LANDING SITE ANALYSIS IN THE LUNAR SOUTH POLAR REGION FOR LUNAR POLAR EXPLORATION MISSION.. H. Inoue[1], M. Yamamoto[1], H. Otake[1], T. Hoshino[1] and D. Asoh[1], [1]Japan Aerospace Exploration Agency (inoue.hiroka@jaxa.jp).

Introduction: The lunar polar region has recently been attracting attention from various countries and companies because of the possible existence of water [1], [2]. JAXA plans a lunar polar exploration mission in the early 2020s. In this mission, a lander will be deployed in limited locations with long-term illumination, and then a rover released from the lander will investigate the availability of water using several scientific instruments. To collate with the remote sensing data that has been already available, the scientific observations will have to be made at multiple distant locations for a longer period than the previous landing missions.

In such a space exploration mission that a lander and a rover will have to perform appropriately, it is significant to find in advance the landing site that satisfies the requirement for the survival of the lander (e.g., long-term sunshine). It is also necessary to conduct the traversability analysis of the rover from the landing site to the expected scientific observation sites.

Previous work [3], [4] have conducted the landing sites analysis for various lunar missions. As analyzed in these papers, it is important to consider not only slopes and obstacles using real images and digital elevation models (DEMs) but also illumination. It is because, in the lunar polar region, the sunshine pattern is not a simple repetition of day and night due to the low solar altitude [5].

In this study, we analyzed the sunshine, earth visibility, and inclination using the altitude data of the moon, and found suitable landing site candidates by conducting numerical simulation. In addition, we analyzed these candidates using high-precision elevation models, and conducted traversability analysis.

Illumination analysis: There have been several papers on sunshine analysis in the lunar polar region [6], [7], [8]. By leveraging the solar conditions in the polar regions, these papers analyzed the 1) locations where shadows continue for a long time locally and 2) locations where sunlight can be obtained. In these illumination analyses, the accuracy of the elevation data used is quite important. This is because even a few meters of projection can cause long shadows in the polar region. We performed illumination analysis using the DEM with 40 meter resolution, which was created by removing artifacts from the original DEM. We analyzed not only the annual sunshine rate, but also the annual number of continuous sunshine days and the number of consecutive shade days. Also, we conducted the analysis of the permanent shadowed region by performing the sunshine analysis for 19 years from 2007. The red dots in Figure 1 represent the points where the sunshine is obtained continuously during the mission and the slope is gentle.

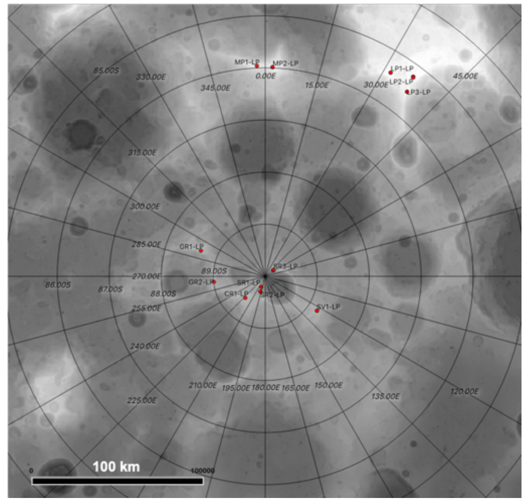

Figure 1: Landing site candidates (red dots) in the lunar south polar region. There are 561 points (i.e., pixels) which fulfil the requirements.

Detailed landing site analysis: We conducted more detailed analysis for the selected landing site candidates. Figure 2 is the simulation results for *de gerlache rim (GR1)* (88.664°S, 68.396°W), which is one of the selected points. The simulation was performed in one-hour intervals for the half-year period from October 2024. The DEM we employed has 5 meter resolution, which is more accurate than the one in the illumination analysis.

In Figure 2, (a) is an illumination ratio map, where the yellow area has a high value. The maximum ratio during the period is 98 %, and the maximum number of continuous sunshine days is 146 days. (b) is the visibility map from/to the Earth's ground station, which shows that the darker the area is, the worse the visibility from the earth's ground station is. In this area, the maximum value is 59 %. (c) is a slope map, where the yellow area indicates a gentler slope. (d) is a map in which the area with a communication visibility with less than 50 % is overlaid in gray on the sunshine map. In this area, the ground station is visible and invisible for two weeks at most points. (e) is an overlay of the sunshine map and the slope map. Points with slope of 10 degrees or more are overlaid in gray. Finally, (f) is a

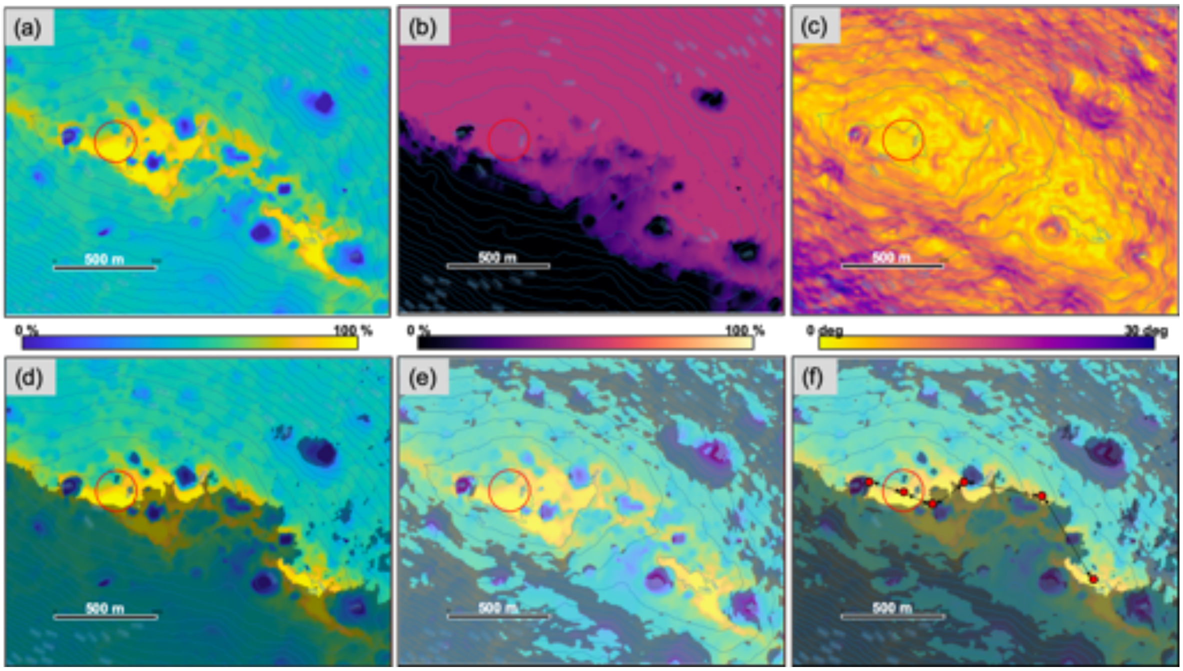

Figure 2: Results of detailed landing site analysis for GR1 region. The contour lines represent elevation.

diagram in which the area with a ground station visibility of less than 50 % and an inclination of more than 10 degrees is overlaid on the sunshine map. Above that, we put way points which are a candidate for observation point. The length of the path connecting them is approximately 2 km, and it can be seen that the slope is a relatively gentle area of less than 10 degrees.

Here, (a) to (f) are on the 1.5 km $\times$ 1.8 km area around GR1, and the red circle is the landing error circle with a diameter of 200 meter. In this mission, we aim to land in a very small area with long-term sunshine in the polar region. Therefore, we consider a landing error of 200 meter from the landing accuracy of SLIM which is JAXA's pinpoint lunar landing mission.

In Figure 2(a), it can be observed that the whole space in the red circle does not enjoy high sunshine rates. Figure 3 is a map on the *continuous sunshine days* where the red circle represents the landing error. The time segment of this simulation is one hour, and the maximum value is 3506 hours (i.e., 146 days). It can be seen that a relatively long continuous illumination of more than 3,000 hours can be obtained for more than half of the circle. However, in the red circle, there is a part where the sunshine can be obtained for only 500 hours continuously; hence, more precise landing accuracy than the diameter of 200 meter will be required.

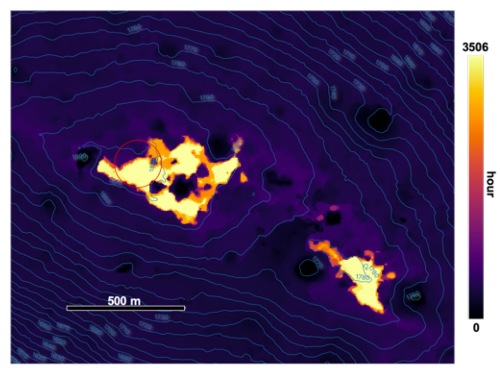

Figure 3: Continuous illumination term.

Future Work: By conducting such an analysis for multiple candidate sites, we will officially determine the landing site under the collaboration with ISRO that will jointly carry out the mission. In addition to the landing accuracy, we also conduct obstacle analysis using NAC images and analysis and select the landing site candidate together with the results.

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