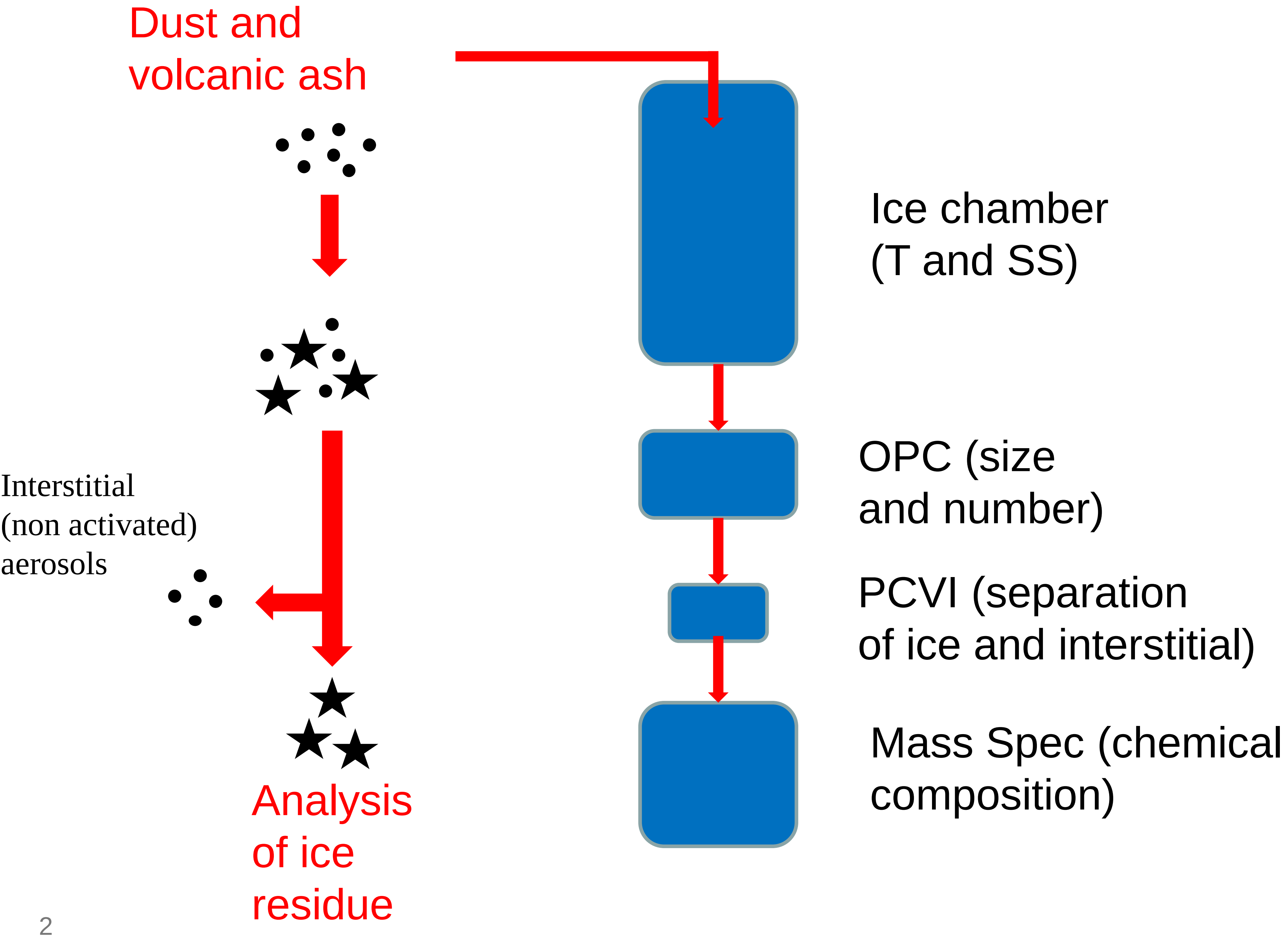
Analyzing ice nuclei of dust and volcanic ash particles

Gourihar Kulkarni

with: Josef Beranek and Alla Zelenyuk

Pacific Northwest National Laboratory, Richland, WA

ASR_Meeting_2012: Ice nucleation breakout session.


Dust and
volcanic ash
Ice chamber
(T and SS)
OPC (size
and number)
PCVI (separation
of ice and interstitial)
Interstitial
(non activated)
aerosols
Mass Spec (chemical
composition)
Analysis
of ice
residue

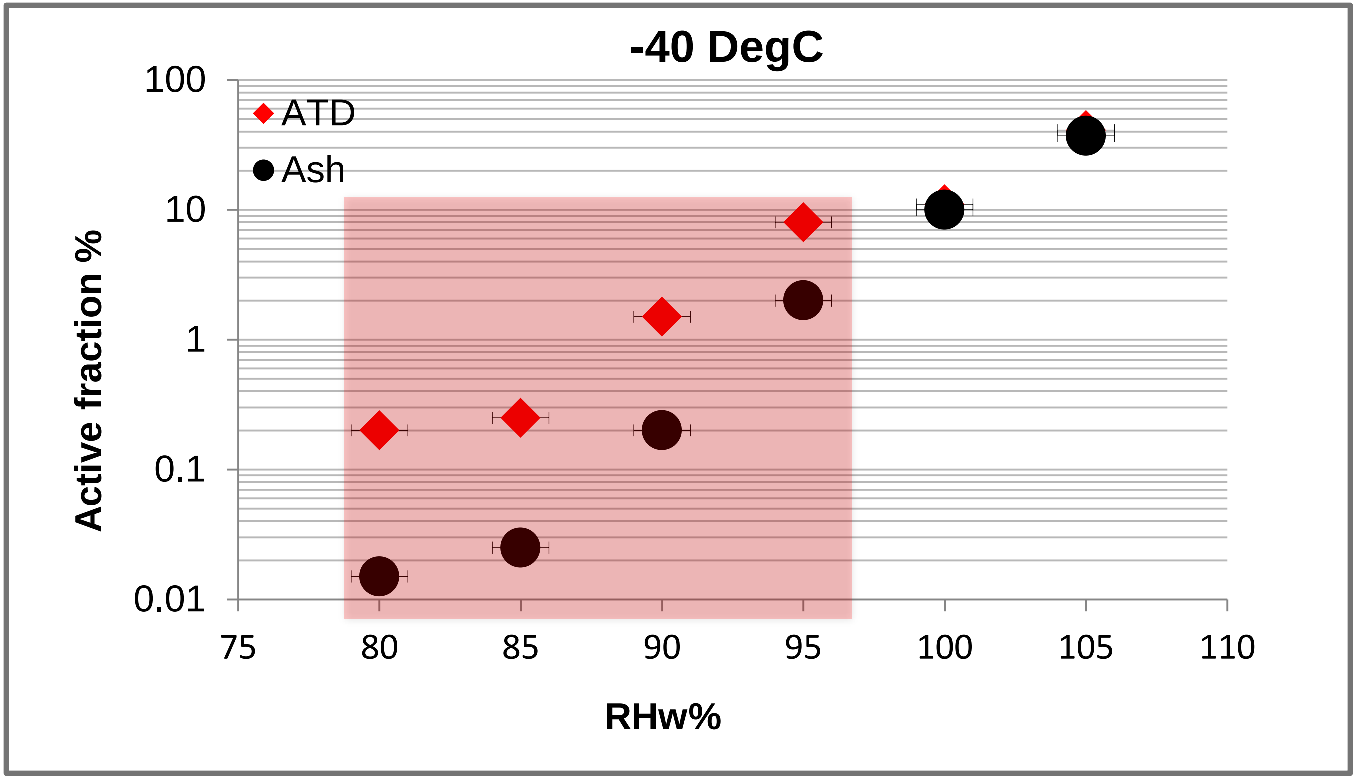
Lab study of Iceland Volcanic Ash

Does volcanic ash acts as Ice Nuclei?

April 2010 eruption of Eyjafjallajökull (or E16)

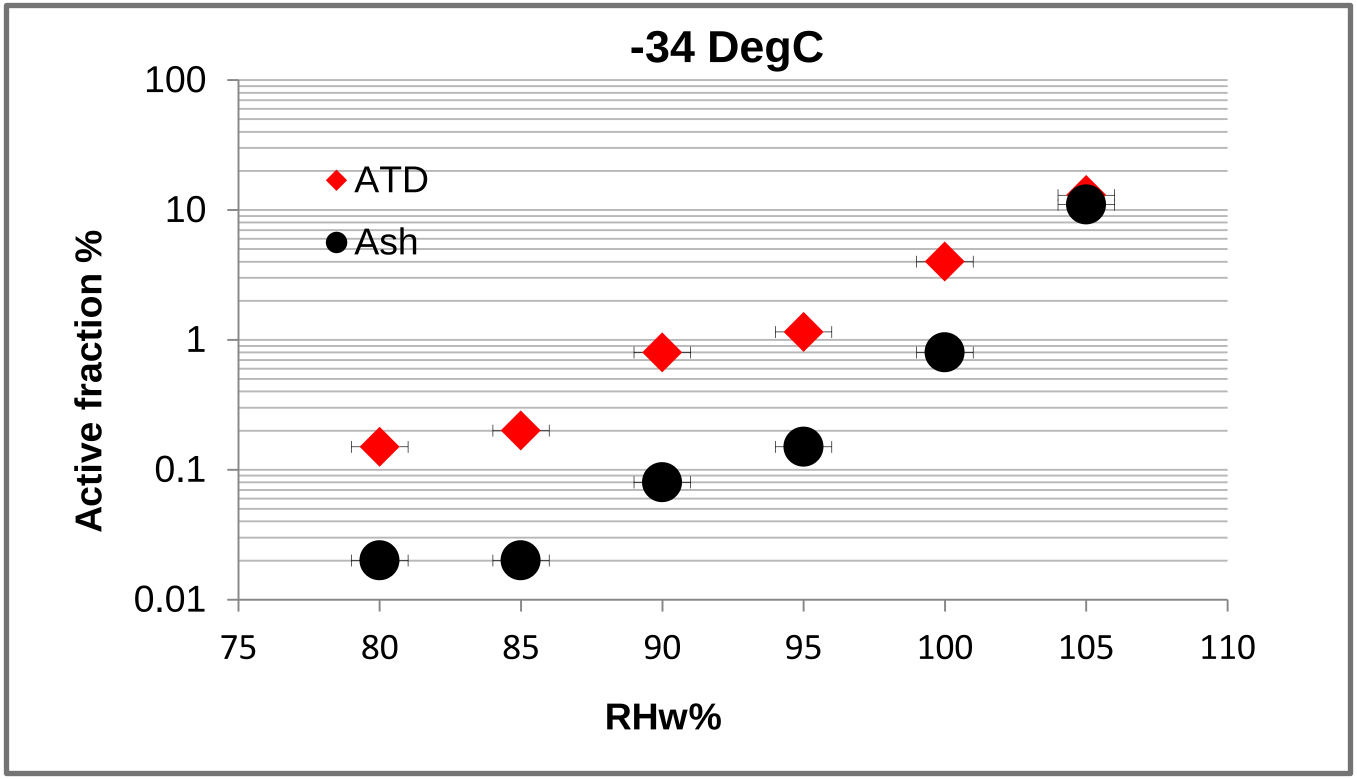
- Volcanic ash was investigated for ice nucleation efficiency (active fraction) at various humidity and temperatures, and analyzed for ice residue chemical composition.
- Active fractions were compared with surrogate atmospheric dust Arizona Test Dust (ATD) active fractions.

Comparison of active fractions.

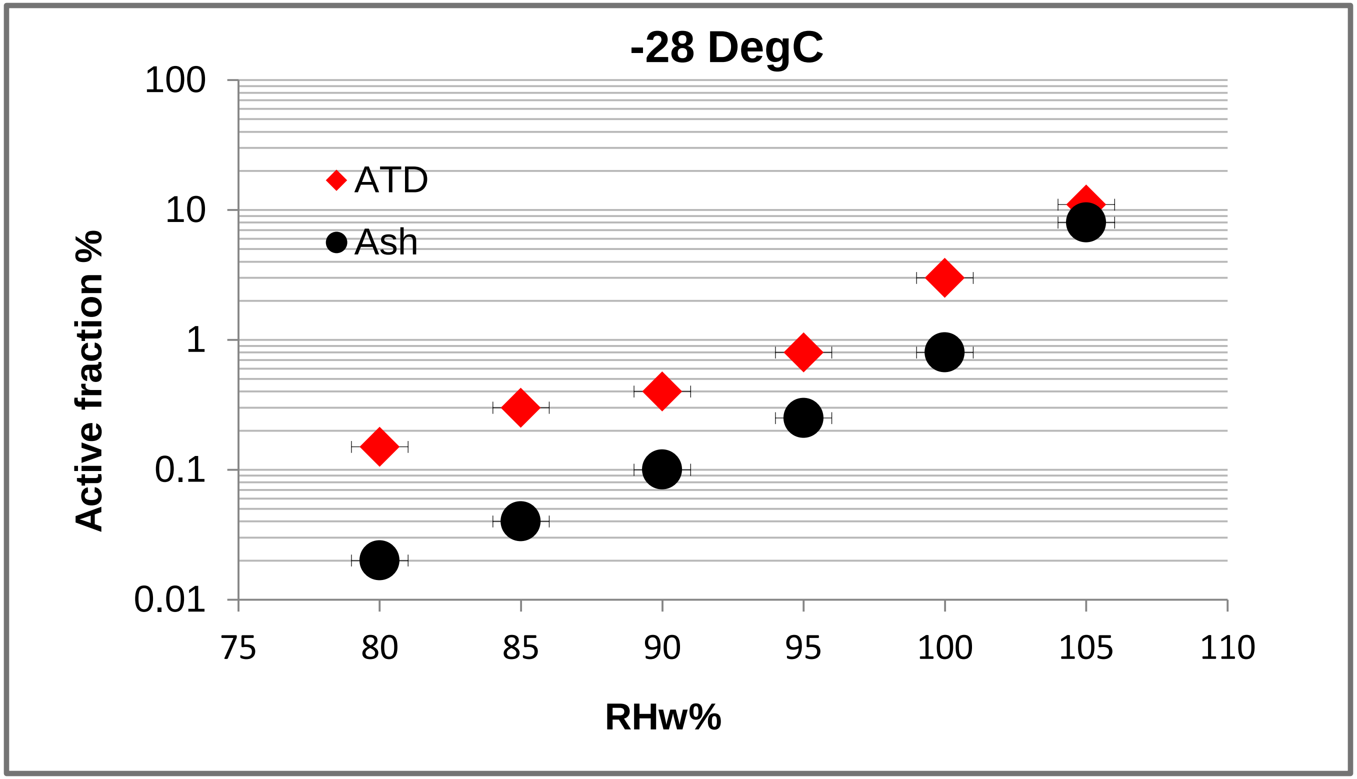


$$Active\ fraction\ =\ \frac{Number\ of\ ice\ crystals}{Total\ number\ of\ particles\ (=constant)}$$

Comparison of active fractions.



Comparison of active fractions.



Understanding why ATD is more effective than ash in forming ice crystal?

1. Compared ice particle residue of ATD and ash particles

ATD elements

Si

Al

Fe

Na

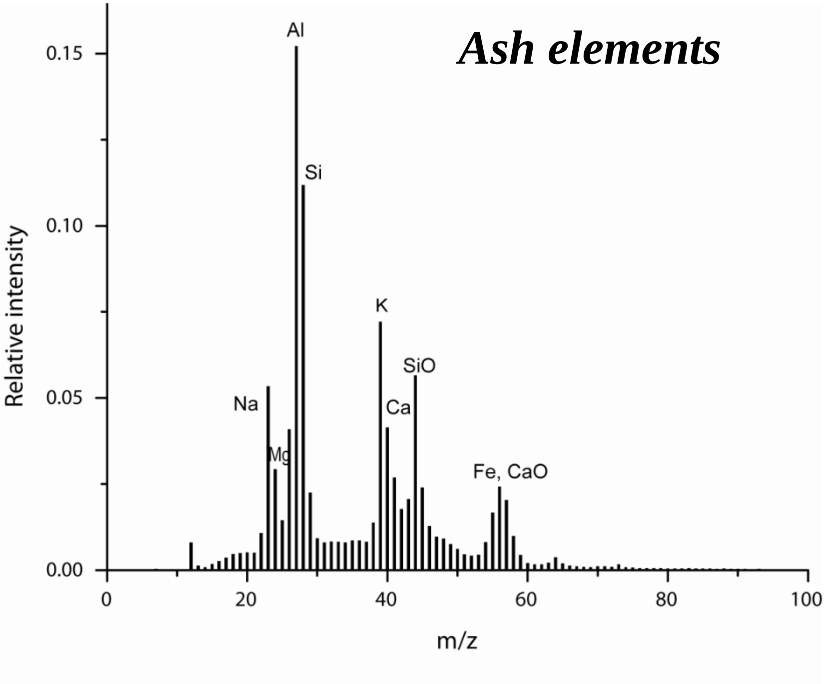
Ca

Mg

Ti

K

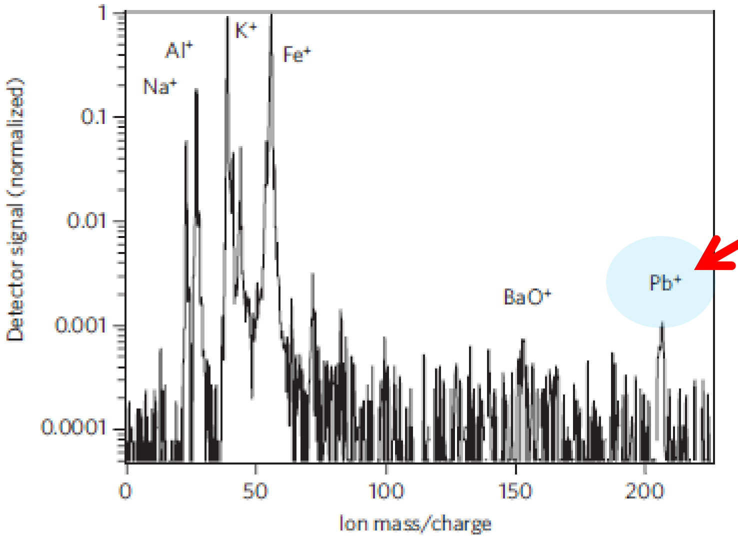
Pb



Trace elements include Mn, Mg, Ti, Ba, Co, Cr, Ni, Sr, V, Cu, Zn

Understanding why ATD is more effective than ash in forming ice crystal?

From literature we know presence of lead increases the ice nucleation efficiency of the particle.

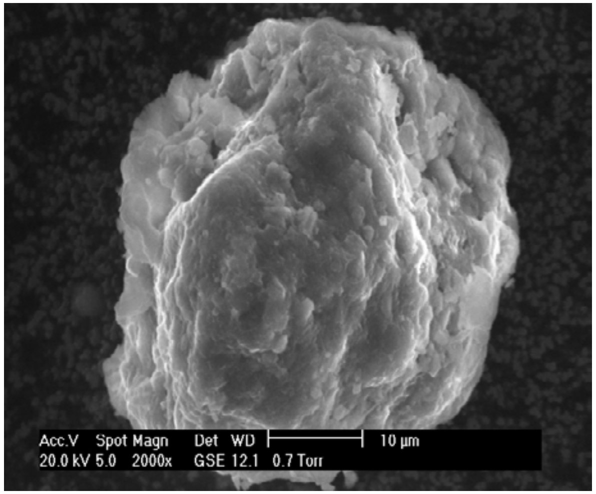


Presence of Pb (lead element) in the ice residue of ATD particle

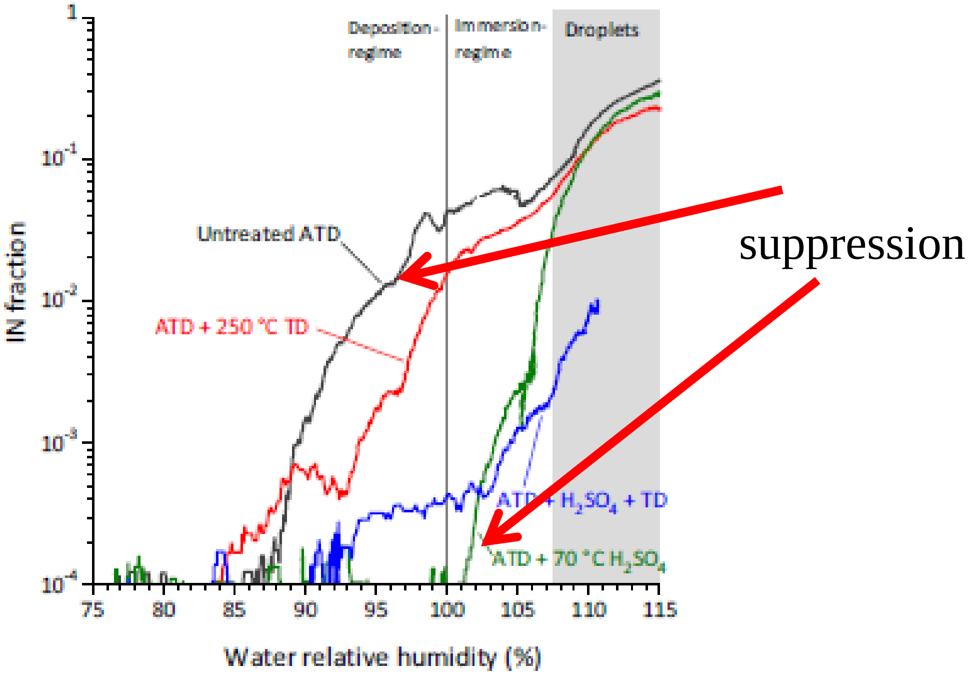
Source: Cziczo et al., Nat. Geo. (2009)

Understanding why ATD is more effective than ash in forming ice crystal?

2. Deactivation of ice nucleation efficiency by the adsorption of SO_2 *&/OR* coating with the sulfuric acid



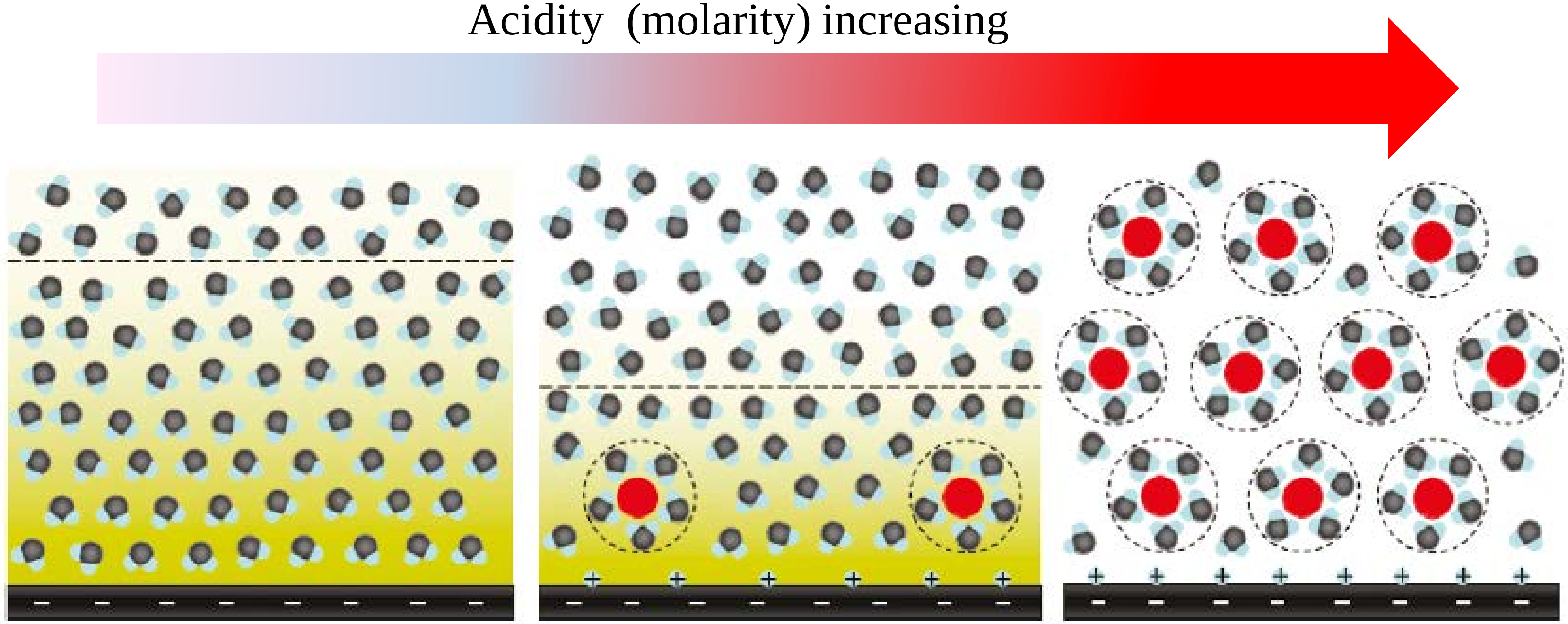
Surface structure of a particle



Source: Sullivan et al., ACP (2010)

Water structure gets distorted at the liquid/solid interface

Acidity (molarity) increasing



Mice surface

Lack of free water molecules at high acidic concentration

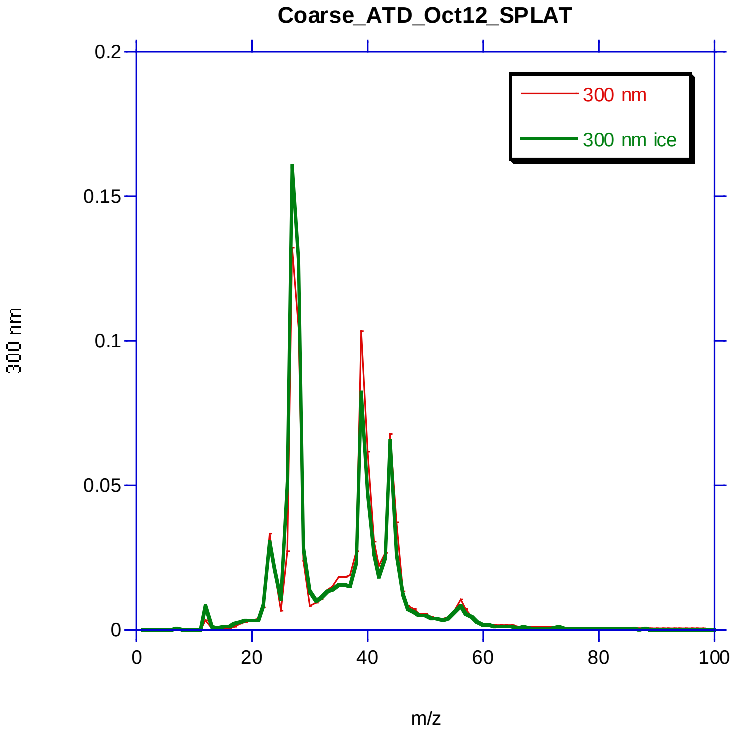
Source: Yang et al., J. Phys. Chem. Lett. (2011)

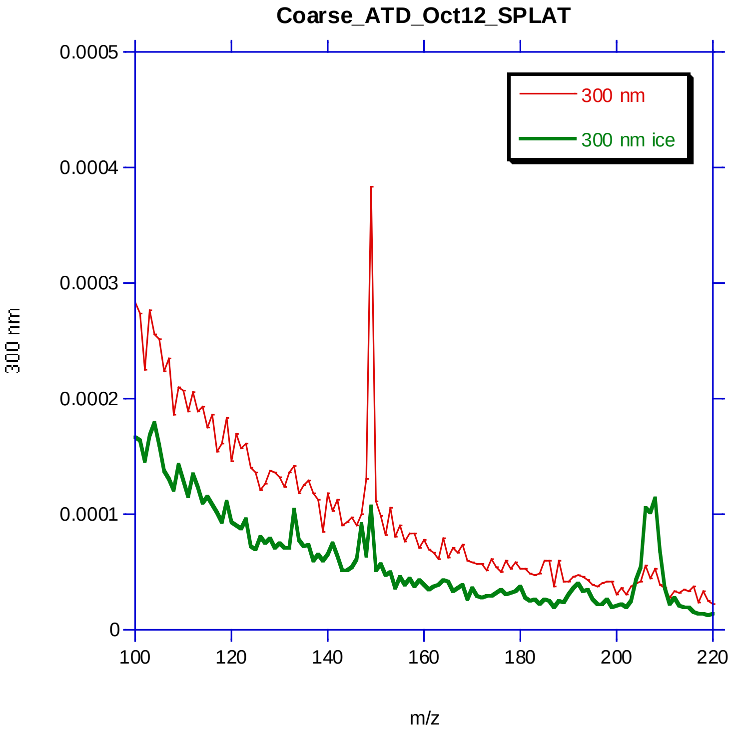
Summary:

- ✓ Volcanic ash (E16 source) acts as IN but less efficient than ATD in deposition ice nucleation regime,
- ✓ Presence of trace elements (e.g. Pb) could modify the ice nucleation properties,
- ✓ Processing the particles with the foreign gases (e.g. SO_2) could suppress the ice nucleation ability of the particles, and
- ✓ Such surface characteristics and processing effects details could be important for developing/constraining ice nucleation parameterizations used in the models.

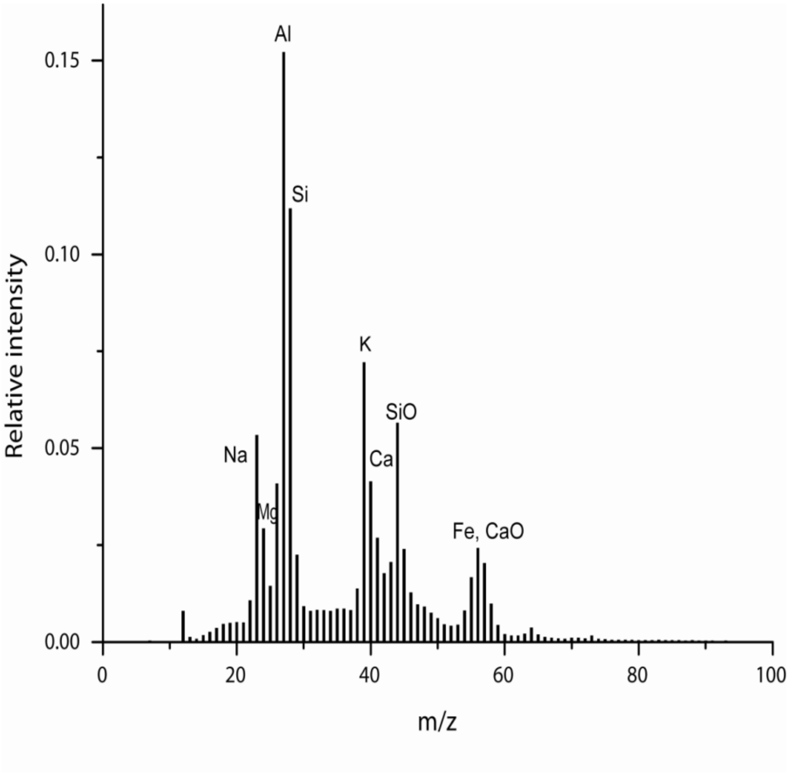
Thank you

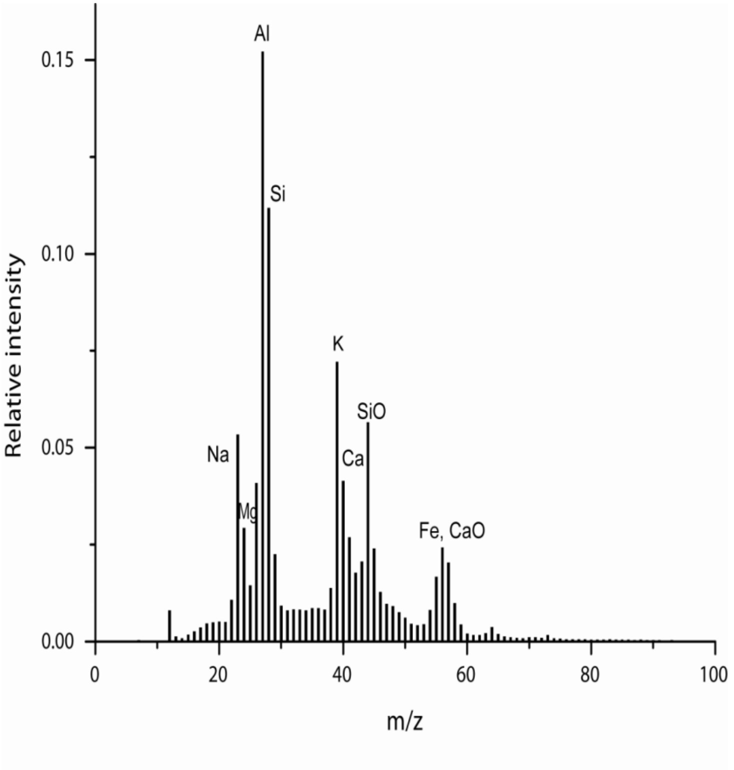
Comparison of bulk ATD and ice residue of ATD



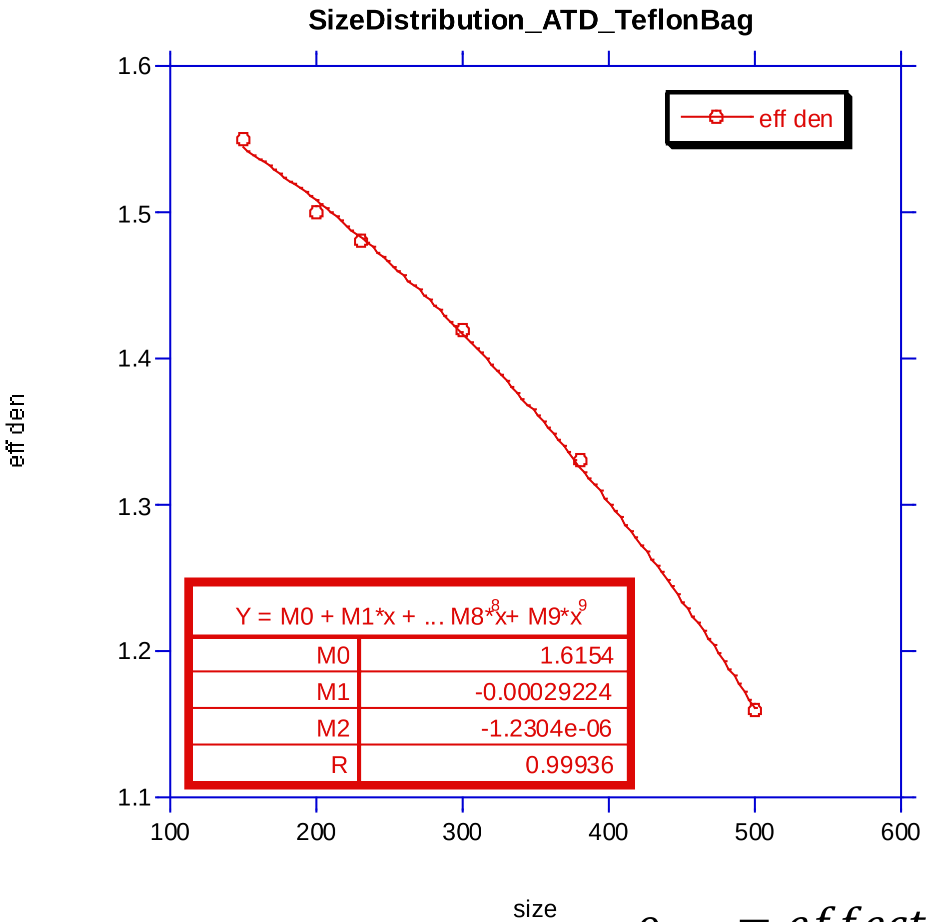


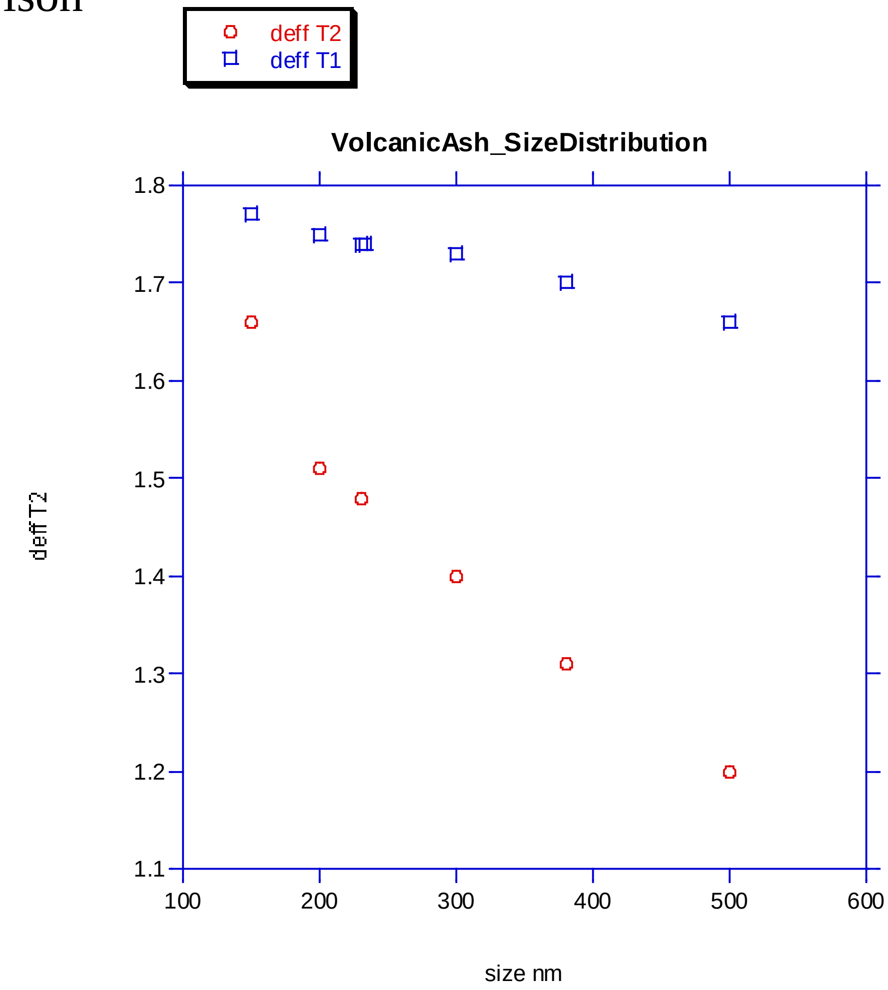
Comparison of bulk ash and ice residue of ash (both are same)





Effective density comparison





$$\rho_{eff} = \frac{d_{va}}{d_m} . \rho_0$$

$\rho_{eff} = effective\ density$

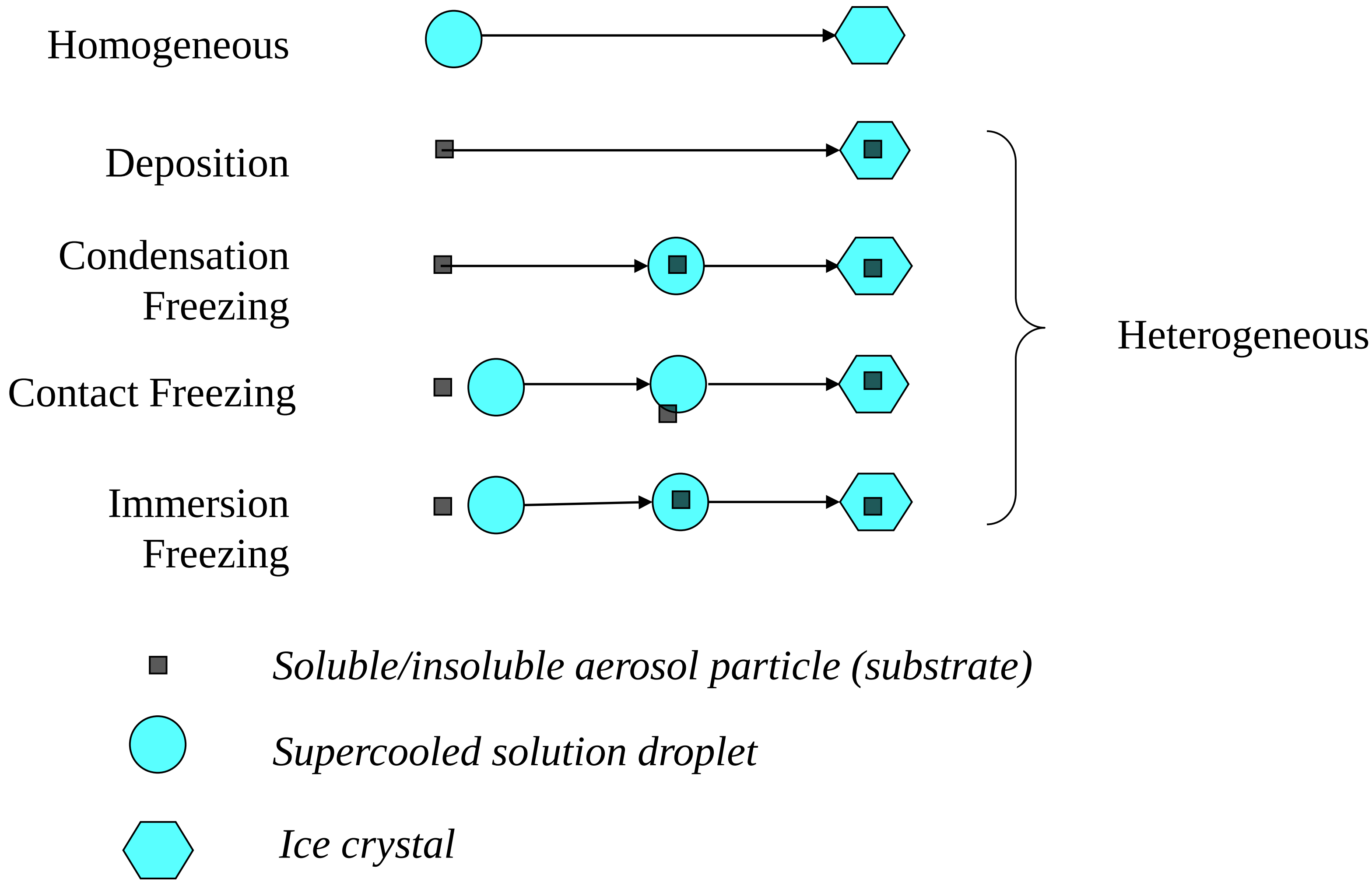
$\rho_o = standardy\ density, 1.0\ g/cc$

$d_{va} = vacuum\ aerodynamic\ diameter$

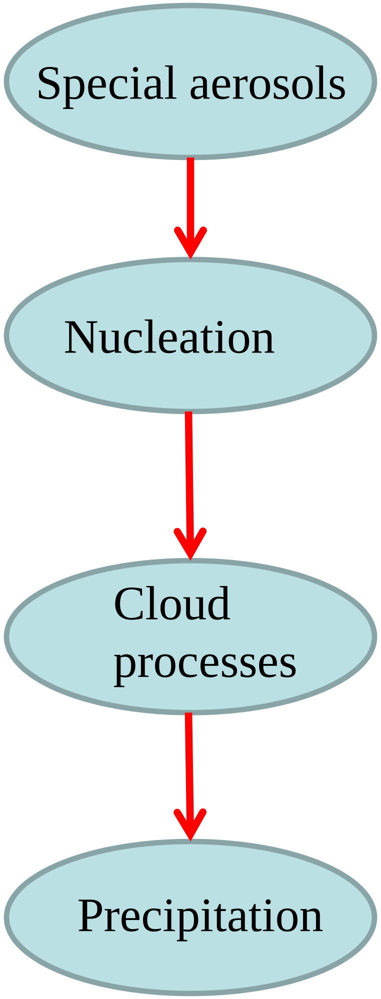
$d_m = mobility\ diameter$

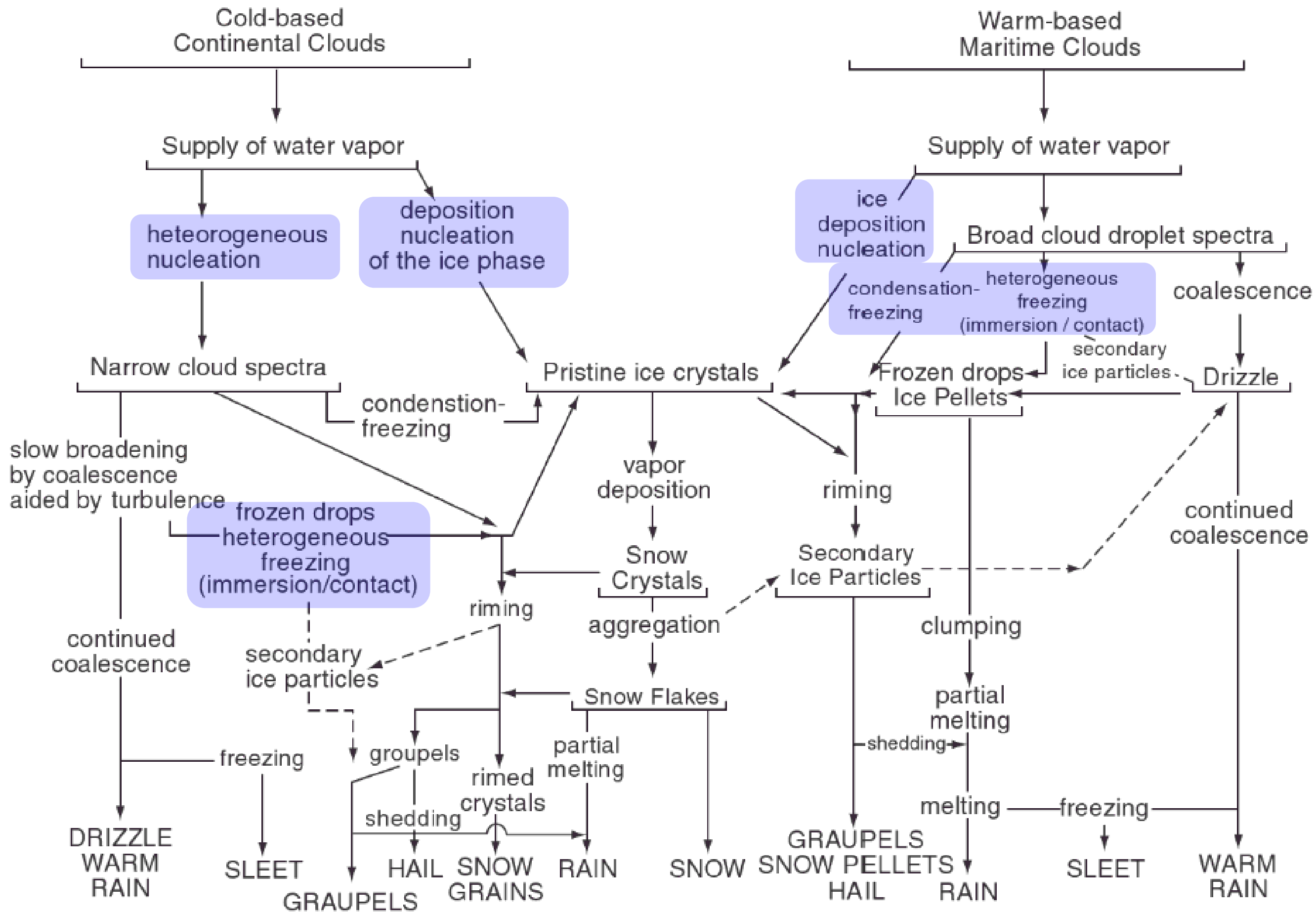
How ice crystals are formed?

Five main Ice Nucleation mechanisms



Broad Motivation to study “Ice Nucleation”





Source: Braham et al. Bull. A. Met. Soc. (1968)

Poor understanding of ice nucleation leads to large uncertainty in the predicting precipitation and further radiative forcing from cloud properties.