Meteorology: Climate

- Climate is the third topic in the B-Division Science Olympiad Meteorology Event.
- Topics rotate annually so a middle school participant may receive a comprehensive course of instruction in meteorology during this three-year cycle.
- Sequence:

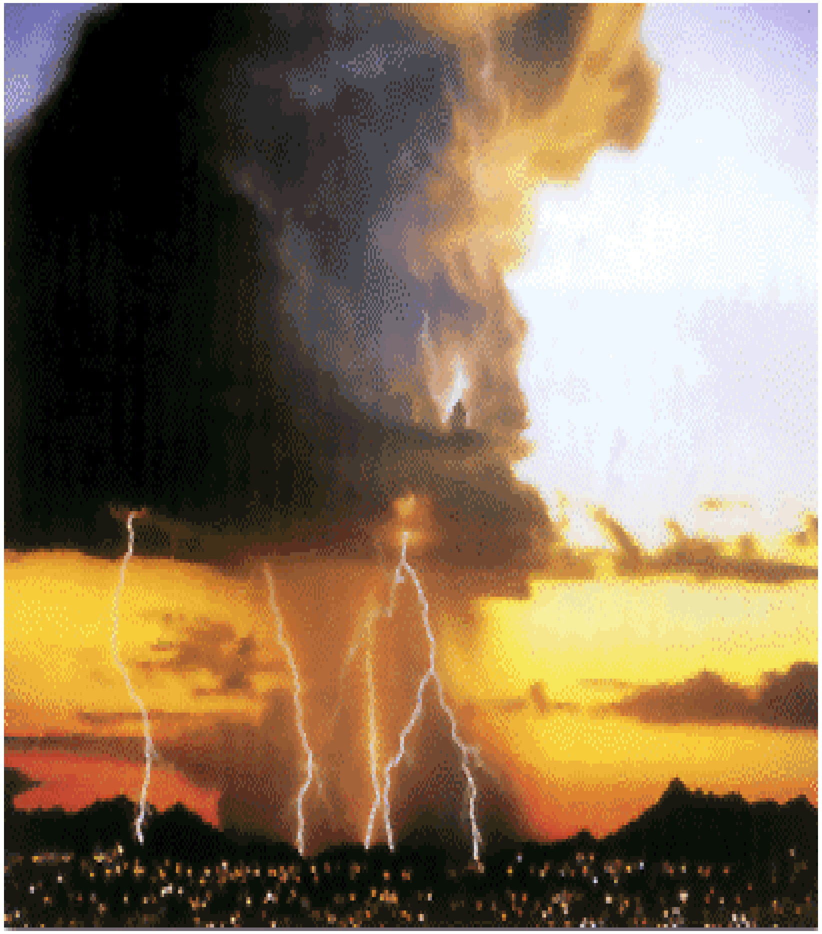
1. Climate (2006)
2. Everyday Weather (2007)
3. Severe Storms (2008)

Weather versus Climate

<u>Weather</u> occurs in the troposphere from day to day and week to week and even year to year. It is the state of the atmosphere at a particular location and moment in time.

http://weathereye.kgan.com/cadet/climate/climate_vs.html

http://apollo.lsc.vsc.edu/classes/met130/notes/chapter1/wea_clim.html



Weather versus Climate

<u>Climate</u> is the sum of weather trends over long periods of time (centuries or even thousands of years).

http://calspace.ucsd.edu/virtualmuseum/climatechange1/07_1.shtml

Weather versus Climate

The nature of weather and climate are determined by many of the same elements. The most important of these are:

1. Temperature. Daily extremes in temperature and average annual temperatures determine weather over the short term; temperature tendencies determine climate over the long term.
2. Precipitation: including type (snow, rain, ground fog, etc.) and amount
3. Global circulation patterns: both oceanic and atmospheric
4. Continentiality: presence or absence of large land masses
5. Astronomical factors: including precession, axial tilt, eccentricity of Earth's orbit, and variable solar output
6. Human impact: including green house gas emissions, ozone layer degradation, and deforestation

http://www.ecn.ac.uk/Education/factors_affecting_climate.htm
http://www.necci.sr.unh.edu/necci-report/NERAch3.pdf
http://www.bbm.me.uk/portsdown/PH_731_Milank.htm

Natural Climatic Variability

Natural climatic variability refers to naturally occurring factors that affect global temperatures. These include, but are not limited to:

1. Volcanic eruptions
2. Variations in the Sun's output
3. Milankovitch Cycles
4. Natural variations in concentrations of CO_2 and other greenhouse gases

Volcanic Eruptions

Volcanic eruptions may impact global climate.

1. Reduces the amount of short wave radiation reaching Earth's surface
2. Reduces the temperature of the troposphere
3. Increases climatic variability

http://www.cotf.edu/ete/modules/volcanoes/vclimate.html

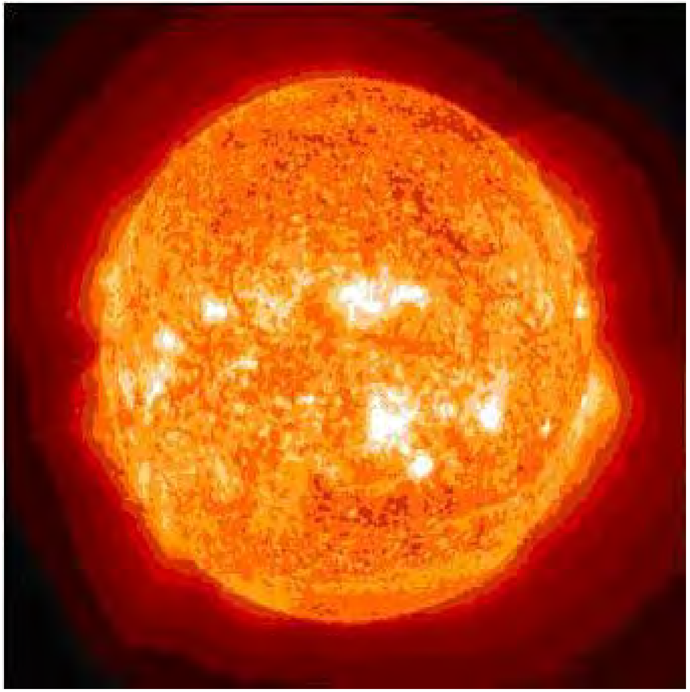
http://earthobservatory.nasa.gov/Study/Volcano/

Variation in Solar Output

- Extremely accurate satellite measurements of the Sun's energy output indicate that solar variability may be as much as 0.1% over an 18 month period.
- A variation of 1% would cause the average global temperature to change by $1^{o}C$. This may be a cause of the current increase in hurricane activity.

  http://vathena.arc.nasa.gov/curric/space/solterr/output.html

  http://news.google.com/news?q=solar+output&hl=en&lr=&sa=N&tab=nn&oi=newsr



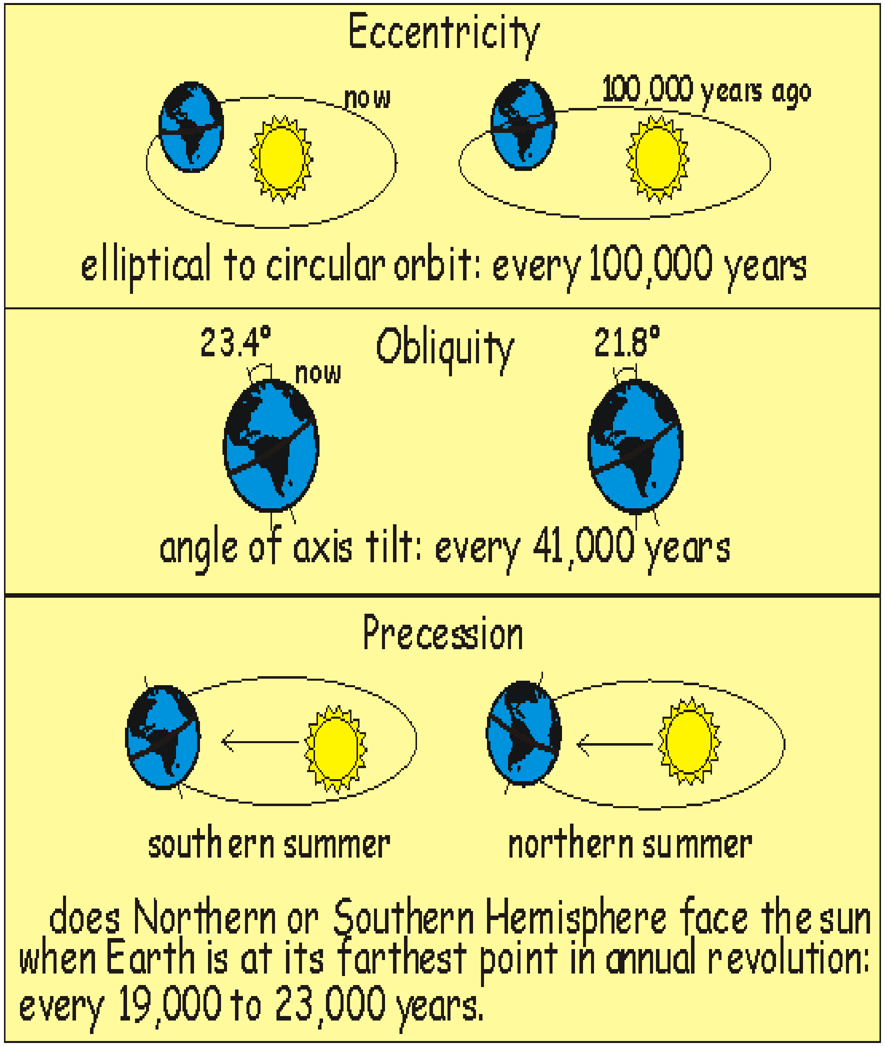
Milankovitch Cycles

Milankovitch identified three cyclical changes he believed relevant to climate change:

1. Orbital eccentricity: 100,000 year cycle
2. Axial Tilt: 42,000 year cycle
3. Precession: 19,000 - 23,000 year cycle

http://deschutes.gso.uri.edu/~rutherfo/milankovitch.html

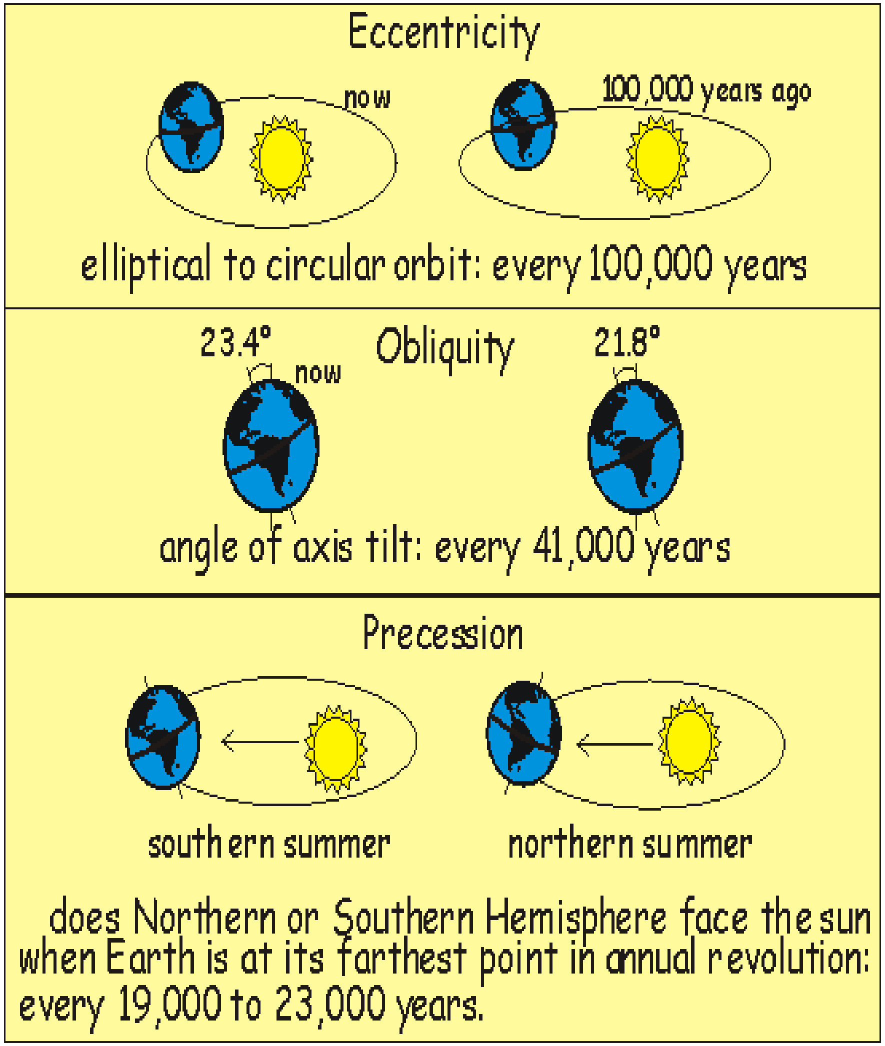
http://www.homepage.montana.edu/~geol445/hyperglac/time1/milankov.htm



Milankovitch Cycles

- To support his hypothesis, Milankovitch calculated the dates when these variations combined to minimize and maximize solar radiation over hundreds of thousands of years.
- The dates coincided with the ice ages.

http://deschutes.gso.uri.edu/~rutherfo/milankovitch.html
http://www.homepage.montana.edu/~geol445/hyperglac/time1/milankov.htm



Natural Variation in Greenhouse Gases

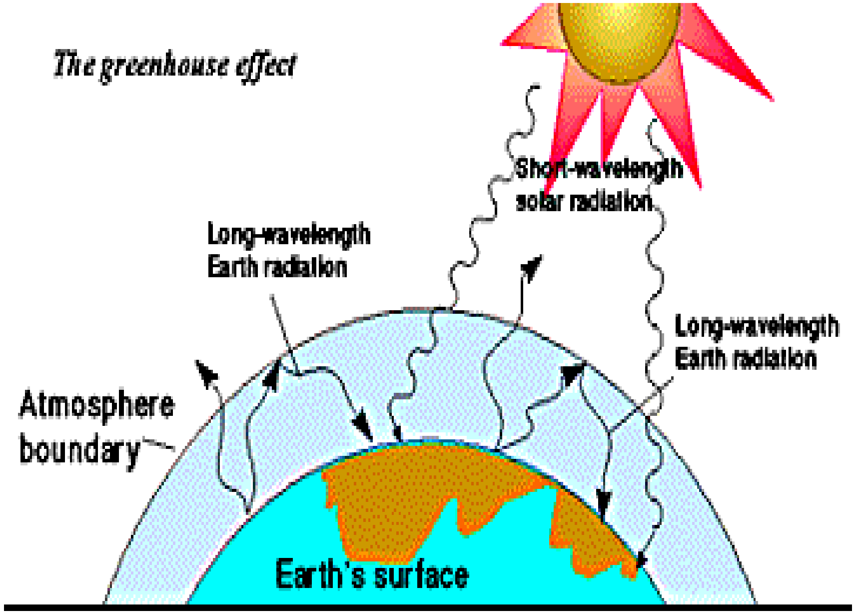
Natural variations in the concentration of greenhouse gases can and do occur.

1. CO_2 is not the only greenhouse gas.
2. H_2O is the **major** green-house gas.
3. High levels of CO_2 are associated with global warming and low levels are associated with global cooling.

http://www.agu.org/eos_elec/99148e.html

http://yosemite.epa.gov/OAR/globalwarming.nsf/content/Emissions.html

http://www.ghgonline.org/

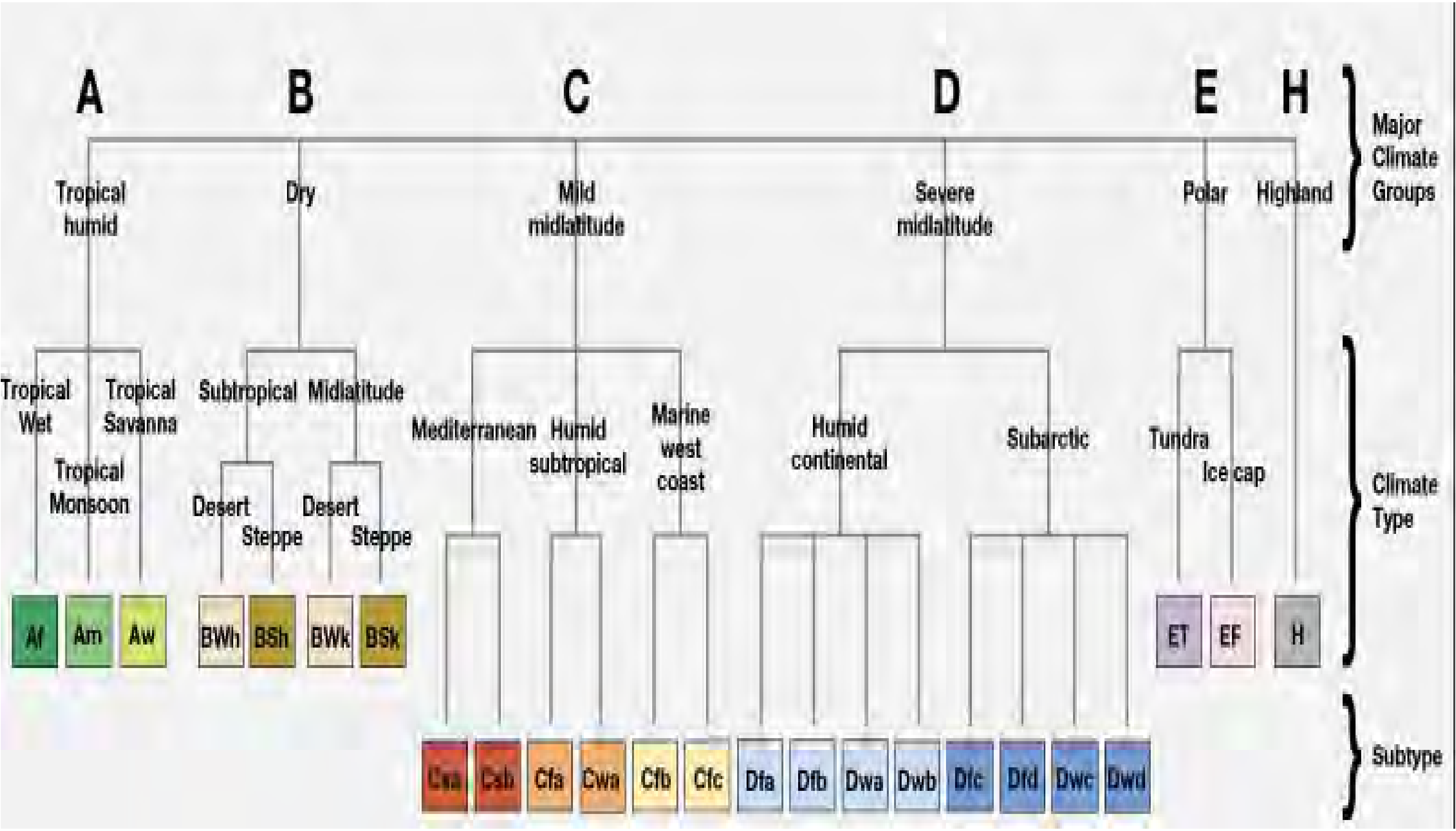


Köppen Classification System

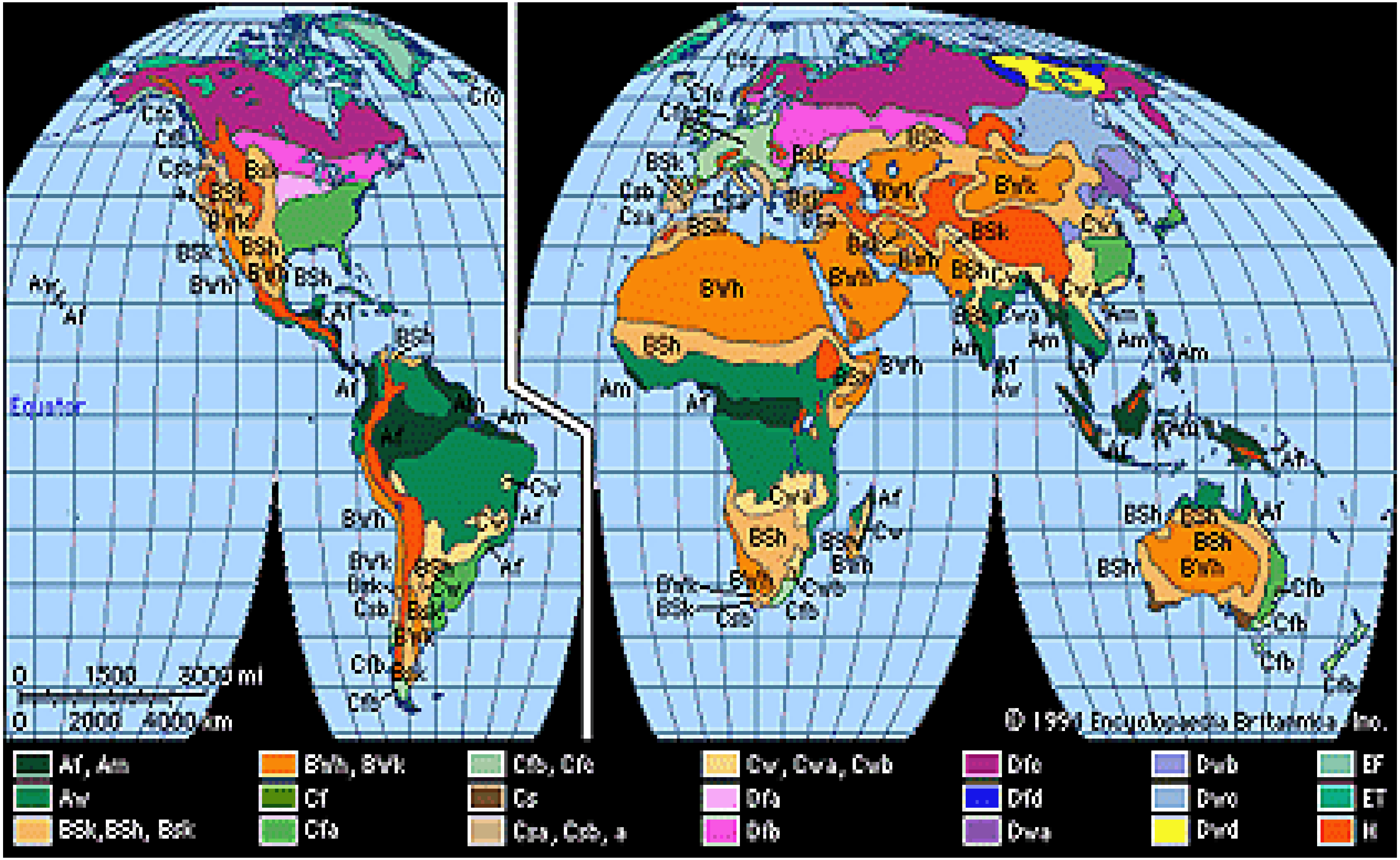
- The Köppen Classification System is the most widely accepted system for classifying world climates.
- This system is based on certain plant assem-blages that correlate temperature with precipi-tation – the major determinants of climate.
- The original system recognized five major climate types, labeled A through E, running in broad bands from equator to poles.

http://geography.about.com/library/weekly/aa011700a.htm
http://www.squ1.com/index.php?http://www.squ1.com/climate/koppen.html
http://www.geofictie.nl/ctkoppen.htm

Köppen Classification System



Köppen Classification System

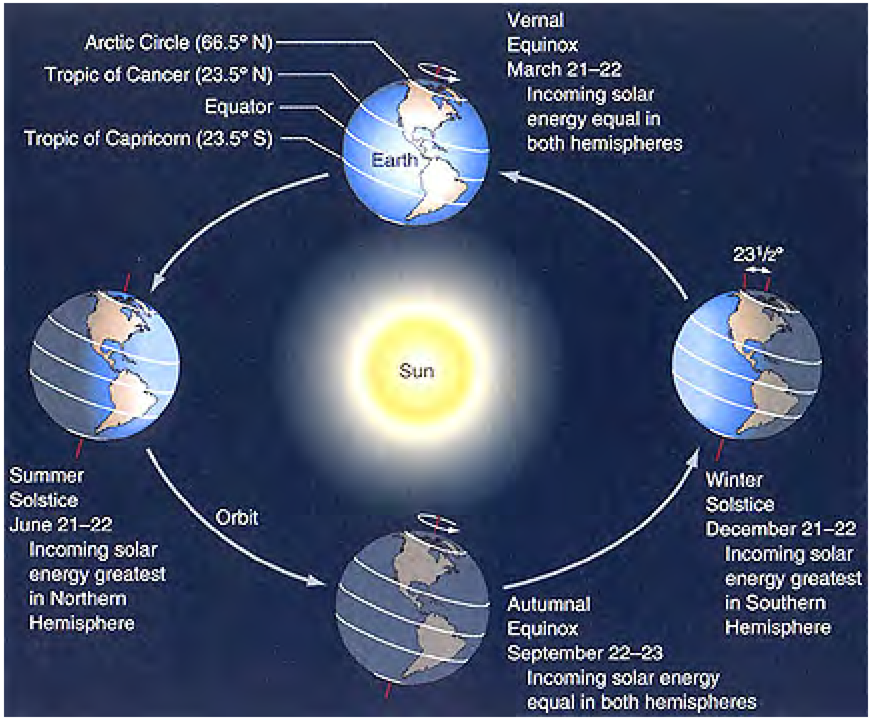


Factors that influence Climate

1. Latitude – insolation – intensity and duration
2. Air Masses – humidity and temperature
3. Pressure systems – global distribution
4. Oceanic Currents – heat exchange
5. Continentality – land mass and mountains
6. Atmospheric Circulation – three cell model
7. Altitude – mimics the effect of latitude
8. Oceans – moderating effect of water

Factors that Influence Climate:
Latitude, Insolation, Intensity and Duration

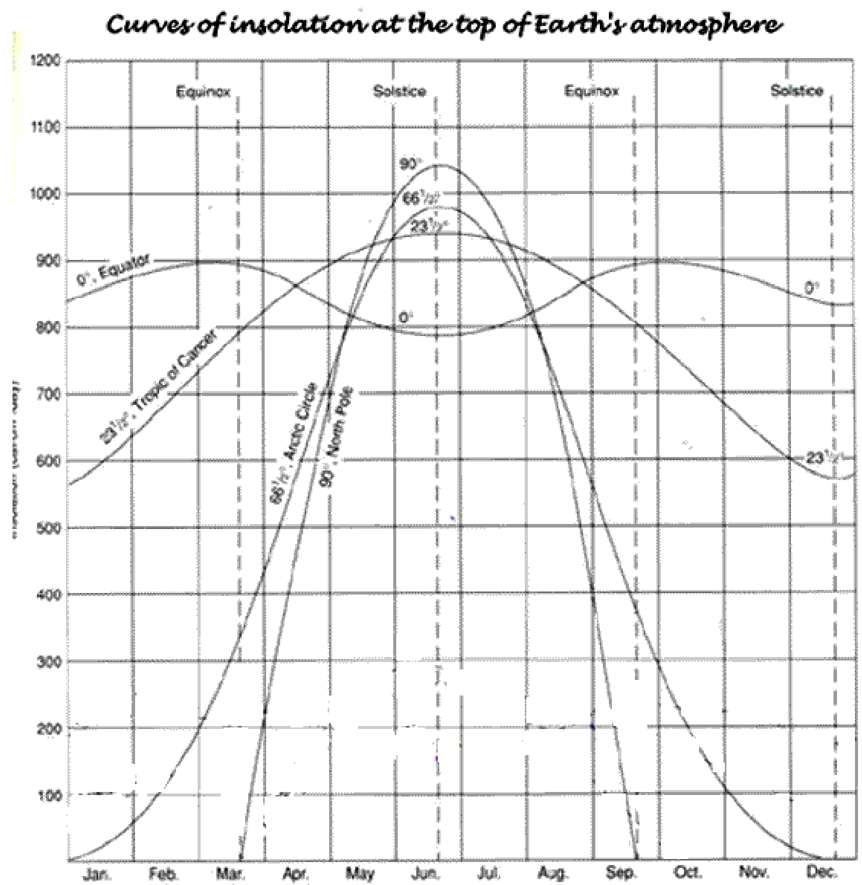
- Axial tilt creates seasons on Earth's surface with different parts of the Earth receiving more or less insolation at different times of the year.
- Annual variations in both intensity and duration occur.



Factors that influence Climate:
Latitude

The amount of incoming solar radiation varies annually by latitude generat-ing seasons and climate. (graph interpretation)

Insolation



http://www.physicalgeography.net/fundamentals/6i.html

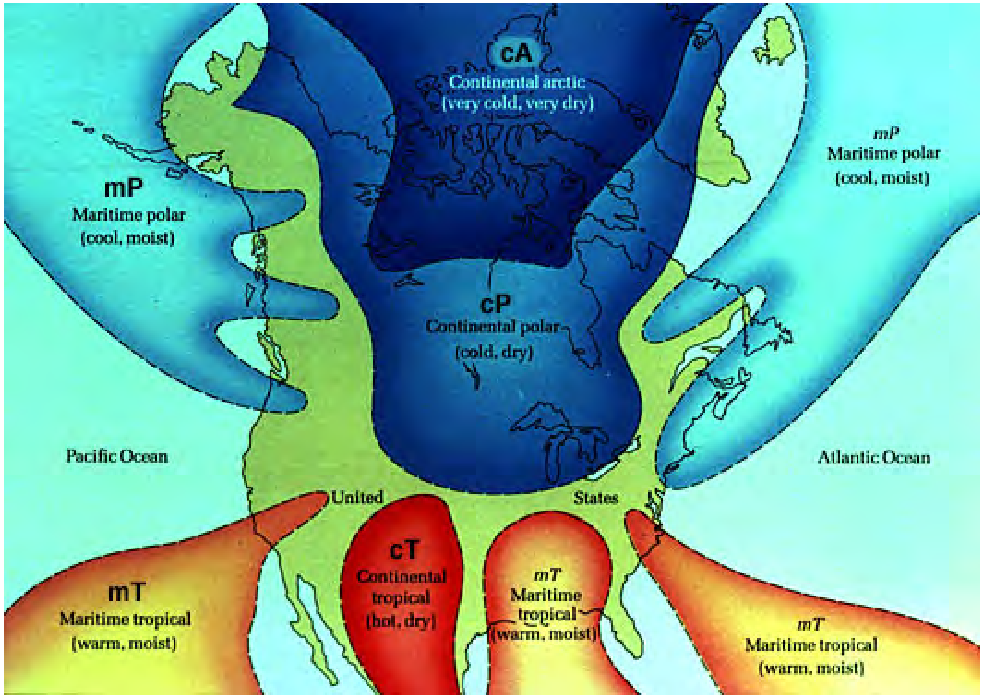
http://en.wikipedia.org/wiki/Insolation

http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/energy/global_insolation.html

http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/980211f.html

Factors that influence Climate: Air Masses

- Air masses tend to be homogeneous, i.e. similar throughout.
- The point of origin of an air mass are indicators of its temperature and moisture content.



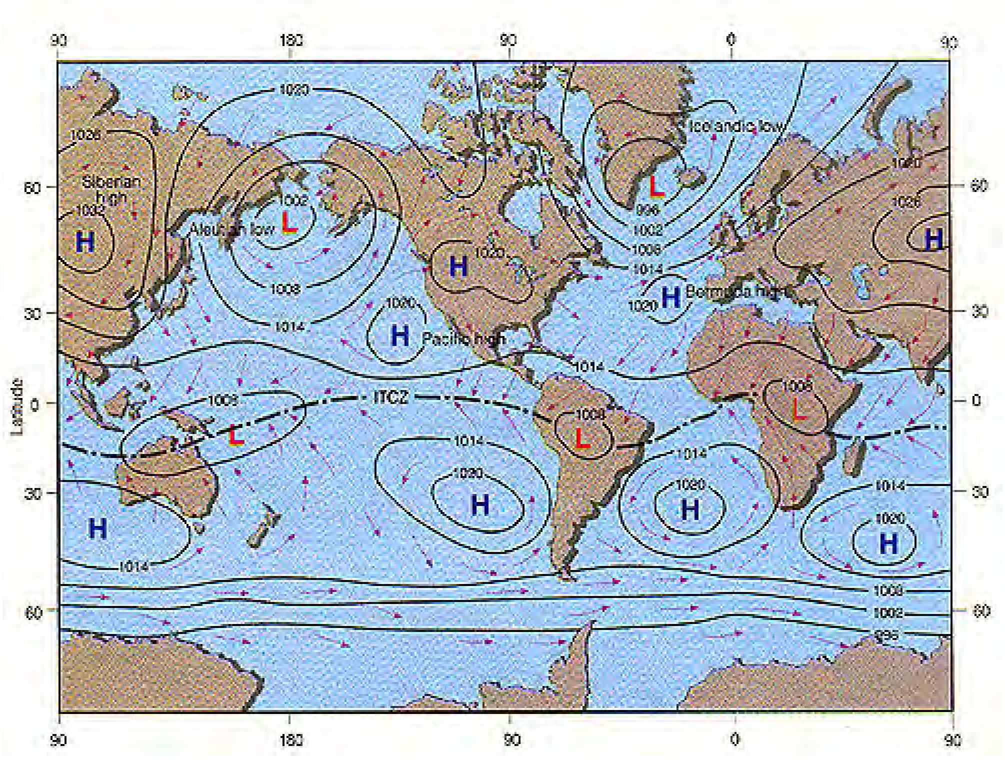
http://www.ecn.ac.uk/Education/air_masses.htm

http://okfirst.ocs.ou.edu/train/meteorology/AirMasses.html

Factors that influence Climate: Global Pressure Distributions

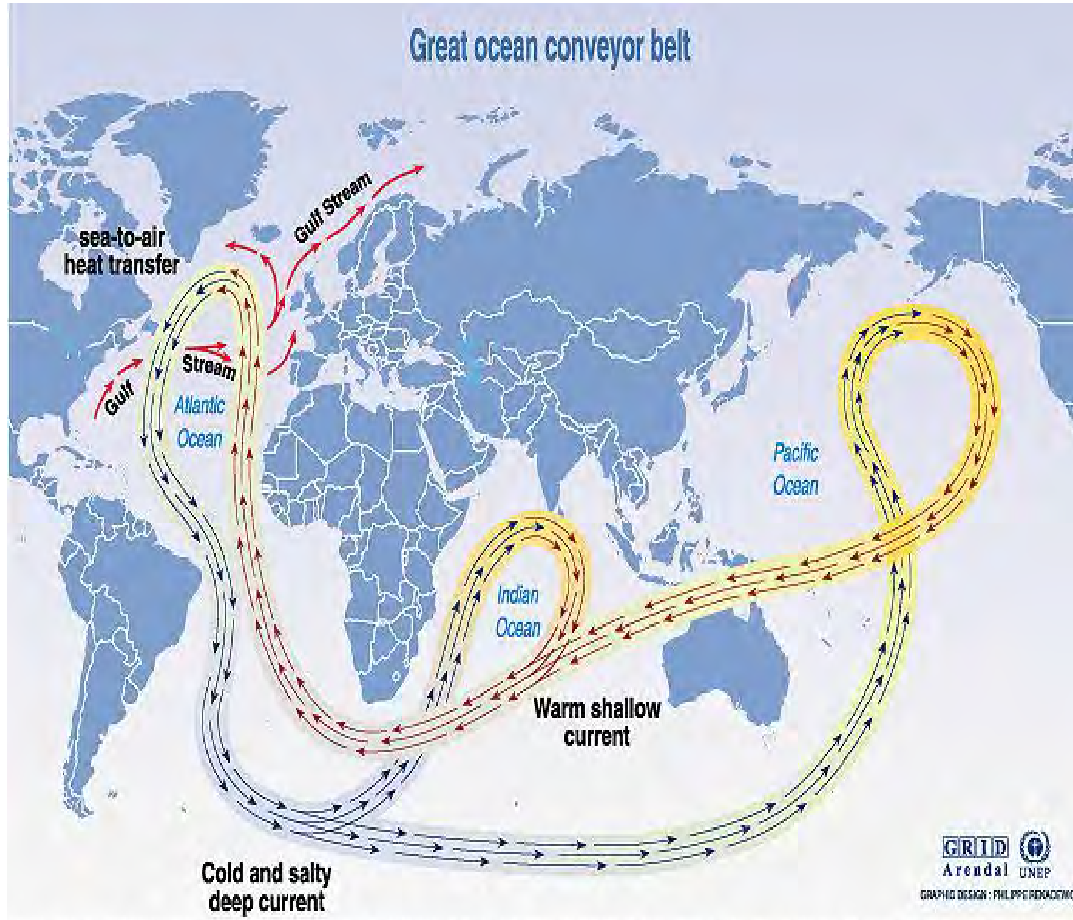
- **Semi-permanent pressure areas:**
- Bermuda-Azores High
- Pacific High
- Aleutian Low
- Icelandic Low
- **Seasonal pressure areas:**
- Siberian High
- Canadian High

  http://apollo.lsc.vsc.edu/classes/met130/notes/chapter11/january_surface_press.html



Factors that influence Climate: Ocean Currents

- North Atlantic deep waters are very cold and salty and therefore very dense.
- They sink and flow southward and are critical for arctic – equatorial heat exchange.

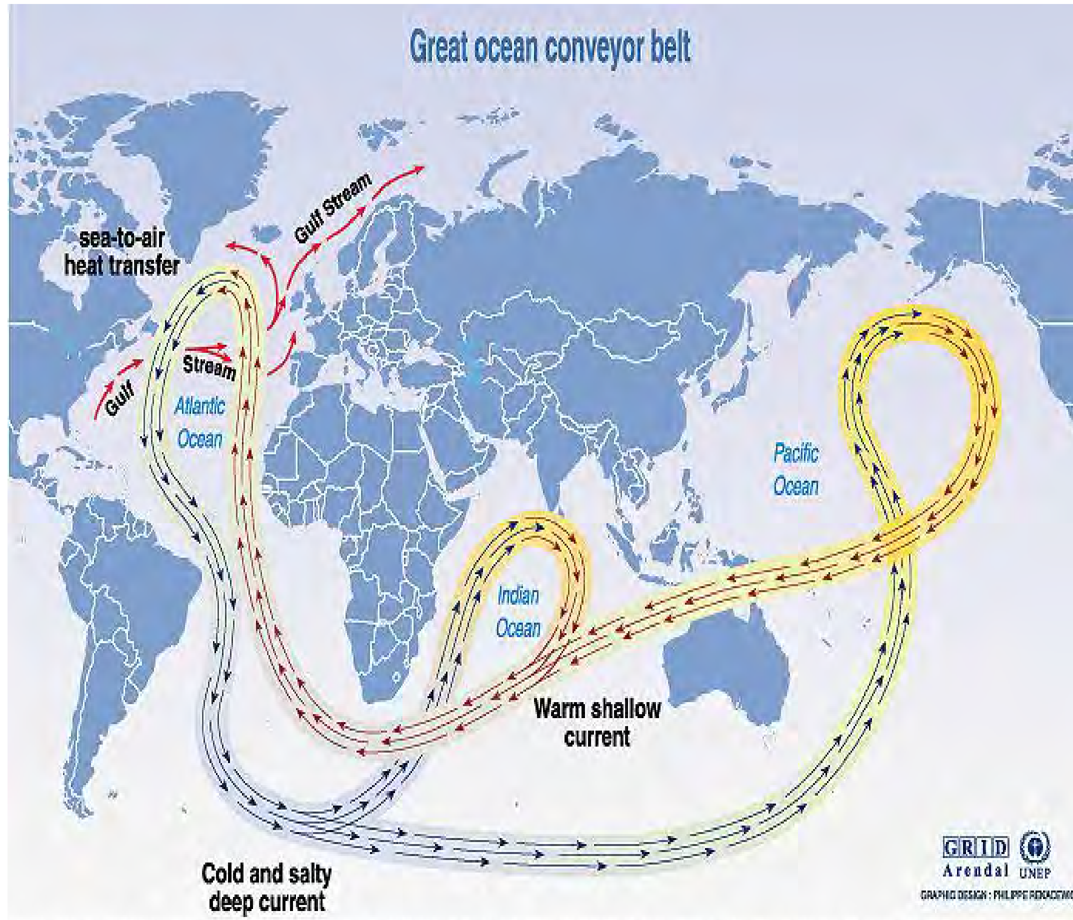


Source: Broecker, 1991, in Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Factors that influence Climate: Ocean Currents

- Disruption of the thermohaline current may work to initiate planetary cool-ing and may develop within decades not millennia.

  http://www.grida.no/climate/vital/32.htm

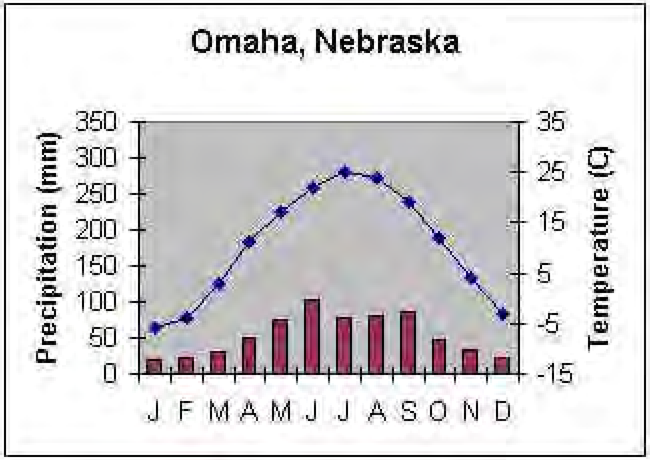


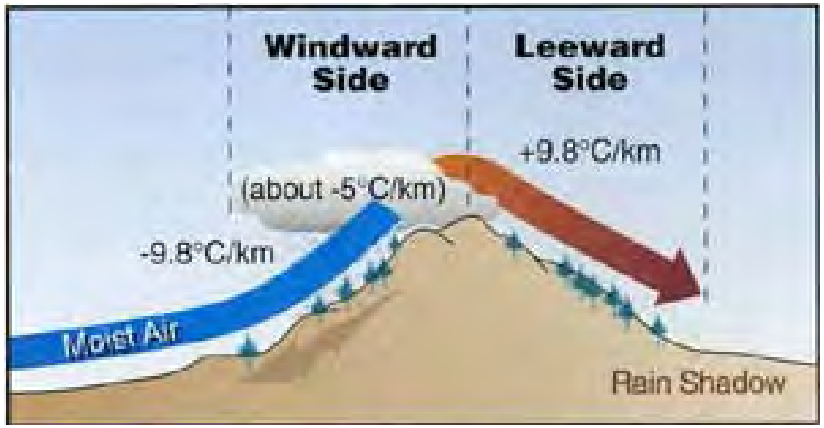
Source: Broecker, 1991, in Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Factors that influence Climate: Continents and Mountains

- Land is quick to heat and cool while water is slow to heat and cool. Large continental land masses like China tend to have more extreme annual temperature ranges and generally less rainfall.

- North – south mountain ranges interrupt prevailing east or west winds causing orographic uplift, expansional cooling of air masses, and precipitation. Windward sides of mountains have wetter climates; leeward side tend to be dry.



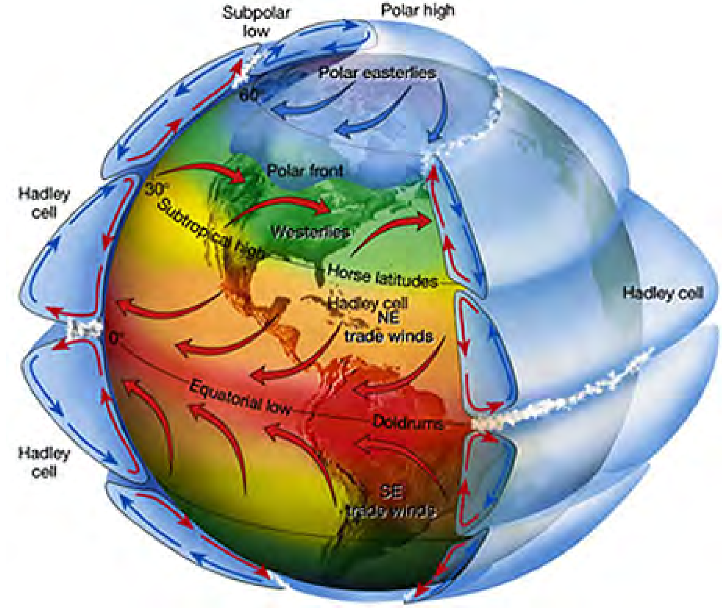


Factors that influence Climate:

Atmospheric Circulation -- Three Cell Model

- In this model, the equator is the warmest location on Earth and acts as a zone of **thermal lows** known as the **Intertropical convergence zone** (**ITCZ**).
- The ITCZ draws in surface air from the subtropics. As it reaches the equator, it rises into the upper atmosphere by **convergence** and **convection**. It attains a maximum vertical altitude of about 14 kilometers (top of the **troposphere**). It then begins flowing horizontally toward the North and South Poles.
- **Coriolis force** causes the deflection of this moving air. At about 30° latitude the air begins to flow zonally from west to east.

Three Cell Model

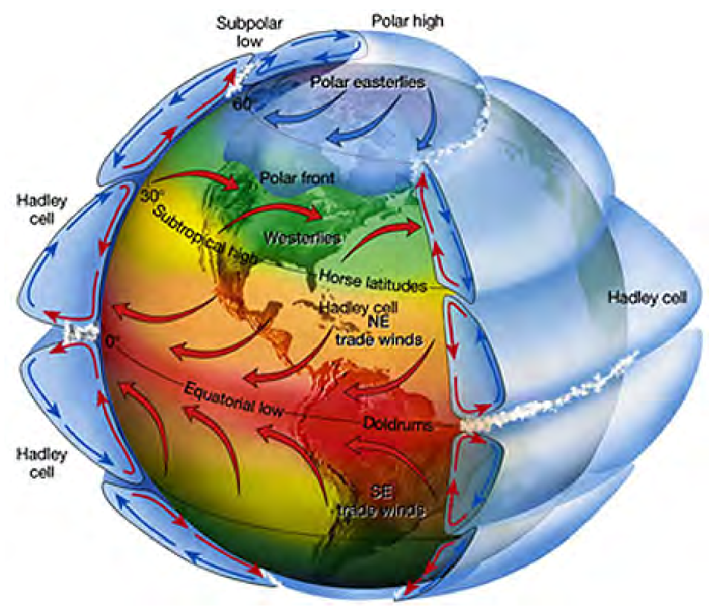


Factors that influence Climate:

Atmospheric Circulation -- Three Cell Model

- This zonal flow is known as the subtropical jet stream. The zonal flow also causes the accumulation of air in the upper atmosphere as it is no longer flowing meridionally.
- To compensate for this accumulation, some of the air in the upper atmosphere sinks back to the surface creating the subtropical high pressure zone. From this zone, the surface air travels in two directions.
- A portion of the air moves back toward the equator completing the circulation system known as the Hadley cell. This moving air is also deflected by the Coriolis effect to create the Northeast Trades (right deflection) and Southeast Trades (left deflection).

Three Cell Model



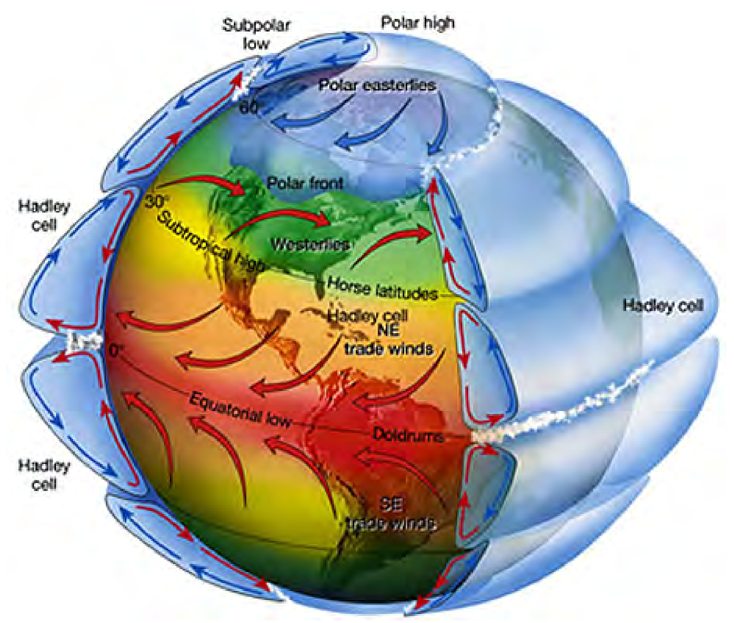
Factors that influence Climate:

Atmospheric Circulation -- Three Cell Model

- The surface air moving toward the poles from the subtropical high zone is also deflected by Coriolis acceleration producing the **Westerlies**.
- Between latitudes 30° to 60° N and S, upper air winds blow generally towards the poles. Coriolis force deflects this wind to cause it to flow W to E forming the **polar jet stream** at ~ 60° N and S.

http://www.physicalgeography.net/fundamentals/7p.html

Three Cell Model

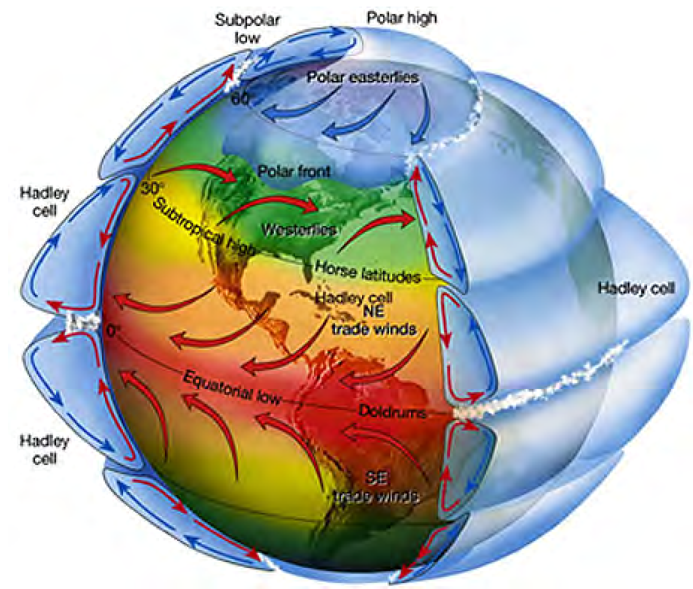


Factors that influence Climate:
Atmospheric Circulation Three Cell Model

- On the Earth's surface at 60° North and South latitude, the subtropical Westerlies collide with cold air traveling from the poles. This collision results in **frontal uplift** and the creation of the **sub-polar lows** or **mid-latitude cyclones**.
- A small portion of this lifted air is sent back into the **Ferrel cell** after it reaches the top of the troposphere. Most of this lifted air is directed to the **polar vortex** where it moves downward to create the **polar high**.

http://www.physicalgeography.net/fundamentals/7p.html

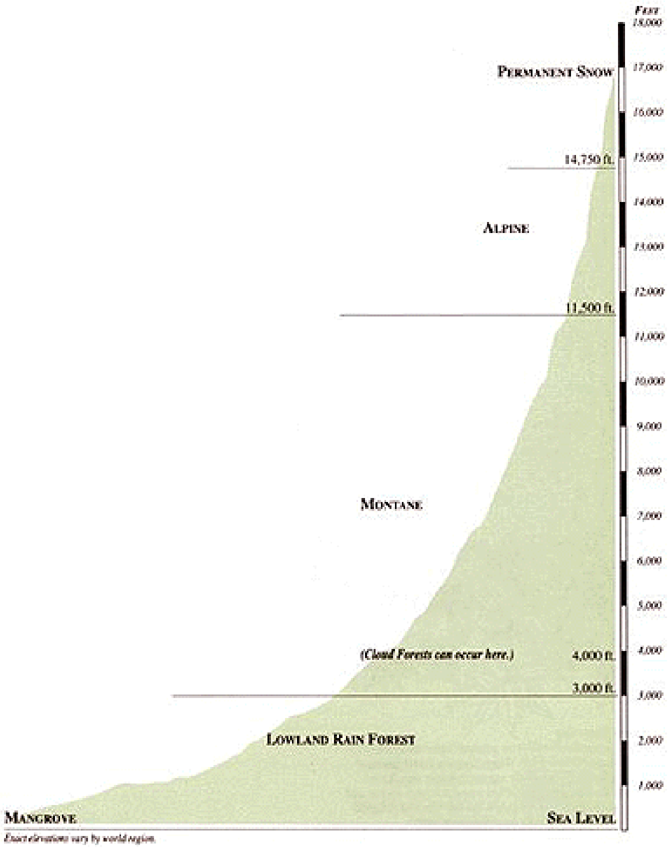
Three Cell Model



Factors that influence Climate:
Altitude Mimics the Effect of Latitude

- For each 1,000 foot rise in altitude there is a 4°F drop in temperature. If, for example, at sea level the average temperature is 75°F, at 10,000 feet the average temperature would be only 35°F.
- This has a dramatic effect on the distribution of plants and animals (the climate).
  http://mbgnet.mobot.org/sets/rforest/explore/elev.htm

Temperature Changes due to Altitude



Factors that influence Climate:
Oceans and the moderating effect of water

- The oceans influence climate over both long and short time-scales.
- The oceans and the atmosphere are tightly linked and together form the most dynamic component of the climate system.
- The oceans play a critical role in storing heat and carbon.

  http://www.gdrc.org/oceans/fsheet-01.html

Earth's Oceans Affect Climate

Factors that Influence Climate:
Oceans and the Moderating Effect of Water

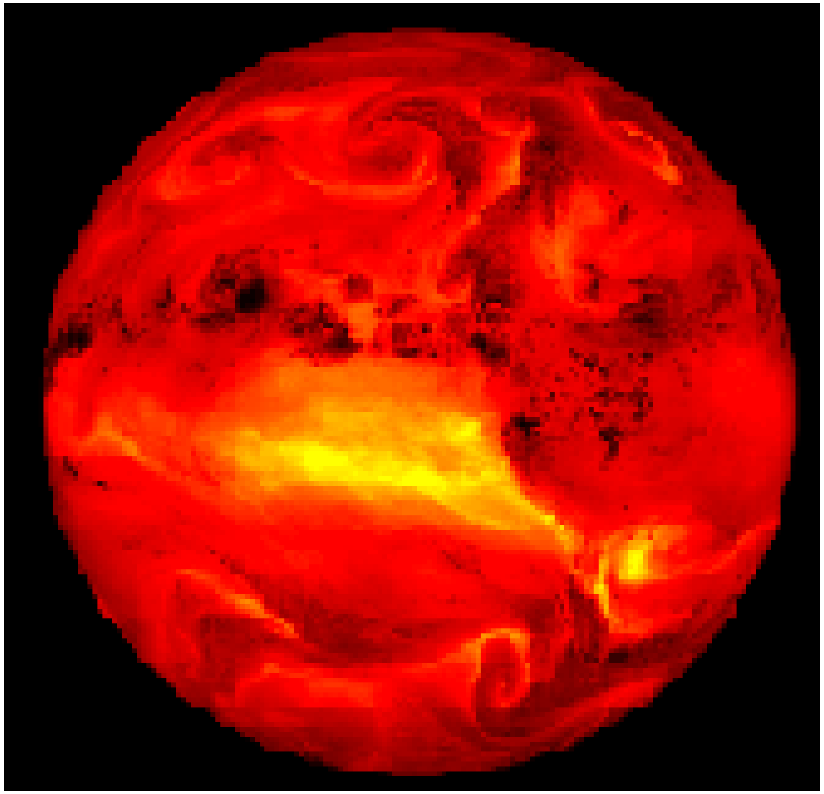
- The ocean's waters are constantly moving about by powerful currents.
- These currents influence the climate by transport-ing heat.
- Currents involved in "deep-water formation" are particularly influential on climate.

http://www.gdrc.org/oceans/fsheet-01.html

Earth's Oceans Affect Climate

Earth's Evolving Atmosphere:
It has changed throughout its 4.5 billion years.

- Not only does the Earth have a complex atmosphere, but that atmosphere has complicated motion and nontrivial behavior.
- The false color image to the right shows the circulation of water vapor in our atmosphere.
- Earth's atmosphere as it is today bears little resemblance to the early atmospheres of Planet Earth.



http://csep10.phys.utk.edu/astr161/lect/earth/weather.html

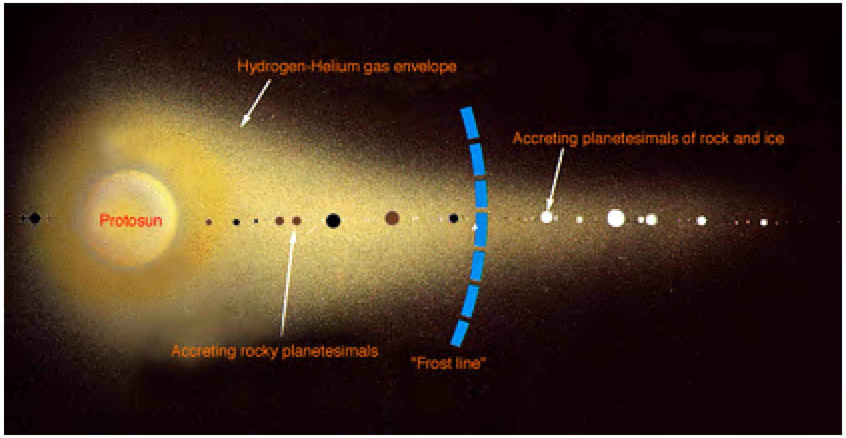
Earth's Evolving Atmosphere: First Atmosphere

- Composition - probably H_2 and He, the stuff of stars
- These gases are relatively rare on Earth compared to other places in the universe. They were probably lost to space early in Earth's history.
- Earth had to accrete more mass and form a differentiated core before an atmosphere could be retained.

(AURA/STScI/NASA)

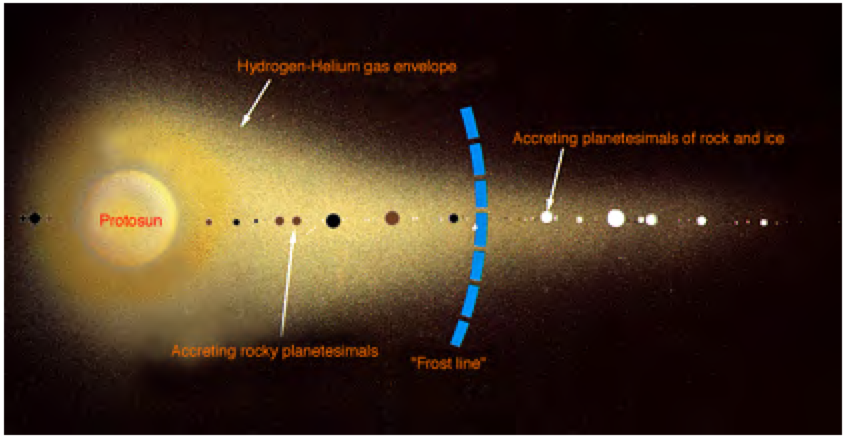
Earth's Evolving Atmosphere: Second Atmosphere

- Earth now had condensed enough mass to hold onto an atmosphere
- The atmosphere was produced by outgassing from ancient volcanoes and meteorite impacts.
- These gasses are similar to those produced by modern volcanoes (H_2O, CO_2, SO_2, CO, S_2, Cl_2, N_2, H_2) and NH_3 (ammonia) and CH_4 (methane).



Earth's Evolving Atmosphere: Second Atmosphere

- No free O_2 at this time (not found in volcanic gases).
- As Earth cooled, H2O produced by outgassing and meteorite impacts could exist as liquid, allowing oceans to form.



http://volcano.und.edu/vwdocs/Gases/origin.html
http://www.globalchange.umich.edu/globalchange1/current/lectures/first_billion_years/first_billion_years.html

Earth’s Evolving Atmosphere: Oceans, Bacteria and Sunlight

- 4.0 to 2.5 bya there was little to no free oxygen even though it was being produced by cyanobacteria and the photo-dissociation of water.
- What free oxygen there was, was coming into equilibrium with vast oceans and being consumed by the weathering process (oxidation of rocks).

- Modern stromatolites nearly identical to those of 4.0 bya.

Earth's Evolving Atmosphere: Oceans, Bacteria and Sunlight

- Once rocks at the surface had been sufficiently oxidized and the ocean were in equilibrium, the atmosphere became enriched with O_2.
- At the same time the atmosphere was being reduced in its CO_2 content by a geochemical process, CO_2 was forced into equilibrium by newly created oceans and through a geochemical process locking it up in shells and rocks.

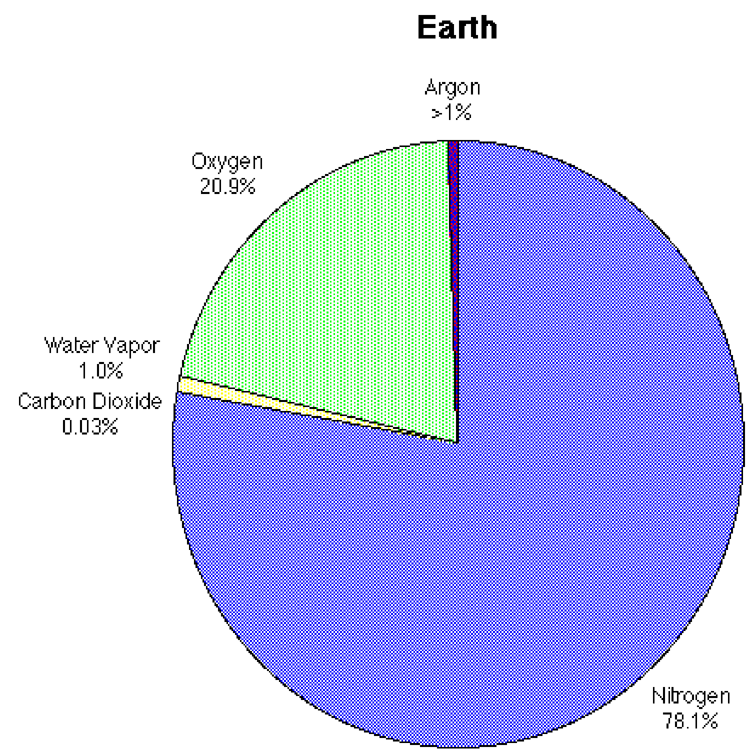
http://www.ucmp.berkeley.edu/bacteria/cyanofr.html

- Modern stromatolites nearly identical to those of 4.0 bya.

Earth's evolving atmosphere: Our Modern Atmosphere

- Our modern atmo-sphere derived from a combination of events
- Photochemical: Inter-action of UV radiation with water molecules releasing O_2
- Photochemical: Inter-action of UV with O_2 molecules to form O_3, or ozone, encouraged the evolution of terrestrial life.

Earth's Present-Day Atmosphere



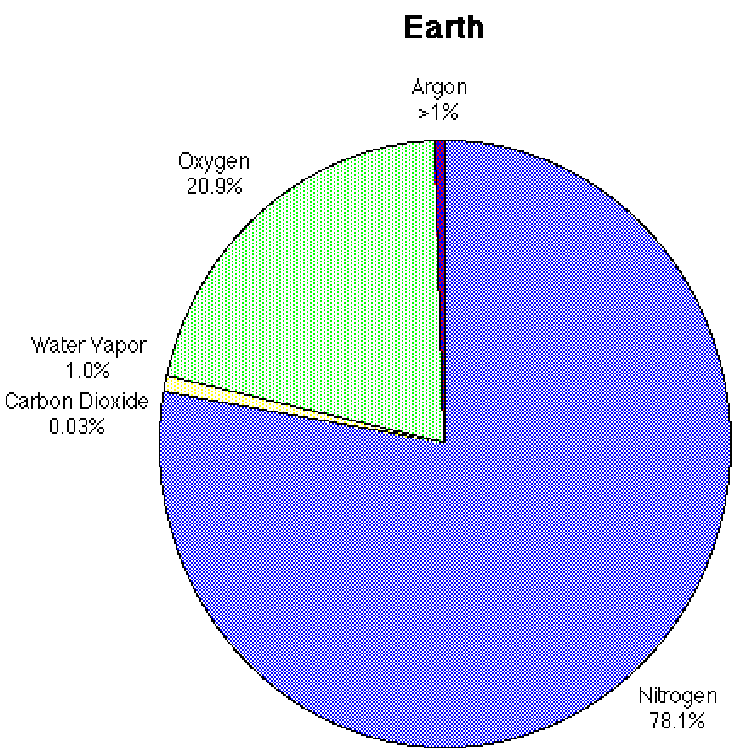
Earth's evolving atmosphere:
Our Modern Atmosphere

- Geochemical: locking up vast amounts of CO_2 in the oceans and ocean sediments
- Biochemical: the production of O_2 by cyanobacteria and later blue green algae and other plants

http://www.physicalgeography.net/fundamentals/7a.html

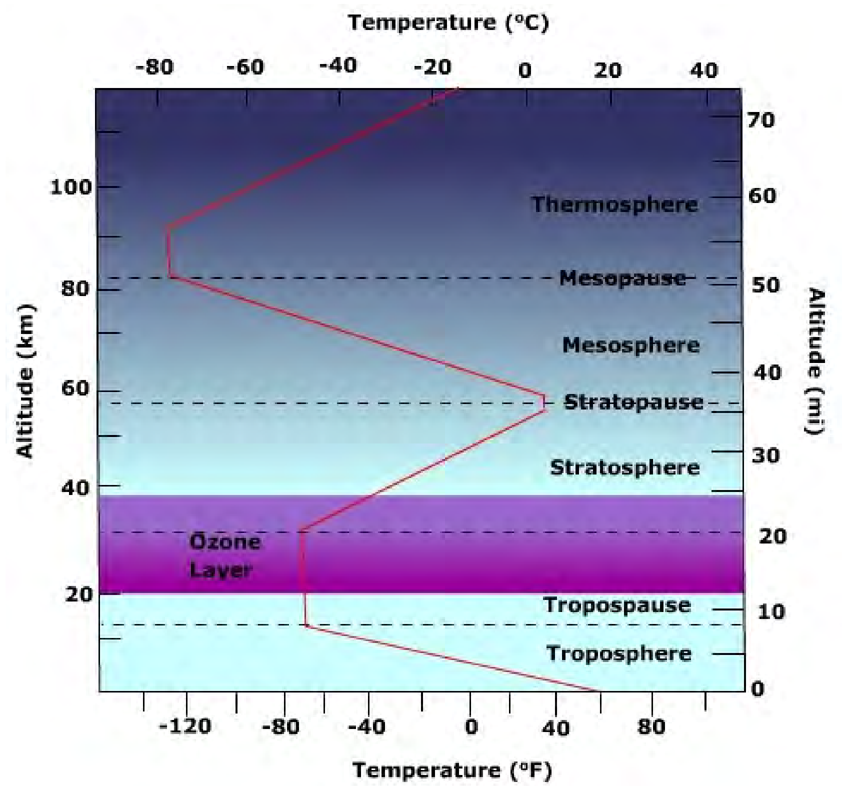
http://science.hq.nasa.gov/earth-sun/science/atmosphere.html

Earth's Present-Day Atmosphere



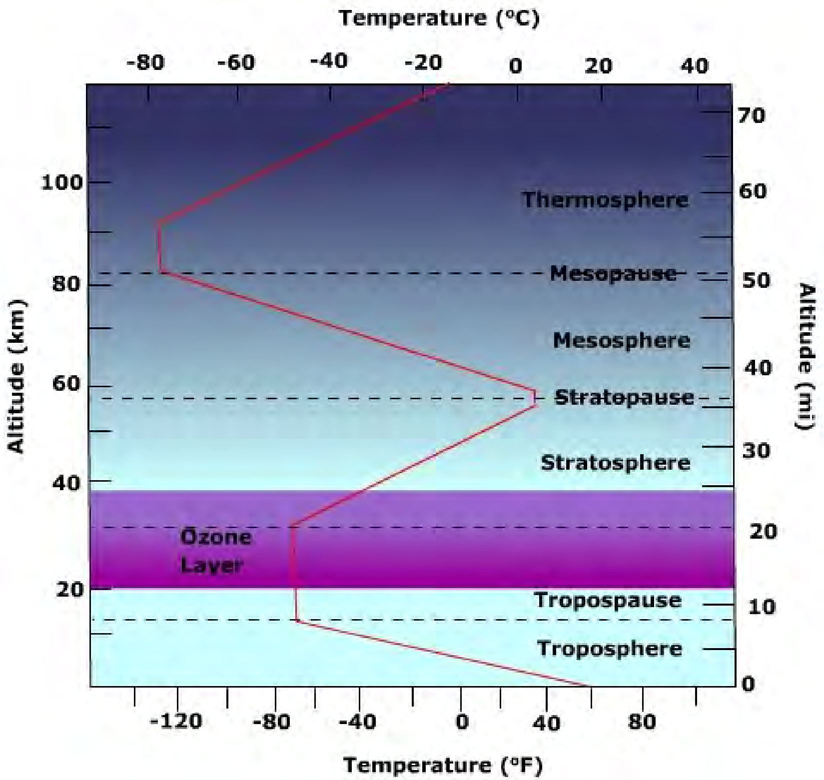
Earth's evolving atmosphere: Our Modern Atmosphere

- Our atmosphere is a thin gossamer veil that allows life on land.
- It has physical structure based upon temperature
- The troposphere is the realm of weather
- Stratosphere houses 90% of the ozone
- Radiosonde measuring devices are routinely launched into the mesosphere.



Earth's evolving atmosphere: Our Modern Atmosphere

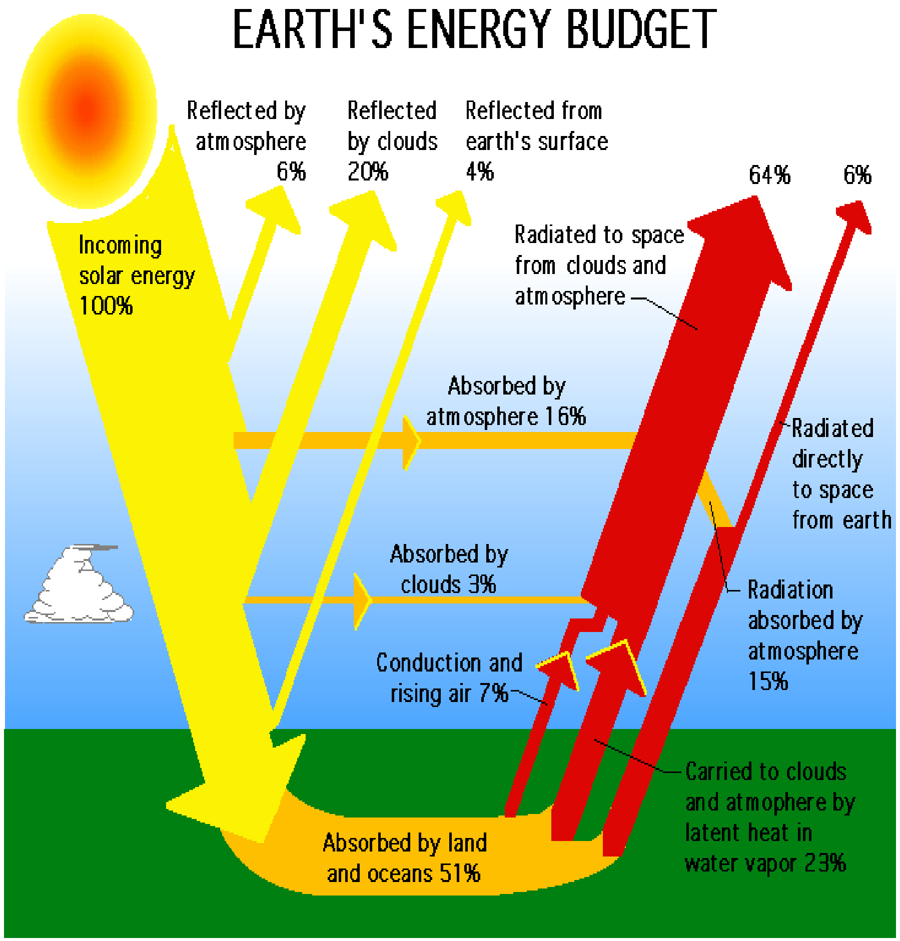
- Aurora occur within the thermosphere.
- Exosphere extends some 10,000 meters and is the buffer between our atmosphere and space
- It is thought that during periods of an active sun that the temperature in the thermosphere can increase by several thousand degrees



Planetary Energy Balance:

Alterations Can Dramatically Impact Climate and Weather

- Absorption and re-emission of radiation at Earth's surface is but one part of an intricate web of heat transfer in Earth's planetary domain.
- Equally important are the selective absorption and emission of radiation from molecules in the atmo-sphere.

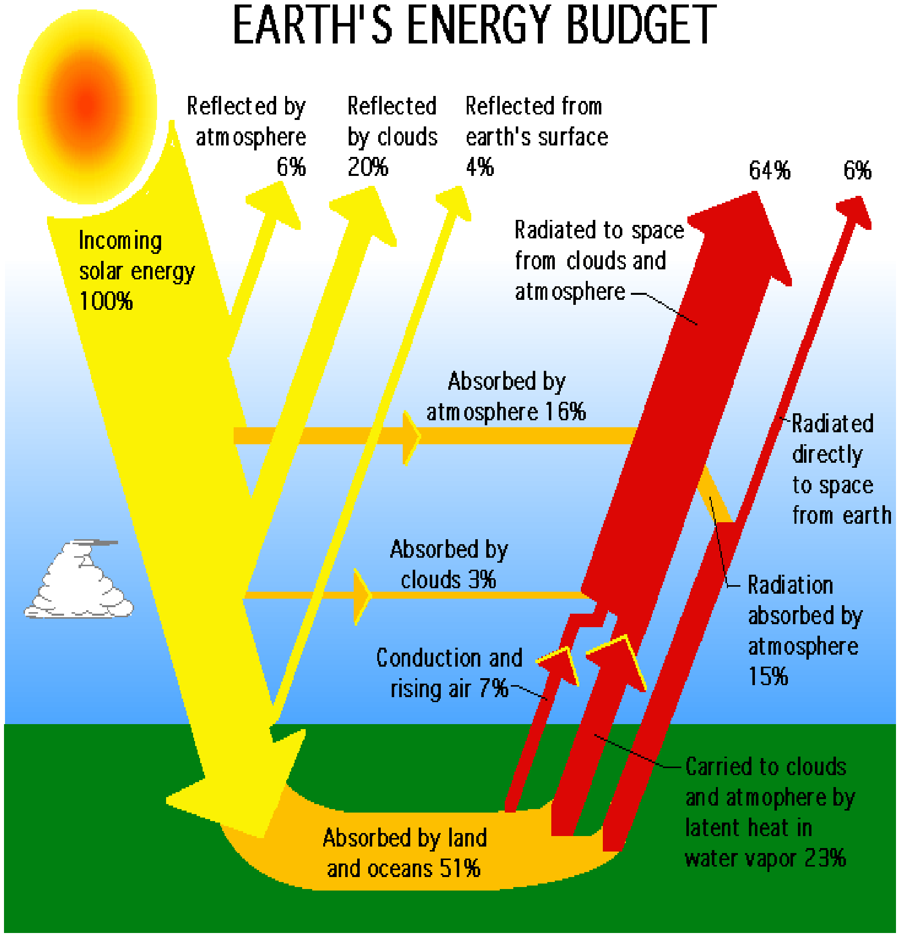


Planetary Energy Balance:

Alterations Can Dramatically Impact Climate and Weather

- If Earth did not have an atmosphere, surface temperatures would be too cold to sustain life.
- If too many gases that absorb and emit infrared radiation were present in the atmosphere, surface temperatures would be too hot to sustain life.

http://okfirst.ocs.ou.edu/train/meteorology/EnergyBudget2.html

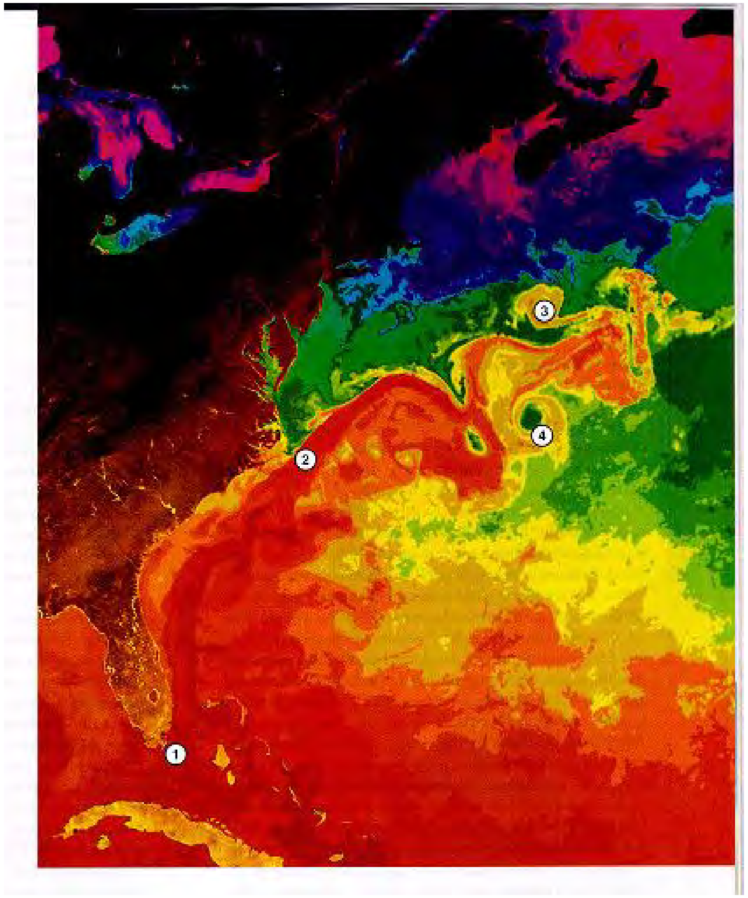


Oceanic and Atmospheric Circulation: The Great Modulators of Climate

- Ocean circulation acts to transfer global heat from the middle latitudes to the poles
- To this end it uses surface circulation patterns and deep water circulation patterns (the thermohaline current)

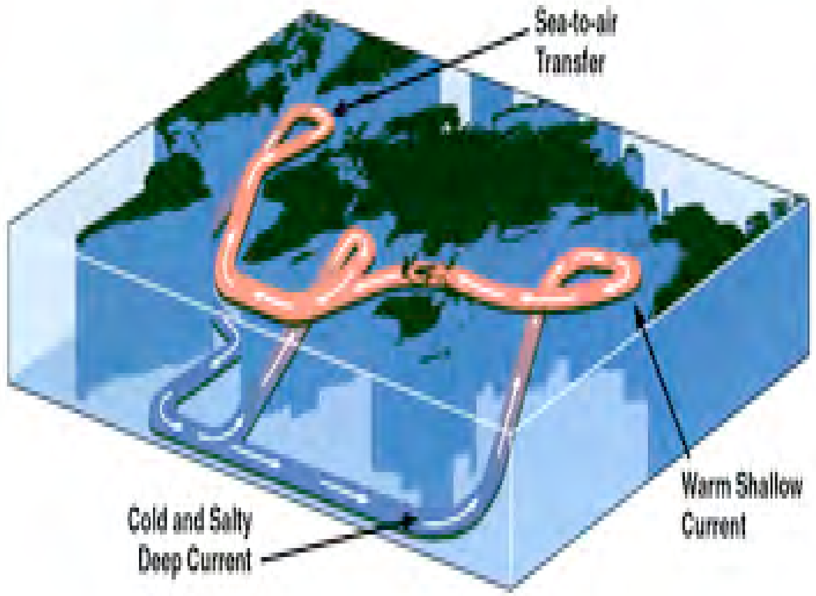
  http://earth.usc.edu/~stott/Catalina/Oceans.html

The gulf steam is a surface current that controls climate in Europe and England



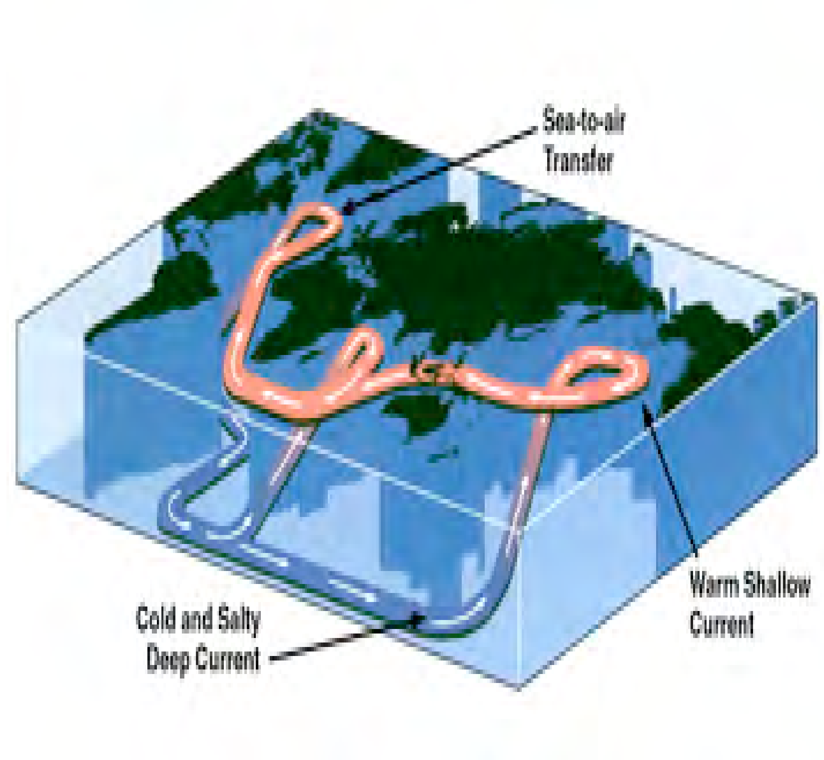
Oceanic and Atmospheric Circulation: The Great Modulators of Climate

- Deep water currents modulate heat exchange between the poles and the equator. and are therefore critical to climate.
- Evidence indicates that in a matter of decades not millennia they can change the climate of Planet Earth.
- The term thermohaline is derived from “thermo” for temperature followed by “haline” for salt.



Oceanic and Atmospheric Circulation: The Great Modulators of Climate

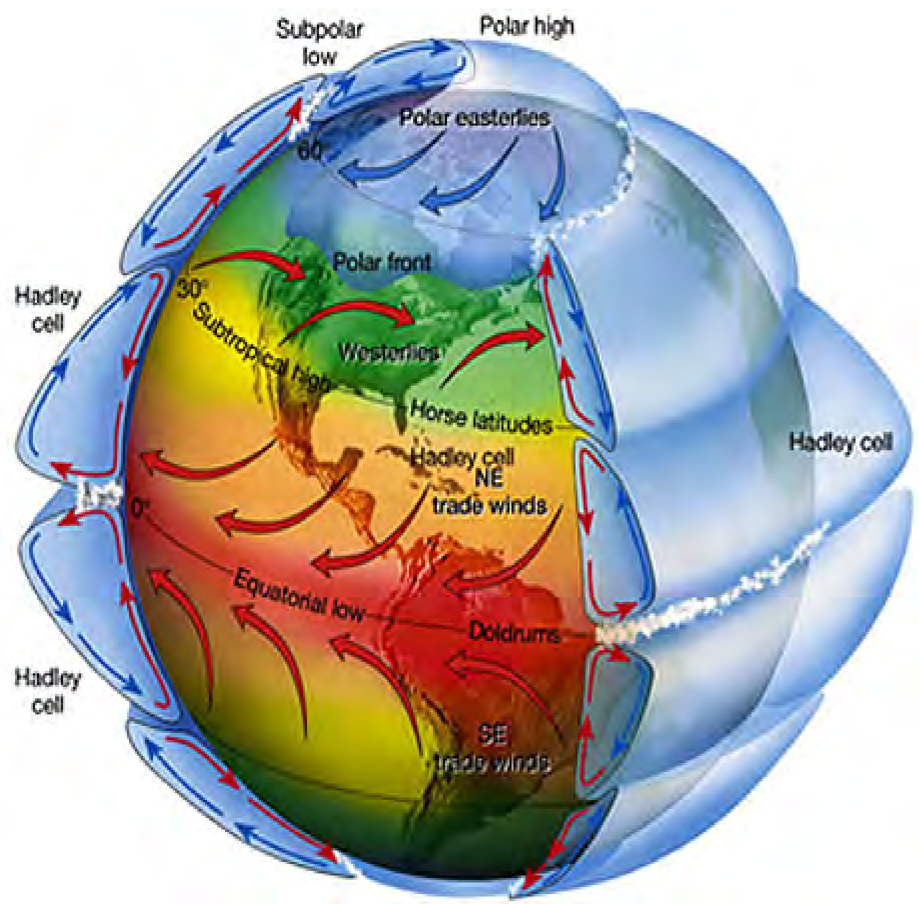
- Thermohaline currents are driven by differences in the density of seawater at different locations.
- Thermohaline currents have a significant vertical component and account for the thorough mixing of the deep masses of ocean water.



http://www.windows.ucar.edu/tour/link=/earth/Water/deep_ocean.html

Oceanic and Atmospheric Circulation: The Great Modulators of Climate

- The atmospheric circulation model (the three cell model) can predict climates on earth.
- It also interacts with surface oceanic currents
- Wind driven circulation is set into motion by moving air masses with the motion being confined primarily to horizontal movement in the upper waters of the oceans.
- Interaction between the two circulates equatorial heat and polar cold thus moderating the temperatures on planet earth and keeping earth zoned for terrestrial life.



Oceanic and Atmospheric Circulation: The Great Modulators of Climate

- The "three cell" circulation model refers to the very general, global pattern of winds.

  1. Hadley cells are thermally direct cells.
  2. Ferrel cells are indirect cells formed from air motions initiated by adjacent cells.
  3. Polar cells are thermally direct cells formed by cold temperatures near the poles.

Oceanic and Atmospheric Circulation: The Great Modulators of Climate

- **Three Cell Model: Hadley Cell**
- The pressure cells between the equator and 30°N and 30°S are known as Hadley Cells, named for George Hadley who suggested their existence in 1735.
- These cells transport heat from the equator to the colder temperate and polar regions.
- Pressure and winds associated with Hadley cells are close approximations of real world surface conditions, but are not representative of upper air motions.

Oceanic and Atmospheric Circulation: The Great Modulators of Climate

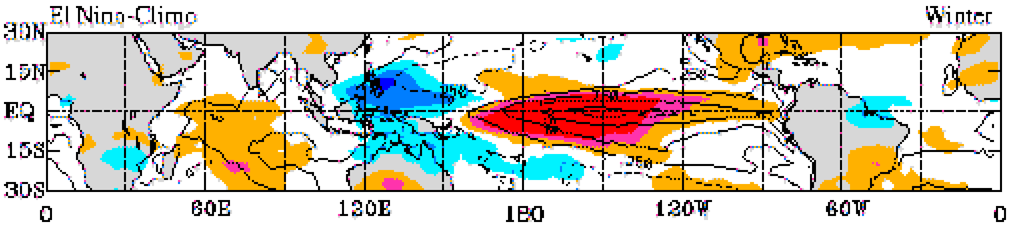
- **Three Cell Model: Polar Cell**
- Air in polar cells becomes very dense due to extremely cool temperatures. This results in sinking motions indicative of high pressure.
- Air moving toward the equator is deflected by the Coriolis effect creating the polar easterlies in both hemispheres.

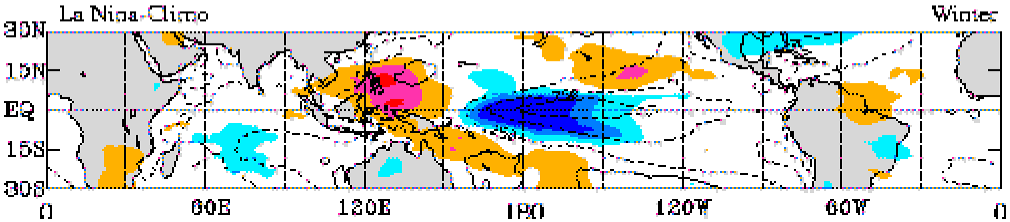
Oceanic and Atmospheric Circulation: The Three Cell Model: Ferrel Cell

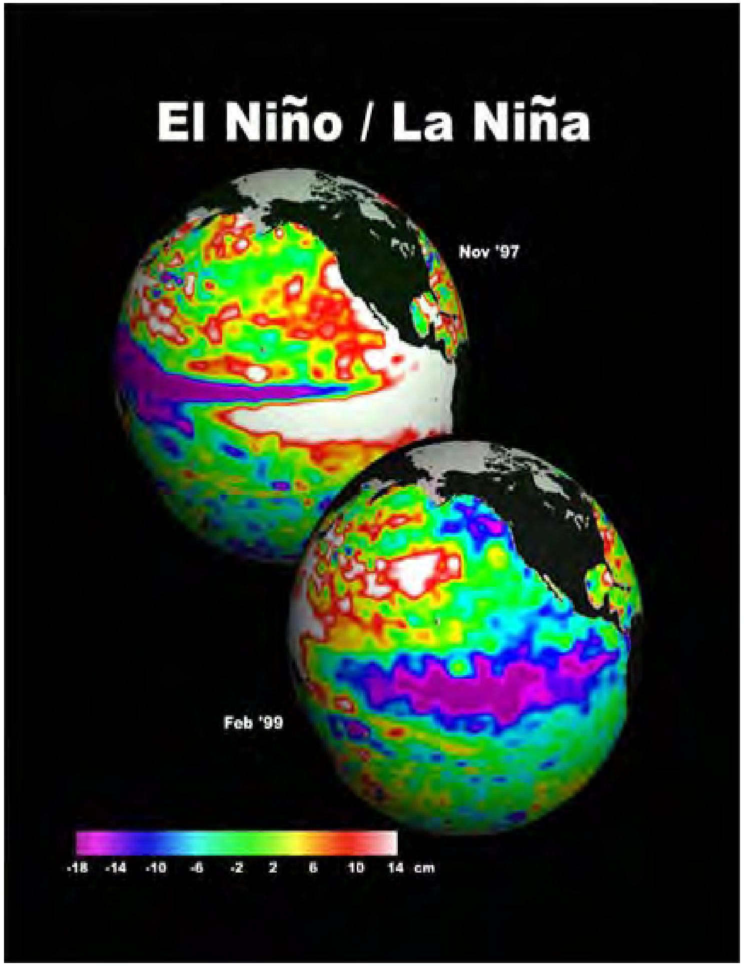
- The Ferrel Cell forms at the mid-latitudes of a rotating planet to balance the transport by the Hadley and polar cells.
- At the surface, Ferrel Cells form the southwesterly prevailing westerlies.
- The Ferrel Cells and Hadley Cells meet at the horse latitudes.

Oceanic and Atmospheric Circulation: The Great Modulators of Climate

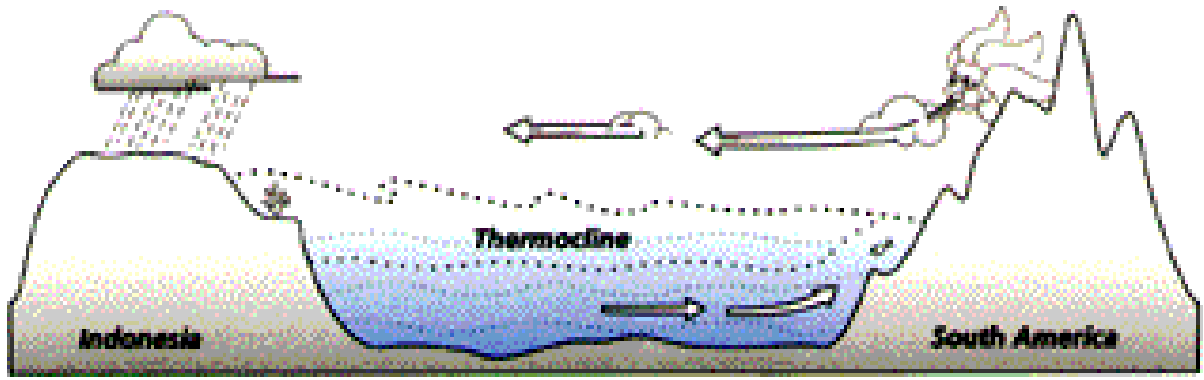
- **El Niño and la Niña**
- **http://topex-www.jpl.nasa.gov/science/el-nino.html**
- **http://www.nationalgeographic.com/elnino/mainpage.html**
- **http://sealevel.jpl.nasa.gov/science/el-nino.html**
- **http://www.nationalgeographic.com/elnino/**
- **http://www.cdc.noaa.gov/ENSO/**







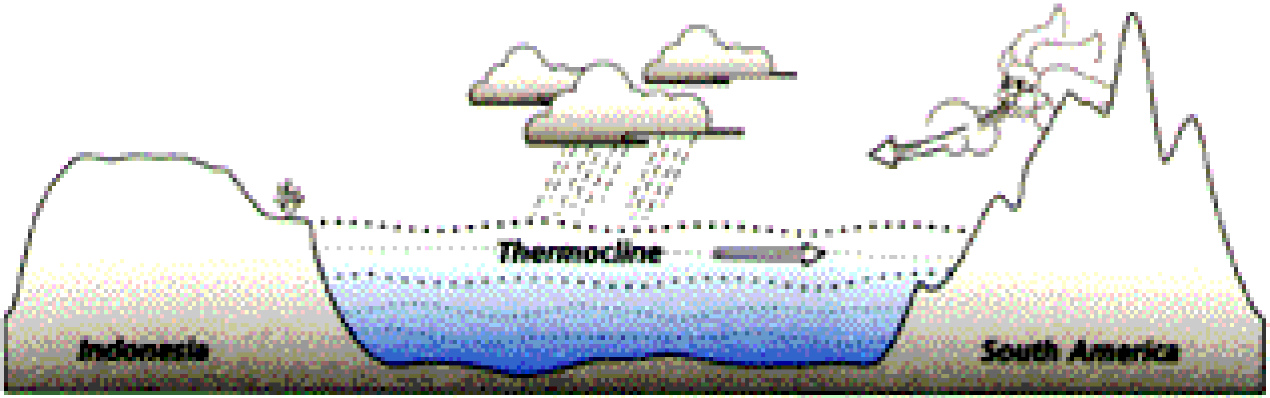
Oceanic and Atmospheric Circulation: The Great Modulators of Climate



Sharron Sample, Curator, SAIC Information Services

- Non **El Niño** conditions: normally, strong trade winds blow from the east along the equator, pushing warm water into the Pacific Ocean. This permits an upwelling of cold waters along the South American coast bringing nutrients to the surface which, in turn, attracts fish.

Oceanic and Atmospheric Circulation: The Great Modulators of Climate

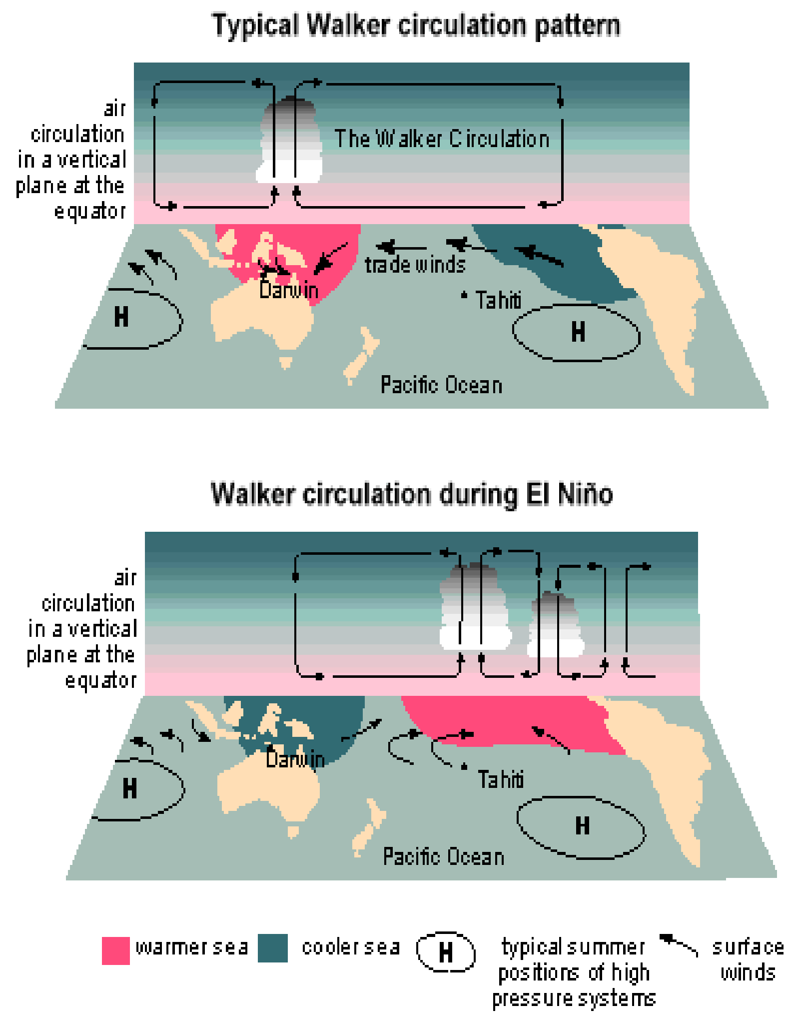


Sharron Sample, Curator, SAIC Information Services

- **El Niño** condition results from weakened trade winds in the western Pacific Ocean near Indonesia, allowing piled-up warm water to flow toward South America. This pile-up prevents cool ocean waters from upwelling, upsetting the food chain.

Oceanic and Atmospheric Circulation: The Walker Circulation

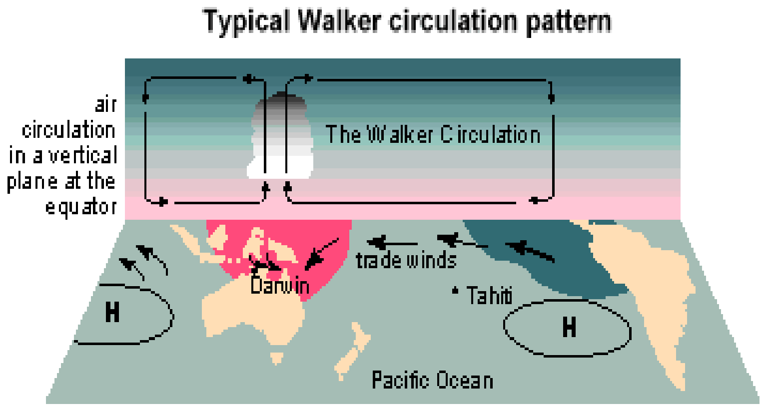
The easterly trade winds are part of the low-level component of the Walker circulation. Typically, the trades bring warm moist air towards the Indonesian region. Here, moving over normally very warm seas, moist air rises to high levels of the atmosphere. The air then travels eastward before sinking over the eastern Pacific Ocean.

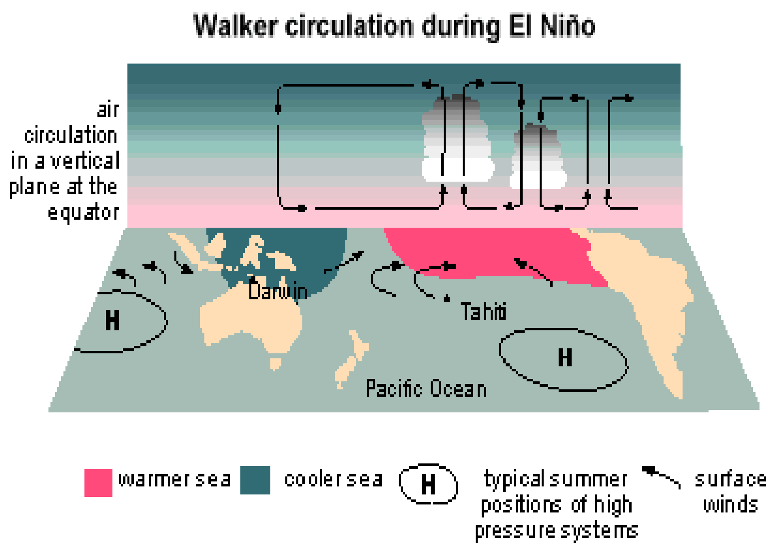


Oceanic and Atmospheric Circulation: The Walker Circulation

- The rising air is associated with a region of low air pressure, towering cumulo-nimbus clouds and rain. High pressure and dry conditions accompany the sinking air. The wide variations in patterns and strength of the Walker circulation from year to year are shown in the diagram to the right.

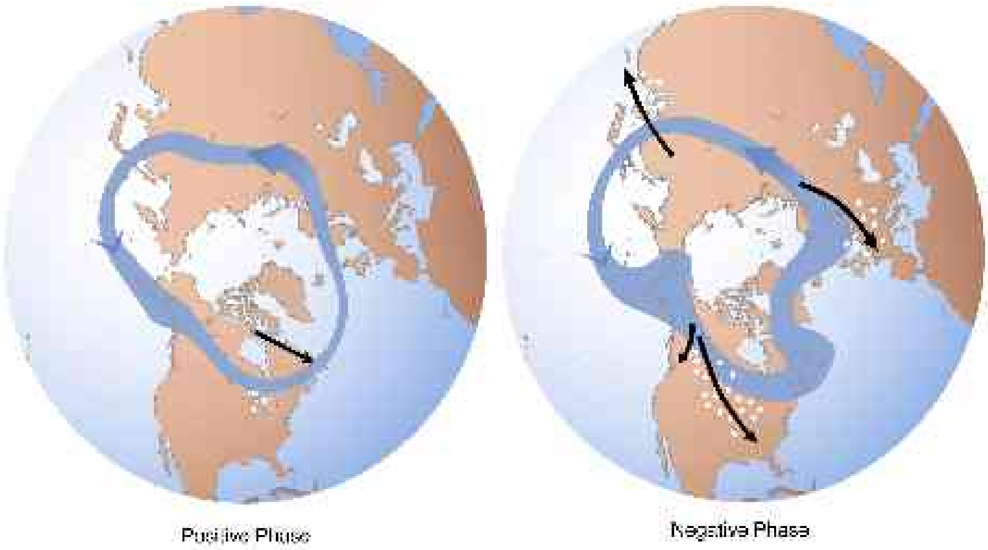
  http://www.bom.gov.au/lam/climate/levelthree/analclim/elnino.htm#four





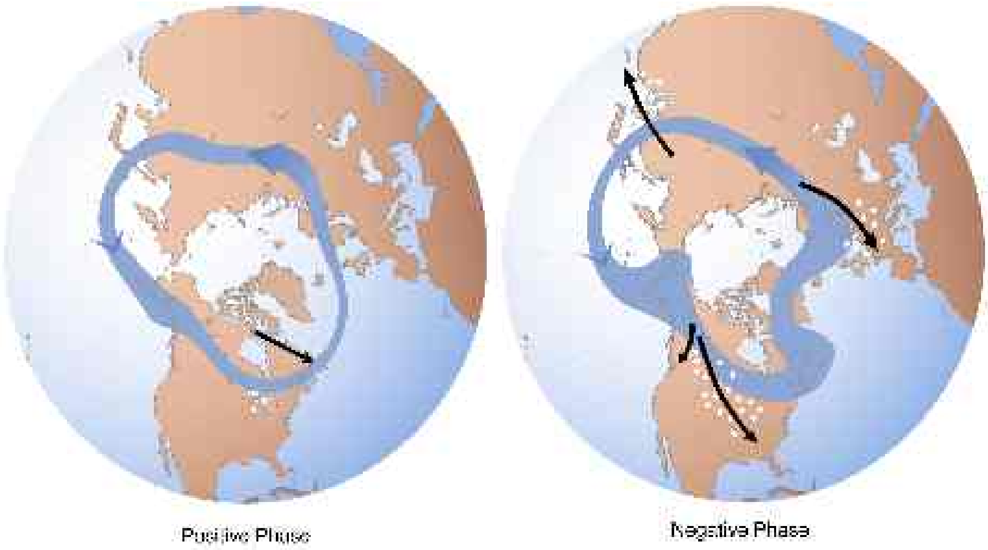
Oceanic and Atmospheric Circulation: The Pacific and Arctic Oscillation

The Arctic Oscillation (AO) appears to be the cause for much of the recent changes that have occurred in the Arctic. Its effects are not restricted just to the Arctic; it also represents an important source of variability for the Northern Hemisphere as a whole.



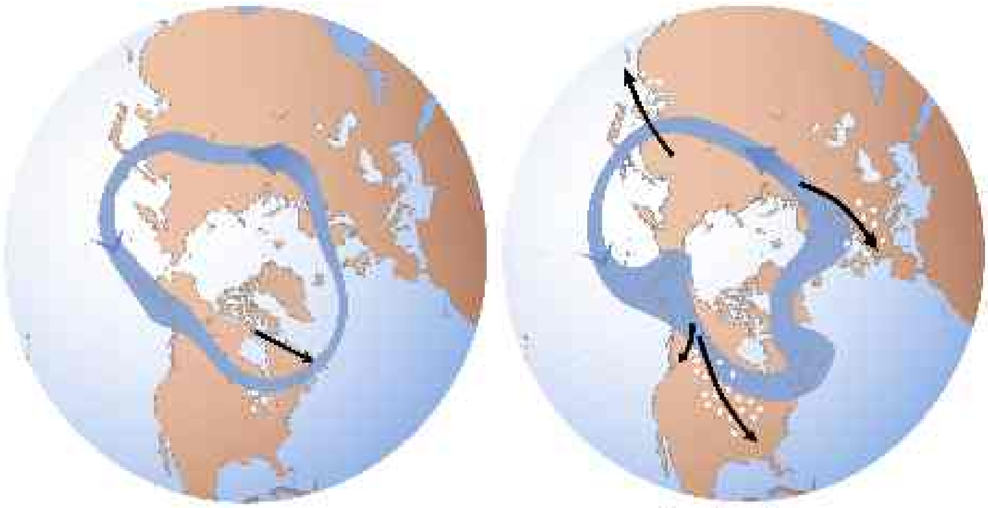
Oceanic and Atmospheric Circulation: The Pacific and Arctic Oscillation

- The Pacific oscillation is strongly correlated with the air-sea interactions in the North Pacific. The effects of abnormal atmospheric conditions over the North Pacific affect both the currents and temperature of the ocean, which in turn, may feedback on the atmosphere.



Oceanic and Atmospheric Circulation: The Pacific and Arctic Oscillation

The ultimate result of variations in these modes is the tangible effect on wintertime conditions in the Bering Sea, Alaska and western Canada.



Positive Phase   Negative Phase

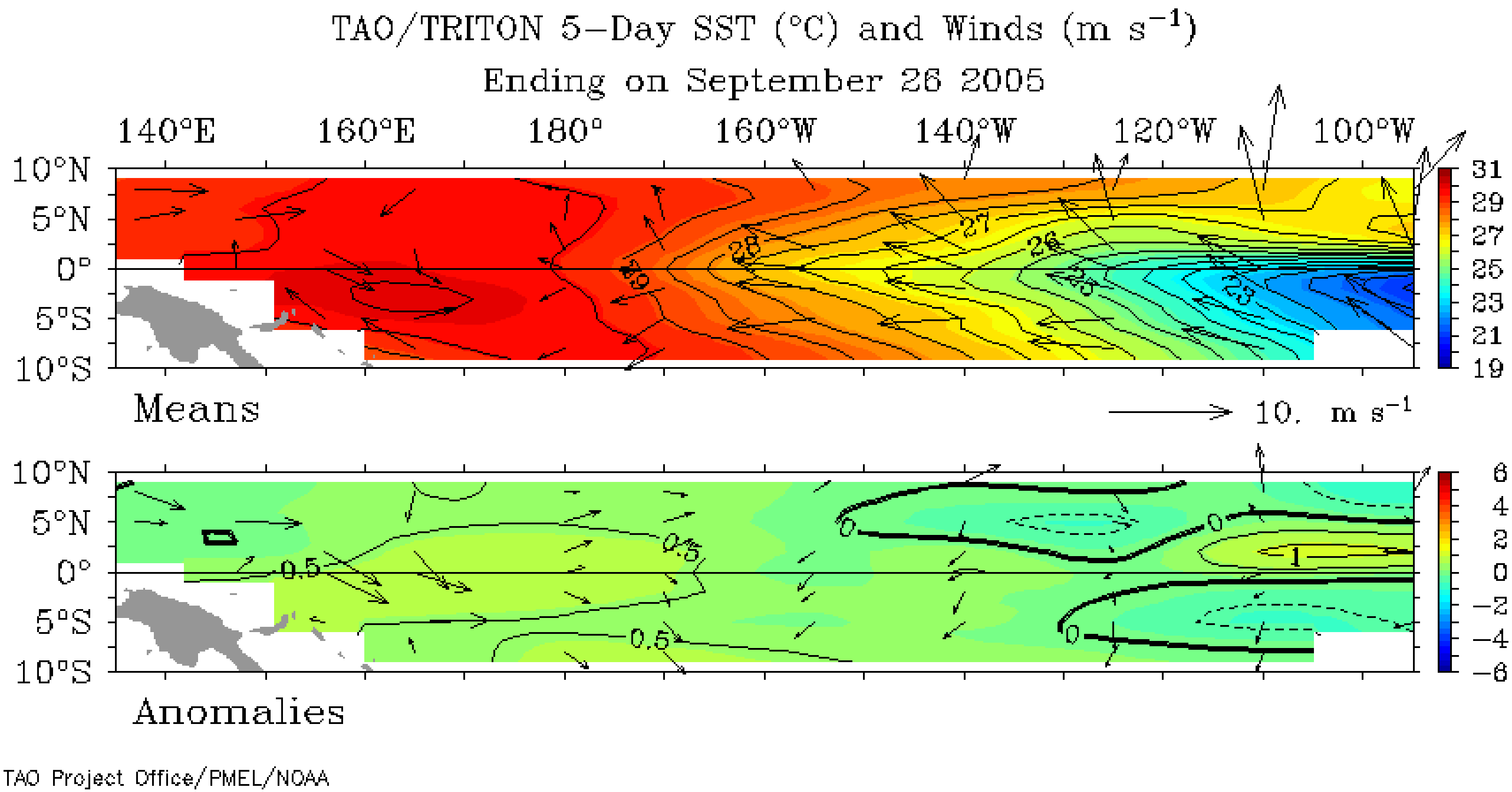
http://www.arctic.noaa.gov/essay_bond.html

Oceanic and atmospheric Circulation: The Southern Oscillation

- The Southern Oscillation is the see-saw pattern of reversing surface air pressure between the eastern and western tropical Pacific. When the surface pressure is high in the eastern tropical Pacific, it is low in the western tropical Pacific, and vice-versa.
- Because the ocean warming and pressure reversals are, for the most part, simultaneous, scientists call this phenomenon the El Niño/ Southern Oscillation, or ENSO for short.

Oceanic and atmospheric Circulation: The Southern Oscillation

- **http://www.grida.no/climate/vitalafrica/english/04.htm**



Paleoclimates of planet Earth

- The climate of Earth has not been constant, in fact it has changed dramatically over time.
- The study of Earth's ancient climates has become a reality as science has developed new technologies.
- Ancient climates of Earth may be discovered or inferred by many means
  - The fossil record – gives us an idea of the climate by knowing plant and animal assemblages
  - Ocean sediments – gives us climatic information over hundreds of thousands of years by study of O^{16}/O^{18} ratios in foraminifera
  - Corals – over hundreds or thousands of years
  - Ice cores – over tens of thousands of years
  - Dendrochronology – over a few thousand years

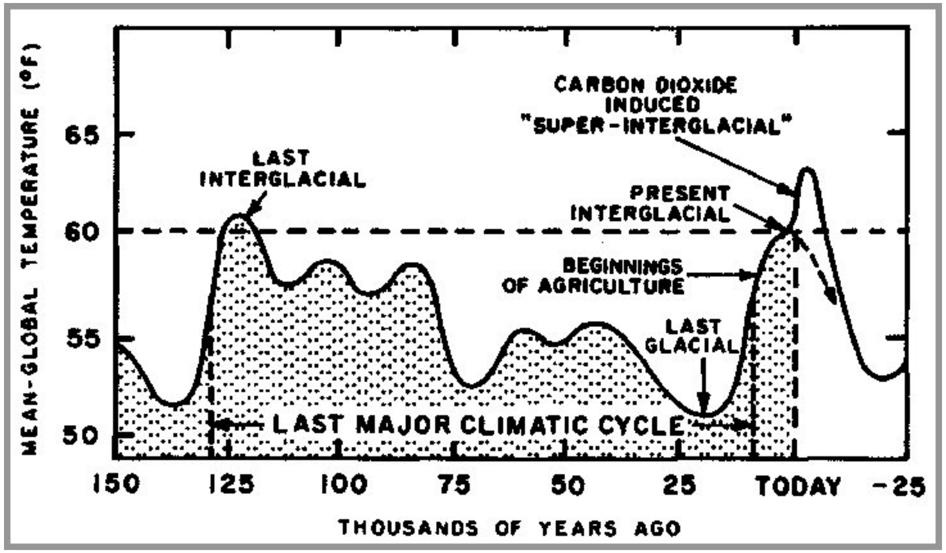
Paleoclimates of Planet Earth: Snowball Earth

- Many lines of evidence support a theory that the entire Earth was ice-covered for long periods 600-700 million years ago. Each glacial period lasted for millions of years and ended violently under extreme greenhouse conditions. These climate shocks triggered the evolution of multicellular animal life, and challenge long-held assumptions regarding the limits of global change.

- http://www.eps.harvard.edu/people/faculty/hoffman/snowball_paper.html
- http://www.eurekalert.org/pub_releases/2005-09/uosc-scd092805.php

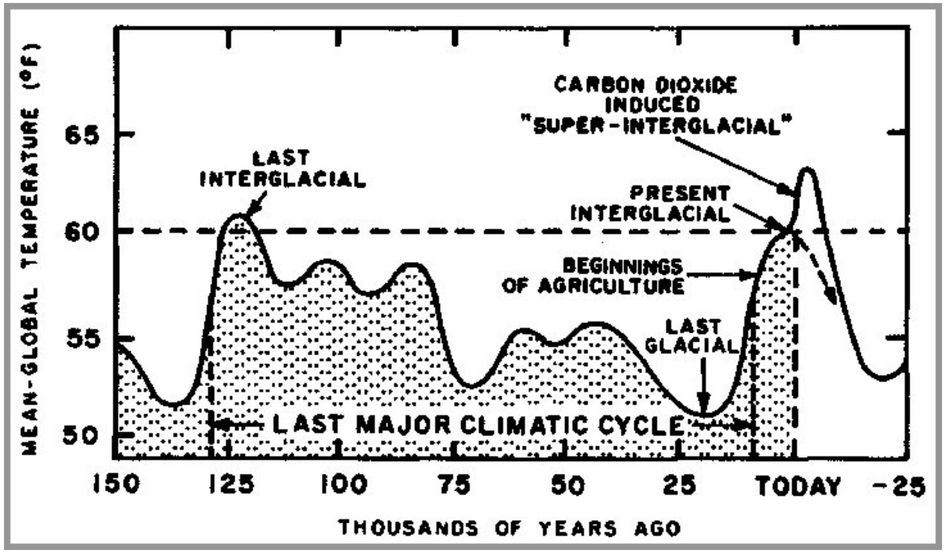
Paleoclimates of Planet Earth: The Pleistocene Ice Ages

- Fluctuations in the amount of insolation (incoming solar radiation) are the most likely cause of large-scale changes in Earth's climate during the Quaternary. Variations in the intensity and timing of heat from the sun are the most likely cause of the glacial/interglacial cycles.



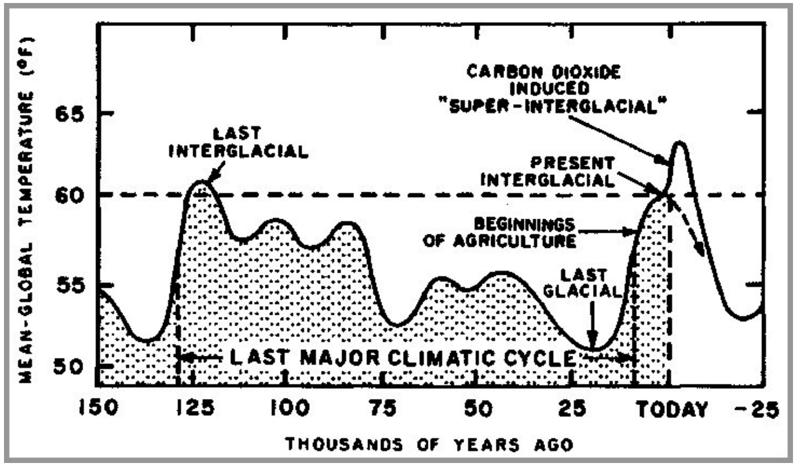
Paleoclimates of Planet Earth: The Pleistocene Ice Ages

- This solar variable was neatly described by the Serbian scientist, Milutin Milankovitch, in 1938.
- There are three major components of the Earth's orbit about the sun that contribute to changes in our climate.



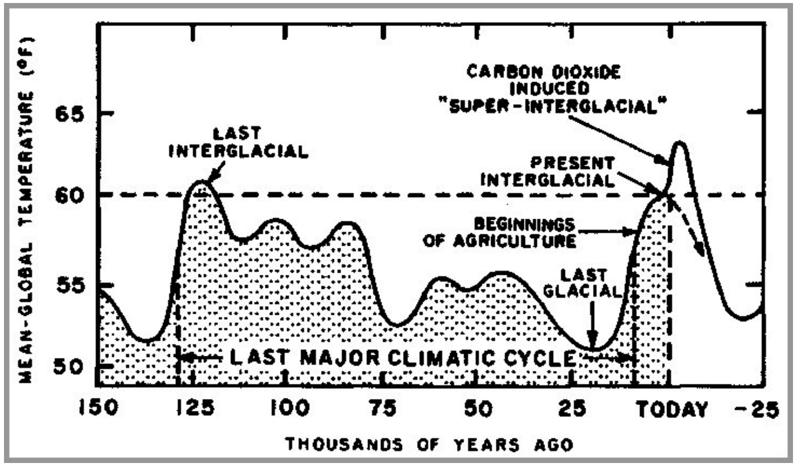
Paleoclimates of Planet Earth: The Pleistocene Ice Ages

First, the Earth's spin on its axis is wobbly, much like a spinning top that starts to wobble after it slows down. This wobble amounts to a variation of up to 23.5 degrees to either side of the axis. The amount of tilt in the Earth's rotation affects the amount of sunlight striking the different parts of the globe. The cycle takes place over a period of 41,000 years.



Paleoclimates of Planet Earth: The Pleistocene Ice Ages

As a result of a wobble in the Earth's spin, the position of the Earth on its elliptical path changes, relative to the time of year. This phenomenon is called the precession of equinoxes. The cycle of equinox precession takes 23,000 years to complete. In the growth of continental ice sheets, summer temperatures are probably more important than winter.



Paleoclimates of Planet Earth: Younger Dryas Cold Period

- Warming at the end of the last ice age ~15,000 years ago melted the ice sheets over North America resulting in an increase in freshwater input to the North Atlantic.
- This reduced the saltiness of seawater, preventing it from sinking, and therefore decreased deep water circulation.

Paleoclimates of Planet Earth: Younger Dryas Cold Period

- Evidence indicates that the reduction in the saltiness of seawater resulted in the shutdown of thermohaline circulation, caused the Gulf Stream to move southward, and reduced heat transport to Northern Europe.
- This interrupted the warming trend at the end of the last Ice Age. Ice core and deep sea sediment records indicate that temperatures in northwest Europe fell by 5˚ Celsius in just a few decades returning the North Atlantic region to Ice Age conditions.

Paleoclimates of Planet Earth: Medieval Warm Period

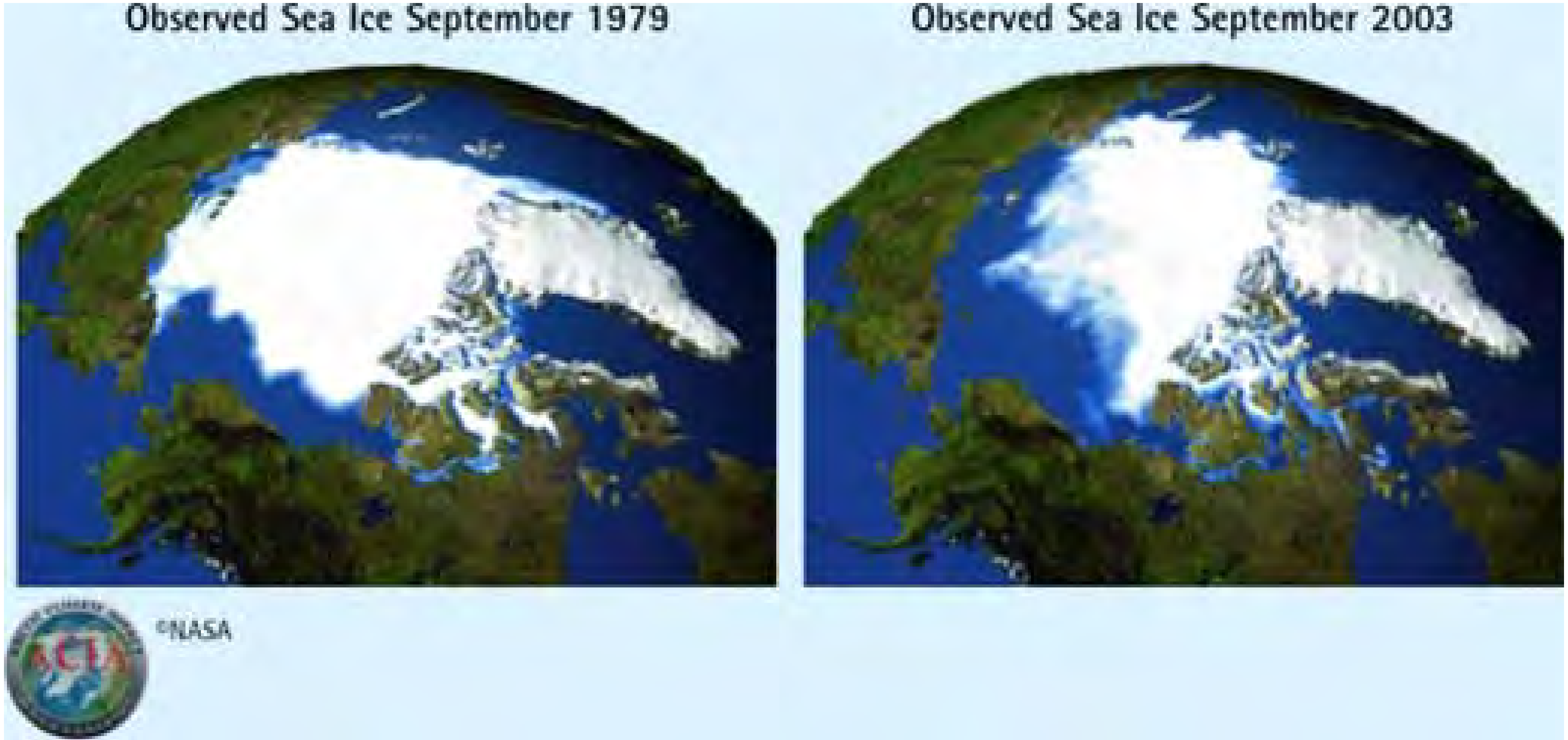
- The Medieval Warm Period was an unusually warm period during the European Medieval period, lasting from about the10th century to about the 14th century.
- The Vikings took advantage of ice-free seas to colonize Greenland and other outlying lands of the far north.
- The period was followed by the Little Ice Age, a period of cooling that lasted until the 19th century when the current period of global warming began.

Paleoclimates of planet Earth: Little Ice Age

- A cold period that lasted from about A.D. 1550 to about A.D. 1850 in Europe, North America, and Asia.
- This period was marked by rapid expansion of mountain glaciers, especially in the Alps, Norway, Ireland, and Alaska.
- There were three maxima, beginning about 1650, about 1770, and 1850, each separated by slight warming intervals.

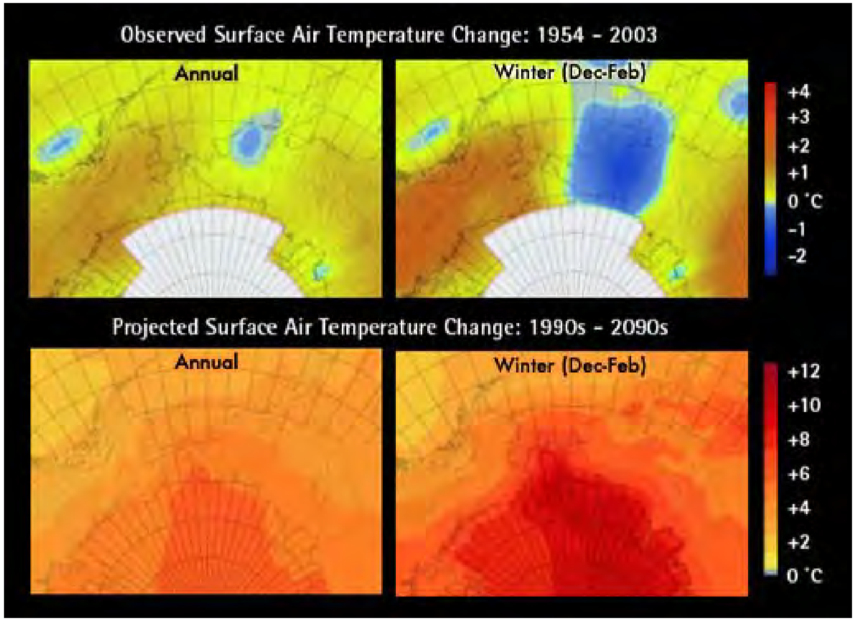
Human Impact on Climate: Global Warming

- Global warming: whether the governments of the world choose to believe it or not, global warming is happening.
- Over the past 50 years, according to the new Arctic climate assessment, temperatures have risen 1^{o} to 3^{o} C in Siberia, and 2^{o} to 3^{o} C in Alaska. The warm-up satisfies early predictions that greenhouse warming would rise fastest near the North Pole.



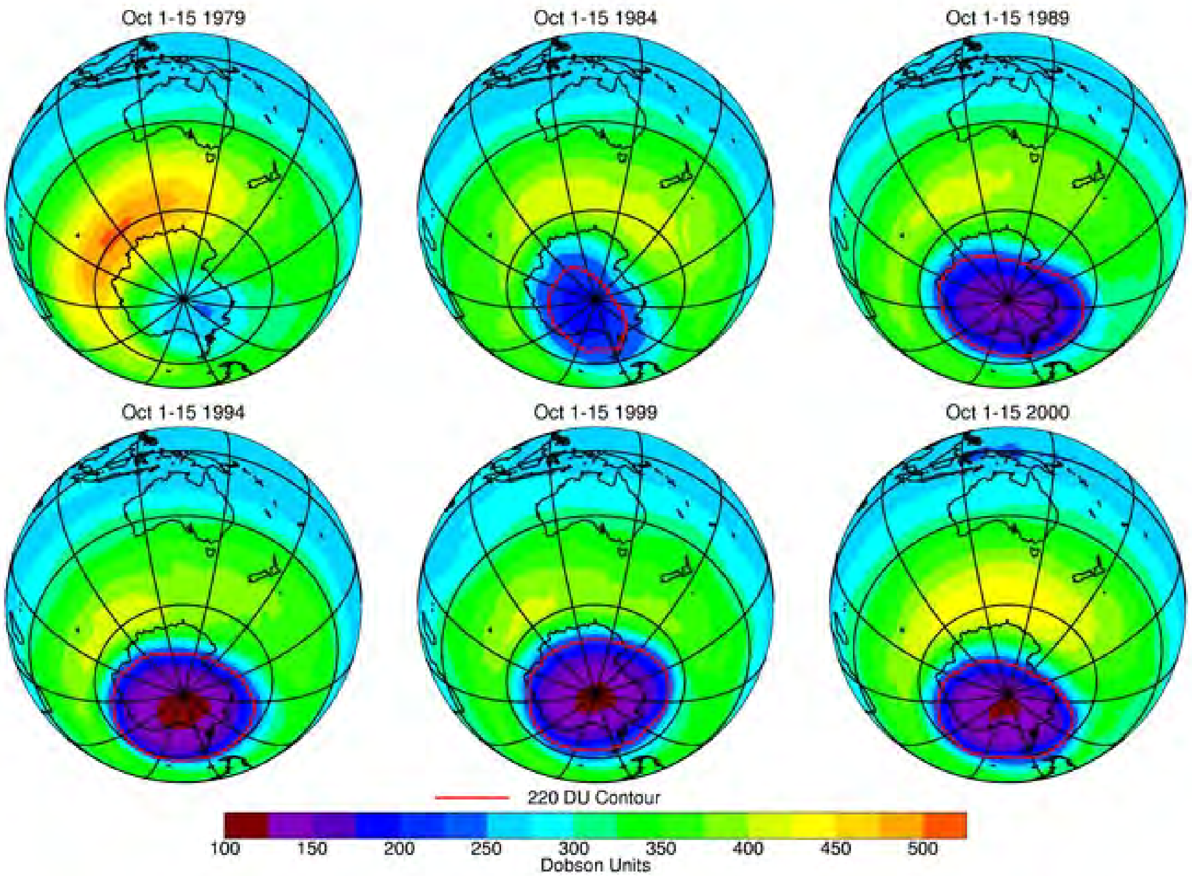
Human Impact on Climate: Global Warming

- The image to the right shows surface air temperatures for 1954 to 2003.
- The change in surface temperature should sober anyone who doubts global warming is upon us
- http://whyfiles.org/211warm_arctic/2.html



Human Impact on Climate: Ozone Depletion

http://www.eduspace.esa.int/eduspace/project/default.asp?document=257&language=en



Human Impact on Climate: Deforestation

Deforestation is the conversion of forest areas to non-forest uses. Historically, this has meant conversion to grassland or to its artificial counterpart, grain fields. The Industrial Revolution complicated the situation further by introducing urbanization and technological uses.

Human Impact on Climate: Deforestation

Generally the removal or destruction of significant areas of forest cover has resulted in a simplified (or degraded) environment with reduced biodiversity. In developing countries, massive deforestation is a leading cause of environmental degradation.

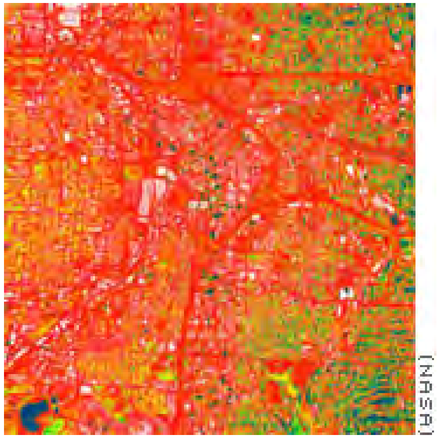
Human Impact on Climate: Urban Heat Island Effect

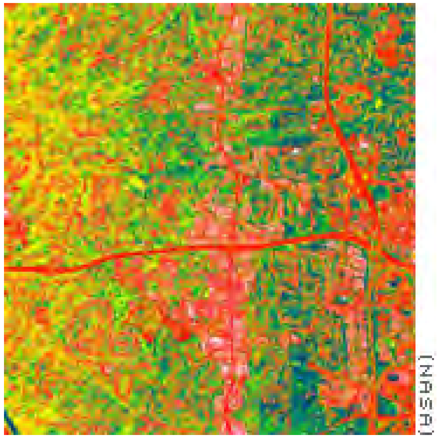
The forest is an enormously valuable resource and the loss, or degradation of the forest can cause severe and irreparable damage to wildlife habitat, and to other economic and ecological services the forest provides. Historically deforestation has accompanied mankind's progress since the Neolithic, and has shaped climate and geography.

http://en.wikipedia.org/wiki/Deforestation

Human impact on Climate:
Urban Heat Island Effect

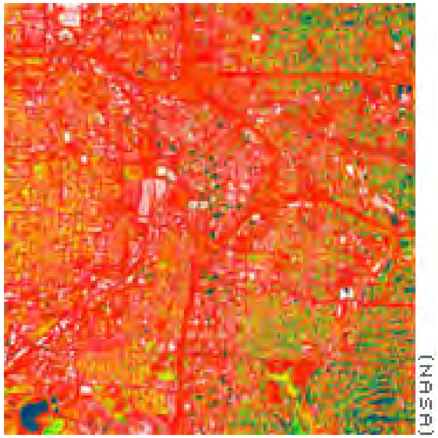
On hot summer days, urban air can be up to 10°F hotter than the surrounding countryside. Not to be confused with global climate change, scientists call this phenomenon the "heat island effect." Heat islands form as cities replace natural land cover with pavement, buildings, and other infrastructure.

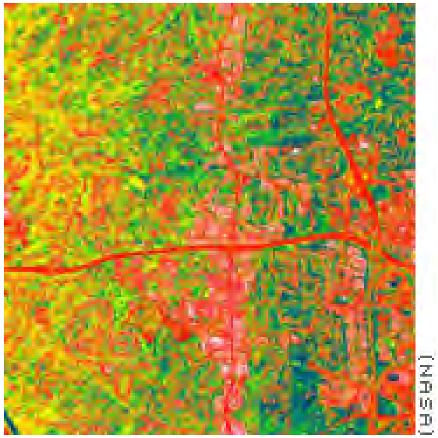




Human impact on Climate:
Urban Heat Island Effect

Increased urban temperatures can affect public health, the environment, and the amount of energy that consumers use for summertime cooling.



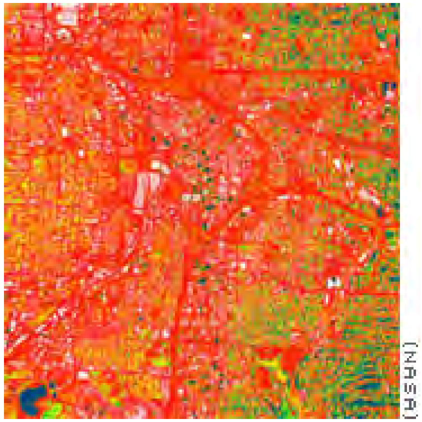


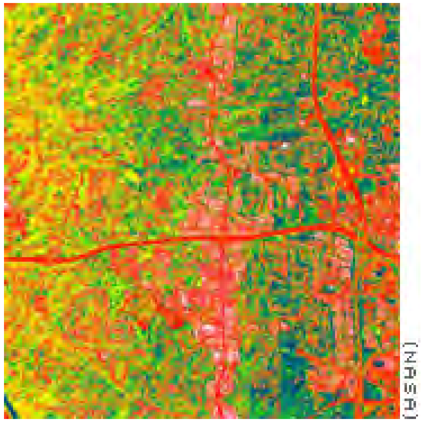
Human impact on Climate: Urban Heat Island Effect

- New York, Atlanta and Salt Lake City are poster cities for a phenomenon common to cities in industrialized nations: They create their own weather.
- When you replace soil and grass with concrete and asphalt, you alter the balance of energy that occurs at the earth's surface.

- http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsLocalHeatIslandEffect.html

Atlanta's heat island (blue is cool and red is HOT!





Earth's Atmosphere and Its Seasons CD

This CD helps students investigate and understand the causes of the seasons, Earth-Sun relationships, the composition of the atmosphere, Sun's role as the main source of energy that drives weather and climate, the greenhouse effect, and much more.

Visit http//www.otherworlds-edu.com for more information.

A Work in Progress: “A Special Invitation”

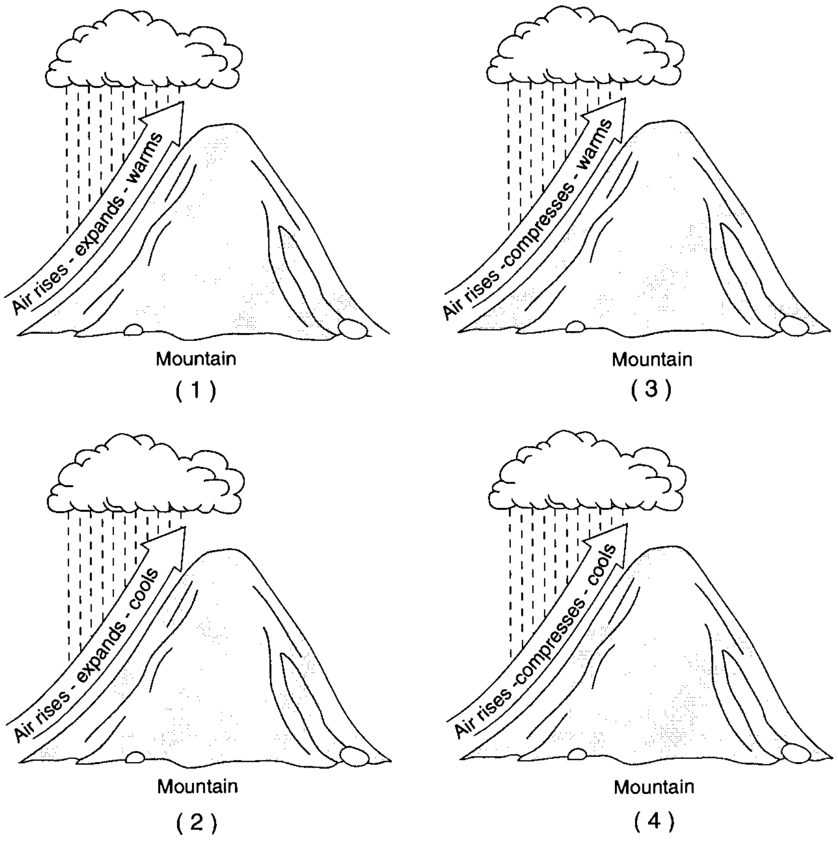
- This presentation is a work in progress.
- Anyone wishing to offer assistance to improve upon it is encouraged to contact Linder Winter at LWothworld@aol.com

Climate Mini-Lab Activities

The remaining slides provide examples of the types of activities participants might anticipate during their event.

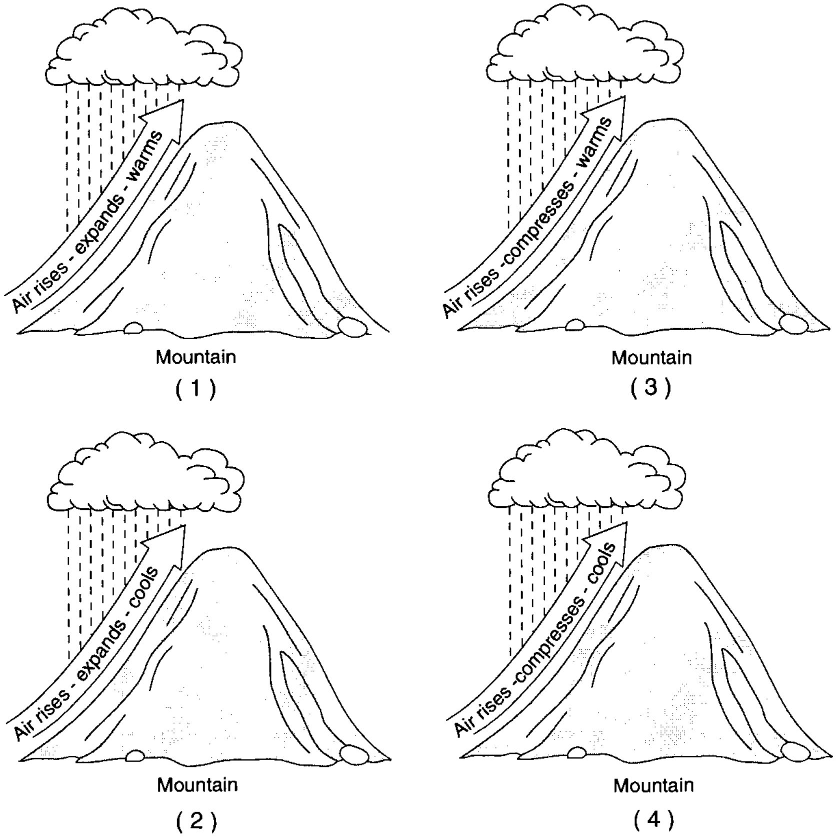
The following exercises have been glean-ed from the New York Regents Earth Science Exams found at: http://www.nysedregents.org/testing/scire/regentearth.html

Sample Climate Activity 1



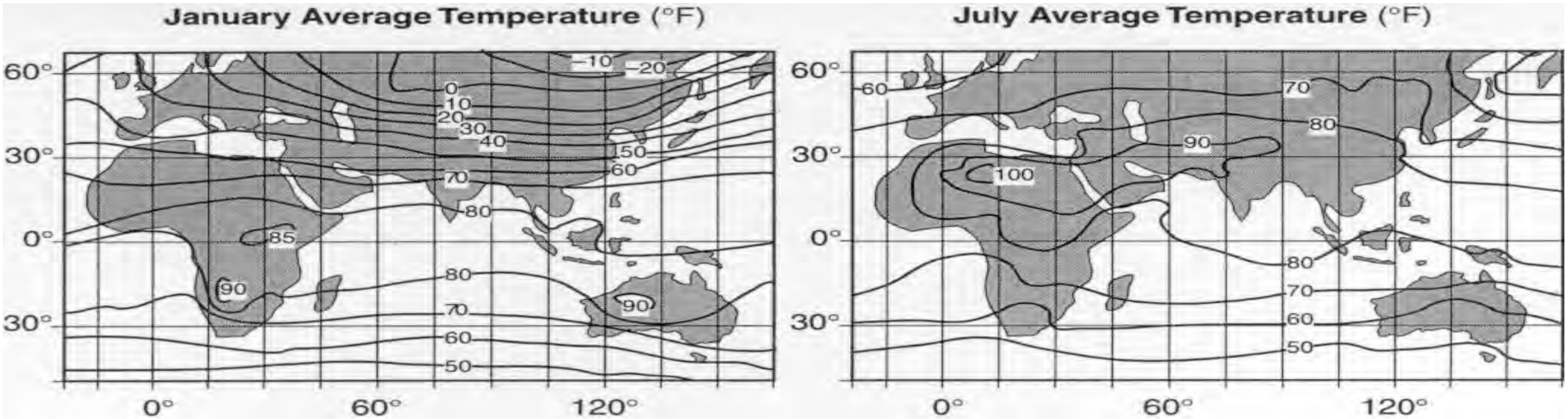
Which diagram best illustrates how air rising over a mountain produces precipitation?

Sample Climate Activity 1



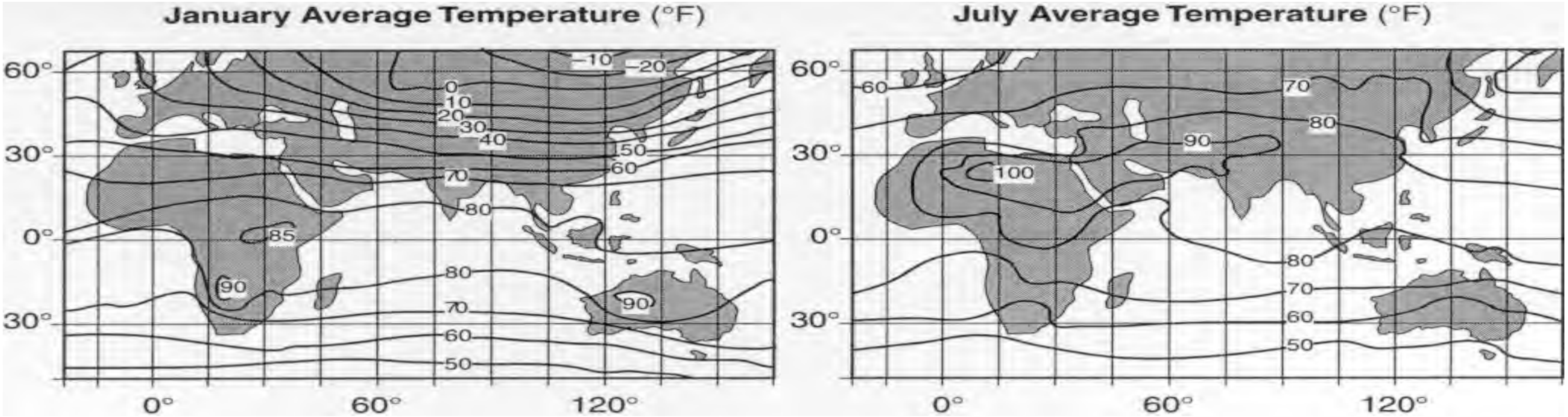
- Which diagram best illustrates how air rising over a mountain produces precipitation?
- The correct response is 2.

Sample Climate Activity 2



At approximately what latitude do the hottest January temperatures occur?

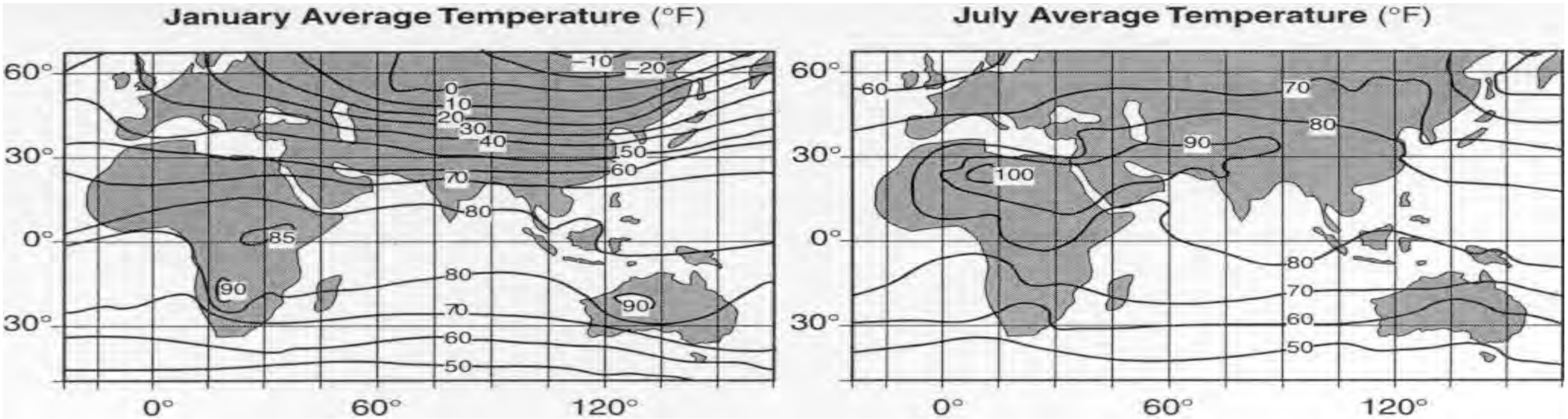
Sample Climate Activity 2



At approximately what latitude do the hottest January temperatures occur?

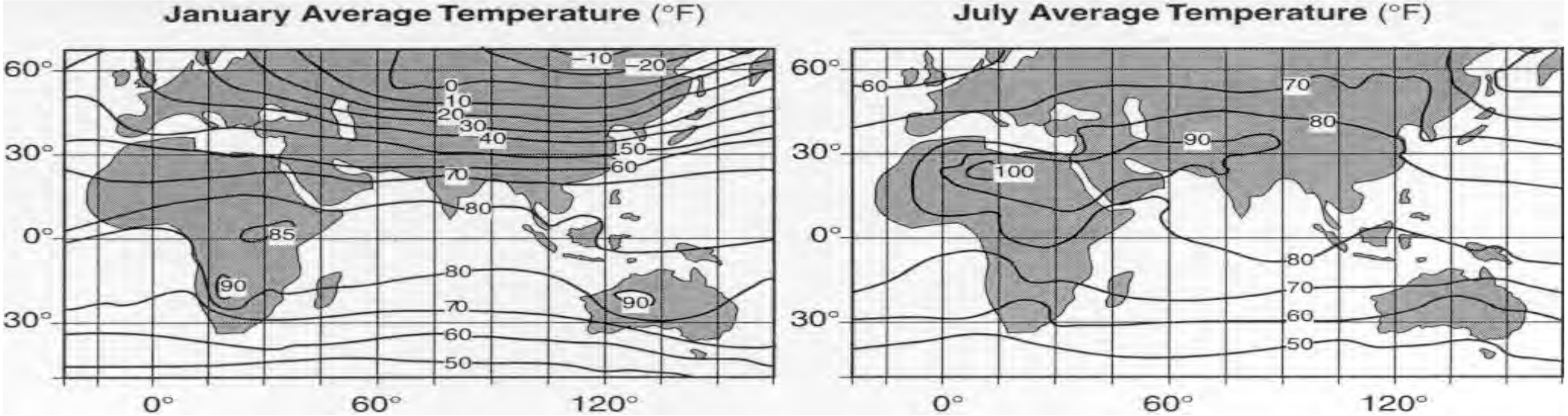
~ 20 Degrees South (+/- 8 Degrees)

Sample Climate Activity 2



There is a smaller temperature change in the Southern Hemisphere from January through July than in the Northern Hemisphere. Explain why the Southern Hemisphere’s larger ocean-water surface causes this smaller temperature change.

Sample Climate Activity 2



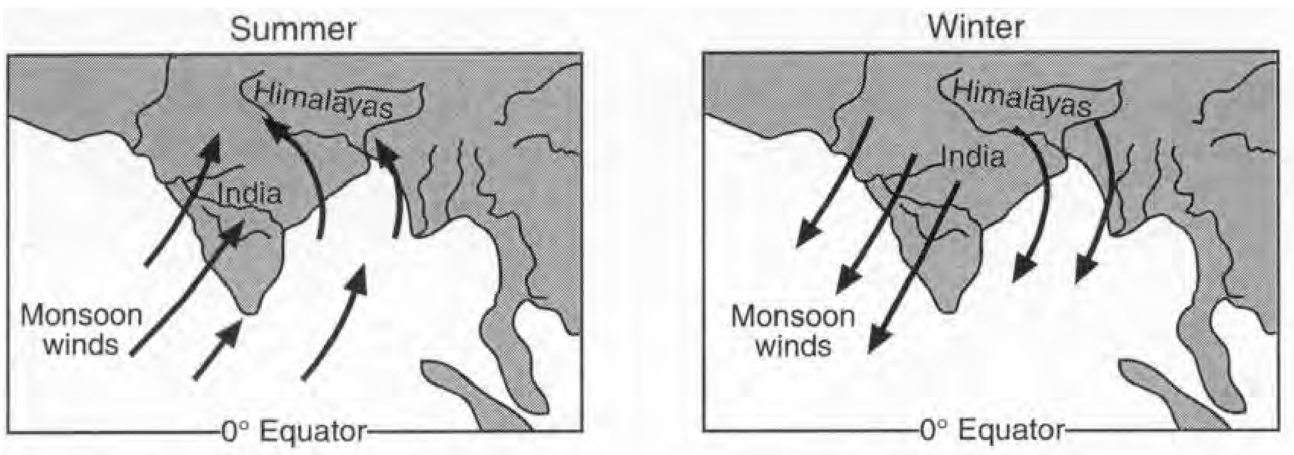
Water has a higher specific heat than the land.

or

Water takes a longer time to heat up and cool down than does land.

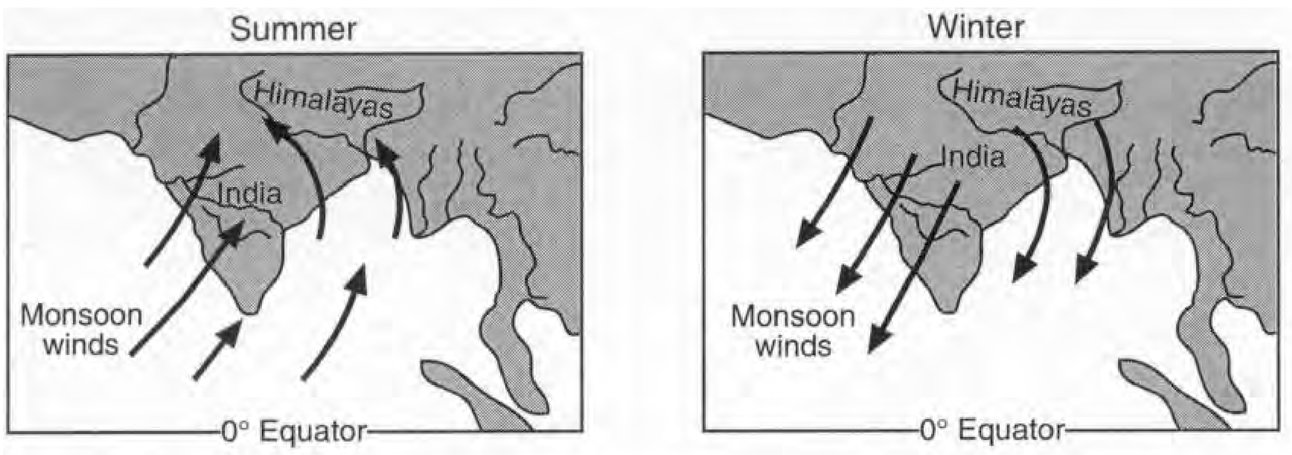
Sample Climate Activity 3

- The arrows on the two maps show how the monsoon winds over India change direction with the seasons. How do these winds affect India's weather in summer and winter?



Sample Climate Activity 3

1. Summer is cooler and less humid than winter.
2. Summer is warmer and more humid than winter.
3. Winter is warmer and less humid than summer.
4. Winter is cooler and more humid than summer.



Sample Climate Activity 3

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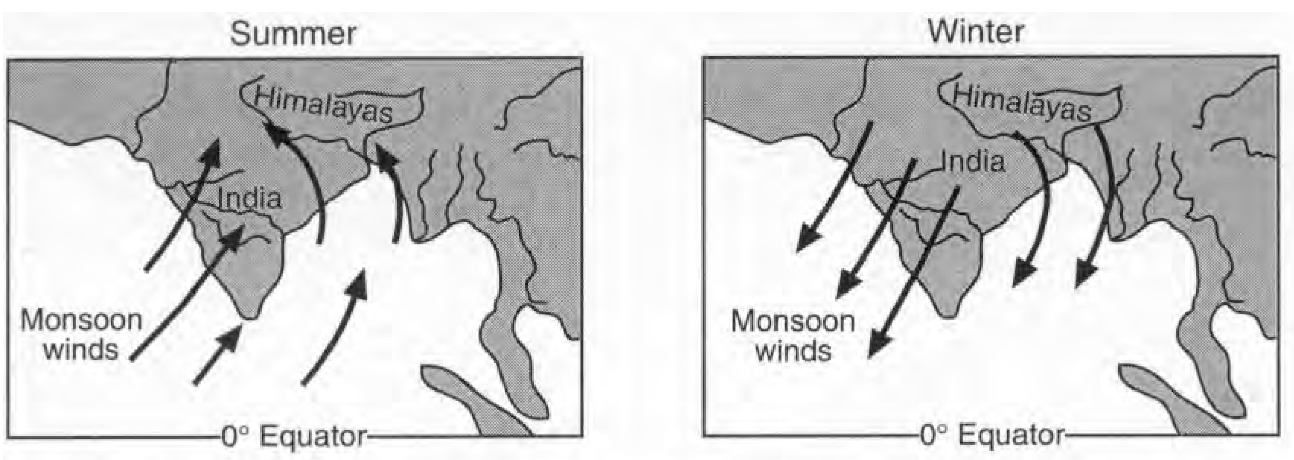
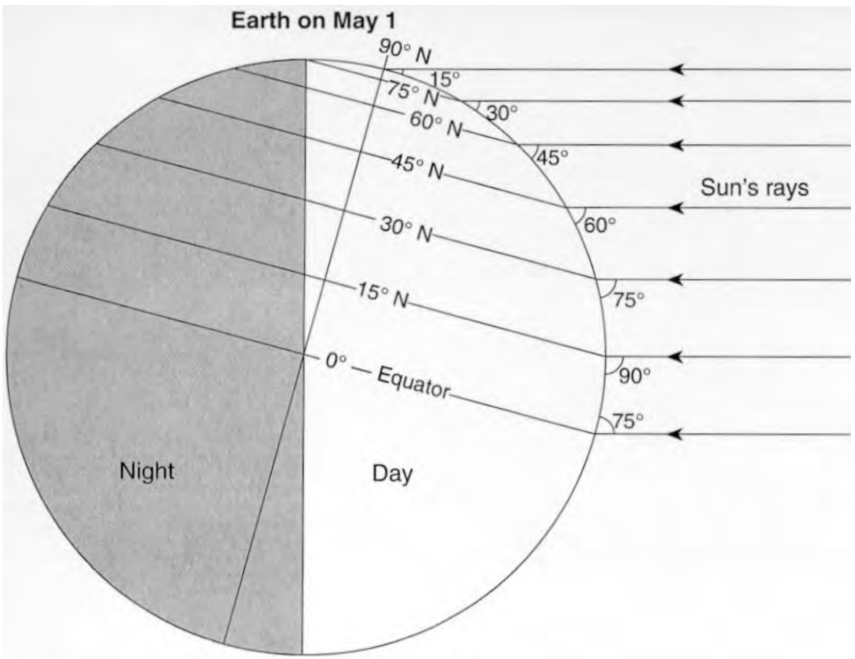


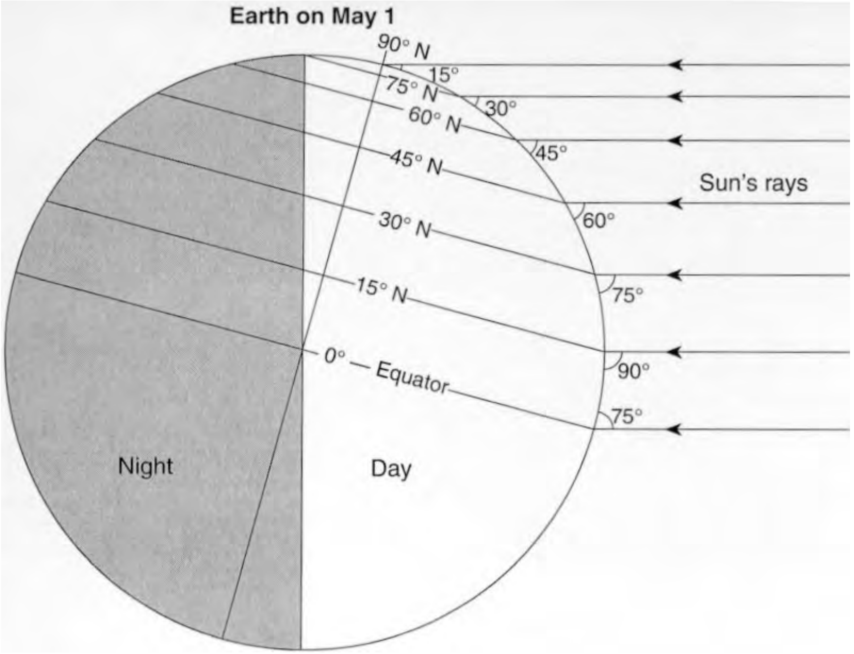
Sample Climate Activity 4



What changes can be expected to occur at 45˚ N over the next several days?

The duration of insolation will (increase; decrease). Temperature will (increase; decrease).

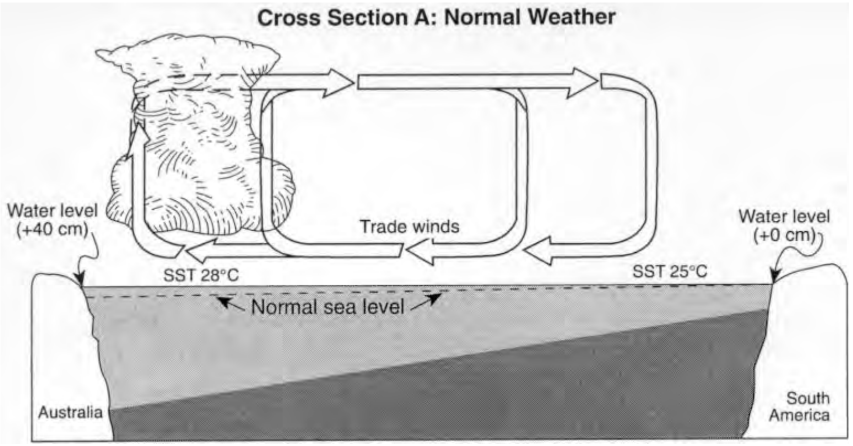
Sample Climate Activity 4

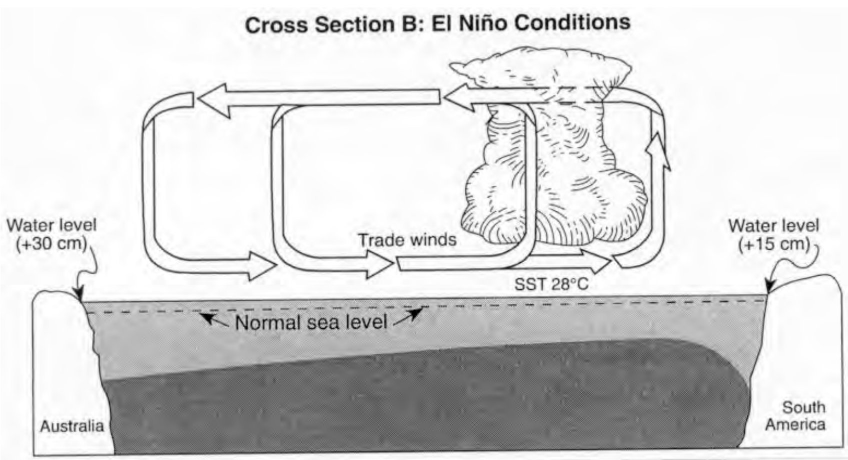


What changes can be expected to occur at 45° N over the next several days?

The duration of insolation will (increase; decrease). Temperature will (increase; decrease).

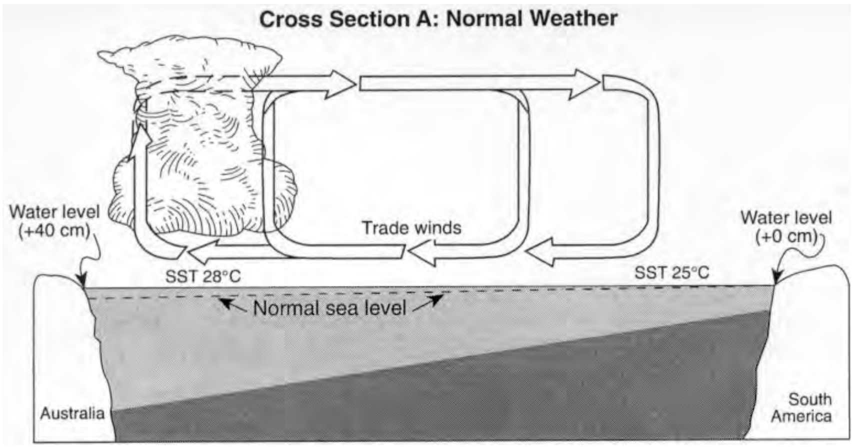
Sample Climate Activity 5

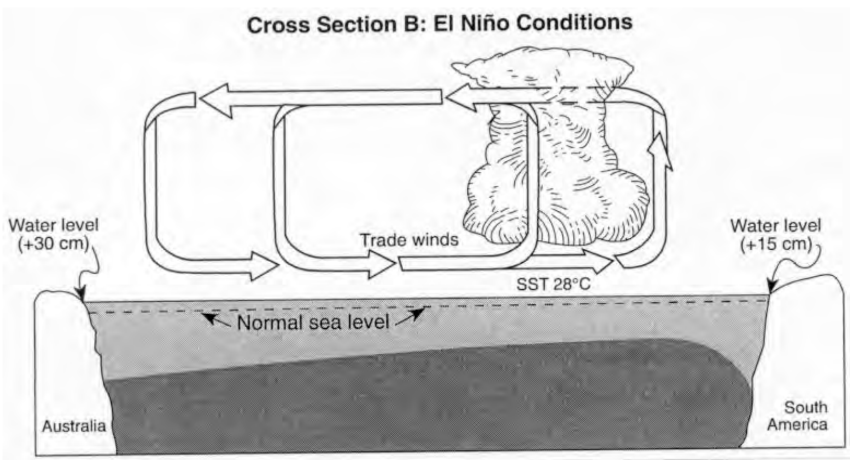




These cross-sections represent the Pacific Ocean and the atmosphere near the Equator during normal weather and during El Niño conditions.

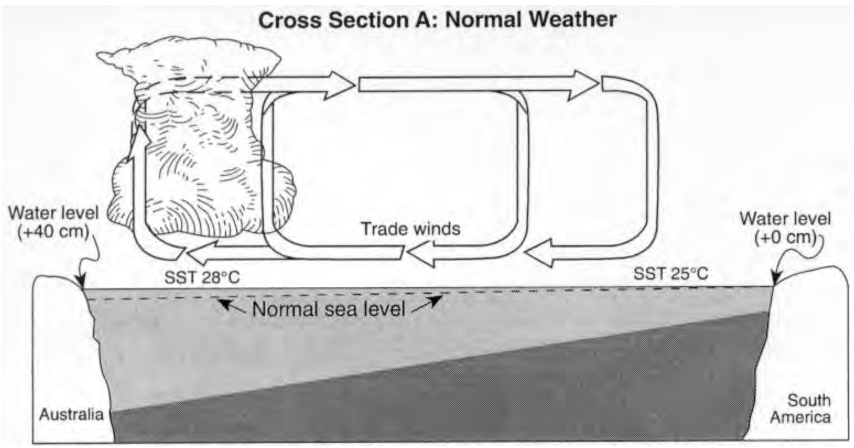
Sample Climate Activity 5

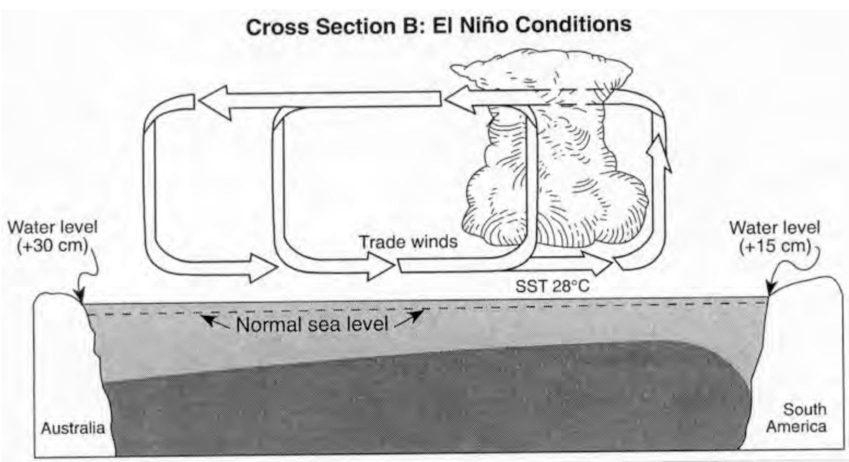




Sea surface temperatures are labeled and trade-wind directions are shown with arrows. Cloud build-up indicates regions of frequent T-storm activity. Change from sea level is shown at the side of each diagram.

Sample Climate Activity 5

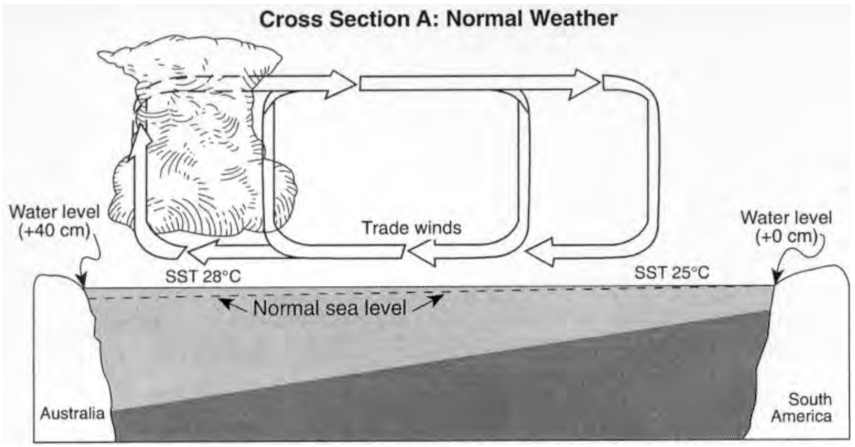


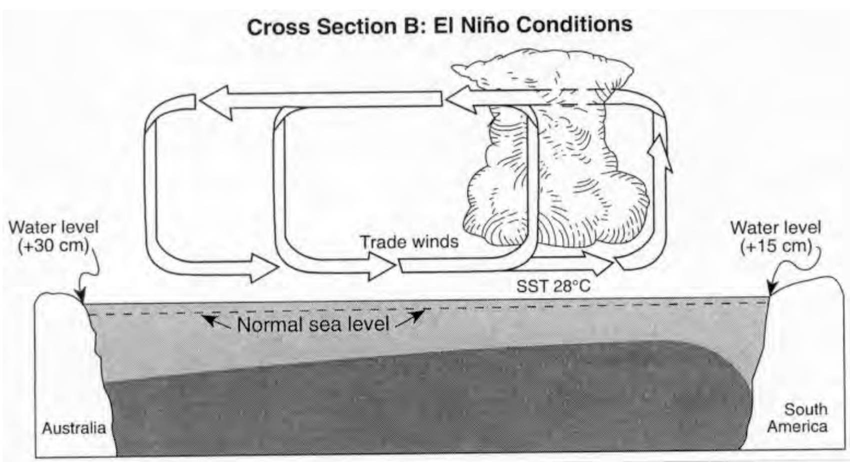


Choose the terms that describe sea surface temperatures during El Niño conditions.

The sea surface temperatures are (warmer; cooler) than normal, and Pacific trade winds are from the (east; west).

Sample Climate Activity 5





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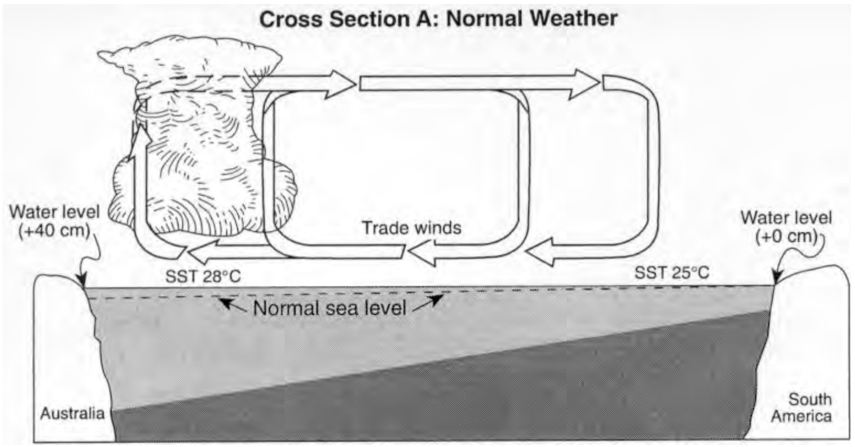
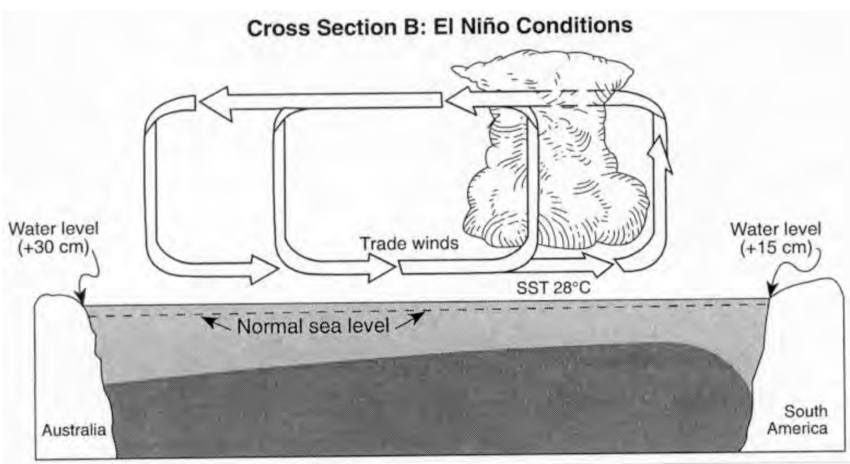




During El Niño conditions, T-storms increase in the E. Pacific because warm, moist air is:

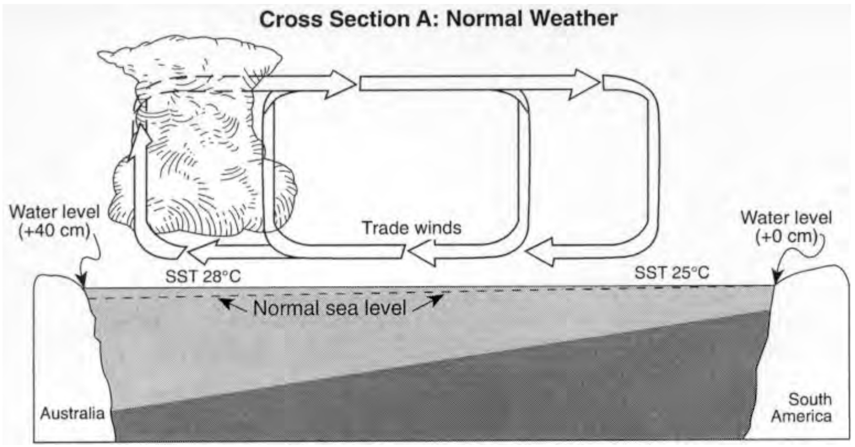
(less or more dense)

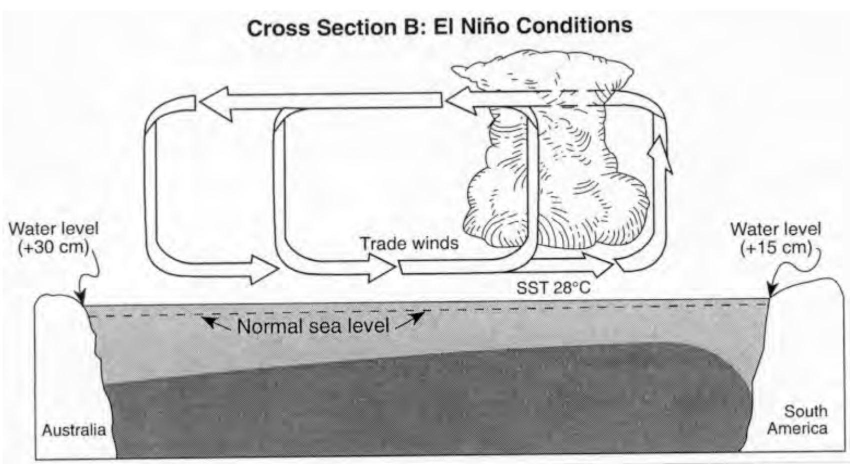
(sinking or rising)

(compressing or expanding)

(warming or cooling)

Sample Climate Activity 5





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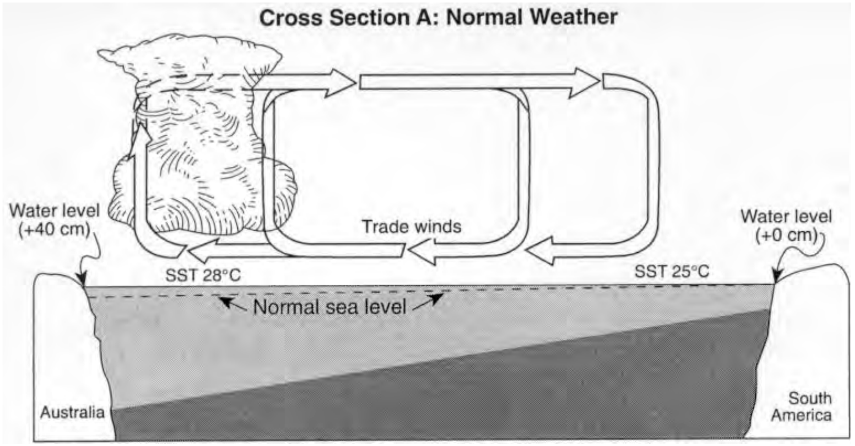
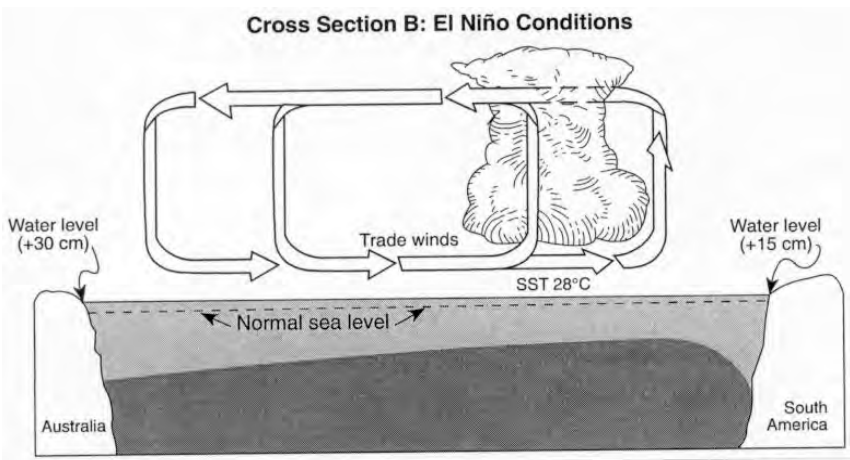
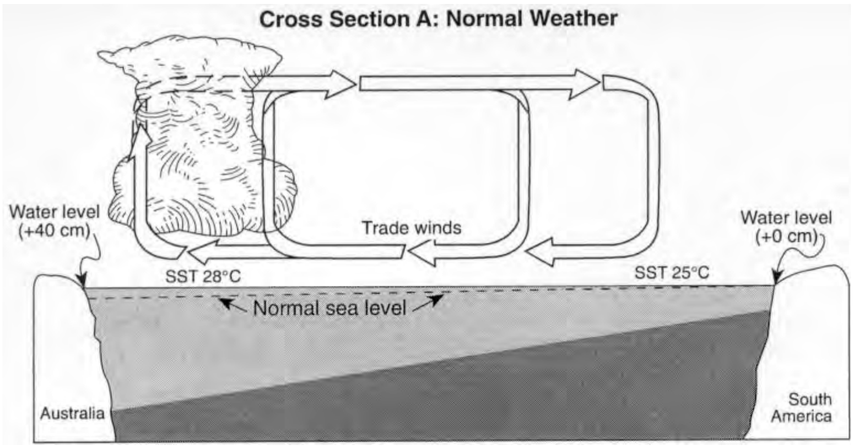


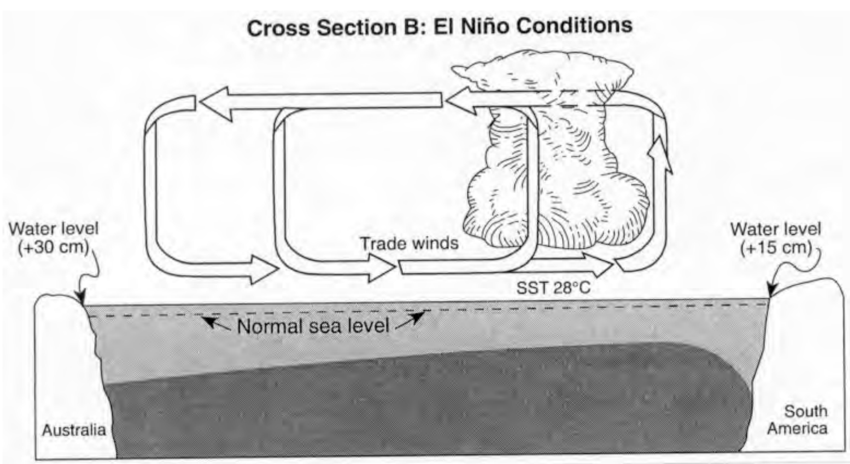


Compared to normal conditions, the shift of the trade winds caus-ed sea levels during El Niño conditions to:

(decrease/increase) at Australia and (decrease/increase) at South America.

Sample Climate Activity 5





Compared to normal conditions, the shift of the trade winds caused sea levels during El Niño conditions to:

(decrease; increase) at Australia and (decrease; increase) at South America.

Sample Climate Activity 5

The development of El Niño conditions over this region of the Pacific has caused:

a. changes in world precipitation patterns.
b. the reversal of Earth’s seasons.
c. increased worldwide volcanic activity.
d. decreased ozone levels in the atmosphere.

Sample Climate Activity 5

The development of El Nino conditions over this region of the Pacific has caused:

a. changes in world precipitation patterns.
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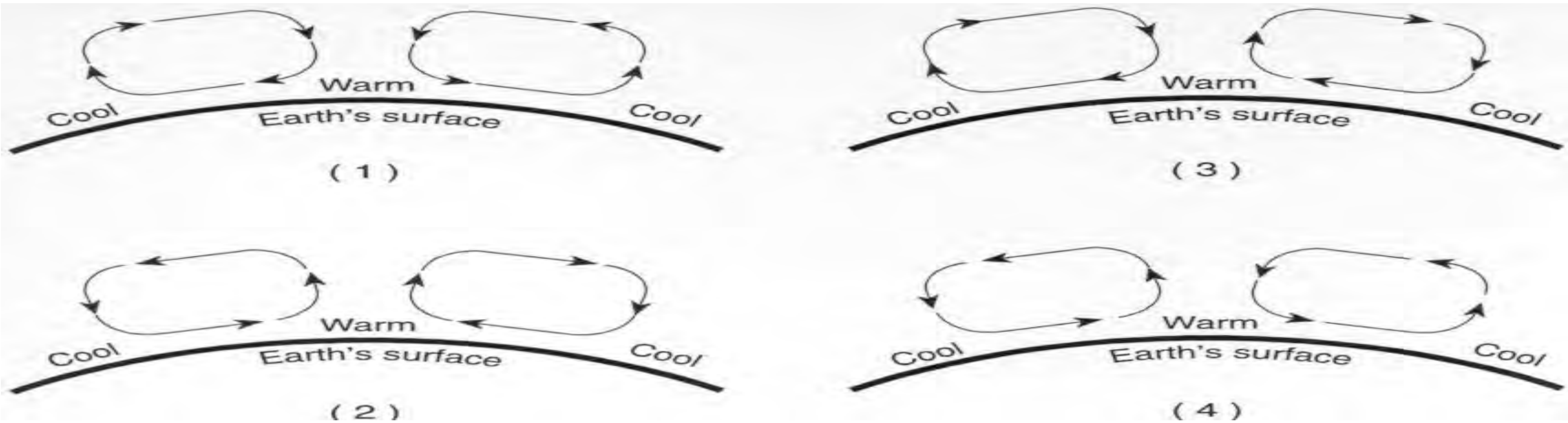
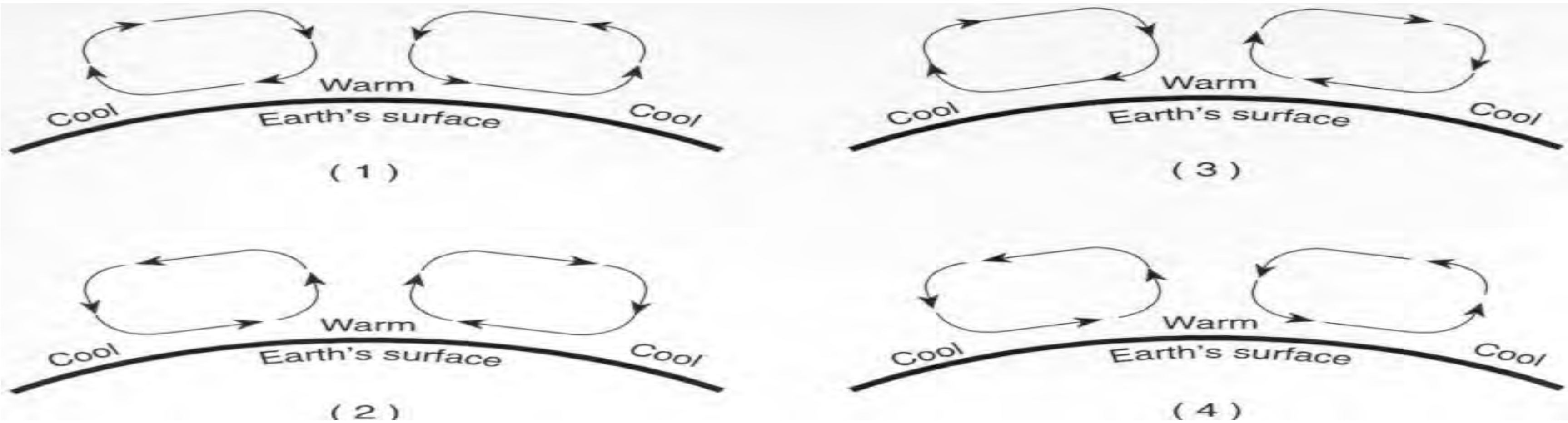
Sample Climate Activity 6



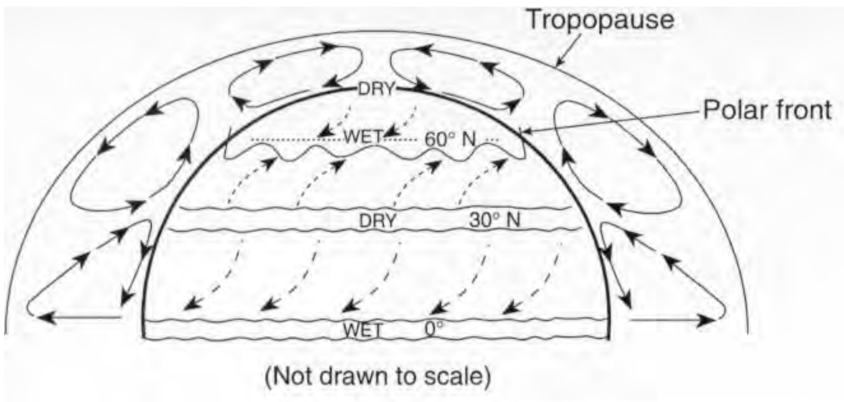
The cross sections show different patterns of air movement in Earth's atmosphere. Air temperatures at Earth's surface are indicated in each cross section. Which cross section shows the most likely pattern of air movement?

Sample Climate Activity 6



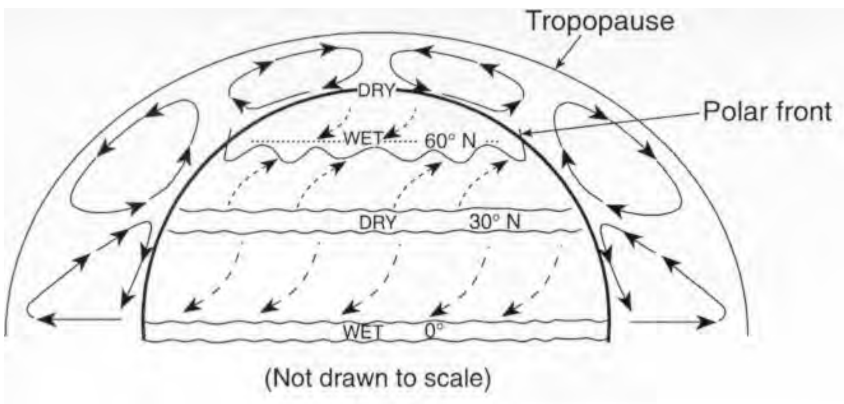
The cross sections show different patterns of air movement in Earth's atmosphere. Air temperatures at Earth's surface are indicated in each cross section. Which cross section shows the most likely pattern of air movement? No. 2

Sample Climate Activity 6



This diagram illustrates the planetary wind and moisture belts in Earth's Northern Hemisphere.

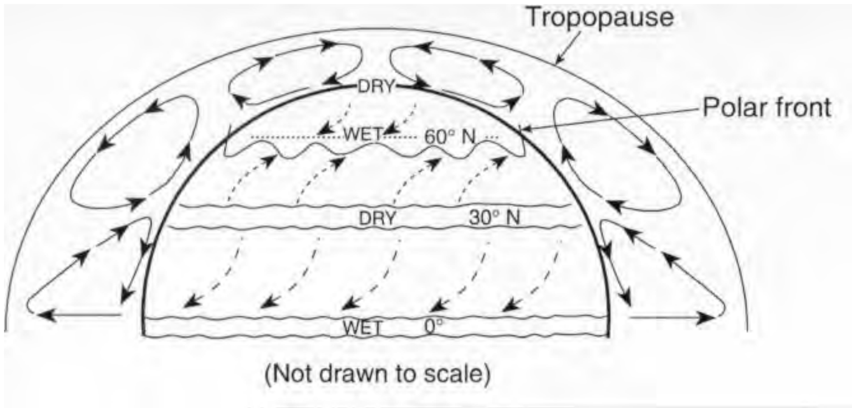
Sample Climate Activity 6



The climate at 90 degrees north latitude is dry because air at that location is usually

1. warm and rising.
2. warm and sinking.
3. cool and rising.
4. cool and sinking.

Sample Climate Activity 6



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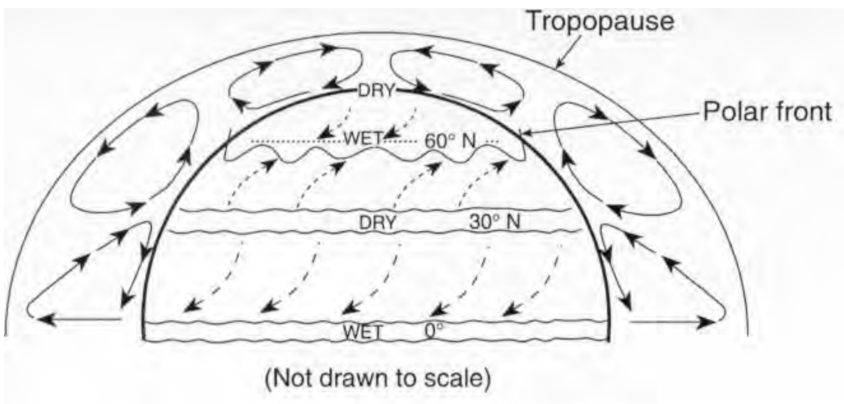
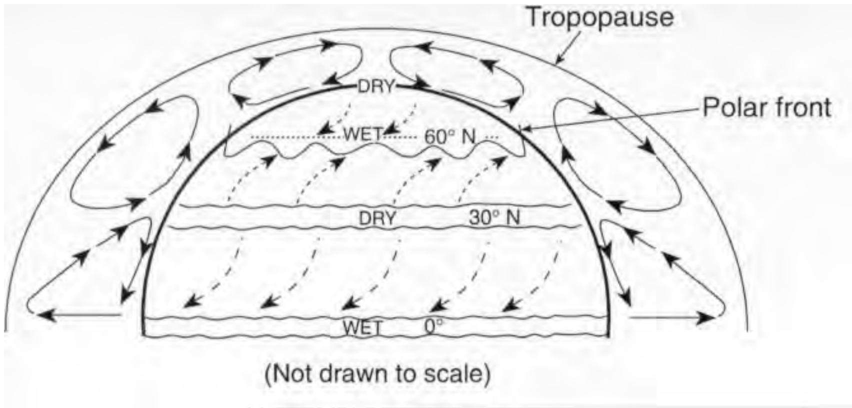
Sample Climate Activity 6



The paths of the surface planetary winds are curved due to Earth’s

1. revolution.
2. rotation.
3. circumference.
4. size.

Sample Climate Activity 6



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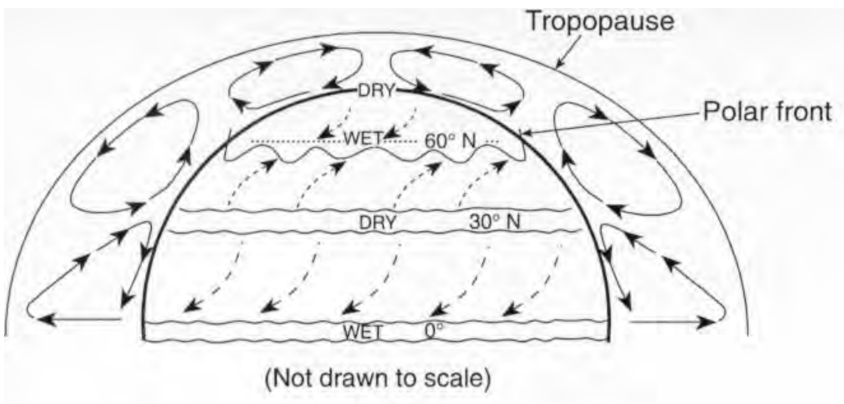
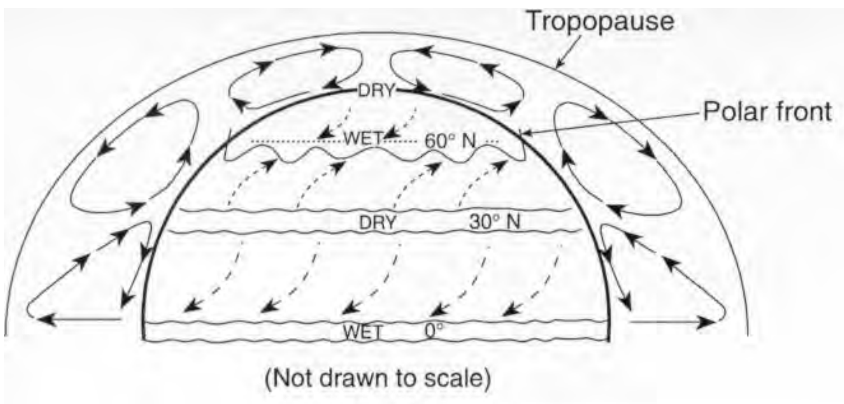


Approximately how far above sea level is the tropopause located?

1. 12 miles
2. 12 kilometers
3. 60 miles
4. 60 kilometers

Sample Climate Activity 6



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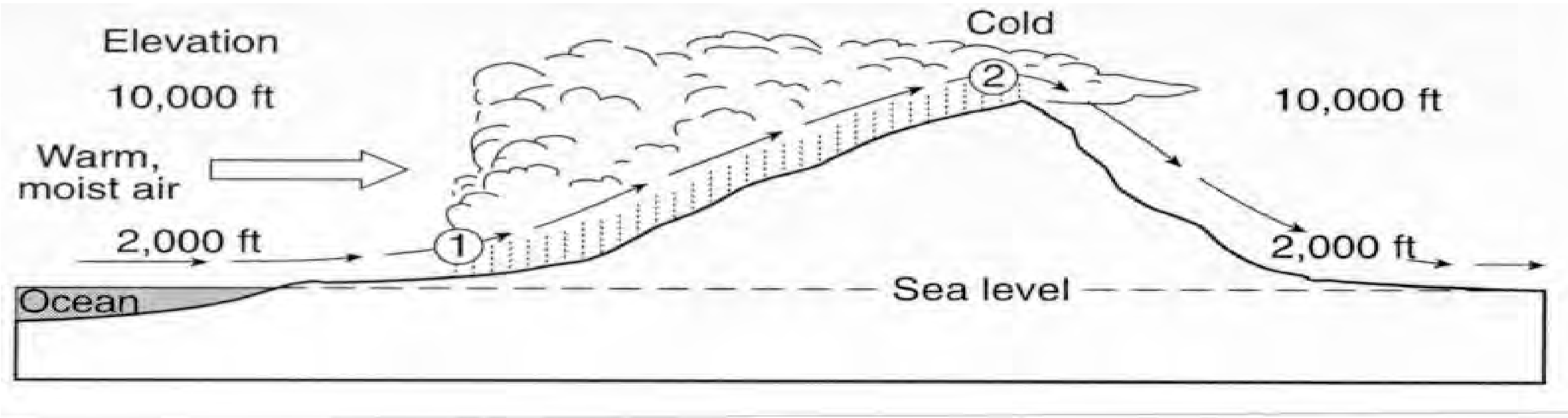
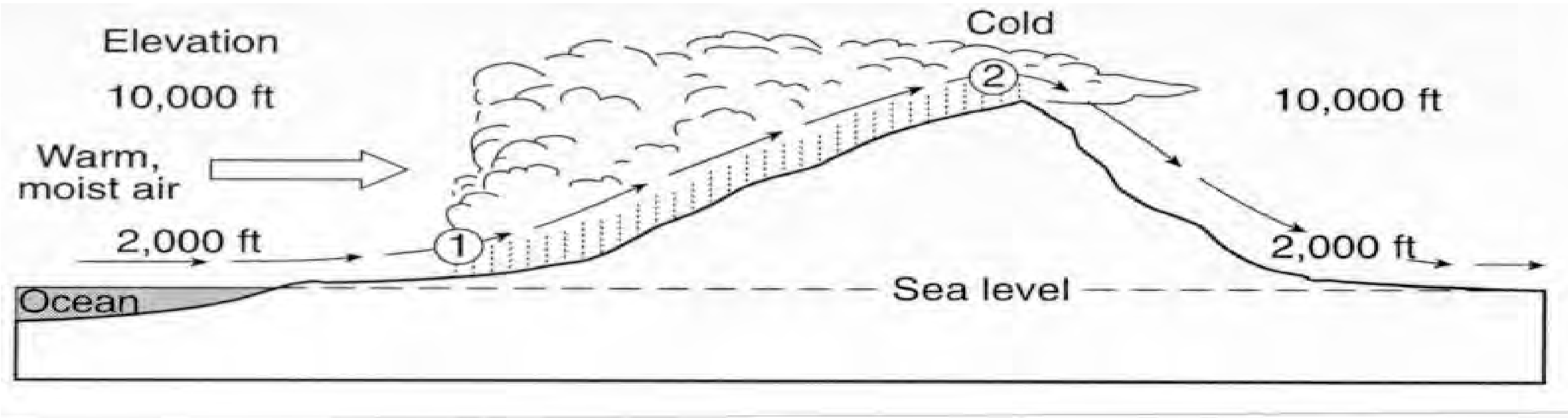
Sample Climate Activity 7



Describe two changes that occur to the warm, moist air between points 1 and 2 that would cause cloud formation.

Sample Climate Activity 7



Describe two changes that occur to the warm, moist air between points 1 and 2 that would cause cloud formation. Possible responses:

air rises; air expands; air cools; temperature reaches the dew point; water vapor condenses