Riding the Climate Rollercoaster 3 T4 2025

3. Climate Change Drivers I: Tectonics, Volcanism and the Biosphere

Malte Ebach

TESEP Regional Co-ordinator

Slides by Rob Kirk & Malte Ebach

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We also wish to pay our respects to Elders past, present and future.

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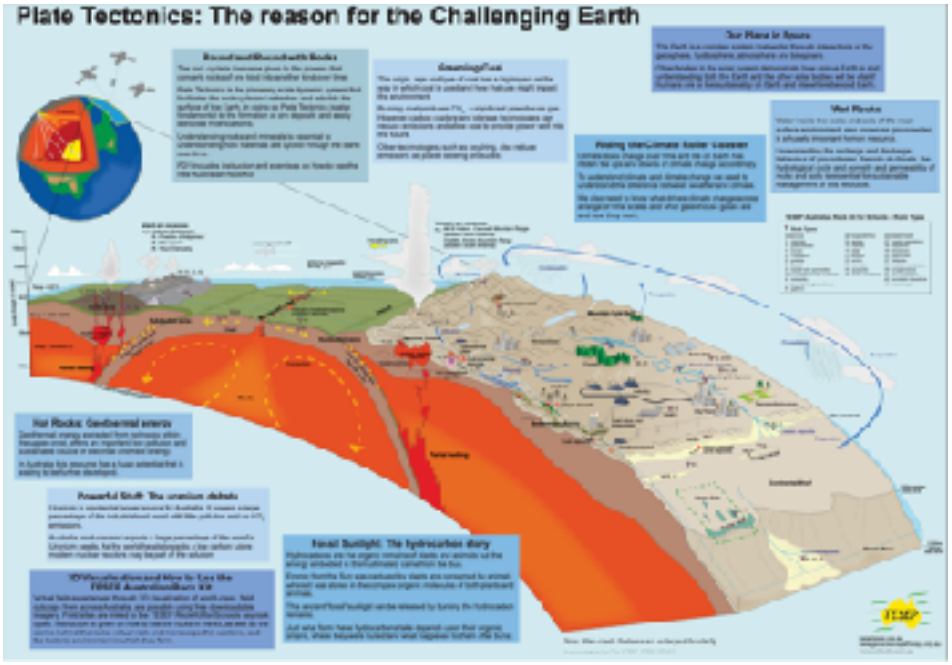

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Australian Curriculum v.9 (F-10)

We will be following the Australian Curriculum v.9 (2022):

- Curriculum content for Years 7-10 only
- Focus on the Earth and Space science sub-strand
- Will follow as many other sub-strands as possible

Australian Curriculum v. 9 (2022): Examples.

Year 10 (Earth and Space Sciences)

"They appreciate how energy drives the Earth system and how climate models simulate the flow of energy and matter within and between Earth's spheres".

- Use models of energy flow between the geosphere, biosphere, hydrosphere and atmosphere to explain patterns of global climate change (AC9S10U04).
- Explain how scientific knowledge is validated and refined, including the role of publication and peer review (AC9S10H01).
- Investigate how advances in technologies enable advances in science, and how science has contributed to developments in technologies and engineering (AC9S10H02).

Australian Curriculum v. 9 (2022): Examples.

Year 10 (Geography)

“develop a range of questions for a geographical inquiry related to a phenomenon or challenge”.

- planning an investigation of a phenomenon or challenge being studied at a range of scales, using digital tools; for example, investigating the causes of human-induced climate change at the global scale and its impacts on Australia, Bangladesh and/or a Pacific Island country at the national scale (AC9HG10S01)

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Climate Change Drivers I: Tectonics, Volcanism and the Biosphere

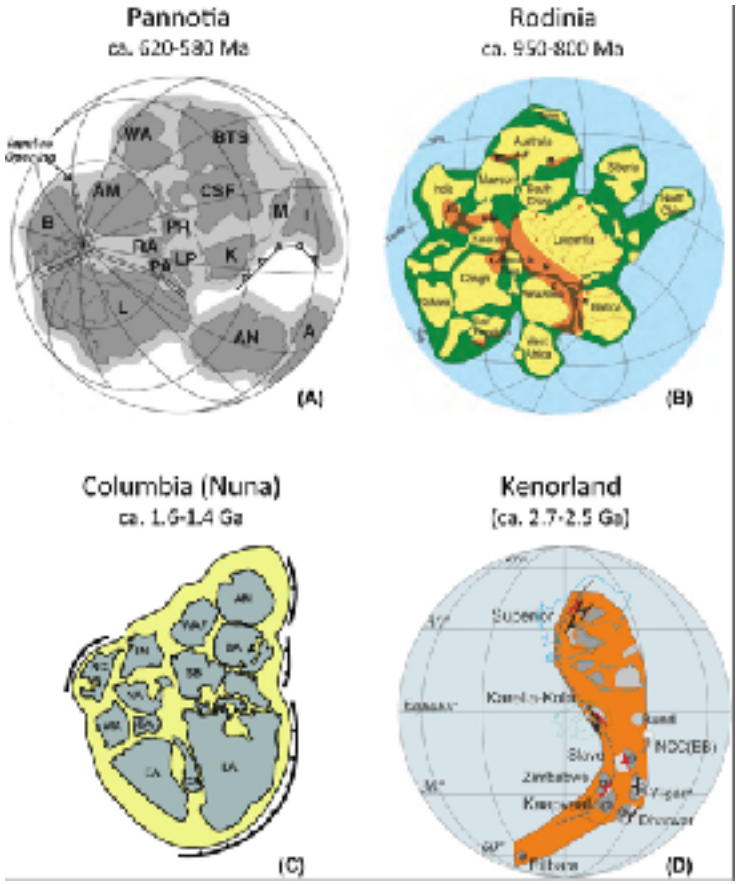
Climate Change Drivers

Tectonics: Formation of Super-continents & Geochemical Cycle

Volcanism: Volcanoes and Large Igneous Provinces

Biosphere: Disruption to the Carbon and Sulfur cycles

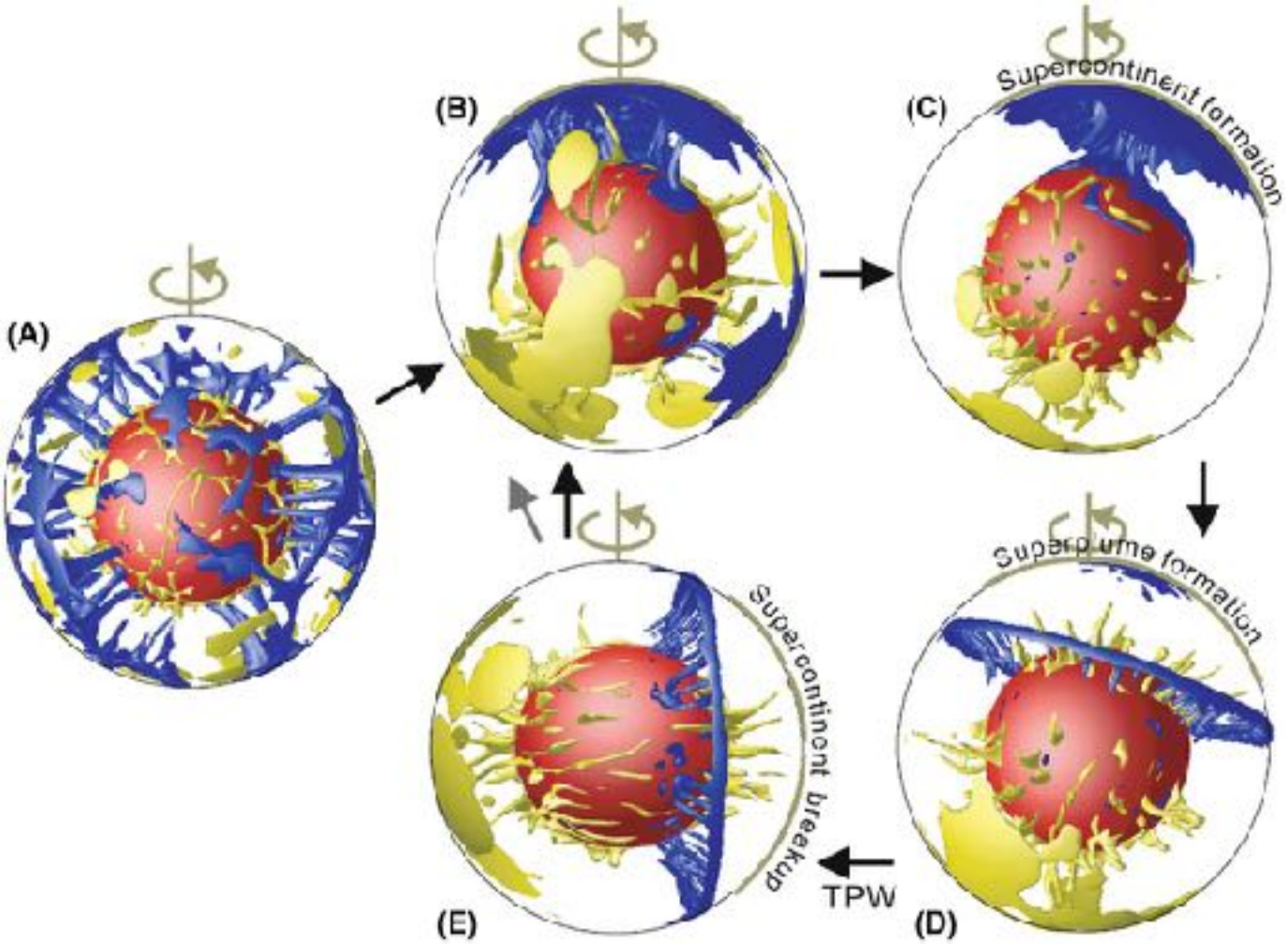
Tectonics and Climate: Supercontinents



Pangea

Source:https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/nyas.14849

Tectonics and Climate: Supercontinents



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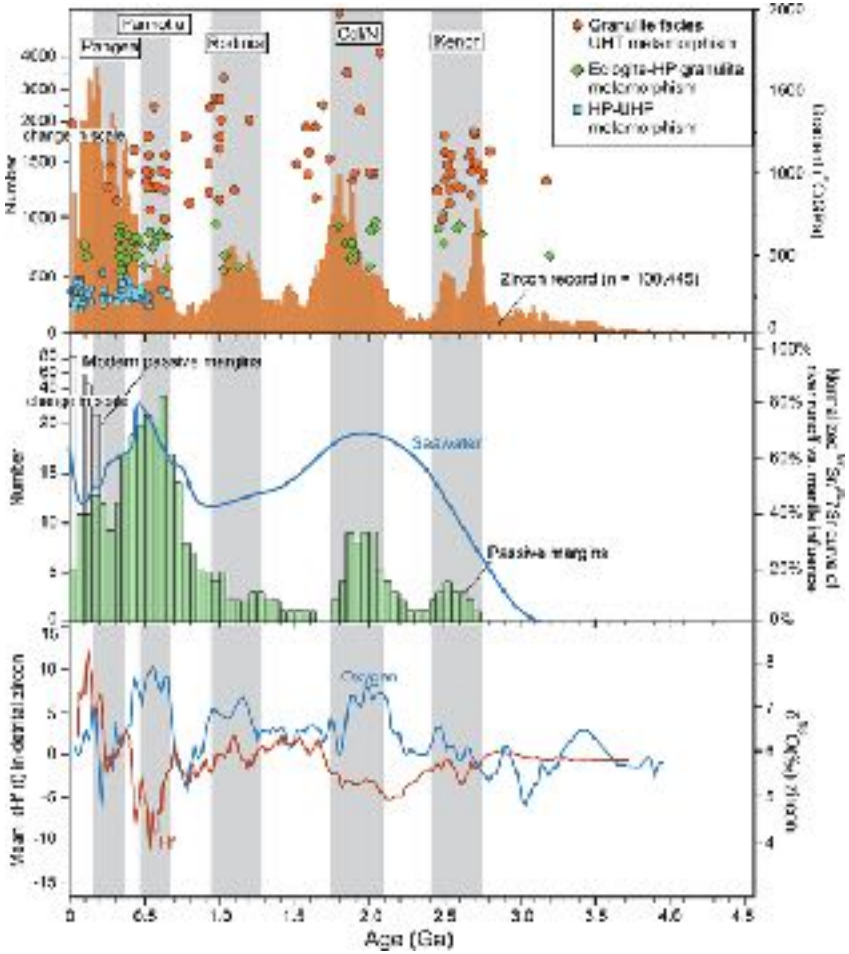
Tectonics and Climate: Supercontinent Formation



Supercontinents lead to mountain building:

More granulite facies (> in regional meta)

More passive margins (> in sedimentation)

Higher nutrient supply to seawater

>>>> Results in climate change:

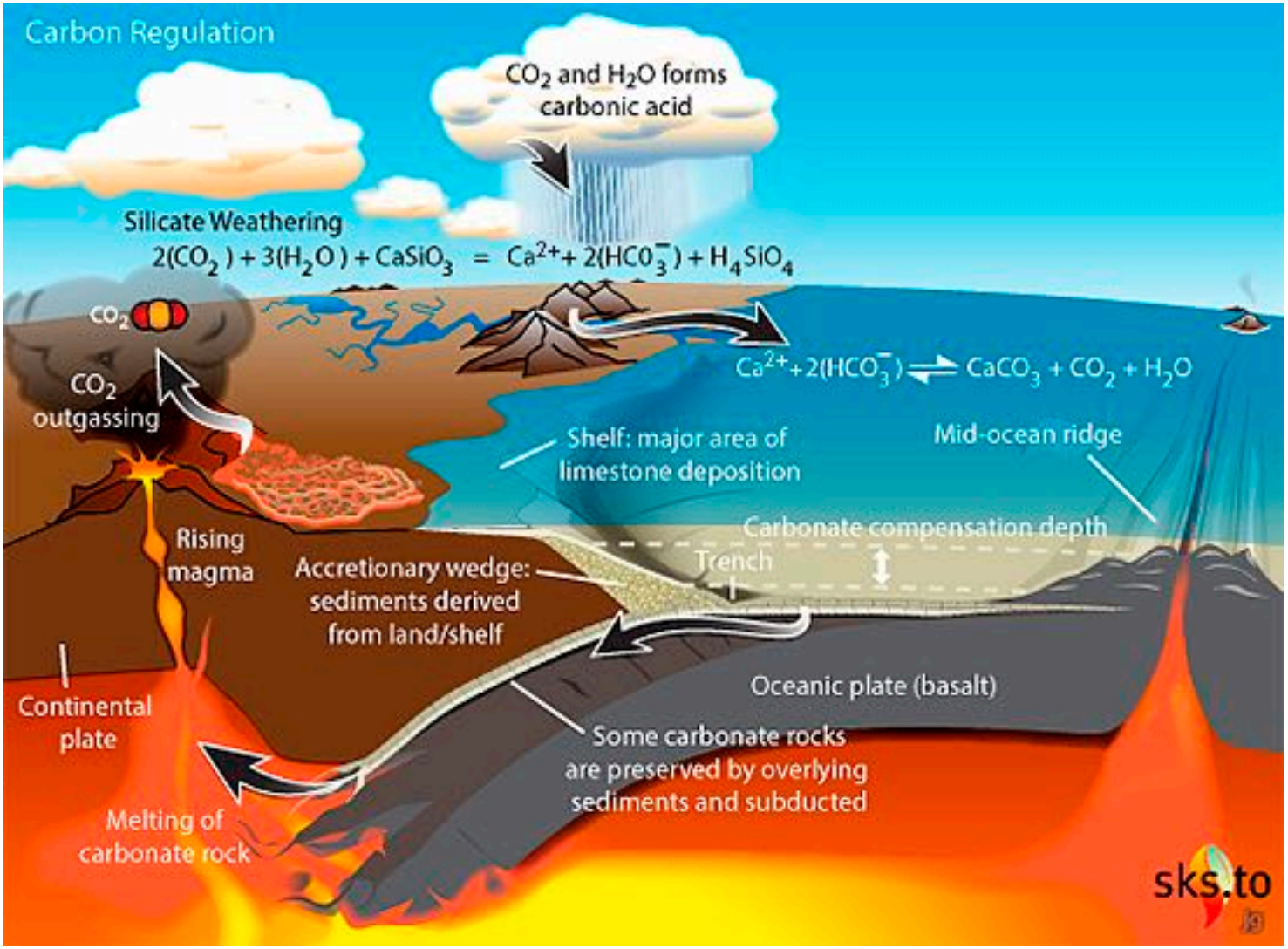
Drawdown on atmospheric CO_2 levels: cooling

Marine productivity: rises in atmos. O_2 levels

Extreme ends of the Carbonate-silicate cycle

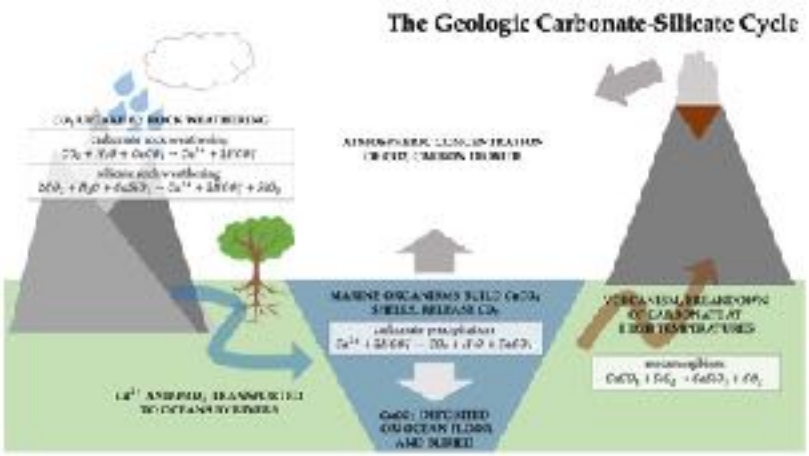
Source:https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/nyas.14849

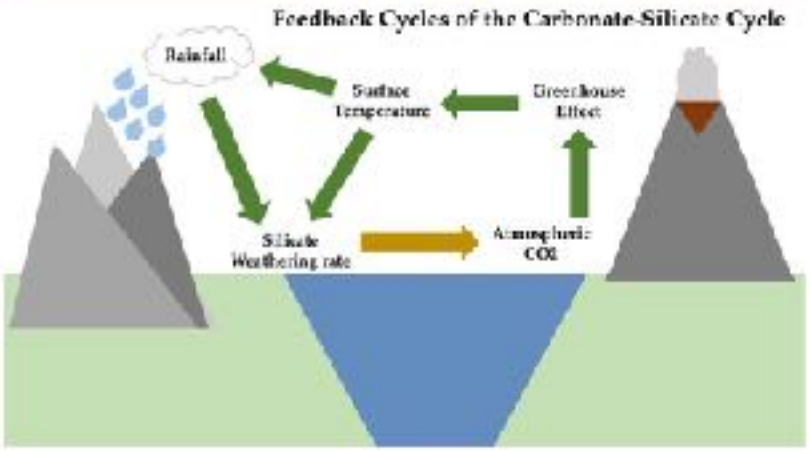
Carbonate-Silicate Cycle (Inorganic Carbon Cycle)



Source: https://en.wikipedia.org/wiki/Carbonate%E2%80%93silicate_cycle#:~:text=The%20carbonate%E2%80%93silicate%20geochemical%20cycle,rocks%20by%20metamorphism%20and%20volcanism.

Carbonate-Silicate Cycle (Inorganic Carbon Cycle)





Regulates CO_2 in the atmosphere:

Carbon removed and buried (= cooling)

Buried sediment become rocks or subducted

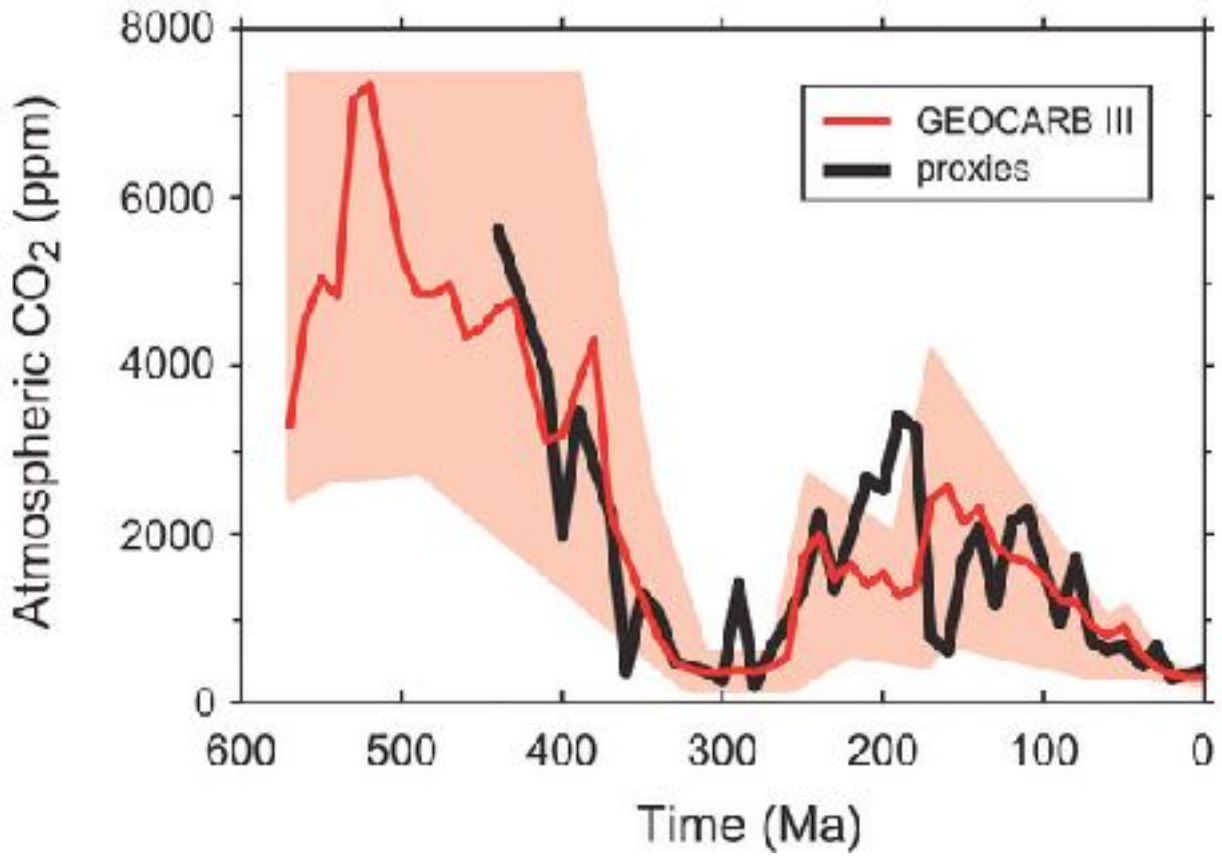
Carbon returned to atmosphere via volcanism

>> Results in climate change (increase in CO_2)

Over long periods of time (100Ma)

Source: https://en.wikipedia.org/wiki/Carbonate%E2%80%93silicate_cycle#:~:text=The%20carbonate%E2%80%93silicate%20geochemical%20cycle,rocks%20by%20metamorphism%20and%20volcanism.

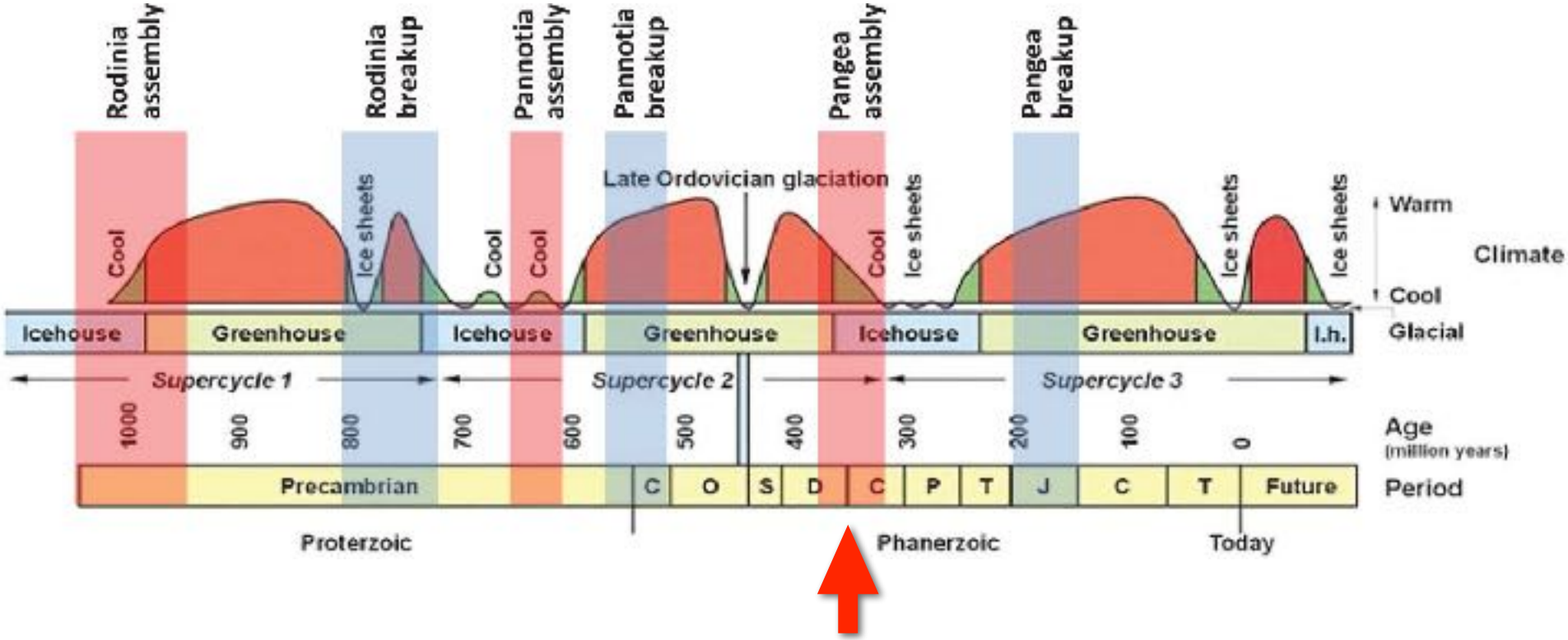
Tectonics and Climate: Supercontinent Formation



Pangea corresponds with drastic reduction in CO_2

Source:https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/nyas.14849

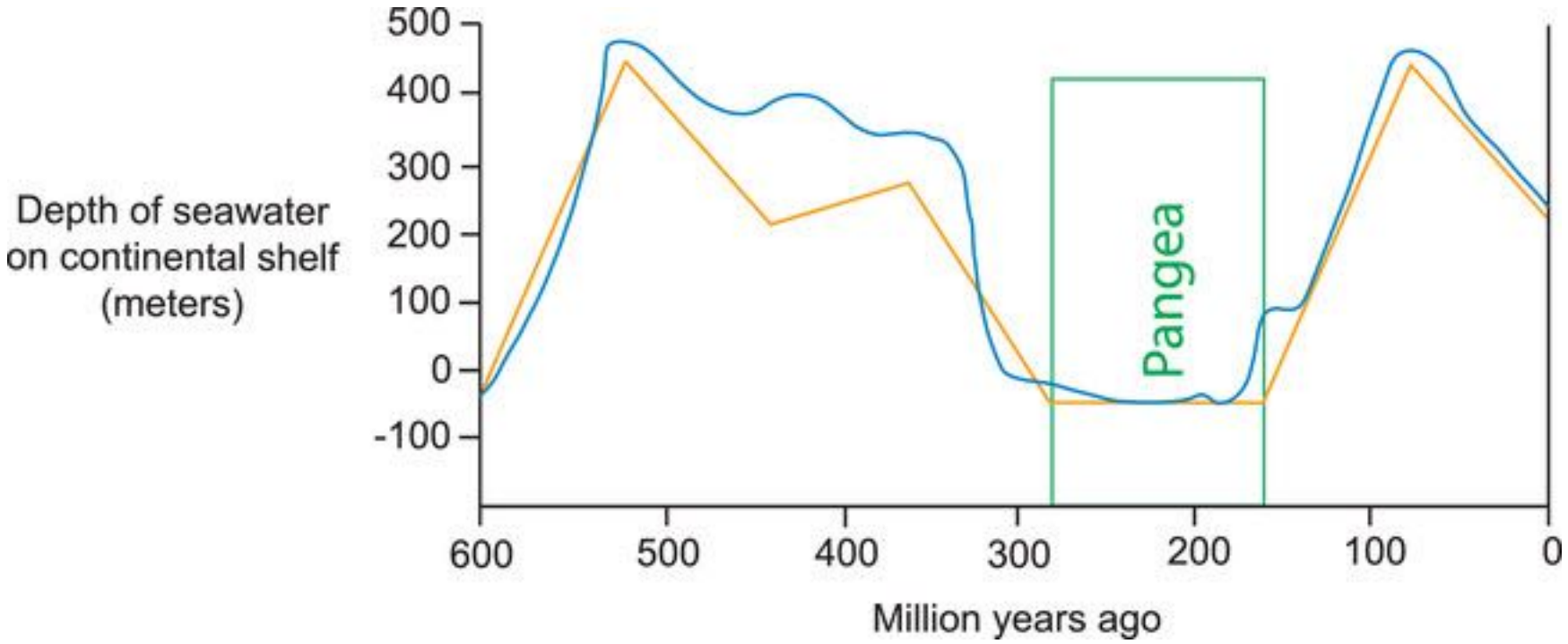
Tectonics and Climate: Supercontinent Formation



Pangea corresponds with changes in icehouse and greenhouse climates

Source:https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/nyas.14849

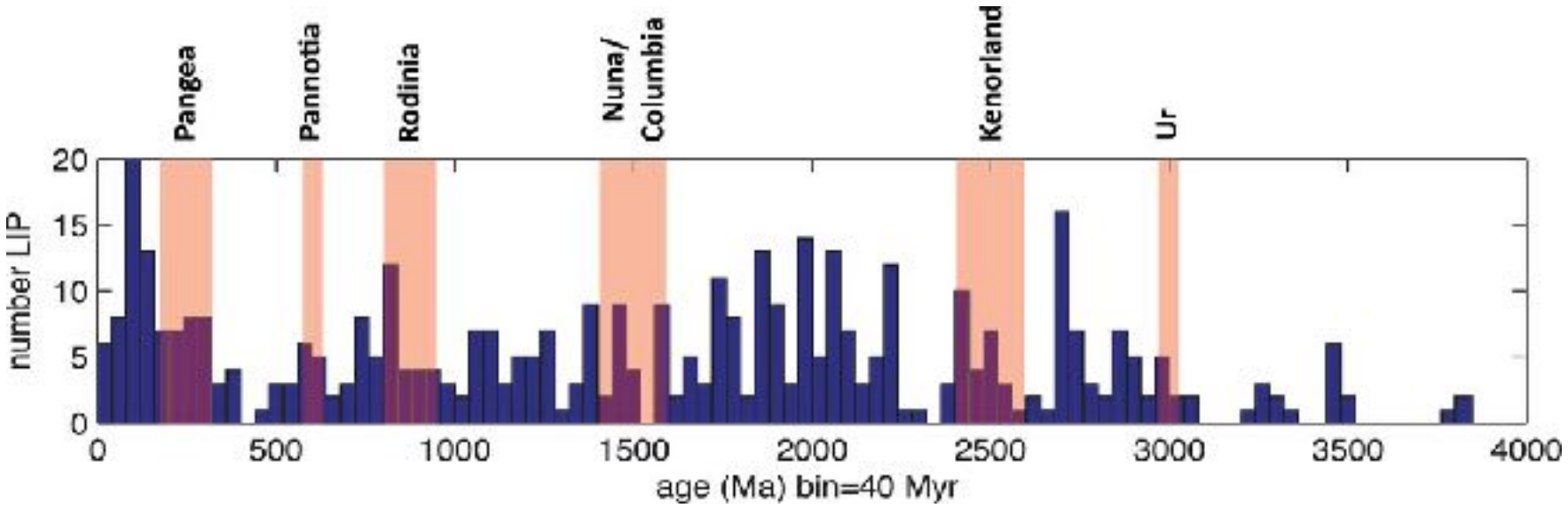
Tectonics and Climate: Supercontinents



Sea level change

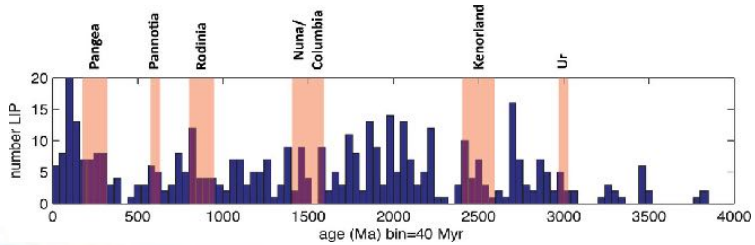
Source:https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/nyas.14849

Tectonics and Climate: Supercontinents



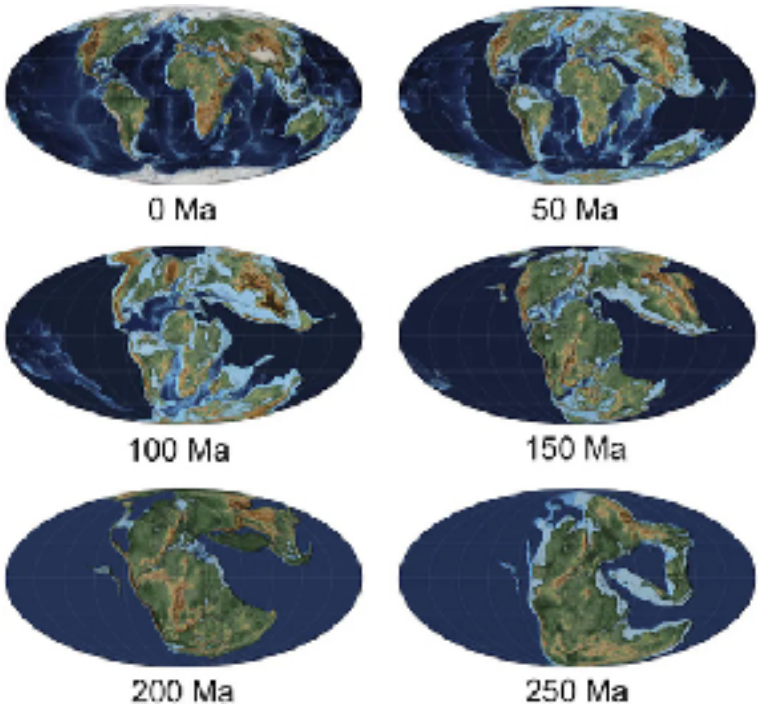
Supercontinent break-up corresponds to volcanism

Source:https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/nyas.14849



~250Ma in the future: Pangea Ultima

Tectonics and Climate: Supercontinent Break-up



Break-up or dispersal leads to volcanism:

Creation of Large Igneous Provinces (e.g., traps)

Contact Metamorphism

Decease in weathering and CO_2 burial

>>>> Results in climate change:

LIP venting of greenhouse gases (warming)

Sea level rises

Extreme ends of the Carbonate-silicate cycle

Source:https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/nyas.14849

Volcanism and Climate: Mount Pinatubo Effect (1991)

Largest Sulphur Dioxide (SO_2) cloud in 20th century*

17 million tonnes of SO_2 released

Global temperature decrease of 0.9c

>>>> Mount Pinatubo Effect:

Sulphur particles in stratosphere are light scattering

Acts as cloud condensation nuclei

Leads to cooling

Geoengineering a manmade Mt Pinatubo Effect

Recent “reverse” Mt Pinatubo Effect

Source: https://www.usgs.gov/observatories/hvo/news/volcano-watch-pinatubo-effect-can-geoengineering-mimic-volcanic-processes

Volcanism and Climate: Mount Pinatubo Effect

International Maritime Organisation new rules:

From 2020 ships to use low-sulphur fuel

Sulphur dioxide leads to acid rain and health issues

Immediate decrease in SO_2 emissions

>>>> Reverse Mount Pinatubo Effect:

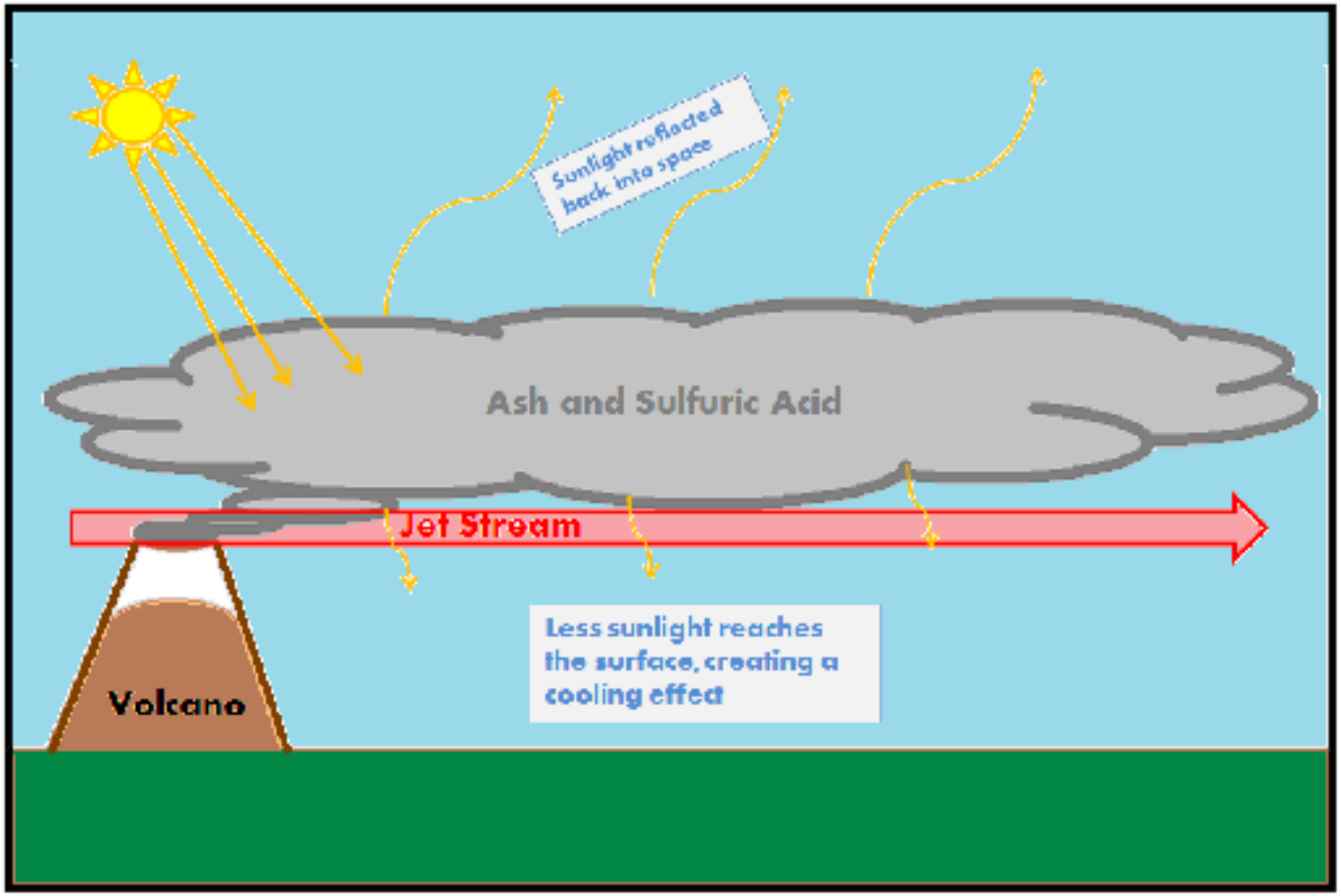
Sulphur particles in stratosphere are light scattering

Fewer particles has lead to warming of surface waters

Increase of surface waters 0.05^{c} by 2025

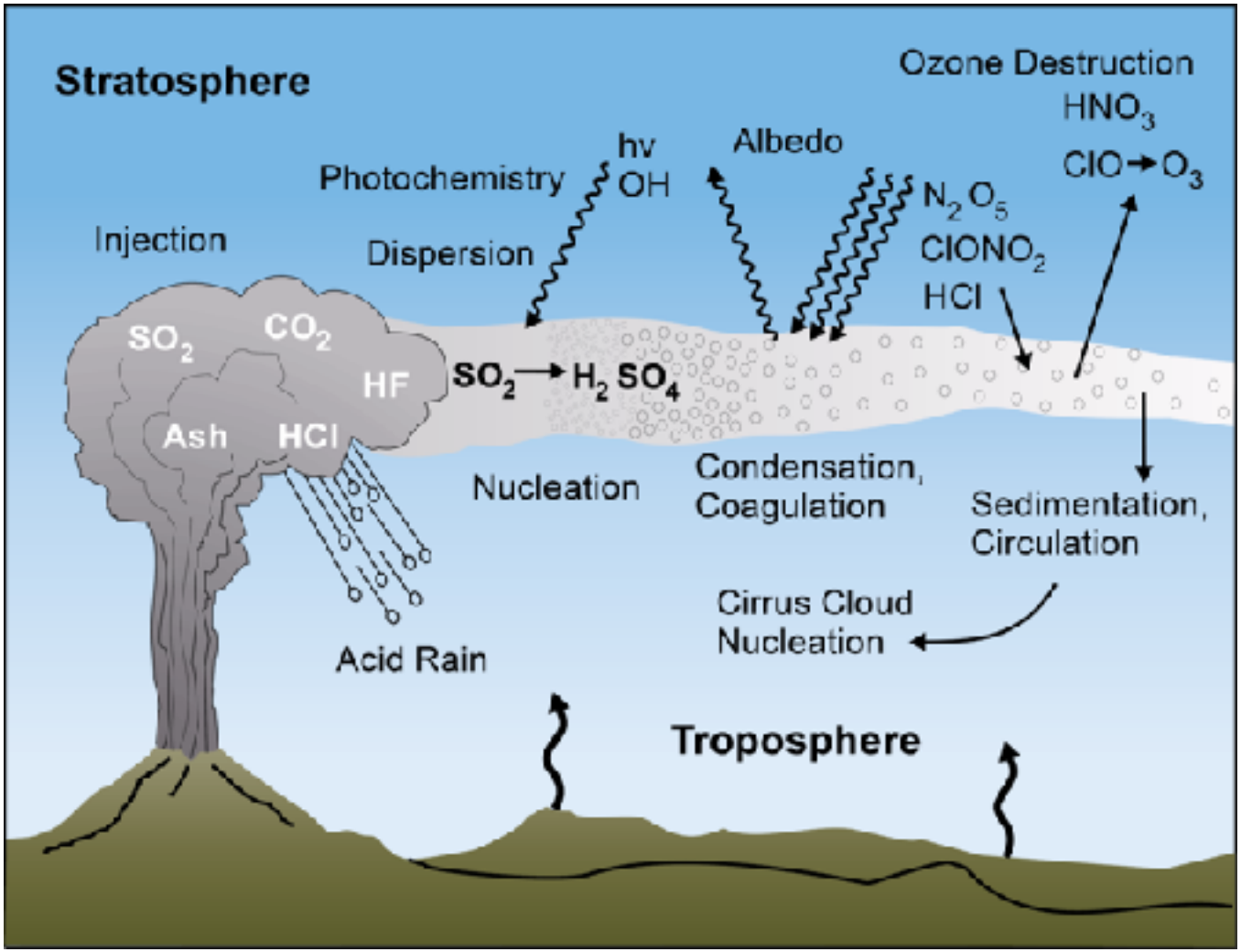
Source: https://www.weforum.org/agenda/2023/07/sea-surface-temperature-imo-low-sulphur-fuel-shipping/

Volcanic eruptions



Major volcanic eruptions have had significant effects on climate because of high SO_2 emissions

Volcanic eruptions



Volcanoes erupt more SO_2 than CO_2.

Human activity produces more CO2 than volcanoes in the 20th century

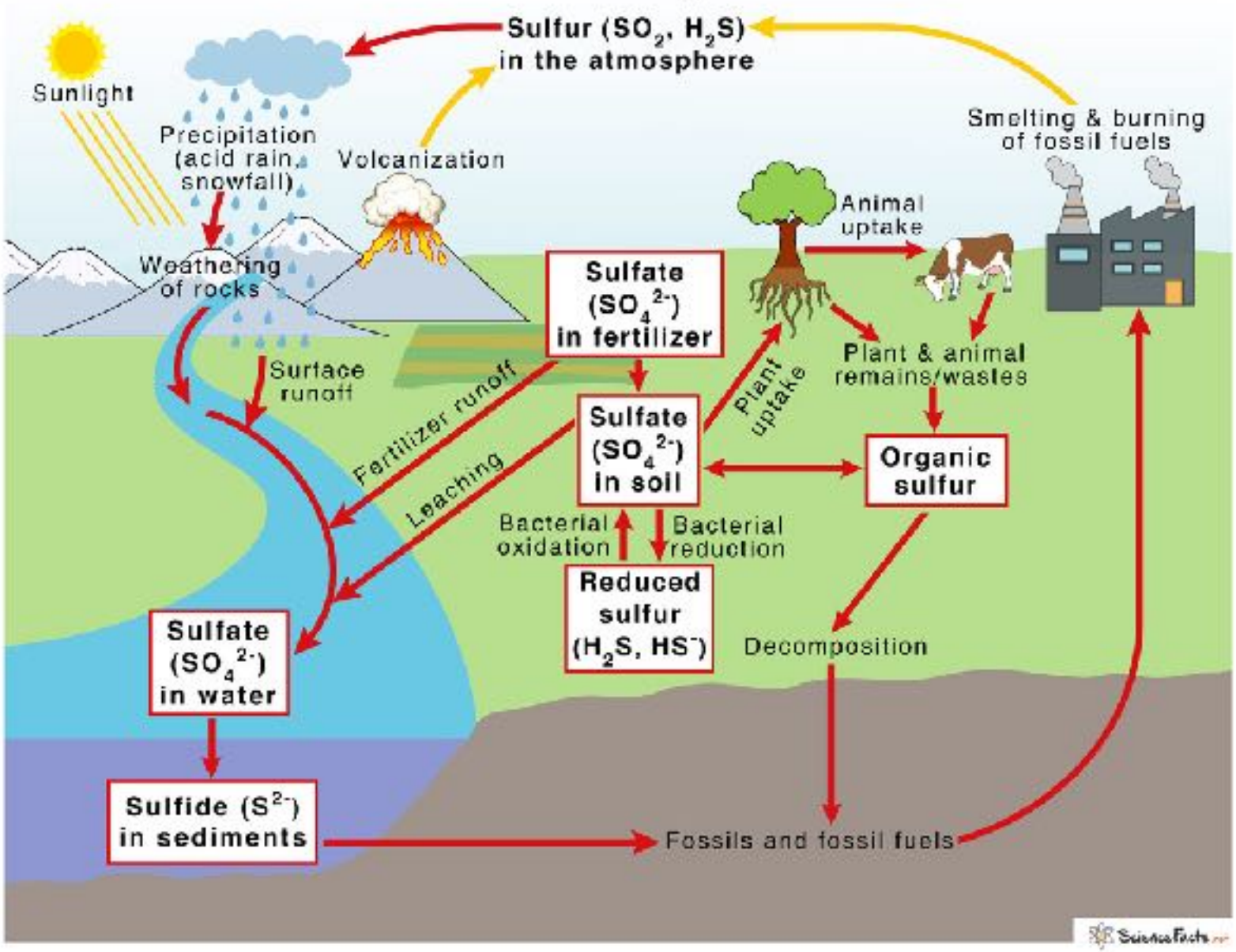
Volcanic eruptions

CO_2 Emitters	Billions of metric tonnes per yer (Gt/y)
Mt Pinatubo (1991)	0.05Gt
Mt St Helens (1981)	0.01Gt
Fuel combustion (2015)	32.3Gt

Number of days for anthropogenic CO_2 to equal a years worth of global volcanism?

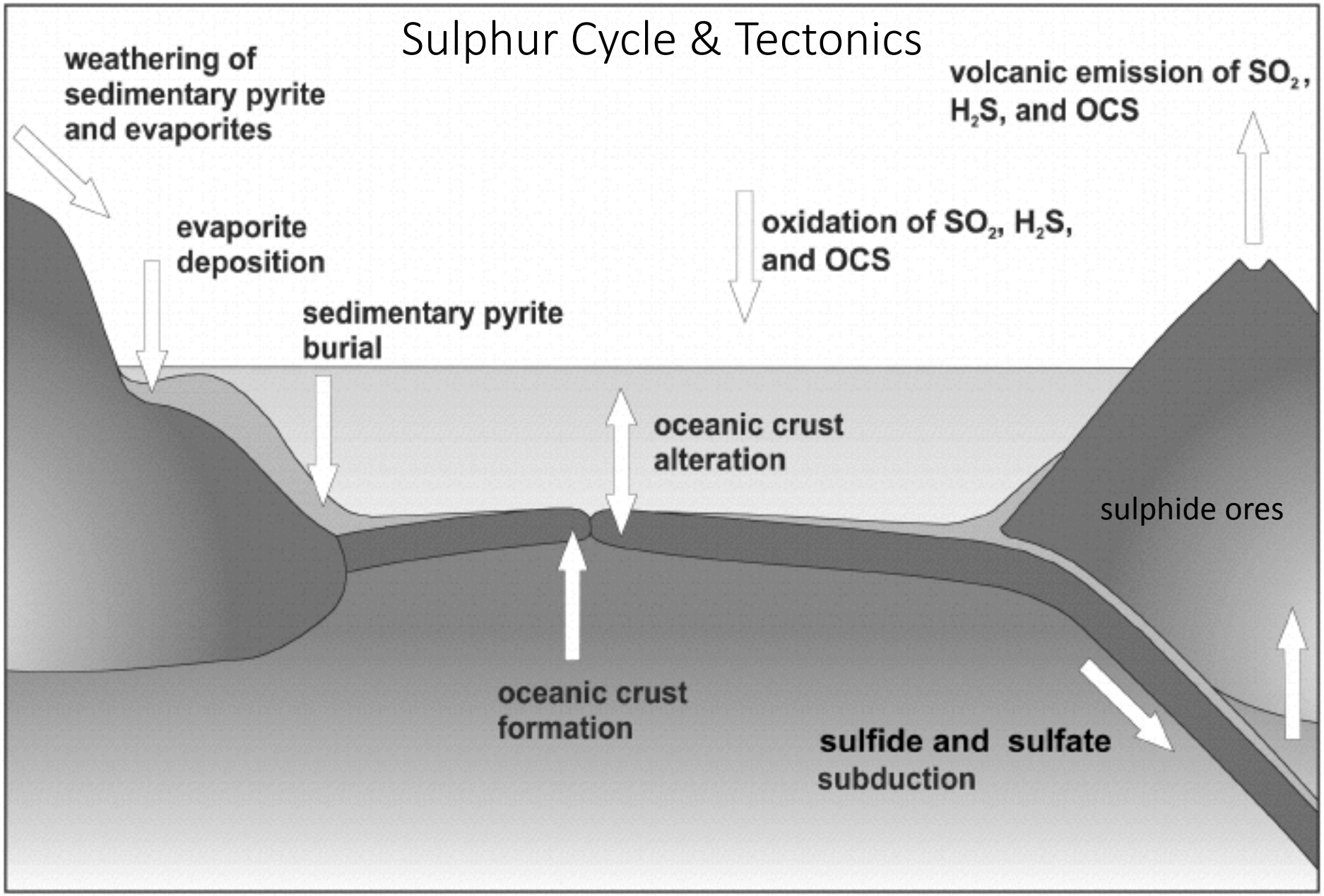
2.7 days

Sulfur Cycle



Short term effects: Saharan dust feeding the Amazon

Sulphur Cycle & Tectonics



News Break

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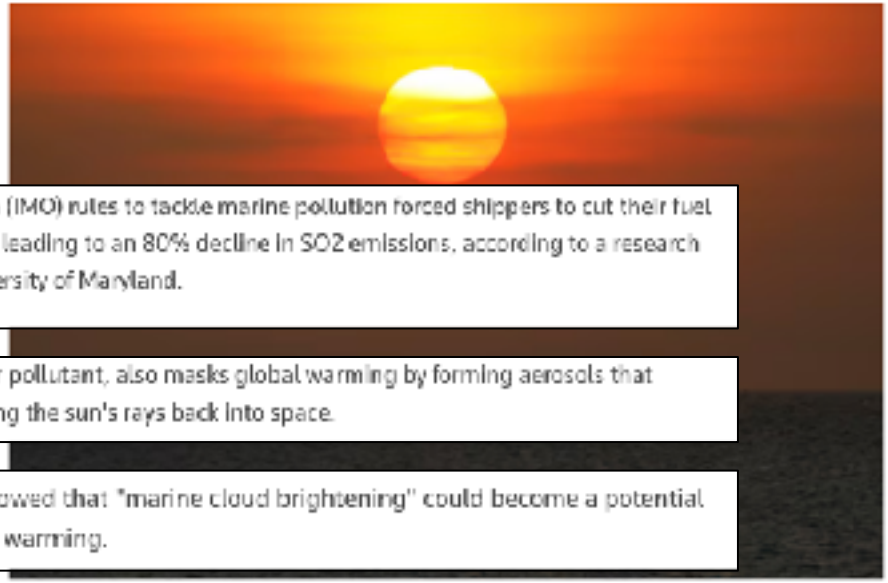
Cleaner shipping fuel is contributing to ocean warming, scientists say

By David Stanway

June 1 2024 2:04 AM GMT+10 · Updated 5 months ago



Aboat sails on the Gulf Of Thailand during the sunset at Ko Samui in Thailand March 3, 2020. REUTERS/Navesh Chitrakar/File Photo

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International Maritime Organization (IMO) rules to tackle marine pollution forced shippers to cut their fuel sulphur content to 0.5% from 3.5%, leading to an 80% decline in SO2 emissions, according to a research team led by Tianle Yuan at the University of Maryland.

SO2, however, besides being a major pollutant, also masks global warming by forming aerosols that thicken and brighten clouds, reflecting the sun's rays back into space.

The authors said their research showed that "marine cloud brightening" could become a potential geoengineering solution to global warming.

communications earth & environment

Article

https://doi.org/10.1038/s43247-024-01442-3

Abrupt reduction in shipping emission as an inadvertent geoengineering termination shock produces substantial radiative warming

Check for updates

Tianle Yuan[1,2], Hua Song[2,3], Lazaros Oreopoulos[2], Robert Wood[1], Huisheng Bian[1,2], Katherine Breen[2,4], Mian Chin[2], Hongbin Yu[2], Donifan Barahona[2], Kerry Meyer[2] & Steven Platnick[2]

Human activities affect the Earth's climate through modifying the composition of the atmosphere, which then creates radiative forcing that drives climate change. The warming effect of anthropogenic greenhouse gases has been partially balanced by the cooling effect of anthropogenic aerosols. In 2020, fuel regulations abruptly reduced the emission of sulfur dioxide from international shipping by about 80% and created an inadvertent geoengineering termination shock with global impact. Here we estimate the regulation leads to a radiative forcing of $+0.2 \pm 0.1 \mathrm{Wm}^{-2}$ averaged over the global ocean. The amount of radiative forcing could lead to a doubling (or more) of the warming rate in the 2020 s compared with the rate since 1980 with strong spatiotemporal heterogeneity. The warming effect is consistent with the recent observed strong warming in 2023 and expected to make the 2020 s

Interpreting the Data

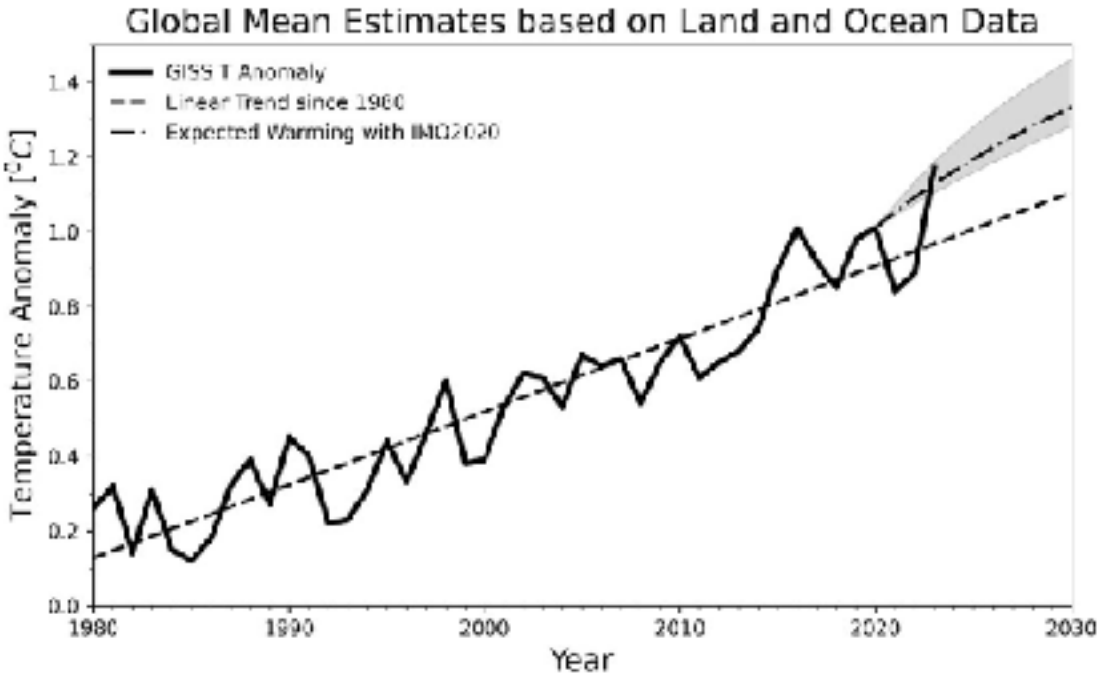


Fig. 3 | Time series of global temperature anomaly since 1980 (Lensen et al., 2019). The trend line is dashed. The expected warming trajectory from the combination of the linear trend and the calculated warming effect from IMO 2020 shock based on the energy balance model. The upper and lower bounds of the expected warming are shown in shades. The baseline period for temperature anomaly is between 1951 and 1980.

The Problem with Modelling

"There seem to be **some mathematical issues** with the key calculation, as the calculated warming from the energy balance model is applied on top of the observed 2020 temperature anomaly, likely 'double counting' some of the warming effect of sulphur reductions. The authors are **using 2020 observations as their baseline starting point**, which already includes some of the effect that are trying to simulate. This placement of the calculated warming is necessary for the conclusion that the warming effect from shipping sulphur reductions is consistent with the observed temperature anomaly in 2023 – without it, it's not possible to make this claim.

The language used in the paper, which is reflected in the press release, frames the change of a shift from high-sulphur emissions from shipping to lower-sulphur emissions as 'inadvertent geo-engineering'".

Dr Laura Wilcox, University of Reading who uses a **"different approach to calculate the climate response to the phasing-out of sulphur from shipping emissions"**

Large Igneous Provinces (LIPs)

Big and very active volcanic regions. Think of Iceland …

Large Igneous Provinces (LIPs)

CO_2 Emitters	Billions of metric tonnes per yer (Gt/y)
Mt Pinatubo (1991)	0.05Gt
Mt St Helens (1981)	0.01Gt
Fuel combustion (2015)	32.3Gt
Deccan traps (66Ma)	35000Gt (in total) or in the next 10,000 years
Central Atlantic (200Ma)	164000Gt (in total)
Siberian traps (250Ma)	208000Gt (in total)

Deccan traps played a moderate role in mass extinction … the bolide did the rest!

Large Igneous Provinces (LIPs)

… and think big

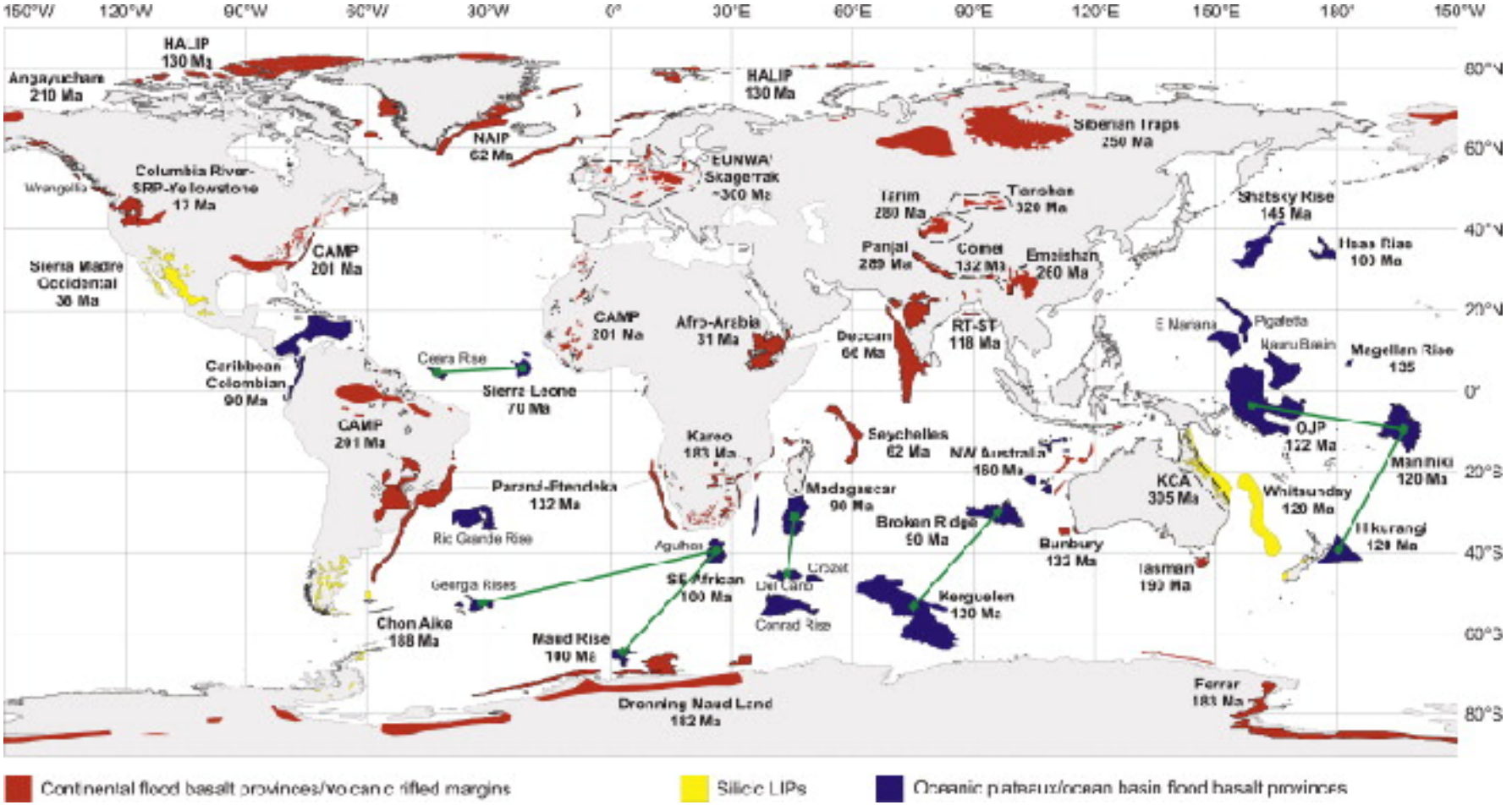
Eyjafjallajökull erupted in 2010

0.024Gt of CO_2 in one year (eruption took 4 months). In 1821 it erupted for over two years

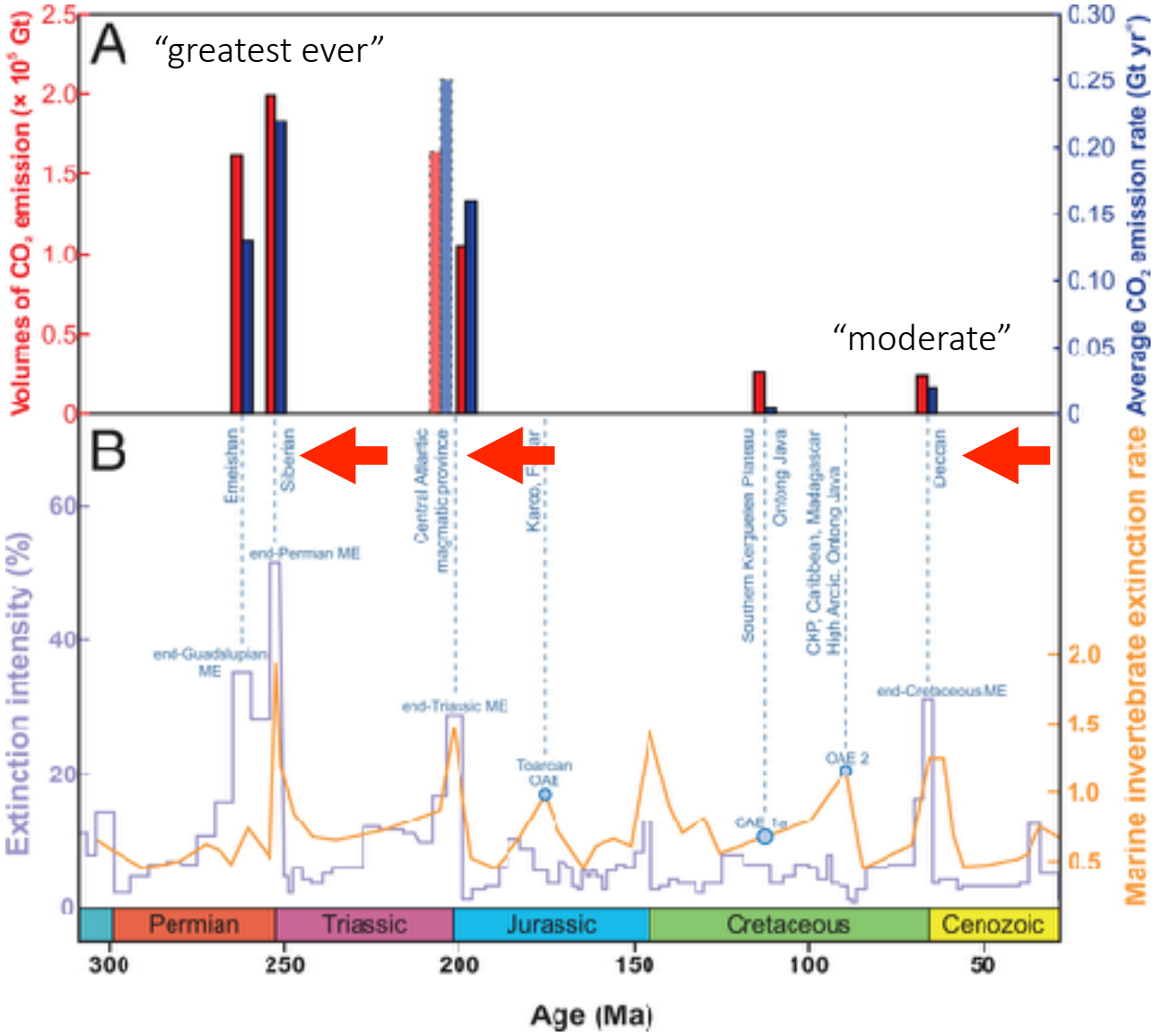
Large Igneous Provinces (LIPs)

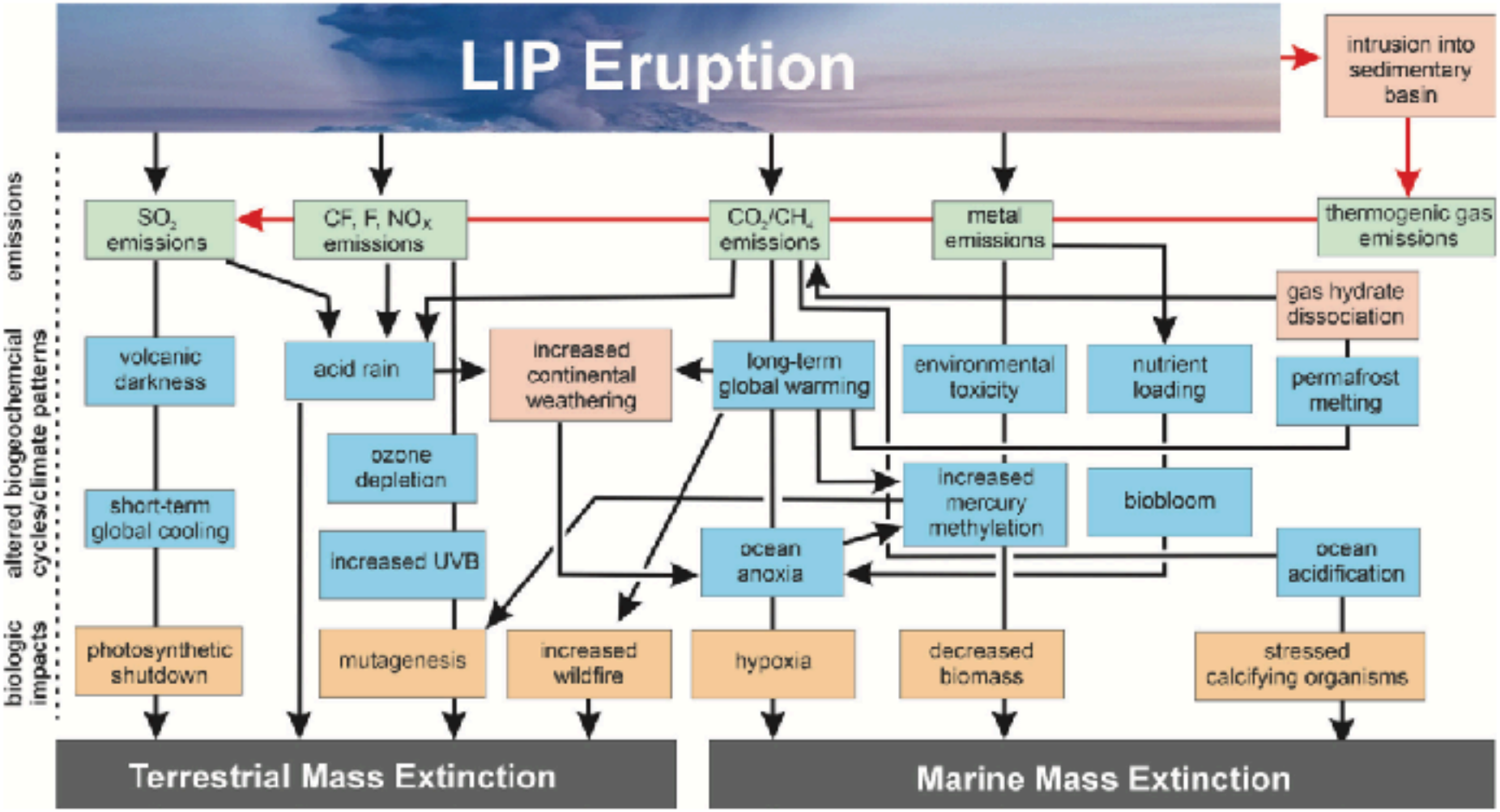
The Siberian traps erupted for 2 million years!

Large Igneous Provinces (LIPs): Where are they?



Large Igneous Provinces (LIPs) through time





"The cascading impacts of a large igneous province eruption and the impacts various emissions have on geochemical cycles and how that affects life, leading to terrestrial and marine mass extinctions. Boxes are colour-coded as follows: green = emissions; blue = altered biochemical cycles and the climatic effects of emissions; tan = biological impacts; and pale pink = altered terrestrial processes"

Disruption to Cycles = Climate Change

Carbon cycle is disrupted by tectonics:

>>>>Formation of Supercontinents

Carbonate end of the C-S cycle

Mountain Building

CO2 is stored

>>>>Dispersal of Supercontinents

Silicate end of the C-S Cycle

Volcanism (i.e., LIP)

CO_2 and SO_2 are released