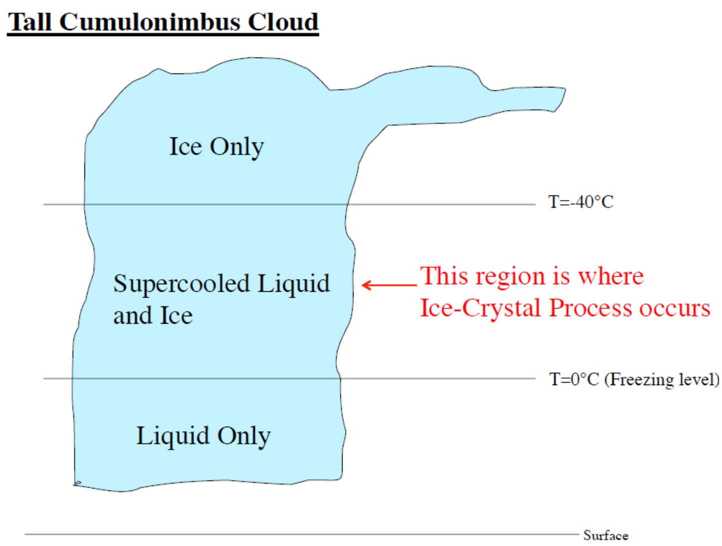
Cloud Physics-Lecture 3

Ice processes



Ice crystals in a cloud can basically form in two ways.

vapor → solid deposition

water → solid freezing

Just as the case with condensation and the formation of water droplets, the formation of ice crystals is much easier if an "ice crystal" nucleus is involved.

Ice nuclei (IN) : We had CCN for liquid water, so we need IN for the freezing process.

Ice or freezing nuclei aid the freezing process

Ice nuclei are rare; only one out of 10 million particles is an effective ice nuclei.

Ice nuclei

- Are less common than Aitken nuclei
- Most effective ice nuclei are those that have the shapes
- Similar to natural ice crystals.
- kaolonite (clay) minerals are effective ice nuclei. are most effective at about -10 °C - Silver iodide, which activates at -4 °C because of the relative sparseness of ice nuclei, ice crystals and super cooled water can coexist at the same time.
- This last point is crucial in the formation of precipitation
- In cold clouds as it gives rise to the **Bergeron process.**

Ice Nucleation

Ice nucleation processes can also be split into Homogeneous and Heterogeneous processes, but complex and not well understood.

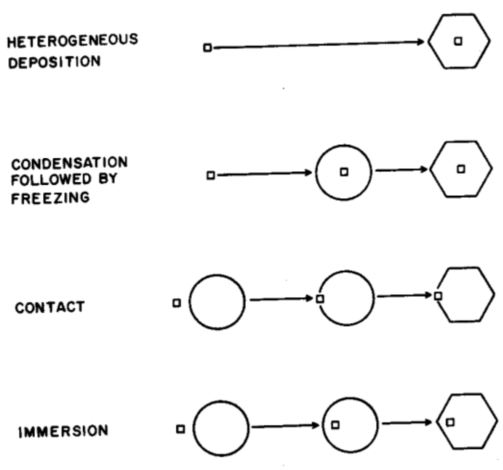
Homogeneous nucleation

Pure water drops do NOT freeze at 0°C, it needs to be colder than -38°C

- ✓ •bigger water drops will freeze at warmer temperatures than smaller drops
- ✓ •smaller water drops require colder temperatures to freeze

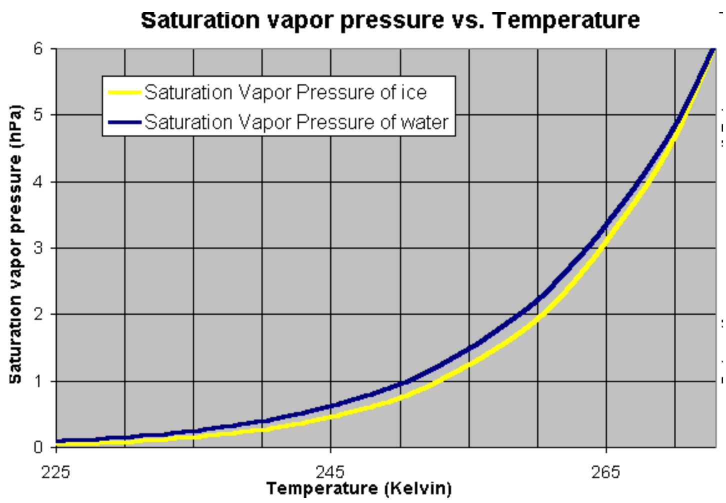
Heterogeneous nucleation

✓ Vapor deposition	Direct transfer of water vapor to nucleus
✓ Condensation-freezing	Condensation of vapor onto surface, followed by freezing
✓ Contact	Collision with supercooled droplets, freezing upon impact
✓ Immersion	Ice nucleus immersed within a drop



ICE NUCLEATION MECHANISMS

Saturation vapor pressure over water and ice



- First, note that e_s(water) > e_s (ice)
- e_s (water) - e_s (ice) is a maximum at **-15°C**
- Hence, it is near this temperature in a cold cloud that ice particles will grow more readily than water particles.

Growth mechanisms

Vapor deposition

- Saturation vapor pressure over water is greater than over ice
- When ice and liquid coexist in cloud, water vapor evaporates from drop and flows toward ice to maintain equilibrium
- Ice crystals continuously grow at the expense of water droplets
- The process of precipitation formation in cold clouds is by ice crystal diffusional growth at the expense of liquid water droplets is known as Bergeron process

Ice-crystal (Bergeron) process

- Water vapor molecules migrate towards the ice crystals.
- Cloud ice crystals grow at the expense of the water droplets.
- Bergeron process arises since e_s ice < e_s water, so ice grows at the expense of super cooled water droplets.

Once ice crystal has grown by diffusion to a size larger than water droplets, it begins to fall and collisions become possible.

Accretion

Ice crystals collide with supercooled droplets, which freeze upon impact - the resultant particle is often referred to as graupel or hail. May fracture or split as it falls, producing more ice crystals.

Aggregation

If ice crystals collide with other ice crystals – they stick together - snowflakes form. Ice crystals can aggregate together to form “snow”“. Sticking” efficiency increases as temperature exceeds –5°C.