Field and Laboratory Explorations of Marine Ice Nuclei


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DOE-ASR CAPI Ice Nucleation Breakout (Potomac, MD)
Research questions and significance of ice nucleating particle (INP) measurement of marine aerosols

- To what extent are oceans sources of the nuclei for ice cloud formation?
- What are sea spray produced ice nucleating particles (INP)?
- Do INP emissions play any role in affecting cloud differences (frequency and phase) over oceans, especially SH?
  - Poor prediction of SH radiation budget by climate models (Trenberth and Fasullo, 2010), too few and too short-lived clouds
  - Prevalence of supercooled cloud tops down to -20°C via MODIS and Calipso (Huang et al. 2012)
  - Low ice crystal concentration (<0.1 L⁻¹ at T > -20°C), only isolated secondary ice (Grosvenor et al. 2012; Chubb et al. 2013)
Real-time and offline INP measurements

**Continuous flow diffusion chamber (CFDC):**

- Inertial impactor at ~2.4 µm
- Aerodynamic size selection
- Sheath flow control
- Nucleation and Growth
- Droplet Evaporation
- Collection and Analyses

**Ambient aerosol**

- Concentrator
- Collection for offline analysis
  - (onto filter or into liquid, frozen)

**Bioanalyses:**

- Pyrosequencing
- qPCR) identification of INA bacteria; heat treatment for selective removal of biological organisms

**Porous support**

- 0.45 µm backing filter
- 0.2 µm PC filter

**Vali (1971):**

\[
\text{n}_{IN} \text{ per ml} = \frac{-\ln(f)}{V}
\]

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CAICE (Center for Aerosol Impacts on Climate and the Environment) Lab Studies

Glass Wave Channel

Marine Aerosol Reference Tank (MART)

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CAICE fresh seawater (Scripps pier) wave-breaking experiments

Basic INP-T spectrum with overlap of methods

Modest dependence on n>0.5μm (mimics airborne inorganic INP)

Methods correspond (robust for many other inter-comparisons)
→ time dependence is a minor factor in assessing the activity spectrum of marine INP.
→ Historical methods (collecting and rinsing particles from filters) have no obvious flaws
Bacteria can mediate INP produced by spray

However, common INP type is SS-OC (sea salt coated with organic carbon, with Mg, sometimes K, P)
Ice nuclei from sea spray particles peak with chl-a in “spiked” phytoplankton blooms (January 2013)

Same SS-OC particles

DeMott et al. (in prep)
“Natural” phytoplankton blooms (January 2014)

No change or degradation during bloom but post-bloom INP enhancement at warmer $T$

Seawater INP units < 200 nm, apparently organic

Notes: 1) INP in filter collections were insensitive to 24 hr. dry in clean air; 2) INP in impingers = filters

DeMott et al. (in prep)
Hill et al. (in prep)
Two distinctly different ocean transects (MAGIC LA-Honolulu versus SHIPPO Incheon to Nome)

MAGIC-IN (July-Sept 2013)

SHIPPO (July 2012)
Ice nucleating particles and aerosol biodiversity measured from ambient marine boundary layer filter collections

Korea Polar Research Institute’s (KOPRI) Summer 2012 SHIPPO (SHIp-borne Pole-to-Pole Observations)

DeMott et al. (in preparation)

INP Conc. (L⁻¹)

100 C heat

DeMott et al. (in prep)
MAGIC-IN: Relatively low INP concentrations over oligotrophic oceans

DeMott et al. (in prep)
Comparison of all studies to remote continental INP data → weaker marine INP sources

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Summary

- Ice nuclei measurements from sea spray directly in lab and from near-surface marine aerosols
  - Reasonable consistency with previous measurements over oceans
  - Typically $\text{INP}_{\text{ocean}} < \text{INP}_{\text{land}}$
  - Varied labile fraction of IN > -20°C, but clear dominance of small organic INP mixed in sea salt particles of all sizes
  - Complex interplay between biological activity, nutrients, and bubble drop emissions impact IN numbers released in sea spray
  - Need further compositional data isolating INP units (underway)

- Next steps: More lab studies, MAGIC analyses, numerical modeling collaborations, new oceanic studies (e.g., SOCRATES), first INP mass spectra collected in last 3 weeks at Bodega Bay.
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