

Chapter 7: Transient Atmospheric Flows and Disturbances

CHAPTER OUTLINE

I. The Impact of Storms on the Landscape

- A. Storms are phenomena that are more limited than the broad-scale wind and pressure systems.
 - 1. They are transient and temporary.
- B. Storms involve the flow of air masses as well as a variety of atmospheric disturbances.
- C. They have short-run and long-run impacts.
 - 1. In some parts of world, have major influence on weather, some on climate.
 - 2. Long-run includes both positive and negative impacts on landscape.
 - a) Positive: promote diversity in vegetative cover, increase size of lakes and ponds, and stimulate plant growth.

II. Air Masses

- A. **Air mass**—a large parcel of air that has relatively uniform properties in the horizontal dimension and moves as an entity. Such extensive bodies are distinct from one another and compose the troposphere.
- B. *Characteristics*
 - 1. Air mass must meet three requirements:
 - a) Must be large (horizontal and vertical).
 - b) Horizontal dimension must have uniform properties (temperature, humidity, and stability).
 - c) Must be distinct from surrounding air, and when moves, must retain that distinction (not be torn apart).
- C. *Origin*
 - 1. Formation occurs if air remains over a uniform land or sea surface long enough to acquire uniform properties.
 - a) **Source regions**—parts of Earth's surface that are particularly suited to generate air masses because they are
 - (1) Extensive
 - (2) Physically uniform
 - (3) Associated with air that is stationary or anticyclonic.
- D. *Classification*
 - 1. Because source region determines properties of air masses, it is the basis for classifying them.
 - 2. Use a one- or two-letter code.
 - 3. Table 7-1 provides a simplified classification of air masses, along with the properties associated with each.
- E. *Movement and Modification*
 - 1. Some air masses remain in source region indefinitely.
 - 2. Movement prompts structural change:
 - a) Thermal modification—heating or cooling from below;
 - b) Dynamic modification—uplift, subsidence, convergence, turbulence;
 - c) Moisture modification—addition or subtraction of moisture.
 - 3. Moving air mass modifies the weather of region it moves through.
- F. *North American Air Masses*
 - 1. Physical geography of U.S. landscape plays a critical role in air-mass interaction.
 - a) No east-west mountains to block polar and tropical air flows, so they affect U.S. weather/climate.
 - b) North-south mountain ranges in west modify the movement, therefore the characteristics, of Pacific air masses.

2. Maritime tropical (mT) air from the Atlantic, Caribbean/Gulf of Mexico strongly influences climate east of the Rockies in the United States, southern Canada, and much of Mexico.
 - a) Primary source of precipitation. Also brings periods of uncomfortable humid heat in summer.
3. Continental tropical (cT) air has insignificant influence on North America, except for bringing occasional heat waves and drought conditions to the southern Great Plains.
4. Equatorial (E) air affects North America only through hurricanes.

III. Fronts

- A. **Front**—a zone of discontinuity between unlike air masses where properties of air change rapidly.
 1. It's narrow but three-dimensional.
 2. Typically several kilometers wide (even tens of kilometers wide).
 3. Functions as a barrier between two air masses, preventing their mingling except in this narrow transition zone.
 4. Though all primary physical properties are involved in a front, temperature provides the most conspicuous difference.
 5. Fronts lean, which allows air masses to be uplifted and adiabatic cooling to take place.
 - a) Lean so much, closer to horizontal than vertical.
 - (1) Always slopes so that warmer air overlies cooler air.
 6. Fronts move in association with the direction of the more active air mass, which displaces the less active.
- B. *Warm Fronts*
 1. **Warm Front**—the leading edge of an advancing warm air mass.
 - a) Brings warm air.
 - b) Results in clouds and precipitation, usually broad, protracted, and gentle, without much convective activity.
 - c) Unstable rising air can result in showery and even violent precipitation.
 - d) Weather maps show ground-level position of warm front; precipitation usually falls ahead of this position.
- C. *Cold Fronts*
 1. **Cold Front**—the leading edge of a cool air mass actively displacing warm air mass.
 - a) Brings cold air.
 - b) Leads to rapid lifting of warm air, which makes it unstable and thus results in blustery and violent weather along cold front.
 - c) Weather maps show ground-level position of cold front (usually has a protruding "nose"); clouds and precipitation tend to be concentrated along and immediately behind the ground-level position.
- D. *Stationary Fronts*
 1. **Stationary Front**—the common "boundary" between two air masses in a situation in which neither air mass displaces the other.
- E. *Occluded Front*
 1. **Occluded Front**—a complex front formed when a cold front overtakes a warm front.

IV. Atmospheric Disturbances

- A. Two types of disturbances: stormy and calm.
- B. Both types have common characteristics:
 1. Smaller than components of general circulation, but extremely variable in size;
 2. Migratory and transient;
 3. Relatively brief in duration;
 4. Produce characteristic and relatively predictable weather conditions.

C. *Major Midlatitude Disturbances*

1. Many kinds of atmospheric disturbances are associated with midlatitudes, which are principal battleground for tropospheric phenomena.
2. Midlatitude cyclones and midlatitude anticyclones are more significant because of size and prevalence.

V. **Midlatitude Cyclones**

1. **Midlatitude cyclone**—large migratory low-pressure system that occurs within the middle latitudes and moves generally with the westerlies; also called lows or wave cyclones, depressions.
 - a) Probably most significant of all atmospheric disturbances.
 - b) Basically responsible for most day-to-day weather changes.
 - c) Bring precipitation to much of the world's populated regions.
2. Characteristics
 - a) Typical mature midlatitude cycle is 1,600 kilometers (1,000 miles) in diameter; has oval shape.
 - b) Patterns of isobars, fronts, and wind flow in Southern Hemisphere are mirror images of those in Northern Hemisphere.
 - (1) In Northern Hemisphere:
 - (a) Circulation pattern converges counterclockwise;
 - (b) Wind-flow pattern attracts cool air from north and warm air from south; creates two fronts.
 - (i) These two fronts divide the cyclone into a cool sector north and west of center and a warm sector south and east.
 - (a) Size of sectors varies with location: on ground, cool sector is larger, but in atmosphere, warm sector is more extensive.
 - (ii) Warm air rises along both fronts, causing cloudiness and precipitation, which follows patterns of cold and warm fronts.
 - (iii) Much of cool sector is typified by clear, cold, stable air, while air of warm sector is often moist and tending toward instability, so may have sporadic thunderstorms. May have squall fronts of intense thunderstorms.
3. Movements
 - a) Midlatitude cyclones move throughout their existence.
4. Lifecycle
 - a) Origin to maturity typically takes 3 to 6 days, then another 3 to 6 days to dissipate.
 - b) Cyclogenesis—birth of cyclones.
 - c) Most common cause believed to be upper-air conditions in the vicinity of the polar-front jet stream.
 - d) Most begin as waves along the polar front.
 - e) Cyclogenesis can also occur on the leeward side of mountains,
 - f) Often bring heavy rain or snowstorms to the northeastern United States and southeastern Canada.
 - g) After cyclonic circulation is well developed, occlusion begins.
 - h) After occluded front is fully developed, cyclone dissipates.
5. Occurrence and Distribution
 - a) Occur at scattered but irregular intervals throughout the zone of the westerlies.
 - b) Route of cyclone is likely to be undulating and erratic, but it generally moves west to east.

VI. **Midlatitude Anticyclones**

1. **Midlatitude anticyclone**—an extensive migratory high-pressure cell of the midlatitudes that moves generally with the westerlies.
 - a) Typically larger than a midlatitude cyclone, but also moves west to east.
 - b) Travels at same rate, or little slower, than midlatitude cyclone.
 - (1) Is prone to stagnate or remain over same region (while cyclones do not).
 - (a) Can cause concentration of air pollutants.
2. Cyclones and anticyclones alternate with one another in an irregular sequence.
 - a) Often a functional relationship between the two.
 - (1) Can visualize anticyclone as a polar air mass with the cold front of cyclone as its leading edge.

VII. Major Tropical Disturbances: Hurricanes

1. **Tropical cyclone**—a storm most significantly affecting the tropics and subtropics, which is intense, revolving, rain-drenched, migratory, destructive, and erratic. Such a storm system consists of a prominent low-pressure center that is essentially circular in shape and has a steep pressure gradient outward from the center.
 - a) Tropical cyclones provide the only break in weather in low latitudes.
 - b) Also called:
 - (1) **Hurricanes** in North and Central America
 - (2) **Typhoons** in western North Pacific
 - (3) **Baguios** in Philippines
 - (4) **Tropical cyclones** in Indian Ocean and Australia
2. **Eye**—the nonstormy center of a tropical cyclone, which has a diameter of 16 to 40 kilometers (10 to 25 miles). In the eye, there are no updrafts, but instead a downdraft that inhibits cloud formation.
3. **Eye wall**—peripheral zone at the edge of the eye where winds reach their highest speed and where updrafts are most prominent.
4. **Eyewall replacement**—the process in which a new wall of storms surrounds the wall of storms circling the hurricane's eye. When this occurs, the inner wall disintegrates so the new wall replaces it. This process tends to weaken the storm.
5. **Origin**
 - a) Form only over warm oceans.
 - b) Coriolis effect plays key role: it's at minimum at equator, and no hurricane has been observed to form within 3° of equator or cross over it.
 - (1) Rare to have hurricane closer than 8° to 10° of equator.
 - c) The exact mechanism of formation is not clear, but they always grow from some preexisting disturbance.
 - (1) Tropical depression—winds of 33 knots (61 kilometers or 38 miles per hour) or less.
 - (2) Tropical storm—winds between 34 and 63 knots ([63 and 117 kilometers] or [39 and 73 miles per hour]).
 - (3) Hurricane—winds of 64 knots (119 kilometers or 74 miles per hour) or more; can double and even triple that minimum.
6. **Movement**
 - a) Most common in North Pacific basin (origination in Philippines and west of southern Mexico and Central America):
 - (1) West central portion of the North Atlantic basin, extending into Caribbean and Gulf of Mexico is third in prevalence.
 - (2) Totally absent from the South Atlantic and from the southeastern part of the Pacific.
 - (a) Absent apparently because the water is too cold and because high pressure dominates.
 - b) General pattern of movement is highly predictable:

- (1) About one-third travel east to west without much latitudinal change.
 - (2) About two-thirds start off on an east–west path and then curve poleward.
 - (a) Exception occurs in southwestern Pacific Ocean north and northeast of New Zealand, where general circulation pattern steers hurricanes, so they travel west to east.
 - (3) Average hurricane lasts a week; those that remain over tropical oceans can live up to 4 weeks.
 - (a) Dies down over continents because energy source of warm, moist air is cut off.
 - (b) Dies down in midlatitudes because cooler environment.
 - (i) In midlatitudes, can diminish in intensity but grow in size and become a midlatitude cyclone.
7. Damage and Destruction
- a) High seas cause the most damage.
 - b) Storm size is key to how much damage is caused, then physical configuration of landscape and population size and density of affected area.

VIII. Localized Atmospheric Disturbances

1. Occur on a more localized scale than do tropical and midlatitude cyclones an anticyclone.
 - a) **Easterly wave**—a long but weak migratory low-pressure system in the tropics between 5° and 30° of latitude.
 - (1) Sometimes intensify into hurricanes.
 - (2) Bring characteristic weather of trade winds with them.
 - b) **Thunderstorm**—violent convective storm accompanied by thunder and lightning; usually localized and short lived.
 - (1) Vertical air motion, considerable humidity, and instability combine to create towering cumulonimbus clouds, so thunderstorms are always associated with this combination.
 - (2) Frequently occur in conjunction with other kinds of storms (hurricanes, tornadoes, fronts [especially cold fronts]) in midlatitude cyclones, and orographic lifting.
 - (3) Associated with other mechanisms that can trigger unstable uplift.
 - (a) Mechanism triggers uplift of warm, moist air.
 - (b) Cumulus stage—updrafts prevail and clouds grow. Rise to above freezing level, where supercooled water droplets and ice crystals coalesce, then fall. Initiate a downdraft.
 - (c) Mature state—updrafts and downdrafts coexist as cloud continues to enlarge (but precipitation is leaving bottom of cloud). Most active time.
 - (d) Dissipating state—downdrafts dominate, and turbulence ceases.
 - (4) Virtually unknown poleward of 60° of latitude.
 - c) **Tornado**—a localized cyclonic low-pressure cell surrounded by a whirling cylinder of wind spinning so violently that partial vacuum develops within the funnel.
 - (1) Has the most extreme pressure gradients known (as much as 100-millibar difference between tornado center and air immediately outside funnel).
 - (a) Extreme pressure difference produces winds of extraordinary speed.
 - (i) How fast are winds?
 - (a) No one knows, because tornadoes blow to bits the anemometer (instrument for measuring speed). Maximum estimates range from 320 to 800 kilometers (200 to 500 miles) per hour.
 - (2) Exact mechanism of formation is unknown.

- (a) Usually develops in warm, moist, unstable air associated with midlatitude cyclone.
- (b) Most often develops along a squall line that preceded a rapidly advance cold front, or along the cold front.
- (c) Spring and early summer are favorable for development because there's considerable air-mass contrast present in the midlatitudes at that time.
- (d) Most occur in midafternoon, at time of maximum heating.
- (e) More than 90% of all reported tornadoes occur in United States,
 - (i) Reflects optimum environmental conditions:
 - (a) Relatively flat terrain of central and southeastern U.S. provides uninhibited interaction of Canadian cP and Gulf mT air masses.
- (f) Waterspouts occur over ocean; have less pressure gradient, gentler winds, and reduced destructive capability.