Imaging and monitoring of lunar shallow subsurface by autocorrelation analysis of ambient noise

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Exploration of lunar water resources could lead to a future use as domestic water and rocket fuel on the Moon, as well as the origin of water. Numerous studies on lunar interior exploration have been conducted using seismic data recorded on the lunar surface during the Apollo missions. These studies applied various analyses by using deep and shallow moonquakes, meteorite, impacts caused by man-made materials such as rockets, and ambient noise. Since there are limitations on the number of seismometers and source instruments that can be sent to the Moon, it is important to develop analysis methods available with with a limited number of instruments. In this study, we extracted reflection response by applying autocorrelation analysis of ambient noise based on seismic interferometry, which can be performed with only one seismometer, to image and monitor subsurface structures.

We used the lunar data recorded at the Apollo 14 site. We estimated daily autocorrelation functions by applying autocorrelation analysis for ambient noise data from 1 February to 31 December, 1974. Because we found that characteristic noise due to the data recording was included in the process of the autocorrelation analysis, we proposed a method to remove the noise. As a result, we succeeded in extracting signals that appeared to be reflected waves from the subsurface at travel times around 2.06 and 2.74 seconds. Because the time interval of these reflected waves was 0.68 sec, these two signals could be interpreted as three- and four-times reflections from the top of the basement at the Apollo 14 site. Furthermore, a stretching interpolation technique was applied to the daily variation of the autocorrelation results to estimate the temporal variation of the seismic velocity change. The monitoring result shows a periodicity of ~29.6 days, which is close the periodicity of surface temperature change on the lunar surface. In addition, the surface temperature change and the seismic velocity change showed a negative correlation. Although similar monitoring results were observed by cross-correlation analysis of ambient noise using more than two stations, only one seismometer was used in our analysis .

The present study successfully imaged and monitored the subsurface structure of the Apollo 14 site using an autocorrelation analysis of ambient noise. Our approach has a potential to estimate the shallow rigidity of the lunar subsurface required for the future construction of a lunar base. In addition, it would contribute to improving the accuracy of the water resources exploration by correcting seismic velocity variation due to temperature variation other than the presence of water ice.

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