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A Three-Dimensional Numerical Simulation of the Atmospheric Injection of Aerosols by a Hypothetical Basaltic Fissure Eruption

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Recently, a number of investigators have debated the theory that the Cretaceous/Tertiary extinctions, which occurred 65 million years ago, were due directly to attenuation of solar radiation by atmospheric pollution emitted by unusually strong volcanic activity (1,2). An essential ingredient of these theories is the assumed injection of atmospheric pollutants, including SO_2 and H_2S in particular, deep into the upper troposphere and the stratosphere. Up until now, attempts to quantitatively predict the depth for such pollutant injection have been made with simple one-dimensional and two-dimensional plume models (3).

Current research being conducted by those investigating the "Nuclear Winter" problem also has direct relevance to this problem. An important part of the "Nuclear Winter" problem has also been the atmospheric injection problem, but by urban fires induced in the aftermath of a nuclear exchange. Although the question was initially addressed using simple one-dimensional plume models (4,5), more recent studies have employed sophisticated three-dimensional cloud models (6-9). An important feature of of those numerical studies was the prediction of additional lofting through latent heating and the simultaneous prediction of microphysics and associated precipitation scavenging. At this time, there continues to be considerable debate over the efficiency of scavenging. Predicted estimates range from 5% to 80% of the material initially lofted. Scavenging has been found to be sensitive to atmospheric humidity, stability, fire intensity, and the microphysics parameterization used to make the calculation. No investigator has been able to demonstrate that the majority of the pollutant emitted by urban fires or firestorms is lofted directly into the stratosphere.

The calculated intensity of basaltic fissure eruptions ($2,500\,KWm^{-2}$), however, represents a much stronger heating rate than that calculated for urban fires ($1 - 140\,KWm^{-2}$, see 7). As a result, one might predict that injection by such intense volcanic activity, would be deeper. However, experience has shown that several other factors also must be considered. For instance, SO_2 is highly soluble and would be scavenged with the highest efficiency. On the other hand, (8) showed that as very intense convective updrafts form, scavenging becomes less efficient simply because there in insufficient time for a precipitation formation process to become established. Instead, pollutants initially immersed within water droplets in reinjected as water droplets evaporate as ice crystals form. Moreover, when a regional scale heat source of this scale persists for several hours, inertial stability resulting from the Earth's rotation becomes important. Tripoli and Kang predicted that a local whirl wind of high inertial stability develops as a result, decreasing convergence into the heat source and lowering the plume height after a period of a few hours.

In this study, we have chosen to simulate the atmospheric response to a hypothetical basaltic fissure eruption using heating rates based on the Roza flow eruption. The simulation employs the Colorado State University Regional Atmospheric Model (RAMS) with scavenging effects as used by (8). The numerical model is a three-dimensional non-hydrostatic time-split compressible cloud/mesoscale model. Explicit microphysics include prediction of cloud, rain, crystal, and hail precipitation types. Nucleation and phoretic scavenging are predicted assuming that the pollutant makes an effective cloud droplet nucleus. Smoke is carried as a passive tracer. Long and short wave radiation heating tendencies, including the effects of the smoke, are parameterized. The longwave emission by the lava surface is neglected in the parameterization and included as an explicit heating term instead.

A regional scale domain of 100 X 100 km in the horizontal and 22 km high is used. The horizontal grid spacing is taken to be 2 km and the vertical spacing is taken to be 0.75 km. The initial atmospheric state is taken to be horizontally homogenous and based on the standard atmospheric sounding.

The fissure is assumed to be 90 km long and oriented in a zig/zag pattern. It is included as a heat and water vapor source over the lowest 0.75 km model depth. A vertically integrated heating rate of $2,500 KW m^{-2}$ is assumed. Smoke input is taken to be $3.4x10^7\, kg\, m^{-2}$. The simulation is integrated for a period of 12 hours.

Results of this simulation will be presented at the meeting, as they are not completed at this writing.

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