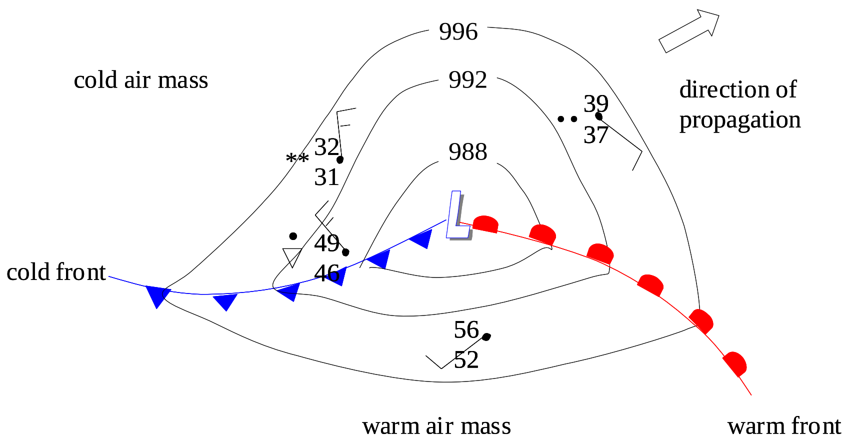
Frontal cyclones

-otherwise known as mid-latitude or wave cyclones. A cyclone is a cyclonically rotating system which, in mid- and high-latitudes is normally associated with the boundary between air masses of different temperature. Such boundaries are called fronts and typically they are related into a wave-like pattern when seen on a surface weather map. Below is a sketch of a frontal cyclone with some of its usual features.



Air masses

An air mass is a body of air having large horizontal extent (several 100’s to 1000’s km) of nearly uniform properties (temperature, humidity).

Air masses are labeled according to their source region in the following manner:

Arctic	A
Polar	P (really sub-polar)
Tropical	T (really sub-tropical)
Equatorial	E

These labels are modified according to the surface type of the source region:

maritime	m
continental	c

Resulting in the following:

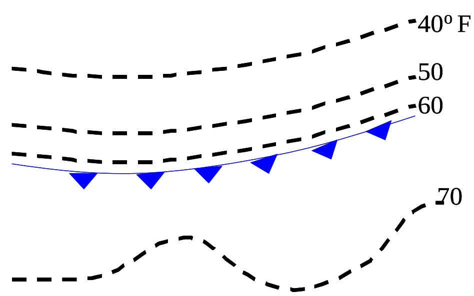
Arctic	A
maritime polar	mP
continental polar	cP
maritime tropical	mT
continental tropical	cT
Equatorial	E

The first four are common over the N-American continent.

Fronts

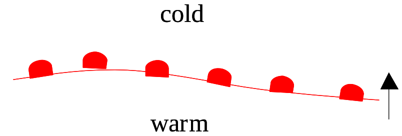
A front is the boundary between two air masses. In reality, we should think of a frontal zone of relatively rapid transition between two air masses. Fronts are sometimes sharp, particularly in the vicinity of a surface low, and at other times are quite diffuse and difficult to identify on a weather map.

As a convention, a front is marked at the northerly limit of the warmer air mass, so that the zone of transition occurs north of the front, e.g.,



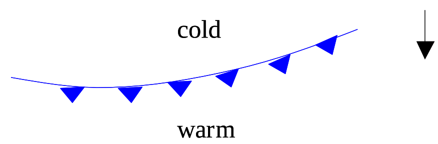
The front is named according to the colder air mass. Thus, the boundary between mT and mP air masses would be called the polar front, while that between mP and A would be called the Arctic front.

Fronts are classified according to their direction of motion. A warm front indicates that warm air is replacing cold air.



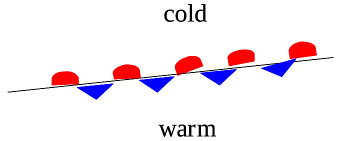
warm front

A cold front represents a situation in which cold air is advancing to replace warm air at the surface:



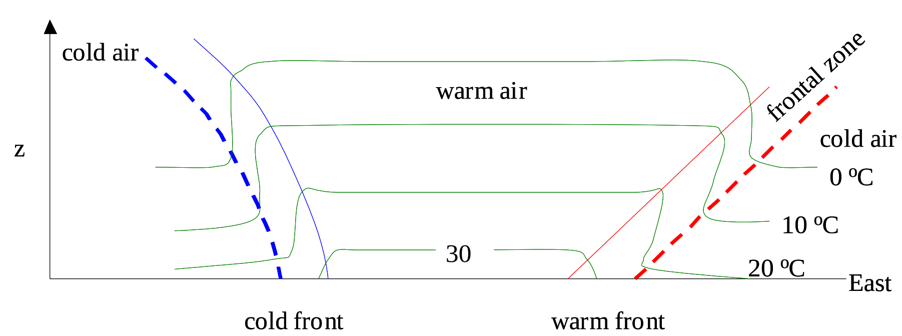
cold front

If a frontal boundary shows no significant motion in either direction, it is stationary and is marked thus:



stationary front

A frontal boundary is continuous in the vertical although fronts are not marked on upper air charts. Because cold air is denser than warm air, it sinks beneath the warm air, and frontal boundaries are sloping boundaries. Generally, the slopes are very gently, ranging from 1:50 to 1:300, with the steeper slopes, say 1:100, being found at cold fronts, and shallower slopes, say 1:200, being observed at warm fronts. These differences are partly due to the effect of friction retarding the advancing cold air (cold front) or retreating cold air (warm front). A cross section of the thermal pattern through a frontal cyclone might look like the following:



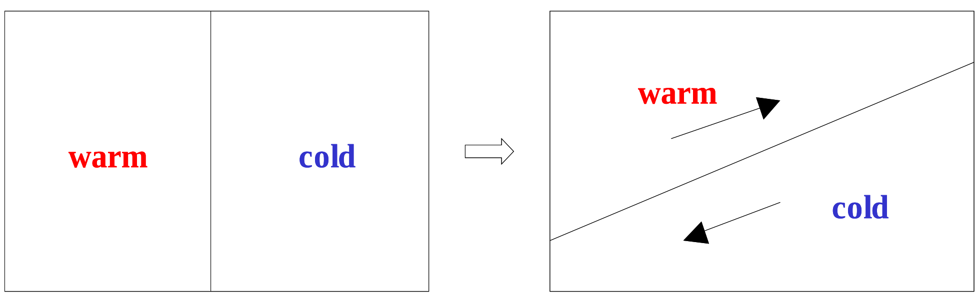
Note that in the diagram the steepness of the frontal slopes are greatly exaggerated.

The attached figures present characteristic patterns of cloudiness and precipitation at warm and cold fronts. Typically, warm fronts are associated with stratified clouds and with steady light to moderate rain, while cold fronts often have cumuliform clods and showery precipitation. Individual cases can, of course, differ considerably from this normal pattern.

Development of a wave cyclone

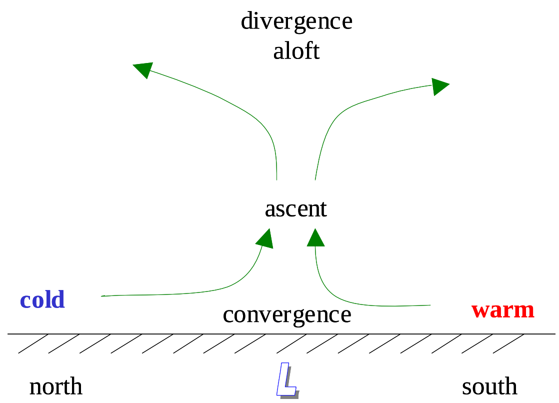
A logical question to ask is “why are fronts associated with mid-latitude cyclones?”. There are basically two parts to the answer:

1) A frontal boundary between warm and cold air masses is a zone of energy conversion in which gravitational potential energy is converted into the kinetic energy of motion.

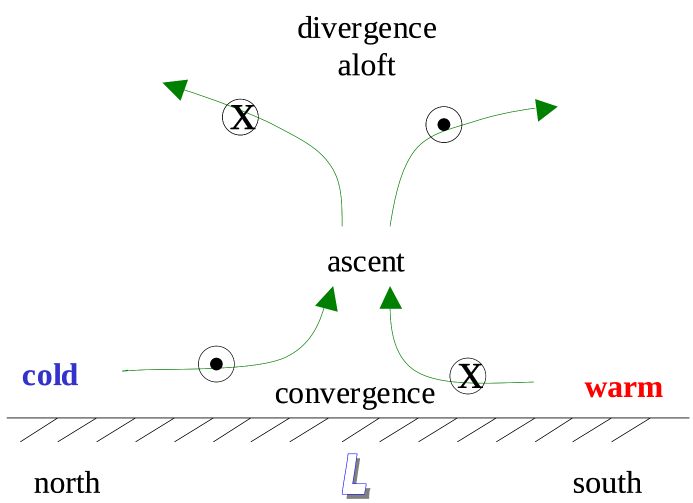


Consider a container with a vertical partition separating warm and cold air. As the partition is removed the cold dense air sinks beneath the warm air which rides over the top. The center of gravity of the system lovers (reducing PE) and motion is created (KE).

2) A cyclone is a region of low level convergence which brings together warm air from the south and cold air from the north, enhancing or at least maintaining the frontal boundary.

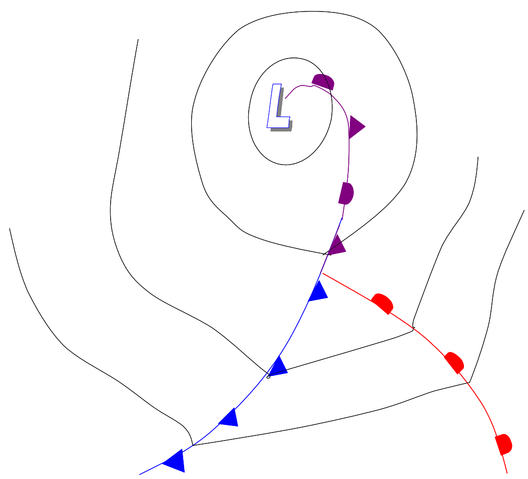


The following diagrams show, first, the hypothetical case of a vertical boundary between air masses inducing motion which is influenced by the Coriolis force to produce cyclonic rotation. The second diagram illustrates three stages in the development of a wave cyclone as would be seen on a surface weather map.

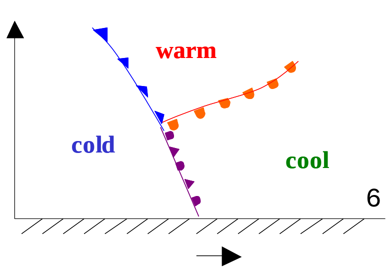


Another Fig

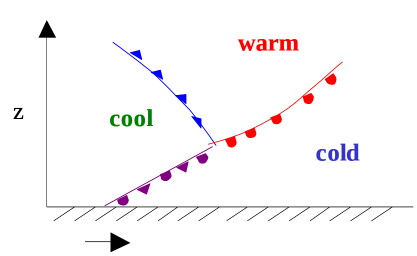
Generally, the advancing cold front moves more quickly than the warm front and eventually clips off and lifts up the warm air near the center of circulation. This process is called occlusion. The warm sector at the surface is now removed from the low center and a boundary is left, as shown in the diagram, between a fresh outbreak of cold air from the northwest and retreating cold air to the east of the low. When the warm air is moved sufficiently far from the strong circulation, a source of energy is lost and the cyclone dissipates. An example of an occluded system is shown in the attached satellite photograph of clouds spiraling in towards a low center in the Gulf of Alaska. The warm air sector extends from the SE up into the cloud mass on the right hand side of the photograph, and is far removed from the low center.



Occluded fronts can be of two types: the more usual cold type occlusion, or the less frequent warm type occlusion. These are illustrated in the following vertical cross-sections, west to east through an occlusion.



cold type occlusion



warm type occlusion

In both cases, the warm air mass is lifted off the ground. On the left, a fresh outbreak of cold air also lifts the modified cool air to the east. On the right, the air coming from the NW is not as cold as the existing air mass to the east and rides up over the top of it. This latter situation might occur when air from the NW has a trajectory over the ocean, while the retreating cold air ahead of the system was a wintertime continental and very cold air mass.

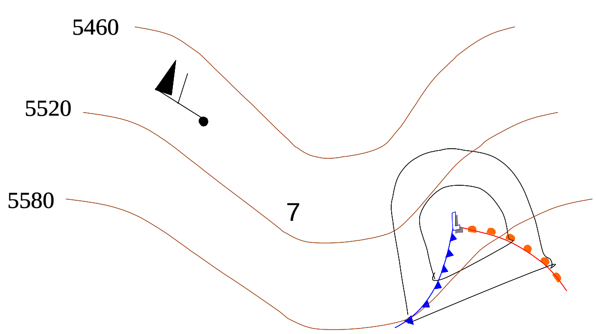
Examples of observed cyclone tracks (March 1989) are also shown on an attached diagram. They generally migrate eastward as dictated by the upper air flow patterns. Tracks range in length from a few hundred km to several thousand km. Preferred locations for their formation are (a) off the eastern coasts of continents as relatively cool air masses are warmed from below by relatively warm waters, and (b) east of N-S mountain ranges such as the Rockies.

Relationship of the wave cyclone to upper air trough

Through the quarter we have seen many examples of frontal cyclones migrating ahead of an upper air trough. There is a good reason for this relationship because the divergence in the upper troposphere at the downwind (east) side of an upper air trough removes mass horizontally creating a center of low pressure at the surface. This “upper air support” is an essential component of any significant wave cyclone.

Between the surface and the upper troposphere there is a continuous slope from the surface low upwards and westward to the trough aloft. This is illustrated in the following diagram.

Superimposing surface and 500ml charts the relationship between trough and low might look like the following.



In the final stages of development of a frontal cyclone, the system occludes and the surface low loses the support from upper air divergence. Typically, the trough aloft closes off into a closed circulation pattern, while the surface low falls back and comes into alignment with it. Thus, we are left with an almost vertically aligned column of rotating cold air which gradually loses its energy. The surface and 500 mb charts might then appear as below