ANALYSIS OF EARTH OBSERVATION SCOPE FROM DIFFERENT POSITIONS ON THE MOON.
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Introduction: In order to get the comprehensive knowledge of the Earth, scientists have been studying and developing Earth observation science and technology for decades. The existing Earth observation systems lack the ability of long-term continuous observation at global scale. Recently years, with the development of the Moon exploration, a new concept platform of Earth observation has been introduced. The Moon-based Earth observation platform has the advantages in Earth observation [1], such as geoscience studies and global change detection because of the need to study the Earth from the holistic and comprehensive perspective.

At present, some discussions have been made in Moon-based observation of the Earth's inner layers [2]. Compared to the space-borne and air-borne platform, the Moon-based Earth observation platform has the characteristics of vast space that can put sensors. Setting sensors on the different positions of the Moon, its observation scope is not clear. Here we introduce the geometric model first. Then, the visibility and Earth observation scope of Moon-based platform is discribed. Finally, a brief discussion of the observation scope differences between different positions on the Moon has been presented in the paper.

Geometric Model: The geometric model of Moon-based platform system is similar to the air-borne and space-borne platform system, but the difference is that the Earth-Moon distance is very large, about 380,000 km. The sensors on the Moon-based platform could observe the whole Earth [3]. The platform, on which the sensors will be built, is not at the geometric center of the Moon, but on its surface. In the following, a geometric model is introduced, starting from two hypotheses:

1) The Moon are regular spherical and the look vector of the sensor always points to the center of the Earth. The imaging error can be ignored when analyzing the observation scope.

2) The light refraction is not considered in this model.

The lunar ephemeris provides the real time position of the Moon and the orientation of the platform [4]. Very high precision lunar ephemeris development ephemeris (DE) is exploitable for Moon exploration [5]. Compared with DE421 and DE405, DE430 has been fit to additional data for the Moon [6]. We select DE430.

For Moon-based platform case, it is necessary to describe the orientation of the Earth because of the very long-term continuously observation [7]. The Earth Orientation Parameters are applied to include a collection of parameters that describe the orientation of the Earth.

The geometric model of Moon-based platform is based on transformation matrix. The model includes six coordinate systems: The selenographic coordinate system, Moon-Centered Moon-Fixed coordinate system, the inertial selenocentric coordinate system, Earth-Centered inertial coordinate system and the Earth-Centered Earth-Fixed coordinate system. By giving the position of the Moon-based platform and the Sun, this model links the Moon-based platform sensor and the observation scope in the Earth-Centered Earth-Fixed coordinate system.

Visibility of Moon-based Platform: Since the Moon is a quite stable body with vast expanses, placing different positions on the Moon have different view. This is a key aspect in determining the availability of Moon-based platform. With the simple geometrical model considerations, the visibility of the Moon-based platform is presented in Fig 1. Moon and Earth rotate both around their own axis and these two axises are not parallel. The coordinates of Moon-based platform in the inertial selenocentric coordinate system must be defined. Parameter N_m is the coordinate of the intersection point between the line O_mO_e and the Moon. The limiting case of the sight line is the tangent between Earth and Moon such as the sight line A_1B_2 is the limiting case of the point B_2.

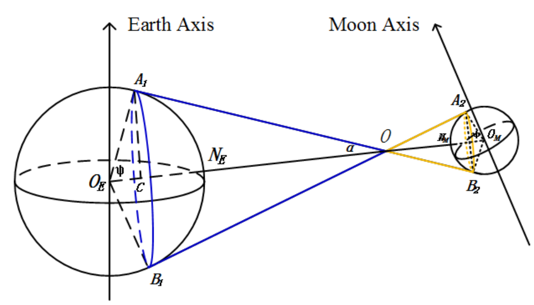
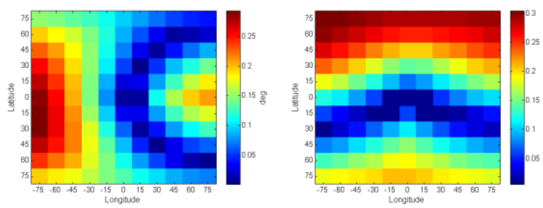


Fig. 1 The illustration of the visibility of Moon-based platform.

Observation Scope: The observation scope is an important index for evaluating the observation performance of the Moon-based platform. The instantaneous field of view of the Moon-based Earth observation is about the whole Moon-facing hemisphere of the Earth. It is mathematically easy to recognize the curve is a space ellipse. The edge of the observation scope is the link line of the points of tangency, which is coplanar. The ellipse can be described as the line of intersection between the Earth and the link line plane. But different positions on the Moon may carry out different observation scope. In order to compare with the observation scope that different positions and the coordinate (0, 0), we calculate the maximum longitudinal difference (Fig. 2(a)) and the maximum latitudinal difference (Fig. 2(b)) according to the observation scope of the year 2016.



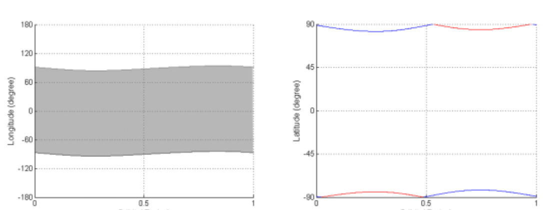
(a) (b)

Fig. 2. (a) The maximum longitude difference between different positions and the coordinate (0, 0) during 2016. (b) The maximum latitude difference between different positions and the coordinate (0, 0) during 2016.

Discussions: Fig 3 provides the latitude and longitude range of the Moon, where the sensors can observe the Earth all the time. The visibility of the Moon-based platform is constantly changing with the relative position of the Moon and the Earth.

Usually, the Maximum libration may reveal up to 8° of longitude on the Moon's back side along the eastern and western limbs corresponding to the longitude range so it is evident that the longitude range is from -96° to 96°. The latitude range is from -81° to 81°, according to the variation of latitude libration. On the basis of this fact, the Moon surface can be divided into multiple regions.

(1) Zone with longitude between -80° and 80° and latitude between -81° and 81°: This is the fully observation zone, sensors can observe the Earth at any time and the Earth appears to rock slightly from side to side and up and down. Setting sensors in this zone, the observation scope difference is very small. The maximum longitudinal difference of observation scope is about 0.4°. Due to the Earth rotation, setting sensors on the limb of this zone may provide a small longitudinal shift which doesn't affect the observation scope significantly. The maximum latitudinal difference of observation scope is about 0.5°. Maybe, setting sensors on the high latitude of the Moon, this will expand the observation area of Arctic region or Antarctic region.



(a) (b)

Fig. 3. (a) The longitude range of the fully observation zone during one orbital period. (b) The latitude range of the fully observation zone during one orbital period. The red part is the far-side of the Moon.

(2) Zone with longitude between -80° and 80° and latitude more than 81° or less than -81°: When setting sensors on this zone, the angle between Moon's orbit and Earth equator plays an important role in the visibility between the Moon-based platform and Earth. In this zone, though we can observe the two polar region of the Earth more, there will be lack of the observation time.

(3) Zone with longitude between 80° and 96° or -80° and -96° and latitude between -90° and 90°: The effect of Moon libration become the main reason to identify the observing days. The closer the sensor is to the limb, the fewer the number of observing days. Similar to the previous region, setting sensors on this zone will face the problem of the short observation time.

(4) Zone with longitude more than ±96° and latitude between -90° and 90°: Setting sensors on this zone could not observe the Earth except on the high latitude of the Moon. And it is obvious that the performance of observing from high latitude is unsatisfactory.

Conclusions: Presented results show that the Moon-based platform sensor are able to fulfill almost Moon-facing hemisphere of the Earth when locating on the fully observation zone. Besides, setting sensors on the high latitude will expand the observation scope of the Arctic region or Antarctic region. Other zones are all lack of the observation time of the Earth and setting sensors on the north pole and south pole of the Moon will have a minimal advantage in observing the Arctic or Antarctic region in contrast to the latitude 70°-80° of the fully observation zone. This suggest that the fully observation zone is the ideal zone to placing the Earth observation sensors.

References: [1] H. D. Guo. et al. (2014) *Sci. China Earth Sci.*, 1771–1779. [2] H. L. Ye. et al. (2016) *IGARSS*, 7729968. [3] H. L. Ye. et al. (2016) *IOP Conf. Ser.:Earth Environ. Sci*, 012024. [4] Mark Jesick. et al. (2012) *Adv. Astronaut. Sci.*, 2327-2344. [5] Hilton. J. L. et al. (2011) *JSR*, 77-80. [6] Folkner, W M et al. (2014) *Interplanetary Network Progress Report*, 1-81. [7] Petit. G. et al. (2010) *Iers Technical Note*, 1-95.