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The Changing Climate
Term Paper
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Volcanism as an Agent of Climate Forcing: The Roles, Extent, and Limitations

Introduction

Volcanoes are not only one of the major shaping processes of earth's surface, but also of earth's atmosphere. Volcanoes are major producers of many gaseous products, including aerosols and greenhouses gases. Both aerosols and greenhouse gases are capable and active participants in climate forcing. There are many examples throughout history of the far reaching and high impact effects of volcanic forcing of climate. Lavas and fiery spouts may, in fact, not be the most dangerous volcanic products after all.

Background Chemistry and Eruptive Products

Volcanoes emit many solid products, such as effusive lava flows, explosive lava bombs, pumices, and scoria [Grunder, 2013]; though the solid volcanic products may be most recognizable to the layperson, it may be the gaseous byproducts of volcanoes that play a larger part in climate forcing. Many gases are produced in gargantuan quantities during a volcanic eruption [USGS, 2014]: (See table 1).

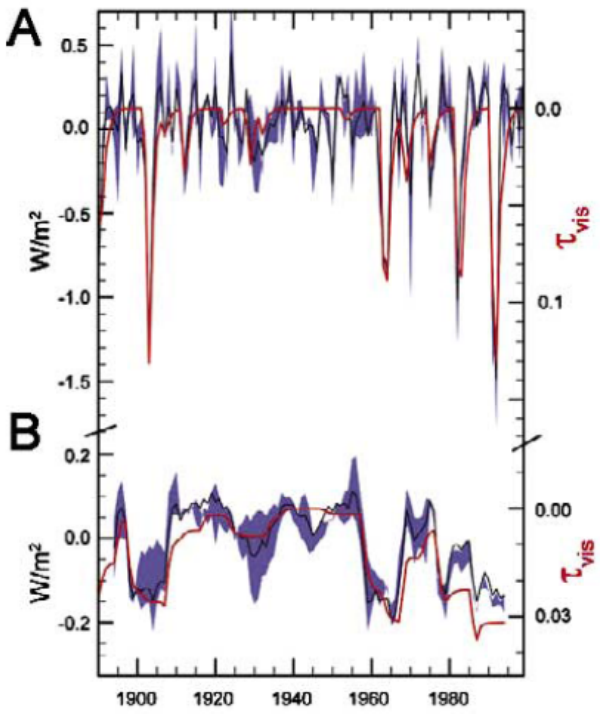
[Table 1: Volcanic Gases]

Volcano Tectonic Style Temperature	Kilauea Summit Hot Spot 1170°C	Erta` Ale Divergent Plate 1130°C	Momotombo Convergent Plate 820°C
H_20	37.1	77.2	97.1
$C0_2$	48.9	11.3	1.44
$S0_2$	11.8	8.34	0.50
H_2	0.49	1.39	0.70
CO	1.51	0.44	0.01
H_2S	0.04	0.68	0.23
HCl	0.08	0.42	2.89
HF	---	---	0.26

Table 1: The most common gases produced by volcanic activity, by percent of volume. [Symonds, et al, 1994]

As is seen in Table 1, the top two volumetrically produced volcanic gases are two of the most potent atmospheric greenhouse gases. These gases serve to add density to the atmosphere. Greenhouse gases transmit short-wave solar radiation and absorb long-wave radiation emitted by the earth. This insulating effect raises the temperature of the earth by keeping more radiation that it emits through the top of the troposphere.

[Figure 1: Volcanic Aerosol Production] [Ammann, et al, 2003]



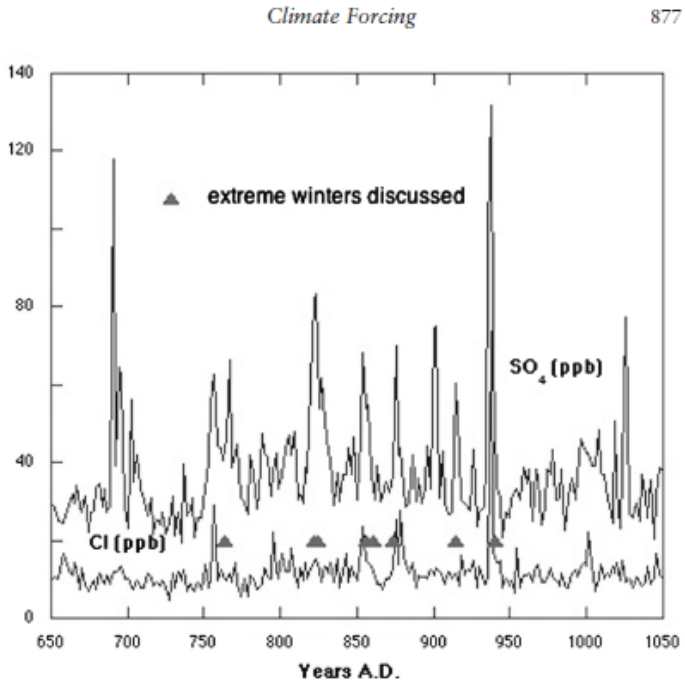
Aerosols are also produced in large quantities by volcanic eruptions. These small particles serve to reflect short-wave solar radiation, preventing this short-wave, high energy radiation from entering the troposphere. The prevention of some solar radiation leads to a drop in total solar irradiance, (TSI), a diminished TSI leads to a cooling earth. Much experimentation has been conducted to distinguish volcanic aerosol production from alternate sources, (See Figure 1). Before humans began producing such large quantities of aerosols, volcanoes were the main source. The extent to which volcanic aerosols limit TSI is quite large, on a regional scale.

Climate Forcing

Once a basic understanding of the gaseous eruptive products of volcanoes is understood, it becomes clear how volcanism could be thought to be a major element of climate forcing. There is however, much more to the impacts of volcanic climate forcing, that just climate focused repercussions.

Historical Example #1 – Cooling

During the period of 750 to 950 A.D., some of the harshest winters were experienced in all of Medieval Europe [McCormick, 2007]. This period was independently deemed crucially important, extreme, and unusually cold; this anomalous set of winters was the subject of a study by McCormick [McCormick, 2007]. This study examined independent proxy data and correlated increased volcanically signature gases to the cold winters; this cold period is observed in several gaseous species, Cl and SO_4 in parts per billion (ppb) [McCormick], (See Figure 2). The cold winters described in McCormick, 2007, have far reaching consequences including a devastated European economy, food shortages, and numerous deaths throughout Europe [McCormick, 2007].



Historical Example #2 – Cooling

Tambora volcano, located in Sumbawa, Indonesia is very large, with a volcanic explosivity index (VEI) of 7 [Robock, 2000]. Tambora has had a history of large eruptions. Among these eruptions was a particularly large one during 1815. This eruption had a dust veil index (DVI/E_{max}) of 3000 [Robock, 2000], which is an extremely large volume of volcanic aerosols [Grunder, 2013]. This large volume of volcanic aerosols in 1815 produced “the Year Without a Summer”, in 1816 (See Figure 3)

[Grunder, 2013]. The year without a summer, was mainly localized to Europe. Even given the somewhat localized nature of this temperature drop, there was a surface air temperature drop of 0.2°C across Europe in the span of one year. (See Figure 3) [Mann et al, 2000]

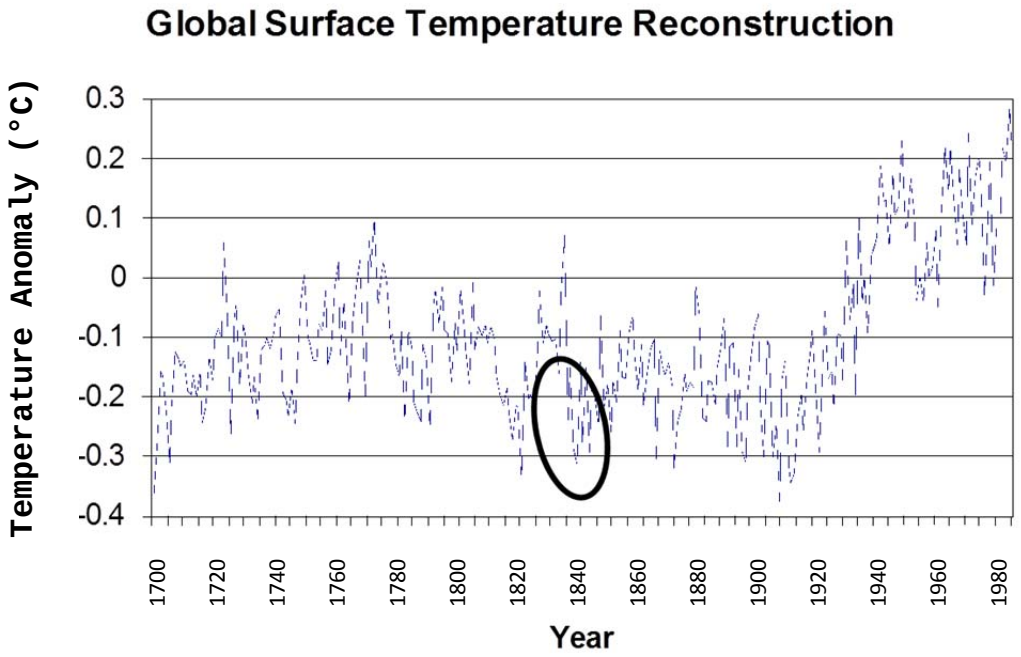


Figure 3: Northern Hemisphere surface air temperatures, from Mann et al. (2000)

1816 just so happened to be the same year that Mary Shelly wrote the essential gothic novel , “Frankenstein”. The author wrote her novel because she was forced to spend an abnormally large amount of time indoors due to the unusually harsh and cold temperatures outside [Grunder, 2013]. This historical example ties volcanic production of greenhouse gases to climate forcing. On a merely interesting and enriching note, this also correlates volcanic forcing of climate change to anthropogenic relevance. Though this only a small change to the world, it is still evidence of climate’s direct impact on human culture. Though the global mean surface temperature was only lowered ~0.2° C during this time, this is still a significant event on such a short timescale of a single year. Most climate changes occur on a more subtle and gradual timescale.

Conclusions

It is true that volcanoes produce both aerosols that block short-wave solar radiation and lead to a trend of global temperature cooling as well as large quantities of CO2 which lead to insulation of the atmosphere and increased reflection of earth emitted long-wave radiation that in turn causes an increase in global temperatures. However, volcanoes are no longer the dominating source of neither aerosols nor CO2. Before humans began dumping greenhouse gases and aerosols into the atmosphere in mass quantities, volcanoes were among the largest producers of CO2, behind biological producers, respiration and decomposition.

Volcanoes have many eruptive products, with the gaseous products being the most relevant to climate forcing, including aerosols and greenhouse gases. There are many historic examples of volcanic driven climate change. Tambora volcano erupted with such a high amount of aerosols that it caused the next summer to be very cold, which helped influence human culture. Medieval Europe experienced a cold set of winters which had far reaching side effects to culture and economy. With many large (VEI >4) volcanic eruptions in the last 100 years [Robock, 2000] and several hundred currently active volcanoes, it is highly likely that, as always, volcanoes are contributing to climate change.

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