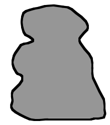
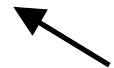
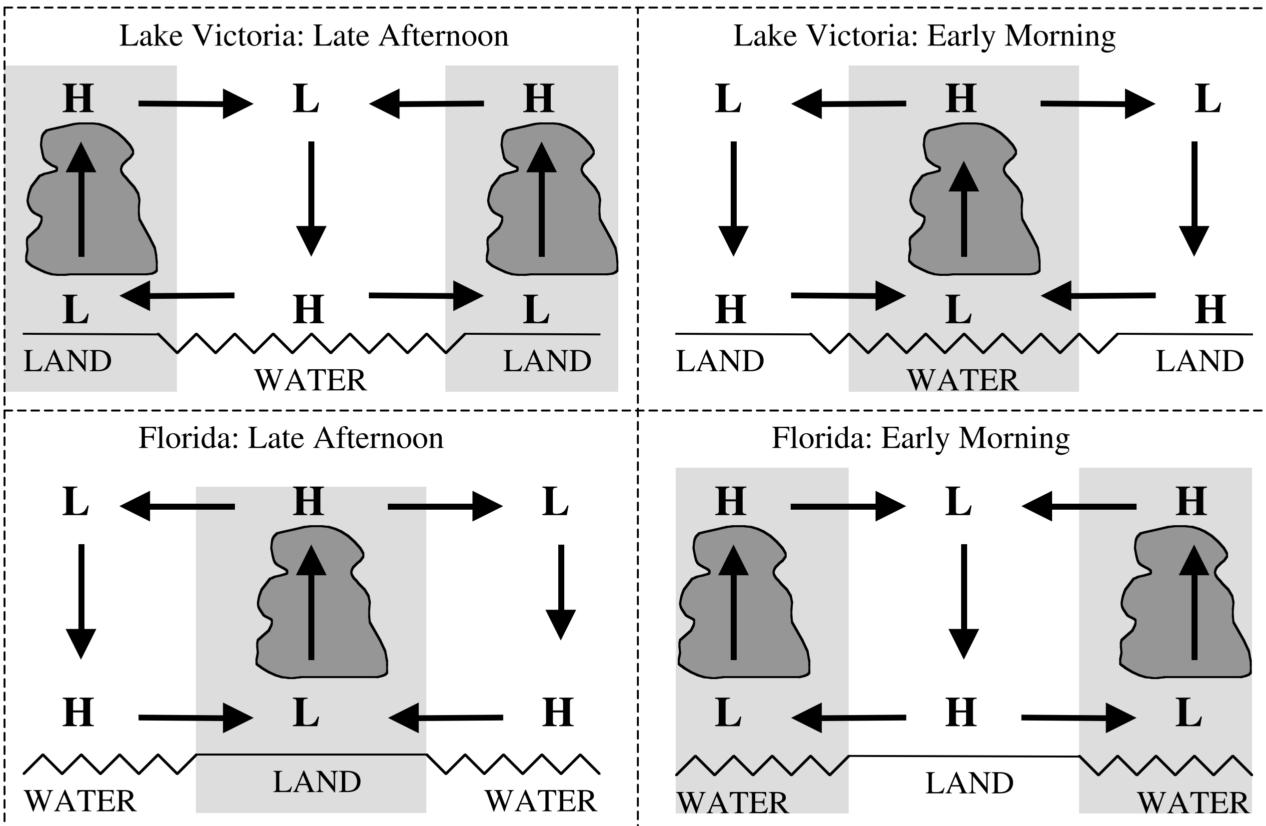
Atmospheric Sciences 101
Mini-Homework Assignment #6 Solutions and Discussion

1. The following cross-sections represent the atmosphere above Lake Victoria (Africa) and Florida at two different times of day. For each situation, label high and low pressure (both near the surface and aloft), and warm versus cold air. Draw the horizontal winds (surface and aloft), vertical motion, and clouds. Label each situation as either a "land breeze" or a "sea breeze."

WARM AIR = CLOUD =  WIND = 

SEA BREEZE LAND BREEZE



SEA BREEZE LAND BREEZE

2. a) The jet stream is a region of strong westerly winds located near the tropopause. Consider an air parcel trapped in the jet stream and circling the Earth. Assume that the parcel follows a circular path with a radius of about 4000 km (this corresponds to a latitude of about 50°N). Calculate the distance traveled by the parcel in making one complete revolution around the Earth. (Hint: circumference of a circle = $2\pi \times$ radius.)
distance = 2*3.14159*4000 km = 25,133 km

b) Assuming that the jet stream is blowing at an average speed of 120 m.p.h., how long does it take for the parcel to travel once around the planet? (1 m.p.h. = 0.45 m/s = 1.61 km/hour.)
speed = 120 m.p.h. = 120 * 1.61 = 193 km/hour
time = distance/speed = 25,133 km / 193 km/hour = 130 hours = 5 days and 10 hours
For comparison, a parcel of air at the surface, trapped in a wind of 20 m.p.h., would travel a distance of 20 (miles/hour)*130(hours)=2600 miles in the same time. So, while a parcel of air at

the surface would barely travel a distance equivalent to the size of the US, a parcel in the jet stream would already have traveled once around the whole planet!

c) Assuming that this wind is in geostrophic balance, calculate the pressure gradient ($\Delta p/\Delta x$) near the tropopause at 50°N. (Use the equation we gave you in class). The rotation rate of the earth is Ω=7.29×10^{-5} 1/s, and near the tropopause the density is about ρ=0.3 kg/m^3. Your answer will have units of kg/m^2s, which you can turn into mb/km using: 1 kg/m^2s^2 = 10 mb/km.

Using the equation for a wind in geostrophic balance, the Pressure Gradient is:

Pressure Gradient = $\Delta p/\Delta x = 2*\Omega*\sin(\Phi)*v*\rho$

where:
$\Omega = 7.29\times10^{-5}$ 1/s
Φ = 50°N and $\sin(\Phi)=0.766$
ρ = 0.3 kg/m^3
v = wind speed = 120 miles/hour = 120 * 0.45 = 54 m/s

(using the conversion factor for the wind speed). Note that all your units have to be consistent. Here, everything is expressed in kilograms, meters and seconds. So:

Pressure Gradient = 2 * 7.29×10^{-5} (1/s) * 0.766 * 54 (m/s) * 0.3 (kg/m^3) = 0.0018 kg/ m^2s^2

And multiplying by the conversion factor:
Pressure Gradient = 0.0018 * 10 = 0.018 mb/km.
This means that around the jet stream, we would experience a pressure change of 0.018 mb for every kilometer across the flow. To get a better idea of the strength of that pressure gradient, we can multiply it by 1000 to see what would the pressure be on a distance of 1000 km. It would be 18 mb. Recalling that the typical pressure gradients that we observe at the surface are around 10 mb/(1000 km) we see that the pressure gradient is stronger aloft (around the jet stream) than it is at the surface, which is consistent, since stronger pressure gradients drive stronger winds (and the jet stream is a lot stronger than the winds at the surface, both because the pressure gradient is larger and because the density of air at the tropopause is much lower).

3. The surface pressure map for February 29, 1999 is drawn on the back of this page. Draw arrows representing PGF_H (the horizontal pressure gradient force), the Coriolis "force", and the geostrophic wind at each point on the figure (we drew a sample over Seattle). Make the length of each arrow proportional to the magnitude. Label each arrow or use color coding (red=PGF, blue=Coriolis, black=wind). Ignore the effects of friction. ***Bonus****: For extra credit, draw and label the frictional force (or use green if you are using color coding) and draw the wind arrow including the effect of friction in pencil next to the non-frictional wind arrow.*