OCES 2003 Assignment 2, Spring 2021

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Model solutions and mark scheme

Problems

1. Just put some numbers in:
   (a) $\rho = 999.9$ kg m^{-3}
   (b) the change in α is irrelevant, β is increased by a factor of 10, so $\rho = 1000.8$ kg m^{-3}
   (c) there are changes in α but $T - T_0 = 0$, and note that the units on S are actually equivalent to g kg^{-1}, so putting the numbers in gives $\rho = 993.5$ kg m^{-3}
   (d) the conversion factor is
   $$1\frac{\mathrm{kg}}{\mathrm{m}^3} = 1\frac{(2.2)\ \mathrm{lb}}{(40\ \mathrm{inch})^3} = 3.44\times10^{-5}\ \mathrm{lb\ inch}^{-3},$$
   so $\rho = 999.9\times3.44\times10^{-5} = 3.4\times10^{-2}$ lb inch^{-3}.

   (1 mark for each right answer to each part, 0.5 marks if essentially right working but wrong answer; 0.5 marks off for answers not in the required from and/or accuracy)

2. Slight trick question, the answer is 'it doesn't matter', because the linear equation of state does not describe compression effects from pressure so there is no need for a distinction.

   (1 mark; 0.5 for wrong answer but some sensible justification)

3. In-situ temperature includes contribution from pressure-volume work, which increases the internal energy content, and the in-situ temperature includes this contribution in the measure. At sufficient large depths, this leads to the in-situ temperature having inversions in the signal, so the resulting signal implies static instability when it is otherwise dynamically stable.

   (0.5 marks for the work related statement(s), 0.5 marks for noting in-situ temperature can wrongly imply temperature inversions when it is otherwise dynamically stable)

4. With $m_{\mathrm{pig}} = 100$ kg, $r = 6\times10^6$ m, and $G = 6\times10^{-11}$ m^3 kg^{-1} s^{-2}, we have
   $$g_{\mathrm{pig}} = 6\times10^{-11}\frac{10^2}{6^2\times10^{12}} = \frac{1}{6}\times10^{-21} = 1.7\times10^{-22}\ \mathrm{m\ s}^{-2},$$
   which is tiny, as expected since $m_{\mathrm{pig}} \ll m_{\mathrm{Earth}}$.

   (0.5 for anything in the range of 10^{-21} to 10^{-22} really, 0.5 marks for giving reason why g_{pig} is so small; 0.5 marks off if numerical answer not in the right form and/or degree of accuracy)

5. SSH is the instantaneous height above the ellipsoid, so ideally draw some squiggles on the blue line and mark on the distance accordingly.

   (0.5 mark for noting SSH is measured relative to ellipsoid, and 0.5 mark for drawing a squiggle on the blue line)

6. (a) clockwise in southern hemisphere so cyclonic

(b) clockwise in northern hemisphere, so anti-cyclonic (there are some speculations that it could change depending on the wind forcing)

(c) the southern hemisphere bit is irrelevant, it's a low pressure eddy so it is cylconic

(d) neither, because it is not rotating around a horizontal axis

(e) a hurricane is a low pressure so it is cyclonic

(f) either via the observation that the Great Red Spot rotates anti-clockwise in the Southern Hemisphere or that it is a high pressure, it is anti-cyclonic

(0.5 mark for each part)

7. There is no wind stress curl with a uniform wind stress, so no Ekman pumping or suction.

   (1 mark or none)

8. The Rossby number is going to be large, so Coriolis effect is negligible, and the claim is not supported. For simplicity, taking U and L to be 1 for argument sake (it's a big and fast toilet), since $f = O(10^{-4})$, $\mathrm{Ro} = 10^4 \gg 1$.

   (1 mark for an estimate of Ro, 1 mark for noting it is huge, and 1 mark for the conclusion.)

9. If we take the same scales as above, it basically says that we need something that rotates about 10^4 faster than Earth for there to be any sensible discernible effect (choosing an f such that $\mathrm{Ro} \approx 1$). Since Earth rotates around itself once every day = 86400 s, roughly speaking you want something rotating around itself once every $86400/10^4 \approx 8$ s or so. Pulsars (objects formed collapsing cores after supernovae) have been known to rotate in the sub-Hertz range (recall 1 Hz = 1 rotation per second), so even short time-scale flows such as toilet flushing will be influenced by the Coriolis effect.

   Aside: pulsars were first observed by Jocelyn Bell, although it was Anthony Hewish (Jocelyn Bell's PhD supervisor) and Martin Ryle who got the Nobel Prize for it. The decision remains controversial (a similar dig at something analogous is "*What was Watson and Crick's greatest discovery? Rosalind Franklin's notes*".)

   (1 mark for finding/quoting/calculating the rotation rate of a pulsar, 1 mark for noting the relevant choice of f can get Ro sufficiently small, 0.5 mark for concluding in the positive, and 0.5 marks for referencing sources)

10. Normally the wind blowing westwards along the equator leads to a surface divergence and thus Ekman upwelling along the equator. If the winds reverse then you get a surface convergence and thus a Ekman downwelling. The associated downwelling would deepen the thermocline, which implies you reduce the nutrient supply to the upper surface, and thus reduce the biological activity. (Standard stuff in for example the El-Niño Wikipedia page.)

    Not required: there is then the *Bjerknes feedback* where the changes in the wind move the equatorial warm waters to the east, which shifts the atmospheric low pressure regions, further changing the longitudinal circulation (the Walker circulation), modifying the winds again, and drives the warm water to the east.

    (1 mark for Ekman downwelling, 1 mark of deepening thermocline, 1 mark for decreasing nutrient supply and biological activity, and 1 mark for referencing.)

!? My incomplete understanding is that θ is not very conservative as it is being moved around by the flow, and is itself not a very good measure of 'heat', which causes problems when we want to talk about the energy cycles in the Earth system. Θ on the other hand is an internally consistent thermodynamic variable (related to *potential enthalpy*), which is much more conservative, and is a much more appropriate variable to measure 'heat', which is needed for working out things like *ocean heat uptake* for example. Θ is the variable being advocated to be used as the international standard (TEOS-10).