# Biological and dust aerosol as sources of ice nucleating particles in the Eastern Mediterranean: source apportionment, atmospheric processing and parameterization

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## Motivation:

- Aerosol-cloud interactions in mixed-phase clouds (MPCs) are key but poorly constrained drivers of hydrological cycle and climate.
- MPCs persistently exist in mountainous terrain where local and remote air masses may be present[1,2,3], which may contain different but distinct ice nucleating particle (INP) populations.
- Planetary Boundary Later (PBL) influence can be significant for INPs relevant for MPCs and follow distinct sources (e.g., INPs from bioaeorosols) and cycles.

Therefore, constraining the abundance and origin of INPs under different atmospheric conditions is important

## Study location and period:

- Helmos Hellenic Atmospheric Aerosol and Climate Change ((HAC)²) station (37.9843° N, 22.1963° E, 2314 m above sea level (a.s.l.)) close to the summit of Mt. Helmos in the Peloponnese, Greece.
- Secondary observation site at Vathia Lakka (VL), 500 m lower than (HAC)²
- Lies at the cross-road of airmasses with continental, marine, Saharan and biomass burning infleunce[4].
- PBL influence includes local pollution and bioaerosols.
- Observations collected during the CALISHTO campaign (October 12 and November 27, 2021)

## Goals:

1. To identify different INP sources at (HAC)² and evaluate the characteristics of these INP sources
2. To evaluate existing INP parameterizations and propose new ones that capture the INP number concentration ($N_{INP}$) better for the wide diversity of INP sources encountered at (HAC)²

## Instrumentation setup

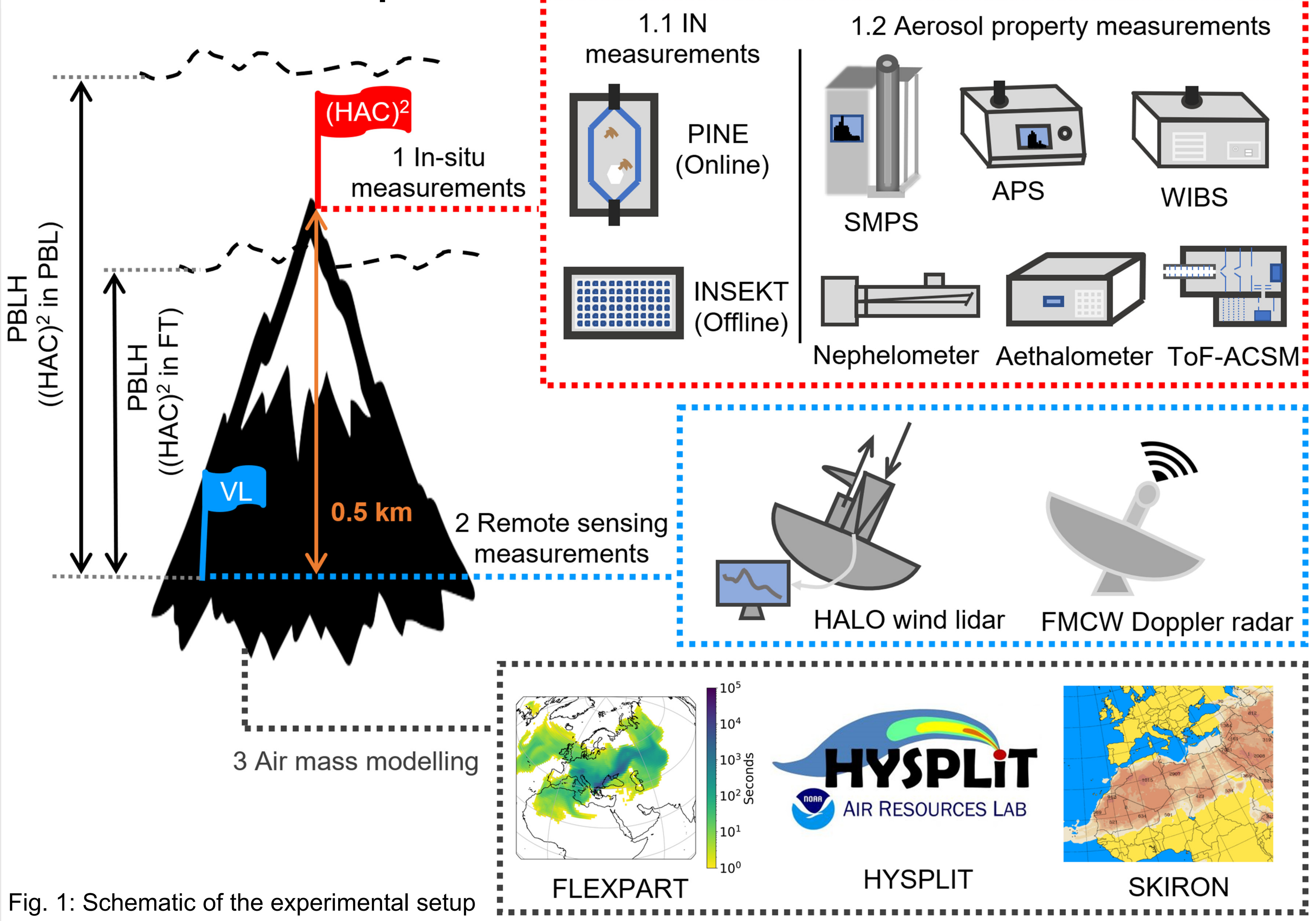


Fig. 1: Schematic of the experimental setup

## Methodology and instruments:

In-situ ice nucleation (IN) and aerosol property measurements at (HAC)², remote sensing measurements at VL and back trajectory analysis for calculating the origin of air masses sampled at (HAC)².

- **Instruments at (HAC)²:** A Portable Ice Nucleation Experiment (PINE), Scanning Mobility Particle Sizer (SMPS), Aerodynamic Particle Sizer (APS), Wideband Integrated Bioaerosol Sensor (WIBS), nephelometer and aethalometer, as well as Time-of-Flight Aerosol Chemical Speciation Monitor (ToFACSM), and an Ice Nucleation Spectrometer of the Karlsruhe Institute of Technology (INSEKT) for off-line IN tests.
- **Instruments at VL:** A HALO wind lidar and a frequency-modulated continuous wave (FMCW) Doppler radar (working at 94 GHz) for remote sensing of wind fields, aerosols and clouds.
- **Modelling experiments:** FLEXible PARTicle dispersion model (FLEXPART) to determine the source regions of aerosol particles, Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) to acquire airmass atmospheric trajectories, and the SKIRON model to obtain dust forecasts.

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## Results:

### Result 1: Footprints of different aerosol sources

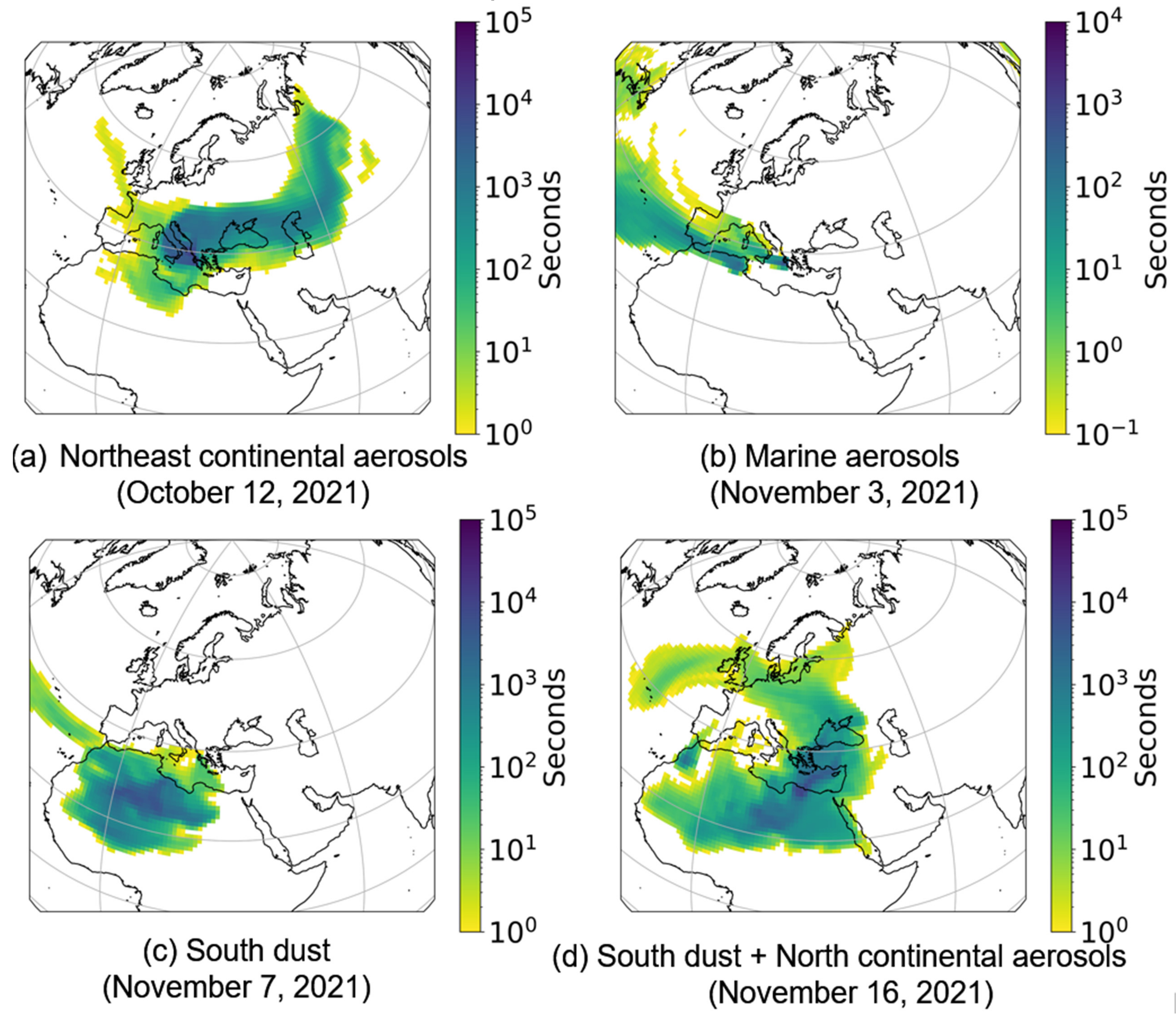


Fig. 2: Exemplary FLEXPART 10 day backward residence time maps (0-500 m a.g.l.).

- **Aerosol sources: Continental air masses, marine air masses and Saharan dust**

### Result 2: Distinct particle properties of different aerosol sources

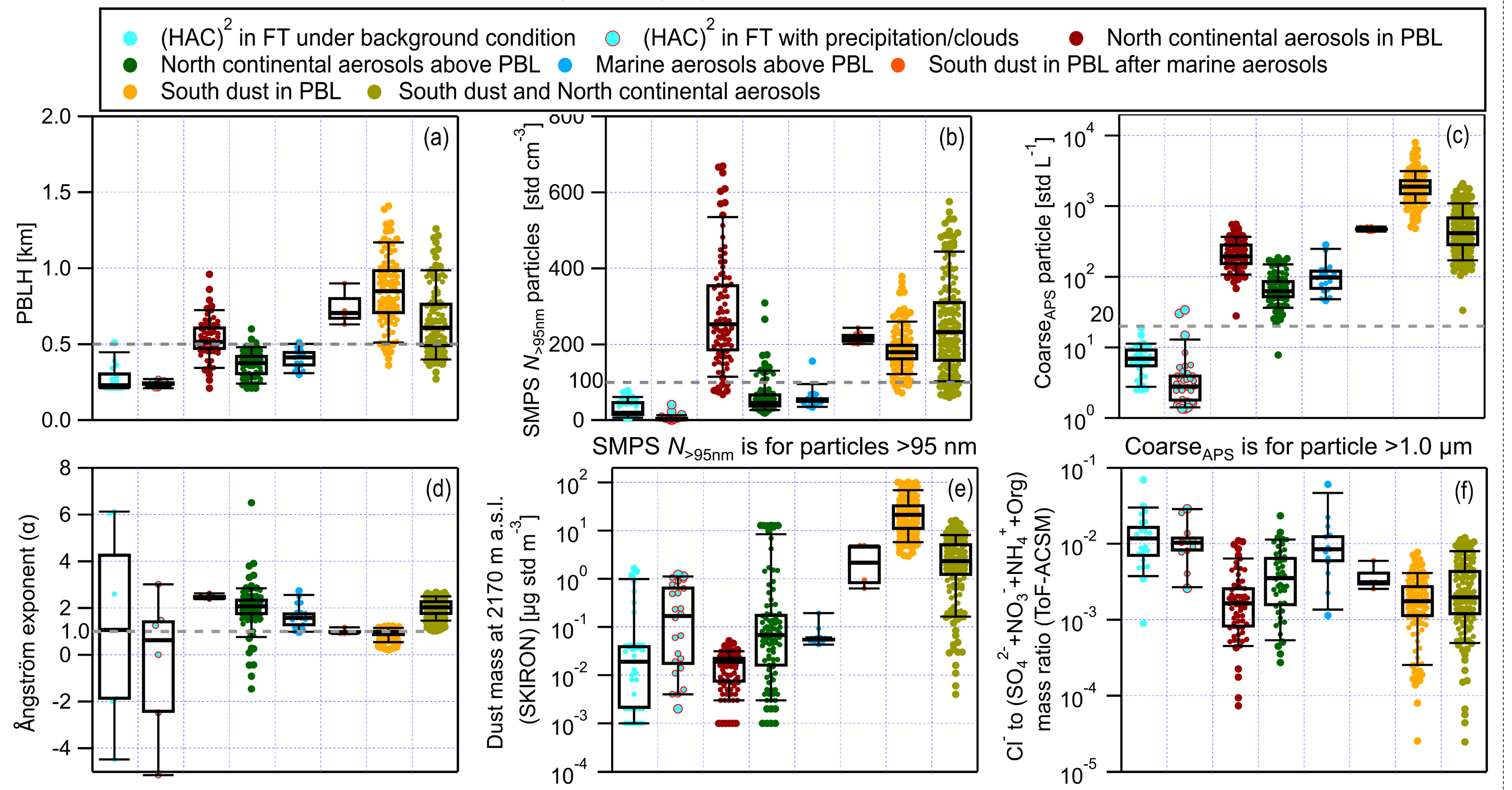


Fig. 3: Box plots for the characteristics of identified aerosol sources.

- **Different aerosol sources show distinct characteristics**
- **PBL condition regulates aerosol properties of air masses from the same region**

Navigation: Result 1 → Result 2 → Result 3 → Result 4

### Result 3: INP abundance of different aerosol sources

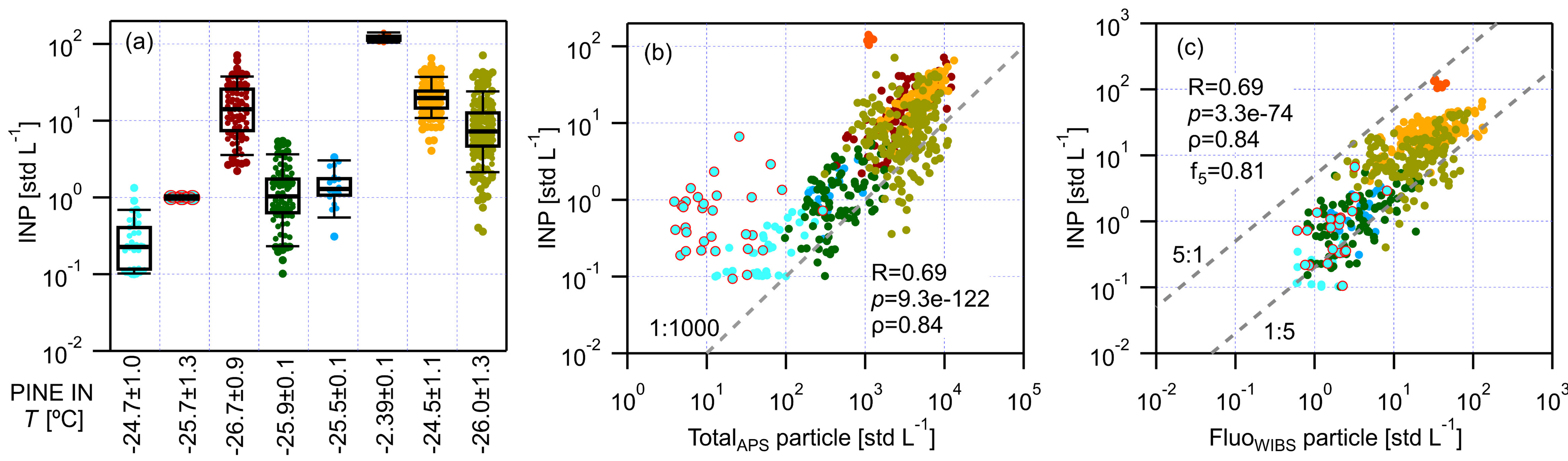


Fig. 4: INP abundance of different aerosol sources and the relation between.

- **INP abundance: Dust > Continental aerosols > Marine aerosols > FT background (also depends on PBL condition)**
- **For all individual aerosol sources, $Fluo_{WIBS}$ shows a more pronounced correlation with $N_{INP}$ comapred to $Total_{APS}$**

### Result 4: WIBS-INP parameterization **outperforms** published parameterizations

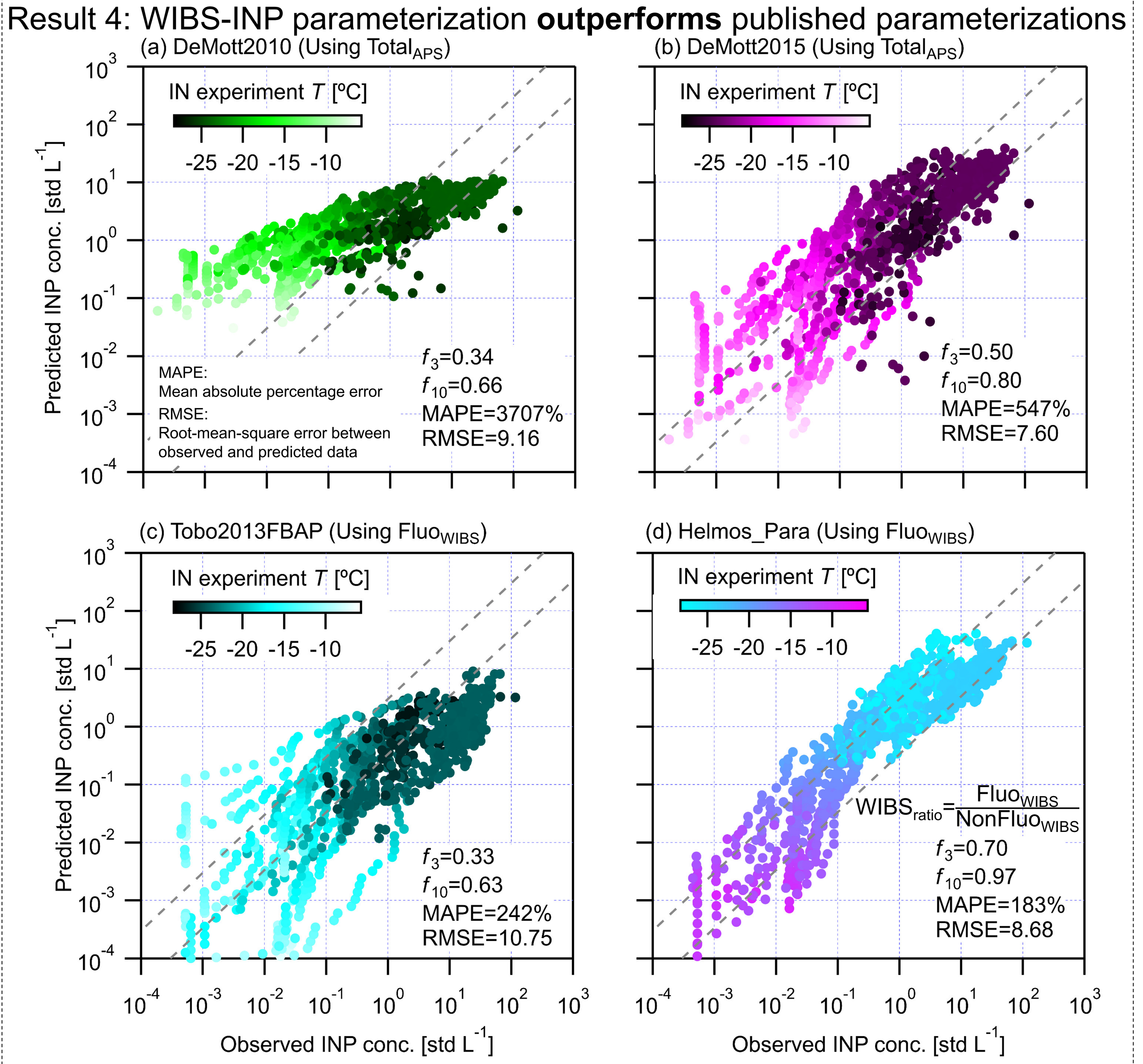


Fig. 5: Different parameterizations for predicting INPs at (HAC)²

| | | |
|---|---|---|
| (a)[5] DeMott2010 | $Total_{APS}$ (std cm⁻³) | $N_{INP} = a(-T)^b * Total_{APS}^{(-cT+d)}$ (a=0.0000594, b=3.33, c=0.0264, d=0.0033) |
| (b)[6] DeMott2015 | | $N_{INP} = cf * Total_{APS}^{(-aT+b)} * exp(-cT+d)$ (cf=3, a=0, b=1.25, c=0.46, d=−11.6) |
| (c)[7] Tobo2013FBAP | $Fluo_{WIBS}$ (std cm⁻³) | $N_{INP} = Fluo_{WIBS}^{(-aT+b)} * exp(-cT+d)$ (a=–0.108, b=3.8, c=0, d=4.605) |
| (d) Helmos_para | | $N_{INP} = exp(aT+b) *(Fluo_{WIBS}/1000)^{(cT+d)} * (WIBS_{ratio})^{(eT+f)}$ (a=−0.097, b=−3.69, c=−0.163, d=−3.04 e=0.024, f=0.441) |

## Summary and Conclusions:

a. Specific INP source apportionment was achieved, demonstrated by the distinct characteristics of different sources, including continental, marine and dust aerosols, as well as a mixture of continental and dust aerosols (Fig. 3)
b. Under FT background condition, the INP abundance (for $T$≈-25°C) is less than 1.0 std L⁻¹, increasing with the influence of marine and continental aerosols (Fig. 4)
c. In the PBL, the INP abundance spans three orders of magnitude and increases following the order of marine aerosols, continental aerosols, and finally, dust plumes (Fig. 4)
d. **$Fluo_{WIBS}$ particles scale to $N_{INP}$ values of different sources better than $Total_{APS}$, highlighting the importane of fluorescent biological aerosol particles from the PBL (Fig. 4)**
e. The new INP parameterization (Helmos_para), incorporating the ratio of fluorescent-to-nonfluorescent particles and predicting >90% of the observed INPs within an uncertainty range of a factor of 10, exhibit **better performance than current widely-used parameterizations** (Fig. 5)

**References:**

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