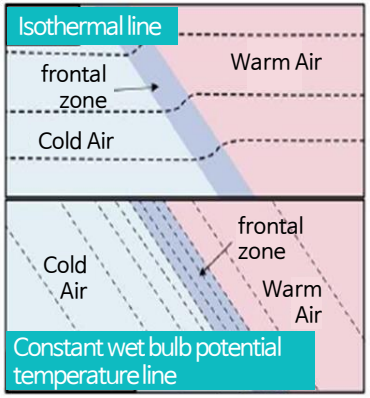
Introduction to Meteorology

26 Air masses and fronts

Introduction

An air mass is an extremely large body of air whose properties such as temperature and humidity are similar. A front is the transition zone between two air masses of different densities and temperatures. When two air masses come into contact, they are not vertically aligned but tilted in a vertical direction depending on the properties of the air masses. The upward extension of a front is referred to as a frontal surface or frontal zone. Fronts are located in the region where air pressure and temperature gradient are greatest.



Contents

Learning objectives

1. Describe the definition and types of fronts
2. Describe the air masses and fronts that influence weather in Korea

Learning Activities

1. Air masses

An air mass is an extremely large body of air whose properties are consistent. Here, 'consistent properties' means that temperature and humidity are uniform horizontally at a given altitude, and 'large' implies that it extends thousands of kilometers. Now, let's take a closer look at the formation, characteristics, modification, and the relationship with the weather.

Learning Activities

1. Air masses

1) Formation

In order for a huge mass of air to acquire uniform characteristics, its source region needs to be flat and of uniform composition with light winds. Therefore, the ideal source regions are those areas where surface high pressure dominates.

High latitude plain covered by snow and ice

Low latitude subtropical ocean and desert

In mid-latitude, a unique air mass can be developed depending on the surface conditions

Learning Activities

1. Air masses

Ideal source regions can be the ice- and snow-covered arctic plains in winter, and subtropical oceans and deserts in summer. Although the mid-latitudes are not good source regions, unique air masses can be developed depending on the surface conditions.

Source region \ Source latitude	Polar (P)	Tropical (T)
Continental (c)	cP (Siberia air mass) Cold, dry, stable	cT (Yangtze river air mass) Hot, dry, stable air aloft, unstable surface air
Maritime (m)	mP (Okhotsk sea air mass) cool, moist, unstable	mT (North Pacific air mass) warm, moist, usually unstable

Learning Activities

1. Air masses

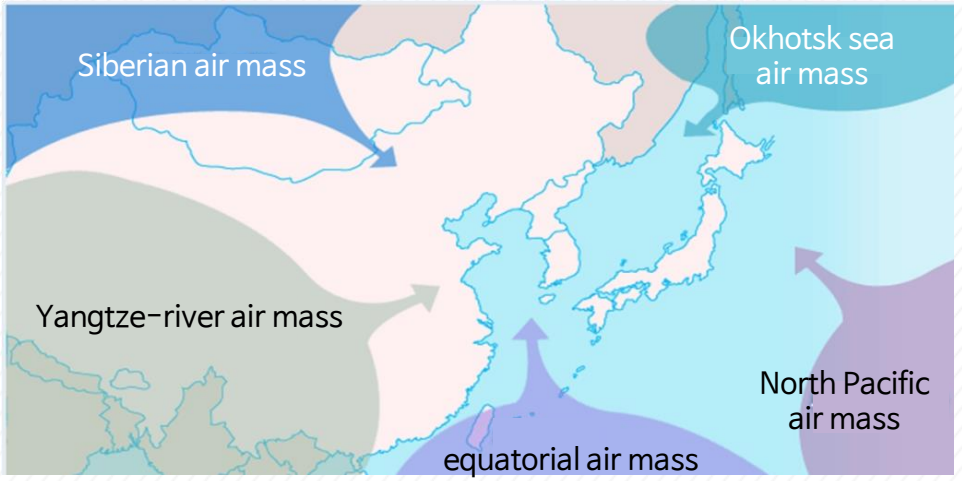
2) Classification

As shown in the figure below, air masses can be divided into continental and maritime, depending on the source regions, and into polar and tropical depending on the source latitude. Also, air masses are classified as arctic, mid-latitude, and tropical, such as continental arctic (cA) and maritime equatorial (mE) air mass. cA is an extremely cold air mass that forms over the Arctic, although it is difficult to distinguish it from the cP.

mE refers to an extremely warm air mass but is no longer used due to the obscure distinction between the air mass and the tropical air mass.

On the other hand, the mid-latitude air mass became more important since the discovery of the polar jet and subtropical jet in the upper troposphere.

The Okhotsk sea air mass develops from spring to early summer along with the sea ice melting in the Sea of Okhotsk and impacts the beginning of Changma. Despite the theoretical classification of the air masses, it is difficult to identify air masses in the weather map because the boundary of each air mass is unclear.



※ Source: www.kma.go.kr

Learning Activities

1. Air masses

3) Modification

Modification of air mass is important due to its impact on local weather systems. Change of air mass is mainly caused by surface heating and mixing, forced uplift by the topography, etc.

When air mass moves from the source region to different region, the temperature and humidity are mixed with another air mass. Temperature can change by heating/cooling and humidity can change by vertical motion and surface moisture intrusion.

When the mixing process takes place slowly over a vast area, fronts are hardly developed. However, when the mixing and change of air masses occur rapidly, a frontal system forms and weather systems, such as precipitation, are accompanied.

For example, the equatorward polar air mass and poleward tropical air mass (which moves above the cold air in the higher latitude) induce a low-pressure system in the high latitudes. At this time, the northward air mass rises to the altitude of a polar jet and forms fronts and precipitation. In this process, heat is converted into kinetic energy, and atmospheric circulation that transports heat and water vapor from low latitudes to high latitudes takes place.

Learning Activities

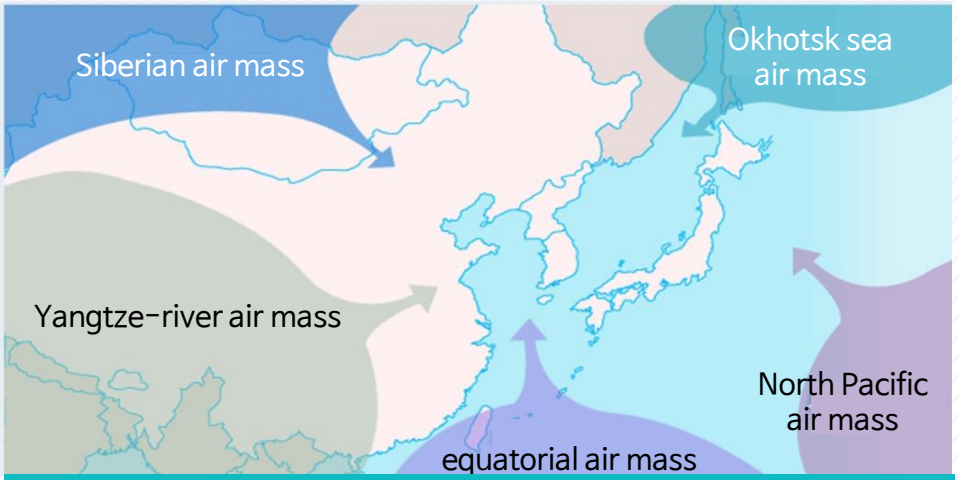
1. Air masses

4) Air mass and weather

The main air masses that affect East Asia are the Siberian air mass, the Okhotsk sea air mass, and the North Pacific air mass. Each air mass has its unique characteristics. Thus local weather depends on the predominant air mass.

In Korea, summer is influenced by the North Pacific air mass. Before the start of the rainy season, the Okhotsk sea air mass affects Korea. The rainy season is affected by the Okhotsk sea, North Pacific, and Siberia air masses. The Siberia air mass strongly influences the rest of the seasons.

The Siberian air mass has a direct impact on the Korean Peninsula during winter. During summer, its location shifts to the south and approaches Korea with modified properties.



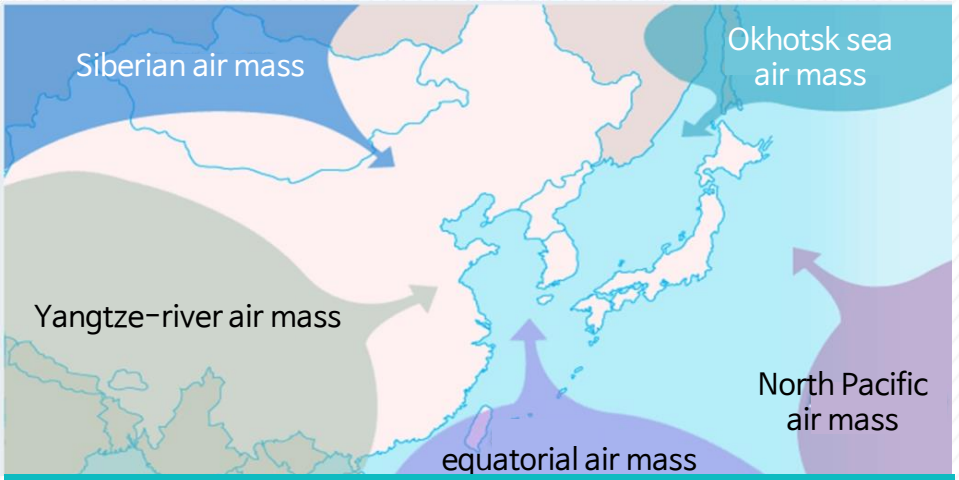
〈Air masses of East Asia〉
※ Source: www.kma.go.kr

Learning Activities

1. Air masses

However, it is difficult to identify the process of the North Pacific high and Okhotsk high affecting the Korean Peninsula on the weather map, except some special cases such as when the eastward propagation of Siberia high becomes slower when it meets the North Pacific (or Okhotsk) high and develops a upper level blocking.

The Okhotsk Sea high is not detectable in the upper layer, while the North Pacific high can be tracked by the displacement of 5880gpm or 5820gpm isobar at 500hPa. Theoretically, the long-wave has retrogression at 500hPa level.



〈Air masses of East Asia〉
※ Source: www.kma.go.kr

Learning Activities

2. Fronts

A front is the transition zone between two air masses (or within an air mass) of different properties. The upward extension of a front is referred to as a frontal surface or frontal zone. It is important because it causes many weather phenomena such as precipitation along a front.

Because the interpretations require subjective judgment, analyzing the existence and location of fronts in the weather map is not yet performed automatically. Let's examine the properties of each front.

Learning Activities

2. Fronts

1) Types of fronts

Fronts can be divided into stationary front, cold front, warm front, and occluded front. The occluded front can be further classified as cold-type and warm-type occluded front, and as polar and cold front depending on its location.

Learning Activities

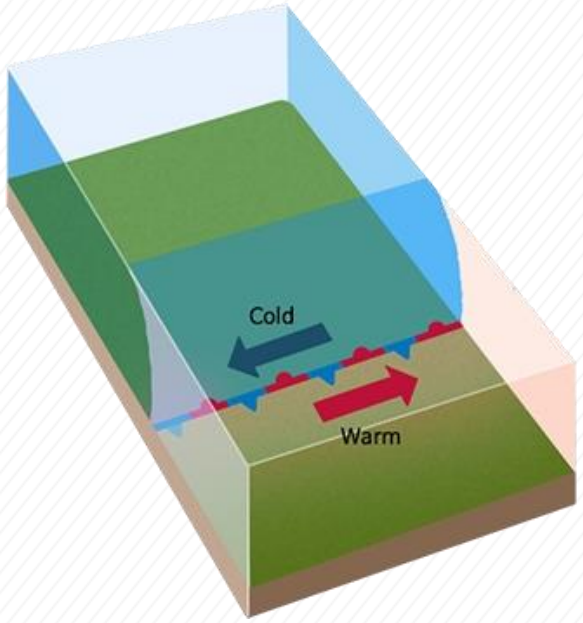
2. Fronts

2) Stationary front

A stationary front has essentially no movement but has easterly to the north and westerly to the south parallel to the front.

During the rainy season in Asia, a stationary front occurs in the southern part of China, between the weakened cP air mass in the north and the weak mT air mass in the south.

The weather along the stationary front is clear to partly cloudy. If the warm (cold) air moves northward (southward), the front will become a warm (cold) front. Stationary fronts often develop into a low-pressure system.

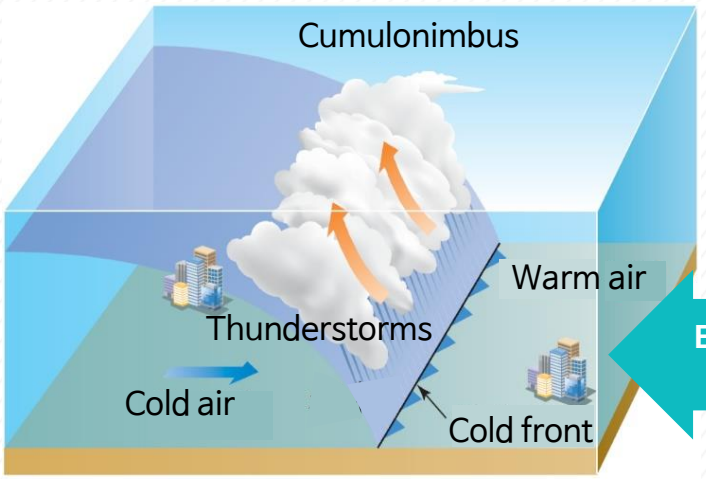


〈Stationary front〉

Learning Activities

2. Fronts

3) Cold front



The cold front occurs when cold, dry, and stable air is replacing warm, moist, and unstable subtropical air. It forms an elongated area to southwest from the low pressure (trough) center. The surface southerly blows ahead of the front, while northerly blows behind it.

In the boundary between cold and warm air masses, the air is very stable and often forms a frontal inversion. In the middle latitudes, cold air mass moves southeast along the westerly, so do the cold fronts.

Very rarely, a southwestward moving cold front formed by the northeasterly can be observed in the east coasts, which is called the back door cold front.

Learning Activities

2. Fronts

Let's look more closely at the active cold front (slow-moving cold front) and inactive cold front (fast-moving cold front). The active cold front occurs when the lower cold air moves faster than the warm upper air. Precipitation is observed behind the front. Ci, Cs, Cu, and Cb occur. The ratio between the vertical and horizontal distance of the front is approximately 1:50.

The inactive cold front occurs when the upper-level warm air moves faster. There is a relatively narrow but often violent band of weather. It often develops into a line of thunderstorms called a squall line.

Temperature, humidity, and the pressure gradients are large in the area where the cold front is located. Temperature and humidity drop rapidly, and pressure increases as the front passes. The winds shift from southwesterly to northwesterly after its passage.

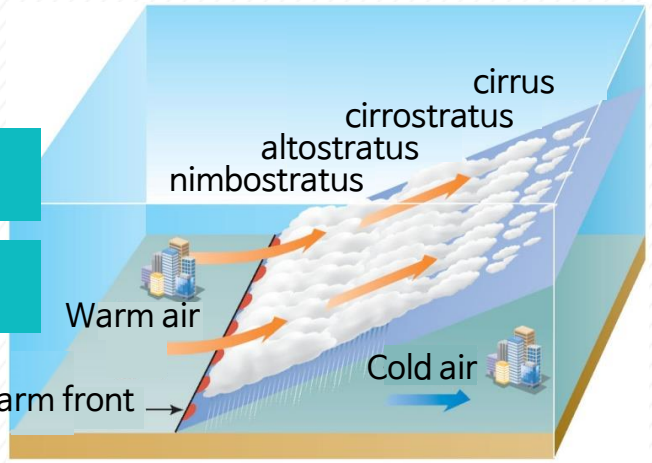
Learning Activities

2. Fronts

4) Warm front

Warm air mass rides over a cold air mass (overrunning)

warm front to the southeast from the center of the low pressure



The phenomenon that a warm air mass rides over a cold air mass is called overrunning. In this case, the warm front will occur southeast from the center of the low pressure.

The warm front is similar to the cold front in that the front develops to the southeast of the low-pressure center, it has a frontal inversion, and it can be divided into the active and inactive front.

On the other hand, it has a gentler slope (about 1:300) compared to the cold front, and the temperature, humidity, and pressure gradients around the front are weaker than the cold front.

The temperature increases and pressure decrease with the passage of the front. Wind direction changes from the southeasterly to southwesterly.

Learning Activities

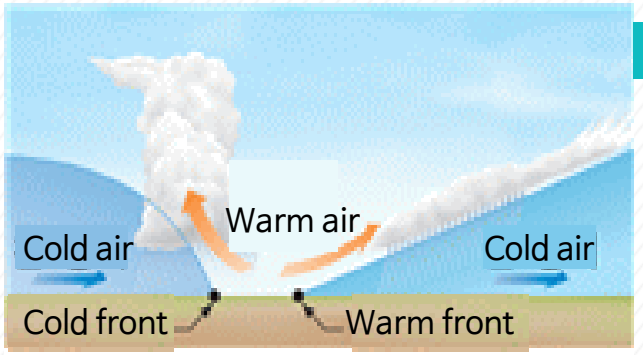
2. Fronts

When a front approaches, cloud gradually changes in the order of Ci, Cs, As, and Ns, so it is easier to detect the warm front than the cold front. Moving closer to the front, stratus and fog can be observed. Cb also occurs during summer.

Learning Activities

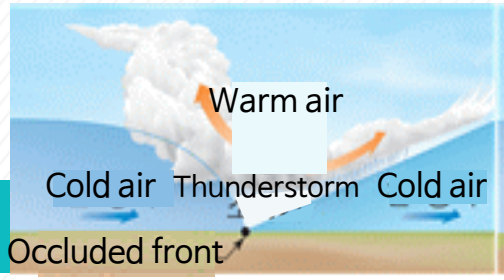
2. Fronts

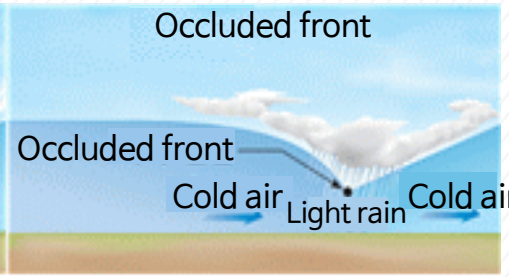
5) Occluded front



A cold front catches up to and overtakes a warm front

Occluded





In overtaken areas, only the characteristic of the warm front or cold front dominates.

Occluded front

Because the cold front is faster than the warm front, a cold front catches up to and overtakes a warm front. The frontal boundary created between the two air masses is called an occluded front. In overtaken areas, only the characteristic of the warm front or cold front dominates.

The warm-type occluded front is the case where only the features of the warm front appear. In warm-type occluded front, the cold air that formed the warm front is colder than the cold air that formed the cold front. Conversely, a cold-type occlusion front shows only the characteristics of a cold front. The weather is not much different from the warm or cold front because the warm or cold front still appears on the upper level.

Learning Activities

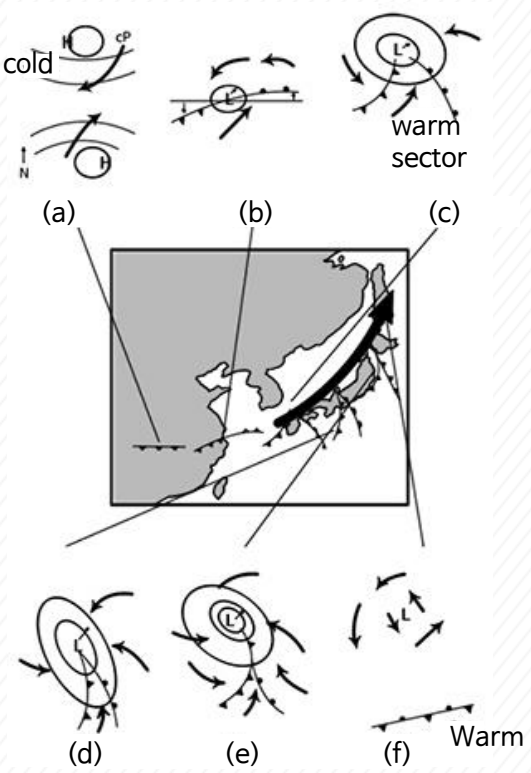
2. Fronts

6) Formation and development of front

The polar front theory was developed by Bjerknes right after World War I and it contributed greatly to atmospheric science. Although many new theories have emerged since then, it still explains the mid-latitude cyclone and weather well.

The presented picture depicts the life-cycle of a mid-latitude cyclone. The three stages in the life cycle are: birth, growth, and decay. In the frontogenesis stage (a), the region of lowest pressure and occluded front are at the junction of the two fronts. Because the outflow axis of the isotherm is more parallel than in (b), the circulation in (a) easily changes temperature gradient promoting the frontogenesis.

Next is the frontolysis stage. In (b) stage, the isotherm more parallel to the inflow axis weakens the temperature gradient. Consequently, the front is likely to disappear. Whether the angle between the outflow and isotherm is greater than 45° determines the frontogenesis and frontolysis.



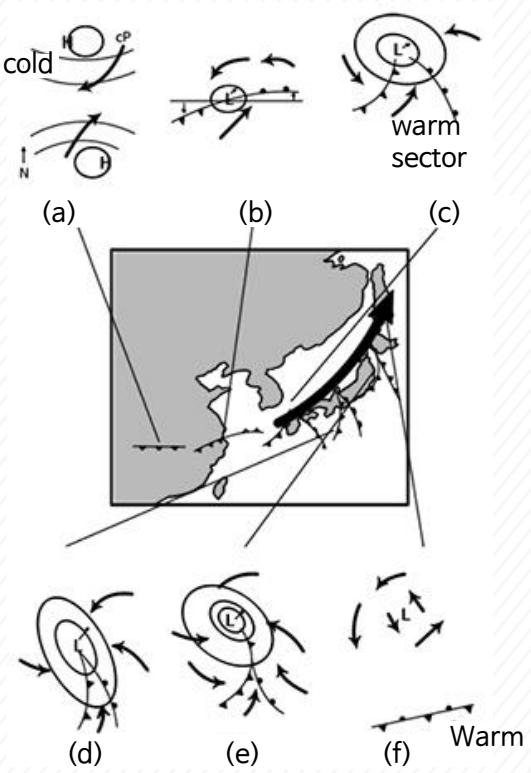
〈The life cycle of a mid-latitude cyclone on the polar front〉

Learning Activities

2. Fronts

Next is the wave cyclone. Since the cyclone forms and moves along the polar front in a wavelike manner, the developing storm is referred to as a wave cyclone. As the cold front and the warm front move along the direction of each leading air flow, the warm front moves north and the cold front moves south. Precipitation forms in the north of both fronts, but in a wide band ahead of the warm front and along a narrow band of the cold front. The region between the cold and warm fronts tends to be partly cloudy, although scattered showers and thunderstorms may develop if the air is conditionally unstable.

Steered by the winds aloft, the system typically moves eastward or northeastward. It gradually becomes a fully developed open wave in 12 to 24 hours as shown in (c). Latent heat release by condensation of the rising air is the major energy source of the open wave.



〈The life cycle of a mid-latitude cyclone on the polar front〉

Learning Activities

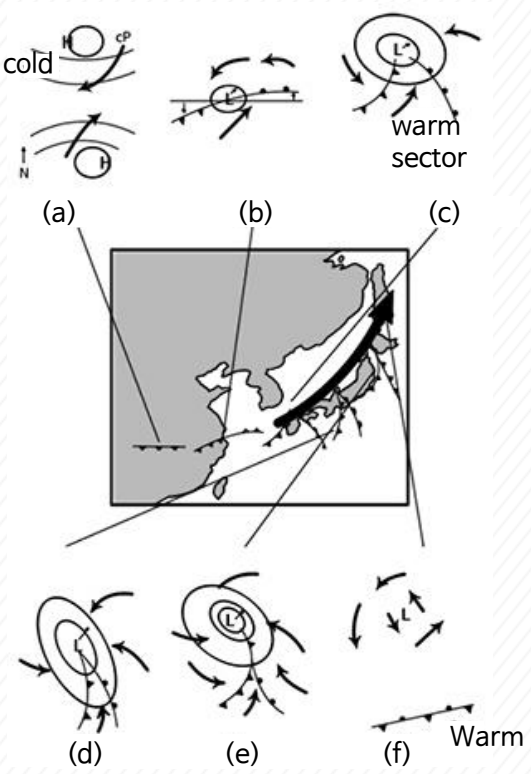
2. Fronts

The thermally direct circulation occurs when the density of the cold air becomes larger, and the center of gravity lowers so that the potential energy is converted into kinetic energy. As the open wave develops, the central air pressure is lowered, the wind speed is strengthened, and the relatively fast cold front squeezes the warm front area. At this point, the storm is usually most intense, with clouds and precipitation covering a large area (stage d).

The triple intersection point is the point where the cold front, the warm front, and the occluded front meet. It appears until the cyclone decays (stage e).

Next is the secondary cyclone. In stage (e), the warm sector shown in stage (c) appears again. The secondary cyclone develops again in the center. The low pressure in the northern part of the warm sector can no longer develop because the warm sector is too far to supply energy.

Finally, the cyclone family is a series of wave cyclones along the front.



〈The life cycle of a mid-latitude cyclone on the polar front〉

Summary

1. Air masses

- An air mass is an extremely large body of air whose properties are consistent.
- ‘Consistent properties’ means that temperature and humidity are uniform horizontally at a given altitude, and 'large' implies that it extends thousands of kilometers.
- For a huge mass of air to acquire uniform characteristics, its source region needs to be flat and of uniform composition with light winds.
- Ideal source regions are the ice- and snow-covered arctic plains in winter, and subtropical oceans and deserts in summer.
- The mid-latitudes are not good source regions, but unique air masses can be developed depending on the surface conditions.

Summary

2. Fronts

A front is the transition zone between two air masses (or within an air mass) of different properties. The upward extension of a front is referred to as a frontal surface or frontal zone. It is important because it causes many weather phenomena such as precipitation along a front.

- Stationary front: A stationary front has essentially no movement but has easterly to the north and westerly to the south parallel to the front.
- Cold front: The cold front occurs when cold, dry and stable air is replacing warm, moist, and unstable subtropical air. It forms an elongated front to the southwest of the low-pressure center.
- Warm front: The phenomenon that a warm air mass rides over a cold air mass is called overrunning. In this case, the warm front will occur southeast from the center of the low pressure.
- Occluded front: Because the cold front is faster than the warm front, a cold front catches up with and overtakes a warm front. The frontal boundary created between the two air masses is called an occluded front. In overtaken areas, only the characteristic of the warm front or cold front dominates.