Lecture 3: Weather/Disturbance

(From *Weather & Climate*)

- ❑ Transients and Eddies
- ❑ Climate Roles
- ❑ Mid-Latitude Cyclones
- ❑ Tropical Hurricanes
- ❑ Mid-Ocean Eddies

Transient and Eddy

❑ Transient: deviations from time mean

$$x' = x - \bar{x}$$

Time Mean

❑ Eddy: deviations from zonal mean

$$\bar{x}^* = \bar{x} - [\bar{x}]$$

Zonal Mean

❑ Why transients/eddies matter to zonal and time means?

$$[\overline{vT}] = [\bar{v}][\bar{T}] + [\bar{v}^*\bar{T}^*] + [\overline{v'T'}]$$

Flux Components

$$[\overline{vT}] = \underset{(1)}{[\bar{v}][\bar{T}]} + \underset{(2)}{[\bar{v}^*\bar{T}^*]} + \underset{(3)}{[\overline{v'T'}]}$$

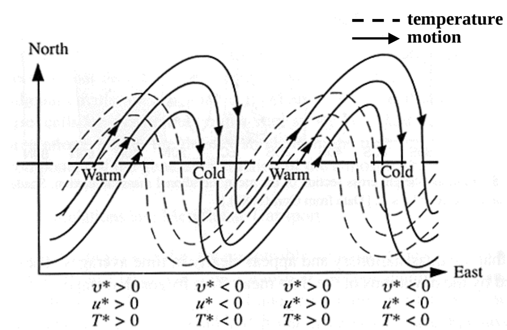
Three components contribute to the zonal- and time-mean transport:

(1) Mean Meridional Circulation (such as the three-cell circulation)

(2) Stationary planetary Waves (such as the wavenumber 1-3 eddies in the Northern Hemisphere).

(3) Transient Eddies (such as the weather systems = midlatitude cyclones and anticyclones).

Transient/Eddy Flux

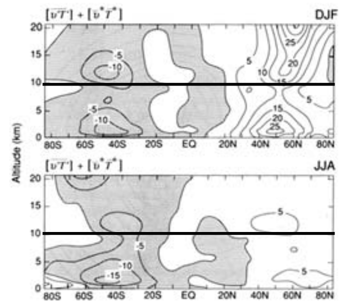


[V*T*] > 0 ➔ On zonal average, eddies transport heat northward.
➔ Eddies contribute to zonal-mean heat transport

Climate Roles of Eddies

- Stationary and transient eddies are important to the poleward fluxes of temperature, moisture, energy, and angular momentum.

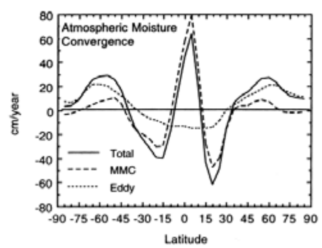
Poleward Flux of Temperature



(From *Global Physical Climatology*)

- Transient eddy fluxes dominant the meridional flux of temperature except in the Northern Hemisphere during winter, when stationary eddies contribute up to half of the flux.
- The low-level maximum in the troposphere is associated with the structure of growing mid-latitude cyclones (I.e., weather systems).

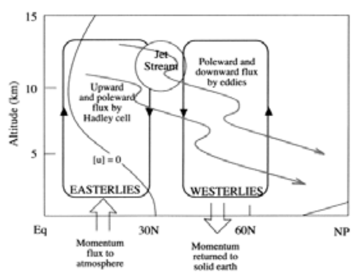
Poleward Flux of Moisture



(From *Global Physical Climatology*)

- Both the mean meridional circulation and eddies transport water and play an important role in determining the nature of the hydrological cycle.
- Moisture convergence in the tropics is dominated by the transport provided by the mean meridional circulation.
- The subtropcs serves as source regions for water vapor.
- Eddies remove water from the tropics and supply it to middle and high latitudes.

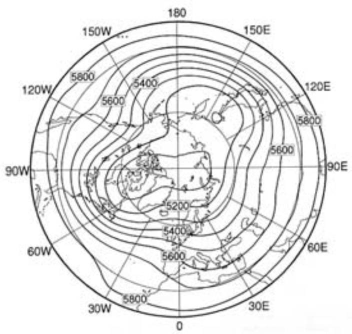
Poleward Flux of Momentum



- In the tropical easterlies, eastward angular momentum is transferred from Earth to the atmosphere via frictional forces and mountain torque.
- This westerly angular momentum is transported upward and then polarward into the Hadley Cell.
- Eddies then transport angular momentum polarward and downward into mid-latitude westerlies.
- In the mid-latitude, the westerly momentum is returned to the Earth.

Stationary Planetary Waves

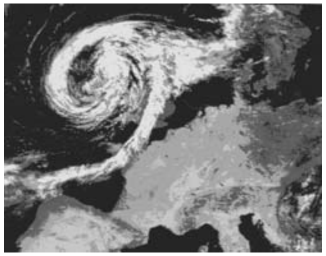
January Height of 500-mb Pressure Surface



(From *Global Physical Climatology*)

- ❑ Stationary: These waves do not move around much and are fixed in certain geographic locations.
- ❑ Planetary: These waves have large wavelengths, one the order of several thousands of kilometers.
- ❑ Wave: Their structures vary in the zonal direction.
- ❑ Stationary planetary waves are forced by large-scale mountains (such as Himalaya and Rocky mountain ranges) and heat contrasts between continents and oceans.
- ❑ Stationary planetary waves are stronger in winter than in summer.

Transient Eddies

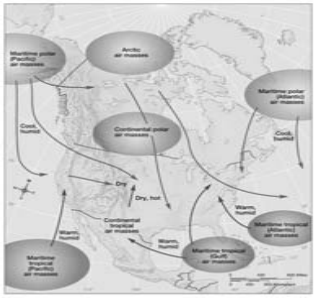


(From *Weather & Climate*)

- ❑ Mid-latitude cyclone and anticyclone are the major transient eddies that play an important role in meridional transports of heat, momentum, and moisture.
- ❑ These mid-latitude weather systems grow from the baroclinic instability associated with the strong north-south temperature gradients in mid-latitudes.
- ❑ Mid-latitude cyclones have typical spatial scales of wavenumbers 5-6 and have typical time scale of 7-10 days.
- ❑ Mid-latitude cyclones are marked by well-defined fronts separating the warm air mass from the south and the cold air mass from the north. (Very different from tropical hurricanes, which do not have frontal features).

Air Masses

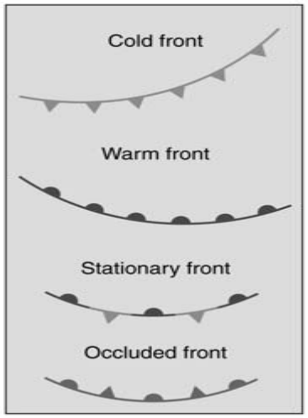
North American air masses and air mass source regions



(from *Weather & Climate*)

- The wettest air is called ***maritime*** air, while the driest is called ***continental.***
- Air deemed, from warmest to coolest, ***tropical***, ***polar***, or ***arctic***
- Once formed, air masses migrate within the general circulation.
- Upon movement, air masses displace residual air over locations thus changing temperature and humidity characteristics.
- Further, the air masses themselves moderate from surface influences.

Fronts

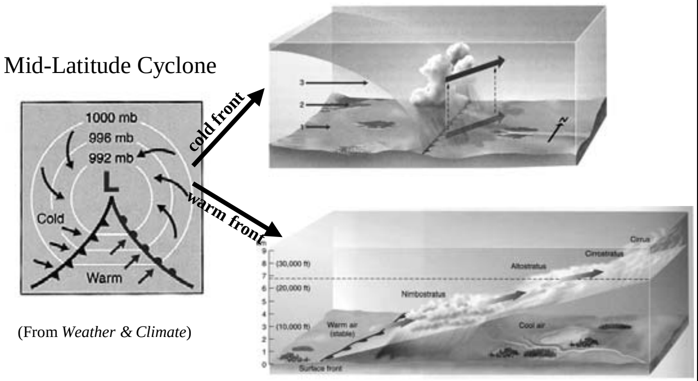


(from *Weather & Climate*)

- ❑ Fronts separate air masses and bring about changes in temperature and humidity as one air mass is replaced by another.
- ❑ There are four general types of fronts associated with mid-latitude cyclones with the name reflective of the advancing air mass.

Cold and Warm Fronts

Mid-Latitude Cyclone



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Cold Fronts

- ❑ Cold fronts form when cold air displaces warm air.
- ❑ Indicative of heavy precipitation events, rainfall or snow, combined with rapid temperature drops.
- ❑ Extreme precipitation stems from rapid vertical lifting associated with the steep cold front boundary profile.
- ❑ Because cold air is dense, it spills across the surface producing a steeply inclined leading edge.
- ❑ Warm moist air ahead of the front is forced aloft with great vertical displacement.
- ❑ This accounts for large vertical cumulonimbus clouds and heavy precipitation.
- ❑ Such sharp transitions between the colder, drier air behind the front and the warmer, moisture air ahead of the front, can be easily detected on satellite images and radar composites.

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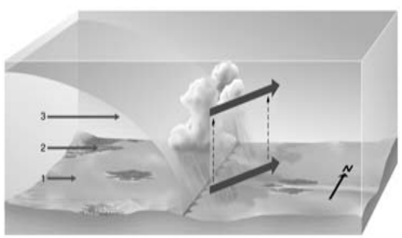
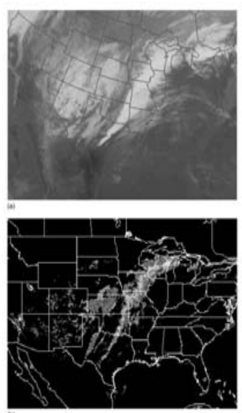
Cold Fronts



(from *Weather & Climate*)



Above: The vertical displacement of air along a cold front boundary

Right: The sharp cold front boundary is evident on both satellite pictures and radar composites

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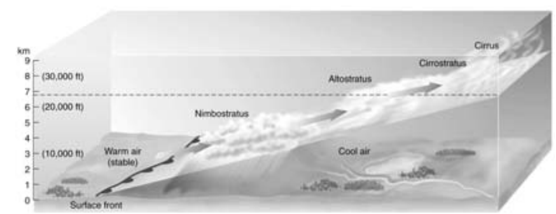
Warm Fronts



(from *Weather & Climate*)

- ❑ Created when warm air displaces colder air.
- ❑ Even though the warmer air advances, it is displaced aloft.
- ❑ This overrunning process places large amounts of warm, moist air over cooler, drier air along extensive spatial areas.
- ❑ Shallow horizontal stratus clouds dominate and bring light precipitation to affected regions
- ❑ Frontal fogs may occur as falling raindrops evaporate in the colder air near the surface.

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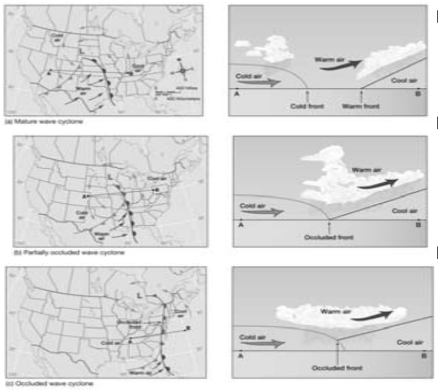
Occluded Fronts



- When two fronts meet, the warm air mass between them is displaced aloft resulting in an occluded front.
- This typically occurs when a cold front closes on, and meets a warm front as it circulates about the low pressure center of a mid-latitude cyclone.
- Cold air now occupies the surface completely around the low while warmer air is displaced aloft.

(from *Weather & Climate*)

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Stationary Fronts

- When two unlike air masses remain side by side, with neither encroaching upon the other, a stationary front exists.
- Fronts may slowly migrate and warmer air is displaced above colder.
- Fronts are zones of transition rather than sharp boundaries.

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Polar Front Theory

- ***Bjerknes,*** the founder of the Bergen school of meteorology, developed polar front theory to describe interactions between unlike air masses and related aspects of the mid-latitude cyclone.

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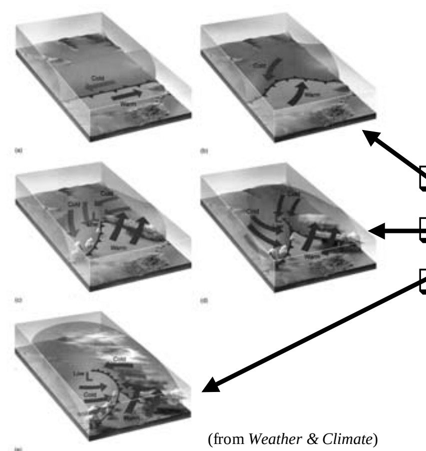
Life Cycle of Mid-Latitude Cyclone



- Cyclogenesis
- Mature Cyclone
- Occlusion

(from *Weather & Climate*)

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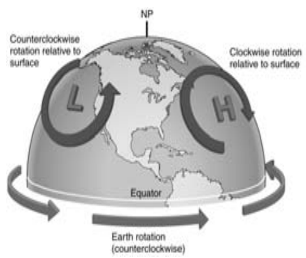
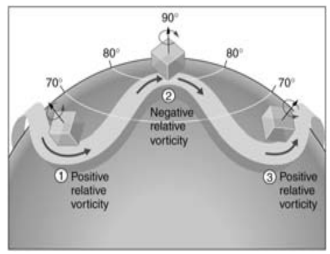
Rossby Wave

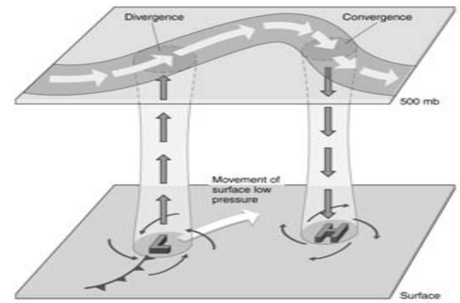




(from *Weather & Climate*)

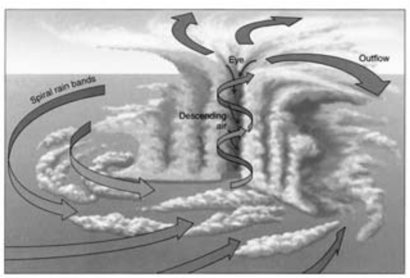
Steering of Mid-latitude Cyclones

(from *Weather & Climate*)



- ❑ The movement of surface systems can be predicted by the 500 mb pattern.
- ❑ The surface systems move in about the same direction as the 500 mb flow, at about 1/2 the speed.

Tropical Hurricane



(from *Weather & Climate*)

- ❑ The hurricane is characterized by a strong thermally direct circulation with the rising of warm air near the center of the storm and the sinking of cooler air outside.
- ❑ The warm core of the hurricane serves as a reservoir of potential energy, which is continuously being converted into kinetic energy by the thermally direct circulation.

Table 12–1 Maximum, Minimum, and Average Number of Hurricanes (and Their Counterparts) per Year over Various Parts of the World's Oceans, 1968 to 1989 (1968 to 1990 for the Southern Hemisphere)

Basin	Maximum	Minimum	Average
Atlantic	12	2	5.4
Eastern Pacific	14	4	8.9
Western Pacific	24	11	16.0
Northern Indian Ocean	6	0	2.5
Southwestern Indian Ocean	10	0	4.4
Southeastern Indian Ocean/Australia	7	0	3.4
Australia/Southwestern Pacific	11	2	4.3
Global	65	34	44.9

Source: Colorado State University

Hurricane Characteristics

- Hurricanes, the most powerful of all storms, have sustained winds of 120 km/hr (74 mph).
- Although of lesser intensity than tornadoes, the much larger size and longer life span makes hurricanes much more devastating.
- Average diameters are approximately 600 km (350 mi) and central pressure averages about 950 mb but may be as low as 870 mb.
- Most energy attained by hurricanes stems from latent heat release in the cloud formation process.
- Hurricanes occur where warm waters abound and during the times of highest SSTs.
- For the N.H., August and September are the most active months.

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Conditions Necessary for Hurricane Formation

- ❑ Hurricanes form only over deep water layers with surface temperatures in excess of ***27 ºC.***
- ❑ Energy is derived from ***latent heat*** release and associated evaporation of water
- ❑ Poleward of about 20º, water temperatures are usually below this threshold
- ❑ Hurricanes are most frequent in late summer and early autumn during high SST times
- ❑ ***Coriolis force*** is an important contributor, and as such, hurricanes do not form equatorward of 5º.

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Table 12–2 The Saffir-Simpson Scale

Category	Pressure mb	Wind Speed km/hr	Wind Speed mph	Storm Surge m	Storm Surge ft	Damage
1	≥ 980	119–154	74–95	1–2	4–5	Minimal
2	965–979	155–178	96–110	2–3	6–8	Moderate
3	945–964	179–210	111–130	3–4	9–12	Extensive
4	920–944	211–250	131–155	4–6	13–18	Extreme
5	< 920	> 250	> 155	> 6	> 18	Catastrophic

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