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Sensitivity of lunar seismic networks

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Introduction

To explore the interior structure of a planet into detail, seismological methods are used. A seismometer network on the Moon was deployed by Apollo astronauts between 1969 and 1972. It transmitted recordings from meteorite impacts, shallow and deep quakes to Earth until 1977. These data helped to learn about a partial molten layer in the lower mantle of the Moon, to recognize tidally induced deep quakes, to wonder about the rare, high frequency, shallow quakes and to correlate meteoroid seismic recordings and meteor showers known from earth based observations

Number of seismic wave arrivals

Nevertheless many questions and uncertainties remain. Knowledge about lunar seismicity depends on the ability to locate moonquakes. The ability to locate depends on the number of detected wave arrivals. The more arrivals are available for a deep moonquake cluster, the more certain its location can be determined (Fig. 1).

For more than half of the known deep moonquake clusters no explicit arrival times are determinable. For less than a quarter of the clusters the volumes containing the possible hypocenter calculated by LOCSMITH [1] are smaller than 300km in diameter. For better location of all clusters we need more arrivals. Therefore we need to install a lunar seismic network with higher sensitivity than the Apollo seismic network, which consisted of 4 stations at the landing sites of Apollo 12, 14, 15 and 16.

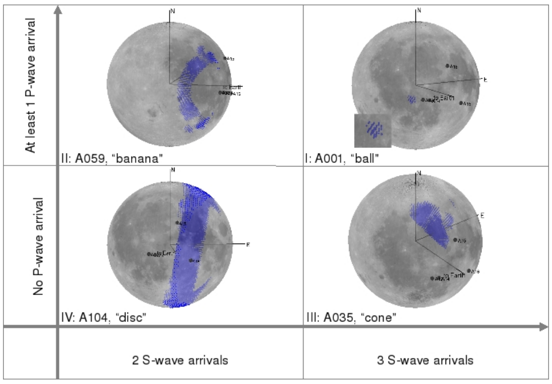

Figure 1: The volumes of possible location of hypocenters can be used to classify clusters according to thenumber of detected compressional (P) and shear (S) wave arrivals. To locate better than 300km you need at least S wave arrivals at least 3 stations and a P wave arrival at 1 station (class I).

Sensitivity of the Apollo seismic network

The detectability of seismic waves depends on the epicentral distance between epicenter and seismometer, the magnitude, depth and focal mechanism of the quake as well as the scattering and attenuation along the ray path. In a first order approximation we calculated the sensitivity of the Apollo seismic network for attenuation depending only on epicentral distance (Fig. 2).

We find that the Apollo network's ability to detect and locate hypocenters is confined to the near side. In the shown first order approximation (Fig. 2) location and often even detection of far side deep moonquakes is impossible.

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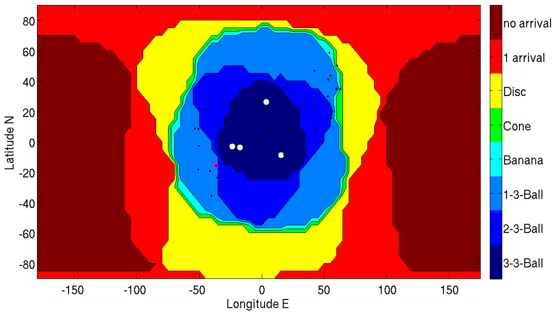

Figure 2: A map of the sensitivity of the Apollo network (white dots), computed from a first order attenuation model depending on epicentral distance only. Colors reflect the expected shape of location uncertainty volumes, depending on the detected arrivals. Good locations are achievable in blue areas, bad in cyan, green and yellow regions and no detection at all for epicenters in red marked regions. Compared to observed locations (for clusters marked by black dots) shows that critical distances for detection of P and S waves are 49 and 82 degrees, respectively.

Consequences for future missions

We show the dependence of the sensitivity on parameters discussed above (depth, magnitude and scattering) and the consequences for optimal network configurations in future missions: how many stations in which positions are necessary for global detection of lunar seismicity. To enhance the sensitivity of the network we need to increase the number of seismometers and the covered surface, more than to increase the sensitivity of the seismometers itself.

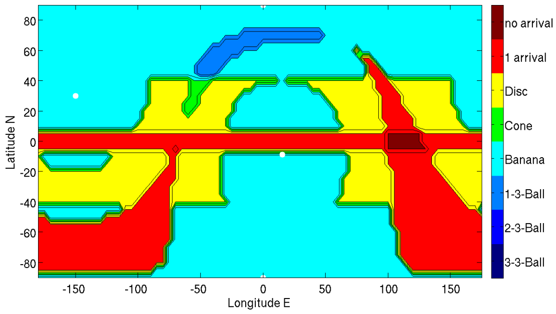

Figure 3: A map of the sensitivity of a possible MoonLite seismic network (white dots). Assumed seismometer positions at lunar North and South Pole, Apollo 16 landing site (15.51°E, -8.97°N) and a far side location at -150°E and 30°N. Colors and critical distances as in figure 2. Using this model, good locations for this network are only achievable in a small region on the northern hemisphere.

References

[1] Knapmeyer (2008), GJI 175 , pp. 975-991
[2] Nakamura (2005), JGR 110, E01001