EARTH'S DYNAMIC SURFACE

UNI – Earth and Environmental Science

Geomorphology – EarthSci 3300/5300

UNIT ONE

Variable Energy

↓

Processes

↓

Change

↓

Products/landforms

Geomorphology

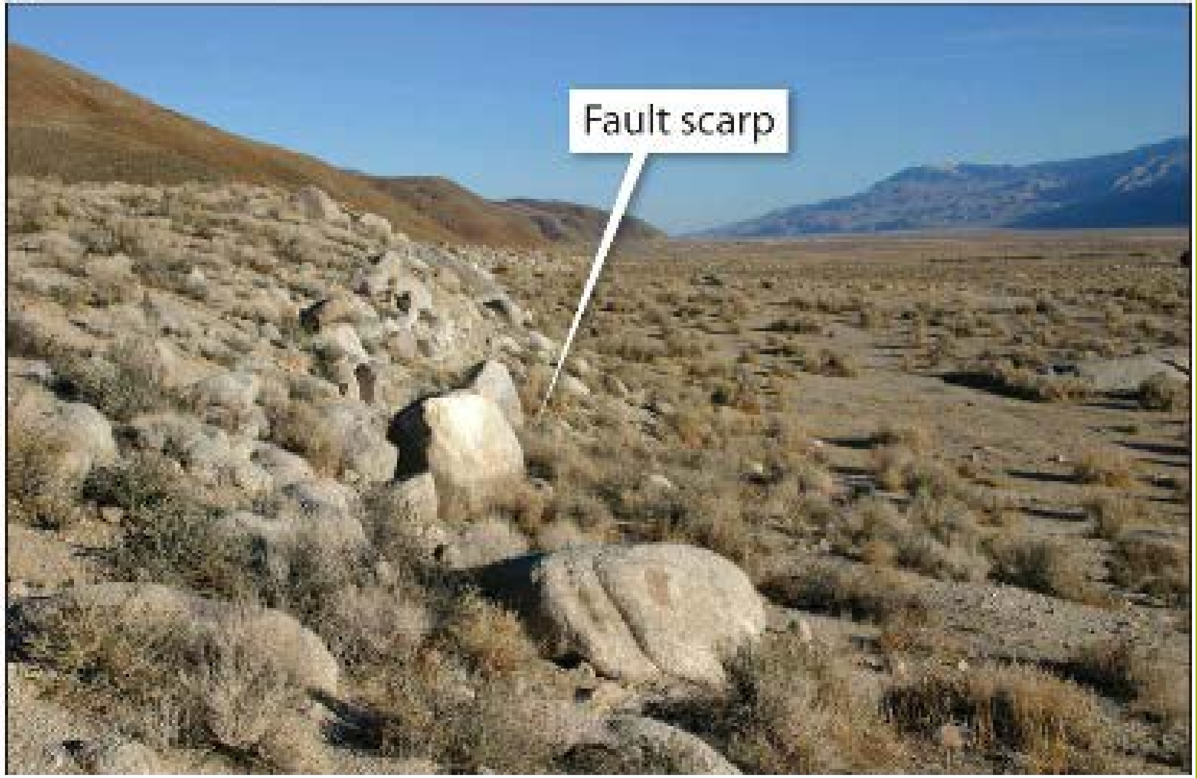
Historical

Process

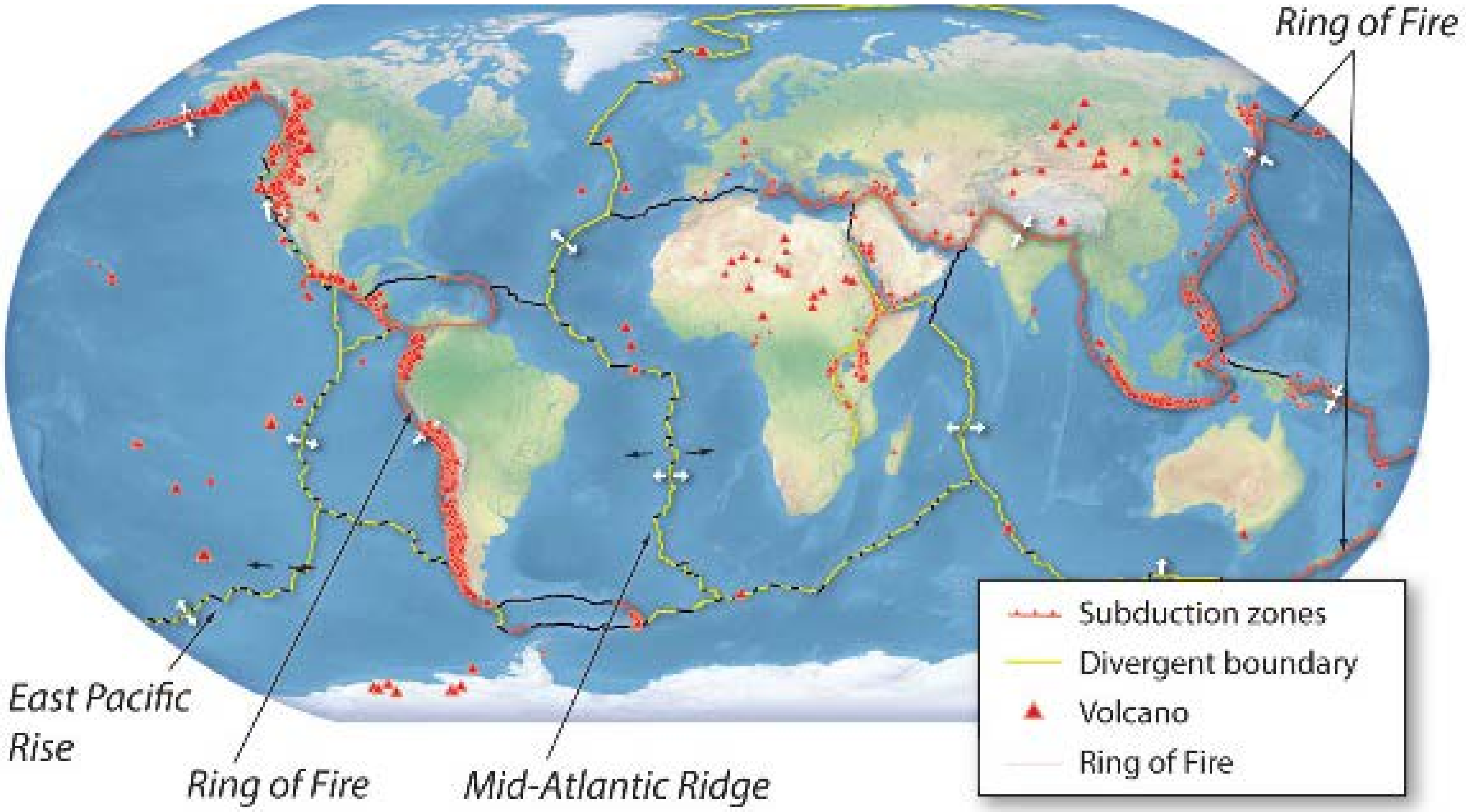
Geosphere
Isostasy
Tectonics
Lithology & structures

Hydrosphere
Climate & Climate Zones
Hydrologic cycles

Biosphere
Ecosystems
Humans

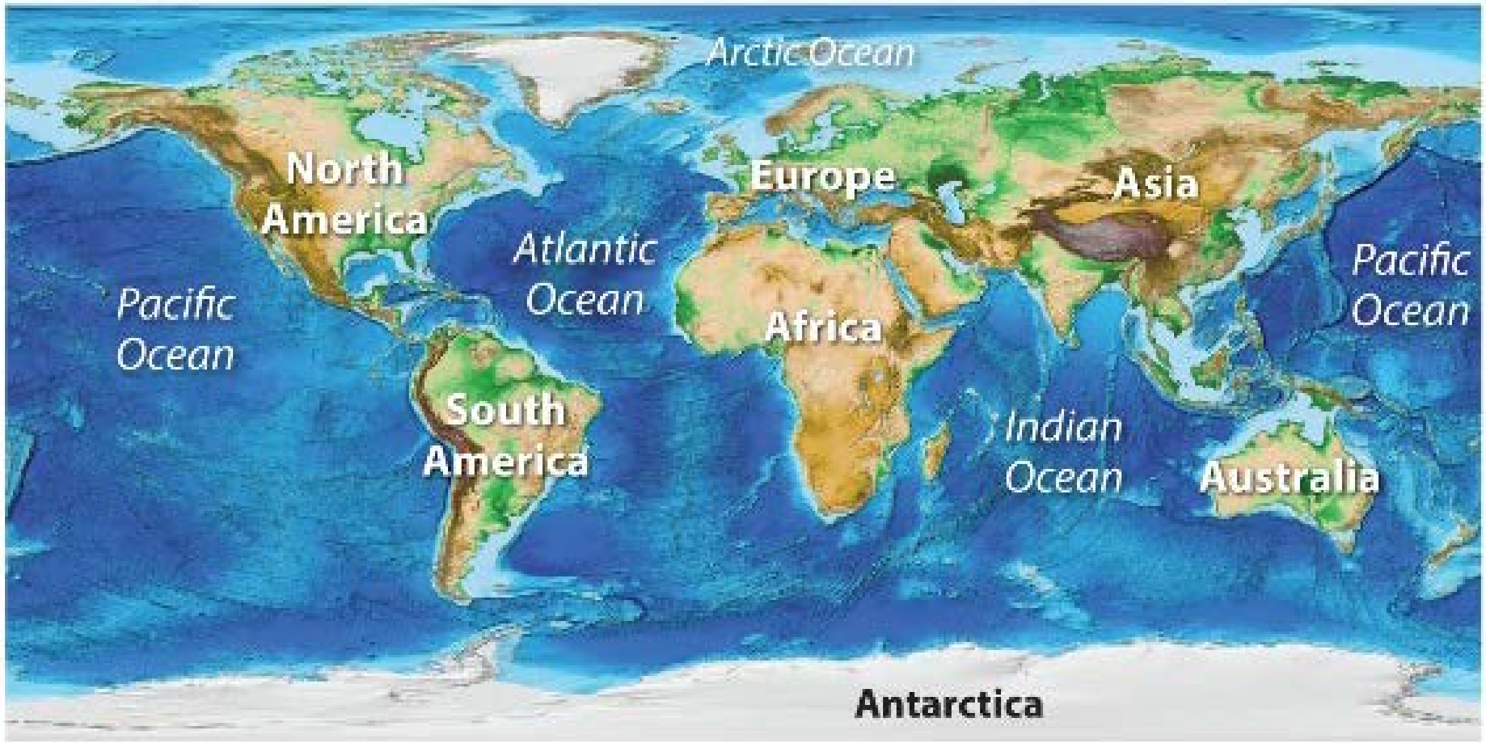


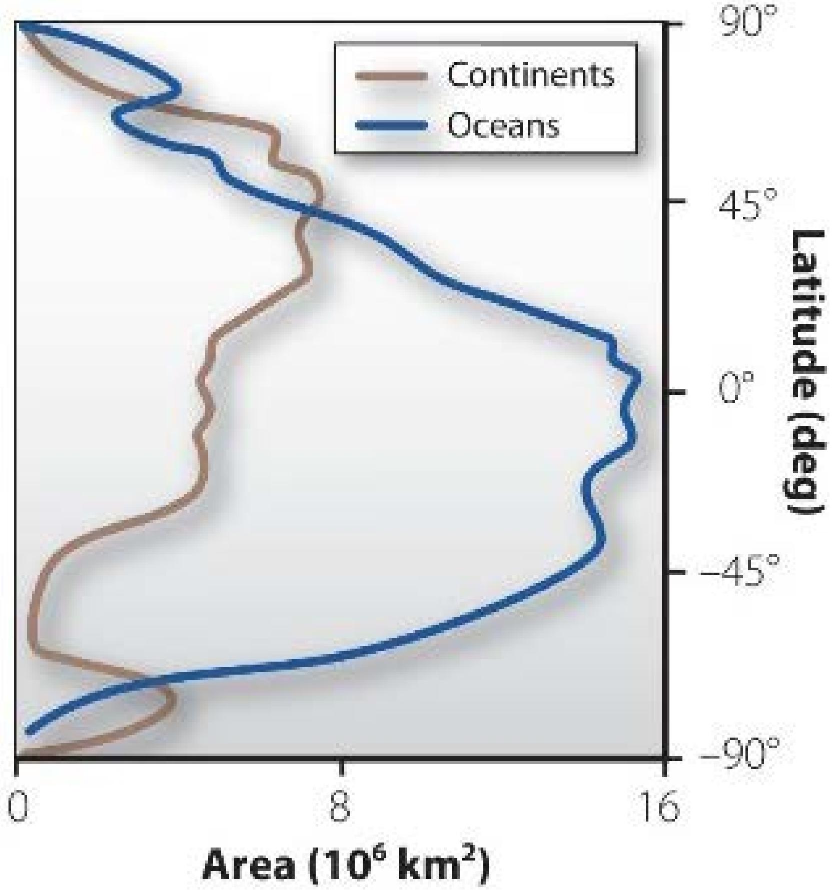
Geosphere



Many of the world's volcanoes are found on and near plate boundaries. The Pacific Ocean Basin is encircled by subduction zones and their associated volcanoes that together form the "Ring of Fire." The Mid-Atlantic Ridge and the East Pacific Rise are divergent plate boundaries where new oceanic crust is created by volcanism. Volcanoes are also common in terrestrial rift zones, such as East Africa.

Cumulative percent of land area above each elevation

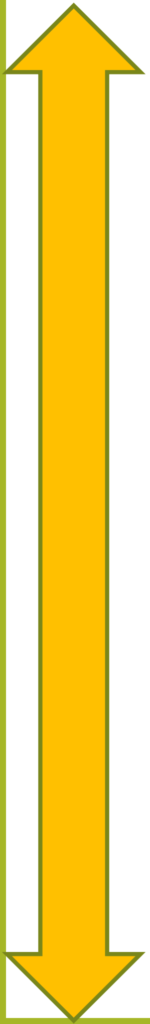


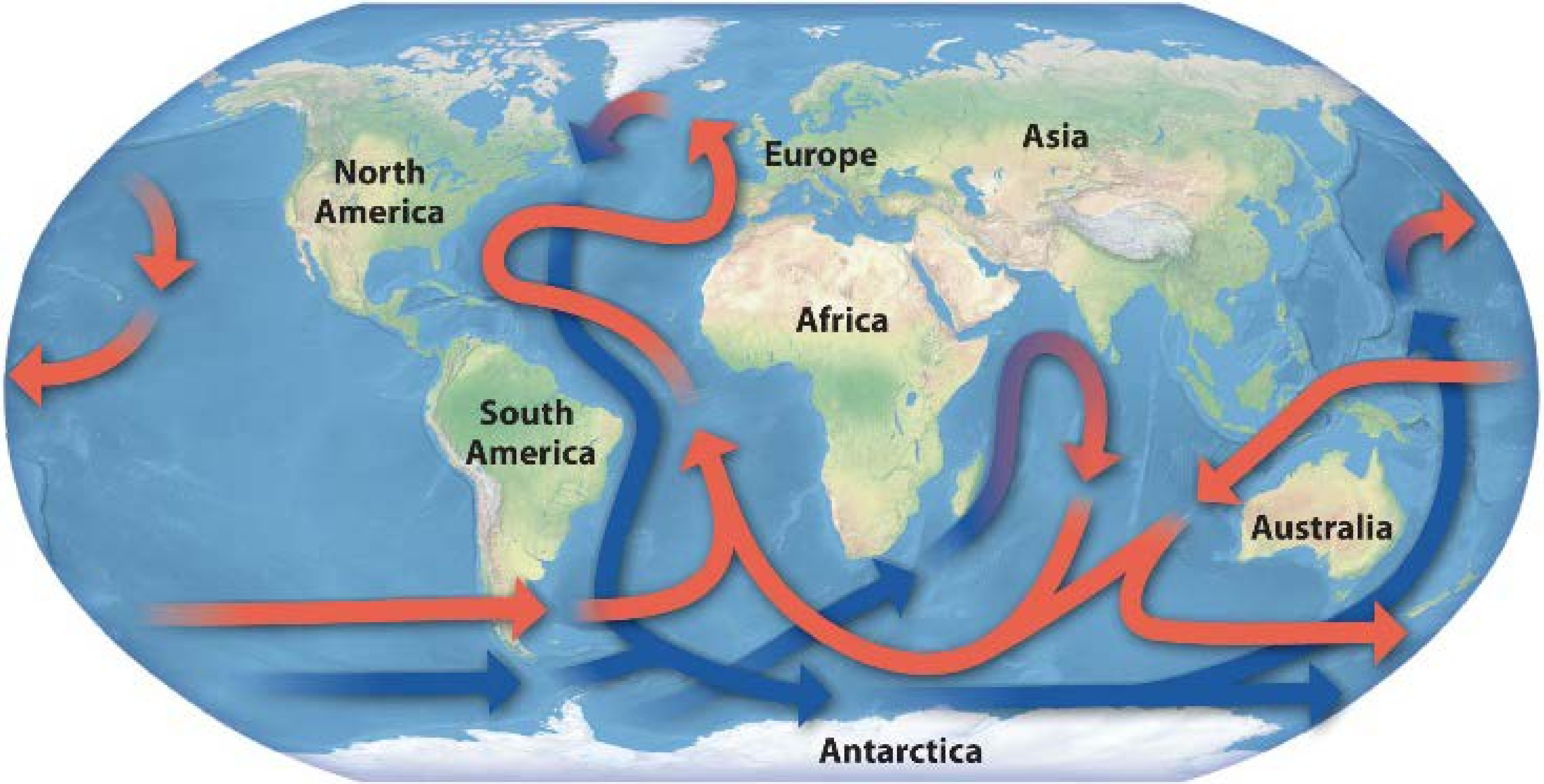


Both the **continents** and the **ocean basins** include large, relatively flat areas. On continents, these flat areas are the **cratons.** Under the oceans, these flat areas are the **abyssal plains.** Areas of higher elevation and **relief** include continental mountain ranges and **mid-ocean ridges.**

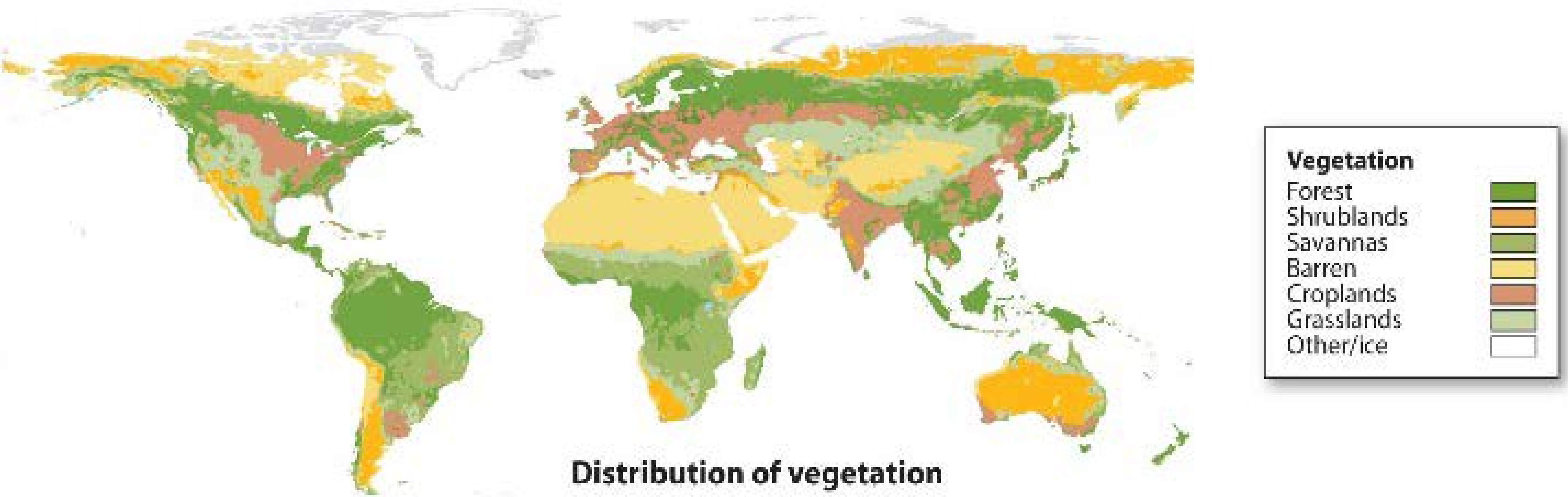
The area of ocean and continents are not equally distributed with latitude. There is more exposed land in the Northern Hemisphere and more ocean in equatorial regions.

Lithology



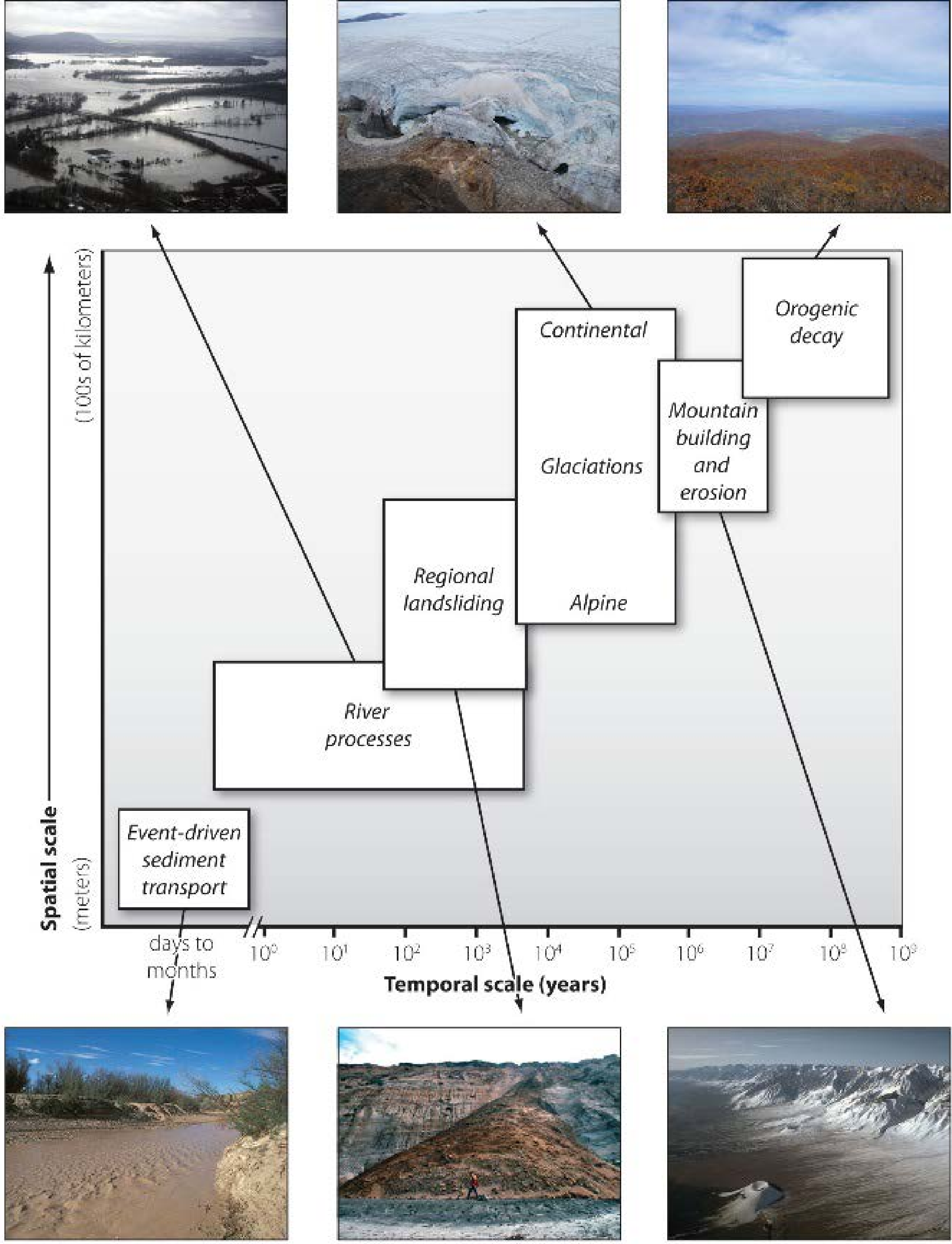


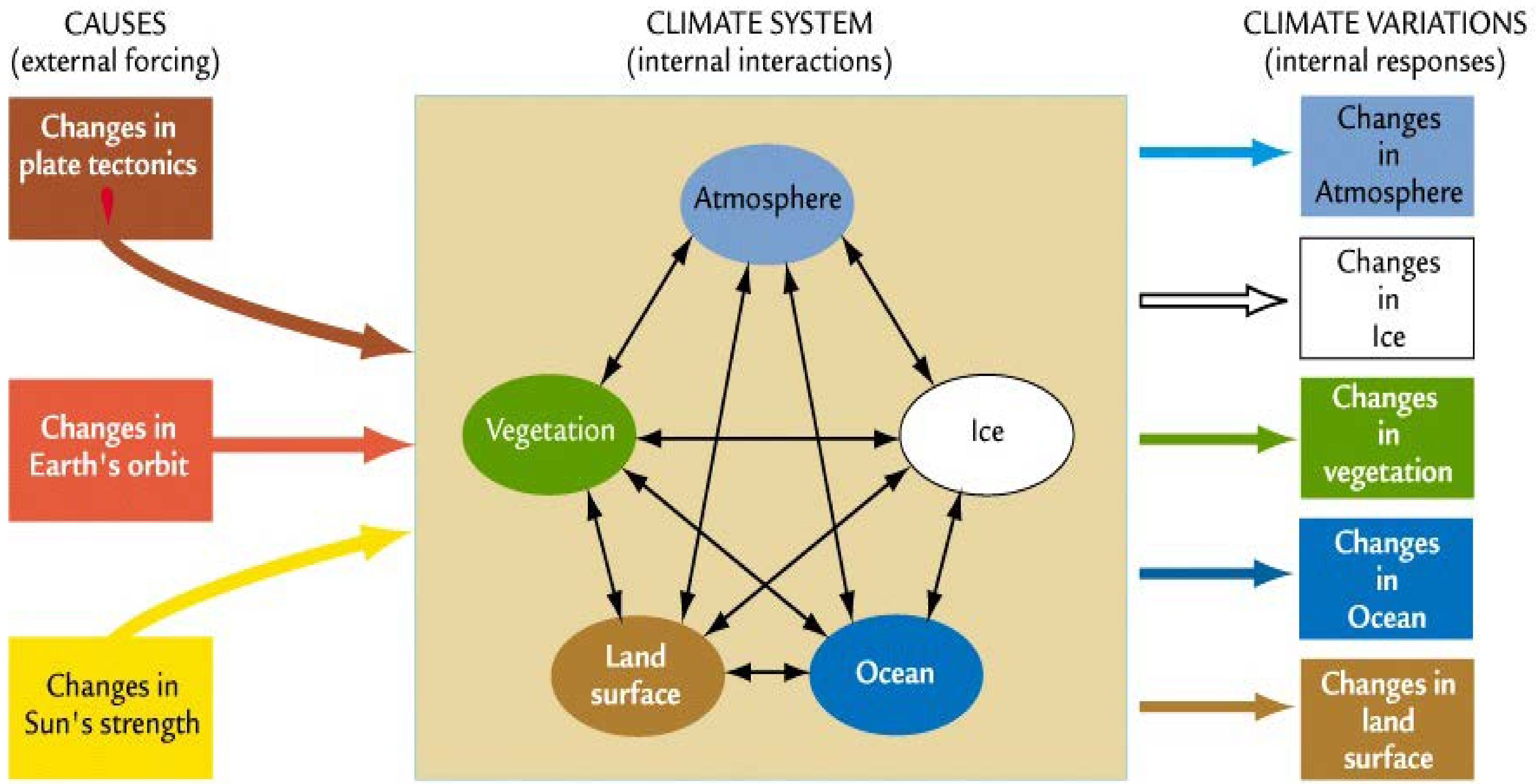
Ocean thermohaline circulation involves sinking of cold, salty water at the poles (shown in blue). This sinking water produces deep cold currents and shallow warm surface currents (shown in red).



Distribution of vegetation

Spatial-Temporal Range of Geomorphology




CAUSES
(external forcing)
CLIMATE SYSTEM
(internal interactions)
CLIMATE VARIATIONS
(internal responses)
Changes in plate tectonics
Changes in Earth's orbit
Changes in Sun's strength
Atmosphere
Vegetation
Ice
Land surface
Ocean
Changes in Atmosphere
Changes in Ice
Changes in vegetation
Changes in Ocean
Changes in land surface

Physiographic Provinces

- Adirondack
- Appalachian Plateaus
- Basin and Range
- Blue Ridge
- Cascade-Sierra Mountains
- Central Lowland
- Coastal Plain
- Colorado Plateau
- Columbia Plateau
- Great Plains
- Interior Low Plateaus
- Lower California
- Middle Rocky Mountains
- New England
- Northern Rocky Mountains
- Ouachita
- Ozark Plateau
- Pacific Border
- Piedmont
- Southern Rocky Mountains
- St. Lawrence Valley
- Superior Upland
- Valley and Ridge
- Wyoming Basin

The United States can be divided into **physiographic provinces** that share similar landforms, similar landscape-forming processes, and in some cases, geomorphic history. For example, the **Coastal Plain** of the southeastern United States is generally a low-relief surface that is underlain in large part by marine or shoreline deposits.

GEOMORPHOLOGY'S FUNDAMENTAL CONCEPTS

REVIEW – in Syllabus

- Concept 1. The same physical processes and laws that operate today have operated throughout geologic time, although not necessarily always with the same intensity as now. (Uniformitarianism)

- Concept 2. Geologic structures are a dominant controlling factor/variable in the evolution of landforms and they are reflected in them.

- Concept 3. To a large degree the Earth's surface relief is a product of geomorphic processes operating at differential rates.

Conservation of Mass

$$I - O = \Delta ST$$

I = Input

O = Output

ST = Storage

Conservation of Energy

Energy is neither created or destroyed, only transferred…

Potential energy

- Matter at rest

Kinetic energy

- Matter in motion

Material routing

Geomorphic systems route/move material from eroding sources to depositional sinks.

Weathering → Erosion → Transportation →

Deposition = *Landscape evolution & dynamics*

Force Balances

Normal stress

$\rho\ g\ z\ \cos\theta$

Shear stress

$\rho\ g\ z\ \sin\theta$

ρ = density of matter

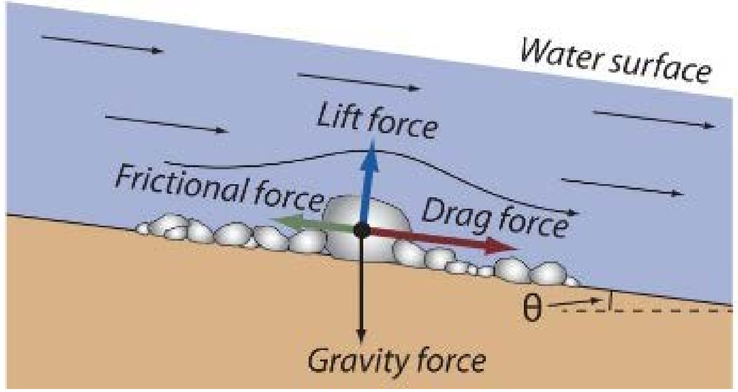
g = gravitational acceleration

z = thickness

θ = angle of slope

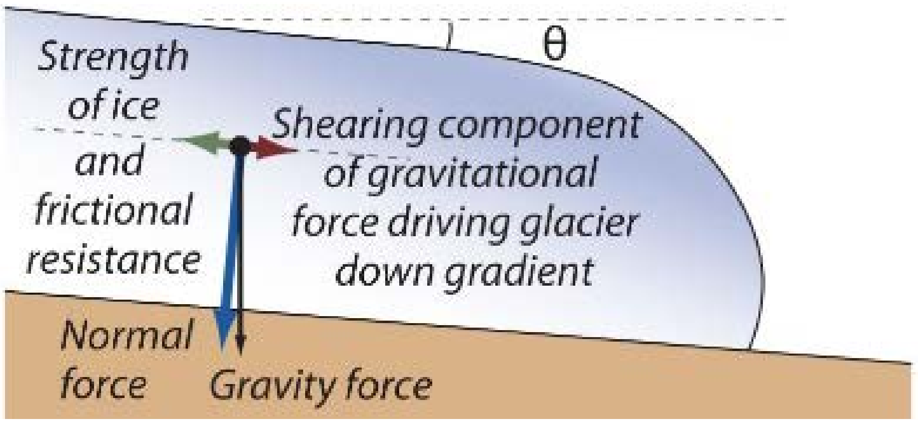
Many surface processes are driven by gravity. To calculate force balances and determine whether a landscape element will be stable, it is helpful to resolve the downslope force into the components resisting and driving movement, respectively oriented perpendicular to the slope (**normal force,** →) and parallel to the slope (**shearing force,** →).

Particle of sediment on streambed



Sediment on a stream bed is subject to a variety of forces. The **gravity force** holds the grain on the bed opposing the **lift force** generated by the current. The current also applies a **drag force** to the grain. The drag force is resisted both by **frictional forces** and by the resistance offered by neighboring grains if the clast is embedded. When the lift and drag forces exceed the forces of gravity and friction,

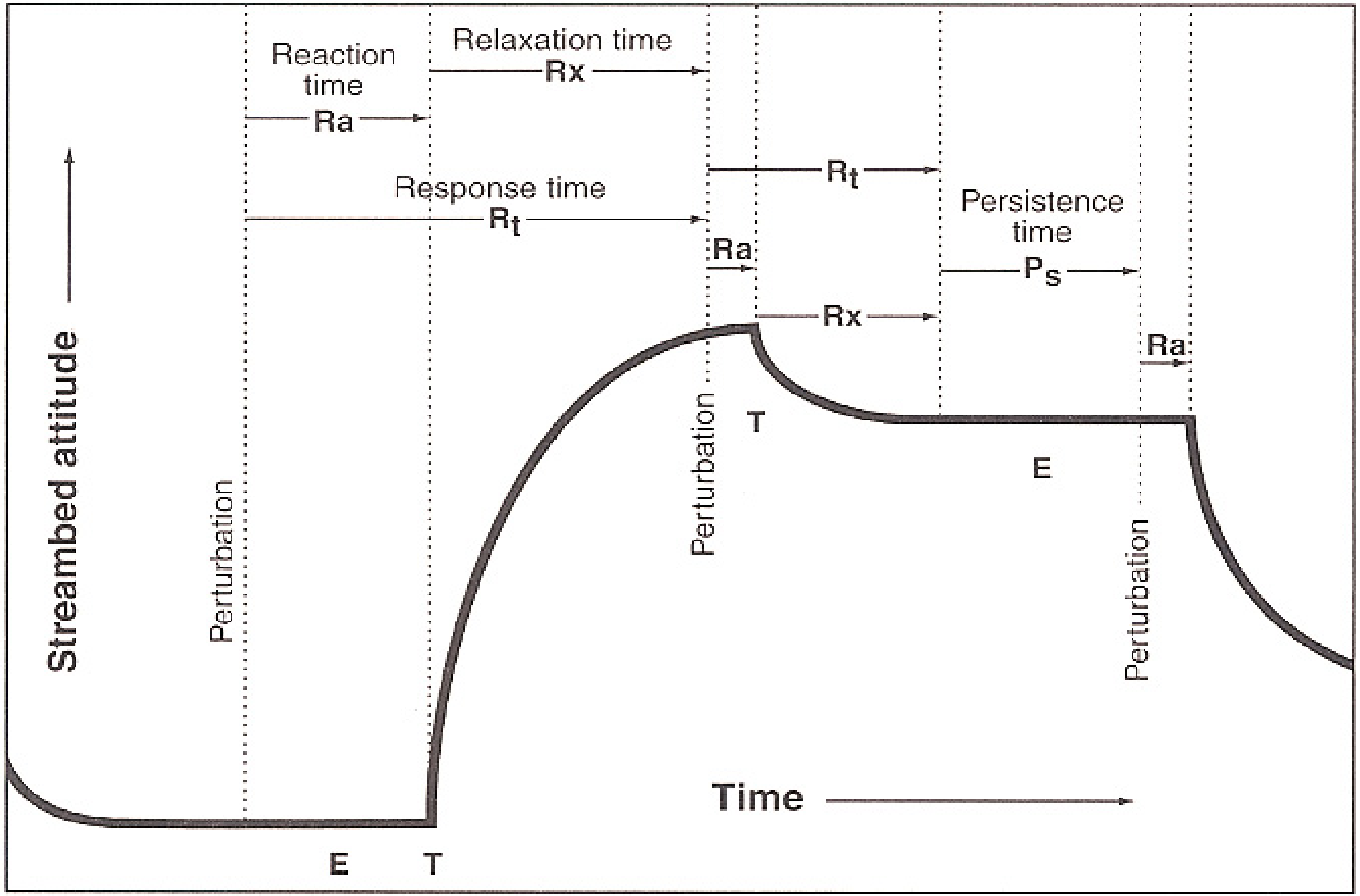
Flowing glacier

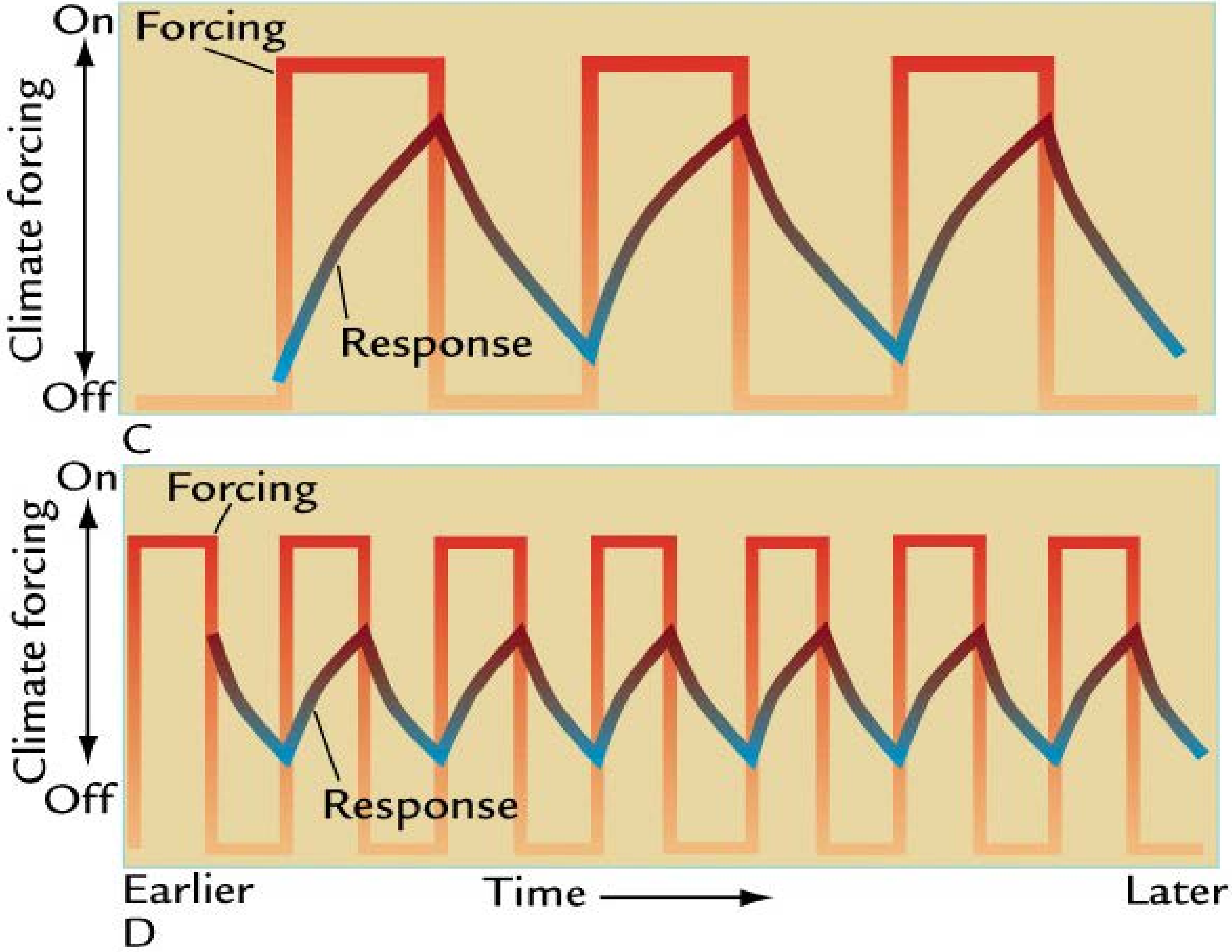


Glaciers flow by deforming and sliding along their bed. The driving force is the shear stress governed by the slope of the ice surface. The **resisting forces** include the strength of ice to resist internal deformation and the frictional resistance to sliding of material at the bed of the ice.

Geomorphic thresholds

Physical, Chemical and or Biological conditions that when reached or exceeded trigger a CHANGE in state or shift t a new range of average conditions.


Reaction time
Ra
Relaxation time
Rx
Response time
R_t
R_t
Ra
Rx
Persistence time
P_s
Ra
Streambed attitude
Perturbation
Perturbation
Perturbation
E
T
T
E
Time

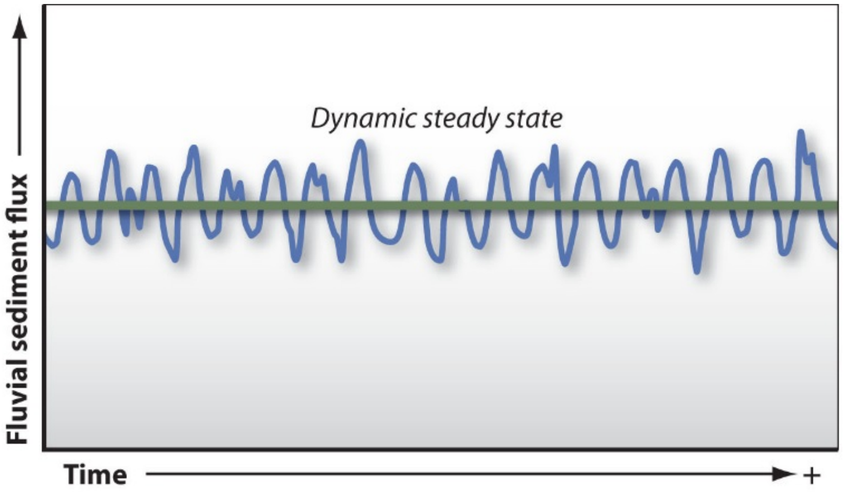

On
Forcing
Climate forcing
Response
Off
C
On
Forcing
Climate forcing
Response
Off
Earlier
Time
Later
D

Equilibrium and steady state

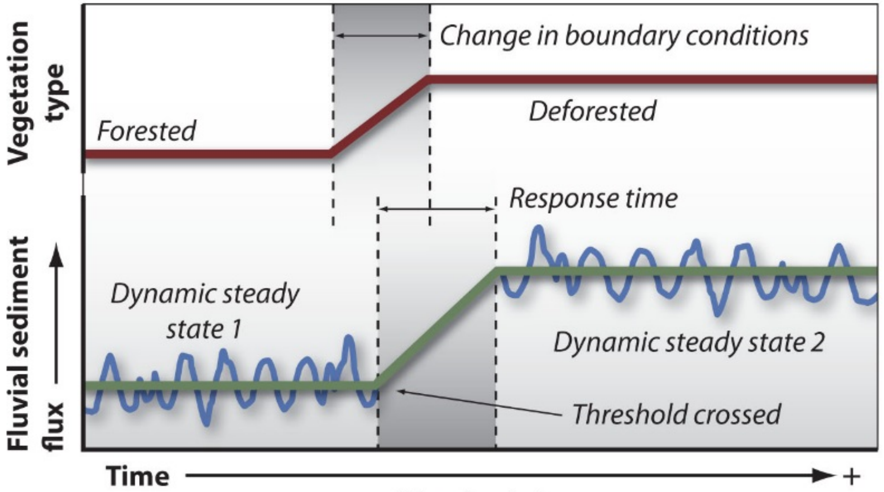
Steady state Vs.

Dynamic state

Response time



The flux of sediment from an undisturbed drainage basin changes over the short term as rainstorms come and go, individual hillslopes fail in mass movements, and riverbanks collapse. Over the long term, the flux of sediment from a drainage basin oscillates around a mean value, producing a **dynamic steady state,** unless there are significant changes in **boundary conditions,** such as climate, vegetation cover, or uplift rate.



Steady state

When boundary conditions change significantly, geomorphic systems adjust. Such adjustment does not happen instantaneously, rather it lags the change in boundary conditions, over a **response time.** In this case, deforestation and land conversion to agriculture increased the fluvial sediment flux to a new and higher dynamic steady state because soils are now disturbed by plowing and thus more vulnerable to erosion.

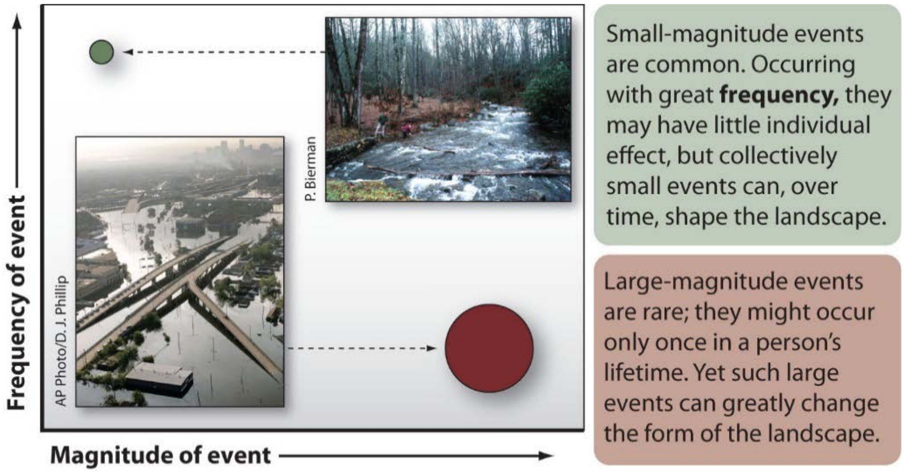
Recurrence intervals and magnitude frequency relationships

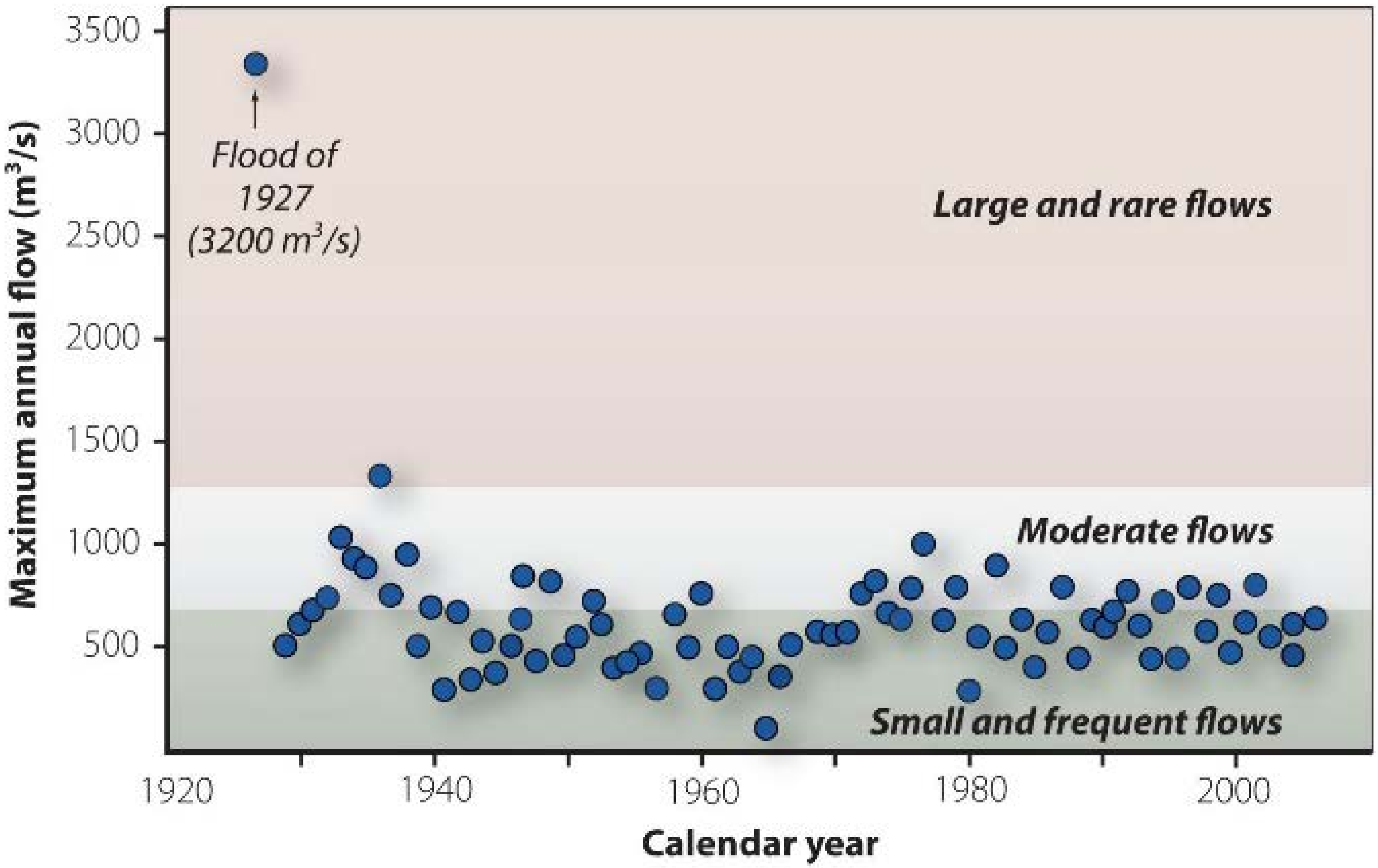
Geomorphic events, while randomly distributed in time, generally have a characteristic/statistical **recurrence interval**, *The average time between events of a similar magnitude*.

Note:

A. Different environments may have different recurrence intervals for the same process.

B. Punctuated equilibrium – Frequent (small) vs. infrequent (large) events and landscape change





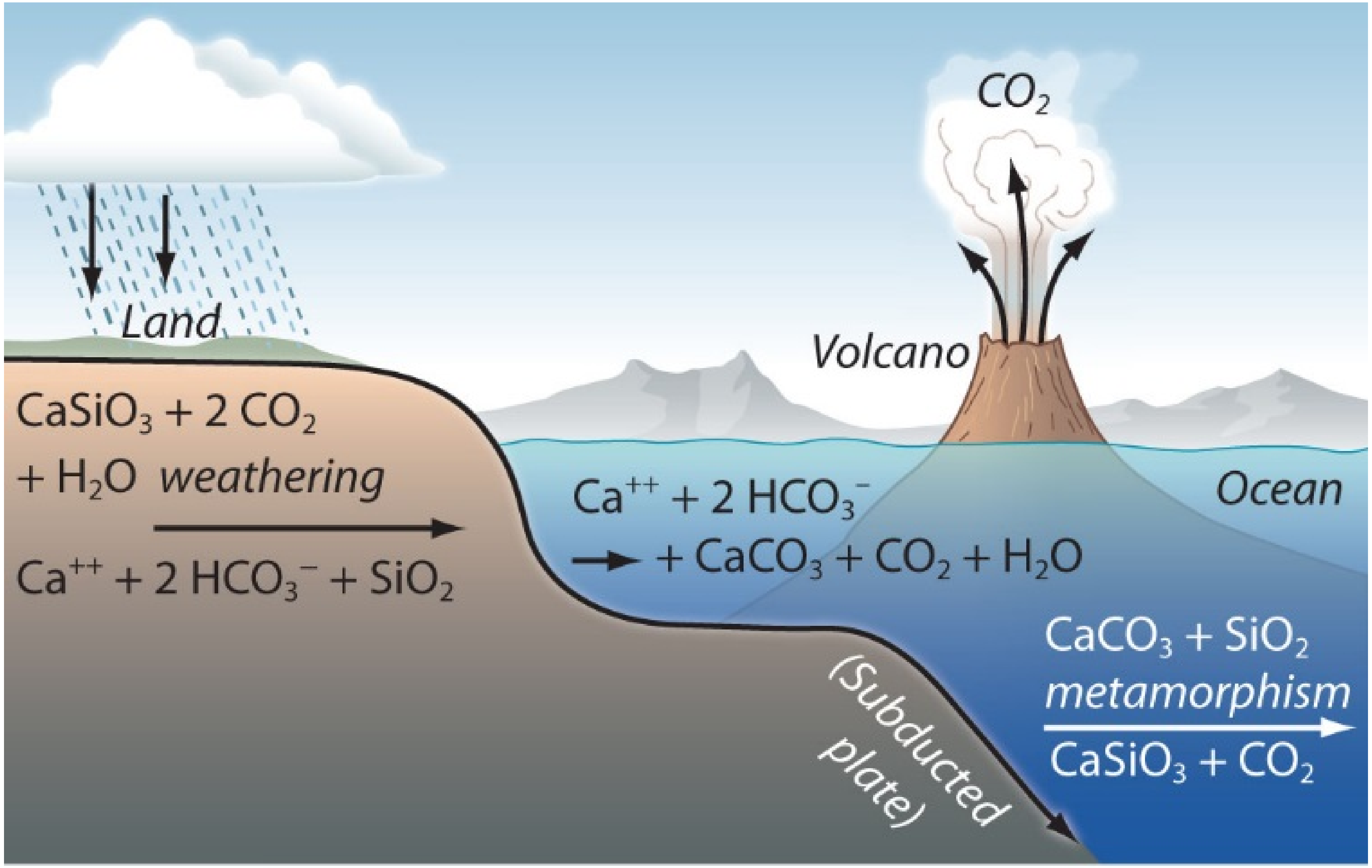
Even in humid, well-watered northeastern North America, there is great variability in maximum **annual flood** flows. On the Winooski River (~2700 km^2) in northern Vermont, the largest annual flood (1927) was almost 20 times greater than the smallest annual flood (1963) and caused immense damage and channel change.

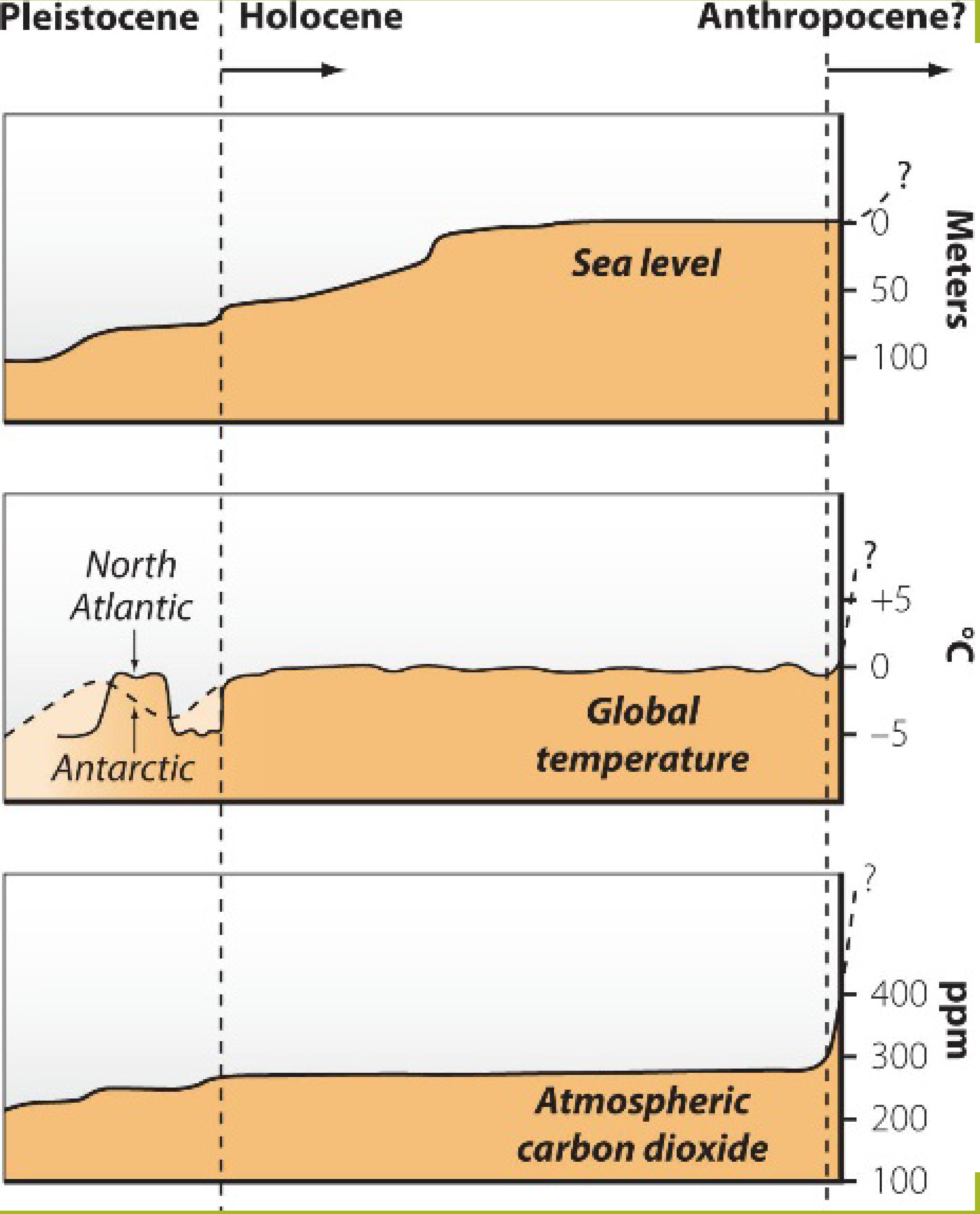
Natural Feedbacks (Important)

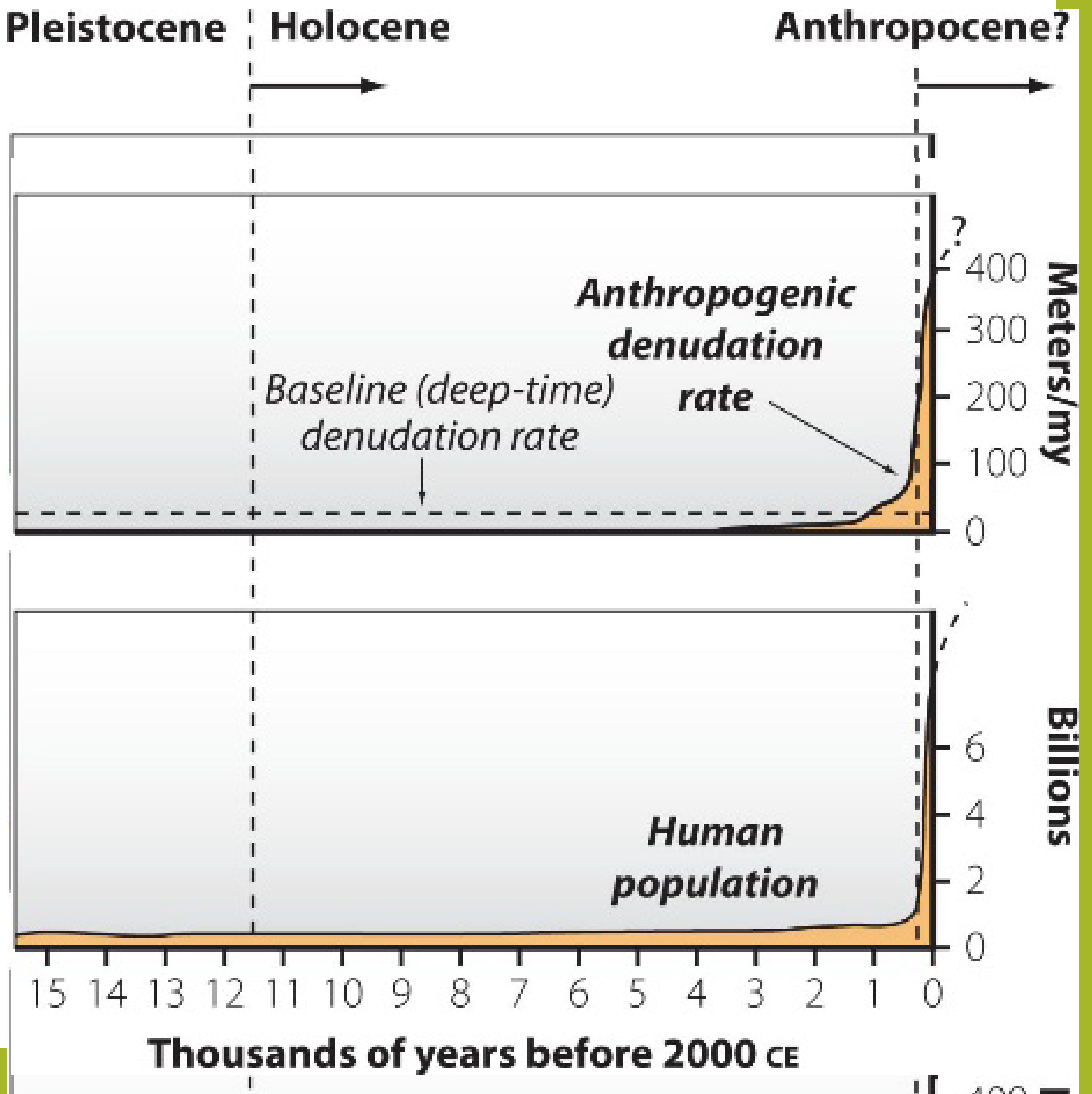
Positive

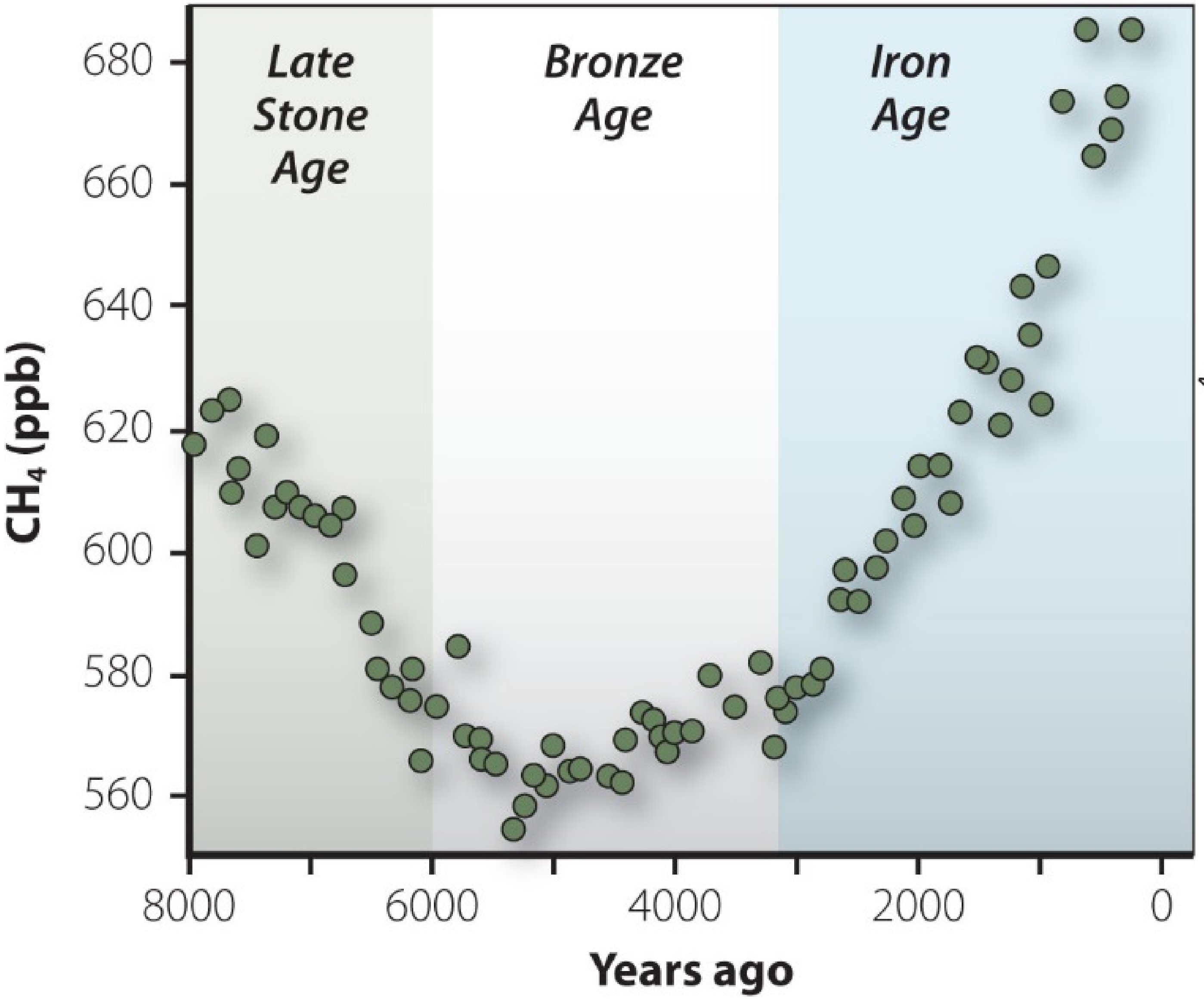
Negative

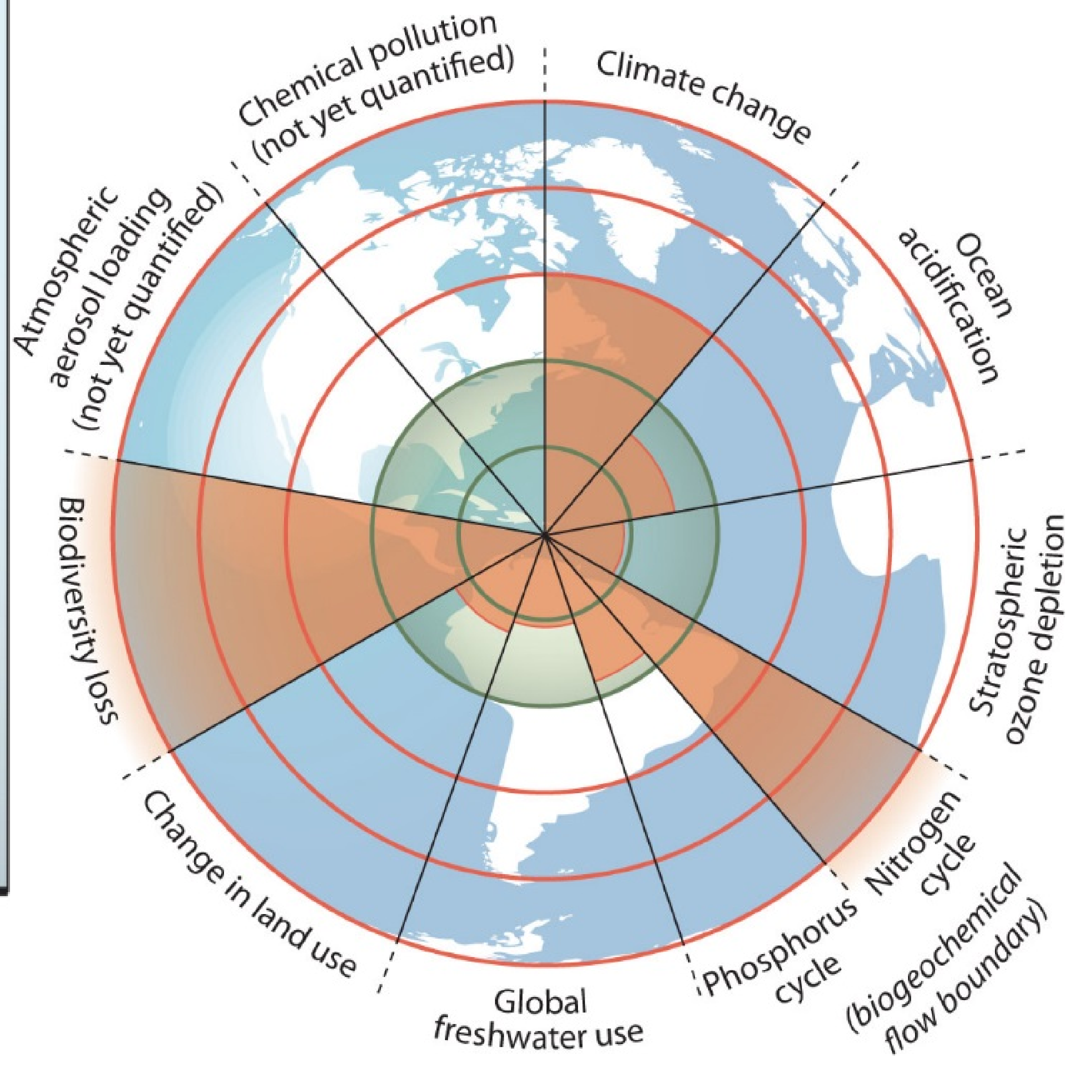
Holocene Vs. Anthropocene Epochs




Pleistocene
Holocene
Anthropocene?
Sea level
Meters
0
50
100
North Atlantic
Antarctic
Global temperature
°C
+5
0
−5
Atmospheric carbon dioxide
ppm
400
300
200
100


Pleistocene
Holocene
Anthropocene?
Anthropogenic denudation rate
Baseline (deep-time) denudation rate
Meters/my
400
300
200
100
0
Human population
Billions
6
4
2
0
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Thousands of years before 2000 CE


Late Stone Age
Bronze Age
Iron Age
680
660
640
620
600
580
560
CH_4 (ppb)
8000
6000
4000
2000
0
Years ago


Chemical pollution (not yet quantified)
Climate change
Ocean acidification
Stratospheric ozone depletion
Nitrogen cycle
Phosphorus cycle
(biogeochemical flow boundary)
Global freshwater use
Change in land use
Biodiversity loss
Atmospheric aerosol loading (not yet quantified)

Knowledge assessment – Chapter 1 – Due next class…

Questions – 2, 10, 16, 27, 29, 33, 34, 35

n = 8

Bonus – “A Brief History of Geomorphology” – Who is your favorite historical geomorphic person, and why?