Volcanic eruptions: The forgotten source of abrupt climate change?

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The “Year Without a Summer”

CLIMATIC AND DEMOGRAPHIC CONSEQUENCES OF THE MASSIVE VOLCANIC ERUPTION OF 1258

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Abstract. Somewhere in the tropics, a volcano exploded violently during the year 1258, producing a massive stratospheric aerosol veil that eventually blanketed the globe. Arctic and Antarctic ice cores suggest that this was the world’s largest volcanic eruption of the past millennium. According to contemporary chronicles, the stratospheric dry fog possibly manifested itself in Europe as a persistently cloudy aspect of the sky and also through an apparently total darkening of the eclipsed Moon. Based on a sudden temperature drop for several months in England, the eruption’s initiation date can be inferred to have been probably January 1258. The frequent cold and rain that year led to severe crop damage and famine throughout much of Europe. Pestilence repeatedly broke out in 1258 and 1259; it occurred also in the Middle East, reportedly there as plague. Another very cold winter followed in 1260–1261. The troubled period’s wars, famines, pestilences, and earthquakes appear to have contributed in part to the rise of the European flagellant movement of 1260, one of the most bizarre social phenomena of the Middle Ages. Analogies can be drawn with the climatic aftereffects and European social unrest following another great tropical eruption, Tambora in 1815. Some generalizations about the climatic impacts of tropical eruptions are made from these and other data.

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Makin, 1260; Bar-Hebraeus, 1286). Because the Middle East has been historically prone to epidemics of bubonic plague, possibly that is what it was.

6. The Flagellants

Flagellation, or scourging, had long been practiced as an occasional form of discipline or penance within Christian monastic communities. In the spring of 1260, however, a popular penitential movement of self-flagellation arose in Perugia, central Italy, and spread south, in the autumn, to Rome and north toward central Europe. Wholly orthodox at first, it attracted not only members of the clergy but all ranks and ages of pious lay people. Early in the following year, though, it degenerated into a heterodox movement of peasants and malcontents, which was put down finally by the ecclesiastical and civil authorities. In its typical manifestation, bands of unshirted male flagellants marched through the streets in double file, uttering hymns and religious slogans and flogging their backs with whips until blood began to flow. Troops of flagellants traveled from town to town. It was one of the oddest mass social phenomena of the Middle Ages.

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Extreme weather events of 535–536 CE

- The sun was dark and its darkness lasted for eighteen months; each day it shone for about four hours; and still this light was only a feeble shadow; the fruits did not ripen and the wine tasted like sour grapes. - Michael the Syrian

- During this year [536 CE] a most dread portent took place. For the sun gave forth its light without brightness ... and it seemed exceedingly like the sun in eclipse, for the beams it shed were not clear. - Procopius of Caesarea

- Crop failures and famine worldwide

- Low temperatures, including summer snowfall, in China

- A “dense, dry fog” in the Middle East, China and Europe

- Drought in Central and Southern America; fall of the city of Teotihuacán

- Scandinavian elites sacrificed large amounts of gold, possibly to appease the angry gods and get the sunlight back

- Probably caused by a volcanic eruption in around 533 CE


Abrupt onset of the Little Ice Age triggered by volcanism
and sustained by sea-ice/ocean feedbacks

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Northern Hemisphere summer temperatures over the past 8000 years have been paced by the slow decrease in summer
insolation resulting from the precession of the equinoxes. However, the causes of superposed century-scale cold
summer anomalies, of which the Little Ice Age (LIA) is the most extreme, remain debated, largely because the natural
forcings are either weak or, in the case of volcanism, short
lived. Here we present precisely dated records of ice-cap growth from Arctic Canada and Iceland showing that LIA
summer cold and ice growth began abruptly between 1275
and 1300 AD, followed by a substantial intensification 1430–
1455 AD. Intervals of sudden ice growth coincide with two of the most volcanically perturbed half centuries of the past millenniu
A transient climate model simulation shows that explosive volcanism produces abrupt summer cooling at these
times, and that cold summers can be maintained by sea-ice/
ocean feedbacks long after volcanic aerosols are removed. Our
results suggest that the onset of the LIA can be linked to an
unusual 50-year-long episode with four large sulfur-rich
explosive eruptions, each with global sulfate loading >60 Tg.
The persistence of cold summers is best explained by consequent
sea-ice/ocean feedbacks during a hemispheric summer
insolation minimum; large changes in solar irradiance are not
required. Citation: Miller, G. H., et al. (2012), Abrupt onset of the
Little Ice Age triggered by volcanism and sustained by sea-ice/ocean
2011GL050168.
Boundary conditions over the past 2000 years

**Insolation (2000 CE minus 0 CE)**

**Equivalent CO₂ concentration**

**Total solar irradiance**

**Radiative forcing due to volcanoes**
Annual-mean Northern Hemisphere temperature
Annual-mean Northern Hemisphere temperature

- Orbital + Greenhouse
  - Year CE: 500 to 2000
  - Temperature anomaly (K)
  - $r = +0.11$

- Orbital + Greenhouse + Solar
  - Year CE: 500 to 2000
  - Temperature anomaly (K)
  - $r = +0.18$
Annual-mean Northern Hemisphere temperature
Annual-mean Northern Hemisphere temperature

 Courtesy of Laura Fernández Donado, Universidad Complutense de Madrid
Palaeoclimate Transient Climate Response

Courtesy of Laura Fernández Donado, Universidad Complutense de Madrid
Volcanic forcing during the 15th century

Northern Hemisphere (Gao et al, 2008)

Southern Hemisphere (Gao et al, 2008)

Global (Crowley et al, 2008)
Volcanic forcing during the 15th century

Northern Hemisphere (Gao et al, 2008)

Southern Hemisphere (Gao et al, 2008)

Global (Crowley et al, 2008)
NH temperature during the 15th century

Original volcanic forcing

Modified volcanic forcing
Australasian climate extremes

OGV–OG Warmest day 3yr window volc composite

OGV–OG Coldest day

OGV–OG Warmest night

OGV–OG Coldest night

Courtesy of Tanya Lippmann, UNSW
Conclusions

- Volcanic eruptions can have catastrophic social and economic impacts. However, the industrial era has been a period of relatively low volcanic activity, so we don’t know the impact that a major eruption would have today.

- There is evidence that volcanic eruptions can push the climate system past tipping points.

- Volcanoes appear to have been the dominant source of forced climate variability over the last millennium.

- Volcanic eruptions offer the potential to directly constrain the transient climate response. However, this requires much more accurate reconstructions of past eruptions and their impacts.