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Influence of basal slip on the propagation and cooling of lava flows

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A thin layer approximation is used for studying of viscous gravity currents on the horizontal topography from a point source. The main difference from a self-similar solution obtained in Huppert (1982) is the account for partial slip of lava on the ground surface. We assume that the slip velocity is proportional to the tangential stress in some positive power. This condition is widely used in polymer science and for the flows on superhydrophobic surfaces. This condition is also applicable for lava flows because of a large roughness of volcanic terrains and the presence of unconsolidated material (ash, lapilli).

The system of Stokes equations was reduced to a non-linear parabolic differential equation. Its solution was found both numerically and by a reduction to an ODE that describes similarity solution. In the latter case there is a dependence between lava mass growth rate and the power exponent in the friction law. It was shown that the presence of basal slip allows much faster propagation of lava flows in comparison with no-slip condition at the ground surface. Analytical solutions were proved by a good comparison with fully 2D axisymmetric finite volume simulations.

Based on the velocity field obtained from a thin layer theory the heat budget of a lava flow was studied for the case of constant lava viscosity. Heat equation was solved in the lava domain with no flux condition at the bottom, radiative and convective fluxes at the free surface and the influx of a fresh magma from a point source. It was shown that due to a strong difference in the velocity profile the distribution of the temperature inside the lava flow is different in the cases of no-slip and partial slip conditions.