Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SEM001-P07 Room:Convention Hall Time:May 26 10:30-13:00

Magnetic imaging as an inverse boundary value problem: Application to mapping of the lunar magnetic anomalies

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Magnetic imaging of the static magnetic field at the surface is mathematically regarded as solving an inverse boundary value problem. It is known that there are three types of the boundary value problem: Dirichlet (the first kind), Neumann (the second kind) and Cauchy (the third kind) problems. For example, the magnetic field at any point over the surface is given by the surface integration of potential values (Dirichlet type), radial components (Neumann type) or magnetic charges (Cauchy type). The kernel of the surface integral is determined from a kind of the boundary value and morphology of the boundary surface. Inversely the boundary value is obtained from observations over (or inside) the boundary surface by solving an inverse boundary value problem such as the deconvolution or the downward continuation.

There have been several equivalent source models of the magnetic imaging at the boundary surface. The equivalent vertical magnetization at the surface is considered to be an inversion of the Dirichlet problem, so that the obtained vertical magnetizations express the surface potential. The equivalent source model of horizontal currents or horizontal magnetizations at the surface is an inversion of the Neumann problem. Although the boundary surface should be closed or infinite in these problems, the methods are approximately applicable to an unclosed region if effects of boundary values in other part of the surface are negligible. In this case, the observation is assumed to be filtered with a rectangular window of a closed or infinite surface. If the observation is distributed along a track, constraints from the discrete sampling should be considered in the analysis, especially in the downward continuation. Therefore, it is needed for improvement on the magnetic imaging method to carefully consider a kind of the boundary value, mathematical properties of the kernel function, observational conditions, noise sources and assumptions of modeling.

Providing the lunar magnetic anomaly map is regarded as the magnetic imaging by a satellite magnetometer. Previous maps of vector fields of the lunar magnetic anomaly have been provided at a certain altitude such as 30 km and 100km. However, those maps show insufficient spatial resolutions when compared with geological and topographical data on the surface. We have developed a new method for the surface vector mapping of the lunar magnetic anomalies observed by a satellite magnetometer. We will discuss the method of surface mapping of the lunar magnetic anomalies and show several examples of mapping results based on the Kaguya and Lunar Prospector datasets.

Keywords: magnetic imaging, inversion, boundary value problem, Moon, magnetic anomaly