HOW VOLCANISM AFFECTS CLIMATE

Climatologists may disagree on how much the recent global warming is natural or man-made but there is general agreement that volcanism constitutes a wildcard in climate, producing significant global scale cooling for at least a few years following a major eruption.

Volcanic activity is constantly ongoing around the globe with a half-dozen or more volcanoes active at any given moment. Most of these are smaller eruptions, however, and their effects are minor, short lived and confined to the lower atmosphere near the volcano. Major eruptions are much rarer. They can eject both ash and gases like sulfur dioxide high into the atmosphere -- 80,000 feet or more. Although much of the ash may fall out within 6 months to a year, sulfur dioxide quickly gets converted to sulfate aerosols, which can reside for two or more years in the stable high atmosphere. These then block some of the incoming solar radiation. The net result is a global cooling. An average cooling of 0.2 to 0.5C over a 2 to 3 year period can occur for a major eruption (de Silva, Robock, others) and has been documented by both surface and satellite observations after major eruptions like El Chichon (Mexico in 1982) and Pinatubo (Indonesia in 1991).

It should be noted that Robock (2003) and others have shown that though major volcanic eruptions seem to have their greatest cooling effect in the summer months, the location of the volcano determines whether the winters are colder or warmer over large parts of North America and Eurasia. According to Robock, tropical region volcanoes like El Chichon and Pinatubo actually produce a warming in winter due to a tendency for a more positive North Atlantic Oscillation (NAO) and Arctic Oscillation (AO) (below left). In the positive phase of these large scale pressure oscillations, low pressure and cold air is trapped in high latitudes and the resulting more westerly jet stream winds drives milder maritime air into the continents.

Robock found high latitude volcanoes like Katmai (Alaska in 1912,) instead favored the negative phase of the Arctic and North Atlantic Oscillations and cold winters (below right). In the negative phase, the jet stream winds buckled and forced cold air south from Canada into the eastern United States and west from Siberia into Europe. Despite the regional differences in winter, globally on an annual basis, volcanic eruptions lead to a net cooling regardless as to the volcano’s latitude.

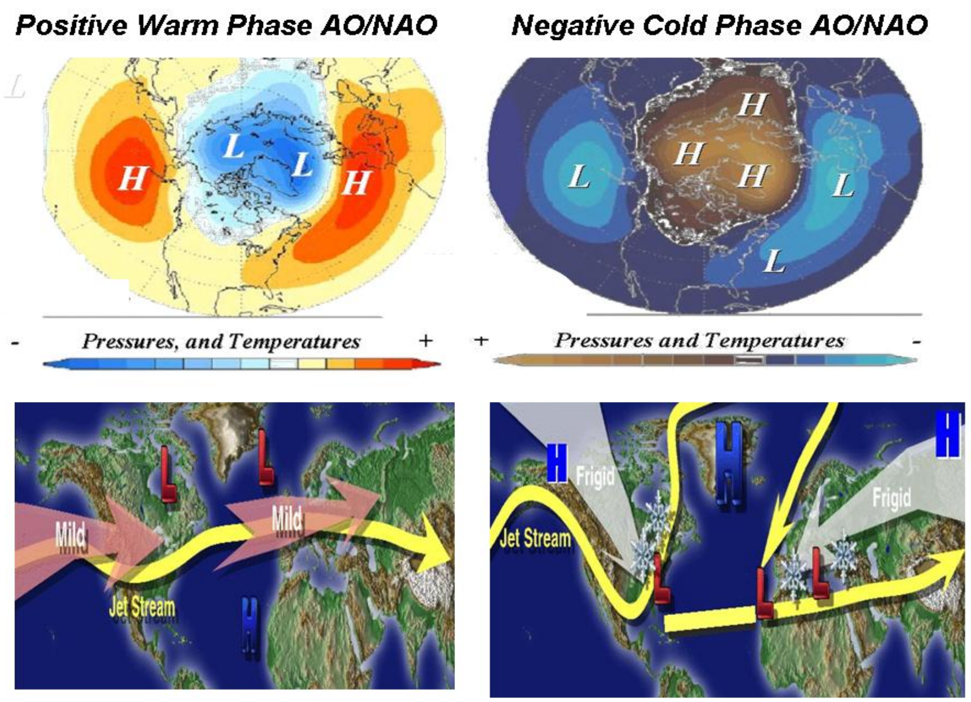

Figure 1: AO/NAO phases. The positive (warm) phase has low pressure and cold air in high latitudes with enhanced westerlies and mid-latitude warmth. The negative (cold) phase has high latitude blocking high pressure which forces the cold air south with amplified troughs and ridges

Major eruptions are relatively rare events and seem to occur in clusters as the chart (stratospheric aerosol as measured by NASA GISS Aerosol Optical Thickness) below shows. The late 1800s to the early 1900s was a very active period with Krakatoa (Indonesia between Java and Sumatra in 1883) as the major event. With a quiet sun, it is no surprise this era was very cold. A quiet sun is associated with lower solar irradiance (energy emission) and less heat input into our atmosphere.

The 1920s to the 1940s was a period of very little volcanic activity that coincided with a rapid increase in solar irradiance and multi-decadal warming in both oceans with a resulting warming of global temperatures. The sun and oceans are believed to be the primary drivers but lack of volcanic ash may have augmented the warming.

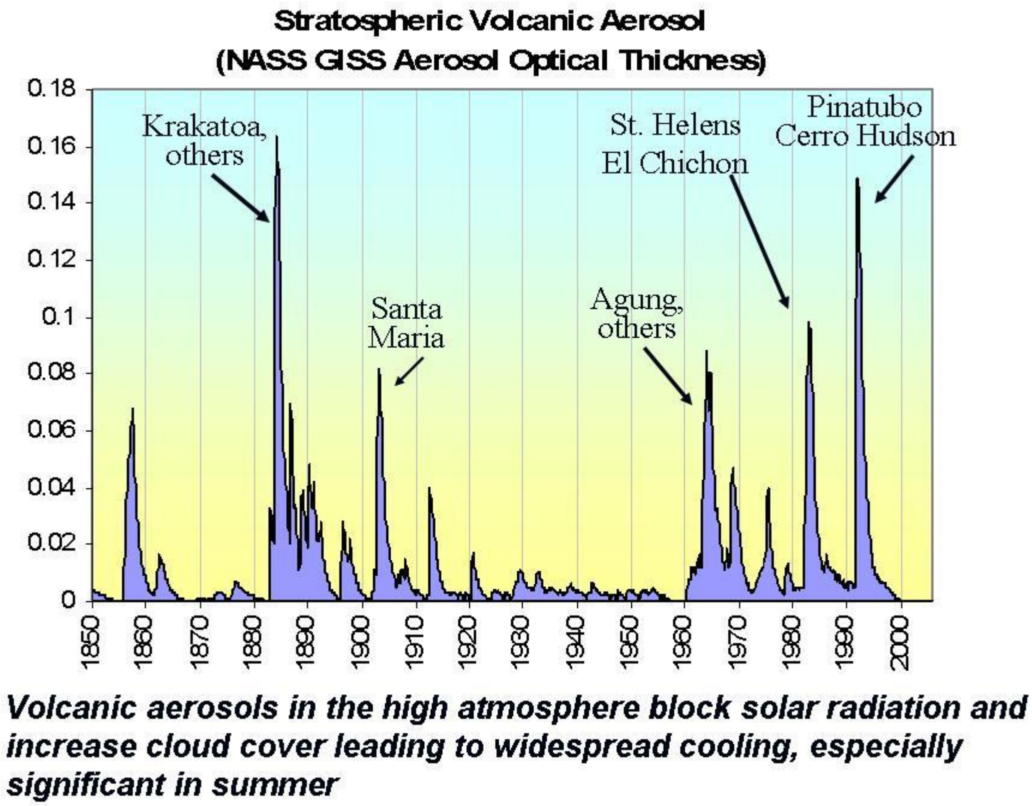

Figure 2: Global stratospheric aerosol loading as estimated by the Aerosol Optical Thickness by Sato of NASA GISS. Notice the tendency for clustering of major eruptional activity in the later 1800s, 1960s and early 1980s and 1990s. Current levels are near or at the low of the entire record.

The 1960s became very active with Mt. Agung as the first of several significant eruptions that kept aerosols levels high much of the decade. This coincided with a quieter sun and cooler cycles in both the Atlantic and Pacific. That decade not surprisingly was the coldest of the last 50 years.

After 1979, even as temperatures began again to rise with an increasingly active sun and a warming in the Pacific (called the Great Pacific Climate Shift), cooler global temperatures followed the major eruptions of Mt. St. Helens (Washington State in 1981) and El Chichon (1982) and Pinatubo and Cerro Hudson (Chili in 1991),. This is clearly evident in graphic above which relates the stratospheric aerosol loading represented as aerosol optical thickness (Sato et al 1998) to the satellite derived lower tropospheric temperatures (Spencer and Christy 2006).

All the warm and cold periods on the satellite derived global temperature graph can be attributed to El Ninos or La Ninas and volcanic eruptions. El Ninos are events characterized by a warming of the east and central tropical Pacific Ocean. The warm water warms the atmosphere and that heat gets carried poleward by atmospheric circulations, resulting in a global rise in temperatures. La Ninas are characterized by colder than normal waters in the east and central tropical Pacific. They usually induce a global cooling.

Indeed most of the warm red spikes in the temperature (top curve) coincide with El Ninos and the cold blue dips from La Ninas. Volcanic eruptions can override El Nino warming. The volcanic cooling associated with the major eruptions in 1982 and 1991 were able to minimize and then offset the warming with the super El Nino of 1982/83 and the El Ninos of the early 1990s on a global basis.

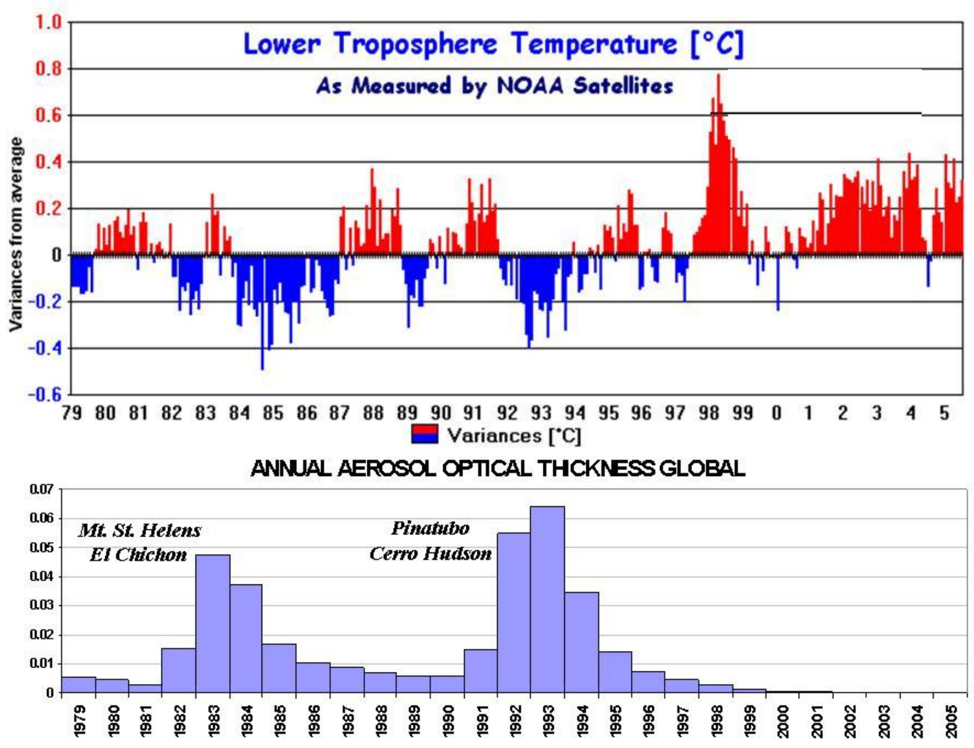

Figure 3: The Christy Spencer satellite derived lower tropospheric global temperature anomalies since 1979 and the corresponding stratospheric aerosol loading (aerosol optical thickness) as estimated by Sato at NASA GISS. Note the cooling with the major eruptions of the early 1980s and 1990s. Note the warmth in recent years with aerosols at their lowest levels of at least the satellite era.

LACK OF VOLCANISM CONTRIBUTING TO RECENT WARMTH?

As both aerosol graphics show, during the last six years, stratospheric aerosols are at an historic low levels (according to James Hansen's NASA GISS group, the level of stratospheric aerosols is now at the very least at the lowest level since direct satellite measurements began in 1979). A cleaner atmosphere, with much below normal aerosol levels would allow more solar radiation to reach the earth's surface, which along with the warm multi-decadal modes in both Atlantic and Pacific may be driving the current continued warming even as the solar input appears to be starting a decline.

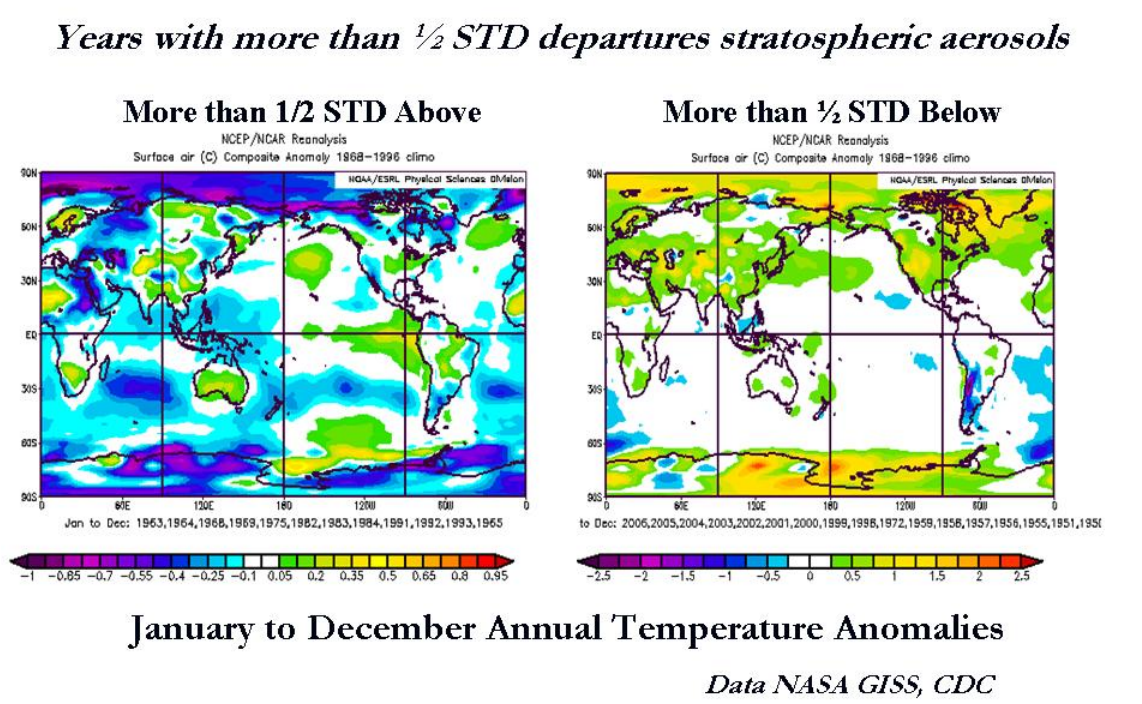

Figure 4: Note during times of high stratospheric aerosols, rather widespread cooling is observed especially in the Polar Regions., eastern Europe and western Asia. During times of low stratospheric aerosol levels, widespread warmth is observed in polar and across mot of the Northern Hemispheric continents.

There is support for this in the data for the United States. Using annual USHCN climate data, I found the average annual temperature during years with a STD more than ½ below normal (low aerosols) to average a +0.72F while during periods of more than ½ STD`above normal a -0.26F.

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Volcanic eruptions and their impact on the earth's climate
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