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Aerosol-INP Closure Results at Two Sites: Zeppelin and Andenes Sites

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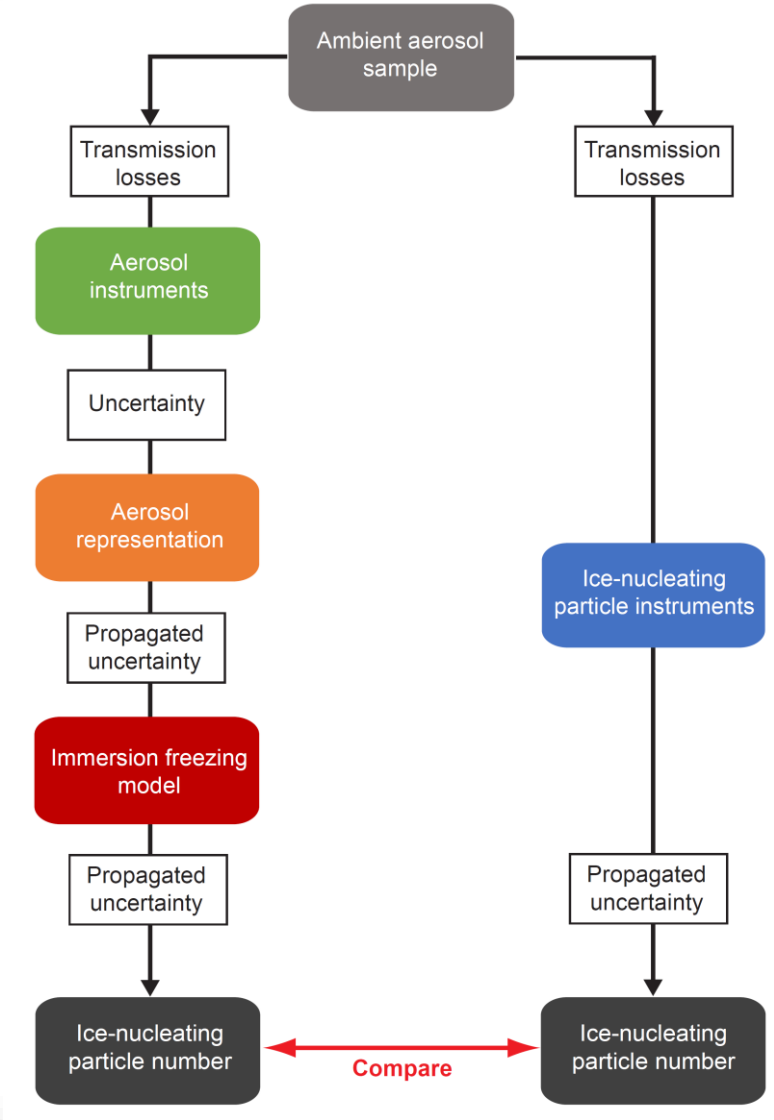
Aerosol-Ice Formation Closure Concept

The aim is to characterize the ambient aerosol population (size, composition) and then to apply immersion freezing parameterizations for known INP types to predict measured INP number concentrations.

More details in Knopf et al., BAMS, 2021

Zeppelin and Andenes (COMBLE) Sites:

- offline INP measurements
- Filter samples -> aliquot freezing arrays
- Aerosol PSD and composition data



Zeppelin and Andenes Site Locations

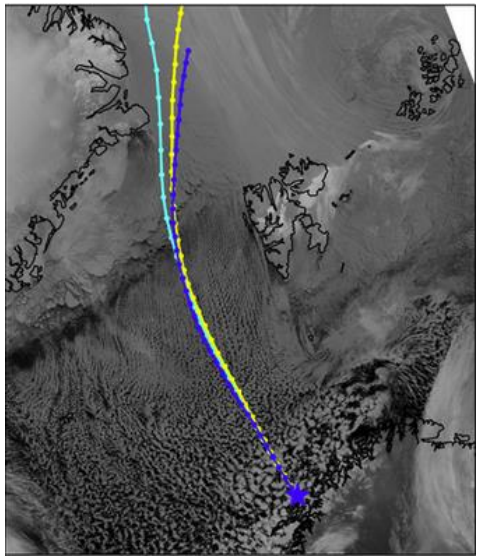
Zeppelin Station

Wikipedia

AMF, Andoya Island

ARM

March 13 case



Aerosol Particle Size Distribution

COMBLE and ZEPPELIN aerosol PSD parameters

Case	COMBLE time	Mode 1 (Aitken)			Mode 2 (Accumulation)			Mode 3 (Coarse)		
		N (cm^{-3})	D (µm)	σ_g	N (cm^{-3})	D (µm)	σ_g	N (cm^{-3})	D (µm)	σ_g
COMBLE	18 UTC March 13	28.43	0.023	1.35	43.32	0.13	1.67	7.14	0.33	1.69
ZEPPELIN	0 UTC March 13	38.97	0.03	1.8	201.21	0.13	2.2	24.58	0.61	1.9

Zeppelin station experiences greater particle numbers.

Assumptions for closure calculations:

- *All particles constitute sea spray aerosol*
- *Assume only 50% of accumulation mode particles are potential SSA-INP*
- *Neglect Aitken mode particles*

Acknowledgments:
Abigail Williams and Lynn Russell
Zeppelin aerosol PSD: R. Krejci, P. Zieger, P. Tunved
Andenes AMF: ARM

Immersion Freezing Parameterization

Apply debated CNT and singular freezing schemes:

- **Alpert et al., 2022**: Provides CNT and INAS parameterization of SSA-INPs

SCIENCE ADVANCES | RESEARCH ARTICLE

ATMOSPHERIC SCIENCE

Ice-nucleating agents in sea spray aerosol identified and quantified with a holistic multimodal freezing model

Peter A. Alpert[1,2]*, Wendy P. Kilthau[2], Rachel E. O'Brien[3,4,5], Ryan C. Moffet[6,7], Mary K. Gilles[3], Bingbing Wang[8,9], Alexander Laskin[8,10], Josephine Y. Aller[2], Daniel A. Knopf[2]*

- **McCluskey et al., 2018**: Provides INAS parameterization of SSA-INPs

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1029/2017JD028033

Key Points:
- Pristine sea spray aerosol is a dominant regional source of ice-nucleating particles at a remote North Atlantic coastal site
- Ice-nucleating particles at a remote

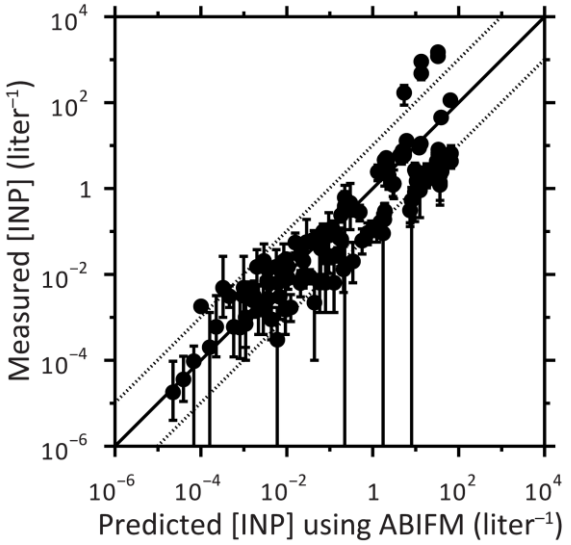
Marine and Terrestrial Organic Ice-Nucleating Particles in Pristine Marine to Continentally Influenced Northeast Atlantic Air Masses

Christina S. McCluskey[1,2], Jurgita Ovadnevaite[3], Matteo Rinaldi[4], James Atkinson[5], Franco Belosi[4], Darius Ceburnis[3], Salvatore Marullo[6,7], Thomas C. J. Hill[1], Ulrike Lohmann[5], Zamin A. Kanji[5], Colin O'Dowd[3], Sonia M. Kreidenweis[1], and Paul J. DeMott[1]

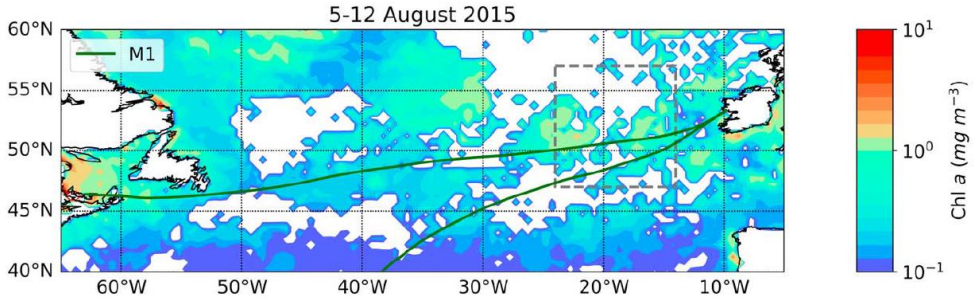
Immersion Freezing Parameterization

Apply debated CNT and singular freezing schemes:

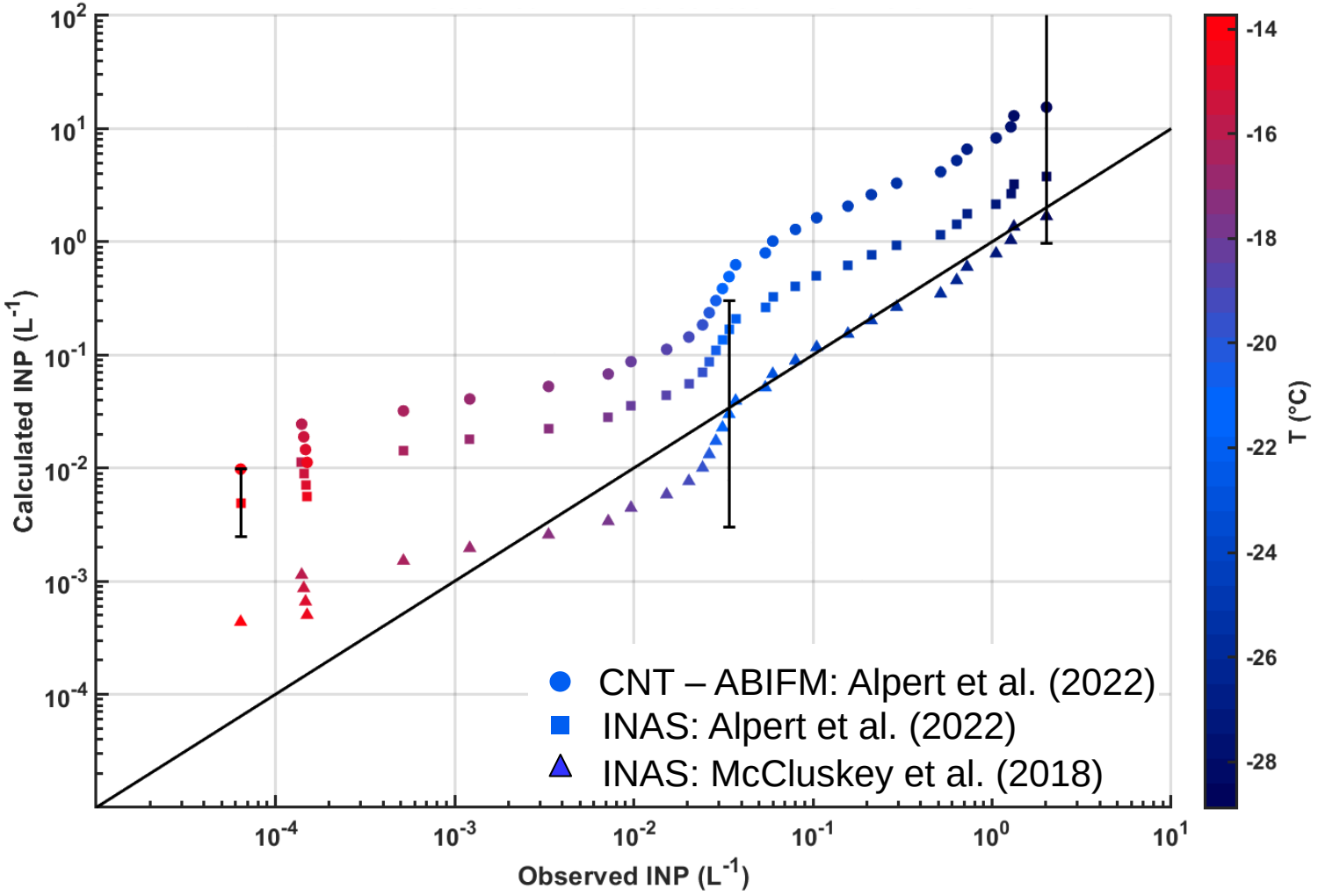
- **Alpert et al., 2022**: Provides CNT and INAS parameterization of SSA-INPs
  - Compilation of many SSA laboratory experiments
  - SSA-INPs identified from particle population
  - SSA ice-nucleating agents determined on 30 nm scale
  - Ambient SSA with same composition display same freezing properties (CARES, ACE-ENA, etc.)



- **McCluskey et al., 2018**: Provides INAS parameterization of SSA-INPs
  - Ambient particles sampled at Mace Head on filter over hours
  - No direct SSA or dust measurement
  - No identification of individual INPs
  - SSA INPs (“pristine”) implied from backward trajectory



Zeppelin: Aerosol – INP Closure



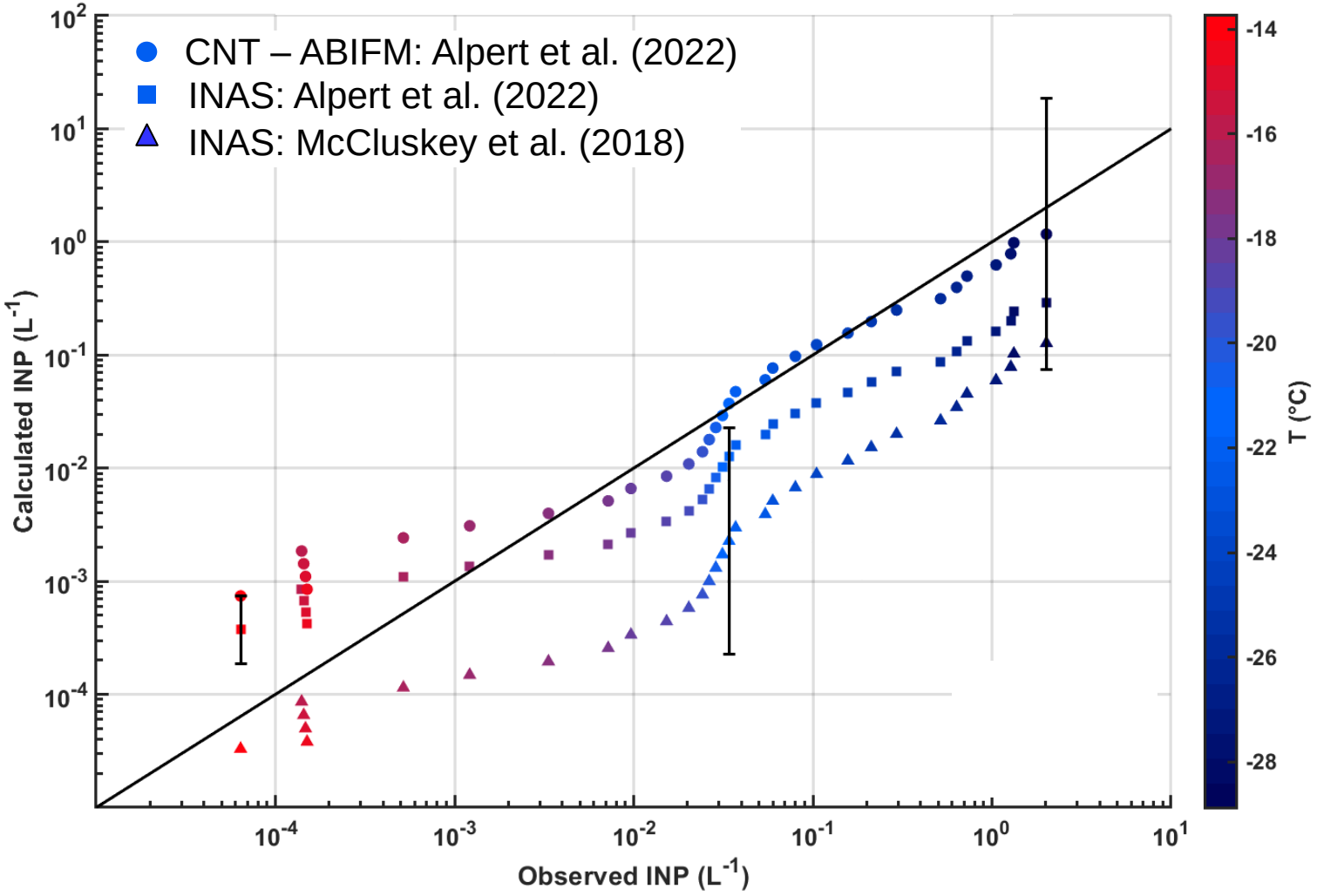
Within typical parameterization uncertainties, agreement is achieved.
CNT activation time: 60 s

McCluskey et al. (2018) shows best agreement.

“Zeppelin aerosol PSD and types are likely not SSA only.”

INP data: Y. Tobo

Andenes Site: Aerosol – INP Closure



CNT – ABIFM by Alpert et al. (2022) shows best agreement.

CNT activation time: 60 s

Within uncertainties, general trend of INP measurements are captured.

COMBLE aerosol PSD and types likely dominated by SSA.

INP data: J. Creamean, P. DeMott

Summary & Conclusions

- Measurement of aerosol properties and INPs allows for closure exercises.
- INP predictions are within an order of magnitude of measurements.
- Ambient particles are dominated by SSA, though at Zeppelin station, particle types may be more diverse in composition, and numbers are greater.
- Andenes Site, AMF, Andoya island, is likely dominated to a greater extent by SSA particles. Here, excellent agreement with parameterization is achieved that is derived from SSA particles.
- Improvements/caveats:
  - We need same time resolution of particle size and composition and INP number concentration.
    - Filter samples are collected over hours whereas PSD and particle composition are measured over much shorter time scales.
  - Under actual cloud conditions predicted INP numbers will differ significantly.