

Daily Temperature Cycle

ANSWER KEY

Part I: Temperature and Radiation

1. According to Figure 4, approximately when will maximum and minimum temperatures occur?

Time of maximum temperature 3-5 PM Time of minimum temperature ~6 AM (sunrise)

2. Based on Figures 4 and 5, why does the temperature increase from 6 AM to 3-5 PM and decrease from 3-5 PM to 6 AM?

Solar radiation that reaches the earth's surface causes the temperature to rise during the day. The absence of solar radiation at the end of an afternoon, combined with the continual flow of outgoing longwave radiation from the earth's surface, causes the surface temperature to decrease through the night.

3. Consider the path of the sun during a clear day represented by Figures 4 and 5. Why is the incoming solar radiation so intense at noon and so weak at sunrise and sunset? (Hint: Think about the angle of incidence.)

Radiation is measured per unit area. In the morning (and evening), when the angle of incidence is small, the radiation is spread across a large area, resulting in a lower intensity per unit area. At noon, the radiation is most intense because the area impacted by the sun's radiation is concentrated. For example, think of a flashlight's rays on a surface and how the intensity changes as the angle of incidence changes.

4. With the help of Figure 5, define the following phrases in terms of outgoing and incoming radiation:

Positive net radiation – Incoming radiation is greater than outgoing radiation. This imbalance causes the temperature to increase.

Negative net radiation – Outgoing radiation is greater than incoming radiation. This imbalance causes the temperature to decrease.

5. Relative to changes in net radiation, when does the temperature decrease and when does the temperature increase in Figure 5?

The temperature decreases when net radiation is negative (more radiation outgoing than incoming). The temperature increases when net radiation is positive (more radiation incoming than outgoing).

6. **(Advanced Students/Meteorology Majors)** Explain why the graph of outgoing terrestrial radiation in Figure 5 is not a horizontal line (i.e., it is not constant with time). In other words, why does the earth emit radiation at different rates at different times?

The outgoing radiation is not constant because warmer bodies radiate more energy than do cooler bodies. Notice the correlation between the diurnal variation of temperature and the diurnal variation of outgoing radiation (Figure 5).

Part II: Other Factors that Influence Daily Temperatures

7. Given the variables discussed above, which environment or location in each pair of environments/locations below will experience the greatest range of daily temperatures?

a) dry region or humid region? Why?

Dry regions will have a greater daily variation because dry regions usually have minimal cloud cover, lack soil moisture, have sparse vegetation, and have minimal precipitation. These factors allow for large daily ranges of air temperature.

b) clear day or overcast day? Why?

A clear day will have a larger diurnal variation because, during the day, more radiation will reach the surface to create a high maximum temperature. At night, more radiation escapes into the atmosphere (and space) to produce a lower minimum temperature.

c) Charleston, SC or Las Vegas, NV? Why?

Las Vegas, NV, has a greater range of daily temperatures because it has a desert-like climate (large temperature range). Even though both cities are at the same latitude, Charleston receives more precipitation and has more vegetation, creating a lower temperature range.

d) New Orleans, LA or Aberdeen, SD? Why?

Aberdeen, for reasons to those given in the answer to c.

8. Assume that rain occurred during the night after the “simulated observations” in Figure 2 were acquired. How quickly will the temperature increase after sunrise as compared to the increase during a typical summer morning that begins with dry ground and clear skies? Explain your answer.

The temperature will increase more slowly (after a rainfall) than on a morning when rain did not occur. The soil should be moist on this morning, and the energy received from the sun will be used to evaporate the water. The process of evaporation is a cooling process. Because much of the sun’s radiation is used to evaporate the water, that energy is not available to heat the air and ground. As a result, the temperature will increase more slowly and reach a lower maximum temperature than might have occurred on a dry day.

9. After a windy summer morning and early afternoon, suppose the air becomes calm. How will the air temperature at the ground level (e.g., Figure 5) change during the afternoon?

Calm day – The ground absorbs radiation more efficiently than does air, so the ground becomes very warm but the air above it is cooler. Because the transfer of heat between the ground and air does not happen quickly or efficiently, a large difference in the temperature exists between ground level and the air aloft. With time, the air adjacent to ground will become warmer than that aloft.

Windy day – The mechanical mixing processes of wind help homogenize the vertical structure of air temperature. The cooler temperatures aloft are mixed down to the surface (cooling the air adjacent to the ground), and the warm air at the surface is transported upward to slightly warm the cool atmosphere aloft.

Example: Think of a pot of soup (not boiling) on a stove. If left undisturbed (ignoring any convection currents), the soup close to the burner will become much warmer than the soup at the top of the pot. However, when stirred (windy), the temperature of the soup will become more homogenous.

10. Look at the plots below of air temperature, solar radiation, and winds measured by ARM at Barrow, AK (Figures 6-8). For each of the three plots, document any time lag between observed changes in solar radiation and corresponding changes in air temperature. Summarize your observations by describing the magnitude of the lag as a function of season, cloudiness, and speed of the winds. If the time lag in any of the plots does not agree with your expectations, provide a hypothesis as to why the expected relationship did not occur.

On 26 April 2002 at the Barrow ARM site (Figure 6): Looking at the overall pattern of the solar radiation curve, solar noon appeared to occur around 2:30 PM. The maximum solar radiation measured was $\sim 525 \text{ W m}^{-2}$ at 4:30 PM, but this spike likely resulted from reflection off of a cumulus cloud (added to radiation from direct sunlight between the clouds). Hence, the lag between solar noon and maximum temperature (2.8°C at $\sim 4 \text{ PM AKDT}$) was similar to that shown in Figure 4. Clouds were evident from the solar radiation measurements and it was a windy day (speeds of $5\text{--}15 \text{ m sec}^{-1}$). Southerly winds may have contributed to the warming during the daytime hours.

On 20 June 2003 at the Barrow ARM site (Figure 7): The lag between solar noon ($\sim 2:30 \text{ PM AKDT}$) and the maximum air temperature ($\sim 5:00 \text{ PM AKDT}$) was expected and was consistent with Figure 4. The maximum of solar radiation was $\sim 700 \text{ W m}^{-2}$ and preceded the maximum air temperature (of $\sim 4^\circ\text{C}$) by 2.5 hours. Wind speeds were on the order $3\text{--}5 \text{ m sec}^{-1}$ during this clear afternoon. Winds did not change direction significantly during the 24-hour period depicted in Figure 7.

On 3 October 2003 at the Barrow ARM site (Figure 8): The lag between the curves of solar radiation and maximum temperature did not reveal a direct relationship. The maximum temperature of the day ($\sim 2.2^\circ\text{C}$) occurred before sunrise while the maximum in solar radiation ($\sim 200 \text{ W m}^{-2}$) occurred between 2 PM and 4 PM. Winds were $3\text{--}8 \text{ m sec}^{-1}$ during most of the day. It appears that southerly winds during the early morning hours resulted in warmer temperatures during the night than during the following daytime hours. In addition, excessive cloudiness dominated the day. The maximum temperature was determined by other factors on this date.

Part III: Radiation Inversions

11. Using Figure 2, will the temperature range between the surface and 1.5 m be greater on a windy night or a calm night? Explain your answer.

The temperature range is greater on a calm night for reasons analogous to those discussed in answers to previous questions.

12. If you were a watermelon farmer and the minimum temperature (at 1.5 m above ground, as in Figure 2) were forecast to be 1°C on a clear, calm night, would you be concerned about your watermelons? Assume that a frozen watermelon is a ruined watermelon. Explain your answer.

I am worried, because the temperature below the thermometer may decrease below 0°C on this clear, calm night. Longwave radiation will escape the earth's surface and, with minimal vertical mixing, will result in significant cooling near the ground.

13. **(Advanced Students/Meteorology Majors)** Radiation inversions form when outgoing radiation from the earth can escape from the lower atmosphere easily and when the layer near the ground is not well-mixed. Given what has been discussed thus far in this laboratory activity, list three conditions that need to be present for an extreme temperature inversion (large increase in temperature from the ground and to a few tens of meters above) to develop near the surface.

(1) Long night; (2) clear night; (3) calm night; or (4) low-humidity night. [Any three of these conditions.]