Feasibility of exploring the resistivity structure of Mars through surface magnetic observation

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The STEP1 concept of Japan Aerospace Exploration Agency plans to potentially deploy three landers equipped with fluxgate magnetometers onto the surface of Mars. Utilizing magnetic data from these landers to explore the resistivity structure is highly intriguing, as it can provide insights into the presence of water within the dry rocks of the crust and mantle. Civet and Tarits (2014) inferred the Martian resistivity structure using global magnetic data from the Mars Global Surveyor satellite. However, resistivity at depths shallower than several hundred kilometers has not been resolved yet due to the adopted periods longer than 1 day. To shed light on the potential existence of water at shallower depths in specific regions and to discuss the possibility of past or current existence of life on Mars, the resistivity at shallow depths should be unveiled by utilizing surface magnetic data and focusing on shorter period magnetic variations. Johnson et al. (2020) and Mittelholtz et al. (2023) reported that the magnetic variations observed by the InSight lander include variations due to ionospheric disturbances in the period range of 100 to 1000s, suggesting the applicability of Earth's surface resistivity exploration methods on Mars.
For resistivity exploration on Mars, the popular magnetotelluric method is challenging because it requires measurements not only of the horizontal components of the magnetic field but also of the horizontal components of the electric field at the surface. The horizontal electric components are usually measured through earthed electrodes by burying them under the surface. However, the unmanned landers planned in the STEP1 concept are unlikely to be capable of burying the electrodes. On the other hand, a potential alternative method is the horizontal spatial gradient method (HSG; Schmucker, 2003). It uses only three components of the magnetic field concurrently observed by at least three observation points. Through analytical solutions, we examined how we can observe the HSG responses under several scenarios with the existence of water on Mars. For example, studies of radar data from the Mars Express spacecraft suggest the presence of liquid water at a depth of 1.5 km in the south polar cap region (Egea-Gonzalez et al., 2022). We found that at a depth of 1.5 km, the HSG method is able to detect a 100 m thick layer with 1.0 S/m conductivity or a 300 m thick layer with 0.1 S/m conductivity when the host rock has conductivity of 0.01 S/m and the magnetic variations due to ionospheric disturbances in the period range of 1 to 100 s are available. In these scenarios, up to 50 % changes are expected in the response amplitude. However, a major concern in applying the HSG method to the STEP1 concept is that the number of points for the array of magnetic observations usually exceeds 5 points when applied on Earth's surface (e.g., Jones, 1980). Therefore, the feasibility of using the minimum three-point magnetic observation for the HSG method should be assessed carefully. We are currently evaluating the feasibility of using only three points in the HSG method with the dataset of Jones (1980). In the presentation, we discuss the feasibility of applying the HSG method to the magnetic data from the three landers in the STEP1 concept in terms of the signal and noise levels of the magnetic data on the Martian surface, the distance between landers, and the expected Martian resistivity structures.

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