

General comments:

This paper introduces several key enhancements to the WRF-Chem v4.8 model aimed at improving the simulation of volcanic eruptions, including the implementation of wet and dry deposition for ash and sulfate, SO₂ oxidation mechanisms, gravitational settling corrections, and the direct radiative effects of volcanic aerosols. The authors also developed the calculation of ash and aerosol radiation, which has the feedback effects to the meteorology. Using the 1991 Mt. Pinatubo eruption as a case study, the authors evaluate the model's performance through both short-term and long-term experiments, demonstrating clear improvements in mass conservation and a better agreement with satellite observations, particularly when radiative feedback is activated.

Overall, the paper presents a thorough and valuable contribution to the field of volcanic plume modeling. The enhancements address important shorts in WRF-Chem's capabilities. Here recommend minor revisions before publication.

Dear Dr. Mingzhao Liu, we appreciate your positive feedback. Below, we address your comments. Our detailed responses are provided in blue. Changes in the text are in *italic*.

Main comments:

1. Fig. 4 and 5 show significant improvements in aerosol and SO₂ transport when radiative feedback is included. To further strengthen the model-satellite comparison, the authors should consider applying satellite-specific Averaging Kernels to the model output. This would account for the vertical sensitivity of the satellite retrievals and enable a more rigorous and physically consistent validation.

We appreciate the reviewer's suggestion to apply satellite-specific averaging kernels to the model-satellite comparison. However, the TOMS SO₂ retrievals used in this study do not provide per-pixel averaging kernels or vertical weighting functions. The TOMS SO₂ product represents a total column amount derived from differential UV backscatter at discrete wavelengths, assuming an effective SO₂ layer height (15–25 km for stratospheric plumes such as Pinatubo (Krueger et al., 1995)). Therefore, applying an averaging kernel, as is possible for OMI or TROPOMI products, is not feasible for the TOMS data. Moreover, the inverted emission scenarios (Ukhov et al., 2023) for ash and SO₂ were based directly on the TOMS SO₂ column loadings and aerosol index (AI) without air-mass-factor corrections.

Krueger, A. J., et al. "Volcanic sulfur dioxide measurements from the total ozone mapping spectrometer instruments." *Journal of Geophysical Research: Atmospheres* 100.D7 (1995): 14057-14076.

Ukhov, A., et al. "Inverse modeling of the initial stage of the 1991 Pinatubo volcanic cloud accounting for radiative feedback of volcanic ash." *Journal of Geophysical Research: Atmospheres* 128.12 (2023).

2. Figure 5 illustrates how radiative feedback alters the spatial pattern and magnitude of the SO₂ plume. The manuscript would benefit from a more detailed explanation of the underlying physical mechanism. Specifically, how does the absorption of solar radiation by ash influencing SO₂ transport and dispersion? A brief discussion linking the radiative heating (e.g., as shown in Fig. 10) to the dynamical response (e.g., enhanced lofting or altered wind patterns) would strengthen the scientific insight of the paper.

We agree, and we have expanded the description of Figure 5 in Section 3.2 by adding the following text: "*The absorption of solar radiation by volcanic ash warms the surrounding air within the ash plume, enhancing its buoyancy. This heating also modifies the plume's vertical and horizontal structure. This dynamical response in*

the RADON run (Fig. 5b) results in a broader SO₂ plume compared to the RADOFF run (Fig. 5c). The altered temperature gradients also modify local wind fields, slightly shifting the transport pathway of SO₂ cloud.”

3. Some abbreviations are not explicitly defined upon first use, such as LW/SW/PRTB/CTRL.

Corrected. Now, abbreviations are properly defined in the text. We also replaced PRTB by RADON and CTRL by RADOFF, as requested by the 2nd reviewer.

4. In conclusion section, it is claimed that an open-source preprocessor called PrepEmisSources is developed. However, there is no detail introduction to this tool. Please expand it for more details.

In the original manuscript, there is a dedicated section ‘Appendix A’, which provides a detailed introduction to this tool. More details on how to use the PrepEmisSources utility are presented in: *Ukhov, A. and Hoteit, I.: PrepEmisSources: a framework for preparing volcanic emissions, <https://doi.org/10.5281/zenodo.16856541>, 2025*. However, we improved the ‘navigation’ to the ‘Appendix A’ in several places where the utility is mentioned in the text.

Technical corrections/suggestions:

L. 85: "fixed and error" -> "fixed an error"

Corrected.

L. 119: "The updated SO₂ concentration(mol mol⁻¹) is calculated":The rate coefficient k is given in units of cm³ molecule⁻¹ s⁻¹. Please verify and ensure unit consistency throughout the calculation

Units analysis shows that the exponential term is dimensionless, which is fine. Thus, this formulation is valid regardless of whether SO₂ is expressed in mol/mol or ppmv. Therefore, no mistake here.