Major points for today

1. Most weather in the continental US results from interactions between large air masses coming from the tropics and the polar regions.

2. Cold and Warm Fronts are masses of cold and warm air, respectively.

3. Cold fronts are quickly moving masses of cold air that thrust moisture-laden warm air up to form storm clouds.

4. Warm fronts are more slowly moving fronts in which warm air slides up over more dense cold air.

5. Mid latitude cyclones are common in North America and result from a breakout of cold air in the far north.
6. Thunderstorms are caused by rapid uplift of moist air in an unstable atmosphere. They are characterized by strong updrafts and downdrafts.

7. Tropical storms, hurricanes, etc., start as low pressure troughs in easterly trade winds. If conditions are right, they can intensify into massive storms.

8. In the big picture, horizontal winds are all about transferring heat from the equator to the poles; whereas severe storms are all about vertical motion of the atmosphere.
Air Masses
Air Mass Properties

• Air masses take on the properties of the underlying surface
• Air masses are classified according to their location of “origin”
• Geographical Characteristics
  - Tropical (T), Polar (P), Arctic (A)
• Surface Properties
  - Maritime (m), continental
• Source region characteristics most prevalent if air mass remains over source region for a long period
Air Mass Classifications

- cP - continental Polar
  - Cold, dry, stable
  - Extremely cold cP air mass may be designated cA (continental Arctic)
- mP - maritime Polar
  - Cool, moist, unstable
- mT - maritime Tropical
  - Warm, moist, usually unstable
- cT - continental Tropical
  - Hot, dry
  - Stable air aloft, unstable surface air
Air Mass Source Regions

- mP Maritime polar air masses
- cA Arctic air masses
- cP Continental polar air masses
- mT Maritime tropical air masses

summer only
Cold and Warm Fronts
A Front – is the boundary between air masses; normally refers to where this interface intersects the ground (in all cases except stationary fronts, the symbols are placed pointing to the direction of movement of the interface (front)).

Warm Front

Cold Front

Stationary Front

Occluded Front
Two air masses entering a region, such as the U.S. middle latitudes, have a front, or transition zone, between the strong temperature and humidity differences.

Four different fronts are used on weather maps.
Characteristics of Fronts

• Across the front - look for one or more of the following:
  - Change of Temperature
  - Change of Moisture characteristic
    • RH, $T_d$
  - Change of Wind Direction
  - Change in direction of Pressure Gradient
  - Characteristic Precipitation Patterns
How do we decide what kind of front it is?

• If warm air replaces colder air, the front is a warm front
• If cold air replaces warmer air, the front is a cold front
• If the front does not move, it is a stationary front
• Occluded fronts do not intersect the ground; they are a warm air mass held aloft by two cold air masses
Typical Cold Front Structure

- Cold air replaces warm; leading edge is steep in fast-moving front shown below due to friction at the ground
  - Strong **vertical motion and unstable air** forms **cumuliform clouds**
  - Upper level winds blow ice crystals downwind creating **cirrus and cirrostratus**
- Slower moving fronts have less steep boundaries — shallower clouds may form if warm air is stable
Typical Cold Front Structure
Typical Cold Front Structure
Typical Warm Front Structure

• In an advancing warm front, warm air rides up over colder air at the surface; slope is not usually very steep
• Lifting of the warm air produces clouds and precipitation well in advance of boundary
• At different points along the warm/cold air interface, the precipitation will experience different temperature histories as it falls to the ground
Typical Warm Front Structure

- Warm air (stable)
- Cool air
- Surface front
- Nimbostratus
- Altostratus
- Cirrostratus
- Cirrus
Cirrostratus

Cirrostratus with Halo

--- Photograph by Robert M. Rauber ---
--- U. of Illinois Cloud Catalog ---
Altostratus

Alto Stratus Castellanus
Midlatitude Cyclones
Hemispheric westerlies typically organized into 4-6 “long waves”
The Wave Cyclone Model
(Norwegian model)

- **Stationary Front**  > nothing happening
- **Nascent Stage**    > a blip becomes a wave
- **Mature Stage**     > cold front races after the warm front
- **Partially Occluded Stage** > cold front catches up with cold front
- **Occluded Stage**   > warm front pushed up by the cold fronts
- **Dissipated Stage** > nothing more to see here folks. All the latent energy has been expended
Lifecyle of a Midlatitude Cyclone

Green shading indicates precipitation.

Takes several days to a week, and moves 1000's of km during lifecycle.
Weather Changes Associated with Wave Cyclones

Figure 6.10, p. 193
48 hr forecast valid 1200 UTC Sun 27 Apr 2008
500 mb Heights (dm) / Isotachs (knots)

12-hour forecast valid 0900 UTC Sat 26 Apr 2008

RUC (21z 25 Apr)
200 mb Heights (dm) / Isotachs (knots)

12-hour forecast valid 0900 UTC Sat 26 Apr 2008

RUC (21z 25 Apr)
Integrated liquid and frozen hydrometeors (all levels)

12-hour forecast valid 0900 UTC Sat 26 Apr 2008

RUC2 model (21z 25 Apr)
• Wave cyclones tend to form in certain areas and travel common paths

• Mid-latitude wave cyclones tend to travel eastward

• Tropical cyclones tend to move westward

Figure 6.11, p. 194
200 mb Heights (dm) / Isotachs (knots)

0-hour analysis valid 1200 UTC Wed 03 Feb 2010

RUC (12z 03 Feb)
Severe Weather
Three Stages of Thunderstorm Development

- Cumulus Stage
- Mature Stage
- Dissipating Stage
The diagram illustrates the stages of cloud development:

1. **Cumulus**
   - Characterized by small, white clouds with upward moving air currents.
   - Represents temperatures around 0°C (-32°F).
   - Model represents clouds with warm air rising and cool air descending.

2. **Mature**
   - Clouds become larger and darker with a mix of upward and downward air currents.
   - Represents changes in air temperature.
   - Model shows a complex interaction of warm and cool air.

3. **Dissipating**
   - Clouds begin to break up with extensive downward currents.
   - Represents colder temperatures.
   - Model shows the dispersal of cloud mass with a focus on cooling.

The diagram captures the dynamic nature of clouds, emphasizing the transition from warmer to colder conditions and the associated changes in air movement.
Severe Thunderstorms

Figure 15.5
Severe Thunderstorm Structure

- Tropopause
- Overshooting top
- Mammmatus
- Anvil
- Wind
- Rain
- Hail

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Turbulence in the fast moving gust front will spawn eddies and possibly roll clouds beneath the shelf cloud.

These clouds spin about a horizontal axis near the ground.
Downbursts

- Can reach wind speeds of ~200 km/hr.
- Damage to forests and man made structures.
- Impacts on aviation.
Tornadoes

appear as dark funnel cloud hanging down from cumulonimbus clouds

Wind speeds may be as high as 100 meters per second (225 miles per hour)

Cause great damage
“Mesocyclone” of rotating winds formed by tilting of horizontal vorticity upwards
Tornadoes

a small but very intense cyclonic vortex in which air spins at a tremendous speed associated with thunderstorms spawned by fronts in mid-latitude regions of North America

Figure 6.14, p. 196
Tropical Cyclones

Hurricanes (western hemisphere) and typhoons (western Pacific in Asia) and cyclone in Indian Ocean

Develop over warm ocean surfaces between $8^\circ$ and $15^\circ$ latitude, migrate westward and curve toward the poles

Tropical cyclones often create tremendous damage due to high winds, high waves, flooding (storm surges) and heavy rains
Easterly Waves

A simple form of tropical weather system is a slow moving trough of low pressure within the tropical easterly wind belts (trades)

Figure 6.16, p. 197
Hurricanes

the most powerful and destructive tropical cyclone in the western hemisphere

Figure 6.17, p. 200
Hurricanes

characteristic central “eye” (clear skies and calm winds) air descends from high altitudes, warming wind speeds are highest at the “eye wall” winds spiral outward creating high wind speeds

Figure 6.18, p. 200
Simpson-Saffir Scale of Tropical Cyclone Intensity

Categories 1 to 5 (5 is the most intense and devastating)

categorized by central pressure, storm surge wave height and mean wind speed
## Simpson-Saffir Scale of Tropical Cyclone Intensity

<table>
<thead>
<tr>
<th>Category</th>
<th>Central Pressure (mb)</th>
<th>Storm Surge (m)</th>
<th>Wind Speed (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Weak</td>
<td>&gt; 980</td>
<td>1.2-1.7</td>
<td>33-42</td>
</tr>
<tr>
<td>2. Moderate</td>
<td>965-979</td>
<td>1.8-2.6</td>
<td>43-49</td>
</tr>
<tr>
<td>3. Strong</td>
<td>945-964</td>
<td>2.7-3.8</td>
<td>50-58</td>
</tr>
<tr>
<td>4. Very Strong</td>
<td>920-944</td>
<td>3.9-5.6</td>
<td>59-69</td>
</tr>
<tr>
<td>5. Devastating</td>
<td>&lt;920</td>
<td>&gt;5.6</td>
<td>&gt;69</td>
</tr>
</tbody>
</table>

Table 6.2, p. 201
Eye on the Landscape

Hurricane Ivan heading for the Florida panhandle on September 15, 2004, as observed by GOES-12. Ivan, joined by Charley, Frances, and Jeanne, was one of four hurricanes to make landfall in the state of Florida in 2004. What else would the geographer see? ... Answers at the end of the chapter.
Folly Beach, South Carolina (Before Hugo)
Folly Beach, South Carolina (After Hugo)
Impact of Tropical Cyclones

low pressure, high winds and the shape of bays can produce sudden rise in water level (storm surge)

flooding may occur inland

activity varies from year to year (number and strength)

season usually from May to November in the south Atlantic region
The atmospheric circulation

the atmospheric circulation transfers heat from equatorial regions toward the polar regions by:

the Hadley cell circulation,

air mass movement

Rossby waves

tropical cyclones
The Atmospheric Circulation

Figure 6.21, p. 205
The “Big Picture”

• We’ve emphasized horizontal transport of energy to balance the planetary energy budget:
  - Hadley Cell
  - Subtropical divergence
  - Midlatitude cyclones and conveyor belts

• What about vertical motion?
  - “Up-warm, down cold”
  - “Up moist, down-dry”

• Severe weather is all about vertical motion, and represents local release of energy that contributes to planetary energy balance