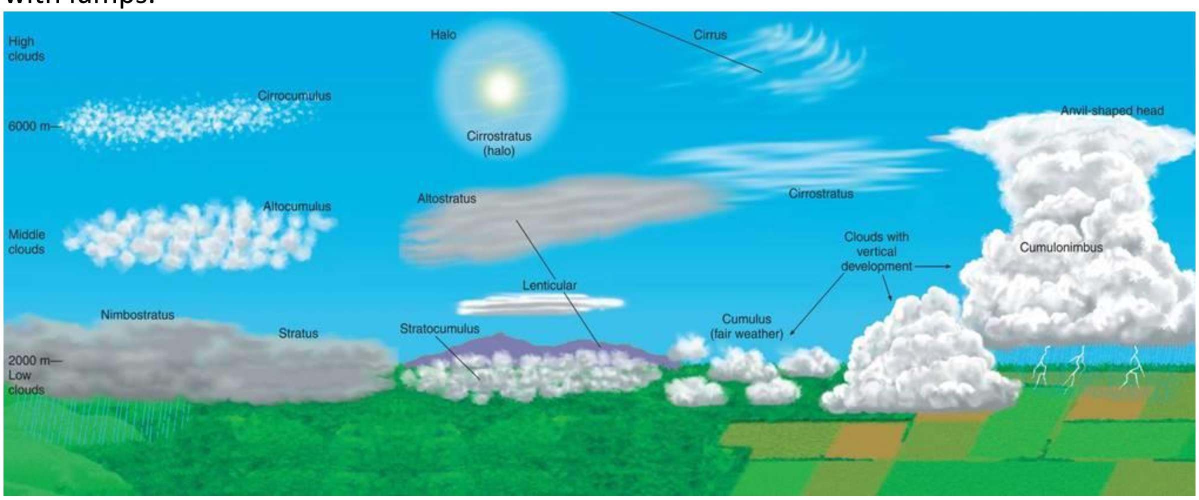
VIII. CLOUDS AND STABILITY:

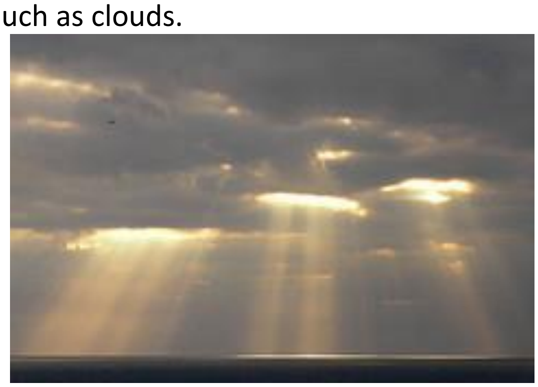
A. Cloud Classification:

1) Clouds are classified with respect to the height of the cloud base --- low, middle, or high.
   a. "Strato" is the first prefix used to indicate cloud base height. Stratus are low clouds, spread out and straight.
   b. "Alto" is the prefix used for middle-level clouds.
   c. "Cirro" is the prefix used for high clouds or "cirrus", from Latin to curl. These are our high, wispy, and feathery ice clouds.

2) We also have 2 suffixes, indicating the degree of vertical development, sheet-like "stratus" or lumpy "cumulus'.
   a. We can combine our prefixes and suffixes in many different ways, so we can have "cirrostratus", "altostratus", "cirrocumulus", and altocumulus". We can even have "stratocumulus", which seems like a contradiction, but actually, those are among the most common clouds on Earth, sheet-like clouds, punctuated with lumps.

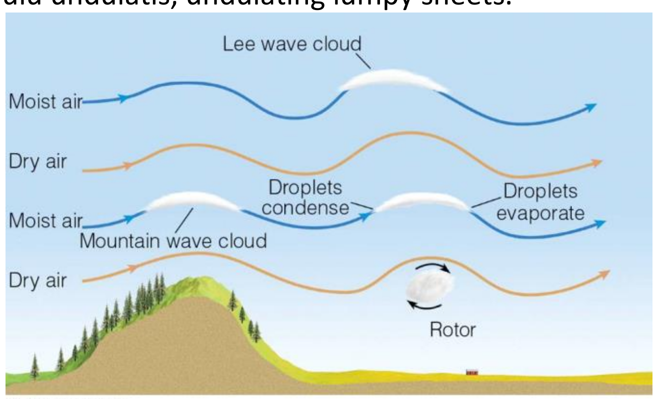


3) The cloud particles reflect all of the colors of visible light to our eyes, which is why they usually appear white. A common sight are these rays from heaven, which are called "crepuscular rays". These ray can occur any time that light is channeled through gaps in objects, such as clouds.



4) We can have subtypes as well. (examples)
   a. **Lenticular** (lens-shaped) clouds sometimes look like flying saucers and result from lifting moist air near mountains.

   b. **Rotor** clouds are the end result of violent downslope winds. They are stratocumulu undulatis, undulating lumpy sheets.



   c. Cumulus humilis are our fair-weather cumulus clouds. Humilis means humble.
   d. When clouds are heavy with rain, we insert the work “nimbo” in the name. Nimbostratus clouds darken the sky in sheets, and cumulonimbus---- that’s our thunderstorm cloud.

B. The recipe for clouds has 2 ingredients: moisture (phase changes) and atmospheric stability (or instability).

1) I already mentioned to you that if we take a blob of air and force it somewhere where the pressure is lower, the air expands.
2) As a result of this expansion, the air cools and if it carries water vapor, its relative humidity rises. We can saturate moist air this way.
3) This was the dry adiabatic approach to saturation.
4) In this thought experiment, we were making us of the air parcel concept.
    a. We followed a sample of air around, monitoring how it's properties, like temperature and relative humidity, changed, but we need to make some assumptions, typically, when we follow air parcels around.

C. The air parcel concept:
1) The air parcel is an important and useful conceptual device in atmospheric sciences.
    a. We make a parcel by gathering together a usually unspecified amount of air and pretend the air is surrounded by an invisible boundary that insulates the parcel air from its surrounding environment.
    b. The parcel boundary, however, is flexible, permitting the air inside to expand or contract as conditions dictate.
    c. The flexibility of the boundary implies that outside and inside pressures will always be the same. . . and thus if the outside pressure drops for some reason, so too will the inside pressure.
        i) In that event, the parcel will expand.
    d. Similarly, an increase in outside pressure will cause the inside pressure to rise accordingly, making the parcel contract.
    e. One very good way of making a parcel's outside pressure to rise or fall is to make the parcel sink or rise in elevation. This is very important.
2) We will eventually see there are other ways of making the pressure change as well.
3) Now consider such an air parcel, consisting of only dry air for now (we'll be adding moisture soon).
    a. Our four principal air parcel assumptions are:
        i) The parcel is sealed from outside air. Thus, there is no mixing of parcel and environmental air once the parcel is created. For a dry air parcel, the mass is fixed.
        ii) Parcel size itself is irrelevant.
        iii) The parcel is insulated from its surrounding environment. Thus, there is no heat transfer by conduction or radiation across a parcel boundary.
        iv) The parcel sides are flexible, which means if outside pressure changes, inside pressure adjusts to match it.
    b. These assumptions may seem ridiculous, but we will show that they're actually pretty good for the parcel concept applications we're going to consider.
    c. Note the fourth point means that a balloon is not a good proxy for an air parcel; the outside and inside pressures are clearly different in that case.
4) Recall the ideal gas law (IGL) here: since the parcel and environmental pressures are always the same, if the parcel is warmer than the environment, it is also less dense.
    a. Thus, if the parcel temperature exceeds that of its surrounding environment, the parcel will want to rise.
    b. Similarly, if we find a parcel to be cooler than its surroundings, it will be more dense, and therefore will want to sink.

5) The important point to keep in mind is this:
   For a dry air parcel, the only way to change its temperature is to change its pressure.

D. Lapse rates: ELR and DALR
1) A lapse rate, specified as ◦C/km or ◦F/mi., quantifies how temperature changes with height under specified conditions.
2) The word lapse implies our expectation that temperature will decrease with increasing elevation.
   a. If the temperature were to increase with height, the lapse rate would be negative.
3) We have three lapse rates with which to contend in atmospheric sciences: ELR, DALR & WALR.
4) The first**, the environmental lapse rate** (ELR), expresses how temperature (T) varies with height (z) in the environment.
   a. Recall that in the "standard atmosphere" we find a temperature drop of about 140◦F over 7-8 miles in the troposphere. This means the tropospheric ELR is roughly 19.5◦F/mi or 6.5◦C/km. We will often round these ELRs to 7◦C/km and 20◦F/mi.
   b. Why does T drop with height z in the troposphere? For all the reasons already discussed, including the facts that air is a poor absorber of visible light and also a poor conductor.
5) Two important points about this oft-cited ELR of about 7◦C/km:
   a. The ELR is NOT FIXED in space and time. It can vary from place to place, from time to time and can vary with height in the troposphere itself.
      i) However, averaged from day to night, winter to summer, land to sea and equator to pole, the mean tropospheric ELR is about 7◦C/km or 20◦F/mi.
      ii) Lapse rates will ultimately tell us if clouds are positively or negatively buoyant.
   b. The ELR can be negative! At night, very close to the ground, air T often increases with height over a shallow depth. This is called a temperature inversion, and the ELR in this instance would be negative. Is it obvious that the stratospheric ELR is also negative?
6) Recall that average sea-level pressure is about 1000 mb and pressure decreases with height.
   a. A general rule of thumb is that pressure decreases roughly 100 mb per kilometer in the lower troposphere, so the pressure one kilometer above your head is ≈900 mb. A tropospheric ELR of 7◦C/km simply means that you expect the temperature to be 7◦C cooler there than at the surface.
7) Now, suppose we make an insulated yet flexible air parcel from that surface air and we make it rise.
   a. We are still assuming there is absolutely no moisture in the air.
   b. As that parcel rises, the pressure outside of the parcel decreases.
   c. Because the parcel boundary is flexible, the inside pressure also goes down.
      i) This permits the parcel volume to expand.
      ii) Expanding air cools, so the T inside the parcel is dropping.
   d. The rate of expansion cooling for dry air is very close to 10°C/km or 30◦F/mi and is called the **dry adiabatic lapse rate** (DALR).
   e. As the parcel rises, the T outside of the parcel is also usually dropping (that's the ELR).
   f. The crucial point here, however, is that outside and inside temperature changes are absolutely INDEPENDENT.

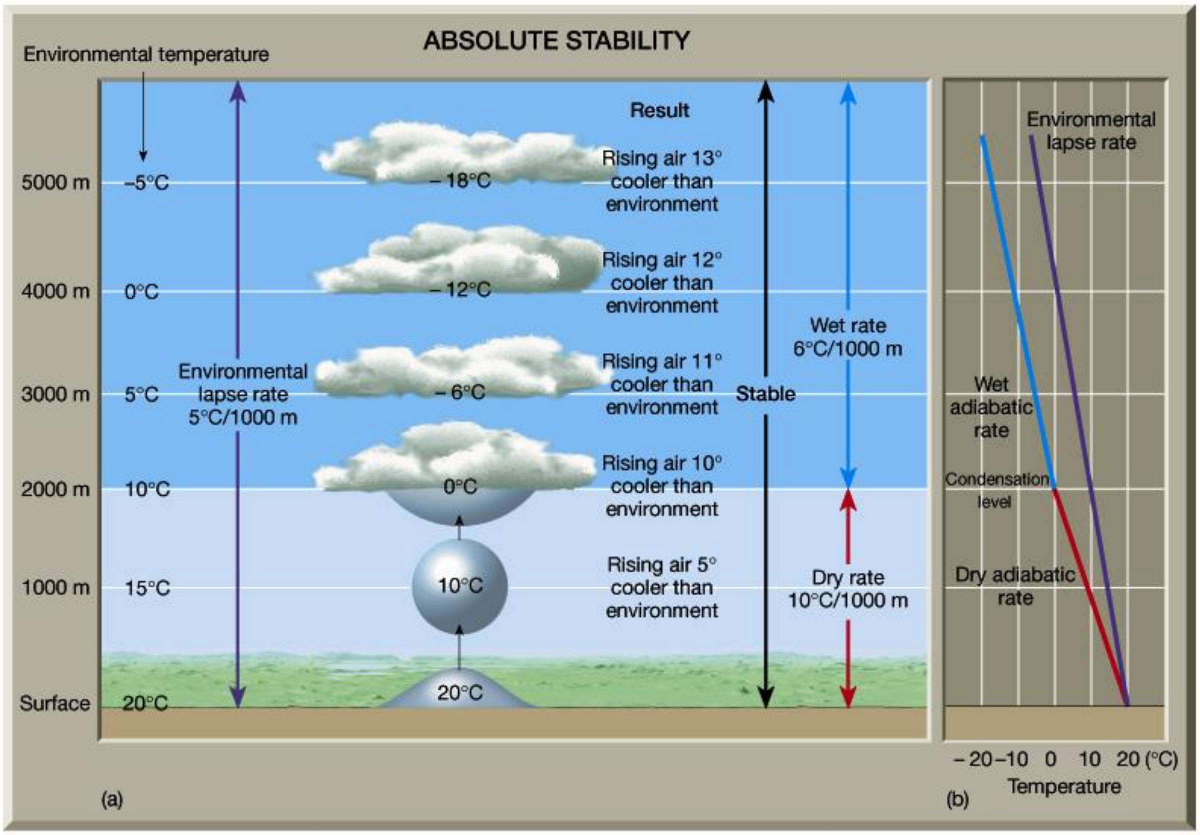
g. The temperature outside of the parcel is dropping because the parcel is moving away from the surface, the troposphere's primary heat source.
h. The temperature inside the parcel is dropping because its volume is expanding in response to the decreasing pressure.
i. It is rare for the environmental and parcel temperatures to change at the same rate. [**This has very strong implications for the notion of atmospheric stability**].

E. Example: The surface T is 20°C and the ELR is 7°/km.
1) What is the T of the environment 2 km above the surface?
2) If you make a perfectly dry air parcel composed of surface air, and lift it 2 km, what would be the parcel temperature be?
3) Compare the temperatures outside and inside the parcel.
4) Compare the pressures outside and inside the parcel.
5) Compare the density of the parcel to that of the environment.
6) Will this parcel try to rise or sink?

F. Example with answers: The surface T is 20°C and the ELR is 7°/km.
1) What is the T of the environment 2 km above the surface? (Ans.: 6°C.)
2) If you make a perfectly dry air parcel composed of surface air, and lift it 2 km, what would be the parcel temperature be? (Ans.: 0°C, since it will cool at the DALR for 2 km.)
3) Compare the temperatures outside and inside the parcel. (Ans.: The parcel is colder by 6_C.)
4) Compare the pressures outside and inside the parcel. (Ans.: The key point is, they are the same. For a surface pressure of 1000 mb, the pressure at that elevation is roughly 800 mb.)
5) Compare the density of the parcel to that of the environment. (Ans.: At the same pressure, colder air is more dense, so the parcel is denser than its surroundings.)
6) Will this parcel try to rise or sink? (Ans.: It will sink, because its density is larger than that in the environment.)

G. Question for thought. Lift a parcel dry adiabatically to several kilometers above the surface. Compare its new density to its original density. Is it larger, smaller, the same, or are you unable to tell? (I won't give you the answer unless you offer both an answer and a justification for your answer to me first.)
1) Up to this point, what's taking place is free convection (heat transport by fluid motion).
2) Further ascent can only occur if the parcel is forced—forced convection.
3) If the parcel were forced to rise much farther, it would become much colder and much denser than its surroundings.
4) In reality, the parcel will likely remain in the environment where it's inside and outside temperatures match.
5) How can nature share all the hot air near the surface with the bitterly cold tropopause, just a few miles above? We've seen that we can't lift hot air very far; it doesn't stay hot.
   a. This illustrates an important concept call atmospheric stability----resistance to vertical displacement.

b. If we loft a parcel of air, its density increases at the same pressure, and it becomes negatively buoyant.
c. If we push the parcel down, its density decreases at the same pressure, and it becomes positively buoyant. This situation is called **absolutely stable**.



H. **Adding moisture**: the WALR
1) The DALR not only applies to absolutely dry air parcels, but also to parcels containing water vapor, so long as the relative humidity (RH) < 100%.
2) Consider what happens to a moist but initially sub-saturated parcel on ascent.
3) At first, the parcel's vapor supply (VS) is fixed, the reason being that nothing has yet occurred to change it.
4) However, as the parcel expands, its vapor capacity (VC) decreases along with T, so the parcel's RH rises.
5) Given sufficient lifting, this parcel will become saturated. This is always true: it is possible to saturate any parcel by lifting, so long as it starts with some finite amount of moisture. (That doesn't mean a source of sufficient lifting will be available; that's another story).
6) What happens once a parcel has been lifted to saturation? Additional lifting will cause further expansion and cooling, further reducing the VC.

7) However, now the parcel's VS has to start decreasing, to keep the parcel's RH from exceeding 100%. [In other words, condensation has started to occur, and vapor is now being transferred to liquid.]
8) Condensation is a warming process, and the latent heat released goes to warming the air within the parcel .
9) As a result, the rising saturated parcel now experiences both expansion cooling AND condensation warming.
10) The net result is that the parcel still cools on ascent, but at a slower rate.
11) This new rate is called the wet adiabatic lapse rate (WALR), and we're going to take it to be 5°C/km or 15°F/mi. [Don't be confused by the terminology: the "dry" in the dry adiabatic actually means sub-saturated, and the "wet" in wet adiabatic really means saturated.
12) Nature's way of lofting surface air to the tropopause is thunderstorms.
    a. Rising air expands and cools because pressure decreases with height (dry adiabatic process).
    b. The RH of rising moist air also increases.
    c. That's how we created a cloud from lifting, because VC decreases quickly as temperature goes up.
    d. Further lifting of saturated air means further expansion cooling, but now there's a vapor excess (super-saturation).
    e. Some of that excess vapor must condense, and condensation is a warming process. What receives the warming? The air in the supersaturated parcel.
    f. The net result is that the cooling rate for the parcel on ascent is cut in half, to 5°C/km. This is the wet adiabatic lapse rate (WALR).
    g. Unlike the DALR, THE WALR is not a constant.

I. Example. Take a parcel with initial T = 30°C and VS = 8 g/kg. [Use the Temperature/moisture table to help answer these questions]:
1) What is the parcel's RH?
2) Lift this parcel 1 km. What is the parcel's new T?
3) What is its new VS? (Remember, VS will not change until saturation is achieved.)
4) What is the parcel's new RH?
5) Lift this parcel another 1 km. What is the parcel's new T?
6) What is its new VS?
7) What is the parcel's new RH?
8) Lift this parcel yet another 1 km. What is the parcel's new T?
9) What is its new RH?
10) What is its new VS? (Remember, VS must decrease as vapor condenses to liquid.)
11) How much of the original vapor has condensed to liquid?
12) Why did the parcel start cooling more slowly?

J. Example with answers.
1) What is the parcel's RH? (Ans.: VC = 28, so RH = 8/28 = 29%).
2) Lift this parcel 1 km. What is the parcel's new T? (Ans.: The parcel is subsaturated, so it cools dry adiabatically. Lifting 1 km causes 10°C of cooling, so the new T = 20°C.)
3) What is its new VS? (Ans: VS is fixed until saturation, so it is still 8 g/kg.)

4) What is the parcel's new RH? (Ans.: new VC = 15 g/kg, so new RH = 53%).
5) Lift this parcel another 1 km. What is the parcel's new T? (Ans.: The still sub-saturated parcel cooled at the DALR down to T = 0_C.)
6) What is its new VS? (Ans.: VS remained fixed at 8 g/kg since the parcel was sub-saturated.)
7) What is the parcel's new RH? (Ans.: New VC = 8 g/kg, so now the parcel is saturated).
8) Lift this parcel yet another 1 km. What is the parcel's new T? (Ans.: The now saturated parcel cools at the WALR, or 5°/km. So, the new T is 5°C.)
9) What is its new RH? (Ans,: Still 100%, as excess vapor condenses to liquid.)
10) What is its new VS? (Ans.: The parcel is saturated, so RH = 100% and VS = VC. Air at T = 5°C can only old 6 g/kg, so that's also the VS).
11) How much of the original vapor has condensed to liquid? (Ans.: The parcel started with 8 g/kg but can only hold 6 g/kg at this point. So, 2 g/kg of vapor has already condensed.)
12) Why did the parcel start cooling more slowly? (Ans,: Expansion cooling has continued as the parcel ascended, but after saturation it became partially opposed by condensation warming.)

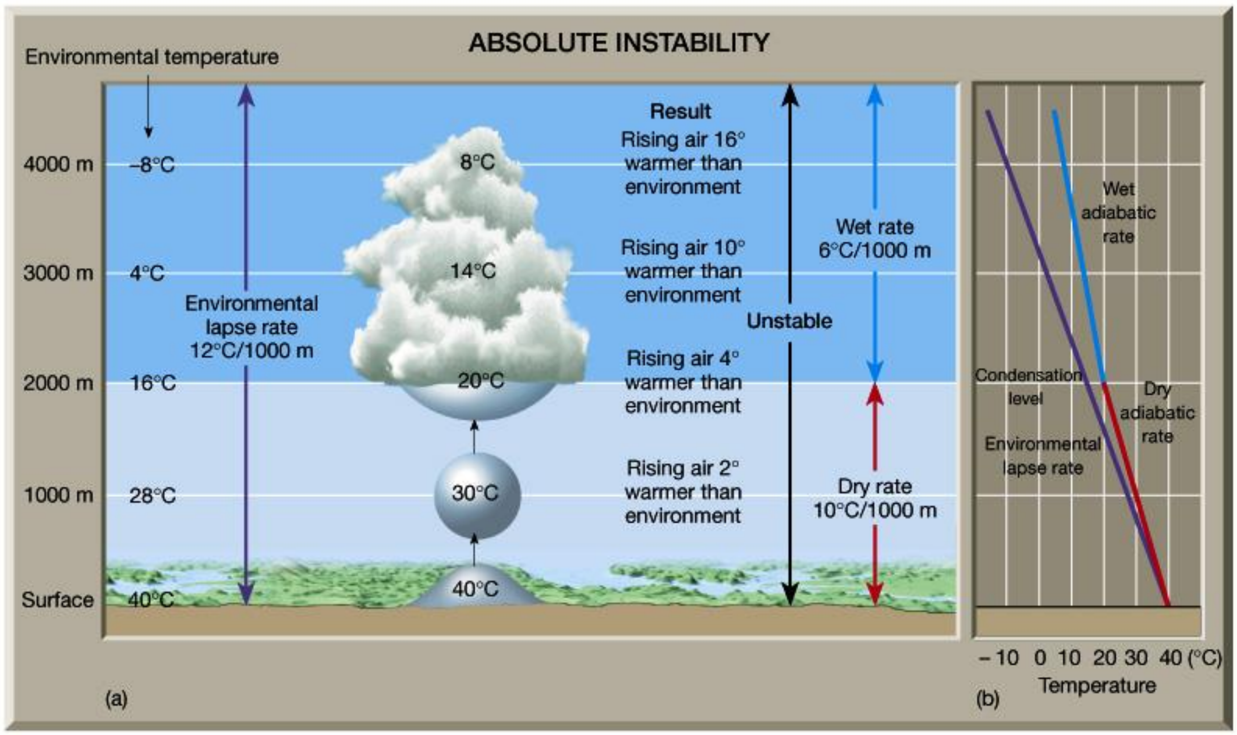
K. **Absolute Instability**:

1) Question #1 for thought: Although we're going to ignore its variation, the WALR is not actually constant. Follow a rising saturated parcel. How would you expect its cooling rate to vary during its ascent: should it increase or decrease, and why? (I won't give you the answer unless you offer both an answer and a justification for your answer to me first.)

a. Let's look at a saturated parcel of air. It starts at the same initial temperature as its environment, 30°C, and holds 28g/kg of water vapor.
b. If we push that parcel up 1 km, it cools at only 5°C. The parcel is now 1°C warmer than its new environment and positively buoyant.
c. At 2 km, the saturated parcel is now 2°C warmer and rising faster.
d. The ELR, usually 6°C/km, is actually larger than the WALR, 5°C/km, so the rising saturated parcel can become warmer than its environment. And the farther it rises, the more its temperature increases in relation to its environment.
e. The reason the atmosphere isn't always in a state of chaotic mixing is that we don't encounter saturated air near the surface very often. Air typically starts off sub-saturated and cooling faster than the ELR before finally reaching saturation.
f. This air usually starts off negatively buoyant, and that's an obstacle to overcome.
g. The state of the rising saturated parcel is called **conditional instability**, that is, conditioned on the presence of moisture and the situation of saturation.

Table 1: Temperature/moisture table

T or Td (°C):	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40
VC or VS (g/kg):	0	0.5	1	1.5	2	3	4	6	8	12	15	22	28	40	50



L. **Conditional Instability**:

1) Let's raise a sub-saturated air parcel. We know it has a temperature and a dew point, reflecting its VC and VS.
   a. If I lift the parcel, its temperature decreases at the DALR.
   b. I also need to reveal now that the dew point of this parcel also drops at about 2°C/km. That's the **dew point lapse rate**. [Actually, that's our fourth lapse rate].
   c. As the parcel moves upward, temperature is higher that the dew point.
   d. The parcel temperature cools at the DALR, since it's sub-saturated, and it gets cold fast.
   e. Its dew point is also decreasing, but at a much slower rate of 2°C/km.
      i) The dew point is decreasing because our parcel is getting larger.
      ii) Its volume is increasing, so the water vapor in the parcel is becoming more spread out.
      iii) That makes collisions more rare, so we actually have to cool the air farther to compensate for all that extra room that the water vapor has to roam in.

f. But the crucial point is these 2 slopes are very different, and they're going to cross. And when they cross, the parcel is saturated. [The RH is 100%].
g. The temperature equals the dew point. This is the **lifting condensation level**, or "LCL". That's the level at which condensation can be achieved by lifting.
h. LCL has another name as well, "cloud base". We've reached cloud base, so what happens next? We're finally saturated.
i. Now we cool at the wet adiabatic lapse rate, roughly 5°C/km.

2) Example: Suppose we take a parcel of surface air, having the same temperature as the environment and a VS of 8 g/kg. This is a case in which it's possible for a surface parcel to become positively buoyant on ascent despite starting off sub-saturated.
   a. The parcel is obviously sub-saturated, since the VC of that air is 28 g/kg.
   b. Lift the parcel, one kilometer at a time, cooling at the DALR as long as the parcel remains sub-saturated.
   c. Note the RH is rising during the ascent. At some point (here, when the parcel reaches 2 km above the ground), the RH reaches 100%. This is called the lifting condensation level (LCL), the level at which condensation can be achieved by lifting, also known as cloud base.
   d. A sub-saturated parcel lifted to the LCL is negatively buoyant.
   e. This air has been saturated by the adiabatic expansion approach.
   f. Now that the parcel is saturated, further lifting proceeds at the smaller WALR rate. As the saturated parcel continues to cool, its VC drops. Excess VS is removed as condensation, and accumulated as liquid water.
   g. It is the presence of condensation warming that makes the WALR less than the dry adiabatic rate.
   h. Does this liquid remain in the rising parcel or does some or all of it fall out as rain? Either can happen, depending on our assumptions. Here, we're carrying the liquid along with the parcel.
   i. Note that when the parcel first starts rising, it quickly becomes colder than its surrounding environment. This is because the DALR > ELR.
   j. Recalling that we presume the parcel has the same pressure as its surroundings, it follows from the Ideal Gas Law that the colder parcel is denser than its environment.
   k. So why was the parcel rising, even though it was more dense? We are probably pushing it – over a mountain, over a front, or by forcing air to converge, etc.. However, if we stop pushing the parcel upwards at any time at which the parcel is colder, it will try to sink back down to its original height level.
   l. Note further, however, that the WALR < ELR. Once the parcel is saturated, it starts cooling at a slower rate than its surroundings.
   m. Thus, temperature difference in °C between Parcel temperature and Environmental temperature is most negative at the LCL, the point at which the cooling rate switches over to the wet adiabatic rate. If you can lift the parcel high enough, it might actually become warmer than the environment. The point at

which parcel and environmental temperatures become equal is called the **level of free convection (LFC)**. Note that is positively buoyant.

n. In this case, the LFC is at 4 km. Not all soundings have an LFC. Springtime Oklahoma soundings usually have LFCs, Los Angeles soundings rarely do.

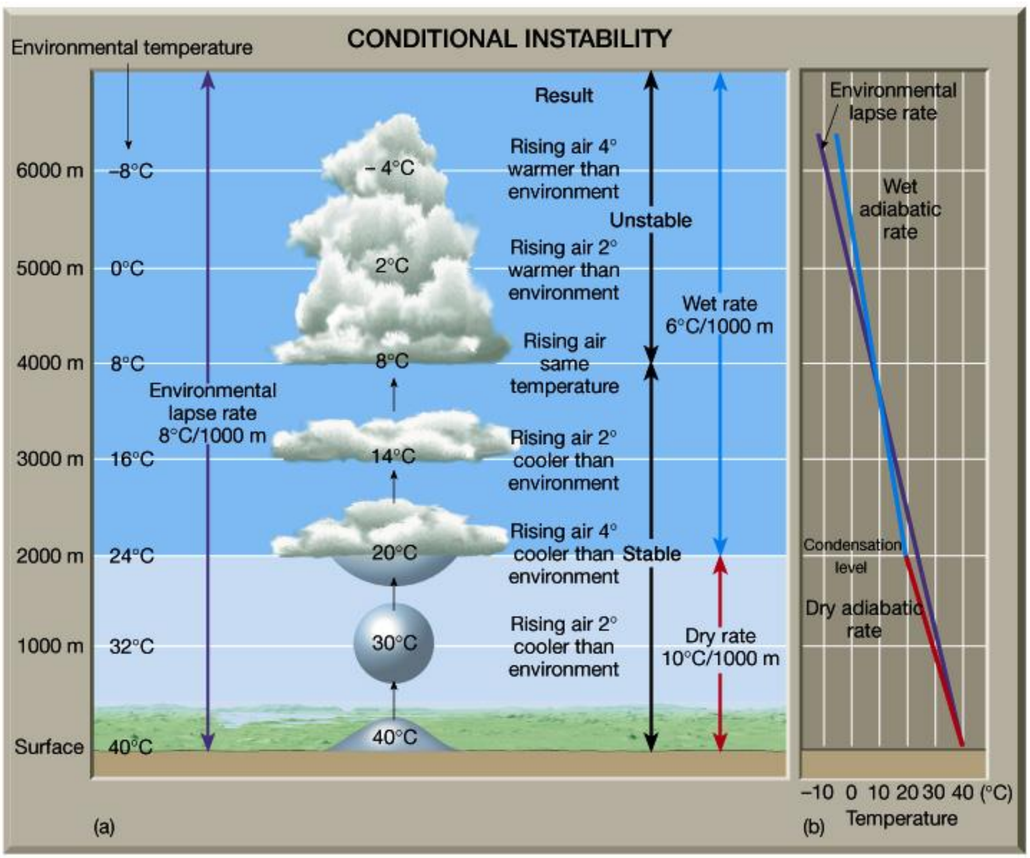
o. Above the LFC, the parcel is warmer than its surroundings, and is able to rise on its own. That is to say, it convects freely, without having to be forced. The parcel will continue rising as long as it is warmer.

p. The parcel will not rise forever, for two reasons.

i) First, the parcel will eventually exhaust its VS; in the example, this happens as the parcel reaches the 6.5 km level. After this point, the cooling rate reverts to the DALR since there is no more vapor to condense.

ii) Second, even if vapor remains, the parcel will eventually reach the stratosphere. In that layer, environmental temperature increases with height.

q. It is inevitable that the parcel will again become cooler than its surroundings. That point is called TOC, or top of cloud, which in the present example resides between 6.0 and 6.5 km. It can also be called the equilibrium level (EQL).



r. The main part of the cloud is warmer than its surroundings and positively buoyant. The lower section, between the LCL and the LFC, is colder, as is the top part of the cloud, slightly above the EQL.

s. Now, we recapitulate and extend with the help of the conditional stability figure above and the graph on the right.
   i) The purple line depict environmental temperature variation in the troposphere (ELR ≈ 7◦C/km) and lower stratosphere.
   ii) The path taken by a sub-saturated surface air parcel is shown in red.
   iii) At first, the parcel cools rapidly with height, at the DALR. Note the parcel is becoming progressively colder with respect to its surroundings. Therefore, ascent must be forced, and this is called ***forced convection***.
   iv) However, saturation is achieved at the LCL (cloud base), above which further ascent is moist adiabatic. Note the parcel is still colder than its environment, but the difference between their temperatures is decreasing as shown in blue. Ascent still requires a push, but the push needed is becoming more gentle.
   v) At the LFC, parcel and environmental temperatures are again equal.
   vi) Above the LFC, the parcel will rise on its own, and convection has become free.
   vii) The parcel will continue to rise until its temperature again becomes equal to its surrounding environment. This is the TOC, our first guess at cloud top.
   viii) Many parcels never reach cloud top, and some will actually overshoot. The latter occurs because those parcels reach the TOC level with some considerable velocity and cannot "stop on a dime". Thus, in very strong thunderstorms, the most quickly rising air will push the cloud top above the nominal TOC.

t. Have you ever looked at a cloud and wondered whether its colder or warmer inside than out?
   i) In the case of a deep cumulus cloud, depicted on the left hand side of the conditional instability Figure, the answer depends on location within the cloud.
   ii) Between the LCL and the LFC, the rising parcels are colder than their surroundings, despite the release of latent heat of condensation within.
   iii) Therefore, the cloud (which is made up of a set of parcels) is colder as well.
   iv) Between the LFC and TOC, the cloud and its parcels are warmer.
   v) The overshooting top is colder.

u. When the ELR resides between the dry and moist adiabatic rates (as it often does in the troposphere), the environment is said to be **conditionally unstable**. . . conditioned on the presence of water vapor.

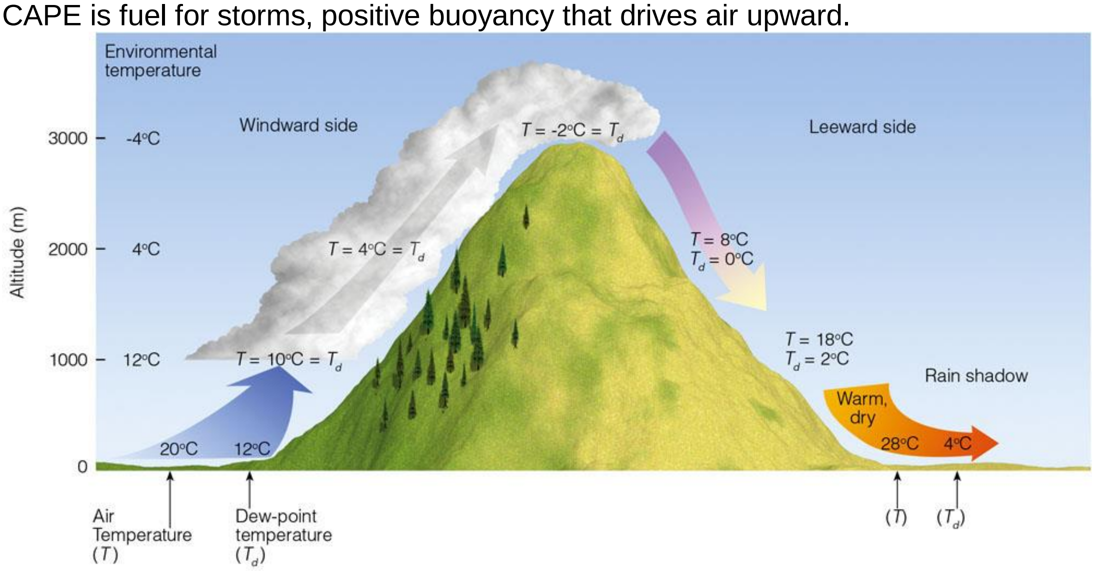
v. A rising sub-saturated parcel would become colder than its surroundings, and want to sink back from whence it came (i.e., **a stable situation**).

w. A rising saturated parcel, however, would become warmer and continue rising (i.e., **an unstable situation**).

x. The situation depicted in the last figure is more common: air starts out sub-saturated (and thus stable) but becomes unstable given sufficient lifting. This means there is sensitivity to the degree of lift, which is often called **meta-stability**.

M. Summary:
   1) We saw that clouds can be beautiful or threatening. They can manipulate light and even make their own.
   2) We familiarized ourselves with some of the descriptive terms we us for these clouds.

3) We made use of the air parcel concept, in which we identify a mass of air and follow it around as its temperature, humidity, and elevation change.
4) How a parcel's temperature changes on ascent depends on whether or not it's saturated.
5) If the parcel is sub-saturated, it cools at the rapid DALR, but we saw that we cannot lift hot, dry air very far at all.
   a. We also saw that we can't make cold air descend very far.
   b. This situation is called "stable", but when the air is saturated, condensation warming partially off sets expansion cooling, resulting is a substantially slower cooling rate, 5°C/km, wet adiabatic lapse rate.
6) The key difference between these 2 rates---the average environmental lapse rate 6.5°C/km fall in between.
7) We can lift hot saturated air a whole lot farther. Water vapor makes the atmosphere a much more interesting and complex place.
8) Temperature in the standard atmosphere decreases with height in the troposphere.
   a. That's the environmental lapse rate, one of our 4 lapse rates.
9) Let's make an air parcel and lift it.
   a. As long as it has moisture, it will saturate on ascent because the air's temperature drops faster than it's dew point.
   b. Once saturated, it will cool more slowly at the wet adiabatic lapse rate, and it might become positively buoyant, given sufficient lift.
   c. But what goes up must come down, if only somewhere else, and some other time.
10) How air comes down, say on the back side of a mountain, depends on how it went up.
   a. Did it keep its condensation?
   b. Did it lose some or all of it to rain or snow?
11) Some days, there's no way to get a storm.
   a. You lack lift.
   b. You don't have the moisture.
   c. You don't have an LFC.
   d. Other days, you do have an LFC, but not enough lift to get air there. On those days, you won't be able to get the convective available potential energy, CAPE, and that's a big forecast problem.
   e. CAPE is fuel for storms, positive buoyancy that drives air upward.



N. Questions:

1) You are driving in your car, and suddenly your windows start fogging up from the inside. Is it better to turn on the defrost heater or the air conditioner?
What does each device do to the car interior's air?

2) On very humid days, we often say the air "feels" heavy. Is moist air denser than dry air at the same temperature? (Hint: Adding water vapor to the air increases the value of the "gas constant" r in the ideal gas law. Remember $P = \rho r T$; where P =pressure, ρ = density, T = Temperature, and r is the gas constant.) Explain.

3) We saw that we have warm air at the ground and bitterly cold air at the tropopause, just a few miles up, and yes, we saw the density decrease with height, and that's why the troposphere is not turning over. But why don't we give some of this warm air to the upper troposphere, and why don't we just grab some of that cold air down and bring it to the surface?

4) How might thunderstorms be different, in intensity and/or depth, if all of the atmosphere's ozone completely and permanently disappeared?

5) You heat a vessel full of water. After is starts boiling, you remove the vessel from the heat and set it aside. After the boiling motion ceases, you dip a metal spoon into the upper layer of the water. The water begins boiling again. Why?

6) What is the difference between a parcel of air that is classified as absolute stable and absolute instable?

7) How are Rotor clouds formed?

8) What is the difference between the wet adiabatic lapse rate (WALR) and the dry adiabatic lapse rate (DALR)? Why?

9) What is the difference between the Lifting condensation Level (LCL) and the Level of free-convection (LFC) for a parcel of air that is classified as conditionally unstable?

10) Why is there a dew point lapse rate? What is it?

11) What are the 4 Lapse Rates in Meteorology?

12) What is the Environmental Lapse Rate (ELR) and how can it be negative?

13) What causes the Equilibrium Level or (Top of the Cloud) layer?

14) What does forced convection mean and why is important?

15) Give 3 reasons why a cloud doesn't release a storm?

16) Why are the winds coming off a leeward side of a mountain range hotter and dryer than the windward side?

17) Where do you find Lenticular clouds?
18) Describe Altocumulas clouds?
19) Describe a Cumulonimbus cloud?
20) Describe a Nimbostratus cloud?