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.

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Volcanic eruptions deplete the ozone layer.
NORMA L 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

Footprints
Sudden warming
Slow cooling
Erratic sequences

Eemian Interglacial
End of Ice Age

NGRIP 2004
Basaltic volcanism warmed the world out of the last ice age.
In only 6 months, it oozed basaltic lava over an area of 85 km², 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.
Laki 1783 (Iceland)

565 km² in 8 months

Temperatures in Europe raised 3.3°C, tens of thousands killed primarily by the effects of SO₂, sulfuric acid, and resulting famine

Eldgjá 935 (Iceland)

800 km² in 3-8 years

Led to the onset of the Medieval Warm Period
Deccan Basalts
7,000,000 km²

Siberian Basalts
11,000,000 km²

Central Atlantic Magmatic Province
500,000 km²

96% marine
70% terrestrial vertebrates

Deccan Basalts
96% marine
70% terrestrial vertebrates

Percent extinction

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$_2$S)

Cause major mass extinctions especially when lasting for long periods

Bárðarbunga largest since 1783—explains why 2016 hottest year
Explosive, aerosol forming, volcanic eruptions

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

Krakatau (1883) cooled ocean for more than 100 years

Multiple eruptions increment world into an ice age

Robock, 2002
Gleckler et al., 2006
Gregory et al., 2006
Stack of 57 globally distributed benthic $\delta^{18}O$ 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.

17 largest out of >200 LIPS

- Siberian basalts
- Deccan basalts
- Uatuma
- Emeishan basalts

Only 104 ages since 540 Ma

- Snowball Earth
- Guibei
- Umkondo
- Mackenzie

The balance of effusive and explosive volcanism explains climate change in detail.
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

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Fundamental problem in the way computer models calculate heat flux

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