OCES 2003 Assignment 4, Spring 2024

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Set on: Monday 6th$^{\text{th}}$ May; due: Monday 13$^{\text{th}}$ May

Model solutions and mark scheme

Problems

(Penalise as appropriate for overly long writing and/or irrelevant information. Penalise heavily for the last questions.)

1. (a) SSS is Sea Surface Salinity. Atlantic SSS is generally higher than Pacific SSS.

   (A climatology is essentially an average, in this case over time, but there is nothing stopping you doing space or *ensemble* average.)

   (1 mark for definition of SSS, and 1 mark for the observation that SSS is higher in the Atlantic.)

   (b) The Agulhas current comes off the South-East of Africa and joins the ACC, but some of it leaks around the coast of South Africa into the Atlantic. The water ends up transporting some of the salt content in the Indian ocean into the Atlantic, leading to changes in the salinity (this route is known as the *warm route*, as opposed to the *cold route* where the water goes all the way round the ACC and then back into the Atlantic).

   (1 mark for something describing the Agulhas leakage, and 1 mark about moving salt from the Indian ocean to the Atlantic ocean. Citation of sources is good practice but gets no marks here.)

   (c) The shear would be between the Agulhas current and the ACC (and presumably a shear in the horizontal, so more a barotropic type instability?)

   (1 mark for the shear between Agulhas current and the ACC.)

   (d) A background shear provides a background vorticity gradient, which vorticity/Rossby waves propagate on, against the direction of the mean flow (in an appropriate frame of reference). These waves have an action-at-a-distance, which leads to mutual interaction that can lead to phase-locking and constructive interference.

   (0.5 marks for wave propagating over the shear region, 0.5 marks for action-at-a-distance, 0.5 marks for phase-locking, 0.5 marks for constructive interference.)

   (e) 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 seawater, from which one could in principle infer for the changes in the various components of the dielectric, 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 and errors. 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`

- https://en.wikipedia.org/wiki/Aquarius_(SAC-D_instrument)
- https://www.esa.int/SPECIALS/Eduspace_Weather_EN/SEMMCPV01FG_0.html

(Give up to 3 marks for any of the following: 1 mark for link between salinity and conductivity, 1 mark for sources of uncertainties, 1 mark for limited spatial resolution of SSS, 1 mark for citations.)

2. (a) The configuration would be temperature stable and salt unstable, so exactly the regime drawn on in Lec 17. Temperature diffuses faster than salt, so the water parcel moved down loses heat and becomes cold and salty, and continues moving down.

   (1 mark for a picture that looks like the one in Lec 17, and 1 mark for the explanation. Do not penalise if student directly takes the figure that I provided in Lec 17.)

   (b) The Lewis number in the ocean would be small, since temperature diffuses faster than salt.

   (0.5 marks for the answer, and 0.5 marks for a justification.)

   (c) Diffusivity would be larger, and the diffusion time would be shorter.

   (0.5 marks for each part.)

   (d) I made this a few years ago:

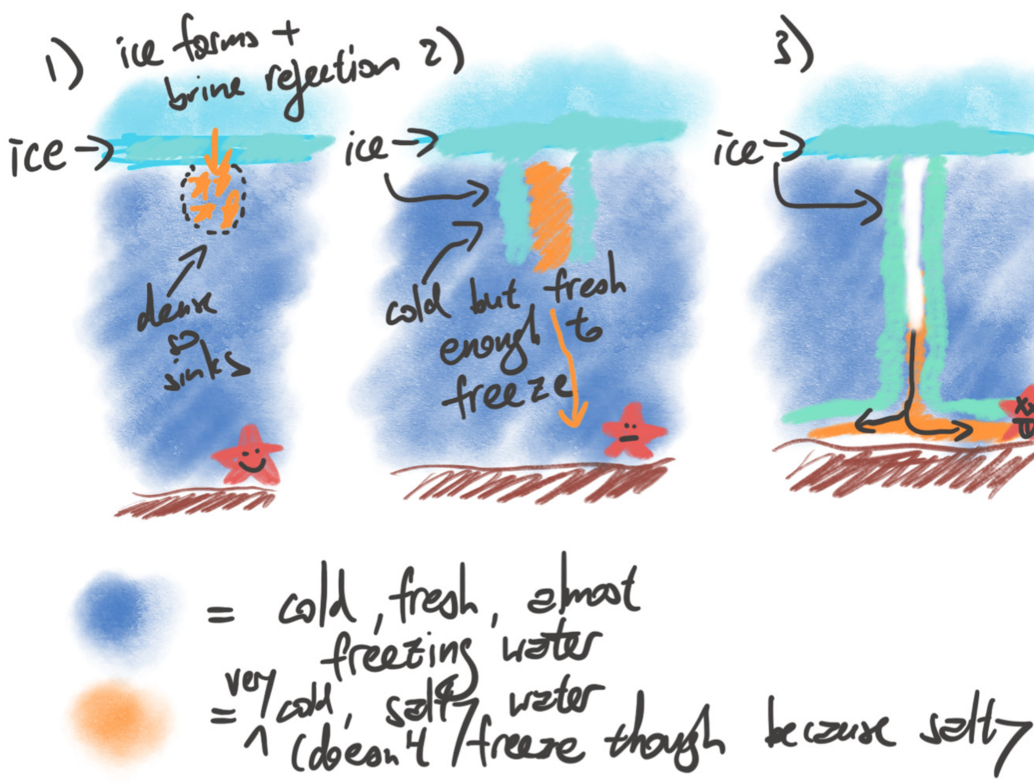

Figure 1: Ice finger of death, with casualty.

(Give up to 2 marks for the following: 1 mark for brine rejection when ice forces, 1 mark for cold salty water leading to sinking, 1 mark for the hollow tube. Citations would be good practice, but no marks are given for that.)

3. Take 1 mark off for every irrelevant sentence (but justify why it is irrelevant).

(a) The pictures given in the Lectures are primarily concerned with the locally vertical forces/accelerations at the equator, but of course there are forces/accelerations at locations away from the equator. The resulting *tide generating force* ends up squeezing the water towards the high and low tide points, and since the ocean is *compressible*, and it's the *convergence* of water arising from the global pull that is leading to the magnitude of SSH signals.

(1 mark for distinction between vertical/radial and horizontal forces/accelerations, 1 mark for the compressibility and convergence of water. Give 0.5 marks as appropriate.)

(b) Semi-diurnal is twice daily, and diurnal is daily. The semi-diurnal forcing (such as M_2) can be suppressed in certain places, leaving the diurnal signals to be the dominant factor (such as S_1) to act; these are related to the *amphidromic points*.

(0.5 marks for each of the definitions, 1 mark for the suppression of the semi-diurnal tides in certain locations on Earth. Give 0.5 marks if dynamical tides *is given as an explanation (it's possible but unlikely, given the recirculating time of the Kelvin waves will disagree with the relevant time-scales presumably.)*

(c) If the system is rotating then we might have issues with being in non-inertial frames, leading to fictitious forces such as centrifugal forces. "Rotation" could mean the Moon rotating about the Earth, the Earth moving rotating about the moon, the system co-rotating, and other options (the sensible one should be the one where both co-rotate about the common centre of mass, or the *barycentre*).

Aside: There is a lot of confusion arises on the internet, books and even official resources (e.g., NASA, NOAA etc. websites), because the choice of rotating frame is ill-defined, leading to statements such as "the centrifugal force is responsible for the other far-side bulge in the tide". In my opinion this is a case where the resource is trying to make it simpler for the lay-person (by avoiding talk about frames of reference and inertial frames), but ultimately does a big dis-service and adds to the prevailing confusion. The simplest view is that you only need a differential in the gravitational field (e.g., Talley's descriptive physical oceanography does a very clean description of it). See multiple resources available online, or the book "Modern Observational Physical Oceanography" by Carl Wunsch on how to do it 'properly'.

(1 mark for non-inertial frame, and 1 mark for noting several possible choices of rotating frames of reference. Bonus 1 mark for identifying the co-rotation about the barycentre being the sensible one to choose.)

!? (Bonus question, no marks) Going to be lazy: `https://en.wikipedia.org/wiki/Surface_Water_and_Ocean_Topography`.