Time: 09:00 to 12:00 hrs Date: August 29, 2019

INSTRUCTIONS:

Students should finish the exam within 3 hours for Witten Test 1 and 2. Please mark "**V**" in the box(es) corresponding to your answer(s) in the ANSWER SHEET.

MARKING SCHEME:

"Choose ONLY ONE correct statement" indicates there is only one correct answer, For these questions, marking will be as follows:

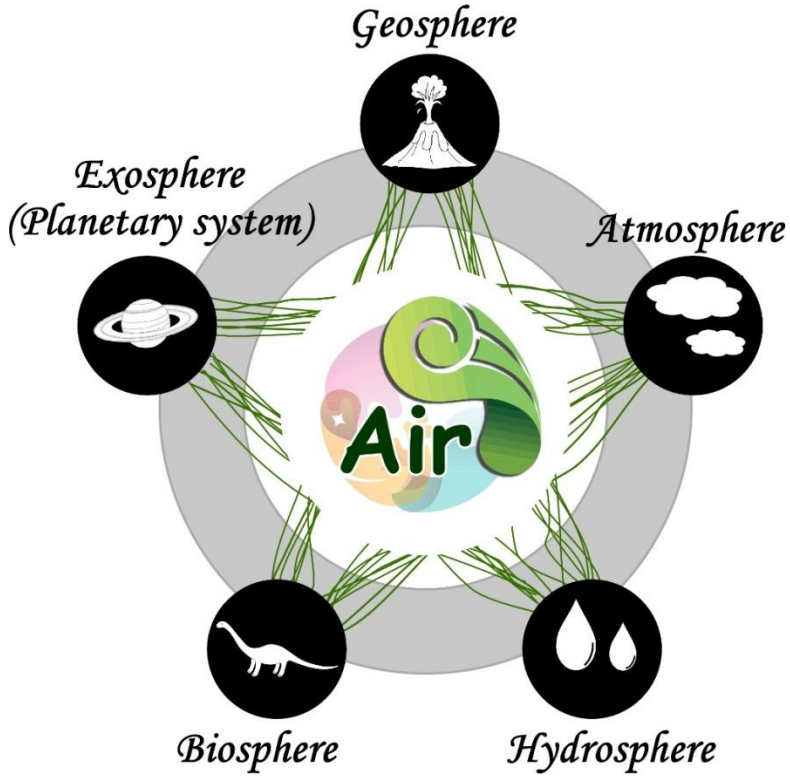
- For **correct** answer: 1 point
- For **incorrect** answer: 0 point
- If several answers are chosen: 0 point.

"Choose ALL the correct statements" indicates there is more than one correct answer. For these questions, marking will be as follows:

- Each **correct** answer: +1 point.
- Each incorrect answer: - 0.5 point. (Minus 0.5 point)
- The combined answers to any question will not be marked less than zero.

Theme: Air

The air is made up of many gases and fine, suspended particles, making it an important medium for the Earth system to store solar energy as well as for the sustenance of life. It stores or absorbs water vapor and energy and redistributes them to the whole Earth in the form of heat, producing winds and the weather system. Air currents occur when various materials move from place to place in response to barometric pressure. The atmosphere surrounding other celestial bodies in the solar system also exhibits various characteristics depending on its composition and proportions of gases.



In this test, we will evaluate your knowledge and thinking ability related to the air surrounding the Earth and the celestial bodies of the solar system in terms of geosphere, atmosphere, hydrosphere, and biosphere.

Introduction to question Q1:

Aerosols are small, solid or liquid particles that float in the atmosphere and are naturally produced by sandstorms, breaking waves and volcanic eruptions besides human activities such as fossil fuel combustion. They generally dominate near the ground. However, when large volcanoes such as the Pinatubo explode, aerosols are produced in the stratosphere, which affect the climate. Figure A shows the type of volcanic gases entering the stratosphere due to volcanic eruptions and the formation of sulfate aerosols. Figure B schematically represents the influence of gases generated by volcanic eruptions.

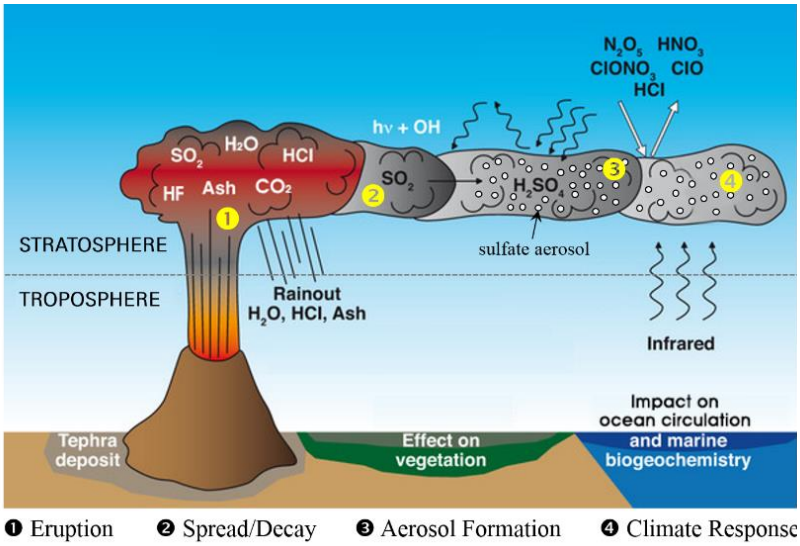


Figure A

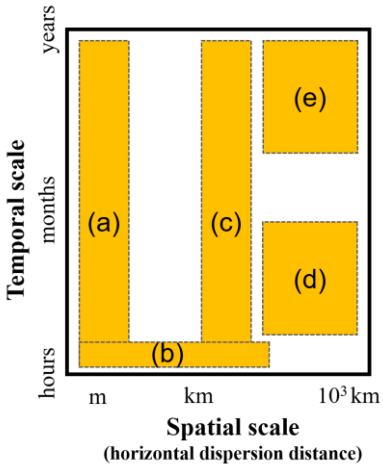


Figure B

Q1) Choose ALL the correct statements.

a) The most abundant gas component of a volcanic eruption is CO_2.

b) Sulfate aerosols cool the Earth's surface.

c) Sulfate aerosols mitigate acidification of the surface.

d) The gases emitted by a volcanic eruption can destroy the ozone layer.

e) In Figure B, the time-space scale affected by sulfate aerosols is best represented by (b).

Introduction to question Q2:

The Earth's atmosphere was significantly different in the past compared to the present. It has changed over time due to the influence of organisms and input of mantle materials. Figure A portrays the compositional change in the Earth's atmosphere and the evolution of life. Figure B shows temporal changes in the atmospheric composition.

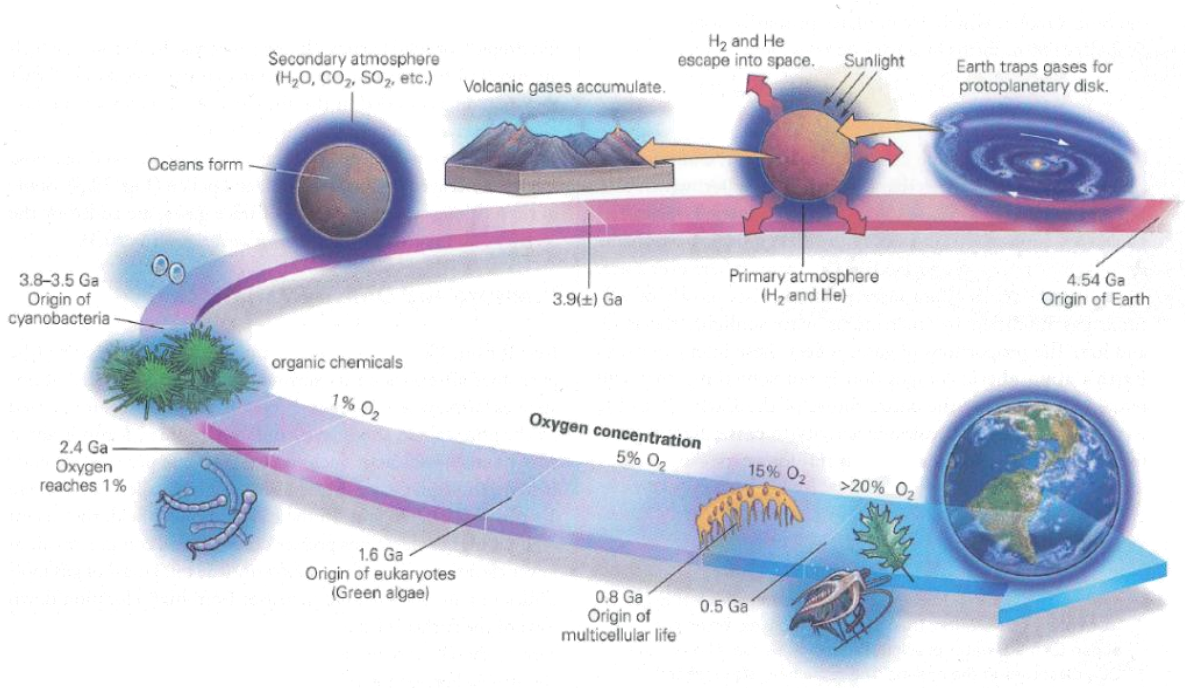


Figure A

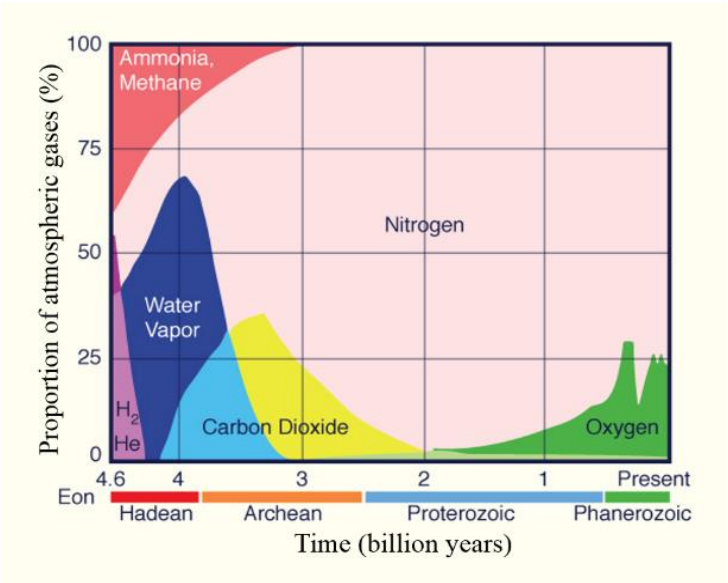


Figure B

Q2) Choose ALL the correct statements as an explanation for this.

a) Today's greenhouse effect is higher than that in the Archaean.

b) The ozone layer formed about one billion years ago.

c) Photosynthesis started for the first time 1.6 billion years ago when eukaryotes appeared.

d) Life was restricted to the oceans two billion years ago.

e) A major reason for the decrease in atmospheric CO_2 content, which accounted for more than 25% of the primordial atmosphere, is the formation of oceans.

Introduction to questions Q3-Q5:

It is important to understand the carbon cycle for better prediction of future climate change because one of the forms of carbon is CO_2, the most discussed greenhouse gas. The atmosphere transfers carbon to other sub-systems of the Earth like lithosphere, hydrosphere, and biosphere on various time scales (Figure A). Thus, the atmospheric CO_2 concentration fluctuates on a daily basis to geological time scales.

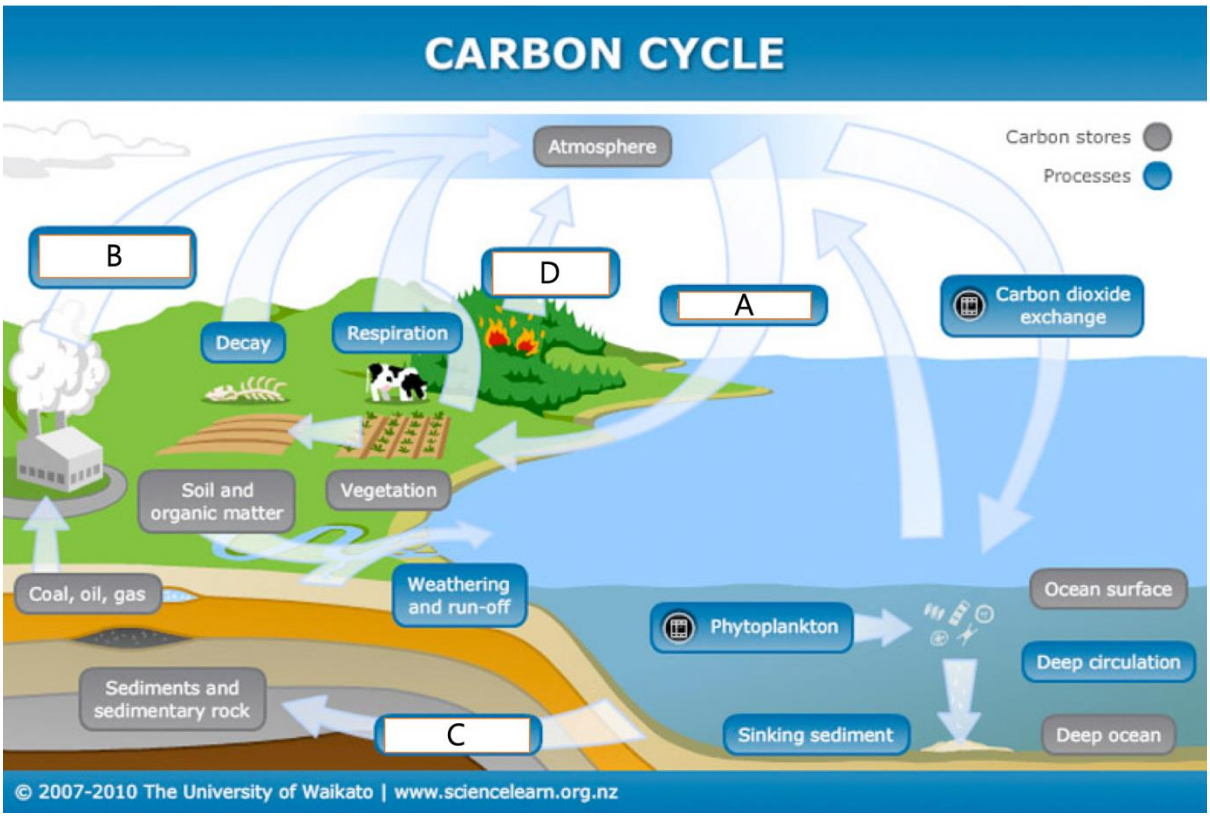


Figure A

Q3) Based on Figure A above, choose ALL the appropriate description(s) of the boxes A-D.

a) Process A related with vegetation in the Southern Hemisphere is the most active during boreal summer.

b) Process B associated with human activity is likely responsible for the recent CO_2 increase in the atmosphere.

c) Process C can permanently isolate carbon from the atmosphere and the ocean.

d) Process D often occurs during hot and wet seasons.

e) Without process A, the Earth's atmosphere cannot consist of abundant free oxygen.

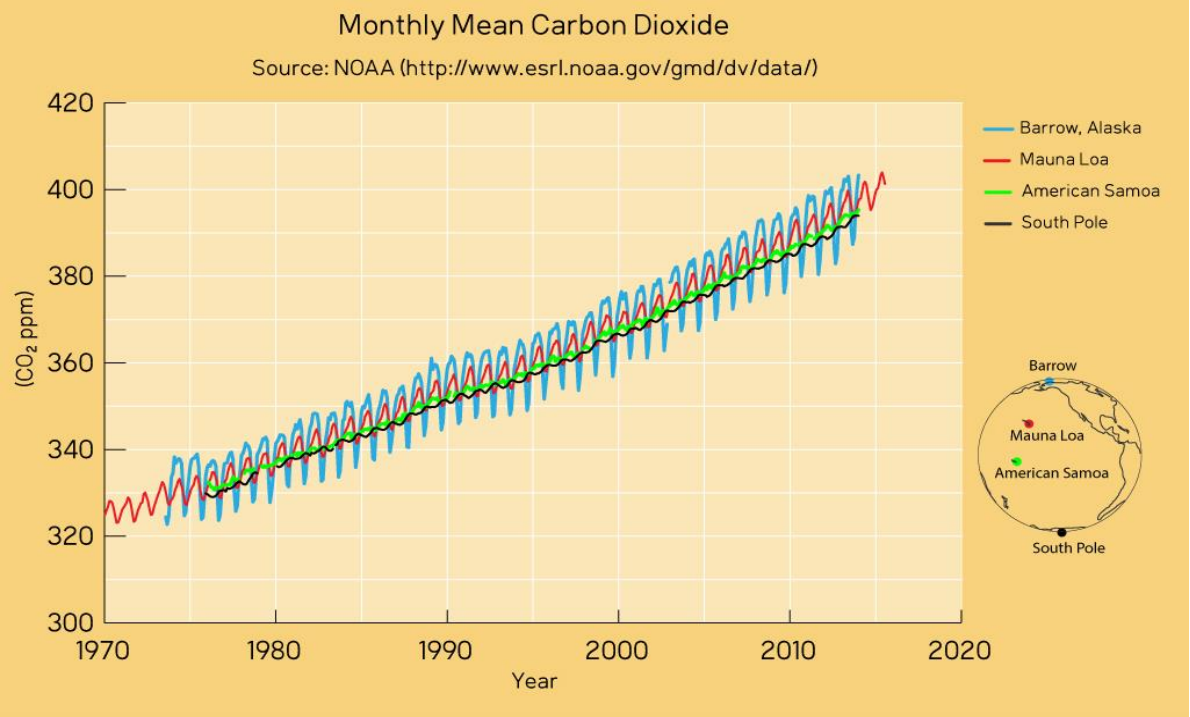


Figure B

Figure B shows the monthly atmospheric CO_2 concentration measured at Barrow, Mauna Loa, American Samoa, and the South Pole, whose locations are shown. The CO_2 concentration has significantly increased since 1958 at all the observatories. In addition to the long-term trend, a noticeable seasonal cycle also can be seen, particularly at Barrow and Mauna Loa.

Q4) Based on Figures A and B above, choose ALL the appropriate interpretation(s) of the seasonal variations of CO_2 concentration.

a) Compared to the Southern Hemisphere, the stronger seasonal cycle of CO_2 concentration in the Northern Hemisphere is attributable to stronger solar radiation during boreal winter.

b) The maximum CO_2 concentration in late spring is mainly due to significant CO_2 emission from the recently melting permafrost.

c) From late spring to autumn, more photosynthesis rather than respiration, of boreal forest is mainly responsible for the low CO_2 concentration in September and October.

d) More CO_2 uptake of ocean is responsible for the low level of CO_2 concentration during summer.

e) The lowest level of CO_2 concentration in early autumn is attributable to the rapid decomposition of organic matter during summer.

f) The larger area of deciduous forests in the Northern Hemisphere accounts for a more noticeable seasonal cycle of CO_2 concentration therein than in the Southern Hemisphere.

g) Combustion of fossil fuels weakens the seasonal cycle of CO_2 concentration.

Figure C displays the amplitudes of the seasonal cycle of CO_2 concentration at Barrow (Alaska) and Mauna Loa (Hawai'i). The seasonal variation of atmospheric CO_2 concentration is high particularly in high latitudes where the continental area is large compared to the oceanic area.

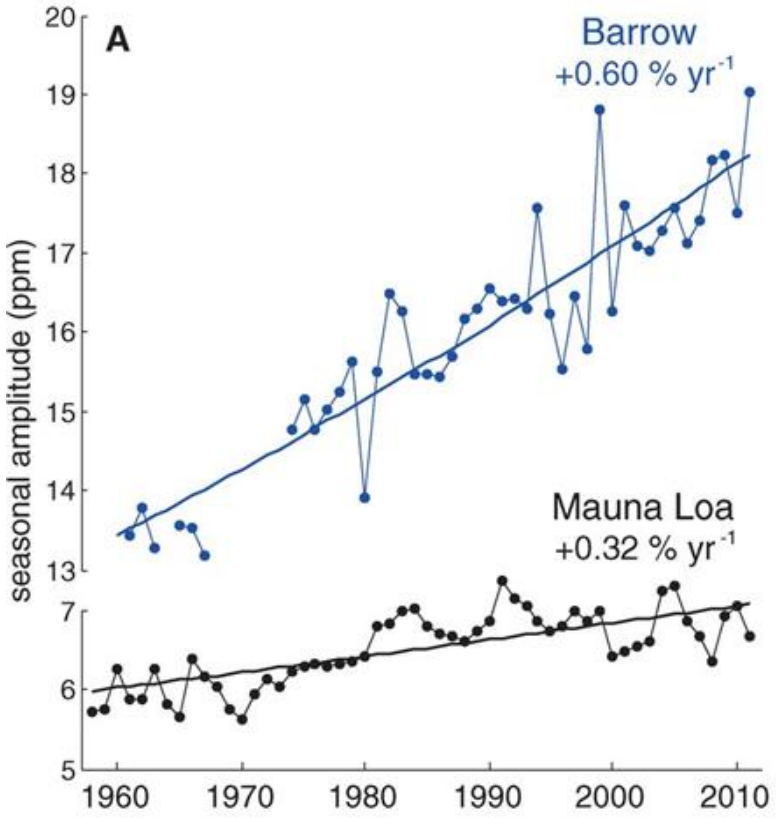


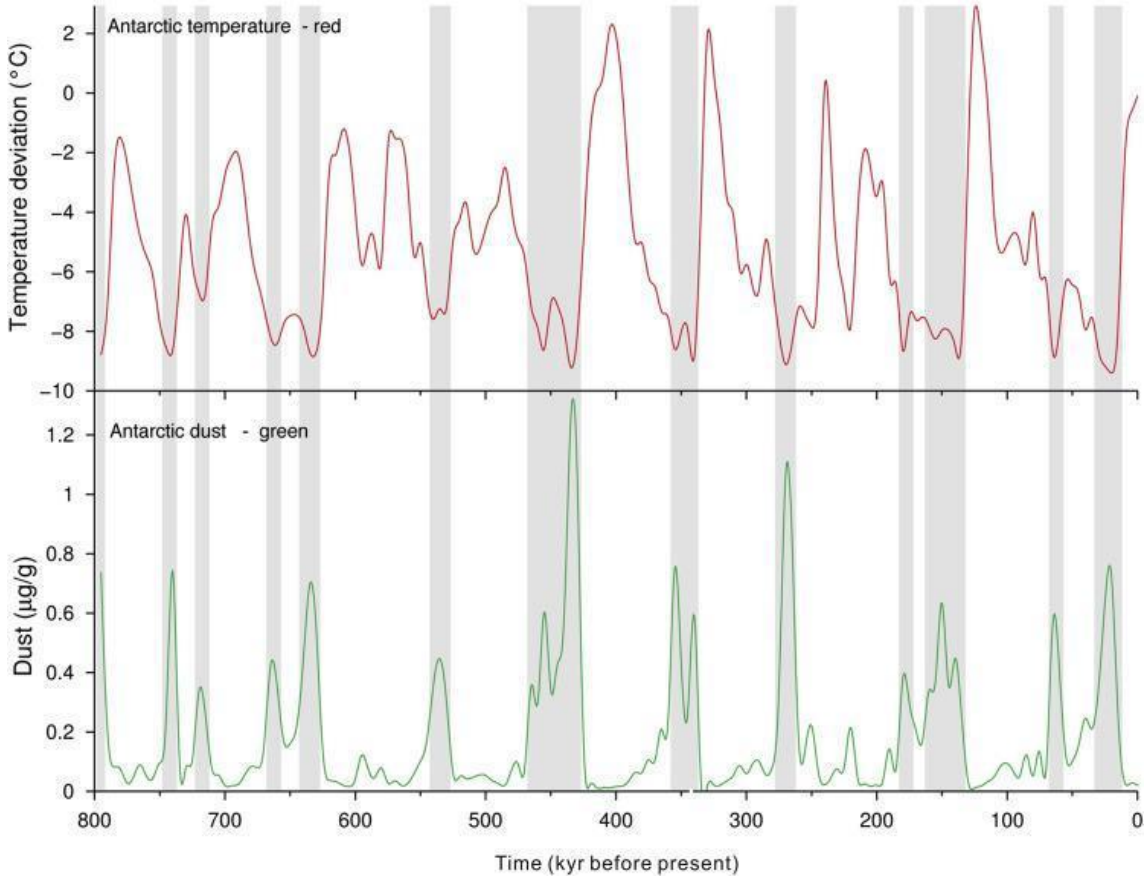
Figure C

Q5) What environmental changes could result in the amplified seasonal variation of CO_2? Choose ALL the correct statements.

a) Desertification
b) More carbon uptake by ocean
c) Tundra greening and shrubification
d) More frequent sunspot activity
e) More volcanic activity
f) Intensive agriculture
g) Increased vegetation productivity

Introduction to question Q6:

The figure below shows variations in temperature and dust amount in Antarctic ice cores during the past 800 ka.



Q6) Choose the only one correct answer based on the figure above.

a) Periods of high concentrations of dust are characterized by high temperature.

b) Increased amounts of dust in the atmosphere during cold periods increase the albedo, resulting in high temperatures

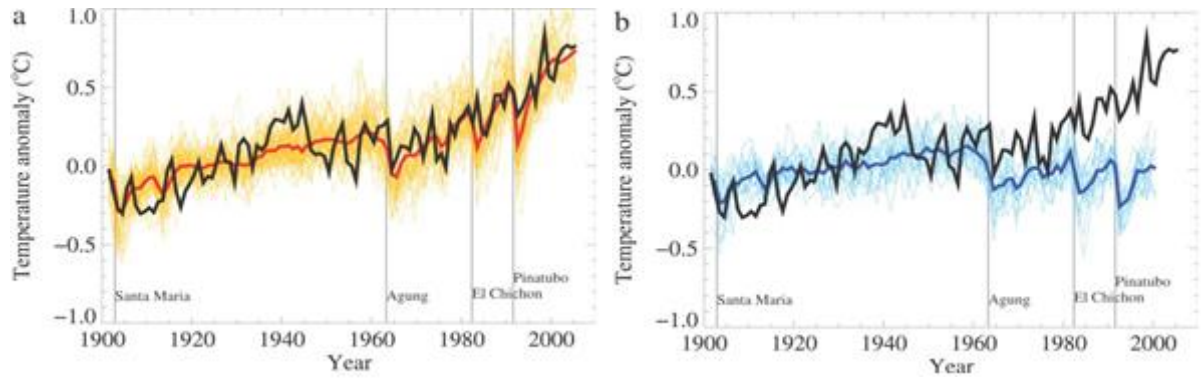
c) Increased amounts of dust in the atmosphere during cold periods lower the albedo, resulting in high temperatures.

d) The dust is spread by winds from large deserts that form during dry periods caused by glacial maximum.

e) The dust is spread by winds from large deserts that form during dry periods caused by glacial minimum.

Introduction to question Q7:

The figures below show global mean surface temperature anomalies relative to the period 1901-1950, as observed (black line) and as obtained from climate model simulations with (a) both human-induced and natural factors (red line) considered and (b) natural factors only (blue line) considered. Vertical gray lines indicate the timings of major volcanic eruptions. The thick red and blue lines shows the average of many different simulations which are represented by thin yellow and blue lines.



Q7) Choose ALL correct explanations describing the findings in the figures above.

a) Natural factors such as volcanic and solar activity caused the rapid warming in the second half of the 20th century.

b) The observed rapid global warming cannot be simulated even if human-induced factors (notably emission of greenhouse gases and aerosols) are included in the state-of-the-art computer climate model simulations.

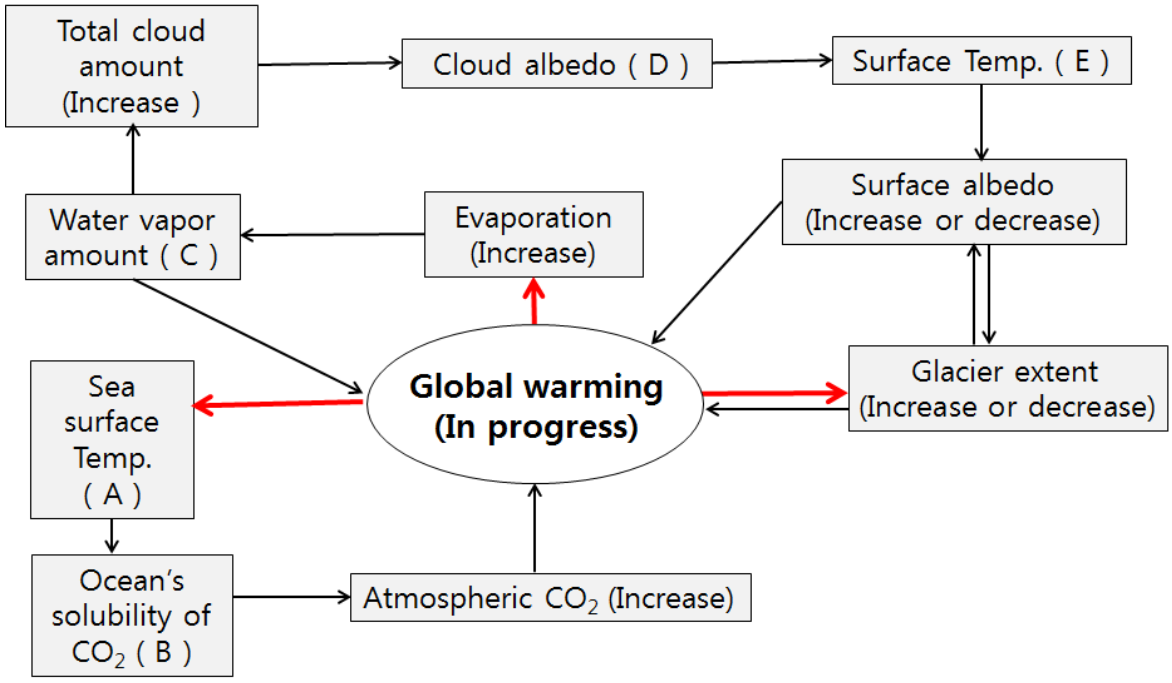
c) Powerful volcanic eruptions, causing cooling at the surface through the injection of ash and aerosols into the stratosphere, could reduce the recent rapid global warming.

d) Computer climate model simulations verified that most of the global warming observed over the past 50 years is very likely due to human activities.

e) The cooling effect of individual volcanic eruptions on global climate is usually short-lived when compared with the long-term warming trend due to the enhanced greenhouse effect.

Introduction to question Q8:

The figure below shows possible feedback relationship between positive and negative related to the 'Global warming is on the way'.



Q8) Choose ALL correct statements pertaining to the figure above. Note: The word that will be fit in (A) through (E) above is either 'decrease' or 'increase'.

a) The atmospheric CO_2 increase from deforestation causes the sea surface temperature rise in this feedback relationship.
b) If the ocean's solubility of CO_2 decreases, the pH of the ocean increases in this feedback relationship.
c) E is 'increase'.
d) Due to the increase in total cloud cover, increasing glacier area induces a positive feedback.
e) Decreasing glacier area leads to a negative feedback.

Introduction to question Q9:

The ozone layer is important because it prevents the harmful ultraviolet rays from reaching the Earth's surface. In 1966, scientists from the British Antarctic Survey discovered a hole in the ozone layer above Antarctica. In 1974, Sherwood Roland suggested that chlorofluorocarbons (CFC's) used in refrigerators and other appliances would destroy the ozone layer.

The Montreal Protocol adopted subsequently, has regulated ozone-depleting substances since 1987. Global efforts have shown that the total ozone reduction has been recovering since 2000. Figure A shows the temporal and spatial distribution of total ozone simulated up to 2065 based on satellite observations from 1971 to 2017. Figure B shows the vertical profiles of ozone pressure (mPa) above Antarctica in 1999 on three dates: Jul. 28, Sep. 29, and Dec. 23.

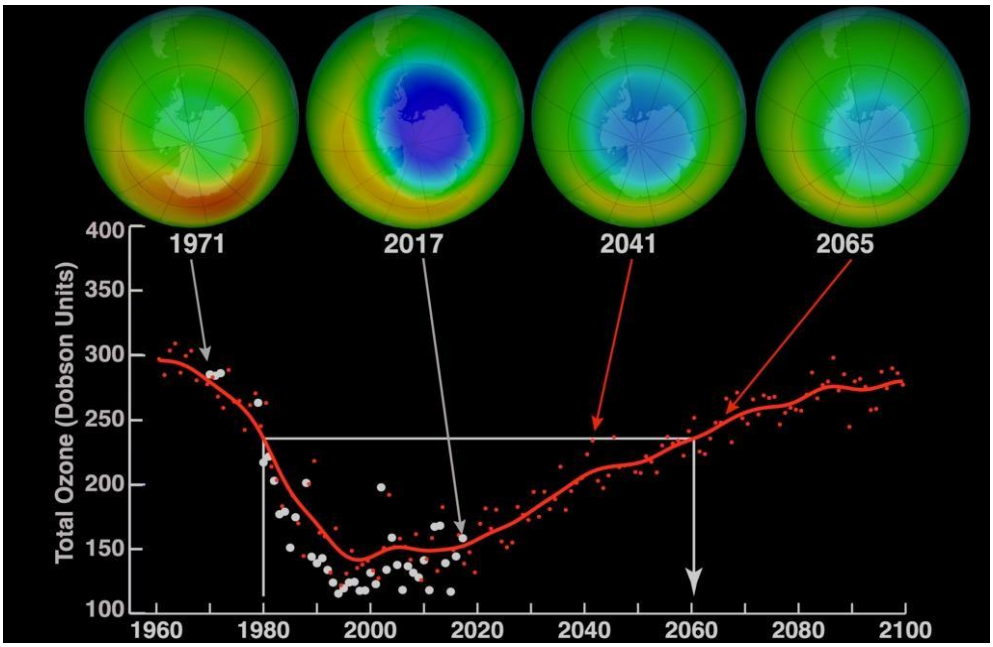


Figure A

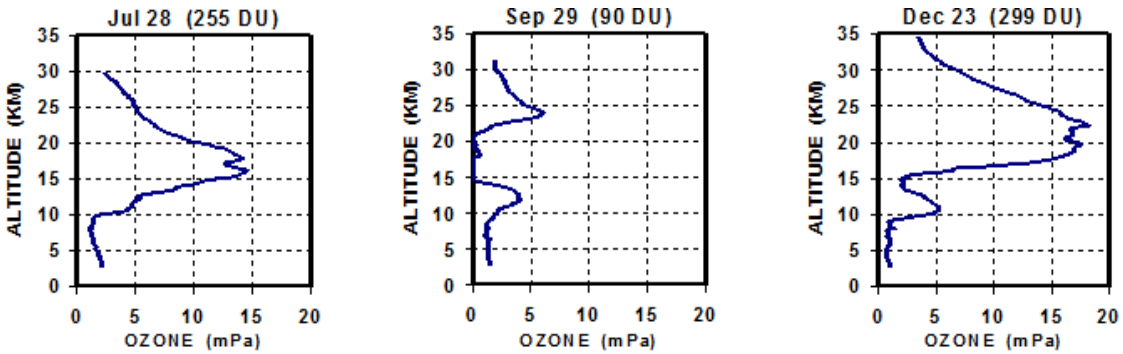


Figure B

Q9) Choose ALL the correct explanations.

a) The size of the ozone hole was larger in 2017 than that in 2000.
b) The ozone hole of Sep. 29, 1999 (Figure B) also occurred at the same time in the Arctic.
c) The amount of ultraviolet rays reaching the Antarctic surface increased further in 2017 than in 1971.
d) The ozone hole above Antarctica was documented during the Southern Hemisphere autumn season.
e) Restoration of the ozone layer shown in Figure B begins from its top.
f) The main cause of ozone depletion and ozone hole formation is chemicals manufactured by humans.

Introduction to questions Q10-Q12:

In normal years, strong trade winds blow over the equatorial Pacific from the east to west. They tend to bring warm waters to the western equatorial Pacific, generating a warm pool around Indonesia.

To make up for this, cold water from the sea bottom comes up (wells up) to the sea surface along the coast of South America and in equatorial regions. The upwelling produces a steep thermocline in the upper ocean, and also generates a sea surface temperature (cold) anomaly in the eastern equatorial Pacific. On the other hand, an upward convective movement in the air generates a tall-high cloud, i.e., cumulus, in the western equatorial Pacific, often resulting in heavy rains there. In contrast, a downward movement of air in the eastern equatorial Pacific tends to result in a dry and sunny weather.

This vertical atmospheric circulation pattern is called the Walker Circulation. If there is a problem with this circulation, El Niño and La Niña occur, which is a phenomenon where the sea surface temperature rises above normal conditions, and vice versa.

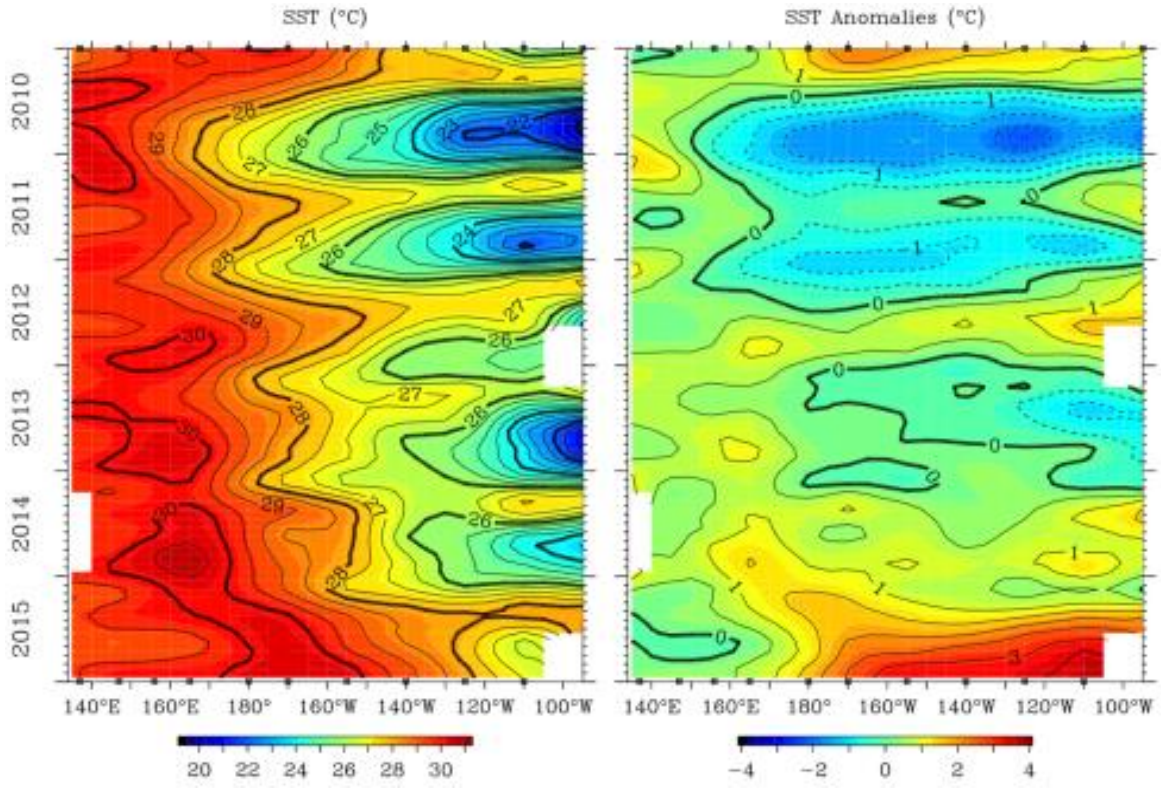


Figure 1. Temporal changes in the sea surface temperatures (left panel) and its anomalies (right panel) after removing the seasonal cycles in the equatorial Pacific. Credit: NOAA.

Q10) Referring to Figure 1 above, choose ALL the correct statement(s) to explain El Niño and La Niña episodes.

a) El Niño episodes occurred every year.
b) Convection is always active in the eastern Pacific where the SST is always high.
c) The trade winds along the equatorial Pacific in El Niño conditions are weaker than those in normal, non-El Niño conditions.
d) A La Niña episode occurred from 2010 to 2011.
e) El Niño episodes are caused by warm water being carried to the western Pacific from the eastern Pacific.
f) In an El Niño episode, Indonesia experiences drought.
g) In an El Niño episode, the sea level is lower than normal along the west coast of South America.

Figures 2(a) and 2(b) show the spatial distribution of SST anomaly (a) and surface chlorophyll-a during El Niño and La Niña, regardless of the order. Figure 3 is a time series of the Southern Oscillation Index (SOI). The SOI is calculated using the sea level pressure (SLP) difference between Tahiti in the central Pacific and Darwin, north of Australia.
Therefore, this index can represent the strength of the Walker circulation, which is a large-scale vertical circulation of air associated with zonal sea level pressure difference in the equatorial Pacific.

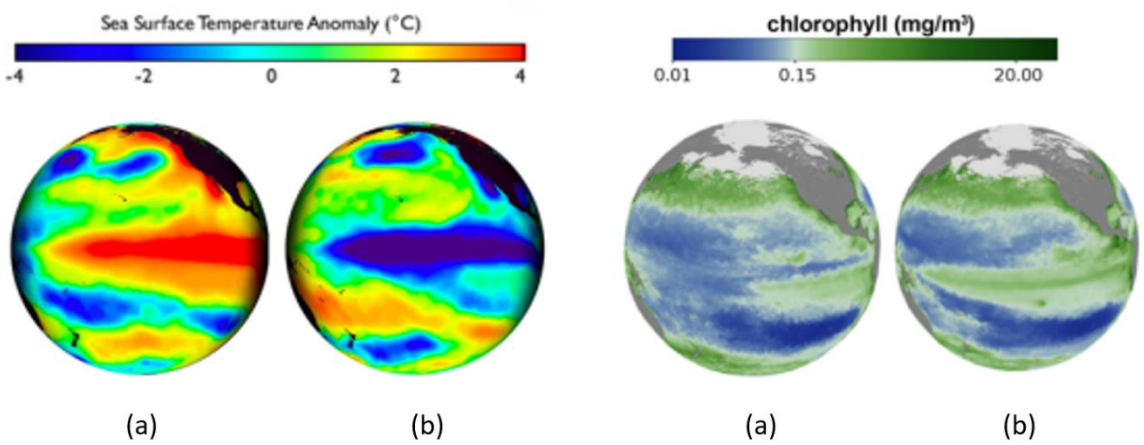
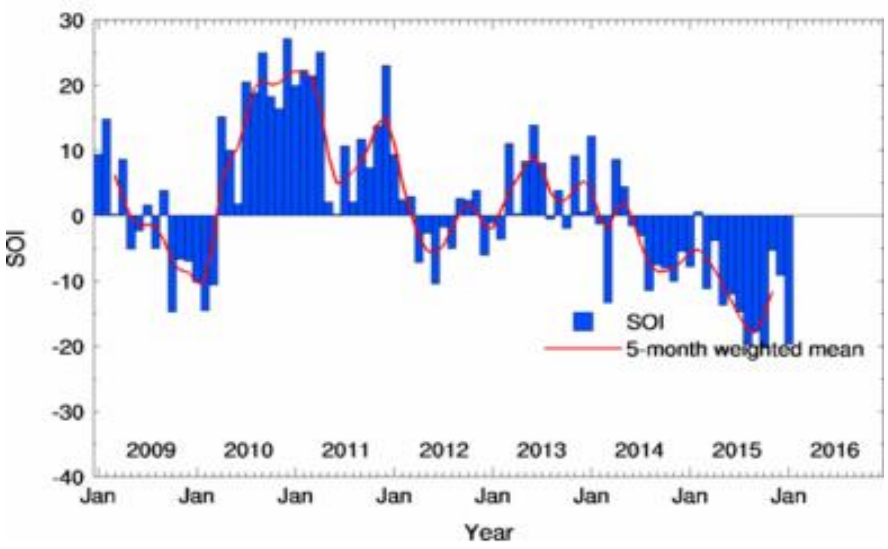


Figure 2. Left panel shows SST anomaly, right panel shows surface chlorophyll-a. (a) and (b) are the data during El Niño and La Niña, regardless of the order.

Figure 3.



Q11) Choose ALL the correct answer(s).

a) (a) corresponds to La Niña and (b) to El Niño.

b) During the period of (a), the Walker circulation is weaker than normal.

c) During the period of (a), fishery potential decreases in the eastern Pacific

d) During the period of (b), a SLP difference between Darwin and Tahiti is reduced compared with a normal year.

e) During the period of (b), the zonal gradient of a thermocline is reduced compared with a normal year.

f) A situation during 2010/2011 is the case of (a), and 2015/2016 is the case of (b).

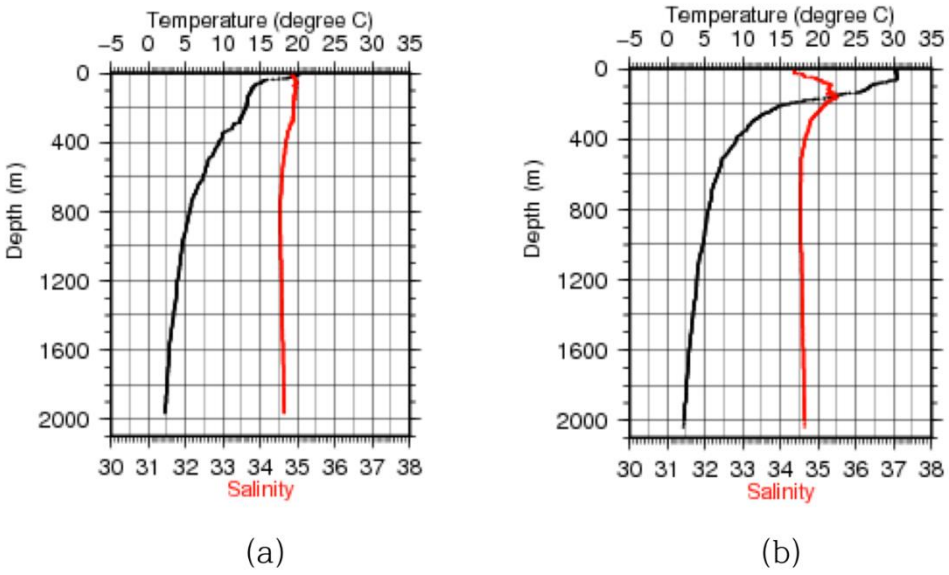


Figure 4. Location of temperature and salinity observations.

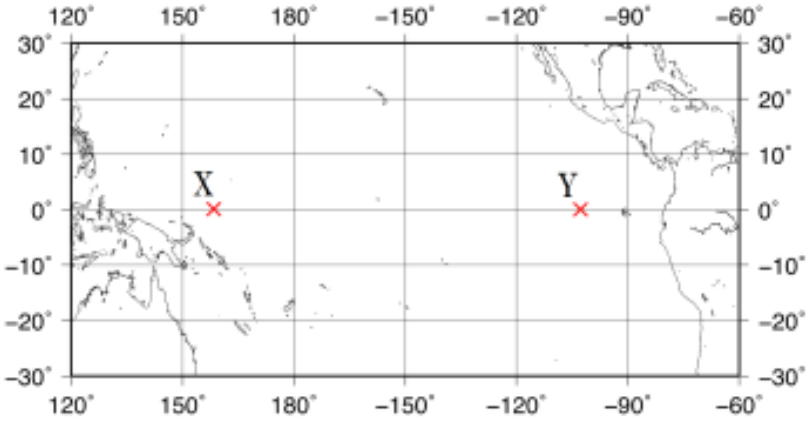


Figure 5. Temperature and salinity profiles observed at X and Y, out of order.

Figure 4 shows the locations of stations X and Y whose temperature and salinity profiles are shown in Figure 5. The profiles were documented in the boreal summer of 2007 when a La Niña occurred.

Q12) Choose ALL the correct answer(s).

a) The profiles documented at station X corresponds to (a).
b) The sea level atmospheric pressure at station X was low compared with a normal year (long-term average) value.
c) The direction of current at both stations X and Y is eastward by the westerly winds.
d) The sea water below 1000 m depth at both stations X and Y were produced near polar regions.
e) The main driving force for deep ocean circulation is ocean surface wind.
f) Around the region of station X, precipitation is greater than evaporation.

Introduction to questions Q13-Q14:

Figure A shows the mid-infrared spectra of the three terrestrial planets in our solar system. Solid lines are the real observed spectra with many absorption features due to the molecules that comprise the atmosphere of each planet, whereas dashed lines are the best-fit black-body curves of the corresponding temperatures. (For example, the spectrum of planet c shows an absorption trough due to CO_2 and is approximated as the 220K black body.)
Figure B shows the atmospheric temperature changes with altitude for the three terrestrial planets, labeled (1), (2), and (3).

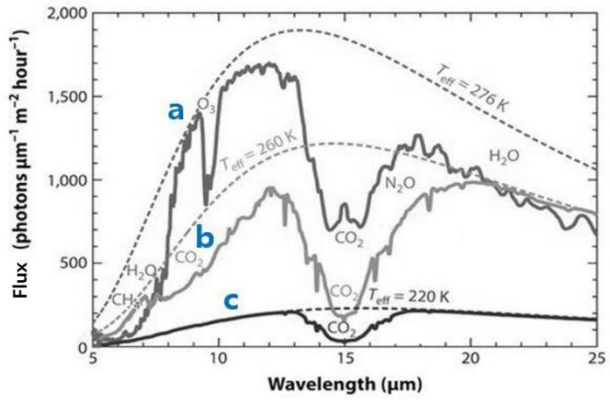


Figure A

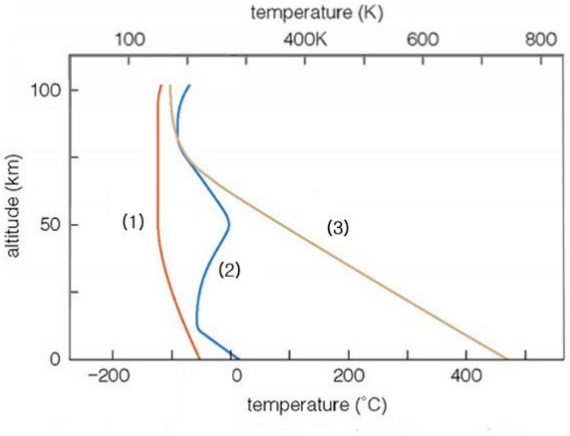


Figure B

Q13) Refer to Figure A and choose ALL the correct statements.

a) Spectra of the planets ‘a’, ‘b’, and ‘c’ are in the visible wavelength.
b) The atmosphere of all the three terrestrial planets contains CO_2.
c) The molecule that is not present in the atmosphere of planets ‘a’ and ‘b’ but present only in the atmosphere of ‘c’ is O_3.
d) In the atmosphere of planets ‘a’, ‘b’, and ‘c’ in Figure A, only H_2O, CO_2, and O_3 may be present.
e) Among the three planets, planet ‘a’ radiates the largest amount of energy.

Q14) Refer to Figures A and B, and choose ALL the correct statements.

a) In Figure B, the atmospheric temperature of planet (1) increases with increasing altitude from the surface.
b) In Figure B, planet (2) has an atmospheric range in which temperature increases with altitude.
c) In Figure B, among the three planets, planet (2) has the highest surface temperature.
d) Planet (1) in Figure B is planet ‘a’ in Figure A.
e) Planet (2) in Figure B is planet ‘a’ in Figure A.
f) Planet (3) in Figure B is planet ‘a’ in Figure A..