INSTRUCTIONS FOR THE WRITTEN TEST

WRITTEN TEST 2 : 2 HOURS

PLEASE ANSWER ON THE ANSWER SHEET

MARKING THE QUESTIONS :

If only one answer is required (only one answer) :
- Correct answer chosen : +1 point
- Wrong answer or several answers chosen : 0 point

If several possible answers :
- For each correct answer : + 1 point
- For each wrong answer : -0,5 point

No question can be marked under 0 (zero). If number of negative points exceeds the positive points, the question will be marked zero : +1-1,5 = 0

IESO 2017 - WRITTEN TEST NUMBER 2

SECTION 1: UNDERSTAND THE INTERACTIONS BETWEEN ATMOSPHERE AND HYDROSPHERE : A SPORTING CHALLENGE !

The “Vendée Globe” is a solo yacht race without assistance, which sets off from Vendée in France and whose objective is to circle the world as fast as possible. Both the start and finish are in Sables d’Olonnes (visible on figure 1A and marked as A in figure 1B. The race began on 6 november, 2016. Armel Le Cleac’h was the winner with a new record of 74 days of non-stop sailing.
The difficulty, especially on a solo voyage, is to find the route where the wind is always favorable, namely at the rear of the boat.

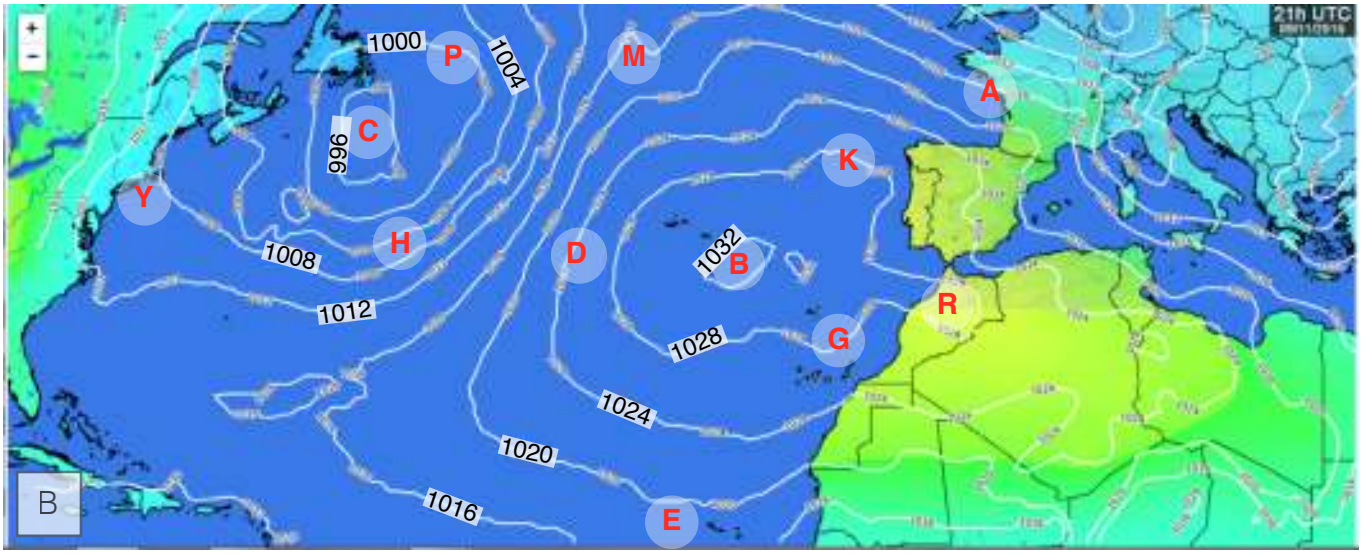

FIGURE 1: (A) Map showing the « Vendée Globe » route. (B) Barometric map of the North Atlantic Ocean and noted points (see question).

Question 1: Yachts make the best use of the dominant winds. According to your knowledge of the direction of winds produced by different air masses, indicate which is the fastest route the competitors should take to reach the Cape Verde islands (E). The barometric conditions shown on the map above remain the same for one week: (only one answer possible)

1- Trajectory AKGE
2- Trajectory AKBE
3- Trajectory AKDE
4- Trajectory AMPCHE

Question 2: Refer to figure 1. At the same time, a sailor decides to take the route Rabat (R)–New York (Y). Which itinerary will be the quickest? (only one answer possible)

1- RGDHY
2- RBDCY
3- RGDPY
4- RKDHY

The figure below shows the competitors' positions after 10 days of racing. A group of yachts (circled) seems to have lagged and is traveling at a slow speed of 2.5 knots (for information, 1 knot (kn) is equivalent to a little less than 2 km/h).

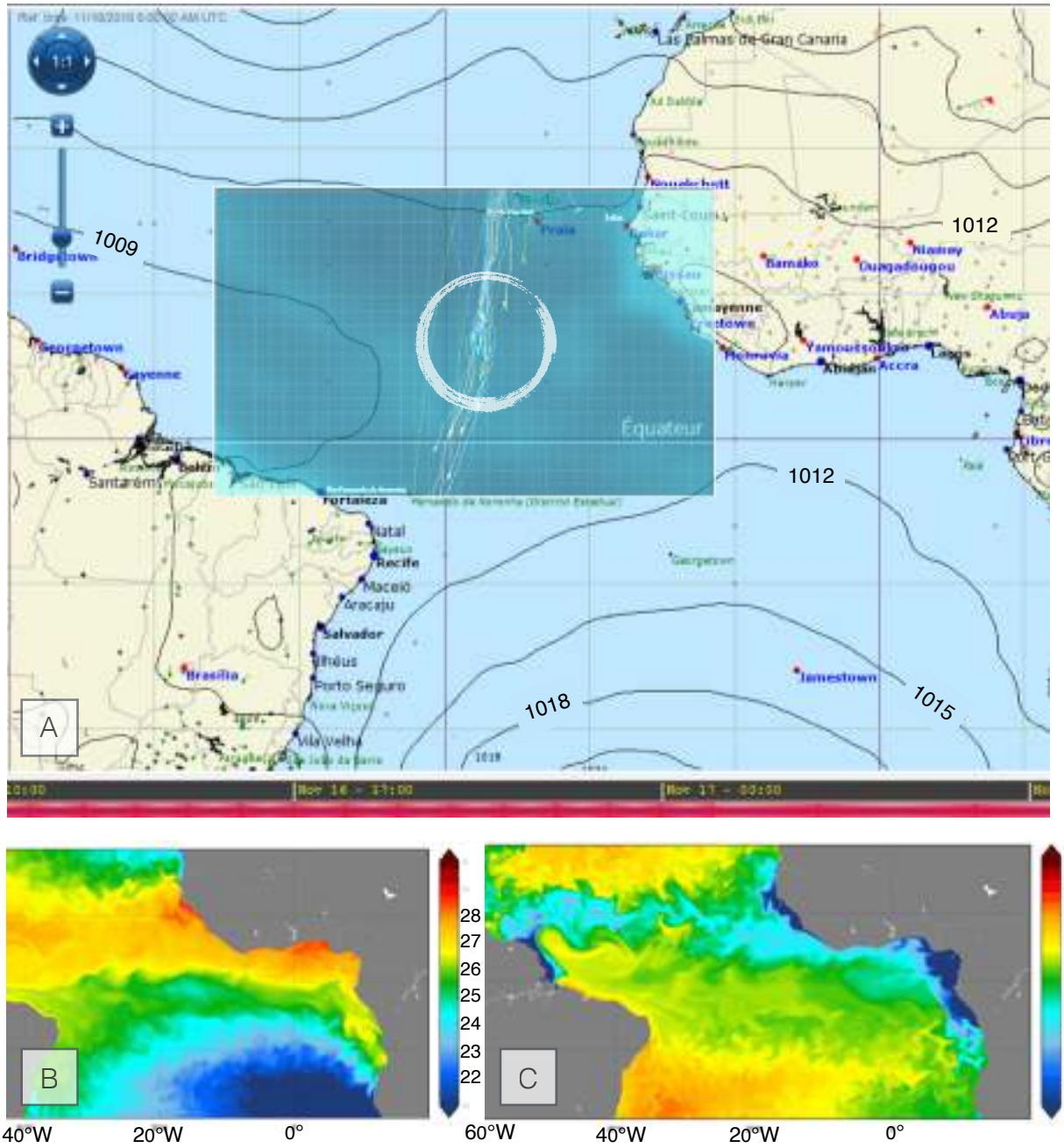

FIGURE 2: Racing zone in the Atlantic Ocean. (A) Barometric chart contour interval is 3 hPa. (B) Map of water temperature in °C. (C) Chart of water salinity in g/l.

Question 3: Which of the choices given below best explains the situation of sailors compelled to travel at a slow speed ? (only one answer possible)
1- The high water temperature prevents the formation of wind.
2- The sailors cross a zone where there are headwinds.
3- The water is very salty and its viscosity slows the sailors.
4- The sailors are trapped in a zone with very weak winds.

Question 4: Refer to figure 2C. The intertropical zone has a salinity which is different from the average (green zones). Choose the most evident cause: (only one answer possible)
1- The water from the big rivers brings down the salinity of the ocean water.
2- In the tropical anticyclonal zones, the air temperature is lower, and thus evaporation weaker.
3- Rainfall is more important in the intertropical convergence zone and it brings down the salinity.
4- The characteristic strong winds in the intertropical convergence zone produce upwelling, which brings less saline water to the surface.

Avoiding areas sheltered from the wind was a preoccupation of all the participants. Kito de Pavant, our sailor for the IESO 2017, remained stuck for several days in the area described in the figures below.

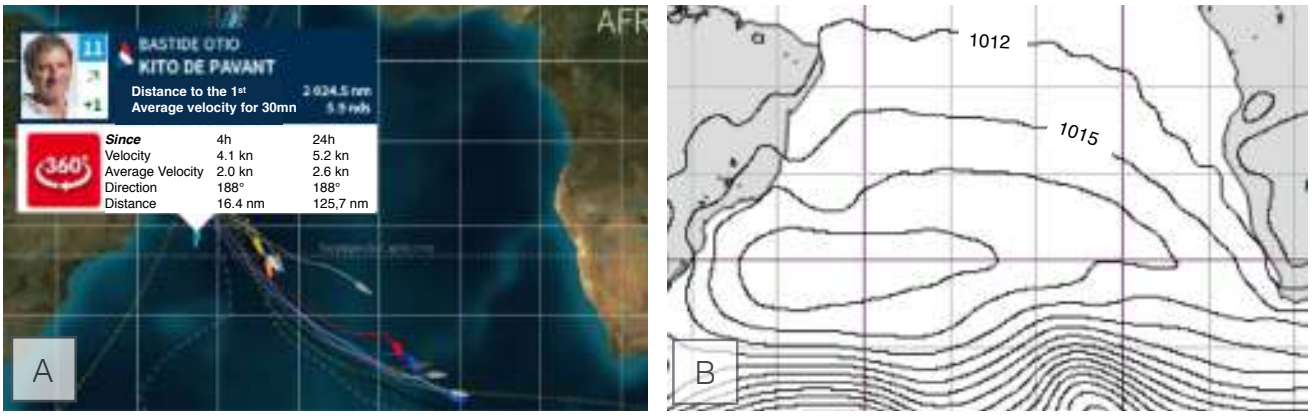

FIGURE 3: Map of the competitor Kito de Pavant's position (blue arrow) and other sailors on 2 December 2016. (A) Position map indicating, among other things, the change of his speed (knot) in the last 24 hours. Distances are indicated in nautical miles (nm), 1nm = 1.85 km. (B) Barometric map of the race area on 12 December, 2016. Contour interval is 3 hPa.

Question 5: Describe the problem Kito de Pavant encountered in this area of the race: (only one answer possible)
1- His yacht was located in the center of a depression characterized by a lack of wind.
2- His yacht was in the center of an anticyclone characterized by a lack of wind.
3- His yacht was in the center of a depression characterized by a shallow trough on the ocean surface which hinders the boat's movement.

Question 6: The winds which circulate around an anticyclone located in the Southern Hemisphere … (several answers possible)
1- rotate clockwise.
2- rotate counterclockwise.
3- are stronger when they approach the center of the anticyclone.
4- are weaker when they approach the center of the anticyclone.

While traversing the Drake Passage south of Cape Horn (southern tip of South America) on 26 December 2016, the oceanographic service recorded the water temperature and salinity as a function of depth along a transect between the southern tip of South America and the northernmost point of the Antarctic Peninsula.

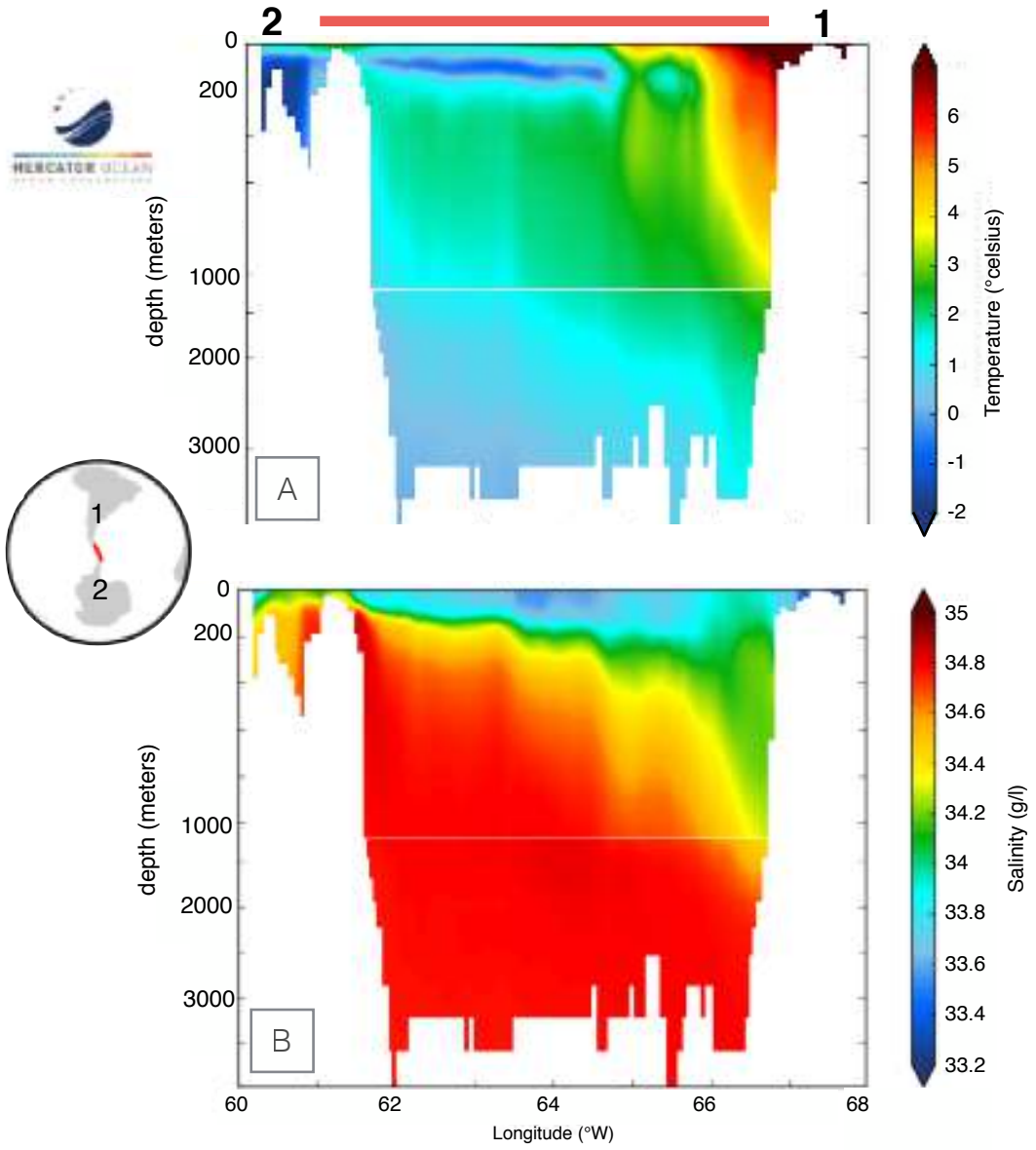

FIGURE 4: Profiles of the change in temperature (A) and salinity (B) of the ocean water on a line along the Drake Passage (visible in the inset showing the planet viewed from the South Pole).

Question 7: Refer to Figure 4. One can say that, at longitude 62.5°W, … (only one answer possible).

1- both the temperature and salinity gradients are normal over the whole depth.
2- only the temperature gradient is abnormal in at least one area.
3- only the salinity gradient is abnormal in at least one area.
4- both gradients are abnormal.

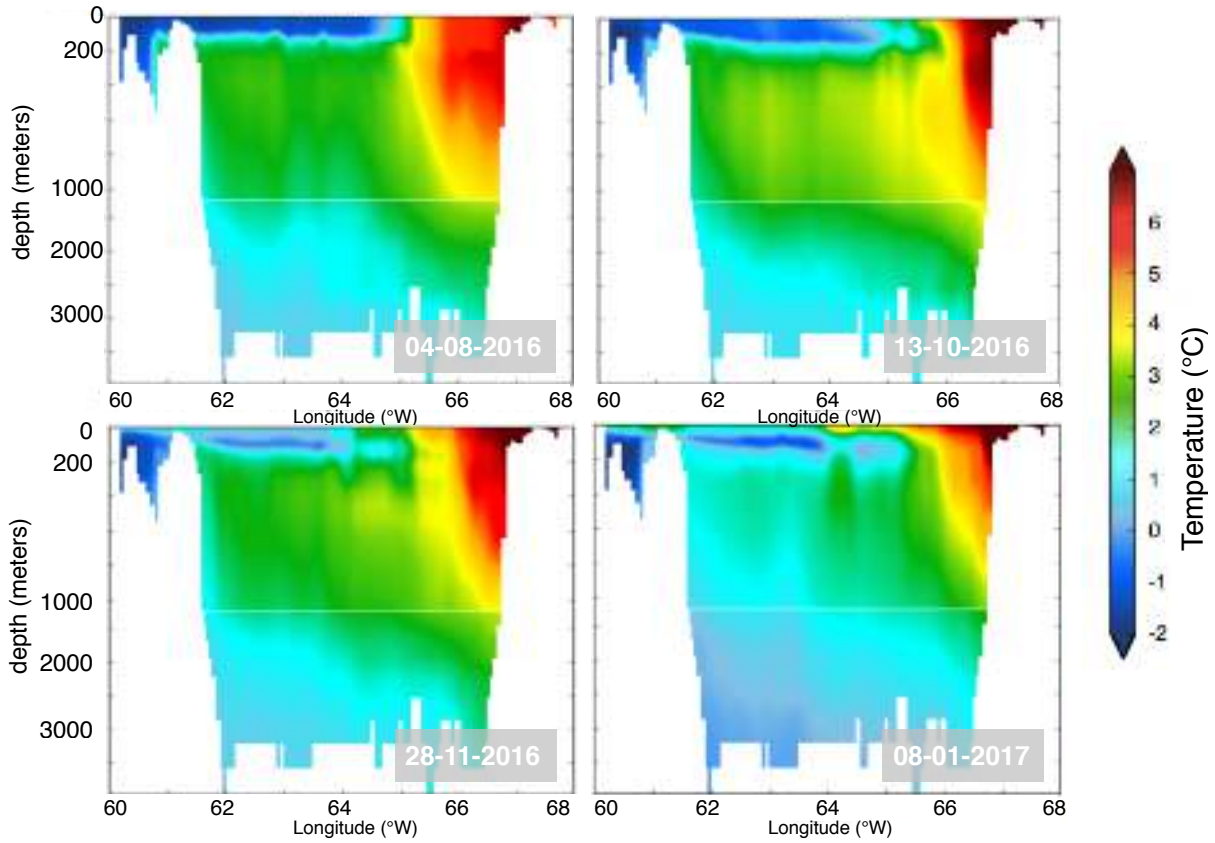

FIGURE 5: Temperature profiles on different dates during August 2016 - January 2017 along transects shown in figure 4.

Question 8: Refer to figures 4 and 5. Which of the following statements are correct ? (several answers possible)

1- The water was colder at 3000m depth compared to the surface during August.
2- The pack ice (floating ice) was located off the Antarctic coast and reached a longitude of 64.5 °W along the transect during August 2016.
3- During January 2017, the pack ice (floating ice) was denser and hence sank.
4- The lower layers of the hydrosphere are composed of colder and more saline water because it is denser.

Passing by the coast of Namibia, the sailors encountered numerous fishing boats heading for the African coast. There are indeed shoals (of fish) in this region.

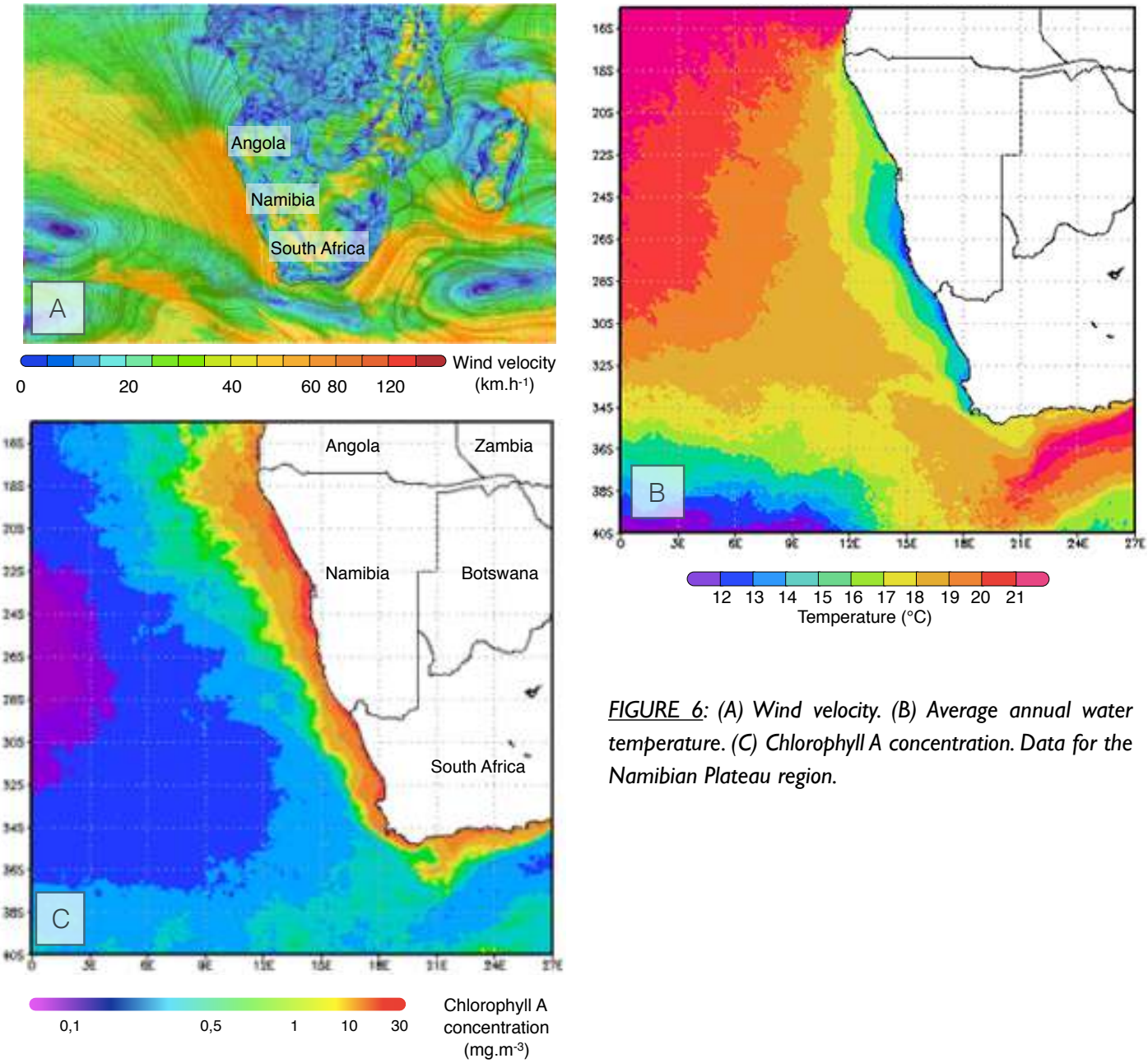

FIGURE 6: (A) Wind velocity. (B) Average annual water temperature. (C) Chlorophyll A concentration. Data for the Namibian Plateau region.

Question 9: Refer to figure 6. Choose all the correct statements below: (several answers possible).

1- The ocean water closer to the coast of Namibia is warmer than that farther away.`
2- This temperature anomaly along the Namibian coast is due to water rising from the depths.
3- The driving force of this rising water is the difference in temperature between deep and shallow waters.
4- The driving force of this rising water is the force of the wind on the surface.
5- The warm water induces high primary productivity, leading to a richness of the food chain (trophic chain) and thus an abundance of fish.
6- The high primary productivity is linked to an increase in nutrients concentration, which sustains a rich food chain (trophic chain).

Question 10 : The Namibian and Angolan continental plateau is known for its abundance of fossil fuels (oil, gas hydrates). The geography and meteorological and climatic conditions have remained approximately the same for several hundred thousand years. The southwest coast of Africa has remained a desert. Which of the following statements are correct ? (several answers possible)

1- The abundance of plankton and the richness of the food chain are necessary elements for the formation of hydrocarbons.
2- Oil is formed at the bottom of the Atlantic Ocean and rises due to the upwelling of water.
3- The organic matter from the continent (dead animals and vegetative matter) is sedimented on the continental plateau and is the main source of hydrocarbons.
4- The organic matter of plankton which is sedimented on the continental plateau must be in anoxic conditions to be transformed into hydrocarbons.

The sailor Kito de Pavant dropped a GPS beacon named IESO2017 into the water upon crossing the Equator on 17 November 2016. This floating beacon drifted solely due to the marine currents and transmitted its latitude and longitude position every hour.

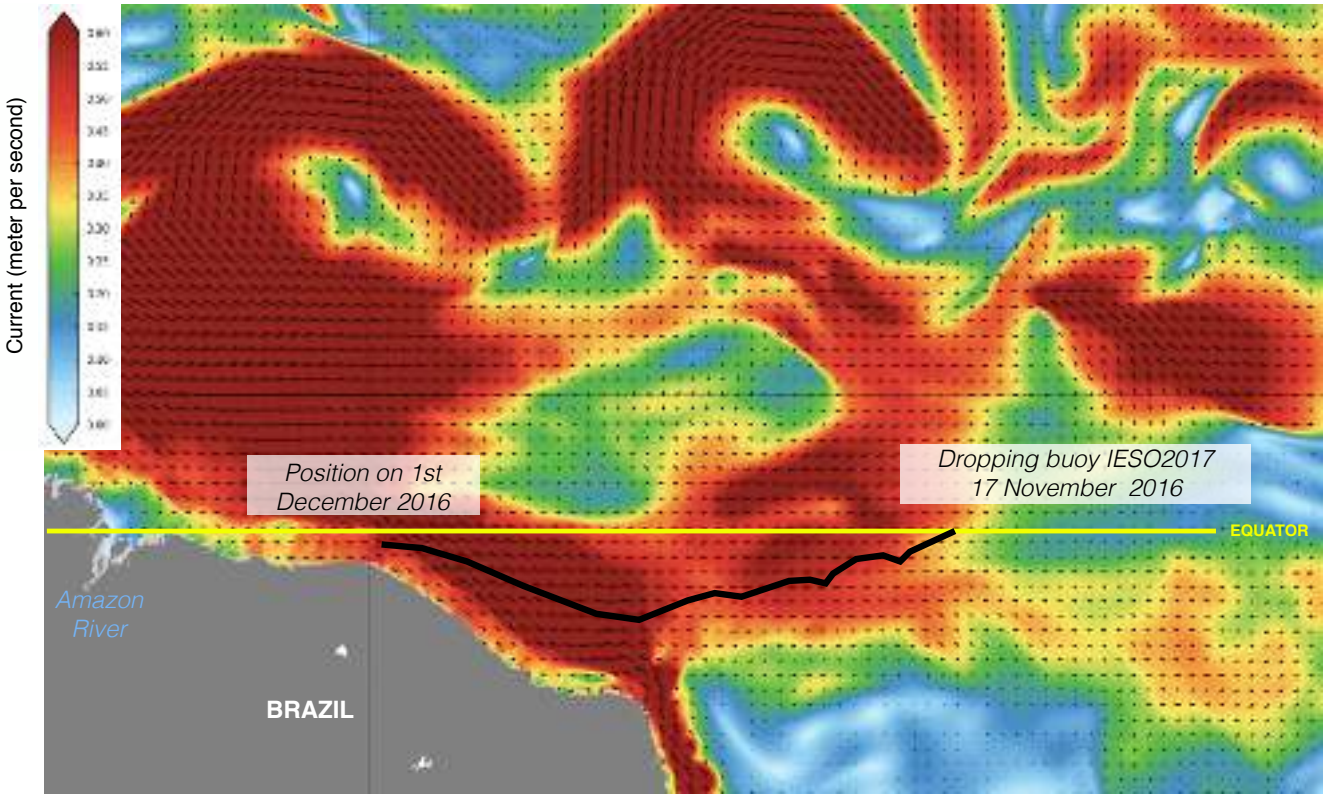

FIGURE 7 : Map of the equatorial Atlantic Ocean. The black line traces the movement of the IESO2017 beacon during 17 November - 1 December 2016. The beacon was placed while crossing the Equator by the skipper Kito de Pavant. The colors indicate the force of the currents, and the arrows specify the direction. The current appearing on this map is called the "Equatorial current".

Question 11: Refer to figure 7. Which of the following statements are correct ? (several answers possible)

1- The current carrying the beacon is caused by the trade winds of the Southern Hemisphere.
2- The current carrying the beacon is caused by the difference in temperature between the east and western parts of the Atlantic.
3- The current carrying the beacon is caused by the difference in salinity between the eastern and western parts of the Atlantic.
4- The current carrying the beacon is caused by the difference in height of the ocean between the east and western parts of the Atlantic.
5- The direction of the current carrying the beacon is influenced by the Coriolis force.

FIGURE 8: Map showing the end stage of the beacon's journey between 15 December 2016 and 4 January 2017. Each symbol corresponds to a daily position at a fixed time (midnight).

Question 12: Analyzing the path of the beacon close to the South American coast (figure 8), choose the correct statement: (only one answer possible)

1- The speed is constant, and the trajectory becomes parallel to the coast.
2- The speed is constant, and the trajectory is not influenced by the approach to the coast.
3- The speed decreases as the beacon approaches the coast due to fresh water current opposing the oceanic current.
4- The speed decreases as the beacon approaches the coast due to a decrease in water depth.
5- The speed increases as the beacon approaches the coast due to fresh water current opposing the oceanic current.
6- The speed increases as the beacon approaches the coast due to a decrease in water depth.

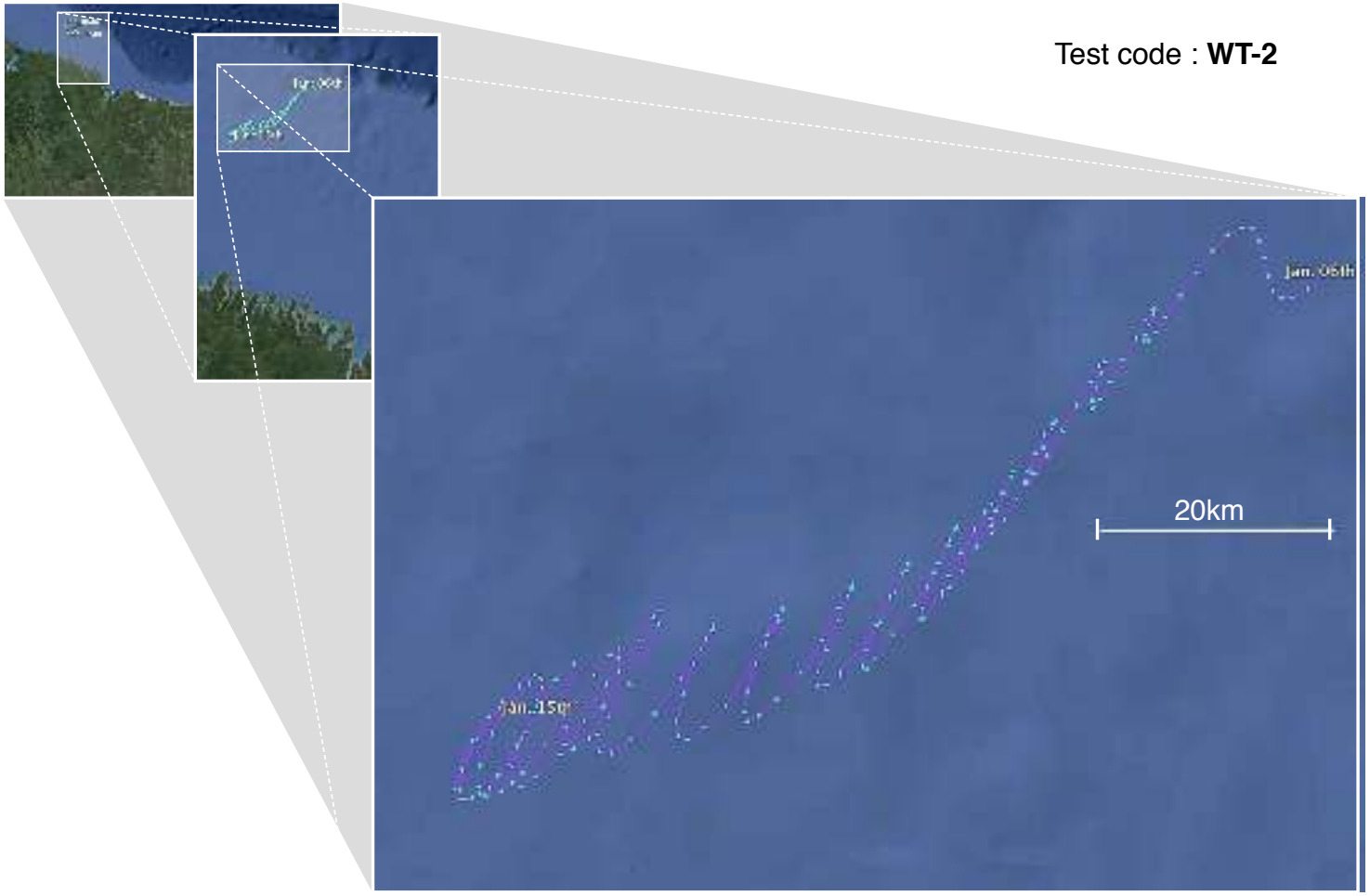

FIGURE 9 :Trajectory of the beacon near the South American coast. Geolocation was measured every hour.

Question 13 : Refer to figure 9 and choose the statement which best describes the beacon's behavior. The observed phenomenon seems to be periodic with an average period of… (only one answer possible)
1- 6 hours.
2- 12 hours.
3- 24 hours.

Question 14 : Among the possible causes listed below, choose the most probable one. This particular pattern of trajectory is due to… (only one answer possible)
1- the turbulent currents caused by the difference in salinity between the inland and offshore waters.
2- the turbulent currents caused by the difference in temperature between the inland and offshore waters.
3- tidal currents.

SECTION 2: STANDING ON THE EARTH, GAZING AT THE PLANETS

During the race, the sailor Kito de Pavant had the opportunity to observe different phases of the Moon. How can we understand what he was able to see?

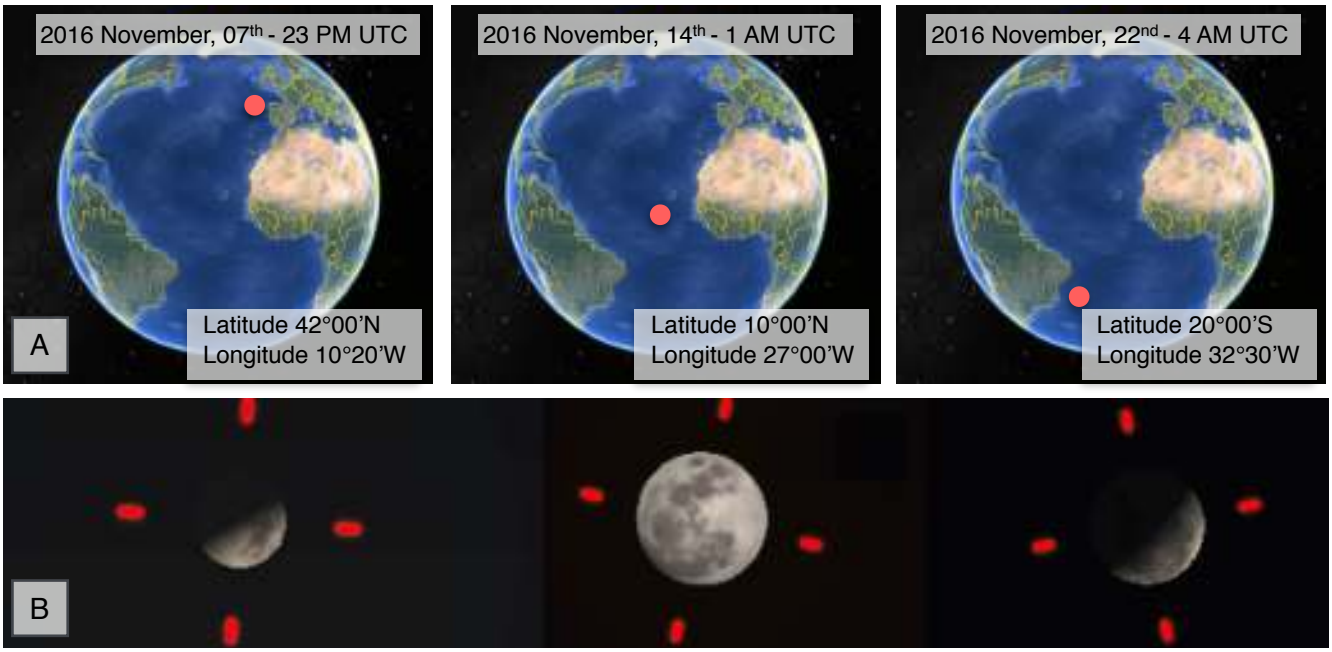

FIGURE 10: (A) Position of the sailor Kito de Pavant during November 2016. (B) The images of the moon that the skipper could see from the corresponding positions.

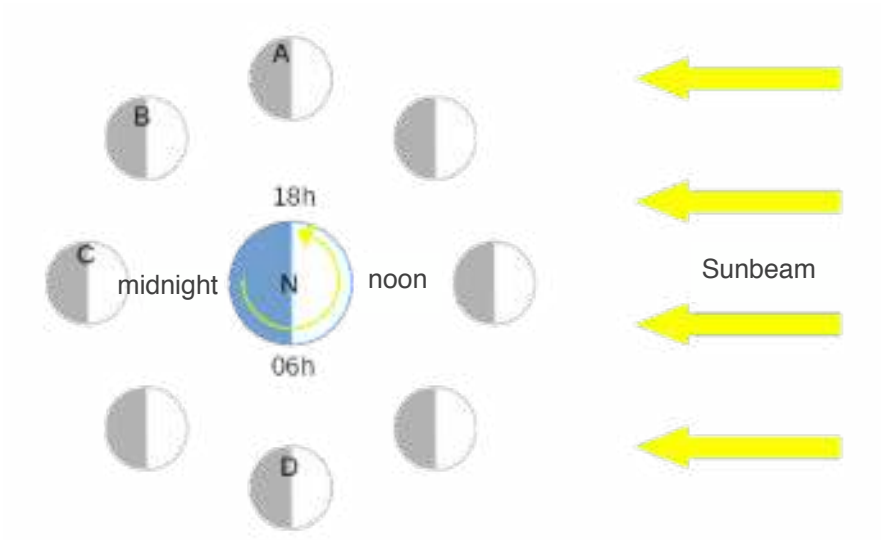

FIGURE 11: Phases of the Moon as a function of the three bodies (the Sun, the Earth, and the Moon).

Question 15: Refer to figure 11. During the night from 7 to 8 November, the position of the Moon relative to the Earth–Sun reference system is… (only one answer possible)

1- A
2- B
3- C
4- D

Question 16: During the night of 14 to 15 November, the Moon reached 90°. This situation… (several answers possible)
1- can be witnessed only when one is located between the tropics.
2- is only possible when the Moon is full.
3- is possible anywhere on the Earth each time the Moon is full.
4- is extremely rare and occurs at most twice a year for a given location.

Question 17: The Moon seen by the sailor on the nights of 7 and 22 November was very similar. This is because… (Only one answer)
1- The Moon's synodic period of revolution is on the order of 14 days.
2- The Moon's sidereal period of revolution is on the order of 28 days. Therefore, one finds the same phase at the halfway point of 14 days.
3- The first and last quarters appear identical because they are not observed in the same hemisphere.
4- The first and last quarters appear identical because they are not observed during the same time of the night.

Question 18: The full moon of 14 November was observable between 18:00 and 6:00 hours. Choose the correct statement: (only one answer possible)
1- This is always the case with a full moon.
2- This is extremely rare. Most of the time, it can be seen starting at noon.
3- This is solely because one is located close to the Equator.

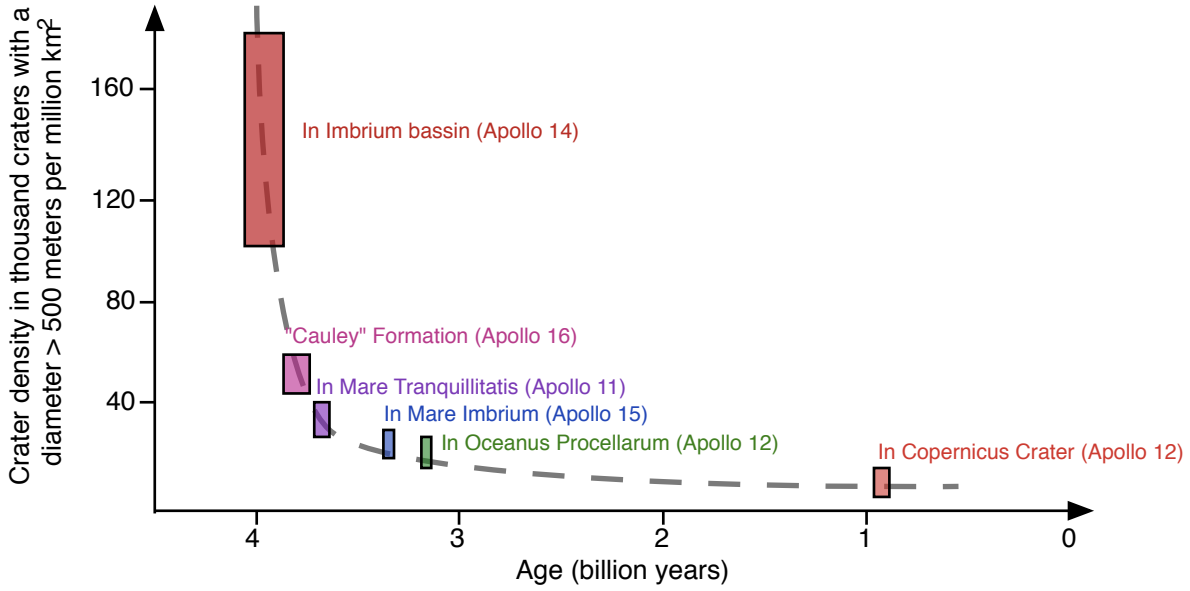

FIGURE 12: Number of craters on the lunar surface and the age of the surface. The dashed curve is the best fit for the observational data (rectangles).

Question 19: Figure 12 indicates a hyperbolic relationship between the lunar crater density and the age of the impacted surface. Which of the following variables effect the exact profile of this inverse relationship ? (several answers possible)

1- the decreasing number of impacting objects since the origin of the Solar System.
2- tectonics, which regenerates the planetary surface.
3- the distance from the planet to the asteroid belt and the Kuiper belt.
4- the period of revolution and the period of rotation of the planet under consideration.
5- the temperature of the impacted surface.
6- the size of the impacted planet.

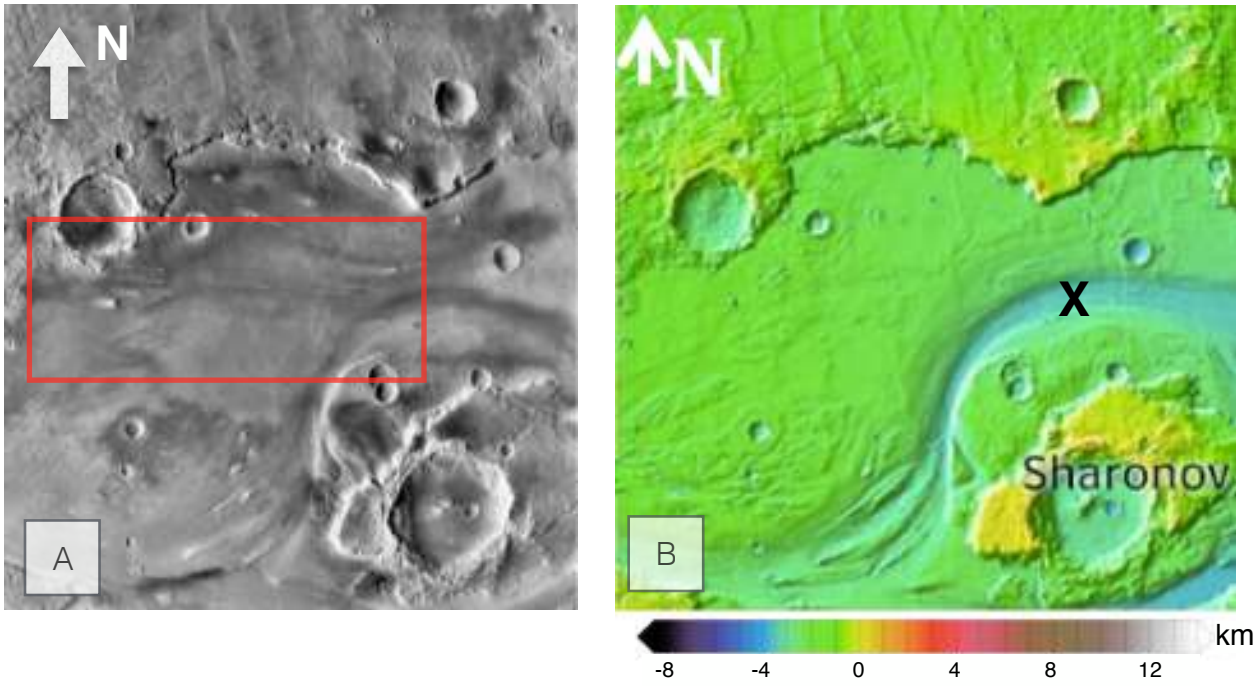

FIGURE 13: Position of the Kasei Valles on the planet Mars. (A) Satellite imagery of the region. The Sharonov crater has a diameter of 100 km. (B) Topographic image of the same region.

Question 20: The river that formed the Kasei Valles at point X flows towards: (only one answer possible)

1- the south
2- the north
3- the east
4- the west
5- the southeast
6- the northwest
7- the southwest

Question 21: There are small streaks linked to the small craters bounded by the red box in figure13A. The accepted explanation is the presence of winds. What are their directions? (only one answer possible)

1- towards the west and northwest.
2- towards the west and southwest.
3- towards the east and northeast.
4- towards the east and southeast.

Question 22: Refer to figure 13. The following geological events can be identified as:
A– Flow of the river **B– Small craters** **C– Large craters in the northwest**
D – Fracture in the north **E– Wind streak.**
Among the relative chronologies (oldest to the youngest) of these events, choose the correct order: (only one answer possible)
1- A / B / C / D / E
2- A / C / D / E / B
3- D / C / A / B / E
4- C / D / B / E / A

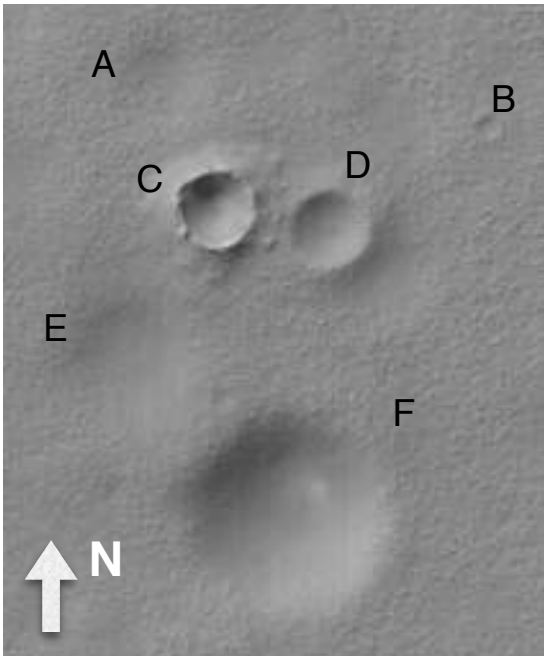

FIGURE 14: Satellite imagery of the Martian region named Sonia Planum. Imagery acquired by the Mars Orbiter Camera (MOC) of the Mars Surveyor (MGS) mission.

Question 23: Refer to figure 14. Which is the correct sequence of the relative ages (oldest to the youngest) of the craters ? (only one answer possible)
1- A / B / C / D / E / F
2- E / F / D / C / B / A
3- C / D / B / A / E / F
4- F / E / A / B / D / C
5- A / E / F / B / D / C
6- C / D / B / F / E / A
7- D / A / E / C / B / F
8- B / D / E / F / A / C

Question 24: There are fewer craters on Venus, Earth, and Mars, compared to the Moon or Mercury… (only one answer)
1- because fewer meteorites struck these planets.
2- due to volcanism that has regenerated the surfaces.
3- because the Earth has been protected by the Moon.
4- due to erosion.

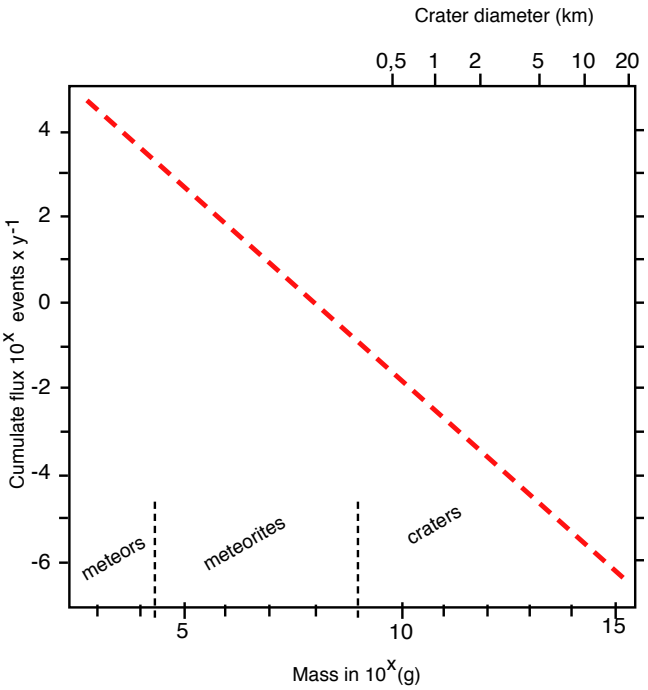

FIGURE 15: Diagram presenting the Hughes scale. The mass of the bodies, crater diameter, and the recurrence of impacts are correlated therein. The values indicated refer to the bodies approaching the Earth at approximately 15.4 km/s speed. Source: Hughes (1992) Space Science Reviews.

Question 25: According to the Hughes scale (figure 15), a body that creates a crater of 5 km diameter on Earth, corresponds at a mass of… (only one answer)
1- 100 Kilotons
2- 0.1 Megaton
3- 10 Megatons
4- 1 Gigaton

Question 26: One such body impacts the Earth at a frequency of… (only one answer)
1- once every century.
2- once every 10,000 years.
3- once every million years.

Question 27: Choose the factors that determine the size of an impact crater on the Earth : (several answers possible)
1- the shape of the body.
2- the mass of the body.
3- the amount of ice on the body.
4- the speed of the body.
5- the density of forest at the site of impact.
6- the weather

Question 28: Refer to figure 15. An impact of magnitude M=5.5, less than 100 km from the seismological station, induced vibrations of an amplitude that was too large to be precisely recorded (saturation phenomenon). The annual frequency of impacts of magnitude "M" on Mars is expressed as $R(M) = 100 \times 10^{(3.5-M)}$; the radius of Mars is 3376 km. Calculate the annual probability that such an event will occur: (only one answer)
1- 2.9%
2- 100%
3- 33%
4- 0.02%

SECTION 2 : A SURPRISING SATELLITE AROUND SATURN

Enceladus is one of the seven major satellites of Saturn. Table 1 shows some remarkable characteristics of this body. Note that its extremely clear surface has facilitated the observation of complex topography, reflecting geology that is difficult to explain for an object of this size. The aim is to study a possible geological current geological activity.

Characteristics of Enceladus					
Physical parameters				**Chemical parameters**	
Diameter (km)	Density ($g \times cm^{-3}$)	Gravity ($m \times s^{-2}$)	Temperature of the surface (K)	Composition in volume	Atmosphere
500	1.2	0.06	73	10% silicates 90% water	Trace (H_2O)

TABLE 1: Physical and chemical parameters of Enceladus.

Question 29: Considering that Enceladus has experienced differentiation, calculate the radius of the silicate core of this satellite: (only one answer)
1- 85 km.
2- 100 km.
3- 115 km.
4- 140 km.

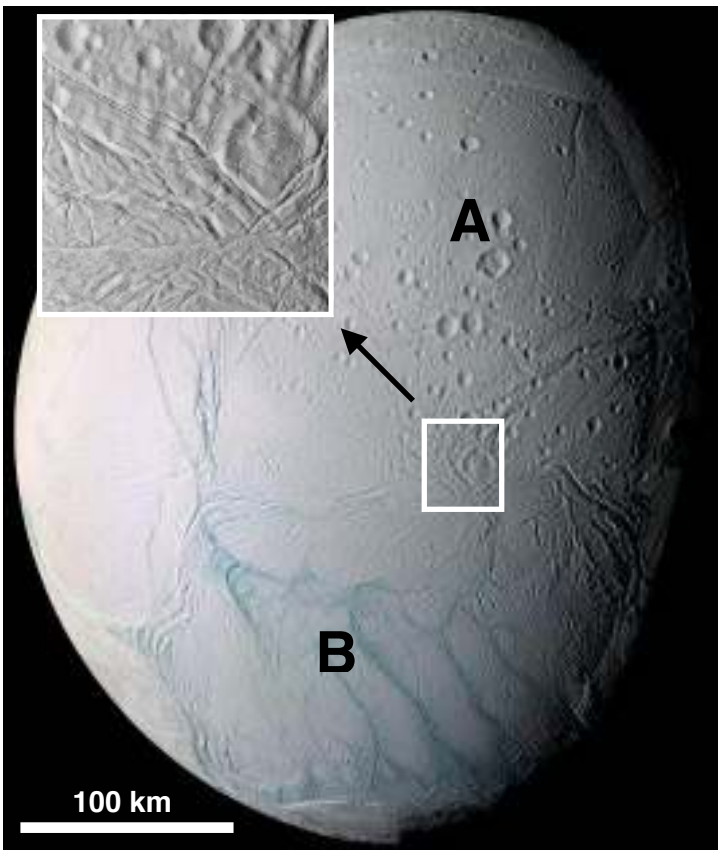

FIGURE 16 : Satellite Imaging of Enceladus obtained by the Cassini probe flying at 1000 km altitude on 14 July 2005 (source: planet-terre.ens-lyon). ***Zone A*** *refers to a major part of the planet, marked by numerous impact craters.* ***Zone B*** *corresponds to the south pole of the satellite, where topographic relief and numerous wrinkles may be seen.*

The zoom presented as inset in figure 16 indicates that the structures of zone B intersect with the craters. Zone B is therefore more recent as suggested by the total absence of craters. Scientists hypothesize that there must be internal activity regularly renewing part of the surface of Enceladus.

Question 30: Using the Earth as an analogy, identify the parameters required to determine the present internal activity of Enceladus: (several answers possible)
1- Atmospheric pressure at the surface of Enceladus from the probe.
2- Surface temperature from the probe.
3- Surface chemistry to detect possible volcanic rocks.
4- Magnetic field.

In terms of the characteristics of Enceladus, the only energy that can maintain tectonics seems to be solar energy. The documents below give some specificities on its thermal state.

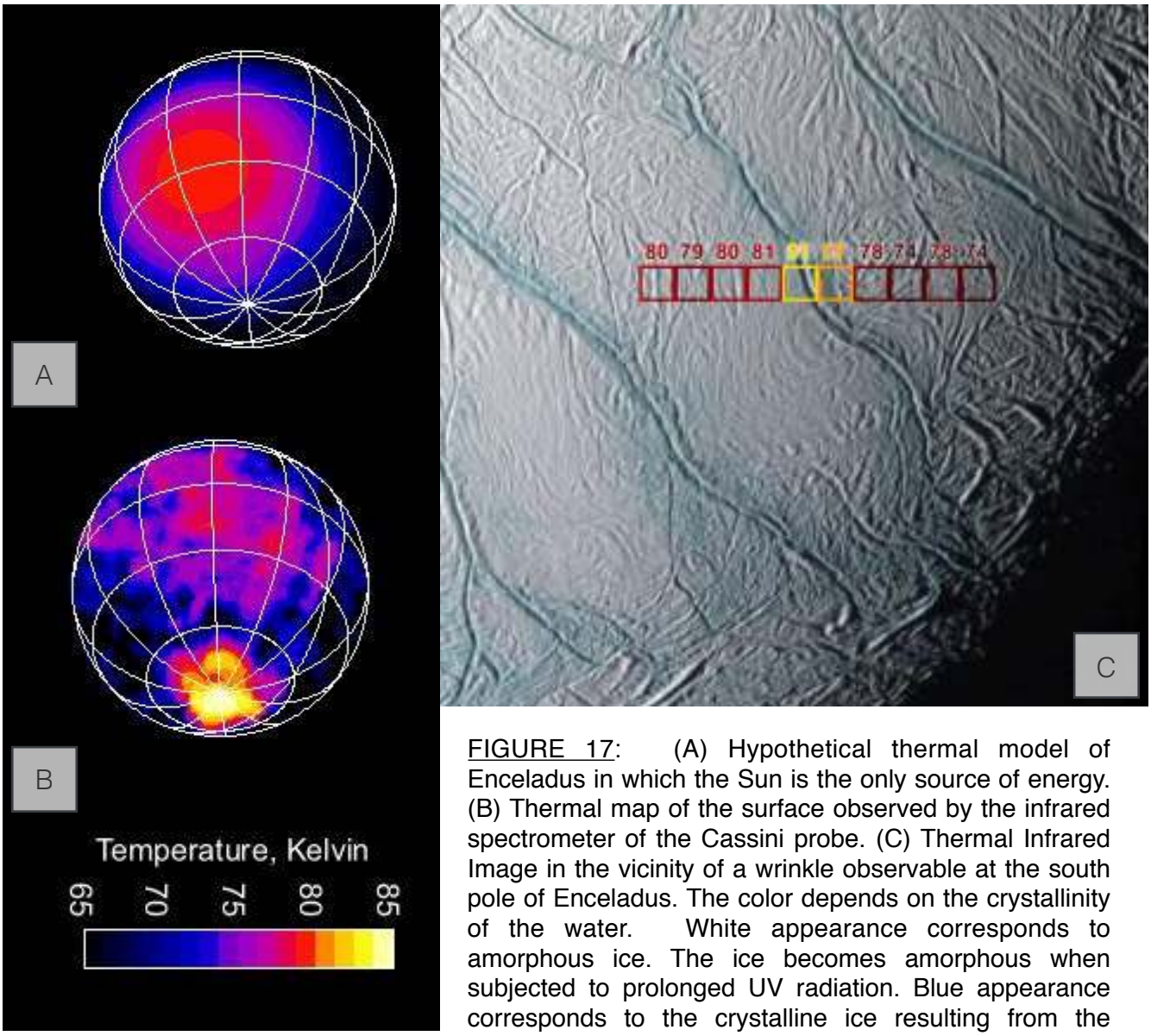

FIGURE 17: (A) Hypothetical thermal model of Enceladus in which the Sun is the only source of energy. (B) Thermal map of the surface observed by the infrared spectrometer of the Cassini probe. (C) Thermal Infrared Image in the vicinity of a wrinkle observable at the south pole of Enceladus. The color depends on the crystallinity of the water. White appearance corresponds to amorphous ice. The ice becomes amorphous when subjected to prolonged UV radiation. Blue appearance corresponds to the crystalline ice resulting from the solidification of water.

Question 31: Refer to figure 17. A comparison between the hypothetical and spectrometer data models suggests that… (only one answer possible)
1- The only source of heat for the satellite is the Sun.
2- The Sun is too far away and has no influence on the temperature of Enceladus.
3- There is a significant heat source at the equator of the satellite.
4- The solar source impacts the surface temperature of Enceladus but there is another heat source located at the South Pole.

Question 32: The numerous wrinkles on the surface at the South Pole are correlated with detectable thermal anomalies. This observation makes it possible to deduce that the wrinkles are… (only one answer)

1- recent tectonic structures made visible by the presence of recently formed ice.
2- recent tectonic structures whose thermal anomaly does not allow for water to exist.
3- very old structures and are an evidence of the erosion caused by a past flow of water on the surface of the satellite.
4- current waterways on the surface of the satellite.

The Cassini probe flew over the mysterious south pole of Enceladus to perform chemical measurements. For this purpose, it activated its Ion and Neutral Mass Spectrometer (INMS) to detect water in its gaseous phase as well as its Cosmic Dust Analyzer (CDA) particle detector to detect particles of water ice.

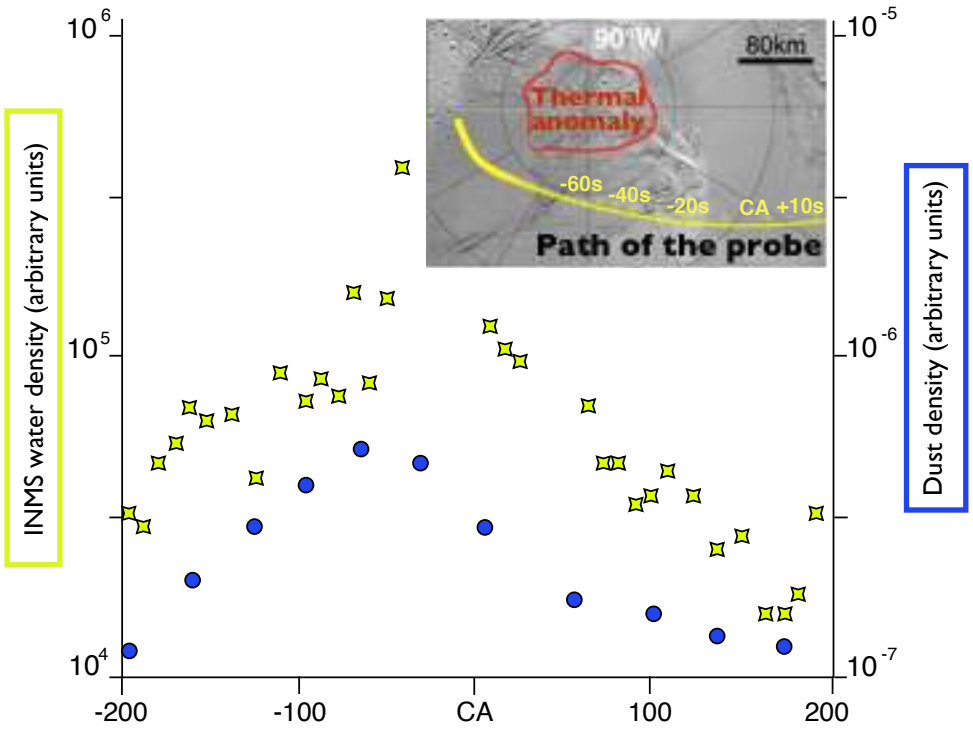

FIGURE 18 : Graph showing the measurements made by the instruments onboard the Cassini spacecraft. The thumbnail picture indicates the probe's flight path near the South Pole. Point closest approach (CA) is the probe's point of passage closest to the ground. Yellow plots correspond to INMS water density and the blue ones to the dust density. Modified from NASA/JPL/University of Michigan/Max Planck Institut 2005 ©

Question 33: Refer to figure 18. The measurements from the Cassini probe indicate that: (several answers possible)

1- The probe recorded the homogeneous presence of particles and water vapor along its path.
2- The probe recorded a diffuse zone (of over 100 km) where particles and water vapor were detected in high concentrations. The zone corresponds to the lowest position of the probe.
3- The probe recorded a constricted zone where water vapor and dust are highly concentrated. The zone corresponds to an area near the thermal anomaly of the South Pole.
4- Outside the zone of high concentration, there is always a small amount of water vapor and particles. Enceladus has a thin atmosphere.

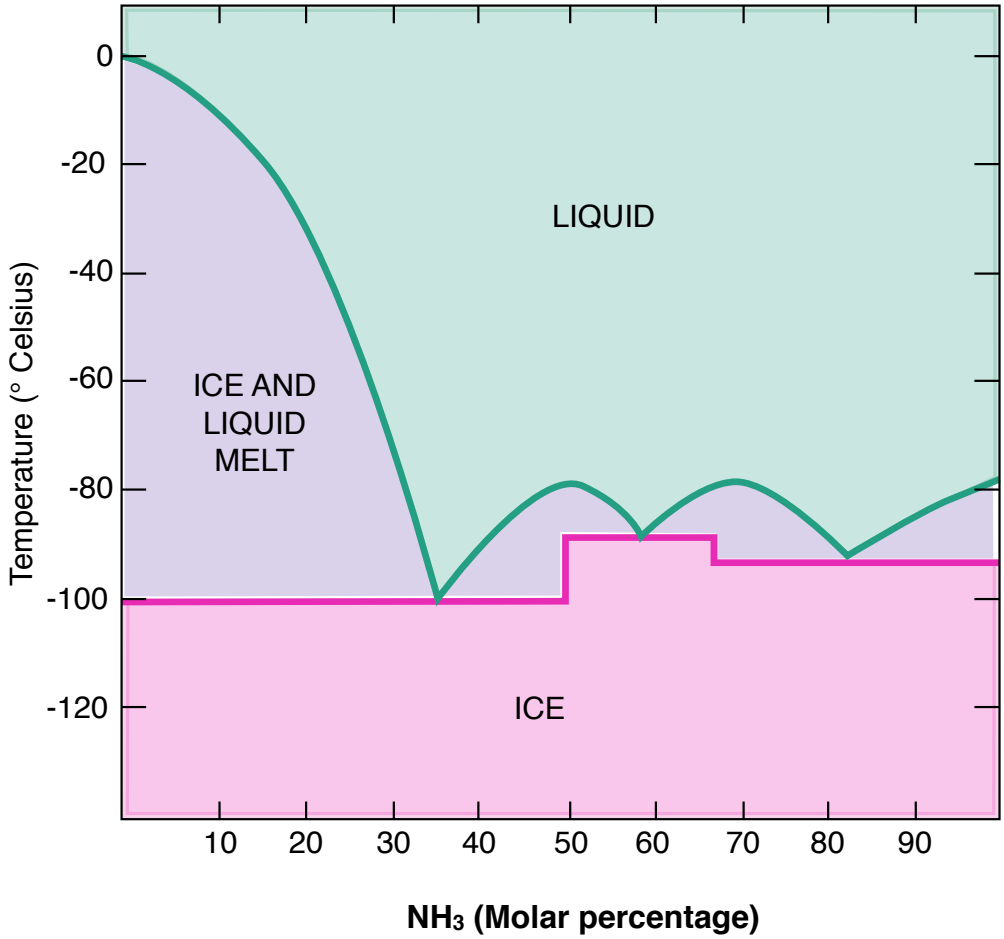

FIGURE 19: Diagram showing the phase changes of an H_2O-NH_3 mixture. The mixture is eutectic, in that it is a mixture of two pure compounds behaving like a single pure compound with respect to its changes of state. The experimental pressure corresponds to that at the surface of the satellite.

Question 34: Refer to the figure 19. Select the mixture that would allow for the minimum melting temperature:
1- A mixture containing 90% ammonia and 10% water.
2- A mixture containing 35% ammonia and 65% water.
3- A mixture containing 65% ammonia and 35% water.
4- A mixture containing 80% ammonia and 20% water.

Question 35: Is the minimum melting temperature, inferred from figure 19, compatible with the conditions of Enceladus ? (several answers possible)
1- The average temperature measured on the surface of Enceladus allows for the melting of the water-ammonia mixture.
2- The temperature measured very locally at the level of the South Pole anomalies allows for the rapid appearance of liquid.
3- No surface condition on Enceladus allows for the appearance of a liquid containing water.
4- The presence of water projected into the atmosphere indicates that internal conditions must allow for its appearance in liquid or gaseous phase.

FIGURE 20 : Photograph of a cryo-volcanic (cryo means ice) eruption on the surface of Enceladus. Analyses indicate that water vapor and ice are ejected. NASA/JPL/Space Science Institute

Question 36: Refer to figure 20. Which of the concluding sentences below are justified ? (several possible answers)

1- The northern part is marked by ancient volcanism and the southern part is an ancient ocean.
2- The surface of Enceladus is heterogeneous. It shows that solar radiation erases the craters by causing a change of state in the ice which reforms a smooth surface.
3- The surface of Enceladus indicates that only one part of the southern hemisphere is recent. It is now frozen and will gradually accumulate impact craters.
4- The surface of Enceladus indicates a very peculiar form of volcanism at the South Pole. Water vapor is ejected into the atmosphere and liquid water spreads over the surface to solidify.
5- The southern part of the satellite is marked by active tectonics maintained by an unexplained source of internal energy.
6- Despite its size Enceladus has an atmosphere, which is maintained by cryo-volcanism.