



*Exploring the World of Science*

University of Michigan Science Olympiad  
2021 Invitational Tournament

# Dynamic Planet C

**Test length:** 50 Minutes

**Team name:** \_\_\_\_\_ **Team number:** \_\_\_\_\_

**Student names:** \_\_\_\_\_



# Intro Page [242 points]

Things you should probably know:

- 1) We don't need complete sentences. As long as you get the point across, that's good enough for us. Lists ARE an acceptable explanation format. That bien sed, f u make nu cents and write like a crackhead, we won't waste time grading it.
- 2) There are 7 tiebreakers. We will go 1-7 in breaking ties.
  - a) If they say "Tiebreaker X with points", that means the question is part of your exam score and will also be used to break ties. You'll notice that much of the higher tiebreakers are with points. That's because they're awesome questions.
  - b) If they say "Tiebreaker X (0 points)" We will only use these questions for tiebreakers, so we would recommend doing these only if you have time.
- 3) We put some mad jokes in the test. Please fake laugh for us.
- 4) The test is split up into sections we find in the rules. Do with this information what you will.
- 5) If you can't see the images, there is an image sheet separate from the test. There is also a pdf version of the test if you need it.
- 6) Your two test writers are: Manish Venumuddula ([manishrv@umich.edu](mailto:manishrv@umich.edu)) & Siri Vangavolu ([vangavolus@gmail.com](mailto:vangavolus@gmail.com)).

If you have any questions about the test, spot any wrongdoings, or really, just wanna jam about anything, reach out to us. We love hearing from you guys! If you just wanna say Hi, please do.

I. Seawater: composition, density, variations in salinity, and sources of salts (20 points)

1. We all know the six major ions present in the oceans, but what are 2 major salts? (1 point)
2. What are the two major processes that affect salinity? (1 point)
3. What is the most common source of the salts in the ocean? (1 point)
  - a) Rocks on Land
  - b) Rivers
  - c) Hydrothermal Fluids
  - d) Sneezes
4. Why is the Atlantic Ocean saltier than the Pacific Ocean? [Supervisor Recommendation: List as many possible answers as you can] [Tiebreaker #3 with points] (5 points)
5. What is the principle that states that the proportions of major salts stay the same relative to each other? (2 points)
6. What is the freezing point of a sample of seawater, given a water freezing constant of  $1.86\text{ }^{\circ}\text{C/m}$  and a salt molarity of 1.07527? (4 points)
7. We are always told that temperature and salinity affect density, but by how much? Calculate the  $\Delta$ Density of seawater given the following: (6 points)
  - a. The thermal expansion coefficient:  $\sim 0.2 \frac{\text{kgm}^3}{^{\circ}\text{C}}$
  - b. Saline contraction coefficient:  $1 \frac{\text{kgm}^3}{\text{psu}}$
  - c.  $\Delta T = 15\text{ }^{\circ}\text{C}$
  - d. Salinity changes from 35 ppt to 38 ppt.

## II. Shortwave and longwave radiation, sensible and latent heat fluxes, geothermal heat, and heat transport (14 points)

1. The Earth emits which kind of radiation? (1 point)
  - a) Shortwave
  - b) Longwave
  - c) Mie scattering radiation
  - d) Sodium pentafluoride waves
2. What is a greenhouse gas? [Supervisor Recommendation: Don't spend too much time on this! A quick and dirty explanation is all we need] (2 points)
3. What's the standard letter to represent heat in a mathematical or chemical context? (1 point)
  - a) H
  - b) S
  - c) U
  - d) R
4. What is the main source of geothermal heat in the Earth? (1 point)
  - a) The Sun
  - b) Residual Heat from the Earth's formation
  - c) Radioactive Decay in the Mantle
  - d) Overeager squirrels in the core
5. Originally, scientists believed basal drag was the primary driving mechanism behind plate movement. However, more recently, scientists believe there is a different driving mechanism behind plate movement. What two processes does this driving mechanism contain? (3 points)
6. What is the difference between sensible heat and latent heat? [Supervisor Recommendation: Don't spend too much time on this! A quick and dirty explanation is all we need] (2 points)

7. Ocean Thermal Energy Conversion is a proposed form of electricity generation that uses the thermal gradient of the ocean to....generate electricity.
- a. If I start with a cubic meter of water at the surface of the ocean at approximately  $25^{\circ}\text{C}$  and leave it at  $0^{\circ}\text{C}$ , how much energy is released? Assume: Specific Heat of  $3.850\text{ J/(g}^{\circ}\text{C)}$ , Density of  $1.0273\text{ g/cm}^3$  & We don't care about Sig Figs. (4 points)
  
  - b. What is the theoretical maximum amount of energy we can capture from this?  
Hint: Carnot's are my favorite vegetable. (Tiebreaker #7, 0 points)

### III. Water temperature, pressure, and the three-layer structure of ocean water (23 points)

1. Describe the relationship between temperature and salinity of ocean water if density is constant. (1 point)
2. Which latitudes have the highest surface salinities? Why? (2 points)
3. Match the thermocline to the halocline at the same latitude.\* (1 point)
4. What are the three layers of the ocean? How are they divided? (2 points)
5. Describe the relationship between salinity content of water and its freezing point. Which layer of the ocean would be the hardest to freeze based on salinity content alone? (4 points)
6. Given the pycnoclines at each latitude, describe how a sound wave would travel from the top layer to the bottom, assuming the sound wave does not dissipate.\* (6 points)
7. Why are the layers of the ocean stratified? How long does it take for a water particle from the bottom layer to move to the middle layer? What about from the middle layer to the surface layer? (3 points)
8. Name the four types of oceanic sediments and describe their origins. (4 points)

IV. Topographic features found at continental margins, estuaries, ocean basins, and mid-ocean ridges (19 points)

1. What are four types of estuaries based on origin? Describe the key topographic features of each. (8 points)
  
  
  
  
  
  
  
  
  
  
2. Describe the two types of continental margins and give two real-life examples of each. (4 points)
  
  
  
  
  
  
  
  
  
  
3. How are submarine canyons formed? (2 points)
  - a) Turbidites
  - b) Displacement/cleaving by plate movements near the continental slope
  - c) Erosion by turbidity currents
  - d) They were clawed into the Earth by an evil space monster
  
  
  
  
  
  
  
  
  
  
4. What two general terms describe the silica content of magma? How do these two types differ in viscosity? Give an example of a rock of each type. (3 points)
  
  
  
  
  
  
  
  
  
  
5. Describe the difference between seamounts and guyots. (2 points)
  - a) Seamounts are underwater, guyots are above ground
  - b) Seamounts have a peak, guyots are flat-topped
  - c) Seamounts are nonvolcanic, guyots are volcanic
  - d) The person asking this question is dumb, there's obviously no difference

V. Processes and features of tectonic plate motion in ocean basins and patterns of age of the ocean floor (17 points)

1. Describe the process of seafloor spreading. (2 points)
2. Who proposed the currently accepted theory of seafloor spreading? What was the previous theory, and who developed it? (3 points)
3. Why are geomagnetic reversals important in relation to seafloor spreading? (2 points)
4. Near what type of margin would the oldest seafloor on Earth be found, and why? (2 points)
5. What is the Wilson Cycle? List and describe its stages. (3 points)
6. What is an aulacogen? How does one form? [Supervisor recommendation: Be specific when answering the second question.] (3 points)
7. Scientists are tracking the movement of two correlated paleomagnetic stripes on the seafloor. The stripes are 140m from each other. How long ago were they created if the spreading rate of that rift is 3cm per year? Show your work (2 points)



VI. Distribution of chemicals (e.g., nutrients, oxygen, metals) in the ocean, as well as vertical and horizontal structure (18 points)

1. What are two ways chemicals and elements can be distributed in the ocean (Vertically or Horizontally)? (4 points)
2. Conservative elements:
  - a. What is a conservative element? (1 point)
  - b. What is the only process that can cause changes in concentration of these types of elements? (2 points)
3. Nutrient-Like elements are elements that are depleted at the ocean's surface due to biological processes(absorption/uptake from plankton). Do nutrient-like elements have longer or shorter residence time than conservative elements? Why? (4 points)
4. Scavenged elements are those that react with other particles and are absorbed into them. Because of this, they generally have fairly short residence times. From that information or previous knowledge you have acquired, what would the general depth profile of a scavenged element look like? (2 points)
  - a) Increase with Depth
  - b) Decrease with Depth
  - c) Doesn't change with depth
5. Stable gases are those that pass from the atmosphere into the ocean until they reach saturation. Do cold or warm waters hold more dissolved gasses? (1 point)
  - a) Cold Waters
  - b) Warm Waters
  - c) Gatorade
  - d) Carbonated Water

6. Over geologic time scales, When organic matter is buried, oxygen levels increase in the atmosphere. What is the basic chemical reaction that describes this? Provide a brief explanation why you chose this equation (4 points)

## VII. Formation of fringing reefs, barrier reefs, and atolls (18 points)

1. Name 3 conditions for coral growth. (1 point)
2. How does coral's symbiotic relationship with zooxanthellae work? [Supervisor recommendation: What do they exchange?] (2 points)
3. Describe the stages of evolution needed for an island reef to become an atoll.(3 points)
4. What is the main nutrient/chemical required for coral reefs to build their skeletons? What happens to this chemical over extremely long periods of time? (2 points)
5. What are patch reefs and where are they found relative to a fringing reef? (2 points)
6. Which section of a fringing reef has the least biodiversity? (1 point)
  - a) Lagoon
  - b) Reef flat
  - c) Fore-reef slope
  - d) Reef crest
7. Are reefs typically high-energy environments or low-energy ones? Why? (3 points)
8. At the end of the Devonian Period, around 356 million years ago, there was a major extinction event that killed almost all corals. Researchers refer to the extinction as the Kellwasser event. Hypothesize what might have caused the extinction of corals at that time and why. [Supervisor recommendation: A wide range of answers will be accepted.] [Tiebreaker #5 with points] (4 points)

## VIII. Waves: Motion, height, wavelength, period, fetch, swell, surf, and tsunamis (19 points)

1. What's wrong with the phrase "tidal wave"? What is it actually referring to? [Supervisor recommendation: describe the causes.] (2 points)
  
2. What is the source of energy for ocean waves? (1 point)
  - a) The sun
  - b) The moon
  - c) The wind
  - d) Gravity
3. What factors affect the height of an ocean wave? (2 points)
  
4. How do water particles move under the surface of the wave? How does this phenomenon affect things that float at the surface? (3 points)
  
5. What are oceanic Rossby waves? Where in the vertical structure of the ocean do they move? [Tiebreaker #4 with points] (4 points)
  
6. A tsunami has been detected in the southwestern Pacific Ocean. It is passing through the Marianas Trench at Challenger Deep. (7 points)
  - a. What are its speed and height at that location, given that Challenger Deep is 11.034 kilometers in depth? Give the speed in m/s and the height in meters.\*
  - b. Once you have calculated the speed of the tsunami, calculate how many minutes it will take to reach Taiwan.



## IX. Surface currents: Warm and cold currents, Coriolis effect, and gyres (11 points)

Ha! You think you got away with less points & questions in this section, just you wait.....

1. Mesoscale Eddies are the oceanic equivalent to storms and are subject to the coriolis effect. What direction does a warm anticyclonic eddy rotate in the Northern Hemisphere? (2 points)
  - a) Clockwise
  - b) Backwards
  - c) Counterclockwise
  - d) Forward
2. Why are Mesoscale Eddies important(List as many reasons as you can think of)? (Tiebreaker #6, 0 points)
3. Labeling Surface Currents: Yeah, we won't ask you mindless questions about these, look 'em up on your own time. Tell us a funny story instead. (0 points)
4. True or False? The Coriolis Force is a real force. (1 point)
5. In the Northern Hemisphere, which way do ocean currents veer? (1 point)
  - a) Left
  - b) Right
  - c) Upside down and sideways
6. Theoretically, if an ocean current was traveling east parallel to the equator(Say, 30 degrees North), which way would the current veer(towards or away from the Equator)? Why? (Hint: What causes the coriolis effect and would that be in play here?) A good explanation is needed here. (7 points)

X. Ekman and geostrophic balances (21 points)

1. What is the net angle displacement caused by the Ekman Spiral? (1 point)
  - a)  $0^\circ$
  - b)  $30^\circ$
  - c)  $45^\circ$
  - d)  $90^\circ$
2. There are two major drivers of gyre rotation. Wind-drive currents and one other process. Explain that entire process. Answer should include: (Geostrophic Bulge, Wind, Coriolis Effect) [Supervisor Note: We expect a thorough explanation. A list explanation is fine.] (Tiebreaker #1, 10 points)
3. What causes western intensification? [Supervisor Note: You can assume that you and the grader already understand the processes involved in Question 2.] (Tiebreaker #2, 10 points)

## XI. Coastal currents: longshore currents, rip currents, and upwelling (12 points)

1. Describe the effects of upwelling on the fishing industry. Why does upwelling have this effect? (3 points)
  
2. What is a longshore current? How are they formed? (2 points)
  
3. Why are longshore currents detrimental to coasts with low-energy environments? (2 points)
  
4. Riptides are the incorrect name for what phenomenon? How are these actually formed? (2 points)
  
5. What kind of underwater topography can make an area more prone to having rip currents? Select all that apply. (2 points)
  - a) Inshore holes
  - b) Reef crests
  - c) Broken sandbars
  - d) Eroded shallows

## XII. Deep ocean circulation, ocean overturning, and water masses (13 points)

1. Why is deep water in the Atlantic much younger than deep water in the Pacific or Indian oceans? (3 points)
2. What are the three major Deep/Intermediate Water Masses? (2 points)
3. Do deep water masses form at high or low latitudes? (1 point)
  - a) High Latitudes
  - b) Low Latitudes
  - c) They form everywhere
  - d) They simply...exist
4. What two things define a water mass? (1 point)
5. In Broecker et. al. (1990a), it is noted that higher Atlantic salinities are the result of a net transfer of water vapor from the Atlantic to the Pacific over the Isthmus of Panama. In the absence of other processes affecting oceanic salinity, this would raise the salinity of the Atlantic by about 1 salinity unit each 1000 years. Since this obviously isn't happening, the Atlantic must be exporting salt to compensate for the lost freshwater. What process is accomplishing this? [Supervisor Recommendation: Don't write more than 10 words] (3 points)
6. What is the name of the ~~blender~~ ocean current sometimes referred to as the "Giant Mixmaster" that plays an instrumental role in mixing NADW, PDW, and other deep water masses leading to redistribution of deep water into the Indian and Pacific Oceans? [Hint: Don't think too deeply, are there even any currents that could distribute water over those two oceans?] (3 points)



### XIII. Relationships between fisheries and ocean circulation (e.g., upwelling, El Niño, Pacific Decadal Oscillation) (11 points)

1. Does La Nina cause an increase or decrease in upwelling the eastern equatorial Pacific? (1 point)
  - a) Decrease
  - b) Increase
  - c) Neither
  - d) Both
2. How does El Nino impact Australia in terms of precipitation? (1 point)
  - a) Increase in Precipitation
  - b) Decrease in Precipitation
  - c) No Change in Precipitation
  - d) Precipitation only varies when I say it does
3. SOI(Southern Oscillation Index) is a standardized teleconnection index that measures the difference in sea-level pressures between Tahiti and Darwin(Near Australia). Specifically,  $SOI = \frac{Standardized\ Tahiti - Standardized\ Darwin}{MSD}$ . It has important implications in weather modeling. If SOI is negative, does that mean we are in El Nino or La Nina? Why? [Supervisor Note: If you're interested in teleconnections indexes or weather modeling, reach out to us!] (4 points)
4. What is the Pacific Decadal Oscillation? [Supervisor Recommendation: Don't spend too much time on this] (2 points)
5. While PDO and El Nino are fun little oscillations, there are many oscillations that have massive impacts across the globe. One such oscillation is the North Atlantic Oscillation(Local manifestation of Artic Oscillation). Name another major oscillation in the world! (2 points)
6. What are the 4 major eastern boundary currents in which coastal upwelling primarily occurs? (1 point)
7. What is a fish? [0 points]

#### XIV. Story Problem: Tales of O'Neer, Vol. II (26 points)

Assistant researcher Iris O'Neer is an intern aboard the small research vessel Dynamic Planet. O'Neer is a very interesting person - his hobbies involve oceanography and eating pie. He bribes his research supervisor with said pie in order to take this boat out for an oceanographic study cruise. He sets off from Cape Hatteras, North Carolina.

The first thing O'Neer does when he gets a significant distance out to sea is dump a bottle of (biodegradable) dye into the water. He assumes that surface currents will eventually carry this dye to \_\_\_\_\_(1) (1 point). He further hypothesizes that the dye will travel primarily by the \_\_\_\_\_(2) (1 point) current.

O'Neer decides that he would like to go someplace warm as his first destination, so he travels to the Strait of Gibraltar, between Spain and Morocco. O'Neer observes a strange phenomenon as he entered the Strait of Gibraltar - the complicated instruments on his boat showed a series of waves below the surface that were totally uncorrelated with the actual surface waves. He consults a local scientist, Sarah, who observes a similar phenomenon in clouds. She says they are \_\_\_\_\_(3) (2 points).

After his brief adventure in Africa, O'Neer heads back across the Atlantic Ocean towards Newfoundland, Canada. On the way, he takes a couple of bathymetric SONAR scans and comes up with this graph:



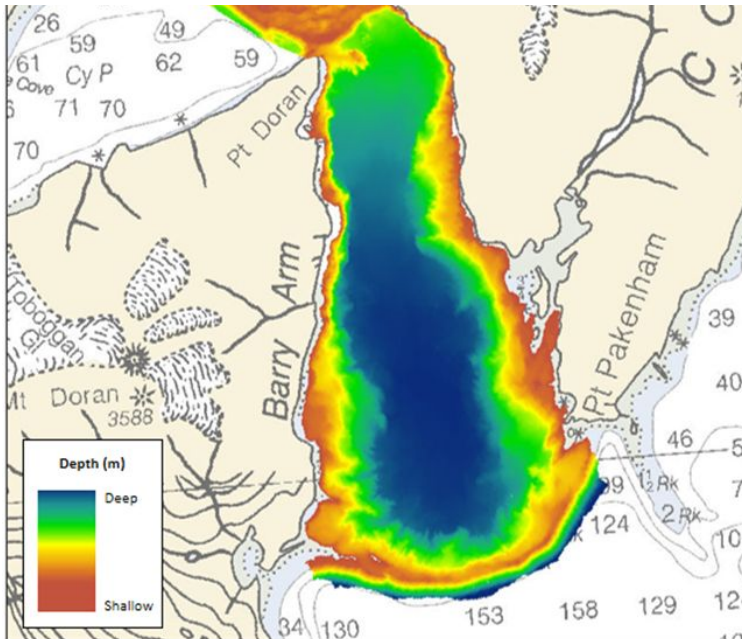
He concludes that the bulge around 4000-4500km is \_\_\_\_\_(4) (1 point) and the little dips and peaks within that region must be \_\_\_\_\_(5) (1 point).

As O'Neer finally nears Newfoundland, he sees some icebergs floating in the ocean. Due to his handy navigating skills and the advent of modern technology, he manages to avoid them. As O'Neer wonders why his research vessel was so close to going the same way as the RMS Titanic, he remembers that the \_\_\_\_\_(6) (1 point) carries the icebergs here. He decides this is as good a place as any to collect some data and grabs his Niskin bottle and

CTD from below deck. What types of data can O'Neer collect? Give two examples.

\_\_\_\_\_ (7) (2 points)

From Newfoundland, O'Neer travels northeast towards Norway. He travels inland and takes another bathymetric scan, getting this profile (ignore the name labels):



He knows that this formation is a \_\_\_\_\_ (8) (1 point), caused by \_\_\_\_\_ (9) (1 point). O'Neer describes the salinity distribution of this basin as \_\_\_\_\_ (10) (2 points). After restocking in Norway, he continues to sail through the Arctic Ocean. He observes many sea arches and sea stacks, caused by \_\_\_\_\_ (11) (1 point) of a \_\_\_\_\_ (12) (1 point). O'Neer reemerges into the Pacific Ocean through the Bering Strait, where he deploys a bottom corer. Give two examples of the types of data he could collect from the sediment sample he gets: \_\_\_\_\_ (13) (2 points).

O'Neer's next destination is Australia, where he hopes to have a relaxing vacation before he heads back home. As he sails along the coast of Japan, he observes a tidal pattern that is recorded below. He deduces that this is a \_\_\_\_\_ (14) (1 point) tide cycle.

Date	Time	Tide Height (ft)
11/17	23:54	0.4
11/18	06:00	3.9
11/18	10:12	3.1
11/18	15:24	4.8
11/18	19:33	2.7
11/18	23:16	0.2

11/19	06:52	3.7
11/19	10:44	3.2
11/19	16:00	4.6
11/19	20:09	2.8
11/20	0:00	0.3
11/20	07:52	3.5

In Japan, O'Neer also observes two different types of beaches: the first is very rocky and exposed, with large sand grains and a short beach face, while the second has a very wide beach face and fine sand grains. He realizes that the first type is a \_\_\_\_\_(15) (1 point) energy coastline and the second is a \_\_\_\_\_(16) (1 point) energy coastline.

When he finally reaches the coast of Australia, O'Neer notices that surfers love a certain type of breaking waves that occur. He observes that the crests of these waves curl over themselves, creating a barrel of air between the crest and trough before the wave collapses. He remembers that one of his professors said these were \_\_\_\_\_(17) (1 point) waves which happen in areas where the ocean floor is/has \_\_\_\_\_(18). (2 points)

While vacationing on a beach in Australia, O'Neer observes that a thick band of shoreline is suddenly exposed, as though the water pulled back significantly. Several rocks and shells are exposed in the sand that would normally be submerged. He decides to go collect some souvenirs for his professors back home, but when he steps into the now-shallower water, he finds that the pull of the water is so strong that he trips. O'Neer is sucked out to sea very quickly. What has happened to him? \_\_\_\_\_(19) (1 point) It is up to you, the reader, to rescue O'Neer. Write him a brief message about how to escape his current danger, and it will be transported to him as soon as you finish this test:  
 \_\_\_\_\_(20) (2 points)

In the future, assuming you have given O'Neer the correct lifesaving advice, he will travel back home. He will (hypothetically, of course) dock back at Cape Hatteras, North Carolina, given he doesn't get shipwrecked by the shifting sandbars. If you would like to see O'Neer's future adventures, search for our tests.