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Inverse Modeling of the Initial Stage of the 1991 Pinatubo Volcanic Cloud Accounting for Radiative Feedback of Volcanic Ash

Alexander Ukhov[1], **Georgiy Stenchikov**[1], Sergey Osipov[2], Nickolay Krotkov[4], Nick Gorkavyi[5], Can Li[6], Oleg Dubovik[3], and Anton Lopatin[7]

[1]King Abdullah University of Science and Technology, Division of Physical Sciences and Engineering, Thuwal, Saudi Arabia
[2]King Abdullah University of Science and Technology, Red Sea Research Center, Thuwal, Saudi Arabia
[3]Laboratoire d'Optique Atmosphérique, CNRS/University of Lille, Lille, France
[4]NASA Goddard Space Flight Center, Greenbelt, MD, United States
[5]SSAI, Lanham, MD, United States
[6]Earth System Science Interdisciplinary Center, University of Maryland, College Park, United States
[7]GRASP SAS, Hauts-de-France, Villeneuve d'Ascq, France

The evolution of volcanic clouds is sensitive to the initial three-dimensional (3D) distributions of volcanic material, which are often unknown. Here, we conduct inverse modeling of the fresh Mt. Pinatubo cloud to estimate the time-dependent emissions profiles and initial 3D spatial distributions of volcanic ash and SO_2. We account for aerosol radiative feedback and dynamic lofting of volcanic ash. It results in a lower (by 1 km for ash) injection height than that without ash radiative feedback. The solution captures the elevated ash layer between 14 and 24 km and the meridional height gradient during the first two days after an eruption. A significant fraction of the emissions (i.e., 6/16.6 Mt of SO_2 and 34/64.22 Mt of fine ash) did not reach the stratosphere. The results demonstrate that the Pinatubo eruption ejected ~78% of fine ash at 12 to 23 km, ~64% of SO_2 at 17 to 23 km, and most of the ash and SO_2 mass for the first two days after the eruption resides in the 15- to 22- km layer. 6 Mt of tropospheric SO_2 oxidized into sulfate aerosol within a week. This outcome might help to explain the discrepancies between the observations and model simulations recently discussed in the literature. The long-term evolution of the Pinatubo aerosol optical depth simulated using the obtained ash and SO_2 initial distributions converges with the available stratospheric aerosol and gas experiment (SAGE) observations a month after the eruption when the tropospheric aerosol cloud dissipated.