Computed tomography reconstruction of sulfur dioxide concentration distributions in the volcanic plume from Miyakejima volcano

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The measurement of a volcanic plume is very important from point of view of volcanology and disaster prevention. Volcanic gases are good indicator for volcanic activity; they cause health hazards and give impact on environments. SO_2 concentration distribution in a cross section of volcanic plume gives us crucial information for evaluating these effects. A volcanic plume width and thickness depend on a direction of wind, wind speed, topography of a volcano and an amount of insolation. In previous studies, SO_2 concentration distributions were measured by flying through a plume at many different elevations by an airplane. Since the observation takes dozens of minutes, a shape of the concentration distribution would significantly change during the traverses. Furthermore, pilots were exposed to toxic gases by flying through the volcanic plumes.

In this study, we would show a new approach for measuring SO_2 concentration distributions by calculating computed tomography (CT) using SO_2 column amounts data which are measured outside of the plumes. To measure SO_2 gas, we used a compact UV spectrometer system (COMPUSS) which is similar to mini-DOAS or FLYSPEC. It can measure SO_2 column amounts (ppm $*$m) by using SO_2 absorption at 305 - 320 nm of scattered ultraviolet skylight.

On August 18, 2004, we mounted three COMPUSSes aiming at three different zenith angles (Pi/4, 0 and -Pi/4, respectively) on a helicopter and flew under a plume about 10 km downwind from Miyakejima. Four traverses were made at a speed of 110-150 km/h at an average altitude of 130 m. Each traverse took less than two minutes. The wind speed at the level of plume was 16.9 m/s. Intervals between each traverse were about 5 minutes. Horizontal width of the plume was about 3 km and the flux of SO_2 was 3000 - 7000 ton/day. There were discrepancies of 13 % between the SO_2 fluxes obtained by the three COMPUSSes. The disagreement is probably due to plume advection during the traverse. We calculated CT reconstructions of SO_2 concentration distributions using SO_2 path-integrated concentration data of three COMPUSSes.

In general, the total number of independent path-integrated data should be equal to the number of pixel. But it is difficult to measure enough number of independent path-integrated data of a volcanic plume. To overcome this problem, CT techniques which assume the smoothness of reconstructed distribution were developed in the realm of environmental hygienics. In this study, we used Low Third Derivative (LTD) method (Price et al. 2000) which can reconstruct smooth and realistic distribution by limiting third spatial derivative of the distribution to low values. The trade-off between residual of integrated data and smoothness was controlled by the weight term (LTD-weight) of least-square technique. Price et al. (2000) determined LTD-weight empirically; We improved it by using Akaike's Bayesian Information Criterion (ABIC).

The horizontal and vertical widths of four reconstructed distributions were about 3 km and 1 - 1.5 km respectively. They were consistent with meteorologic models and previous studies of volcanic plumes. The maximum concentrations at the cross-section of the plume were more or less 1 ppm and the profile of the concentration distribution significantly changed between the traverses.