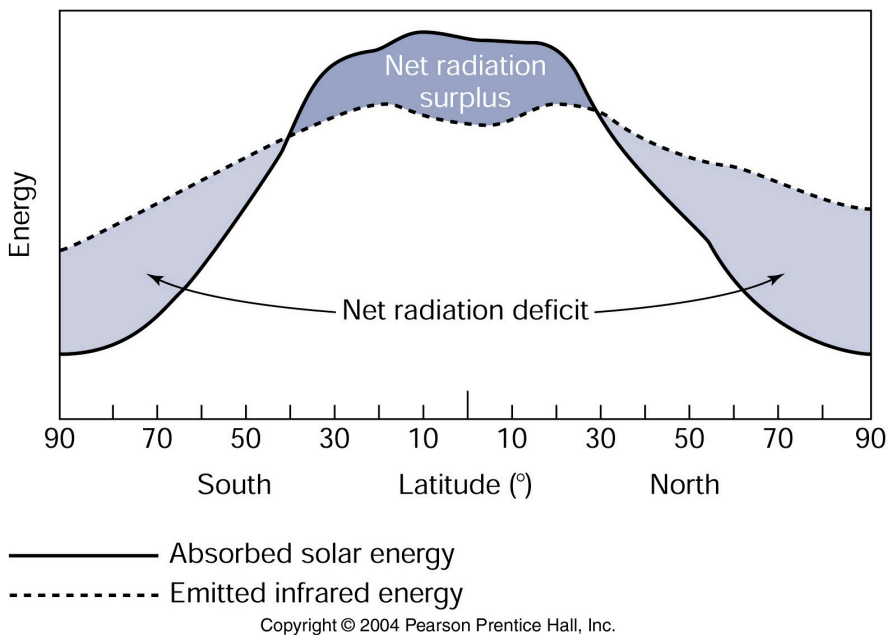


Total points: 100
ATOC 1060-001 Homework #3

INSTRUCTIONS: Make sure that you answer all of the questions for maximum credit. Use appropriate units on all numerical answers and answer non-numerical questions with complete sentences. Please write neatly when completing this assignment – if we can't read your answer you will not get credit for it.

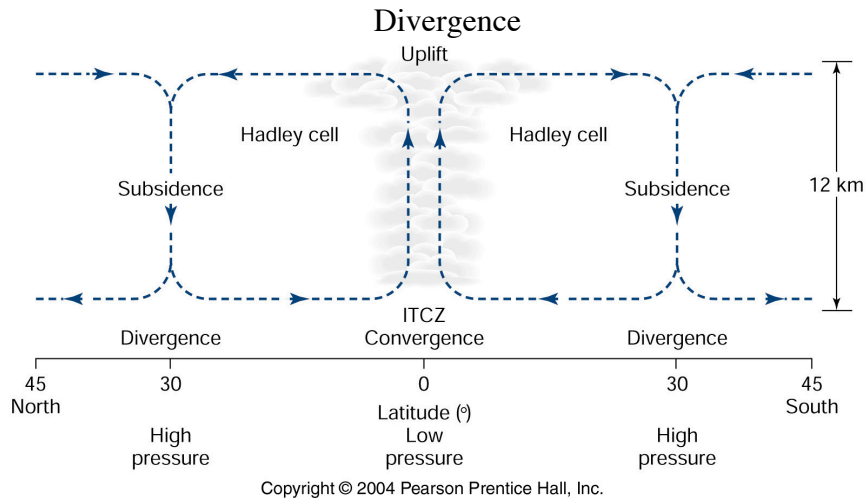
1. 1a) Draw a graph showing the variation of incoming solar energy and outgoing infrared radiation with latitude, (3pts) and indicate the regions of energy surplus and energy deficit. (3pts)



- 1b) Explain why the latitudinal distribution of energy surplus and energy deficit is important for atmospheric circulation. (4pts)

The latitudinal energy gradient produces atmospheric temperature and pressure differences that force the atmosphere to circulate, carrying warmer air toward the poles and colder air toward the equator. These circulations move energy from regions where there is a surplus to regions where there is a deficit.

2. 2a) Use a schematic diagram to illustrate the Hadley Cells. On the diagram, label each part of the Hadley Cells – convergence, divergence, uplift, subsidence; also label the latitudes at which each process happens, and the sea level pressure (high or low) associated with the uplifts and subsidences. (6pts)



Note: Surface convergence to the (ITCZ) at the equator – 1pt; uplifts - 1pt; upper-level divergence at the equator – 1pt; subsidence in both hemispheres – 1pts; latitude labels – (0, 30S, 30N) 1pt; Sea level pressure (low at ITCZ, high at 30N and 30S) – 1pt.
 No point deductions if they do not draw and label the surface “divergence” and upper level “convergence” at 30S and 30N.

2b) Why do the Hadley circulations change seasonally? (3pts)

Because the distribution of solar energy varies with the season, the locations of tropical convection, ITCZ, and high-pressure systems vary with season, and thus Hadley circulation changes seasonally.

2c) How are the tropical northeasterly trades and southeasterly trades formed? (3pts)

The northeasterly trades and southeasterly trades are the lower branches of Hadley cells in the Northern and Southern Hemispheres, respectively. When the poleward moving upper-level air associated with the Hadley Cell sinks in the subtropics, it causes divergence at the surface (see above figure for Hadley cell) and part of the air flows toward the equator as the lower-branch of the Hadley cell. When the air flows toward the equator, Coriolis force deflects it toward the right in Northern Hemisphere and toward left in Southern Hemisphere, forming the easterly components, and thus the northeasterly and southeasterly trades.

3. 3a) Assume Figure 1a shows the surface pressure distribution in middle latitude, which includes the state of Colorado. Point A represents Boulder, Colorado. Assume the atmosphere is frictionless. At point A, draw the pressure gradient force (PGF) (3pts), Coriolis Force (CF) (3pts), and geostrophic wind (V_g) (4pts).

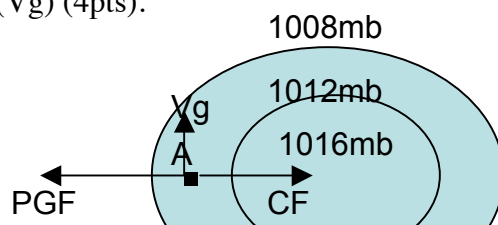
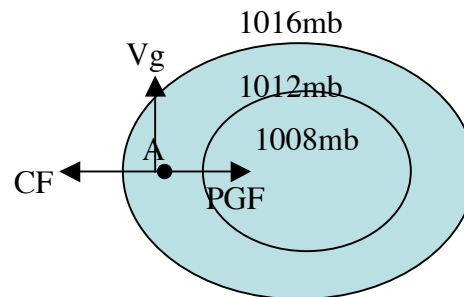


Figure 1a. Surface pressure distribution.

3b) Figure 1b shows the pressure distribution in Southern Hemisphere. Point A represents Hobart, Australia. At point A, draw the PGF (3pts), CF (3 pts), and Vg (4pts).

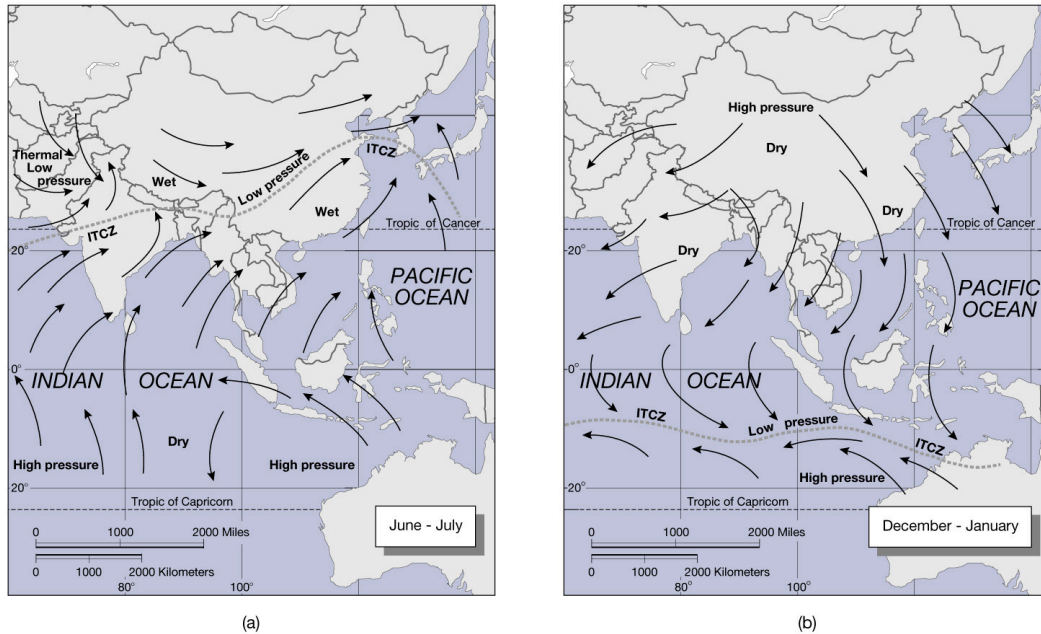
Figure 1b. Surface pressure distribution.



4. Discuss the land-ocean contrasts in (i) absorbing/reflecting solar radiation, (3pts) (ii) upward/downward heat transfer, (4pts) and (iii) heat capacity. (3pts) These contrasts play important roles in causing land-sea breeze and monsoon.

- (i) Generally, the albedo of the land is much higher than that of the ocean; consequently, the ocean absorbs more solar radiation than land at the same latitude;
- (ii) Heat transfer: Ocean surface quickly transfers heat downward by mixing and upward by convection; Land quickly transfers heat upward by convection, but slowly transfers heat downward by thermal conduction (land thermal conductivity is lower than the ocean);
- (iii) Heat capacity: water heat capacity is 3-4 times of that of dry soil.

5. 5a) Sketch the Asian summer and winter monsoon (4pts).



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The monsoon flow over Southeast Asia. a) summer; b) winter.

5b) Explain the processes that drive the Asian summer monsoon and winter monsoon. (summer monsoon 3pts; winter monsoon 3pts)

(a) Summer heating of the Tibetan Plateau produces intense convection and low surface pressures, drawing in moist air from the Indian Ocean to the south. Due to Coriolis effects, winds are deflected toward the right in Northern Hemisphere, forming the southwest monsoon. (b) The reverse occurs in winter, when low temperatures and extensive snow cover on the plateau produce high surface pressures, subsidence, and outflowing air. Due to Coriolis effects, winds are deflected toward the right in NH, forming the northeast monsoon.

6. What is latent heat of vaporization? (2pts) Write down its quantitative value at 100°C (2pt) Explain why latent heat is important for the redistribution of energy between atmosphere and ocean (or between atmosphere and land). (4pts)

The latent heat of vaporization is the energy needed to convert liquid water to water vapor. It is 2260 kJ/kg at 100°C. Thus, it takes 2260 kJ of energy to convert 1 kilogram of water at 100°C to water vapor. When water from the ocean (or land) evaporates, the ocean loses energy to the atmosphere through latent heat flux. When water vapor in the atmosphere condenses, energy is released. Therefore, latent heat is important for the redistribution of energy.

7. Explain the causes of relatively high rainfall in ITCZ (3pts) and Polar Front Zone (PFZ) (3pts), and low rainfall in the subtropical high regions. (4pts)

Most rainfall situations occur with some form of uplift, or rising of air masses. Large-scale uplift occurs near the PFZ due to the cold air in polar area meeting with the warmer air from

subtropics. The lighter, warmer air flows on top of the colder, denser air. When the warm air is lifted, it becomes cool and supersaturated. Condensation occurs and thus produces precipitation. Near the ITCZ, surface convergence lifts the air up and produces rainfall. In the subtropical high areas, sinking prevails. When air sinks it becomes warmer, which makes the air become less saturated and therefore does not favor precipitation.

8. In the subtropics, oceanic circulations are dominated by the Subtropical Gyres (STG). Describe the formation mechanism of the STG. (5pts)

Westerly winds at mid-latitudes and easterly trades at lower latitudes drag the ocean surface in motion due to friction (see Fig 5-1 of the text book). As soon as the water starts to move, it subjects to effects of Coriolis force, which tends to deflect the motion toward right in Northern Hemisphere (NH) and toward left in Southern Hemisphere (SH). Observations show that this deflection tends to be approximately 20-40° (or 20-25°) from the wind direction. Drag of wind stress due to friction combined with Coriolis effects produces the clockwise STG in NH and counter-clockwise STG in SH.

9. Figure 2 shows the surface wind direction in the mid-latitude North Pacific. In figure 2 draw the direction of Ekman transport. (5pts)

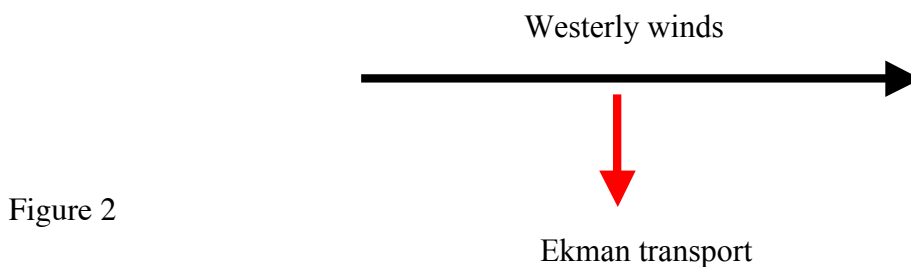


Figure 2

10. Figure 3 shows the observed surface winds and sea surface temperature (SST) in the eastern tropical Pacific Ocean. Explain how the equatorial cold tongue and cold SST near the eastern boundary of the south Pacific are formed. [You may use schematic diagrams to support your discussion; but the schematics are not required.] (10pts)

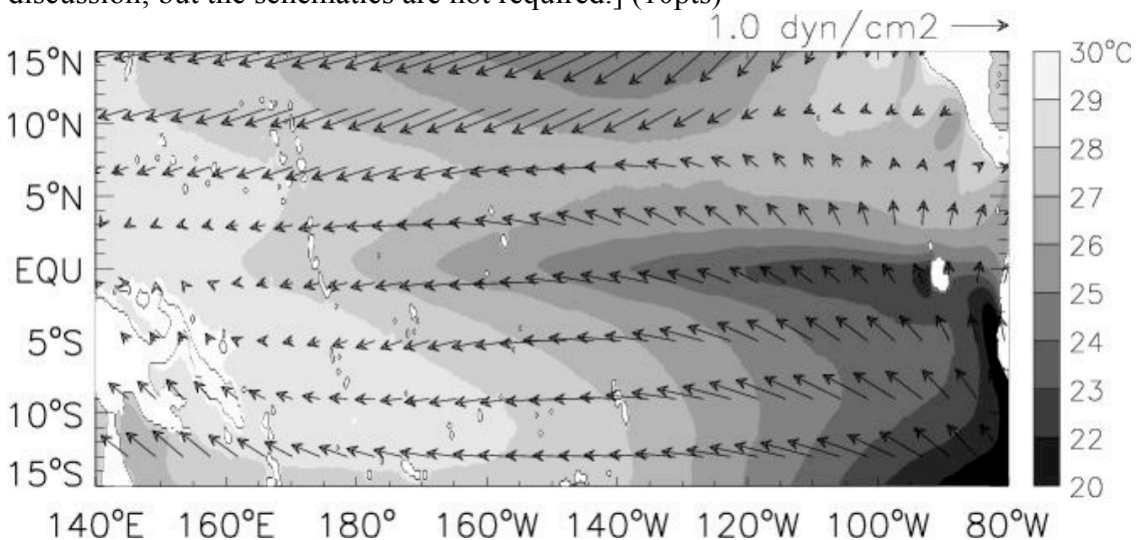
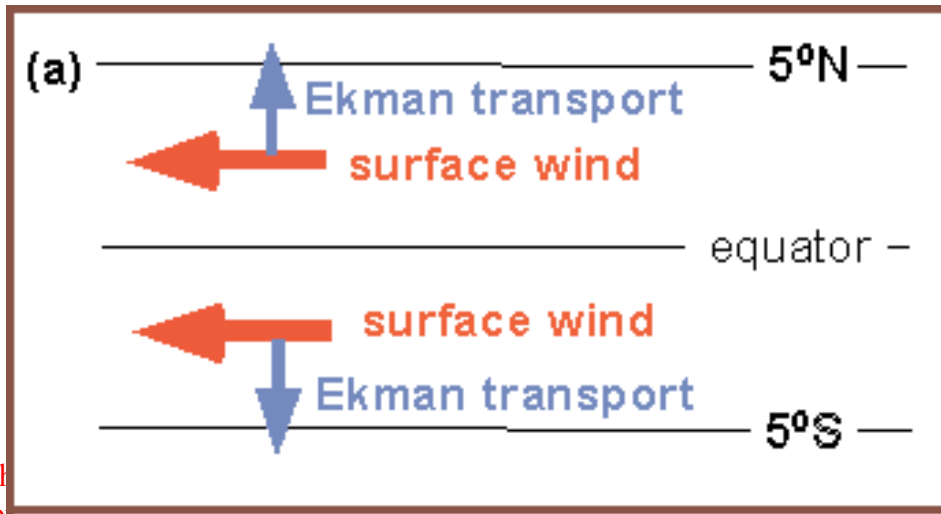


Figure 3. Observed SST (gray shade) and surface wind stress (arrows) in the eastern tropical Pacific Ocean. The water is cold in the eastern equatorial basin and along the east coast of the south Pacific.

Equatorial cold tongue: Easterly wind components cause equatorial Ekman divergence, moving the warmer surface water poleward and causing upwelling of the colder, subsurface water to the surface. This produces the cold tongue. See figure below.



Along the equator, the Ekman transport is divergent, which causes coastal upwelling and thus produces the cold SST there. See schematic diagram below.

