ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL FOUR

INSTRUCTIONAL GUIDE

SECTION 2

EO M436.02 – DESCRIBE AIR MASSES AND FRONTS

Total Time: 90 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Review and prepare the demonstration located at Attachment A.

Prepare the slides located at Attachments B and C.

Photocopy the handout located at Attachment D for each cadet.

Prepare the learning stations located at Attachments E–I.

Photocopy a set of the fronts worksheets located at Attachment J for each cadet.

PRE-LESSON ASSIGNMENT

Nil.

APPROACH

An interactive lecture was chosen for TPs 1 and 2 to orient the cadets to air masses and fronts and generate interest in the subject.

An in-class activity was chosen for TP 3 as it is an interactive way to present types of fronts and associated weather.

INTRODUCTION

REVIEW

Nil.

OBJECTIVES

By the end of this lesson the cadet shall be expected to describe air masses and fronts.

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IMPORTANCE

It is important for cadets to describe air masses and fronts as knowledge of this material helps them to understand changes in weather conditions. Being able to describe air masses and fronts provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursing future aviation training will require.

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Teaching point 1 **Explain weather in an air mass.**

Time: 10 min Method: Interactive Lecture

WEATHER IN AN AIR MASS

There are three main factors that determine the weather in an air mass:

- moisture content,
- the cooling process, and
- the stability of the air.

Moisture Content

Continental air masses are very dry and little cloud develops. The high moisture content in maritime air may cause cloud, precipitation, and fog.

The Cooling Process

Even if the air is moist, condensation and cloud formation only occur if the temperature is lowered to the dewpoint. The cooling processes that contribute to condensation and the formation of clouds are:

- contact with a surface cooling by radiation,
- advection over a colder surface, and
- expansion brought about by lifting.

Cloud formation within an air mass is not uniform. For example, clouds may form in an area where the air is undergoing orographic lift even though the rest of the air mass is clear.

The Stability of the Air

In stable air, stratus cloud and poor visibility are common, whereas in unstable air, cumulus cloud and good visibility are common.

Characteristics of Cold Air Masses and Warm Air Masses

Cold air masses (eg, arctic and polar air masses) will typically have the following characteristics:

- instability,
- turbulence,
- good visibility,
- cumuliform clouds, and
- precipitation in the form of showers, hail, and thunderstorms.

Warm air masses (eg, tropical air masses) will typically have the following characteristics:

- stability,
- smooth air,
- poor visibility,

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- stratiform clouds and fog, and
- precipitation in the form of drizzle.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS:

Q1. What are the three main factors that determine weather in an air mass?

Q2. What are the cooling processes that contribute to condensation and the formation of clouds?

Q3. What are the characteristics of a warm air mass?

ANTICIPATED ANSWERS:

A1. Moisture content, the cooling process, and the stability of the air.

A2. Contact with a surface cooling by radiation, advection over a colder surface, and expansion brought about by lifting.

A3. Stability, smooth air, poor visibility, stratiform clouds and fog, and precipitation in the form of drizzle.

Teaching point 2 **Define and explain types of fronts.**

Time: 15 min Method: Interactive Lecture

FRONTS

A front is the transition zone between two air masses. The interaction of air masses along their frontal zones is responsible for weather changes.



Conduct the demonstration outlined at Attachment A to illustrate the mixing of warm and cold air masses:

(1) Allow the cadets to move closer so they can observe what will happen.

(2) Have the cadets predict what will happen when the divider is removed.

(3) Observe the action between the red and blue colored water.



The blue-dyed water represents a cold air mass and the red-dyed water represents a warm air mass. The area where these two air masses meet and mix is a front.



Show the slides located at Attachment B as fronts are presented.

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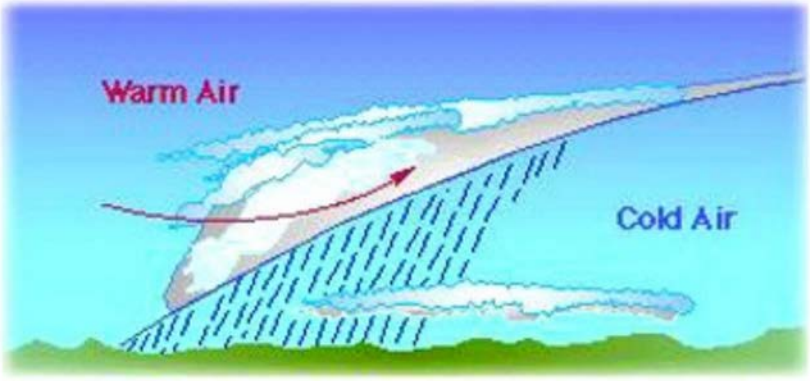
The blue water (colder and more dense) will slide underneath the warmer water which is the same that occurs to the air.



Note. From Remote Sensing Tutorial by N. Short, 2005, Federation of American Scientists. Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

Figure 1 Cold Front

The cold air mass is more dense and therefore sinks, undercutting the warm air which will ascend over the cold air.



Note. From Remote Sensing Tutorial by N. Short, 2005, Federation of American Scientists. Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

Figure 2 Warm Front

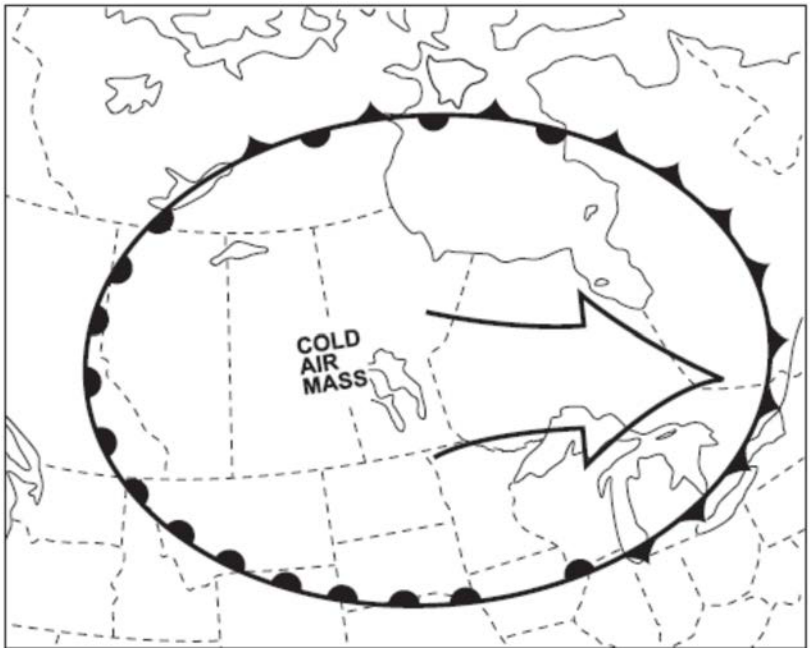


Show the slides located at Attachment C as front symbols are presented.

An air mass is a large section of the troposphere with uniform properties of temperature and moisture in the horizontal. An air mass can be several thousands of kilometers across and takes on the properties from the surface over which it formed.

Formation over ice and snow of the artic will be dry and cold. Formation over the South Pacific will be warm and moist. Formation over a large body of water is moist and is referred to as maritime air. An air mass over a large land area is dry and is referred to as continental air.

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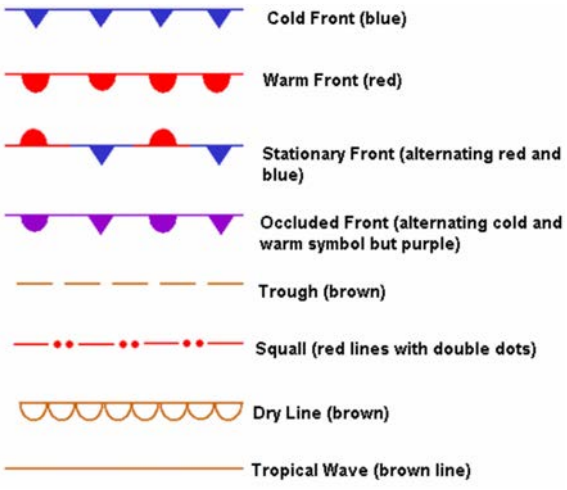


Note. From Air Command Weather Manual (p. 6-8), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

Figure 3 Air Masses and Fronts



Distribute the handout located at Attachment D to each cadet. Cadets will label each symbol as the information is presented.



Note. From "Weather", About.com, by R Oblanck, Copyright 2009 by The New York Times Company. Retrieved February 27, 2009 from http://weather.about.com/od/frontsandairmasses/qt/front_symbols.htm

Figure 4 Front Symbols

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CONFIRMATION OF TEACHING POINT 2

QUESTIONS:

Q1. Define a front.

Q2. What does the interaction of air masses along their frontal zones cause?

Q3. Explain what happens when a cold air mass and a warm air mass meet.

ANTICIPATED ANSWERS:

A1. A front is the transition zone between two air masses.

A2. Changes in the weather.

A3. The air in a cold air mass is more dense and therefore sinks, undercutting the warm air. The air in a warm air mass will ascend over the cold air.

Teaching point 3 **Conduct an in-class activity to describe types of fronts and associated weather.**

Time: 55 min Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is to have the cadets identify different types of fronts and their associated weather.

RESOURCES

- Pen / pencil,
- Coloured pencils / markers,
- Fronts information sheets located at Attachments E–I, and
- Fronts worksheets located at Attachment J.

ACTIVITY LAYOUT

Set up and clearly mark five learning stations, located at Attachments E–I.

ACTIVITY INSTRUCTIONS

1. Distribute all five fronts worksheets and a pen / pencil to each cadet.
2. Divide the cadets into groups of two or three and place each group at one of the learning stations.
3. Have the cadets fill out the appropriate fronts worksheet for that station.



At learning stations with more than one diagram the cadet can choose which one to draw.

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4. After nine minutes have the groups rotate to the next station until each group has completed all five stations.

5. Review the fronts worksheets as a class and answer any questions.

SAFETY

Nil.

CONFIRMATION OF TEACHING POINT 3

The cadets' participation in the activity will serve as the confirmation of this TP.

END OF LESSON CONFIRMATION

QUESTIONS:

Q1. What are the characteristics of a cold air mass?

Q2. What clouds indicate the passing of a warm front?

Q3. What is the term for the wedge-shaped mass of warm air lying above the colder air masses in an occluded front?

ANTICIPATED ANSWERS:

A1. Instability, turbulence, good visibility, cumuliform clouds, and precipitation in the form of showers, hail, and thunderstorms.

A2. Cirrus, cirrostratus, altostratus, nimbostratus, and stratus.

A3. Trowal.

CONCLUSION

HOMEWORK / READING / PRACTICE

Nil.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 3, Annex B, Aviation Subjects–Combined Assessment PC.

CLOSING STATEMENT

There are two basic types of weather: air mass and frontal. Knowledge of air masses and fronts is crucial for understanding weather patterns and making accurate predictions of changing weather conditions. This knowledge is essential for future aviation training and for potential instructional duties at the squadron.

INSTRUCTOR NOTES / REMARKS

It is recommended that the three periods required for this EO be scheduled consecutively.

Cadets who are qualified Advanced Aviation may assist with this instruction.

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Verify against the official publication.

REFERENCES

A3-044 CFACM 2-700 Air Command. (2001). *Air Command weather manual*. Ottawa, ON: Department of National Defence.

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

C3-334 Short, N. (2005). "Remote Sensing Tutorial". *Federation of American Scientists*. Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

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WARM AND COLD FRONT DEMONSTRATION OUTLINE

1. Fill a thermos / cooler / bottle with warm water and another with cold water.



Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

Figure A-1 Air Mass Equipment

2. Add a few drops of red food colouring to the bottle with warm water.
3. Add a few drops of blue food colouring to the bottle with cold water.
4. Shake / stir each bottle to evenly mix the colouring and water.
5. Place the empty jars together to ensure an exact match.
6. Fill one jar to almost overflowing with blue-dyed water and the other jar with red-dyed water.



Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

Figure A-2 Jars Filled

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7. Place an index card or a plastic coated paper on the top of the warm (red-dyed) water jar and press down around the edges of the jar to make a seal.



Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

Figure A-3 Card Over Red Jar

8. Place the warm water jar over the top of the cold water jar so that the edges meet.



Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

Figure A-4 Jars Stacked with Card Inserted

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9. Have an assistant gently remove the paper once the jars are stacked on each other, keeping the jars together (do this over a sink or container to catch any water that may leak out).



Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

Figure A-5 Jars Stacked with Card Removed

10. Keeping one hand on each jar, slowly turn the jars to one side while holding the centre together.



Note. Created by Director Cadets 3, 2009, Ottawa, ON: Department of National Defence

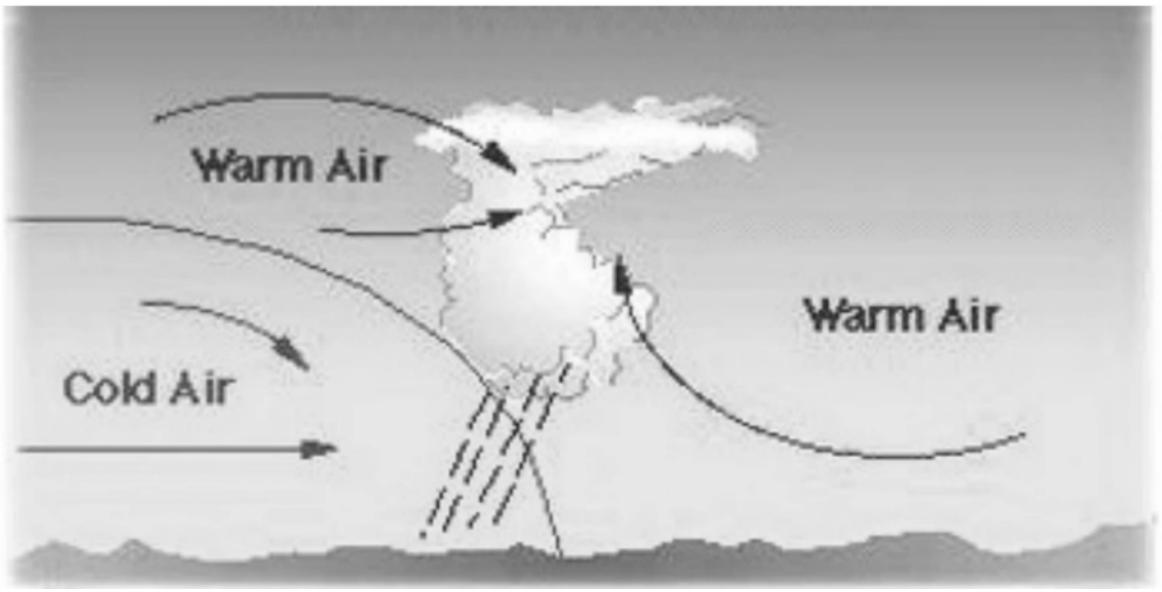
Figure A-6 Turn Jars on Side

11. Observe the action between the red and blue colored water.

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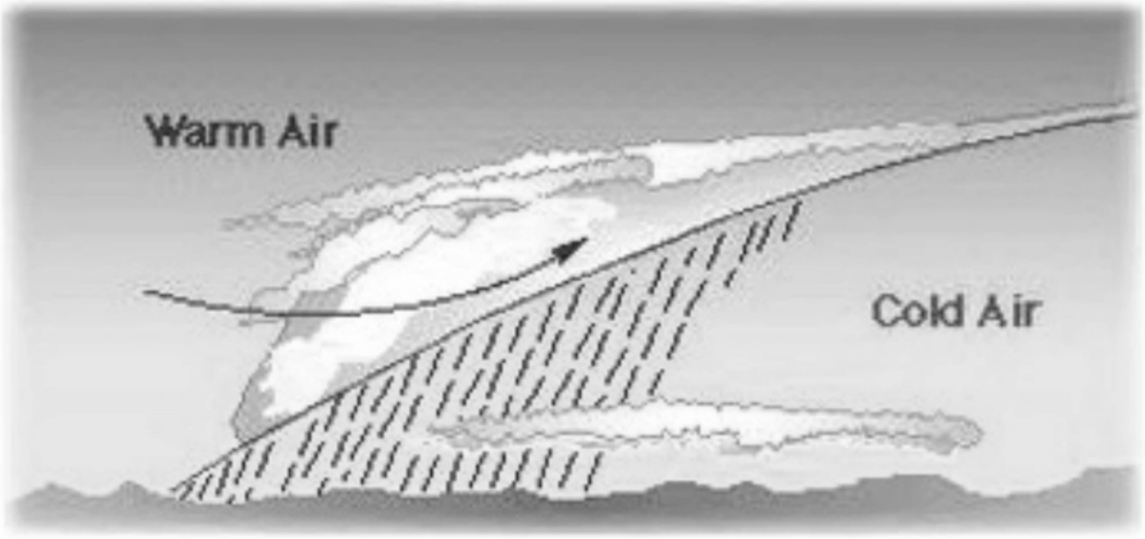
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Note. From Remote Sensing Tutorial by N. Short, 2005, Federation of American Scientists. Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

Figure B-1 Cold Front



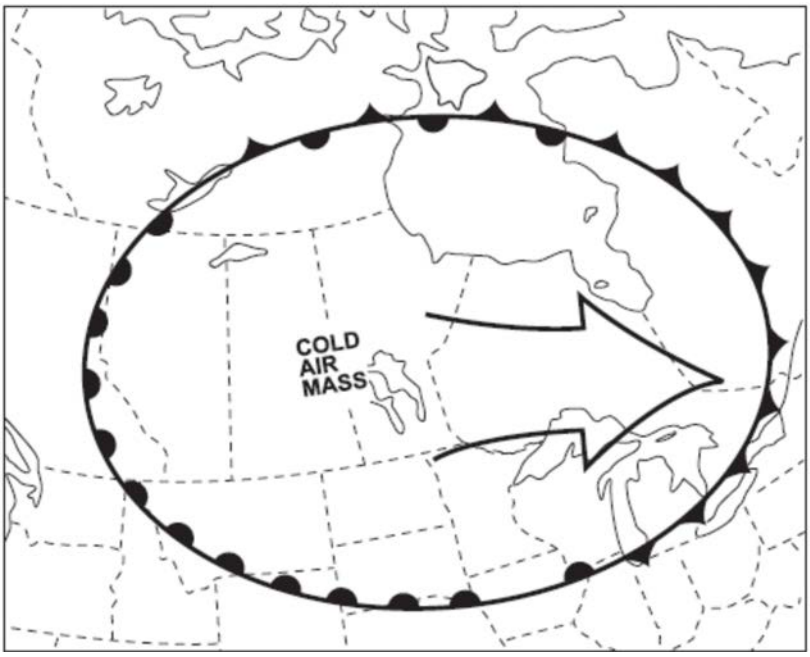
Note. From Remote Sensing Tutorial by N. Short, 2005, Federation of American Scientists. Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

Figure B-2 Warm Front

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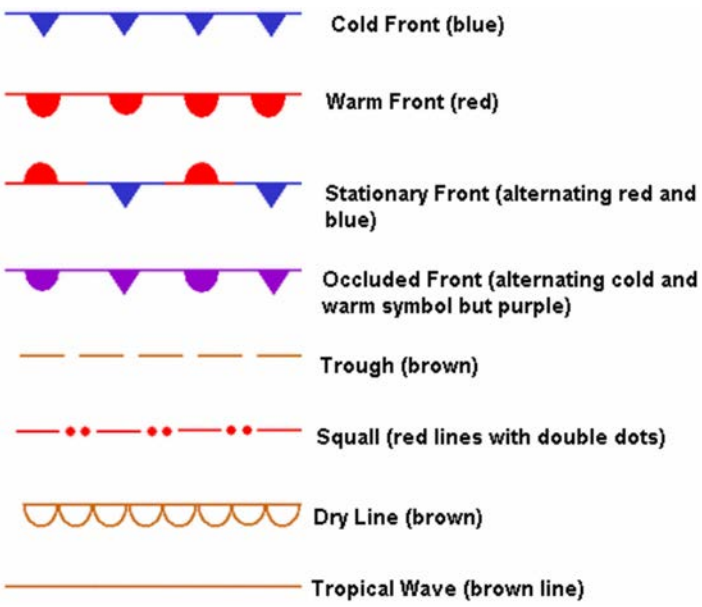
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Note. From Air Command Weather Manual (p. 6-8), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

Figure C-1 Air Masses and Fronts



Note. From "Weather" About.com, by R Oblanck, Copyright 2009 by The New York Times Company. Retrieved February 27, 2009, from http://weather.about.com/od/frontsandairmasses/qt/front_symbols.htm

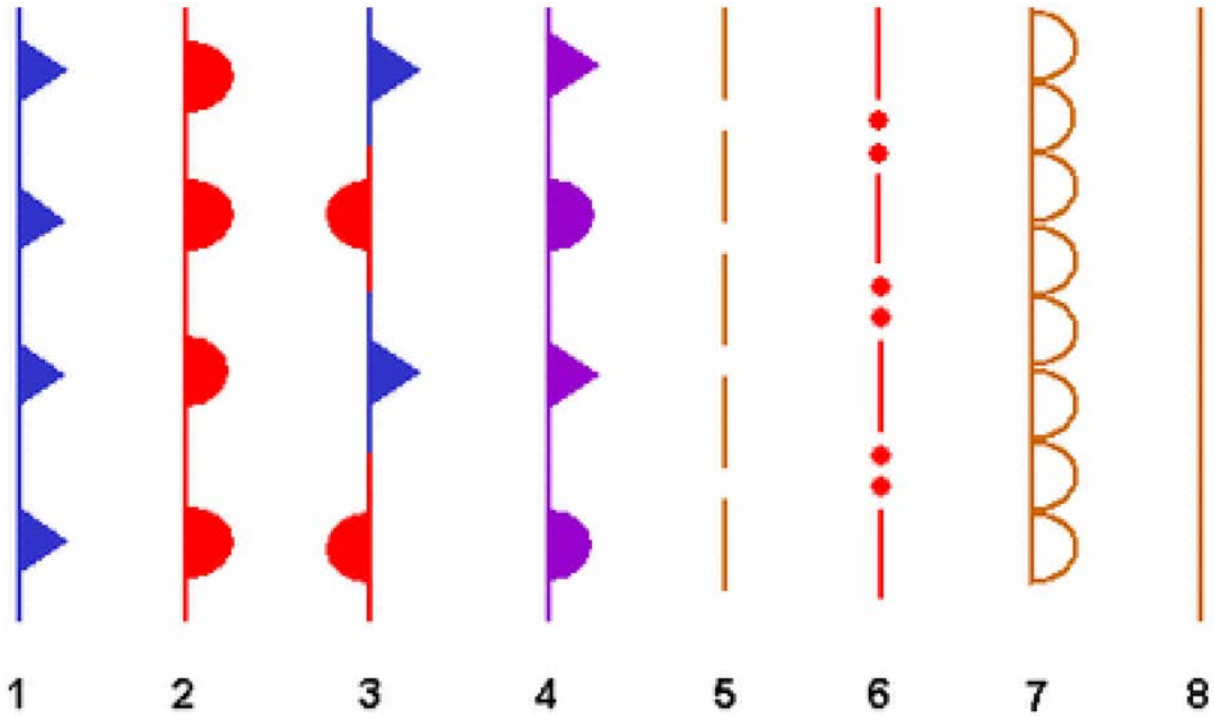
Figure C-2 Front Symbols

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WEATHER MAP SYMBOLS



	Front	Colour
1		
2		
3		
4		
5		
6		
7		
8		

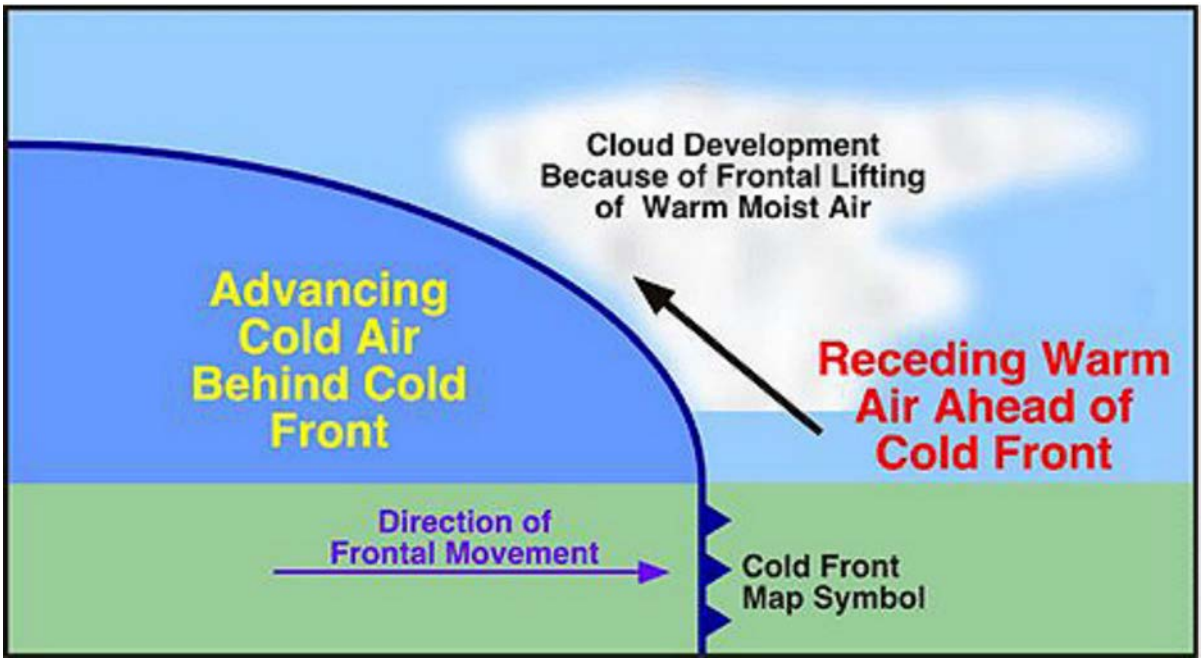
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COLD FRONT

A cold front is the part of a frontal system along which cold air is advancing.



Note. From Remote Sensing Tutorial by N. Short, 2005, Federation of American Scientists. Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

Figure E-1 Cold Front

When a mass of cold air overtakes a mass of warm air, the cold air, being denser, stays on the surface and undercuts the warm air violently. The slope of the advancing cold front is quite steep as surface friction slows the air at the surface, allowing the upper air to catch up. The rapid ascent of warm air gives rise to a relatively narrow band (only about 50 nautical miles) of cumuliform cloud that frequently builds up into violent thunderstorms.

The severity of the weather depends on the moisture content and stability of the warm air mass that the cold air mass is undercutting and the speed of the advancing cold front. If the warm air is very moist and unstable, towering cumulus clouds and thunderstorms are likely to develop, bringing heavy showers in the form of rain, snow, or hail. A slower moving cold front advancing on more stable and drier air will produce stratus or altocumulus clouds with light or no precipitation.

A squall line, a continuous line of thunderstorms, sometimes develops ahead of a fast moving cold front. The weather brought about by a squall line is extremely violent, including rapid shifts in wind, heavy rain or hail, and thunder and lightning. Pilots should avoid squall lines at all costs.

A sharp fall in temperature, a rise in pressure, and rapid clearing usually occur with the passage of the cold front.

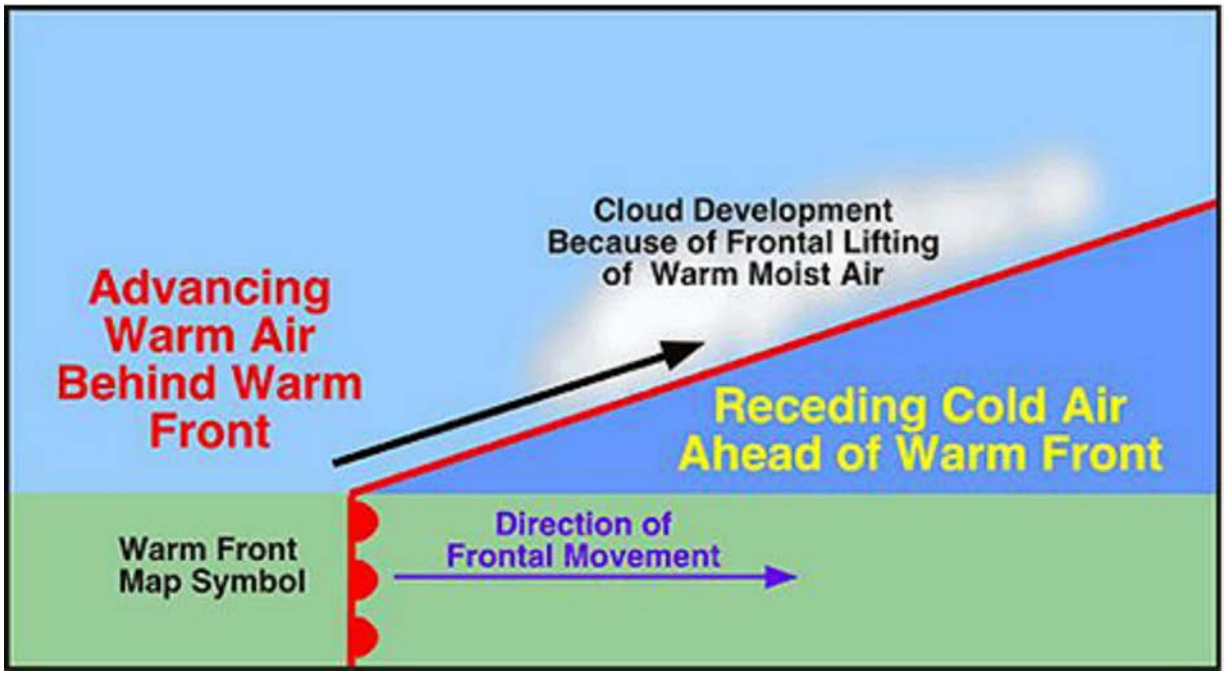
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WARM FRONT

A warm front is the part of a frontal system along which cold air is retreating.



Note. From Remote Sensing Tutorial by N. Short, 2005, Federation of American Scientists. Retrieved February 26, 2009, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

Figure F-1 Warm Front

As a mass of warm air advances on a retreating mass of cold air, the warm air, being lighter, ascends over the cold air in a long gentle slope. As a result of this long gentle slope and the relatively slow speed of warm fronts, the cloud formation associated with them may extend for 500 or more nautical miles in advance. If the warm air is moist and stable, these clouds develop in a distinctive sequence:

1. cirrus,
2. cirrostratus,
3. altostratus,
4. nimbostratus, and
5. stratus.

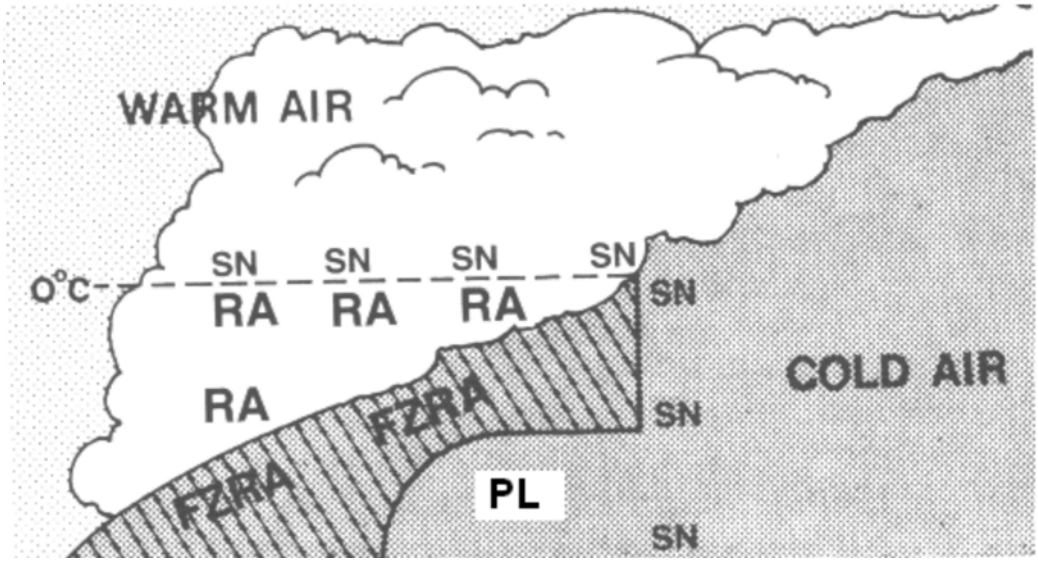
The clouds indicating the passing of a warm front can easily be remembered using the mnemonic "C-CANS".

If the warm air is moist and unstable, cumulonimbus and thunderstorms may be embedded in the stratiform layers, bringing heavy showers.

Warm fronts bring low ceilings and restricted visibility for a considerable length of time due to their slow movement.

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In winter, when temperatures in the cold air are below freezing and temperatures in the lower levels of the warm air are above freezing, snow and freezing rain can be expected. Snow (SN) falls from the part of the warm air cloud that is high and therefore below freezing. Rain (RA) falls from the lower warm air cloud but becomes supercooled as it falls through the cold air mass. This creates freezing rain (FZRA) and ice pellets (PL). Therefore, icing is a problem associated with warm fronts in winter.



Note. From From the Ground Up: Millennium Edition (p. 145), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

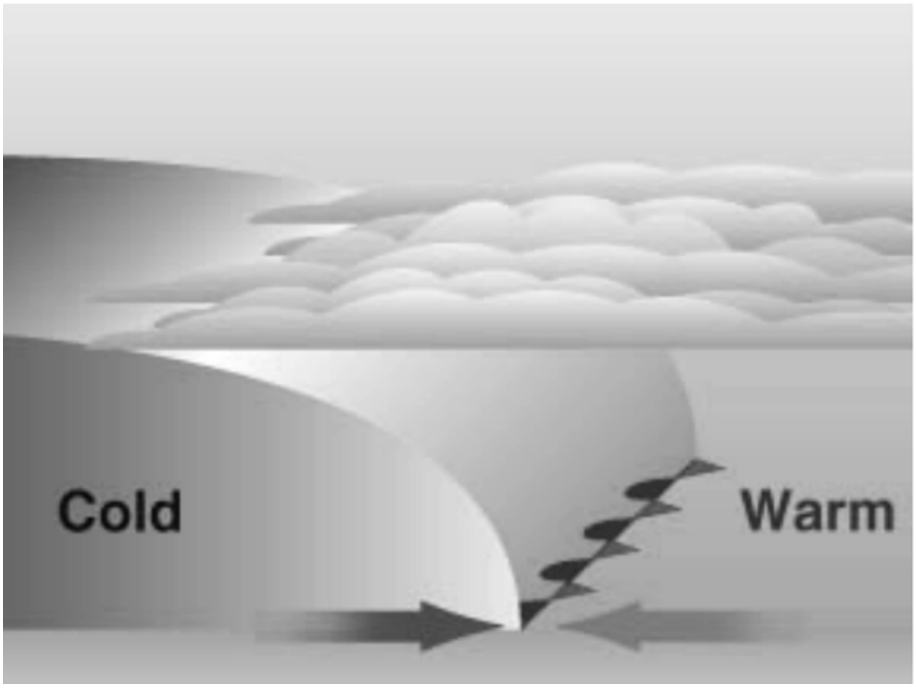
Figure F-2 Precipitation in a Warm Front in Winter

The passing of the warm front is marked by a rise of temperature due to the entry of the warm air, and the sky becoming relatively clear.

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STATIONARY FRONT

A stationary front is the part of a front along which the colder air is neither advancing nor retreating.



Note. From Geography for Kids, KidsGeo.com, Copyright 1998–2000. Retrieved October 17, 2008, from http://www.kidsgeo.com/geography-for-kids/0129-stationary-fronts.php

Figure G-1 Stationary Front

A stationary front occurs when the front does not move because the opposing air masses are of equal pressure. The weather conditions are similar to those associated with a warm front, (low cloud, and continuous rain or drizzle) although generally less intense and not so extensive. Usually a stationary front will weaken and eventually dissipate. Sometimes, however, it will begin to move after several days, becoming either a cold front or a warm front.

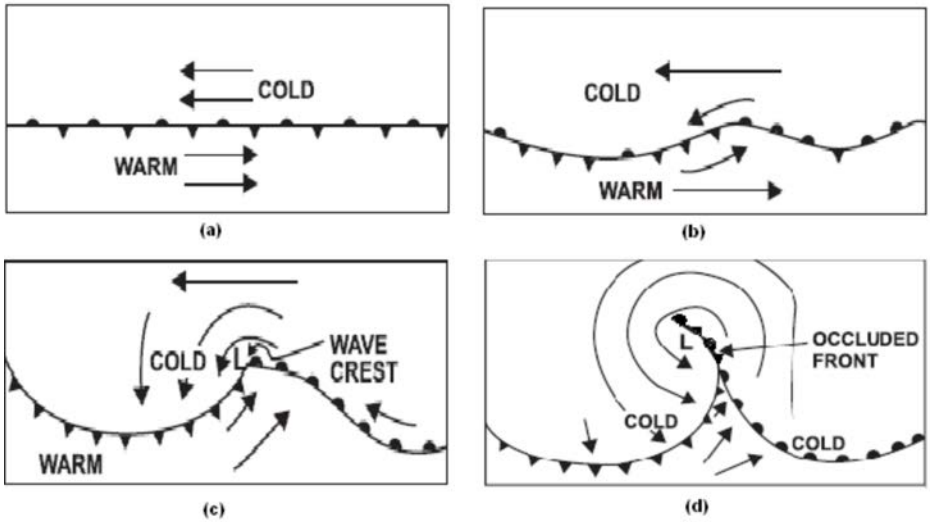
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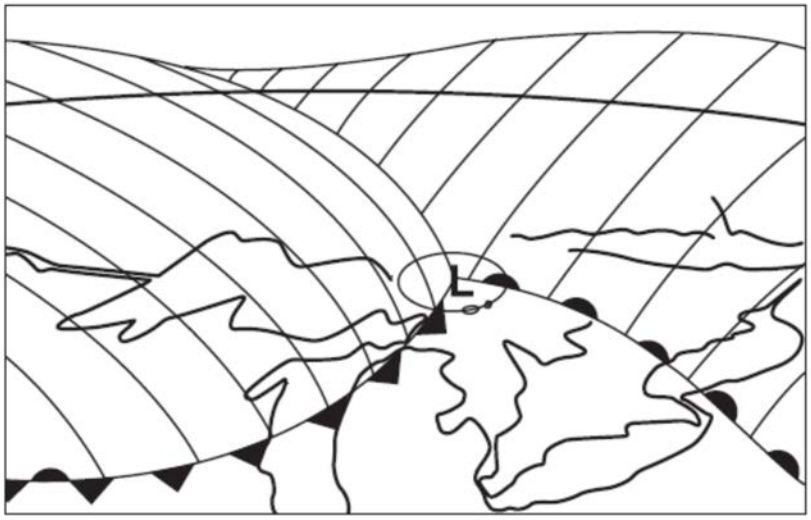
OCCLUDED FRONTS

A wave-like disturbance sometimes forms on a stationary front. This can develop into a small low known as a depression. As the depression forms, one section of the front begins to move as a warm front and the other section as a cold front. Over time, under certain atmospheric conditions, the cold front gradually overtakes the warm front and lifts the warm air entirely from the ground forming a single occluded front. Basically, the cold air catches up with itself as it flows around the low pressure area.



Note. From Air Command Weather Manual (pp. 7-12 and 7-14), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

Figure H-1 Occluded Front Formation

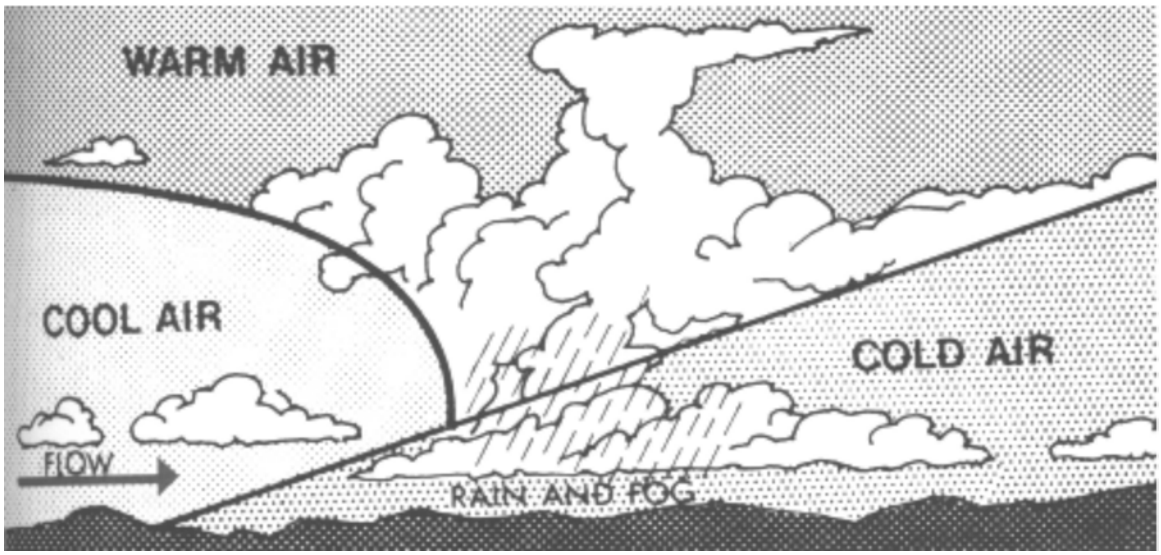


Note. From Air Command Weather Manual (pp. 7-13), 2004, Winnipeg, MB: Wing Publishing Office. Copyright 2004 by Her Majesty the Queen in Right of Canada.

Figure H-2 Frontal Depression

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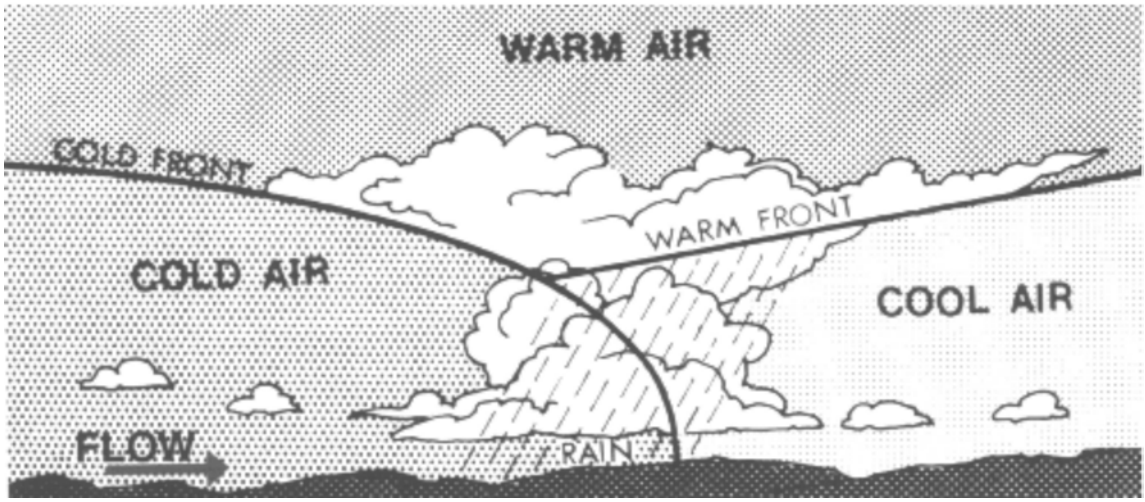
If the cold air is not as cold as the air it is overtaking (cool air advancing on cold air), the front is known as a warm occlusion.



Note. From From the Ground Up: Millennium Edition (p. 143), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

Figure H-3 Warm Occlusion

If the cold air is colder than the air it is overtaking (cold air advancing on cool air), the front is known as a cold occlusion.



Note. From From the Ground Up: Millennium Edition (p. 143), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.

Figure H-4 Cold Occlusion

In both warm occlusions and cold occlusions, three air masses are present: a cool air mass, a cold air mass, and a warm air mass lying wedge-shaped over the colder air. The wedge-shaped mass of warm air is known as a trowal.

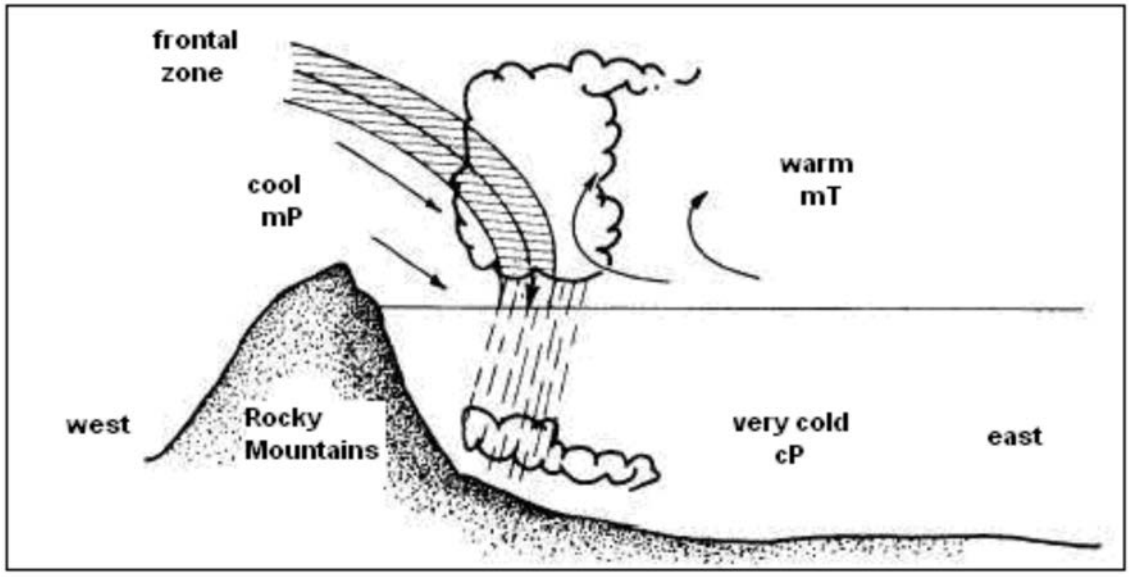
Both warm occlusions and cold occlusions have much the same characteristic as warm fronts, with low cloud and continuous rain. If the warm air is unstable, cumulonimbus clouds may develop; they are more likely to occur and bring about heavy turbulence, lightning, and icing in a cold occlusion.

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UPPER FRONTS

An upper cold front can form in two ways:

- A cold front advancing across the country may encounter a shallow layer of colder air resting on the surface. The cold front will then leave the ground and ride up over the colder, heavier air.



Note. From Integrated Publishing, Aerographer / Meteorology, Copyright 2003 by Integrated Publishing. Retrieved October 20, 2008, from http://www.tpub.com/content/aerographer/14312/css/14312_121.htm

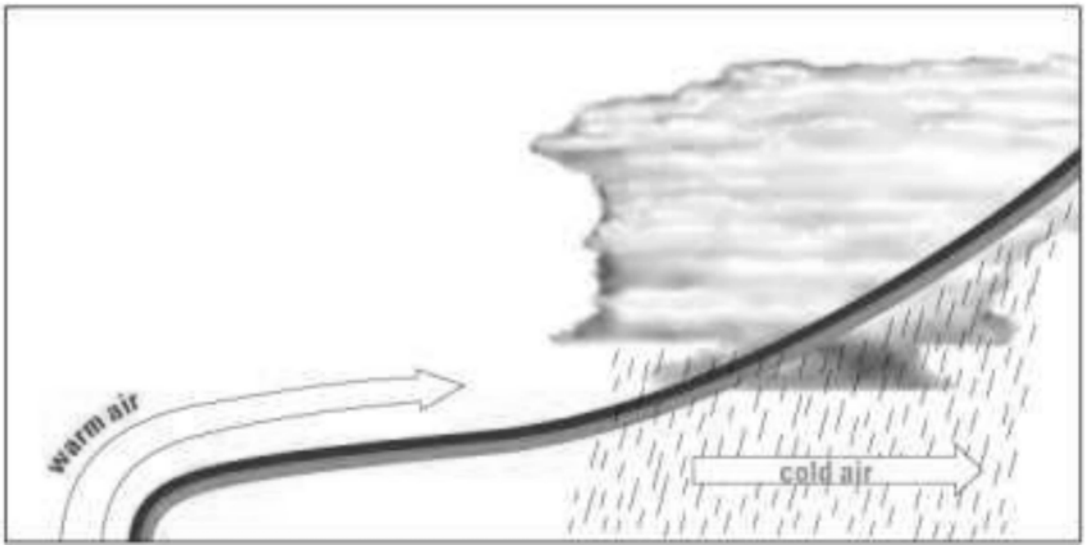
Figure I-1 Upper Cold Front

- The structure of the advancing cold front is such that the cold air forms a shallow layer for some distance along the ground in advance of the main body of cold air. This causes the frontal surface of the main mass of cold air to be very steep. The line along which the frontal surface steepens is also known as an upper cold front.

An upper warm front can form in two ways:

- An advancing warm front rides up over a layer of cold air trapped on the ground. A change of air mass is not experienced on the ground because the front passes overhead.
- The surface of the cold air that is retreating ahead of an advancing warm front is almost flat for some distance ahead of the surface front and then steepens abruptly. The line along which the surface of the retreating cold air steepens sharply is also called an upper warm front.

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Note. From Weather and Frontal Systems, 2004, Meteorological Services of Canada. Copyright 2004 by Environment Canada. Retrieved October 20, 2008, from http://www.qc.ec.gc.ca/meteo/Documentation/Temps_fronts_e.html

Figure I-2 Upper Warm Front

Weather in upper fronts can be particularly hazardous in winter. Similar to warm fronts, rain from the warmer air falls through the layer of cold air on the surface causing freezing rain and icing conditions.

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COLD FRONT

DEFINITION:

ASSOCIATED WEATHER:

INTERESTING FACTS:

DIAGRAM:

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WARM FRONT

DEFINITION:

ASSOCIATED WEATHER:

INTERESTING FACTS:

DIAGRAM:

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STATIONARY FRONT

DEFINITION:

ASSOCIATED WEATHER:

INTERESTING FACTS:

DIAGRAM:

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OCCLUDED FRONTS

DEFINITION OF WARM OCCLUSION:

DEFINITION OF COLD OCCLUSION:

ASSOCIATED WEATHER:

INTERESTING FACTS:

DIAGRAM:

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UPPER FRONTS

UPPER COLD FRONT FORMATION:

1.

2.

UPPER WARM FRONT FORMATION:

1.

2.

ASSOCIATED WEATHER:

DIAGRAM:

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