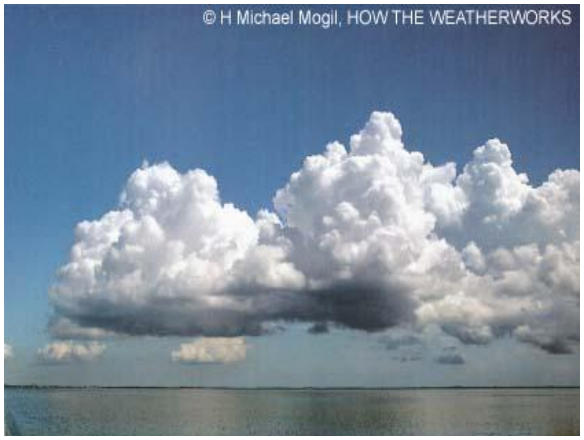
- Clouds are classified mainly by their visual characteristics and height
- They look different because they have different contents
- 3 primary types and many sub-types

Stratus

Cumulus



Cirrus

Stratus Clouds

Characteristics:

- ***Can be at any altitude – stratus just means that they form a horizontal layer***
- ***They are often at low altitude in bad weather (nimbostratus)***
- ***Fog is a stratus cloud hugging the ground***
- ***They are formed by weak, but widespread vertical motion (~10 cm/s)***
- ***The are made of a moderate density of cloud drops , LWC~.1 g/m^3***
- ***Cumulus or cirrus can also form a layer (Stratocumulus and cirrostratus)***

Cumulus Clouds

Characteristics:

- ***Can be at any altitude – cumulus means "heaping"***
- ***They develop more vertically than horizontally.***
- ***When they form rain they become cumulonimbus***
- ***They are formed by strong vertical motion, sometimes 25 m/s updrafts***
- ***Strong vertical motion and cumulus clouds result from free convection that comes from instability***
- ***If that vertical motion is deep enough, ice can form in upper part of the cloud***
- ***Ice crystals and strong motion -> charge separation ->lightning***
- ***They have the greatest LWC: from .5 to 4 g/m^3 depending of updraft rate***

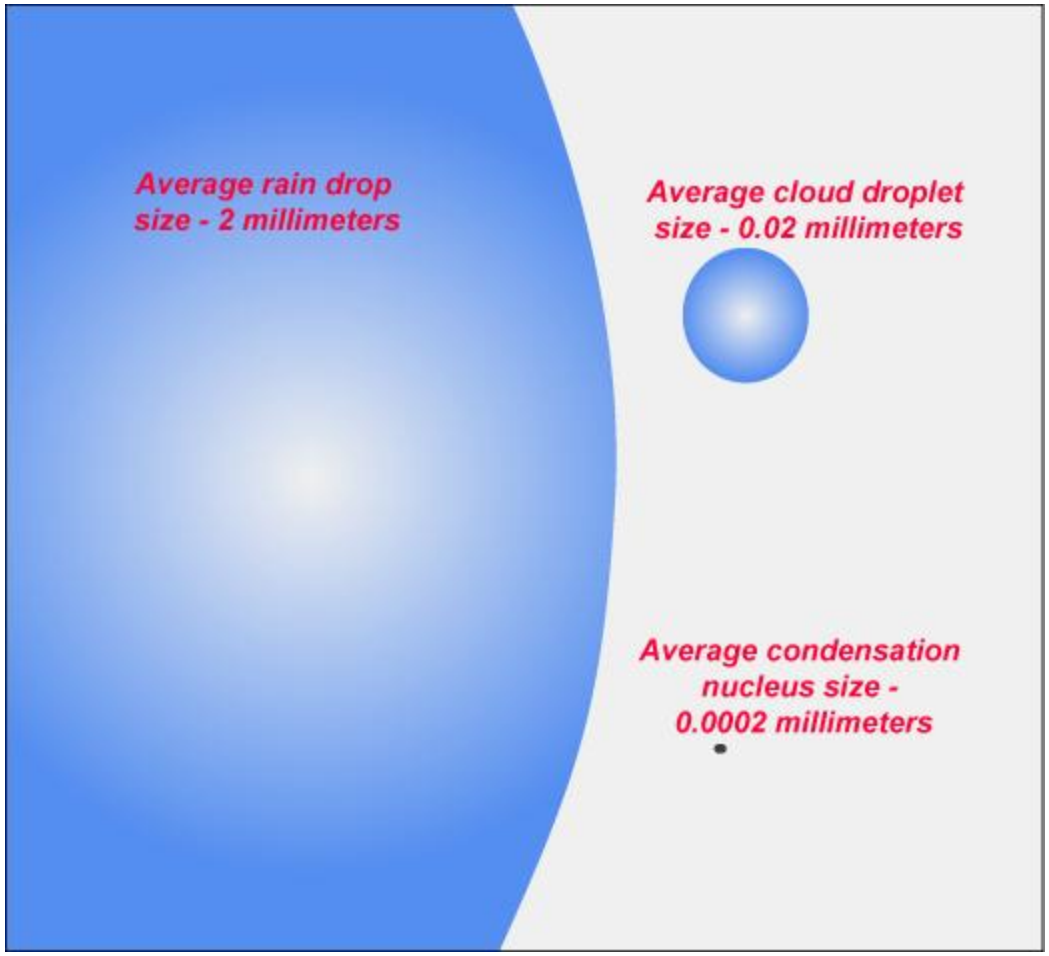
Cirrus Clouds

Characteristics:

- ***Are composed of tiny ice crystals, not liquid cloud drops***
- ***Usually form only when T< -25 C***
- ***They are formed by weak vertical motion (~5 cm/s)***
- ***The are made of a small density of ice crystals , IWC~.05 g/m^3***
- ***Sometimes generated by jet exhaust (contrail)***
- ***Often initiated as anvils of cumulus clouds striking the tropopause-lid***
- ***Important effects due to widespread radiative impact***

Cloud Height

Cloud height	Cloud types
Low (below 2 km, 6500 ft)	Fog Stratus Nimbostratus Stratocumulus Stratus fractus Cumulus humulis Mammatus Funnel
Middle(2-6 km, 6500-20000ft)	Cumulus humulis Cumulus mediocris Stratocumulus Altostratus Altocumulus
High (6+ km, 20000 ft+)	Cirrus Cirrostratus Cirrus uncinus/fibratus Pileus cloud
Large vertical span	Cumulus castellanus Cumulus congestus Cumulonimbus



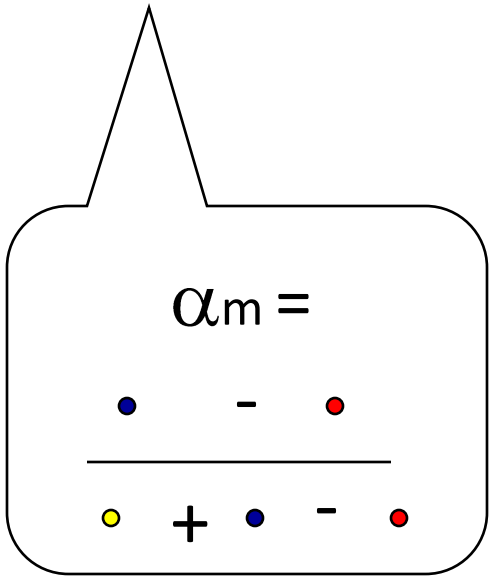
CCN: Cloud Condensation Nuclei

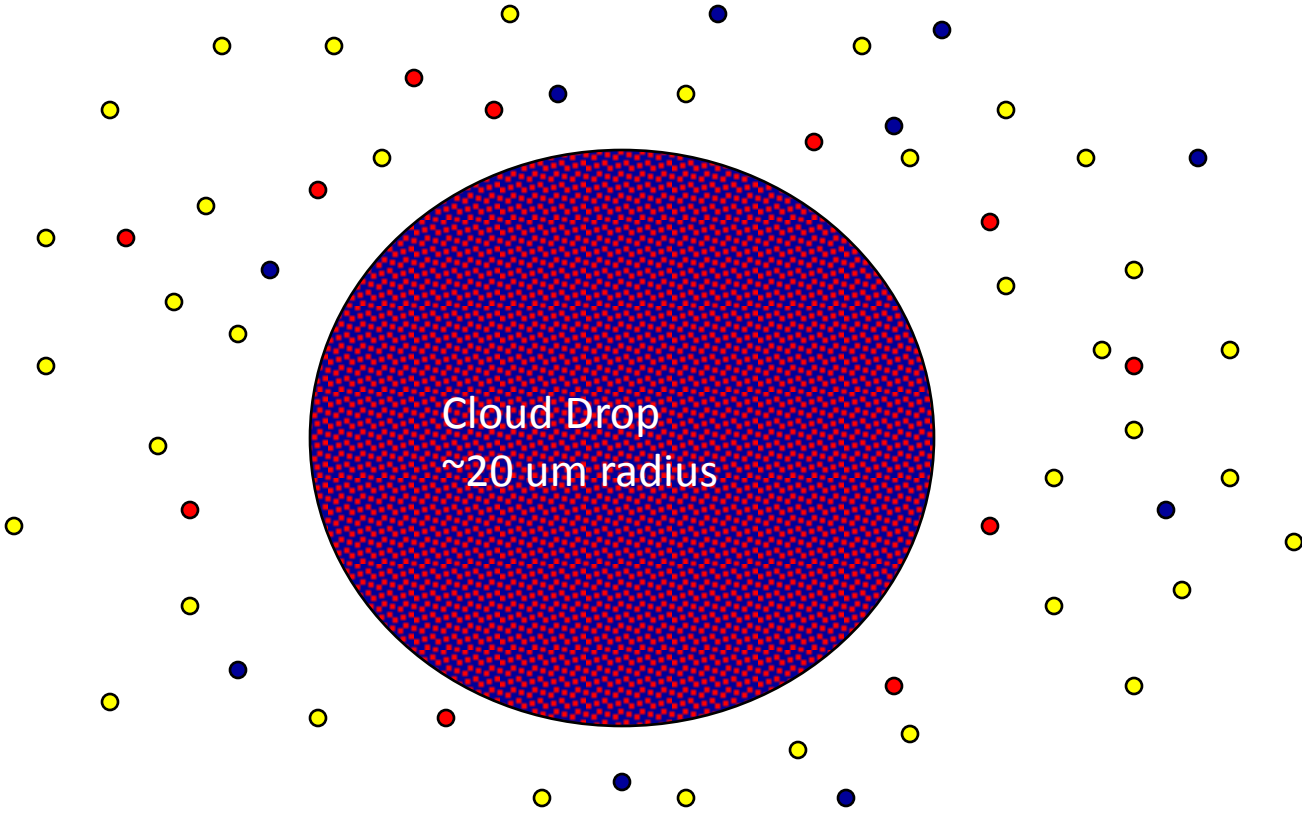
- Needed to turn supersaturation into liquid drops (a site is needed for condensation)
- This is referred to as “drop nucleation” – a big uncertainty in the science of clouds
- CCN are preferentially hydrophillic
- Can be composed of dust, bacteria, pollen, pollutants, acid drops, salt, and others
- Ice nuclei have slightly different characteristics

Vapor deposition into water drops

$$\alpha_m = \frac{\text{“net” molecules added}}{\text{molecules impinging - molecules vaporizing}}$$

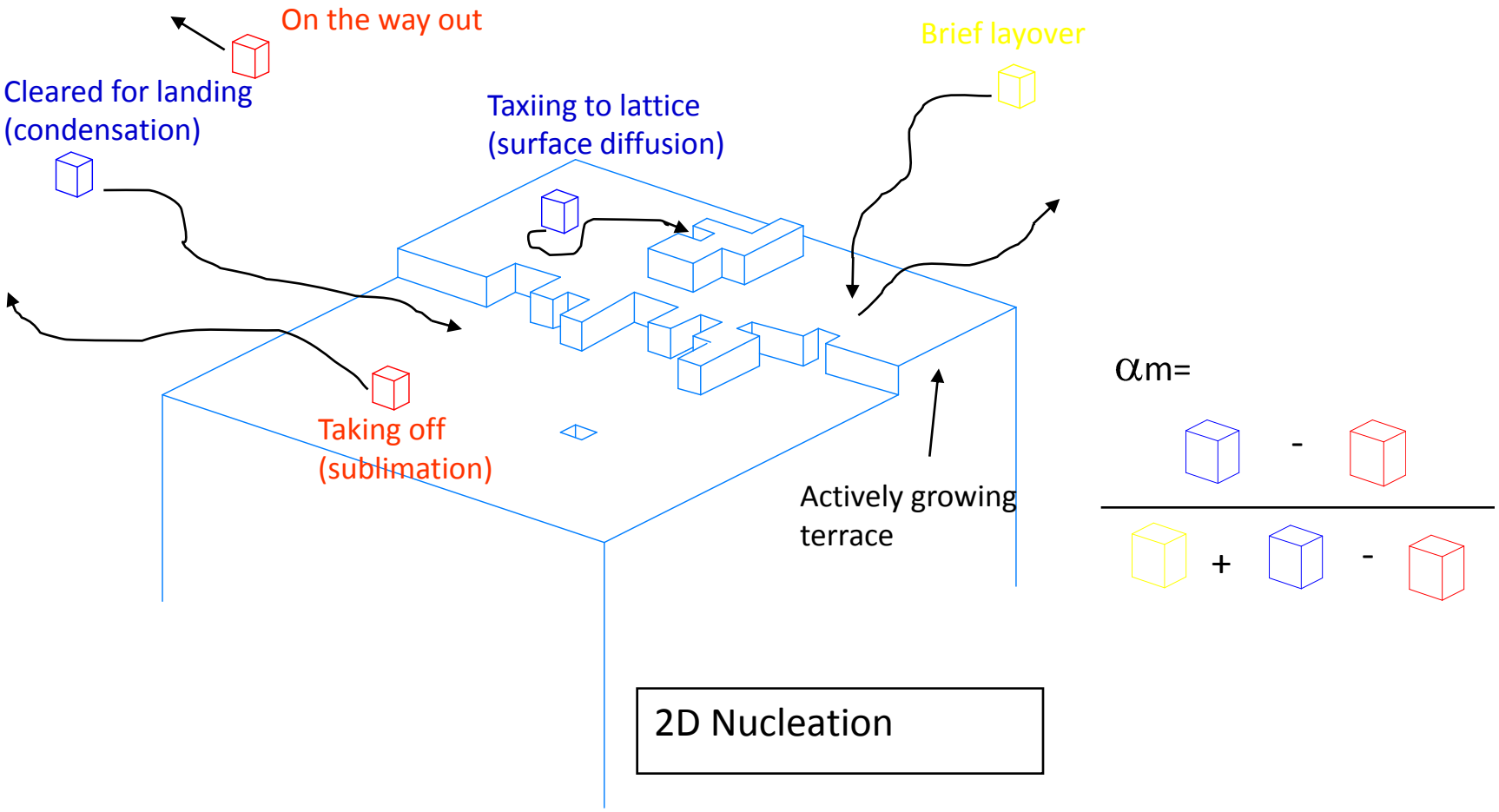
- Will make it in
- Made it out
- Will be rejected



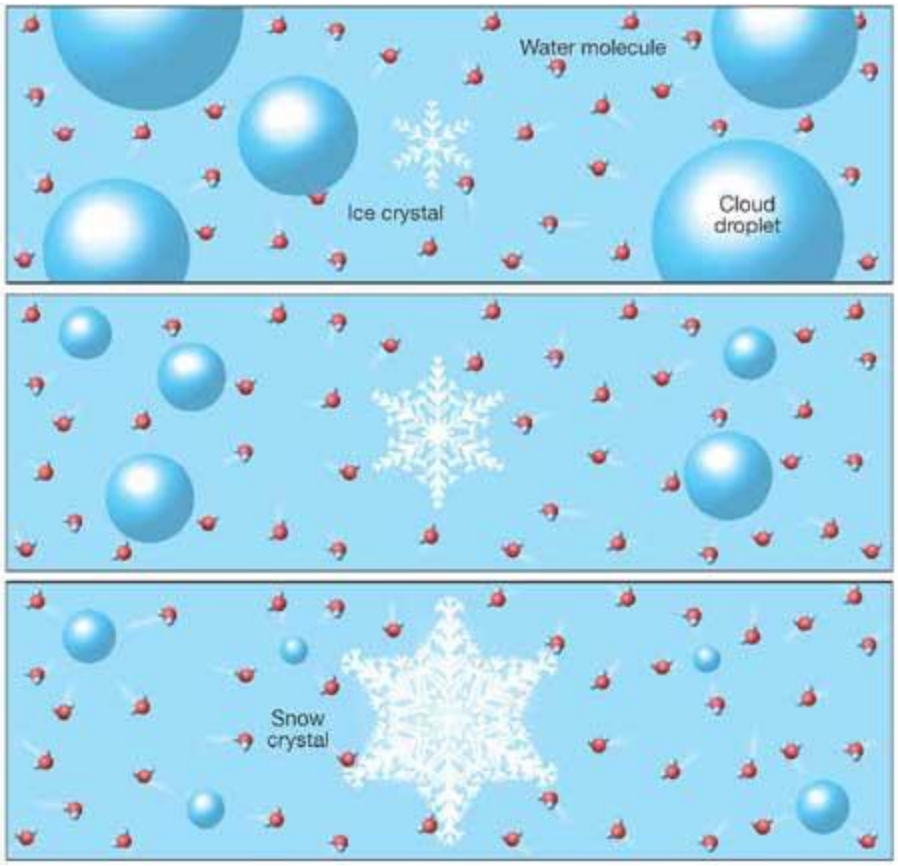


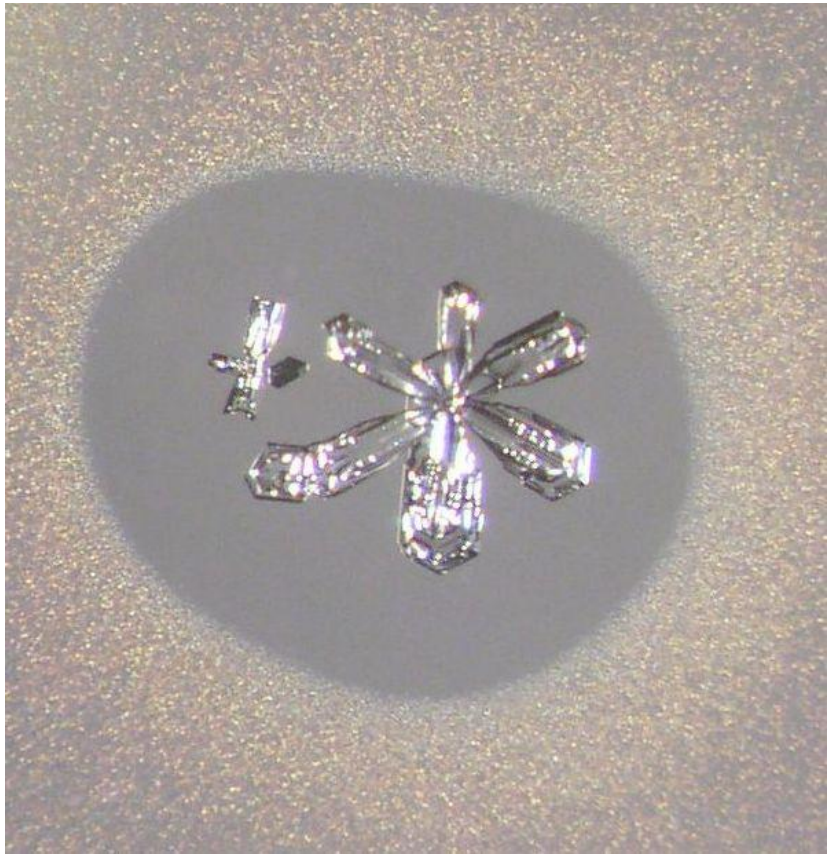
Vapor deposition onto ice surfaces

- Average coefficients help determine net mass growth rate
- Relative local coefficients determine habit type
- Local coefficient is a function of temperature and moisture density
- Mechanism for coefficient temperature function is an enduring mystery
- Mechanism of incorporating incident molecule into lattice is also unknown



2D Nucleation

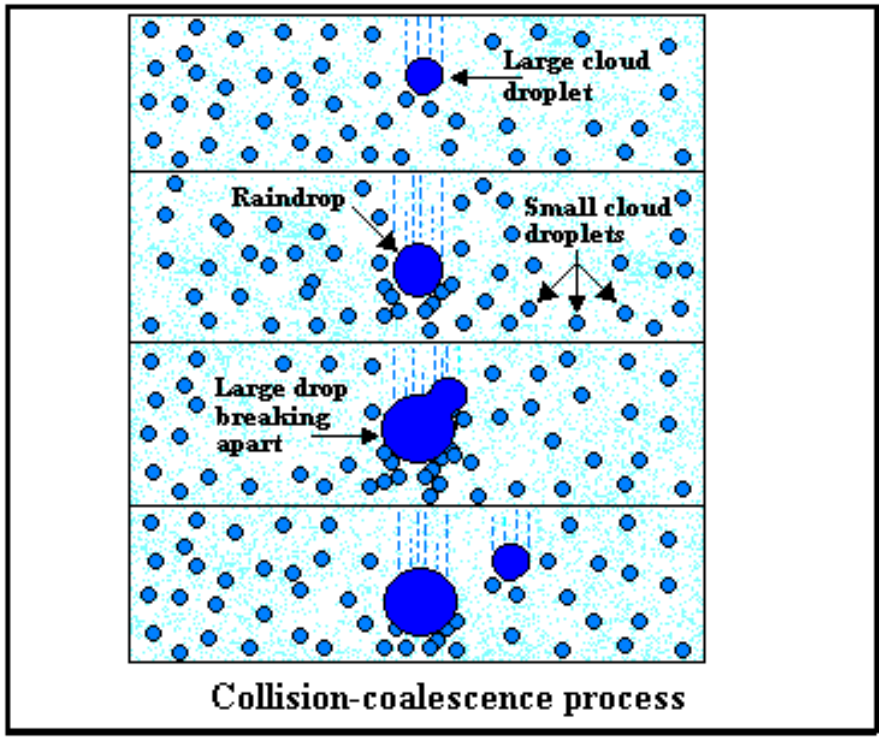


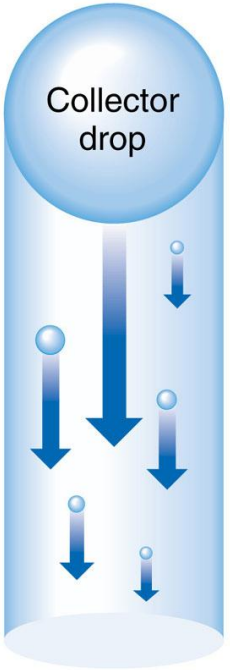


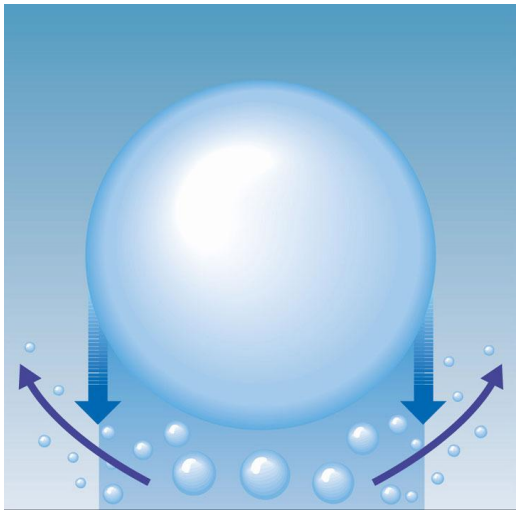
Bergeron-Findeison Process

- The saturation vapor over water is greater than ice (see phase diagram)
- This is caused by the greater difficulty in breaking 100% vs 80% of H-bonds
- Vapor tries to move from high concentration -> low concentration (law of diffusion)
- Thus, when water and ice surfaces are nearby, the vapor moves from high concentration (water surface)->lower concentration (ice surface), allowing ice to grow as water evaporates
- This is the major form of ice crystal growth in mixed-phase clouds
- This process contributes to many stages of the precip. process

Little drops->Big drops: Collision-Coalescence

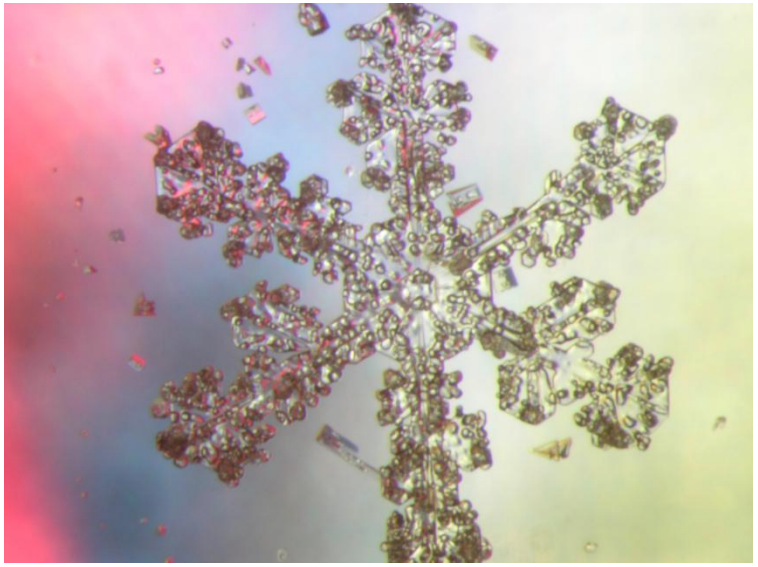


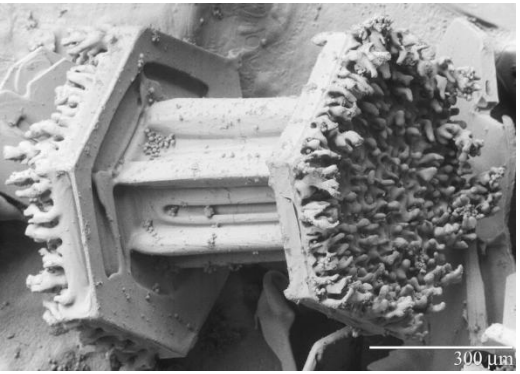


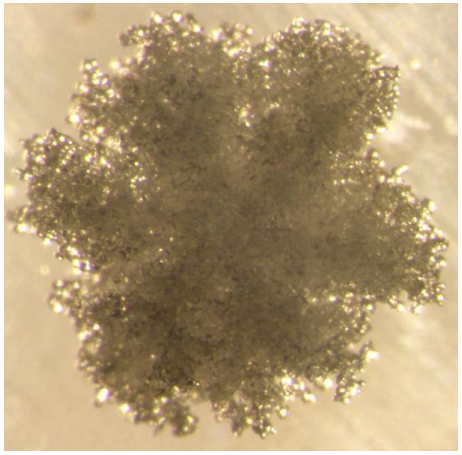


Riming->graupel->Hail

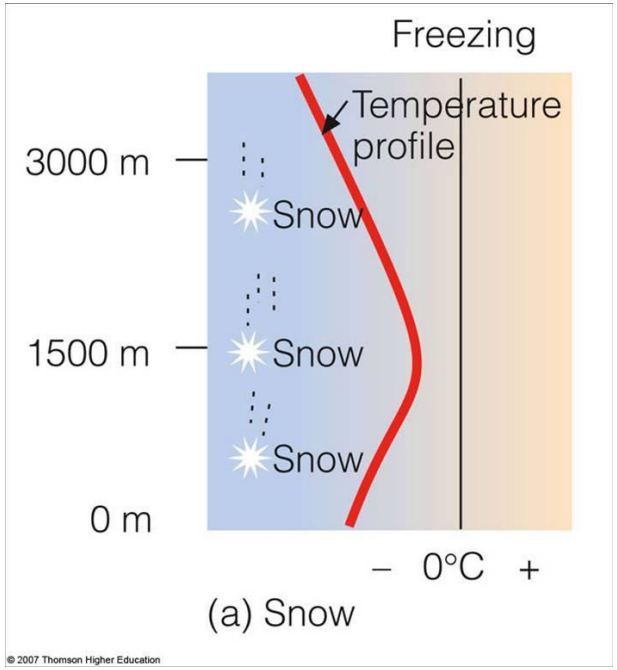
(a) Falling ice crystals may freeze supercooled droplets on contact (accretion), producing larger ice particles.

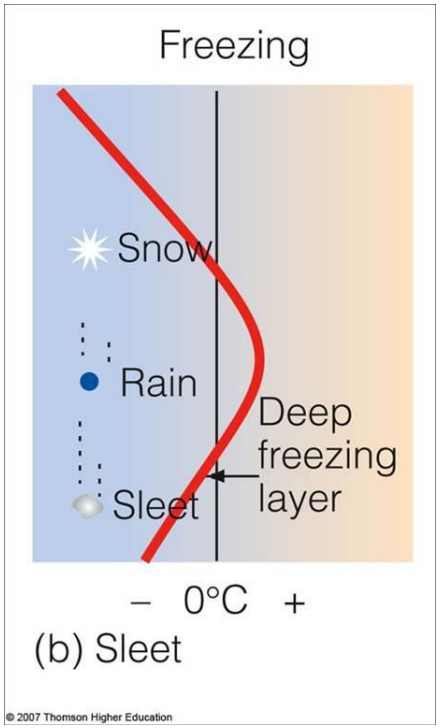


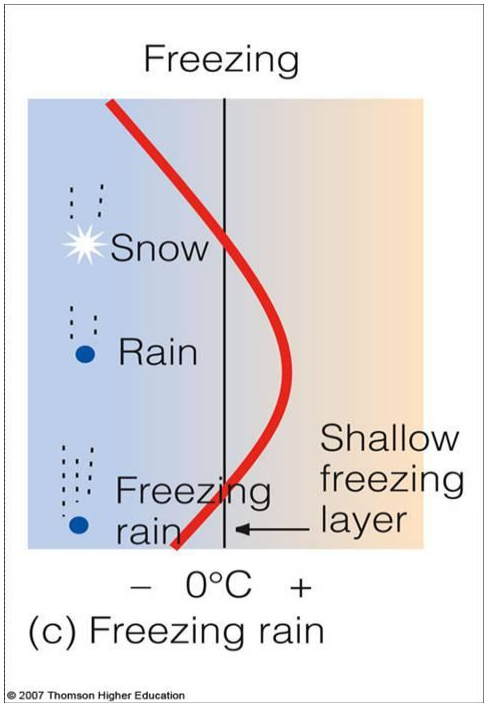


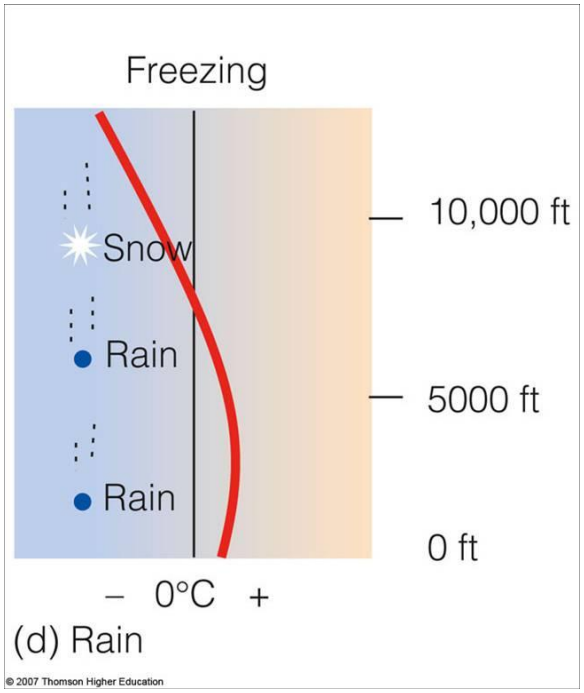


Frozen precip. scenarios

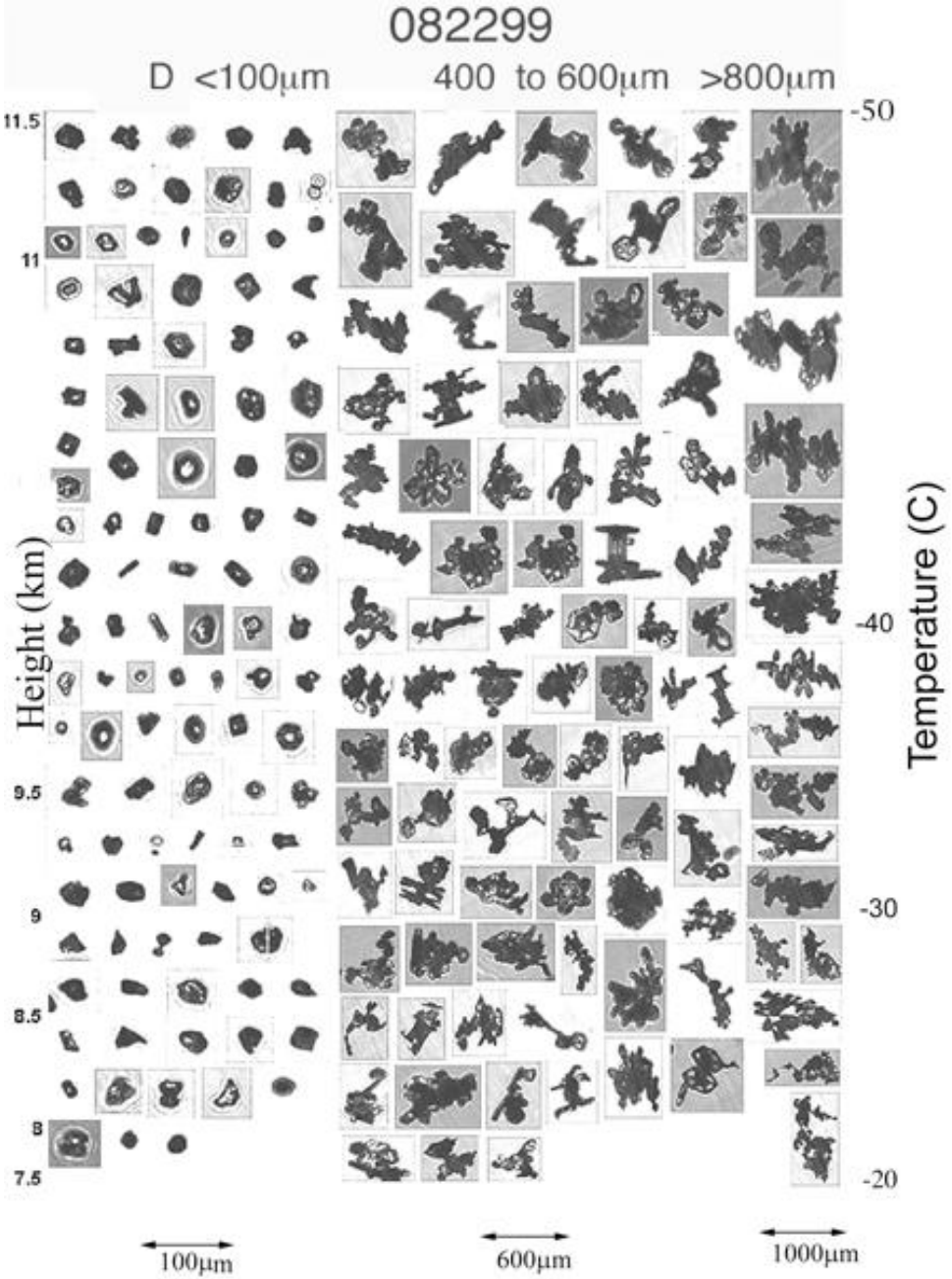








Crystals photographed in cirrus clouds by aircraft-borne probe



Weather Modification and cloud seeding


FIGURE 3,1
Effects of seeding Alto-Stratus Clouds over Green Bay, Labrador: 45 minutes after seeding with dry ice.

Witches concoct a brew to summon a hailstorm.

"After the bomb, Dad came up with ice" – Kurt Vonnegut, *Cat's Cradle*, on the invention of "ice-nine".