Improving the simulation of INP concentrations with new long-term PINE observational dataset

Ross Herbert[1], Benjamin Murray[1], Ken Carslaw[1], Stephen Arnold[1], Anthony Jones[2], Mark Tarn[1], Martin Daily[1], Larissa Lacher[3] Ottmar Möhler[3], Alex Böhmländer[3], Naruki Hiranuma[4], Aidan Pantoya[4], Evelyn Freney[5], Céline Planche[6], Antoine Canzi[6]

[1] University of Leeds, UK [2] UK Met Office [3] KIT [4] WTAMU, Texas
[5] CNRS, Clermont-Ferrand [6] UCA, Clermont-Ferrand

Natural Environment Research Council

M-Phase

UNIVERSITY OF LEEDS

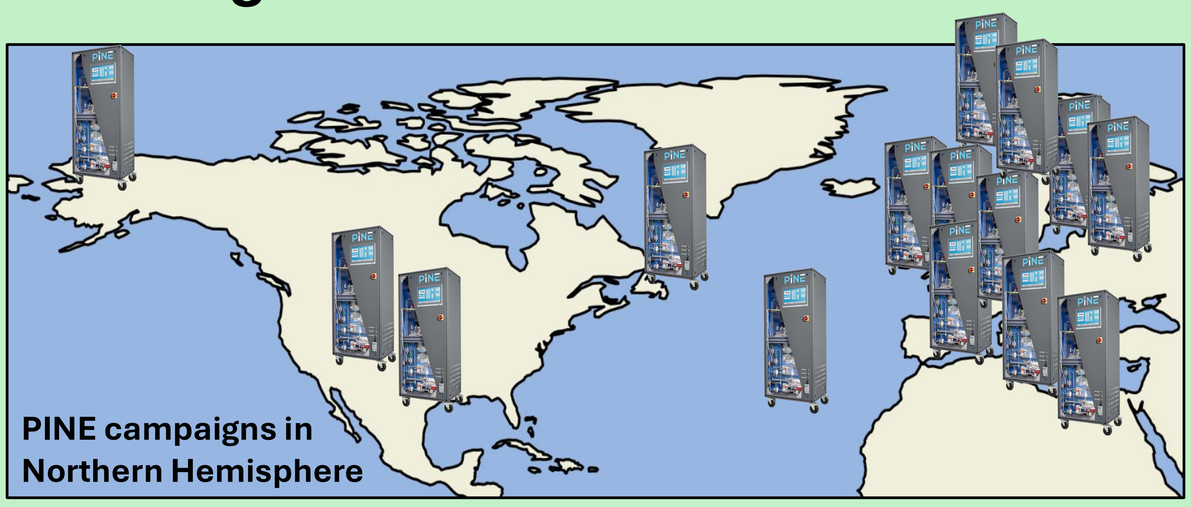
1. Introduction

Ice nucleating particles (INPs) influence the climate through modifications to cloud radiative properties and precipitation. To quantify the role of INPs on the climate we must first ensure our INP models are accurate, and for this we require good observations. Most INP measurements are made over short time periods using a range of methods/techniques. **In this study we evaluate our INP model against 18 datasets from a single INP instrument that provides long-term ambient measurements.**

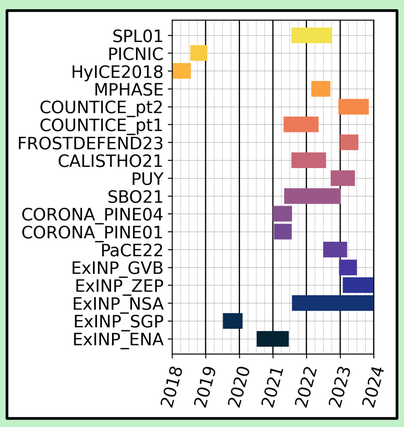
2.2 The model (UKESM)

- Met Office UKESM[1] in global configuration (~ 1.5° resolution).
- Nudged ERA5 meteorology to run alongside PINE campaigns.
- Dust and sea-spray interactively simulated by UKCA-mode[2].
- INPs calculated offline from sea-spray and dust aerosols.
  - Empirical dust parameterization of $n_s(T)$ from soil samples, which include mineralogical and biological components.
  - Temporally/spatially matched to 6-hr PINE measurements.

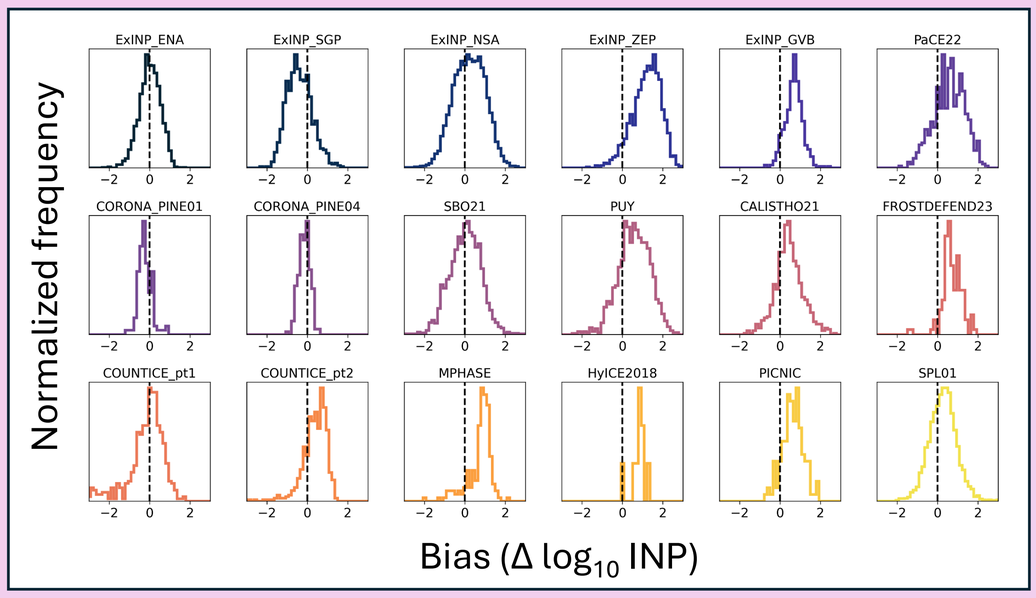
2.1 The global PINE dataset



The **P**ortable **I**ce **N**ucleation **E**xperiment **PINE**[3] chamber measures ambient INP concentrations automatically (< 10 mins) across a range of freezing temperatures. PINE campaigns have been conducted across the Northern Hemisphere, giving us an unprecedented INP database for evaluating our global INP model.

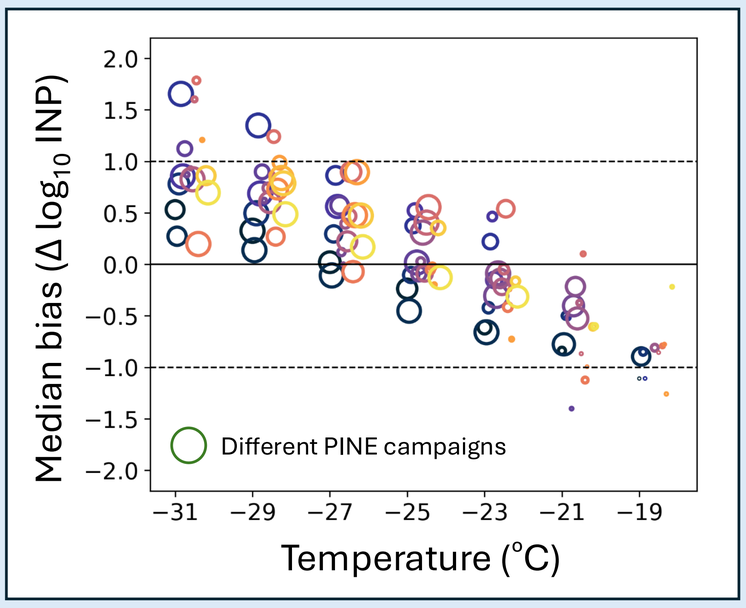


3.1 Distribution of model – measurement bias



- Ideally, we would see a narrow peak around zero bias.
- Most datasets are centered close to zero.
- Some are positively biased, indicating the model is producing too many INPs.

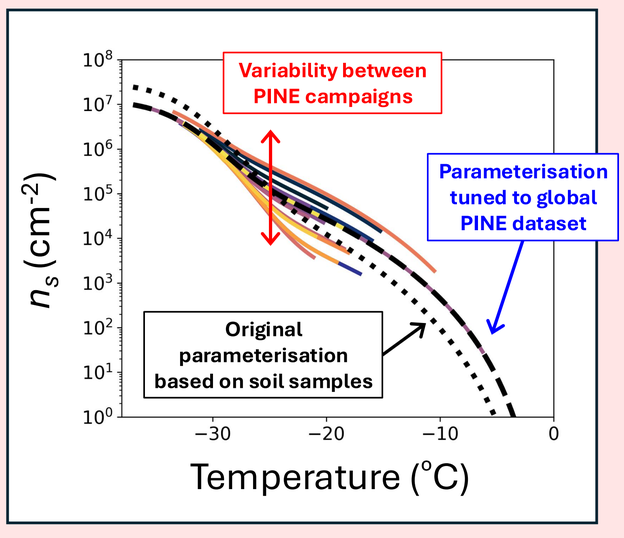
3.2 T-dependent bias



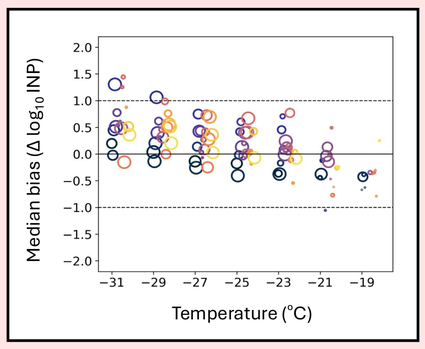
- Model ~ reproduces the INP measurements within factor of 10.
- Strong T-dependent bias evident.
- Model producing too many INPs at low T, too few INPs at high T.

3.3 What $n_s(T)$ parameterisation minimises bias?

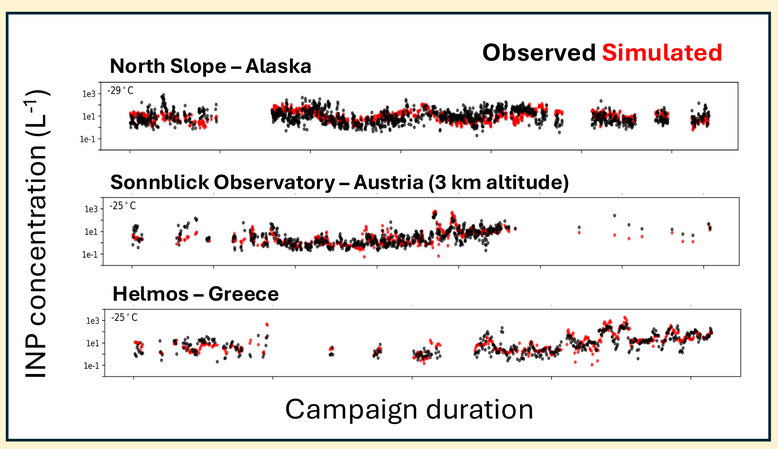
- Minimise $n_s(T)$ against global-PINE datasets.
- Campaign-dependent $n_s(T)$'s demonstrate regional variability.
- $n_s(T)$ using all PINE data suggests we are missing INP activity at high temperatures.



The 'tuned' $n_s(T)$ using all PINE datasets removes a lot of the remaining bias (and almost all temperature-dependence).



3.4 Amazing time series!



- Surprisingly skilled at reproducing short- and long-term variability.

4. Conclusions

The PINE measurement database provides an unprecedented opportunity for INP model evaluation on long timescales and at multiple temperatures. Our INP model reproduces PINE measurements within an order of magnitude but is missing INPs at higher temperatures. Only small changes to $n_s(T)$ are needed to improve the model.

References: **[1]** Sellar et al., 2020, JAMES, 10.1029/2019MS001946 **[2]** Mann et al., 2010, GMD, 10.5194/gmd-3-519-2010 **[3]** Möhler et al., 2021, AMT 10.5194/amt-14-1143-2021