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Historical Evidence for a Connection Between Volcanic Eruptions and Climate Change

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Considerable evidence for a connection between volcanic eruptions and climate change exists in the form of historical and proxy records of climatic change such as instrumental temperatures, tree rings, and agricultural records, and observations of volcanic disturbances of the atmosphere such as "dry fogs" and "dim sun" conditions, and proxy evidence from acidity anomalies in ice cores. A number of studies have compared the times of historical volcanic aerosol clouds with changes in atmospheric temperatures on regional, hemispheric and global scales. These involve either a direct comparison of individual significant eruption years with temperature records, or a comparison of eruption years with composited temperature records for several years before and after a chosen sets of eruptions . The various studies give similar results--the composites show a northern hemisphere cooling of 0.2 to 0.3°C for 1 to 3 years after eruptions for a number of eruptions grouped together, and individual volcanic events that produced significant aerosol clouds such as Krakatau, 1883 or Tambora, 1816 are followed by a hemispheric cooling between 0.3 to 0.7°C for 1 to 3 years after the eruptions.

Some studies have challenged the connection between individual eruptions and climate change . Mass and Portman (1989) recently suggested that the volcanic signal was present, but smaller than previously thought. It was limited to those eruptions that created the densest aerosol clouds, and was enhanced by subtracting out other sources of interannual variability, e.g. the El Nino/Southern Oscillation. These authors stress that the volcanic "signal" of a few 10ths of a degree C is of the same order as "background" temperature variations in non-volcanic years. Moreover, it may be that stratospheric aerosol clouds have some effect on the ENSO phenomena, either triggering them, or intensifying already existing ENSO patterns. P. Handler has also suggested a connection between stratospheric aerosols and the strength of the yearly Indian monsoonal precipitation, so that climatic perturbations by volcanic aerosols may be more pervasive than commonly thought.

In a study designed to test the idea that eruptions could cause small changes in climate, Hansen and others (1978) chose one of the best monitored eruptions at the time, the 1963 eruption of Agung volcano on the island of Bali. Their observational temperature data showed a 0.5°C cooling at the surface in the tropics and a stratospheric warming (from the presence of the aerosols) of more than 6°C in the two years after the eruption. Using a simple radiation-balance model, in which they simulated an aerosol cloud in the tropics, they were able to reproduce this basic pattern of temperature change in the tropics and subtropics.

There may be natural limits to the atmospheric effects of any volcanic eruption . Pinto and others (1989) have recently proposed self-limiting physical and chemical effects in eruption clouds. Model results suggest that aerosol microphysical processes of condensation and coagulation produce larger aerosols as the SO_2 injection rate is increased (rather than a larger number of particles of the same small size). Larger particles have a smaller optical depth per unit mass than do smaller ones; they also settle out of the stratosphere at a faster rate, restricting the total number of particles in the stratospheric cloud. These processes may act to moderate the impact of volcanic aerosol clouds on the earth's radiation budget and climate, and suggest that volcanic aerosol effects might be self limiting -- eruptions of the magnitude of Tambora, 1815 or the AD 536 eruption may be reaching that size where self-limiting effects become increasingly important.

The key to discovering the greatest effects of volcanoes on short-term climate may be to concentrate on regional temperatures where the effects of volcanic aerosol clouds can be amplified by perturbed atmospheric circulation patterns, especially changes in mid-latitudes where meridional circulation patterns may develop. Such climatic perturbations can be detected in proxy evidence such as decreases in tree-ring widths and frost damage rings in climatically sensitive parts of the world, changes in treelines, weather anomalies such as unusually cold summers, severity of sea-ice in polar and sub-polar regions, and poor grain yields and crop failures. For some eruptions, such as Tambora, 1815, these kinds of proxy and anecdotal information have been summarized in great detail in a number of papers and books. These studies lead to the general conclusion that regional effects on climate, sometimes quite severe, and unevenly distributed across the globe, may be the major impact of large historical volcanic aerosol clouds.