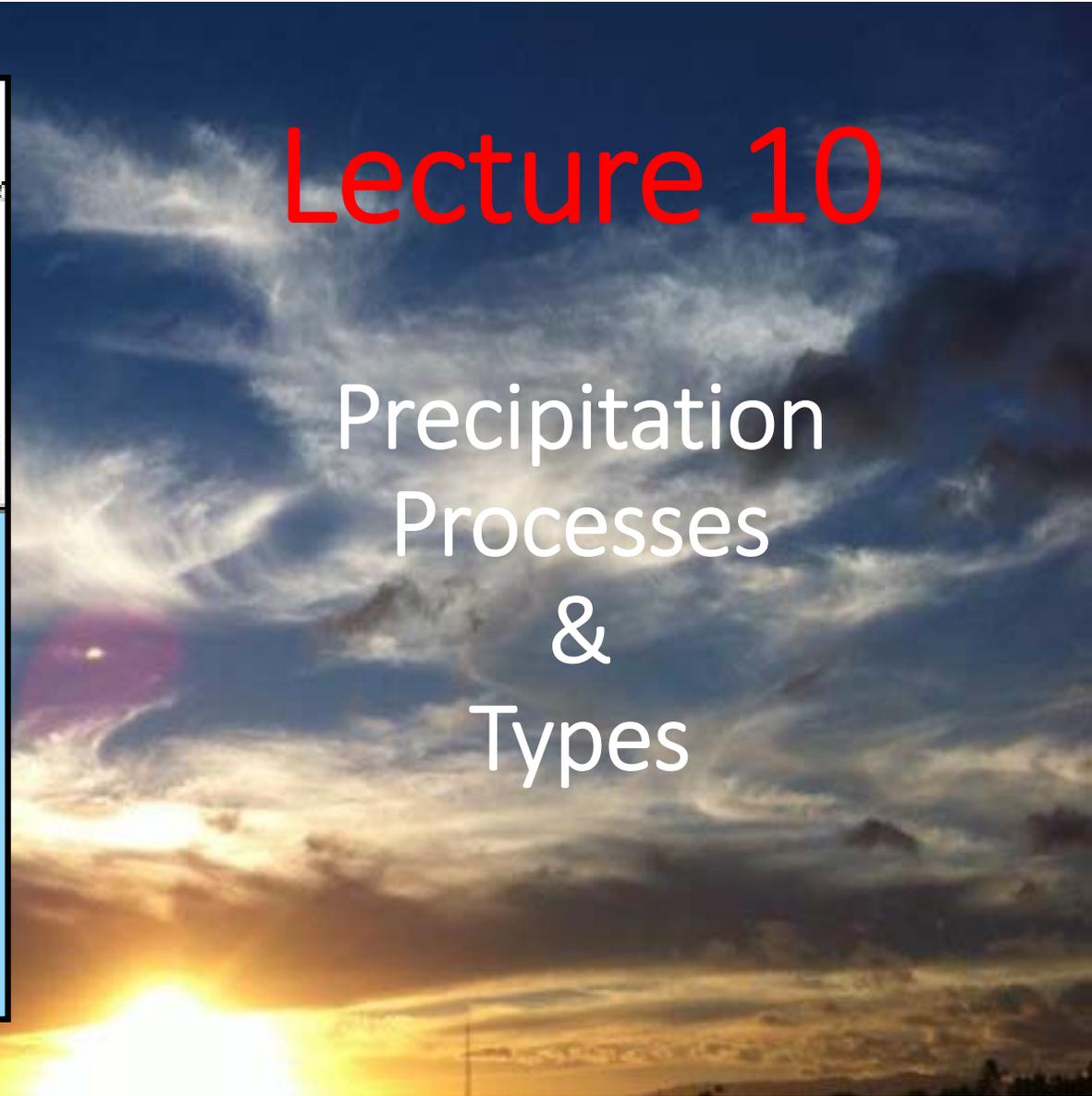


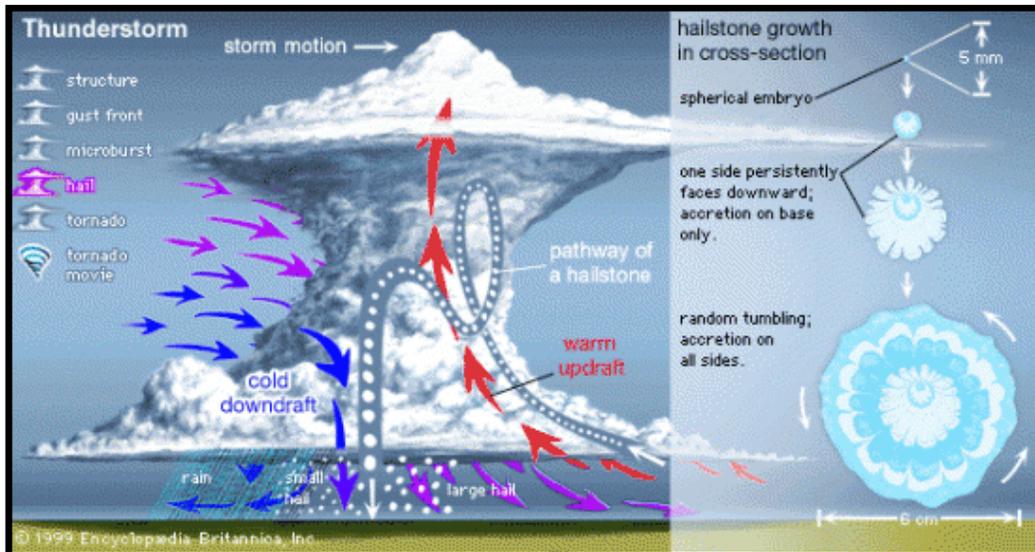
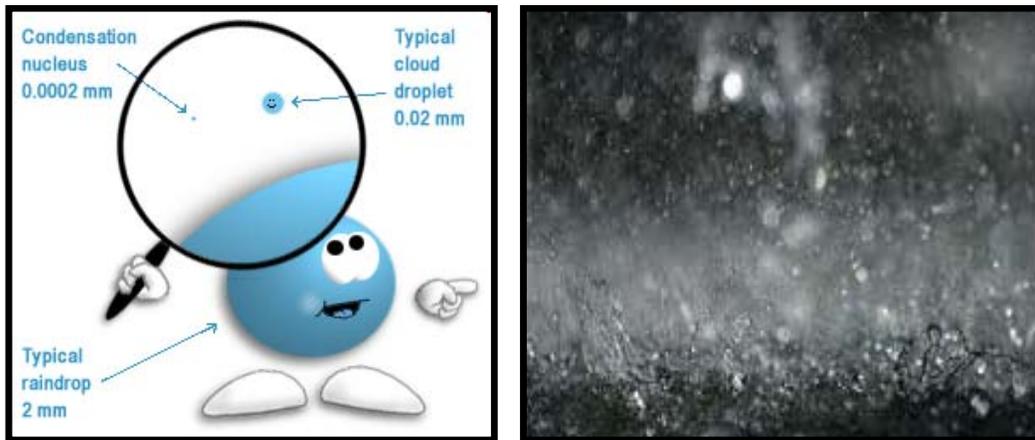


Lecture 10

Precipitation Processes & Types



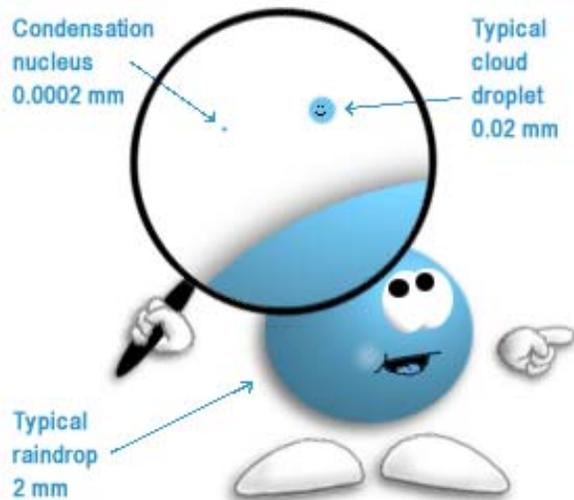
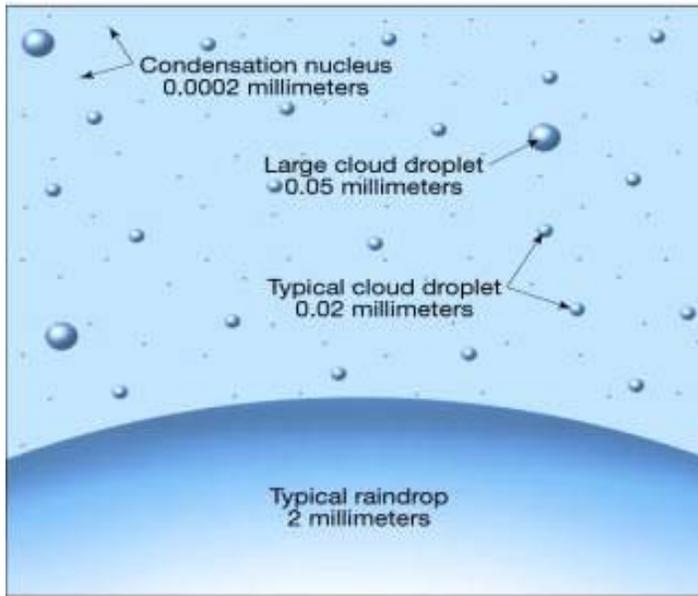
Learning Goals for Part 2 of Chapter 5



1. Be able to describe how precipitation forms in **COLD** and **WARM** Clouds.
2. Be able to describe how **RAIN**, **SNOW**, **SLEET**, **FREEZING RAIN**, **GLAZE**, **RIME** form.
3. Be able to describe how **HAIL** Forms.

How Precipitation Forms

- It's actually really hard to make a rain drop
 - Cloud drops are **VERY TINY (0.02 mm)**
 - Rain drops are **VERY BIG (2 mm)**
- **There has to be a mechanism for cloud drops to join together to form rain droplets.**
 - **100 times larger in diameter.... but it's more than that.... it's VOLUME!!!**

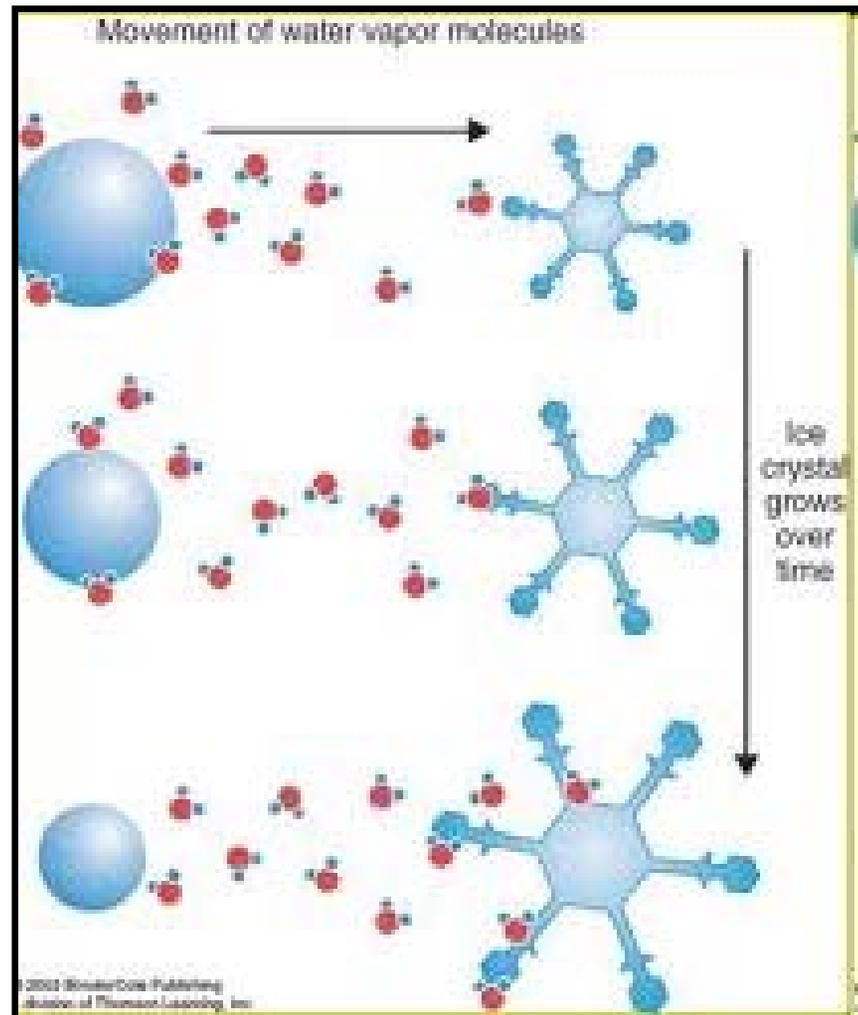


Cloud Drop ○

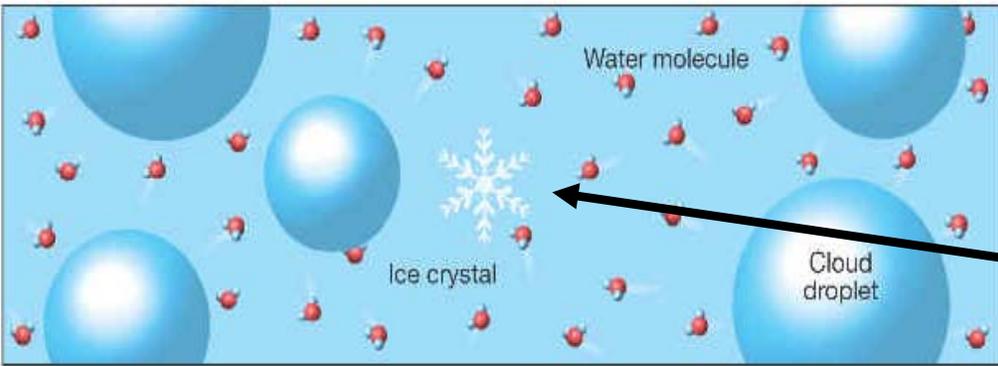
**It takes 1 MILLION cloud droplets
to make 1 rain drop!!**

Precipitation in Cold Clouds

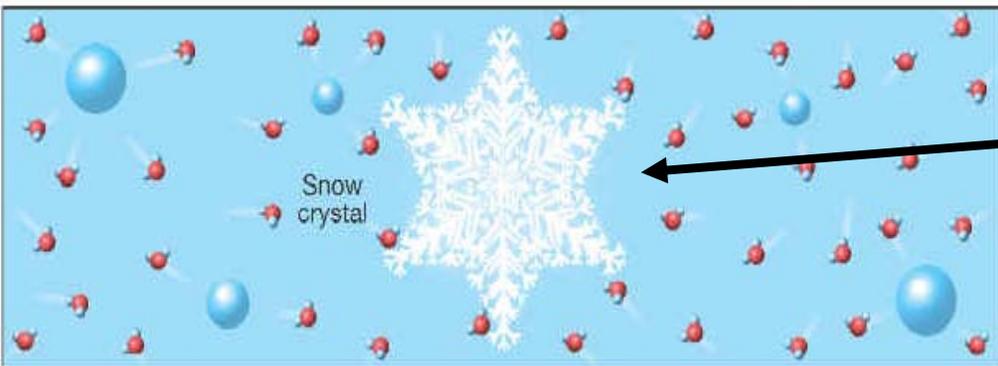
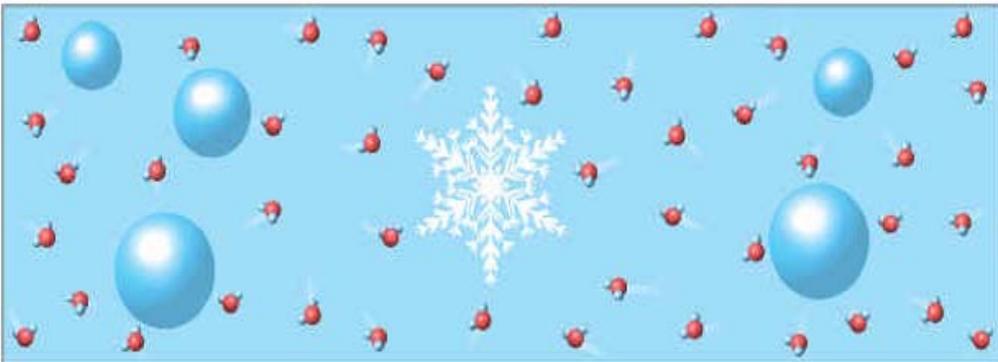
- Ice, water and water vapor exist at the same time.
- Cloud drops **DON'T FREEZE** at 0C!!
- Liquid water won't freeze until -40C
 - **SUPERCOOLED**
- Supercooled water freezes when it touches a **Freezing Nuclei**
 - **FN are rare**



The Bergeron Process



One little ice crystal and lots of water droplets



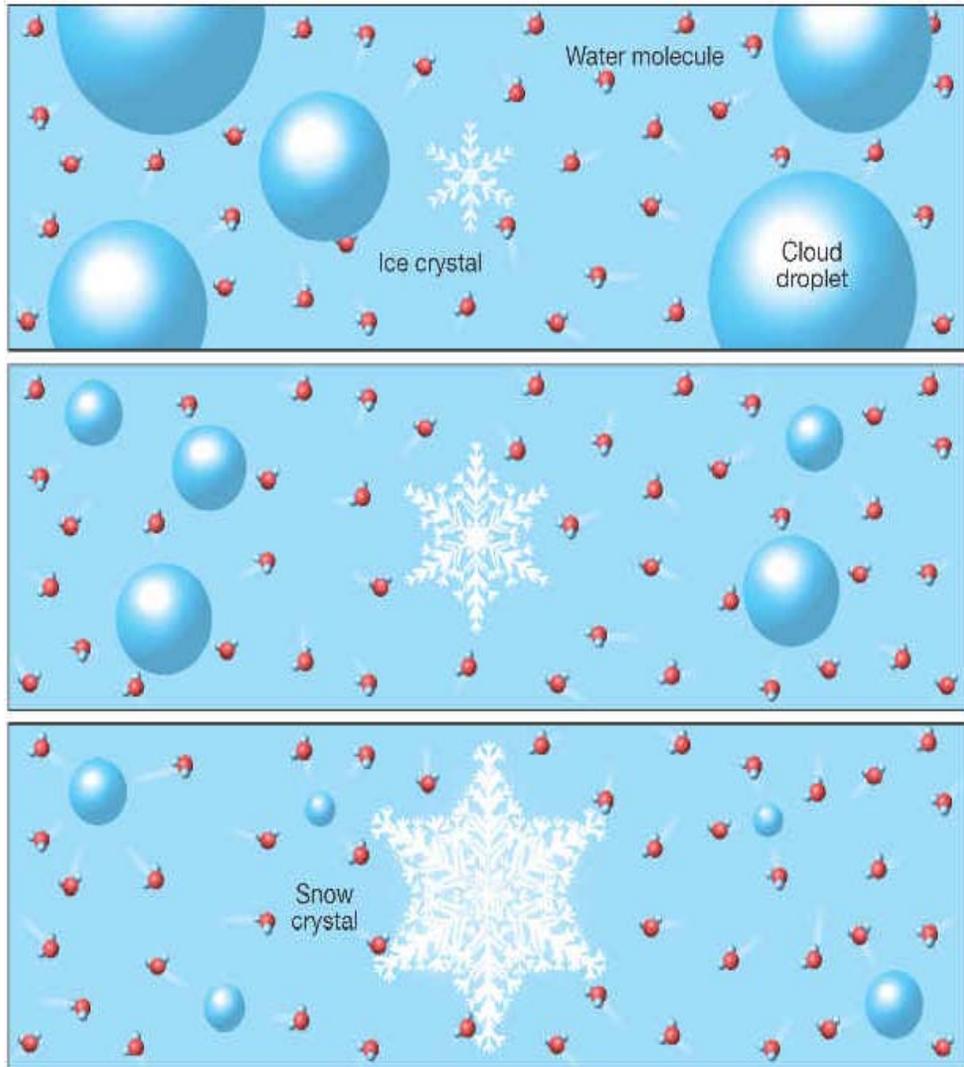
Grows Bigger by "Stealing" moisture from the Cloud droplets



Bergeron Process

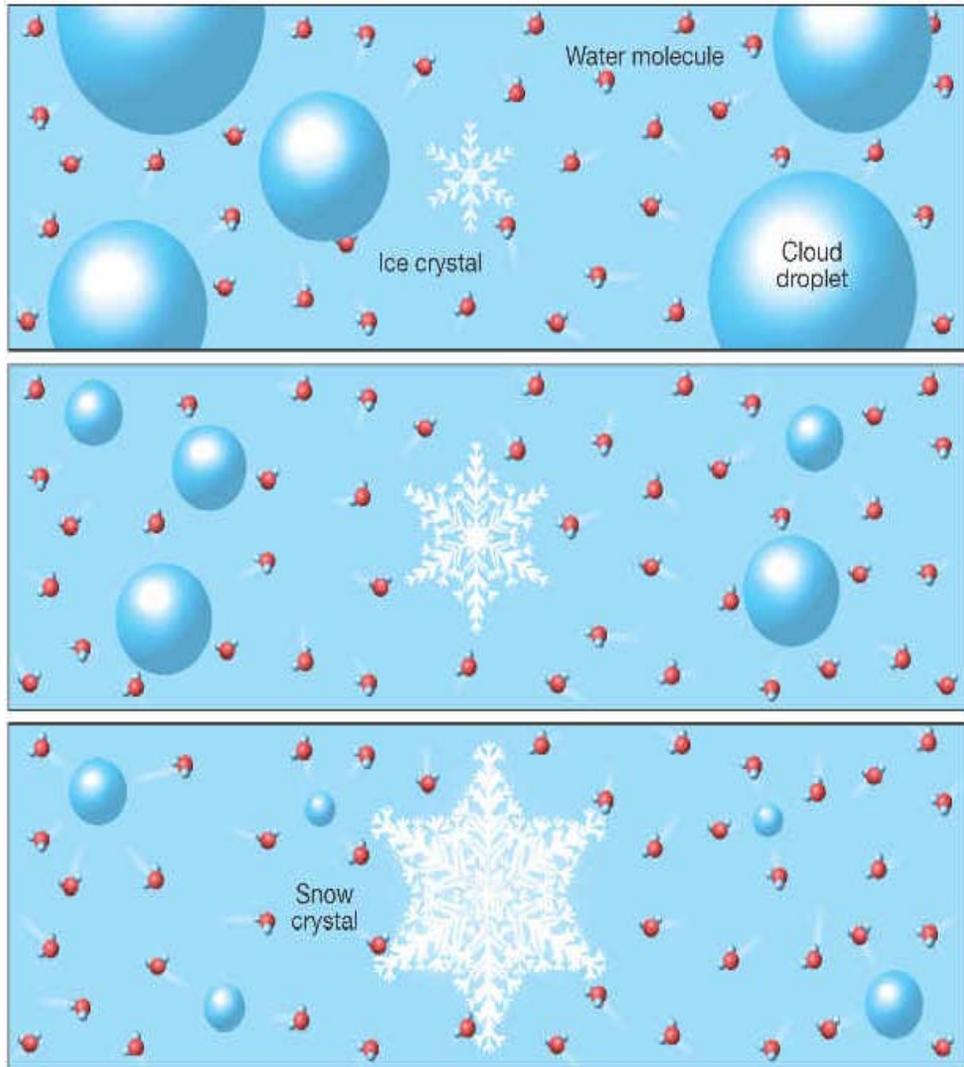
- Eventually the ice crystals will grow **large enough** to fall.
- The Bergeron Process often results in **liquid precipitation**.
 - As the crystals grow and fall, they pass through the base of the cloud, which may be above freezing.
 - This causes the crystals to melt and fall as rain.

The Bergeron Process Summary - 1



- The air reaches **saturation** and some of the resulting droplets will come in contact with **freezing nuclei** (assuming they have reached the activation temperature).
- There is then a combination of **ice crystals** and **supercooled water droplets**.
- From the perspective of the supercooled droplets, the air is in equilibrium at saturation, but from the perspective of the ice crystals, the air is supersaturated.

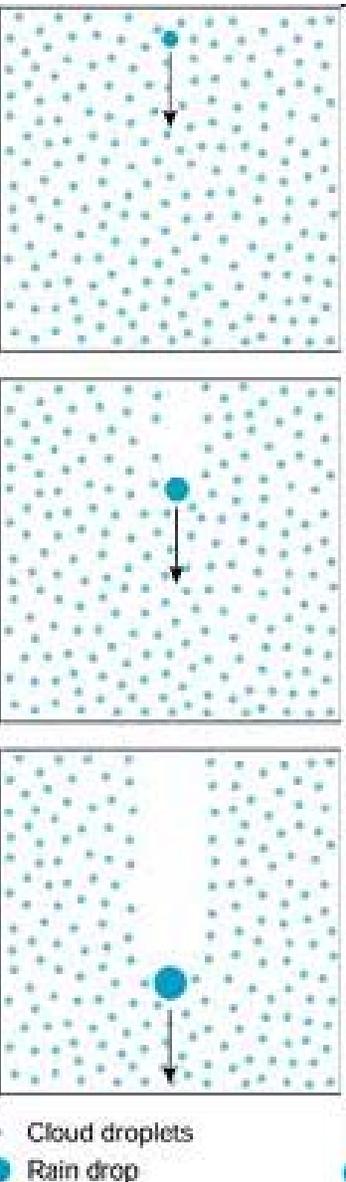
The Bergeron Process Summary - 2



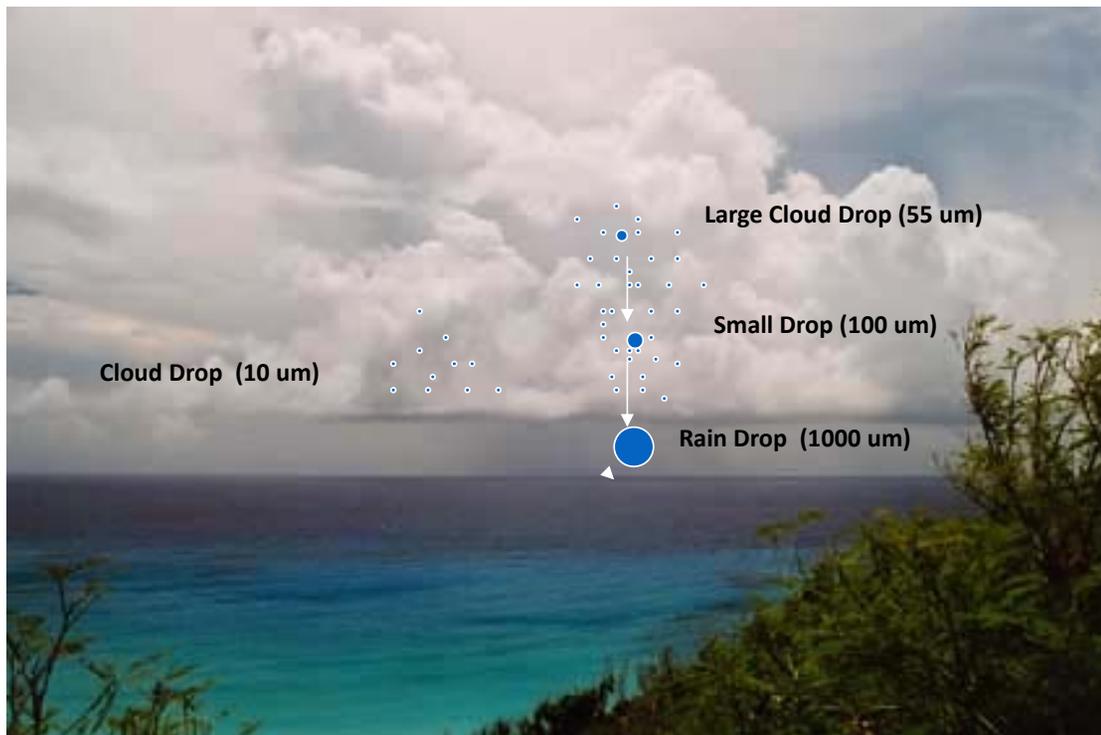
- Therefore, **water vapor will sublimate on the ice crystals**. Since the amount of water vapor in the air has decreased, and from the perspective of the supercooled water droplet, the air is subsaturated, the supercooled water will evaporate until the air once again reaches saturation.
- The process then continues. In short summary, **the ice crystal grows through sublimation at the expense of the supercooled water droplet**.

Precipitation in Warm Clouds

- In warm clouds there are no Ice Crystals so the Bergeron Process can't operate
- **Collision-Coalescence** a.k.a. Bump and Stick
- Need **one BIGGER** than average Cloud Drop
 - Really large aerosol (CCN) → Start Big.... End Big
 - Entrainment Mixing (evaporation and redistribution)
 - Turbulence (smashing together of droplets)



Collision-Coalescence

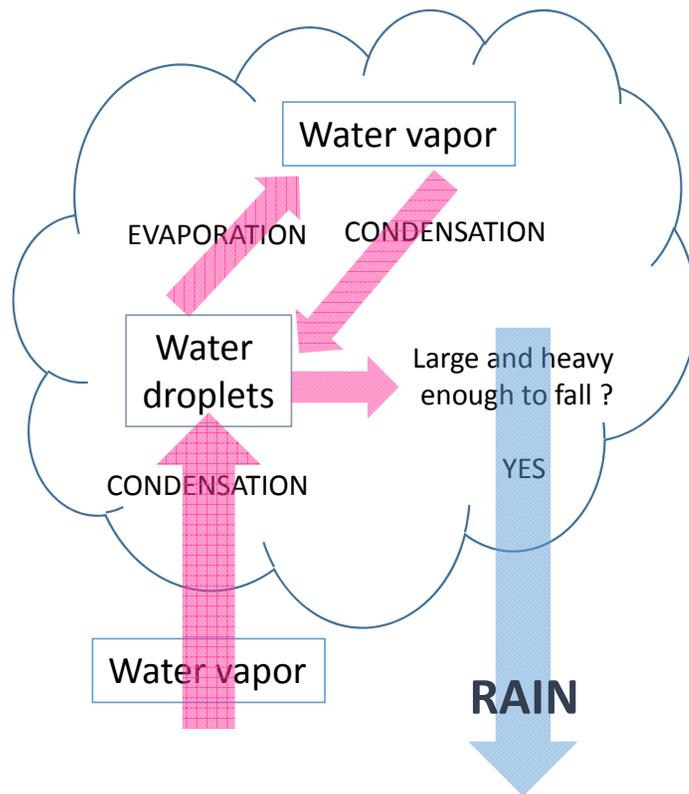


BIG drops fall FASTER than SMALL drops!!!!

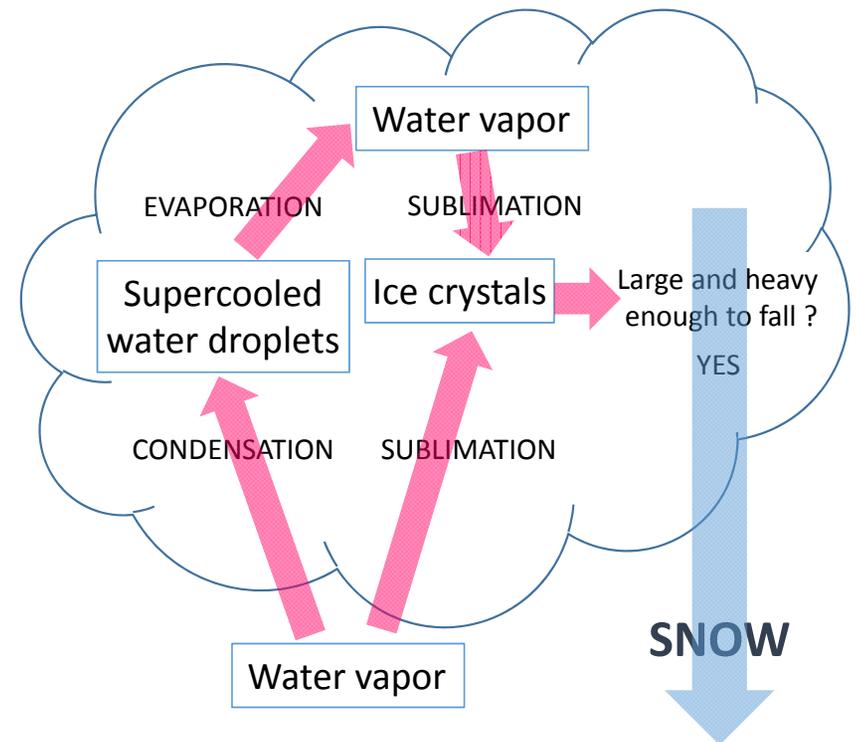
- **Terminal Velocity** matters
 - the highest velocity attainable by an object as it falls through the air.
- Sum of the **drag force** and **buoyancy** equals the downward force of **gravity**.
- If cloud drops were all the same size could they bump into each other?
 - **NO**

Precipitation Summary

Warm cloud



Cold cloud



Forms of Precipitation

- Here in Hawaii our dominant form of precipitation is RAIN due to our warm temperatures.
- Snow is seen on Big Island.
- Hail occurs here too.
- Sleet, Glaze and Rime do not.



• Snow – ice



• Sleet and Glaze – ice



• Rain – liquid



• Hail – Ice



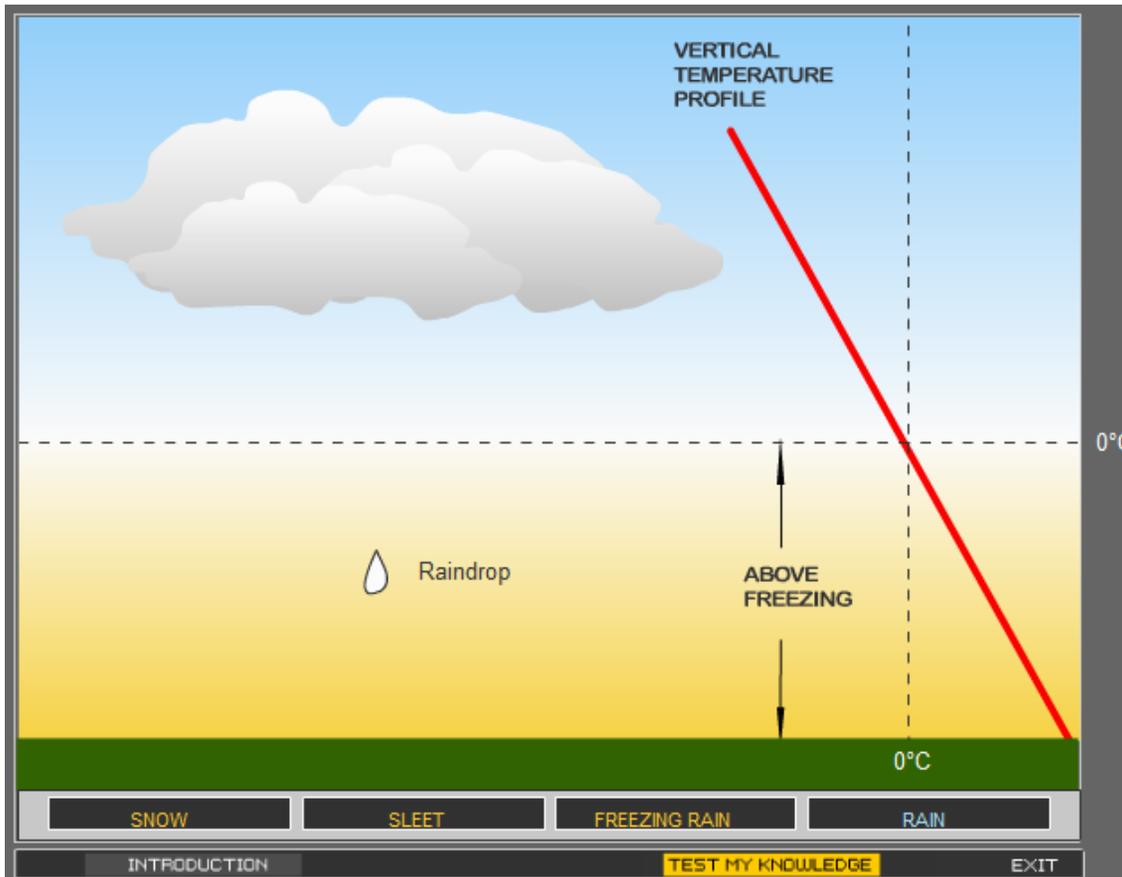
• Rime - ice

Rain

- Drops of water that fall from a cloud and have a diameter of **at least 0.5 millimeter**.
- Most rain starts as **SNOW** and **MELTS**
- Small drops are called **DRIZZLE** and **MIST**
- **Virga** – Rain that evaporates before reaching the surface.
- **Flooding** can be severe – **Flash Flood Warnings**



Atmospheric Profile for Rain



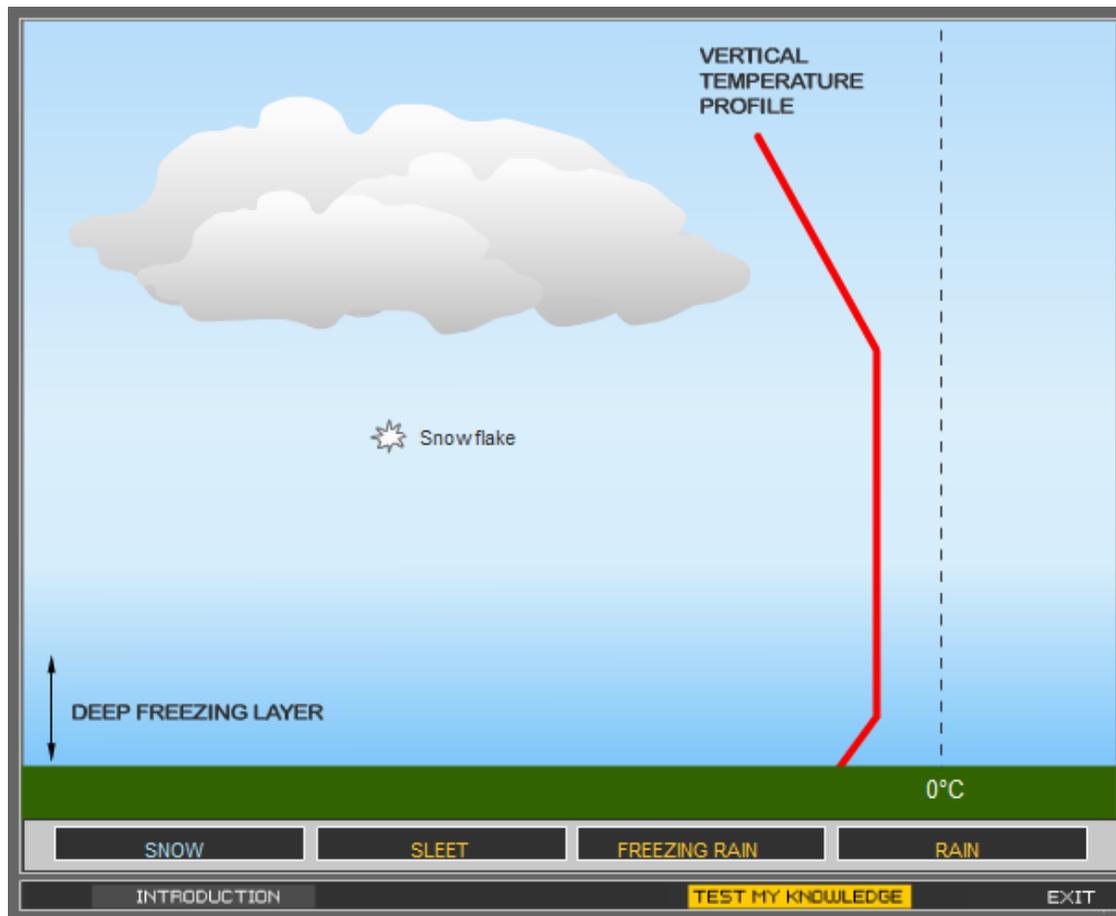
- Atmosphere is warm, **above freezing**, from the surface through to the cloud layer.
- Rain can start out as an **ice crystal** (Bergeron Process) or as a **large droplet** (Collision-Coalescence).
- Hits the surface as a **liquid**.

- Ice crystals and clumps of Ice crystals
- **Very Cold Conditions:**
Individual crystals make “light snow”
- **‘Warmer’ Cold Conditions:**
Crystals form clumps “wet snow”
- Mauna Kea and New Zealand are the main locations with snow in the Pacific Region

Snow



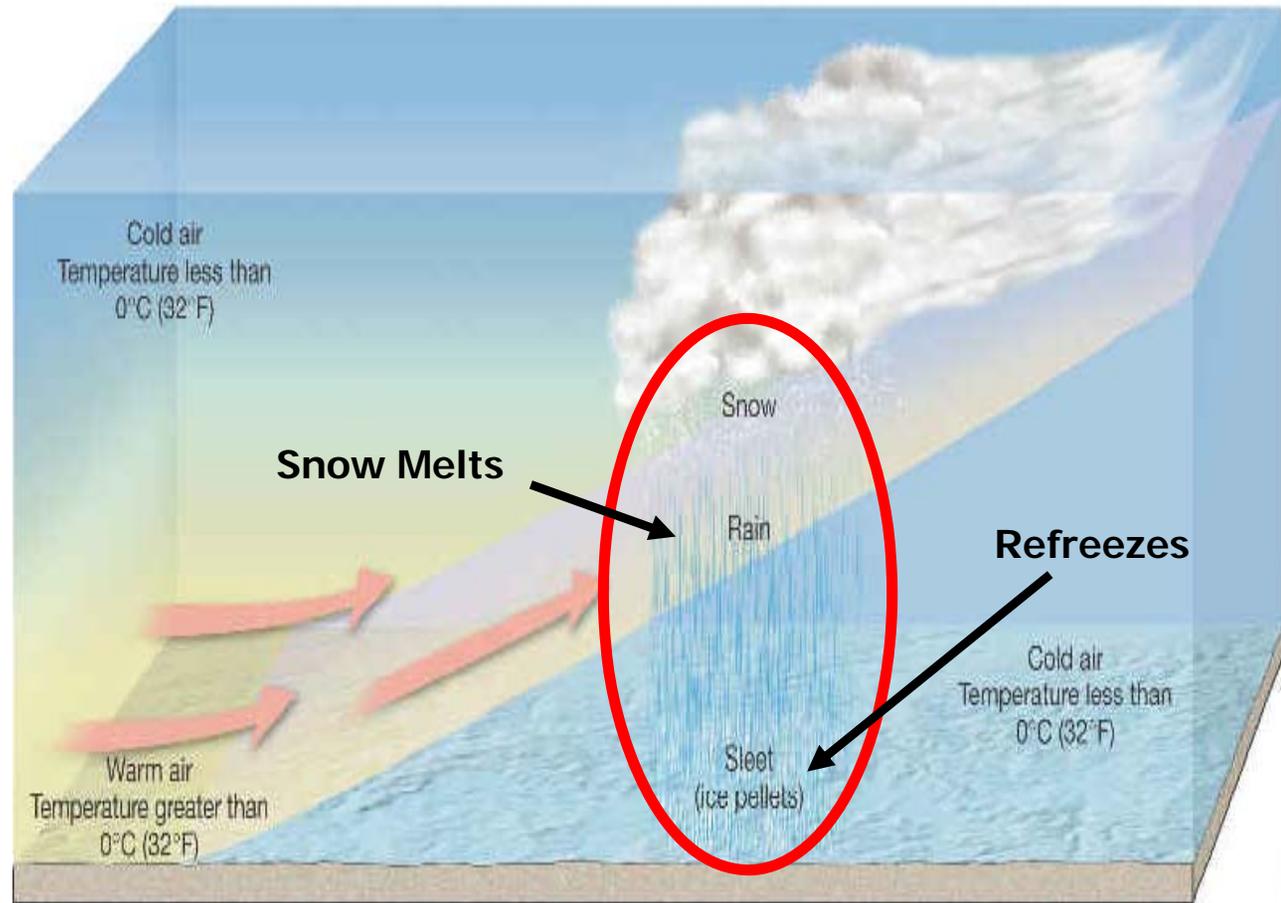
Atmospheric Profile for Snow



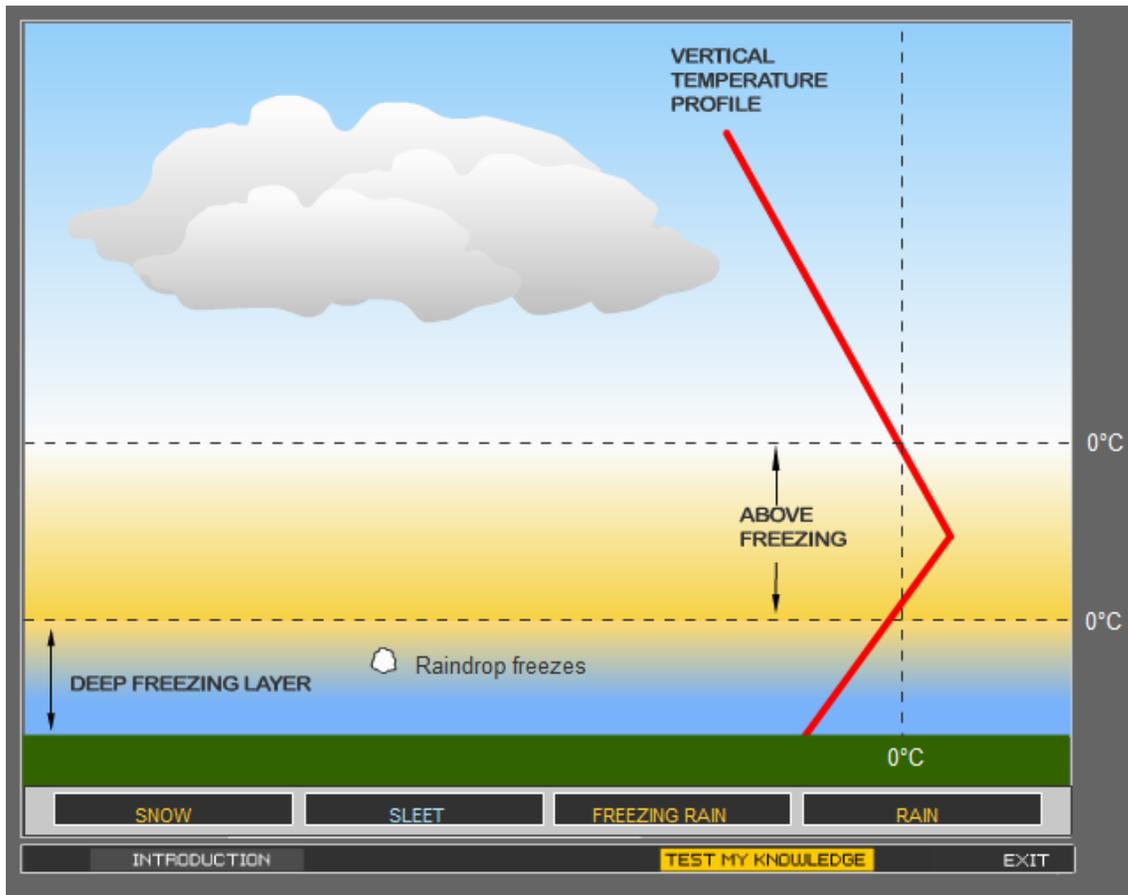
- Atmosphere is cold, **below freezing**, from the surface through to the cloud layer.
- Snow will start out as an **ice crystal** (Bergeron Process) with the crystals continuing to grow.
- Hits the surface as **solid ice crystals**.

Sleet

- Rain that freezes near the surface
- Wintertime phenomenon
- **Clear** to translucent pellets (**Ice Pellets**)



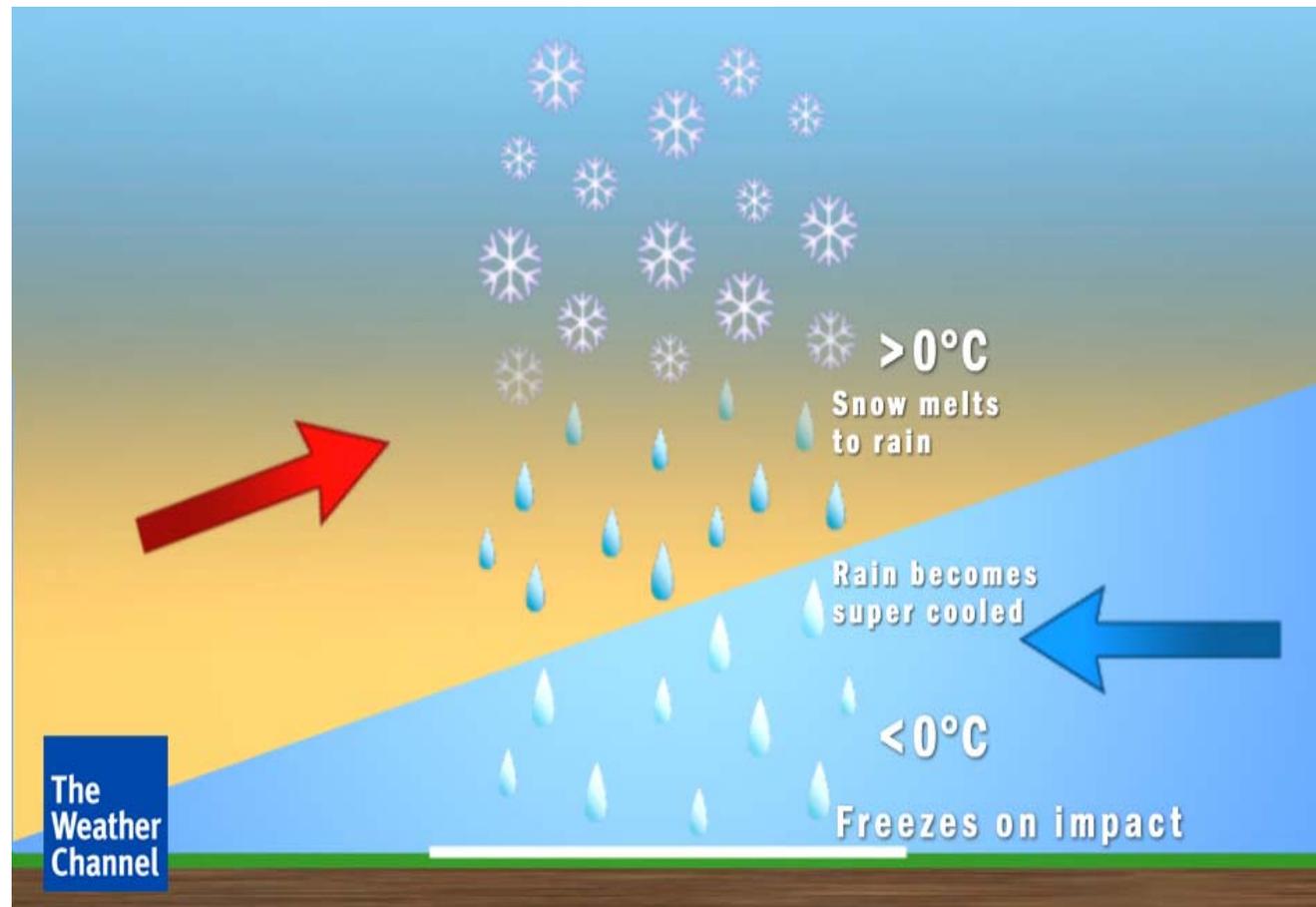
Atmospheric Profile for Sleet



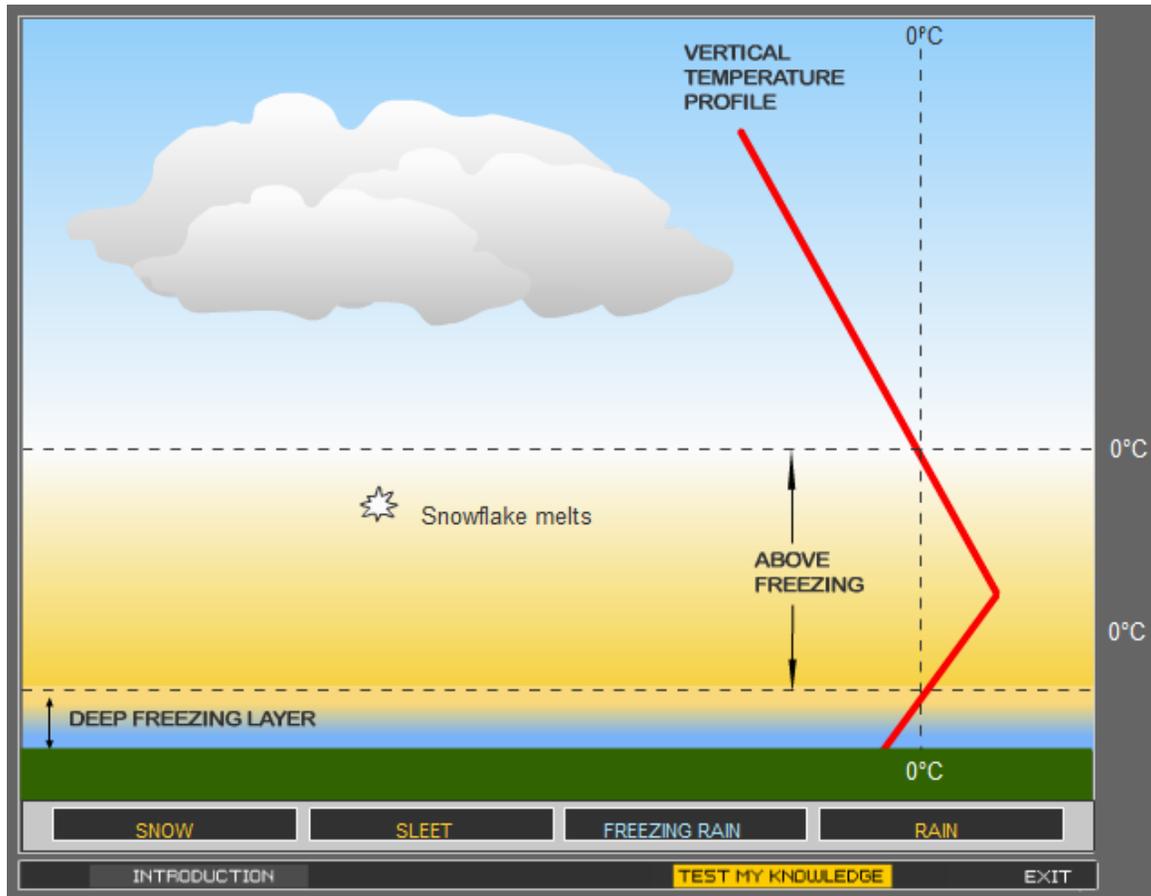
- Atmosphere is cold, **below freezing**, in the cloud layer and at the surface. However, in the case of sleet there is a layer in between that is **above freezing**.
- Snow will start out as an **ice crystal** (Bergeron Process) with the crystals continuing to grow.
- Melts in the warm, above freezing, layer.
- Precipitation transforms from snow → rain → ice pellet (sleet)
- Hits the surface as **solid ice pellets**.

Freezing Rain and Glaze

- Rain or drizzle that falls in liquid form and then **freezes upon striking a cold object or ground.**
- The coating of ice is called **Glaze.**

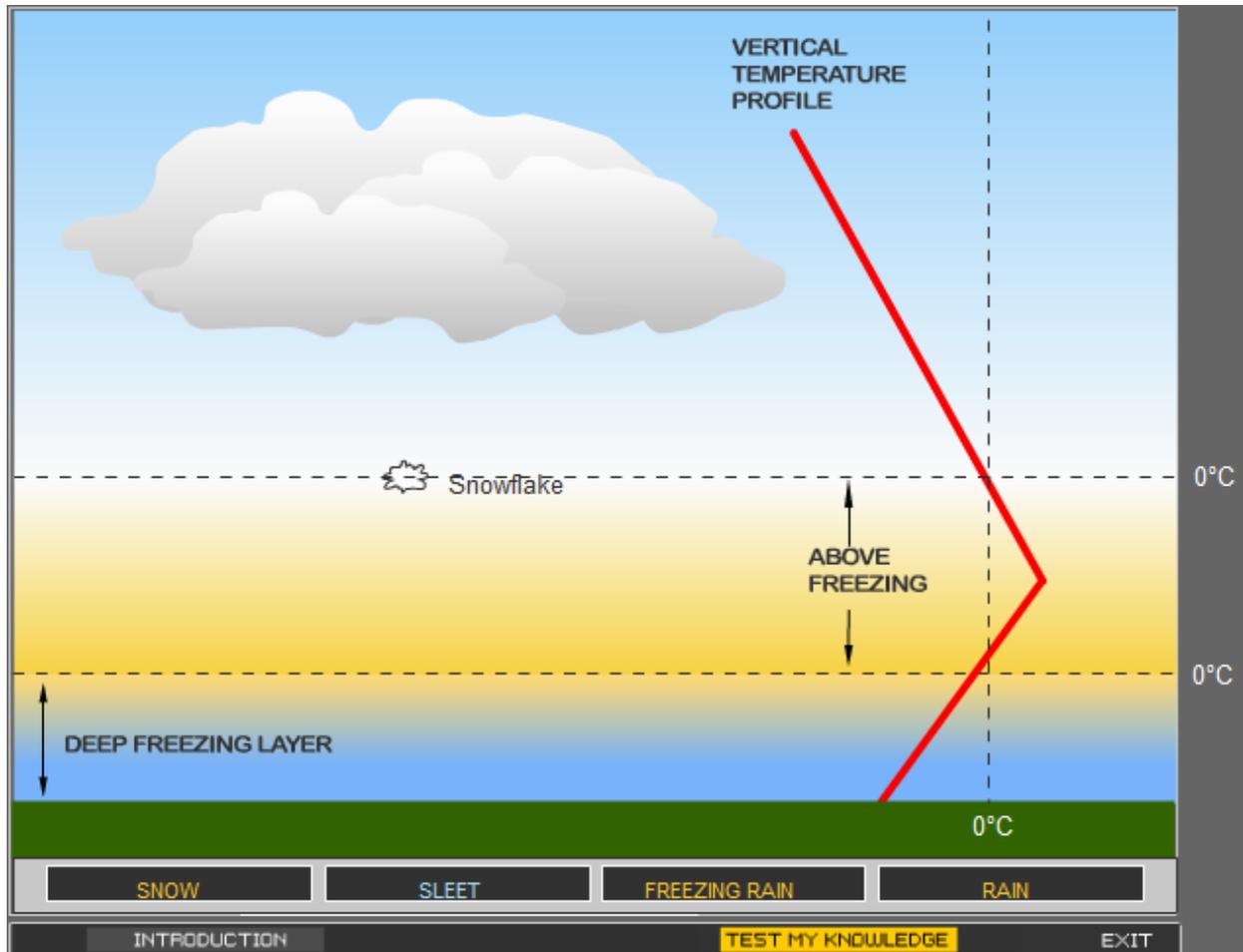


Profile for Freezing Rain



- Atmosphere is cold, **below freezing**, in the cloud. Then, above the surface there is a warm, **above freezing**, layer than melts the snow.
- Then, just at the surface there is a layer of **below freezing** air (just above the surface) that causes the rain drop to **freeze** on contact with the surface.

Interactive Images for Precipitation



- All of the previous diagrams are actually interactive images that you can access from the link below:
- http://apollo.lsc.vsc.edu/classes/met130/notes/chapter7/51_Sleet/A_51.swf

Hail

- Just for fun: The Hawaiian word for hail “*huahekili*” means “thunder fruit”
- Rounded **WHITISH** Pellets and Irregular lumps of ice
- Usually 1-5 cm
 - Can weigh up to a pound.
- Can be very destructive and damage cars, crops, and even kill people!



Hail Formation in Words

- Produced in a **Cumulonimbus** cloud
- **Grauple** or **large frozen rain drops** act as embryos
 - **ACCRETION:** They accumulate supercooled water, adding new layer
- Violent, **upsurging air currents** within the storm carry these embryos up through the cloud.
 - Low liquid water makes a white layer
 - Higher liquid water makes a clear layer
- When the updraft can **no longer keep it aloft** it falls to the surface.
- The more violent the storm the larger the hail can become.

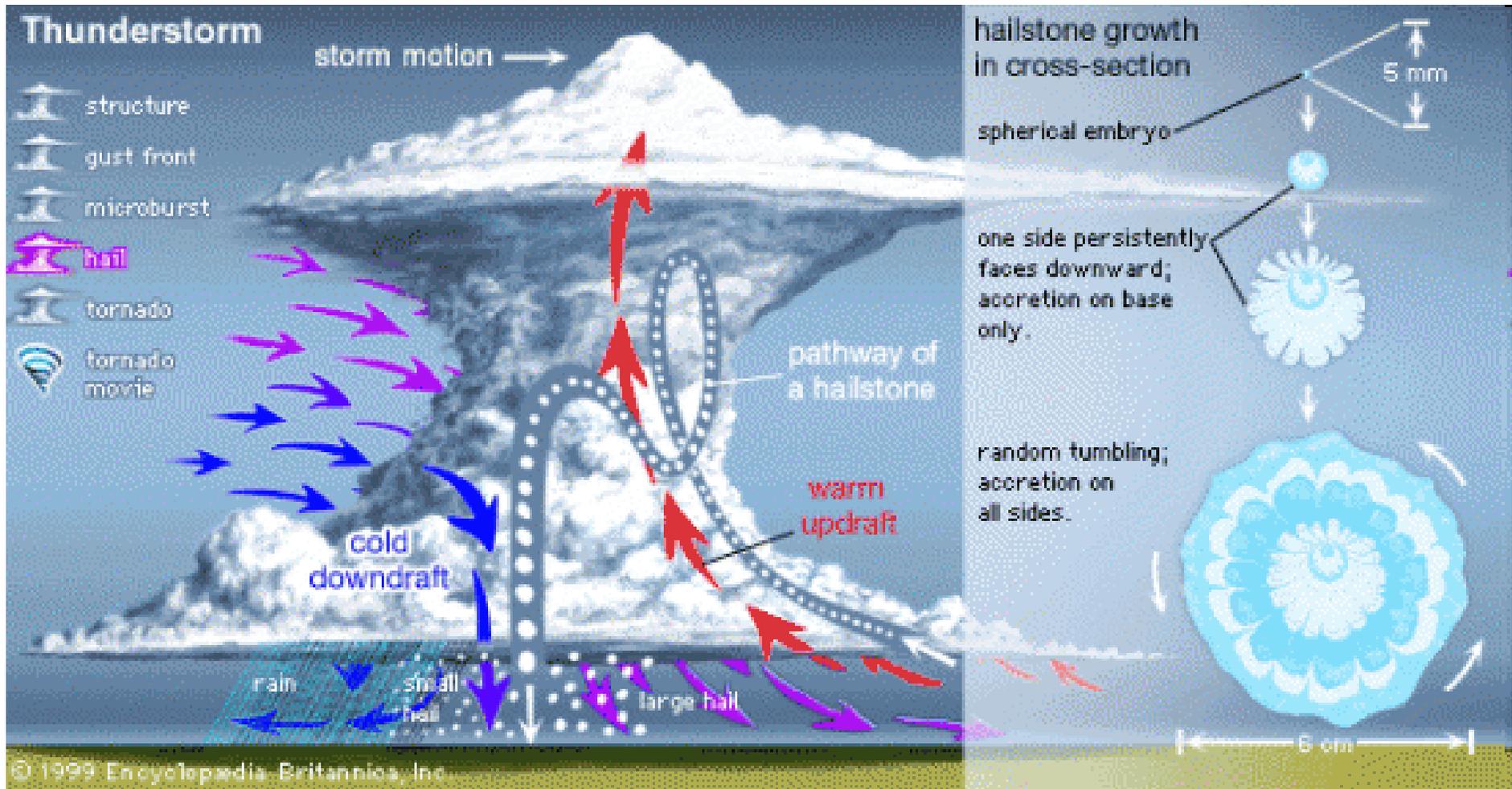


Record-setting hailstone from the Hawaii 'supercell' thunderstorm that hit the Hawaiian island of Oahu.

A final measurement of the [hailstone](#), which dropped from the skies on March 9, places it at 4.25 inches long, 2.25 inches tall and 2 inches wide (10.8 by 5.7 by 5 centimeters).

The previous record was only 1 inch in diameter. In fact penny-size (just under an inch) or quarter-size (1 inch in diameter) hailstones, have been reported just eight times in Hawaii.

Hail Formation Diagram



Baseball Sized Hail in Action

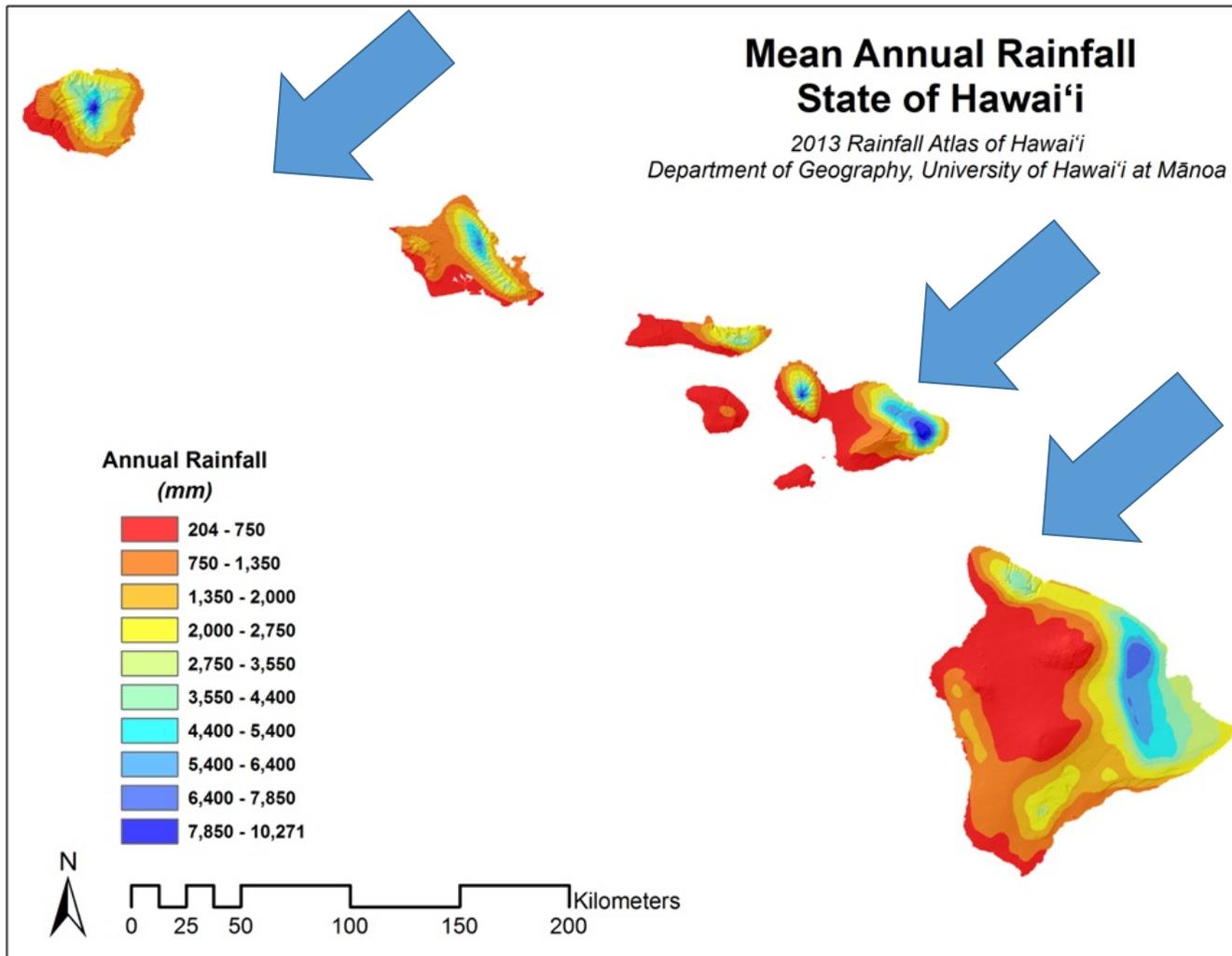


<https://www.youtube.com/watch?v=OFv2W7Duqiw>

Rime

- This is a deposit of **ice crystals**
- Formed by freezing of **supercooled fog** or cloud droplets **on objects whose surface is below freezing**

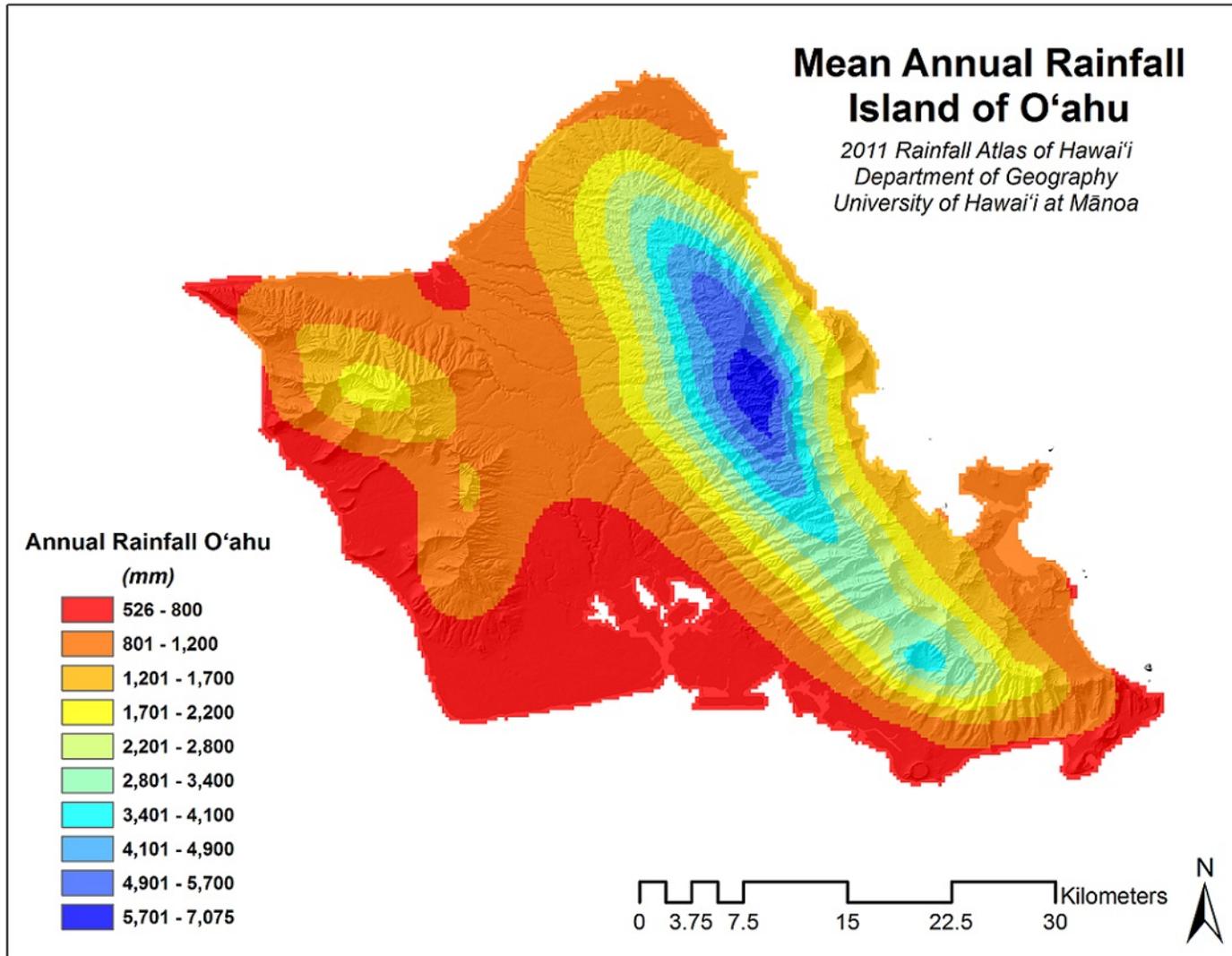




State of Hawai'i Precipitation

- Notice the increase in rain on the **windward** side of the islands?
- Notice the **rain shadows** on the **leeward** sides of the islands?
- **What direction does the prevailing wind come from?**

Oahu Precipitation



- **Orographic Lifting** is responsible for the increase in rain over the Ko'olaus and the Wai'anae.
- Honolulu is in the **rain shadow!**

Key Information 1

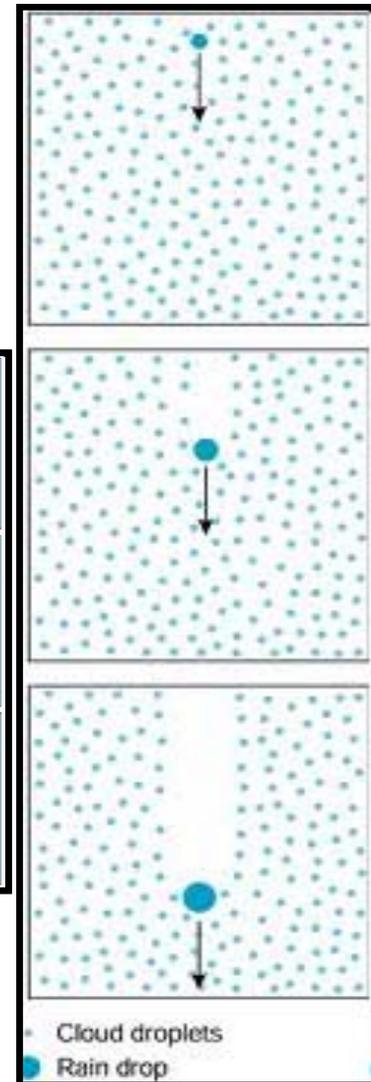
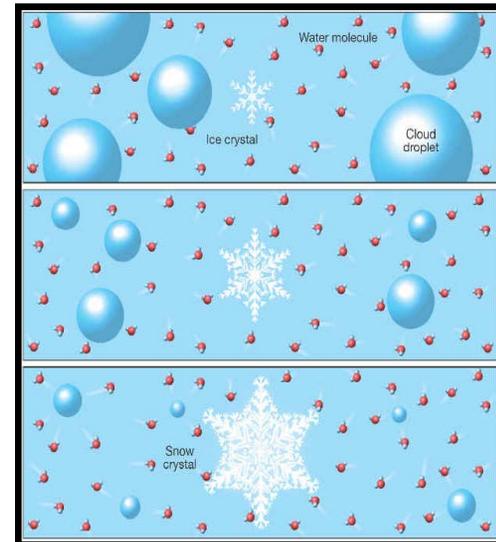
1. Be able to describe how precipitation forms in **COLD** and **WARM** Clouds.

• COLD Clouds –The Bergeron Process

- Presence of supercooled liquid water, ice crystals and water vapor
- Ice crystals grow at the expense of supercooled liquid drops
- Eventually the ice crystals will grow large enough to fall (and melt).

• WARM Clouds – Collision Coalescence

- Droplets (NO ICE) bump into each other and merge/stick together.
- Need one BIGGER than average Cloud Drop to start the process.
- Droplets grow large enough to fall as rain.



Key Information 2

2. Describe how **RAIN**, **SNOW**, **SLEET**, **GLAZE**, **RIME** form.

RAIN

- Atmosphere is above freezing, from the surface through to the layer below cloud. Rain can start out as liquid or ice. Hits the surface as a liquid.

SNOW

- Atmosphere is below freezing, from surface through to cloud layer. Starts as ice and continues to grow. Hits the surface as solid ice crystals.

SLEET

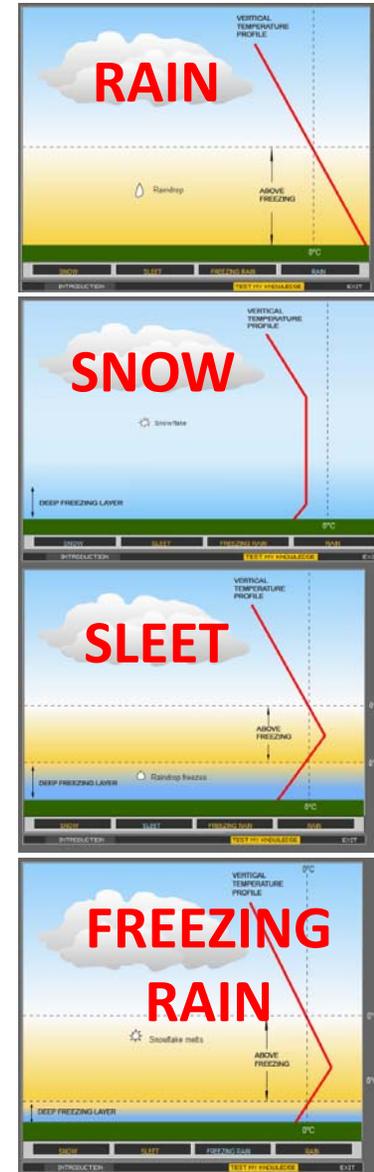
- Atmosphere is freezing → not freezing → freezing. However, in the case of sleet there is a layer in between that is above freezing. Precipitation transforms from snow → rain → ice pellet (sleet).

FREEZING RAIN

- Rain or drizzle that falls in liquid form and then freezes upon striking a cold object or ground. The coating of ice is called Glaze.

RIME

- This is a deposit of ice crystals. Formed by freezing of supercooled fog or cloud droplets on objects whose surface is below freezing



Key Information 3

3. Be able to describe how **HAIL** Forms.

- Produced in a Cumulonimbus cloud
- Grauple or large frozen rain drops act as embryos
- Violent, upsurging air currents within the storm carry these embryos up through the cloud.
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