The vertical gradient sounding method revisited

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The vertical gradient sounding (VGS; Law and Greenhouse, 1981) method is known as an alternative to the magnetotelluric (MT) method especially in marine electromagnetic (EM) soundings. In early 1990's, it had been a topic of active research and a series of good literature were published during that period (e.g., Ferguson et al., 1990; Shimakawa and Honkura, 1991; Heinson et al., 1993). Since it makes use of the attenuation of the horizontal geomagnetic components relative to those on the sea surface, or more practically, those on land sites, it has an advantage over the conventional MT method that it can be applied even in the absence of geoelectric field measurements at the seafloor. Furthermore, it has recently been pointed out that the VGS method is free from galvanic distortions because it never uses geoelectric field variations (Toh et al., 2006), which is a great merit over existing EM methods that rely on the E-field.

However, the VGS method was sometimes found incompetent especially in its application to the seafloor EM data observed in the closed marginal sea (Toh et al., 2004). In contrast, there are a couple of successful case studies using the method in the open ocean. Toh et al. (2006) applied the method to seafloor EM array data on the Philippine Sea plate to yield a two-dimensional (2D) electrical section as deep as the mantle transition zone, while the subducting Pacific plate beneath the Izu-Ogasawara arc was clearly imaged up to 200km depth by the VGS method using another array data traversing the arc from east to west (Toh, Shibuya and Goto, 2003). The malfunction of the method can be attributed to the three-dimensionality of the marginal sea (the Japan Sea in this case) that critically depends on measures of the EM distance such as the skin depth, the inductive scale length, the adjustment distance and so on. It, therefore, is noteworthy that blind use of the VGS method may lead to misunderstanding of the electrical structure beneath. Rigorous selection of valid VGS periods should be made before application of the method.

The intent of this paper is to clarify to what extent and situation we can rely upon the VGS method. In other words, it is to show the ability as well as the limitation of the method in terms of the measures of EM distance. When working with long enough periods, there exist some cases in which the conductive seawater behaves as if it were the insulating atmosphere due to lack of induced electric currents within the ocean. The electric field caused by charges built up at coastlines of the marginal sea prevents those currents to flow. Another case study in the back-arc region of Southwest Japan will be presented in order to demonstrate the ability of a combination of seafloor MT and VGS methods in determination of a 2D electrical section beneath the back-arc.