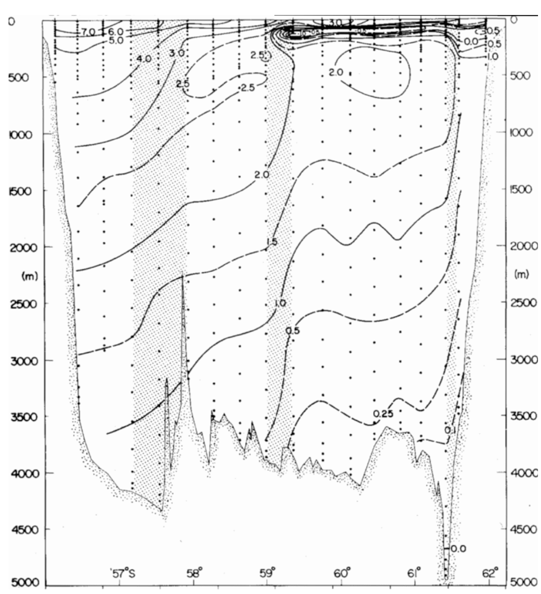
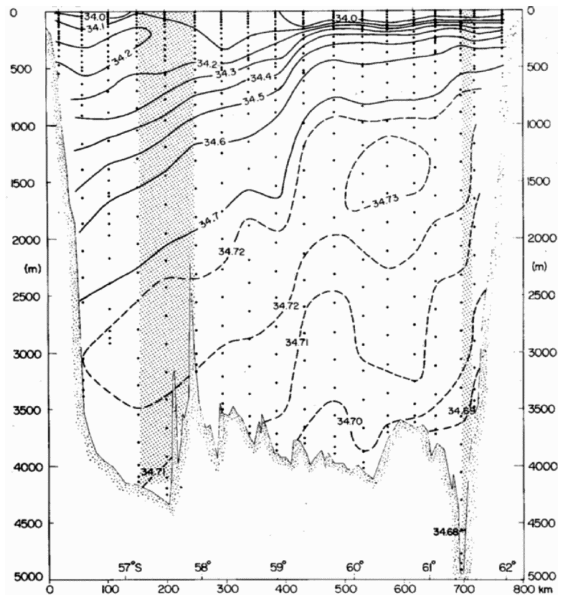
Problem sheet 2

1. The hydrographic method, used by oceanographers for decades to determine the large-scale geostrophic circulation, is based on the thermal wind equations. Shown below are hydrographic sections of potential temperature and salinity across the Drake Passage.



temperature (°C)



salinity ($^o/_{oo}$)

The width of the section is 800 km. You can assume density is related to temperature and salinity through a linear equation of state with expansion coefficients: $\alpha \approx 1 \times 10^{-4}\mathrm{K}^{-1}$, $\beta \approx 0.8 \times 10^{-3}(^o/_{oo})^{-1}$.

(a) By substituting the approximate, linear, equation of state for the ocean into the appropriate thermal wind equation show that

$$\frac{\partial u}{\partial z} = -\frac{g}{f}\left(\alpha\frac{\partial T}{\partial y} - \beta\frac{\partial S}{\partial y}\right),$$

and therefore the change in zonal velocity over a depth Δz can be approximated as

$$\Delta u = -\frac{g\,\Delta z}{f\,\Delta y}\,(\alpha\,\Delta T - \beta\,\Delta S),$$

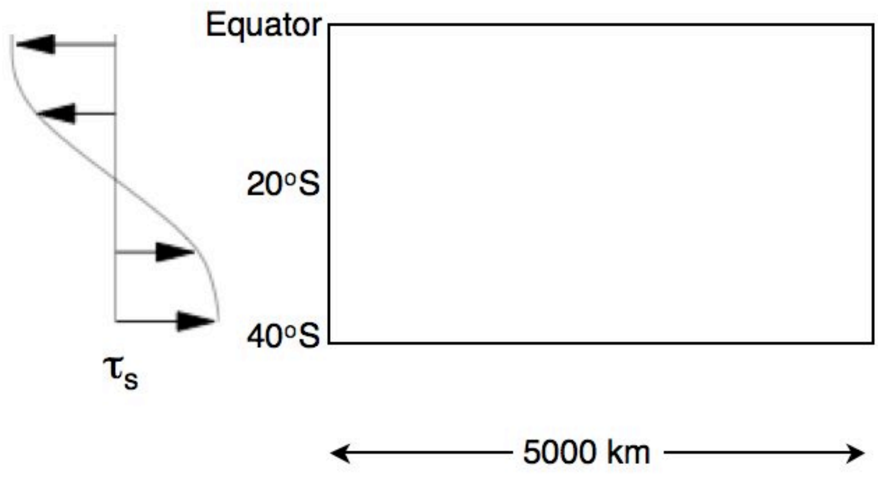
where ΔT and ΔS are the horizontal temperature and salinity differences across the section and Δy is the width of the section.

(b) Hence estimate Δu between depths of 4 km and 3 km, 3 km and 2 km, 2 km and 1 km, 1 km and 0 km.

(c) Using you answers to (b), and assuming a level of no motion at 4 km, estimate the mean surface velocity through the Drake Passage.

(d) Estimate the Antarctic Circumpolar Current transport through the Drake Passage.

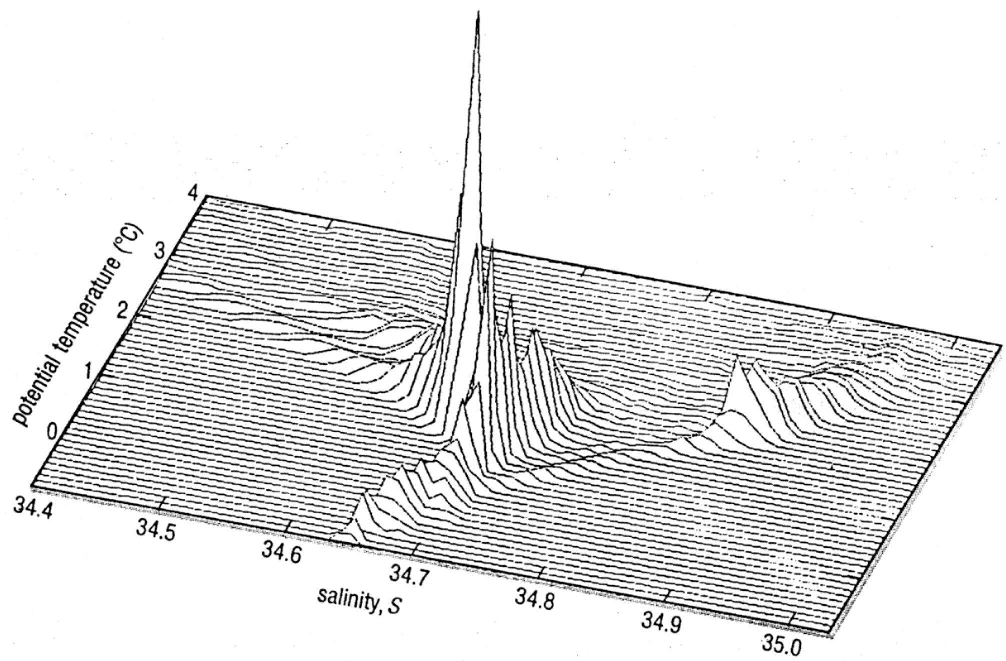
2. In the following figure, the subtropical South Atlantic is modelled as a rectangular basin, exposed at its surface to a zonal wind stress which varies with latitude as shown.



(a) Sketch the distribution of the Ekman transports within the basin. Hence deduce the direction of the vertical velocity at the base of the Ekman layer.

(b) By considering the vorticity balance of the water column, explain what this vertical velocity means for the depth-integrated meridional flow beneath the Ekman layer. Sketch the circulation predicted by Sverdrup balance, and also any boundary currents required to close the circulation.

3. The following figure below shows a three-dimensional T-S diagram for the global ocean; the vertical elevation indicates the volume of water with the given T-S characteristics.



(a) Identify North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW) on the T-S diagram; can you suggest why Antarctic Intermediate Water (AAIW) is virtually invisible on the T-S diagram?

(b) The largest peak on the T-S diagram corresponds to the deep water mass found in the

Pacific and Indian Oceans, sometimes known as Pacific/Indian Ocean Common Water, and believed to result from the mixing of AAIW, NADW, and AABW. Assuming that the mean T and S of AAIW are 4°C and 34.4 respectively, and reading suitable mean values for NADW and AABW from the T-S diagram, estimate the relative proportions of AAIW, NADW, and AABW which make up Pacific/Indian Ocean Common Water.

4. Evaporation exceeds freshwater input to the Mediterranean (i.e., input from rivers and precipitation) by $7 \times 10^4 \mathrm{m^3 s^{-1}}$.

   (a) Assuming that the mean salinity of water flowing into the Mediterranean is $36.3\,^o/_{oo}$, and the mean salinity of water flowing out of the Mediterranean is $37.8\,^o/_{oo}$, write down budget equations for volume and salt and use these to calculate the rate at which Mediterranean Water outflows through the Straits of Gibraltar. A diagram may be helpful.

   (b) The Mediterranean contains about $3.8 \times 10^6 \mathrm{km^3}$ of water. Estimate how long it would take to recycle this entire body of water.