Report: 2026 computing time at HLRE-4

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Project:	1547
Project title:	Stratospheric aerosol modeling with ICON-HAM & ICON-ART
Allocation period:	2026-01-01 to 2026-12-31
Principal Investigator:	Robert Wagner

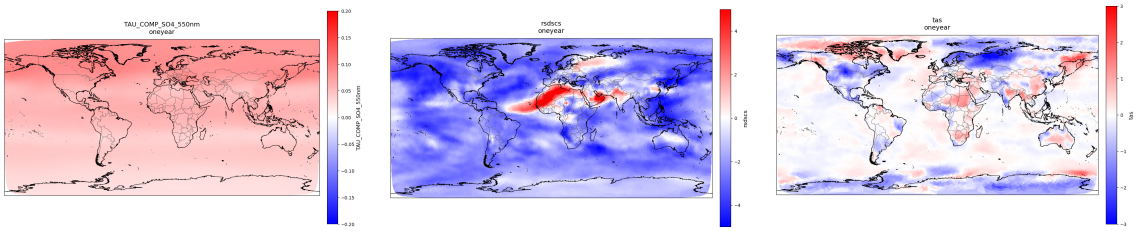
Summary

This report presents the starting phase of a continuous project on the modeling of stratospheric aerosol injection. The first phase, presented within this report, evaluates the ability of the global aerosol-climate model ICON-HAM and ICON-ART to reproduce the stratospheric aerosol plume from the June 1991 Mount Pinatubo eruption, focusing on the global aerosol transport and the implication on atmospheric aerosol load and subsequent changes in the Earth's radiative balance and atmospheric and surface temperature response.

For this report, simulations performed with the aerosol-climate model ICON-HAM will be shown. The simulations were performed by running in an unnudged setting using an interactive aerosol scheme on the R2B4 icosahedral grid, which corresponds to a nominal horizontal resolution of roughly 160 km with 47 vertical levels [2]. In order to archive the project aims, after an intense model setup period to correctly implement the Mt. Pinatubo emissions, two simulations have been performed: a perturbed run including a detailed representation of the Mt. Pinatubo eruption in 1991 and a control run with the prescribed climatology of volcanic emissions that do not account for individual eruptions. Both simulations use the same model version, configuration and initial conditions until the day before the eruption, and thus differ only in the SO_2 injection. The simulation started in January 1991, allowing about five and a half months of spin-up before the eruption so that a reasonable background circulation is established. In the perturbed run, the eruption of Mount Pinatubo (15°N, 120°E) is represented by a single injection of 25 Tg of SO_2 on 15 June 1991. The SO_2 is distributed vertically between 15 and 25 km, consistent with the observed altitude of the initial plume [1]. However, for computational efficiency, we decided to injected the total SO_2 on the main eruption day instead of distributing it over the whole eruption period. After the eruption, both simulations run until January 1993, covering roughly 18 months of aerosol formation, transport, and deposition.

Key findings

In the perturbed run, the SO_2 is rapidly converted to sulfate, with most of the injected mass oxidized to SO_4 already by the end of July 1991. During the first couple of months after the injection the stratospheric aerosol distributes smoothly around the globe, producing a nearly uniform increase in SO_4 aerosol optical depth (AOD) at 550 nm relative to the control run. Averaged over the first year after the



(a) AOD of SO_4 at 550 nm. (b) Clear-sky SW downward flux at surface. (c) 2 m surface temperature.

Figure 1: Global maps of perturbed-minus-control differences, averaged over July 1991–June 1992.

eruption (July 1991–June 1992), the perturbed-minus-control difference (Fig. 1a) shows a pronounced latitudinal band structure, with the strongest signal at Arctic latitudes, where the average AOD increase by about 0.2. Because this is an annual mean, it includes the months of polar night, so the large Arctic AOD does not translate into a correspondingly large shortwave forcing there.

The clear-sky downward shortwave (SW) flux at the surface (Fig. 1b) is not uniformly reduced, despite the globally optically thick stratospheric sulfate layer. Most regions receive less SW radiation than in the control run, as expected due to the strong scattering and reflection of SO_4 in the SW spectrum, but some regions show the opposite sign, with more SW radiation reaching the surface. The all-sky fields show less coherent patterns, with positive and negative anomalies of 1.5–2 $W\,m^{-2}$ as a result of changes in prevailing weather patterns likely linked to the free-running model architecture. The 2 m temperature response (Fig. 1c) is equally patchy but shows overall a cooling over the land surfaces. As sea surface temperatures (SSTs) are yet prescribed in the model and do not respond to an atmospheric signal, so the cooling signal is confined to land and most pronounced in the mid- and polar latitudes with a cooling of up to 3 K.

References

[1] M. Patrick McCormick, Larry W. Thomason, and Charles R. Trepte. Atmospheric effects of the Mt Pinatubo eruption. *Nature*, 373(6513):399–404, February 1995.

[2] M. Salzmann, S. Ferrachat, C. Tully, S. Münch, D. Watson-Parris, D. Neubauer, C. Siegenthaler-Le Drian, S. Rast, B. Heinold, T. Crueger, R. Brokopf, J. Mülmenstädt, J. Quaas, H. Wan, K. Zhang, U. Lohmann, P. Stier, and I. Tegen. The Global Atmosphere-aerosol Model ICON-A-HAM2.3–Initial Model Evaluation and Effects of Radiation Balance Tuning on Aerosol Optical Thickness. *Journal of Advances in Modeling Earth Systems*, 14(4):e2021MS002699, April 2022.