EAS4305/6305 **Midterm Exam**

Time: 12:00 – 13:15AM, October 25th, 2018
Closed book and **calculator & 1-page (double side) cheat sheet is allowed**

***Write your answers in the blank sheets provided, put page numbers, and when it's finished, staple them together to submit.**

Potentially useful constants and units
1 Sv = 1 x 10^6 m^3s^{-1}
1 bar = 10^5 Pa = 10^5 Nm^{-2} = 10^5 kg s^{-2} m^{-1}
g = 9.8 ms^{-2}
$\rho \sim 1025$ kgm^{-3}
c_p = 3,900 $Jkg^{-1}K^{-1}$
R = 6,370 km
Ω = 0.7 x 10^{-4} s^{-1}
sin(15°)=0.26
sin(20°)=0.34
sin(30°)=0.50

Multiple-choice questions (3pts x 10 = 30pts)

1-1 The shape of *Geoid* is affected by:
(a) Surface wind stress
(b) Anomalies in gravitational acceleration
(c) Coriolis effect
(d) Density of the seawater

1-2 Which tracer is a conserved property in the interior ocean?
(a) Temperature
(b) Salinity
(c) Nitrate
(d) Oxygen

1-3 Which instrument can measure the Lagrangian velocity of ocean currents?
(a) CTD instrument
(b) Surface drifters
(c) Satellite altimeter
(d) ADCP on a mooring

1-4 Dynamic height is:
(a) Depth of isopycnals
(b) Sea surface height relative to the geoid
(c) Eustatic sea level
(d) Average tidal gauge measurements

1-5 *Vertically integrated* wind-driven Ekman transport in the southern hemisphere is:

(a) directed 45 degree to the right of the wind stress
(b) directed 45 degree to the left of the wind stress
(c) directed 90 degree to the right of the wind stress
(d) directed 90 degree to the left of the wind stress

1-6 *Brine rejection* means:

(a) mixing of seawater and freshwater at the estuary
(b) evaporation leaves behind salty surface water
(c) precipitation dilutes salinity of surface water
(d) salt is excluded from ice crystals when seaice forms

1-7 The effect of adiabatic compression:

(a) decreases temperature
(b) increases density
(c) decreases potential temperature
(d) increases salinity

1-8 The *potential density* σ_1 is defined according to:

(a) reference temperature of 1°C
(b) reference pressure of 1 dbar
(c) reference pressure of 1,000 dbar
(d) the linear equation of state

1-9 Isopycnals are surfaces of:

(a) constant potential temperature
(b) constant density
(c) constant pressure
(d) constant potential density

1-10 Subtropical mode water is typically found in:

(a) thermostad
(b) mixed layer
(c) dichothermal layer
(d) Salinity minimum layer

2. Short answer questions (6 pts x 5 = 30 points, answer in a few sentences)

2-1 Draw typical vertical profiles of salinity in the subtropical North Pacific and in the subtropical North Atlantic. Identify major water masses in the profile. Briefly explain the differences.

2-2 Observed salinity is typically the highest in the subtropics, not at the equator or poles. Why?

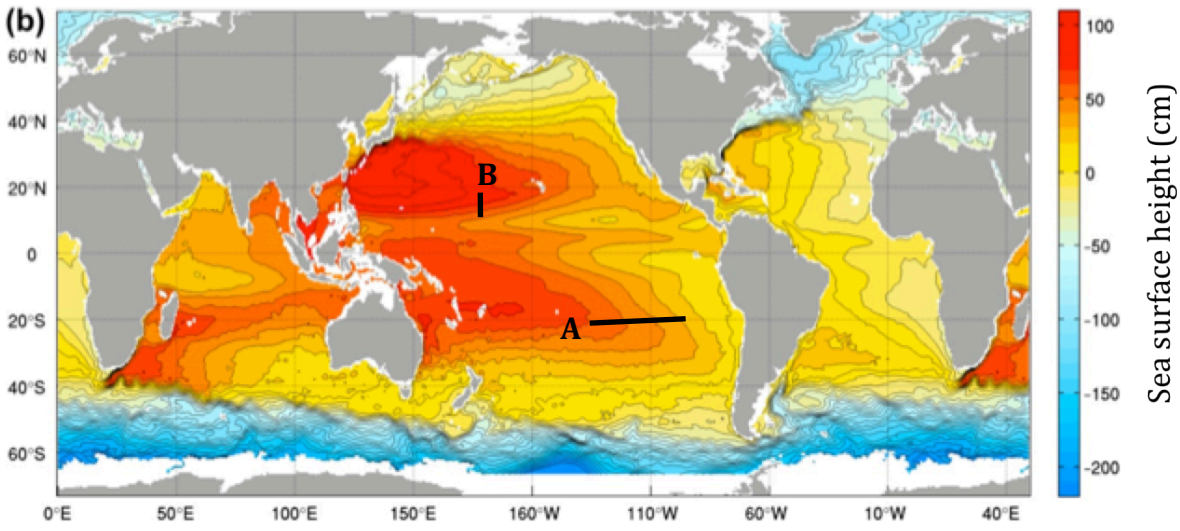
2-3 Give one example for each of *Lagrangian* and *Eulerian* observations of ocean currents.

2-4 There are two major mechanisms for the global sea level rise in a warming climate. What are they?

2-5 Explain the meaning of thermobaricity

3. Long answer question (40 pts)

3-1 (4 pts x 5 = 20 pts) The map below is a satellite observation of sea surface height in the units of cm. Contour interval is 10 cm.



(a) Thermodynamic Equation of State of seawater tells us that water with higher temperature expands. However, this map shows the sea surface height is at its highest at the subtropics, not at the equator. Why?

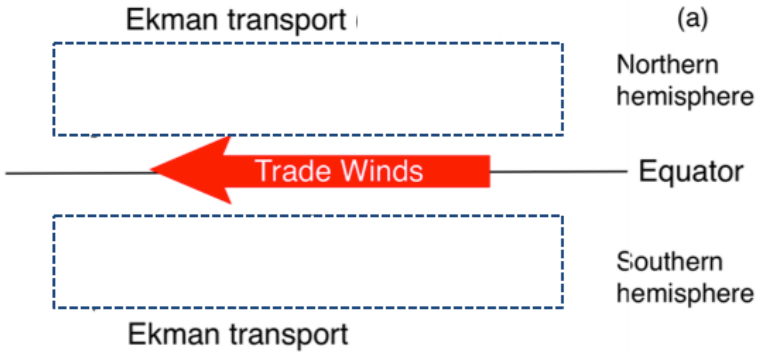
(b) Consider the **geostrophic balance** at the section marked by A in the South Pacific. Draw arrows indicating the directions of the pressure gradient and Coriolis force, and the implied geostrophic current. Remember that this is in the southern hemisphere.

(c) Estimate the speed of the average geostrophic current. Please show your work with units. You may approximate 1 degree in longitude or latitude to be 100km (=10^5m).

(d) Consider the section marked by B in the North Pacific. Draw arrows indicating the directions of the pressure gradient and Coriolis force, and the implied geostrophic current.

(e) Estimate the speed of the average geostrophic current. Please show your work.

3-2 (4 pts x 5 = 20 pts) The diagram below shows a conceptual diagram looking down over the tropical oceans centered at the equator. The red arrow indicate the predominantly westward (trade) wind stress over the surface ocean. Note that this wind stress occurs over the entire tropical domain, not just over the equator. Questions (d,e) are optional extra credit for undergraduates (EAS4305).



(a) What is the balance of forces supporting the Ekman current?

(b) In the diagram, write arrows for the zonal (east-west) component of the force balance and explain the orientation of the meridional (north-south) Ekman transport in the northern hemisphere.

(c) Repeat (b) but for the southern hemisphere.

(d) Considering the pattern of Ekman transport, what is the sense of vertical velocity (upwelling/downwelling) along the equator?

(e) Based on your answer to (d), sketch the shape of thermocline and sea surface height as a function of latitude.