Volcanoes control climate change with subduction-related, explosive, aerosol-forming eruptions causing slow, incremental cooling and rift-related, basaltic, effusive eruptions causing rapid warming in sequences that are sporadic and clearly not cyclic but average a few thousand years

USGS

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United States Geological Survey
retired
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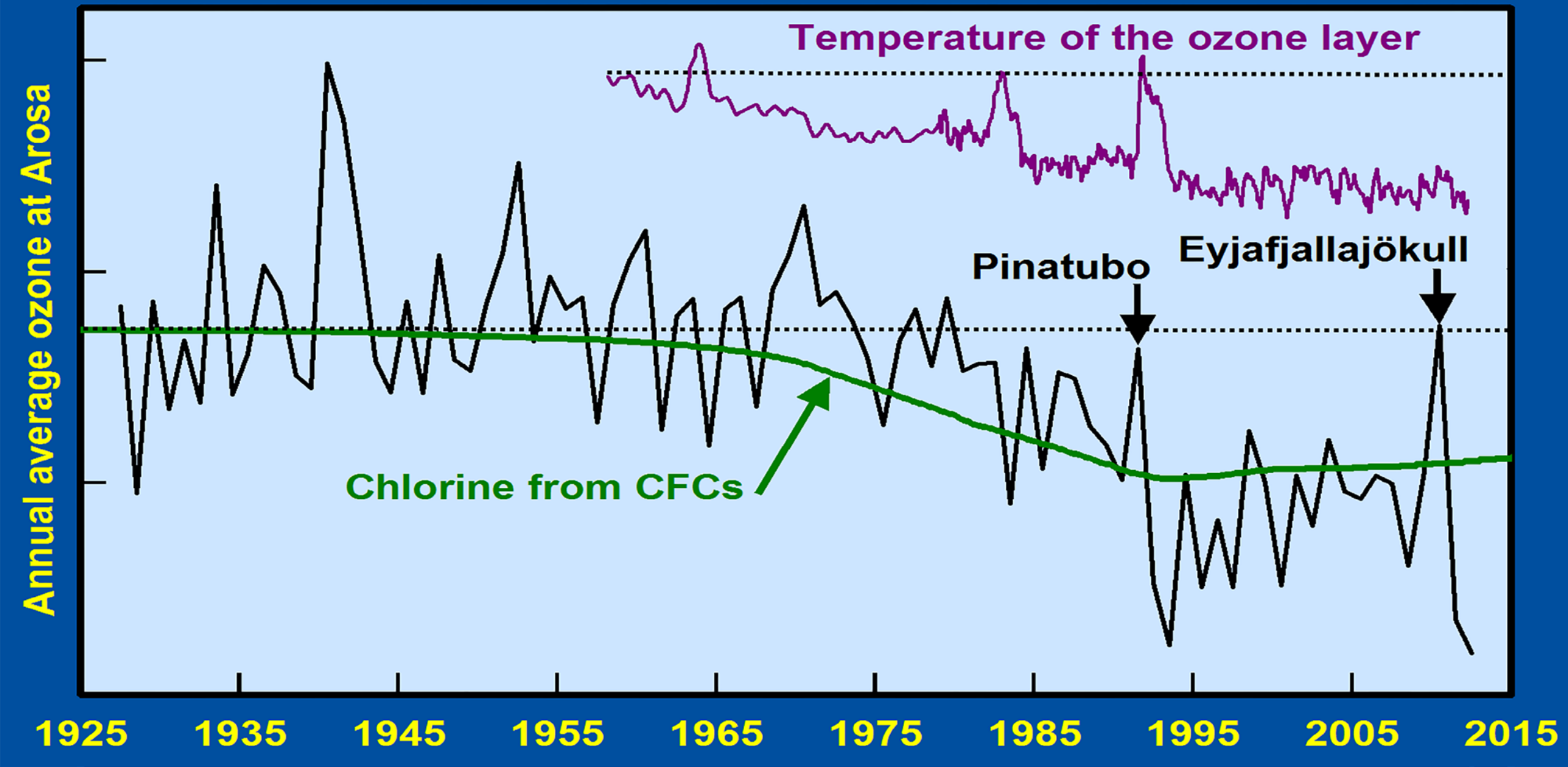
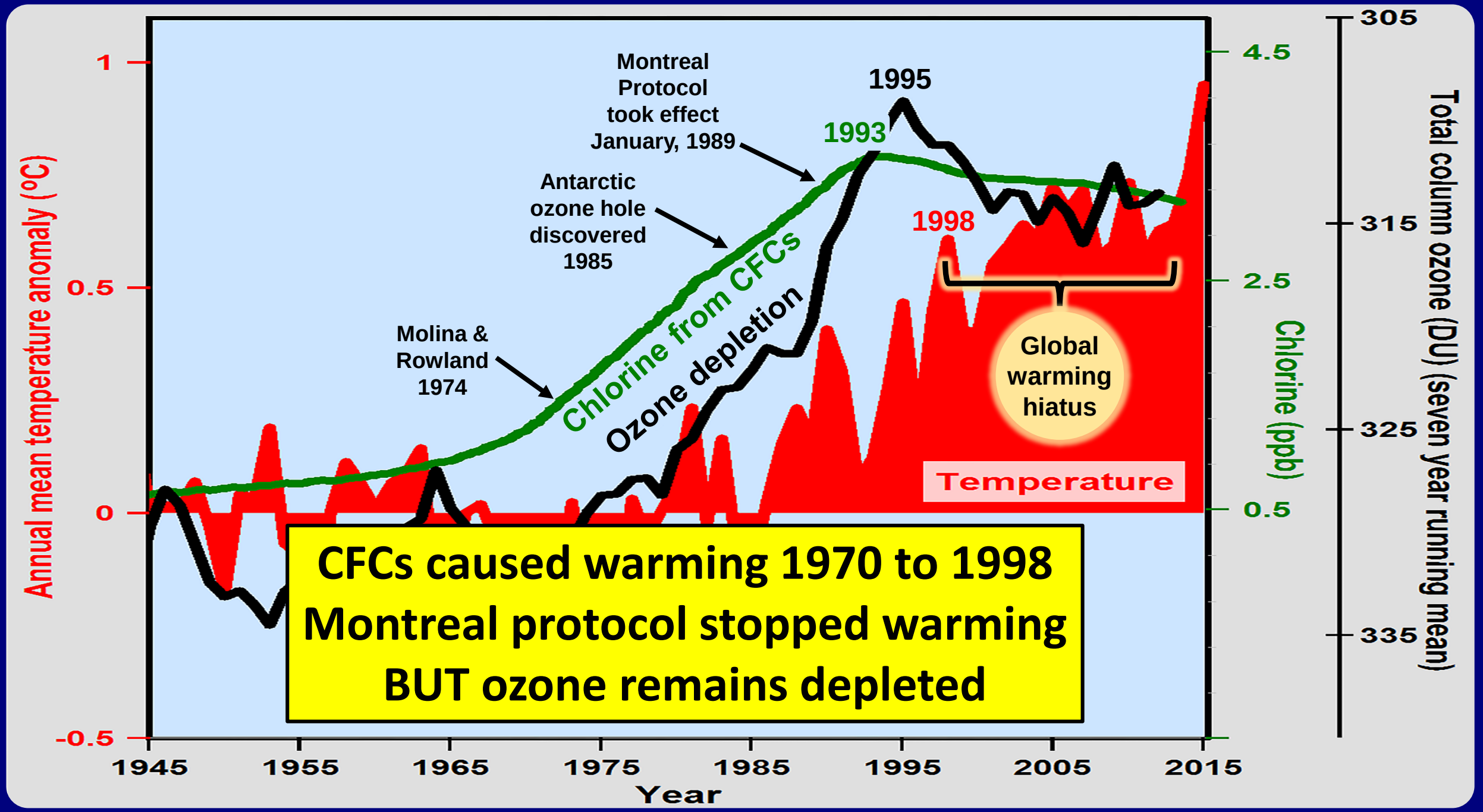
Volcanic eruptions deplete the ozone layer



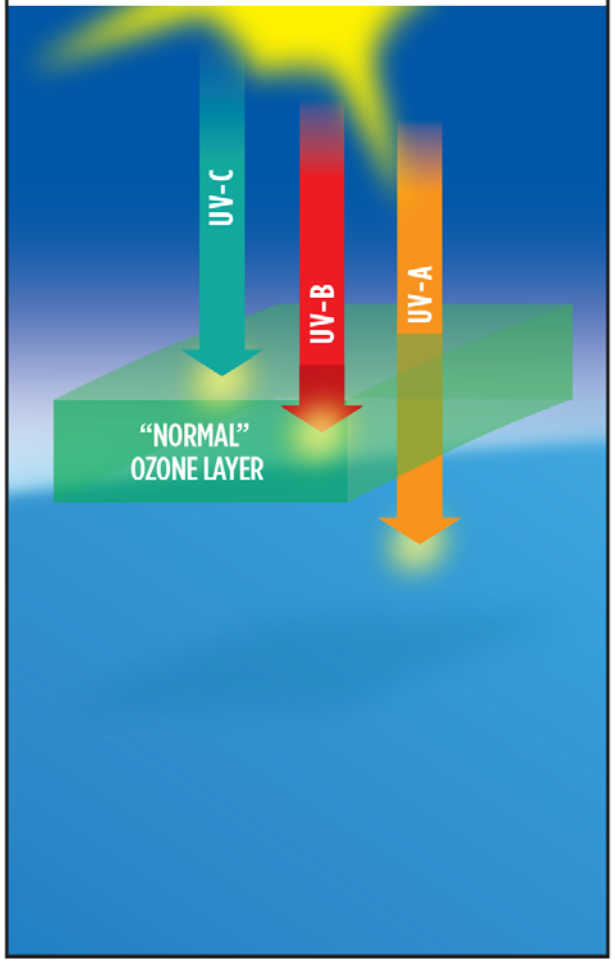

Annual mean temperature anomaly (°C)
1
0.5
0
-0.5
1945
1955
1965
1975
1985
1995
2005
2015
Year
4.5
2.5
0.5
Chlorine (ppb)
305
315
325
335
Total column ozone (DU) (seven year running mean)
Montreal Protocol took effect January, 1989
Antarctic ozone hole discovered 1985
Molina & Rowland 1974
1995
1993
1998
Chlorine from CFCs
Ozone depletion
Global warming hiatus
Temperature
CFCs caused warming 1970 to 1998
Montreal protocol stopped warming
BUT ozone remains depleted

NORMAL CONDITIONS

UV-C keeps atmosphere warm

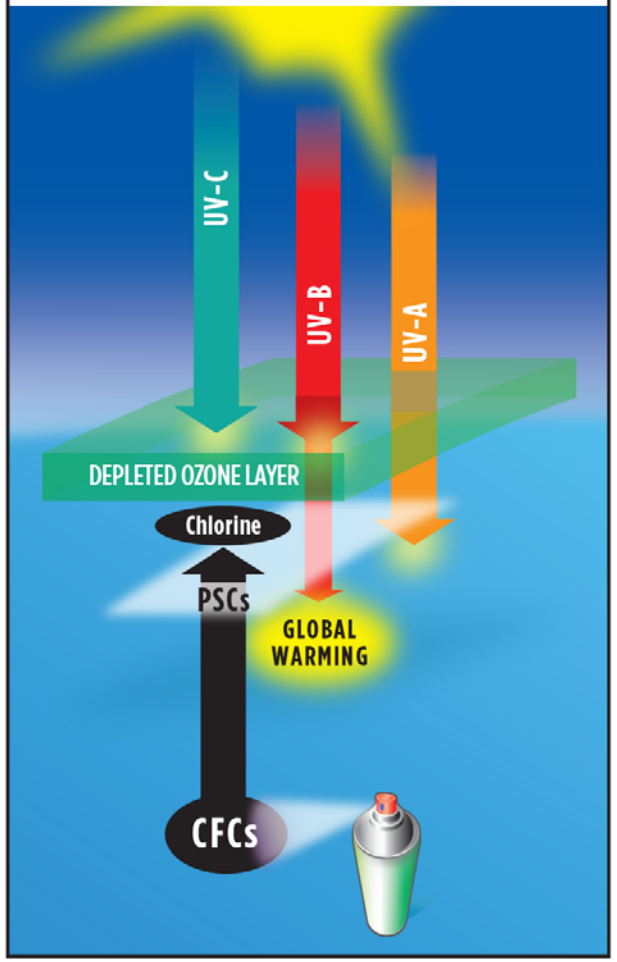
UV-B keeps ozone layer warm

UV-A & sunlight keeps Earth warm



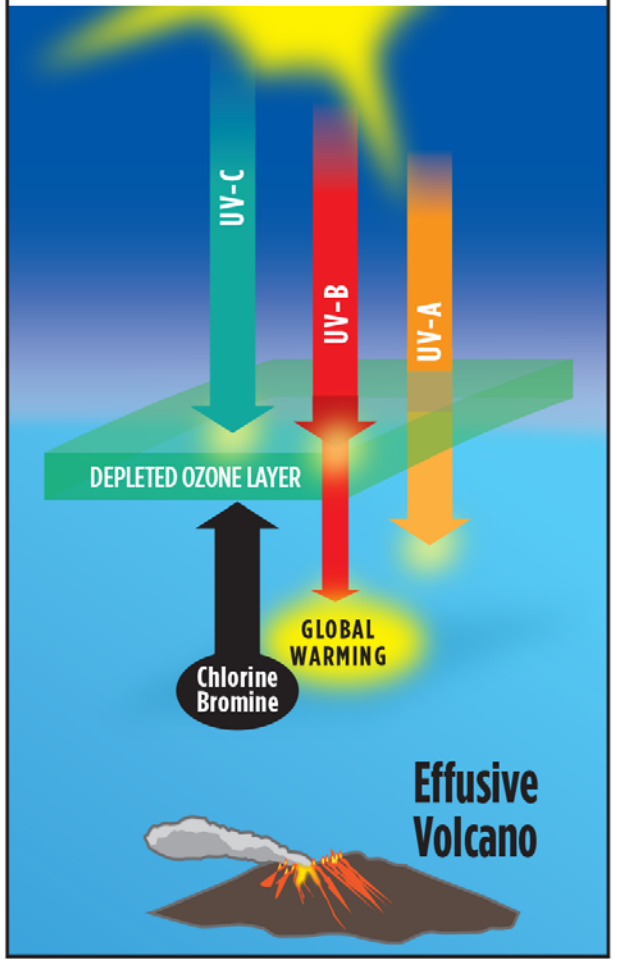
GLOBAL WARMING

CFCs in polar stratospheric clouds (PSCs) release chlorine depleting ozone cooling ozone layer & warming Earth



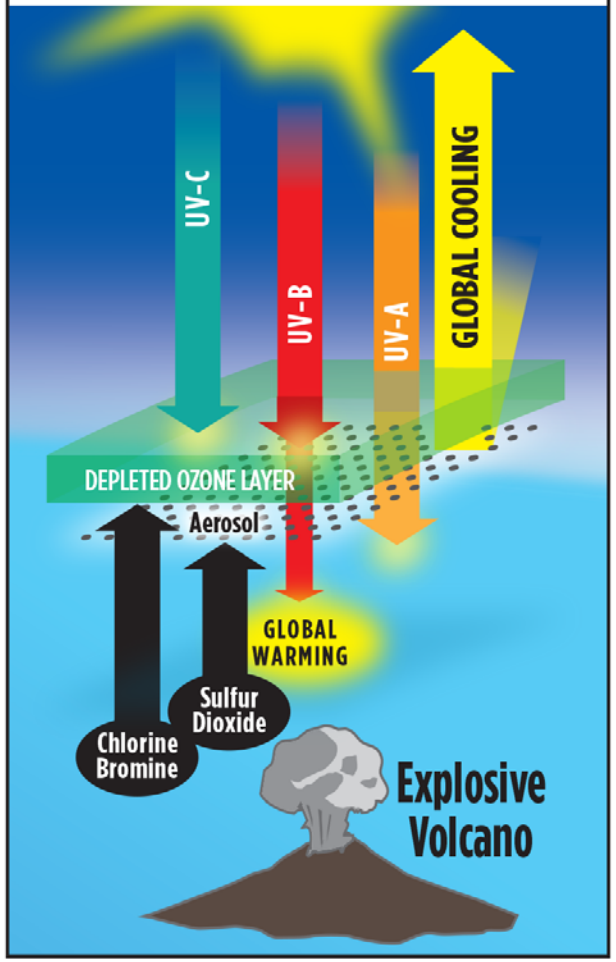
GLOBAL WARMING

Volcanoes release **Chlorine & Bromine** depleting ozone cooling ozone layer & warming Earth



GLOBAL COOLING

Explosive volcanoes also eject **Sulfur Dioxide** into stratosphere forming aerosols that reflect & disperse sunlight causing net cooling of Earth



Global Warming

Effusive

rift-related

Minimal aerosols

Duration >months

Global Cooling

Explosive

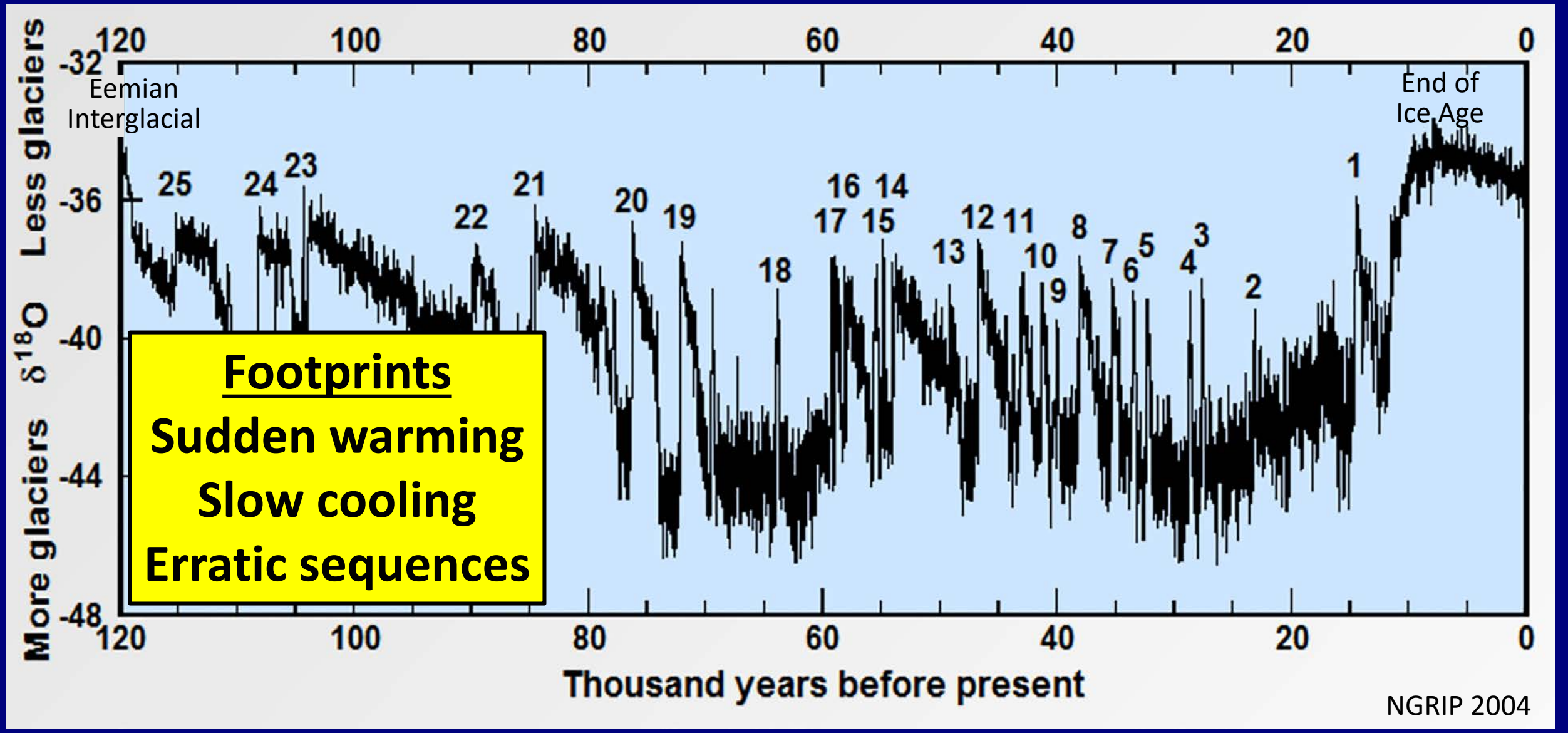
subduction-related

Extensive aerosols

Frequency per century

Erratic sequences of rapid warming followed by slower cooling

Dansgaard-Oeschger events observed in Greenland ice

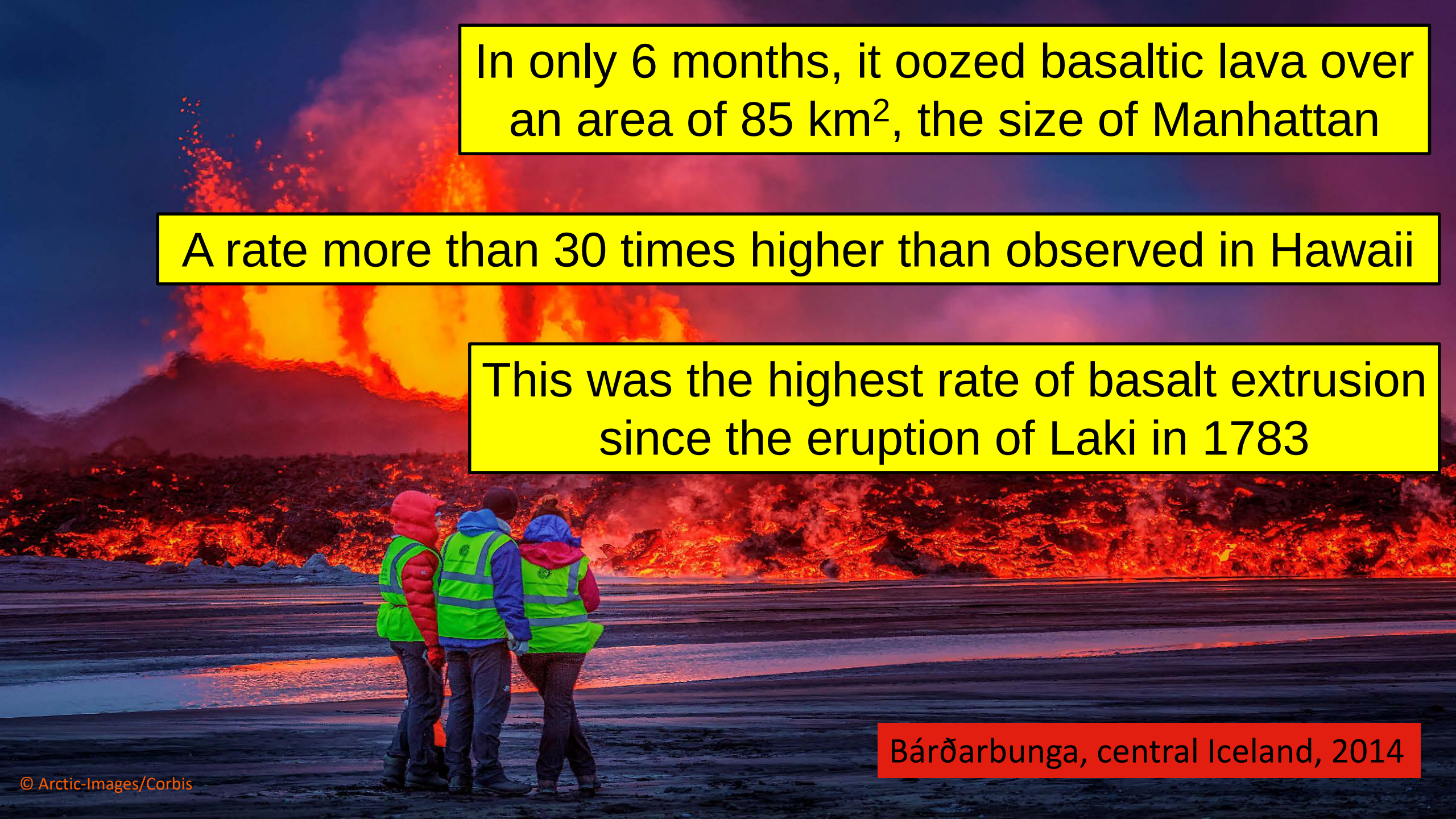


NGRIP 2004

Basaltic volcanism warmed the world out of the last ice age

WARM
COOL
$\delta^{18}O$ per century
-34
-38
-42
1200
600
0
Volcanic sulfate per century
25
20
15
10
5
0
Thousand years before present

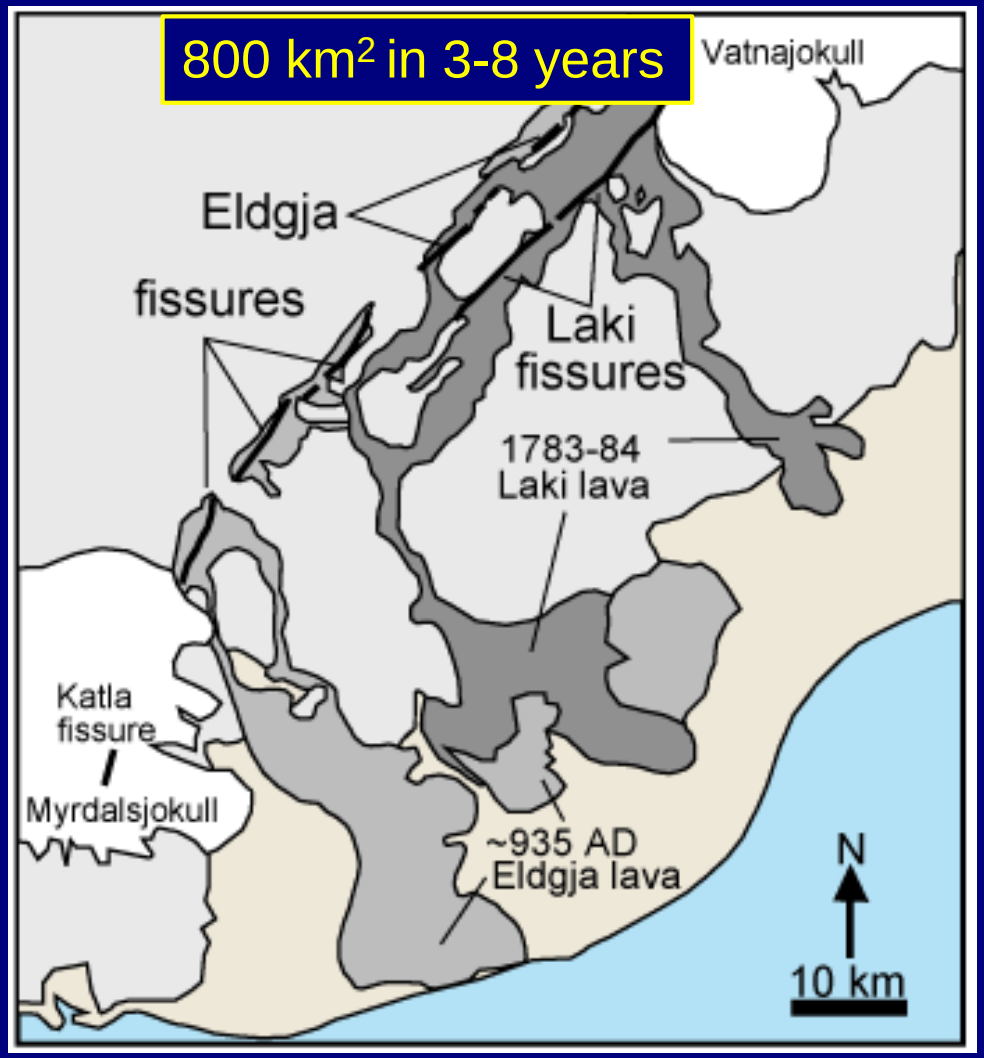
Zielinski et al., 1996


In only 6 months, it oozed basaltic lava over an area of 85 km^2, the size of Manhattan
A rate more than 30 times higher than observed in Hawaii
This was the highest rate of basalt extrusion since the eruption of Laki in 1783
Bárðarbunga, central Iceland, 2014
© Arctic-Images/Corbis

Laki 1783 (Iceland)

Temperatures in Europe raised 3.3°C, tens of thousands killed primarily by the effects of SO_2, sulfuric acid, and resulting famine

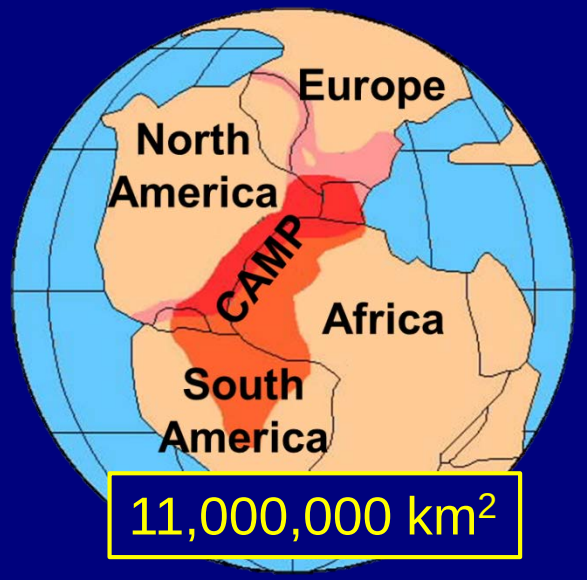
Eldgjá 935 (Iceland)

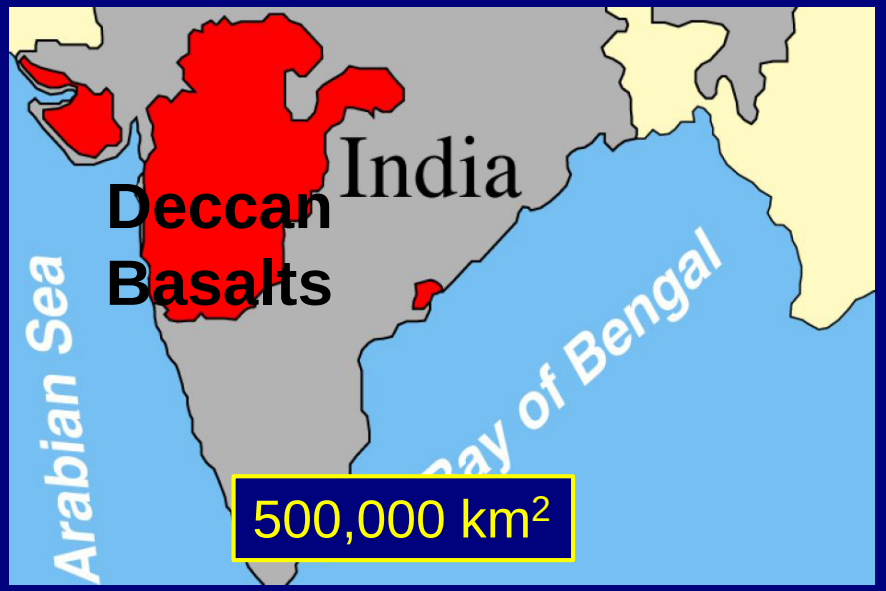


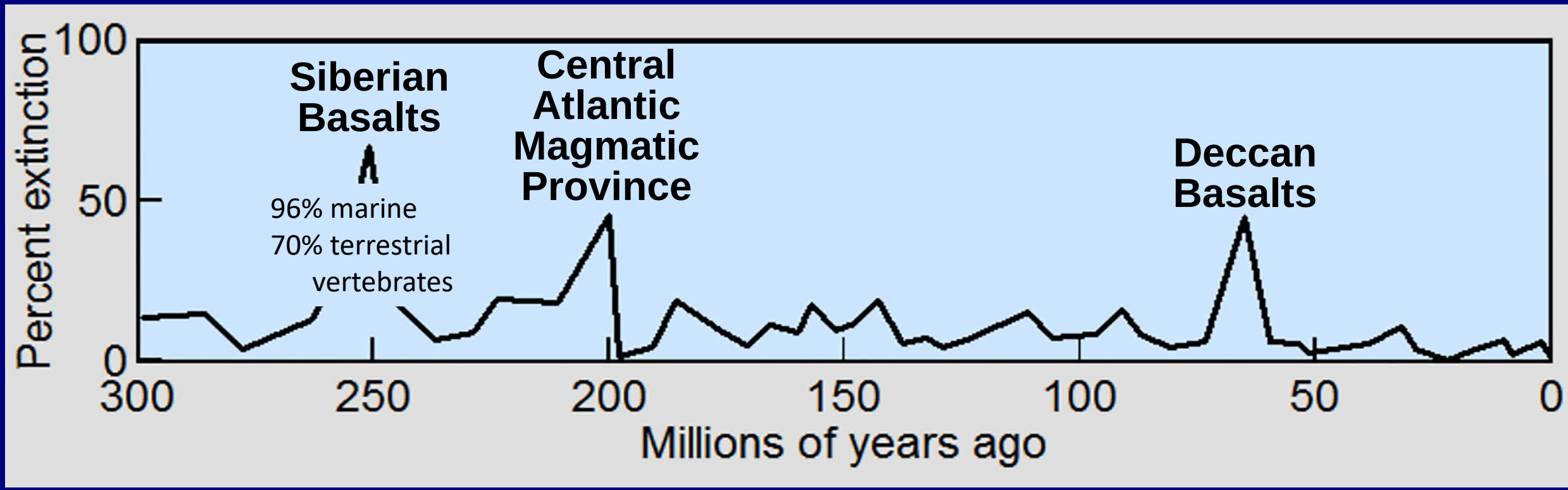
volcano.oregonstate.edu

Led to the onset of the Medieval Warm Period


Arctic Ocean
Finland
Санкт-Петербург
Moscow
Волгоград
Caspian Sea
Sea of Okhotsk
Якутск
Lake Baikal
Siberian Basalts
7,000,000 km²


Europe
North America
CAMP
Africa
South America
11,000,000 km²


India
Deccan Basalts
Arabian Sea
Bay of Bengal
500,000 km²


Percent extinction
100
50
0
Siberian Basalts
96% marine
70% terrestrial vertebrates
Central Atlantic Magmatic Province
Deccan Basalts
300
250
200
150
100
50
0
Millions of years ago

Rift-related, effusive, basaltic, volcanic eruptions warm Earth suddenly

Extrude basaltic lava for months to hundreds of thousands of years

The greater the duration, the greater the warming and extinctions

Range in size from Hawaii to Large Igneous Provinces (LIPs)

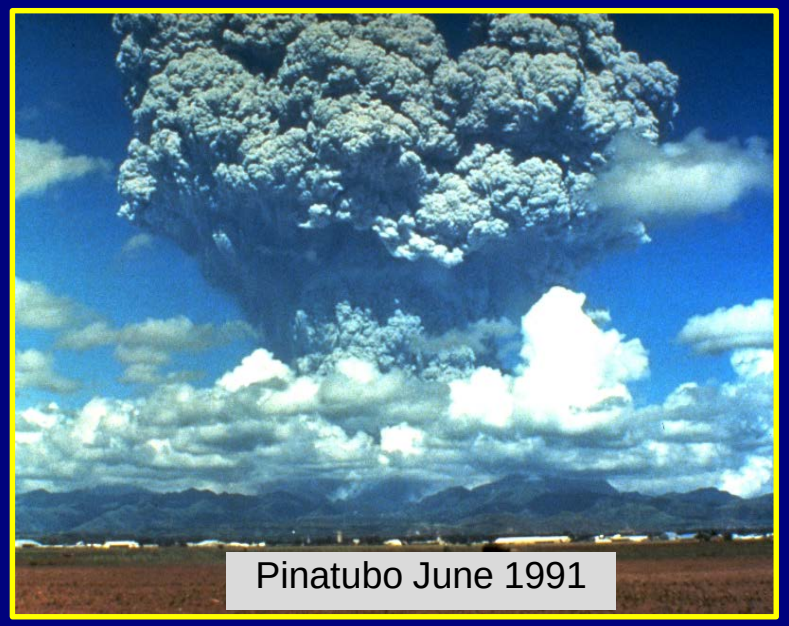
Cause major warming of air and, over millennia, of oceans

Cause major ocean acidity (sulfuric acid from SO_2 and H_2S)

Cause major mass extinctions especially when lasting for long periods

Bárðarbunga largest since 1783—explains why 2016 hottest year

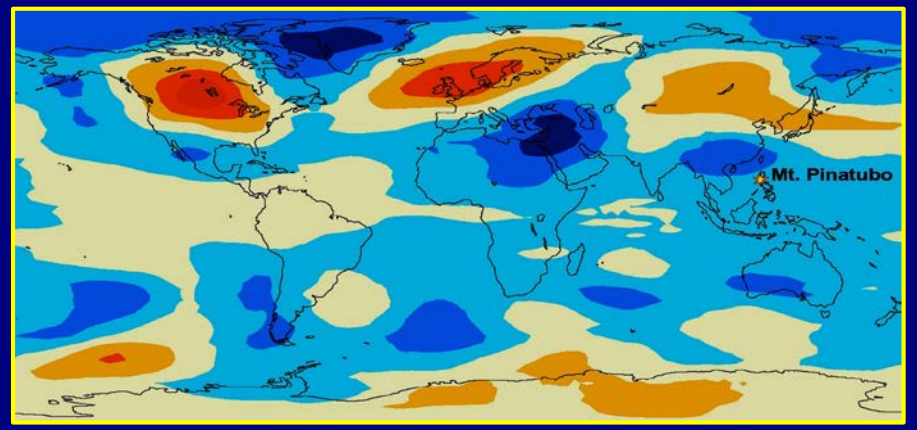
Explosive, aerosol forming, volcanic eruptions



USGS

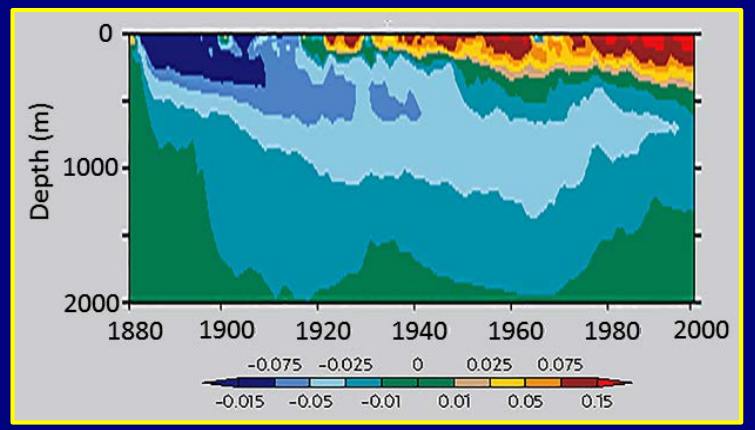
- Typical above subduction zones
- Erupt for days, may recur within 500 to 1000 years
- Deplete ozone causing short-term warming
- Form aerosols in the lower stratosphere that last for years, scattering and reflecting solar energy, causing net global cooling 0.5°C, 3 years

Pinatubo warmed 3.5°C world
Dec 1991 to Feb 1992



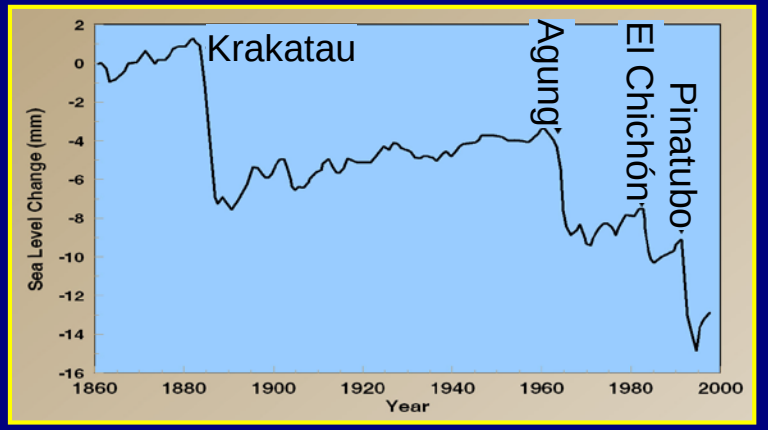
Robock, 2002

Krakatau (1883) cooled ocean
for more than 100 years



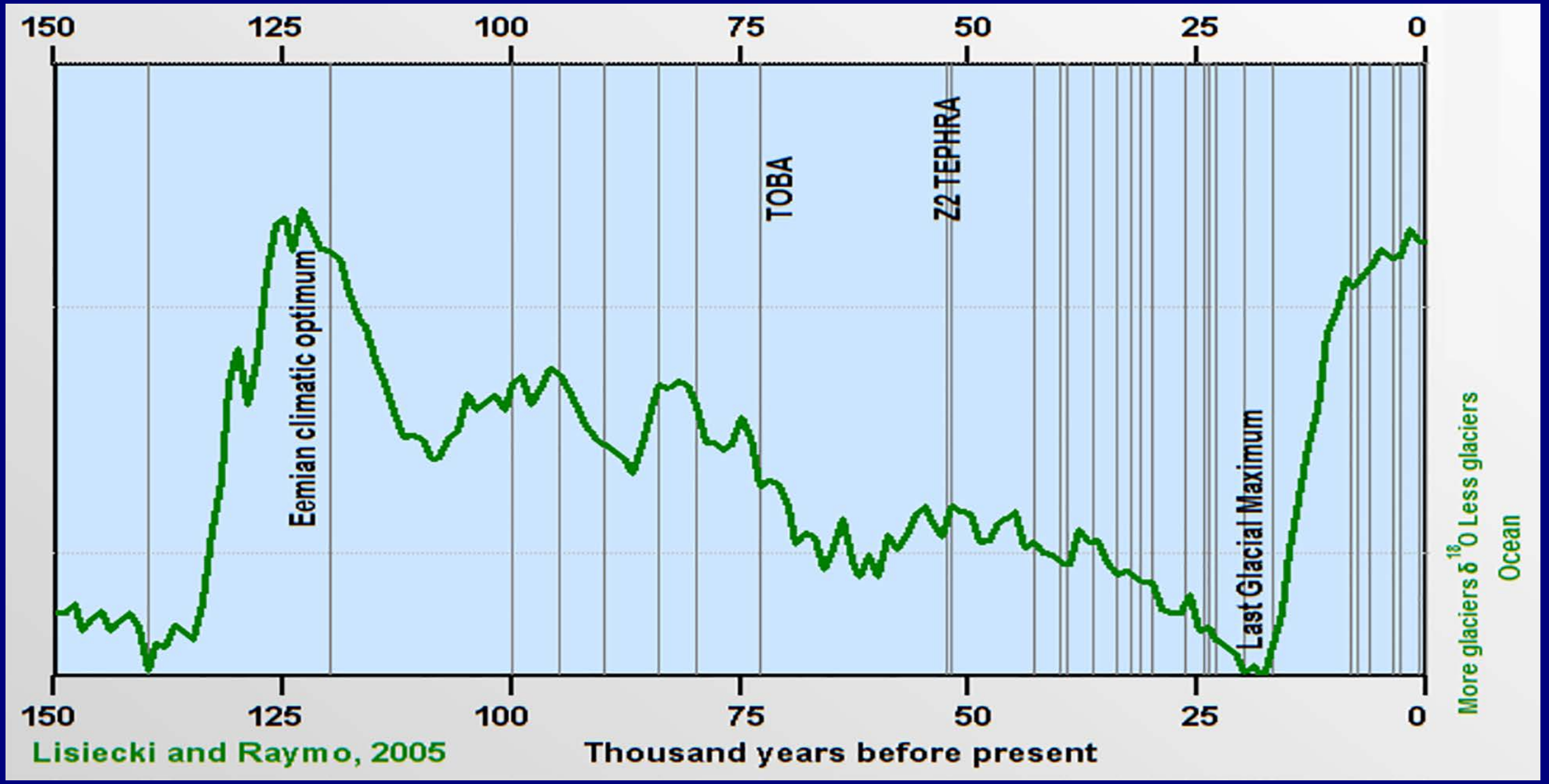
Gleckler et al., 2006

Multiple eruptions increment world
into an ice age

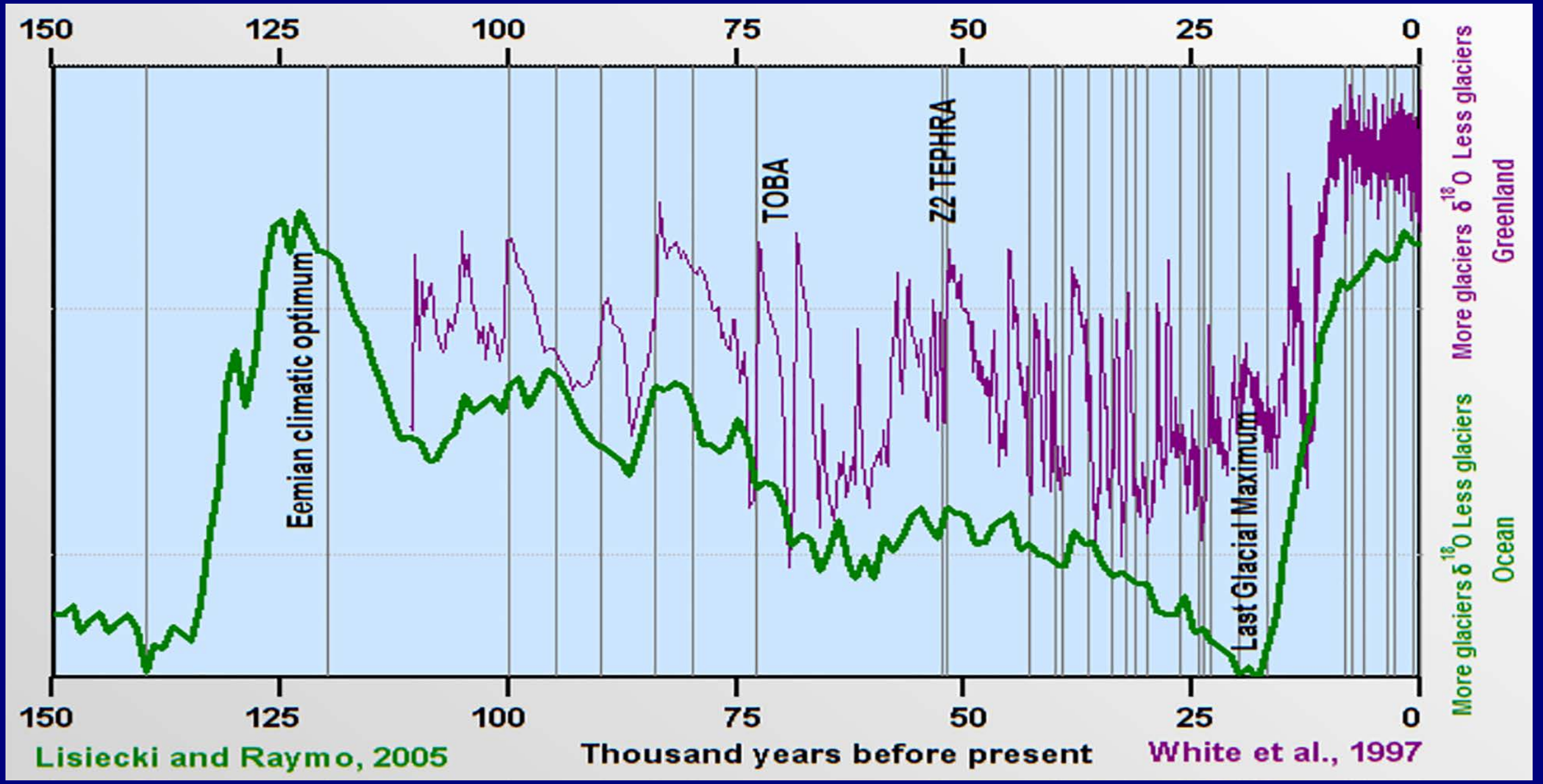


Gregory et al., 2006

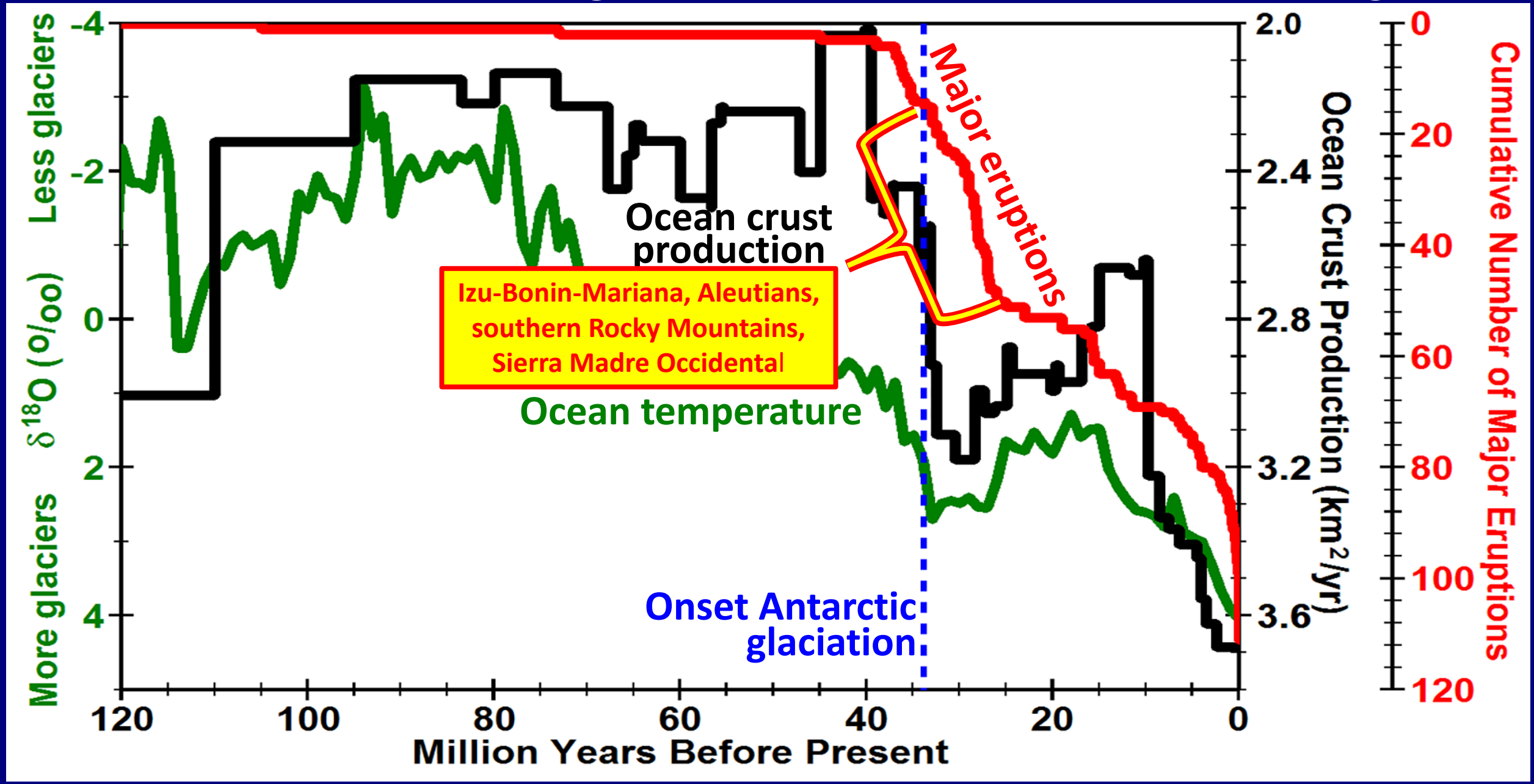
Stack of 57 globally distributed benthic $\delta^{18}O$ records



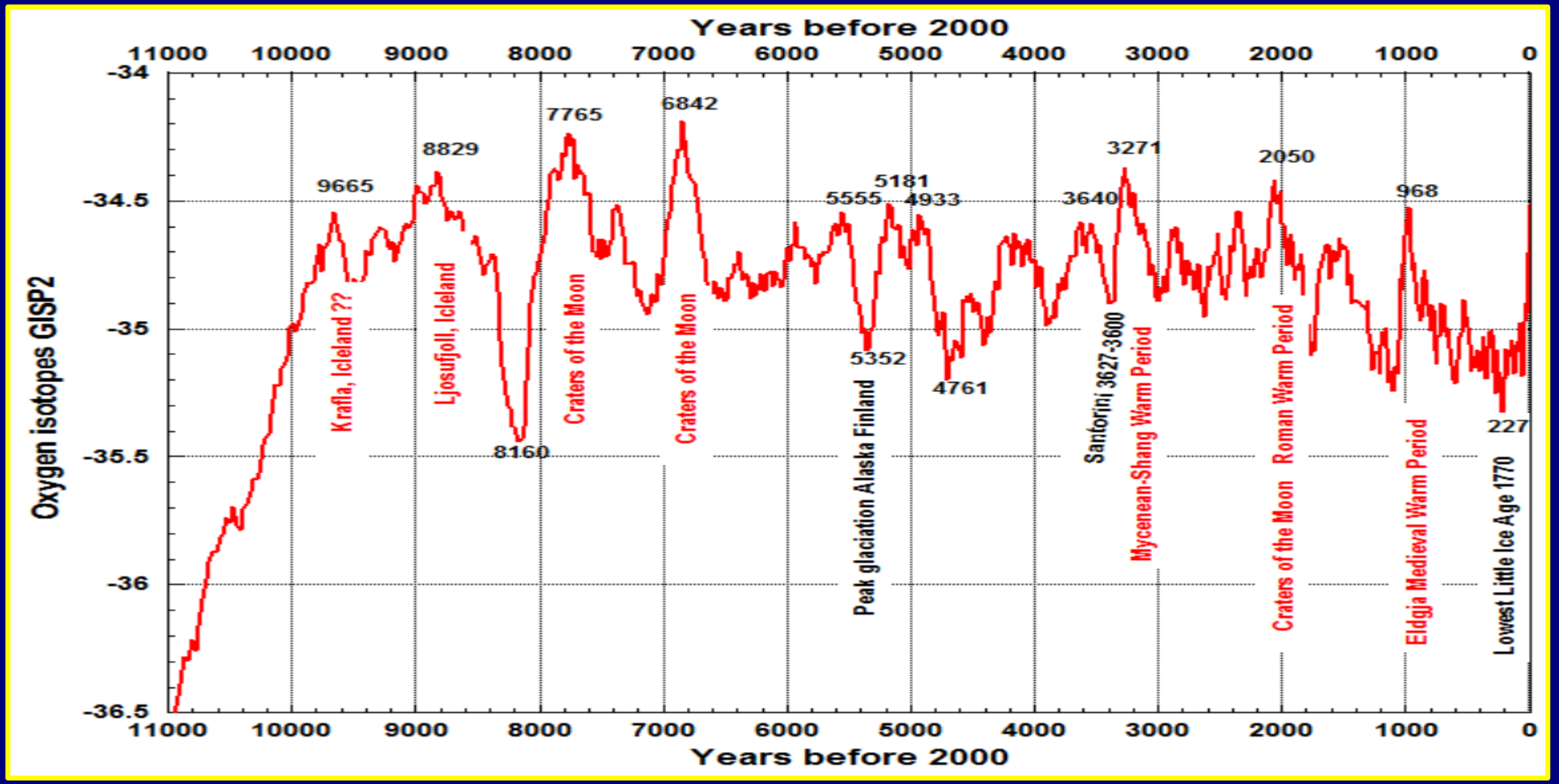
Greenland ice core $\delta^{18}O$ records

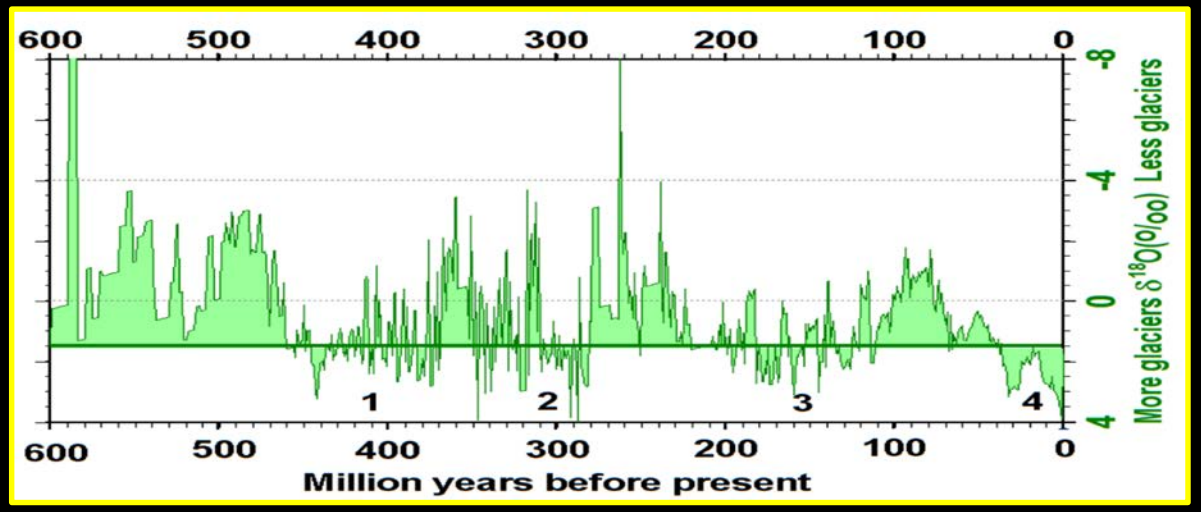


Onset of Antarctic glaciation and the recent ice age

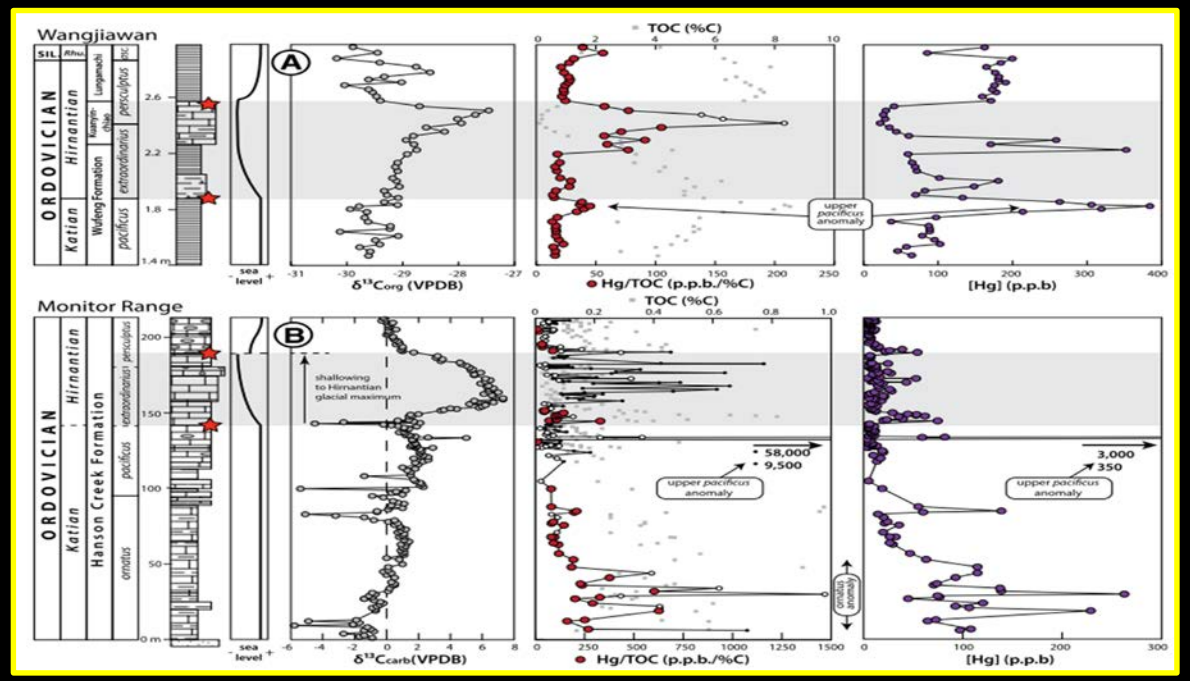


Holocene temperatures and volcanism



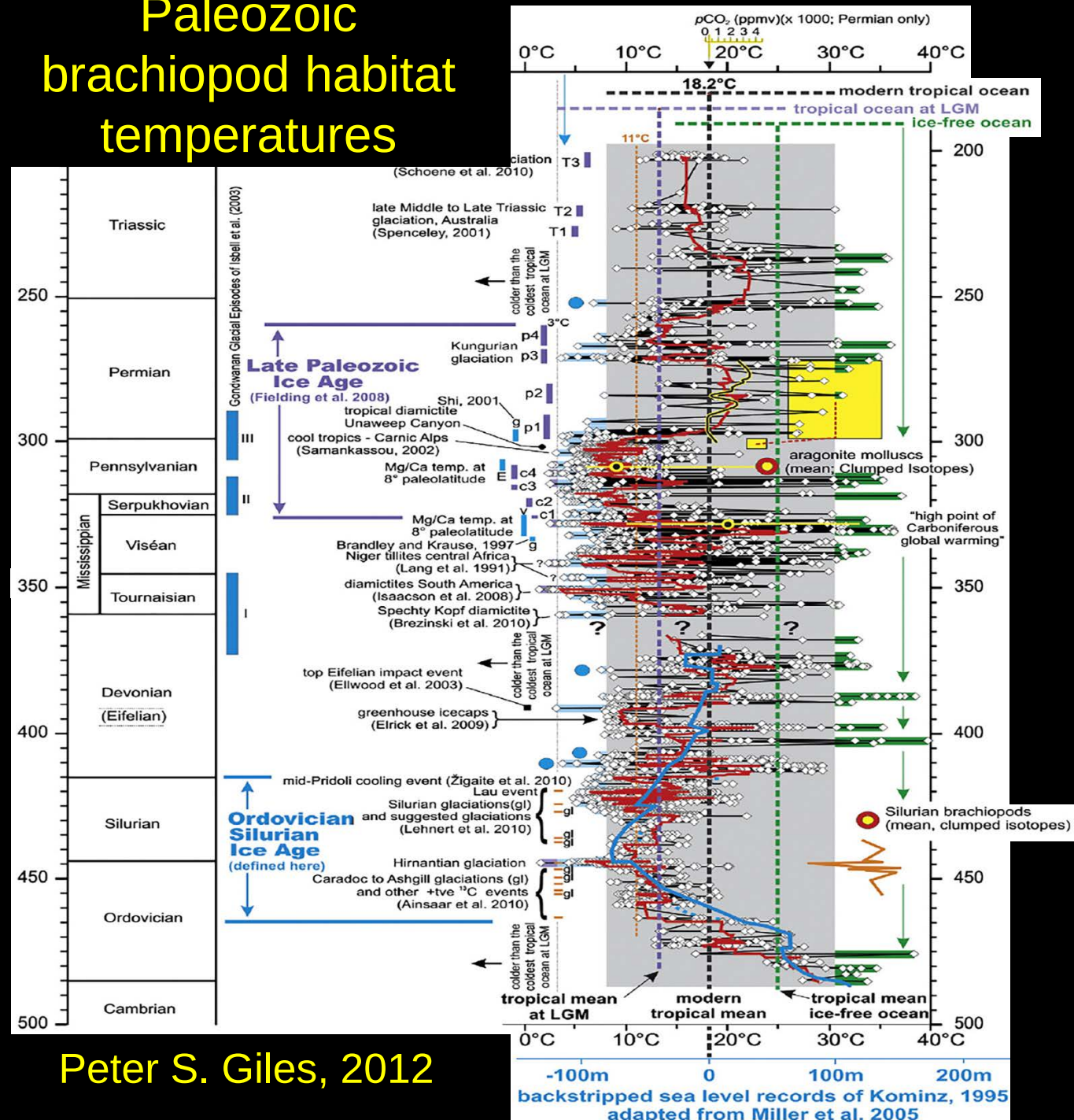


Ordovician mercury (Hg) enrichment by LIP basaltic volcanism



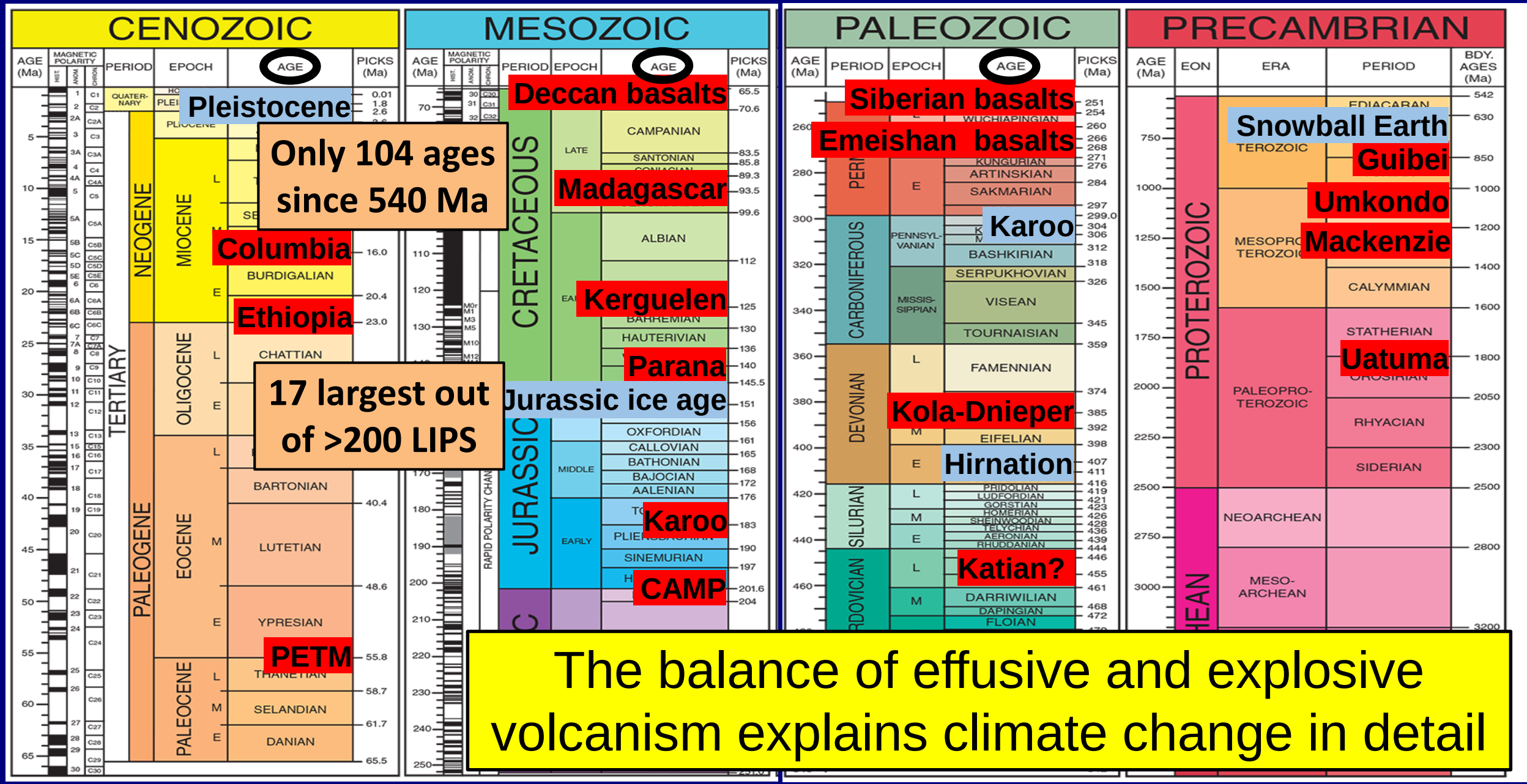
David S. Jones et al., 2017

Paleozoic brachiopod habitat temperatures



Peter S. Giles, 2012

Large Igneous Provinces punctuate the geologic time scale

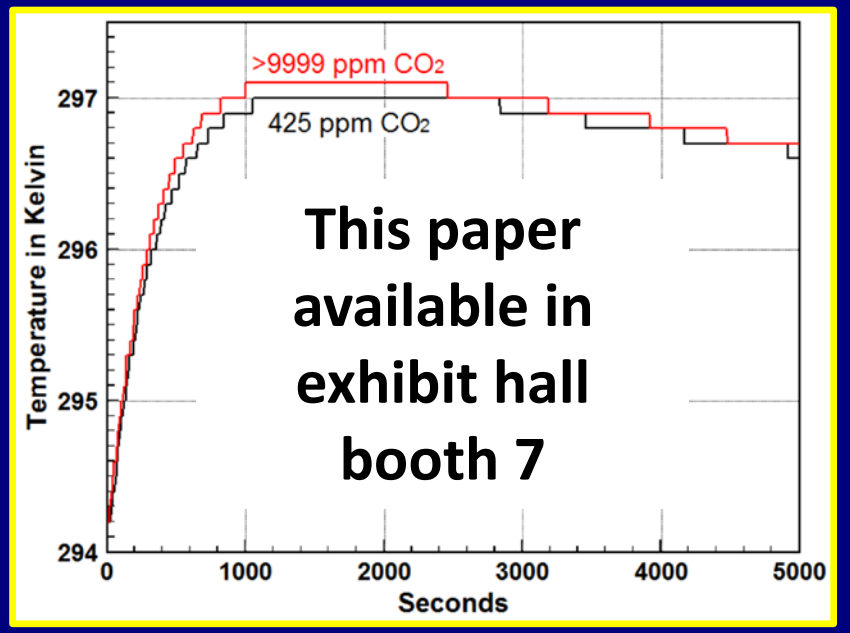


Geological Society of America Time Scale

(LIPs from Ernst 2014)

So what is the role of CO_2 in global warming?

CO_2 has never been shown by experiment to actually cause warming



CO_2 cannot explain most periods of warming throughout the geologic record

CO_2 does not absorb enough heat to warm Earth

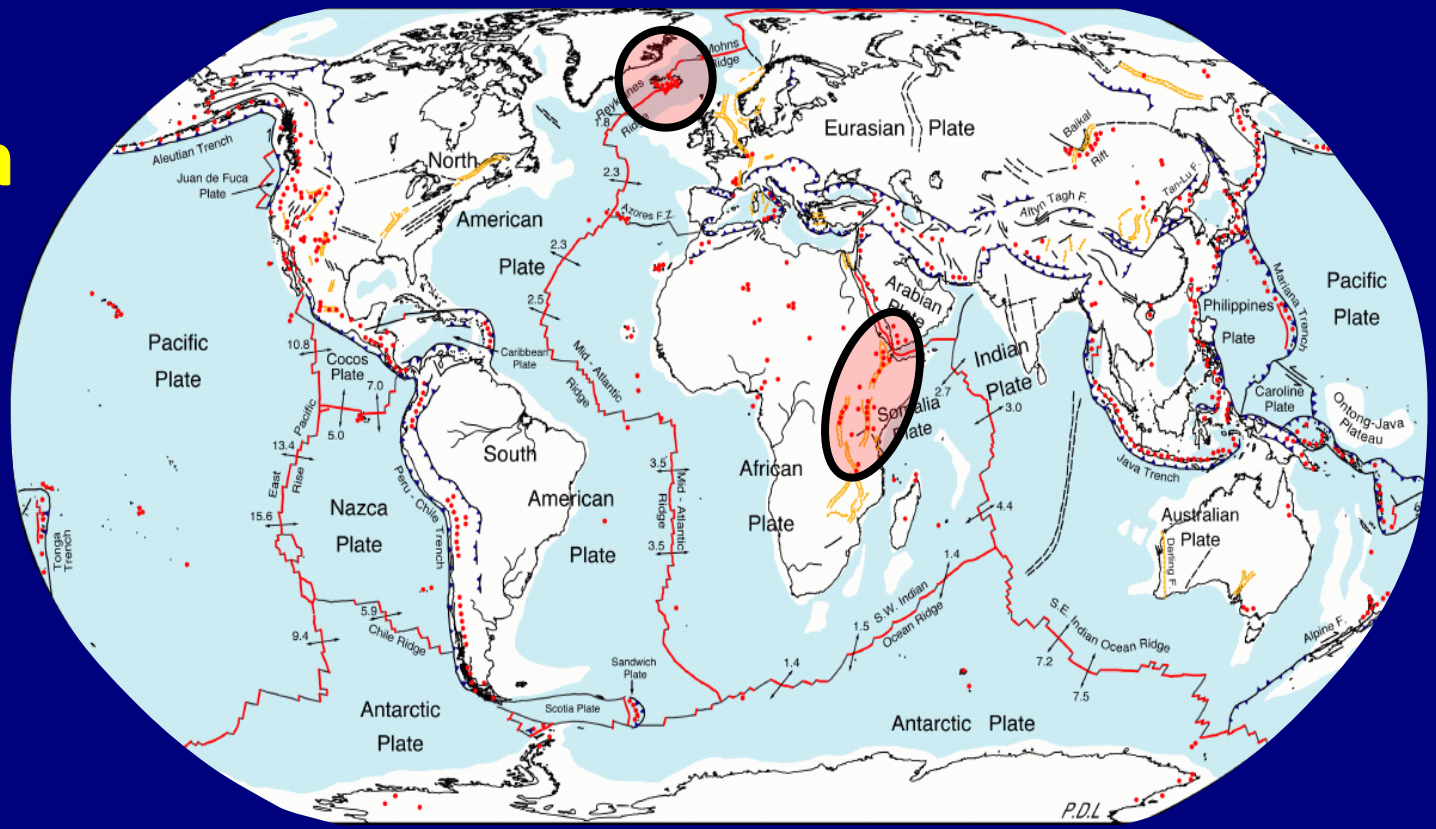
Fundamental problem in the way computer models calculate heat flux

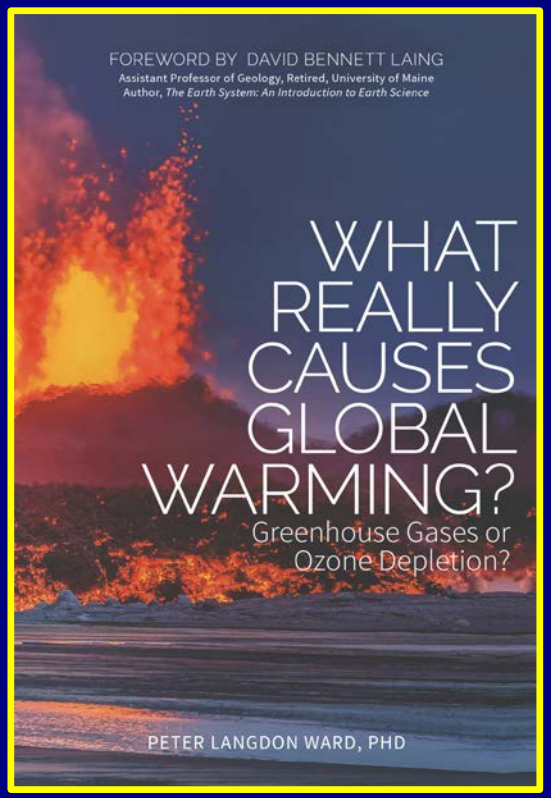
Atmospheric concentration of CO_2 may simply be a proxy for ocean temperature

Volcanoes Rule

WhyClimateChanges.com

We are not in an ice age now thanks to Iceland and the East African Rift





peward@Wyoming.com