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Interactive comment

Interactive comment on "Particle Aging and Aerosol–Radiation Interaction Affect Volcanic Plume Dispersion: Evidence from Raikoke Eruption 2019" *by* Lukas Ole Muser et al.

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This paper uses the ICON-ART modelling system to study the effects of volcanic aerosol dynamics (alterations in aerosol size and composition due to particle aging) and aerosol-radiation feedbacks on the dynamics of volcanic clouds. It is known that the strong absorption of fine ash particles can cause thermal disequilibrium with the surrounding atmosphere, potentially altering the atmospheric dynamics. However, in-depth studies are scarce in the literature and this paper is an important step forward. The authors show results for the 2019 Raikoke eruption, using measurements from different satellite instrumentation for model validation; TROPOMI and AHI for SO2/ash column mass retrievals, and MOIS/VIIRS/CALIOP/OMPS-LP for cloud top height. It is difficult to extract conclusions from a single example but, overall, I think this paper is very relevant to show the potential effects of both phenomena on model forecasts. I do recommend publication with minor revisions detailed below.

- ICON-ART is run for 3 scenarios: AERODYN_rad (aerosol dynamics + radiation), no_AERODYN_rad (no dynamics) and AERODYN_no_rad (no radiation), which allow isolating the effects of dynamics and radiation. These are actually in competition, with dynamics enhancing premature settling and radiation uplifting the cloud (as nicely shown in Figure 8). To what extent can these two effects counterbalance? This is somehow discussed in Sec 3.3., but it would be great to compare AERODYN-rad results with the no_AERODYN_no_rad ICON case. Note also that, to my knowledge, all operational volcanic cloud forecast systems do not include neither dynamics nor radiation and therefore the no_AERODYN_no_rad (not shown) would actually mimic current setups.

- Figure 4 is very interesting but panels (c)-(e) (and (d)-(f)) are difficult to distinguish and should highlight differences better (e.g. using a log scale). A better option could be plotting relative differences (in percent) between both model configurations, using AERODYN_rad as the “true”. Is it a 10\% or a 100\%? Difficult to say from (d)-(f) with the contour range used.

- On the other hand, and related to the point above, I missed some figure or text showing the impact on the atmospheric dynamics when switching on the AERODYN_rad module. To what extent is the vertical wind field advecting the cloud modified by thermal perturbations? Can you quantify? I understand that this question may fall beyond the objective of the paper, but it could be of interest to the volcanic cloud modelling community. Ensemble forecast strategies are gaining more and more attention, and these rely on perturbing uncertain variables like the eruption source parameters or the wind field (but rarely the vertical component). As a result, an interesting question it to assess whether (vertical) wind perturbations caused by radiation feedbacks are comparable to typical uncertainties in NWP models. If in the range, an ensemble of off-line models could still capture this effect, at least to some extent.

- The aerosol dynamics module (ARODYN) has pre-defined initial aerosol size distributions, which (if I am not wrong) are evolved according to prognostic equations. How does the aging mechanism depend on this initial condition? Particle distributions can vary notably from one eruption to another, and a single representation could be misleading.

- Model validation. Several plots compare model results with observations. However, I missed some quantitative metric values; e.g. SAL, Figure Merit of Space or others. These are by far more objective than color plots (e.g. Figs 4, 5), which can trick depending on the scale and color binning. Given that a main objective of the paper is to "assess if representations of aerosol dynamics and aerosol-radiation interactions are beneficial for forecasts", quantitative metrics would help asking this question more objectively.

- Line 84. "density values less"?

- Line 257. It is stated that the source term in ICON-ART is set between 8 and 14 km a.s.l. Does it mean a 6 km thick cloud? This seems quite inconsistent with the TROPOMI retrievals, which assume 1 km thickness at 15 km a.s.l.

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