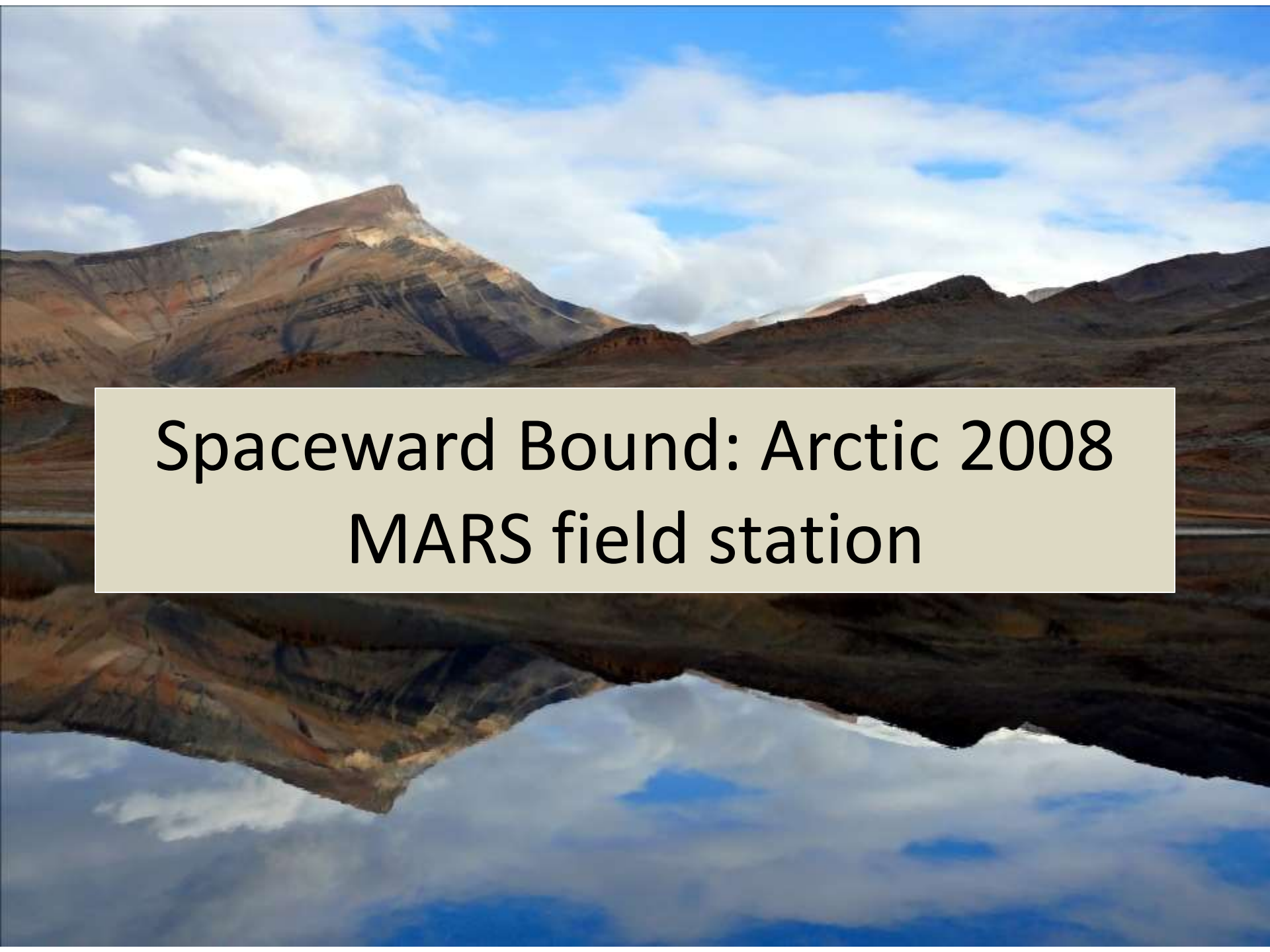


Spaceward Bound: Arctic 2008 MARS field station


McGill Arctic Research Station
Axel Heiburg Island

Meet the Team

Chris McKay

Planetary Scientist

Space Science Division
NASA Ames Research Center
Expedition Lead

What does life need???

Interview questions

1) What is the most essential ingredient for life?

- Liquid water

2) What other things are needed for life?

- Matter/nutrients and energy

Interview questions

3) Where in our solar system do scientists think life may have existed and why?

- Mars (used to have liquid water)
- Europa and Ganymede (moons of Jupiter) and Enceladus (moon of Saturn) may have liquid water under the surface
- Titan (largest moon of Saturn) has liquid methane on its surface

Interview questions

4) What do organisms need liquid water for?

- To grow and reproduce

5) What is the difference between a dormant and a metabolizing organism?

- Metabolizing organisms can grow and reproduce

Define metabolism

- All the chemical reactions needed to live and grow
- Ex: digestion, respiration, synthesizing (making thing)


Is there or was
there
life on Mars?

Getting There


Canada


Kenn Borek Air Ltd.

Phoenix Rover landing site, north polar region of Mars, 2008

Mars, Axel Heiberg and Antarctica all contain polar dry deserts

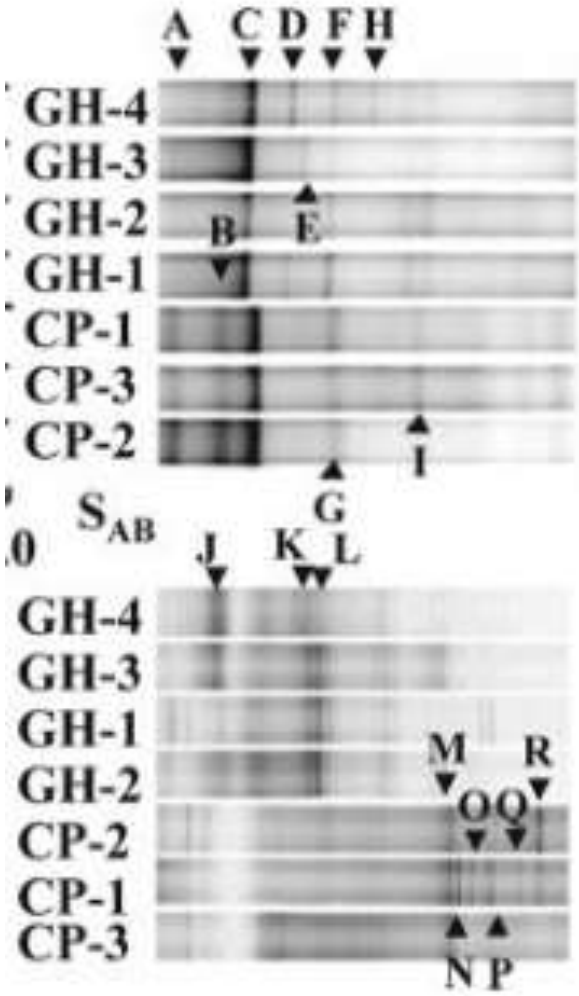
Spaceward Bound Arctic 2008 Mission

- Compare life in extreme environments
- Develop ways to look at fossilized life in rock layers on earth and on mars
- Monitor glacial retreat on Axel Heigburg

Look at microbes living just above permafrost

Study organisms living in perennial springs

Similar DNA banding patterns found in Arctic and Antarctic bacteria



A-B-C- *Thiomicrospira psychrophila* (98%)
D- Cold seep clone CS2.1 (98%)
E- Hydrothermal vent clone B01R010 (93%)
F- *Cytophaga* sp. AN-B14 (97%)
G- *Halanaerobium* sp. AN-B15B (98%)
H- Cold seep clone FE2MidBac23 (91%)
I- *Thiobacillus* sp. EBD bloom (99%)
J- Arctic clone oBS65f.24 (94%)
K- Marine clone E_FO8 (94%)
L- Hydrothermal vent clone pEPR127 (90%)
M- Antarctic clone ELB25A-042 (99%)
N- Halophilic archaeon PalaeII (98%)
O- *Haloarcula vallismortis* (95%)
P- Haloarchaeon str. PW1.1 (95%)
Q- Antarctic haloarchaeon clone ORGANIC4_A (97%)
R- Hydrothermal sediment clone 7A09 (89%)

Looking for microbial fossils in dried up springs

Try out a rover similar to ones sent to Mars


Looking for fossils = Looking for organic molecules

Looking for fossils = looking for organic molecules

1) Why was the Curiosity rover looking for organics?

Living things made of organic molecules

2) Why would it be difficult to find organics on mars?

They are broken down in Mars harsh environment

3) Why was Curiosity sent to Gale Crater on Mars

Contains layers of rock deposits carved out by water

Retreating Glaciers

Island-wide ice loss approaches 60 km^2 over 42 years

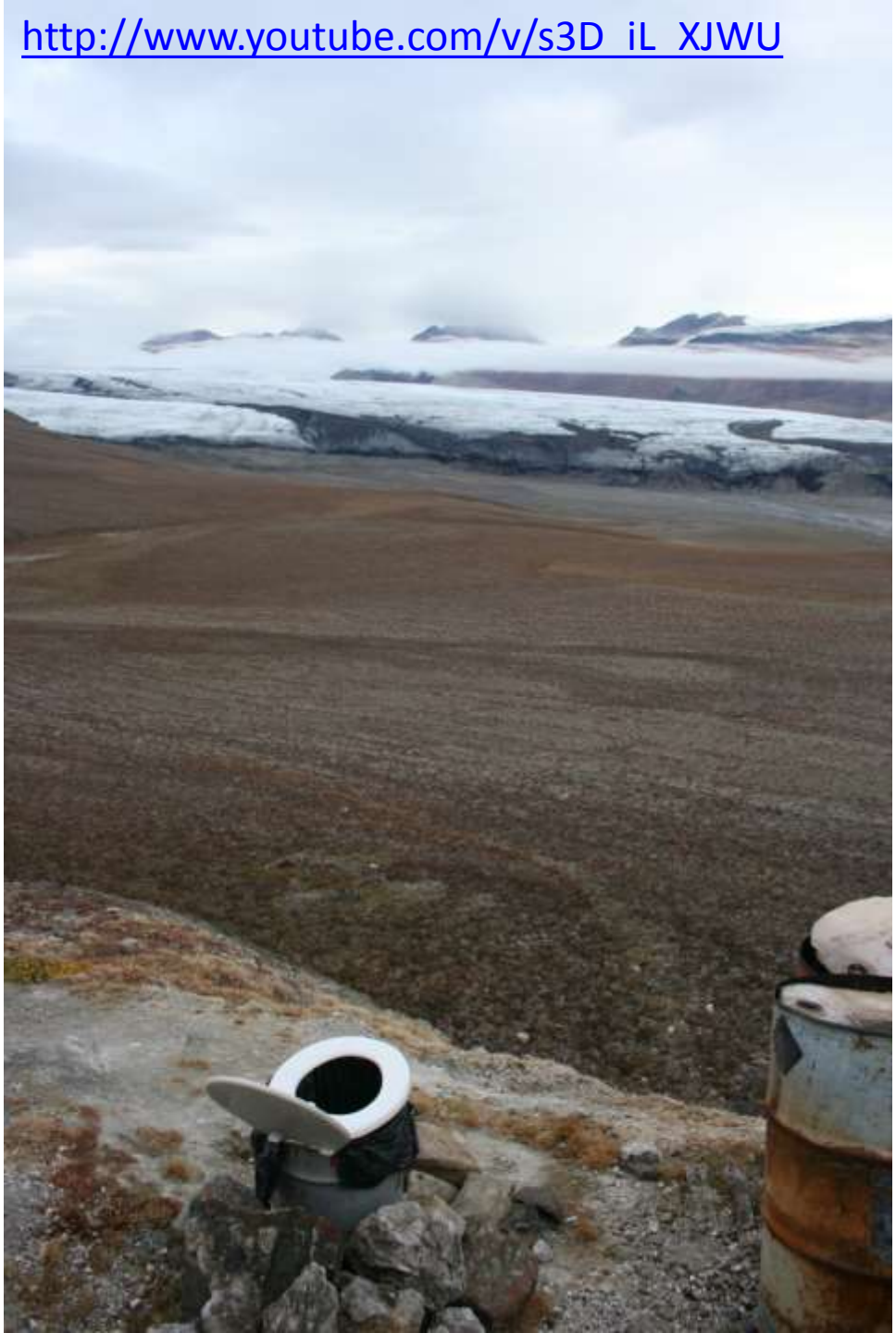
Source: Journal of Glaciology, Volume 57, Number 206, December 2011, pp. 1079-1086(8)

Summer in the Arctic

Base Camp


McGill Arctic
Research Station
MARS
McGill
McGill University

http://www.youtube.com/v/s3D_iL_XJWU



Science Can Be Fun!!!!

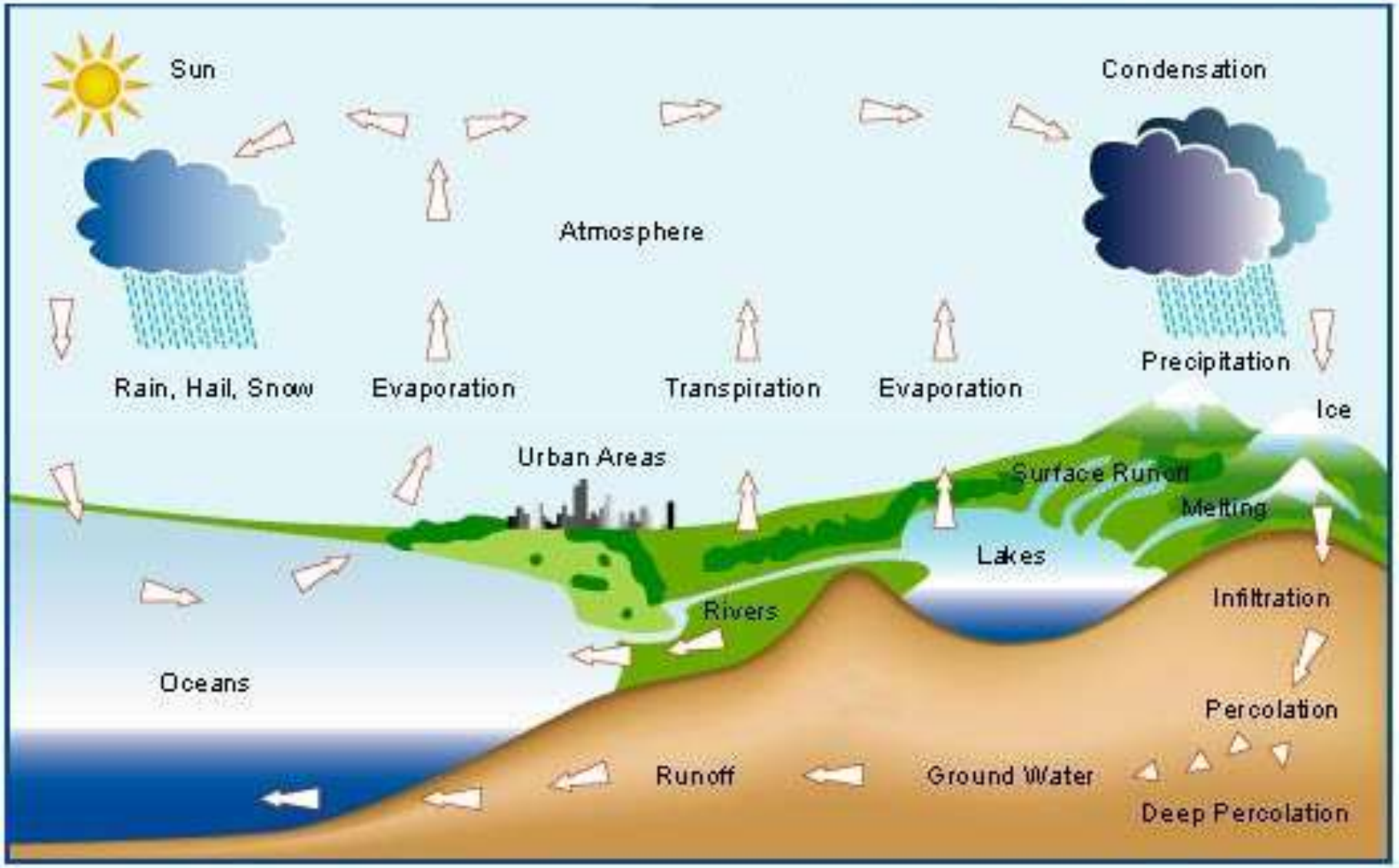
All Living Things Require 3 Things:

- Liquid water
- Building blocks =Nutrients (CHNOPS)
- Energy Source

List as many properties of water as you can

- Polar solvent
- High heat capacity (moderates climates, cools engines…)
- Expands when heated (ex: thermal expansion of ocean),
- Contracts when cooled until it reaches $4^{o}C$ then expands

Hydrologic (Water) cycle



http://www.yvw.com.au/waterschool/seniors/images/watercycle.jpg

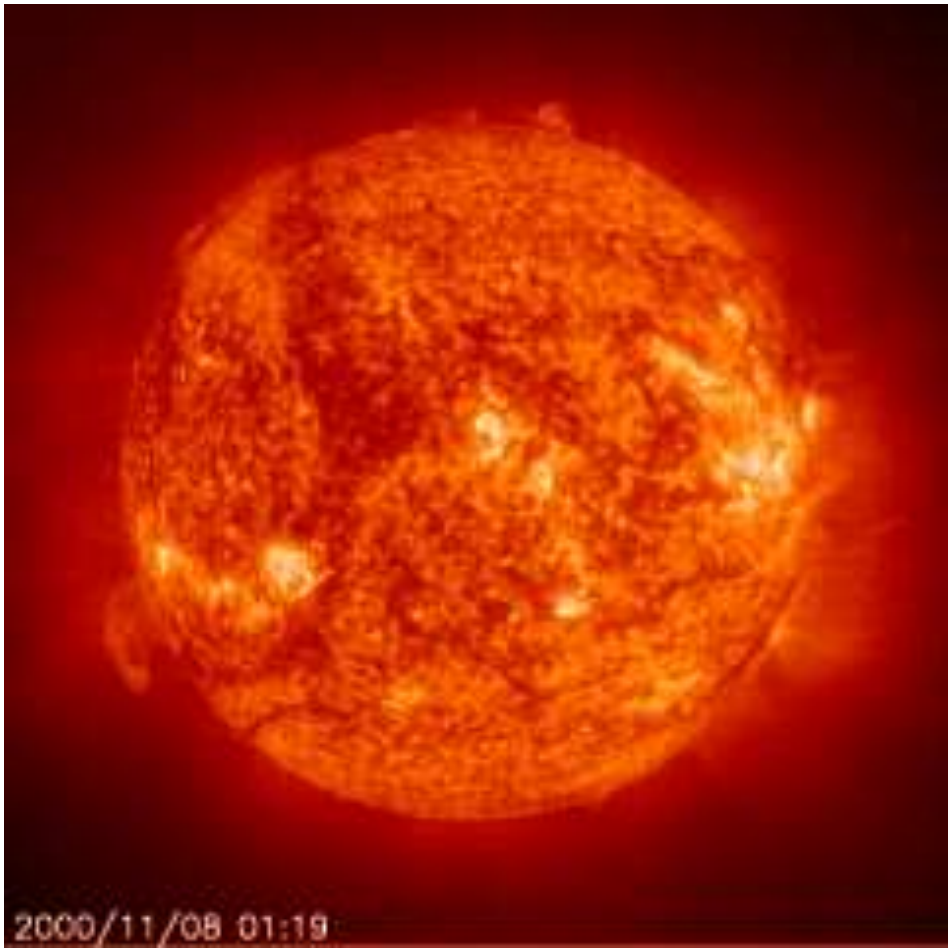
Water vocabulary

- Transpiration = water loss from plants
- Runoff = movement from land to ocean
- Estuary = where freshwater meets ocean
- Watershed = area of land drained by runoff
- Percolation = seeping of water thru soil and porous rock
- Groundwater = underground water reservoirs

Chemistry Review

- What is the difference between evaporation and sublimation????

Energy for Hydrologic and Biogeochemical Cycles comes from Sun

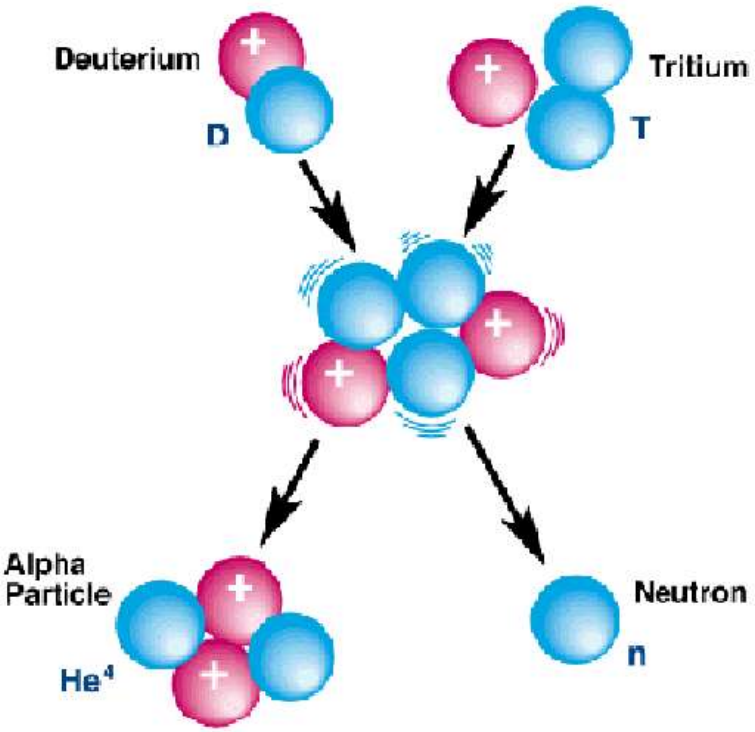


Fusion → Solar radiation

- Fusion = joining 2 light nuclei → 1 heavier one)

Deuterium + Tritium → Helium

$^{2}H + {}^{3}H \rightarrow {}^{4}He + 1n$



http://silas.psfc.mit.edu/hutchinson/asa2002/dt_reaction.png

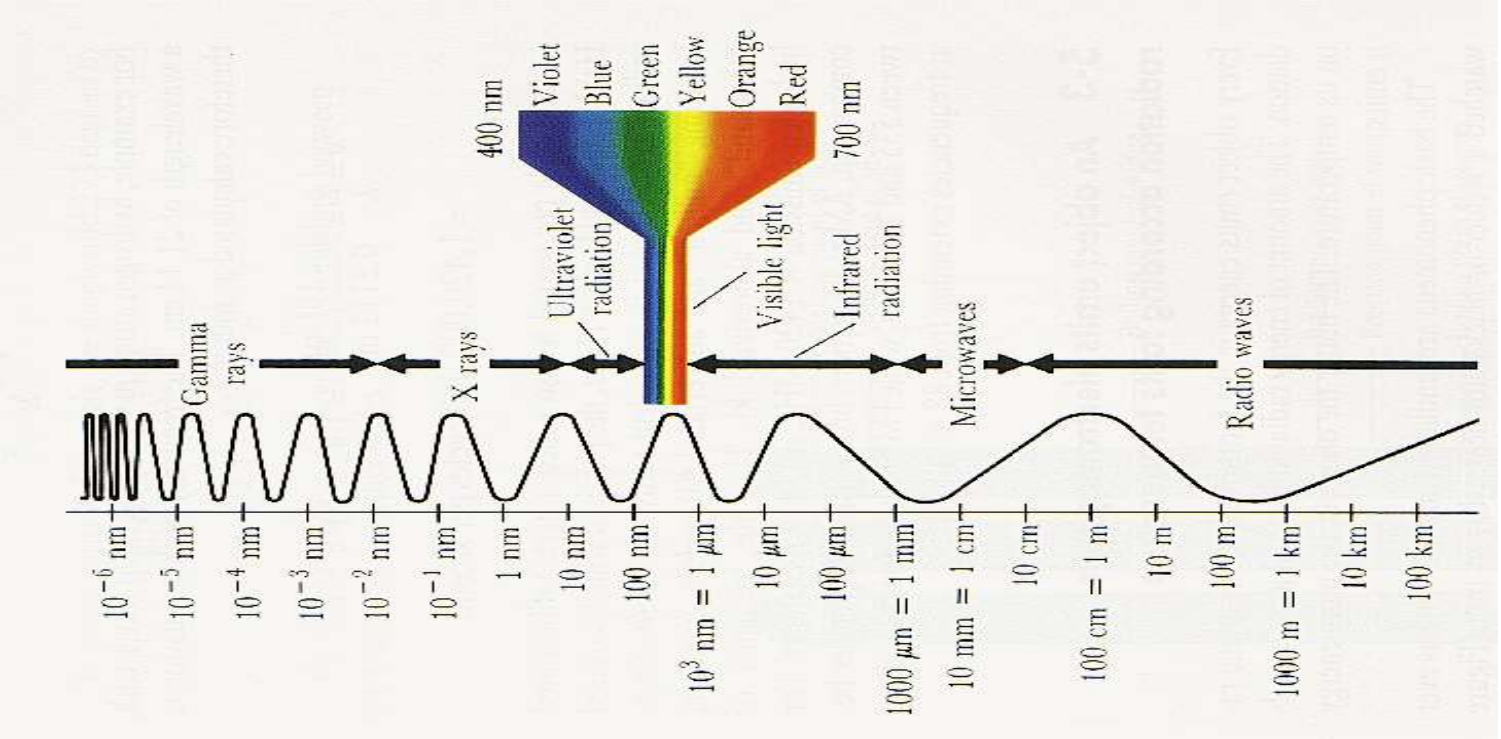
Solar radiation: fusion

- Fusion requires lots of energy and extremely high temps to get going but

- releases a tremendous amount of energy

http://www.noaanews.noaa.gov/stories/images/solarradiaton110900.gif

Solar Radiation = electromagnetic rays (visible, infrared, and UV radiation)



http://praxis.pha.jhu.edu/pictures/emspec.gif

Most solar energy never reaches earth

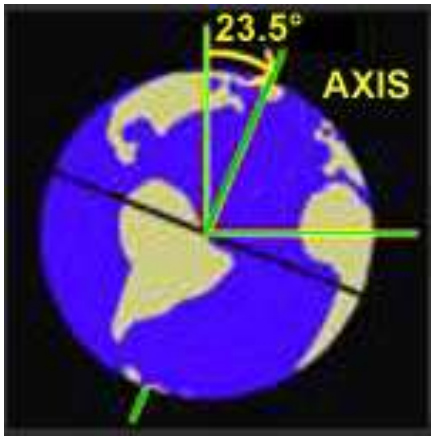
- Albedo = measure of reflection
  - High albedo = reflects a lot
    - Ex: glaciers, glass, snow
  - Low albedo = absorbs a lot
    - Ex: forests and pavement
- 30% of sunlight is reflected away by clouds, snow, ice, and oceans
- 70% absorbed and runs the hydrologic cycle, drives winds and ocean currents, powers photosynthesis and warms the planet

Uneven heating of earth's surface → Weather and climates

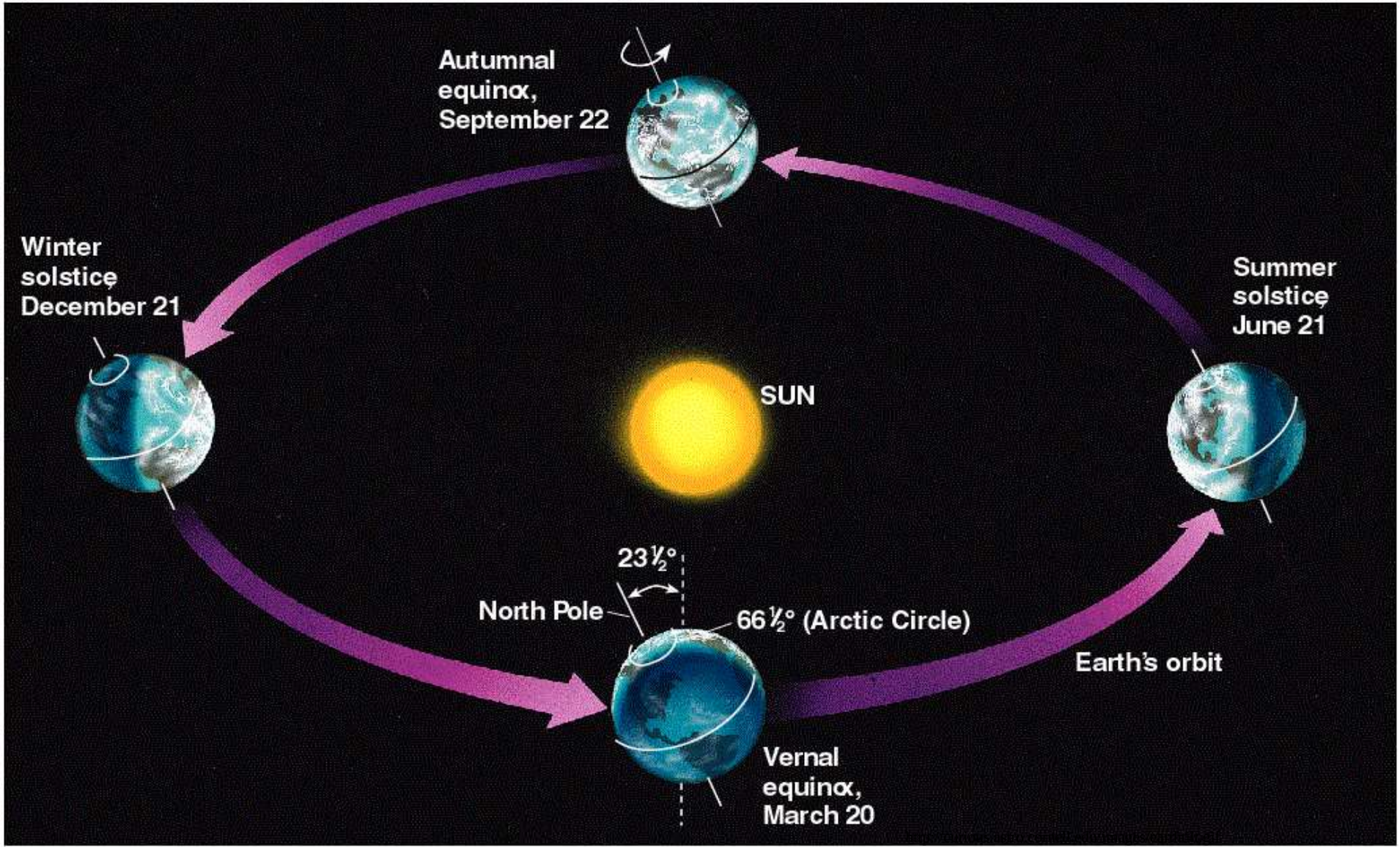
- Heat moves from sources → sinks
- Heat transfers → movement of air masses and water currents
- Convection = cyclical transfer of heat within a fluid
  - Heat air → less dense → rises → cools → more dense → sinks → gets heated …
- Convection → air and ocean currents → weather and climates

Weather and climates

- Earths spherical shape and <u>23.5º</u> tilt → → seasons and weather
  - Warm air from equator rises and flows towards poles, cools, and falls
  - Cold air from poles sinks, flows towards equator



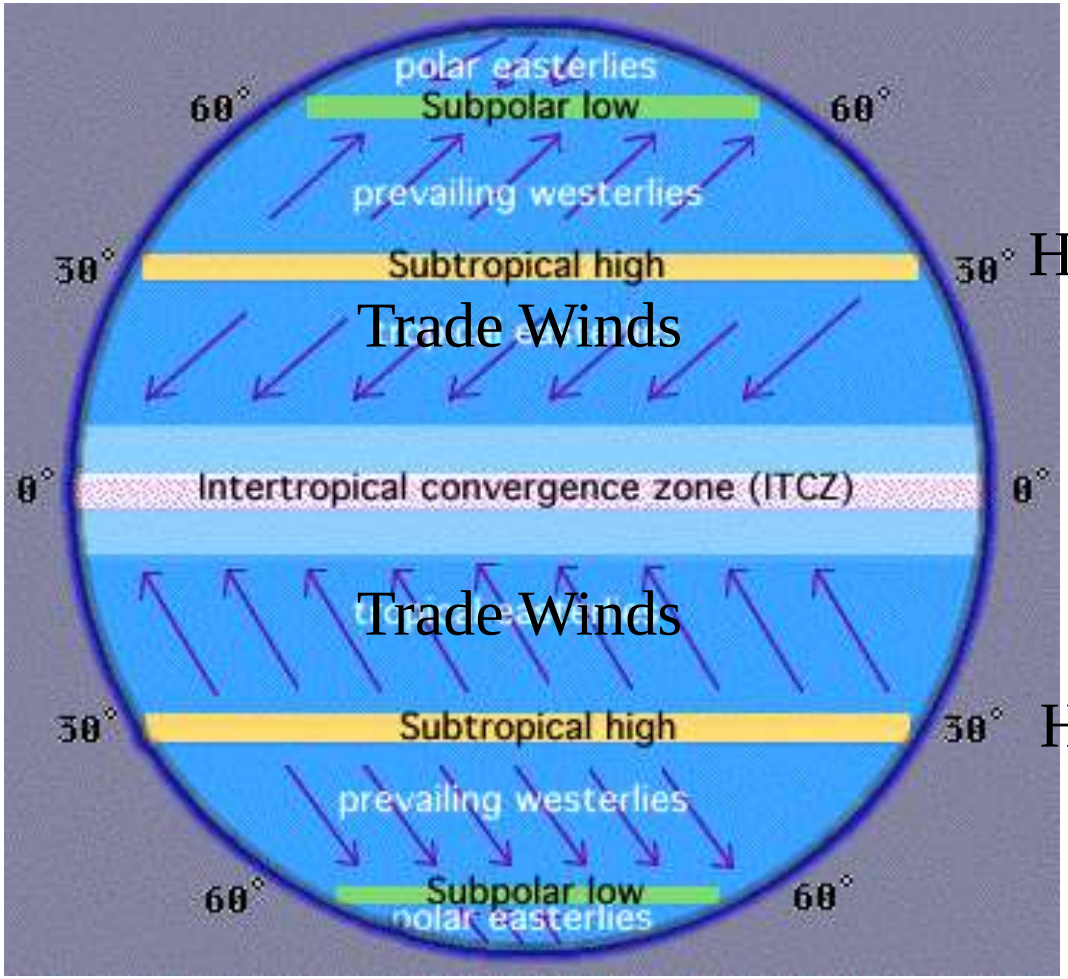
Earths revolution around sun and tilt→ seasons



Coriolis Effect

- Rotation of earth → swerving of winds
- Atmospheric circulation (caused by spin and uneven heating → surface winds

Weather: Prevailing winds



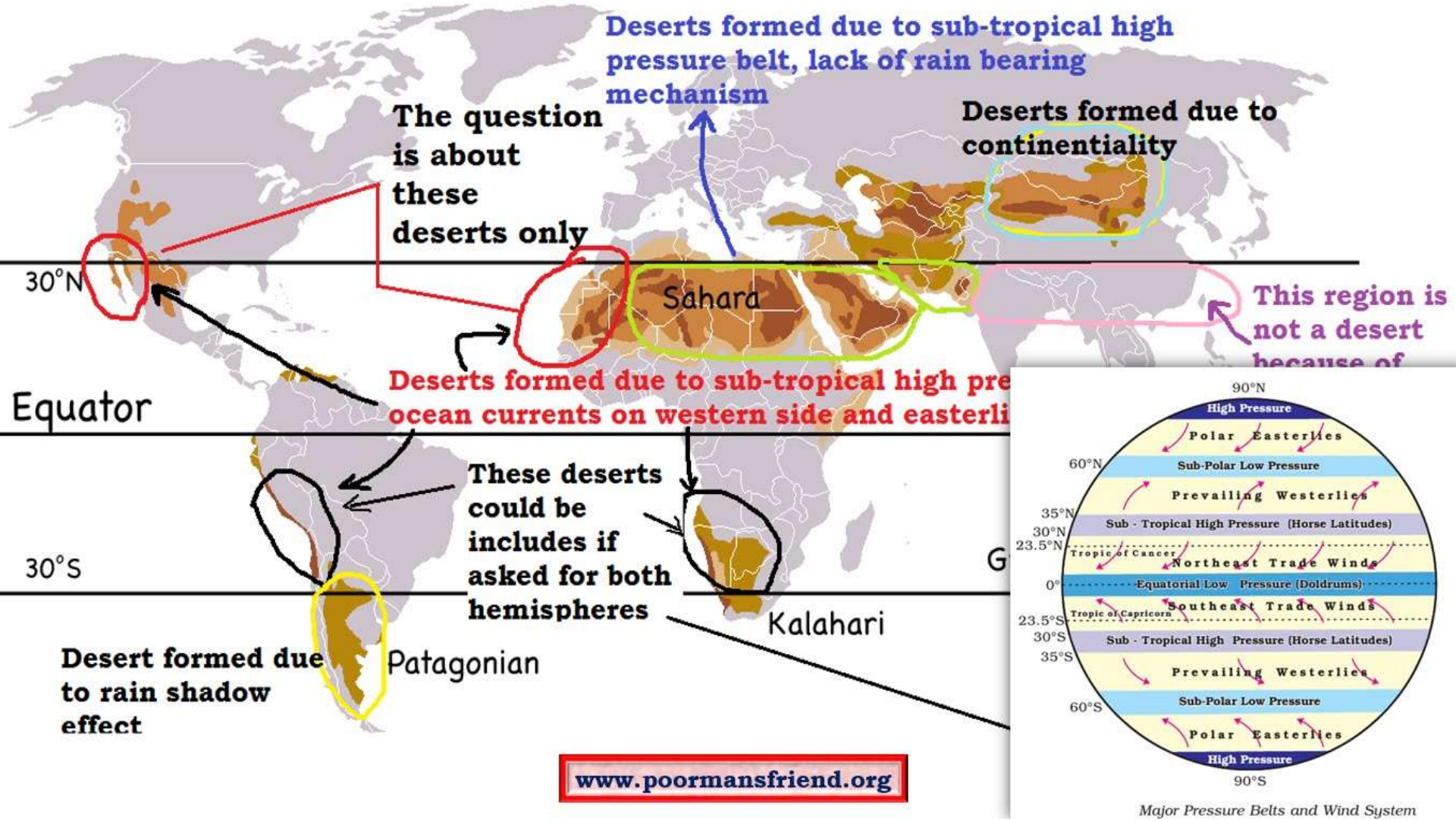
Horse latitudes

Doldrums

Horse latitudes

http://ww2010.atmos.uiuc.edu/guides/mtr/hurr/gifs/mvmt1.gif

Deserts most common between horse latitudes



Winds carry air

- Atmosphere = 21% O_2, 78% N_2, 1% (everything else – CO_2, H_2O, pollutants…)
  - ex. of pollutants:
  - CH_4, O_3, dust particles, CFC's, Photochemical smog, acidity…

- Pollutants are carried by wind

Air pressure

- Atmosphere becomes less dense as you move away from the surface (→ lower pressure)
- Cold, dry air is more dense (high pressure) than warm, moist air (low pressure)
- When high and low pressures meet → fronts
- **The greater the pressure differential the greater chance of bad weather (storms)**

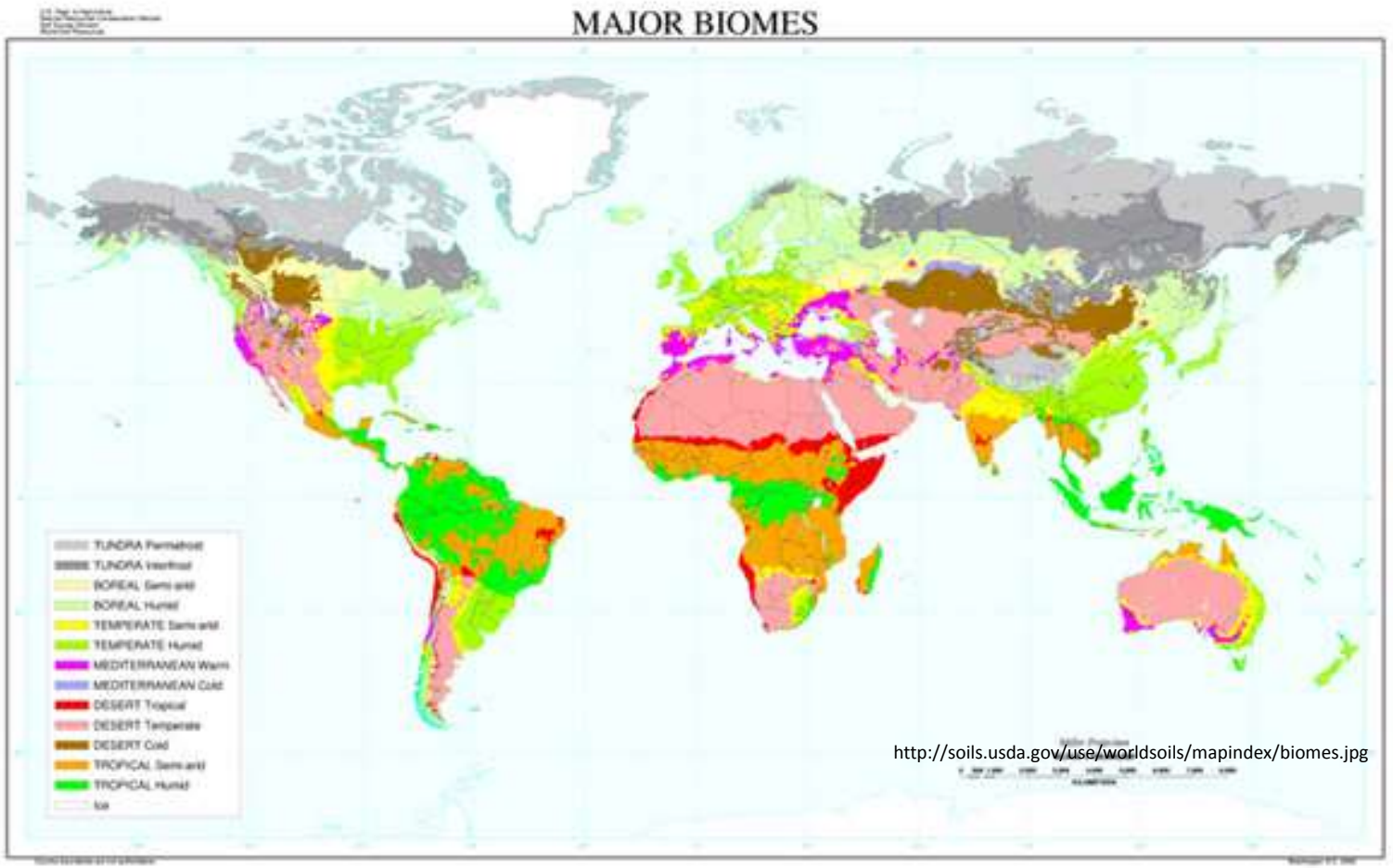
Weather and Climate whats the difference

- Weather = conditions in atmosphere at a given time

- Climate = average weather in an area over period of years (temp. & moisture) → biomes/climax communities

Biomes = Large geographic areas having similar ecosystems

Ex: desert, tundra, grasslands, forest…



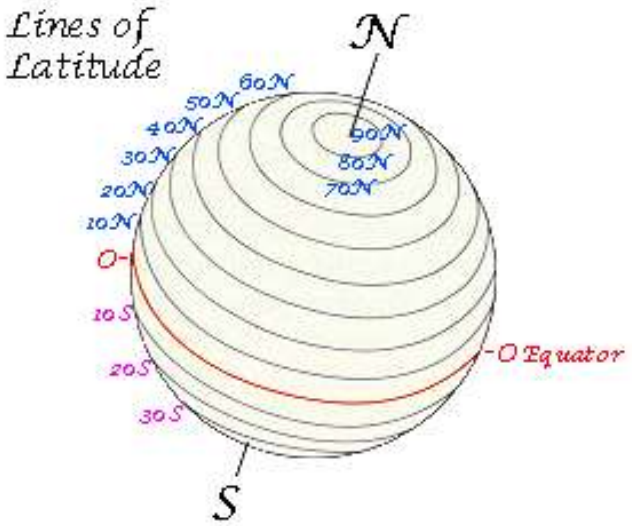
List physical characteristics →the type of biome (community) in an area

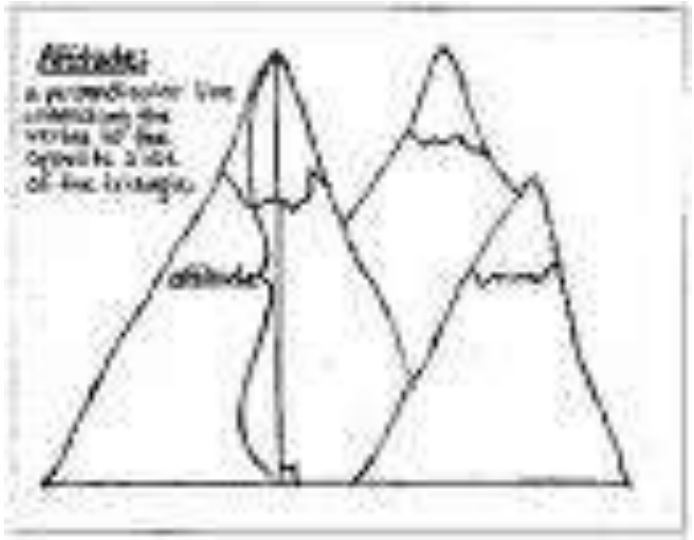
- Temperature
- Latitude
- Precipitation
- Altitude


snow

Biomes

- Inc. latitude = Inc. altitude
  - Ex: climb Mt. Marcy move from mixed deciduous forest→ coniferous → alpine tundra





http://academic.brooklyn.cuny.edu/geology/leveson/core/graphics/mapgraphics/latsnum.gif

http://www.math.okstate.edu/~rpsc/dict/Altitude.htm

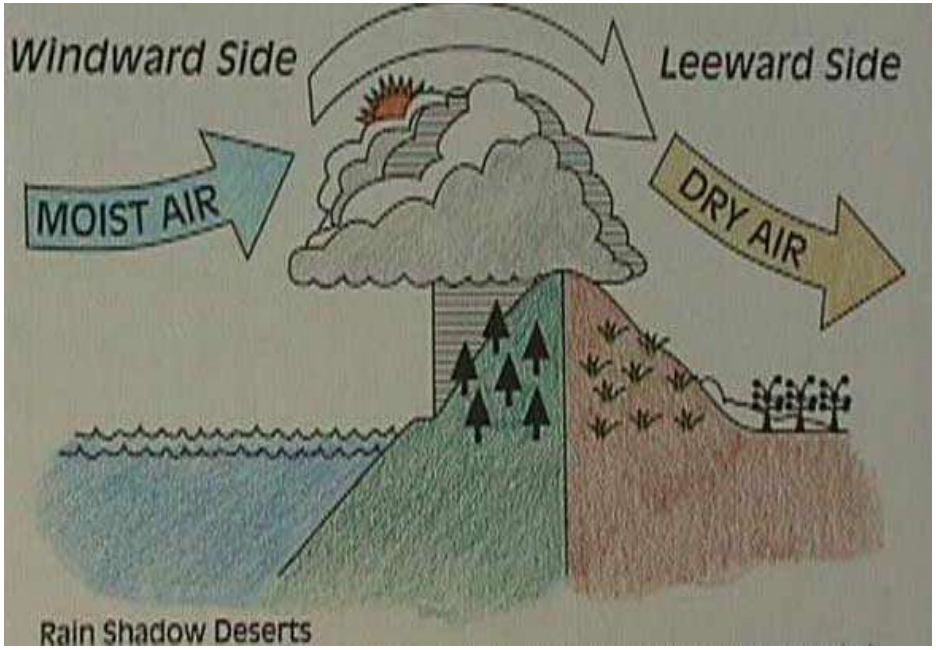
Precipitation

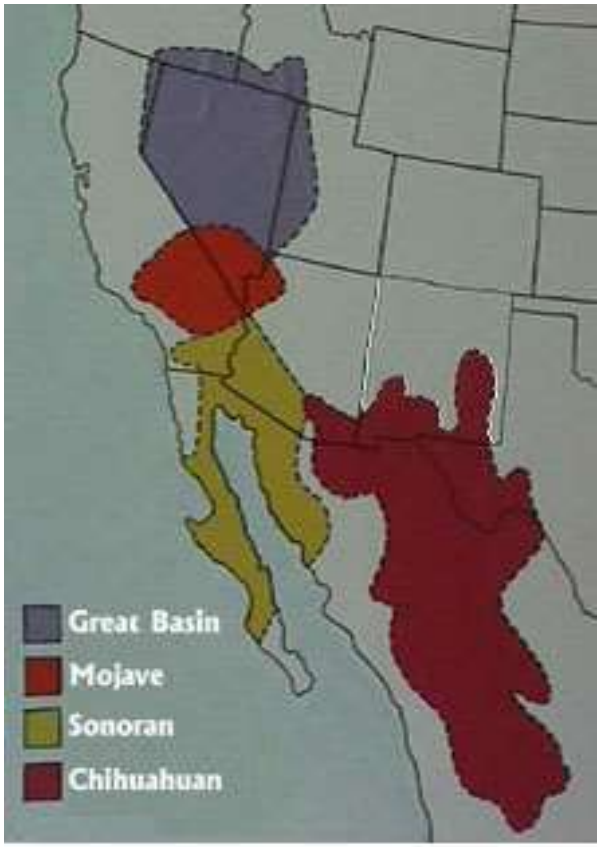
- Warm moist air rises → cools → condenses
  - Saturation point = when air cannot hold anymore water

- Air is dried as it flows over large land masses
  - Continental interiors are drier
  - (explains why we have forests on the east coast and prairies in midwest)

Describe the Rain Shadow

- Arid or semiarid land occurring on the leeward-side of a mountain



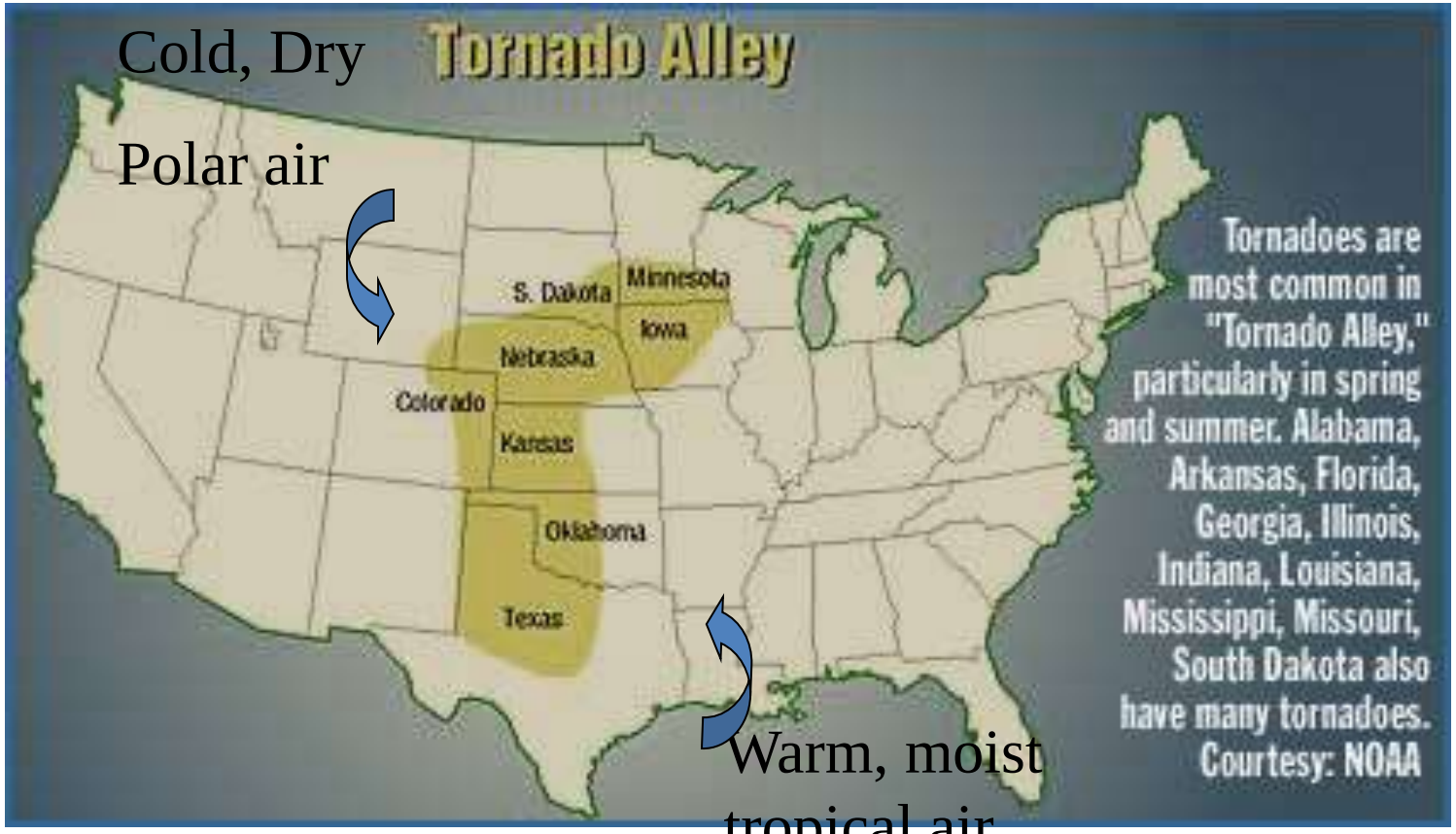


Deserts of North America

Tornadoes

- Rotating funnels of air containing severe thunderstroms
  - Occur where cool dry air collides with warm humid air
  - US = severe storm capital of the world → most tornadoes
  - More common in spring in the Great Plains States and Midwest

Tornado Alley

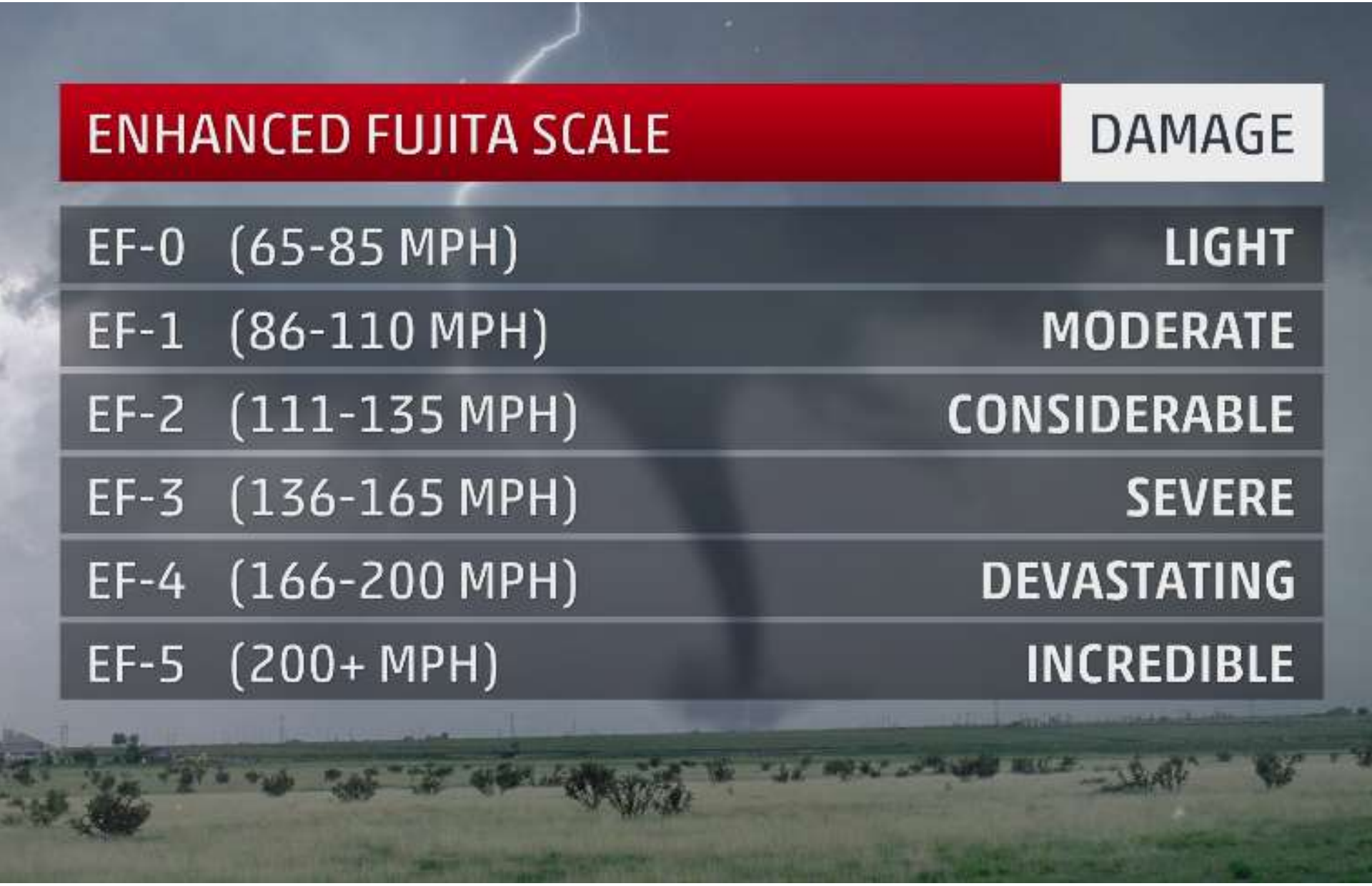


http://whyfiles.org/013tornado/2.html

Fujita Scale

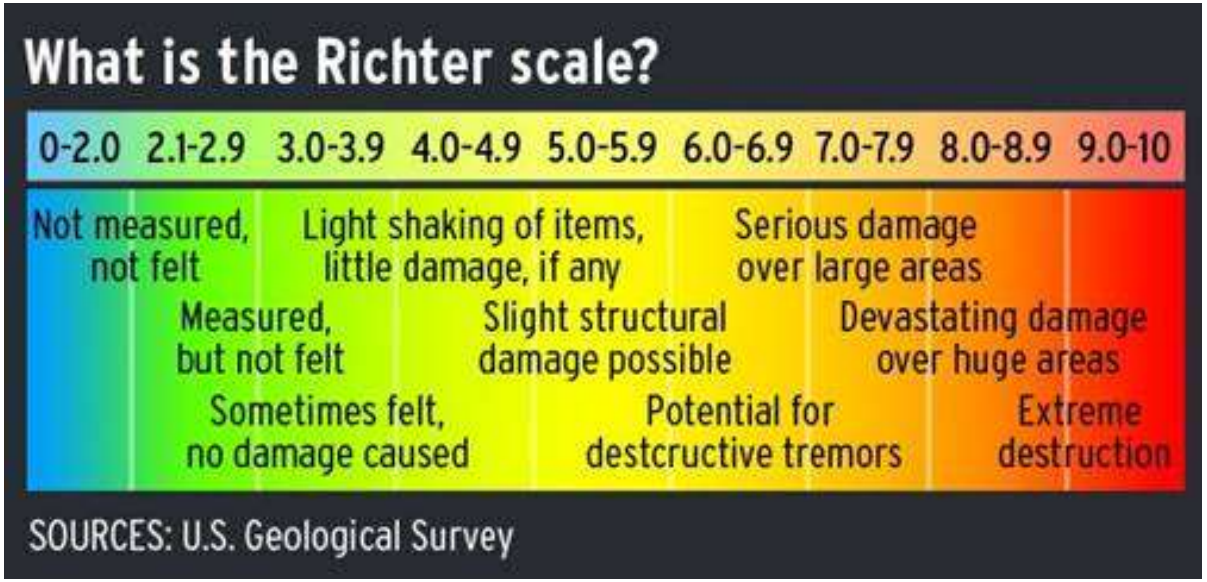
- Ranks tornadoes by the amount of damage they can cause
  - F- 0 and 1 are considered weak
  - F- 2 and 3 are strong
  - F- 4 and 5 are violent

http://www.nssl.noaa.gov/NWSTornado/pic19.jpg


ENHANCED FUJITA SCALE
DAMAGE
EF-0 (65-85 MPH)
LIGHT
EF-1 (86-110 MPH)
MODERATE
EF-2 (111-135 MPH)
CONSIDERABLE
EF-3 (136-165 MPH)
SEVERE
EF-4 (166-200 MPH)
DEVASTATING
EF-5 (200+ MPH)
INCREDIBLE

Earthquakes measured using 2 scales

- Richter scale



- Moment of magnitude scale (**used by most scientists = more accurate**)

Oceans

- Cover ¾ of the earth's surface
- 1 continuous body of water divided into 4 sections
  - Pacific
  - Atlantic
  - Indian
  - Arctic

http://www.solcomhouse.com/oceans22.gif

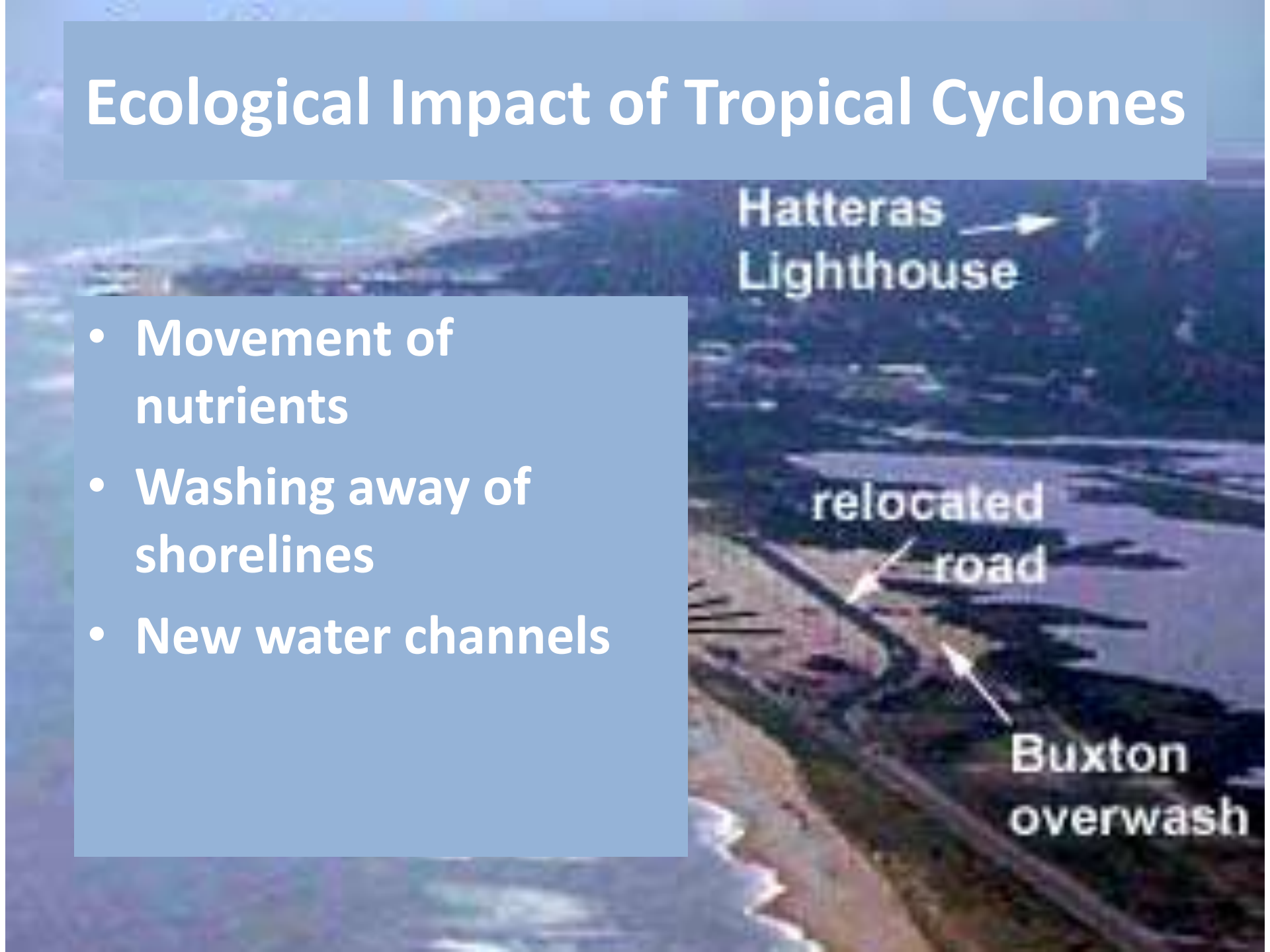
Tropical Cyclones

- Strong winds over warm oceans → large spinning masses of air ~ 500 miles in diameter
  - Hurricanes in the Atlantic
  - Typhoons in the Pacific
  - Cyclones in Indian Ocean

} >75mph winds

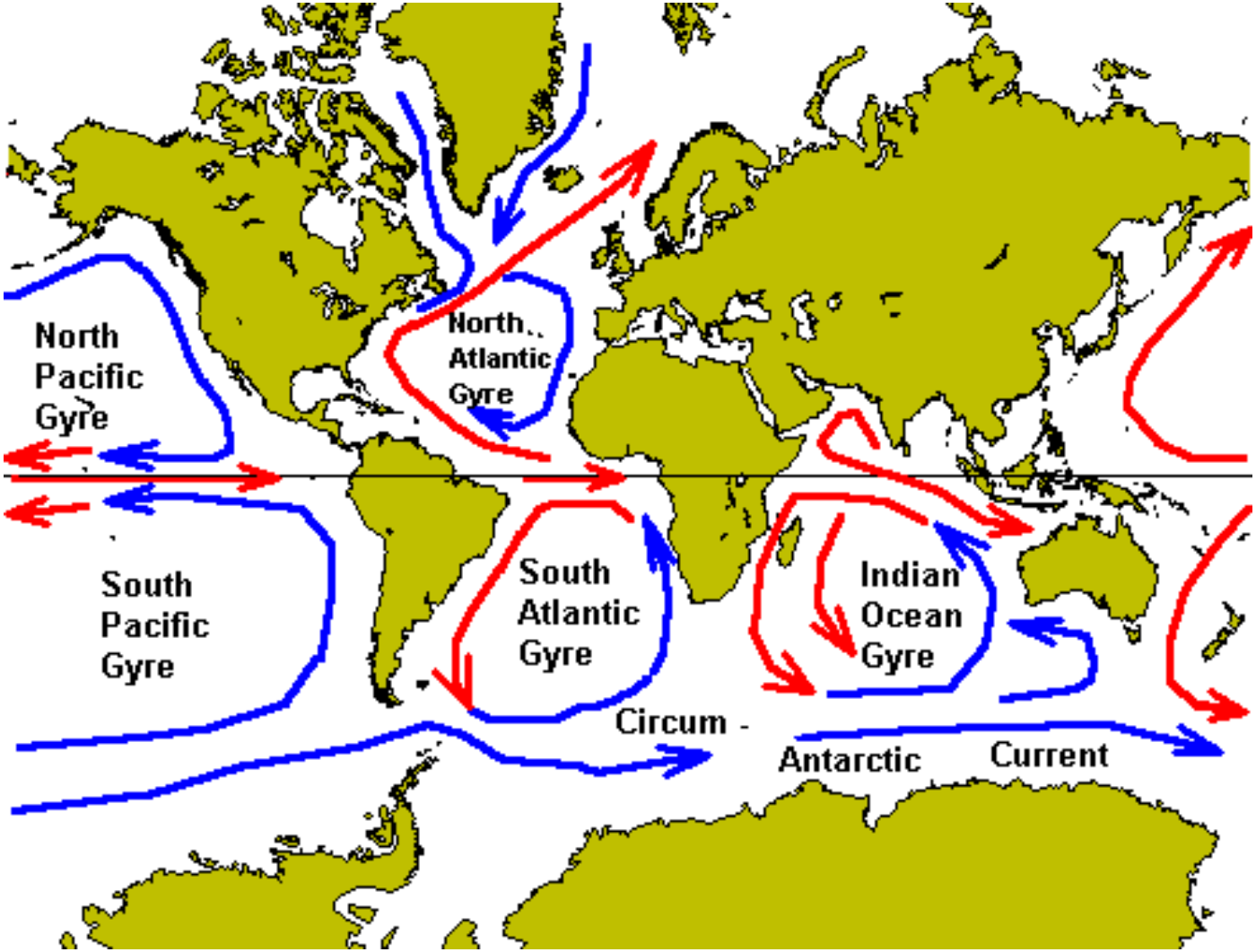
Ecological Impact of Tropical Cyclones

- Movement of nutrients
- Washing away of shorelines
- New water channels



Oceans

- Pacific is the largest
- Surface winds → currents
- Prevailing winds → circular currents of water called gyres
  - Northern hemisphere = clockwise
  - Southern hemishpere = counter-clockwise



http://www.uwgb.edu/dutchs/GRAPHIC0/Oceans/OceanCurrents.gif

North Pacific Gyre: aka Pacific Trash Vortex

Plastics in the ocean

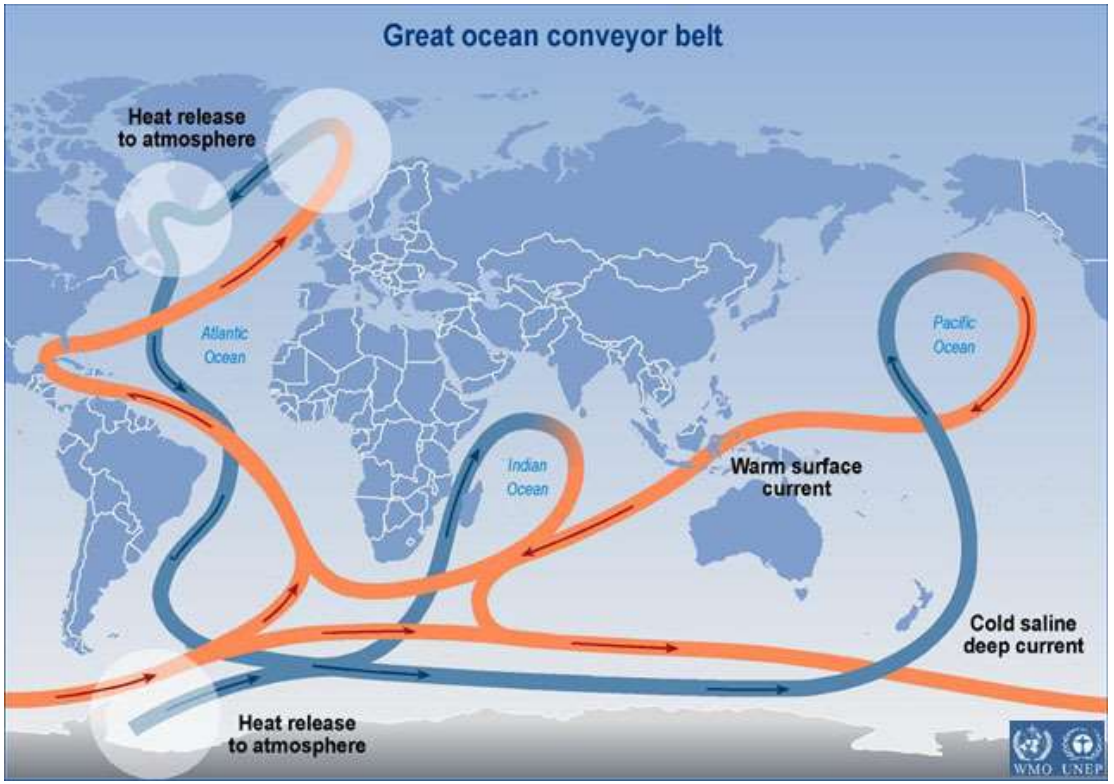
Plastics =

- petroleum based
- polymers
- toxins
- ex:
- phthalates and BPA =
- endocrine disruptors)

http://beachcare.org/_img/pollution/plastic/Boat-sea-plastic-krichim.jpg

Ocean Conveyor belt

- Loops of both warm shallow water and cold deeper, saltier water
- Affects global climates
- Warms Europe



http://www.wunderground.com/education/conveyor.jpg

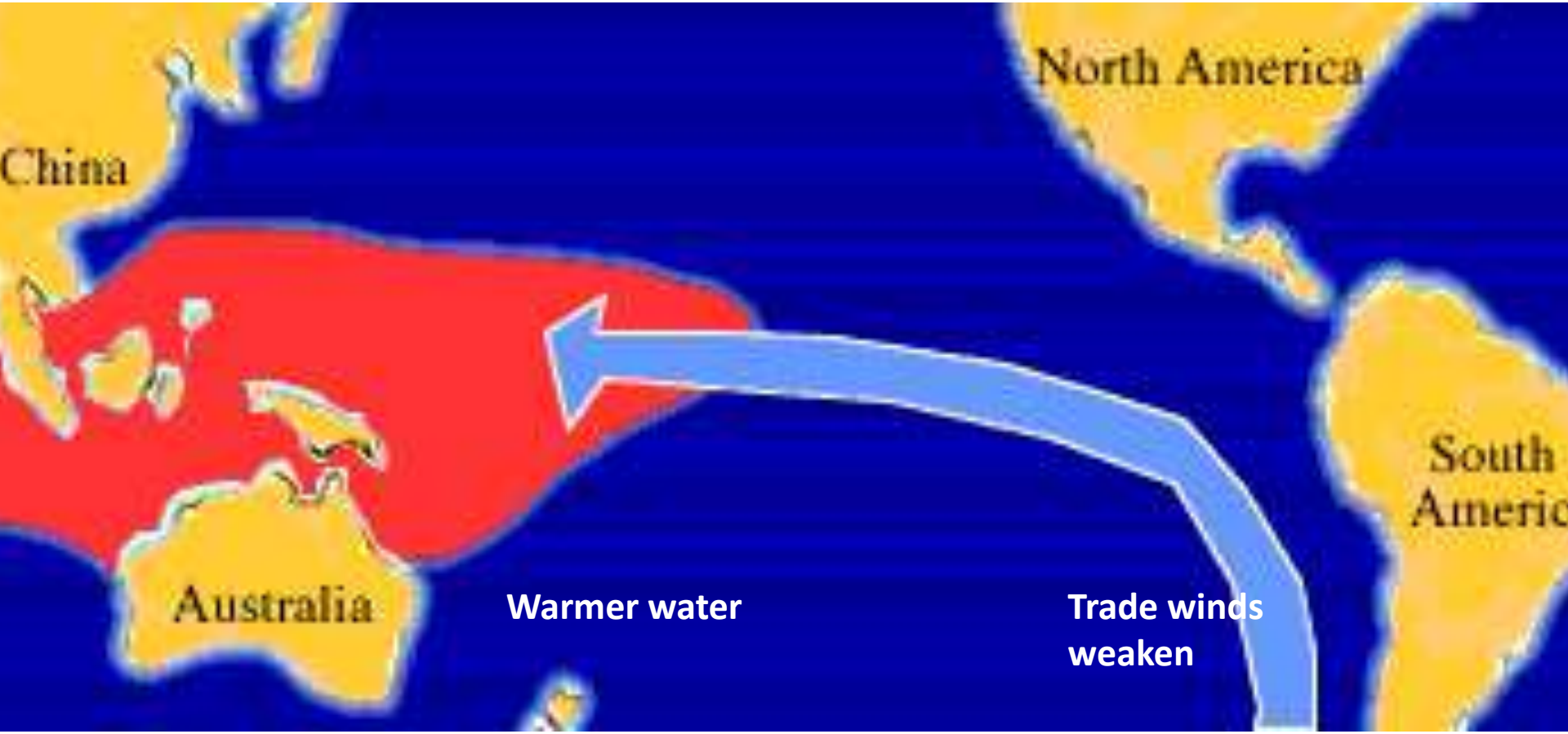
Vertical ocean currents

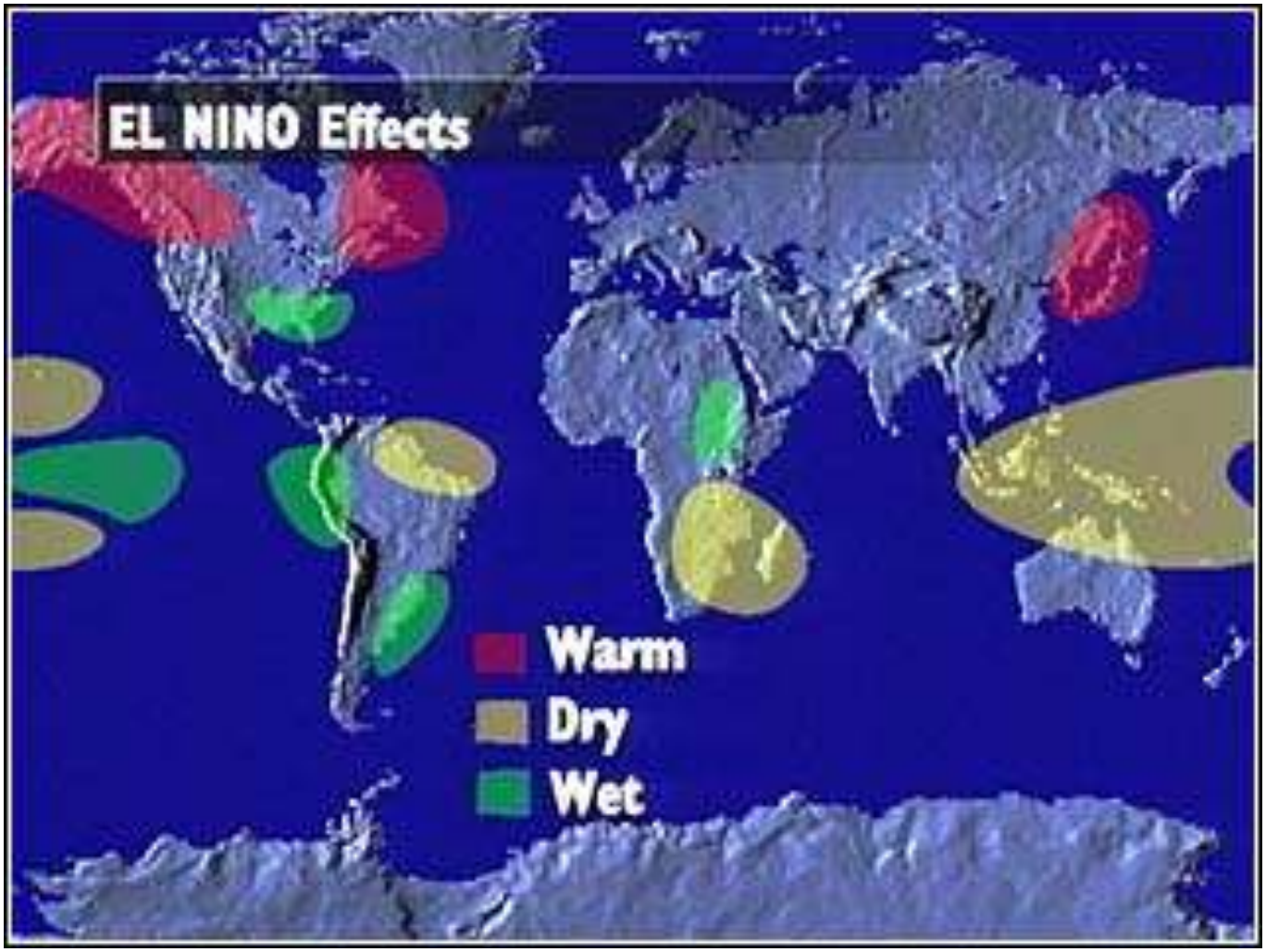
- Varying water densities → vertical currents
- Cold water = saltier and sinks

- Strong Trade Winds → Upwelling
  - Cold salty water from the poles sinks as it moves away from poles → Displaced water is forced up from the bottom bringing nutrients with it
  - phytoplankton depend on these nutrients

ENSO

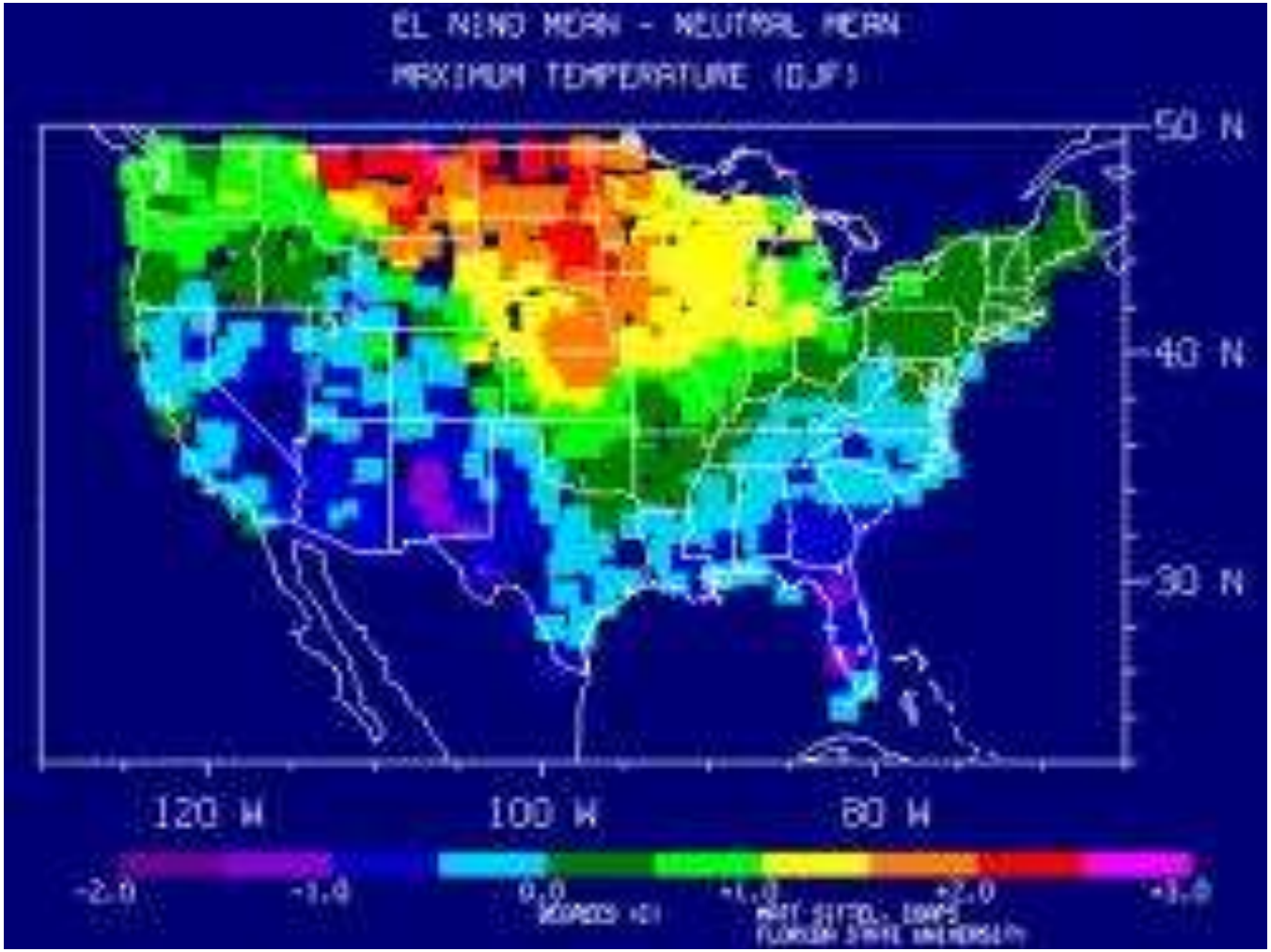
- El Nino Southern Oscillating event
  - El Nino and La Nina
- **El Nino** = **Periodic warming** of surface waters
- Ocurs every 3-7 years in the **Tropical Pacific**
- Changes weather around the globe
  - Some areas become drier, some wetter, some warmer, come colder
- **El Ninos decrease Trade winds→ dec. upwelling**
  - Negative impact on some fish (anchovies)
  - Positive impact on other fish which require warmer temps to reproduce


North America
China
South
Americ
Australia
Warmer water
Trade winds
weaken

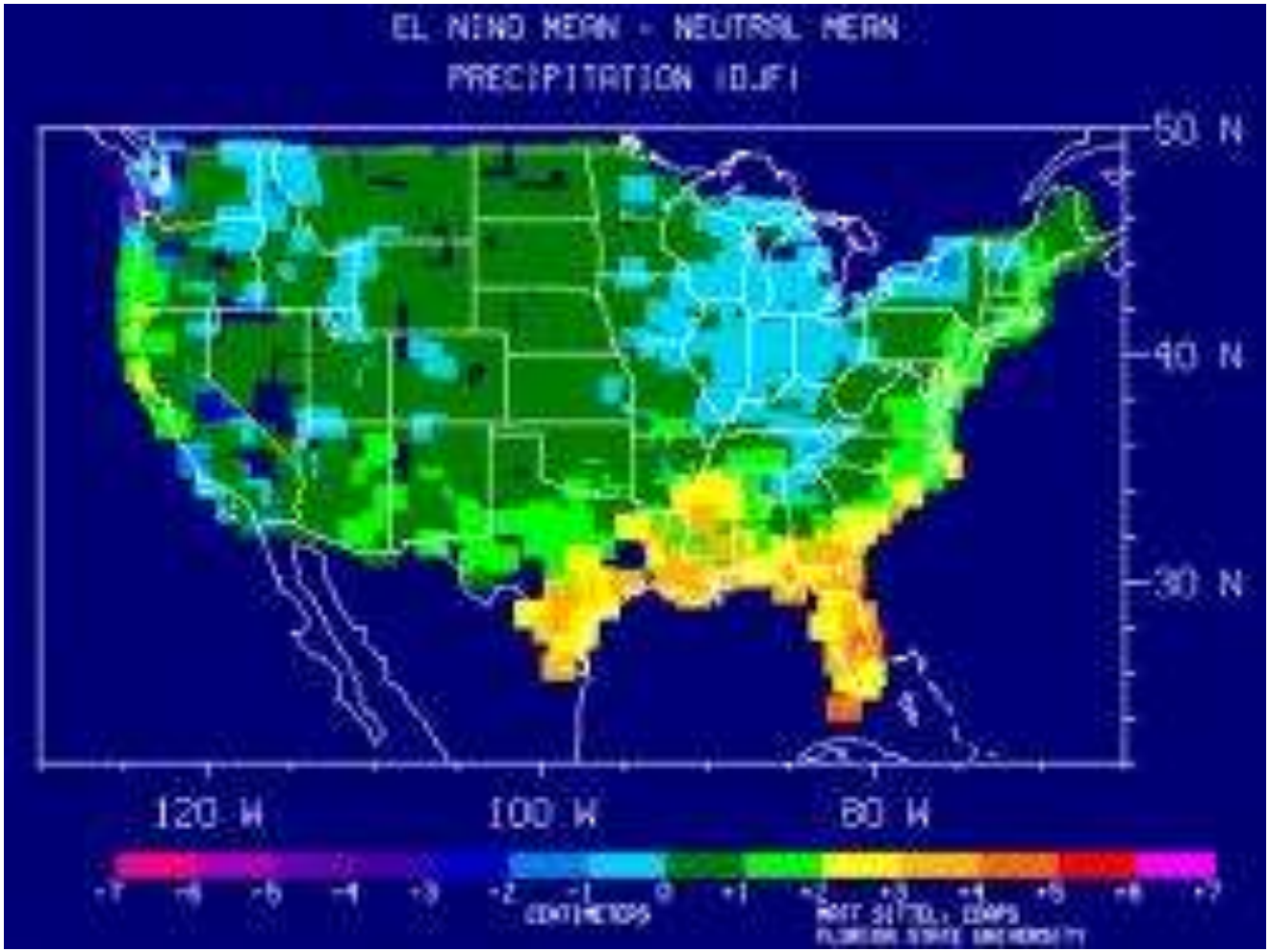


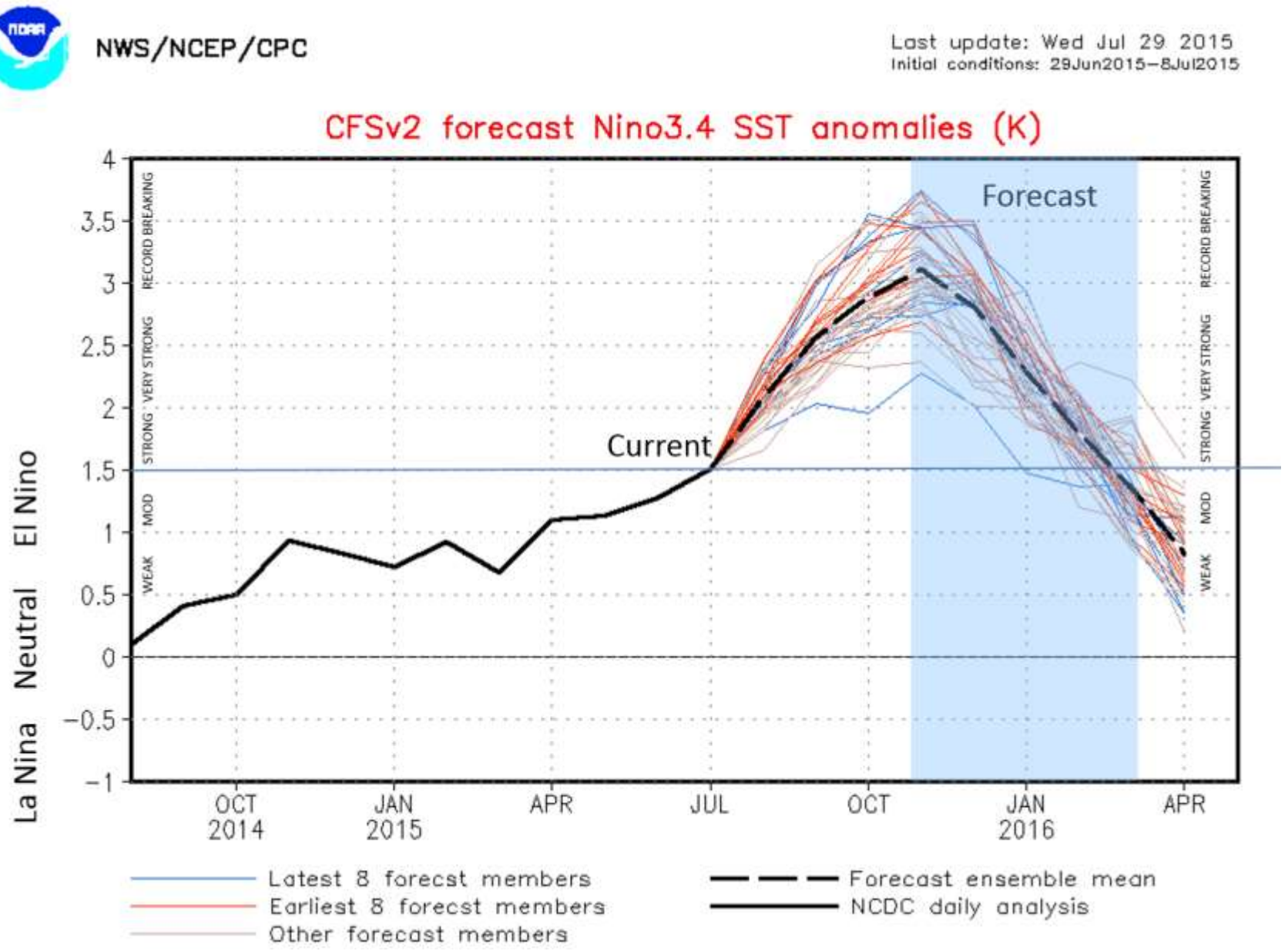
http://www.cnn.com/WEATHER/9708/20/el.nino/effects.lg.jpg

NOAA PMEL predictions for winter El Nino changes in temperatures based on a statistical analysis of data.

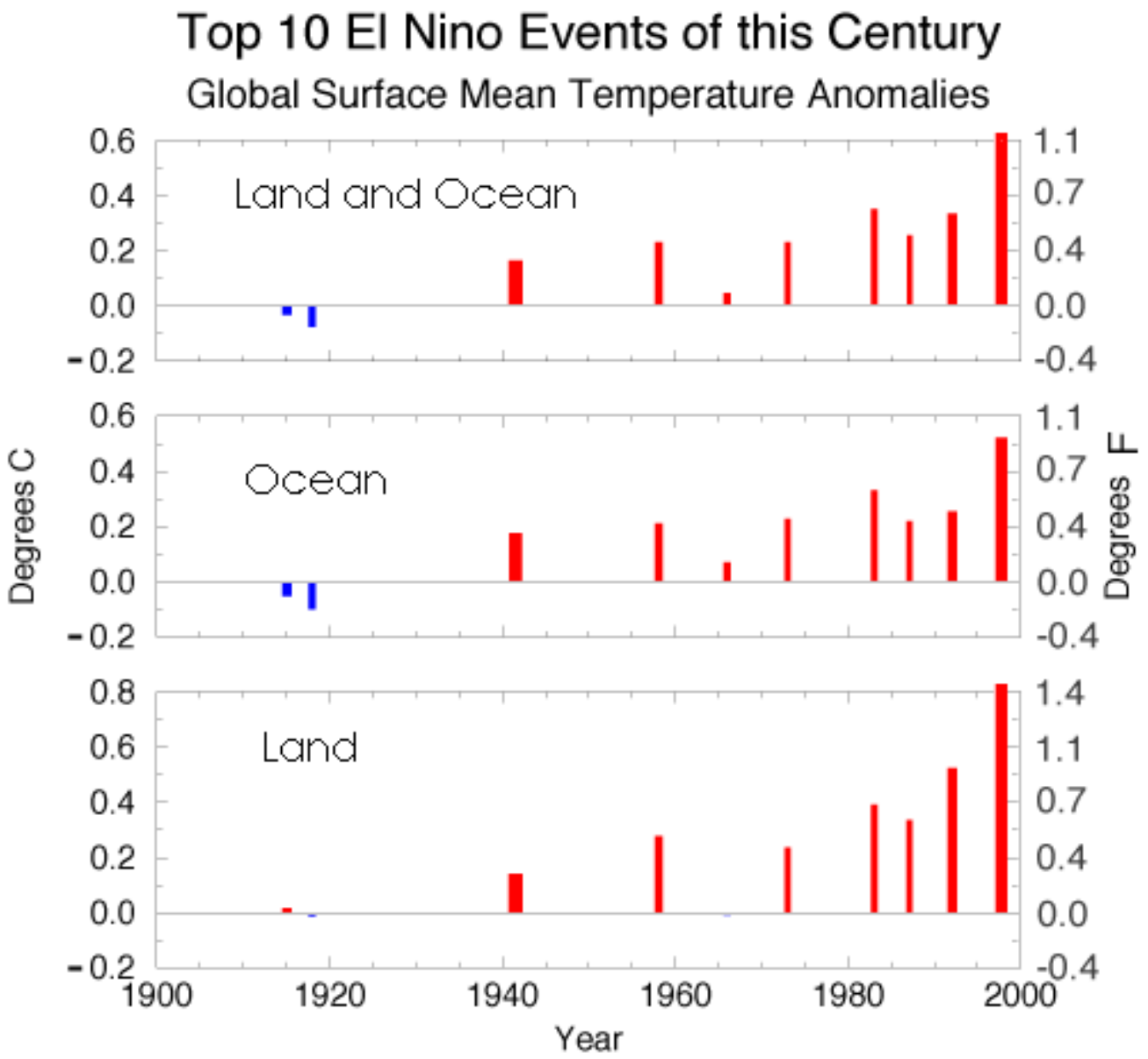


NOAA PMEL predictions for winter El Nino changes in precipitation




NWS/NCEP/CPC
Last update: Wed Jul 29 2015
Initial conditions: 29Jun2015–8Jul2015
CFSv2 forecast Nino3.4 SST anomalies (K)
Forecast
Current
RECORD BREAKING
STRONG
VERY STRONG
MOD
WEAK
La Nina
Neutral
El Nino
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
OCT 2014
JAN 2015
APR
JUL
OCT
JAN 2016
APR
Latest 8 forecst members
Earliest 8 forecst members
Other forecast members
Forecast ensemble mean
NCDC daily analysis

Discuss 2 El Nino related trends in the later half of the century



La Nina

- Occurs when surface waters of the Pacific cool
- Often occurs after El Nino
- La Nina → increased number of hurricanes in the Atlantic and
- increased drought and Santa Ana Winds in California → wildfires

Summary

ENSO Alert System Status: La Niña Watch

ENSO-Neutral conditions are present.*

Equatorial sea surface temperatures (SSTs) are near-to-below average across the central and eastern Pacific Ocean.

La Niña conditions are favored (~55%-65%) during the Northern Hemisphere fall and winter 2017-18.*

* Note: These statements are updated once a month (2nd Thursday of each month) in association with the ENSO Diagnostics Discussion, which can be found by clicking here.

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf

Earth Science Review

Earth science

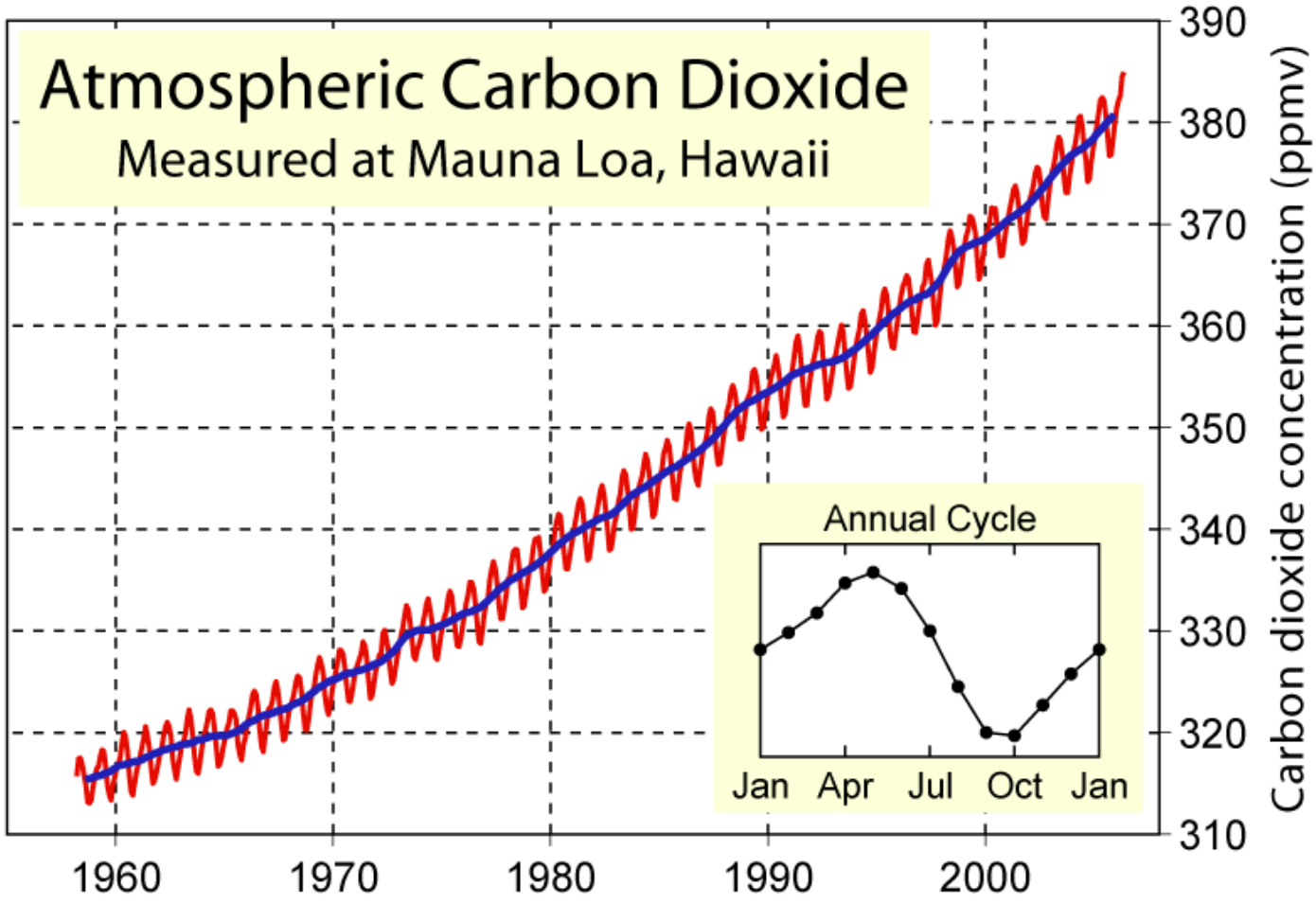
Carbon cycle

- Photosynthesis = pulls carbon out of atm. → dec. CO_2 and inc. O_2
- Respiration, decomposition, combustion = puts CO_2 back into atm.
- Anaerobic respiration = produces CH_4 (methane)
- CO_2 and CH_4 = Greenhouse gases →global warming

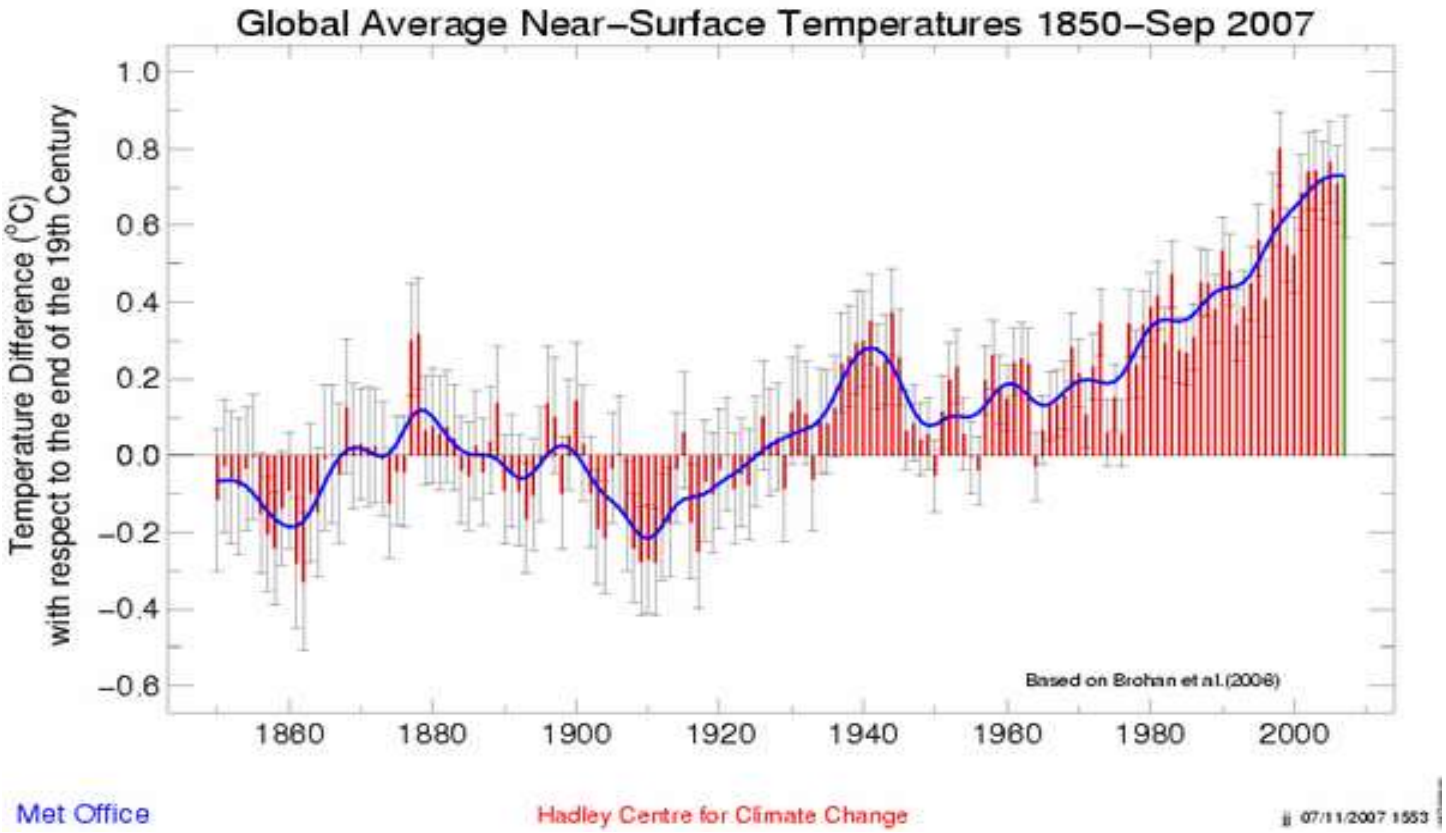
Human impact on carbon cycle during 20^{th} century

- Burn fossil fuels → inc. CO_2
- Cut down trees = remove carbon sinks → inc. CO_2

Annual CO_2 fluctuations due to seasonal differences in photosynthetic activity



Compare CO_2 inc. with mean global temperature inc. → support that inc. greenhouse gases → global warming



http://www.metoffice.gov.uk/research/hadleycentre/CR_data/Monthly/Hadplot_globe.gif

Global warming

- Rising sea levels due to thermal expansion of oceans
- Changing climates → changing habitats → inc. extinctions
- Inc. in severe storms
- Global warming → decreased snow → dec. in albedo → more heat absorbed → inc. warming

Nitrogen cycle

- Fixation = N_2 gas → ammonia (NH_3)
  - Anaerobic soil **bacteria** (ex: rhyzobium) and cyano**bacteria** in water, lightening, volcanoes, combustion
- Nitrification = NH_3 → NO_3 (nitrate) gives nitrifying **bacteria** energy
- Assimilation = plants absorb ammonium and nitrite ions → proteins
- Ammonification = decomposers (**bacteria**) convert nitrogenous wastes → ammonia
- Denitrification = **bacteria** reduce NH_3 → N_2 gas

Human Impact on Nitrogen cycle during the 20th century

- More than doubled amt of “fixed nitrogen”
- Production of and use of chemical fertilizers → inc. N in runoff → eutrophication
- Eutrophication = nutrient enrichment in aquatic env. → inc algae → inc decomposition → dec. O_2
- Burning fossil fuels → inc in Nitrogen oxides (No_x)
- NO_x → photochemical smog, acid rain, ozone depletion
- NO_x = greenhouse gases → global warming

Phosphorus Cycle

- Has no gaseous phase
- Phosphorus is limiting in many ecosystems because it forms stable insoluble compounds in most environments.
- Erodes from rocks, dissolved in water absorbed by plants → ATP and DNA
- Animals excrete phosphorus wastes (ex: guano) and decomposers → phosphate
- Runs off into oceans → deposits become part of sea floor where it remains for years

Human Impact on the Phosphorus Cycle

- Accelerate the loss of phosphorus from the land.
- Clearcutting, large scale agriculture removes phosphorus from soil → runoff into water
- Fertilizer runoff and sewage effluent → eutrophication → algal growth → inc. decomposition → dec. O_2

Sulfur Cycle

- Many gaseous forms but most sulfur is in rocks
- Released by volcanoes, anaerobic decomposition (swamps, bogs, tidal flats), marine algae, burning of fossil fuels (esp. coal)

Human Impacts on Sulfur Cycle

- Burning fossil fuels (esp. coal), refining petroleum, and smelting → SO_2 → acid rain
- Acid rain damages trees and aquatic life

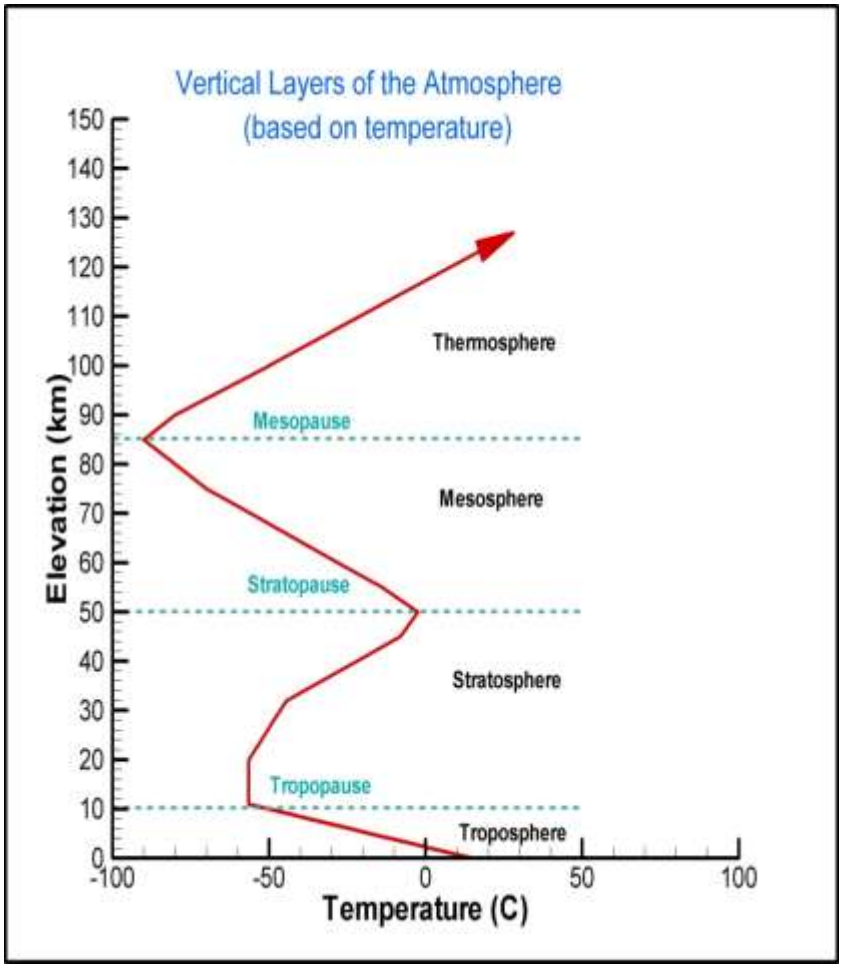
- Remember Sulfur Compounds → Acids

Earth and rocks

- Fe most abundant in core
- O most abundant in crust (Si = 2nd)
- Earthquakes and volcanoes occur at plate boundaries
- Volcanoes → lots of ash → dec. sun → global cooling
- Volcanoes → N and S → acid rain
- Earthquakes measured on Richter scale and moment of magnitude scale.
- Earthquakes in ocean → tsunami's (massive waves

Atmosphere

N_2	78.084%
O_2	20.946%
Argon	0.9342%
CO_2	0.0381%
Water Vapor	about 1%
other	0.002%



Note: O_2 is a product of photosynthesis

Layers of atmosphere

- Trophosphere = where whether happens, most molecules here
- Stratosphere = ozone layer
- Mesosphere = coldest layer
- Thermosphere = ions → northern lights
- Exosphere = lowest pressure

Ozone

- Ozone layer in stratosphere absorbs UV rays
- CFC's (**Cl, F, Br** compounds - in refrigerants → Ozone depletion → inc. skin cancer, cataracts and decreased photosynthesis
- Ozone levels lowest during Antarctic Spring (Oct.)
- **Montreal Protocol** = global effort to dec. CFC's
- Ozone in trophosphere = component of photochemical smog → dec. visibility, harms plants, → respiratory problems and global warming

Weather and climates

- Albedo = reflective power (glass, ice and snow = hi) (plants and black pavement = lo)
- Polar regions radiate more heat than they get but do not get progressively colder due to transport of heat through atmosphere and oceans
- Tropics = equator = warm (receive more direct solar radiation)
- 23° tilt and revolution → seasons
- Temp differences and coriolis effect → weather
- Know the prevailing winds (pg119)

Oceans (covers most of the planet)

- Only 2.5% water on earth = freshwater,
- Prevailing winds → currents = gyres (in N hemisphere)(in S)
- Cold = dense = saltier = sinks → vertical mixing → upwelling = bring nutrients to surface
- Ocean conveyor belt → warms Europe
- Global warming → thermal expansion of ocean→ changes climates

El Nino Southern Oscillation (ENSO)

- Periodic warming of Tropical Pacific
- → weak trade winds → decreased upwelling → fewer nutrients
- Warmer water and dec. upwelling = good for some species (ex: shrimp) bad for others (ex: anchovies)
- → change in weather patterns (heavy snow in W and ice storms in E

La Nina

- Follows El Nino = Cooler tropical Pacific surface waters → stronger trade winds → more upwelling = good for fisheries
- La Nino → stronger Santa Ana winds in Calif. → drought and wind → wildfires
- Stronger hurricanes in Atlantic

Tornadoes

- Most in US
- Measured on Fujita Scale

Tropical Cyclones

= Hurricanes in Atlantic, typhoons in Pacific, and cyclones in the Indian Ocean

→ massive effects on coastal ecocystems