OCES 2003 Assignment 1, Spring 2023

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Set on: Fri 17th Feb; due: Fri 24th Feb

Model solutions and mark scheme

1. (a) (This is almost word for word the same as Q1(d) in Assignment 1 of last year by the way.)
Since transport is speed multiplied by cross section, and cross section here is $100 \times 10^3 \cdot 1500\ \mathrm{m}^2$, so velocity is

$$\frac{30 \times 10^6\ \mathrm{m}^3\ \mathrm{s}^{-1}}{100 \times 10^3 \cdot 1500\ \mathrm{m}^2} = \frac{30}{10 \cdot 15}\ \mathrm{m\ s}^{-1} = \frac{3}{15}\ \mathrm{m\ s}^{-1} = 0.2\ \mathrm{m\ s}^{-1}.$$

The question however asks you to give the answer in knots, and since 1 knot = $0.514\ \mathrm{m\ s}^{-1}$, dividing answer above by the conversion factor gives 0.39 knots accurate to 2dp.

(1 mark for the answer in standard units, 1 mark for answer in knots. Take 0.5 marks off if answer in knots is correct but not given in 2dp.)

(b) We have

$$0.3\ \mathrm{m\ s}^{-1} \times (100 \times 10^3 \cdot 100\ \mathrm{m}^2) + 0.2\ \mathrm{m\ s}^{-1} \times (100 \times 10^3 \cdot 1400\ \mathrm{m}^2) = 31 \times 10^6\ \mathrm{m}^3\ \mathrm{s}^{-1} = 31\ \mathrm{Sv}.$$

(1 mark for appropriately splitting the transports, 1 mark for answer in Sv.)

(c) We have instead

$$0.3\ \mathrm{m\ s}^{-1} \times (100 \times 10^3 \cdot 100\ \mathrm{m}^2) + V\ \mathrm{m\ s}^{-1} \times (100 \times 10^3 \cdot 1400\ \mathrm{m}^2) = 30 \times 10^6\ \mathrm{m}^3\ \mathrm{s}^{-1},$$

where we want to solve for V. Re-arranging appropriately, I make it $V = 0.193\ \mathrm{m\ s}^{-1}$ accurate to 3dp.

(1 mark for appropriately forming the calculation, 1 mark for the answer. Take 0.5 marks off if answer is correct but not given in 3dp.)

In this instance, the velocity shear has increased. Driving a flow harder does not necessarily increase its transport, because increases in the velocity shear can lead to more instabilities, which can act as a brake transport increase, e.g. *eddy saturation* phenomena in the Southern Ocean. (This example is rather artificial and I am not saying WBCs are eddy saturated.)

2. See Fig. 1.

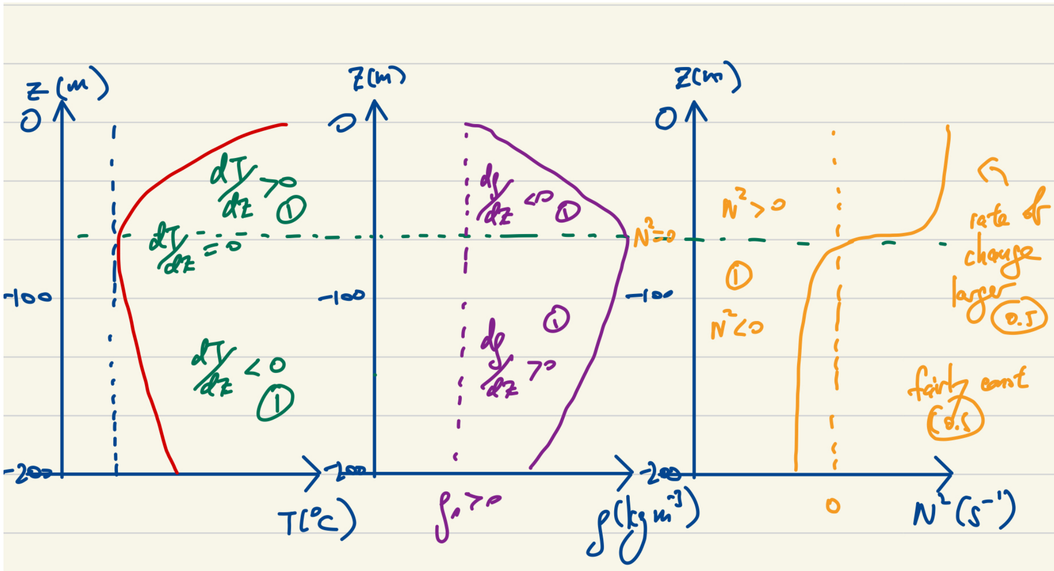

Figure 1: Temperature as a function of depth. Note that depth is given on the vertical axes, while the thing being measured is on the horizontal axes (normally it would be the other way round).

(a) *(1 mark each for positive and negative gradient, above and below the turning point respectively.)*

(b) In the bottom part we have temperature decreasing as you go up the water column, so density is **increasing**. Pass the turning point, the density decreases.

(1 mark each for the increasing and decreasing part. Take 0.5 marks if the turning points do not coincide maybe. Technically I suppose the decrease above the turning point should be larger, so that the end point at the top is further left than the starting point at the bottom, but that is assessed in the next part.)

(c) N^2 is negative and fairly constant below the turning point, and positive and fairly constant above the turning point. The constant above the turning point should be larger than the constant below the turning point.

(0.5 marks each for the positive and negative N^2. 0.5 marks for the roughly constant N^2, and 0.5 marks for the constant being larger at the top than the bottom.

(d) The $N^2 < 0$ indicates unstable stratification so should not really be there and density inversions are unstable. Given the depths we are dealing with, this is unlikely an issue of using *in-situ* temperature, which only really manifests with very large depths. Either you got really lucky (unlikely), or there is an error in the instrumentation for temperature (more likely), given we are assuming we plotted the data correctly.

(1 mark for no it shouldn't really be there, and 1 mark for a likely and/or defensible explanation. Give 0.5 marks in the explanation part if the answer is 'we got really lucky', since that is possible as I haven't marked on the axes. Give 0.5 marks in total if answer is yes it should be there, together with some mention of potential density.)

3. (a) EBCs here are wider than WBCs but with a substantially smaller transport if we are taking the lower estimate. Since EBCs are wider by about a factor of 9 with a smaller transport by about a factor of

3, the depth needs to *decrease* by a factor of 27 for EBCs to have the same speed as WBCs. Since we assumed the depth extent is about the same, the speeds of EBCs have to be slower.

(0.5 marks for wider and 0.5 marks for smaller transport. 0.5 marks for slower, and 0.5 marks for a sufficiently sensible justification.)

(b) The lower end estimate of the transport is 10 Sv, so

$$\frac{10 \times 10^6 \text{ m}^3 \text{ s}^{-1}}{900 \times 10^3 \cdot 600 \text{ m}^2} = 0.018518 \text{ m s}^{-1},$$

which is 0.019 m s^{-1} accurate to 3dp.

(1 mark formulating the problem and 1 mark for the answer. Take 0.5 marks off if answer is correct but not given in 3dp.)

(c) Mostly to do with the shifting of the thermocline.

- shifting wind patterns that is upwelling favourable leads to shoaling of thermocline (and vice versa; spring/summer phases of monsoon, strengthening of trade winds, La Niña)
- shoaling of thermocline leads to more nutrient availability, increasing bioproductivity
- shoaling of thermocline leads to the oxygen minimum zone shoaling as well, which forces respiring organisms to be confined to near the surface (that's good for fish yields)
- deepening of thermocline on the other hand leads to decrease in nutrient supply from upwelling, as well as shifting the oxygen minimum zone lower, which can have consequences for fisheries leading to stock crashes (particularly strong during El-Niño episodes)

(Up to 2.5 marks for talking about changes in the physical state, and impacts on biogeochemical, ecological and/or economical consequences. 1 mark for appropriate referencing. 0.5 marks for writing (not going over length, writing in full sentences. not too many grammatical/spelling errors).

!? (No marks bonus question.) You would for sure lose a big chunk of the internal waves that arises from the flow over the sill, which would have some effect in the internal mixing (cf. lec 10, and lec 18).

Over the long time-scale, would probably also lose some of the salinity characteristic of the NADW since some of the Med Sea water contributes to the NADW, and there is no sill holding back the Med Sea water which probably limits the formation of the salty characteristic (it might just get mixed out).

I suppose sea level would decrease a bit because the volume of the ocean has increased? Probably very marginal change though.