SIO 210 Problem Set 2
October 17, 2019 Edited Oct. 18, 2019; Edited Oct. 20, 2019
Due October 24, 2019 (1 week)

If you work together on these, please make sure that you understand the concepts and use your group discussion to help with your understanding.

1. (a) The California Current is a oceanic region along the west coast of North America. The upwelling region of the California Current is closest to the coast. This region is approximately 2000 km long along the coast and 100 km wide off the coast. Suppose that there is a net heating of this entire strip at a rate of 75 W/m^2 in the annual mean. If this heat is applied to the top 100 m of the ocean, calculate how much it will warm in one year. Assume that density is approximately 1025 kg/m3 and specific heat is approximately 4000 J/(kg °C). Assume that this layer is well mixed. Assume there is no volume transport into or out of the layer.

Assuming that the initial temperature is 10°C, what is the final temperature?

Which information given above is irrelevant to your answer to this part?

(b) Now consider this as a steady state balance. In the California Current, water flows in towards the shore, upwells along the coast, warms, and flows offshore at the sea surface. Assume that the inflow is at 8°C, and the surface outflow is at 12°C.

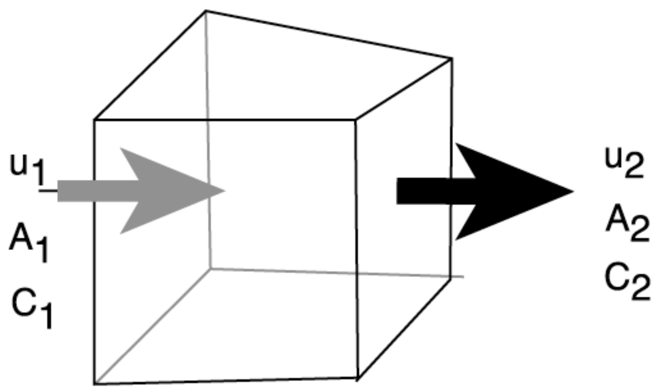
Using information given in (a), calculate the overturning (upwelling) volume transport in this system. Unlike in (a), there IS a volume transport into and out of the CA Current. This calculation considers only the layers moving into the upwelling region and moving out of the upwelling region. You do not look at the actual process within the heating region, only at the total amount of heat applied, with an assumption that processes within the heating strip changs the inflow into the outflow
It might be helpful to make a sketch of this.

Which information given in (a) is irrelevant for this part?

(c) Farther north along the coast, off Canada and Alaska in the Alaska Current, there is net precipitation. If there is net precipitation of 100 cm/yr in a strip the same size and depth as in (a), calculate how much the water column will freshen in one year. Assume that the initial salinity is 33 psu.
What is the final salinity?

2. Consider the concentration in a volume of the ocean of a conservative tracer (call it chlorofluorocarbon or CFC). The units of concentration are (moles tracer)/(kg seawater), that is, moles/kg.

Consider flow of this tracer through the volume in the figure. There is flow into the left side of the volume and flow out of the right side of the volume. The inflow has a tracer concentration C_1 and velocity u_1. The outflow has a tracer concentration C_2 and velocity u_2. The area of the inflow is A_1 and the area of the outflow is A_2. (There is no flow across any other surface.)



u_1 = 0.1 m/sec
A_1 = 10 kilometers x 100 meters
C_1 = 0.8 pmol/kg,

u_2 = ???
A_2 = 5 kilometers x 100 m,
C_2 = 1.0 pmol/kg

$\rho = 1025\ kg/m^3$

a) Calculate u_2

b) What is the FLUX of tracer on the left side (where the values are C_1, u_1, A_1)?

c) What is the TRANSPORT of tracer on the left side (C_1, u_1, A_1)?

d) What is the TRANSPORT of tracer on the right side (C_2, u_2, A_2)?

e) Compare answers (c) and (d). What do you think is happening to the tracer within the volume? (CFCs for instance are conservative tracers, and come from the atmosphere.)

3. The Pacific Ocean is approximately 10,000 km wide. Its upper layer ("wind-driven gyre") is approximately 1,000 m deep. Consider a west-to-east cross-section at about 24°N across the whole width of the Pacific, from Asia to North America, for this layer. Assume that there is a narrow northward western boundary current (Kuroshio) and a very broad southward flow across most of the section. For the following questions, assume that velocity does not vary with depth within this layer.

(a) If the southward flow is 1 cm/sec, calculate the total southward volume transport, in MKS units. (Ignore the western boundary current for this calculation.)

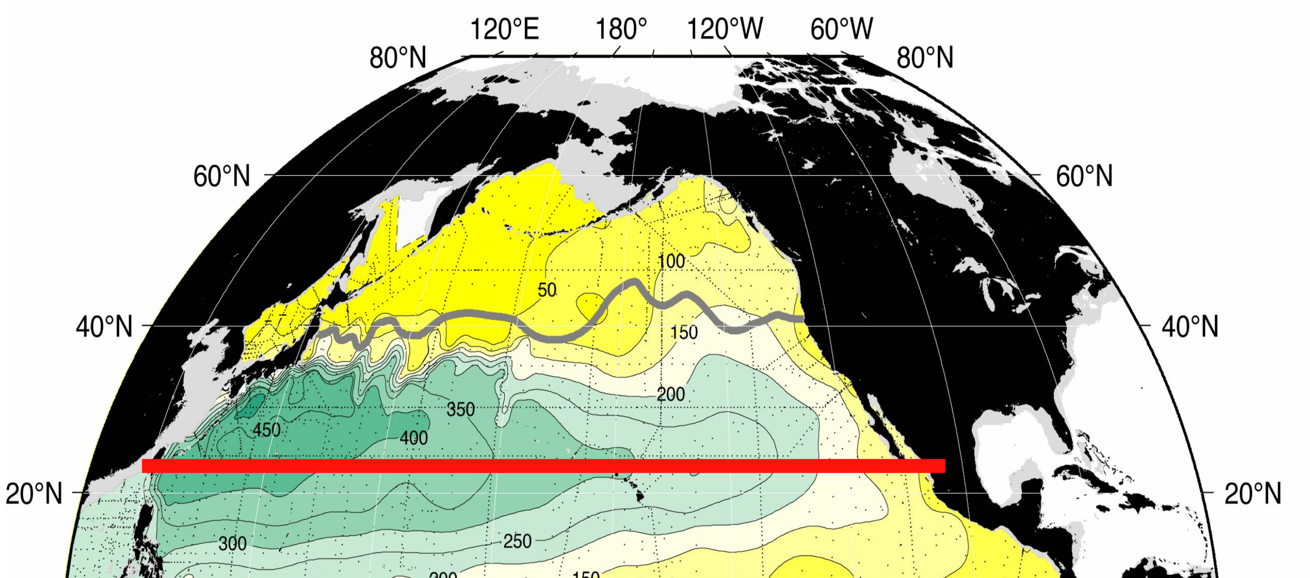
(b) If this same amount of water returns northward in a western boundary current that is 100 km wide (and still 1 km deep), calculate the average northward velocity of the western boundary current.

(c) If the average oxygen content of the northward flow in the western boundary current is 150 μmol/kg, calculate the net northward transport of oxygen in the western boundary current, in units of μmol/sec. Use the information from (b) to calculate.

(d) Suppose this circulation transports 1 PW of heat northward. If all of the northward flow is of one temperature and all of the southward flow is of another temperature, what is the temperature difference between the northward and southward flow? Use typical (uniform) values for density and specific heat, as given in class or in a textbook.

(e) Explain why I asked you to calculate a temperature difference in (d), rather than the actual temperature.

(f) Calculate the average air-sea heat flux between this section and the northern edge of the Pacific Ocean (Japan/Russia/U.S./Canada). Use very simplified assumptions about the width and length of this region (i.e. don't worry about calculating the exact dimensions, just approximate it). (Ignore Bering Strait – assume there is no leakage out of this large "box".)



4. Suppose you measure temperature at the end of the SIO pier at the same time every day for ten years. Assume 1 year = 365 days (ignore leap years).

(a) Is this measurement Eulerian or Lagrangian? Define both terms.

(b) What is the Nyquist frequency for your time series?

(c) What is the fundamental frequency for your time series?

(d) Will you be able to resolve the seasonal cycle for this time series? Explain.

(e) Will you be able to resolve the diurnal cycle (daily cycle) with this time series? Explain.

(f) Will you be able to detect significant climate signals with this time series, assuming that climate time scales in the North Pacific are 15 years to 40 years?

(g) Will you be able to detect significant climate trend with this time series?

5. Diffusivity κ has units of (length)^2 / time.

a) The molecular diffusivity of temperature in water is 0.0014 cm^2 /sec. Approximately how long would it take for temperature to diffuse 50 meters? You do not need an elaborate equation or to solve anything. Just use a dimensional argument based on units of κ.

b) Describe very briefly (1-2 sentences) what we mean by "eddy diffusivity".

c) What is a common source of vertical eddy diffusivity? (what can cause it?)

d) What is a common source of horizontal eddy diffusivity? (what can cause it?)

e) Approximately how large are vertical and horizontal eddy diffusivities?

f) Approximately how long would it take for temperature to diffuse 50 meters if it diffuses through vertical eddy diffusivity? (Use vertical diffusivity value from lecture or DPO text.)

g) Approximately how long would it take for temperature to diffuse 50 kilometers if it diffuses through horizontal eddy diffusivity? (Use horizontal diffusivity value from lecture or DPO text.)