

USES0 2022



Hydrosphere

Instructions:

- Section I consists of 10 multiple choice questions, with each question worth 2 points. There is only one correct option on multiple choice questions
- Section II consists of 2 multipart free response questions
- A calculator is allowed; show all work for calculations unless otherwise stated
- Recommended time management: 30 minutes on each section

Section I

1. Consider a tropical cyclone with geostrophic winds located above a uniform open ocean. Which of the following best describes the effect the cyclone would have on the ocean circulation directly beneath it?
 - A. Upwelling
 - B. Downwelling
 - C. Upwelling in the Northern Hemisphere and downwelling in the Southern Hemisphere
 - D. Downwelling in the Northern Hemisphere and upwelling in the Southern Hemisphere
 - E. Little to no effect

2. An oceanographer measures the horizontal flow velocity in a water column at a latitude of 45°N and finds two highs: one at the surface of 1 m/s east and another near the bottom of 3 m/s south. Assuming water movement is only affected by ideal Ekman transport, which of the following is closest to the direction of net horizontal flow through the column?
 - A. ESE
 - B. SSE
 - C. S
 - D. SSW
 - E. SW

3. Amphidromic points are locations that have zero tide amplitude for a harmonic constituent of a tide. Which of the following is the primary cause of the circular rotation of tides in a basin around an amphidromic point?
 - A. Water temperature
 - B. Basin depth
 - C. Height of tidal crests
 - D. Coriolis effect

4. The surface topography of ice sheets typically plays a larger role than the bed topography in determining the direction of subglacial (beneath the glacier) water flow. Suppose that at a glacier bed, water flows uphill from point A to point B. Which of the following **must** be true?
 - A. The ice surface is level while the bed topography is not.
 - B. The ice surface elevation is greater at point A than point B.
 - C. The difference between the surface and bed elevation is greater at point A than point B.
 - D. The slope of the surface topography is greater than the bed topography.
 - E. The slope between points A and B are in the same direction for surface and bed topography.

5. Shown below is a map of Arctic sea ice cover. Sea ice extent in the map is higher than the annual average extent of ice cover.

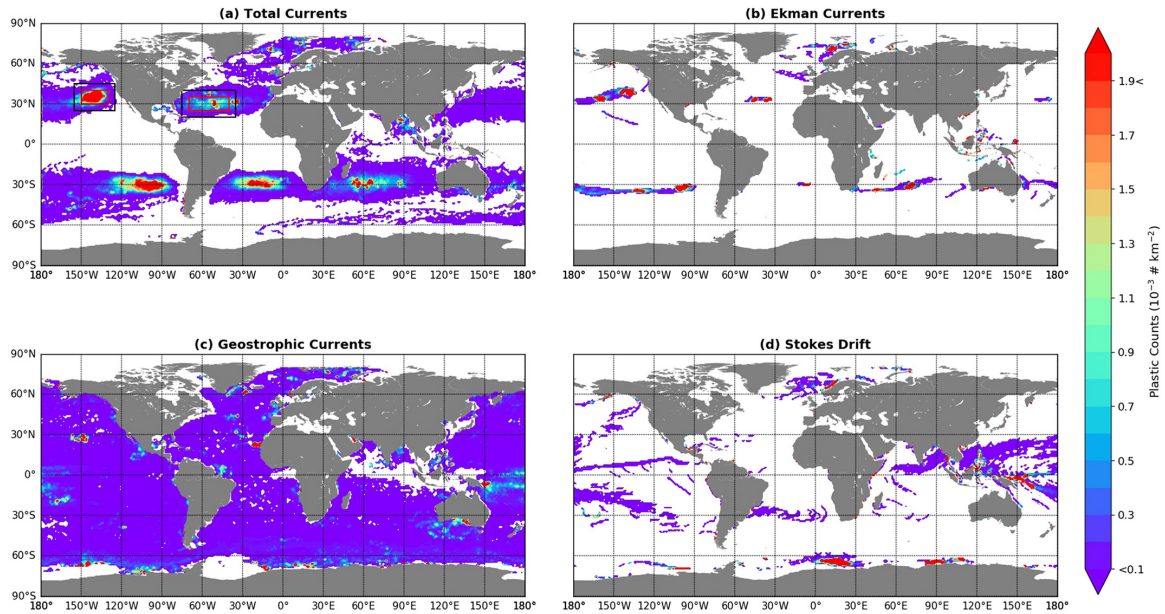


Which of the following statements is/are true?

- I) The map could represent the extent of Arctic sea ice cover in October.
- II) The pattern of ice cover in the boxed region is created by clockwise gyres.
- III) Dissolved surface oxygen levels at A are likely higher than at B.

- A. I only
- B. II only
- C. III only
- D. I and II
- E. I and III
- F. II and III

6. The global distribution of microplastics is controlled by ocean currents. A Lagrangian particle-tracking experiment is conducted in an ocean model using estimates of isolated components of overall surface flow (geostrophic, Ekman, and Stokes drift). Plastic particles are spread evenly on the surface ocean and left to drift. The particle density after 13 years is shown below.



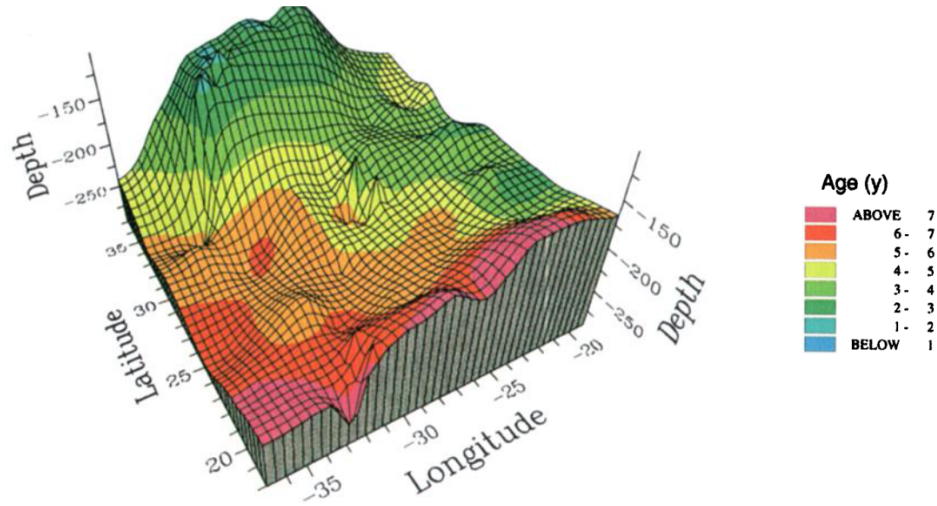
(Onink et al., 2019)

Which of the following statements is/are true?

- I) The microplastic distribution is largely controlled by geostrophic currents since most ocean currents are in geostrophic balance.
 - II) Microplastics tend to congregate in areas where there is Ekman-driven downwelling.
- A. I only
 - B. II only
 - C. I and II
 - D. None

7. Tritium (^3H) is a radioactive isotope of hydrogen that decays to helium-3 (^3He). Measuring the distribution of these isotopes is useful in studying the ventilation and circulation of the upper ocean.

The concentrations of ^3H and ^3He are collected from a section of the North Atlantic. At each location, a subsequent radioactive decay age is calculated using the concentrations of ^3H and ^3He . Shown below is the ^3H - ^3He age on the 1026.6 kg m^{-3} isopycnal.



(Jenkins, 1998)

Which of the following is **not** true? (*Hint: consider how the calculated age changes with depth along the isopycnal.*)

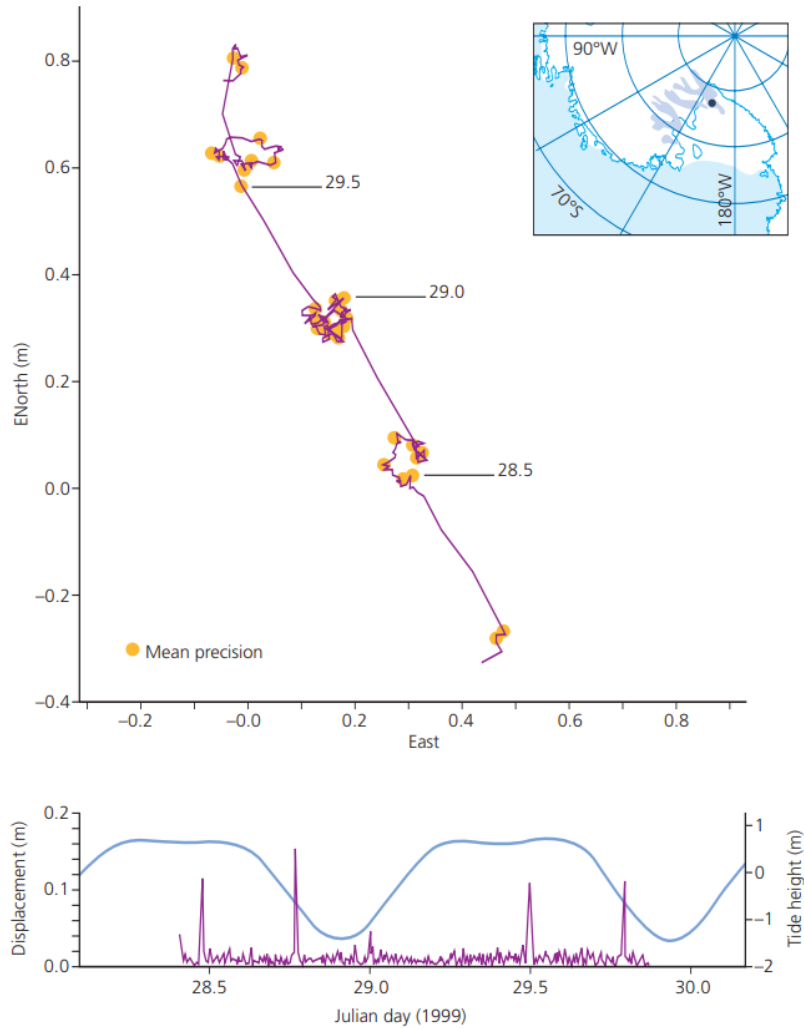
- A. ^3H is introduced into the ocean from the atmosphere
- B. The ^3H - ^3He age is an imperfect indicator of the time-since-surface-ventilation due to mixing
- C. The flow through this section is primarily southeast, parallel to ^3H - ^3He isochrons
- D. The average ^3H - ^3He age over the 1027 kg m^{-3} isopycnal would be greater than the average age over the 1026.6 kg m^{-3} isopycnal

8. Which of the following statements is/are true about carbon cycling in the ocean?

- I) Nonaggregated dead organic matter has a greater carbon input than aggregated organic matter.
- II) Ocean circulation can bring old carbon from the seafloor to the surface.
- III) There is less carbon stored in the ocean than the atmosphere.

- A. I only
- B. II only
- C. I and II
- D. II and III
- E. I, II, and III
- F. None

9. The Whillan's Ice Stream is located in the West Antarctic Ice Sheet and exhibits a stick-slip cycle of motion at its grounding zone. Shown below is this motion (purple line) and the tidal height (blue line) at the grounding zone of the Whillan's Ice Stream. Which of the following statements are true regarding this ice stream?

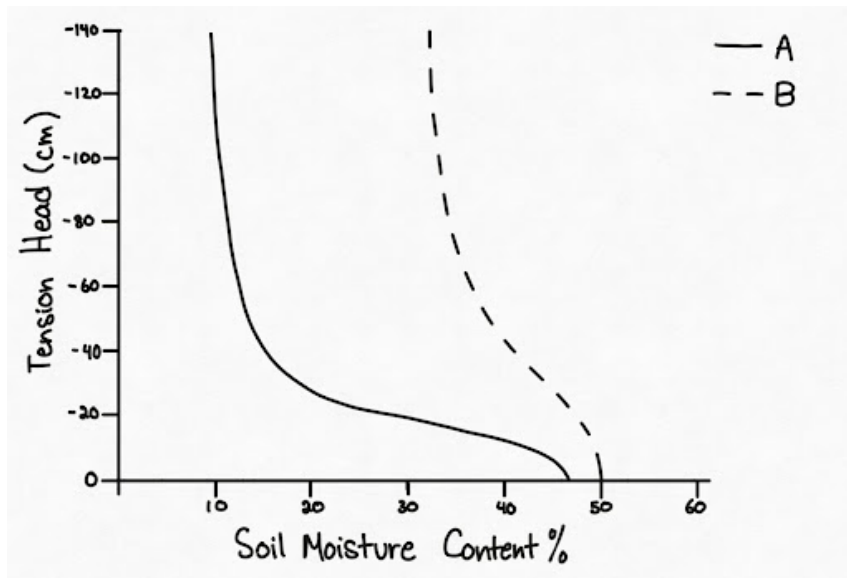


(Bindschadler, 2003)

- I) The grounding zone of the Whillan's experiences a semidiurnal tidal pattern.
- II) The correlation between stick-slip and the tidal pattern are likely stronger at spring tide than at neap tide.
- III) During flood tide, the increase in backstress likely outweighs the reduction in normal stress from the increased buoyancy of the ice stream.

- A. I only
- B. II only
- C. III only
- D. I and II only
- E. II and III only
- F. I, II and III

10. The diagram below plots soil moisture content versus tension head for two soils. Tension head is defined as the attractive force between soil particles and the water molecules as a result of adhesion. Given this information, which of the following is **false**?



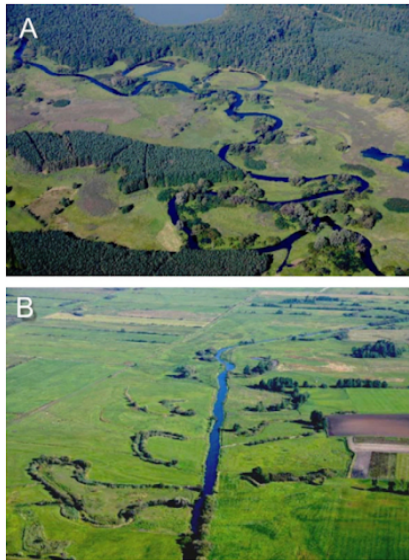
- A. Soil A has a larger average particle size than soil B.
- B. Soil B would serve as a good aquitard.
- C. After a rainstorm that completely saturates the soil, plants could draw more water from Soil A than Soil B.
- D. During a period without precipitation, Soil A would maintain its moisture content more effectively than Soil B.

Section II: Problem 1

Question	1	2	3	4	5	Total
Points	5	4	4	1	1	15 (30%)

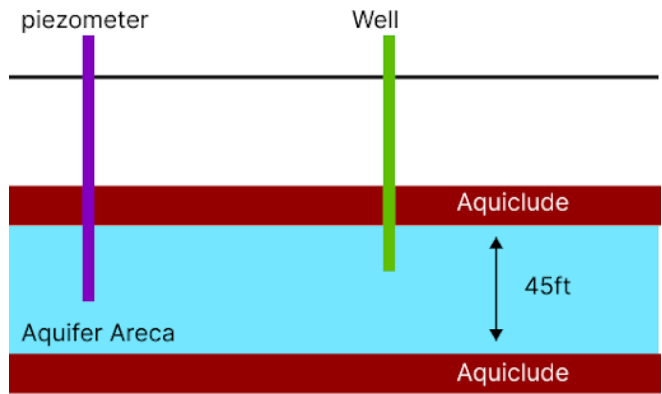
As anthropogenic climate change intensifies and we continue to draw on water resources, the hydrologic cycle continues to be altered. The following questions ask you to think about potential changes to our freshwater systems.

- The following parts ask about lake mixing in light of climate change.
 - (1 point) Which of the following types of lakes is most likely to be the first to experience decreased lake turnover as a result of global warming?
 - Warm monomictic (mixes once annually in winter)
 - Cold monomictic (mixes once annually in summer)
 - Dimictic (mixes twice annually in spring and fall)
 - Polymictic (mixes throughout year)
 - (2 points) Explain your reasoning to the question above.
 - (2 points) Name two potential consequences of reduced lake turnover on lake chemistry. Explain why for each consequence.
- Below is the before (A) and after (B) of the Drweca River in Poland before and after channelization (channel straightening).



Answer the following questions regarding this area.

- (2 points) How is downstream flooding expected to change? Be sure to mention the lag time between precipitation and flooding along with the height of the flood peak.
- (2 points) Would you expect the land in this image to become more or less fertile as a result of channelization? Explain your response.



3. (4 points) Aquifer Areca, shown in the image above, is an idealized confined aquifer with a uniform thickness of 45 ft and an area of 1000 acres. After 280,000 cubic feet of water is extracted from the aquifer by the well, the piezometer senses a pressure drop of 0.25 psi (pounds per square inch). Assuming that the water is drawn evenly from the entire aquifer, what is the compressibility α of the aquifer in $\text{m s}^2 \text{kg}^{-1}$? **Show your work**, your answer, and give your answer to 3 significant figures. Relevant formulas and units are given below:

Storativity (S): $S = S_s b$ (for confined aquifers only)

Defined as the volume of water that can be released per horizontal area per unit decline in hydraulic head. In this equation, S_s represents specific storage and b represents the thickness of the aquifer.

Specific storage (S_s): $S_s = (\rho g(\alpha + \eta\beta))$

Defined as the volume of water that can be released per volume of aquifer per unit decline in hydraulic head. In this equation, ρ represents the density of water, g represents gravitational acceleration, α represents aquifer compressibility, η represents porosity, and β represents the compressibility of water.

ρ	1000 kg m^{-3}
g	9.81 m s^{-2}
η	0.35
β	$4.4 \times 10^{-10} \text{ m s}^2 \text{ kg}^{-1}$
1 ft^3 of water	62.4 lbs
1 acre	43,560 ft^2
1 m	3.28 ft

4. (1 point) Land subsidence occurs as a result of overdrawing water from an aquifer. If land starts subsiding drastically faster per unit amount of water pumped out of, it is a sign that the aquifer has most likely transitioned from a(n):
- Elastic to inelastic compaction.
 - Inelastic to elastic compaction.
 - Pressure head greater than zero to a pressure head of zero.
 - Pressure head of zero to a pressure head greater than zero.
5. (1 point) **True/False:** In areas with nitrate and phosphate contamination in well water, streams are likely disconnected from the water table.

Section II: Problem 2

Question	1	2	3	4	5	6	Total
Points	2	5	3	2	2	1	15 (30%)

Sea level has fluctuated throughout geologic history on time scales as long as tectonics to those as short as present climate change. The following questions address some important considerations for the causes and effects of sea level change in both historical and modern contexts.

- (2 points) Counter to what one might expect, the average sea surface height (SSH) at any given location does not always conform to the height of the geoid. Briefly explain how ocean circulation contributes to this discrepancy.
- One long-term influence on sea level is the creation and splitting of supercontinents, which affects the total volume of ocean basins as well as the global climate.

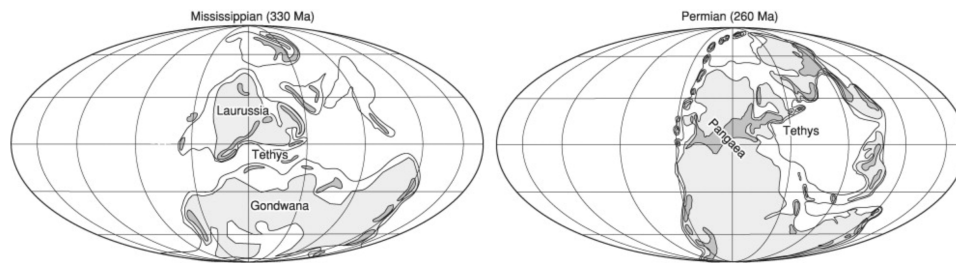


Figure 1: Arrangement of continents over two geologic periods.

- (3 points) Compared to the Permian, is the Mississippian associated with higher or lower sea level? Explain using relationships between the supercontinent cycle, seafloor spreading, and ocean basin volume.
- (2 points) The supercontinent cycle also impacts climate, another major influence on sea level. Explain whether the change in climate from the Mississippian to Permian period enhances or reduces the effect of ocean basin volume on sea level.

Increasing ocean heat content drives sea level rise because of the thermal expansion of water.

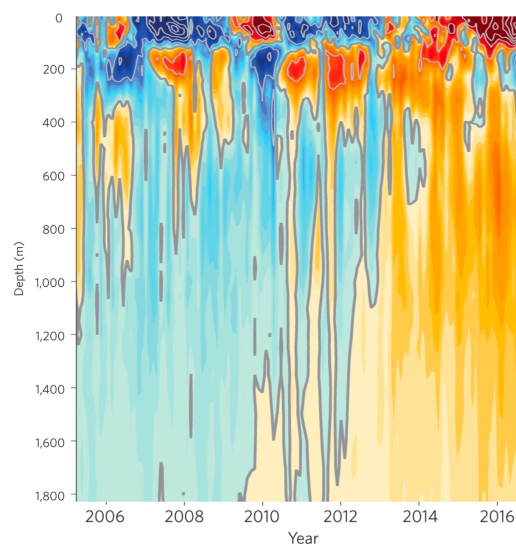
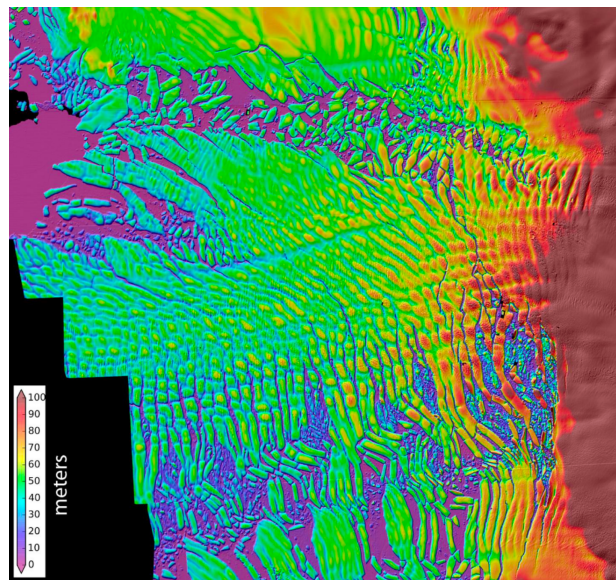


Figure 2: Average ocean temperature by depth and year. Intervals of $0.05\text{ }^{\circ}\text{C}$ are marked by gray contours, with warm and cool colors representing warming and cooling anomalies, respectively. (Wijffels et al., 2016)

3. (a) (1 point) At which of the following depth ranges would one best detect relatively long term changes in ocean heat content?
- A. 0 m
 - B. 75–125 m
 - C. 200–250 m
 - D. 300–400 m
 - E. > 800 m

(b) (2 points) Justify your previous answer.

4. (2 points) The figure below illustrates the fracturing ice shelf of the Thwaites Glacier to the right (color indicates elevation). Warming waters also contribute to sea level rise by inducing ice melt. Briefly describe how ice shelf break up can lead to the acceleration of Thwaites.



5. (2 points) Despite melt from the Greenland ice sheet significantly contributing to global sea level rise, little local sea level rise has been observed at the Greenland coast so far. Describe two reasons why this may be. (*Hint: both relate to gravity.*)
6. (1 point) Other locations across the globe experience much more severe effects of sea level rise, such as many island and atoll nations. Current changes in sea level exacerbate coastal flooding even where coasts are at an elevation greater than the highest high tide. Name one possible cause responsible for this.