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Design of the optimized seismic network to investigate the lunar interior structure

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The lunar interior structure is the clue of the origin and the evolution of the Moon. The four seismic stations of Apollo seismic network provided us many pieces of information about lunar seismicity and lunar interior structure. However, due to some limitations of the measurement system and to the geometry of the seismic network, we have not been able to gain sufficient information about the deep interior of the Moon, including the core, from the Apollo seismic data. This scientific challenge is partly driving many space agencies in the deployment of new seismic stations on the lunar surface. For example, the deployment of one or two seismic stations is planed in SELENE-2 JAXA mission, and projects with 2 to 4 seismic stations are under study by NASA. The International Lunar Network initiative is coordinating these efforts. If these future stations are deployed over the same period, we could construct a seismic network possibly larger, and certainly more sensitive in a broader range of frequencies, than the Apollo seismic network.
In this study, we have investigated the geometry of the seismic network in order to obtain the best scientific gain from the new lunar seismic experiments. The primary objective on current lunar science is to reveal the lunar core size and its composition, and obtain the information about the initial material which constitutes the Moon and its formation. Apollo seismic experiments revealed the existence of deep moonquakes that occurred repeatedly at identical sources depending on tidal constraints. We have calculated the travel times and ray-path of seismic core-phases from the deep moonquake nests whose sources were located from the Apollo seismic data and searched the position to detect most numbers of PKP phases. If we can specify the location of the observed event using P and S arrivals on the same record, we would obtain the information about the lunar core from only one station data. The existence of such configuration depends on the core seismic structure. We searched the best position by changing the core radius (200-450km) for a completely liquid core (assuming Vp=5 km/s).
In addition, we are also interested in the structure of the lunar mantle, especially existence and/or the depth of the velocity discontinuity in the mantle. Understanding of them will give us useful information about lunar evolution, such as the differentiation of the Moon. Therefore, we investigated the optimized network configuration to determine the velocity structure in the mantle, re-locate the known deep moonquake sources and locate a uniform distribution of meteoroid impacts. The optimized configuration is decided so as to minimize the a posteriori errors of the model parameters (the velocity structure and the location of deep and meteoroid events) using a linear inversion method. We have searched many geometries of the seismic network consisting of 3 or 4 stations using Monte Carlo simulations (neighborhood algorithm).
In this presentation, we will indicate some designs of network configuration optimized for body waves under the constraint of future lunar seismic missions and discuss the improvement of the lunar interior model attained by the new observations. Finally, we will demonstrate that the ground based detection of meteoroid impacts on the moon is greatly improving the determination of the seismic lunar interior structure.

Keywords: planetary exploration, lunar seismic exploration, moonquake, seismic network, optimization problem, Monte Carlo simulation