Ecosystems Overview

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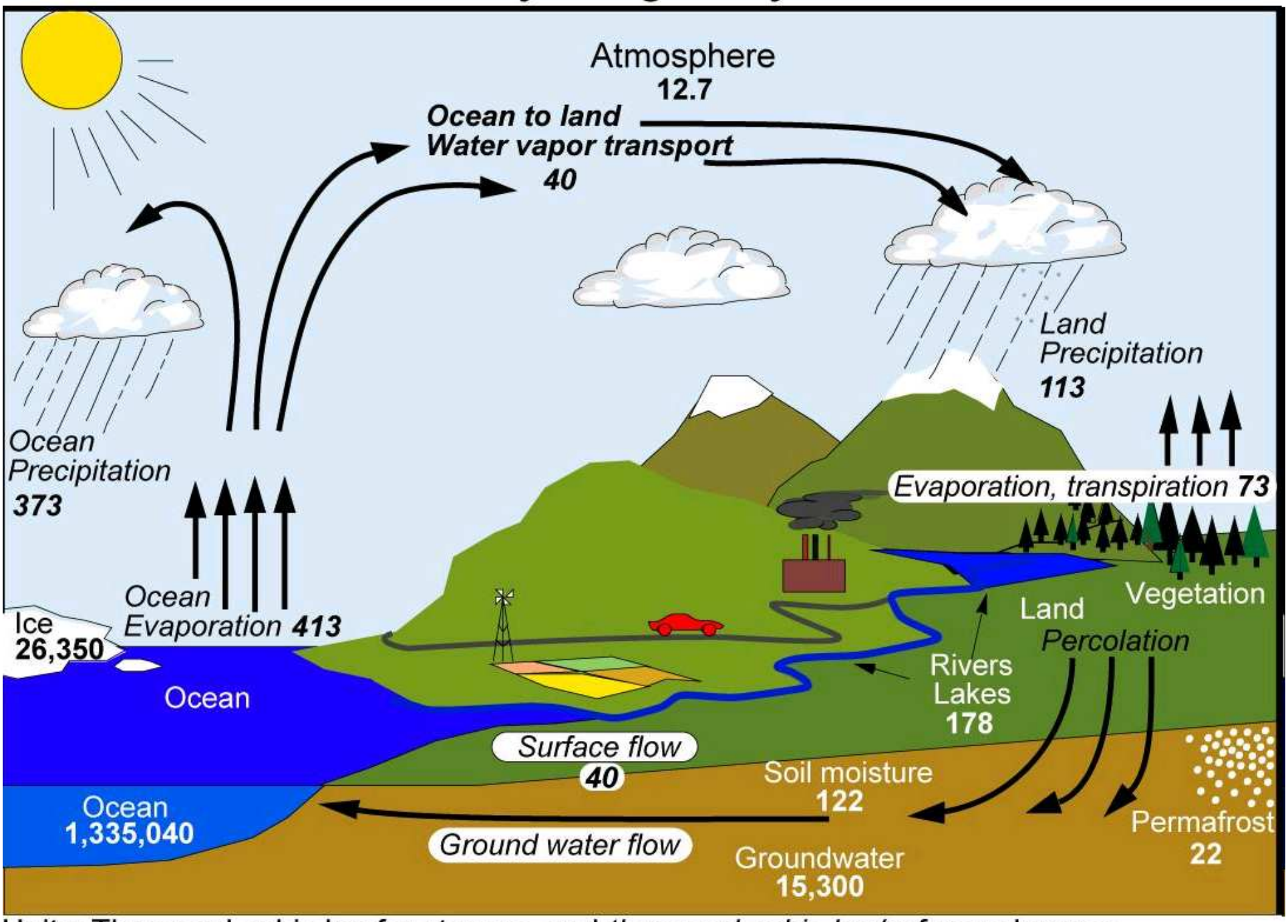
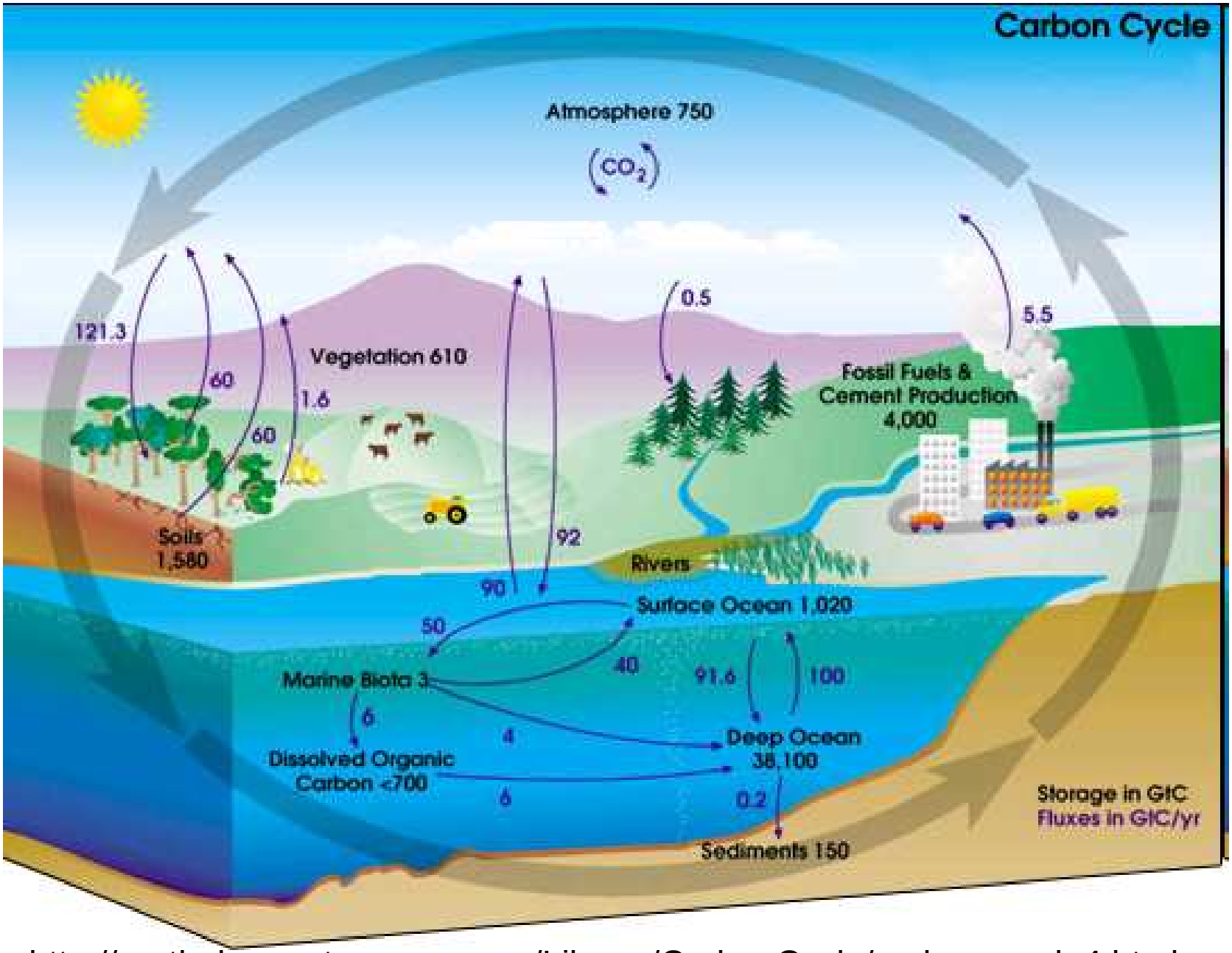
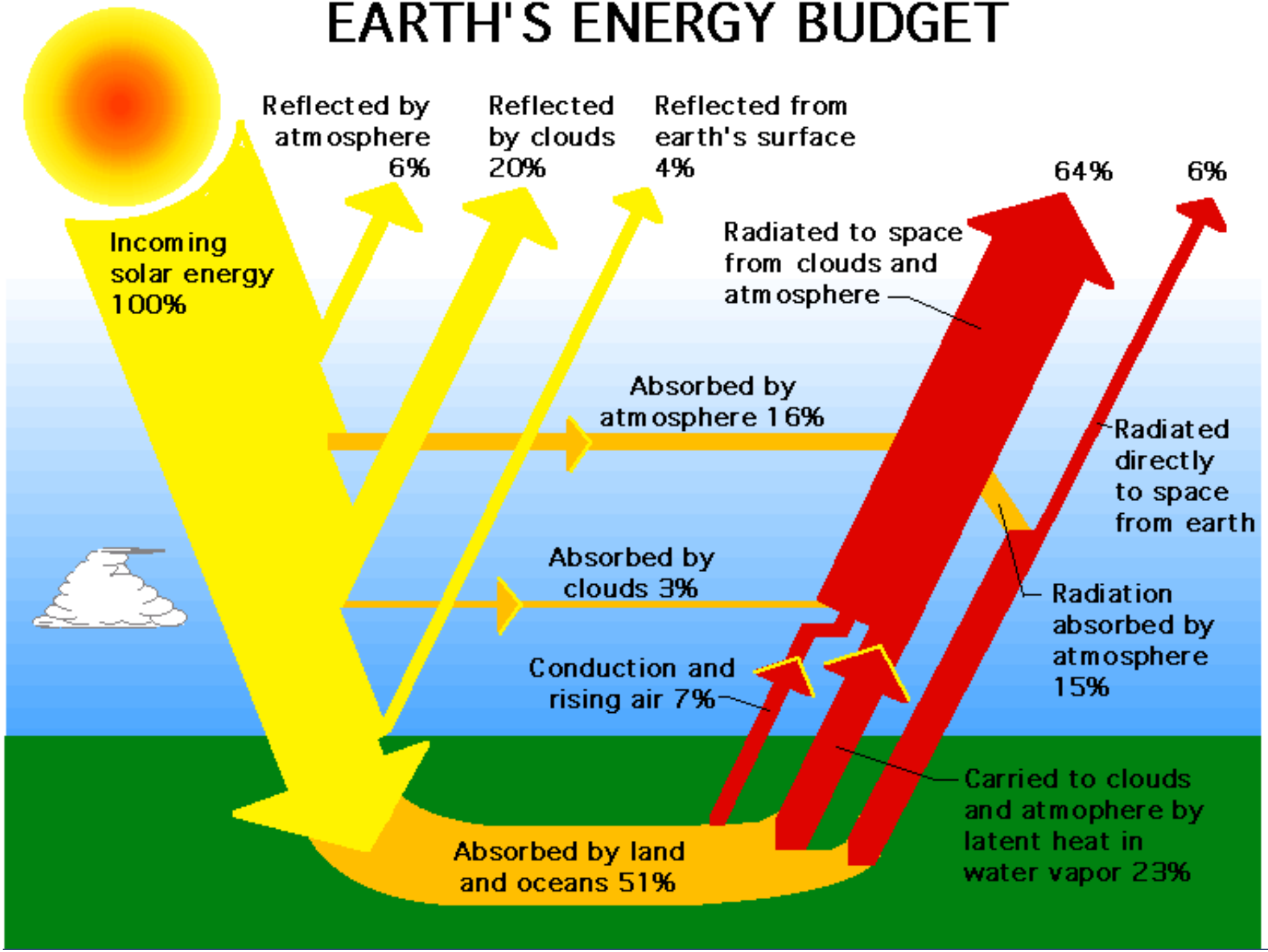
Hydrological Cycle



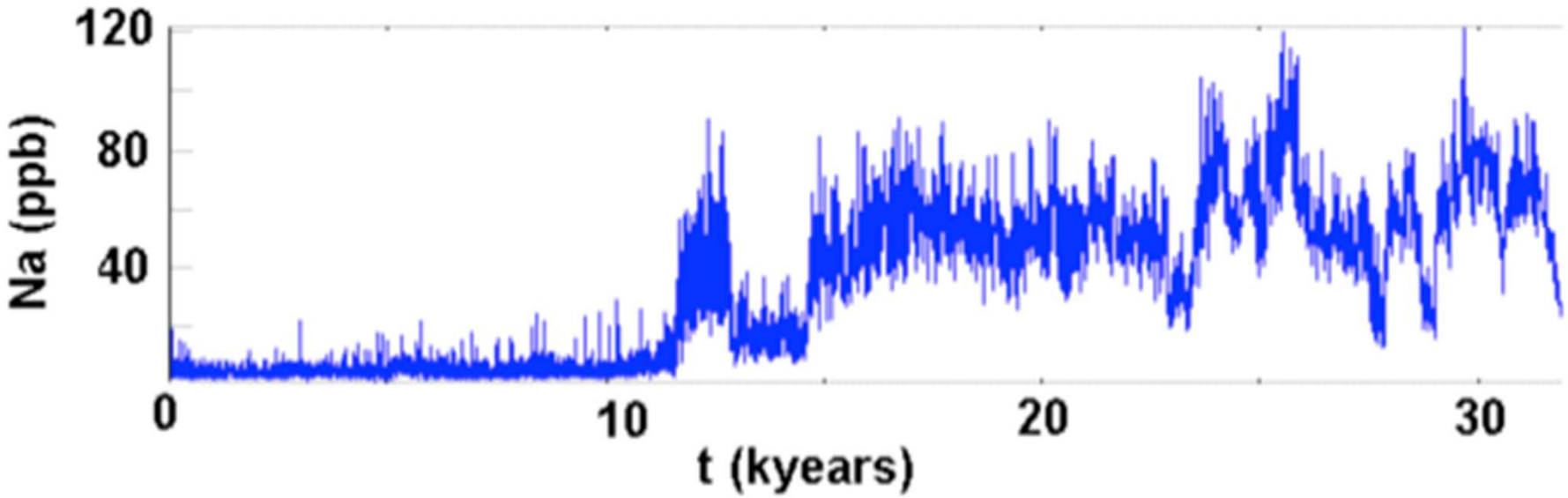


http://earthobservatory.nasa.gov/Library/CarbonCycle/carbon_cycle4.html

EARTH'S ENERGY BUDGET

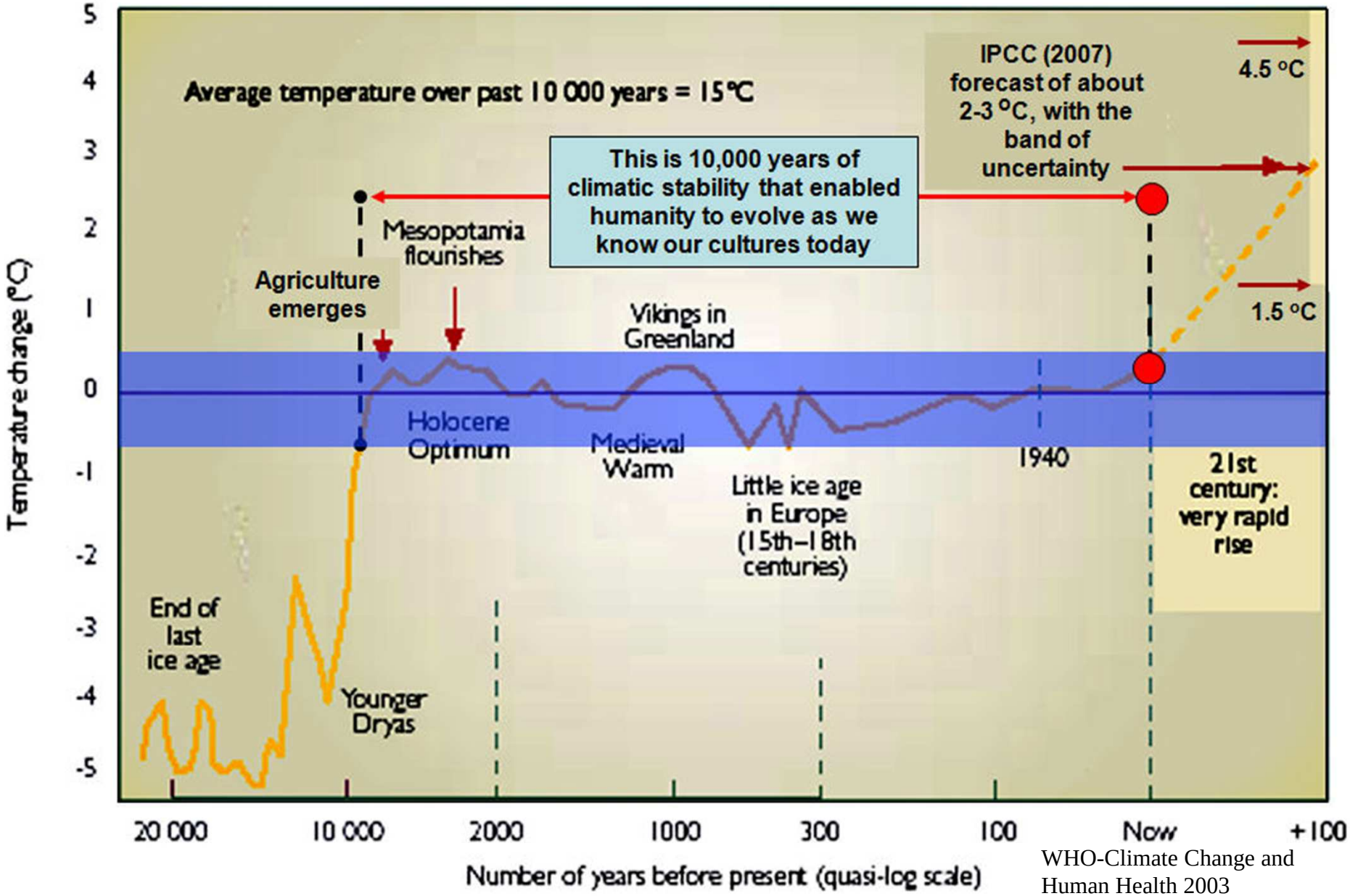


Climate Stability



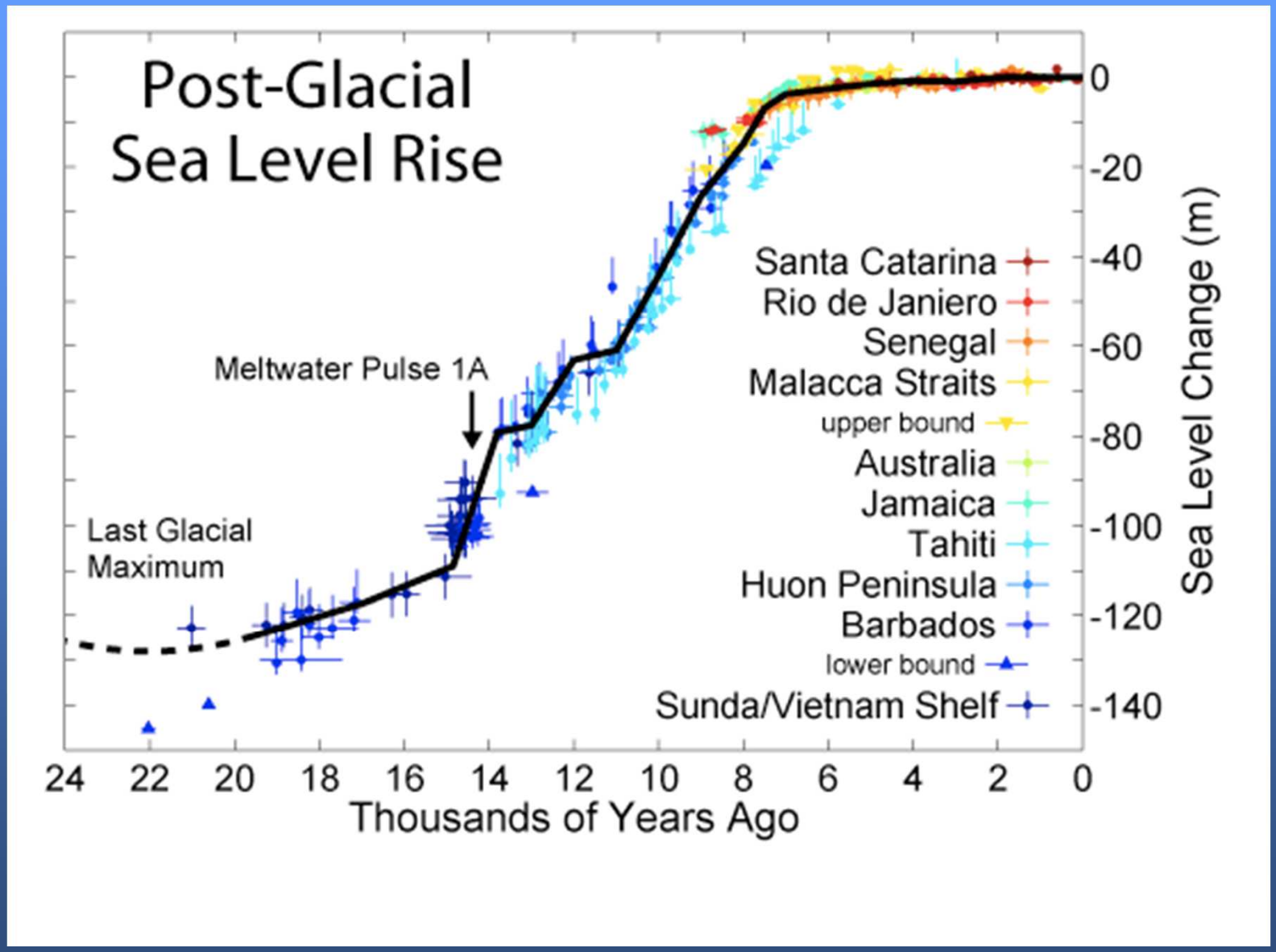
Sodium concentration in Greenland ice core

Holocene Temperature Range



WHO-Climate Change and Human Health 2003

Sea Level Rise



Plots by Robert A. Rohde for
Global Warming Art: http://www.globalwarmingart.com/

Climate Stability is a Key Factor

In Development of Agriculture and Complex Societies

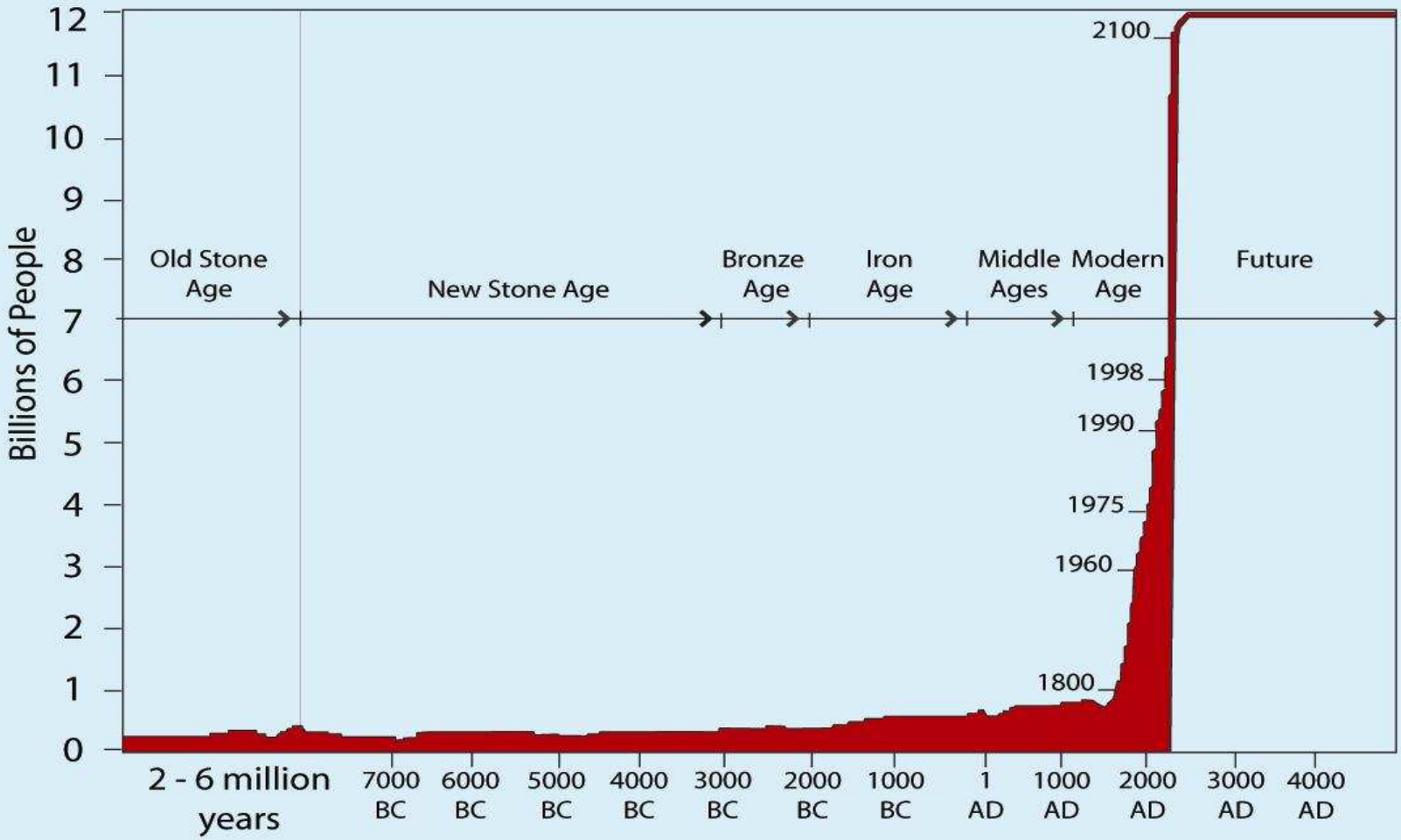
•The stable climate at the end of the Younger Dryas ~11,570 years ago was new to humans

• Long term stability allowed multiple independent agricultures and animal domestications to develop (Piperno & Pearsall, Academic, 1998; Feynman & Ruzmaikin, Climate Change, 2007)

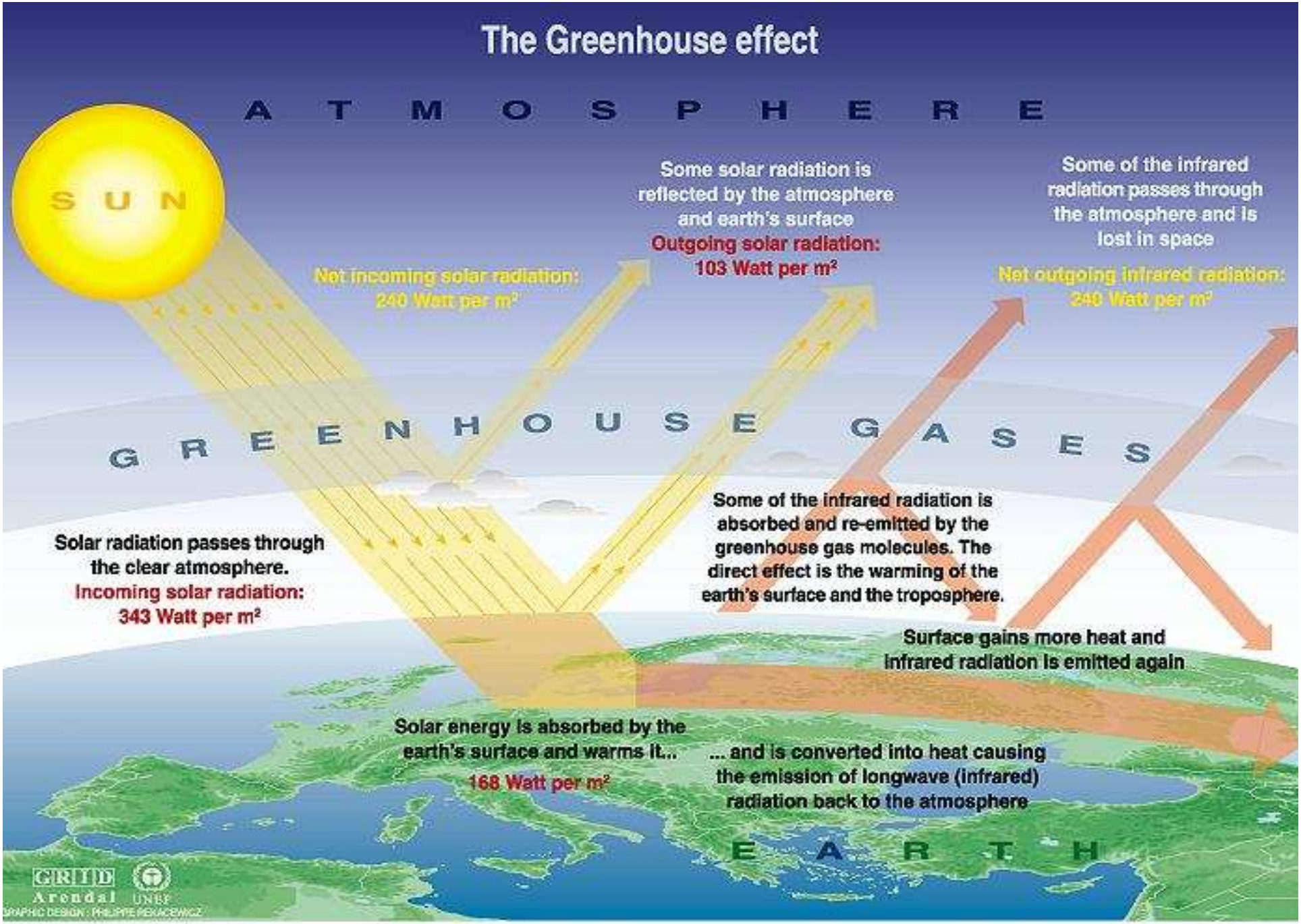
• Agriculture and complex societies seem to take ~1000 years of stability to get organized

Place	Species	Starting (ybp)
Levant	wheat, legumes, sheep	10,500
China	rice, millet, pig, silkworm	9,500
Meso-america	maize, beans, squash, turkey	9,000
Andes & Amazonia	squash and gourds	10,000
Eastern US	sunflower, goosefoot	by 4,500

World Population Growth through History

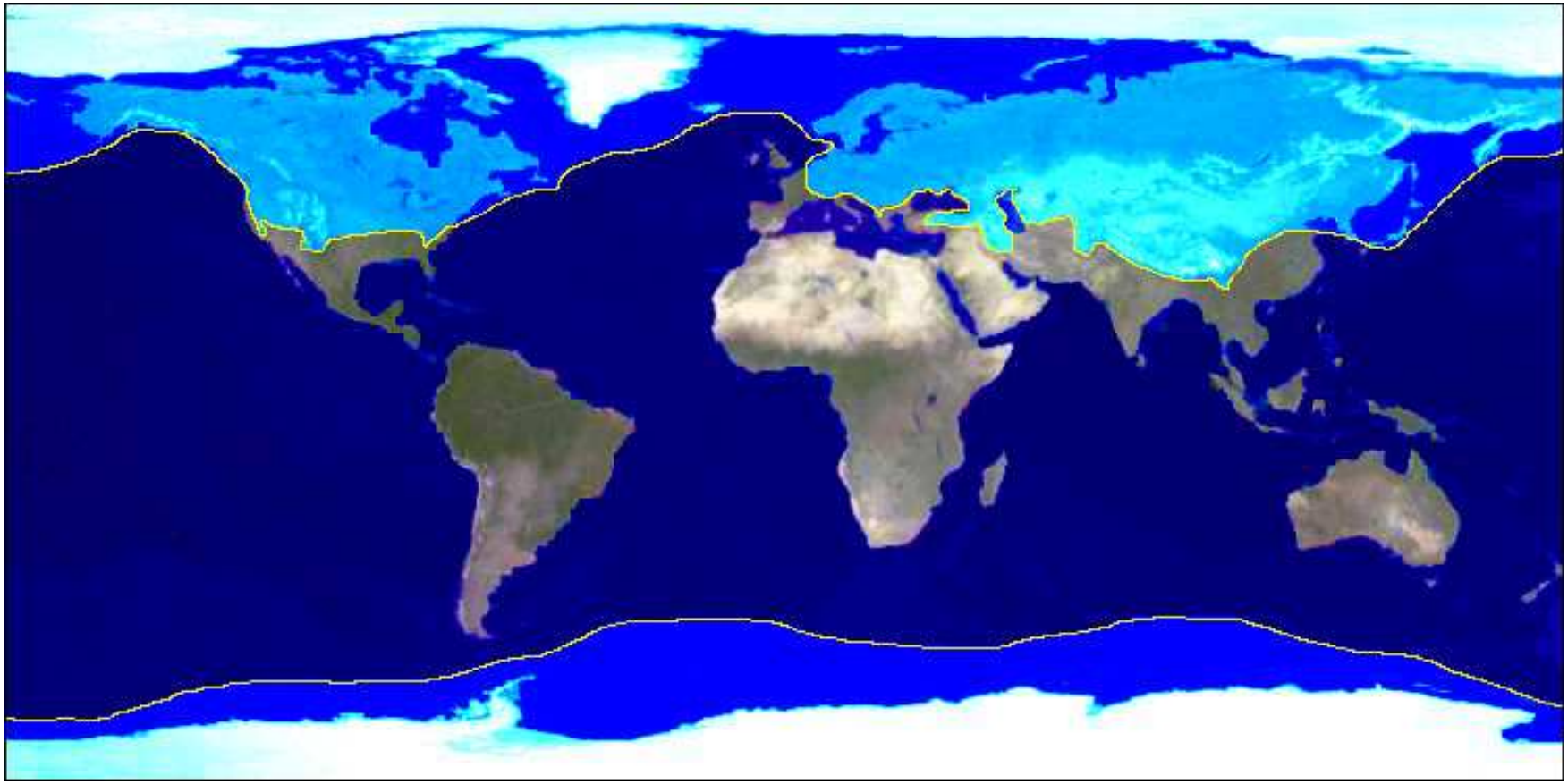


SOURCE: "Population: A Lively Introduction," Joseph A. McFall, Jr., Population Bulletin, Volume 46, Number 2, October, 1991, pages 1-43, Population Reference Bureau, Washington, D.C.



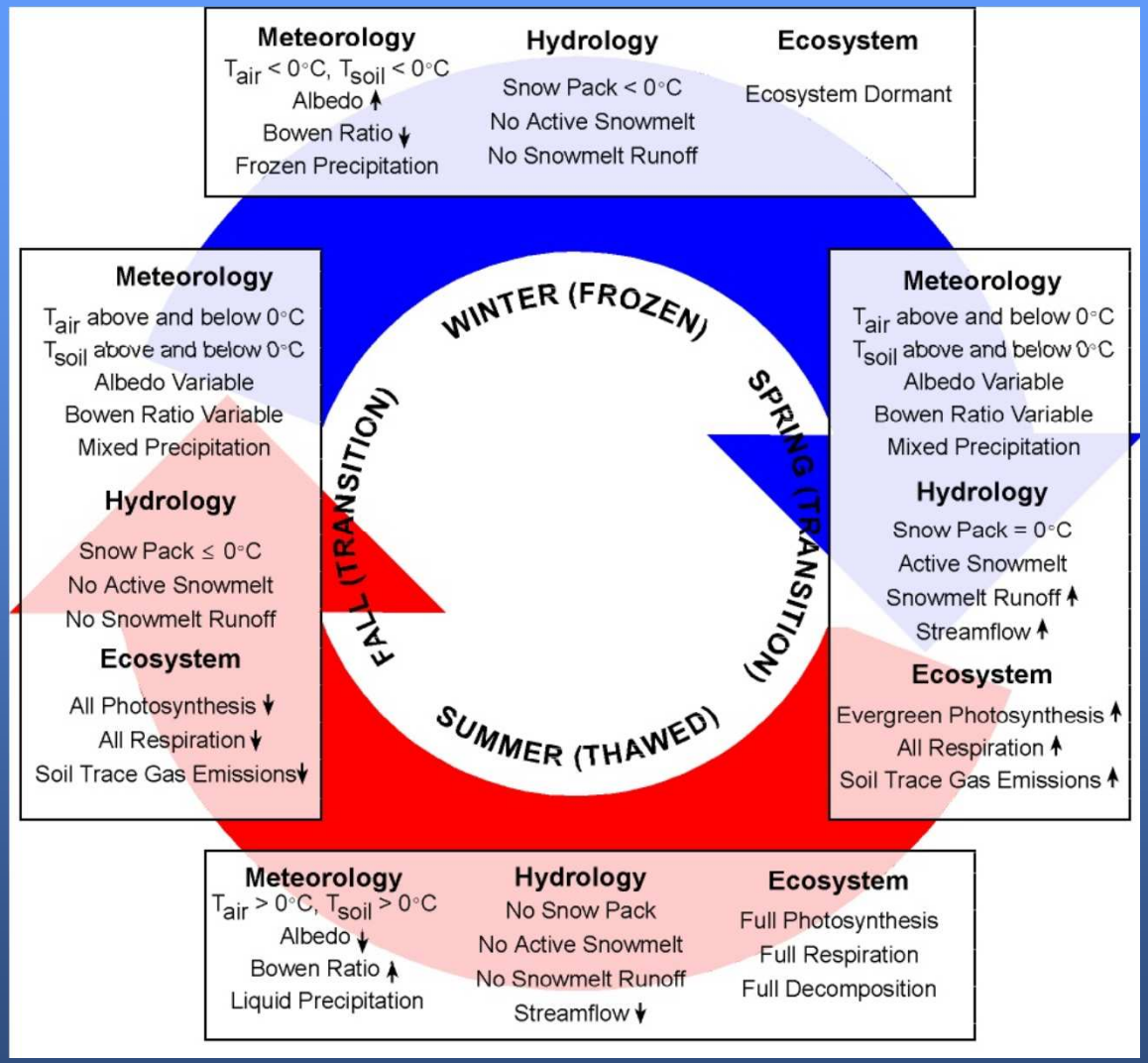
Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

The Cryosphere



Approximate distribution of frost and ice effects. All land areas shaded light blue or white (north of the yellow line in the northern hemisphere, and Antarctica), and with elevations over 1000 m compose the terrestrial cryosphere. This demarcation is based on a 0□C mean temperature during the coldest month, approximately 0.25 m of frost penetration one year in ten, and 100 days of ice on navigable waterways (based on figure provided courtesy of ERDC-CRREL).

Importance of Freeze/Thaw



Conceptual diagram showing the general effects of freeze/thaw status and snow on meteorological, hydrological, and ecosystem processes throughout the year.

Ecosystem Fundamentals

- Ecosystem (abiotic factors and biotic)
- Symbiosis
- Communities
- Habitat
- Niche –
  - Competitive Exclusion
  - Resource Partitioning
  - Competition - intraspecific, interspecific
- Succession

Ecosystem

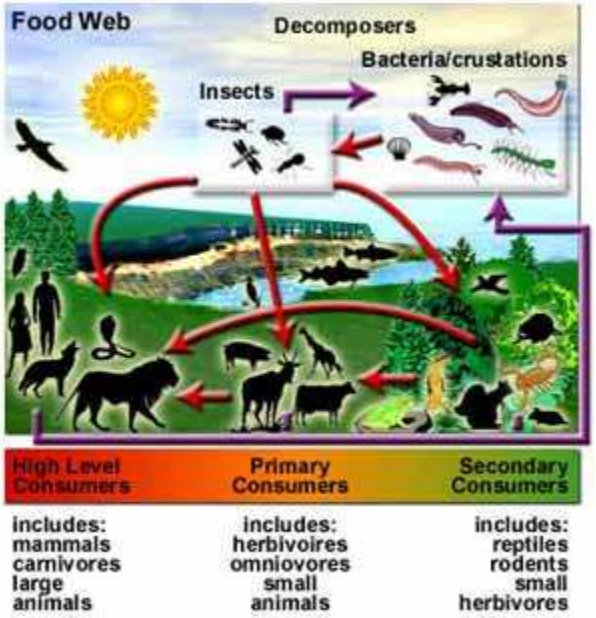
- Abiotic factors
- Non-living components
  - Temperature, Light, Nutrients, etc.
- Biotic factors – Living components
  - Autotrophs, heterotrophs, detritivores
- Abiotic and Biotic factors

Ecosystem defined

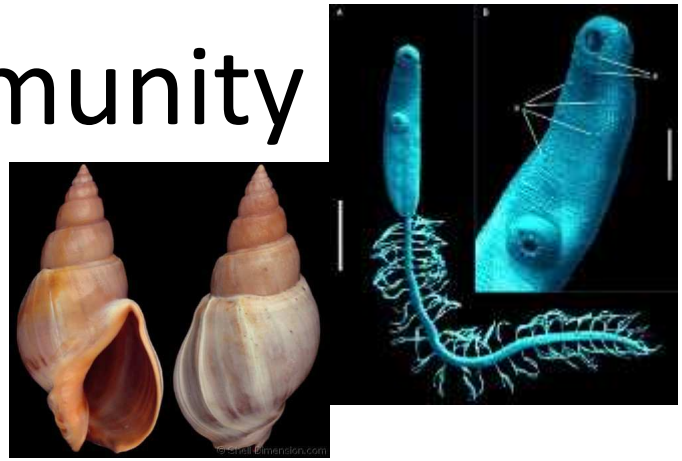
- Ecosystem – abiotic and biotic factors
- Biotic factors = Biological Community
  - all the populations of organisms living and interacting in a particular area
- Biological community and physical environment

Biological Community

- Often understood through food webs.
  - Problem?



Biological Community



- What about other types of interactions that are not depicted on food webs?
- Parasites – estimate that dramatically outnumber free-living diversity by about 50%!
- Visit http://dailyparasite.blogspot.com/ For more parasite details.

San José Gulf of Argentina. *Opechona sp.* uses the intertidal snail *Buccinanops cochlidium* as a first intermediate host. The parasite sets up shop within the snail's gonads where it starts cloning itself, eventually castrating the snail through destruction of the gonad tissue.

Symbiosis – close ecological relationship

- Coevolution - Two (or more) species affect each other's evolution reciprocally
  - Involves species that have a close ecological relationship
  - Examples include:
    - plant and pollinator
    - predators and prey
    - parasite and host
    - herbivore and plant
    - plant and seed disperser

Kinds of symbiosis

- Win-win: mutualism
  - Both partners benefit

Mutualism—oxpecker and ox

Kinds of symbiosis 2

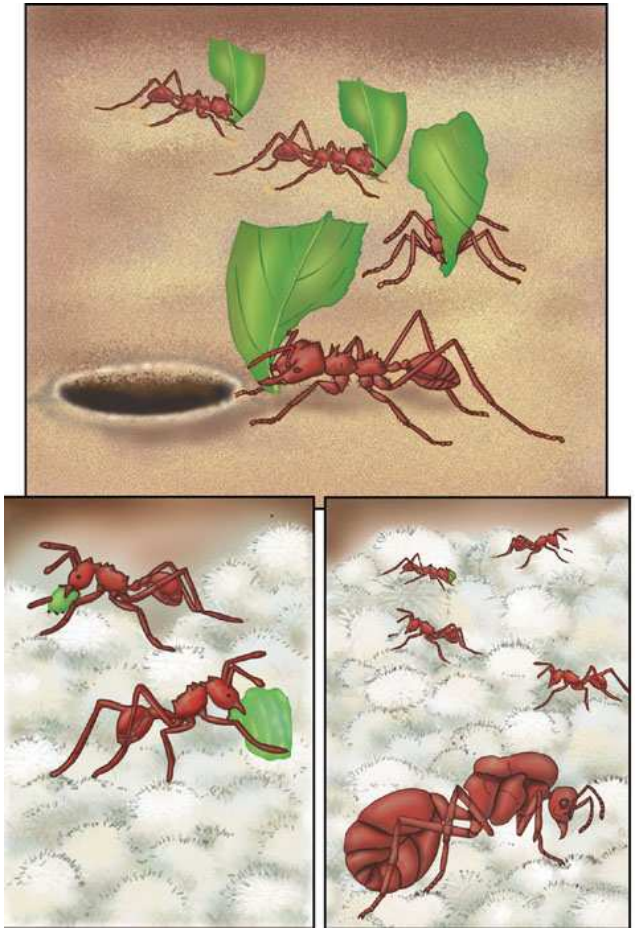
- Win-neutral: commensalism
  - One partner benefits, the other is not harmed
  - Some biologists argue true commensalism does not exist

Commensalism—clownfish and anemone

Kinds of symbiosis 3

- Win-definitely lose
  - Herbivory
  - Predation
  - Parasitism

- These symbioses sometimes result in arms races



Herbivory—ants and plants

- Above ground, ants cut small pieces of leaves and carry them to their underground nests where the chewed leaves enrich soil. Into this soil, bits of fungi grow and provide food for the ants.

Predation—tiger and deer

Other ecosystem components

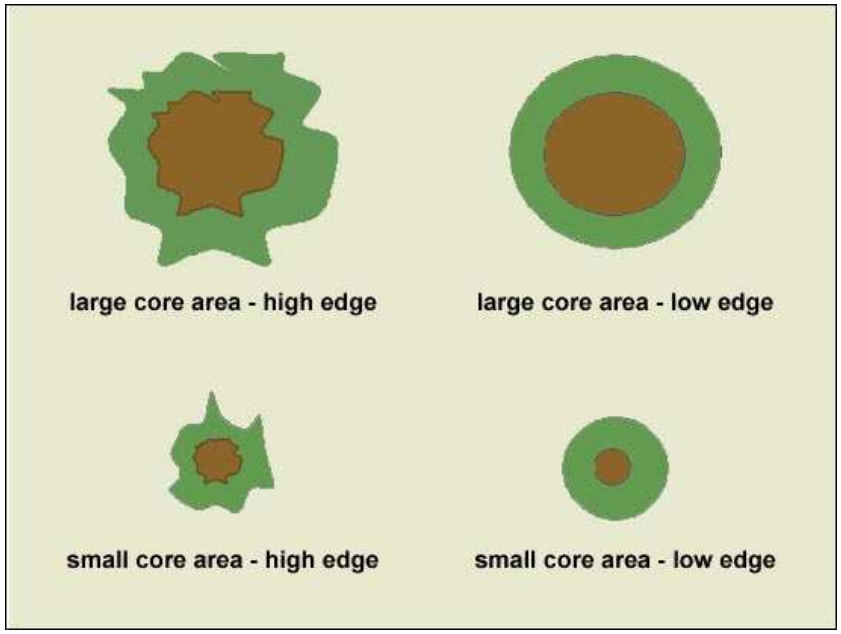
- Habitat – the place or set of environmental conditions in which a particular organism lives
  - Connection to physical environment

Edge Effect

- The boundary between one habitat and its neighbors.

Large block of forest
25% edge habitat
75% interior habitat

Small fragment
50% edge habitat
50% interior habitat



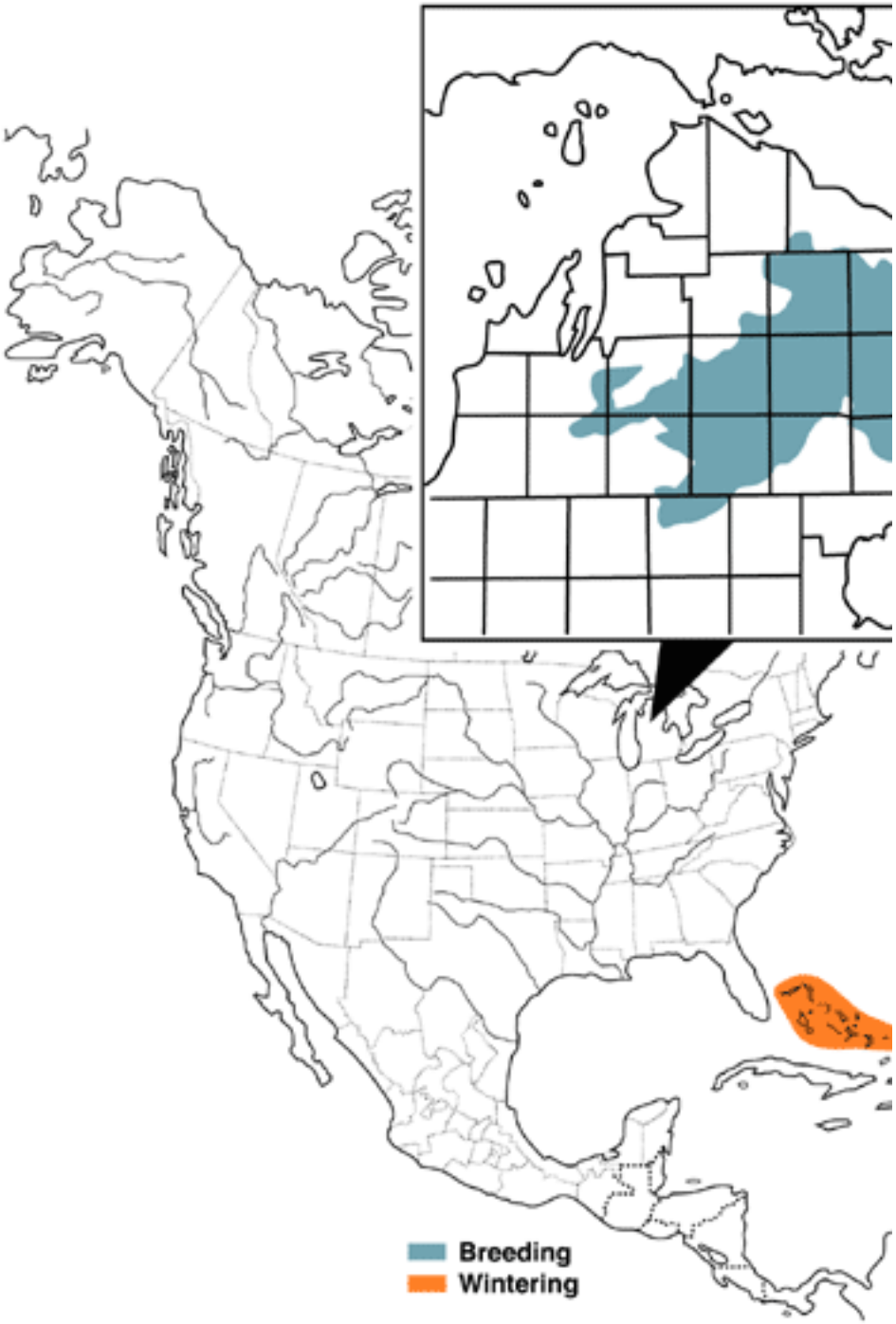
Some Species Adapted to Edge

- Poison Ivy
- Grasses
- Brown Headed Cowbirds

Kirtland’s Warbler and Brown Headed Cowbird

Young Jack Pine Forest

- Dense >160 acres of YOUNG Jack Pine – Upper Penninsula of Michigan.



Other ecosystem components

- Ecological niche – the role a species plays in a biological community
  - Generalists and specialists (fig/wasps)
- Competitive Exclusion
  - No two species can occupy the same ecological niche. The more efficient species will exclude the other.
- Resource Partitioning – niche evolution
  - Time (day and night – spiny mice, bats and swallows
  - Space/food

Competition

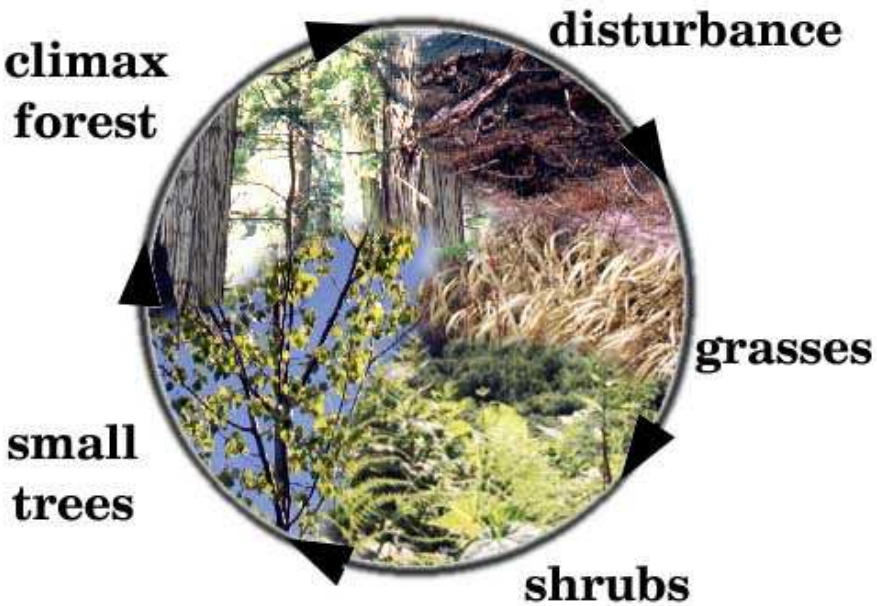
- Interspecific – between species

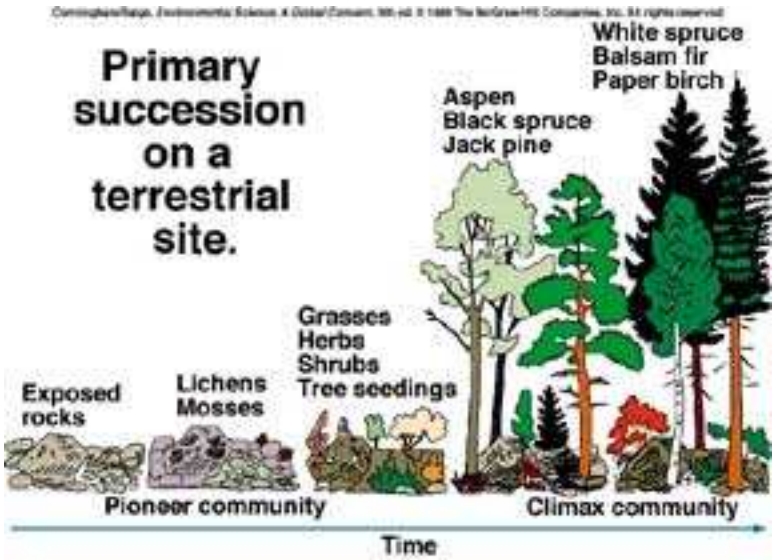
- Intraspecific – within species (natural selection)

Niche Disruption – Brown Anole Invasion Into Green Anole Habitat

Succession

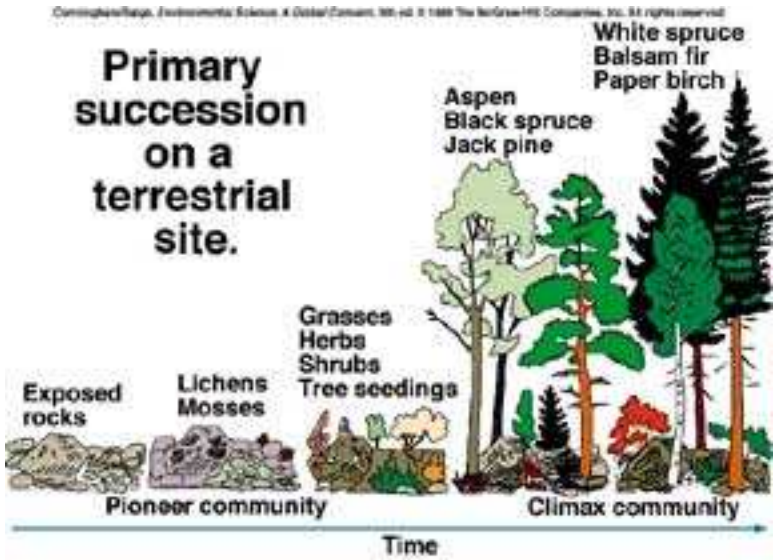
- Primary – no soil
  - glacier, volcano lava
- Secondary – disturbed community regrows
  - Old Field, Secondary Forest, Wildfires, Volcano
- Pioneers





Succession

- Jack Pine – Regrow with fire
- So the warbler story is not just a habitat fragmentation story, but a succession disruption story



Global Biomes

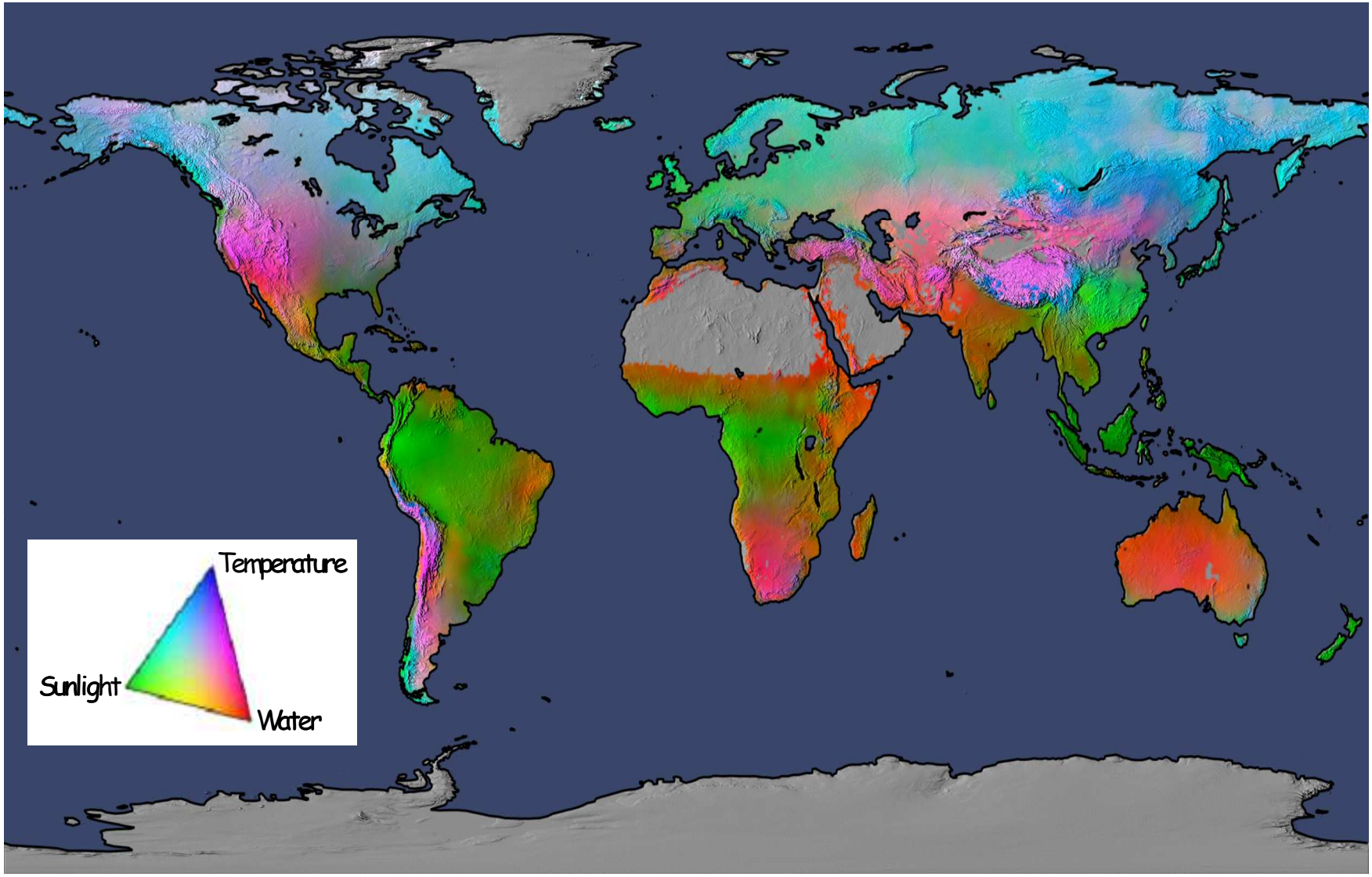
Major factors determining the distribution of terrestrial biomes:

- Latitude: Arctic, boreal, temperate, subtropical, tropical.
- Humidity: humid, semi-humid, semi-arid, and arid.
  - seasonal variation: e.g. rainfall
  - dry summer, wet winter: Mediterranean climate.
- Elevation: Similar to latitude

Fundamental classifications:

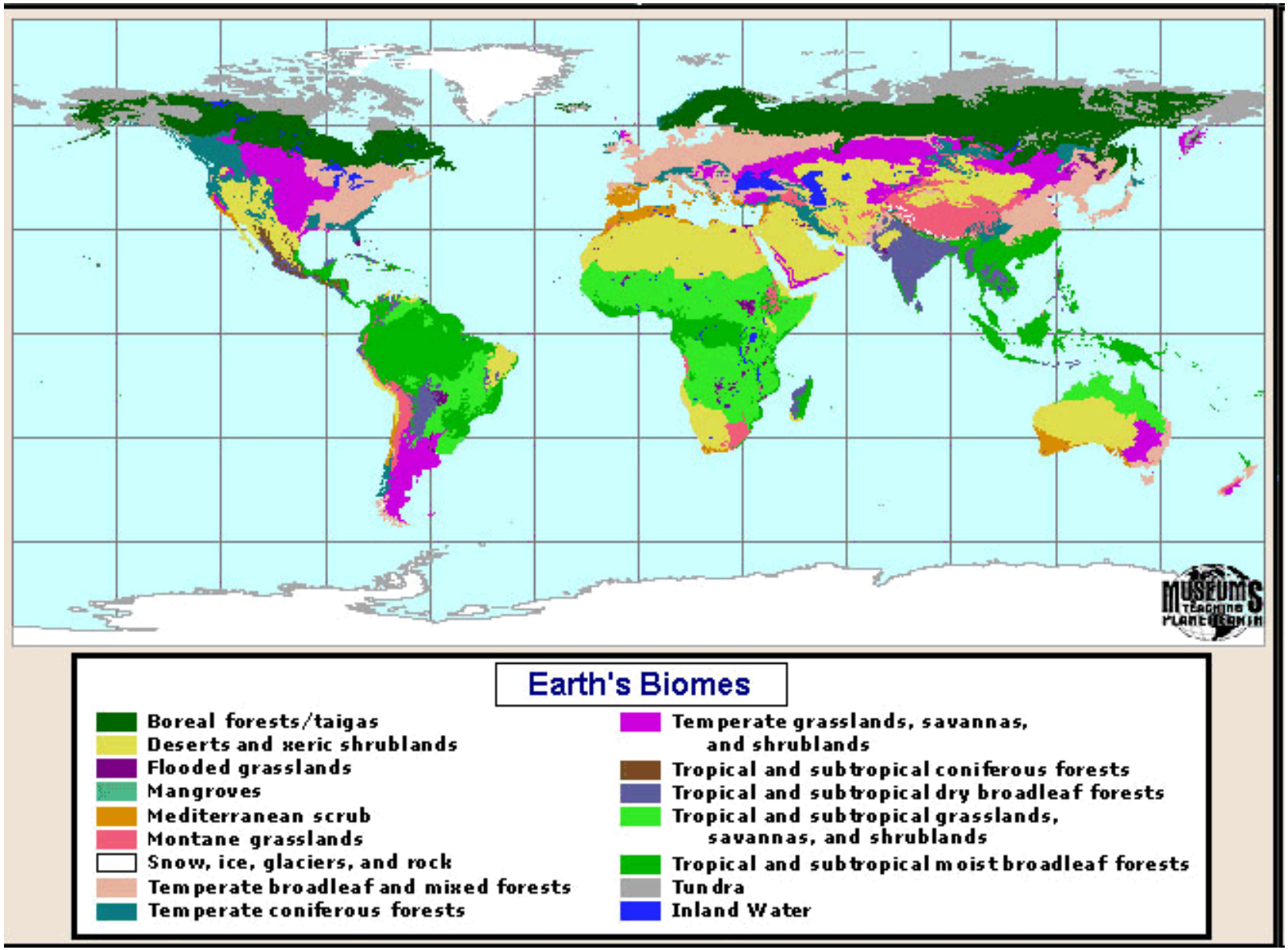
- Terrestrial (land) biomes
- Aquatic biomes (including Freshwater biomes and Marine biomes)

Potential Climate Limitations to Vegetation Growth

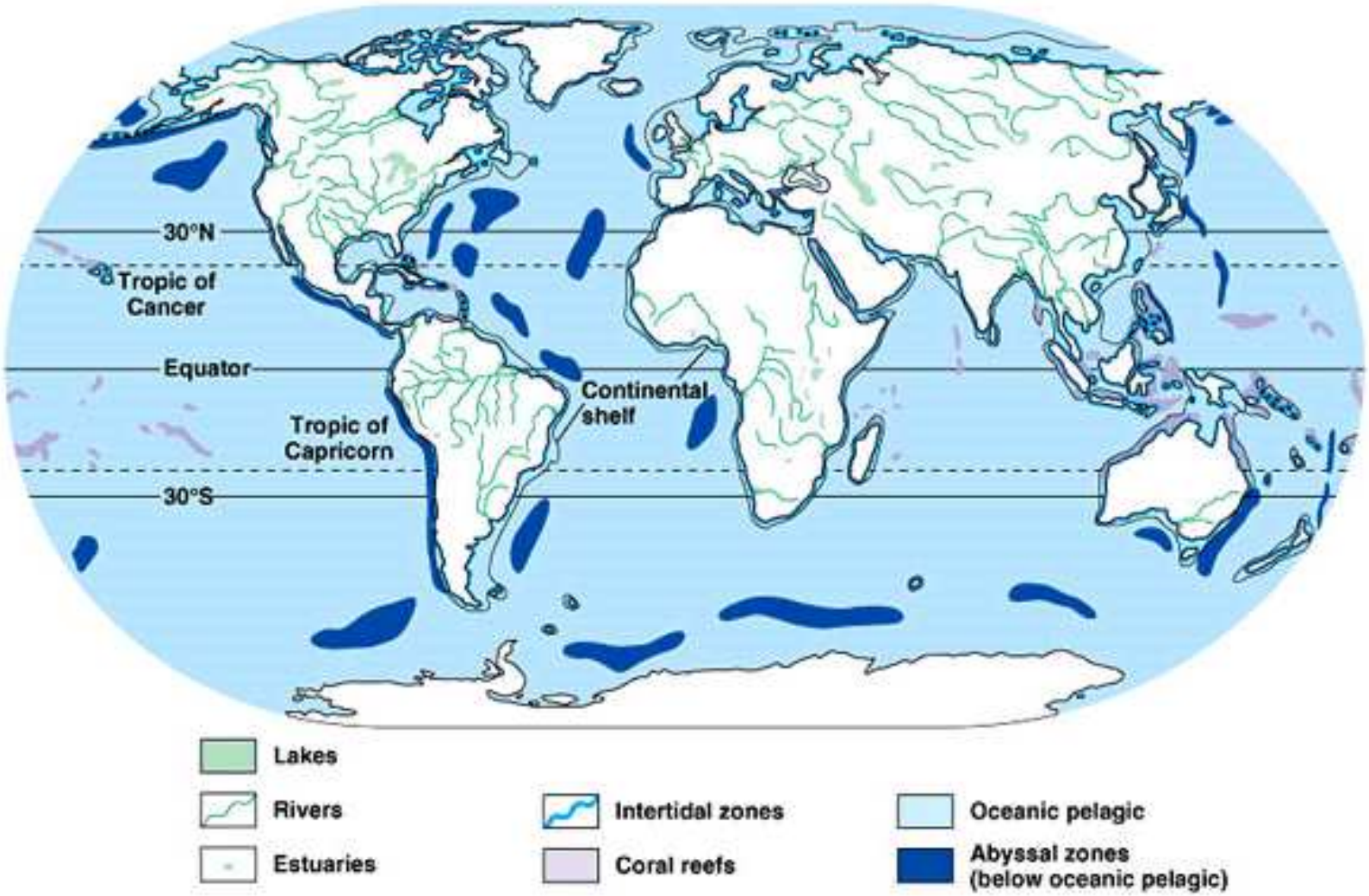


Nemani et al., *Science*, 2003

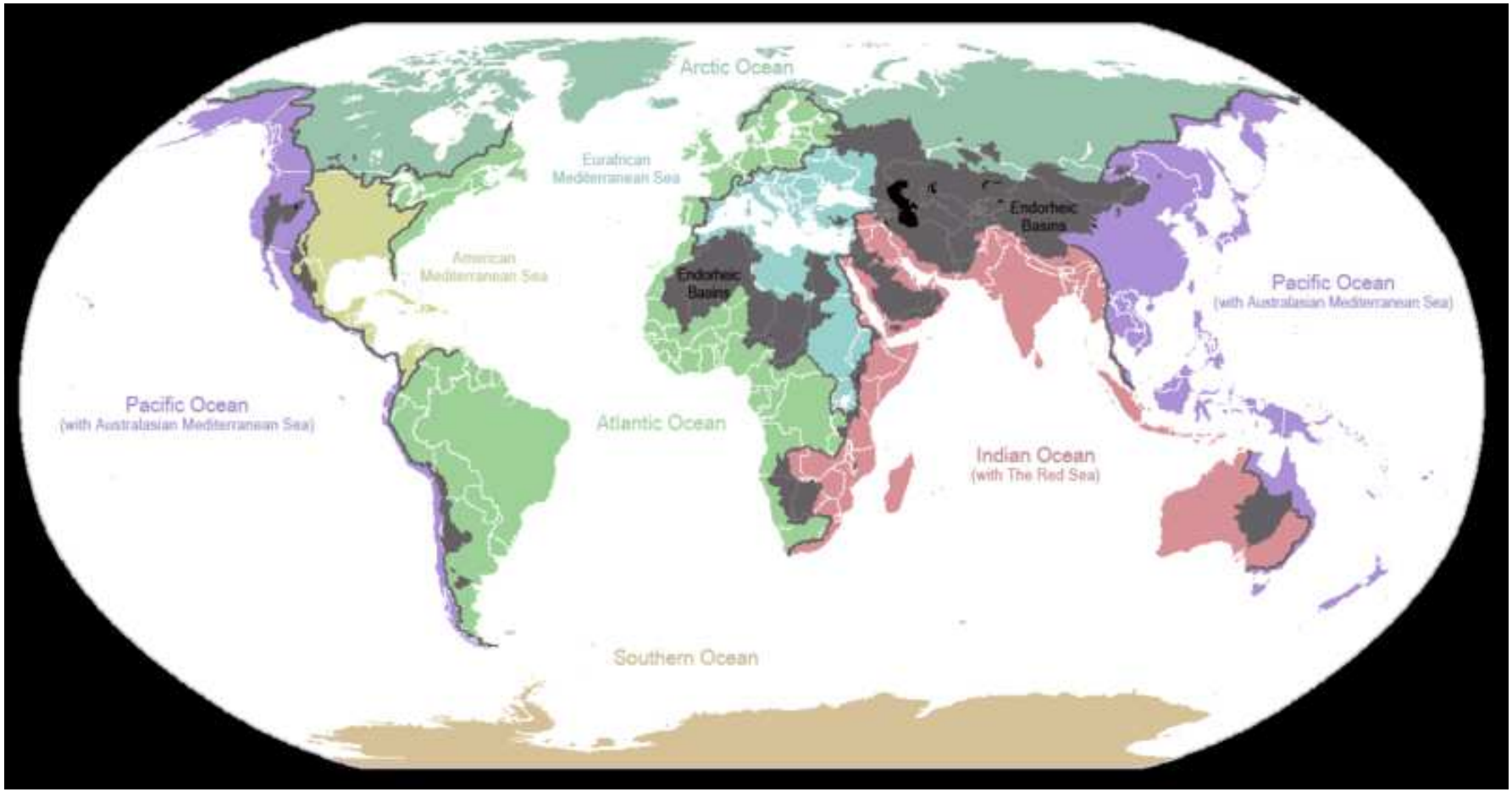
Earth's Terrestrial Biomes



Aquatic Biomes



Freshwater Biomes



WETLANDS

WHAT IS THE DIFFERENCE BETWEEN A SWAMP AND A MARSH?

A **SWAMP** is a wetland with woody plants like trees and often grows in freshwater.

A **MARSH** is a wetland with grasses, but no trees. It often grows in brackish (1000 mg/L) or even saltier water.

NEW JERSEY MEADOWLANDS: FROM SWAMP TO MARSH

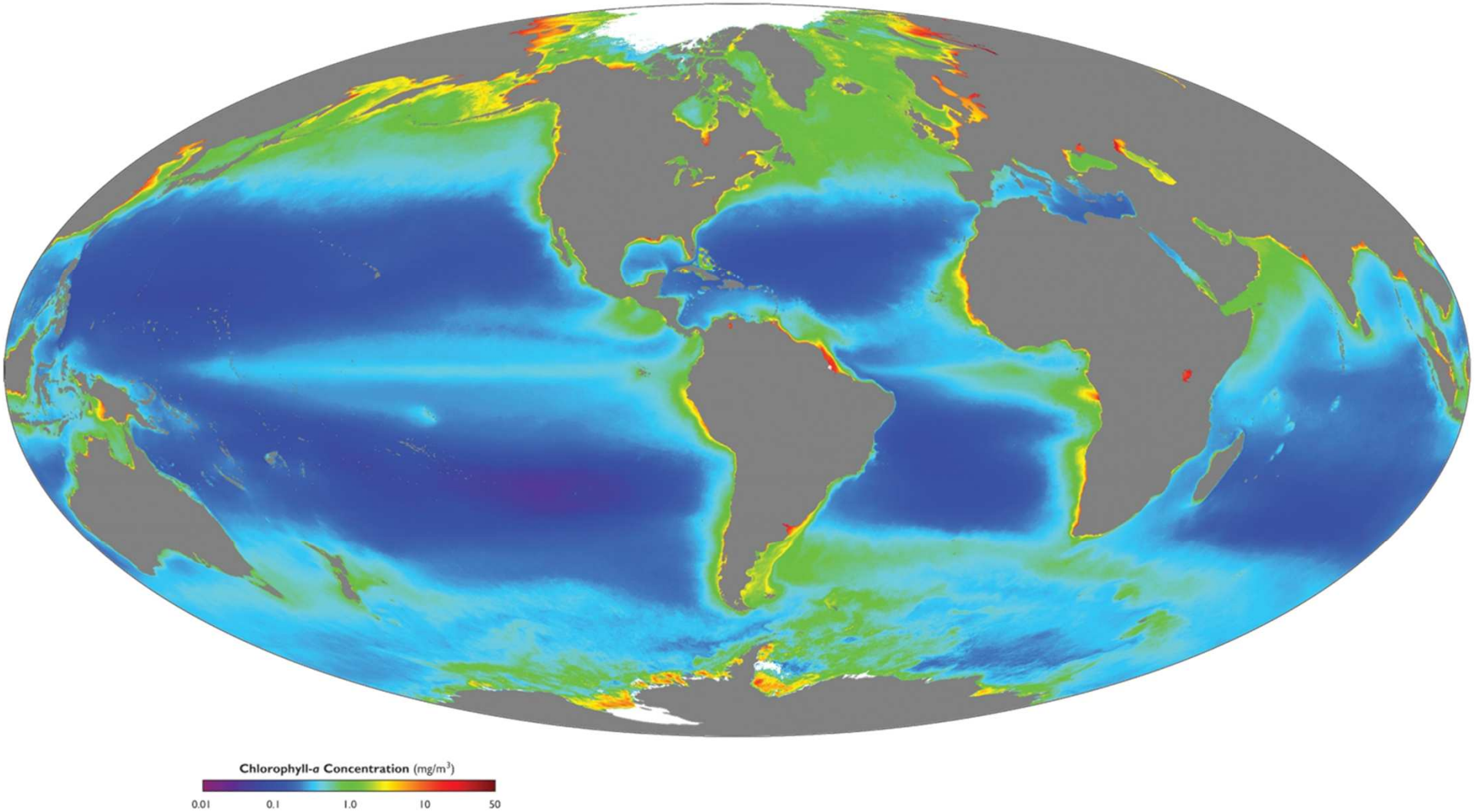
200 years ago—Cedar Tamarack Swamp

The New Jersey Meadowlands used to be filled with tall cedars and tamarack trees that grew in the wet swampy habitat. People cut them down, and they were also killed by SALT!

1922 to Today—Reedy Marsh

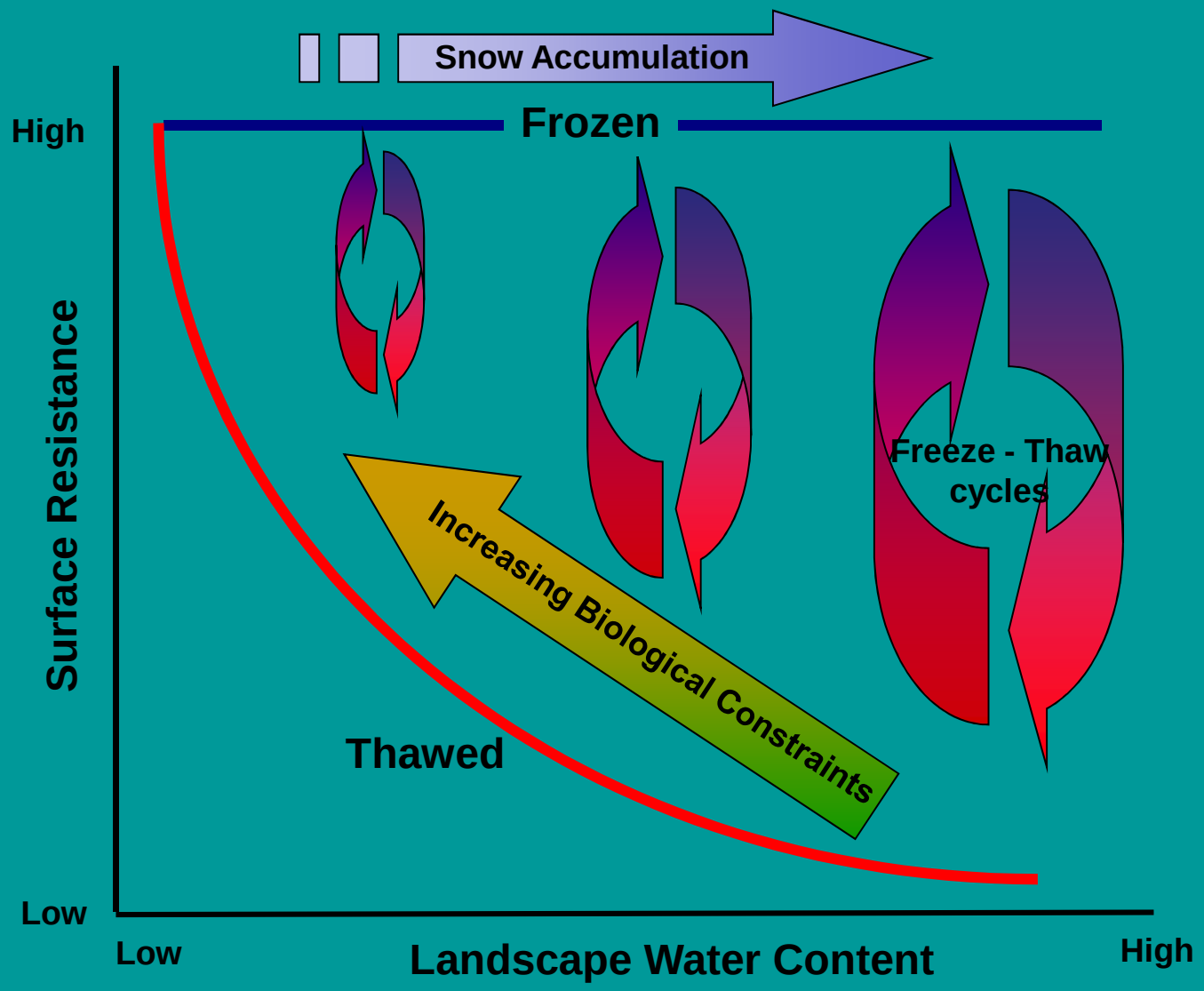
In 1922, the Hackensack River was dammed, cutting off the flow of freshwater to the Meadowlands. The water became saltier, killing trees and leading to the growth of the salt tolerant reedy grasses that you can see today.

The Restless Ocean



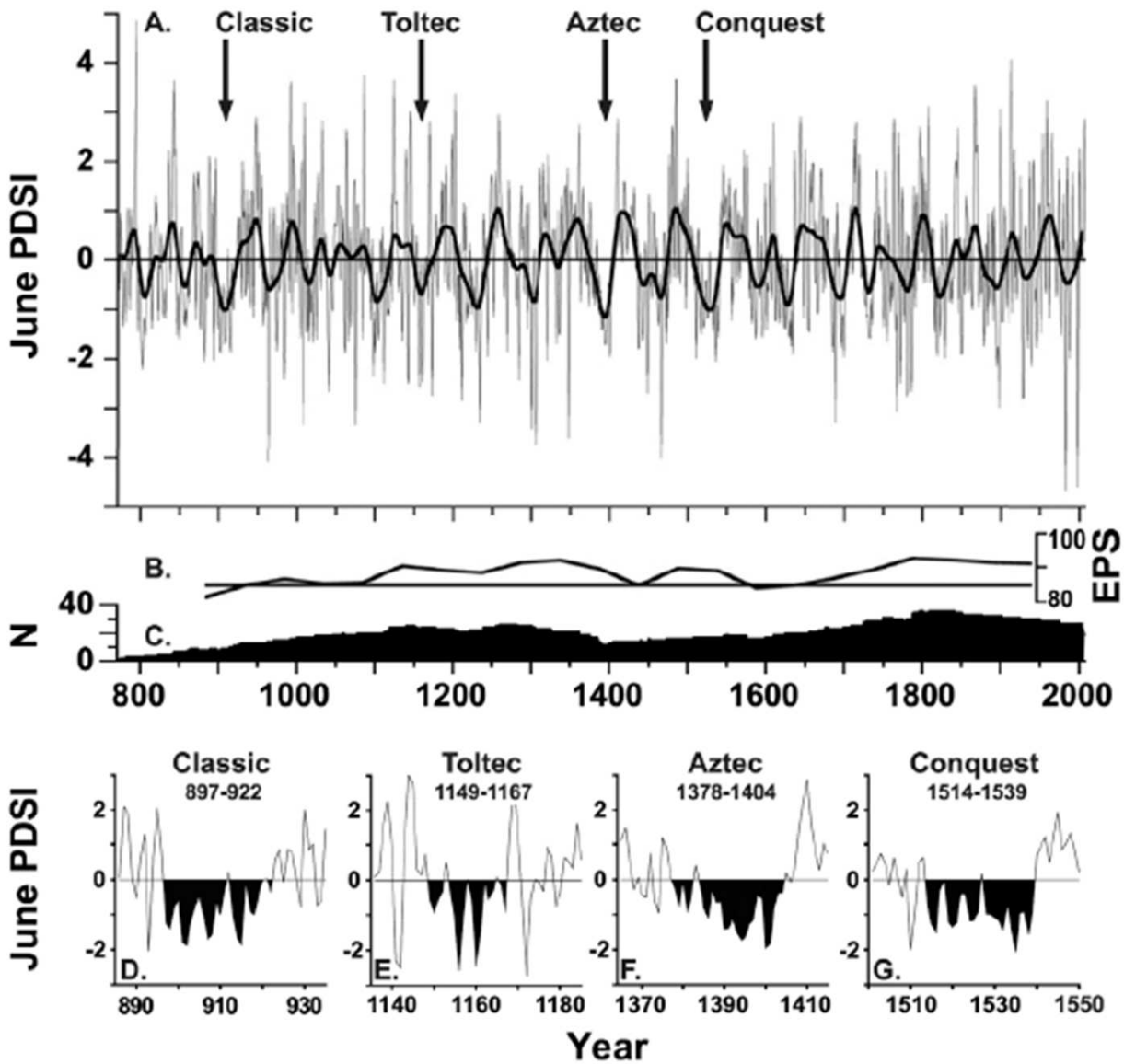
Average phytoplankton chlorophyll concentration between September 1997 and August 2005

Terrestrial Water Mobility Constraints to Ecosystem Processes

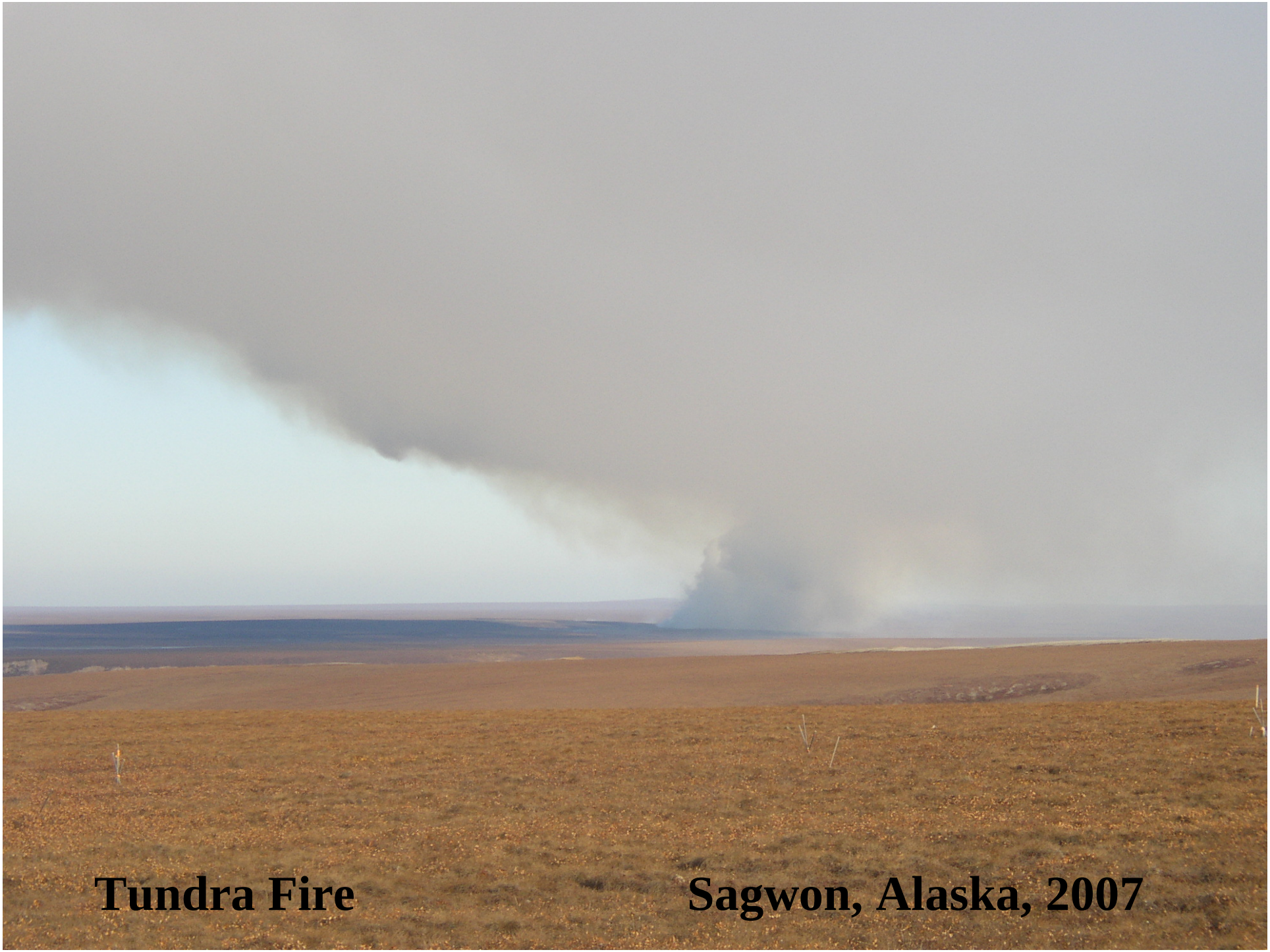


Conceptualization of the relationship between landscape water content and the bulk surface resistance to land-atmosphere latent energy and water exchange, vegetation productivity and sequestration of atmospheric CO_2. Decreasing water content imposes increasing constraints to CO_2 exchange, as do seasonal and episodic freezing. Accumulation of snow during cold seasons allows for increased water availability (high water content) for growth processes after snow melt and landscape thaw.

Mesoamerican Megadroughts



GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L05703, doi:10.1029/2010GL046472, 2011


Tundra Fire
Sagwon, Alaska, 2007

Species diversity vs. richness

- **Species richness**: the number of species present in a given area

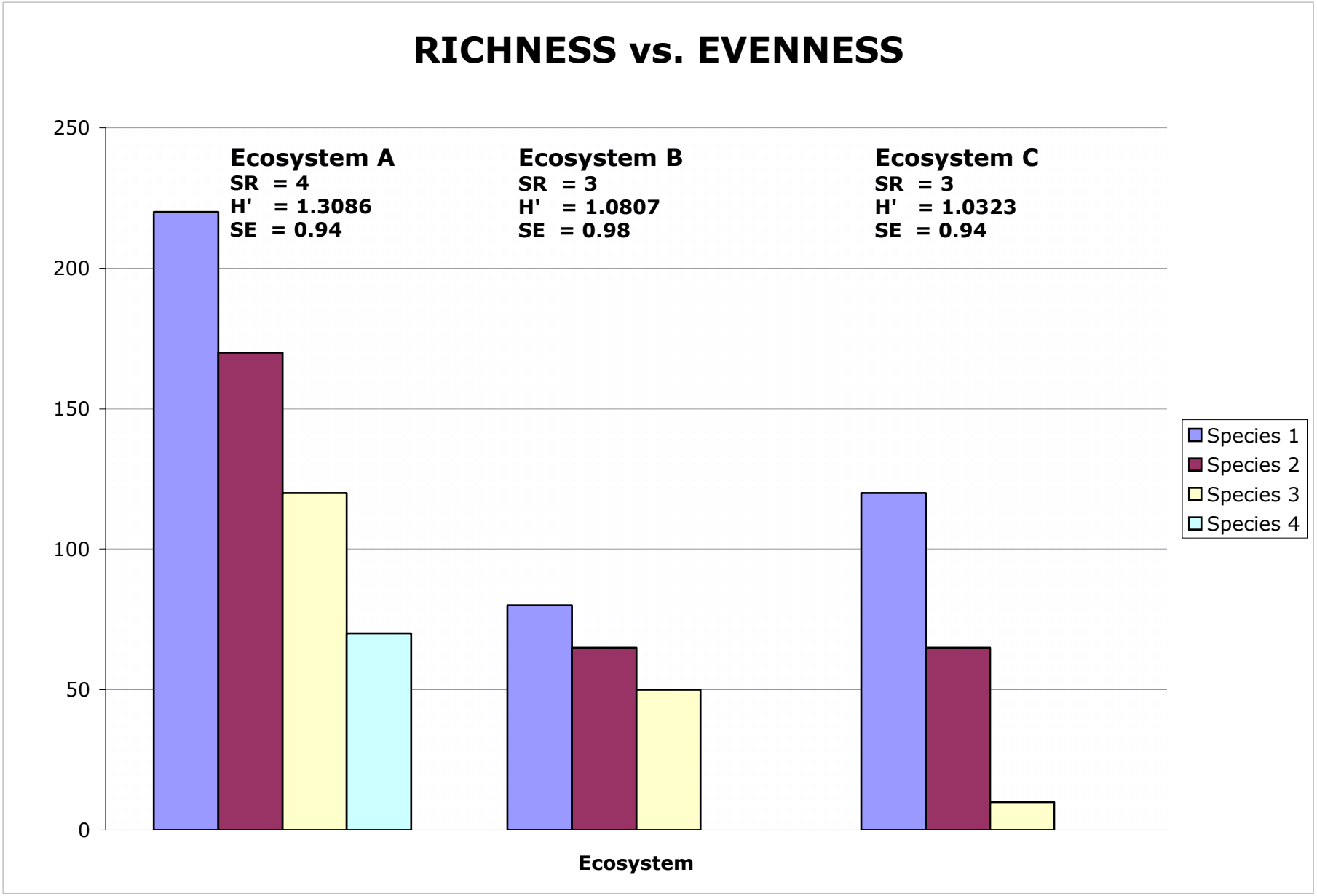
- **Species diversity**: species number weighted by measure of importance, such as abundance, productivity or size

For example:

Shannon's diversity index (H) = $-\sum \rho_i \ln \rho_i$

$\boldsymbol{\rho_i}$ is the proportion of the total number of specimens of species **i** expressed as a proportion of the total number of specimens for all species in the ecosystem.

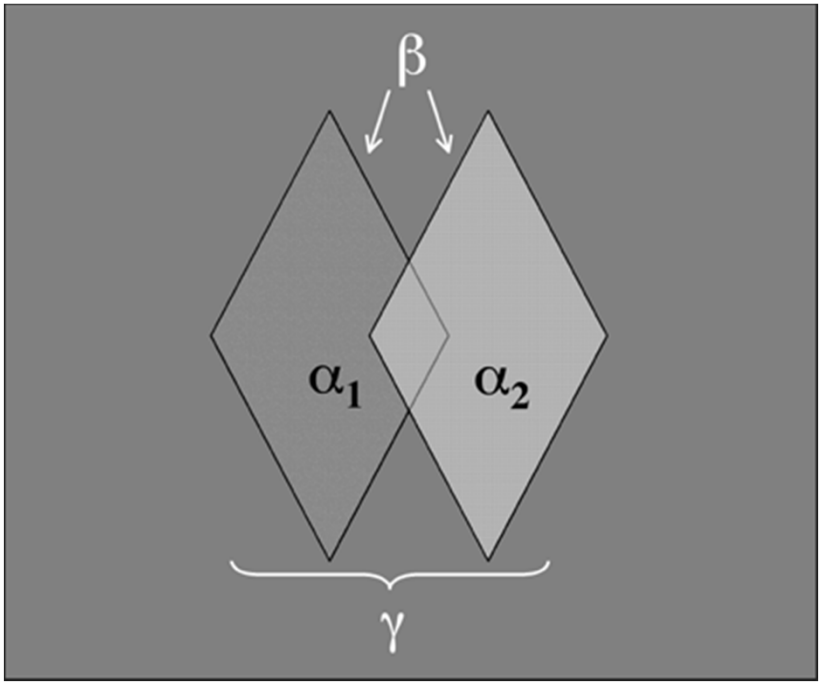
Many people use the term "species diversity" when they mean species richness



Adapted from: Hunter, M. Jr. 2002. Fundamentals of Conservation Biology. Second Edition. Blackwell Science, Massachusetts, U.S.A.

Spatial scales and diversity

- **Alpha-diversity**
  - Measured locally, at a single site
- **Beta-diversity**
  - Measures the uniqueness; the difference between two sites
- **Gamma-diversity**
  - Measured over a large scale, same concept as alpha-diversity



Adapted from: Meffe et al. 2002. Ecosystem management: adaptive, community-based conservation. Island Press, Washington, D.C., U.S.A.

Alpha Diversity

- The number of species that can coexist in the same ecosystem by using different portions of it

Source: Harrison ©AMNH

Baobab tree, in Sahel zone, Senegal

Beta Diversity

- The number of species unique to one region relative to another. This gives a measure of the relative change in species diversity between areas.

Source: Harrison © AMNH

Gamma Diversity

- **Gamma diversity** is a measure of the overall diversity for all ecosystems within a large region.

May be considered to be “geographic-scale” species diversity

Alpha, beta and gamma diversity for hypothetical species of birds (A-N) in three different ecosystems.

This example is based on the hypothetical example given by Meffe et al. (2002: Table 6.1).

Hypothetical species	**Woodland habitat**	**Hedgerow habitat**	**Open field habitat**
A	X		
B	X		
C	X		
D	X		
E	X		
F	X	X	
G	X	X	
H	X	X	
I	X	X	
J	X	X	
K		X	
L		X	X
M			X
N			X

Alpha diversity	10	7	3
Beta diversity	Woodland vs. hedgerow: 7	Hedgerow vs. open field: 8	Woodland vs. open field: 13
Gamma diversity	14		

Can gamma diversity = alpha diversity? Yes!

- Consider the flowering plants of Antarctica!
- a single grass species, *Deschampsia antarctica*, and a small cushion-forming plant or pearlwort, *Colobanthus quintensis*.
- These species usually co-occur.

Source: Koy ©AMNH-CBC

Contrast Antarctica with a landscape in Vietnam

Lunde © AMNH/CBC

Global Biodiversity Gradient

Biodiversity is not distributed evenly across the planet:

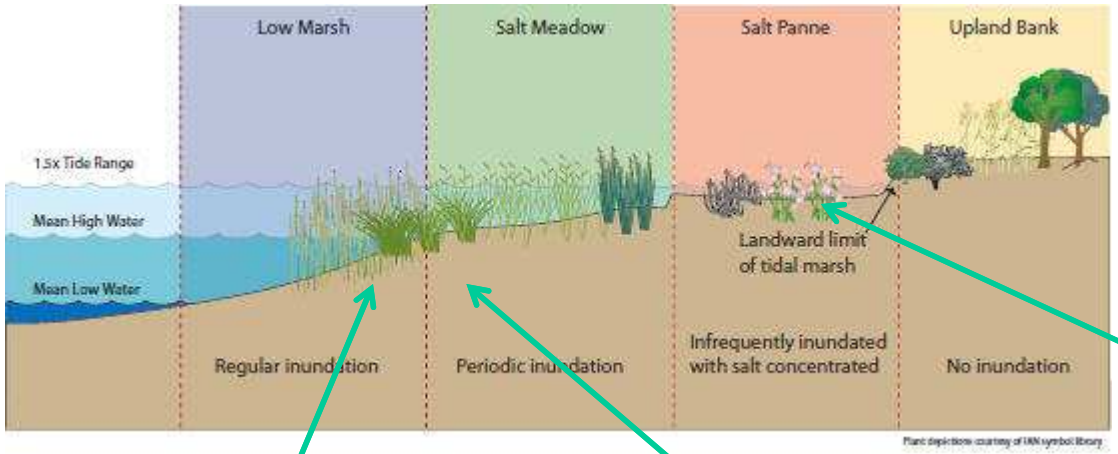
Source: Kristan Hutchison,NSF: US Antarctic Program

Source: Sterling ©AMNH-CBC

Species diversity for most taxa is lowest near the poles, and increases toward the tropics, reaching a peak in tropical rain forests (may contain more than half the species on Earth).

Invasion of *Phragmites australis in* New England Salt Marshes

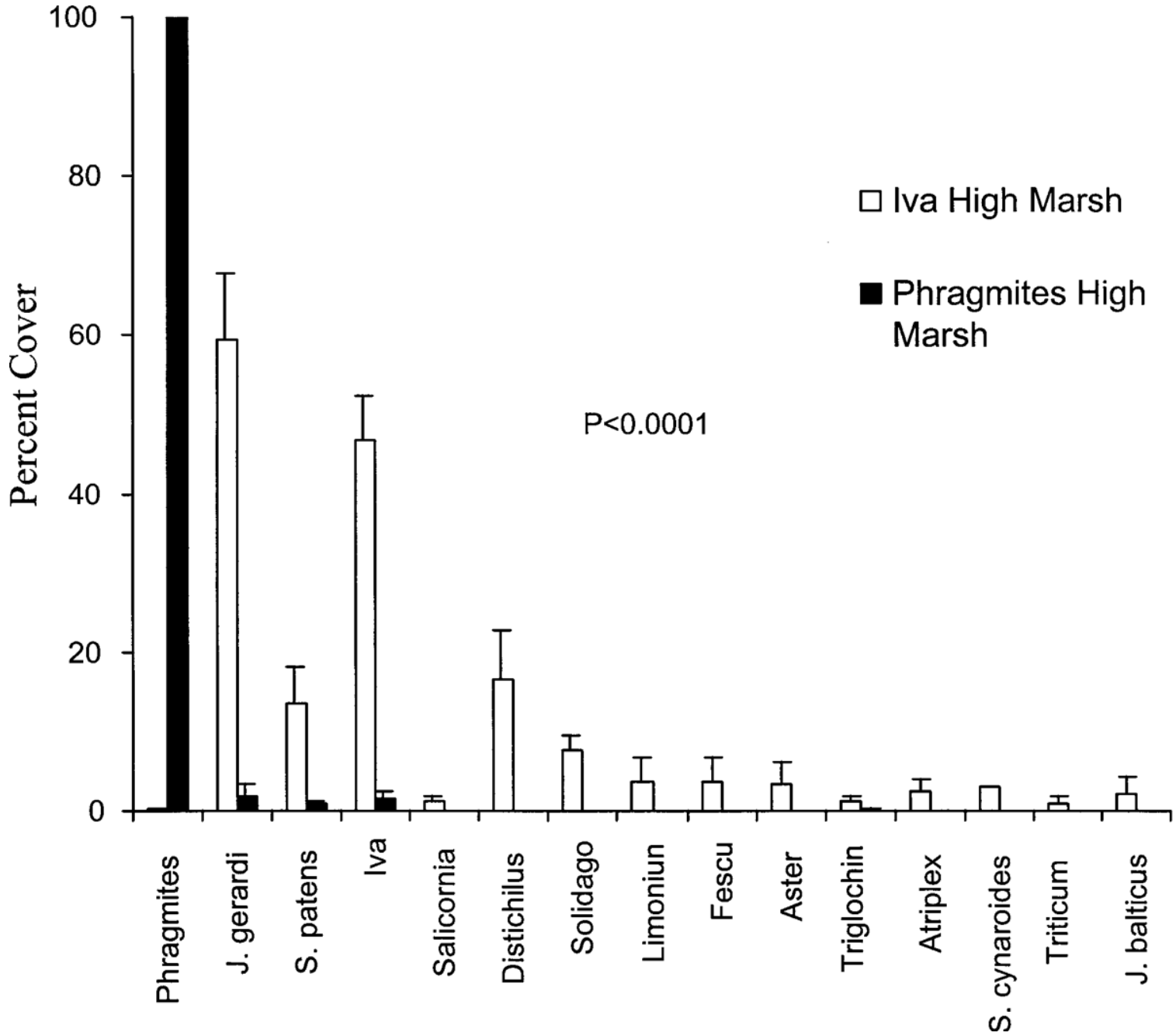
PhragmitesI Invasive



Spartina alterniflora

Spartina patens

Iva frutecens


Percent Cover
100
80
60
40
20
0
Iva High Marsh
Phragmites High Marsh
P<0.0001
Phragmites
J. gerardi
S. patens
Iva
Salicornia
Distichilus
Solidago
Limoniun
Fescu
Aster
Triglochin
Atriplex
S. cynaroides
Triticum
J. balticus

How is this an example of a disruption to evolution?

Evolution Disruption: Adaptations Are No Longer Adaptive

- Organisms have adaptations which were selected by their surrounding ecosystem.
- Change the ecosystem – no longer adapted
- Invasives can change ecosystem all on own (brown tree snake in Guam)
- People can change habitat – now native species not as well adapted as invasive (Phragmites)

Invasive Species Are One Example of Human Caused Disruption to Evolution:

- Unprecedented Influx of Invasives
- Changing habitat makes invasives more likely to thrive (Phragmites, native and non-native earthworms in CA, edge habitats,minor mussel invasion from Red Sea to Mediterranean via Suez Cana coexist for 125 years, then habitat change and displaces native mussel)
- What about global climate change?

Case Study: Global biodiversity consequences of local introductions:

Source: ©AMNH

British Government introduced the Nile perch (Lates niloticus) to Lake Victoria in 1954.

Nile perch population exploded in the 1980s; native cichlid populations then crashed

Lake Victoria cichlids

Source: Boulenger, G.A. (1907). Zoology of Egypt: the fishes of the Nile. Plate 91. Hugh Rees Limited, London.

Alpha vs. Gamma Diversity

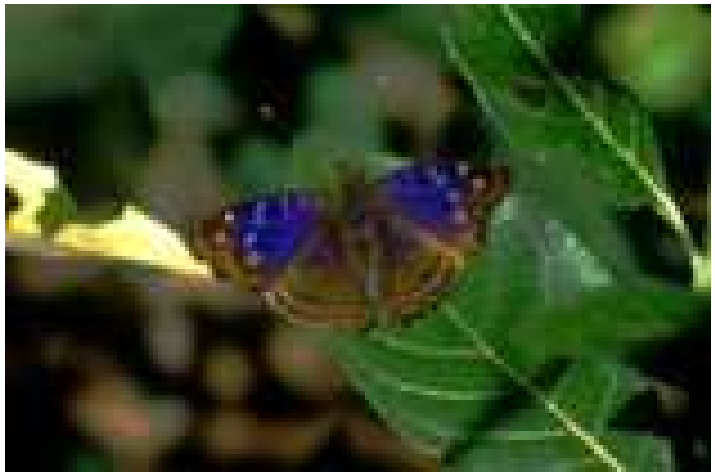
Local Diversity (alpha) increased initially, then crashed:

- Hundreds of cichlids native to the Lake Victoria
- Humans introduced 1 species, which increased the alpha biodiversity until the perch population exploded in the 1980s and decimated the cichlids

Global Diversity (gamma) decreased: perhaps 200 species lost globally

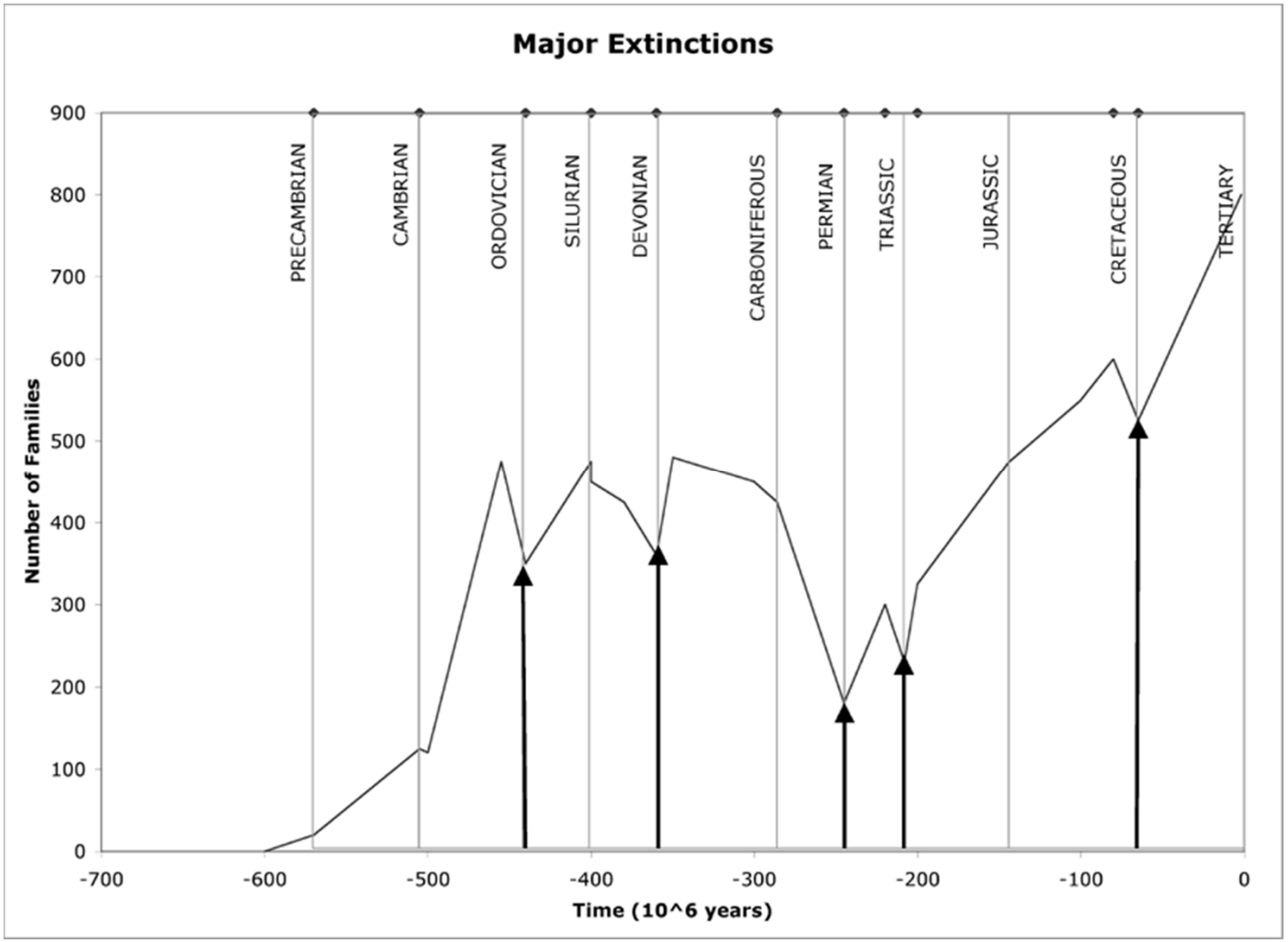
Evolution of Biodiversity

- Life on Earth 3.7 - 3.85×10^9 years old
- Evolutionary history shapes contemporary physical and biological environment
- Current diversity of species is a product of the processes of extinction and speciation



Source: Frey ©AMNH-CBC

The Major Extinction Events



Adapted from Kaufman and Mallory (1986) 'The Last Extinction' fig 2.1

Recovery time from previous extinctions

- Evolution required 10 million years or more to attain prior levels of species diversity

Sixth mass extinction

Homo sapiens (humans) may be the cause of a sixth major extinction in history.

Reasons for extinction:

–human population

–pollution

–global climate change

–over hunting

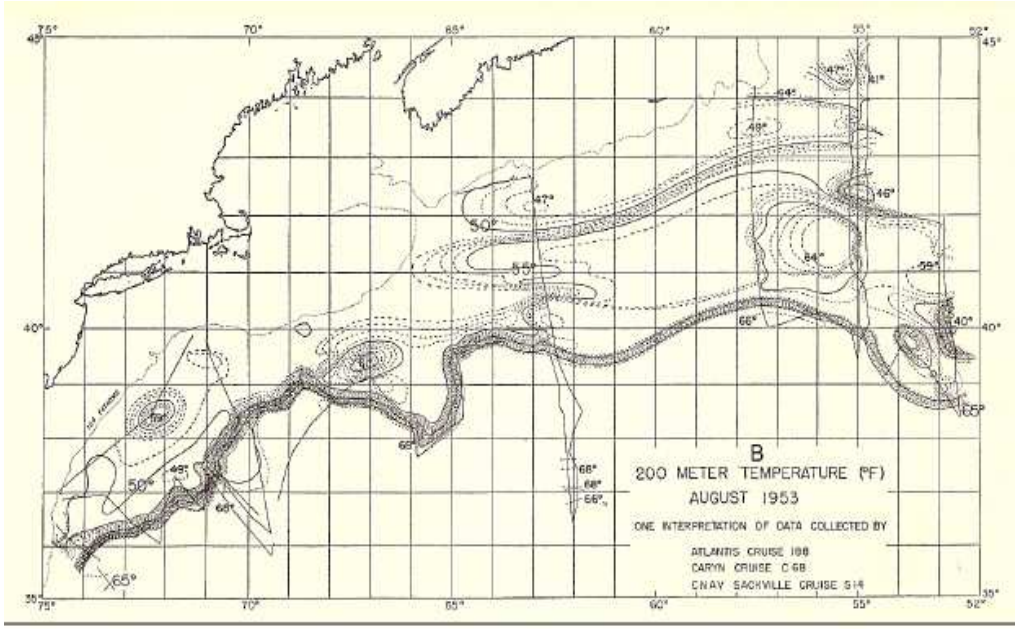
Source: ©AMNH

The extinct dodo bird

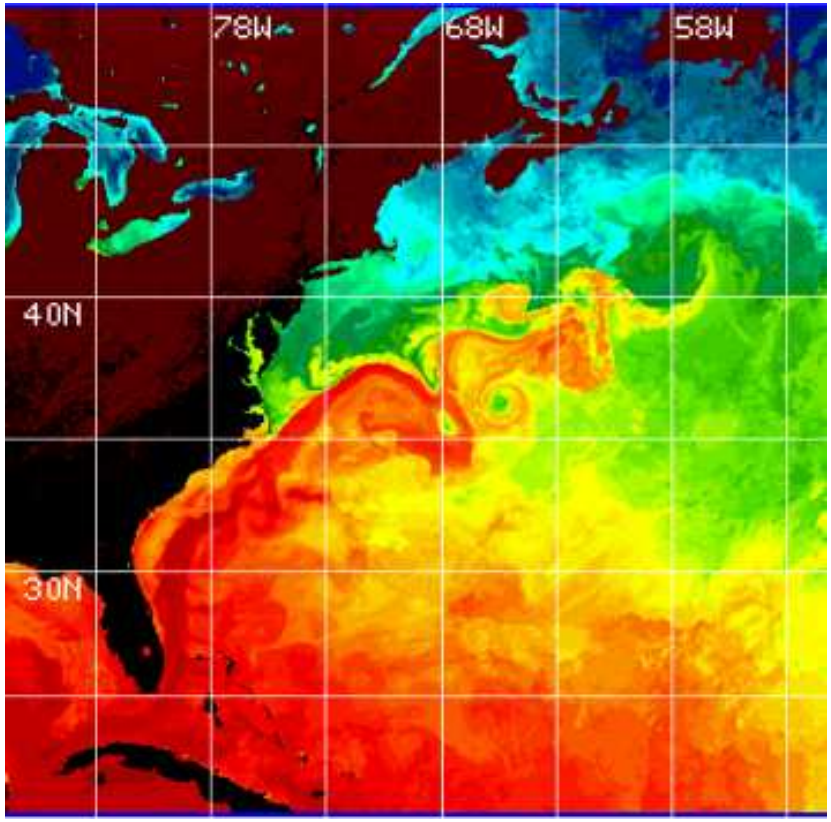
How a 6th mass extinction might differ from previous mass extinctions

- causes - apparently human induced
- rate - possibly greater
- possible breadth of taxonomic groups affected
- it can be stopped or at least slowed!

The Gulf Stream



Stommel 1965: Multiple current hypothesis



1970s: Single current observations

NASA's Earth Observing Satellite Fleet

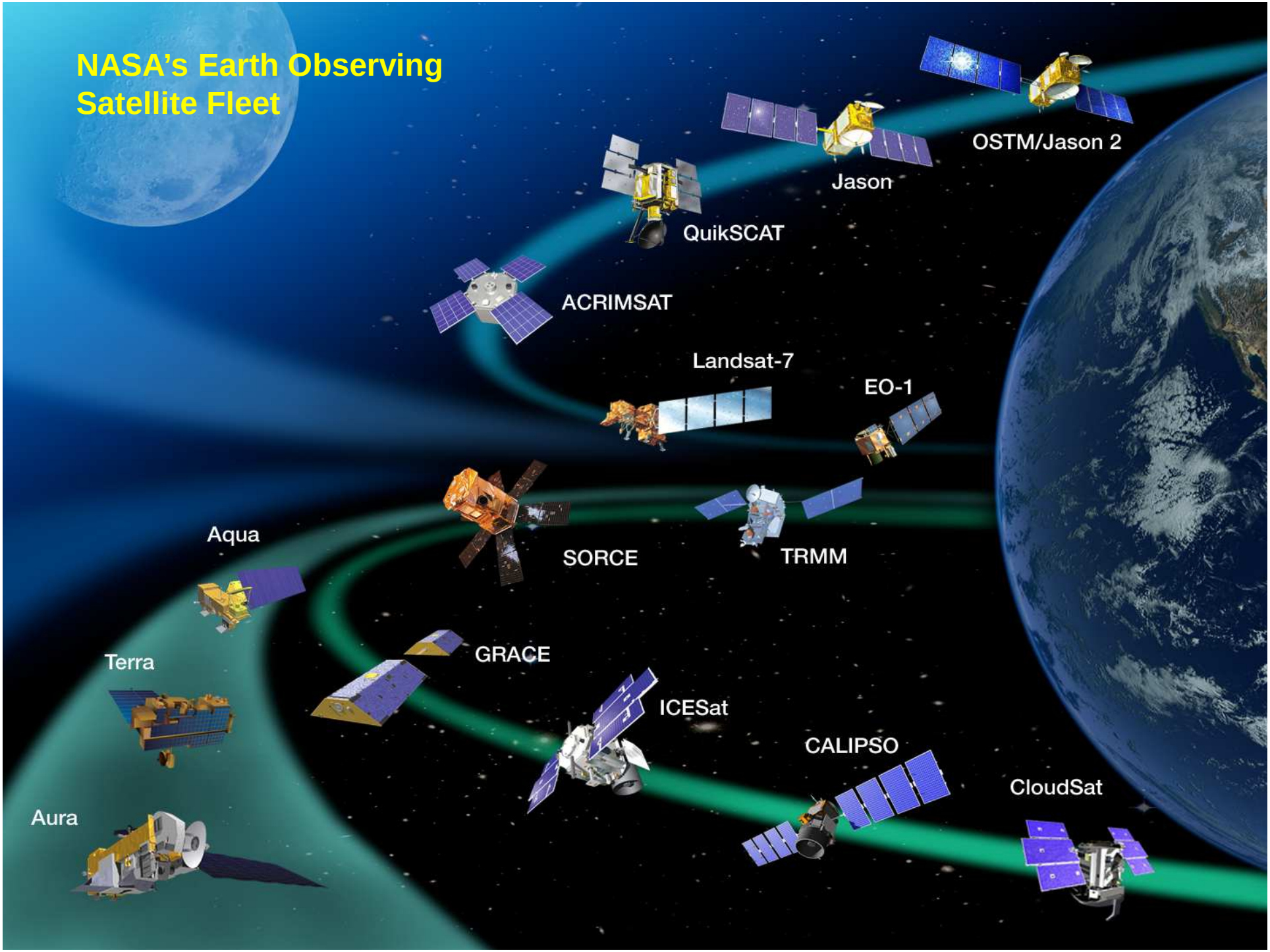
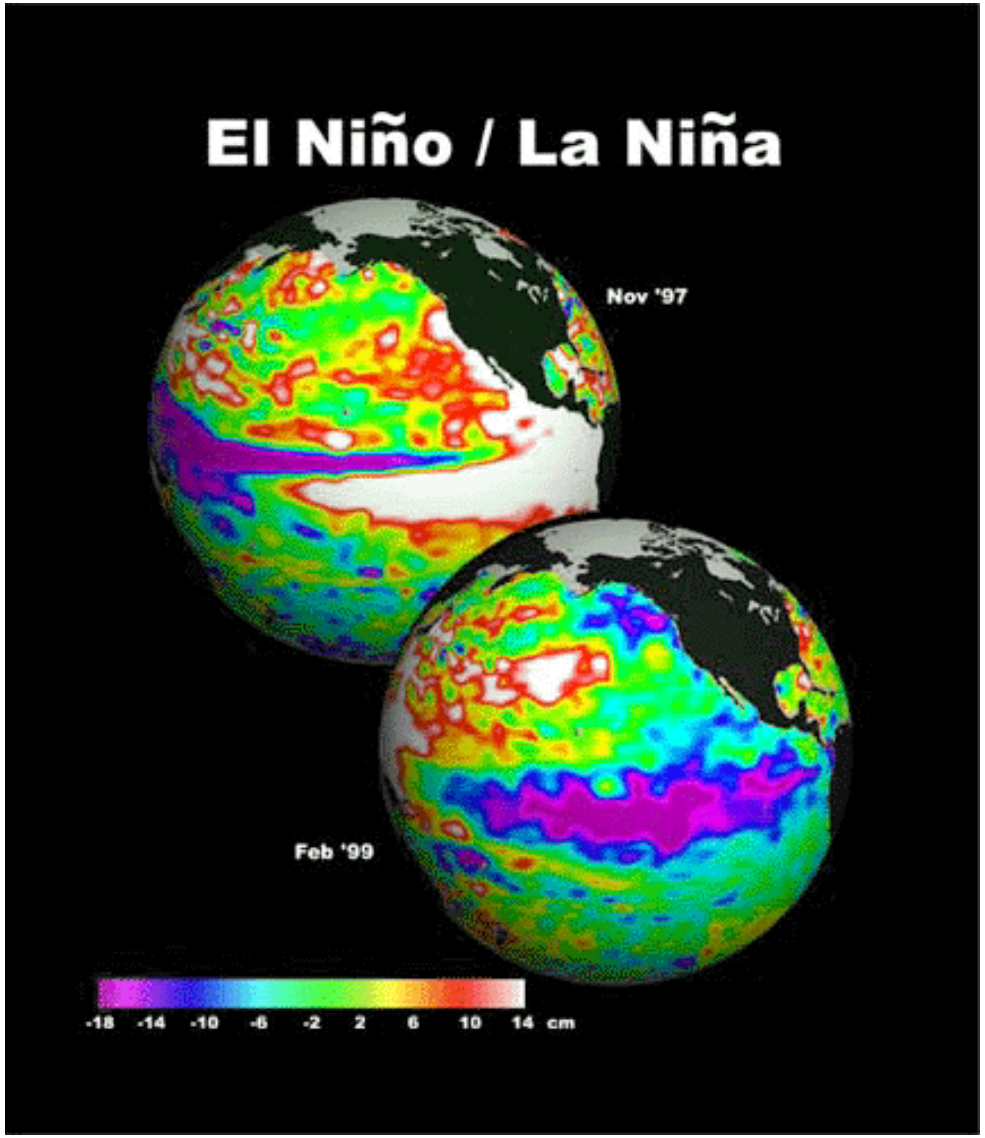


IMAGE EXAMPLES

TOPEX altimeter data identified the presence of El Nino and El Nina events in the Pacific Ocean

(http://topex-www.jpl.nasa.gov)

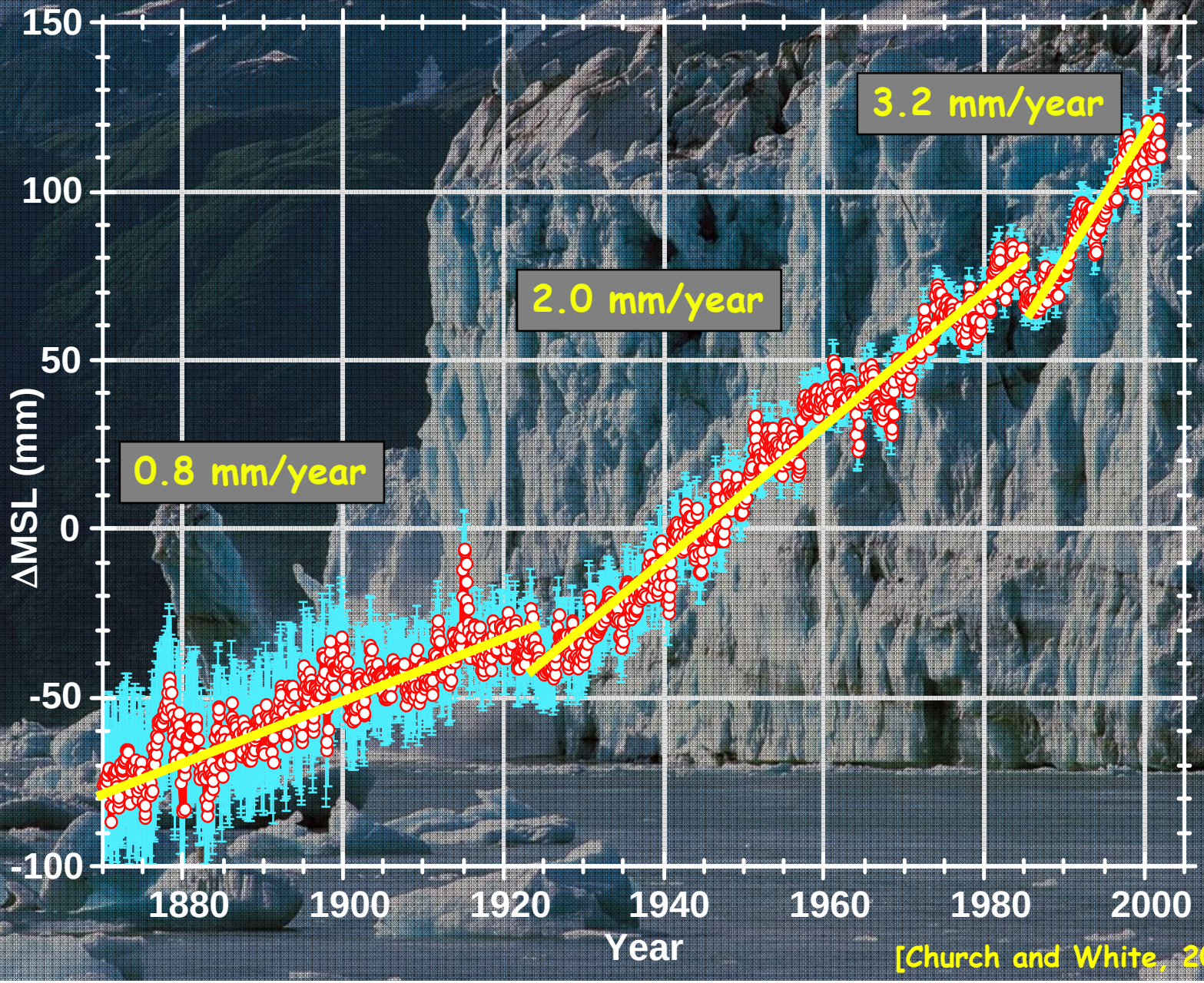


The Changing Role of Fire on Earth
(D. P. Roy and C. O. Justice – SDSU and UMD)

October 26, 2003

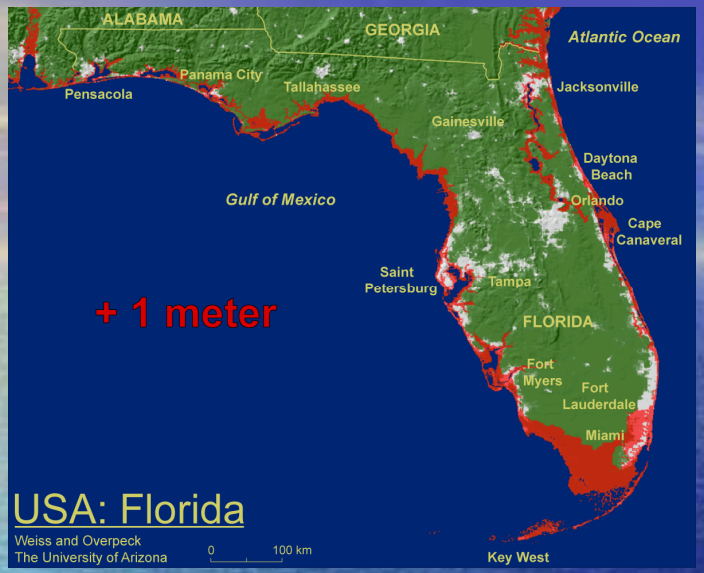
Station Fire, 2009

Tide Gauge Observations

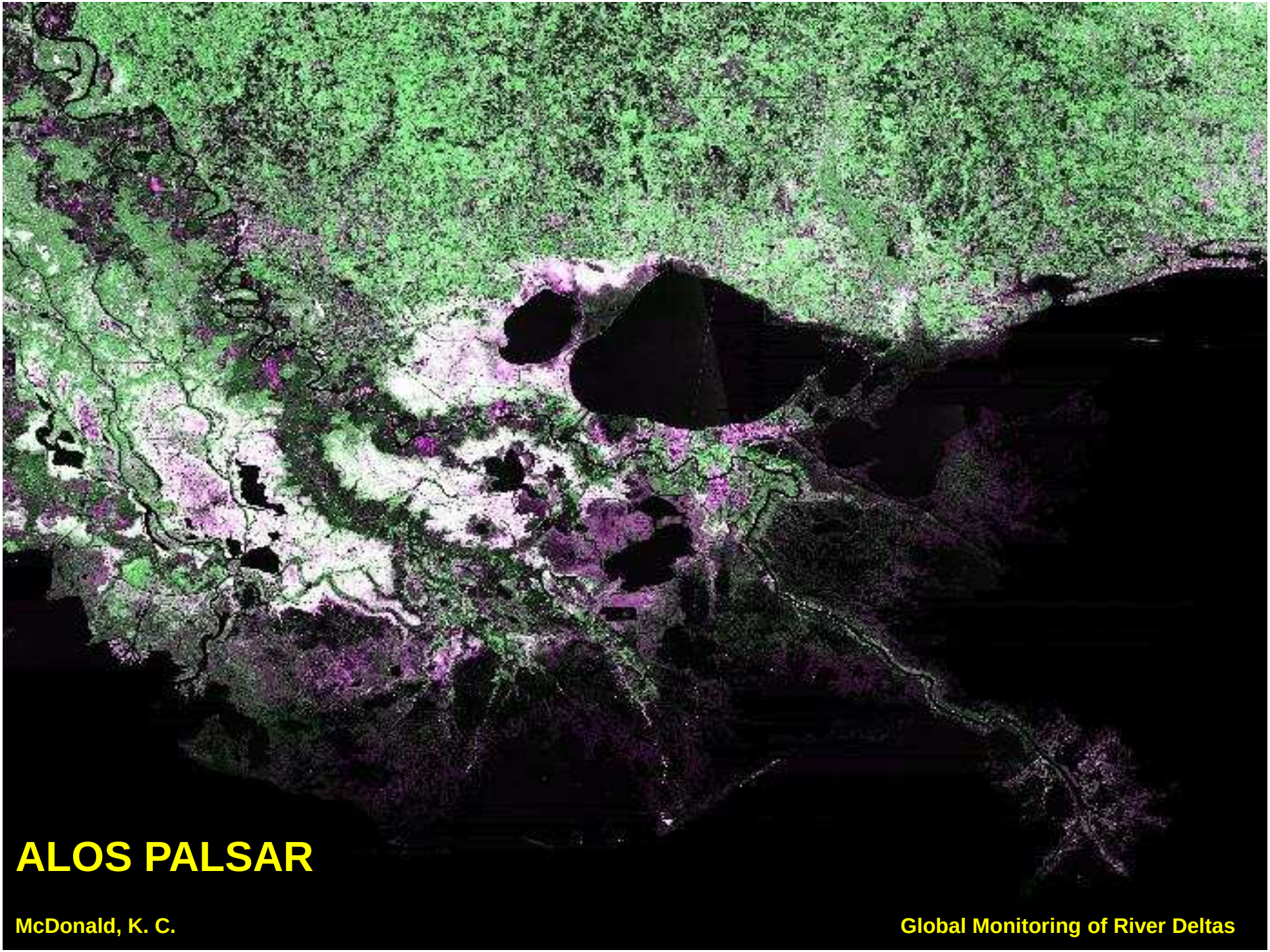


[Church and White, 2006]

Coastal Impacts

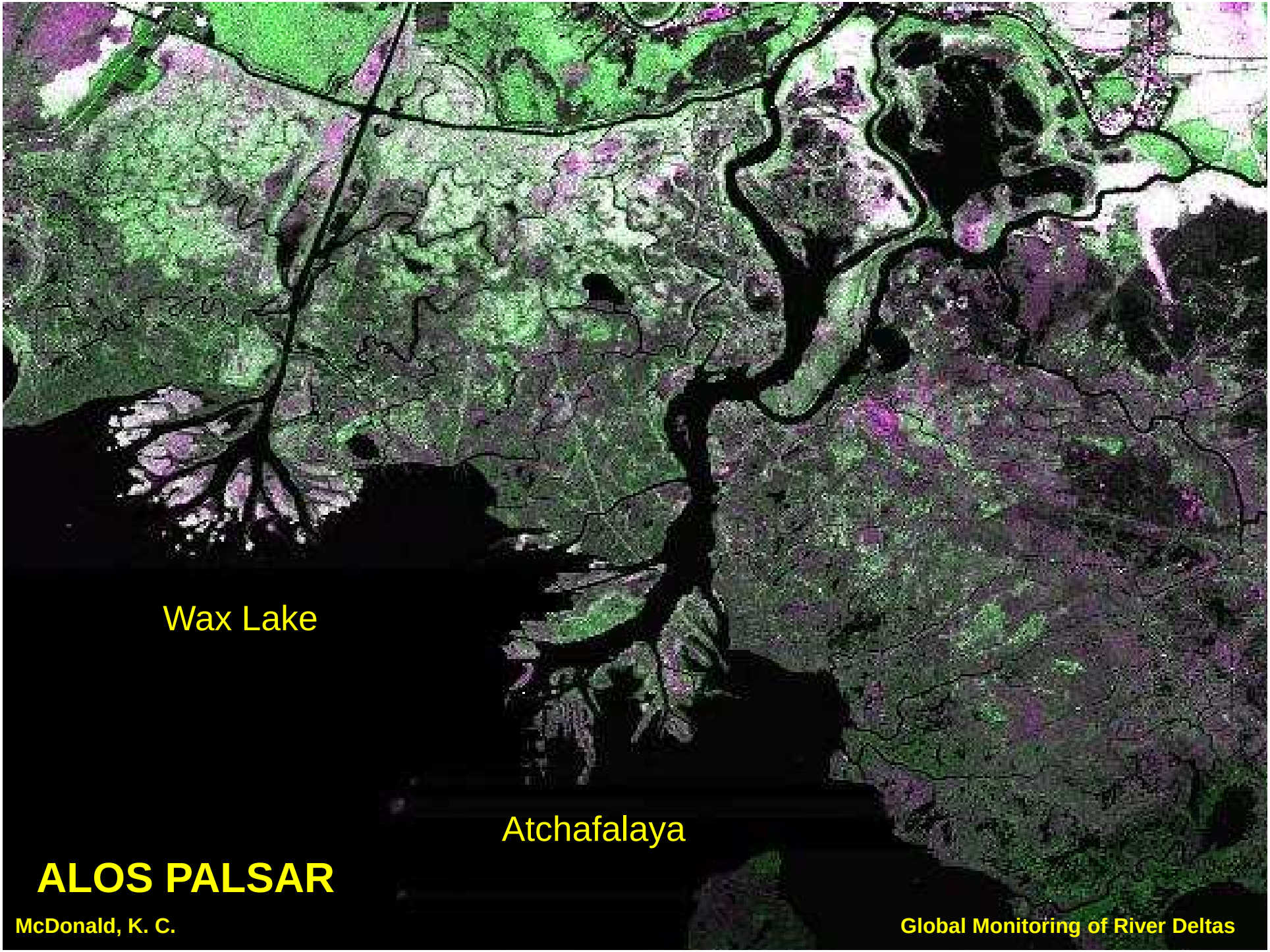


40% of the world's population lives within 100 km of the coast!



McDonald, K. C.

Global Monitoring of River Deltas



ALOS PALSAR