

Global Weather Dynamics Notes

- **Weather dynamics** is the study of how the motion of water and air causes weather patterns.
- The main components of earth that influence weather are the atmosphere, the land forms (lithosphere), and water (hydrosphere) in its various forms.
 - About 70% of Earth is covered by oceans and other bodies of water.
- **Weather** is best described as the set of environmental conditions encountered from day to day, whereas **climate** is the set of environmental conditions averaged over many years.

Global Geography

- When looking at global map, the 0° **longitudinal line** passes vertically directly through Greenwich, England. **Longitude** is measured east or west of the 0°.
 - Example: The tip of Cape Breton lies at 60° west longitude.
- **Latitude** is the angle measured north or south of the equator.
 - Example: The border between the western Canadian provinces and the United States lies along the 49° latitude line.
- The world is divided into the **northern** and **southern hemispheres**, as well as the **eastern** and **western hemispheres**.

Earth's Energy Balance

- Almost all the energy used on Earth to sustain life and cause our changing weather systems comes from the sun.
 - Just the right amount of energy is returned to space from Earth to keep the average surface temperature about 15°C.
- Energy can be transferred by three different methods in order to help maintain Earth's energy balance:
 1. **Radiation** is the transfer of energy by means of waves.
 - A medium is not required, hence the sun's energy reaching us from space.
 - The **electromagnetic spectrum** consists of several types of radiation waves listed in order of increasing energy.
 2. **Conduction** is the transfer of energy through the collision of particles.
 - It occurs most easily in metals, but it also occurs in substances on Earth's surface, including rock, sand, and soil.
 3. **Convection** and **advection** are the transfer of energy by movement of particles in a liquid or gas (a **fluid**).
 - Convection transfers energy vertically and advection transfers energy horizontally.
 - These concepts are often applied in order to understand changing weather systems.
 - The motion of molecules in liquid water or water vapor transfers heat through convection, causing the formation of clouds.
- Reflection and Absorption of Energy
 - The energy reflected by the Earth back into space depends on the Earth's albedo
 - High albedo: reflects a lot of energy, absorbs little

- Low albedo: reflect little energy, absorbs a lot
- Heat sink: object or material that absorbs energy and becomes warmer (ex. Water)
- Heat capacity: how much energy it takes to increase a substance's temperature

The Seasons

- Much of Earth's weather, especially our changing seasons, is caused by Earth's revolution around the Sun combined with the tilt of Earth's axis.
- The Earth rotates around its axis once each day. The axis is tilted at an angle of 23.5°.
 - Around June 21 (the summer solstice, the longest day of the year), the Northern Hemisphere is at its maximum tilt toward the Sun. The Sun's rays are hitting the Northern Hemisphere's surface most directly at this time.
 - Around December 21 (the winter solstice, the shortest day of the year), the Northern Hemisphere is at its maximum tilt away from the Sun. The Sun's rays are hitting the Northern Hemisphere's surface at a steep angle, and we experience the effects of winter. The opposite happens in the Southern Hemisphere.
 - On the equinoxes (the vernal equinox around March 21 and the autumnal equinox around September 23), the Sun's rays strike Earth's surface at the equator straight on. At these times, day and night are of equal length everywhere on Earth.

The Atmosphere

- The **atmosphere** is the blanket of air and moisture that surrounds Earth.
- Its density is higher at sea level, where molecules are pressed together by the weight of the air above.
 - As the height above sea level increases, the density of the air decreases.
- The vacuum of space begins approximately 500 km above sea level.
- Our atmosphere consists mainly of...
 - Nitrogen (78%)
 - Oxygen (21%)
 - Small amounts of other gases such as argon, carbon dioxide, and water vapour.
- Life as we know it would not be able to exist without the atmosphere.
 - O₂, CO₂, and O₃ all play vital roles.
 - Plays a role in the water cycle.
 - Offers protection from meteors because of its frictional effects.
 - Gases such as H₂O and CO₂ trap energy in the form of heat radiated from the ground and therefore keep the temperature within life-supporting range.

The Hydrosphere

WATER DISTRIBUTION

- Snow, ice, water in rivers and lakes, and water vapour in the atmosphere make up only a small portion of all the water on Earth – most of the water is found in oceans.
- The **hydrosphere** is formed by all of Earth's water, both fresh and salt.

- Only about 2.5% of the hydrosphere is fresh water, most of which is frozen in glaciers and in the ice caps around the North and South Poles.
- Even though Canada has just 0.5% of the world total population, we have almost 10% of the world's supply of fresh water.

THE WATER CYCLE

- Our weather systems depend greatly on water in its three states: solid, liquid, and gas.
- The process:
 - Energy, mostly from the sun, causes the water to **evaporate** or ice to **sublimate**. As it rises, the vapor **condenses** into fog, mist, and clouds. Sometimes the vapour may cause ice crystals in a process called **deposition**.
 - The resulting precipitation falls to the ground and the process starts again.

CLOUDS AND FOG

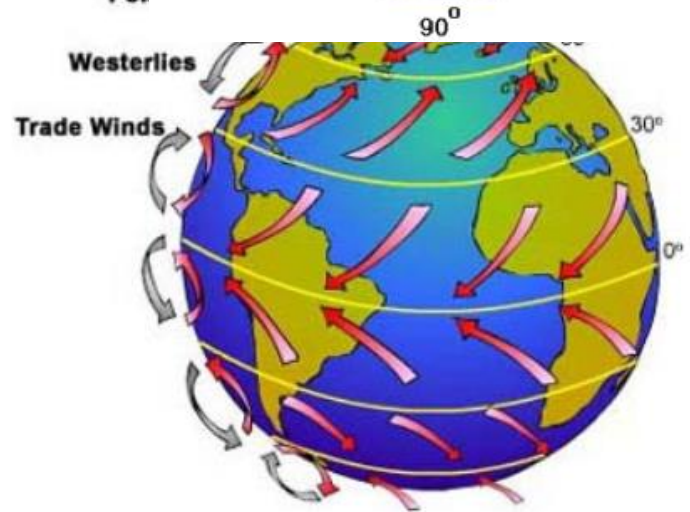
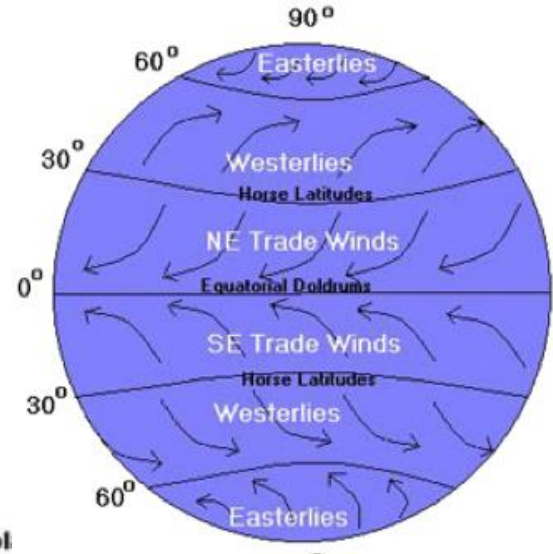
- Clouds are obvious indicators of weather and weather systems.
 - Most condensed droplets of water in a cloud are very small and easily carried by air molecules.
 - Once thousands of these tiny droplets join together to form a raindrop, gravity will pull it toward the ground.
- Clear skies allow solar energy to pass through the atmosphere and strike the surface.
 - How will this affect evaporation? Increased
- Clouds build up
 - Clouds have a high albedo. What does this mean?
 - Reflect much of the solar energy back to space, reducing the amount reaching the surface
 - Absorb Infrared radiation from the sun and emitted from Earth's surface
- Land has a low **heat capacity**
 - Heats up and cools down much more quickly than water
 - This influences cloud formation and local weather effects
 - *High heat capacity*: Takes a long time to change temperature, but holds that temperature well
 - *Low heat capacity*: Changes temperature easily, but loses that temperature easily
- Water in lakes, rivers, oceans, & plants gains energy from the Sun directly or the surroundings.
 - Energy causes the water molecules to move more rapidly: Warms up
 - The water will change from a liquid to a vapour: Evaporation
 - Rises to higher elevations where **pressure is lower** and **temperature is cooler**
 - Changes in to a liquid: Condensation
 - What if it is really cold? Ice crystals form
- **Why doesn't it rain whenever there are clouds up above?**
 - Water droplets are very small (small enough to be carried by air molecules)
 - In order to form a raindrop that will drop to the ground, thousands of droplets must be combined so that the force of gravity is strong enough to pull the drop downwards
- Cloud formation can be classified into three main categories:

1. **Convection clouds** are formed wherever solar energy is absorbed by water and other surfaces.
 - Moist air near the surface is heated, becomes less dense, and rises.
 - At higher altitudes, the decreased pressure allows for the air to expand and cool because the particles lose energy as they get farther apart.
 - The water vapour also cools, and to the point that it condenses, forming clouds.
 2. **Frontal clouds** form where the front of a large moving mass of air meets another mass of air at a different temperature.
 - Warm air masses are less dense than cold air masses and usually contain more water vapour.
 - When the warm air is pushed upward, the same cooling process occurs (as mentioned before) and clouds will form.
 3. **Orographic clouds** (“Oro” –Gr. *oros* means mountain) form when air moves up a mountain.
 - Like the others, the air expands at the lower pressure and cools, condensing the water vapour enough to cause cloud formation.
- Cloud classification begins with...
 - Two general shapes:
 1. **Cumulus clouds** have a heaping rounded shape.
 - They tend to grow vertically as a result of convection currents, frontal movement, or orographic lifting.
 - They usually indicate unstable weather
 2. **Stratus clouds** have a flattened, layered shape.
 - They tend to grow horizontally as a result of a warm air mass overrunning a cold air mass.
 - They usually indicate stable conditions
 - And, after shape, clouds are classified according to their altitude in the atmosphere (**alto** and **cirrus**), and the word **nimbus** indicates a rain holding cloud.
 - **Fog** is actually a cloud that forms near the ground and it can form in a few different manners:
 - Commonly on clear nights, when there are no clouds to reflect the radiated energy from the Earth back to the surface, the surface air cools and water condenses.
 - When warm air passes over snow-covered ground.
 - When moist sea air drifts over a cold current or seashore.
 - At the beginning stages of orographic cloud formation.

Motion of the Earth

EARTH'S SPIN AND PREVAILING WINDS

- **Earth's Spin:** eastward on its axis once every 24 hours
 - Causes winds to twist toward the right in the northern hemisphere and toward the left in the southern hemisphere creating the **Coriolis Effect**
 - Earth's rotation causes anything that moves long distances to appear to change direction
 - Least noticeable at the equator and most noticeable near the poles
- **Prevailing Wind Patterns**
 - Winds are one of the most important contributors to weather.
 - Local/regional (small areas) or major (large areas) wind patterns.
 - Winds over large areas are called **Prevailing Winds**.
 - Affect weather around the world.
 - Causes: Convection currents, Earth's Eastward rotation

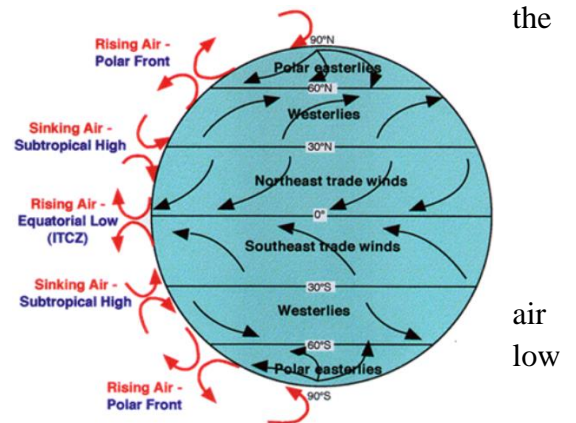


Northeast Trade Winds

- Solar energy strikes most directly at the equator heating air, land & water
- Warmed air forms a convection current (equatorial convection current)
- Warm air rises, expands, leaving behind an area of lower pressure
- The rising air moves Northward
- Around 30° latitude, cools, dense, sinks creating high pressure area
- Air at the surface moves away from the area of high pressure toward the low-pressure area at the equator (the moving surface air twist to the right as it moves South)

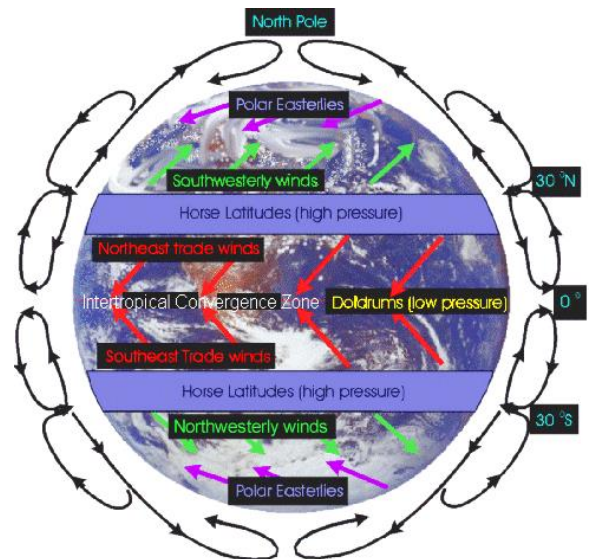
• Mid-latitude Westerlies

- At 30° latitude some of the descending air from equatorial convection current is deflected northward (away from the high-pressure area)
- Toward a low pressure area around 60° latitude
- This low pressure area is formed by another convection current (mid-latitude convection current)
- As it begins to rise its warm air meets polar cold
- The surface air moving north toward the area of pressure becomes part of this convection current
- The air twist to the right as it flows northward



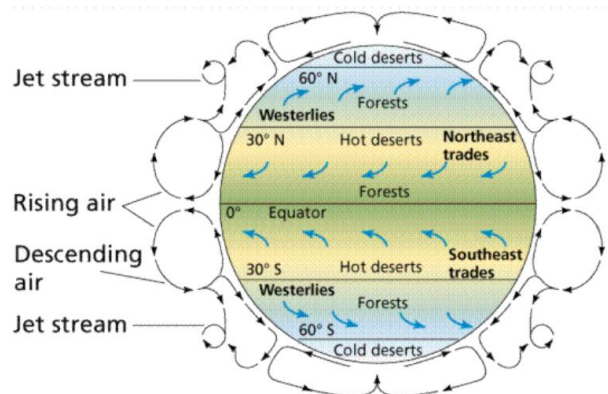
• Polar Easterlies

- Air is cold and dense, travels Northward
- Sinks, creating a high-pressure area at the surface
- The surface air moves southward away from this high-pressure area
- Causing the Polar Easterlies
- When polar air reaches a latitude of about 60°
- Meets the rising warmer air from the mid-latitude convection currents
- As rising air cools it drops again to complete the convection
- Currents with some air moving toward the equator and the rest toward the North Pole



• High altitude Eastward-flowing wind: Jet stream

- **Equator:** 7000 m, warm air rises high
- **At 30°:** 5000 m, pressure here is lower
- Air moves from high pressure to low pressure
- Air from the equator moves northward, twisting to the right
- 60° North latitude where at 7000 m the pressure is even lower than at 30°
- Air moves from higher pressure to lower pressure



• Effects of Prevailing Winds

- Help distribute large amounts of solar energy from the equator to the colder parts of the world
- Return flow of colder air southward.
- Carry moisture causing a variety of precipitation.

- **Rising air** is warm and moist, **falling air** is cool and dry.
- **Near the equator:** Two sets of convection currents meet: Cloudy and rainy weather
- **30° North latitude:** The cool falling air is dry (desert-like conditions) ex. Gobi Desert, Sahara, Great Basin, Sonoran
- **60° North latitude:**
 - air systems meet and rise
 - Creates unsettled conditions of cloud and precipitation (wind storms are stronger in winter because the Arctic region receives no sunlight so it gets cold rapidly)
 - Produces larger temperature difference between polar and equator (*larger differences in pressures...stronger winds*)

MAJOR OCEAN CURRENTS

- **Oceans are very important in Weather dynamics**
 - *Mainly oceans at the equator*
 - Energy from the sun is circulated using **Ocean currents!**
 - **Conveyor belt** → Transports energy from warmer areas to colder areas
 - **Causes of ocean currents:** convection currents, winds, Earth's rotation, the shape of the continents, heat capacity of water, salt quantity in oceans
- **Convection currents:** Warm water tends to travel from the equator toward the Poles. Cold water tends to travel in the opposite direction.
 - As warm (less dense) water moves away from the equator, it is replaced by cooler, denser water. It is also influenced by prevailing winds and the Coriolis Effect (currents).
 - Currents on East sides of continents tend to be slow moving. Currents on West sides of continents tend to be fast moving.
- **Oceans:** Heat sink, High heat capacity
 - As Gulf Stream flows northward, water evaporates, leaving saltier water. Saltier water is denser and sinks (creating deep water currents). It is replaced by warm, less dense water.
- **Effects of ocean currents:**
 - Gulf Stream warms Norway and Iceland
 - Ocean current that reaches Peru in western South America is cold (air above is dry) - deserts
 - Along Western side of Pacific Ocean, warm waters evaporate, form clouds, produce large quantities of precipitation
 - Ocean currents are responsible for coastal regions being cooler in the summer and warmer in the winter.
 - Large bodies of water moderate the climate.
 - The high heat capacity of the oceans causes seasonal changes to lag behind.
 - Air above warm ocean currents becomes warmer and less dense forming low-pressure systems

