A Data-Driven Approach to Modelling a Global Distribution of Ice Nucleating Particles

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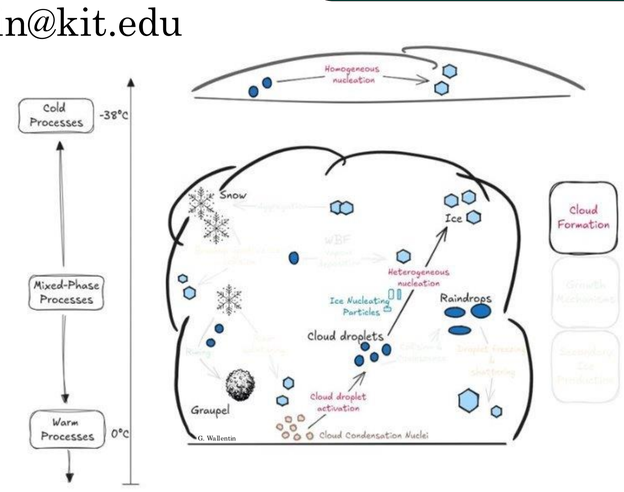
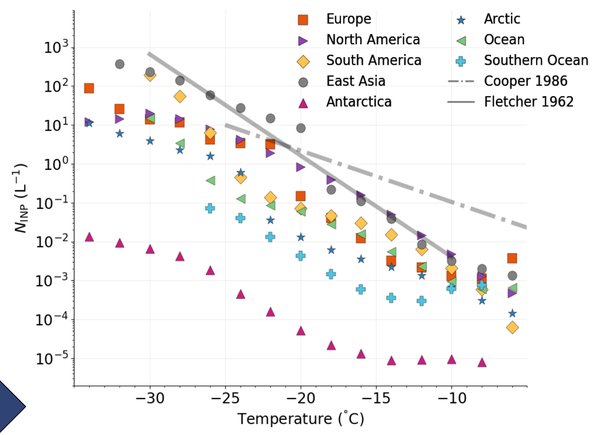
The Problem

Ice nucleating particles (INPs) are crucial for cloud ice formation in the mixed-phase temperature range



Measurements of INPs are scarce in time and space

Note the strong temperature dependence!

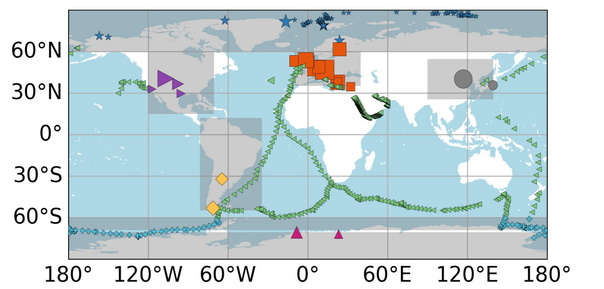


Their variability across space and time is difficult to capture with aerosol-independent models. Instead simplistic, temperature-dependent equations are defined to model this process globally

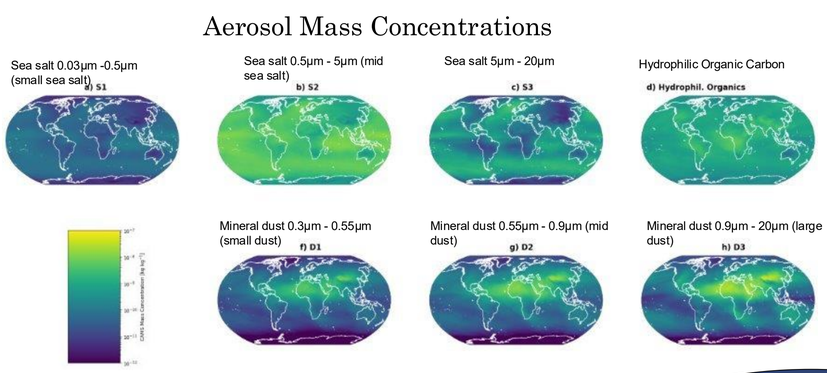
Solution: Predict INPs based on machine learning

The Method

Collect INP data



Collocate CAMS aerosols

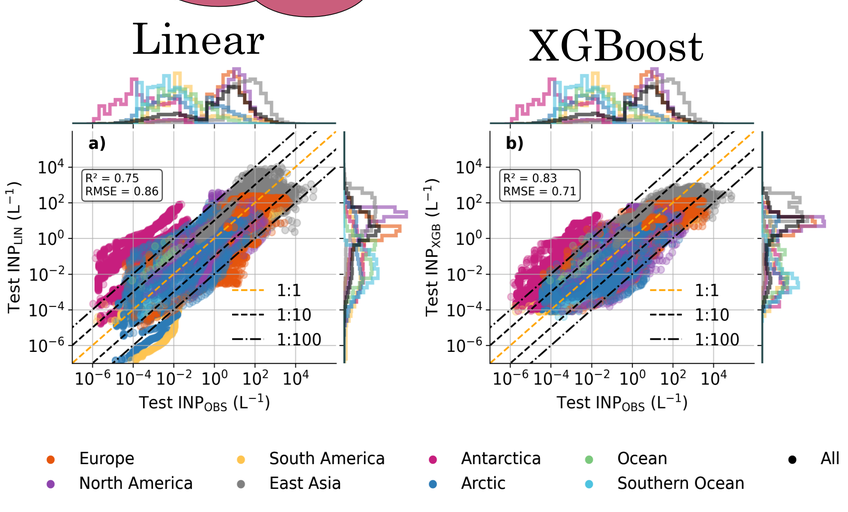


Train an XGBoost Regression Model

XGBoost is an ensemble of decision trees, based on simple yes-or-no questions where the trees are trained sequentially

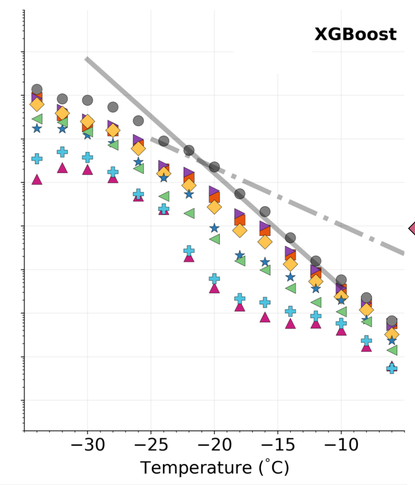
The Results

1: Does it work?

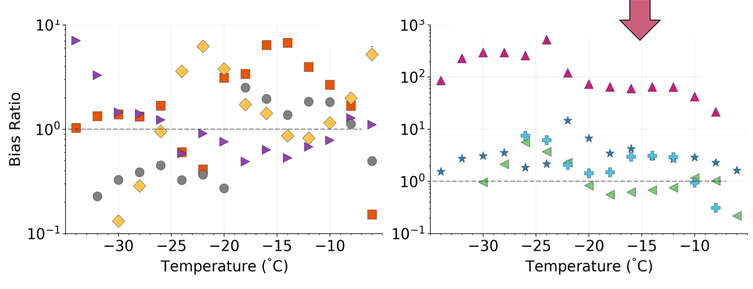


- Observed vs predicted INP concentrations separated by region.
- The linear regression benchmark performs well but XGBoost has better scores (R^2 and RMSE)
- Antarctica is difficult to predict due its small dataset used for training, less well-constrained aerosol reanalysis and difficulties predicting extreme outliers.

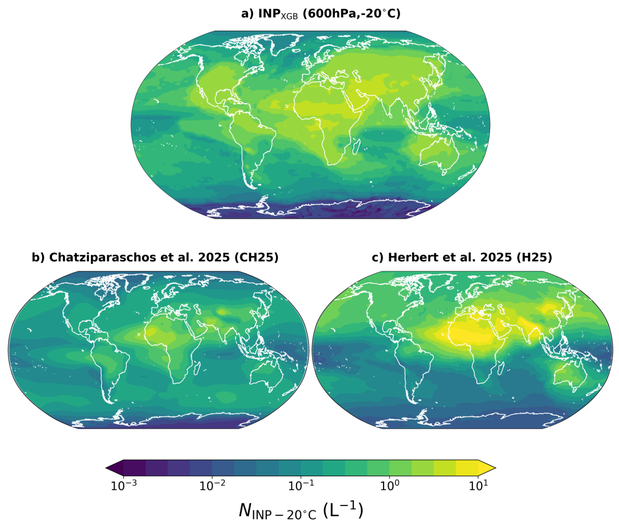
2: Is there a strong temperature dependence?



- INP concentrations is predicted at surface level
- The strong temperature dependence is captured
- Most regions compare well with observations (above)
- Mean bias (below), model mean/obs. mean shows a good agreement within mostly 1 order of magnitude



3: Realistic spatial distribution?



- INP concentration predicted at 600hPa at an activation temperature of -20°C to explore the global spatial distribution
- Comparison with aerosol-aware models with assumption based INP concentrations calculated from prognostic aerosols show a decent agreement with peaks over deserts and lower values over Antarctica and remote regions

The Conclusions

- Even with a small dataset it is possible to predict a realistic global INP distribution
- Regional climatological INP spectra (with temperature) can be extracted and agree within mostly one order of magnitude of the observations
- Spatially varying immersion freezing is possible to model without prognostic aerosols