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An Analysis of Illumination and Communication Conditions near the Lunar South Pole based on Kaguya data

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Contents

- ESA Lunar Lander
- Study concept and framework
- Illumination analyses
- Communication analyses
- Conclusions and impact on system design

ESA Lunar Lander

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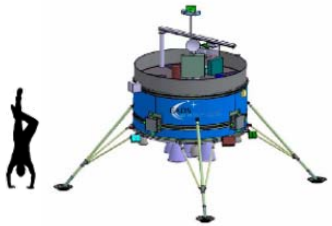
Soft precision landing in the Lunar South Pole Region with hazard avoidance

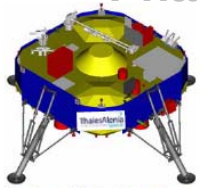
Objectives

Prepare for future human exploration of the Moon

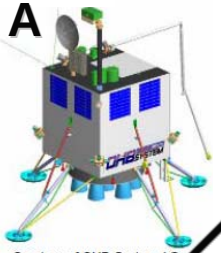


Courtesy of Astrium GmbH

Phase A



Courtesy of Thales Alenia Space



Courtesy of OHB-System AG

Soyuz launch from *Centre Spatial Guyanais* in 2018

Phase B1 baseline

No use of Radioisotope Heater Units (RHU)

Study concept

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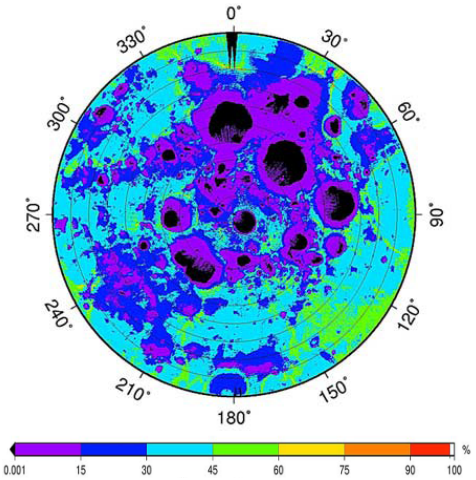
Previous sudies

% of Illumination over given period



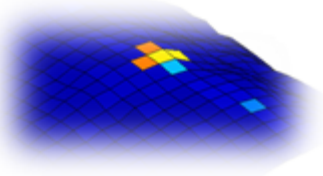
Noda et al. Geophys. Res. Lett., 35

Lander design

Light
Darkness

New Approach

&



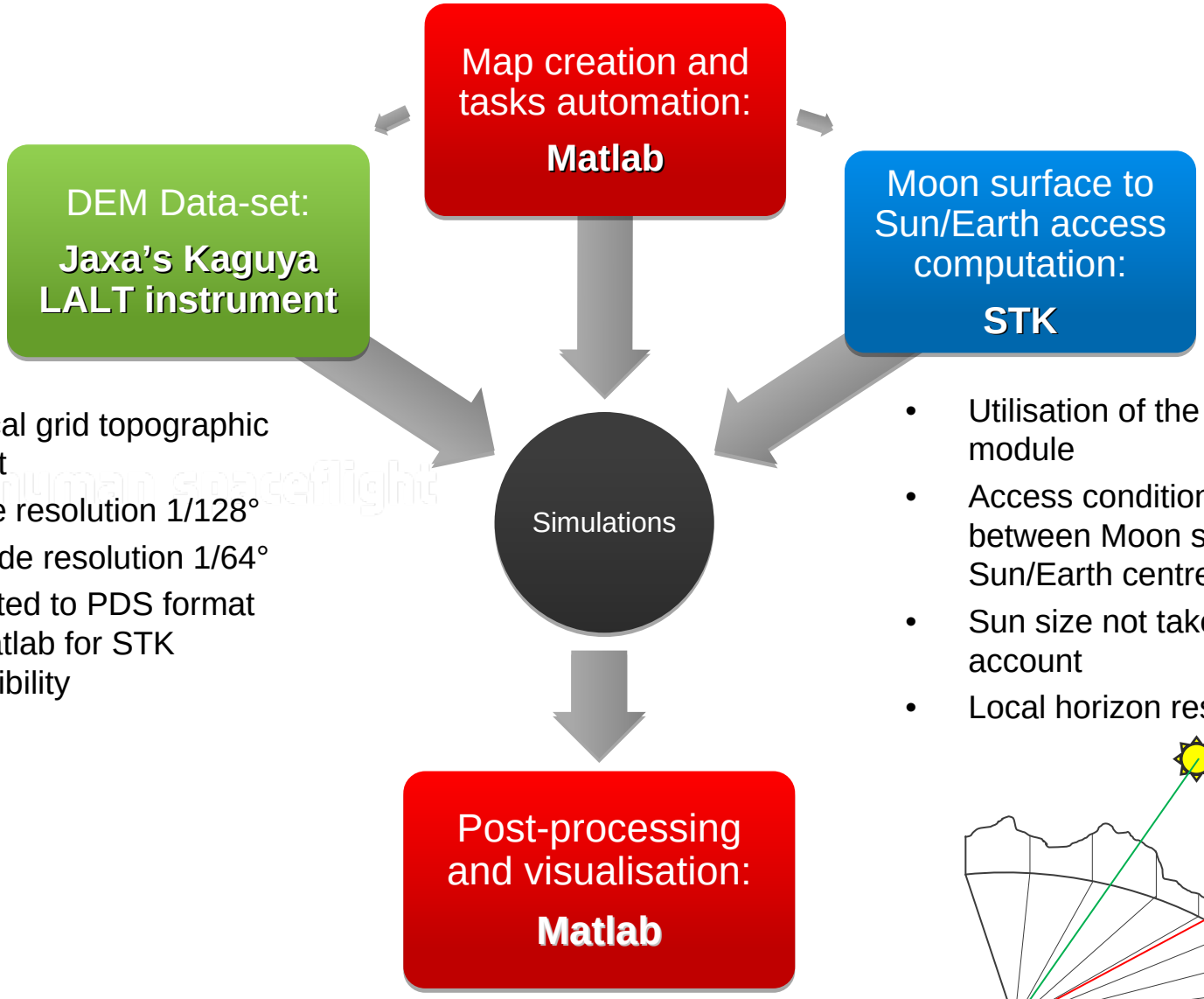
Longest **Q**uasi-**C**ontinuous **I**llumination **P**eriod (LQCIP)

Light/darkness patterns

- Favourable patterns
- associated area

Lander design

Study Framework



- Spherical grid topographic data set
- Latitude resolution 1/128°
- Longitude resolution 1/64°
- Converted to PDS format with Matlab for STK compatibility

- Utilisation of the Connect module
- Access condition is direct line between Moon surface and Sun/Earth centre
- Sun size not taken into account
- Local horizon resolution is 0.5°

Global Analysis: Method

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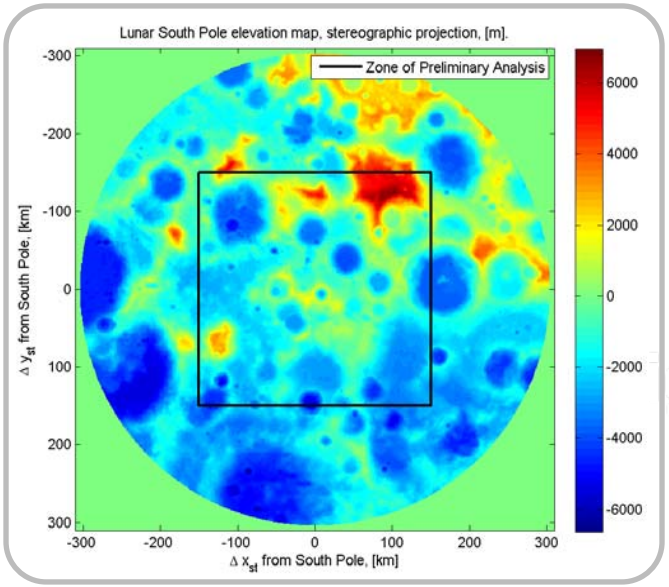
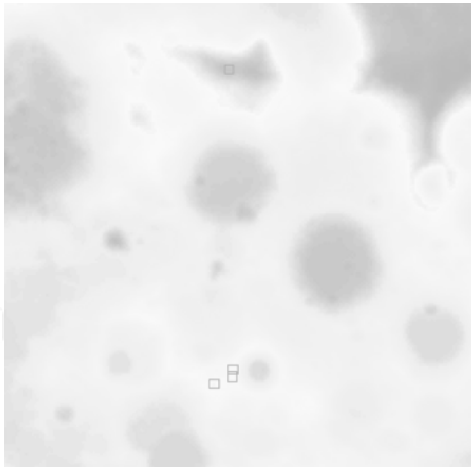
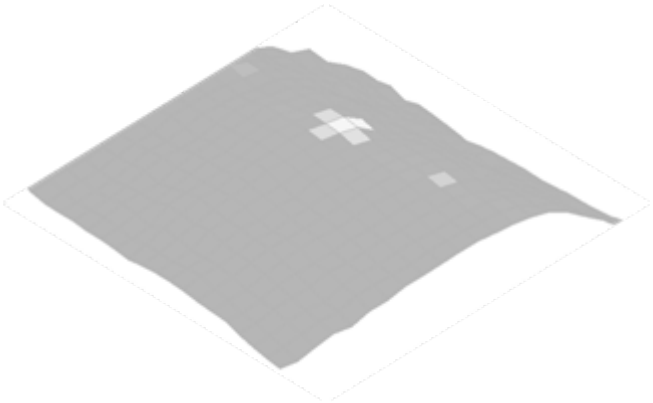
Locate the most promising regions with favourable illumination conditions at the Lunar South Pole







- Analysis on 300km-side square centred on South Pole
- Altitudes of -1km and higher
- **500**-metre resolution gridding
- Year of analysis: **2018**
- Solar-Array height above ground: **2 metres**
- TCS and batteries allow darkness periods of **55 hours**

Global Analysis: Results

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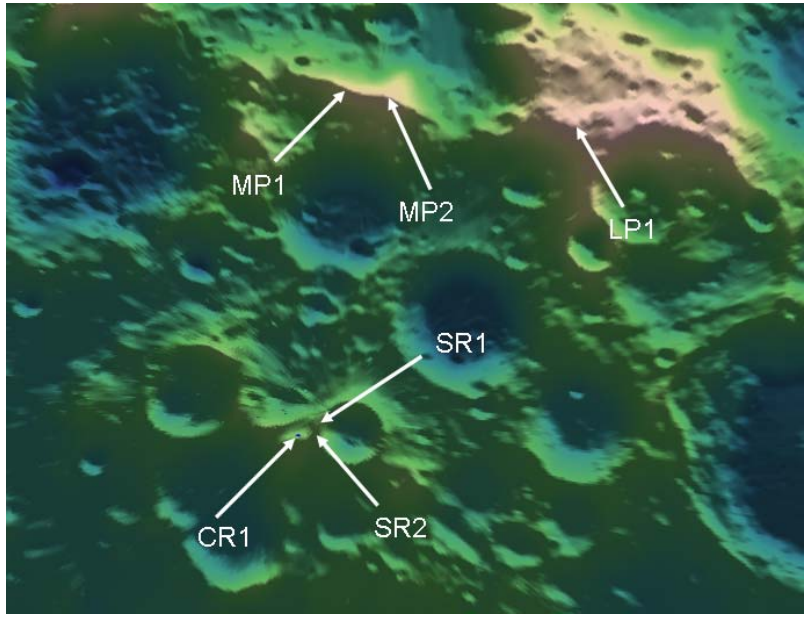
- Assessment based on
  - Duration of LQCIP
  - size of the area
- 6 principal Region Of Interest (ROI)
  - 3 in South Pole vicinity
  - 2 on Mapalert peak
  - 1 on Leibnitz Beta plateau
- Around 6 months of quasi-continuous illumination, up to 10 months. (55h filter)
- Secondary ROI identified but less attractive



6 primary ROI

ID	Region name	Longest illumination period [days]	Location (Lat/Lon [deg])
Primary areas			
SR1	Shackleton Rim	274	(-89.7788, -153.4349)
SR2	Shackleton Rim	234	(-89.6871, -161.5651)
CR1	Connecting Ridge	316	(-89.4632, -137.4896)
MP1	Malapert Peak	196	(-85.9756, -2.1124)
MP2	Malapert Peak	203	(-86.0236, 2.6133)
LP1	Leibnitz beta Plateau	203	(-85.4406, 31.8517)

Detailed Analyses: Method

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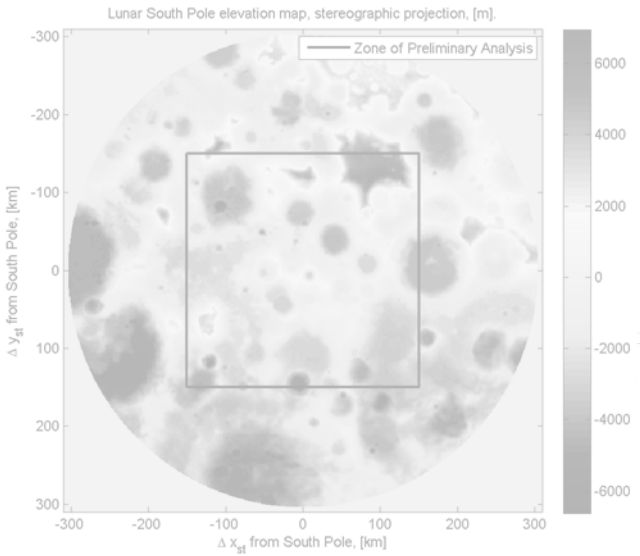
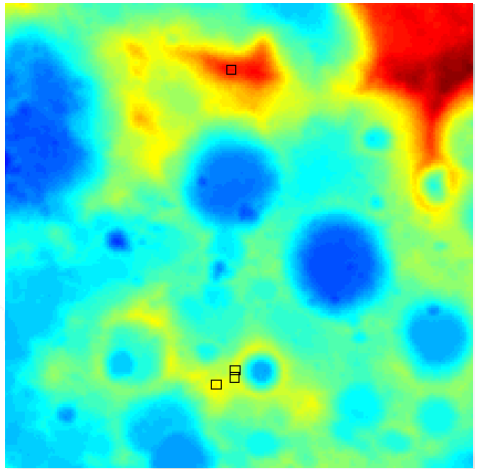
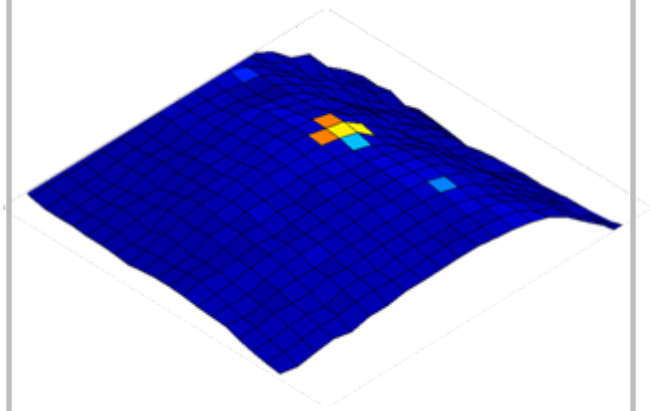
Detailed illumination and communication analyses of every ROI

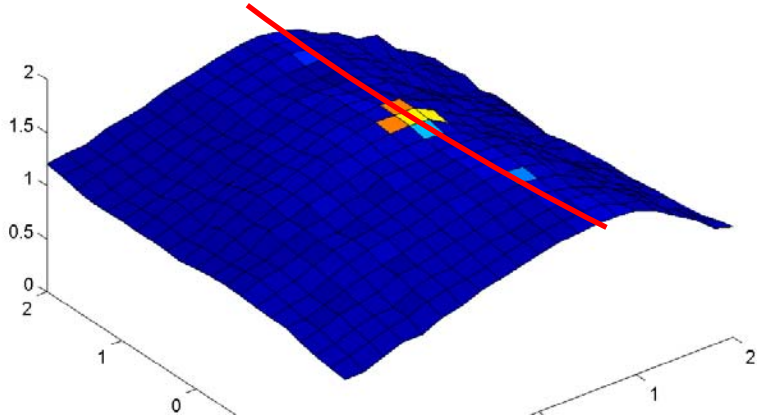




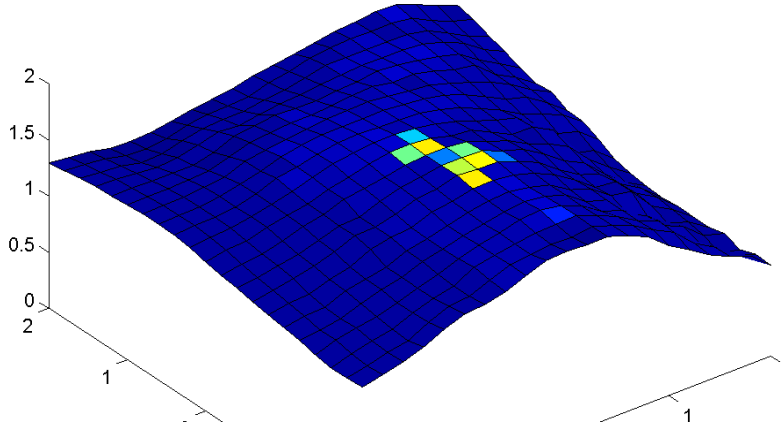


- Analyses on 4x4km area around identified ROI
- **200**-metre resolution gridding
- Solar-Array height above ground: **2 metres**
- TCS and batteries allow darkness periods of **55 hours**
- 2D or 3D terrain maps
- Colour-scale represents the longest quasi-continuous illumination period
- Value is for centre of pixel

Detailed Analyses: results

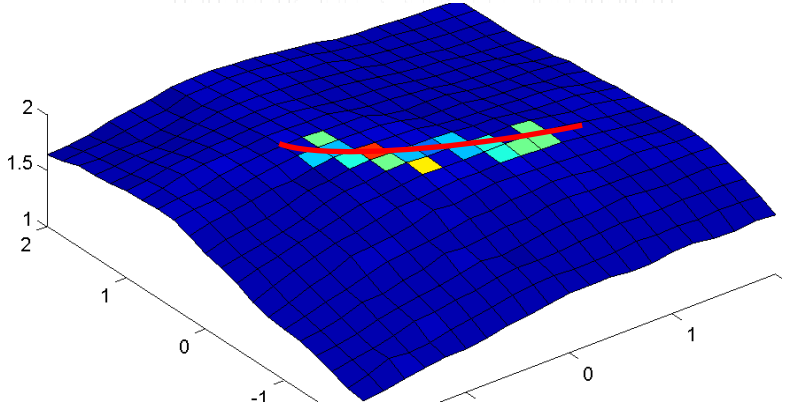


SR1: 273 days (8.9 months)

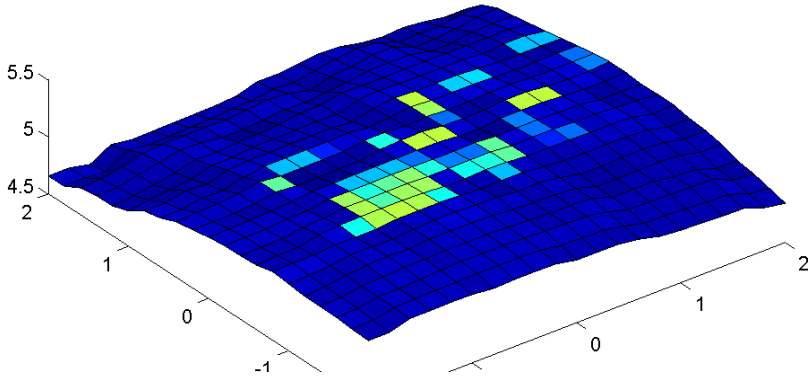


SR2: 233 days (7.6 months)

Duration of the longest quasi continuous illumination period for the 4 ROI

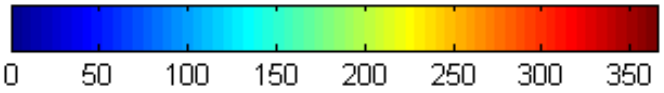


CR1: 301 days (10 months)



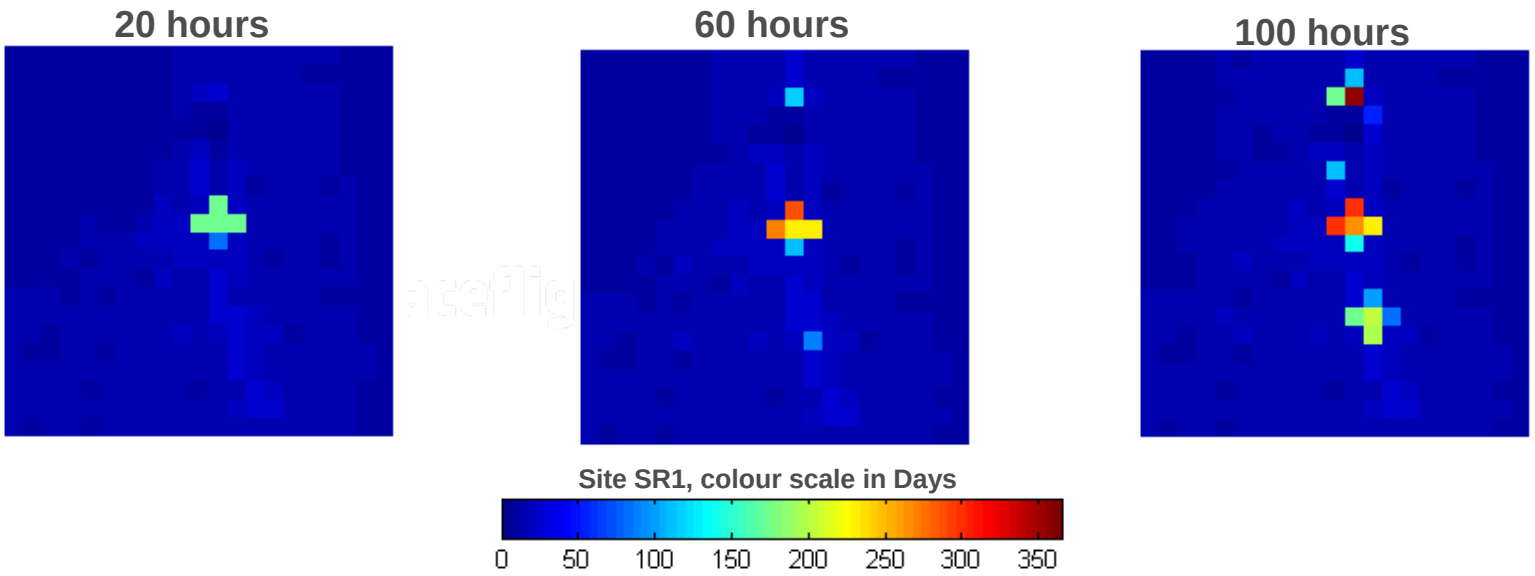
MP2: 203 days (6.6 months)

Colour scale in Days



Influence of night survivability

- Different night survivability can be achieved depending on the Lander design



The darkness duration the lander can withstand has little effect on the size of the favourable zones but longer night survivability enables longer mission duration.

Influence of height above the ground

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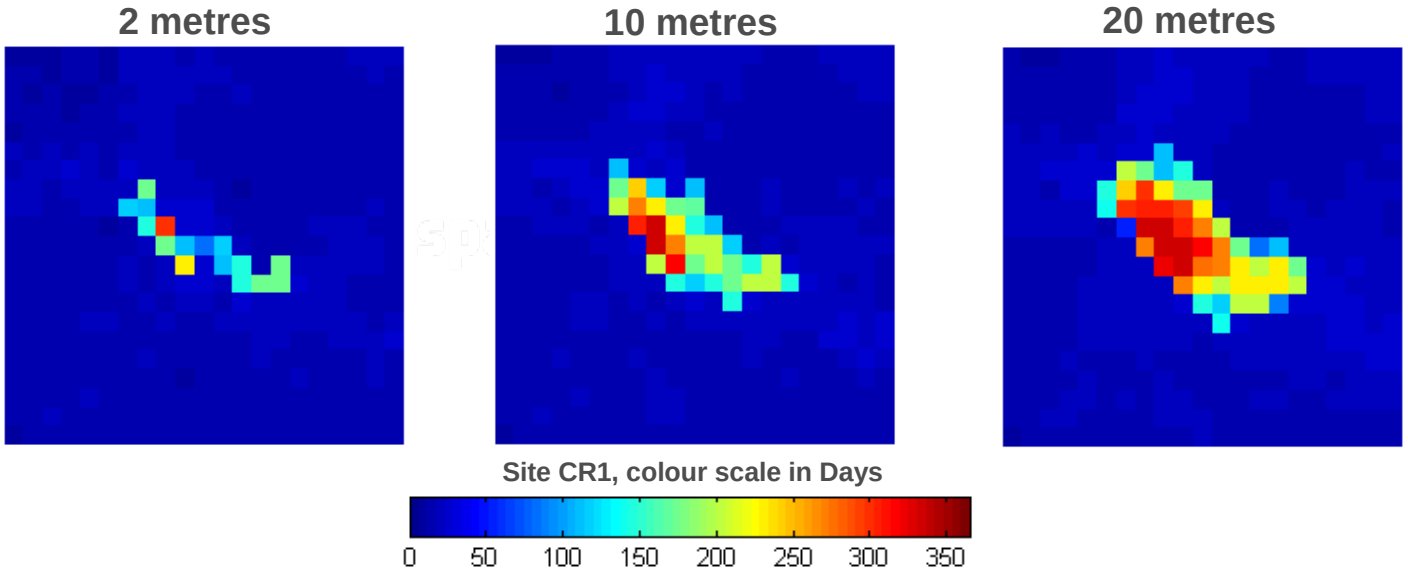
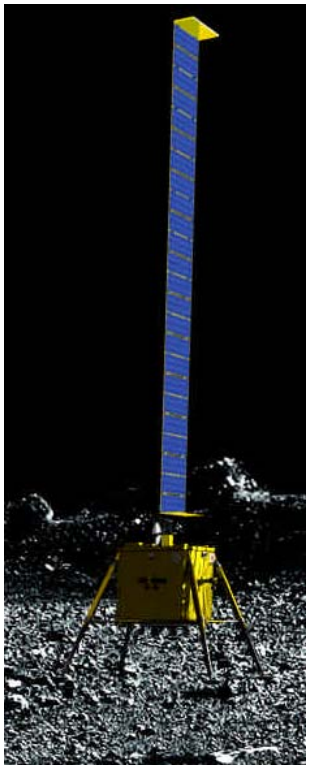
- Baseline design: Solar arrays at 2 metres height
- Alternative concept: tower-mounted solar arrays: heights of 10 and 20 meters





Courtesy of Jaxa

IAC-09.A3.2B.1

A tower mounted solar array provides a significant increase in the mission duration and in the extent of the favourable area.

Direct-to-Earth communication around Lunar South Pole

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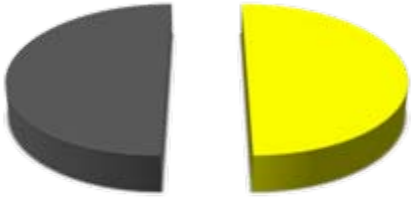
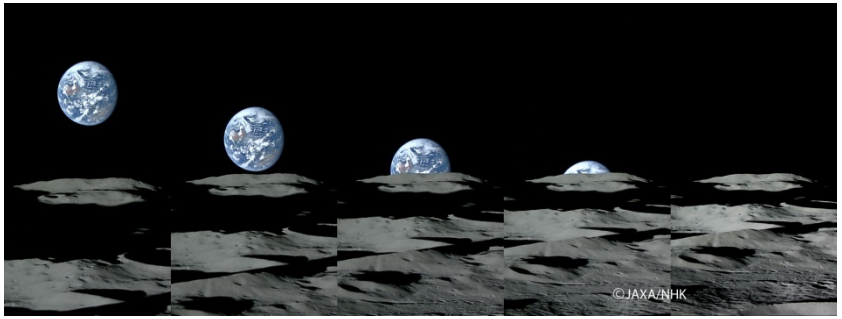
Spherical Moon

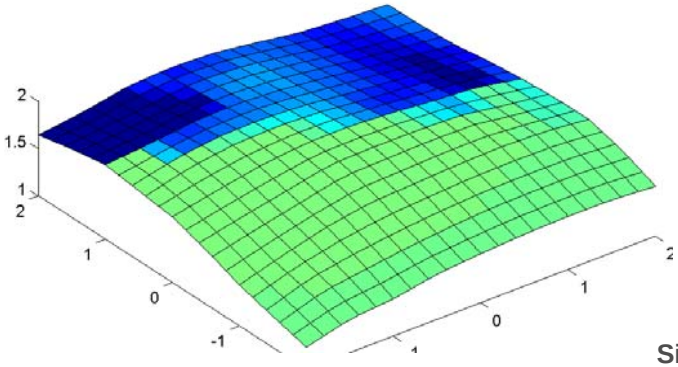


14 days light/14 days Earth visibility cycles at Poles



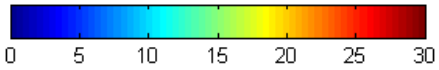
With terrain

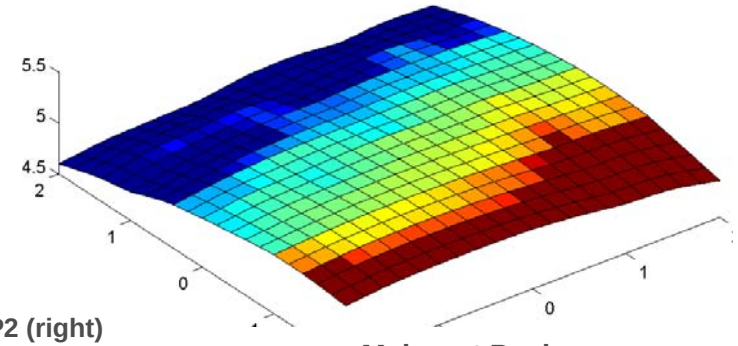
Average duration of Earth visibility



Connecting Ridge

Sites CR1 (left) and MP2 (right)
Colour scale in Days

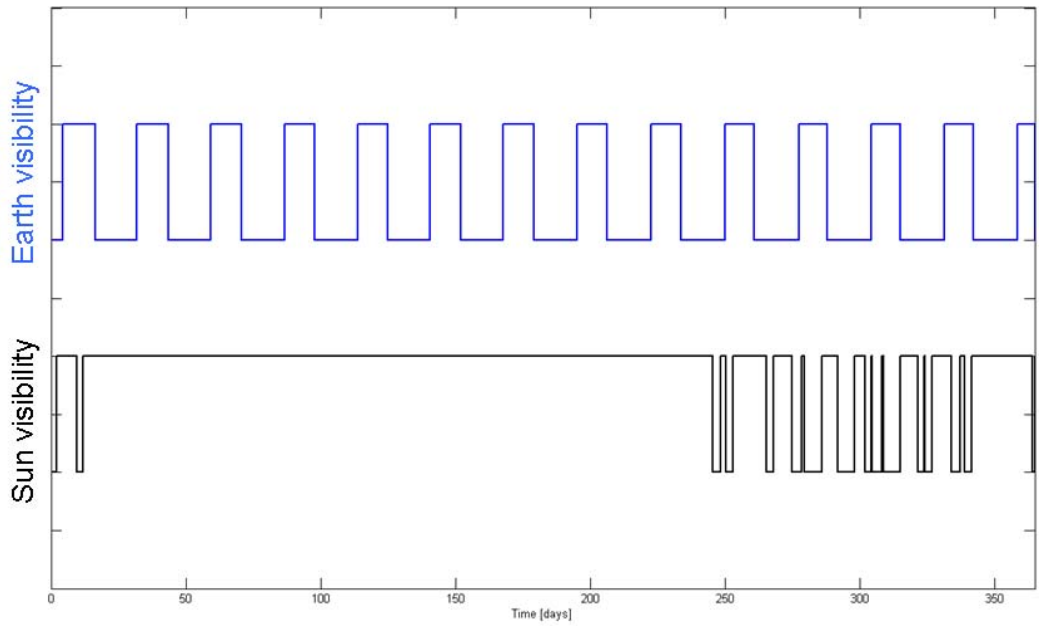




Malapert Peak

Landing opportunity

- Sun and Earth visibility patterns are independent
- Landing prefered while in visibility of both Sun and Earth.



Combined Sun and Earth visibility over 1 year

Illumination and communication conditions contrain the landing opportunity and hence the mission schedule

Conclusions

- Peaks of eternal light do not exist
- 4 ROI were identified with LQCIP of 6 to 10 months (55h survivability)
- Sizes of ROI range from 200 to 800 metre wide

- No direct-to-Earth communication at Lunar South Pole
- From 40% to 100% of Earth visibility
- Earth and Sun visibility are not synchronised

- Better survivability → longer LQCIP
- Higher solar arrays → longer LQCIP and bigger ROI size
- One optimal landing opportunity per year
- Constraints on landing accuracy, TCS, battery mass, …

- Further work shall be conducted during Phase B1 using more accurate data-set and considering the use and validation of more tailored tools.

Thank you !

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Backup slides

Earth-Moon System geometry

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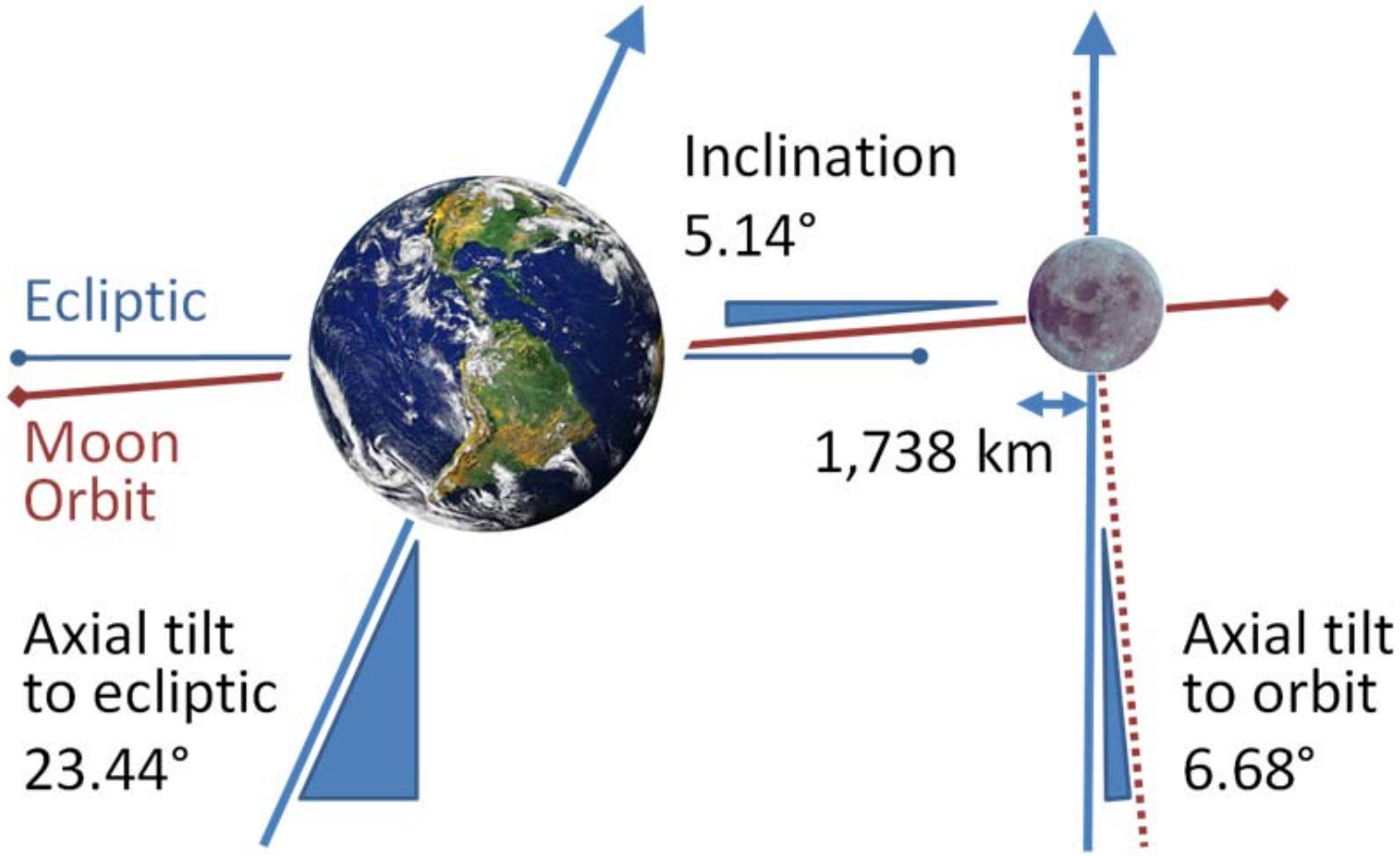

Sun and Earth path in the Lunar South Pole sky

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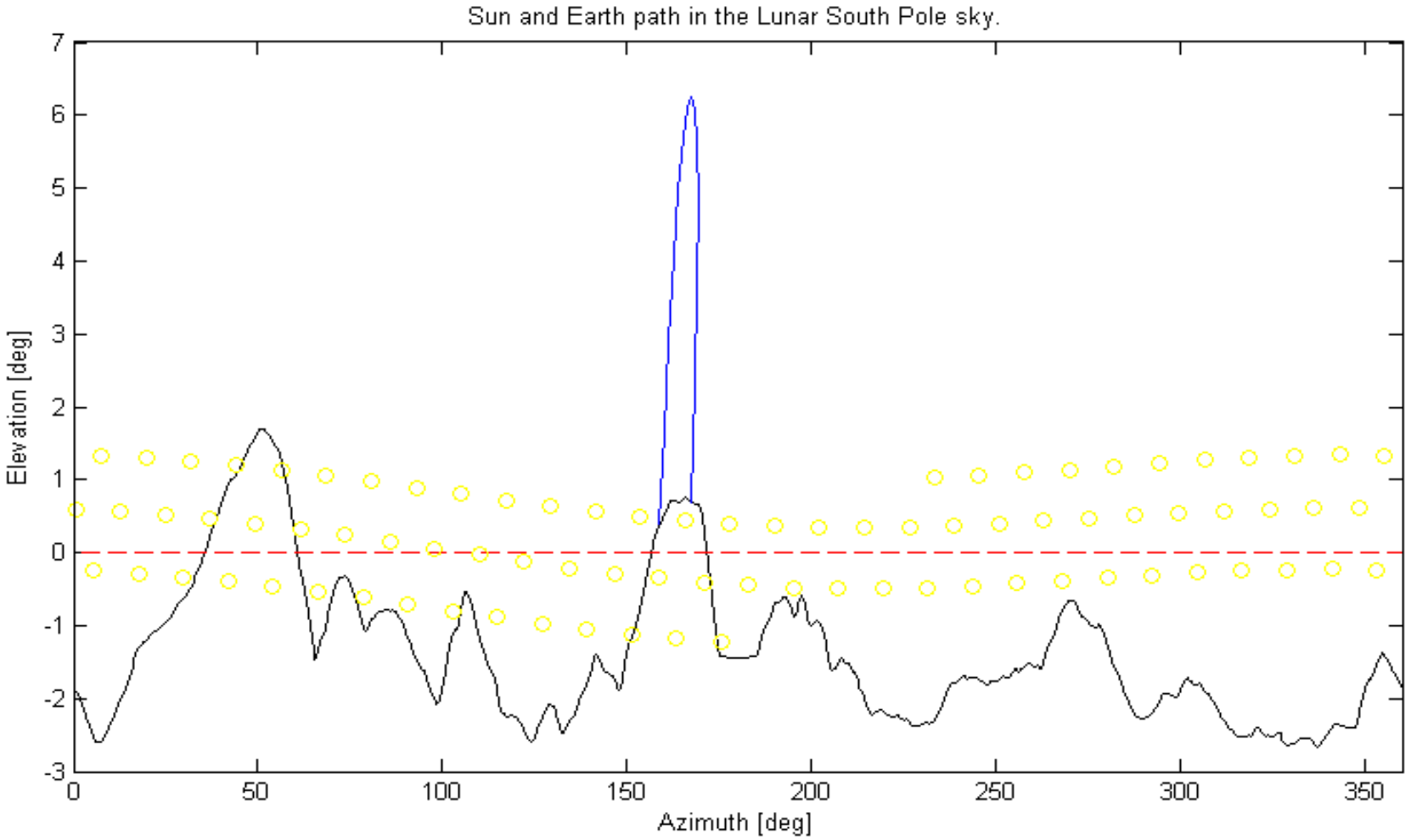
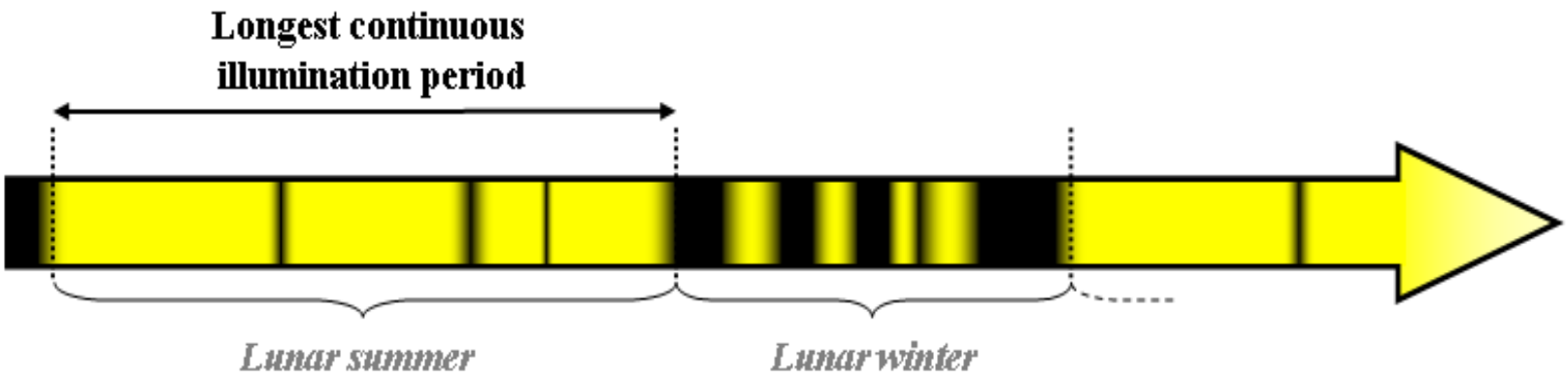
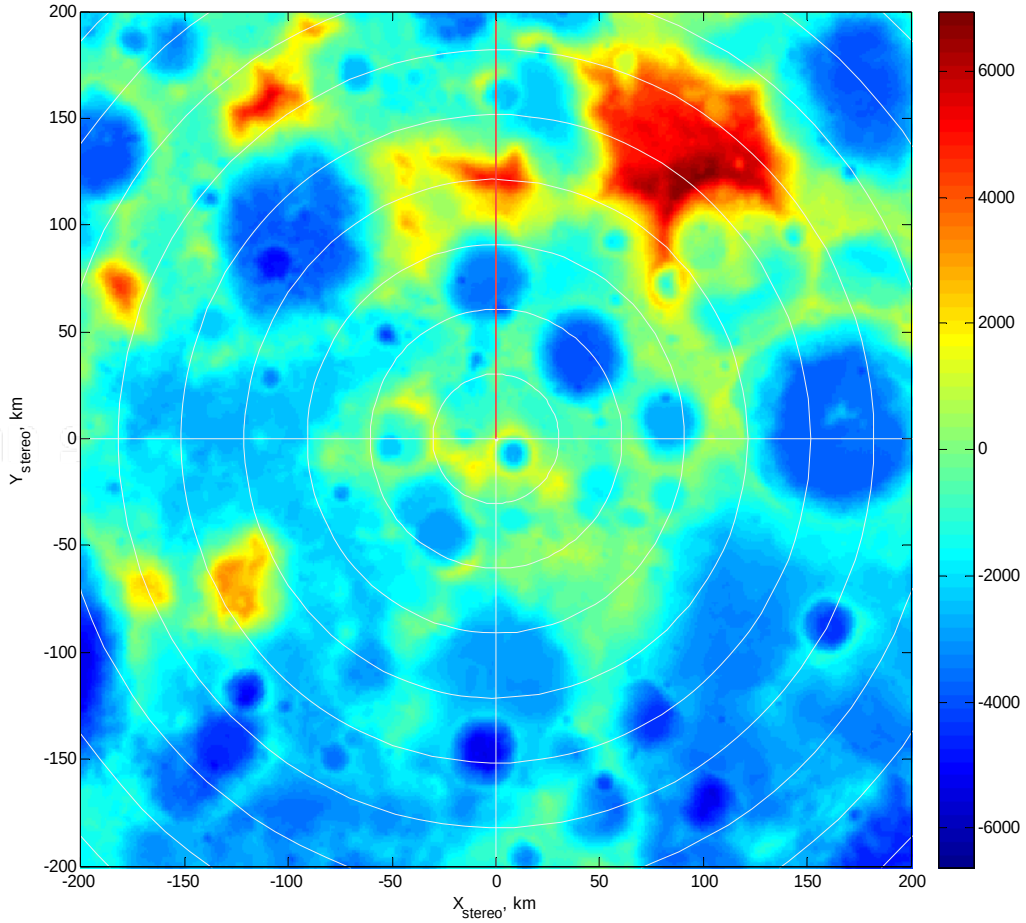


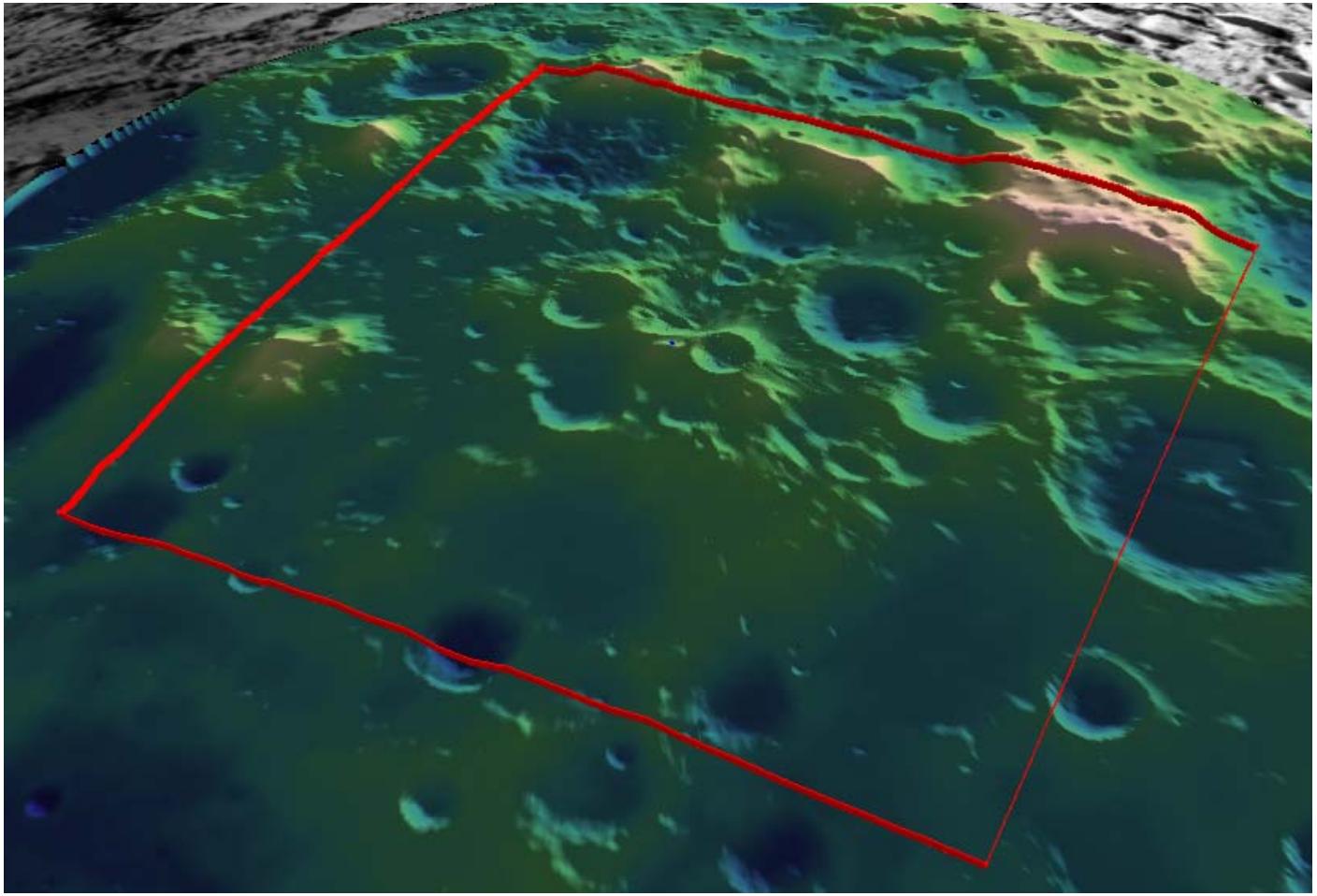
LQCIP


Longest continuous
illumination period
Lunar summer
Lunar winter

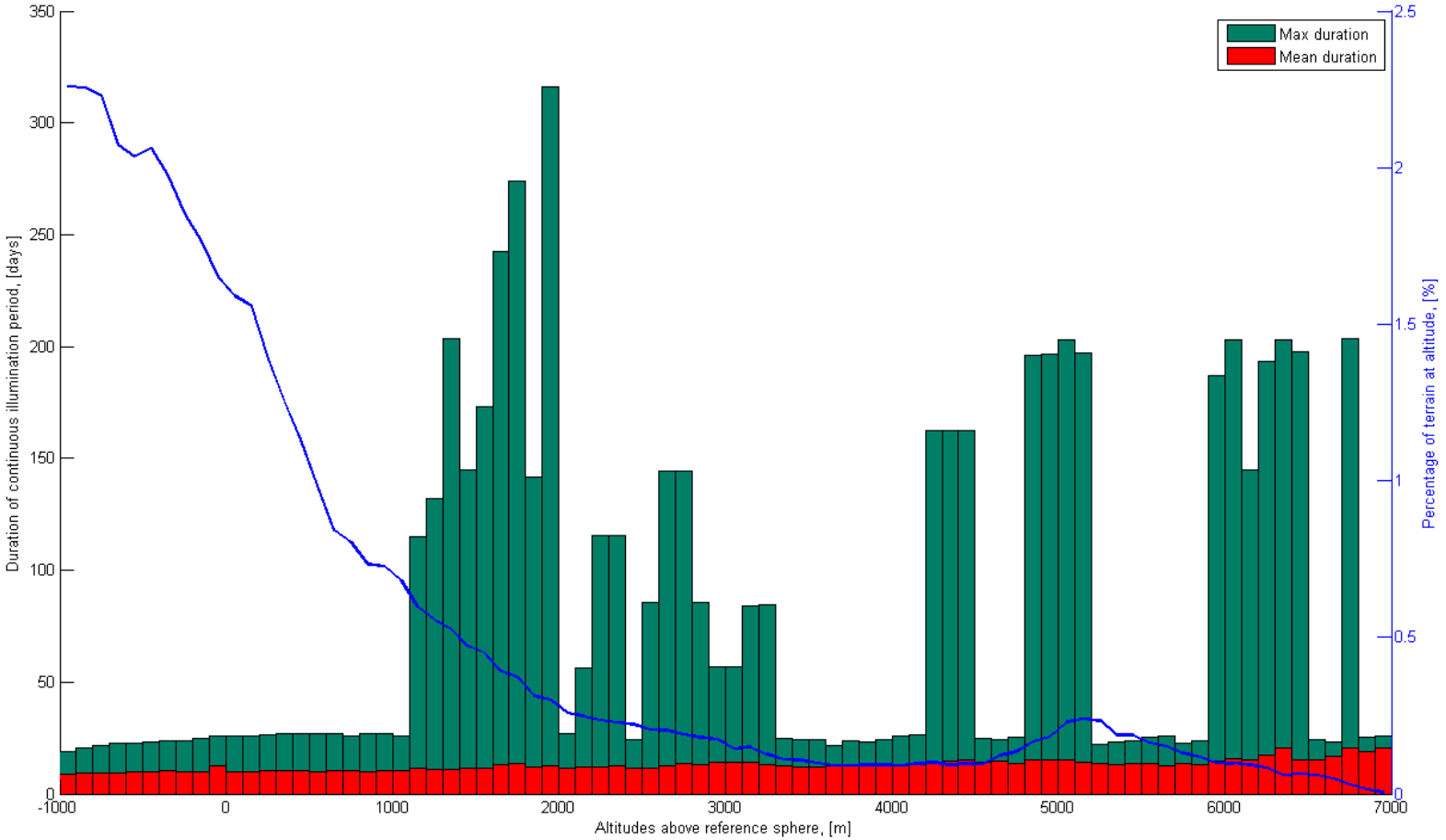
Lunar South Pole map



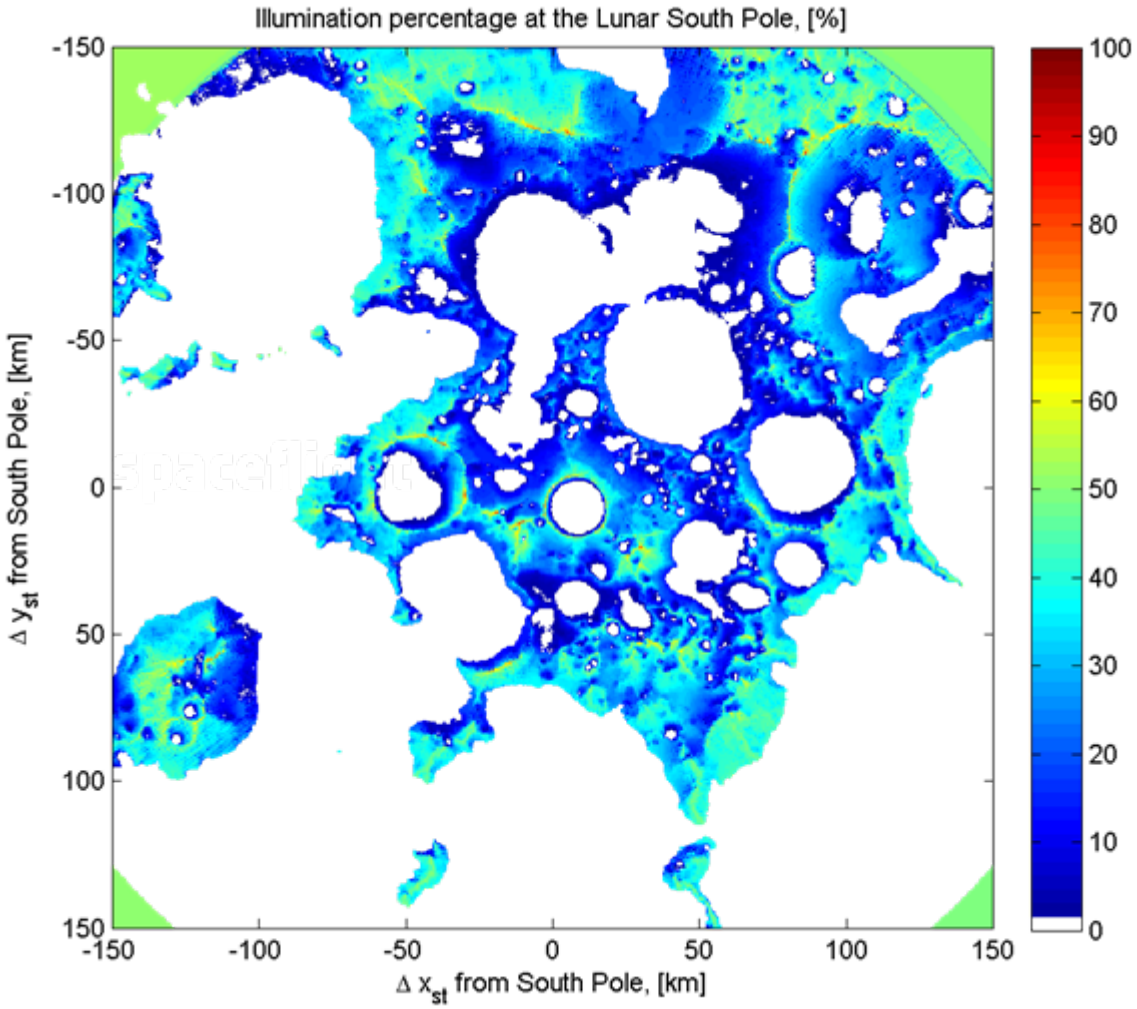
Global analysis zone



Global analysis statistics



Percentages of Illumination



Lunar South Pole feature names

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