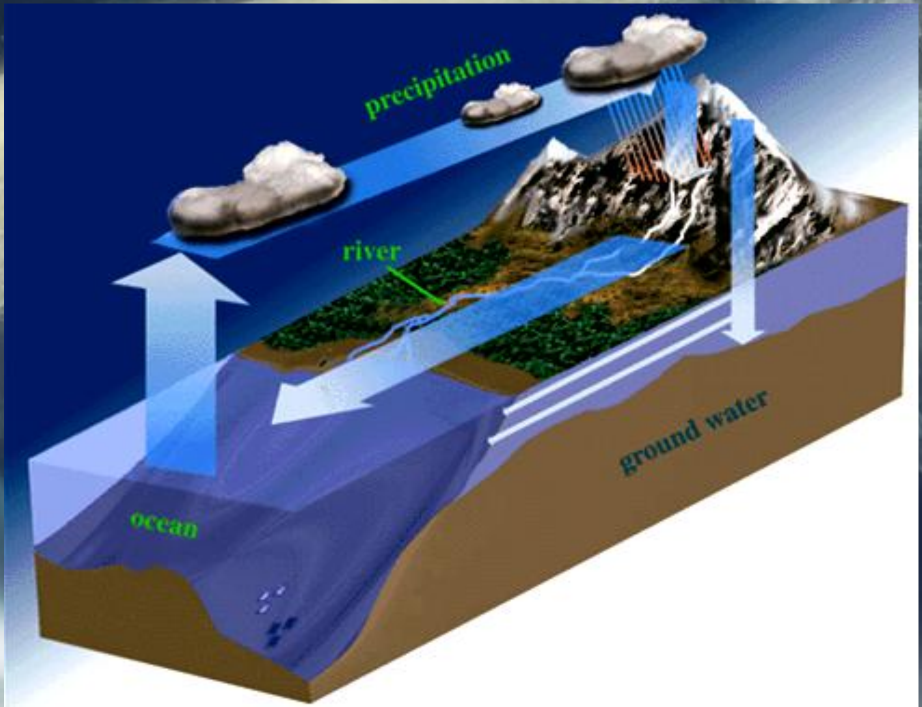


The Hydrosphere:
Lecture 2: Climate, Soils and Vegetation

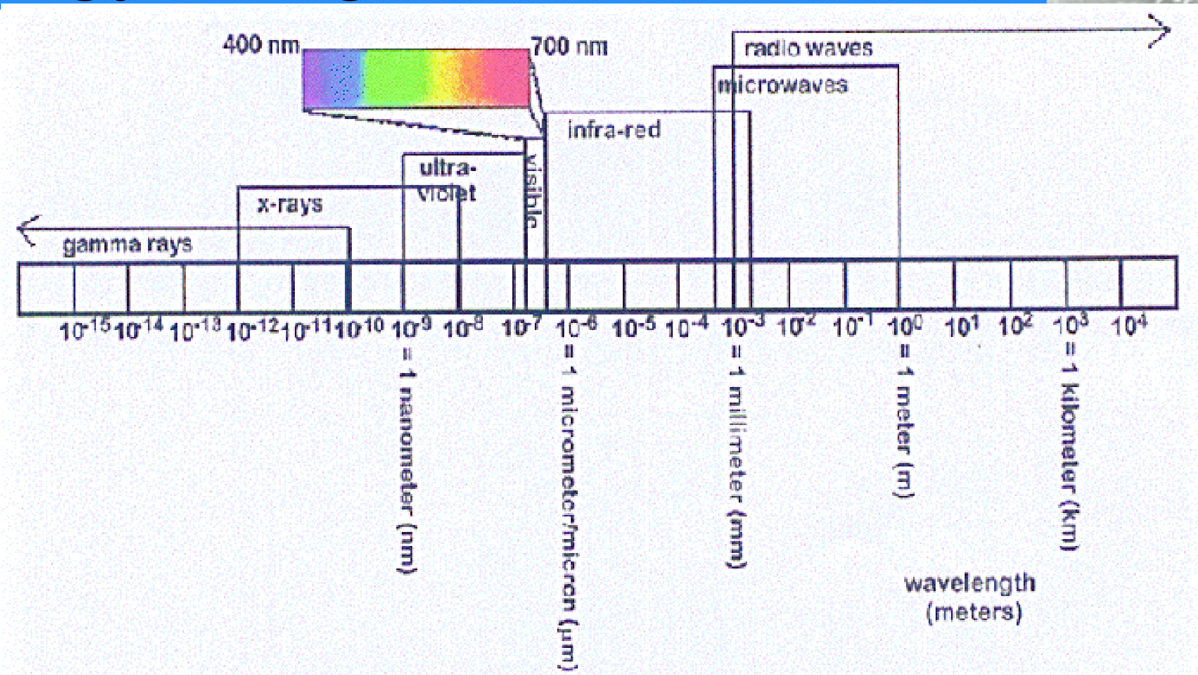
The Earth’s Energy Budget

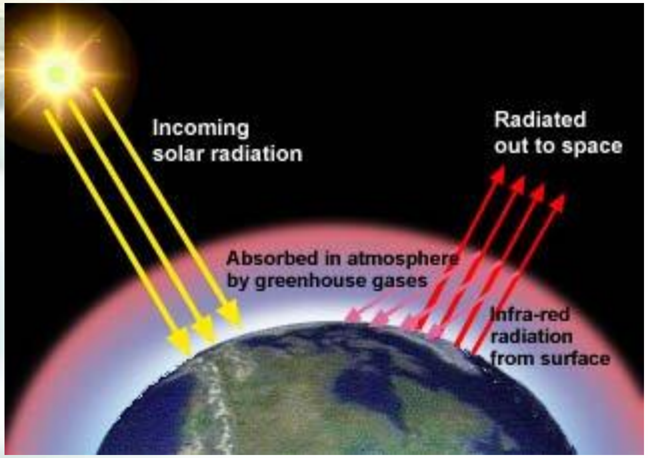
Principle: Absorption and re-emission of radiation at the earth's surface is only one part of an intricate web of heat transfer in the earth's planetary domain. Equally important are selective absorption and emission of radiation from molecules in the atmosphere. If the earth did not have an atmosphere, surface temperatures would be too cold to sustain life. If too many gases which absorb and emit infrared radiation were present in the atmosphere, surface temperatures would be too hot to sustain life.

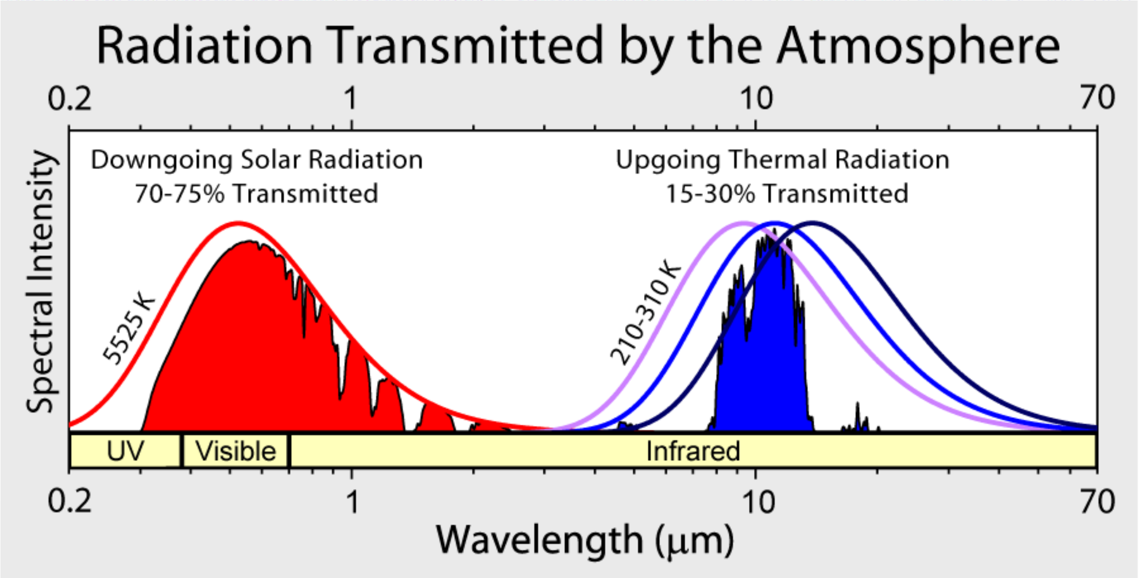
- TEST: http://education.jlab.org/reading/energy_budget.html

The Earth's Energy Budget

- Planck's law describes the spectral radiance of electromagnetic radiation at all wavelengths emitted in the normal direction from a black body at temperature T
- Electromagnetic Spectrum
- Shortwave & Longwave Radiation

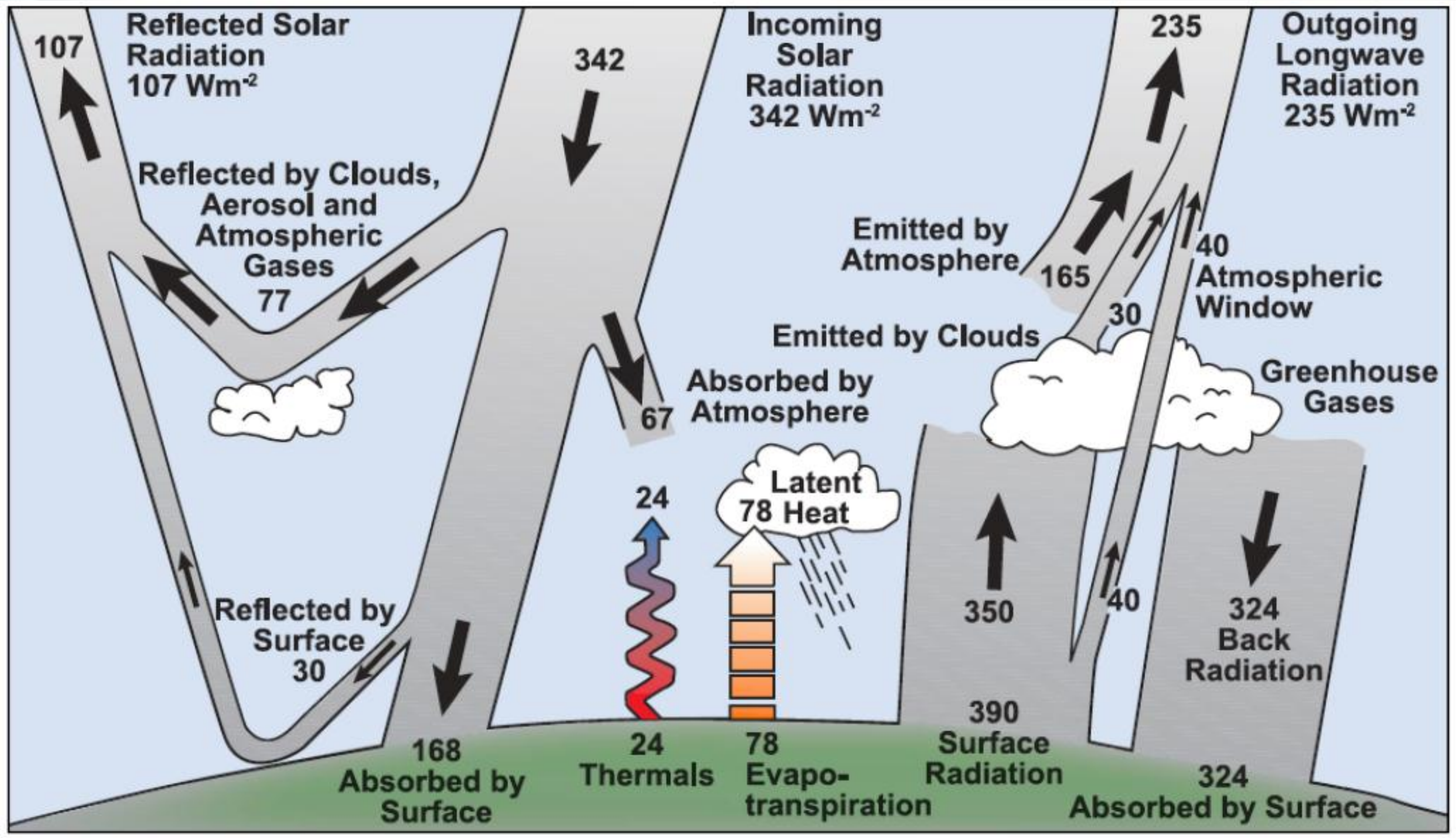




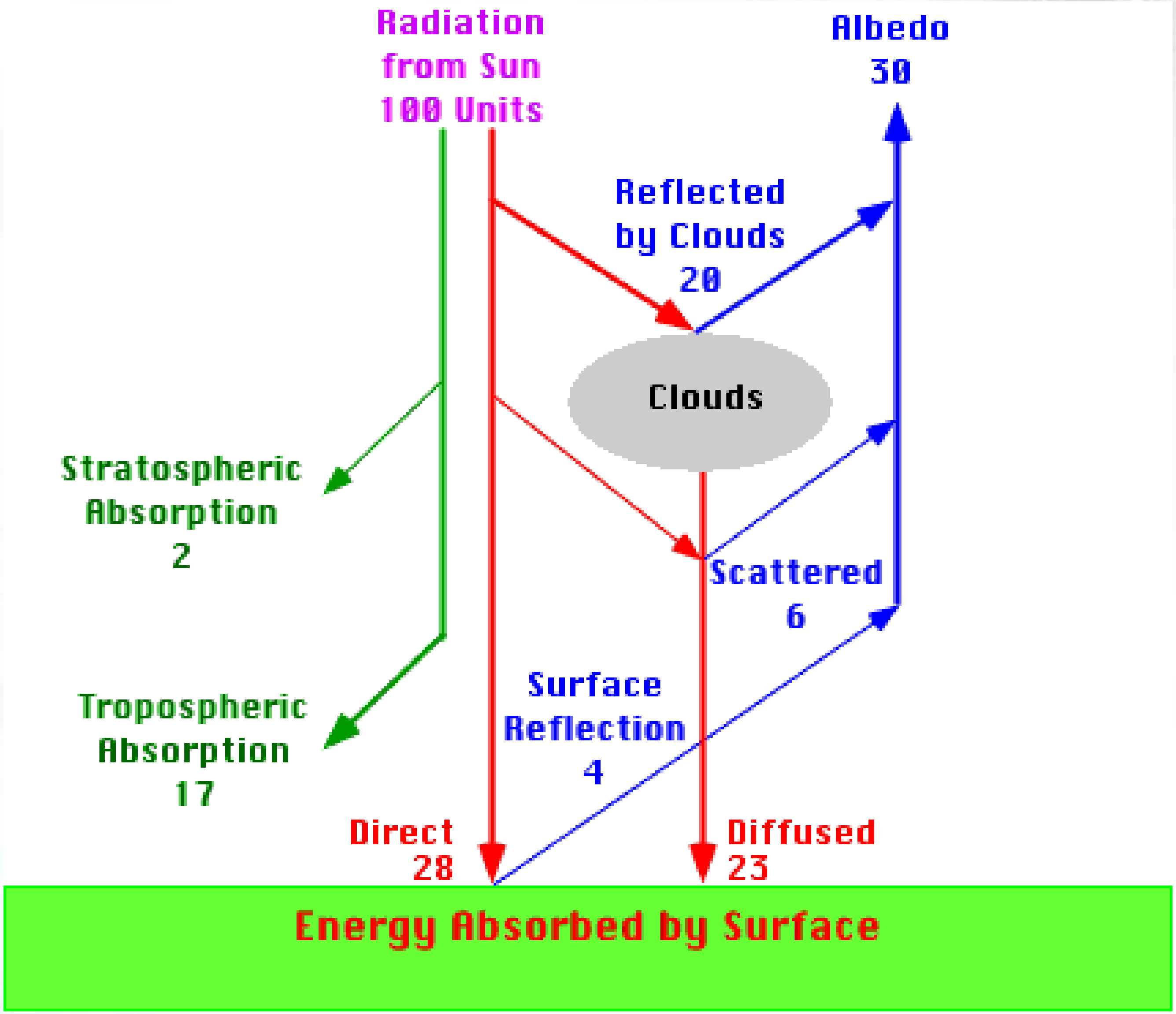


The Earth's Energy Budget

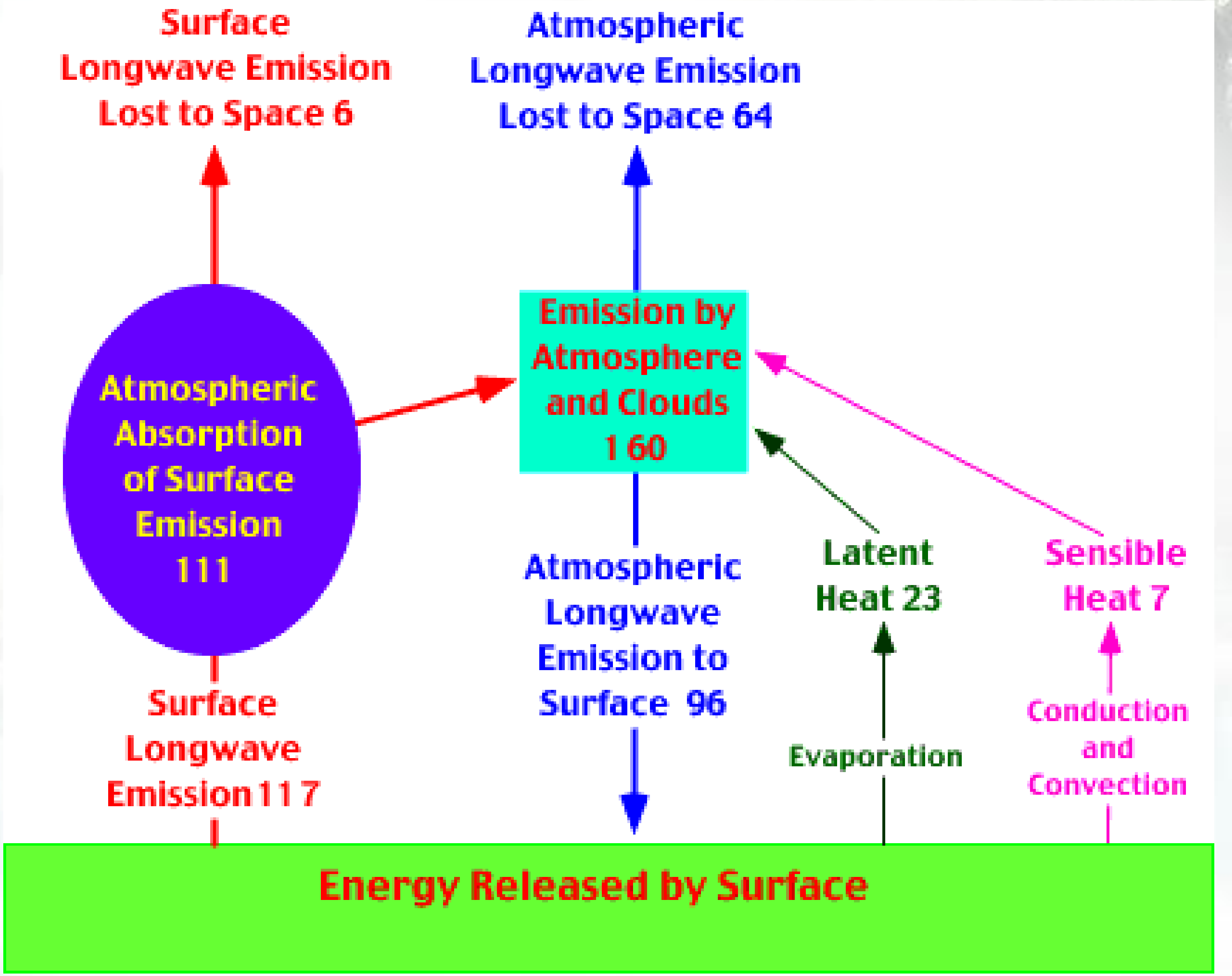
- Incoming Solar Radiation must be transferred to Earth Radiation:
  - Reflected, Absorbed, Emitted
  - Transferred through latent heating
  - Conduction/convection



Global shortwave radiation cascade.

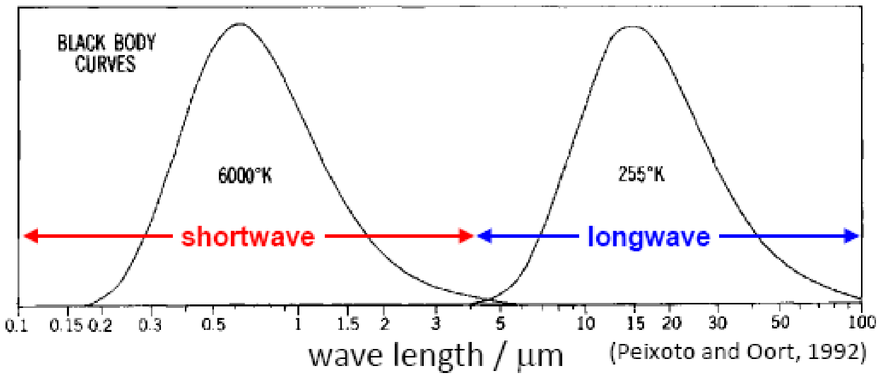


Global longwave radiation cascade



Radiation: Shortwave & Longwave

$$R_n = (SW_{\downarrow} + SW_{\uparrow}) + (LW_{\downarrow} + LW_{\uparrow})$$



Longwave:

Stefan-Boltzmann constant

$$LW_{\uparrow} = \varepsilon_s \, \sigma \, T_s^4 \quad + \; (1 - \varepsilon_s)\, LW_{\downarrow}$$

Ground temperature

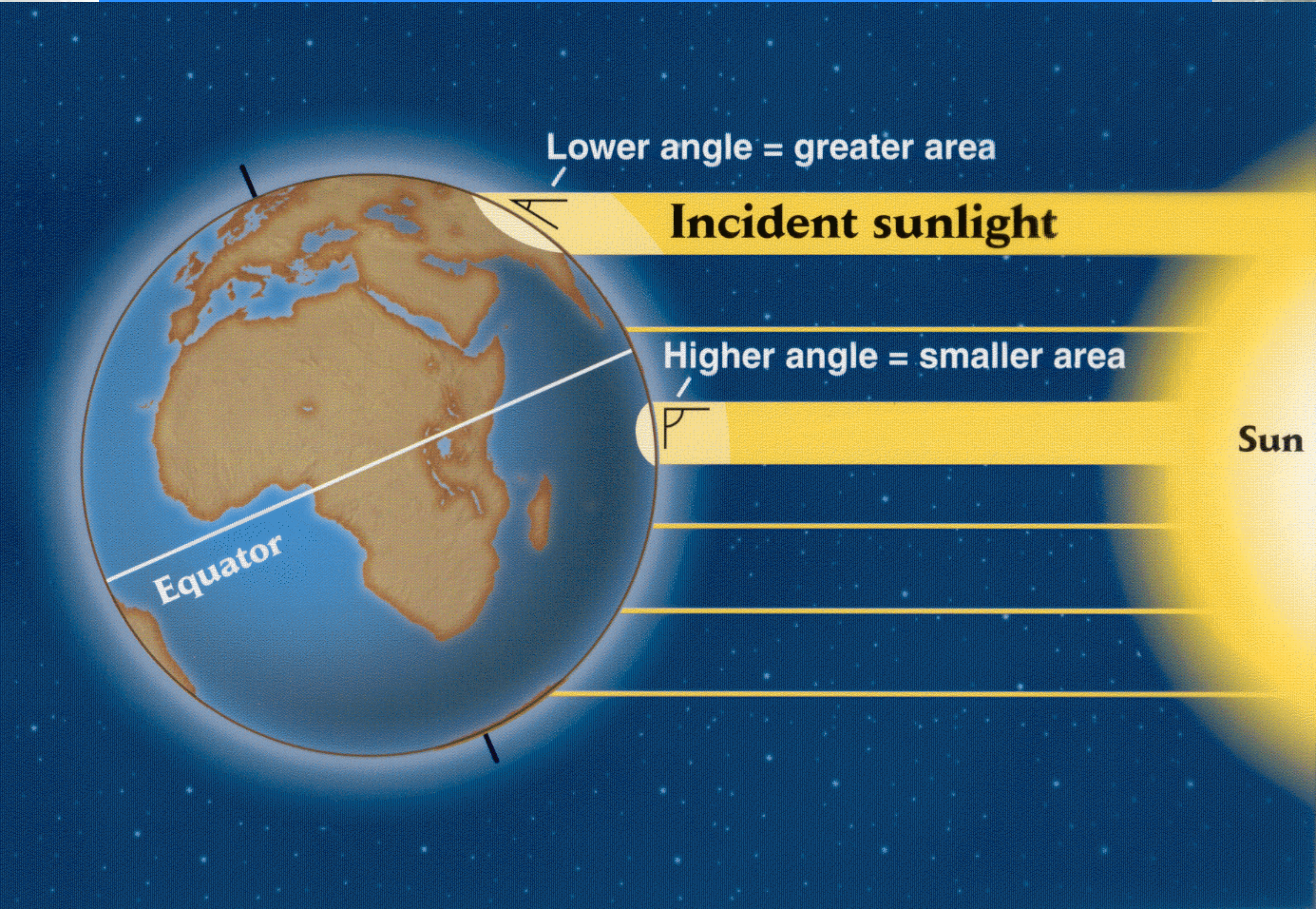
Ground emissivity

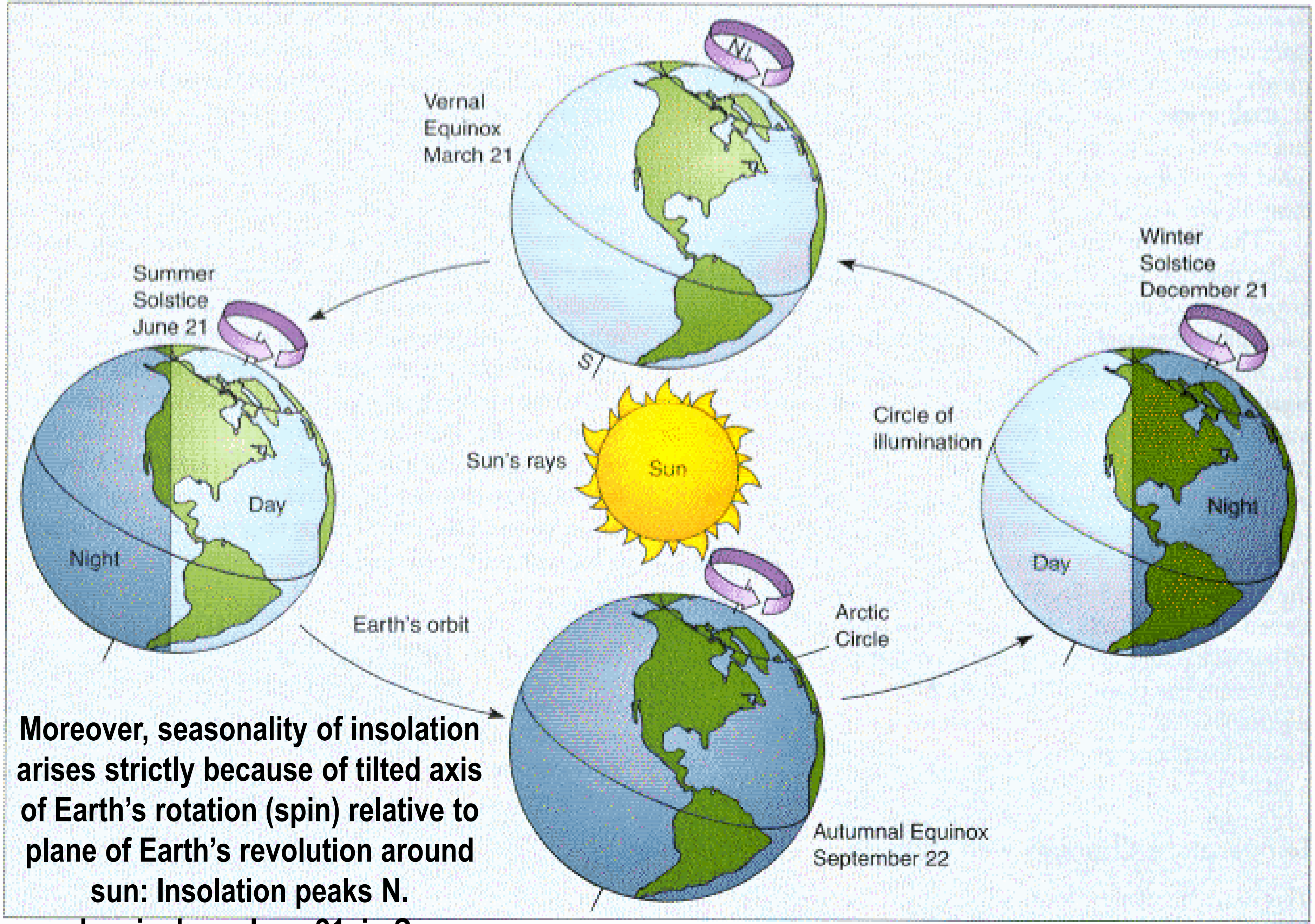
$$LW_{\downarrow} = \varepsilon_a \, \sigma \, T_a^4$$

Air temperature

Atmospheric emissivity = f(T_a, RH, Cloud cover)

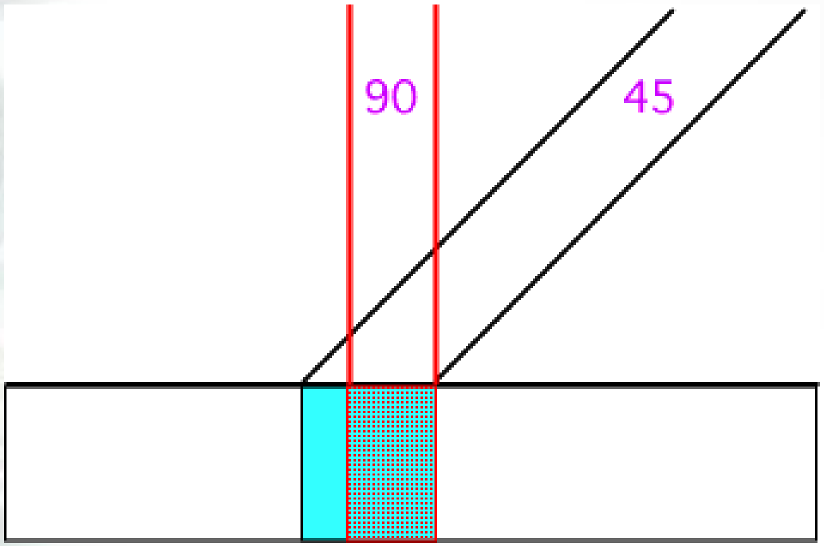
Visual illustration of latitudinal gradient of insolation





Moreover, seasonality of insolation arises strictly because of tilted axis of Earth's rotation (spin) relative to plane of Earth's revolution around sun: Insolation peaks N. hemisphere June 21, in S. hemisphere December 21.

Solar Radiation in Atmosphere



SIN 80 = 0.98 or 98%

SIN 70 = 0.94 or 94%

SIN 60 = 0.87 or 87%

SIN 50 = 0.77 or 77%

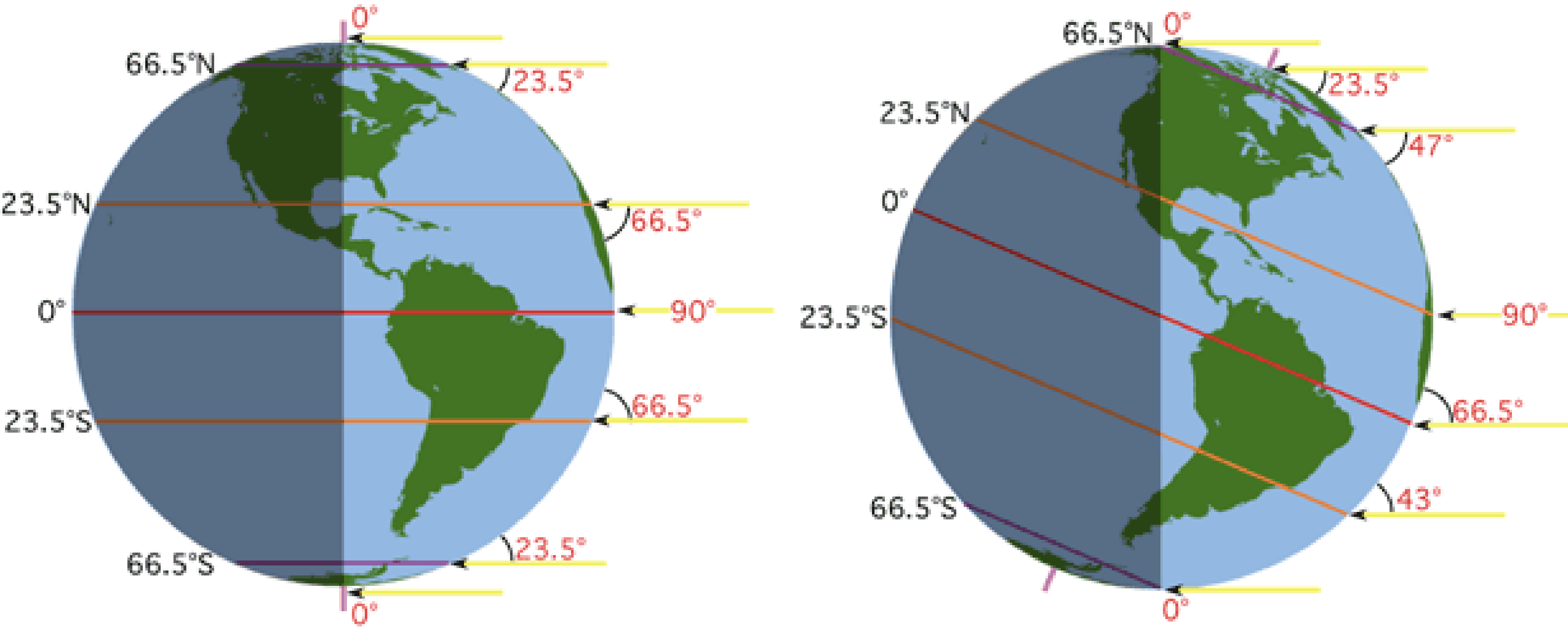
SIN 40 = 0.64 or 64%

SIN 30 = 0.50 or 50%

SIN 20 = 0.34 or 34%

SIN 10 = 0.17 or 17%

SIN 0 = 0.00 or 0%



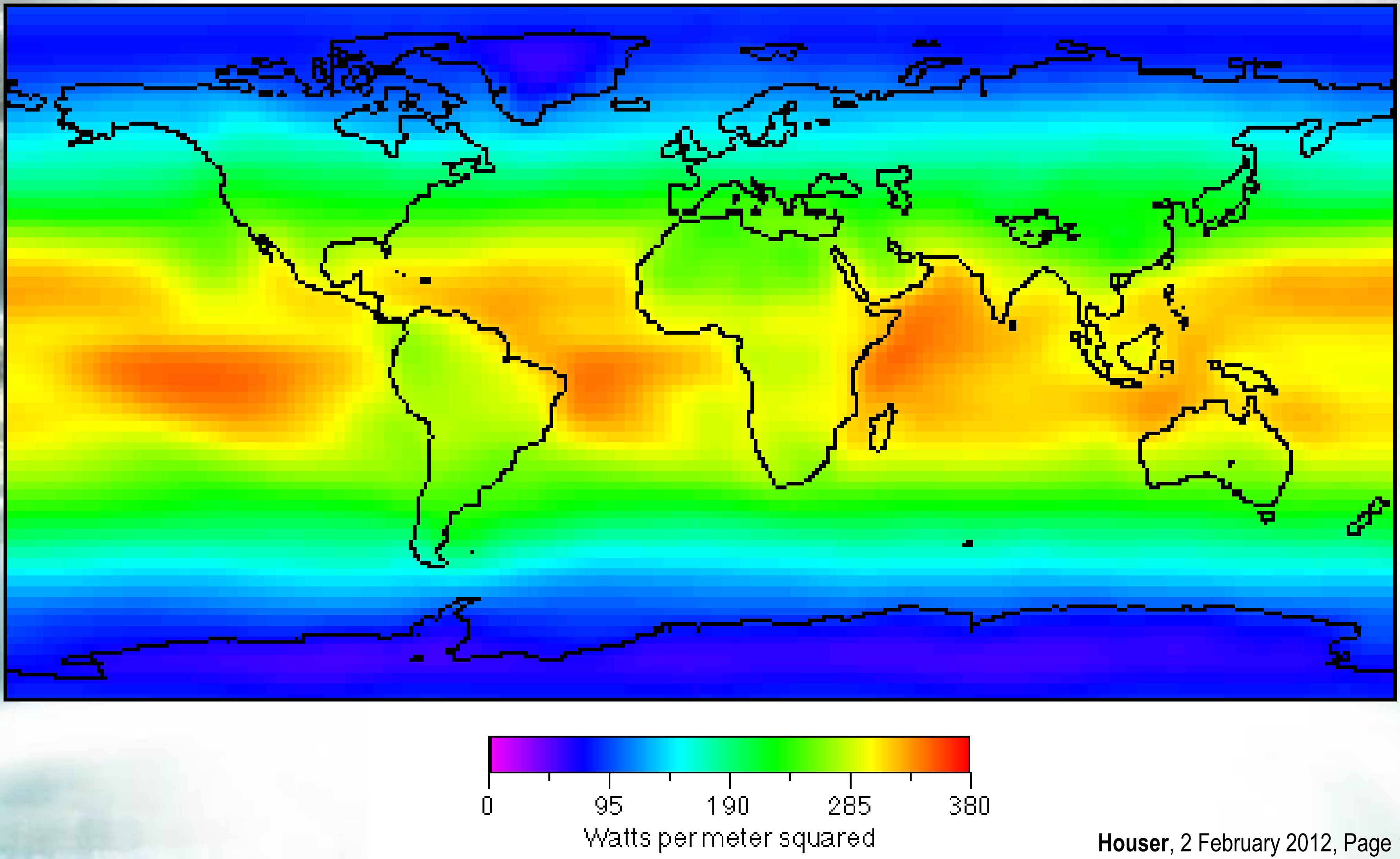
Altitude of the sun at solar noon can also be calculated with the following simple equation:

Altitude A = 90 - Latitude L +/- Declination D

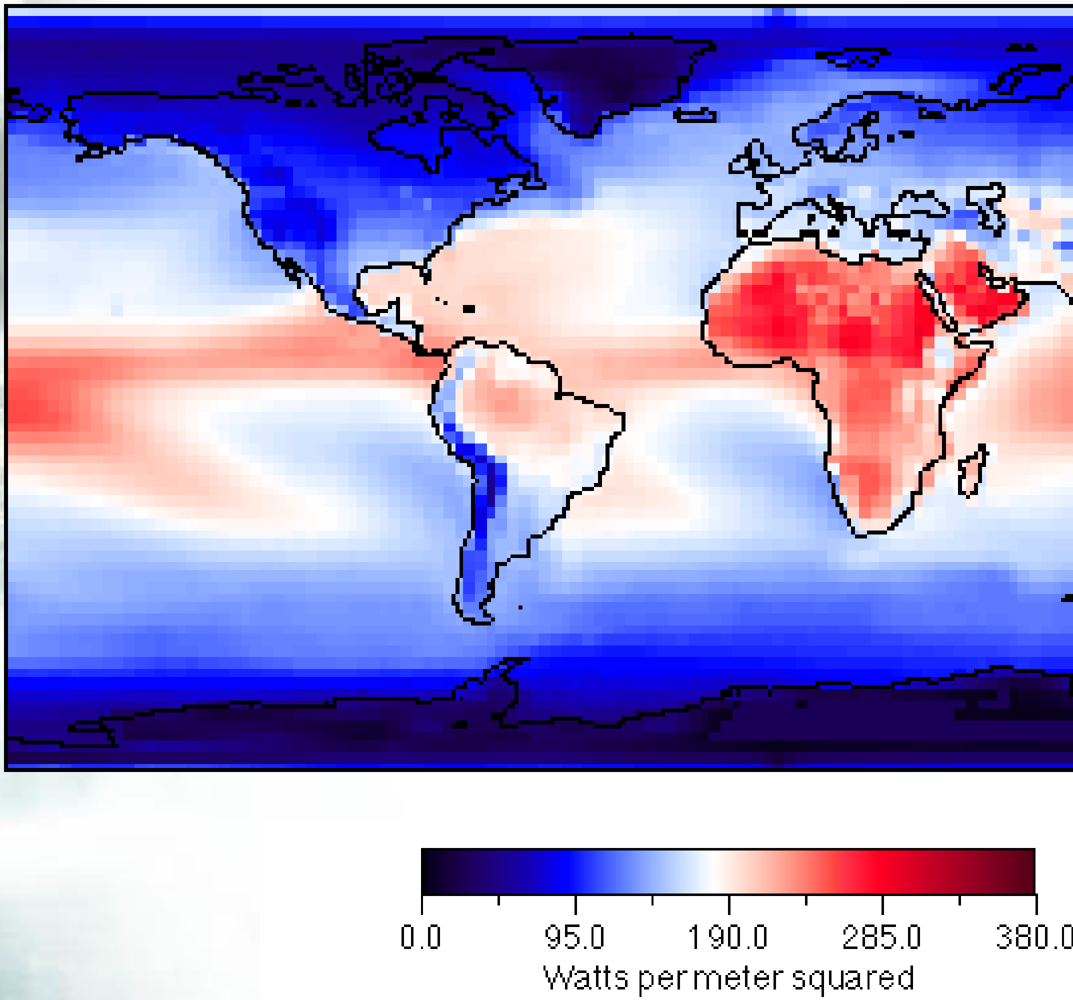
When tropical latitudes and this equation gives a number > 90, then:

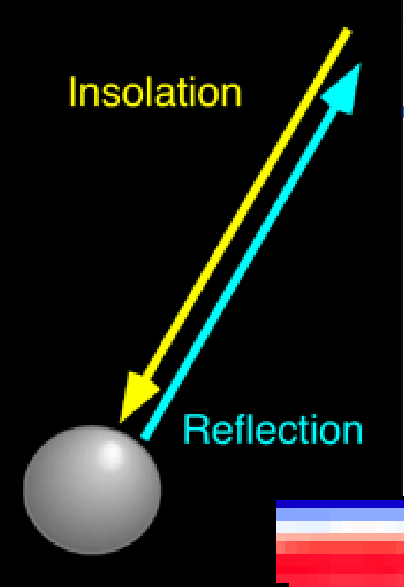
Altitude A = 90 - (originally calculated Altitude A - 90)

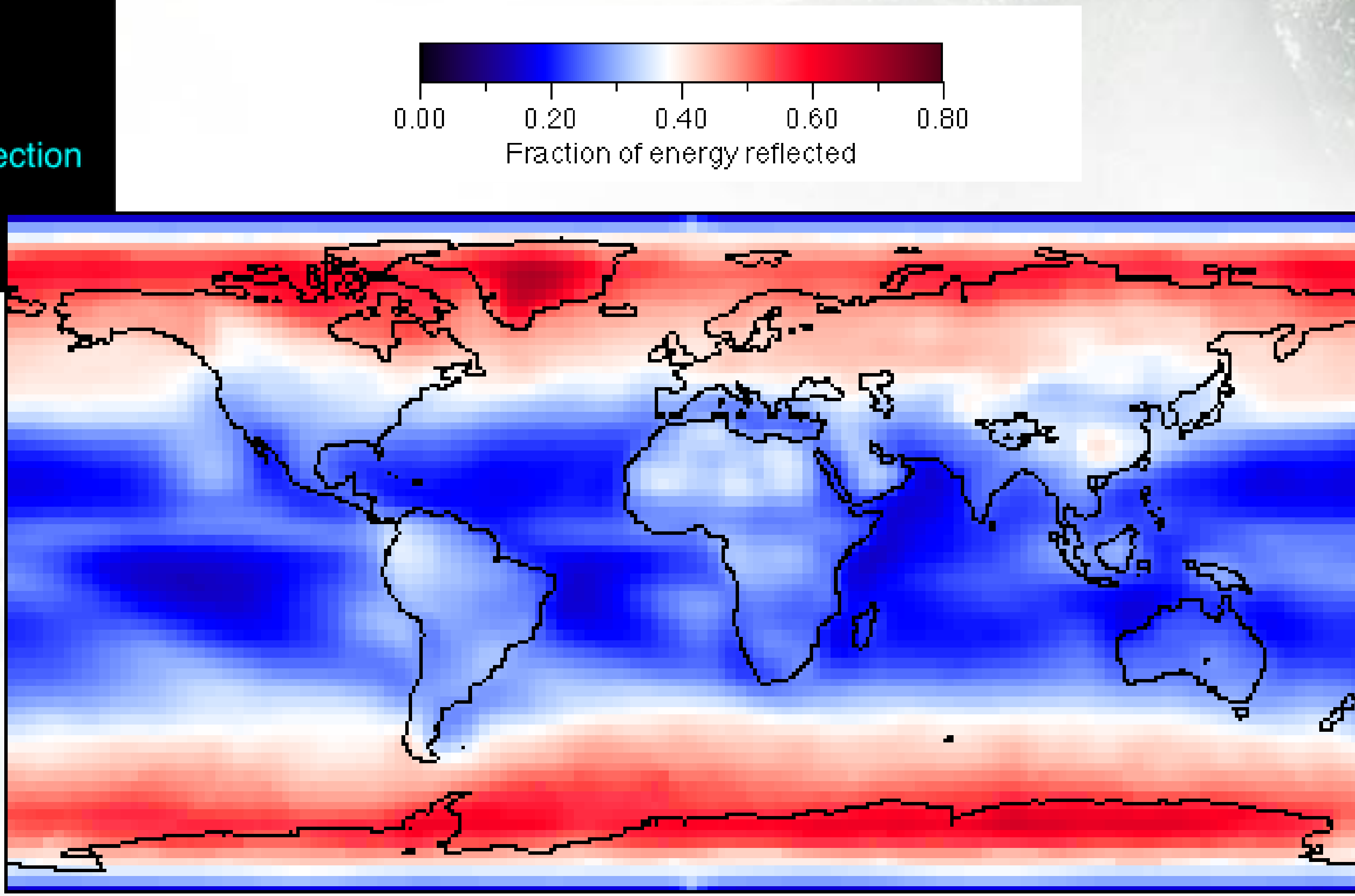
annual pattern of **solar radiation absorption** at the Earth's surface for the year 1987.



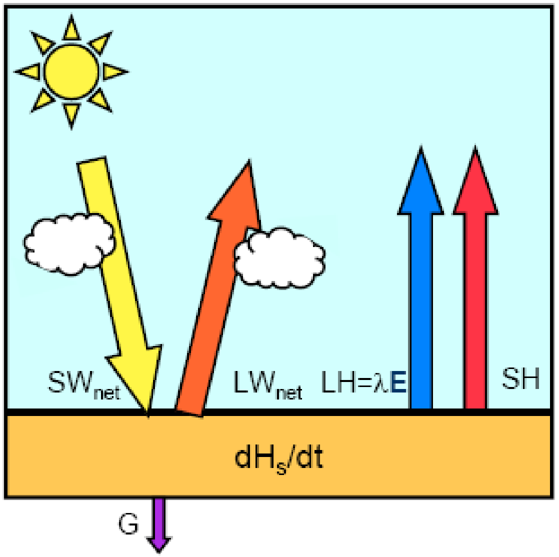
Annual (1987) quantity of outgoing longwave radiation absorbed in the atmosphere.




Insolation
Reflection


0.00
0.20
0.40
0.60
0.80
Fraction of energy reflected

The Surface Energy Budget



For a surface volume

$$dH_s / dt = R_n - \lambda E - SH - G$$

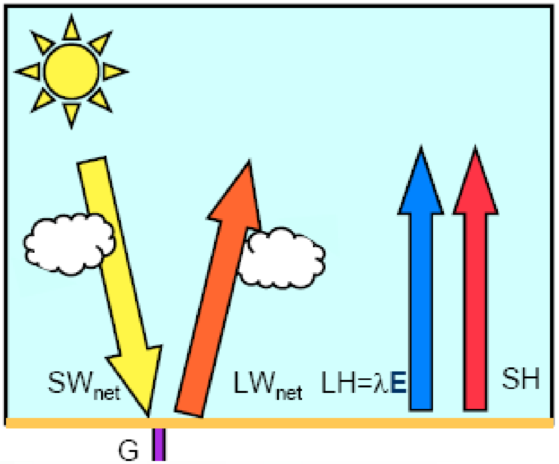
Ground heat flux

Net radiation

Sensible heat flux

Latent heat flux (also LH)

$$R_n = (SW_{\downarrow} + SW_{\uparrow}) + (LW_{\downarrow} + LW_{\uparrow})$$



For a surface area

$$R_n = \lambda E + SH + G$$

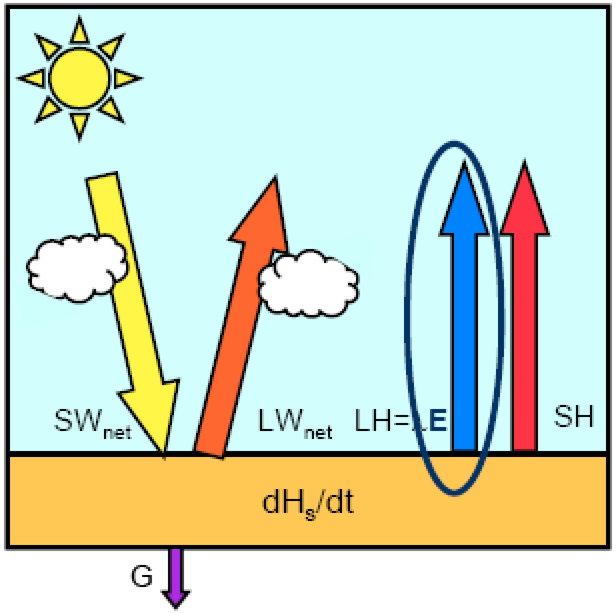
Ground heat flux

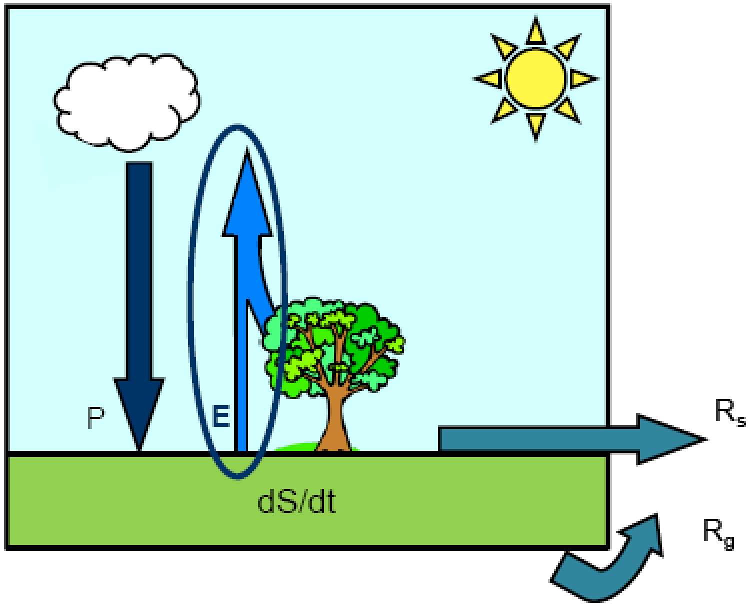
Net radiation

Sensible heat flux

Latent heat flux (also LH)

Linkage between Water & Energy Cycle

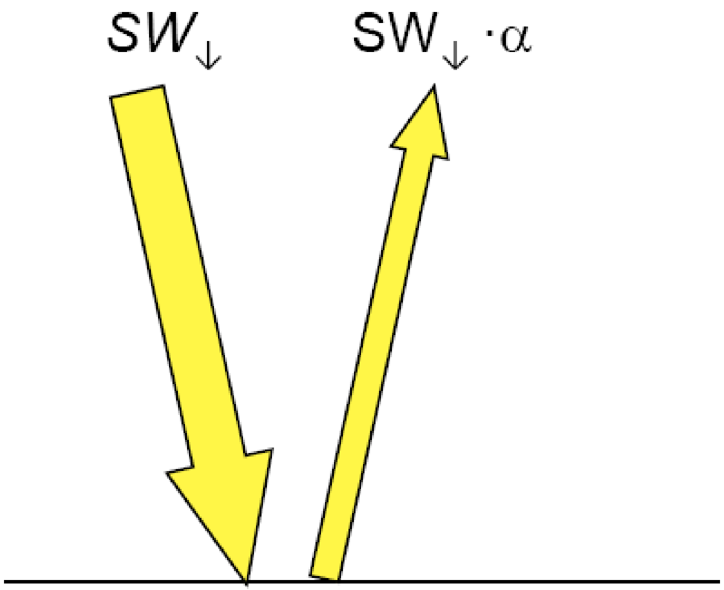




The partitioning of the net incoming energy (net radiation) in the latent and sensible heat fluxes is controlled by soil moisture if it is the limiting factor for evapotranspiration

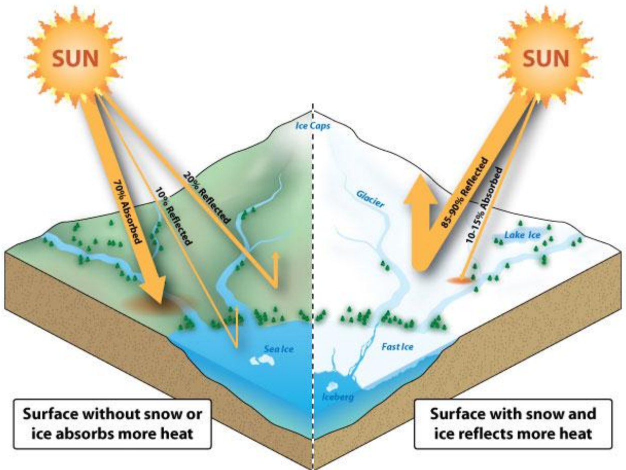
Radiation: Albedo

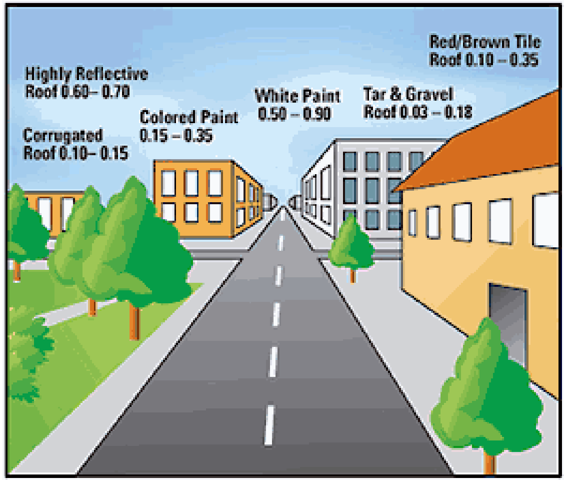
Albedo = reflectivity of a surface for shortwave radiation (UV, visible and NIR)



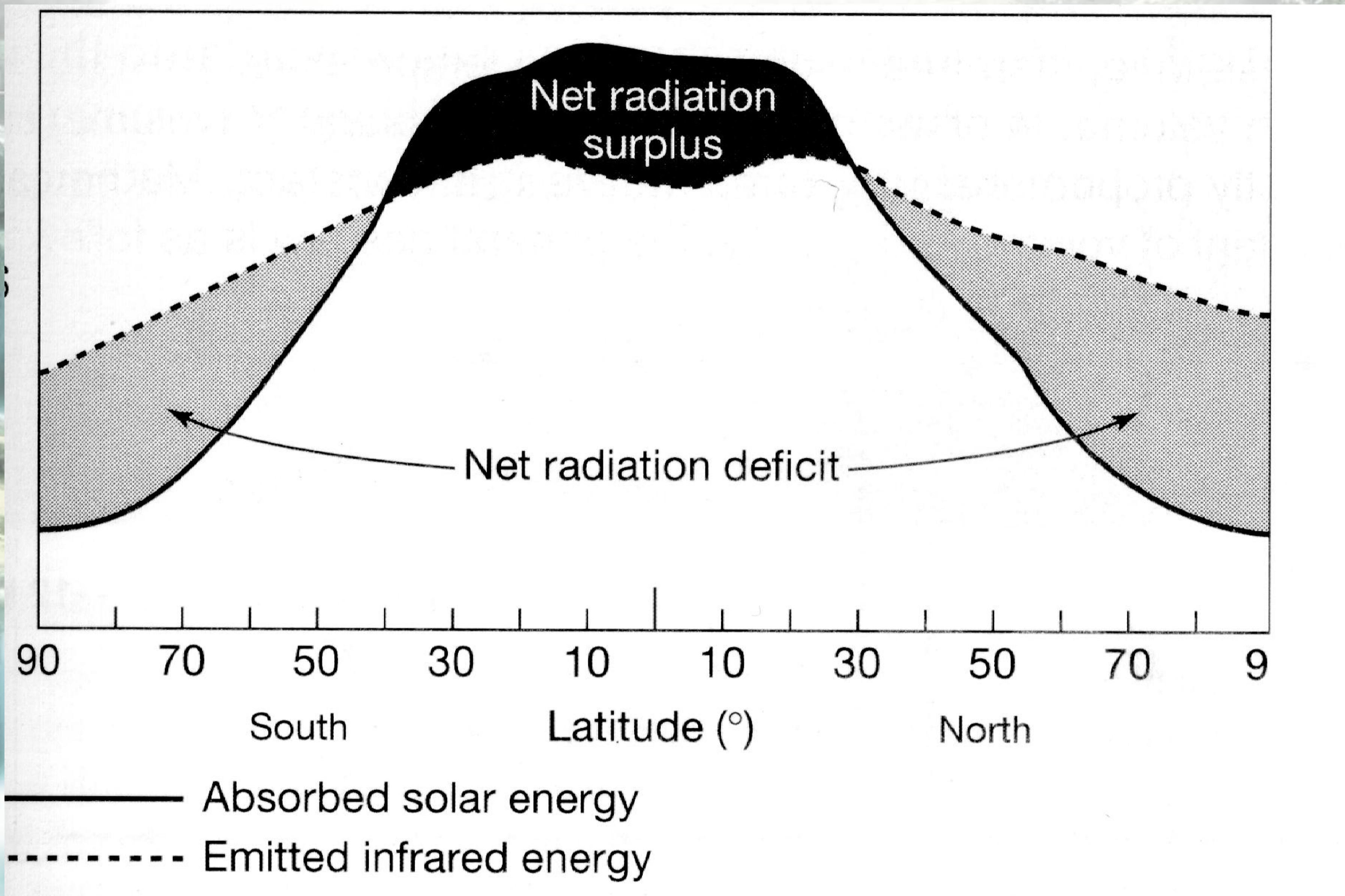
Surface	Conditions	Albedo (α)
Snow	old / fresh	0.45 / 0.85
Clouds	100 m thick (d = 3)	0.4
	500 m thick (d = 9)	0.7
Ice		0.25-0.35
Oceans, Lake	Zenith angle 30°	0.05
	60°	0.10
	85°	0.6
Grassland		0.2-0.3
Forest		0.1-0.2
Global mean	planetary (incl. clouds)	0.3
	surface	0.15

(Dingmann 1993, IPCC 2007, Corti and Peter 2009)



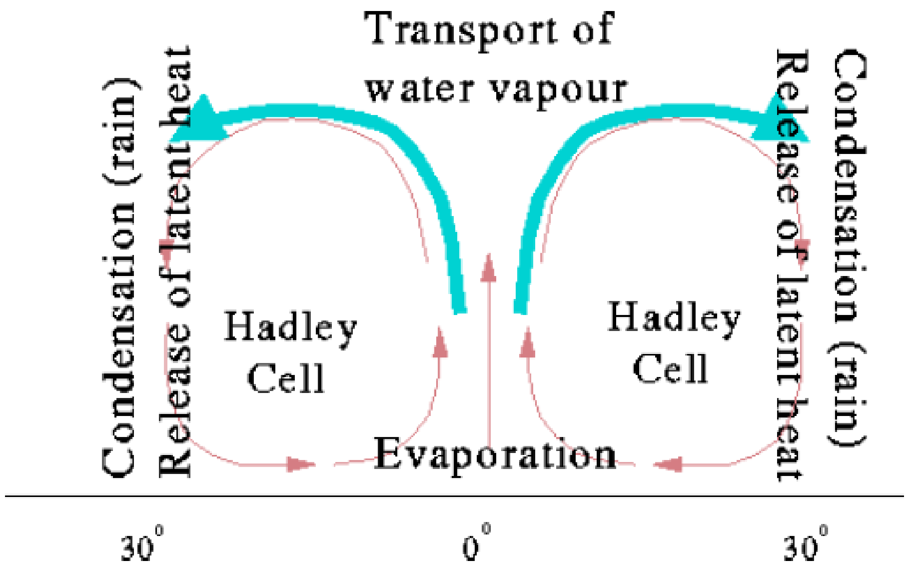


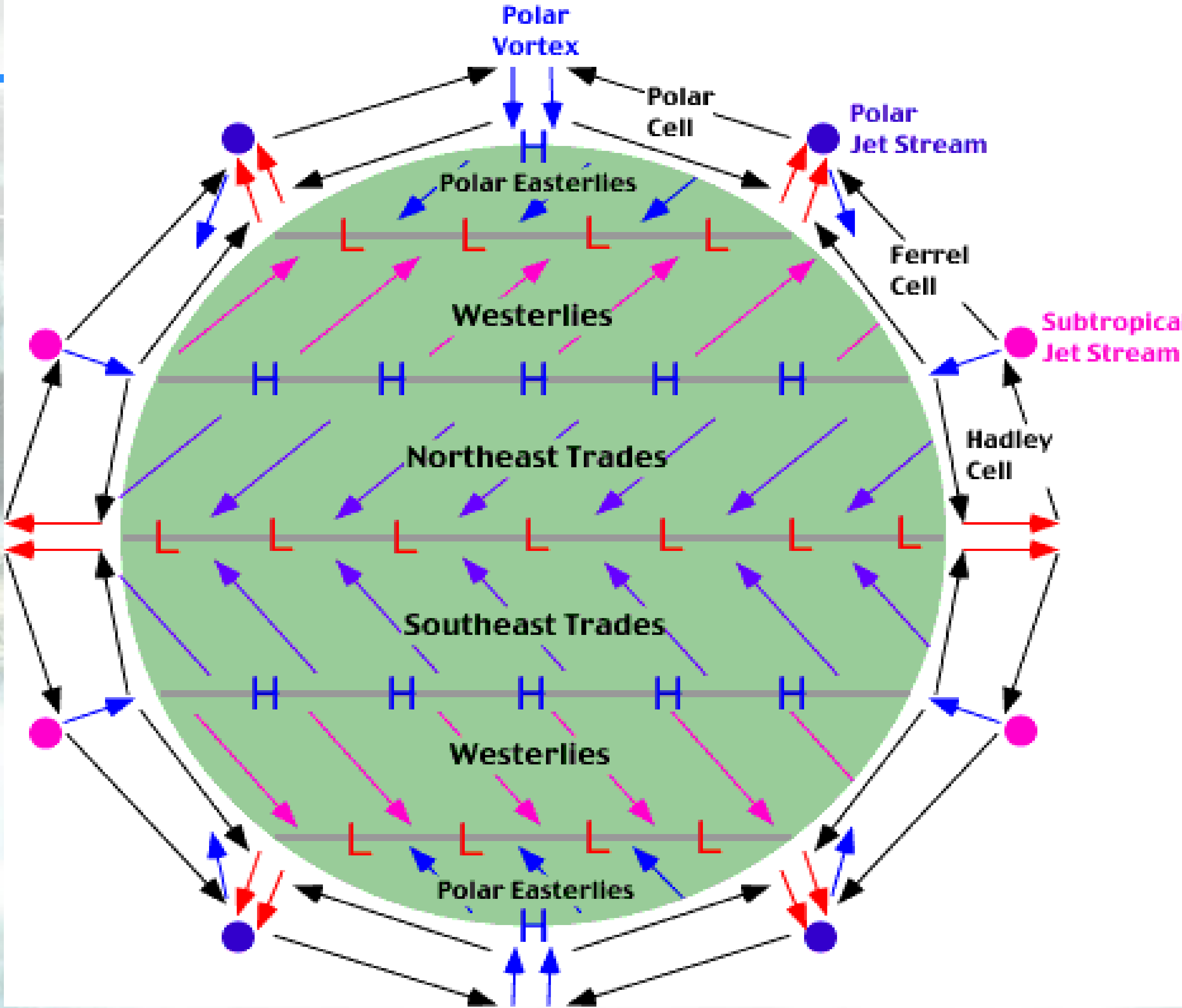
Global Energy Redistribution



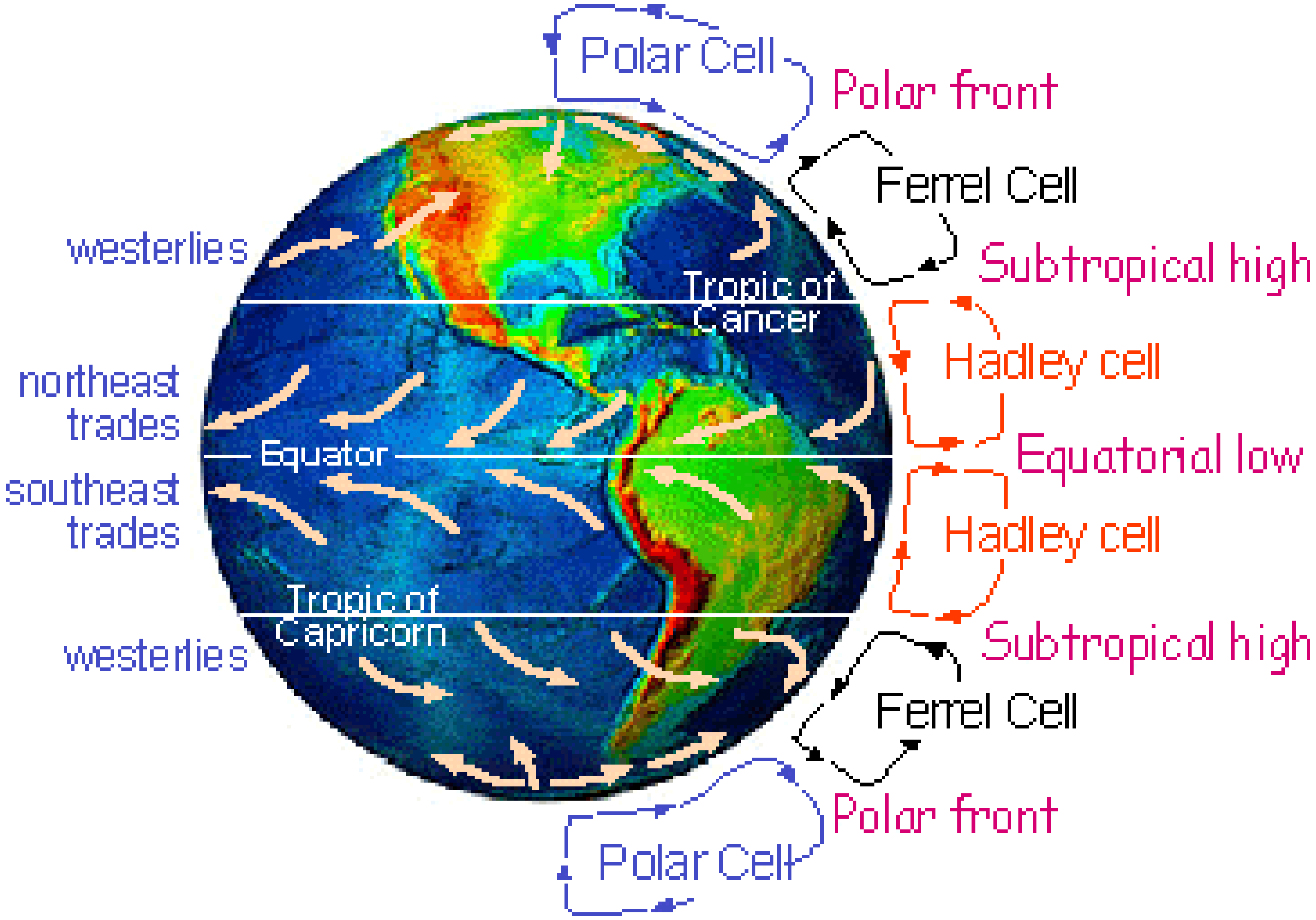
Latitudinal Energy Transfer

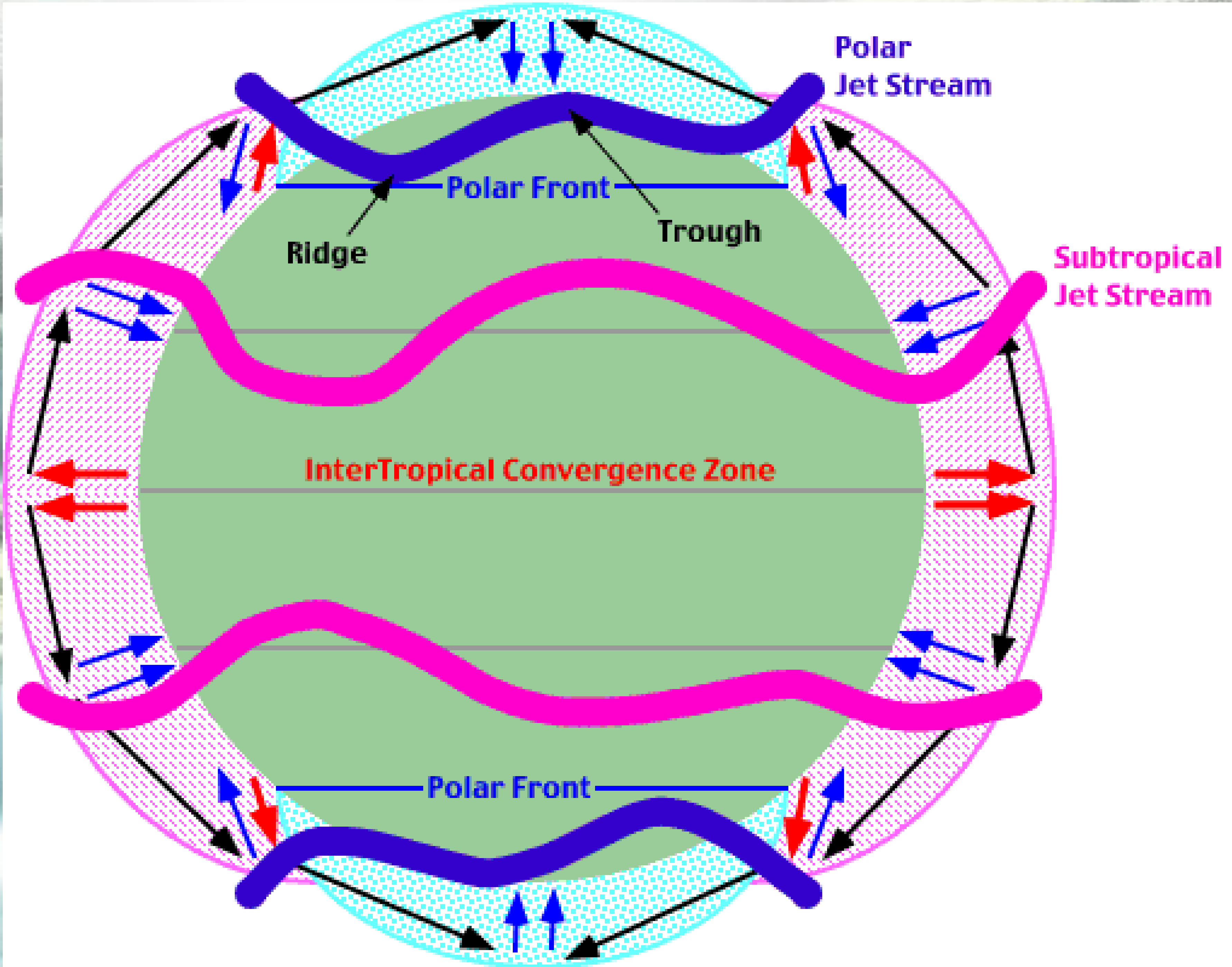
- Movement of water vapour in the atmosphere represents the movement of energy in the form of latent heat.
- The latent heat content of water vapour can have a profound effect on the efficiency with which heat is transported

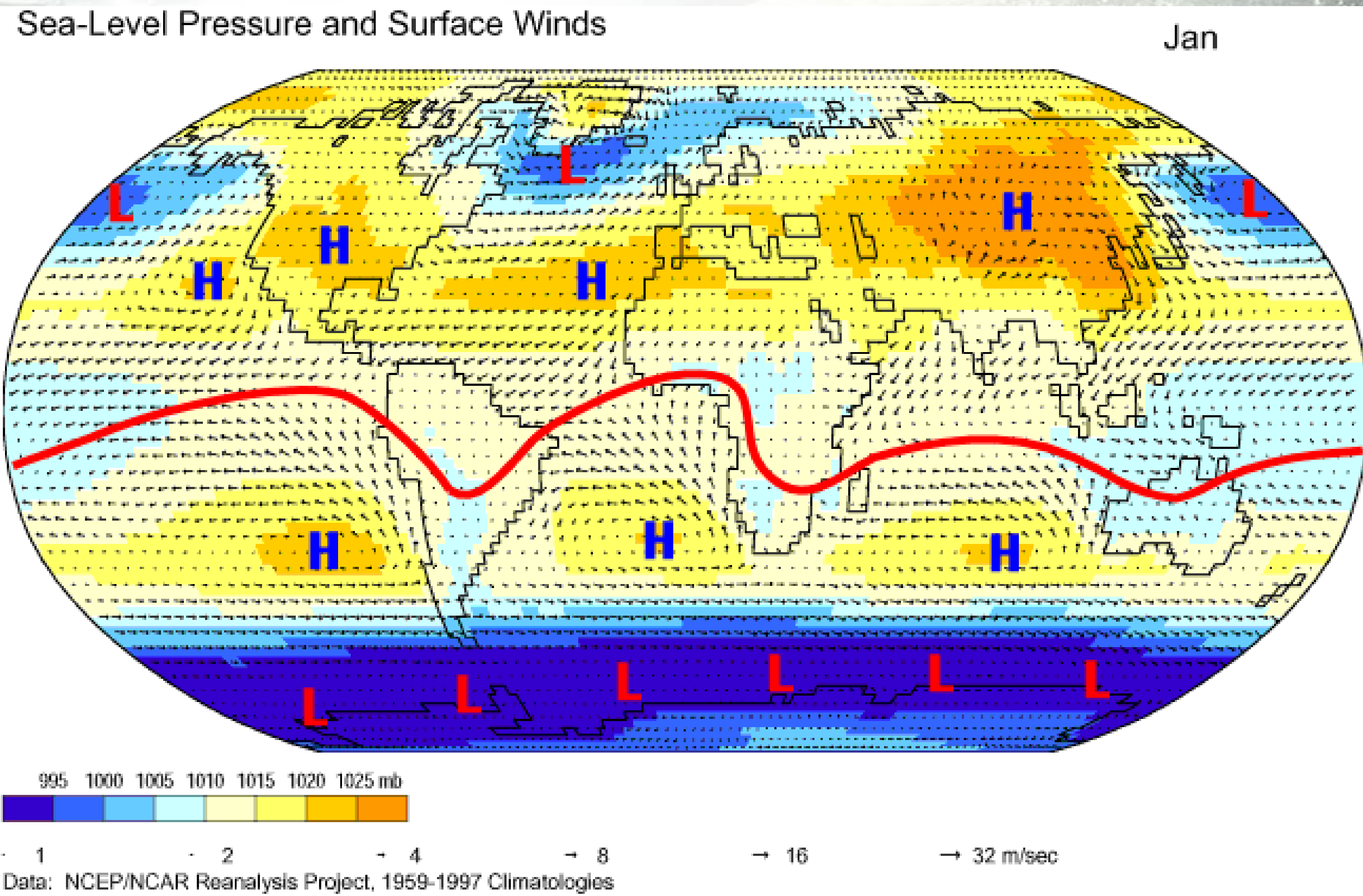




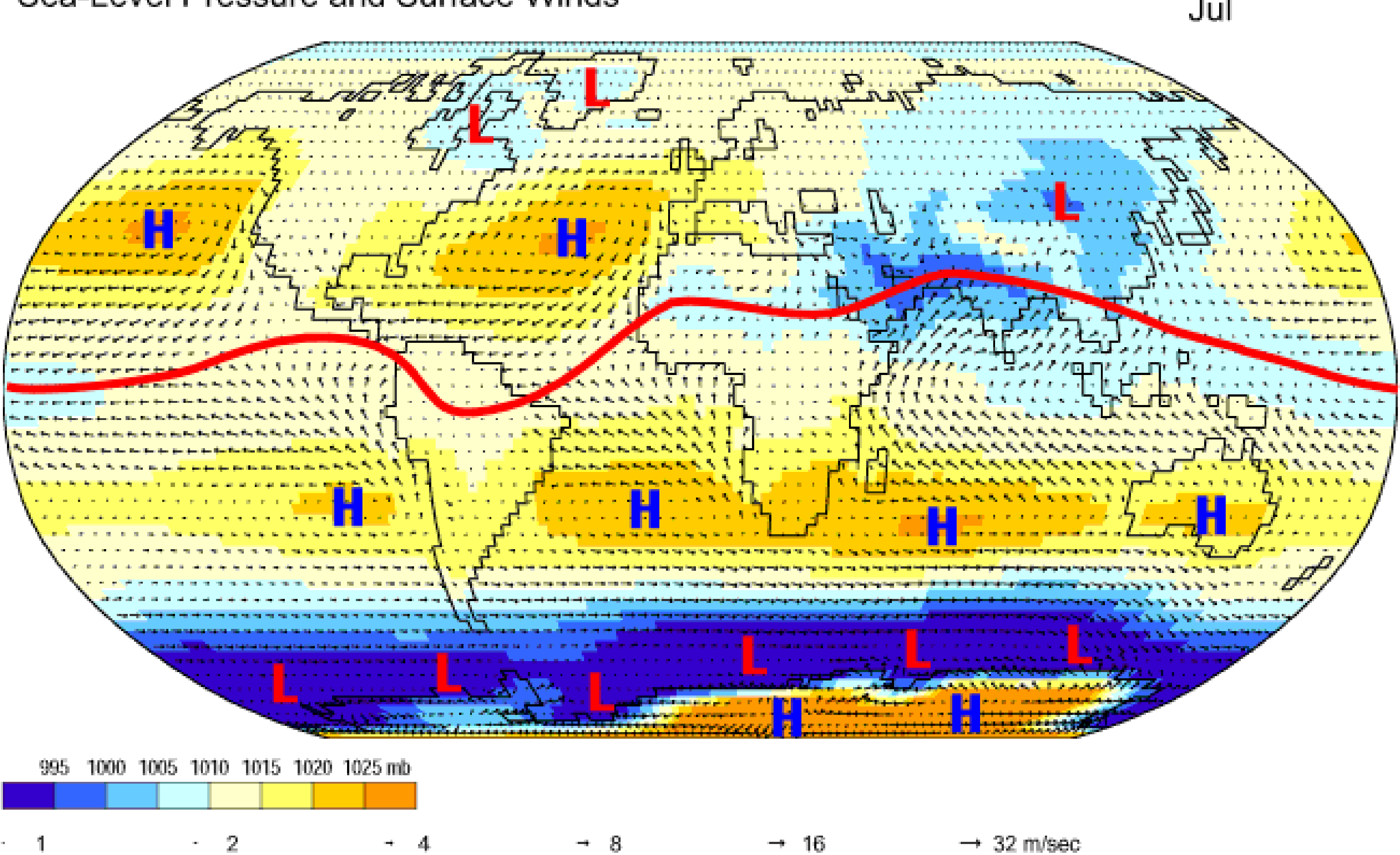
Polar Vortex
Polar Cell
Polar Jet Stream
Polar Easterlies
Ferrel Cell
Westerlies
Subtropical Jet Stream
Hadley Cell
Northeast Trades
Southeast Trades
Westerlies
Polar Easterlies


Polar Cell
Polar front
Ferrel Cell
Subtropical high
westerlies
Tropic of Cancer
Hadley cell
northeast trades
Equator
Equatorial low
southeast trades
Hadley cell
Tropic of Capricorn
Subtropical high
westerlies
Ferrel Cell
Polar front
Polar Cell


Polar
Jet Stream
Polar Front
Ridge
Trough
Subtropical
Jet Stream
InterTropical Convergence Zone
Polar Front


Sea-Level Pressure and Surface Winds
Jan
L
L
L
H
H
H
H
H
H
H
L
L
L
L
L
L
995 1000 1005 1010 1015 1020 1025 mb
1
2
4
8
16
32 m/sec
Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies

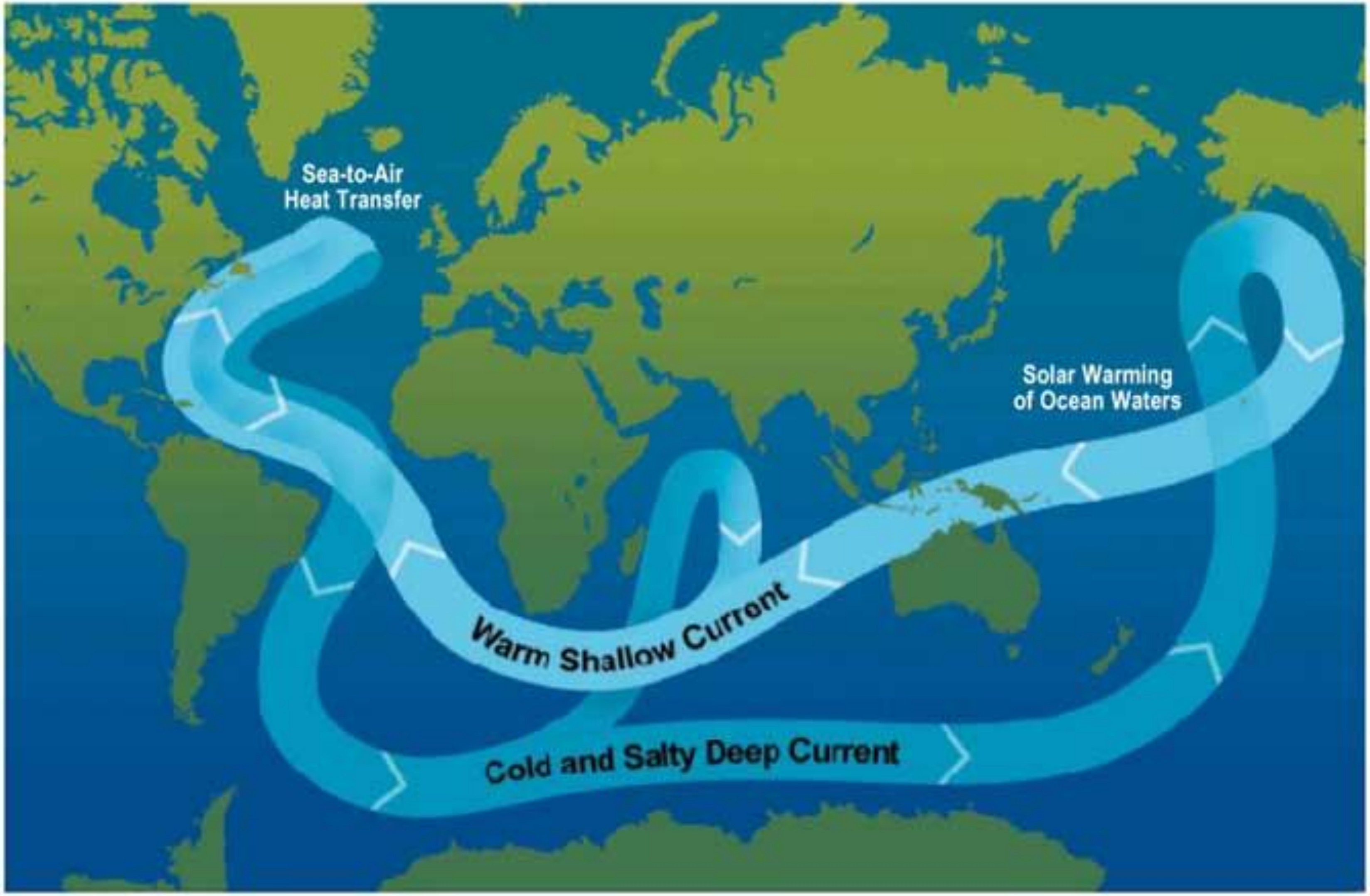
Sea-Level Pressure and Surface Winds



Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies

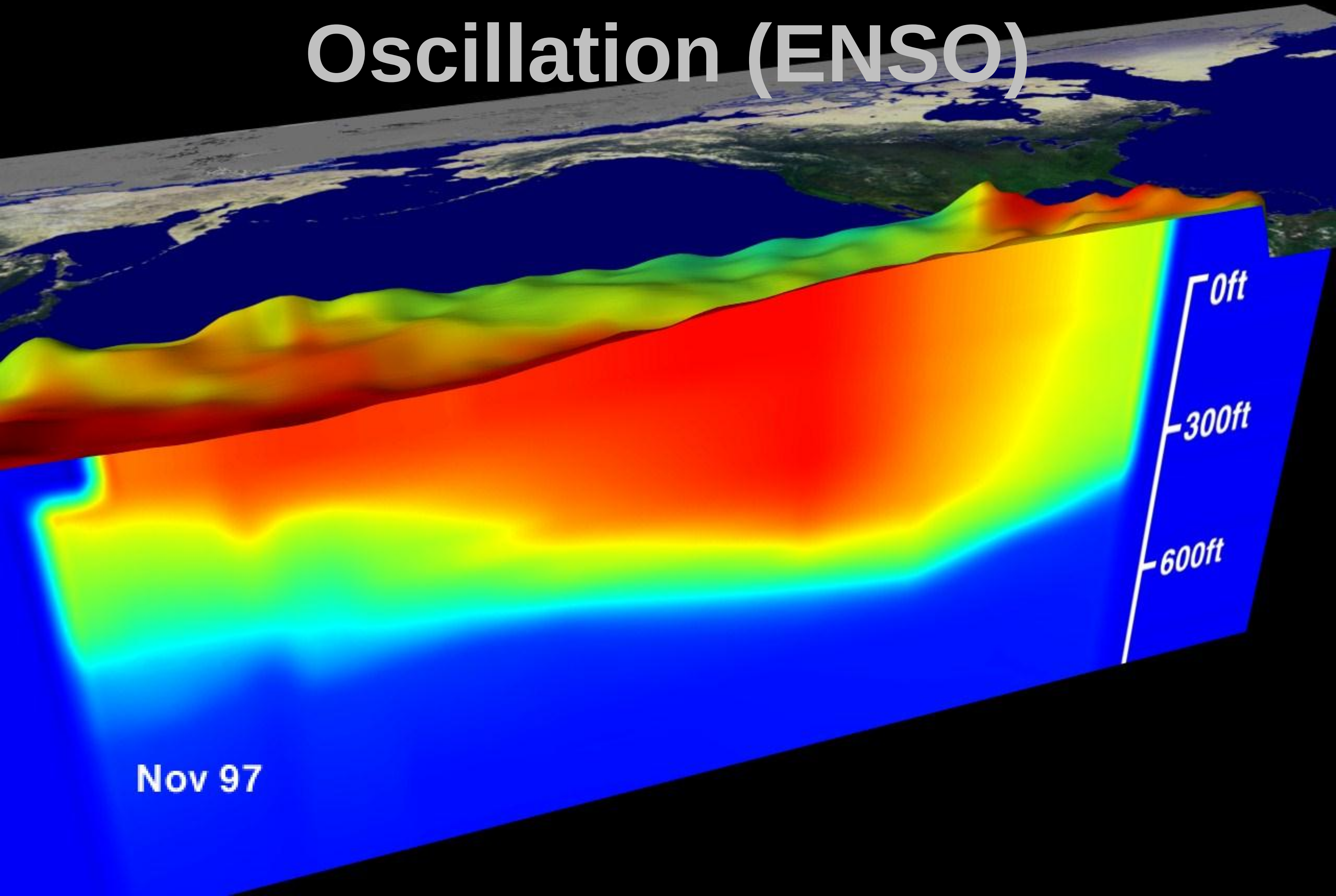
Image courtesy:
National Geophysical Data Center
http://www.ngdc.noaa.gov/paleo/ctl/images/belt.jpg

Ocean Circulation Conveyor Belt



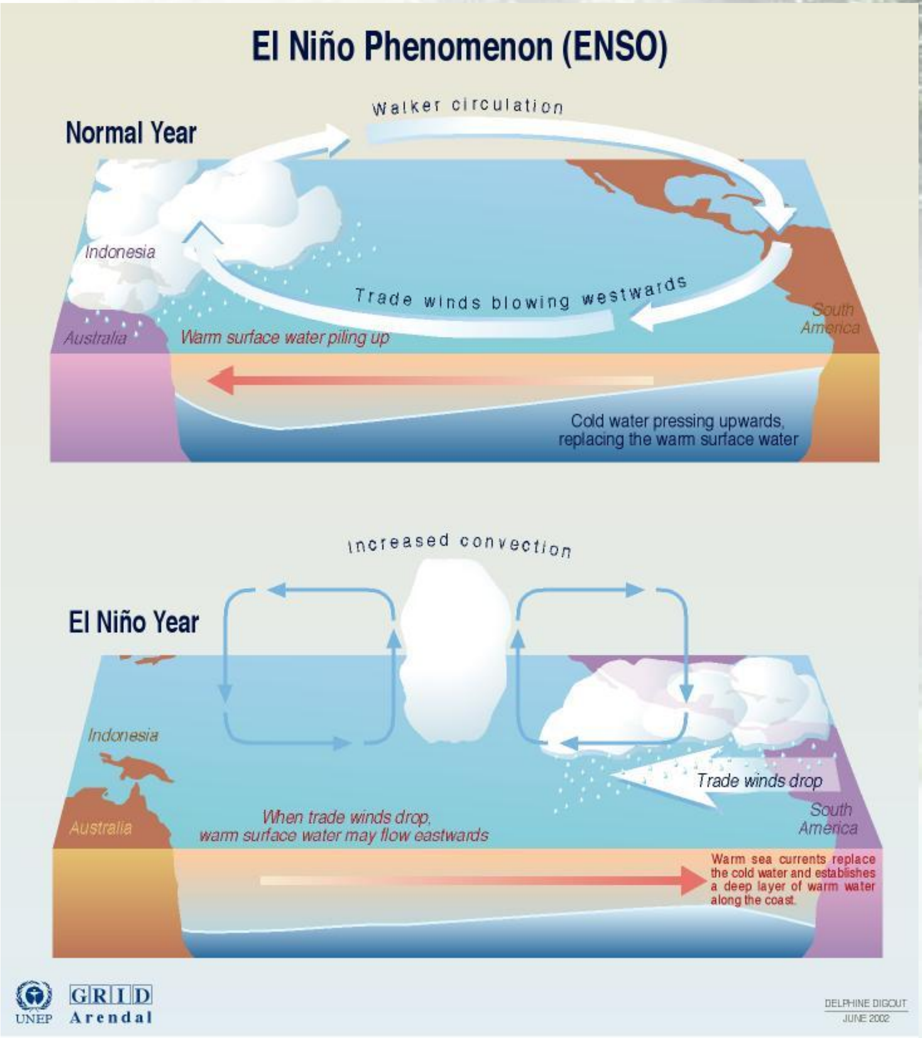
The ocean plays a major role in the distribution of the planet's heat through deep sea circulation. This simplified illustration shows this "conveyor belt" circulation which is driven by differences in heat and salinity. Records of past climate suggest that there is some chance that this circulation could be altered by the changes projected in many climate models, with impacts to climate throughout lands bordering the North Atlantic.

El Niño – Southern Oscillation (ENSO)

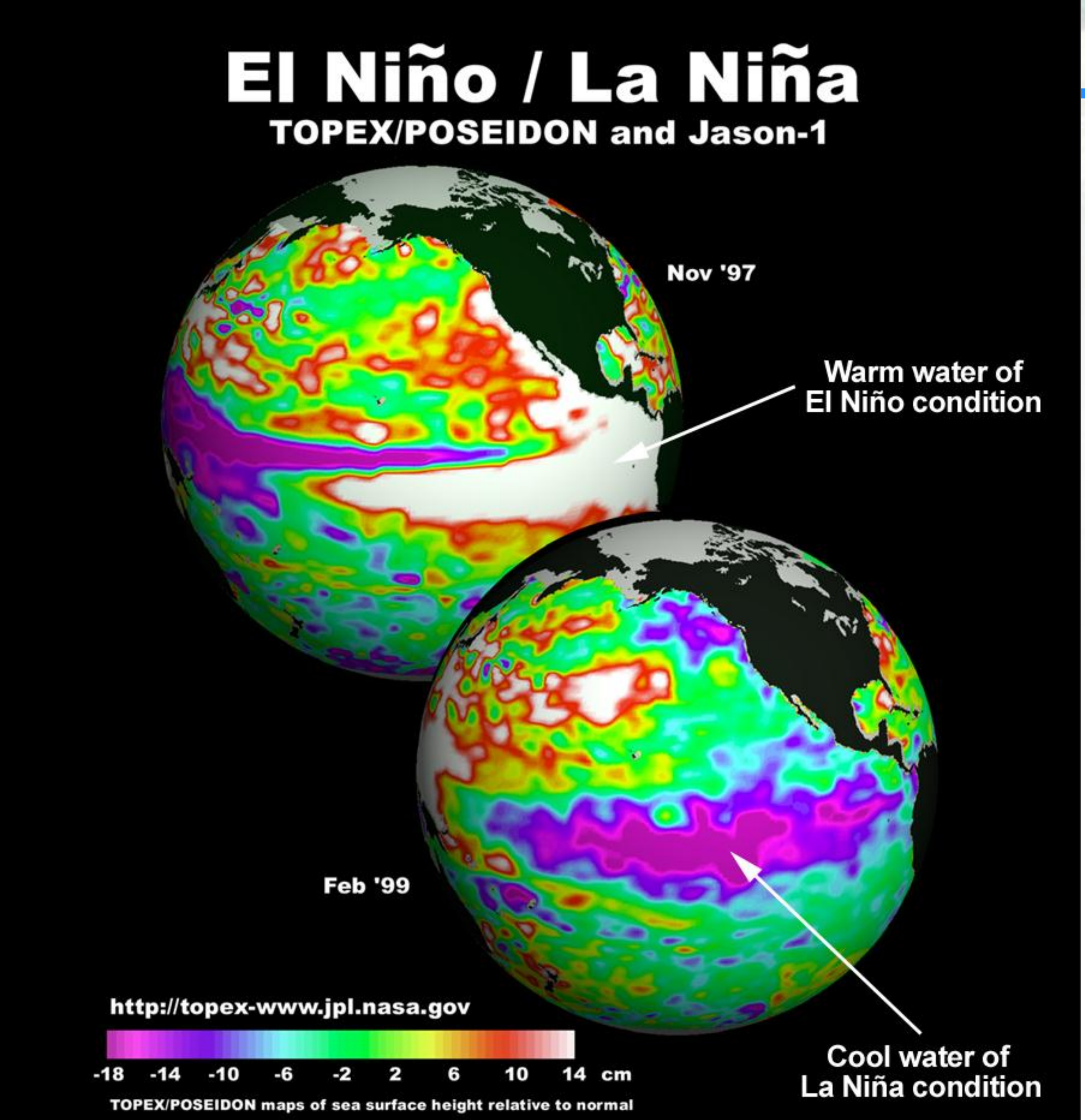


Definitions

- El Niño – An anomalous warming in eastern Pacific ocean temperatures
- La Niña – An anomalous cooling in eastern and central Pacific ocean temperatures
- Southern Oscillation – Pressure fluctuations in the tropics with centers of action in the western Pacific/eastern Indian Oceans and the southeastern Pacific

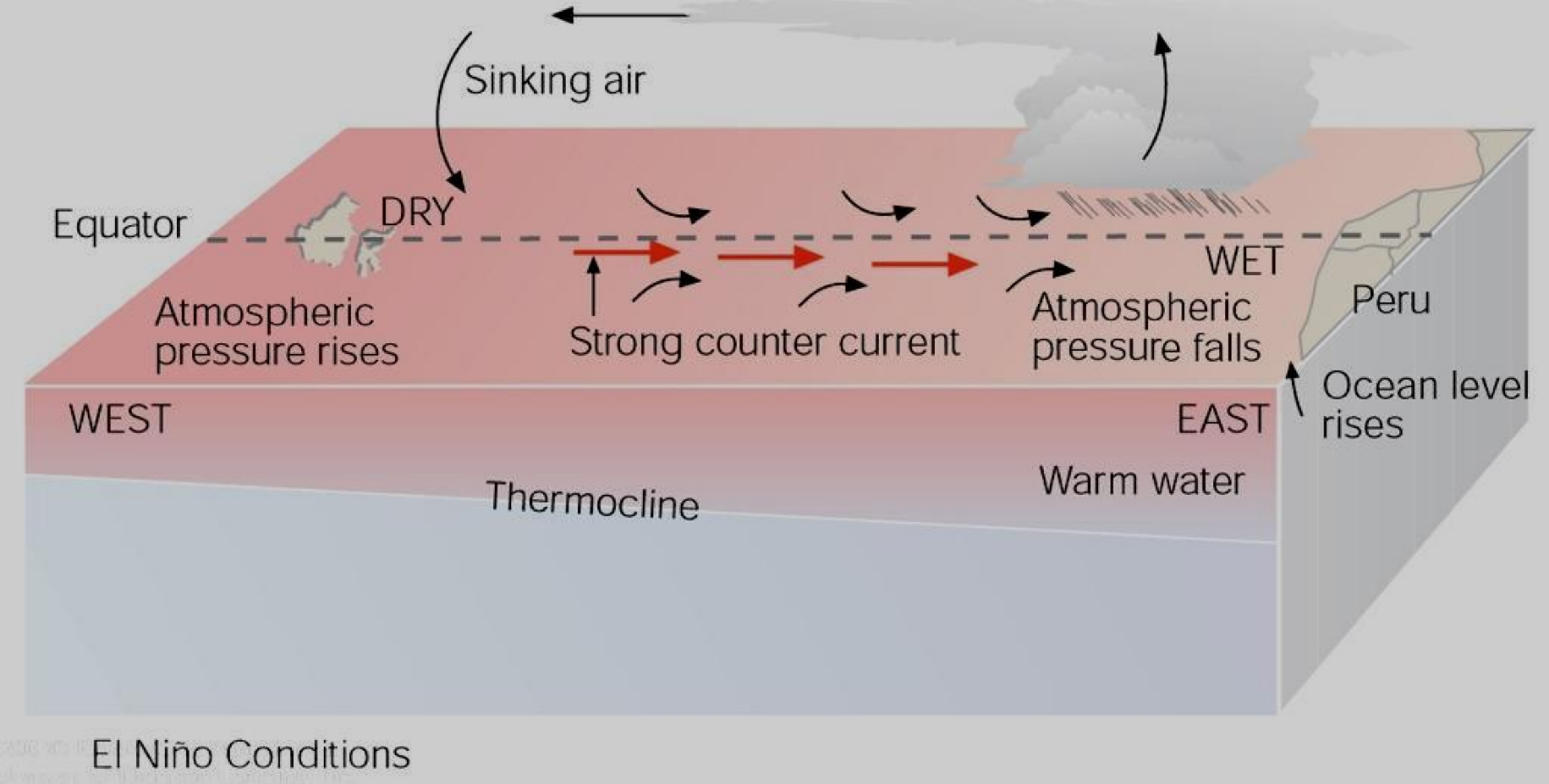


Sources: Climate Prediction Center-NCEP; NOAA.



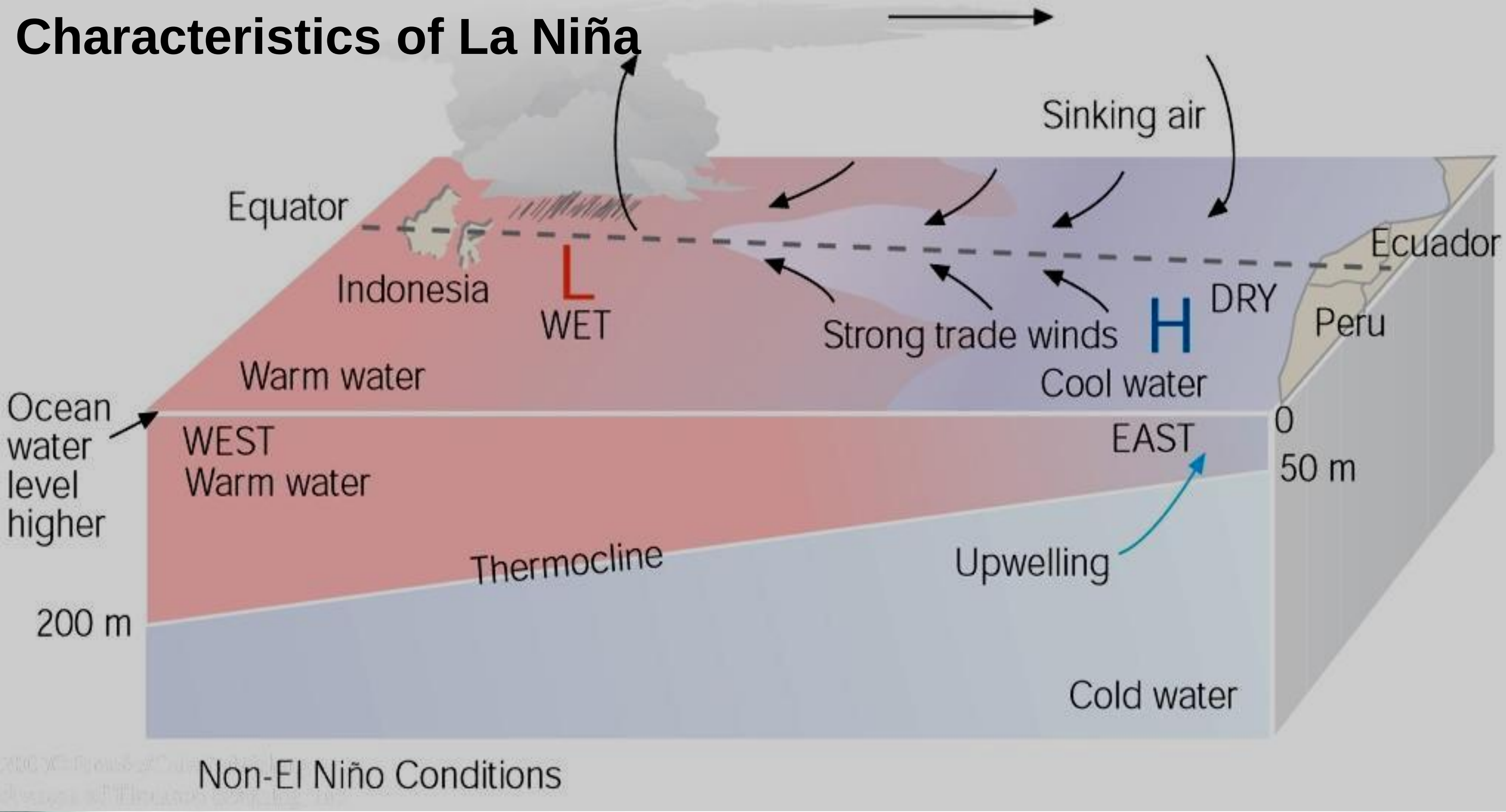
http://scijinks.jpl.nasa.gov/en/educators/gallery/oceans/NinoNina_L.jpg

Characteristics of El Niño



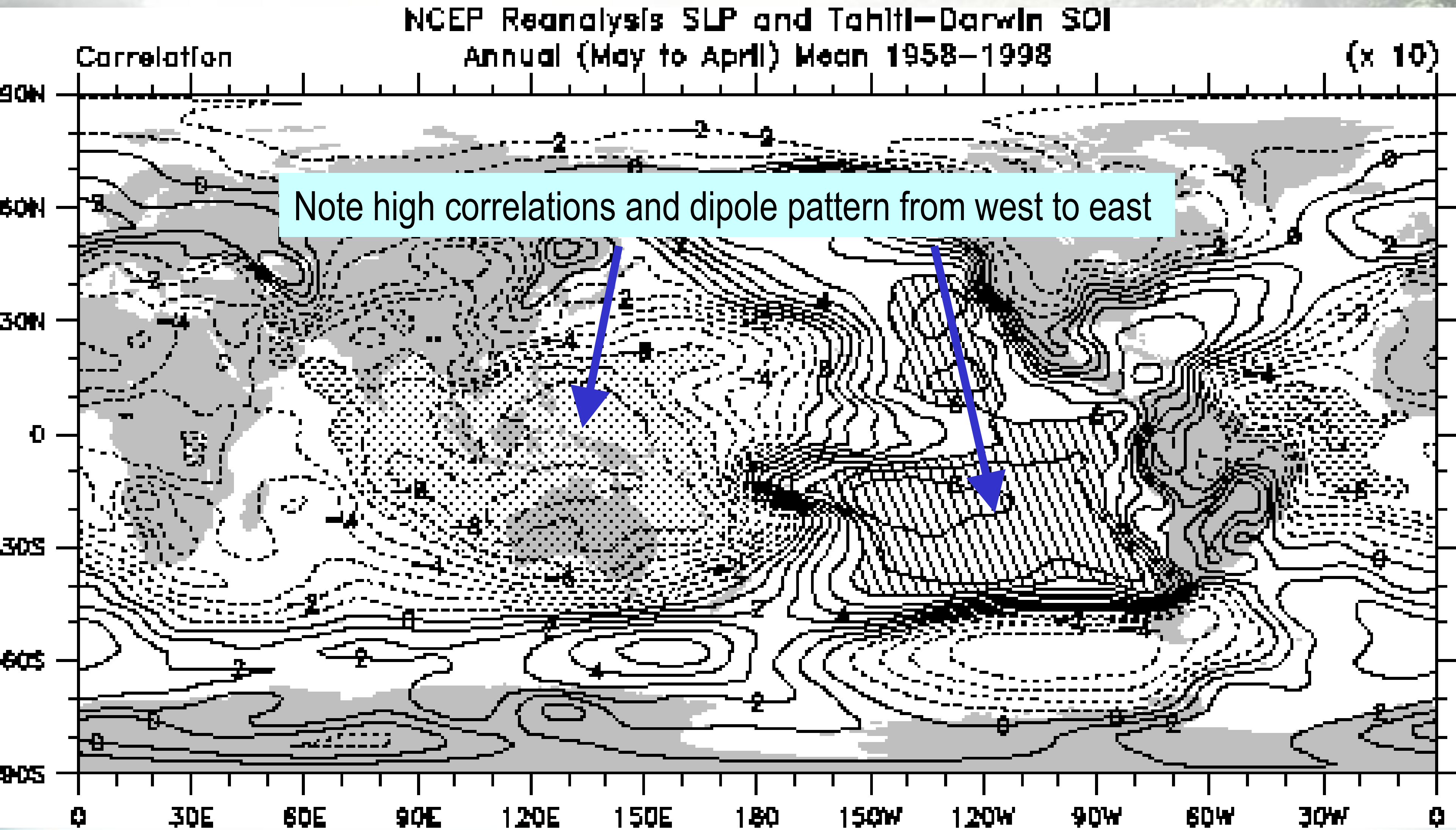
- Anomalous low (high) pressure in the eastern (western) Pacific
- Weak or even reversed trade winds across Pacific
- Dry (Wet) conditions in the west (east) Pacific
- Deep thermocline in the east – upwelling capped

Characteristics of La Niña



- Anomalous low (high) pressure in the western (eastern) Pacific
- Stronger than normal trade winds across Pacific
- Dry (Wet) conditions in the east (west) Pacific
- Deep thermocline in the west – shallow in the east

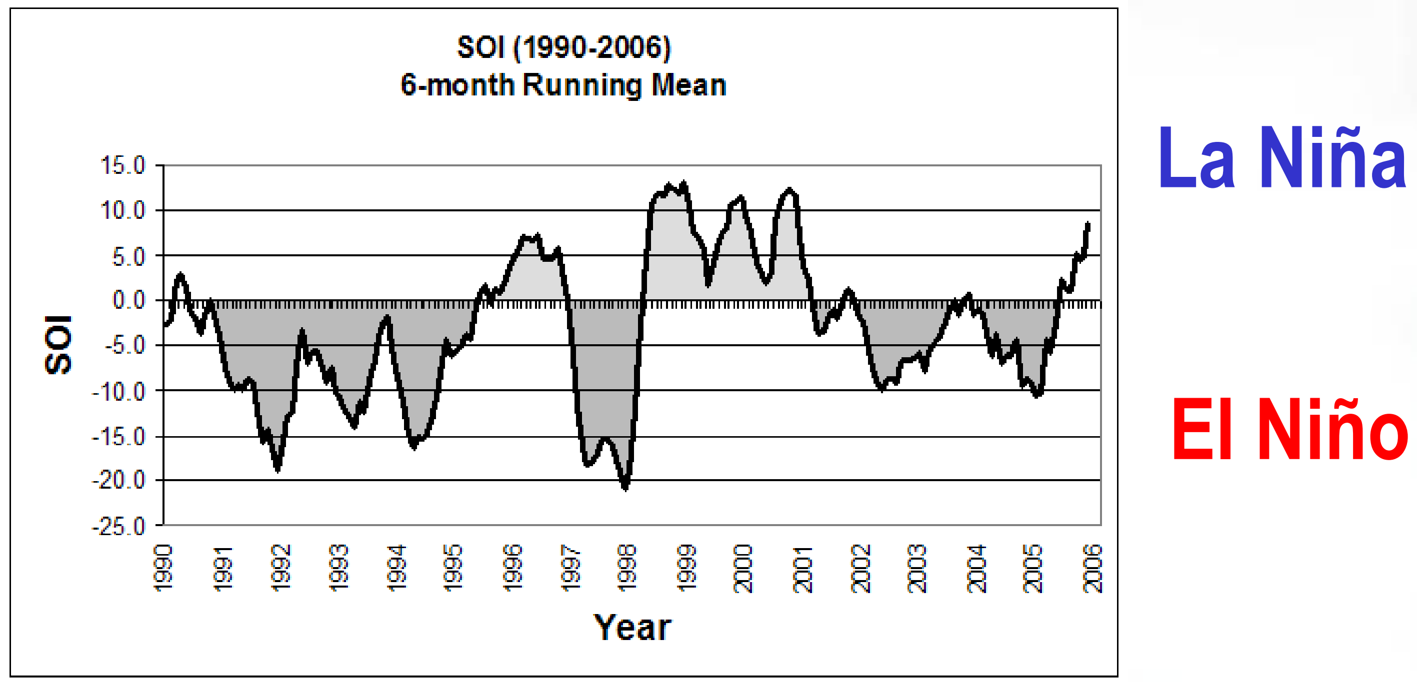
Southern Oscillation



Correlation between Southern Oscillation Index and Sea Level Pressure

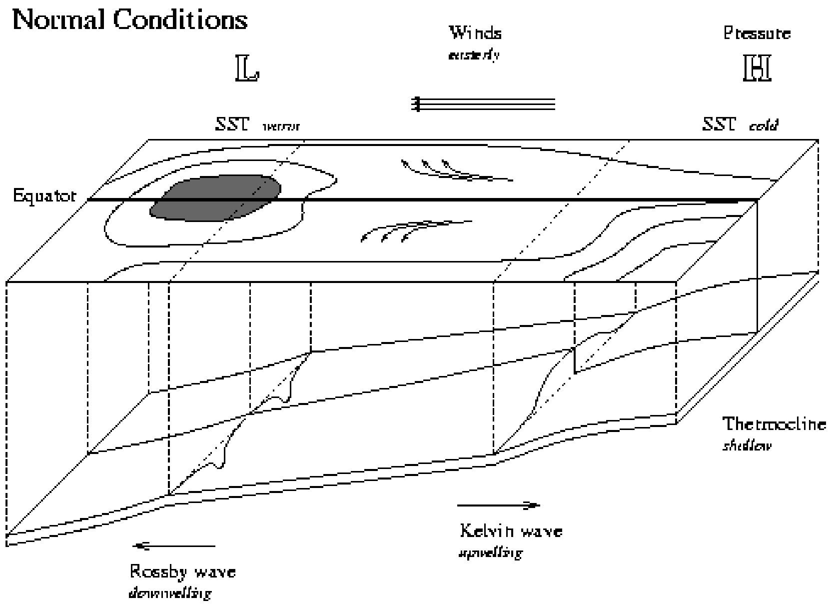
Determining Phase of the ENSO

- Southern Oscillation Index (SOI)
  - Tracks see-saw in pressure between eastern Pacific/Indian Ocean and central Pacific
  - Uses pressure observations from Tahiti and Darwin, Australia
    - Seasonal trends removed
  - Usually analyzed as a 3-6 month running mean



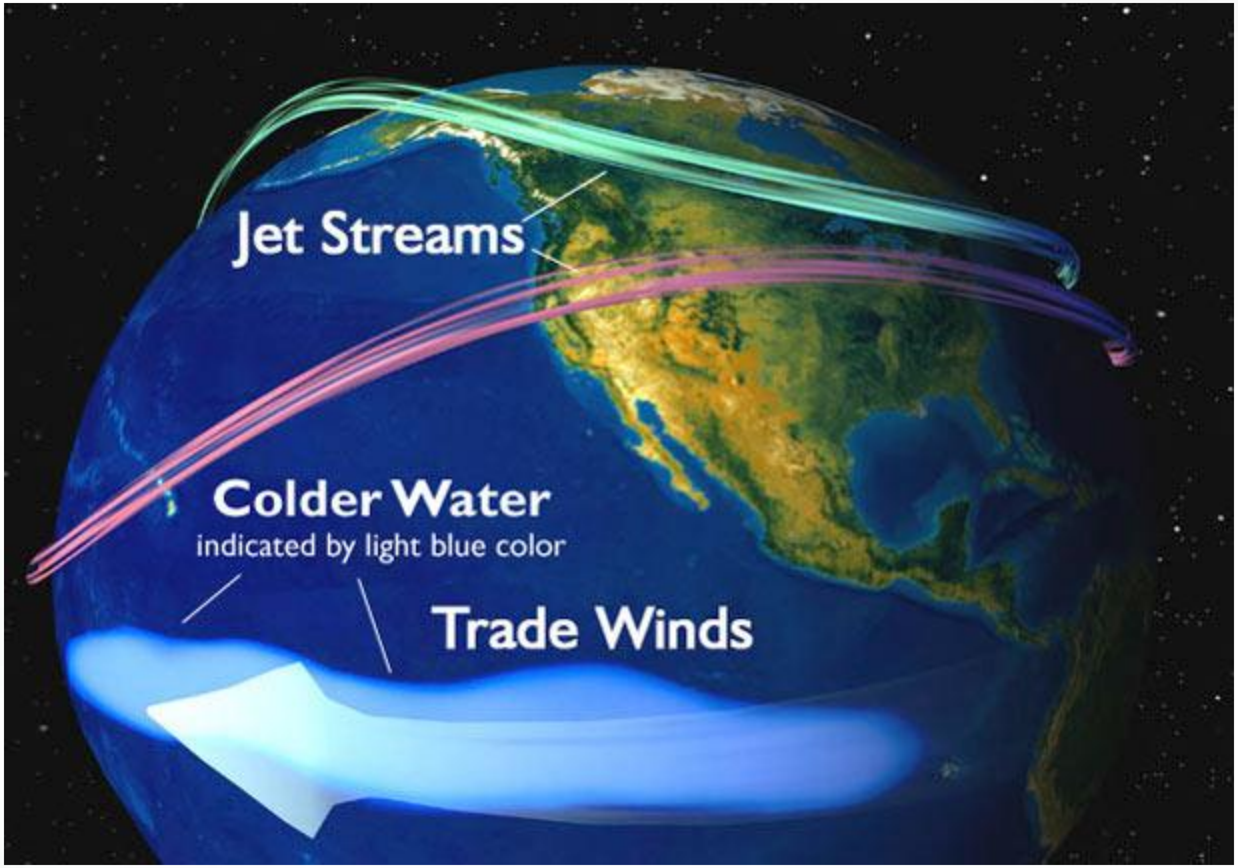
Physical Explanation of ENSO

- Bjerknes – Circular relationship between ocean and atmosphere changes
  - Could not determine which came first
- 1960's – Oceanic Kelvin and Rossby waves identified as having key roles
  - Kelvin waves move eastward at 2-3 m/s
  - Rossby waves more westward at 0.6 – 0.8 m/s
  - Both carry energy and momentum gained from surface wind stresses



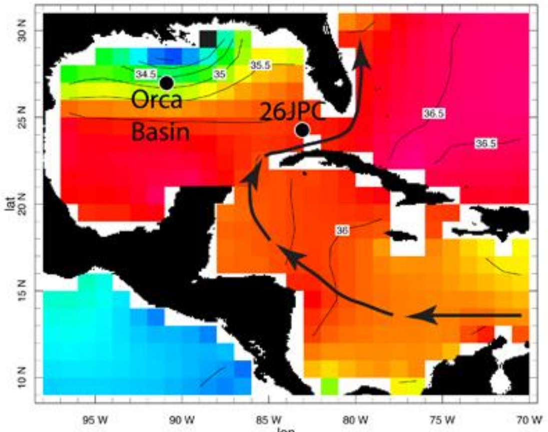
Stochastic Theory

- Coupled ocean-atmosphere system is actually stable
  - Not vulnerable to perturbations
- ENSO events triggered by random forcings from the atmosphere
- Attractive because it suggests that ENSO cycles should be irregular in both length and frequency
  - Matches observed behavior of ENSO



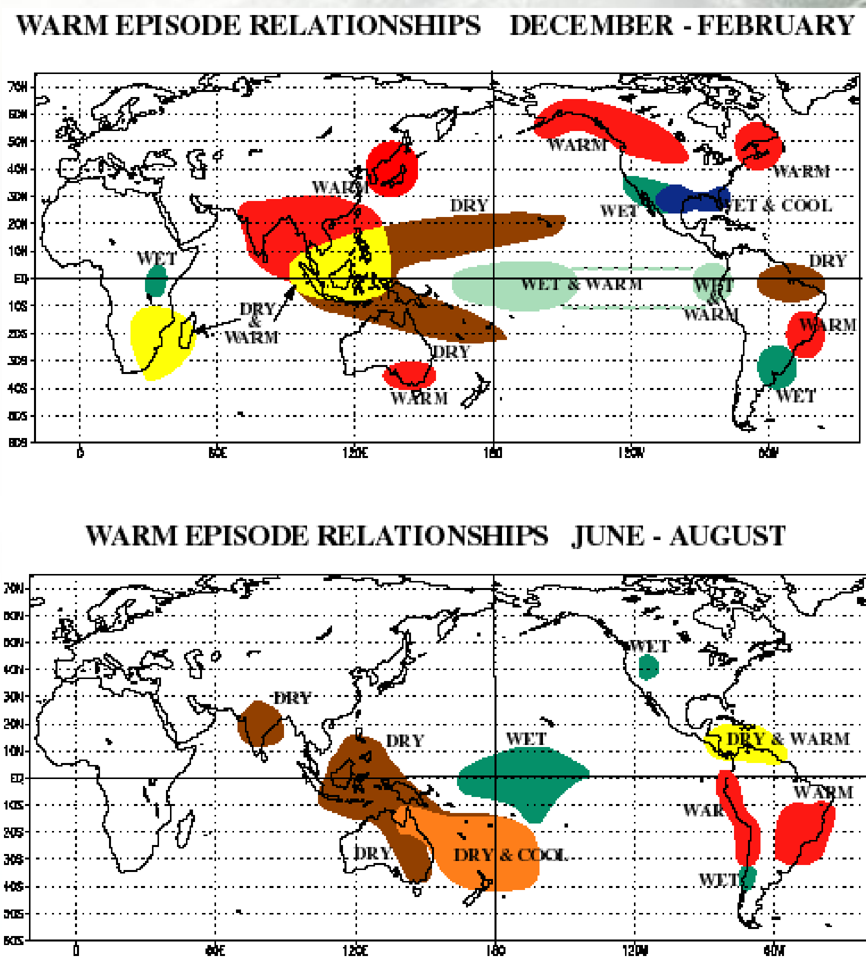
ENSO Teleconnections

- Tropical Cyclone Frequency
  - ENSO alters general circulation of atmosphere
  - Favored areas of tropical cyclogenesis shift
  - Reduced frequency during EN include:
    - Australia: Convection shifts east, monsoon trough weakens
    - Northwest Pacific (west of 160°E): Monsoon trough shifts away from area
    - Atlantic: Upper-level (200 mb) westerlies increase, increased vertical wind shear

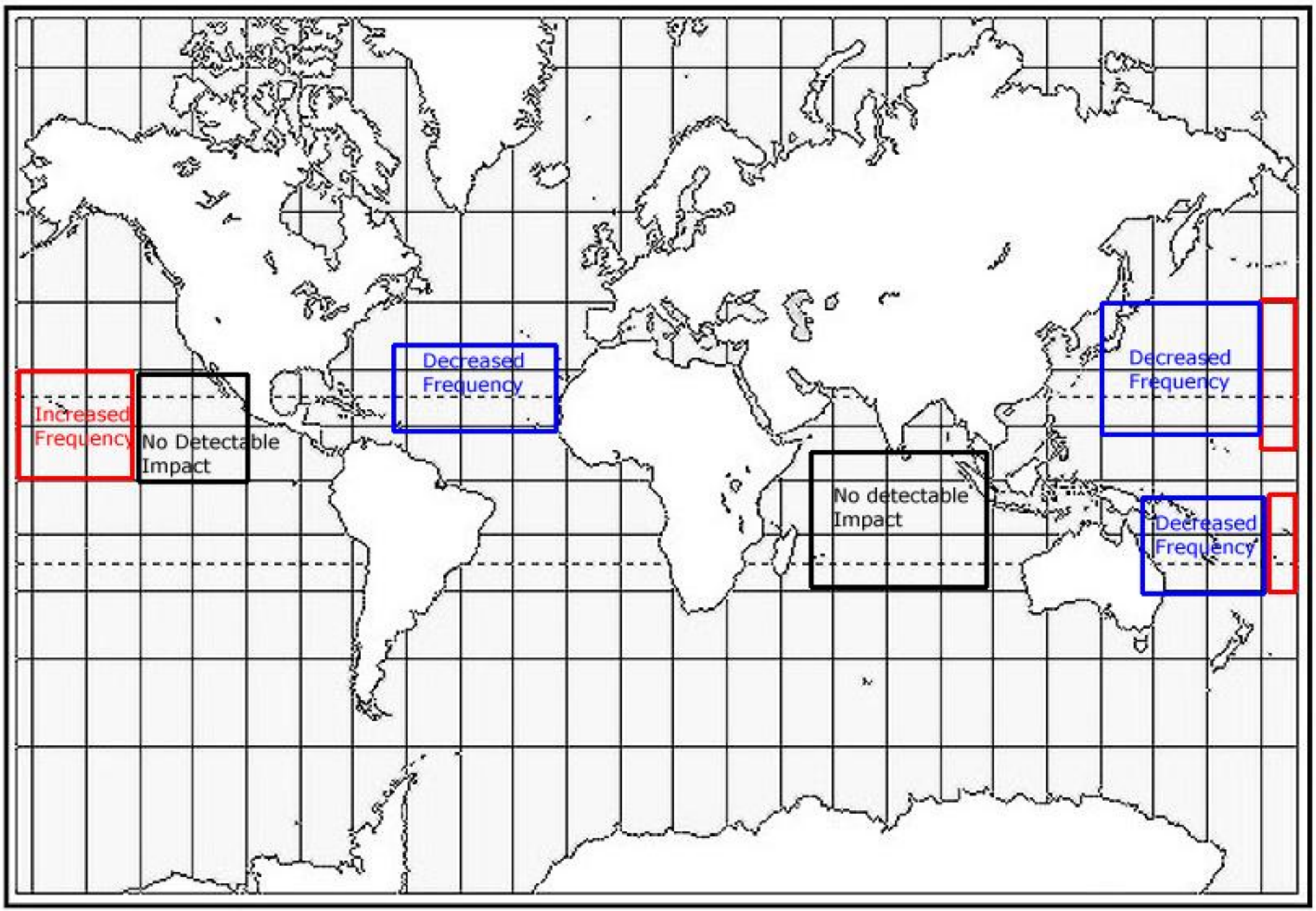


ENSO Teleconnections

- Tropical Cyclone Frequency
  - Increased frequency during EN events:
    - NW Pacific (east of 160°E to Dateline): Monsoon trough shifts into this area
    - NE Pacific (140°W to Dateline, near Hawaii): Increased convection due to warmer SSTs
  - No detectable change
    - NE Pacific (east of 140°W)

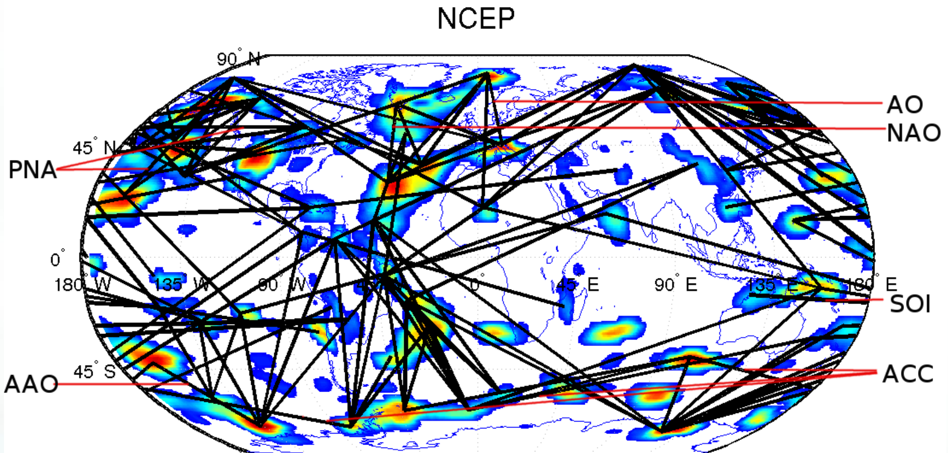


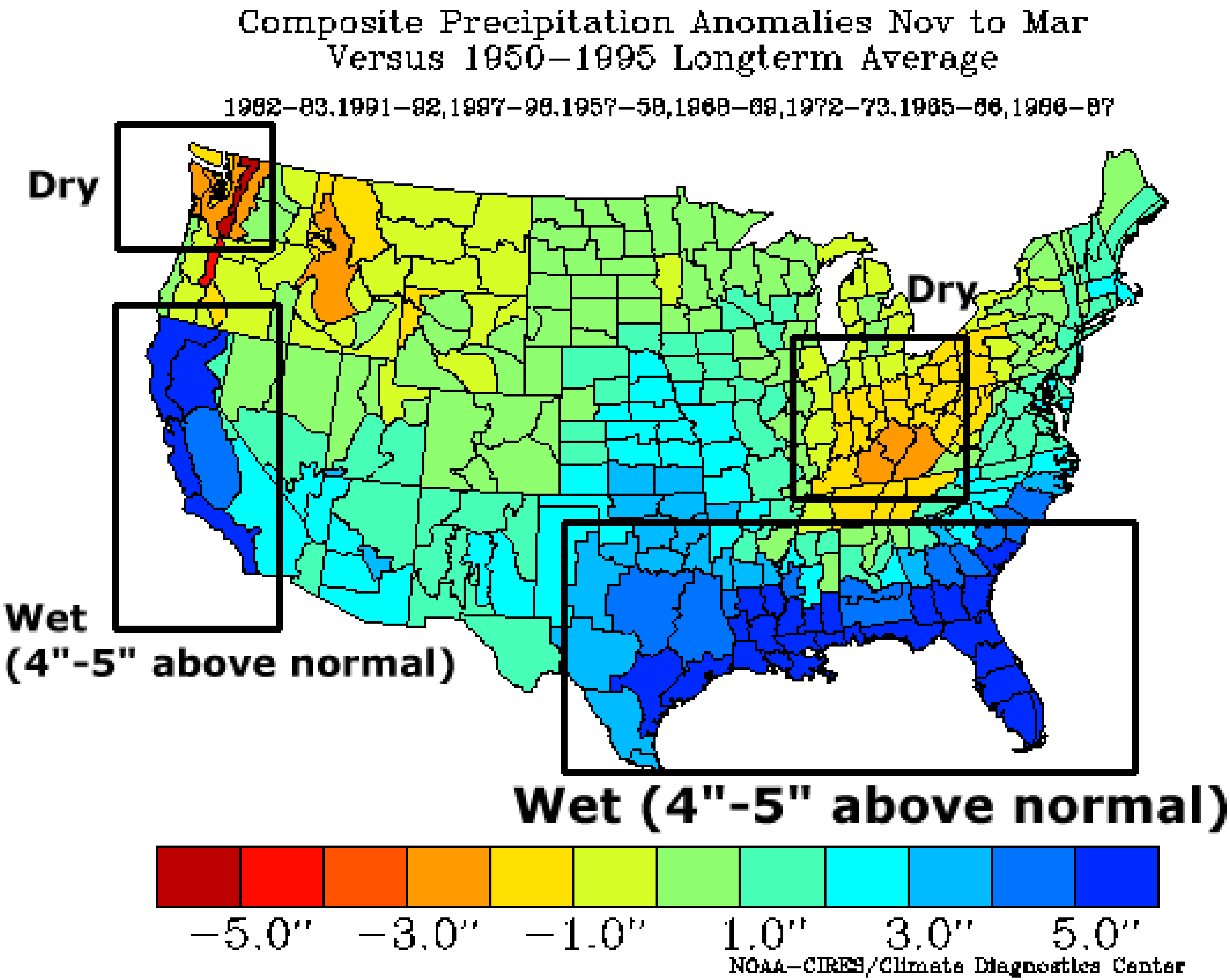
Climate Prediction Center
NCEP

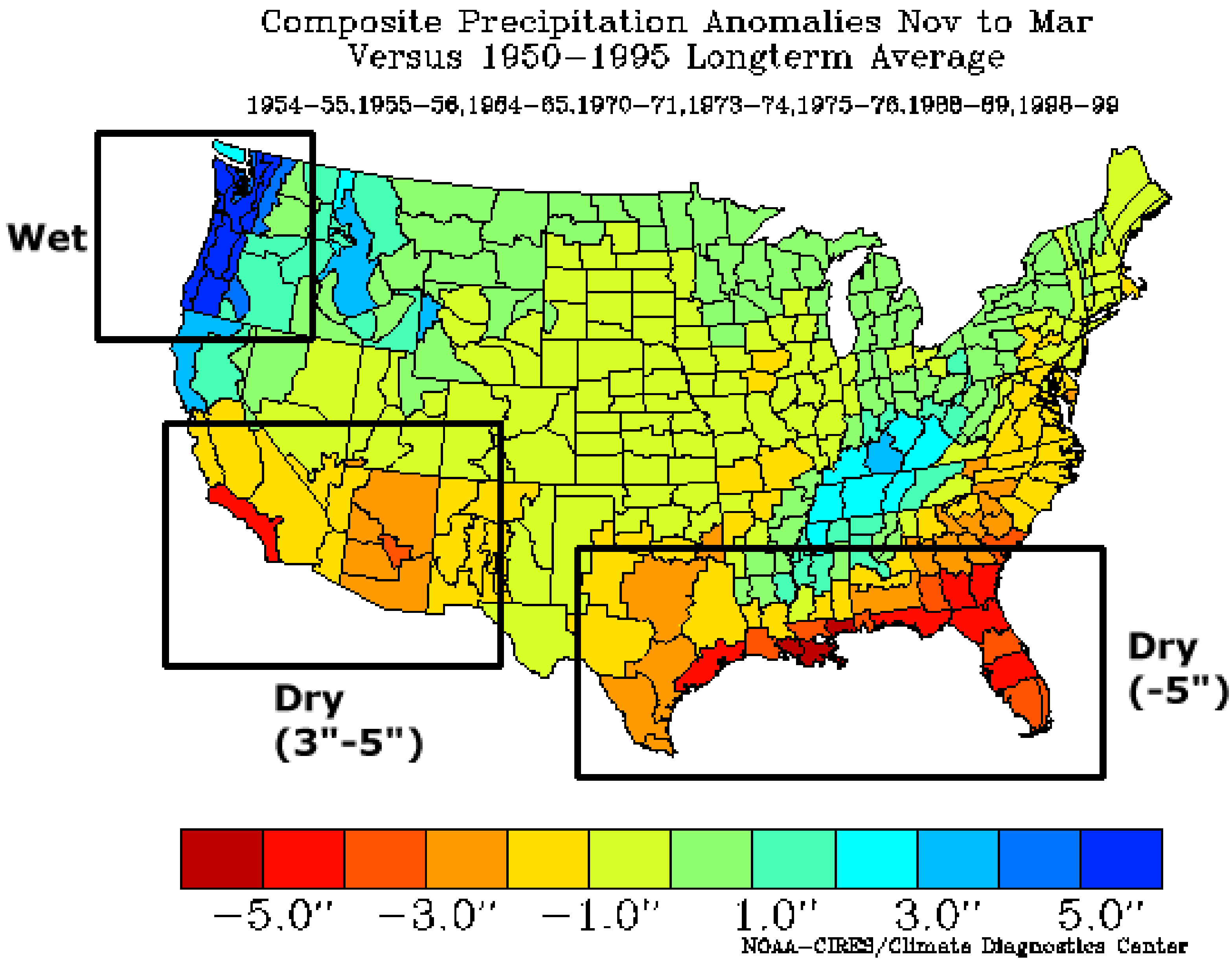

Increased Frequency
No Detectable Impact
Decreased Frequency
No detectable Impact
Decreased Frequency
Decreased Frequency

ENSO Teleconnections

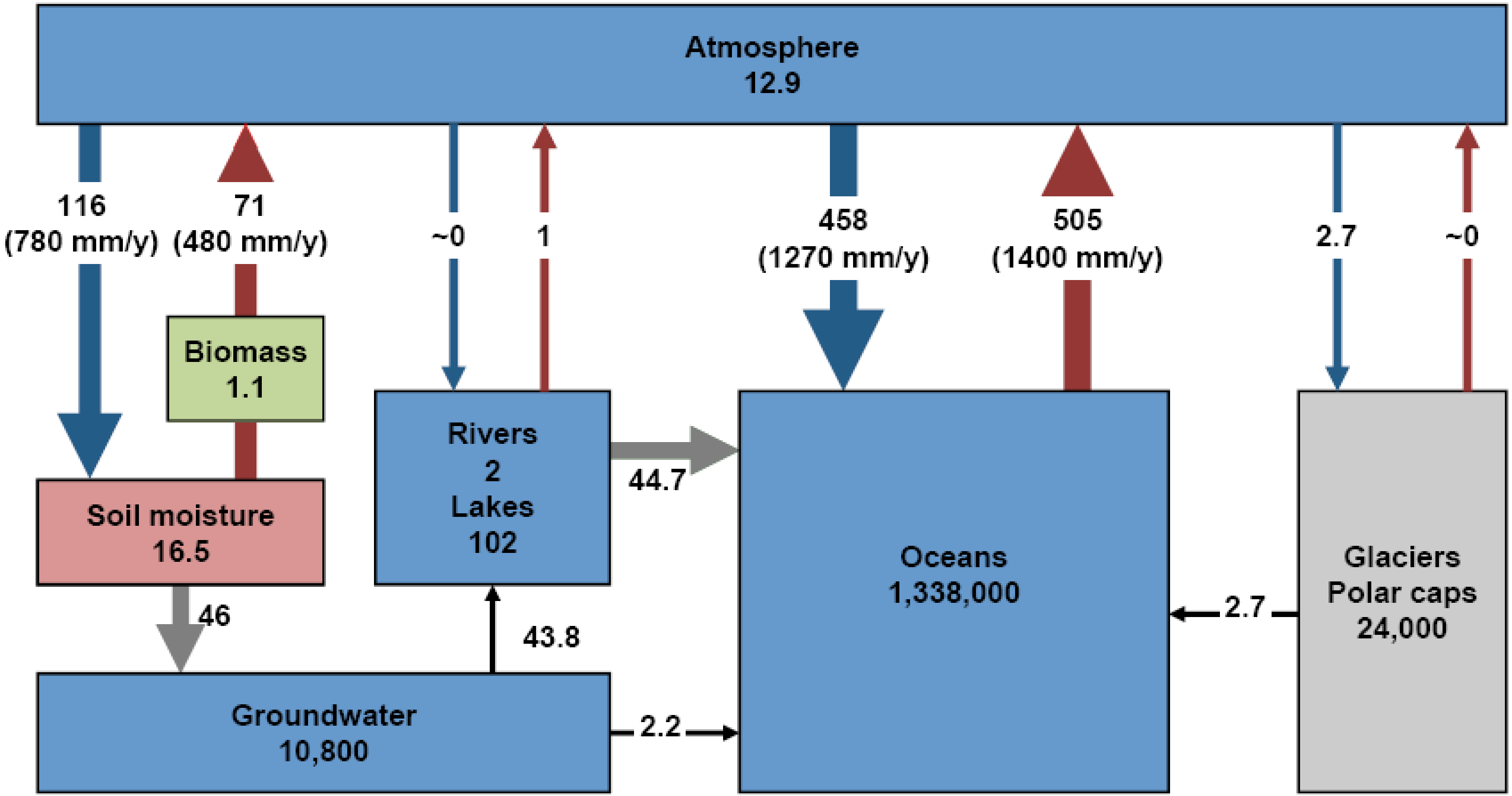
- United States weather
  - Changes from shifts in weather patterns (jet streams, storm tracks) forced by SST changes
  - Major US precipitation changes during EN events:
    - Southeast US experiences anomalous precipitation
    - California coast experiences high precipitation
    - Pacific NW and Midwest generally drier
  - Main factor is shift in sub-tropical jet that brings storms into southeast and southwest US
  - La Niña exhibits generally opposite patterns




Composite Precipitation Anomalies Nov to Mar
Versus 1950–1995 Longterm Average
1982–83,1991–92,1997–98,1957–58,1968–69,1972–73,1965–66,1986–87
Dry
Dry
Wet
(4"-5" above normal)
Wet (4"-5" above normal)
−5.0″
−3.0″
−1.0″
1.0″
3.0″
5.0″
NOAA–CIRES/Climate Diagnostics Center


Composite Precipitation Anomalies Nov to Mar
Versus 1950–1995 Longterm Average
1954–55,1955–56,1964–65,1970–71,1973–74,1975–76,1988–89,1998–99
Wet
Dry
(3"-5")
Dry
(-5")
−5.0"
−3.0"
−1.0"
1.0"
3.0"
5.0"
NOAA–CIRES/Climate Diagnostics Center

Global Hydrologic Cycle: Stocks and Fluxes

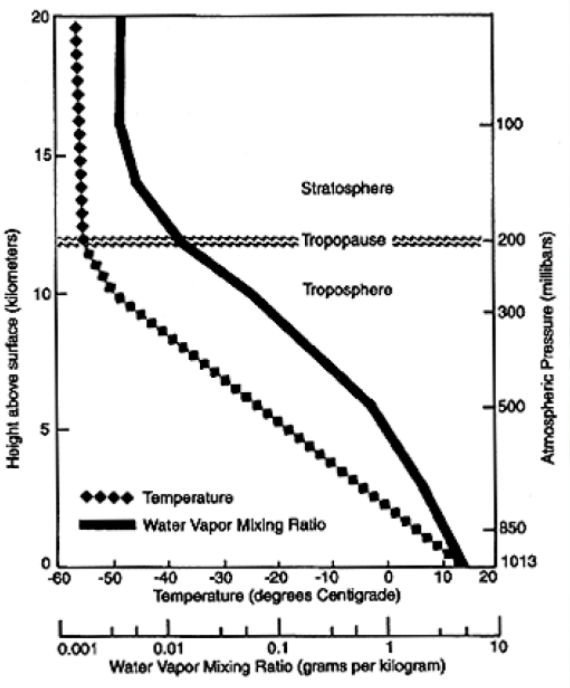


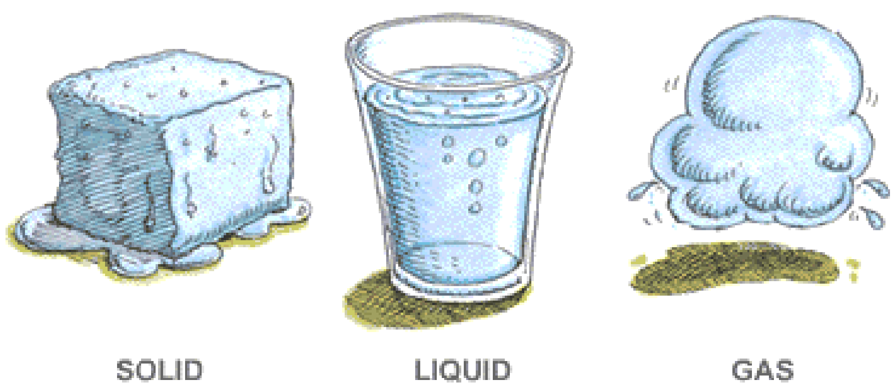
(after Dingmann 1993; based on data from Shiklomanov and Sokolov 1983)

Numbers in boxes:	Volumes [1000 km³]
Numbers next to arrows:	Fluxes [1000 km³/y]
(Numbers in brackets):	Fluxes [mm/y], with respect to oceans / land surface (area oceans: 3.61 10⁸ km²; area land: 1.49 10⁸ km²)

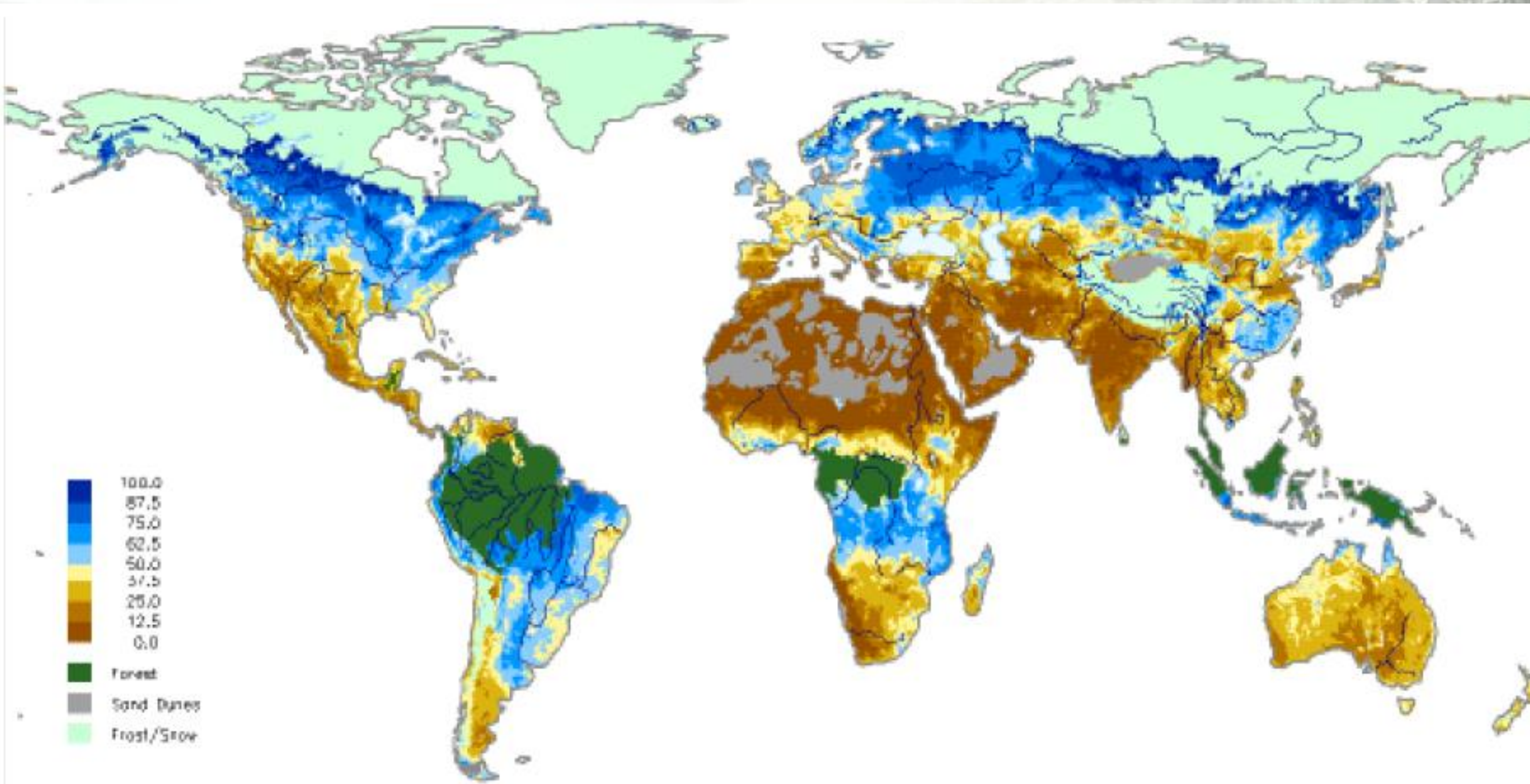
Water in the Atmosphere

- **Water vapour to be distributed unevenly in the atmosphere**,
- Water vapour decreases rapidly with height as the atmosphere gets colder.
- Nearly half the total water in the air is between sea level and about 1.5 km above sea level.
- Less than 5-6% of the water is above 5 km, and less than 1% is in the stratosphere,
- Relative humidity also tends to decrease with height, from an average value of about 60-80% at the surface 20-40% at 300 mbar (9 km).
- But water is very important!





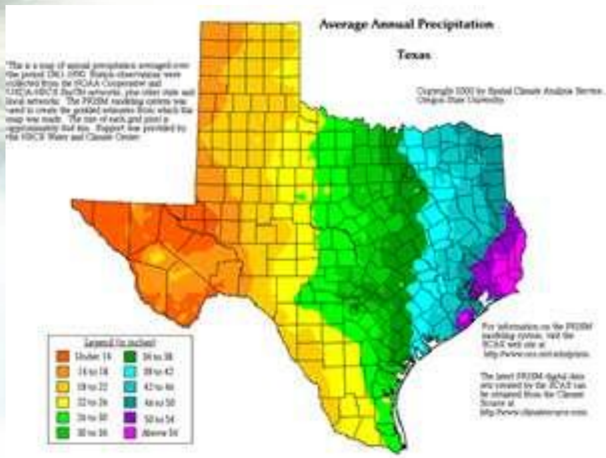
Water in the Soil

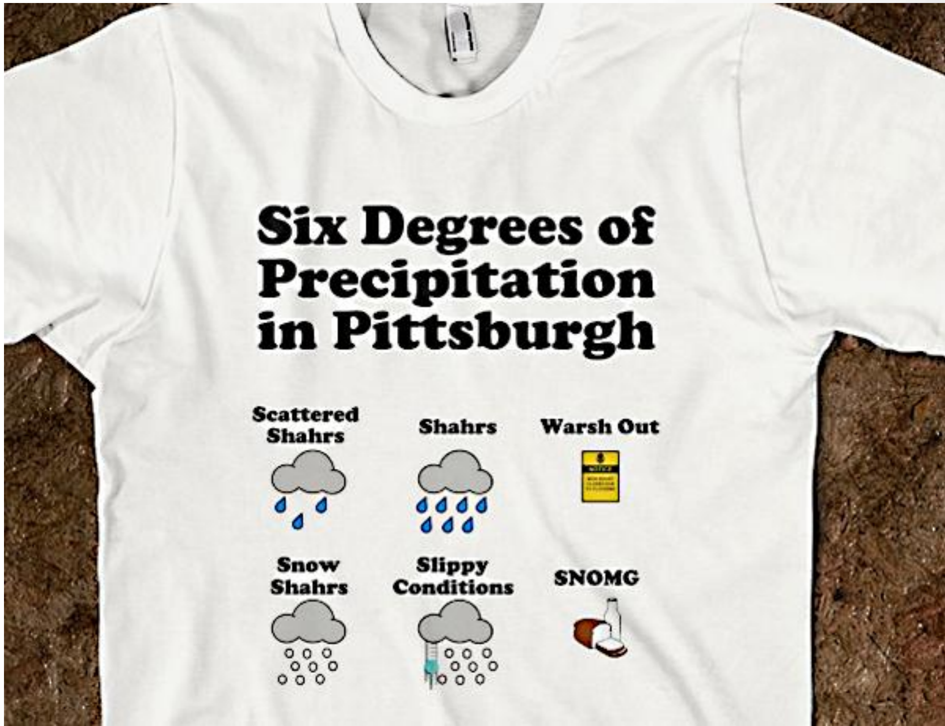


Soil moisture controls energy partitioning
Soil moisture controls runoff partitioning
Soil moisture – vegetation – evaporation processes are critical links between the water and carbon cycles

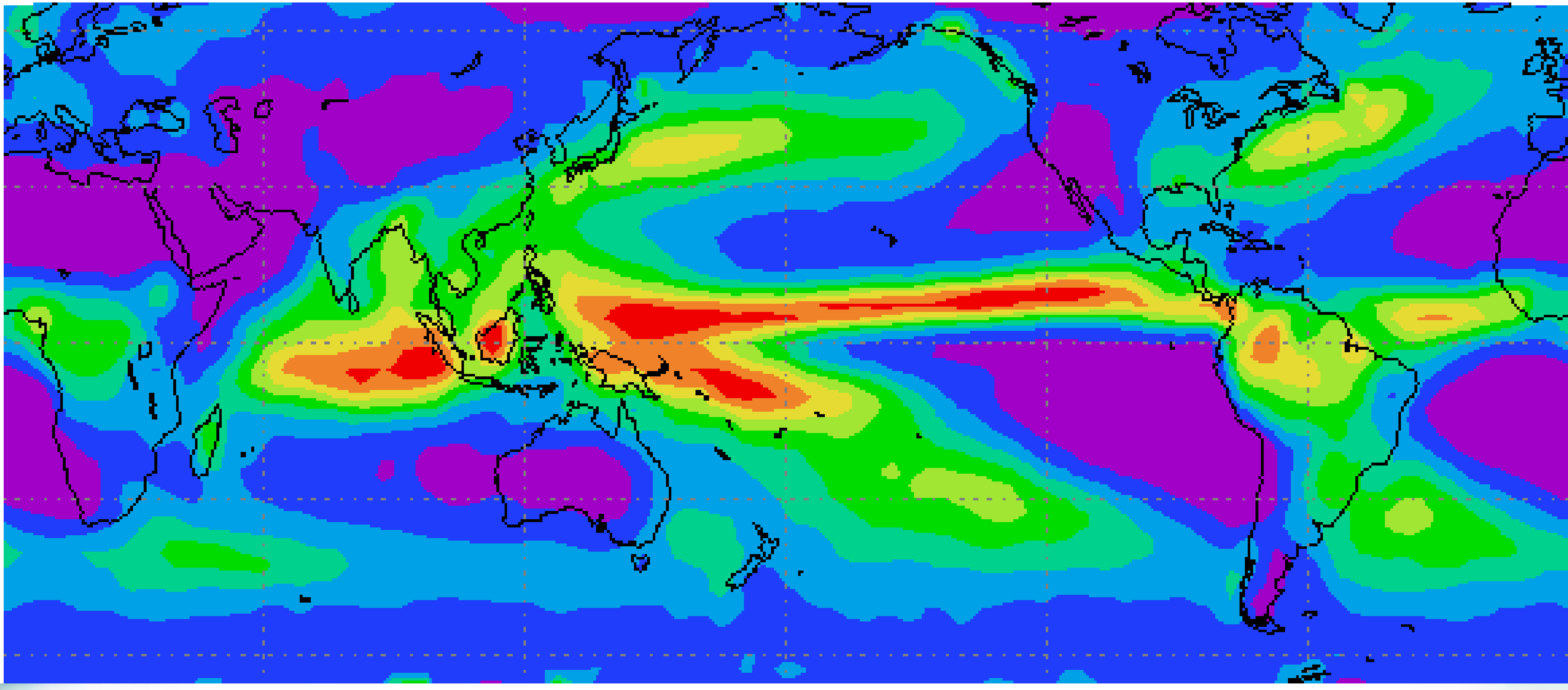
Precipitation

- Highly variable: Influence on vegetation, droughts, and floods, also effects large-scale circulation of atmosphere AND oceans
- 2/3 of precipitation occurs in tropics
- Atmospheric forcing caused by variability in location of latent heat release is main driver of dynamical interaction between atmosphere, ocean, and land
- Surface processes important to understand precipitation effects over land
  - Amazon: high degree of recycling between rainfall and evapotranspiration
  - Deserts: environment maintained by surface processes
- Cloud microphysics, atmospheric moisture, and more control intensity, scales, and timing of rainfall

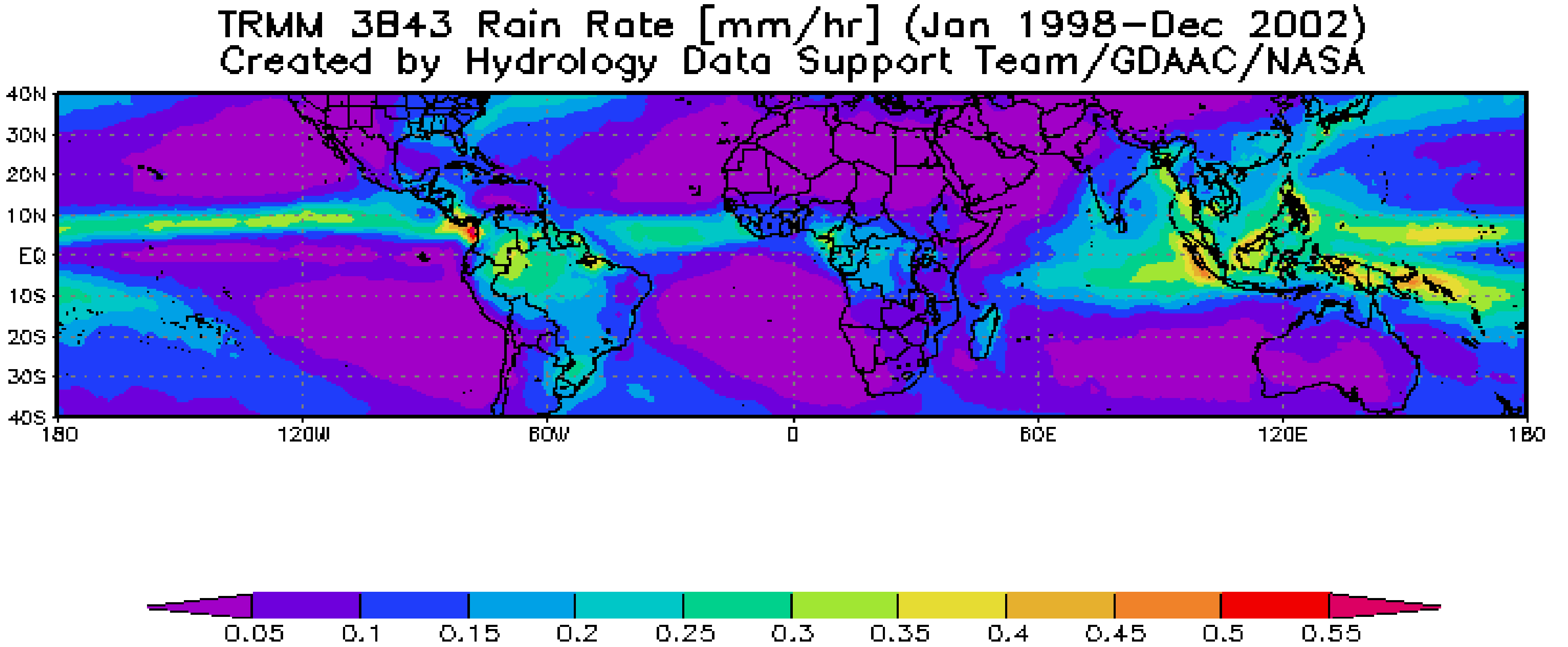




Global Precipitation Climatology Project (GPCP)

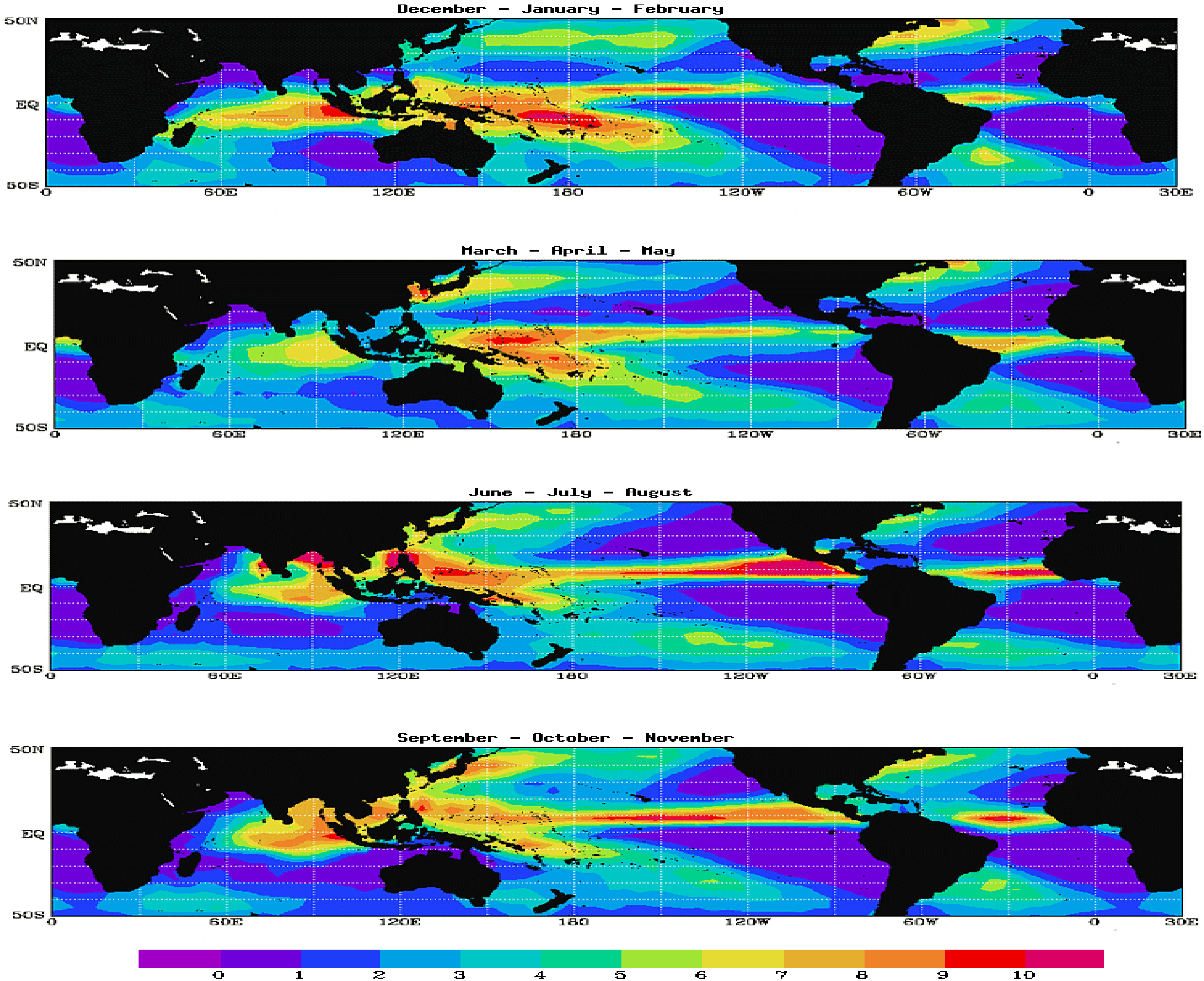


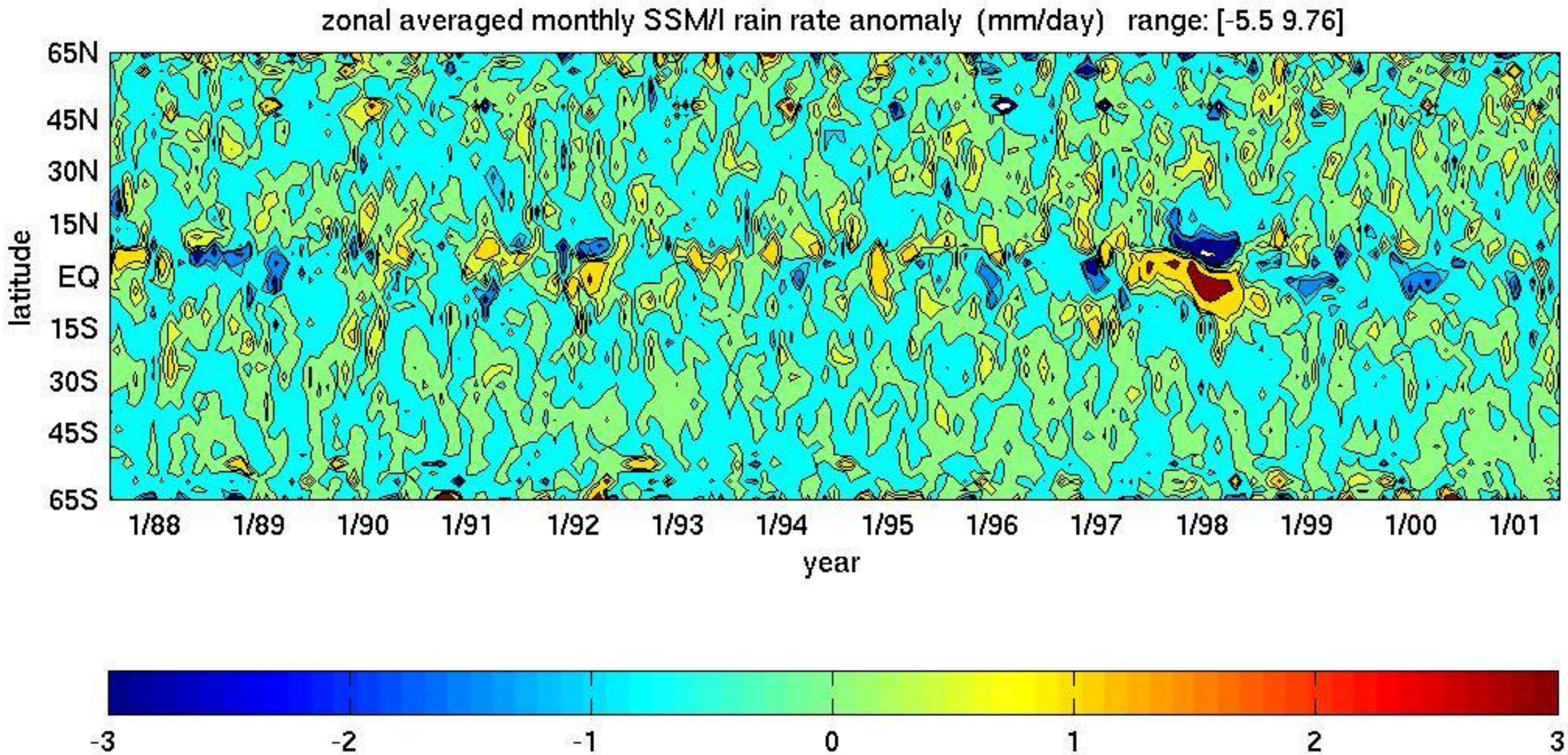
Five year TRMM Rain Rate Climatology



URL: http://Daac.gsfc.nasa.gov
→ hydrology → TRMM On-line Analysis
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/hydrology/TRMM_analysis.html

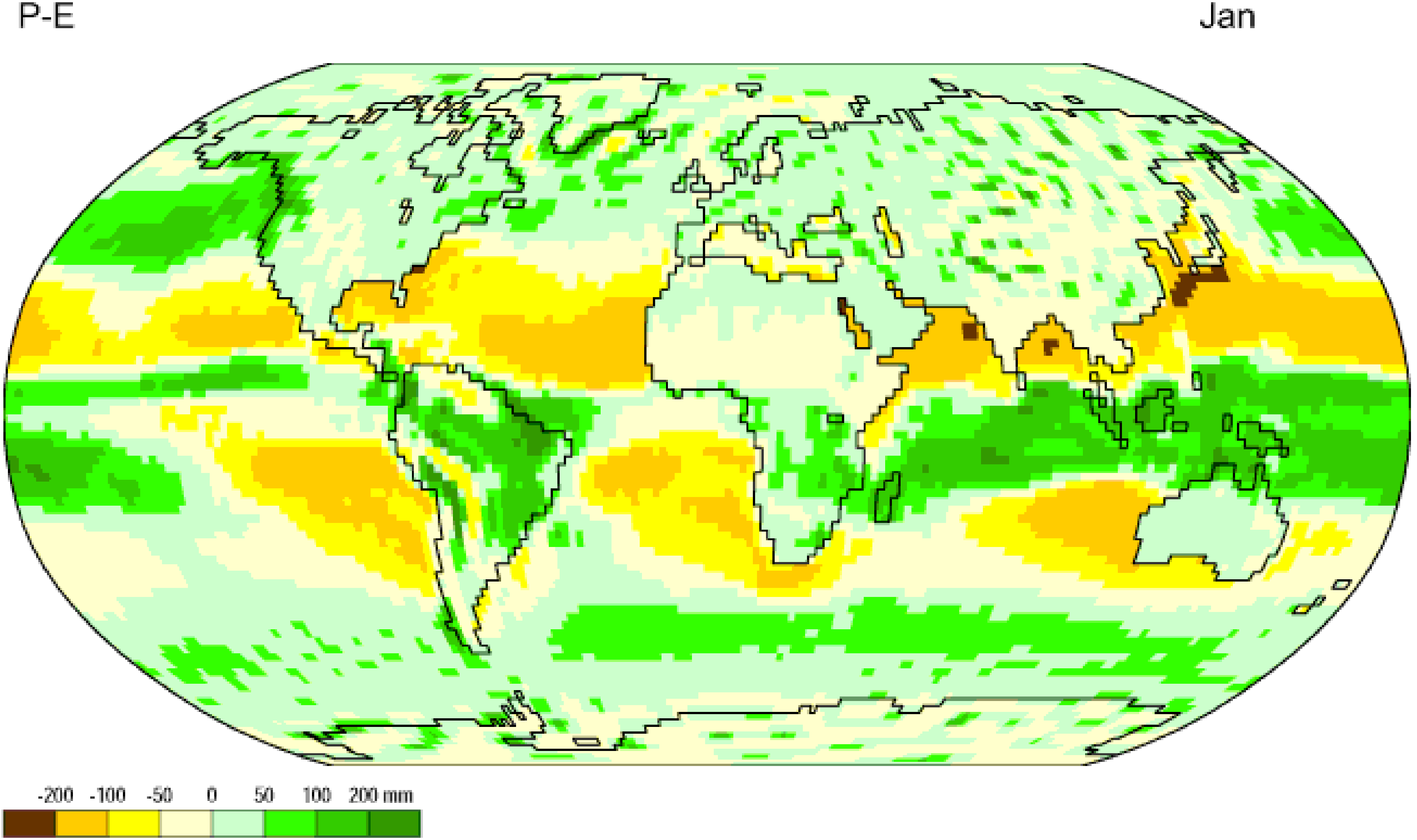
SSM/I Seasonal Precipitation Climatology (mm/day)





zonal averaged monthly SSM/I rain rate anomaly (mm/day) range: [-5.5 9.76]
65N
45N
30N
15N
EQ
15S
30S
45S
65S
latitude
1/88
1/89
1/90
1/91
1/92
1/93
1/94
1/95
1/96
1/97
1/98
1/99
1/00
1/01
year
-3
-2
-1
0
1
2
3

Precipitation minus evapotranspiration for an average January, 1959-1997

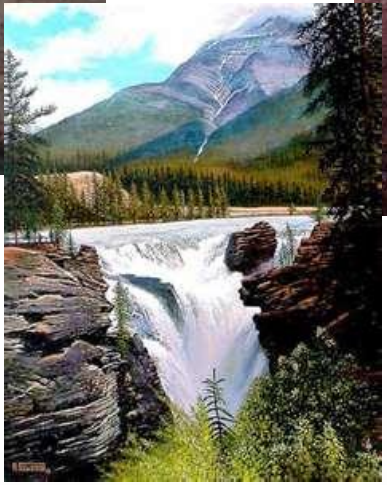


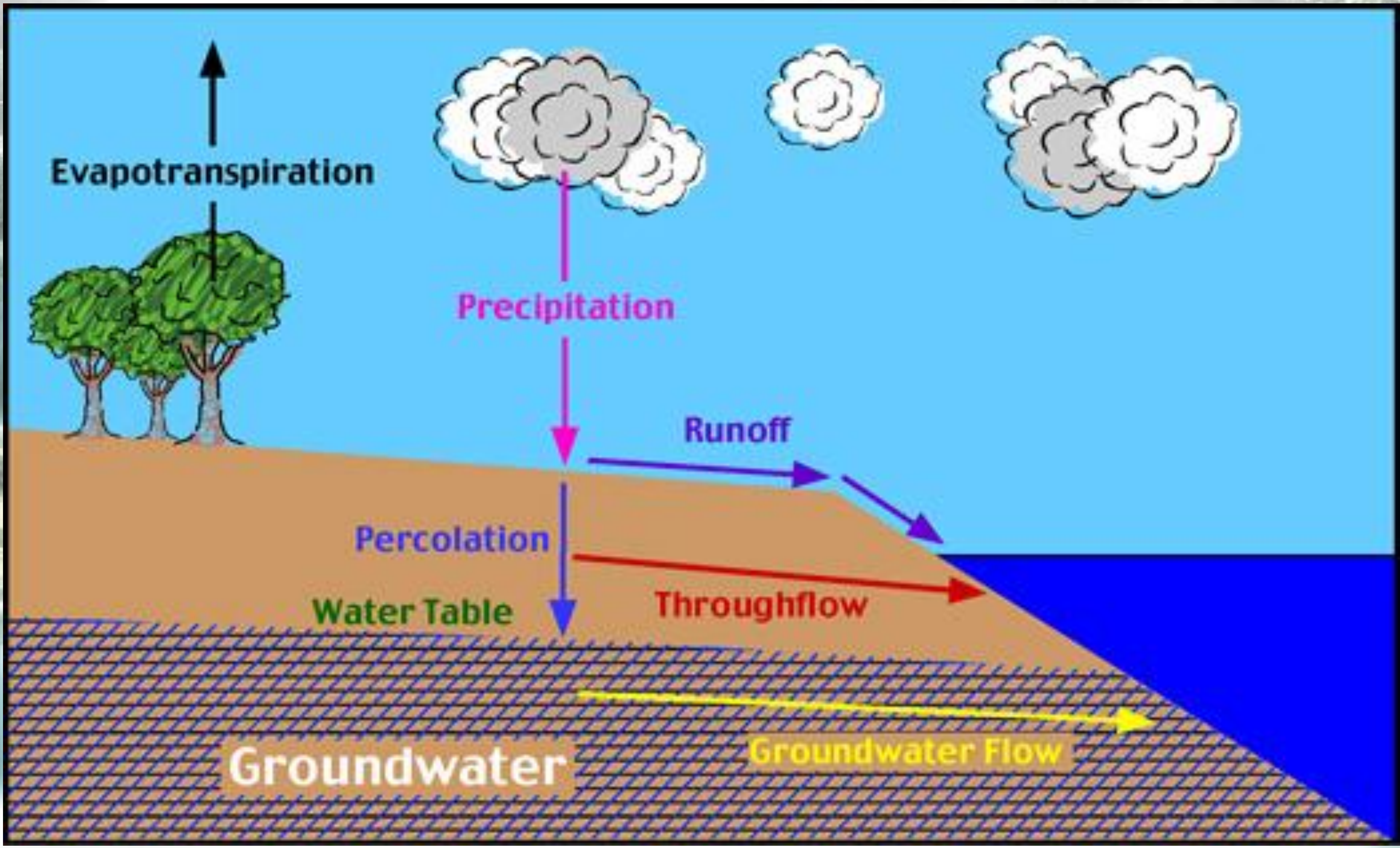
Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies

http://geography.uoregon.edu/envchange/clim_animations/

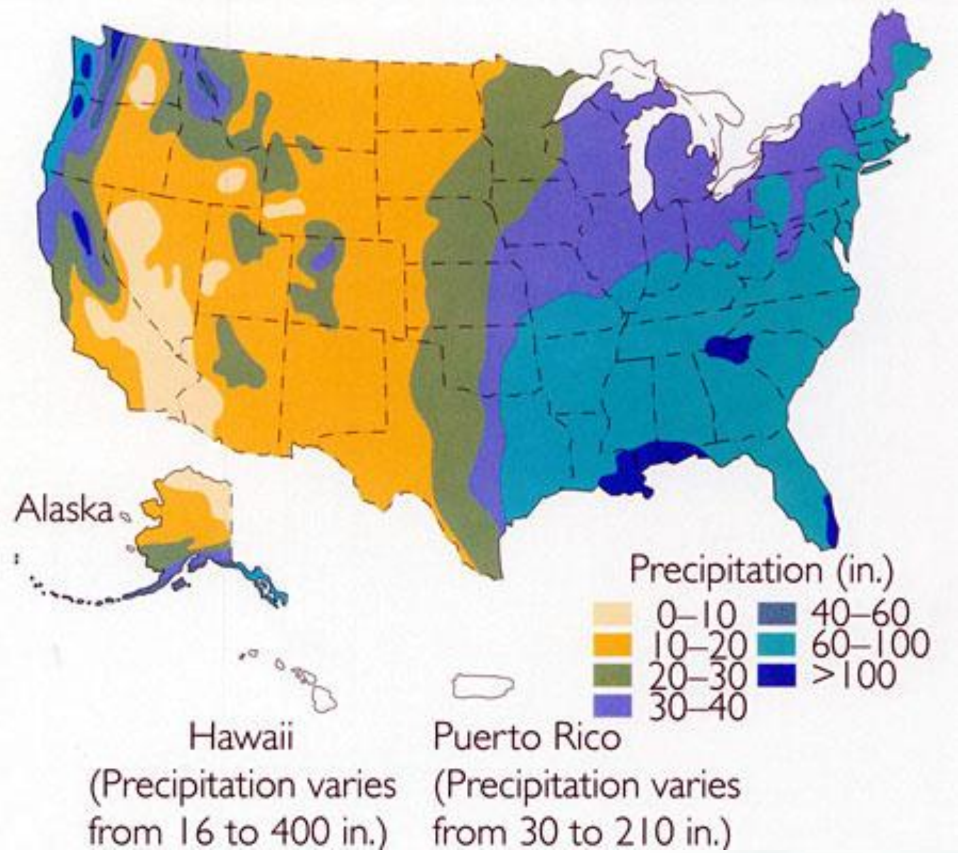
Runoff

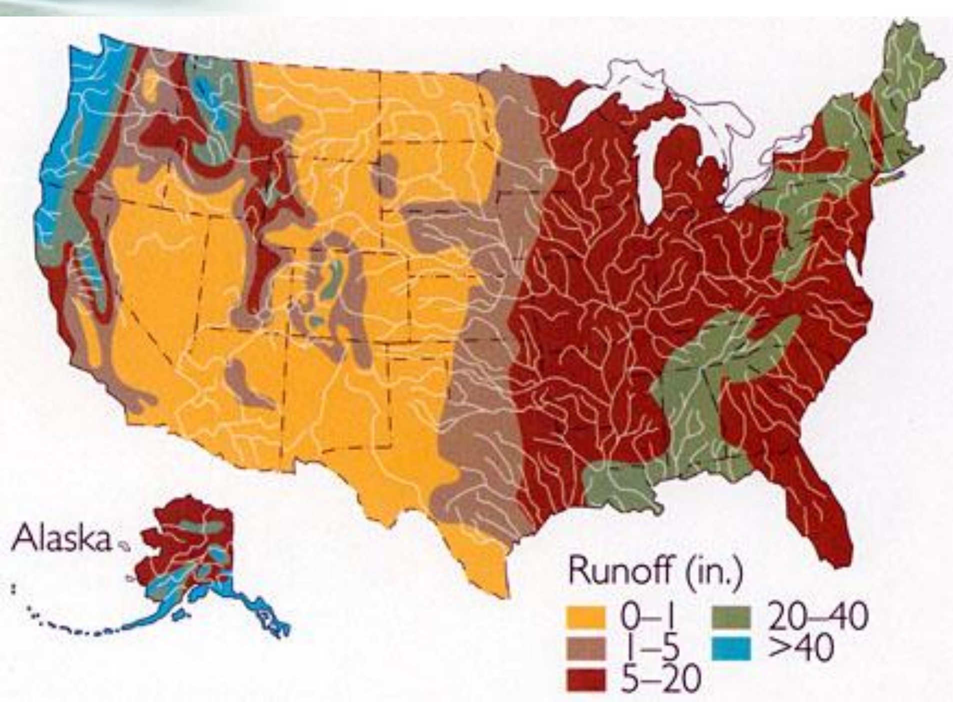
- Most carried by major rivers
- 70 rivers account for 50% of world's runoff
- Amazon River carries 25% of world's runoff!
- streamflow accounts for 85-90% of total sediment transport to the ocean basins (glaciers account for 7%)
- Stored in lakes, wetlands, artificial reservoirs



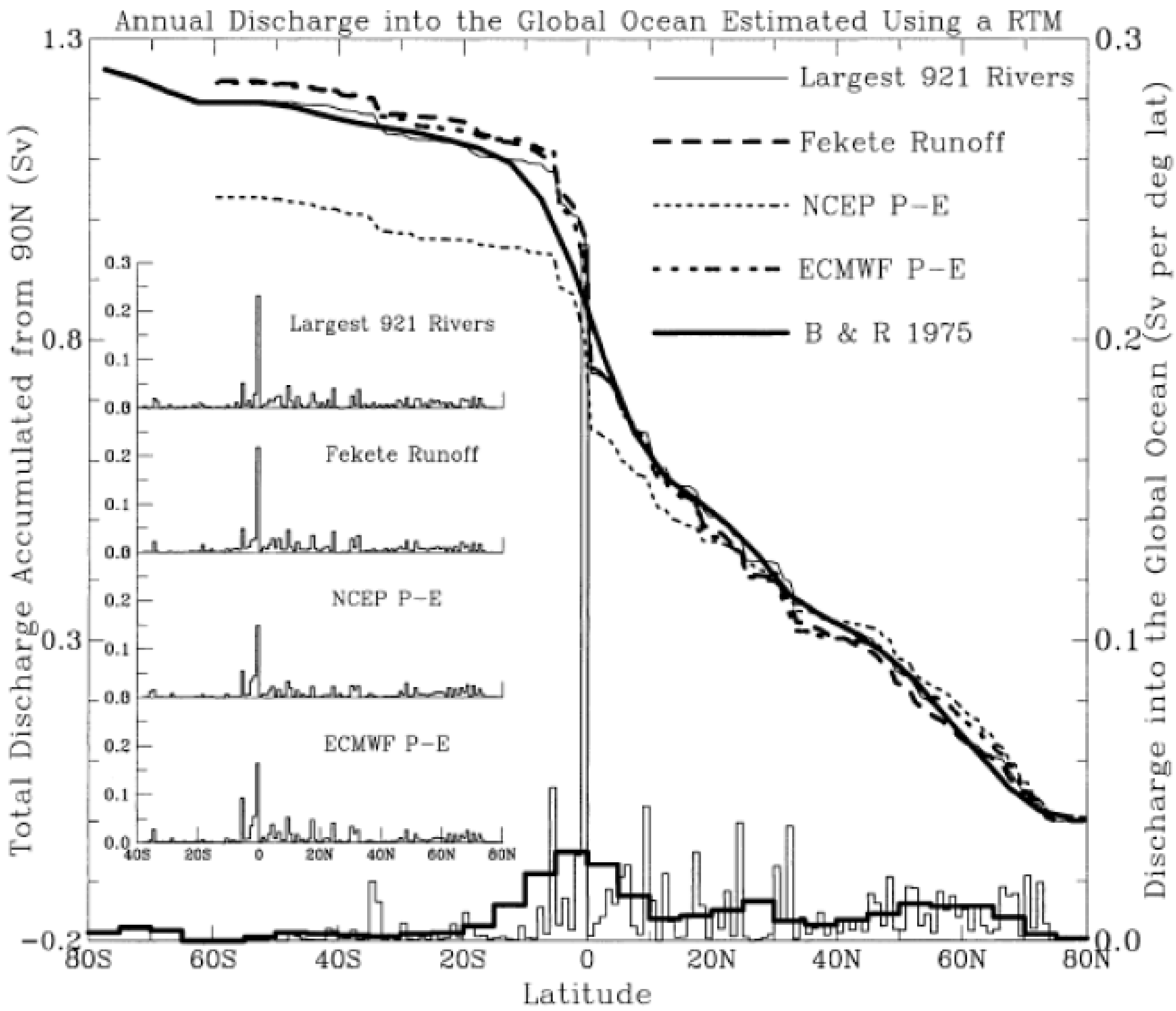

Evapotranspiration
Precipitation
Runoff
Percolation
Throughflow
Water Table
Groundwater Flow
Groundwater

Hydrologic Cycle: Runoff





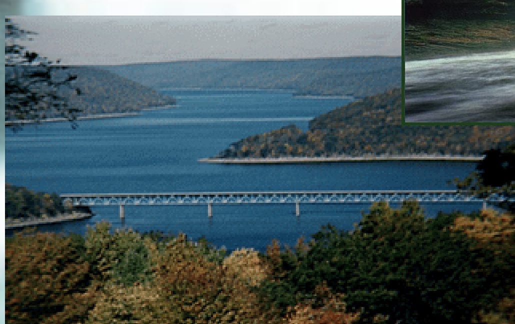
Global River Runoff

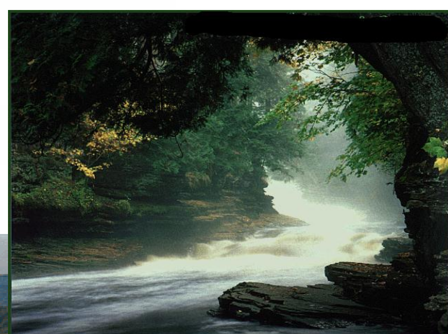


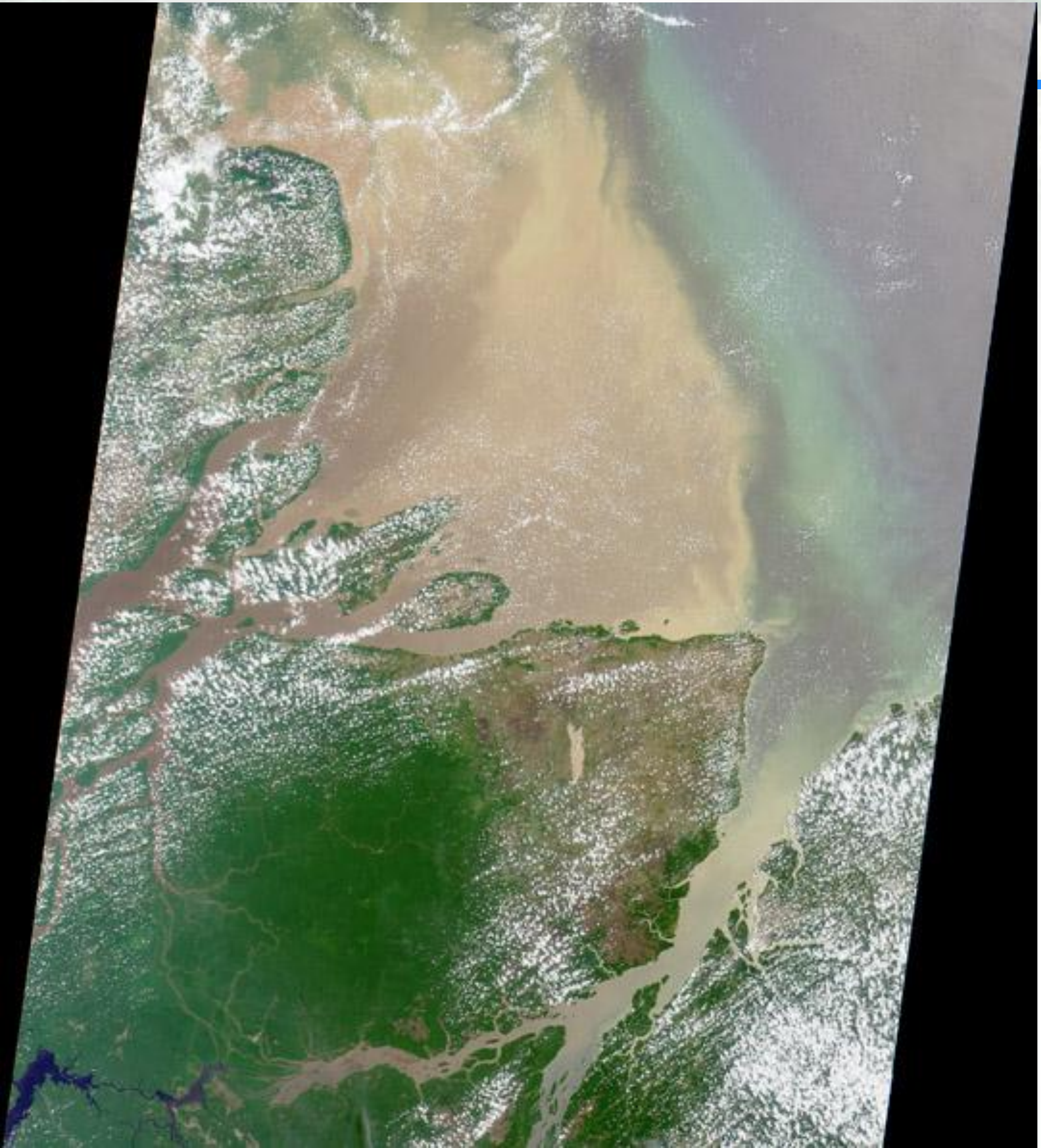
Trenberth, 2002, J. Hydrometeorol.

Importance of large rivers

- The world's 50 largest rivers account for 57% of the global discharge, while their total drainage area is only 43% of the global actively drained land areas (i.e. this excludes glaciers and deserts).
- Adding the next 150 largest rivers increases these to 67% and 65%, respectively,
- Adding the next 721 rivers from their dataset of stations changes the numbers only moderately (to 73% and 68%, respectively).







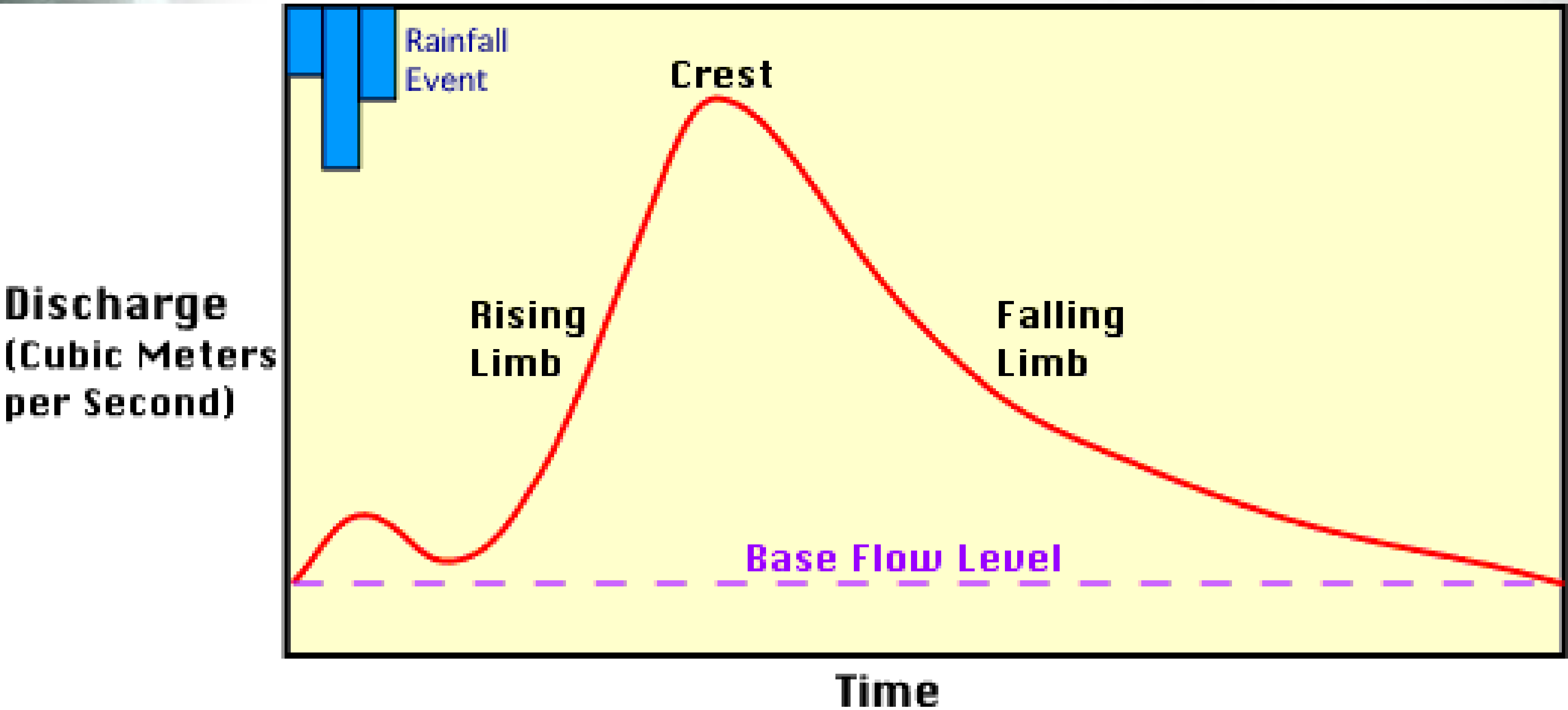
http://earthobservatory.nasa.gov/Newsroom/NewImages/Images/amazon_mouth.jpg

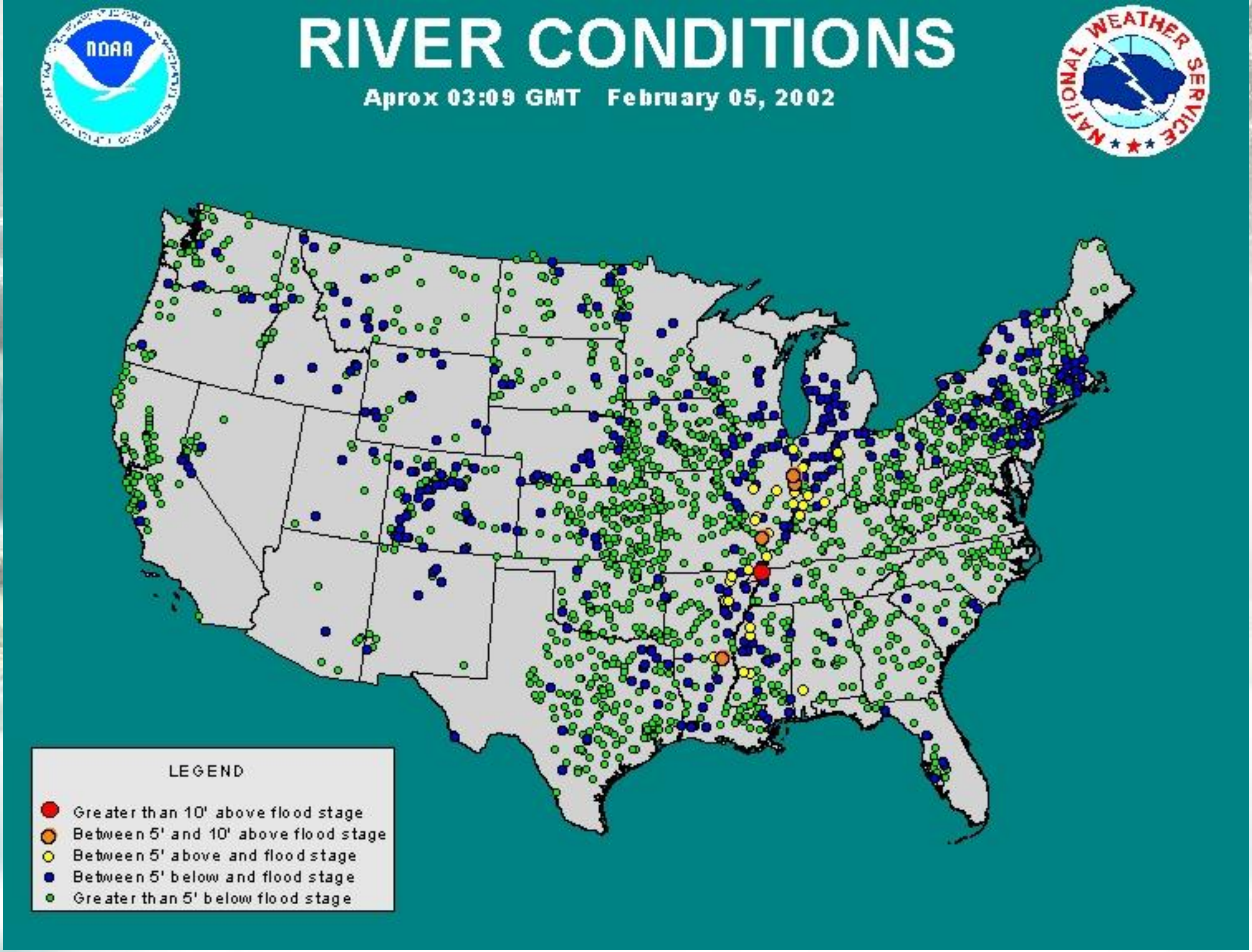
Multi-angle Imaging Spectroradiometer's (MISR's) vertical-viewing (nadir) camera on September 8, 2000, during Terra orbit 3862.

The Yellow River discharges over a billion tons of sediment into the Bohai Bay. The river delta is being extended steadily at a rate of 0.5 km per year, adding roughly 40 sq km of land in the process.

Hydrograph

Discharge: Q = W x D x V

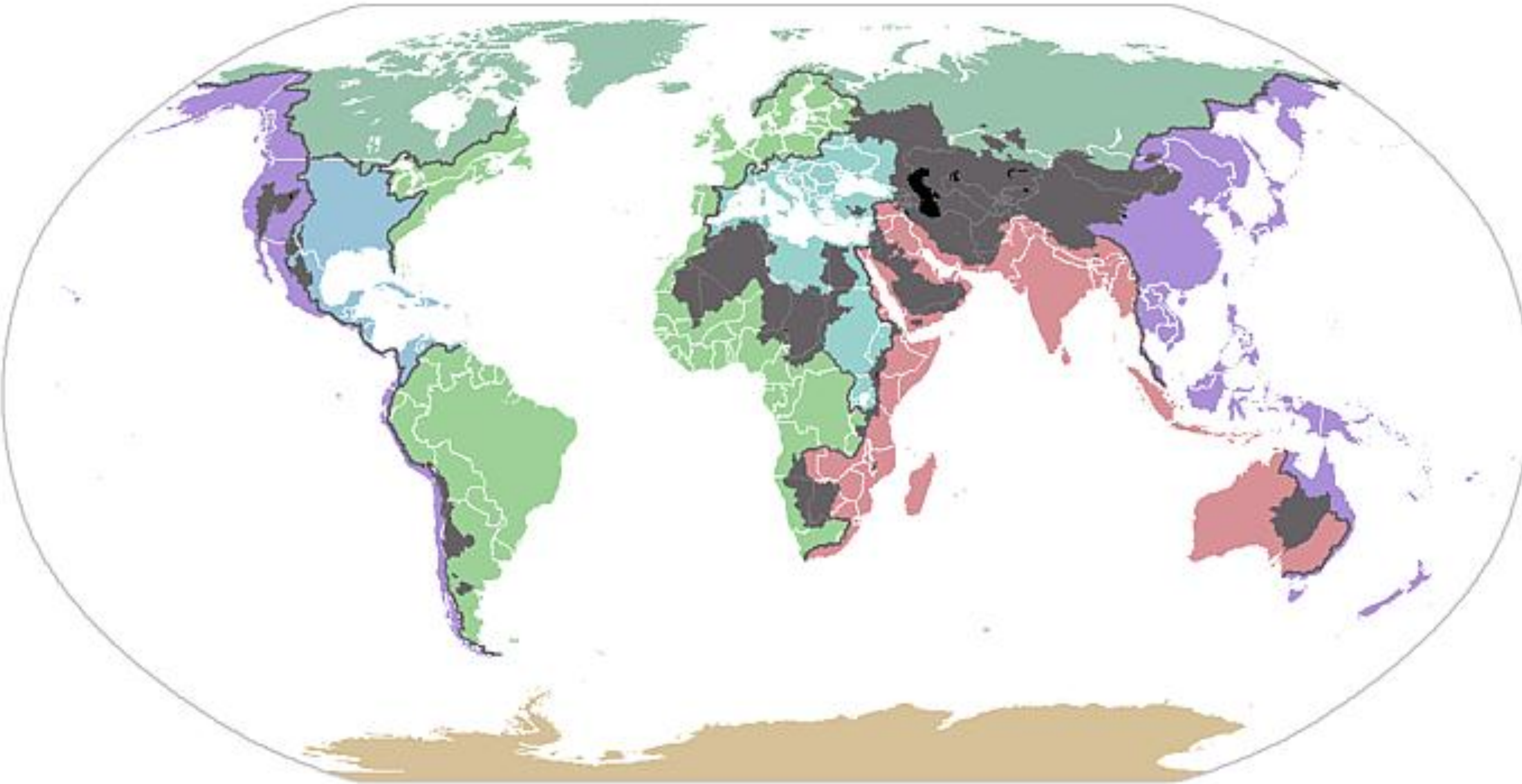




http://www.nws.noaa.gov/oh/hic/index.html

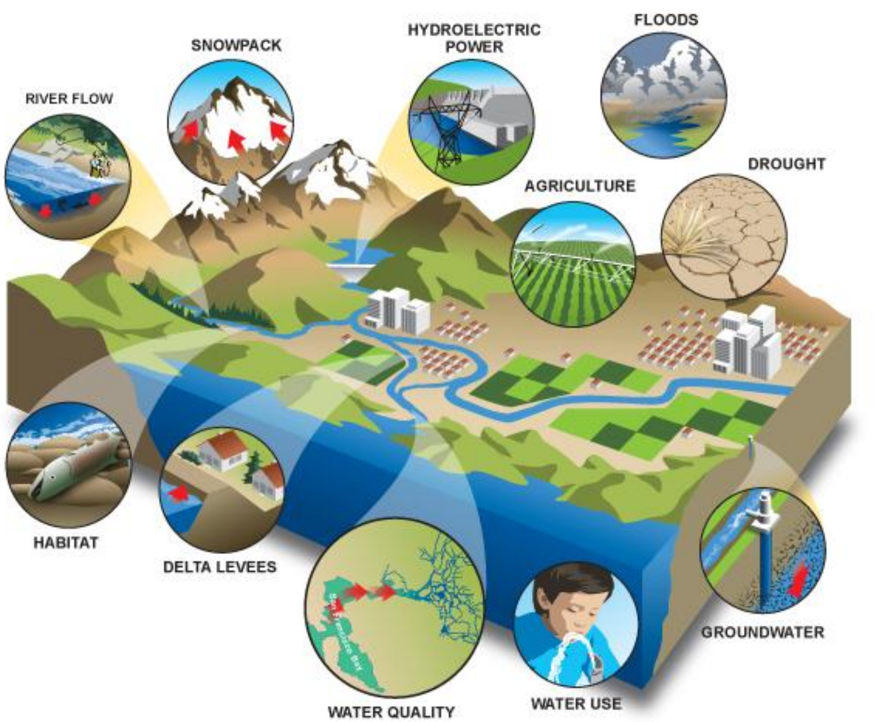
Global Hydrologic Cycle: Global Watersheds

- Map showing drainage basins for the major oceans and seas; grey areas are endorheic basins that do not drain to the ocean.



Global Hydrologic Cycle: Climate Change

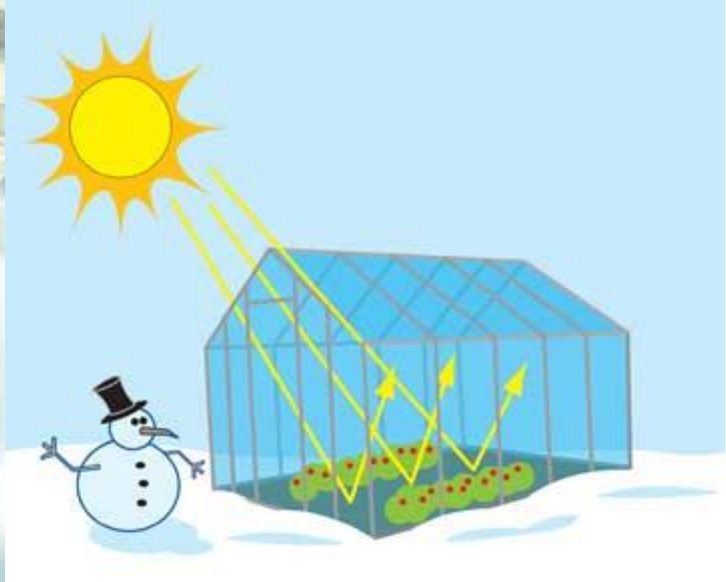
- **How is energy distributed to the earth's surface?**
- **What are greenhouse gases and the greenhouse effect?**
- **Impact of an increase in atmospheric CO_2 on greenhouse effect**
- **Recent changes in greenhouse gas concentrations**
- **Relationship between the greenhouse effect and global warming**

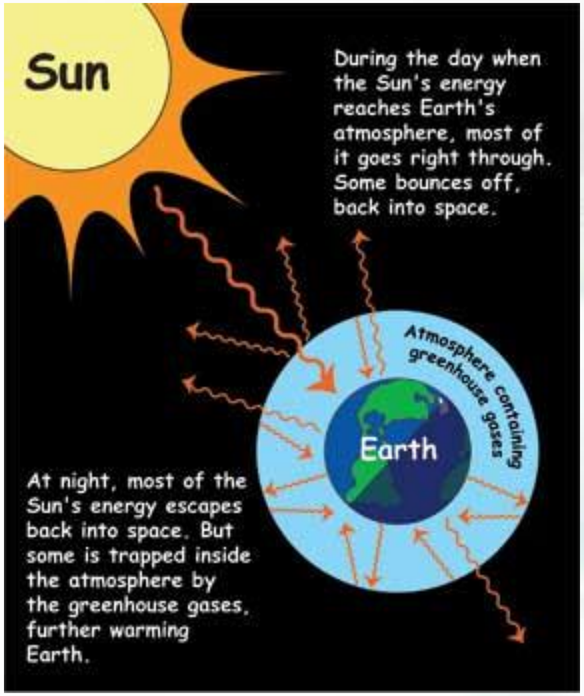


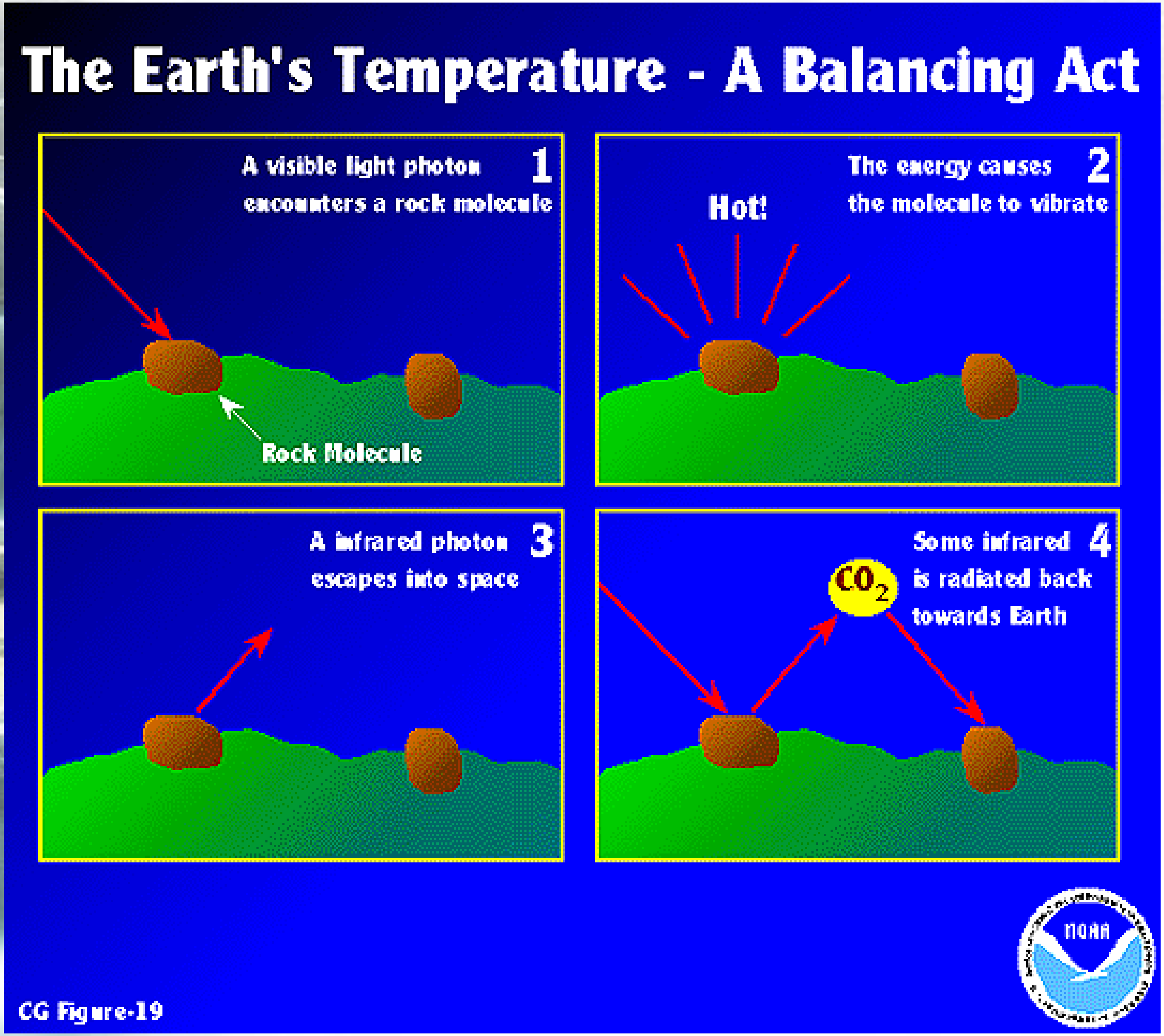
The "Greenhouse Effect"

- The Earth's surface thus receives energy from two sources: the sun & the atmosphere
  - As a result the Earth's surface is ~33°C warmer than it would be without an atmosphere

Greenhouse gases are transparent to shortwave but absorb longwave radiation
  - Thus the atmosphere stores energy





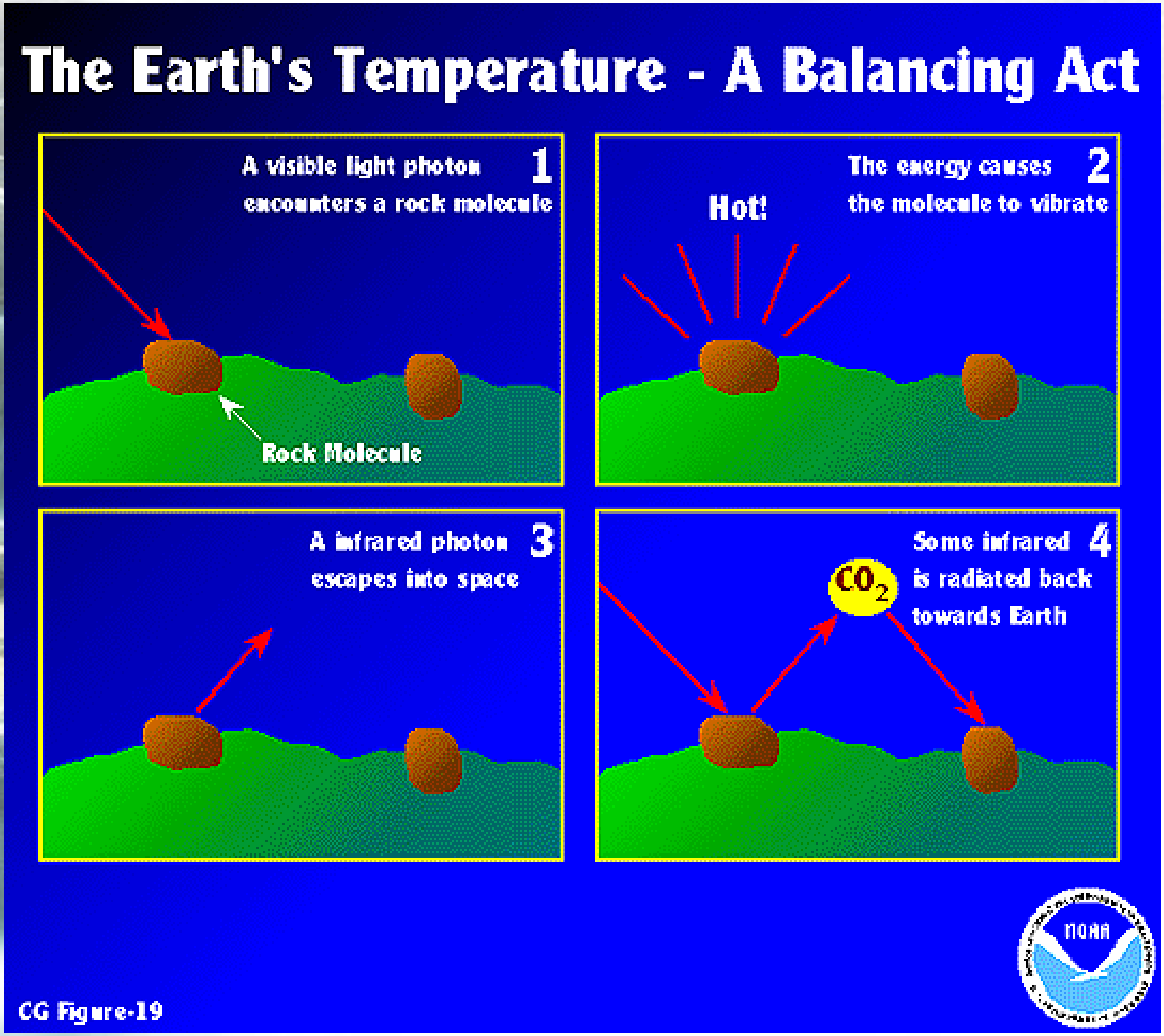


1. Shorter, high Energy wavelengths Hit the earths Surface

2. Incoming energy Is converted to heat

3. Longer, infrared Wavelengths hit Greenhouse gas Molecules in the atmosphere

4. Greenhouse gas Molecules in the Atmosphere emit Infrared radiation Back towards earth



3. Longer, infrared Wavelengths hit Greenhouse gas Molecules in the atmosphere

4. Greenhouse gas Molecules in the Atmosphere emit Infrared radiation Back towards earth

78% nitrogen

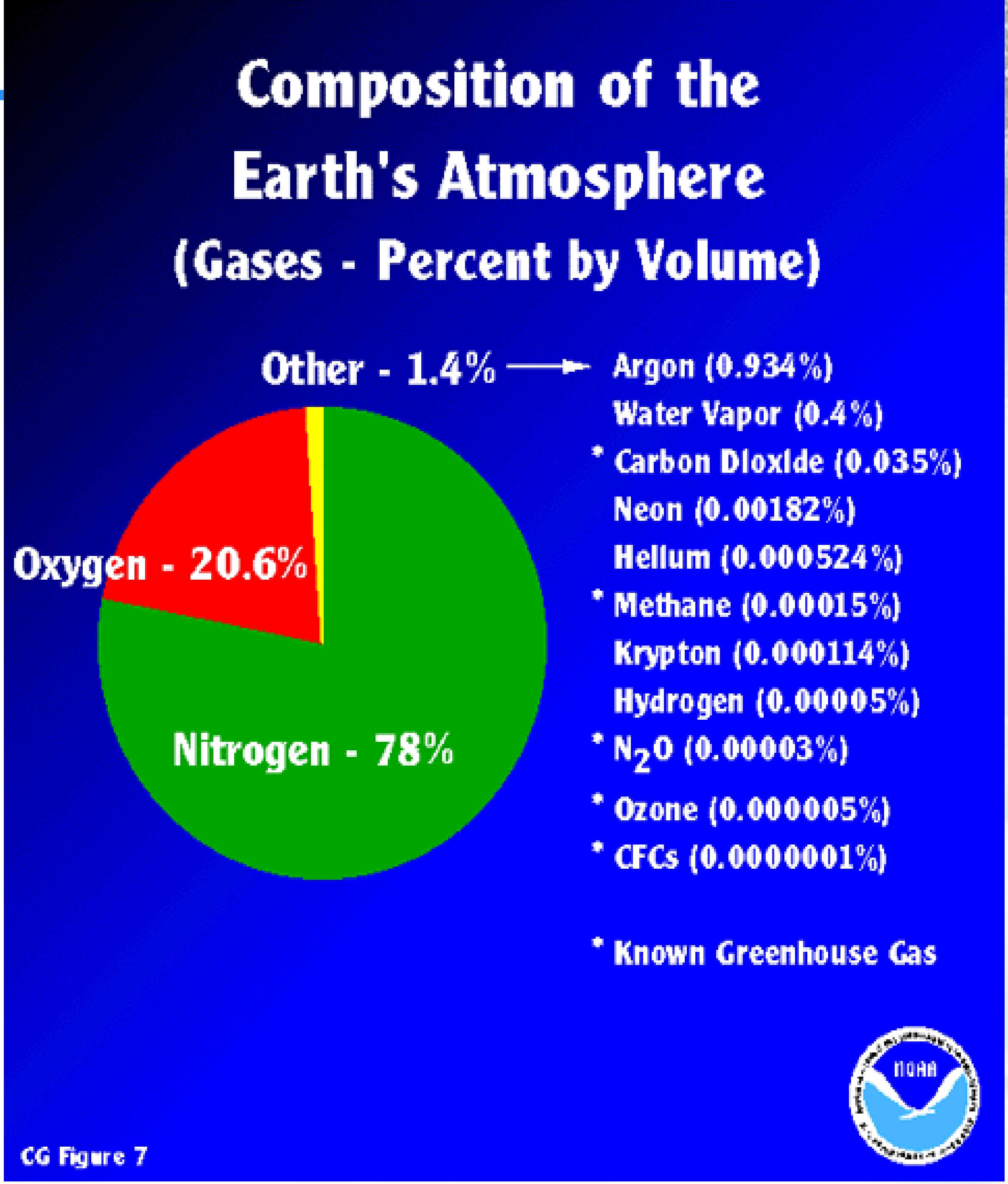
20.6% oxygen

< 1% argon

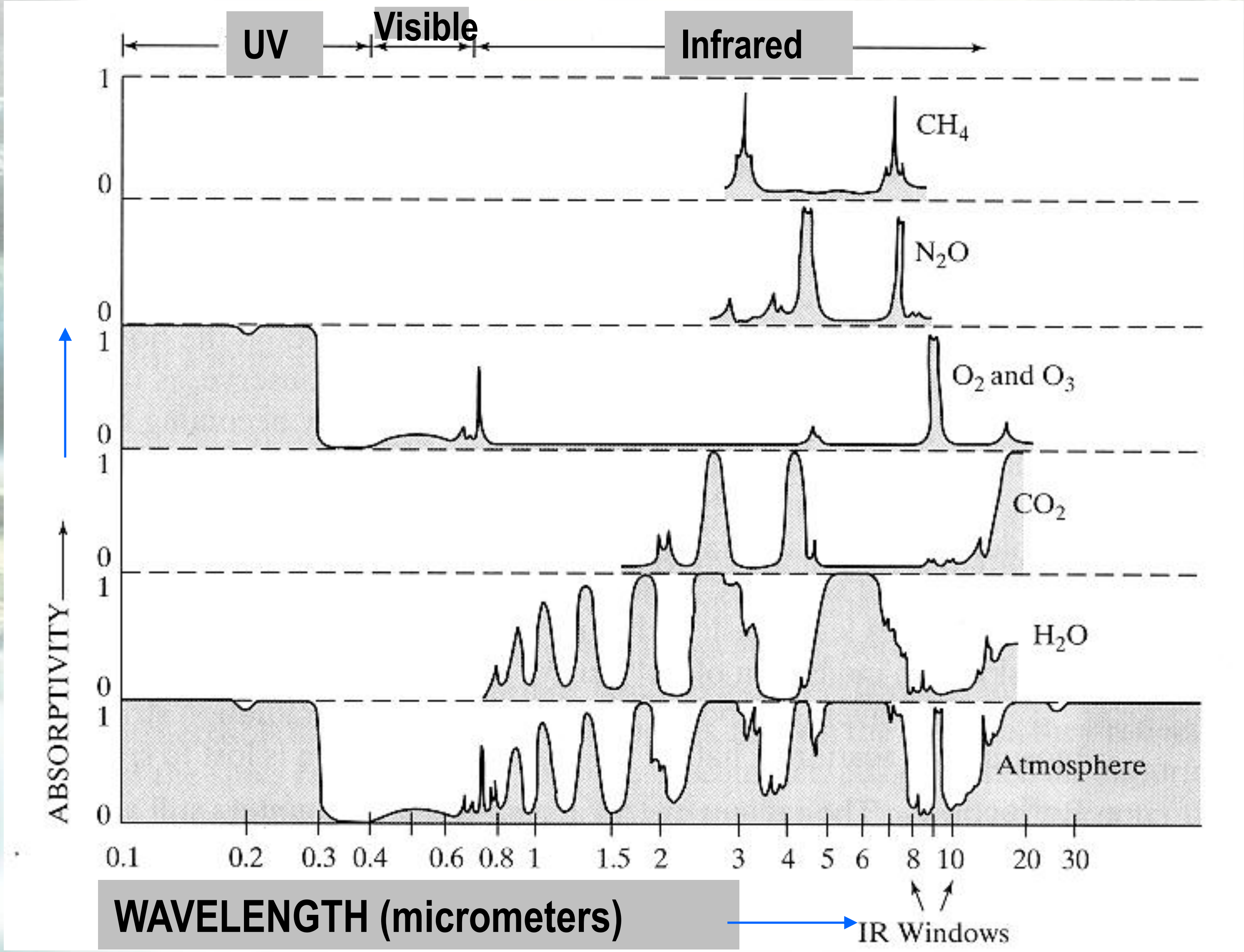
0.4% **water vapor**

0.036% **carbon dioxide**

traces gases:
Ne, He, Kr, H, O_3
Methane, **Nitrous Oxide**



Absorption Spectra of Atmospheric Gases



CH_4

N_2O

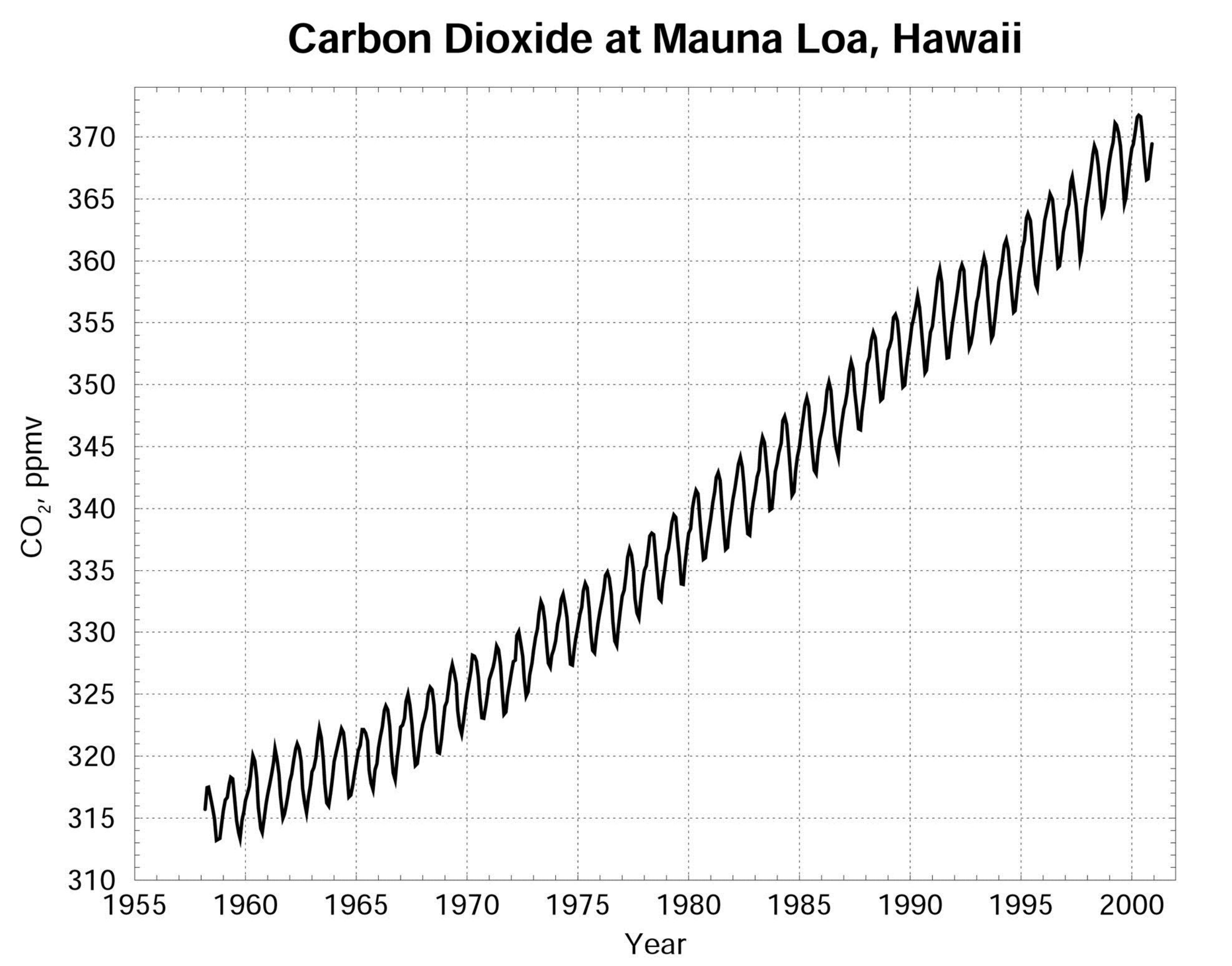
O_2 & O_3

CO_2

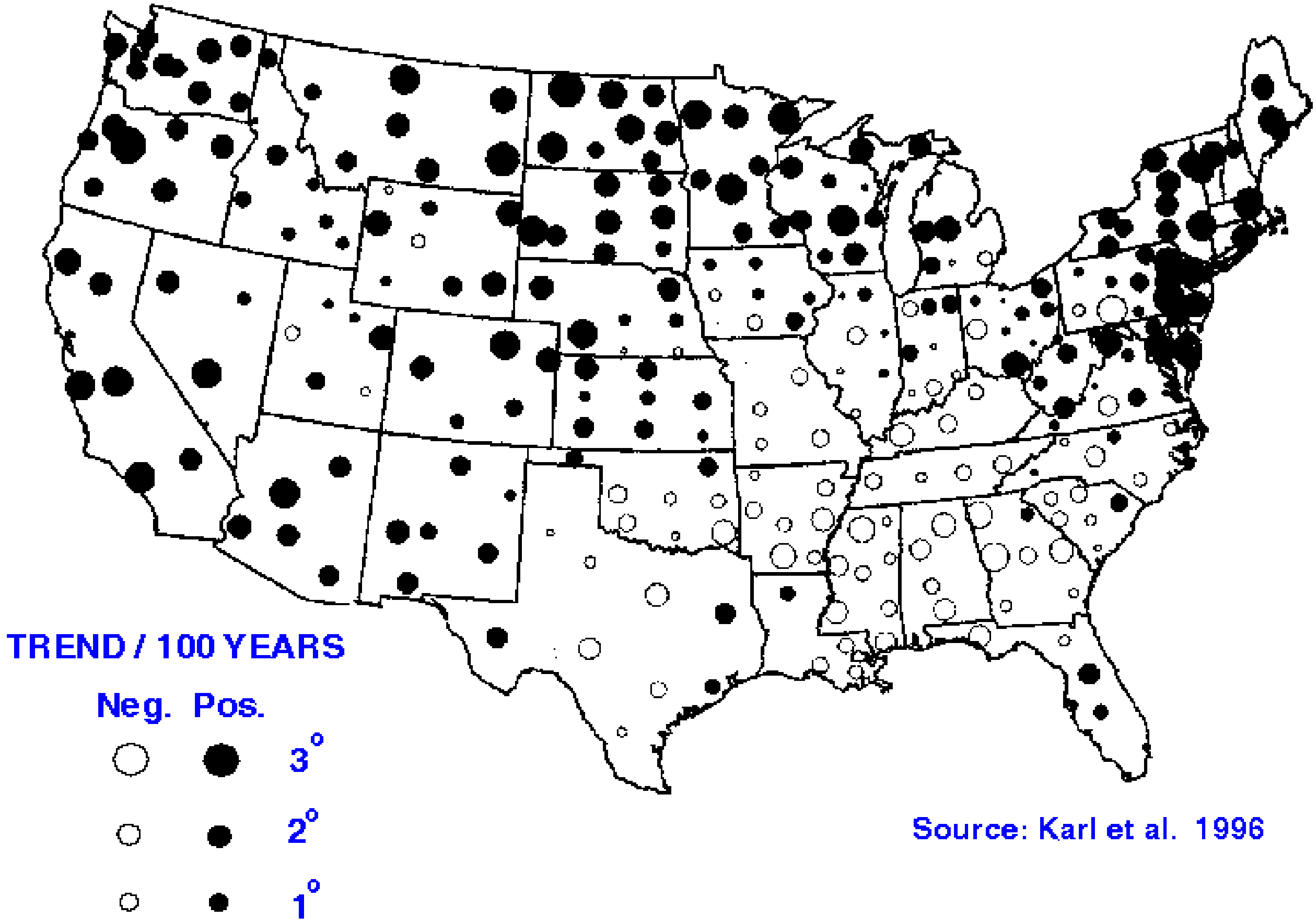
H_2O

atmosphere

Anthes, p. 55


Carbon Dioxide at Mauna Loa, Hawaii
370
365
360
355
350
345
340
335
330
325
320
315
310
CO2, ppmv
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year

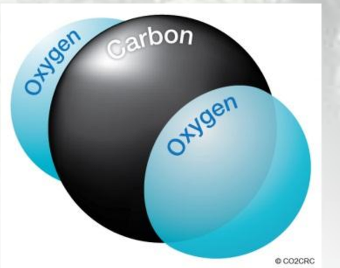
1900 - 94 TEMPERATURE TRENDS



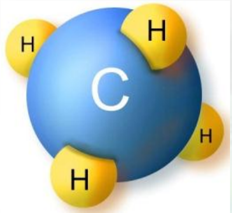
Source: Karl et al. 1996

Selected Greenhouse Gases

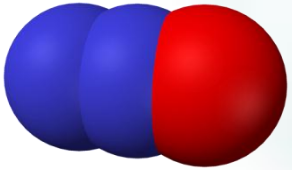
- **Carbon Dioxide (CO_2)**
  - Source: Fossil fuel burning, deforestation
  - Anthropogenic increase: **30%**
  - Average atmospheric residence time: **500 years**



- **Methane (CH_4)**
  - Source: Rice cultivation, cattle & sheep ranching, decay from landfills, mining
  - Anthropogenic increase: **145%**
  - Average atmospheric residence time: **7-10 years**

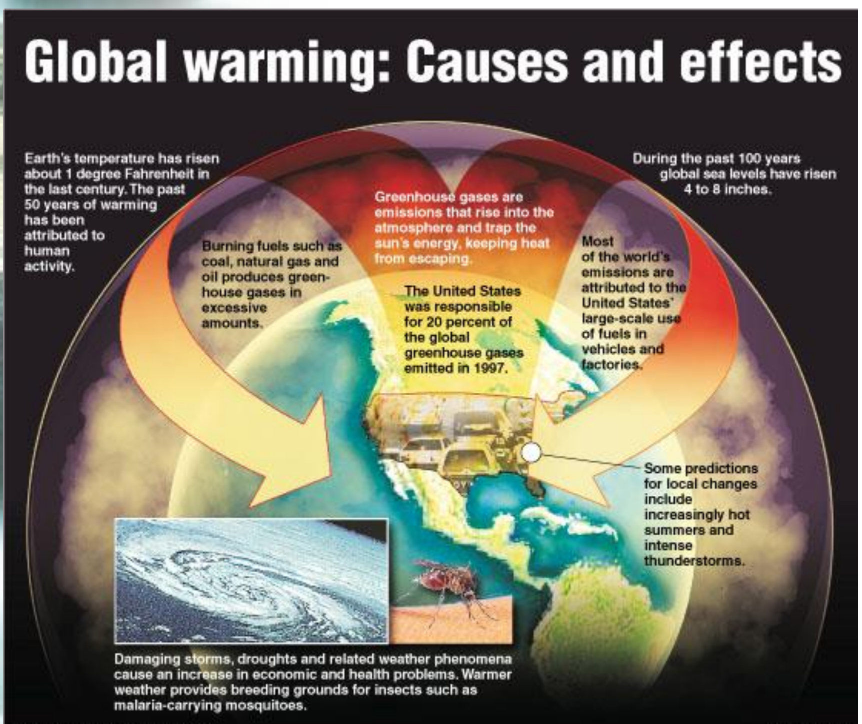


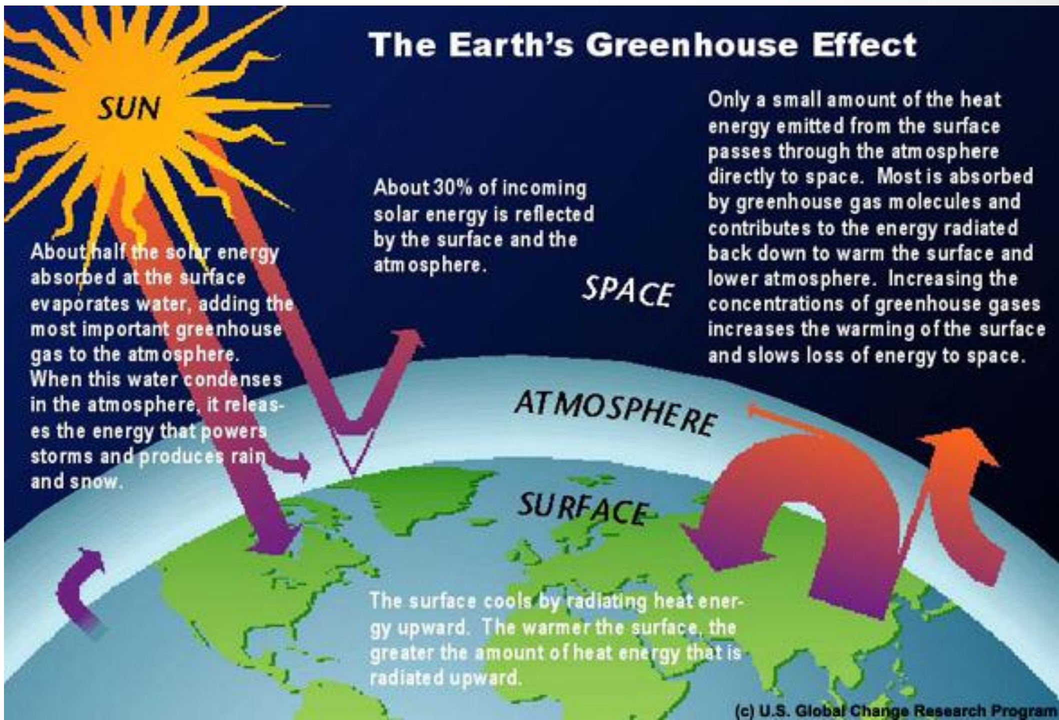
- **Nitrous oxide (N_2O)**
  - Source: Industry and agriculture (fertilizers)
  - Anthropogenic increase: **15%**
  - Average atmospheric residence time: **140-190 years**



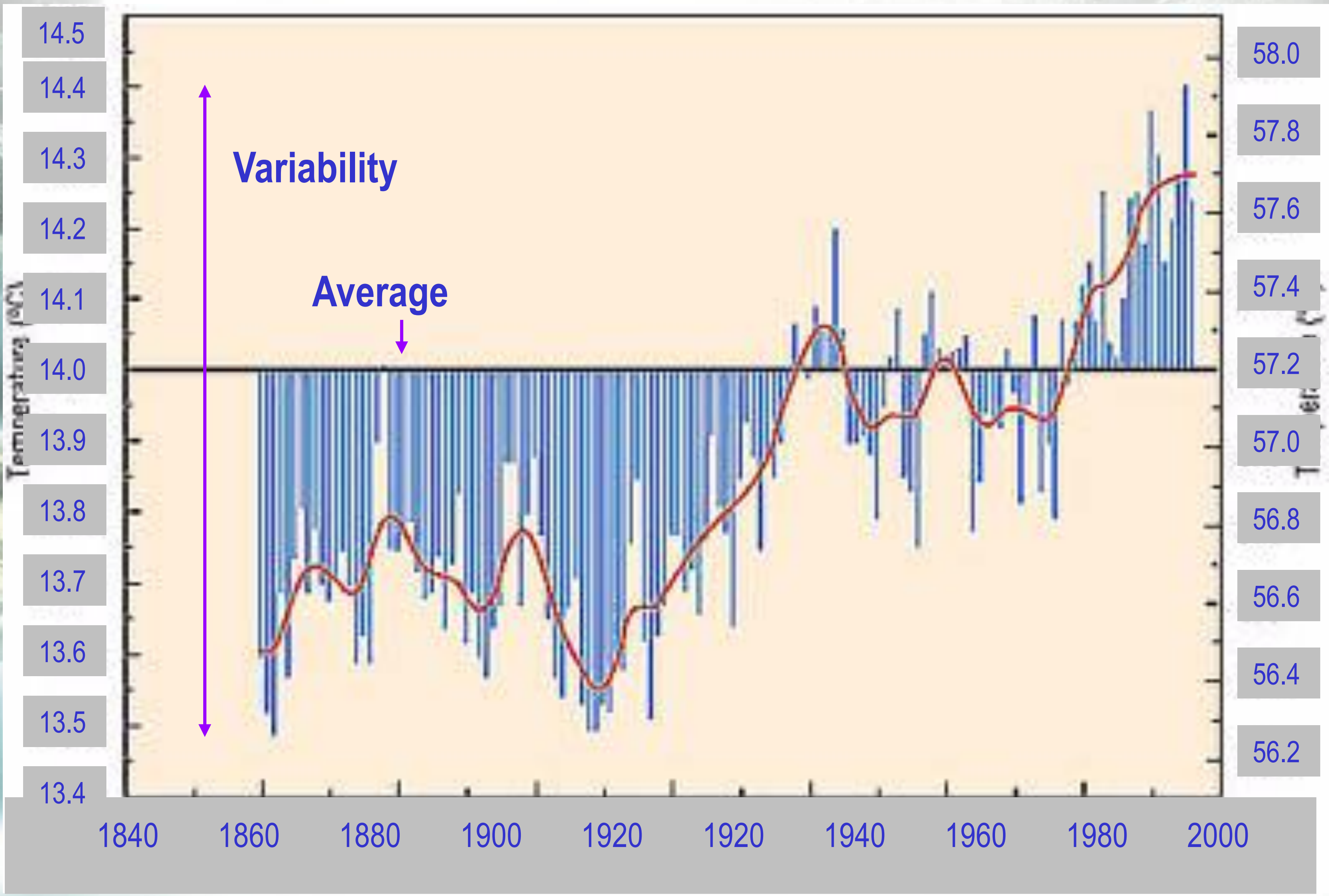
Greenhouse Effect & Global Warming

- The ***"greenhouse effect"*** & ***global warming*** are **not** the same thing.
  - Global warming refers to a rise in the temperature of the surface of the earth
- An increase in the ***concentration of greenhouse gases*** leads to an increase in the the ***magnitude of the greenhouse effect***. (Called enhanced greenhouse effect)
  - This results in global warming





Climate Change vs. Variability



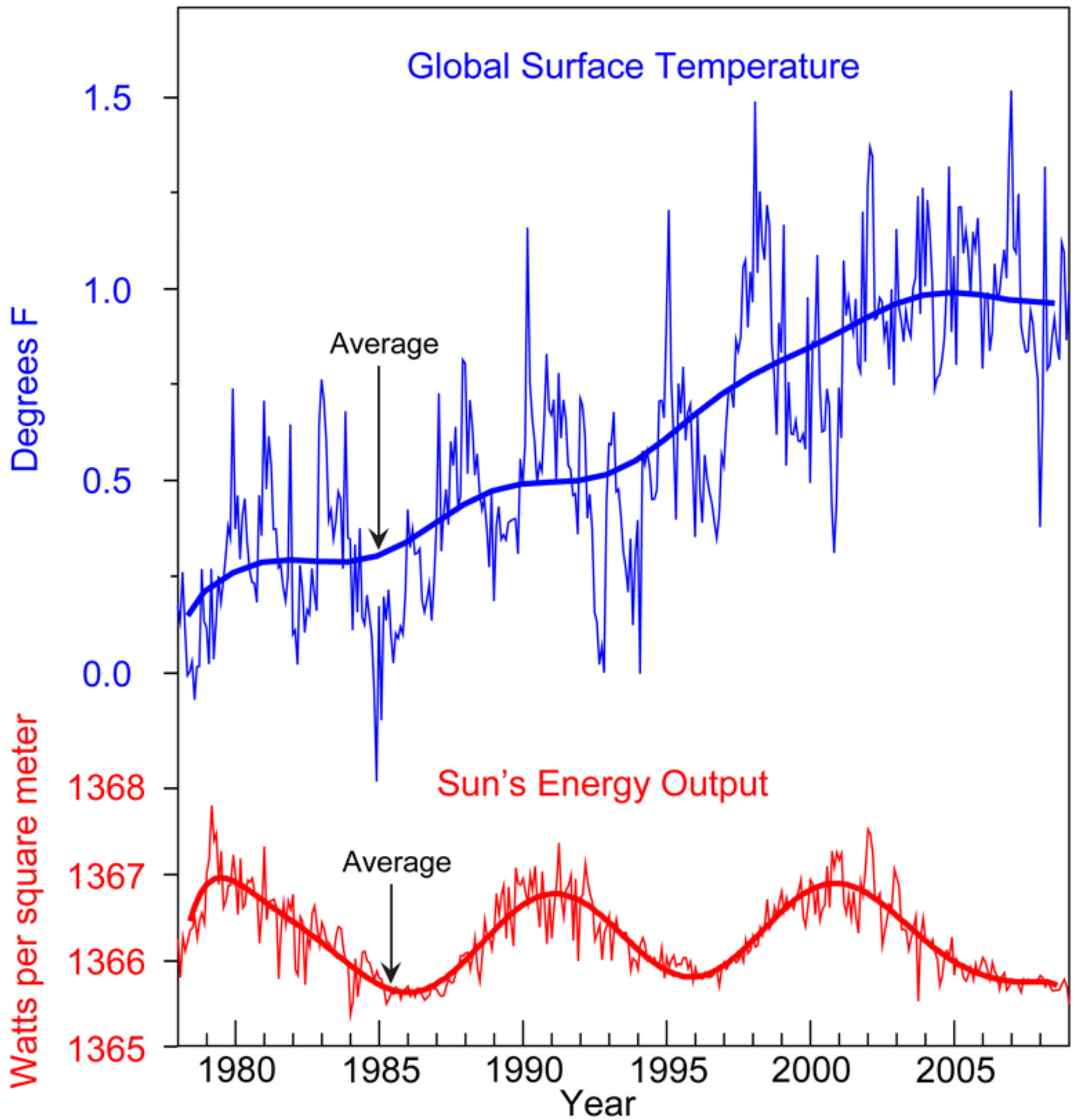
www.gcrio.org/ipcc/qa/cover.html (modified)

Climate Change vs. Variability

Climate variability is natural.

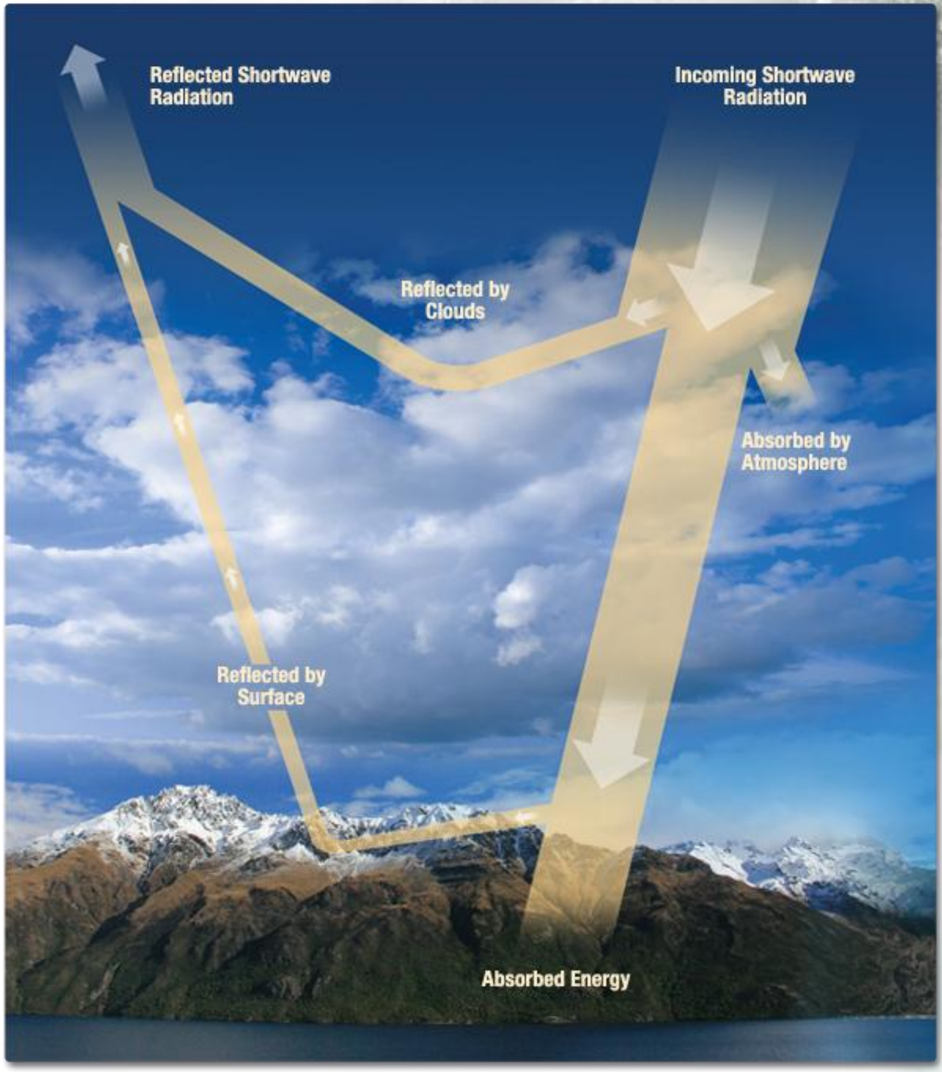
Even in a stable climate regime, there will always be some variation (wet/dry years, warm/cold years) A year with completely "average" or "normal" climate conditions is rare

The challenge for scientists is to determine whether any increase/decrease in precipitation, temperature, frequency of storms, sea level, etc. is due to climate variability or climate change.

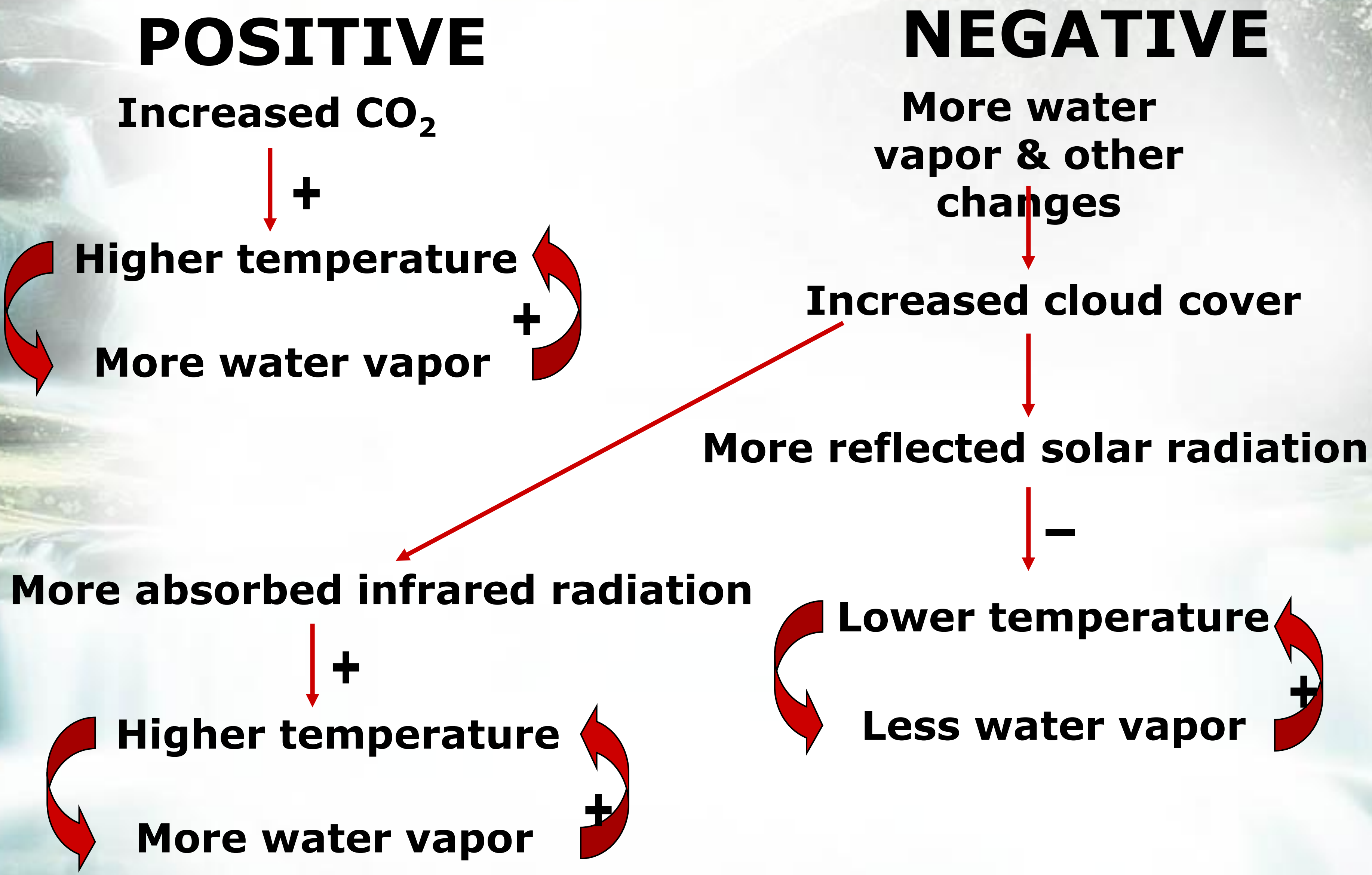


Clouds & Radiation

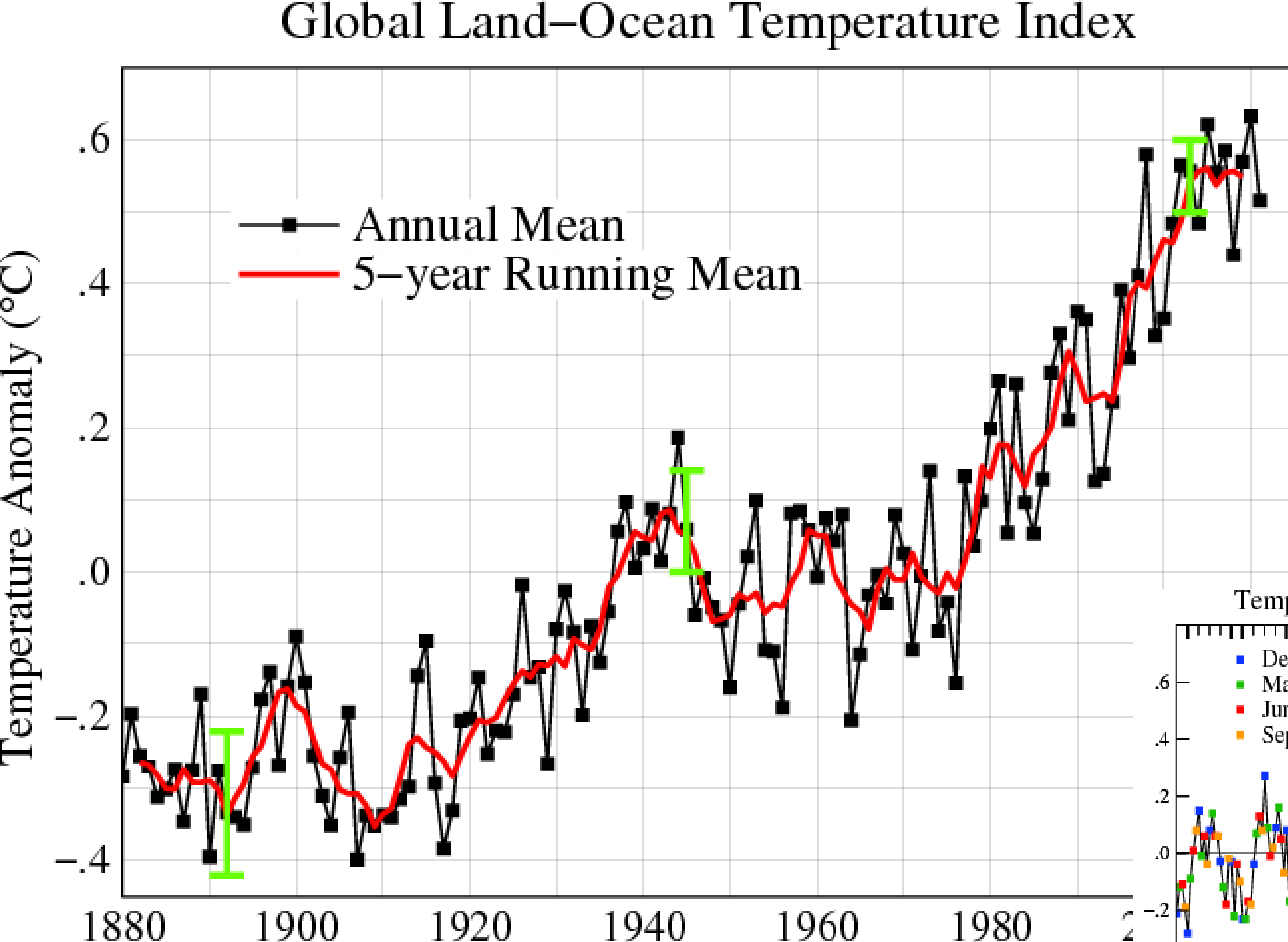
- Clouds play multiple roles as scatterers and absorbers of radiation
- Global Cooling or Warming?
  - CO_2 increases may change cloud microstructure, height, and water content
  - Higher clouds → warming
  - More water content → higher albedo → cooling
  - Special considerations to other pollutants, which can create more CCN, increasing albedo
- Increased convective clouds, cirrus clouds?
- Location of cloudiness on the Earth

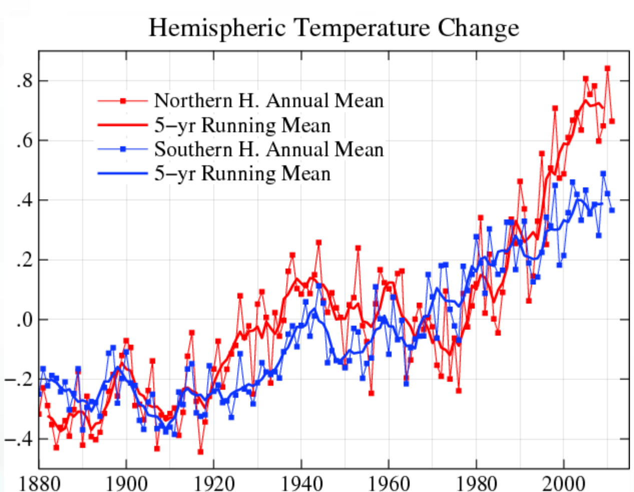


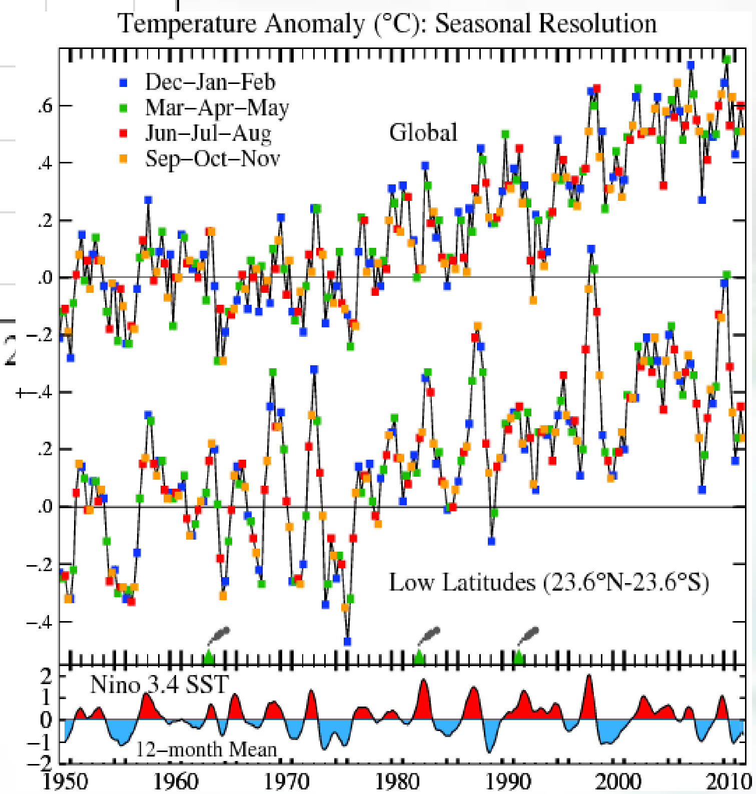
Atmospheric Feedbacks



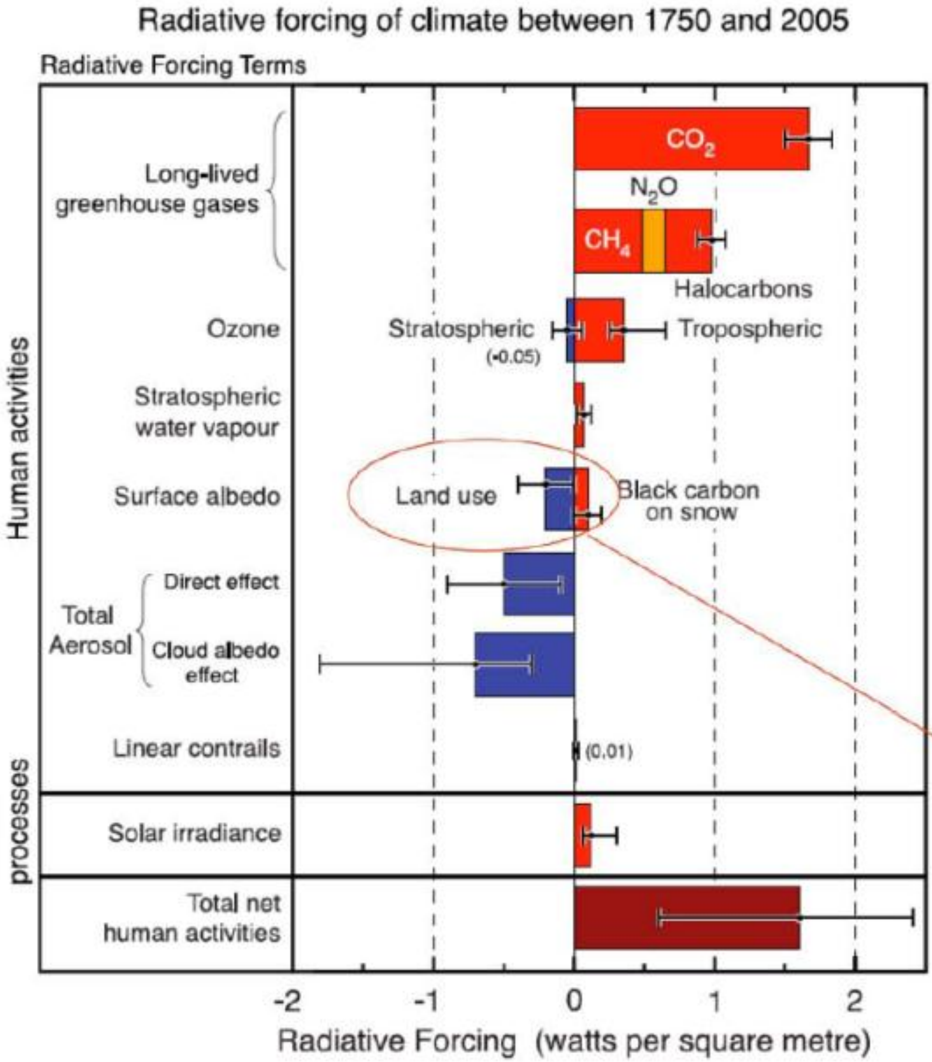

s. harris


Global Land–Ocean Temperature Index
Annual Mean
5–year Running Mean
Temperature Anomaly (°C)
.6
.4
.2
.0
–.2
–.4
1880
1900
1920
1940
1960
1980


Hemispheric Temperature Change
Northern H. Annual Mean
5–yr Running Mean
Southern H. Annual Mean
5–yr Running Mean
.8
.6
.4
.2
.0
–.2
–.4
1880
1900
1920
1940
1960
1980
2000


Temperature Anomaly (°C): Seasonal Resolution
Dec–Jan–Feb
Mar–Apr–May
Jun–Jul–Aug
Sep–Oct–Nov
Global
Low Latitudes (23.6°N-23.6°S)
Nino 3.4 SST
12–month Mean
1950
1960
1970
1980
1990
2000
2010

Radiative fording of climate change



FAQ 2.1, Figure 2. *Summary of the principal components of the radiative forcing of climate change. All these radiative forcings result from one or more factors that affect climate and are associated with human activities or natural processes as discussed in the text. The values represent the forcings in 2005 relative to the start of the industrial era (about 1750). Human activities cause significant changes in long-lived gases, ozone, water vapour, surface albedo, aerosols and contrails. The only increase in natural forcing of any significance between 1750 and 2005 occurred in solar irradiance. Positive forcings lead to warming of climate and negative forcings lead to a cooling. The thin black line attached to each coloured bar represents the range of uncertainty for the respective value. (Figure adapted from Figure 2.20 of this report.)*

NB: For land use changes, only impacts through albedo changes are considered here

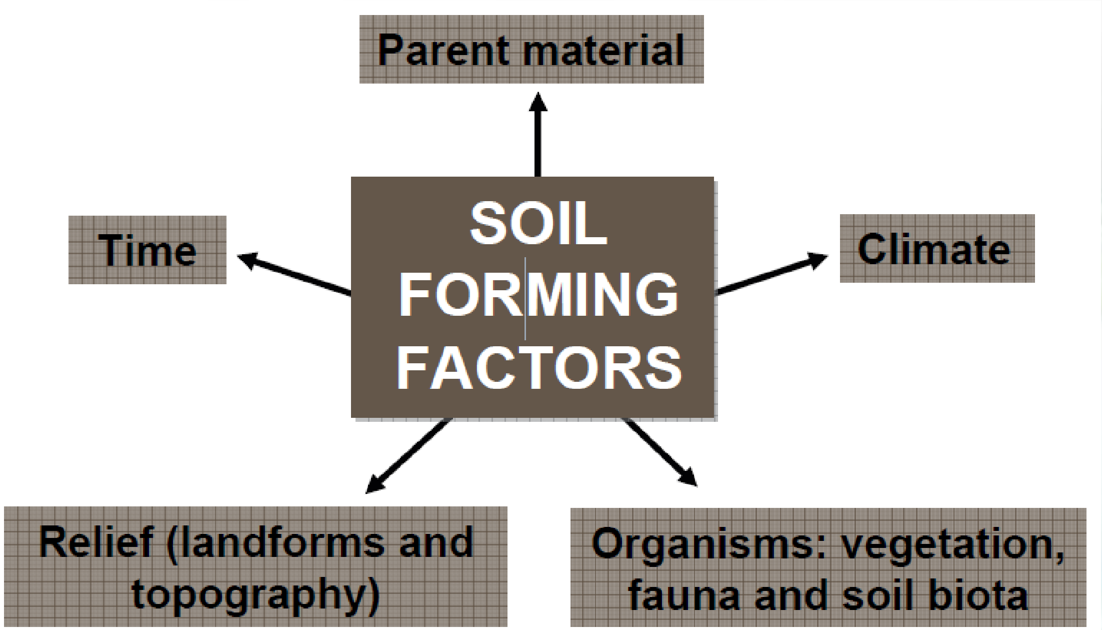
Soil: some definitions

Soil can be defined as the solid material on the Earth's surface that results from the interaction of weathering and biological activity on the parent material or underlying hard rock.

The study of soils as naturally occurring phenomena is called **pedology** (from the Greek word *pedon*, meaning soil or earth).

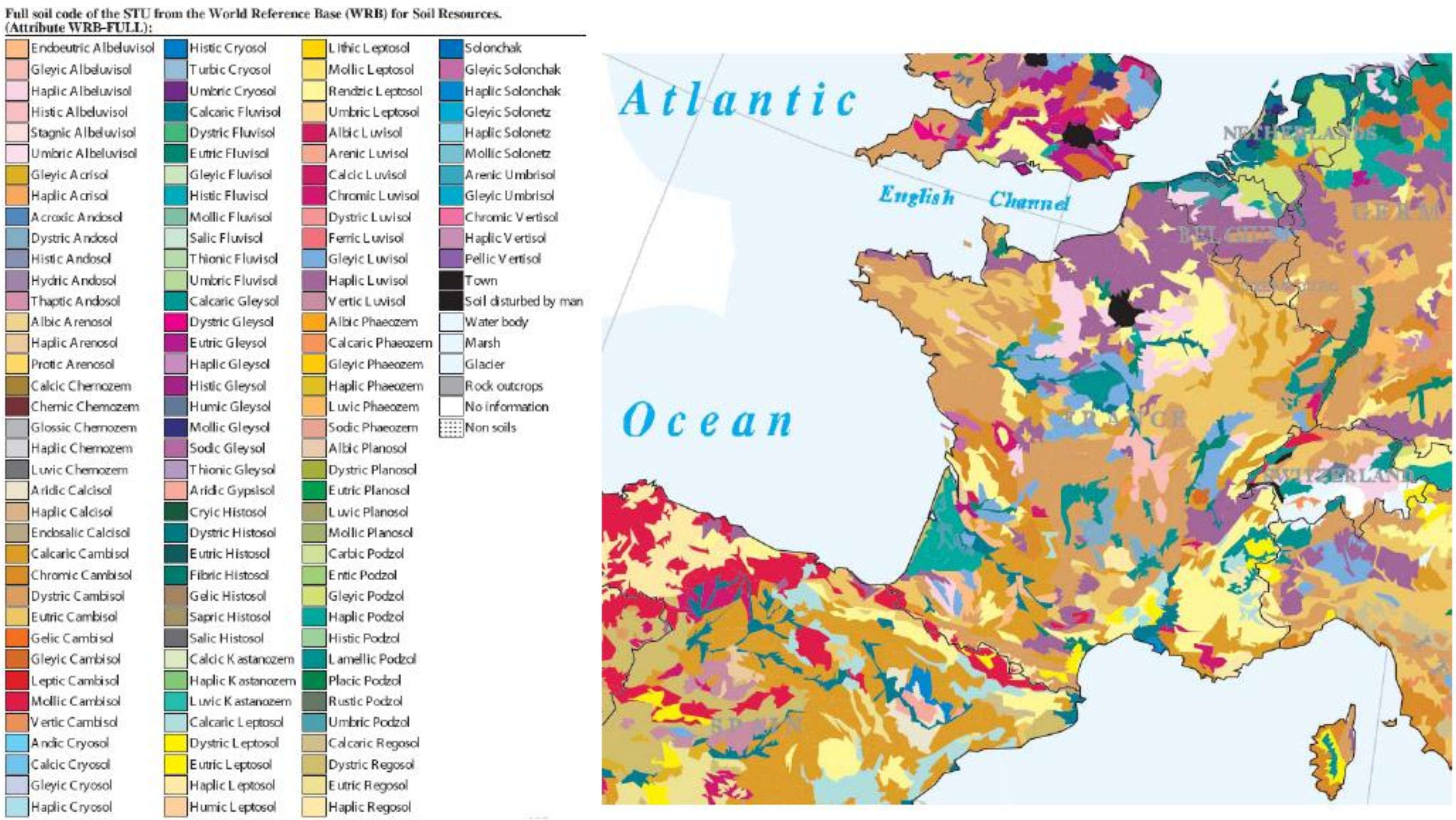
Pedology takes into account:

- factors and processes of soil formation
- soil characteristics
- distribution of soil types



Soils are complex:

Soils consist of a vertical sequence of layers, so-called **horizons**. The sequence and composition of horizons is by no means arbitrary → Soil classification



(European Soil Database)

Soils are complex:

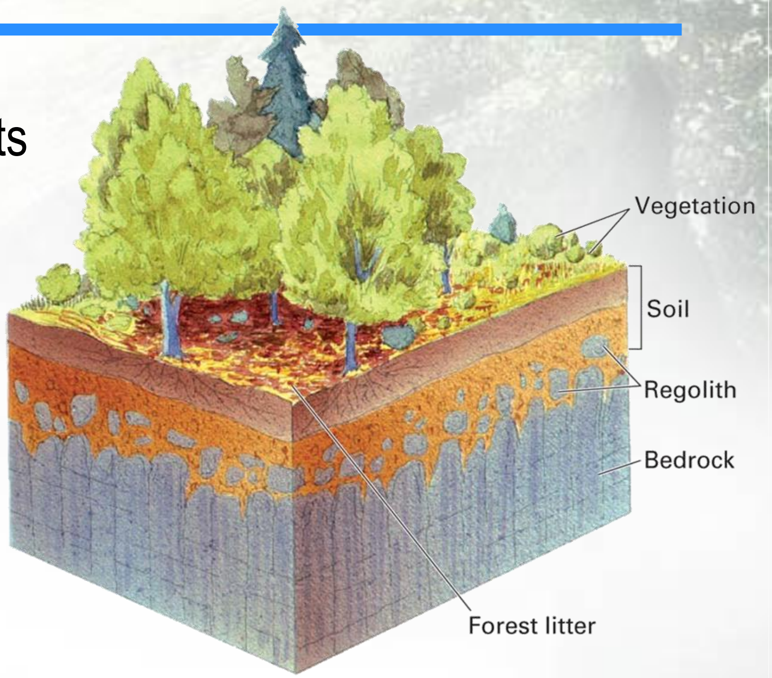
- Soils have a unique structural characteristic serving as a basis for their classification: A vertical sequence of layers, called horizons.
- A horizon (Uppermost soil layer): Weathered layer containing an accumulation of humus and microbial biomass mixed with small-grained minerals to form aggregate structures.
- B horizon: In mature soils characterized by an accumulation of clay
- C horizon: Little or no humus accumulation or soil structure development.
- These simple letter designations are supplemented in several ways

(Encyclopædia Britannica, 2008)

The Nature of the Soil

Soil: natural terrestrial surface layer containing living matter and supporting, or capable of supporting, plants

- Soil contains:
  - Mineral matter from rock material
  - Organic matter
    Humus: finely divided, partially decomposed organic matter in soils
  - Air
  - Water



Parent material: inorganic material base from which soil is formed

The Nature of the Soil

Soil Color and Texture

Color in soil:

- Black: humus particles
- Red/yellow: iron oxides
- White: mineral salts (dry climate)
- Ash-gray: light colored mineral matter (cold, moist climates

The Nature of the Soil

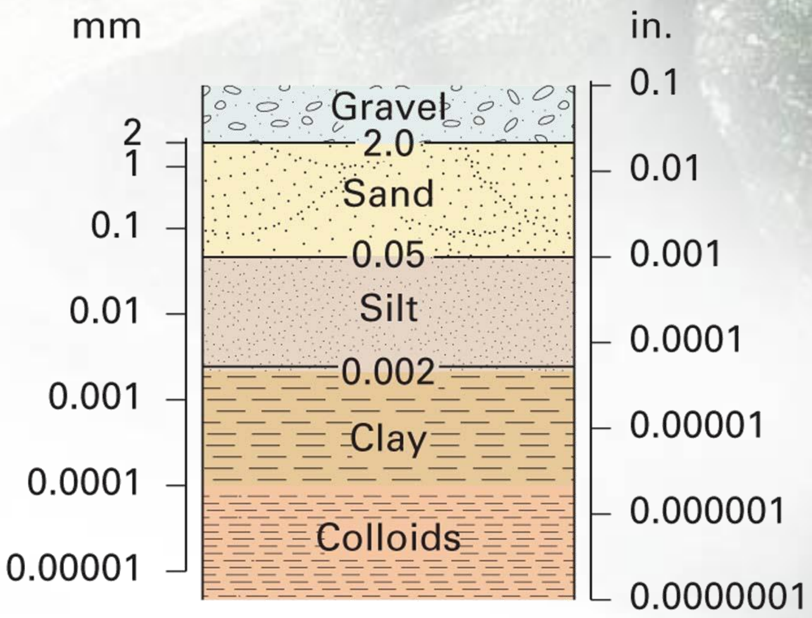
Soil Color and Texture

Soil Texture: descriptive property of the mineral portion of soil based on varying proportions of sand, silt, and clay

Loam: soil with substantial proportion of each of the three size classes

Soil texture determines water holding ability:

- Coarse-textured (sandy) soils allow water to pass through
- Fine-textured soils hold water

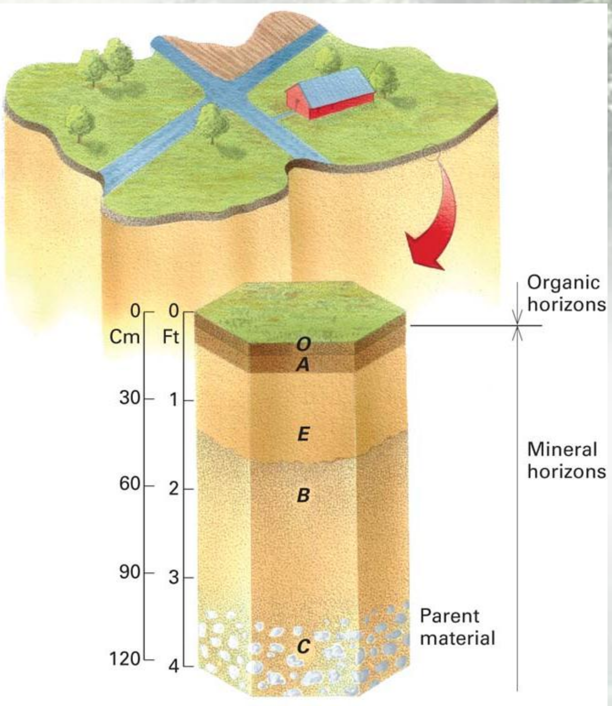


Soil Development

Soil Horizons

Soil Horizon: distinctive layer of soil, more or less horizontal, set apart from other layers by differences in physical and chemical composition

Soil Profile: display of soil horizons on the face of a freshly cut vertical exposure through the soil



Organic Horizons:

- O_i horizon: formed from recognizable organic material
- O_a horizon: humus, decomposed, not recognizable

Mineral Horizons:

- A horizon: rich in organic matter
- E horizon: clay particles and iron/aluminum oxides are removed from E horizon
- B horizon: receives clay particles and oxides washed down from higher layers
- C horizon: parent mineral matter of the soil

The Global Scope of Soils

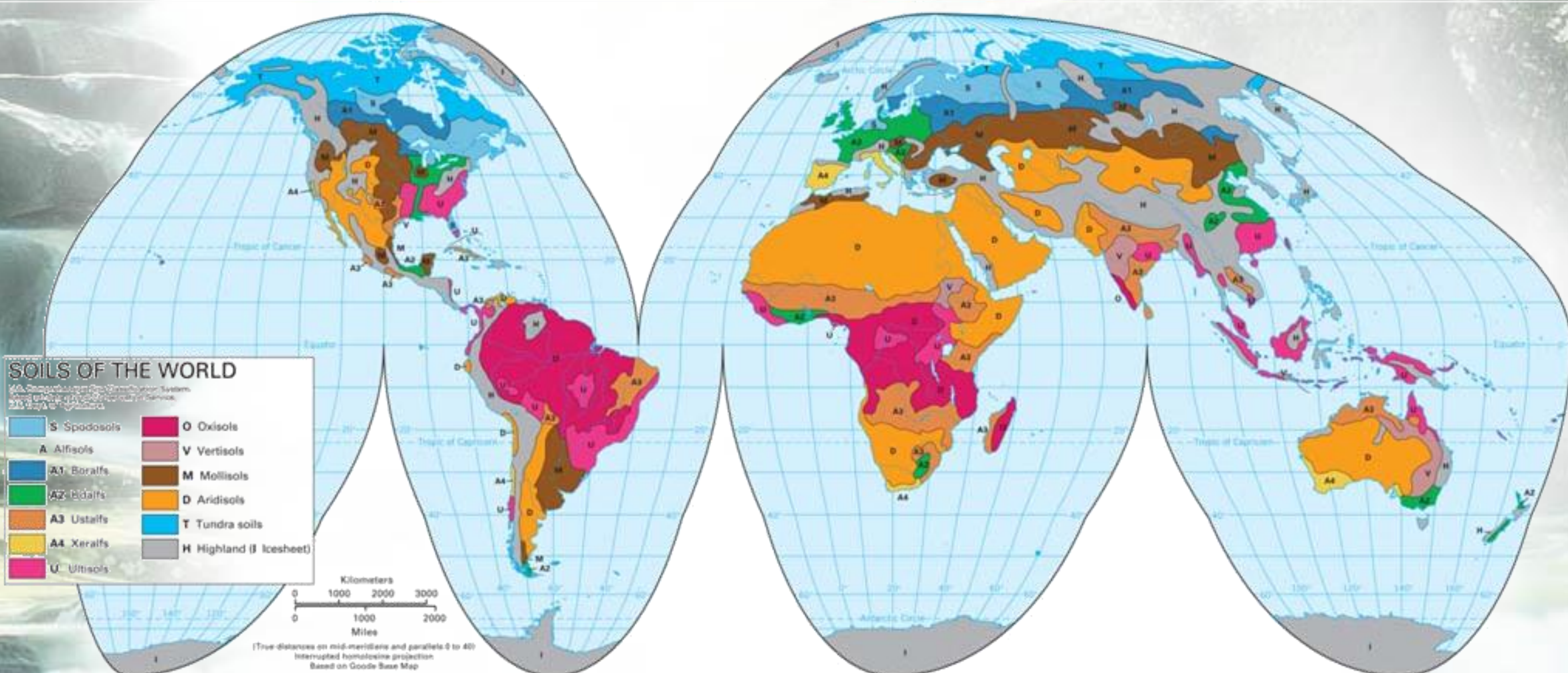
Soil Orders: eleven soil classes that form the highest category in soil classification

Soil Orders TABLE 15.1

Group I	
Soils with well-developed horizons or with fully weathered minerals, resulting from long-continued adjustment to prevailing soil temperature and soil-water conditions.	
Oxisols	Very old, highly weathered soils of low latitudes, with a subsurface horizon of accumulation of mineral oxides and very low base status.
Ultisols	Soils of equatorial, tropical, and subtropical latitude zones, with a subsurface horizon of clay accumulation and low base status.
Vertisols	Soils of subtropical and tropical zones with high clay content and high base status. Vertisols develop deep, wide cracks when dry, and the soil blocks formed by cracking move with respect to each other.
Alfisols	Soils of humid and subhumid climates with a subsurface horizon of clay accumulation and high base status. Alfisols range from equatorial to subarctic latitude zones.
Spodosols	Soils of cold, moist climates, with a well-developed *B* horizon of illuviation and low base status.
Mollisols	Soils of semiarid and subhumid midlatitude grasslands, with a dark, humus-rich epipedon and very high base status.
Aridisols	Soils of dry climates, low in organic matter, and often having subsurface horizons of accumulation of carbonate minerals or soluble salts.
Group II	
Soils with a large proportion of organic matter.	
Histosols	Soils with a thick upper layer very rich in organic matter.
Group III	
Soils with poorly developed horizons or no horizons, and capable of further mineral alteration.	
Entisols	Soils lacking horizons, usually because their parent material has accumulated only recently.
Inceptisols	Soils with weakly developed horizons, having minerals capable of further alteration by weathering processes.
Andisols	Soils with weakly developed horizons, having a high proportion of glassy volcanic parent material produced by erupting volcanoes.

Visualizing Physical Geography

The Global Scope of Soils



The Global Scope of Soils

Oxisols, Ultisols, and Vertisols

Soils of low latitudes

Warm temperatures, plentiful water, long time available for soil development

Oxisols:

- Moist, low latitude climates
- Lack of distinct horizons
- Extreme weathering of soil minerals
- Dominated by iron and aluminum oxides
- Red/yellow color
- Low base status

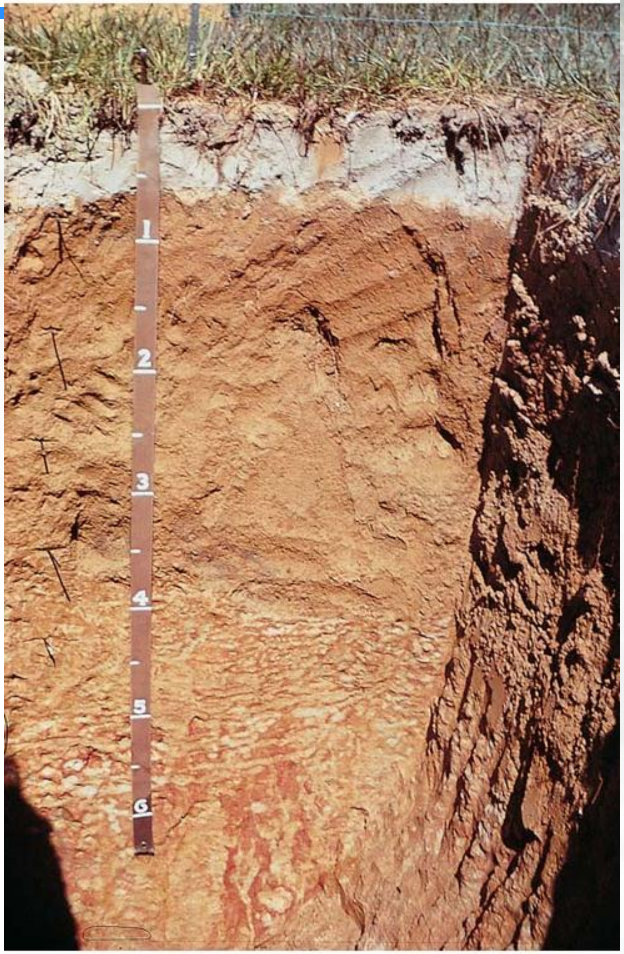
Visualizing Physical Geography

The Global Scope of Soils

Oxisols, Ultisols, and Vertisols

Ultisols

- Tropical climates with dry season
- Similar to Oxisols
- Subsurface clay horizon
- Low base status
- Iron/aluminum oxides may harden into brick-like blocks when exposed to air

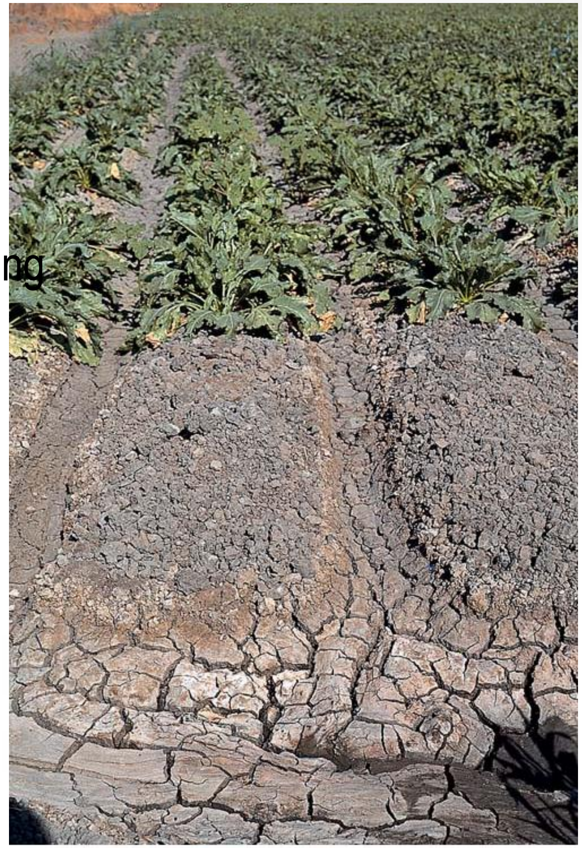


The Global Scope of Soils

Oxisols, Ultisols, and Vertisols

Vertisols

- Subtropical and tropical climates with pronounced dry season
- Black in color
- High clay content
- High base status
- Clay minerals shrink when dry, producing cracks
- Soil constantly mixed

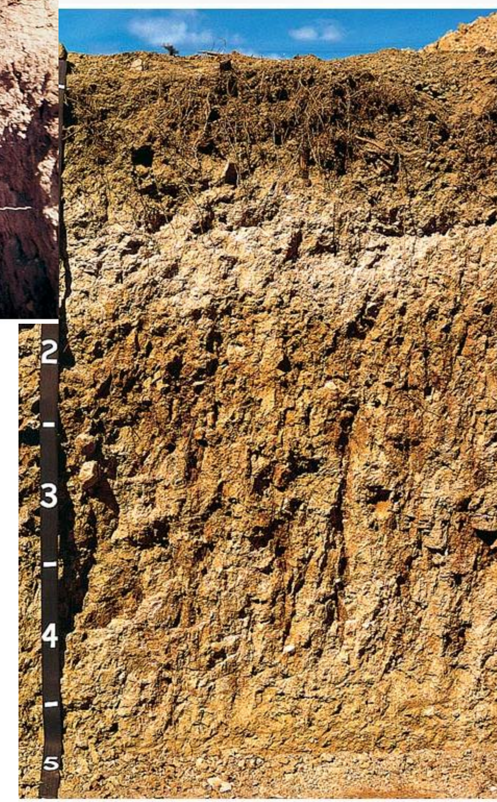


The Global Scope of Soils

Alfisols and Spodosols

<u>Alfisols</u>

- Wide distribution, range in climates
- Characterized by clay-rich horizon produced by illuviation
- *Boralfs*: cold boreal forests; gray surface horizon, brownish subsoil
- *Udalfs*: midlatitudes; brownish
- *Ustalfs:* warmer climates; brownish to reddish
- *Xeralfs:* Mediterranean climate; brownish or reddish

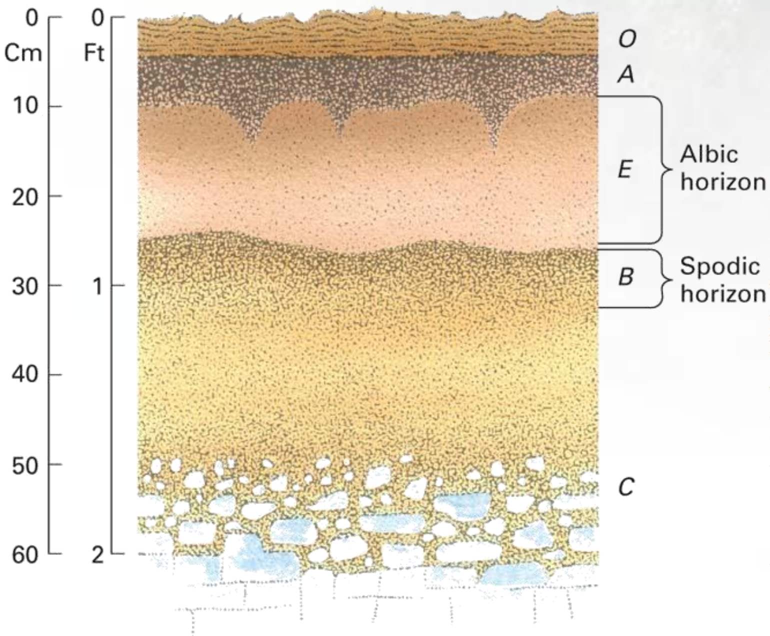


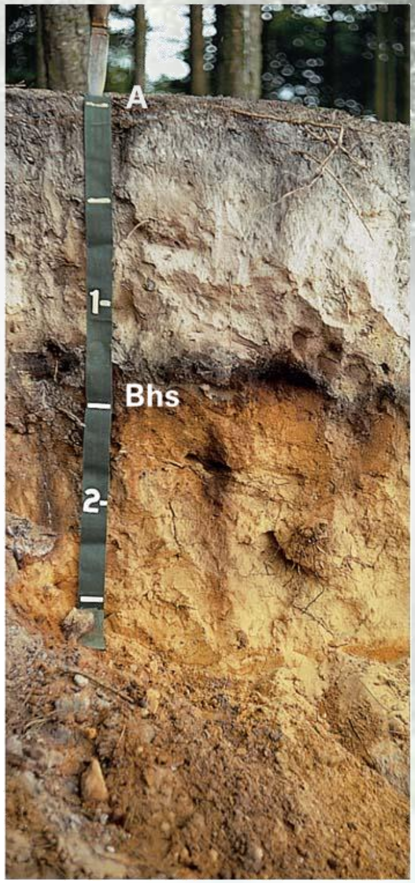
The Global Scope of Soils

Alfisols and Spodosols

Spodosols

- Associated with glaciated regions, young soils
- Parent material coarse sand, little clay
- Poor, acid soils
- Often support conifer forests

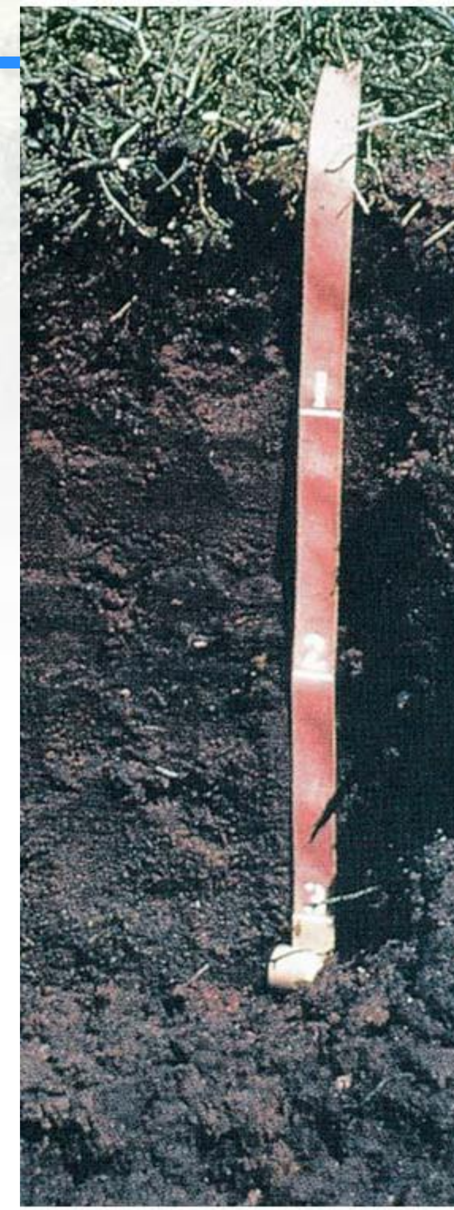




The Global Scope of Soils

Histosols

- Found in northern, glaciated regions
- Associated with Spodosols
- Very high organic content
- Formed by accumulation of dead organic matter
- Formed in lakes, ponds, bogs
- “Peats”, “mucks”
- Very fertile when drained
- Dried peat used for mulch and fuel



The Global Scope of Soils

Entisols, Inceptisols, and Andisols

Entisols: mineral soils without distinct horizons

- Worldwide distribution
- Parent material not suitable for horizon formation, or
- Young soil
- May be poor soil, or very fertile

Inceptisols: soils with weakly developed horizons

- Young soil
- Local occurrence
- May be silt deposited by rivers
- May be very fertile

Andisols: soils developed from volcanic ash

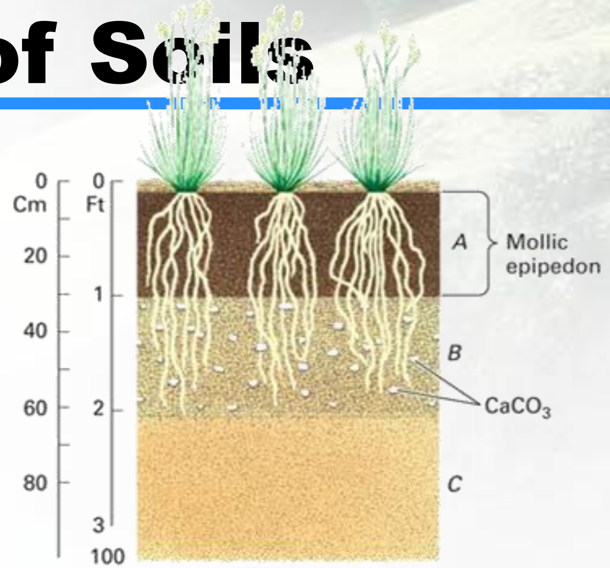
- Found in local patches
- Generally fertile

The Global Scope of Soils

Mollisols

Mollisols

- Grassland soils of semiarid and subhumid climates in midlatitudes
- Characterized by very thick dark brown to black surface horizon ("mollic epipedon")
- Good texture, high base status
- Among most fertile soils in world
- Used for grain production
- *Borolls*: cold climate suborder
- *Udolls*: moist climates, prairies
- *Ustolls*: semiarid, short-grass prairies
- *Xerolls*: Mediterranean climate

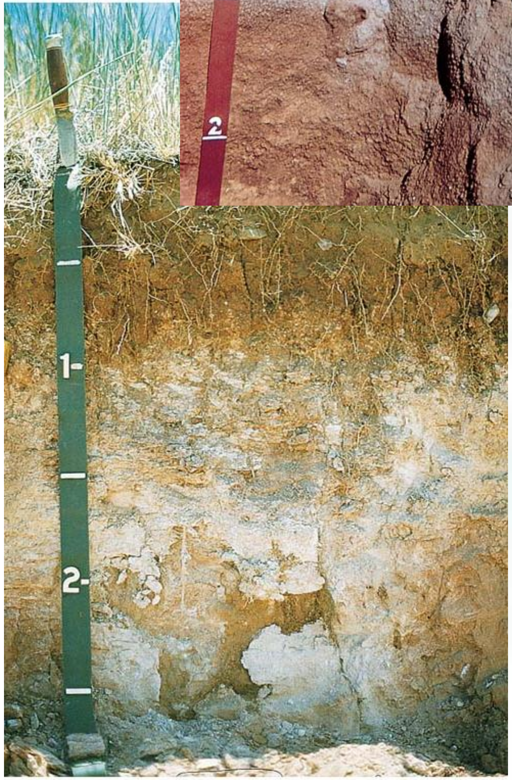


The Global Scope of Soils

Desert and Tundra Soils

Aridisols

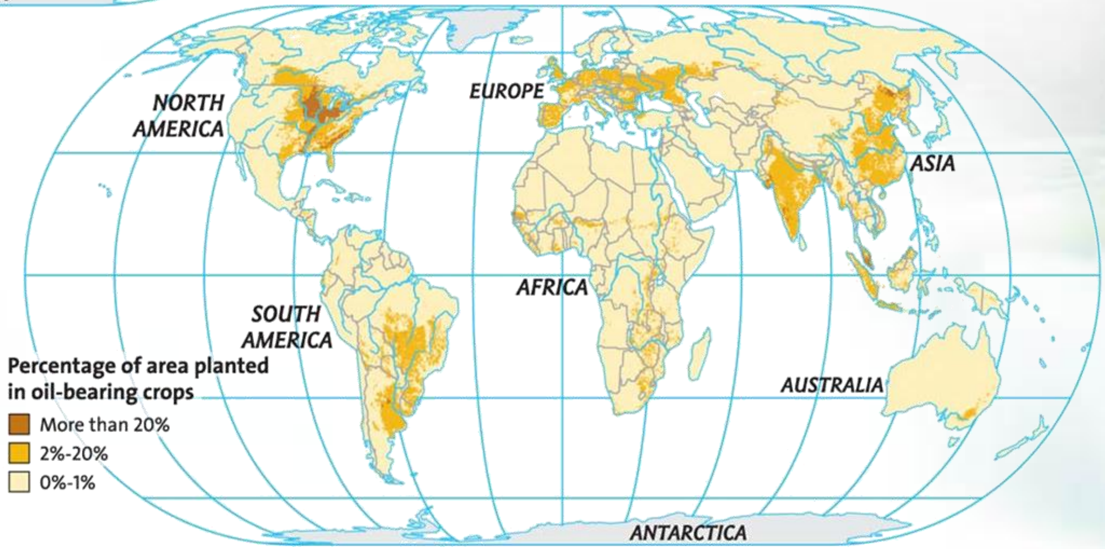
- Desert climate, sparse vegetation
- Low organic matter, high in salts
- May have subsurface horizon of calcium carbonate or soluble salts
- Used for grazing, but productive when irrigated



Tundra soils poorly developed

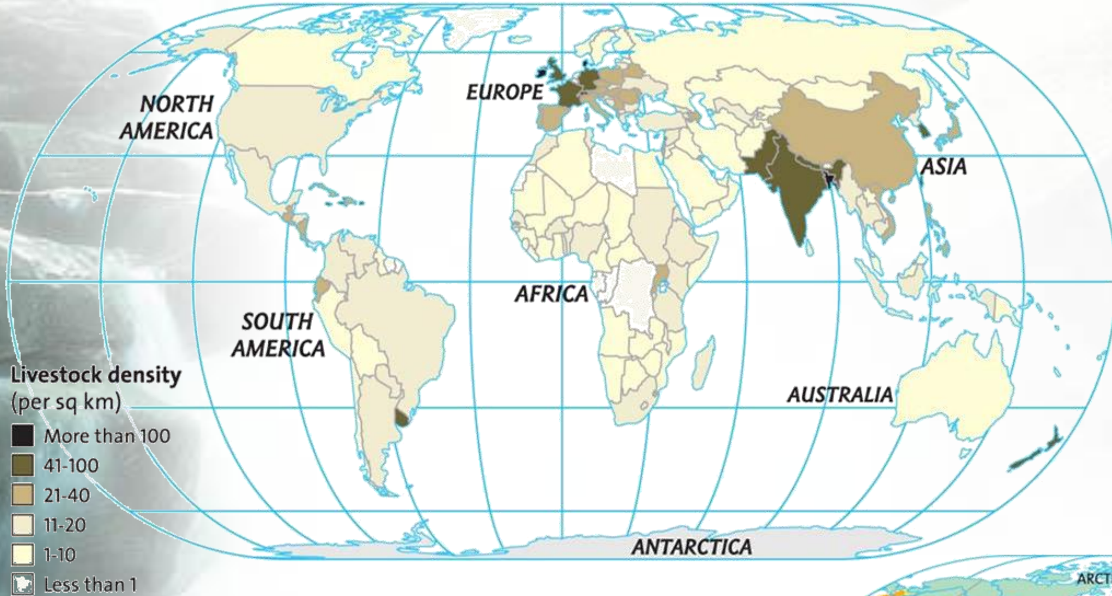
- Recent parent material
- Repeated freezing and thawing
- Soil may be saturated with water
- Cold temperatures restrict development
- Inceptisols common

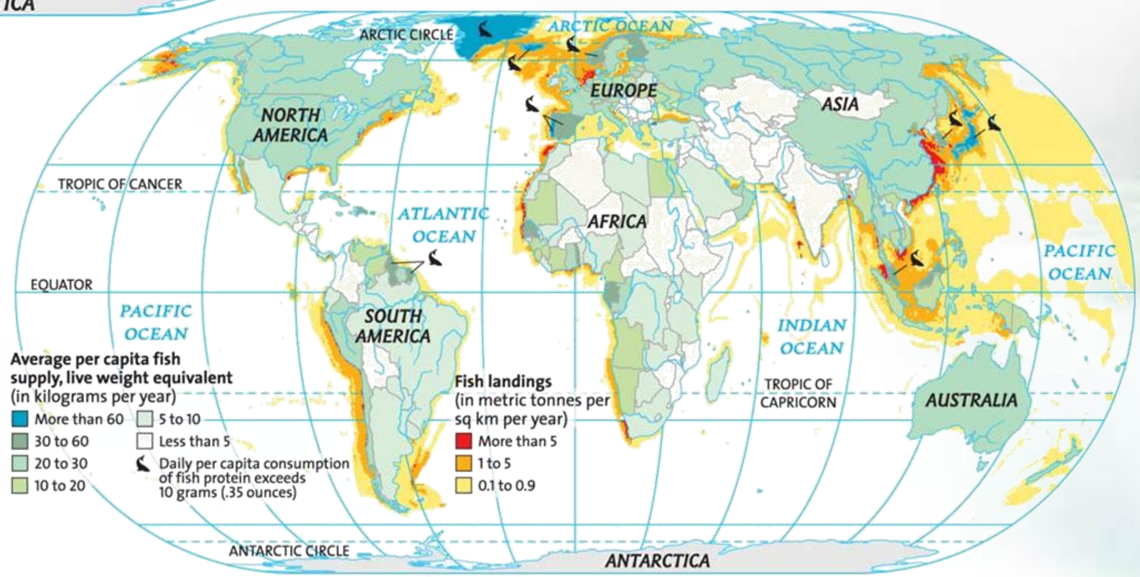
Global Agriculture



Visualizing Physical Geography

Global Agriculture





The Global Scope of Soils

Global Climate Change and Agriculture

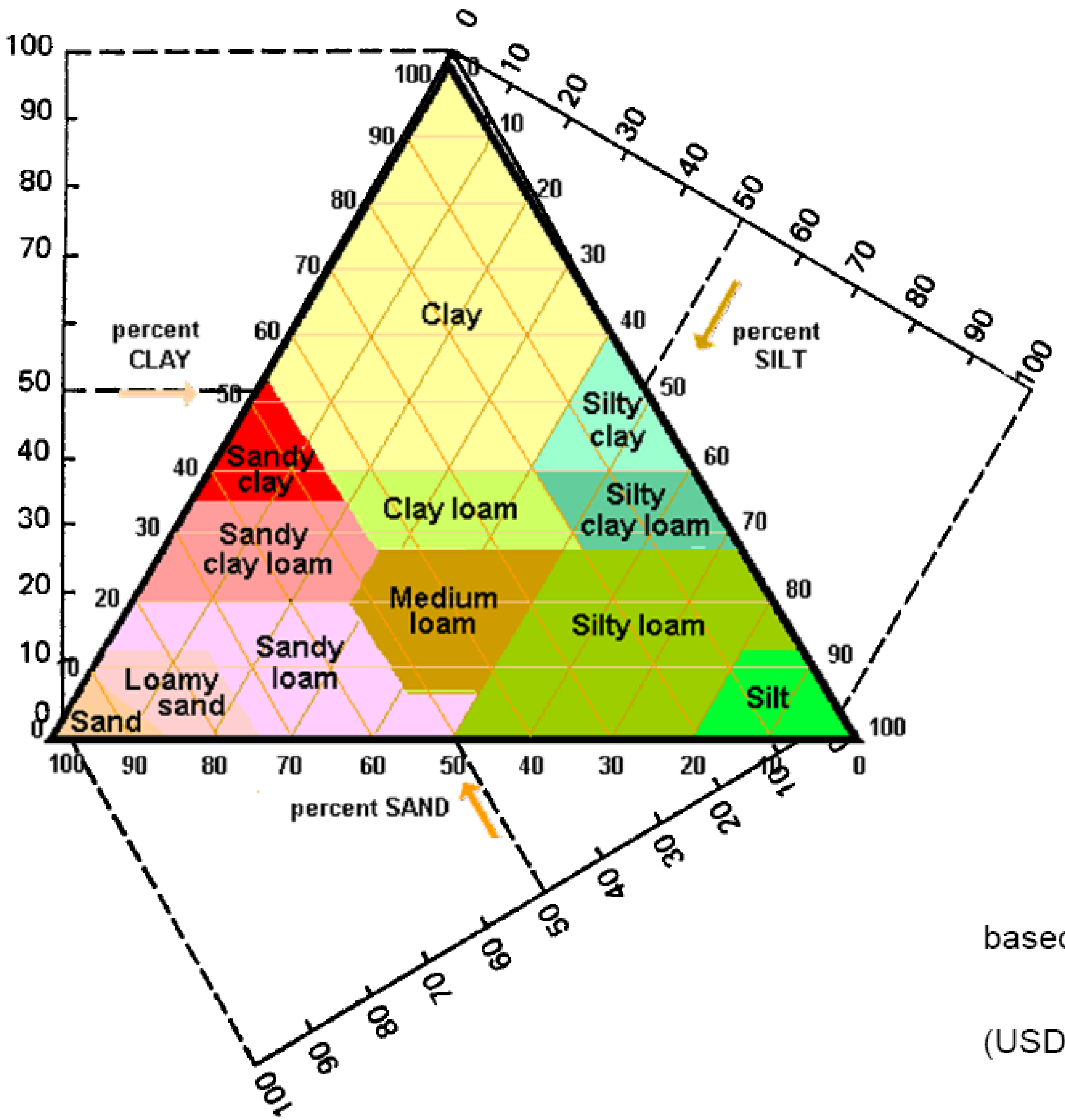
Global climate change likely to bring:

- Increased temperatures
- Summer droughts
- Change in rainfall patterns
- More extreme events

Potential effects on agriculture:

- Immediate impact positive: High temperatures→ crops grow faster
- Later impacts negative: water stress, slowed growth from high temperatures and droughts
- Higher CO_2 levels: crops and weeds grow faster
- Effects vary by region
- If temperatures increase more than 2.5ºC, food demand likely to exceed supply

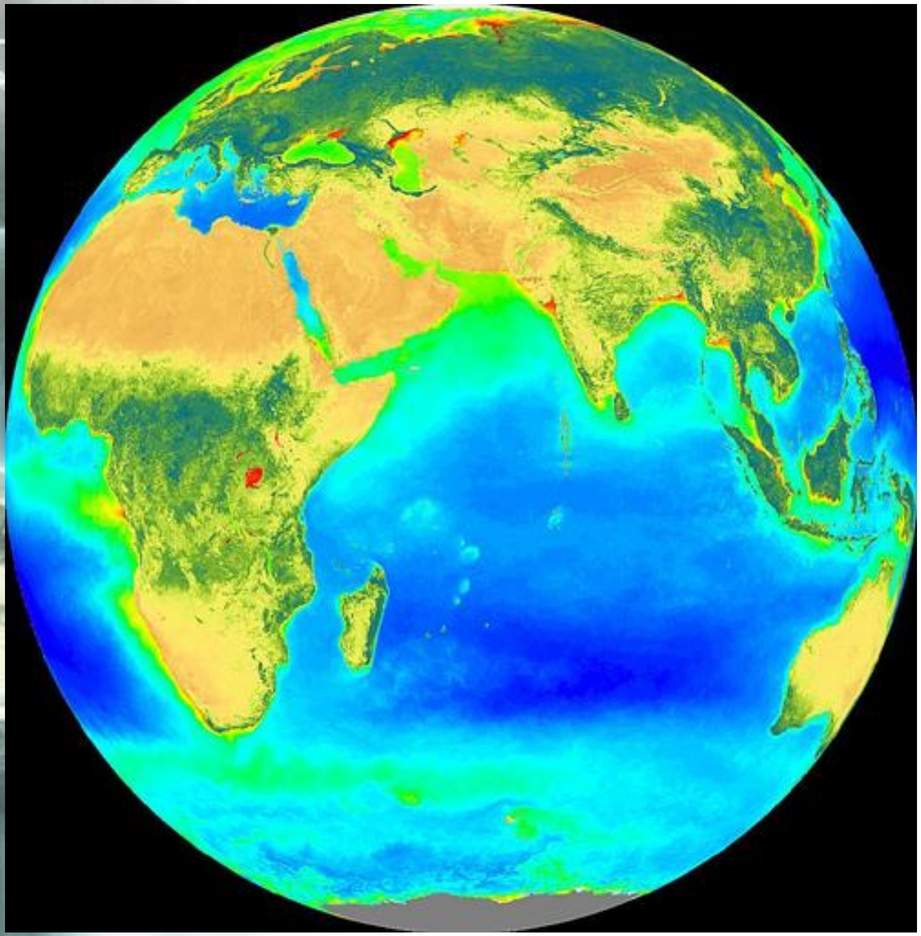
Soil triangle:

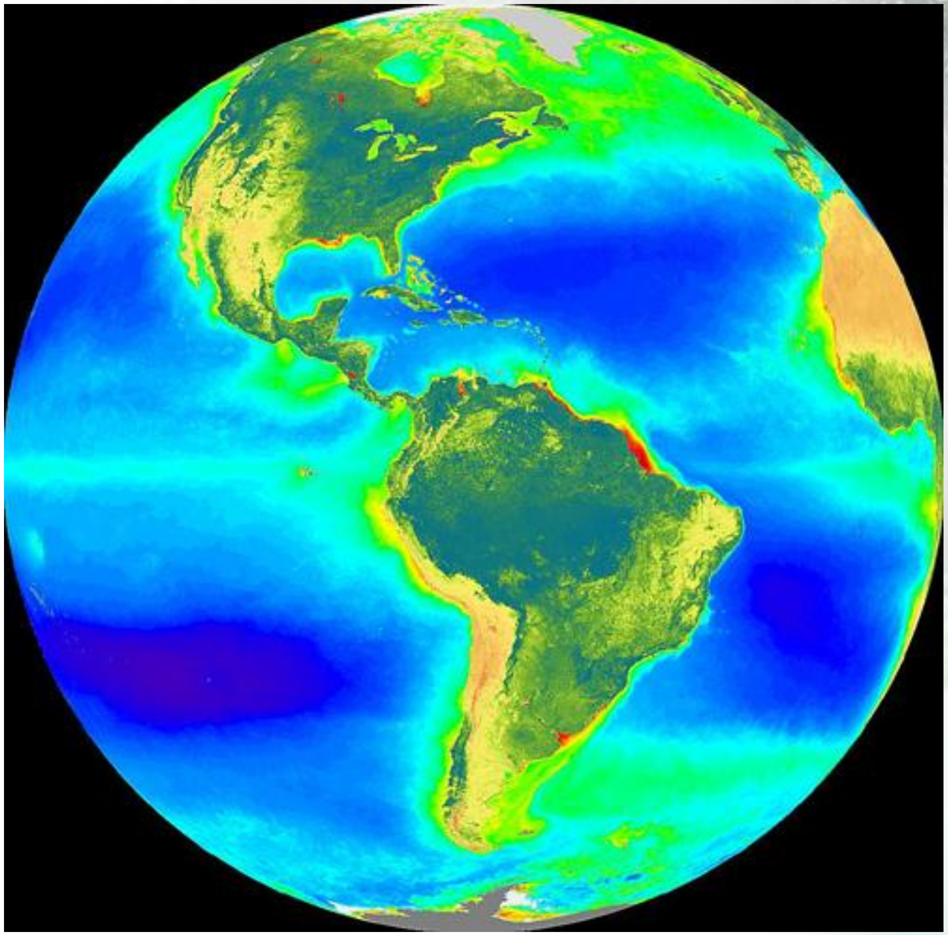


Percentages are based on mass fraction

(USDA Classification)

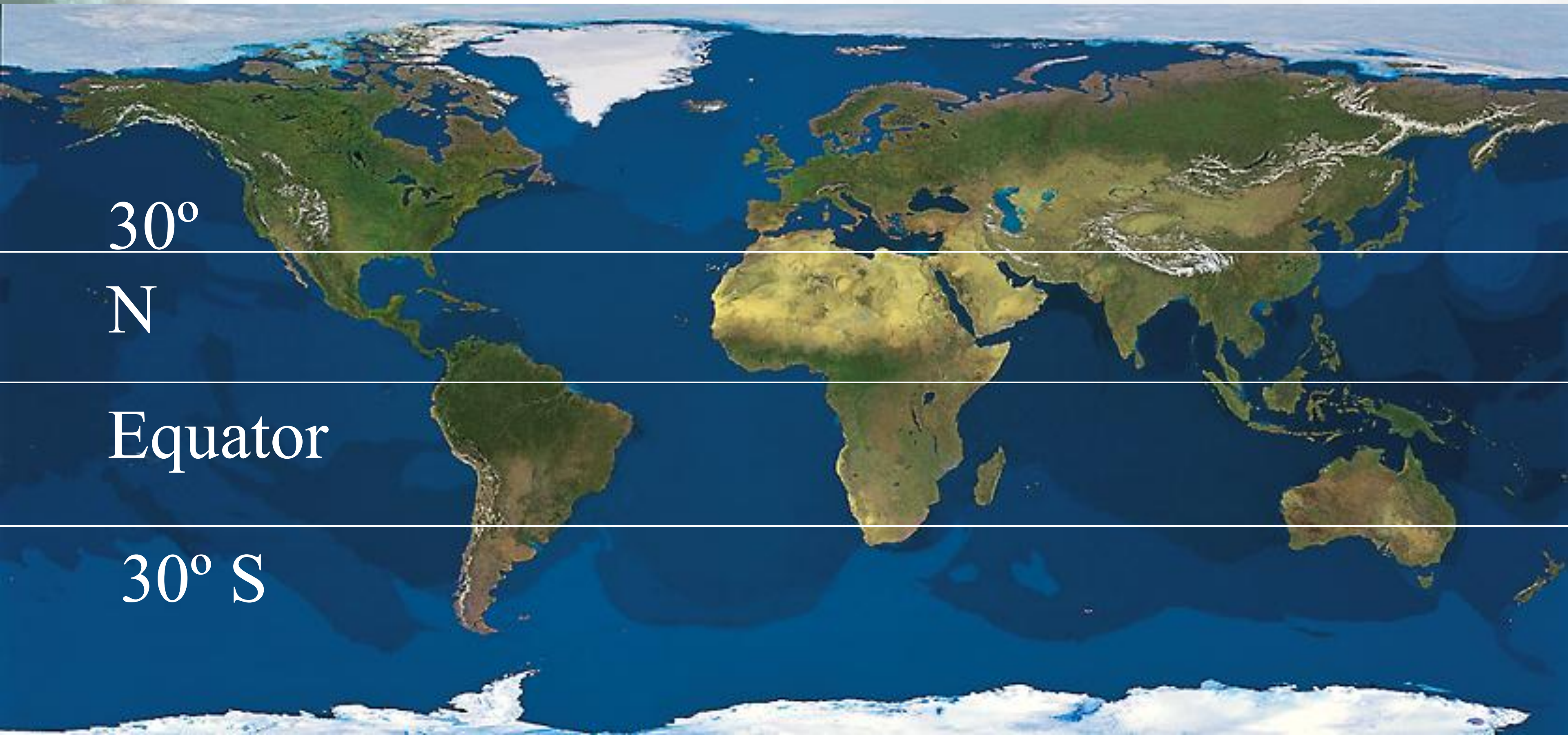
Global Vegetation Mapping



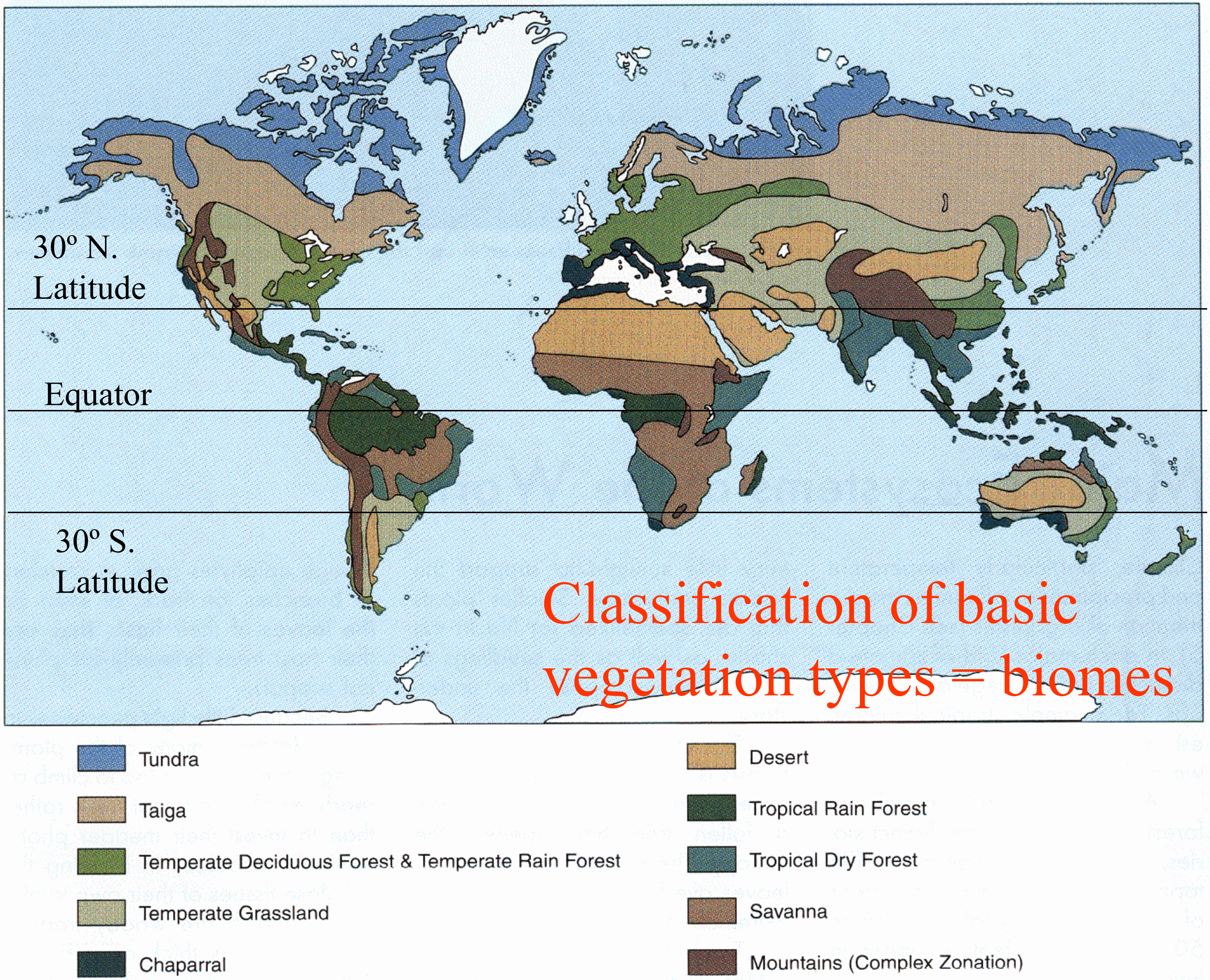


SeaWiFS Ocean Chlorophyll Land NDVI

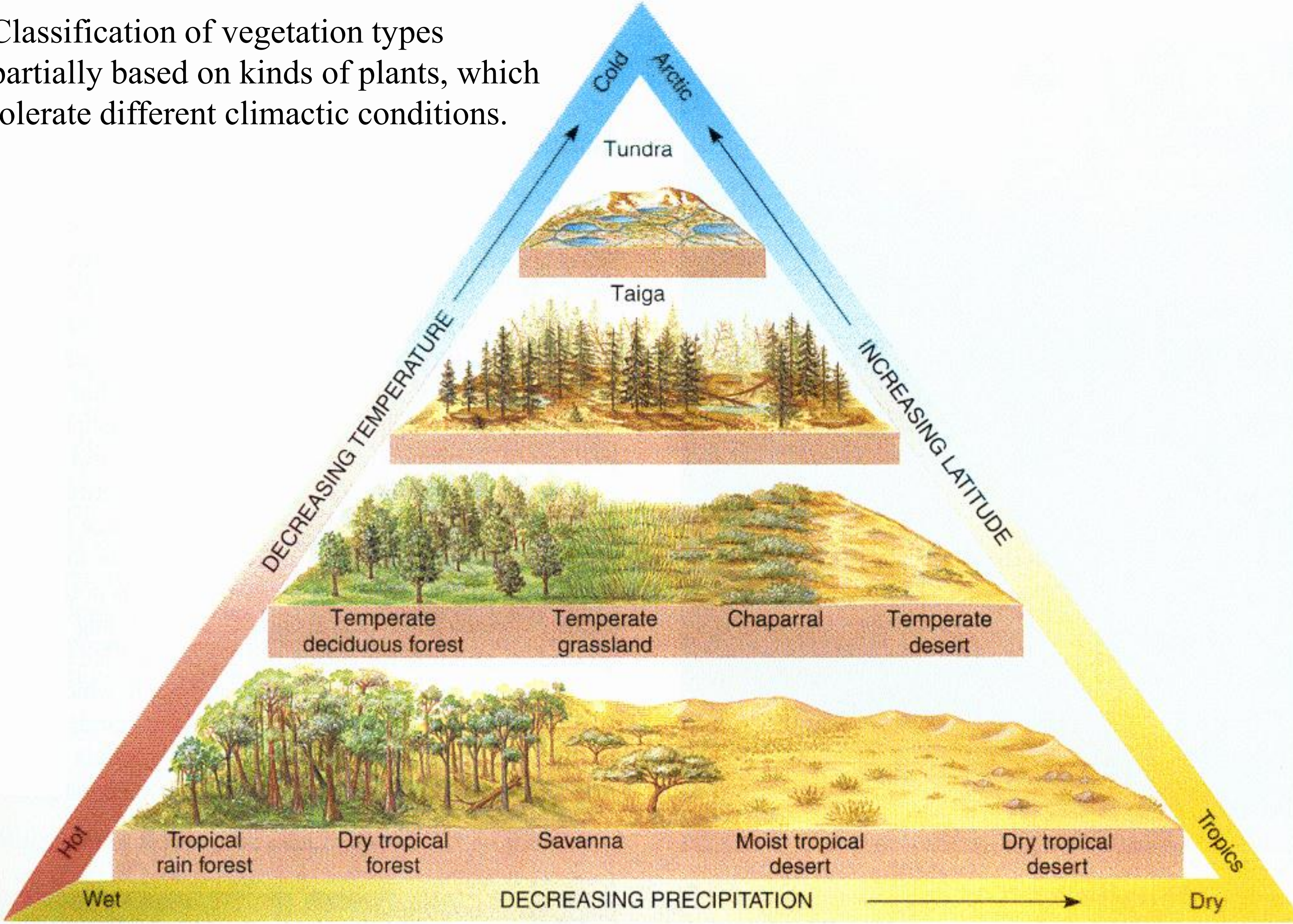
The foregoing principles and forces explain much of the global patterns in vegetation types (depending on temperature, moisture): Wetter vegetation (forests) green, drier (grassland, desert) tan to brown, cold (arctic, alpine) areas white.



Classification of basic vegetation types = biomes



Classification of vegetation types partially based on kinds of plants, which tolerate different climactic conditions.



Holdridge's life zone system is one of most widespread, quantitative schemes for classification of vegetation, land types