SMS-204: Integrative marine sciences. Assignment #4

You have a choice of **one of three**(!) sub-questions (A, B or C). Do one (you can get 10pts of *extra credit* for each additional one). It is valued at (60/100).

A. Annual cycle of temperature in the Gulf of Maine as observed from a buoy (60/100): Look at http://gyre.umeoce.maine.edu/buoyhome.php and choose a data buoy for which there are temperature measurements at least at two depths (or surface and air temperature). Go to http://neracoos.org/datatools/climatologies_display, select that buoy on the top left of the graph, select the temperature depth you want (or air) and select the "averaging time period" to be daily (you will have to plot the water data below the surface closest to the surface). Click on "2019" below the graph and on "view climatology data table". Copy the data into a spreadsheet program for ***plotting by yourself*** (you may have to use the command 'paste special' and choose 'text').

Plot the annual cycle that is the change in temperature as function of day-of-the-year near the surface. (10pt)

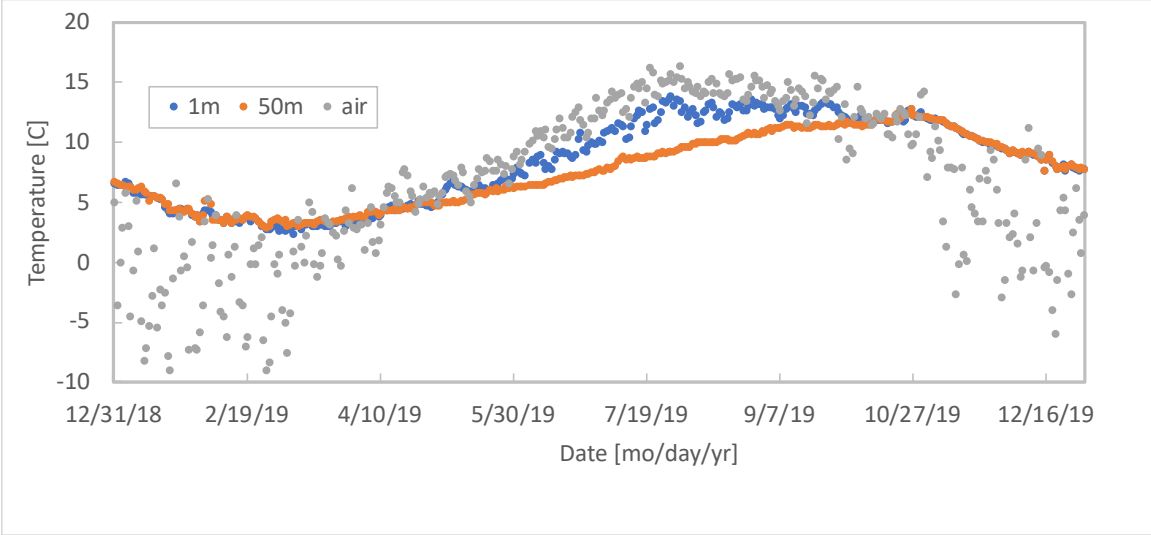

Figure 1. Annual temperature cycle at buoy I01 (Eastern Maine Shelf) for the air, 1m (surface) and 50m depth below surface.

1. Note the maximal and minimal temperatures and when they occur. (10pt)

	air	1m	50m
Min temp value [C]	-9.18	2.17	2.68
Max temp value [C]	16.27	13.73	12.70
Min temp date	2/27/19	3/9/19	2/27/19
Max temp date	8/1/19	7/29/19	10/27/19

2. Explain the observation with regards to the annual cycle of the sun radiation in the Gulf of Maine (10pt).

Maine is in the mid-latitudes of the Northern Hemisphere. The sun angle and hence day-length varies significantly between winter and summer. Sun radiation is near maximum near the longest day of the year (6/21) and least during the shortest day of the year (12/21). These are periods of maximal heating and cooling respectively. However, the air/ocean continue to warm/cool after them, but more slowly. Maximal/minimal temperatures occur near when the net heat flux is close to zero, and about to change sign. Air has more extreme temperatures compared to water, likely due to winds coming from the arctic and southern latitude with wide range of temperatures. This year the coldest and warmest day of the year where similar to those for surface water. Near surface waters exhibit larger fluctuations than deep waters as it is in closer contact with the atmosphere and the air-sea interface (where evaporative cooling, convection, conduction and radiation occur), as well as affected by continental runoff. Water at depth is only affected by convection (mixing down of cold denser water), conduction (diffusion of heat between layers) and advection (motion of water masses into/out of where the array is deployed). Coldest day at depth is similar to surface (as it is driven by convection) while warmest is significantly later than surface as warming at depth continues longer while surface begins to cool but convection has not reached 50m depth.

3. Is the coldest day also the shortest? Is the warmest day the longest? If the answer is no, why do you think it is not? (10pt)

Coldest day is not the shortest and the warmest day is not the longest. Reason is that the ocean continues to be cooled after the shortest day of the year and warmed after the longest day of the year.

4. Compare the result obtain in your graph with another graph you generate of:

a. the annual cycle of the temperature in the air at the same location **OR**

b. the annual cycle of temperature at 20m depth or deeper at the same location. (10pt)

Plot **both** on the **same** graph.

See Figure 1.

5. Based on what ***you have learned*** regarding heat and temperature explain why there are (or are not) differences between the two temperature time series? (10pt)

See Figure 1. Water vs. air: Water has a much larger heat capacity and hence its daily fluctuations are much smaller than those in the air. In addition the air can be advected from far away (winds) while currents are significantly slower, further decreasing the fluctuations in the ocean.

WRT depth, in the summer stratification start at the surface (warming) with slow penetration of heat to depth. In the fall, cooling from above drives convection which cause homogenization of ever increasing surface layers causing deep layer to keep warming until mixing from above causes them to cool. Once the surface mixed layer is deeper than 50m the whole surface layer cools together.

B. Annual cycle of temperature at the two opposite ends of the Gulf of Maine as observed by satellite (60/100). Go to NASA's remote sensing portal, Giovanni at: https://giovanni.gsfc.nasa.gov/giovanni/
You will have to register to this site to get the data you need (done via the login tab). Select 'Oceanography', and 'Sea Surface Temperature at 11 microns (day)' by clicking the square near it. At the top of the page, click on 'Time-series' within which select 'Area-averaged'. Select 'Date Range' from 1/1/2019->12/31/2019. Then 'Select Region': one within the Bay of Fundy / NE Gulf of Maine and one in the SW Gulf of Maine in front of MA/NH/Southern Maine. Do it by using the map tool, moving to and focusing in on the region and drawing a bounding box within it. Plot data by pushing the 'Plot Data' button at the bottom of the page. Once the figure plotted, use the 'download' button on the left to download the data (ASCII CSV) for *your own* plotting (the graph should be done by you). To change click on 'user input' on the left-hand side.

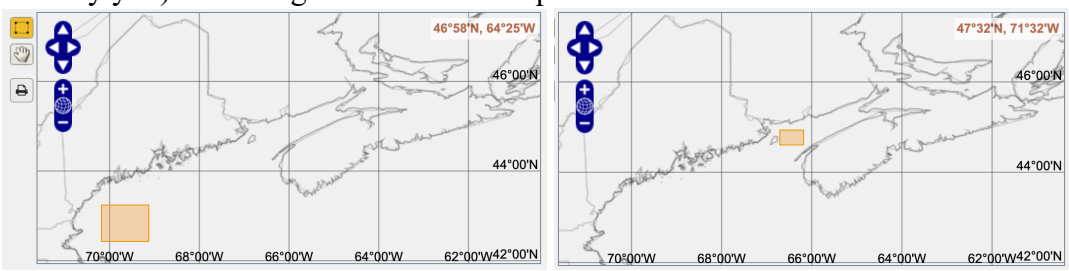

Figure 2. Areas averaged to obtain data

1. Plot the annual cycle that is the change in temperature as function of time of the year at both locations on the same graph, with a label for each. (20pt)

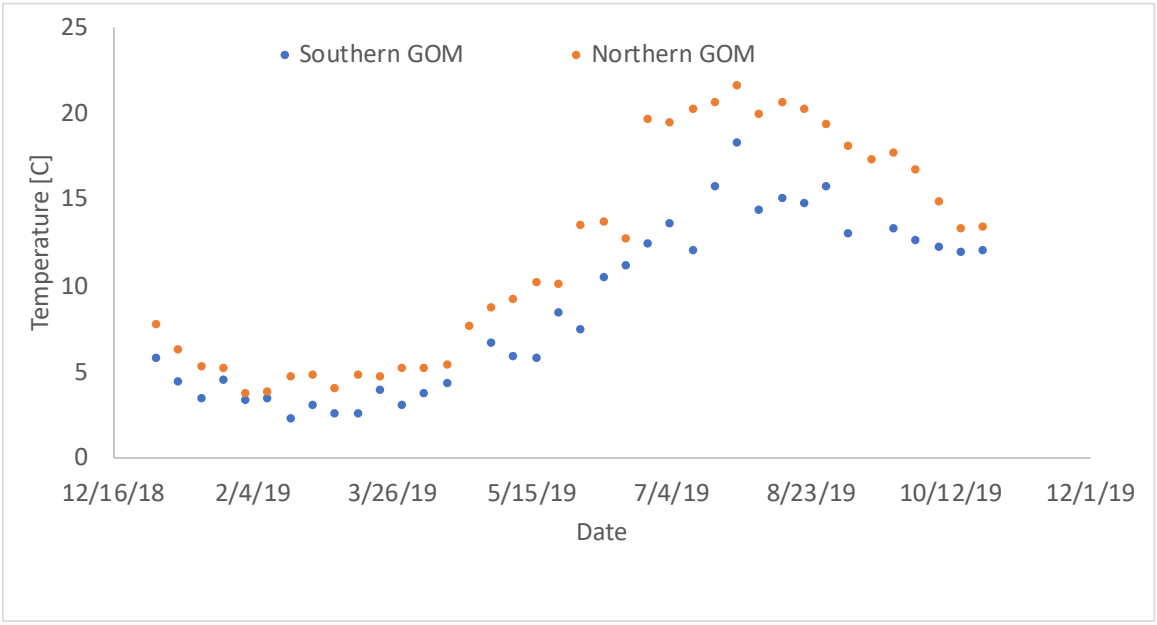

Figure 3. Annual cycle in the two areas in the GOM. Notice missing data at the end of the year.

2. Note the maximal and minimal temperatures and when they occur. (10pt)

	Southern GOM	Northern GOM
Min temp value [C]	3.63	2.18
Max temp value [C]	21.51	18.12
Min temp date	2/2/19	2/18/19
Max temp date	7/28/19	7/28/19

3. Explain the observation with regards to the annual cycle of the sun radiation in the Gulf of Maine. (10pt).

The GOM is in the Northern Hemisphere. Maximal flux of radiation is near June 20th and minima is near Dec. 20th. However, the ocean keeps warming after the maximum and keeps cooling after the minimum. The days of maximum and minimum temperature are the days when the net heat flux is zero. Note that to avoid issues of storms or heat waves, one needs to look at a smoothed trend as weather events affect the time of extremum but the general trends are of warming until Jul.-Sep and cooling until Feb-Mar.

4. Is the coldest day also the shortest? Is the warmest day the longest? If the answer is no, why do you think it is not? (10pt)

No. This is because these days are near the day of maximal flux but the ocean keeps cooling/warming following the shortest/longest days.

5. Based on what ***you have learned*** regarding heat and temperature explain why there are (or are not) differences between the two temperature time series? (10pt)

The Bay of Fundy is colder throughout the year because it is further North (sun is at a more oblique angle all year around) and because it experiences vigorous tidal mixing with cold water from below all year (Strongest tides in the world. I did not expect you to know this).

C. Annual cycle of temperature at the top 1000m of the ocean as measured with a profiling float. Go to http://www3.mbari.org/chemsensor/floatviz.htm. Choose a float that has at least profiled for the full 2019 year (you will need to plot temperature as function of date to see that).

1. (10pts) Use the tool to plot:
   a. The float trajectory (x-axis longitude, y-axis: latitude).
   b. Temperature (y-axis) as a function of date (x-axis).
   c. Temperature (x-axis) as a function of depth (y-axis). You can download the figure by right clicking on it and saving the image. Include the plots in your homework.

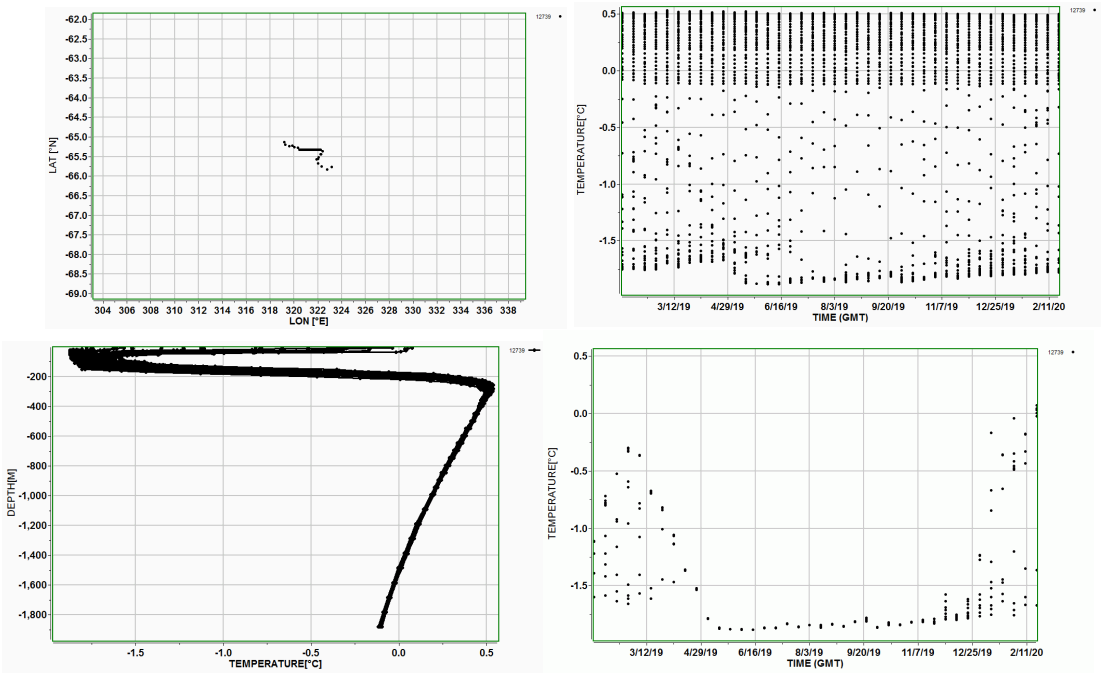

Figure 3. Trajectory, temperature as function of time and as function of depth for float 12739SOOCN deployed in the Southern Ocean. The last panel is temperature as function of time for the upper 50m (obtained using the 'Enter Min and Max Depth range for data used in Time Series Plot (X Var = Date)' feature on the bottom right).

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2. How does the amplitude of the temperature seasonal change varies with depth? Why (10pts)?

Most of the change in this near ice station occurs at the surface. Because salinity is so important to density deeper water are actually warmer. Near the surface the changest temperature the most between December and April (the So. hemisphere summer) while it is quite constant the rest of the year (the float is likely under ice).

3. Note the maximal and minimal temperatures and when they occur. (10pt)

	Southern Ocean, near the surface
Min temp value [C]	-1.87
Max temp value [C]	-0.29
Min temp date	6/13/19
Max temp date	2/23/19

4. Explain the observation with regards to the annual cycle of the sun radiation in the location where the float was (10pt).

The float is in the Southern Ocean. Maximal flux of radiation is near Dec. 20th and minimal is near Jun. 20th. However, the ocean keeps warming after the maximum and may keep cooling after the minimum. In this case, because the float gets below the surface ice cover, the ocean actually is insolated and warms from below by diffusion during much of the winter. Hence it is coldest just near when it gets stuck under the ice.

4. Is the coldest day also the shortest? Is the warmest day the longest? If the answer is no, why do you think it is not? (10pt)

The coldest day IS near the shortest due to the fact that the floats get stuck under the ice and starts warming henceforth. The warmest, is significantly after the longest.

5. Based on what ***you have learned*** regarding heat and temperature explain why there are (or are not) differences between surface and depth? (10pt)

*We have **not** covered high latitude dynamics in class, so I don't expect you to know this. In high latitude, fresh water contributes significantly to the density and hence temperature inversion exist as seen for this float. Warmer salty water advected to this location are found at 400m. Ice formation insulate surface water and also make them saltier, creating some convection below the ice. When it melts it makes fresher water near the surface and hence contributes to near surface stratification.*

2. Unit conversion (MKS stands for meter, kilogram, seconds) (30/100):

- How many ml's are there in 0.01m^3? How many litters? How many cm^3?

10,000 ml, 10 l, 10,000 cm^3

- A river is flowing at 10km/day. How much is it in cm/s?

10,000m x 100cm/m / (day=86,400s) = 11.6cm/s

- An organism weighing 2kg has a velocity of 40cm/s as it sinks through water. What is its kinetic energy in MKS (= SI) units?

2kg x 0.4^2 $(m/s)^2$ /2 = 0.16 J

- What are the mass and volume fluxes in MKS (= SI) units of a stream (density 1g cm^{-3}) flowing at an average speed 0.3 m/s with a 250 cm width and 300mm depth?

Volume flux: 0.3 m/s x 2.5 m x 0.3 m = 0.225 m^3/s

Mass flux = Volume flux x density = 0.225 m^3/s x 1000kg/m^3 = 225 Kg/s

- What distance (in kilometers) does a tuna swimming at 110 cm s^{-1} swim in a day?

Distance = 1.1 m/s x 86,400s/day = 95040m/day = 95.04 km/day

- What is, approximately, the density of water in g/ml, g/cm^3 and kg/m^3?

Water density ~1g/ml = 1g/cm3 = 1000kg/m^3

3. Watch the NASA's short movie on the greenhouse effect (https://www.youtube.com/watch?v=ZzCA60WnoMk) and other materials you can find to answer the following (10/100):

- What is the difference between the incoming/outgoing radiation into/from the Earth surface?

The radiation coming in from the sun is at wavelengths (visible radiation). The outgoing radiation is at longer wavelengths (near infrared radiation) which are absorbed by greenhouse gases. The outgoing radiation is absorbed by the atmosphere while the incoming radiation can pass through greenhouse gases. The atmosphere radiation is re-radiated to the Earth and to space.

- How different would the Earth temperature be w/o the greenhouse effect? Would it be more or less suitable to life?

Without the greenhouse effect the temperature of the Earth will be ~30 degrees C cooler which will make the Earth less suitable to life as it is today.

4. Extra credit (10pts): Scientists have found that a Hershey kiss has 26 Calories (= 26,000 calories) and claim that if we can convert this energy to mechanical energy, without loss, it could lift an SUV 2m up in the air (see: http://www.npr.org/templates/story/story.php?storyId=6700905&sc=emaf).
Evaluate this claim and calculate how high you could lift a 6,000lb heavy SUV.
Energy in a kiss = 26Cal = 26 × 4184 Joules = 108,784 J.
Potential energy of a 6,000lb SUV 2m above ground: mgh = 6,000lb × 0.45kg lb^{-1} × 9.81m s^{-2} × 2m = 52,974J.
Since the energy in the Hershey kiss > the potential energy in the lifted SUV the scientists claim is correct!
The height to which one could lift it:
108,784 Joules (=26,000calories x4.18Joules/calorie)/ (6,000lb × 0.45kg lb^{-1} × 9.81 m s^{-2})~4.1m!

This page was last edited on 3/9/2020