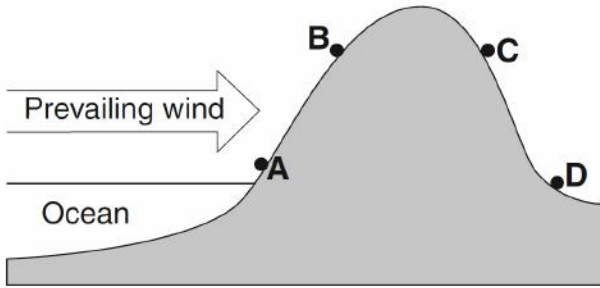


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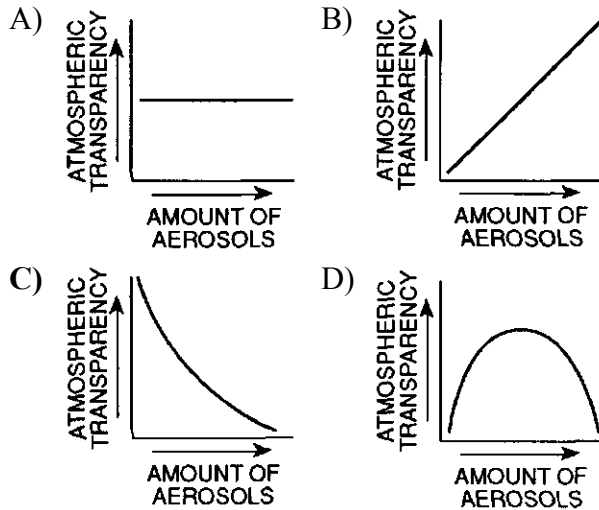
1. The cross section below represents four locations on a mountain. The arrow indicates the prevailing wind direction.



Which location has the warmest and most arid climate?

- A) A B) B C) C **D) D**

2. Which graph best shows the relationship between transparency of the atmosphere and the amount of aerosols (tiny particles) put into the atmosphere?



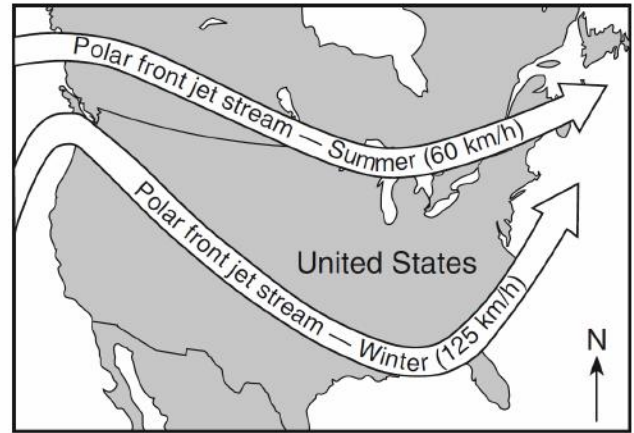
3. According to the Koppen Climate Classifications, a tropical moist climate has an annual rainfall of approximately

- A) 10 inches B) 25 inches
C) 60 inches D) 45 inches

4. Which surfaces will show a high albedo and a low albedo respectively:

- A) lake; snow B) forest; lake
C) forest; snow **D) snow; lake**

5. The map below shows a typical position and average velocity of the polar front jet stream during two different seasons.



For the eastern United States, the change of the polar front jet stream from this summer position to this winter position causes

- A) warmer temperatures farther north and causes storms to move more slowly
 B) warmer temperatures farther north and causes storms to move more rapidly
 C) cooler temperatures farther south and causes storms to move more slowly
D) cooler temperatures farther south and causes storms to move more rapidly

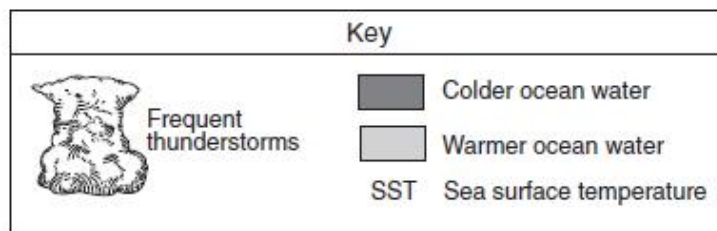
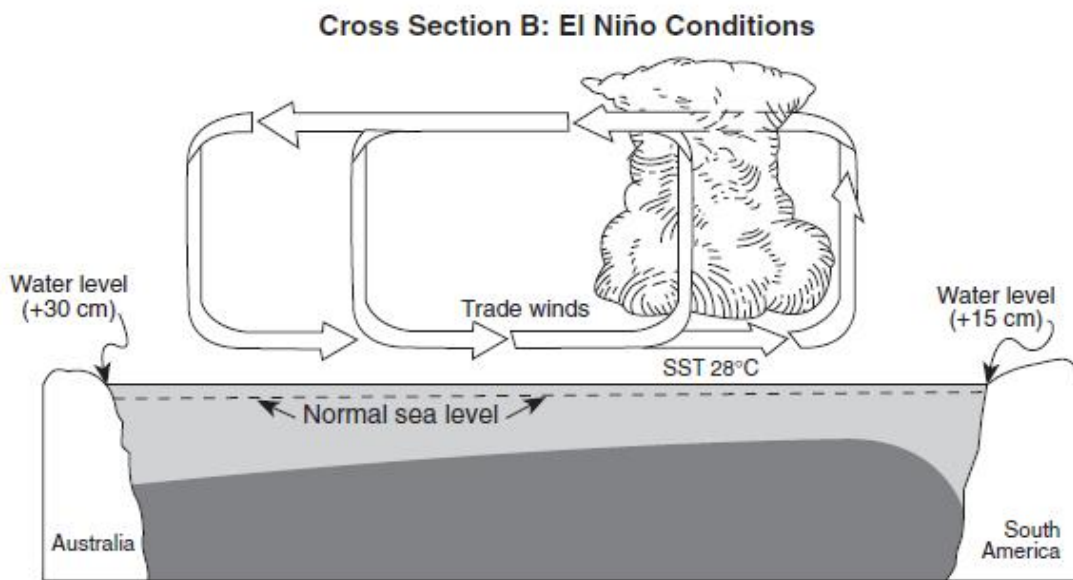
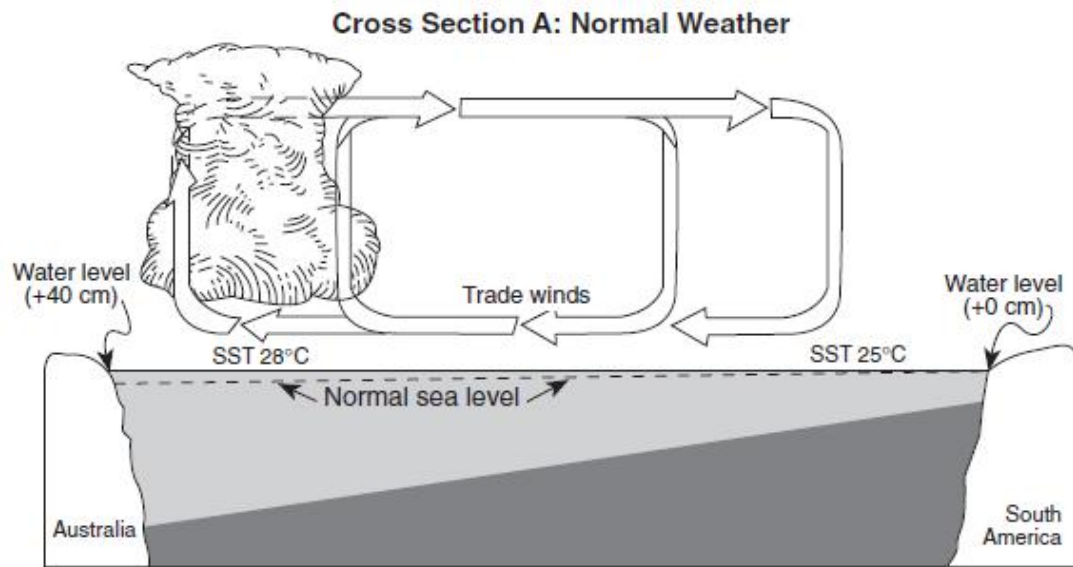
6. As altitude increases in the troposphere and stratosphere, the air temperature

- A) decreases in the troposphere and increases in the stratosphere**
 B) decreases in both the troposphere and stratosphere
 C) increases in the troposphere and decreases in the stratosphere
 D) increases in both the troposphere and stratosphere

7. El Cuy is a South American city located at 40° south latitude. The first day of winter at this location occurs on June 21. During which month would the coldest day of the year most likely occur at this location?

- A) May **B) July**
 C) November D) January

8. Base your answer to the following question on the two cross sections below, which represent the Pacific Ocean and the atmosphere near the Equator during normal weather (cross section *A*) and during El Niño conditions (cross section *B*). Sea surface temperatures (SST) are labeled and trade-wind directions are shown with arrows. Cloud buildup indicates regions of frequent thunderstorm activity. The change from normal sea level is shown at the side of each diagram.

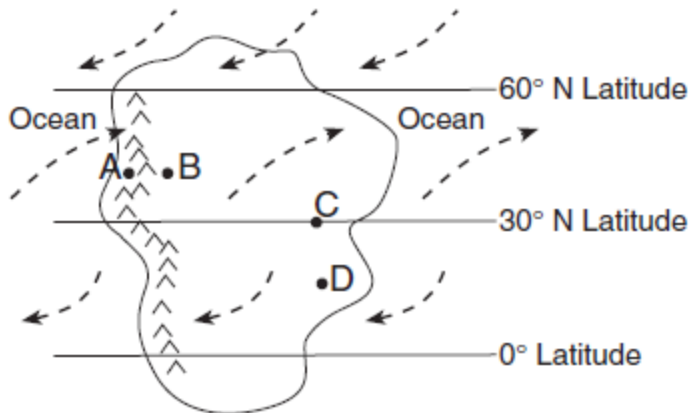


During El Niño conditions, thunderstorms increase in the eastern Pacific Ocean region because the warm, moist air is

- A) less dense, sinking, compressing, and warming
- B) less dense, rising, expanding, and cooling**
- C) more dense, sinking, compressing, and warming
- D) more dense, rising, expanding, and cooling

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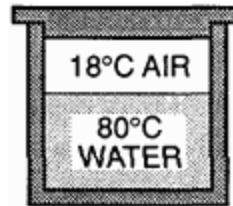
9. Base your answer to the following question on the map below, which shows an imaginary continent on Earth. Arrows represent prevailing wind directions. Letters *A* through *D* represent locations on the continent. Locations *A* and *B* are at the same latitude and at the same elevation at the base of the mountains.



The climate at location *C* is much drier than at location *D*. This difference is best explained by the fact that location *C* is located

- A) farther from any mountain range
 B) closer to a large body of water
 C) at a latitude that experiences longer average annual daylight
D) at a latitude where air is sinking and surface winds diverge
10. Low, thick clouds in the atmosphere _____ solar radiation, while high thin clouds _____ incoming solar radiation.
- A) transmit; reflect **B) reflect; transmit**
 C) reflect; absorb D) emit, transmit
11. When Earth cools, most of the energy transferred from Earth's surface to space is transferred by the process of
- A) conduction B) reflection
 C) refraction **D) radiation**
12. A snow covered surface has just as much albedo as:
- A) cumulus clouds**
 B) a desert surface
 C) a black top parking lot
 D) a forest

13. The diagram below shows a sealed container holding 250 milliliters of water at 80°C. The air above the water had an original temperature of 18°C.

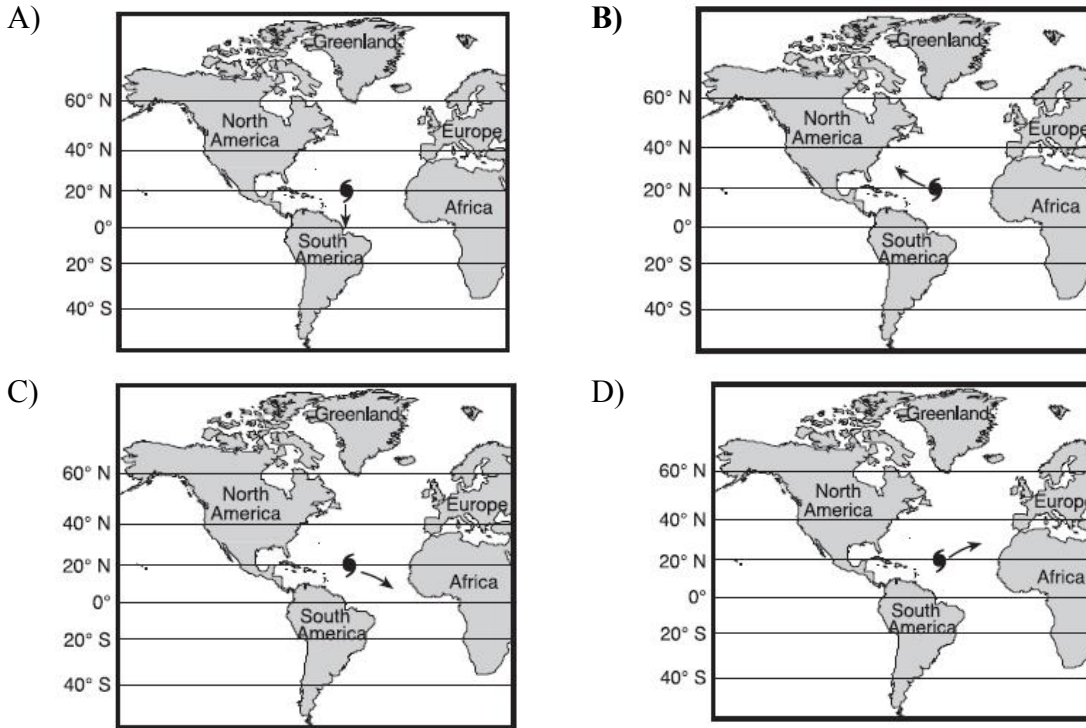


Assuming that the container does not transfer heat, which statement most accurately describes the energy exchanges inside the container?

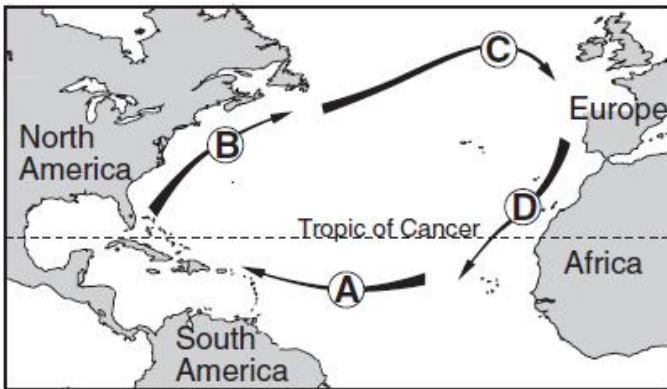
- A) The air gains more heat energy than the water loses.
 B) The air gains less heat energy than the water loses.
C) The air gains the same amount of heat energy that the water loses.
 D) No energy is exchanged between the water and the air.
14. Most scientists infer that a major factor in the increased rate of melting of Earth's glaciers is
- A) a decrease in the output of energy from the Sun
 B) a decrease in Earth's atmospheric transparency
 C) an increase in Earth's orbital distance from the Sun
D) an increase in carbon dioxide in Earth's atmosphere
15. What caused the the "Year without a Summer" throughout Europe and New England in 1816?
- A) the 6 month eruption of Mount Pinatubo
B) the 4 month eruption of Mount Tambora
 C) the increase of carbon dioxide in the atmosphere due to industrialization
 D) the shut down of thermohaline circulation
16. Climate change in the Paleocene-Eocene Thermal Maximum (PETM) is associated with
- A) the mass extinction of benthic foraminifera
 B) expansion of subtropical dinoflagellates
 C) appearance of modern mammals in Europe and North America
D) All of the above

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17. Which map below shows the most likely storm track for a hurricane in the Atlantic Ocean?



18. The arrows labeled *A* through *D* on the map below show the general paths of abandoned boats that have floated across the Atlantic Ocean.



Which sequence of ocean currents was responsible for the movement of these boats?

- A) South Equatorial → Gulf Stream → Labrador → Benguela
- B) South Equatorial → Australia → West Wind Drift → Peru
- C) North Equatorial → Koroshio → North Pacific → California
- D) North Equatorial → Gulf Stream → North Atlantic → Canaries**

19. Compared to the climate conditions of dry inland locations, the climate conditions of locations influenced by a nearby ocean generally result in

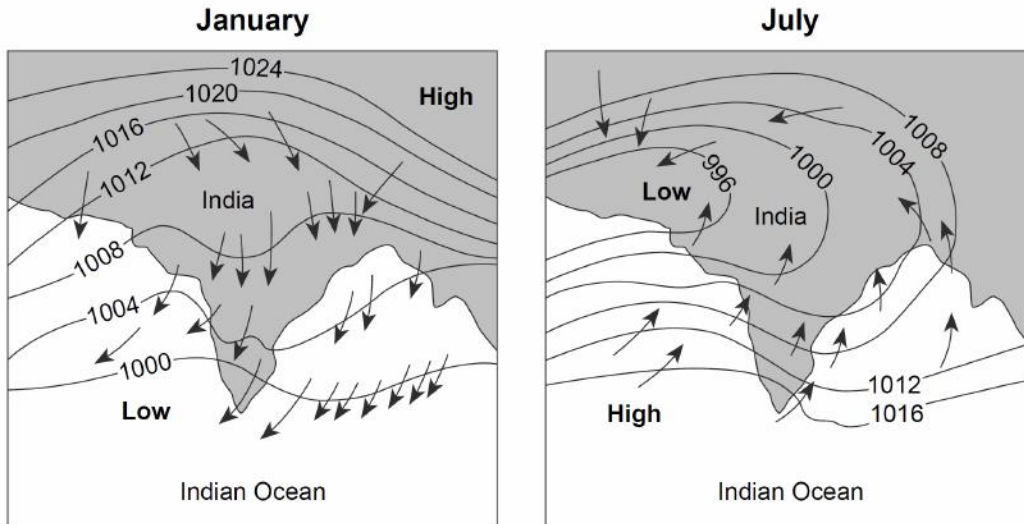
- A) hotter summers and colder winters, with a larger annual range of temperatures
- B) hotter summers and colder winters, with a smaller annual range of temperatures
- C) cooler summers and warmer winters, with a larger annual range of temperatures
- D) cooler summers and warmer winters, with a smaller annual range of temperatures**

20. Which factor causes the surface of Lake Ontario to cool at a slower rate than the surface of the land along the shore of the lake?

- A) Evaporating water releases more heat into the lake than into the land.
- B) Lake water has a higher specific heat than land.**
- C) Water vapor cools the lake as it condenses.
- D) Sunlight passes through the top layers of the lake water.

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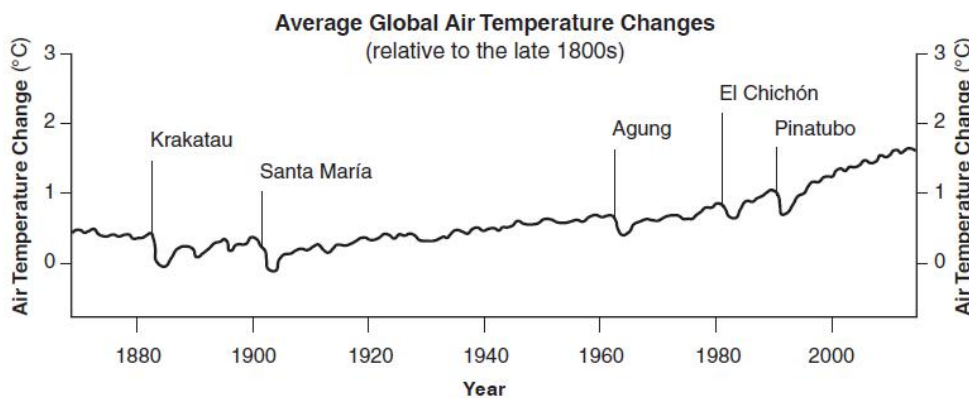
21. Arrows on the maps below show differences in the direction of winds in the region of India and the Indian Ocean during January and July. Isobar values are recorded in millibars.



Heavy monsoon rains usually occur in India during

- A) January, when winds blow from the land
- B) January, when winds blow toward high pressure
- C) July, when winds blow from the ocean**
- D) July, when winds blow toward high pressure

Base your answers to questions 22 and 23 on the graph below and on your knowledge of Earth science. The graph shows the average global air temperature changes that have occurred since the late 1800s. Five volcanoes that experienced major eruptions during this time period are indicated.



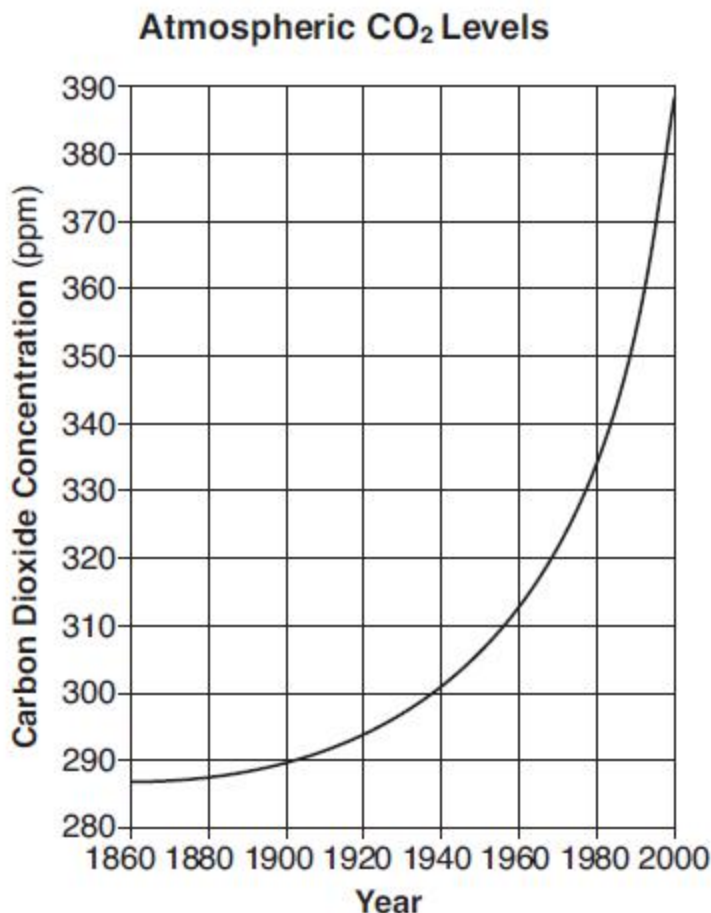
22. Which conclusion can be made from the data shown in the graph?

- A) Volcanic eruptions occur in a cyclic and predictable pattern.
- B) Volcanic eruptions have generally increased in strength since the late 1800s.
- C) Global air temperatures are warmer today than they were in the late 1800s.**
- D) Global air temperatures have had fewer changes since 1950.

23. In the years immediately after each volcanic eruption occurred, average global air temperatures

- A) **decreased because volcanic gases and dust blocked insolation**
 - B) decreased because molten rock released heat
 - C) increased because volcanic gases and dust blocked insolation
 - D) increased because molten rock released heat
-

24. The graph below shows changes in carbon dioxide concentrations in Earth's atmosphere over a 140-year period. Carbon dioxide concentrations are shown in parts per million (ppm).



This significant change in CO₂ concentration is most likely caused by

- A) decreased cloud cover, and is predicted to decrease average global temperatures
 - B) decreased volcanic activity, and is predicted to increase average global temperatures
 - C) **increased use of fossil fuels, and is predicted to increase average global temperatures**
 - D) increased El Niño activity, and is predicted to decrease average global temperatures
-

25. The primitive atmosphere of the Earth contained all of the following gases except

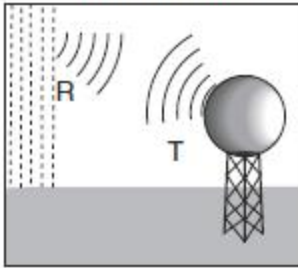
- A) carbon dioxide
- B) methane
- C) water vapor
- D) **oxygen**

26. Thermohaline Circulation is driven by differences in ocean water

- A) volume
 - B) mass
 - C) weight
 - D) **density**
-

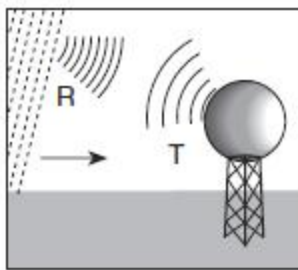
27. Base your answer to the following question on the diagrams below and on your knowledge of Earth science. The diagrams represent electromagnetic waves being transmitted (*T*) by a Doppler radar weather instrument and waves being reflected (*R*) by rain showers. This instrument produces computer images that show the movement of rainstorms.

A Stationary Rain Shower



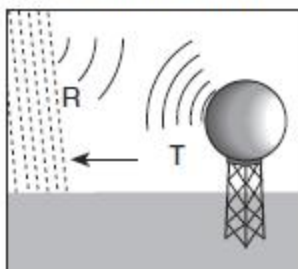
The reflected wavelengths (*R*) from a stationary rain shower are equal to the transmitted wavelengths (*T*).

A Rain Shower Moving Toward the Instrument



The reflected wavelengths (*R*) from a rain shower moving toward the instrument are shorter than the transmitted wavelengths (*T*).

A Rain Shower Moving Away from the Instrument



The reflected wavelengths (*R*) from a rain shower moving away from the instrument are longer than the transmitted wavelengths (*T*).

This Doppler radar instrument transmits electromagnetic energy in the form of microwaves. Some microwave wavelengths are between the wavelengths of

- A) gamma rays and x rays
- B) **infrared and radio waves**
- C) ultraviolet and infrared
- D) x rays and ultraviolet

28. An effect of global warming is due to

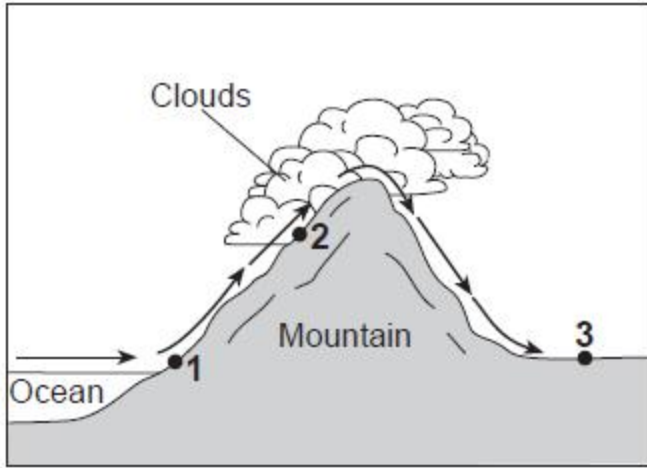
- A) the Faint Young Sun
- B) **a slowdown of thermohaline circulation**
- C) Earth's radioactive budget
- D) Sea ice albedo

29. According to the Faint Young Sun paradox, the Sun's output would have been _____ as intense during the first epoch.

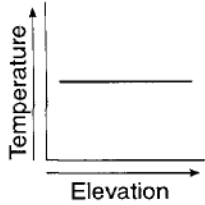
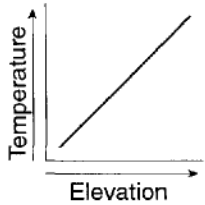
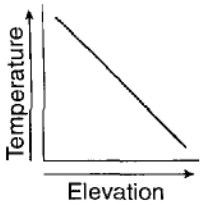
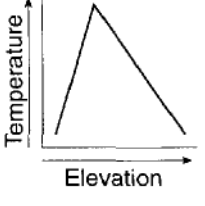
- A) 95 percent
- B) **70 percent**
- C) 10 percent
- D) 26 percent

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30. Base your answer to the following question on the diagram below, which shows air movement over a mountain range. The arrows indicate the direction of airflow. Points 1 through 3 represent locations on Earth's surface.

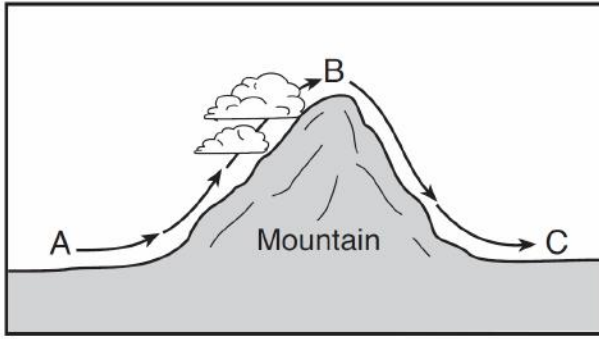


Cloud formation at location 2 is the direct result of air that is rising,

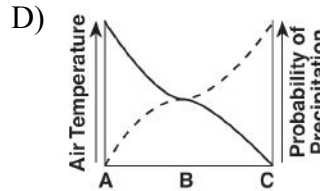
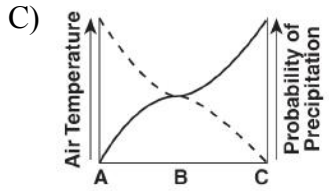
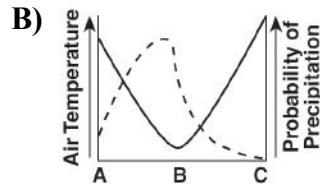
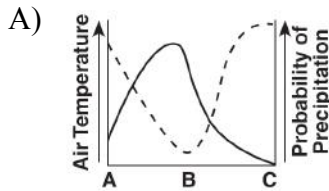
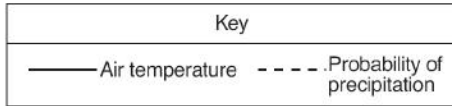
- A) **expanding, and cooling** B) expanding, and warming
C) compressing, and cooling D) compressing, and warming
31. Which graph best shows the general effect that differences in elevation above sea level have on the average annual temperature?
- A)  B) 
- C)  D) 
32. The Earth's energy budget measures the
- A) impact that carbon dioxide and methane gas have on the Earth
B) impact that clouds have on the Earth
C) flow of electromagnetic radiation in and out of the Earth
D) **All of the above**
33. According to the most recent Berkeley Earth study, "sudden drops in the early [Earth] temperature record (1753 to 1860) correspond to..."
- A) **volcanic events**
B) meteorologic events
C) asteroid events
D) Sun spot cycles
34. Large volcanic eruptions sometimes send dust and ash into the stratosphere. After these eruptions, global air temperatures are often
- A) **cooler than normal because the atmosphere is less transparent**
B) cooler than normal because the atmosphere is more transparent
C) warmer than normal because the atmosphere is less transparent
D) warmer than normal because the atmosphere is more transparent

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35. The diagram below shows the flow of air over a mountain, from location *A* to *B* to *C*.



Which graph best shows how the air temperature and probability of precipitation change during this air movement?



36. The Koppen Climate Classifications include all of the following except

- A) **Tundra**
- B) Moist Subtropical
- C) Polar
- D) Moist Continental

37. The Young Sun paradox of the primitive Earth's atmosphere can be explained by

- A) the Paleocene-Eocene thermal maximum
- B) the deep ocean current conveyor belt
- C) **an increase in greenhouse gas amounts than previously thought**
- D) the Mount Tambora eruption

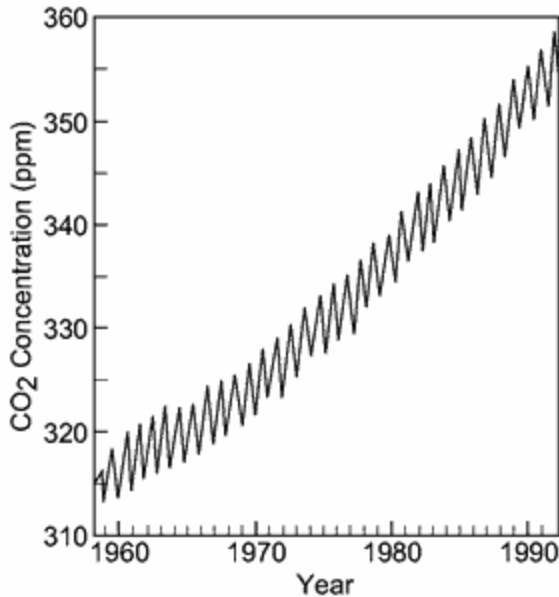
38. Which group of substances is arranged in order of *decreasing* specific heat values?

- A) iron, granite, basalt
- B) copper, lead, iron
- C) dry air, water vapor, ice
- D) **liquid water, ice, water vapor**

39. Even if there is a decrease in anthropogenic greenhouse gases, there still would be a certain amount of carbon dioxide, methane, and nitrous oxide concentrations in the troposphere due to

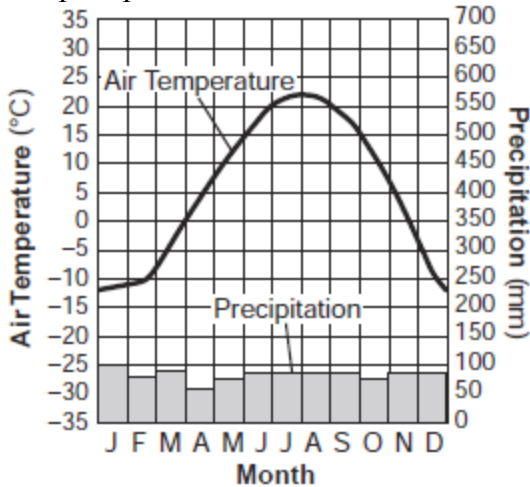
- A) Volcanic eruptions
- B) Forest fires
- C) **Both choices A and B**
- D) None of the above

40. The graph below shows the change in carbon dioxide concentration in parts per million (ppm) in Earth's atmosphere from 1960 to 1990.



The most likely cause of the overall change in the level of carbon dioxide from 1960 to 1990 is an increase in the

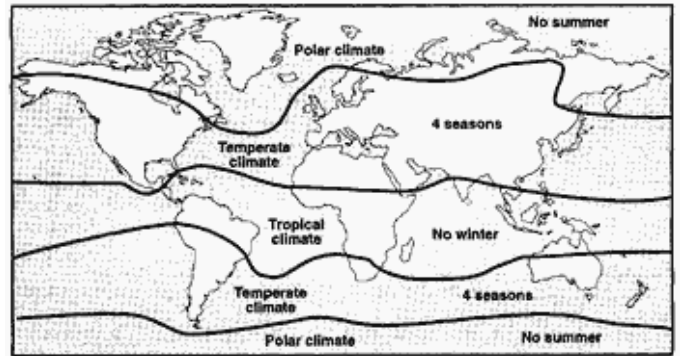
- A) number of violent storms
 - B) number of volcanic eruptions
 - C) use of nuclear power
 - D) use of fossil fuels**
41. The graph below shows the yearly air temperature and precipitation of a location on Earth.



This location would be most likely at a latitude of

- A) 0°
- B) 35° S
- C) 50° N
- D) 90° N

42. The map below shows the major climate zones on Earth.

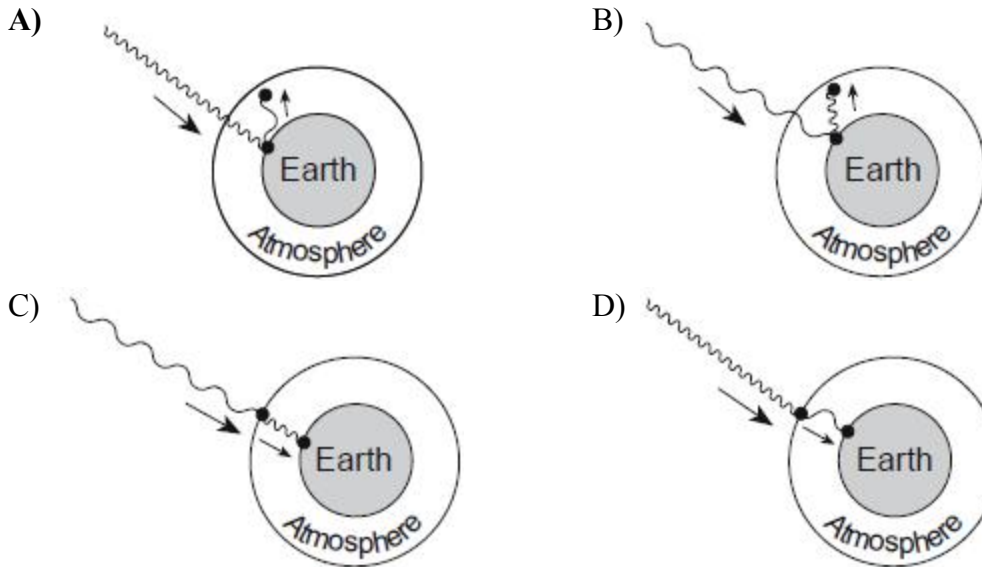
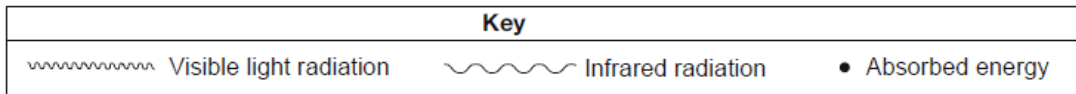


The primary factor controlling these climate zones is

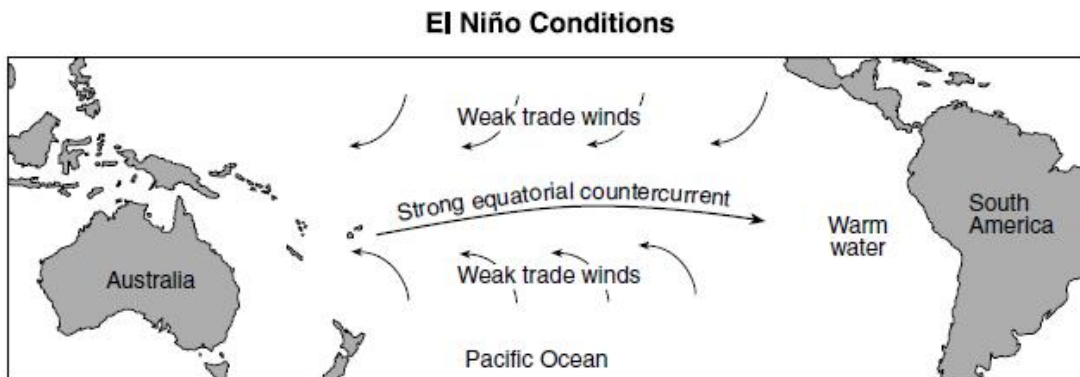
- A) elevation
 - B) solar time
 - C) latitude**
 - D) longitude
43. With the development of many models for climate change predictions, it is evident that the main factors of climate shift is due primarily to:
- A) Increases in anthropogenic carbon dioxide, methane, nitrous oxide
 - B) Black carbon aerosols from volcanic eruptions
 - C) Carbon dioxide from forest fires
 - D) All of the above**
44. Which ocean current brings warm water to the southeastern coast of Africa?
- A) Agulhas Current**
 - B) Benguela Current
 - C) West Australian Current
 - D) Equatorial Countercurrent
45. Weather-station measurements indicate that the dewpoint temperature and air temperature are getting farther apart and that air pressure is rising. Which type of weather is most likely arriving at the station?
- A) a snowstorm
 - B) a warm front
 - C) cool, dry air**
 - D) maritime tropical air

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46. Which diagram best represents how greenhouse gases in our atmosphere trap heat energy?



47. The map below shows the weak trade winds and strong equatorial countercurrent in the Pacific Ocean during El Niño conditions. This causes warm surface ocean water to migrate eastward, lowering the atmospheric pressure above this warm water.



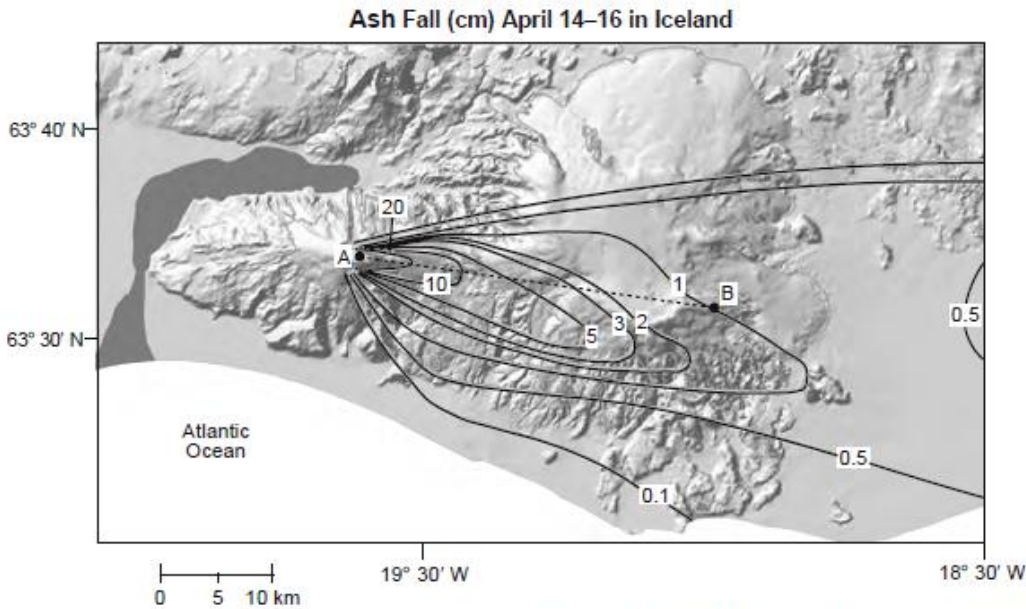
What are the most likely changes to atmospheric temperature and precipitation along the west coast of South America during El Niño conditions?

- A) lower temperatures and lower amounts of precipitation
- B) lower temperatures and higher amounts of precipitation
- C) higher temperatures and lower amounts of precipitation
- D) higher temperatures and higher amounts of precipitation**

48. Base your answer to the following question on the reading passage and map below and on your knowledge of Earth science. The passage provides information regarding the eruption of a volcano in Iceland. The map shows the thickness of ash deposits, in centimeters (cm), during the first three days of the eruption. Point *A*, representing the volcano's location, and point *B*, representing a location on Earth's surface, are connected with a reference line.

Iceland Volcano Eruption Spreads Ash Cloud over Europe

On April 14, 2010, Eyjafjallajökull volcano, located in southern Iceland, explosively erupted, sending large volumes of volcanic ash high into the atmosphere. Much of the ash fell quickly to Earth, as seen in the map, but large quantities remained airborne and spread over Europe. Most of the ash was transported within the atmosphere below 10 kilometers. Air traffic across the Atlantic and throughout Europe was severely disrupted, as airlines were forced to keep jet aircraft on the ground.

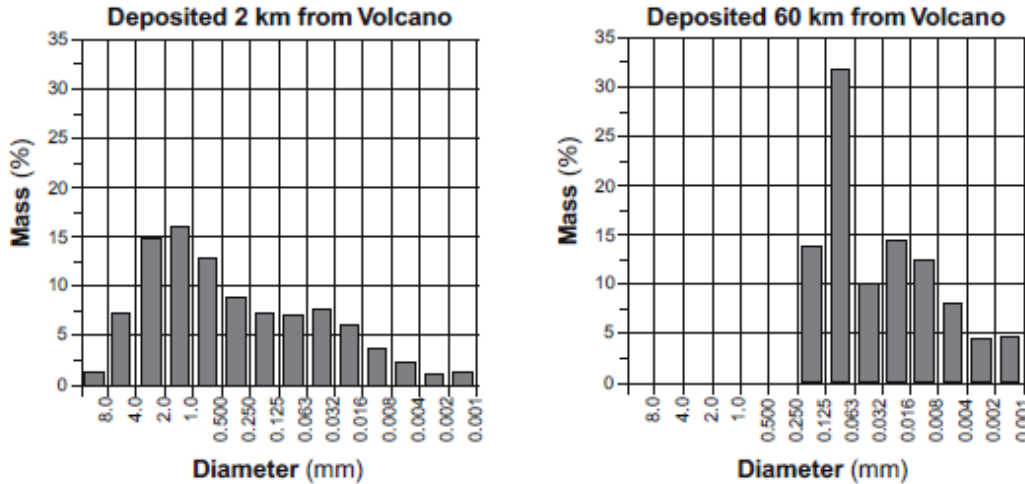


Source: Ash generation and distribution from the April-May 2010 eruption of Eyjafjallajökull, Iceland, Gudmundsson et al., *Scientific Reports*, August 14, 2012 (adapted)

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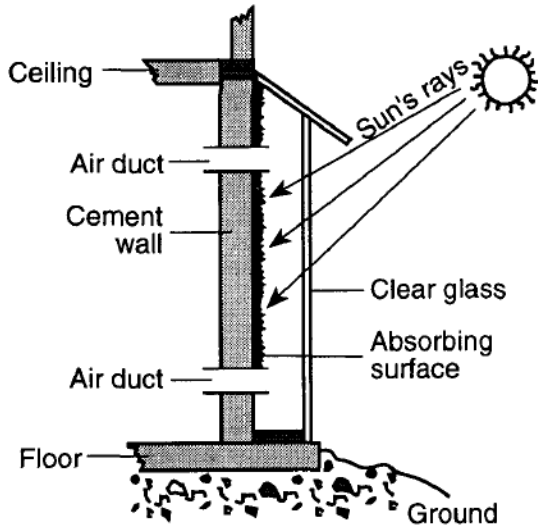
The graphs below indicate the percent by mass of different diameters of ash particles deposited at 2 kilometers and 60 kilometers from the volcanic eruption.

Volcanic Ash Deposited from the April 14-16 Eruption



Describe how the size of the deposited ash particles changed with increased distance from the volcano.

49. Base your answer to the following question on the diagram and table below. The diagram shows a cross section of a solar-energy collecting system constructed as a portion of a wall of a house. It consists of an energy-absorbing surface, a clear glass covering, and air ducts through the wall into the house. The table gives the house temperatures during a spring day. No other heat source is available for the house.



Time of Day	House Air Temperature (°C)
6 a.m.	12
8 a.m.	14
10 a.m.	16
noon	19
2 p.m.	22
4 p.m.	20

What is the purpose of the clear glass covering of this solar collector?

- A) The glass radiates infrared energy.
- B) The glass radiates ultraviolet energy.
- C) **The glass allows short-wave radiation to enter and traps long-wave reradiation.**
- D) The glass allows long-wave radiation to enter and traps short-wave reradiation.

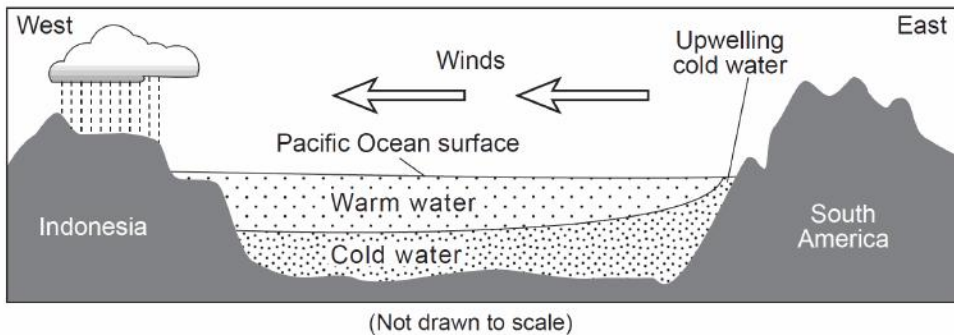
50. Base your answer to the following question on the passage and cross section below and on your knowledge of Earth science. The cross section represents a generalized region of the Pacific Ocean along the equator during normal (non-El Niño) conditions. The relative temperatures of the ocean water and the prevailing wind direction are indicated.

El Niño

Under normal Pacific Ocean conditions, strong winds blow from east to west along the equator. Surface ocean water piles up on the western part of the Pacific due to these winds. This allows deeper, colder ocean water on the eastern rim of the Pacific to be pulled up (upwelling) to replace the warmer surface water that was pushed westward.

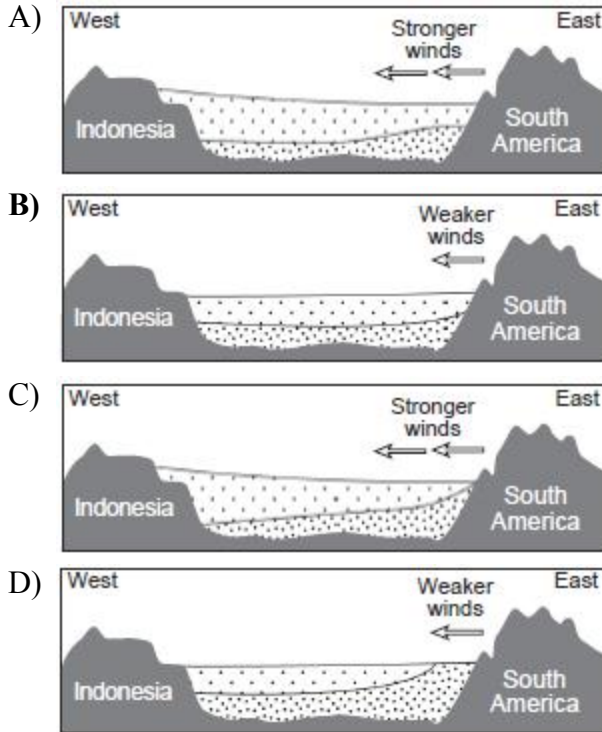
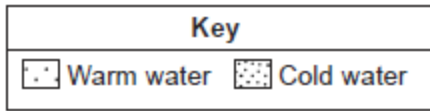
During an El Niño event, these westward-blowing winds get weaker. As a result, warmer water does not get pushed westward as much, and colder water in the east is not pulled toward the surface. This creates warmer surface ocean water temperatures in the east, allowing the thunderstorms that normally occur at the equator in the western Pacific to move eastward. A strong El Niño is often associated with wet winters along the northwestern coast of South America and in the southeastern United States, and drier weather patterns in Southeast Asia (Indonesia) and Australia. The northeastern United States usually has warmer and drier winters in an El Niño year.

Normal Pacific Ocean Conditions (non-El Niño years)



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Which cross section best represents the changed wind conditions and Pacific Ocean temperatures during an El Nino event? [Diagrams are not drawn to scale.]



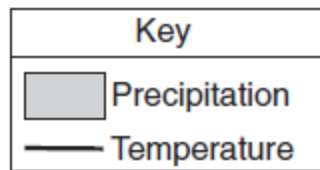
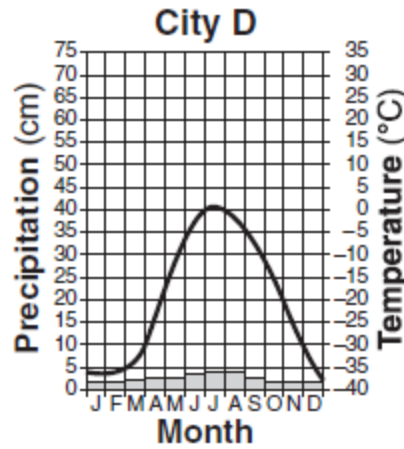
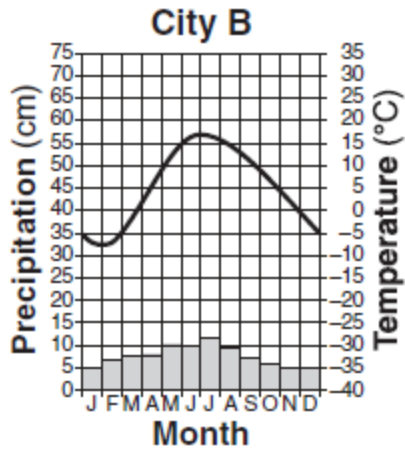
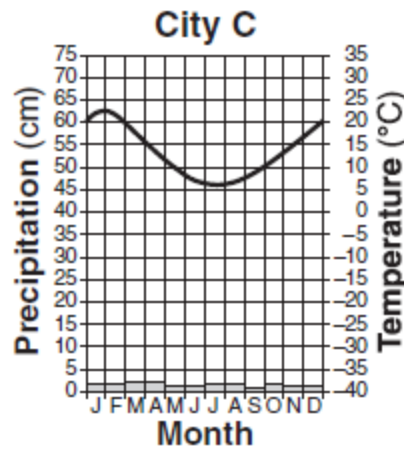
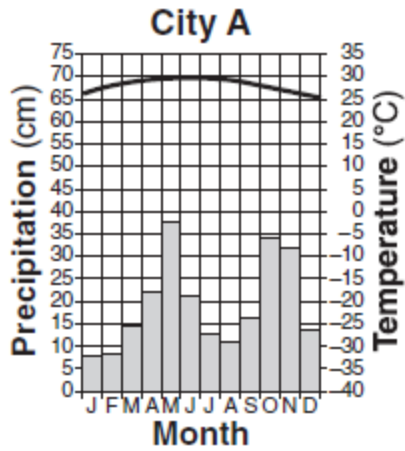
51. The table below shows the latitude and the average yearly temperature for four different cities.

City	Singapore	Calcutta	Washington, D.C.	Moscow
Latitude	1° N	23° N	39° N	56° N
Average Yearly Temperature	81°F	79°F	57°F	39°F

It can be inferred from this table that the cities at higher latitudes have

- A) lower average yearly temperatures because these cities receive insolation at a higher angle during the year
- B) lower average yearly temperatures because these cities receive insolation at a lower angle during the year**
- C) higher average yearly temperatures because these cities receive insolation at a higher angle during the year
- D) higher average yearly temperatures because these cities receive insolation at a lower angle during the year

Base your answers to questions 52 and 53 on the climate graphs below, which show average monthly precipitation and temperatures at four cities, A, B, C, and D.



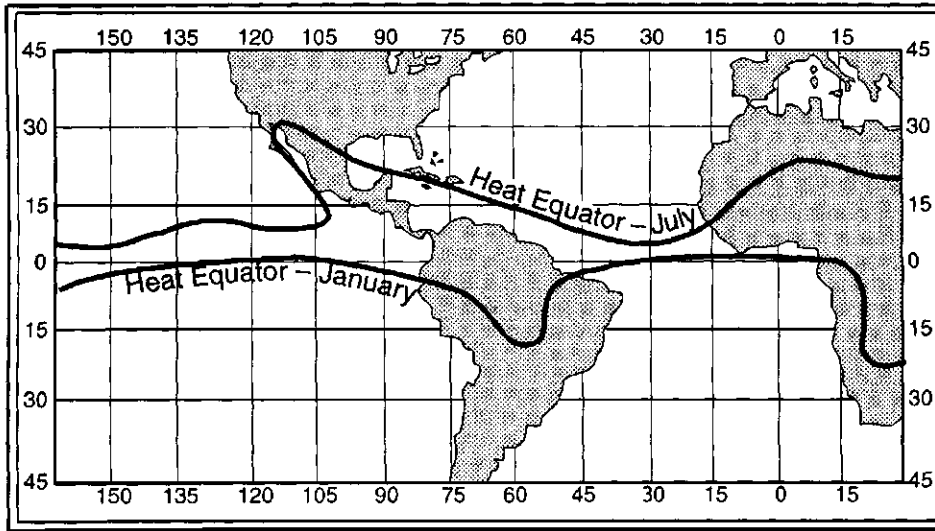
52. Very little water will infiltrate the soil around city D because the region usually has

- A) a frozen surface
- B) nearly flat surfaces
- C) a small amount of runoff
- D) permeable soil

53. It can be concluded that city C is located in the Southern Hemisphere because city C has

- A) small amounts of precipitation throughout the year
- B) large amounts of precipitation throughout the year
- C) its warmest temperatures in January and February
- D) its warmest temperatures in July and August

54. Base your answer to the following question on the map below, which shows the location of the Heat Equator for July and January. A Heat Equator is a line connecting the locations of the highest average monthly temperatures.



Why does the location of the Heat Equator change more over the land than over the oceans?

- A) Land temperatures are cooler than ocean temperatures.
- B) The prevailing winds change direction as they pass over land.
- C) Hurricanes form over oceans and cool the water surfaces.
- D) Oceans have a higher specific heat than land.**

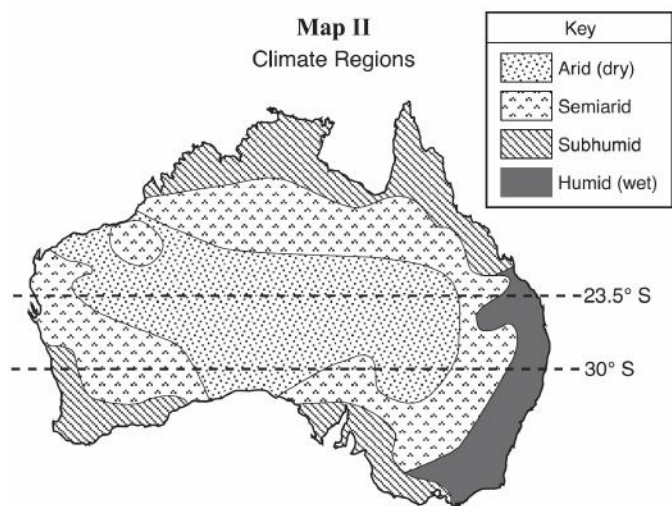
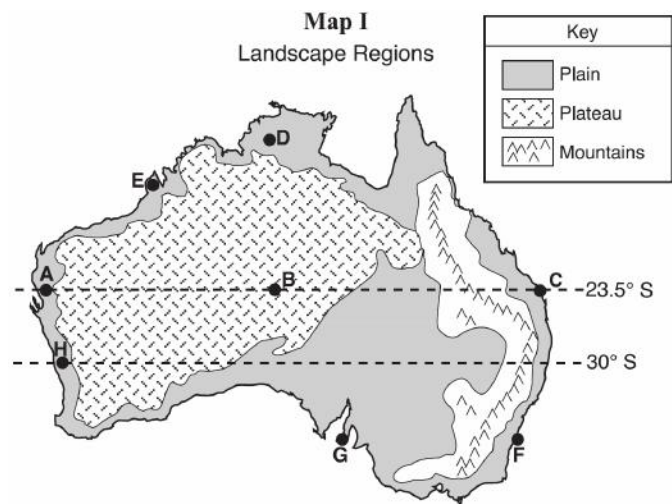
55. Deep-ocean currents are initiated by the

- A) salinity changes in the ocean
- B) formation of sea ice**
- C) density changes
- D) All of the above

56. What best explains why, in early spring, ice remains longer on Lake Erie than on the surrounding land areas when the air temperature is above freezing?

- A) Water has a higher specific heat than land.**
- B) Energy is needed for water to evaporate.
- C) Cool winds from the surrounding land cool the ice on the lake.
- D) Air temperature does not affect water temperature.

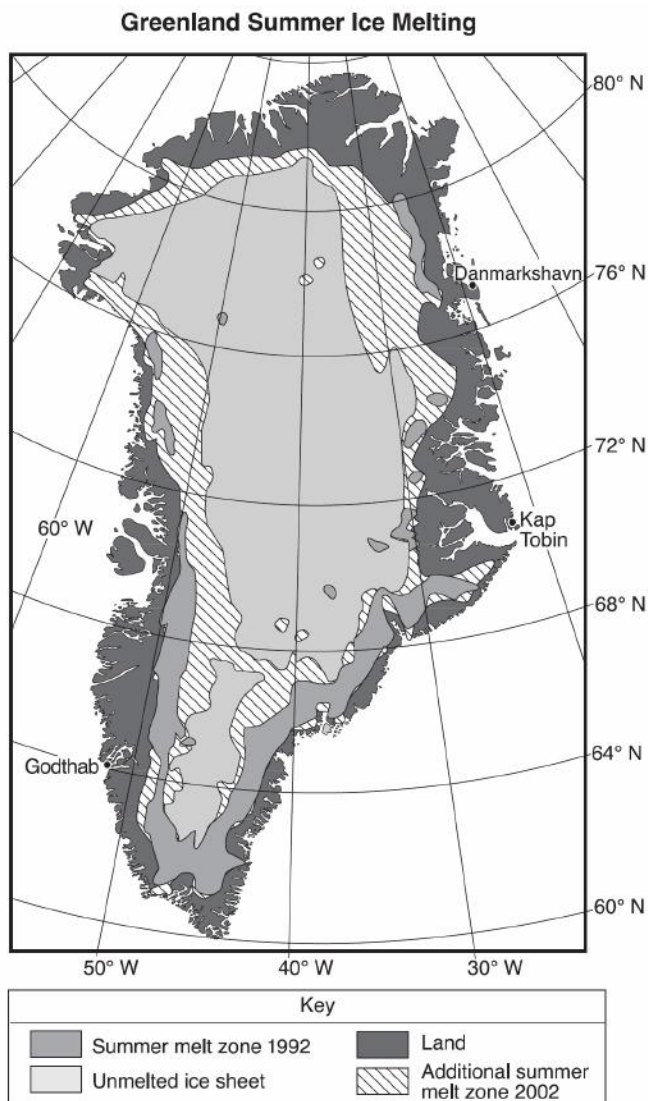
57. Base your answer to the following question on the two maps for Australia below. Map I shows Australia's major landscape regions. Letters *A* through *H* represent locations in Australia. Map II shows Australia's general climate regions.



Which two locations have the driest climates?

- A) *A* and *B* B) *G* and *H* C) *C* and *F* D) *D* and *E*

58. Base your answer to the following question on the following map and passage. The map shows the extent of summer ice-melt zones on Greenland in 1992 and 2002. The summer melt zone is an area where summer heat turns snow and ice around the edges of the ice sheet into slush and ponds of meltwater. Three coastal locations are shown on the map.



Arctic Meltdown

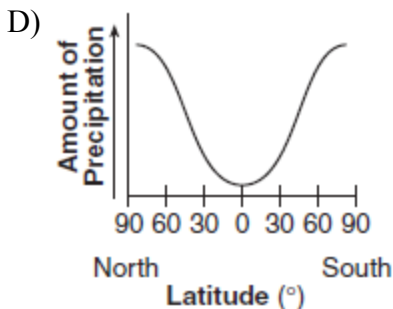
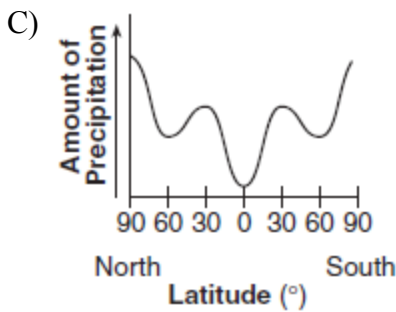
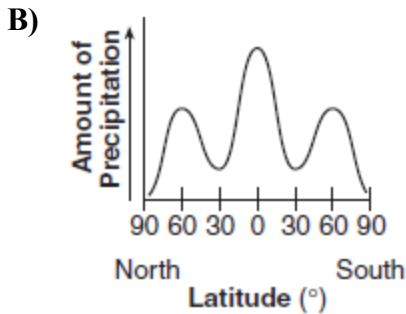
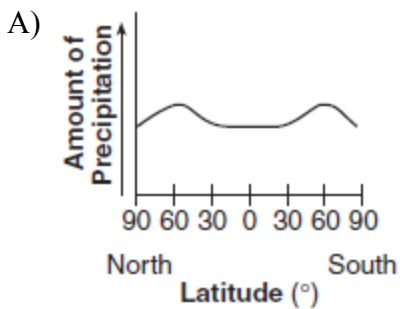
Scientists are concerned because average arctic temperatures are rising. The Greenland Ice Sheet, the dominant area of continental ice in the arctic region, broke all previous records for melting in 2002.

In 2004, the total amount of ice resting on top of the continental crust in the arctic region was estimated to be about 3,100,000 cubic kilometers. If all this ice were to melt, the ocean levels would rise approximately 8.5 meters. A reduction in ice-covered areas exposes more land surfaces. This increases absorption of insolation and accelerates arctic warming. Scientists continue to collect data to define the role of greenhouse gases in the warming of the arctic region.

Two of the greenhouse gases that may be responsible for the increased ice melting in Greenland are

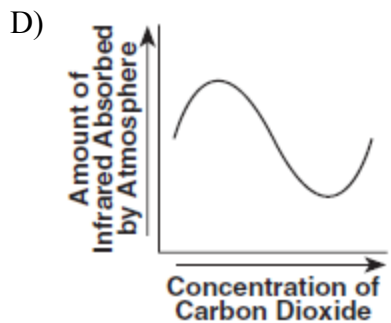
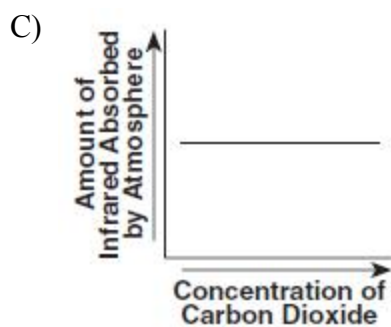
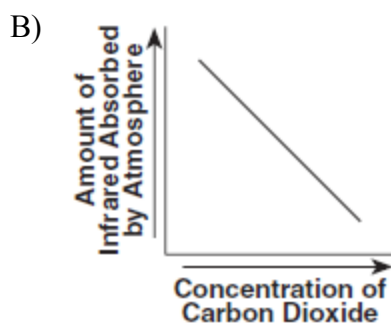
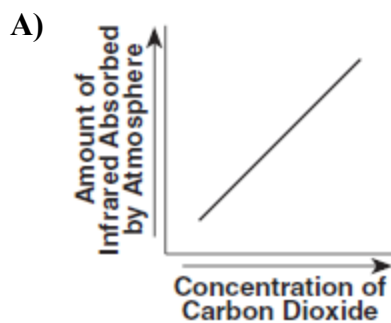
- A) nitrogen and oxygen
- B) oxygen and silicon
- C) hydrogen and helium
- D) carbon dioxide and methane**

59. Which graph best shows the average annual amounts of precipitation received at different latitudes on Earth?



Science Olympiad Division B: Meteorology
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60. Which graph best shows the relationship between the concentration of carbon dioxide in Earth's atmosphere and the amount of infrared radiation absorbed by the atmosphere.



Answer Key
Sci Oly Meteorology Rustin

- | | | | |
|-----|-----------------|-----|--|
| 1. | <u>D</u> | 37. | <u>C</u> |
| 2. | <u>C</u> | 38. | <u>D</u> |
| 3. | <u>C</u> | 39. | <u>C</u> |
| 4. | <u>D</u> | 40. | <u>D</u> |
| 5. | <u>D</u> | 41. | <u>C</u> |
| 6. | <u>A</u> | 42. | <u>C</u> |
| 7. | <u>B</u> | 43. | <u>D</u> |
| 8. | <u>B</u> | 44. | <u>A</u> |
| 9. | <u>D</u> | 45. | <u>C</u> |
| 10. | <u>B</u> | 46. | <u>A</u> |
| 11. | <u>D</u> | 47. | <u>D</u> |
| 12. | <u>A</u> | 48. | — A greater
percentage by mass
of smaller ash
particles was carried
farther. — The larger
particles were
carried shorter
distances. — They
tend to be a smaller
size. |
| 13. | <u>C</u> | 49. | <u>C</u> |
| 14. | <u>D</u> | 50. | <u>B</u> |
| 15. | <u>B</u> | 51. | <u>B</u> |
| 16. | <u>D</u> | 52. | <u>A</u> |
| 17. | <u>B</u> | 53. | <u>C</u> |
| 18. | <u>D</u> | 54. | <u>D</u> |
| 19. | <u>D</u> | 55. | <u>B</u> |
| 20. | <u>B</u> | 56. | <u>A</u> |
| 21. | <u>C</u> | 57. | <u>A</u> |
| 22. | <u>C</u> | 58. | <u>D</u> |
| 23. | <u>A</u> | 59. | <u>B</u> |
| 24. | <u>C</u> | 60. | <u>A</u> |
| 25. | <u>D</u> | | |
| 26. | <u>D</u> | | |
| 27. | <u>B</u> | | |
| 28. | <u>B</u> | | |
| 29. | <u>B</u> | | |
| 30. | <u>A</u> | | |
| 31. | <u>C</u> | | |
| 32. | <u>D</u> | | |
| 33. | <u>A</u> | | |
| 34. | <u>A</u> | | |
| 35. | <u>B</u> | | |
| 36. | <u>A</u> | | |
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