Large volcanic eruptions affect climate in many more ways than just cooling

Peter L. Ward
Teton Tectonics

In 1991, Pinatubo erupted ≤921 Mt water, ≤234 Mt carbon dioxide and ≤19 Mt sulfur dioxide. The sulfur dioxide reacted primarily with OH and 3 parts water to form a sulfuric acid aerosol 20 to 23 km high, circling the earth in 21 days, reflecting sunlight, cooling the earth ~0.5°C. Maximum cooling in the tropics occurred 3 months later, but sulfate mass mixing ratios did not return to background until 1998. Models suggest sea level dropped 5 mm. The aerosol absorbed solar and infrared energy, warming the lower stratosphere ~3°C, decreasing the temperature gradient, increasing winter warming at middle to high latitudes. The aerosol induced many changes in the atmosphere. Despite the eruption of large amounts of carbon dioxide, atmospheric concentrations decreased until the aerosol had largely dissipated. Settling of the aerosols probably increased cirrus clouds, increasing warming. Global precipitation and river runoff decreased 3 and 3.7 standard deviations below normal. While water vapor in the lower troposphere decreased with cooling, the eruption increased water vapor in the upper troposphere and lower stratosphere. Its effects are unclear but imply warming. OH concentrations decreased ≤10%, causing a sharp increase in methane and carbon monoxide. Ozone levels decreased as much as 20% in some areas and the diameter of the ozone hole increased 17% in 1992. Each of these cooling and warming processes has a time constant of days to years in the atmosphere, but in the ocean, they can induce effects with time constants of years to centuries. Gleckler et al. (2006), comparing results from 12 climate models, show that water from the cooled ocean surface sinks hundreds of meters and that its effects are still observable 120 years after the Krakatoa eruption of 1883. Gregory et al. (2006) show such cooling steps accumulate during frequent eruptions. If cool water sinks, warm water must rise; but where? One measure of ocean currents is the Southern Oscillation. Each of the largest sulfur-emitting eruptions since 1600 (Huaynaputina, Laki, Tambora, Krakatau, Santa Maria, Novarupta, Pinatubo) were in the same year as moderate to strong El Niños but were typically followed by very strong El Niños within 6 to 8 years (Data: Bradley and Jones, 1992). During El Niños, warm water heats the tropical Pacific atmosphere. Many ocean currents are affected over short time scales by atmospheric teleconnections but then affect atmospheric conditions over longer time scales. The sum of these processes with different time constants varies when the rate of volcanic activity changes by orders of magnitude. Ward (2009, doi:10.1016/j.tsf.2009.01.005) presents data suggesting large eruptions occurring on average once per century (current rate) provide only short-term changes in climate, but when they occur every few decades, they supplement Milanković cycles and increment the world into ice ages, and when they occur as often as once per year, they cause rapid global warming. Volcanic-like sulfate deposited in Greenland from man burning fossil fuels between 1930 and 1980 was as high as the highest levels of sulfate deposited during rapid warming at the end of the last ice age. Man did not eject sulfur into the stratosphere, but it remained in the atmosphere long enough to be deposited in Greenland. Understanding how volcanoes caused abrupt warming in the past would help us understand how man is causing abrupt warming today.