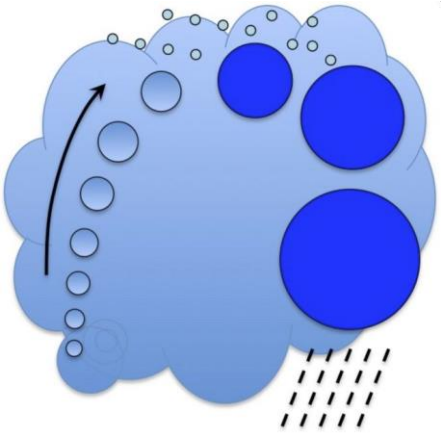
Cloud Physics-Lecture 2

Droplet growth - Precipitation Formation

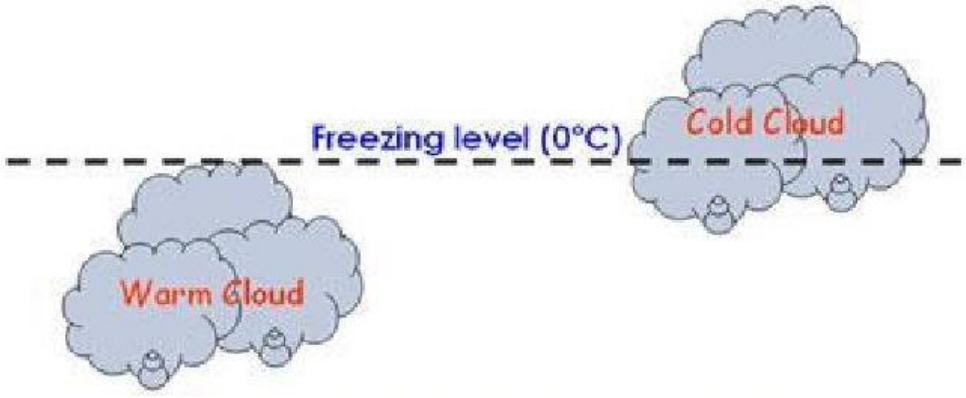


Need a mechanism – for cloud droplets to grow into rain drops

Warm clouds exist where the cloud top is below freezing level.

I.e. cloud that is only in the liquid phase. Cold clouds primarily exist where the cloud top temperature is above freezing level.

Water, supercooled water, ice



Growth of cloud droplets in warm clouds

In warm clouds, droplets can grow by 2 ways

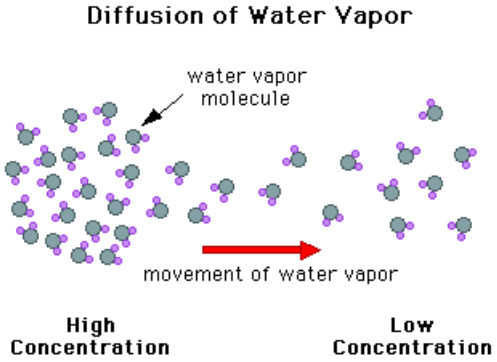
(1)Condensation – diffusional growth process

2) Collision and coalescence process

Warm clouds lie completely below the 0° isotherm

Diffusional growth

Droplet growth, or evaporation, is described by diffusional growth theory. Droplets grow if the saturation vapour pressure at their surface is less than that of their environment. Likewise droplets shrink, if the saturation vapour pressure at their surface exceeds that of their environment.



Diffusional growth summary:

- Accounted for vapor fluxes to/away from droplet.
- Growth slows down as droplets get larger, size distribution narrows.
- Inefficient mechanism for generating large precipitation sized cloud drops (requires hours).
- Condensation does not account for precipitation (another mechanism is needed for “warm” clouds)

Terminal Velocity

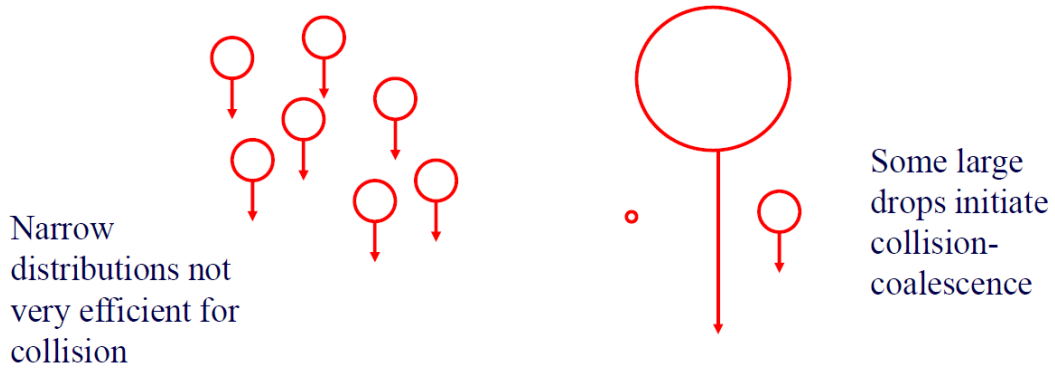
- Gravity makes things fall, constant force -> acceleration
- Air-drag force increases with the speed of the falling object
- Eventually gravity and air-drag become equal -> the body falls at constant speed.
- This velocity is called terminal velocity.

The terminal velocity depends on

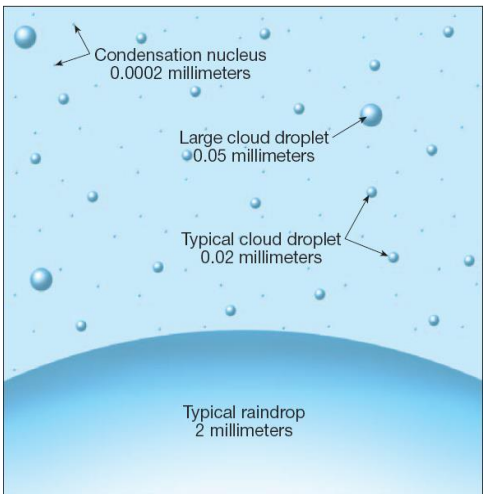
- Shape of the body;
- Size of the body;
- Mass of the body;
- Air properties (density)

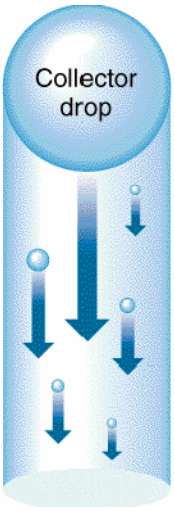
Collision-Coalescence process

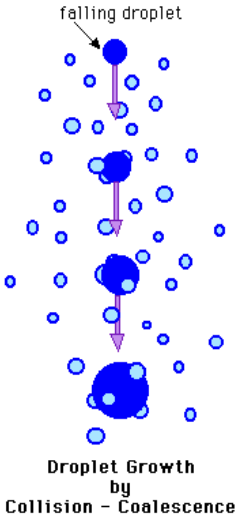
Additional process needed to grow droplets to precipitation size - Collision and coalescence
This is a dominant process for precipitation formation in warm clouds



Some cloud droplets grow large enough and will start to fall in the cloud. Since the bigger drops fall faster than the smaller drops, they will "collect" the smaller drops - the bigger drop grows.



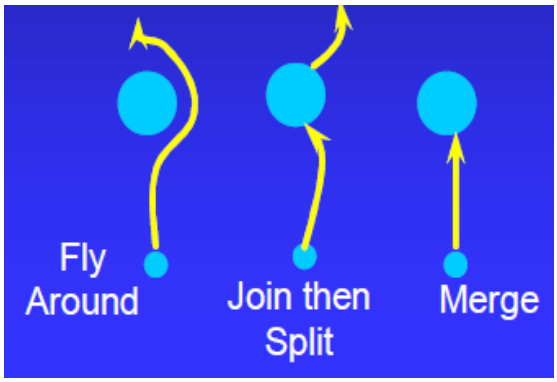




Larger drops fall faster than smaller drops, overtaking and capturing a fraction of those lying in their paths.

If large drops collide with the smaller drops and merge with them, this process is called coalescence.

Not all small drops will merge with the larger ones, some will be swept aside in the airstream around the drop.



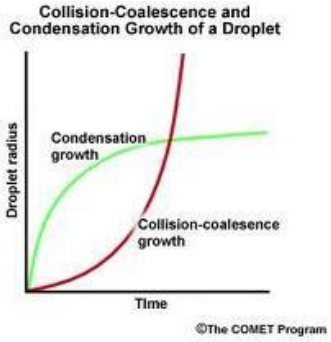
The ratio of the actual number of collisions to the number for complete geometric sweep-out is called **collision efficiency,** and depends on the size of the collector drop and the sizes of the collected droplets.

- some cloud droplets must be larger than others in order for collisions to take place and form a raindrop
- larger drops may form through random collision of droplets
- as cloud droplets fall air slows the drops descent
- the amount of air resistance depends on the size of the drop and the rate of the fall
- the speed of the falling drop increases until the air resistance equals the pull of gravity
- at that point the drop reaches its **terminal velocity**.

Collision always does not guarantee coalescence. When a pair of droplets collide, several types of interactions are possible.

1. They may bounce
2. They may coalesce and remain permanently united
3. They may coalesce temporarily and separate
4. They may coalesce temporarily and then break into a number of small drops .

The type of interaction depends upon the drop size and collision trajectories, and also influenced by the existing electrical forces and other factors.



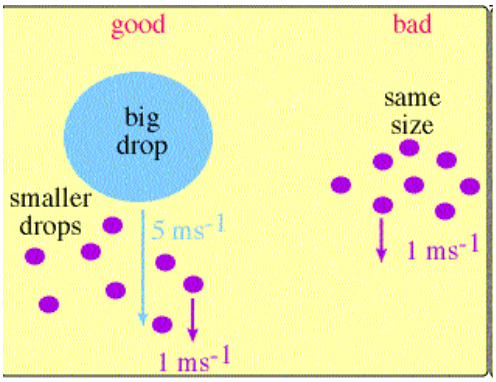
Coalescence efficiency = number of coalescences/ number of collisions

The growth of a drop by the collision–coalescence process is governed by the collection efficiency

Collection efficiency = Collision efficiency X Coalescence efficiency

When the drops are all smaller than 100 um, it is usually assumed that the coalescence efficiency is unity, So that collection efficiency is identical to the collision efficiency.

Factors promoting droplet growth by collision-coalescence



- Different drop sizes
- Thicker clouds
- Stronger updrafts

Precipitation is favoured in clouds with

- Large liquid water content (i.e., deep cumulus)
- Broad drop spectrum
- Large drops (must be larger than ~20 mm)
- Large vertical extent

Droplet Growth in a Shallow Stratus Deck

- Often, drops will evaporate from shallow stratus before reaching the ground
- or you may get drizzle if they are large enough.