MSC 301: Introduction to Physical Oceanography
Fall 2018 · Homework 01

Carefully answer the following questions using complete English sentences wherever appropriate. You may discuss the questions with each other; however, each person must submit their own answers, including plots.

1 Water column profile (15 points)

a. What is meant by a vertical water column profile? (2 points)

A vertical profile is the relationship between some property (such as temperature, nutrients, or dissolved oxygen) and depth. Put another way, a vertical profile illustrates how a property changes as one goes deeper into the water column.

b. Describe, in words, a typical *temperature* profile for the upper 2000 m of the ocean. What units are most commonly used in oceanography? (2 points)

Generally speaking, temperature is ***inversely proportional*** *to depth; that is, temperature decreases as depth increases. It is commonly reported in* ***degrees Celsius****.*

c. Describe, in words, a typical *salinity* profile for the upper 2000 m of the ocean. What units are most commonly used in oceanography? (2 points)

Generally speaking, salinity is ***proportional*** *to depth: it increases as depth increases. Thus, deep water is saltier than surface water. Salinity is commonly reported in nondimensional* ***practical salinity units (psu)*** *or* ***parts per thousand (ppt)****.*

d. What is the physical property that relates temperature and salinity? Describe, in words, the relationship between this new property and each of the two properties above (*i.e.*, how does this new property change with respect to temperature and salinity?) What is the equation called that calculates this property? (7 points)

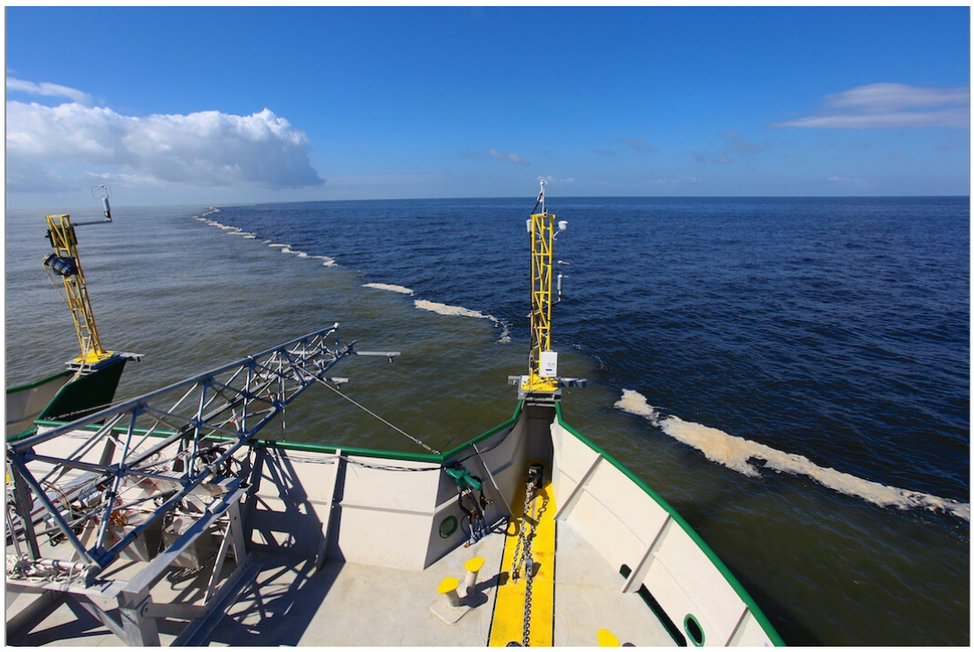
Density *relates temperature, salinity, and pressure and is calculated using the* ***equation of state****. Temperature and density are* ***inversely proportional*** *such that density increases as temperature decreases. Conversely, salinity and density are* ***proportional*** *to each other: as salinity increases, so too does density.*

e. Describe, in words, a typical profile of the physical property from part (d.) for the upper 2000 m of the ocean. What units are most commonly used in oceanography? (2 points)

Density typically ***increases*** *with depth in the upper 2000 m of the ocean and is measured in* $\boldsymbol{kg \cdot m^{-3}}$*.*

2 Field Application (35 pts)

Consider the photo below, which was taken last year during a field experiment in the northern Gulf of Mexico, in the vicinity of the Mississippi River.



a. Suppose you are a physical oceanographer aboard the R/V *Walton Smith* during the experiment. You happen to be on the upper deck enjoying the sun and fresh air when you hear someone yell, "Wow! Check that out!" You quickly capture this photo of the intriguing sight. What qualitative observations can you make? State at least two. (4 points)

Among several possibilities: (1) there exists a stark contrast in ocean color along the ocean front, with clearer blue water on the far side and greener, more turbid water closer to the ship; (2) marine debris and foam has arranged itself in a narrow band along the front, with no visible debris floating away from the line (at least within the camera field of view); (3) surface capillary waves are visible on the far side of the front, while the left side appears noticeably flatter; (4) there appears to be greater cloud formation on one side of the front than the other.

b. On board with you is a representative from the University of Miami outreach office who plans to publish an article about your research cruise, but she knows very little about oceanography. She has never seen this phenomenon before and asks you what is going on. How would you respond to her, keeping in mind that she is taking notes for her article as you speak? Relate concepts from Chapters 2 and 3 in your response. (Hint: Remember where you are located!) (5 points)

This sharp ocean front is the result of ***the Mississippi River outflow meeting the Gulf of Mexico water****. The water doesn't immediately mix, as one might expect, because they have different physical properties: the Mississippi River water is fresher than the salty Gulf of Mexico water. This creates a* ***strong density gradient****, especially near shore. The murkiness of the river water is likely due to a combination of factors including dissolved and possibly*

even suspended particulate matter (picked up as the river flowed over the continent), increased nutrient levels (such as from fertilizers, runoff, etc.), and higher primary productivity (due to the nutrients). In comparison, the calm Gulf of Mexico water is much cleaner and clearer (we like to say ***"less turbid"****), which is why the front is so easily visible with the naked eye.*

As an aside: the surface wave phenomenon remains an open question in oceanography, though many theories exist. The foam accumulation is caused by converging surface currents and downwelling along the front. We'll return to this later in the semester.

c. You decide to take two CTD profiles, one on either side of this ocean front. How do you expect the profiles to differ and why? (3 points)

The Mississippi River water, on the left side of the front (as shown in the photo), should be comparably ***fresher****, and therefore* ***less dense****, than the Gulf of Mexico water on the opposite side of the front. The sharpest contrast in salinity is expected near the surface because fresh water, being less dense than salt water, is expected to be "overtop" the salty Gulf of Mexico water. Temperature variations might also be observed, depending on the time of year and proximity to the mouth of the river. In winter and spring, for example, the Mississippi River water, which originates at high latitudes, might be noticeably cooler than the subtropical Gulf of Mexico water.*

d. When you get back to shore, you realize that, in the excitement of the moment, you made a serious rookie mistake that you vow never to make again: you neglected to record in your field log where each profile was taken. Carefully plot the temperature and salinity profiles from the accompanying data file, being sure to label all axes. (8 points)

Two points for each plot: is it correct, clear, and properly labeled?

e. Calculate the density profile at each station. Plot your results, being careful to label all axes. (4 points)

Two points for each plot: is it correct, clear, and properly labeled?

f. Using your physical oceanography expertise and your response to (c), determine where each profile was taken. Briefly justify your conclusion. Quantitative justifications will receive the most points. (Hint: It may be helpful to "zoom in" on the upper 10 m of the water column in your plots.) (5 points)

Profile 1 is Mississippi River outflow on the left side of the front (as shown in the photo), while Profile 2 is the Gulf of Mexico water on the far side. One way to justify this is by considering the density and salinity profiles in the upper 10 m of the water column. At the surface, Profile 2 is 3 kg·m^{-3} more dense and $>$ 4 psu saltier than Profile 1. Knowing that fresh water is less dense than salt water and that the Mississippi River outflow is fresh, one can conclude that the water to the left of the front (in the photo) is river outflow.

g. What scientific questions can you formulate from this photo? State at least three. They may be related to physical oceanography or to your major, or both. (6 points)

Any well articulated science questions that reflect 300-level thinking will be accepted, 2 points each.