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Impact of wind speed variability on the surface energy balance and boundary-layer stability in central Alaska

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The pre-ALPACA (Alaskan Layered Pollution And Chemical Analysis) 2019 winter campaign took place in Fairbanks, Alaska, in November—December 2019. One objective of the campaign was to study the life-cycle of surface-based temperature inversions and the associated surface energy budget changes. Several instruments, including a 4-component radiometer and sonic anemometer were deployed in the open, snow-covered UAF Campus Agricultural Field. The surface energy budget at the UAF field exhibited two preferential modes. In the first mode, turbulent sensible heat and net longwave fluxes were close to 0 W m^{-2} , linked to the presence of clouds and generally low winds. In the second, the net longwave flux was ≈ -50 W m^{-2} and the turbulent sensible heat flux was ≈ 15 W m^{-2} , linked to clear skies and the presence of a local flow. The development of surface temperature inversions at the UAF field was hindered compared to other locations in Fairbanks because the flow sustained vertical mixing. Indeed, the wind speed at 2 m was around 5 m s^{-1}, above the estimated critical wind speed threshold for sustainable turbulence in the MWST (Minimum Wind speed for Sustainable Turbulence) framework. Despite the clear skies, the local flow maintained a weakly stable state of the boundary layer.

These results suggest there is significant variability of Arctic boundary-layer stability due to variations in the near surface wind speed, even in anticyclonic, clear-sky conditions. Accurate representation of the stable boundary-layer by meso-scale models therefore requires that they reproduce the wind-driven transition between weakly stable and strongly stable states correctly. The impact of parameters such as stability functions and roughness length on the modelled transition thus represents an important follow-up question to this study.