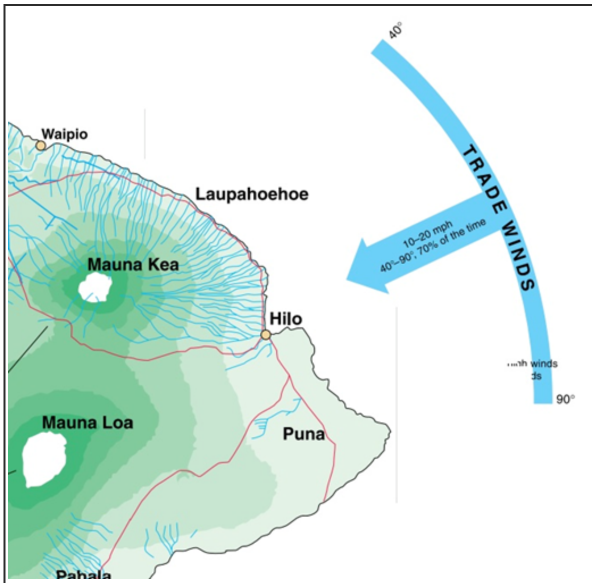
Hawai'i Physical Geography: Classic Kohala - Orographic Effect and Rainshadow

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

Started: May 18 at 1:55pm

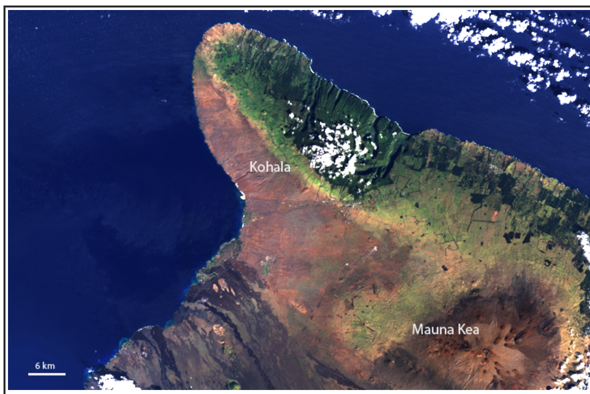
Quiz Instructions

INTRODUCTION



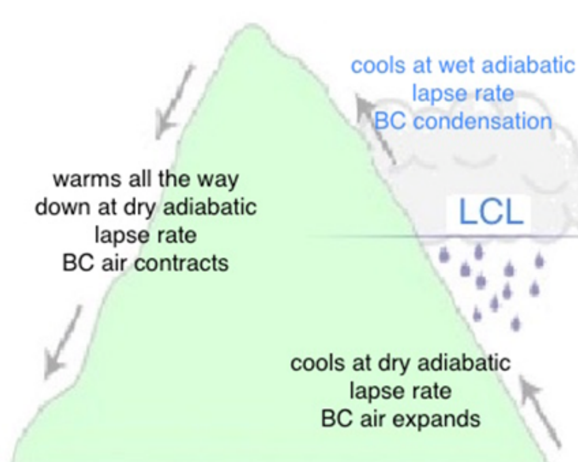
During much of the year, a large ridge of high pressure is situated northeast of the Hawaiian islands. This subtropical high causes winds to blow consistently from the northeast, especially during the summer - these are called the trade winds and typically lead to clouds and rain on the eastern sides of the island (windward) with dry, stable air sinking along the western side (leeward).

Northeast trade winds prevail most (70%) of the year and generally blow 10-20 mph. Exceptionally strong and gusty trade winds occur when the sub-tropical high of the central North Pacific Ocean intensifies. These can reach 40-60 mph in the coastal zone of Hawaii, sometimes for several days at a time.

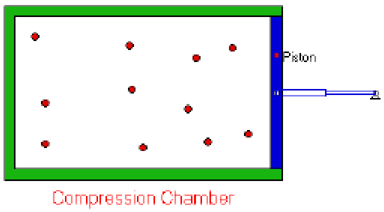


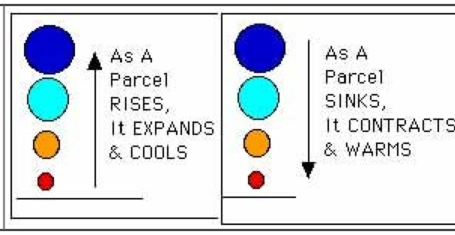
On Hawaii's Big Island, prevailing Pacific trade winds from the northeast bring higher levels of rainfall to northern mountain slopes, called the orographic (mountain) effect. Clouds hover over the lush, dark green rainforests on the rainy windward slopes, while drier western slopes appear mostly earthy-brown. The sharp contrast in vegetation is from the rainshadow effect -- seen in this Landsat image

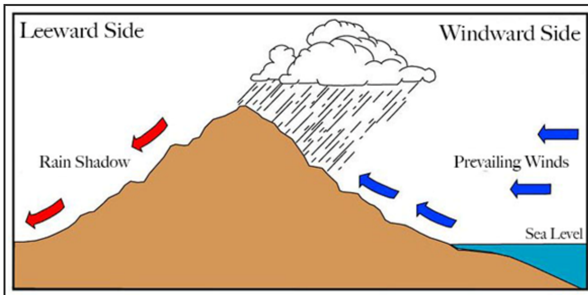
On the Hawaiian Islands, rainshadowing occurs when coastal trade winds coming from the northeast push air up the mountains (orographic effect. These easterly winds are forced to rise. As the air rises, it cools. Clouds form (lifting condensation level or LCL). There's rain as a result. However, on the lee (western) side, the air only warms from compression. Thus, there is a lot less rain on the rainshadow (lee or western) side.



The key to this lab is understanding what happens when air is compressed and when air is decompressed. Compression increases friction of the air molecules and warms the air. When the molecules are further apart, they cool. This warming and cooling does not involve the input or output of energy, and its called adiabatic warming and adiabatic cooling.





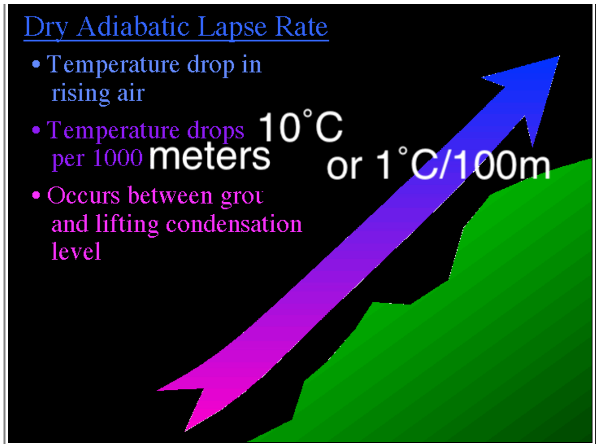


This is a view of of Kohala volcano looking north, where the eastern side is on the right. The trade winds are forced up and over a topographical barrier. The windward side will be cloudy and wet as air ascends, cools, and reaches the dew point (cloud formation occurs) The lee side will be warmer and drier as the air descends – and this is called the rainshadow.

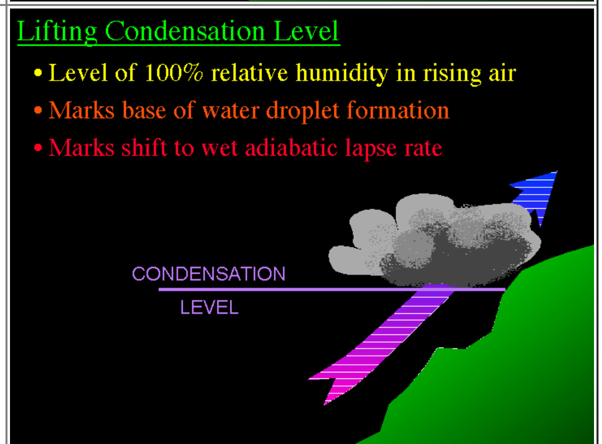
Watch this video - and then read the explanation below.

There's a lot going on here and this video shows the three key stages of air going up and down the Kohala volcano. This table explains what you are seeing in the embedded video

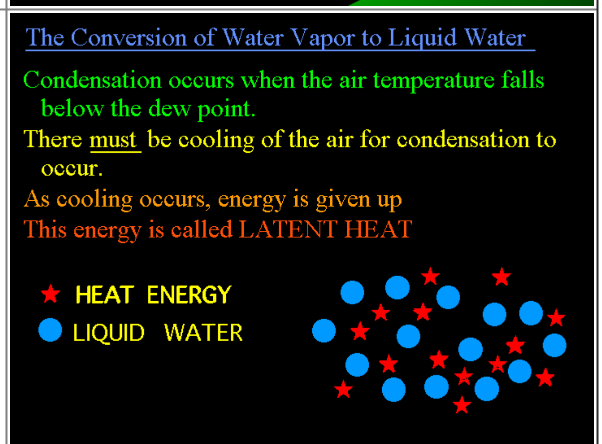
• 0 to 25 seconds: air at sea level encounters the volcano and is forced to rise. As it rises, the gas decompresses and cools. This dry adiabatic rate of cooling from just uplift is **10˚C per 1000 meters**.	



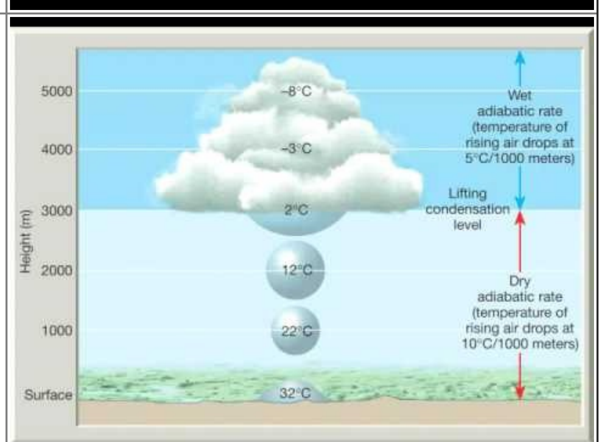
- at 26 seconds: enough cooling has gone on for the air to reach the dew point. When the air temperature is the same as the dew point, cloud formation (condensation) begins to occur. This is called the the lifting condensation level (LCL)



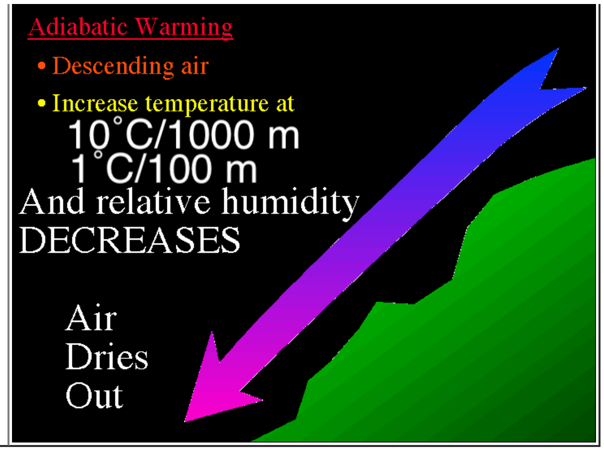
- at 26 seconds: Condensation releases latent heat (heat that was absorbed when the water evaporated). It is like tiny bits of heat being released into the condensing cloud. This release of heat does counteract the cooling of the air that is still going on as it rises (and expands). If there's more water vapor to condense (like the tropical trade wind air of Hawai'i) there's more latent heat released



- 26 to 58 seconds: The wet (or moist) adiabatic lapse rate is not as drastic of a temperature change as the air goes up. In Hawaii, it is typically **5˚C per 1000 m**. This slower rate of cooling is due to the release of energy (latent heat) when water vapor is turned into liquid (in the form of cloud droplets).



- 59 seconds to the end: As air descends down the western slope of Kohala, it only warms. The air is compressed, and the condensed water vapor (clouds) evaporate. This warming means the air can hold more moisture, and there is a lot less rain.

Adiabatic warming (compression) is the reason for rainshadows.	

The question sequence for this lab is as follows, where Questions 1-3 have few points, because you are just being walked through a tutorial, step-by-step. But to force you to go through this tutorial, points are accrued.

QUESTION 1: Determine the elevation at which clouds begin to form (lifting condensation level) as air is lifted up the volcano slope of Kohala.

QUESTION 2: Then, determine the temperature of the air near the top of the Kohala volcano.

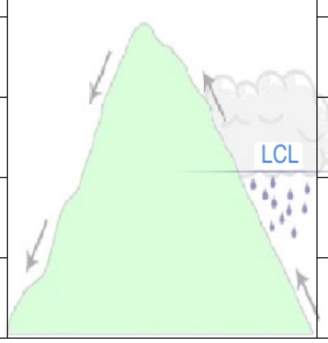
QUESTION 3: Then, determine the temperature and the precipitation amount when the air returns all the way down the lee (western) slope back at sea level. What is the difference in precipitation from the the start at sea level on the windward side?

Look at the precipitation when your avatar returns to sea level (on the rainshadow leeward side), and compare it to the precipitation at the starting position (on the windward side).

QUESTION 4: Do all of this again, but for yourself.

These questions all involve knowing what the temperature is to start with, of the trade winds approaching the eastern coastline of Kohala volcano. For questions 1-3, this is **25˚C: the temperature of the air at sea level** on the eastern side You will also need to know the dew point (the temperature at which clouds begin to form, due to water vapor condensation): **15˚C, the dew point.**

As you walk through questions 1-3, you may want to print out this chart below. Its is just a png file, so you can save it to your desk top and print it out:

LEEWARD SIDE (WEST)				WINDWARD SIDE (EAST)		
Elevation (m) & Coordinates	Rainshadow T (˚C)	Rainshadow P (mm)		Elevation (m) & Coordinates	Windward T (˚C)	Windward P (mm)
						

Question 1: Determine the elevation at which clouds begin to form (lifting condensation level) as air is lifted up the volcano slope of Kohala and the precipitation at that location.

Step 1: Fast Travel to 20.1438. and -155.5371, and assume this spot is at sea level. If you want, you can fill out the lower right 3 boxes as follows, where 2300	**0 m** 20.1438, -155.6371	**START** 25	2300

<table>
<tr><td>is the precipitation in millimeters. You will need this amount of precipitation at the start for question 3.</td><td></td></tr>
<tr><td>Step 2: Walk the avatar up the eastern slope of Kohala to 500 m at 20.1474. -155.6472, and figure out the air temperature and write down the precipitation amount.

Then, go up (or fast travel) to 1000 m at 20.1192. -155.6665. and figure out the air temperature and write down the precipitation amount.</td><td>With the air cooling 1˚C/100 m, the air is 5˚C cooler at 500 m, and 10˚C cooler at 1000m.
<table><tr><td>1000 m
20.1192,
-155.6665</td><td>15
Dewpoint/
LCL</td><td>4000</td></tr><tr><td>500 m
20.1474,
-155.6472</td><td>20</td><td>2400</td></tr></table>
You have the answer! The LCL is at 1000 m where there is 4000 mm of precipitation.</td></tr>
</table>

Question 2: Then, determine the temperature of the air near the top of the Kohala volcano.

Step 1. Assume that 1500 m is the top elevation. This is 500 m higher than the LCL.

Step 2. Use the Wet Adiabatic Lapse Rate (you were told this is 5˚C/1000 m or 0.5˚/100). Thus, the air would be 2.5˚ C cooler at 1500 m than at 1000 m. That would be **12.5˚C at 1500 m. This is the answer to question 2.**

Question 3: Determine the temperature and the precipitation amount when the air returns all the way down the lee (western) slope back at sea level. Also, determine the differences in temperature and precipitation from the starting position on the eastern side at sea level.

Step 1. Start the air at 1500 m with a temperature of 12.5˚C. This means that there's 1500 m of adiabatic warming when the goes all of the way back down the coast. Remember - you use the rate of warming of 10˚C/1000 meters, because the air is being compressed without any condensation.

Step 2. Calculate the right about of warming and add that warming to 12.5˚C.

Step 3. Jump the avatar to this sea level location at 20.0480. -155.8355 . Write down the amount of precipitation at this location.

Step 4. Compare the rainfall with the starting amount (remember that was 2300 mm). How much did the rainfall decrease?

SUMMARY OF QUESTIONS 1-3:

The air rises and cools at the dry adiabatic lapse rate (10˚ C per 1000 m and that is 5˚ C per 500 m). Thus, the air reaches the 15˚C dew point at 1000 m. From that point, it cools at 2.5˚ C per 500 m and so its 12.5˚ C at the summit at about 1500 m. Then, it warms 15˚ C as its drops 1500 m. *The rate of warming going down the leeward side is always 10˚ C/1000 m, because there's only air compression going on* **(**no latent heat release).

You'll probably notice that the maximum mean annual precipitation does NOT occur at the highest elevation (as you might expect). It occurs as the air is rising up towards the high points of Kohala volcano. The reason for this is complicated, but it has to do with the air drying a bit because of the influence of the trade wind inversion. [Descending air from higher up in the atmosphere mixes with the trade wind moisture and the amount of water vapor drops a bit).

The intense drop off in precipitation on the lee (west) side is due to the rainshadow effect of descending and warming air, just as the increase in rainfall on the eastern (windward) side is due to the uplift (orographic effect) of the trade winds.

QUESTION 4: **Follow a parcel of air from sea level, up and over Kohala if the starting temperature along the eastern coastline where you are given the starting temperature and the starting dew point. Use the blank chart above to take notes as you:**

1. **Calculate the temperature changes along the way every 500 meters.**
2. **Determine the elevation that clouds start to form (the lifted condensation level).**
3. **Determine how much warmer the air is at the coast between the western side and eastern side of Kohala.**
4. **Determine the mean annual precipitation (MAP) at the given longitude and latitude locations.**

HINT: You will see the answer to question 4 in this format ... that in this example matches questions 1-3:

Clouds start to form at about 1000 m. The air is about 2.5˚C warmer on the western side than the eastern side. Mean annual precipitation goes from 2300 mm (0 m), to 2400 mm (500 m), to 4000 (1000 m), to 3300 (1500 m), to 800 mm (1000 m on the west side), to 400 mm (500 m on the west side), to 250 mm (0 m) on the west side.

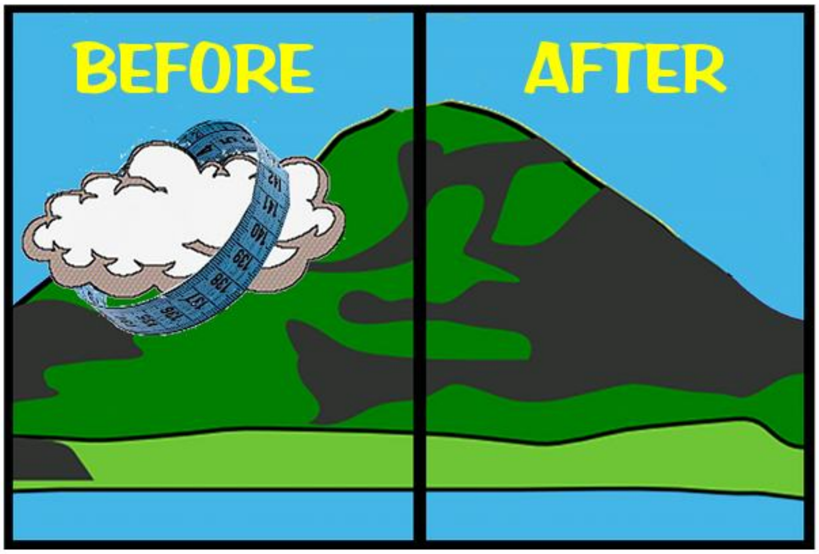
This video explains how to think about the trade wind air mass that is uplifted on the east side of Kohala volcano and goes down the west side. The video explains how to make the calculations of air temperature change associated with going up and over and down this volcano on the Big Island. The video refers to a PDF file - but that information is now put in the canvas question. The idea of this video is to walk you through the general steps you will do, but the specifics are based on the question that canvas randomly assigns you from the pool.

https://www.youtube.com/watch?v=J5etqqYrw7E (https://www.youtube.com/watch?v=J5etqqYrw7E)

(https://www.youtube.com/watch?v=J5etqqYrw7E)

This is for your amusement - created by a previous GPH 111/112 student. And if you are the sort of person who likes to create cartoons, please send your creation to your instructor!

Tired of trying to lose that stubborn rain?
Sick of feeling puffy and bloated?



We've harnessed one of nature's best kept secrets*, and for a low price YOU can be rid of that rain once and for all!*****

* It is not a secret, at all. Adiabatic Industries, LLC. claims no rights to ownership or creation of the naturally occurring and potentially inevitable adiabatic processes which may cause a cloud (hereafter you, yours, participant, or customer) to perspire at high altitudes.
** Price could include loss of life as you know it. Adiabatic Industries, LLC. assumes no liability for loss of liquid water, damage, or death as a result of using not-our-product we are selling.
*** Offer applies only to clouds who are eligible to participate in interaction with substantial topographical barriers, namely mountains. Despite the general outcomes anticipated in participation, Adiabatic Industries, LLC. claims no responsibility, and provides no guarantee, that your moisture droplets will have the opportunity to mature into raindrops. If you are not of Orographic lifting ancestry, your results may vary substantially or be nonexistent.

Disclaimer: Images shown are not real participants. Images have been edited to enhance visual representation of potential outcomes.

Question 1 **1 pts**

Question 1: Determine the elevation at which clouds begin to form (lifting condensation level) as air is lifted up the volcano slope of Kohala and the precipitation at that location.

Step 1: Fast Travel to 20.1438. and -155.5371, and assume this spot is at sea level. Assume that the starting temperature of the air is 25˚C and the dew point is 15˚C.

Step 2: Then, go up (or fast travel) to 1000 m at 20.1192. -155.6665. and figure out the air temperature and write down the precipitation amount.

- ◯ The LCL is at 500 m where there is 3000 mm of precipitation
- ◯ The LCL is at 1000 m where there is 4000 mm of precipitation
- ◯ The LCL is at 1500 m where there is 5000 mm of precipitation

Question 2

1 pts

Question 2: Then, determine the temperature of the air near the top of the Kohala volcano.

Step 1. Assume that 1500 m is the top elevation. This is 500 m higher than the LCL.

Step 2. Use the Wet Adiabatic Lapse Rate (you were told this is 5˚C/1000 m or 0.5˚/100). Thus, the air would be 2.5˚ C cooler at 1500 m than at 1000 m.

- ◯ 22.5˚C at 500 m
- ◯ 12.5˚C at 1500 m
- ◯ 10.5˚C at 1200 m

Question 3

2 pts

Question 3: Determine the temperature and the precipitation amount when the air returns all the way down the lee (western) slope back at sea level. Also, determine the differences in temperature and precipitation from the starting position on the eastern side at sea level.

Step 1. Start the air at 1500 m with a temperature of 12.5˚C.   This means that there's 1500 m of adiabatic warming when the goes all of the way back down the coast. Remember - you use the rate of warming of 10˚C/1000 meters, because the air is being compressed without any condensation.

Step 2. Calculate the right about of warming and add that warming to 12.5˚C.

Step 3. Jump the avatar to this sea level location at 20.0480. -155.8355 . Write down the amount of precipitation at this location.

Step 4. Compare the rainfall with the starting amount (remember that was 2300 mm). How much did the rainfall decrease?

- ◯ The temperature on the western (rainshadow) side at sea level would be 27.5˚C with the precipitation at 250 mm. This is 2.5˚C warmer and 2050 mm drier than when the air parcel started up Kohala at sea level on the windward side.
- ◯ The temperature on the western (rainshadow) side at sea level would be 17.5˚C with the precipitation at 800 mm. This is 2.5˚C warmer and 3200 mm drier than when the air parcel started up Kohala at sea level on the windward side
- ◯ The temperature on the western (rainshadow) side at sea level would be 22.5˚C with the precipitation at 400 mm. This is 5˚C warmer and 2000 mm drier than when the air parcel started up Kohala at sea level on the windward side

Question 4

5 pts

Follow a parcel of air from sea level, up and over Kohala. Calculate the temperature changes along the way every 500 meters. The correct answer will have three parts:

(1) **Calculate at what elevation the clouds start to form (lifting condensation level).**

(2) Determine out how much warmer the air temperature is at the coast line on the western side of Kohala than the sea level on the eastern side of Kohala.

(3) In the geovisualization, determine the mean annual precipitation (MAP) at the given longitude and latitude locations as the parcel of air goes up and then down Kohala.

SELECT THE CLOSEST ANSWER TO WHAT YOU CALCULATE. Do not worry if your numbers are a bit different. The slight differences are due to slightly different values in surrounding pixels that you select as opposed to the nearby ones that we select.

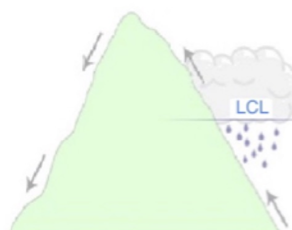
The following chart will help you take notes as you analyze what happens to the air parcel. Remember, the air goes east (right) to west (left), not like you read.

This is a blank chart that you can use to take notes for question A2 that you are given in canvas.

DEWPOINT = 18˚C

STARTING Air TEMPERATURE =19˚ C

Use the locations in the chart below.

Elevation (m) & Coordinates	Rainshadow T (˚C)	Rainshadow P (mm)		Elevation (m) & Coordinates	Windward T (˚C)	Windward P (mm)
1500 m 20.0925 -155.7395				1500 m 20.0925 -155.7395		
1000 m 20.0565 -155.7458				1000 m 20.1392 -155.7552		
500 m 20.0116 -155.7493				500 m 20.1870 -155.7785		
				use this cell for notes on dewpoint elevation		

0 m 19.9996 -155.8234				START HERE: 0 meters (the game reads 35 m, but to make the calculations easy use 0 m instead of 35 m) 20.2466 -155.7905		

- ◯ Clouds start to form at about 1000 m. The air is about 2.5˚C warmer on the western side than the eastern side. **Mean annual precipitation goes from 2500 mm (0 m), to 2750 mm (500 m), to 3700 (1000 m), to 3200 (1500 m), to 1500 mm (1000 m on the west side), to 600 mm (500 m on the west side), to 250 mm (0 m) on the west side.**
- ◯ None of the answers listed are even close. Thus, this is the best answer.
- ◯ Clouds start to form at about 100 m. The air is about 7˚C warmer on the western side than the eastern side. **Mean annual precipitation goes from 1200 mm (0 m), to 2600 mm (500 m), to 3300 (1000 m), to 2200 (1500 m), to 800 mm (1000 m on the west side), to 40 mm (500 m on the west side), to 250 mm (0 m) on the west side.**
- ◯ Clouds start to form at about 200 m. The air is about 6.5˚C warmer on the western side than the eastern side. Mean annual precipitation goes from 2000 mm (0 m), to 2500 mm (500 m), to 3500 (1000 m), to 3000 (1500 m), to 1500 mm (1000 m on the west side), to 650 mm (500 m on the west side), to 250 mm (0 m) on the west side.

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