What is Climate?

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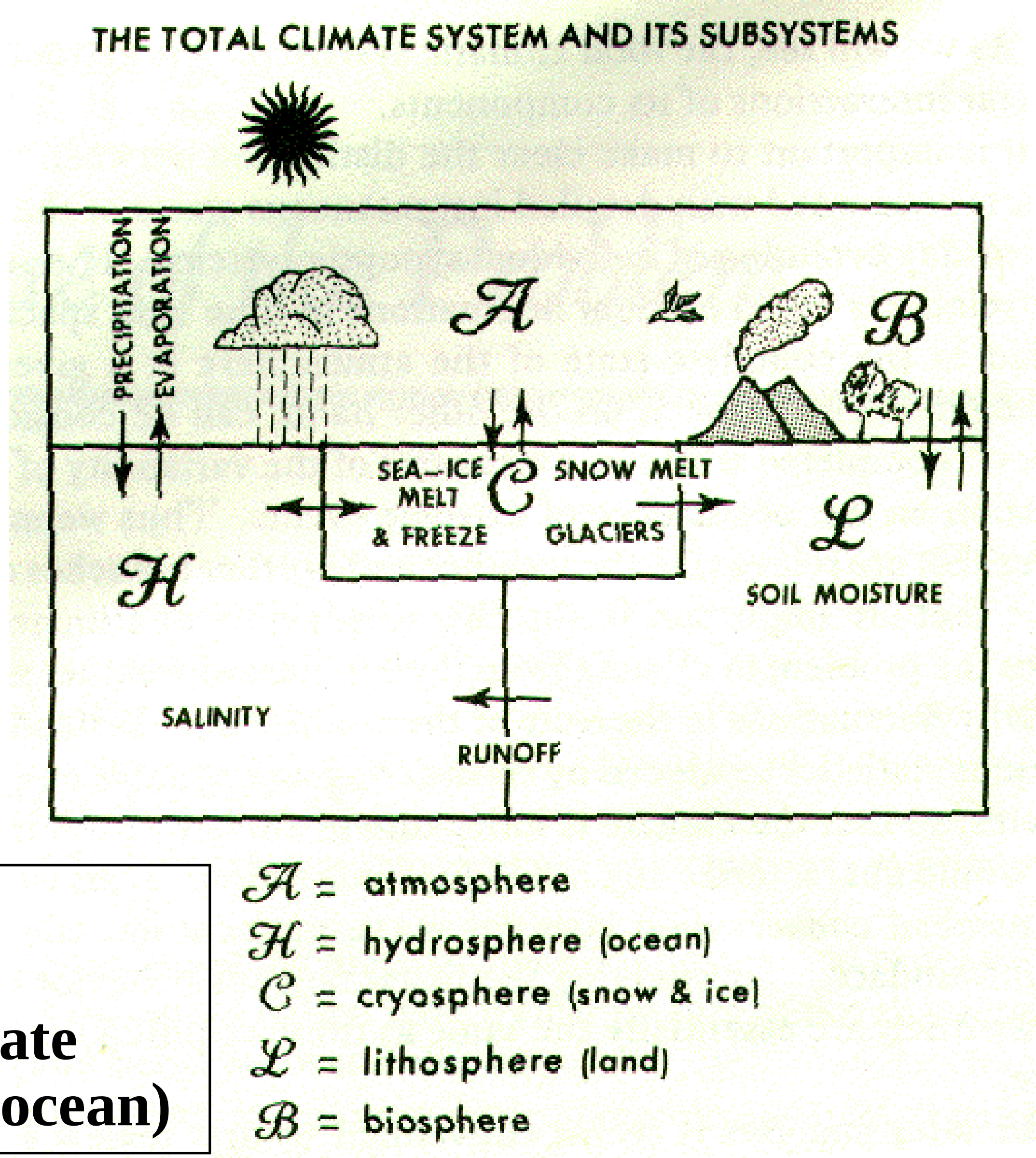
4 April 2002

Climate
- synthesis of weather in a particular region
- monthly averages
- climate influences life
- life sensitive to climate

- Temperature & Precipitation



Main points about Climate
- Uneven solar heating
- Heat transported to compensate (50% atmosphere and 50% in ocean)

Simplistic Overview of Global Climate

SUN
•Heats the Earth unevenly

ATMOSPHERE
•Circulation acts to redistribute heat

OCEAN
•Circulation acts to redistribute heat

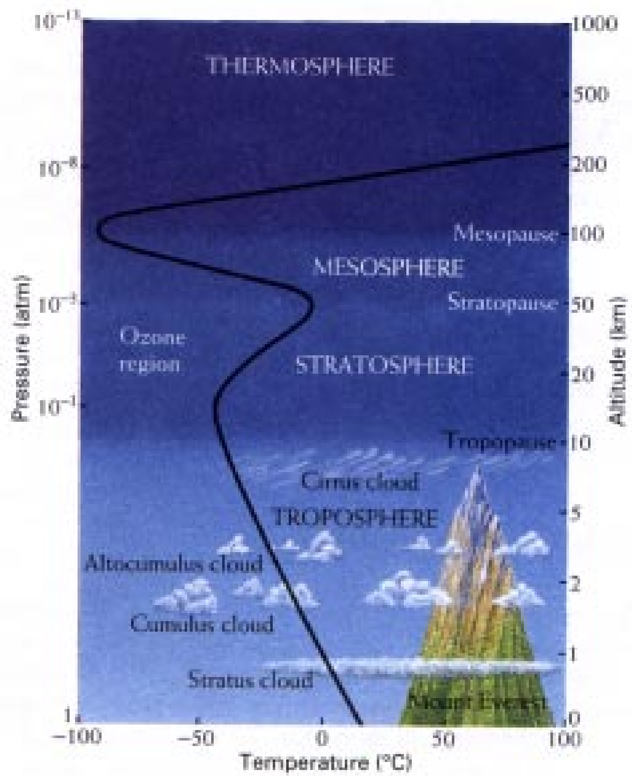
LAND
•Influences the job of the atmosphere and ocean

CLIMATE
•Complex state of affairs that result due to the above

Temperature

- **Most widely recognized variable**
- **Global average temperature @ surface of earth 288˚K, 15˚C, or 59˚F**
- **Coldest -128˚F in Antarctica to warmest of 136˚F in Libya**

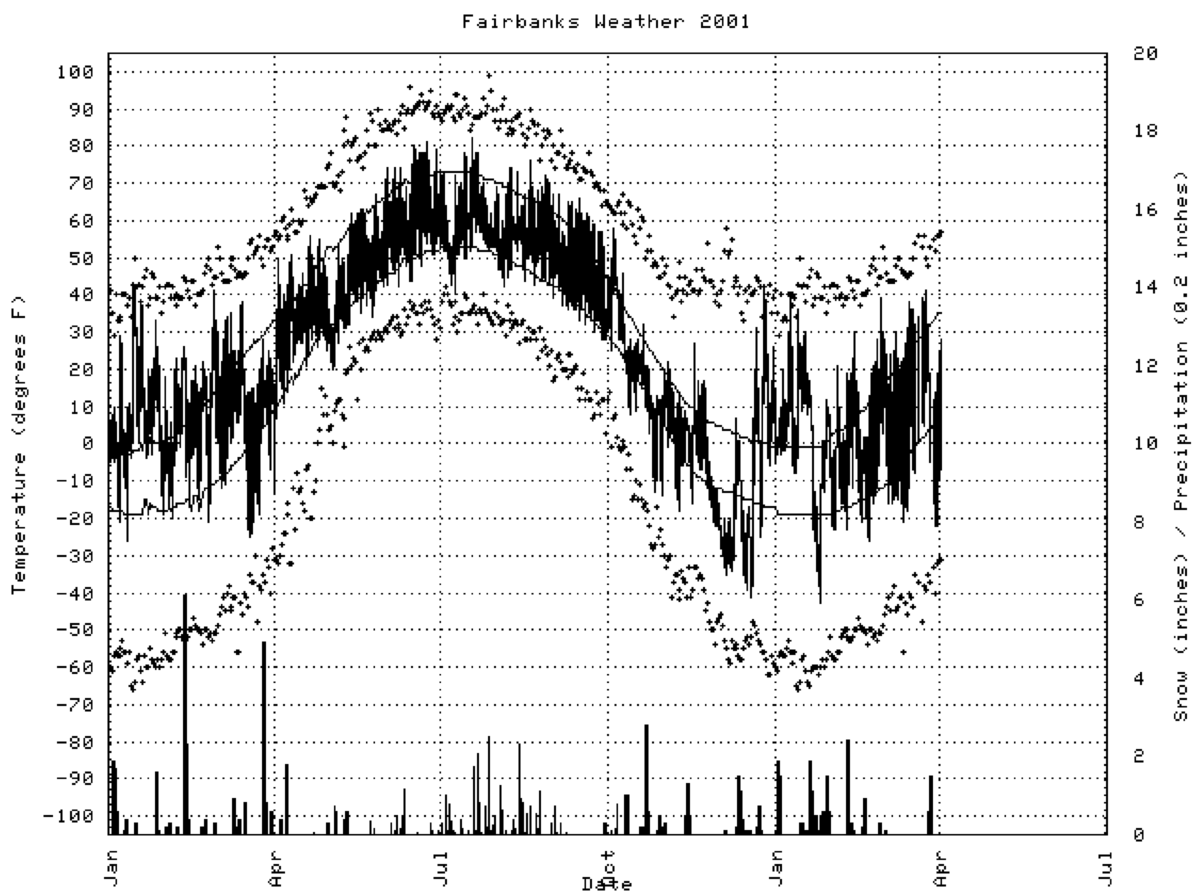
Lapse rate - temperature variation with height



The variation of atmospheric pressure and temperature with altitude above Earth's surface. The regions of the atmosphere are noted, and the Himalayas are drawn in for perspective.

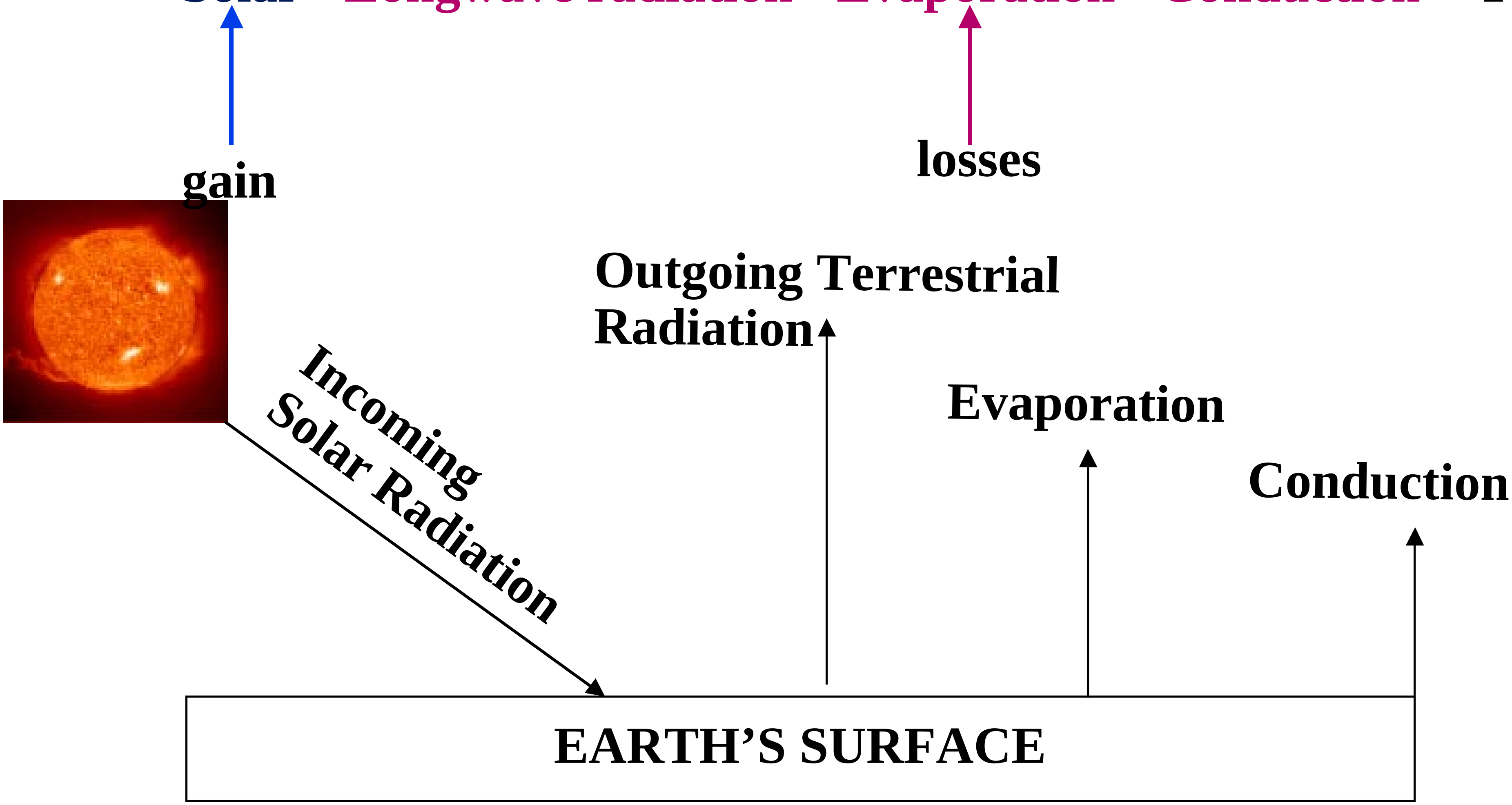
Monthly Temperature Extremes for Fairbanks

# years 42	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	All-time record
MAX	50	47	53	74	89	96	94	90	84	65	46	44	96
MIN	-61	-58	-49	-24	-1	31	35	27	3	-27	-46	-62	-62



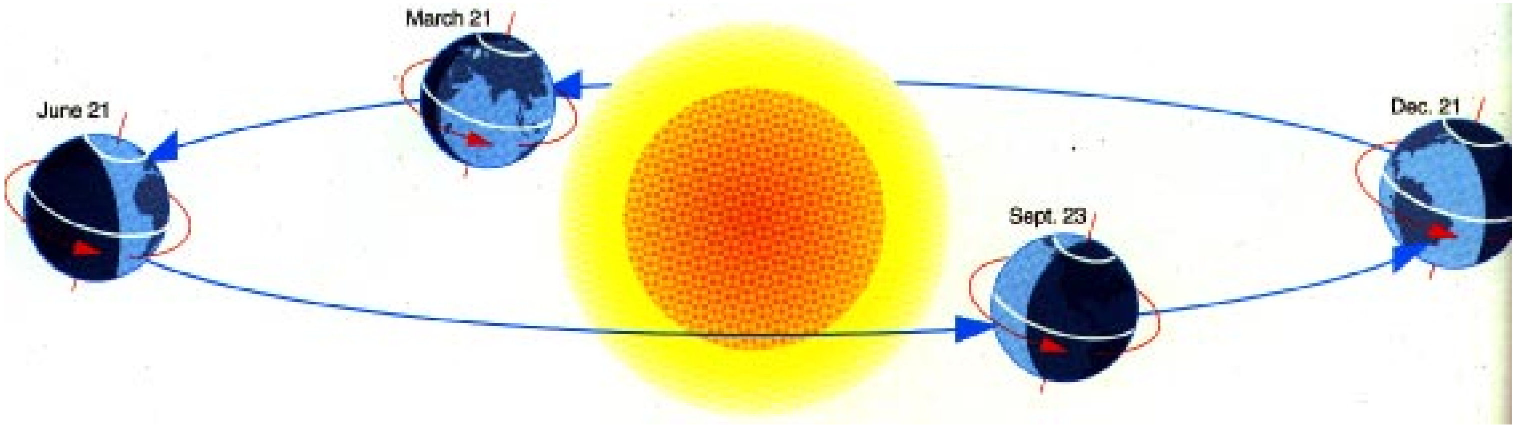
Balance at Earth's surface

Solar - Longwave radiation - Evaporation - Conduction = Tota

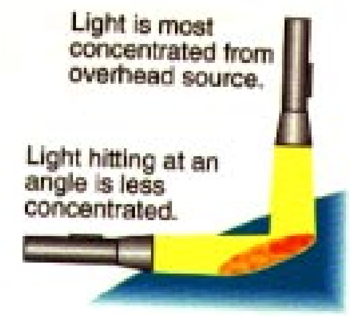


Ocean temperature function of
- **'Total' heat**
- **heat brought by currents**

Seasons results from 23.˚ degree tilt of earth's axis

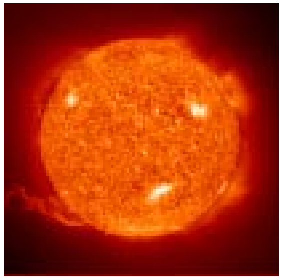


Sun is closest to earth in January and farthest in July
What if the earth's axis did not tilt?



Tropics get more solar radiation per area than poles.
Sun is more directly overhead, spread over less area.
What if the earth's axis did not tilt?

Amount of Solar radiation arriving at earth inversely proportional to distance squared



149,600,000 km from Sun
1.49×10^{11} m ($R_{S\text{-}E}$)

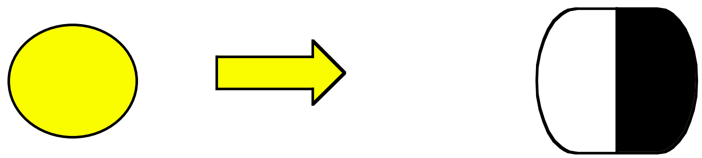
- Radiance at sun’s surface (S_s) is 6.3×10^7 W/m^2
- Radius of sun (R_s) 7.0×10^8 m

$$S_0 R_{S-E}^2 = S_s R_s^2 \qquad S_0 = S_s \frac{R_s^2}{R_{S-E}^2} \approx \boxed{1380\, Wm^{-2}}$$

Solar Constant - amount of solar radiation reaching the top of the earths atmosphere

Planetary Albedo is total amount of Solar radiation reflected by earth

- **Average global albedo is 30% (0.3)**
  function of clouds and reflectivity of surfaces
- **Average solar radiation reaching surface is 241W/m²**

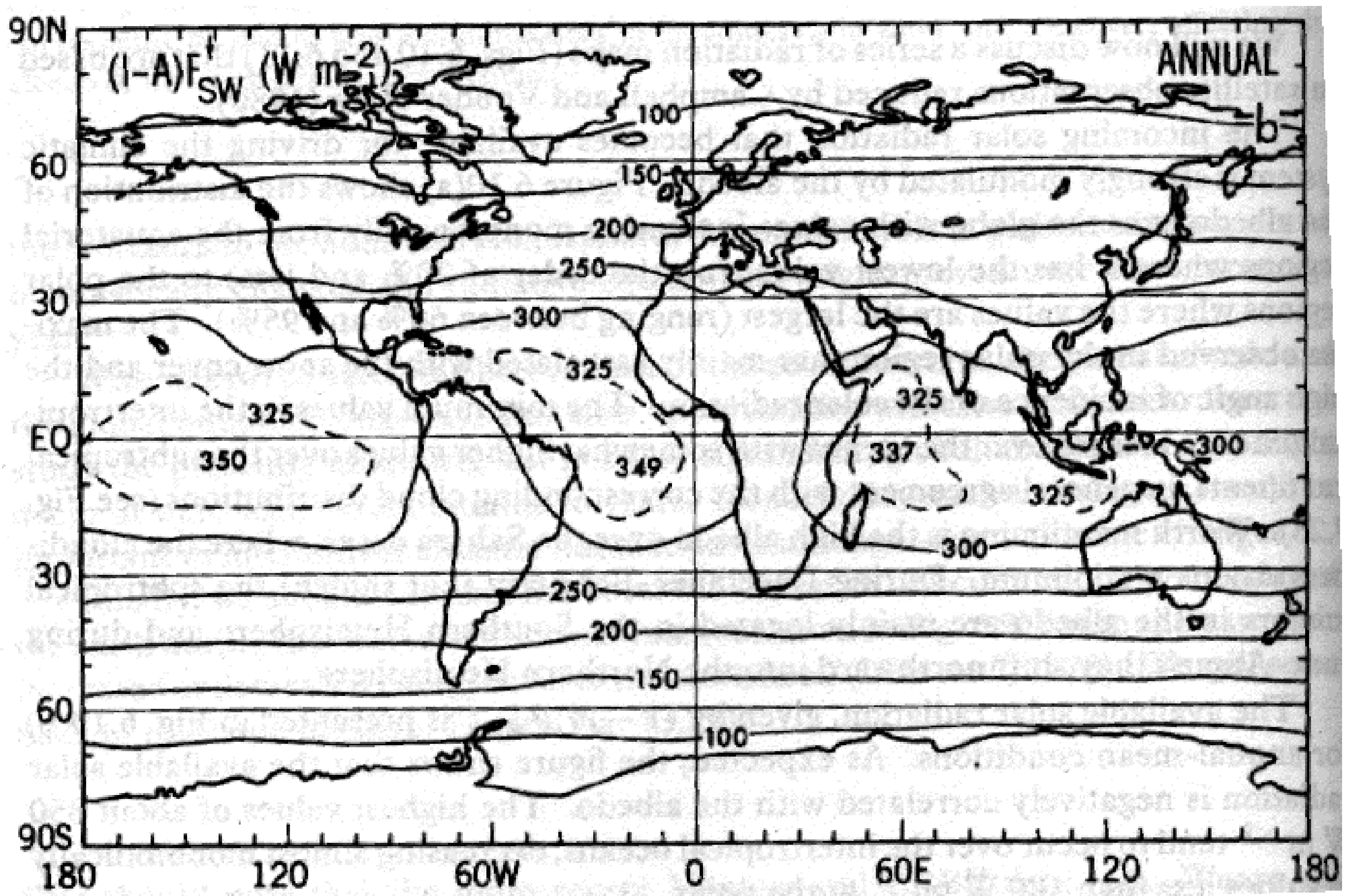


Area of Earth's disk being bathed in sunlight

$$\frac{(1-A)S_0\pi R_E^2}{4\pi R_E^2} = \frac{(0.7)(1380)}{4} = 241Wm^{-2}$$

Total Area of Earth's surface

Distribution of Solar Energy in Watts per meter squared



•**Net Solar 3 times greater in Tropics than at Poles**

Chemical Composition of Atmosphere

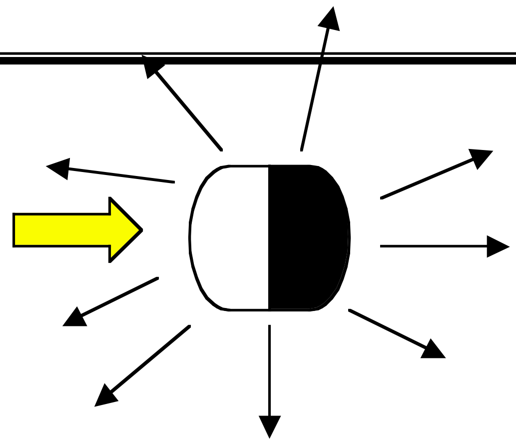
Atmospheric composition (by volume), top three gasses

- **78% Nitrogen (N_2)**
- **21% Oxygen (O_2)**
- **1% Argon**

Gasses important for absorption and emission of radiation < 1%

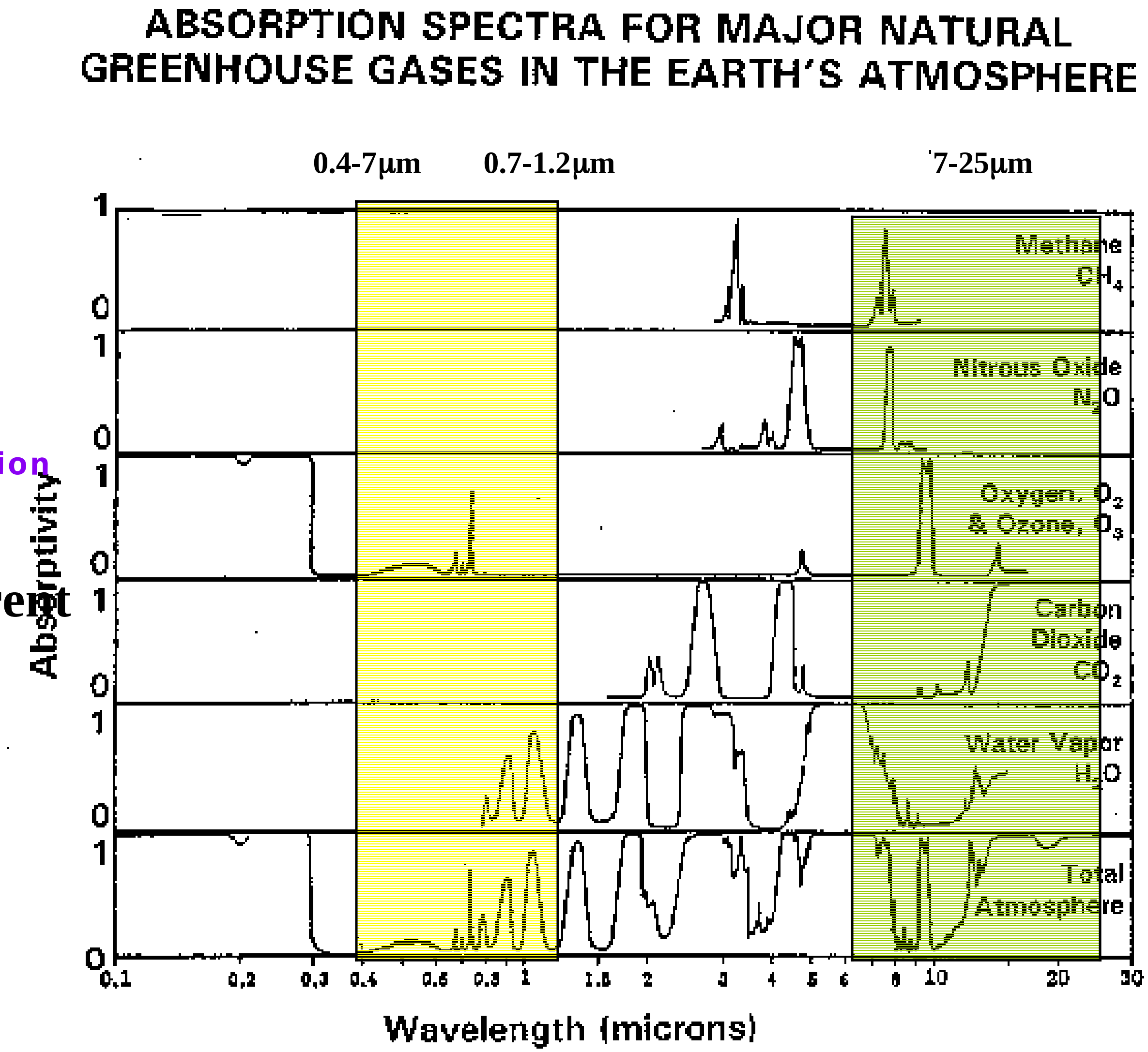
- **water vapor**
- **CO_2, carbon dioxide**
- **Ozone**

Infrared Radiation emitted by earth some absorbed by atmosphere



incoming solar radiation

outgoing terrestrial radiation

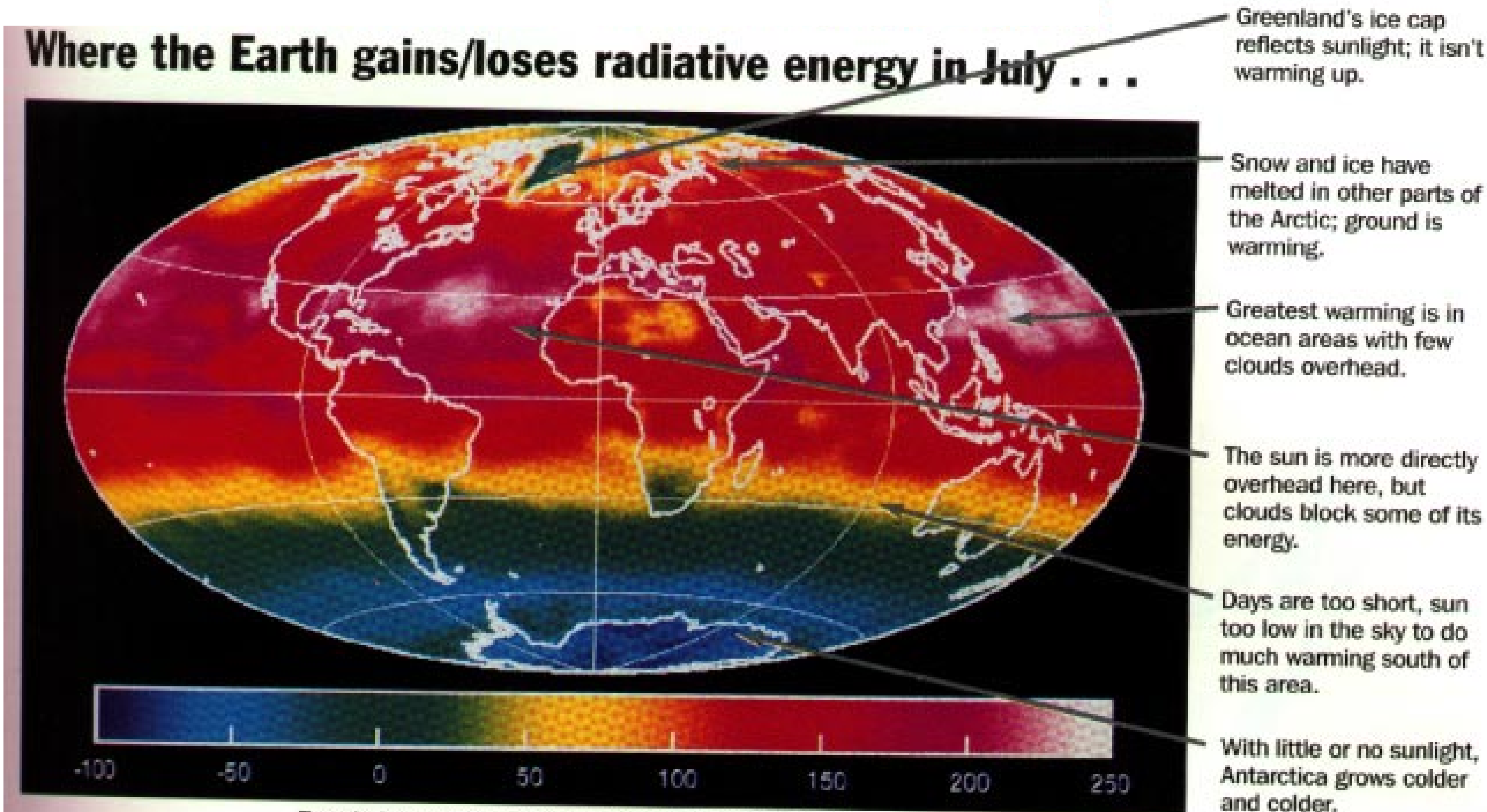


[After J. N. Howard, 1959: *Proc. I.R.E. 47*, 1459; and R. M. Goody and G. D. Robinson, 1951: *Quart. J. Roy. Meteorol. Soc. 77*, 153]

Solar Absorption (yellow)
0.4-.7 µm (visible, 45%) transparent
0.7-1.2 µm (near i.r., 37%)

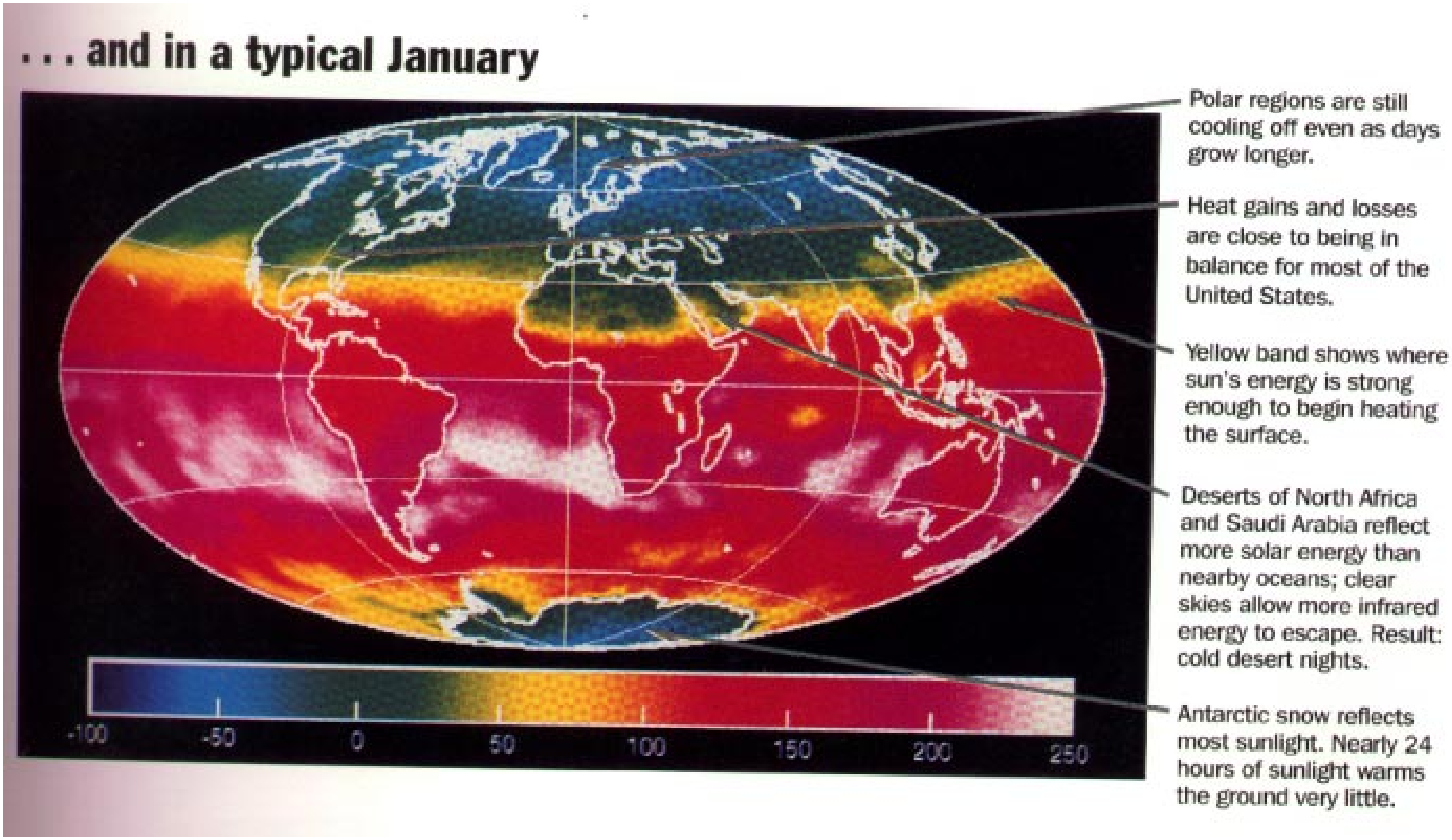
Atmospheric Absorption (green)
7-25 µm (far i.r., 37%)
9.6 µm Ozone
< 8 µm Water
11-15 Carbon Dioxide
> 15 Water Vapor

Net Radiative (Sum of incoming and outgoing) Heat in July

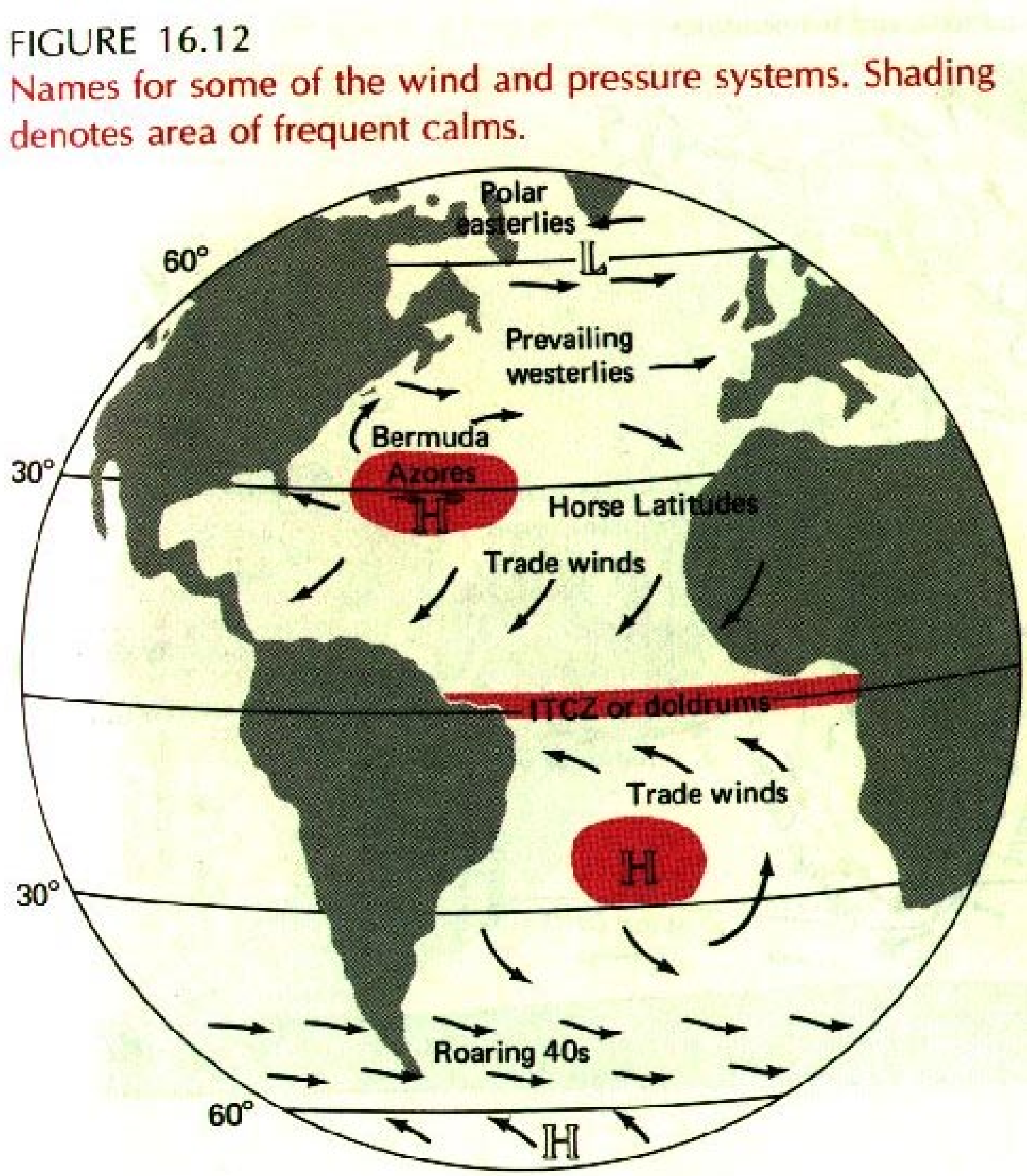


The color keys on both pictures show the average number of watts per square meter of energy being absorbed or lost by the land and sea. Minus numbers show where the Earth's surface is losing heat. Zero shows where the energy coming in and going out is in balance. Plus numbers show energy gain.

Net Radiative Heat in January



Global Wind pattern



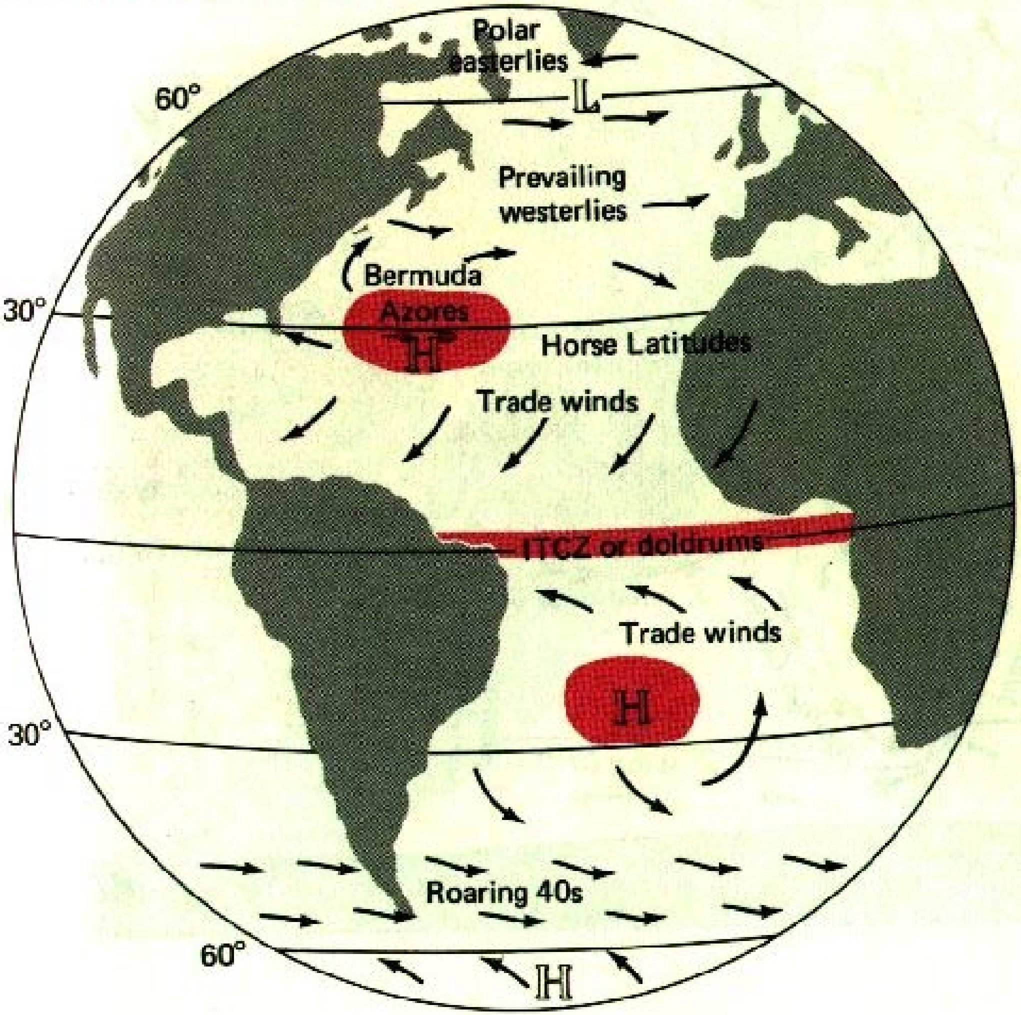
Easterlies (from east)

Westerlies (from west)

Easterlies

Global Wind pattern

FIGURE 16.12
Names for some of the wind and pressure systems. Shading denotes area of frequent calms.

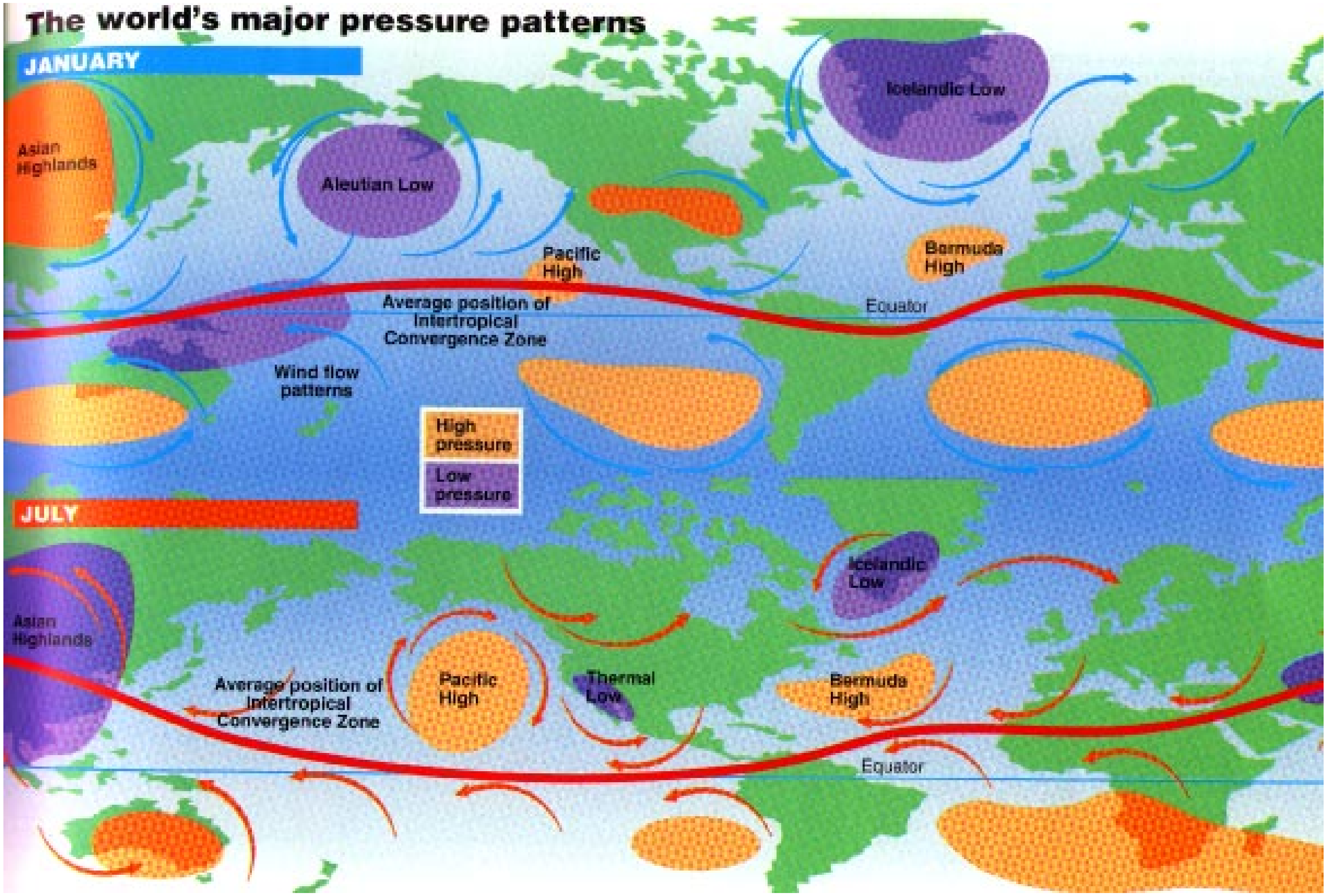


Easterlies (from east)

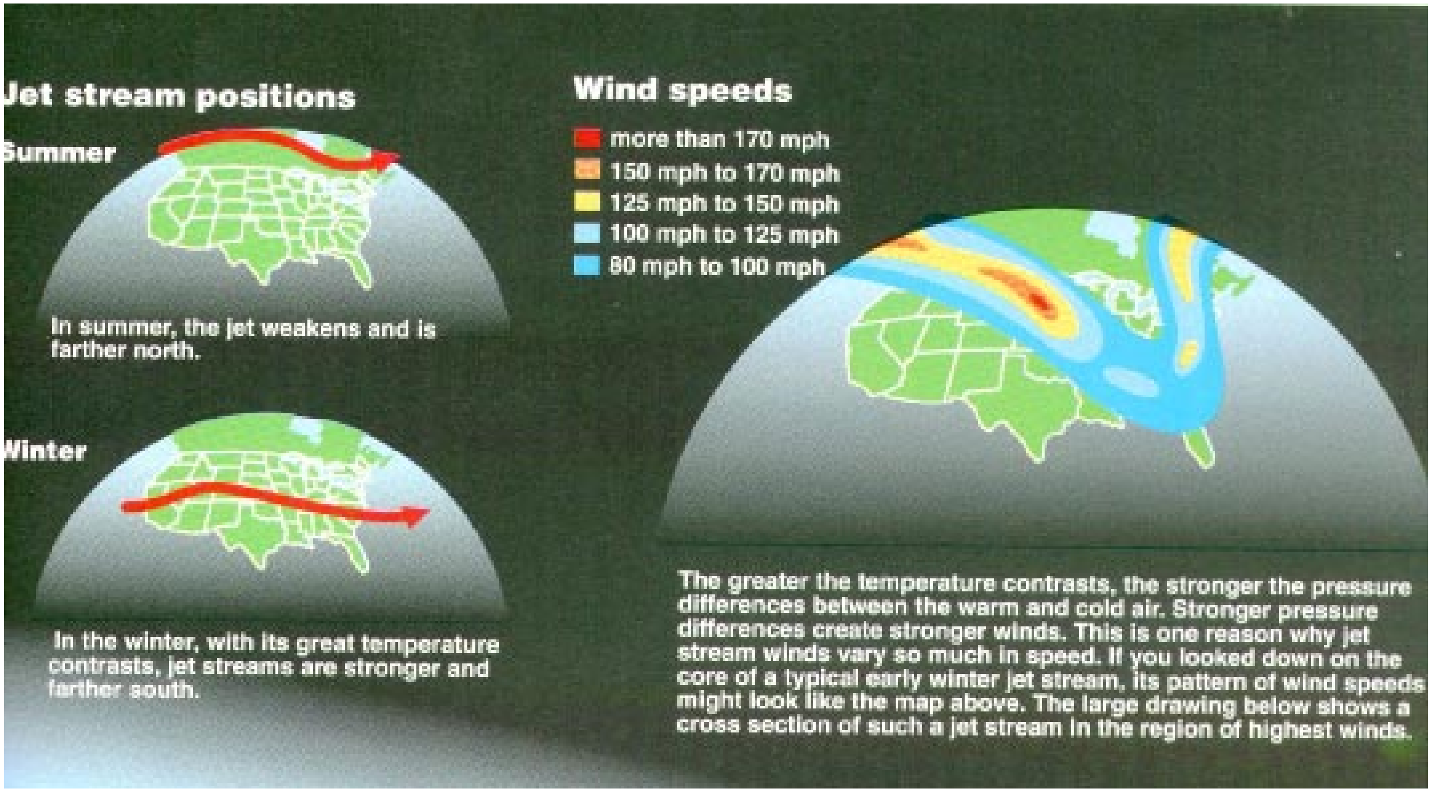
Westerlies (from west)

Easterlies

Surface Pressure and Wind Patterns



Northern Hemispheric Jet Stream: River of Air



Average Surface Circulation of World Ocean

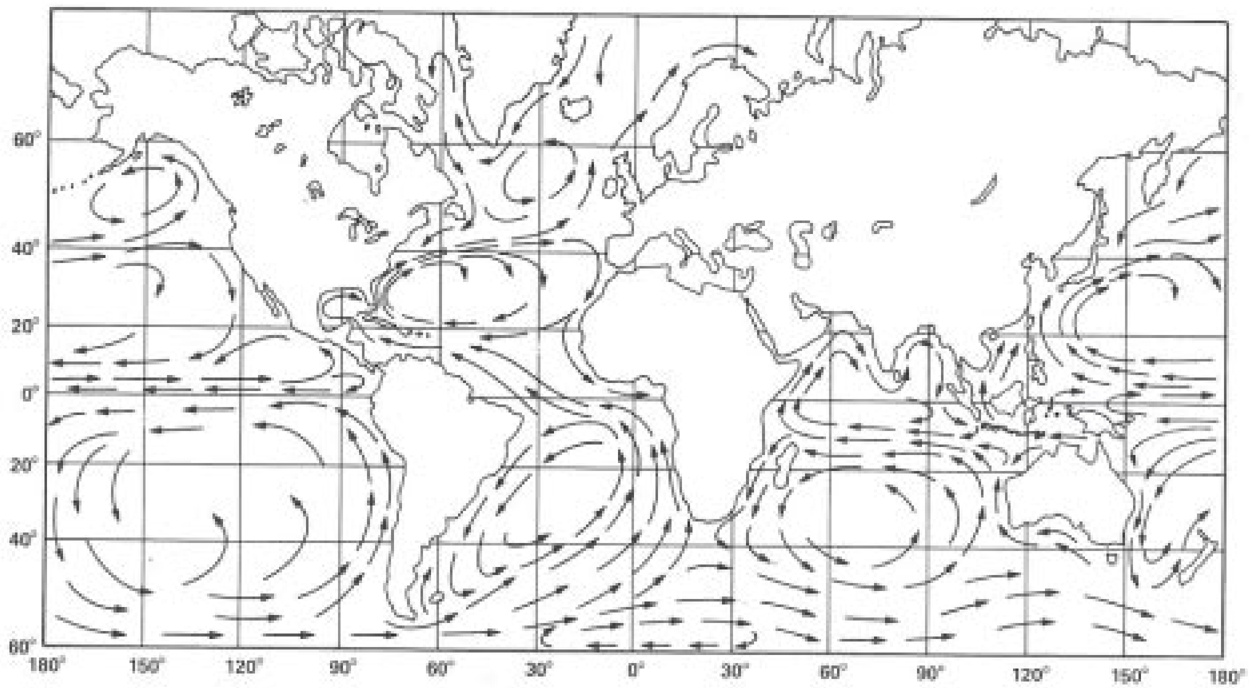


Figure 9.15. Drift currents of the earth.

- Ocean drift currents - wind generated motion
- Eastward (westward) currents in westerly (easterly) wind regions
- North equatorial counter current, exception

Air versus Sea Water and Land

	Air	Water	Land -inorg (org)
Density kg/m^3 at 0˚C	1.275	1000	2600(1300)
Specific Heat c_p (liquid water) at 0˚C, J/kg˚C	1004	4182	733 (1921)

- Oceans temperatures change slower than air (or land)
- Solar radiation absorbed into greater depth of ocean than land
  ==> faster cooling/warming of land than ocean

Topographic Impacts on Climate are Important

- **Northern Hemisphere versus Southern Hemisphere**
- **Coastal Climates - temperate**
- **Continental Climates - hot summers and cold winters**
- **Midwestern US Storms**
- **Mountains**

    Alps - southern Europe warm

    Himalayas - monsoon circulation

Global Climate Map Influenced by latitude & topography

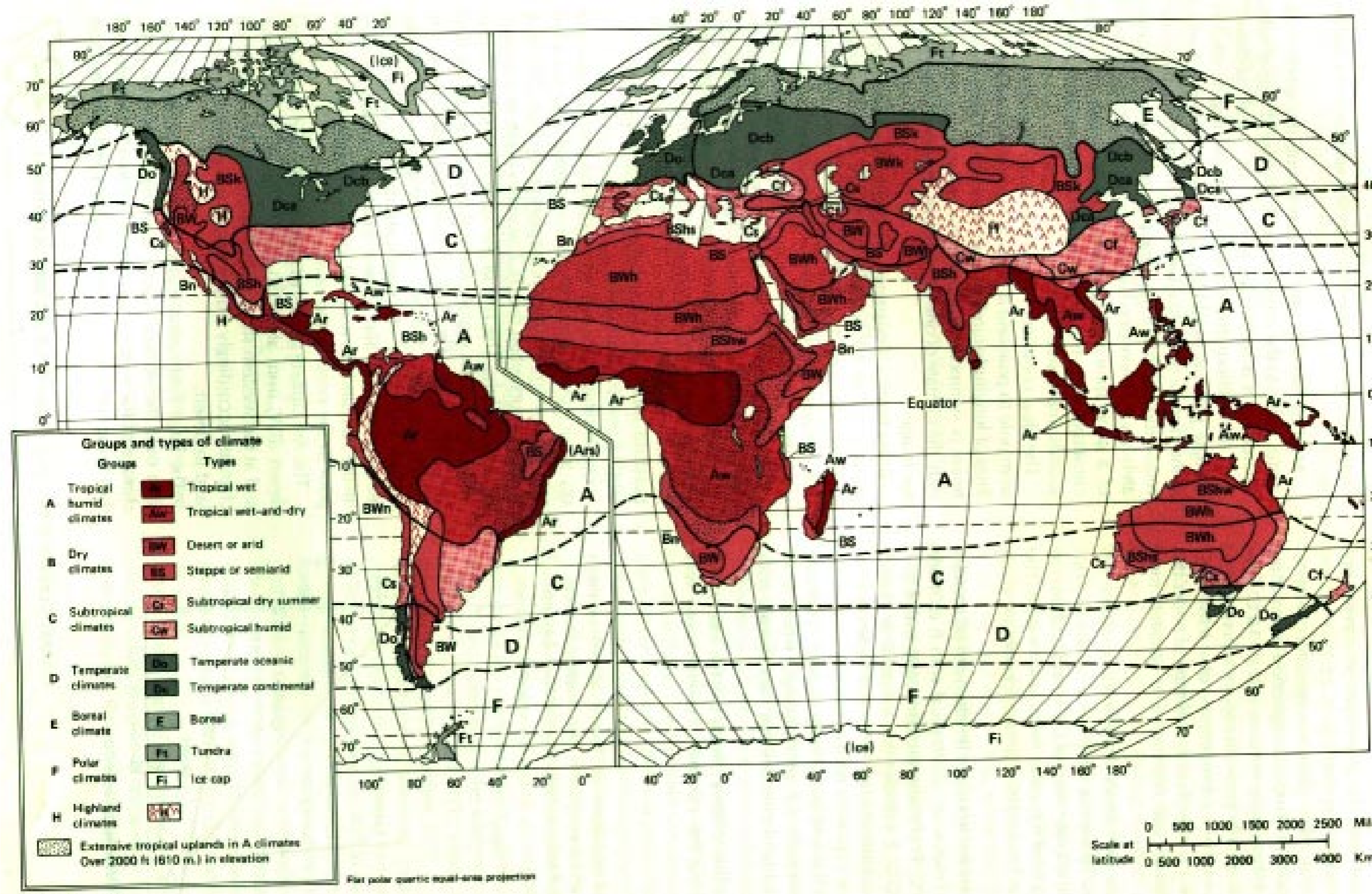
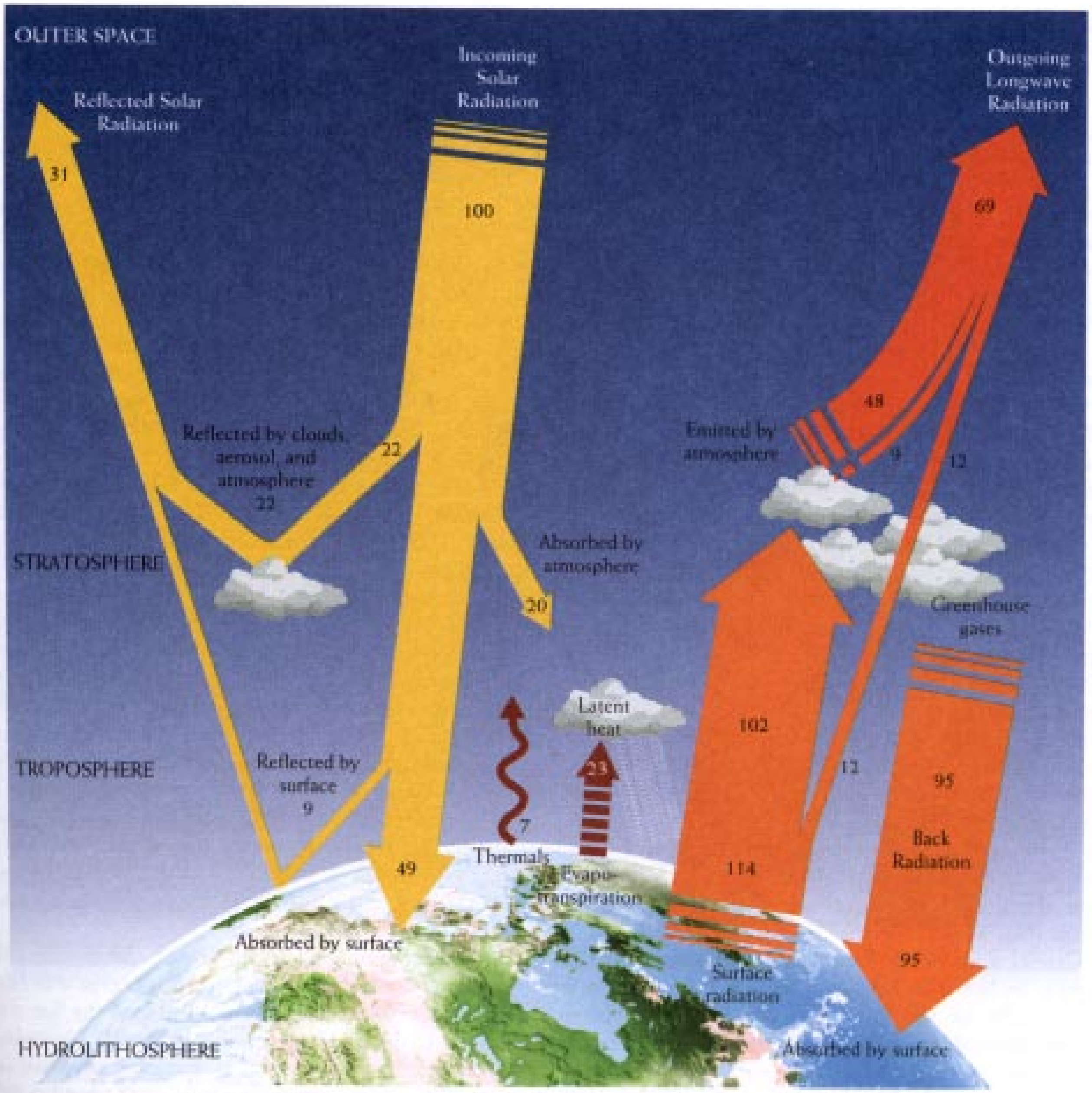
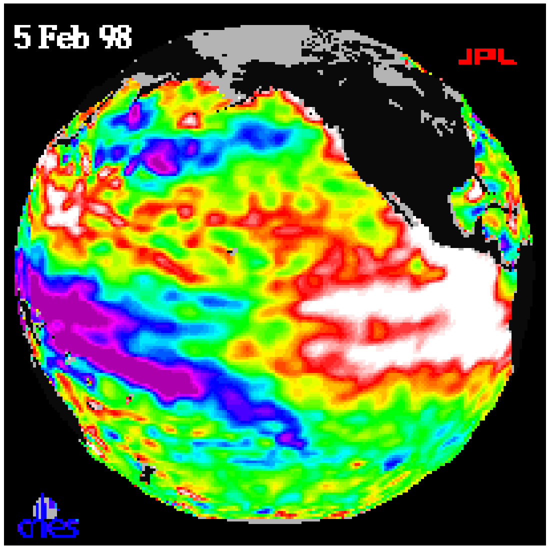


FIGURE 22.2
Climate map of the world.



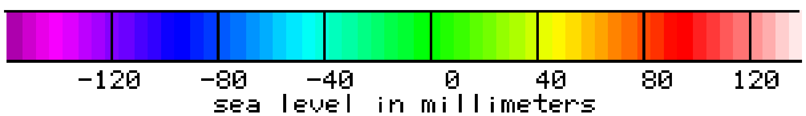
The annual mean global energy balance for the Earth–atmosphere system. Latent heat *is that heat supplied to the atmosphere upon condensation of water vapor. The numbers are percentages of the energy from the incoming solar radiation.*

1997-98 El Niño Declared Warmest Ever



- Historical Background
- 3-7 years irregular
- Tied to Seasonal cycle

WHITE= sea level 5 - 12 in. above normal
water warmer than normal by up to 10 degrees F



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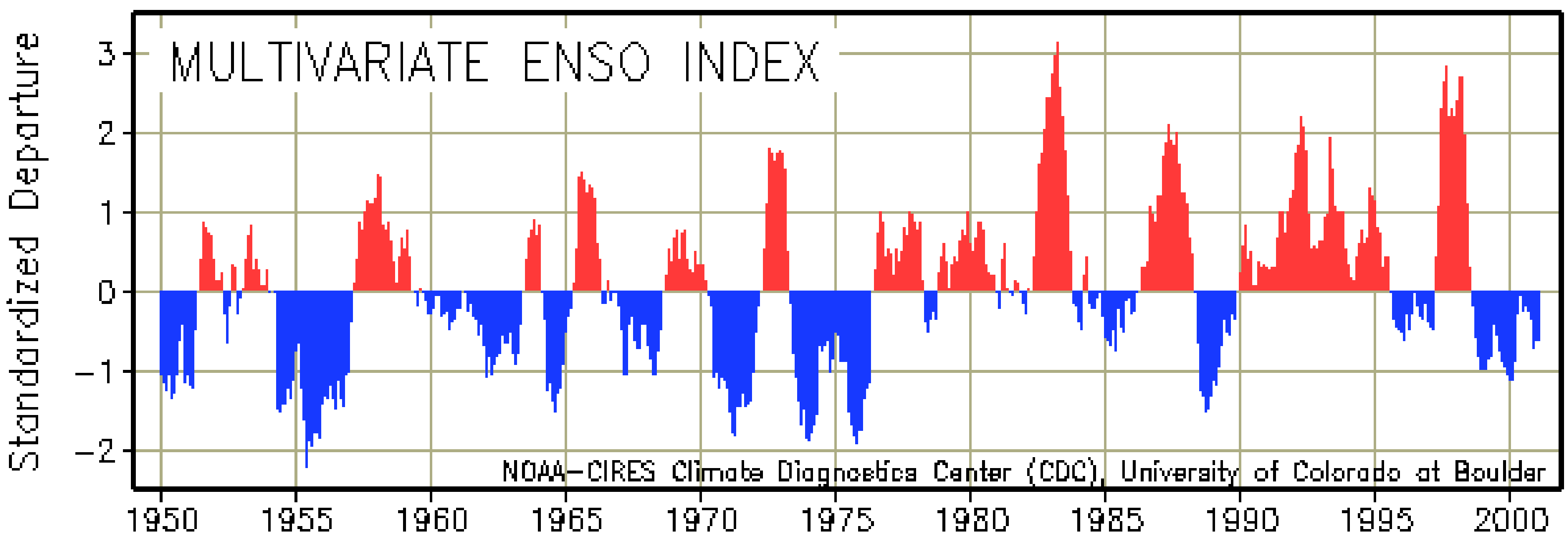
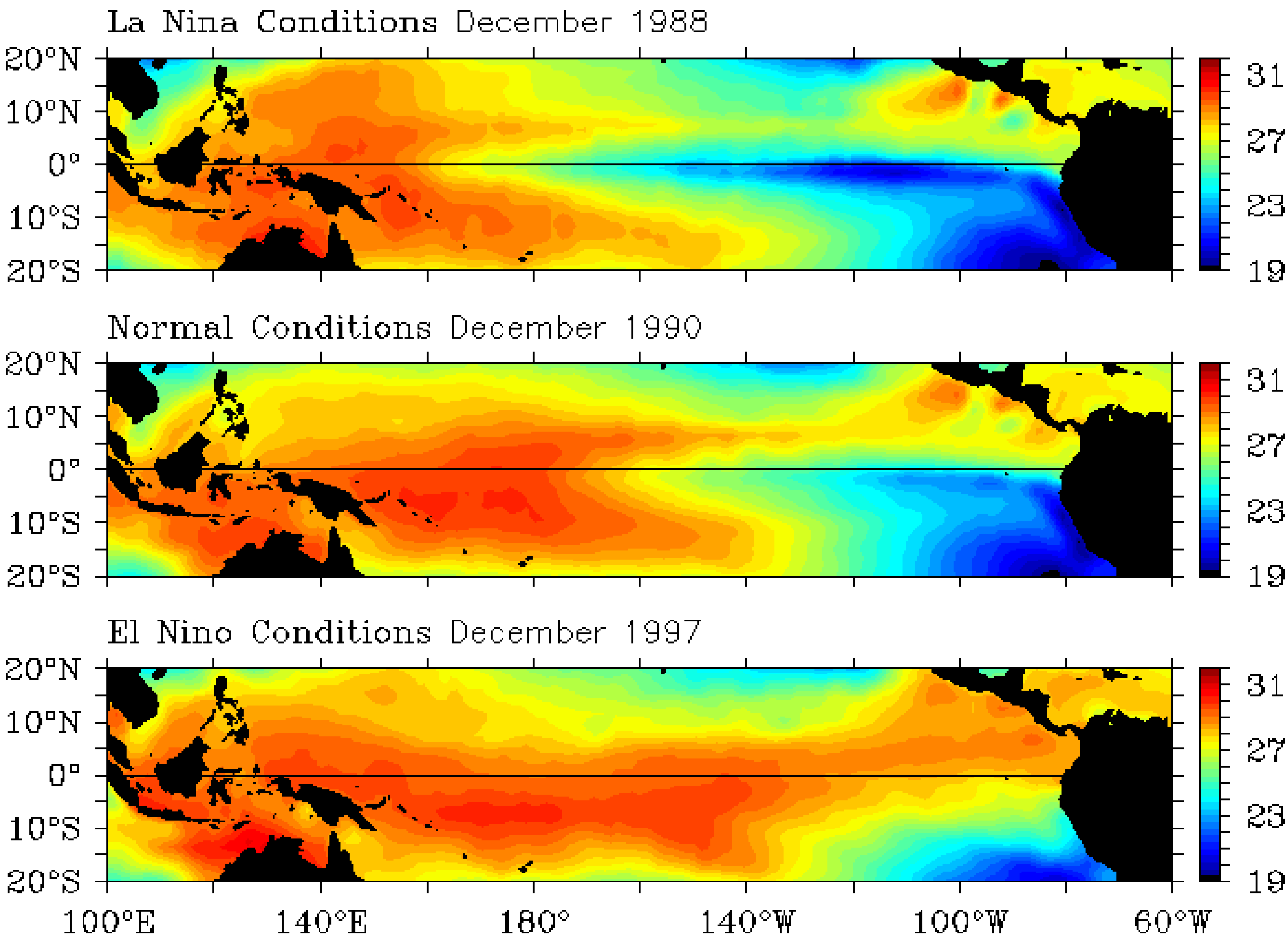
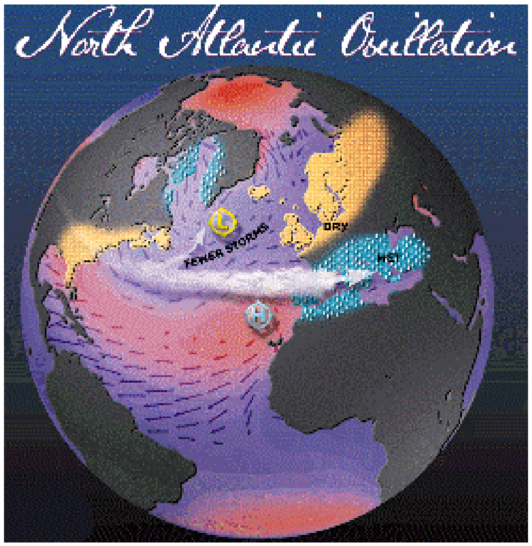


Cold, Neutral, and Warm Equatorial Pacific SSTs

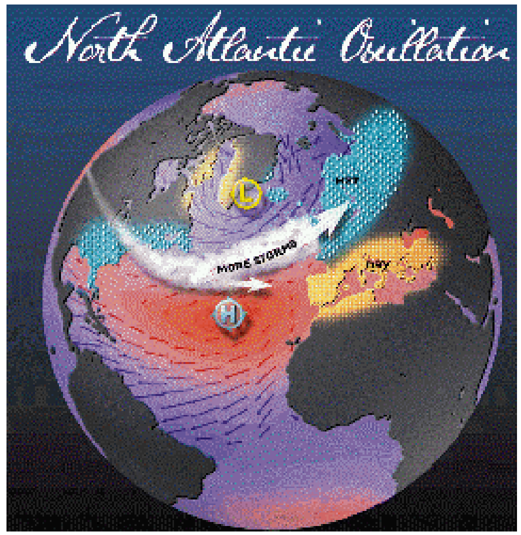


North Atlantic Oscillation

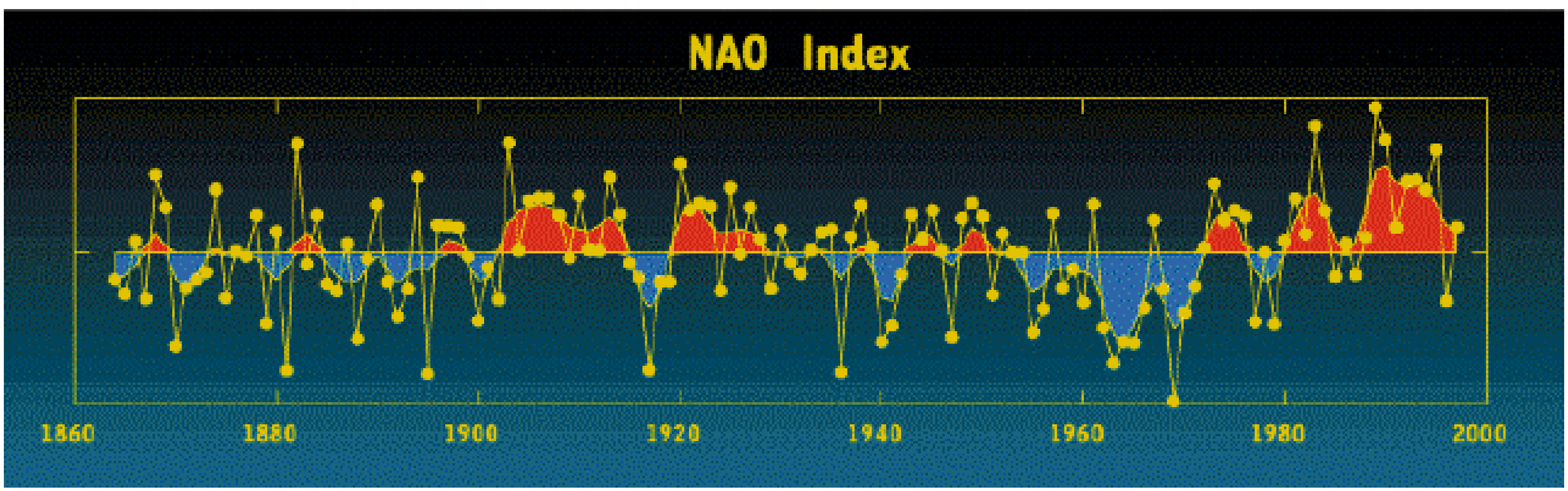
Negative Phase



Positive Phase

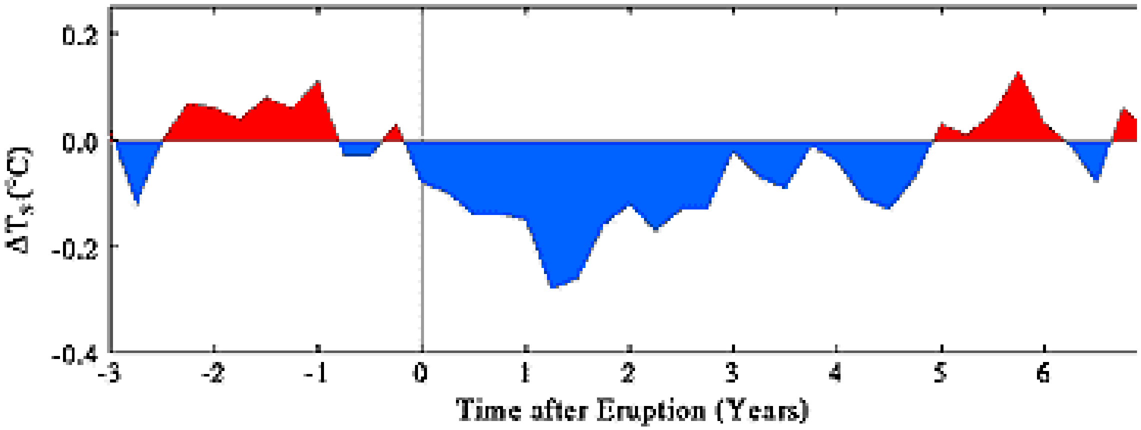


- **Positive Phase**
  Stronger pressure gradien
  More storms
- **Negative Phase**
  Weaker pressure gradient
  Fewer storms



Volcanic Eruptions act to Cool Climate

Replaying an Earth-atmosphere interaction that has occurred since time began, Mt. Pinatubo in The Philippines erupts on June 17, 1991, injecting sulfur gases and dust into the stratosphere and causing two years of moderate global cooling.



Composite global surface temperature change near the time of the five volcanos producing the greatest optical depths since 1880: Krakatau (1883), Santa Maria (1902), Agung (1963), El Chichon (1982) and Pinatubo (1991).

•The main gas emitted by the volcanos, sulfur dioxide, over a period of weeks combines with oxygen and water to form sulfuric acid gas.
• This gas then condenses into fine droplets or "aerosols" that form a haze, similar to the haze
• Volcanic haze scatters some of the incoming sunlight back to space, thus reducing solar heating of the Earth's
surface.

Summary

- **Climate**
  - **Uneven Solar Heating between Equator and Poles**

- **Heat Balance of the Climate**
  - **'Greenhouse' effect operates naturally**

- **Heat Transport for Balance**
  - **Ocean and Atmosphere are important for balance**

- **Examples of Natural Climate Variability**
  - **El Niño**
  - **North Atlantic Oscillation**
  - **Volcanic Eruptions**

- **What next?**
  - **Anthropogenic Increase of Greenhouse Gases**
  - **Evidence for Change**
  - **Change vs Natural Variability**