

Biogeochemical Cycles and the Earth System

Energy and Material Flows Through the Atmosphere,
Hydrosphere, Lithosphere, and Biosphere

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Biology 1030

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House Republicans working to undermine the Clean Air Act

<http://goo.gl/xH78j>

- ▶ TRAIN Act (HR 2401, Transparency in Regulatory Analysis of Impacts on the Nation)
 - ▶ Blocks the Cross-State Air Pollution Rule (<http://goo.gl/hZai9>)
 - ▶ Blocks the Mercury and Air Toxics standards (<http://goo.gl/Zfq5s>)
 - ▶ Repeals or blocks standards that would save 130,000 lives and avoid 1 million asthma attacks (<http://goo.gl/LXTCg>)

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House Republicans working to undermine the Clean Air Act

<http://goo.gl/xH78j>

- ▶ HR 2250, EPA Regulatory Relief Act: Industrial boilers and solid-waster incinerators
- ▶ HR 2681, Cement Sector Regulatory Relief Act: Cement plants
- ▶ According to EPA testimony, HR 2250 alone, in 3 years, would cause:
 - ▶ 32,500 more premature deaths
 - ▶ 19,500 more heart attacks
 - ▶ 208,000 more asthma attacks

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Results of Exam I

- ▶ Max:
- ▶ Mean:
- ▶ Median:

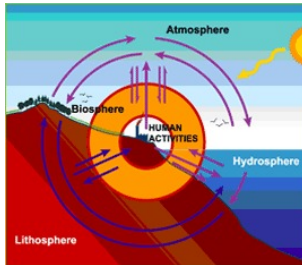
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Friday's Discussion

- ▶ Overpopulation & Overconsumption

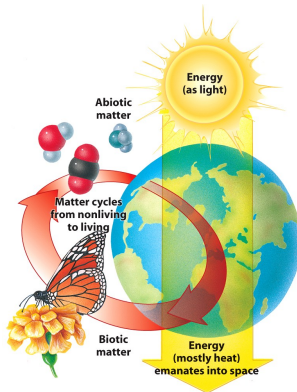
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Material cycles through the biosphere

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Recall...

The Biosphere is thermodynamically open but **materially closed**.



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Modeling biogeochemical cycles

1. Definition of system and subsystem boundaries (reservoirs and compartments)
2. Prediction and evaluation of transport paths
3. Evaluation of fluxes
4. Mathematical modeling

See Mackenzie (1998)

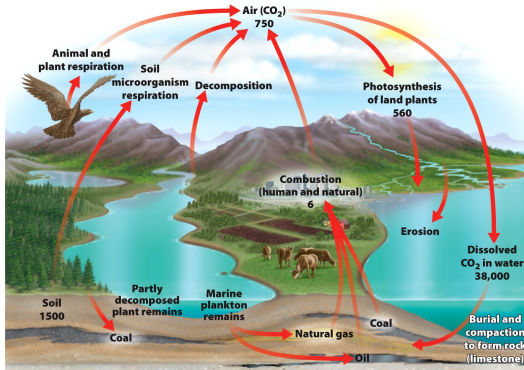
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Five major cycles

1. Carbon
2. Nitrogen
3. Phosphorus
4. Sulfur
5. Water

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Carbon cycle



Photosynthesis and respiration are part of the carbon cycle.

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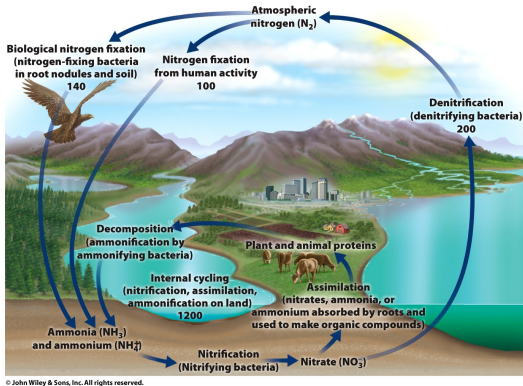
References

Anthropogenic changes to the carbon cycle

- ▶ Carbon concentration expected to reach double preindustrial levels by middle of twenty-first century
- ▶ Primary source of carbon increase is the combustion of fossil fuels (coal, oil, natural gas)
- ▶ Carbon increase believed to be a primary driver of anthropogenic climate change

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Nitrogen cycle



Nitrogen is abundant in the atmosphere, but requires nitrogen fixation to be used in the Biosphere.

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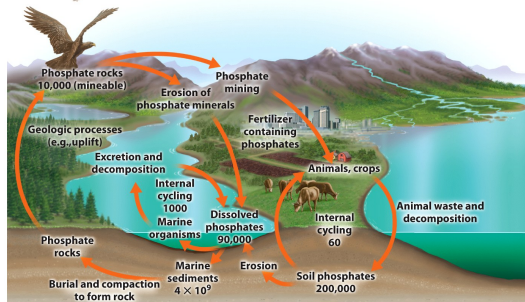
References

Anthropogenic changes to the nitrogen cycle

- ▶ Doubled the quantity of fixed nitrogen entering the global cycle
 - ▶ Reduces species richness of terrestrial ecosystems
 - ▶ Carried by runoff into lakes, streams, ocean where stimulates production of biomass whose decomposition creates anoxic “dead zones”
 - ▶ Poisons groundwater
- ▶ Combustion of fossil fuels also produces nitrogen oxides, which produce photochemical smog and acidic precipitation

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Phosphorus cycle



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Phosphorus does not combine with other elements as a gas, and rarely enters the atmosphere.

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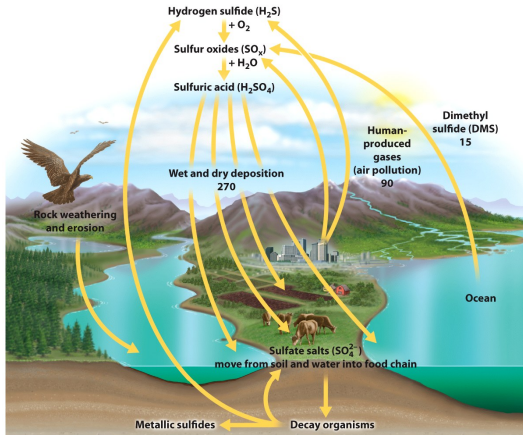
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Anthropogenic changes to the phosphorus cycle

- ▶ Accelerating loss of phosphorus from land to hydrosphere
- ▶ Leads to water quality problems and is effectively lost from terrestrial phosphorus cycle

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Sulfur cycle



Most sulfur is found in sedimentary rocks and minerals, where it is released by erosion.

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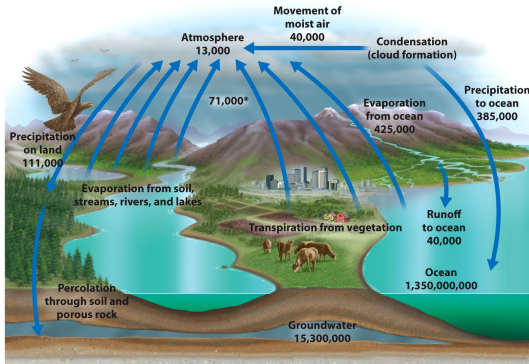
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Anthropogenic changes to the sulfur cycle

- ▶ Coal combustion releases significant quantities of sulfur into atmosphere
- ▶ Leads to acidic precipitation
- ▶ Generates human-health hazards

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Water (hydrologic) cycle



Water is a basic requirement for all life, and comprises much of the mass of most organisms.

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Anthropogenic changes to the water cycle

- ▶ Production of aerosols leads to the formation of clouds that do not produce precipitation
- ▶ Climate change could significantly alter hydrologic cycle
 - ▶ Alter precipitation patterns
 - ▶ Ice melting could alter marine salinity
 - ▶ Warmer air holds more water vapor, which traps significant amounts of heat, causing even warmer air temperatures (positive feedback loop)

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Atmospheric conditions

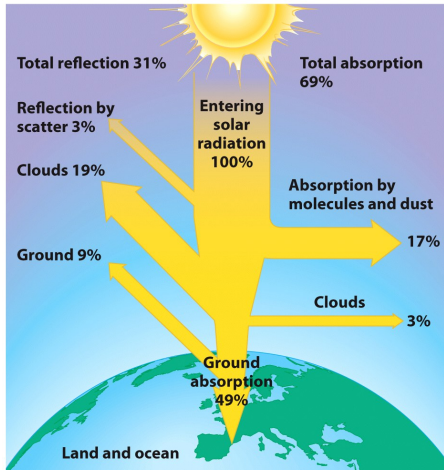
Weather Immediate conditions at a given point in the atmosphere

Climate Average conditions at a given point

- ▶ Temperature
- ▶ Precipitation

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Solar radiation budget



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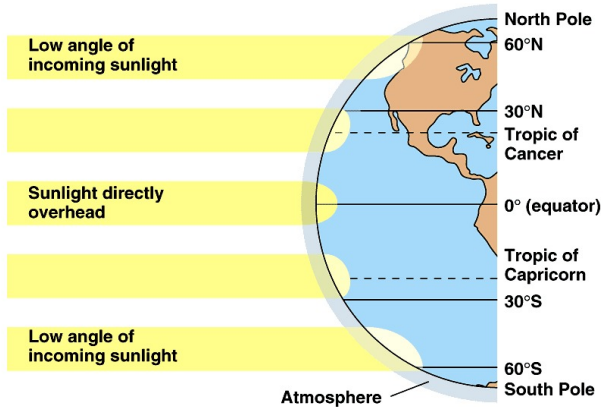
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Latitude and angle of incidence



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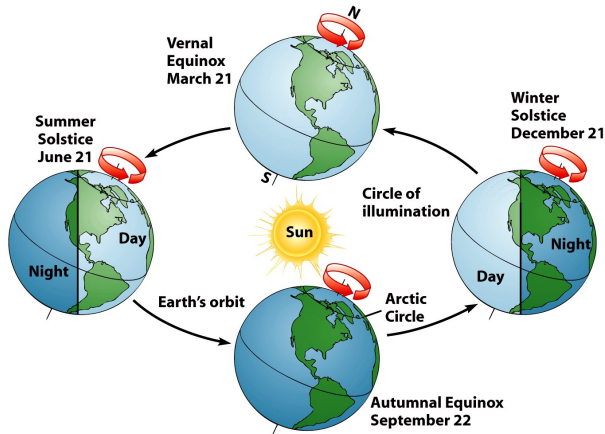
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Seasonal variation in solar radiation



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Seasonal changes are caused by the Earth's axial tilt rather than its distance to the sun.

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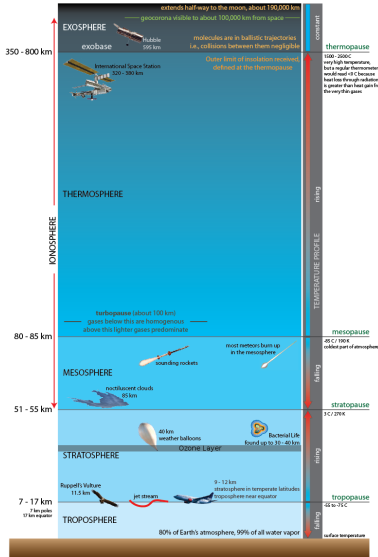
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Composition of the atmosphere



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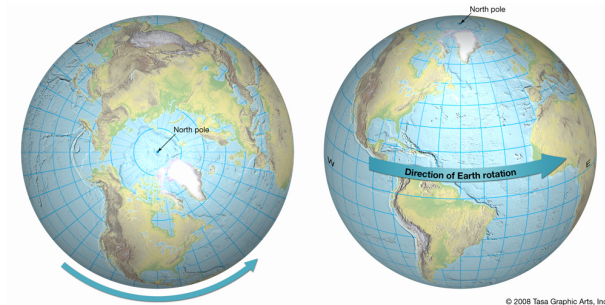
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Coriolis Effect



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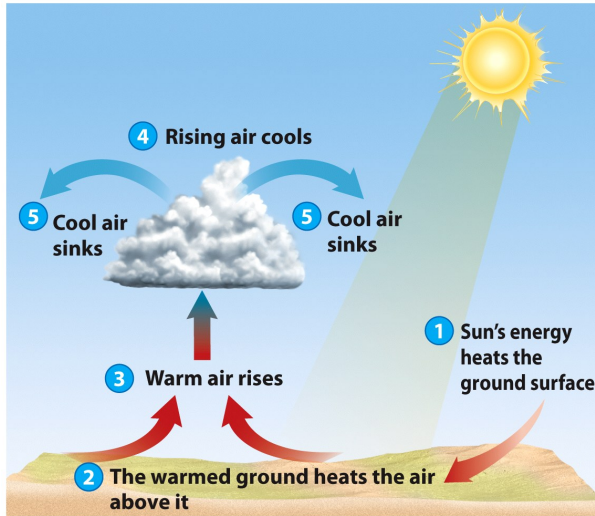
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Convection



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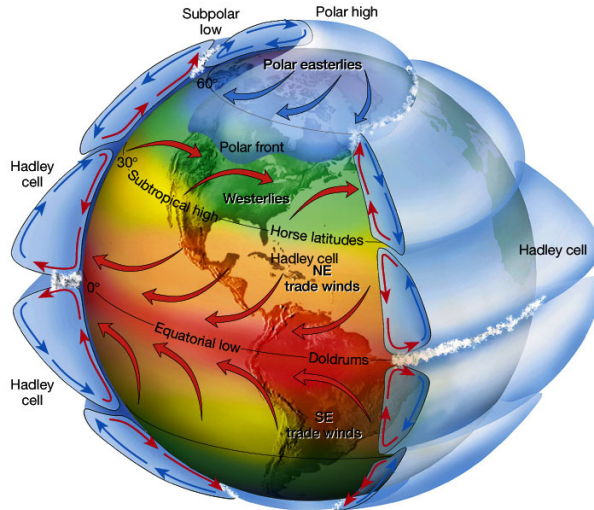
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Global circulation



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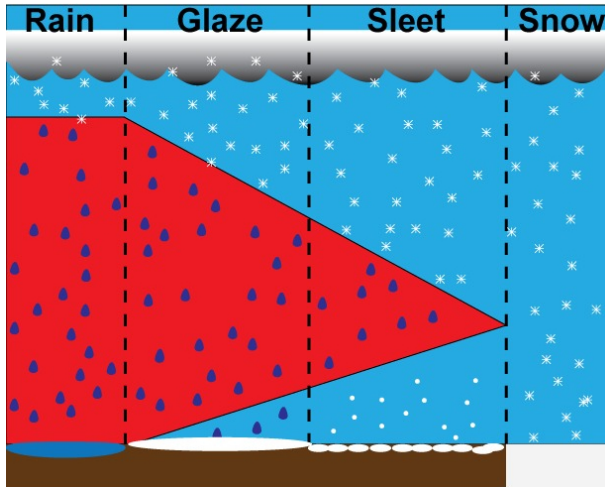
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Types of precipitation



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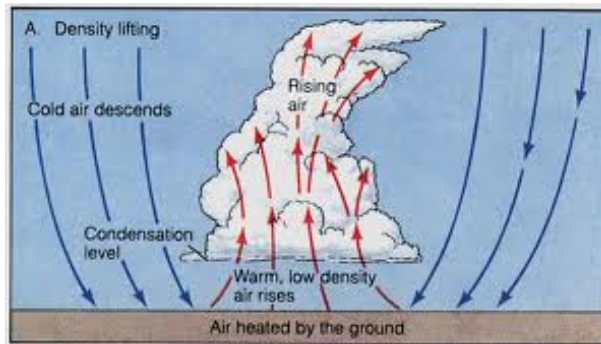
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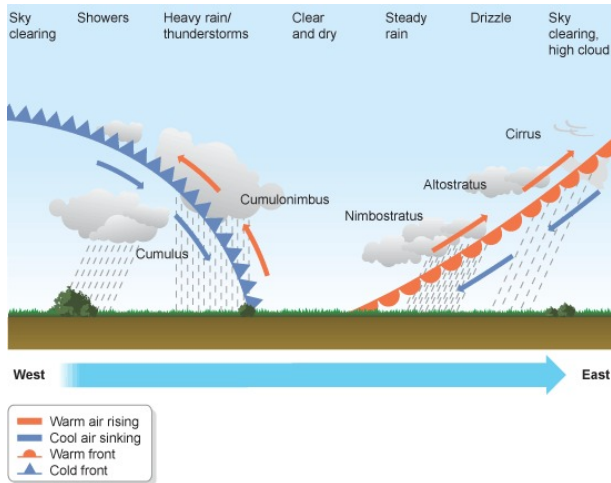
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Frontal precipitation



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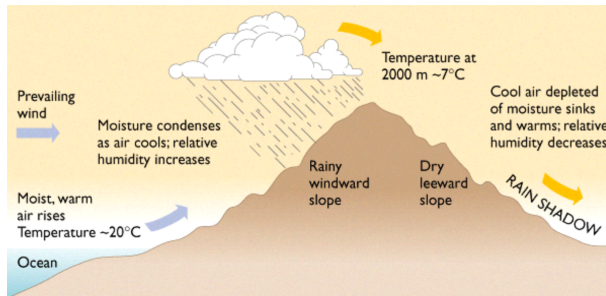
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Orographic precipitation



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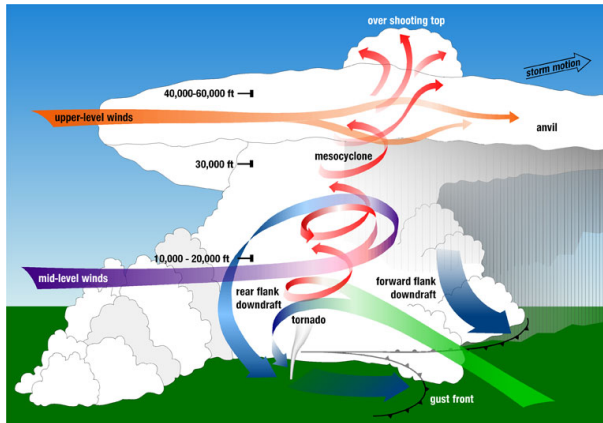
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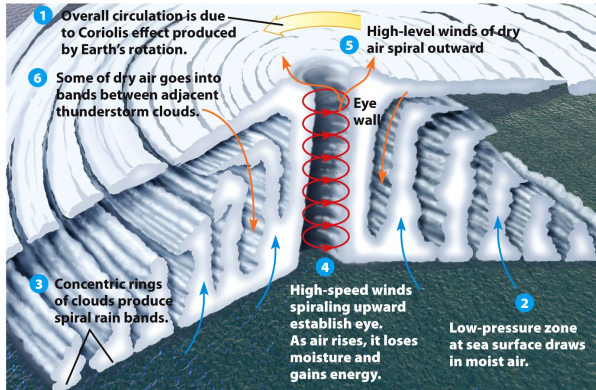
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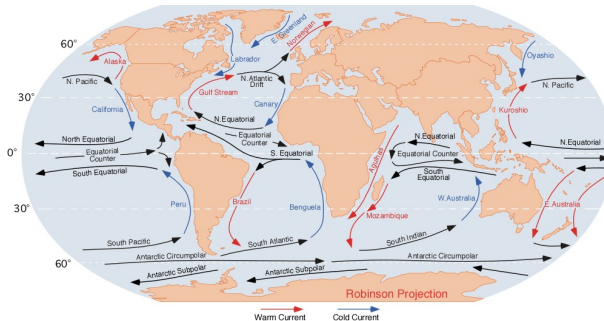
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Surface currents



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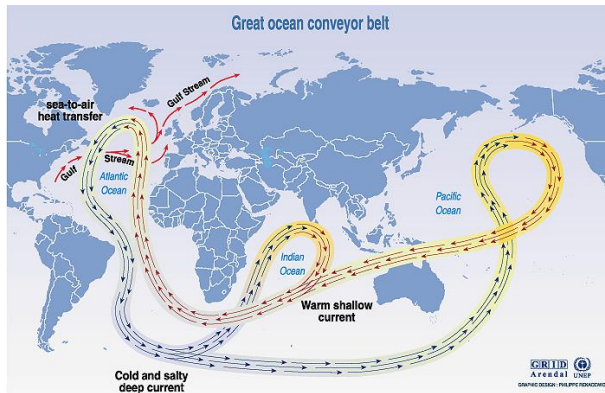
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References

Thermohaline conveyor



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.

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Differences in land area



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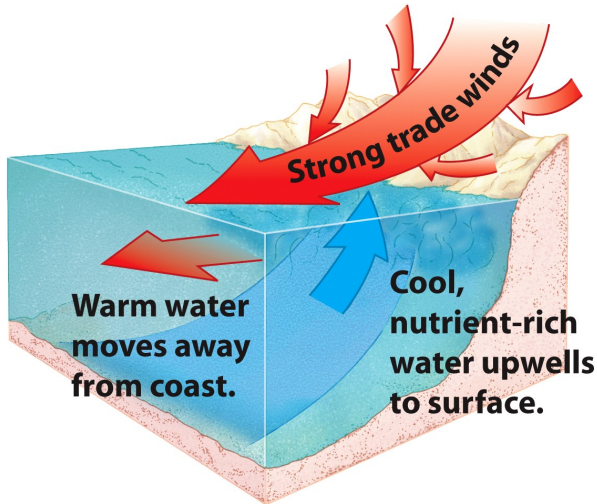
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Nutrient delivery from upwelling



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Normal upwelling along Peruvian coast

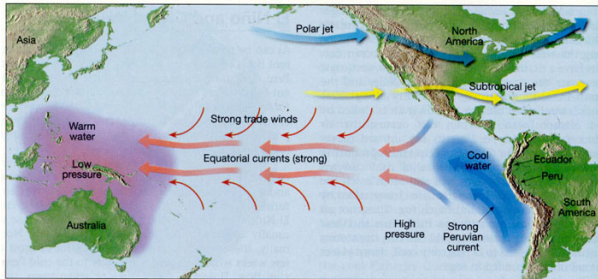


Fig.6 Normally, the trade winds and strong equatorial currents flow toward the west. At the same time, an intense Peruvian current causes upwelling of cold water along the west coast of South America.

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Current reversal in an El Niño event

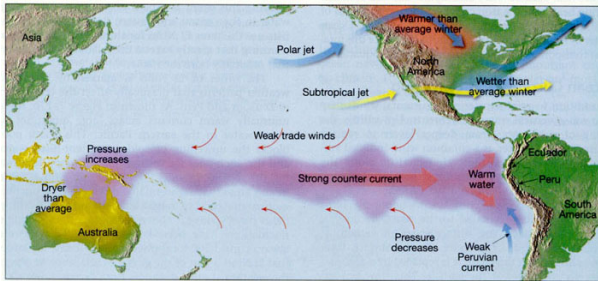


Fig.14 Upon the advent of an ENSO event, the pressure over the eastern and western Pacific flip-flops. This causes the trade winds to diminish, leading to an eastward movement of warm water along the equator. As a result, the surface waters of the central and eastern Pacific warm, with far-reaching consequences to weather patterns.

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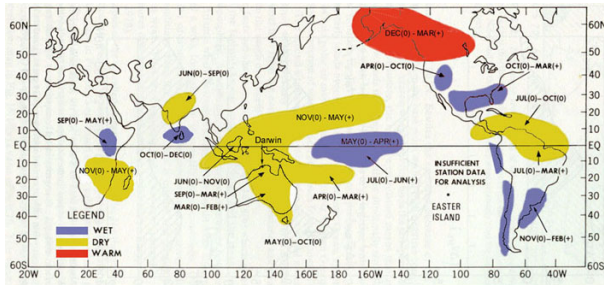
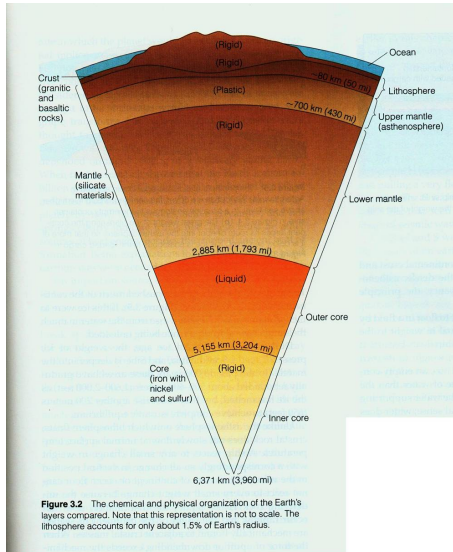


Fig.16 Schematic representation of typical ENSO-related precipitation anomalies over the globe. Red encloses relatively warm regions and blue encloses relatively wet regions. The approximate period of extreme conditions relative to the typical El Niño year (0) is also shown (adapted from Peixoto 1993)

Layered Earth



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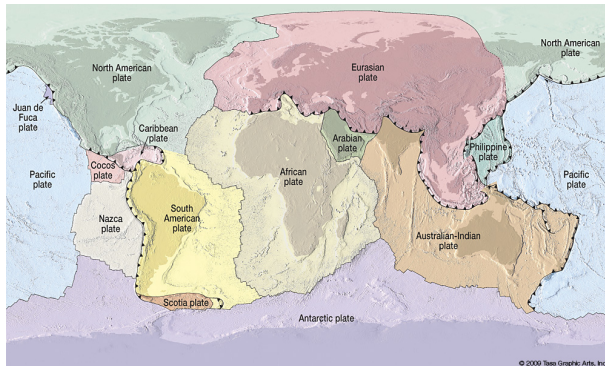
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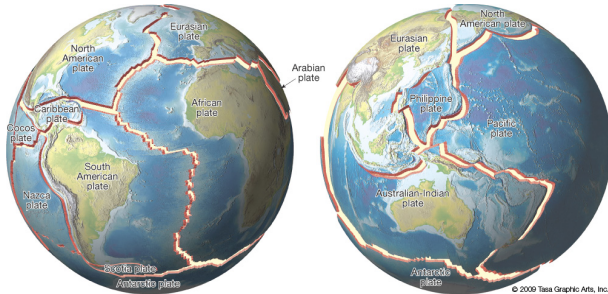
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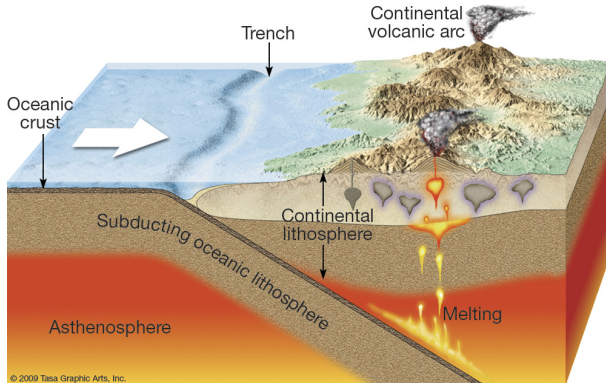
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Convergent plate boundary



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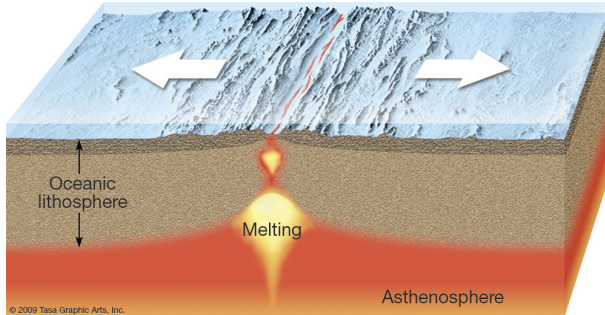
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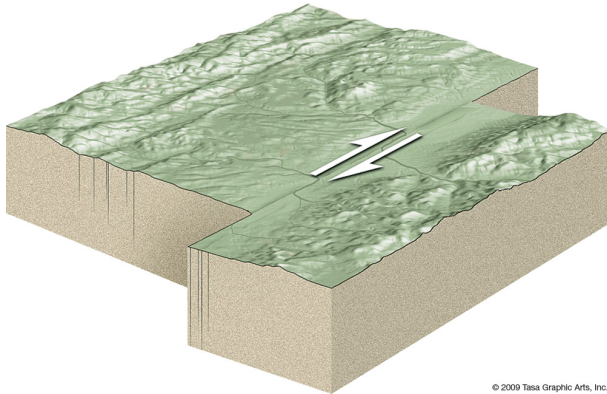
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Transform plate boundary



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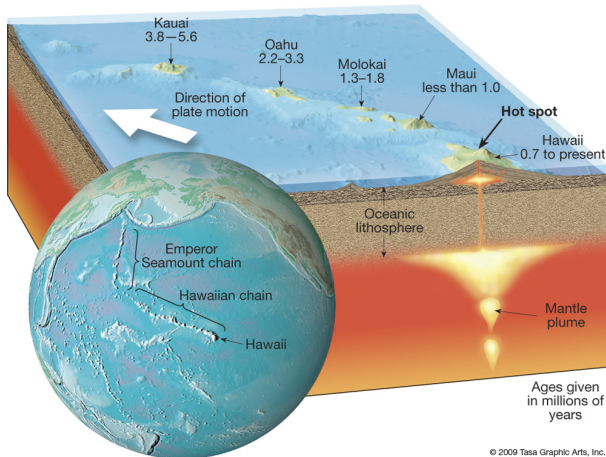
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Magma upwelling



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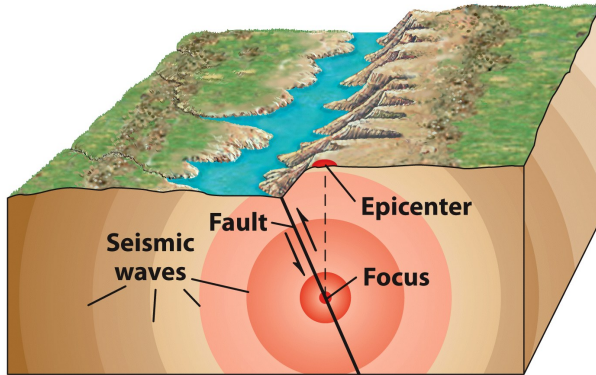
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Earthquake



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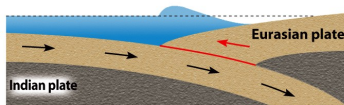
Tsunami

Indian Ocean



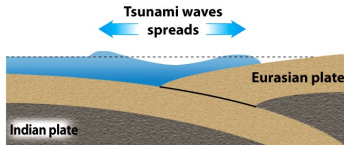
1 Before the earthquake

Stress builds and seafloor gradually deforms at subduction zone along Indian and Eurasian plate boundary.



2 Earthquake strikes

Earthquake causes Eurasian plate to thrust up and over the Indian plate, displacing a large volume of overlying water.



3 Tsunami radiates outward

Tsunami spreads rapidly in two directions.

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