Response to reviewer comments: Effect of volcanic emissions on clouds during the 2008 and 2018 Kilauea degassing events

Katherine H. Breen[1, 2], Donifan Barahona[1], Tianle Yuan[1, 3], Huisheng Bian[1, 3], and Scott C. James[4]

[1]NASA, Goddard Space Flight Center, Greenbelt, MD, USA
[2]Universities Space Research Association, Columbia, MD, USA
[3]Joint Center for Earth Systems Technology. University of Maryland, Baltimore County, MD, USA
[4]Baylor University, Departments of Geosciences and Mechanical Engineering, Waco, TX, USA

Correspondence: Donifan Barahona (donifan.o.barahona@nasa.gov)

Review Reports

The authors thank the reviewers for the thorough comments. Responses are given below.

Reviewer 2 comments and authors' responses

Congratulation for this work. the revision has substantially improved the quality of the paper. Most of my comments have been properly addressed and I recommend the paper for publication. However, I would like the authors to clarify the following points:

Comment: *regarding the use of satellite observation in the model: I understand that OMI data is used to feed the model with volcanic S02 emission. But the answer to my question on the use of data assimilation of satellite observation to estimate aerosol concentrations or other state variables is not clear. I suggest to clearly state this in the model section. Besides, one needs to distinguish between data assimilation used to constrain the time trajectory of the model and the use of satellite observation as a forcing variable (emission)*

Response: Simulation of aerosols is described in Section 3.1 as follows:

> Transport of aerosols and gaseous tracers such as CO were simulated using the Goddard Chemistry Aerosol and Radiation model (GOCART) (Colarco et. al., 2010), which interactively calculates the transport and evolution of dust, black carbon, organic material, sea salt, and SO_2. Dust and sea salt emissions are prognostic whereas biomass burning and antropogenic emissions of SO_2, black carbon, and organic carbon are obtained from the Modern Era Retrospective Reanalysis for Research and Applications-Version 2 (MERRA-2) dataset (Randles et. al, 2017). ... Using the evolving meteorological fields from GEOS, for each time step GOCART simulates the advection (using a flux-form semi-Lagrangian method, (Lin et. al., 1996)), convective transport, and the wet and dry deposition of aerosol tracers.

The nudging of the model state using the "replay" technique is explained in section 3.2 as follows:

To account for model drift all simulations were run in "replay" mode, where pre-computed analysis increments from MERRA-2 were applied to nudge the model state (i.e., horizontal winds and temperature) to the reanalysis every six hours.

To address the reviewer's concern, we have expanded the description in Section 3.2 to clarify the difference between nudging the model state, which indirectly affects the aerosol, and directly nudging aerosol concentrations:

. . . **Aerosol concentrations are indirectly constrained by the reanalysis since their transport and evolution, as well as the emission of dust and sea salt, depend on the model state (i.e., winds and temperature). The emission of sulfate precursors (SO2) is constrained using satellite retrievals as described in Section 3.1. However aerosol concentrations were not directly nudged to the MERRA-2 product, even though the aerosol increments are also available (?). Doing so would have limited the response of clouds to aerosol (via aerosol activation) and vice-versa, the response of aerosols to cloud formation and precipitation (via scavenging).**

Comment: *The authors have not properly addressed my first comment about "What is the actual contribution of this study to previous works exploiting volcanic emission to characterize the impact of aerosols on ice and liquid cloud processes" . The justification wrt to Kilauea event is fine, but the readers expect a clear understanding of what is the contribution of the paper to the more general topic on the interactions between volcanic emission and aerosol-cloud interaction processes.*

Response: We have clarified the contribution of this work in the Introduction as follows:

. . . However analyses of ice clouds and of the impacts of the 2018 event on cloud properties and evolution has not yet been reported. This work constitutes a substantial contribution towards identifying ACI signatures for liquid and ice macro and microphysical processes and their sensitivity to aerosol loadings and CCN/INPs.

Comment: *the following statement added for CALIPSO is not clear : For each level, the gridbox fraction of cloudy, clear, and uncertain areas sum to 1, with the JJA seasonal mean uncertainty (2006–2008) $\leq$ 0.05 above the boundary layer (Chepfer et al., 2010) . . .*

Response: We have clarified the statement about GOCCP cloud fraction uncertainty as follows:

. . . The seasonal mean uncertainty (2006–2008) for GOCCP cloud fraction is ≤ 0.05 above the boundary layer (Chepfer et al., 2010).