WEATHER STABILITY AND INSTABILITY

Semester – III
CC5: Climatology
Unit II: Atmospheric Phenomena Climatic Classification

Study Material Prepared by
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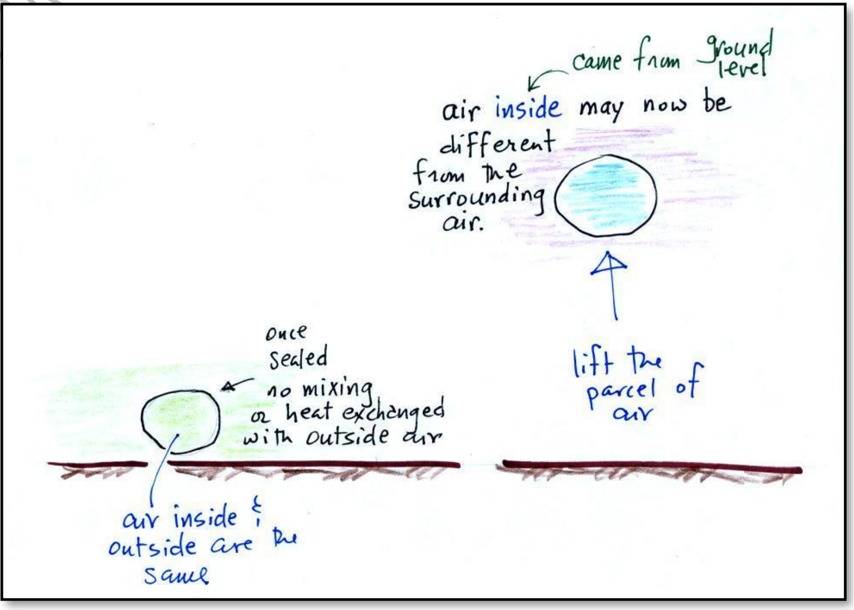
Introduction:

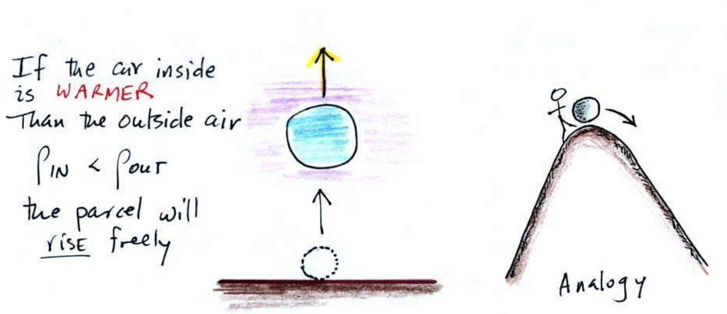
Earlier in this course we learned that stable atmospheric conditions can lead to a build-up of air pollutants. Thunderstorms on the other hand form when the atmosphere is unstable. We are now going to look at this topic in a little more detail. Meteorologists look for situations that might make the atmosphere unstable because this could warn of severe weather.

We'll start with a relatively easy to understand conceptual test that we can perform to determine whether the atmosphere is stable or unstable.

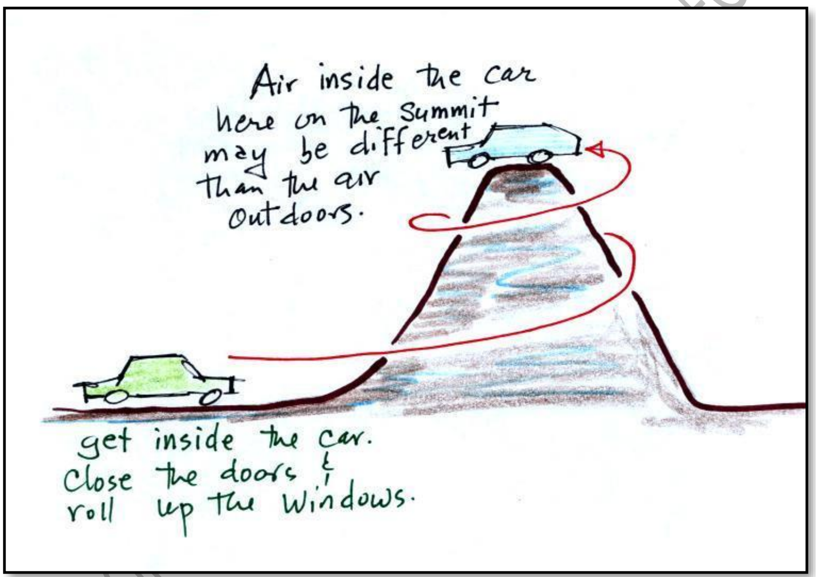


You simply take some air and isolate it in a parcel. At this point the air inside the parcel is exactly the same as the air outside (same temperature, density, and pressure). We'll assume that once the air is sealed in the parcel it can't mix or exchange heat with the surrounding air.

Next you imagine lifting the air. The air parcel will expand and the air in the parcel will cool somewhat. After being lifted, the air inside the parcel may have a different temperature than the surrounding air outside the parcel. This is because the inside the parcel is "insulated" from the surrounding air.

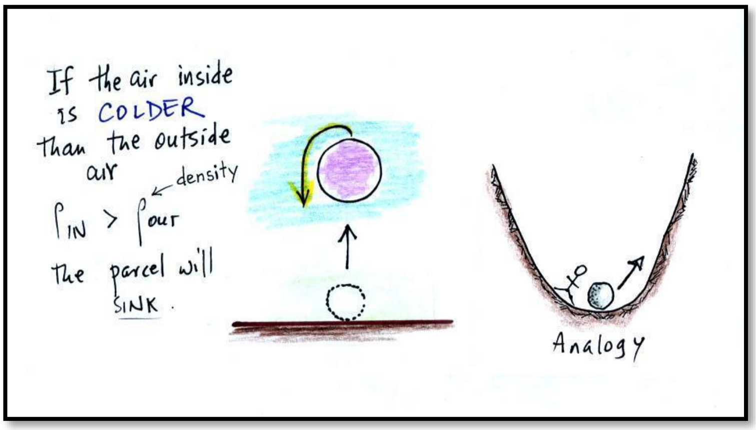


In some ways this is like getting inside an automobile and driving up to the top of a mountain. You might have the heater or maybe the air conditioner running in the car. In either event, once you arrive at the mountain summit the air inside the car would probably have a different temperature than the air outside.



Once we have lifted the air we let go of the parcel and watch to see what happens next. If the air comes back to where it started, the atmosphere is stable. If the air continues to rise the atmosphere is unstable.

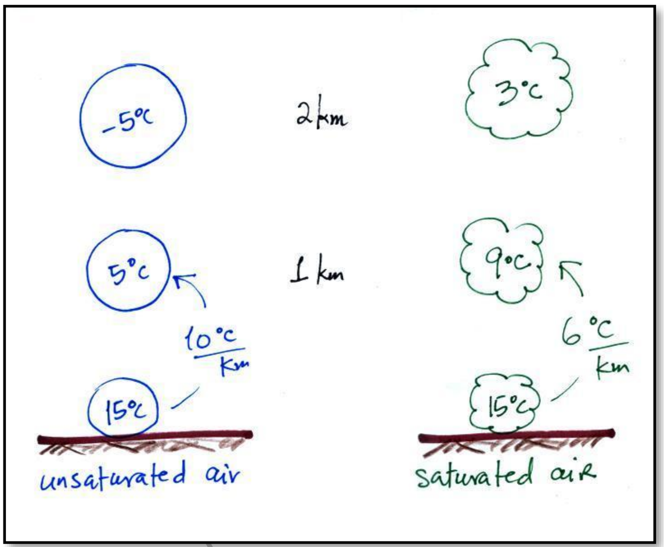
In the figure above the air in the parcel has ended up colder and denser than the surrounding air. In this case the parcel would sink back to the ground.



In the analogy shown above at right you can imagine giving the rock in the picture a shove then watch to see what happens. In the situation shown above the rock would roll part way up the slope but then stop, turn around, and come back down to where it started.

Now the lifted air parcel has found itself warmer and less dense than the surrounding air. It will continue to float upward on its own. This indicates an unstable situation.

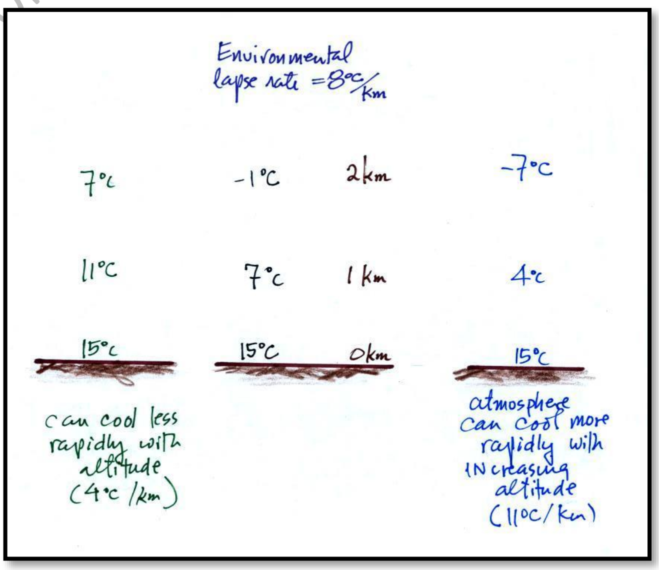
We need a little more information to be able to perform the test described above. First, we need to know how quickly a rising parcel of air will cool.



Unsaturated air (relative humidity less than 100%) always cools at a rate of 10o C/km. This is known as the dry adiabatic lapse rate. The term lapse rate just means rate of decrease with increasing altitude, adiabatic means that heat is not being exchanged between the air inside and outside the parcel.

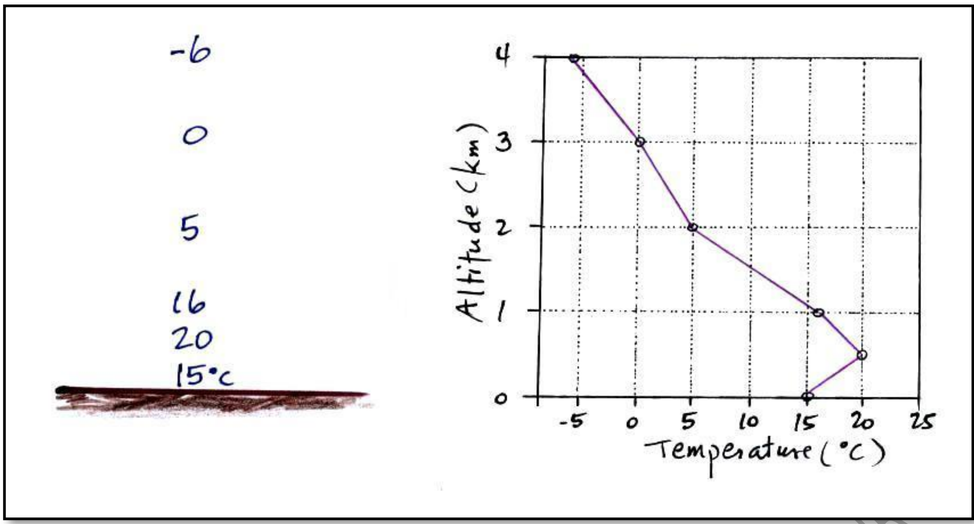
Saturated air cools a little more slowly, we will use an average rate of 6o C/km (the moist adiabatic lapse rate). As saturated air rises, expands, and cools, condensation releases latent heat inside the parcel. The latent heat energy offsets and reduces the cooling due to expansion. There isn't enough latent heat energy to cause the rising parcel to warm.

We also need to know the temperature of the atmosphere at different altitudes above the ground.

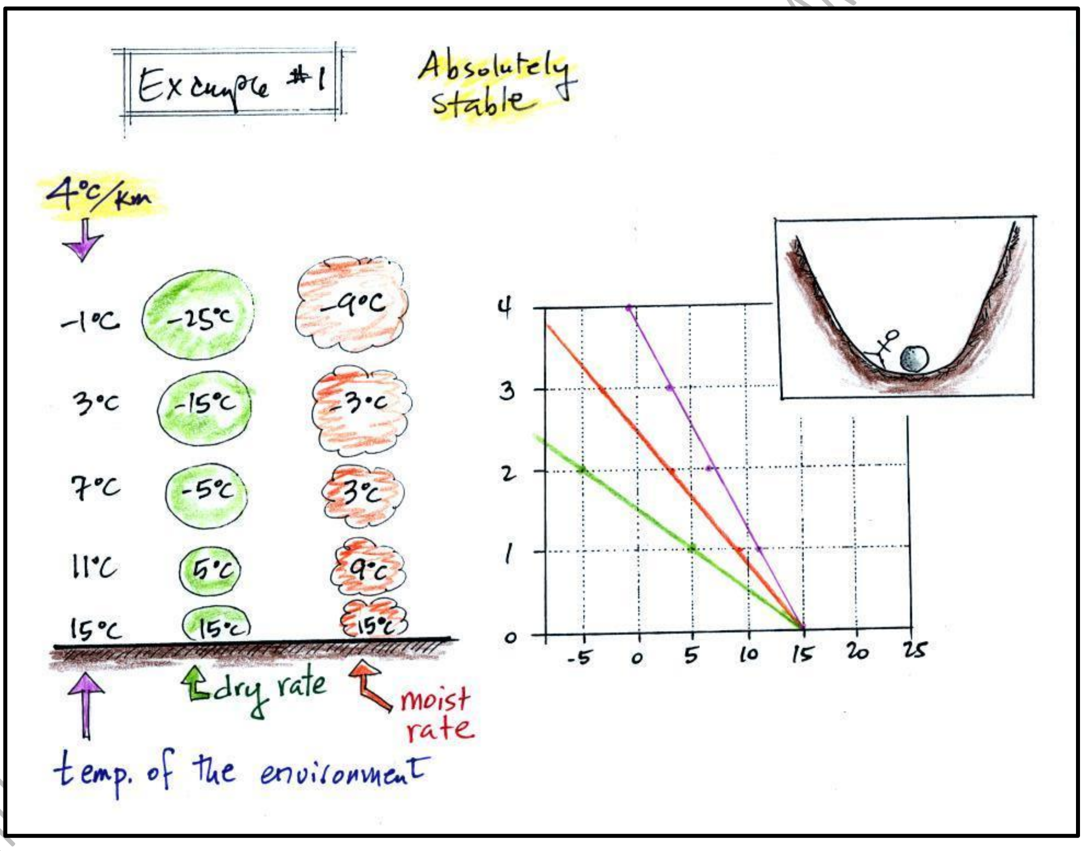


The atmosphere can do just about anything. The middle figure shows temperature decreasing at a rate of 8o C/km (the environmental lapse rate). The left and right examples show the air cooling more slowly and more rapidly, respectively, with increasing altitude.

Usually atmospheric temperature doesn't decrease at a uniform rate as shown above. A more realistic example is shown below.



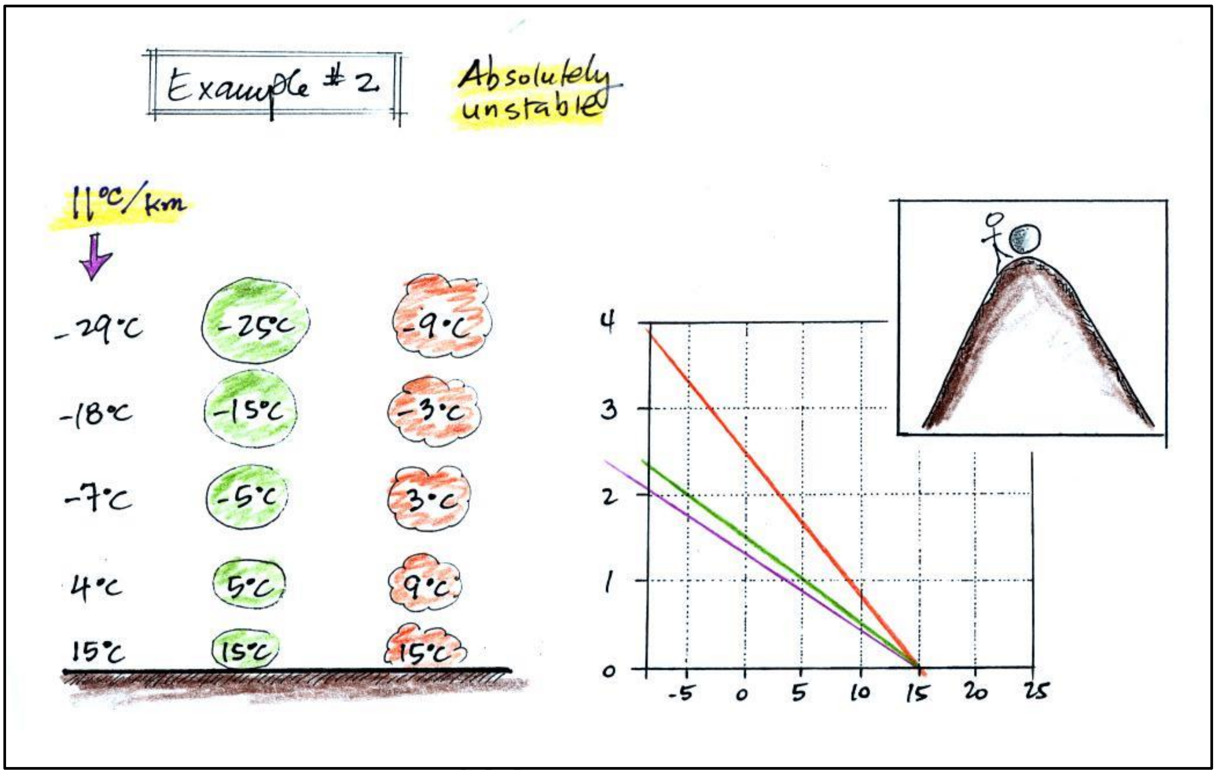
A plot of temperature versus altitude is called a sounding. We now have all the tools we need.



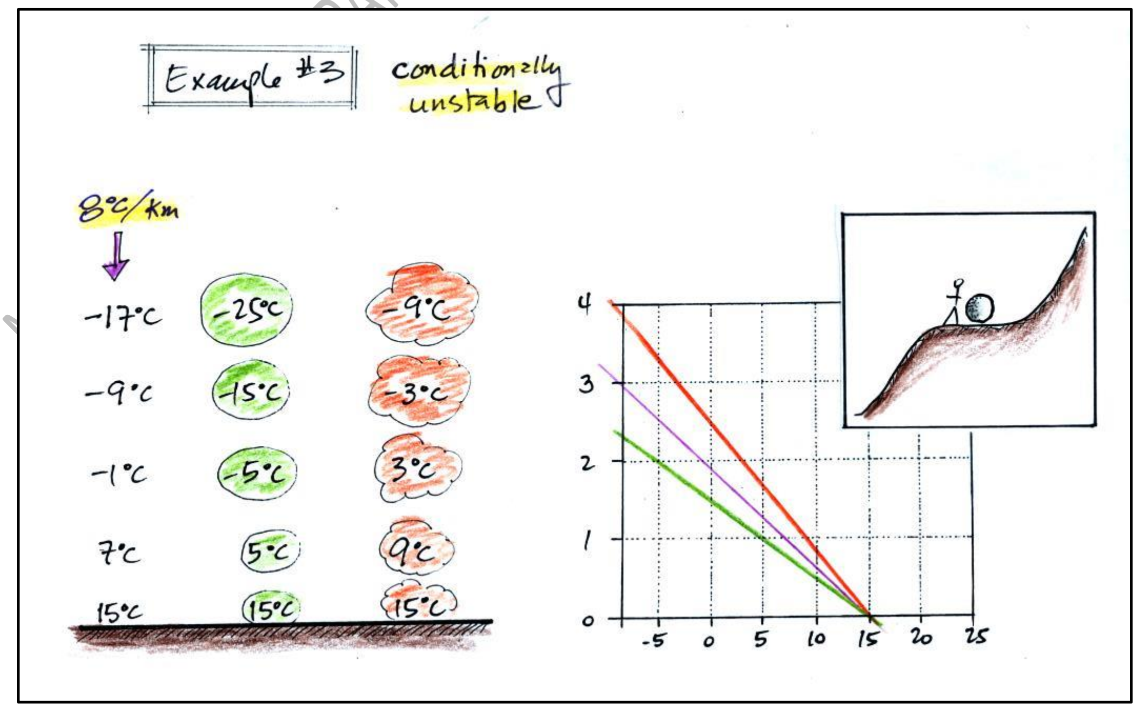
In this first example we assume the environmental lapse rate is 4º C/km. This is shown in the left column of figures in the figure above. The next two columns show the temperature inside rising parcels of unsaturated (green) and saturated (orange) air (they cool at 10º C/km and 6º C/km). The environmental temperatures and the parcel temperatures are also plotted on a graph on the right side of the figure.

The parcel curves (green and red) lie to the left of the purple, environment, curve. Rising parcels of unsaturated or saturated air will both end up colder and denser than the surrounding environmental air. If they are lifted and released, they will sink back to the ground. The atmosphere is absolutely stable in this situation.

We'll change the environmental lapse rate to 11º C/km in Example #2.



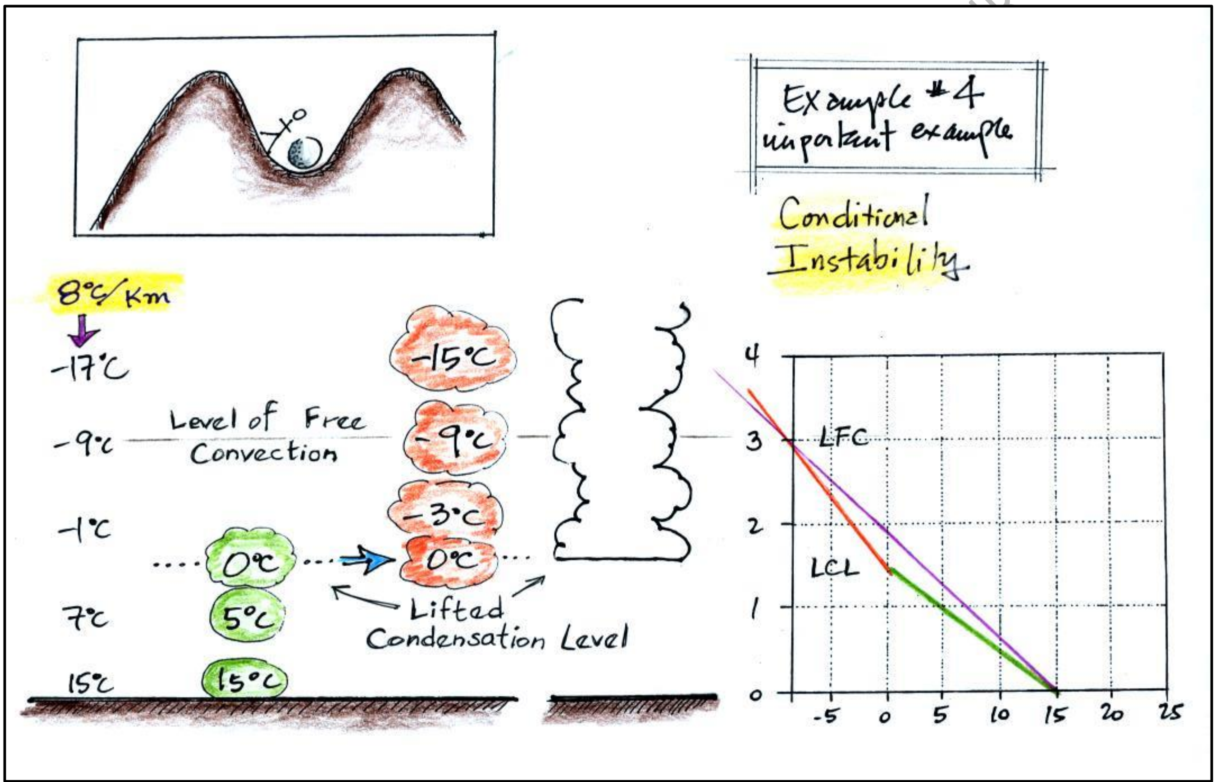
Now, because the atmosphere is cooling so quickly with increasing altitude, lifted parcels of both unsaturated and saturated air end up warmer and less dense than the surrounding



air. Both the orange and green curve lie above and to the right of the purple curve on the graph. When released these parcels will continue to rise on their own. The atmosphere is absolutely unstable in this case.

We'll pick an intermediate value, 8° C/km, for the environmental lapse rate in the next example. The atmosphere is conditionally unstable. A rising parcel of unsaturated air ends up cooler and denser than the surroundings. A parcel of saturated air, which cools at a slower rate, ends up warmer than the air around it. The condition for instability is that the air must be saturated. It was a little harder coming up with a rock/hill analogy in this case. The condition for instability in that case is the direction of the initial push that you give to the rock.

We'll leave the environmental lapse rate the same for the last and most instructive example.



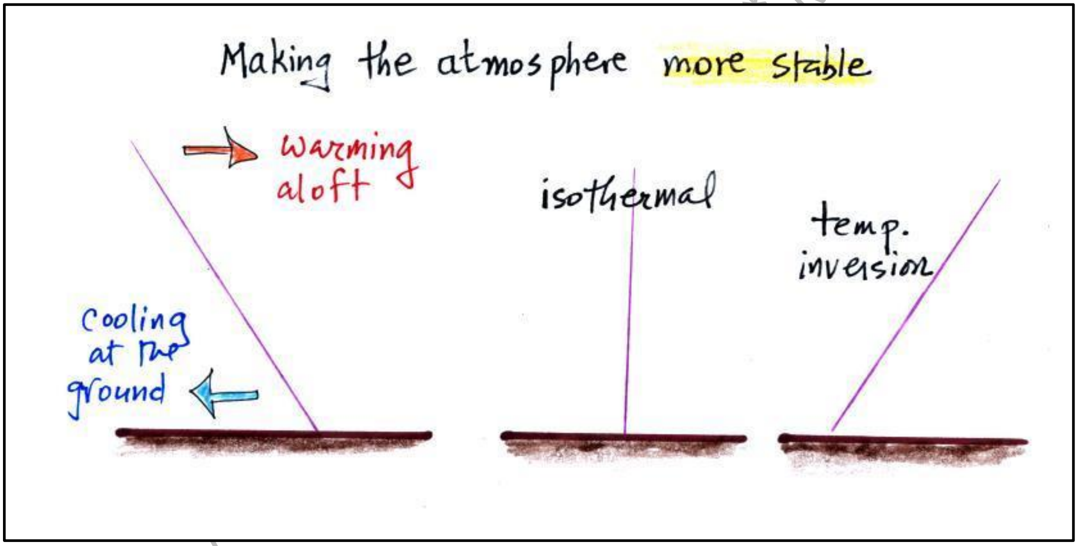
In this case the parcel of air starts out unsaturated. It becomes saturated when lifted to 1.5 km altitude, once it has cooled to a temperature of 0° C. This is called the Lifted Condensation Level (LCL) and you would see cloud begin to form at this point. From that point on upward the rising parcel will cool at the moist adiabatic rate.

Initially the rising parcel is colder and denser than the surrounding air. If the parcel is lifted to 3 km it has the same temperature as the air around it. If lifted above 3 km the parcel air finds itself warmer and less than the air outside. If lifted just a little bit beyond 3 km altitude the parcel will be able to continue to rise on its own. 3 km in this case is the Level of Free Convection (LFC).

The atmosphere is conditionally unstable in this case. A rising parcel must first of all become saturated. Then it must be lifted to and just above the level of free convection.

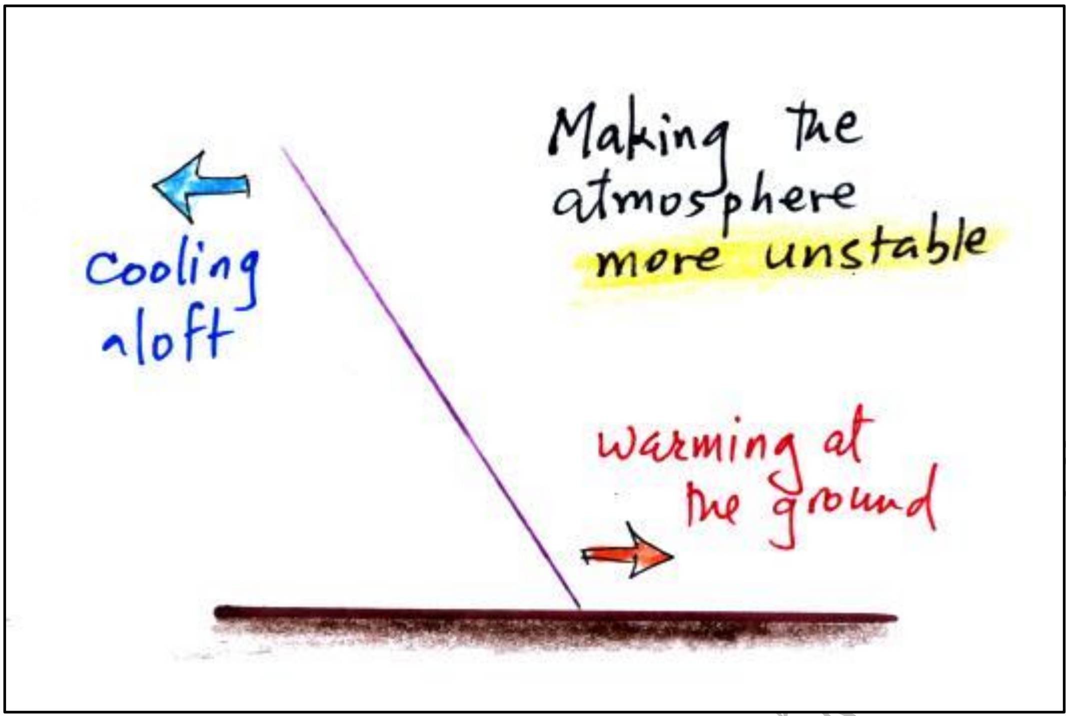
environmental lapse rate	atmospheric stability
less than the MALR (eg. 4° C/km)	absolutely stable
between the DALR & the MALR (eg. 8° C/km)	conditionally unstable
greater than the DALR (eg. 11° C/km)	absolutely unstable

The value of the environmental lapse rate is one of the main factors that determines whether the atmosphere will be stable or unstable.



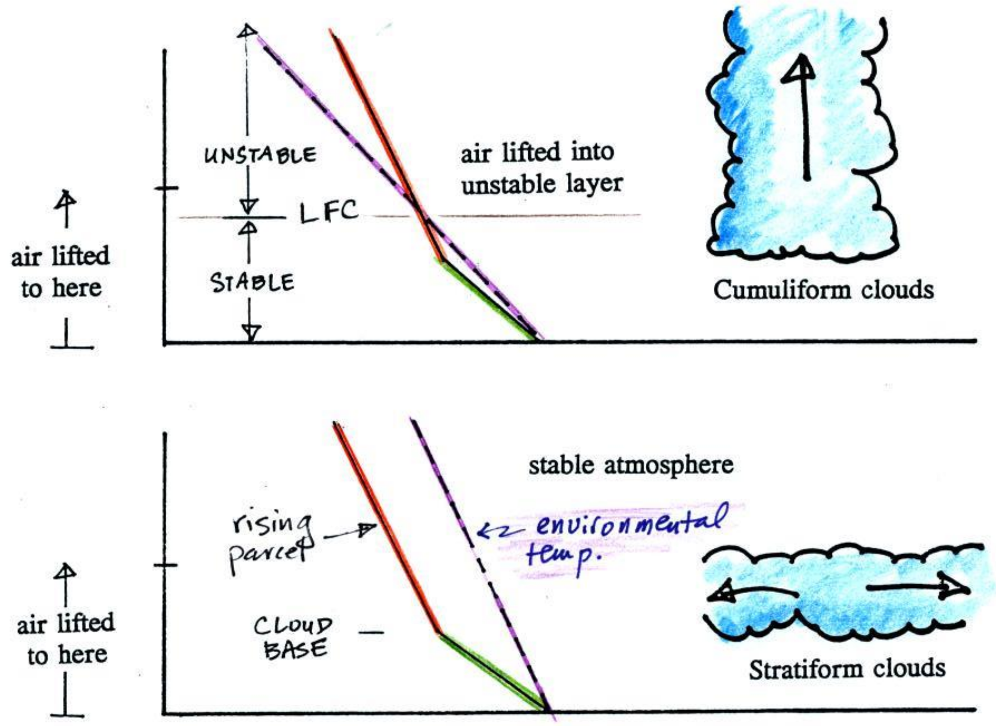
Warming the air above the ground and/or cooling the air next to the ground will make the atmosphere more stable. The ground and the air above it cool during the night. The atmosphere is usually most stable early in the morning.

A temperature inversion represents an extremely stable situation. Rising parcels always cool with increasing altitude (at either the dry or moist rate). In an inversion the surrounding air gets warmer and warmer with altitude. The difference between the cold parcel air and the warmer surroudings gets larger and larger with increasing altitude.



Sunlight warms the ground and the air next to it during the day. This steepens the environmental lapse rate and makes the atmosphere more unstable. Cooling air above the ground has the same effect.

One last figure before we leave this topic. The figure shows the different types of clouds that form in stable and conditionally unstable conditions.



The violet curve shows the environmental temperatures as a function of altitude. The other curve the temperature of a rising parcel of moist air. The rising parcel starts out unsaturated and follows the green portion of the curve. Once it becomes saturated it begins cooling at the moist rate and follows the orange line.

The top figure shows a conditionally unstable situation. Because the parcel is lifted above the Level of Free Convection (LFC) it is able to continue rising on its own and develops into cumuliform cloud (perhaps a thunderstorm).

The air in the lifted parcel does become saturated but never becomes warmer than the surrounding air. The parcel won't go any higher than it is lifted. Stratiform clouds tend to form under these conditions.

Important Questions:

1. **What is Stability?**
2. **Briefly discuss about the different factor of stability.**
3. **What is Instability?**
4. **What is NLR?**
5. **What is ELR?**
6. **What is DALR?**
7. **What is WALR/MALR?**

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