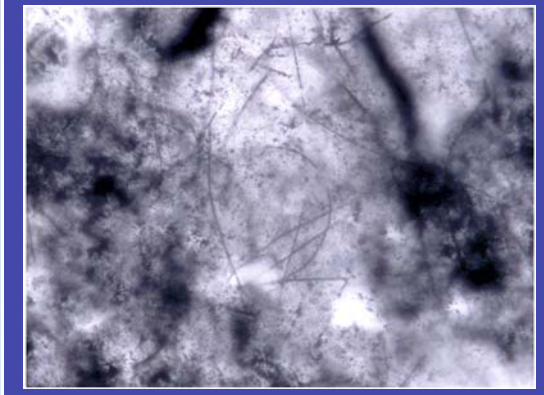
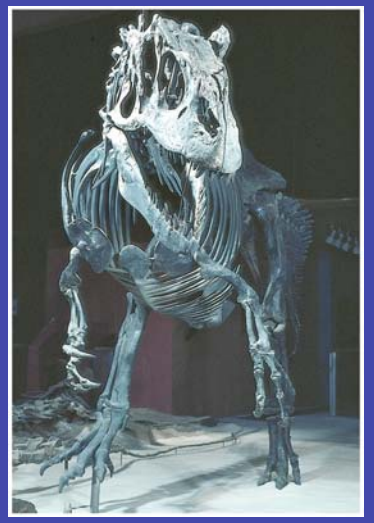
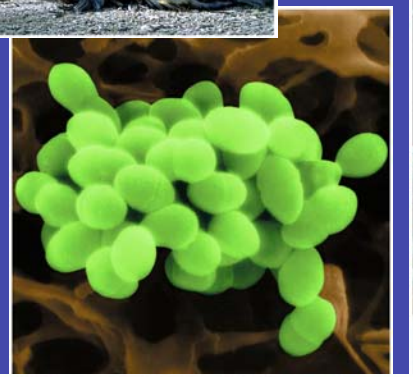
Why should a geologist be studying climate?









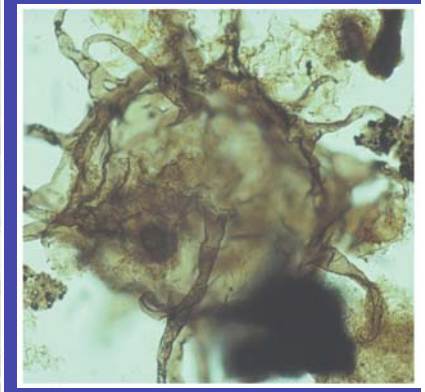




What defines <u>INTERVALS</u> on geologic timescale?







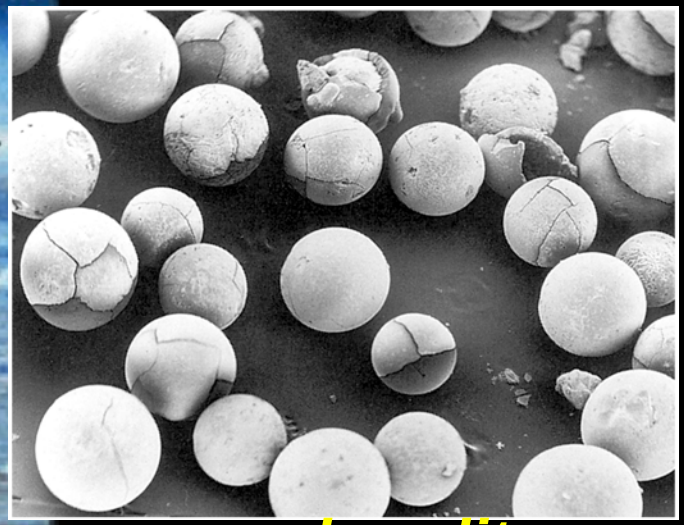
10 km across ***(not to scale!)***



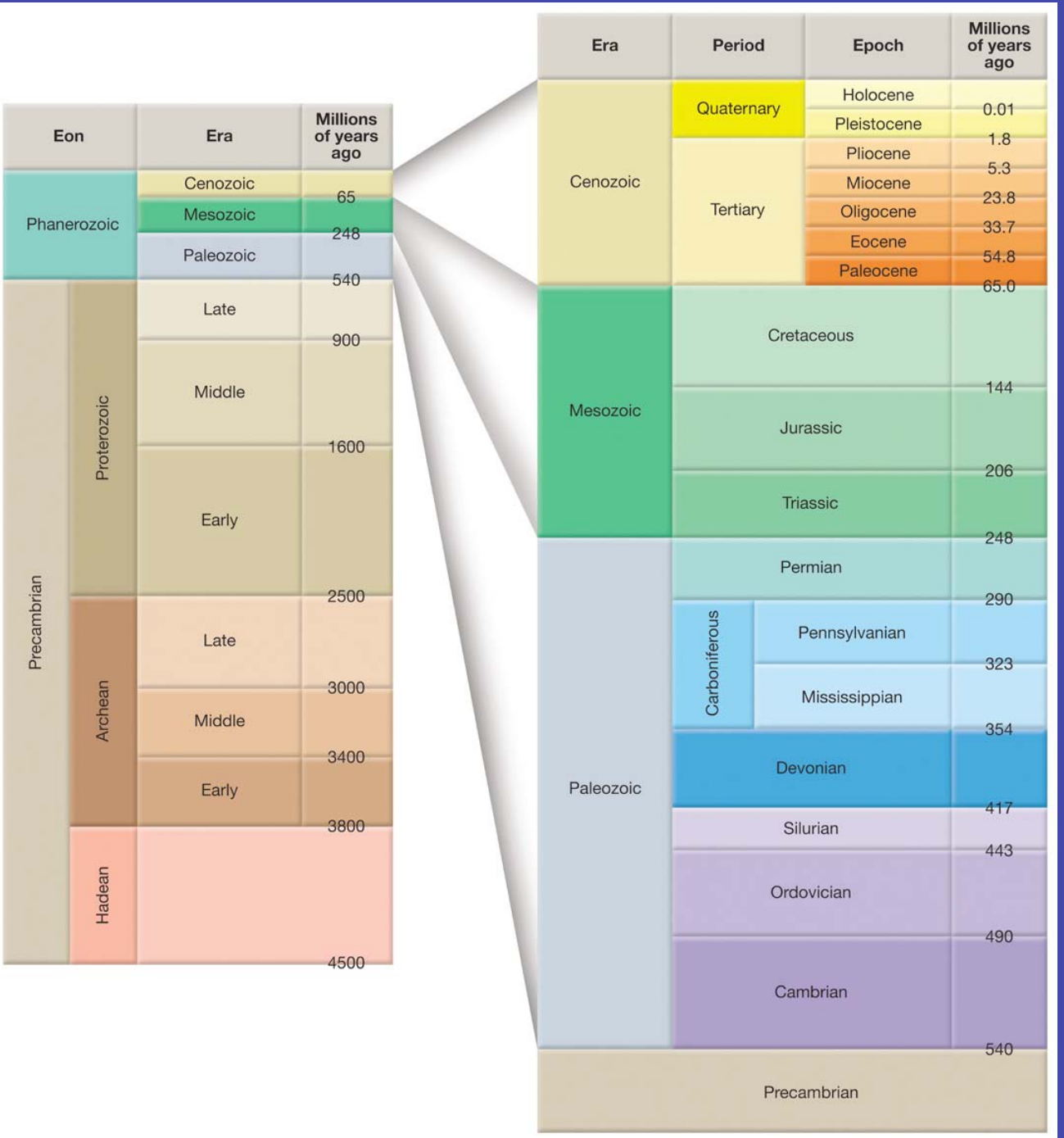
What defines

<u>BOUNDARIES</u>

on geologic timescale?



spherulites



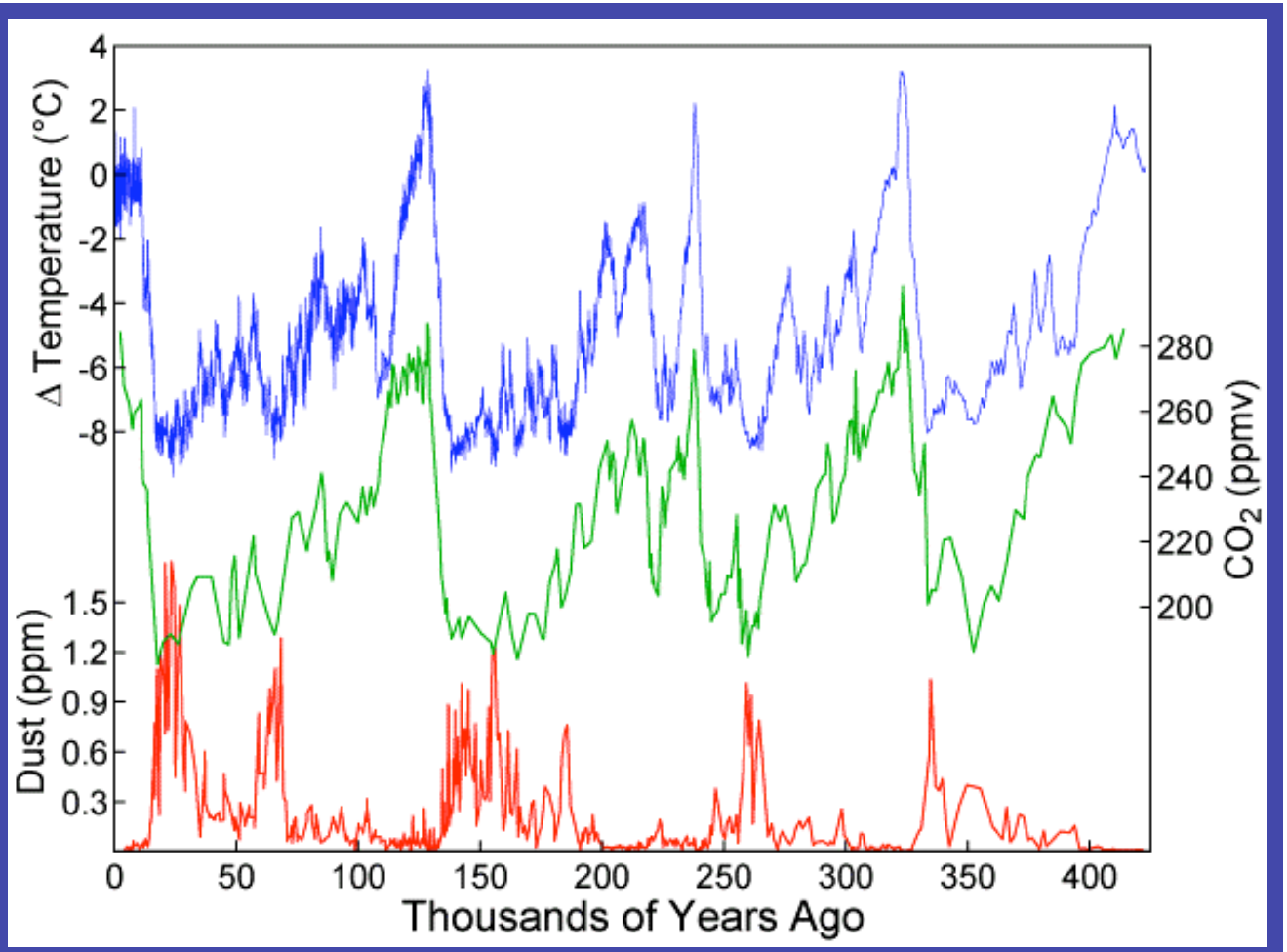
CLIMATE change

is responsible for the organization of the GEOLOGIC timescale



Principle of Uniformitarianism
"present is the key to the past"

Era	Period	Epoch	Millions of years ago
Cenozoic	Quaternary	Holocene	0.01
		Pleistocene	1.8
	Tertiary	Pliocene	5.3
		Miocene	23.8
		Oligocene	33.7
		Eocene	54.8
		Paleocene	65.0
Mesozoic	Cretaceous		144
	Jurassic		206
	Triassic		248
Paleozoic	Permian		290
	Carboniferous	Pennsylvanian	323
		Mississippian	354
	Devonian		417
	Silurian		443
	Ordovician		490
	Cambrian		540
Precambrian			



Past climate change may help us to predict the future



What are the (non-human) drivers of climate change?



What do these striations result from?



Continental glaciation is most likely cause of glacial striations





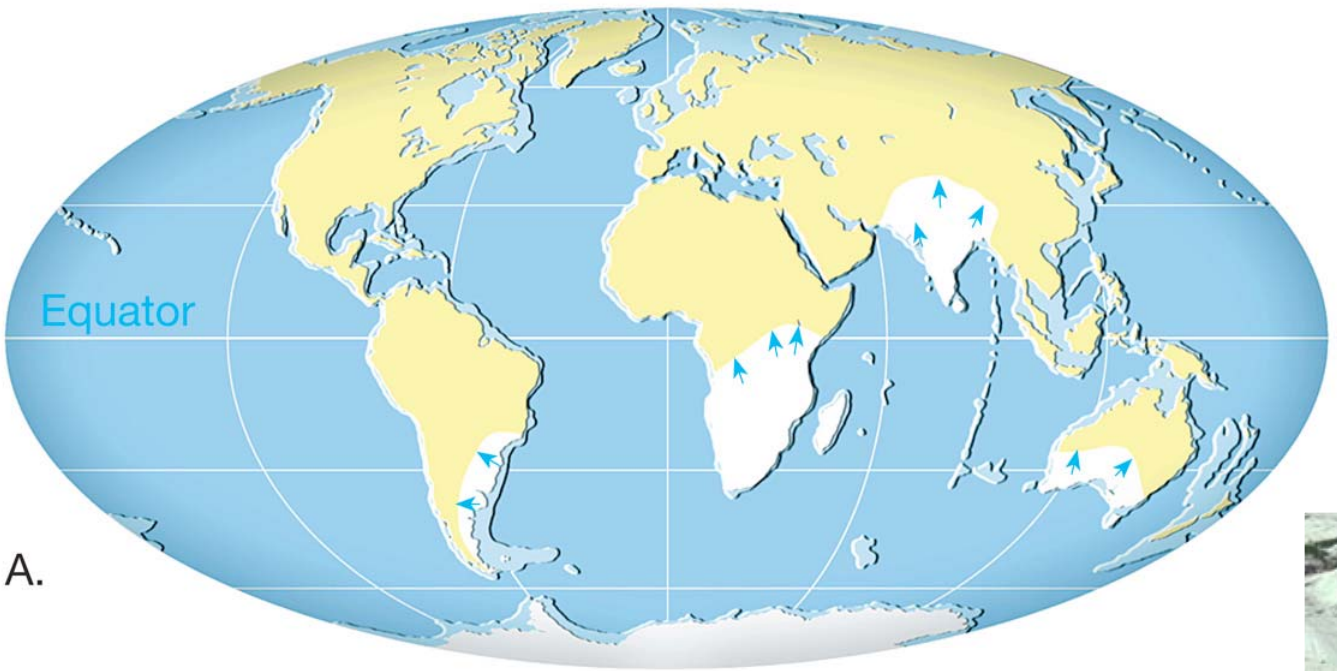
Would glacial striations form in environments like these?





Glacial remnants in Africa are explained by:

1) plate tectonics







Alligator fossils found on Ellesmere Island

78° North (north of Greenland)

54.8-33.7 Mya Eocene



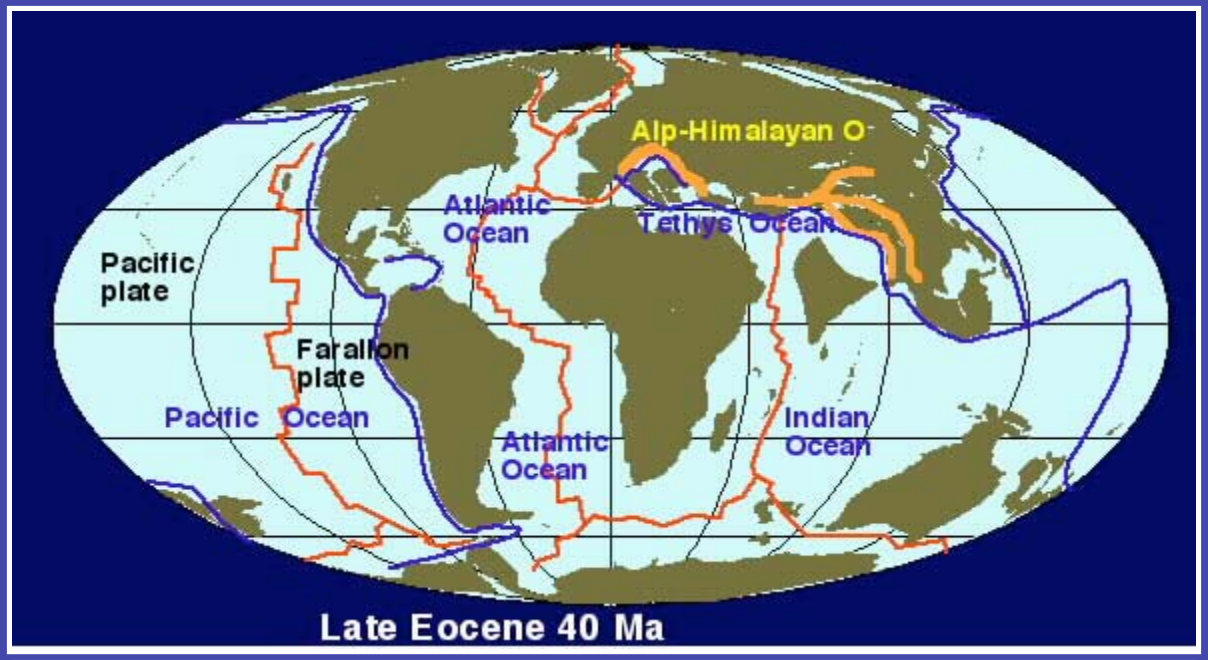


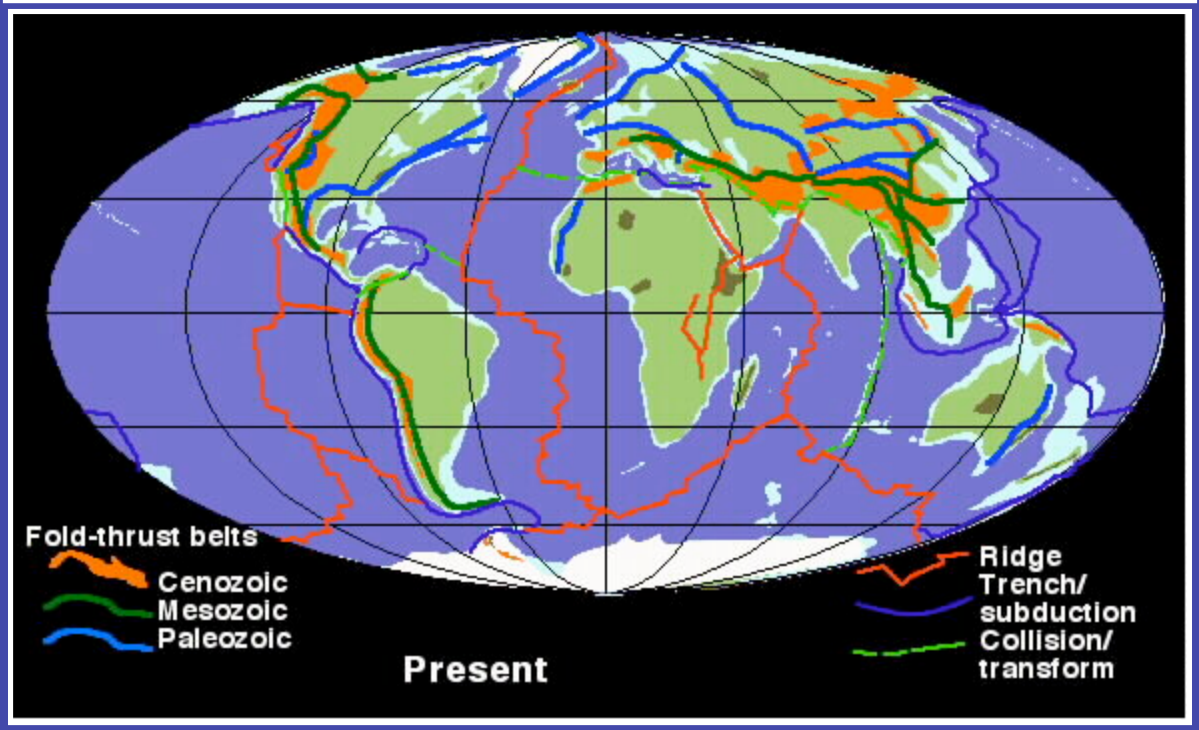




Fossil palm fronds from Eocene (54.8-33.7 Mya) in Wyoming

Did plate tectonics cause this?



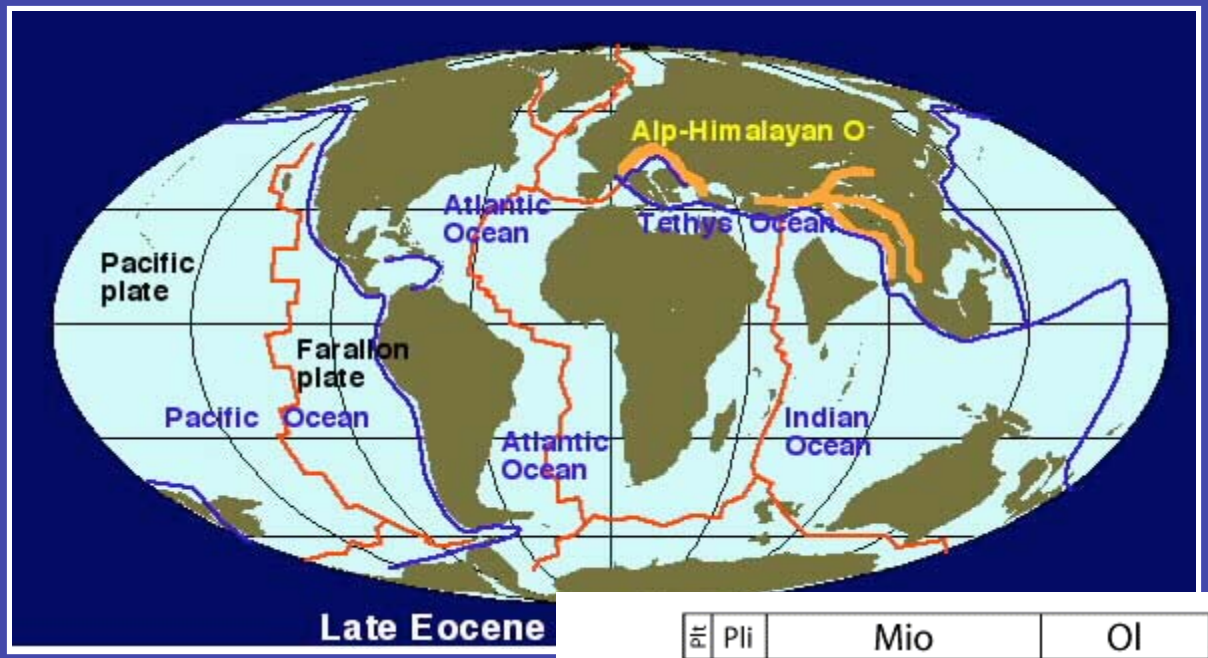


Have the positions of Wyoming and Ellesmere changed much over the last 40 Mya?

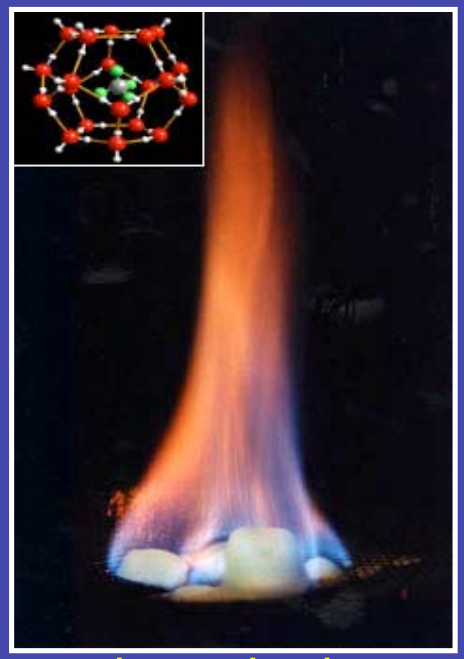
Eocene thermal optimum
NOT caused by plate tectonics



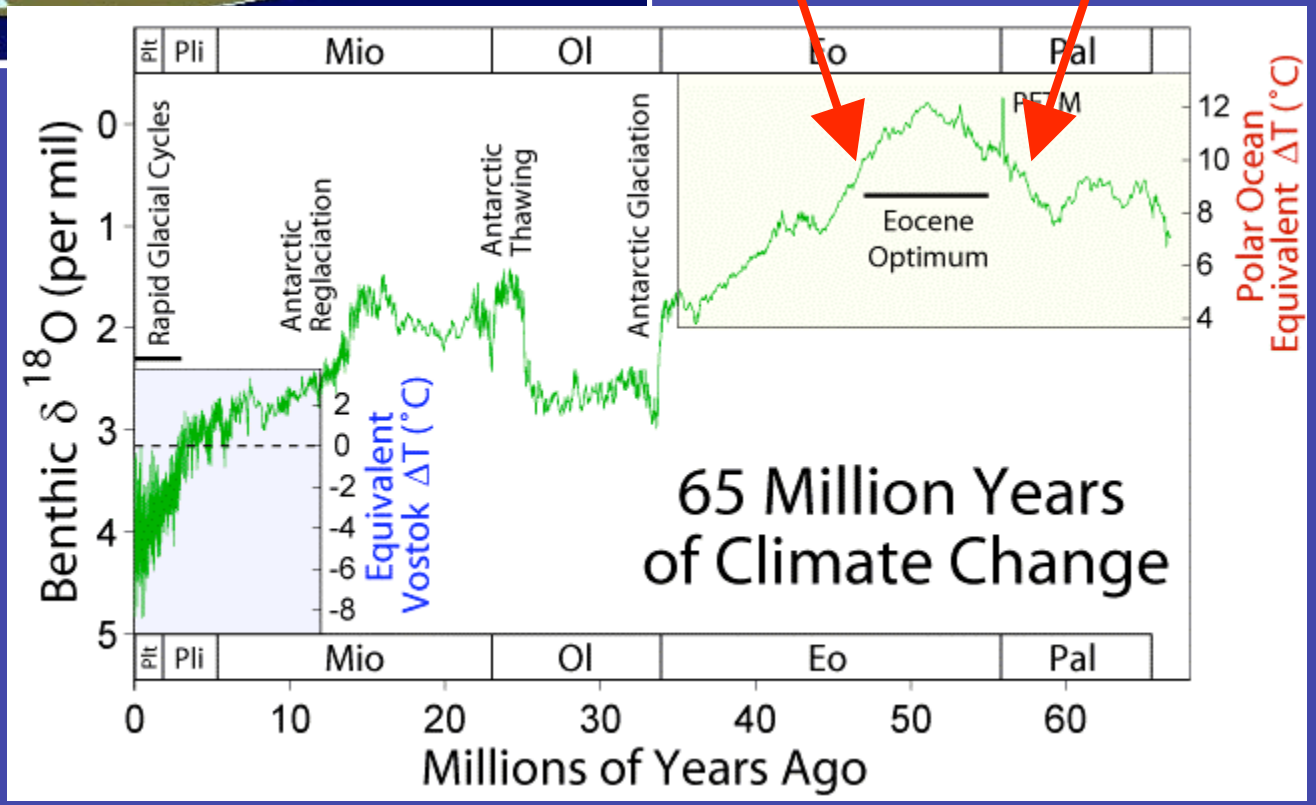




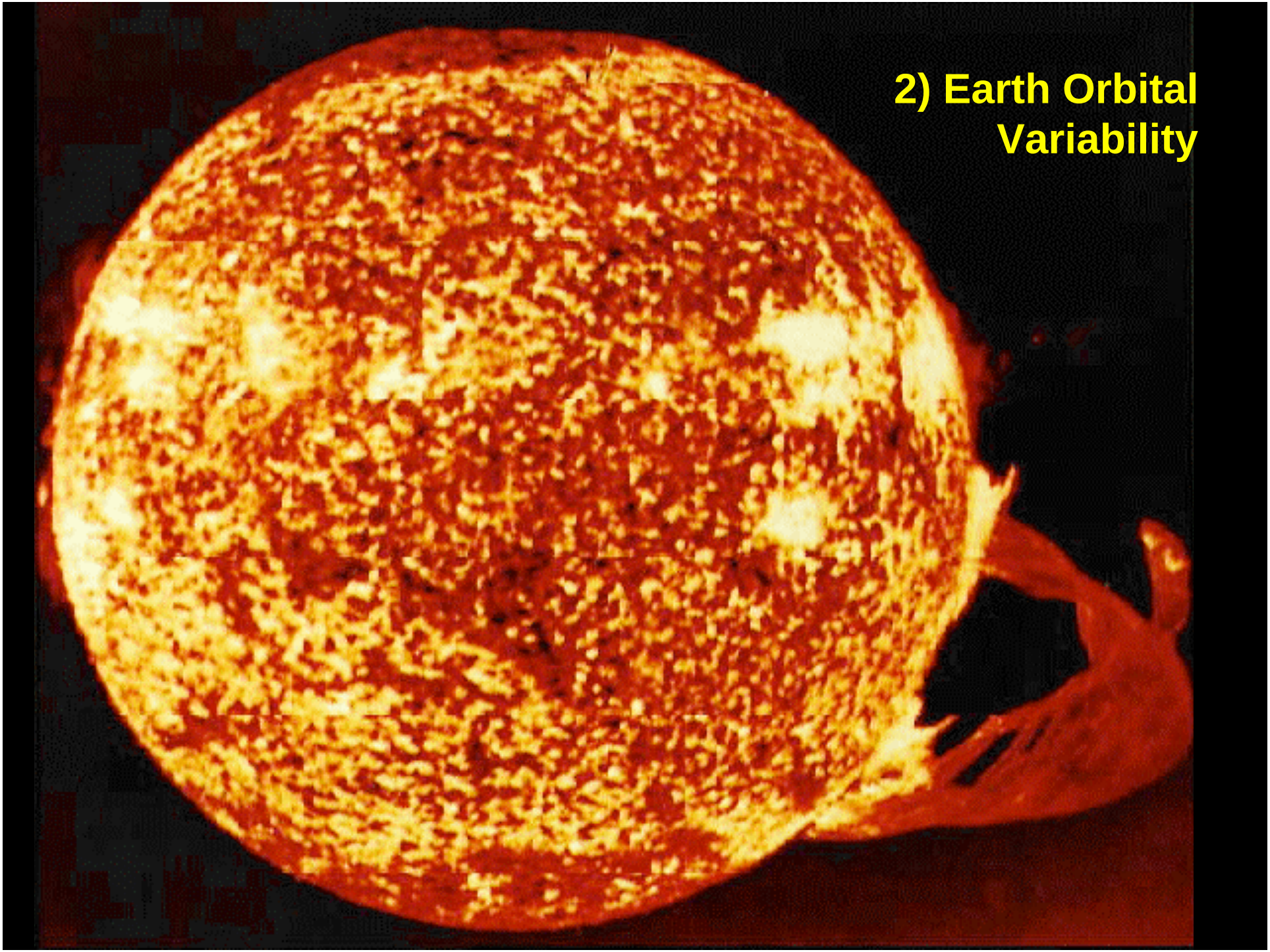
What was going on here to change global temperature?



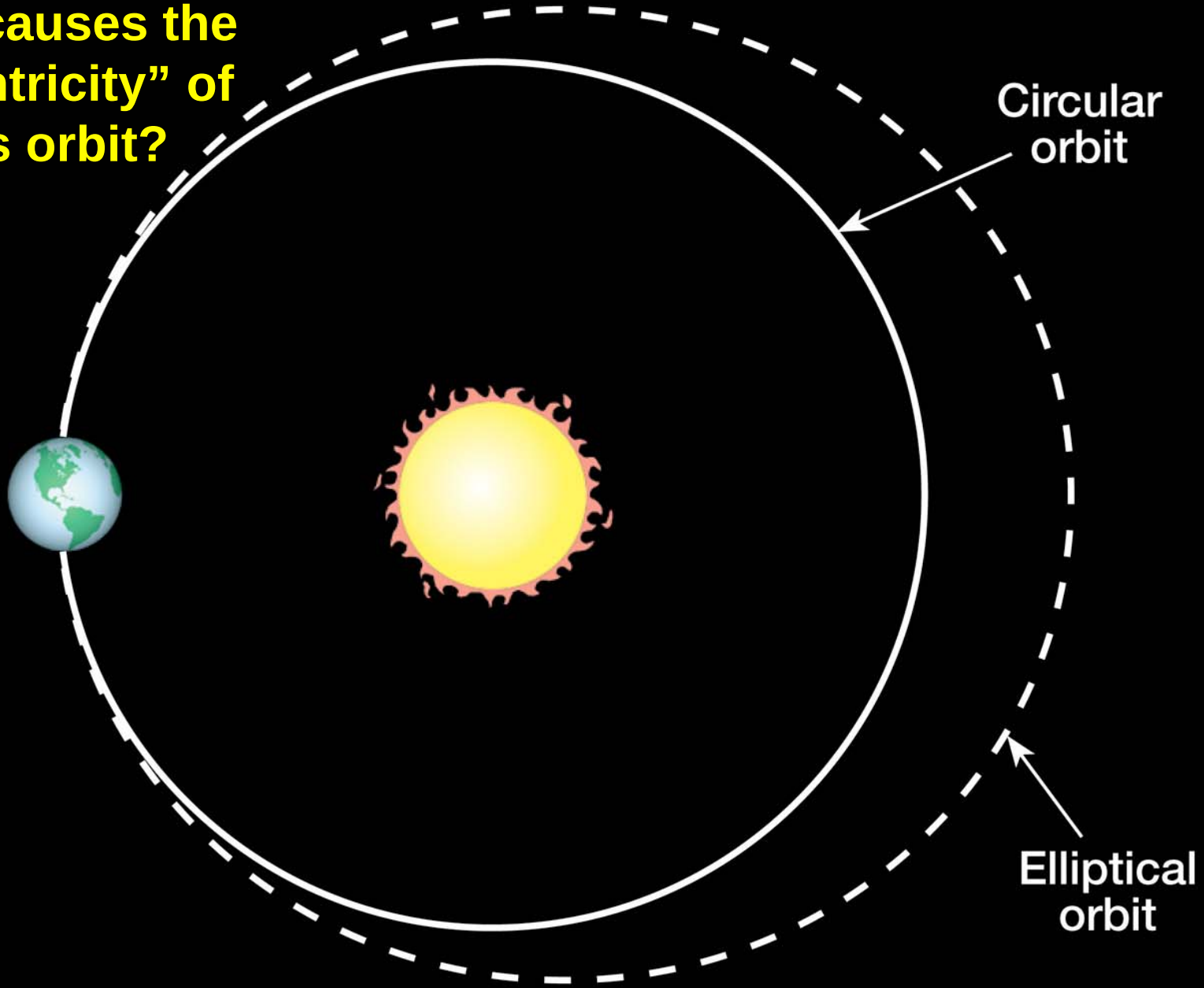
methane hydrates



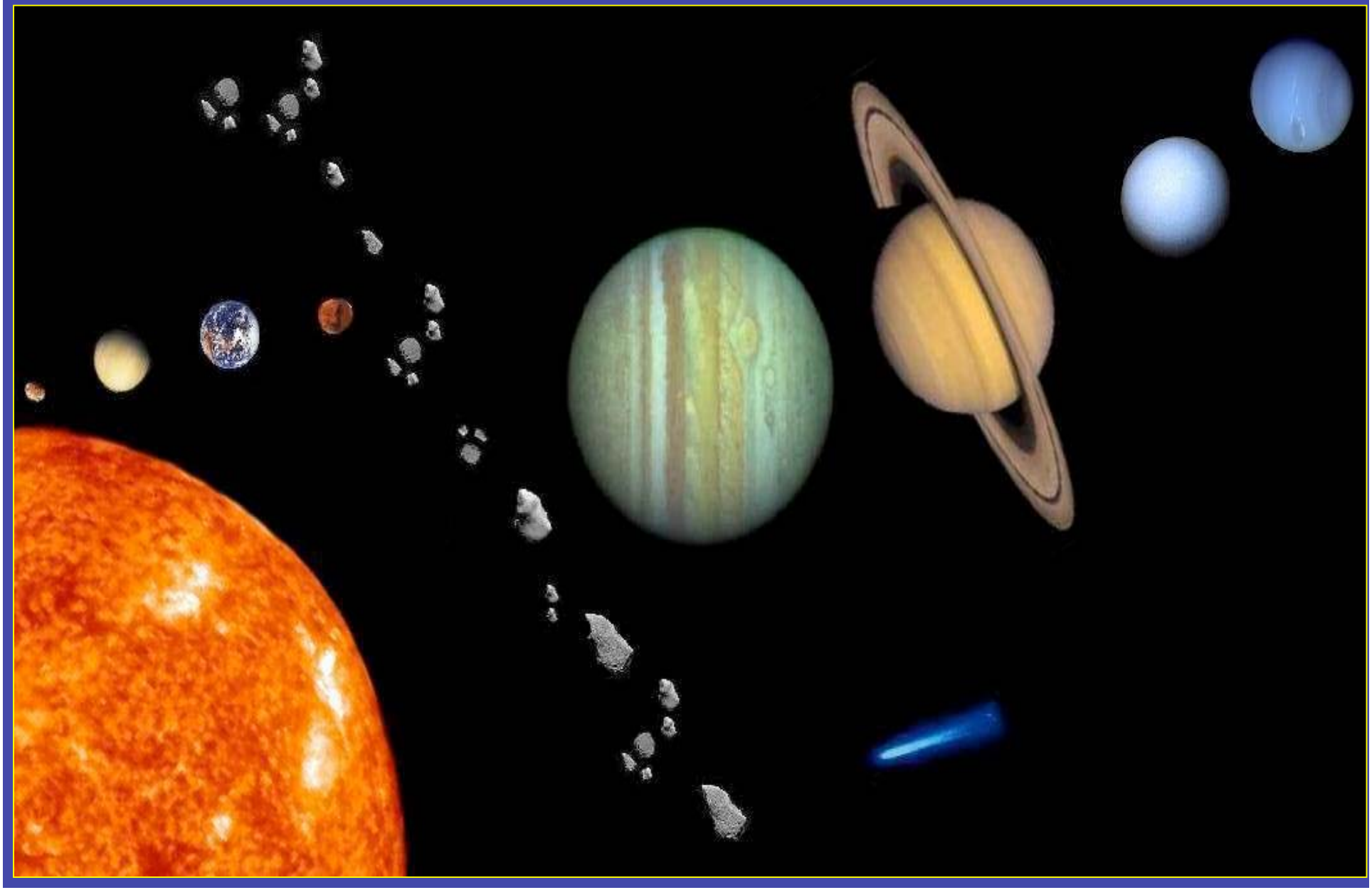
What else besides plate tectonics can cause climate changes over long timescales?


2) Earth Orbital
Variability

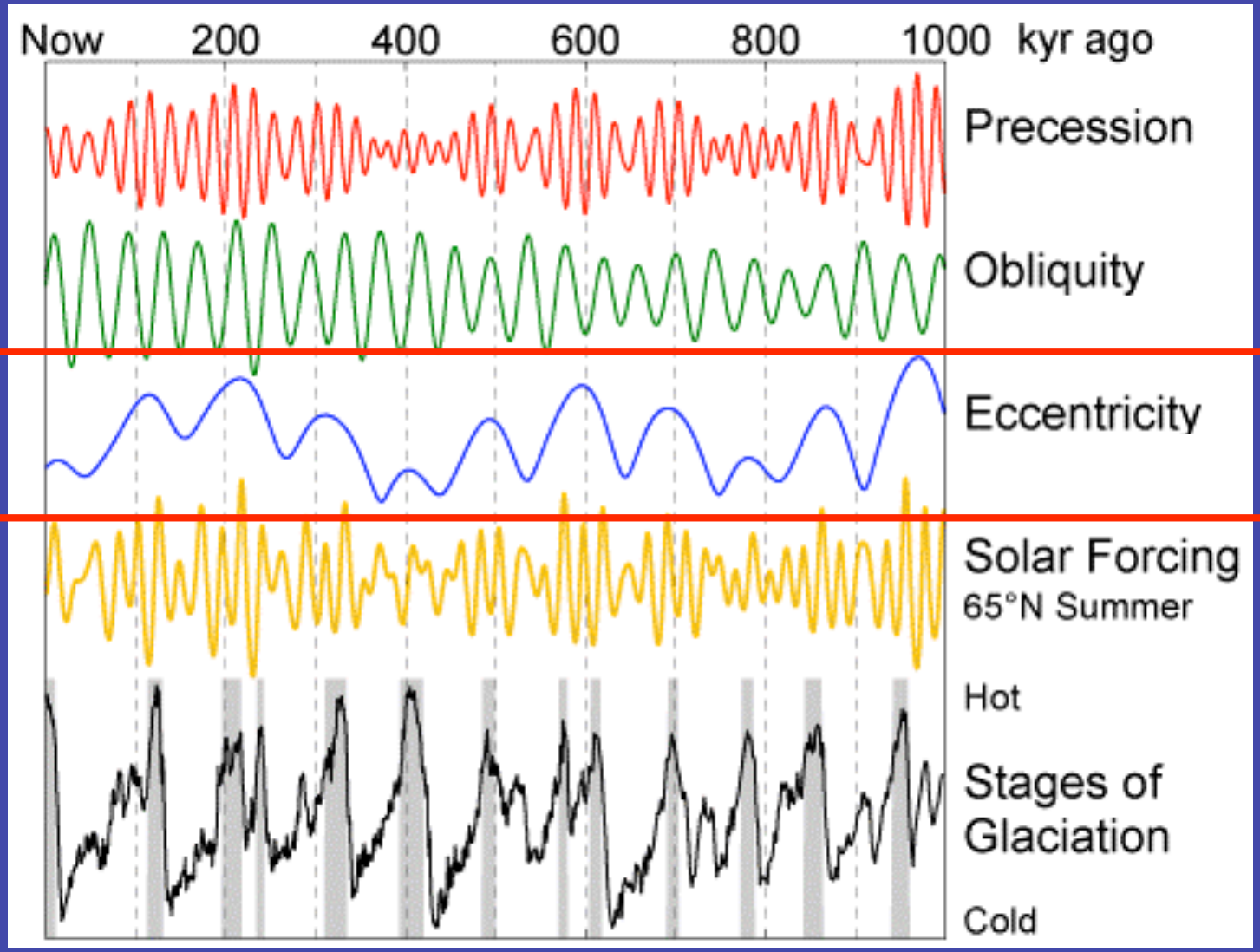
What causes the "eccentricity" of Earth's orbit?



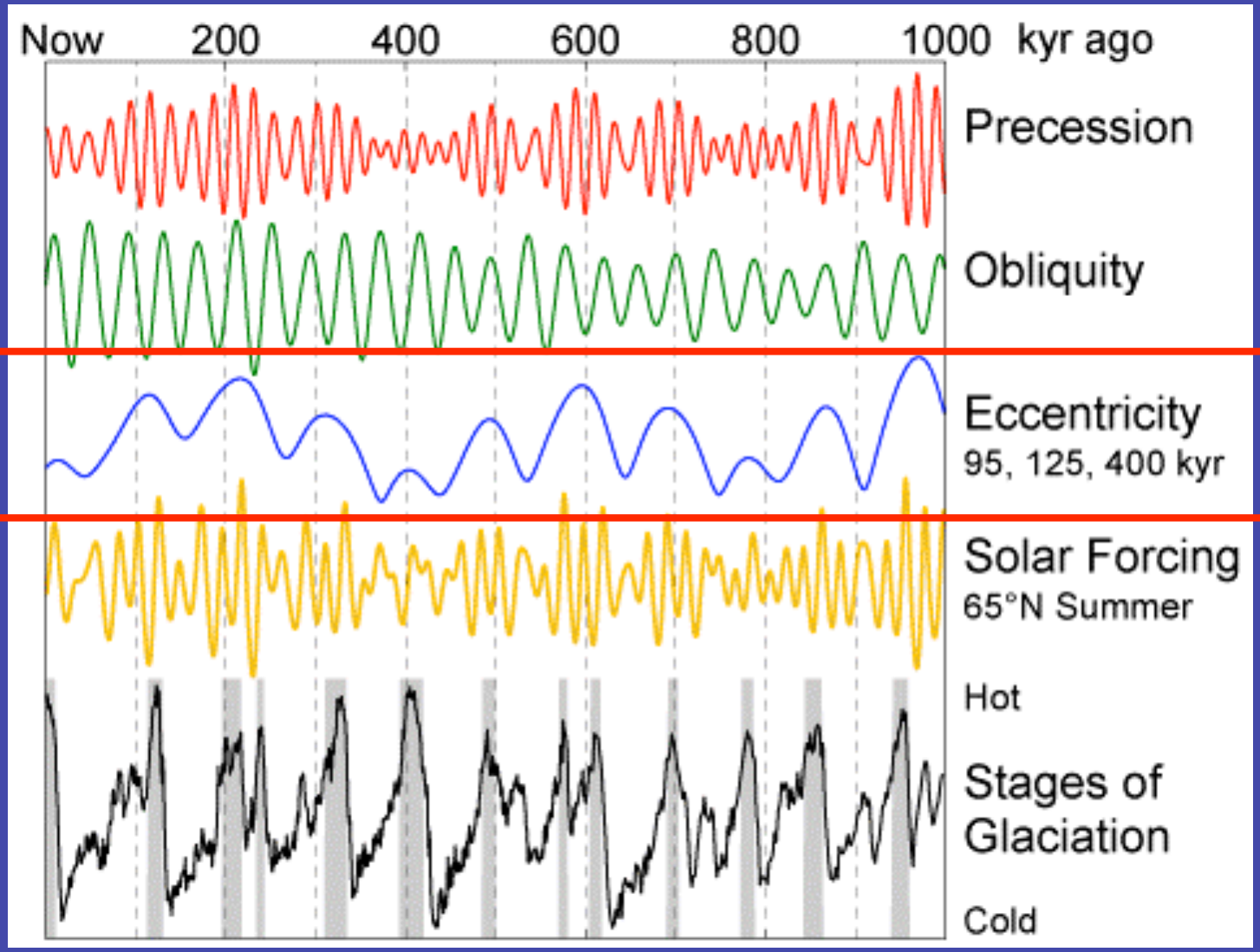
Gravitational interactions with the orbits of Jupiter and Saturn



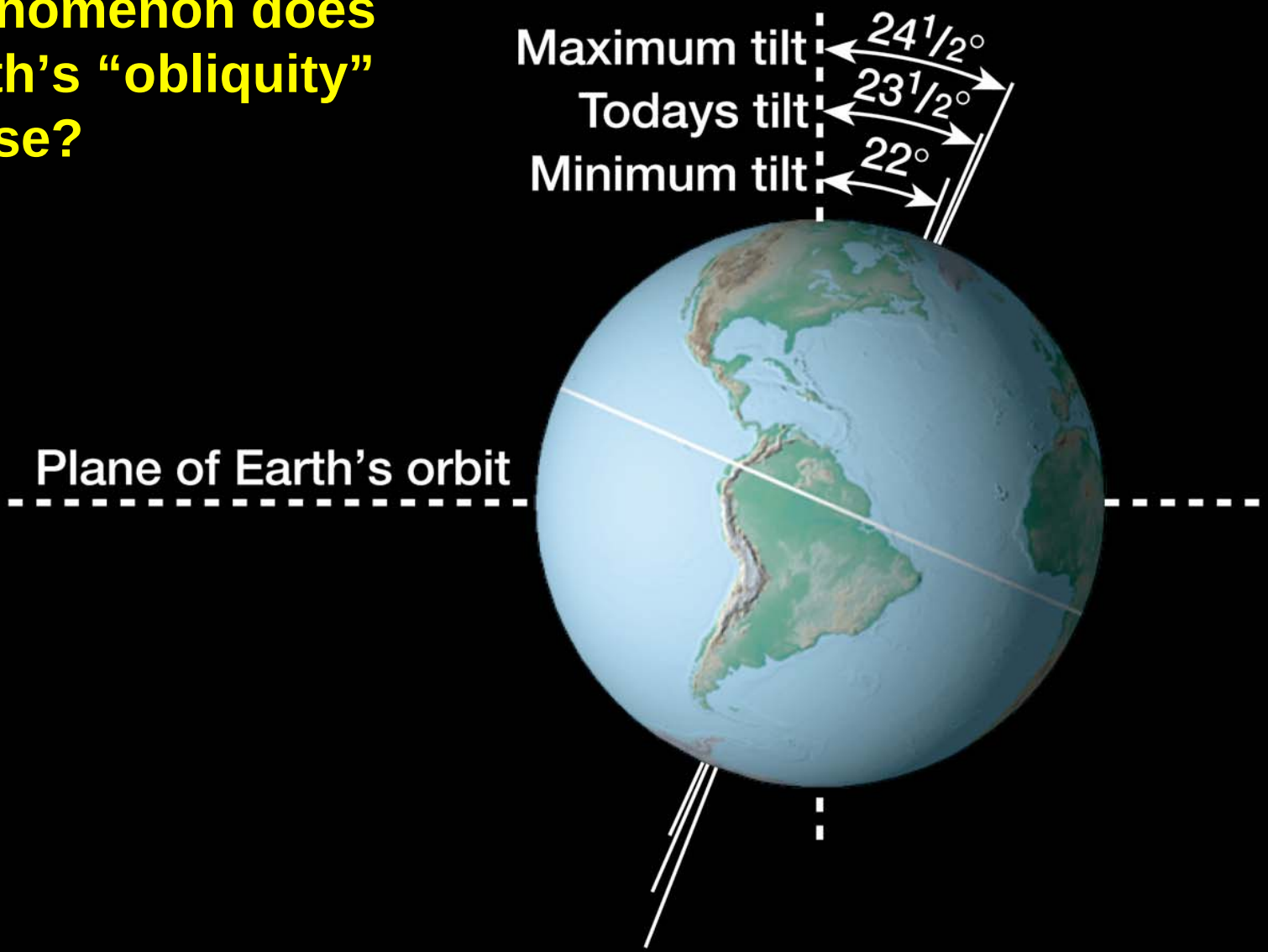
What is the period of Earth's eccentricity?



What is the period of Earth's eccentricity?

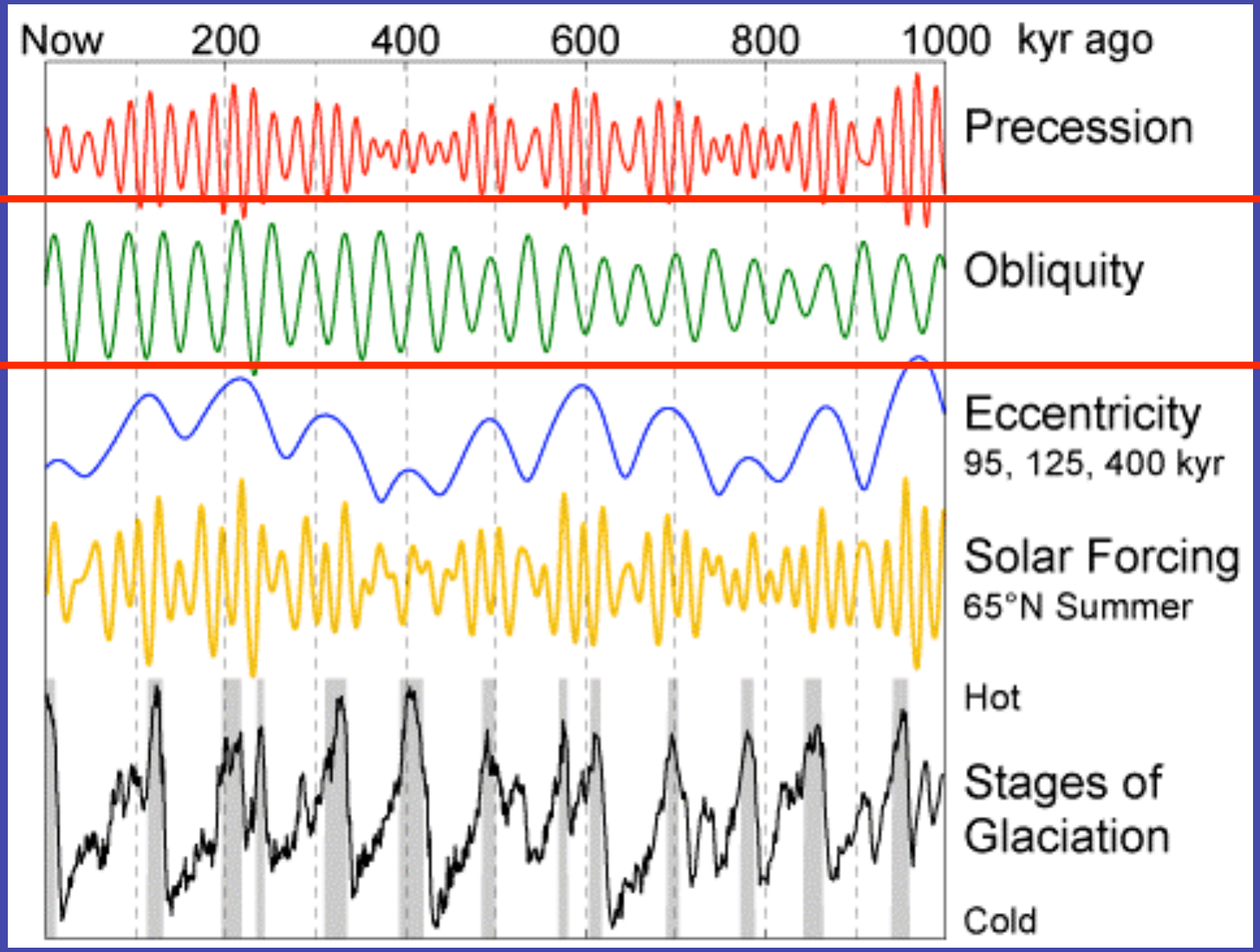


What familiar climate phenomenon does Earth's "obliquity" cause?

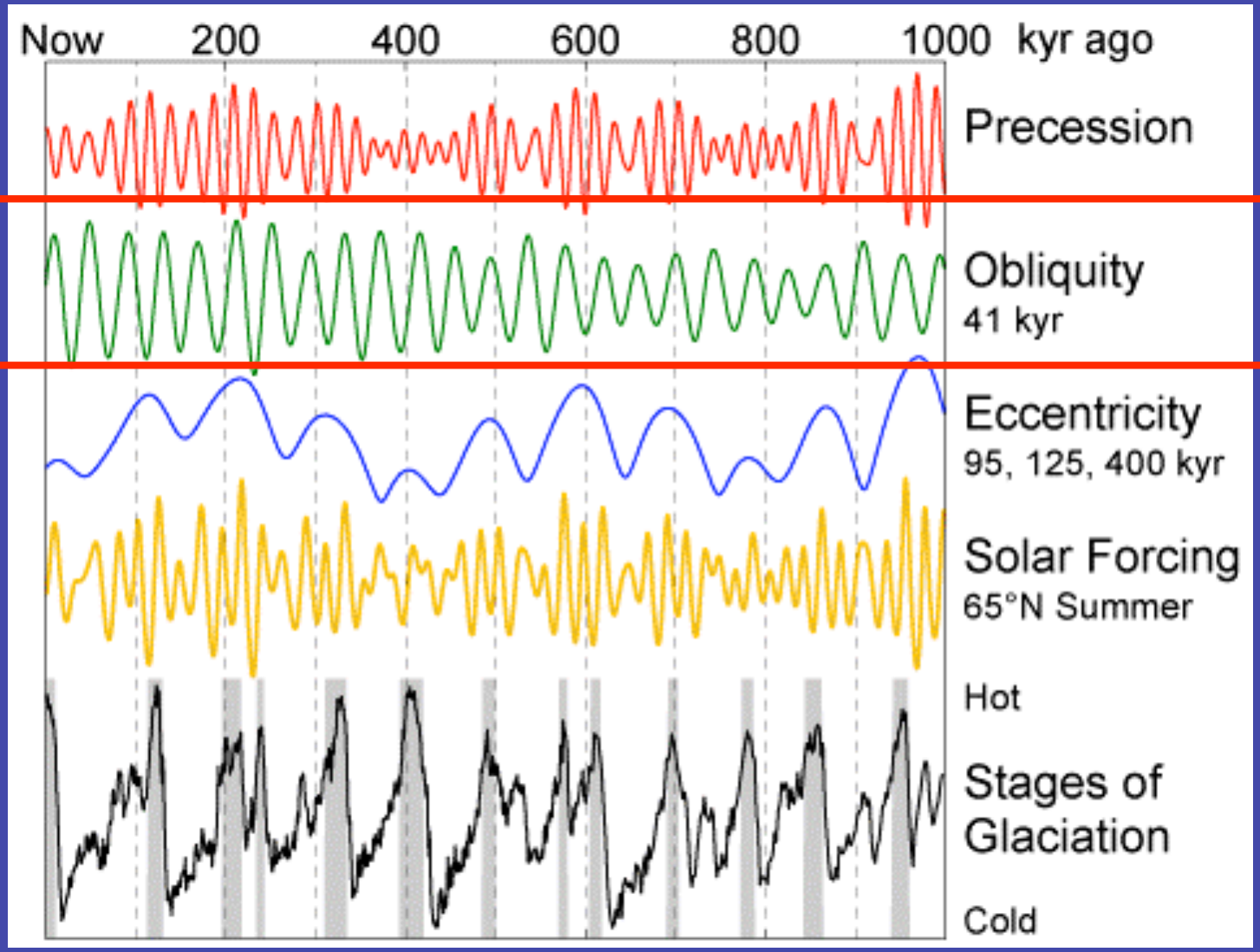



Seasonality results from Earth’s obliquity

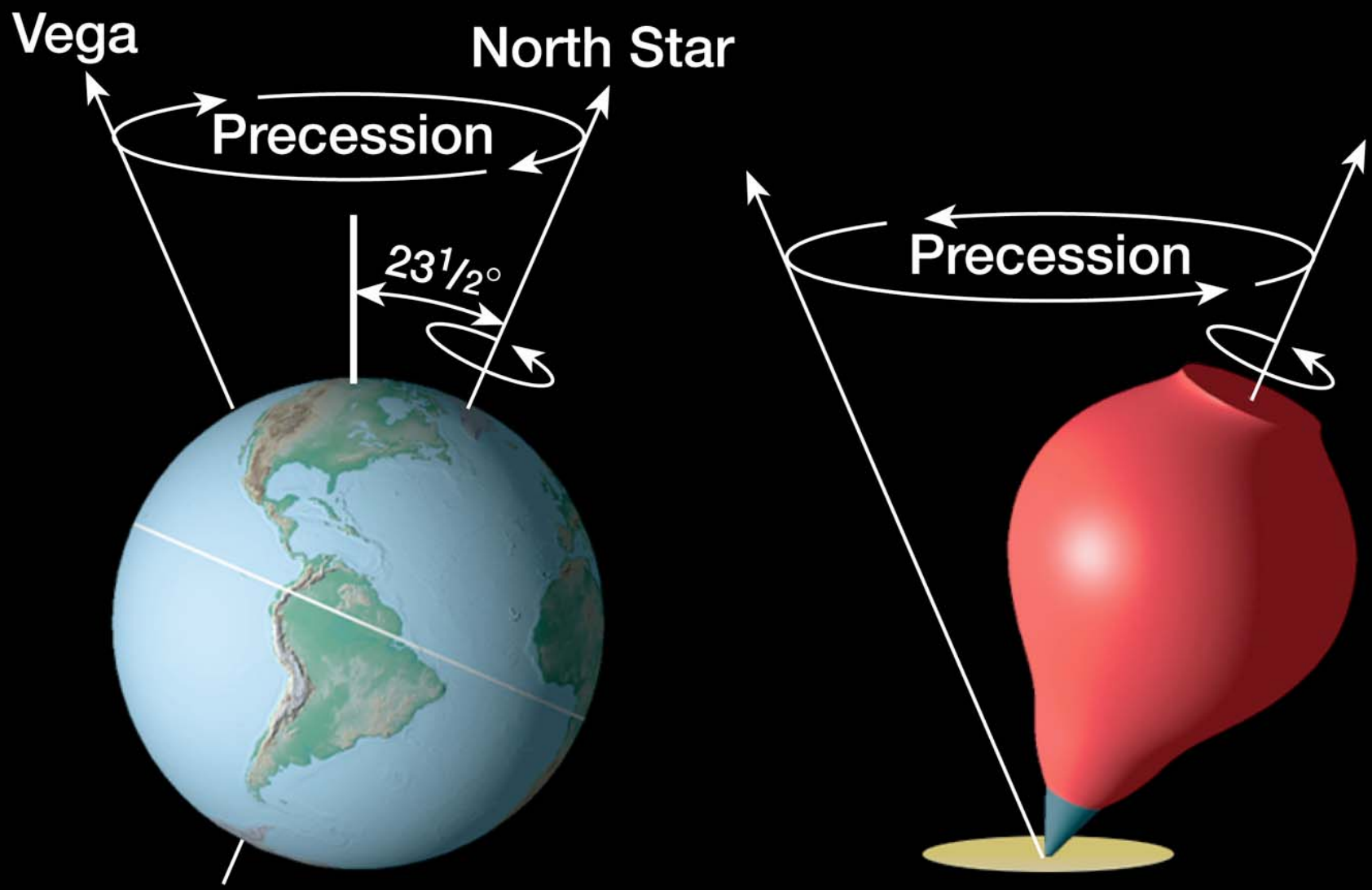
What is the period of Earth's obliquity?



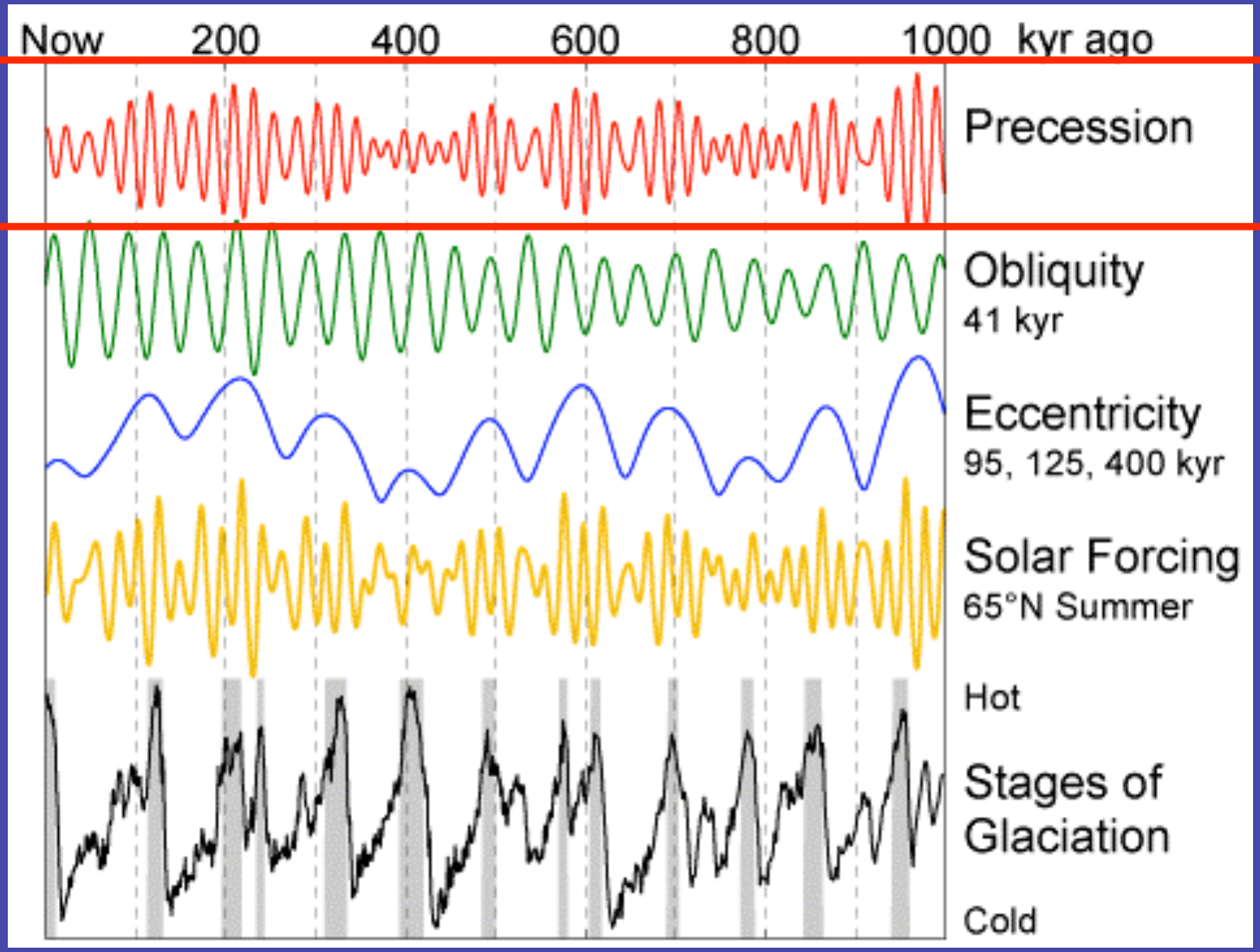
What is the period of Earth's obliquity?



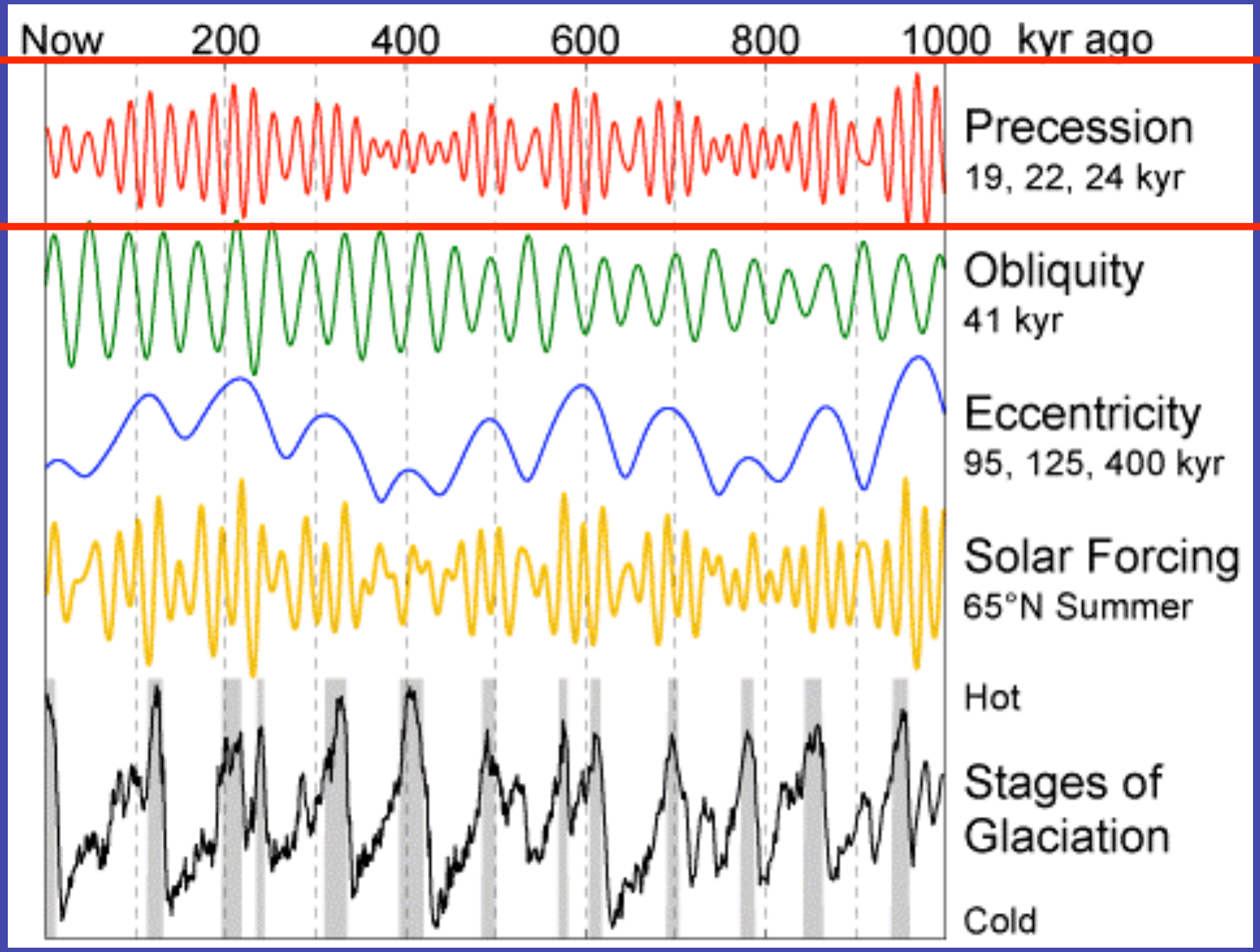
“Precession” of the equinoxes occurs due to tidal forces from Sun and Moon



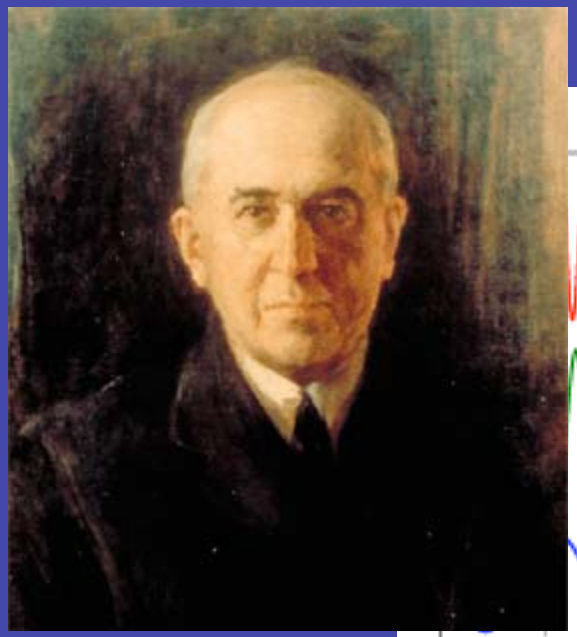
What is the period of Earth's precession?



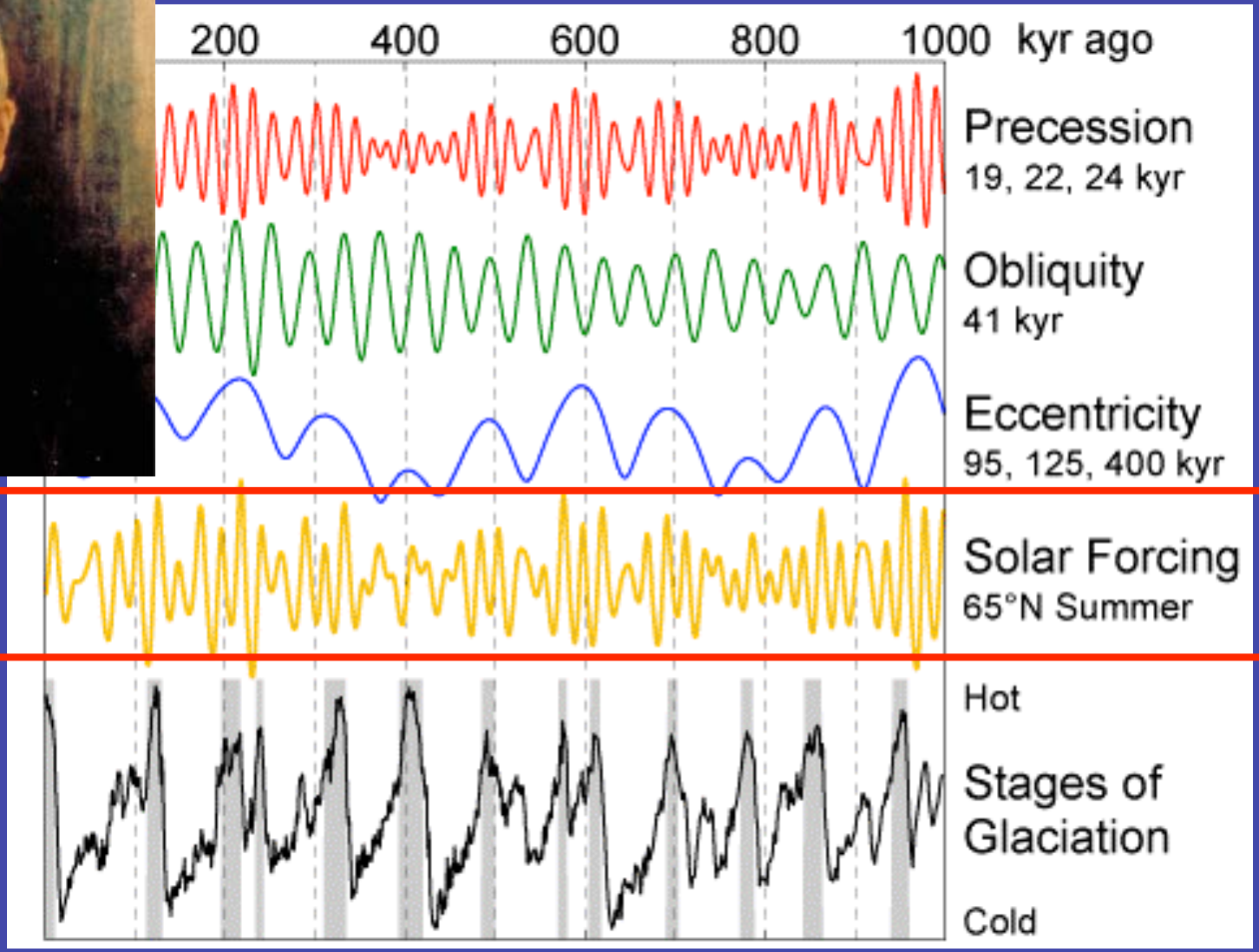
What is the period of Earth's precession?



Combined solar forcing known as “Milankovitch cycles” 1920



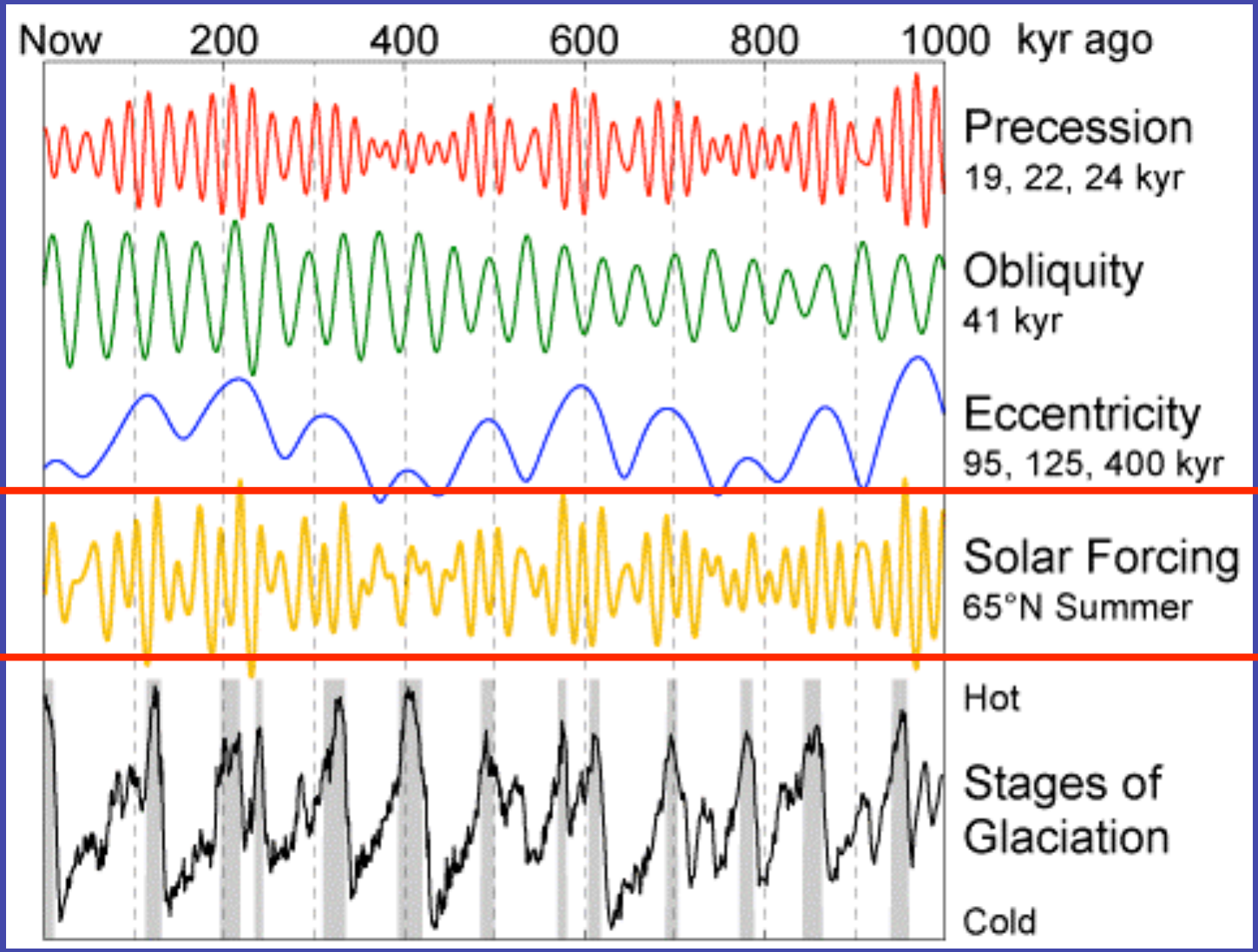
Serbian engineer, climatologist, geophysicist



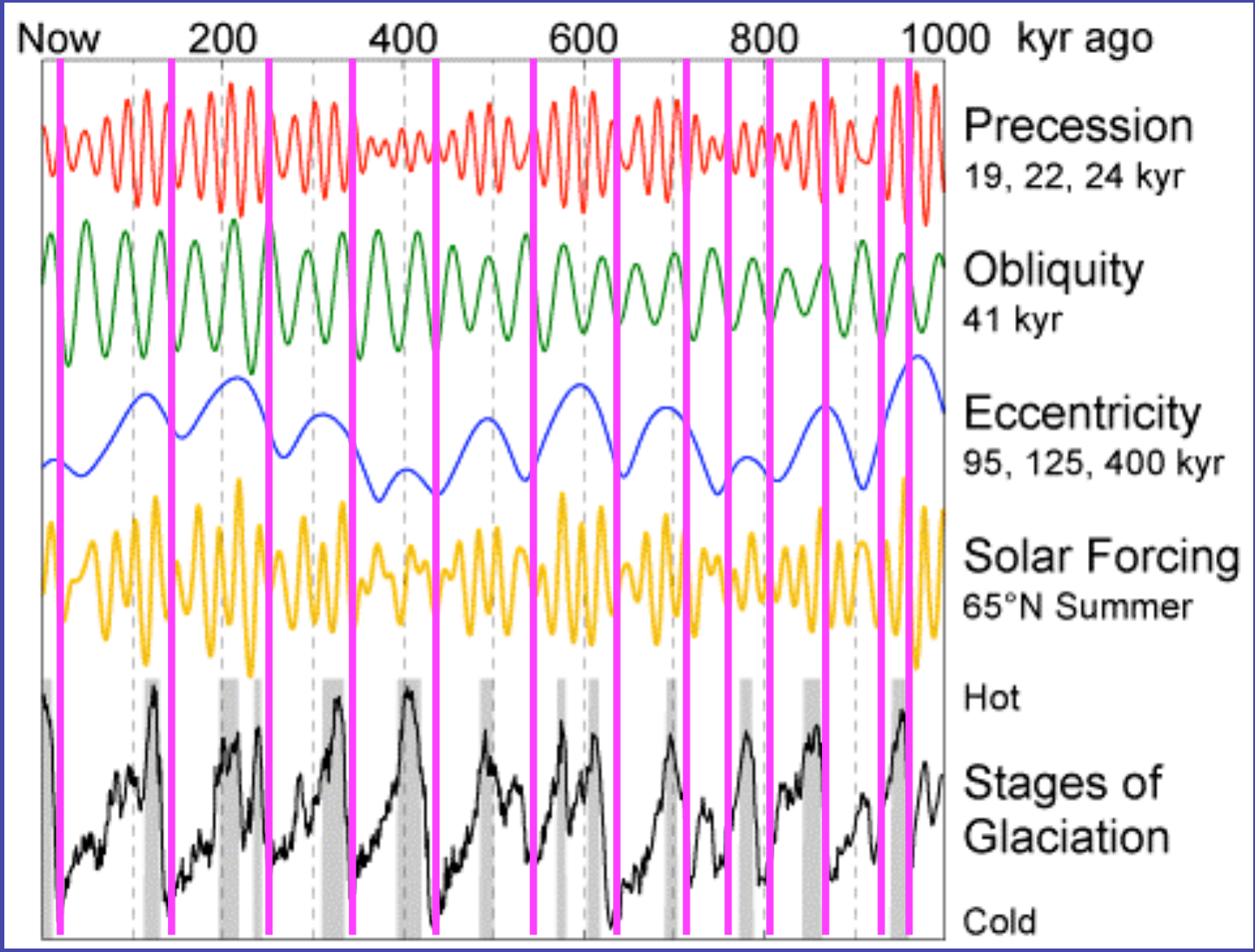
Deep sea sediments record Milankovitch cycles over 500 Kya



Milankovitch cycles influence glacial cycles



How have glacial cycles changed over last 1000 Kya?

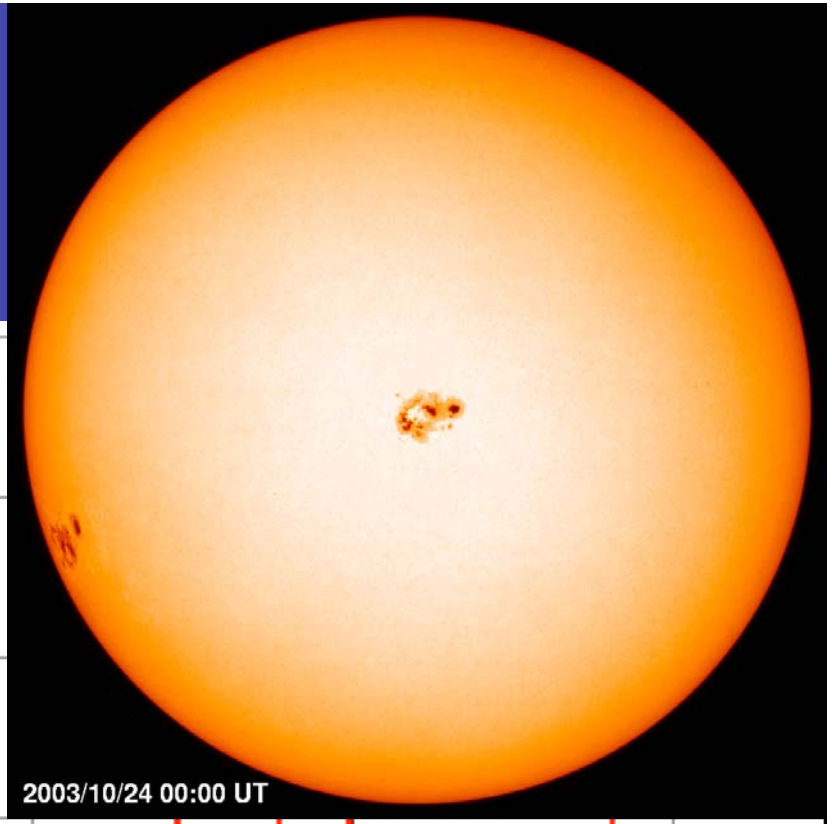


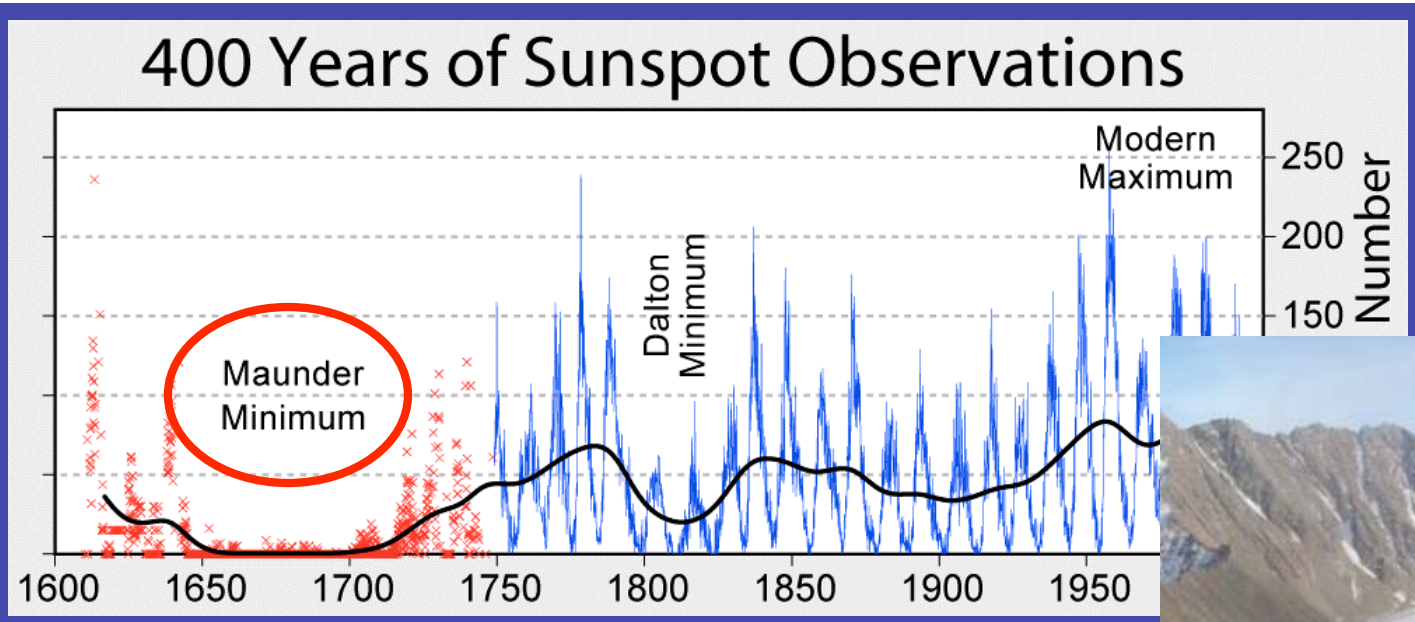
What else besides:

1) plate tectonics
2) orbital changes (Milankovitch cycles)
3) …?

can cause natural climate changes?

3) Variations in solar intensity …sunpot activity





Little Ice Age (~1550-1850 AD) caused by low sunspot count



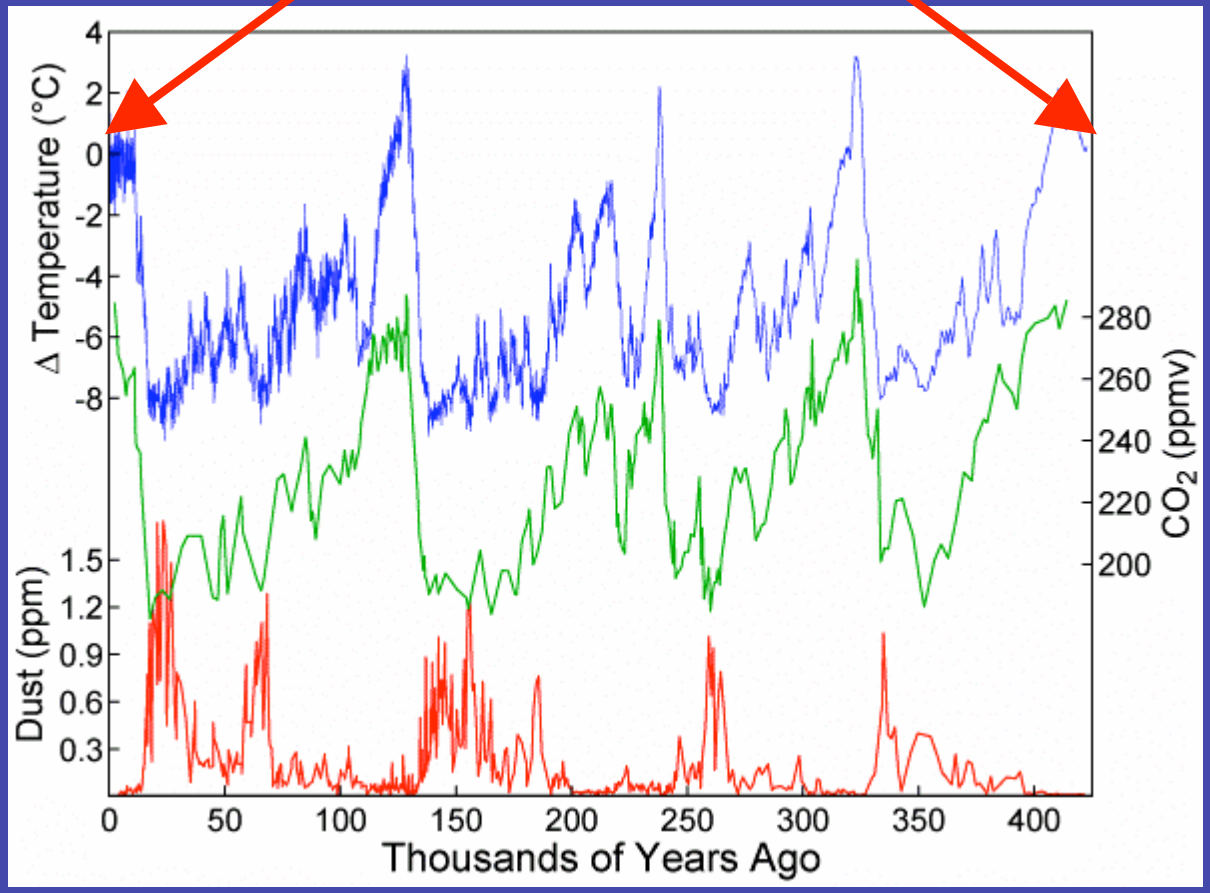




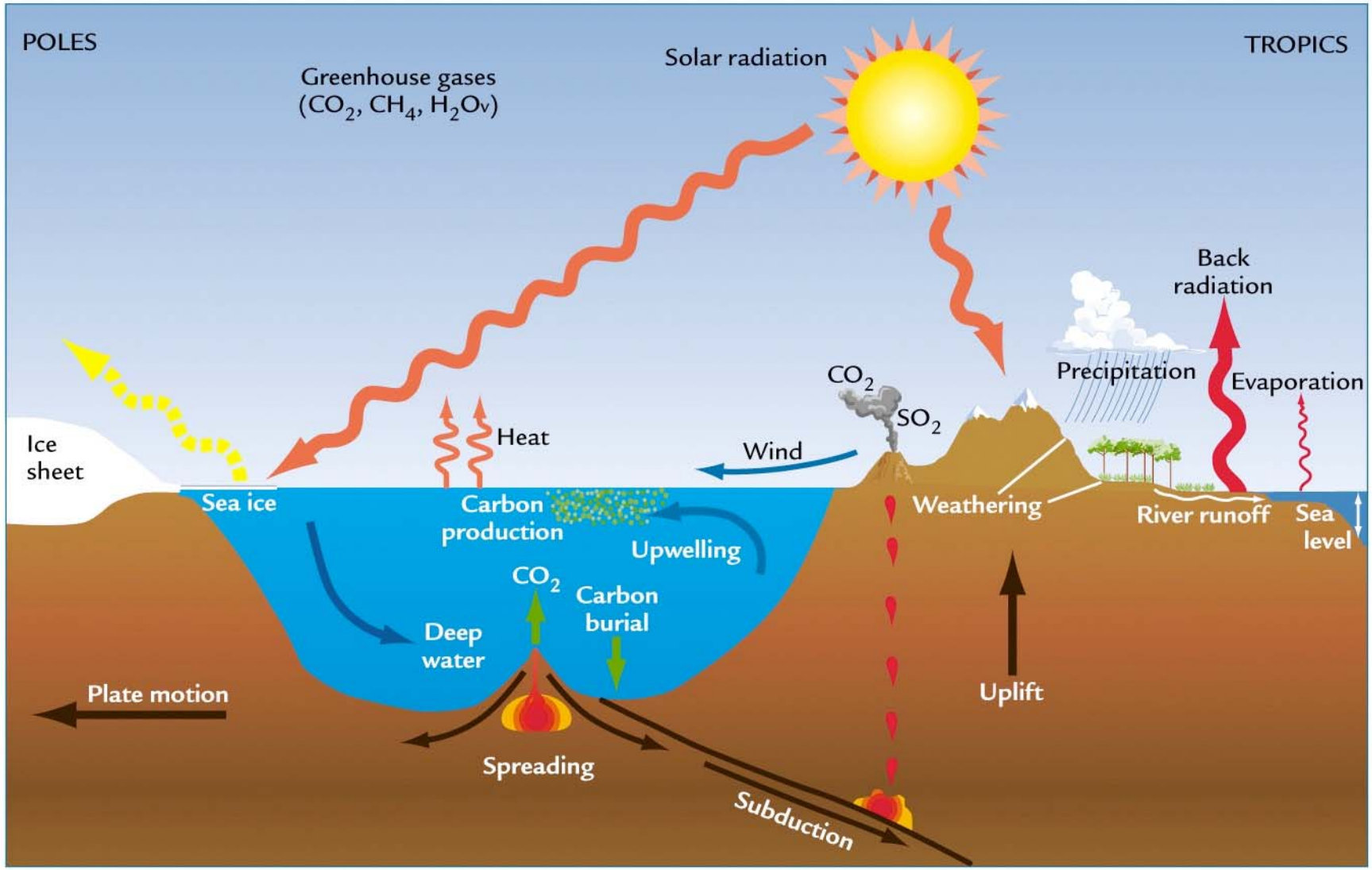
Mt. Tambora 1815

NATURAL causes of global climate change:

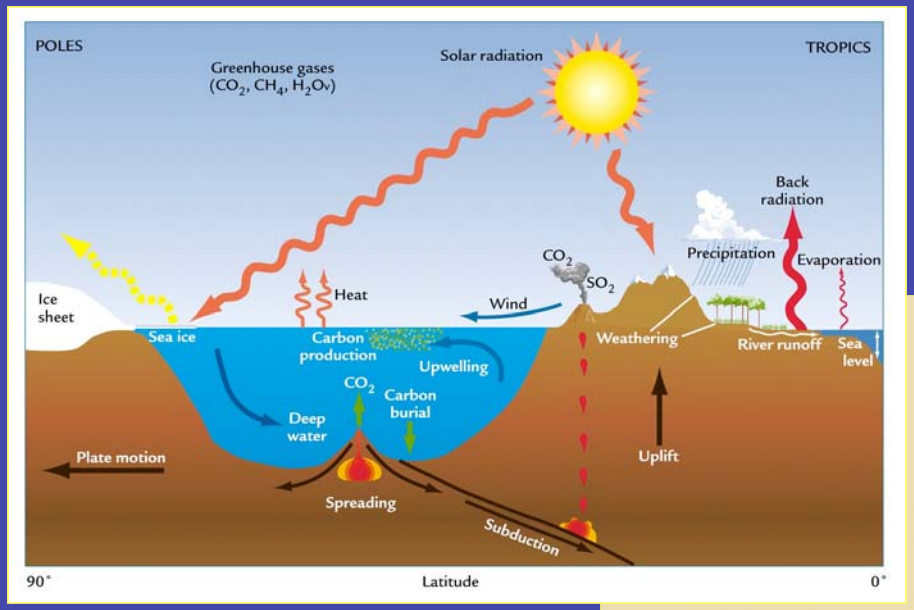
1) plate tectonics
2) orbital changes
3) solar intensity

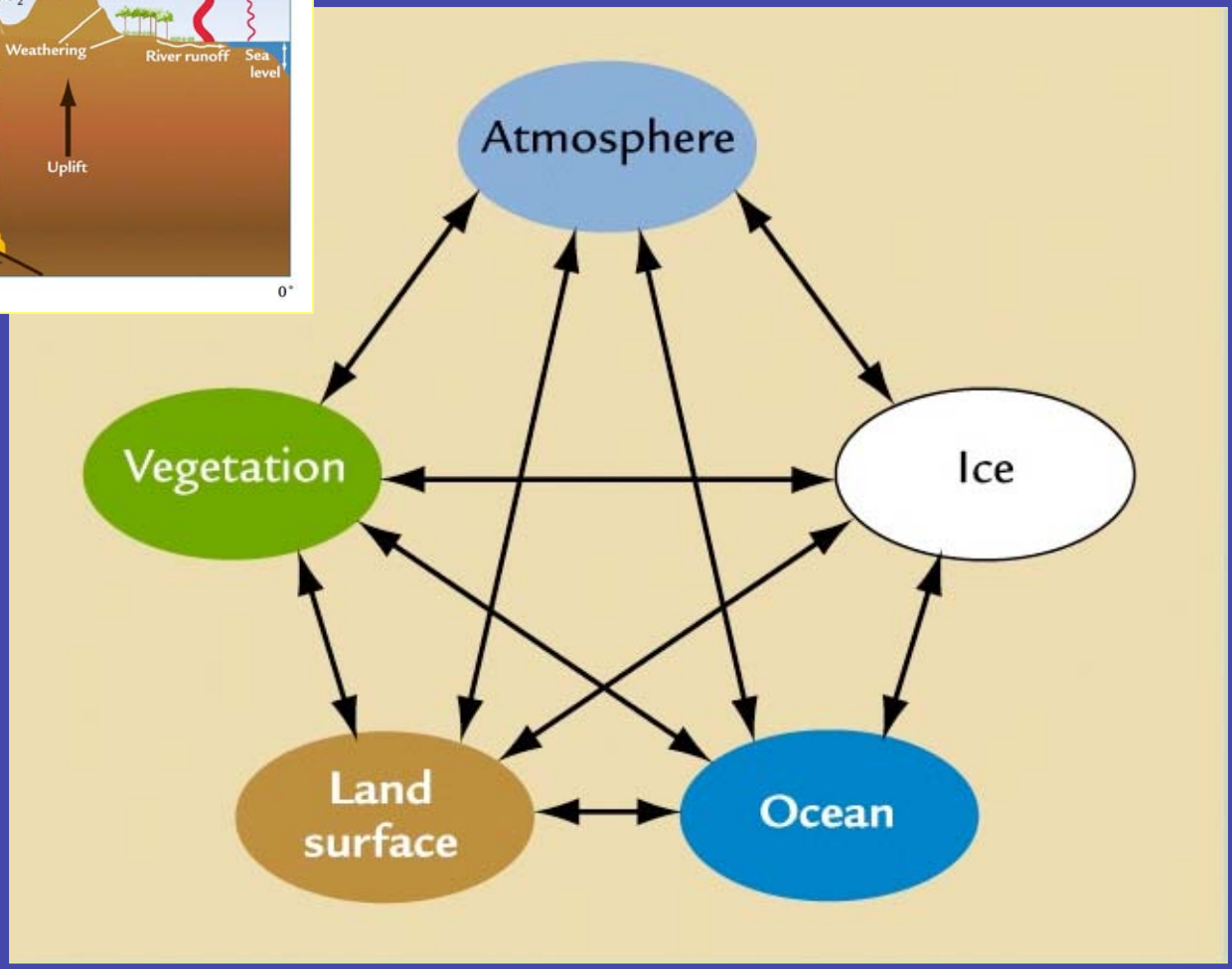


Climate system is complicated - how can we simplify?



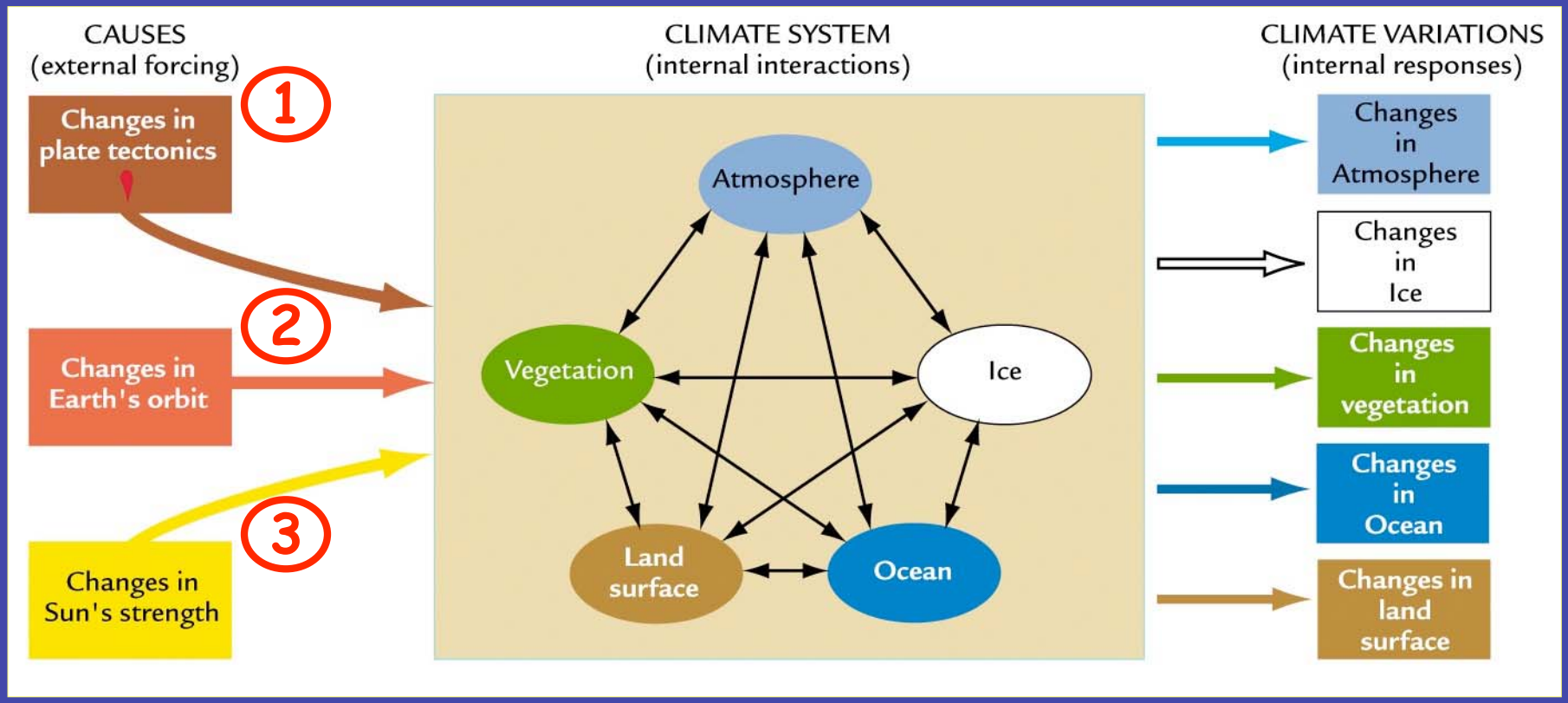
Earth's Climate Components Simplified



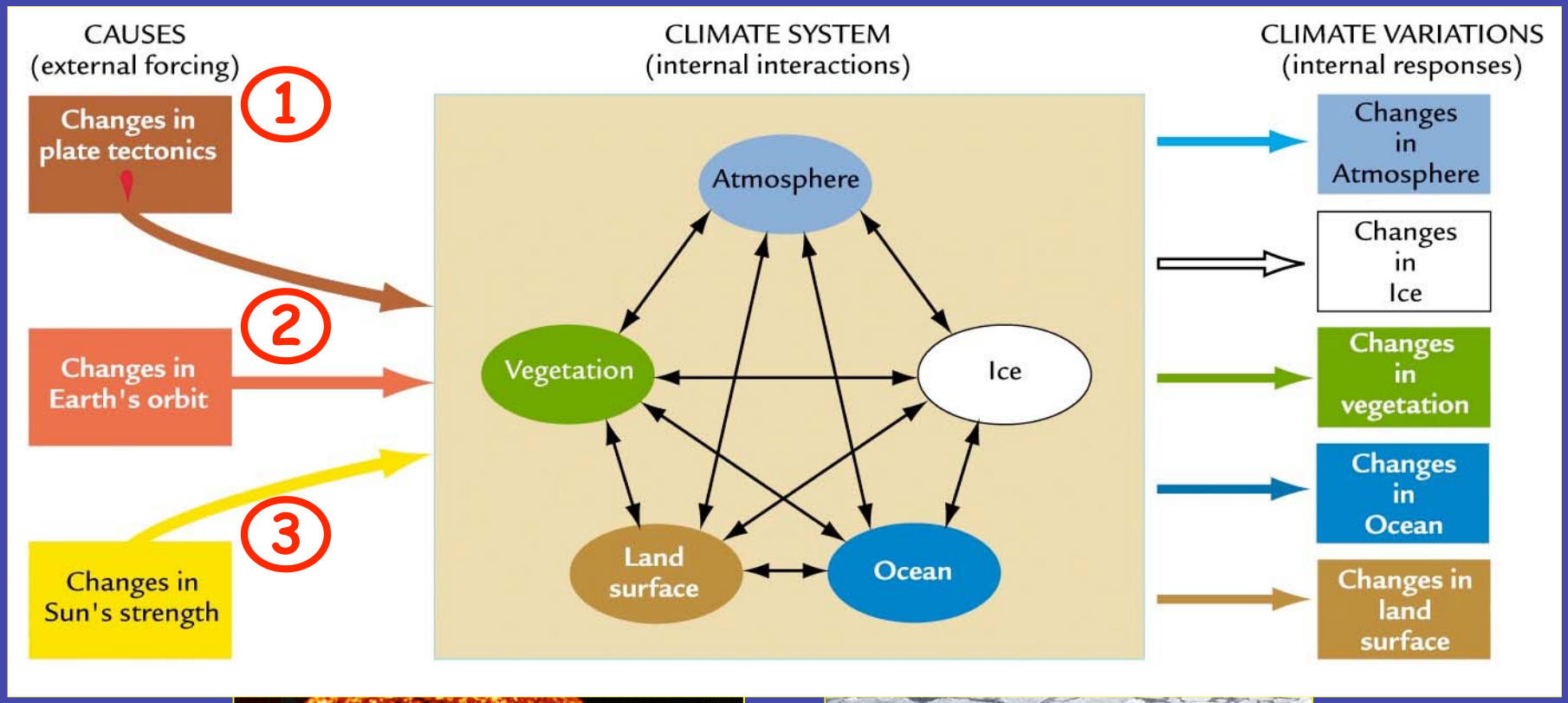


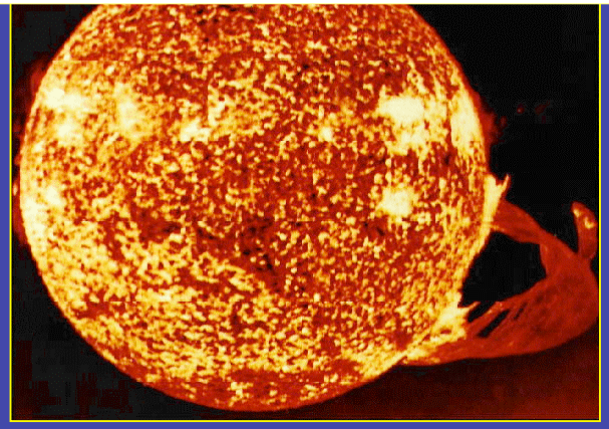
5-part system

Forcing and response – “cause and effect”



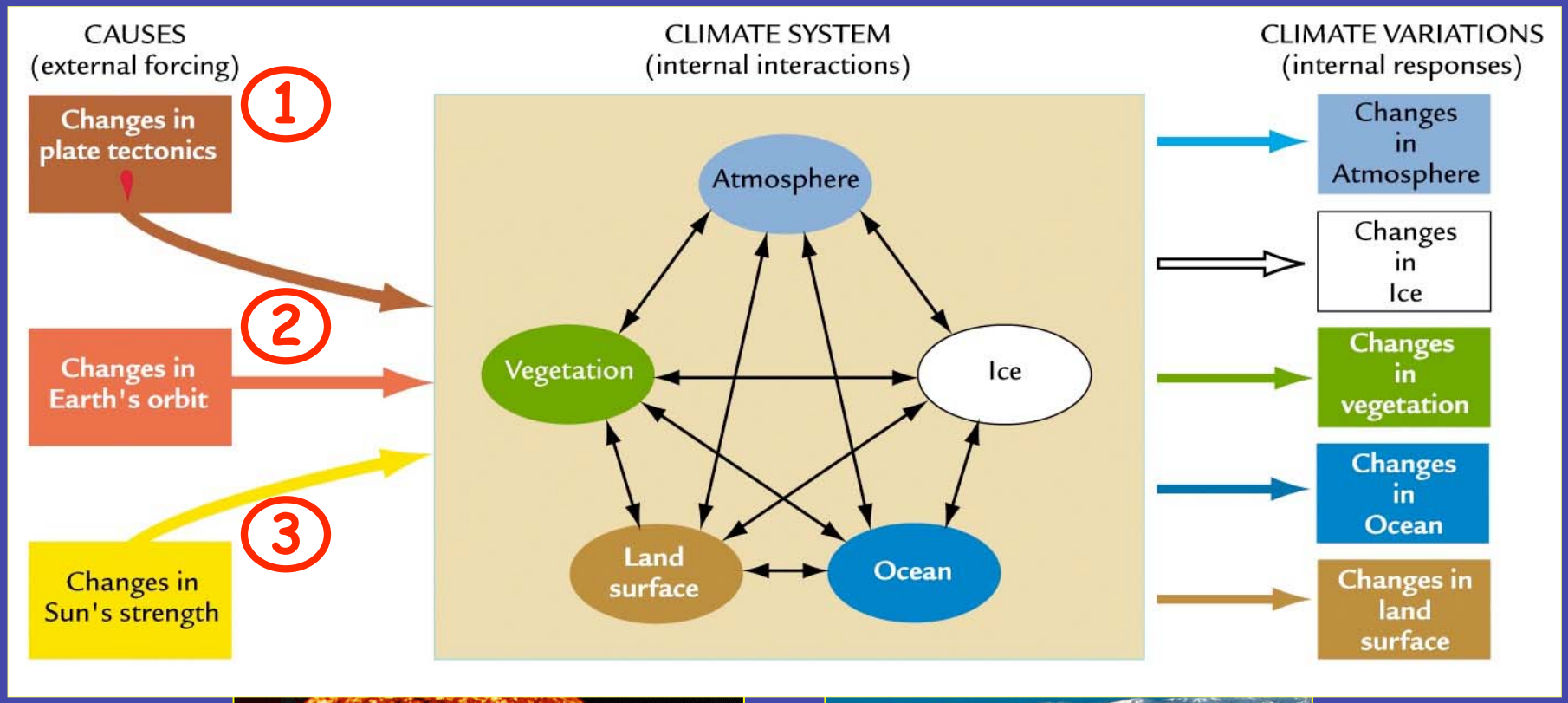
Forcing and response – “cause and effect”

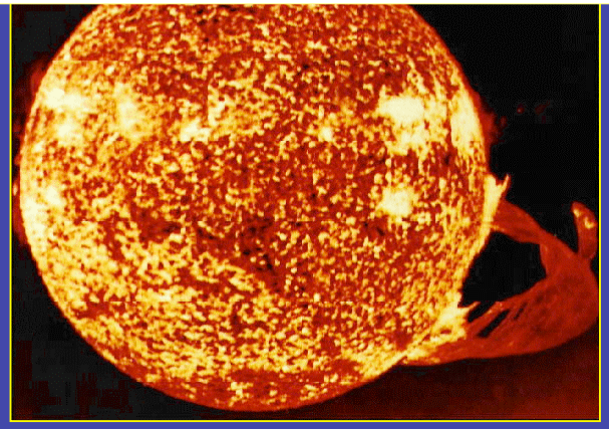




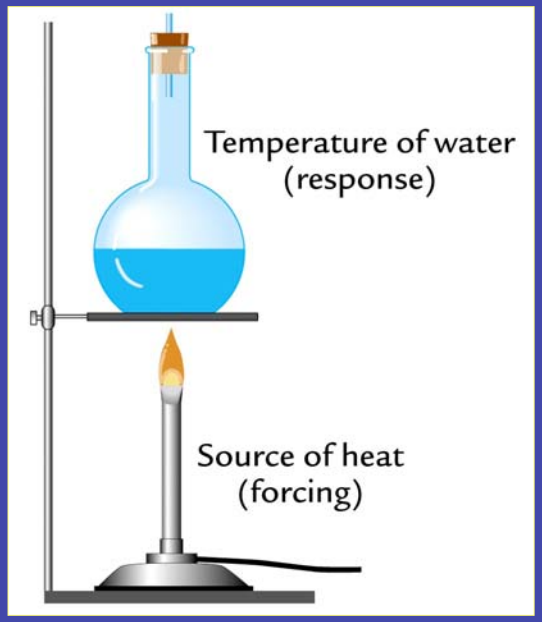


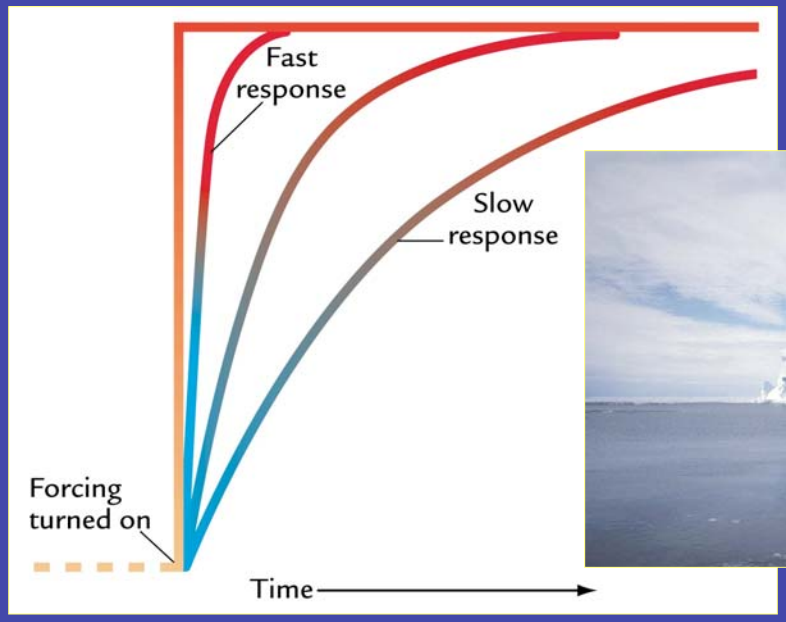
Forcing and response – “cause and effect”







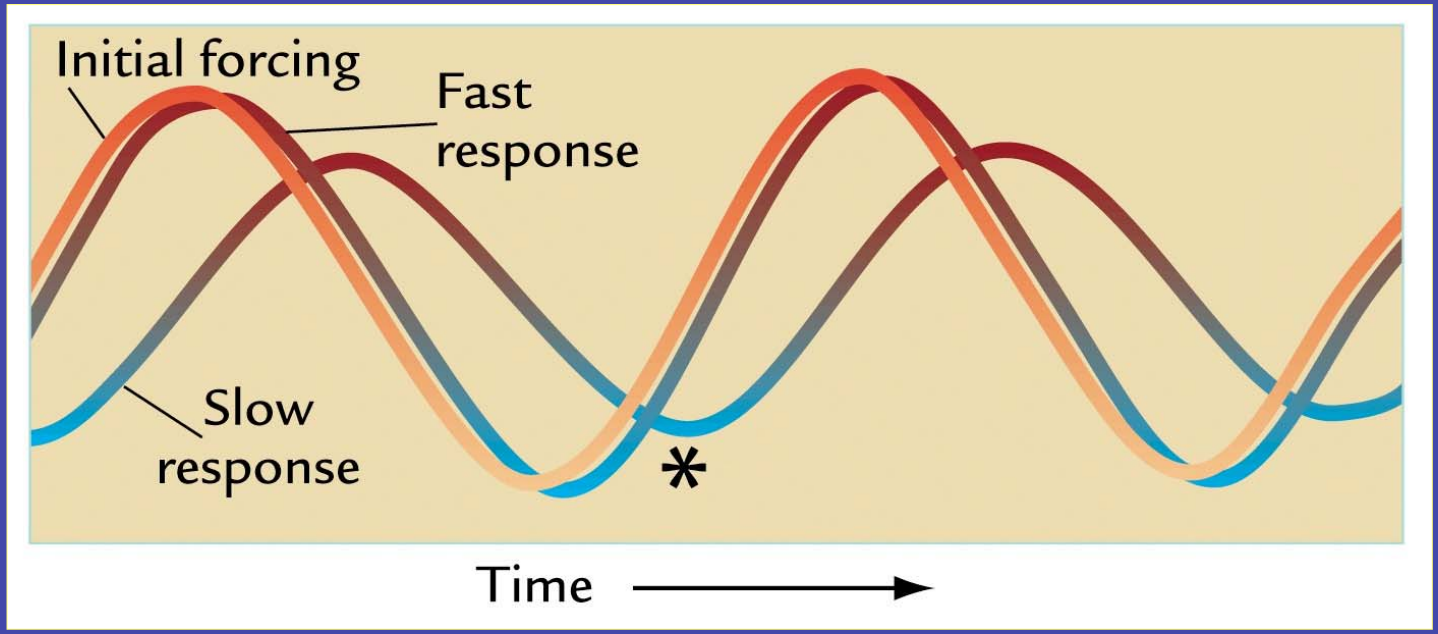




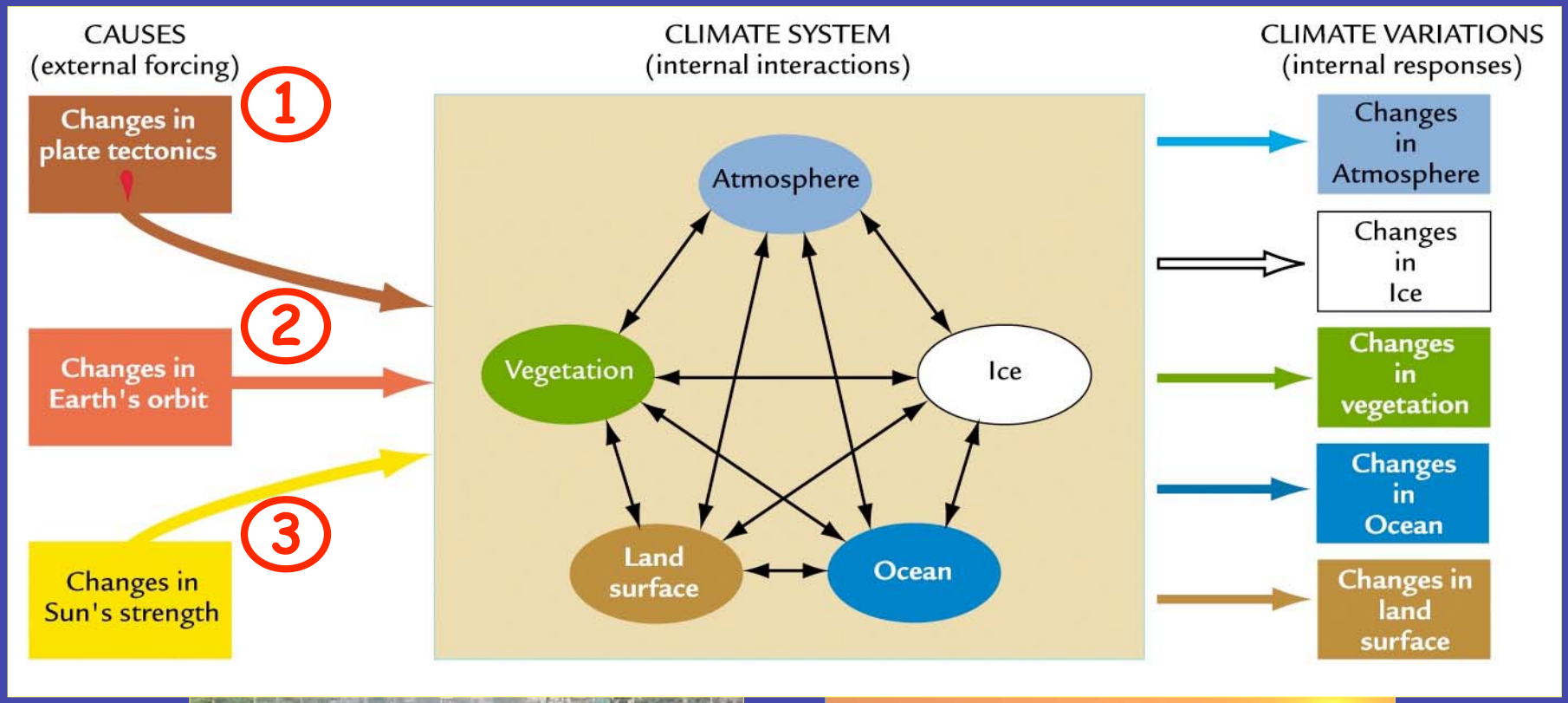


Lag time:

The time it takes a system to react to a change in forcing



Earth's Climate Components – The Human Factor



4





Speed of Forcing

Speed of Response

CAUSES
(external forcing)

- Changes in plate tectonics
- Changes in Earth's orbit
- Changes in Sun's strength

How quickly does climate react?

CLIMATE VARIATIONS
(internal responses)

- Changes in Atmosphere
- Changes in Ice
- Changes in vegetation
- Changes in Ocean
- Changes in land surface



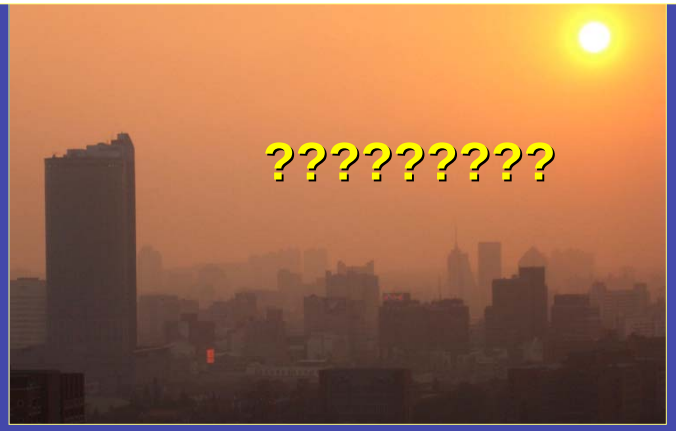


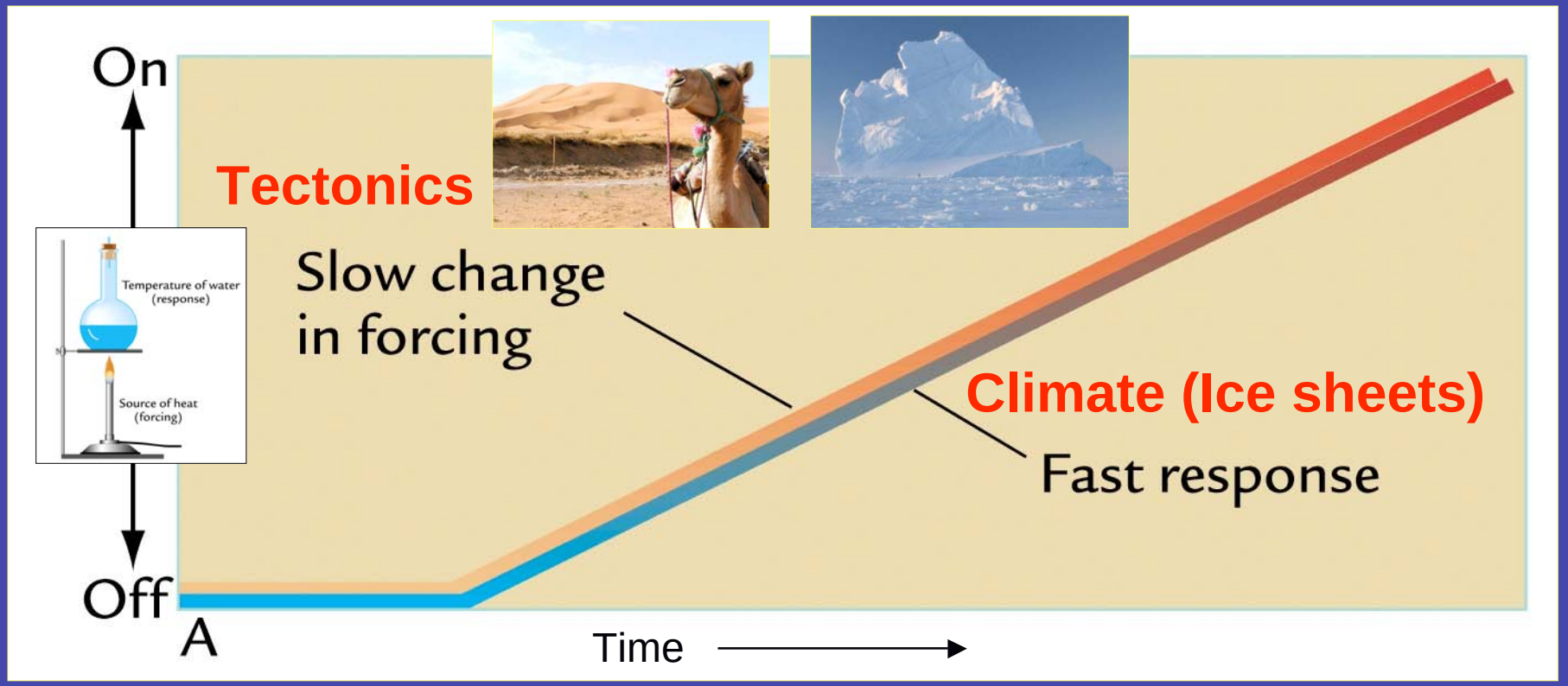
Speed of Forcing

Speed of Response

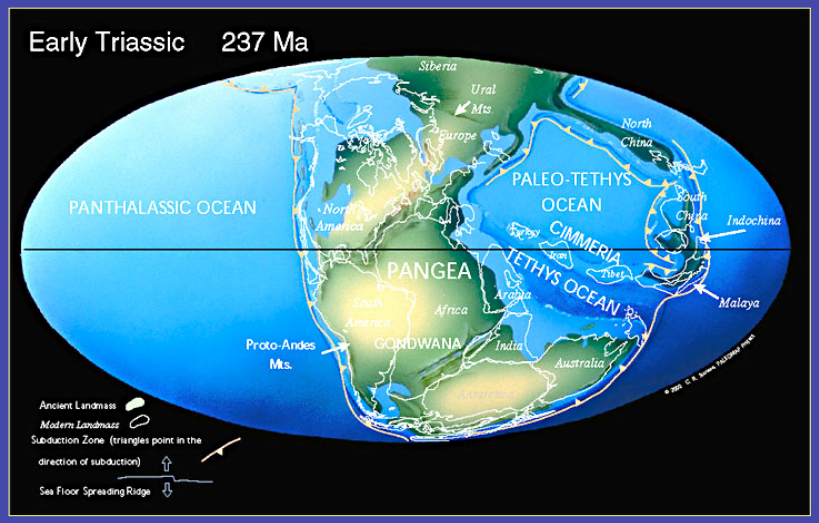
CAUSES (external forcing)		CLIMATE VARIATIONS (internal responses)	
Changes in plate tectonics	100's of millions of yrs	Hours to Weeks	Changes in Atmosphere
		Hours to 10,000 yrs	Changes in Ice
Changes in Earth's orbit	40,000-100,000 yrs	Hours to Centuries	Changes in vegetation
		Days to 1,500 yrs	Changes in Ocean
Changes in Sun's strength	10,000s of yrs	Hours to Months	Changes in land surface

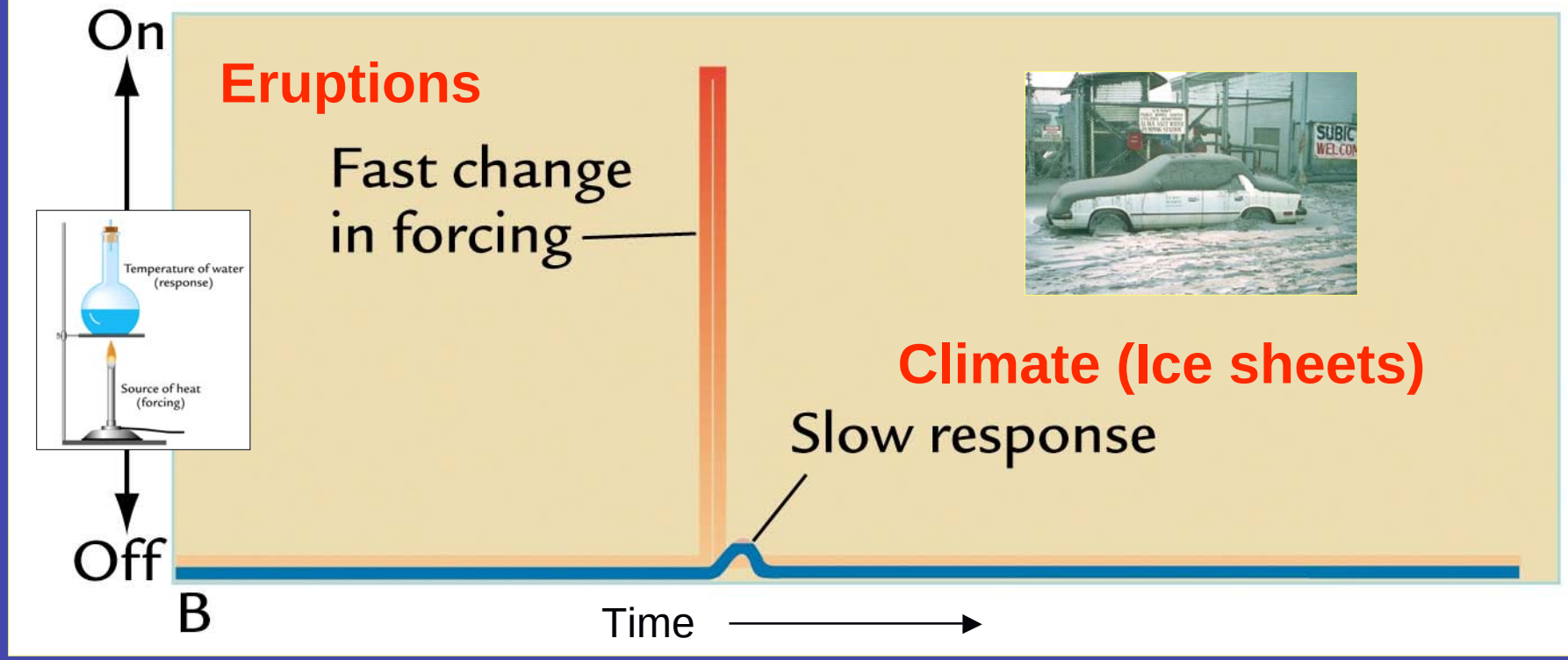





On
Off
Temperature of water (response)
Source of heat (forcing)
Tectonics
Slow change in forcing
Climate (Ice sheets)
Fast response
A
Time



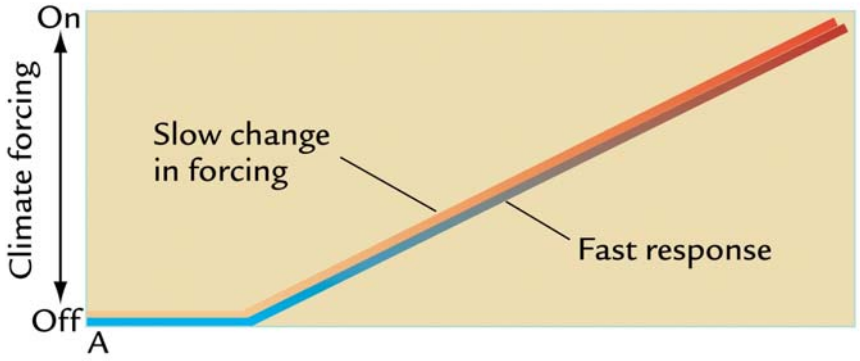

Early Triassic 237 Ma
Siberia
Ural Mts
Europe
North China
PANTHALASSIC OCEAN
North America
PALEO-TETHYS OCEAN
CIMMERIA
Indochina
PANGEA
TETHYS OCEAN
Arabia
Malaya
South America
Africa
Proto-Andes Mts.
GONDWANA
India
Australia
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge


On
Off
B
Temperature of water (response)
Source of heat (forcing)
Eruptions
Fast change in forcing
Climate (Ice sheets)
Slow response
Time

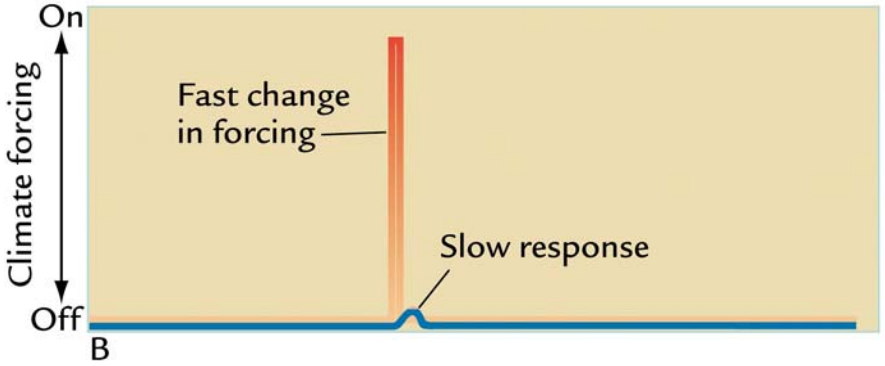

Krakatoa, 1883


Pinatubo, 1991

Forcing = Slow, Response = Big



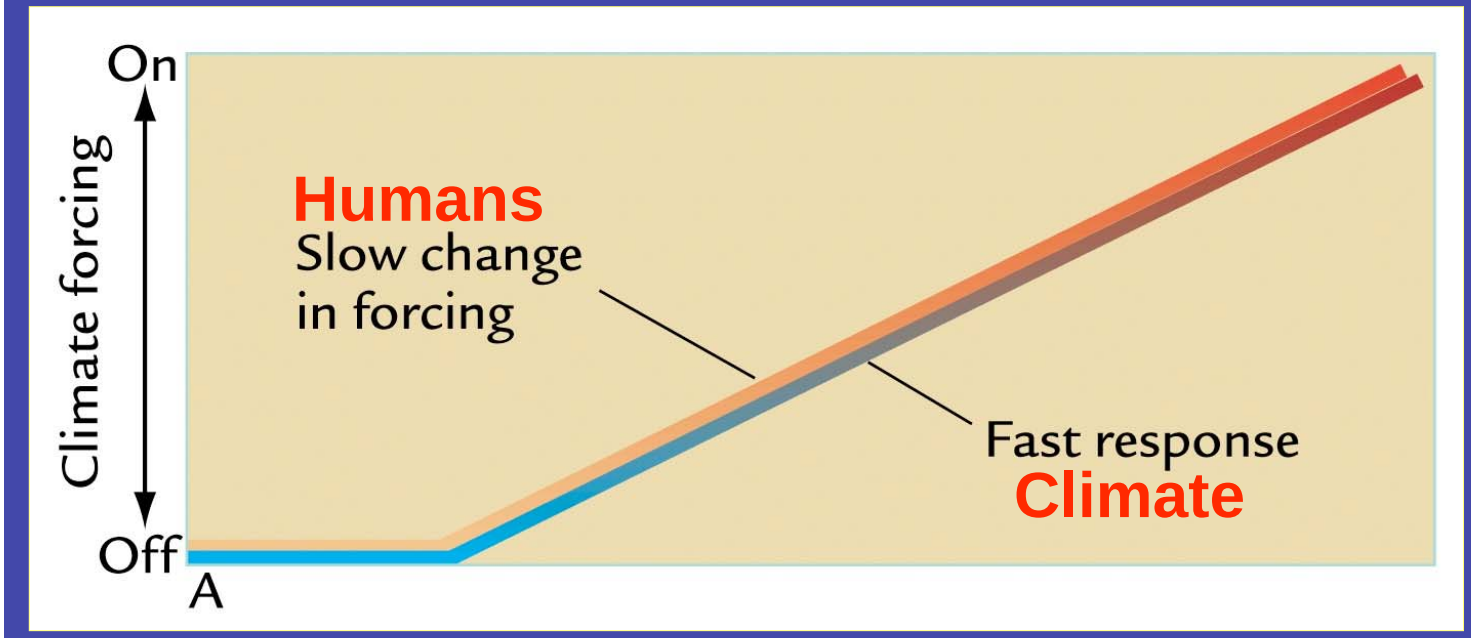
Forcing = Fast, Response = Small

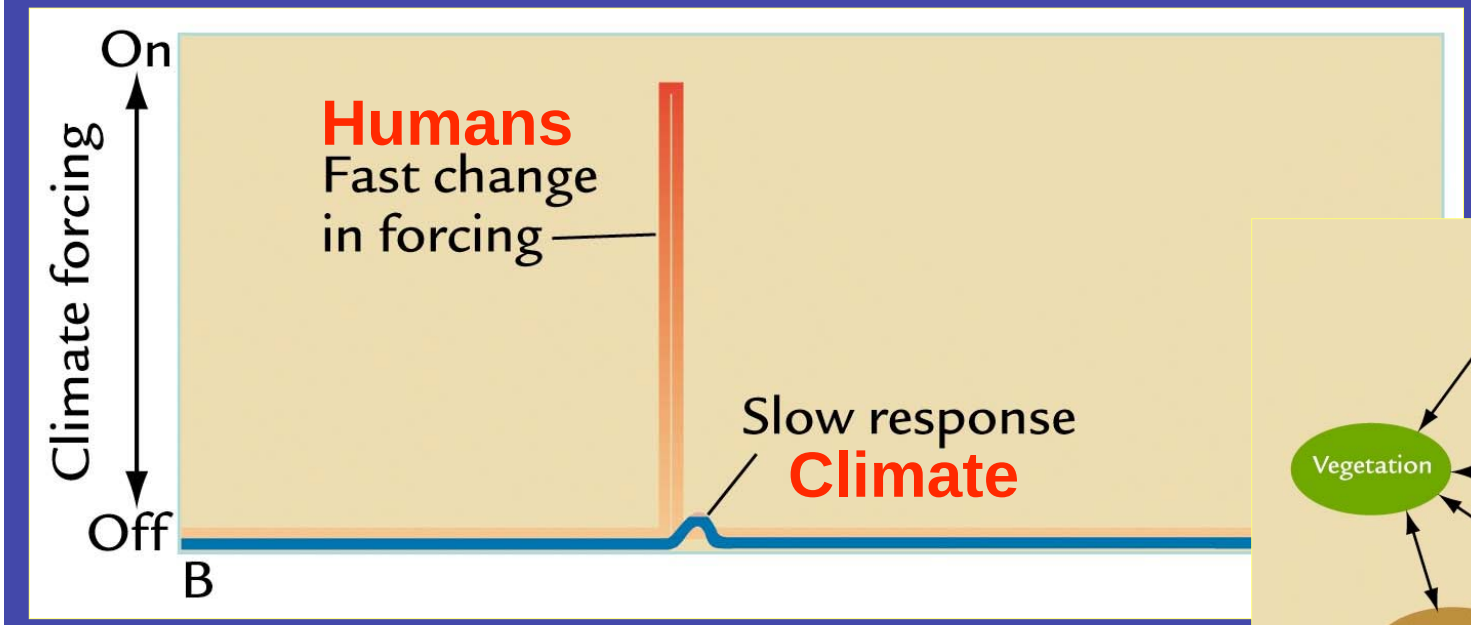


Time →

1) If a forcing is slow relative to a response, the system can reach equilibrium

2) If a forcing is fast relative to a response, the system does not reach equilibrium





How does <u>human</u> forcing

act on the <u>natural</u> system

?

