INVERSE PROBLEM FOR THE VOLCANIC ERUPTION SOURCE PARAMETERS IN THE CASE OF EXTREMELY SMALL GRAIN-SIZE DATA SETS: A CASE STUDY OF EXPLOSION EVENTS AT KIZIMEN AND BEZYMIANNY VOLCANOES, KAMCHATKA

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Over recent decade, state-of-the-art limited area numerical models of atmospheric dynamics and pollutant transport have become widely used to simulate volcanic ash dispersion and fallout at mesoscale (20–2000 km). Apart from solving important task of ash cloud forecast, such simulations provide a basis to constrain mass parameters of a particular explosion event, including total erupted mass (TEM), total grain size distribution (TGSD), and vertical mass distribution (VMD) of ash particles within eruption column through direct comparison of model predicted ash particle mass loadings against deposit data. The present study addresses to the general inverse problem in the context of determining the above parameters under common conditions of low signal to noise ratio, unknown distribution of model errors, highly limited amount of deposit data, and wide range of particle fall velocities. A second-order accurate perturbation method of solution to the underlying non-linear ill-posed problem is proposed based on Green's function approach to obtain statistically stable and consistent estimates of TEM, TGSD, and VMD through selecting a best-fit subset of aerodynamically distinct subpopulations of free and aggregate particles from a trial set employed to simulate a polycomponent ash fall. In spite of some important limitations the proposed approach has important advantage compared to more conservative sedimentological techniques as it provides an intrinsic consistency among the derived estimates for the source mass parameters, spatial and grain-size characteristics of the deposit dispersal pattern, atmospheric wind field, and particle settling rates.

As an example, VEI=2–3 explosion events on Kizimen Volcano (the January 13, 2011, vulcanian explosion, TEM ≈1.5 Mt) and Bezymianny Volcano (paroxismal phase of the December 24, 2006, sub-Plinian eruption, TEM≈5 Mt) are considered (Fig.1), for which detailed simulations of meteorological fields and aggregated ash fallout have been previously performed with RAMS/HYPACT atmospheric modeling system (Moiseenko, Malik 2015a,b). A marked feature of the derived VMDs is a strong secondary maximum in the lower troposphere (Fig.2) which reflects appreciable contribution of ash falling out of co-pyroclastic flow ash clouds and partially collapsing eruption column.
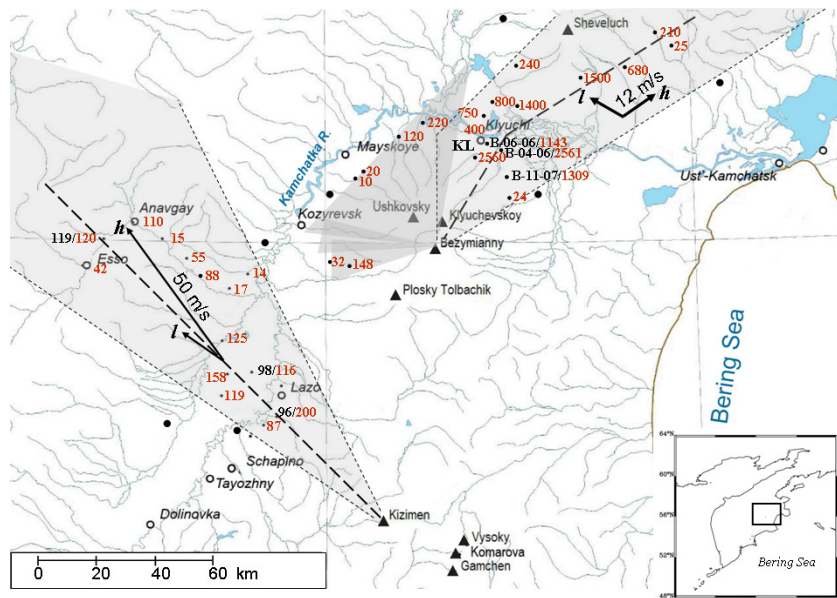

Fig.1. A schematic representation of the BZ06 and KZ11 ash fall deposit patterns, with the main dispersal axes shown with dashed lines. The areas shaded in light gray represent deposits from the KZ11 ash fall and the BZ06 plinian fall in the paroxysmal phase of the eruption. The dark shaded area WSW–N from Bezymianny marks the area of ash fall from co-PF clouds and the lower part of the BZ06 eruption column. Numbers colored in red are the measured mass loads (g/m2). Black arrows show wind speeds and directions at heights of the ash plumes (h) and 850 mbar (~1.5 km a.s.l.) (l) at the time of ash falls basing on atmospheric soundings at Kluchi rawinsonde station.
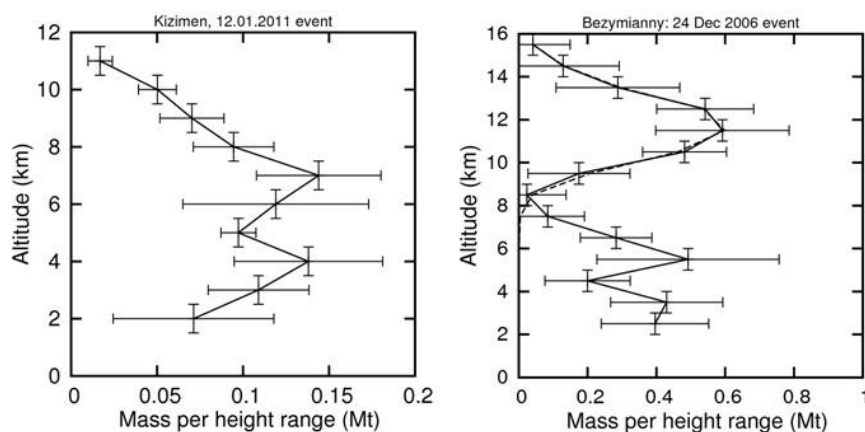
Fig.2. Vertical mass distribution of ash particles (<1000 μm) within eruption column produced by the January 12, 2011, explosion event at Kizimen volcano (left) and paroxismal phase of the December 24, 2006, eruption at Bezymianny volcano (right). Horizontal bars indicate ±2 standard error interval for the corresponding estimates. Vertical bars give the respective altitude ranges within the columns.

The model predicted TGSD of the KZ11 ash fall is unimodal (Fig.3a) peaking at phi=5 (31–63 μm size bin) and probably representative for the particle size distribution of the initial population of ash particles from vent-originated plume, with small addition of fine ash from the co-PF clouds, since the unimodality was found to be a common feature of other ash fall deposits produced by vulcanian type explosions. The predicted bi-modal structure of the TGSD of the BZ06 plinian fall (mushroom cloud) (Fig.3b) reflects most probably a size selective nature of aggregation process which plays appreciably more important role in the BZ06 fallout compared to that from the KZ11 eruption.

We also discuss some future work ideas for application of the developed inversion technique to larger eruptions for better quantification of atmospheric and volcanological factors affecting ash dispersal and fallout on regional and global scales.
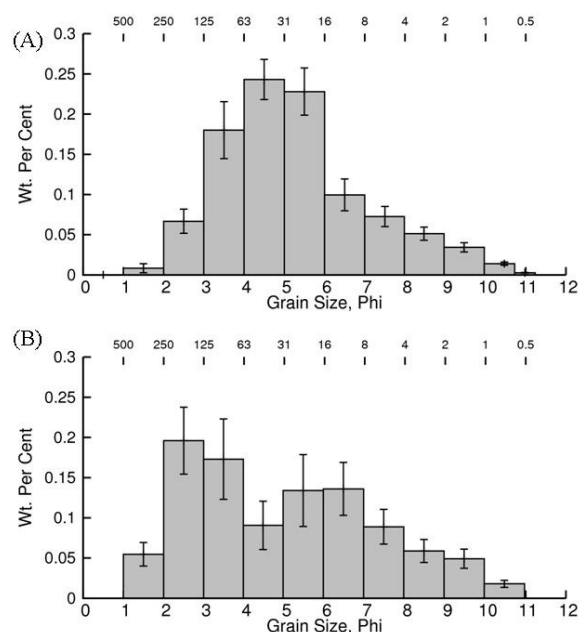

Fig.3. The model–retrieved TGSD (±2 standard error) of ash particles from the KZ11 ash fall deposit (eruption cloud and Co-PF plumes) (A) and the BZ06 Plinian fall deposit from the umbrella cloud (B).

References

Moiseenko, K.B., Malik, N.A. Estimation of total discharges of volcanic ash using atmospheric transport models // *Vulkanologiya i Seismologiya, 2015a. № 1. Pp. 35–55.*

Moiseenko, K.B., Malik, N.A. Reconstruction of the ashfall at Bezymyanny Volcano during the eruption of December 24, 2006, by using a mesoscale model of atmospheric transport of ash particles // *Izvestiya, Atmospheric and Oceanic Physics, 2015b, Vol. 51, No. 6, pp. 585–598.*