Stability and Cloud Formation

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1 Introduction

Clouds are everyday phenomena that hold a surprising amount of complexity. Ranging from fluffy and thick, to wispy as hair, to flat expanses of gray, each shape can tell you something about the atmosphere that formed it. They can also indicate if there's good or bad weather ahead! But what drives the formation of these ubiquitous structures? Read on to find out.

2 What Causes Weather?

Weather is the condition of the atmosphere at a certain place at a certain time. It encompasses temperature, precipitation, cloud cover, as well as less obvious variables - humidity, for example, plays a large role in weather. Weather varies and shifts from place to place, constantly changing. However, what exactly causes these changes?

2.1 Uneven heating*

The most basic answer to this question is the sun. The atmosphere is a system, and any system needs an energy source to avoid succumbing to entropy. Regarding this one, the shortwave radiation of the sun's light is what maintains the constant change. However, due to the uneven heating of the earth, there are differences in weather.

Different materials need different amounts of energy to change temperature - this is why metal benches get really hot in the summer, while wooden ones remain comparatively cool. The amount of energy needed to raise one gram of a substance one degree Celsius is called the **specific heat**. Oceans heat up a lot slower than continents because water has a higher specific heat than land.

This is important because the air above the planet's surface is almost entirely heated by the ground below it. Incoming solar insolation is largely in the form of shortwave radiation (with shorter wavelengths and higher energy, such as visible, ultraviolet, etc.), which passes through the atmosphere without being absorbed. Once it's taken in by the land or ocean, though, the energy is reradiated in the form of longwave radiation (with longer wavelengths and lower energy, such as infrared) - which can be transferred into the surrounding air.

Additionally, sunlight hits different parts of the Earth at different angles. Closer to the equator, the rays become more perpendicular to the ground, maximizing radiation per unit area and therefore increasing the temperature.

The closer to the equator and the more land beneath it, the hotter an air mass will get.

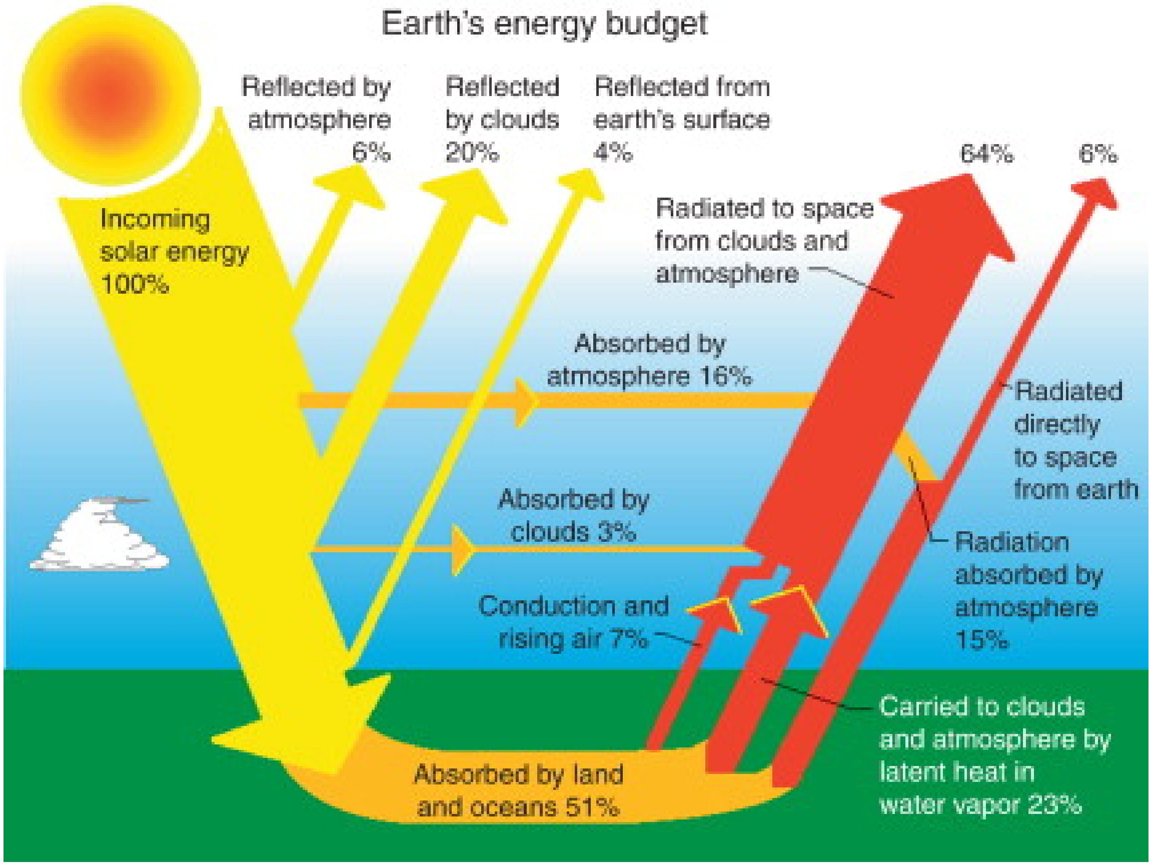

Figure 1: Absorption of the sun's energy (Credit: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/radiation-balance)

2.2 Temperature*

The temperature of an air parcel is important because it determines how the air moves. Warm air rises, as higher temperatures mean higher rates of movement in the molecules that make up the air itself. This makes the air spread out, expand, and become less dense than cooler air.

Conversely, cold air sinks, because the movements of the molecules slow, causing the air to become denser and sink underneath warmer air. A convection cell, in regards to weather, is a system where air is heated near the surface of the Earth, rises to sufficient altitude, is cooled by the decreasing temperatures, and falls back to the ground to be heated again. Where the air is heated and rising becomes what is called a **surface low**, as there is air flowing away from the area. The area of sinking air is then, appropriately, a **surface high**, as there is air flowing towards the area.

As air flows from areas of high pressure to an adjacent low-pressure zone, the high generates a downward vertical movement to compensate for the losing air. Similarly, there will also be an upward movement at the ground-level low. In this way, the air cycles up and down and back up again. Because of the verticle movement powered by the pressure gradient, low pressures at ground level correspond to warm, rising air, which in turn correspond to clouds and bad weather. Inversely, high pressures are associated with cool, sinking air, meaning clear skies and stable atmosphere.

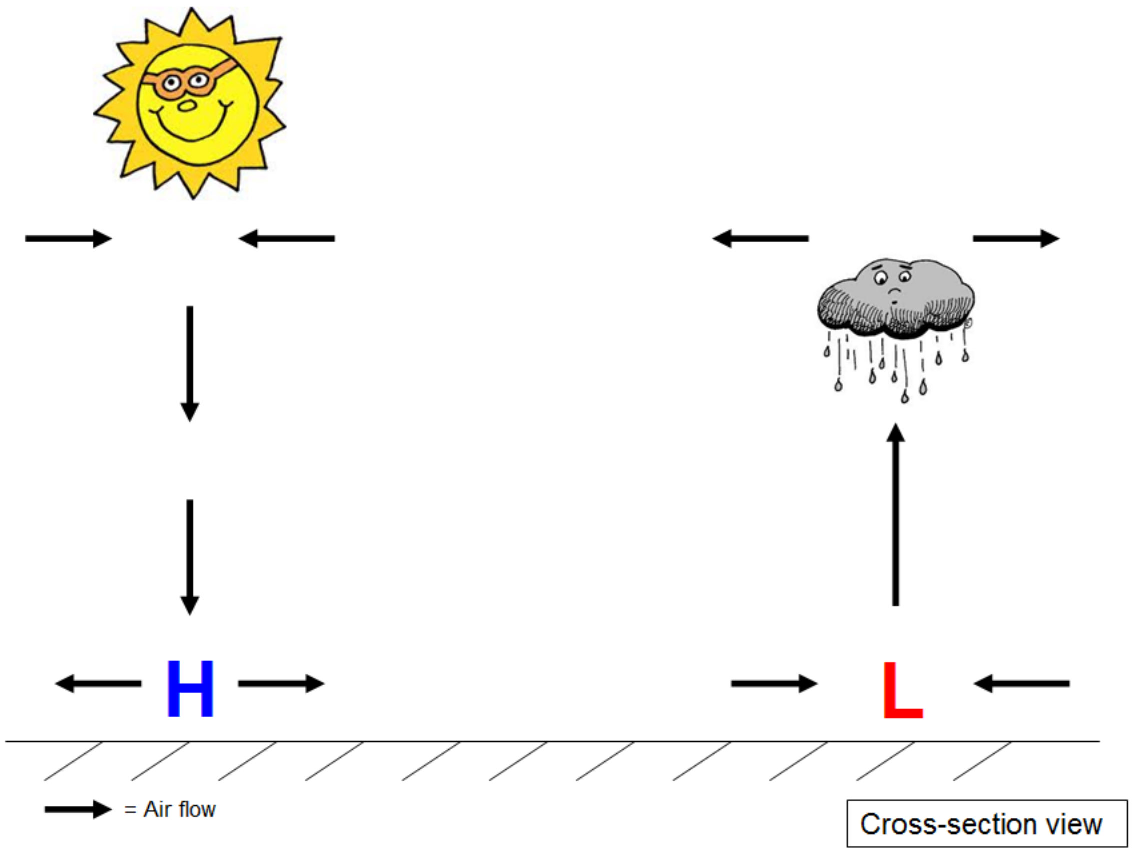

Figure 2: Weather at surface highs and lows (Credit: https://weatherworksinc.com/news/high-low-pressure)

2.3 Humidity*

Humidity is also a factor controlling our weather. Air can only hold so much water vapor. If it is oversaturated, the water can start condensing out, forming the tiny droplets that make up clouds and the larger drops of precipitation. Clouds are made of tiny droplets of water and tiny flakes of ice, which came from evaporated and condensed water. **Cold air holds less water than warm air**; this is why clouds are usually at very high altitudes. This is also why surface lows cause clouds, while highs don't. The rising warm air cools in the upper atmosphere, meaning it can hold less moisture. As the air reaches saturation, condensation occurs and may become a cloud. Sinking air, however, warms as it nears the surface. This means it can actually hold more moisture, so it is unlikely to form any clouds.

Clouds that touch the ground are referred to as fog. Fog occurs often when there is an extremely high amount of water in the atmosphere or when it gets too cold at the surface for water to stay in the air parcel.

*These sections are also covered in Air Masses and Fronts - some of the text there is reused in this handout. Only simple and common cases are discussed here but there may be other conditions of cloud or fog formation.

3 Adiabatic Process

The adiabatic process refers to the heating or cooling of an air parcel without releasing or absorbing heat from its surroundings. This kind of heating and cooling is different from the kind over a stove or in the refrigerator. It is caused by differences in pressures, and can create a variety of interesting meteorological effects.

3.1 What is adiabatic heating and cooling?

When a parcel of air rises, it spreads out. This leads to less interaction between the particles, meaning the air cools in a process called adiabatic cooling. In ideal conditions, the only thing cooling a rising air mass is the adiabatic process. However, in real life, the air at high altitudes is very cold and the air is continuously losing heat to its surroundings.

The inverse applies with adiabatic warming. When air is put under more pressure, the air molecules start to interact more, meaning the air heats up. In this way, a wind going up and down a mountain is going to cool then warm as it rushes down the other side.

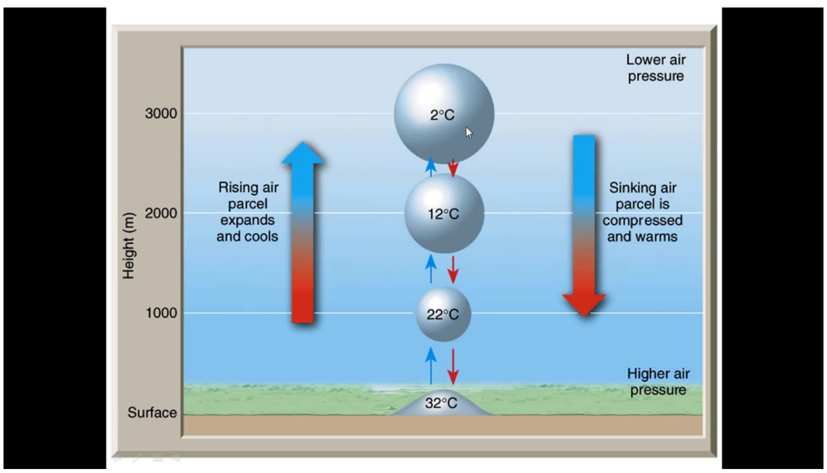

Figure 3: Adiabatic heating and cooling (https://www.youtube.com/watch?v=nS5ReAWncHc)

3.1.1 Rain-shadow effect

On mountain ranges near the sea, it is easily seen that the side of the mountains facing the ocean gets more rain than the other side. This is due to the aforementioned adiabatic process - when moisture-laden air rushes inland from the sea, it is forced upwards by the geography where it cools and condenses into rain.

Therefore, the side facing the sea, or “windward side,” is cool and humid. However, after the air mass summits the peak, it begins to fall down the mountain under the influence of gravity. This air, having condensed all its moisture out, no longer precipitates. Additionally, the compression of the mass after returning to normal pressure means the air mass also it heats up, making the side opposite the sea, or the ”leeward side,” hot and dry.

Chinook winds are another way of referring to downslope-flowing, hot, dry air on the leeward side of a mountain.

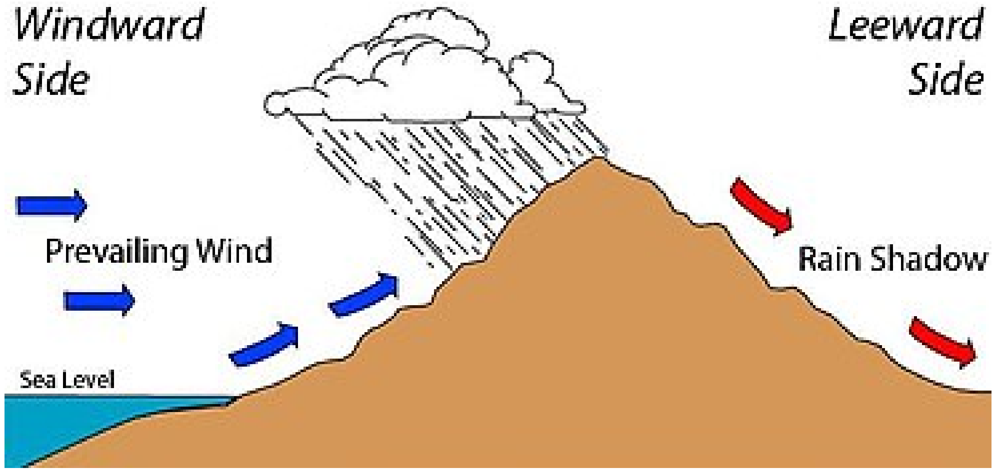

Figure 4: The rain shadow effect (https://en.wikipedia.org/wiki/Rain$_{s}hadow$)

Practice 3.1 (USESO Open Exams 2021, Section I Q23) Oftentimes,a sudden warm wind may descend from mountains and evaporate up to a foot of snow in less than a day, leading to their nickname,"snow eaters. "Why do Chinook winds such as "snow eaters" lead to a sudden increase in temperature?

(A) A chinook wind travels long distances over desert areas, retaining heat, before being diverted into cooler areas nearby.

(B) A chinook wind warms through adiabatic heating after travelling over and descending from a mountain.

(C) A chinook wind gains moisture after travelling over a body of water, leading to an increased environmental lapse rate that warms the wind.

(D) A chinook wind follows a warm front, bringing heat to previously cold areas.

Solutions or Suggested Answer:
B. Chinook winds are a type of foehn wind, which are descending winds that warm due to adiabatic compression (and hence,warming).

4 Lapse rates

4.1 What is a dew point?

In previous sections, we have mentioned that air can only hold a certain amount of moisture. At a certain point, the water will have to condense out, as it can no longer remain in the atmosphere. The dew point is the temperature at which this condensation of water will begin.

Figuring out the dew point is important for both humidity reasons and for cloud altitude calculations. Let's investigate how to measure humidity.

4.1.1 Dry/wet bulb temperature

This process involves two thermometers, one normal, one with a wet cloth wrapped around its bulb. The energy taken by evaporation cools the wet cloth to a temperature lower than that of ambient air. The drier the air, the lower the temperature recorded by the wet bulb thermometer. However, the wetter the air, the less difference there is as less water can evaporate. To the extent that the dry bulb (ambient air) temperature is equal to the wet bulb temperature, it indicates no evaporation on the wet bulb and that the air mass is at the dew point.

You find a dew point by subtracting the wet-bulb temperature from the dry-bulb temperature, then using a chart to find the % relative humidity (the percent of the maximum amount of water the air can hold that is currently occupied.) Then, plug that number into a dew point chart, along with the air temperature, to find the value of the dew point.

The appropriate charts are listed below.

Relative Humidity (%)

Dry-Bulb Temperature (°C)	Difference Between Wet-Bulb and Dry-Bulb Temperatures (C°)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
−20	100	28														
−18	100	40														
−16	100	48														
−14	100	55	11													
−12	100	61	23													
−10	100	66	33													
−8	100	71	41	13												
−6	100	73	48	20												
−4	100	77	54	32	11											
−2	100	79	58	37	20	1										
0	100	81	63	45	28	11										
2	100	83	67	51	36	20	6									
4	100	85	70	56	42	27	14									
6	100	86	72	59	46	35	22	10								
8	100	87	74	62	51	39	28	17	6							
10	100	88	76	65	54	43	33	24	13	4						
12	100	88	78	67	57	48	38	28	19	10	2					
14	100	89	79	69	60	50	41	33	25	16	8	1				
16	100	90	80	71	62	54	45	37	29	21	14	7	1			
18	100	91	81	72	64	56	48	40	33	26	19	12	6			
20	100	91	82	74	66	58	51	44	36	30	23	17	11	5		
22	100	92	83	75	68	60	53	46	40	33	27	21	15	10	4	
24	100	92	84	76	69	62	55	49	42	36	30	25	20	14	9	4
26	100	92	85	77	70	64	57	51	45	39	34	28	23	18	13	9
28	100	93	86	78	71	65	59	53	47	42	36	31	26	21	17	12
30	100	93	86	79	72	66	61	55	49	44	39	34	29	25	20	16

Figure 5: A relative humidity chart (https://en.wikipedia.org/wiki/Rain$_s$*hadow*)

Dew-point Temperatures (°C)

Dry-Bulb Temperature (°C)	Difference Between Wet-Bulb and Dry-Bulb Temperatures (°C)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
–20	–20	–33														
–18	–18	–28														
–16	–16	–24														
–14	–14	–21	–36													
–12	–12	–18	–28													
–10	–10	–14	–22													
–8	–8	–12	–18	–29												
–6	–6	–10	–14	–22												
–4	–4	–7	–12	–17	–29											
–2	–2	–5	–8	–13	–20											
0	0	–3	–6	–9	–15	–24										
2	2	–1	–3	–6	–11	–17										
4	4	1	–1	–4	–7	–11	–19									
6	6	4	1	–1	–4	–7	–13	–21								
8	8	6	3	1	–2	–5	–9	–14								
10	10	8	6	4	1	–2	–5	–9	–14	–28						
12	12	10	8	6	4	1	–2	–5	–9	–16						
14	14	12	11	9	6	4	1	–2	–5	–10	–17					
16	16	14	13	11	9	7	4	1	–1	–6	–10	–17				
18	18	16	15	13	11	9	7	4	2	–2	–5	–10	–19			
20	20	19	17	15	14	12	10	7	4	2	–2	–5	–10	–19		
22	22	21	19	17	16	14	12	10	8	5	3	–1	–5	–10	–19	
24	24	23	21	20	18	16	14	12	10	8	6	2	–1	–5	–10	–18
26	26	25	23	22	20	18	17	15	13	11	9	6	3	0	–4	–9
28	28	27	25	24	22	21	19	17	16	14	11	9	7	4	1	–3
30	30	29	27	26	24	23	21	19	18	16	14	12	10	8	5	1

Figure 6: A dew point chart
(http://eaglecoatings.com/products/thermal/supertherm/dewpoint-chart/)

4.1.2 Types of lapse rates

The most important thing governing the movement of an air mass, and therefore the weather, is temperature. However, temperatures are constantly changing, and at different rates. Recall that the specific heat of water is greater than that of land; it is greater than that of air, too. Therefore, humid air cools down slower than dry air. Additionally, the rate of cooling and temperature of an air parcel can differ from the environment around it.

There is yet another complication when considering temperatures and air masses. As you can see from the chart above, the dew point is a function of temperature and humidity. This also means that as an air mass ascends, the dew point will change, as the mass cools both adiabatically and from heat loss.

In order to resolve all of these variables, as well as finding out when and where an air mass will reach the dew point, lapse rates are needed.

A **lapse rate** is the change in temperature with respect to height in the atmosphere. There are different kinds of lapse rates, all dealing with different types of air conditions. The four most common are as follows.

- DALR
  - The dry adiabatic lapse rate, or the lapse rate for a parcel of "dry air." Dry air is defined as an air mass that has not reached the dew point; any parcel that fits this description cools by at this lapse rate, regardless of original humidity. The DALR is equal to 9.8°C per km. This means a dry air mass will cool 9.8°C for every kilometer it ascends.
- MALR

- The moist adiabatic lapse rate, where "moist" refers to air parcels that are saturated, or in other words, at or below its dew point temperature. The MALR is usually equal to around 5°C per km. This means a moist air mass will typically cool 5°C for every kilometer it ascends. Notice how the MALR is less than the DALR - this is because the water in the air mass needs a lot of energy to change temperature, resulting in a slower cooling rate.

- ELR
  - The environmental lapse rate, or the rate at which the ambient air (**not a vertically moving air parcel**) cools with altitude. The average ELR is at around 6.5°C per kilometer, though usually you will be given a value by the problem. This means that typically the environment will cool 6.5°C every kilometer you ascend.

- DPLR
  - The dew point lapse rate. As its calculation depends on the air temperature, it too will change with altitude. (See the previous chart.) As an air mass ascends, the dew point will change for about 2°C/km, described as the average DPLR. Though like the ELR, the problem will likely specify a value.

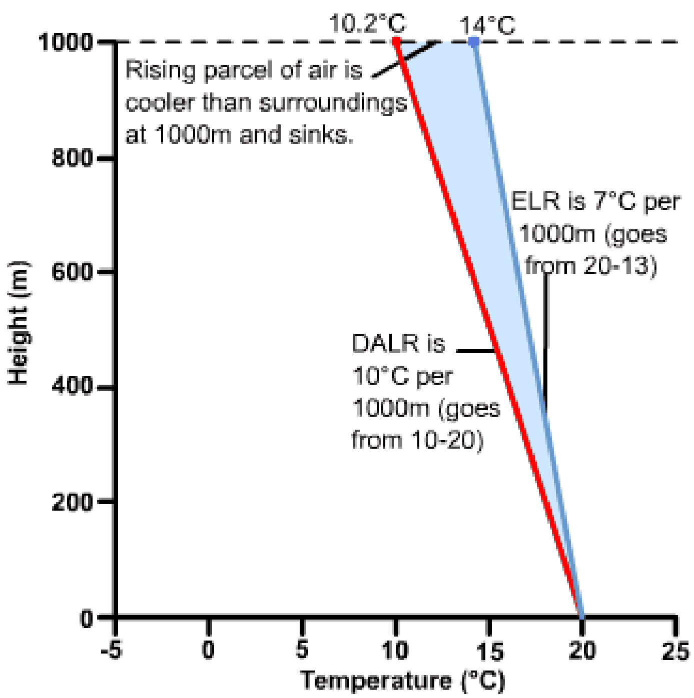

Figure 7: A relative humidity chart (https://s-cool.co.uk/a-level/geography/weather-conditions/revise-it/lapse-rates-and-microclimate)

If given a problem with the ELR, DALR, WALR, and DPLR, as well as their surface-level values, and asked to solve for the cloud base, simply format each variable as an y = mx + b equation. The x in this context is the kilometers ascended, while the y is the value of the variable's temperature.

Then, calculate where the DALR and DPLR lines intersect. This is where the air mass rises sufficiently to cool to the dew point. Only when an air mass is saturated can it begin to form clouds; the altitude at which the mass first hits the dew point is the lowest possible region of cloud formation.

For example, if given an original parcel temperature of 20 degrees C and a DALR of 10oC per km, as well as a dew point of 14oC at sea level and an DPLR of 2oC per km, you would format the DALR line as the equation y = -10x + 20. The DPLR, similarly, is formatted as y = -2x + 14.

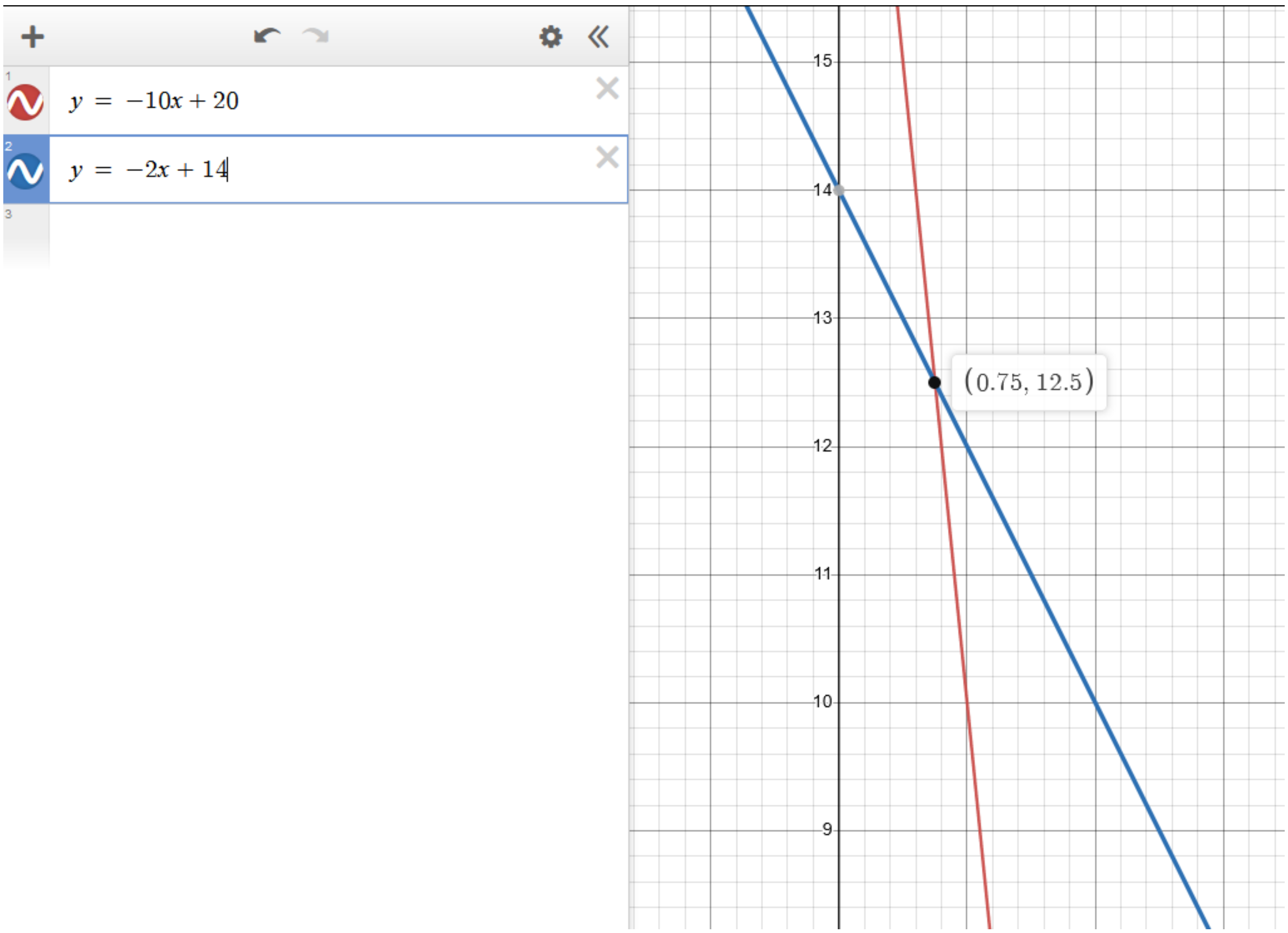

Figure 8: The intersection of two lapse rates

In this scenario, the cloud base is at 0.75 kilometers, where both the air mass' and the dew point temperature is 12.5oC. Though it is solved graphically, an algebraic solution will work similarly.

Practice 4.1 (USESO Training Camp Exams 2022, Atmosphere Section I Q2)
A parcel of air starts at sea level with a temperature of 26°C and a dew point of 14°C. The environmental lapse rate is 8°C/km with a temperature of 28°C at sea level. At what height would the parcel need to be raised to become unstable?
Assume a dry adiabatic lapse rate (DALR) of 10°C/km, wet adiabatic lapse rate (WALR) of 6°C/km and dew point lapse rate (DLR) of 2°C/km.
(A) 1.5 km.
(B) 3.4 km.
(C) 4.0 km.
(D) It is absolutely stable.
(E) It is already unstable at the surface.

Solutions or Suggested Answer:
C. The air parcel must fulfill two requirements to become unstable: 1) the environmental lapse rate must be greater than the adiabatic lapse rate, and 2) the parcel temperature must be greater than or equal the environmental temperature. This solution demonstrates one approach to finding the minimum elevation that fulfills these requirements.
Because the environmental lapse rate is less than the DALR but greater than the WALR, the atmosphere is conditionally unstable. At the surface, the air parcel is stable by the condition of being unsaturated (notice that the dew point is lower than the parcel temperature — adiabatic cooling follows the DALR and the parcel will be colder than the environment). The parcel becomes saturated at the height at which the parcel temperature reaches the dew point, and thereafter the environmental lapse rate will be lower than the adiabatic lapse rate following the WALR. To find this height Ha, we equate expressions for the dew point and parcel temperature at Ha:
$26°\text{C} - \text{Ha} \times 10°\text{C/km} = 14°\text{C} - \text{Ha} \times 2°\text{C/km}$
$\text{Ha} = 1.5$ km.
The first requirement has been fulfilled, but at 1.5km the parcel temperature (11°C) is still less than the surroundings (16°C). To find the additional height Hb that the parcel must be raised, we equate expressions for the parcel temperature (now cooling at the WALR) and environmental temperature at Hb:
$11°\text{C} - \text{Hb} \times 6°\text{C/km} = 16°\text{C} - \text{Hb} \times 8°\text{C/km}$
$\text{Hb} = 2.5$ km.
Finally, adding these two heights yields 4km. This is the height at which a parcel will continue rising in a conditionally unstable atmosphere, also known as the level of free convection.

4.2 Stability

The stability of the atmosphere refers to how much movement is occurring within it. Air with large amounts of vertical movement is referred to as unstable, while air with little vertical movement is stable. Depending on the values of the relevant lapse rates, the stability of an environment can be split into four groups.

- Absolute
  - Absolute stability is the most stable of the four. It occurs when the MALR is greater than the ELR. This means that even moist air, which cools slower than dry air, is unable to rise in the air column, leading to its categorization as minimal vertical movement.
- Conditional
  - Conditional unstability occurs when the ELR is greater than the MALR but less than the DALR. This means dry air cannot ascend, but if an air mass manages to reach its dew point, it would be able to rise. This requirement of "reaching dew point temperature" is why this kind of atmosphere is referred to as conditional.
- Neutral
  - Neutral stability occurs when the ELR is equal to the lapse rate of an air mass, which can be either dry or moist, depending on conditions; a neutrally stable atmosphere for a dry air parcel may not be so for a moist one. This atmosphere neither encourages nor prevents vertical movement.
- Instability
  - The most unstable kind of atmosphere, instability occurs when the ELR is greater than both the MALR and DALR. This means any air parcel, regardless of saturation, is able to ascend into the atmosphere above it.

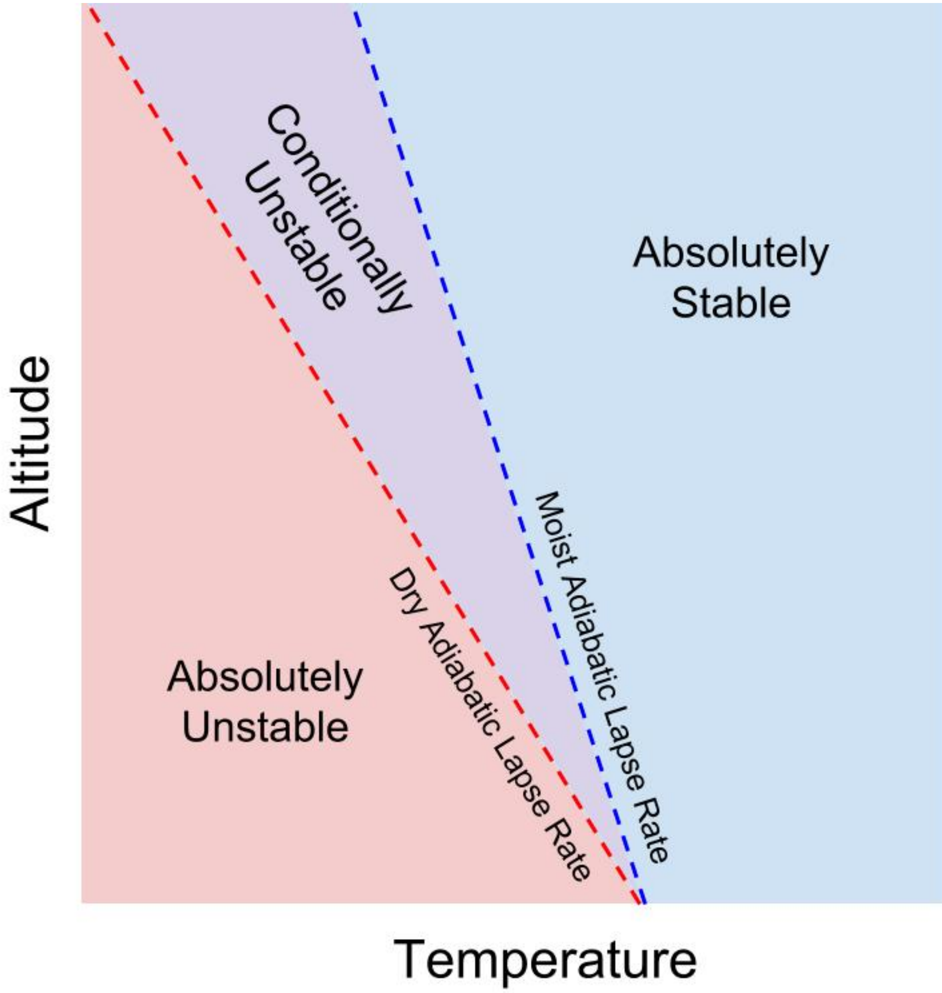

Figure 9: Illustrating stability (https://gpres.weebly.com/lapse-rates.html)

The reason lapse rates determine how air masses can rise is because cold air cannot ascend into warmer air. If the rate at which an air mass loses heat is faster than that of its environment, it will eventually reach a point where it is trying to move into air hotter than itself. For this reason, if the ELR is less than both the moist and dry lapse rates of an air parcel, there is no way for that parcel to rise.

5 Clouds

5.1 How are clouds formed?

Clouds are masses of tiny ice crystals or water droplets in the atmosphere. They can vary greatly in size, shape, and altitude, all of these variables illuminating a small part of the cloud's formation as well as the conditions it indicates.

As stated above, clouds form when air cools sufficiently so that it can no longer hold the amount of water it carries. This water condenses onto tiny particles, called **cloud condensation nuclei**, to form the water droplets that make up the mass of a cloud. Condensation nuclei can be any number of things - bits of dust and soot, yes, but also sulfates from volcanic activity and sea salt from ocean spray. Overall, the droplets collide and merge larger by the collision-coalescence; or touches the freezing nuclei and grow by the Bergeron process, then become larger and larger until they drop.

Find out more about the origins of clouds by continuing on below.

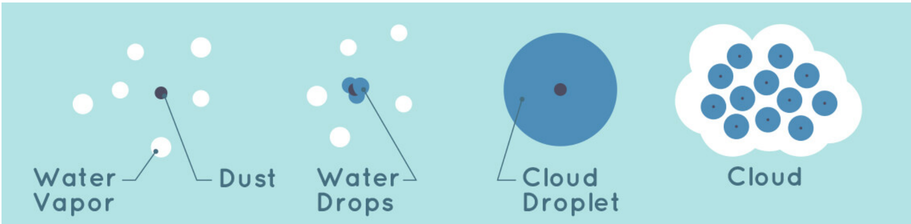

Figure 10: Condensation nuclei (https://climatekids.nasa.gov/cloud-formation/)

5.2 Cloud types**

There are an innumerable amount of cloud types, so much so that scientists have created an organizational system emulating that of biology. There exist a number of cloud genera, each with their own cloud species. However, in USESO, only the most basic knowledge of cloud types are needed. The four most important classes of cloud are as follows.

**USESO does not require the memorization of cloud types, but this is still very important and basic for studying meteorology.

- Cumulus
  - Cumulus clouds are large, fluffy, and white - everything a stereotypical cloud is. They have such significant vertical development because of their environment of formation - an indicator of atmosphere instability. If there's scattered cumulus clouds in an otherwise clear sky, it usually indicates a thin layer of instability, as well as a cold front passing through. However, they can develop precipitation and even morph into thunderstorms! These clouds have short lifespans, often around one hour or so, as a result of the unstable atmosphere. After that, if they don't turn into storm clouds, they tend to dissipate rapidly.

Figure 11: Cumulus clouds (https://en.wiktionary.org/wiki/cumulus)

- Stratus
  - Stratus clouds are flat, uniform, and gray or white. These are the clouds that cause dreary, overcast days, and tend to form closer to the ground than the other varieties. Due to their formation in stable atmospheres, stratus clouds can linger for hours before breaking up. Weather conditions underneath these can range from clear to light, steady drizzle, but they also are the clouds that cause fog and mist when in contact with the ground. Caused by the slow lifting of air that occurs in warm fronts, these clouds may develop storms as well.

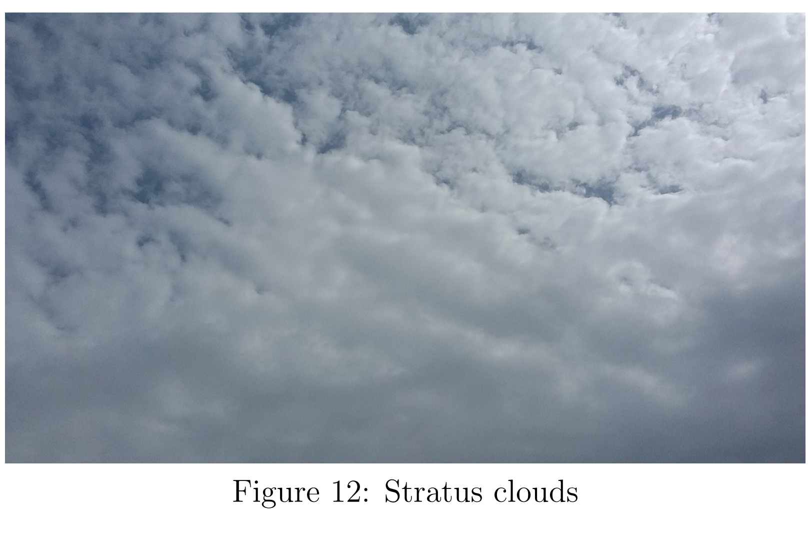

Figure 12: Stratus clouds

(https://commons.wikimedia.org/wiki/File:Stratus$_{c}$*louds.jpg*)

- Cirrus
  - Cirrus clouds are thin, wispy, and light. They occur at the greatest height of the three categories. Usually, warm, dry air is lifted to a very high altitude, where it condenses onto nuclei carried by global wind patterns. They may produce rain, but the precipitation never reaches the ground. The rain shaft evaporates in midair, creating a structure called a virga. They often occur at the beginning of a warm front. Scattered cirrus may indicate fair weather, but more dense patterns predict a change in weather coming shortly.

Figure 13: Cirrus clouds (https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/clouds/high-clouds/cirrus)

- Nimbus
  - Nimbus clouds are a general name for storm clouds, or clouds that produce precipitation. It is used as a prefix or suffix, such as cumulonimbus or nimbostratus to indicate the stormy version of these classic clouds.
    * Cumulonimbus - these clouds are massive, towering from a height of near-surface all the way to the tropopause some 36,000 feet above. It is often tipped to one side and had a anvil-like top. The cumulonimbus' anvil-like tops are a result of the convection hitting the stratosphere's temperature inversion and not being able to rise further. Sometimes, if internal convection is significant, the sheer momentum of the rising warm air can propel it past this boundary. When this happens, it is called an **overshooting top.**

      Cumulonimbus is often linked with severe storm weather. Inside these clouds are powerful convection systems that are the driver of the storm. The strong wind shear inside the storm, which causes the cloud's column to tip to one side, provides a path for the sinking convection branch to not collide with the upward branch - carrying the heat and water supply to the storm. This aids the storm formation and allows the cloud the grow. Only when the downward branch is so massive that the upward supplying branch is accidentally cut off can the storm come to a halt. These storms are powerful, being the only kind that can generate thunder and lightning, but their power comes at the cost of their stability. They often do not last more than an hour.

Figure 14: Cumulonimbus clouds (https://aviation.stackexchange.com/questions/16700/why-is-the-cumulonimbus-cloud-formation-so-dangerous)

* Nimbostratus - less impressive than the cumulonimbus, these thick and layered clouds produce storms as well. Their more stable origins mean they indicate persistent, continuous, moderate-to-heavy precipitation. They are usually indicative of a warm or occluded front and can last for as long as the front takes to pass by.

  Unlike cumulonimbus, their vertical convection is not significant, and they are less severe weather-wise. Instead of quick and intense deluges, these clouds linger with lighter rains.

Figure 15: Nimbostratus clouds (https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/clouds/mid-level-clouds/nimbostratus)

5.3 Heights**

The height of a cloud is often indicated with a prefix, but some cloud types are more associated with specific altitudes. The height of a cloud determines many things, such as the amount of cloud cover or the chance of precipitation developing. Read on to find out more.

**USESO does not require the memorization of cloud types, but this is still very important and basic for studying meteorology.

- High Clouds
  - Like cirrus, these clouds typically have the prefix cirro- in their names (e.g. cirrostratus). They are made of ice and supercooled water, tend to be transparent, and have little chance of precipitation. They also often indicate stormy weather soon. Cirrocumulus is referred to as "mackerel skies" due to its scale-like appearance.
- Middle Clouds
  - These clouds use the name "alto" - altocumulus, altostratus, and so on and so forth. Altocumulus indicates settled weather, while altostratus may indicate a coming warm front and can descend to become a nimbostratus. Altocumulus can also result from a breaking up of an altostratus.
- Low Clouds
  - Having no common prefix, there are many clouds that belong to this family - nimbostratus, stratocumulus, cumulus, and even cumulonimbus, though the latter can stretch all the way to the cirrus level. Stratocumulus can be found in a wide range of conditions and do not indicate much of anything, though even a drizzle would be a surprising amount of precipitation from this cloud.
- Instability
  - The most unstable kind of atmosphere, instability occurs when the ELR is greater than both the MALR and DALR. This means any air parcel, regardless of saturation, is able to ascend into the atmosphere above it.

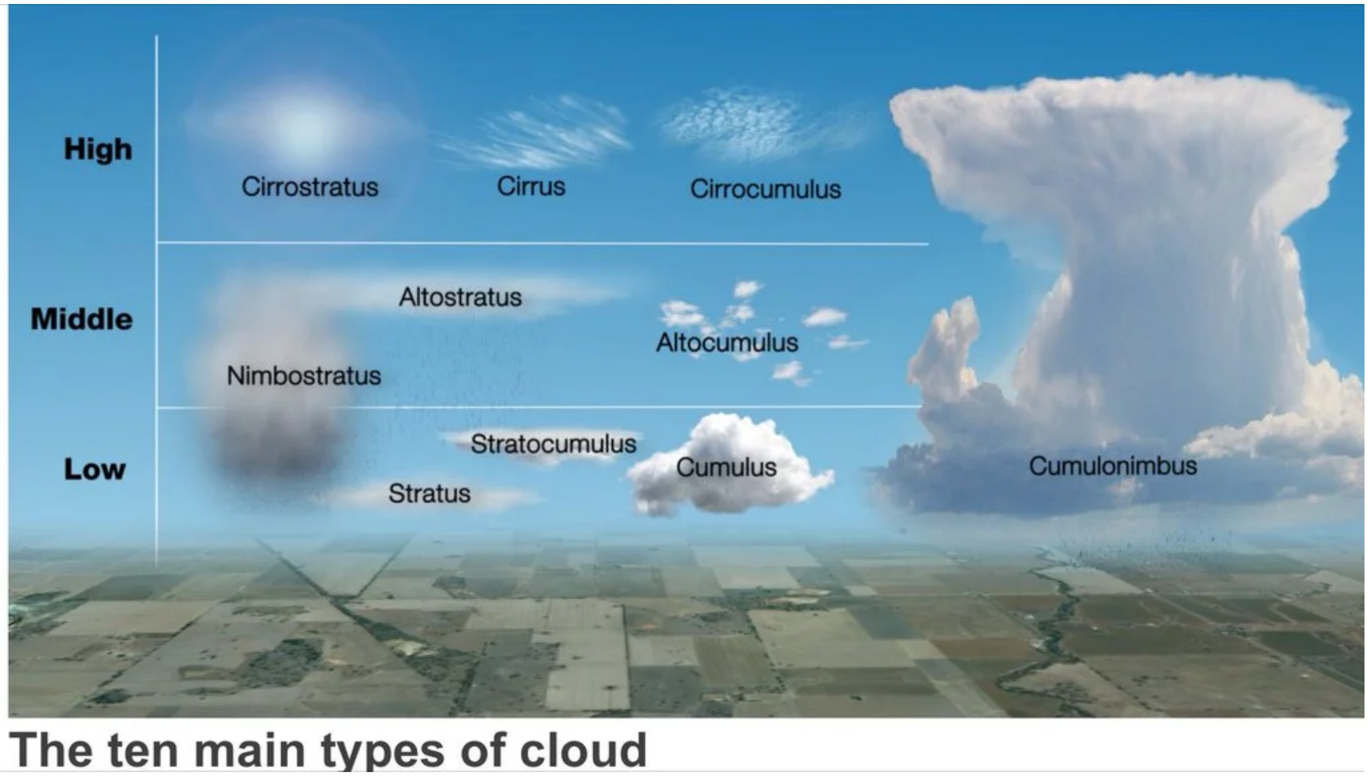

Figure 16: The ten main types of clouds
(https://www.wsav.com/news/the-ten-main-types-of-clouds/)

6 Conclusion

Clouds are easily observable but hard to interpret. They come in all shapes and sizes, each combination of traits indicating a certain slew of conditions, such as but not limited to temperature, humidity, air stability, and more. By understanding some of the basics of these incredible structures, one may learn how to utilize the world around them to infer about the past, gather information on the present, and predict the conditions of the future - a worthy pursuit, no matter what field it is followed in.