The past as the key to the present, and as a guide for the future

UCMP Short Course, March 7, 2015

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2) **What drives global temperature change on geological timescales?**
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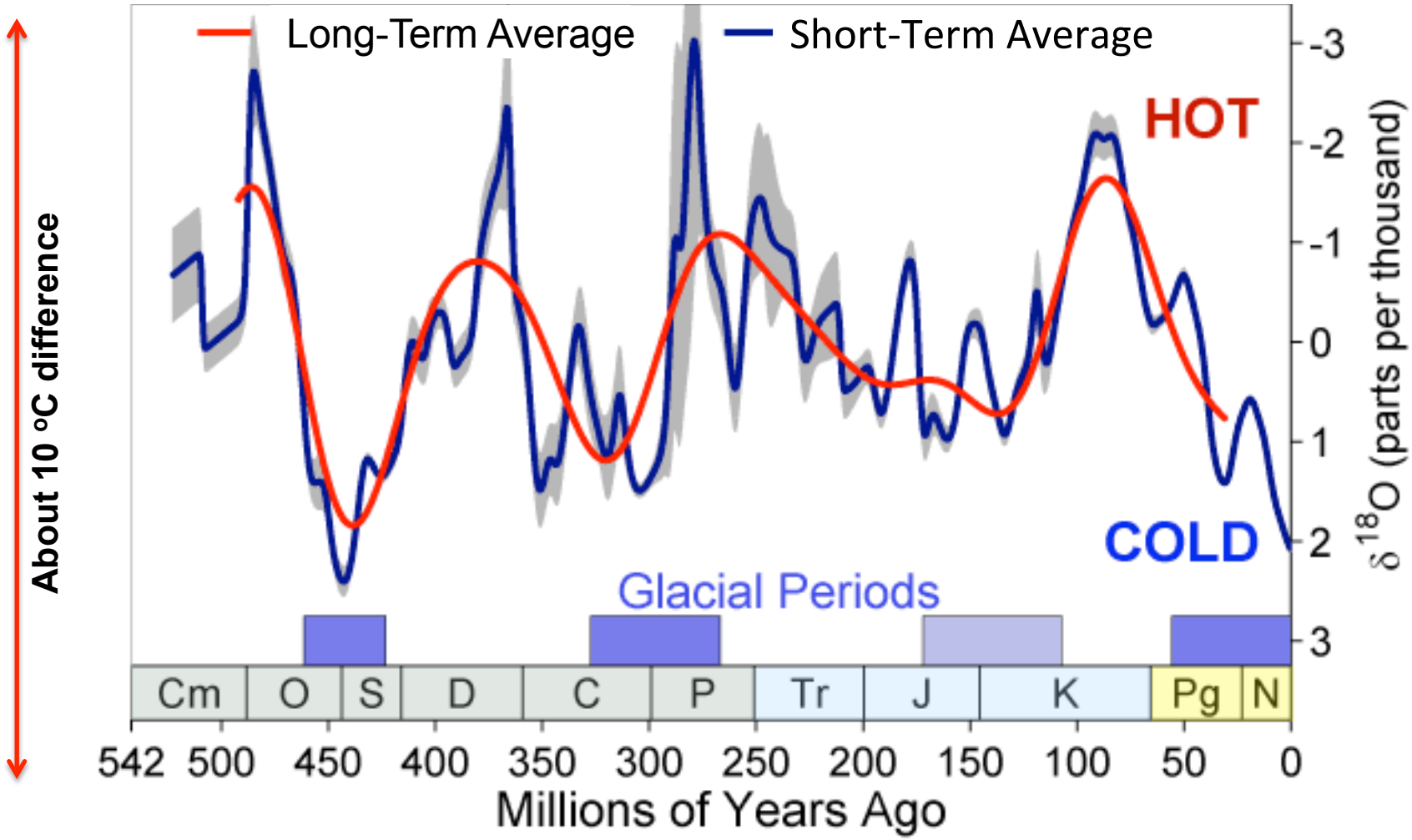
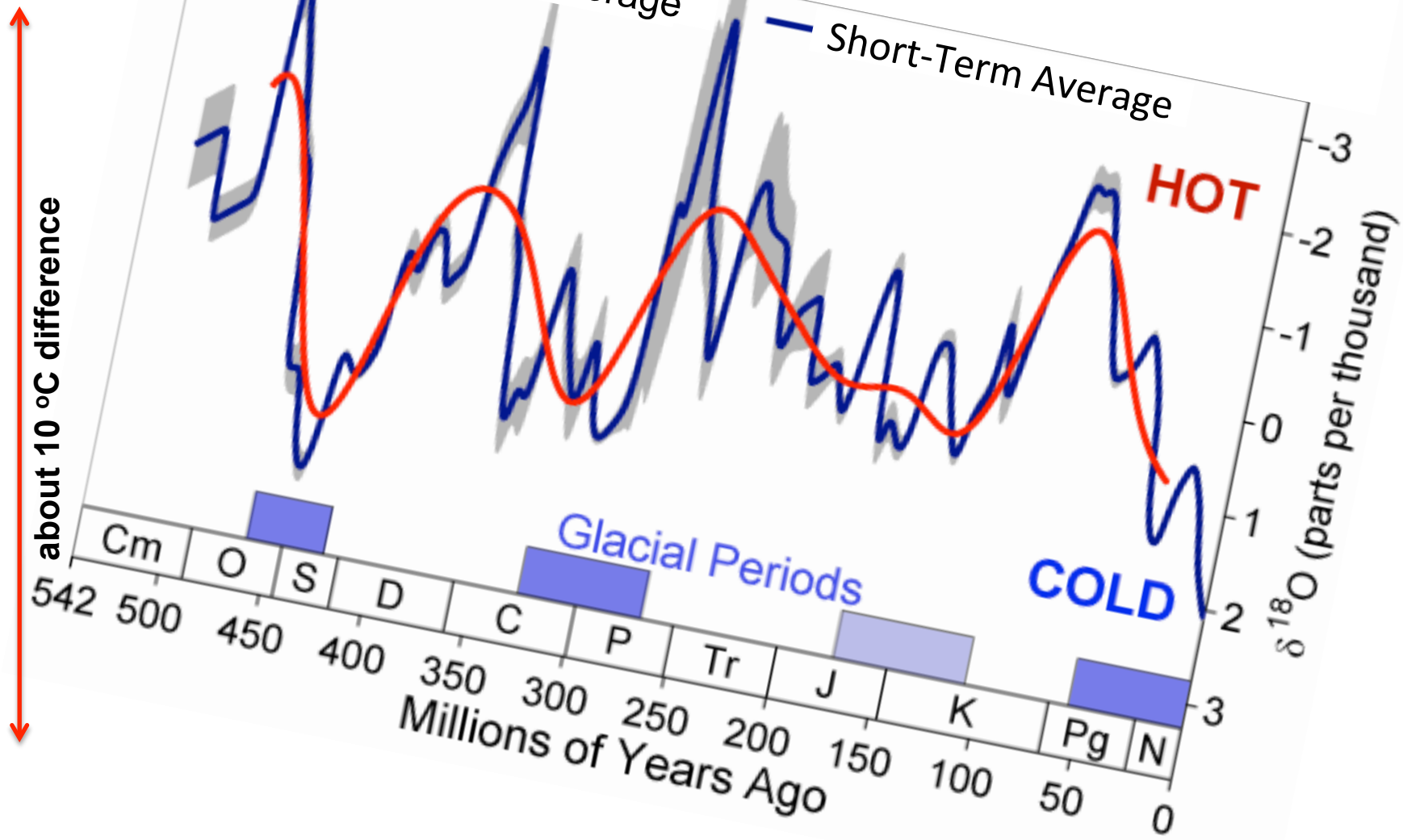
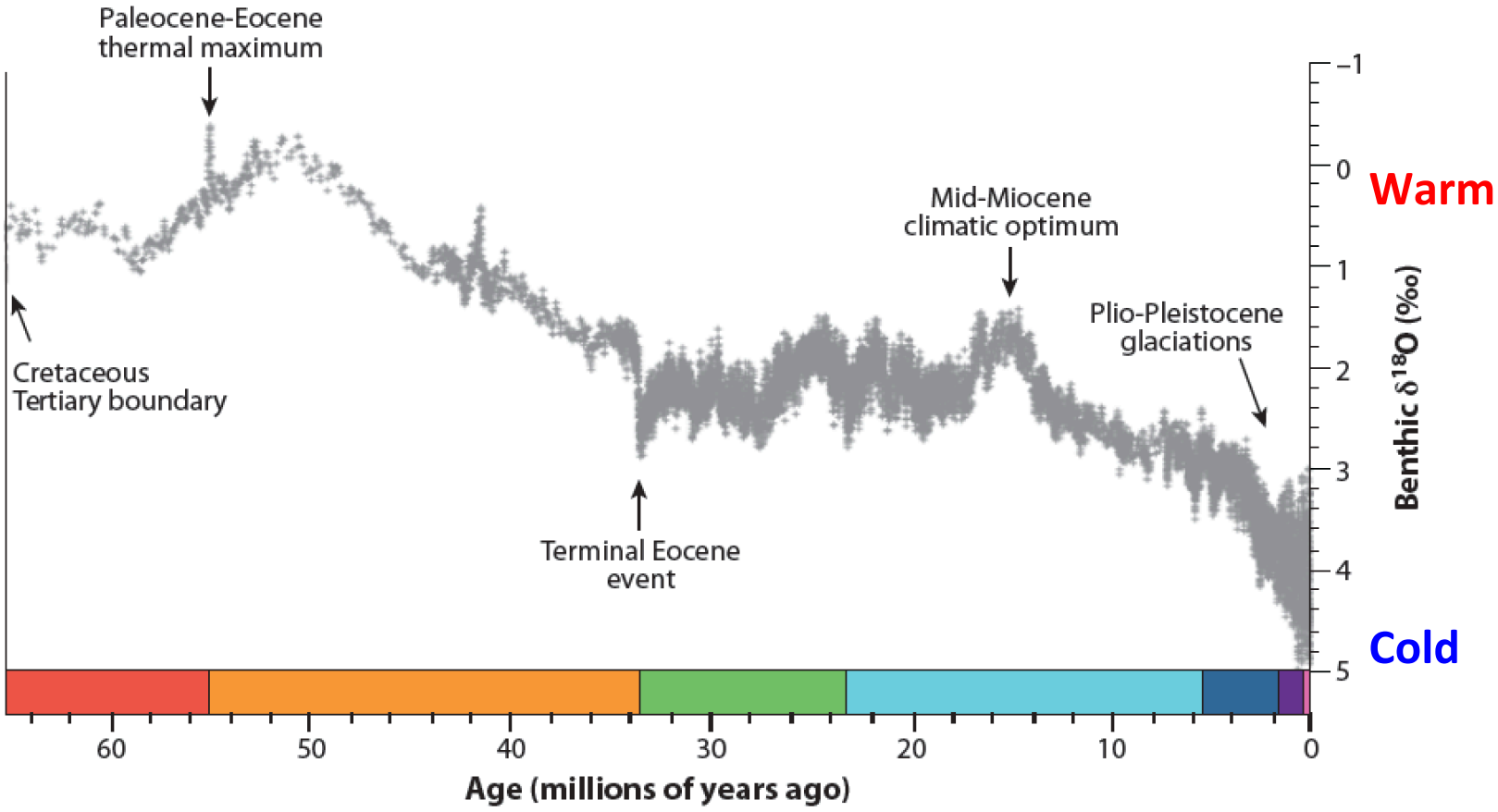
The last few million years are unusually cold

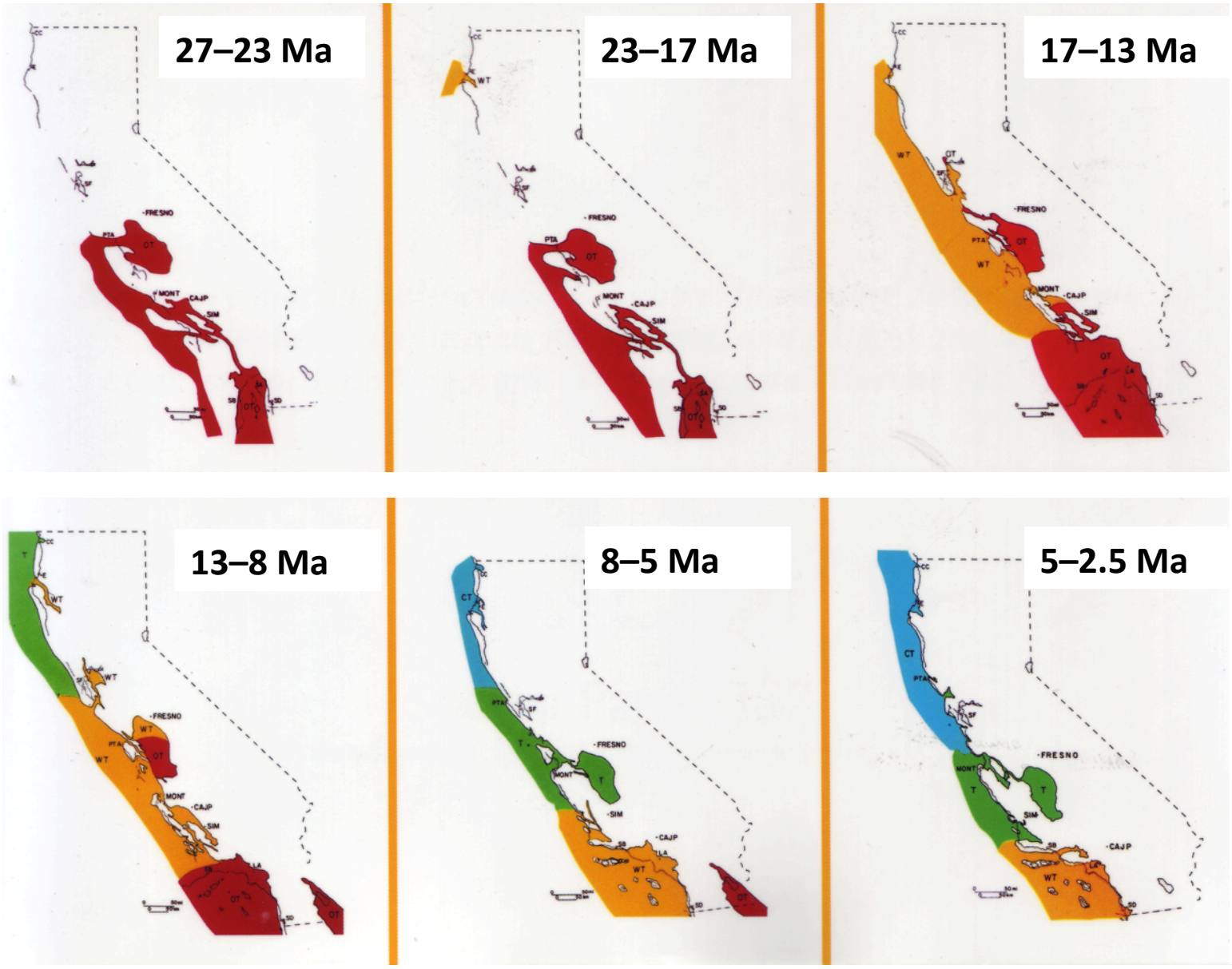



about 10 °C difference
Long-Term Average
Short-Term Average
HOT
COLD
Glacial Periods
Cm
O
S
D
C
P
Tr
J
K
Pg
N
542 500 450 400 350 300 250 200 150 100 50 0
Millions of Years Ago
-3
-2
-1
0
1
2
3
δ18O (parts per thousand)

Temperature over the last 66 million years ago – sustained cooling in the last 15 million years.



Cooling of the ocean over the last ~15 million years



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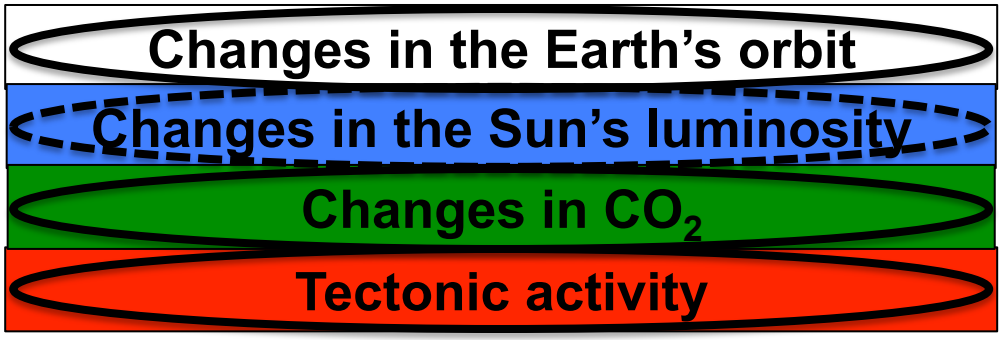
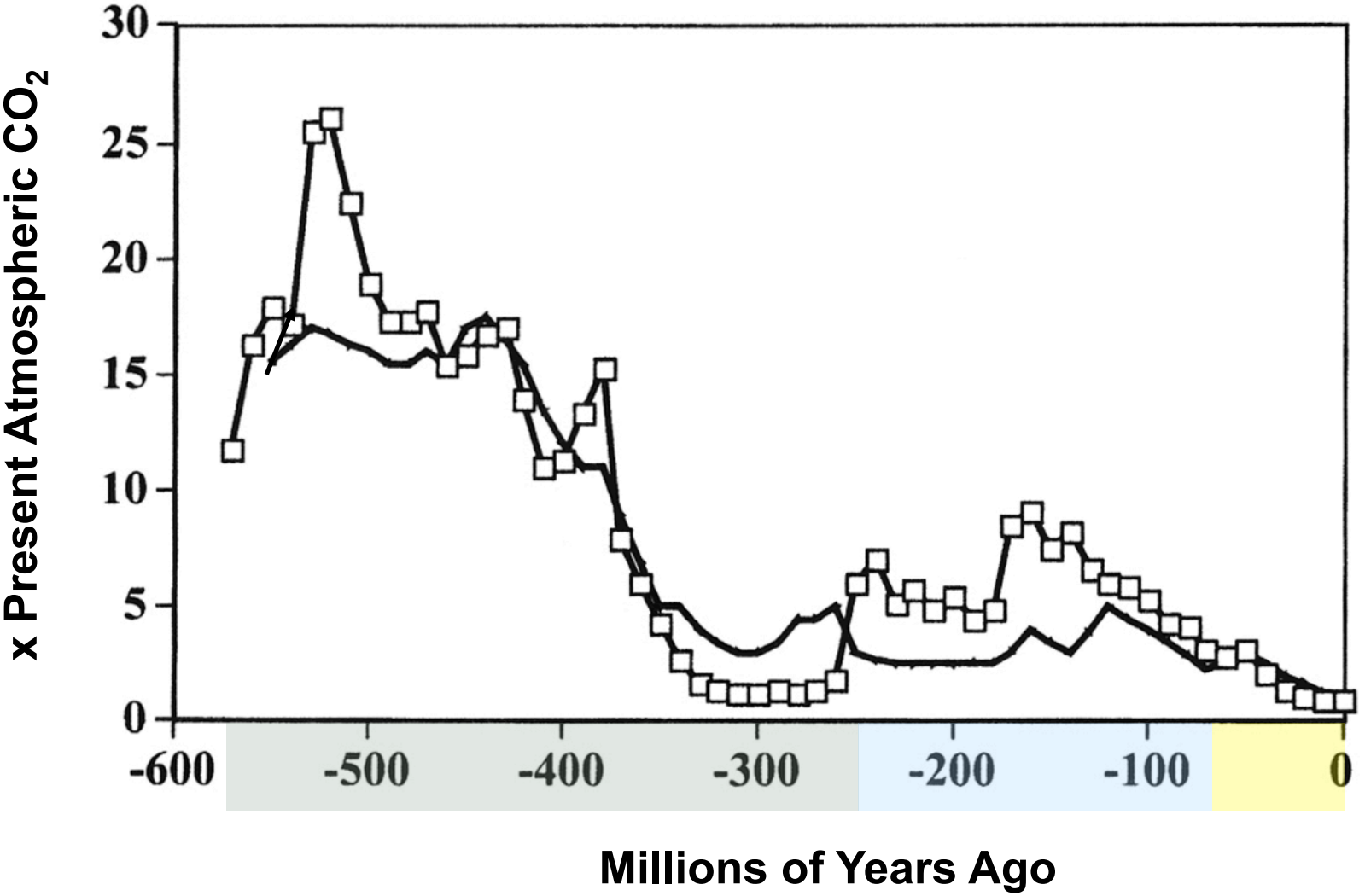
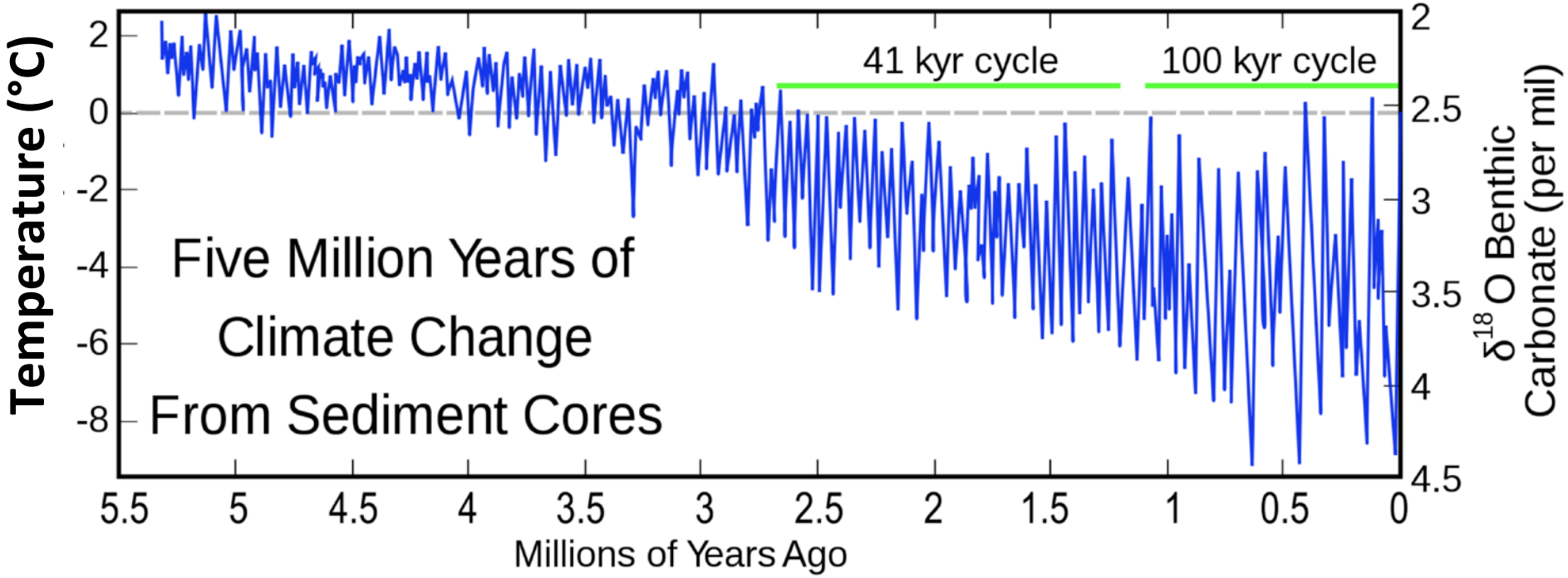
What drives temperature change?



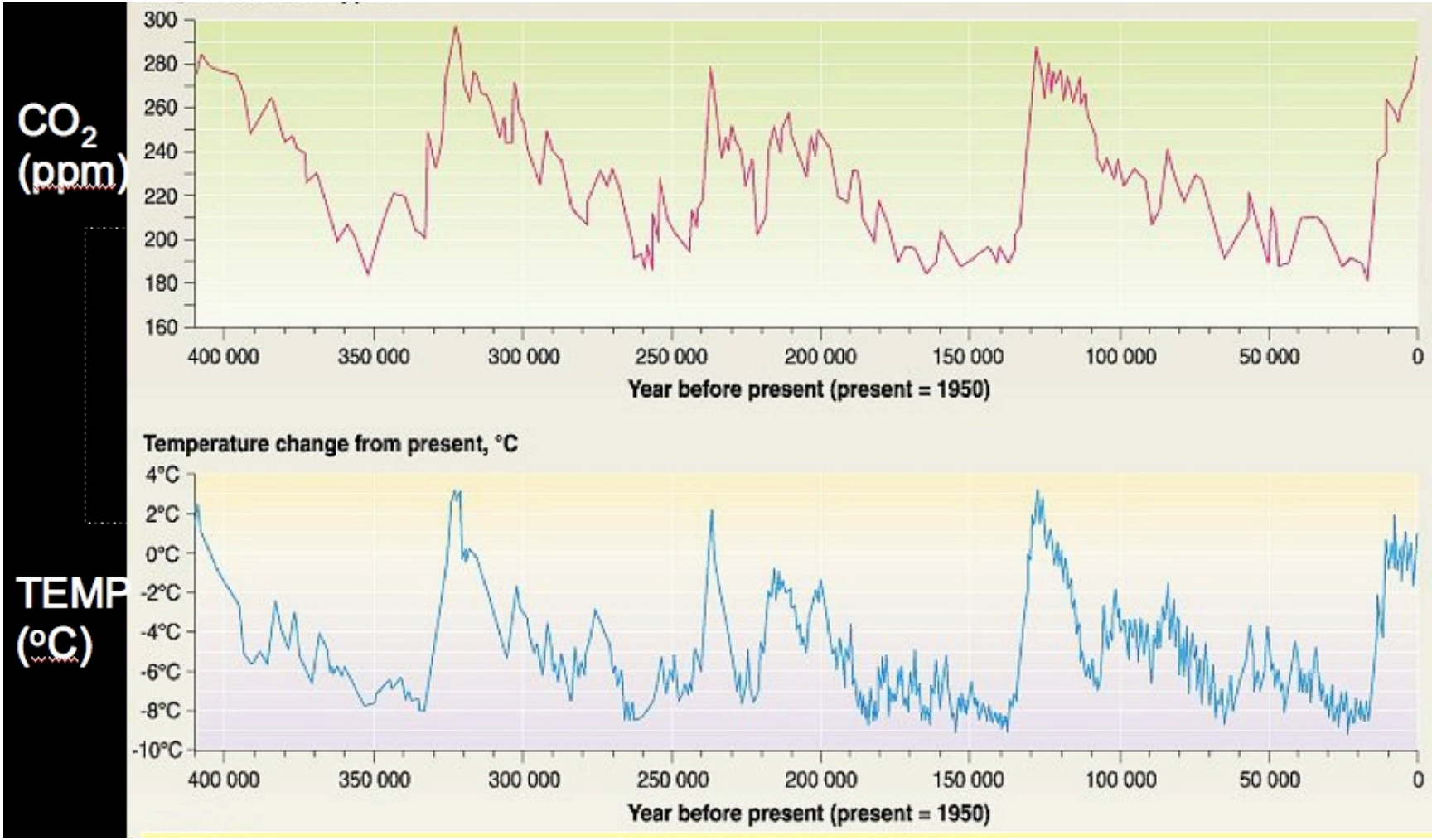
Cooling trend towards the present correlates with decreased CO_2



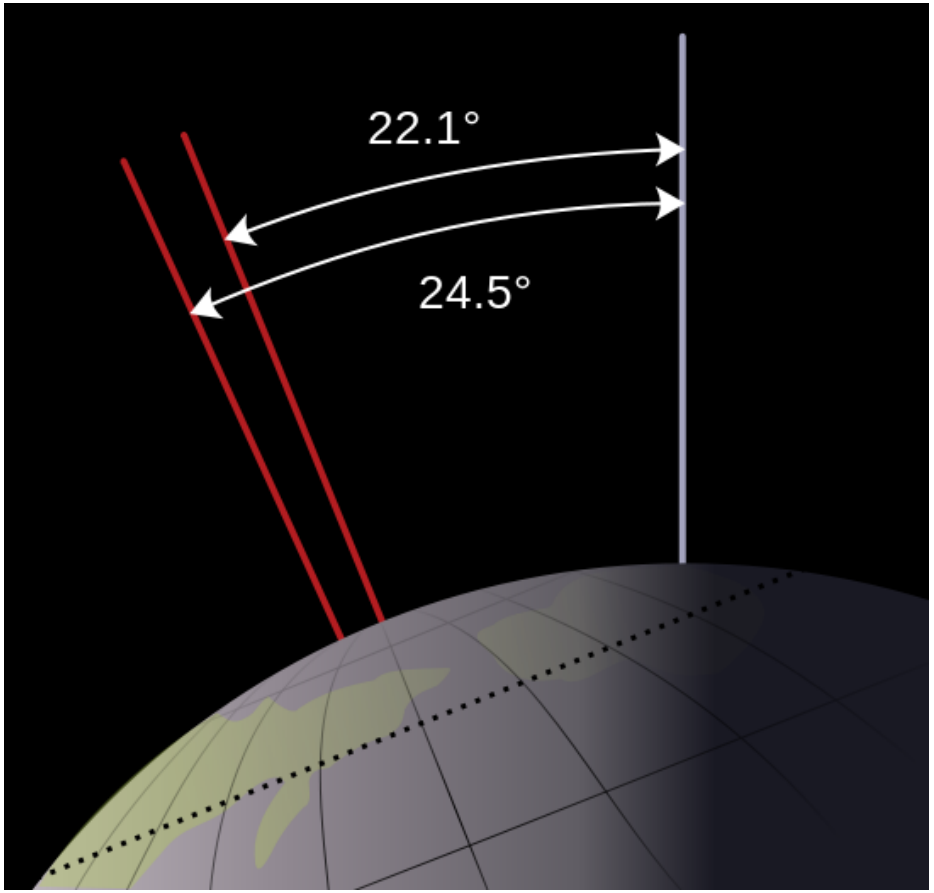
Temperature change over the last 5 million years – can see oscillations on top of the cooling trend



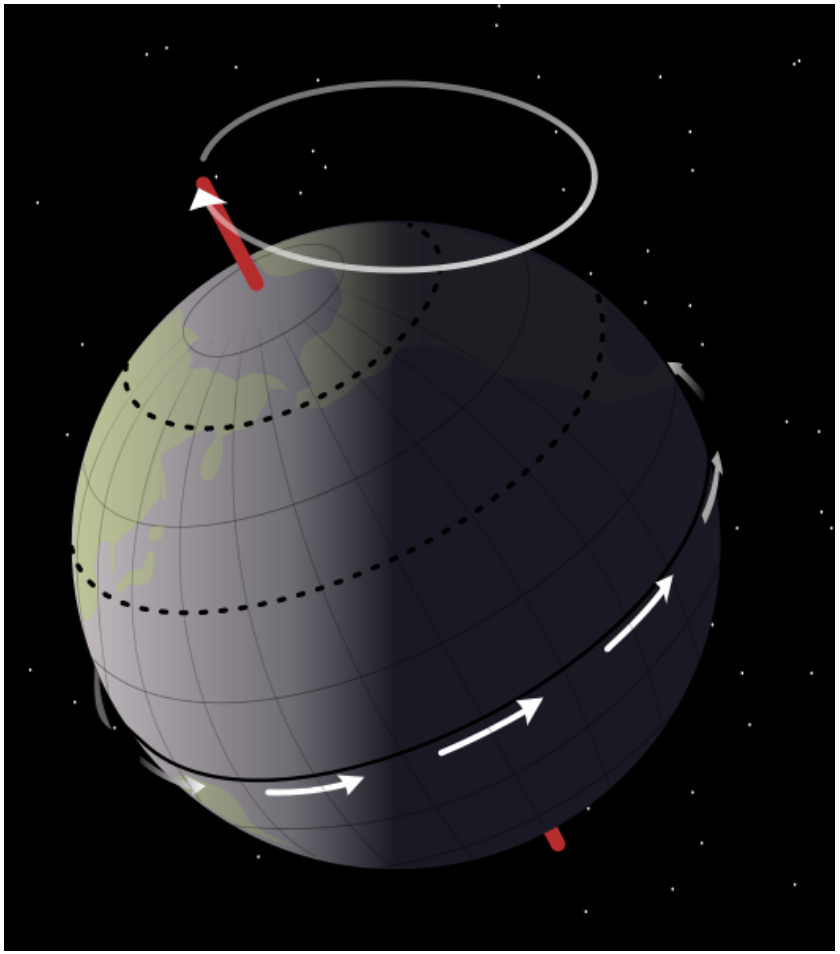
Easier to see over the last 400,000 years



Variation in the Direction of the Earth's Spin Relative to its Orbit
(due to Moon and Sun Tides)

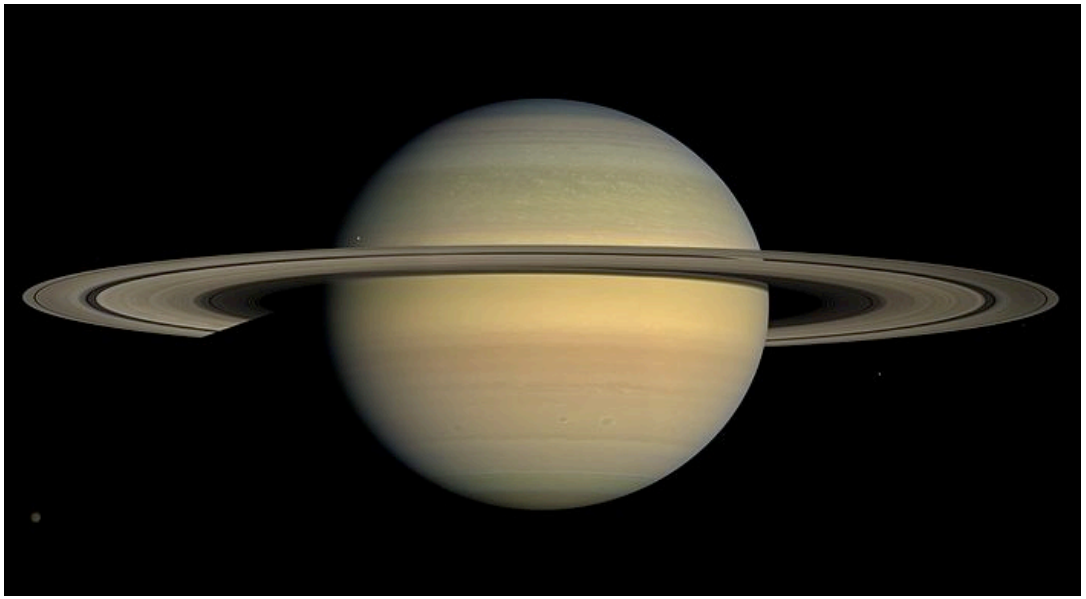


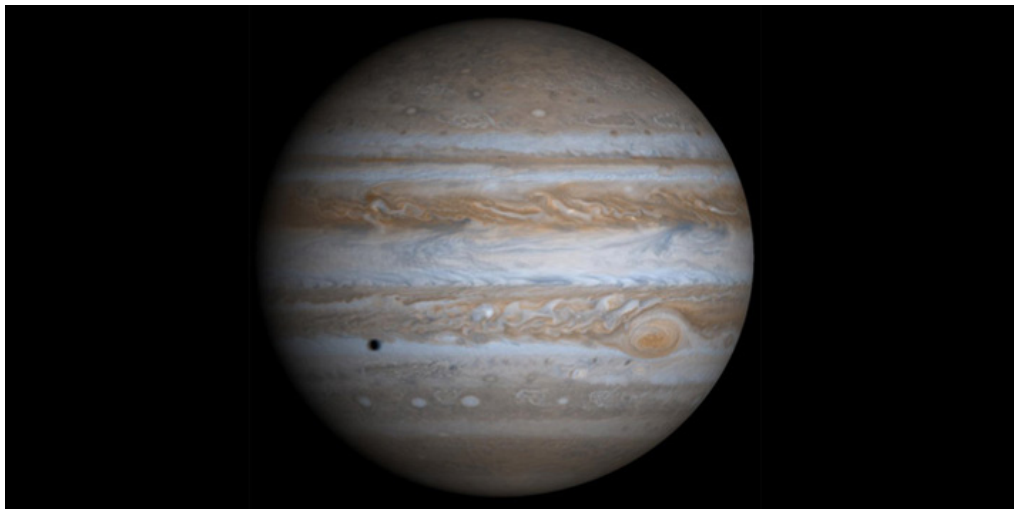
Tilt varies with period of 41,000 yrs



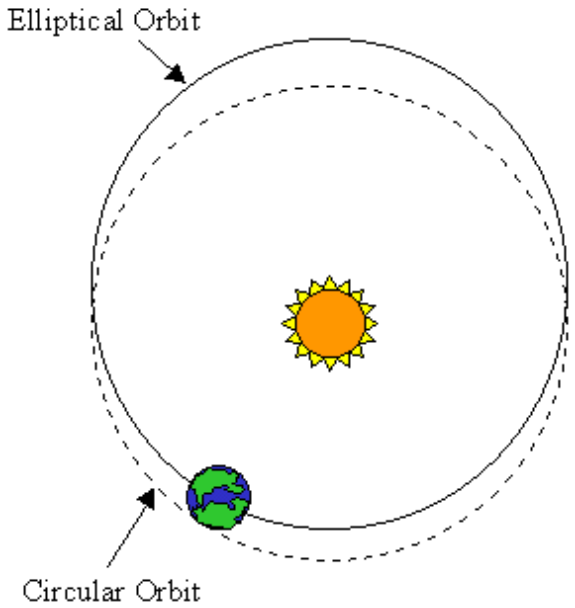
Precession of direction of tilt with a period of 26,000 yrs

Variation in the Eccentricity of the Earth's Orbit

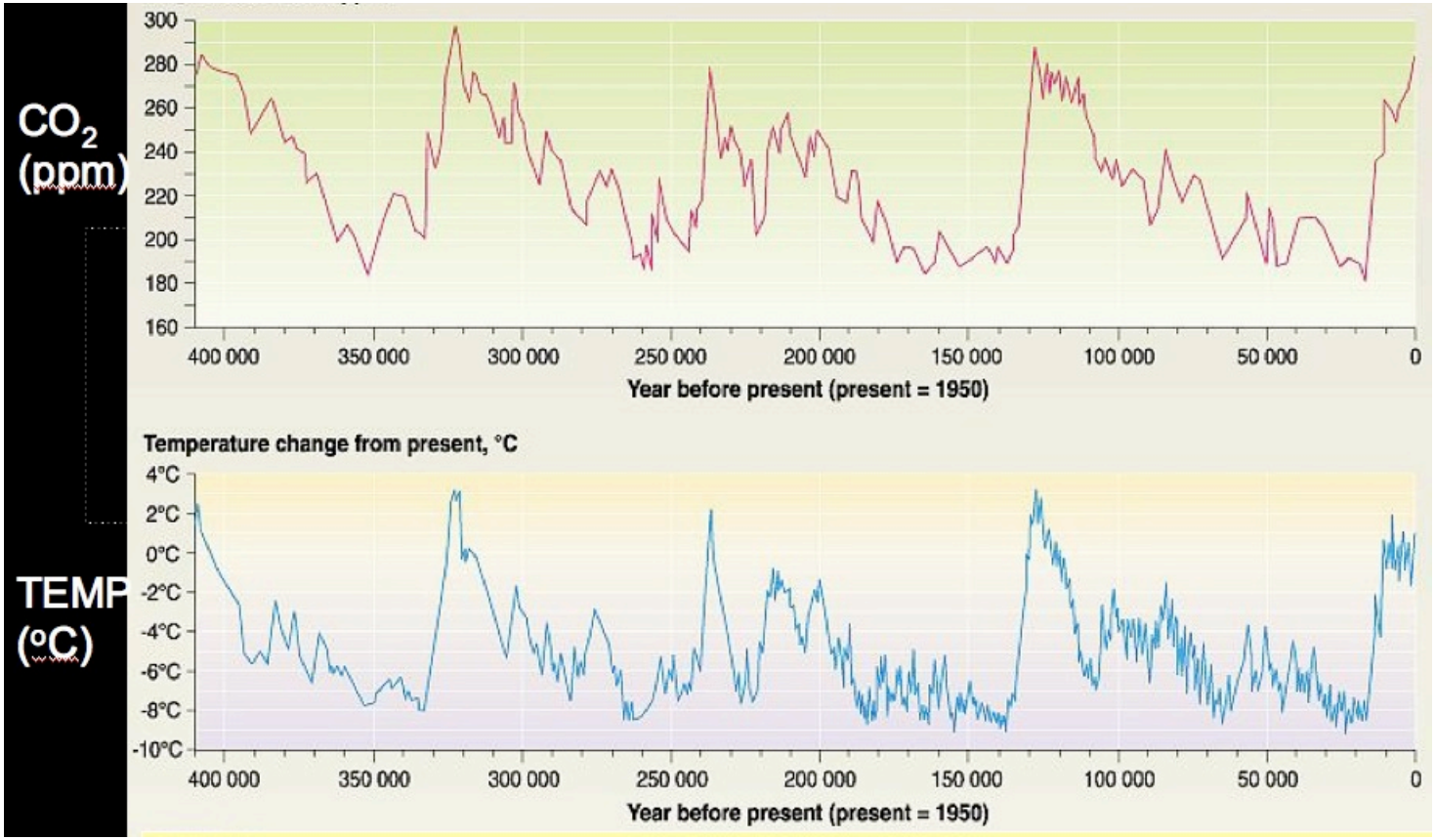




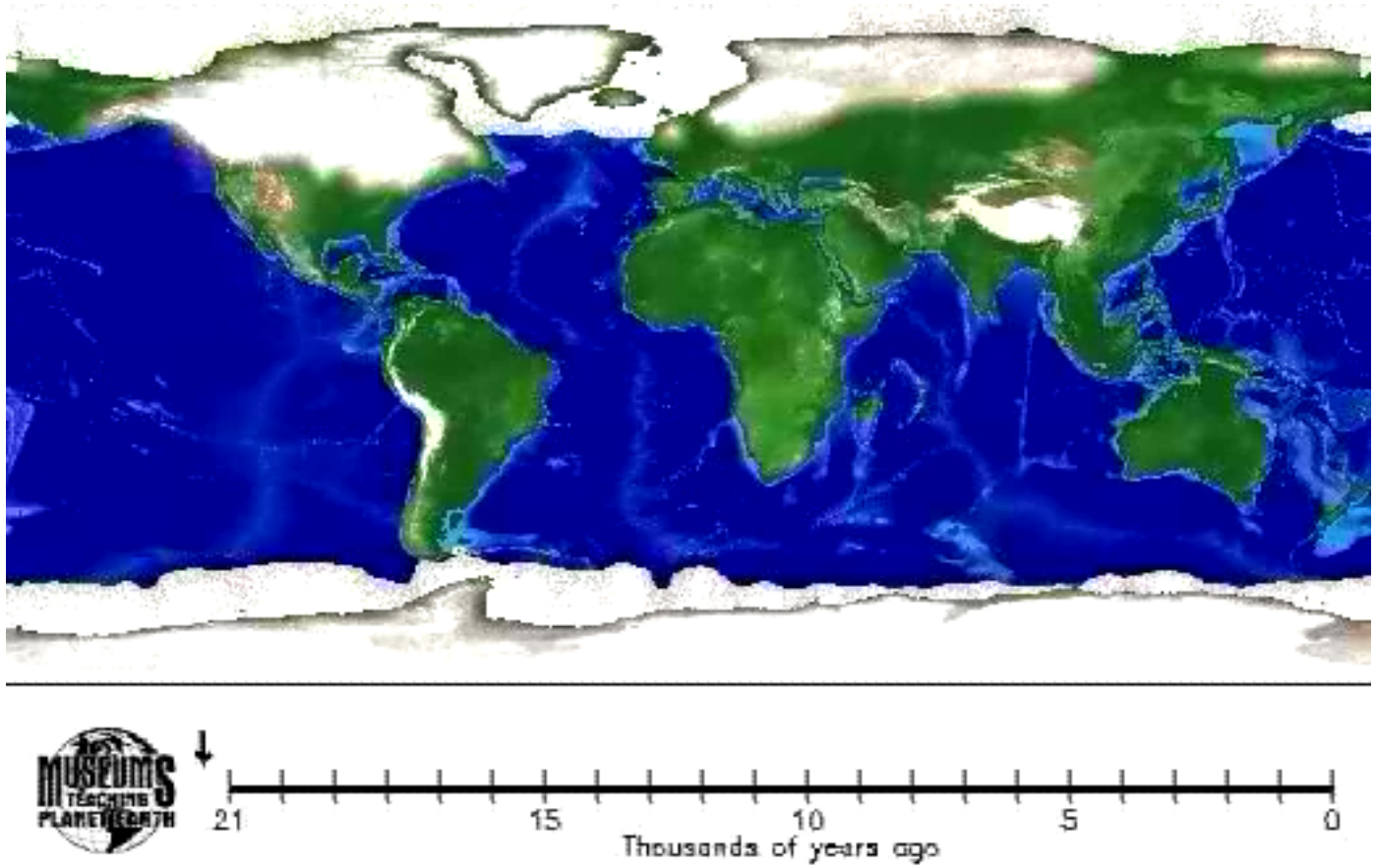
Jupiter & Saturn's Gravity Cause the Earth's Orbit to Change Shape Roughly Every ~100,000 yrs



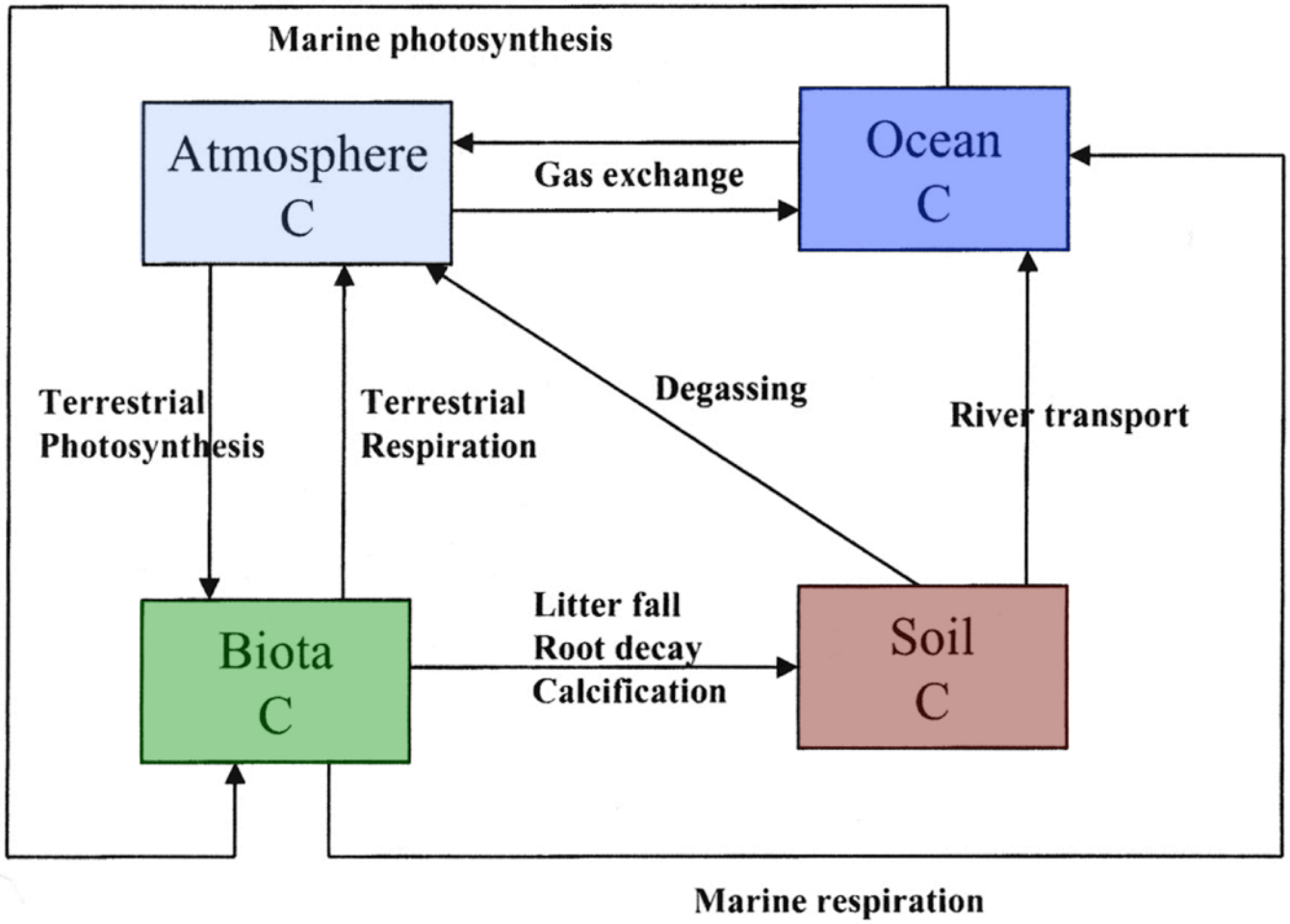
So, orbital variation (Milankovitch cycles) drives these oscillations in the Earth's climate



The Last Ice Age



Short-term Carbon Cycle:
Transfer between atmosphere, oceans, and life

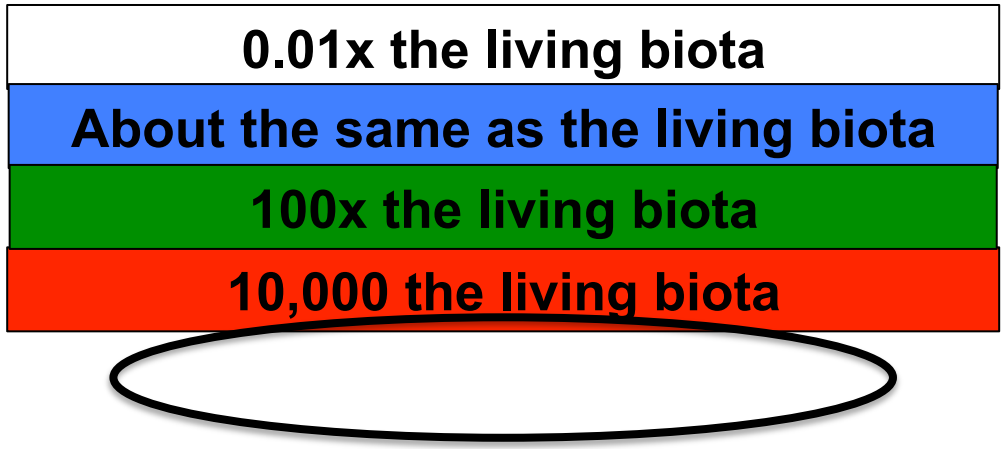


Transfer rates between reservoirs: Days to 10,000 years

Amount of Carbon in the Short-Term Cycle

Source of Carbon	x (Terrestrial biosphere C)
Oceanic dissolved inorganic C	56
Soil C	6
Atmospheric CO_2	1.2
Terrestrial biosphere	1
Marine biosphere	0.01

How much carbon is stored in rocks?



Long-Term Carbon Cycle Includes Rocks

Source of Carbon	x (Terrestrial biosphere C)
Carbonate C in rocks	100,000
Organic C in rocks	25,000
Oceanic dissolved inorganic C	56
Soil C	6
Atmospheric CO_2	1.2
Terrestrial biosphere	1
Marine biosphere	0.01

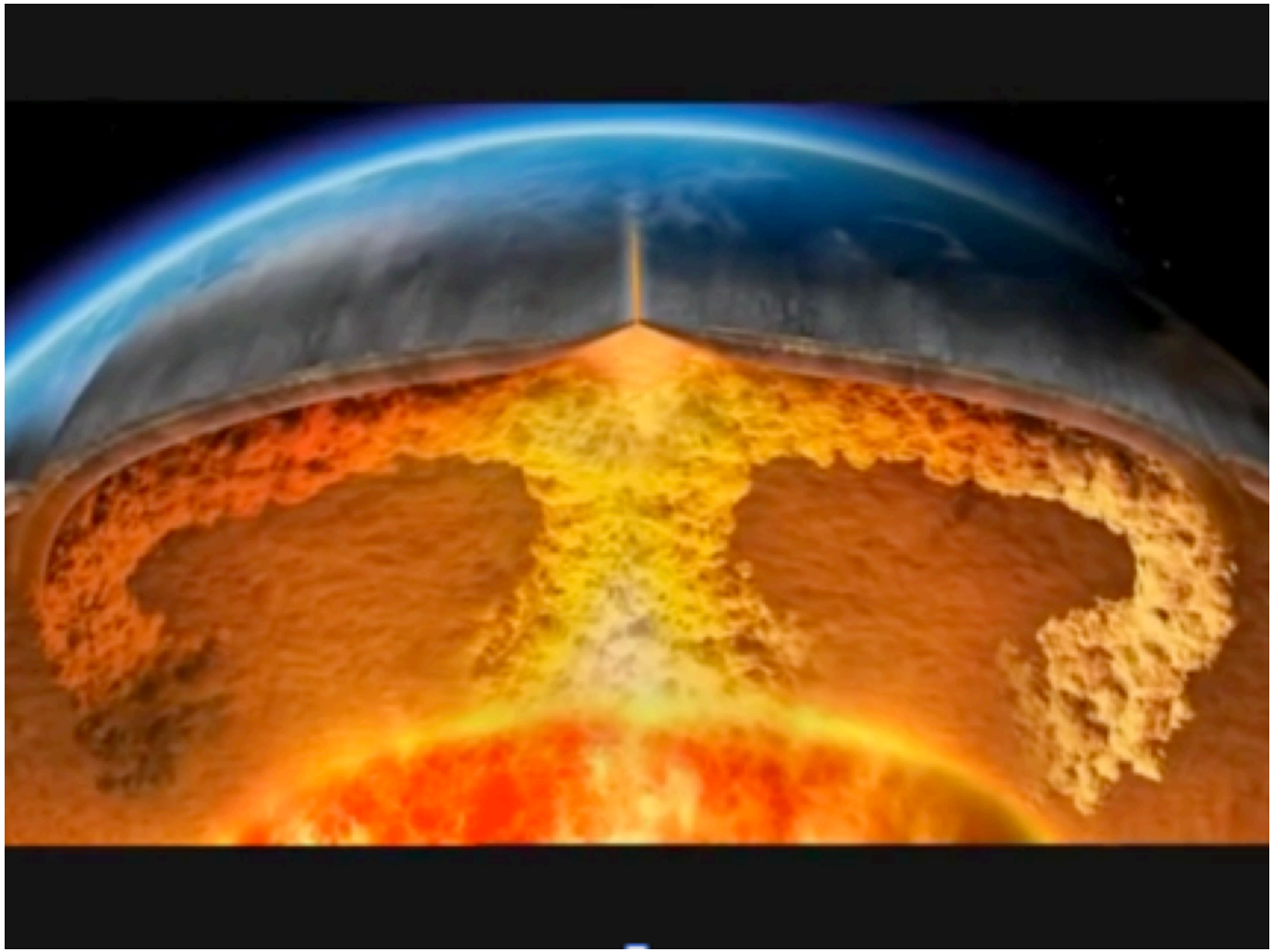
Long-term Carbon Cycle: Transfer of carbon to and from rocks – important because there is HUGE amount of Carbon in rocks.

BUT the transfer to and from the atmosphere is VERY slow

In 100 years:

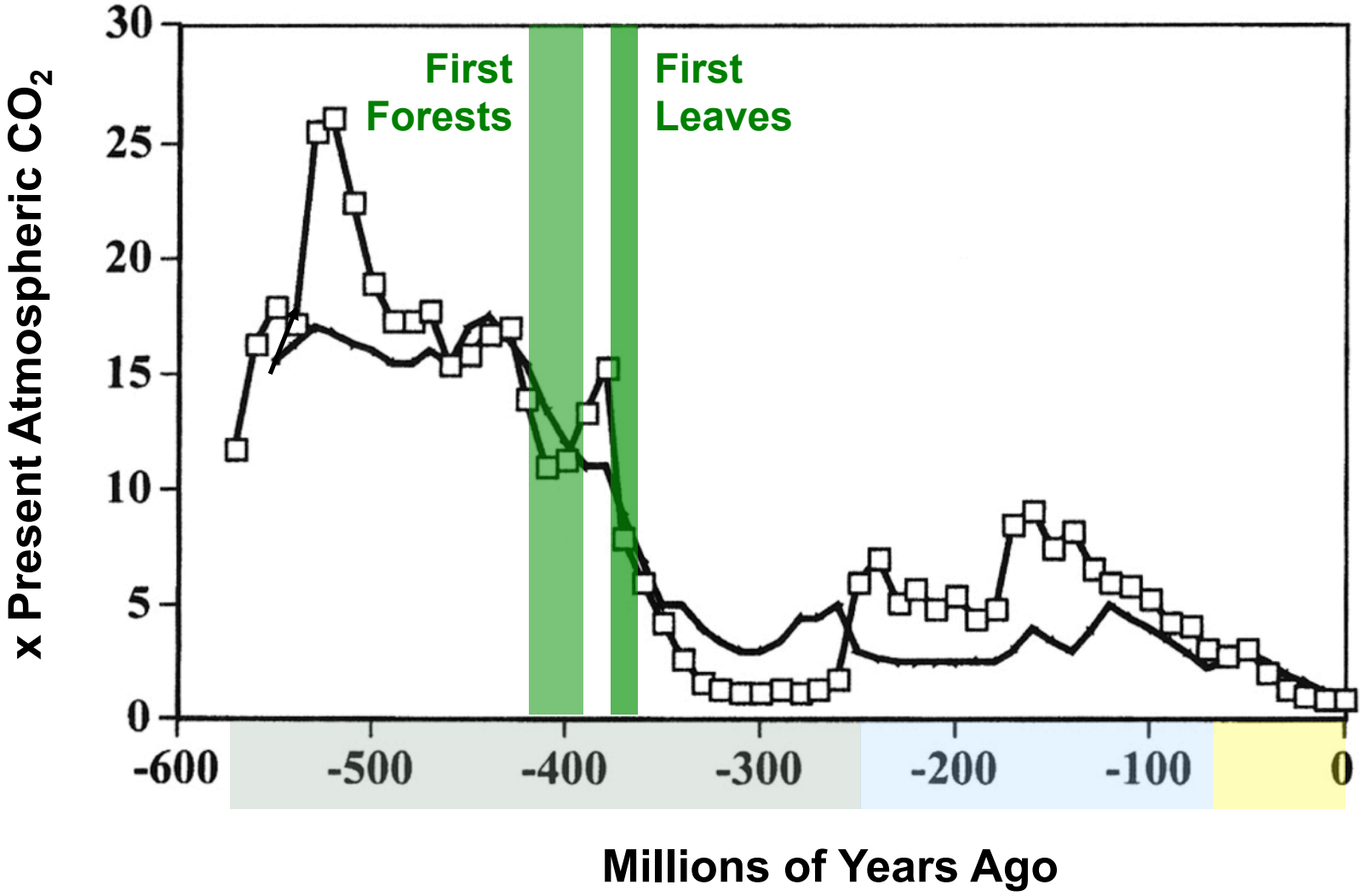
- **Only 1% of the CO_2 in the atmosphere is converted to limestone by weathering.**
- **Only 0.5% and 1.5% of the current amount of the CO_2 in the atmosphere is released by volcanic eruptions.**

The Return Part of the Long-Term Carbon Cycle



https://www.youtube.com/watch?v=ryrXAGY1dmE

The evolution of the first forests had a major impact on CO_2



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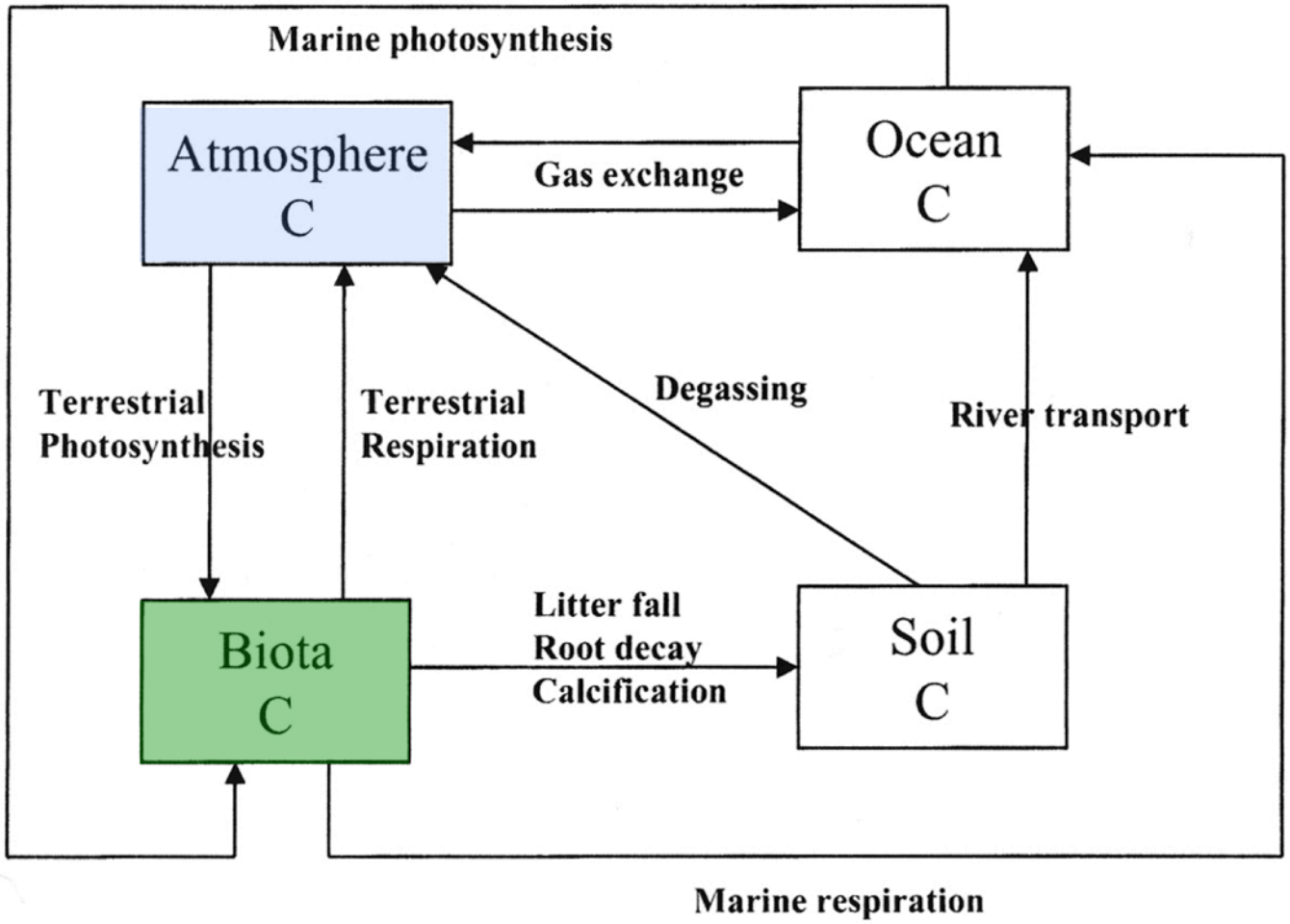

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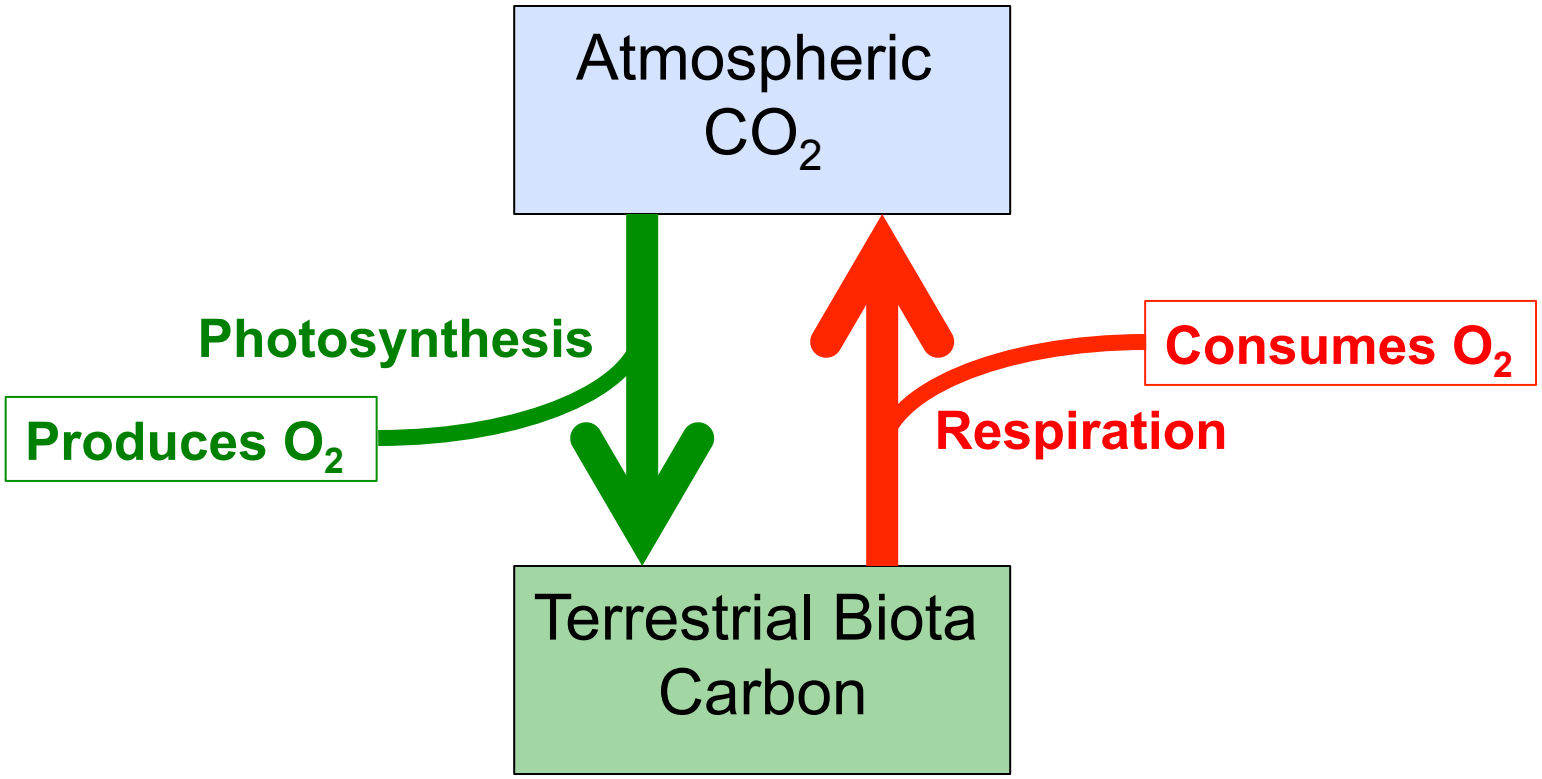

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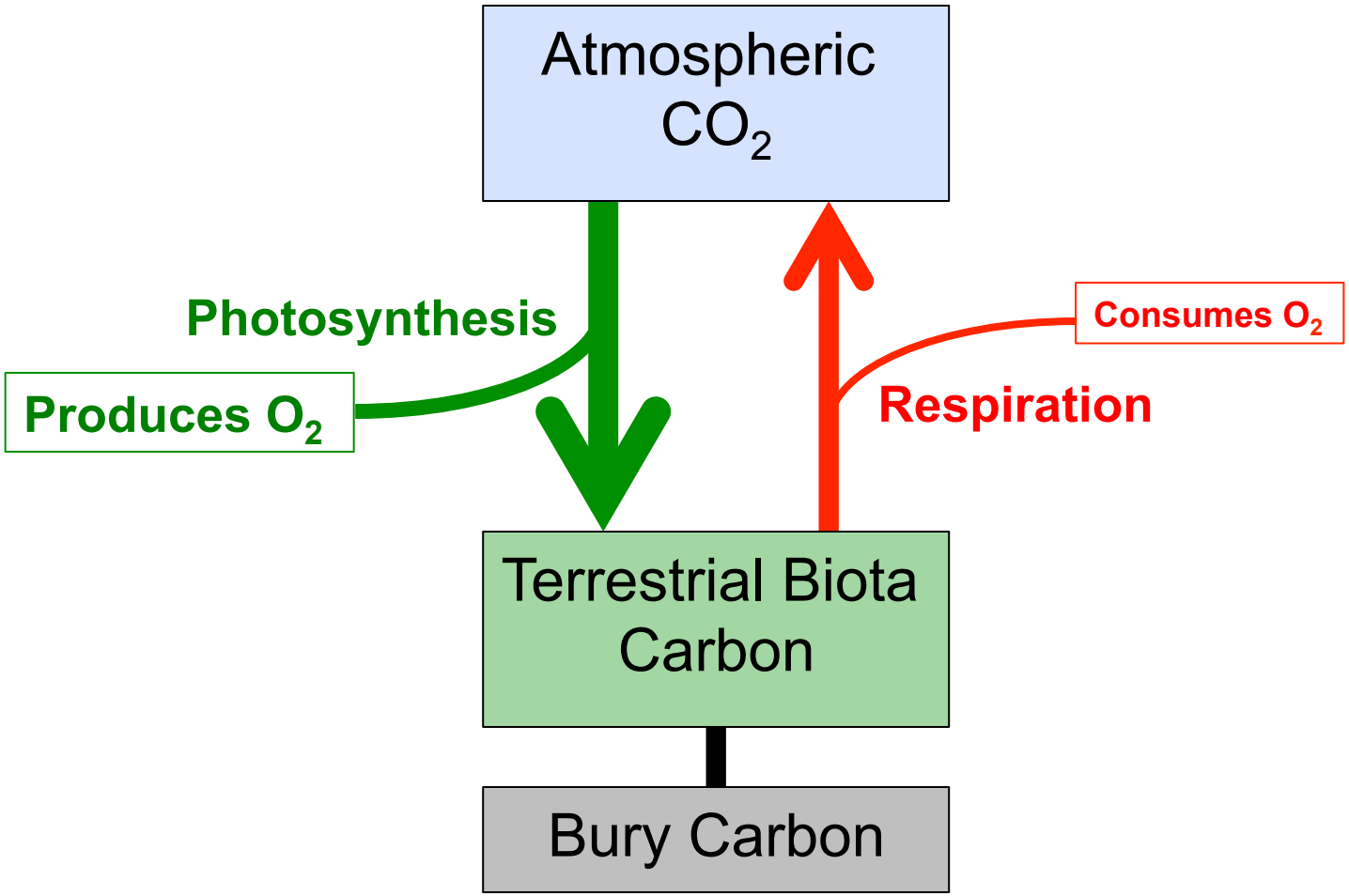
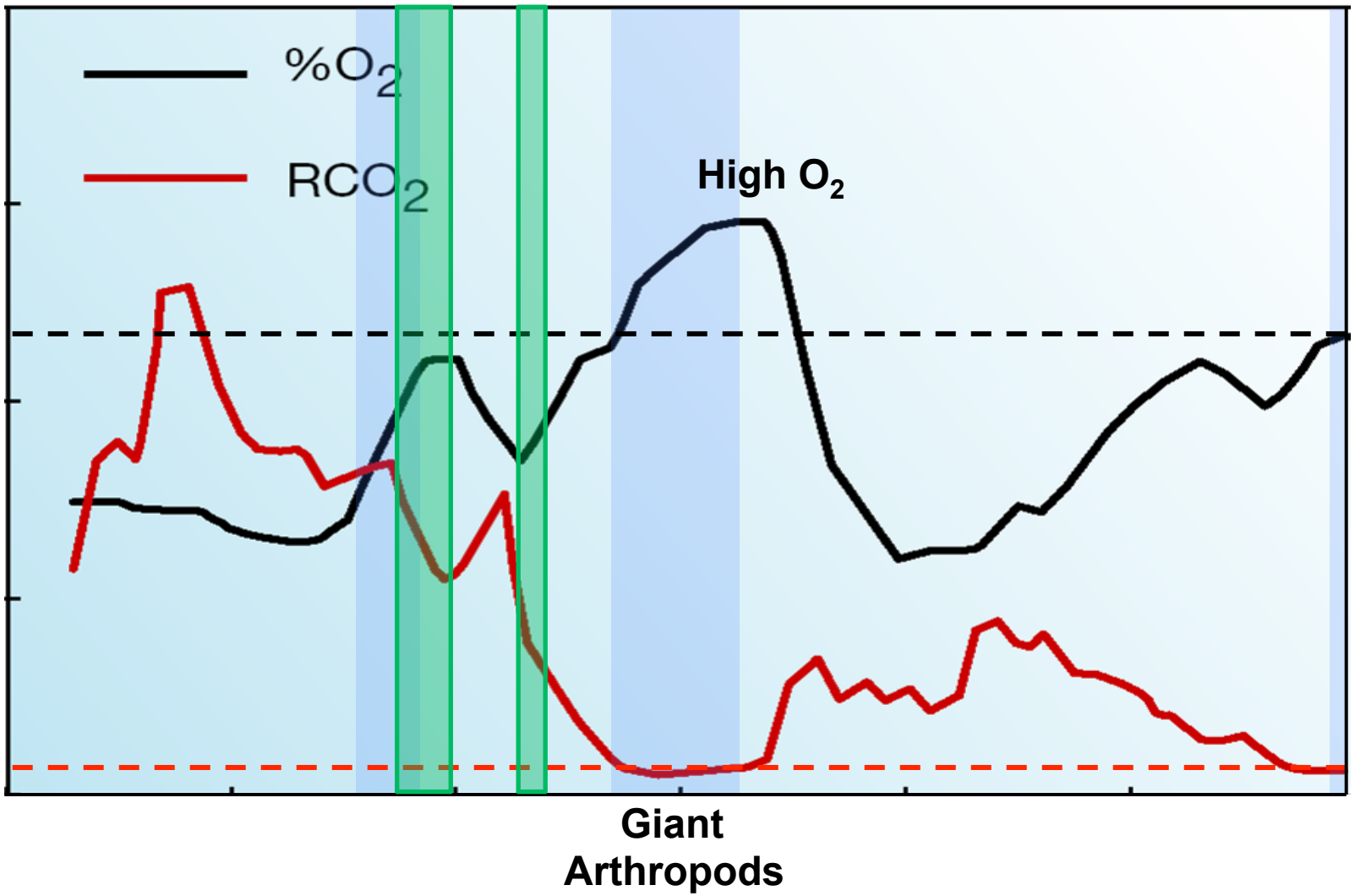


The First Great Forests Drastically Altered the World

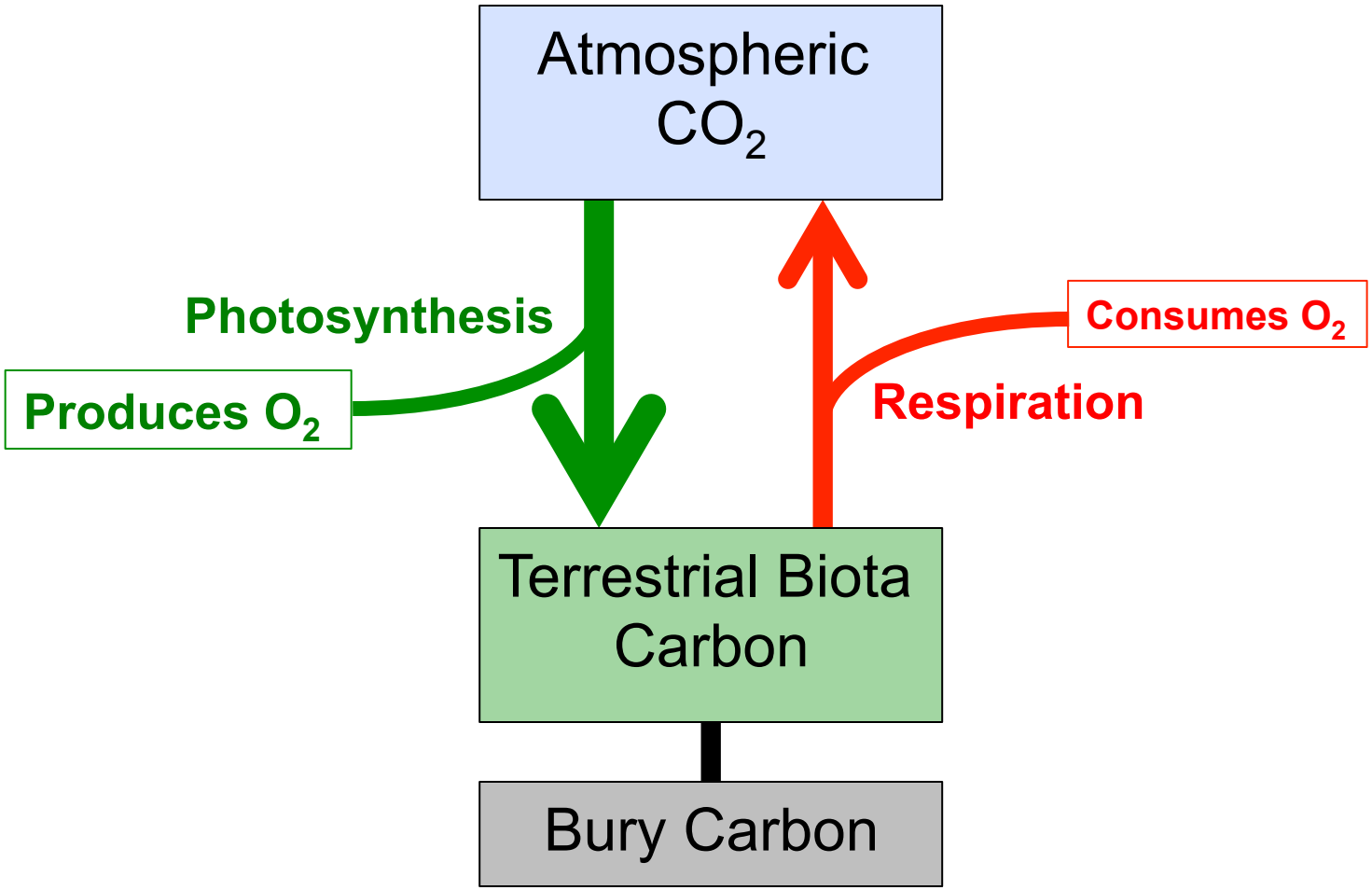


High Oxygen and Giant arthropods

The Great Carboniferous (360-300 million yrs ago) Forests

Our short-circuiting the long term carbon cycle ….

Short-term Carbon Cycle:
Transfer between atmosphere, oceans, and life



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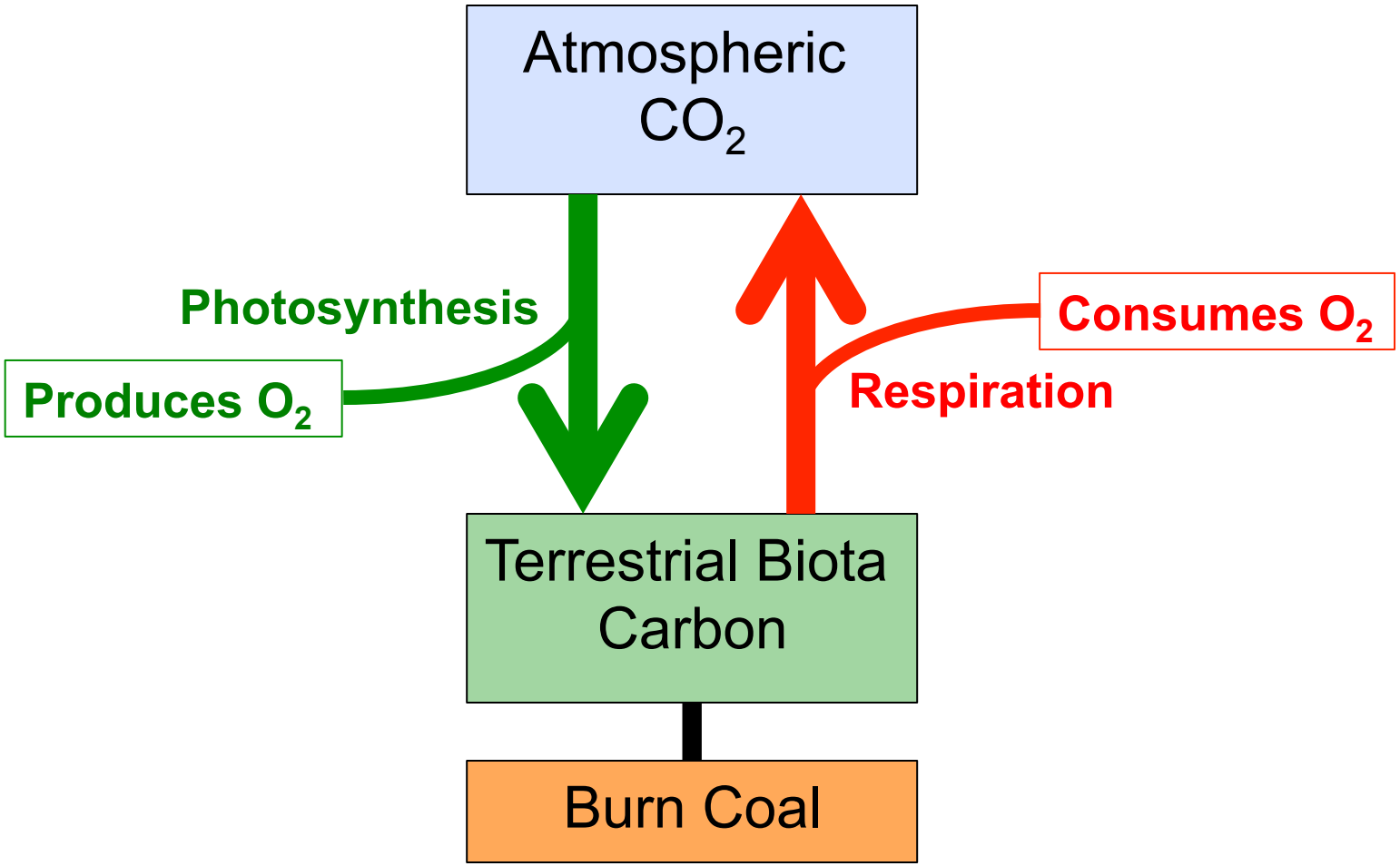

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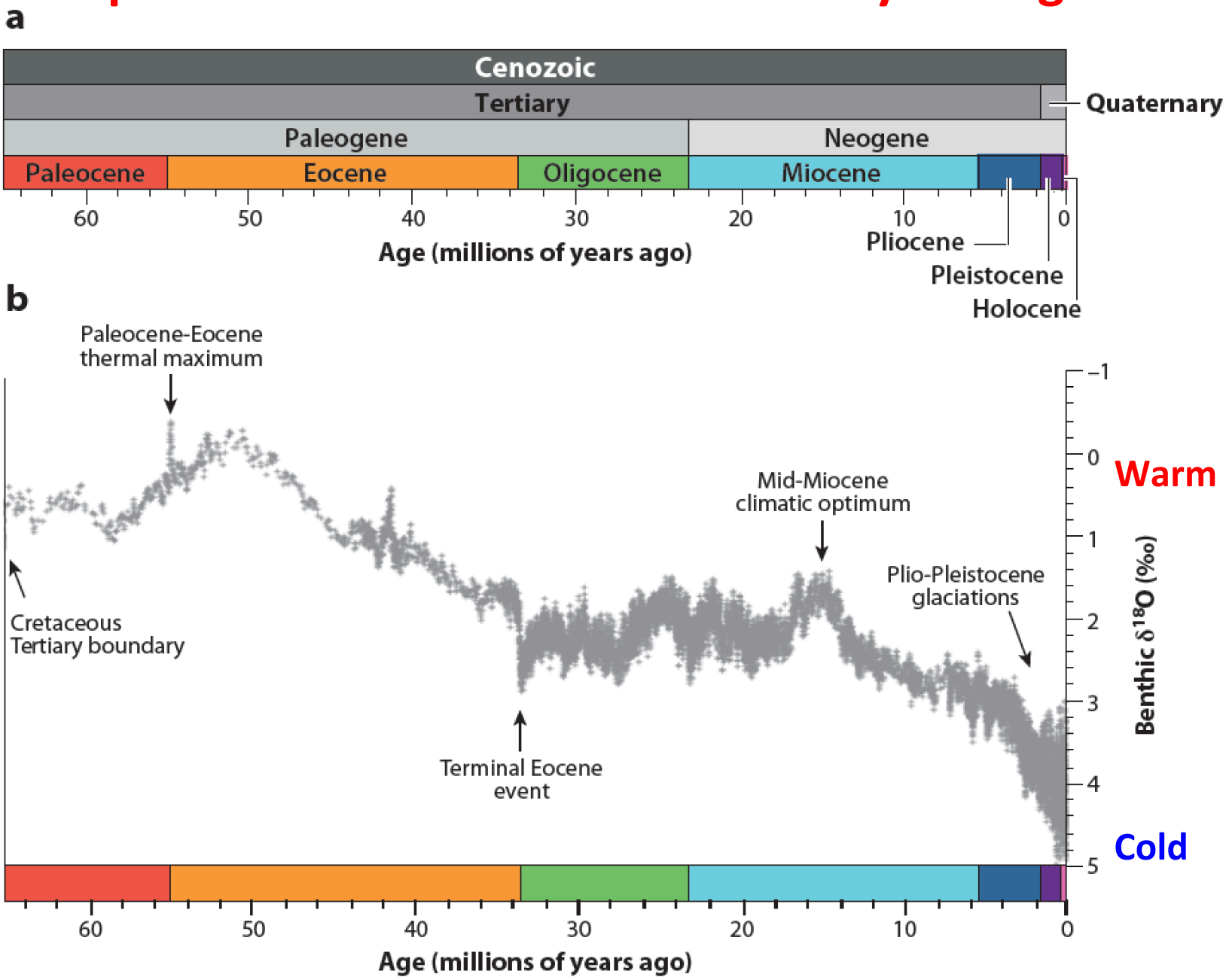
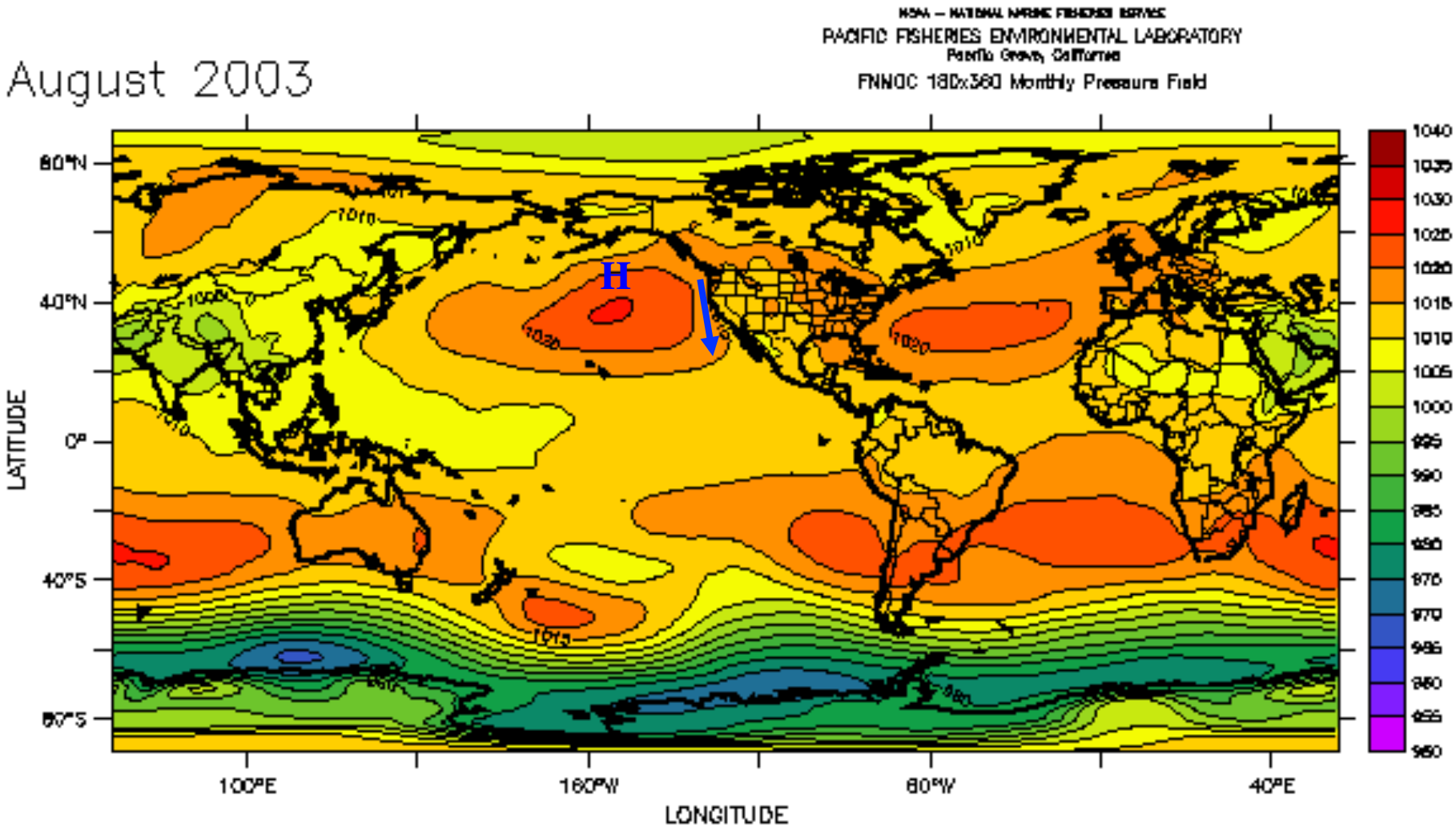
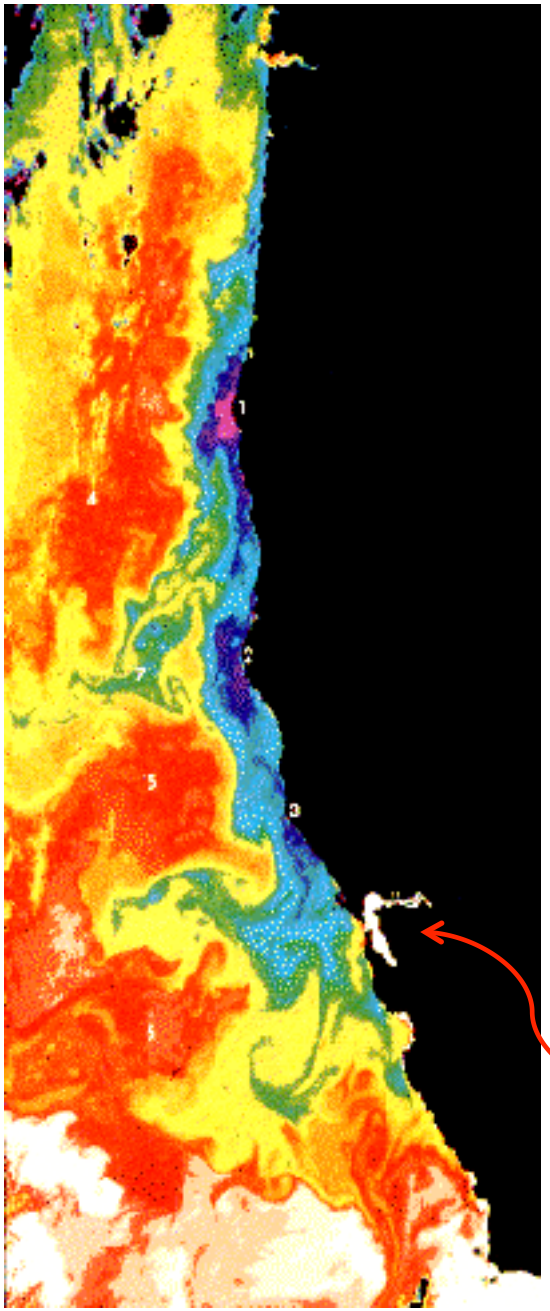
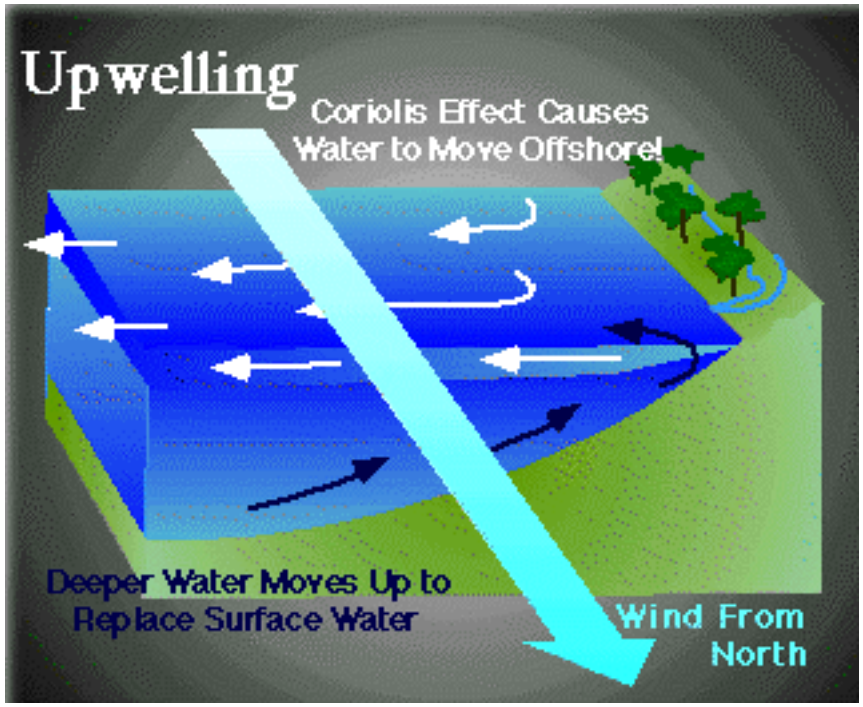
Temperature over the last 66 million years ago.





Pressure Reduced to MSL (mb)



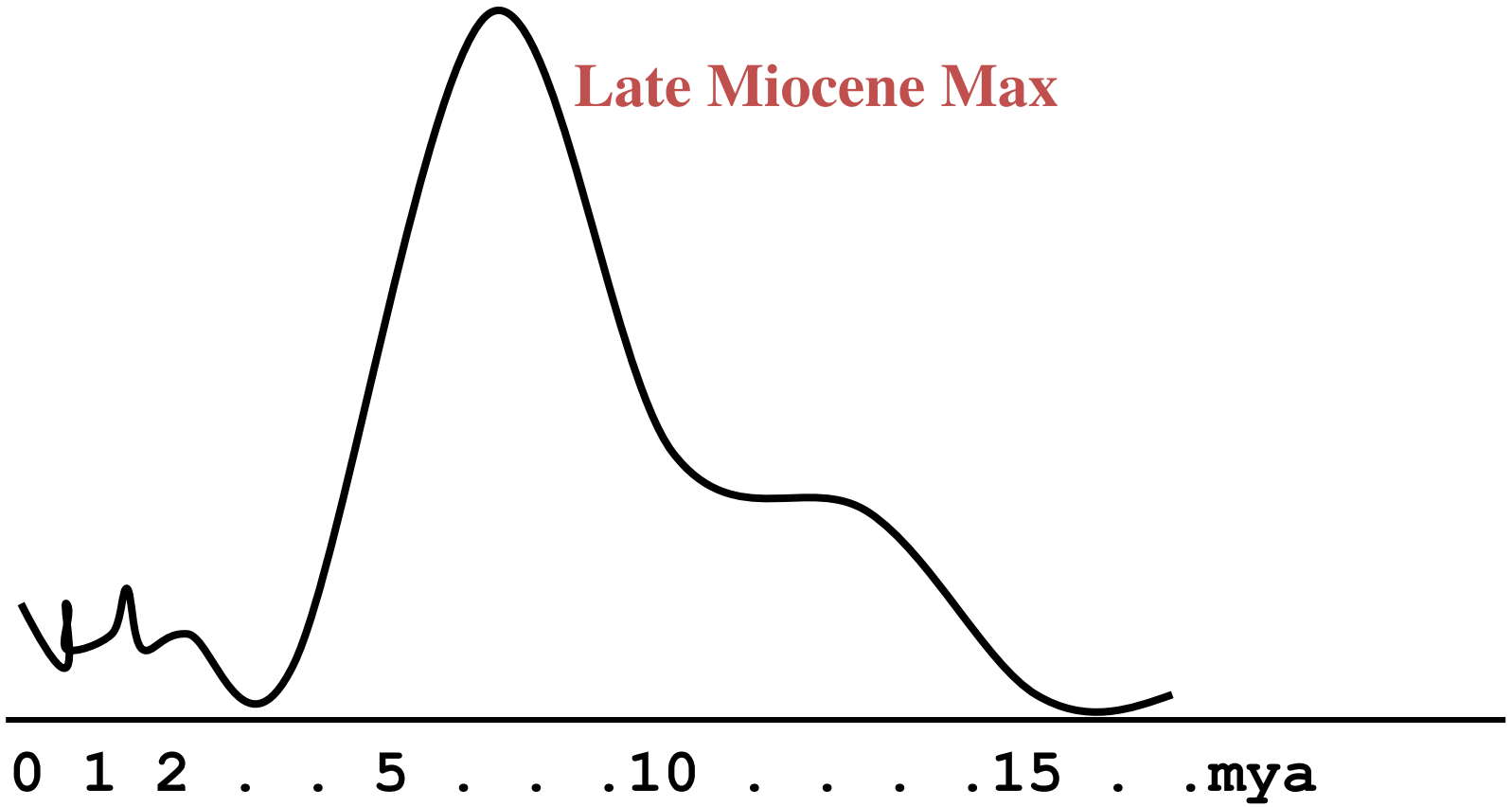


Coastal Upwelling – cold, nutrient rich water surfaces at the coast

San Francisco Bay

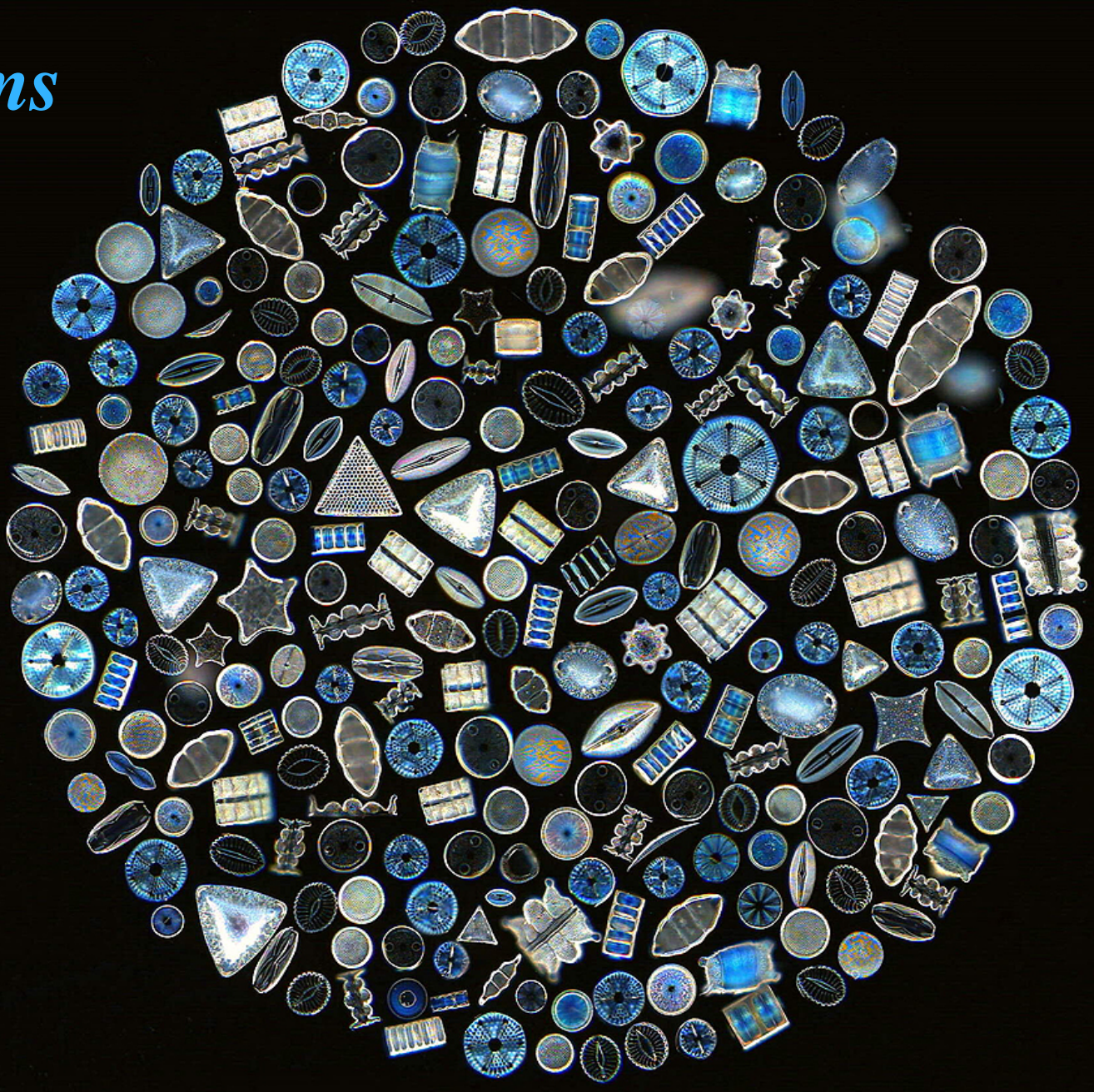

Kelp forests

Northern Pacific diatom accumulation – a measure of biological productivity



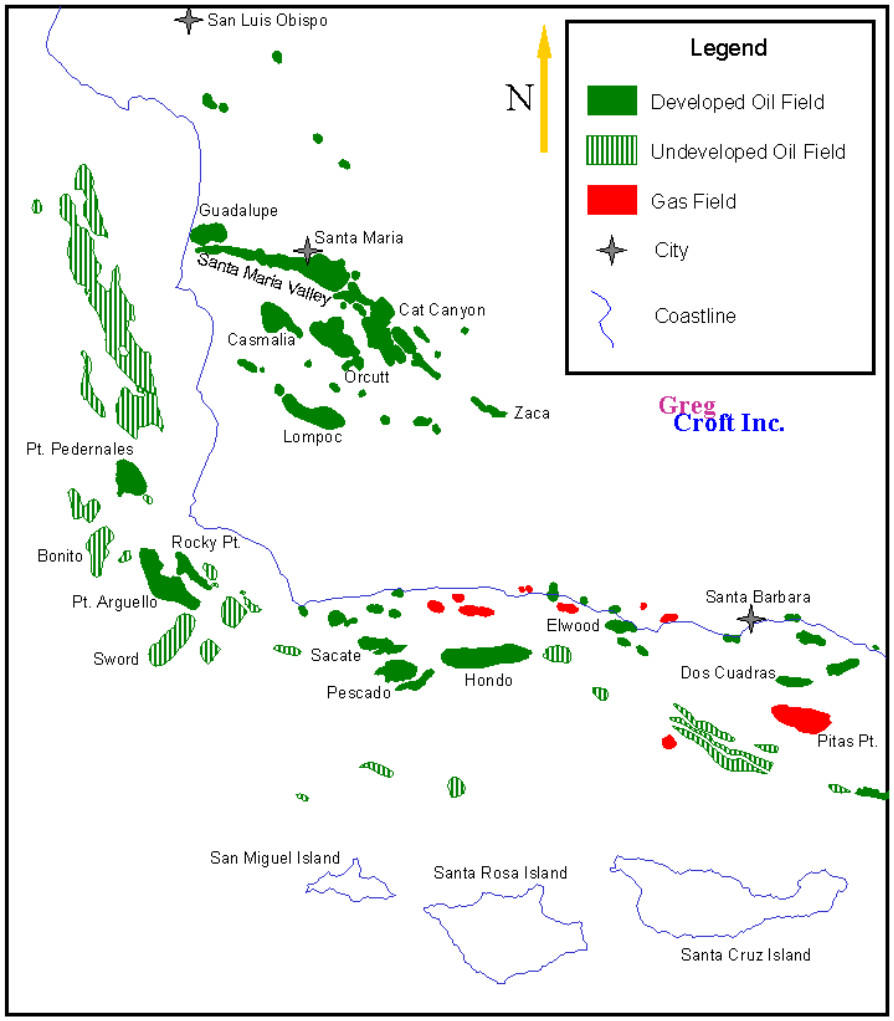
Barron (1998); Barron *et al*. (2002); Barron & Baldauf (1990)

Diatoms



Southern CA oils - derived from the Miocene diatoms

Oil Fields of The Santa Maria Basin and Adjacent Offshore Areas, California




Santa Monica
Los Angeles
Montebello
Playa Del Rey
Inglewood
Whittier
Sante Fe Springs
Potrero
El Segundo
Rosecrans
Lawndale
Dominguez
West Coyote
Torrence
Anaheim
Long Beach
Pacific Ocean
Long Beach
Seal Beach
Wilmington
Huntington Beach
10 miles
N
10 km


Los Angeles


Huntington Beach
100's of fun travel pictures at http://RVforSaleGuide.com


West Los Angeles, 1920s

Then uplift over the last 5 million years + Cooling = Reinstatement of year-long river flow

Uplift included the Sierra, Colorado Plateau, Rockies, Transverse & Coast ranges.

Snow melt sustains rivers, e.g., the San Joaquin, Colorado, etc.

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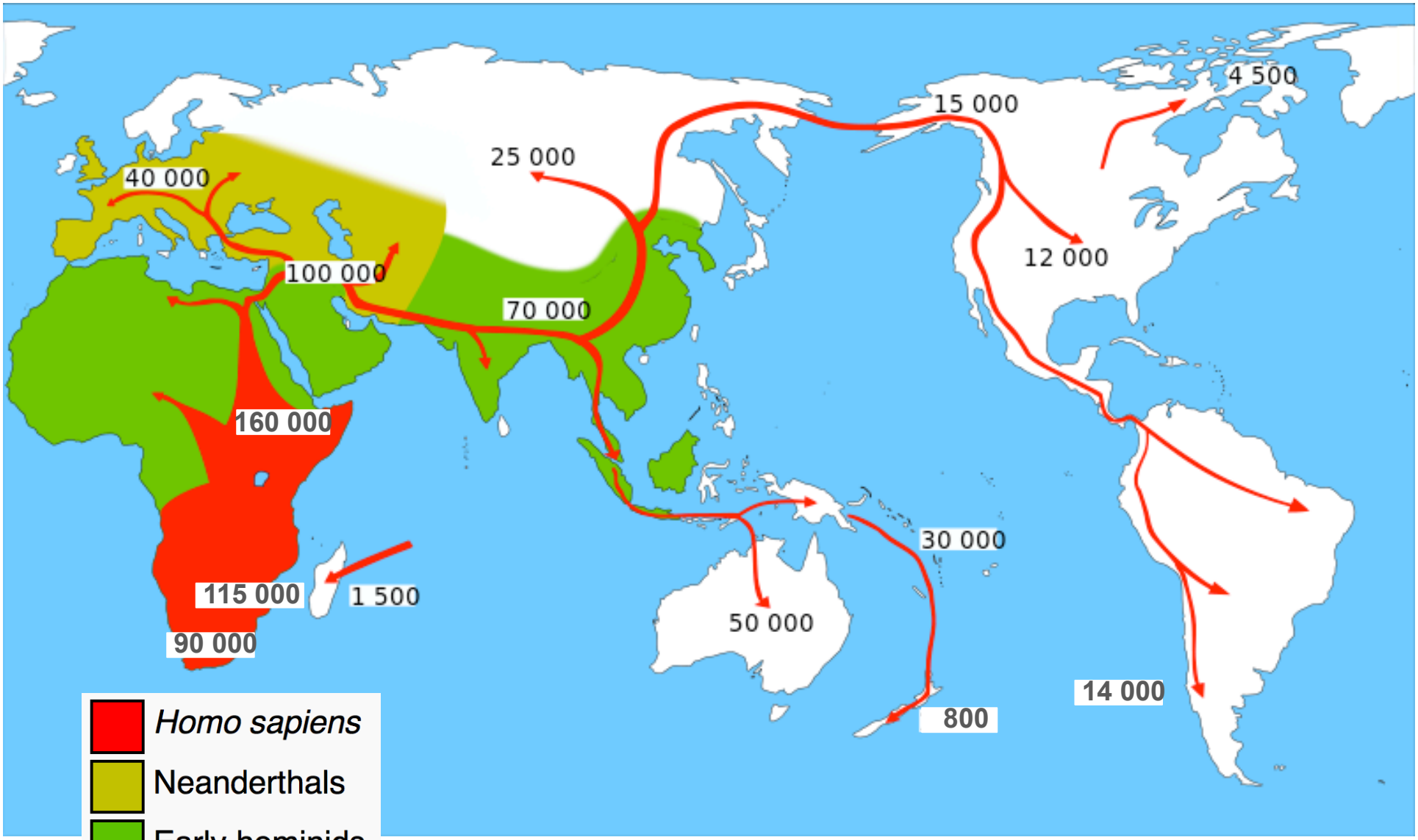
Homo sapiens first seen 160,000 years ago



Islands: Human impact depressingly clear

Examples

<u>Pacific Islands</u>: estimated 8,000 extinct species or populations of birds, roughly 20% of global bird diversity in the last 10,000 years.

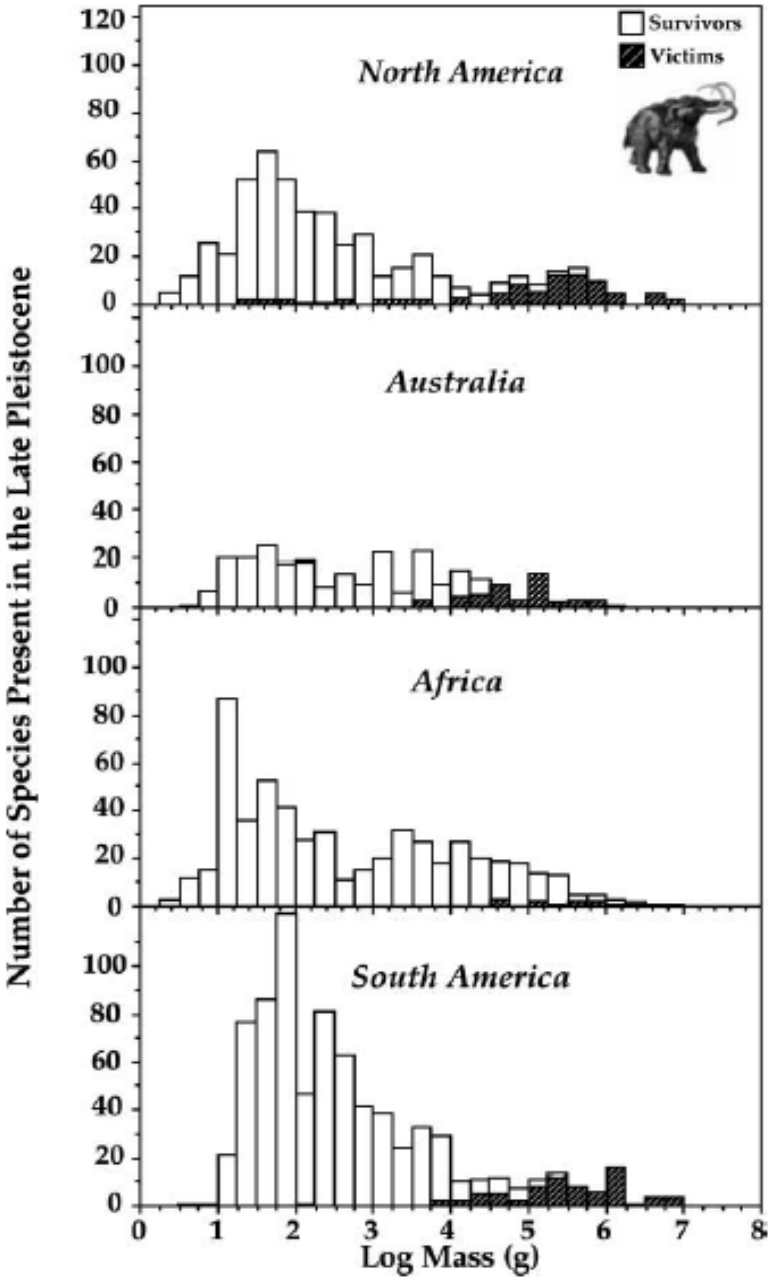
<u>New Zealand</u>: 60% loss of bird species, including nearly all flightless birds.

<u>Madagascar</u>: 50% of its lemurs (all >10 kg), 2 hippos, 2 giant flightless birds, tortoise.

Megafaunal Extinctions (Large Mammals)

With special thanks to Dr. Tony Barnosky (Berkeley) (here with Governor Brown)

Victims Mostly Large Animals

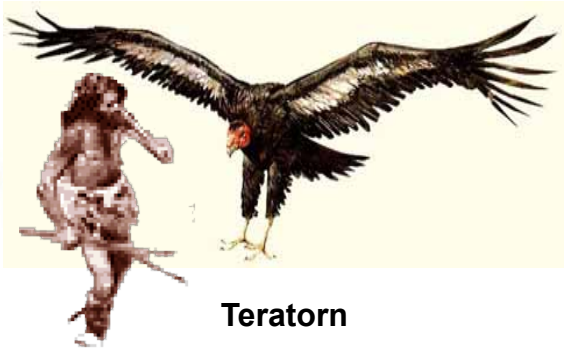


Ground Sloth

Short-faced Bear

Globally extinct:
97 genera

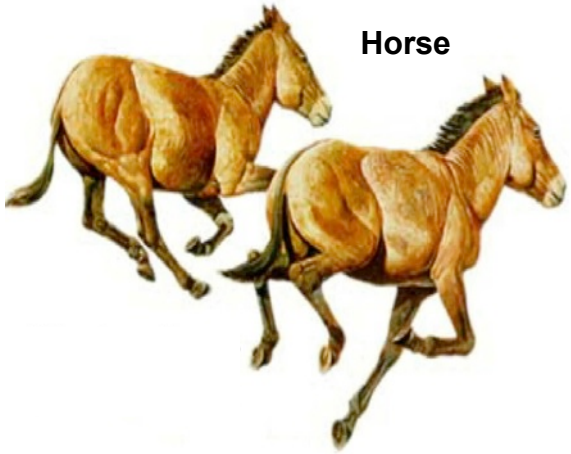
Sabertoothed Cat



Teratorn

Extinct from one continent

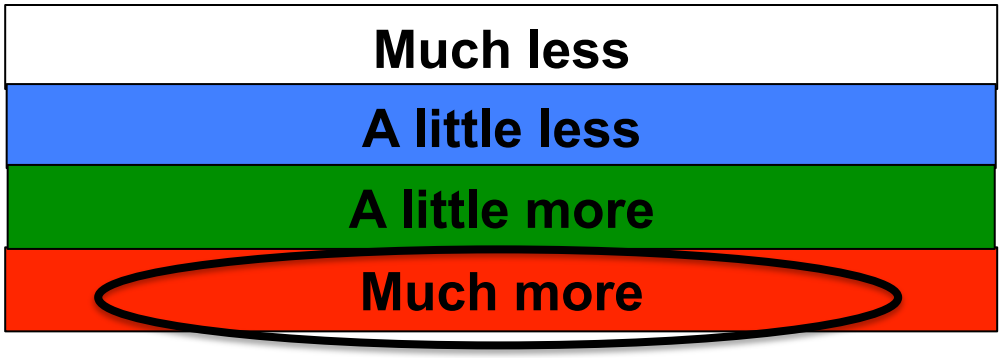
121 genera



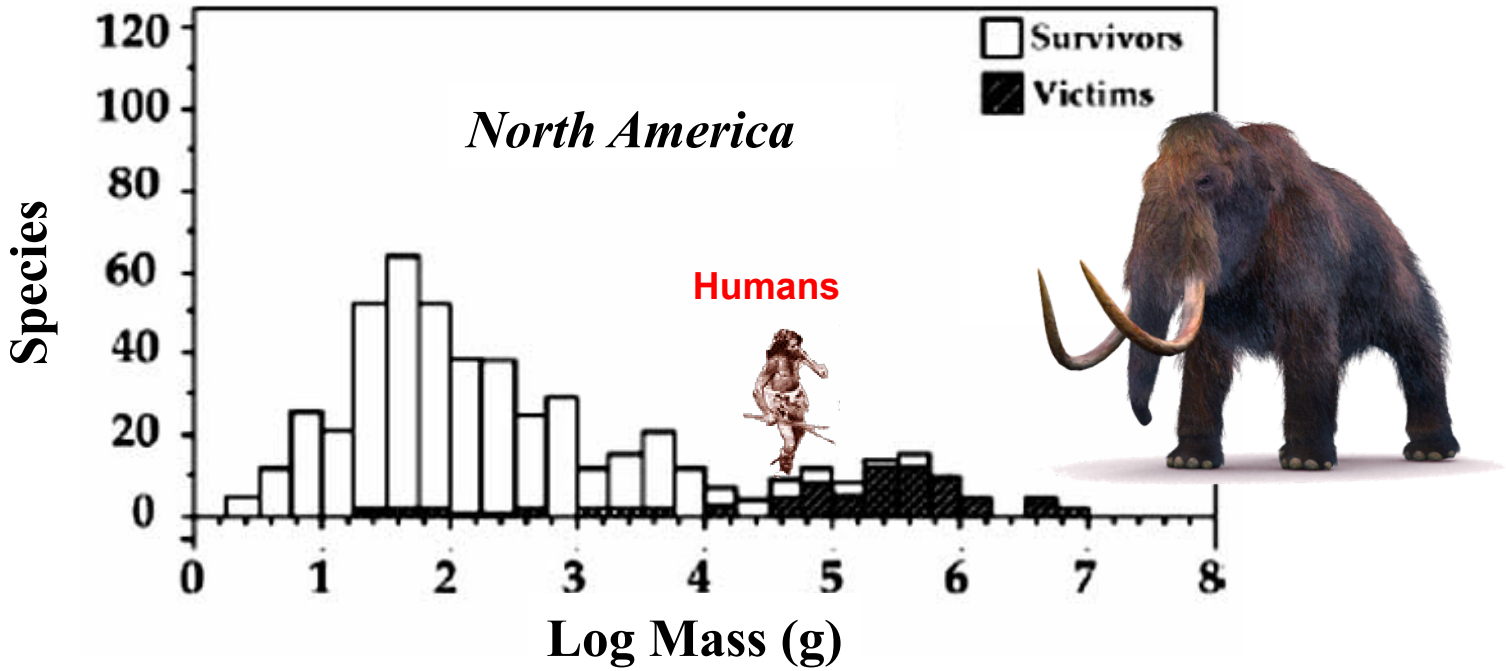
Horse

American Lion

Large mammals have a major impact on vegetation and produce greenhouse gases such as methane (burps more than farts). How does megafaunal biomass today compare with the biomass prior to the megafaunal extinctions?

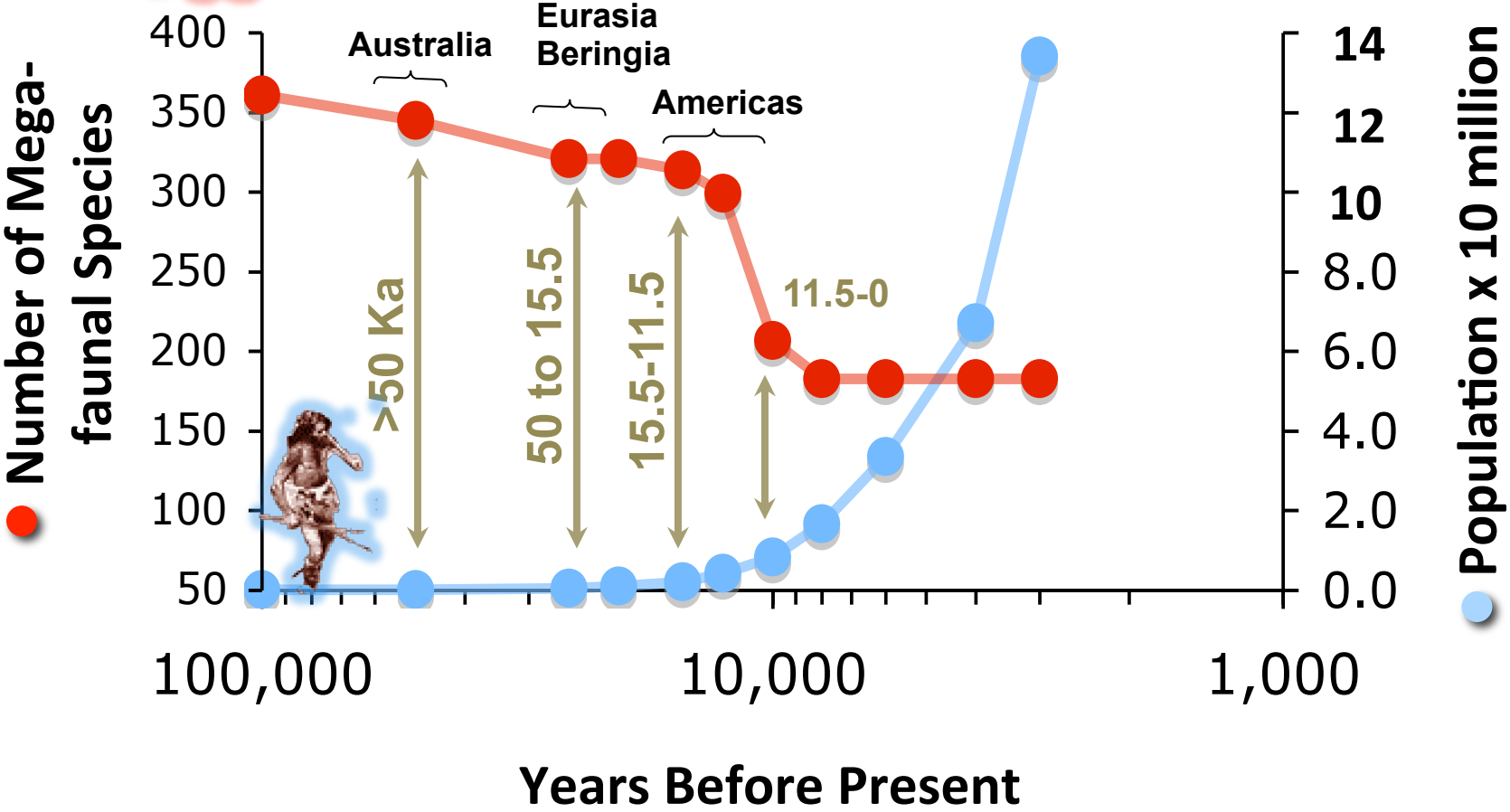


How does our view change if include Humans in our analysis?

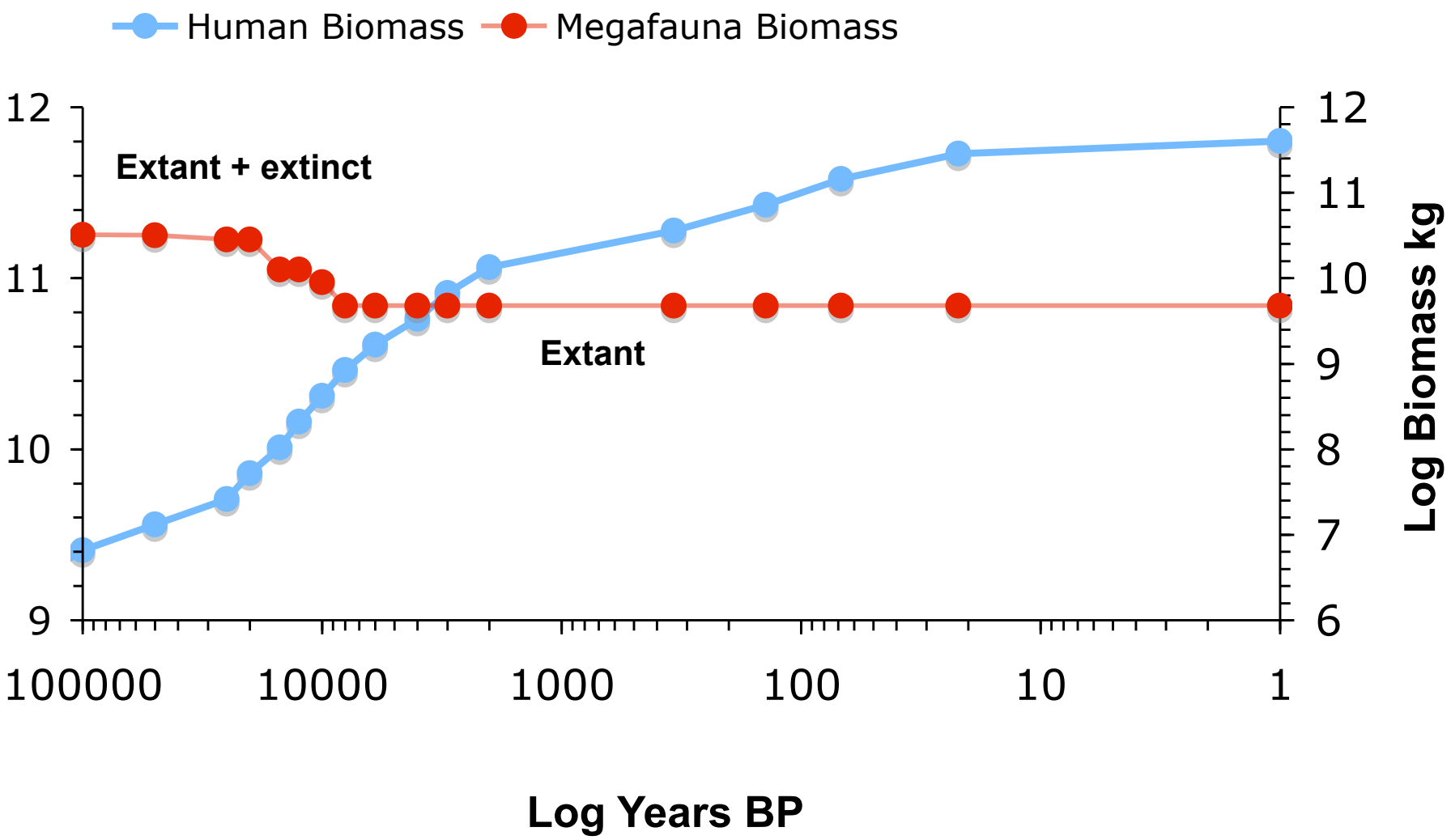


We are a megafaunal species!

Megafaunal Loss vs. Global Human Population Growth

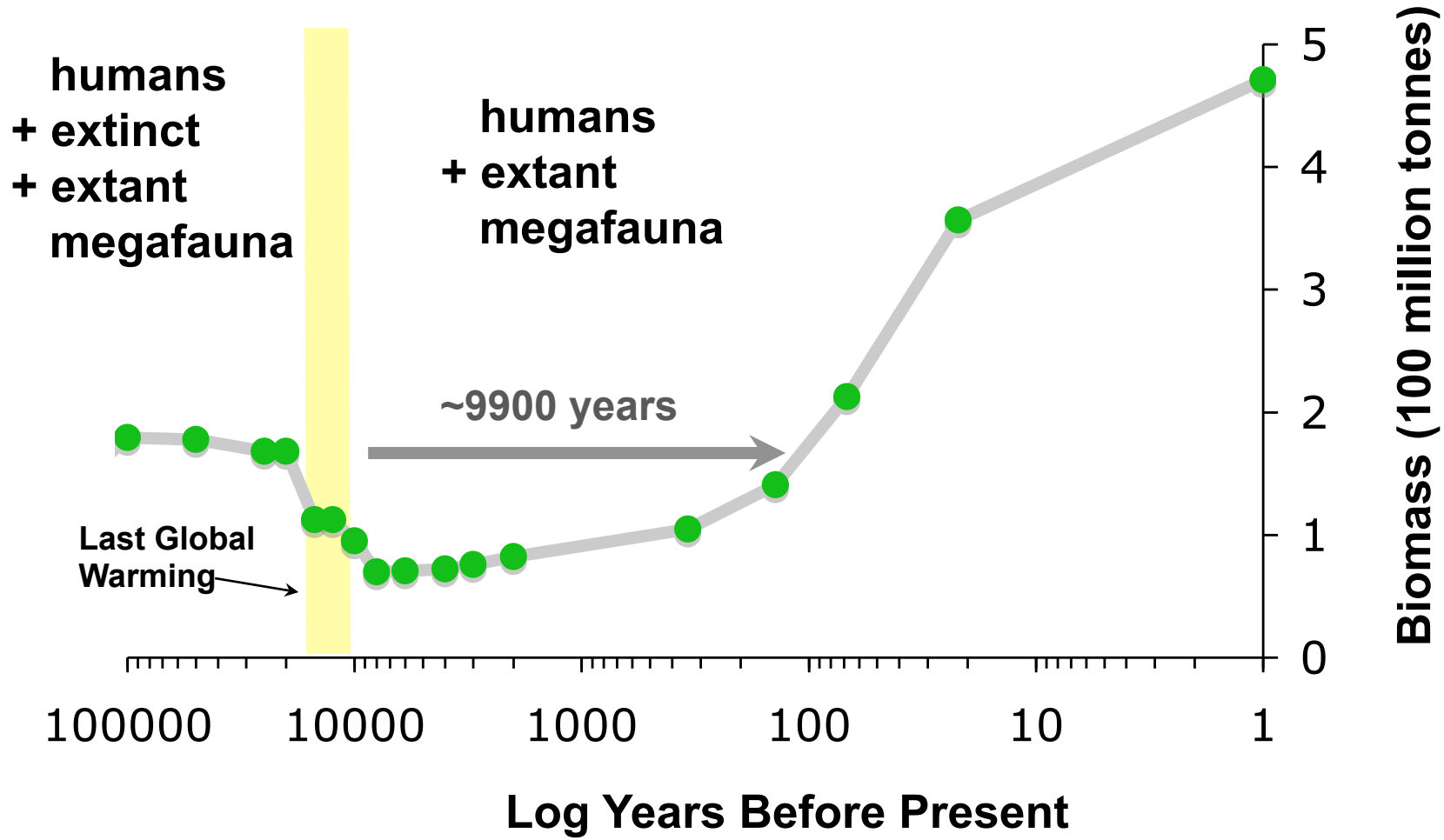


Megafauna Lose Biomass as Humans Gain Biomass



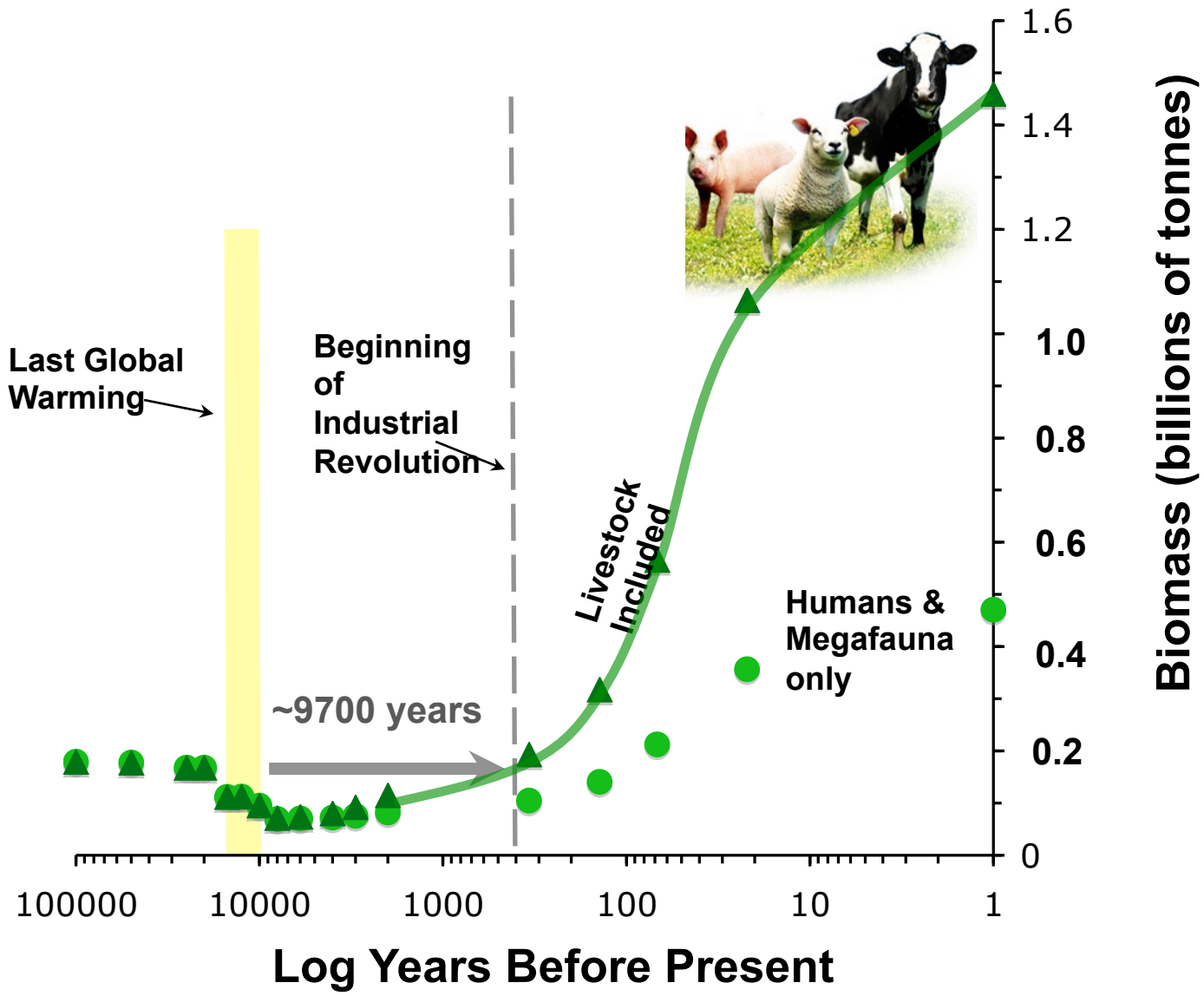
Biomass recovery

. . . took a long time



When we add in our megafaunal farm animals!

- ***Using borrowed energy from fossil fuels***



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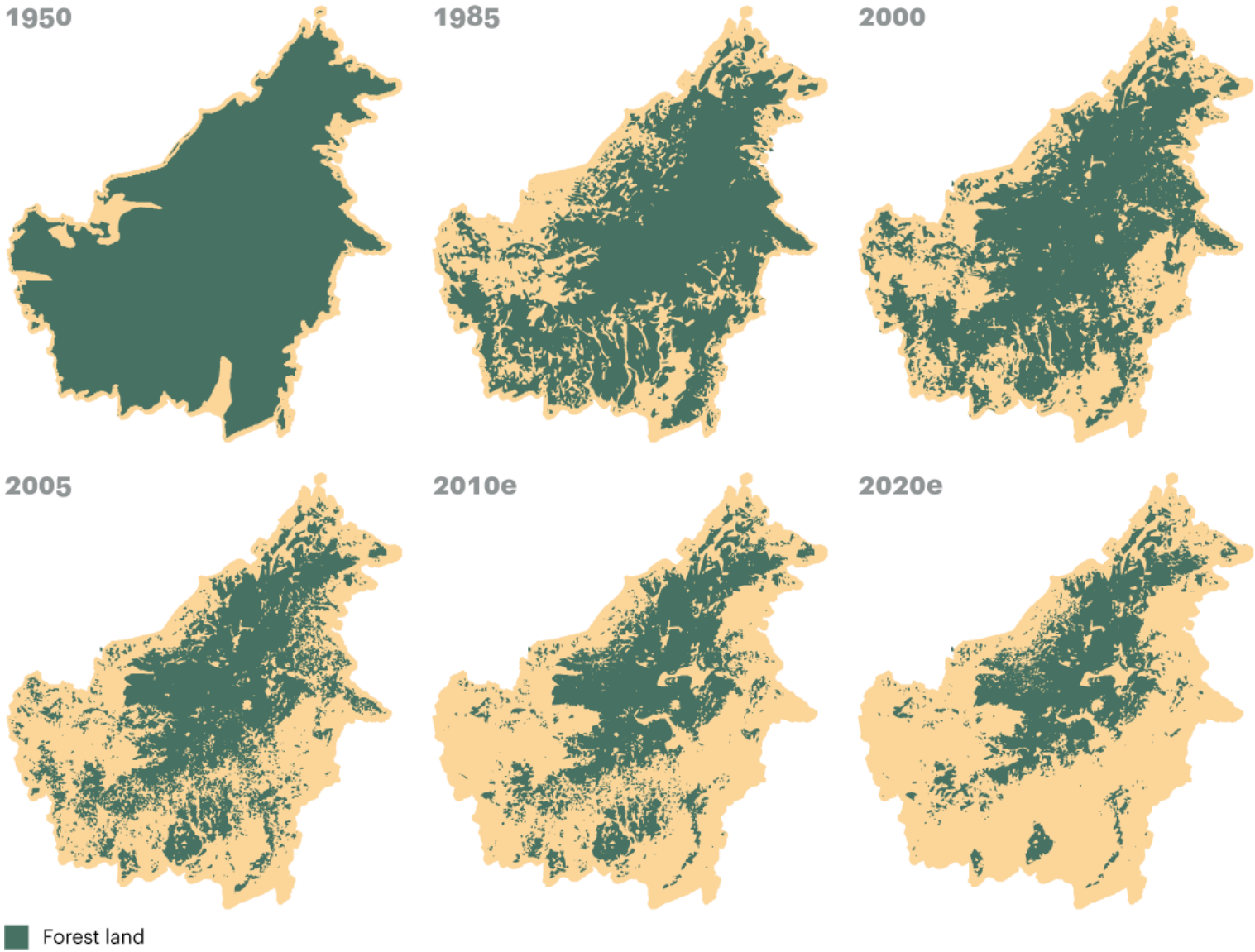
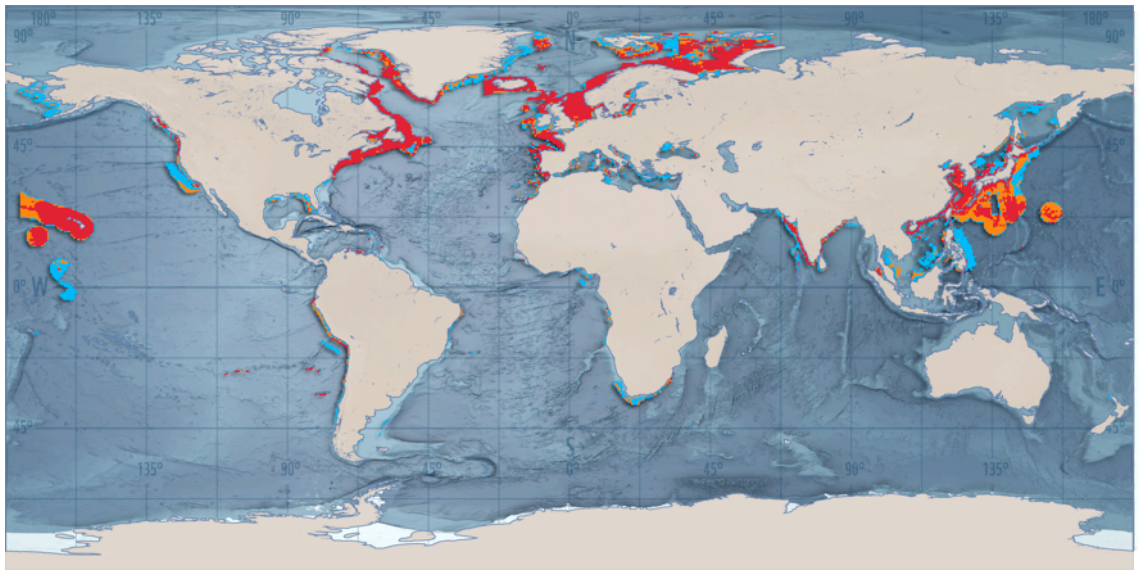
Deforestation in Borneo, 1950-2020



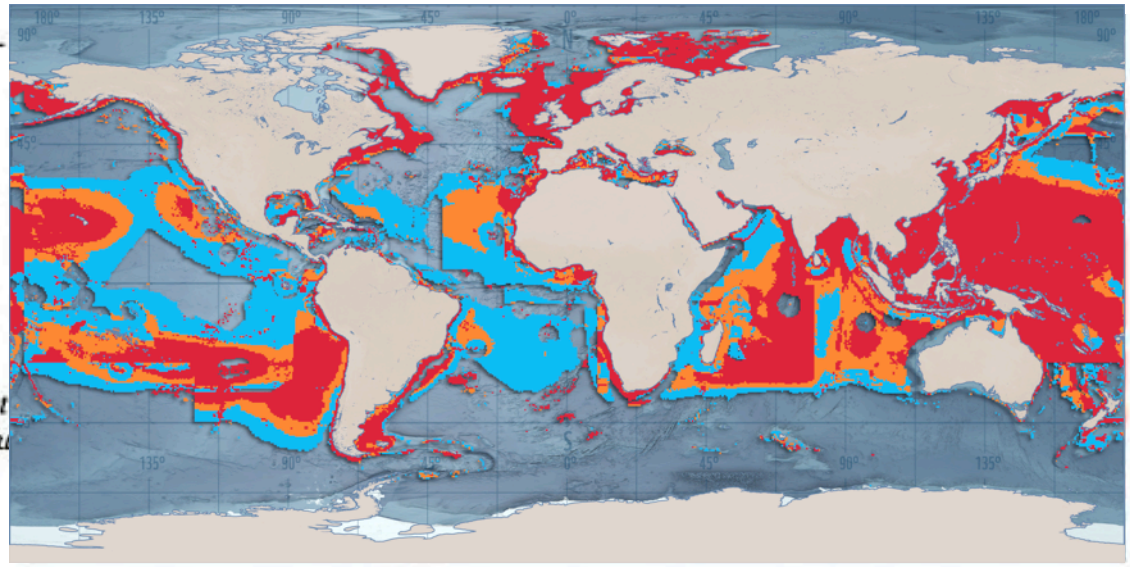
Source: WWF Germany

Global Footprint of European Fishing Activities

1950



2006



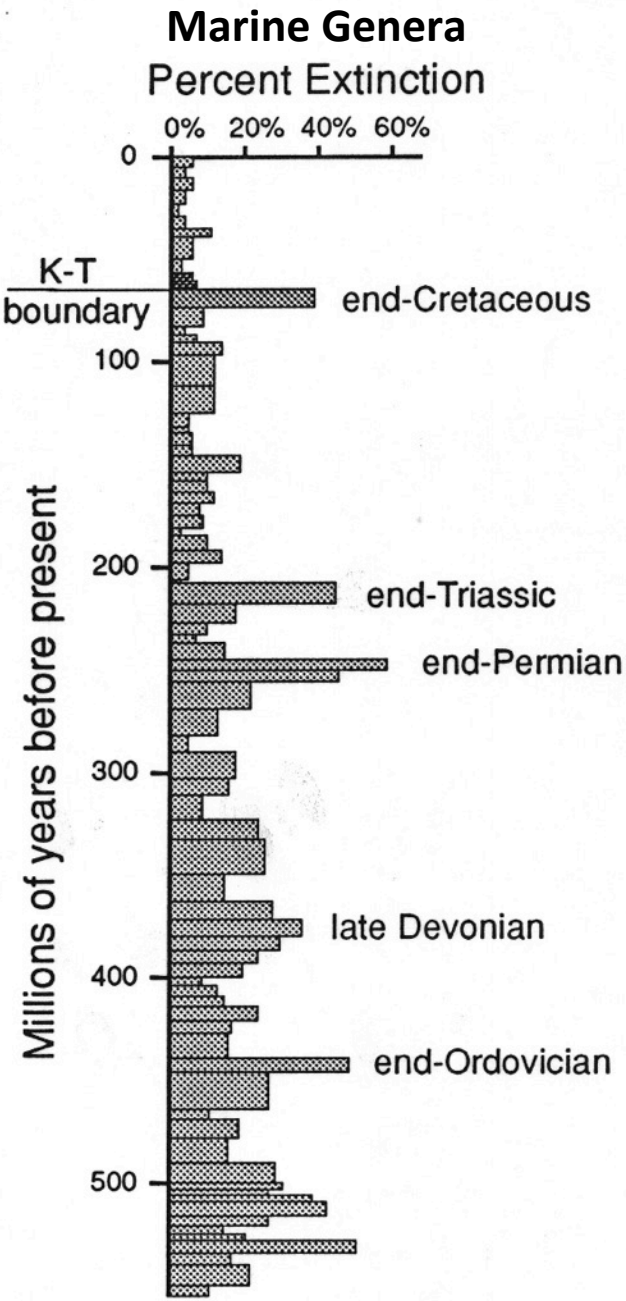
Key

- At least 10% PPR extraction
- At least 20% PPR extraction
- At least 30% PPR extraction

PPR is a value that describes the total amount of food a fish needs to grow within a certain region.

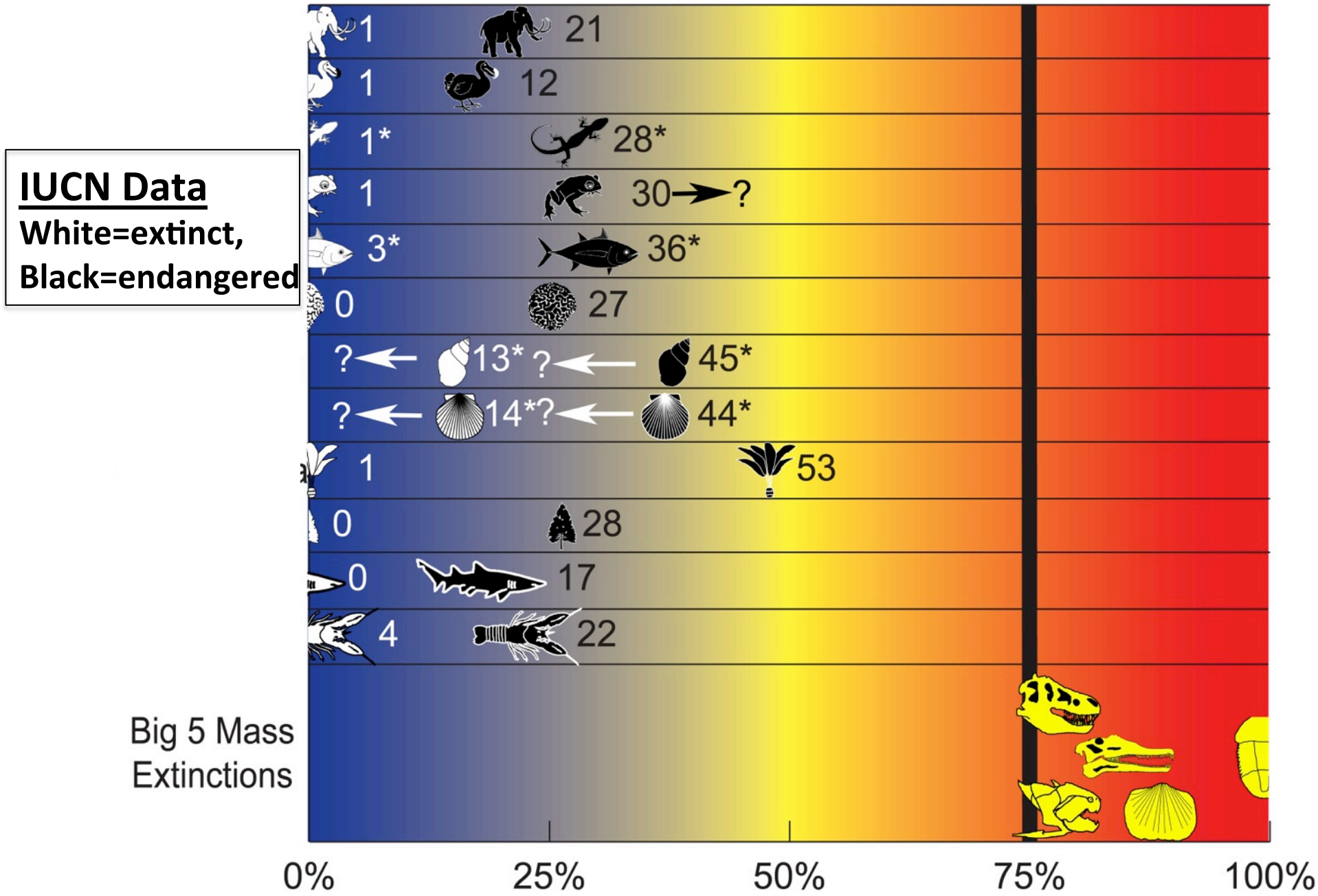
What happens when you remove top predators from reefs

Extinction on Geological Timescales

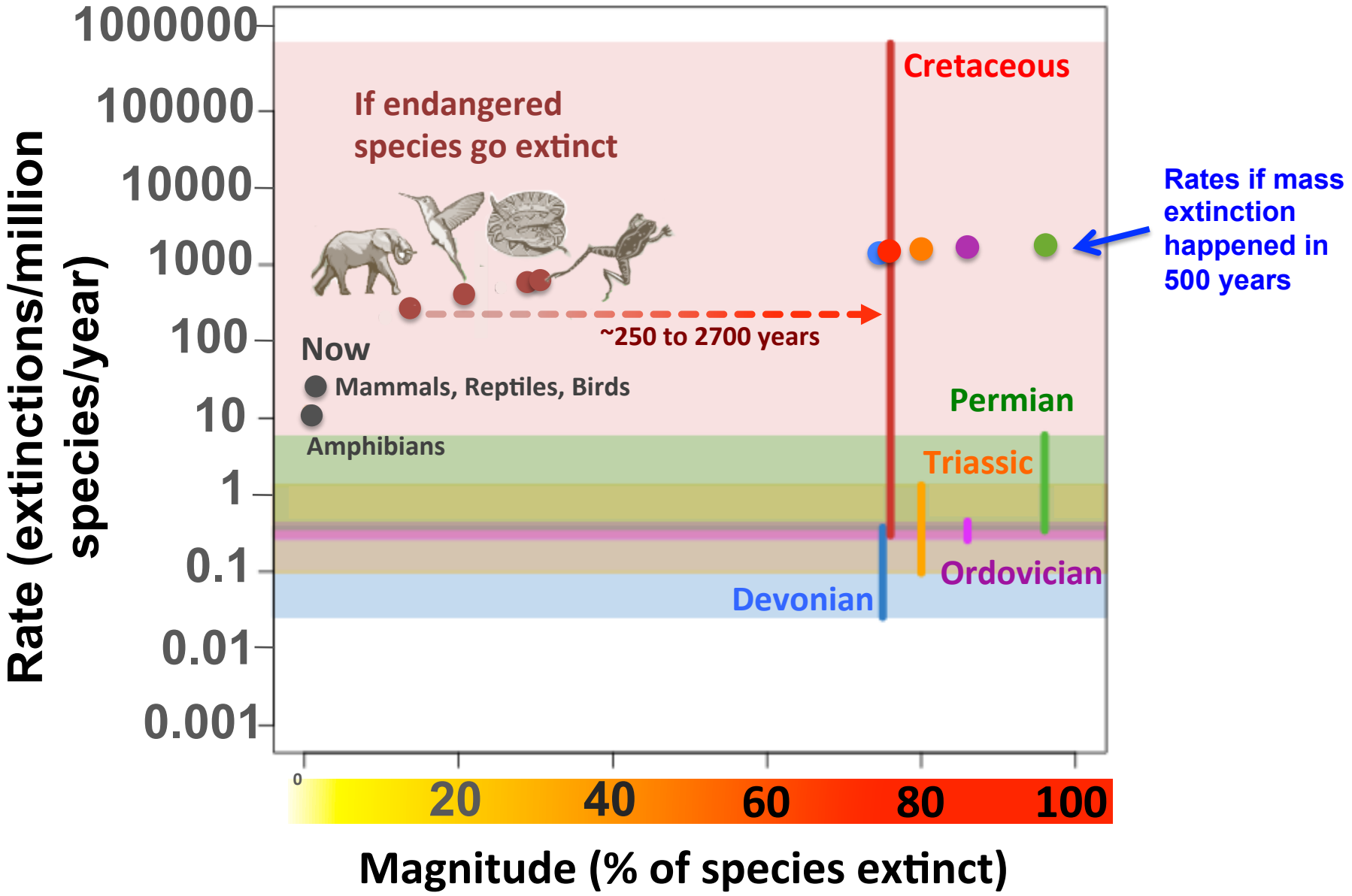


Over the last 540 million years the Earth has experienced 5 major mass extinctions. How do current human-caused extinction compare?

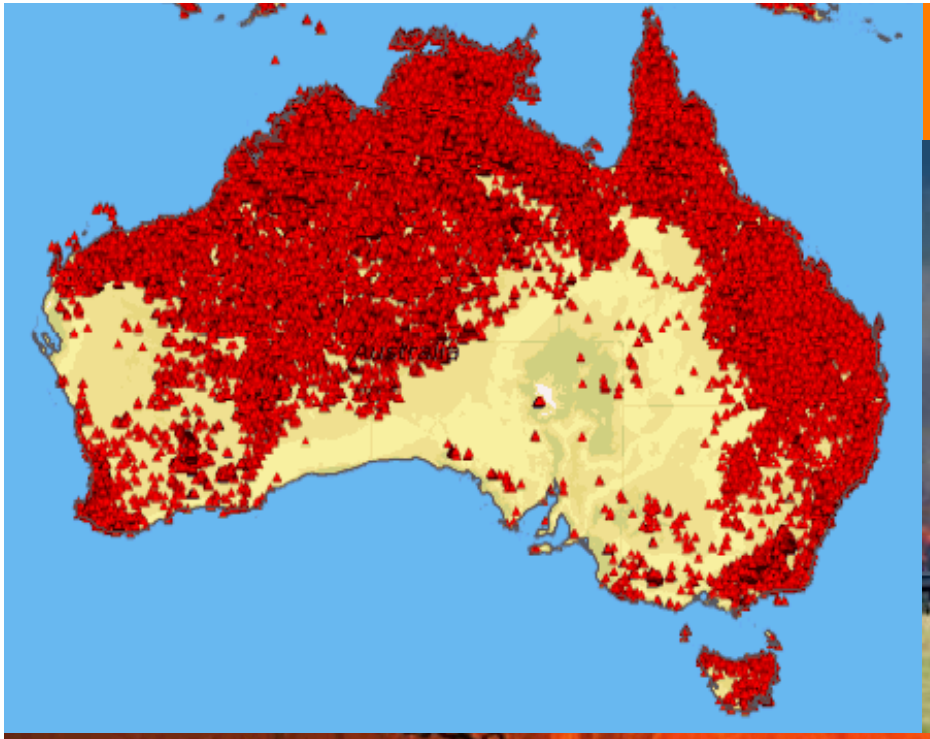
By MAGNITUDE we are NOT in a Mass Extinction



By RATE we are in a Mass Extinction



Bushfires 1997-2008



Bushfire in Bunyip State Forest, Tonimbuk, near Melbourne, Feb 7, 2009 (AAP)