

California Lapse Rate Worksheet

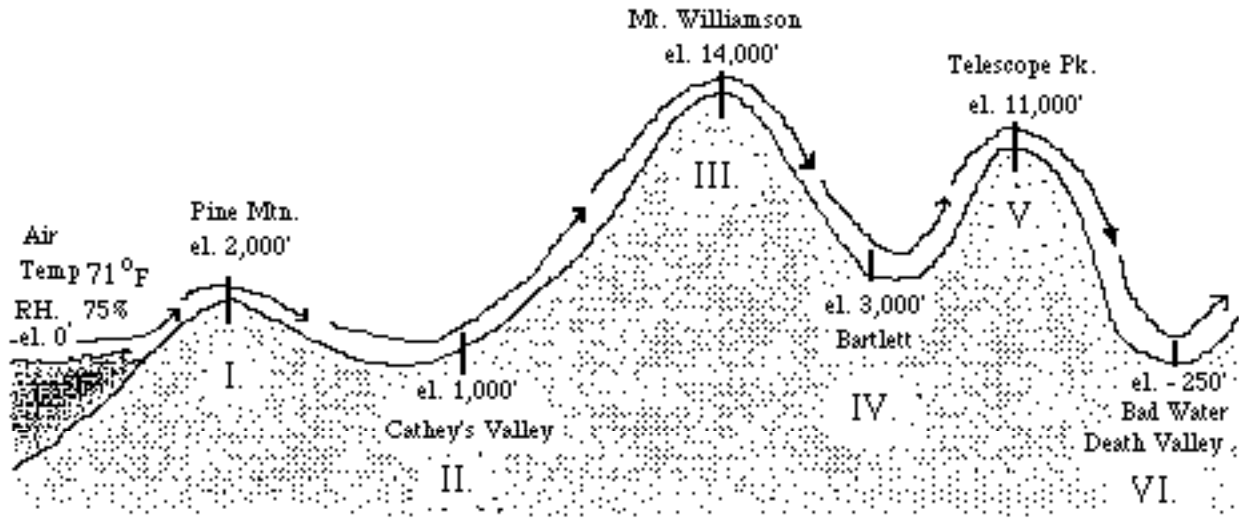
Assume that stable air moves over the land adiabatically, starting at sea level (0' elevation) and that no more water may be added by evaporation after leaving the coast.

Use the following lapse rates:

Dry lapse rate = 5.5°F/1,000 ft. (.55°F/100')

Average lapse rate = 3.3°F/1,000 ft. (1.5°F/500')

Wet lapse rate = 3.0°F/1,000 ft.



Part I. Pine Mtn. First you must determine the dew point temperature, and then determine the elevation that the air will become saturated. The air is going to rise dry adiabatically until it reaches that dew point temperature at the calculated elevation. Finally, you use the wet lapse rate up the remaining elevation to the top of Pine Mtn.

a. Calculate dew point temperature.

$$e_a = Rh \times e_s / 100$$

(Note: 71°F = 22°C. e_s at 22°C = 19.43 g/m³ from the table of vapor densities)

$$e_a = \frac{75\% \times 19.43 \text{ g/m}^3}{100} = 14.57 \text{ g/m}^3$$

read table. find 14.57 g/m³, read temperature = 17 °C (63°F) = dew point temperature ($e_s = e_a$)

b. Difference in air temperature from dew point = 71°F - 63°F = 8°F

c. Elevation that air will reach the Dew Point. How high will the air go until it reaches dew point?
take Dry Lapse Rate (.55°F/100' divide into 8°F to find elevation)

$$\frac{8^\circ\text{F}}{.55^\circ\text{F}/100'} = 14.53 \text{ hundreds of feet or } 1,453' \text{ (call it } 1500' \text{ for simplicity)}$$

So the air will be **saturated at 1500'** at a temperature of **63°F = t_d** or dew point temperature.

Now Continue to the top of Pine Mtn. (el. 2000') Going from 1500' to 2000'

- a. 2000' - 1500' = 500' elevation gain using the wet lapse rate.
- b. wet lapse rate = 3°F/ 1000' or 1.5°F/500'
- c. so the **temperature** at Pine Mtn. must be **61.5 °F (16° C)**
Air cools as it rises (gas law) so subtract 1.5°F from 63°F and since the air is saturated the **Rh. must be 100%**.
- d. Draw a cloud on the left side of Pine Mtn. with a base of 1500' and top at 2000'
- e. Note that the **new e_a** = 13.63 g/m³ This is the e_s for air at a temperature of 16°C (61.5°F).
The difference between 14.57 and 13.63 g/m³ is about 1 g/m³. This is the amount of liquid water left behind on the windward side of the Coast Ranges.

Part II. Temperature and Relative Humidity at Cathey's Valley.

- a. Air goes down (descends) from 2000' to 1000'. Use Dry Lapse Rate since air warms as it drops. (gas law)
- b. 1 thousand feet down at a rate of 5.5 ° F / 1000' = 5.5 ° warmer than 61.5 = 67°F
- c. **Temperature** at Cathey's Valley = **67°F**
- d. Now Compute Relative Humidity at Cathey's Valley

Remember $Rh = e_a/e_s \times 100$ $e_a = 13.63 \text{ g/m}^3$ and (67°F = 19°C e_s from table = 16.31g/m³)
(see Part I e. above)

$$Rh. = \frac{13.63 \text{ g/m}^3}{16.31 \text{ g/m}^3} \times 100 = 84\%$$

Part III. Temperature and Humidity at Mt. Williamson

- a. Since you went down from Pine Mtn. (you added 5.5 degrees) to Cathey's Valley, and now you must go up to Mt. Williamson, so you will must subtract the same amount (5.5 degrees) as you rise up the mountain from 1000' to 2000'. (Down dry, up dry since the air is not saturated until it reaches 2000' as it was on Pine Mtn. top)
- b. It is logical therefore for the temperature at the 2000' level of Mt. Williamson to be 61.5 °F and be saturated there since that was what happened at the top of Pine Mtn. (particularly since **no water vapor can be added to the air only lost from it**).
- c. Use the wet lapse rate from the 2000' level to the top of Mt. Williamson.

d. 14,000' - 2000' = 12,000' cooling (gas law) as it rises at the wet lapse rate = 3°F/1000'

$$12 \times 3 = 36 \text{ degrees cooler.}$$

e. So $61.5^\circ - 36^\circ = 25.5^\circ \text{ F} = \text{Temperature at the top of Mt. Williamson}$

f. **Rh. at Mt. Williamson = 100 % since the air is saturated.**

g. **Note:** $25.5^\circ \text{ F} = -4^\circ \text{ C}$ so the new $e_s = 3.66 \text{ g/m}^3$ (from the vapor density table)

h. The difference between 13.63 g/m^3 and 3.66 g/m^3 is about 10 g/m^3 . This is 10 times the amount of water left behind on the Coast Range. This precipitation usually falls in the form of snow in the winter, and provides the fresh water for urban and agriculture in California.

Part IV. Bartlett

a. Temperature: Elevation difference = **11 thousands of feet** (14,000' - 3,000' = 11,000')

b. Air is going down so it is warming, the e_s is increasing so no clouds can form.

Therefore you use the Dry Lapse rate of **5.5°F/1000'**.

c. $5.5 \times 11 = 60.5$ degrees

d. Descending air warms by compression (gas law) so you add 60.5 degrees to 25.5 degrees (the temperature at the top of Mt. Williamson).

e. $60.5^\circ \text{ F} + 25.5^\circ \text{ F} = 86^\circ \text{ F}$ **Temperature at Bartlett = 86°F**

f. **Humidity at Bartlett**

$$e_a = 3.66 \text{ g/m}^3 \text{ (from part III g.)}$$

$$e_s = 30.38 \text{ g/m}^3 \text{ (covert } 86^\circ \text{ F to } 30^\circ \text{ C then look up } e_s \text{ in table = } 30 \text{ g/m}^3 \text{)}$$

$$\text{g. Rh} = \frac{3.66 \text{ g/m}^3}{30.38 \text{ g/m}^3} \times 100 = 12\%$$

Part V . Telescope Peak

Temperature

a. Elevation difference = **8 thousands of feet** (3,000' up to 11,000')

b. Air cools as it rises (gas law)

c. Use Dry lapse rate (**5.5°F/1000'**) because the air must rise to 14,000' in order to become cold enough to reach 100% Relative Humidity and top of Telescope Pk. is only 11,000' high.

d. $5.5 \times 8 = 44$ °F difference in temperature

e. That is 44°F **cooler** (air rising - gas law) than Bartlett (86°F) = $86 - 44 = 42^\circ \text{ F}$ **at Telescope Pk.**

Relative Humidity

- Convert 42 °F to 6°C (table) 6°C air can hold 7.2 g/m³ = e_s
- e_a = 3.66 g/m³ (from part III g.) Note: that is the last place the air was saturated.
- Rh = $\frac{3.66 \text{ g/m}^3}{7.2 \text{ g/m}^3} \times 100 = 51\%$

Part VI. Bad Water Death Valley

Temperature

- Elevation difference = **11.25** thousands of feet 11,000' - (-250') = 11,250'
- Air is descending and warming (gas law) so use dry lapse rate (no clouds can form) = **5.5°F/1000'**
- 5.5 X 11.25 = 62 degrees
- add 62 degrees to temperature on top of Telescope Pk. (42 °F)

Temperature at Bad Water is 62°F + 42°F = 104 °F

Relative Humidity

- 104 °F = 40 °C = e_s of 51.19 g/m³ (from vapor density table)
- e_a is still 3.66 g/m³ (from part III g.) Note: that is the last place the air was last saturated.
- Rh = $\frac{3.66 \text{ g/m}^3}{51.19 \text{ g/m}^3} \times 100 = 7\%$

This ends calculations.

Other Things of interest.

The **western** sides of the mountains are called the **windward** sides of the mountain.

The **eastern** sides are called the **leeward** side.

The coast range has clouds on its windward side and this cuts off moisture to the leeward.

The Central Valley of California is therefore to the leeward of the coast range and in the **rain shadow** of the coastal mountains. That is why the base of the clouds in the sierra was at 2000' , and why the lower elevations of the Sierra Nevada are so dry.

Most of the water is condensed out of the air on the windward side to the Sierra Nevadas. This moisture is necessary to provide water to the farms of the central Valley, where 25% of all of the fruits and vegetables are grown in the United States using irrigation water held in reservoirs. This water comes from rain and snow.

The area to the leeward of the Sierras is without clouds and dry. Here begins the great Basin and Range desert of the American west. This is a **rain shadow desert** and goes most of the way to the Rocky Mountains almost 1000 miles to the east.

It is 104°F in Death Valley. All of this temperature gain from the coast (over 30°F) is caused by latent heat released into the air as water condensed. The sun never rose on this exercise.