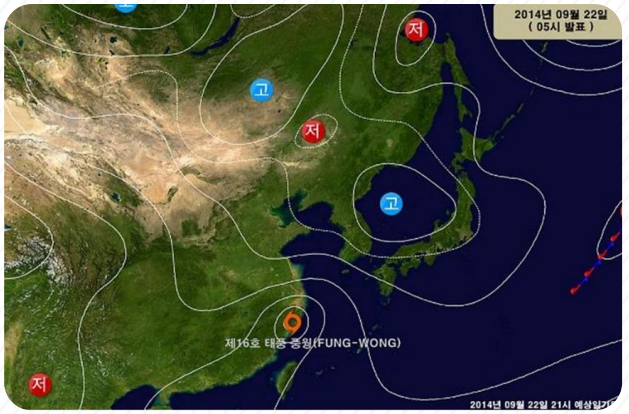
Introduction to Meteorology

27 Mid-latitude cyclones

Introduction



It is called anticyclone or high (cyclone or low) where the atmospheric pressure is higher (lower) than the surroundings.
Near the surface high, air flows outward and circulates clockwise in the northern hemisphere and counterclockwise in the southern hemisphere. On the other hand, near the surface low, because the atmospheric pressure is lower than the surroundings, air flows inward and rotates counterclockwise in the northern hemisphere, and clockwise in the southern hemisphere. This circulation is called a cyclone. The air that converges into the center rises and develops a storm.
Cyclones can be roughly classified into tropical cyclones and mid-latitudes cyclones depending on their genesis location. The mid-latitude cyclone comprises the cyclones that form over the polar regions. Tropical cyclones differ from mid-latitude cyclones.
The typhoon that affects Korea in late summer and early autumn is a kind of tropical cyclone. The main energy source of a tropical cyclone is the latent heat, while the energy source of the mid-latitude cyclone is temperature gradient and associated potential energy. Mid-cyclones are often accompanied by fronts, but the tropical cyclones are not. The intensity of the wind is relatively strong in tropical cyclones.

Contents

1. Structure and life cycle of the mid-latitude cyclones
2. Characteristics of the mid-latitude cyclones

Learning objectives

1. Explain the structure of mid-latitude cyclone.
2. Describe the development and decaying processes of mid-latitude cyclone.
3. Explain the characteristics of mid-latitude cyclone.

Learning Activities

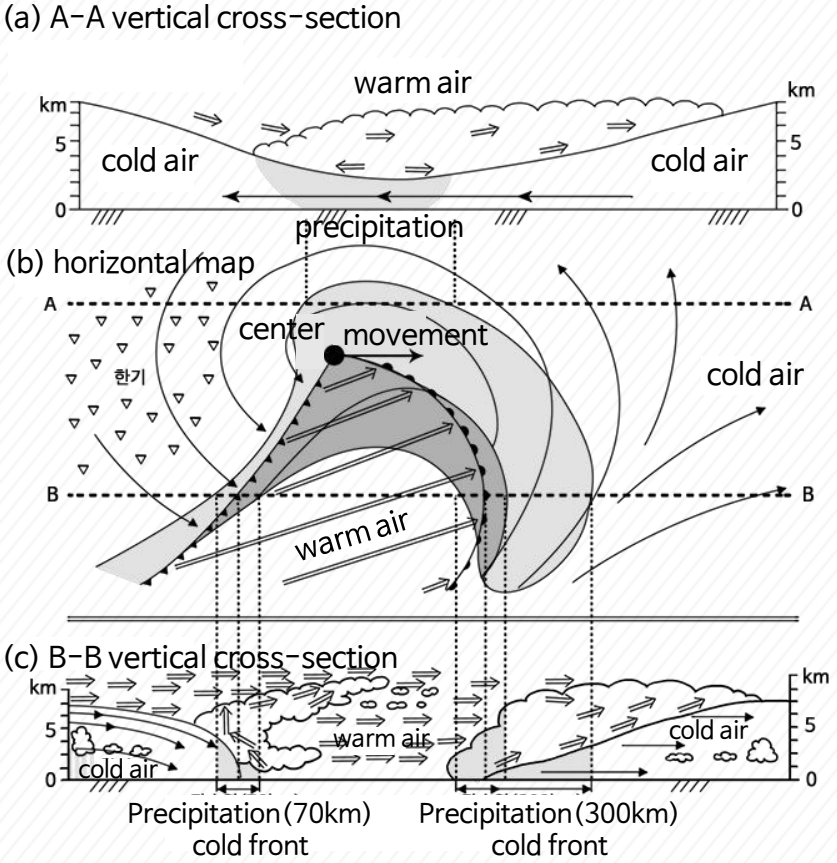
1. Structure and life cycle of the mid-latitude cyclones

1) Structure

The mature phase of the cyclone is shown in the figure. (b) is the surface horizontal map. In contrast to the tropical cyclone which is almost symmetric to the axis, the mid-latitude cyclone is characterized by a warm front extending to the southeast from the center and a cold front extending to the southwest. Let's take a closer look at the structure of the mid-latitude cyclone.

The extratropical cyclone is a phenomenon that occurs on the boundary between the warm and cold fronts. The wind direction is counterclockwise in the northern hemisphere. The warm air from the south moves over the warm front ahead of the cyclone, and cold air following the cold front enters the warm sector.

The precipitation area develops along the warm and cold fronts. This can be seen in (c), which is a vertical cross-section along the straight-line B-B shown in Figure (b).



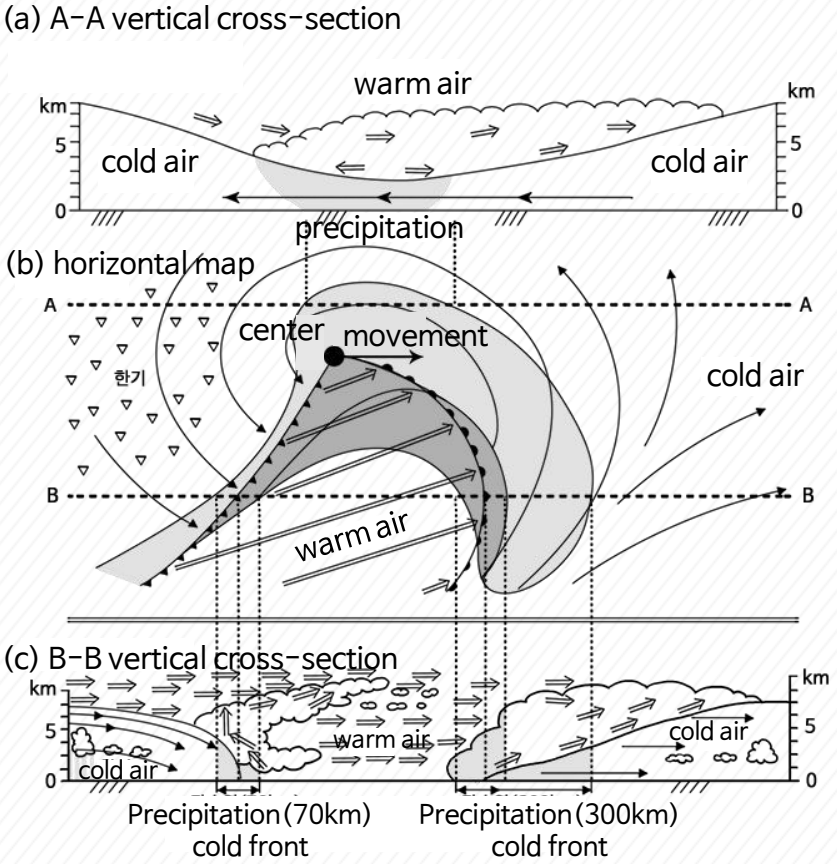
Learning Activities

1. Structure and life cycle of the mid-latitude cyclones

In the vicinity of the cold front, clouds develop vertically due to the rising warm air and result in a narrow precipitation zone. In the warm front region, stratus and precipitation in the broad region can be observed.

As you can see in the figure, the range of warm air increases to the east, north, and west as altitude increases.

In the cross-section of A-A, since the surface does not intersect with both fronts, the surface is occupied by a cold air mass from the east to the west.



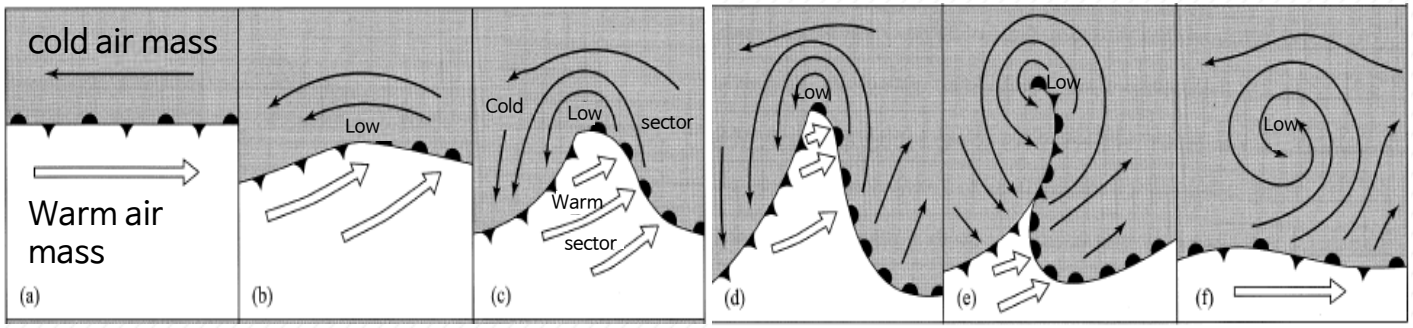
Learning Activities

1. Structure and life cycle of the mid-latitude cyclones

2) Life cycle

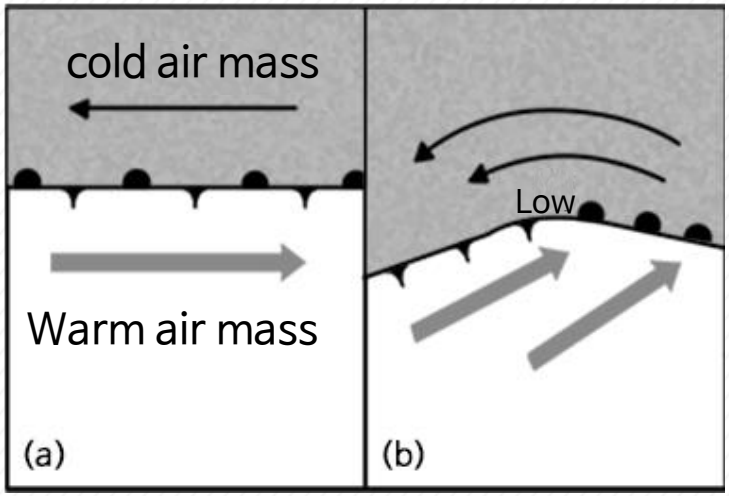
Mid-latitude cyclone usually generates on the cold front which is a boundary between tropical air mass and cold air mass. Cyclone activity, like many other meteorological phenomena, is constantly repeating the processes of development, growth, and decay. It plays a crucial role in the general circulation.

Cyclogenesis → **Mature stage** → **Occluded stage** → **Dissipating stage**



Learning Activities

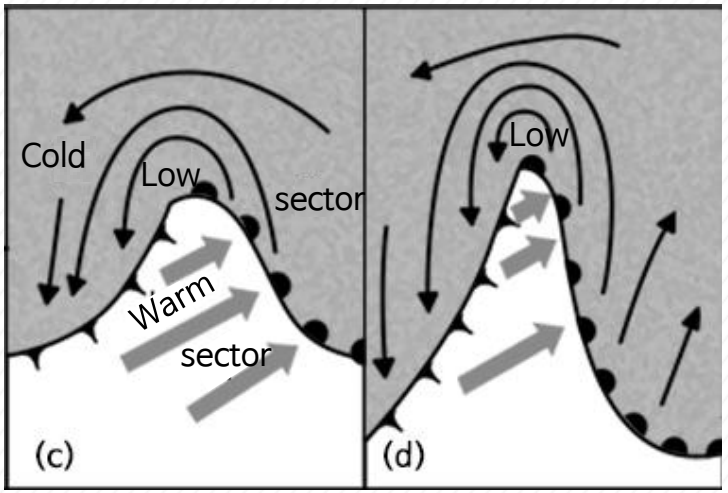
1. Structure and life cycle of the mid-latitude cyclones



During the cyclogenesis stage, a boundary separates opposing fronts of cold and warm air and waves form. Cyclonic shear begins to occur when the warm and cold fronts slide against one another, generating the spinning motion. As the cyclone gets stronger, it moves to the same direction with the wind in the warm sector.

Learning Activities

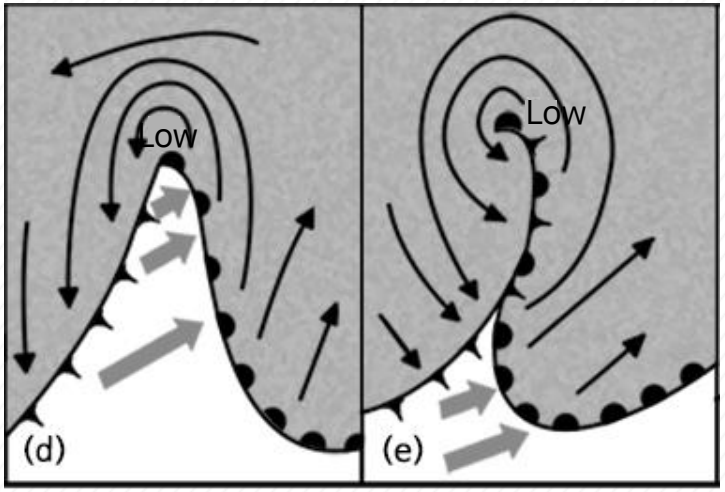
1. Structure and life cycle of the mid-latitude cyclones



During the cyclone's mature stage, the wave formed during the cyclogenesis becomes larger. The warm sector spreads greatly northward, and the cold air mass moves southward behind the cold front. Warm air in a warm sector that moves northward and rises above the cold air mass in the warm front.

Learning Activities

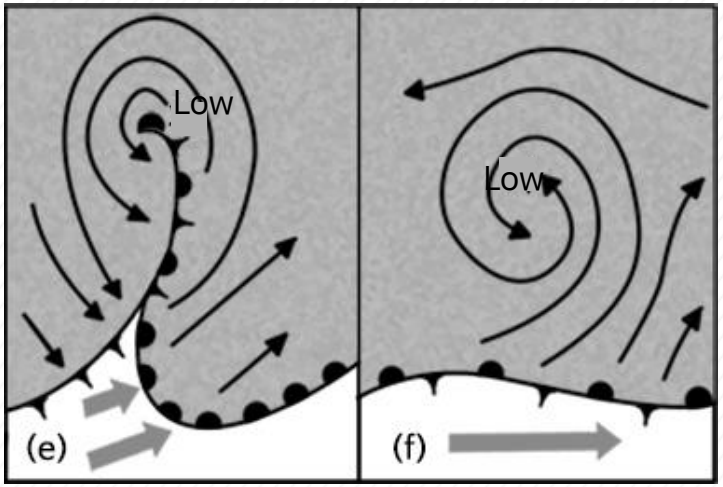
1. Structure and life cycle of the mid-latitude cyclones



During the occluded stage, as the cold front approaches the warm front, the occluded front begins to develop.

Learning Activities

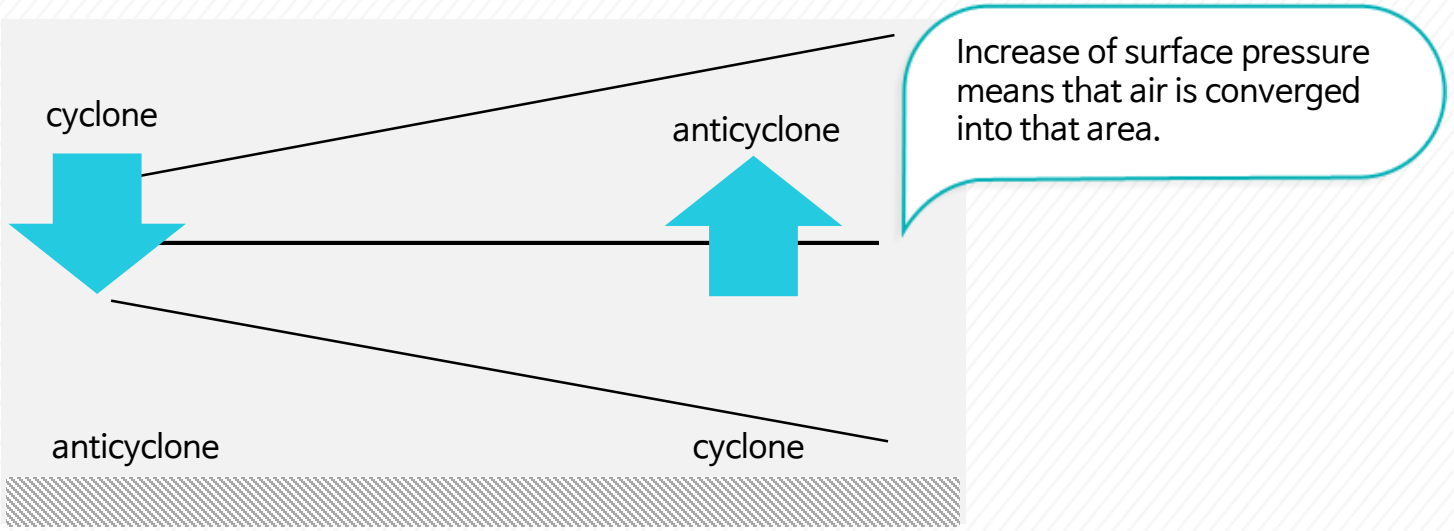
1. Structure and life cycle of the mid-latitude cyclones



In the dissipating stage, the occluded front lengthens, and surface cyclonic flow can be observed only in the cold air mass. The central pressure gradually rises, and it changes to warm air mass.

Learning Activities

1. Structure and life cycle of the mid-latitude cyclones



〈Change of surface pressure〉

Learning Activities

1. Structure and life cycle of the mid-latitude cyclones

3) Development process

The change in atmospheric pressure can be interpreted as a change in air mass per unit area if the change in gravity is negligible. Therefore, an increase of surface pressure means that air is converged into that area.

There are a few cases how this can happen. If the temperature of the air column is low, the volume of air will be reduced, and the air column will shrink in the vertical direction. Although the contraction in the horizontal direction is also expected in this case, the influence is negligible. Because the air pressure in the upper level is low, the ambient air will converge, and the surface will have a higher pressure than the surrounding. Although the air diverges near the surface, the surface high persists because of the strong convergence in the upper-level.

The opposite occurs for the surface low. If the air is warmed, the height of the column is increased resulting in a high pressure in the upper level. As the upper-level air will diverge, the surface air pressure will decrease. The low-level convergence does not exceed the upper-level divergence so that the surface low pressure persists.

In both cases discussed above, surface friction plays a major role in allowing air to move from high to low pressure. Generally, the stronger the friction, the greater the mass of air moving from the high pressure to the low pressure. Looking at the isobars and the measured wind angle over the land and ocean, the ocean has weaker values. However, the low pressure or high pressure can be developed without considering the surface friction.

Learning Activities

1. Structure and life cycle of the mid-latitude cyclones

The surface lows or highs are not simply determined by the surface pressure, but by the upper-level circulation. Therefore, it is better to interpret the surface pressure system as a shadow of upper-level pressure patterns.

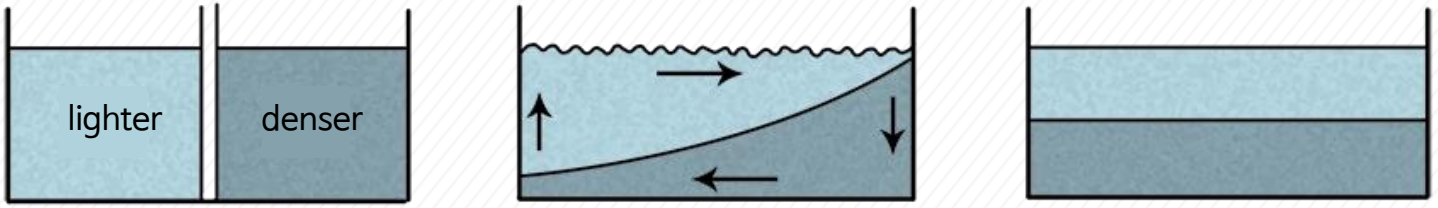
The temperature advection acts to strengthen and weaken the storm system, and the advection of vorticity (or variables related to momentum) acts to propagate the wave. The warm advection induces a mid-latitude cyclone.

However, the warm advection at the surface associated with the upper-level vorticity advection contributes greatly to the development of the mid-latitude cyclone rather than the warm air advection itself. Advection of cold air develops a surface high.

Learning Activities

2. Characteristics of the mid-latitude cyclones

1) Energy source



(a) (b) (c)

Figure (a) shows a case in which a light fluid (corresponding to the warm air) and a heavy fluid (corresponding to a cold air) are side by side in the water tank with a wall in the middle. If this wall is removed, the heavier fluid will slump under the lighter one (b) until eventually reaching an equilibrium with the lighter fluid layered on top of the denser fluid (c).

Learning Activities

2. Characteristics of the mid-latitude cyclones

(a) (c)

Comparing figure (a) and (c), we can see that the center of the fluid, that is, the center of gravity, goes down. It indicates that part of potential energy is converted to kinetic energy and it is called the available potential energy.

The energy source of the extratropical cyclone is mainly the potential energy as well as the latent heat release when clouds form due to the uplift of air.

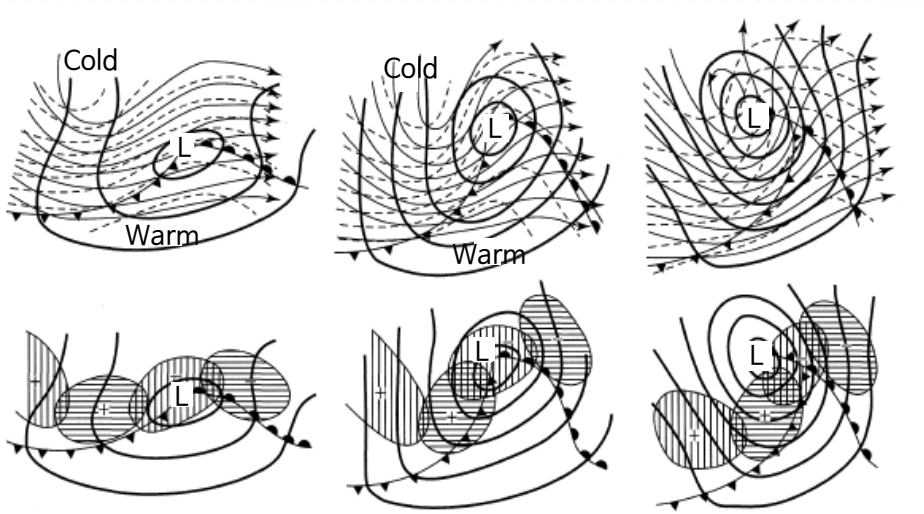
Learning Activities

2. Characteristics of the mid-latitude cyclones

2) Temperature and pressure

When the temperature is averaged vertically from the surface to 5km, the constant temperature line (isotherm) is shown as the dotted line in the figure. In the upper level, it can be seen that the westerly wind and the isotherm are meandering north and south as a wave.

In the developing cyclone, as the upper-level temperature field and the pressure field are not completely parallel, the isotherms and the isobars intersect. To the west (east) of the low, the cold (warm) air moves equatorward (poleward) along the upper-level flow. Therefore, the surface pressure increases to the west (due to the heavier and colder air) and decreases to the east of the cyclone.



(a) Cyclogenesis (b) Developing stage (c) Mature stage

—— : Surface isobar ------ : Averaged temperature from the surface to 5km altitude

→ : isobar at 5km

: Large surface pressure change by convergence and divergence of air

: Large surface pressure change by warm and cold advection

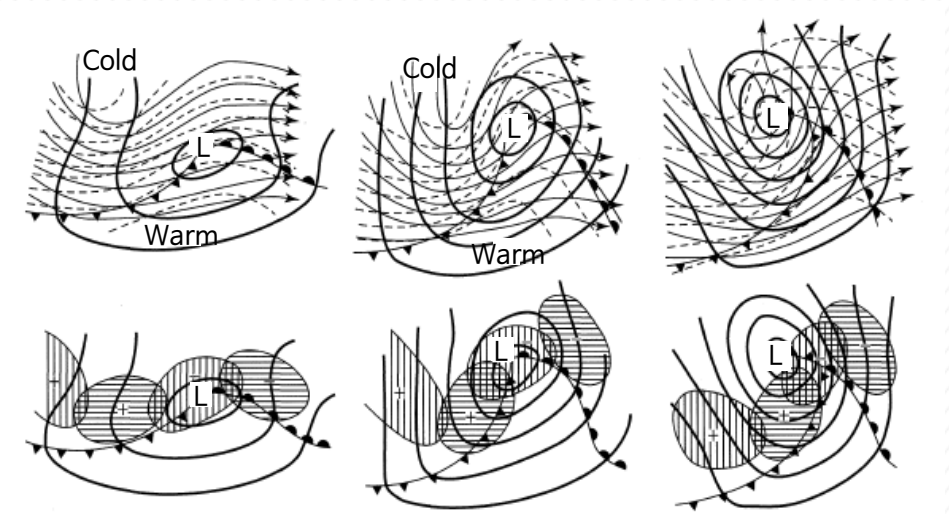
Learning Activities

2. Characteristics of the mid-latitude cyclones

The increase in the cyclonic flow by convergence/divergence and by temperature advection is shown to the east of the center, which indicates an eastward propagation.

Near the center of the low, the amount of divergent air in the upper level is larger than the convergent air near the surface. Such divergence is superimposed to the westerly and induces a wavelike pattern aloft.

In other words, if the upper-level divergence is greater than the surface convergence, a cyclone develops.



(a) Cyclogenesis (b) Developing stage (c) Mature stage

—— : Surface isobar ------ : Averaged temperature from the surface to 5km altitude

→ : isobar at 5km

: Large surface pressure change by convergence and divergence of air

: Large surface pressure change by warm and cold advection

Learning Activities

2. Characteristics of the mid-latitude cyclones

3) Characteristics

Mid-latitude cyclones initiate over the land and ocean and develop mainly over the ocean. The major energy source is the potential energy, and it develops with the frontal systems.

The central atmospheric pressure of an intense cyclone is about 950 hPa. Compared to the tropical cyclone, the mid-latitude cyclone has broader area and higher central pressure. The maximum wind speed is only around 25m/s.

It usually propagates to east or northeast with the speed of 30~50 km/h. Because of the broad horizontal scale, the thunderstorm does not stop immediately even after the cyclone passes by. The storm lasts for several days over the ocean.

Learning Activities

2. Characteristics of the mid-latitude cyclones

Classification	Mid-latitude cyclone	Tropical cyclone (typhoon, hurricane, etc.)
Genesis region	Initiate over the land and ocean, and develop mainly over the ocean	It mainly occurs over the tropical or subtropical ocean during summer.
Energy source	Potential energy and latent heat energy are the main energy sources.	The latent heat released by condensation of water vapor mainly becomes an energy source.
Active period	In summer when the meridional temperature gradient is large.	Mainly during the warm season. It is dependent on the location of the inter-tropical convergence zone.
Shape and size	A long oval shape with the major axis about 5,000km	A circular isobaric line. 200 km~1,500 km in diameter.
Presence of fronts	Accompanied by a warm front, cold front, and occluded front.	Not accompanied with fronts. If front appears according to the northward movement of the tropical cyclone, it is treated as an extratropical cyclone.
Minimum pressure	The central atmospheric pressure is 950 hPa in a strong cyclone. The minimum value of the Aleutian Low pressure is recorded as 926 hPa (October 26, 1977). Compared to the tropical cyclone, it covers a broader area with higher central pressure and the pressure reduces gradually.	Occasionally less than 900hPa. Compared to the mid-latitude cyclone, the central pressure is lower and the pressure gradient is larger.

Learning Activities

2. Characteristics of the mid-latitude cyclones

Classification	Mid-latitude cyclone	Tropical cyclone (typhoon, hurricane, etc.)
Wind speed	Maximum wind speed is about 25m/s. The radius of storm zone with 20m/s wind is about 2,000km.	Compared with the mid-latitude cyclone, the area is smaller, but the maximum wind speed is extremely stronger. It reaches to 50m/s or more over the ocean. For large typhoons, the radius of storm zone with 20m/s wind is about 800km.
Progress	Propagates to east or northeast with approximately 30~50km/h (maximum 80km/h).	To the south (north) of 25°N, it tends to move northwest (northeast). The propagation speed to the northwest is about 20 km/h, and it gradually accelerates afterward.
Thunderstorm	Since the affected area is large, the thunderstorm continues even after the cyclone passes by. The storm continues for several days over the ocean.	Thunderstorm stops immediately when the tropical cyclone passes by. The duration of the storm is several hours in a given location.
Eye	There is no clear phenomenon as in the case of a typhoon, but the wind near the center of the mature cyclone is weak.	Usually, there is the eye of a tropical cyclone.

The comparison between the mid-latitude cyclone and the tropical cyclone is described in the table above.

Summary

1. Structure and life cycle of the mid-latitude cyclones

- The mid-latitude cyclone is characterized by a warm front extending to the southeast from the center and a cold front extending to the southwest. It has a warm sector to the south, and cold air to the east, north, and west.
- The extratropical cyclone is a phenomenon that occurs on the boundary between the warm and cold fronts.
- The direction of the wind is counterclockwise in the northern hemisphere. The warm air in the south moves over the warm front ahead of the cyclone, and cold air enters the warm sector with the cold front.
- The precipitation area develops along the warm and cold fronts.

The mid-latitude cyclone has cyclogenesis, mature stage, occluded stage and dissipating stage.

- During the cyclogenesis stage, cold and warm front form. As cyclone gets stronger, it moves to the same direction with the wind in warm sector.
- During the mature stage, the wave formed during the cyclogenesis becomes larger. The warm sector spreads greatly northward, and the cold air mass moves southward behind the cold front.
- During the occluded stage, as the cold front approaches the warm front, the occluded front begins to develop.
- In the dissipating stage, the occluded front becomes longer and surface cyclonic flow can be observed only in the cold air mass.

Summary

2. Characteristics of the mid-latitude cyclones

- Mid-latitude cyclones initiates over the land and ocean, and develop mainly over the ocean.
- Potential energy is the main energy source.
- Active period is summer when the meridional temperature gradient is large.
- Accompanied by warm front, cold front and occluded front.
- The central atmospheric pressure is 950 hPa in a strong cyclone.
- Compared to the tropical cyclone, it covers broader area with higher central pressure and the pressure reduces gradually.
- Maximum wind speed is about 25m/s.
- Propagates to east or northeast with approximately 30~50km/h (maximum 80km/h).
- Since the affected area is large, the thunderstorm continues even after the cyclone passes by. The storm lasts for several days over the ocean.