The Atmosphere

Energy
Circulation
Climate
Composition
Chemistry
Pollution

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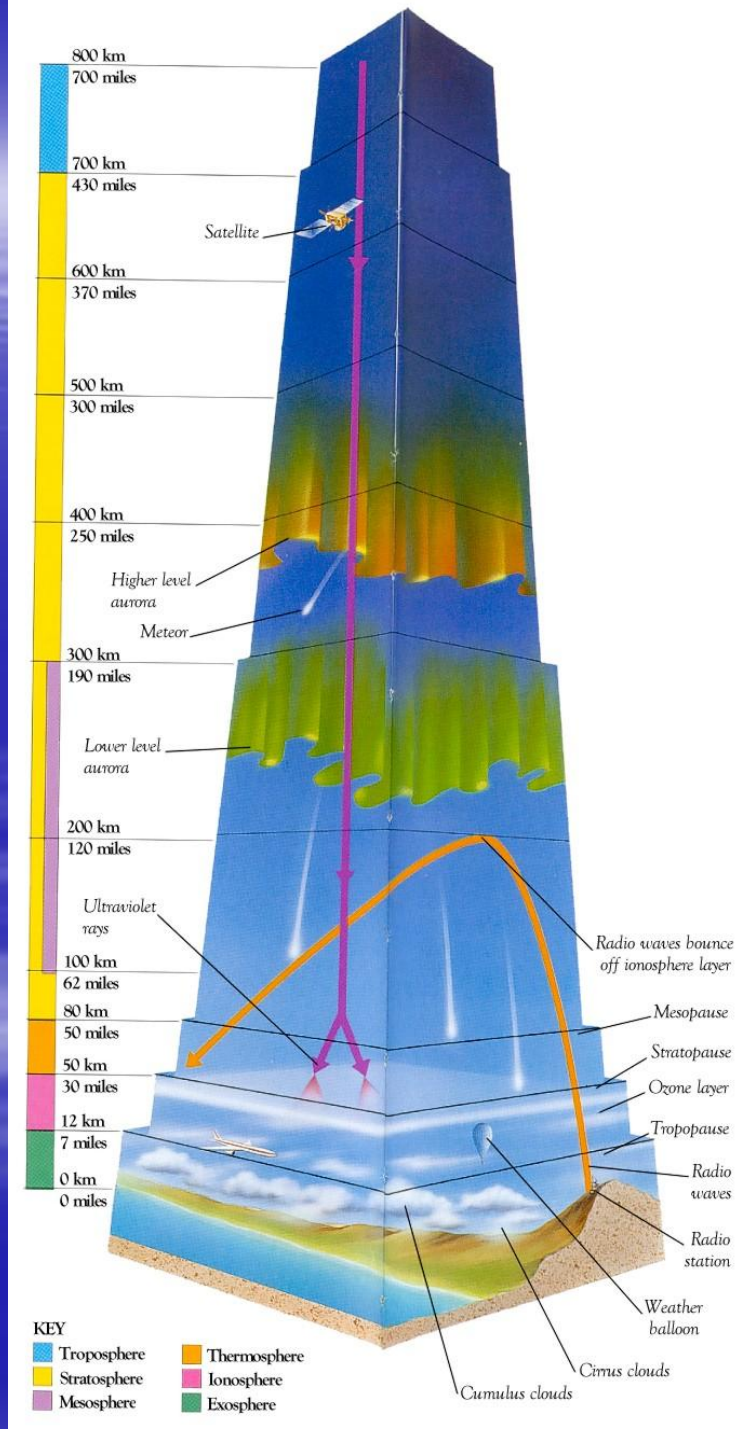
Important role of the atmosphere

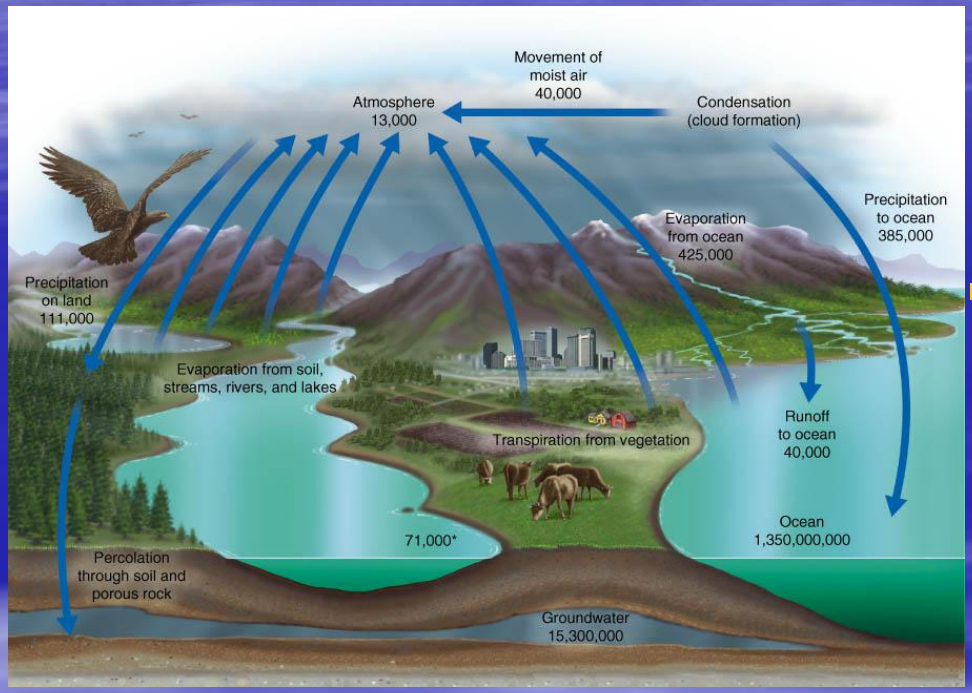
- It gives us air, water & heat.
- Protects us against harmful rays of the sun and against meteorites.

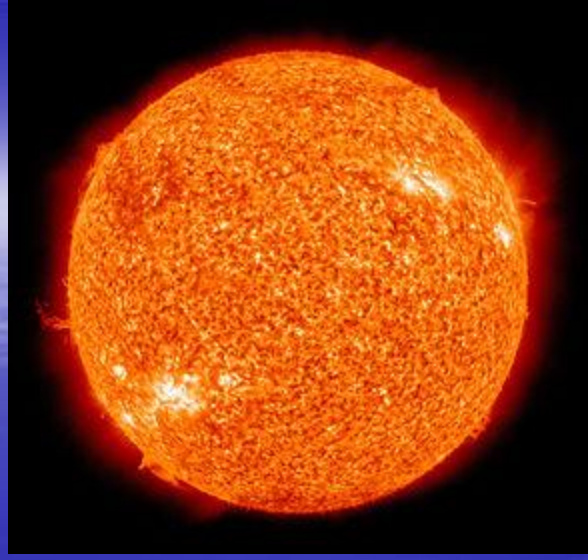
  Allows visible light & some infrared to the surface.

  Interaction between atmosphere & solar energy gives us weather & climate.



Important role of the sun





- The sun makes life on earth possible.
  - Warms the planet & atmosphere
  - Powers the hydrological cycle and biogeochemical cycles
  - energy captured by organisms to make food molecules

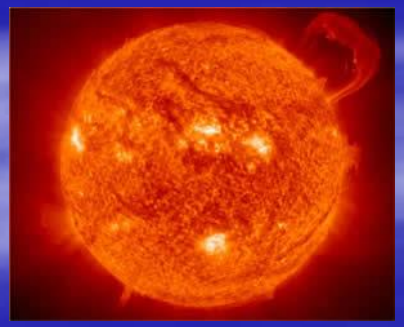
Carbon dioxide + water + sunlight ⟶ glucose + water + oxygen

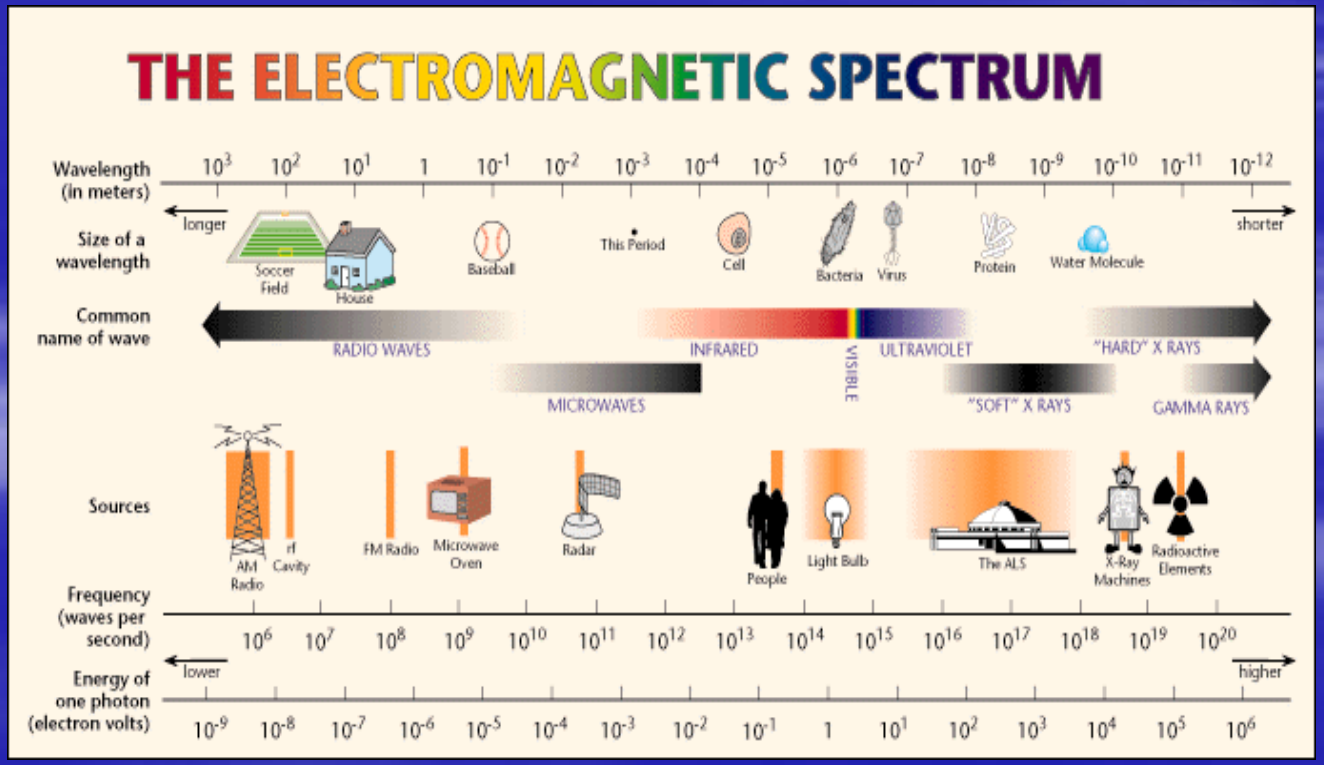
Glucose + oxygen ⟶ carbon dioxide + water + energy

Solar radiation

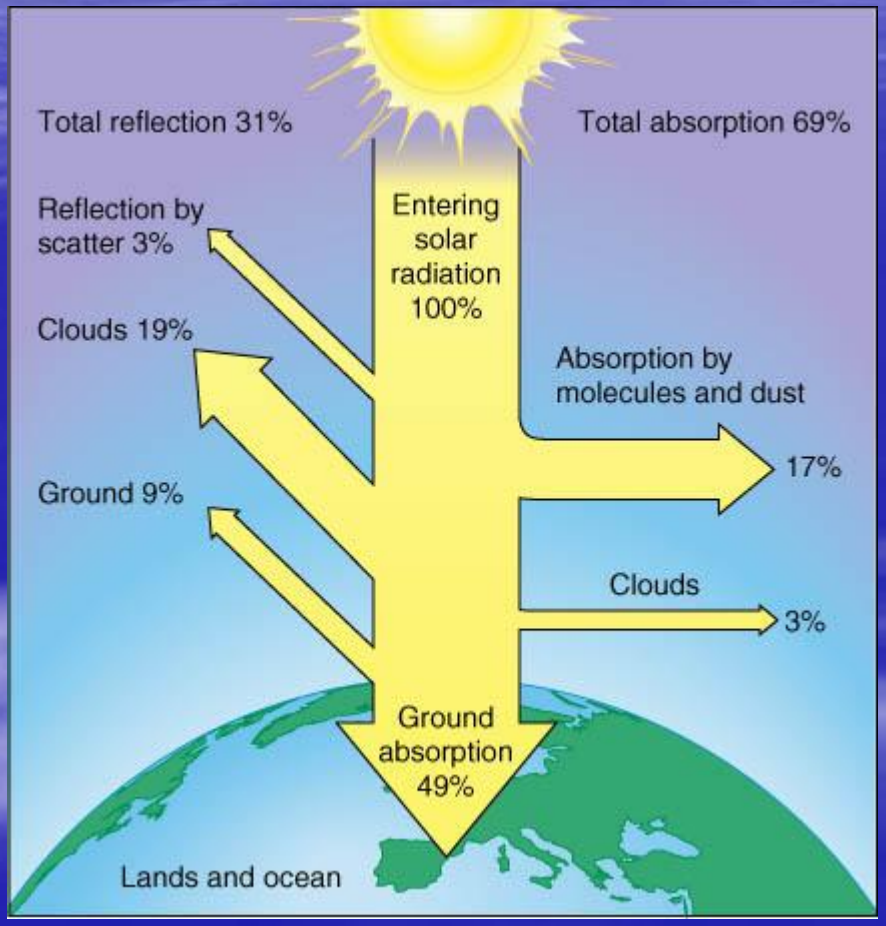
- Sun's energy is product of massive nuclear fusion reaction.
  - Emitted into space as electromagnetic radiation
  - Mainly visible light, infrared and ultraviolet radiation
  - Important for atmospheric chemistry

- ~ 1 billionth of the total energy released by the sun strikes our atmosphere



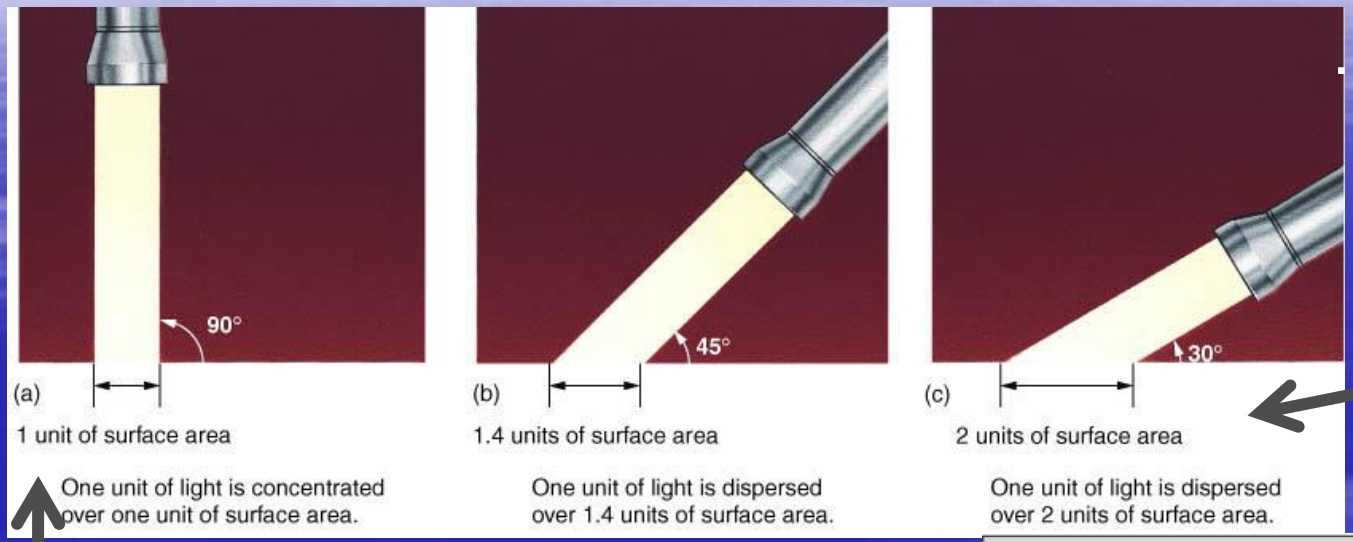


Fate of solar radiation that reaches the Earth



- ~ 31% of the solar radiation that falls on Earth is reflected by clouds & other surfaces
  - Albedo is proportional reflectance of Earth's surface.
- Remaining ~ 69% of solar radiation is absorbed by atmosphere and surface
- Energy lost by continual radiation of long-wave infrared (heat) energy to space

Solar radiation changes……



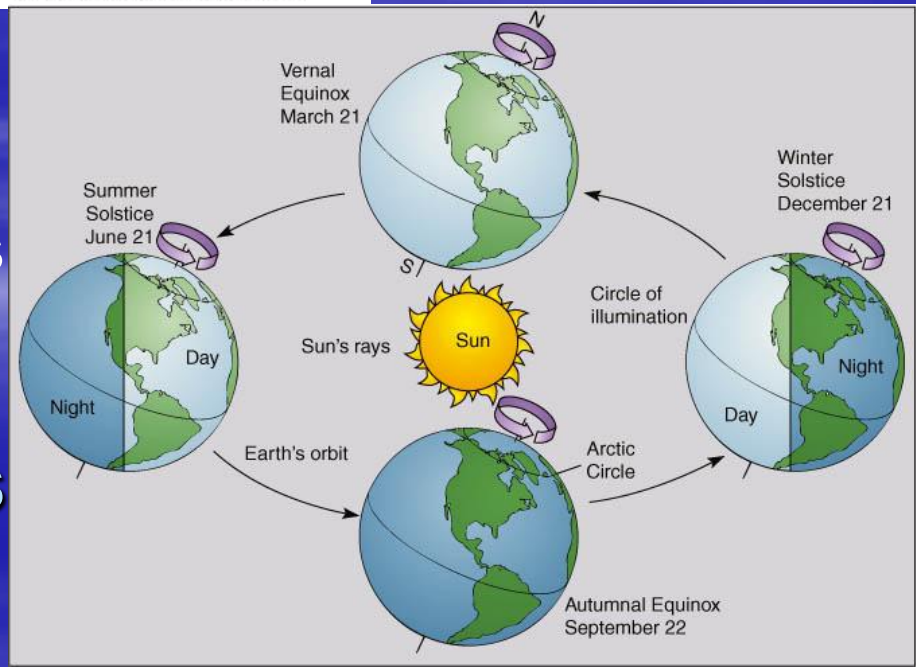
e.g. equator

……..with latitude...due to roughly spherical shape

e.g. towards the poles

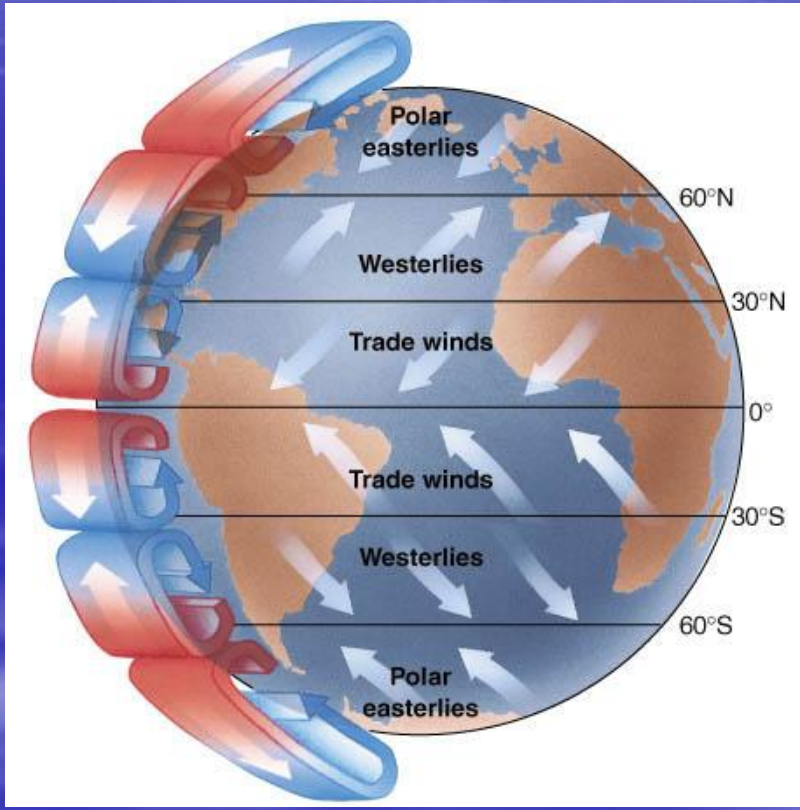
……..with season...due to Earth's inclination on its axis

…….temperature changes

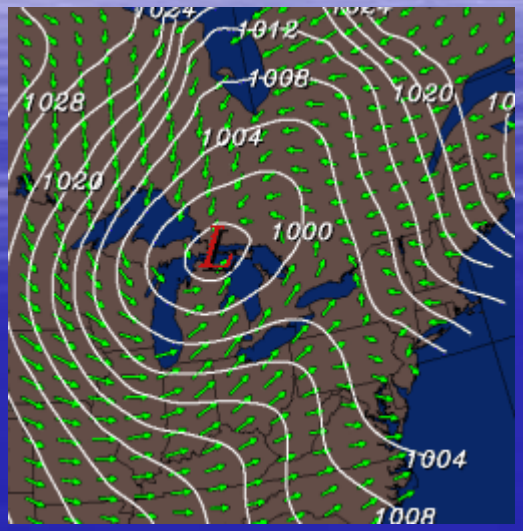


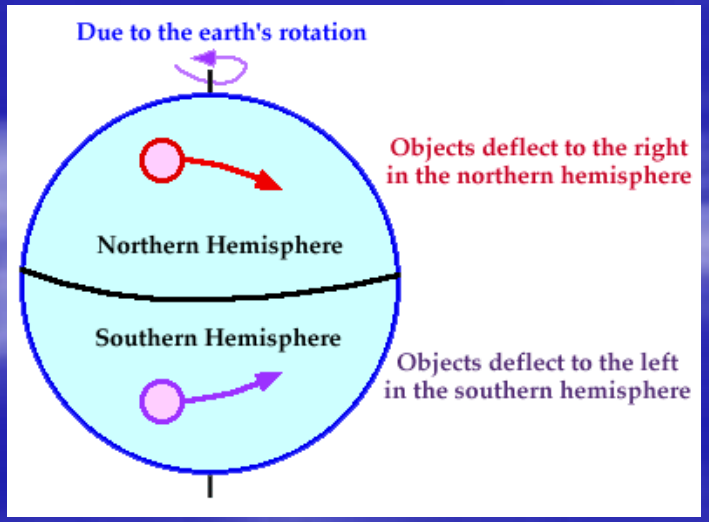
Global Atmospheric Circulation Patterns

- Differences in temperature driven by variations in amount of solar radiation reaching earth drive the circulation of the atmosphere.
- Warm air rises at equator and starts to move polewards. As it rises, it expands and cools. The air chills to sink to the surface at ~30 degrees north and south latitudes.
- Similar upward movement and returning flow at higher latitudes.
- Constant transfer of heat from the equator towards the poles. As it returns it cools the land.



Horizontal movements - surface winds

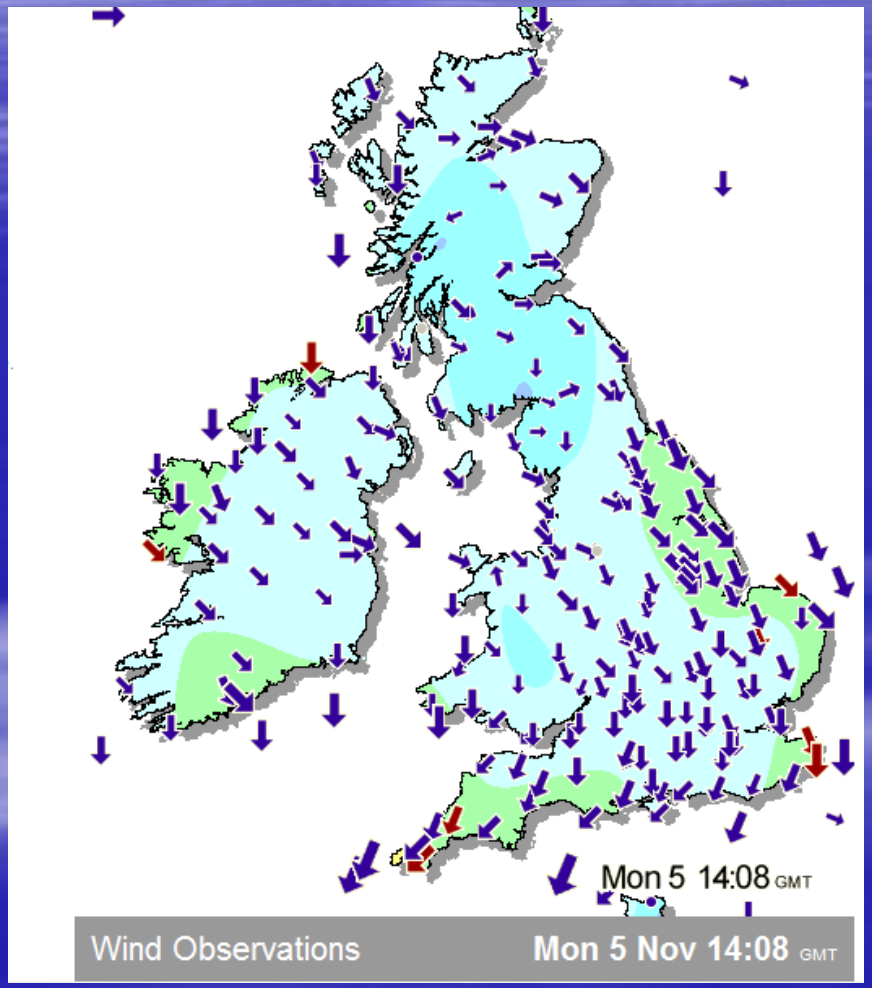


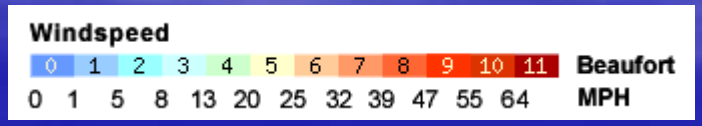


- Turbulent gust, eddies, lulls result of differences in atmospheric pressure & rotation of Earth. Result of

1. Pressure
   - Winds blow from high to low pressure. The greater the pressure difference, the stronger the wind.
2. Rotation of Earth
   - Earth rotates from west to east
   - This causes air to be deflected from its path and swerve to the right of the direction in which it is travelling (in NH). This tendency is known as the ***coriolis force***.

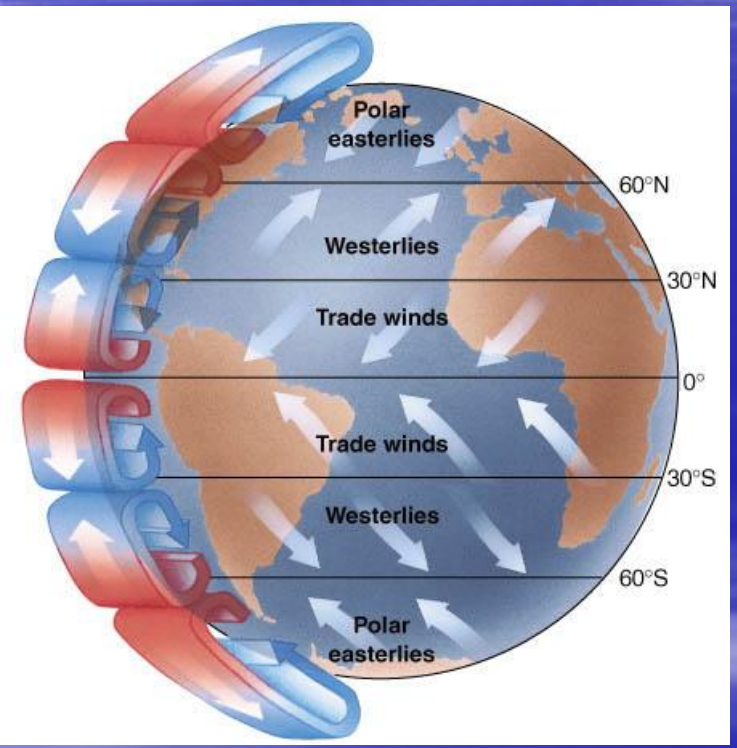
Today's surface winds



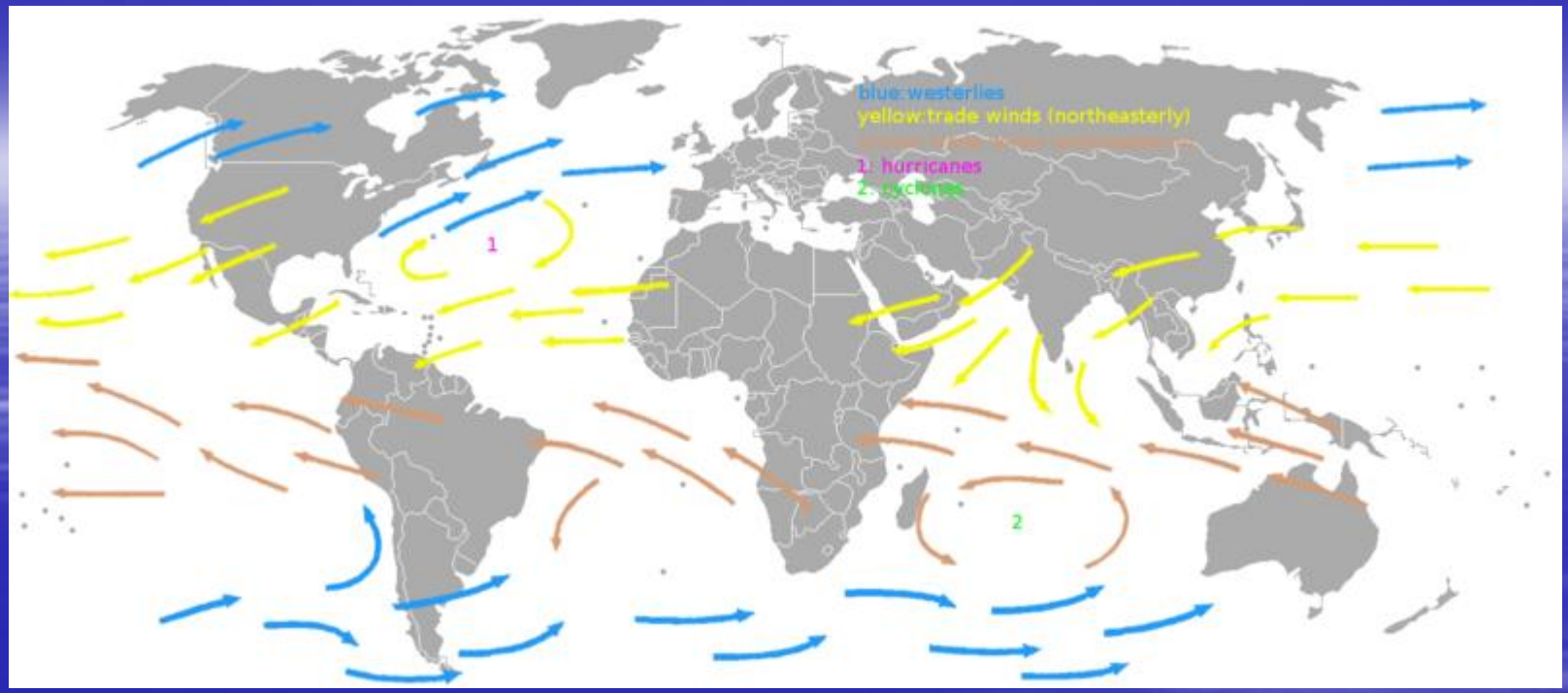


Prevailing surface winds

(major surface winds that blow more or less continually).



- The atmosphere has three prevailing winds:
- Polar easterlies
  - Polar winds
  - Blow from NE near North Pole, from SE near South Pole
- Westerlies
  - Midlatitude winds
  - Blow from the SW in NH, from NW in SH
- Trade winds
  - Tropical winds
  - Blow from the NE in NH, from SE in SH



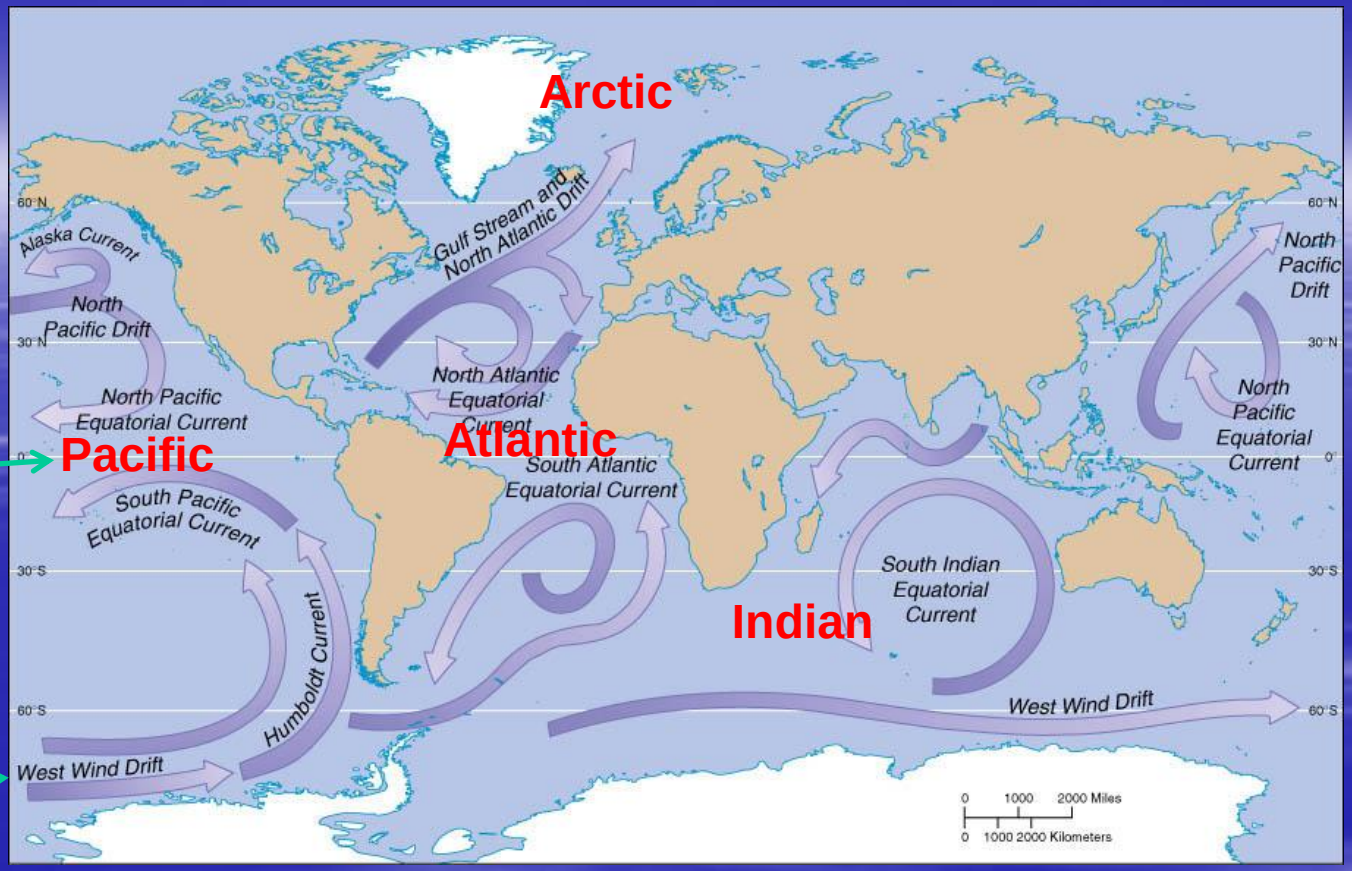
Trade winds

- Name originates from early 14th century
- Important for sailing ships seeking a course along which the winds can be expected to blow in the direction of travel
- Act as steering flow for tropical storms

Surface winds – link to Global Ocean

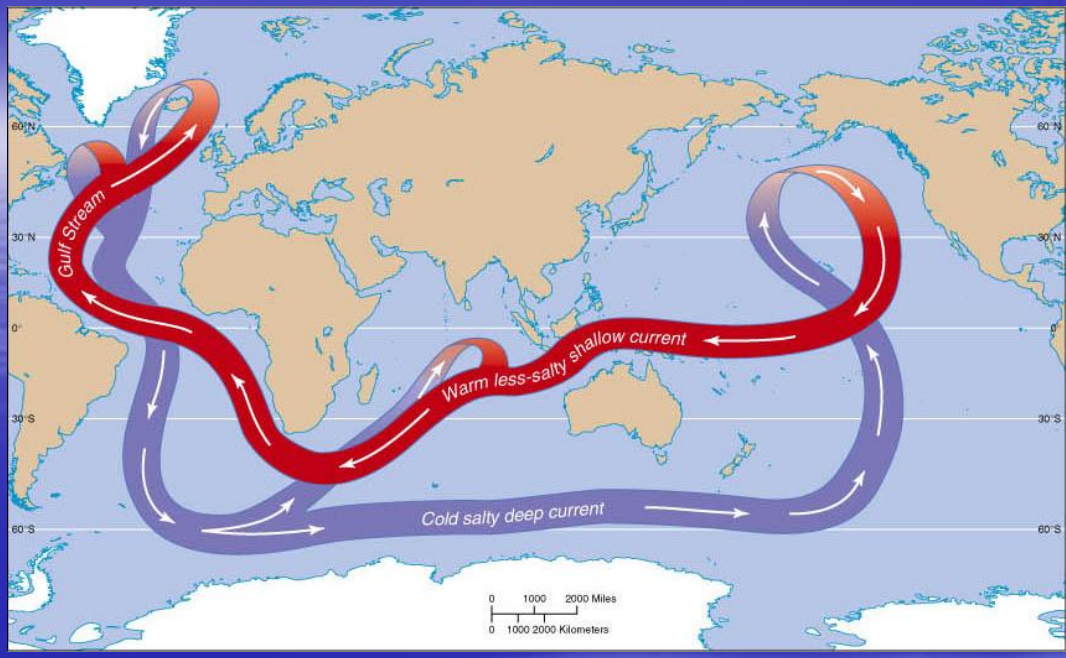
Trade winds

Westerlies



- The persistent prevailing winds blowing over the ocean produce mass movements of surface ocean water - ***currents***.
- Prevailing winds generate circular ocean currents – ***gyres***.
  - e,g in North Atlantic, the tropical trade winds tend to blow towards the west, whereas the westerlies in the midlatitudes blow towards the east.
    - A clockwise gyre established in the North Atlantic.

Thermohaline circulation



- Varying density of seawater affects deep ocean currents
  - Colder, or saltier water is denser than warmer, less salty water.

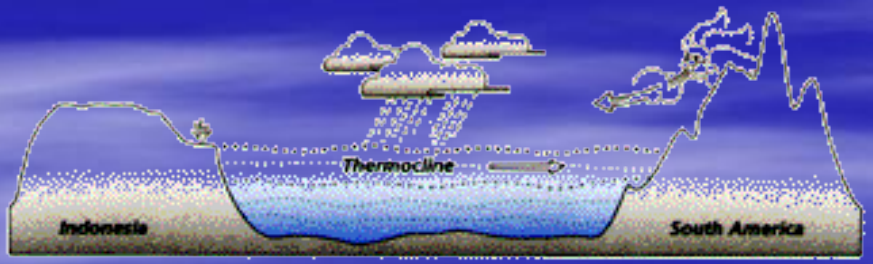
- Deep ocean currents often travel in different directions & speeds to surface currents.
  - Coriolis force stronger at depth
  - the figure opposite shows the present circulation of shallow and deep currents, known as the ***ocean conveyer belt***.

- The ocean conveyer belt affects regional and possibly global climate
  - e.g. heat delivered from tropics to Europe
  - Heat transferred to atmosphere and cooled water sinks
  - e.g. shift in equilibrium of conveyer belt can affect global climate

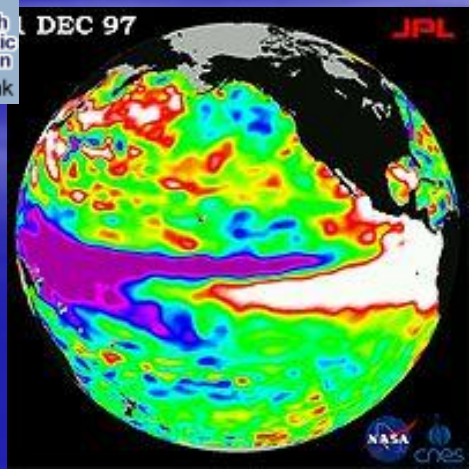
Ocean interactions with the atmosphere

- El Niño-Southern Oscillation – every 3 to 7 years, last 1 to 2 years.
- ENSO is a period of warming of surface waters of the tropical East Pacific that alters both oceanic & atmospheric circulation patterns

Normal Pacific pattern – cold water upwelling off South America

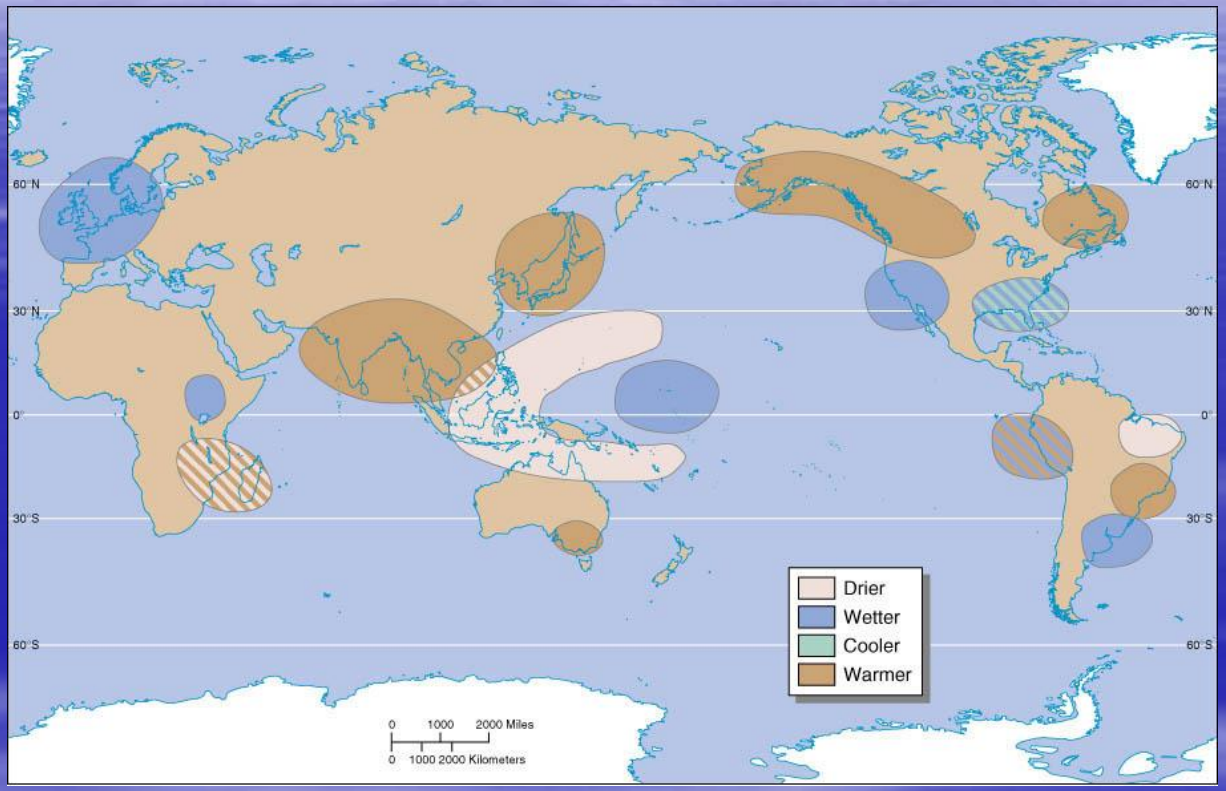


El Niño Conditions – trade winds relax. Central and east Pacific warm.



The 1997 El Niño observed by TOPEX/Poseidon. The white areas off the tropical coasts of South and North America indicate the pool of warm water

Changed climate patterns associated with El Niño

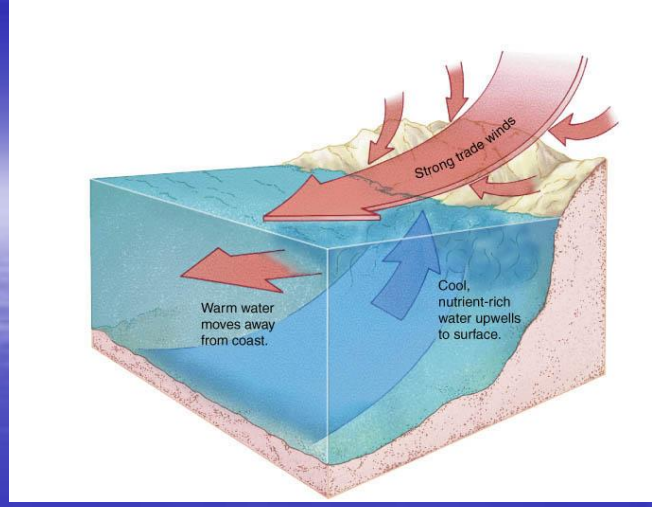


- El Nino can drastically alter climate in many areas remote from the Pacific Ocean. As a result of ENSO, some areas are drier, some wetter, some cooler, & some warmer than usual. Typically, northern areas of the US are warmer during the winter, whereas southern areas are cooler & wetter.

Impacts of El Nino

Droughts in Australia

Floods in Equador and Peru
Snowstorms in western US, ice storms in Canada.

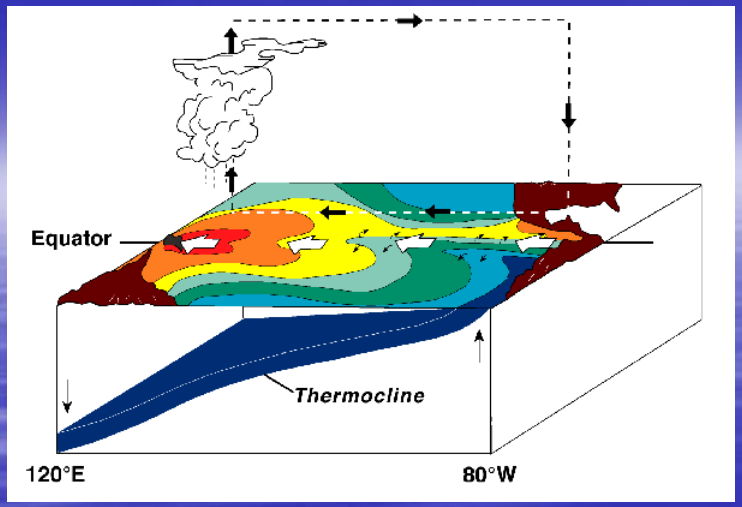


Along the west coast of South America, El Niño reduces the upwelling of cold, nutrient-rich water that sustains large fish populations.

Other species thrive

Economic implications

Newspaper headlines from Southern California papers in 1983 describe the influences of El Niño

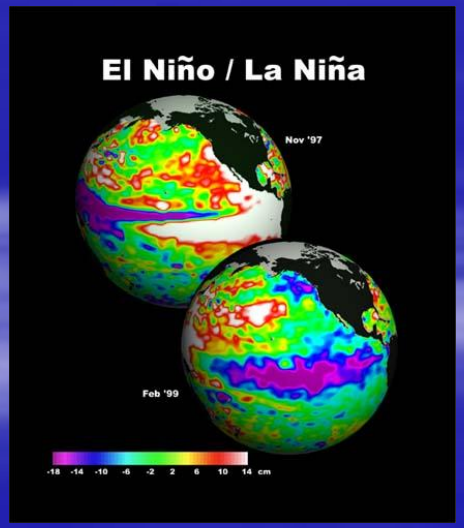


La Niña Conditions.
Warm water is further west than usual.

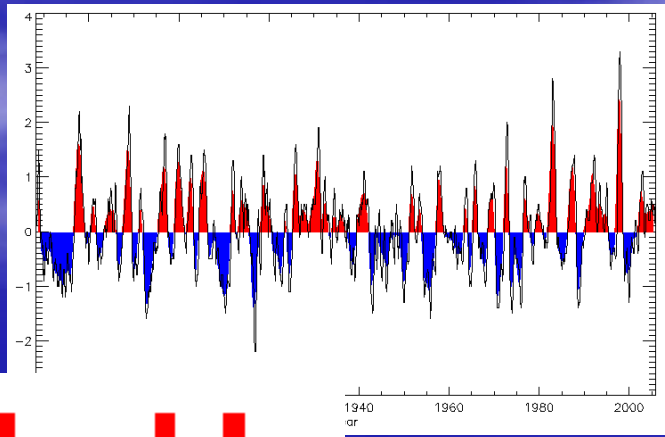
La Niña

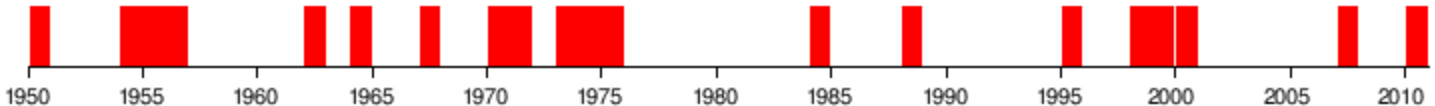
- Occurs when the surface water temperature in the eastern Pacific becomes unusually cool, & westbound trade winds become unusually strong.
  - 6.7 degree C cooling of E Pacific in just 20 days in spring 1998.

- Often occurs after an El Niño event.
  - Affects weather patterns, but effects are more difficult to predict.



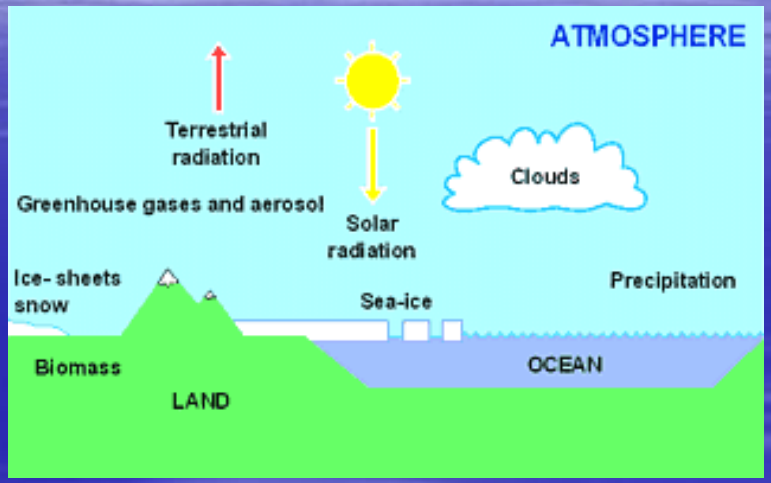
ENSO index:
Red=El Niño,
Blue=La Niña

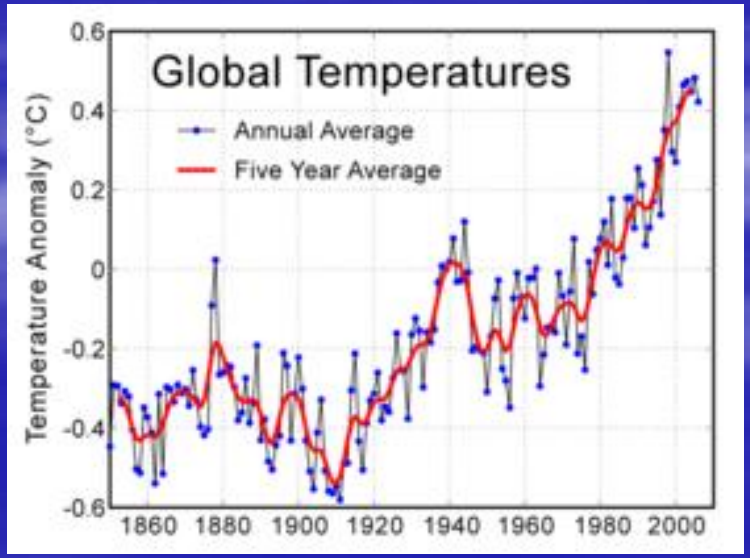




Climate

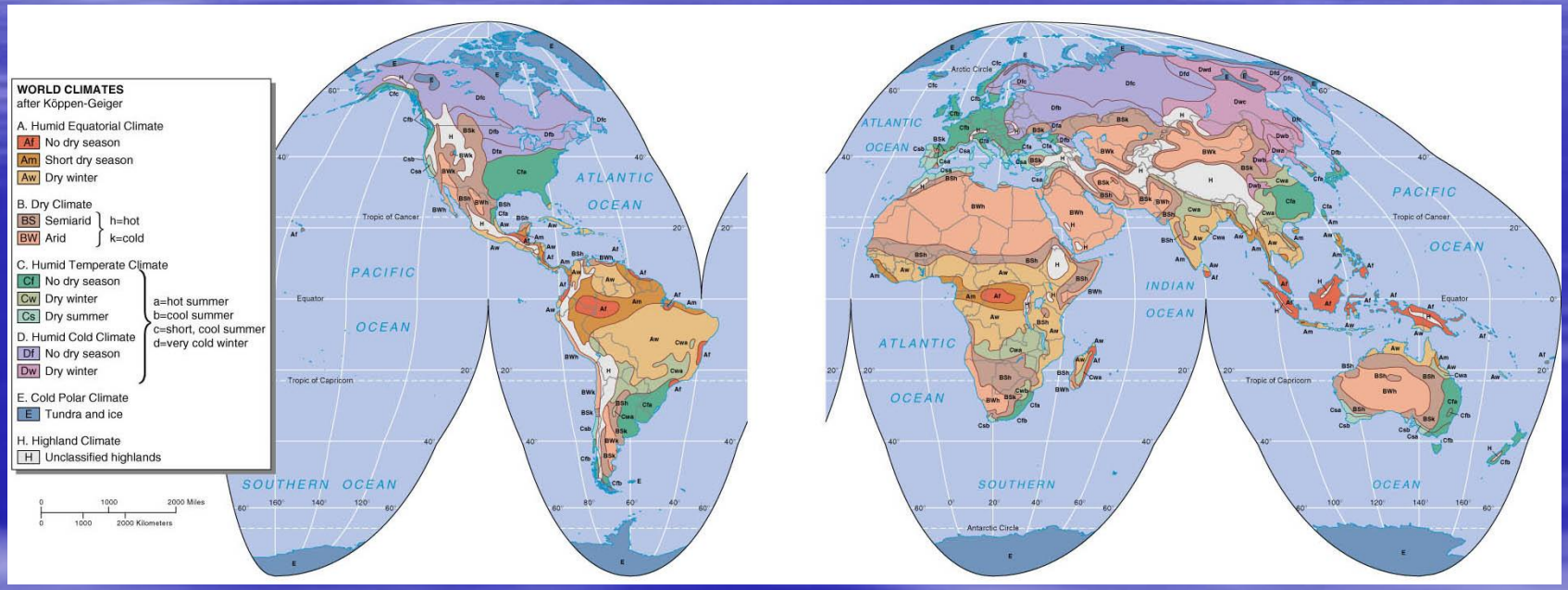
- The two most important factors that help determine an area's climate are ***temperature*** and ***precipitation***.
- Other climate factors include wind, humidity, fog, cloud cover, & lightning.
- Unlike weather, climate ***changes slowly***, over hundreds or thousands of years.





Classifying Climate

Climate comprises the average weather conditions that occur in a place over a period of years.



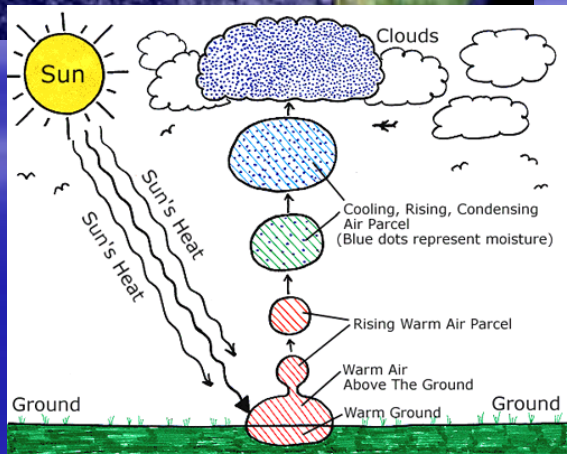
- Wladimir Köppen developed the most widely used system for classifying climates in the early part of the twentieth century.
  - Based on observation that various types of vegetations are associated with different climates, particularly temperature and precipitation.
  - The map above shows a world climate map modified from Köppen.

Precipitation

Atacama Desert, Chile,
0.05 cm average annual rainfall

Mt Waialeale, Hawaii,
1,200 cm average annual rainfall

- Varies dramatically & affects the distribution & variety of organisms present.
- Variation due to many factors. For example,
  - In Tropics due to equatorial uplift - thunderstorms.
  - Strong winds picking up water from surface of tropical ocean – tropical cyclones
  - Collision of cool dry air with warm humid air - tornadoes
  - Presence of mountains

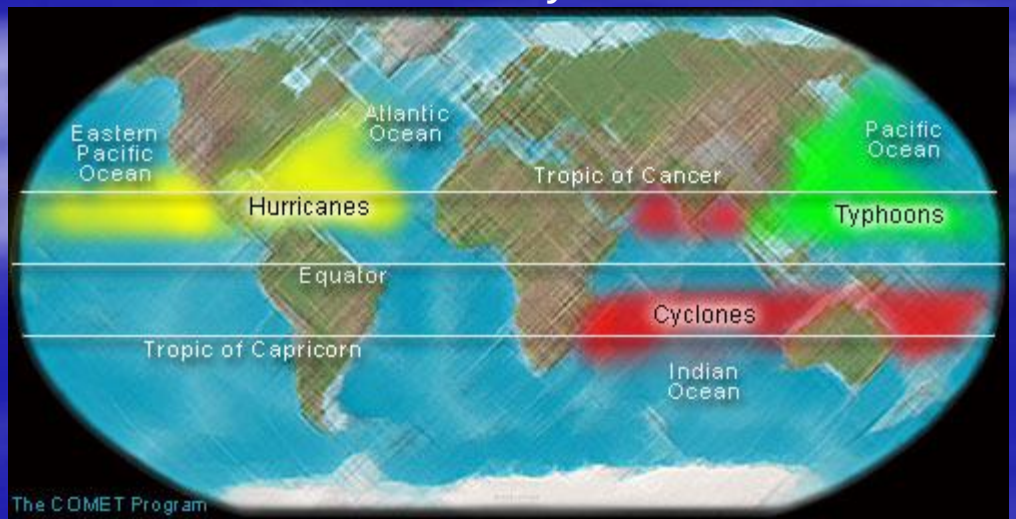


Tropical Cyclones

- Giant, rotating tropical storms with winds of at least 119 km per hour.
- Form as strong winds pick up moisture over warm surface waters of the tropical ocean and start to spin as result of Earth's rotation.
- Most prevalent in summer & autumn

  Atlantic – hurricanes / Pacific – typhoons

  Indian – cyclones



Three tropical cyclones at different stages of development.

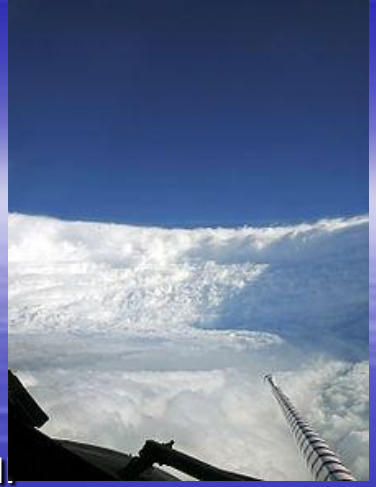
The weakest, on the left, demonstrates only the most basic circular shape.

The storm at the top right, which is stronger, demonstrates spiral banding and increased centralization

The storm in the lower right, the strongest, has developed an eye.

Cyclone / hurricane damage

- Strong winds
  - Some greater than 250 km per hou
- Formation of storm surges
  - Waves that rise as much as 7.5 m above ocean surface
- Torrential rainfall
  - e.g. Hurricane Katrina (2005)
  - second most intense storm to hit the US
  - the most costly
    - total property damage was estimated at $81 billion
  - and the third deadliest
    - 1,836 people lost their lives
  - 2012 Hurricane Sandy



Images of Hurricane Katrina, August 28, 2005. Left from NOAA WP-3D hurricane hunter aircraft

Flooding in New Orleans

Tornadoes (or twisters)

- A tornado is a powerful, rotating funnel of air associated with severe thunderstorms.
- Form when a mass of cool, dry air collides with warm, humid air, producing a strong updraft of spinning air on the underside of a cloud.
- Spinning funnel is called a tornado when it descends from the cloud and touches the ground

Wind velocity: may reach 480 km per hour (300 miles per hour)

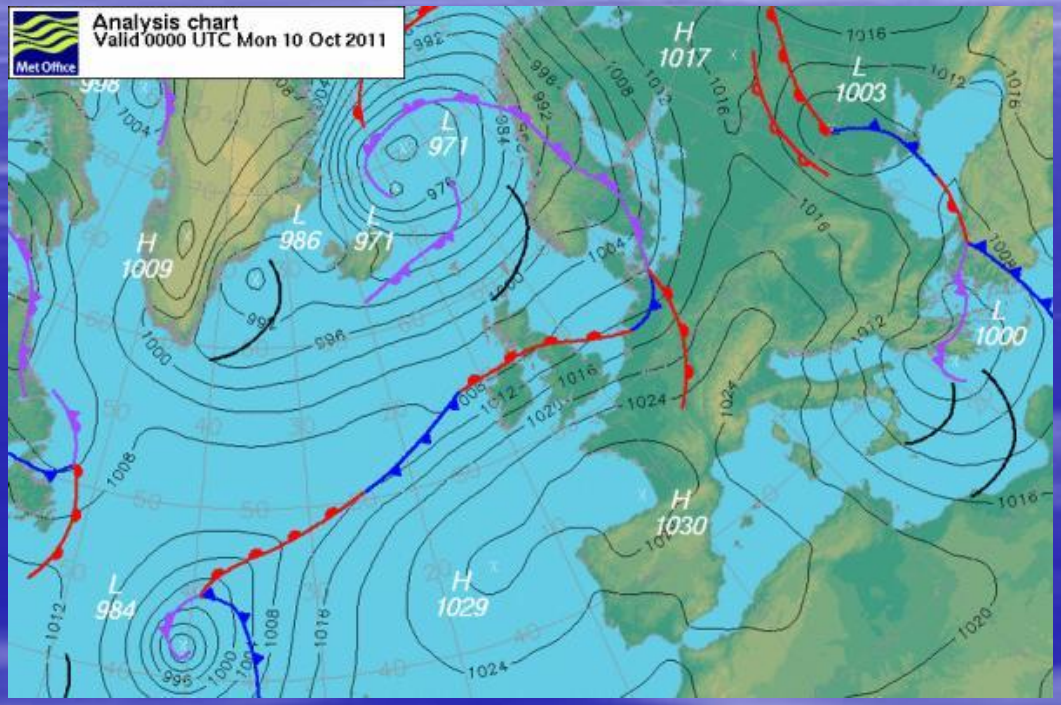
Size range from 1 m to 3.2 km (2 miles) wide

Last from several seconds to 7 hours or more

Travel from several meters to more than 320 km (200 miles)

http://www.metoffice.gov.uk/education/secondary/students/tornadoes.html

Weather



- **Weather** refers to the conditions in the atmosphere at a given place and time
  - Weather changes ***relatively quickly***, from one hour to the next & from one day to the next.

Useful resources

- Enviroweb

- http://www.pmel.noaa.gov/tao/elnino/la-nina-pacific.html
- http://www.metoffice.gov.uk/education/higher/index.html

- Raven & Berg (2004). Environment. 4th Edition. Wiley International.
- Graedel & Crutzen (1998). Atmospheric Chemical Change. An Earth-System Perspective.

Next lecture
Atmospheric chemical composition

- Atmospheric Chemical Cycles
  - Carbon
  - Sulphur
  - Nitrogen cycles
- Role of rainwater
- Particulate matter
- Stratospheric & tropospheric ozone