Unit #6 ES 100 lecture outline and related internet links.

For this unit read chapters 18, 19, and 20. Start with the chapter summaries. Learn the key terms and answer the review questions. The readings are required before class. The lectures and films augment and clarify the readings. The ends of chapter questions are in order of the material presented in the text. The CD Rom at the back of the book has additional material to help you.

Chapter #18 Air Pressure and Wind Objectives:

After reading, studying, and discussing Chapter 18, you should be able to:

- Describe air pressure, how it is measured, and how it changes with altitude.
- Explain how the pressure gradient force, Coriolis effect, and friction influence wind.
- Describe the movements of air associated with the two types of pressure centers.
- Describe the idealized global patterns of pressure and wind.
- Discuss the general atmospheric circulation in the mid-latitudes.
- List the names and causes of the major local winds.
- Describe El Niño/La Niña and the global distribution of precipitation.

Outline:

I. Atmospheric pressure
  A. Force exerted by the weight of the air above
  B. Weight of the air at sea level
    1. 14.7 pounds per square inch
    2. 1 kilogram per square centimeter
  C. Decreases with increasing altitude
  D. Units of measurement
    1. Millibar (mb) – standard sea level pressure is 1013.2 mb
    2. Inches of mercury – standard sea level pressure is 29.92 inches of mercury
  E. Instruments for measuring
    1. Barometer
      a. Mercury barometer
        1. Invented by Torricelli in 1643
        2. Uses a glass tube filled with mercury
      b. Aneroid barometer
        1. "Without liquid"
        2. Uses an expanding chamber
    2. Barograph (continuously records the air pressure)

II. Wind
  A. Horizontal movement of air
    1. Out of areas of high pressure
    2. Into areas of low pressure
  B. Controls of wind
    1. Pressure gradient force
      a. Isobars – lines of equal air pressure
      b. Pressure gradient – pressure change over distance

2. Coriolis effect
    a. Apparent deflection in the wind direction due to Earth's rotation
    b. Deflection is
        1. To the right in the Northern Hemisphere
        2. To left in the Southern Hemisphere
3. Friction
    a. Only important near the surface
    b. Acts to slow the air's movement

C. Upper air winds
1. Generally blow parallel to isobars – called geostrophic winds
2. Jet stream
    a. "River" of air
    b. High altitude
    c. High velocity (120-240 kilometers per hour

III. Cyclones and anticyclones

A. Cyclone
1. A center of low pressure
2. Pressure decreases toward the center
3. Winds associated with
    a. In the Northern Hemisphere
        1. Inward (convergence)
        2. Counterclockwise
    b. In the Southern Hemisphere
        1. Inward (convergence)
        2. Clockwise
4. Associated with rising air
5. Often bring clouds and precipitation

B. Anticyclone
1. A center of high pressure
2. Pressure increases toward the center
3. Winds associated with
    a. In the Northern Hemisphere
        1. Outward (divergence)
        2. Clockwise
    b. In the Southern Hemisphere
        1. Outward (divergence)
        2. Counterclockwise
4. Associated with subsiding air
5. Usually bring "fair" weather

IV. General atmospheric circulation

A. Underlying cause is unequal surface heating
B. On the rotating Earth there are three pairs of atmospheric cells that redistribute the heat
C. Idealized global circulation
1. Equatorial low pressure zone
    a. Rising air
    b. Abundant precipitation
2. Subtropical high pressure zone
    a. Subsiding, stable, dry air
    b. Near 30 degrees latitude

c. Location of great deserts
d. Air traveling equatorward from the subtropical high produces the trade winds
e. Air traveling poleward from the subtropical high produces the westerly winds

3. Subpolar low pressure zone
a. Warm and cool winds interact
b. Polar front – an area of storms

4. Polar high pressure zone
a. Cold, subsiding air
b. Air spreads equatorward and produces polar easterly winds
c. Polar easterlies collide with the westerlies along the polar front

D. Influence of continents
1. Seasonal temperature differences disrupt the
a. Global pressure patterns
b. Global wind patterns

2. Influence is most obvious in the Northern Hemisphere

3. Monsoon
a. Seasonal change in wind direction
b. Occur over continents
1. During warm months
a. Air flows onto land
b. Warm, moist air from the ocean

2. Winter months
a. Air flows off the land
b. Dry, continental air

V. Circulation in the mid-latitudes
A. The zone of the westerlies
B. Complex
C. Air flow is interrupted by cyclones
1. Cells move west to east in the Northern Hemisphere
2. Create anticyclonic and cyclonic flow
3. Paths of the cyclones and anticyclones are associated with the upper-level airflow

VI. Local winds
A. Produced from temperature differences
B. Small scale winds
C. Types
1. Land and sea breezes
2. Mountain and valley breezes
3. Chinook and Santa Ana winds

VII. Wind measurement
A. Two basic measurements
1. Direction
2. Speed

B. Direction
1. Winds are labeled from where they originate (e.g., North wind – blows from the north toward the south)

2. Instrument for measuring wind direction is the wind vane

3. Direction indicated by either
a. Compass points (N, NE, etc.)
b. Scale of 0° to 360°

4. Prevailing wind comes more often from one direction

C. Speed – often measured with a cup anemometer

D. Changes in wind direction

1. Associated with locations of
   a. Cyclones
   b. Anticyclones
2. Often bring changes in
   a. Temperature
   b. Moisture conditions

VIII. El Niño and La Niña

A. El Niño

1. A countercurrent that flows southward along the coasts of Ecuador and Peru
   a. Warm
   b. Usually appears during the Christmas season
   c. Blocks upwelling of colder, nutrient-filled water, and anchovies starve from lack of food
2. Strongest El Niño events on record occurred between 1982-83 and 1997-98
3. 1997-98 event caused
   a. Heavy rains in Ecuador and Peru
   b. Ferocious storms in California
4. Related to large-scale atmospheric circulation
   a. Pressure changed between the eastern and western Pacific called the Southern Oscillation
   b. Changes in trade winds creates a major change in the equatorial current system, with warm water flowing eastward
   5. Effects are highly variable depending in part on the temperatures and size of the warm water pools

B. La Niña

1. Opposite of El Niño
2. Triggered by colder than average surface temperatures in the eastern Pacific
3. Typical La Niña winter
   a. Blows colder than normal air over the Pacific Northwest and northern Great Plains while warming much of the rest of the United States
   b. Greater precipitation is expected in the Northwest

C. Events associated with El Niño and La Niña are now understood to have a significant influence on the state of weather and climate almost everywhere

IX. Global distribution of precipitation

A. Relatively complex pattern

B. Related to global wind and pressure patterns

1. High pressure regions
   a. Subsiding air
   b. Divergent winds
   c. Dry conditions
   d. e.g., Sahara and Kalahari deserts
2. Low pressure regions
   a. Ascending air
   b. Converging winds
   c. Ample precipitation
   d. e.g., Amazon and Congo basins

C. Related to distribution of land and water
1. Large landmasses in the middle latitudes often have less precipitation toward their centers
2. Mountain barriers also alter precipitation patterns
a. Windward slopes receive abundant rainfall from orographic lifting
b. Leeward slopes are usually deficient in

Chapter #19 Weather patterns and Severe Storms
Objectives:

After reading, studying, and discussing Chapter 19, you should be able to:

- Explain what an air mass is.
- Describe how air masses are classified.
- Describe the general weather associated with each air mass type.
- Discuss the differences between warm fronts and cold fronts.
- Describe the primary mid-latitude weather producing systems.
- List the atmospheric conditions that produce thunderstorms, tornadoes, and hurricanes.

Outline:
I. Air masses
A. Characteristics
1. Large body of air
a. 1600 km (1000 mi.) or more across
b. Perhaps several kilometers thick
2. Similar temperature at any given altitude
3. Similar moisture at any given altitude
4. Move and affect a large portion of a continent
B. Source region – the area where an air mass acquires its properties
C. Classification of air an mass
1. Two criteria are used to classify air masses
a. By the latitude of the source region
1. Polar (P)
a. High latitudes
b. Cold
2. Tropical (T)
a. Low latitudes
b. Warm
b. By the nature of the surface in the source region
1. Continental (c)
a. Form over land
b. Likely to be dry
2. Maritime (m)
a. Originate over water
b. Humid air
2. Four basic types of air masses
a. Continental polar (cP)
b. Continental tropical (cT)
c. Maritime polar (mP)
d. Maritime tropical (mT)

D. Air masses and weather
1. cP and mT air masses are the most important air masses in North America, especially east of the Rockies
2. North America (east of the Rocky Mountains)
a. Continental polar (cP)
1. From northern Canada and interior of Alaska
a. Winter – brings cold, dry air
b. Summer – brings cool relief
2. Responsible for lake-effect snows
a. cP air mass crosses the Great Lakes
b. Air picks up moisture from the lakes
c. Snow occurs on the leeward shores of the lakes
b. Maritime tropical (mT)
1. From the Gulf of Mexico and the Atlantic Ocean
2. Warm, moist, unstable air
3. Brings precipitation to the eastern United States
3. Continental tropical (cT)
a. Southwest and Mexico
b. Hot, dry
c. Seldom important outside the source region
4. Maritime polar (mP)
a. Brings precipitation to the western mountains
b. Occasional influence in the northeastern United States causes the "Northeaster" in New England with its cold temperatures and snow

II. Fronts
A. Boundary that separates air masses of different densities
1. Air masses retain their identities
2. Warmer, less dense air forced aloft
3. Cooler, denser air acts as wedge
B. Types of fronts
1. Warm front
a. Warm air replaces cooler air
b. Shown on a map by a line with semicircles
c. Small slope (1:200)
d. Clouds become lower as the front nears
e. Slow rate of advance
f. Light-to-moderate precipitation
g. Gradual temperature increase with the passage of the front
2. Cold front
a. Cold air replaces warm air
b. Shown on a map by a line with triangles
c. Twice as steep (1:100) as warm fronts
d. Advances faster than a warm front
e. Associated weather is more violent than a warm front
1. Intensity of precipitation is greater
2. Duration of precipitation is shorter
f. Weather behind the front is dominated by
1. Cold air mass
2. Subsiding air
3. Clearing conditions

3. Stationary front
    a. Flow of air on both sides of the front is almost parallel to the line of the front
    b. Surface position of the front does not move
4. Occluded front
    a. Active cold front overtakes a warm front
    b. Cold air wedges the warm air upward
    c. Weather is often complex
    d. Precipitation is associated with warm air being forced aloft

III. Middle-latitude cyclone
A. Primary weather producer in the middle-latitudes
B. Life cycle
1. Form along a front where air masses are moving parallel to the front in opposite directions
    a. Continental polar (cP) air is often north of the front
    b. Maritime tropical (mT) air is often south of the front
2. Frontal surface takes on a wave shape with low pressure centered at the apex of the wave
3. Flow of air is counterclockwise cyclonic circulation
3. Warm front and cold front form
4. Cold front catches up to warm front and produces an occlusion
5. Warm sector is displaced aloft
6. Pressure gradient weakens and fronts discontinue
7. Storm comes to an end
C. Idealized weather
1. Middle-latitude cyclones move eastward across the United States
    a. First signs of their approach are in the western sky
    b. Require two to four days to pass over a region
2. Largest weather contrasts occur in the spring
3. Changes in weather associated with the passage of a middle-latitude cyclone
    a. Changes depend on the path of the storm
    b. Weather associated with fronts
        1. Warm front
            a. Clouds become lower and thicker
            b. Light precipitation
            c. After the passage of a warm front
                1. Winds become more southerly
                2. After passing, warmer temperature is experienced (mT air mass)
        2. Cold front
            a. Wall of dark clouds
            b. Heavy precipitation
                1. Hail
                2. Occasional tornadoes
            c. After the passage of a cold front
                1. Wind becomes north to northwest
                2. Drop in temperature as a cP air mass moves in
                3. Clearing skies
D. Role of airflow aloft
1. Cyclones and anticyclones
    a. Generated by upper-level air flow
    b. Maintained by upper-level air flow
    c. Typically are found adjacent to one another

2. Cyclone
    a. Low pressure system
    b. Surface convergence
    c. Outflow (divergence) aloft sustains the low pressure
3. Anticyclone
    a. High pressure system
    b. Associated with cyclones
    c. Surface divergence
    d. Convergence aloft

IV. Severe weather types
A. Thunderstorms
1. Features
    a. Cumulonimbus clouds
    b. Heavy rainfall
    c. Lightning
    d. Occasional hail
2. Occurrence
    a. 2000 in progress at any one time
    b. 100,000 per year in the United States
    c. Most frequent in
        1. Florida
        2. Eastern Gulf Coast region
3. Stages of development
    a. All thunderstorms require
        1. Warm air
        2. Moist air
        3. Instability (lifting)
            a. High surface temperatures
            b. Most common in the afternoon and early evening
    b. Require continuous supply of warm air and moisture
        1. Each surge causes air to rise higher
        2. Updrafts and downdrafts form
    c. Eventually precipitation forms
        1. Most active stage
        2. Gusty winds, lightning, hail
        3. Heavy precipitation
    d. Cooling effect of precipitation marks the end of thunderstorm activity
B. Tornadoes
1. Local storm of short duration
2. Features
    a. Violent windstorm
    b. Rotating column of air that extends down from a cumulonimbus cloud
    c. Low pressures inside causes the air to rush into
    d. Winds approach 480 km (300 miles) per hour
    e. Smaller suction vortices can form inside stronger tornadoes
3. Occurrence and development
    a. Average of 770 each year in the United States
    b. Most frequent from April through June
    c. Associated with severe thunderstorms
    d. Exact cause of tornadoes formation is not known

e. Conditions for the formation of tornadoes
1. Occur most often along a cold front
2. During the spring months
3. Associated with huge thunderstorms called supercells

4. Characteristics
a. Diameter between 150 and 600 meters (500 and 2000 feet)
b. Speed across landscape is about 45 kilometers (30 miles) per hour
c. Cut about a 10 km (6 miles) long path
d. Most move toward the northeast
e. Maximum winds range beyond 500 kilometers (310 miles) per hour
f. Intensity measured by the Fujita intensity scale

5. Tornado forecasting
a. Difficult to forecast because of their small size
b. Tornado watch
1. To alert the public to the possibility of tornadoes
2. Issued when the conditions are favorable
3. Covers 65,000 square km (25,000 square miles)
c. Tornado warning is issued when a tornado is sighted or is indicated by weather radar
d. Use of Doppler radar helps increase the accuracy by detecting the air motion

C. Hurricanes
1. Most violent storms on Earth
2. To be called a hurricane
a. Wind speed in excess of 119 kilometers (74 miles) per hour
b. Rotary cyclonic circulation

3. Profile
a. Form between the latitudes of 5 degrees and 20 degrees
b. Known as
1. Typhoons in the western Pacific
2. Cyclones in the Indian Ocean
c. North Pacific has the greatest number per year
d. Parts of a hurricane
1. Eyewall
a. Near the center
b. Rising air
c. Intense convective activity
d. Wall of cumulonimbus clouds
e. Greatest wind speeds
f. Heaviest rainfall
2. Eye
a. At the very center
b. About 20 km (12.5 miles) diameter
c. Precipitation ceases
d. Winds subsides
e. Air gradually descends and heats by compression
f. Warmest part of the storm
c. Wind speeds reach 300 km/hr
d. Generate 50 foot waves at sea

4. Hurricane formation and decay
a. Form in all tropical waters except the
1. South Atlantic and
2. Eastern South Pacific

b. Energy comes from condensing water vapor
c. Develop most often in late summer when warm water temperatures provide energy and moisture
d. Initial stage is not well understood
1. Tropical depression – winds do not exceed 61 kilometers (38 miles) per hour
2. Tropical storm – winds between 61 to 119 km (38 and 74 miles) per hour
e. Diminish in intensity whenever
1. They move over cooler ocean water
2. They move onto land
3. The large-scale flow aloft is unfavorable

5. Destruction from a hurricane
a. Factors that affect amount of hurricane damage
1. Strength of storm (the most important factor)
2. Size and population density of the area affected
3. Shape of the ocean bottom near the shore
b. Saffir-Simpson scale ranks the relative intensities of hurricanes
c. Categories of hurricane damage
1.Storm surge - large dome of water 65 to 80 kilometers (40 to 50 miles) wide sweeps across the coast where eye makes landfall
2. Wind damage
3. Inland flooding from torrential rains

Chapter 20 Climate Objectives:

After reading, studying, and discussing Chapter 20, you should be able to:

- Explain what is meant by Earth's climate system.
- Discuss the factors that give every location a distinctive climate.
- Describe the Köppen system of climate classification.
- List the five principal climate groups of the Köppen system and describe the criteria used to define each group.
- Describe the location and general characteristics of the principal climate groups.

Outline:

I. The climate system
A. Climate is an aggregate of weather
B. Involves the exchanges of energy and moisture that occur among the
1. Atmosphere
2. Hydrosphere
3. Solid Earth
4. Biosphere, and
5. Cryosphere (ice and snow)

II. World climates
A. Every location has a distinctive climate
B. The most important elements in a climatic description are
1. Temperature, and
2. Precipitation

III. Climate classification
- A. Brings order to large quantities of information
- B. Many climatic-classification systems have been devised
- C. Köppen classification of climates
  1. Best known and most used system
  2. Uses mean monthly and annual values of temperature and precipitation
  3. Divides the world into climatic regions in a realistic way
  4. Boundaries Köppen chose were largely based on the limits of certain plant associations
  5. Five principal climate groups
     - a. Humid tropical (A)
     - b. Dry (B)
     - c. Humid middle-latitude with mild winters (C)
     - d. Humid middle-latitude with severe winters (D)
     - e. Polar (E)
  6. A, C, D, and E climates are defined on the basis of temperature characteristics
  7. Precipitation is the primary criterion for the B group

IV. Köppen climates
- A. Humid tropical (A) climates
  1. Winterless climates, with all months having a mean temperature above 18°C
  2. Two main types
     - a. Wet tropics
       1. High temperatures and year-round rainfall
       2. Luxuriant vegetation (tropical rain forest)
       3. Discontinuous belt astride the equator
       4. Strongly influenced by the equatorial low pressures
     - b. Tropical wet and dry
       1. Poleward of wet tropics and equatorward of the tropical deserts
       2. Tropical grassland (savanna)
       3. Seasonal rainfall
- B. Dry (B) climates
  1. Evaporation exceeds precipitation and there is a constant water deficiency
  2. Boundary determined by formulas involving the three variables
     - a. Average annual precipitation
     - b. Average annual temperature
     - c. Seasonal distribution of precipitation
  3. Two climatic types
     - a. Arid or desert (BW)
     - b. Semiarid or steppe (BS)
       1. More humid than arid climate
       2. Surrounds desert
  4. Causes of deserts and steppes
     - a. In the low latitudes
       1. e.g., North Africa to northwestern India, northern Mexico, southwestern U.S.
       2. Coincide with the dry, stable, subsiding air of the sub-tropical high-pressure belts
     - b. Middle-latitude deserts and steppes
       1. Due to their position in the deep interiors of large landmasses and/or the presence of high mountains
       2. Most are located in the Northern Hemisphere
- C. Humid middle-latitude climates with mild winters (C climates)

1. Average temperature of the coldest month is below 18°C but above -3°C
2. Subgroups
    a. Humid subtropics
        1. Eastern sides of continents
        2. 25 to 40 degree latitude range
        3. Hot, sultry summers
        4. Mild winters
        5. Winter precipitation is generated along fronts
    b. Marine west coast
        1. Western (windward) side of continents
        2. 40 to 65 degrees north and south latitude
        3. Onshore flow of ocean air
        4. Mild winters and cool summers
    c. Dry-summer subtropics
        1. West sides of continents between latitudes 30 and 45
        2. Strong winter rainfall maximum
        3. Often called a Mediterranean climate

D. Humid middle-latitude climates with severe winters (D climates)
    1. Average temperature of the coldest month is below -3°C and the warmest monthly mean exceeds 10°C
2. Land-controlled climates
3. Absent in the Southern Hemisphere
4. Subgroups
    a. Humid continental
        1. Confined to the central and eastern portions of North America and Eurasia between 40 and 50 degrees north latitude
        2. Severe winter and summer temperatures
        3. High annual temperature ranges
        4. Precipitation is generally greater in the summer than in the winter
        5. Snow remains on the ground for extended periods
    b. Subarctic
        1. North of the humid continental climate
        2. Often referred to as the taiga climate
        3. Largest stretch of continuous forests on Earth
        4. Source regions of cP air masses
        5. Frigid winters, remarkably warm but short summers

E. Polar (E) climates
1. Mean temperature of the warmest month is below 10°C
2. Enduring cold
3. Meager precipitation
4. Two types of polar climates
    a. Tundra climate (ET)
        1. Treeless climate
        2. Almost exclusively in the Northern Hemisphere
        4. High annual temperature range
    b. Ice cap climate (EF)
        1. No monthly mean above 0°C
        2. Permanent ice and snow

F. Highland climates
    1. Usually cooler and wetter than adjacent lowlands
    2. Great diversity of climatic conditions
    3. Best described by the terms *variety* and *changeability*

V. Human impact on global climate
  A. Humans have been modifying the environment over extensive areas for thousands of years
      1. By using fire
      2. By overgrazing of marginal lands
  B. Most hypotheses of climatic change are to some degree controversial
  C. Global warming
      1. Water vapor and carbon dioxide absorb heat and are largely responsible for the greenhouse effect of the atmosphere
      2. Burning fossil fuels has added great quantities of carbon dioxide to the atmosphere
  D. The atmosphere response
      1. Global temperatures have increased
          a. Balance of evidence suggests a human influence on global climate
          b. Globally averaged surface temperature is projected to increase by 1.4 to 5.8°C by the year 2100
      2. The role of trace gases
          a. Atmospheric race gasses
              1. Methane
              2. Nitrous oxide
              3. Certain chlorofluorocarbons
          b. Absorb wavelengths of outgoing Earth radiation
          c. Taken together, their warming effects may be nearly as great as carbon dioxide

VI. Climate feed-back mechanisms
  A. Possible outcomes of altering the climate-system
  B. Two types
      1. Positive -feedback mechanisms reinforce the initial change
      2. Negative-feedback mechanisms produce results that are just the opposite of the initial change and tend to offset it

VII. Some possible consequences of global warming
  A. Altered distribution of the world's water resources and the affect on the productivity of agricultural regions
  B. Rise in global mean sea level
  C. Changing weather patterns
      1. Higher frequency and intensity of hurricanes
      2. Shifts in the paths of large-scale cyclonic storms
      3. Changes in frequency and intensity of heat waves and droughts