

Atmospheric Moisture

ANSWER KEY

Part I: Thermodynamic Principles

Rising air is an important ingredient in low-pressure systems, thunderstorms, and hail formation. Thus, it is important to understand how meteorological variables change when air rises. Questions 1–3 address some of these changes.

1. Air cools as it rises. Assume that an unsaturated **air parcel** cools at the rate of 10°C for every kilometer it rises in the atmosphere. If an air parcel's temperature initially is 15°C and it is forced upward 1 km before it stops rising, what is its final temperature?

Final Temperature = 5°C

The change in height to 1 km cooled the parcel by 10°C .
 $15^{\circ}\text{C} - 10^{\circ}\text{C} = 5^{\circ}\text{C}$

2. If a parcel were to rise above the level where its relative humidity (RH) is 100%, what happens to the water in the air parcel? What happens to the parcel's relative humidity as it continues to rise above that level?

When the parcel reaches 100% RH, it will condense some moisture to form liquid droplets. At this point, the RH is still 100% and it remains at 100% until the parcel descends or is somehow mixed with drier air.

3. (**Advanced Students/Meteorology Majors**) As in question 1, an unsaturated air parcel with an initial temperature of 15°C is forced upward 1 km before it stops rising. The parcel's initial relative humidity was 50%. If the amount of water vapor in the rising air parcel does not change, what is the new relative humidity of that parcel at 1 km? Use Figure 1 and the fact that $\text{RH} = (e/e_s) \times 100\%$. Show your work.

Relative Humidity = $\sim 100\%$

Use Figure 1. The saturation vapor pressure (e_s) at sea level was 18 mb at 15°C . Because the initial relative humidity was 50%, the actual vapor pressure (e) at sea level was 9 mb. At 1 km, the new $e_s \approx 9$ mb. Because the moisture in the parcel did not change, e still is 9 mb. Thus, the relative humidity at 1 km is $\sim 100\%$. ($\text{RH} = e \div e_s \times 100\% = 9 \div 9 \times 100\% = 100\%$.)

4. Table 1 contains temperature observations from Phoenix, AZ and Miami, FL. Explain why a large difference exists between the two sets of observations. Note the differences in the daily range of temperature (i.e., range = maximum – minimum).

PHX temperature range is 30°F ($113^{\circ}\text{F} - 83^{\circ}\text{F} = 30^{\circ}\text{F}$) and MIA temperature range is 14°F ($95^{\circ}\text{F} - 81^{\circ}\text{F} = 14^{\circ}\text{F}$). The air in Phoenix is much drier than the air in Miami. Because moist air retains heat more effectively, the overnight temperature in Miami was close to the daytime maximum. In Phoenix, the air is very dry and thus does not easily retain heat. Heat gained during the day is lost at night, but the greenhouse gas (in this case, water vapor) in the atmosphere over Miami absorbs longwave radiation and re-emits it toward earth.

5. **(Advanced Students/Meteorology Majors)** Using Table 1, Figure 1, and the fact that $RH = (e/e_s) \times 100\%$, fill in Table 2 to calculate the relative humidity values from Phoenix (PHX) and Miami (MIA) at the times when the day's temperature was at both its maximum and minimum. Assume that the dew point (T_D) is constant during the day for each station.

Table 2 – Worksheet for Use in Calculating Relative Humidity

	T_D (in °F)	$e(T_D)$ (in mb)	T_{MIN} (in °F)	$e_s(T_{MIN})$ (in mb)	RH (%) at time of T_{MIN}	T_{MAX} (in °F)	$e_s(T_{MAX})$ (in mb)	RH (%) at time of T_{MAX}
PHX	40	8	83	38	21	113	96	8
MIA	79	34	81	36	94	95	56	61

Part II: Condensation and Evaporation

6. Assume that the skies were clear at both Phoenix and Miami for the observations in Table 1. Also assume that both cities received the same amount of incoming solar radiation at the earth's surface. If the ground in Miami was moist and the ground in Phoenix was dry, how can the moisture of the ground help explain the observed temperatures? [Hint: Think about how the incoming solar energy would be partitioned between latent heat and sensible heat.]

Insolation at Miami is divided into both latent and sensible heat because there is moisture to evaporate. Therefore, there is less sensible heat at Miami than Phoenix and the air temperature is cooler than Phoenix.

7. If virga were seen below a cumulonimbus cloud, would the air just below cloud base (i.e., within the virga) be cool or warm? Explain your answer.

Because rain from above evaporates as it falls into the surface air, cooling occurs. Energy from the surrounding air is used to change the state of water from liquid to vapor form. Thus, the environmental air transfers heat energy to the water molecules during the evaporation process. The temperature below cloud base is cool.

Part III: Moisture Advection

Figures 2-5 show the evolution of the dew point and wind fields across parts of the central U.S. and Mississippi Valley during the day of 10 November 2004. Relatively high dew points are shaded green and relatively low dew points are shaded brown. Wind speed and wind direction are displayed as vectors, with longer vectors representing stronger winds. A continental U.S. map of dewpoint temperatures is inset on each figure to provide an overall view of the near-surface moisture field.

During this day, the air across Louisiana and central/southern Texas was very moist. Dew points during the early morning (Figure 2) across Missouri and Illinois were relatively low. Examine the changes in the near-surface moisture from 3:00 AM to 1:00 PM CST on 10 November 2004 using Figures 2–5.

8. Describe the changes in the dew point field across central Illinois from 3:00 AM to 1:00 PM CST. [Note: You may find it helpful to describe differences in dew points with numerical values (e.g., “The dew point increased from 15°C to 20°C.”).]

Dew points across Illinois between 3 AM and 7 AM were near 0°C, with only minimal differences in the dewpoint field across the state. By 10 AM, a gradient of dew point stretched from northeastern IL, where dew points were near 0°C, to southwestern IL, where dew points ranged from about 5°C to 8°C. By 1 PM, dew points had increased statewide, with a moisture tongue extending from southwestern IL to the Chicago metro area. Maximum dewpoint temperatures were around 8–10°C.

9. Describe the changes in the dew point field across western and middle Tennessee from 3:00 AM to 1:00 PM CST.

Between 3 AM and 7 AM, there was little change in the dew points across western and middle TN, where the air had about the same moisture content as across Illinois. By 10 AM and through 3 PM, the dew points decreased about 2–4°C.

10. List the **prevailing wind direction** and relative speed (e.g., light NW winds, strong SE winds, calm winds) at the following locations and times:

- a. Central IL @ 3:00 AM CST = light southerlies to calm
- b. Central IL @ 10:00 AM CST = light to moderate S and SSW winds
- c. Central IL @ 1:00 PM CST = moderate SW winds
- d. Southwest MO @ 3:00 AM CST = light SE winds
- e. Southwest MO @ 10:00 AM CST = light to moderate S and SSE winds
- f. Southwest MO @ 1:00 PM CST = moderate S and SSE winds
- g. Western & Middle TN @ 3:00 AM CST = calm winds
- h. Western & Middle TN @ 10:00 AM CST = light S and SSE winds
- i. Western & Middle TN @ 1:00 PM CST = light to moderate southerlies

11. Using your answers from question 10, what caused the changes in dew point across central Illinois?

Surface moisture increased during the day across central Illinois as a result of moist air advection. Winds advected moisture from the Gulf of Mexico through LA, AR, and MO into IL.

12. Using your answers from question 10, what caused the changes in dew point across western and middle Tennessee?

Surface moisture decreased during the day across western and middle Tennessee as a result of dry air advection. Winds advected drier air from northern AL and GA into TN.

13. What type of moisture advection occurred over southwest Missouri between 3:00 AM and 1:00 PM CST?

Moist air advection

14. What type of moisture advection occurred over eastern Kentucky between 3:00 AM and 1:00 PM CST?

No winds -> no advection