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Interactive comment on "PLUME-MoM-TSM 1.0.0: A volcanic columns and umbrella cloud spreading model" *by* Mattia de' Michieli Vitturi and Federica Pardini

Julien Savre (Referee)

julien.savre@lmu.de

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The paper entitled "PLUME-MoM-TSM 1.0.0: A volcanic columns and umbrella cloud spreading model" by de' Michielli Vitturi and Pardini presents and validates a coupled approach to simulate volcanic plumes and umbrella. The plume model relies on a classical steady-state, one-dimensional approach where the plume's development is determined by solving a system of equations characterizing bulk plume properties. Once the plume reaches its level of neutral buoyancy, outputs from the plume model serve as inputs to an umbrella model based on two-dimensional shallow water equations. Another novel aspect of the approach is the inclusion of a hybrid spectral-moment based

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model to represent ash size/mass distributions. The approach also allows the modeling of aggregation by approximating (summing over the bins) the integrals describing the smoluchowski coagulation equation.

As a non-expert in the field of volcanic plume modeling, I am not in a position to judge the scientific relevance of the methods introduced and the accuracy of the results presented. As such, I have mostly focused my review on the overall structure and readability of the manuscript. With that in mind, I would recommend accepting the manuscript for publication provided that the authors implement the various minor corrections that I am suggesting. Some of my most important comments are listed below, but the full list of comments (including many technical corrections) can be found in the attached annotated manuscript.

Minor comments:

Section 2.1: The section is rather dense and I would recommend dividing it into several subsections.

Section 2.1: Could you please consistent in the way the function eta is called. It is sometimes referred to as number density function, NDF, mass distribution, distribution of mass fraction...

Eq (5) onward: I don't understand why you suddenly dropped x and t from eta.

Eq (8): Is there a citation you could add for these expressions?

Eq (10): I don't understand in which situation each case is used. Is there a criterion that allows you to switch from case to case?

Figure 2 actually didn't help me understand, and it would be nice to explicitly explain that in the text. By the way, you never explain clearly how you calculate the coefficients alpha, beta and gamma. This is really missing from the model description.

Section 2.2: I am missing an equation for the plume size/radius. You should at least indicate somewhere how this quantity is determined.

line 194: You state that the plume equations are solved in a 3D coordinate system, and yet, all equations are written in 1D. I believe all plume equations assume an axisymmetric plume and are derived in a cylindrical coordinate system. Could you please correct?

line 198: You define Phi as an angle, but you already introduced the notation previously for the Krumlein scale. Similarly, you later use w to denote the vertical plume velocity, sedimentation velocities and the specific humidity. Could you please use different notations to denote different variables?

Eq (13): Should be supported by a citation.

Eq (14)-(15): Shouldn't the integrals be replaced by sums since, after all, what you do is simply summing over bins.

Eq (17)-(18): The ËĘ notation is not defined. line 300: I would suggest explicitly stating that x_w is the mass fraction of total water, and that the various contributions from vapor, liquid and ice are determined as described in the appendix.

lines 333-335: I believe that you forgot to mention here all the extra steps described in Appendix A1 to partition condensed water between liquid and ice. This should be mentioned.

Eq (40): Several parameters are poorly defined. In particular, C_D, gamma, u_nbl, v_nbl and w_nbl (and nbl indices in general) are not defined in the text. I would also suggest explaining the physical meaning the two terms on the right hand sides of the equations.

Eq (41): Again, function chi is not defined.

lines 409-419: How do you initial the atmospheric background profiles? Nothing is said here about where the data comes from. By the way, a longer description of atmospheric profiles determination is given in 3.2. I don't understand if the same method was used also to constrain the experiments run in 3.1. If yes, then the whole part should be moved to the beginning of 3.1. If no, then something is missing from3.1 anyway.

lines 427-428 and fig 5: I am very very surprised to see so much ice formed all of a sudden while no liquid water is present. It seems like at the top of the plume, all the water is found in ice form, there is no more water vapor. This points to a serious caveat of the model. Perhaps a mistake in the formulation of the liquid-ice partitioning method? In any case, you need to comment on that issue and discuss possible reasons for these extreme ice fractions.

Figure (6): I would suggest rewriting the caption like: "Same as figure 5 but for the second event."

Figure (7): Does the color scale represent time? You should add a title to the color bar to specify that.

Section 3.2: As said previously, is the method described here to initialise the atmosphere similar to what was used in 3.1? If yes, this should come earlier. Also, this is absolutely not clear to me if the sensitivity experiments shown here are based on the same case study as in 3.1 or are purely idealized. The connection (or lack thereof) between the simulations in 3.1 and 3.2 should be more clearly stated.

line 645: Which parameters have been constrained? Except perhaps for C_D which was tuned to reproduce observations, we can't really say that model parameters have been constrained.

equation (A3): e_l is not defined.

lines 704-705: Which of the two temperature is used then? Or under which conditions one or the other is used? More generally, I found the whole part between equations (A8) and (A10) very confusing.

Eq (A9): So if understand the equation well, when mixed-phase conditions prevail, x_lw is first calculated at T=0C, and then corrected using a linear function of the temperature such that it would be 0 at -40C? Then, the ice fraction is simply the total condensed water fraction - x_lw?

line 722: It says that several settling velocity models are implemented. But which one is used in your experiments then? This is never said. More generally, I would recommend only describing the one model that has actually been used.

Please also note the supplement to this comment:
https://gmd.copernicus.org/preprints/gmd-2020-227/gmd-2020-227-RC3-supplement.pdf

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