

SIO 210 Introduction to Physical Oceanography
Mid-term examination
Friday, October 31, 2008; 2:00-2:50 PM

Open notes and calculator allowed. No books, no electronics (laptops, blackberries, etc.)
(100 total points.)

Possibly useful expressions, values and equations

$$1 \text{ Sv} = 1 \times 10^6 \text{ m}^3/\text{sec}$$

$$\rho = 1025 \text{ kg/m}^3$$

$$F \sim \rho V(S_o - S_i)/S_m$$

$$c_D = .001$$

$$c_p = 3850 \text{ J/kg } ^\circ\text{C}$$

$$Q = \rho c_p T$$

acceleration + advection + Coriolis force = pressure gradient force + gravity + friction

Multiple choice (4 points each, 20 points total)

For each problem, **circle the CORRECT answer.**

1. Within an Ekman layer,

- (a) the velocity vector at some depth is in the opposite direction to the surface velocity vector
- (b) the transport is to the right of the wind stress in the southern hemisphere
- (c) molecular viscosity dominates over eddy viscosity
- (d) advection balances friction

2. Chlorofluorocarbons

- (a) are naturally-occurring tracers of ocean flow
- (b) interact with ozone within the ocean
- (c) are found in all regions and depths of the ocean
- (d) are conservative tracers of ocean flow

3. Eddy diffusivity

- (a) has units of $\text{kg m}^3/\text{sec}$
- (b) is important for the vertical structure of the ocean's density field
- (c) turns to the right with depth
- (d) is uniform throughout the ocean

4. The Coriolis force

- (a) causes surface waves to deflect to the right as they approach the beach in the northern hemisphere
- (b) causes Ekman transport to the left of the wind in the southern hemisphere
- (c) causes bathtubs to swirl as they drain
- (d) includes the effect of centrifugal force

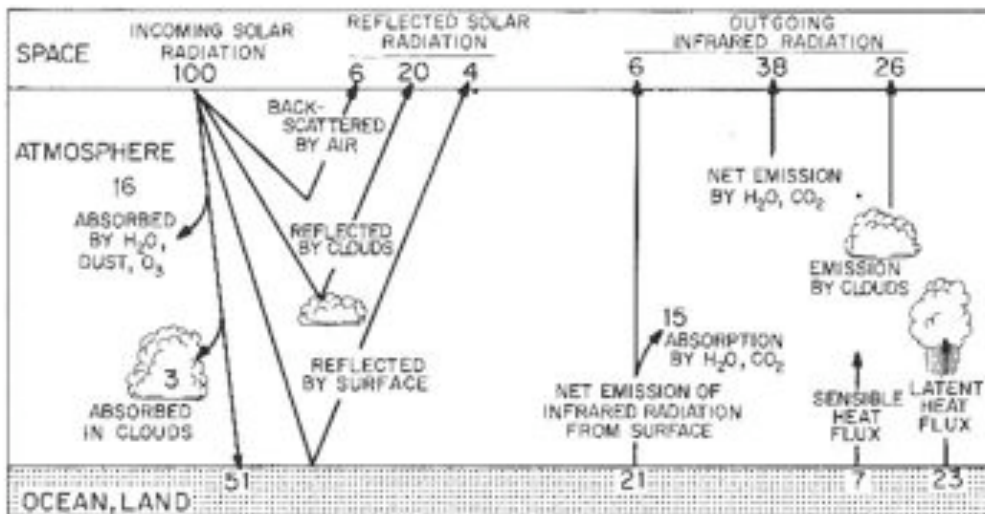
5. Inflow into the Black Sea is saltier than the outflow. Therefore

- (a) freshwater transport is out of the Black Sea
- (b) salt transport is into the Black Sea
- (c) there is net mass loss within the Black Sea
- (d) sea level is rising in the Black Sea

Short answer (10 points each, 50 points total)

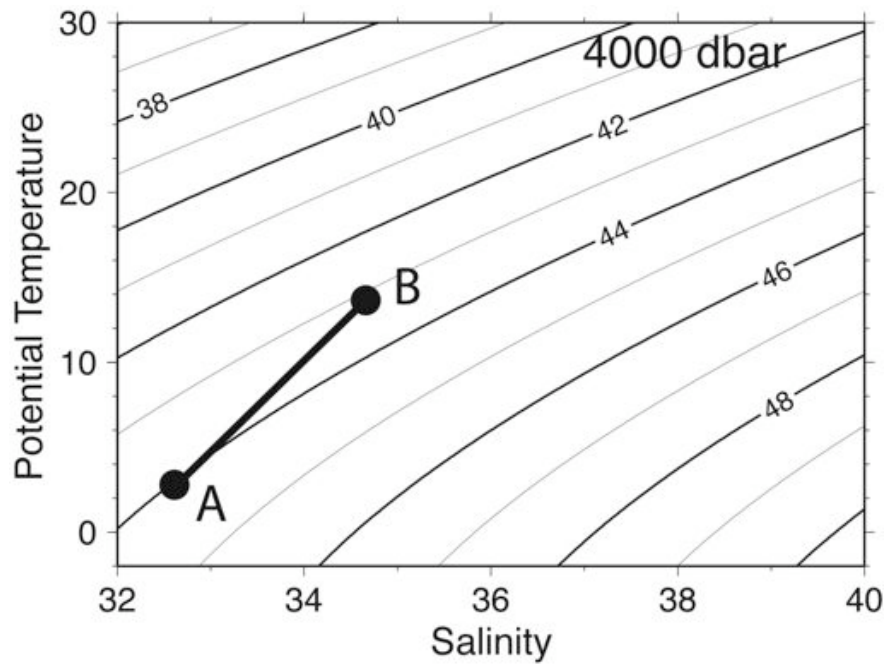
6. The figure shows components of the global heat balance. Five of the pathways involve the ocean surface.

Choose one of these ocean pathways and describe how an increase in ocean surface temperature might affect it.



7. Explain why the surface winds blow from east to west in the tropics (within 30° latitude of the equator).

8. The following plot shows contours of potential density relative to 4000 dbar.



(a) Relative to this reference pressure of 4000 dbar, which water parcel is denser, A or B?

(b) **On the plot**, sketch the contours of potential density relative to 0 dbar. (This is schematic, but should include the proper orientation relative to the contours that are shown.)

(c) If the two parcels, A and B, are brought to the sea surface adiabatically, is their density difference (at the sea surface) likely to be GREATER or LESSER than it is at 4000 dbar? Explain your answer.

9. What is the force balance in geostrophic flow? Explain how we justify dropping all the other terms in the momentum equation in favor of just these terms.

10. The compressibility of seawater depends on temperature. Explain how this affects *sound speed*. Include in your answer whether sound speed is higher or lower for warmer water, and why.

Longer problems (15 points each, 30 points total)

11. Suppose the ocean is in a steady state, with net precipitation in one region (say, the whole Pacific Ocean) and net evaporation in another region (say, the whole Atlantic/Indian Ocean). Suppose the net precipitation is 1 Sv in the Pacific and net evaporation is 1 Sv in the Atlantic/Indian. Suppose that the net volume exchange between the two oceans is 20 Sv (freshwater from the Pacific to the Atlantic/Indian and saltier water from the Atlantic/Indian back to the Pacific).

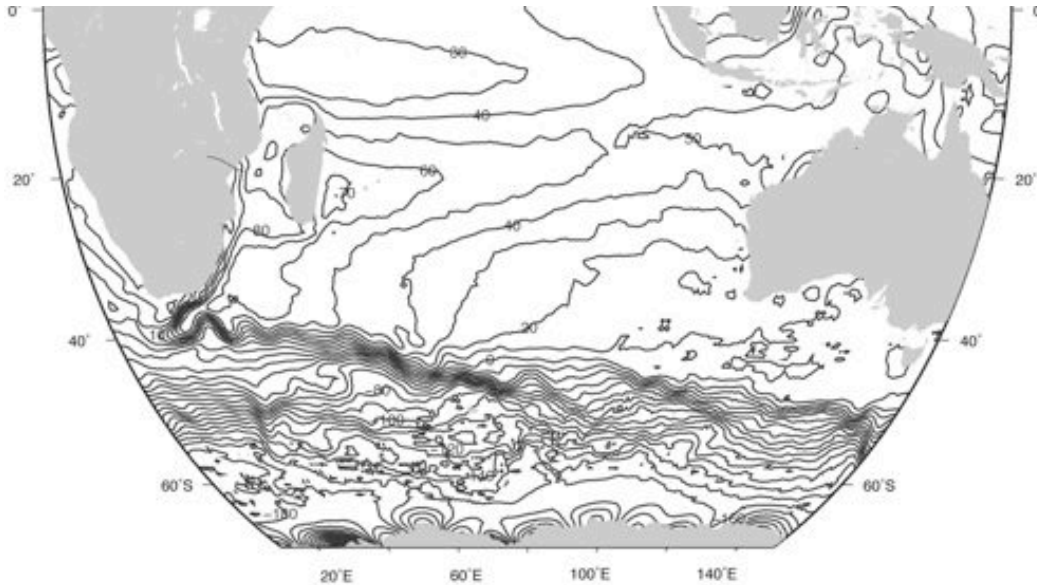
(a) What is the net freshwater transport between the two oceans? (very short answer)

(b) Calculate the salinity difference between the two oceans. (Assume that the mean salinity of the whole ocean is 35.)

(c) How might this salinity difference affect the potential for deep water formation in the two oceans, compared with each other?

12. (a) On the map, which shows steric height at the sea surface in the Indian Ocean, locate a high pressure zone. (Mark it on the map).

(b) On the same map, indicate the direction of the geostrophic ocean currents around the high pressure that you located in (a).



(c) In this box, sketch the sea surface height across the top, crossing the high pressure you marked in (a). Indicate the direction of the geostrophic currents at the sea surface.

(d) Assume that these currents decay (are weaker) with increasing depth. Sketch the isopycnal slopes in the water column beneath the sea surface height.

