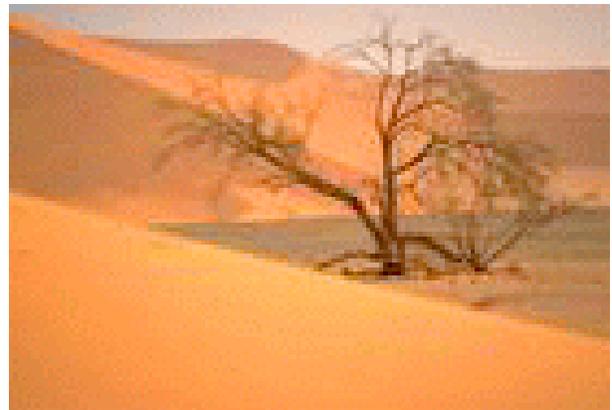


# WEATHER



# Weather

**Weather** is the set of environmental conditions encountered from day to day in a particular location.

**Climate** is the set of environmental conditions averaged over many years for a geographic location.

Weather is due to atmospheric and ocean circulation. The oceans and the air over the oceans are not static but are in constant motion. First we will look at atmospheric circulation and its causes.

## ATMOSPHERIC CIRCULATION

Atmospheric circulation accounts for two-thirds of the heat transferred from tropical to polar regions. Atmospheric circulation is caused by two major factors.

### **C**uneven solar heating due to latitude

more heat is absorbed at the Earth's equator than at the poles due to the following

a) nearer the poles sunlight strikes Earth's surface at a smaller angle of incidence,

thus the energy is spread over a larger area (ex. shine a flashlight on a wall and

change the angle of incidence, the area of the wall lighted increases but the

intensity per unit area decreases-less energy per unit area).

b) sunlight striking the poles must pass through a thicker layer of atmosphere, thus

less energy reaches Earth's surface.

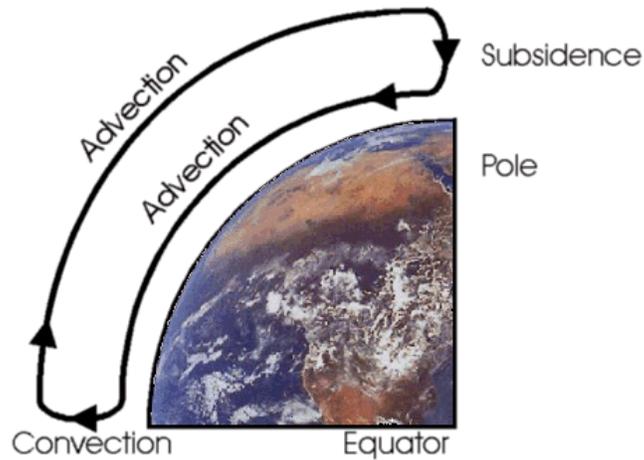
c) high reflectivity of ice and snow at the poles means less energy is absorbed by

Earth.

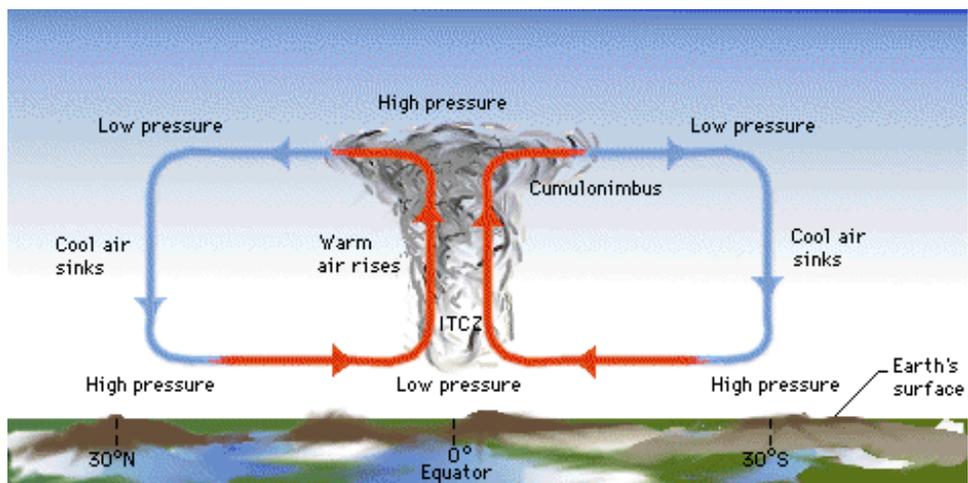
### **C**uneven solar heating due to the seasons

The Earth is tilted relative to the Sun creating seasons which adds to the uneven heating of the Earth.

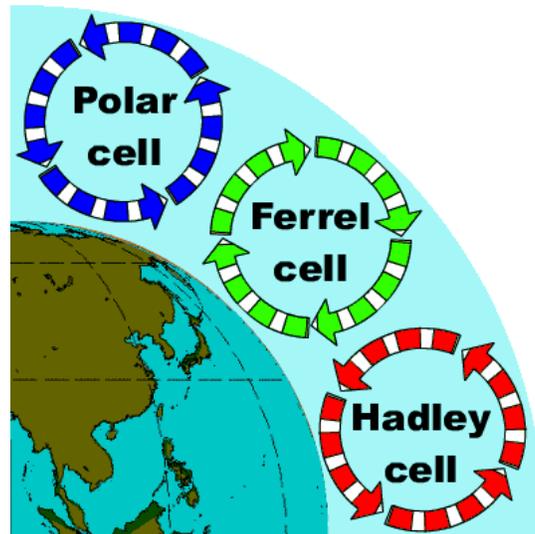
This uneven heating of the Earth sets up convection currents in the atmosphere.



These convection currents are called atmospheric circulation cells. From the equator to each pole three atmospheric circulation cells are set up. The first circulation cell extends from the equator to approximately 30° latitude and is called a **Hadley cell** (named after George Hadley who postulated this air circulation in 1735).



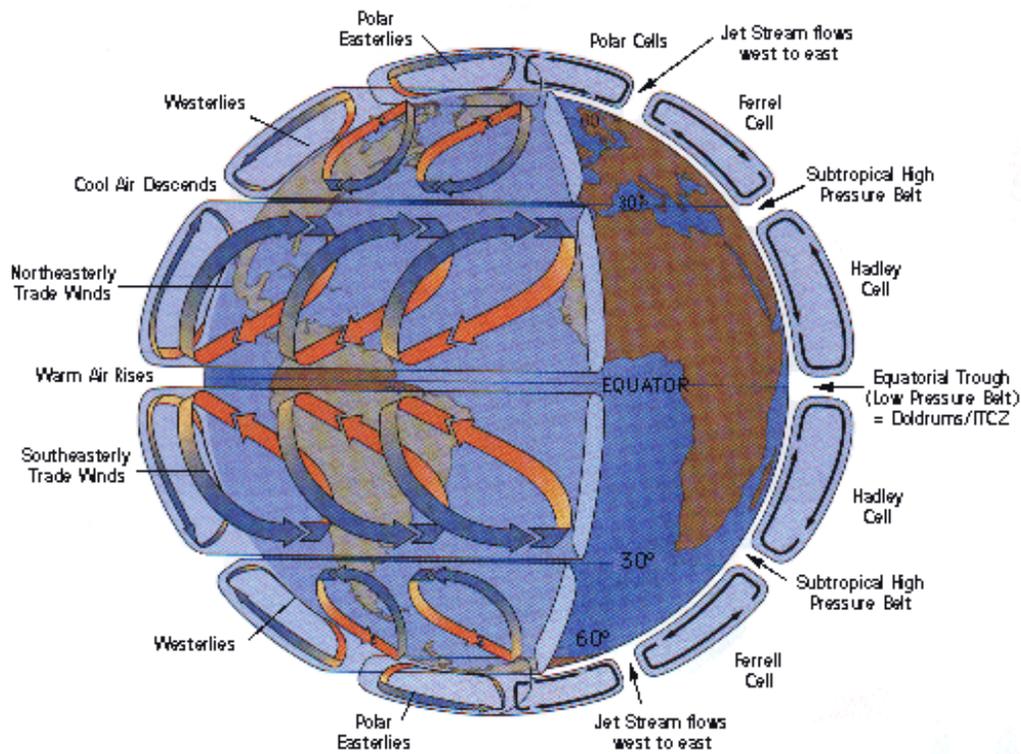
The second circulation cell extends from 30° latitude to 60° latitude and is called a Ferrel cell (William Ferrel discovered its existence in the mid-nineteenth century). The third circulation cell extends from 60° latitude to the pole and is called a **Polar cell** (see the diagram, Nelson Science 10 page 517).



Near the equator air, warmed by solar radiation, rises and moves away from the equator to the poles creating an area of **low pressure** at the equator. Cooler air from the mid latitudes moves in to replace the rising air, thus convection currents are set up. When this warmer air has travelled about one third of the way to the pole it has lost enough moisture (in the form of precipitation) and heat to the upper layers of the atmosphere that it begins to descend to the surface and flow across the Earth's surface back to the Equator creating an area of **high pressure** at 30° latitude. Some of the Hadley cell descending air is joined by descending air from the Ferrel cell and at the surface moves towards the pole where it is heated and rises at 60° latitude forming an area of **low pressure** at this latitude. This second circulation cell is the (**Ferrel cell**). This process is repeated from 60° latitude to the pole forming the third cell called the **Polar cell**. At the poles air

is descending creating an area of **high pressure**.

These cells would be aligned in a north south direction but for one more effect, the **Coriolis Effect**. This effect does not create air movement, but merely influences the direction of the air movement. The rotation of the Earth to the East causes a deflection of these wind cells. The amount that the cells are deflected varies according to latitude due to the fact that although the Earth rotates at a constant rate of  $15^\circ$  per hour no matter where you are on Earth, the speed with which the Earth rotates varies (due to changing circumference) according to location on Earth. The net result is that the cell rotation is not merely deflected from a north-south direction but is also twisted in a curved path.



In the figure on page 517 in Nelson Science 10, the arrows denoting wind direction are slightly twisted. These twisted arrows are only part of the circulation cells. These arrows are actually closed circulation loops of rising and falling air that twist away from a north-south direction. Where the Hadley and Ferrel cells (and the Ferrel and Polar cells) meet high level air is coming together and twisting to the right( due to the Coriolis Effect) creating high level eastward-flowing winds called **jet streams** (see the orange eastward arrows on the diagram on page 517 Nelson Science 10). These **jet streams** also affect weather as the seasons change. The uneven heating of the Earth(creating convection circulation cells) and the Coriolis Effect caused by the rotating of the Earth(creating a twisting of the circulation cells and the jet stream) sets up wind patterns on the surface of the Earth called **prevailing wind patterns**.

#### **EFFECTS OF PREVAILING WINDS ON THE WEATHER**

Rising air at the equator creates an area of **low pressure**. As the air rises, it cools creating clouds and rain. Around the Earth at the equator weather tends to be cloudy and rainy. At approximately 30° latitude around the Earth, the cooler, dryer air begins to fall creating an area of **high pressure** resulting in desert-like conditions. At 60° latitude, warmer air begins to rise creating an area of **low pressure** with cloudy, rainy conditions possible. At the poles, cooler, dryer air descends creating an area of **high pressure** again with little precipitation.

#### **AIR MASSES AND CLOUD FORMATION**

An **air mass** is a large body of air with nearly uniform temperature, humidity, and density. Air masses passing over cool, dry land become cool, dry, and dense resulting in zones of **high pressure**. Another term for an area of high pressure is **anticyclone** which has a clockwise rotation (in

the Northern Hemisphere). Air masses passing over warm water become warm, humid, and less dense, forming zones of **low pressure** that rotate counterclockwise (in the Northern Hemisphere). These areas of low pressure are called cyclones. **Cyclones** are rotating low pressure air masses in which winds converge and rise.

Air masses with different densities will not mix when they approach each other. The boundary between air masses of different densities is called a **front**. When a cold air mass advances and lifts a warm air mass a **cold front** occurs. When a warm air mass is blown on top of a retreating cold air mass a **warm front** occurs. In both cases clouds form and precipitation may fall.

**Clouds** form when warm air rises and cools resulting in water vapour in the air condensing into water droplets. When there is enough water vapour present the condensing water droplets may join into raindrops and precipitate. There are three major ways that clouds are formed.

**Convective clouds** are created when air near the Earth's surface absorbs heat energy from the warmer surface of the Earth, causing the air to gain moisture and rise forming clouds.

**Frontal clouds** are created where a front is formed between two air masses with different densities.

**Orographic clouds** form when warm air moves up a mountain.

**Fog** is a cloud that forms near the Earth's surface in a number of ways.

On clear nights the Earth's surface radiates heat which escapes to the upper atmosphere causing the air near the ground to cool, allowing fog to form.

Warm air passes over snow-covered ground

C warm, moist ocean air moves over a cooler body of water or shoreline

C moist air rises up the side of a mountain

## STORMS

Uneven flow of air within or between circulation cells causes weather events. Storms are spinning areas of unstable air occurring between (extratropical cyclones) or within (tropical cyclones) circulation cells. The development of storms can lead to three levels of communication on public broadcasting systems.

**Weather Watch** - conditions are present for extreme weather to occur.

**Weather Advisory** - severe weather is predicted to happen which may cause inconveniences.

**Weather Warning** - extreme weather is highly likely to occur in your area.

The two major classifications of storms are **extratropical cyclones** and **tropical cyclones**.

## TROPICAL CYCLONES

**Tropical cyclones** form within **one humid air mass** usually between 10° and 25° of latitude in both hemispheres (in the Hadley cells). Tropical cyclones can have different names depending where they happen.

C **hurricanes** are tropical cyclones that occur in the North Atlantic and eastern Pacific.

C **typhoons** are tropical cyclones that occur in the Northwestern Pacific or in the China Sea.

C **tropical cyclones** are tropical cyclones that occur around Australia or in the Indian Ocean.

The formation of all tropical cyclones is the same. When surface water temperatures are at least 27° C, warm humid air near the equator rises rapidly enough and high enough such that when the water vapour condenses sufficient heat energy (latent heat energy is released when water changes

from a liquid to a vapour) is released which further increases the rate at which air rises. The intensity of the storm builds rapidly like a runaway train. The central core of a tropical cyclone is called the eye of the storm. Less powerful storms are called tropical storms and tropical depressions.



## EXTRATROPICAL CYCLONES

Extratropical cyclones form at the boundary between the Polar and Ferrel cells - the polar front. These storms occur mainly in the mid-latitudes. They are called extratropical storms because they occur outside the tropics. When a cold air mass meets a warm air mass a twisting or counterclockwise cyclonic action begins. Wind speed increases much like a spinning figure skater increases rotation speed by pulling their arms close to their body. Air rushing toward the centre rises and leaves a low pressure zone at the centre. The rising, expansion, and cooling of warm, mid-latitude air causes clouds to form and precipitation to fall. One particularly violent type of storm is called a **thunderstorm**.

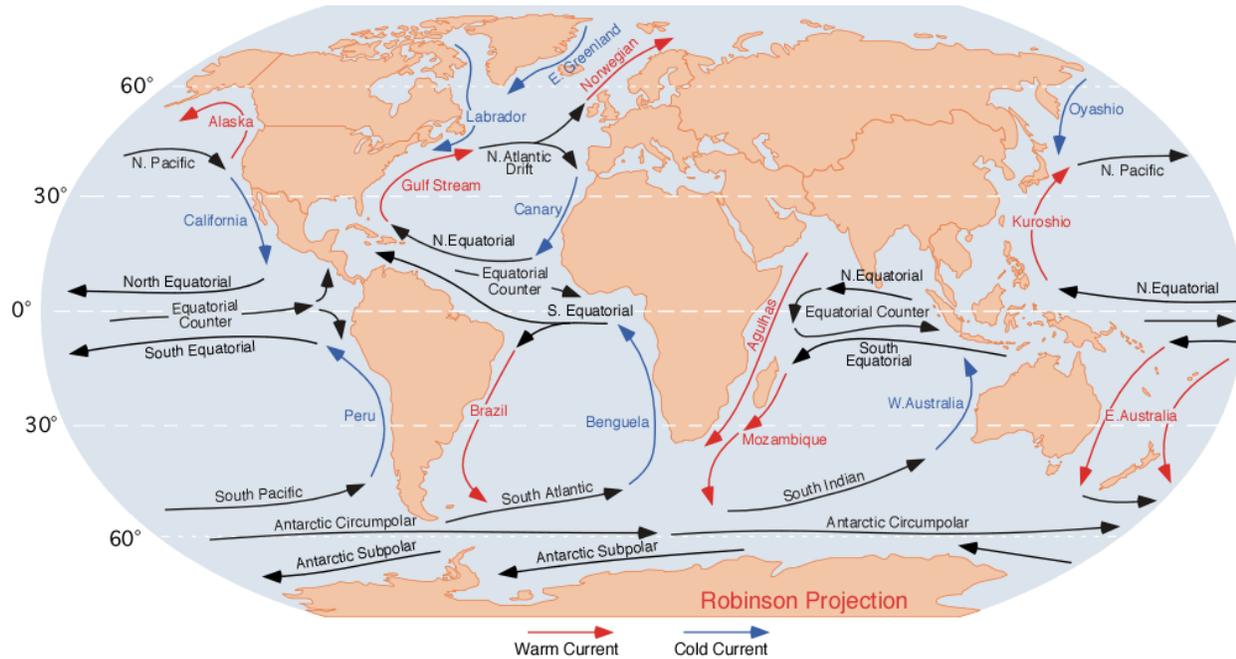
Another type of extratropical cyclone is called a **tornado**. They sometimes form in very severe thunderstorms. The strongly uplifting air begins spinning counterclockwise which forms a funnel cloud.



A third type of extratropical cyclone is a **blizzard**. Blizzards develop in Canada and the northern United States when a warm air mass from the Gulf of Mexico and/or the Atlantic Ocean meets a cold Arctic air mass under a strong jet stream. Blizzards also rotate counterclockwise.

## OCEAN SURFACE CIRCULATION

Ocean circulation, while not as important as atmospheric circulation in transferring heat energy around the Earth, accounts for much of the remaining heat transfer from the equator to the poles.



Ocean circulation has two major causes.

Cwind

Cuneven heating of oceans and gravity

Water at the equator is heated by solar energy to a greater extent than water away from the equator. This causes water to expand more at the equator resulting in the sea level at the equator being 8 cm higher than the sea level at the poles. In essence, gravity causes equatorial water to slide downhill to the poles. The shape of the continents and the Coriolis effect cause the ocean currents to assume a circular pattern that mimics the path of the winds on

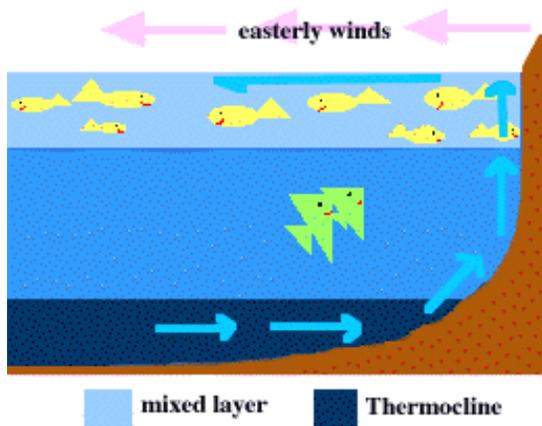
Earth (see the diagrams on page 525 & 536 in Nelson Science 10). These ocean currents have a direct affect on weather over the planet. For example, the Gulf Stream gives Great Britain a temperate maritime climate while other locations on Earth with similar latitude experience quite cold winters. In the summer, the east coast of North America is hot and humid because wind blows on shore after passing over the warm Gulf Stream. By contrast, on the west coast wind is cooled when it passes over the cool California Current (an offshoot of the North Pacific Current) causing San Francisco to have cooler damper summer months than its latitude would suggest. The oceans act as a **heat sink** due to the high **heat capacity** of water. Water heats slowly due to this high heat capacity but conversely, once heated, cools slowly. The moderate falls and late winters on the east coast of Canada are a direct result of the warm waters of the Gulf Stream giving up its heat and keeping temperatures relatively moderate late in the fall.

#### **EL NINO (LITTLE CHRIST CHILD - occurs at Christmastime, usually in a 7 year cycle)**

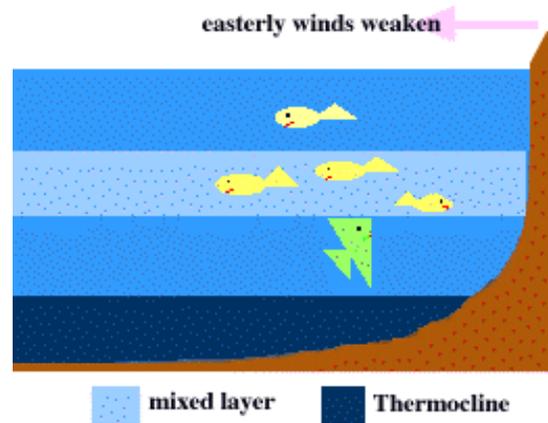
These events occur in their most severe form every 20 to 50 years, usually in December. Ocean current circulation in the Pacific Ocean( both surface and deep water) is completely reversed (See Figure 3 page 613 Nelson Science 10). Atmospheric and surface water temperatures go through cycles from low to normal to high and back again. This causes ocean currents, surface winds, and atmospheric pressures to go through cycles also. El Nino occurs when the surface temperatures of the Pacific Ocean off the coast of South America are higher than average. The resulting reversal of both the air and water currents can lead to quite dramatic changes in weather. Off the coast of South America, the normally cool rising waters that bring nutrients to the surface for fish to feed on reverses its flow. The water is much warmer than usual and the nutrients are absent resulting in the collapse of the fishing industry. In the winter, El Nino pushes the polar jet

stream farther north than normal thus preventing cold Arctic air from reaching Eastern Canada and the Eastern United States. As a result, winters are milder than average. El Nino also pushes the subtropical jet stream farther south than normal, causing higher than average levels of precipitation in the southern regions of North America. The likelihood of hurricanes is also reduced.

During Non-El Nino

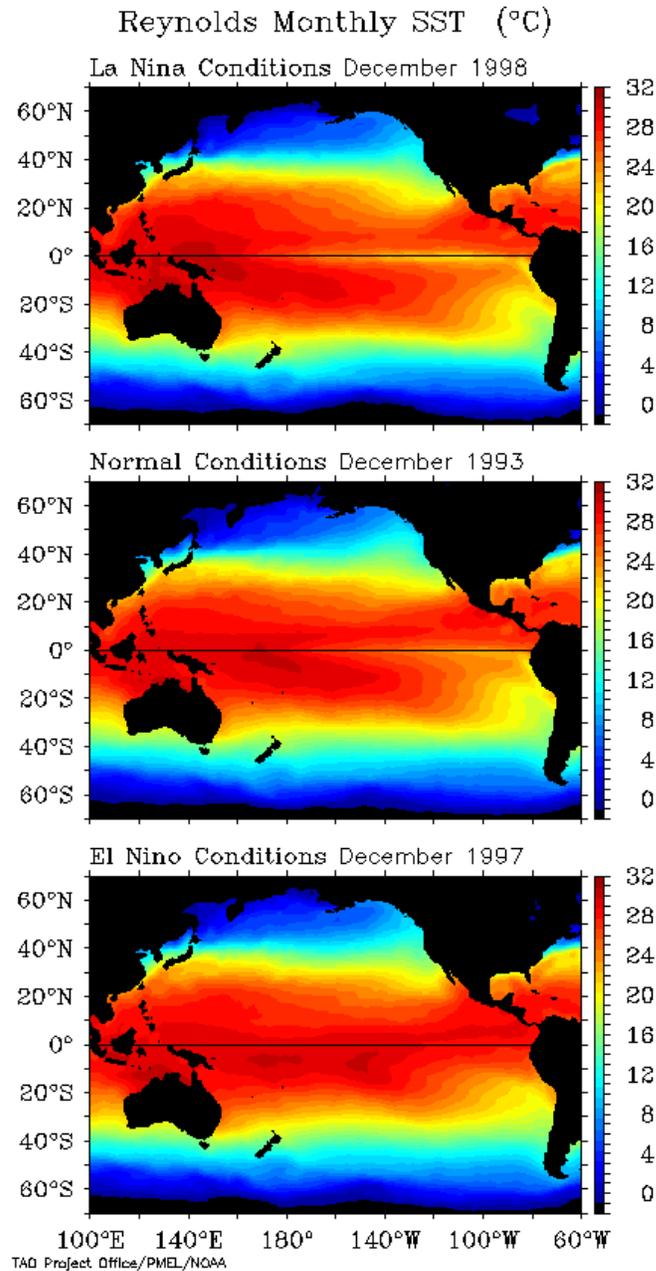


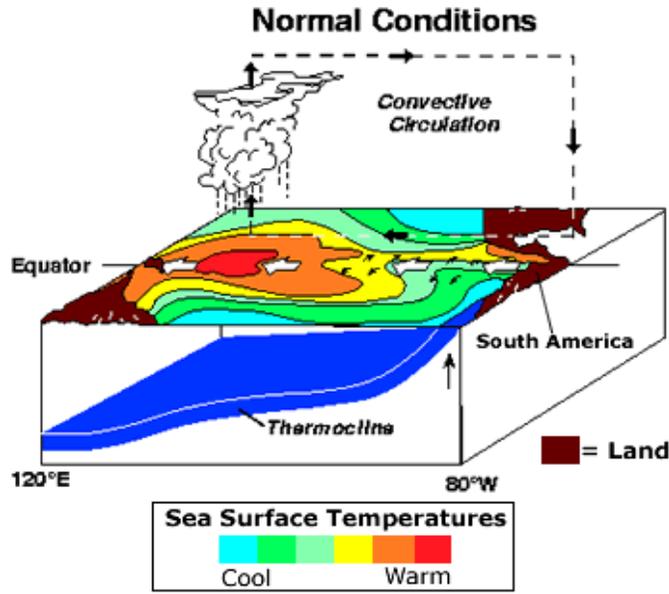
During El Nino



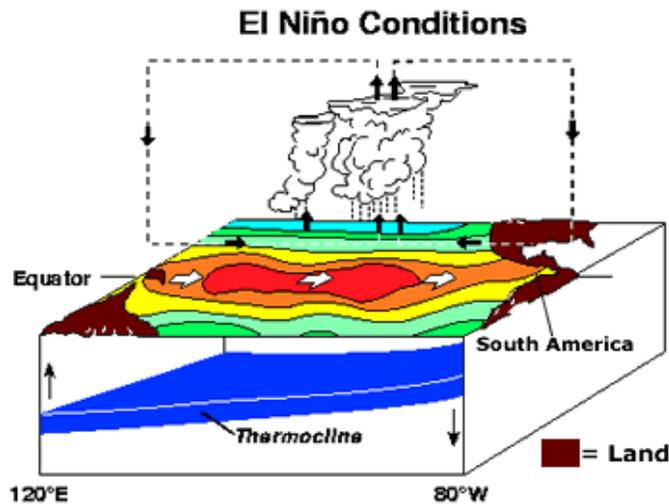
## LA NINA (LITTLE GIRL)

La Nina is a shift to colder than average ocean temperatures in the Eastern Pacific Ocean. Indonesia and northern Australia receive higher than normal precipitation. The subtropical jet stream above North America shifts northward allowing for hurricanes to develop more easily.

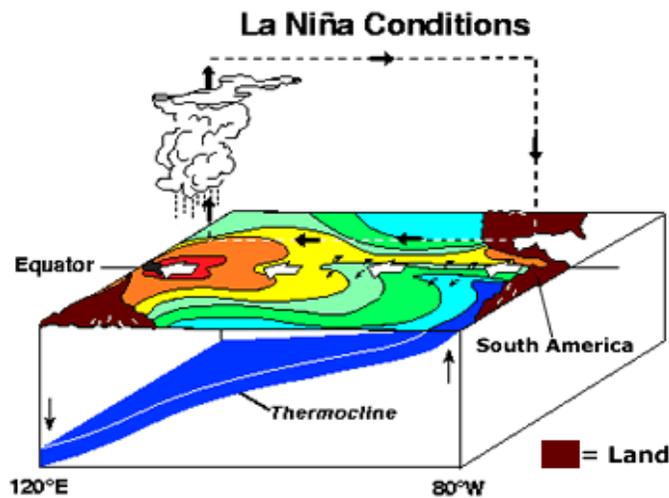




**Normal Conditions**  
 Under normal conditions, deep warm water in the western Pacific produces a low pressure region with heavy storm activity, while the eastern Pacific is a dry, high pressure area with shallow warm water. Surface winds blow from east to west, while upper winds blow from west to east. The thermocline is deeper, and sea level higher, in the western Pacific than in the east.



**El Niño Conditions**  
 During El Niño, warm surface water appears farther east and is spread over a broader area. Weak Highs form east and west of the Low, and surface and upper level winds are both weaker than normal. The thermocline is deeper and flatter overall, making average sea level of the eastern Pacific higher than normal.



**La Niña Conditions**  
 La Niña episodes are characterized by the westward shift of warm water. This produces stronger Highs and Lows, with stronger than normal surface and upper level winds. Warm water is abnormally deep in the western Pacific and abnormally shallow in the eastern Pacific. The slope of the thermocline becomes steeper, and sea level is higher than normal in the west and lower than normal in the east.

## Website

[http://www.classzone.com/books/earth\\_science/terc/navigation/home.cfm](http://www.classzone.com/books/earth_science/terc/navigation/home.cfm)

### Sustainability

#### Investigations

Unit2 - Paper or Plastic

Unit 5 - Global Climate Change Affect Life on Earth

Ch 14 - How does groundwater move through ground?

#### Visualizations

Ch 1 - Evidence of the carbon Cycle

### Chemistry

#### Investigations

Ch 5 - Building models of atoms

#### Visualizations

Ch 5 - 3-D models of molecules

Ch 22 - 3-D model of water

### Weather(atmospheric circulation)

#### Visualizations

Ch 4 - Earth's Yearly Revolution (uneven heating due to Earth's tilt)

Ch 19 - Coriolis Effect over Earth's Surface

Ch 20 - Warm and cold fronts

#### Investigations

Ch 20 - Low develops into a storm system

#### Visualizations

Ch 20 - Thunderstorms

Ch 20 - Hurricanes

Ch 20 - Tornadoes

### Weather(ocean circulation)

#### Visualizations

Ch1 - Earth from a New perspective

Ch 24 - Global Surface Currents

## **Investigations**

Unit 6 - Can we blame El Nino for wild weather?

## **Oceanography**

### **Investigations**

Ch 8 - Breakup of Pangaea

Ch 10 - P & S wave movement

Ch 18 - Which way does the wind blow?