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Geoscientific
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Discussions

Interactive comment on “Plume-SPH 1.0: A three-dimensional, dusty-gas volcanic plume model based on smoothed particle hydrodynamics” *by* Zhixuan Cao et al.

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General Comments

This paper presents an initial effort toward developing a plume model with comprehensive physics based on the smoothed particles hydrodynamics method. To my knowledge, this is the first numerical model of volcanic plumes adopting this technique and this is a good addition to the existing models. While the model, the derivation of the discretised equations and the computational techniques are satisfactory for a reader expert in SPH, a few more details would help in the comprehension other readers. The scientific content of the paper could be improved by a better and extended descrip-

tion of the applications. Overall, the manuscript represent a substantial contribution to modellingÂăscience within the scope of Geoscientific Model Development and it is suitable for publication after some improvements and corrections are made. These are described below.

Specific comments

Abstract

Line 8. What does dynamic and thermodynamic equilibrium with surrounding air mean? No relative velocity? Same temperature? I think it is an equilibrium between volcanic gas and particles.

Line 23. The model is not really compared with the top height of the Pinatubo eruption, because atmospheric conditions are changed from real ones (no wind in imposed, weak vs strong in Costa et al 2016); in addition, MER is fixed. So, it is more a comparison with results from other 3D models, for an eruption with the same MER estimated for Pinatubo 1991.

Section 1.3

Page 4, lines 23-25. It is not clear to me why interface tracking or interface capturing are mentioned here for mesh based method. I think all the existing 3D Eulerian models (based on mesh based method) do not model the interface between the plume and the atmosphere. While I understand that this represent a big advantage for other applications of SPH, for example for dam-break problems, because it allows to solve only for the “flow” region and not fir the surrounding, for a volcanic plume mixing between plume and air is important and I don’t really see a clear interface between them. Please clarify and expand the point.

Section 3. SPH method

Sometime equation are referenced before they have been introduced. See for example lines 23 and 24 at page 10 where there is a reference to Eqs. 34 and 35, which are in introduced in the next subsection.

Again, at page 10, sentence at lines 25-26 should be referred to the discretised version of the equations, while discretisation is presented later in the section.

Page 11, line 1. It is written “region of compact support” before having stated the properties of the weighting function. Maybe add an equation that define this property:

w(x-xb,h) = 0 if |x-xb|>kh

for some k, i.e. the support is proportional to the smoothing length.

A suggestion… Probably the issues raised above could be solved moving the content of section 3.2 to section 3.1, after equation 26.

Section 3.3

Page 12, line 22. The “sink” term has been added to eq. 42, representing the discretised form of mixture equation. If the term is associated with a phase change, it would be better add it in the equation for a phase and not for the mixture with density rho.

Page 12, lines 24-25. “ The drag force term should show up only when dynamics 25 disequilibrium between different phases is considered”. In this case is the summation in the last term of eq. 43 only extended to particles of a different phase?

Section 3.4

Page 13, line 5. Please define “particle disorder”.

Section 3.5

Page 14, line 5. how sound speed of a particle is defined for the gas-solid mixture? Please add an equation

Page 14, line 5. What is the order of magnitude of the time step for the tests presented, with a fully explicit scheme?

Section 3.6,

Page 14, line 8. “ The classical SPH method was known to suffer from tensile instability and boundary deficiency.” Please describe there problems with some example, in order to help the readers not expert in SPH.

Page 14, line 14. “Equation (55) implies that ….=1”. Why? It is not equation 55 which implies the term is equal to 1, but the properties of the kernel. Furthermore, this is true for the integral (not discretised) formulation, and only for points far away from the boundary (see Chen et al., 1999).

Section 3.7

Page 14, line 21-22. “ Numerical simulation of multiphase flows is usually difficult due to the existence of complex evolving interfaces between phases.”

This is true when the different phases are immiscible. But in the application investigated, the volcanic plume, phases are not immiscible and mixing is very important. So, there is no need to track the interface between phases Eulerian grid-based numerical methods. Conversely, standard formulations of SPH cannot resolve fluid mixing and instabilities at flow boundaries. IT should be discussed in the paper if, and how, this is has been addressed in the model presented.

Please take a look at:

J. I. Read, T. Hayfield, O. Agertz; Resolving mixing in smoothed particle hydrodynamics, Monthly Notices of the Royal Astronomical Society, Volume 405, Issue 3, 1 July 2010, Pages 1513–1530

Section 3.8.1

Page 16, line 10. For a reader like me who is more familiar with Eulerian and mesh-based formulation, it would be good to state at the beginning that, differently from RANS (Reynolds Averaged Navier-Stokes) equations, which are time-averaged equations of motion, here the Lagrangian average is in space and not in time.

Section 3.8.2

Page 20, line 8. Is this equation the definition of F_{ab} or a property? If this is the definition, where is the argument of the function F?

Section 3.9.1 Wall boundary condition.

Please discuss the limitation of this approach when a complex topography is considered. In particular, how could you deal with convex geometries?

Section 3.9.3

Keeping the pressure constant at atmospheric boundary can represent a problem when particles exit from the domain and choosing a larger computational domain cannot be the solution for long simulations. A better way to implement the boundary conditions at the exit would be to impose a condition on the total pressure (p_rho-0.5*rho*uˆ2, where p_rho=p-rho*g*h). This allow to have pressure changes at the boundaries associated with outflow.

Section 4. Verification and validation

deals with the numerical resolution of the equations of the model, not with the agreement between the model and reality. It checks no code errors have been introduced in the code and one way to do it is a comparison with analytical solutions. I think it is better to simply rename the section "Applications" or “Results”.

Section 4.1

Page 25, line 24. Please look also at the results from this paper:

Ezzamel, Adam, Pietro Salizzoni, and Gary R. Hunt. "Dynamical variability of axisymmetric buoyant plumes." Journal of Fluid Mechanics 765 (2015): 576-611.

Page 26. Please put figure 6 and 7 together as to subplots

Page 26, line 12. The expression for the Gaussian profile should be written as an equation (on a single line and numbered) and the terms should be defined after it is introduced, before writing the expression for the straight line.

Page 27. Please put figure 8 and 9 together as to subplots

Page 28, line 1. Please write the straight line expression as an equation on a single line.

Page 28, lines 8-9. “results, a small disparity in both velocity and concentration are observed near the boundary of the jet.” Looking at figure 10, it seems that near the boundary of the jet there are regions without particles, and this could be the reason of the differences with experimental results. The emptying of particles in region with steep density gradients is described in section 3.4 of this paper:

Ritchie, Benedict W., and Peter A. Thomas. "Multiphase smoothed-particle hydrodynamics." Monthly Notices of the Royal Astronomical Society 323.3 (2001): 743-756.

Look for example at their figure 9.

Page 28. End of section. The paper presents also details about the numerical implementation and the parallelisation of the code, so it would be interesting to have more info for this test about computational cost, number of particles, core/cpu used, ...

Section 4.2.1

Page 29, lines 7-8. From Costa et al. 2016 "For the erupted particles, only two size classes were considered, representing coarse ash (Φc) and fine ash (Φf), each comprising 50 wt.% of the erupted particles " Here I cannot find any info about particles...

Page 29, line 13. In Fig. 1B it is plotted the meteo profile where it is also shown the presence of wind. Please clarify.

Page 30. Why there are no figures showing a 2d section of the plume, as done for the previous test? It would be interesting to see a vertical section of some variables (for example instantaneous value of mixture velocity modulus) and velocity streamlines, as shown in Cerminara et al.

Page 30, line 1. The averaging technique of Cerminara et al. is defined for grid-based eulerian models. It would be interesting to know the details of the implementation of the technique for the SPH code (perhaps in an appendix).

Page 30, lines 1-4. “ As particles distribute in a disordered manner in the space in SPH simulation results. We first project simulation results (on disordered particles) onto a pre-defined grid before doing time average and spatial integration. The project method is the basic SPH kernel based interpolation.” These lines are confused, please check.

Page 30, line 11. Eq. 95 is referenced here, so it should be written immediately after this sentence.

Page 32, end of section. In this section it would be good to have more details on the simulation (number of particles, computational cost, number of cores/cpu), and also to make a comparison with the other models regarding the time needed for a simulation.

Technical corrections.

See pdf attached

Please also note the supplement to this comment:
https://www.geosci-model-dev-discuss.net/gmd-2017-119/gmd-2017-119-RC1-supplement.pdf

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