# Field and Laboratory Explorations of Marine Ice Nuclei

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# 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<sup>-1</sup> at T> >-20°C), only isolated secondary ice (Grosvenor et al. 2012; Chubb et al. 2013)

#### Trenberth and Fasullo (2010)





of cloud ice fraction



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### Real-time and offline INP measurements



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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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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





# Ice nuclei from sea spray particles peak with chl-a in "spiked" phytoplankton blooms (January 2013)



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## "Natural" phytoplankton blooms (January 2014)







#### Two distinctly different ocean transects (MAGIC LA-Honolulu versus SHIPPO Incheon to Nome)



### Ice nucleating particles and aerosol biodiversity measured from ambient marine boundary layer filter collections



# MAGIC-IN: Relatively low INP concentrations over oligotrophic oceans







## Comparison of all studies to remote continental INP data $\rightarrow$ weaker marine INP sources





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# Comparison of all studies to remote continental INP data $\rightarrow$ weaker marine INP sources



# Summary

- Ice nuclei measurements from sea spray directly in lab and from near-surface marine aerosols
  - Reasonable consistency with previous measurements over oceans
  - Typically  $INP_{Ocean} < INP_{Iand}$
  - 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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