

Science 1206 Unit 4: Weather Dynamics

The Earth

- The earth is tilted on a rotating axis (the axis is a line from N to S pole).
- Rotates around the sun in an elliptical path.
- 70% of the earth's surface is water.
- 30% is land with varying landforms.
- Has an atmosphere that contains air, water vapor, particles of dust and chemicals.

Weather and Climate

- Weather Dynamics** :The study of how the movement of water and air causes weather patterns
- Weather** – is a set of environmental conditions encountered from day to day.
- Climate** – is a set of environmental conditions averaged over many years.

Global Geography

- Longitude** – angle measured east or west of line zero that passes through Greenwich, England. (Cape Breton Island is 60° West longitude). Vertical lines that run north to south
- Latitude** – angle measured north or south of the equator. Canada/US border lies along the 49° north latitude. Horizontal lines that run east to west.
- Northern Hemisphere** - North of the equator
Contains 2 important latitudes:
 - Tropic of Cancer** – 23.5° N latitude is the most northerly region reached by the sun's vertical rays. First day of summer June 21st.
 - Arctic Circle** – 66.5° N latitude. Most northerly location reached by the sun's rays on the first day of winter approx. December 21st.
- Southern Hemisphere** - South of the equator
Contains 2 important latitudes:
 - Tropic of Capricorn** = 23.5°S latitude
 - Antarctic Circle** = 66.5°S latitude

Tropics

- Large equatorial region between the Tropic of Cancer and the Tropic of Capricorn

Polar Regions

- North of Arctic Circle and South of Antarctic circle

Mid-latitudes

- Between the tropics and polar regions
- Most of Canada is in this area

Earth's Energy Balance

- Almost all the energy necessary to sustain life and influence weather come from the sun.
- Without this energy life could not exist. This energy is used to keep plants growing and the average surface temperature of the earth at 15°C
- The sun is our primary energy source and this energy is transferred to air, land and water

- Particles that make up the air, land and water absorb the energy and this effects their movement which in turn determines weather patterns
- Thus the sun is the ultimate cause of changing weather systems on a global scale

Kinetic Molecular Theory

- All matter is made up of particles that are in constant motion because they possess *kinetic energy* (energy of motion)
- The speeds at which the particles of a substance move as well as the distance between the particles determine the physical state of the substance ie. both factors increase going from solids to liquids to gases
- Temperature is a measure of the average kinetic energy of the particles of a substance or how “hot” or “cold” something is. The greater the temperature, the greater the average kinetic energy and thus the faster the particles move
- Heat (Thermal Energy) is the total kinetic energy of all particles of a substance and is transferred from a warm object to a cooler one due to a difference in temperature

Energy Transfer

Radiation

- This is the transfer of energy by waves.
- This is the only type that does not require a medium like water and sound waves. They can travel through space. It can travel in a vacuum therefore no particles are required This is the method that the sun’s energy reaches us here on earth.
- There are many forms of radiant energy that reaches us (note the electromagnetic spectrum in the text).

Conduction

- The transfer of energy through a material by the collision of particles (particles that vibrate) that make up that material
- Conduction is the transfer of energy through the collision of particles in a solid
- It occurs most easily through materials such metals but to a lesser extent in **rock, sand, soil and water**

Convection

- Transfer of energy in a liquid or gas
- The energy in convection is transferred vertically

Advection

- Transfer of energy in a liquid. This liquid could be either a gas or water.
- The energy in advection is transferred horizontally
- Important in cloud formation

- All of these methods are important in understanding how weather systems operate and it is through these methods of energy transfer that help maintain the earth’s energy balance and distribute energy around the world.

Reflection/Absorption of Energy (p 506)

- The solar energy that reaches the earth is either reflected or absorbed depending on the *albedo* of the substance
- Of the sun's energy 27% is reflected by clouds and particles in the atmosphere and never reaches the earth's surface.
- 3% is reflected off the earth's surface back into space.
- The land, water (oceans, ponds, etc) and ice absorb 50% of the sun's energy The clouds absorb 20% of this energy.
- Much of the energy that reaches the earth is reflected back and some is re-absorbed. It depends on the **albedo** of the material in question (**albedo** – ability to reflect radiant energy).
- The solar energy absorbed drives the water cycle and weather systems

Albedo - a measure of the percentage of light an object reflects

High albedo:

- objects that reflect a lot of light
- snow, clouds and light-coloured areas (sand, pale rocks and deforested areas)

Low albedo

- Objects that absorb more light than they reflect
- Dark surfaces such as asphalt, dark soil and dark forests

Heat Sinks - An object that absorbs energy and becomes warmer

- Water and air are the earth's major heat sinks since they can hold a lot of heat.
- Ex: The oceans absorb solar energy which causes water to move and transfer energy into the ocean depths (convection)
- Soil and rock are poor heat sinks because heat is transferred (conducted) slowly

Heat Source - Any warm body such as water or land in contact with colder air

- Recall that heat is transferred from a warm object to a cooler one

Heat capacity – an important property that indicates how much heat energy a substance must absorb to increase its temperature.

- Soil and rock are poor heat sinks – low heat capacity
- Water and air are good heat sinks – high heat capacity because it can hold a lot more heat.
- This difference in heat capacity explains why a lake takes longer to heat up during the day than does land (takes more energy to increase the temperature of the water).
- However, the lake takes longer to cool off in the evening than does land because the water releases the energy more slowly.

Latent Heat

- Latent Heat** : A measure of the attraction between particles in a substance. Eg: when changing state from a solid to a liquid to a gas attractions must be overcome
- Latent Heat of Fusion (Melting)**: The amount of energy that must be absorbed by a substance in order to melt.
- Latent Heat of Vaporization (evaporation)**: The amount of energy that must be absorbed by a substance in order to evaporate

Seasons

- Our changing seasons depend upon the Earth's revolution around the sun combined with the tilt of the earth's axis
- Earth **revolves** (orbits) the sun elliptically and **rotates** (spins) around an internal axis that is tilted at an angle of 23.50 with respect to its plane of orbit around the sun
- Earth's rotation on its axis causes day and night
- The beginning of each season is marked by solstices and equinoxes:
- **Solstice**: 'Sun stands still' ie. does not move any further north or south
 - Summer: day of maximum daylight hours
 - Winter: day of minimum daylight hours
- **Equinox**: 'Equal night' ie. day and night are of equal length
- **Summer Solstice** - June 21, the first day of summer
 - N.H. is at its maximum tilt toward the sun so it is the maximum daylight period
 - Sun is over the Tropic of Cancer (N.H.) so sun's rays are hitting N.H. most directly, therefore the sun's rays have their maximum intensity since they are concentrated over a smaller surface area
- **Autumnal Equinox** - September 23, the first day of fall
 - Sun is directly over the equator
 - The sun is above the horizon for 12 hours and below the horizon for 12 hours
- **Winter Solstice** - December 21, the first day of winter
 - N.H. is at its maximum tilt away from the sun it is the minimum daylight period
 - Sun is over the Tropic of Capricorn (S.H.) so sun's rays are hitting N.H. at a steep angle, therefore the sun's rays have their minimum intensity since they are spread over a larger surface area
- **Vernal Equinox** - **March 21, the first day of spring**
 - Sun is directly over the equator
 - The sun is above the horizon for 12 hours and below the horizon for 12 hours

The Atmosphere

- It is a blanket of air and moisture that surrounds the earth.
- It is most dense at sea level because of the pressure of the air above pressing down.
- As you ascend the atmosphere becomes thinner and at about 500 Km there is hardly any atmosphere
- Near the earth's surface, atmosphere is composed of:
 - 78% Nitrogen.
 - 21% Oxygen.
 - Remainder other gases such as, Carbon Dioxide, Argon, Neon, Helium, Krypton, Hydrogen, and Ozone.
- **Atmospheric Layers**
 - Differ in altitude (elevations, heights above sea level), temperature, composition and pressure

- All layers are thicker above the equator than above the poles because air above the equator is warmer and therefore it expands and takes up more space than the cold air above the poles

• Troposphere

- The atmosphere is thicker at the equator than at the poles due to the temperature is higher at the equator. This causes the air to expand more.
- Layer closest to the earth's surface it extends to an altitude of about 16 Km at the equator and about 8 Km at the poles.
- Contains most of the atmosphere's moisture and is responsible for our weather patterns.
- As the altitude increases in the troposphere the temperature decreases going from on average 15 degrees C at the surface to -50 degrees at its upper limits.
- by about 6°C for every 1000m rise
- *temperature gradient = change in temperature over a distance*
= - 6°C per 1000m for this layer

• Tropopause (Not a Layer, but important)

- This is a very thin layer that separates the troposphere from the stratosphere.
- Here the temperature increases rather than decreases due to the amount of ozone present. Ozone has the ability to absorb more ultraviolet radiation and therefore increase the temperature.
- This increased temperature in the Tropopause is important because the higher this temperature the more separation there is between the troposphere and the next layer.

• Stratosphere

- This layer contains very little moisture and extends for some 50 Km. It exists from about 12 Km to 50 Km.
- It contains more Ozone than any other layer and that protects the earth's surface from ultraviolet radiation.
- As altitude increases, temperature increases because of the large amount of ozone

• Mesosphere

- This is the middle layer (meso – means middle) of the earth's atmosphere.
- The temperature in the mesosphere is very cold reaching as low as -75 degrees C
- The density of the gases at this level is very low, and this layer extends from about 50 to 80 Km

• Thermosphere

- As its name implies the temperature in the thermosphere is much higher. Its average temperature is around 30 degrees C.
- This increased temperature is due to the fact that this layer absorbs x-rays (the highest energy electromagnetic radiation).
- Also called the ionosphere because the radiation causes the atmosphere to become ionized. This produces the aurora or the northern lights.
- Layer extends from 80 to 500 Km

•Exosphere

- Very thin outer layer where there is almost no atmosphere at all. The most common element in this layer is hydrogen.
- The temperature is very cold and it can be called outer space
- Altitude: 500 km to

•Notice that in each layer the temperature will either increase or decrease. This change is known as a **temperature gradient**. The temperature gradient for the troposphere is about -6 degrees C for every 1000 M

Supporting Life

- The atmosphere contains gases necessary for life, including O₂, N₂ and CO₂ makes life possible.
- Oxygen and Nitrogen in the atmosphere are needed to support life. Carbon Dioxide is needed for green plants.
- Ozone provides protection against UV radiation by absorbing it. Prevents the burning of plants and animals
- Important role in the water cycle – all organisms require clean water.
- Protects from meteors, most will burn up as they enter the atmosphere due to frictional effects and high speeds.
- Temperature regulation – keeps the average temperature within a life supporting range.
- Water vapor and gases like carbon dioxide trap heat energy radiated from the ground (Radiant energy)
- (Jet stream) – circulates air around the globe and help maintain a fairly constant balance of energy around the world

Atmospheric Pressure

- Is the pressure the air exerts as gravity pulls it towards the center of the earth
- It is greatest at sea level where the molecules are closest together, as altitude increases the pressure decreases
- Other factors affecting atmospheric pressure are:
 - Air rising or falling – this affects the temperature and wind currents.
 - Pressure Gradient - A measure of the amount the atmospheric pressure changes across a set distance. This change can be either vertical or horizontal.
 - Example: If you were to place your hand in still water the pressure on your hand would be constant. If you move your hand forward the pressure is higher on the front of your hand (compression effect) and lower on the back of your hand.
- Horizontal Gradient:(Figure 4b, p.512)
 - Shows horizontal pressure gradients using lines of equal air pressure = isobars
 - Isobars close together = high pressure gradient; indicates strong winds
 - Isobars farther apart = low pressure gradient; indicates lower wind speeds
 - Isobars are used on weather maps to indicate low and high pressure systems as well as the direction and speed of winds
- Vertical Gradient:(Figure 4a, p.512)
 - Shows that the pressure decreases rapidly with increasing altitude

Measuring Atmospheric Pressure

- Pressure is measured in KPa (Kilopascals)
- Kilo = 1000 1KPa = 1000 pascals
- 100 KPa = 100 000 Pa
- A Barometer is used to measure air pressure. The most common types of barometers are called aneroid barometers. It is a sealed chamber with flexible sides (or an aneroid cell) connected to a scale. The term aneroid refers to the fact that it does not use water to help determine pressure.
- As air pressure decreases, the container expands
- As air pressure increases, the container contracts

Prevailing Winds

- The winds are one of the most important features when discussing weather.
- **Wind** can be defined as the movement of air in the atmosphere.
- Some winds are local while others are prevailing.
- **Local winds** – occur in a fairly small region.
- **Prevailing winds** – affect large areas

Coriolis Effect

- The earth's rotation causes anything that moves long distances to appear to change direction. This is called the Coriolis effect – after Gaspard de Coriolis.
- The earth's rotation creates an apparent force ("Coriolis force") that deflects moving air to the right of its initial direction in the Northern Hemisphere and to the left of its initial direction in the Southern Hemisphere.
- The effect is proportional to wind speed; that is, deflection increases as wind strengthens.
- When viewed from a point above the North Pole, Earth rotates eastward or counterclockwise
- Objects in motion in the N.H. appear to move to the right
- To understand how this affects the prevailing winds you need to understand how the Coriolis Effect works

Diagram:

Causes of Prevailing Winds

- There are combinations of things that cause prevailing winds. They are:
- Convection currents
- Earth's eastern rotation
- Trade Winds
 - Solar energy strikes most directly near the equator heating the air, land, and water. This warm air rises and creates convection currents. These currents are called **equatorial convection** currents
 - The rising air leaves behind a region of low pressure
 - The rising air starts to move northward when it reaches the top of the troposphere
 - At around 30° north it has cooled sufficiently (becomes denser) and starts to fall
 - This creates a region of high pressure in front of the falling air
 - The air at the surface moves away from the high pressure towards the low pressure that was generated near the equator
 - The Coriolis effect causes this air to twist to the right generating the **northeast trade winds**. (They twist left in the southern hemisphere - *southeast trade winds*)

•Mid-latitude Westerlies

- Occur between 30° and 60° latitude
- At 30° latitude some of the warm air from the equatorial convection current meets cold polar air creating a low pressure around 60° latitude. The surface air moving north twists to the right in the northern hemisphere (left in Southern hemisphere) to form the *mid latitude westerlies*.

•Polar Easterlies

- Occur between 60° latitude and the poles
- Near the poles the air is cold and dense. This air sinks and moves toward the equator. The Earth's rotation cause this air mass to twist to the right in the northern hemisphere (left in South) causing the *easterlies*.

•Jet Streams

- High altitude, fast moving, winds in the troposphere that generally flows from west to east over the mid-latitudes.
- The jet streams separate cold polar air to its north from warmer air to its south.

Summary:

- Air pressure gradients, or the difference between regions of high and low air pressure, impel air in the direction of lowest pressure, creating wind. The larger the air pressure gradient, the greater the wind is speed. The Coriolis effect also affects wind speed and direction.

Effects of Prevailing Winds

- They help to distribute large amounts of solar energy around the globe. Pushing warm air north and colder air south.
- They also carry moisture that helps to distribute a variety of precipitation types around the world.
- Near the equator, where two sets of convection currents meet (from north and south hemispheres) and rise weather tends to be cloudy and rainy.
- At about 30° N latitude; the falling air is very dry and we get desert conditions.
- At 60° N latitude, two air systems meet and we get more rain and cloudy conditions.

Hydrosphere and Water Cycle

- The hydrosphere is defined as **all** the water that exists on the planet.

Water Distribution

- 95.5% of the earth's water is salt water contained in the oceans.
- Of the remaining 4.5% is fresh water and is distributed as follows:
 - Glaciers and polar ice caps 87.3%
 - Underground water 12.3%
 - Surface and atmospheric water 0.4%. This supply is further divided as follows:
 - Lakes 90%
 - Atmosphere 9%
 - Rivers 1%
- Energy from the sun causes the surface water to change state from a liquid or a solid into a vapor

Water Cycle

- The means by which heat energy is transferred between the hydrosphere and the atmosphere
 - the processes involved include evaporation (l → g), condensation (g → l), sublimation (s → g or g → s), precipitation, percolation and runoff
 - Solar energy causes *evaporation* from bodies of water and from plant leaves (*transpiration*) as well as *sublimation* of ice.
 - The water vapor (gas) rises and as pressure and temperature decrease with increasing altitude, the vapor undergoes *condensation* to form fog, mist and clouds
 - and/or *sublimation* into ice crystals
 - Precipitation* falls to the surface in the form of rain, snow, etc.
- Water seeps into the ground (*percolation*), and enters bodies of water as runoff from land.

Major Ocean Currents

•Oceans play a very important role in the weather dynamics of the earth because they are so vast and act as a good heat sink. The main reason why they have the ability to absorb so much heat is that there is very little land mass at the equator and that is where the sunrays are most direct. One of the most important ways of moving this heated water around the earth is by ocean currents.

Results of these currents are:

- Warmer winters with ice free harbors for many northern countries that are affected by the Gulf Stream.
- Colder currents from the northern and far southern regions are warmed as they migrate near the equator
- Causes of the ocean currents:
 - Convection currents.
 - Winds across the oceans.
 - The earth's rotation.
 - Shape of the continents.
 - Heat capacity of water
 - the amount of salt in the oceans

•Convection Currents

- Water at the equator absorbs the intense, direct rays of the sun and becomes heated
- Warm water tends to travel from the equator towards the north and south poles and cold water tends to migrate towards the equator.
- The warmed less dense water at the equator starts moving northward and southward away from the equator. It is replaced by cooler denser water. It is also influenced by the prevailing winds and the twisting action of the Coriolis Effect

•Prevailing Winds

- Ocean currents tend to follow the prevailing winds blowing at the surface

•Earth's Rotation

- Because of Earth's eastward rotation currents on the *west sides* of oceans tend to be narrow and fast moving and those on the *east sides* of oceans are wide and slow moving

- Shape of the continents**

- Where currents encounter a landmass they are deflected away from the path produced by the prevailing winds.
- As the currents come close to the continents they are forced to travel along the coastline. The eastward rotation of the earth causes the west side currents to be thinner and travel at a speed of ~ 6.5km/h while the currents on the eastern side are wider and travel at a speed of ~1.1 km/h. The Antarctic Circumpolar Current is the only one that travels all the way around the world.

- Heat Capacity of Water**

- Oceans act as huge heat sinks so they heat up slowly and, once heated, cool down slowly
- High heat capacity of water creates a lag in seasonal changes in relation to daylight hours:
 - For example:
 - June 21 is the longest day (most sunlight) in Northern Hemisphere (and should be the middle of summer) but the warmest months are June, July, and August instead of May, June, and July.
 - December 21 is the shortest day (should be the middle of winter) and the coldest months are December, January, and February instead of November, December, and January.
 - Ocean currents also affect the air pressure above them. Warm currents have warm air above them and the pressure is less dense. This creates low-pressure systems.

- Amount of Salt**

- The amount of salt in the water also plays a role in that as the warm water from the Gulf Stream migrates north it evaporates producing a higher concentration of salt in the water. This water is denser and sinks creating deep ocean currents. It is replaced by warmer less dense water.

Effects of Ocean Currents

- Creation of rain forests**

- Warm currents heat the air above them which increases the air's ability to carry moisture which creates rain forests on the *east side* of continents

Eg: Brazilian rain forest of eastern South America

- Warm currents that reach areas (British Columbia) where the air is cooler will form clouds and produce considerable precipitation

- Creation of deserts**

- Cool currents cool the air above them which decreases the ability of the air to hold moisture which creates deserts on the *west side* of continents

•Eg: desert area in Peru of western South America

- Moderation of temperature**

- A coastal area will tend to have cooler summers and milder winters than an inland location at the same latitude due to the moderating affect of a large body of water ie. it prevents the extremes in temperature

•Eg. St.John's is warmer in winter than Ottawa because of the warm moist air brought northward by the Gulf Stream

- Ocean currents are responsible for coastal regions being cooler in the summer and warmer in the winter (Newfoundland is a good example)

Clouds and Fog

•As the air warms water vapor causes the moisture in the ground, and water to evaporate. Warm air is less dense than cold air and rises into the atmosphere. Once it reaches higher elevations, it cools and condenses into clouds. Not all clouds will produce rain or snow because the droplets that make up the clouds are so small and are easily suspended by the atmosphere. There needs to be thousands of these droplets combine before precipitation will occur.

•Convection Clouds

- Where air near the ground absorbs energy from heated surfaces and starts to rise because it is warmer and less dense.
- The rising warm air carries water vapor up into the atmosphere.
- At higher altitudes the air pressure is thinner and the gases expand and cools because the particles lose energy as they move further apart.
- The water vapor also cools and condenses forming clouds
- Diagram:

•Frontal Clouds

- Form where the leading edge of a large moving mass of air meets another mass of air at a different temperature.
- Warm air masses generally are less dense and contain more moisture than cold air masses.
- As the cold denser air mass pushes under the warmer air mass it pushes it up. The warm air expands cools and forms clouds
- Diagram:

- **Orographic Clouds**

- Clouds that form as warm air moves up a mountain (orographic lifting) the pressure decreases and the temperature decreases thus forming clouds.
- Sometimes clouds form partway up the mountain leaving the peak in sunshine.
- Diagram:

- **Fog Formation**

- Fog, like other types of clouds, forms because of a change in temperature
- Fog is actually a cloud that forms near the ground.
- In general, it occurs when water vapor within warm air is cooled and condenses into fog near the surface
- Fog is formed in 4 ways:
 - When energy near the surface radiates upward but is not reflected back to earth by clouds. The air near the ground cools allowing the water vapor to condense into fog.
 - When warm air passes over snow. A sharp decrease in the temperature of the warm air causes the moisture to condense and form fog.
 - When warm ocean air meets either cold ocean currents or colder air at the shoreline. This is the type of fog we find here in NF.
 - When moist air rises up the sides of mountains during orographic lifting

- **Cloud Classification**

- Clouds are divided into two main groups:

- **Cumulus Clouds**

- Billowing, rounded shape that tend to grow vertically
- Indicate unstable weather
- Usually form as a result of convection currents, orographic lifting or when a cold air front pushes into a warm air mass

- **Stratus Clouds**

- Flattened layered shape that tend to grow horizontally
- Derived from a word meaning spread out
- Created from a warm air front over riding a colder air mass
- Generally indicate stable weather

- **Rules for Naming Clouds**

- Names are given according to their altitude
- Low level clouds have the simple names **cumulus** and **stratus**

- Medium level clouds have the prefix **alto**, meaning higher
- High level clouds have the prefix **cirrus**, meaning curly lock of hair
- Rain holding clouds are called **nimbus**

Weather Forecasting

- The study of weather forecasting is called meteorology.
- Those who forecast weather are called meteorologists.
- There is a relationship between air speed and its related pressure. It states:
- As the air speed increases the pressure will decrease.
- That principle is called Bernoulli's principle that states that:
 - Where the air speed of a fluid is high, the pressure is low and where the speed of a fluid is low the pressure is high.

North American Weather Systems

- Weather at the equator is easy to predict due the fact that the conditions do not change that often; it is generally warm and humid.
- We can say the same about the weather conditions at the poles; it is generally cold and dry.
- The mid latitude regions are much more difficult to predict because the weather conditions change so often.
- A weather system is a set of temperature, wind, pressure, and moisture conditions that exist for a certain region and moves as a unit for a period of days.
- Air Masses** – a large body of air in which the temperature and moisture content at a specific altitude are fairly uniform.
 - They may be as small as 100 km up to 1000 km across.
 - These air masses affect the regional weather conditions in their respective areas.
 - Where these weather conditions meet in the mid latitudes and interact it creates the weather systems we see on a day-to-day basis in Canada.
- North American Air Masses:

Air Masses	Temperature	Moisture Content	Where they form	Direction they move
Maritime Polar (West Coast)	Cool	moist	Over North Pacific Ocean	Northwest to southeast
Maritime Polar (East Coast)	Cool	moist	Over North Atlantic Ocean	Northeast to southwest
Continental Polar	Cold	dry	Over mid-polar Regions of N.A.	North to south

Maritime Tropical (West Coast)	warm	moist	Over South Pacific Ocean	Southwest to northeast
Maritime Tropical (East Coast)	warm	moist	Over South Atlantic Ocean	Southeast to northwest
Continental Tropical	warm	dry	Over mid-southern U.S. & northern Mexico	South to north

Fronts:

- **Low-Pressure Systems:** tend to bring cloudy skies and stormy weather Fig 2 p 547
- **Front:** the boundary between a cold air mass and a warm air mass
- **Warm front:** the leading edge of a warm air mass
- **Cold front:** the leading edge of a cold air mass
- **Occluded front:** forms when a cold front catches up with a warm front; the warm air is lifted above the earth's surface and is cut off from the cooler air below
- **Stationary front:** A stationary front occurs when the boundaries between the air masses is fairly stable and are not influenced by the jet stream. The front will remain that way until the faster moving jet stream air pulls up the air.

Low Pressure Systems

- Results from a warm air mass coming in contact with a cold air mass.
 - The two masses of air do not mix well so a front (boundary) forms between them.
 - At the start of the low pressure system the front is not moving.
 - Air in the jet stream pulls air up from both air masses creating low-pressure regions near the ground.
- This low-pressure region then starts pulling air in from the surrounding region and starts to spin in a counterclockwise direction (why?).
- As the jet stream continues to pull more air up more air is pulled in from the region.
 - The warm air front rises bringing moisture with it and the cold air front pushes under the warm air.
 - A large region of precipitation develops ahead of the warm front because the jet stream is pulling more air away.
 - Where the cold front is pushing the warm front upward considerable cloud formation occurs
- Diagram:
- Most of these clouds are cumulonimbus that brings heavy precipitation.
 - As the two fronts continue to swirl together they will reach a point where the cold front catches up to the warm front.
 - At this point an occluded front form.
 - This is a single front and indicates that the storm is weakening.
 - Finally the storm ends as the flow of air upward from the low-pressure area stops.
 - There is no more pushing up of warm air.

Diagram:

- Cyclogenesis: the process of forming a cyclone
- Cyclone: a low-pressure system that rotates counterclockwise (in the Northern Hemisphere) and usually brings cloudy, stormy weather

High-Pressure Systems:

- An anticyclone** is a high-pressure system that spins clockwise (in the Northern Hemisphere) and usually brings clear skies
- Instead of the air rising creating a region of low pressure the air falls thus creating a high-pressure system.
- In Canada the **cold high-pressure systems** result from the cold dense arctic air falling bringing with it clear skies and cold temperatures.
- Warm high-pressure systems:** form at 30° latitude, when air in the equatorial convection currents that are heading northward becomes colder and more dense and move downward, toward the surface.

Regional Weather

- Thermals:
 - Localized updrafts
 - Local convection currents set up during the day
 - Thermals are formed: On a clear, sunny day, solar energy warms the land. The land absorbs the energy and converts it into heat, which warms the nearby air. The warm air expands, becomes less dense and rises. The rising warm air is replaced by cooler, denser air which sets up a convection current.
 - Diagram:

- Sea Breeze:

- A convection thermal that flows from a large body of water toward the land
- In early morning, solar energy warms the land faster than the water. Warm air above land rises and moves out over the water. Warm air is replaced by cooler air from above the water which sets up a convection current.
- Diagram:

- Land Breeze:

- Reverse of a sea breeze where the land cools faster than the oceans.
- a convection thermal that flows from the land toward a large body of water
- Is form: As the sun sets, the land cools down faster than the water. Warmer air above water rises and moves in over the land. Warm air is replaced by cooler air from above the land which sets up a convection current.
- Diagram:

- Lake Effect Snow

- When an air mass moves across a large body of water it picks up moisture. In winter the air above the land is colder than the air above the water, therefore when the air blows onshore the colder air temperature causes the moisture to change to snow.
- Diagram:

•Chinook Winds:

- As air moves over the mountains it loses its moisture.
- As the dry cold air falls down the lee side of the mountain it absorbs heat.
- This warm dry air can create summer like conditions during the winter months
- The air that sinks on the east side is warm and dry producing the warm, dry Chinooks
- Diagram:

Precipitation:

- It can be defined as water that reaches the ground as either a solid or a liquid.
- Occurs when air reaches its saturation point and the water vapor in the air condenses to form liquid droplets. When many droplets join together they become heavy enough to fall to the surface
- The type of precipitation that reaches the surface depends on the temperature in the atmosphere, and, more importantly, the temperature near the ground
- Liquid forms: drizzle, rain and dew
- Solid forms: snow, ice pellets (sleet), hail, frost and freezing rain
- Drizzle:**
 - Drizzle is a fine water droplet between 40 μm and 0.5 mm in diameter.
 - Depending on the intensity of the precipitation, both rain and drizzle can be classified as light, moderate or heavy
- Rain:**
 - Rain consists of falling water with a diameter between .5 mm and 5 mm.
 - If the droplet is larger it will break into pieces as it falls through the air.
- Dew:**
 - Dew forms when the moisture in the air condenses on a cool surface like the grass in the early morning.
 - If the surface is very cold the water vapour sublimates resulting in frost.
- Freezing Rain:**
 - Raindrops that are close to freezing and strike a cold object on or near the ground.
 - They freeze instantaneously.
- Ice Pellets: (Sleet)**
 - This is a solid form of water.
 - They form when snow falls through a region of warm air and partially melt.
 - They then fall through a colder region of air and refreeze.
 - These ice pellets are hard enough to bounce off the ground when they strike.

- Snow:**

- Snow forms when water droplets and a few ice crystals form.
- The ice crystals grow and combine to form snowflakes.
- If the temperature remains cold the snow falls to the ground as dry snow.
- If the snowflakes pass through a region of warmer air they can melt slightly and fall to the ground as wet snow.

- Hail:**

- Hail is a solid form of water that is created in cumulonimbus clouds high in the troposphere.
- Frozen raindrops move up and down in highly active thunderclouds, each cycle they become larger in diameter.
- They will remain suspended in the air currents until they are too heavy then they fall to the ground.
- Some hailstones can have as much as 20 layers.

Humidity:

- Humidity is the measure of water vapor that is in the atmosphere.
- It affects how comfortable we feel.
- If the humidity is low we feel comfortable but if it is high we find that there is no way to keep cool (Why?).
- Clouds formed when the humidity is low generally evaporate quickly but if they form when the humidity is high they will linger for a very long time.
- Low humidity = Evaporation can occur from bodies of water
- High humidity = Evaporation cannot occur; condensation can occur producing clouds &/or fog
- Relative humidity** is the measure of the amount of water vapor actually in the air as a percentage of the maximum amount of water vapor the air could hold at that temperature.
 - Warm air can hold more moisture than cold air.
 - Figure 1 (p.558)* shows the maximum concentration of water vapor in dry air (in g/kg) at different temperatures to give 100% humidity = *saturated air*
 - Saturation of air occurs when the air is holding the maximum amount of water vapor it can at that temperature – its relative humidity is 100%
- Dew is water vapor that has condensed on colder objects such as grass in the early morning
- Dew forms when the relative humidity is 100% - this is called the dew point.
- During the day the ground absorbs energy quickly, and at night it loses this energy equally as fast. When the temperature of the ground is at or below the dew point the water vapor in the air condenses out as droplets on the plants etc.
- When the skies are cloudy the earth radiates energy and the clouds absorb it, the clouds in turn radiate the energy back to the ground. That is why dew forms mainly on nights when the skies are clear.
- Steam on a bathroom mirror or water on the outside of a cold glass forms in the same way as dew.

Relative Humidity Calculations

• *Ex1: If the concentration of water vapor at 0°C is 1.9 g/kg of dry air, what is the relative humidity?*

• *See figure 1 Figure 1 (p.558)*

$$\begin{aligned} \bullet \text{Relative humidity} &= \frac{\text{concentration}}{\text{Max concentration}} \times 100\% \\ &= \frac{1.9 \text{ g/kg}}{3.8 \text{ g/kg}} \times 100\% \\ &= 50\% \end{aligned}$$

• *Example 2: Determine the concentration of water vapor in air at 20°C when the relative humidity is 50%*

• *See figure 1 Figure 1 (p.558) Maximum concentration= 15.0 g/kg*

$$\begin{aligned} \bullet \text{Con} &= \frac{(\text{R.Hum}) (\text{Max con})}{100} \\ &= \frac{(50) (15.0 \text{ g/kg})}{100} \\ &= 7.5 \text{ g/kg} \end{aligned}$$

Determining Relative Humidity

- To determine relative humidity you would use a psychrometer.
- An instrument that uses two thermometers, one dry and open to the air the other covered with gauze that is made wet when you wish to use the instrument.
- It works on the principle that dry air will cool the wet gauze faster than damp air.
- To operate the device simply wet the gauze and then spin it.
- After a few minutes check the temperature of both thermometers.
- In general the temperature of the wet thermometer will be lower than the dry one .
- Subtract the wet thermometer value from the dry one and then use the table to determine the relative humidity.
- When the air is saturated (100% humidity) both thermometers will have the same temperature reading; if not saturated, the wet-bulb will have a lower reading than the dry-bulb
- *Ex 3: The air temperature in a classroom is 22°C and the wet-bulb temperature is 17°C. Determine the relative humidity of the room.*
- 22°C - 17°C = 5°C
- Look for 22°C on the left side and look for 5°C. The intersection is the relative humidity 61%

Effects of Humidity

- The amount of humidity in the air affects many things such as frost or dew forming on the ground in the early morning. It also affects how we feel.
- **High humidity**
 - Normally, when a person perspires, evaporation of perspiration removes heat from the body and cools it down
 - In the summer, the humidity is high in the air because evaporation does not occur, therefore perspiration cannot easily evaporate making the person feel uncomfortably hot

- **Low humidity**

- In winter when the air is dry, evaporation occurs quickly because the air can hold a lot more moisture, so the skin can become uncomfortably dry

Weather Forecasting Technology

- Today weather forecasting is accurate for about three days.
- This is due to the technology and methods we now use for gathering weather information.
- There are a number of things that haven't changed but computer technology has allowed us to generate better and more accurate models of how weather systems will move.
- Things such as forecasting temperature, wind speed, atmospheric pressure, and humidity have remained the same. The main difference with these items is our ability to get this information distributed quickly to those who need it.
- Weather satellites and aircraft have greatly improved our ability to collect data.
- **Weather Satellites**-An orbiting spacecraft that regularly gathers weather-related data and images and relays them to weather stations on the ground
- **Low-orbit satellites:**
 - Orbit about 1000 km above the poles
 - Low level satellites travel around the poles every two hours collecting data such as infrared and microwave energy.
 - Gather data that is used to detect changes in air temperature and water vapor at different levels of the atmosphere, as well as global wind patterns
- **High-orbit satellites:**
 - Orbit about 36,000 km above the equator
 - High level satellites detect electromagnetic radiation from various levels of the atmosphere, provide images that show cloud cover, earth's physical features & amount of infrared radiation from the atmosphere
 - The combined efforts of all these satellites provide a comprehensive image of the earth's weather
- **Doppler Radar** works like a police radar system
 - Can detect the direction and speed at which air masses are moving
- **Weather balloons** are helium-filled balloons that are launched 2 or more times per day from weather stations across North America
 - Carry instruments that collect data on temperature, pressure, humidity and ice-crystals
 - Can also be used to determine speed and direction of winds
- **Other Ground-Based Technology:**
 - Thermometer – Current, minimum maximum temperatures
 - Anemometer – Wind Speed and Direction
 - Aneroid Barometer – Atmospheric Pressure
 - Rain Gauge – Rainfall
 - Hydrometer – Relative Humidity
- **Computer Technology** - Data from satellites, weather balloons and ground-based instruments are gathered, stored and analyzed by computer software – Weather Models
- Computers linked to satellite communication systems allows info to be sent around the world

Extreme Weather

- **Weather System:** a set of temperature, wind, pressure and moisture conditions for a certain region, that moves as a unit over a period of days
- **Thunderstorms** - A storm with lightning, thunder, heavy rain and sometimes hail
 - Results from the uplift of air and moisture high into the troposphere
- **Tornadoes** - Form in the most severe thunderstorms
 - Fast rising air begins spinning, forming a funnel of air and moisture. As it rises it turns to the right due to the Coriolis Effect.
 - Travel at speeds of up to 100 km/h
- **Floods** - Excess of water from rain, rivers, or oceans that form over land that cannot soak up any more water.
 - 2 Types:
 - **Flash** - quick onset; difficult to predict (eg. Badger, NL)
 - **Broadside** – cover a large land area; seasonal, predictable floods (eg. Monsoon Flooding)
- **Drought** - occur whenever precipitation is very low over a long time period
 - common in areas at or near 30° latitude (high pressure areas)
 - eg. Dust Bowl of 1930's in the prairies
- **Hurricane, Typhoons, and Tropical Cyclones** - All are cyclones: massive high-energy low pressure systems which have resulted from the large amounts of energy from hot, tropical marine air masses spinning off of equatorial ocean areas.
 - The names are different due to the regions in which they are found.
 - Hurricanes - Atlantic Ocean
 - Typhoons - Pacific Ocean
 - Tropical Cyclone - Indian Ocean
- **Blizzards** - Severe snow storms with strong winds (> 55 km/h) and low temperatures
 - Can develop when a warm moisture-laden air mass moves northward and meets a cold Arctic air mass, under a strong jet stream.
- **Ice Storms** - Freezing rain that lasts for several hours
 - Can occur when a warm air mass meets a cold air mass and the cold air mass pushes the warm one upward.
 - The moisture in the warm condenses into clouds and ice crystals. As ice crystals fall through air mass they melt to form rain.
 - The raindrops fall through cold air mass, cool and then freeze instantly when they hit a cold object on the ground
- **Heat Wave** - A period of more than 3 days at or above 32°C
 - Can occur when southern continental air masses produce long term warm, high pressure systems as they fall over regions in central Canada.
 - Often exaggerated over cities where it may produce a “temperature inversion” which traps warm air and pollution over these regions preventing normal convection from occurring.
 - Can feel hotter with high humidity
 - Humidex Scale: combines the temperature and relative humidity to give a temperature indicating how it feels to humans Table 1 p 605

•**Extreme Cold** - Can occur when large polar air masses may be drawn southward by advection bringing much cooler than normal temperatures.

- Can feel colder with high winds

- Wind chill factor - takes into account the cooling effect of wind to indicate what the temperature would feel like with the wind Table 2 p 606 + Fig 4

•**El Nino and La Nina** - Major changes in the seasonal weather systems in the South Pacific resulting from the changes in the ocean convection currents

- El Nino** - Caused by high surface water temperatures and water levels in the western Pacific

- an abnormal warming of surface ocean waters

- May result in warm temperatures in Canada Fig 3 p 613

- La Nina** - Caused by low surface water temperatures in the eastern Pacific

- cooler than normal sea-surface temperatures

- May result in colder temperature in Canada