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# 1. Carbon cycle exploration

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Problem Set B due Aug 4, 2021 20:30 IST   Completed



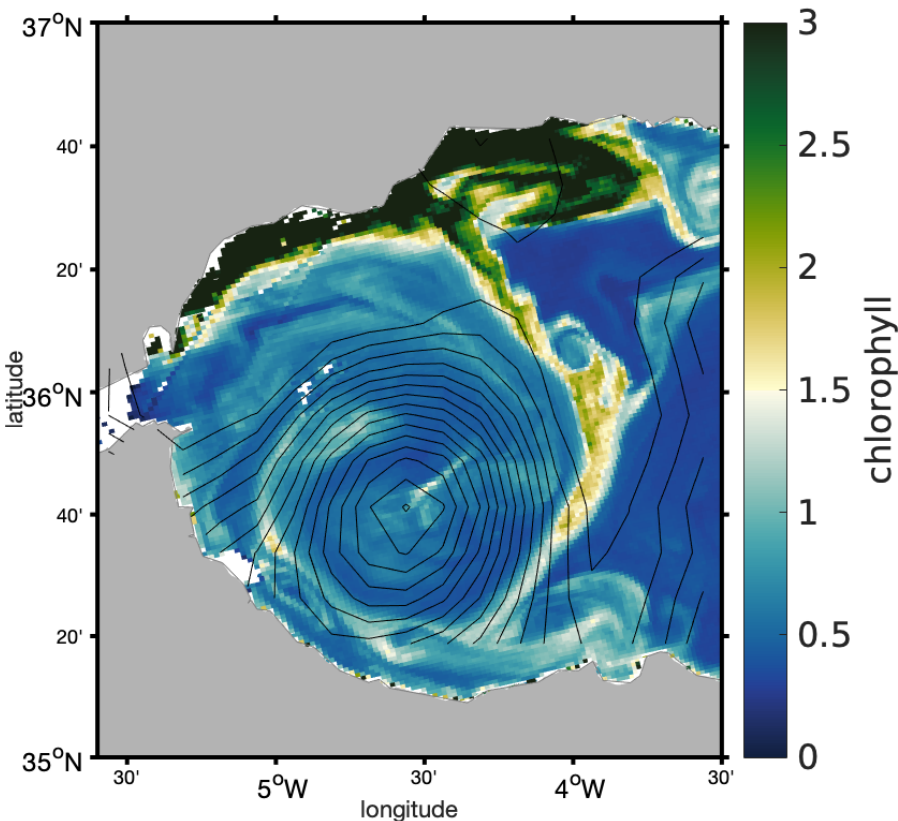
Apply

Problem 1(a)

3/3 points (graded)

The Earth's oceans take in more than one quarter of the human emitted carbon dioxide, converting it via photosynthesis into primary source oxygen. However, climate change is affecting how effectively the oceans are absorbing carbon dioxide to mitigate the greenhouse effect, which could further accelerate global warming. (See for example [Southern Ocean Climate Sink](#).)

Ocean currents redistribute heat and carbon dioxide in the oceans. To understand ocean currents to better model cycles of carbon dioxide absorption, oceanographers use satellite data. The image below was generated from two types of satellite data – sea surface height contours are obtained from altimeters, and chlorophyll concentrations are obtained through photographs (the missing photograph is due to cloud interference). The concentration of chlorophyll is used as a proxy for the primary production of oxygen from carbon dioxide through photosynthesis.



**Figure 11:** Sea surface height (contours) obtained from AVISO altimeters (radar) and chlorophyll concentration acquired from photos from NASA MODIS-Aqua. Data obtained and image created by Mara Freilich March 11, 2020 in the Mediterranean Sea. Used with permission.

Answer the following questions for the function  $h(x, y)$ , the sea level height measured in meters. Use the fact that the highest sea level point can be observed at  $(4^\circ 30' W, 35^\circ 40' N)$  in the image above. Note that the plot is centered on the point  $(4^\circ 30' W, 36^\circ N)$ .

1. Is the partial derivative  $h_x$  positive, negative, or zero at  $(4^\circ 30' W, 36^\circ N)$ ?

☐ positive

☐ negative

☒ zero



2. Is the partial derivative  $h_y$  positive, negative, or zero at  $(4^\circ 30' W, 36^\circ N)$ ?

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2. Is the partial derivative  $h_y$  positive, negative, or zero at  $(4^\circ 30' W, 36^\circ N)$ :

☐ positive

☒ negative

☐ zero



3. Which has larger magnitude (absolute value)?

☒  $h_y$  at  $(4^\circ 30' W, 36^\circ N)$

☐  $h_y$  at  $(4^\circ 30' W, 35^\circ 40' N)$



Solution:

At the point  $(4^\circ 30' W, 36^\circ N)$  the level curve appears to be a horizontal line. Thus the partial  $x$  derivative is zero. As you move in the positive  $y$  direction, the height decreases, thus the partial  $y$  derivative is negative. The partial  $y$  derivative has largest magnitude in the locations where the level curves are closest together. Thus the partial  $y$  derivative is larger at  $(4^\circ 30' W, 36^\circ N)$  than at  $(4^\circ 30' W, 35^\circ 40' N)$ .

Submit

You have used 2 of 2 attempts

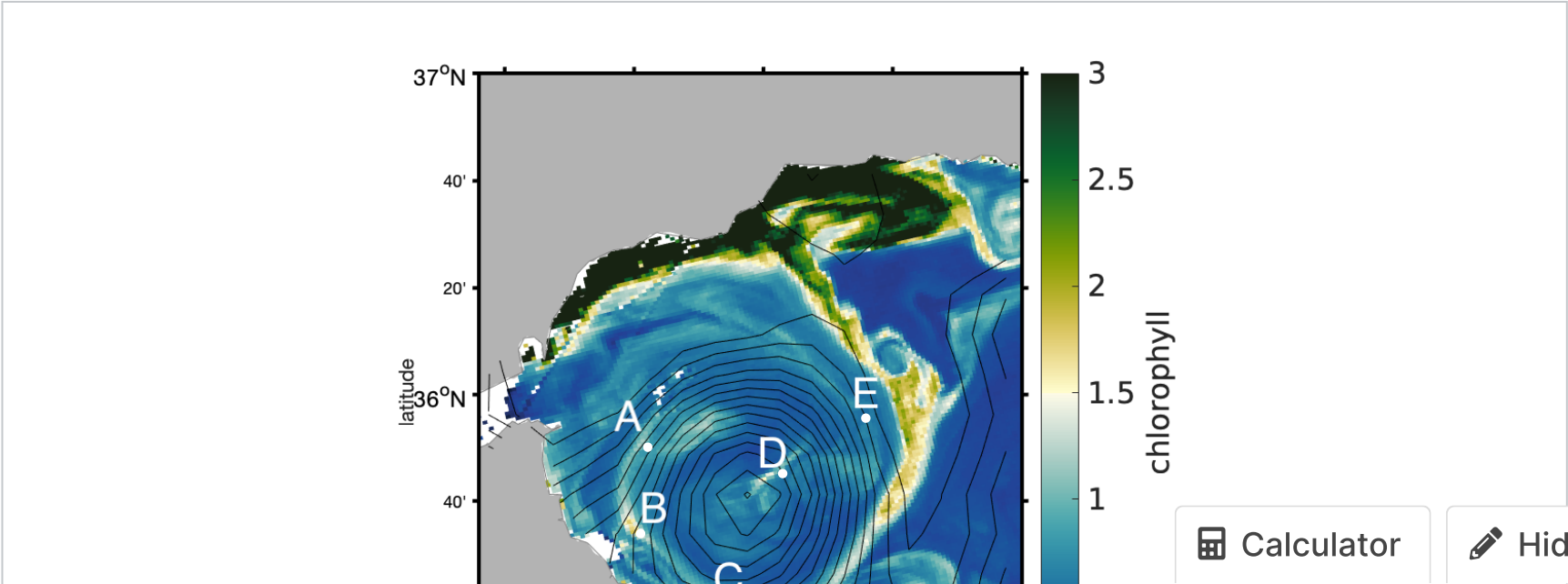
**i** Answers are displayed within the problem

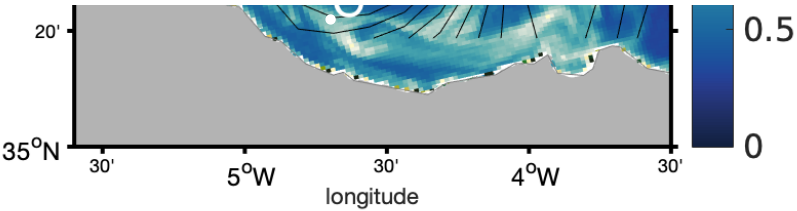
Problem 1(b)

1/1 point (graded)  
Ocean currents, responsible for the flow of heat and carbon, are created by the interaction of surface winds and the rotation of the Earth, which gives rise to the Coriolis effect. These forces create a vertical churning of waters, bringing carbon rich deep sea waters up to the surface, which then emit carbon into the atmosphere. Oceanographers are interested, for this reason among others, in tracking and monitoring evidence of high concentrations of carbon rising to the surface to provide more accurate models of ocean behavior and better predict the complicated dance of carbon emission and absorption.

Consider the concentrations of chlorophyll obtained from satellite photographs in the image below. The dark green shows highest concentrations, light yellow and white lower concentrations, and the blue regions of very little chlorophyll. We can consider high concentrations of chlorophyll to be evidence of high amounts of carbon absorption or regions of vertical currents bringing deep sea water rich in carbon up to the surface.

We expect ocean current to move along level curves. You can see evidence of these currents in the paths of chlorophyll through the ocean.





**Figure 12:** Sea surface height (contours) obtained from AVISO altimeters (radar) and chlorophyll concentration acquired from photos from NASA MODIS-Aqua. Data obtained and image created by Mara Freilich March 11, 2020 in the Mediterranean Sea. Used with permission.

Identify locations on the image where the chlorophyll concentrations move along (tangent to) level curves.

☒ A

☐ B

☒ C

☐ D

☒ E



**Solution:**

The concentration of chlorophyll is approximately tangent to level curves curves at locations A, C, and E. At locations B and D there appear to be large concentrations of chlorophyll, corresponding to an algae bloom. Such blooms indicate large carbon sinks or regions where deep water currents are bringing carbon rich water up to the surface.

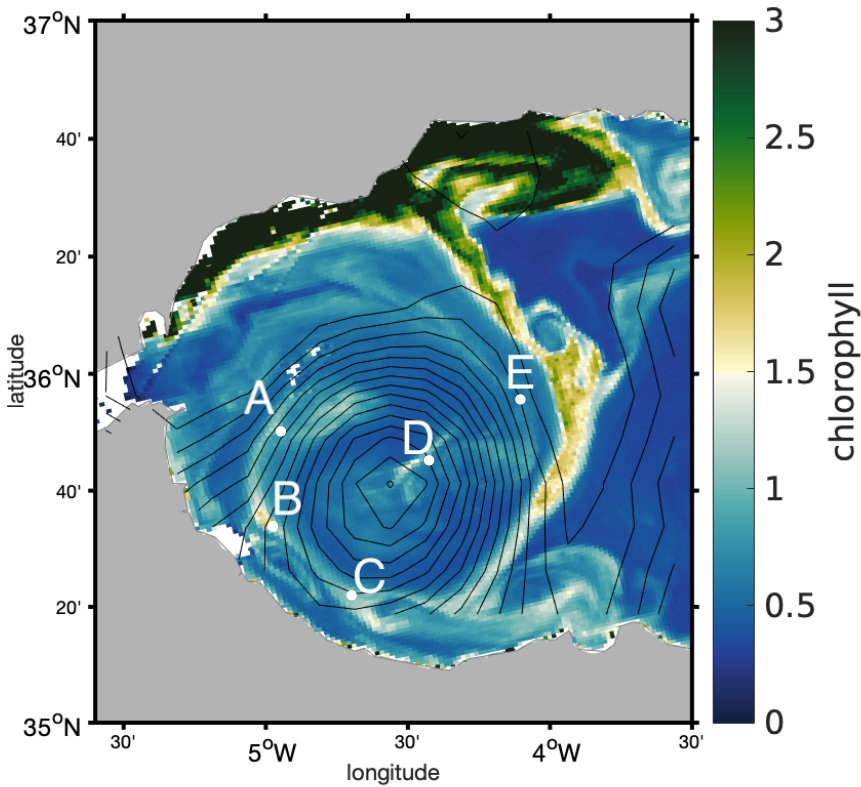
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You have used 2 of 7 attempts

**i** Answers are displayed within the problem

Problem 1(c)

0 points possible (ungraded)



**Figure 13:** Sea surface height (contours) obtained from AVISO altimeters (radar) and chlorophyll concentration acquired from photos from NASA MODIS-Aqua. Data obtained and image created by Mara Freilich March 11, 2020 in the Mediterranean Sea. Used with permission.

Which of the following may be reasons that the chlorophyll is not moving directly along the level curves?

(This problem is worth zero points. It is here to get you thinking, but we do not expect you to know the answer! This question is central to modern oceanography research.)

- ☒ The currents are 3-dimensional, so surface level curves are only telling part of the story
- ☒ The sea surface height level curves are taken as average from radar data collected, thus there is an error in the curves drawn
- ☒ There are concentrations of carbon that lead to algae bloom unrelated to direct ocean currents and are related to deep undersea events
- ☐ Algae have dynamics of motion that allow them to move against currents



Solution:

Discuss why you selected the choices you did in the discussion forum below.

The answer to this type of question is exactly what oceanographers and other climate scientists study. You can see how multivariable calculus is essential to even begin to model the processes involved in absorbing carbon and producing oxygen. Attempting to model both the chemistry and the fluids and the temperature involves multiple interdependent variables that satisfy many complex relationships.

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You have used 3 of 10 attempts

Answers are displayed within the problem

1. Carbon cycle exploration

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I totally love the real-world applications of these questions!

2

While this is quite a basic application,,just learning about one aspect of oceanography can keep you from falling asleep. Thanks for k...

[Staff] Unit 2

6

Can you release Unit 2 early? If not PSETs atleast lecture videos and recitations.

Carbon/Carbon Dioxide/GHG's

3

This is off the subject of the math. I would like to point out that you are using carbon and carbon dioxide interchangeably without ex...

Problem 1a

5

Is the level curve at the point (4°30'W, 36° N) really horizontal? I would say it's vertical. Or is it a silly question?

highest value contour at ~ 4°35'

2

I was thrown by the fact that 4°30' lies well to the right of what should be the highest contour - surely the highest point should lie wi...

[Staff] Possible glitch

5

I've finished Problem Set 1B, and all problems are shown as completed on the Progress page, but this item is not checked off on the ...

Pro-tip

3

On Windows 10 + Chrome, if the image of the chlorophyll map is too small,,you can right click + open image in a new tab. Hope this i...

1C ungraded Problem set status

2

Is it correct that because Problem 1C is ungraded, that is why I'm seeing the 1B Problem Set as incomplete in the schedule? I cannot ...

pset1b - 1(a) - where is (x,y) = (0,0)?

Which quadrant of the xv plane is does this image represent? Quadrant I or something else?

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10/7/21, 1:55 AM

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Carbon cycle exploration Problem 1b

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