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Interactive comment on "PLUME-MoM 1.0: a new 1-D model of volcanic plumes based on the method of moments" *by* M. de' Michieli Vitturi et al.

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This paper describes a new and significantly different form of 1-D volcanic plume model, which treats the grain-size distribution (GSD) in the ascending plume as a continuously variable function rather than a collection of discrete size classes. It uses this formulation to examine how particle fallout changes the GSD as a function of height, and how other plume properties, like total plume height, change as the initial grain-size distribution is varied.

The paper is scientifically rigorous, clearly written, and the results in my opinion are significant, showing that the GSD doesn't vary much from the bottom to the top of the

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plume for the GSD values considered. The paper requires a lot of description and mathematical derivation to present the approach. Readers who are not interested in the methodology as much as in the results may not be willing to slog through all the mathematics to get to the good stuff. My only suggestion to address this is that a few sentences be added to the Introduction emphasizing the geologic importance of the questions that this new approach can address.

In the Introduction, your description of the value of using a continuously variable function is too vague to present a clear image of the problem and its importance. Much of problem is in a single sentence on lines 12-14 of page 3747, which describes the limitations of models that do not use continuously variable functions. I would change this line by deleting the ". . . " in the following: "Both approaches make proper treatment of the continuous variability . . . of particles and gas bubbles difficult".

In Section 2, it would be worthwhile adding a qualitative statement at the beginning or end of this section saying how the number-based moments, Sauter mean diameter in particular, differ from corresponding moments calculated by mass-based methods. The Sauter mean diameter appears to be an average diameter based on the number of particles rather than mass. Because there are more small particles than big ones, this mean diameter should be less than a mass-based mean diameter. Is this correct? Would the same apply for the moments of density and other properties?

A few key assumptions of the model should be stated more explicitly. For example I could see from the energy equation that phase changes in water were not considered, but I didn't see this point explained in the text.

Many specific comments that follow, but no other major comments. I think the paper is important, well written, and is a significant contribution to the literature on plume dynamics.

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Specific comments:

Page 3747: Lines 12-13: deleting "of fundamental physical and chemical properties of the dispersed phases" will make this sentence more concise and meaningful. Lines 14-19: could you cite some of the literature that you say makes the point in this sentence? Line 24: Many readers (including me) will be unfamiliar with the method of moments. What fundamental physical quantities are balanced in a population balance equation? And what are "moments" in physical terms? A general statement relevant to the Introduction. I am familiar with only one other 1-D plume model that treats the GSD as a continuous function and analyzes its change with height. Veitch and Woods [2001] looked at changes in the GSD with height in a plume due to particle aggregation. Veitch and Woods isn't mentioned in this paper, but perhaps should be. Could one modify PlumeMom to calculate changes in GSD due to aggregation? This might be a selling point of this approach, since particle aggregation has proven very hard to model quantitatively by other methods.

page 3748, line 7: what do you mean by "the implementation of the quadrature"? Line 10: Uncertainty in what? What physical properties are you studying, whose uncertainty you want to incorporate?

Page 3749: Equation 1: What terms on the right-hand side of this equation are different for different moments? It seems that this f_j(D) would have to be different, but it's not clear to me how. Also, perhaps mention that the second and third moment assume a spherical shape. Or if this is not the case, what do they assume? And what does the superscript i on Dˆi mean? Line 20: it would be helpful to explain briefly what the Sauter mean diameter means physically. I thought this was a diameter based on number concentration of particles but in Fig. 2 it shows the Sauter mean diameter as being larger than the mass-based mean, which one would not expect from a numbers-based diameter.

Page 3750: line 14: add "such" before "as settling velocity". line 15: change "function"

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to “functions”.

Page 3751: Equation 3: actually, using the method of Bonadonna and Phillips, density at diameters intermediate between D1 and D2 are interpolated on a log scale of phi, not on a linear scale of D as this equation indicates. Equation 4: what is the physical meaning of the different moments of density? Line 8: What are D* and rho*? Lines 11-12: you define volumetric averaged density as the mass of particles per unit volume. Does “per unit volume” mean per unit volume in the jet or plume? Per unit volume of each particle? If per particle (as implied later), perhaps say “average mass per unit volume of particles”

Page 3752: line 10: Put “Pfeiffer et al. (2005); Textor et al. (2006a, b)” in parentheses. Equation 8: what is the physical meaning of the moments of settling velocity? Maybe this could be addressed by just moving the statement (line 3 of the next page) that they represent surface and volume-weighted averages to the line immediately above the equation.

Page 3753: Line 5: change “particles” to “particles’”, to make it possessive.

Page 3756: Line 13-14: bulk density means mass of particles per unit volume of particles? Mass of particles per unit volume of plume mixture? If the latter, maybe say “mass of particles per unit volume of plume mixture”, or something similar.

Page 3757: Equations 22, 23: If this is a 3-D coordinate system, shouldn’t there be three momentum conservation equations? Also, in the equation for horizontal momentum (22), I’ve generally thought of the the change in momentum of the gaseous phase (first term on the right-hand side) as being equal to the horizontal momentum contained in the entrained air (2*r*rho_atm*U_e*w). Your formulation is a little different. Perhaps you could add a sentence explaining your formulation.

Page 3758: Equation 24 (energy equation): Do you mention anywhere that you are not considering phase changes of water? It looks from this equation like you are not

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considering it, but I don't see that you mention this point in the anyplace in the text. Line 18: What do the superscript B's represent? Also, defining the rho terms on this line as bulk densities seems misleading (at least to me). In order for the denominators on the top and bottom of eq. 26 to be consistent, the rho's must be the mass (or air, water vapor etc.) per unit volume plume mixture, not per unit volume of air or water vapor. Perhaps refer to them as the mass of each component per unit volume of plume fluid. (maybe I missed it).

Page 3760: Line 15: change "particles number" to "particle numbers"

Page 3762: Equation 40: If these are ODE's, the LHS of eq. (40) should be dy/ds rather than partial(y)/partial(s). Equation 41: perhaps add a multiplication symbol on the RHS between ds and f().

Page 3764: Line 14 and elsewhere: change "particles family" to "particle family" Line 23: change "particles size distribution" to "particle size distribution"

Page: 3765: Line 9: change "then writes as" to "is then written as" Equations 44: does "log2" mean the log base 10 of 2? Maybe write as log_10(2). Or, if you mean the natural log, then write ln(2). Pages 3765-3768: this is quite a slog through this section. It's not clear exactly where you're going. Adding a sentence at the beginning of Section 4.2.1 stating your objective in deriving these formulas might help readers keep their interest.

Page 3769: Line 5: the term "weak plume without wind" makes no sense to me, since a weak plume is generally defined as one that is bent over by wind [Sparks et al., 1997, p. 279]. "Low-flux plume without wind" may be more accurate. Line 16: you use a normal distribution? Not lognormal? Line 13: can you provide a reference for the standard atmosphere cited here? Line 17: change "expresses" to "expressed". Line 18: Are you describing three different model runs, or a single model run with the output portrayed in three different ways?

Page 3772: a nicely written and illuminating summary of the Latin Hypercube and gPCE alternatives to MCMC modeling.

Page 3773: Still illuminating. I'm not a specialist in the mathematics of these techniques and can't critique them. It's a little unclear to me what the form of equation 55 would be if fully expanded. For example, if zeta were a vector of 3 variables, would P1 represent three families of polynomial coefficients; one for each variable?

Page 3774: the values contoured in the lower panels of Fig. 7 were not initially very clear to me. You call them response functions in the caption, and on page 3773 (line 17). Are these the values of gamma(zeta) in eq. 55? Perhaps referring to gamma(zeta) as a response function would clarify. Also, it would help to mention that the values contoured in the lower panels are the same as those plotted in the upper panels (e.g. top mean phi for panel 1). Lines 22-30: I would say that the points you make in these few lines are the most significant of the paper, for readers interested in geologically relevant findings.

Page 3775: Line 4: change "reduce" to "reduces". Line 5: change "relvance" to "relevance". Line 6: change "entrained aid" to "entrained air". lines 13-14: "The mean and the SD of the TGDS at the top of the eruptive column clearly reflects the corresponding values at the bottom, with a small effect on the mean size at the top of larger values of the bottom SD". What does this mean?

Page 3776: Line 10: I'm a little confused about which of the sensitivity indices (Si or Ti) is displayed in Fig. 9.

Figure 2 caption, line 4: change "forth" to "fourth". Figure 5: the light gray curves on this figure are hard to see on my computer screen. Darkening them should make them more visible. Figure 6 caption: change "Two parameters Latin Hypercube" to "Two-parameter Latin Hypercube"

References:

Sparks, R. S. J., M. I. Bursik, S. N. Carey, J. S. Gilbert, L. S. Glaze, H. Sigurdsson, and

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Veitch, G., and A. W. Woods (2001), Particle aggregation in volcanic eruption columns, J. Geophys. Res., 2001(B11), 26,425-426,441.

Interactive comment on Geosci. Model Dev. Discuss., 8, 3745, 2015.

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