Image focusing of conductive anomaly in CSEM data-space inversion using minimum support gradient regularization

*Takuto Minami[1], Hisashi Utada[1], Mitsuru Utsugi[2]

1. Ocean Hemisphere Research Institute, Earthquake Research Institute,The University of Tokyo, 2. Graduate School of Science, Kyoto University

Efficient and effective volcano monitoring methods attract more and more interests of society recently. An electromagnetic (EM) volcano monitoring system named ACTIVE (Utada et al., 2007) is one of reasonable solutions to monitor resistivity structures of volcanic edifices. ACTIVE system consists of several transmitters that transmit square-wave electric currents into the ground through two electrodes and induction-coil receivers for the vertical component of the induced magnetic field. Analyses of data obtained by controlled-source electromagnetic (CSEM) methods based on the transient-EM (TEM) technique have been traditionally done by using analytical solutions with the assumption of one-dimensional layered earth (e.g. Kanda et al., 1996; Srigtomo et al., 2008). Although Mitsuhata et al. (2002) conducted so-called 2.5-dimensional (2.5-D) inversions, which deal with a 2-D model space and three-dimensional (3-D) sources at the same time, to reveal 2-D resistivity structures from TEM data set. However, application of the method to problems in volcanos should suffer from effects of complicated 3-D topography. Utada et al. (2007) reduced the non-linear 3-D problem into a linear one based on the Born approximation and succeeded in obtaining temporal changes in resistivity structure from ACTIVE data set without full 3-D inversions. However, they found ambiguous images of obtained temporal changes and smaller anomalies due to the heavy non-linearity of the original problem.

In this study, we developed a new 3-D inversion code for ACTIVE, by adopting an edge-based finite element method with unstructured tetrahedral mesh (e.g. Schwartzbach and Haber, 2013), data-space Gauss-Newton scheme (e.g. Kordy et al., 2016), and regularization by minimum support gradient (Xiang et al., 2017). Unstructured tetrahedral mesh allows us to change the spatial resolution of mesh efficiently in the vicinity of sources and receivers, and to express real topography accurately. The data-space Gauss-Newton scheme is reasonable for the case where the number of data is much smaller than that of model parameters, such as ACTIVE problem. Minimum support gradient regularization, presented by Xiang et al. (2017) originally for MT problems, can reduce the surface area of the obtained conductive anomaly and thereby focus the image of anomaly. We conducted synthetic inversion tests to confirm efficiency of our inversion method and to seek an efficient source-receiver configuration for ACTIVE observation, by prescribing a resistivity structure including a conduit-like conductive anomaly beneath the real active Nakadake 1st crater of Aso volcano as a true model. Our inversion method succeeded in delineating the conductive anomaly correctly with minimum support gradient regularization, especially for the top and side boundaries of the anomaly. Furthermore, we found that two or more sources dramatically improve inversion results as Mitsuhata et al. (2002) pointed out in their 2.5-D inversion implementations. In the presentation, we introduce our new inversion method, and report the results of synthetic inversion tests and efficiency of minimum support gradient regularization in inversions for ACTIVE data.

Keywords: ACTIVE, controlled-source, inversion, volcano, monitoring

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