Supplement of Atmos. Meas. Tech., 19, 4601–4615, 2026
https://doi.org/10.5194/amt-19-4601-2026-supplement

Atmospheric Measurement Techniques
Open Access
EGU

Supplement of

Reaching new heights: Profiling Upper altitudes For Ice Nucleation (PUFIN) on the Atmospheric Radiation Measurement (ARM) tethered balloon systems

Jessie M. Creamean et al.

Correspondence to: Jessie M. Creamean (jcream07@rams.colostate.edu)

Supporting methods

Equivalent potential temperature calculations

Because the iMet-XQ2 accuracy is limited (see Summary section), we use the more reliable TBSIMET observations to examine equivalent potential temperature (θe), calculated following Bolton (1980), which is well suited for assessing atmospheric stratification and boundary-layer mixing. Additionally, for the CRG February flights the iMet-XQ2 data were not recorded in the INP flight data files, although iMet-XQ2 measurements were taken for the July flights. TBSIMET data are available from the ARM Data Center (https://adc.arm.gov/discovery/results/s::tbsimet).

To calculate θe, TBSIMET data (altitude, temperature, pressure, relative humidity) were first preprocessed by removing unrealistic, non-NaN spikes in altitude observations and converting altitude from kilometers to meters. The profiles were then averaged into 10-m vertical bins; within each bin the mean altitude, temperature (°C), pressure (hPa), and relative humidity (%) were computed. Dew point temperature (T_d) in each bin was estimated from the binned temperature and relative humidity using the Magnus–Tetens approximation. Saturation vapor pressure at T_d was computed and the mixing ratio r (kg kg−[1]) obtained via $r = \varepsilon e_s/(p - e_s)$ with $\varepsilon = 0.622$. Potential temperature θ was calculated from the binned temperature and pressure, and equivalent potential temperature was computed using the Bolton (1980) formulation: $\theta e = \theta \exp((L_v r)/(c_p T_d(K)))$, where L_v is latent heat of vaporization ($\approx 2.5\times10^6$ J kg^{-1}), c_p is the dry-air specific heat at constant pressure (≈ 1005.7 J kg^{-1} K^{-1}), and $T_d(K)$ is T_d in kelvin. Uncertainty in θ_e was estimated as the one-standard-deviation of θ_e values computed for each original sample within a bin (i.e., compute θ_e per sample, then take the binwise standard deviation).

To determine whether the boundary layer at the PUFIN sampling altitudes was well mixed or stratified, we evaluated θ_e only within the altitude ranges where PUFIN was deployed. If the vertical variation (minimum to maximum) in θ_e was ≤ 1 K, the layer was considered well mixed; if > 1 K, it was classified as stratified. Variability in θ_e could manifest as discrete layers or as a continuous vertical gradient.

References

Bolton, D.: The Computation of Equivalent Potential Temperature, Mon. Wea. Rev., 108, 1046–1053, https://doi.org/10.1175/1520-0493(1980)108%3C1046:TCOEPT%3E2.0.CO;2, 1980.

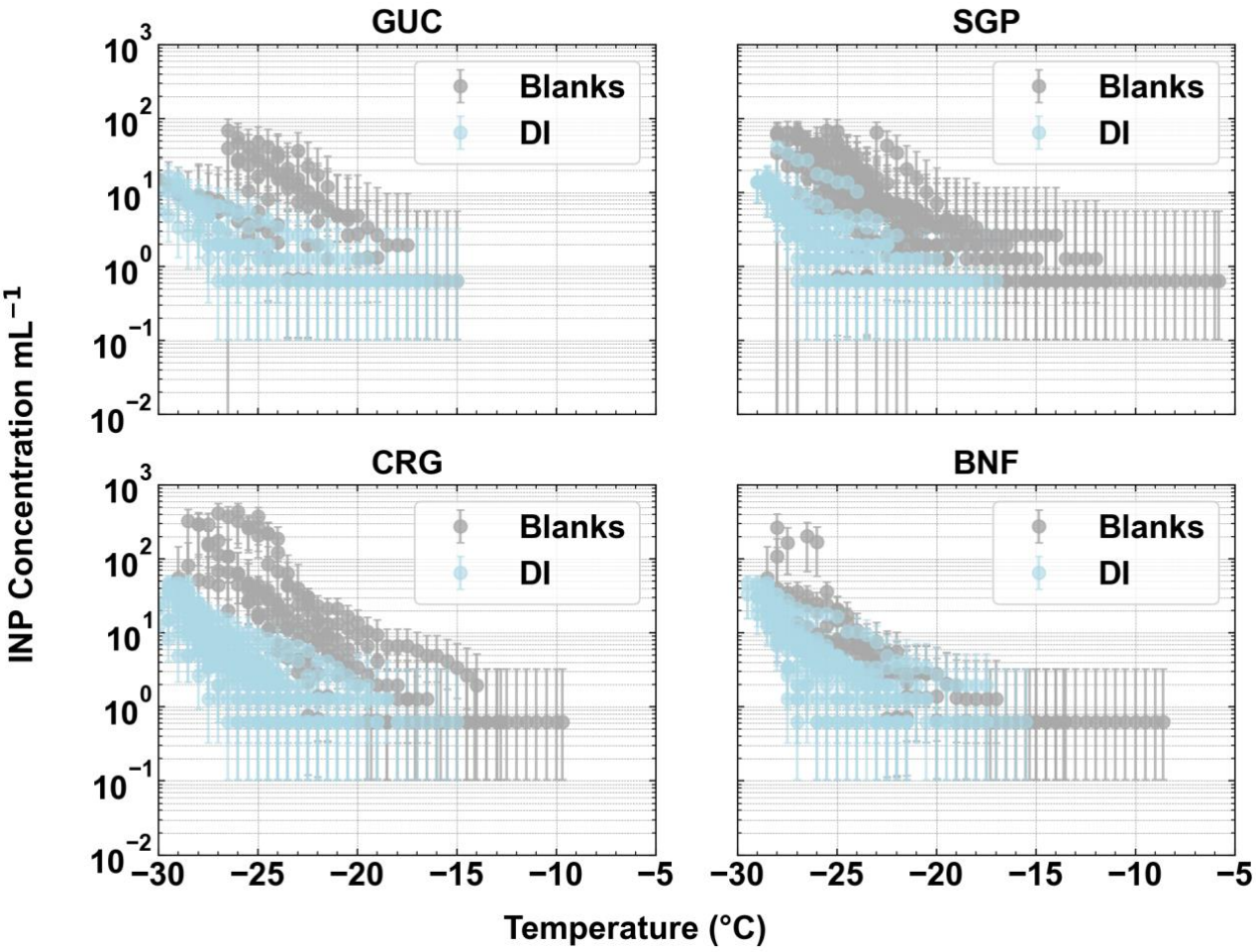

Figure S1. Handling blanks and deionized water (DI) backgrounds from each deployment of the IcePuck (GUC and SGP) and PUFIN (CRG and BNF). INP concentration is displayed per mL of suspension liquid for the blanks compared to the DI background.

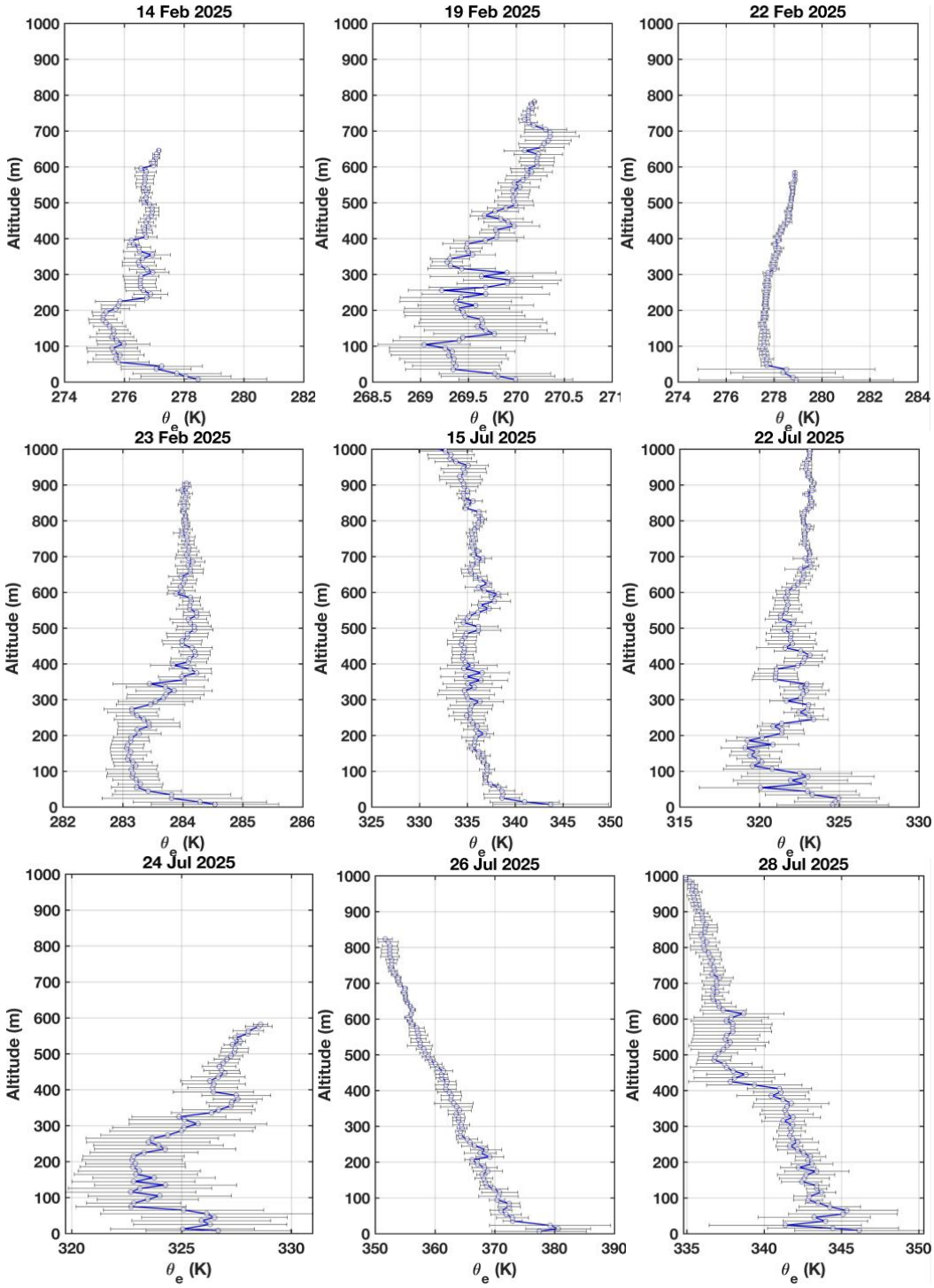

Figure S2. Vertical profiles of equivalent potential temperature (θ_e) in degrees K calculated based on Bolton (1980) from TBSIMET data from the CRG flights where PUFIN flew. Data are binned by every 10-m AMSL and focused on the lower 1000 m of the flight. Error bars represent one standard deviation.

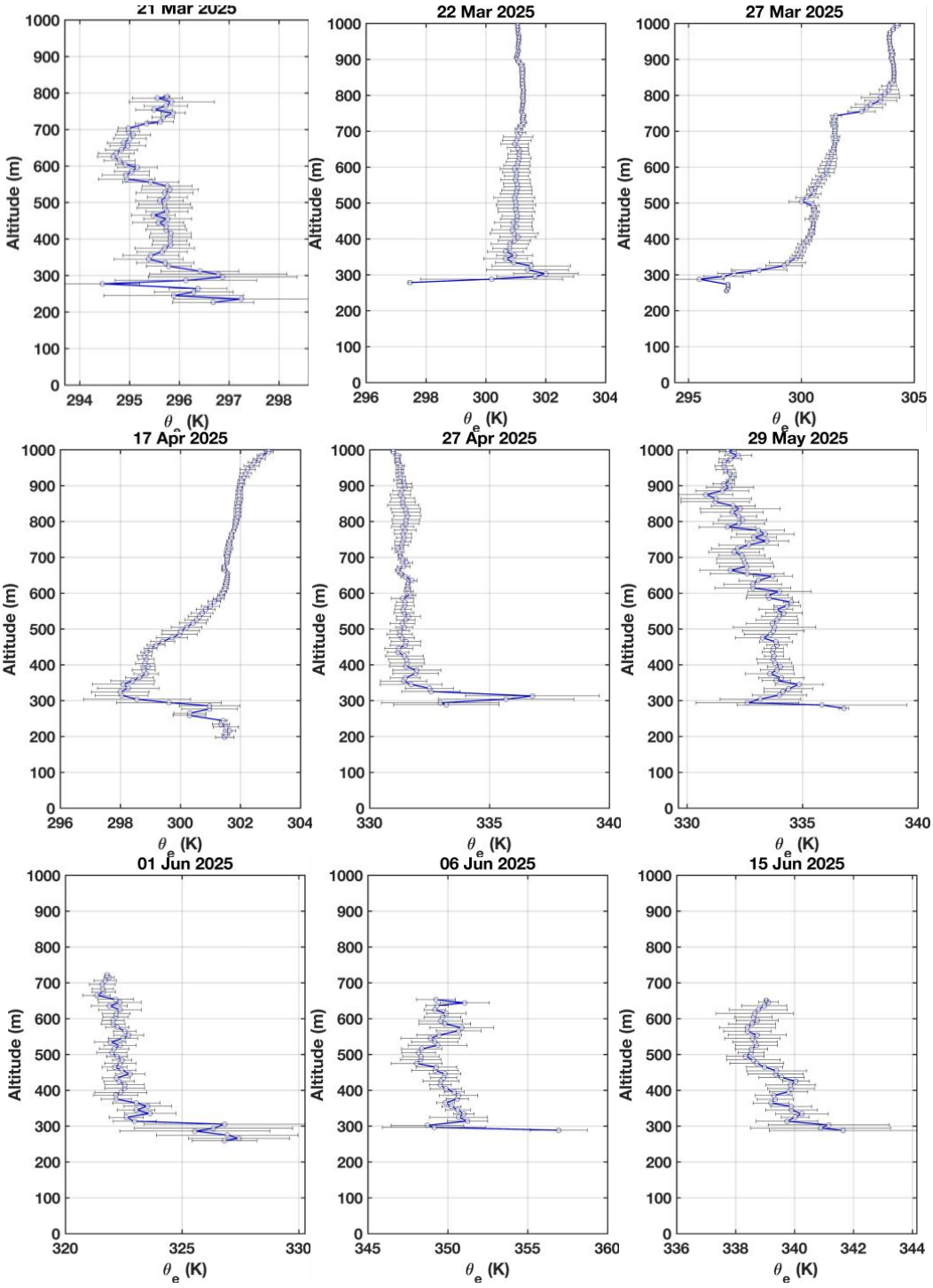

Figure S3. Same as Figure S4, but for BNF.

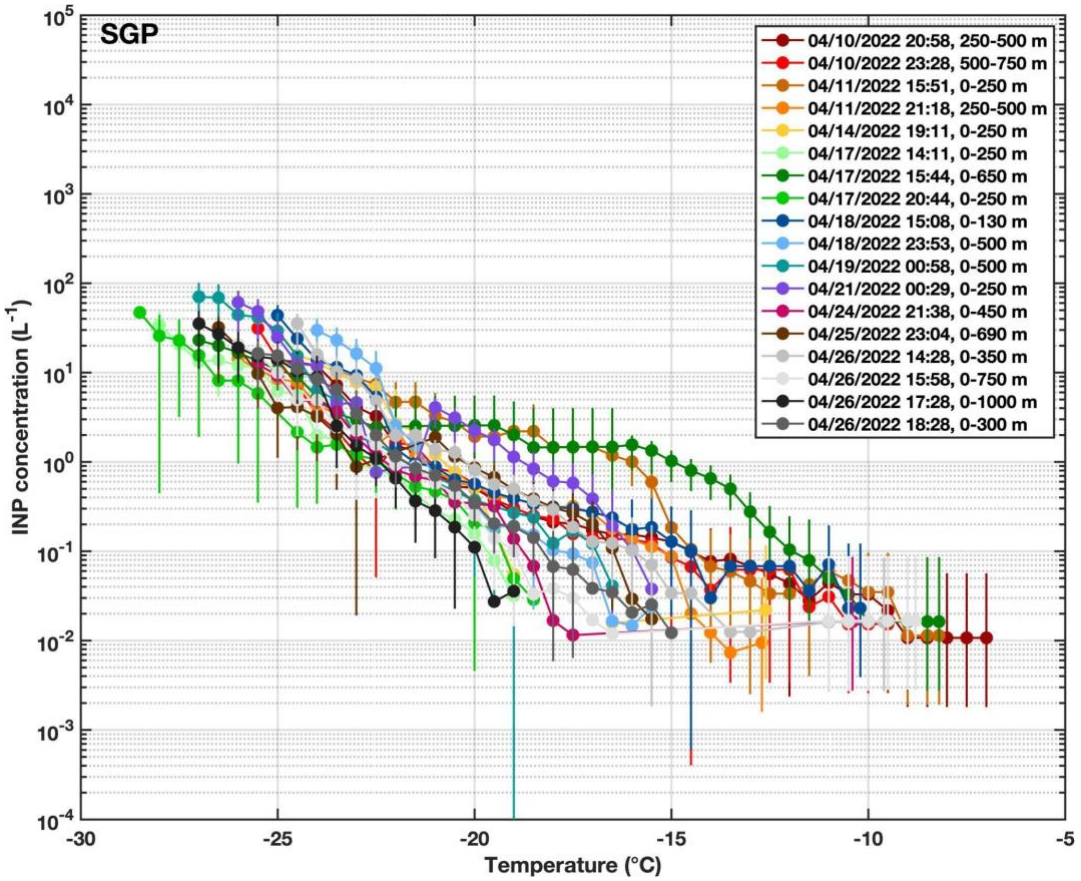

Figure S4. Same as Figure 5, but for SGP in April 2022.

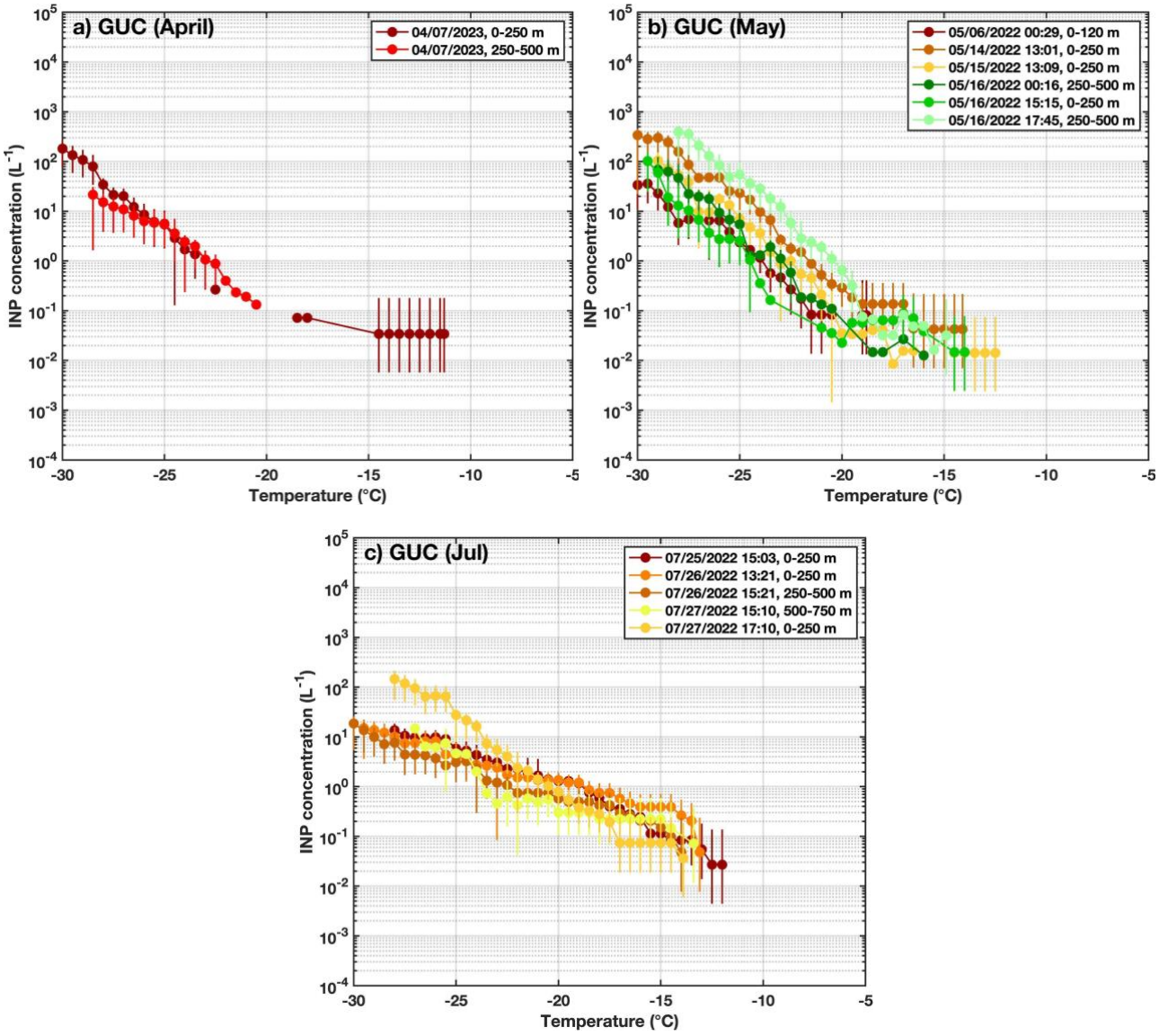

Figure S5. Same as Figure 5, but for GUC in a) April 2023, b) May 2022, and c) July 2022.

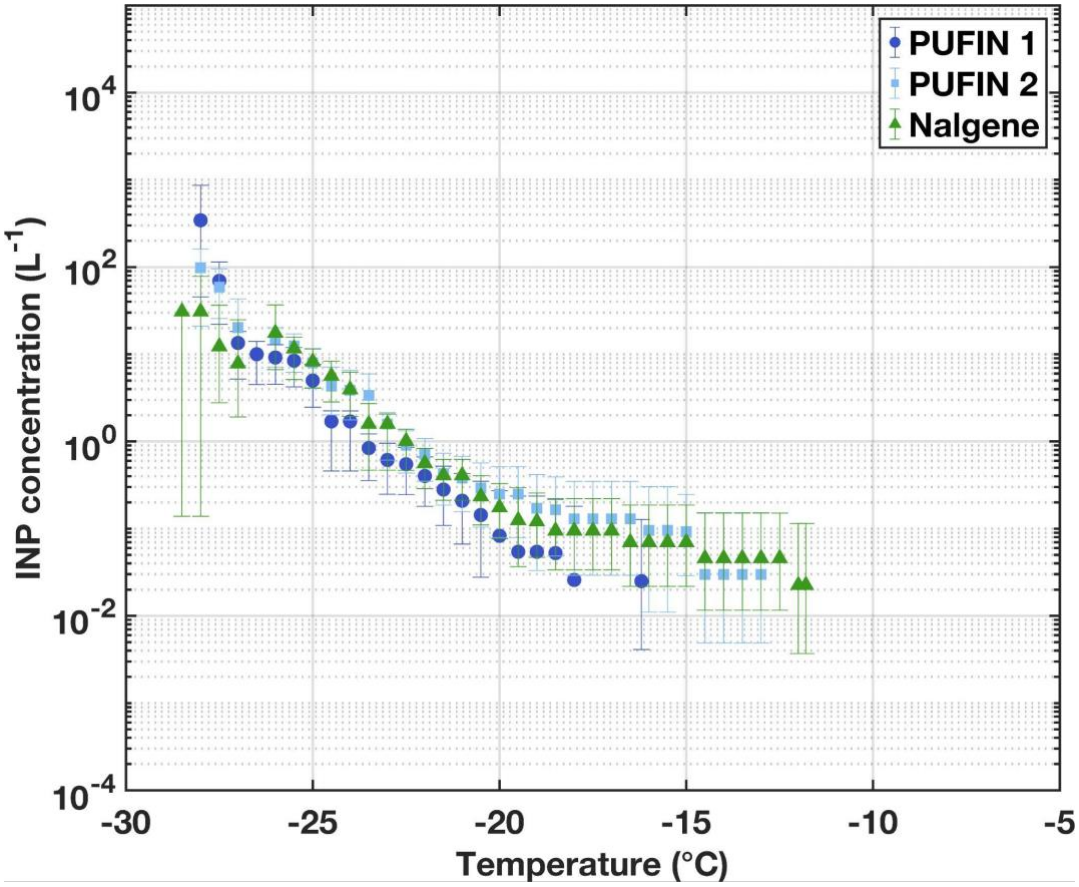

Figure S6. Cumulative INP spectra from both PUFIN units and the ARM ground-based Nalgene® filter unit (Creamean et al., 2025) for a 30-minute intercomparison test conducted outside the CSU building where the INS is housed.