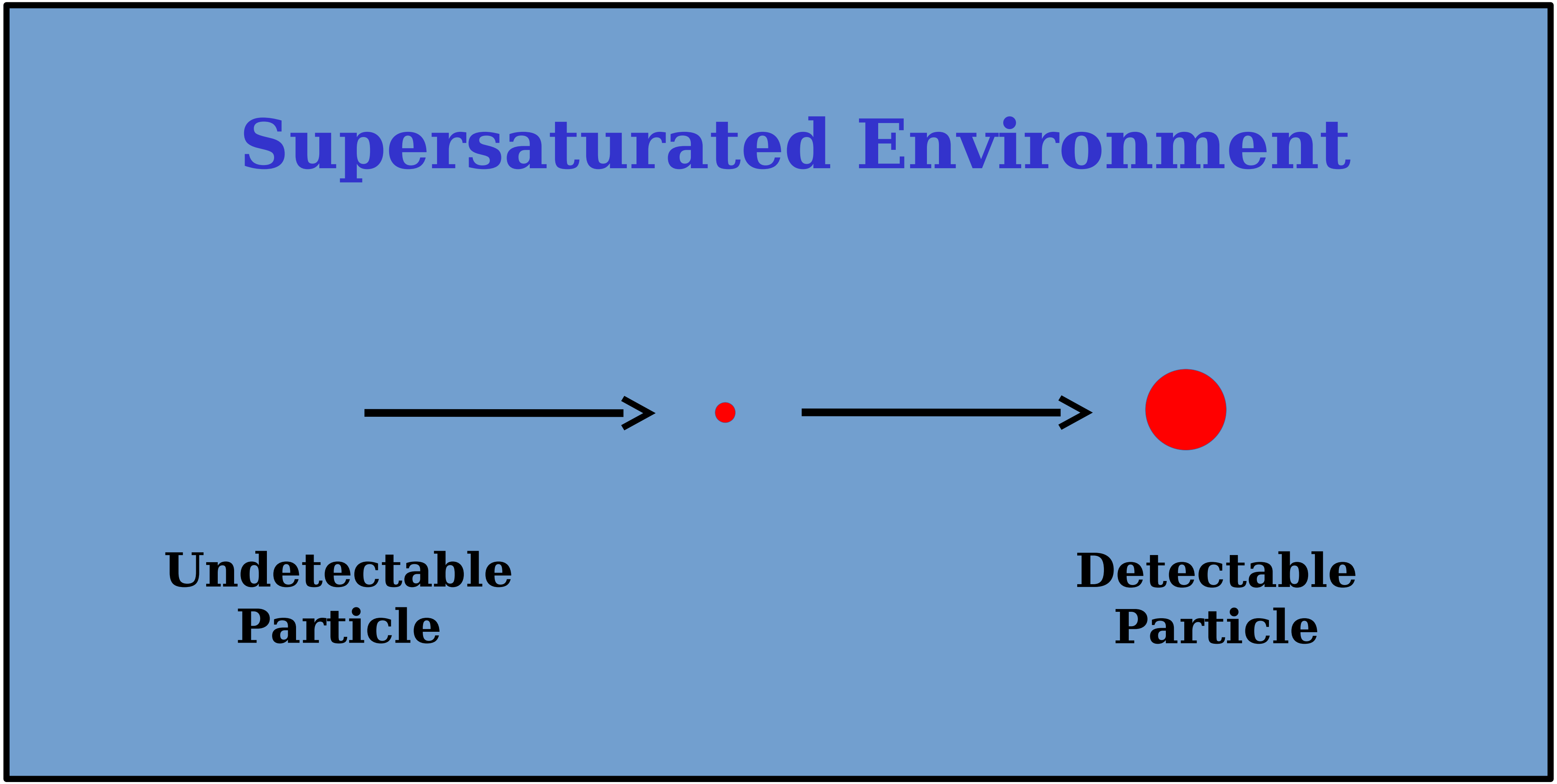
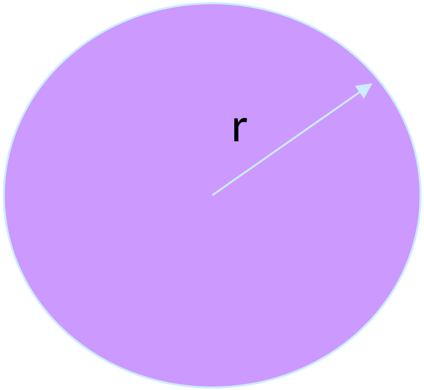
Droplet Growth



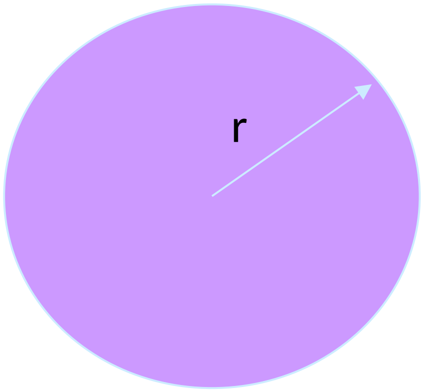
Factors Affecting Growth of Droplets

- Curvature Effect
- Solute Effect
  - Droplets grow when more water molecules at surface go into the droplet than escape from the surface.



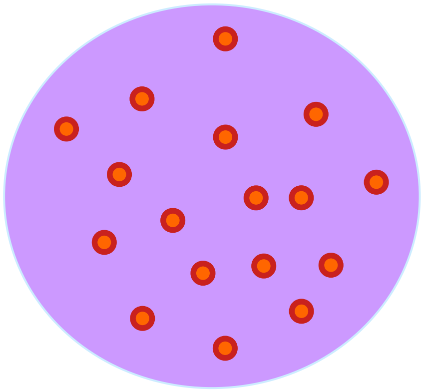
Effect of Curvature

- Effect of curvature is to enhance the equilibrium vapor pressure by a factor of 1/r.
- Small droplets have a difficult time to keep from evaporating.
- This is the primary reason for the fact that large aerosols make better CCN.



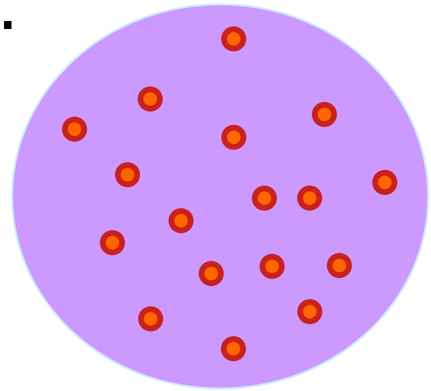
Solute Effect on Droplet Growth

- Effect of dissolved substances in the water is to lower the vapor pressure required for equilibrium.
- The more concentrated the dissolved substance, the greater the depression of the equilibrium vapor pressure.
  - Saltier droplets need less supersaturation to survive.



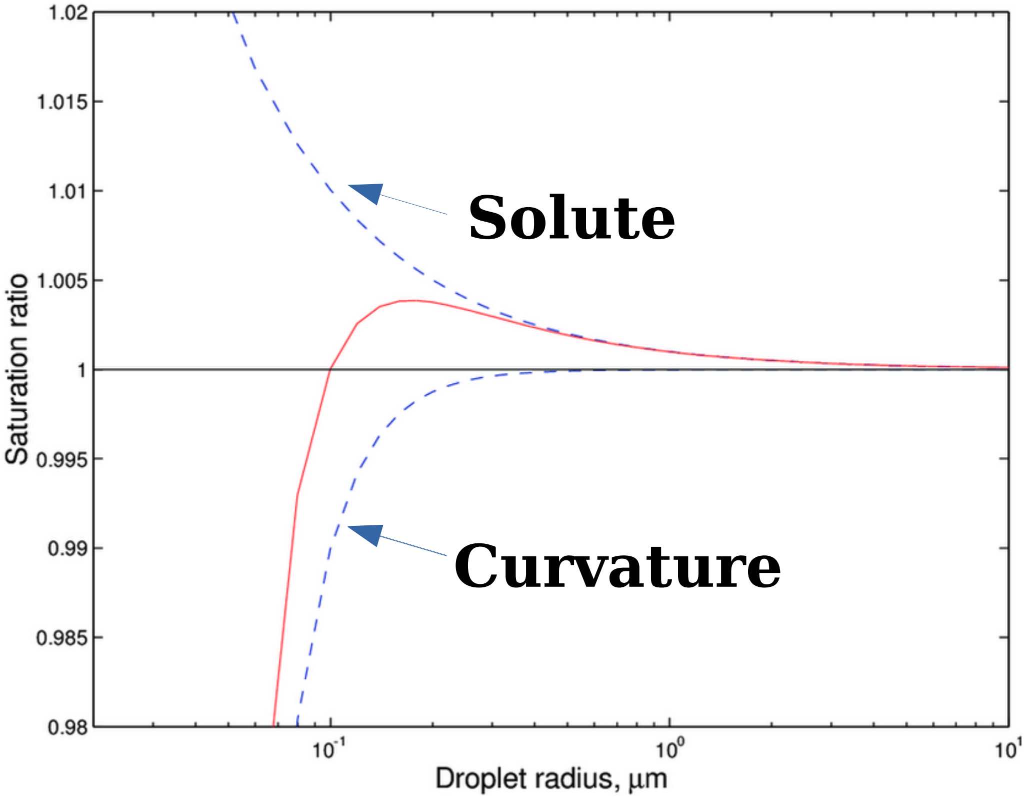
Soluble Particle Affect on Growing Droplet

- As water begins to condense on the soluble particle, the concentration of salt is very high.
- As more and more water vapor condenses (the bigger the droplet gets), the more dilute the solute becomes and the smaller the solute effect becomes.



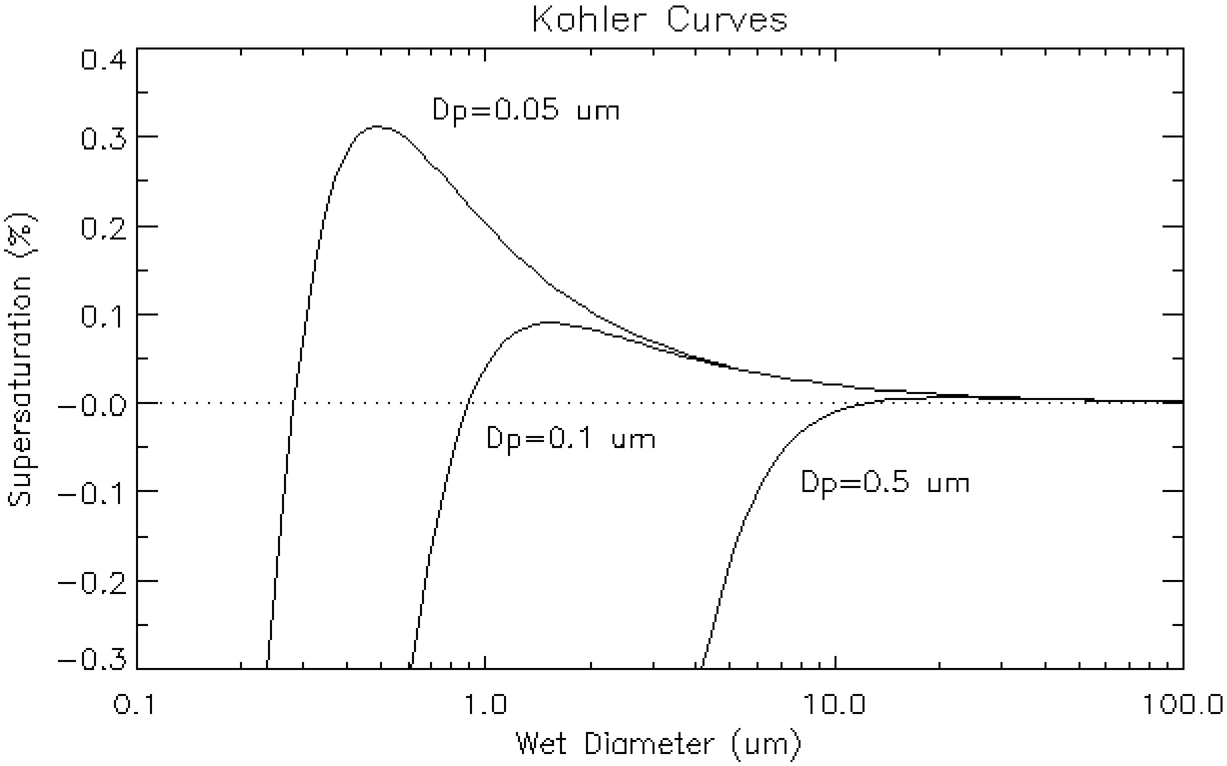
Equilibrium around a Small Droplet

- Combining the Three Effects
  - Clausius-Clapeyron Relationship
    - Temperature
  - Curvature Effect
    - Radius of the Droplet
  - Solute Effect
    - Characteristics of the Cloud Condensation Nucleus



Köhler (Koehler) Curves

- Families of curves showing the effects of curvature and solute on the vapor pressure required for equilibrium.

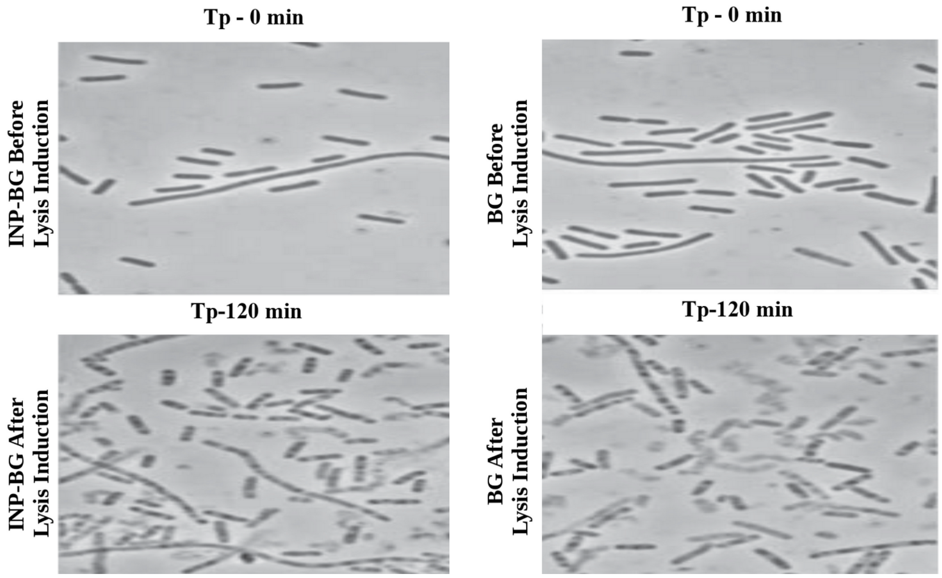


Cloud Formation

- Rising air expands and cools.
- Relative humidity increases.
- Hygroscopic/soluble/large CCN activate.
- Drops Grow.
- Relative humidity continues to increase past 100% and more droplets form.
- Droplets exceed critical size and continue taking up available water vapor even supersaturation decreases.
- Relative humidity starts decreasing back toward 100% and no new droplets are formed.

Sources Ice Nuclei

- Certain Types of Clay
- Certain Bacteria

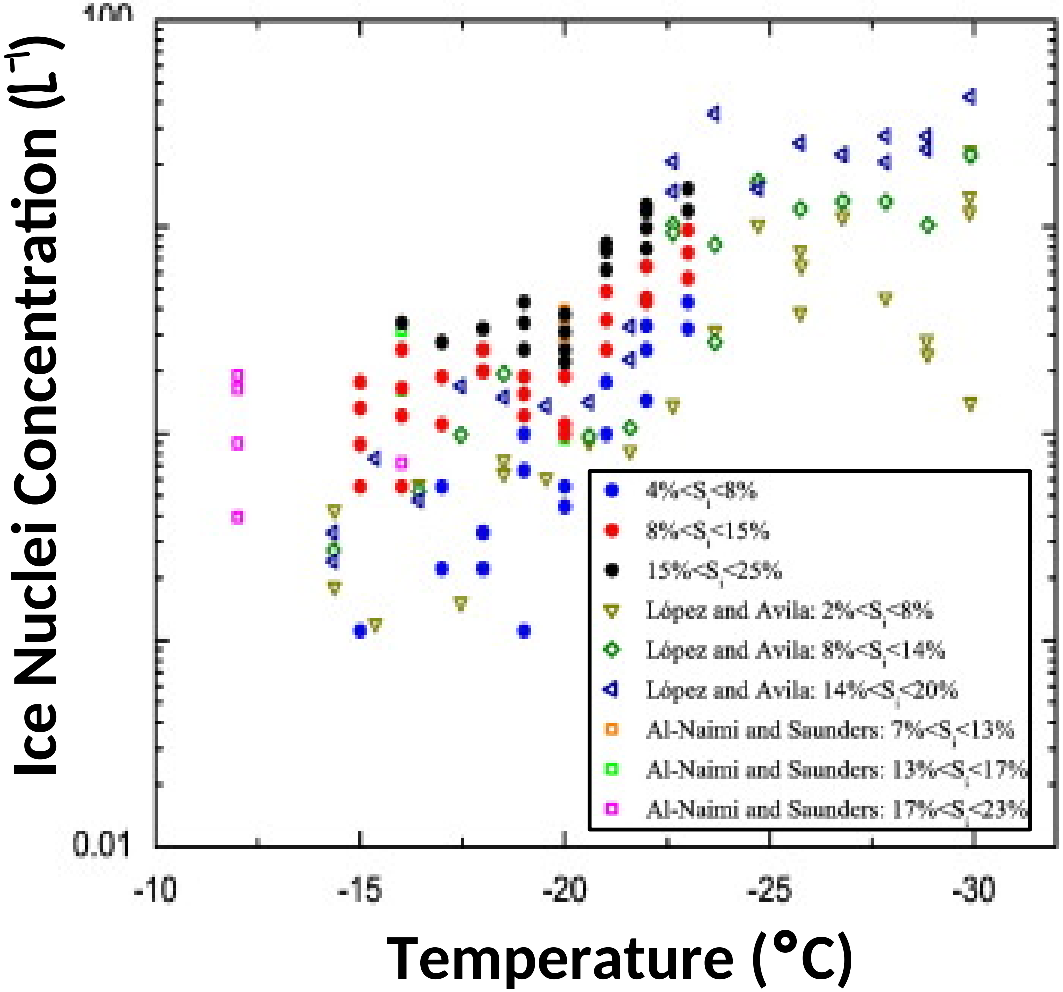


Nucleation

- Homogeneous Nucleation
- Heterogeneous Nucleation (Supercooled Droplets)
  - Similar in concept to supersaturation.
  - Statistical process.
  - A supercooled drop will freeze after a long enough time.

Effectiveness of Ice Nuclei

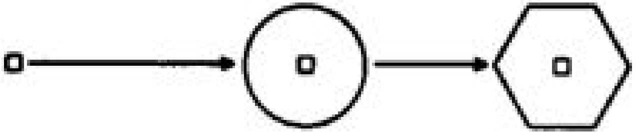
- Effectiveness is often measured by "threshold temperature".
- Threshold temperature is when one particle in 10,000 will produce an ice crystal.
- Different substances have different threshold temperatures ranging from about -5 °C to -40 °C.



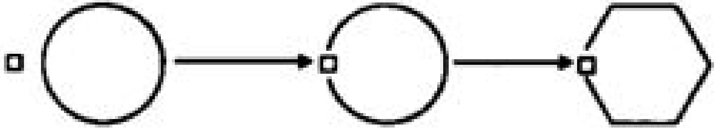
Activation of Ice Nuclei

- Deposition (Sublimation)

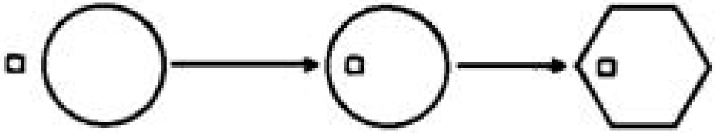
- Condensation-freezing (Absorption)



- Contact Nucleation

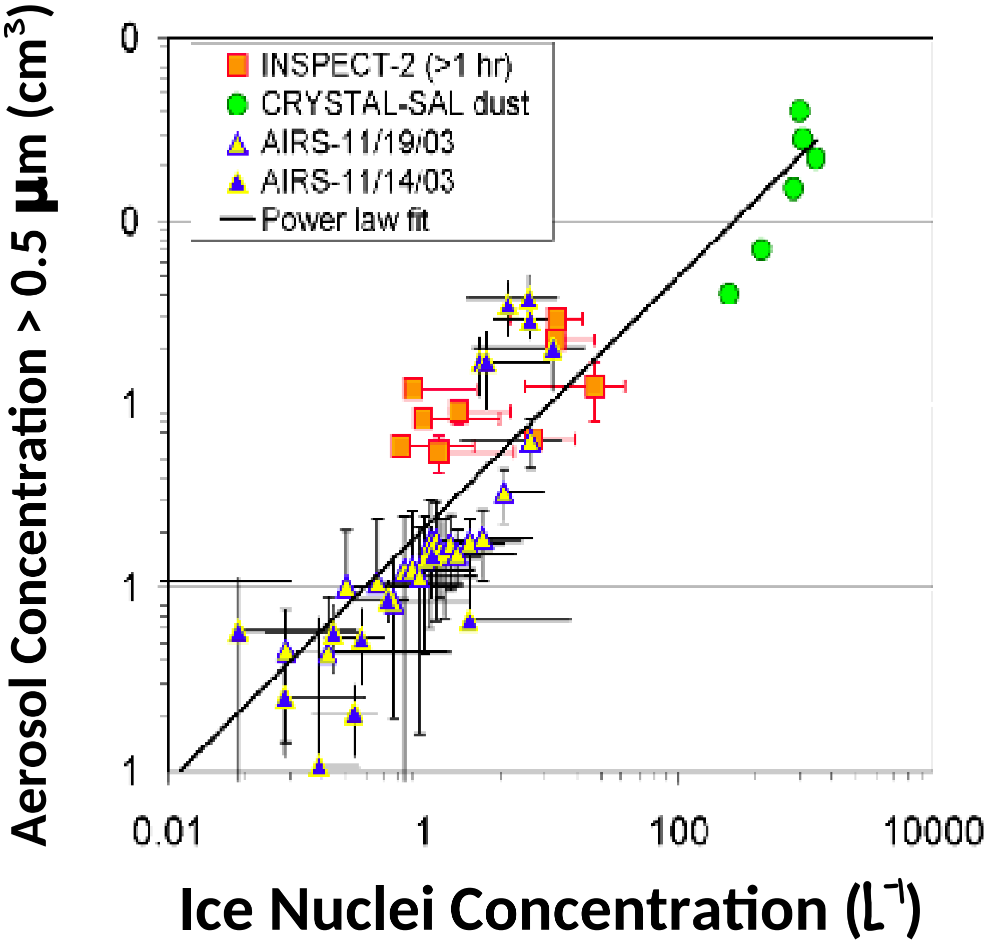


- Immersion (Bulk Freezing)



Concentration of Ice Nuclei

- Depends upon temperature, ice nuclei concentrations are commonly measured at -20 °C.
- At -20 °C concentrations are often 10^3 m^{-3} or lower. (Cloud droplet concentrations are typically of the order of 10^8 m^{-3})
  - Important point in most weather modification programs.



Relative Concentrations