Parameterizing ice nuclei concentration dependence on aerosol concentration, temperature, and composition

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Science Question

Do simplified relations exist between aerosol physical and chemical properties and the number concentrations of **ice nuclei (IN)** for improving global modeling of aerosol effects on mixed phase clouds and precipitation?

Approach

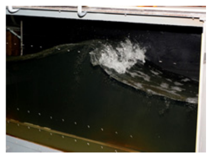
DeMott et al. (2010): Used large data base of IN measurements (CSU continuous flow diffusion chamber) with co-sampled aerosol data, including DOE studies (MPACE), to parameterize IN number concentration as a power law function of aerosol concentration at sizes >0.5 μm and temperature.

Does the DOE ISDAC study data fit?

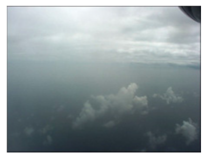
Consider subsets of these results that may reflect compositional dependencies of ice nucleation, and acquire new data on this topic.

Smoke: prescribed burns (Longleaf Pine), Newton, GA

PBAP (primary biological aerosol particles) dominant in large aerosol, Manitou Forest, CO



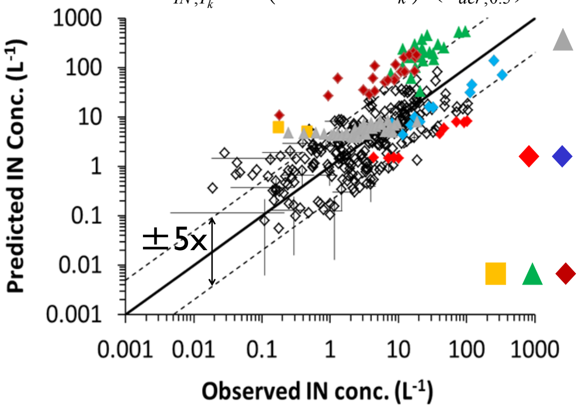
Seawater spray: CAICE wave channel, Scripps/UCSD, CA



Dust: Saharan Aerosol Layer (SAL) from NSF/NCAR C-130, St. Croix, USVI

Results

$$n_{IN,T_k} = a(273.16 - T_k)^b (n_{aer,0.5})^{(c(273.16 - T_k)+d)}$$



▲ ISDAC IN (3 days) conc. consistent with global parameterization

◆ ◆ IN conc. under-predicted in Saharan (red) and Asian (blue) dust plumes.

■ ▲ ◆ IN conc. over-predicted for pollution (yellow), smoke (green) plumes, and sea spray (maroon) particles.

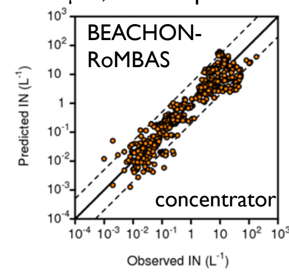
The "global" parameterization form represents background aerosols, well-mixed and at distance from key sources. Dominance of specific aerosol types suggests different relations between the number concentrations of IN (n_{IN,T_k} (l^{-1} STP) and > 0.5 μm aerosols ($n_{aer,0.5}$ (cm^{-3} STP))

Parameterizations of ice nuclei concentrations for specific aerosol compositions

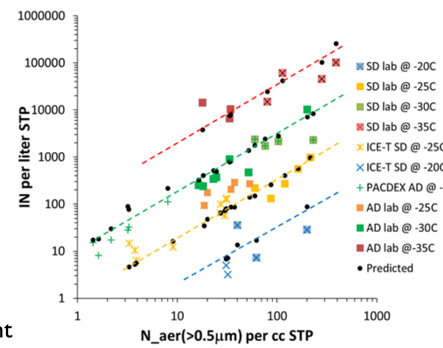
Measurements of IN and size-resolved aerosol concentrations over the wide dynamic ranges possible in IN-perturbed atmospheric situations, through use of special aerosol concentrators, or via purposeful generation of specific aerosol surrogates in laboratory studies indicate a common and simplified relation between all IN types, aerosols larger than 0.5 μm, and temperature.

$$n_{IN,T_k} = (n_{aer,0.5})^a \cdot 10^{(b(273.16 - T_k)+c)}$$

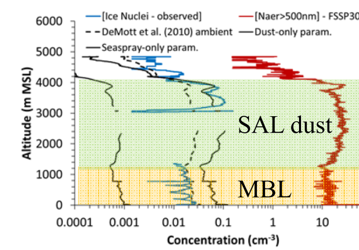
Aerosol type	$T_{Exp.}$ (°C)	a	b	c
Saharan/Asian dust	-15 to -35	1.25	-0.2	-5.05
Smoke (GA)	-20 to -32	0.707	-0.2	-5.95
Seaspray (CAICE)	-20 to -32	0.695	-0.2	-6.23
Forest site (PBAP)	-10 to -32	1.5	-0.2	-4.6



Example: Data vs. param. and use of particle concentrator to broaden dynamic range for measurements in PBAP-dominated region.



Example: initial analysis for dusts (commonality noted).



Application: ICE-T descent profile shows different layers where parameterizations succeed or fail due to aerosol composition.

Concluding remarks

It appears feasible to consider the contributing sources of IN from different aerosol types in parameterizations use in numerical models. This should improve IN predictability.

References. DeMott, P.J., A. J. Prenni, X. Liu, et al.,, 2010: Predicting global atmospheric ice nuclei distributions and their impacts on climate, Proc. Natnl. Acad. Sci., 107 (25), 11217-11222.

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