Comments on "Turbulent boundary layer shear flows as an approximation of base surges at Campi Flegrei (Southern Italy), by Dellino et al. (2004)"☆

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Dellino et al. (2004) use some principles of sediment mechanics to estimate the flow behaviour of base-surge deposits at Astroni and Agnano-Monte Spina in Southern Italy. To do so, they assume quasi-steady, incompressible shear flow for the basal part of the surges. Hypothesizing that, at the transition between a basal, inversely graded bed and an overlying, finely laminated bed, the Shields criterion and suspension criterion are simultaneously valid, they combine the two criteria to get:

$$U_*^2 = [0.015gD(\rho_s - \rho_f)]/\rho_f \tag{1}$$

and

$$U_*^2 = [4gD(\rho_s - \rho_f)]/[3C_d\rho_f] \tag{2}$$

where U_* is the shear velocity of the flow in cm s^{-1}, g is the gravity acceleration (981 cm s^{-2}), D is the grain size in cm, ρ_s and ρ_f are the particle and flow densities in g cm^{-3}, and C_d is a dimensionless drag coefficient with a value of 1.

For the U7 Astroni base-surge, they use ρ_s=1.19 g cm^{-3} and D=7 cm for the basal unit (Eq. (1)), and ρ_s=2.0 g cm^{-3} and D=0.0467 cm for the upper unit. Simultaneous solution of the two equations gives the same shear velocity of 111.95 cm s^{-1} with a flow density of 0.0097 g cm^{-3}.

According to Dellino et al. (2004), 7 cm is the diameter of the largest grain found by them in the basal unit, whereas 0.0467 is the median size of the upper, finely laminated bed. They do not give details on the mineral composition of these grains, but the densities of 1.19 g cm^{-3} for the 7-cm grain and 2.0 g cm^{-3} for the 0.0467-cm grains, which were obtained by picnometric techniques, are exactly those required for the two results to coincide to the nearest cm, not only for a flow density of 0.0097 g cm^{-3}, but also for any flow density between 0.001 and 0.01. Changing only the grain density in Eq. (1) to 1.5 instead of 1.19 g cm^{-3}, for example, would always cause U_* values for Eq. (1) to exceed those of Eq. (2) for any value of ρ_f between 0.001 and 0.01.

This remarkable result for the U7 Astroni surge is repeated for the E2 Agnano-Monte Spina surge, where ρ_s=1.28 g cm^{-3} and D=8.7 cm for the basal unit (Eq. (1)) and ρ_s=2.1 and D=0.06 cm for the upper

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unit (Eq. (2)). Again, the system is so perfectly balanced that ρ_f can be any value between 0.001 and 0.01 for U_* to coincide.

One can argue that this is because of the natural equilibrium maintained by aerodynamic forces and particles in the surges, but only so if all the assumptions made by Dellino et al. (2004) are correct, which is not the case.

Eq. (1) is derived from the Shields (1936) criterion as adapted by Miller et al. (1977) for eolian transport. However, the equation is valid for the entrainment of grains, not their deposition from a state of transport. A glance at the well-known Hjulström (1939) diagram shows that, for a 7-cm quartz grain, entrainment takes place at a flow velocity of 100 cm s^{-1}, whereas deposition only starts when the current velocity drops to about 20 cm s^{-1}. As the 7-cm grain in the basal layer of the Astroni surge was deposited from transport, Eq. (1) is simply not valid. Moreover, the fact that this bed is inversely graded suggests non-turbulent behaviour in this part of the flow, for which the Shields criterion does not apply either. In fact, Dellino et al. (2004) themselves use the term “traction carpet”, which has nothing to do with traction (as pointed out, e.g., by Le Roux et al., 2004), but refers to a dense, highly sheared zone at the base of a gravity flow.

Eq. (2), attributed by Dellino et al. (2004) to Le Roux (1992), but actually derived from Newton’s Law of Settling, also requires the fluid density ρ_a and not the flow density ρ_f as used by Dellino et al. (2004). The flow density is given by Dellino op cit. as:

$$\rho_\mathrm{f} = (1 - C)\rho_\mathrm{a} + C\rho_\mathrm{s} \tag{3}$$

where C is the particle concentration, estimated from the ratio of the bed/flow thickness by Dellino et al. (2004) to be (20:10,000)=0.002. Solving for ρ_a in Eq. (3) would thus give an air density of 0.0057 g cm^{-3}, and using this value in Eq. (2) gives U_*=146 cm s^{-1} instead of 112 cm s^{-1}.

Eq. (2) provides a more practical (and theoretically correct) way to estimate the flow velocity, and there is in fact no need to match its results with those of Eq. (1). Dellino et al. (2004) refer to the Bagnold (1966) suspension criterion, which states that particles are kept in suspension as long as the shear velocity of the flow (U_*) exceeds their settling velocity (W). This has in fact been verified by, inter alia, Le Roux and Brodalka (2004). The grains occurring in deposits formed from settling should have a fall velocity just exceeding the flow shear velocity at that point. The settling velocity can be obtained fairly accurately from a series of equations by Le Roux (1992, 2002, 2004) if the general size, density and shape of the grains, as well as the density and viscosity of the surge are known. To calculate the latter properties, however, its temperature and pressure are required, which may not be easily obtained.

To summarize, it appears that Dellino et al. (2004) obtained remarkable results in spite of some erroneous assumptions, which shows that caution should be exercised in this kind of estimation. It so happens that virtually any fluid density between 0.001 and 0.01 g cm^{-3} could have been used to give the same result for both equations, which would yield widely different shear and mean velocities for these base-surges.

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