Introduction to Meteorology

18 High and low pressure

Introduction

On a weather chart, you can see a number of isobars, high pressures (H) and low pressures (L). The reason why these high and low pressures are displayed in the weather map is not only for the convenience of interpretation, but also due to their importance on weather.

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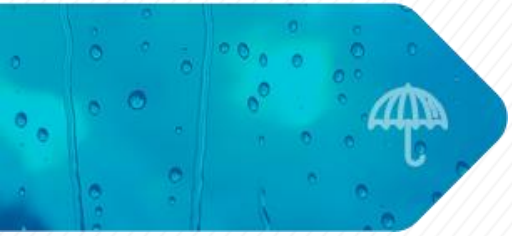


Learning objectives

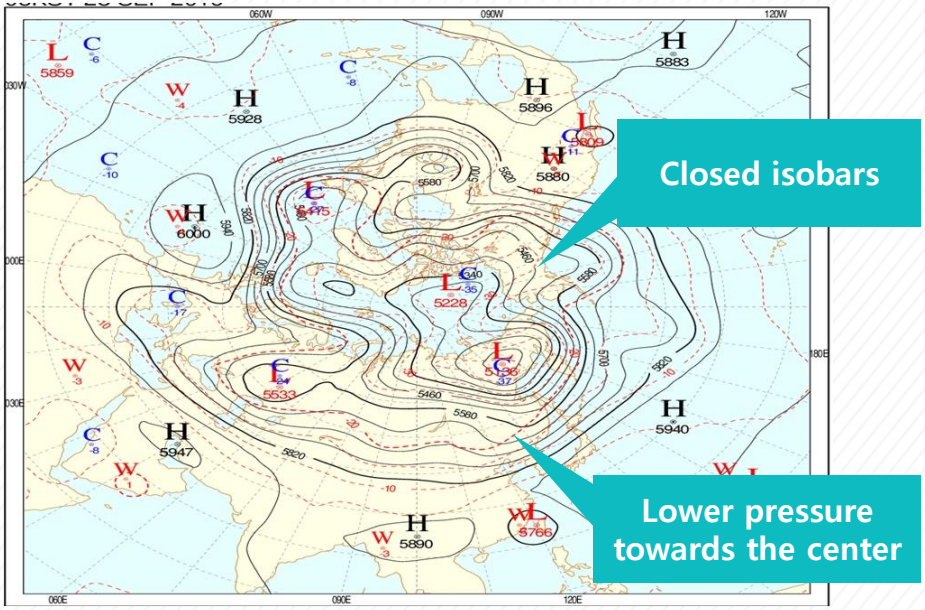
1. Explain highs and lows.
2. Compare various types of high and low pressure systems.
3. Explain weather phenomena depending on high and low pressure systems.

Learning Activities

1. Lows

A low is an area with lower pressure than its vicinity. In general, the term "lows" or "highs" refers to the synoptic scale systems displayed in the weather map. Surface low pressure enclosed by labeled isobars, and the pressure becomes lower toward the center.

A low can be also observed in upper-level charts. Low pressure is indicated by a region with lower height toward the center. Air does not move straight toward the low pressure center due to the influence of the Coriolis force.



※ Source: Korea Meteorological Administration

Learning Activities

1. Lows

Around the surface low (in Northern Hemisphere), wind blows counterclockwise toward the center of the low pressure by the influence of the surface friction. In upper-level low, airflow is not directed toward the center of the low pressure but parallel to isobars.

In the case of the low pressure developed near surface, the air moves toward the center and can instantly increase the pressure in the center weakening the low. In order for the low pressure system to continuously develop, air that moves inward toward the center must go somewhere. The air begins to flow up and spread apart. Surface convergence, rising motion, and upper level divergence make the low pressure system persist in the surface. If the upper level divergence is stronger than the surface convergence, the surface low continues to develop.

Low pressure can be classified into tropical extratropical cyclone and tropical cyclone depending on its genesis region. It can also be classified as warm low and cold low based on the location where the cyclone develops and the temperature distribution of its surrounding.

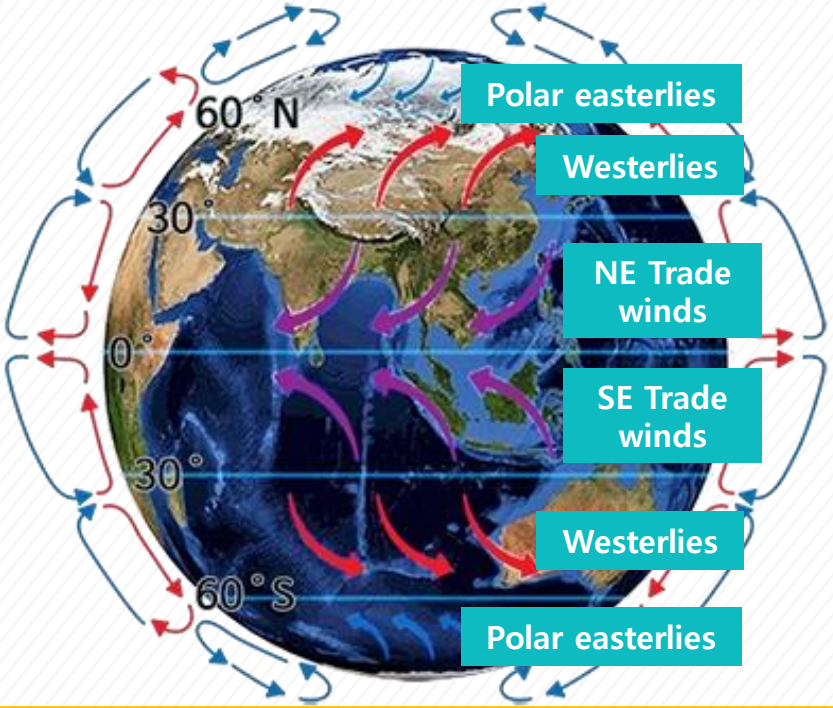
Learning Activities

1. Lows

1) Extratropical cyclone and tropical cyclone

The extratropical cyclones, which are also called the mid-latitude cyclones or Wave Cyclones, are low-pressure systems that occur in mid-latitude regions. In general, extratropical cyclone is classified as migratory cyclone because it tends to move from west to east due to the influence of westerlies. In addition, it is a synoptic weather system accompanying with high pressure systems that can be seen every day. It is associated with weather phenomena such as cloud, wind, heavy rain and thunderstorm.

The extratropical cyclone is associated with frontal system and is mainly generated in regions of high baroclinic instability with strong temperature gradient (30˚N to 60˚N in the Northern hemisphere, and 30˚S and 70˚S in the Southern hemisphere). Extratropical cyclones are closely related to upper level Jet stream.



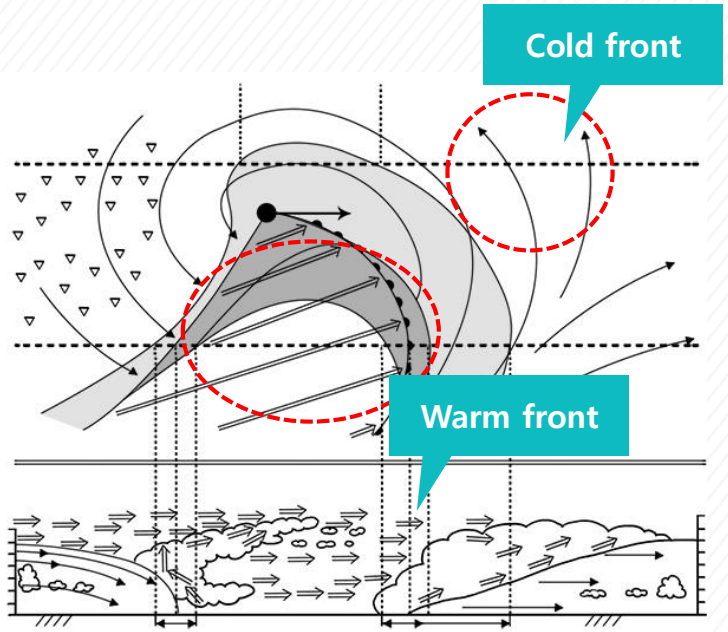
Extratropical cyclone genesis is related to Jet stream

Learning Activities

1. Lows

The jet stream is westerly wind aloft resulted from the steep pressure gradient in association with latitudinal temperature gradient. The Jet stream refers to the region where the westerly wind shows the maximum. Since the meridional temperature gradient is the largest in the mid-latitude, and the temperature gradient increases with higher altitude, the Jet stream develops in the upper-level mid-latitude. The convergence and divergence by the variation of upper-level Jet induce surface high and low pressure, and this low pressure system is the extratropical cyclone.

The extratropical cyclones are associated with fronts. Because of the cyclonic rotation, relatively warm air from the lower latitudes moves to the northeast and forms a warm front, whereas relatively cold air in the northwest moves to southeast and forms a cold front. This process promotes meridional transport of energy in the lower troposphere, which is one of the most important roles of the extratropical cyclone. Clouds are generated not only at the center of the cyclone, but on the frontal surface which result in precipitation along the front.



Learning Activities

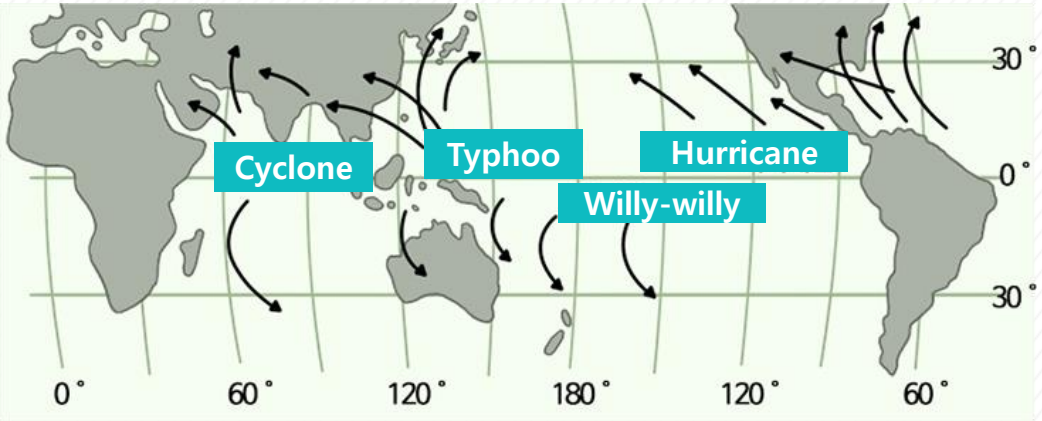
1. Lows

The lifecycle of extratropical cyclone was first introduced by a conceptual model by J. Bjerknes, a Norwegian scientist, in 1918 and has been gradually modified through observations.

Low pressure systems in the trade winds zone often develop as tropical cyclones. Tropical cyclones occurs over the ocean with sea surface temperature above 27˚C. Tropical cyclone can be categorized as depressions, tropical storms, and hurricane depending on the maximum wind speed.

Typhoon, which often accompanies with strong wind and rain, develops in the tropical ocean where warm air and moisture can be supplied. It gradually moves to higher latitude and resolves the thermal imbalance between the low and high latitudes caused by solar radiation.

Hurricane has several different names depending on where it origins. The tropical cyclone is called Typhoon over the western north Pacific, Willy-willy in Australia, and Cyclone over the Indian Ocean.



〈Hurricane formation regions〉

Learning Activities

1. Lows

The isobars of the tropical cyclone appear almost circular. Generally, the spacing of isobars in tropical cyclone is much closer than that of extratropical cyclones, indicating the pressure gradient force and wind are stronger. Because the pressure gradient is the maximum at the center of the tropical cyclone, the wind is the strongest near the center.

Tropical cyclones occur mainly in the western Pacific, eastern Pacific, Indian Ocean, the Gulf of Mexico, and Atlantic Ocean, etc. In the northern hemisphere, the active season of tropical cyclone is from June to October, and in the southern hemisphere, from November to May.

In the tropical cyclone, as it goes towards the center, the wind changes from a geostrophic wind to a cyclostrophic wind, because the pressure gradient force and centrifugal force dominates and the Coriolis and frictional forces are negligible.

When the pressure gradient force and centrifugal force are in equilibrium state, the wind blows parallel to the isobars, so air cannot penetrate towards the center. This creates an eye at the very center. The eye is a region of light wind ranging tens of kilometers in diameter.

Air masses that could not enter the typhoon's eye would rise around the eye and diverge into the upper layer and induce a weak descending motion in the eye which prevents cloud formation. Therefore, adjacent to the eye is the eyewall, a ring of intense thunderstorms that whirl around the storm center with a strong ascending motion.

Learning Activities

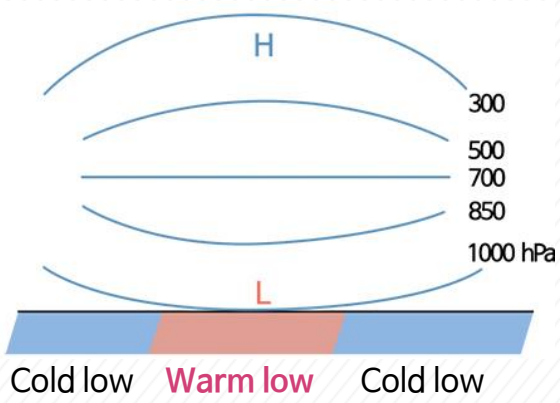
1. Lows

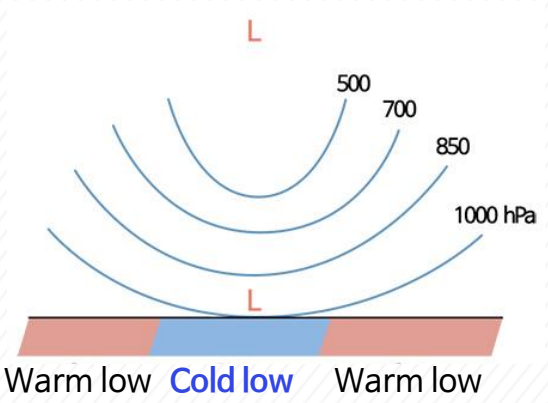
2) Warm low and cold low

Warm and cold lows are categorized according to the distribution of the temperature in the vicinity where the low develops. The warm low refers to the low pressure which is warm at the center and shows symmetrically cold temperature distribution in the surroundings.

The warm low gradually becomes weaker as it goes upward, and it can turn into a high at upper levels. Typical warm lows include the Siberian Low that develops over the summer continent.

The cold low refers to the low pressure which is cold from the center and shows relatively warm temperature distribution from the surroundings. The cold low shows a stronger low pressure toward the higher altitude. Typical cold lows include Aleutian Low and Icelandic Low.



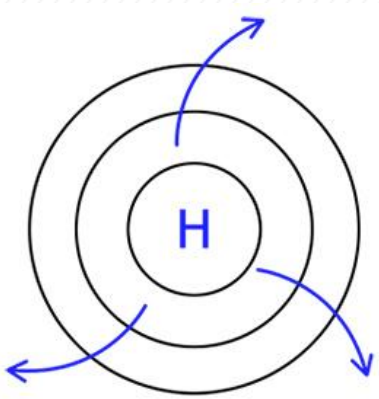


Learning Activities

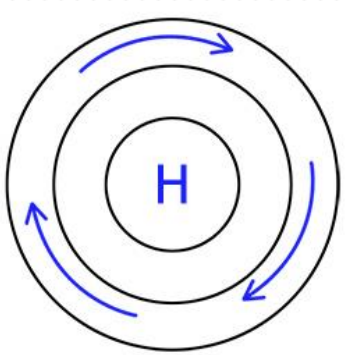
2. High pressure

What is a high? A high is a higher-pressure area than the surrounding area. It is depicted by closed isobars, and the pressure becomes higher toward the center. In upper level, a high is indicated by a region with elevated height toward the center.

In a surface high, air flows clockwise outward the center of the high due to the influence of the friction. In the upper level, air does not move outward from the center because the air is not affected by friction and swirls in a clockwise direction parallel to the isobars in the Northern Hemisphere.



Surface high



Upper-level high

Learning Activities

2. High pressure

In the surface high, the air moves from the center to the outside, so the pressure in the center drops quickly. In order to maintain the high pressure, it is necessary to constantly replace the air that is emitted from the center. This is possible by the sinking air.

In the surface high, air is adiabatically compressed and clouds are not generated due to the descending air. Pressure gradient force is generally weaker than the low pressure system, and the isobars are far apart, so the strength of the wind is weaker. As the movement of a high is slower than that of a low, the weather does not change rapidly in a high pressure system.

The highs can be classified into stationary high and migratory high, and into warm anticyclone and cold anticyclone depending on the horizontal temperature distribution.

Learning Activities

2. High pressure

1) Stationary high and migratory high

High pressures can be classified into relatively large stationary high and relatively small migratory high that moves eastward with the westerlies in mid-latitudes.

Stationary high develops in response to large terrain or land-sea distributions. The Siberian high that affects Korea in winter and the North Pacific high that extends to the vicinity of Korea during summer can be examples. In winter (summer), high (low) pressure is formed over continents, and low (high) pressure over oceans. Siberian high is caused by a cold heavy air due to the strong surface radiative cooling in winter.

The cold air at the poles moves to low latitudes along the troughs of the waves, forming high pressure. The North Pacific high pressure appears clearly from October to March. Most of the Eurasian continent is covered by Siberian high during December to February. The center of Siberian high is usually in Mongolia, and it does not move for a long period of time.

The North Pacific high in summer is associated with the descending branch of the Hadley cell. The descending motion causes adiabatic warming. The North Pacific high develops mainly in summer, and the center of the high pressure can be located near Ogasawara Islands, the central part of the North Pacific Ocean, and the northern part of the Hawaiian Islands.

The Okhotsk high also affects Korea. It generally develops in March through October, and is most pronounced in June to July. It is not as large as the Siberian high or North Pacific high, and the period is not long. Furthermore, the occurrence frequency and development intensity are irregular. Along with the North Pacific high, it plays an important role for the development of Changma front.

Learning Activities

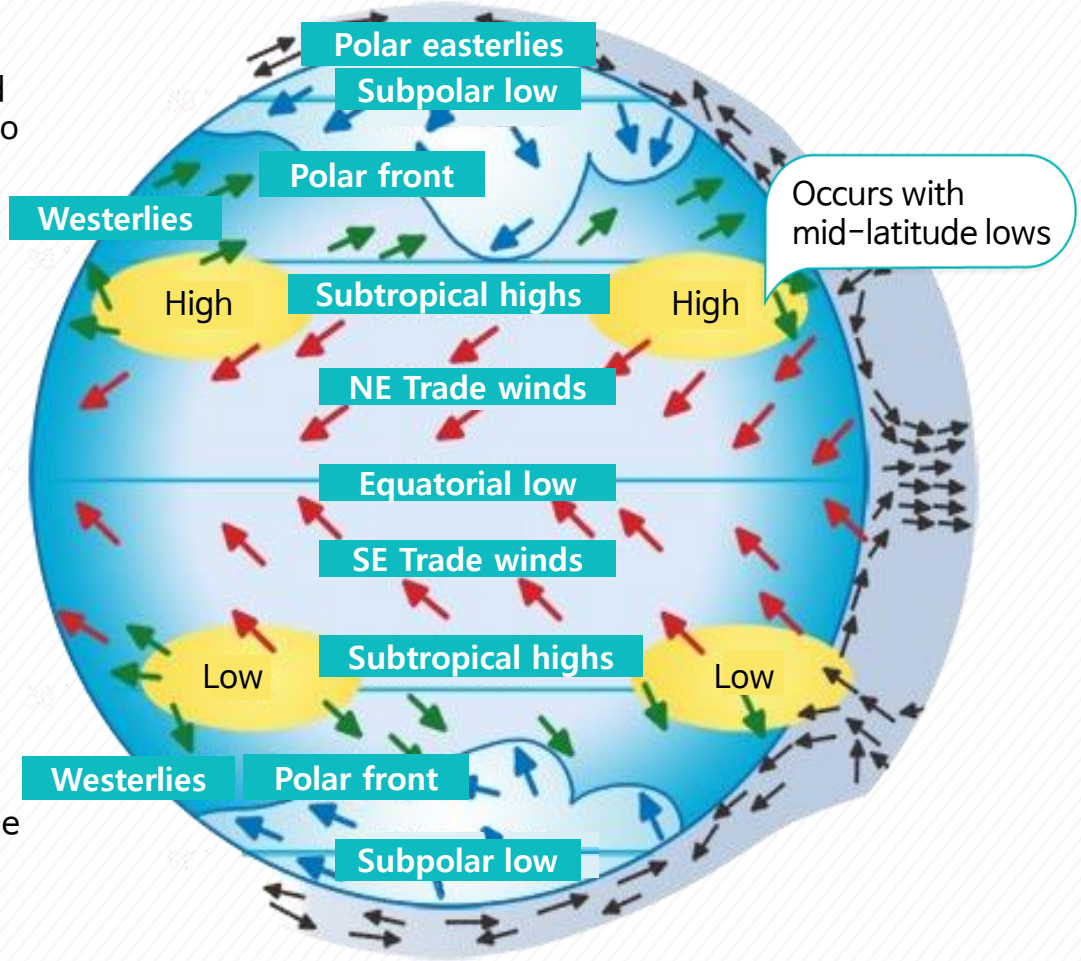
2. High pressure

The highs and lows in the mid-latitude move eastward about 10° per day, which approximately corresponds to 10 $m\ s^{-1}$. These mid-latitude highs and lows periodically change the weather for about a week.

These migratory highs are related to cold fronts and rapid weather changes in mid-latitudes.
The migratory highs developed within the westerly zone show a combination of the warm and cold types.

Migratory highs are characterized by asymmetric temperature distribution with respect to its center, unlike the stationary high. This causes a vertical titling. Migratory high typically has two centers.
The eastern center is the cold anticyclone below the upper trough, and the western center is the warm anticyclone. The Jet stream ridge is always above this center.

Both the formation and eastward movement of the high are due to the influence of the westerlies in the mid-latitudes.



Learning Activities

2. High pressure

2) Warm high and cold high

As mentioned earlier, warm and cold highs are classified according to the horizontal distribution of temperature in the vicinity of high pressure.

If the high pressure area is warmer (colder) than the surroundings, it is called the warm (cold) high. At the center of a warm high, since the rate of pressure decrease is smaller than that of the surroundings, the high becomes more dominant as it goes to the upper level.

On the other hand, in the case of the center of a cold high, the decrease rate of the atmospheric pressure with increasing height is larger than that of the surroundings, so its characteristics as a high get weaker in upper layer at about 3km.

Therefore, the warm high is a high level anticyclone, and cold high is a low level anticyclone. The warm highs develop over the subtropics in between the westerlies and trade wind zone. Cold highs appear primarily in high latitude regions. Typical cold highs include the Siberian high, which is a high level anticyclone. However, most of highs cannot be clearly distinguished by warm or cold highs because they are usually a combination of warm and cold highs.

Summary

1. Lows

- A low is an area with lower pressure than the surrounding area.
- In the northern hemisphere, around a low, the wind blows counterclockwise to the center of the low pressure.
- Low pressure can be classified into tropical extratropical cyclone and tropical cyclone depending on the region of its origin.
- Tropical cyclone
  - Forms in the Tropics (Latitude 8~25˚)
  - Pressure gradient force and wind are the maximum near the center.
  - In the Northern hemisphere, it occurs mainly from June to October and has the maximum occurrence in September.
- Warm and cold lows are categorized according to the distribution of the temperature in the vicinity of the lows.
- Warm low
  - Low pressure area with warmer temperature at the center than the surroundings.
  - Low level cyclone which loses its characteristics at upper levels.
  - Siberian low
- Cold low
  - Low pressure area with colder temperature at the center than the surroundings.
  - High level cyclone which becomes clearer at upper levels.
  - Aleutian Low and Icelandic Low

Summary

2. Highs

- A high is an area with higher pressure than the surrounding area.
- Classified as a stationary and migratory highs
- Stationary high develops in response to large terrain or land-sea distributions and has long duration.
  - North Pacific high is a high level anticyclone which affects Korea during summer.
  - Siberian high is a low level anticyclone caused by surface radiative cooling during winter.
  - Okhotsk high is most pronounced in June to July. Along with the North Pacific high, it plays an important role for the development of Changma front.

- Migratory highs are relatively small and stay shorter than the stationary highs. It develops within the westerly zone.
- The highs and lows in the mid-latitude move eastward about 10° per day, which approximately corresponds to a speed of 10〖 m s^{-1}. These mid-latitude highs and lows periodically change the weather for about a week.
- Warm and cold highs are classified according to the horizontal distribution of temperature.

Summary

2. Highs

- Warm high
  - High pressure area warmer than the surroundings
  - High level anticyclone
  - North Pacific high
- Cold high
  - High pressure area colder than the surroundings
  - Low level anticyclone
  - Siberian high