

The Earth-Atmosphere System

ANSWER KEY

1. The earth is closer to the sun in January than July (Figure 1). Why is it colder across the Northern Hemisphere during January than during July?

In spite of the changing distance between the sun and the earth, it is colder across the Northern Hemisphere during January than during July because the angle of incidence of sunlight is more obtuse during January. [In addition, during the winter, solar radiation must travel through a deeper layer of the atmosphere to reach the surface, permitting greater absorption, reflection, and scattering of the sunlight.]

2. Using knowledge about the angle of incidence (Figure 2), how intense (bright) is the sunlight on a clear day at your personal residence on (a) December 21 versus March 22? (b) On June 21 versus September 21? (c) What is the significance of these dates? (d) During what season(s) are the hours of daylight the greatest?

Using the campus of the University of Oklahoma as an example location, sunlight is the most intense and daylight is the longest on June 21 – the date when the sun appears the highest at solar noon. It is least intense and the days are the shortest on December 21, when the sun is lowest on the southern horizon at solar noon. The intensity of sunlight on March 21 and September 21 should have been identical because those two days were ~12 hours long; the intensity of sunlight on the two equinox dates should have been a value in between the values observed on the two solstice dates.

3. Point a flashlight at a globe of the earth. If the total amount of sunlight radiated from a flashlight per second were expressed in units called watts, why would it make sense to describe solar radiation received at a point on the globe in watts per square meter (i.e., per unit area) versus only in watts?

Because the angle of incidence determines the surface area across which a given solar beam is absorbed, the greater the angle, the larger the area in which a unit beam is spread. Using 'per unit area' (in this case, per square meter) is a way to normalize observed values so that they may be compared from site to site.

4. For each Oklahoma Mesonet station in Figure 6, (a) determine the time of sunrise (i.e., when the value of solar radiation increases from zero). (b) Why are the times of sunrise for these three sites either the same or different?

Sunrise at BEAV ~7:15 AM Sunrise at BLAC ~7:05 AM Sunrise at VINI ~6:55 AM

The times of sunrise are consistent with the fact that Vinita is the most eastern location while Beaver is the most western location. The sun rose first and set first at Vinita and rose/set last at Beaver. These values were approximated by noting that data values are plotted every 15 minutes; solar radiation at Vinita appeared to increase from zero shortly before the 7:00 AM observation, with that for Blackwell shortly after 7:00 AM.

5. Using Figure 6, (a) approximately how many hours and minutes (to the nearest 15 minutes) are the solar radiation values above zero for each station? (b) Are these lengths of time the same? (c) Why or why not?

The length of a day on September 10 at these three Mesonet sites (Vinita, Blackwell, and Beaver) was ~12 hours and 45 minutes. This particular 'length of day' is consistent with the fact that the autumnal equinox had not occurred yet; hence sunlight should last longer than 12 hours. The equinox occurred only ~11 days later.

6. Using Figure 6, (a) what is the maximum magnitude of solar radiation (in watts per square meter) at each Mesonet station? (b) If the acceptable measurement error of a Mesonet pyranometer is $\pm 5\%$, then do you believe that significant differences in solar radiation values exist between the stations? (c) Why or why not?

Max at BEAV $\sim 875 \text{ W/m}^2$ Max at BLAC $\sim 860 \text{ W/m}^2$ Max at VINI $\sim 850 \text{ W/m}^2$

The differences between the three sites are not significant because the error of the sensor is plus or minus 43 Watts per square meter.

7. Using Figures 6 and 7, is the total amount of sunshine on a clear day the only determining factor in how warm or how cold a location will be?

The total amount of sunshine is not the only determining factor in how warm or cold a location will be. Other factors, such as wind speed, vegetation, and soil moisture, play a role.

8. Instead of using BEAV, BLAC, and VINI in Figure 6, how would you expect the graph to look if data from BLAC (north-central Oklahoma), SPEN (central OK), and BURN (south-central OK) were plotted (see Figure 5 for site locations)? How would these station changes affect your answers to Questions 4, 5, and 7?

In spite of the fact that three north-south stations are at about the same longitude, this September 10th date occurred before the autumnal equinox. As a result, Burneyville should have had the latest time for sunrise [remember, the sun rises just north of east prior to the autumnal equinox] while Blackwell should have observed the earliest sunrise. A similar argument holds true for sunset. Hence, the day should have been just a few minutes longer at Blackwell than at Burneyville. Rounding to the nearest 15 minutes, however, the length of the day at these north-south sites should appear to be 12 hours and 45 minutes long.

Because Burneyville is at a more southern location, the rays of sunshine are more perpendicular to the ground at Burneyville than at the other two sites. Burneyville should have observed a larger value of solar radiation at the time of its solar noon compared to the value observed at Blackwell.

The total amount of sunshine is not the only determining factor in how warm or cold a location will be. Hence, the location of the stations do not affect the answer to Question 7.

9. What does your answer to Question 8 say about light from the sun striking the earth throughout the year? That is, what factors determine how much solar radiation strikes a point on the earth on a clear day?

Assuming clear skies, the amount of sunlight that strikes a given location on the earth varies constantly throughout a calendar year. The factor with the greatest influence on the amount of sunlight is the angle of incidence (i.e., latitude of the station). Another factor that determines how much solar radiation strikes a point is the depth of the atmosphere through which a beam of sunlight must pass.

10. (a) If the earth were not tilted on its axis, would the amount of daylight hours at a given point on the earth's surface change during the year? (b) Please explain your answer. (c) List 2-3 different meteorological conditions that the earth would experience if its tilt angle were increased to 40 degrees.

a. If the earth were not tilted on its axis, seasons would not exist. All locations on the earth would have 12 hours of daylight and 12 hours of darkness every day of the year. This condition would occur because no place on earth would be tilted preferentially to receive any more or any less sunlight from the earth than any other place.

b. The actual tilt of the earth is 23.5° . As a result, the tropics are located between 23.5°N (Tropic of Cancer) and 23.5°S (Tropic of Capricorn). The equinoxes occur when the sun is directly overhead at noon at the equator. During the northern hemisphere summer, the sun shines directly overhead at noon in regions between the equator and the Tropic of Cancer. On the summer solstice for the northern hemisphere (the day with the most amount of daylight), the sun is directly overhead at the Tropic of Cancer. This day also has the smallest amount of daylight for the southern hemisphere. During the winter season in the northern hemisphere, the sun's energy is focused directly between the equator and the Tropic of Capricorn as the northern hemisphere is tilted away from the sun.

c. If the tilt angle were increased to 40 degrees, the tropics would move north and south by 16.5° (i.e., the Tropic of Cancer would be 40°N). As a result, the warm, tropical conditions as currently observed in Mexico and Central America would occur as far north as Reno, NV; Kansas City, MO; and Washington, DC. The sun would be directly overhead at 40°N on the summer solstice for the northern hemisphere. In addition, the Arctic regions would stretch equator-ward to 50°N and 50°S . (The real Arctic circle is located at 63.5° which is $90^\circ - 23.5^\circ$, so the fictitious Arctic circle is $90^\circ - 40^\circ = 50^\circ$). As a result, the mid-latitude belt would occupy only 10 degrees of latitude, and the regions that experience 24 hours of darkness in the winter would stretch to 50°N . Seasonal changes over the mid-latitude areas would be greatly amplified. For example, the summer season would be much warmer and the days would be much longer. [The meteorological effects would include a much greater imbalance in the heating of the tropics and cooling of the poles, resulting in much more intense high and low pressure centers, troughs, ridges, etc.]