Clouds

Reading: A&B: Ch. 5,6

1. Introduction

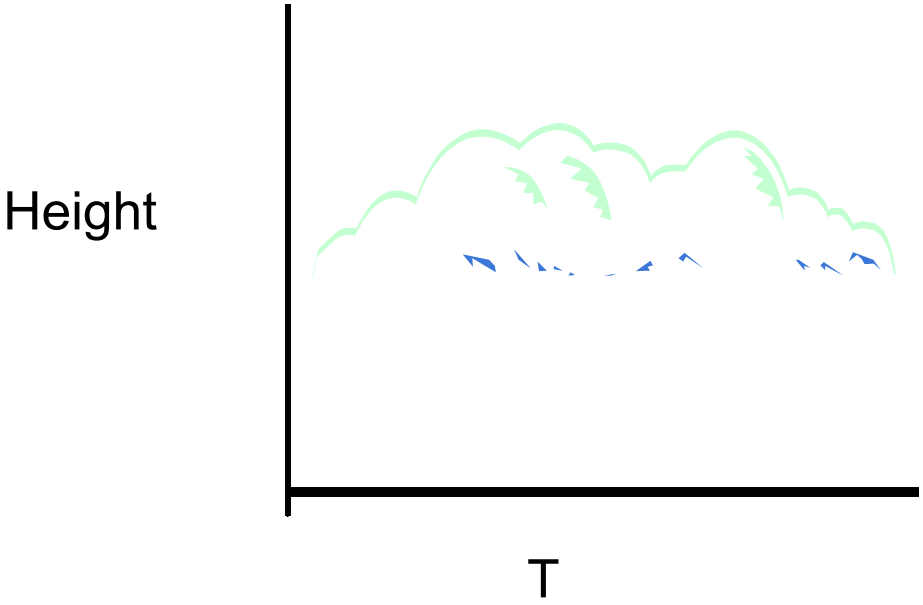
Recall

- Condensation: water vapor (gas) ⇒ liquid
  May lead to formation of dew, fog, cloud etc
  Different but all require **saturation**
- Saturation occurs when either:
  - Water vapor is added to the air
  - Air is **cooled** to its T_{dew} - most common

2. Cooling

a. Radiation cooling - during evening hours
- dew, fog

b. When **air lifts** - Most common
- cooled adiabatically (DALR if unsaturated)
- If parcel rises high enough - cool sufficiently - **condensation level**
- Above this point air continue to rise but now at SALR
- SALR < DALR ⇒ does not cool as rapidly



3. Stability

Different types of clouds form depending on the **stability**
Recall : stability - air tendency to mix vertically

1. **Unstable** - air tendency to rise
   - o Clouds towering
   - o Heavy precipitation
   - o **Cumulus** type

2. **Stable** - air tendency to sink - resists upward movement
   - o Air forced aloft by other means e.g. front, mountains
   - o Clouds widespread
   - o Little vertical thickness compared to horizontal
   - o Precipitation, if any, light to moderate
   - o Overcast
   - o **Stratus** type

4. Cloud types

3 basic **forms**

1. Cumulus
2. Stratus
3. Cirrus

http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cld/cldtyp/home.rxml

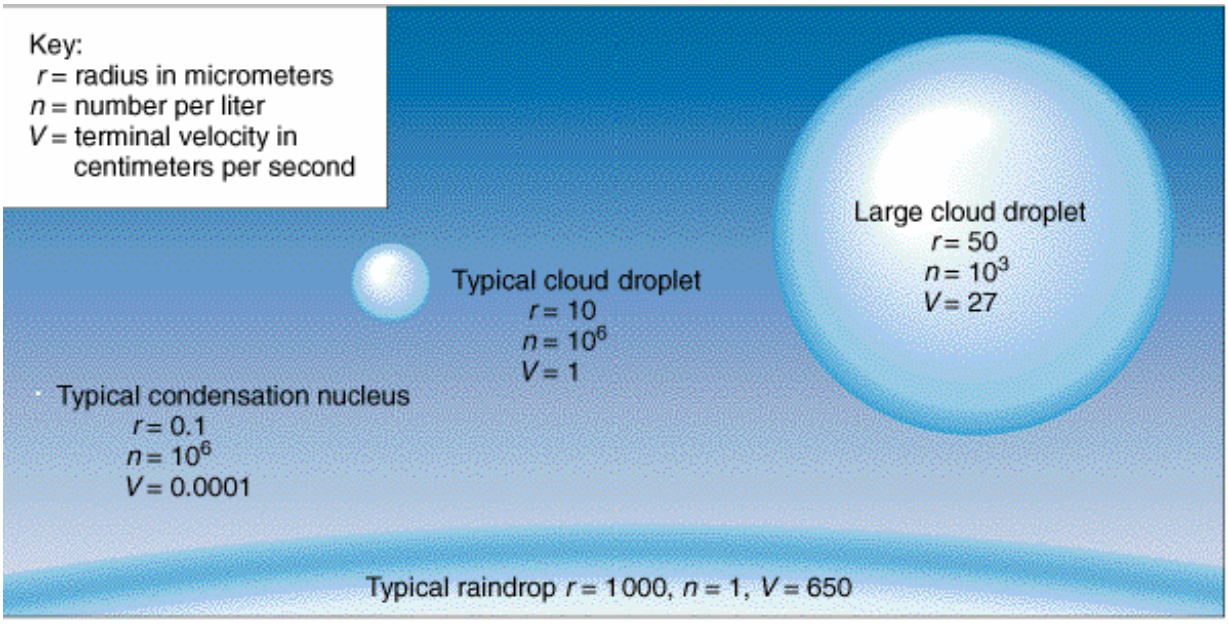
Height:

1. High > 6000 m
2. Middle 2000- 6000 m
3. Low <2000 m
4. Clouds of vertical development
   base low extend to high altitudes (>6000+ m)
   Unstable - powerful vertical acceleration
   Cumulonimbus

5. Cloud Formation

- Condensation (gas ⇒ liquid)
- Air must be saturated - cooled to T_{dew} or water added
- Must be a **surface** on to which water condenses
  - o Surface - in the atmosphere: Cloud Condensation Nuclei (CCN or CN)
  - o If CCN are absent can have > 100% RH i.e. doesn't condense
  - o CCN - microscopic dust, smoke, salt particles
    - Normally large numbers in the atmosphere
    - Salt particles - hygroscopic, they freely absorb water
  - o When condensation takes place
    - initial growth of cloud droplets very rapid
    - diminishes quickly because H_2O availability ⇓
    - Even in very moist air - growth of these cloud droplets by additional moisture is slow

Clouds consist of billions of tiny droplets
- so minute they remain suspended in the air



Takes about 1 million cloud droplets to form 1 rain drop

⇒ Condensation by itself is not responsible for formation of rain

Cloud droplets < 20 μm
- o Small size ⇒ fall very slowly
  - o Takes 48 h to fall 1000 m - never occur ⇒ evaporate

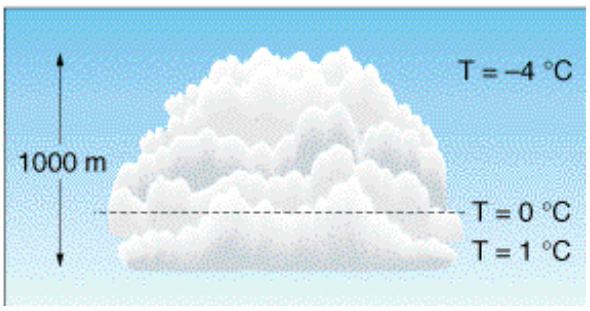
Raindrop - large enough to reach ground i.e. survive

6. Formation of Precipitation

Two mechanisms
- Bergeron
- Collision - coalescence

a. Bergeron - cold cloud process
Two properties of water
1) Pure water doesn't freeze at 0°C.
   Pure water suspended in air doesn't freeze until -40°C
   Supercooled - liquid water < 0°C
   Will freeze if:
   a) agitated sufficiently
   b) come into contact with solid particles with ice/crystalline structure
      - **Freezing Nuclei (FN)** - sparse in the atmosphere
        - Don't generally become active until T<-10°C

0- -10°C	Clouds primarily supercooled H_20
-10 - 20°C	Liquid and ice crystals co-exist
<-20°C	Clouds generally composed entirely of ice crystals



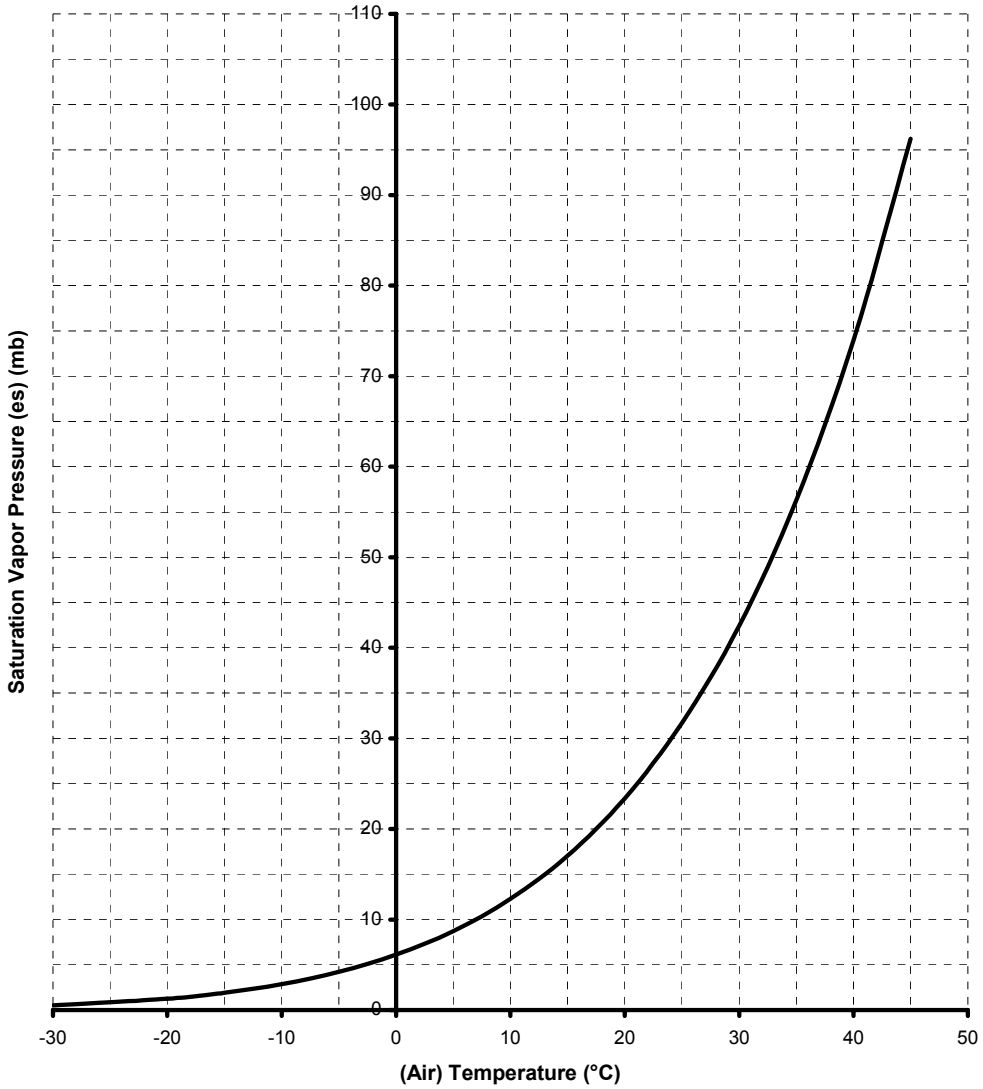
2) Saturation vapor pressure (e_s)

$e_{s\ ice} < e_{s\ water}$ same T

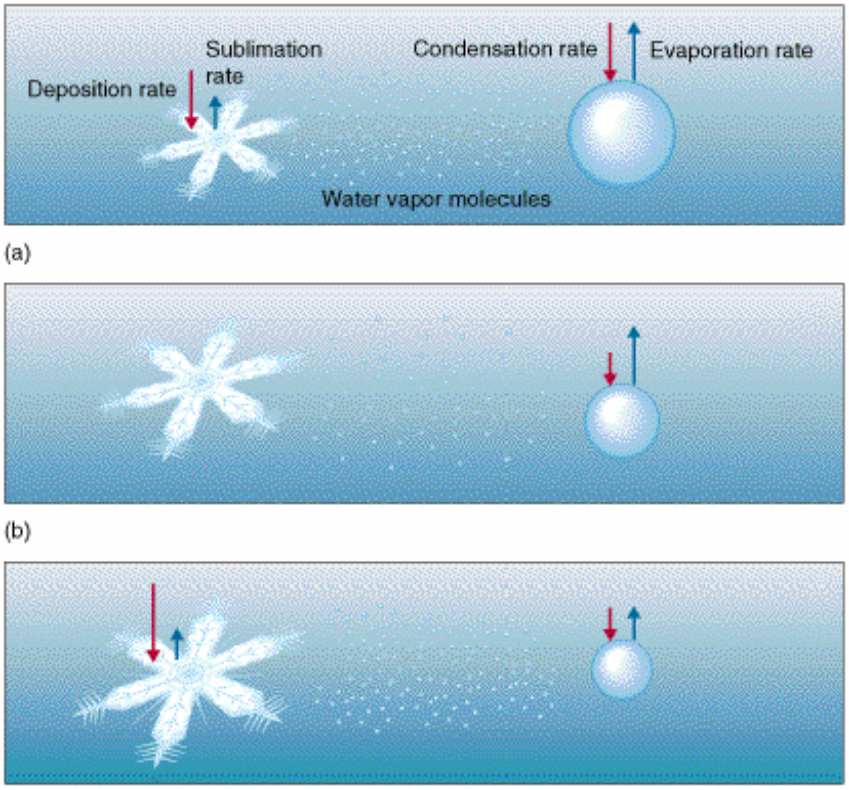
solid liquid

easier to lose molecules

ice crystals grow at the expense of liquid water



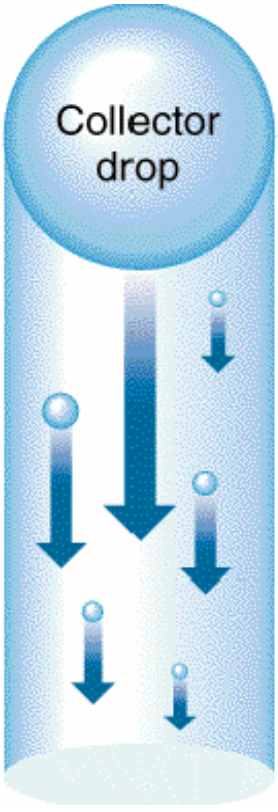
Ice crystals grow
Fall
Break
Lifted by vertical ascent of the air

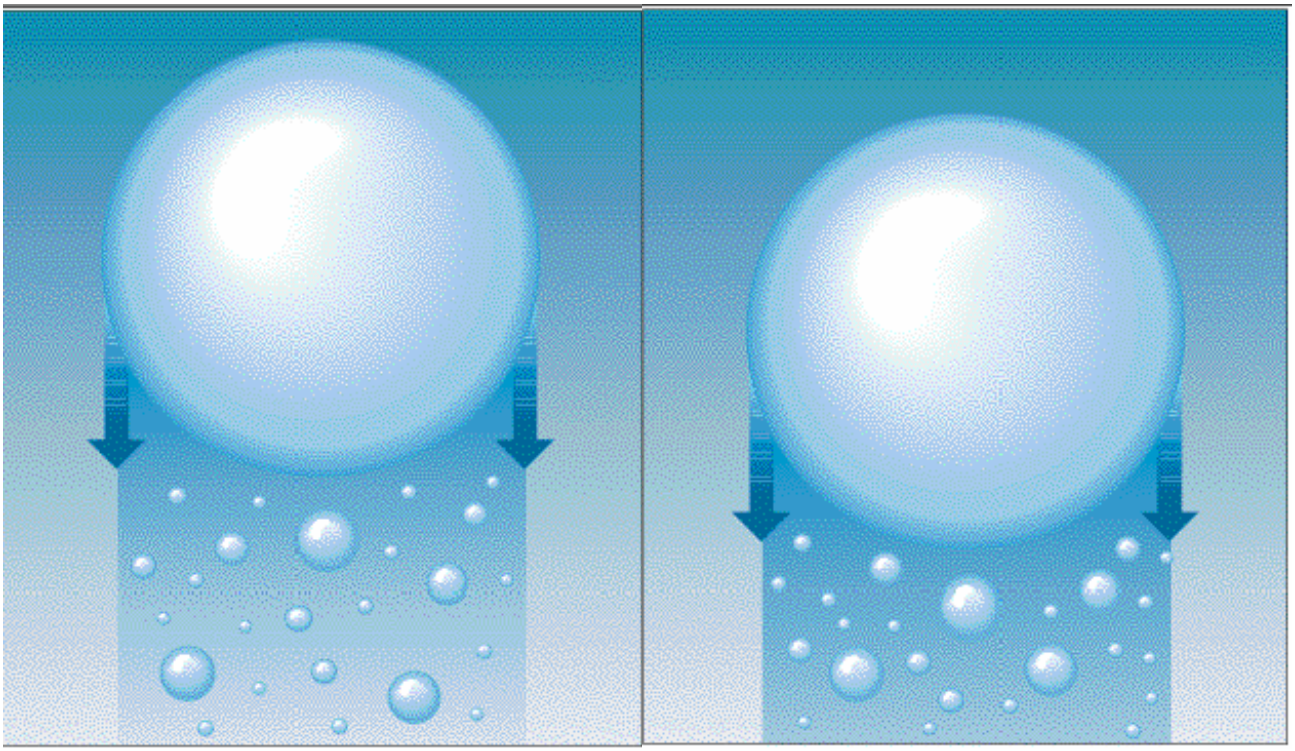


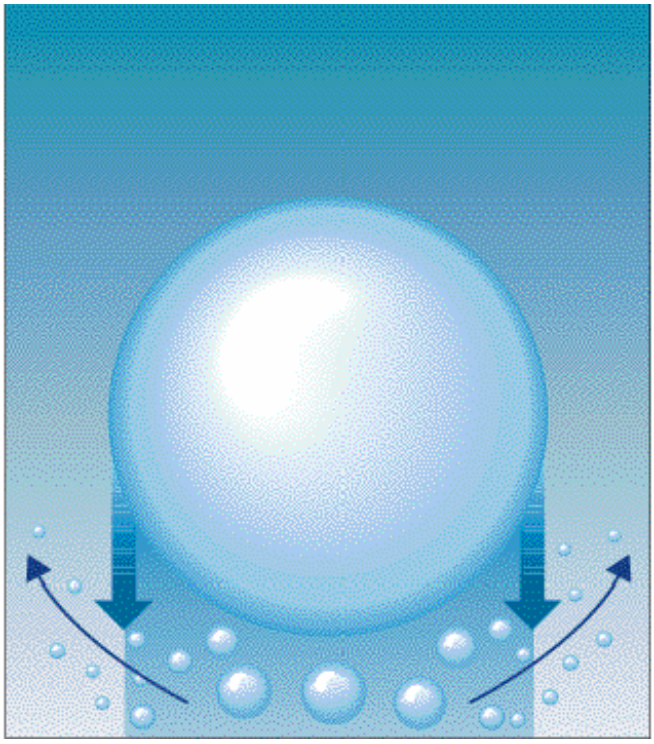
Use this knowledge in cloud seeding (Ag I)

b. Collision - Coalescence - warm cloud > 0°C

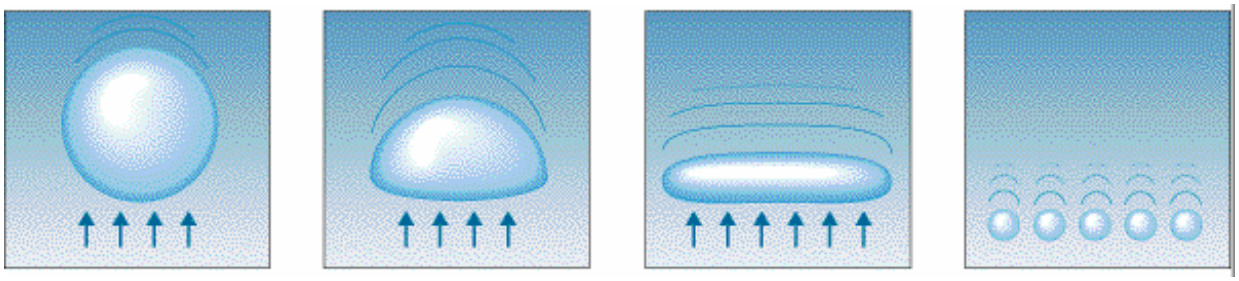
- Giant condensation nuclei
  - Hygroscopic particles - sea salt
- Larger particles fall faster - collide with smaller (slower) particles
  - May coalesce
  - Millions of collisions ⇒ produces something large enough to survive to the surface without completely evaporating
  - Need clouds with great vertical extent
  - Need abundant moisture







- Raindrops may break up if
  - Large size (max ≈ 5 mm) when falling 30 km h^{-1}
  - Surface tension - holds the drop together
    - Surpassed by the drag imposed by the air



7. Forms of precipitation

Liquid or solid dependent

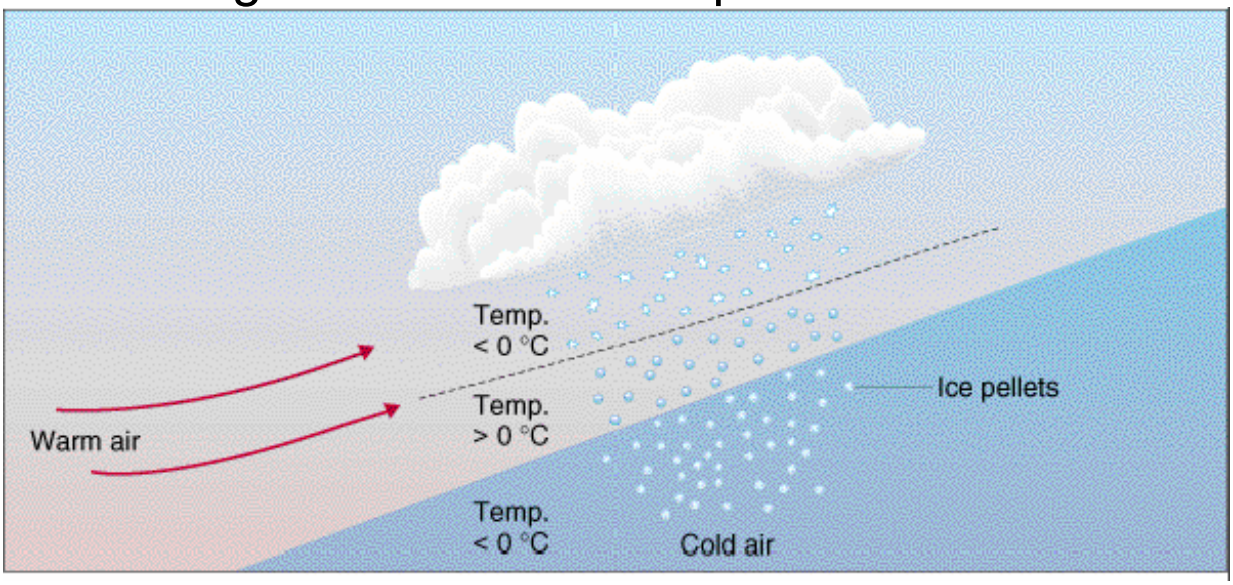
- on formation process
- environment between bottom of cloud and surface

Snow

- has not melted - still crystals
- form depends history: T, humidity

Sleet

- small clear translucent particles of ice
- melts, then freezes in the air above the surface
- no larger than the rain drops formed

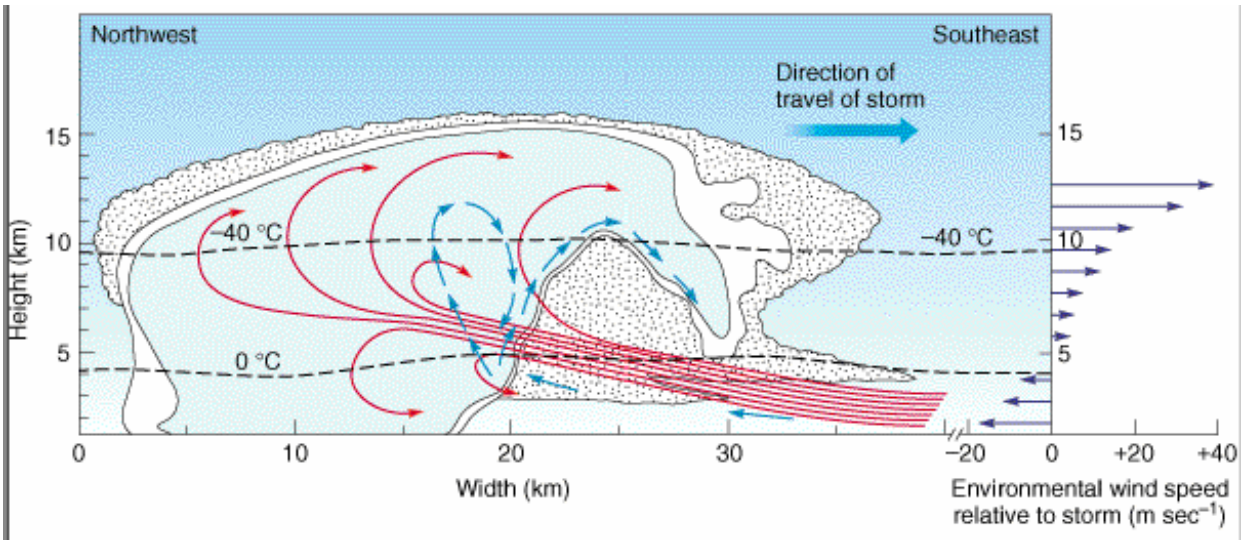


Freezing Rain (glaze)

- Vertical T similar to that for sleet BUT subfreezing air near the ground is not thick enough to allow raindrops to freeze
- Rain becomes supercooled
- Freezes when collides with solid objects

Hail

- Concentric shells of different densities and degress of opaqueness
- Diameter 1 to > 10 cm
- Cumulonimbus clouds
  - o vertical extent
  - o strong updrafts
  - o abundant supply of supercooled H_20
  - o length of path through the cloud



8. Fog

- Visibility < 1 km
- Air wet with millions of water droplets
- Formation and location different to cloud
- Formation = Used to distinguish types

1. Radiation or Ground Fog

Cause: radiative cooling

- Best on clear nights with shallow layer of moist air overlain by drier air

- Ground cools rapidly - moist doesn't absorb much L↑
  - o Surface Inversion (warm air over cool air)
  - o Moist lower layers quickly become saturated
    - ⇒ Fog forms

- Longer the night - longer the time of cooling

$\Rightarrow$ greater the likelihood of fog

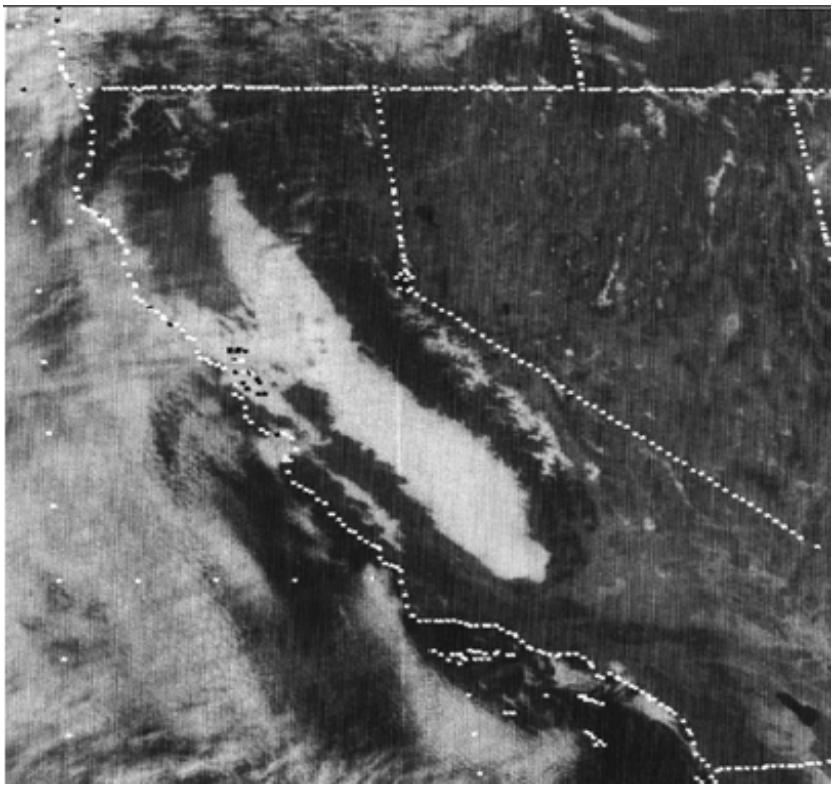
- Radiation fog - most common late fall/winter

- Slight wind < 2.5 m s^{-1} promotes fog development brings more air into contacts with the ground
- Strong wind - prevents radiation fog from forming mixes air near the surface with drier air above
- Valley bottom - cool air drain down, rivers - moist air

2. **Advection Fog**

Cause: warm moist air moves over a cold surface
Surface has to be sufficiently cool to reduce the T to T_{dew}

- Involves movement of air
- Surface H_20 near the coast is colder than surface water offshore
    - San Francisco - summer breeze Golden gate bridge



2. Upslope Fog

Cause: Moist air flows up an elevated plain, hill

Air gradually rises, expands, cools

If sufficient ⇒fog

3. Evaporation Fog

Cause: Water added to air by evaporation

e.g. breath out on a cold day

Steam Fog - above a heated swimming pool