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

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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 SO₂. 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 SO₂ 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 SO₂ at 17 to 23 km, and most of the ash and SO₂ mass for the first two days after the eruption resides in the 15- to 22- km layer. 6 Mt of tropospheric SO₂ 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 SO₂ initial distributions converges with the available stratospheric aerosol and gas experiment (SAGE) observations a month after the eruption when the tropospheric aerosol cloud dissipated.