Lightning in the Peaks: Lapse Rates and Stability

ⓘ This is a preview of the published version of the quiz

Started: May 18 at 4:34pm

Quiz Instructions

As the heated air rises off the surface, it cools according to temperature lapse rates.

These lapse rates are simply the rate that temperature changes with height in the atmosphere. You may have worked with these lapse rates in the previous labs this semester, but below you can find a description of the lapse rates used in this lab.

Dry Adiabatic Lapse Rate – imagine filling a giant balloon filled with air at the surface, and then you drag the balloon up into the atmosphere. The balloon will expand because of lower air pressure, and the molecules inside the balloon will be further apart. This results in cooling at a lapse rate of about 10 ˚C per 1000 meters when the air is “dry” (no clouds).

Moist (wet) Adiabatic Lapse Rate – imagine that your rising giant balloon cooled enough to reach the dew point (the temperature when the water vapor in the atmosphere condenses and starts to form cloud droplets). When condensation occurs, heat is released (latent heat of about 580 calories per gram of water). This latent heat release slightly offsets the dry adiabatic cooling from expansion, and so the temperature change is a bit less. Just how much less depends on how much water is condensing.

This first question looks specifically at the lifted condensation level (LCL). This is the height that the air parcel is cooled dry adiabatically to dew point. This height in the atmosphere is the lowest possible height with the present conditions that clouds could form. You calculate this height by taking your starting temperature and lifting it up into the atmosphere. When the parcel rises, it will cool adiabatically as it expands. First, at the dry adiabatic lapse rate if it is warmer than dew point, and then change to the wet adiabatic lapse rate at the LCL, as condensation begins and clouds form.

EXAMPLE QUESTION
Fast travel to Flagstaff (35.1983 N , -111.6513 W) . With a dew point of 9.5^{o}C, what is the height of the lifted condensation level and air temperature 3000m above the surface if the air there is lifted adiabatically?

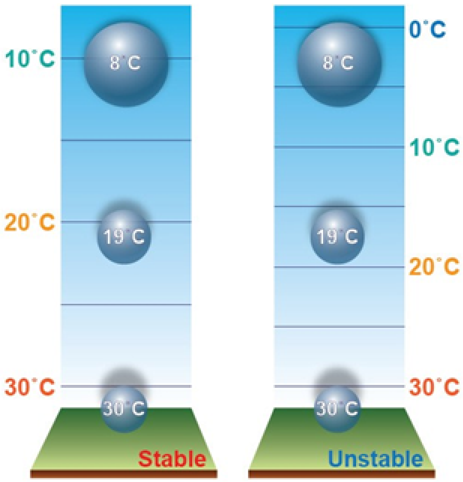
In this example, the air parcel starts above dew point, so you use the dry adiabatic lapse rate of 10^{o}C per 1000m or 5^{o}C per 500m. By cooling at this rate, the air parcel reaches dew point (9.5oC) at 3565 meters. This is the lifted condensation level. Now, since the parcel has reached dew point, the air parcel will cool at the wet adiabatic lapse rate, as clouds (condensation) is occurring. When this condensation occurs, some extra heat is transferred into the air temperature from this phase change from gas to a liquid. Above this height, the parcel is forming clouds, and cooling at 3^{o}C/500m.

HEIGHT (500m)	*Parcel*
5065m	3.5 – 3 = 0.5^{o}C
4565m	6.5 – 3 = 3.5^{o}C
4065m	9.5-3 = 6.5^{o}C
3565m	14.5 -5 =9.5^{o}C **LCL**
3065m	19.5-5 = 14.5^{o}C
2565m	24.5 – 5- 19.5^{o}C
2065m (START)	24.5^{o}C

ANSWER: The LCL occurs at 3565 meters and the air temperature is 0.5^{o}C 3000m above Flagstaff. That is the lowest point that clouds can possibly form.
Try to imagine the impact that different humidity would have on this example. In drier circumstances, where would the LCL be?

The second part of this question looks at atmospheric stability. Depending on the air temperature that the air parcel finds itself rising into, the air parcel will either continue to rise, stagnate, or sink back towards the surface. For this lab, we will primarily just be focusing on stable or unstable environments.

If an air parcel is warmer than the surround environmental air temperature, it is described as unstable. Think of this like a hot air balloon on a cool morning. Warm air is less dense and more buoyant than cold air, so the air parcel (or hot air balloon) rises quickly up into the air. This allows the air parcel to continue to cool until it reaches dew point and form clouds.



If an air parcel is cooler than the surrounding environmental air temperature, it is described as stable. The air is denser, and less buoyant than the surrounding air, and it will tend to sink back towards the surface. This type of environment leads to sunny skies, as the air parcels cannot continue to rise and reach dew point to form clouds.

The clouds that form as a result of atmospheric stability are directly linked with the amount of moisture found in the atmosphere. The air is more likely to be stable if the dew point is lower, leading to less heat through condensation in the air parcel. This stable atmosphere is more likely in the pre-monsoon months of May and June, while unstable and conditionally unstable conditions occur when more moisture is present in the atmosphere. That is because both the dew point, as well as the environmental lapse rate change as summer progresses.

You can see an example of the stability conditions below for a lapse rate parcel location calculated from the example above. You'll have your own environmental lapse rate and location to consider when making your own calculations. But you will have to make the same selection. You will have to pick whether A or B is the environmental condition that will be the most favorable for thunderstorm formation.

HEIGHT (500m)	*Parcel*	*Environment A*	*Environment B*
5065m	0.5°C	1°C	-11.5°C
4565m	3.5°C	5°C	-5.5°C
4065m	6.5°C	9°C	0.5°C
3565m	9.5°C **LCL**	13°C	6.5°C
3065m	14.5°C	17°C	12.5°C
2565m	19.5°C	21°C	18.5°C
2065m (START)	24.5°C	-	-
Condition	-	**STABLE**	**UNSTABLE**

In Environment A, the parcel is always cooler than the surrounding air, so it is likely to sink and be stable. Environment B has air constantly cooler than the parcel, so the air will rise, becoming unstable, and reaching the lifting condensation level (LCL) at 3565 meters when it reaches dew point.

The parcel is warmer than the environment AT ALL HEIGHTS, thus unstable, in Environment B.

Question 1

5 pts

Step 1:

Fast travel to a relatively flat location out in the eastern edges of Flagstaff (35.1983 N , -111.6513 W). Observe the air temperature at that location, and you should hopefully also observe a cluster of lightning as well.

Your goal is to determine the correct atmospheric conditions necessary to have produced a strong convective thunderstorm above this spot, leading to the cluster of lightning observed at the location.

To start, let's find the temperature of the air parcel if it is lifted adiabatically from its starting position, up to 6100m if t**he dew point for this location is 13.5C.**

Fill in the atmospheric lapse rate chart below, make sure you use the correct dry (10C/km or 5C/500m) or wet (6C/km or 3C/500m) adiabatic lapse rate.

Height (500m)	Parcel
6100m	Air Temperature End [Select]
5600m	
5100m	
4600m	
4100m	

3600m	
3100m	
2600m	
2100m	Air Temperature Start: [Select]

Step 2:
From the table above, determine the lifted condensation level (the elevation that the dew point occurred). This height is the lowest place for clouds to form, and means that the air parcel will be cooling at the wet adiabatic lapse rate, instead of the dry adiabatic lapse rate.

Lifted Condensation Level: [Select]

Step 3:
Now, compare your temperature values from the previous table, and figure out what environmental temperature conditions below would best support an unstable air mass and lightning at your location in the geovisualization.

Environment favorable for forming a thunderstorm: [Select]

Height	*Environment A*	*Environment B*
6100m	-6.5	0
5600m	-3	3
5100m	0.5	6
4600m	4	9
4100m	7.5	12
3600m	11	15
3100m	14.5	18
2600m	18	21
2100m	-	-

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