Structure of the Atmosphere & General Air Circulation

Marine Meteorological Course for Royal Oman Navy

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Content

- 1- Structure of the Atmosphere

- Vertical Profile
- Layers of Atmosphere
- Comparison between Stable and unstable weather
  (by using A radiosonde from weather balloon)

- 2- Composition of Air

- Gases and Percentages
- Origin of each element and circulation

- 3- General Air Circulation

- LOW - HIGH - Coriolis Force
- 3- cells Pattern
- Tropics
- ITCZ

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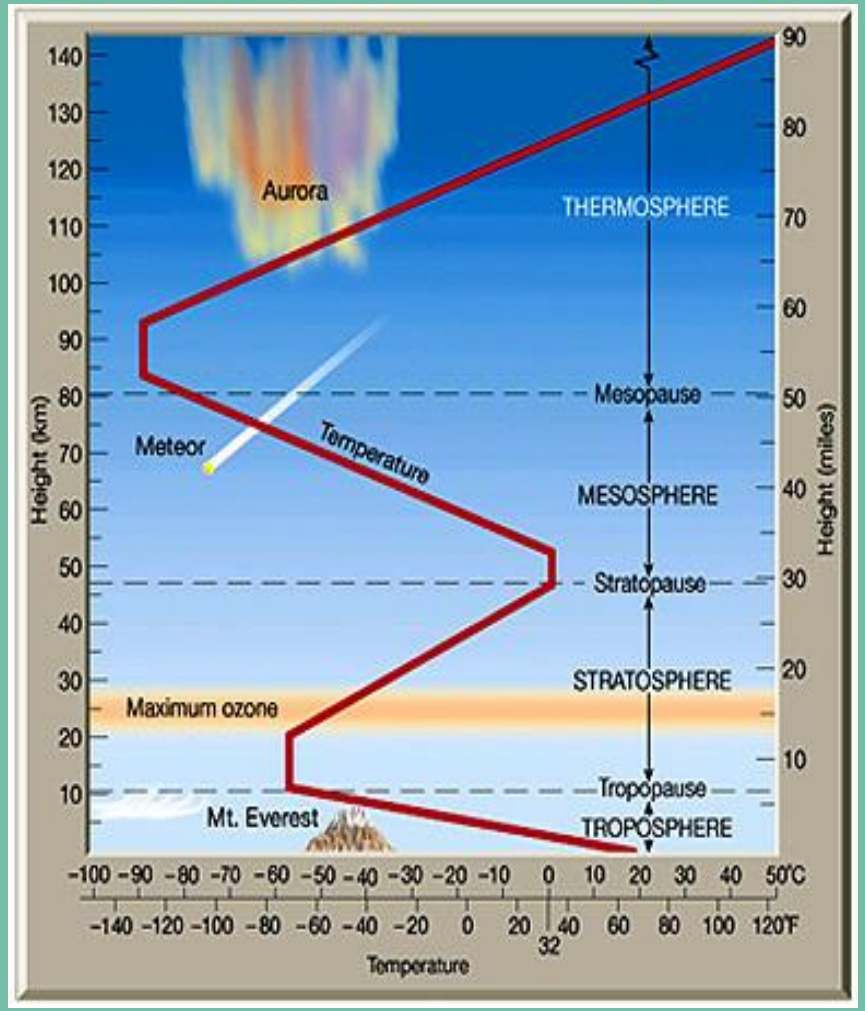
The Vertical Structure of the Atmosphere:

- Complex variation of temperature with height.
- There are five layers in the structure of the atmosphere depending upon temperature. These layers are:

(Troposphere, Stratosphere, Mesosphere, Thermosphere, and Exosphere)

- Earth's radius ~ 6400km
- Atmospheric thickness ~ 100km
- Most of the "weather action" that affects surface occurs below ~ 12km
- On average in Earth's atmosphere, the air pressure approximately drops in half for every 5.5 km increase in altitude.



Troposphere:

- It is considered as the lowest layer of Earth's atmosphere.
- Surface to roughly 10 km (~250 hpa to 1000 hPa)
- ~3/4 of mass of atmosphere in this layer
- Most weather occurs in this layer
- This layer has water vapor and mature particles.
- Temperature generally decreases with height in this layer (by ~6.5C per km, 3.6 F per 1000 ft)
- The top of troposphere is called the tropopause.
- Midlatitude jet stream tends to be strongest near the tropopause.
- Above the tropopause is the stratosphere.

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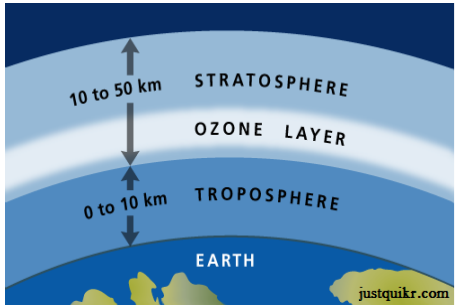
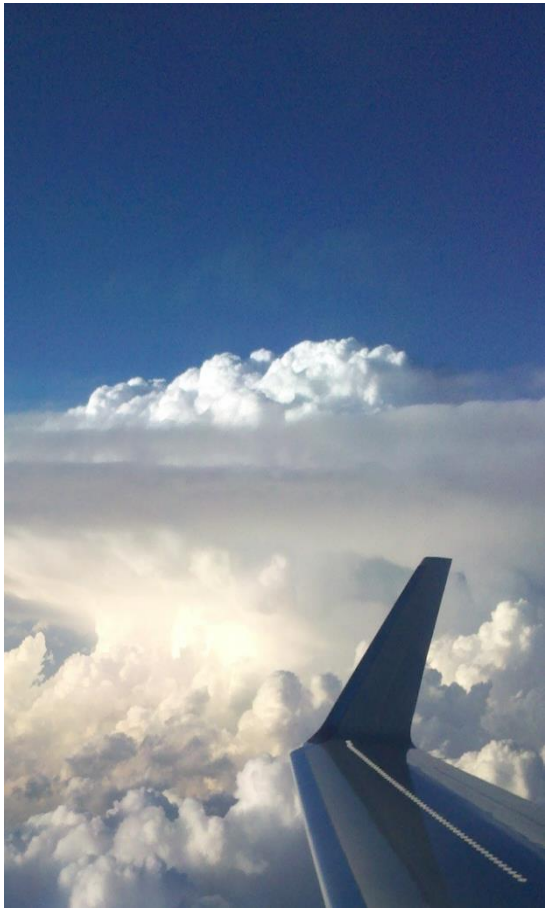
Stratosphere:

- 10-50 km above the surface
- Temperature constant or INCREASING with height
- Stable (not a lot of vertical mixing) and dry
- Only occasionally get overshooting tops from convection pushing into this layer
- The ozone layer within the stratosphere absorbs (UV) radiation, and reradiates it in the infrared (heat).

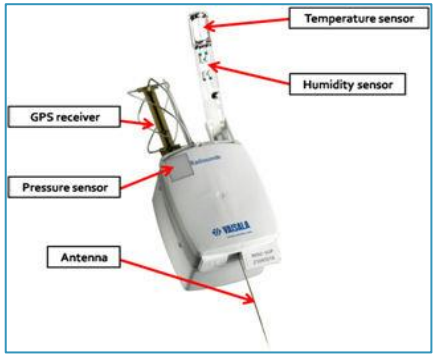
➢ Objects Flying in this Layer:
- Weather Balloons

➢ Features:
- Ozone Layer



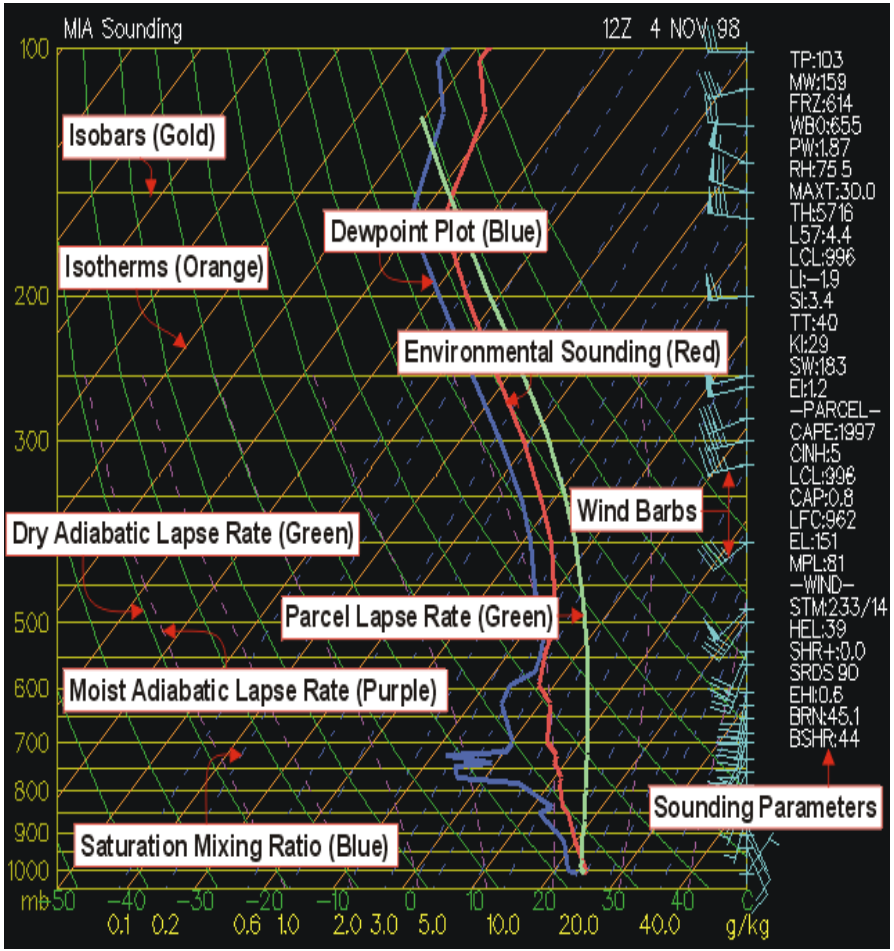


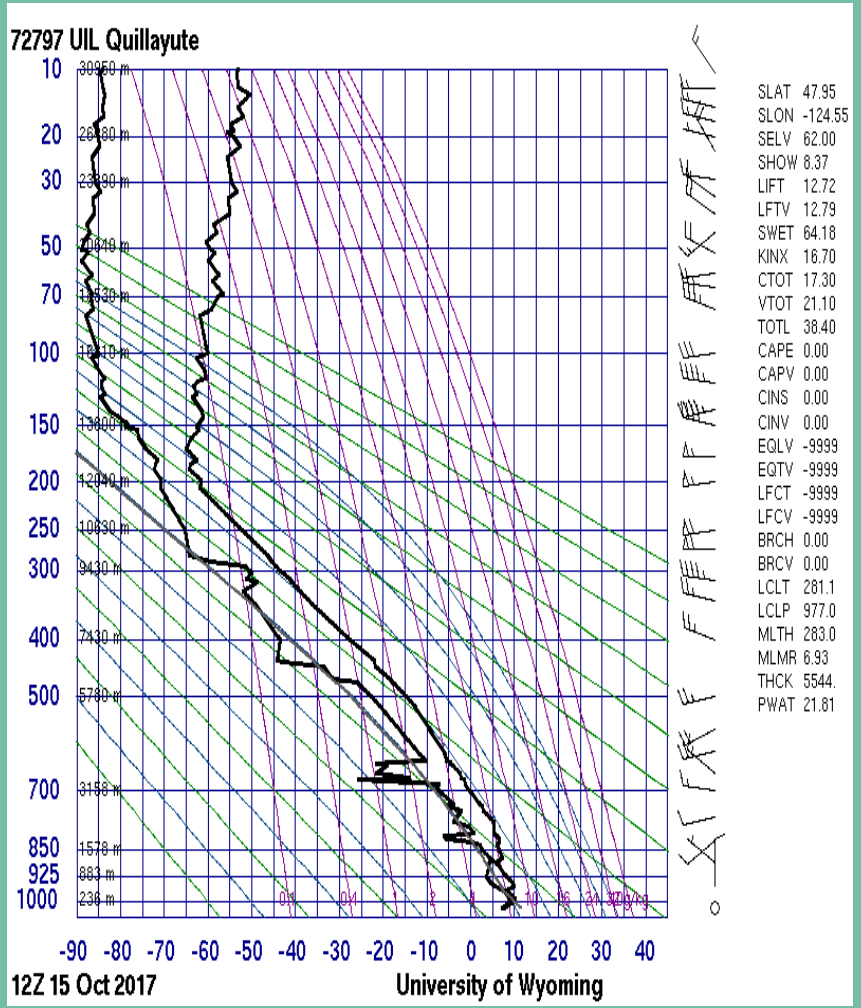
Weather Balloon:



This Video is taken by: Aysha Al.Q

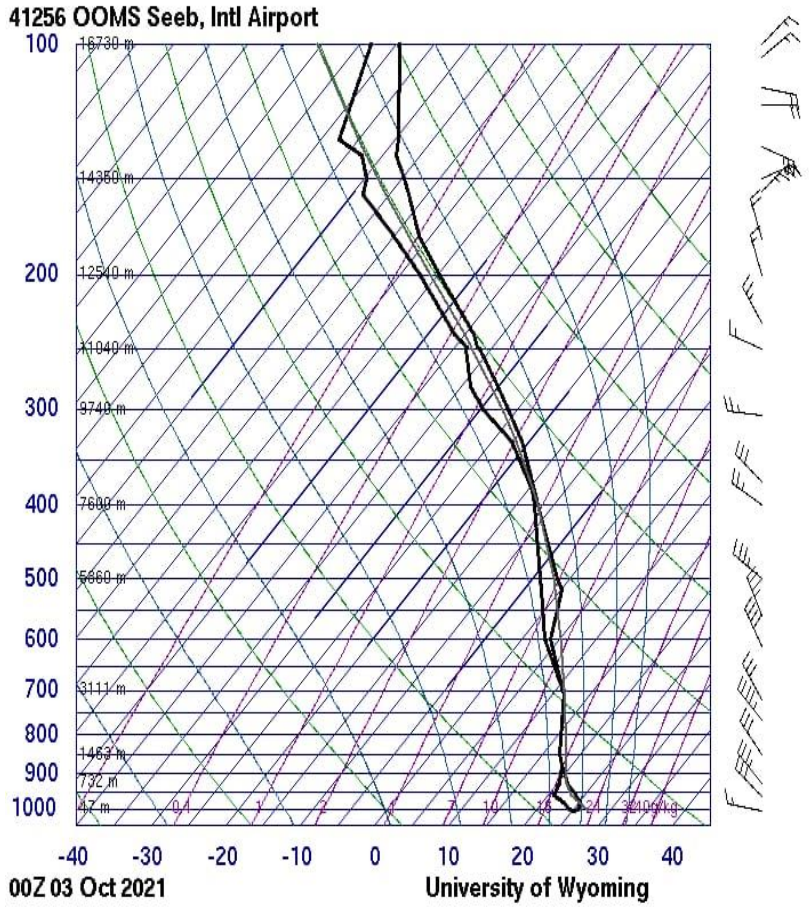
Skew-T Parameters

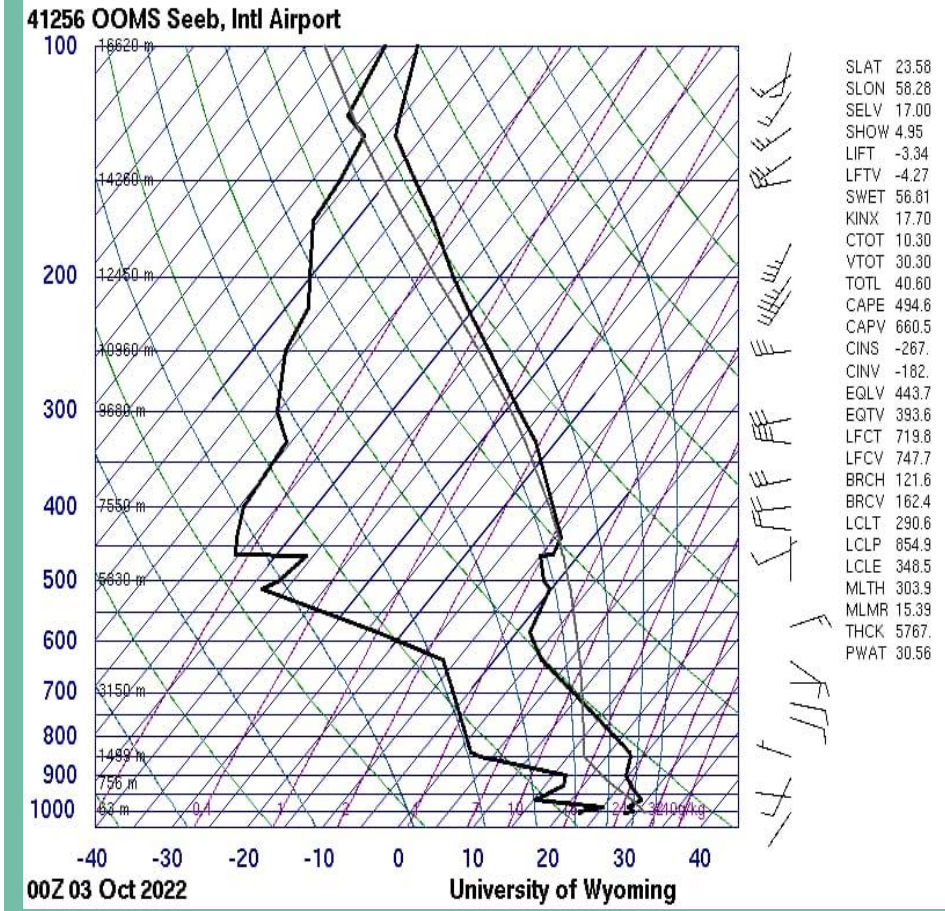




Comparison between Stable and unstable weather condition

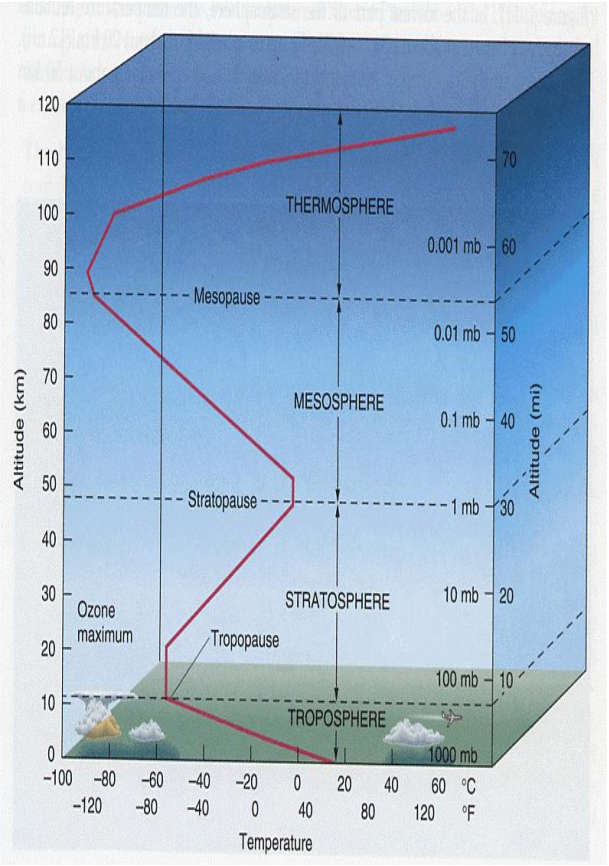
(A radiosonde example for same day / different two years)





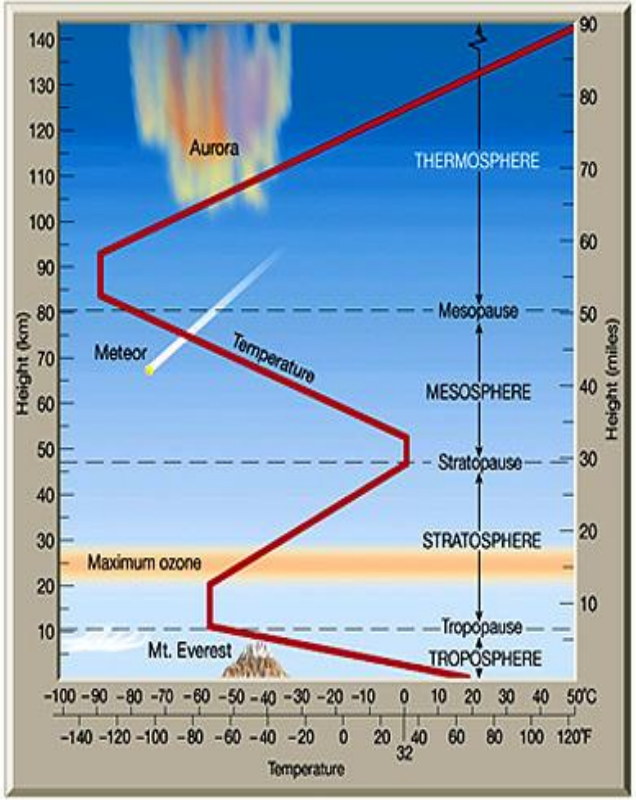
Mesosphere:

- **Mesosphere (“in-between” sphere) (50-80 km)**
- **Air molecules are able to lose more energy than they absorb.**
- **heavy metals such as iron, potassium, silicon and other refractory materials**
- **This cooling effect is particularly large near the top of the mesosphere.**
- **Most meteors from space burn up in this layer.**
- **Features: Occasional meteors**



Thermosphere:

- In thermosphere, oxygen molecules absorb solar rays and warms the air.
- Because this layer has a low air density, the absorption of small amount of solar energy can cause large temperature increase.
- The air temperature in the thermosphere is affected greatly by solar activity.
- Temperature increases with altitude above 90 km, and is constant above 200 km.
- The highest temperatures in the atmosphere can be found in the thermosphere, 2000 K can occur.
- Objects Orbiting in the Layer: Space Shuttle & International Space Station



Composition of Air:

- The atmosphere is a mixture of:
  - – gases
  - – microscopic solid particles
  - – water droplets

- Atmospheric Gases can be divided into 2 classes:
  - Permanent – Gases that form a constant proportion of the atmospheric mass.
  - Variable – Gases whose distribution in the atmosphere varies in both time and space.

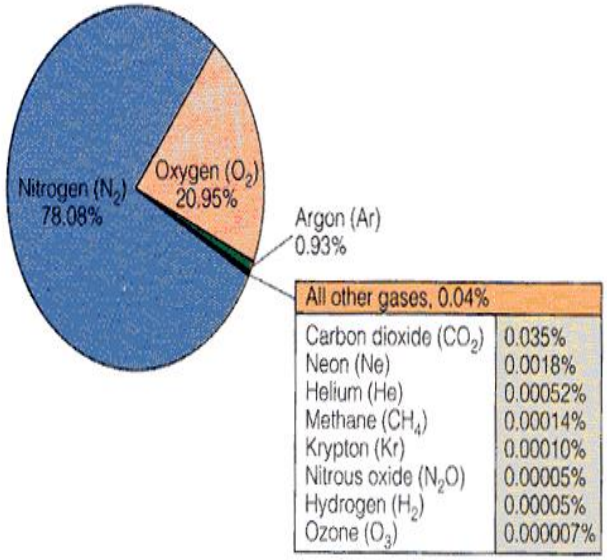


Figure 12.2 Composition of dry, aerosol-free air in volume percent. Three gases—nitrogen, oxygen, and argon—make up 99.96 percent of the air.

Permanent Gases

Constituent	Formula	Percent by Volume	Molecular Weight
Nitrogen	N_2	78.08	28.01
Oxygen	O_2	20.95	32.00
Argon	Ar	0.93	39.95
Neon	Ne	0.002	20.18
Helium	He	0.0005	4.00
Krypton	Kr	0.0001	83.8
Xenon	Xe	0.00009	131.3
Hydrogen	H_2	0.00005	2.02

Variable Gases

Constituent	Formula	Percent by Volume	Molecular Weight
Water Vapor	H_2O	0.25	18.01
Carbon Dioxide	CO_2	0.036	44.01
Ozone	O_3	0.01	48.00

General Air Circulation

Coriolis Force

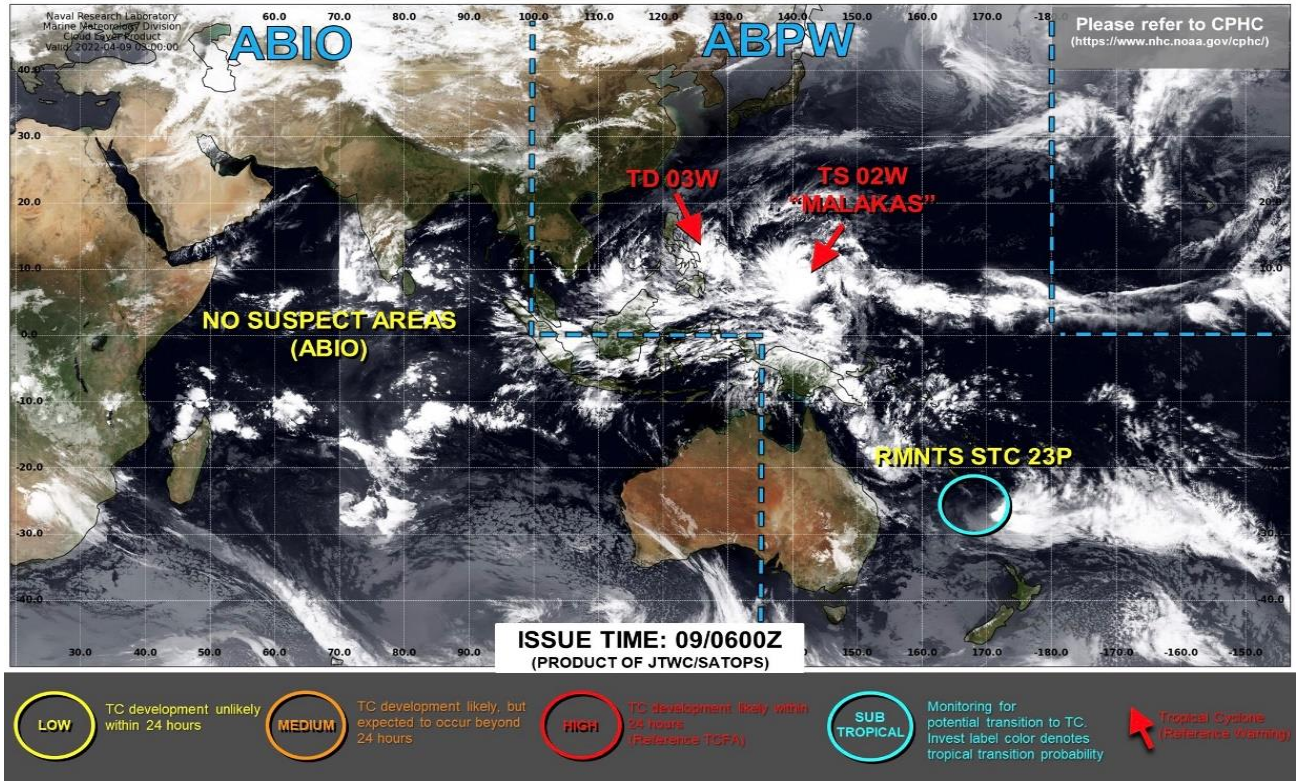
- Once air has been set in motion by the pressure gradient force, it undergoes an apparent deflection from its path, as seen by an observer on the earth. This apparent deflection is called the "Coriolis force" and is a result of the earth's rotation.

- As air moves from high to low pressure in the northern hemisphere, it is deflected to the right by the Coriolis force. In the southern hemisphere, air moving from high to low pressure is deflected to the left by the Coriolis force.

- The amount of deflection the air makes is directly related to both the speed at which the air is moving and its latitude. Therefore, slowly blowing winds will be deflected only a small amount, while stronger winds will be deflected more. Likewise, winds blowing closer to the poles will be deflected more than winds at the same speed closer to the equator.

Question

Why are there no cyclones at the equator ?



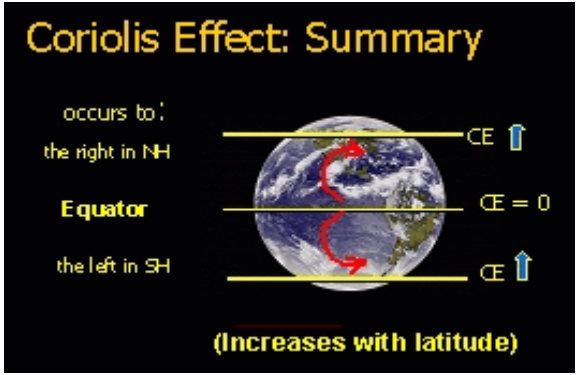
Coriolis Effect

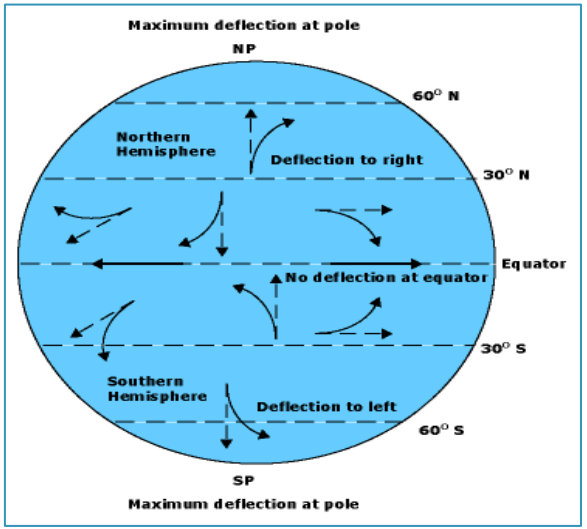
- F=2VΩsin A
- Where V is velocity, Ω is angular velocity and sinA is latitude.

- At equator, sinA=sin0°=0

- That's why at equator F=0

- Because there is no turning of the surface of the Earth (sense of rotation) underneath a horizontally and freely moving object at the equator, there is no curving of the object's path as measured relative to Earth's surface. The object's path is straight, that is, there is no Coriolis effect.

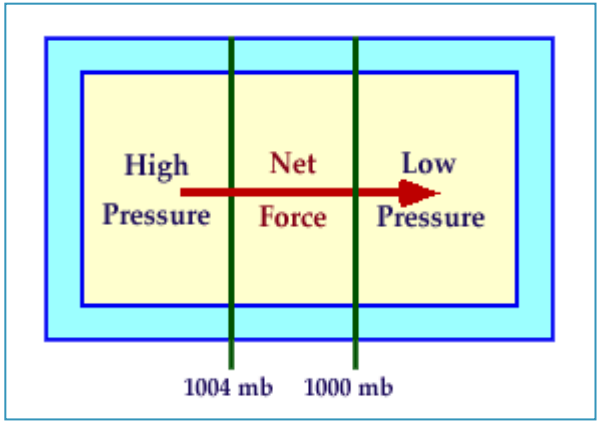


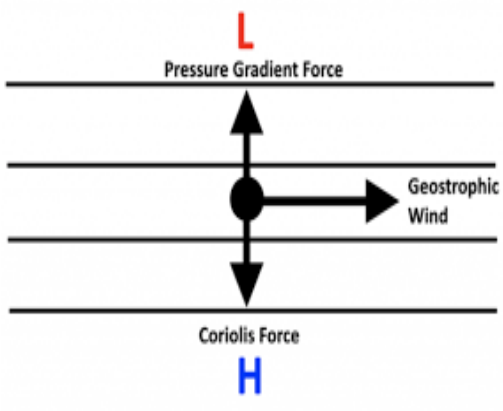


Coriolis Effect

Pressure Gradient Force PGF

- Directed from high to low pressure
- The change in pressure measured across a given distance is called a "pressure gradient".





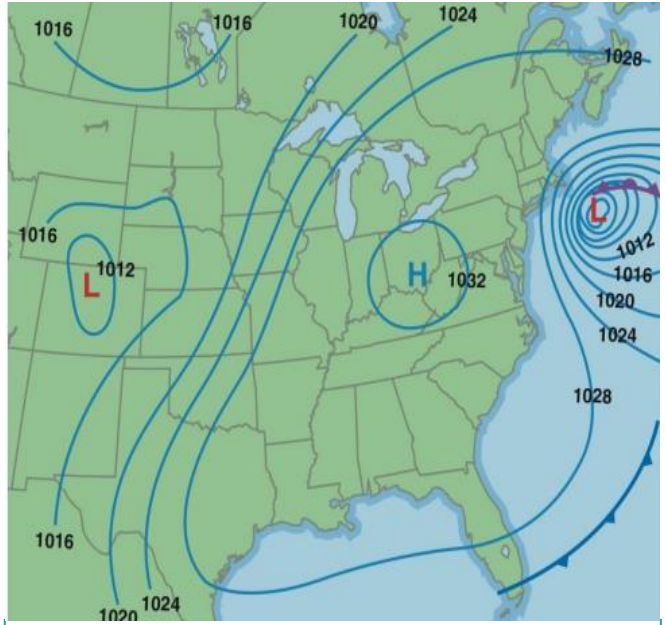
The pressure gradient results in a net force that is directed from high to low pressure and this force is called the "pressure gradient force".

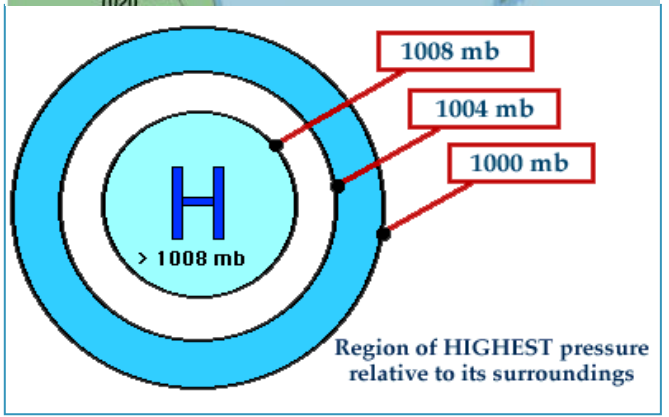
High Pressure anticyclone

- A high pressure center is where the pressure has been measured to be the highest relative to its surroundings. That means, moving in any direction away from the "High" will result in a decrease in pressure. A high pressure center also represents the center of an anticyclone and is indicated on a weather map by a blue "H".

- Winds flow clockwise around a high pressure center in the northern hemisphere, while in the southern hemisphere, winds flow counterclockwise around a high.

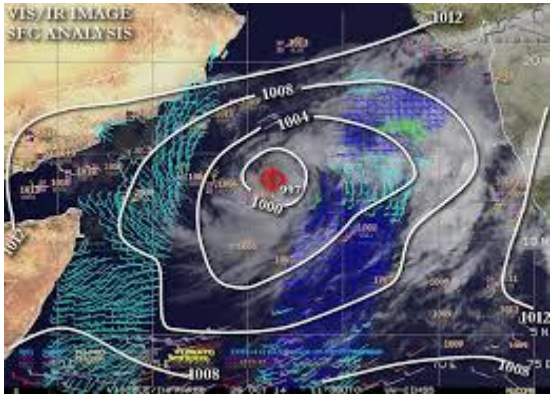
- Sinking air in the vicinity of a high pressure center suppresses the upward motions needed to support the development of clouds and precipitation. This is why fair weather is commonly associated with an area of high pressure.



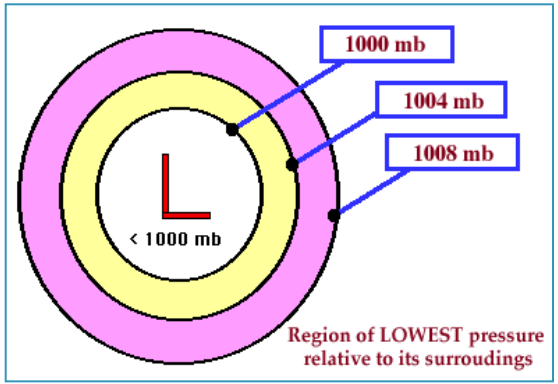


Low Pressure cyclones

- A low pressure center is where the pressure has been measured to be the lowest relative to its surroundings. That means, moving in any horizontal direction away from the "Low" will result in an increase in pressure. Low pressure centers also represent the centers of cyclones



- A low pressure center is indicated on a weather map by a red "L" and winds flow counterclockwise around a low in the northern hemisphere. The opposite is true in the southern hemisphere, where winds flow clockwise around an area of low pressure.
- Rising motion in the vicinity of a low pressure center favors the development of clouds and precipitation, which is why cloudy weather (and likely precipitation) are commonly associated with an area of low pressure.

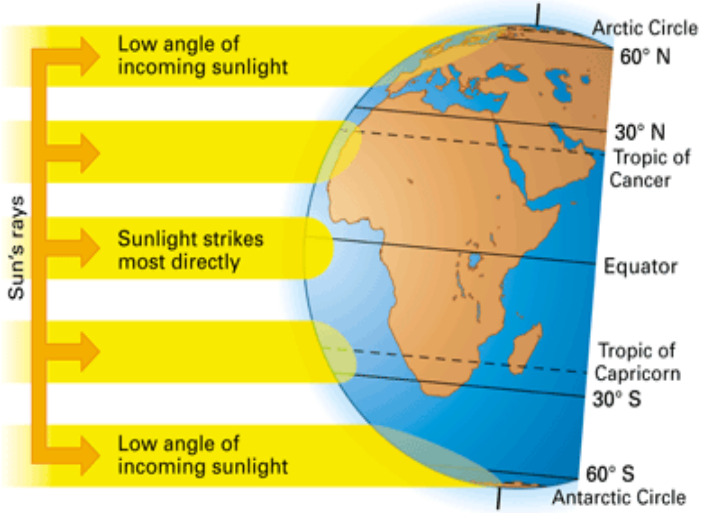


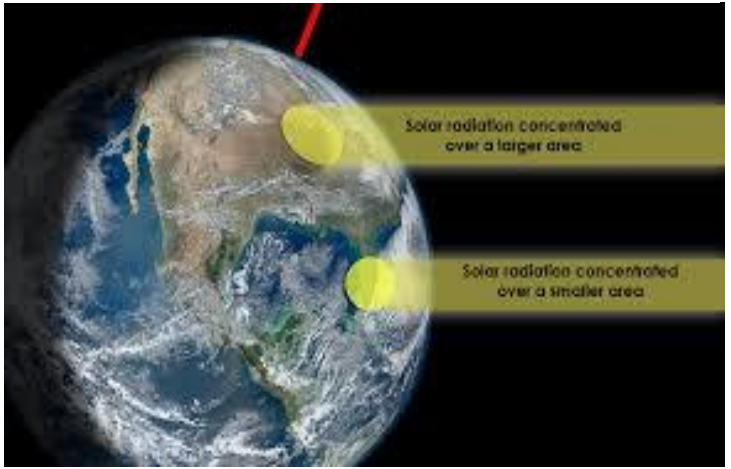
Global Air Circulation

- Energy from the Sun heats the entire Earth, but this heat is unevenly distributed across the Earth's surface. Equatorial and tropical regions receive far more solar energy than the midlatitudes and the polar regions.

- The tropics receive more heat radiation than they emit, while the polar regions emit more heat radiation than they receive. If no heat was transferred from the tropics to the polar regions, the tropics would get hotter and hotter while the poles would get colder and colder.

- Around 60% of the heat energy is redistributed around the planet by the atmospheric circulation and around 40% is redistributed by the ocean currents.

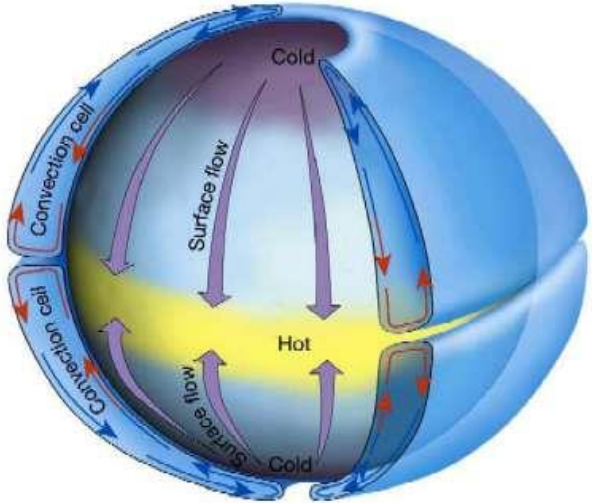


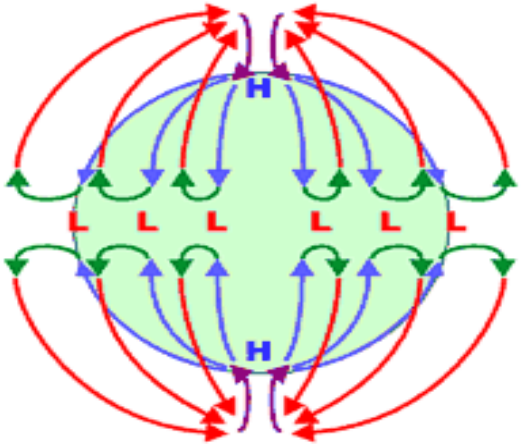


Global Air Circulation

Single-Cell Circulation

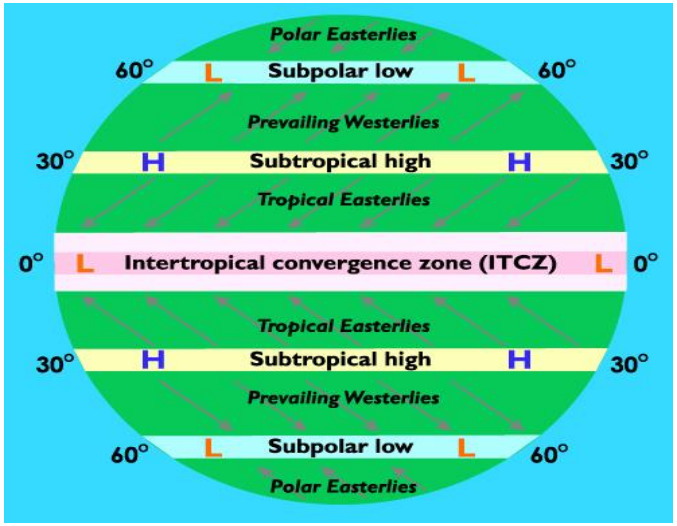
- One way to transfer heat from the equator to the poles would be to have a single circulation cell where air moved from the tropics to the poles and back. This single-cell circulation model was first proposed by Hadley in the 1700's.
- Air circulation around the globe would be simple (and the weather boring) if the Earth did not rotate and the rotation was not tilted relative to the Sun.

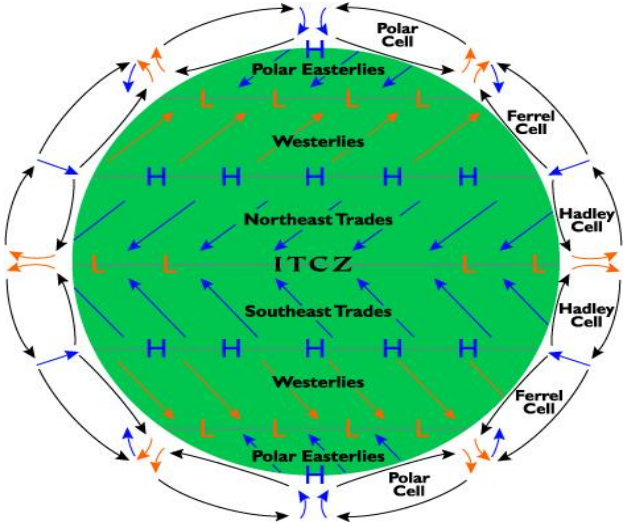




Global Air Circulation (3-Cells Pattern)

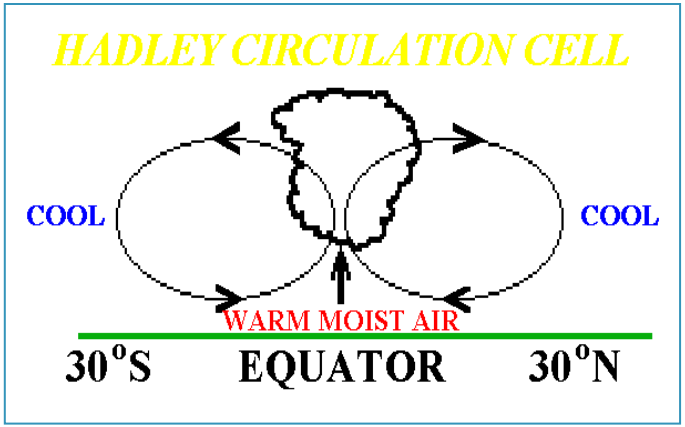
- Since the Earth rotates, its axis is tilted and there is more land in the Northern Hemisphere than in the Southern Hemisphere, the actual global air circulation pattern is much more complicated. Instead of a single-cell circulation, the global model consists of three circulation cells in each hemisphere. These three cells are known as the tropical cell (also called the Hadley cell), the midlatitude cell and the polar cell.

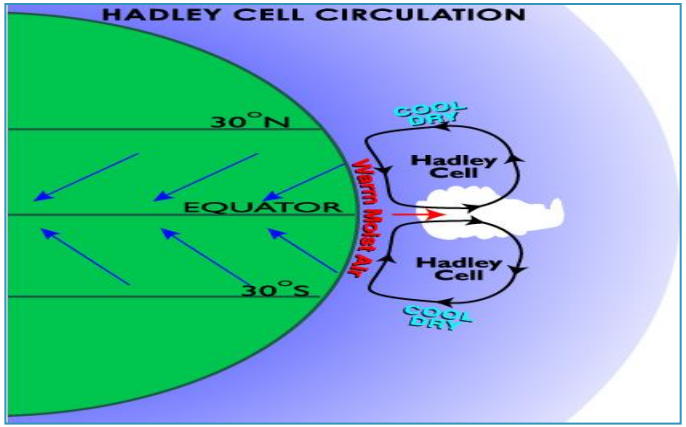




Hadley Cell

- **The Hadley cell is the strongest of the three cells of circulation and is formed as warm air rises above the Equator and starts to flow northward. The northward flow deflects to the right, due to Coriolis, becoming an upper-level westerly flow. As this air moves northeastward toward the pole, it cools and a portion of it sinks at about 30°N. This sinking air spreads northward and southward as it nears the surface. The southward moving air again deflects to the right, becoming the northeasterly trade winds.**

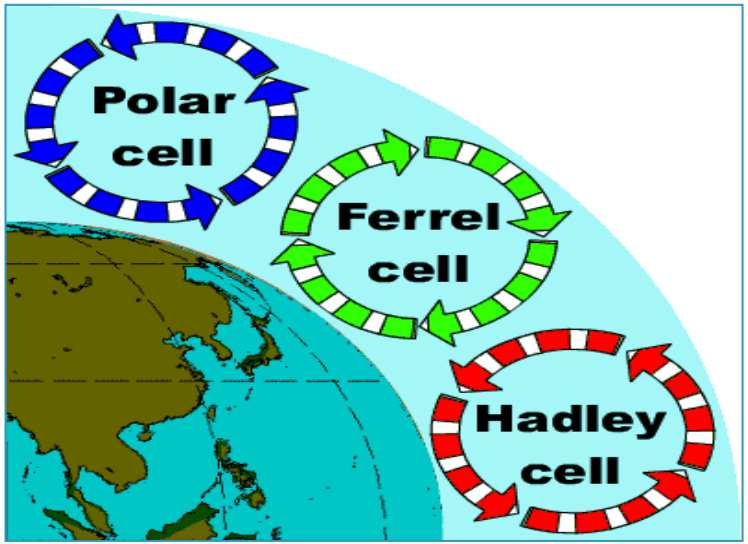


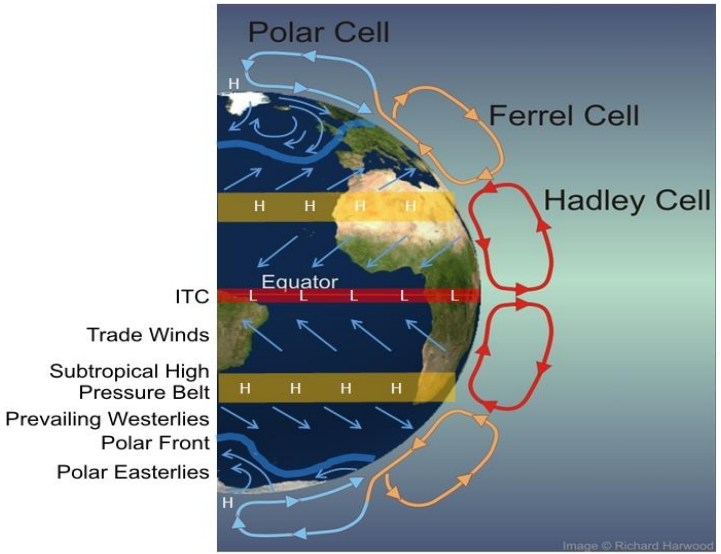


Ferrel cell

- This cell is named after William Ferrel who published his observations in a medical journal in 1856.
- The mid-latitude circulation cell between the Polar cell and the Hadley cell is called the Ferrel cell.
- It is believed the cell is a forced phenomena, induced by interaction between the other two cells.

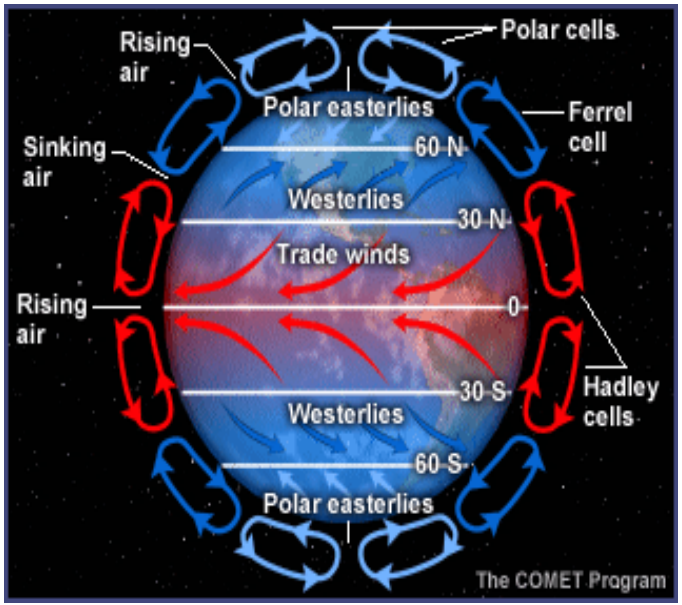
stronger downward vertical motion and surface convergence at 30°N coupled with surface convergence and net upward vertical motion at 60°N induces the circulation of the Ferrel cell.

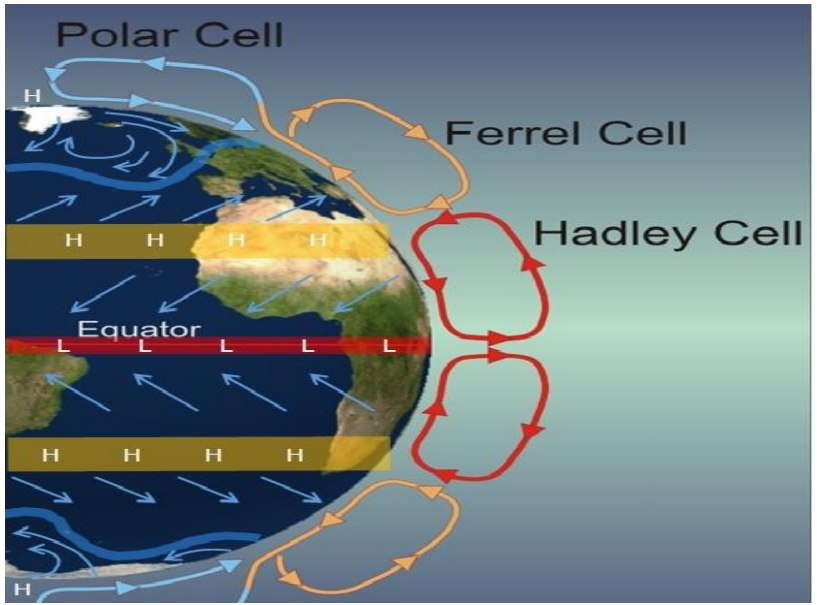




Polar Cell

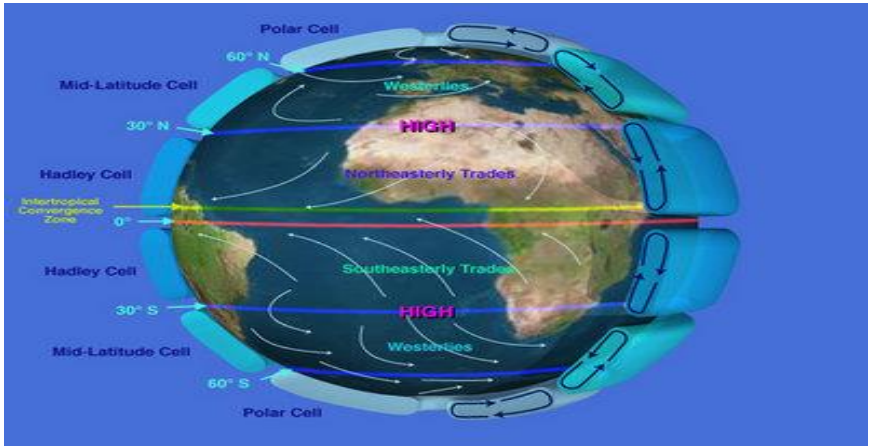
- This is the northernmost cell of circulation and its mean position is between 60°N and the North Pole.
- At the pole, cold, dense air descends, causing an area of subsidence and high pressure.





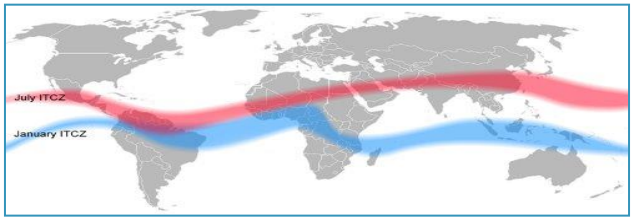
Trade Winds

- The ***trade*** winds are a pattern of wind that are found in bands around the Earth's equatorial region. The trade winds are the prevailing winds in the tropics, blowing from the high-pressure area in the horse latitudes towards the low-pressure area around the equator. The trade winds blow predominantly from the northeast in the northern hemisphere and from the southeast in the southern hemisphere.
- The trade winds act as the steering flow for tropical cyclones that form over world's oceans, guiding their path westward.

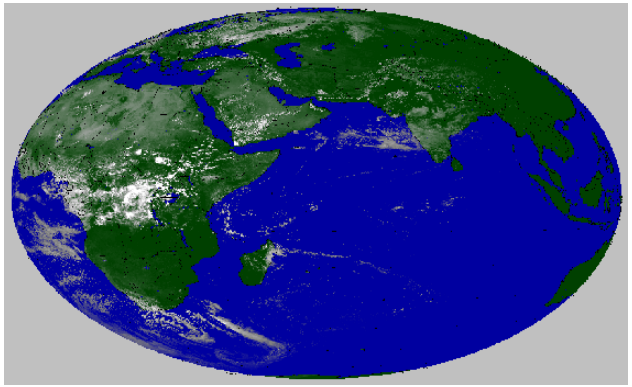


InterTropical Convergence Zone (ITCZ)

- In visible image , a long band of convective cloudiness extends across the image, ranging between 3 deg. and 8 deg north during winter
- The position of the ITCZ near the equator because of the prevalent sea surface temperatures in this region.



http://www.sciencedaily.com/releases/2013/09/130923155540.htm



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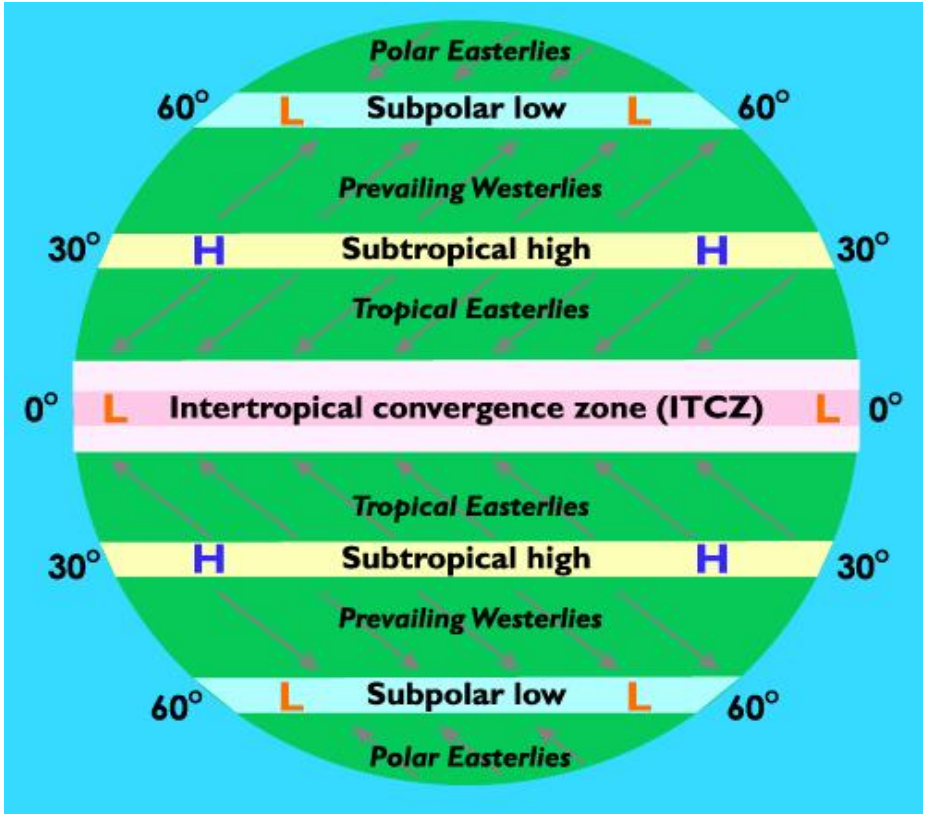
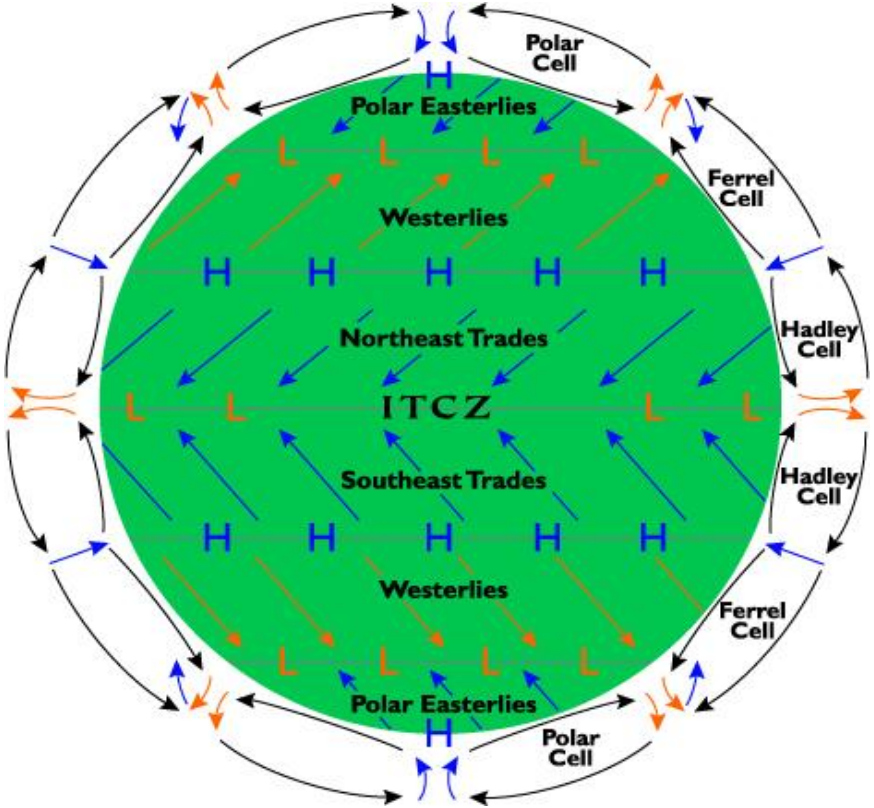
https://ttweathercenter.com/2022/05/01/the-intertropical-convergence-zone-itcz/

Wind patterns

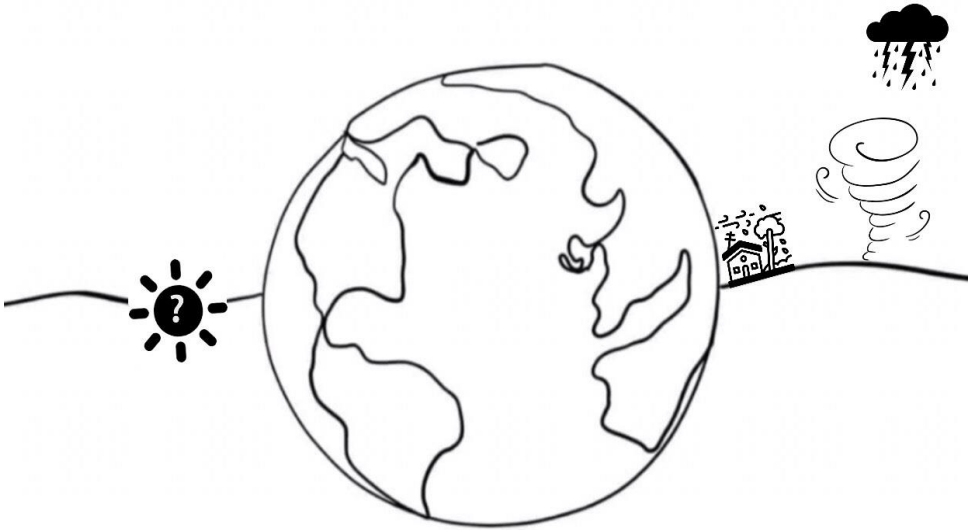


Circulation



THANK YOU

QUESTIONS ???



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Thank You!