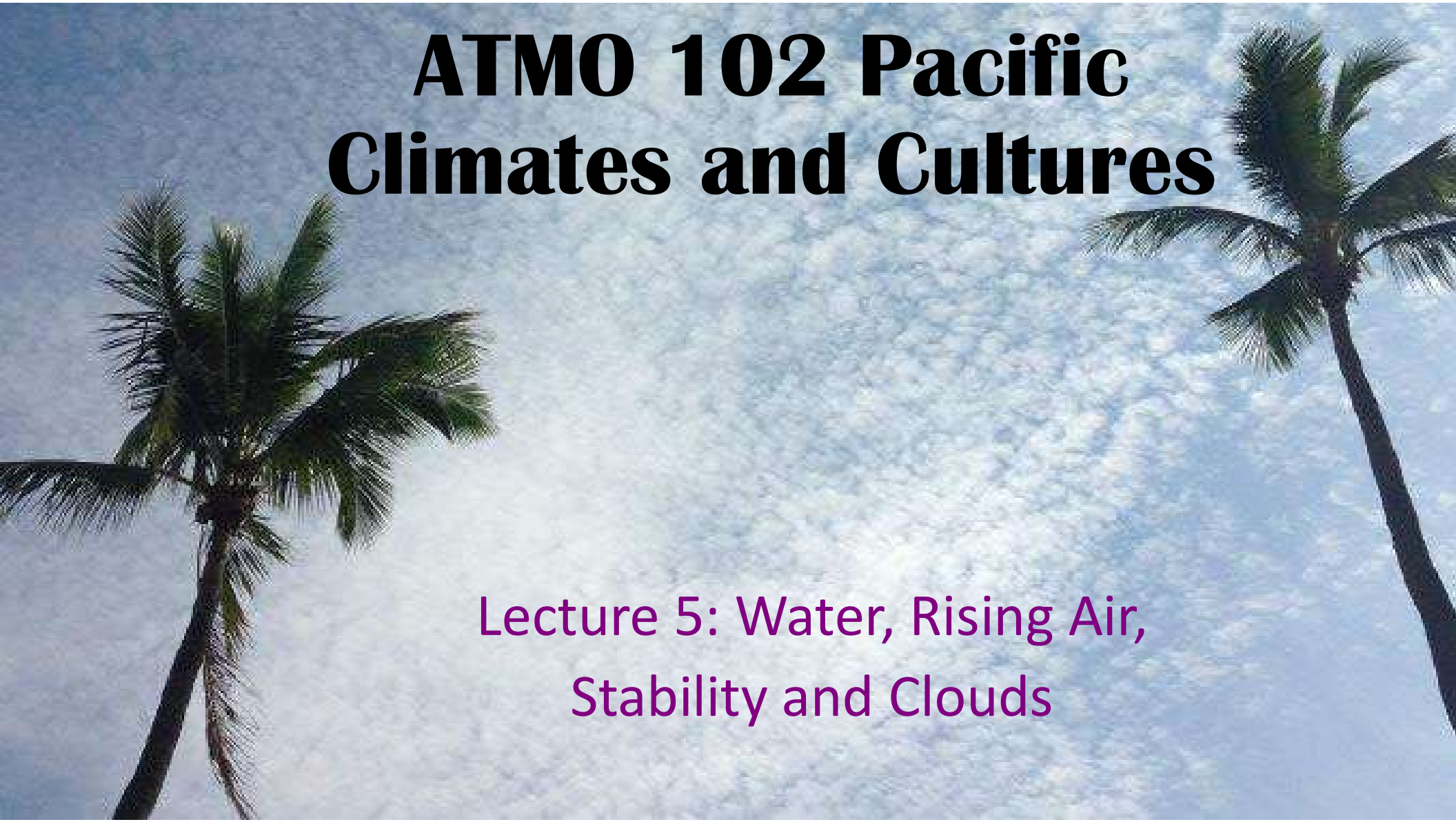
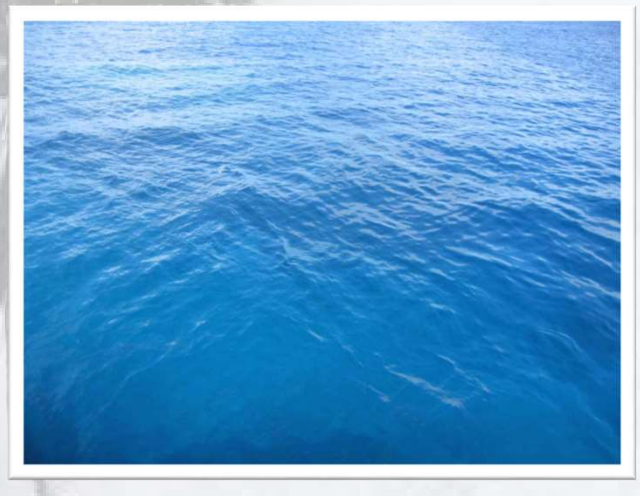


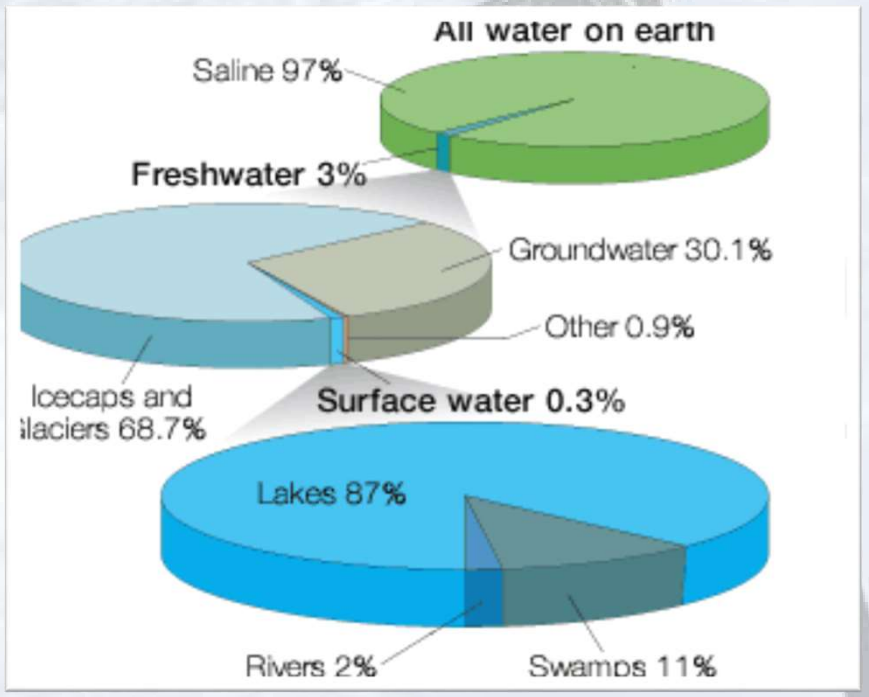
ATMO 102 Pacific Climates and Cultures

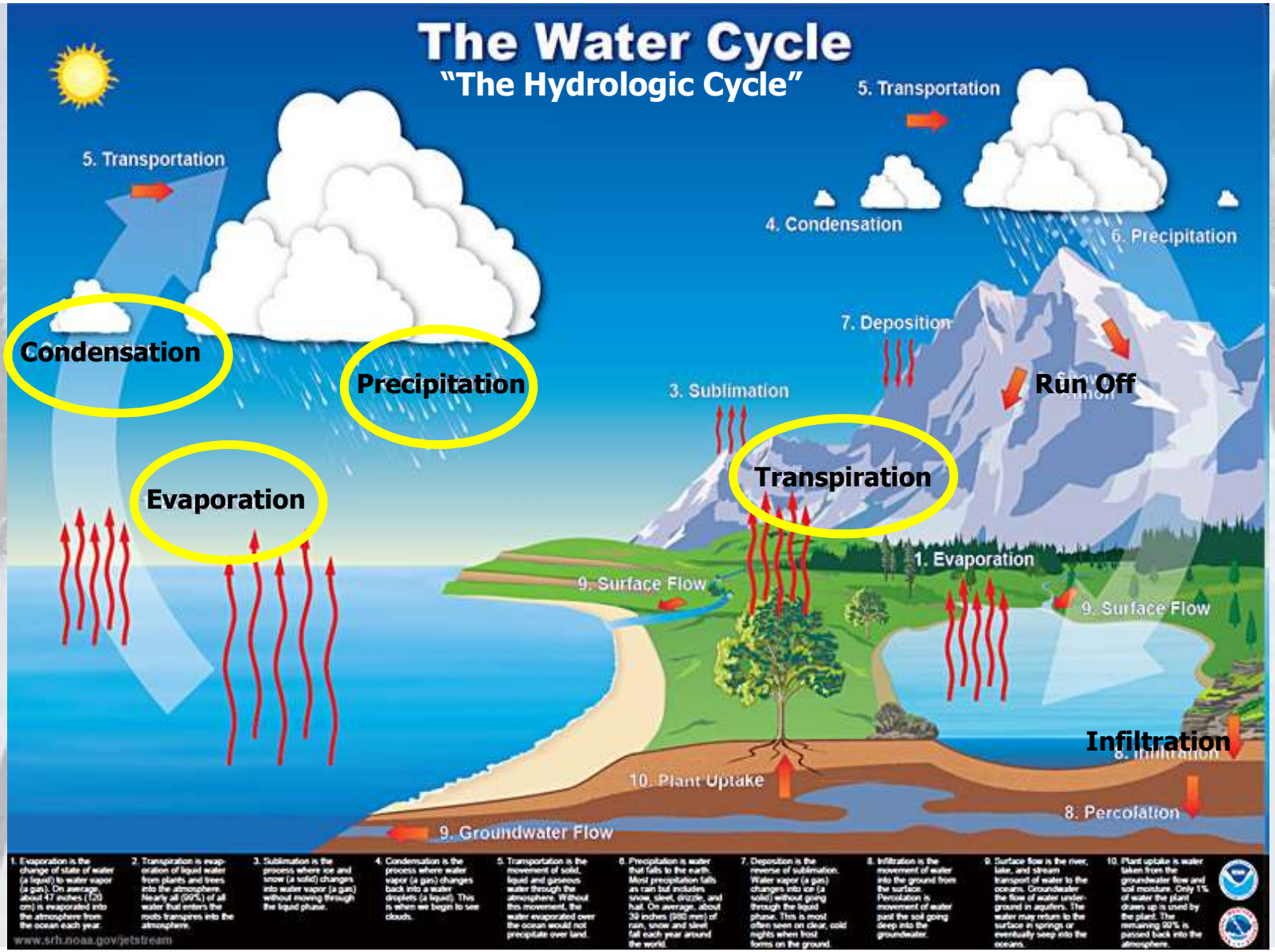
Lecture 5: Water, Rising Air, Stability and Clouds

Water, water, everywhere, but not a drop to drink….

- **Oceans account for most of water (>97%)**
  - Not readily useable by humans or plants
- **Ice sheets in Antarctica and Greenland (~3%)**
- **Atmosphere has only a little (0.001%)**

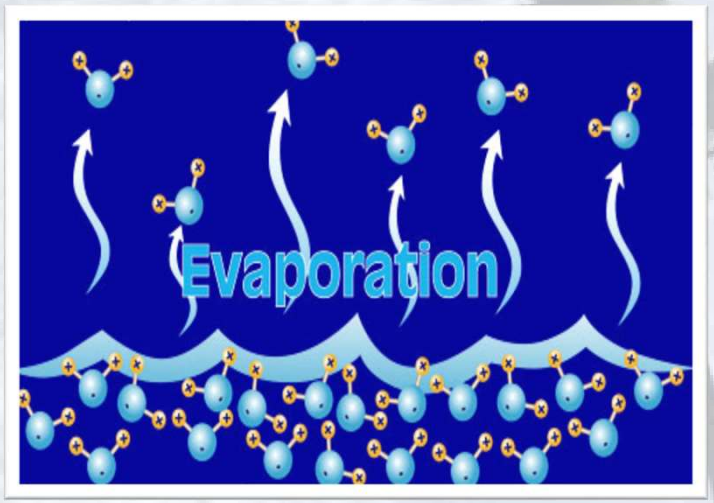





The Water Cycle
"The Hydrologic Cycle"
5. Transportation
4. Condensation
6. Precipitation
7. Deposition
Run Off
3. Sublimation
Condensation
Precipitation
Transpiration
Evaporation
1. Evaporation
9. Surface Flow
9. Surface Flow
Infiltration
10. Plant Uptake
8. Percolation
9. Groundwater Flow
www.srh.noaa.gov/jetstream

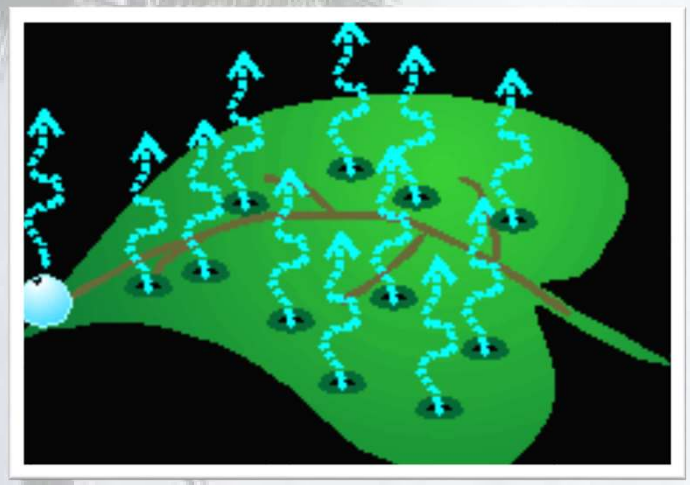
Processes Involving Water in the Atmosphere

- **Evaporation – Requires Energy**
  - The process by which a liquid is transformed into a gas
  - Powered by the Sun!
  - Solar Radiation heat up the water molecules until they are "freed" from the liquid state
  - Heat is absorbed during evaporation



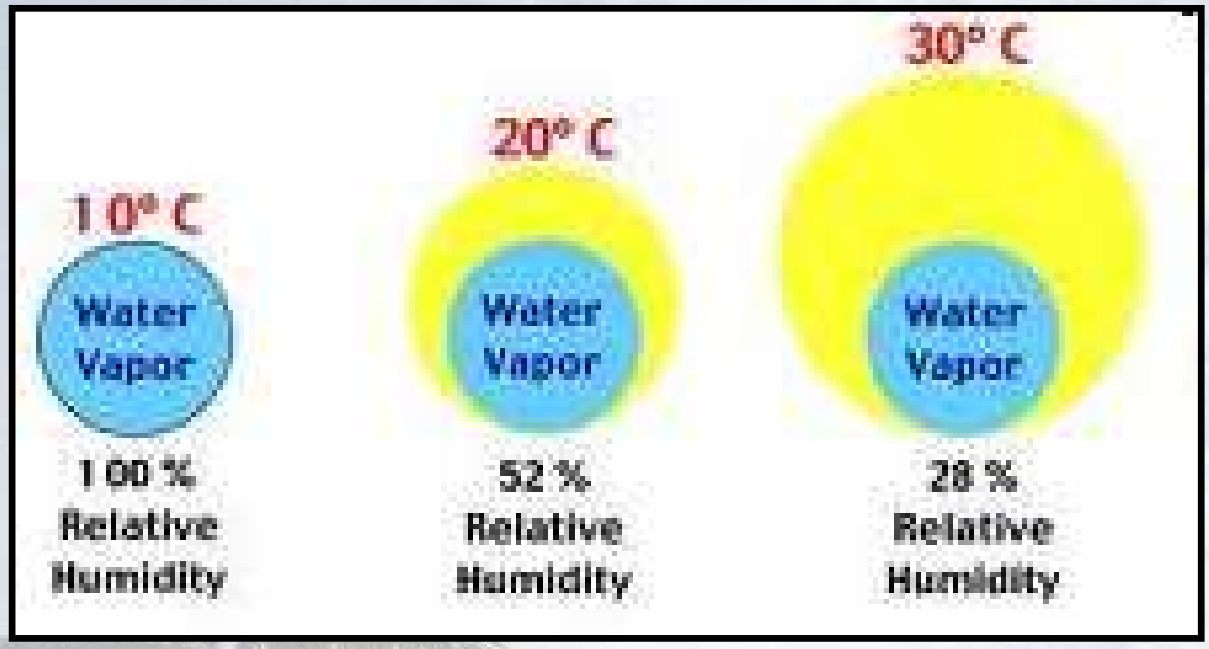
- **Condensation – Releases Energy**
  - The change from a gas to a liquid
  - Responsible for the formation of clouds
  - **Heat is released during condensation**

Processes Involving Water in the Atmosphere



- **Precipitation – Over Land & Oceans**
  - Falling liquid or solid in the atmosphere.
  - Returned the water to the ocean or soaks into the ground
  - Balances Evaporation
    - **Average annual precipitation equals evaporation.**

- **Transpiration**
  - The release of water vapor to the atmosphere by plants
  - Plants uptake water through their roots that fell as precipitation
  - Not as important as evaporation

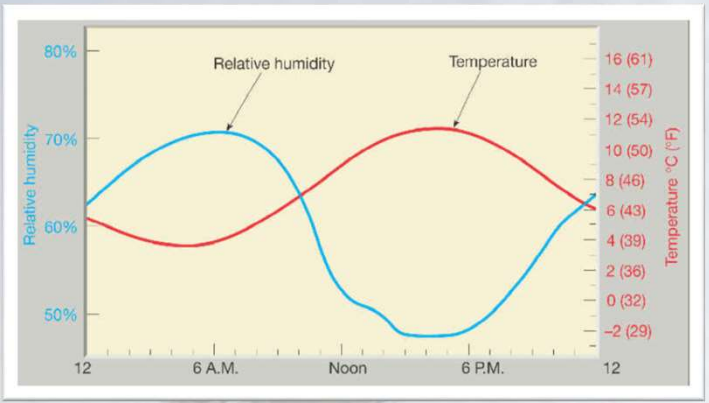


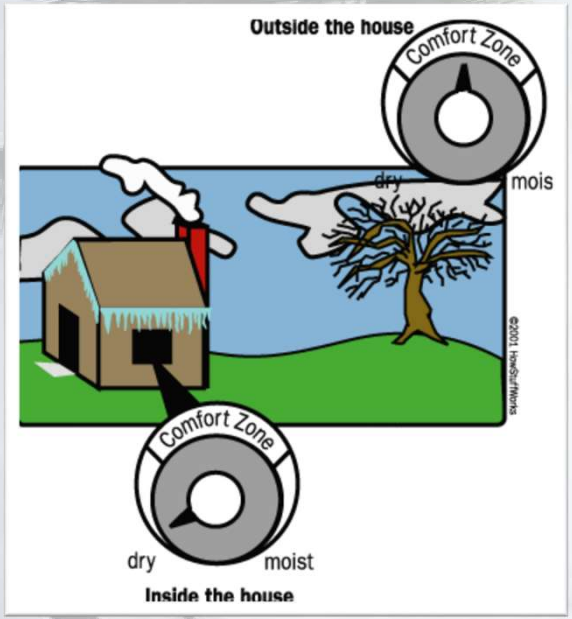
Relative Humidity

- The ratio of the air's **actual water vapor content** compared with the **amount of water vapor required for saturation** at that **temperature** and **pressure**

$$\text{Relative Humidity} = \frac{\text{Water vapor content}}{\text{Water vapor capacity}} \text{ X 100 percent}$$

Natural Changes in Humidity

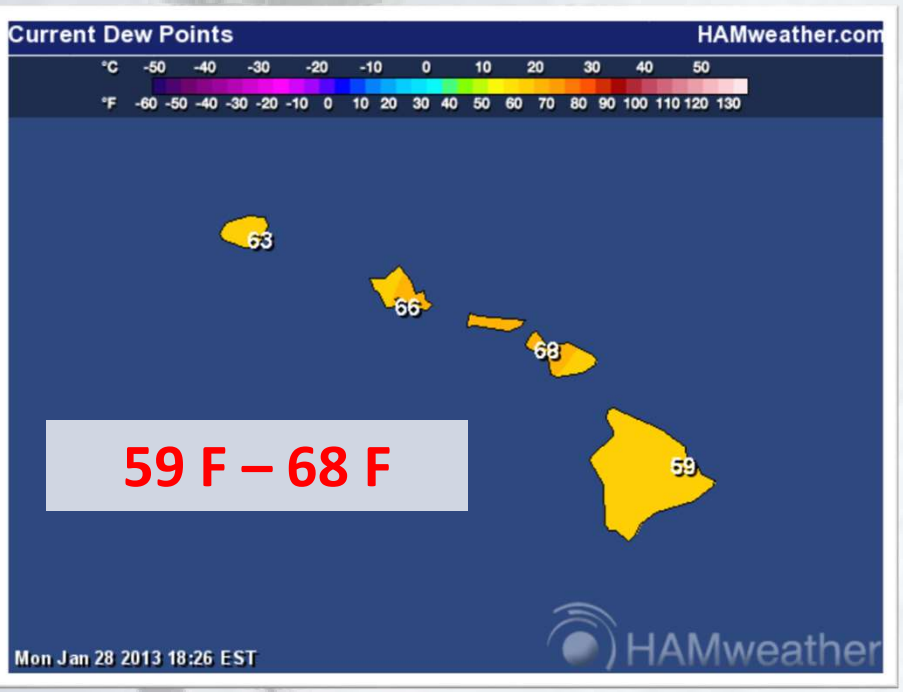




1. Daily changes in temperatures (daylight verses nighttime temperatures)

2. Temperature changes that result as air moves **horizontally** from one location to another

3. Temperature changes caused as air moves **vertically** in the atmosphere

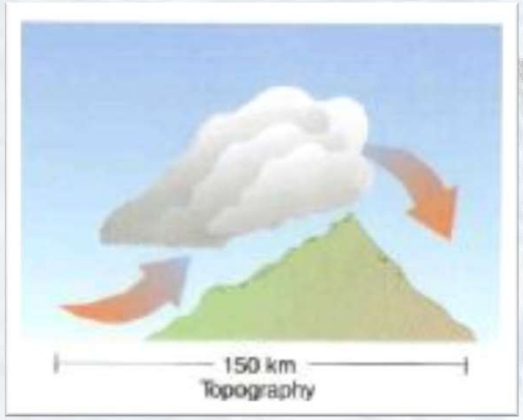


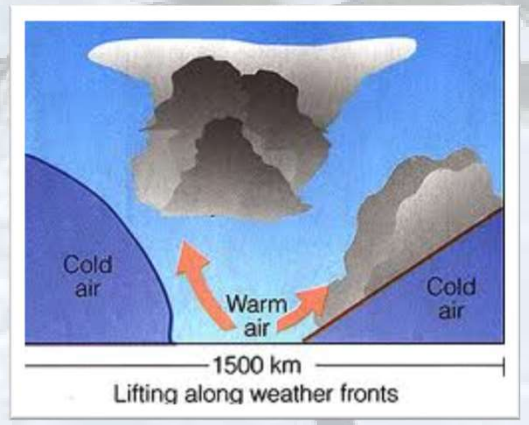
Dew Point Temperature

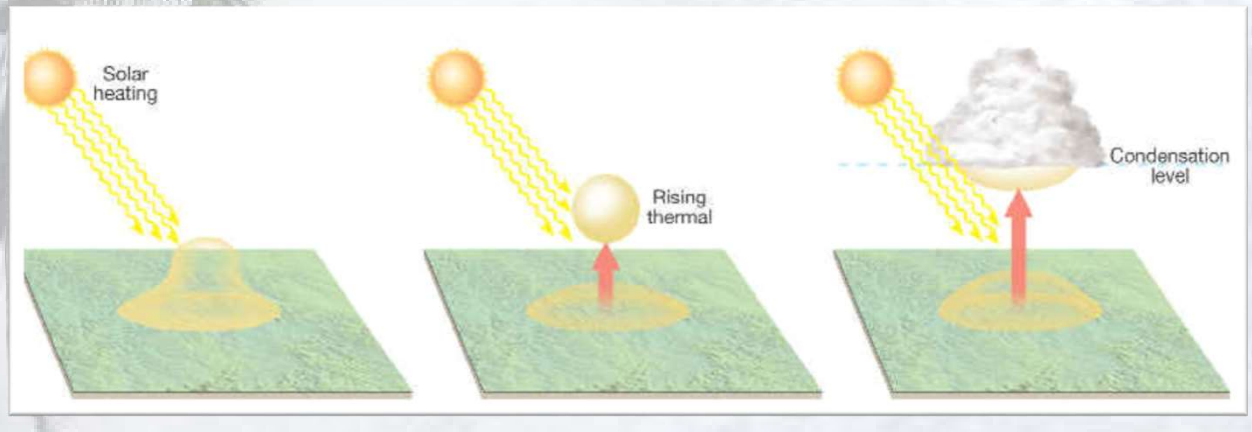
- The **temperature** at which air needs to be **cooled** to reach **saturation**
- It is a measure of the **actual moisture content** of a parcel of air.
- The term **dew point** stems from the fact that during the night objects at the surface often cool below the dew-point are a coated with dew.
- When the dew point exceeds **~65F** it is considered humid by most people
- A dew point above **75F** is considered unbearable.

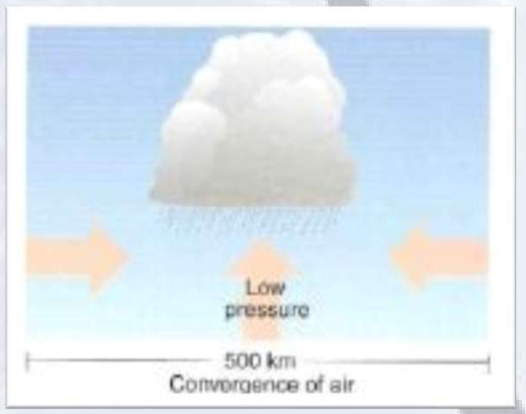
Processes that Lift Air

1. Orographic Lifting
2. Frontal Wedging
3. Convergence
4. Localized Convective Lifting (differential heating)

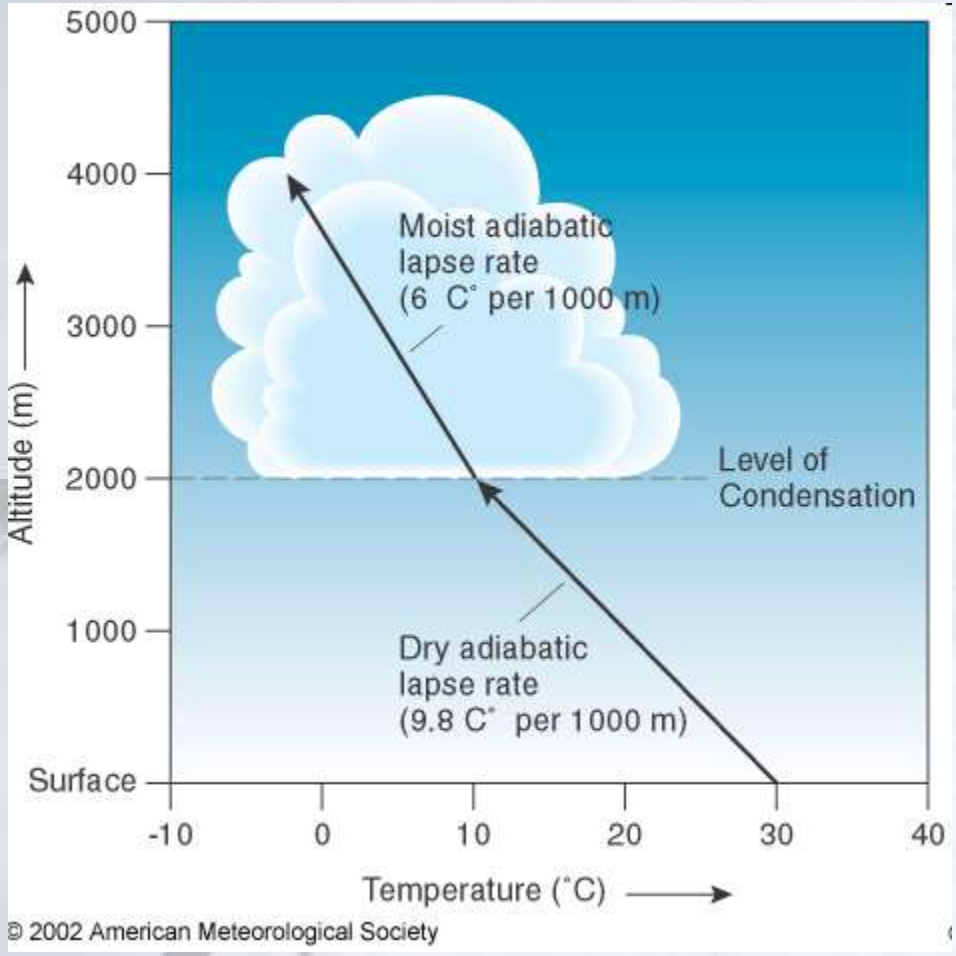




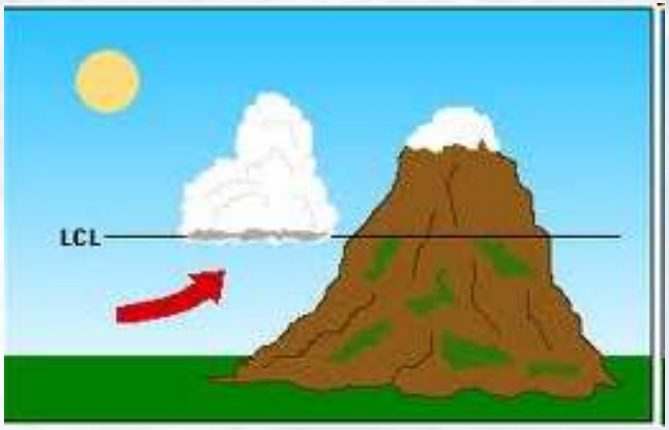




Lifted Condensation Level (LCL)

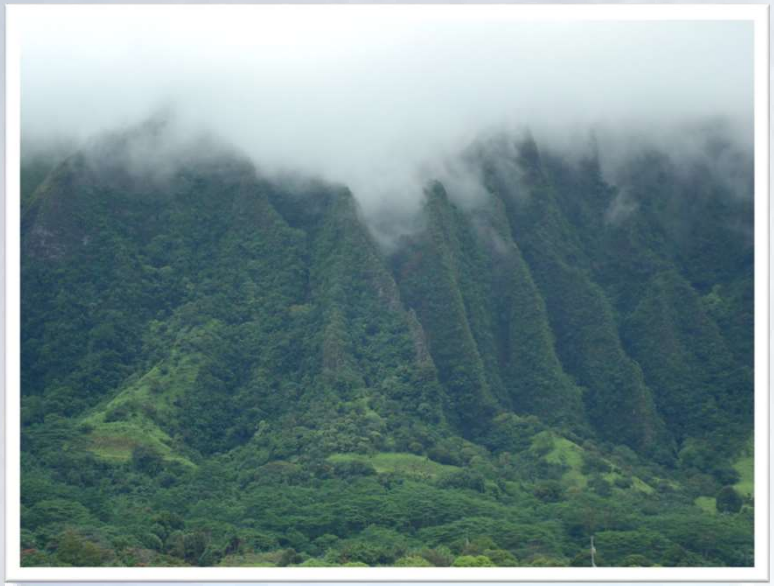


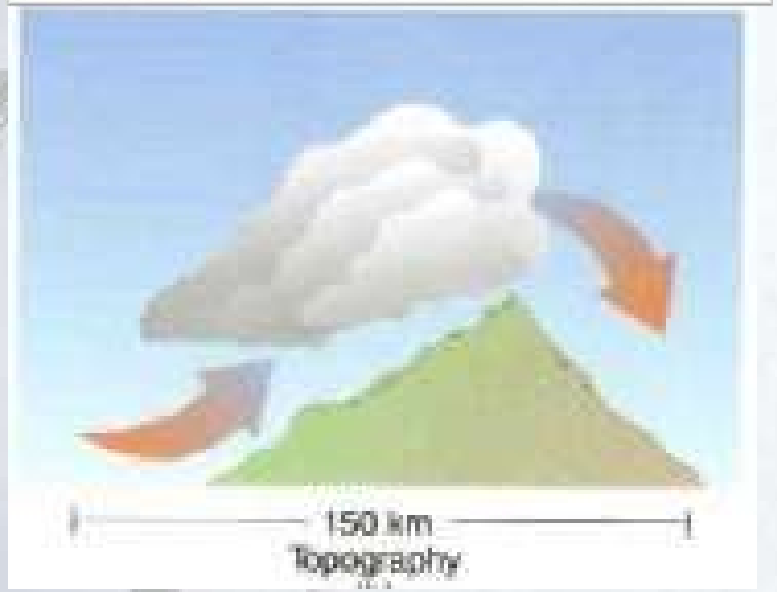
- The height at which rising air that is cooling at the dry adiabatic rate becomes saturated and **condensation** begins.



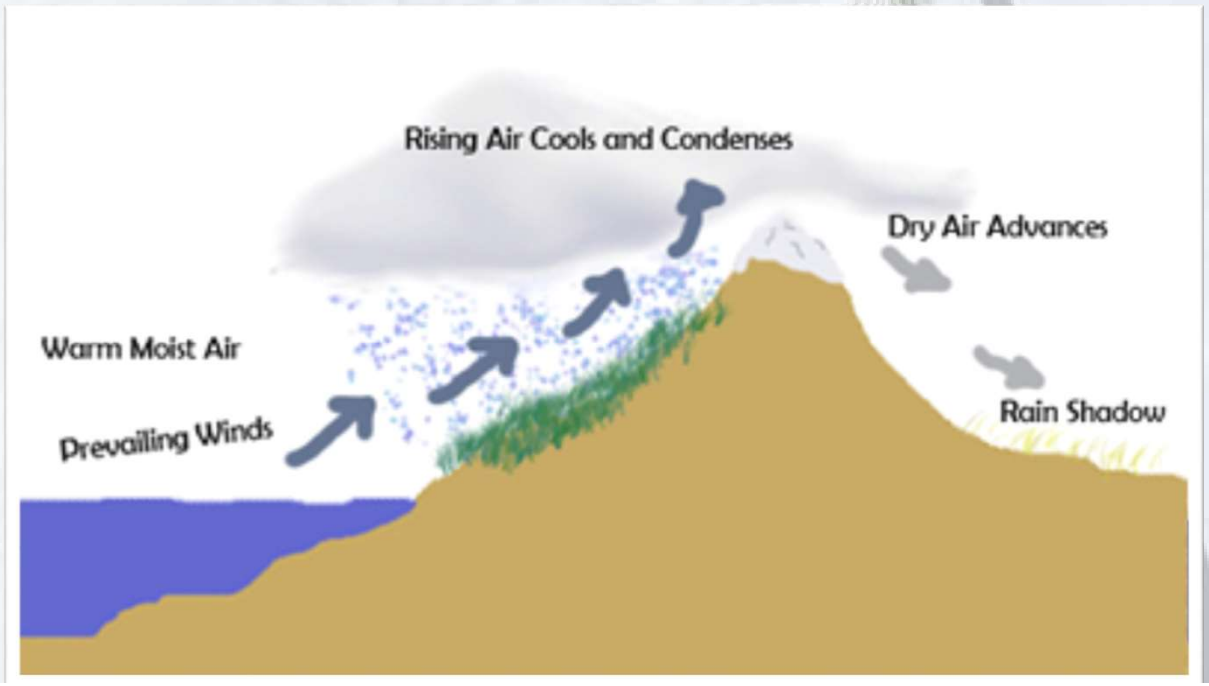
Why most clouds have FLAT bottoms!!!

Orographic Lifting



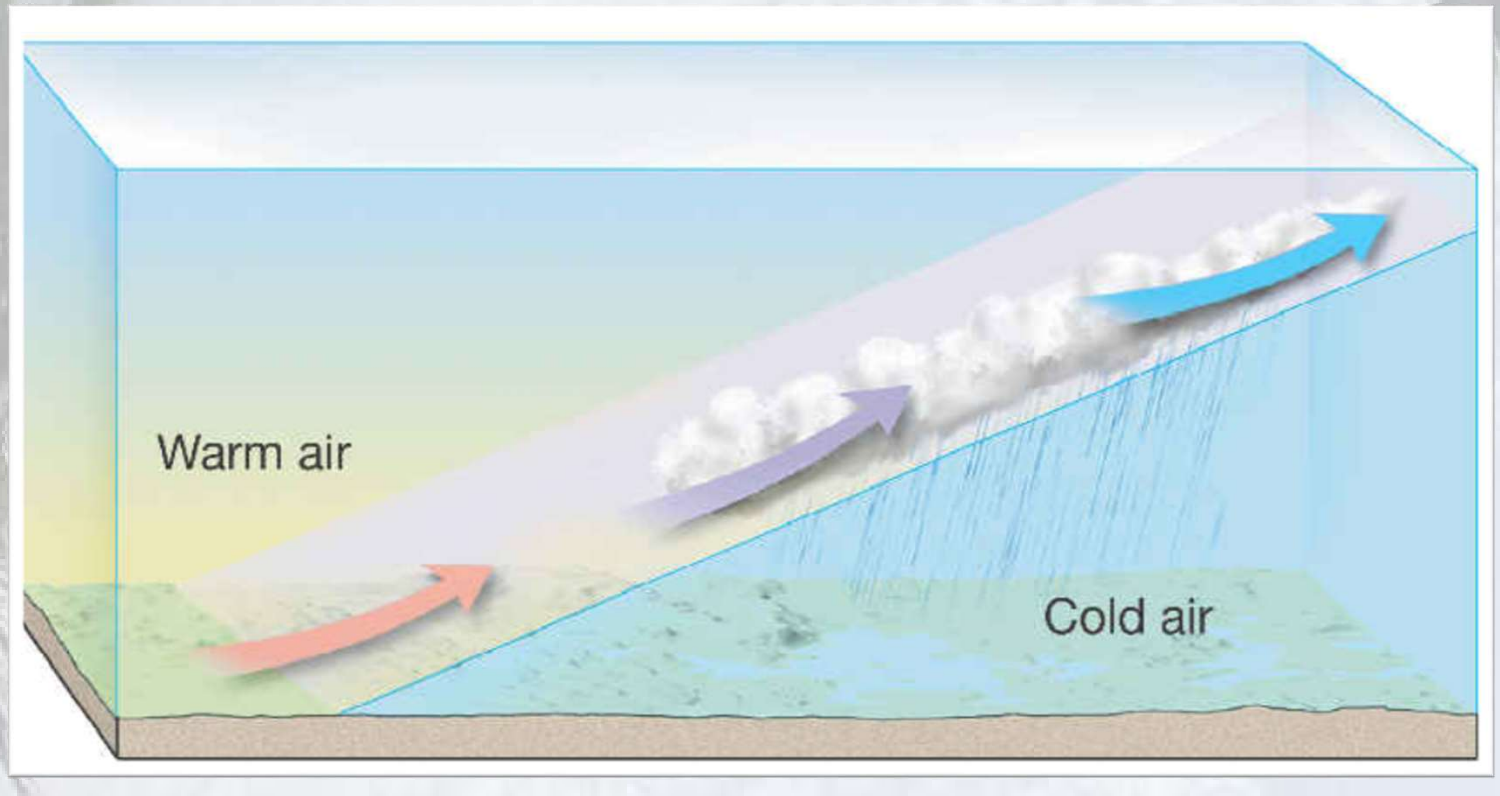


- Air is **forced to rise over** a mountainous or topographic barrier
- Rain shadow desert



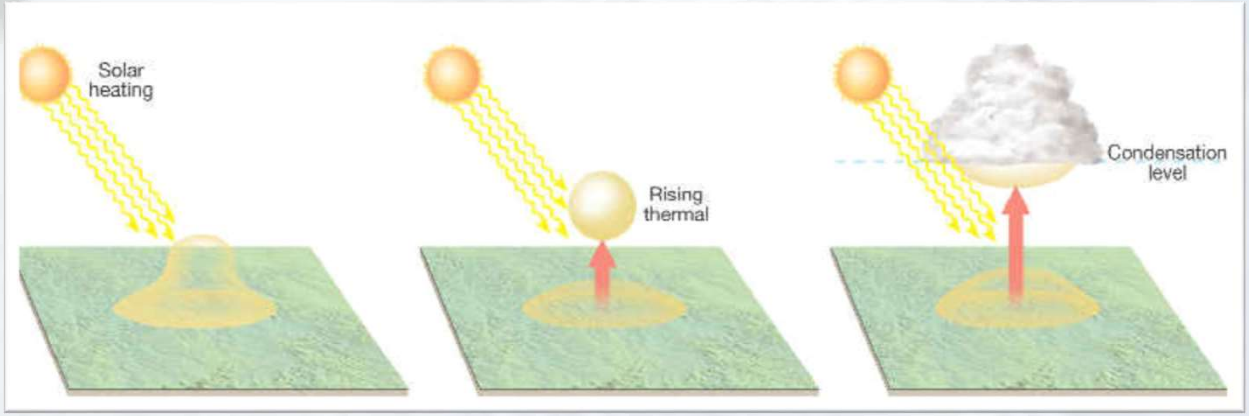
Frontal Wedging

- Warmer, **less dense air**, is forced over cooler, denser air
- **Front** – when warm and cold air collide



Localized Convective Lifting

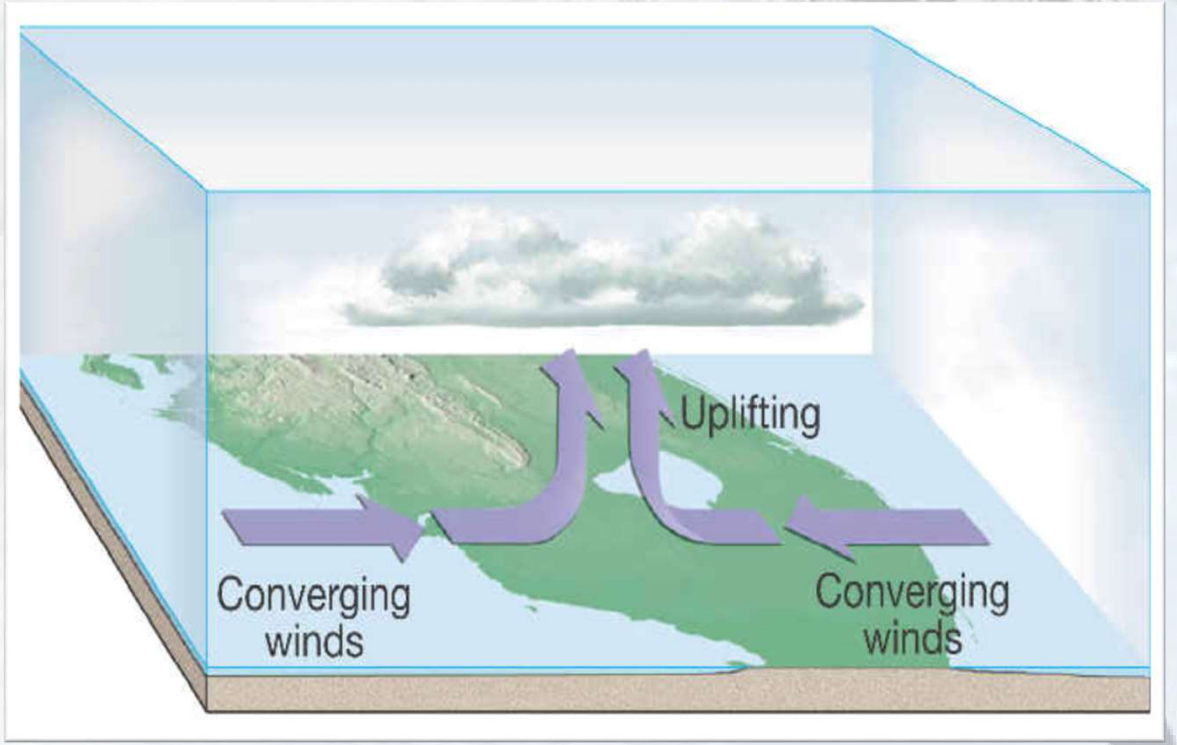
- **Unequal heating** of Earth's surface causes pockets of air to be warmed more than the surrounding air.
- Buoyant parcels (**thermals**) of hot air rise.
- After reaching the **LCL** they form clouds.

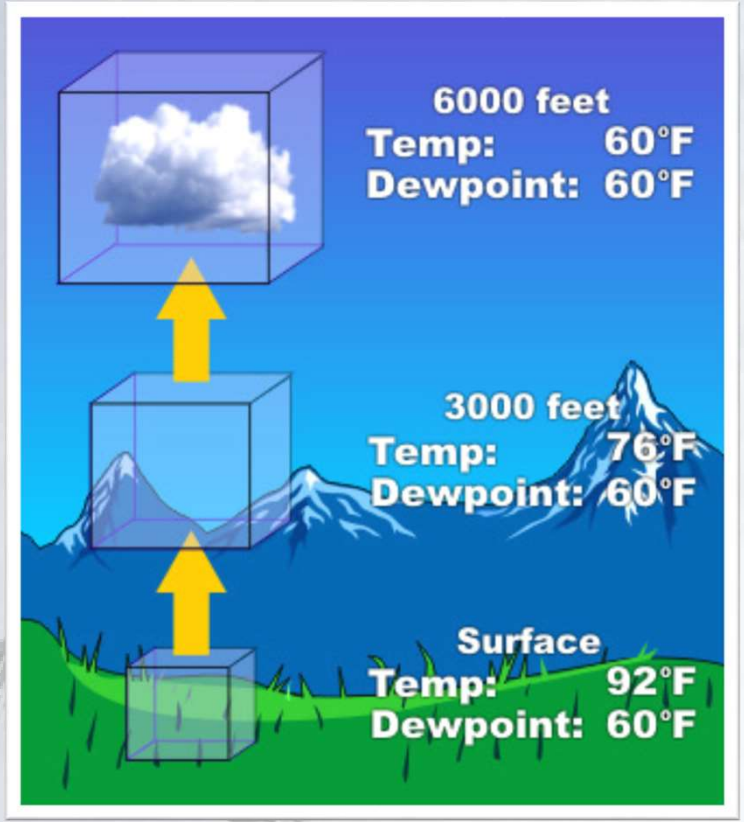


Convergence

- When air flows in from **more than one direction** (not a front) can collides
  - It cannot go down.
  - It goes up.

- Often happens over islands and other regions where two bodies of water are located closely together





Air Parcels… What are they?

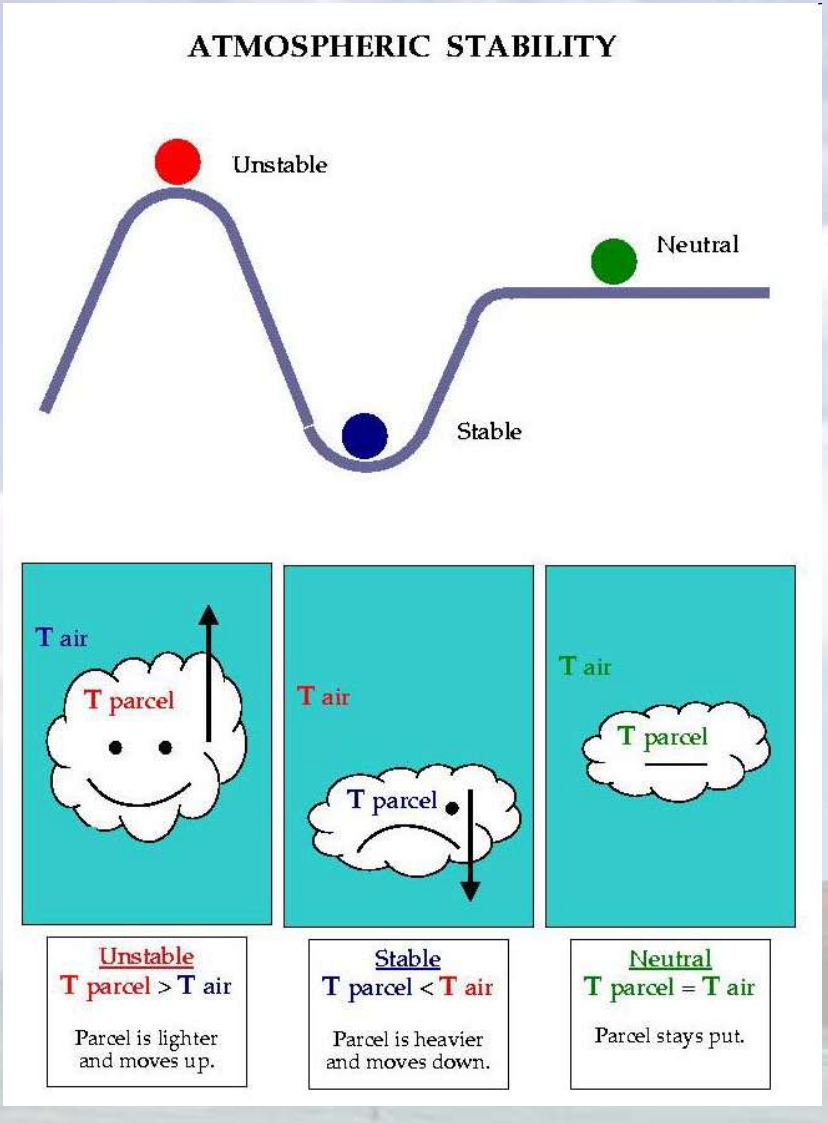
- **A Parcel is an imaginary volume of air**
  - Typically a few hundred cubic meters in volume
  - Acts independently of the surrounding air
  - It is assumed that no heat is transferred into, or out of it
  - **HIGHLY IDEALIZED**
- **We use them to talk about the likelihood that air will rise up or sink down.**
  - We need to know this if we want to predict if clouds will form.

When air is allowed to **expand**, it **COOLS**.

When air is **compressed**, it **WARMS**.

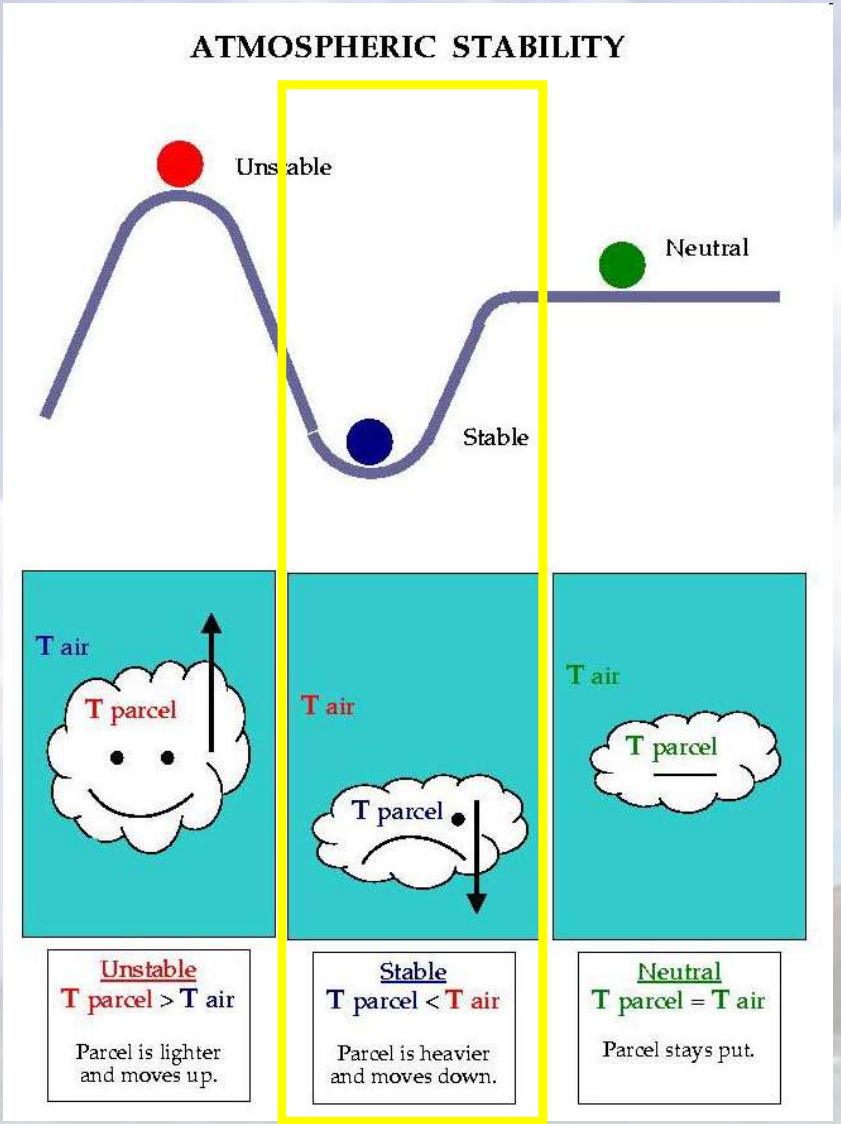

Stability and Clouds

Atmospheric Stability



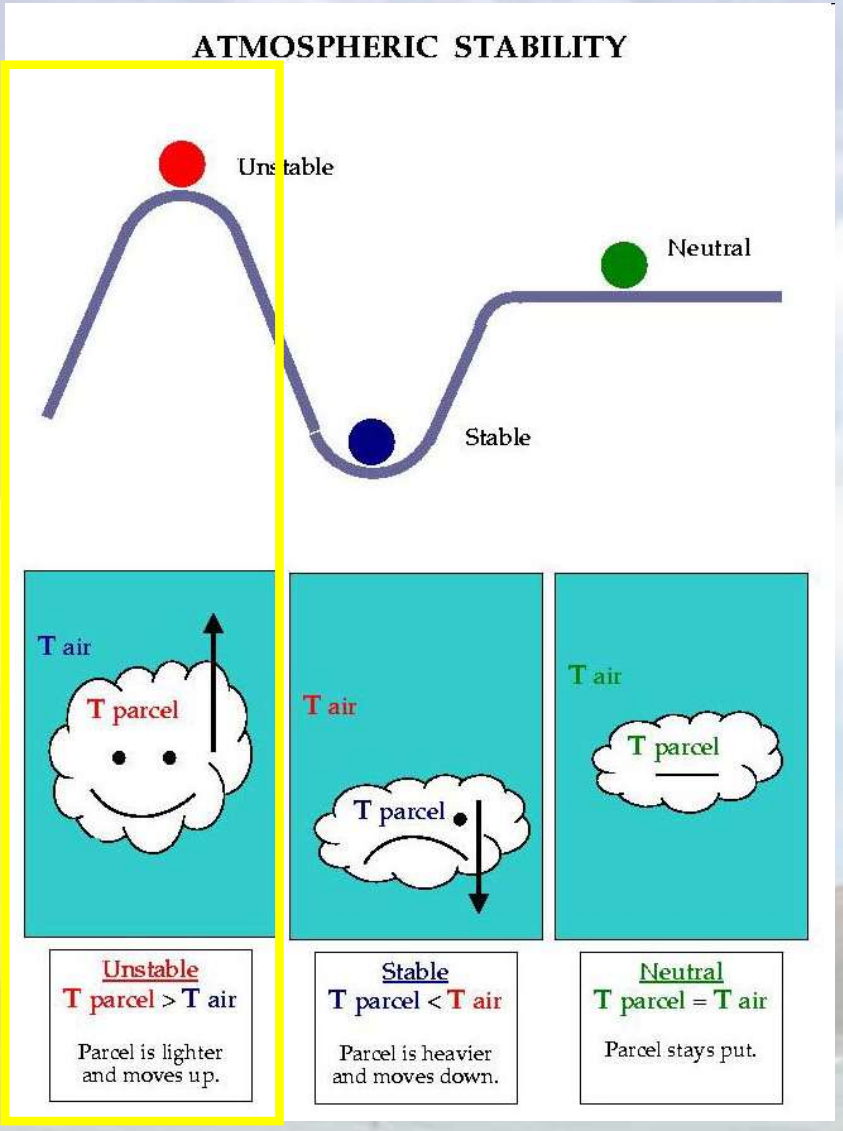
- When air rises it cools and eventually produces **clouds**

- By comparing a parcel of air to its surrounding you can tell if will rise or sink



Atmospheric Stability

- **Stable Air**
  - If a parcel were cooler than the surrounding environment, it would be more dense
  - If allowed to do so it would sink back to it's original position
  - Air of this type **resists vertical motion**



Atmospheric Stability

- **Unstable Air**
  - If a parcel were warmer than the surrounding environment, it would be less dense
  - If allowed to do so it would rise until it reached an altitude where it's temperature **equaled** that of its surroundings.

Stability and Daily Weather

- In general, when **stable air** is forced aloft, the associated clouds have little vertical thickness, and precipitation, if any, is light.

- In contrast, clouds associated with **unstable air** are towering and frequently accompanied by heavy rain.
  - e.g. the thunderstorms we had last fall were caused by unstable air related to passing hurricanes

Clouds!

- A cloud can be defined as **any visible aggregate of tiny droplets of water or tiny ice crystals, or a mixture of both**.
  - They are beautiful and are the main features in many folktales, mele, oli and other stories and art.
  - They help meteorologists, and the ancient Polyneisans, figure out what's going on in the atmosphere and what will happen in the future.
  - The basic Hawaiian word for cloud is ***ao***, but there are many cloud descriptions.
  - Clouds are also named after colors, with ***'ele'ele*** referring to a black cloud and ***ke'oke'o*** to a white cloud. A sheltering cloud is called ***ho'omalumalu*** and a threatening cloud, ***ho'oweliweli***.

Dr. Griswold LOVES Clouds!

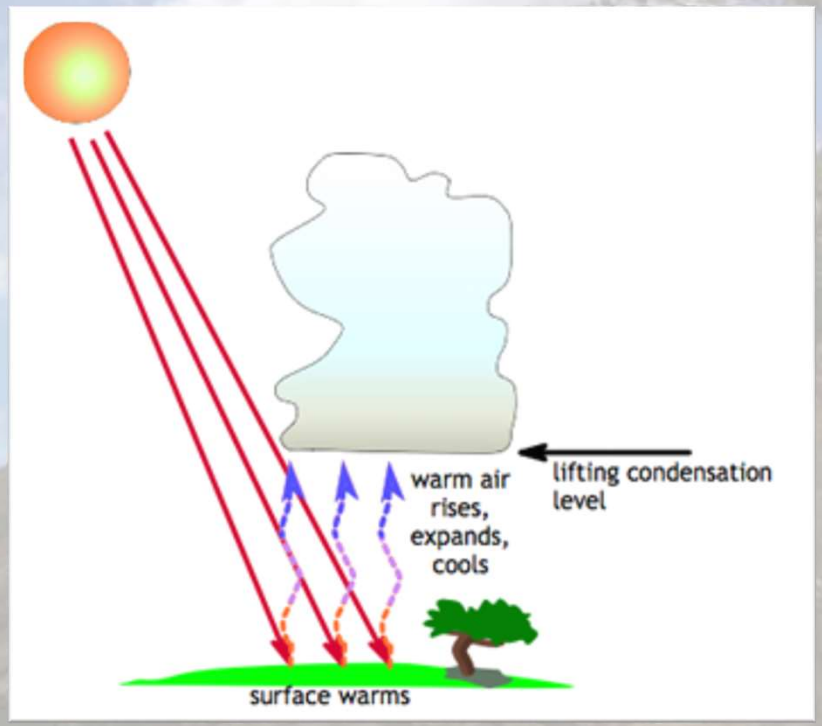
- **Sky:** The word for sky is ***lani***.

Recipe for a Cloud

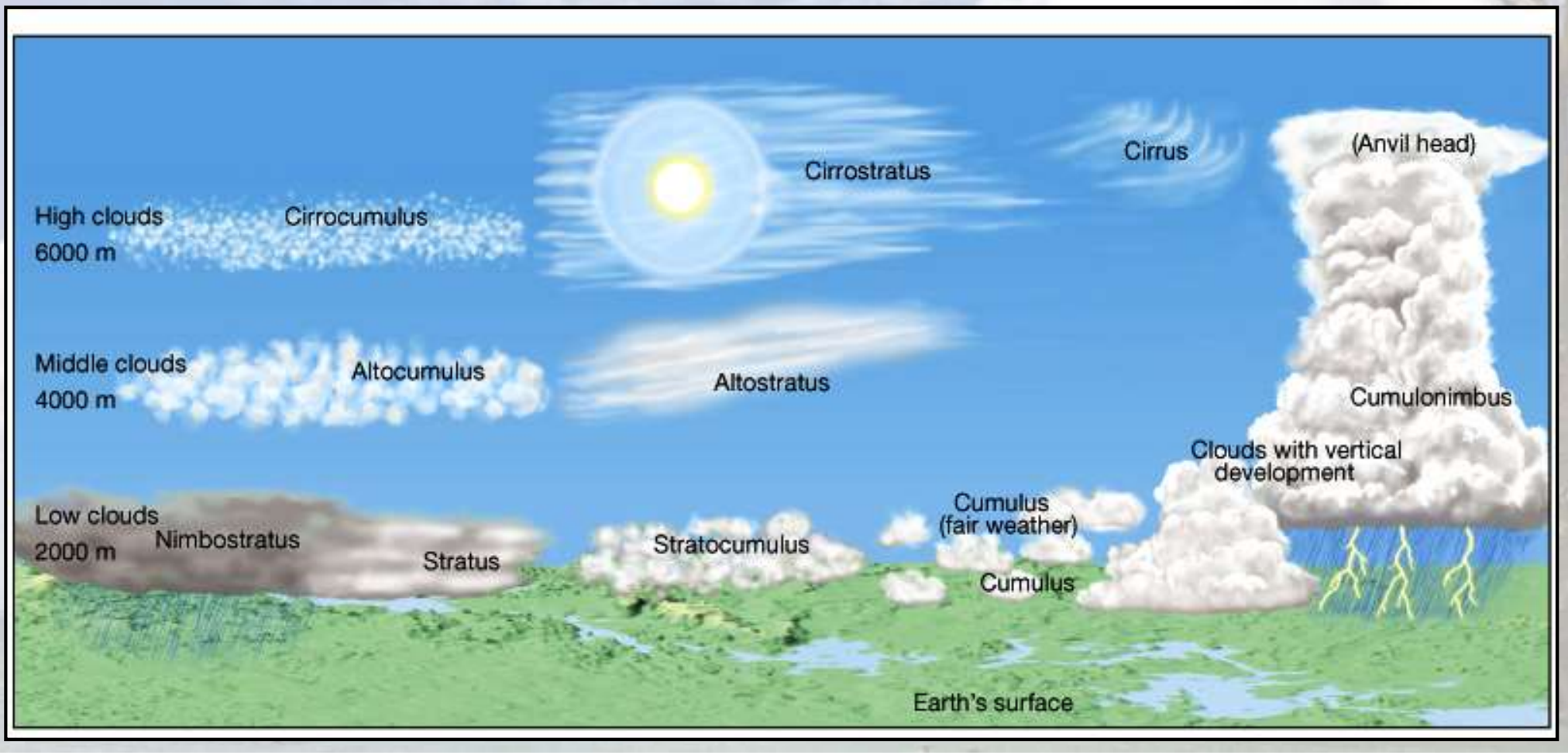
1. **Cloud Condensation Nuclei (CCN)**
   - Particles of sea salt, dust, other materials
   - Serve as the surface for water vapor to condense upon

2. **Rising Air**
   - By one of the methods described on Tuesday.
   - Causes cooling
   - Condensation occurs at the LCL

3. **Water Vapor**

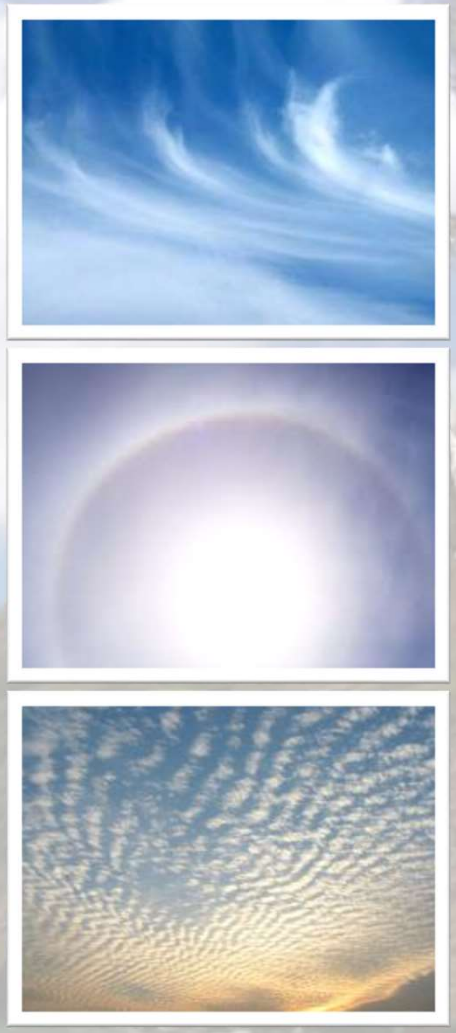


Cloud Classification



High Clouds

- **Cirrus**
  - Fibrous, “mare’s tails”
  - **pūrehurehu/ pūrerehu** – in Maori
- **Cirrostratus**
  - White, produces halo
  - Approach of warm front
- **Cirrocumulus**
  - White, small cells or ripple
  - looks like “Fish Scales”
  - **māra kūmara a Ngātoro-i-rangi** – in Maori
- Above 6000 m (20,000 ft)
- **ICE ONLY**
- No Significant Precipitation



Middle Clouds

- **Altocumulus**
  - Large patches of rounded masses or rolls
  - Usually water droplets
- **Altostratus**
  - Formless layer of grey cloud cover
  - Sun is only visible as a bright spot.
  - NO Halos
- Between 2000-6000 m (6,500-20,000 ft)
- **Mostly Water**
- Infrequently Precipitates Snow or Drizzle

Low Clouds

- **Stratus – *ao loa*** – in Hawaiian
  - Uniform layer covering most of sky
  - Sometimes precipitation
  - **pūtahi** – in Maori
- **Stratocumulus**
  - Scalloped bottom, covering most of sky
  - Long parallel rolled or blobs
- **Nimbostratus**
  - Chief precipitation producers (light but for a long time)
  - Associated with Stable conditions
  - **okewa** – in Maori
- Below 2,000 m (6,500 ft)
- **LIQUID ONLY**

Clouds with Vertical Development

- **Cumulus - *aopua'a*** – in Hawaiian
  - Individual masses that develop into vertical domes or towers
  - Tops often resemble cauliflower
  - Form on clear days

pua'a – means PIG in Hawaiian

'opua – A bank of Trade Wind Cumulus

- **Cumulonimbus**
  - When Cumulus grow out of control
  - Dark, dense, billowing clouds
  - **VERY TALL** 12-20 km (7-12 miles)
  - ***aopehupehu*** – *Clouds that are swelling up*

- Bases are low (below 2,000 m) Tops up to 20 km!!
- **Water at the base, can have ice if they grow tall enough**
- Related to **unstable** air

Hawaiian Words Related to Clouds

Ancient Hawaiians—while not familiar with English names of cloud formations like cumulus, cirrus, stratus, and nimbus*—did have their own words for most standard formations and also for many left undistinguished by Westerners.

To early Hawaiians clouds threatened rains and storms and portended evil as well. They appeared in clusters, banks, and layers, assumed long and short formations, and created majestic pillars and images above the horizon and in masses aloft. They reflected colors, including those of the rainbows.

Hawai'i enjoys the great variety and beauty of its clouds.

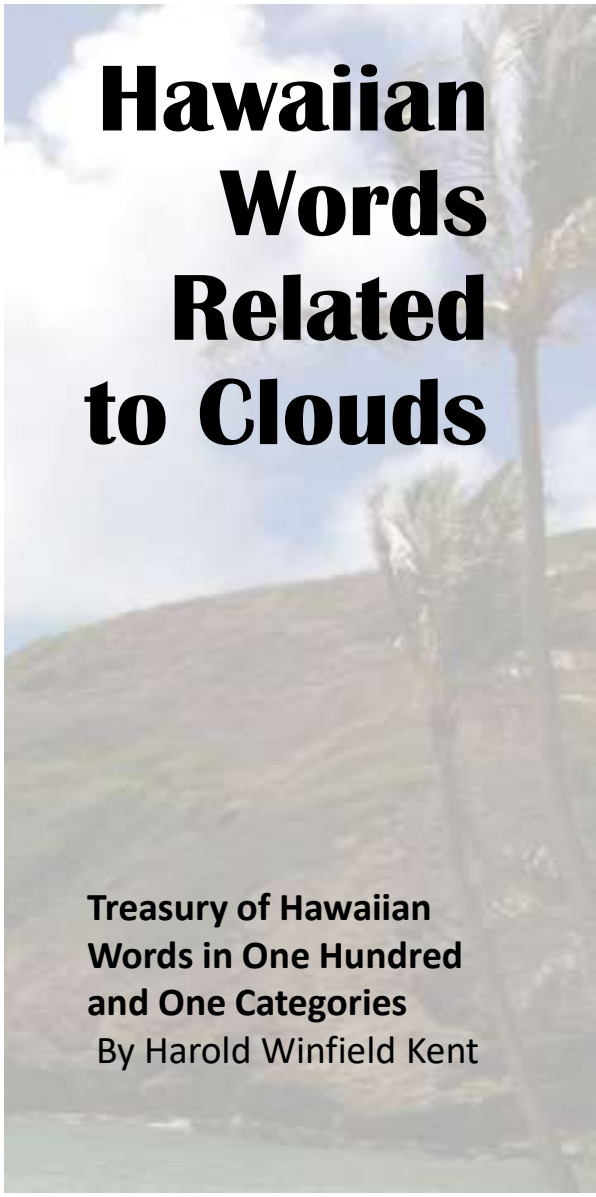
Treasury of Hawaiian Words in One Hundred and One Categories
By Harold Winfield Kent

'āla'apapa. Long cloud formation.
'ālewalewa. Cloud or smoke floating on the air.
ānuenue. Rainbow. (Kin. 9:13; Ezek. 1:28.)
ao. General term for clouds.
ao akua. Godly cloud. *Fig.*, rainbow. (PE.)
ao 'ele'ele. Black cloud.
ao ho'opehupehu. Billowy, as a cloud.
ao kāhe'a. A kind of cloud as it appears on the horizon. No other data. (A.)
aokū. Cloud of rain or mist.
ao loa. Long cloud, high or distant; a stratus cloud. *O Kū ke aoloa, o Kū ke aopoko,* Kū is the long cloud, Kū is the short cloud.
aonuiho'olahalaha. Broad mass of clouds extending over a great space. (A.)
ao 'ōpiopio. White cloud. (PE.)
ao 'ōpua. Sharp-pointed clouds as they appear in the sky. *Me he mau ao 'ōpua la e kau ana, pela ke kau o ka make māluna o na kanāka,* as sharp-pointed clouds hang in the sky, so death hangs over men. See **'ōpua.**
ao panopano. Dark, thick cloud.
ao poko. Short cloud.
ao pōpolohua. Dark, bluish cloud. See **pōpolohua.**
ao pua'a. Fog or cloud banks assembling over mountains, frequently a sign of rain.
ao uli. Blue cloud, i.e., a blue sky, the firmament.

*There is no word for nimbus in Hawaiian.

'awa'awa. Fog, mist, spray.
'e'a'e'a. Cloudy; to cloud up.
'ena. Opening in the clouds, said to be like the jaw of an *a'u* (swordfish) and a sign of rain. (PE.)
hākuma. Thick cloud threatening rain.
hea. Cloudy, misty.
he ao newenewe. Thick, billowy cloud near the sea.
He ao ho'omākōmakō. A thick black cloud.
He ao 'ōnohi 'ula'ula. Expression signifying a rain or storm is near. A cloud with a rainbow is an example.
he oho pa'apū. Thickly or solidly covered over with fog or clouds.
ho'okokohi. Threatening, as a cloud. *He ao ho'okokohi,* threatening, as a thick, black cloud.
ho'onākolo. A rolling of thunder, roaring of the surf.
'ilio. Cloud with a threat or omen.
ka'alelewa. Clouds that are driven swiftly or just float through the air (1 Tes. 4:17.)
ka'apeha. An impressive, large mass of clouds.
kaha'ea. Cumulus or cirrocumulus cloud; a cloud reaching over the heavens, of several colors—variegated black, blue, white, and others—a frequent sign of rain.
kākai. Cloud that hovers near the ground. (A.) See **pali loa.**
ka 'ōpua ha'aheo i ka lewa, the cloud billow stands proudly in the high air.
kaula 'ela'e. Cloudless sky where details in the distance are plain.
kaupua. Elevated cloud of singular appearance; banks of clouds. *He kaupua maila nā ao,* the clouds are gathering in banks.
Keaonui. Farmers prayed to this god, Big Cloud, to protect their fields.
Kela'aonui. Farmers prayed to this god, Big Black Cloud, to protect the beginnings of their food plantings.
kia ao. Cloud pillar. (Nah. 12:5.)
kiawe'ula. Cloud, reddish or streaked with red.
kī'ikau. Clouds patterned in strips as alternating black and white; variegated.
kilo lani. Predictor who can "read" the clouds.
kī'o wao. Mist or cloud that almost always settles on the hills of O'ahu.
ko'i'ula. Rising, floating cloud of rainbow or reddish hue. See **uakoko.**
kōkōlī'i. Thick, black cloud.
Kona kai 'opua i ka la'i; ka hawanawana, Kona seas with cloud billows that promise peace.

kūoa. Cloud standing in an upright position. *Lit.,* standing cloud.
lalahiwa. Black, as a cloud.
liki. Rainbow; the bending of an arch upward, as a rainbow.
mākahakaha. The ceasing and clearing of rain; the slow dropping of rain.
māla'e. Cloudless sky.
manino. Calm and quiet after a storm.
māuli. Obscure cloud seen from a distance.
mōla'ela'e. Clear, bright, unobstructed.
nānā ao. Interpreter of clouds for signs and omens.
nulu. To rise and float off, as clouds or smoke. See **pōnulu.**
'ohu. Light cloud on a mountain.
'ōkupu. To rise and cover with dark-colored clouds, especially applied to clouds out on the ocean.
'ōnohi. Segment of a rainbow.
'ōpua. Cumulus cloud; narrow-pointed clouds hanging on the horizon; clouds of a singular shape seeming to rise out of the sea. *'O Kona kai 'ōpua i ka la'i, 'ōpua hīnano kau i ka mālie,* Kona with its billowy clouds and sea in the calm with puffy clouds like *hīnano* blossoms resting in the calm. See **ao 'ōpua.**
'ōpua kī'i. Clouds in the morning or evening taking shape as images.
ōpū ao. Cluster of clouds.
'ōwa'awa'a. Thick clouds portending a storm.
'owela. Land and vegetables scorched in the sun; cloudless drought.
pa'apū i na ao. Cloudy and thick.
paekī'i. Row of clouds on the horizon. *Lit.,* row of images.
pa'ihi. Cloudless.
pālāmoa. Bluish cloud. When seen in the east in the morning, it is considered a sign of rain.
pali kaulu 'ole ka lani. Serene sky without clouds.
pali loa. Cloud that lies low near the shore. See **kākai.**
pāpalaōa. Smooth kind of cloud indicating rain or wind. The name is derived from its resemblance to the fish *palaoa,* a whale or sea-elephant.
paulihiwa. Great thickness of dark, heavy clouds. (A.)
pōhai 'ula. Red cloud, as of dust.
po'ipū. Sky covered over with clouds.
polohiwa. Shining, black cloud.
poluluhi. Thick and heavy, as watery clouds hanging in the atmosphere.
pōnulu. To rise like a thick column of smoke. See **nulu.**



pōpolohua. Blue, as the sky on a clear day; cloudless. (A.)
pōpuakaʻi. Place where pointed cloud clusters rise out of the sea.
pūlawa. To cover the sky with thick clouds or fog, rendering land and mountains invisible.
Pulelehua kea. Greater Magellanic Cloud. *Lit.*, white butterfly. (PE.)
Pulelehua uli. Lesser Magellanic Cloud. *Lit.*, dark butterfly. (PE.)
pululuhi. Hazy, foggy, cloudy.
pūnohu. Ascend as smoke, mist, or cloud.
pūnuhu. Cloud standing apparently erect, reflecting rainbow colors.
puʻunohu. Foot of a cloud hanging on a mountain; a thick cloud.
uakoko. Reflection of rainbow colors in an oncoming, erect, rain-cloud. *Lit.*, rain blood.
ua lanipili. Long-lasting, heavy rain; cloudburst. *He ua lanipili*, a shower touching the heavens. Clouds as they appear to touch the horizon. *Lit.*, sky to adhere.

Hawaiian Words Related to Clouds

Treasury of Hawaiian Words in One Hundred and One Categories
By Harold Winfield Kent

Types of Fog

- **FOG** = a cloud with its base at or very near the ground.

- **Fogs formed by Cooling**
  - Radiation Fog
  - Advection Fog
  - Upslope Fog

- **Fogs formed by Evaporation**
  - Steam Fog
  - Frontal Fog

Discussion if there's time

- **How does the naming of clouds differ when we compare our modern method to the names of the Hawaiians?**

The Hawaiian words for clouds are extremely descriptive of specific situations.