OCES 2003 Assignment 4, Spring 2022

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Set on: Thur 5th$^{\text{th}}$ May; due: Thur 12$^{\text{th}}$ May

Model solutions and mark scheme

Problems

1. (a) Heat is being lost from the ocean to the atmosphere, or the water is losing buoyancy / gaining density. Unstable vertical density gradients lead to convective motion and denser water sinks.

   (1 mark for gaining density or losing buoyancy, 1 mark for sinking because of static instability, water being more dense, or similar.)

   (b) For fixed temperature, freshwater is not as dense salty water, and so would not sink as deep as cold salty water, which would reduce the rate of deep water formation.

   (1 mark for water not as dense and 1 mark for reduced rate of deepwater formation, or reduced amount of deepwater, or similar.)

   (c) Reducing the deepwater formation of NADW would likely weaken the AMOC, weaken the global MOC and reduce the overall heat transport, and probably shoal the global pycnocline. (These are effects that have been found in numerical *hosing* experiments, and there is evidence for these happening in the past, e.g. Younger dryas period.)

   (1 mark for reduced NADW, 1 mark for weakening AMOC, 1 mark for weakening MOC I guess and/or shoaling of pycnocline, and 1 mark for appropriate citations etc. (but if answer is good without citation just give full credit). Take 0.5 marks off for every 30 words over the 150 limit.)

2. Some of this is from the finals of 20/21.

   (a) M2 refers to the lunar semi-diurnal (twice daily) tidal forcing, so the frequency is about 12 hours; the spectral peak refers to the tides being forced that has the semi-diurnal signal (which is perhaps obvious if you read the horizontal log axis, since this is one along from $10^0 = 1$, so it should be two cycles daily). From that, a change of units gives

   $$\gamma = 2\ \text{day}^{-1} = \frac{2}{3600 \times 24}\ \text{s}^{-1} = 0.00002\ \text{Hz}.$$

   (1 mark for the lunar semi-diurnal and/or twice daily forcing for M2, 1 mark for the calculation; use half marks as necessary [e.g. wrong answer right working], no penalty for using 12.whatever *as the M2 frequency, but do not accept anything that is not* 0.00002*, since a period of 12 and 13 should still give that answer at the requested degree of accuracy.)*

   (b) There is a transfer of power from the lower modes (at the lower frequency) to higher modes, by instability, turbulence, triad interactions and/or others. The scale of motion is going from large to small.

   (1 mark for noticing higher frequency correspond here to lower modes, either by heuristic argument, via the dispersion relation, or otherwise, 1 mark for instabilities some sort of excitation of lower modes; use 0.5 marks as necessary)

(c) Something like (moored) ADCPs and/or CTD type equipment (e.g. temperature loggers) will do. Moorings with ADCPs and CTDs would be ideal, but then you need to put a mooring in. Mounted ADCPs to get the vertical velocities would be probably be ok but might be more subject to noise, so CTDs or temperature loggers would be more robust. You probably want quite high frequency (below 5 minutes) to resolve the waves at higher frequencies, certainly more frequent than 12 hours to actually get data to resolve the semi-diurnal tide signal.

(0.5 marks for some naming of instruments, 1 mark for some sort of description of the relative merits of the instruments, and 0.5 marks for something on frequency of observation.)

3. To measure SST the satellites essentially measure infra-red radiation, which is proportional to the temperature of the object. SSS is more complicated: there is a link between conductivity and salinity, and changes in conductivity lead to slight changes in the emissions at the microwave band. So what the satellite actually measure are the changes in the microwave emissions from sea water, from which one could in principle infer for the changes in the various components of the dielectric, and from that imply a conductivity, and from that obtain a measurement of the salinity.

   All of this is subject to the fact that all of these emissions can change depending on the emission angle, surface roughness, get scattered by various things in the atmosphere (at the low and high atmosphere). For a satellite zooming around Earth at fairly fast speeds, there are uncertainties in the actual satellite location, lags between location and receiving signal, instrumentation errors, and others, all of which lead to uncertainties. In that sense the uncertainties in measuring signals related to SST are much better constrained than SSS. SSS measurements are particularly bad near coasts because of various wave scattering issues.

   Sample of sources (all accessed on Apr 16 2023):

   - `https://earthobservatory.nasa.gov/blogs/fromthefield/2012/09/11/measuring-salinity-from-spa`
   - `https://en.wikipedia.org/wiki/Aquarius_(SAC-D_instrument)`
   - `https://www.esa.int/SPECIALS/Eduspace_Weather_EN/SEMMCPV01FG_0.html`

   (2 marks for describing how to measure SST, 2 marks for describing SSS, 1 mark for discussion of sources of uncertainties, 1 mark for any other information (which could be sources of uncertainties), 2 marks for references. Take marks off as appropriate for going over 2 page limit, irrelevant and/or wrong details, such as that may arise from using ChatGPT. Note we are not to penalise for using ChatGPT et al., but for using ChatGPT et al. poorly*.)*

!? (Bonus question, no marks) See assignments 4 Q3 from 20/21.