OCES 2003 sort of finals, Spring 20212

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Set on: Thurs 26$^{\text{th}}$ May; due: Thurs 26$^{\text{th}}$ May

Model solutions and mark scheme

Problems

1. *(This question mostly tests for material recall)*

   (a) Essentially potential density/temperature is the density/temperature that has some of the pressure contributions removed. The "referenced the sea level" means the reference depth is taken to be the sea level.

   Or, to be more technical, in-situ density is the density/temperature measured at some depth, while the potential density/temperature is the density/temperature of a water parcel that has been moved adiabatically (without mass and heat exchange with surroundings) to some reference depth.

   (1 mark for the potential bit and 1 mark for the referenced bit. Give 0.5 marks as appropriate.)

   (b) Thermal wind shear relation related to the horizontal gradients of the density with the vertical gradients of the geostrophic flow. It should be the potential density that we are using.

   (1 mark for the thermal wind bit and 1 mark for density bit. Give 0.5 marks as appropriate.)

   (c) The examples I can immediately think of are:

   - in-situ temperature changes gradient as depth increases (e.g. Marianna trench profile), implying there should/might be static instability when there isn't
   - a very stratified ocean with in-situ density, so very little vertical motion, when we know from watermass properties that isn't true (e.g. salinity signatures in NADW waters)
   - no ACC with in-situ density, since there are no tilting isopycnals

   (0.5 marks for stating each scenario, and 0.5 marks for a sensible explaining/pointing out the inconsistencies.)

2. *(This question tests for material recall and logical thinking.)* I am going to do both parts at the same time:

   - increase in the Ekman up/downwelling because of increasing wind *gradients* (or wind stress curl)
   - increase in the residual overturning in the Southern Ocean, because eddy part is fixed while Ekman part is increasing
   - Southern Ocean pycnocline deepens (or increases in depth) due to increased tilt in the isopyncnals from the increase in the residual overturning
   - increase in the ACC transport because of increased isopycnal tilt via thermal wind
   - NADW vertical extent should increase because the global pycnocline should be pulled down by the Southern Ocean pycnocline (assuming all else is the same)
   - OHC might be expected to increase assuming all else is the same, since the deeper pycnocline allows heat to penetrate deeper into the ocean interior via isopycnal pathways

   (0.5 marks for answer and 0.5 marks for explanation for each case. For part the first one, only accept increase in gradients or wind stress curl. For the fourth part, only accept answer if thermal wind is invoked.)

3. *(This question tests for logical thinking and a bit of computation.)*

   - Respectively (angular) frequency, Coriolis parameter, buoyancy frequency, and the horizontal/vertical wavenumbers.

     (0.5 marks for each. Can also give full marks if answer contains waffle but includes BOTH units and the physical explanations of the quantity.)

   - Phase and group velocity respectively describe the propagation of a fixed point of the wave and a fixed point of the wave envelope. If we are dealing with non-dispersive waves then the group and phase velocity would be identical, but then the scalar product of it won't be zero, as implied by the statement that "internal waves have a phase and group velocity that are perpendicular".

     (0.5 marks for each definition of phase and group velocity; allow for use of wavepacket. 0.5 mark for some definition of dispersive waves, and 0.5 marks for arguing/demonstrating why internal waves are dispersive.)

   - Surface gravity waves should have a higher frequency and horizontal phase speed for $k_x \gg 1$ (so short waves).

     We have respectively $\omega \sim N k_x / k_z$ and $\omega \sim k_x \sqrt{gH}$, and we would expect $\sqrt{gH} \ll N/k_z$ assuming k_z is not allowed to go to zero (otherwise these waves would not be internal waves). Putting some numbers in, $\sqrt{gH} \sim \sqrt{10 \times 4000} = 200$, while $N/k_z \sim 10^{-5}/(2\pi/4000) \sim 10^{-3} \ll 200$, so the (angular) frequency and horizontal phase speed (which is just the angular frequency divided by the horizontal wavenumber k_x) should be much higher.

     (0.25 marks for surface gravity waves have higher angular frequency, and 0.25 marks for the analogous case for horizontal phase velocity. 0.5 for each of the respective arguments, and 0.5 marks for some sort of computation.)

4. *(This question tests for material recall, and going further with logical deduction.)* This question is actually a variation of the OCES 2003 midterm question in Spring 2021.

   There is no β in this setting (as long as you are not on the 'edges' of the cylinder), so there is no Sverdrup balance, no Western intensification, and the gyres would be fairly symmetric in longitude.

   (1 mark for no β, 1 mark for explanation why there is no β, 1 mark for no Sverdrup balance, 1 mark for no Western intensification; give 0.5 marks for symmetric gyre if Western intensification not mentioned. Give no more than 2 marks in total for some sort of attempt at explaining how gyre circulations work even if the line of logic is completely off target.)