CHAPTER 13

PO 336 – IDENTIFY METEOROLOGICAL CONDITIONS

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 1

EO M336.01 – DESCRIBE PROPERTIES OF THE ATMOSPHERE

Total Time: 30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, 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.

Create a slide of the divisions of the atmosphere located at Annex A.

Bring resources needed for demonstration in TP 2.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to introduce the cadet to the properties of the atmosphere.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have described properties of the atmosphere.

IMPORTANCE

It is important for cadets to describe properties of the atmosphere to enhance their understanding of how weather conditions are created.

Teaching Point 1 | **Describe the Composition of the Atmosphere**

Time: 5 min | Method: Interactive Lecture

COMPOSITION OF THE ATMOSPHERE

The atmosphere is composed of a mixture of invisible gases. These gases make up the majority of the atmosphere. There are also small particles of dust and debris in the lower levels of the atmosphere.

The Breakdown of the Major Gases

At altitudes of up to 250 000 feet above sea level (ASL), the atmosphere is composed primarily of nitrogen, oxygen, argon, carbon dioxide, hydrogen, water vapour, and several other gases. Each of these gases comprises a certain percentage of the atmosphere.

- **Nitrogen.** Nitrogen is the most abundant gas by percentage of the atmosphere at 78 percent.
- **Oxygen.** Oxygen is the second most abundant gas by percentage of the atmosphere at 21 percent.
- **Other.** The rest of the gases make up approximately 1 percent of the atmosphere.

The Importance of Water Vapour

Water vapour is found only in the lower layers of the atmosphere. The amount of water in the atmosphere is never constant, but it is the most important of the gases from the standpoint of weather. It can change from a gas into water droplets or ice crystals and is responsible for the formation of clouds.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. How much of the atmosphere is composed of nitrogen?

Q2. How much of the atmosphere is composed of oxygen?

Q3. From the standpoint of weather, which gas is the most important?

ANTICIPATED ANSWERS

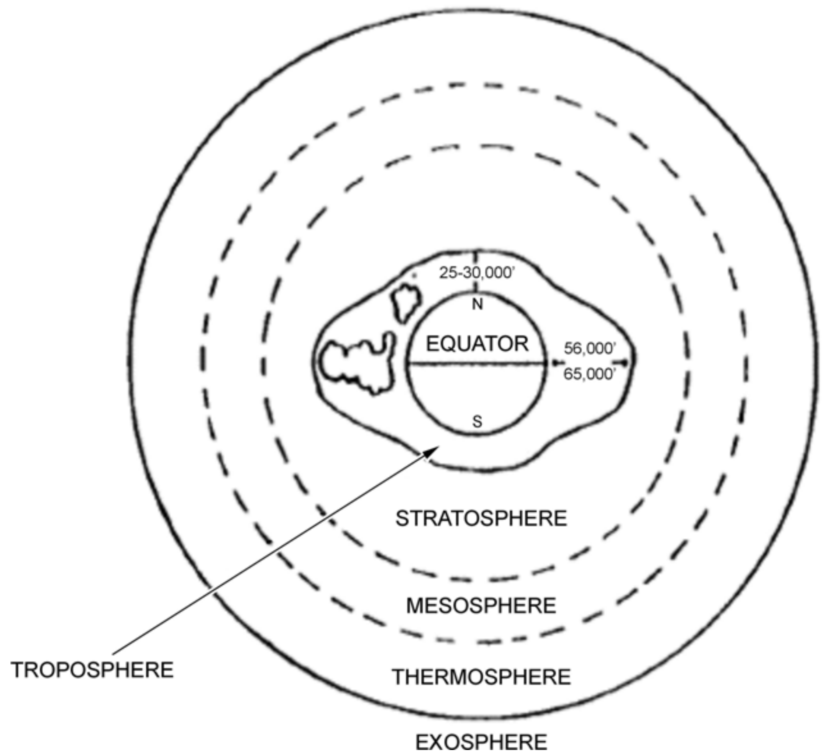
A1. 78 percent.

A2. 21 percent.

A3. Water vapour.

Teaching Point 2	**Illustrate the Divisions of the Atmosphere**
Time: 10 min	Method: Interactive Lecture

DIVISIONS OF THE ATMOSPHERE



A. F. MacDonald and I. L. Peppler, From the Ground Up, Aviation Publishers Co. Limited (p. 123)

Figure 13-1-1 The Four Layers of the Atmosphere

The atmosphere is divided into four distinct layers which surround the earth for many hundreds of miles. These layers are the:

- troposphere,
- stratosphere,
- mesospehere, and
- thermosphere.

The exosphere is not actually a layer of the atmosphere; it is actually the first vestiges of outer space.

Show the slide located at Annex A.

Illustrate each layer of the atmosphere using the tennis ball or small globe and the clear plastic bowls. Place the tennis ball on a table, and as you introduce a new layer of the atmosphere, place a plastic bowl over the tennis ball.

The Troposphere

The troposphere is the lowest layer of the atmosphere. The troposphere starts at ground level and extends to varying heights ASL (see Figure 13-1-1). Within the troposphere air pressure, density and temperature decrease with altitude. Temperature will drop to a low of -56 degrees Celsius. Most weather occurs in this layer of the atmosphere due to the presence of water vapour as well as strong vertical currents caused by terrestrial radiation. Terrestrial radiation causes the troposphere to extend to varying altitudes. There is more radiation at the equator than at the poles.

The phenomenon known as the jet stream exists in the upper parts of the troposphere.

The top of the troposphere is known as the tropopause, which acts as a boundary between the troposphere and the stratosphere.

The Stratosphere

The stratosphere extends 50 000 feet upwards from the tropopause. The pressure continues to decrease in the stratosphere. The temperature will gradually rise to 0 degrees Celsius. It is in the stratosphere that the bulk of the ozone layer exists. This prevents the more harmful solar radiation from reaching the earth's surface, which explains the rise in temperature.

The top of the stratosphere is called the stratopause, which acts as a boundary between the stratosphere and the mesosphere.

The Mesosphere

The mesosphere is characterized by a decrease in temperature. The temperature will reach a low of -100 degrees Celsius at 275 000 feet ASL. It is in the mesosphere that meteorites will usually burn up.

The top of the mesosphere is known as the mesopause, which acts as a boundary between the mesosphere and the thermosphere.

The Thermosphere

The highest of the four layers, the thermosphere is so named due to its intense temperatures. This is the first layer to be affected by solar radiation and what few oxygen molecules there are in this layer will absorb a high amount of that radiation. The actual temperature will vary depending on solar activity, but it can exceed 15 000 degrees Celsius.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. Name the four layers of the atmosphere.

Q2. In which layer does most weather occur?

Q3. In which layer is the ozone layer found?

ANTICIPATED ANSWERS

A1. Troposphere, stratosphere, mesosphere, and thermosphere.

A2. The troposphere.

A3. The stratosphere.

Teaching Point 3	Explain International Civil Aviation Organization (ICAO) Standard Atmosphere
Time: 5 min	Method: Interactive Lecture

ICAO STANDARD ATMOSPHERE

The decrease in temperature, pressure and density with altitude is not constant, but varies with local conditions. For the purposes of aviation, it is required that an international standard be set. Different regions have different standards.

The Basis of ICAO Standards in North America

The ICAO standard for North America is based on the summer and winter averages for 40 degrees north latitude. These averages include air pressure, air density and air temperature.

The Assumptions for Standard Atmosphere in North America

ICAO standards for North America assume the following conditions:

- the air is a perfectly dry gas;
- a mean sea level pressure of 29.92 inches of mercury;
- a mean sea level temperature of 15 degrees Celsius; and
- temperature decreases with altitude at a rate of 1.98 degrees Celsius per 1 000 feet.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. Why is there an international standard atmosphere?

Q2. What is the basis for ICAO standard atmosphere in North America?

Q3. What are the four assumptions used in the ICAO standard atmosphere for North America?

ANTICIPATED ANSWERS

A1. The decrease in temperature, pressure and density with altitude is not constant, but varies with local conditions.

A2. The ICAO standard for North America is based on the summer and winter averages for 40 degrees north latitude.

A3. ICAO standards for North America assume the following conditions:

- the air is a perfectly dry gas;
- a mean sea level pressure of 29.92 inches of mercury;
- a mean sea level temperature of 15 degrees Celsius; and
- the rate at which temperature decreases with altitude is 1.98 degrees Celsius per 1 000 feet.

Teaching Point 4	Explain the Properties of the Atmosphere
Time: 5 min	Method: Interactive Lecture

PROPERTIES OF THE ATMOSPHERE

The properties of the atmosphere allow for various weather conditions. There are three principle properties:

- **Mobility.** This property is the ability of the air to move from one place to another. This is especially important as it explains why an air mass that forms over the arctic may affect places in the south.
- **Capacity for Expansion.** The most important of the three properties. Air is forced to rise for various reasons. As the air pressure decreases, the air will expand and cool. This cooling may be enough for condensation to occur and clouds to form, creating precipitation.
- **Capacity for Compression.** The opposite of expansion, compression occurs when the air has cooled and becomes denser. The air will sink, decreasing in volume and increasing in temperature.

Factors Affecting the Properties of the Atmosphere

There are three factors which affect the properties of the atmosphere: temperature, density and pressure. Temperature changes air density which creates the vertical movement of the air, causing expansion and compression. The vertical movement creates pressure differences, which causes mobility across the surface as the air moves horizontally to fill gaps left by air that has moved vertically.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. What are the three properties of the atmosphere?

Q2. Which is the most important property of the atmosphere?

Q3. What are the three factors affecting the properties of the atmosphere?

ANTICIPATED ANSWERS

A1. Mobility, capacity for expansion and capacity for compression.

A2. Capacity for expansion.

A3. Temperature, density and pressure.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. Name the four layers of the atmosphere.

Q2. Why is there an international standard atmosphere?

Q3. Which is the most important property of the atmosphere?

ANTICIPATED ANSWERS

A1. Troposphere, stratosphere, mesosphere, and thermosphere.

A2. The decrease in temperature, pressure, and density with altitude is not constant, but varies with local conditions.

A3. Capacity for expansion.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-803/PG-001, Chapter 3, Annex B, Aviation Subjects – Combined Assessment PC.

CLOSING STATEMENT

Understanding why weather occurs will allow the cadet to anticipate what could happen to the flying conditions in the near future. This will be useful for all areas of life from flight planning to deciding whether or not to take an umbrella.

INSTRUCTOR NOTES/REMARKS

N/A.

REFERENCES

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.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 2

EO M336.02 – EXPLAIN THE FORMATION OF CLOUDS

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, 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.

Create slides of Annexes B to I.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to introduce the concepts of cloud formation.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have explained the formation of clouds.

IMPORTANCE

It is important for cadets to know how clouds form as it will enhance their knowledge of meteorology and their ability to predict weather.

Teaching Point 1	**Explain Cloud Classification**
Time: 5 min	Method: Interactive Lecture

CLOUD CLASSIFICATION

Clouds are classified based on type of formation and cloud height.

Types of Formation

There are two main types of cloud formations:

Show slide of Annex B.

- **Cumulus.** Cumulus clouds are formed by air that is unstable. They are cottony or puffy, and are seen mostly during warmer seasons. Cumulus clouds may develop into storm clouds.

"Victoria Weather", by UVic, School-Based Weather Station Network. Retrieved November 1, 2007, from http://www.victoriaweather.ca/clouds

Figure 13-2-1 Cumulus Cloud

- **Stratus.** Stratus clouds are formed in air that is stable. They are flat and can be seen year round, but are associated with colder temperatures.

Show slide of Annex C.

"Victoria Weather", by UVic, School-Based Weather Station Network. Retrieved November 1, 2007, from http://www.victoriaweather.ca/clouds

Figure 13-2-2 Stratus Cloud

Cloud Height

Clouds are also classified based on their height above ground level (AGL). There are four main categories:

- **Low Clouds.** The bases of low clouds range from the surface to a height of 6 500 feet AGL. Low clouds are composed of water droplets and sometimes ice crystals. Low clouds use the word stratus as either a prefix (eg, stratocumulus) or a suffix (eg, nimbostratus).
- **Middle Clouds.** The bases of middle clouds range from 6 500 to 23 000 feet AGL. They are composed of ice crystals or water droplets, which may be at temperatures above 0 degrees Celsius. Middle clouds use the prefix of "alto" (eg, altocumulus).
- **High Clouds.** The bases of high clouds range from 16 500 to 45 000 feet, with an average of 25 000 feet in the temperate regions of the earth. High clouds are composed of ice crystals. High clouds use the prefix of "cirrus" or "cirro" (eg, cirrocumulus).
- **Clouds of Vertical Development.** The base of these clouds may be as low as 1 500 feet AGL and may rise as high as the lower reaches of the stratosphere. They may appear as isolated clouds or may be seen embedded in layers of clouds. Clouds of vertical development are associated with thunderstorms and other phenomena which occur during the summer months.

Show slide of Annex D.

The following chart includes a brief description of the more common cloud types.

Cloud Name	Cloud Family	Cloud Description
Cirrus	High	High, thin, wispy clouds blown by high winds into long streamers. Cirrus clouds usually move across the sky from west to east. They generally indicate pleasant weather.
Cirrocumulus	High	Appear as small, round white puffs. The small ripples in the cirrocumulus sometimes resemble the scales of a fish. A sky with cirrocumulus clouds is sometimes referred to as a "mackerel sky."
Altocumulus	Middle	Appear as grey, puffy masses, sometimes in parallel waves or bands. The appearance of these clouds on a warm, humid summer morning often means thunderstorms will occur by late afternoon.
Altostratus	Middle	A grey or blue-grey layer cloud that typically covers the entire sky. In the thinner areas of the cloud, the sun may be dimly visible as a round disk. This cloud appears lighter than stratus clouds.
Stratus	Low	Uniform grey layer cloud that often covers the entire sky. They resemble fog that does not reach the ground. Usually no precipitation falls from stratus clouds, but sometimes they may drizzle.
Nimbostratus	Low	Dark grey layer clouds associated with continuously falling rain or snow. They often produce precipitation that is usually light to moderate.
Stratocumulus	Low	A series of rounded masses that form a layer cloud. This type of cloud is usually thin enough for the sky to be seen through breaks.
Cumulus	Vertical Development	Puffy clouds, which are thick, round, and lumpy. They sometimes look like pieces of floating cotton. They usually have flat bases and round tops.
Cumulonimbus	Vertical Development	Thunderstorm clouds that form if cumulus clouds continue to build. Violent vertical air currents, hail, lightning, and thunder are associated with the cumulonimbus clouds.

Director Cadets 3, 2007, Ottawa, ON: Department of National Defence

Figure 13-2-3 Common Clouds

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. How are clouds classified?

Q2. What are the two types of cloud formations?

Q3. What are the four categories of cloud height?

ANTICIPATED ANSWERS

A1. By type of formation and height.

A2. Cumulus and stratus.

A3. Low clouds, middle clouds, high clouds and clouds of vertical development.

Teaching Point 2	**Explain Air Stability**
Time: 5 min	Method: Interactive Lecture

AIR STABILITY

At the surface, the normal flow of air is horizontal. Disturbances may occur, which will cause vertical currents of air to develop. This is normally caused by a change in temperature. If the air that is displaced resists the change, then it is said to be stable. If it does not resist the change then it is unstable. When air rises, it expands and cools.

Stable Air. If a mass of rising air is cooler than the air that it comes in contact with, then it will sink back to its original position. Stable air may have the following affects on flight characteristics:

- poor low-level visibility (fog may occur),
- stratus type cloud,
- steady precipitation,
- steady winds, which can change greatly with height, and
- smooth flying conditions.

Unstable Air. If a mass of rising air is still warmer than the new air around it, then the air mass will continue to rise. Unstable air may have the following affects on flight characteristics:

- good visibility (except in precipitation),
- cumulus type cloud,
- showery precipitation,
- gusty winds, and
- moderate to severe turbulence.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. What may create vertical currents?

Q2. What is stable air?

Q3. What is unstable air?

ANTICIPATED ANSWERS

A1. A change in temperature.

A2. When a mass of rising air is cooler than the air that it comes in contact with, then it will sink back to its original position.

A3. When a mass of rising air is warmer than the new air around it, then the air mass will continue to rise.

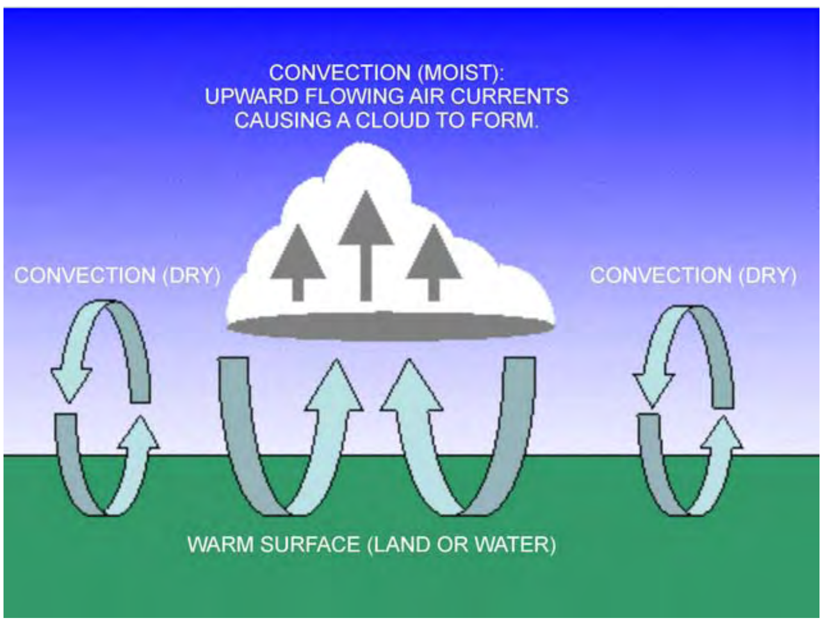
Teaching Point 3	**Explain Lifting Agents**
Time: 10 min	Method: Interactive Lecture

LIFTING AGENTS

Rising currents of air affect many weather conditions. There are five conditions that provide the lift required to initiate rising currents of air.

Show slides of Annexes E to I as applicable.

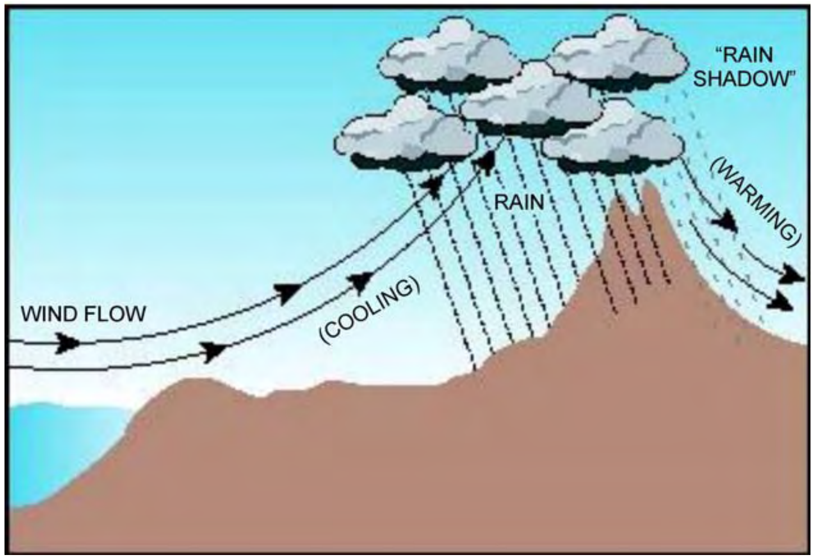
Convection. The air is heated through contact with the earth's surface. As the sun heats the surface of the earth, the air in contact with the surface warms up, rises, and expands. Convection may also occur when air moves over a warmer surface and is heated by advection.



WeatherQuestions.com, 2007, What is Convection. Copyright 2007 by WeatherStreet. Retrieved March 17, 2008, from http://www.weatherquestions.com/What_is_convection.htm

Figure 13-2-4 Convection

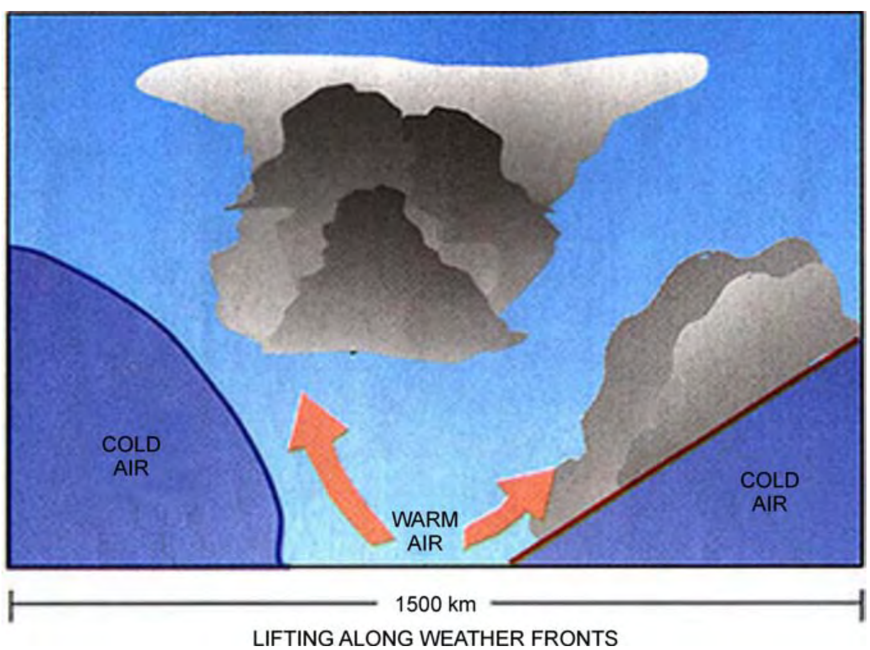
Orographic Lift. Orographic lift occurs when the sloping terrain forces the air upward. This process can be exaggerated if the air mass is already.



Water Encyclopedia, by G. H. Taylor, 2007, Water as a Climate Moderator. Copyright 2007 by Advameg. Retrieved March 17, 2008, from http://www.waterencyclopedia.com/Ce-Cr/Climate-Moderator-Water-as-a.html

Figure 13-2-5 Orographic Lift

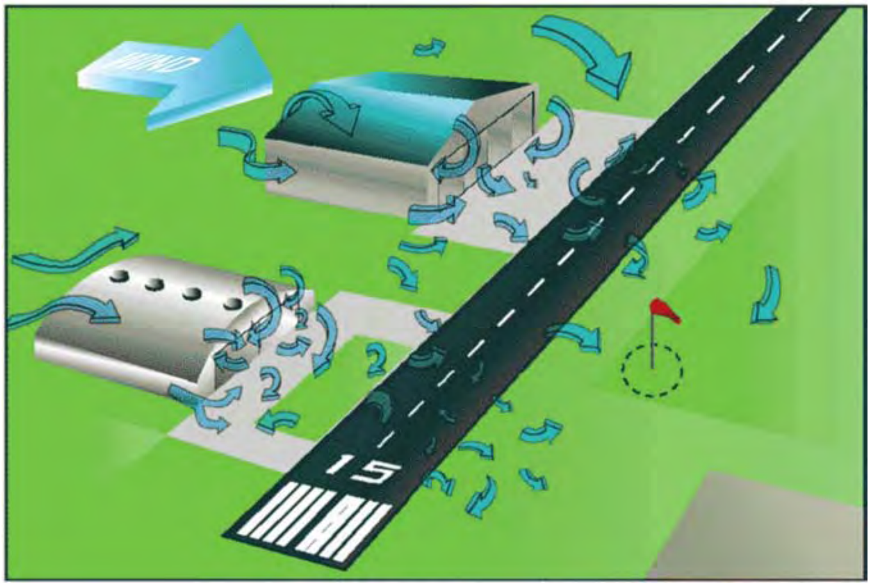
Frontal Lift. When different air masses meet, the warmer air is forced upwards by the denser cold air. This process may be exaggerated if the warm air mass becomes unstable.



Federation of American Scientists, by N. M. Short, Sr, 2007, Atmospheric Circulation: Weather Systems. Copyright 2007by FAS. Retrieved March 17, 2008, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

Figure 13-2-6 Frontal Lift

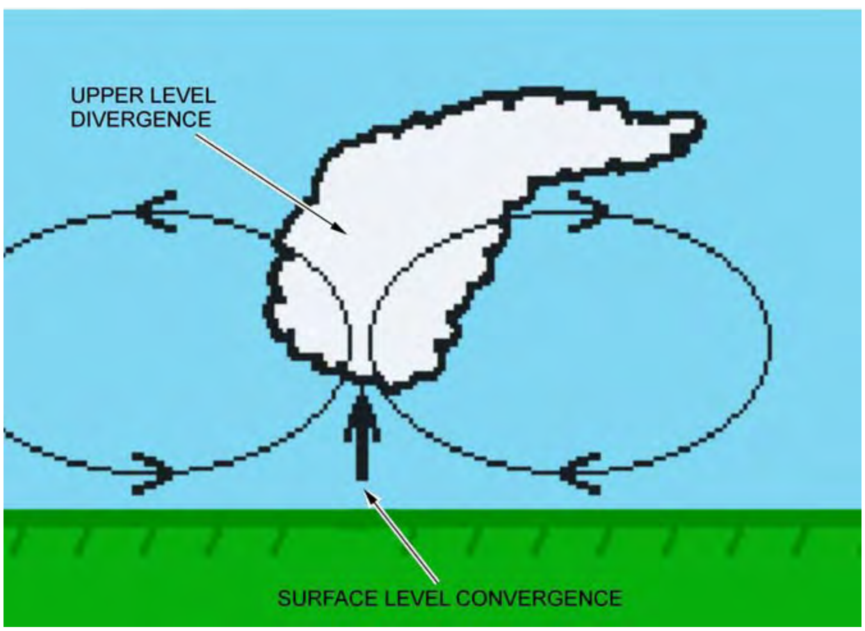
Mechanical Turbulence. Air moving over the ground may be affected by terrain that is not as pronounced as mountains. Forests, buildings, large ditches and quarries also affect the air through friction. This friction causes eddies, which are usually confined to the first few thousand feet of the troposphere. This process may be exaggerated if the air mass becomes or is already unstable.



Free Online Private Pilot Ground School, 2006, Aviation Weather–Principles. Copyright 2006. Retrieved March 17, 2008, from http://www.free-online-private-pilot-ground-school.com/Aviation-Weather-Principles.html

Figure 13-2-7 Mechanical Turbulence: Man-Made

Convergence. In a low pressure system, the wind blows toward the centre of the system. The excess air that collects here is forced upward to higher altitudes.



The Weather Doctor, by K. C. Heidron, PhD, 2002, What Goes Up: Part 3 Convergence and Divergence. Retrieved March 17, 2008, from http://www.islandnet.com/~see/weather/elements/whatgoesup3.htm

Figure 13-2-8 Convergence

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. Explain how convection (as a source of lift) occurs.

Q2. Explain orographic lift.

Q3. Explain frontal lift.

ANTICIPATED ANSWERS

A1. Convection is caused by heating of the air that is in contact with the surface of the earth.

A2. Orographic lift occurs when the sloping terrain forces the air upward.

A3. When different air masses meet, the warmer air is forced upward by the denser cold air. This process may be exaggerated if the warm air mass becomes unstable.

Teaching Point 4	**Describe Cloud Formation**
Time: 5 min	Method: Interactive Lecture

CLOUD FORMATION

Clouds are formed by the lifting agents and air stability.

Clouds are formed in two ways. Either the temperature drops to the saturation point of the air or the temperature is constant but the amount of water in the air increases.

Relating Lifting Agents to Air Stability

Each of the lifting agents described have an effect on, or is affected by, air stability. Convection, for example, is normally associated with unstable air since heat causes the convection, and is also a source of instability in the air.

Another example would be orographic lift, which is usually associated with stable air. After the air has been forced up by the terrain, it cools and becomes dense. The effect is similar to positive stability in an airplane.

Relating Air Stability to Types of Formation

Air stability will have a direct affect on cloud formation. Clouds created in stable air will form as stratus-type clouds. Clouds formed in unstable air will form as cumulus-type clouds.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. What are the two ways in which a cloud forms?

Q2. How does orographic lift relate to air stability?

Q3. What cloud type will form in stable air?

ANTICIPATED ANSWERS

A1. Either the temperature drops to the saturation point of the air or the temperature is constant but the amount of water in the air increases.

A2. After the air has been forced up by the terrain, it cools and becomes dense. The effect is similar to positive stability in an airplane.

A3. Clouds created in stable air will form as stratus-type clouds.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. What are the two types of cloud formation?

Q2. Define unstable air.

Q3. What cloud type will form in unstable air?

ANTICIPATED ANSWERS

A1. Cumulus and stratus.

A2. When a mass of rising air is warmer than the new air around it, then the air mass will continue to rise.

A3. Clouds created in unstable air will form as cumulus-type clouds.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-803/PG-001, Chapter 3, Annex B, Aviation Subjects – Combined Assessment PC.

CLOSING STATEMENT

Knowing how a cloud is formed will help predict the weather conditions that may exist. Conversely, knowing the weather conditions will assist in determining what clouds will form later in the day, and it may be possible to predict what the weather for the day will be.

INSTRUCTOR NOTES/REMARKS

N/A.

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.

ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 3

EO M336.03 – EXPLAIN THE EFFECTS OF AIR PRESSURE ON WEATHER

Total Time:	30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, 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.

Create slides of Annexes J to O.

Photocopy handouts of Annex P for each cadet.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to introduce the cadets to the effects of air pressure.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have explained the effects of air pressure on weather.

IMPORTANCE

It is important for cadets to explain the effects of air pressure on weather in order to appreciate patterns of weather and the movement of air.

Teaching Point 1	**Explain the Polar Front Theory**
Time: 10 min	Method: Interactive Lecture

Certain terms used in this document are meant to be relative; they may not necessarily have a fixed value. For example, low pressure system does not necessarily mean that the pressure of the air is lower than mean sea level. It means that the air pressure in that system is lower than the air pressure around the system.

POLAR FRONT THEORY

The Polar Front theory was conceived by Norwegian meteorologists, who claimed that the interaction between the consistently high pressure area over the Arctic (and Antarctic) and the relatively lower pressure areas over the lower latitudes may provide force to the movement of air.

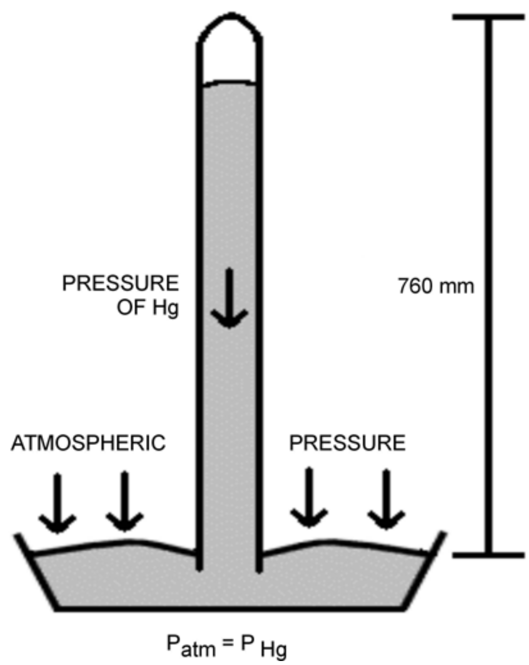
Definition of Atmospheric Pressure

Show slide of Annex J.

Atmospheric Pressure. The pressure of the atmosphere at any point due to the weight of the overlying air. Pressure at the surface of the earth is normally measured using a mercury barometer and is expressed in mm of mercury (mm Hg) or inches of mercury ("Hg). The barometer is essentially an upside-down graduated, test tube that is partially immersed in a bowl of mercury. As the pressure of the air over the bowl increases, the mercury is forced further up the test tube, providing a higher reading.

Pressure is a force and, in meteorological work, it is common to use hectopascals (hPa) to measure pressure. One hectopascal is 1 000 dynes (a unit of force) of force exerted on a 1 cm^2 area.

The average pressure of the atmosphere at sea level is normally expressed as 760 mm Hg (29.92 "Hg), which is the same as 1013.2 hPa. Public radio and television weather broadcasts (such as the Weather Network or Environment Canada) will express pressure in kilopascals (kPa). One kPa is equal to 10 hPa, so that 1013.2 hPa would be equal 101.32 kPa.



Chemistry Tutorial Notes, Department of Chemistry, Texas A&M University, 2006, Properties of Gases, Copyright 2006 by Texas A&M University. Retrieved April 4, 2008 from http://www.chem.tamu.edu/class/majors/tutorialnotefiles/pressure.htm

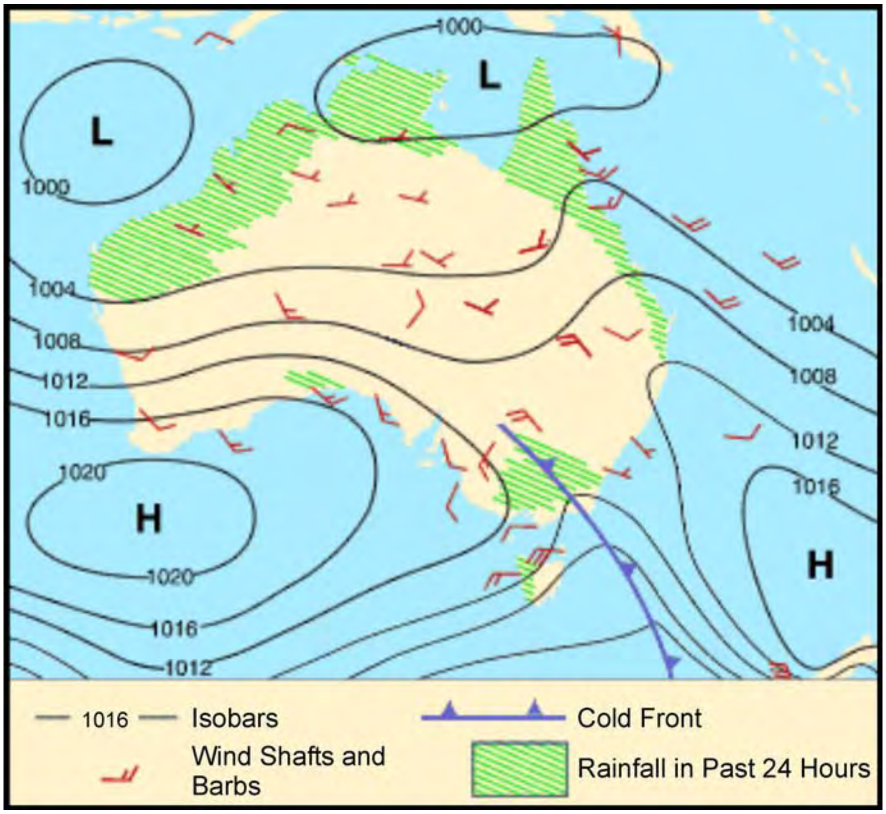
Figure 13-3-1 Barometer

Pressure Systems

There are pressure reading stations all over North America. Each station will send its readings to a main forecasting office, which will plot the information on a weather map.

Show slide of Annex K.

- **Isobars.** Areas of like pressure are joined by lines called isobars (from Greek *isos* [same] and *baros* [weight]). On a weather map, isobars will look similar to contour lines found on a topographical map. The isobars form roughly concentric circles, each circle being four hPa different than the circles before and after it. Groups of isobars will indicate areas of relatively high pressure, or relatively low pressure.



Australian Government, Bureau of Meteorlogy, 2008, Air Masses and Weather Maps, Copyright 2008 by Commonwealth of Australia, Bureau of Meteorology. Retrieved April 7, 2008 from http://www.bom.gov.au/info/ftweather/page_7.shtml

Figure 13-3-2 Isobars on a Weather Map

- **Low Pressure Areas.** Low pressure areas (often called lows, cyclones, or depressions) are areas of relatively lower pressure, with the lowest pressure in the centre. Lows will normally move in an easterly direction at an average rate of 800 km per day during the summer and 1 100 km per day in the winter. Lows are associated with thunderstorms and tornadoes, and do not stay in one place for very long. In the northern hemisphere, air moves around a low pressure in a counter-clockwise direction.
- **High Pressure Areas.** High pressure areas (often called anti-cyclones) are areas of relatively higher pressure, with the highest pressure in the centre. Winds are usually light and variable. High pressure areas move very slowly, sometimes staying stationary for days at a time. In the northern hemisphere, air moves around a high in a clockwise direction.

An Air Mass Over the Polar Regions

Polar air is typically cold and dry.

An Air Mass Over the Equatorial Regions

The air over the equator is tropical, therefore warm and moist.

Movement at the Polar Front

The transition zone between the polar air and the equatorial air is known as the polar front. Due to the differences in the properties of the two air masses, many depressions (low pressure areas) form along the polar front. The cold air moves from north-east to south-west in the northern hemisphere, while the warm air moves in the opposite direction. The result is constant instability as the cold air bulges south and the warm air bulges north. The cold air moves faster than the warm air and eventually envelopes it.

The movement of the air at the polar front is thought to be a cause for the circulation of air in the troposphere.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What is a hectopascal?

Q2. Which direction does the air move around a low pressure in the northern hemisphere?

Q3. What is the transition zone between the polar air and the tropical air known as?

ANTICIPATED ANSWERS

A1. One hectopascal is 1 000 dynes of force exerted on a 1 cm^2 area.

A2. Counter-clockwise.

A3. Polar front.

Teaching Point 2	**Explain That the Properties (eg, Pressure) of an Air Mass are Taken From the Area Over Which it Forms**
Time: 5 min	Method: Interactive Lecture

PROPERTIES OF AN AIR MASS

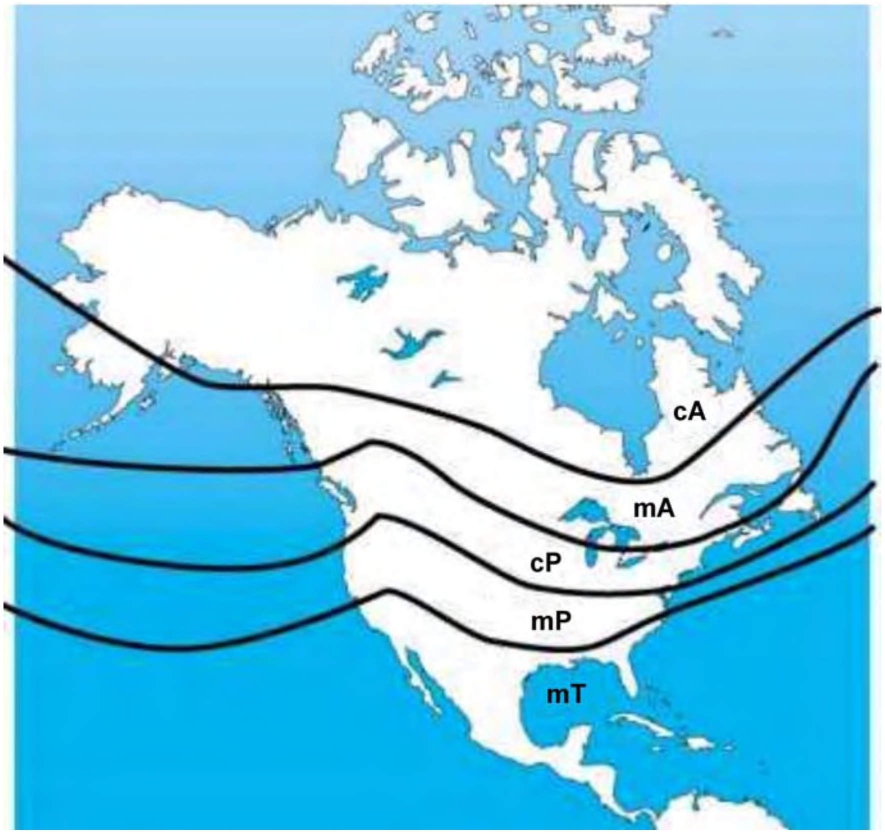
Weather forecasts used to be based solely on the existence and movement of pressure systems. Meteorologists currently base their predictions on the properties of air masses, of which pressure is only one factor.

An air mass may be defined as a large section of the troposphere with uniform properties of temperature and moisture along the horizontal plane. This means that if a horizontal cross-section was taken of an air mass, one would see layers within the air mass where the temperature and the amount of moisture would be the same throughout.

An air mass will take on the properties of the surface over which it has formed. An air mass, which has formed over the Arctic would be cold and dry, while one, which formed over the Gulf of Mexico would be warm and moist.

Air masses may be described as:

- **Continental Air Mass.** Since the air mass formed over land, this will be a dry air mass.
- **Maritime Air Mass.** Since the air mass formed over water, this will be a moist air mass.
- **Arctic Air Mass.** Since the air mass formed over the Arctic, this will be a cold air mass.
- **Polar Air Mass.** Since the air mass formed over the Polar region, this will be a cool air mass.
- **Tropical Air Mass.** Since the air mass formed over the Tropical region, this will be a warm air mass.



Meteorological Service of Canada, 2004, Frontal Systems, Copyright 2004 by Environment Canada. Retrieved April 7, 2008 from http://www.qc.ec.gc.ca/meteo/Documentation/Front_e.html

Figure 13-3-3 North American Air Masses

Show slide of Annex L.

These types of air masses are usually combined to describe the properties of temperature and moisture. For example, over Atlantic Canada one might find a maritime polar air mass, which will be cool and moist. Meanwhile prairie winters usually see continental polar or continental arctic, which will be either cool and dry or cold and dry. The five air masses in North America indicated in Figure 13-3-3 include:

- Continental Arctic (cA),
- Maritime Arctic (mA),
- Continental Polar (cP),
- Maritime Polar (mP), and
- Maritime Tropical (mT).

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. What is the definition of an air mass?

Q2. Where does an air mass obtain its properties from?

Q3. What are five air masses in North America?

ANTICIPATED ANSWERS

A1. An air mass may be defined as a large section of the troposphere with uniform properties of temperature and moisture along the horizontal plane.

A2. An air mass will take on the properties of the surface over which it has formed.

A3. Continental air mass, maritime air mass, arctic air mass, polar air mass, and tropical air mass.

Teaching Point 3	**Explain the Creation of Wind**
Time: 5 min	Method: Interactive Lecture

WIND

Wind is a major factor in flight planning and flight characteristics. Pilots must constantly be aware of the direction and speed of wind during all parts of the flight, but especially during the landing sequence.

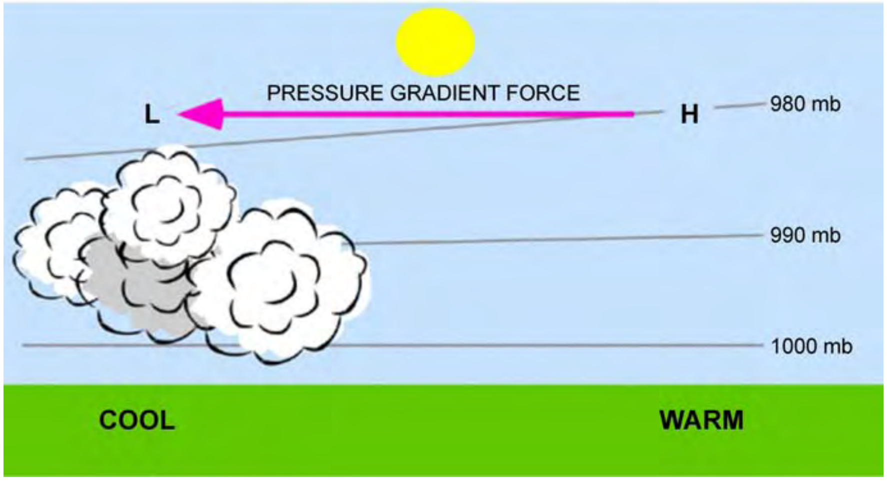
The Definition of Wind

Wind. The horizontal movement of air within the atmosphere. Wind normally moves parallel to the isobars of a pressure system. Since isobars are not straight lines, this means that the wind direction will vary at different locations along the pressure system. Wind also moves in different directions based on whether the pressure is a low or high system.

Show slide of Annex M.

Pressure Gradient

The pressure gradient is the rate of change of pressure over a given distance measured at right angles to the isobars. If the isobars are very close together, the rate of change will be steep and the wind speed will be strong. If the isobars are far apart, the rate of change will be shallow and the wind speed will be weak.



PhysicalGeography.net, Dr. M. Pidwirny, University of British Columbia Okanagan, 2007, Introduction to the Atmosphere, Copyright 2007 by M. Pidwirny. Retrieved April 7, 2008 from http://www.physicalgeography.net/fundamentals/7o.html

Figure 13-3-4 Pressure Gradient

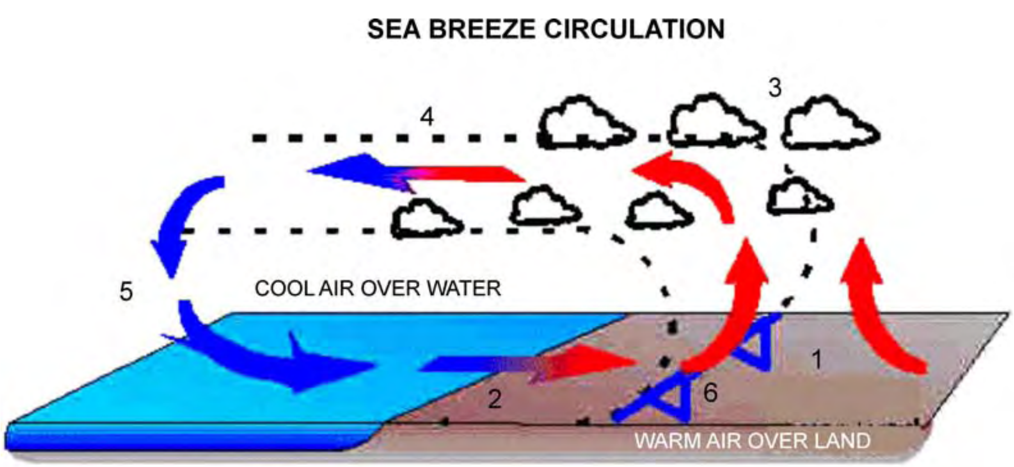
Land and Sea Breezes

Land and sea breezes are caused by the differences in temperature over land and water.

Show slides of Annexes N and O.

Note that the term breeze is used here as a technical term and has no bearing on wind strength.

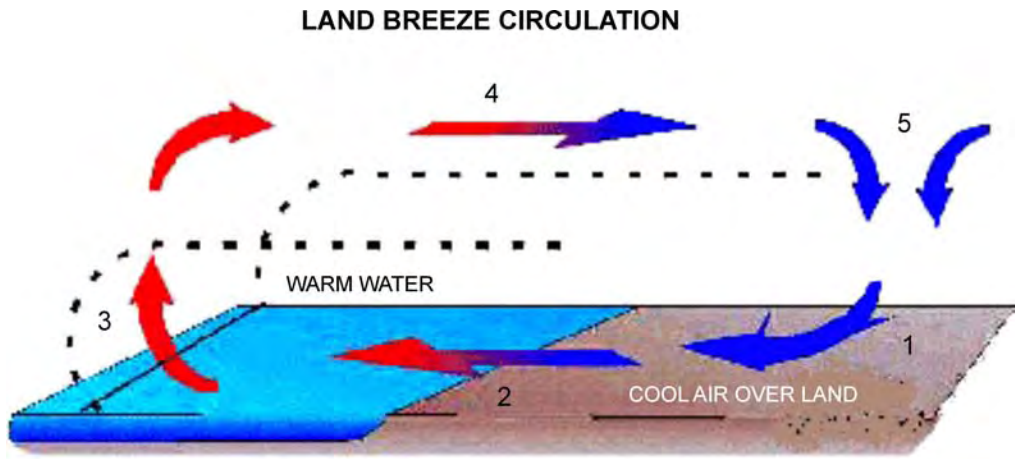
The sea breeze occurs during the day when the land heats up more rapidly than the water. This creates a lower pressure area over the land. The pressure gradient caused by this change is usually steep enough to create a wind from the water.



The Weather Doctor, K. C. Heidron, PhD, 1993, Sea and Land Breezes, Copyright 1998 by K. C. Heidron PhD. Retrieved April 7, 2008 from http://www.islandnet.com/~see/weather/elements/seabrz.htm

Figure 13-3-5 Sea Breeze

The land breeze occurs at night when the land cools down faster than the water. This creates a higher pressure over the land. The pressure gradient now moves the air from the land to the water.



The Weather Doctor, K. C. Heidron, PhD, 1993, Sea and Land Breezes, Copyright 1998 by K. C. Heidron PhD. Retrieved April 7, 2008 from http://www.islandnet.com/~see/weather/elements/seabrz.htm

Figure 13-3-6 Land Breeze

Land and sea breezes are local and affect a small area only.

Diurnal Variation

Surface winds are generally stronger during the day than at night. This is due to the heating processes, which occur during the day, creating vertical currents and pressure gradients. At night, when the heating processes cease, the vertical currents diminish and the pressure gradients become shallower.

Coriolis Force

As air moves from a high pressure system to a low pressure system, the air will not flow directly from one to the other. The rotation of the earth causes a deflection to the right (in the northern hemisphere). This force is known as Coriolis Force. Coriolis Force also explains why air moves clockwise around a high, and counter-clockwise around a low pressure system.

Veering and Backing

Veering is a change in wind direction clockwise relative to the cardinal points of a compass while backing is a change in wind direction counter-clockwise. For example, when the wind veers it will increase in direction from 090 degrees to 100 degrees; when it backs it will decrease in direction from 100 degrees to 090 degrees.

Veering and backing normally occur with changes in altitude. An increase in altitude will normally see a veer in wind direction and an increase in wind speed. A decrease in altitude will normally see a backing in wind direction and a decrease in wind speed. These changes are due to an increase in friction with the surface of the earth in the lower altitudes, and a decrease is friction in the higher altitudes.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. Define pressure gradient.

Q2. Why do sea breezes occur?

Q3. What is veering?

ANTICIPATED ANSWERS

A1. Pressure gradient is the rate of change of pressure over a given distance measured at right angles to the isobars.

A2. Sea breezes occur during the day when the land heats up more rapidly than the water, creating a lower pressure over the land.

A3. Veering is a change in wind direction clockwise relative to the cardinal points of a compass.

Teaching Point 4	Explain the Relationship Between Pressure Systems, and Wind Strength and Direction
Time: 5 min	Method: Interactive Lecture

RELATIONSHIP BETWEEN PRESSURE SYSTEMS AND WIND

Pressure and wind are interrelated, with one being the cause of the other.

Low Pressure Areas

Low pressure areas are the cause of all air movement as described by the Polar Front theory. Wind blows in a counter-clockwise direction around the low, and inwards to the centre of the system. Wind tends to be strong in a low as the pressure gradient is relatively steep causing the system to move fast over the ground. Low pressure systems are generally associated with brief periods of poor weather, as the inward flow of air acts as a vacuum.

High Pressure Areas

The wind in a high pressure areas blows in a clockwise direction around the high and outwards from the centre of the system. Wind tends to be weak in a high as the pressure gradient is normally relatively shallow causing the system to move slowly over the ground. High pressure systems are usually associated with fair weather, as the outward flow of air acts as a shield against bad weather.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. What direction does the wind blow around a low pressure system in the northern hemisphere?

Q2. What direction does the wind blow around a high pressure system in the northern hemisphere?

ANTICIPATED ANSWERS

A1. Counter-clockwise and inwards.

A2. Clockwise and outwards.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. What is the transition zone between the polar air and the tropical air known as?

Q2. What is the definition of an air mass?

Q3. Why do sea breezes occur?

ANTICIPATED ANSWERS

A1. Polar front.

A2. An air mass may be defined as a large section of the troposphere with uniform properties of temperature and moisture along the horizontal plane.

A3. Sea breezes occur during the day when the land heats up more rapidly than the water, creating a lower pressure over the land.

Distribute handout of Annex P.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-803/PG-001, Chapter 3, Annex B, Aviation Subjects – Combined Assessment PC.

CLOSING STATEMENT

Air pressure has a significant affect on weather around the world. Low pressure systems create movement of air, which circulates the air masses around the world. The air masses are the source of the actual weather conditions that we are exposed to.

INSTRUCTOR NOTES/REMARKS

N/A.

REFERENCES

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.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 4

EO M336.04 – EXPLAIN THE EFFECTS OF HUMIDITY AND TEMPERATURE ON WEATHER

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, 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.

Gather the resources required for the in-class activity in TP 3.

Create slides of Annex Q.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for TPs 1, 2, 4, and 5 to introduce temperature, humidity and precipitation to the cadets.

An in-class activity was chosen for TP 3 as an interactive way to provoke thought about temperature and humidity.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall be expected to explain the effects of temperature and humidity on weather.

IMPORTANCE

It is important for cadets to be able to explain the effects of temperature and humidity on weather as it will allow the cadet to make more informed decisions about activities in the field, in aviation or whether to wear a raincoat.

Teaching Point 1	**Explain Humidity**
Time: 10 min	Method: Interactive Lecture

HUMIDITY

Humidity is a representation of the moisture or water vapour, which is present in an air mass. While water vapour is a small percentage of the overall atmosphere, it is the only gas which can change into a solid or a liquid in ordinary atmospheric conditions. It is this characteristic which causes most weather to develop.

The moisture in an air mass originates from a body of water over which the air mass forms or passes. This body of water may be a pond or an ocean. The size of the body of water determines how much water is available for the air mass to collect, while the rate of evaporation will determine how much of that water is collected by the air mass. Water may exist in the atmosphere in two forms: invisible (gaseous) or visible (water droplets [liquid] or ice crystals [solid]).

Condensation

Condensation is a process by which a gas changes into a liquid by becoming denser. This is usually caused by a cooling process. The air is cooled to a certain temperature at which the water vapour will condense into water.

Sublimation

Sublimation is a process by which a gas changes into a solid without first becoming a liquid. This is usually caused by freezing. Sublimation occurs whenever snow, ice or hail fall from the sky. This process usually occurs in the winter, but may occur during exceptional summer storms.

Dew Point

Dew point is the temperature to which unsaturated air must be cooled, at a constant pressure, in order to become saturated. The temperature and dew point are responsible for the creation of clouds and precipitation. If the difference between the temperature and the dew point is small, then the air is considered to be nearly saturated and a small drop in temperature will see the formation of clouds or precipitation.

Relative Humidity

Relative humidity is the ratio of the actual amount of water present in the air compared to the amount of water which the same volume of air would hold if it were saturated. Temperature and pressure must remain the same, otherwise the relative humidity will change. Saturated air will have a relative humidity of 100 percent, while perfectly dry air will have a relative humidity of zero percent.

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. Define condensation.

Q2. Define dew point.

Q3. Define relative humidity.

ANTICIPATED ANSWERS

A1. Condensation is a process by which a gas changes into a liquid by becoming denser.

A2. Dew point is the temperature to which unsaturated air must be cooled, at a constant pressure, in order to become saturated.

A3. Relative humidity is the ratio of the actual amount of water present in the air compared to the amount of water which the same volume of air would hold if it were saturated.

Teaching Point 2	Explain Temperature
Time: 15 min	Method: Interactive Lecture

TEMPERATURE

Temperature represents the amount of heat in a given object, such as the human body or air. Temperature is measured using a thermometer. In aviation weather reports, temperature is normally expressed in degrees Celsius.

The Source

The source of the energy which warms the earth and its atmosphere is the sun. Solar radiation is transmitted to the earth and its atmosphere. Some of the solar radiation is absorbed by the stratosphere, while the rest passes through to be absorbed by the earth's surface. The earth then radiates heat into the troposphere through terrestrial radiation. It is terrestrial radiation that heats the troposphere, and is why the further one gets from the surface of the earth, the lower the temperature will be in the troposphere.

The atmosphere is heated from below not from above.

Diurnal Variation

During the day, the solar radiation exceeds the terrestrial radiation and the surface of the earth becomes warmer. At night, solar radiation ceases, and the terrestrial radiation causes the surface of the earth to cool. This is called diurnal variation and causes the heating and cooling of the atmosphere.

Seasonal Variation

The axis around which the earth rotates is tilted compared to the plane of orbit around the sun. The result is that the amount of solar radiation that strikes the surface of the earth varies from season to season. In the northern hemisphere, the months of June, July, and August are warm, while the months of December, January, and February are cold.

The Heating Process

Air is a poor conductor of heat. The following are four processes which assist in getting warm air into the higher levels of the atmosphere:

- **Convection.** Air over a warm surface becomes buoyant and rises, allowing cooler air to move into the vacant location. This vertical current of air distributes the heat to the higher levels.
- **Advection.** Horizontal movement of cool air over a warm surface allows the cool air to be heated from below.
- **Turbulence.** Turbulence created as the result of friction with the surface of the earth causes a mixing process which moves the heated air to other areas of the atmosphere.
- **Compression.** There are instances where air masses are forced down, such as air moving down the leeward side of a mountain. The air pressure increases as the air mass moves further down, compressing the air mass. This compression forces the particles together, creating heat. This phenomenon is also called subsidence.

The Cooling Process

Since the atmosphere is heated from below, the temperature usually decreases with altitude. The rate of temperature change is known as a lapse rate. The lapse rate is only a guideline as there is a variation in air masses and cooling processes. The following are three main cooling processes:

- **Radiation Cooling.** At night the temperature of the earth decreases with terrestrial radiation and cools the air in contact with the ground. Radiation cooling only affects the lower few thousand feet of the atmosphere.
- **Advection Cooling.** Air from a warm region moves over a cold region and cools the air.
- **Adiabatic Process.** As air is warmed it will begin to rise and as it rises it will expand and cool. In a rising current of air, the temperature decreases at a rate that is entirely independent of the surrounding, non-rising air.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. How is the atmosphere heated?

Q2. Identify the four heating processes.

Q3. Identify the three cooling processes.

ANTICIPATED ANSWERS

A1. The atmosphere is heated from below not from above.

A2. Convection, advection, turbulence, and compression.

A3. Radiation cooling, advection cooling, and adiabatic process.

Teaching Point 3	**Describe the Effects of Temperature on Relative Humidity**
Time: 10 min	Method: In-Class Activity

THE EFFECTS OF TEMPERATURE ON RELATIVE HUMIDITY

Temperature will affect the relative humidity of an air mass by changing the volume of the air mass.

As the temperature of the air mass increases, the air mass will expand increasing the volume of the mass. The result is that the relative humidity will decrease, as the air mass has a higher capacity for water. This assumes that there is no change in the amount of water in the air mass.

As the temperature of the air mass decreases, the air mass will contract, decreasing the volume of the mass. The result is that the relative humidity will increase, as the air mass has a lower capacity for water. This assumes that there is no change in the amount of water in the air mass.

ACTIVITY

OBJECTIVE

The objective of this activity is to illustrate the effects of temperature on relative humidity.

RESOURCES

- Water,
- Paper towel,
- One small plastic cup per cadet, and
- One large plastic cup per cadet.

ACTIVITY LAYOUT

N/A.

ACTIVITY INSTRUCTIONS

1. Distribute one small cup and one large cup to each cadet.
2. Fill each small cup three quarters full of water. This will represent an air mass with a relative humidity of 75 percent.
3. Have the cadet pour the water from the small cup into the large cup. The large cup represents the results of increasing the temperature of the air mass.
4. Have the cadets estimate the percentage of the large cup which now contains water.
5. Fill the large cup of water to 80 percent. This will represent the continued evaporation of water from all sources into the air mass.
6. Have the cadets pour the large cup into the small cup. This will represent the results of cooling the air mass to the dew point. The water that does not fit into the small cup is the precipitation.
7. Have the cadets clean up the water.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 3

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

Teaching Point 4	**Explain the Effects of Temperature and Humidity on Weather**
Time: 5 min	Method: Interactive Lecture

THE EFFECTS OF TEMPERATURE AND HUMIDITY ON WEATHER

Temperature and humidity have a major effect on the weather. Together they will determine cloud formation and precipitation.

Dew Point

The temperature of the air mass will change during the heating and cooling processes. As the temperature nears the dew point, the air will become more saturated. This increases the relative humidity and allows clouds to form.

Relative Humidity

As the relative humidity increases, the weight of the air mass also increases. When the dew point is reached, the air will become saturated, and clouds will form. Once the air mass has reached 100 percent relative humidity, any addition of water or drop in temperature will cause precipitation.

Precipitation

Precipitation may be solid or liquid, depending on the temperature of the air mass. Snow will occur if the air mass has a temperature below freezing. Rain will occur in an air mass which has a temperature above freezing. The temperature in the air mass will change with altitude, so that the water may freeze at higher levels of the air mass. Frozen precipitation such as hail and even snow has been seen in the summer months.

CONFIRMATION OF TEACHING POINT 4

QUESTIONS

Q1. What is the effect of dew point on weather?

Q2. How does relative humidity affect the creation of precipitation?

Q3. How is it possible for hail or snow to occur in the summer months?

ANTICIPATED ANSWERS

A1. As the temperature nears the dew point, the air will become more saturated.

A2. Once the air mass has reached 100 percent relative humidity, any addition of water or drop in temperature will cause precipitation.

A3. The temperature in the air mass will change with altitude, so water may freeze at higher levels of the air mass.

Teaching Point 5	**Explain Types of Precipitation**
Time: 10 min	Method: Interactive Lecture

TYPES OF PRECIPITATION

Show slides of figures located at Annex Q.

There are seven main categories of precipitation listed by the World Meteorological Organization (WMO). Each one is created depending on temperature and cloud type. Types of precipitation include:

- **Drizzle.** Precipitation in the form of small water droplets which appear to float. In temperatures near freezing, water droplets may freeze on contact with objects. This is known as freezing drizzle.

- **Rain.** Precipitation in the form of large water droplets. Freezing rain will occur when water droplets, which have retained their liquid form in freezing conditions, make contact with an object and freeze.
- **Hail.** Formed in clouds, which have strong vertical currents (such as thunderstorms), hail is the result of a water droplet which has been prevented from exiting the cloud by the vertical currents, until it has reached a particular mass. The stronger the vertical currents, the larger the hailstones. Softball-sized hailstones have been seen in the Prairies and tropical areas, where large thunderstorms commonly occur. The hailstone in Figure 13-4-1 has a circumference of 47.63 cm (18.75 inches) and weighs almost 1 kg (2 pounds).

UCAR Communications, Staff Notes Monthly, 2003, One Hail of a Storm, Copyright 2003 by University of Carolina. Retrieved April 2, 2008, from http://www.ucar.edu/communications/staffnotes/0308/hail.html

Figure 13-4-1 Hailstone

- **Snow Pellets.** If the water region where the cloud is receiving water from is shallow, then the droplet will not form the hard shell that a hailstone would have. The pellet falls as a soft pellet of snow.

Climber.org, by S. Eckert, 2006. Graupel–Snow Pellets, Lighter and Smaller Than Hail, Copyright 2006 by Climber.org. Retrieved April 2, 2008, from http://www.climber.org/TripReports/2006/1473.html

Figure 13-4-2 Snow Pellets

- **Snow.** Snow is the result of sublimation. Flakes are an agglomeration of ice crystals and are usually in the shape of a hexagon or star.

Neatorama, 2007, Snow-donut. Copyright 2007 by Neatorama. Retrieved April 2, 2008, from http://www.neatorama.cachefly.net/images/2007-03/snow-donut.jpg

Figure 13-4-3 Snow Doughnut

- **Ice Prisms.** Created in stable air masses at very low temperatures. Ice prisms are tiny ice crystals in the form of needles. They can form with or without clouds. Sometimes confused with ice fog.

Ohio Weather Library, by B. Plonka, 2008, Unusual Weather. Copyright 2008 by Ohio Weather Library. Retrieved April 2, 2008, from http://www.owlinc.org/unusualweatherpg7.html

Figure 13-4-4 Ice Prisms

- **Ice Pellets.** Ice pellets are raindrops, which are frozen before contacting an object (as opposed to freezing rain, which freezes after contact with an object). They generally rebound after striking the ground.

CONFIRMATION OF TEACHING POINT 5

QUESTIONS

Q1. What are the seven types of precipitation?

Q2. What process creates snow?

Q3. What is the difference between ice pellets and freezing rain?

ANTICIPATED ANSWERS

A1. Drizzle, rain, hail, snow pellets, snow, ice prisms and ice pellets.

A2. Sublimation.

A3. Ice pellets freeze before contacting an object while freezing rain freezes after contact.

END OF LESSON CONFIRMATION

QUESTIONS

Q1. Define dew point.

Q2. Explain how the atmosphere is heated.

Q3. Explain the effect of dew point on weather.

ANTICIPATED ANSWERS

A1. Dew point is the temperature to which unsaturated air must be cooled, at a constant pressure, in order for it to become saturated.

A2. The atmosphere is heated from below not from above.

A3. As the temperature nears the dew point, the air will become more saturated.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

This EO is assessed IAW A-CR-CCP-803/PG-001, Chapter 3, Annex B, Aviation Subjects – Combined Assessment PC.

CLOSING STATEMENT

Weather is an amazing aspect of nature, which has a great impact on how we live our lives. Being aware of what causes weather will assist cadets in making decisions about outdoors activities.

INSTRUCTOR NOTES/REMARKS

Video resources are available for purchase through flight training centres or aviation supply websites. These videos may be used to augment instruction.

REFERENCES

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.

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ROYAL CANADIAN AIR CADETS

PROFICIENCY LEVEL THREE

INSTRUCTIONAL GUIDE

SECTION 5

EO C336.01 – READ AN AVIATION ROUTINE WEATHER REPORT (METAR)

Total Time:	60 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-803/PG-001, 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.

Gather sample METARs from the NavCanada aviation weather website.

Create a slide of Annex R.

Photocopy Annex S for each cadet.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for TPs 1 and 2 to introduce the cadets to a METAR.

An in-class activity was chosen for TP 3 as an interactive way for the cadets to practice reading a METAR.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have read a METAR.

IMPORTANCE

It is important for cadets to read a METAR as it will enable them to determine weather conditions for flying in the local area.

Teaching Point 1 | **Describe a METAR**

Time: 10 min | Method: Interactive Lecture

Weather is a major factor in aviation. Pilots must constantly watch the weather around them as weather will effect the way an aircraft operates. In particular, pilots must review the weather prior to going flying to decide whether it is safe to fly.

Show the slide of examples located at Annex R.

DEFINITION

METAR is the name given to the international meteorological code used in aviation routine weather reports. These reports describe the existing weather conditions at a specific time and location. In other words, the METAR is a snapshot of the current weather; it is not a forecast.

FREQUENCY OF REPORTS

Normally, METAR observations are taken and disseminated on an hourly basis. METARs are only valid for the time that they are issued, not for the hour in between reports. METARS are normally issued every hour, on the hour as weather does not normally change much in an hour.

SPECIAL WEATHER REPORTS (SPECI)

There are times when the weather may change drastically in a short period of time. When this happens a SPECI is issued. SPECIs can be issued at any time. They will normally follow the last METAR issued and in sequence from oldest to newest as more SPECIs are issued. SPECIs use the same code as a METAR, but will start with SPECI.

WHERE METARS ARE AVAILABLE

METARs can be found at several locations. The three most common locations are:

- NavCanada's aviation weather website,
- a Flight Services Station (FSS),
- a Flight Information Centre (normally accessed by phone).

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What does a METAR describe?

Q2. How often is a METAR observation normally issued?

Q3. Why is a SPECI issued?

ANTICIPATED ANSWERS

A1. The existing weather conditions at a specific time and location.

A2. METARS are normally issued every hour, on the hour.

A3. When the weather may change drastically in a short period of time.

Teaching Point 2	**Review Terminology Used in METARs**
Time: 25 min	Method: Interactive Lecture

TERMINOLOGY USED IN METARS

Indicate on the slide of Annex R each of the following groupings as they are covered.

METAR is a code used in aviation weather reporting. This code is based on the World Meteorological Organization's (WMO) standards and conventions. A METAR is organized into sections with each section always showing in the same order.

Report Type

The report name is given in the first line of the text. The name will show as either METAR or SPECI.

Station Indicator

Each weather reporting station in Canada is assigned a four letter identifier, starting with the letter C. The remaining three letters are an abbreviation of the reporting station, where the first letter identifies what type of station it is.

An example would be CYOW for the reporting station at Ottawa/MacDonald-Cartier International Airport. The C means the station is Canadian, the Y means the station is co-located with an airport, and OW is the airport identifier.

Date and Time of Observation

The date and time of the observation are given in a six-digit grouping, based on universal coordinated time (UTC). The first two digits signify the day of the current month, while the last four digits signify the time of the day. The official time of the observation is given for all METAR reports that do not deviate more than 10 minutes from the top of the hour. SPECIs will have the time reported to the exact minute.

For example, a METAR will show as: 091000Z, which means that the observation was taken on the ninth day of the month at 1000 hrs UTC (or within 10 minutes of that hour).

For example, a SPECI will show as: 091036Z, which means that a significant change in weather was observed on the ninth day of the month at 1036 hrs UTC.

Report Modifier

This field may contain two possible codes: AUTO or CCA. AUTO indicates that the report is primarily based on observations from an automated weather observation station (AWOS). CCA is used to indicate corrected reports, where the first correction is CCA, the second is CCB, and so on. Both AUTO and CCA may be found in the same report.

Wind

This group reports the two-minute average wind direction and speed. Direction is always three digits, given degrees true but rounded off to the nearest 10 degrees. Speed is normally two digits, and is given in knots (nautical miles per hour or kt). A reading of 00000 kt indicates calm winds.

For example, 35016 will read as: winds are 350 degrees true (rounded off) at 16 kts.

If gust conditions exist, the direction and speed will be followed by a G and the maximum gust strength. A gust must be 5 knots stronger than the 10-minute average wind speed.

For example, 35016G25 will read as: winds are 350 degrees true at 16 kts gusting to 25 kts.

Prevailing Visibility

Prevailing visibility is the average visibility at the reporting station. The prevailing visibility is reported in statute miles (sm) or fractions of a statute mile.

Runway Visual Range

This is only included if the prevailing visibility is less than 1 sm, or the runway visual range is less than 6 000 feet. This group will start with an R, then the runway number (eg, 06) and position (eg, L for left, R for right, C for centre), followed by the runway visual range in hundreds of feet. This is based on a 10-minute average.

For example, R06L/1000V2400FT/U will read as: the minimum runway visual range for runway 06 left is 1 000 feet and the maximum is 2 400 feet with an upward trend.

Present Weather

This section indicates the current weather phenomena at the reporting station. This may include precipitation, obscuration, or other phenomena. This section will include all phenomena that exist, varying the length of the section between reports.

Each phenomenon is represented by a code, which may be two to nine characters in length. Each code may include one or both of the following prefixes:

- **Intensity.** (-) indicates light, (+) indicates heavy, and no symbol indicates moderate.
- **Proximity.** Used primarily with precipitation or tornadoes, VC will precede certain phenomena meaning that they are in the vicinity (5 sm) of the station, but not actually at the station.

Distribute the handout located at Annex S.

For example, VCFZRABLSN+SNVA would translate to: In the vicinity of the airport there is freezing rain, blowing snow, heavy snow, and volcanic ash.

The abbreviations used for present weather are a mixture of English and French root words. FZ comes from freezing, while BR comes from brumé (mist), and FU comes from fumée (smoke).

Sky Conditions

This group reports the sky condition for layers aloft. The group will include how much of the sky is covered measured in oktas (eighth of the sky) and the height of the clouds in hundreds of feet above ground level (AGL). The sky cover is represented by an abbreviation related to how many oktas of the sky are covered.

- SKC = sky clear, no cloud present.
- FEW = few, greater than zero to two eighths cloud cover.
- SCT = scattered, three eighths to four eighths cloud cover.
- BKN = broken, five eighths to less than eight eighths cloud cover.
- OVC = overcast, eight eighths cloud cover.
- CLR = clear, clear below 10 000 feet AGL.

Cloud height is represented by a three digit number, which when multiplied by one hundred equals the actual height AGL. There will be one entry for every layer of cloud.

For example, SCT025 would translate to: scattered cloud at 2 500 feet AGL.

Temperature and Dewpoint

This group reports the air temperature and dewpoint temperature, rounded to the nearest whole degree Celsius. A negative value will be preceded by (M). A (/) will separate the two values.

Altimeter Setting

This group reports the altimeter setting at the reporting station in inches of mercury. The group starts with (A), which will be followed by four digits, which directly relate to the actual value of the altimeter setting. Place a decimal after the second digit in order to read this group.

For example, A3006 would translate to: altimeter setting is 30.06 inches of mercury.

Remarks

This group will usually include cloud types in each layer as well as opacity, general weather remarks, and sea level pressure measured in hectopascals. The sea level pressure will always be the last entry in a METAR, prefaced by SLP. Sea level pressure is translated by either adding a 9 or a 10 in front of the value given. The goal is to make the number as close to 1 000 as possible.

For example, SLP 123 would translate to: sea level pressure is 1012.3 hPa.

For example, SLP 998 would translate to: sea level pressure is 999.8 hPa.

SLP actually represents the station pressure or the theoretical sea level pressure at the reporting station.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. How are date and time expressed in a METAR?

Q2. What does the present weather section indicate?

Q3. What is the last entry of a METAR?

ANTICIPATED ANSWERS

A1. The date and time of the observation are given in a six-digit grouping, based on universal coordinated time (UTC).

A2. This section indicates the current weather phenomena at the reporting station.

A3. The sea level pressure will always be the last entry in a METAR.

Teaching Point 3	**Demonstrate and Have the Cadets Read a METAR**
Time: 15 min	Method: In-Class Activity

ACTIVITY

OBJECTIVE

The objective of this activity is for the cadets to read a METAR.

RESOURCES

Five or six examples of METARs.

ACTIVITY LAYOUT

Arrange the classroom to enable both individual and small-group work.

ACTIVITY INSTRUCTIONS

1. Project a sample METAR and demonstrate reading it.
2. Distribute examples of METARs.
3. Have the cadets work in pairs to decipher a METAR in three minutes.
4. Correct the cadets' work.
5. Have the cadets work in pairs to decipher a second METAR in two minutes.
6. Correct the cadets' work.
7. Repeat Steps 5. and 6. as often as possible until examples are exhausted.

SAFETY

N/A.

CONFIRMATION OF TEACHING POINT 3

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

END OF LESSON CONFIRMATION

The cadets' participation in reading METAR will serve as the confirmation of this lesson.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

Reading a METAR is a skill which can be transferred to many other outdoor activities. The code used may also be found in aviation forecasts, which cover larger areas. This can be used for camping trips, trip planning and checking to see if your flight the next morning will be delayed.

INSTRUCTOR NOTES/REMARKS

Recent METARs can be found at http://www.flightplanning.navcanada.ca/cgi-bin/CreePage.pl?Langue=anglais &NoSession=NS_Inconnu?Page=forecast-observation&TypeDoc=html. Click on the METAR/TAF icon and then enter the airport name or identifier.

REFERENCES

C2-044 Transport Canada. (2007). *Aeronautical Information Manual*. Retrieved October 2, 2007, from http://tc.gc.ca/publications/EN/TP14371/PDF/HR/TP14371E.PDF.

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.

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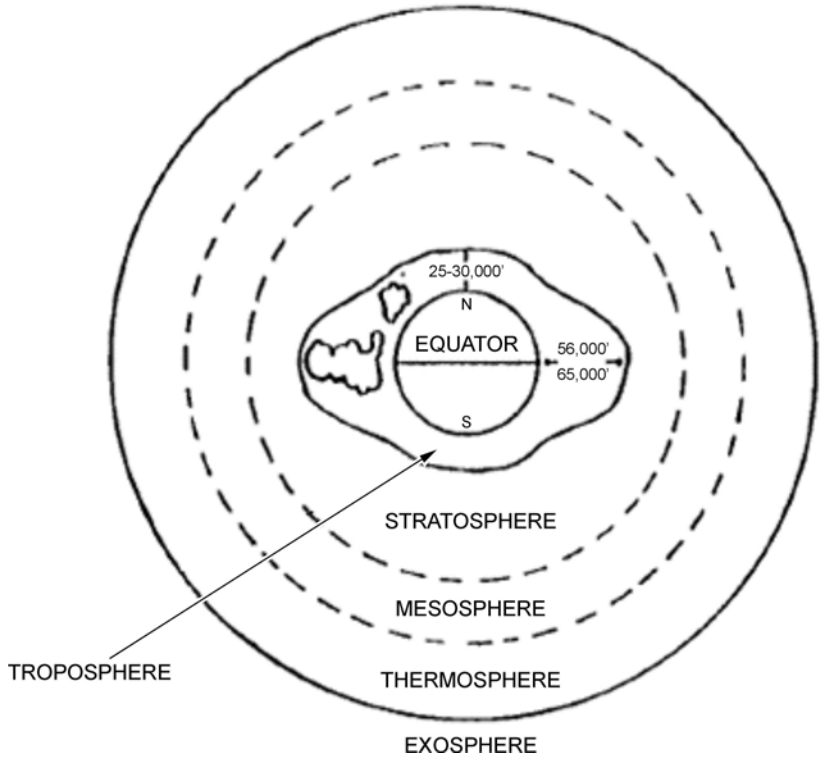
DIVISIONS OF THE ATMOSPHERE



A. F. MacDonald and I. L. Peppler, From the Ground Up, Aviation Publishers Co. Limited (p. 123)

Figure 13A-1 The Four Layers of the Atmosphere

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CUMULUS CLOUD

"Victoria Weather", by UVic, School-Based Weather Station Network.
Retrieved November 1, 2007, from http://www.victoriaweather.ca/clouds

Figure 13B-1 Cumulus Cloud

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STRATUS CLOUD

"Victoria Weather", by UVic, School-Based Weather Station Network. Retrieved November 1, 2007, from http://www.victoriaweather.ca/clouds

Figure 13C-1   Stratus Cloud

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COMMON CLOUDS

Cloud Name	Cloud Family	Cloud Description
Cirrus	High	High, thin, wispy clouds blown by high winds into long streamers. Cirrus clouds usually move across the sky from west to east. They generally indicate pleasant weather.
Cirrocumulus	High	Appears as small, round white puffs. The small ripples in the cirrocumulus sometimes resemble the scales of a fish. A sky with cirrocumulus clouds is sometimes referred to as a “mackerel sky”.
Altocumulus	Middle	Appear as grey, puffy masses, sometimes in parallel waves or bands. The appearance of these clouds on a warm, humid summer morning often means thunderstorms will occur by late afternoon.
Altostratus	Middle	A grey or blue-grey layer cloud that typically covers the entire sky. In the thinner areas of the cloud, the sun may be dimly visible as a round disk. This cloud appears lighter than stratus clouds.
Stratus	Low	Uniform grey layer cloud that often covers the entire sky. They resemble fog that does not reach the ground. Usually no precipitation falls from stratus clouds, but sometimes they may drizzle.
Nimbostratus	Low	Dark grey layer clouds associated with continuously falling rain or snow. They often produce precipitation that is usually light to moderate.
Stratocumulus	Low	A series of round mass that form a layer cloud. This type of cloud is usually thin enough for the sky to be seen through breaks.
Cumulus	Vertical Development	Puffy clouds, which are thick, round, and lumpy. They sometimes look like pieces of floating cotton. They usually have flat bases and round tops.
Cumulonimbus	Vertical Development	Thunderstorm clouds that form if cumulus clouds continue to build. Violent vertical air currents, hail, lightning, and thunder are associated with the cumulonimbus clouds.

Director Cadets 3, 2007, Ottawa, ON: Department of National Defence

Figure 13D-1 Common Clouds

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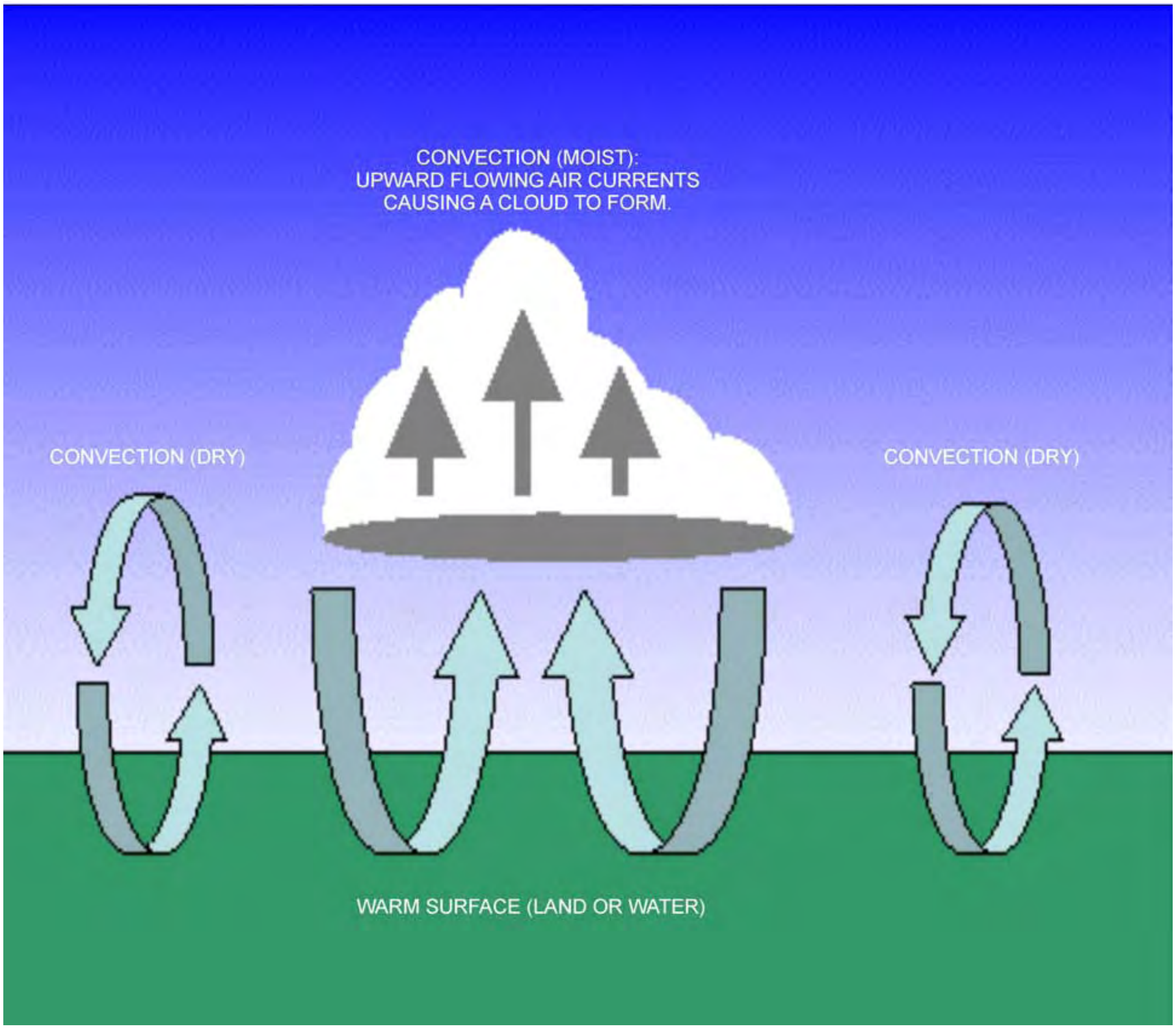
CONVECTION



WeatherQuestions.com, 2007, What is Convection. Copyright 2007 by WeatherStreet. Retrieved March 17, 2008, from http://www.weatherquestions.com/What_is_convection.htm

Figure 13E-1 Convection

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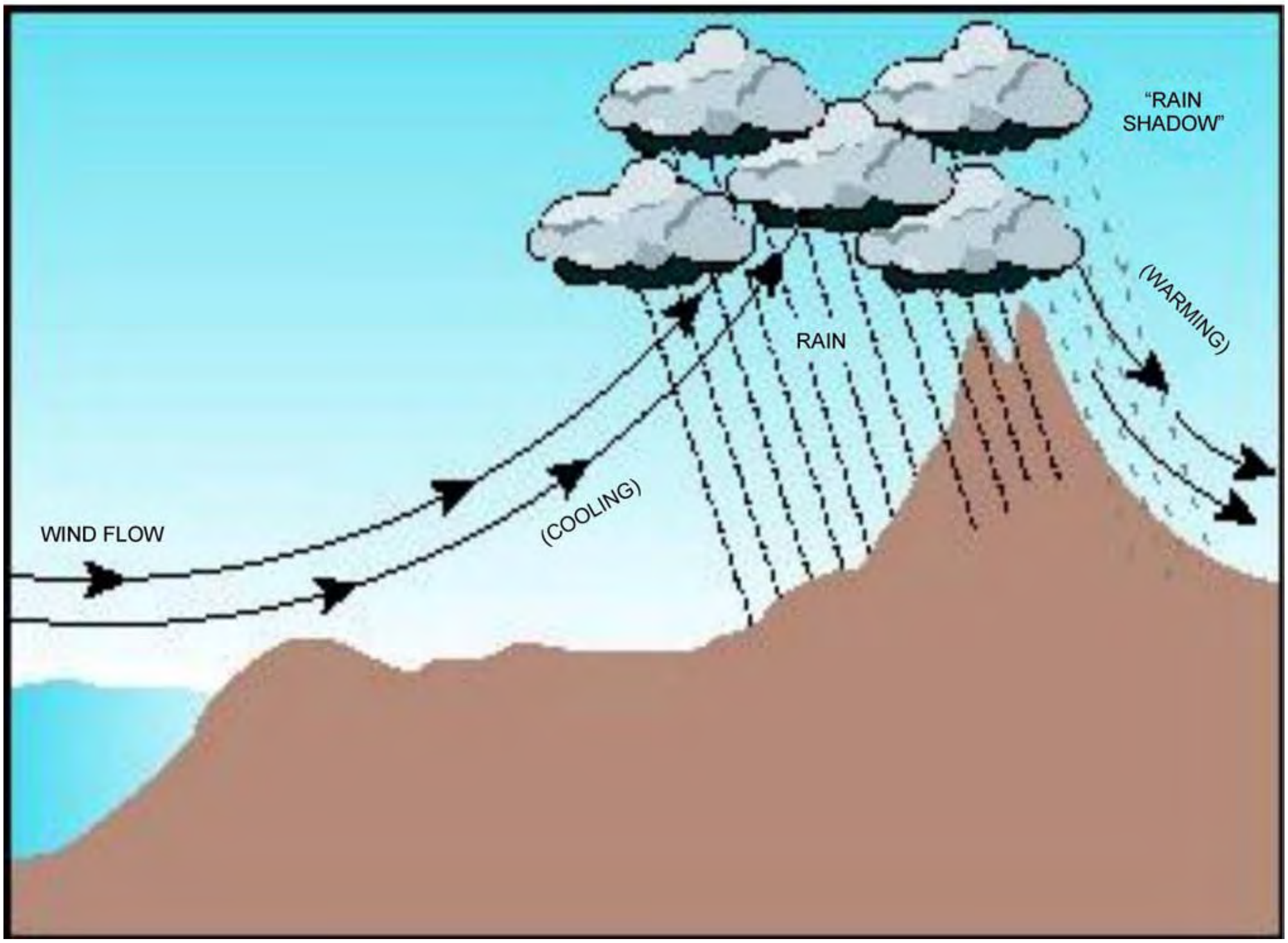
OROGRAPHIC LIFT



Water Encyclopedia, by G. H. Taylor, 2007, Water as a Climate Moderator. Copyright 2007by Advameg. Retrieved March 17, 2008, from http://www.waterencyclopedia.com/Ce-Cr/Climate-Moderator-Water-as-a.html

Figure 13F-1 Orographic Lift

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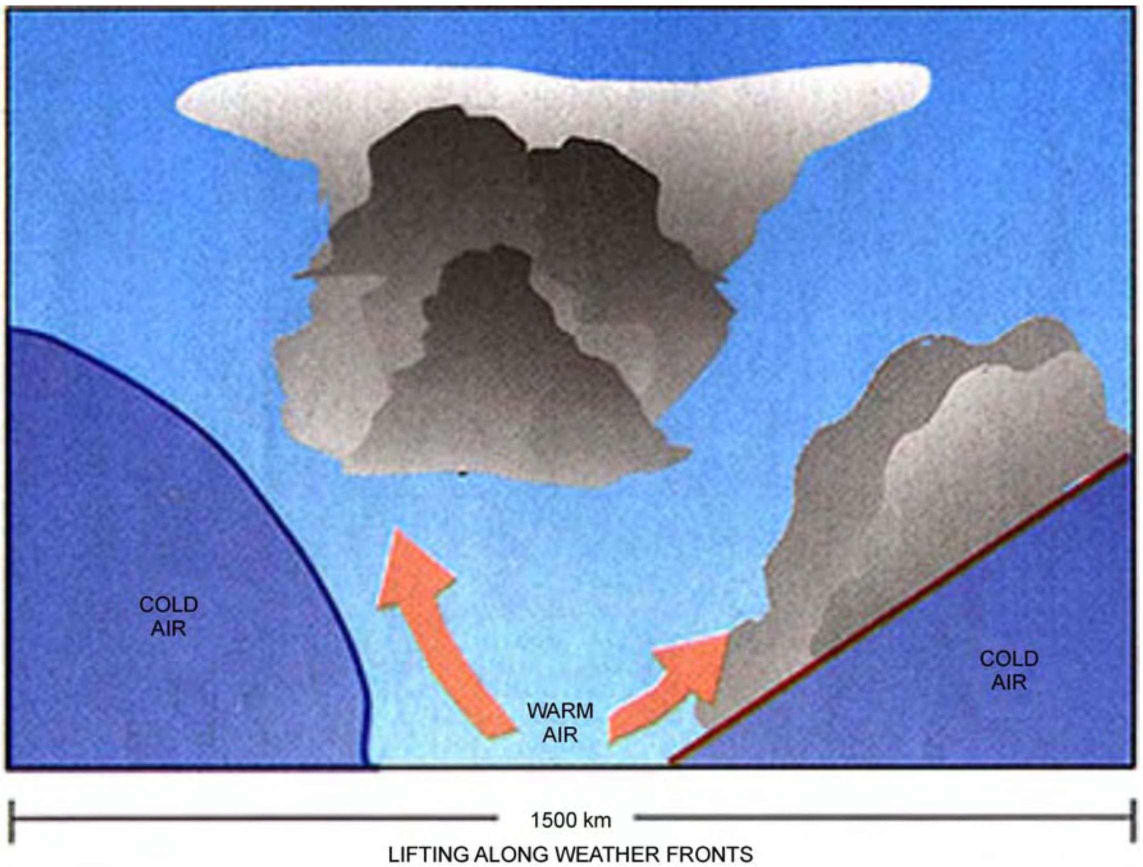
FRONTAL LIFT



Federation of American Scientists, by N. M. Short, Sr, 2007, Atmospheric Circulation: Weather Systems. Copyright 2007 by FAS. Retrieved March 17, 2008, from http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1c.html

Figure 13G-1 Frontal Lift

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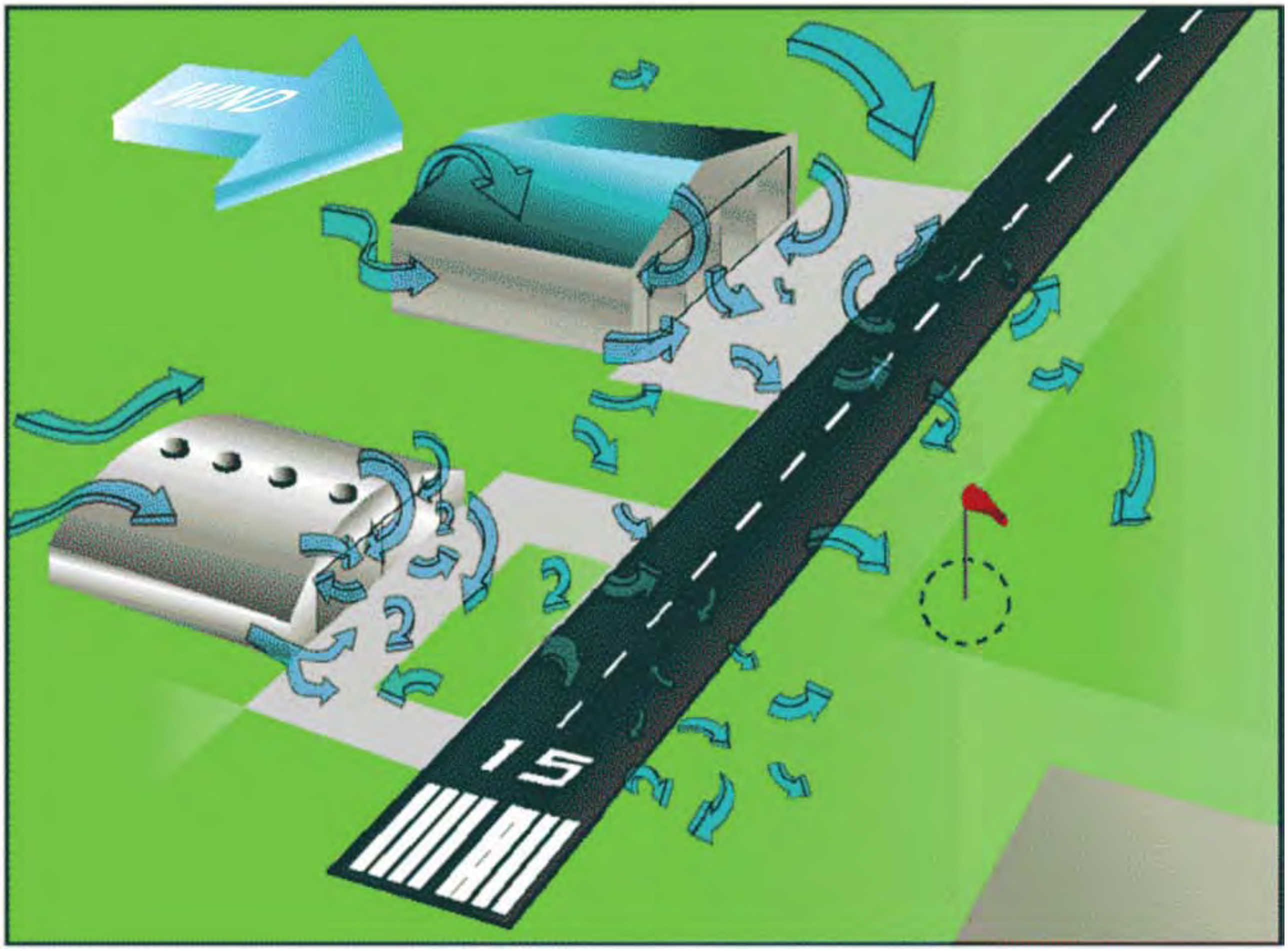
MECHANICAL TURBULENCE: MAN-MADE



Free Online Private Pilot Ground School, 2006, Aviation Weather–Principles. Copyright 2006. Retrieved March 17, 2008, from http://www.free-online-private-pilot-ground-school.com/Aviation-Weather-Principles.html

Figure 13H-1 Mechanical Turbulence: Man-Made

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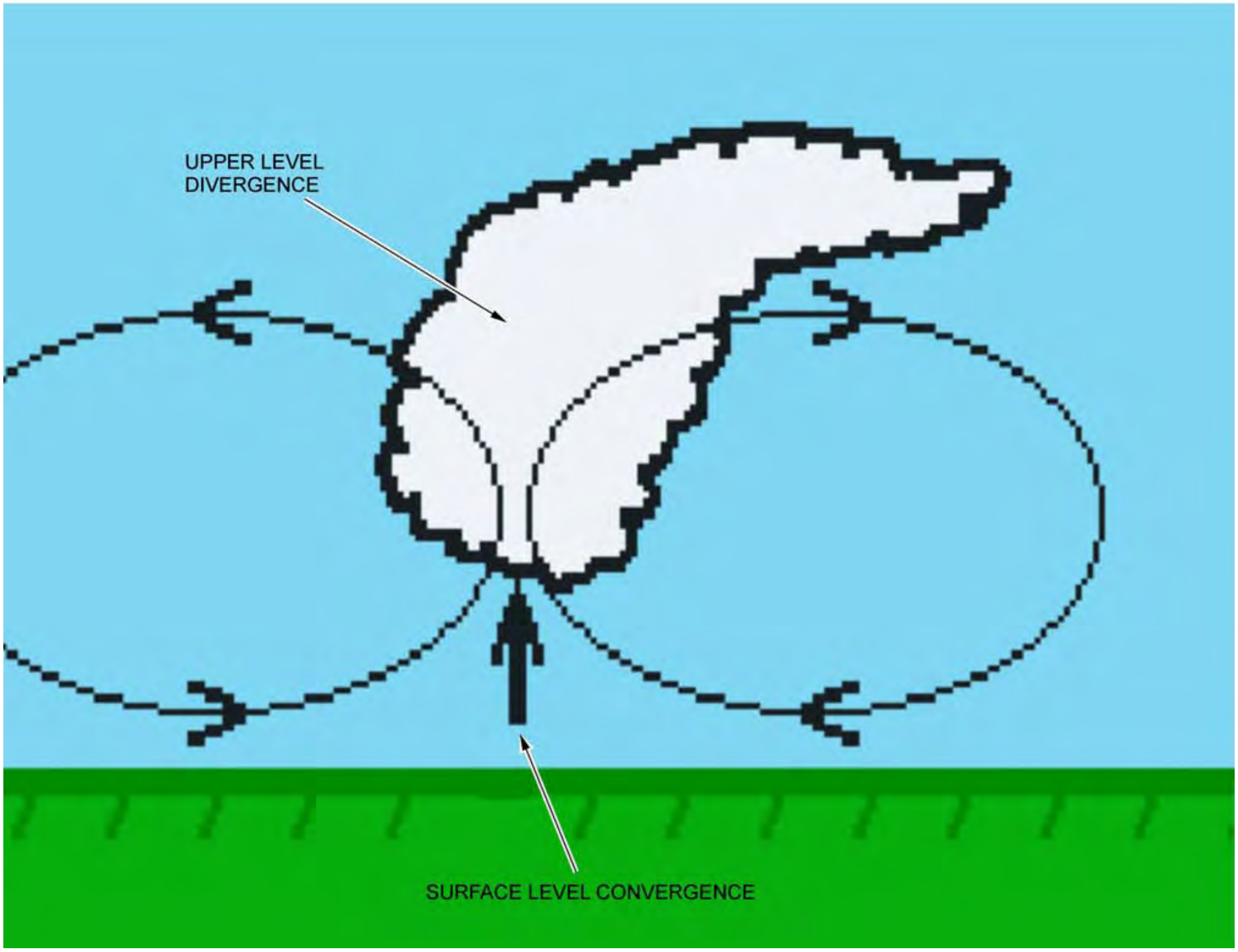
CONVERGENCE



The Weather Doctor, by K. C. Heidron, PhD, 2002, What Goes Up: Part 3 Convergence and Divergence. Retrieved March 17, 2008, from http://www.islandnet.com/~see/weather/elements/whatgoesup3.htm

Figure 13I-1 Convergence

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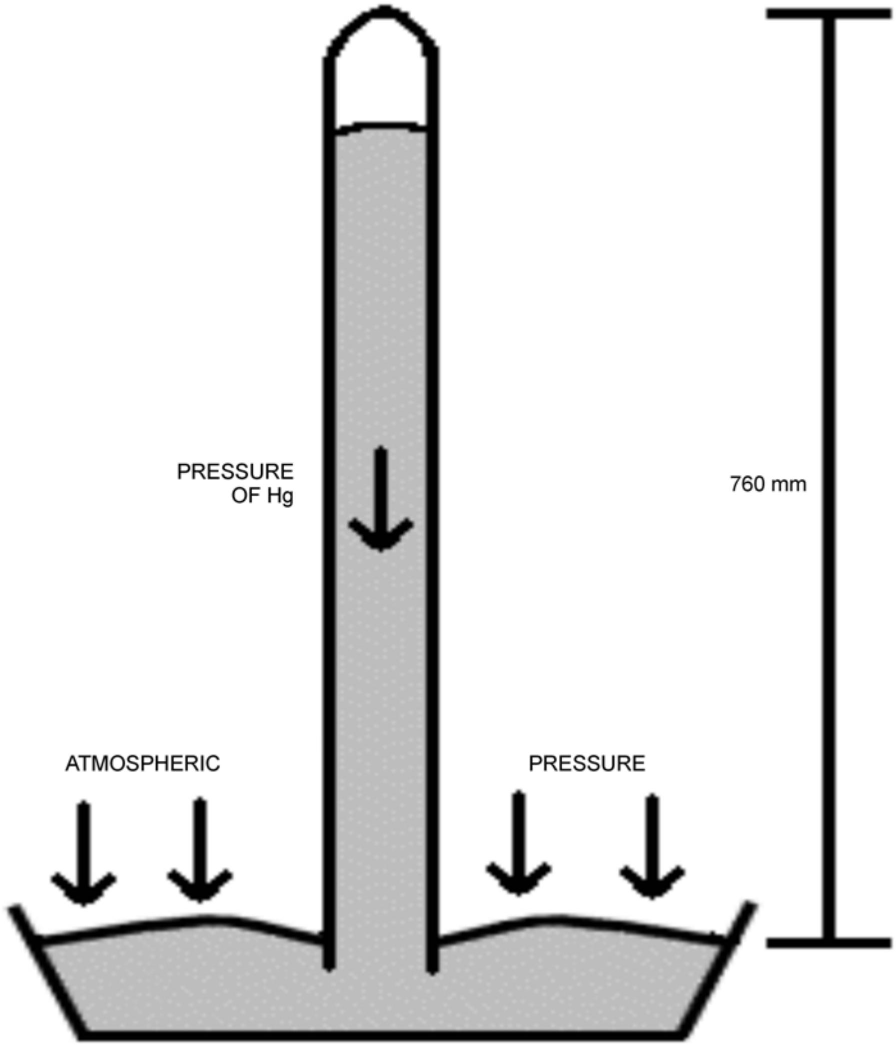
BAROMETER



$P_{atm} = P_{Hg}$

Chemistry Tutorial Notes, Department of Chemistry, Texas A&M University, 2006, Properties of Gases, Copyright 2006 by Texas A&M University. Retrieved April 4, 2008 from http://www.chem.tamu.edu/class/majors/tutorialnotefiles/pressure.htm

Figure 13J-1 Barometer

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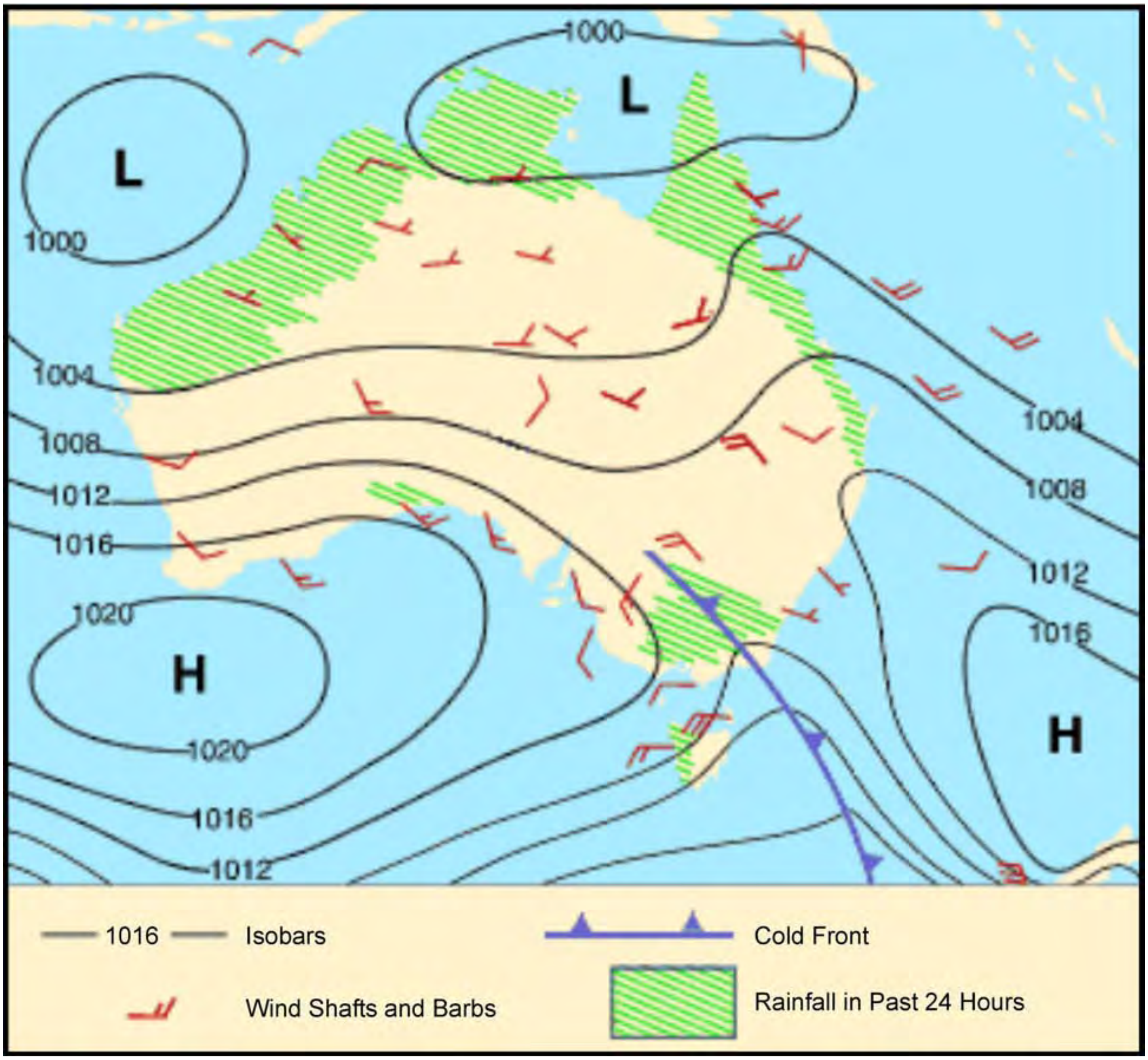
ISOBARS ON A WEATHER MAP



Australian Government, Bureau of Meteorology, 2008, Air Masses and Weather Maps, Copyright 2008 by Commonwealth of Australia, Bureau of Meteorology. Retrieved April 7, 2008 from http://www.bom.gov.au/info/ftweather/page_7.shtml

Figure 13K-1 Isobars on a Weather Map

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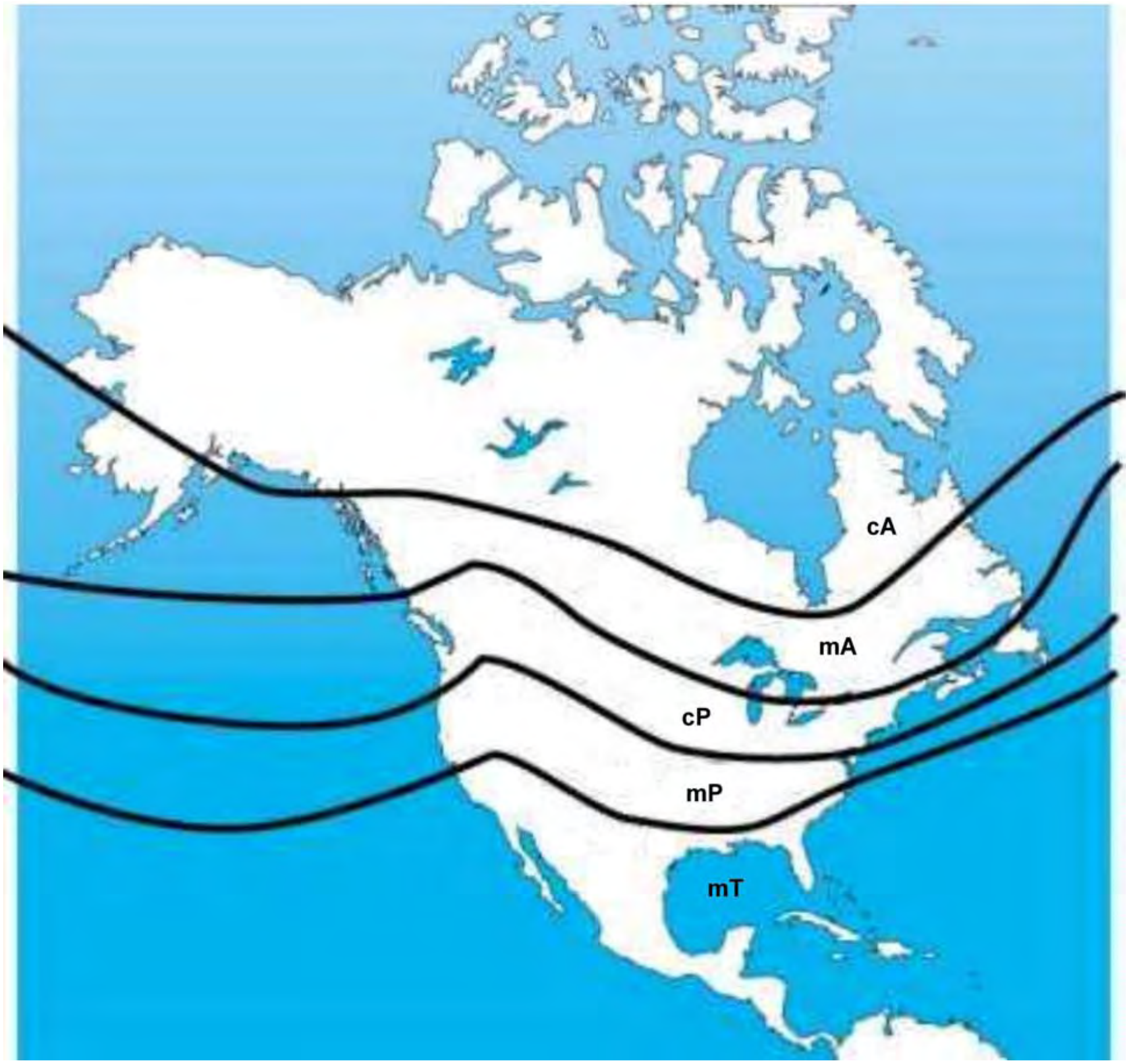
NORTH AMERICAN AIR MASSES



Meteorological Service of Canada, 2004, Frontal Systems, Copyright 2004 by Environment Canada. Retrieved April 7, 2008 from http://www.qc.ec.gc.ca/meteo/Documentation/Front_e.html

Figure 13L-1 North American Air Masses

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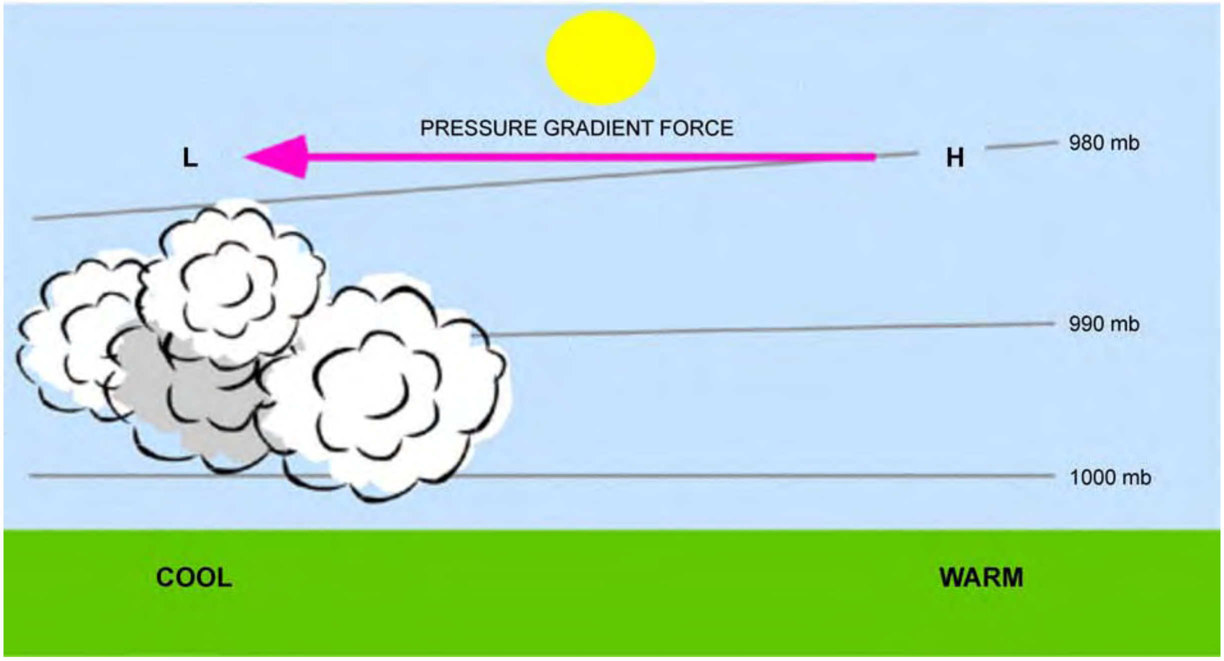
PRESSURE GRADIENT



PhysicalGeography.net, Dr. M. Pidwirny, University of British Columbia Okanagan, 2007, Introduction to the Atmosphere, Copyright 2007 by M. Pidwirny. Retrieved April 7, 2008 from http://www.physicalgeography.net/fundamentals/7o.html

Figure 13M-1 Pressure Gradient

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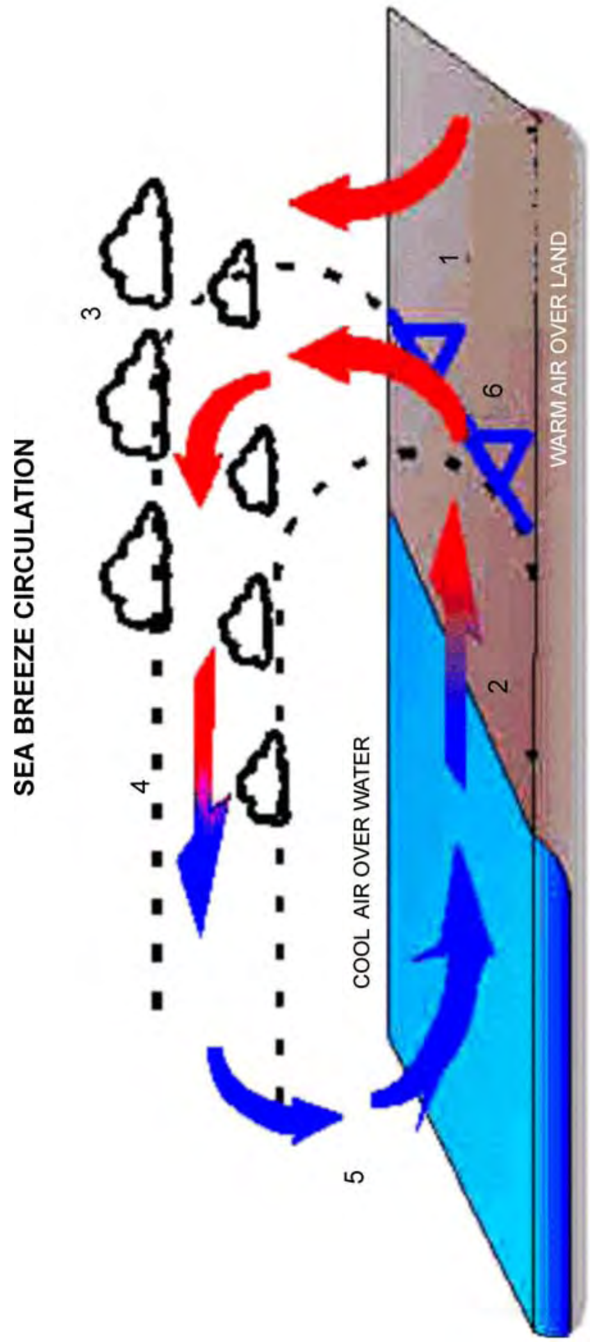
SEA BREEZE



The Weather Doctor, K. C. Heidron, PhD, 1993, Sea and Land Breezes, Copyright 1998 by K. C. Heidron PhD. Retrieved April 7, 2008 from http://www.islandnet.com/~see/weather/elements/seabrz.htm

Figure 13N-1 Sea Breeze

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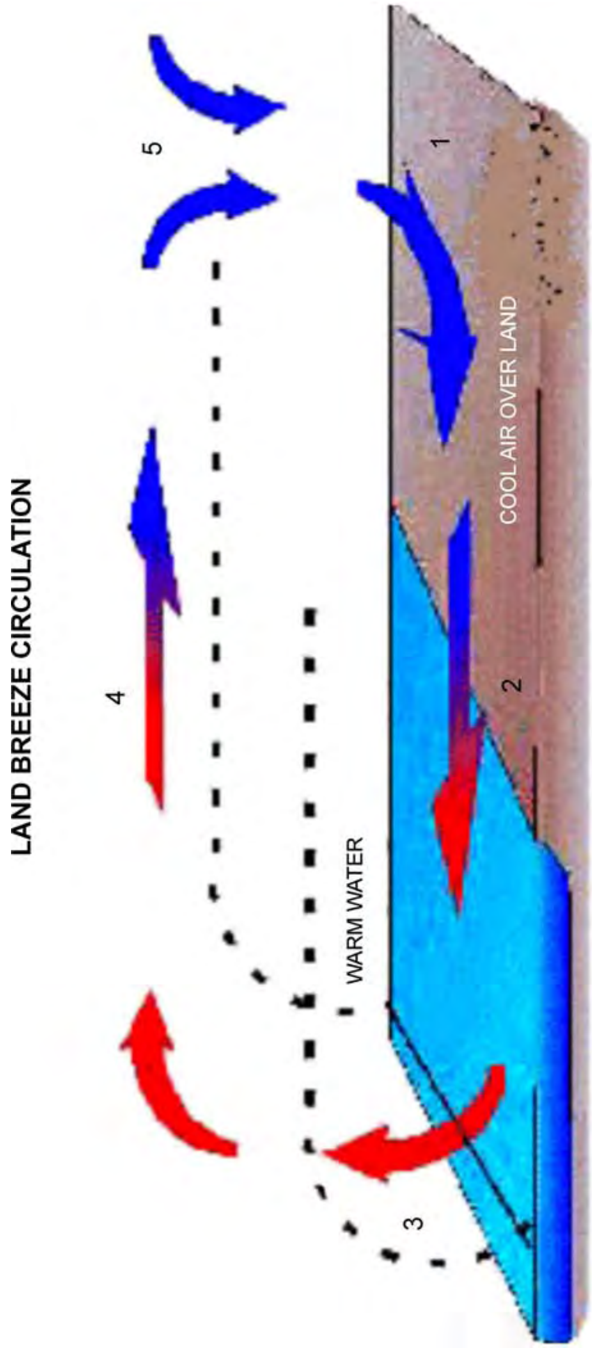
LAND BREEZE



The Weather Doctor, K. C. Heidron, PhD, 1993, Sea and Land Breezes, Copyright 1998 by K. C. Heidron PhD. Retrieved April 7, 2008 from http://www.islandnet.com/~see/weather/elements/seabrz.htm

Figure 13O-1 Land Breeze

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DEFINITIONS

Atmospheric Pressure. The pressure of the atmosphere at any point due to the weight of the overlying air.

Isobars. Areas of like pressure are joined by lines called isobars (from Greek *isos* [same] and *baros* [weight]).

Low Pressure Areas. Low pressure areas (often called lows, cyclones, or depressions) are areas of relatively lower pressure, with the lowest pressure in the centre.

High Pressure Areas. High pressure areas (often called anti-cyclones) are areas of relatively higher pressure, with the highest pressure in the centre.

Continental Air Mass. Air mass will be dry as it formed over land.

Maritime Air Mass. Air mass will be moist as it formed over water.

Arctic Air Mass. Air mass will be cold as it formed over the Arctic.

Polar Air Mass. Air mass will be cool as it formed over the Polar region.

Tropical Air Mass. Air mass will be warm as it formed over the Tropical region.

Wind. The horizontal movement of air within the atmosphere.

Pressure Gradient. The rate of change of pressure over a given distance measured at right angles to the isobars.

Sea Breeze. Occurs during the day when the land heats up more rapidly than the water.

Land Breeze. Occurs at night when the land cools down faster than the water.

Diurnal Variation. This is due to the heating processes which occur during the day, creating vertical currents and pressure gradients. At night, when the heating processes cease, the vertical currents diminish and the pressure gradients become shallower.

Coriolis Force. The rotation of the earth causes a deflection to the right (in the northern hemisphere). Coriolis Force also explains why air moves clockwise around a high, and counter-clockwise around a low pressure system.

Veering and Backing. Veering is a change in wind direction clockwise relative to the cardinal points of a compass while backing is a change in wind direction counter-clockwise caused by friction with the earth's surface.

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TYPES OF PRECIPITATION

UCAR Communications, Staff Notes Monthly, 2003, One Hail of a Storm, Copyright 2003 by University of Carolina. Retrieved April 2, 2008, from http://www.ucar.edu/communications/staffnotes/0308/hail.html

Figure 13Q-1 Hailstone

Climber.org, by S. Eckert, 2006, Graupel–Snow Pellets, Lighter and Smaller Than Hail, Copyright 2006 by Climber.org. Retrieved April 2, 2008, from http://www.climber.org/TripReports/2006/1473.html

Figure 13Q-2 Snow Pellets

Neatorama, 2007, Snow-donut. Copyright 2007 by Neatorama. Retrieved April 2, 2008, from http://www.neatorama.cachefly.net/images/2007-03/snow-donut.jpg

Figure 13Q-3 Snow Doughnut

Ohio Weather Library, B. Plonka, 2008. Unusual Weather. Copyright 2008 by Ohio Weather Library. Retrieved April 2, 2008 from http://www.owlinc.org/unusualweatherpg7.html

Figure 13Q-4 Ice Prisms

SAMPLE METAR AND SPECI

METAR CYHZ 111700Z 28009G16KT 15SM FEW250 00/M11 A2990 RMK CS0 SLP134=

METAR CYHZ 111800Z 29015KT 15SM FEW250 01/M10 A2989 RMK CI0 SLP128=

METAR CYHZ 111900Z 30008KT 15SM FEW250 02/M12 A2987 RMK CI0 SLP123=

SPECI CYYJ 111744Z CCA 23019G24KT 20SM -SHRA BKN014 BKN030 BKN120 09/07 RMK SC5SC1AC1=

SPECI CYYJ 111744Z 23019G24KT 20SM -RA BKN014 BKN030 BKN120 09/07 RMK SC5SC1AC1=

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WORLD METEOROLOGICAL ORGANIZATION CODE FOR PRESENT WEATHER

QUALIFIER					WEATHER PHENOMENA			
INTENSITY or PROXIMITY 1	**DESCRIPTOR 2**		**PRECIPITATION 3**		**OBSCURATION 4**		**OTHER 5**	
Note: Precipitation intensity refers to all forms combined.	**MI**	Shallow	**DZ**	Drizzle	**BR**	Mist (Vis ≥ 5/8 SM)	**PO**	Dust/sand Whirls (Dust Devils)
	BC	Patches	**RA**	Rain	**FG**	Fog (Vis < 5/8 SM)	**SQ**	Squalls
	PR	Partial	**SN**	Snow	**FU**	Smoke (Vis ≤ 6 SM)	**+FC**	Tornado or Waterspout
	DR	Drifting	**SG**	Snow Grains				
- Light	**BL**	Blowing	**IC**	Ice Crystals (Vis = 6 SM)	**DU**	Dust (Vis ≤ 6 SM)	**FC**	Funnel Cloud
	SH	Shower(s)						
Moderate (no qualifier)	**TS**	Thunderstorm	**PL**	Ice Pellets	**SA**	Sand (Vis ≤ 6 SM)	**SS**	Sandstorm (Vis < 5/8 SM) (+SS Vis < 516 SM)
			GR	Hail				
+Heavy	**FZ**	Freezing	**GS**	Snow Pellets	**HZ**	Haze (Vis ≤ 6 SM)	**DS**	Dust storm (Vis < 5/8 SM) (+DS Vis < 516 SM)
VC In the vicinity			**UP**	Unknown precipitation (AWOS only)	**VA**	Volcanic Ash (with any visibility)		

Transport Canada, Aeronautical Information Manual, Transport Canada (p. 145)

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