Reports

The Mount St. Helens Volcanic Eruption of 18 May 1980: Minimal Climatic Effect

Abstract. *An energy-balance numerical climate model was used to simulate the effects of the Mount St. Helens volcanic eruption of 18 May 1980. The resulting surface temperature depression is a maximum of 0.1°C in the winter in the polar region, but is an order of magnitude smaller than the observed natural variability from other effects and will therefore be undetectable.*

The 18 May 1980 eruption of Mount St. Helens volcano in Washington State sent ash particles and gases into the lower stratosphere. Early reports indicated that the volume of material erupted and the energy of the explosion were quite large, placing this event in the same class as other volcanic eruptions that were believed to have an effect on climate (*1*). I therefore used a climate model to simulate the effects of this volcano. Although several previous studies have modeled the effects of large volcanic eruptions on climate (*2–7*), the one presented here is, to my knowledge, the first in which both the effects of the latitude and month of the eruption and the latitudinal and seasonal response of the model have been investigated.

After volcanic dust is injected into the stratosphere, it spreads in latitude as the concentration decays in time (*2*). In addition, gas-to-particle conversions, primarily involving sulfur compounds, create very small particles with a long stratospheric residence time. The exact nature of the stratospheric dust veil from Mount St. Helens is not known, as observations are still being made and analyzed and gas-to-particle conversions are still occurring. Therefore, for this preliminary study I used a simplified theoretical model of the dust veil, assuming Gaussian diffusion in latitude and exponential decay in time. The model is based on results of Cadle *et al.* (*4*) and is described in detail in (*2*). The relative concentration per 10° latitude band is shown in Fig. 1a. Experiments were also conducted with the chronology of Hansen *et al.* (*3*), which allows time for sulfate formation; the results were almost the same, as discussed later.

The results of Harshvardhan (*5*), who presented the net radiative impact of a stratospheric aerosol layer of optical depth 0.1 as a function of latitude and month, were used to produce the forcing for the climate model. He found that the albedo effect (reducing the incoming radiation at the surface) far outweighed the infrared effect (increasing the incoming radiation) except during the polar winter, when the sun does not shine. The largest reduction, greater than 5 W/m^2, was found in the polar spring through fall, with values less than 3 W/m^2 in the tropics. An increase of 0.5 W/m^2 was found in the polar winter.

It was assumed that the initial optical depth of the Mount St. Helens dust veil was 0.1 averaged over a 10° latitude band. The values in Fig. 1a were therefore multiplied by the values in figure 10 of Harshvardhan (*5*) to provide the forcing for each 10° latitude band in the climate model. This forcing should be considered an upper bound on the effects of the volcano, unless a thick layer of sulfate particles develops. While lidar measurements of the optical depth in the center of the eruption cloud immediately after the eruption were large, maxima measured by ground-based and satellite instruments even 1 week after the eruption yielded an optical depth of less than 0.01 (*8*). In addition, the forcing in the model was assumed to apply over entire 10° latitude bands, not just in the plume center, where the measurements were made.

The climate model used in this study

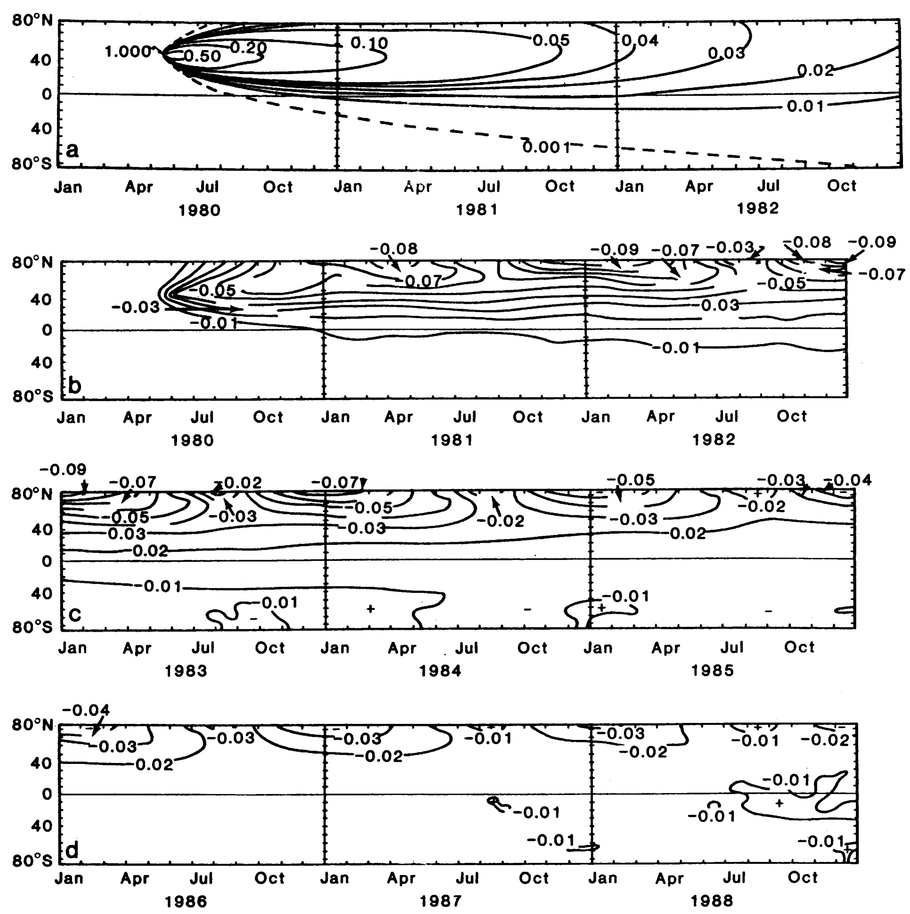

Fig. 1. (a) Relative concentration of volcanic dust from Mount St. Helens per 10° latitude band assumed as forcing for climate model. (b to d) Surface temperature difference (degrees Celsius) between control run and climate model simulation using the forcing in (a) with interactive snow and ice.

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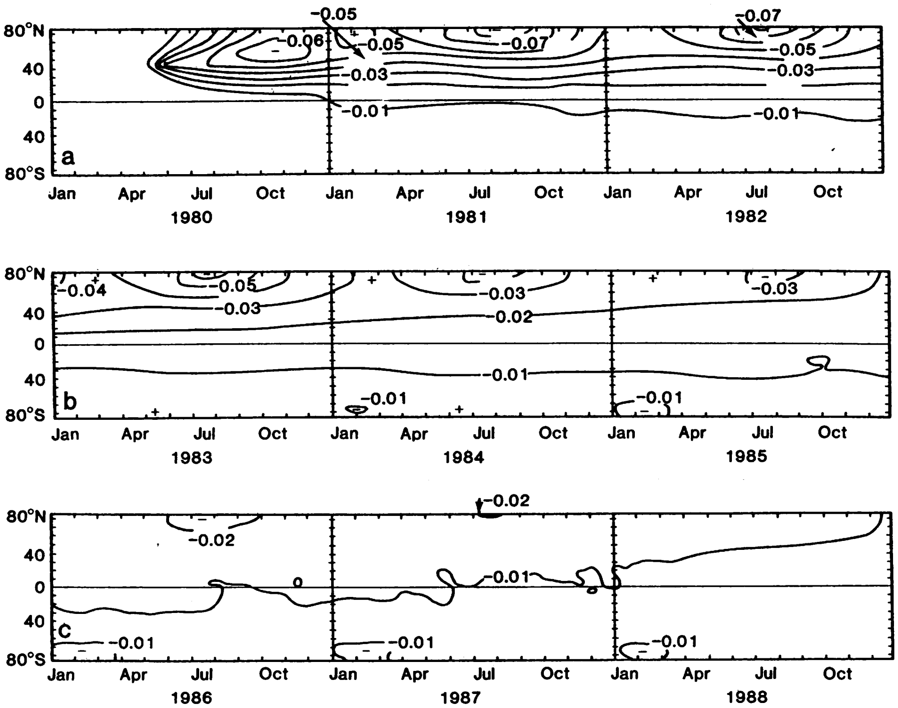

Fig. 2. Same as Fig. 1, b to d, with constant snow and ice at their model climatological values.

has been used for other experiments (*6*, *9*). It is an energy-balance numerical model with 15-day time steps on an 18 by 2 grid (10° latitude bands, separate boxes for land and ocean) (*10*). Incoming and outgoing radiation are considered in detail and horizontal energy transports by the atmosphere and ocean are parameterized. Although an effort is made to include the important climate mechanisms in the model, it is much simpler than the real climate system, and the results should be viewed with this in mind.

Radiation perturbations as described above were applied to the model. Figure 1, b to d, shows the temperature difference (degrees Celsius) between a control run, which reproduces the same climate year after year, and the volcano experiment for the standard model, and Fig. 2 shows the results for an experiment in which snow and ice were kept fixed at their monthly values in the control run and not allowed to interact with the perturbed climate. Several observations and conclusions can be drawn from these results.

1) The amplitude of the maximum effect of the Mount St. Helens eruption will be less than 0.1°C and will occur in the north polar area. This is much less than the interannual standard deviation of the monthly mean zonally averaged temperature for the same region, which is about 2.5°C in the winter and greater than 1°C in the summer (*11*). Therefore, it will be very difficult to measure the effect of the volcano on surface temperatures because of the signal-to-noise problem. The hemispheric average temperature drop was less than 0.04°C in this experiment.

2) The maximum cooling effect will be in January 1982 in the polar region (Fig. 1, b to d). Each succeeding polar winter also has a maximum cooling, although the forcing has its maximum cooling in the summer and even has warming in the winter.

3) The maximum effect from the experiment with constant snow and ice is in the summer (Fig. 2). This is what would be expected from the forcing, which indicates that the winter response in the standard run (Fig. 1, b to d) is due to nonlinear effects of the snow- and ice-albedo feedback. This also suggests that anomalous snow and ice patterns may be useful as climatic indices and predictors of anomalous weather because of their long time scale.

4) The maximum response in both experiments is initially at the latitude of maximum forcing, but within a few months it moves to the pole. This occurs because the higher latitudes have lower thermal inertia (due to the lack of open ocean water), the maximum of the dust concentration has moved to the pole (Fig. 1a), and the radiative forcing is highest at the pole (*5*).

5) The amplitude of the maximum response is smaller in the experiment with constant snow and ice, which demonstrates how this feedback amplifies the climatic response. The relative strength of the response with and without this feedback cannot be determined solely from this experiment because of the seasonal and latitudinal nature of this particular forcing.

Two other experiments were conducted that gave essentially the results outlined above and did not change any of the conclusions. They are discussed in detail in (*12*). In one experiment, instead of using the results of Harshvardhan, a constant radiative effect of -3 W/m^2 was multiplied by the dust veil value (Fig. 1a). The relative seasonal responses for both model runs were the same, with only slightly different amplitudes. In the other experiment the time chronology of Hansen *et al.* (*3*) was used to produce a version of Fig. 1a in which sulfate buildup was allowed for. Only minor changes at the beginning of the runs resulted.

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References and Notes

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10. The basic energy-balance equation solved in the model for surface air temperature over land and water separately for each latitude band with a 15-day time step is

$$C\frac{\partial T}{\partial t} = Q(1-\alpha) - I - \text{div}\, F$$

where T is temperature, t is time, C is thermal inertia, Q is incoming solar radiation, α is planetary albedo, I is outgoing infrared radiation, and F is horizontal energy transport by atmospheric and oceanic motions. See (*9*) for a discussion of the model.
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13. I thank C. Villanti for drafting the figures. Computer time was provided by the Goddard Laboratory for Atmospheric Sciences. This research was supported by NSF grant ATM-7918215.

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