Change of falling dynamics of ash particles during transient eruption revealed by high speed camera imaging and grain size analysis

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Change of processes of size segregation and aggregation is expected in a course of transient eruption due to quick change of physical condition in a volcanic cloud. The change must influence aerodynamic properties of ash particles which largely control dynamics of volcanic cloud.
This study combined the results of high-speed camera imaging and grain size analysis on simultaneously collected sample to discuss change of falling dynamics of ash particles during transient eruption. We observed ash particles from vulcanian eruption which started at 10:44 with new emission at 11:23 JST on 26th of March 2016. Falling continued from 10:57 to 12:11 at the field site. The imaging of falling ash by high-speed camera were done on 10:57-10:58, 11:33-11:34 and 12:00-12:01, and the image analysis provided falling velocity and size of ash particles. Sampling of falling ash with high temporal resolution (intervals were one or five miutes) was performed simultaneously with the imaging to determine ash falling rate for grain size classes (FRGS) of deposit.
The ash falling rate at the field experiment site shows three phases as: (1) maximum ash falling rate at first 1 minutes (10:57-10:58) and following decrease for 7 minutes. (2) The rate increases and has secondary peak at 10 minutes after the starting (11:07-11:08), and the decreases. (3) The rate gradually increases again, has thirdly peak at 11:47-11:52, and decreases to the end of falling. The falling velocity of ash particles ranges from 0.2 to 7.0 m/s. The size and velocity of falling ash decreases from phase (1) to (2) and then increases from phase (2) to (3). Density of falling ash particles (ρ_{ash}) is derived from equation of a balance between downward force by gravity and the drag force due to resistance of air around spherical particle from Reynolds number (*Re*) and drag coefficient (*Cd*). The calculated density decreases from phase (1) (2200-2500 kg/m^3) to (2) (200-2000 kg/m^3), and then increases to phase (3) (500-2200 kg/m^3). The FRGS changes with progress of the ash falling, and exhibits unimodal, bimodal or trimodal distributions. The size of coarser peak (size range is 0.05-5 mm) in unimodal and bimodal FRGS decreases from 10:57 to 11:37, and size range of fine peak increases from 0.007-0.009 to 0.005-0.05 mm through phase (1) and (2). For the phase (3), the trimodal distributions are found in 11:37-11:52, and changes to bimodal distribution toward the end of the falling event (11:52-12:11).
The combination of the results of high speed imaging and grain size analysis reveals change of falling dynamics of ash particles during a transient eruption. The change of density of falling ash particles showed by the imaging demonstrates increase of ash aggregate from phase (1) to (2). This is also confirmed by development of bimodal distribution where coarser and finer peaks represent particles falling as individuals and aggregates, respectively. The decrease of size in coarser peak in the bimodal distribution shows the size segregation during sedimentation. In contrast, the widening of size range in finer peak suggests size depending efficiency on the aggregation. The particle with size of 0.007-0.009 mm is scavenged by coarse particles (0.5-3mm) which falls early. Fine particle with size of 0.007-0.009 mm starts to make aggregate with size of few 0.1 mm found in the imaging. The secondary peak (11:07-11:08) of ash falling rate can be caused by aggregation enhanced sedimentation. The trimodal distribution found in the phase (3) can be explained by supply of ash particles by new ash emission at 11:23. The new ash emission causes increase of fraction of individual falling particle, evidenced by

increase of the density of falling particles from the imaging. Overall, the falling dynamics of ash particles changes during a transient eruption, and is explained by increase of volume fraction of aggregate having size dependency in its formation.

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