

Unit 9 Section 1 Lab

Part 1: Orographic Precipitation, Lapse Rates and Stability

Background:

The environmental lapse rate (ELR), is the negative of the actual change of temperature with altitude of the stationary atmosphere at a specific time and specific location. The ELR at a given place varies from day to day and even during each day.

The dry adiabatic lapse rate (DALR) is the negative of the rate at which a rising parcel of dry or unsaturated air changes temperature with increasing height, under adiabatic conditions. Unsaturated air has less than 100% relative humidity, i.e. its temperature is higher than its dew point. The term adiabatic means that no heat transfer (energy transfer due to a temperature difference) occurs into or out of the parcel. Air has low thermal conductivity, and the bodies of air involved are very large, so transfer of heat by conduction is negligibly small.

Under these conditions, when the air is stirred (for instance, by convection), and a parcel of air rises, it expands, because the pressure is lower at higher altitudes. As the air parcel expands, it pushes on the air around it, doing work; since the parcel does work and gains no heat, it loses internal energy, and so its temperature decreases. (The reverse occurs for a sinking parcel of air.)

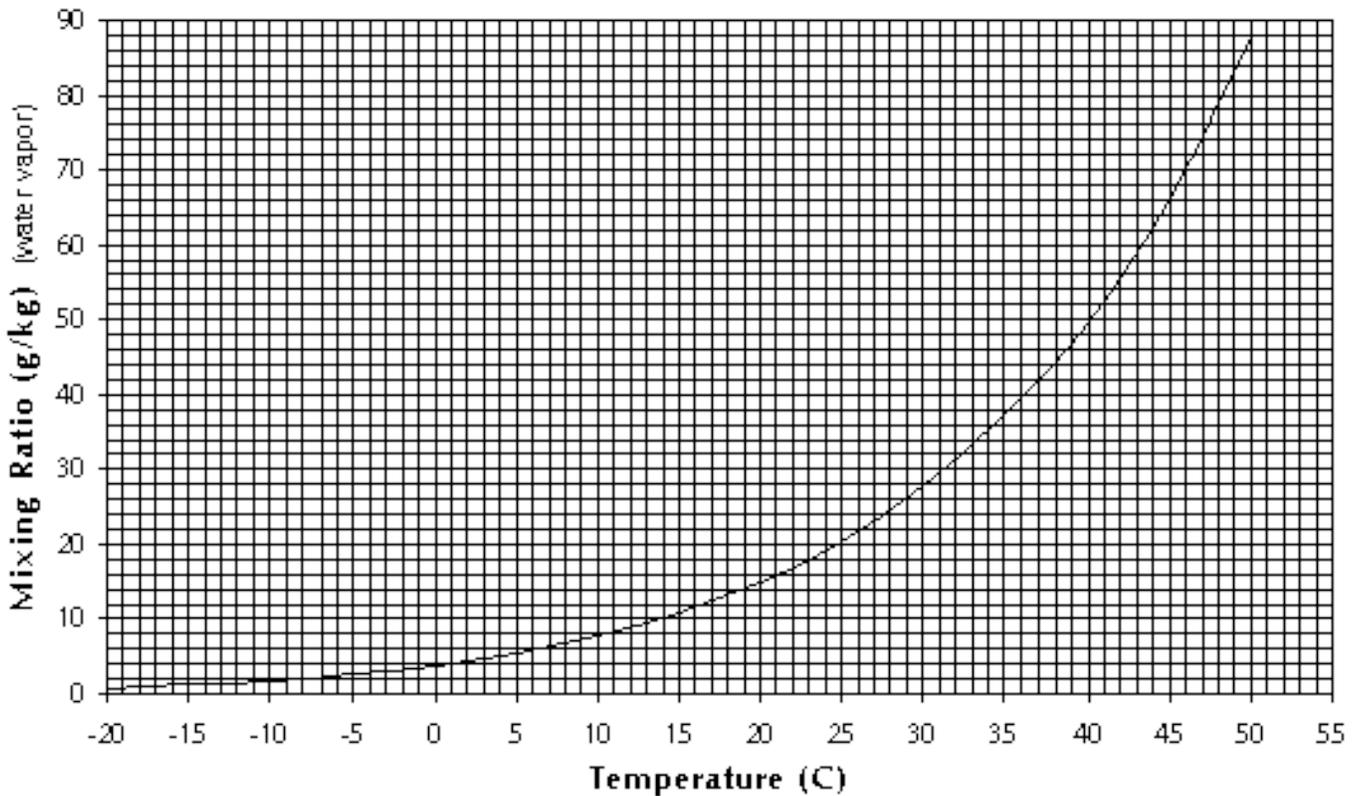
When the air is saturated with water vapor (at its dew point), the moist adiabatic lapse rate (MALR) or saturated adiabatic lapse rate (SALR) applies. It varies strongly with the moisture content.

Questions:

1. Table 6.1 below gives some information about parcels of air at five weather stations. Use the saturation curve in Figure 6.1 and your knowledge of adiabatic processes to fill in the rest of the table, assuming that the parcels of air are forced to rise.

Weather Station	A	B	C	D	E
Air temperature at ground level (°C)	13	33	23	32	30
Water vapor content of the air (g/kg)	5	10			17
Dew point temperature (°C)			15	18	22
Condensation level (m)					

TABLE 6.1 Rising Air Parcels at Five Weather Stations



2. Table 6.2 provides information on the environmental lapse rate (ELR) from a weather balloon. Table 6.2 also provides information on the air temperature and dew point for two air parcels at ground level (0 m).

- Draw a graph of the environmental lapse rate (ELR) data presented in Table 6.2 on the graph provided (Figure 6.2) and connect the points with straight line segments.
- Draw a graph that represents the adiabatic temperature change that results when Parcel A is forced to rise from the surface to an elevation of 1200m. Do this on the same graph (Figure 6.2) as the ELR for part (a).
- Draw a graph that represents the adiabatic temperature change that results when Parcel B is forced to rise from the surface to an elevation of 1200m. This should be done on the same graph (Figure 6.2) as the ELR for part (a).

- d. Label the portion of the graphs for Parcels A and B (Figure 6.2) where the air is cooling at the dry and saturated adiabatic rates.
- e. Label the level at which condensation occurs and clouds develop.
- f. Decide at what elevations the parcels of air are stable or unstable and label the graph (Figure 6.2) clearly.

Environmental Lapse Rate		Parcel A Dew point temp. = 14 °C	Parcel B Dew point temp. = 16°C
Altitude (m)	Air Temp. (°C)		
0	16.0	18.0	18.0
100	15.0	17.0	17.0
200	15.0	16.0	16.0 Saturated
300	14.0	15.0	15.4
400	13.0	14.0 Saturated	14.8
500	12.0	13.4	14.2
600	14.0	12.8 Not Rising	13.6 Not Rising
700	13.5	12.2	13.0
800	13.0	11.6	12.4
900	12.0	11.0	11.8
1000	12.0	10.4	11.2
1100		9.8	10.6
1200	10.0	9.2	10.0

TABLE 6.2 Environmental Lapse Rate Data and Rising Parcels of Air

3.
 - a. Between what altitudes does a temperature inversion occur?
 - b. Label the graph (Figure 6.2) where the inversion occurs.
4.
 - a. Is the density of parcel A greater at the earth's surface or at 1200 meters?
 - b. Why?
5.
 - a. At 1200 m, is the air surrounding parcel B be more, less, or the same density as the air inside parcel B?
 - b. Why?
6.
 - a. Which parcel produced the cloud with the lowest (nearest to the surface) cloud base?
 - b. Why?
7.
 - a. Which parcel produced the cloud with the most vertical development?
 - b. Why?
8. Which parcel is more likely to produce precipitation?

Part 2:
Adiabatic Processes and Orographic Precipitation

Orographic precipitation occurs on the windward side of mountains and is caused by the rising air motion of a large-scale flow of moist air across the mountain ridge, resulting in adiabatic cooling and condensation.

In mountainous parts of the world subjected to relatively consistent winds (for example, the trade winds), a more moist climate usually prevails on the windward side of a mountain than on the leeward (downwind) side. Moisture is removed by orographic lift, leaving drier air on the descending (generally warming), leeward side where a rain shadow is observed.

Orographic precipitation is well known on oceanic islands, such as the Hawaiian Islands, where much of the rainfall received on an island is on the windward side, and the leeward side tends to be quite dry, almost desert like, by comparison. This phenomenon results in substantial local gradients of average rainfall, with coastal areas receiving on the order of 500 to 750 mm per year (20 to 30 inches), and interior uplands receiving over 2.5 m per year (100 inches). Leeward coastal areas are especially dry 500 mm per year (20 inches) at Waikiki, and the tops of moderately high uplands are especially wet – ~12 m per year (~475 inches) at Wai'ale'ale on Kaua'i).

In South America, the Andes mountain range blocks most of the Atlantic moisture that arrives in that continent, resulting in a desert like climate on the Pacific coast of Peru and northern Chile, since the cold Humboldt Current ensures that the air off the Pacific is dry as well. On the leeward side of the Andes is the Atacama Desert of Chile. It is also blocked from moisture by mountains to its west as well. Not coincidentally, it is the driest place on earth.[6] The Sierra Nevada range creates the same effect in North America forming the Great Basin desert, Mojave Desert and Sonoran Desert.

Figure 6.3 below shows a parcel of air starting at point A, which is at sea level (0 meters). The temperature of the air at point A is 25°C and the water vapor content is 15g/kg. Refer to Figure 6.1 (in Part 1) for information on the saturation mixing ratio. The parcel is forced to rise over the mountain, eventually ending at point D, which is also at sea level (0 meters).

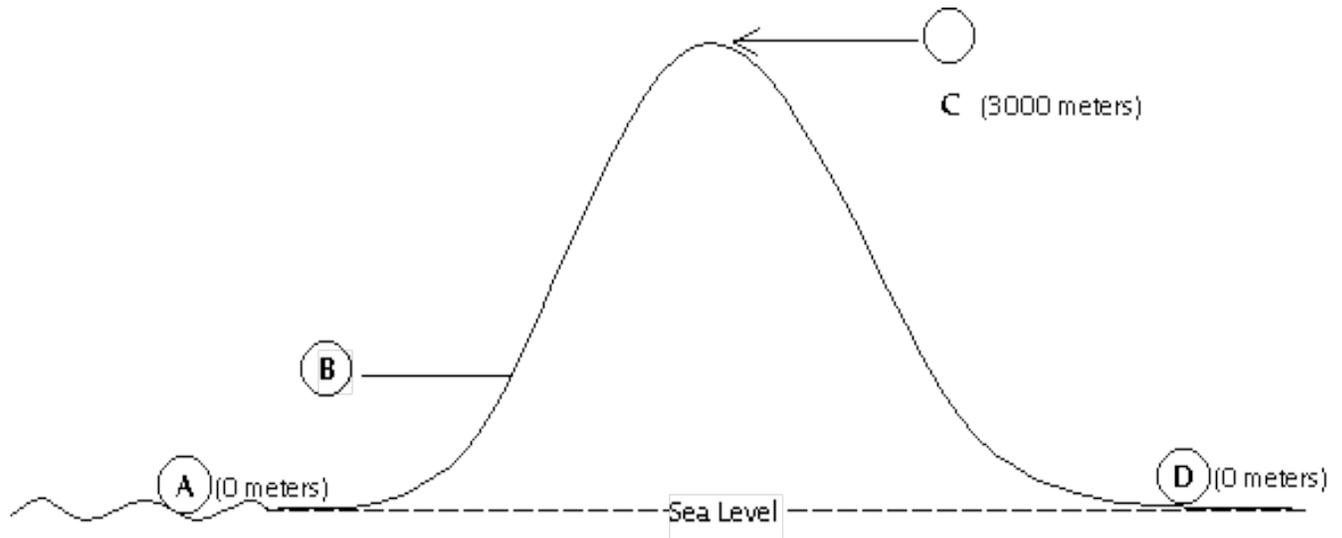


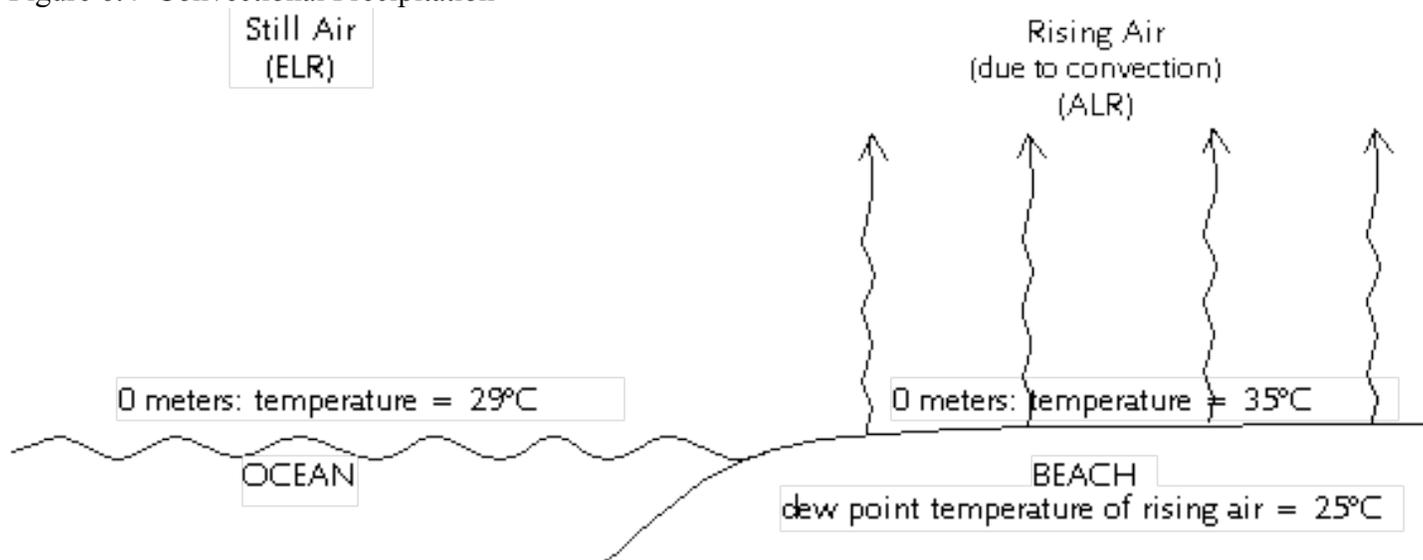
Figure 6.3 Orographic Precipitation

1. What is the elevation of position B, the base of the cloud?
2. What is the temperature of the parcel of air at the top of the mountain, position C, assuming the height of the mountain is 3000 meters?
3. What is the temperature of the parcel at position D, assuming that all the moisture was lost on the windward side of the mountain and the air stayed below the saturation point as it sank down the leeward side?
4. a. Is the temperature at position D the same, higher than, or lower than the temperature at position A?
b. Why?
5. a. . As the air subsides down the leeward side of the mountain would you expect the relative humidity to increase, decrease, or stay the same?
b. Why?

Part 3: Instability and Convectonal Rainfall

Cloud development may result from convection of warm moist air. This happens when the earth surface is heated, especially on sunny afternoons. Energy is transferred from the surface to the air above, causing the air to warm and rise. Convectonal uplift, with subsequent cloud development, is especially important along coasts where moist air masses move onshore from the ocean. Rapid heating of the ground surface, compared to the ocean, during the summer results in air over the land being much warmer than air over the ocean. Once heated, the warm air becomes unstable and rises, leading to the formation of cumulus clouds and possible scattered showers (convectonal precipitation). Thermal convection along coasts rarely results in widespread rains. This scenario of cloud development is represented in Figure 6.4 below. Think of the air over the surface labeled "Ocean" as the air of the surrounding environment (or still air), which is cooling at an environmental lapse rate (ELR) of $0.52^{\circ}\text{C}/100\text{m}$. Over the beach, the land is heating the air causing convectonal uplift. The air rises and cools at the adiabatic lapse rate of temperature (ALR). Recall that the rate at which the air cools depends on whether the air is saturated or unsaturated. Use the information provided about the air above the ocean (still air) and the air over the beach (rising air due to convection) shown in Figure 6.4 to answer the following questions.

Figure 6.4 Convectonal Precipitation



1. Fill in the pertinent data.

Environmental lapse rate =

Dry adiabatic lapse rate =

Saturated adiabatic lapse rate =

2. a. Draw a graph of the ELR from 0 meters up to an elevation of 3000 meters to represent the still air over the ocean on the graph paper provided (Figure 6.5).
 - b. Draw a graph of the adiabatic lapse rates of temperature (dry and saturated) from 0 meters up to an elevation of 3000 meters for the rising air over the land on the same graph paper as the ELR (Figure 6.5).
3. Label the DALR and SALR portions of the adiabatic lapse rate graph.

4. a. Label the portion of the atmosphere where the rising air is unstable.
- b. Label the portion of the atmosphere where the rising air is stable.
5. At what elevation will the base of the convectonal cloud form?
6. What is the elevation of the top of the cloud?
7. What is the air temperature at the top of the cloud?