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Buoyancy of plume-sourced ash clouds: implications for ash transport modelling.

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Volcanic plumes ascend high into the atmosphere where they spread out at a level of neutral buoyancy to form intrusions. The structure of these intrusions depends on the relative strength of the intrusions, the ambient wind and the local atmospheric stratification. In a strong wind, moderate to weak sized eruptions form bent over plumes while in more powerful eruptions or in eruptions with a weak wind, they typically form umbrella clouds, which spread in all directions. Irrespective of the wind the plumes reach dynamical equilibrium with the wind field further from the volcanic source. The motion of such plume-fed intrusions is governed by buoyancy. The spreading of intrusions is controlled by the volumetric flux of the feeding plume at the height of neutral buoyancy and the density stratification in the atmosphere, but not by the density of the intrusion itself. For the case of a symmetrically spreading umbrella cloud the thickness decreases with distance. Although more complex in detail, intrusions affected by the wind also thin quite rapidly with distance. Buoyancy thinning can explain why ash clouds are observed to become very thin quite close to source. Advection diffusion models are now widely used to forecast ash clouds dispersal and ash deposition. Such models typically assume ash is dispersed vertically above the source and assume ash particles act as heavy (sedimenting) tracers that are spread by atmospheric diffusion. Buoyancy effects are ignored. We contend that such models are not a correct description of the physics of ash clouds in regions where buoyancy effects are significant. For very powerful eruptions buoyancy effects are dominant to distances of hundreds of kilometres or more; it seems unlikely that an advection-diffusion model could reproduce observed ash distributions since such models cannot have upwind or very extensive cross-wind spreading. For weaker plumes that are markedly affected by wind, advection-diffusion models are useful mathematical descriptions that can be calibrated to give good forecasts of ash transport. However, this does not mean they are good physical models of the process. Models of buoyancy spreading suggest that it can be the main cause of lateral spreading of wind blown clouds to significant distances (perhaps tens or hundreds of kilometres). Operational models of ash dispersal are likely to remain structured as advection diffusion models, so they may need some empirical adjustments to take account of buoyancy. For example it might be better to have source terms, which assume ash is concentrated in narrow height intervals above the source (at one or more discrete levels rather than distributed vertically). It seems unwise to continue using such models for very powerful eruptions.