AIR OCEAN INTERACTIONS

I. Interaction between air and water takes place in several ways some are

- A. evaporation of water makes air moist. Latent heat that goes into the water vapor fuels storms as water condenses
- B. Salt particles are used for condensation
- C. Storms produce winds that drive currents
- D. Wind pushes water which causes changes in pressure in the ocean

II. Water has greater frictional drag than air so currents in water move more slowly than in air

- A. rate of speed anywhere from several km a day to several km per hour.
- B. Coriolis has an effect on water movement as well
  - 1. deflection to right or left is anywhere from 20^0 to 45^0
  - 2. Unlike the air the currents spiral in semi closed circular whirls called “gyres”
    - a. N Atlantic gyre – Gulf stream move warm air northward on west side of Atlantic and cold air southward in east side
    - b. N Pacific gyre similar
    - c. Southern hemisphere similar but gyres flow in opposite directions
    - d. Eastern continental edge usually has warm currents; west, cooler
    - e. about 40% of heat transfer is by ocean current; without them there would be a more radical change in temperature from equator to poles

III Upwelling and Ekman spiral and transport

- A. The rising of nutrient rich cold waters from lower depths to the surface is “upwelling”
  - 1. importance is that nutrients and sunlight are usually separated in the ocean so upwelling brings them together allowing primary producers to function
  - 2. “Clines” are places where there is a more dramatic change in some quality
    - a. thermocline: heat drops off at about 50 meters
    - b. halocline: change in salinity
    - c. changes in density
    - d. changes in nutrients
    - e. changes in oxygen
- B. Ekman Spiral and transport
  - 1. As water on the surface moves, it causes lower levels to move as well
    - a. each level is affected by Coriolis so each level shifts further
    - b. at ~100 meters, water is flowing in the opposite direction of surface water
    - c. net transport of water is about 90^0 from direction of surface water.
    - d. On US west Coast southward moving cool water is transported away from the coast causing upwelling of cold bottom water, so Medocino has coldest water since the current flow there directs water away from the shore.

IV. El Niño and Southern Oscillation.

- A. Normal conditions: high pressure (dry) over eastern Pacific pushes water westward promoting upwelling. Nutrient rich waters rise to the sunlit surface. Western is wet and under low pressure. Strong trade winds
- B. El Niño conditions: conditions reverse (oscillates) Low pressure over eastern Pacific (wet), upwelling ceases. Much rain, mudslides in Peru; forest fires and drought in Indonesia
  - 1. economic problems. Fishing industry devastated; food chain problems, fish die, birds die, carcasses of dead animals on beaches and in water, fishmeal not available for chicken food, switch to soymeal. Prices for chickens and eggs rise. Farmers

switch to plat soy rather than wheat – flour shortages. Western Pacific has crop failures, forest fires, starvation

2. Oscillation takes place every 2 – 7 years. Changes occur in the jet streams which have an impact around the world. Distant impacts are called **"Teleconnections"**

V. Other oscillations

A. Pacific Decadal Oscillation

1. occurs in N. Pacific with 20-30 year oscillation

a. warm phase – unusually warm water over W. Coast of N. America and cold water in the western and central Pacific. The Aleutian low in the strengthens and storms are driven into Alaska and California while in general the rest of the NW Coast is drier than normal. Winters tend to be drier over the Great Lakes and cooler and wetter in the American South. Salmon populations increased in Alaska and diminished in the lower Pacific NW . The last warm phase began in 1977 and continued into mid 1998.

b. The cooler phase have cooler than average surface water along the Coast of N.A. and an area of warmer than normal surface water extends from Japan to the Central North Pacific. Winters over the NW US tend to be cooler and wetter than average, wetter over the great lakes and warmer and dried in the S US. Salmon fishing diminishes in Alaska and picks up along the NW Coast.

B. North Atlantic Oscillation (cycle varies dramatically) This oscillation has an effect on Europe and the East Coast of the US.

1. Positive phase. In the winter, the Icelandic low pressure drops, and in the Bermuda high, rises. The difference between them determines the pressure gradient between them. The greater the pressure gradient difference the stronger the westerlies. These send strong cyclonic storms into northern Europe where winters tend to be wet and mild. In the eastern US the winters tend to be wet and relatively mild, while N. Canada and Greenland tend to be cold and dry.

2. Negative phase: The atmospheric pressure in the Iceland low and environs rises while the Bermuda high weakens. This reduces the pressure gradient and weaker westerlies that steer fewer and weaker winter storms across the Atlantic to Europe. Southern Europe and the Mediterranean area experience wet weather while N Europe is usually cold and dry. The NE Coast of the US is similarly cold and dry and Greenland and N. Canada experience mild winters.

C. Arctic Oscillation: This is closely related to the NAO. In the AO the changes are between atmospheric pressure in the Arctic and the regions to the south. These cause changes in the upper level westerly winds.

1. Positive or warm phase. Strong pressure differences produce strong westerly winds aloft that stop cold Arctic air from traveling into the US, so winters tend to be warmer than usual. With the cold Arctic air fixed in place, Greenland and Newfoundland winters tend to be severe. The strong westerly winds over the Atlantic lead storms into N Europe and with them mild wet weather.

2. The negative phase reverses things. A small pressure difference between the arctic and regions to the south produce weak westerlies aloft. Cold arctic air can penetrate further south producing colder than normal winters over much of the US while Newfoundland and Greenland experience warmer than usual winters.

VI. Air masses. An air mass is an extremely large body of air whose properties of temperature and humidity are fairly similar in any horizontal direction.

A. Source regions are regions where the air masses form with their uniform characteristics.

B. Characteristics:

a. generally flat and of uniform composition with light surface winds

b. The longer the air mass remains in place over the source region, or the longer the path over which it moves, the more likely it will pick up the characteristics of the surface below.

c. Ideal source regions are usually dominated by high surface pressure (snow and ice covered arctic plains in winter and warm subtropical oceans in summer).

d. The middle latitudes are poor for this because temperature and moisture vary considerably. The middle latitudes are transition zones and are not good source regions. Air masses tend to interact in this area.

C. Classification:

m=maritime
c= continental
P=Polar
T=Tropical
A= Arctic region
By combining these one can get:
cA
cP
cT
mP
mT

D. When the cold dry air moves across relatively warm bodies of water like the Great Lakes, heavy snow showers may form called Lake–Effect snows, usually on the downwind side of the lakes.

E. Mountain ranges tend to change the nature of the air mass either by blocking it as often happens with the Rockies, or by causing compressional warming when the air mass moved over the mountain and warms and compresses as it descends.

F. Fronts are regions of transition between air masses.

1. Stationary fronts occur when two air masses. In mid latitudes, warm tropical air might be immediately adjacent to cold polar air and there is little movement.

2. Cold fronts form where cold air moves into warmer air. Cold fronts are characterized by a sharp contrast in temperature and moisture. The wind direction shifts abruptly from the cold to warm air (a pressure trough). He sharp turn in isobars is good guidance to the position of the cold front on the weather map. Cold fronts are usually narrow and appear with clouds and precipitation, typically the convective types. Note the position of the clouds and showers relative to the front as warm air is undermined by the cold front. Warm air forced up produces clouds which produce showers across the front.

3. Warm fronts are located where warm air moves into cooler air, The pressure trough and wind shift are usually not as pronounced at the warm front as the cold. The pressure trough is still a good indication of the location of the front.
Warm fronts move more slowly than cold fronts. It overruns the cold air and being warmer moves over it. A cold front coming behind the warm wedges underneath and displaces it easily because of the cold having a greater density.

The section between the 2 fronts is called the "warm sector". This often shrinks in time as the cold front moves quicker. As warm air moves over the cold air clouds form with precipitation with a more extensive area.

4. Occluded fronts these occur when an advancing cold front catches up to a warm front.

VII. Mid-latitude cyclone development

A. Wave cyclone

Weak pressure disturbance appears as warm air starts to move poleward and upward, while cold air is moving toward the equator.(a) Convergence and upward motion cause clouds to form poleward of the warm front. This is often the first hint on radar.

B. Deepening cyclone

The central pressure falls and the low is now delimited by several closed isobars (b) Cold and warm fronts are far apart and warm sector is broad.

C. Mature cyclone

Fully developed with well-defined cold and warm fronts with a relatively low central pressure (c) with easily recognizable comma shape cloud band

D. Occluded stage

Cold air wraps around the central low which becomes isolated as the warm (d) sector is separated from the center. Only a small bit left along the occluded front.

E. Decaying stage

The cyclone decays as the air column fills in and the central pressure increase. Clouds are there but dissipate

F. The whole cycle may take 2 – 6 days depending on the time of the year, mid-latitude temperature gradients and other environmental conditions.

VIII. The vertical structure of the cyclone

A. The pressure minimum is not found vertically, but rather slopes toward the west.

B. If a surface cyclone is to deepen, it needs to be under the area of upper level divergence, which is East of the trough. As the upper air moves without friction it moves the trough over the low and the region of upper level divergence moves further east and the tilt moves east. The converging air no longer has an upper level outlet and convergence now adds air mass to the air column increasing the pressure. "The Low Fills In"

C. This double pattern of convergence/divergence has two major effects:

1. Net convergence adds to the air column causing the pressure below to rise. Net divergence however removes air from the column causing pressure to fall.
2. Air cannot accumulate indefinitely so air must move in a new direction. At 300 hPa we are at the tropopause and there is a strong temperature inversion and stable stratospheric air blocking upward movement so the air sinks downward. The region of convergence becomes a region of subsidence as well as rising surface pressure. Diverging air is replaced by air rising from below and is a region of upward motion as well as falling surface pressure.

D. Upper level divergence is necessary for the mid-latitude cycle to develop, but it isn't enough. If the atmosphere is too stable, it resists upward movement even with the upper level divergence. So these cyclones need relatively weak atmospheric stability where the incipient low is forming. This is why we find cyclones having a tendency to develop over the oceans, where during winter the relatively warm water heats the air near the surface which produces weak stability.

E. Basically the mid-latitude cyclone has exchanged warm and cold air across the mid latitude temperature gradient which results in a net flow of heat toward the poles.