Time: 14:00 to 17:00 hrs **Date: August 29, 2019**

INSTRUCTIONS:

Students should finish the exam within **3 hours for Witten Test 3 and 4**. 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:

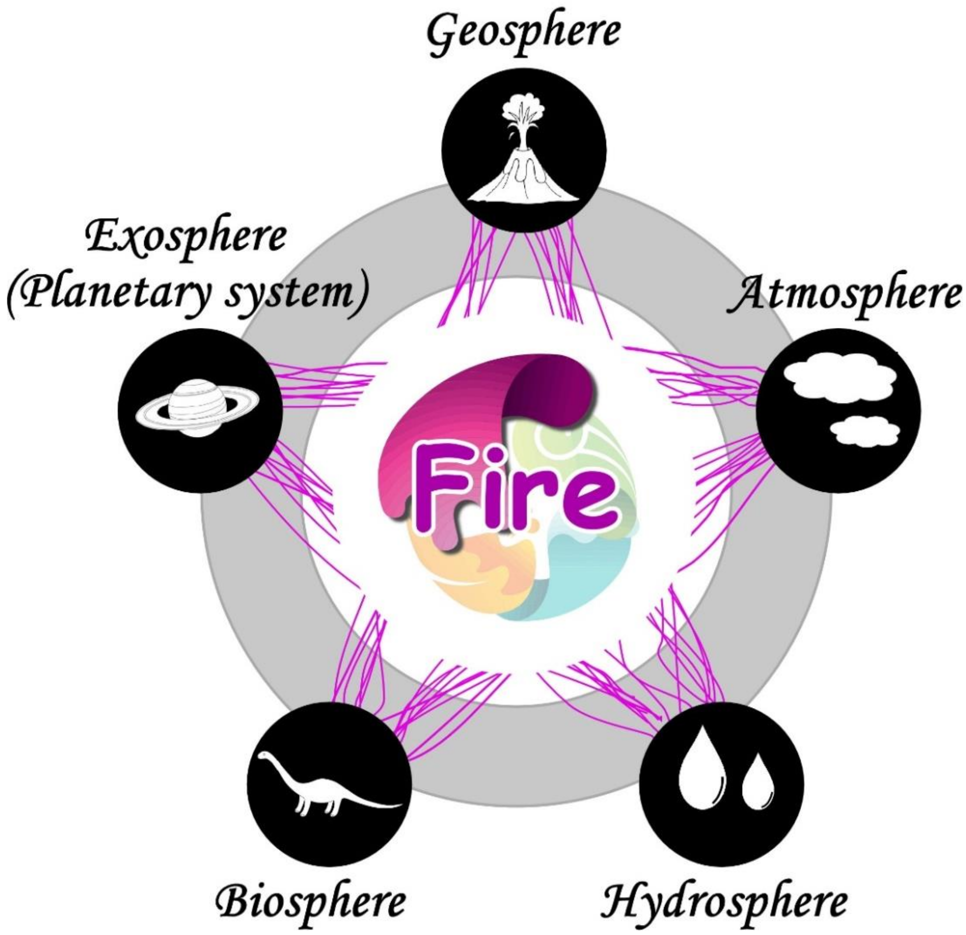
- For **correct** answer: 1 point
- For **incorrect** answer: 0 point
- If several answers are chosen: 0 point.

"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: Fire (Heat & Energy)

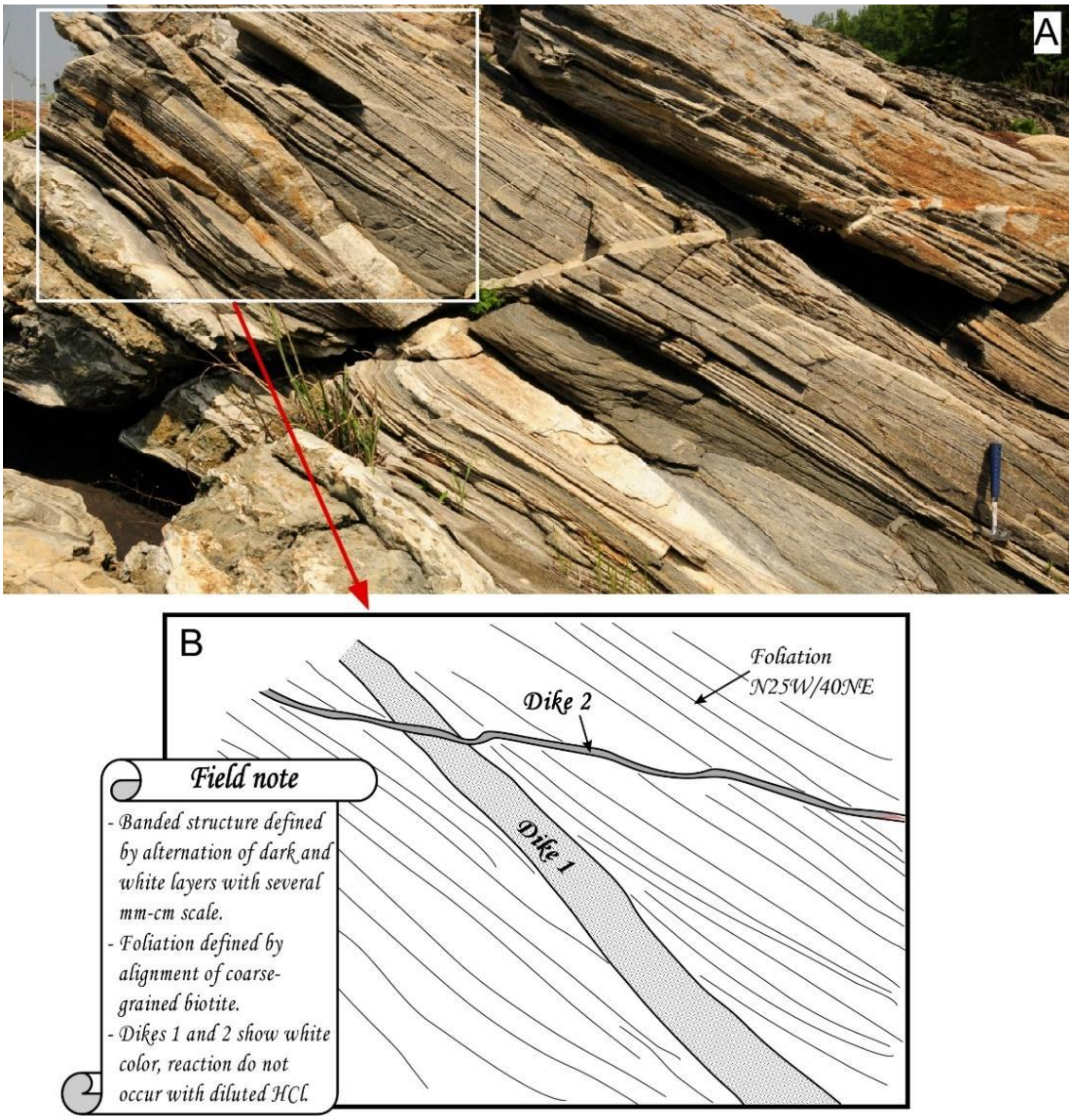
There are various sources for the Earth's heat and energy. Although most of the heat for the Earth system comes from the Sun, there are heat sources inside the earth as well. According to the plate tectonics and plume tectonics theories, the heat of the early Earth and the decay of radioactive isotopes inside the Earth caused catastrophic events such as earthquakes and volcanoes by convection and moving the mantle.
The energy inside the Earth is beneficial to humans (e.g., hot springs, geothermal power generation). Within the Earth system, energy does not stay in one place or dissipate but moves constantly, changing forms.



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

Introduction to questions Q1-Q3:

Figure A is a photo of an outcrop. Figure B is a sketch of the area covered by the white rectangle in Figure A that shows the major geological features, along with partial field notes.



Q1) Select ALL correct statements that relate to this outcrop.

a) The foliation formed by the overburden pressure.

b) The banded structure resulted from regional metamorphism.

c) The foliated rock is marble.

d) Quartz and feldspar is a major mineral of Dike 1.

e) Calcite is a major mineral of Dike 2.

f) Calcite is a major mineral of Dikes 1 and 2.

Q2) What is the chronological order of the different rock units? Choose only one correct answer.

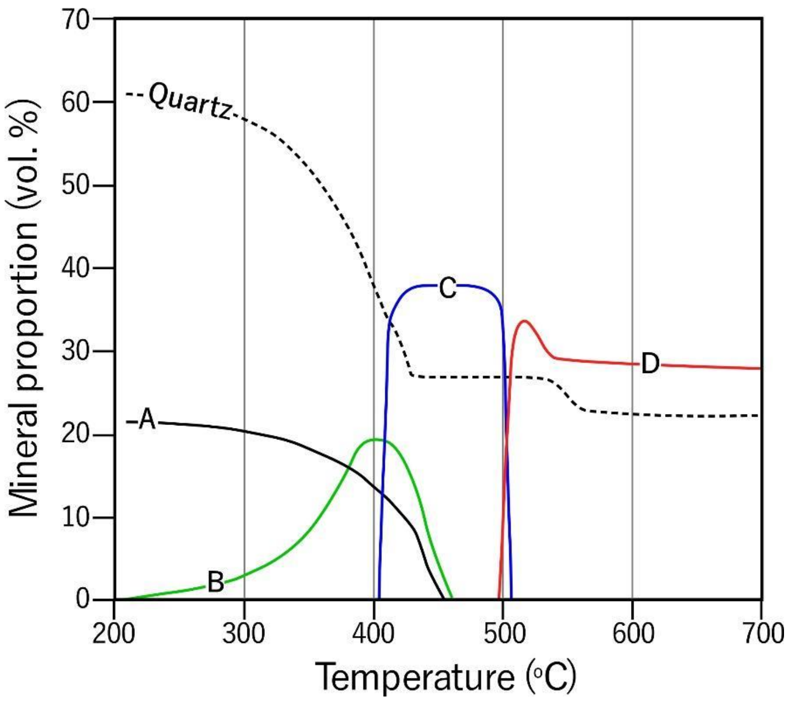
a) Dike 1 is the oldest rock unit as it shows no evidence of compression.
b) Dike 2 is the oldest rock unit as it shows no evidence of compression.
c) The foliated unit is older than Dike 2, but younger than Dike 1.
d) The foliated unit is the oldest, as the dikes show no evidence of compression.
e) The foliated unit is the oldest as it appears beneath the dikes.

Q3) Which of the geological principle is used to determine the correct answer to Q2? Choose only one correct answer.

a) Original horizontality
b) Superposition
c) Faunal succession
d) Unconformity
e) Cross-cutting relationship

Introduction to question Q4:

The figure below shows the change in the modal proportion (volume %) of the metamorphic minerals A to D that formed by thermal metamorphism involving temperatures of up to 700 °C.



Q4) Select ALL the correct statements.

a) The coexistence of minerals A and B indicates low-temperature (below 400℃) metamorphism.

b) Minerals B and C occur together at about 500 ℃.

c) The occurrence of mineral C indicates a limited range of metamorphic temperature.

d) The coexistence of minerals C and D indicates a metamorphic temperature of 600 ℃ or higher.

e) Minerals C and D occur at a further distance from the igneous intrusion compared to minerals A and B.

f) The relative proportions of metamorphic minerals can be changed due to temperature increase during metamorphism.

g) The water content within metamorphic minerals increases due to temperature increase during metamorphism.

Introduction to questions Q5-Q6:

In the deadliest California wildfire season in 2018, a total of 8,527 fires burned 766,439 ha of land area. This is the largest area burned as per the records of the California Department of Forestry and Fire Protection and the National Interagency Fire Center.

Figure A shows the county fire spreading out on a hillside in Guinda, California on July 1, 2018.

Figure B is the visible radiation satellite imagery of the area on the same day.

Smoke and clouds can easily be distinguished by their color in the satellite imagery. It includes dark carbon particles such as black and brown particles, which are a major issue in the context of climate change.

Figure A

Figure B

Q5) Based on the two figures, choose ALL the appropriate description(s) regarding the dark carbon particles.

a) The dark carbon particles absorb more incoming solar radiation in the atmosphere than clouds.

b) The dark carbon particles in the atmosphere can increase the Earth's surface temperature in the short-term.

c) The dark carbon particles may cause an inversion layer in the atmosphere.

d) The dark carbon particles are rarely transported in the atmosphere to other places from its source.

Figure C

Fossil fuel combustion also releases dark carbon particles into the atmosphere.

After getting deposited on the glacier, they influence the local radiation energy budget and also significantly darken the area as can be seen in Figure C.

Figure D displays the time series of the length of an Alpine glacier (Fig D-3). It abruptly shrank since the late 19th century. To establish the reason for this rapid retreat of the glacier, scientists investigated several possible factors, i.e., winter precipitation (Fig D-1), summer temperature (Fig D-2), and the estimated soot emission (Fig D-4) from Europe.

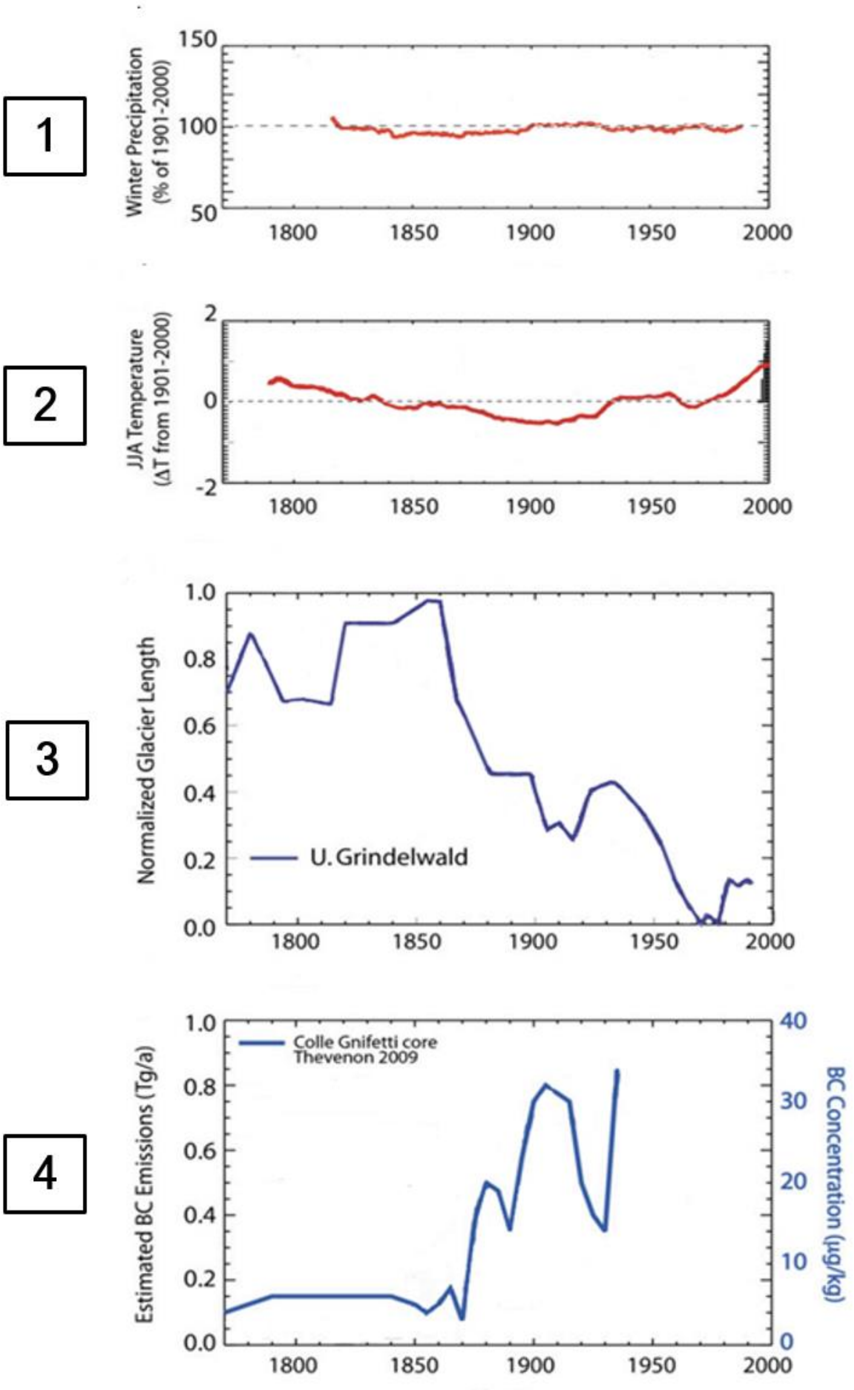


Figure D

※ JJA in y-axis of Fig. D-2 is summer seasons of June, July, and August. BC in y-axis of Fig. D-4 is Black Carbon.

Q6) Following the information above, Choose ALL the appropriate interpretations for the fast retreat of the glacier.

a) The Alpine glacier began to decrease abruptly because summer temperature rose sharply in the late 19th century.

b) The gradual decrease in winter precipitation is responsible for the recent retreat of the Alpine glacier.

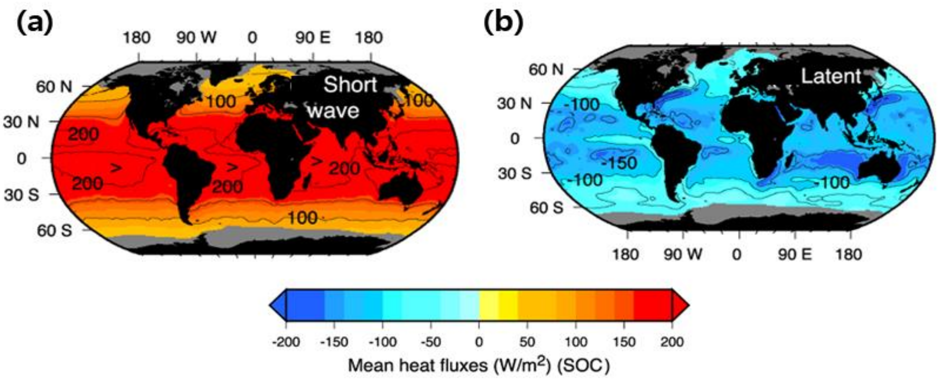
c) The retreat of the Alpine glacier in the late 19th century is not likely related with temperature.

d) The industrial soot likely accounts for the retreat of the Alpine glacier.

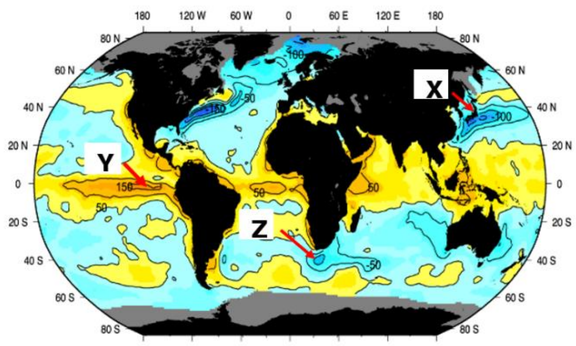
e) More snowfall in the 20th century was responsible for the fast retreat of the Alpine glacier.

Introduction to question Q7:

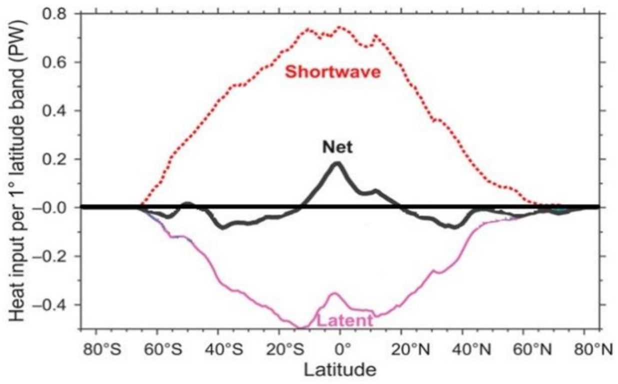
The ocean and atmosphere are constantly exchanging heat as shown in the figures below. Figure (a) shows the distribution of annual mean value of the incoming solar radiation; Figure (b) is the latent heat loss of the ocean through evaporation.
We can obtain the net heat flux distribution (c) by subtracting the total amount of heat loss due to evaporation, from the incoming solar radiation. (Positive sign represents heat transfer from the atmosphere to the ocean; the opposite is true for negative sign.)
Figure (d) shows the latitudinal distribution of each of the three components (a), (b), and (c).
The net heat flux distribution in the Equatorial Pacific is related to El Niño which is complex weather patterns resulting from variations in warmer average ocean temperature.



(c)



(d)



Q7) Choose ALL correct answers.

a) The amount of (a) will increase if a huge volcano erupts.

b) The major mechanism of heat transfer from the ocean to the atmosphere is evaporation as shown in Figure (b).

c) In addition to latent heat, there are other processes by which oceans lose heat to the atmosphere.

d) The sea surface salinity at 20°N and 20°S is lower than that in the equatorial region.

e) A warm and saline current flows in the area marked X.

f) The amount of net heat flux in the area marked Y will increase when El Nino occurs.

g) Y has the lowest sea surface temperature among the areas X, Y, and Z.

h) Ocean current around the area Z plays an important role in transferring heat from the Indian Ocean to the Atlantic Ocean.

Introduction to questions Q8-Q9:

Despite being active, the Sun looks static in the visible wavelength region.
Figure A shows the Sun's images in the (a) visible and (b) extreme ultraviolet wavelengths. Image (c) is the solar magnetogram documented on October 28, 2003.
The dark spots in (a) are sunspots. Image (c) shows the magnetic field strength in the direction of the line of sight. Here, regions with no magnetic field are shown in gray and those with different polarities denoted as black and white. The bright part in the lower center of (b) is a solar flare.
Flares give out enormous amounts of matter and energy. The emitted light and charged, energetic particles reach the Earth and impact the Earth's environment and human life. When a large flare occurs, such light and matter will take a certain time to reach the Earth.

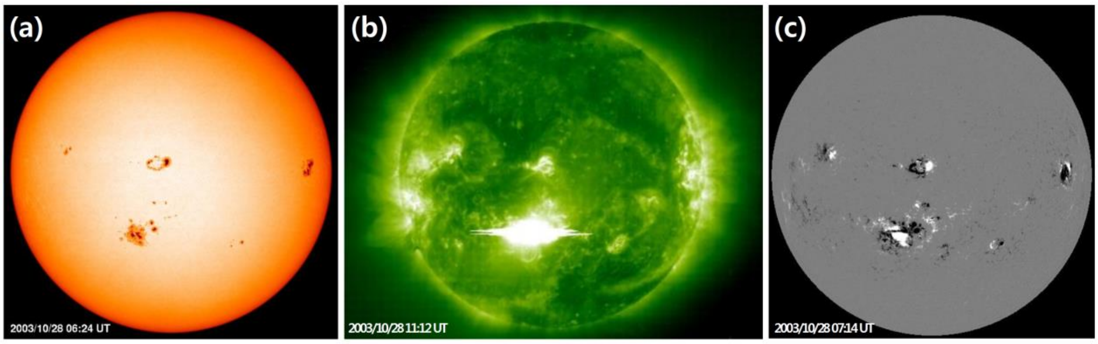


Figure A

Figure B shows the arrival time and duration of light at various wavelengths, charged particles (energetic particles), and solar winds from the Sun reaching the Earth. If observational data of the Sun are shared on a real time basis with the space environment forecasting system, damage to the Earth's environment can be reduced.

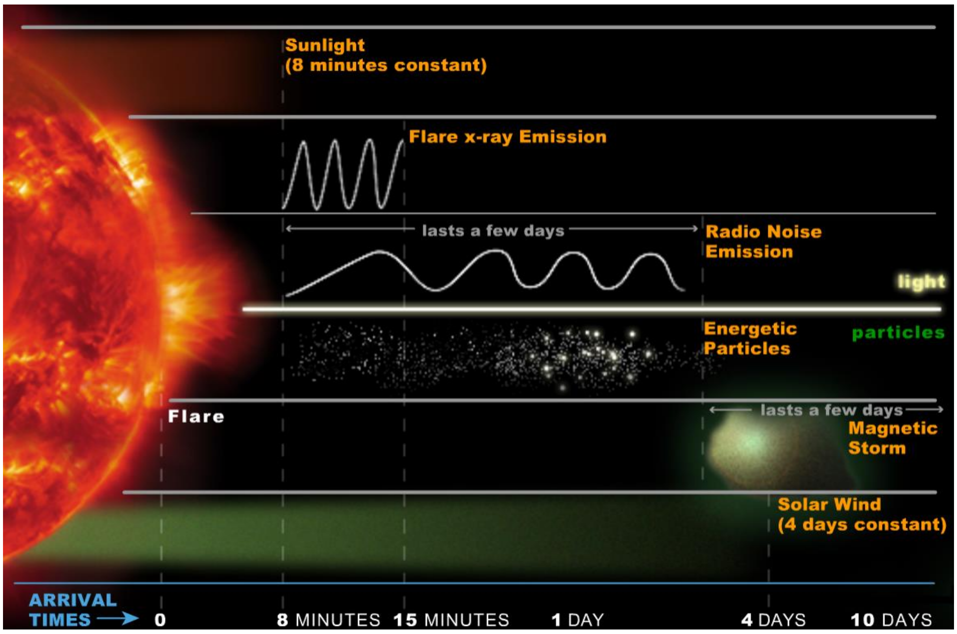


Figure B

Q8) Select ALL the correct statements that can be inferred from Figure A.

a) The magnetic field is strong around sunspots.
b) The magnetic field is weak around sunspots.
c) The size of the flare is independent of the size of the sunspot.
d) If the Sun has many large sunspots for a long time, the average temperature of the Earth will rise.
e) Where a flare occurs, the density of gas is lower compared to where there is no flare.

Q9) Based on Figure B, choose ALL the correct statements.

a) The visible light takes about eight minutes to reach the Earth.
b) The visible light travels faster than the flare X-ray emission.
c) Energetic particles with higher mass arrive first at the Earth.
d) Most high energy particles reach the Earth within four days.
e) The high energy particles emitted from the Sun disturb the Earth's magnetosphere, generating magnetic storms.
f) The high energy electromagnetic waves emitted from the Sun disturb the Earth's magnetosphere, causing magnetic storms.
g) The space weather around the Earth due to solar activity can be predicted by observing changes in the sunspots.

Introduction to question Q10:

Mars exploration Rover, “Curiosity” has been building a database since it landed on Mars in 2012, continuously monitoring the environment such as temperature and pressure of Mars.
Figures A and B are showing the temperature and pressure changes of Mars measured at the Gale Crater (near the Martian equator) where the “Curiosity” landed during ~1300 Sol after landing.
‘Sol’ is the unit of day on Mars. The graphs show both the maximum and minimum of each value by date. Figure A also compares the temperature change of Mars with the annual temperature change in Los Angeles.
The Martian atmosphere is chiefly composed of carbon dioxide. There is a 'polar cap’ (polar region) where cooled carbon dioxide exists as dry ice. The polar cap increases or decreases in volume depending on the season.

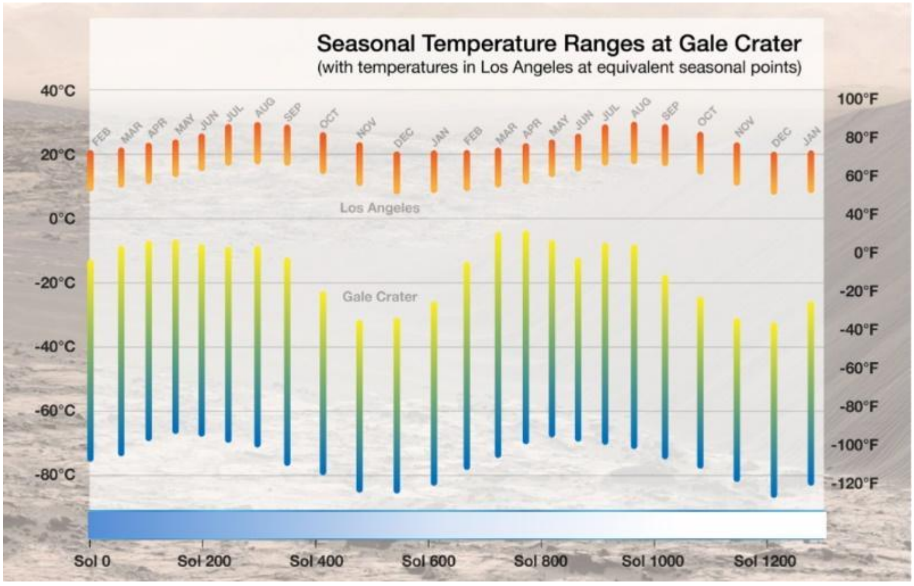


Figure A

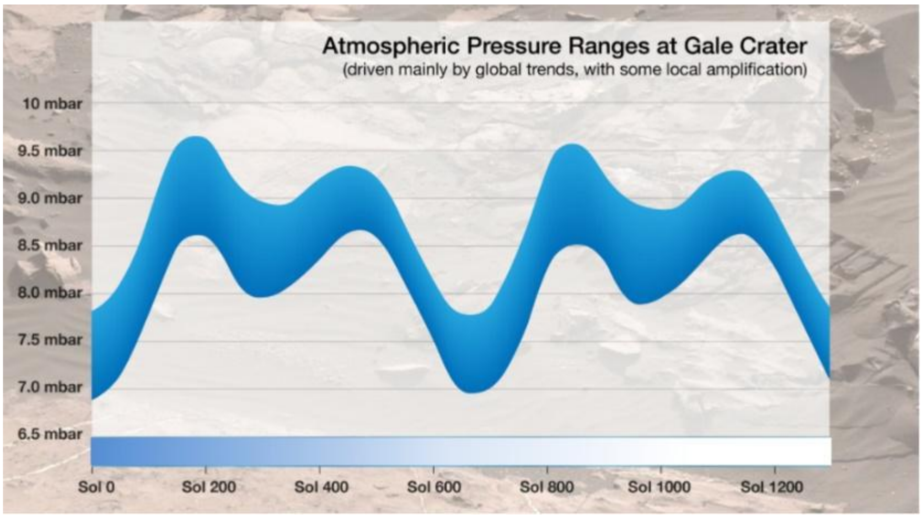


Figure B

Q10) Select ALL the correct answers for Figures A and B.

a) One year on Mars is about 350 Sol.

b) The Sol 900 period corresponds to the Martian summer in the Gale Crater.

c) The diurnal difference in temperature at the Martian surface is larger than that at the Earth's surface.

d) The annual range in temperature at the Martian surface is larger than that at the Earth's surface.

e) The Martian surface temperature is lower than the Earth's surface temperature because Mars is smaller than the Earth.

f) The Martian atmospheric pressure is similar to the Earth's atmospheric pressure.