

# OCES 2003 Assignment 4, Spring 2024

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Set on: Mon 6<sup>th</sup> May; due: Mon 13<sup>th</sup> May

## Blurb

- Assignments have a maximum mark out of 20, although you will see that there are 22 marks available to get in total, i.e. if you get 22/20 you still only get credit for 20/20
  - 16-17 is roughly around the A- boundary
  - anything below 8 is probably a fail
- Please show working in calculation
  - no working + wrong answer = no credit whatsoever
  - some working + wrong answer = partial credit
  - generically, give things to 2 decimal place and provide the appropriate units (marks are allocated for these), unless otherwise specified
- No answers except the 'hard' ones should need more than a paragraph / half a page, and excess answers that are not to the point will be penalised
- Type up the assignment or send a photo of your written up work in (the former is preferred), and the only request I have is no Microsoft Word documents (you can type up things with Word but export it as a pdf if you do)
  - write in full sentences where appropriate
  - particularly poor and/or scrappy presentation will have a mark that can be taken off
- There will be a rigid mark scheme, and model solutions will be available in due course
  - the TAs only mark the stuff, you should come to the instructor for arguing marks, and note the re-marking can result in marks going up or down

!!! By handing something in, you agree to the usual Academic Honour code and Integrity declarations. For more, see [http://qa.ust.hk/aos/academic\\_integrity.html](http://qa.ust.hk/aos/academic_integrity.html). Cases for plagiarism (whether intended or not, it is the “act” that matters) gets a penalty ranging from

- zero on the question concerned
- a fixed penalty starting from around 1/3 of the total marks
- zero for the whole assignment/midterm/final

The following counts as plagiarism (and is a non-exhaustive list):

- copying word for word *any* (i.e. one or more) sentence without quote marks regardless of whether it is cited or not, e.g. *Yer a Jedi, Harry* (Gandalf of House Stark)
    - \* use quote marks if need be, e.g. “*Yer a Jedi, Harry*” (Gandalf of House Stark), although don’t do it too often, because then one could argue you are not passing any of your thoughts through
    - \* any more than around three usages in text is probably excessive
  - copying without citation or wrong citation, e.g. “*Yer a Jedi, Harry*”, or “*Yer a Jedi, Harry*” (Jon Snow of Tatooine)
  - changing a few words but sentence largely the same, e.g. *You, Harry, sir, are a Jedi* (Mithrandir of Winterfell)
- Turnitin will pick out most of the aforementioned things
  - Cases can be contested but will lead to an official review, where the penalty may go up and/or down, and could result in an Academic Misconduct case being filed (see <https://acadreg.ust.hk/generalreg.html#b>)

## Problems

- Question here relates to the overturning circulation and somewhat to instabilities. Below on the left is a SSS climatology from the World Ocean Atlas below (see Lec 5; the right panel is a zonal average of the SSS climatology):

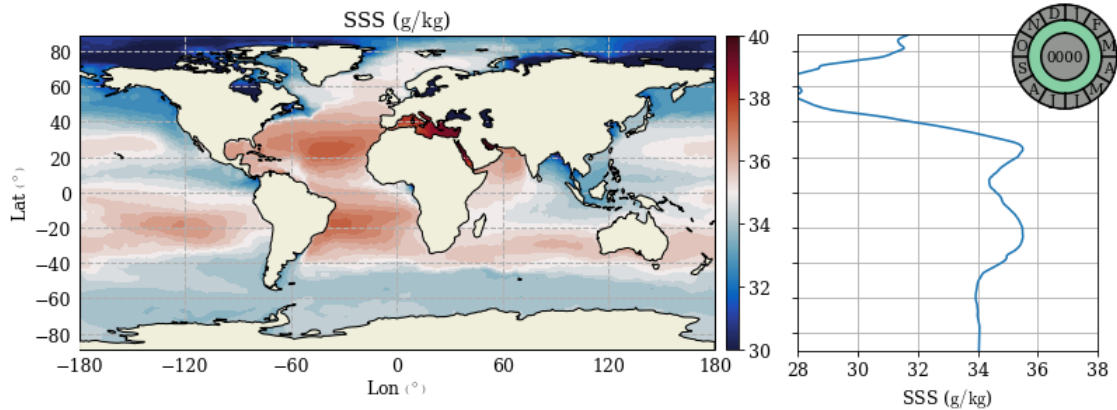


Figure 1: SSS climatology from WOA13.

- What is SSS? Comment on the Atlantic SSS relative to the Pacific SSS (larger, smaller, the same, not comparable etc.). [2 marks]
- The observation about SSS for the Atlantic is somewhat true for the Atlantic relative to the Pacific in general with regards to the salt content at depth also. One suggestion is that the differences in the salt content is to do with the differences in oceanic supply (evaporation minus precipitation is different but doesn't account for all the differences). One such supply pathway is from the *Aghulas current* on the East/South-East coast of Africa. But given the Aghulas current is a Western Boundary Current flowing Eastward, how does it supply salt into the Atlantic? (Hint: look up and describe what *Aghulas leakage*). Cite any sources you use, and don't write more than half a page for this. [2 marks]
- The Aghulas retroflection ends up shedding mesoscale eddies known as *Aghulas rings* via a shear instability, which can also carry salt anomalies into the Atlantic. But where is the large-scale shear in the velocity coming from here that leads to the shedding of these eddies? (Because an instability of the Aghulas rings themselves might end up destroying the rings, reducing the transport by these *Lagrangian Coherent Structures*.) [1 mark]
- Explain in your own words in no more than half a page (and cite sources if appropriate) on the mechanism explaining how shear instabilities arise in terms of Rossby/vorticity waves. [2 marks]
- One thing that gives us observations of the global SSS are satellites. But how do satellites measure the salinity remotely, given the common way of measuring in-situ salinity is either by titration, or by measuring the conductivity? Look up and describe in your own words on how satellites measure the SSS, comment on the expected sources of error, and limitations with the approach.

Cite any sources you do use, and do not write more than a page on this. (Hint: The gold standard for satellites is to do with measuring conductivity, so look up how satellites measure conductivity. There are some papers leveraging machine learning from other satellite channels; don't talk about those here.)

[3 marks]

2. In Lec 17 we talked about instabilities. Going to expand a bit more on the convective type instabilities here.

- (a) Double-diffusive instabilities on Earth are usually classified either as a *salt fingering* regime, or an *diffusive layering* regime. Look up what salt fingers are, and draw out the regime in which that could arise, and explain how the instability arises using a parcel type argument as used in the lecture. Cite any sources you do use, and write no more than half a page on this (excluding the drawing).

[2 marks]

- (b) The Lewis number is a ratio between diffusivities. Suppose this is defined as  $Le = \kappa_S / \kappa_T$ , the ratio of salt and thermal diffusivities. Is this number large, small, zero or others in the ocean? Justify your answer.

[1 mark]

- (c) Salt fingering might be expected to lead to enhanced vertical mixing. Relative to the molecular diffusivity and diffusion time, what would we expect for the magnitude of the vertical effective diffusivities, and the associated vertical diffusion time (larger, smaller, the same, not comparable)? Justify your answer.

[1 marks]

- (d) Look up and draw schematics that explain how *brinicles* form ("underwater fingers of death", <https://www.youtube.com/watch?v=lAupJzH31tc>; these things tend to only happen in the high latitudes). Cite sources as appropriate.

[2 marks]

3. Some harder questions about tides. Do not write more than around four sentences for the explanation to each part below, cite sources if you want; overly long explanation and irrelevant information will be **heavily** peanlised.

- (a) If you work out the forces and the associated accelerations due to the direct pull of the moon, these numbers are tiny. But the observed tides can have an amplitude of about a meter or so, which seems to be an apparent contradiction (e.g., we are not stretched by a meter every day when the moon passes by, even if the ocean is). Provide an explanation and resolution to this apparent contradiction.

[2 marks]

- (b) In Lec 18 we showed that the astronomical forcing by the moon is semi-diurnal, and so most places on Earth would be expected to have semi-dirunal tide, but in fact some places on Earth only experience a diurnal tide (e.g. regions in the Gulf of Mexico). Define the meanings of semi-diurnal and diurnal, and explain why some places still only experience a diurnal tide in terms of sea level measurements.

[2 marks]

- (c) In Lec 18 I provided an explanation for the tides as a differential in the gravitational field, without invoking any rotation whatsoever. If the system is rotating then extra fictitious forces (e.g., centrifugal forces) might be introduced, but why? Speculate on some subtleties with what is meant by

'rotation' here, and how that might complicate the picture. (Hint: what is the 'right' rotating frame of reference)? (Hint: Lec 8 might help.)

[2 marks]

- !/? (Bonus question, no marks + for interest only) The next generation of satellite altimetry as part of the SWOT mission recently begin returning data. Look up and write some things about the history of SWOT, the associated scientific objectives, technical details, and others. Comment on challenges with data sizes etc. as well.
- !/? (Bonus question, no marks + for interest only) The Moon raising the tide actually leads to spindown of the Earth and the Moon moving away (it's a few centimeters per year). Look up and explain what is happening; it's related to the content in Lec 8 actually.