Project: **1093**

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

Principal investigator: **Christian von Savigny**

Report period: **2019-01-01 to 2019-12-31**

As **VolImpact** started in spring 2019 and some projects even later during the year, not all of the proposed work could be carried out in 2019. This is in particular relevant for VolDYN, for which a position is still open. Short summaries of the contributions from the different VolImpact projects are listed below.

VolPlume contributions

The eruption of Raikoke volcano in June 2019 was simulated using ICON-ART. The main objective is to investigate the aerosol aging and its impacts on optical properties and plume dispersion. Four sets of experiments were and are conducted with aerosol dynamics and radiation interaction on and off. The preliminary results show that the model satisfactorily reproduces the observed ash and SO_2 clouds (Fig.1). The discrepancies stem from the assumed emission profile and the fact that tracers are considered passive and non-interactive in this simulation. The experiments are still ongoing to analyse the sensitivity of the simulations to different chemical mechanisms, aerosol-radiation interaction and injection profiles.

VolCloud contributions

In the reporting period, the volcanic fissure eruption of the Holuhraun volcano has been simulated, as proposed. The model used was the ICOsahedral Non-hydrostatic (ICON) model in numerical weather prediction (NWP) configuration (Zängl et al., 2015). In the first step after project start in mid-July, an idealised perturbation to the cloud condensation nuclei (CCN) concentration was chosen (c.f. Costa-Surós et al., 2019 using the model as in Heinze et al., 2017). A key idea was to investigate the adjustments of tropospheric clouds to the CCN perturbation. The satellite- and GCM-based study of Malavelle et al. (2017) that received a large amount of attention in the field, suggested a small overall change in cloud liquid water path (LWP). The pair of simulations for the domain around Iceland (Fig. 2) showed the expected significant and systematic increase in cloud droplet number concentration (Fig. 3). The LWP perturbation, however, in the simulation is also systematic (positive, i.e. increase in LWP, implying a negative contribution to the effective radiative forcing), albeit small and superimposed on a noisy signal resulting from internal variability (weather noise). The hypothesis on the basis of this is now that the overall signal is systematic and in terms of forcing important, but possibly not identifiable in observations. In the next year, model sensitivity studies and comparisons to data will be performed to test this hypothesis and to clarify the importance of the different modelled processes.

VolARC contributions

In 2019, Ozone Mapping and Profiling Suite (OMPS) measurements from Limb Profiler (LP) were processed in order to obtain profiles of stratospheric aerosol extinction coefficient at 869 nm (Ext869). As a result, not only a dataset with individual Ext869 profiles, but also level three climatologies with 10-day and monthly average Ext869 profiles covering the period from March 2012 to September 2019 were created. As it can be seen from Figure 3, there is an obvious increase in Ext869 after volcanic eruptions and wildfires. In the tropics (from 30° to -30°), after the volcanic eruptions the perturbation in Ext869 reaches higher altitudes with a certain time lag. This is a result of the so-called tape-recorder effect, which is a result of the active convection near the equator. The altitude as well as the length of the perturbation depends on the strength of the eruption and location of the volcano. For example, the perturbation from the Kelut eruption (2) is more pronounced in the tropical region of the Southern Hemisphere, where it happened, and is barely visible in the mid-latitudes of the Northern Hemisphere. At the same time, the 2017 Canadian Wildfires, which occurred at 51° N, are seen in both mid and tropical latitude bands of the Northern Hemisphere, but did not impact the Southern Hemisphere at all.

We have also started to work on first experiments with ICON-ART-A, the ICON version with climate physics and aerosol microphysical and chemical processes. We plan to perform simulations of the sulfate transport following a recent eruption. The results will be compared to satellite observations. We have performed short simulations of the test-suite. To include the emissions of volcanic eruptions still has to be included in the model and is part of the next steps and first test simulations.

VolDyn contributions

Most simulations planned for 2019 in VolDyn have been postponed to 2020, since the original PI of VolDyn left the project to take a new position in Canada. Work in 2019 focused on the development of EVA, specifically on the inclusion of aerosol optical properties in the lower most extratropical stratosphere. First simulation tests with a prototype EVA v2 should occur by the end of 2019. Also the UA-ICON simulations planned to be performed by the PhD student at Uni Greifswald had to be postponed due to the necessity for her to get acquainted with the topic.

VolClim contributions

The ICON-ESM simulations which were originally planned for 2019 have to be postponed to 2020 as the ICON-ESM control run is not available yet. Instead we have performed an early 19th century ensemble (1800-1829) with the MPI-ESM1.2-LR with an updated volcanic forcing data set to study the role of small to moderate volcanic eruptions in the early 19th century. The model results lie in the range of the Northern Hemisphere tree ring data (Wilson et al., 2016) for the time between the 1809 and the Tambora eruption indicating that the small eruptions might be one cause of the extended cold period after 1809 (Figure 5).

Figures*:*

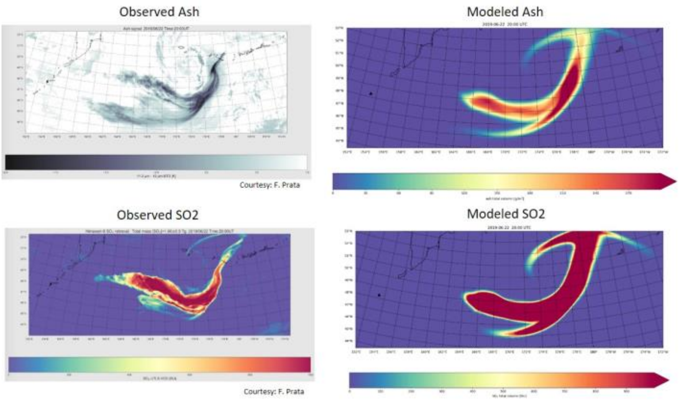


Figure 1. Observed (left) and simulated (right) volcanic ash and SO2 total column concentrations on 22.06.2019 after Raikoke eruption

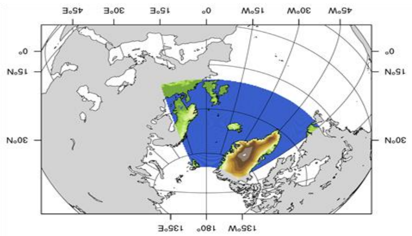
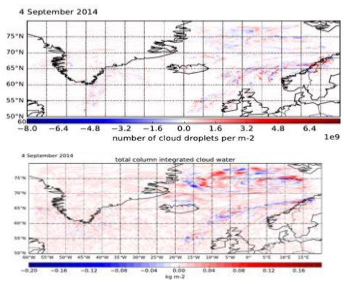


Figure 2: Grid definition (orography as colour scale) for the ICON-NWP simulation of the Holuhraun volcano on Iceland (centre of the domain).

Figure 3: Change in (top) cloud droplet number burden (m-2) and (bottom) cloud liquid water path (kg m-2) on day 4 of the simulation in response to an idealised extra CCN due to the volcanic aerosol



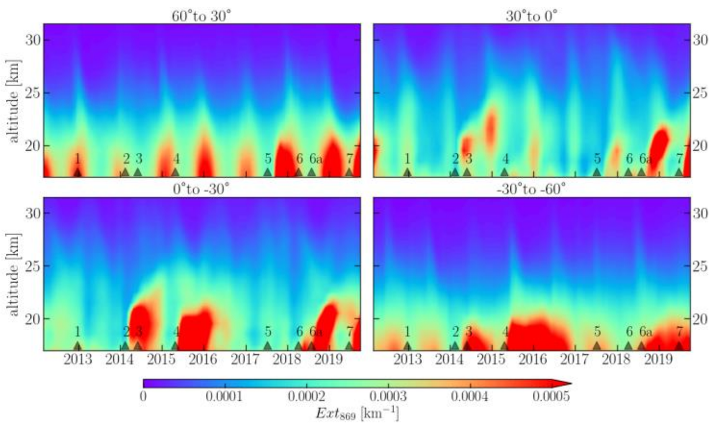


Figure 4: Monthly mean aerosol extinction coefficient (Ext869) distribution with time and altitude. Ext869 was retrieved from OMPS-LP measurements and averaged over longitude in 30° latitude bins. The triangles with numbers represent volcanic eruptions and biomass burning events: 1. Copahue, 2. Kelut, 3. Sangeang Api, 4. Calbuco, 5. Canadian Wildfires, 6 and 6a. Ambae, 7. Raikoke.

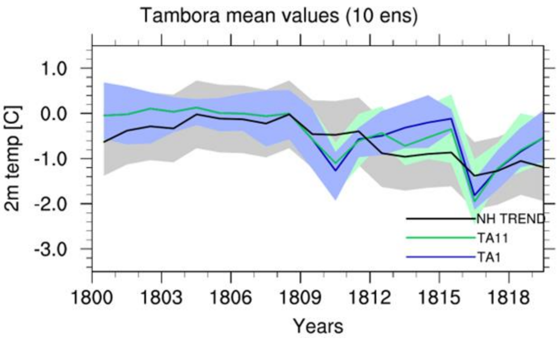


Figure 5: Comparison of NH summer land temperature anomalies between MPI-ESM simulations with (TA11) and without (TA1) small eruptions and NH temperature reconstruction from tree rings (Wilson et al., 2016 black solid line). Anomalies are taken with respect to a 1000 year control run. The colored solid lines represents the ensemble mean. The shaded grey area indicates the range of uncertainties for the tree ring data, while the shaded colored areas indicate the range of variability in the simulations.

References

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