Project: **1093**

Project title: **Revisiting the volcanic impact on atmosphere and climate – preparations for the next big volcanic eruption (VolImpact)**

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Report period: **2021-11-01 to 2022-10-31**

Below, we summarize the main contributions of the different VolImpact projects.

VolPlume contributions

We studied the ash aerosol aging and sulfate production during the first four days following the 2021 La Soufrière eruption with the ICON-ART modeling system. We compared our simulated aerosol distribution and composition with observations from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) instrument, Multiangle Imaging SpectroRadiometer (MISR) Research Algorithm, and radar reflectivity from the Barbados Cloud Observatory (BCO). We show that online coupling is essential to adequately model the emissions and plume development close to the volcano (Fig. 1). This work gives the first direct comparison of aerosol aging in volcanic eruption plumes between simulations and observations (Bruckert et al. in review 2022).

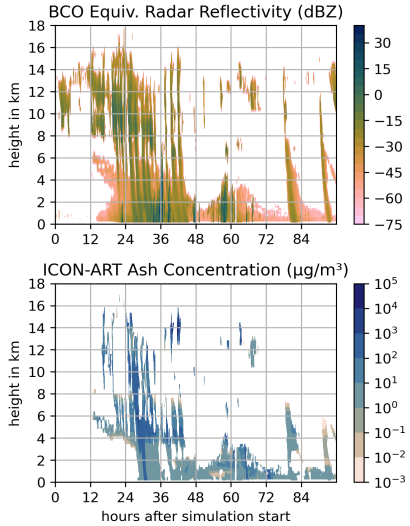

Figure 1: BCO equivalent radar reflectively in dBZ (top) and ICON-ART ash concentration (bottom) above Barbados in μg/m3;

To enable multiphase flow, we have extended the equation set of ICON-ART with the lower boundary condition. To test these implementations we perform idealized and real case experiments of volcanic eruptions and compare the results with observations and eruption plume models.

VolARC contributions

Within VolARC we compare the results of simulated volcanic eruptions to satellite observations. Results of SAGEIII satellite products show a reduction of the effective radii of sulfate aerosols after the eruption of the volcanoes of Raikoke in June 2019 and Ulawun in June and August 2019. We simulated the three eruptions with ECHAM5-HAM, a GCM coupled to a detailed aerosol micro-physical scheme. To gain a better understanding of micro-physical processes which are involved in the decrease of the particle size, we varied injection rates and altitudes of the eruptions. Additionally, the parameterization of the nucleation was updated to Mättäänen et al, (2018). This allowed us to study nucleation processes in the lower stratosphere without gaps, which were caused by conditions outside of the parameter range of the former parameterization. The realistic interplay of condensation, coagulation and nucleation is important to simulate the reduced particle size in the lower tropical stratosphere shortly after the eruption.

VolCloud contributions

We have studied the cloud response to the 2014 Holuhraun eruption. We simulated the initial phase of this eruption using the ICON-ART model and analyzed the results of different sensitivity runs. We then compared the results with observational (MODIS-Aqua) data. The results showed a very good agreement with the observations. In our studies, we conducted two different simulations, in one of which the volcanic emission is considered, while in the other one it is not (Plume and No-plume simulations). The results showed well the effect of volcanic aerosols on the different hydrometeors and process rates. Figure 2 illustrates the vertical profile of the riming process and graupel mass concentration in these two simulations and in different regions (inside and outside of the plume). Cloud droplet size in the Plume simulation are smaller than in the No-plume simulation because in the first case more aerosols are competing for the available water vapor. As a consequence, the riming process, which highly depends on this factor, is decreasing in the plume simulation. Graupel formation is also a process which is affected by the riming process, so we expected to see the reduction of graupel in the Plume case. The results confirm our expectation.

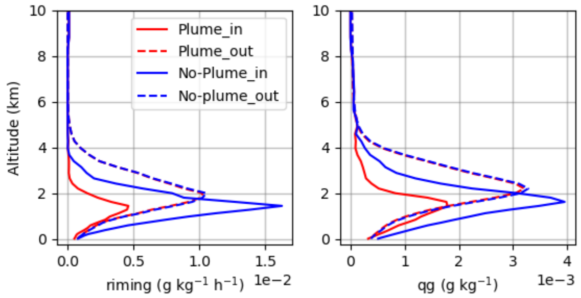

Figure 2: Vertical profile of the riming process (left), and graupel mass mixing ratio (right) in the Plume (red) and in the No-plume (blue) simulations. Solid lines illustrate these variables inside the plume (everywhere SO2>1 DU), and dash lines show them outside of the plume (everywhere SO2<1 DU). These variables were averaged over the time and the horizontal domain.

Related results were published in Haghighatnasab et al. (2022), on the basis of the early studies reported about last year. Besides, we have now also simulated the 2021 La Soufrière and the 2020 Kilauea volcanic eruptions and the analysis in comparison to satellite observations is ongoing.

VolDyn contributions

VolDyn investigates the impact of strong volcanic eruptions on the middle atmosphere with a specific focus on the mesosphere region. We continued to analyze results from idealized volcanic simulations using UA-ICON that we performed during 2021. Transformed eulerian mean diagnostics were crucial for us to understand the dynamical mechanism and unfortunately we spent more time on these analysis than expected. Finally, we were successful in applying these analytical tools to our model system and output structure. Our results indicate a warming of the summer mesopause region in the first post-volcanic winter that seemed to be caused by hemispheric coupling in the summer hemisphere and is potentially enhanced by inter-hemispheric coupling from the winter stratosphere.

VolClim contributions

The impact of volcanic forcing on tropical precipitation has been investigated in a large ensemble framework containing 100 realizations for idealized equatorial volcanic eruptions of different eruption strengths. In general, only equatorial eruptions with sulfur emission stronger than 10 Tg S lead to significant and substantial monsoonal changes. The decreased monsoon precipitation is strongly tied to the weakening of the regional tropical overturning as a consequence of less moist static energy exported away from the ITCZ (d'Agostino and Timmreck, 2022).
Emerging cloud resolving simulations offer the unique possibility to gain insight into the sensitivity of the TTL and the stratospheric water budget to external forcing, i.e large volcanic eruptions. We have therefore employed the ICON-A model at 10 km horizontal resolution in perpetual January mode for a control run and a volcanically perturbed scenario. Our results show that even in convection resolving simulations the cold point (CP) warming by the volcanic aerosols dominates the changes in the stratospheric water vapor budget. The TTL seems to be robust to external forcing, keeping the flux partitioning into slowly ascending water vapor and frozen hydrometeors constant even under large perturbations

References

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