LUNAR POLARIMETRY FROM ITS ORBIT WITH KPLO/POLCAM: PHASE-ANGLE COVERAGE

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Introduction: The Korea Pathfinder Lunar Orbiter (KPLO) is scheduled to launch in July 2022. KPLO will orbit the Moon at an altitude of 100 ± 30 km during the nominal mission of up to 1 year. Onboard KPLO, the Wide-Angle Polarimetry Camera (PolCam) will measure the polarimetric properties of the lunar surface from its orbit for the first time.

The Degree of linear polarization (P) is a function of phase angle (α), the angle created by the Sun, the lunar surface, and the observing instrument. The function $P(\alpha)$ can be parameterized using values $P_{\max}$ and $\alpha_{\max}$ as well as $P_{\min}$, α_{inv}, $\alpha_{\min}$, and polarimetric slope $h = \left.\frac{dP(\alpha)}{d\alpha}\right|_{\alpha=\alpha_{\text{inv}}}$ [1-2]. It is necessary to measure P at several different phase angles to determine the relationship between P and α. When onboard a lunar orbiter, a nadir-viewing camera can cover α only up to $90° + \frac{\text{field-of-view}}{2}$. PolCam's optical heads are tilted from the nadir direction to cover larger α range including the typical lunar $\alpha_{\max}$, as well as the negative portion of P at $\alpha < 20°$. In this work, we analyze the phase angle coverage of PolCam for the year using a simulated orbit of the KPLO for the year 2021, provided by Korea Aerospace Research Institute (KARI).

A Wide-angle Polarimetry Camera (PolCam): PolCam will measure the degree of linear polarization at wavelengths of 430 nm and 750 nm and obtain reflectance at 320 nm. Two identical cameras are mounted with 45° tilt from the nadir point. Each camera views left or right across the track of the orbiter that passes above both lunar poles with 10° field-of-view (FOV). The lunar surface of latitudes up to ±70° will be observed with spatial resolution of 80 m at altitude of 100 km.

The parameters of $P(\alpha)$ will be retrieved from measurements of degree of linear polarization at various phase angles. Then they can be used to determine structure characteristics of the lunar surface such as the distribution of median grain size, $\langle d \rangle$, the median size of surface particles [1-7] and their internal opacity [8]. Additionally, the reflectance ratios at 320 nm and 430 nm will be used to retrieve the map of titanium abundance on the Moon [9].

Phase-angle Coverages: At an altitude of 100 km, each orbit of KPLO around the Moon takes ~2 hours. The longitudinal shift between two sequential orbits is ~32.4 km, which corresponds to ~1.07° at the equator. The swath of each PolCam camera is ~38.9 km (~1.28°) at this altitude, resulting in a slightly overlapped area between two sequential orbits.

With a tilt angle of 45° and a 10° field-of-view, PolCam's FOV center of the left or right camera can cover α-range from 0° to ~140° (Figure 1). Considering the 10° FOV of each camera, the observing region has differences in phase angle up to ~10°. Differences in longitude approach values up to ~1.28° at the equator and approach values up to ~3.75° at latitudes of ±70°.

Figure 2 shows the α-coverage along the longitudes for the year when crossing over the equator. It is clear that there are more than 20 observational opportunities when the orbiter crosses over the equator. At above higher latitudes, the angle between the incident plane and the scattering plane becomes larger, increasing lower end of α up to ~35° at the latitude of 70° N. Since data at $\alpha > 40°$ are used in retrieving $P_{\max}$ [10], PolCam's polarimetry at high latitude region is still useful for the positive portion of $P(\alpha)$.

During the year, PolCam's observational tracks are well-distributed throughout longitudes, latitudes, and phase-angles, allowing construction of the map of $P_{\max}$ and other polarimetric characteristics. It is desirable to obtain measurements at $\alpha > \alpha_{\max}$ to retrieve $P_{\max}$ with smaller uncertainty. When the number of observations at $\alpha > 90°$ is as small as one, the root-mean-square discrepancy in $P_{\max}$ estimation increases to ~0.5%p [11].

25° Tilted Case: When the tilt angle for both cameras decreases to 25° instead of 45°, the high end of α is lowered to ~120°. In this case, only regions with latitude less than ±50° can be observed when $0° \leq \alpha < 40°$ and a large observational gap appears at longitudes from 60° to 120° and over latitudes from −70° to +70°.

Nadir-viewing case: When a single, nadir-viewing camera is used for the polarimetry from the lunar orbit, the high end of α is lowered to ~95°. Regions with latitude higher than ±45° and ±70° cannot be observed when $0° \leq \alpha < 40°$ and $40° \leq \alpha < 75°$, respectively. When $110° \leq \alpha < 145°$, there is a large observational gap at longitudes from 60° to 120° and latitudes from −30° to +30°. The total number of opportunities also decreases significantly.

Semiannual Yaw-flip Case: Depending on the configurations of the solar panel, some polar orbiters rotate their yaw 180° semiannually, at a Sun beta angle of 0°, to keep the Sun in its solar array. In this case, the left- and the right-viewing camera view regions of $\alpha \leq$

50° and $\alpha \geq 40°$, respectively. As the two cameras are identical and view opposite directions across the track at the same tilt angle, rotating the yaw 180° only interchanges the viewing regions of the two.

When it is not possible to operate both cameras simultaneously, as in the case of a shortage of power or data transfer, the viewing camera must be chosen carefully. We note that the yaw-flip maneuver is currently not considered for KPLO.

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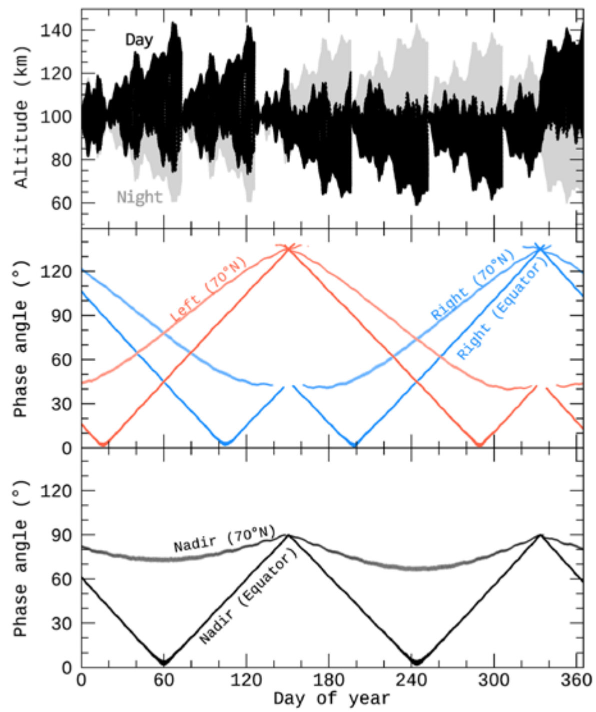

Figure 1 Simulated altitudes of KPLO above the equator (upper panel), PolCam's phase-angle coverage of the left- (red) and right-viewing (blue) cameras and the sub-orbiter direction (black) above the equator and 70°N (middle and lower panel) for the year.

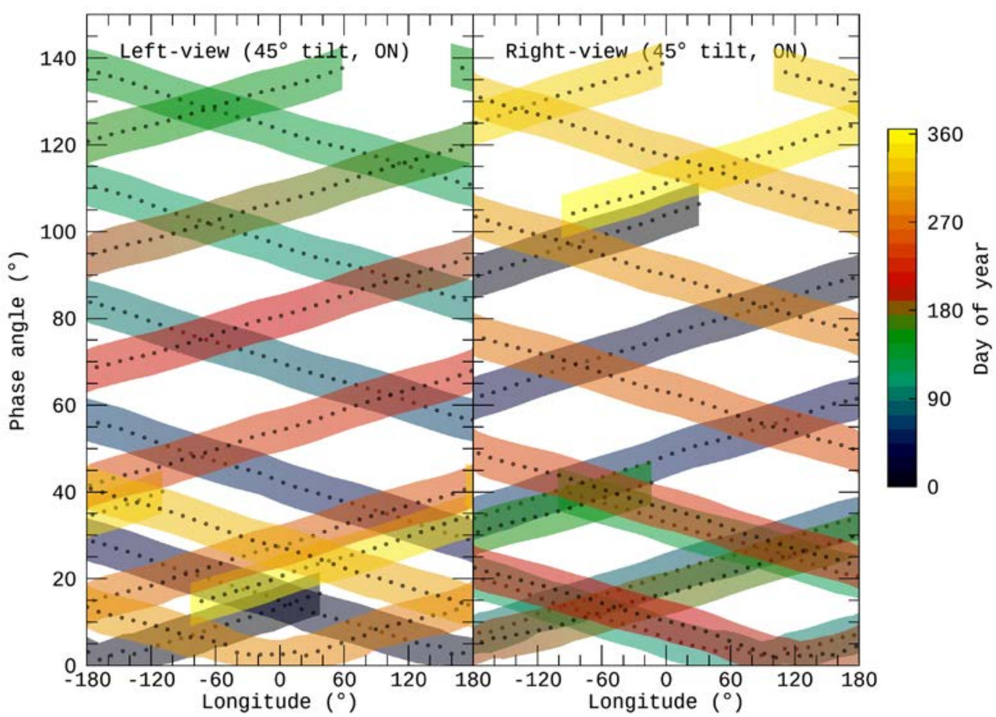

Figure 2 PolCam's phase-angle coverage swath of the left- and right-viewing cameras as a function of longitudes when the orbiter passes over the equator. The dots are the FOV centers at every 10 orbits around the Moon .