Asymmetric space weathering in Northern and Southern Hemispheres on the Moon

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ABSTRACT

- We reproduce Sim et al., who studied the space weathering asymmetry inside lunar craters, using the extended lunar crater database and the improved techniques.
- Unlike previously known, northern and southern hemispheres seem not to be symmetrically affected along the ecliptic plane. In particular, the degree of weathering on the opposite walls is significantly asymmetric near the equator.
- We speculate that this unexpected result is caused by asymmetric impact flux or angle of meteoroids in the northern and southern hemispheres on the Moon.

INTRODUCTION

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At higher latitudes, lunar regolith has brighter reflectance and less red (i.e. less mature) caused by lower flux. Which space weathering agents enter along the ecliptic plane and affect soil maturation more?
Solar wind particles or Micro-meteorites?
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Hemingway et al. @Icarus · Nov 2015
Solar wind particles enter along the ecliptic plane!
Reduced flux should occur both at swirls and toward higher latitudes.
3 45 34

Jeong et al. @ApJS · Nov 2015
Micro-meteorites (as well as solar wind particles) enter along the ecliptic plane! Grain size monotonically increases as the latitude increases.
8 16 36

Sim et al. @GeoRL · Nov 2017
Solar wind particles weather the lunar regolith more than micro-meteorites! Pole-facing walls are brighter and less red than their equator-facing counterparts as latitude increases.
5 13 41

Trang & Lucey @Icarus · Mar 2019
Both of them, but it is difficult to estimate what affects more...
Nano- and micro-phase iron abundances are lower at higher latitudes, which suggests lower solar wind and micro-meteoroid impact flux at these latitudes.
2 20 61

DATA

➢ Lunar Crater Database

- We adopt the lunar crater database provided by Robbins et al. (2018) to consider larger number and smaller size of craters than Sim et al. (2017), which used lunar impact crater database provided by the Lunar and Planetary Institute (LPI).

	Sim et al. (2017)	This Study
Database	LPI (2015)	Robbins et al. (2018)
# of craters	1872 (of 8716)	26,802 (of ~1.3 million)
Diameter	5 ~ 120 km	2 ~ 120 km
Latitude	-50° ~ +50°	-60° ~ +60°

※ Craters smaller than 2 km in diameter cannot be recognized due to spatial resolution (~60 m/pixel) of lunar global map data, even though they are well-preserved.

➢ Lunar Global Map Data

- DEM : the improved lunar **d**igital **e**levation **m**ap at a typical vertical accuracy ~3 to 4 m
- Reflectance : ultraviolet-visible (415, 750, 900, 950, 1001 nm) and near-infrared (1000, 1050, 1250, 1550 nm) of SELENE multiband imager

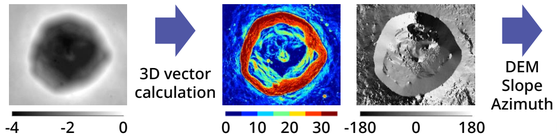
Mission	LRO + SELENE	SELENE
Instrument	LOLA + Terrain Camera	Multiband Imager
Data Type	DEM	Reflectance
Transformed Data	Slope, Aspect (= Azimuth Angle)	Optical Maturity (= OMAT)
Resolution	~60 m/pixel	

※ All data cover latitudes within ±60°.

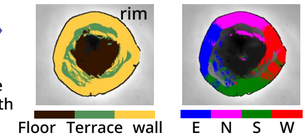
METHODS

We improved the analysis methods of Sim et al. (2017).

1. Extract DEM of craters & Produce slope and azimuth angle.

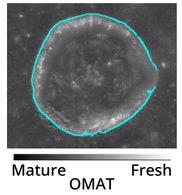


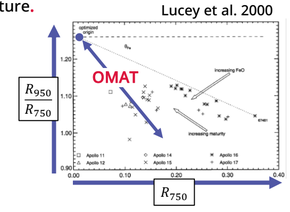
2. Detect structures of well-preserved craters & Divide wall-quadrants of each crater.



3. Extract reflectance of craters, Align to DEM, & Calculate Optical Maturity (OMAT) of craters.

The smaller OMAT, the more mature.



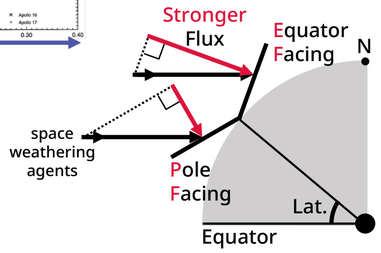


Degree of optical maturity with the Euclidean distance to a "hyper-mature" point in a space of 750 nm reflectance vs. 950 nm/750 nm color

4. Analyze latitudinal trends using EF and PF walls.

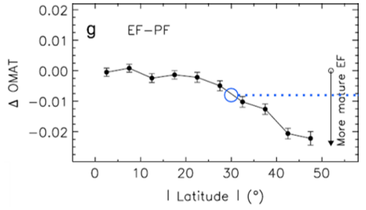
Impact flux of space weathering agents is stronger on EF wall than on PF wall!

★ As latitude increases, flux difference of EF and PF wall increases. (= Δflux [$flux_{EF\ wall}$ – $flux_{PF\ wall}$] increases.)



RESULTS

Figure 1. Result of Sim et al. (2017)



➢ Latitudinal Trends of Δ (= [Equator Facing] – [Pole Facing])

- ΔOMAT of all craters (dark solid line in **Fig. 2**) is consistent with the previous study (**Fig. 1**), it should be close to zero near the equator and increases toward higher latitudes.
- It means that incident angles of EF and PF walls are similar near the equator because space weathering agents are known to enter along the ecliptic plane.
- However, in **Fig. 2**, ΔOMAT in the N (red solid line) and S (blue solid line) hemispheres are not close to zero near the equator.

Figure 2. Results of this study

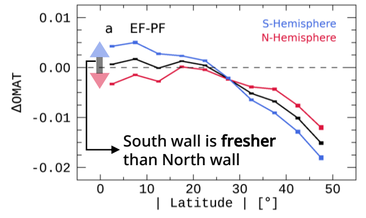


Figure 3. One sample of craters near the equator

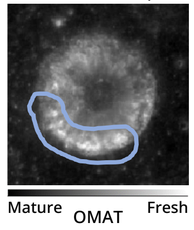
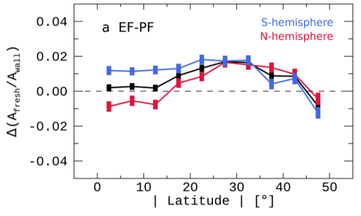


Figure 4. EF-PF of ratio of fresh area to wall-quadrant area.



➢ Cause of the Asymmetries at Lower Latitudes

- Many craters near the equator have fresh regions more on South wall than on North wall (**Fig. 3**).
- These asymmetric features at lower latitudes are also evident in statistical analysis (**Fig. 4**).
- ★ We speculate that this unexpected result is caused by asymmetric impact flux or angle of meteoroids in the N and S hemispheres on the Moon.