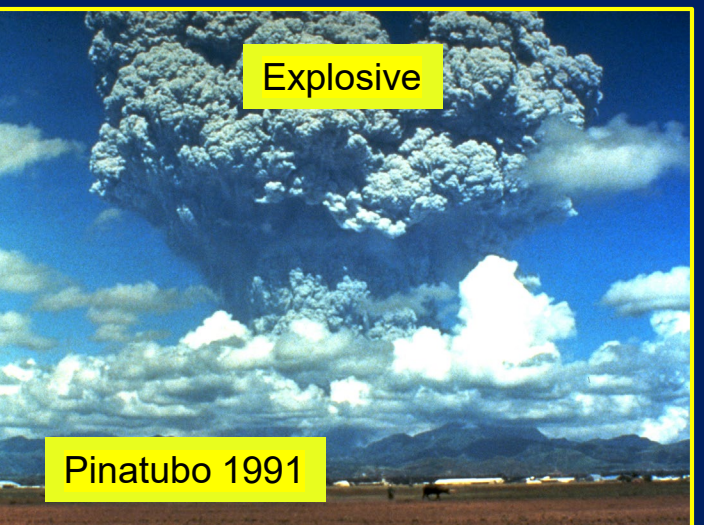
15A.1: Throughout the Holocene, extensive basaltic lava flows that formed primarily in sub-aerial rift zones and covered hundreds of square kilometers of land were contemporaneous with short periods of major, rapid, global warming

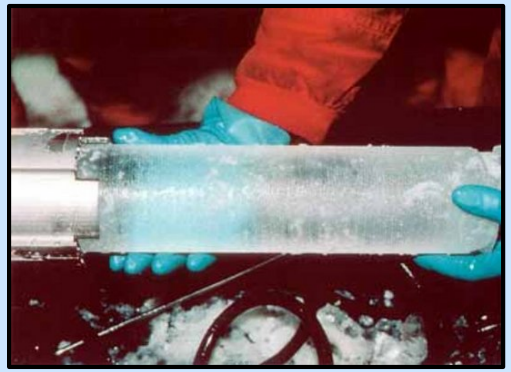
Session 15A: Climate Change: Past, Present, and Future



Peter L. Ward
US Geological Survey retired

AMS January 10, 2019

Basaltic volcanism warmed the world out of the last ice age



-34
-38
-42
WARM
Temperature proxy
COOL
1200
600
0
Volcanic sulfate per century (ppb)
Pre-boreal warming
Bølling warming
Last glacial maximum
12,000 to 9500
25
20
15
10
5
0
Thousand years before present
White Et al. 1997
Zielinski et al. 1996

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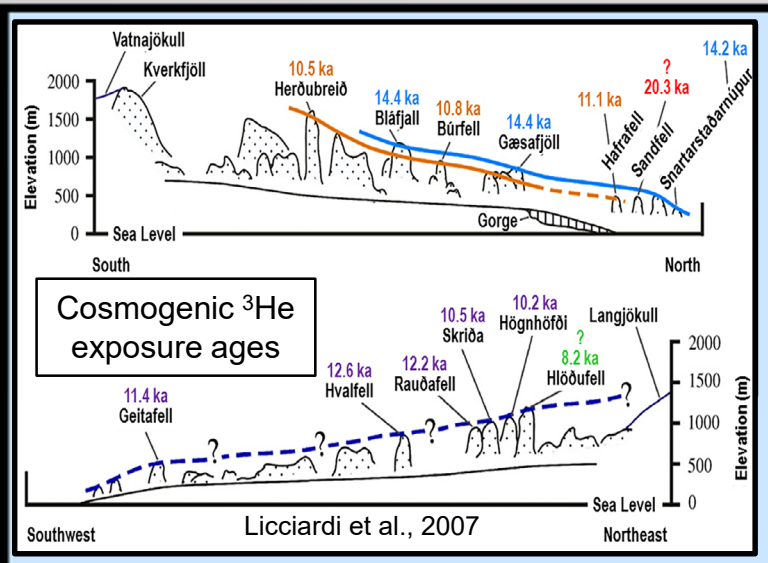

12 of 13 best dated tuyas were active during the Bølling or Pre-boreal warmings

Bølling warming

Pre-boreal warming

12,000 to 9500

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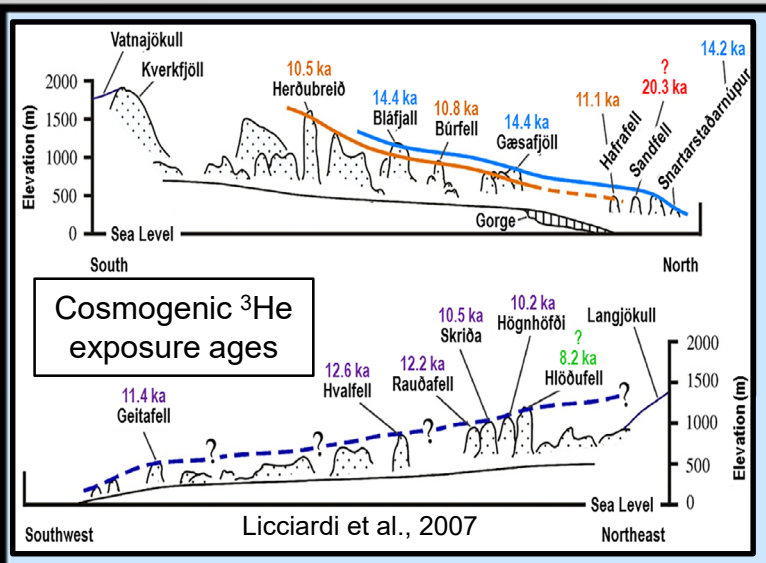

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WARM
Temperature proxy
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1200
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Volcanic sulfate per century (ppb)

Bølling warming

Pre-boreal warming

It took 2500 years of major volcanism to warm the ocean out of the last ice age

The heat content of the ocean is very, very large

12 of 13 best dated tuyas were active during the Bølling or Pre-boreal warmings

12,000 to 9500

25 20 15 10 5 0

Thousand years before present

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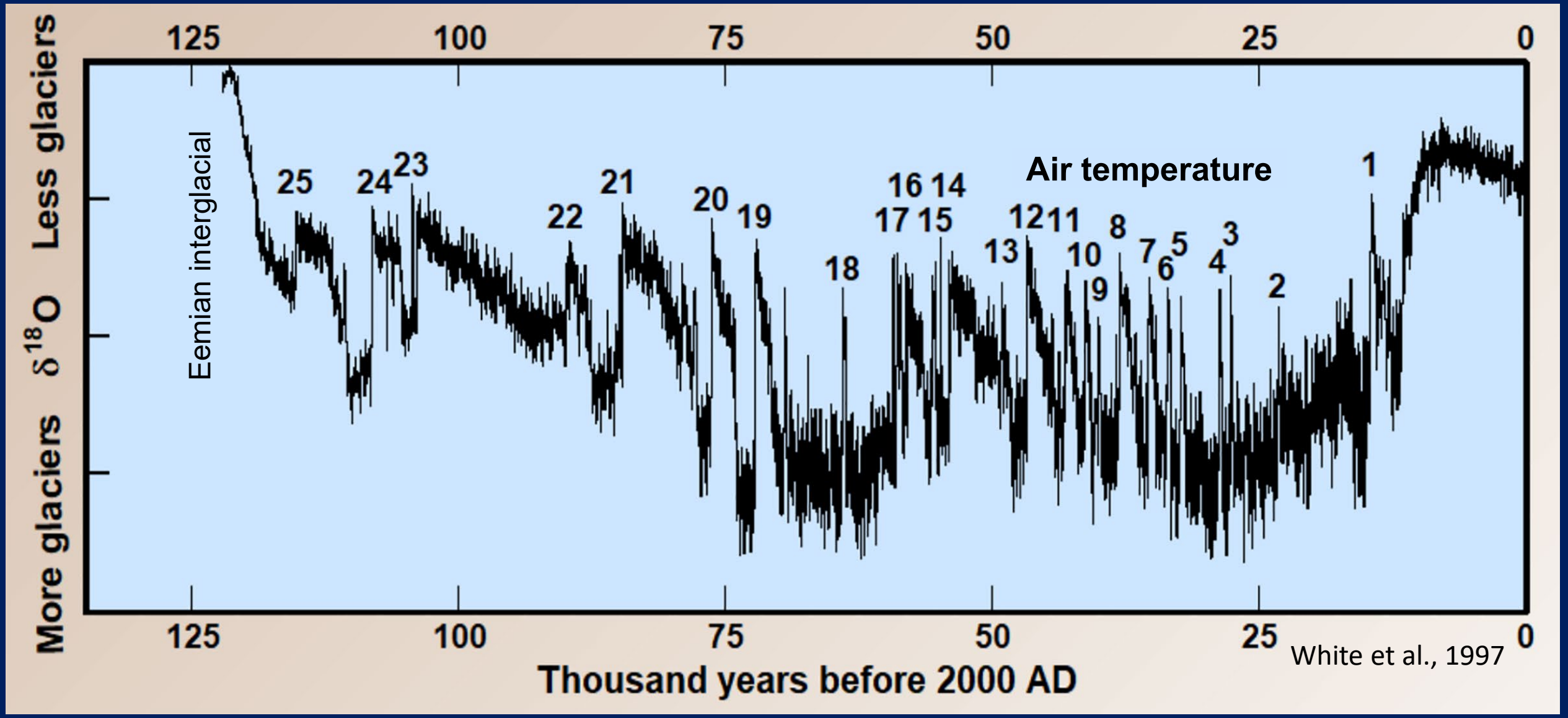

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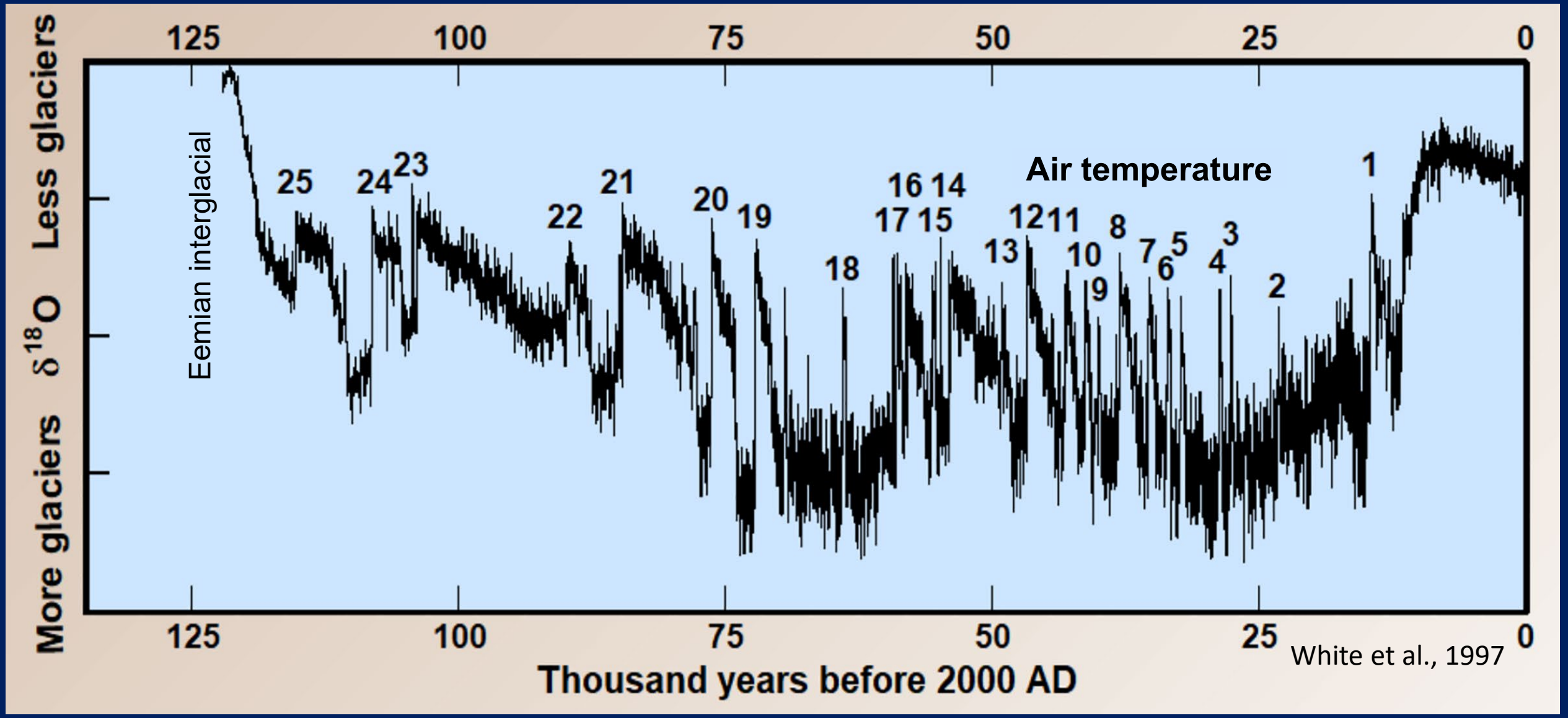
The footprints of climate change: Erratic sequences of rapid warming followed by slow, incremental cooling over millennia



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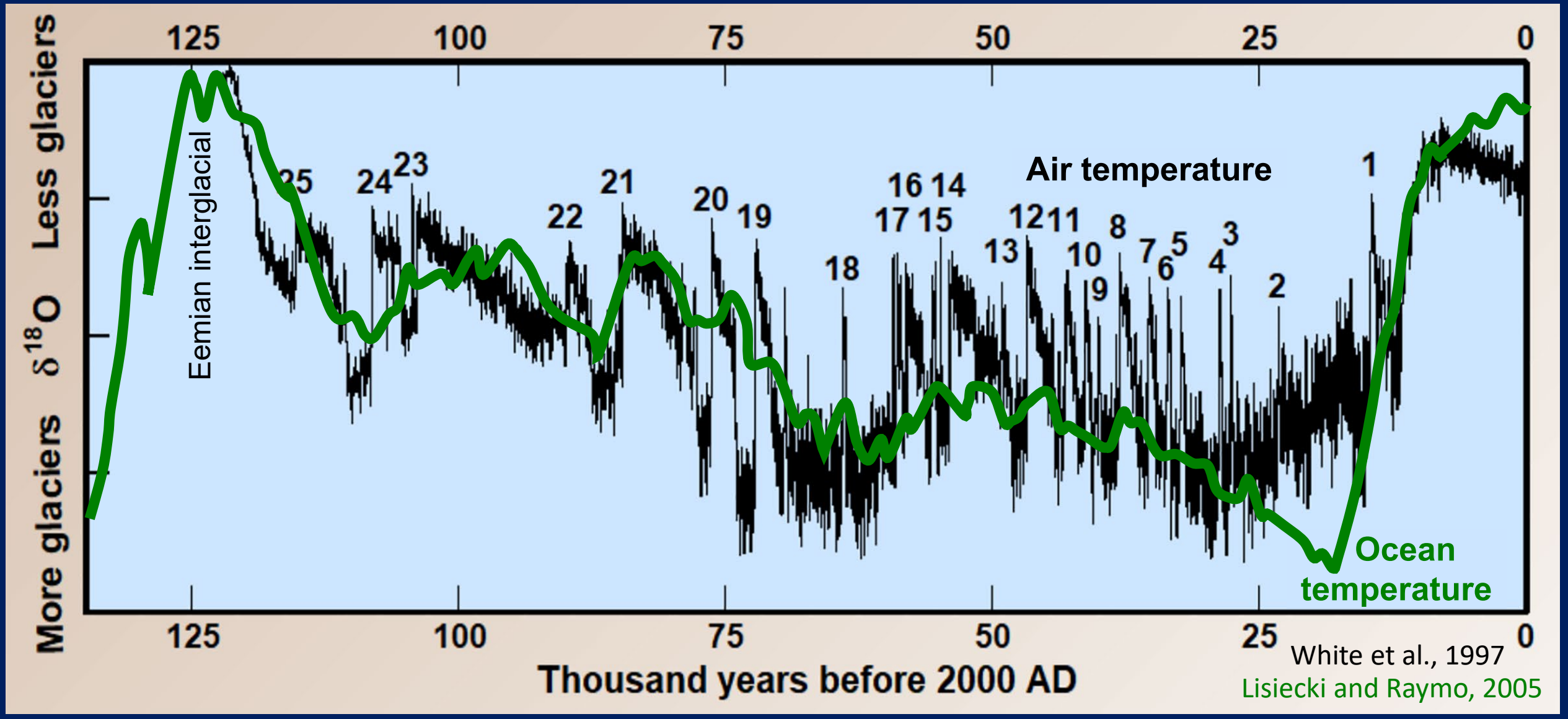

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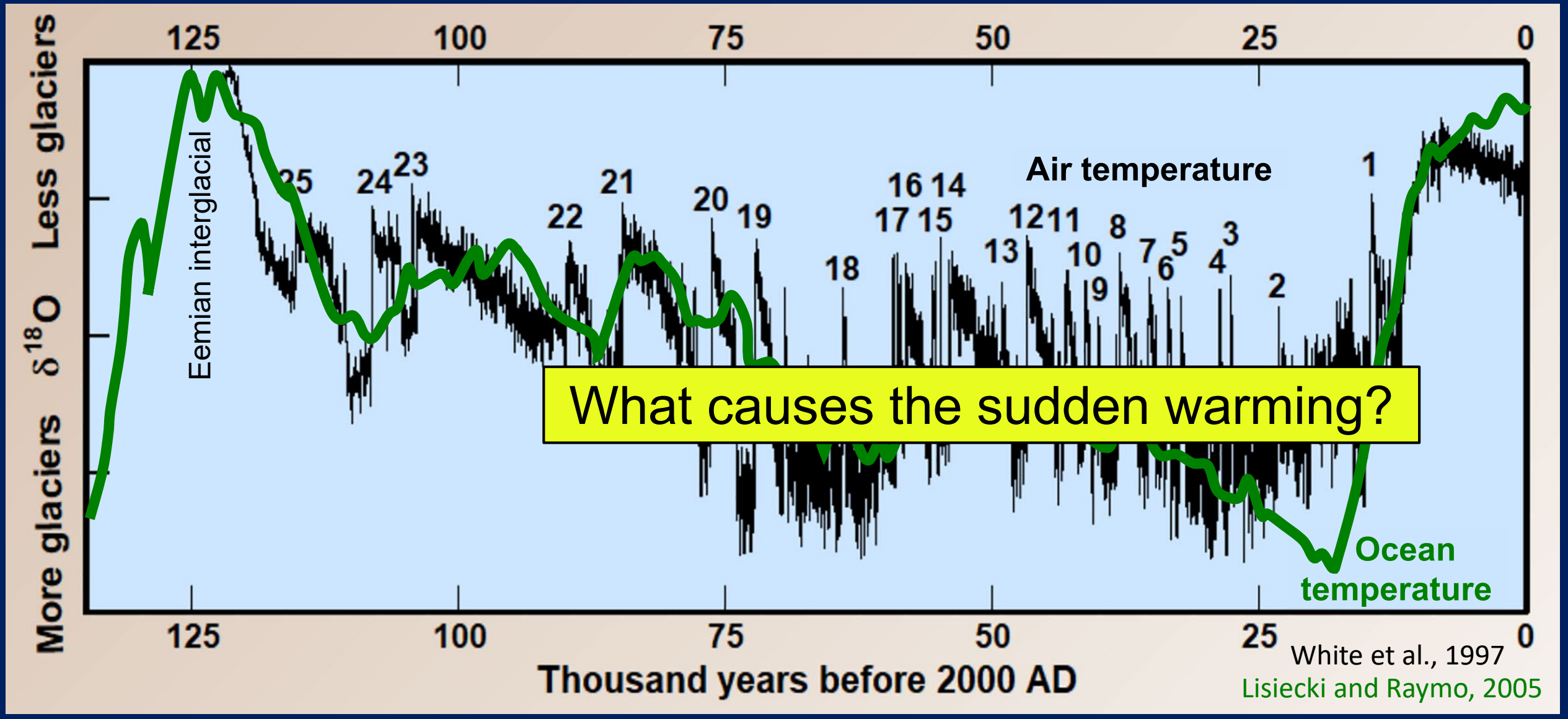

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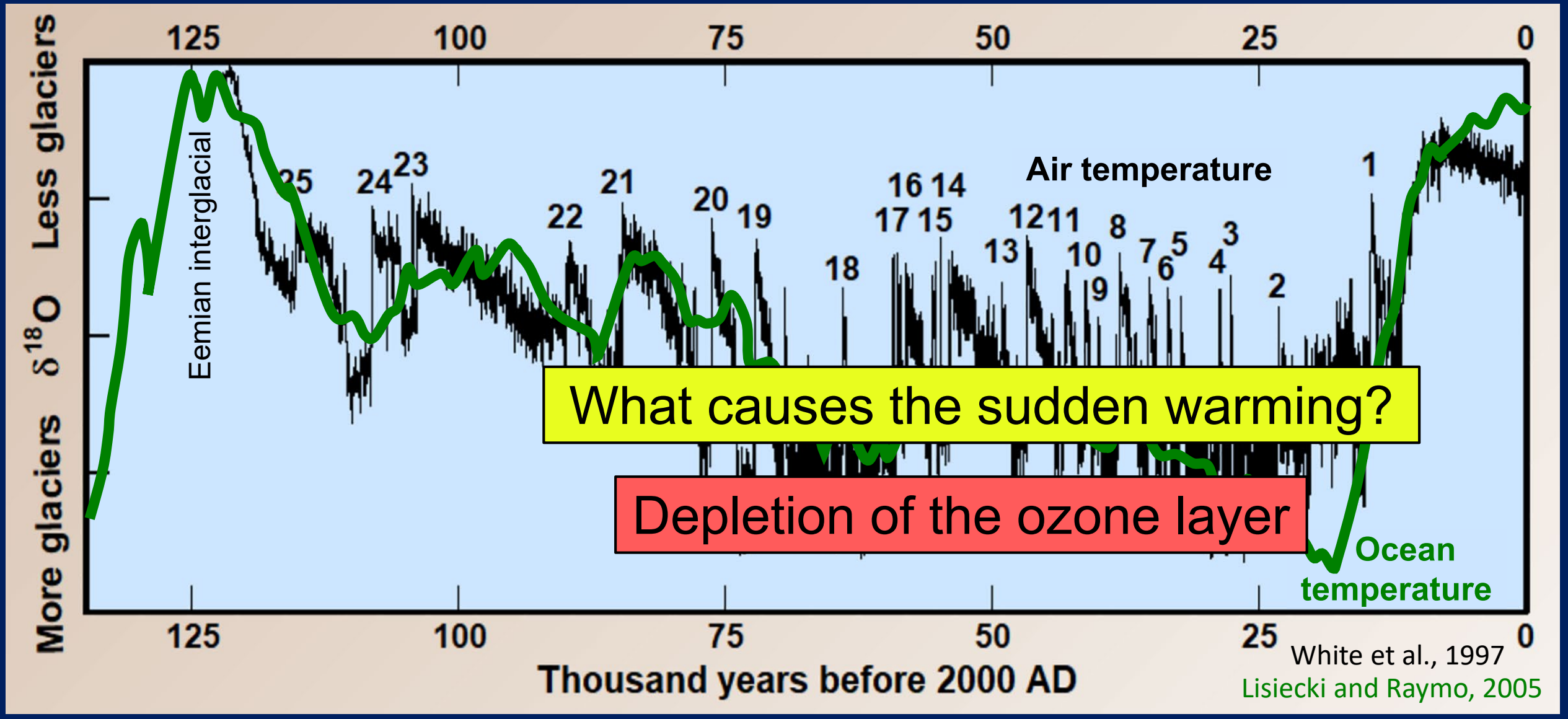

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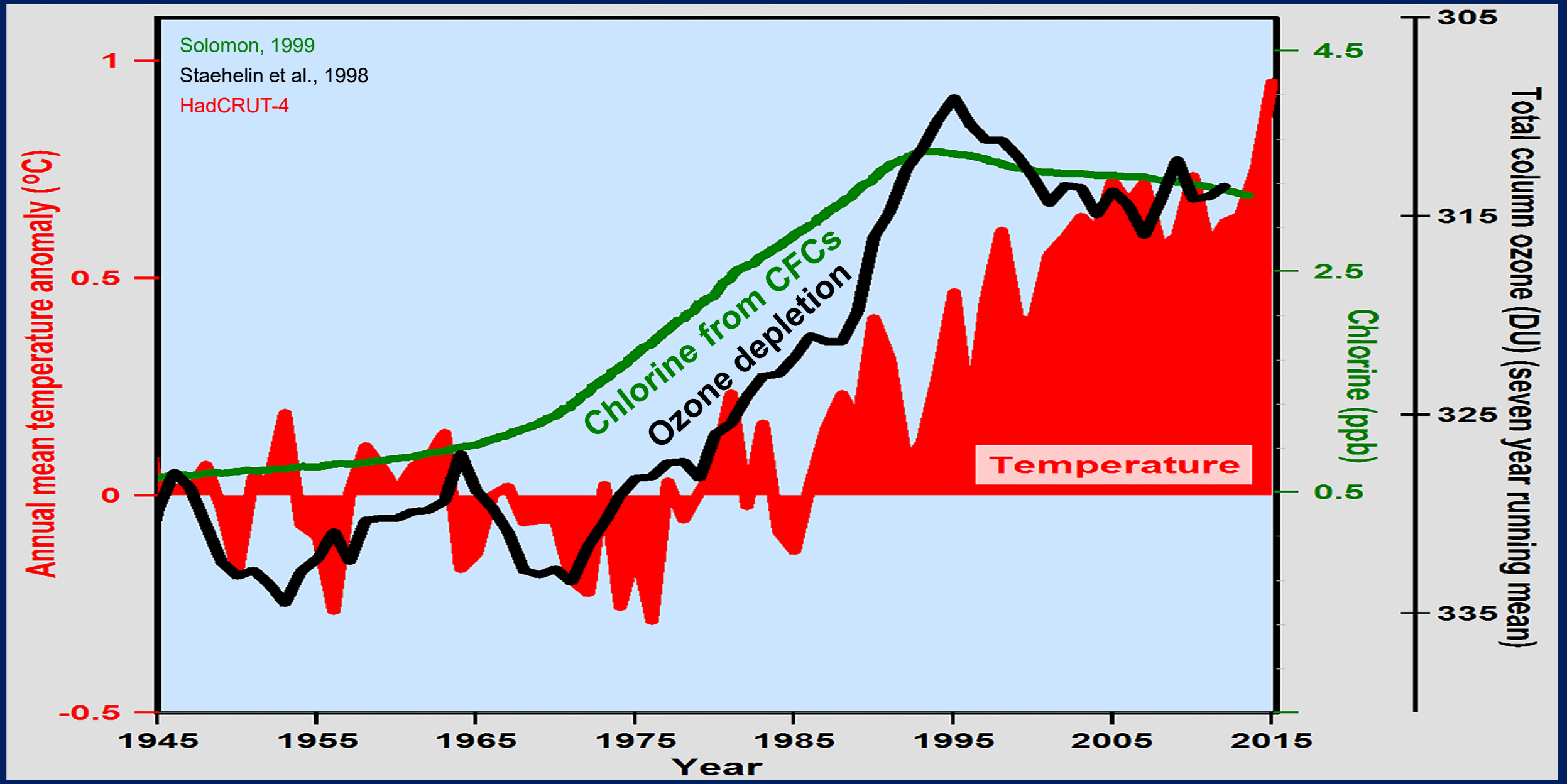
Human-caused global warming



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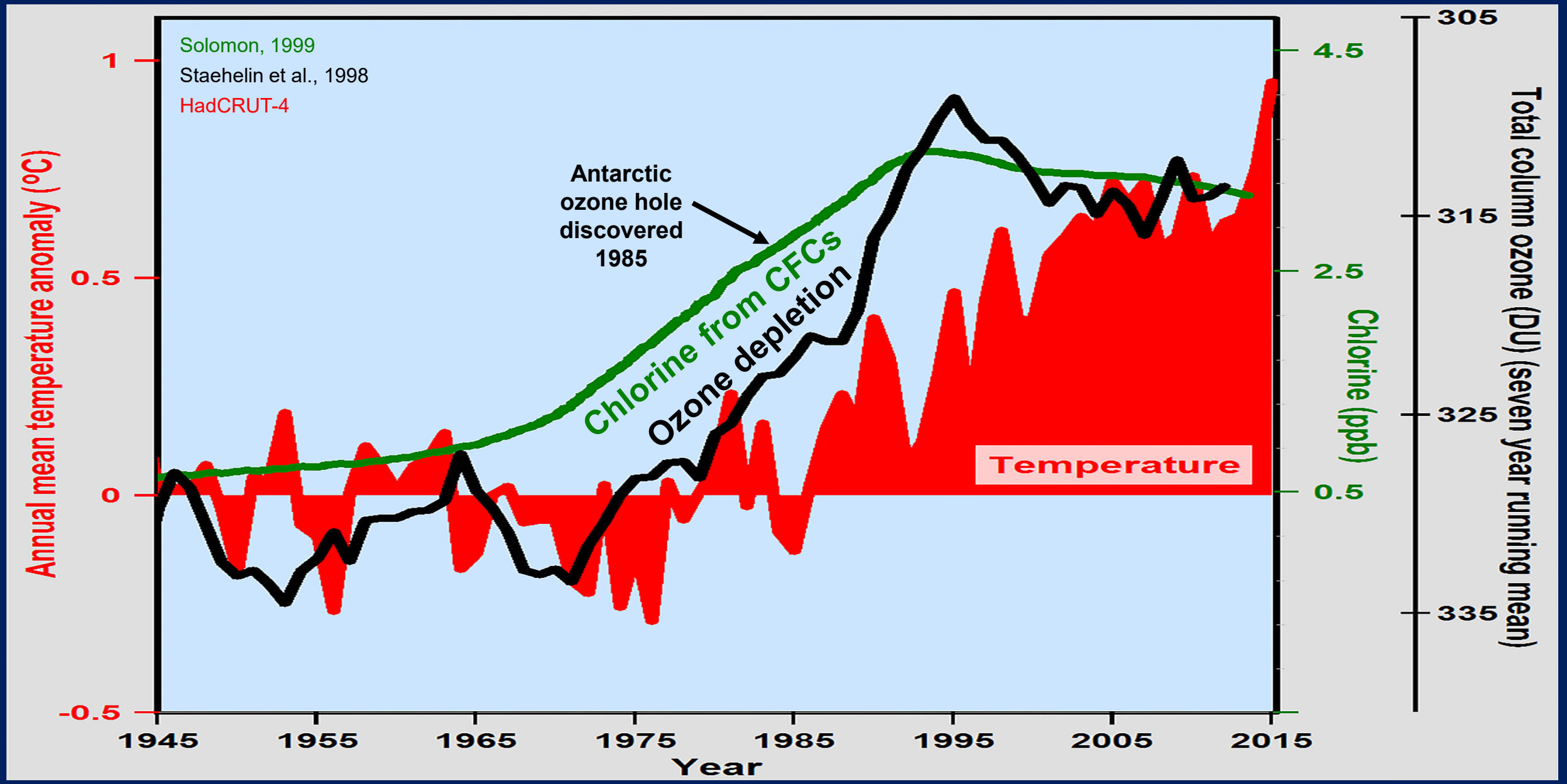

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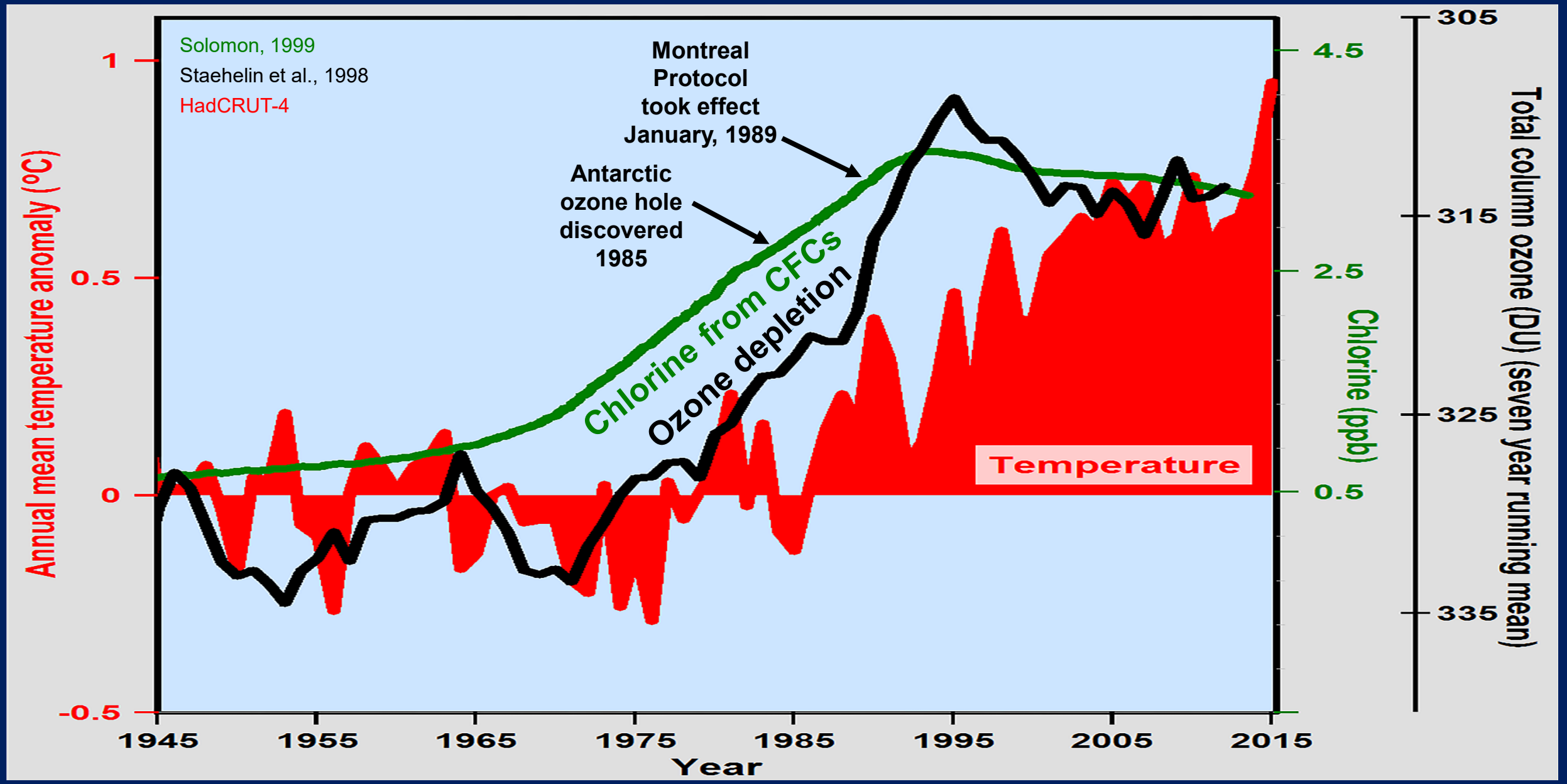

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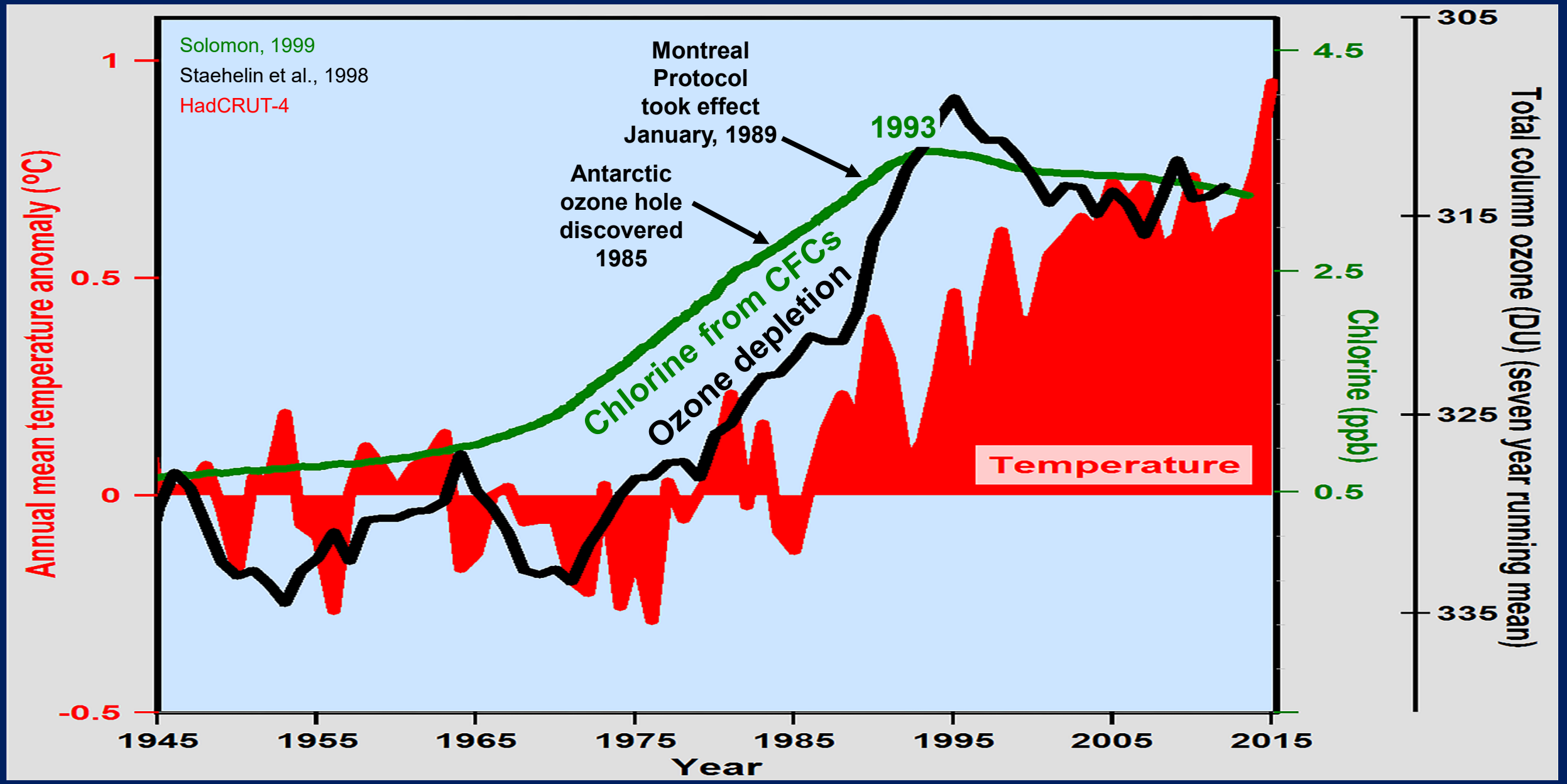

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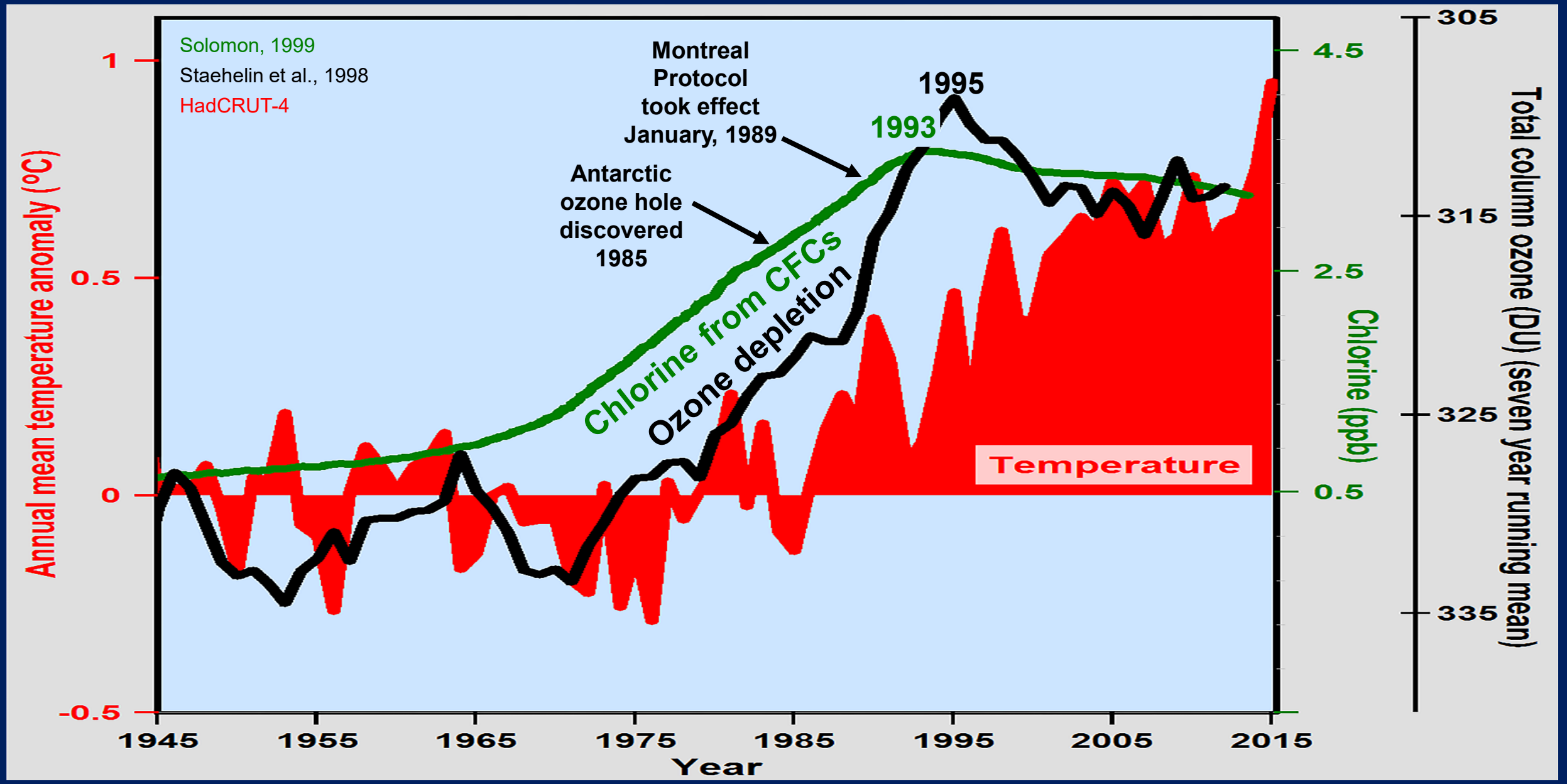

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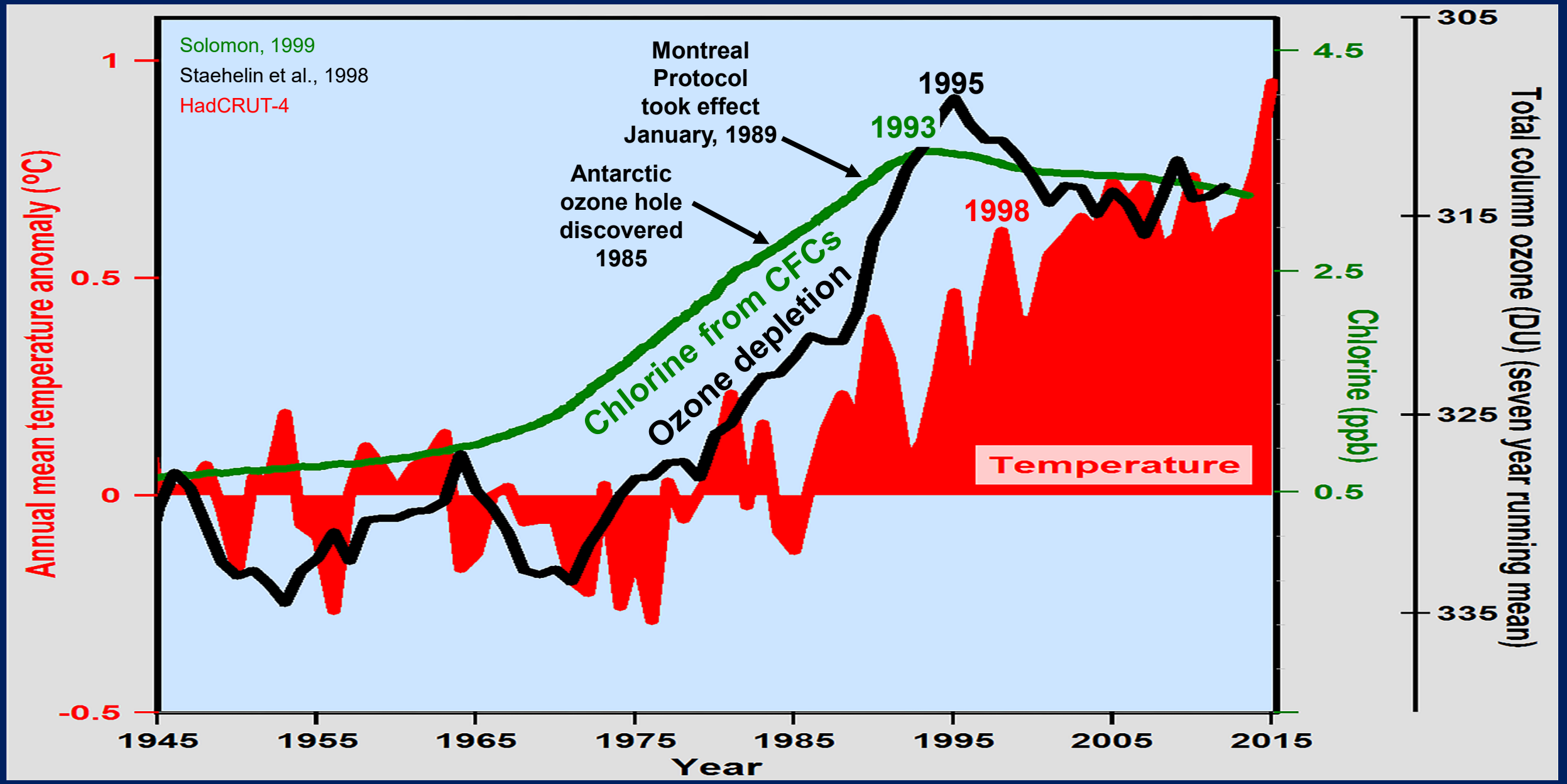

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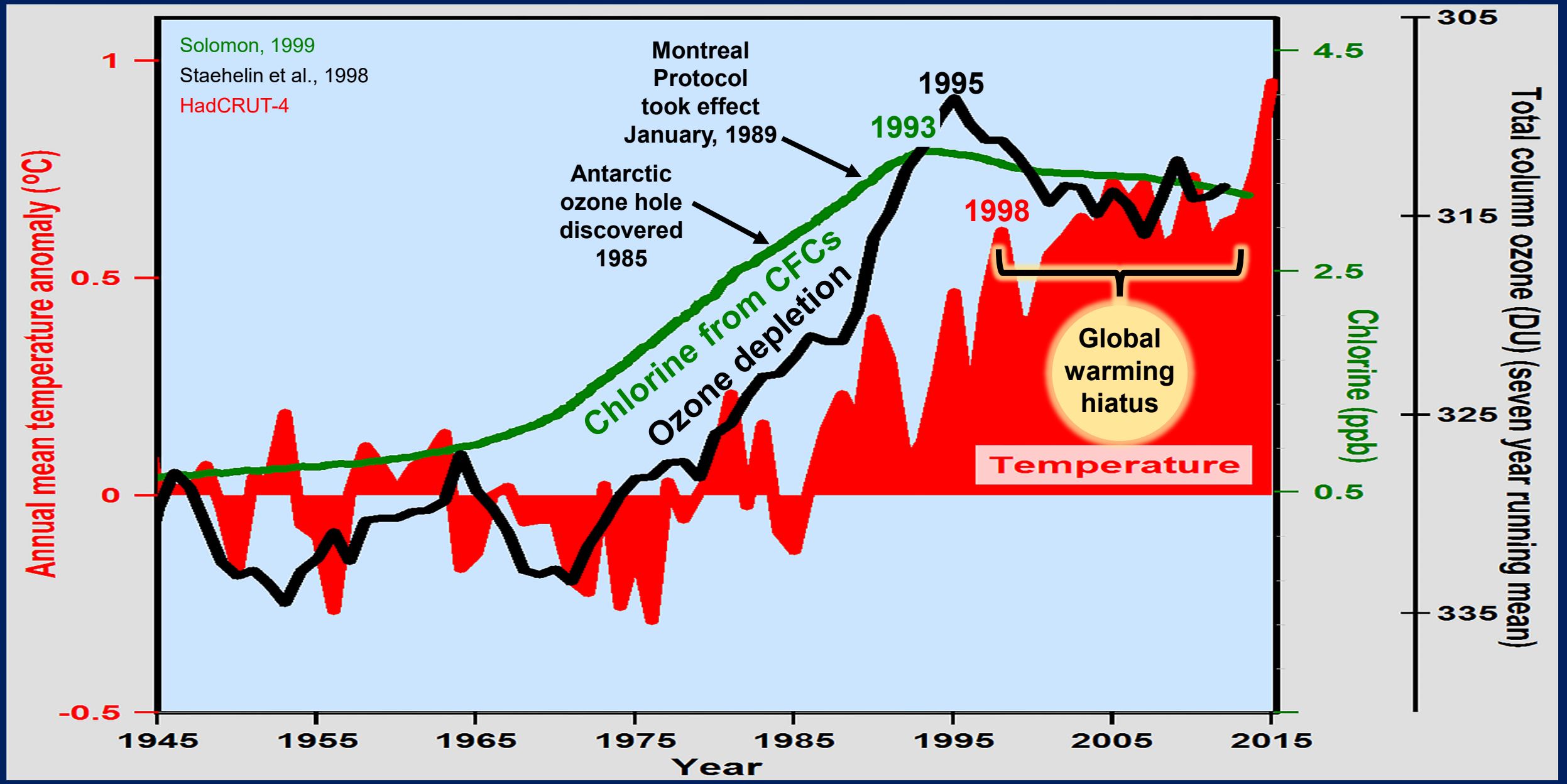
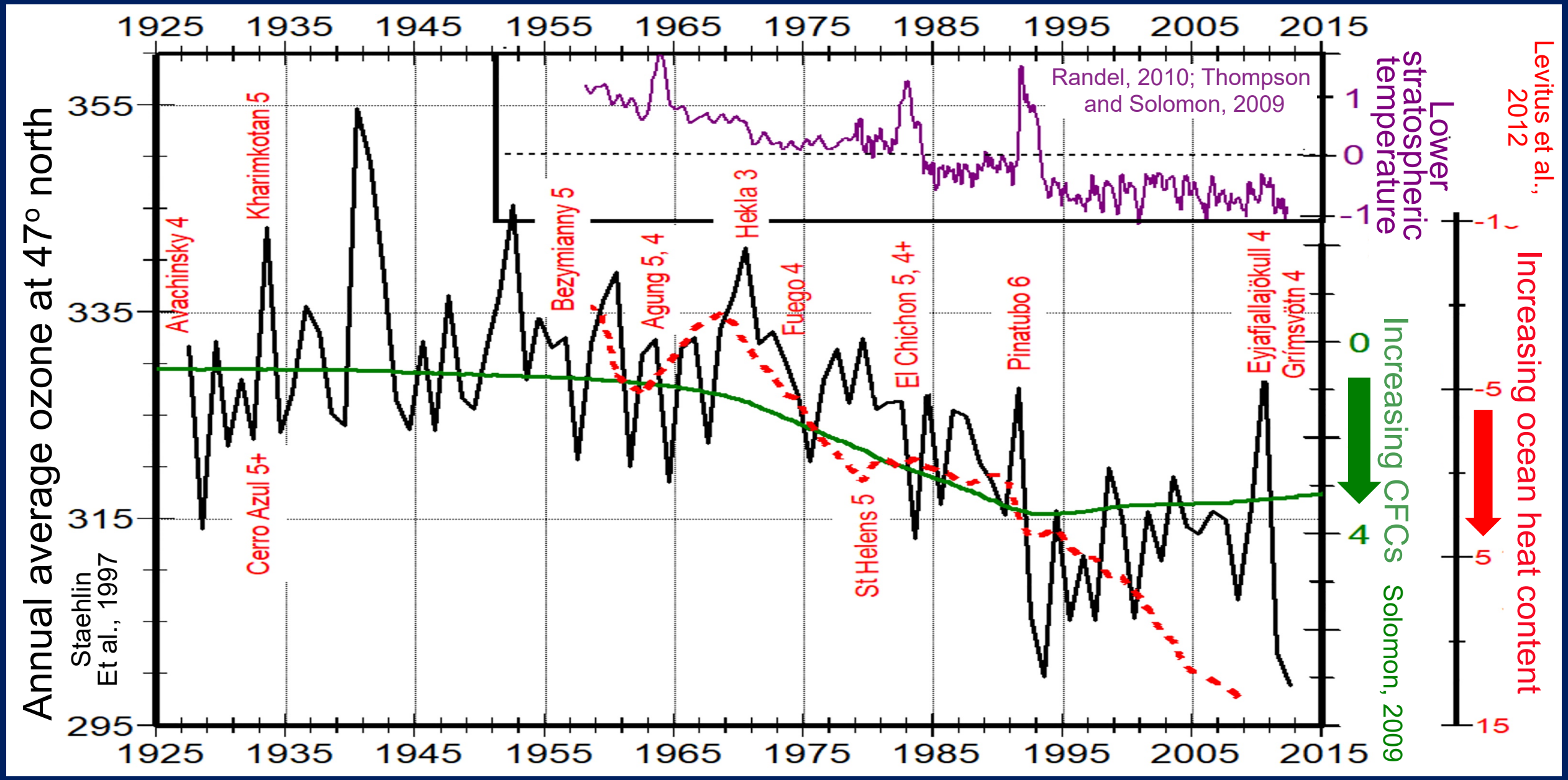


Ozone depleted by **humans** and by volcanic eruptions



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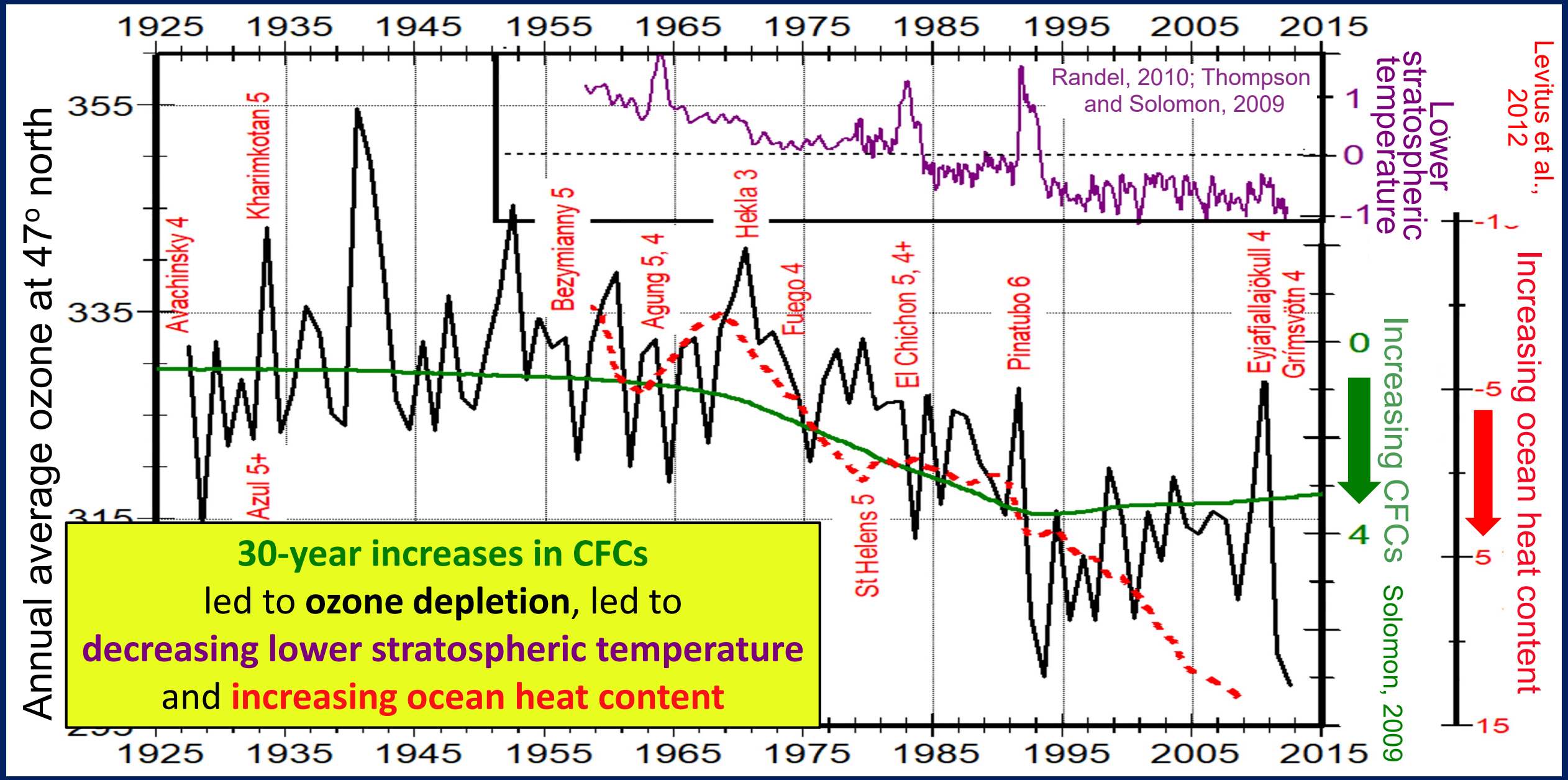

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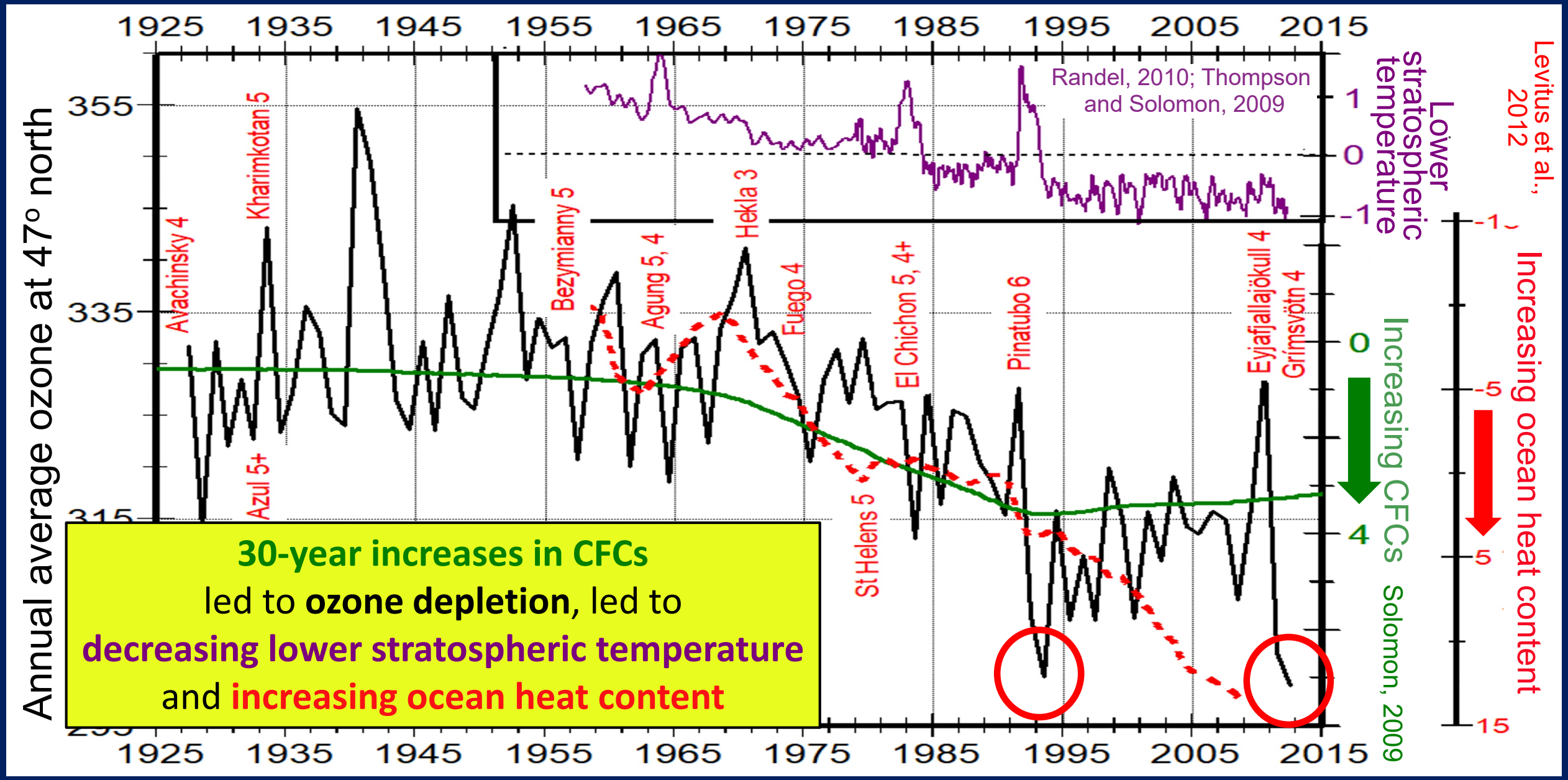

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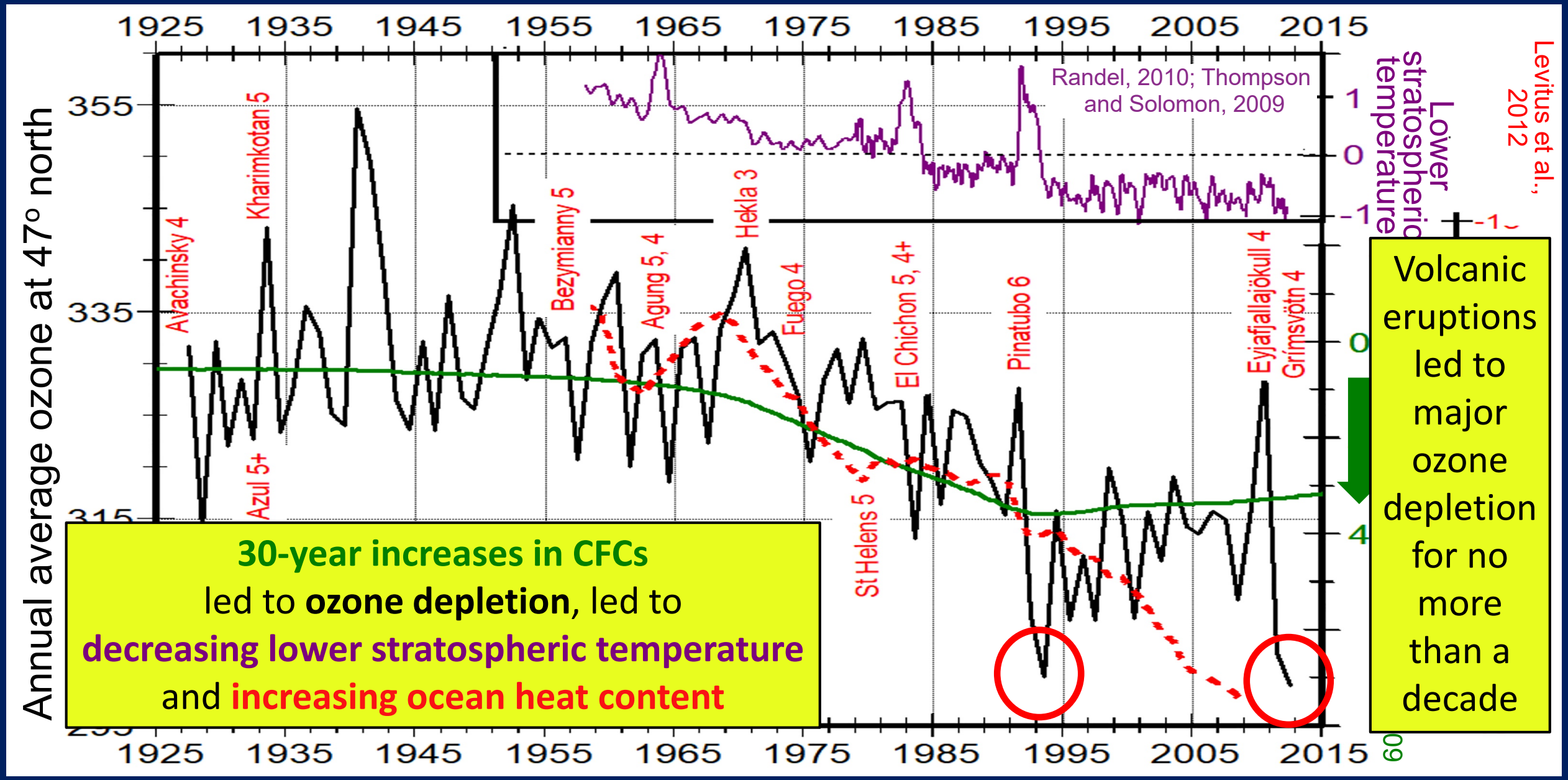

30-year increases in CFCs
led to **ozone depletion**, led to
decreasing lower stratospheric temperature
and **increasing ocean heat content**

Volcanic eruptions led to major ozone depletion for no more than a decade

Major explosive volcanic eruptions cause net cooling

Pinatubo 1991

Major effusive flows of basaltic lava that cause net warming

Bárðarbunga 2014

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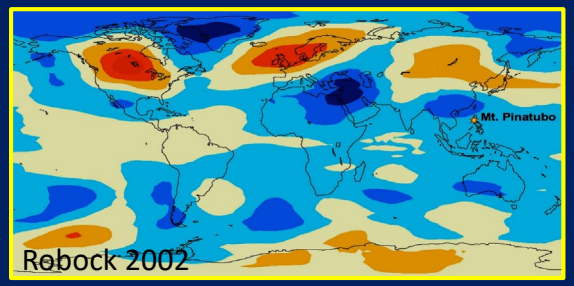

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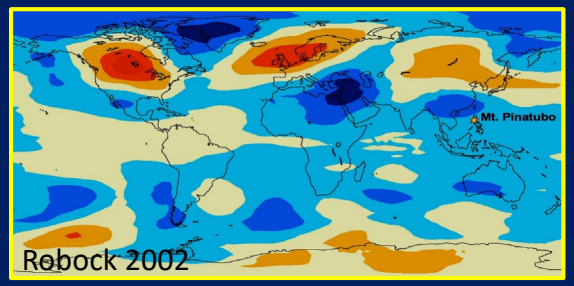

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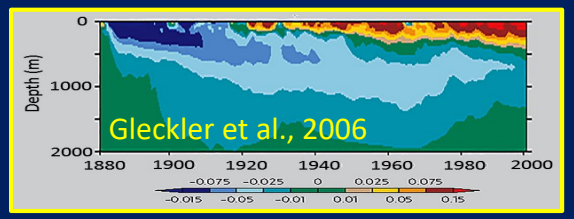

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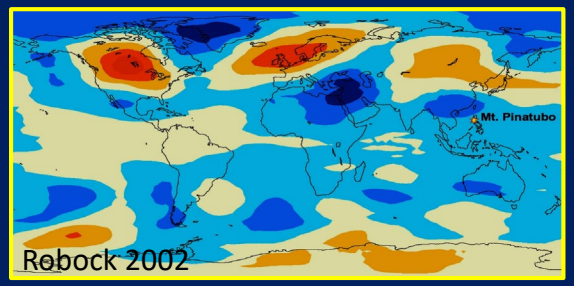

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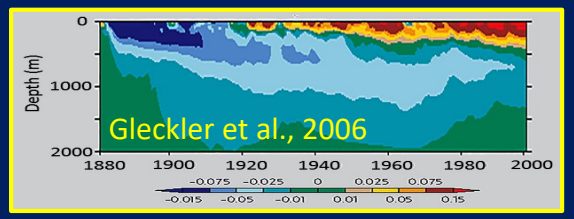

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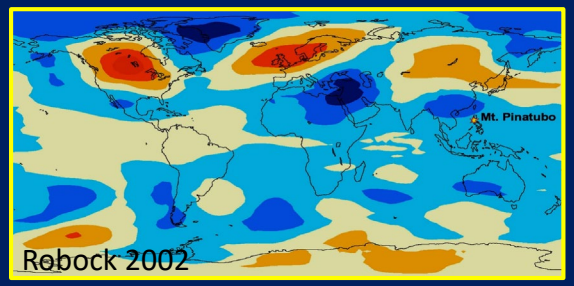

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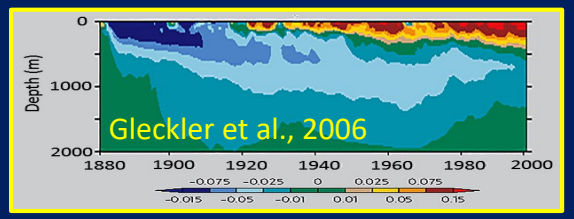

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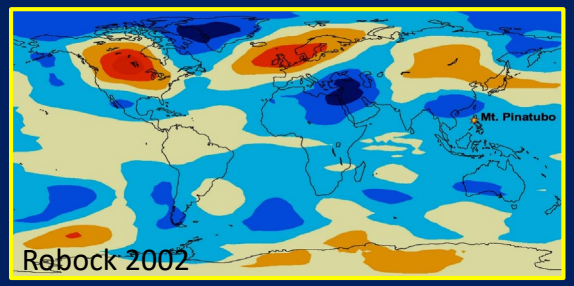

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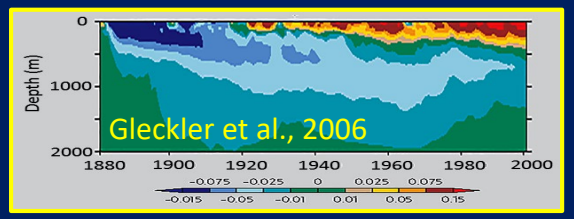

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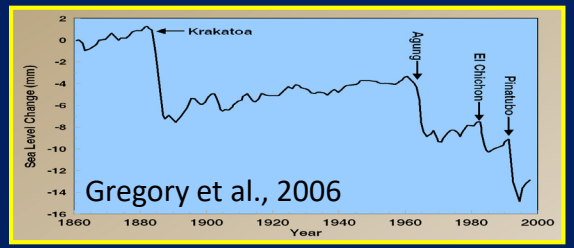

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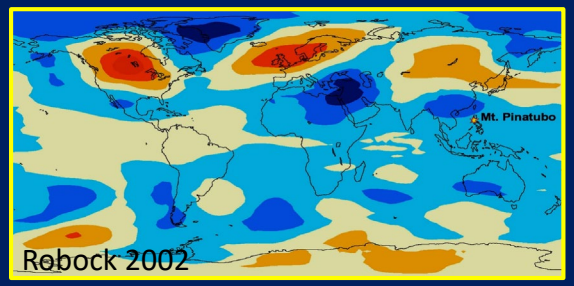

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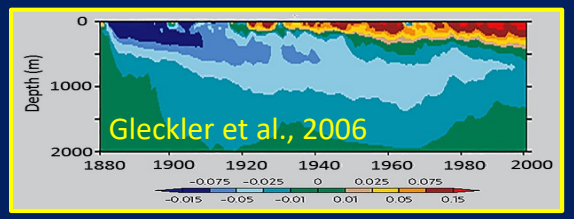

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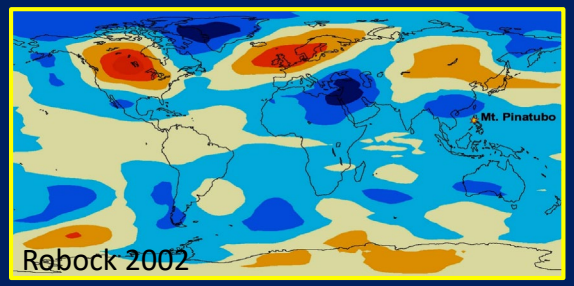

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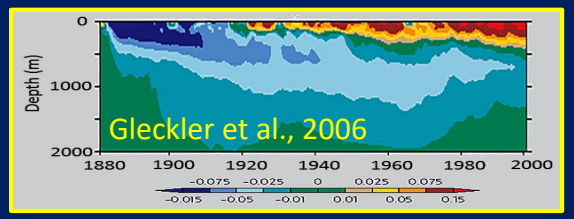

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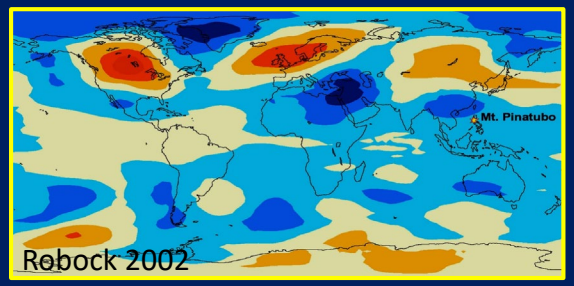

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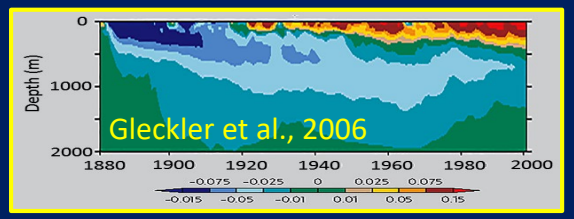

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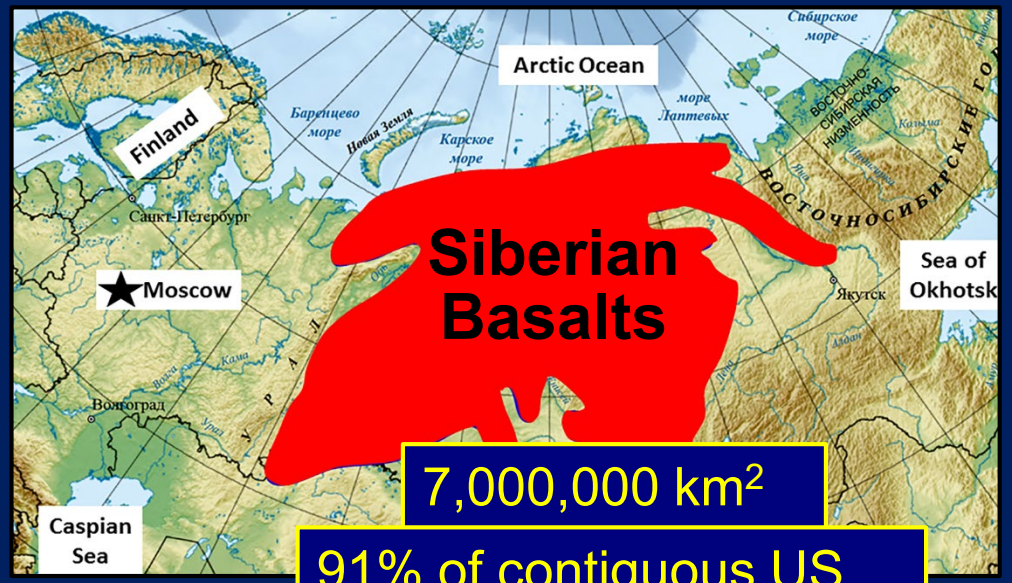
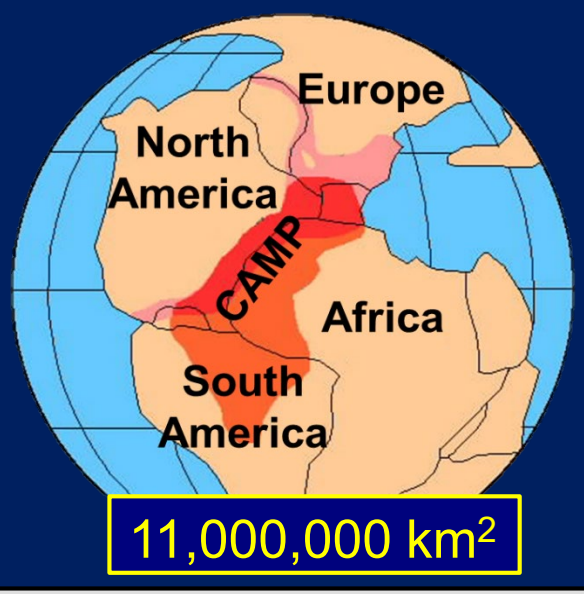
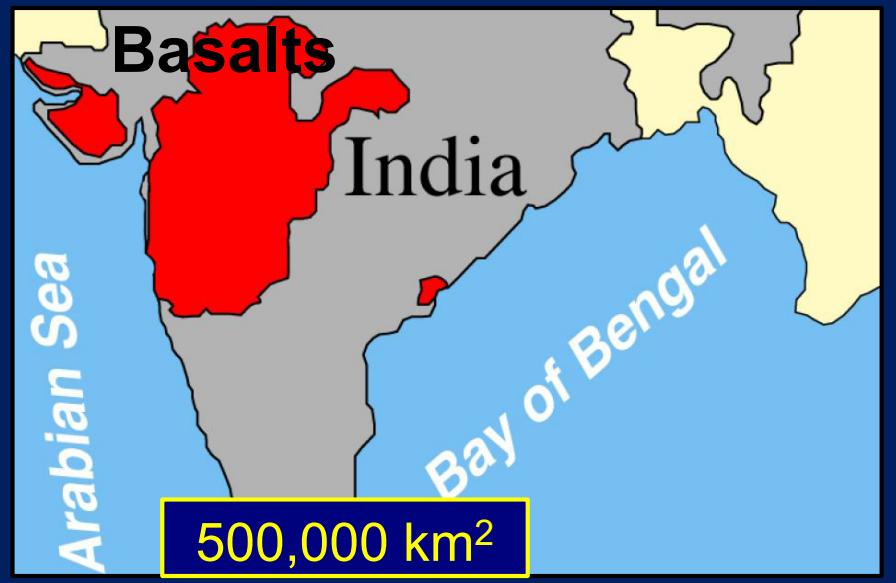
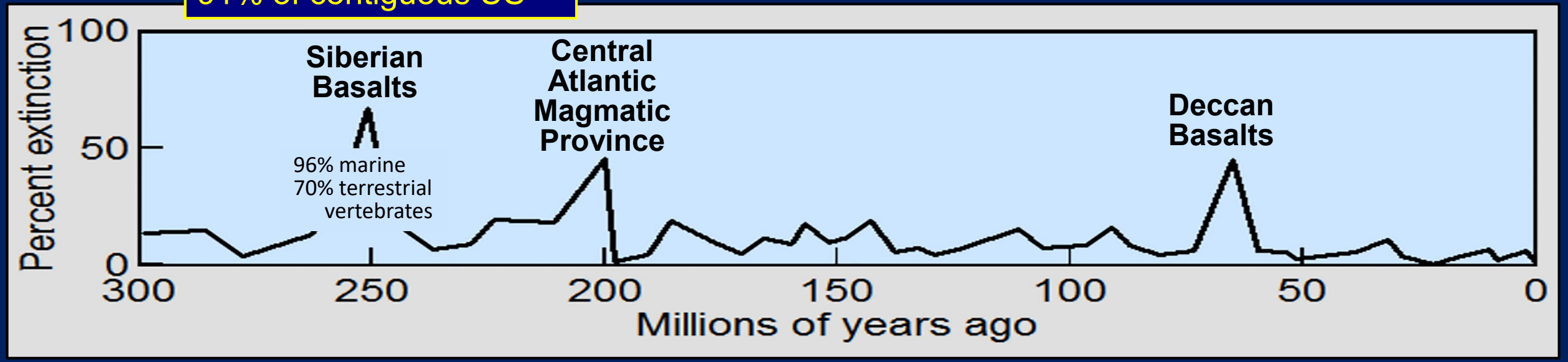
Siberian traps: 251 Ma covered 7 million km^2 for more than 100,000 years

Three of the largest flood basalts were contemporaneous with three of the largest mass extinctions









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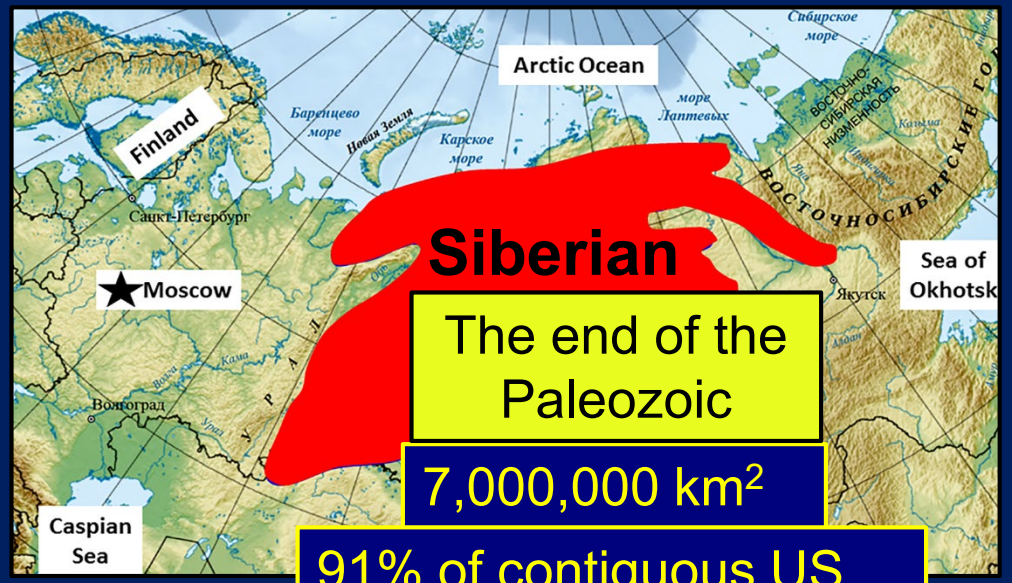

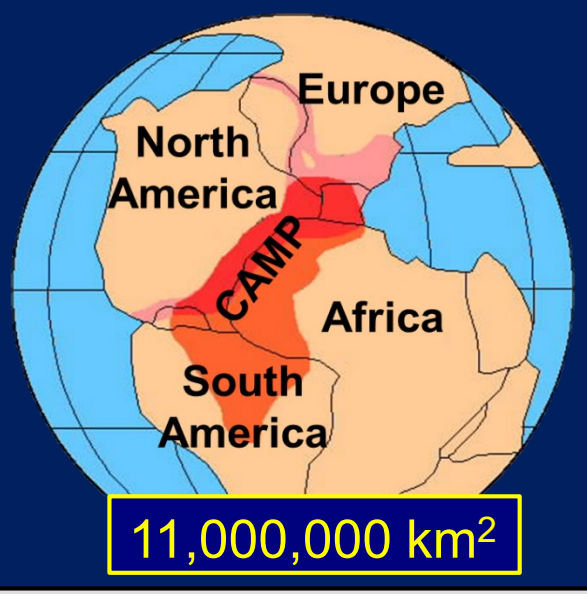

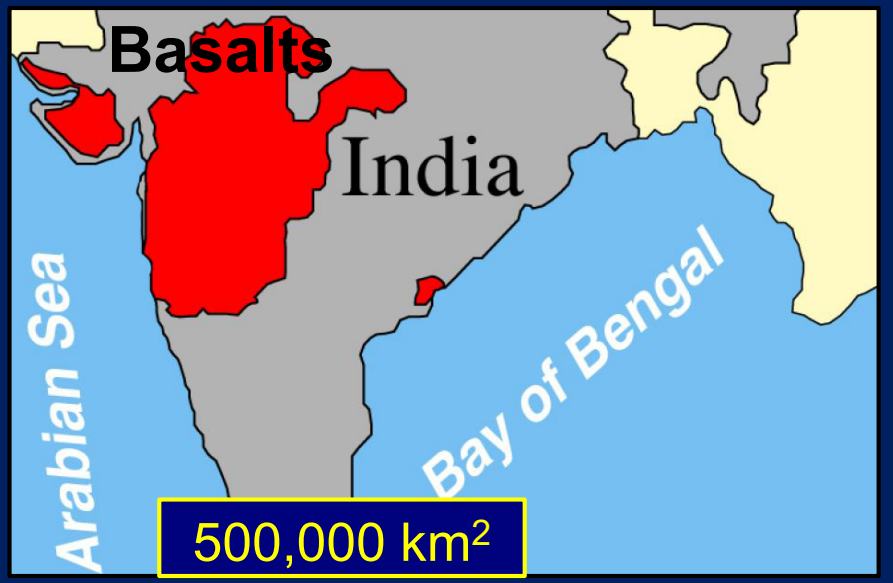

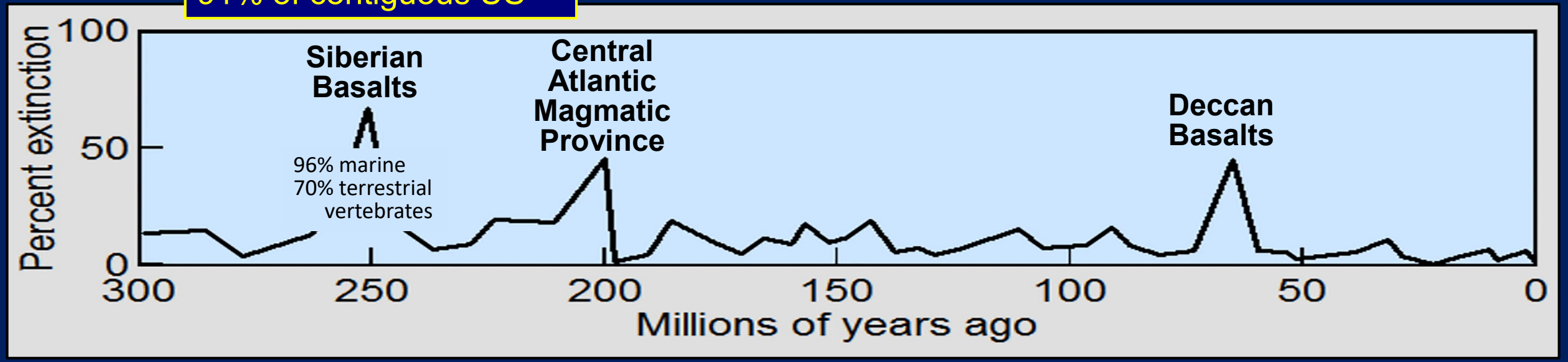

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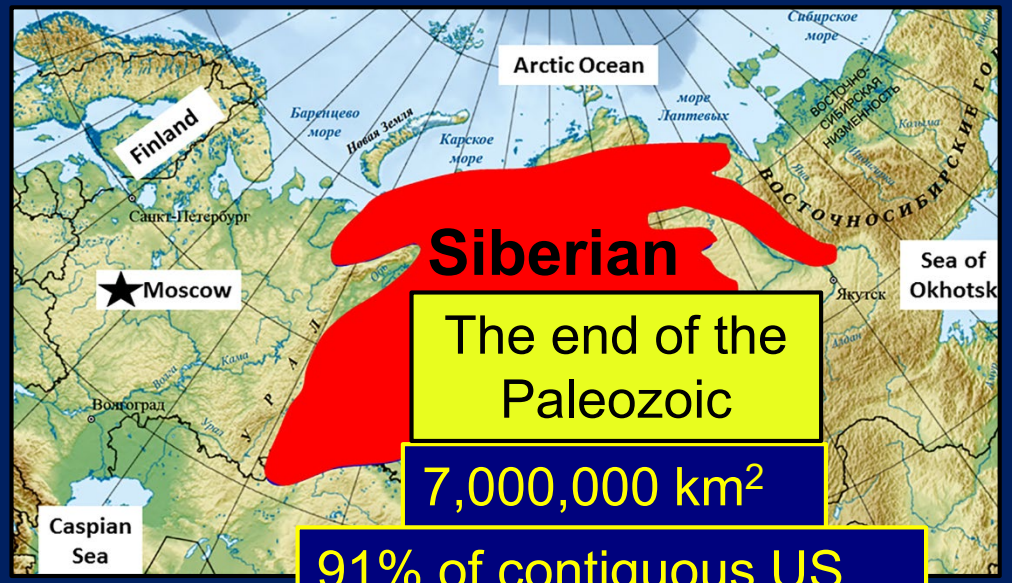

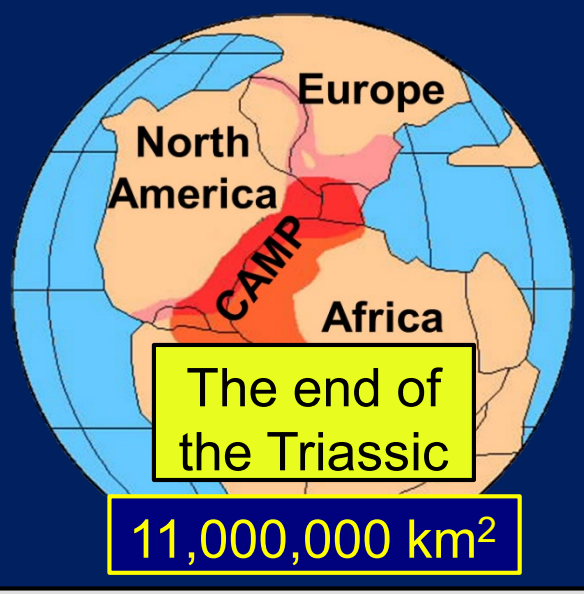

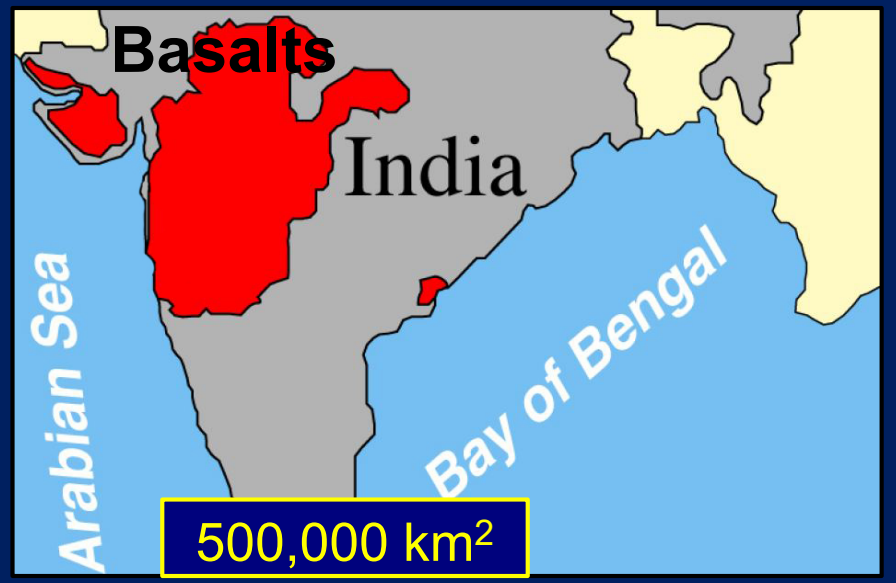

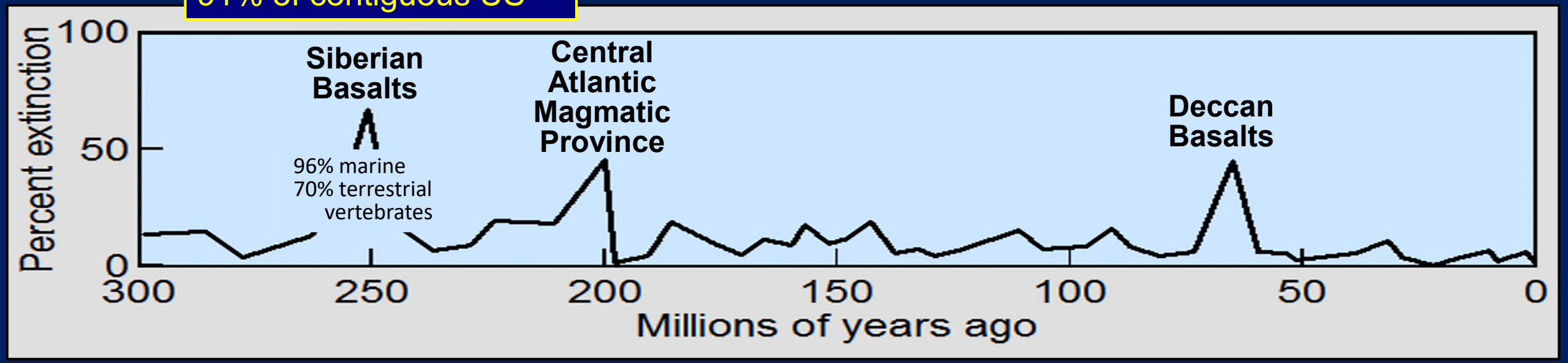

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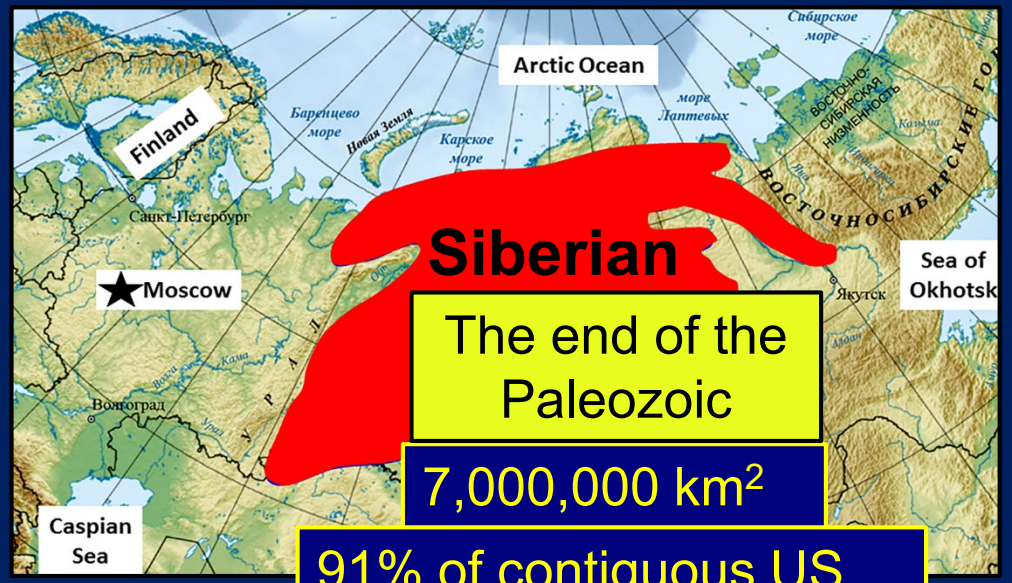
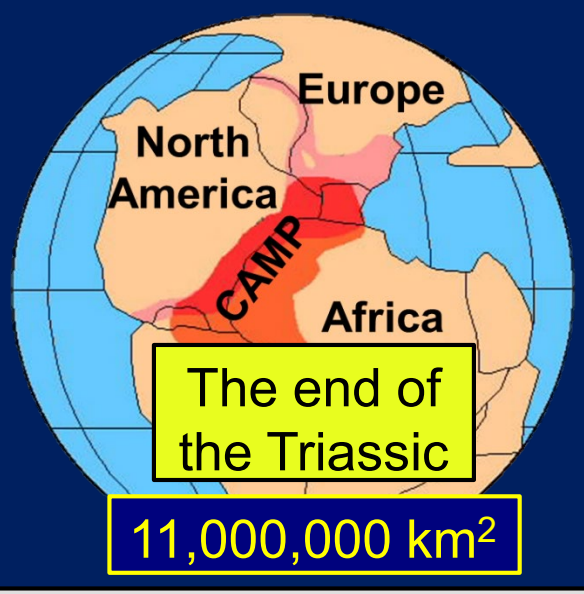
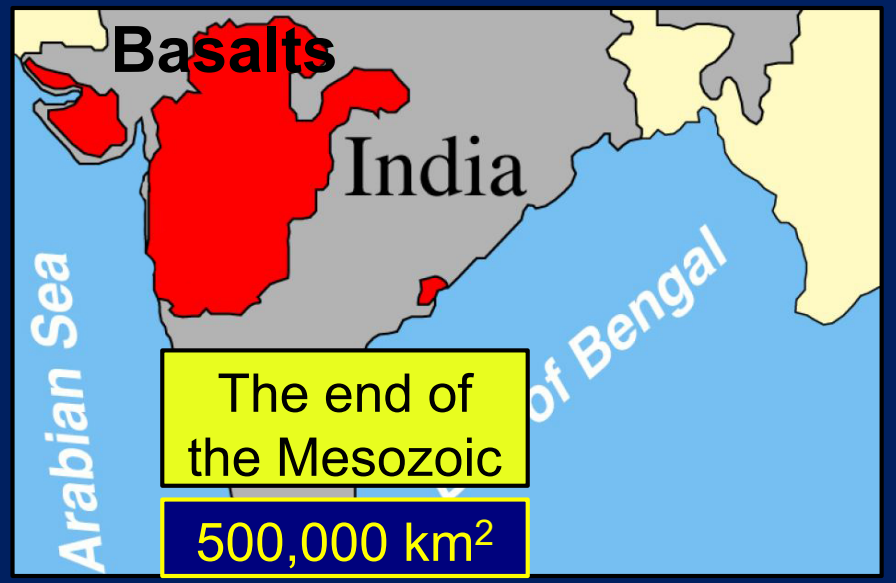
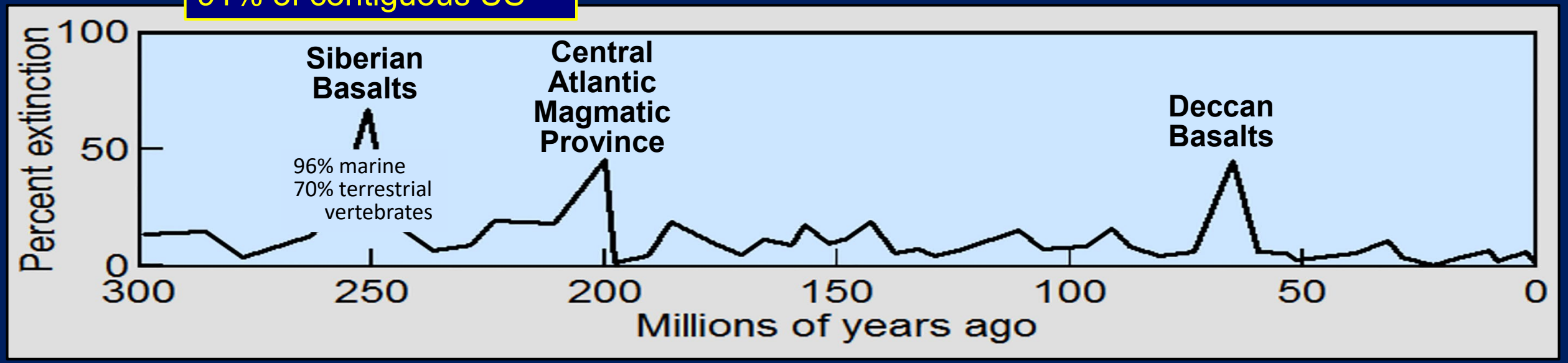
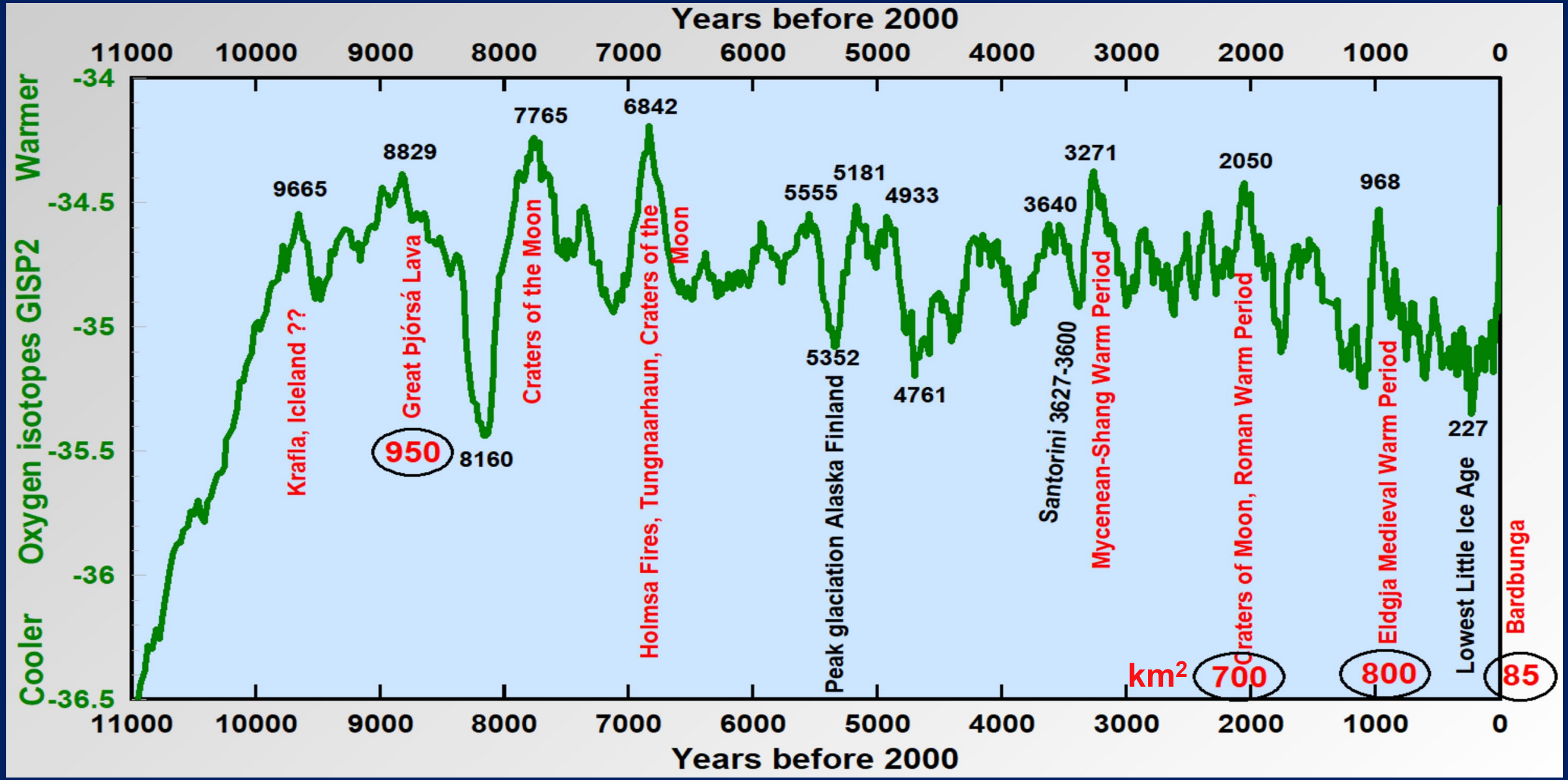




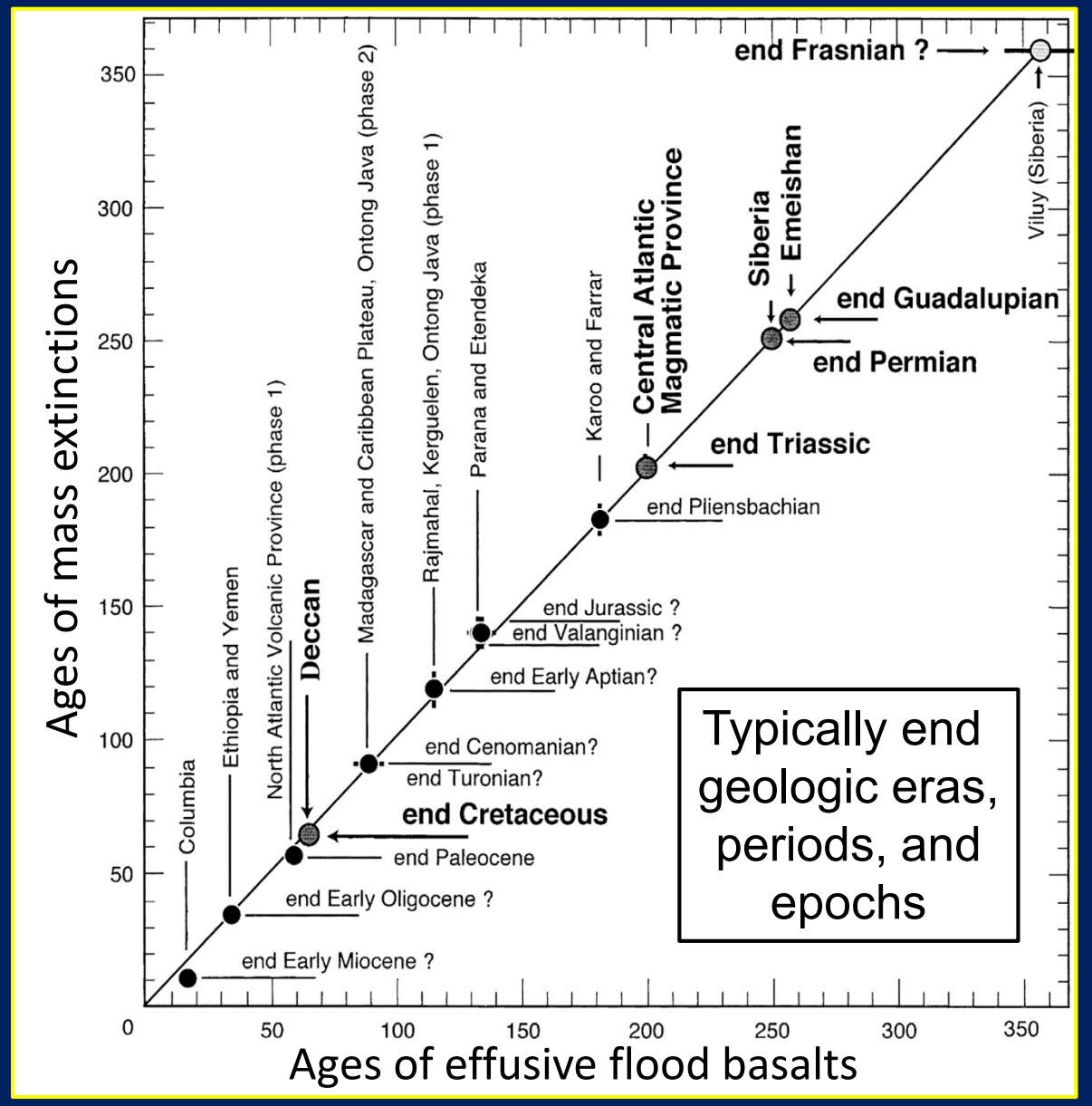




Temperatures and volcanism throughout the Holocene



Associated with end of time units



Courtillot and Renne 2003

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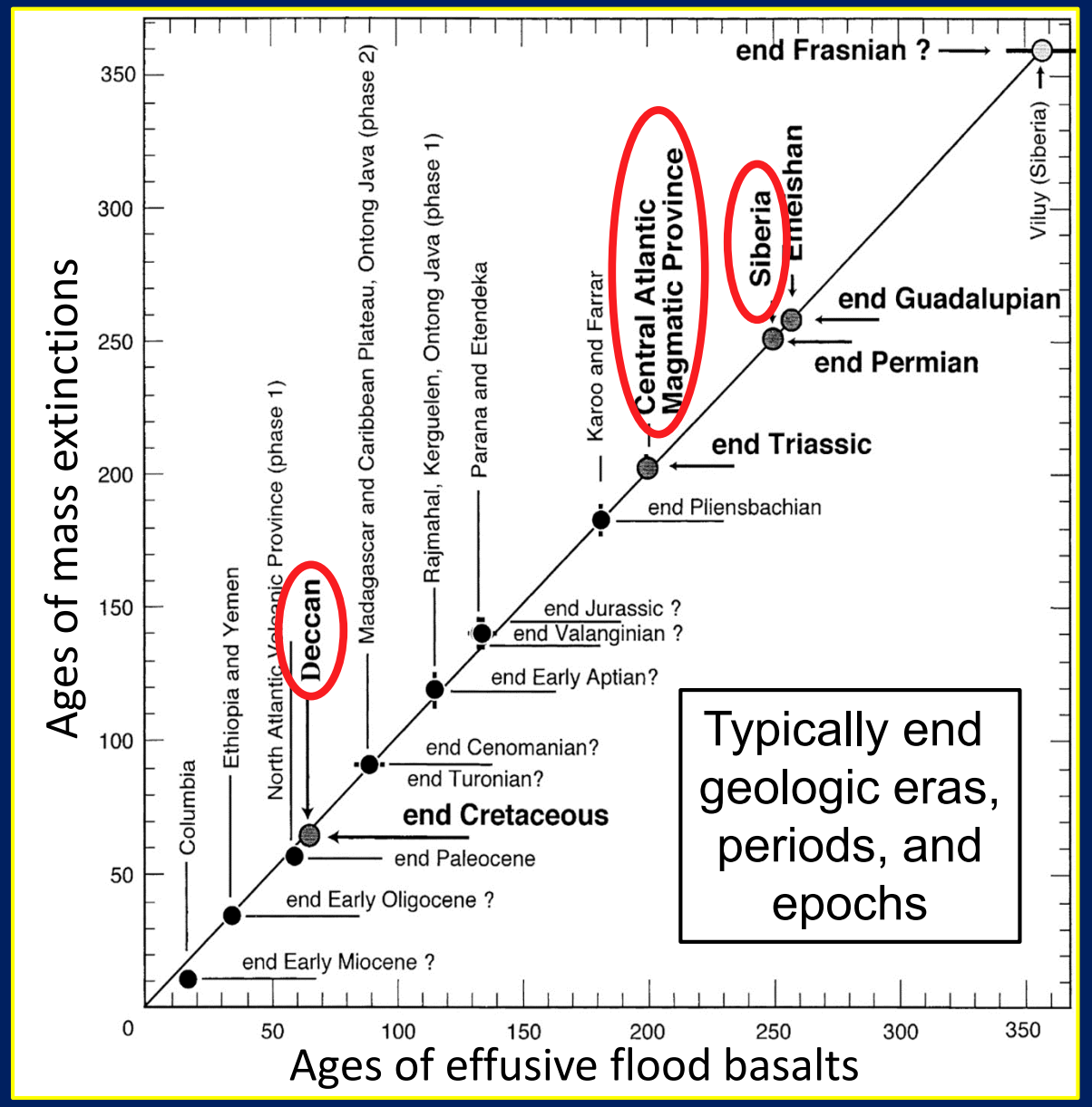

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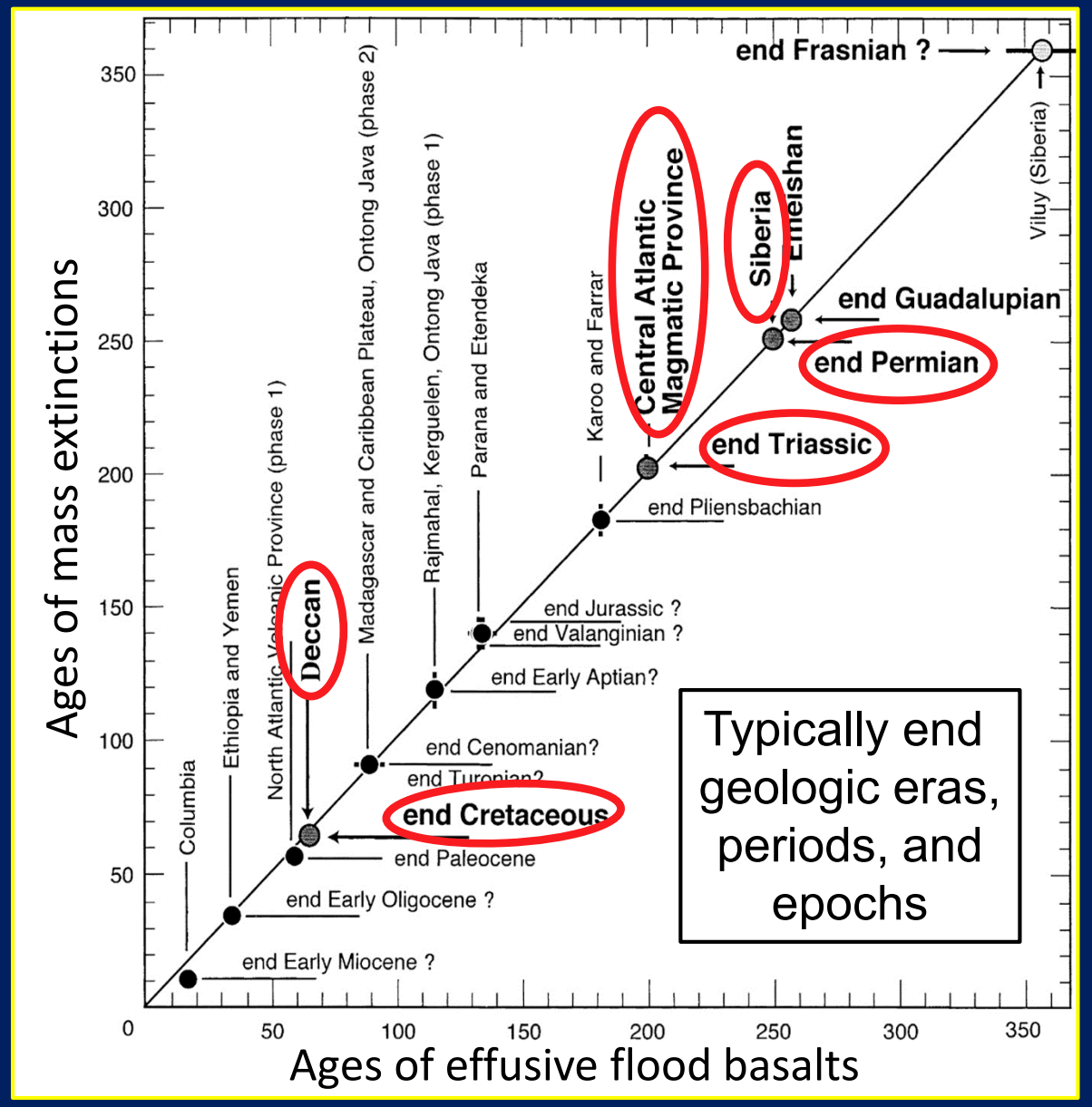

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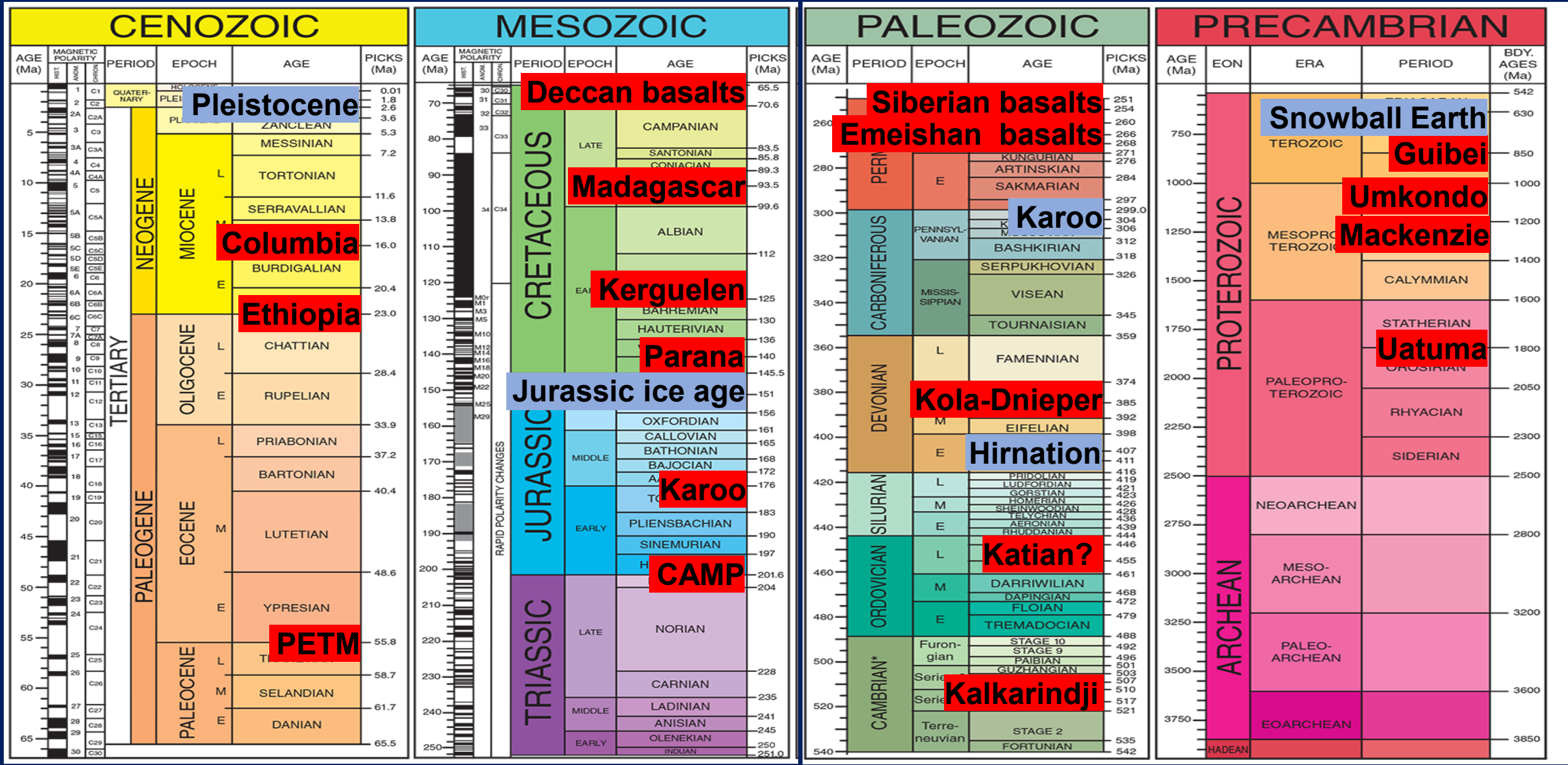
Large Igneous Provinces punctuate the geologic time scale



Geological Society of America Time Scale

Ages of LIPs from Ernst 2014

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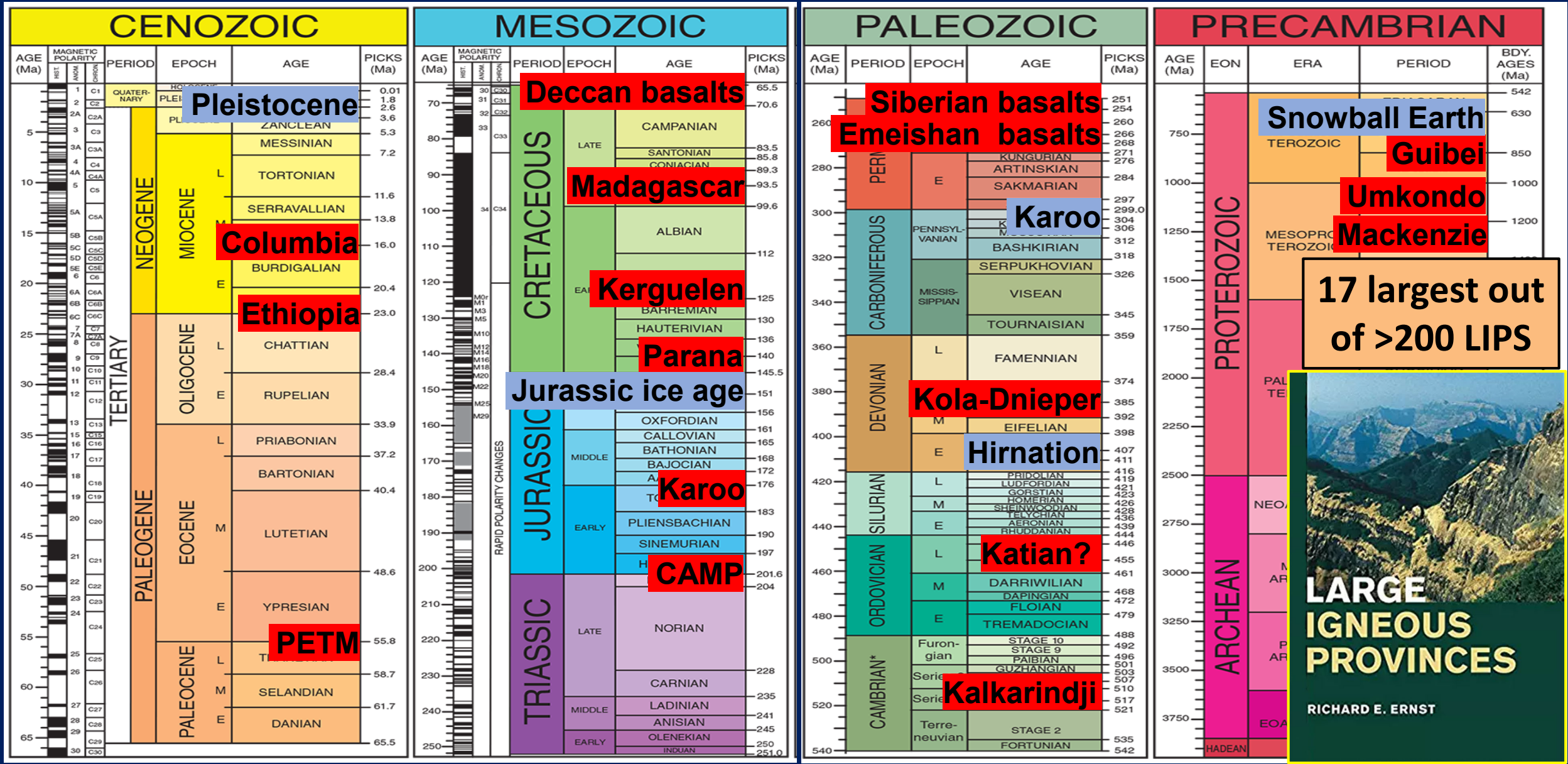

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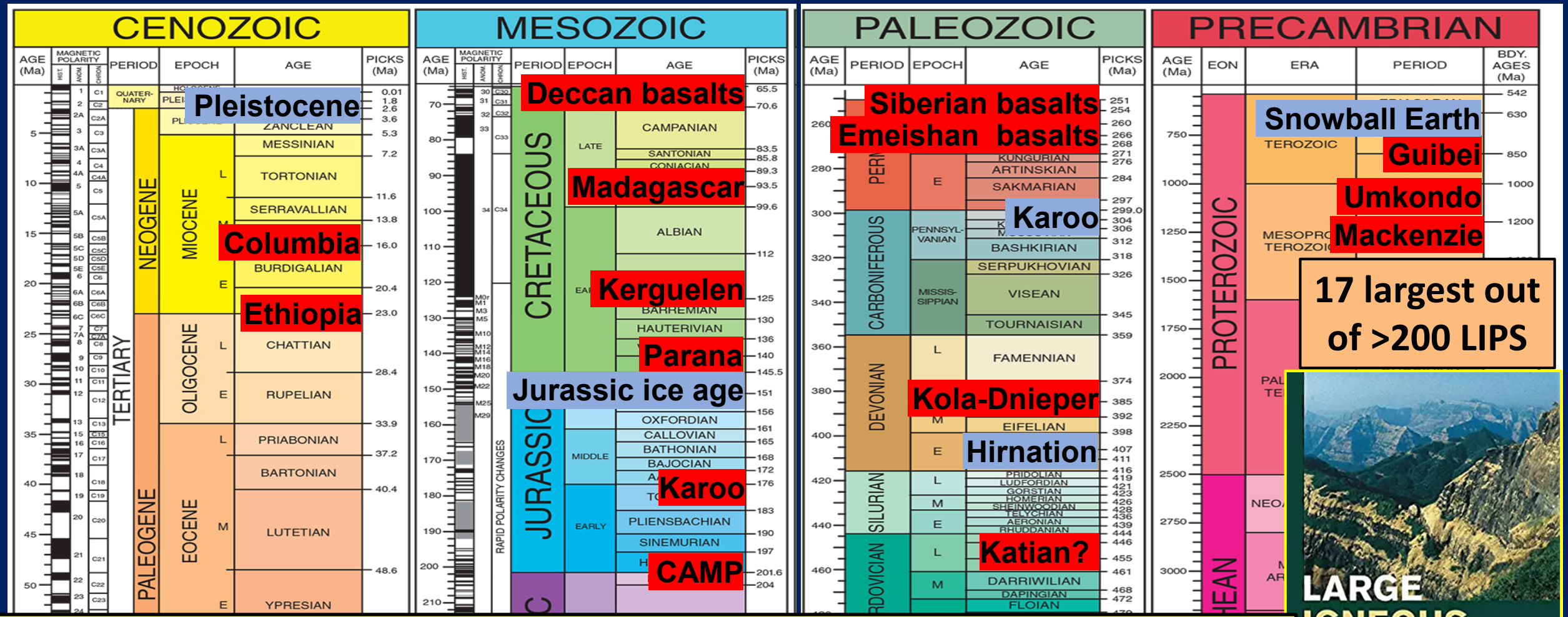

The balance of effusive and explosive volcanism due to plate tectonics explains climate change in detail

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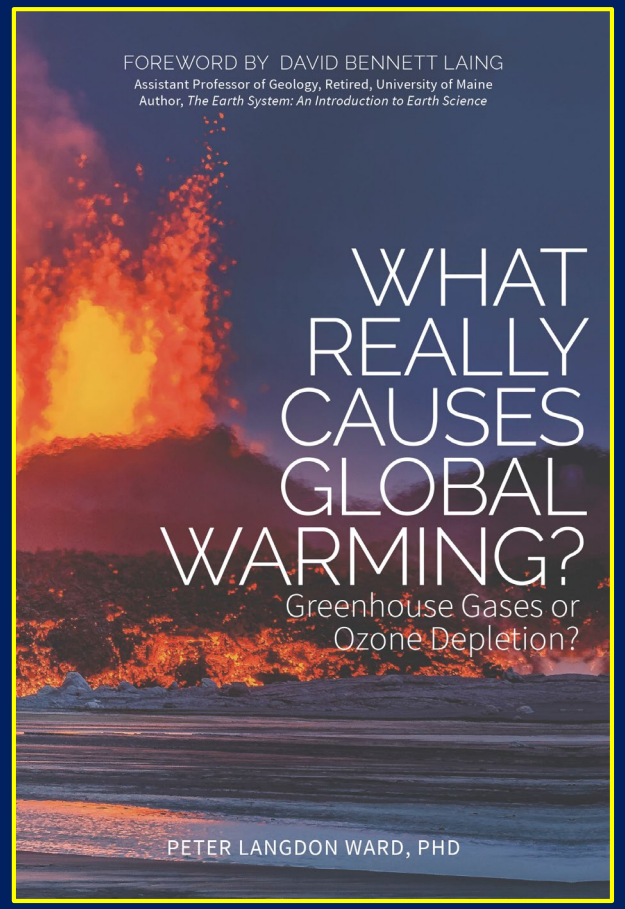
6. MOST IMPORTANT: Substantial warming in the future is NOT anticipated unless there are very rare, major basaltic lava flows.

Volcanoes Rule

WhyClimateChanges.com



See also AMS 2019 poster 476:
The most unexpected surprise in climate change

WhyClimateChanges.com

Physically-Impossible.com

JustProveCO2.com

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