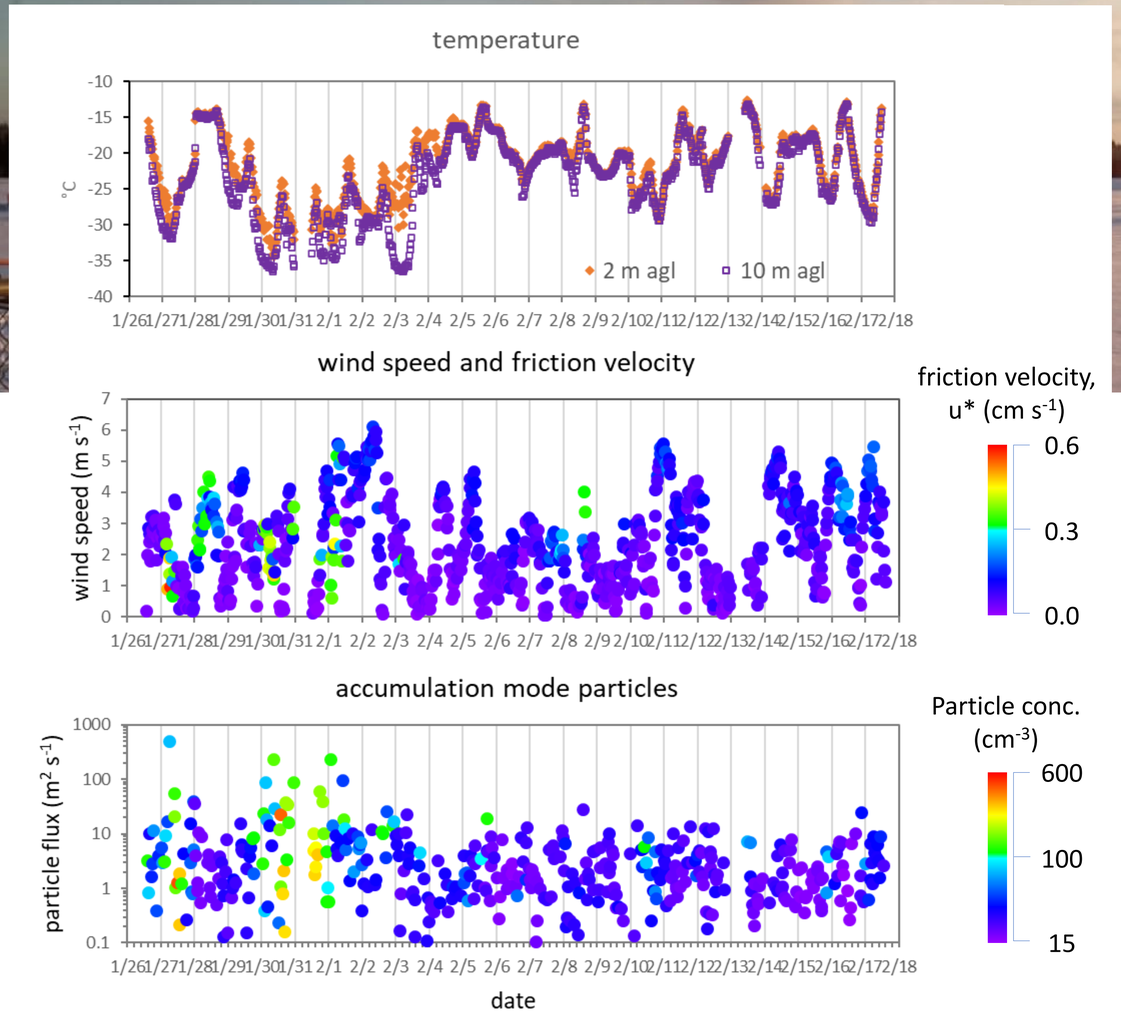


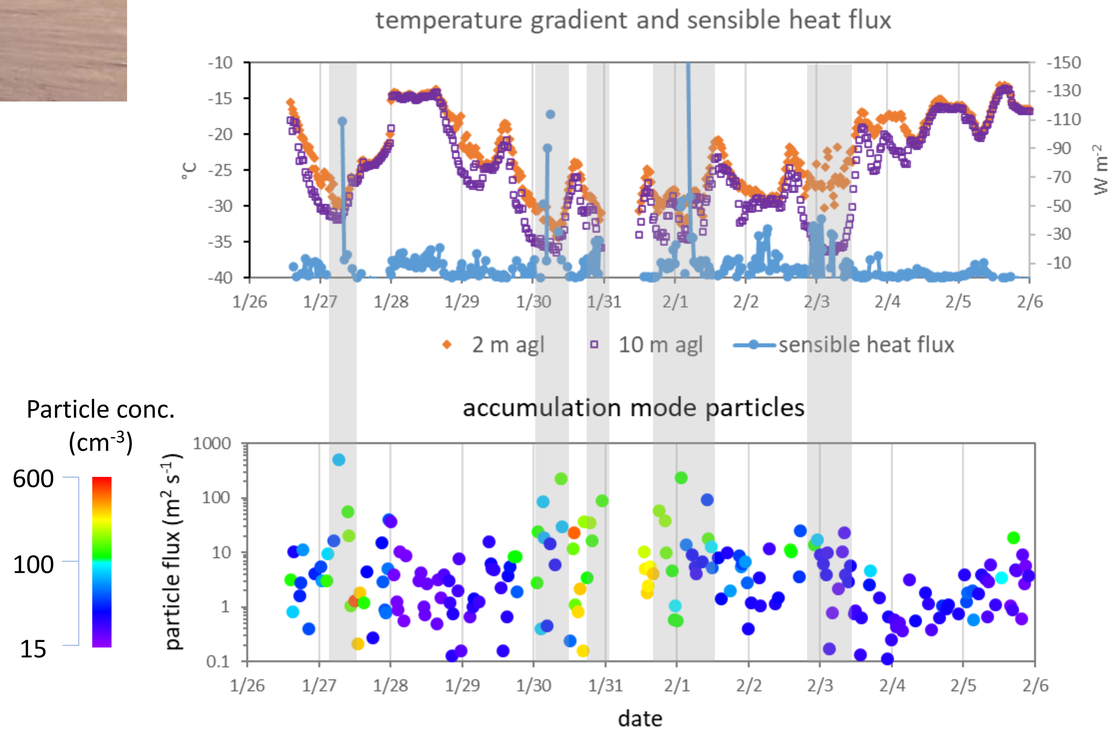




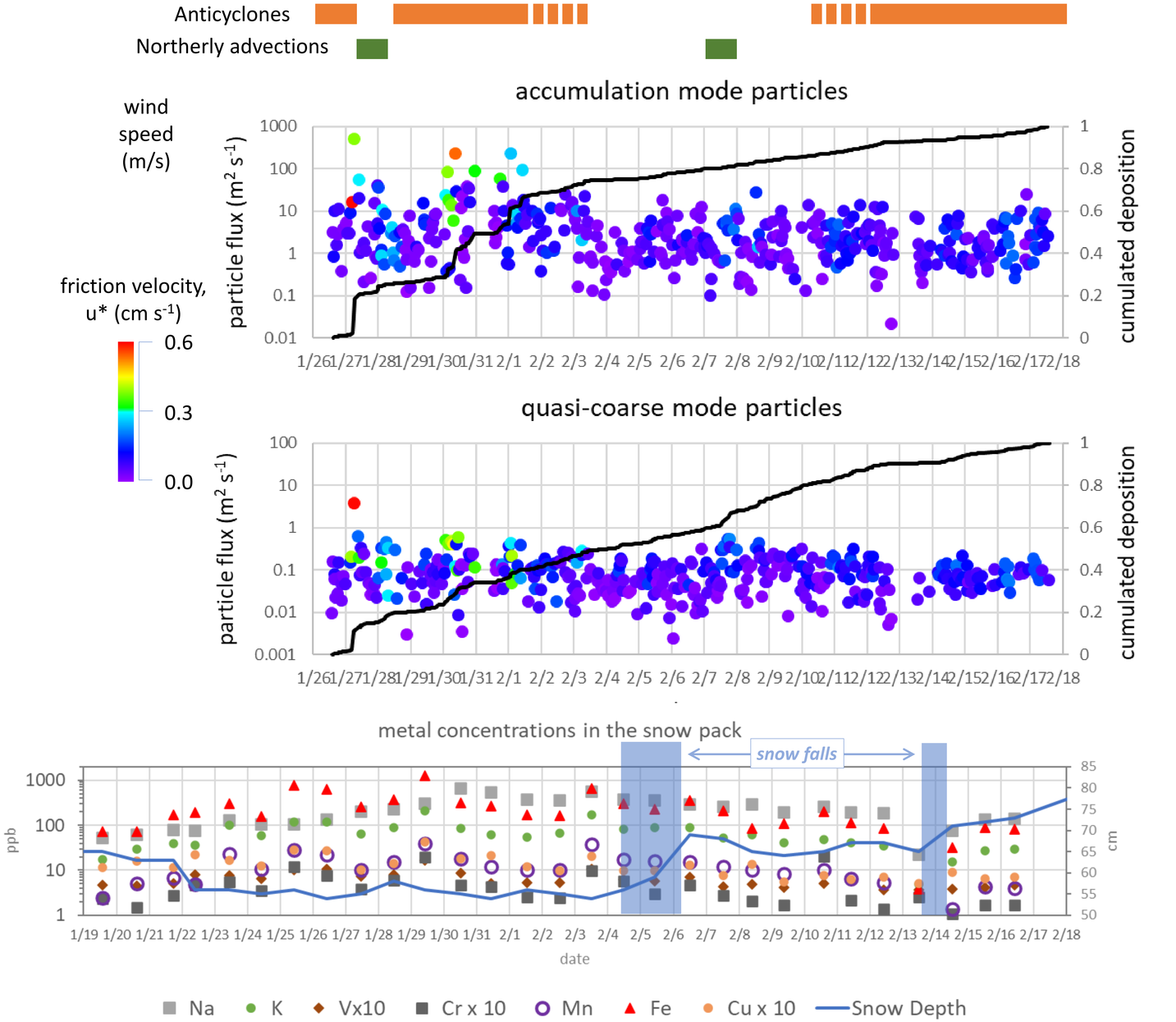

Depositional particle fluxes during the first part of the campaign (first anticyclon) reached 70% of total dry depositions (as particle per square meter) for accumulation mode particles, while larger aerosols («quasi-coarse») show a more uniform deposition throughout the measurement period. The peaks in downward particle fluxes are often associated to high friction velocities (u

The first anticyclonic period is characterised by frequent, long-lasting pronounced shallow surface-based inversions. However, contrary to the downtown areas, wind speed at 10 m agl often exceeded 3 m/s and the thermal inversions were often interrupted before reforming (Maillard et al., Boundary Layer Meteo 2022). At the times when the surface thermal gradients shrinked, the downward sensible heat flux was often (not always) accompanied by a flow of accumulation mode particles.



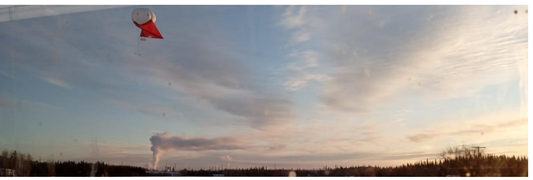



Sampling of surface snow was conducted at the UAF Farm site on a daily basis between 19 Jan and 16 Feb. During the first dry period, the snowpack first became compact then remained approximately constant in depth. During these days of stable weather conditions (first anticyclone), which were also the days of more serious air pollution and with stronger aerosol dry depositions, metal concentrations in the surface snowpack progressively increased. The snowfalls occuring in the following days formed a new layer with reduced concentrations of pollutants. The overall dataset (including the determination of metals in PM10 samples collected regularly at the site) will provide quantitative information about the role of dry depositions in determining snow chemical composition in this area of the world.



# *next steps*

- More in-depth analysis of the PBL processes linking shallow surface-based inversions formation and break-up and particle fluxes during ALPACA.
- Quantitative comparison between downward aerosol fluxes and aerosol components in the snowpack by including an estimate or mass fluxes of metals determined in PM samples collected during the campaign.
- Compare depositions in the snowpack at UAF with those at downtown sites characterized by different meteorology and particle concentrations.
- Evaluate the representativeness of the aerosol depositions determined during ALPACA for the wider pan-Arctic environment with comparison with dry depositions observations in different environments.





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