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Geoscientific Model Development Discussions
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Interactive comment on "A semi-implicit, second order accurate numerical model for multiphase underexpanded volcanic jets" *by* S. Carcano et al.

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We thank Prof. Taras Gerya for his constructive comments and suggestions. In order to improve the paper, we have addressed them as follows:

Question 1 - Add resolution test to Figs. 3, 4 to show variability/convergence of results with changing numerical resolution.

In response to the reviewer's comment, we have run additional tests that we are going to include in the revised manuscript. We have repeated the simulations shown in Figures 3 and 4 of the paper with different spatial resolution, in order to analyze how the results change with the grid size. We show the axial profiles of gas pressure obtained with different grid resolutions ($\Delta x = 1, 0.625, 0.5, 0.25, 0.2$ mm, inlet diameter is D_v=10 mm) with second order methods in Figure 1. Moreover, the estimates of the Mach disk height are shown in Figure 2. We observe how the Mach disk height estimate improves with grid resolution and the second order method described in the paper is able to provide a reliable estimate of the Mach disk position even with coarse meshes.

Question 2 - Add short discussion/outlook section on future improvements of physical correctness, numerical accuracy and computational efficiency of 3D numerical models for strongly advective 3D multiphase volcanic flows (e.g., the potential for implementation of local mesh refinement, characteristics/markers-based non-diffusive advection schemes etc.)

We are going to add in the conclusive section of the paper a discussion on possible further improvement of the numerical model.

For what concerns model formulation, the most critical aspect pertains to particle thermodynamics, since particle-particle collisions are non-negligible for volume concentrations above about 10^{-3} (Gidaspow, 1994). To improve model reliability in such regimes, we are moving from the present formulation (implying a semi-empirical description of solid pressure and equation of state) to a more rigorous closure based on the kinetic theory of dispersed granular materials. However, in the present application, such improvement is not critical since the dynamics is strongly driven by gas pressure terms and gas-particle drag, whose form is well established.

Concerning numerical accuracy, the use of numerical approximations of order higher than two may not be a major concern, if only volcanologic applications are considered, due to the large uncertainties in the available data and especially in the initial conditions. Local mesh refinement techniques may certainly improve code efficiency on large-scale numerical simulations but would require a complete code re-engineering. However, in order to improve the description of the later stages of volcanic eruptions, where turbulence effects become more important, and in view of different applications of the multiphase model to industrial applications, we are planning to further improve the accuracy by adopting spatial discretizations based on discontinuous Galerkin schemes, which allow to increase the order of the approximation while retaining a compact stencil.

Concerning computational efficiency, we are also looking at explicit time discretizations, such as Runge-Kutta methods, that have beew widely applied in the literature to solve gas-dynamics problems at high Mach numbers.

Interactive comment on Geosci. Model Dev. Discuss., 6, 399, 2013.

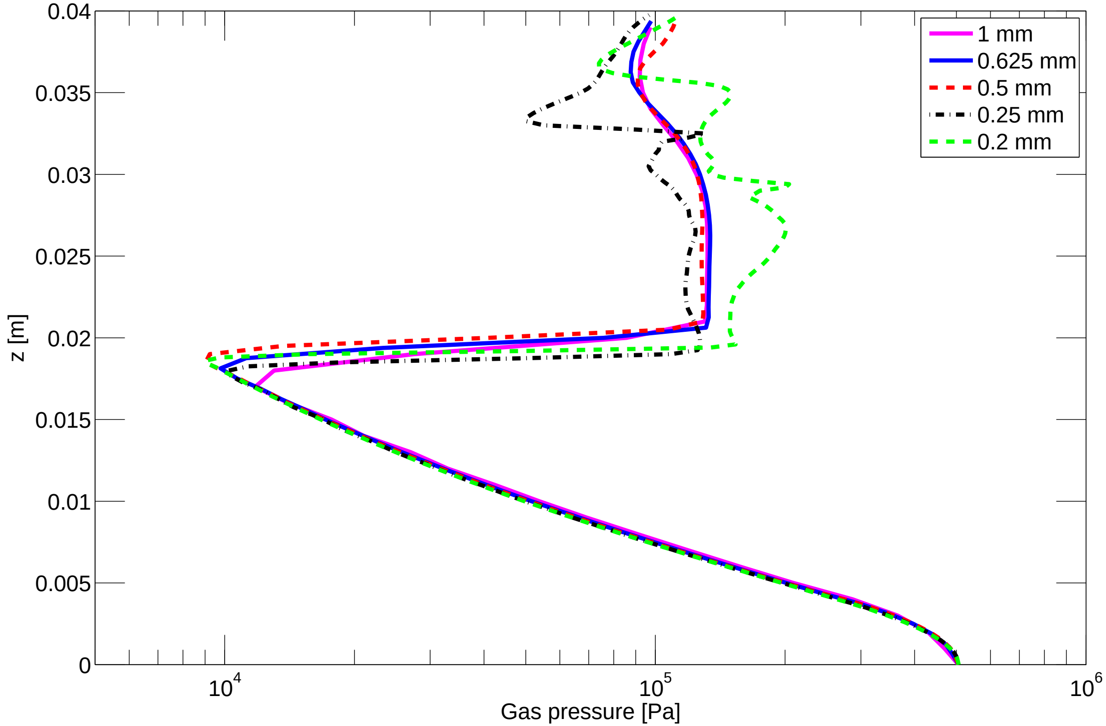

Fig. 1. Second order method. Axial profiles of gas pressure for the test case described in Table 1, with $K = 5$, obtained with different grid resolutions.

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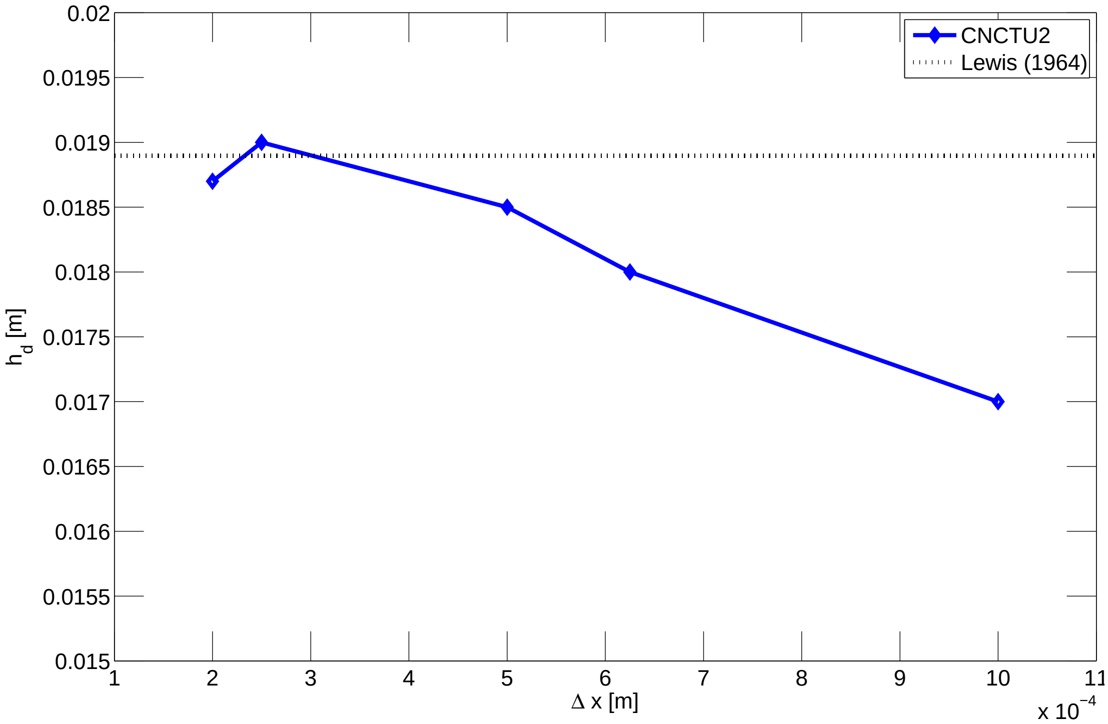

Fig. 2. Estimate of the Mach disk height obtained with second order methods with different grid resolution. Comparison with the theoretical estimate.