AN ANALYSIS OF ILLUMINATION CONDITIONS BY ALTITUDE FOR A LANDING SITE NEAR THE LUNAR NORTH POLE. Hiroka Inoue, Hisashi Otake, Makiko Ohtake, Mitsuo Yamamoto, Takeshi Hoshino, Takanobu Shimada, Satoshi Tanaka, Koichi Masuda, Hitoshi Morimoto, Sachiko Wakabayashi, and Tatsuaki Hashimoto, Japan Aerospace Exploration Agency, Sagamihara, Kanagawa, Japan. (e-mail: inoue.hiroka@jaxa.jp).

Introduction: The Japan Aerospace Exploration Agency (JAXA) launched a Moon orbiter, Kaguya, in September 2007 and succeeded in putting it into an orbit approximately 100 kilometers above the Moon in October. This Moon orbiter has provided us with a significant amount of scientifically valuable Lunar data. Besides Japan, various other countries all over the world have succeeded in obtaining Lunar observation data using Moon orbiters such as NASA's Lunar Reconnaissance Orbiter (LRO). The future objective of Moon exploration is to investigate the existence of volatiles such as water and sodium, and to search their potential usefulness. Since valuable resources are likely to exist in the lunar polar region, some countries are currently planning landing missions around the lunar poles. JAXA is also considering a Moon polar exploration mission whose purposes are to investigate the existence of lunar resources and to study their potential. For such a mission, we must select a landing site with long-term desirable sunlight conditions because the mission period is expected to be long due to the observation at the site. Illumination condition analysis of the south pole has been well studied, but that of the north pole is insufficient even though a superiority of the south pole for a landing site has not fully examined. Landing site selection is critical for the mission accomplishment in the polar region, so much previous work has well analyzed illumination conditions in the Moon polar region [1, 2]. The Moon has more undulating terrain than the Earth, so sunshine conditions change remarkably with the altitude or sunshade. Hence, we determine an appropriate landing site and calculate the illumination conditions for the landing site assuming three different altitudes.

Data and Method: We employed Digital Elevation Model (DEM) data obtained by the Lunar Orbiter Laser Altimeter (LOLA) of LRO and the Terrain Camera (TC) of Kaguya. In addition, we used the SPICE toolkit to calculate the position of the Sun. By combining the DEM data and Sun position, we can calculate the ratio of solar disc occulted by the horizon [3]. We first conducted the simulation over a 60km square around the lunar north pole. In Figure 1a, the red regions indicate suitable landing sites that have more than 70% sunshine days and more than 50% visible sun discs. Within the red regions, there are especially favorable sites that satisfy the conditions that the surrounding area also has good sunshine and smaller differences in height. Figures 1b and 1c are enlarged figures of 1a and indicate one example of an especially favorable landing site (33.44°W, 89.66°N). For the candidate landing sites, we did not regard the Sun as one light source but separated it into 52 sun discs, and simulated illumination for altitudes of 0.5, 1.0, and 1.5 meters.

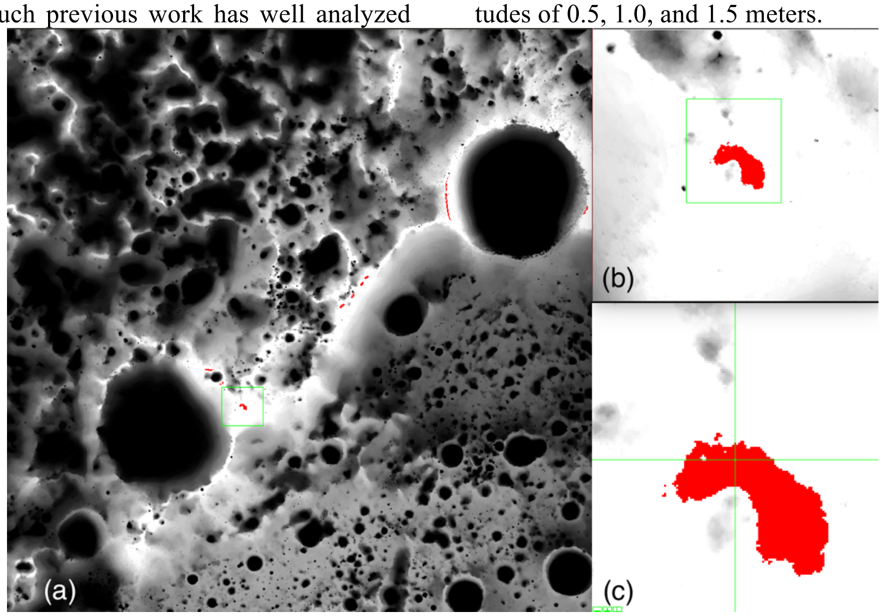

Figure 1. (a) Sunshine duration over a 60km square around the lunar north pole obtained from LRO and Kaguya terrain data (2 m/pixel). The projection is stereographic. (b) and (c) Enlarged figures of (a).

Results: Figure 2a and 2b represent changes of Sun visibility with each altitude. The time shows the days since 1st January 2023. Figure 2a shows the ratio of solar disc for one year at each altitude. Because Sun visibility is one (i.e., we can obtain 200 continuous Sun visible days) regardless of the altitude tested, the sunshine at the site is found to be suitable. Figure 2b presents the simulation results for the first four months with large differences of sunshine with height, indicating that the sunshine changes remarkably with altitude. For example, in the first few days, the solar disc visibility ratio is zero at an altitude of 0.5 meters, but it exceeds 0.8 at 1.0 meter altitude. Therefore, it is better to conduct illumination simulation at a relatively higher altitude, where solar array panels are expected to exist on the future Moon surface. Figure 4 indicates the relation between the ratio of a visible solar disc and the number of days with that ratio. It was found that there are more than 3 months with a low sunshine ratio (0 to 20%). However, according to Figure 3, continuous shade is at most 9 days. The lander will have to move to a region with favorable sunshine or wait for the Sun to rise without actively exploring.

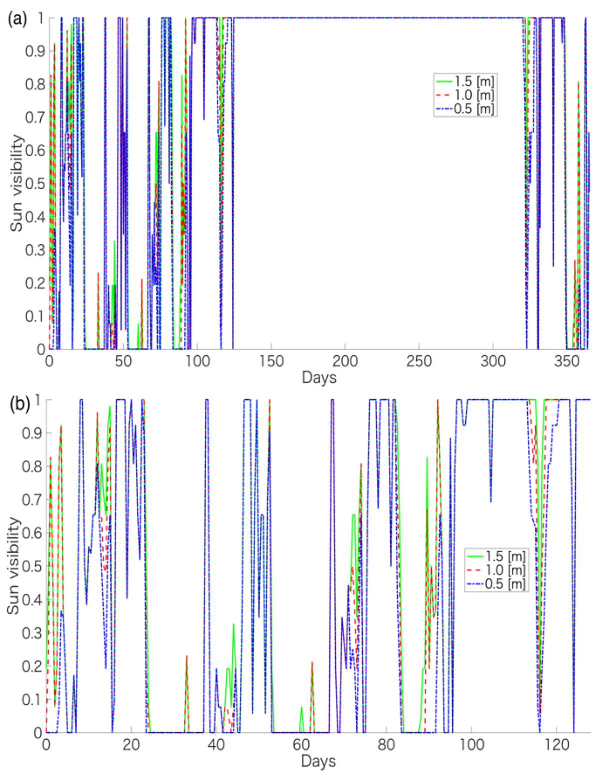

Figure 2. Changes of Sun visibility with altitude. Sun visibility means the ratio of the visible solar discs versus the total number of solar discs: In this simulation, the total number of solar discs is 52. (a) presents the results in one year. (b) presents that in four months.

Conclusion: This paper presents the illumination simulation results of an especially favorable landing site using LRO and Kaguya data. We can obtain the detailed sunshine conditions or its difference with altitude by conducting simulation with changing altitude. Future work will focus on the illumination simulation for a wider range of regions for precise landing site selection. In addition, we must evaluate the influence of resolution of input DEM data on illumination conditions.

References: [1] H. Noda, H. Araki, S. Goossens, et.al. (2008) *Geophtsical Research Letters, Vol. 35, L24203*. [2] Benjamin Vanoutryve, et.al. (2010) *International Planetary Prove Workshop, Barcelona.* [3] E. Mazarico, G. A. Neumann, et.al. (2011) *Icarus*, *211*(2), 1066-1081.