Investigating diurnal changes in the normal albedo of the lunar surface at 1064 nm: A new analysis with the Lunar Orbiter Laser Altimeter

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INTRODUCTION thermal environment at the Moon

Nighttime

Daytime

Temperature (K)

0 400
INTRODUCTION  

temperature-dependent spectral changes

Data from Hinrichs et al. (1999)
INTRODUCTION

Temperature-dependent spectral changes

Data from Hinrichs et al. (1999)
INTRODUCTION temperature-dependent spectral changes

Data from Hinrichs et al. (1999)
INTRODUCTION  temperature-dependent spectral changes

Reflectance at 1064 nm

Lunar soil 67711
Orthopyroxene En86

Data from Hinrichs et al. (1999);
Hinrichs and Lucey (2002)
How does the surface reflectance of the Moon, as measured from orbit by LOLA at 1064 nm, change over the course of a lunar day?
Determine the reflectance and temperature of the surface for local hours 07:00–16:00 in 1° x 1° spatial bins from 65°S to 65°N.
Determine the **reflectance** and temperature of the surface for local hours 07:00–16:00 in 1° x 1° spatial bins from 65°S to 65°N.

Detector 3
Determine the **reflectance and temperature** of the surface for local hours 07:00–16:00 in 1° x 1° spatial bins from 65°S to 65°N.
RESULTS: Diurnal reflectance changes

Determine the **reflectance and temperature** of the surface for local hours 07:00–16:00 in 1°x 1° spatial bins from 65°S to 65°N.

- **0°N, 180°E**
  - **07:00**: Brighter
  - **08:00**: Colder
  - **294 K**

- **0°N, 0°E**
  - **12:00**: Warmer
  - **13:00**: Darker
  - **392 K**
RESULTS diurnal reflectance changes

Local time 07:00–08:00

Detector 1

Normal albedo at 1064 nm

0.10

0.30
RESULTS diurnal reflectance changes

Local time 09:00–10:00

Normal albedo at 1064 nm

Detector 1
RESULTS *diurnal reflectance changes*

Local time 12:00–13:00

Normal albedo at 1064 nm

Detector 1

- 0.10
- 0.30
RESULTS diurnal reflectance changes

Normal albedo at 1064 nm

Local time 14:00–15:00

Detector 1
RESULTS diurnal reflectance changes

Normal albedo at 1064 nm

Local time 07:00–08:00

Detector 1
RESULTS diurnal reflectance changes

Normal albedo at 1064 nm

Local time 09:00–10:00

Detector 1
RESULTS diurnal reflectance changes

Local time 12:00–13:00

Detector 1

Normal albedo at 1064 nm

0.10

0.30
RESULTS  diurnal reflectance changes

Normal albedo at 1064 nm

<table>
<thead>
<tr>
<th>Local time</th>
<th>Detector 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:00–15:00</td>
<td>0.10</td>
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</tbody>
</table>

Detector 1
RESULTS diurnal reflectance changes

Local time 07:00–08:00

Normal albedo at 1064 nm

Detector 1
RESULTS diurnal reflectance changes

Normal albedo at 1064 nm

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<th>0.10</th>
<th>0.20</th>
<th>0.30</th>
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</table>
|Detector 1

Local time 09:00–10:00

Latitude
-60°S to 60°N
Longitude
-180° to 180°
RESULTS diurnal reflectance changes

Local time 12:00–13:00

Normal albedo at 1064 nm

Detector 1

0° 60°N 30°N 0° 30°S 60°S
RESULTS

Normal albedo at 1064 nm

Local time 14:00–15:00

Detector 1
RESULTS diurnal reflectance changes

What temperature-dependent changes are occurring?

Brighter when colder

Darker when colder

positive

negative

ΔR/ΔT
1. LOLA measures a higher surface reflectance across the lunar surface at colder temperatures.
2. The change in albedo is relatively small (only a few %) from 07:00 to 12:00.
3. The $\Delta R/\Delta T \times 1000$ is [-1 0] 1/K on average.
Where are the greatest temperature-dependent changes occurring?

Lemelin et al. (2016)
We observe a higher normal albedo of the lunar surface when the temperature is lower, as measured by LOLA at 1064 nm.

This is consistent with:
1. Laboratory observations of pure minerals. 
   (Singer and Roush, 1985; Roush and Singer, 1986, 1987; Hinrichs and Lucey, 2002)
2. Ground-based observations of A-type asteroids. 
   (Lucey et al., 1998)
3. Spacecraft-based observations of Eros. 
   (Lucey et al., 2002)

On the space-weathered Moon, the magnitude of temperature-dependent spectral effects is relatively low.

Ongoing work consists of determining the causes of these changes.

Future science of and from the Moon should account for temperature-dependent spectral effects.
IMPLICATIONS LOLA as a mineralogical sensor

Reflectance

Orthopyroxene En86

Olivine Fo86

Temperature (K)

Data from Hinrichs et al. (1999)
IMPLICATIONS LOLA as a mineralogical sensor

Olivine

Low-Ca Pyroxene

Clinopyroxene

Plagioclase
INTRODUCTION temperature-dependent spectral changes
Where are the greatest temperature-dependent changes occurring?

\[ \frac{\Delta R}{\Delta T} \times 1000 \]

- less
- more

0°, 60°N, 30°N, 0°, 30°S, 60°S
INTRODUCTION temperature-dependent spectral changes

Data from Lucey et al. (1998)
IMPLICATIONS LOLA as a mineralogical sensor

Where are the greatest temperature-dependent changes occurring?

Lemelin et al. (2016)
Plot (R,T) for 7-16 for regions that are ortho rich

1.

Data from Hinrichs et al. (1999)

IMPLICATIONS LOLA as a mineralogical sensor
RESULTS diurnal reflectance changes

Local time
07:00

Temperature (K)

50  |  400
RESULTS diurnal reflectance changes

Local time
08:00

Temperature (K)

50  400
RESULTS diurnal reflectance changes

Local time
09:00
RESULTS diurnal reflectance changes

Local time
10:00

Temperature (K)

50  100  200  300  400
RESULTS diurnal reflectance changes

Local time
11:00

Temperature (K)
50 500
RESULTS diurnal reflectance changes

Local time
12:00

Temperature (K)
50 - 400
RESULTS diurnal reflectance changes

Local time

13:00

Temperature (K)

50  400
RESULTS: Diurnal reflectance changes

Local time: 14:00

Temperature (K):
- 50
- 400
RESULTS diurnal reflectance changes

Local time

15:00

Temperature (K)

50  400
IMPLICATIONS future measurements