The effect of volcanic eruptions on climate

Recently there has been a lot of research in the field of climate change, and much of it is focused on anthropogenic affects on climate. However, there has also been a great deal of research focused on natural Earth processes and how they affect the climate (Robock 2000). One natural process which significantly impacts climate is volcanic eruptions. Volcanic eruptions affect the climate of the earth in many ways (Zielinski et al 1997). Volcanic ash ejected during eruptions effect climate by reflecting solar rays back into space, and thus cooling the surface of the Earth. Another way volcanoes affect the Earth's climate, is the emission of many different types of volcanic gasses.

Volcanic gasses including CO_2, H_2O vapour, and different kinds of sulfur gasses such SO_2 and H_2S, affect the climate in very different ways (Robock 2000). CO_2 and H_2O vapour generally act as green house gasses and work towards heating the Earth's surface temperature. Sulfuric gasses affect climate in more complicated ways which is mainly a function of the concentrations of these gasses in the atmosphere (Ward 2009). This paper will examine the role volcanic eruptions have in affecting climate through the ejection of volcanic ash and the emission of different volcanic gasses including CO_2, H_2O vapour, and sulfuric compounds, and the impact certain historic volcanoes have had on climate by ejecting all of these kinds of particles. Effects of Volcanic Ash on Climate

When Volcanoes erupt they eject large amounts of volcanic ash into the atmosphere (Robock 2000). These particles generally stay in the atmosphere for only a couple of weeks to a couple months. After this time they settle out of the air and become deposited in between sedimentary beds However, while these particles are in the atmosphere they spread around the globe very quickly and affect the earth's climate for the short term of their suspension.

When the ash is suspended in the atmosphere, it has a strong effect on surface temperatures. Robock (2000) explains that the intensities of the diurnal cycle are reduced for regions under the airborne ash clouds. Diurnal cycles refer to the patterns exhibited on a 24 hour time period that continue day to day such as temperature, tides, etc. He explains that the daily temperatures of the Earth's surface are lowered by a couple of degrees because there is less solar insulation which is the amount of sunlight falling on a given area. This decrease in solar insulation is due to the volcanic ash's ability to backscatter the sun's solar rays back into space; therefore, cooling the surface of the Earth.

Not only does volcanic ash affect surface temperatures, it also affects the Earth's precipitation levels during its time of suspension. A study by Wallace et al (1994) examines the composition of the magmatic material which gets ejected from a volcano in the form of ash during eruptions. He explains that the main component in this ash is the anhydrite $CaSO4$. This anhydrite ash will readily absorb water to form the mineral gypsum $CaSO4 \bullet 2H2O$. When the anhydrite absorbs water, it will take it directly from regular rainclouds. This reduction in rain cloud moisture will decrease the amount of precipitation that reaches the Earth's surface leading to potential droughts in certain regions.

Effects of Volcanic CO_2 and H_2O on Climate Volcanoes release many types of gasses when they erupt and within a short amount of time these gasses, like the volcanic ash, circle the globe. According to a study by Bluth et al (1992), the gasses released during the 1982 El Chicho´n eruption in Mexico and the 1991 Mt Pinatubo eruption in the Philippines were scattered around the whole Earth within three weeks. However, unlike volcanic ash which almost always completely settles out in a few months, these volcanic gasses can stay in the atmosphere for many years (Robock 2000). Some gasses like CO_2 and H_2O vapour act as greenhouse gasses warming the surface of the Earth by trapping in the sun's radiation (Cassadevall et al 1983).

Compared to the total anthropogenic emissions of greenhouse gasses, the effect CO_2 and H_2O vapour have on global warming is relatively low, but spikes in greenhouse gas levels can be seen when major eruptions occur (Cassadevall et al 1983). During the Mt St Helens eruption in 1980, Cassadevall et al (1983) used a gas chromatograph to measure the average daily emissions of CO_2 gas which he combined to form the average monthly emissions. He recorded that for six months following the eruption over 5000 metric tons of CO_2 were released per day then after six months the emission rates slowly declined. The CO_2 and H_2O vapour released during eruptions does have a marginal effect on the climate, but by far the most influential gases on Earth's climate are the sulfuric gasses released.

Effects of Volcanic SO_2 on Climate The most common sulfuric gas released from volcanic eruptions is SO_2. The effect that SO_2 has on climate is much more complicated than other volcanic gasses such as CO_2 and H_2O vapour.

SO_2 also affects Earth's climate much more severely than volcanic ash, CO_2 and H_2O gasses (Zeilinski et al 1997).

The kind of effect SO_2 has on the climate is directly related to its concentrations in the atmosphere and thus the amount of volcanic activity during a given time frame (Robock 2000). When SO_2 is released from volcanoes, it readily reacts with H_2O and OH^- compounds to form sulfuric acid H_2SO_4. Sulfuric acid acts like a typical aerosol reflecting solar rays back into space away from the Earth's surface much in the same way the volcanic ash does. However, unlike volcanic ash the H_2SO_4 aerosols have about the same size radius as visible light. Both visible light and the H_2SO_4 aerosols have a common radius of 0. 5μ (microns).

This common radius allows a more effective backscattering of light rays than other particles such as the volcanic ash; making H_2SO_4 aerosols very effective at decreasing the temperature of the Earth's surface (Robock 2000). However, the SO_2 does not always have a cooling effect on the surface of the Earth. If there are inadequate amounts of H_2O and OH^- in the atmosphere, not all of the SO_2 will be able to form sulfuric acid (Ward 2009). If this happens, the SO_2 will act as a very effective greenhouse gas which will increase the rate of global warming.

Therefore, if the rate of volcanic activity is very high during a given time frame, there will not be enough H_2O and OH^- to react to form sulfuric acid aerosols, and the SO_2 will increase the temperature of the Earth's surface; however, if rates of volcanic activity are relatively low, like they are today, the SO_2 will form sulfuric acid which will work to decrease the temperature of Earth's surface (Ward 2009).

Research by Ward (2009) shows that there are four principal rates of SO_2 emissions that are possible from volcanic eruptions. If SO_2 emissions are relatively low, corresponding to the absence of any major volcanic eruptions for many decades, all of the SO_2 is reacted to form sulfuric acid which effectively backscatters solar rays. The backscattering of solar rays can drastically cools the Earth, and increases the potential for the Earth to go into an ice age.

The second scenario is if there are moderate rates of SO_2 emissions which are roughly equal to one very large eruption every few decades. In this scenario most of the SO_2 is reacted to produce sulfuric acid which generally produces a slight cooling effect of the Earth's surface. Normally the result of moderate SO_2 emissions is 2-3 years of weather that is 1-5°C lower than average temperatures.

If there are high rates of SO_2 emissions, which are the result of more than one large volcanic eruption every year, large amounts of the SO_2 remain non-reacted and produce dramatic warming effects. These warming effects progressively increase the temperature of the Earth by a couple of degrees for as long as the SO_2 is in the atmosphere.

The last possible scenario is if SO_2 emission rates are extremely high. This extreme SO_2 emission rate corresponds to over 100, 000 flood basalts in less than 1 million years. Flood basalts are massive volcanic eruptions or a whole series of eruptions that cover broad areas of land with basaltic lava.

The huge amounts of SO_2 emitted causes intense global warming and acid rain leading to the destruction of many environments and to mass extinctions of species. Some believe this is the reason dinosaurs became extinct 65 million years ago (Ward 2009).

Conclusion From recent and historical studies of how specific parts of a volcanic eruption affect the climate it is clear that it is not always simple to estimate the overall climate changes related to an eruption. There are a few distinct kinds of particles which affect the climate of the Earth in very different ways. Volcanic ash acts to backscatter solar rays back into space away from the Earth, and thus cools the Earth by decreasing the amount of solar insulation on the Earth's surface.

Volcanic ash can also greatly affect precipitation levels because of the large anhydrite $CaSO_4$ content which readily absorbs water from rain clouds to form the mineral gypsum $CaSO_4 \bullet H_2O$. Both CO_2 and H_2O vapour act as greenhouse gasses which trap solar rays between the Earth's surface and its outer atmosphere. This greenhouse effect causes the temperature of the Earth's surface to increase. Sulfuric gasses have a more complicated effect on climate. If the levels of SO_2 emissions are generally low than all of the SO_2 will react with H_2O and OH^- to form H_2SO_4 an aerosol which will backscatter solar rays and cool the Earth.

If the levels of SO_2 emissions are generally high than there will be too much SO_2 to react with H_2O and OH^- and the remaining SO_2 will very effectively contribute to the greenhouse effect. Looking at these effects and at a few examples of past eruptions, it is clear volcanoes can determine the climate of the Earth.