A One-dimensional Steady State Model of a Buoyancy-generating Turbulent Plume and its Application to Volcanic Eruption Columns

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I will talk about a one-dimensional steady state model of turbulent plumes in which the buoyancy flux significantly increases with height. This model clearly suggests the importance of the formulation of the increase in buoyancy flux due to thermal expansion of entrained air to appropriately describe the fundamental features of volcanic eruption columns. An analytical solution of a simple form is specifically derived for an idealized axisymmetric turbulent plume of a linearly increasing buoyancy flux in a uniform environment. The solution predicts that the upward velocity of the plume is constant along the height, in contrast to the upward velocity of a common incompressible plume, the velocity of which decreases inversely proportional to the third root of the height. More realistic plumes in both uniform and density-stratified environments are also investigated by modifying the one-dimensional model. The model yields several scaling parameters, some of which are used to estimate the terminal height of an eruption column. Numerical investigations using the parameters indicate that the thermal energy in an eruption column is exhausted for heating and expanding entrained air before reaching the terminal height. Numerical investigations also imply that the buoyancy flux in an eruption column may be less than half of that predicted by the conventional theory of an incompressible plume. The discussion based on the present model also sheds new light on the physical background of the superbuoyant behavior of an eruption column.

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