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A Next Generation Lunar Orbiter

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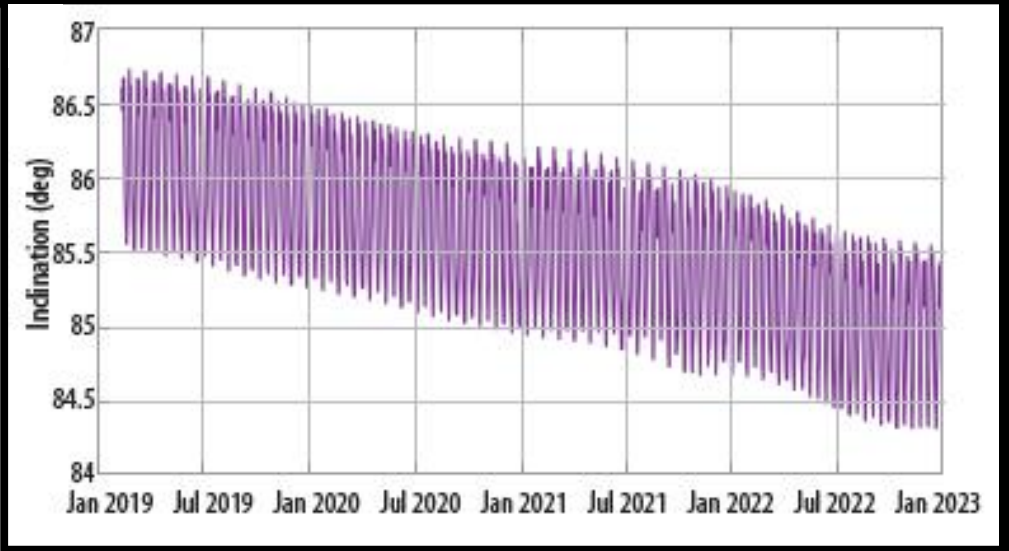
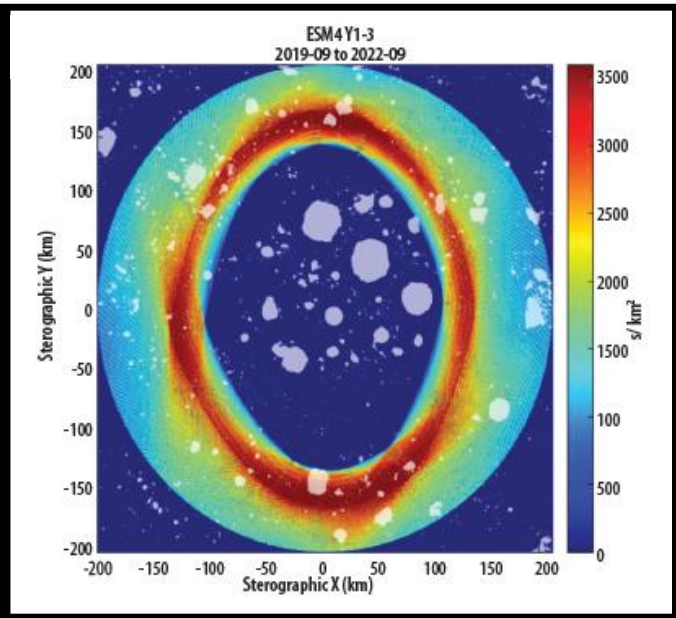
LUNAR ORBITER
THE NEXT GENERATION

The Lunar Reconnaissance Orbiter has revolutionized our view of the Moon. It is also an aging asset with a limited lifetime.

- LRO and international orbiters have revealed that the Moon is more geophysically and geochemically complex than we knew a decade ago.
- The Moon's composition and volatile inventory are heterogeneous on multiple scales. Our understanding is limited by spatial resolution.
- LRO's coverage of the poles is degrading as its orbital inclination decreases.

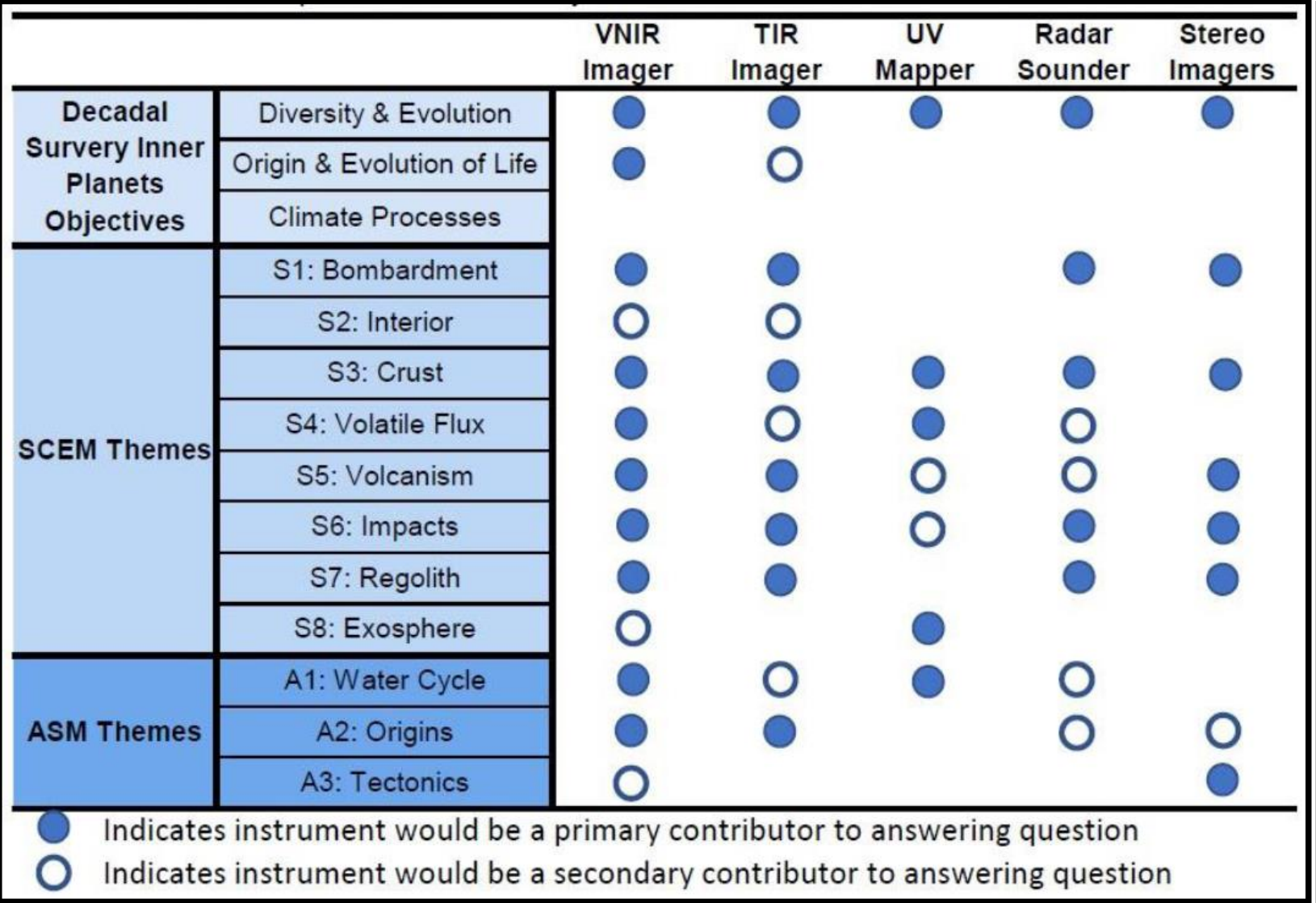




A Next Generation Lunar Orbiter offers high spatial and temporal resolution to address complexity of the lunar surface and interior.

- A sustained program of lunar science and exploration requires advanced instruments that provide global coverage at high spatial and temporal resolution, isolate the scale of volatile heterogeneity, and search below the surface.
- NASA should consider the need for a long-term orbital asset to support Artemis south polar operations.
- Human activity at the south pole will cause changes on the lunar surface. NASA should place a high priority on monitoring human activity and resulting changes in the lunar environment.

NGLO will be a critical tool to address major outstanding questions in lunar science.



		VNIR Imager	TIR Imager	UV Mapper	Radar Sounder	Stereo Imagers
Decadal Survery Inner Planets Objectives	Diversity & Evolution	●	●	●	●	●
	Origin & Evolution of Life	●	○			
	Climate Processes					
SCEM Themes	S1: Bombardment	●	●		●	●
	S2: Interior	○	○			
	S3: Crust	●	●	●	●	●
	S4: Volatile Flux	●	○	●	○	
	S5: Volcanism	●	●	○	○	●
	S6: Impacts	●	●	○	●	●
	S7: Regolith	●	●		●	●
	S8: Exosphere	○		●		
ASM Themes	A1: Water Cycle	●	○	●	○	
	A2: Origins	●	●		○	○
	A3: Tectonics	○				●

● Indicates instrument would be a primary contributor to answering question

○ Indicates instrument would be a secondary contributor to answering question

- Notional payload addresses every SCEM and ASM theme.
- Volatile sources, sinks, and transportation processes key to understanding Moon-space system.
- Volcanic processes and surface materials linked to interior composition and evolution.

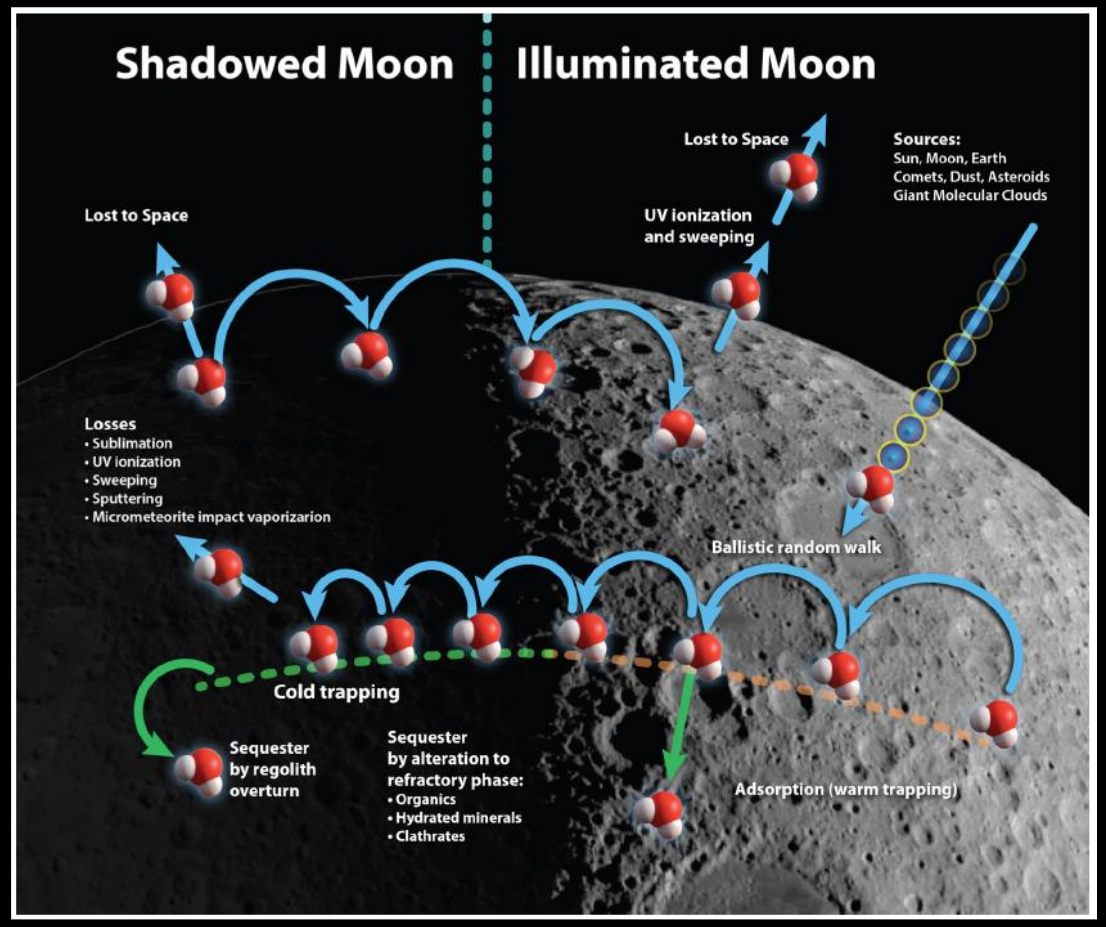
The NGLO notional payload provides unprecedented spatial resolution over a wide wavelength range.

Instrument	Spatial/Spectral Resolution	Data Products	Mass	Power
Hyperspectral TIR Imager	• 10 cm^{-1} spectral sampling • 5 – 17 μm spectral range • 25 m/px spatial resolution	Mineralogy; regolith temperature; rock abundance; thermal inertia; roughness; space weathering	25 kg	15 W
Hyperspectral VNIR Imager	• 7 – 17 nm spectral sampling • 0.3 – 5.1 μm spectral range • 10 m/px spatial resolution	Mineralogy; volatile abundance; space weathering	37 kg	22 W
UV Imaging Spectrograph	• 115 – 315 nm spectral range • 50 m/px spatial resolution	Water ice mapping; exospheric OH, Mg, Fe, Si detection; space weathering	7.7 kg	9 W
P-Band Radar Sounder	• 1 m depth resolution • 4 – 140 m sounding depth • ~100 m along-track resolution	Buried ice, rocks, lava flows, lava tubes; ilmenite content; surface roughness; heat flow (with passive radiometer)	15 kg	67 W
Color Stereo Imager	• 50 cm/pixel spatial resolution • 6 colors from 350 – 1150 nm	High resolution multispectral stereo imagery; digital elevation models	23 kg	22 W

- Advanced payload on a large platform, long-lived orbiter provides stability and high temporal resolution.

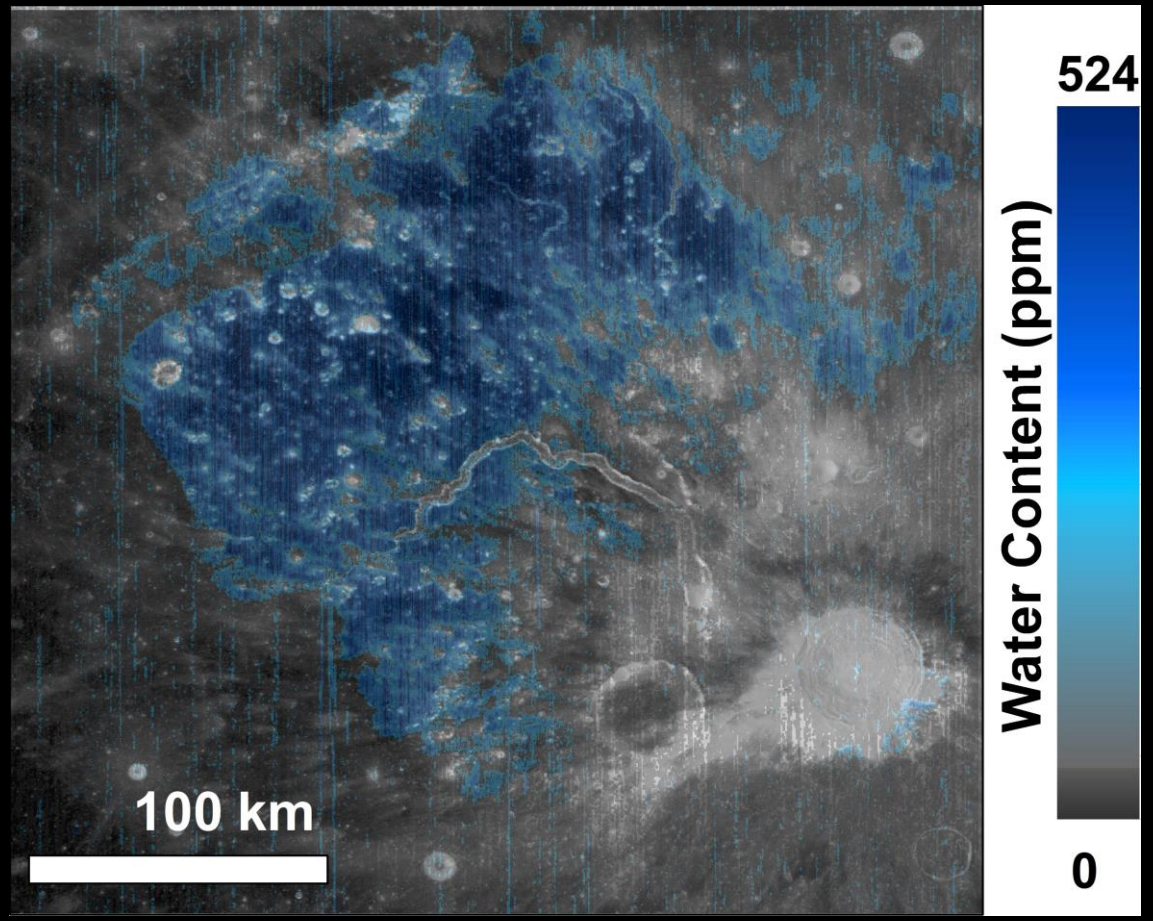
Mapping of volatile sources and sinks is key to understanding the lunar water cycle.

The Sun drives the formation, transportation, and loss of OH and H_2O on the lunar surface.



https://www.kiss.caltech.edu/final_reports.html

Aristarchus Plateau
Indigenous water in pyroclastic glass

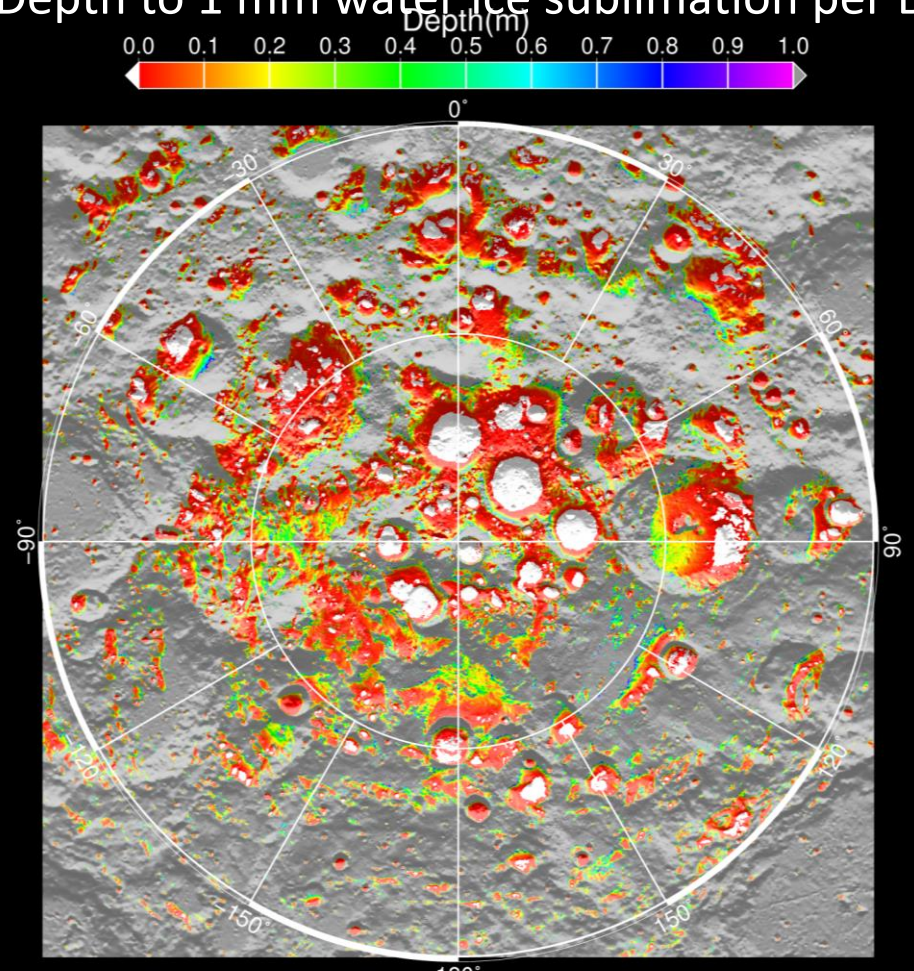


Glotch et al. in review

New measurements will provide high spatial and temporal resolution maps of the lunar water cycle and provide new information about water ice at depth.

South Pole

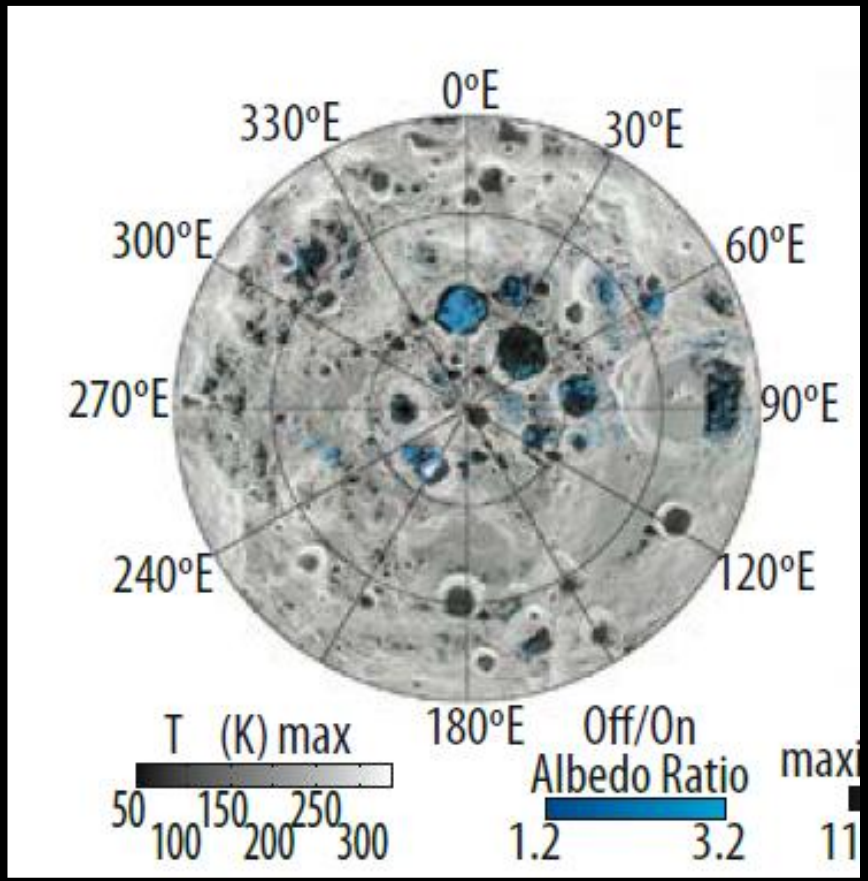
Depth to 1 mm water ice sublimation per BY



https://www.kiss.caltech.edu/final_reports.html

South Pole

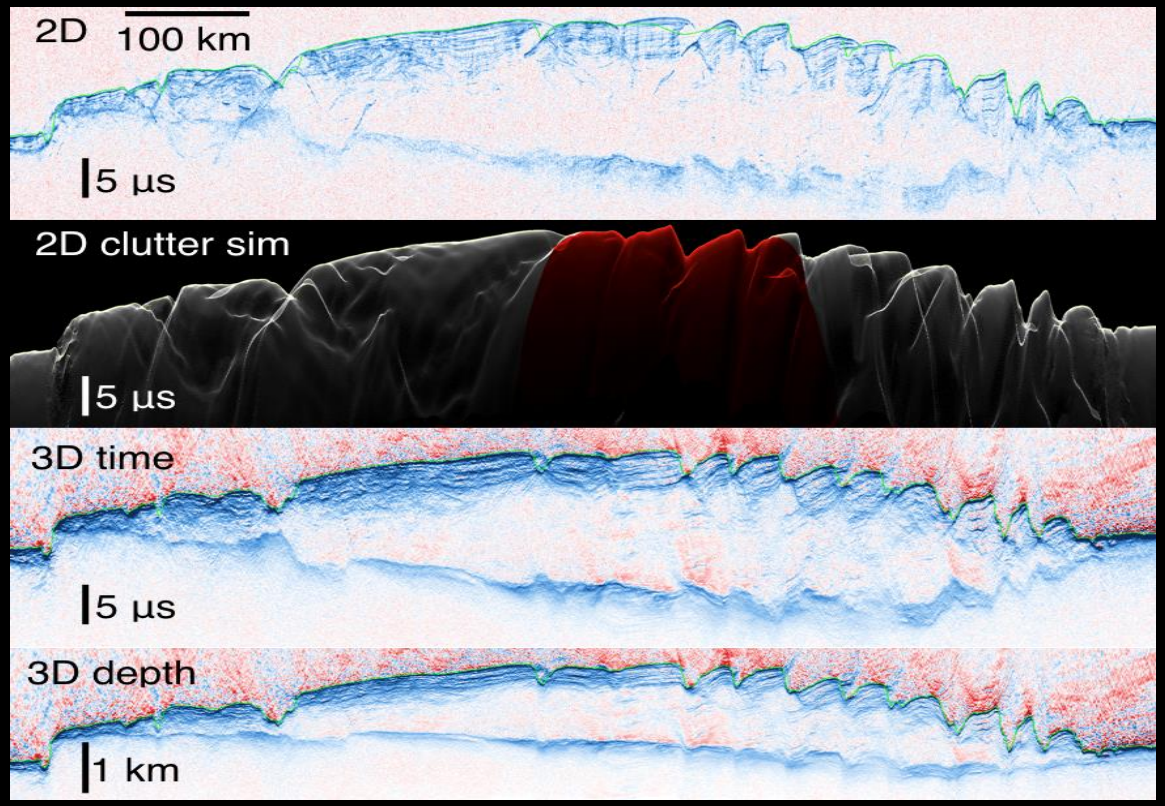
Surface water frost mapped in UV by LAMP



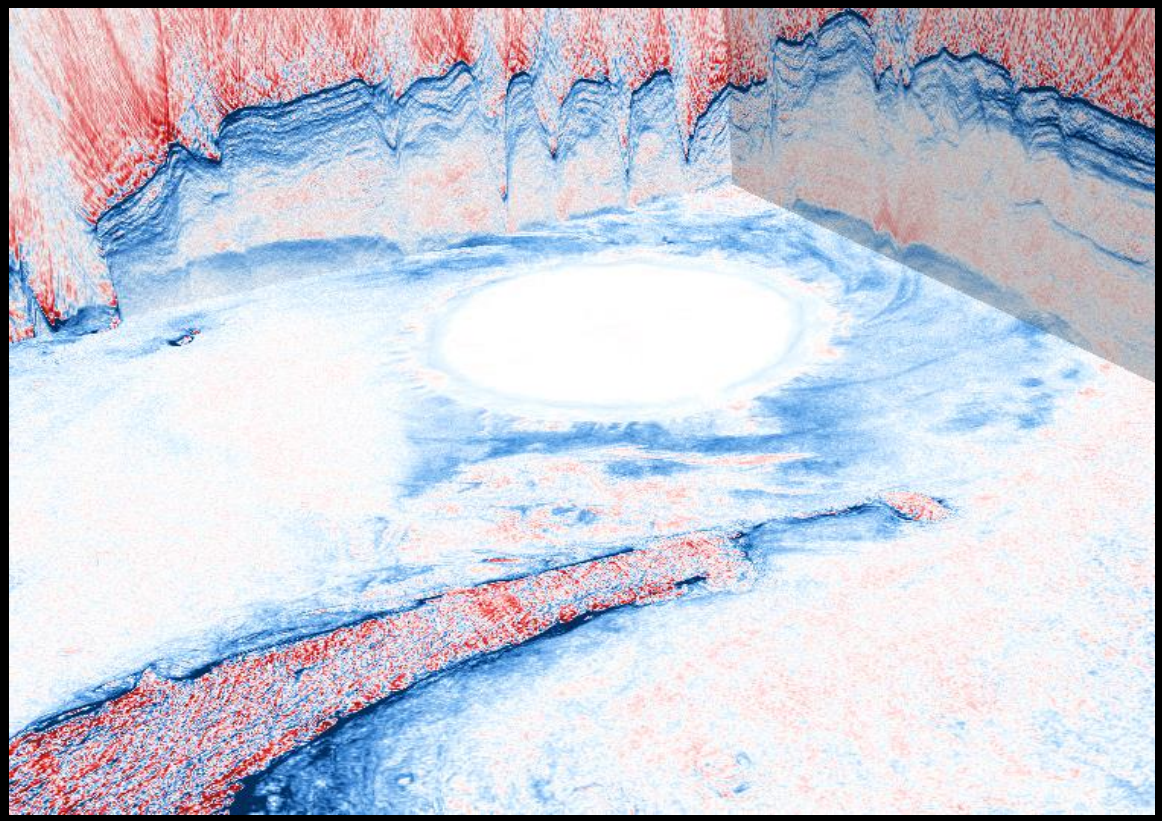
Hayne et al. 2015

High resolution mapping of the lateral distribution of volatiles should be expanded to the third dimension for estimation of available resource volumes.

Mars South Pole
2D radargrams map subsurface interfaces



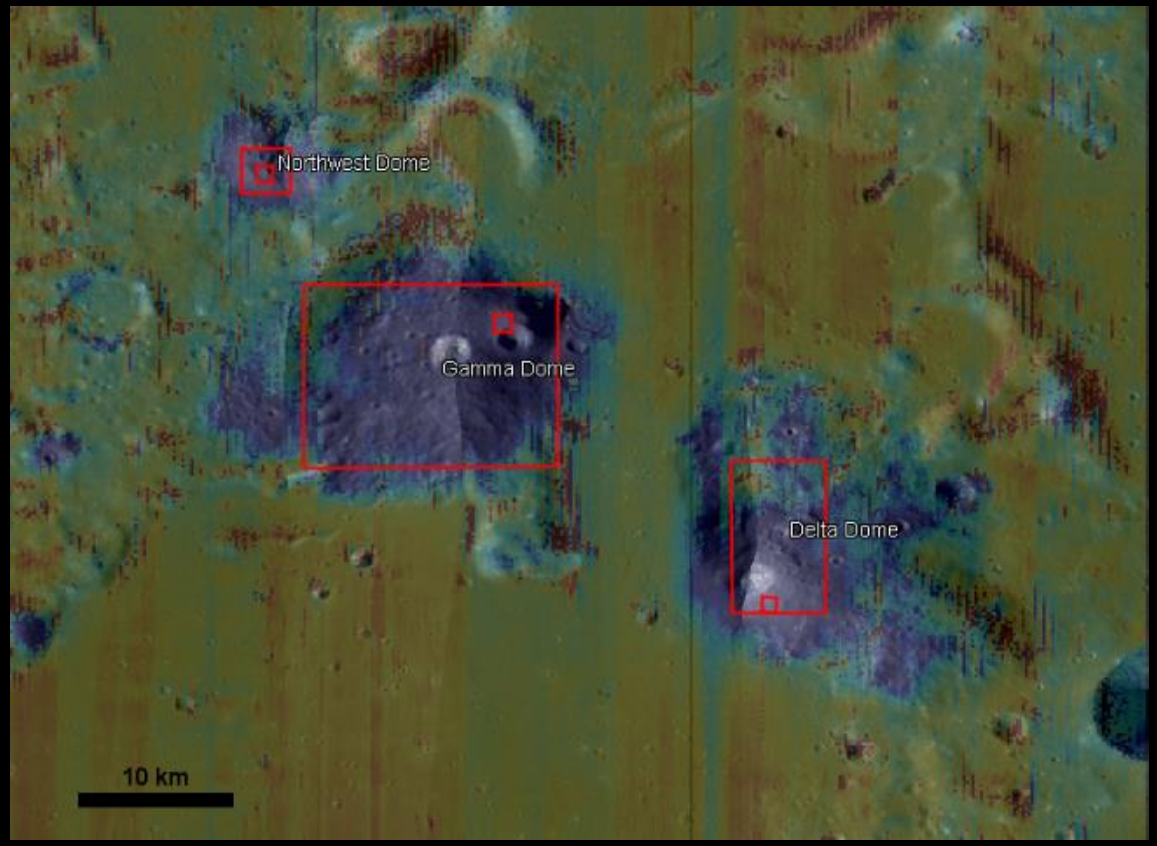
Mars South Pole
3D volumes constructed from multiple passes



Putzig et al. 2016

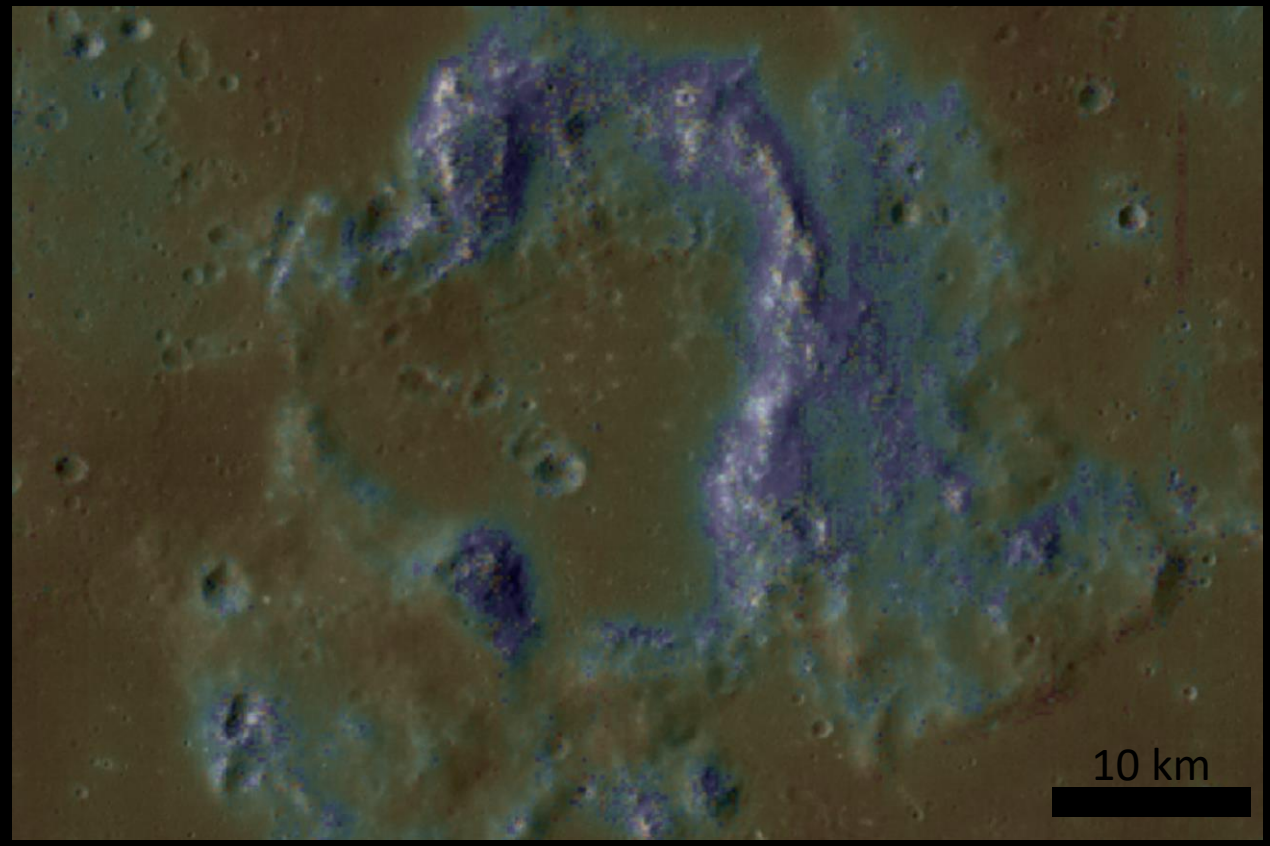
Identification of compositionally extreme surface units provides information about lunar interior composition and evolution and fills a gap in the sample collection.

Gruithuisen Domes
Diviner CF map indicates silicic compositions



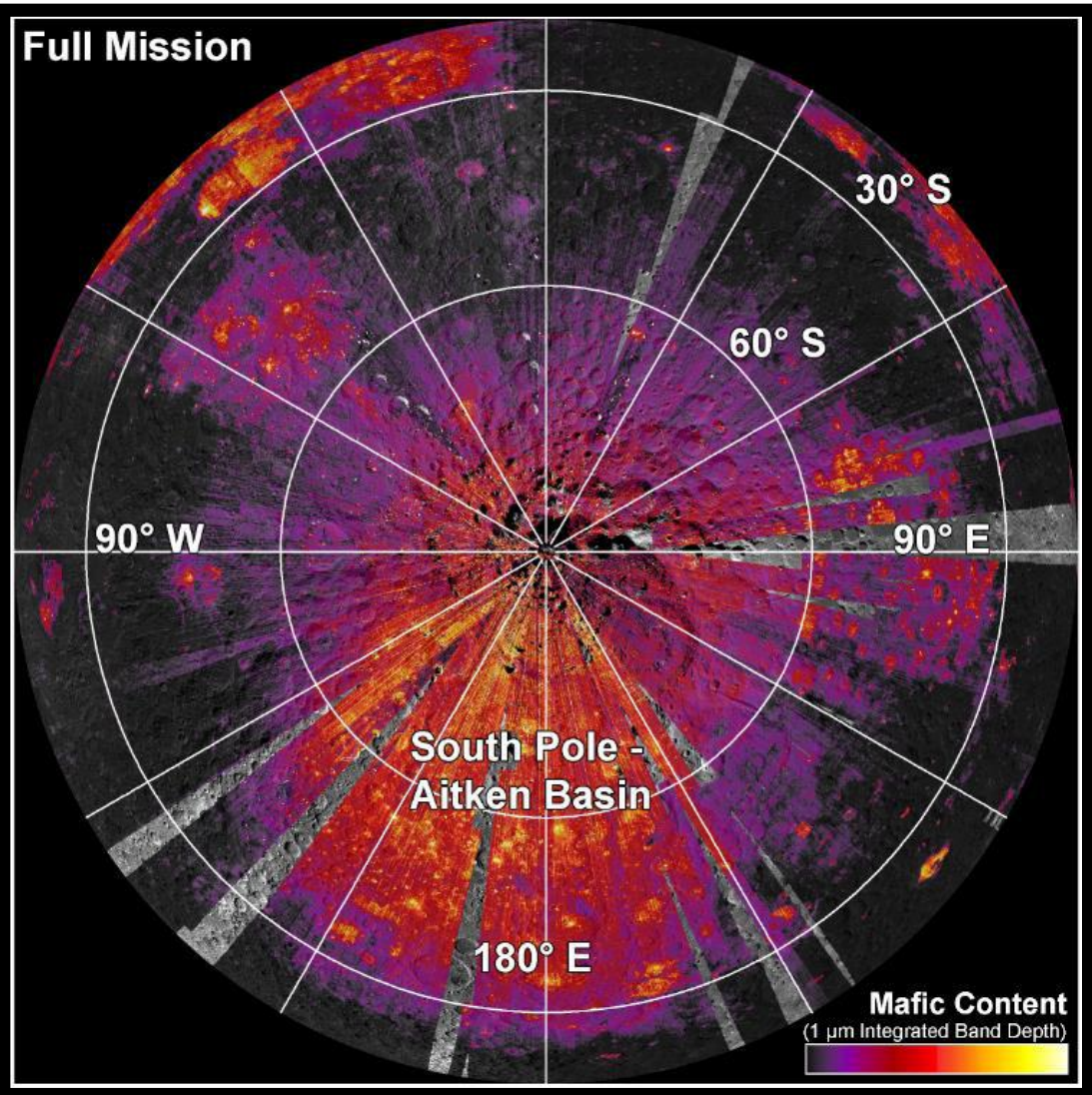
Shirley et al. 2020

Wolf Crater
Potential intermediate composition

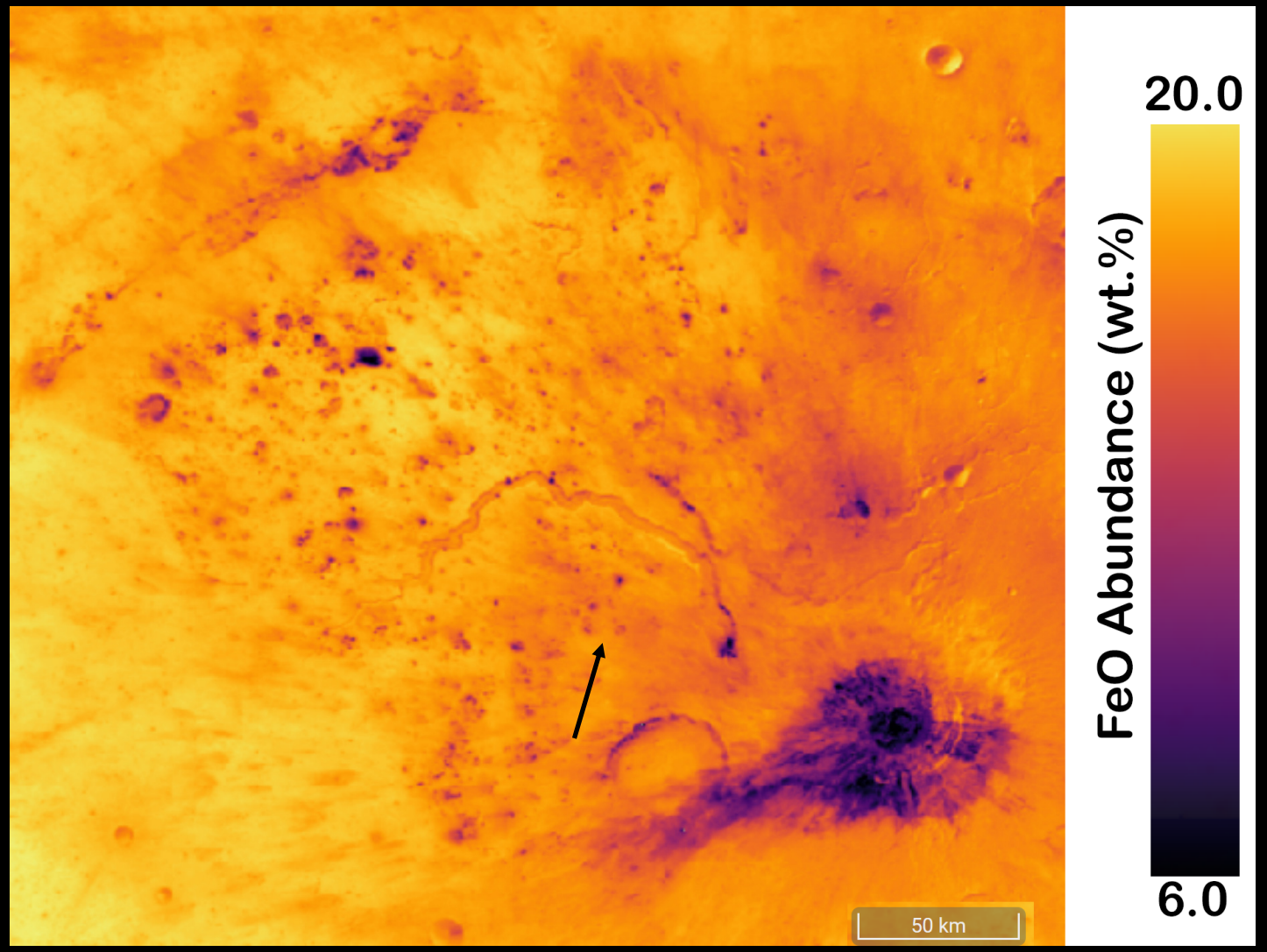


Greenhagen et al. in prep

High resolution compositional maps will provide context for Artemis and CLPS landing sites.



Moriarty et al.



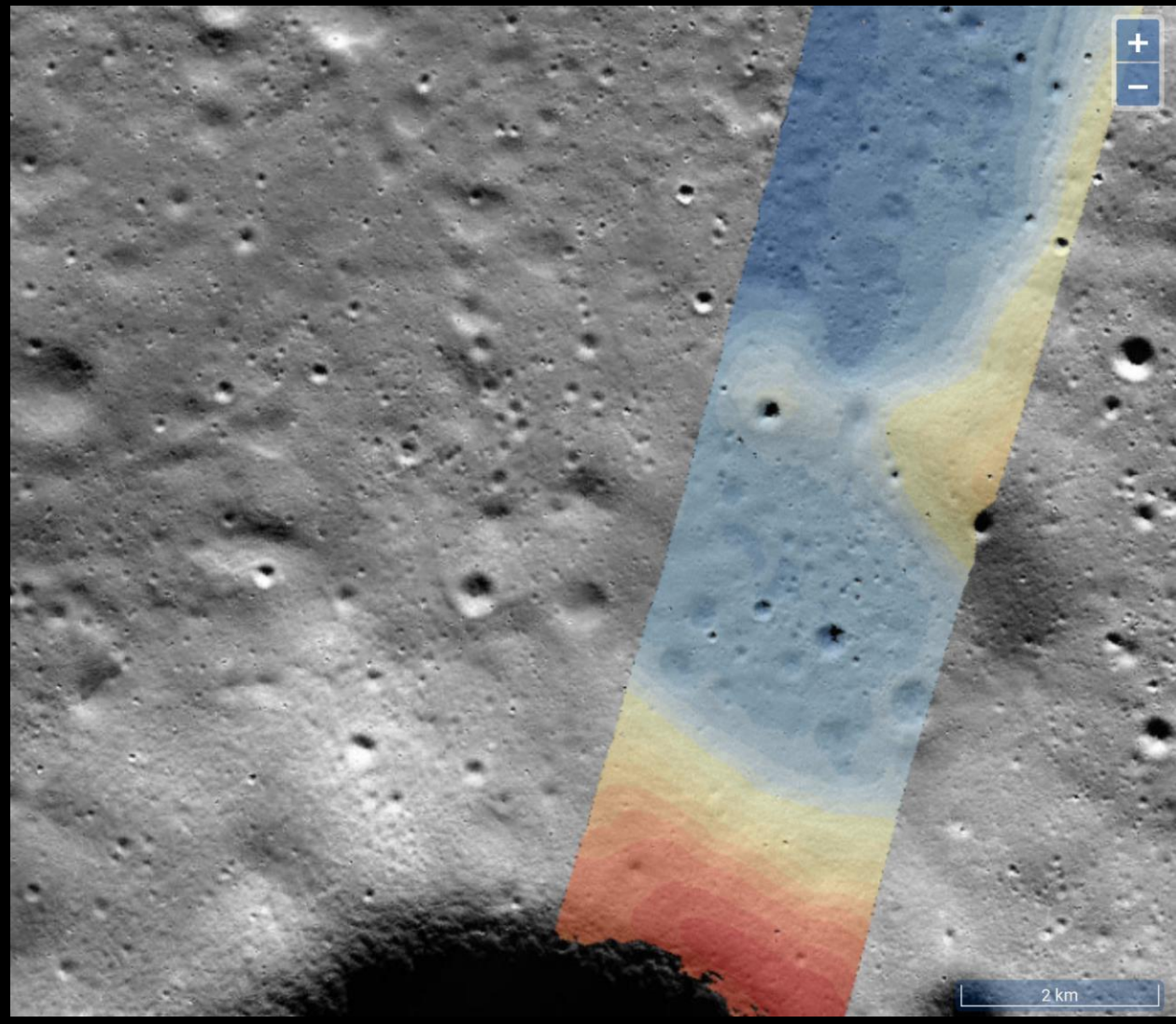
Glotch et al. in review

NGLO will enhance our understanding of numerous other key science and exploration questions.

- The NGLO notional payload (UV/VNIR/TIR) is ideally suited to study *space weathering* at a variety of spatial scales.
- P-band sounding radar would address key questions regarding the constructional history of the lunar mare, including mapping buried subsurface flow margins and searching for lava tubes.
- Radar/ microwave radiometer has the potential to measure geothermal heat flux.
- High resolution stereo imagery provides detailed shapes and slopes of craters, contributing to our understanding of crater degradation processes and rates.

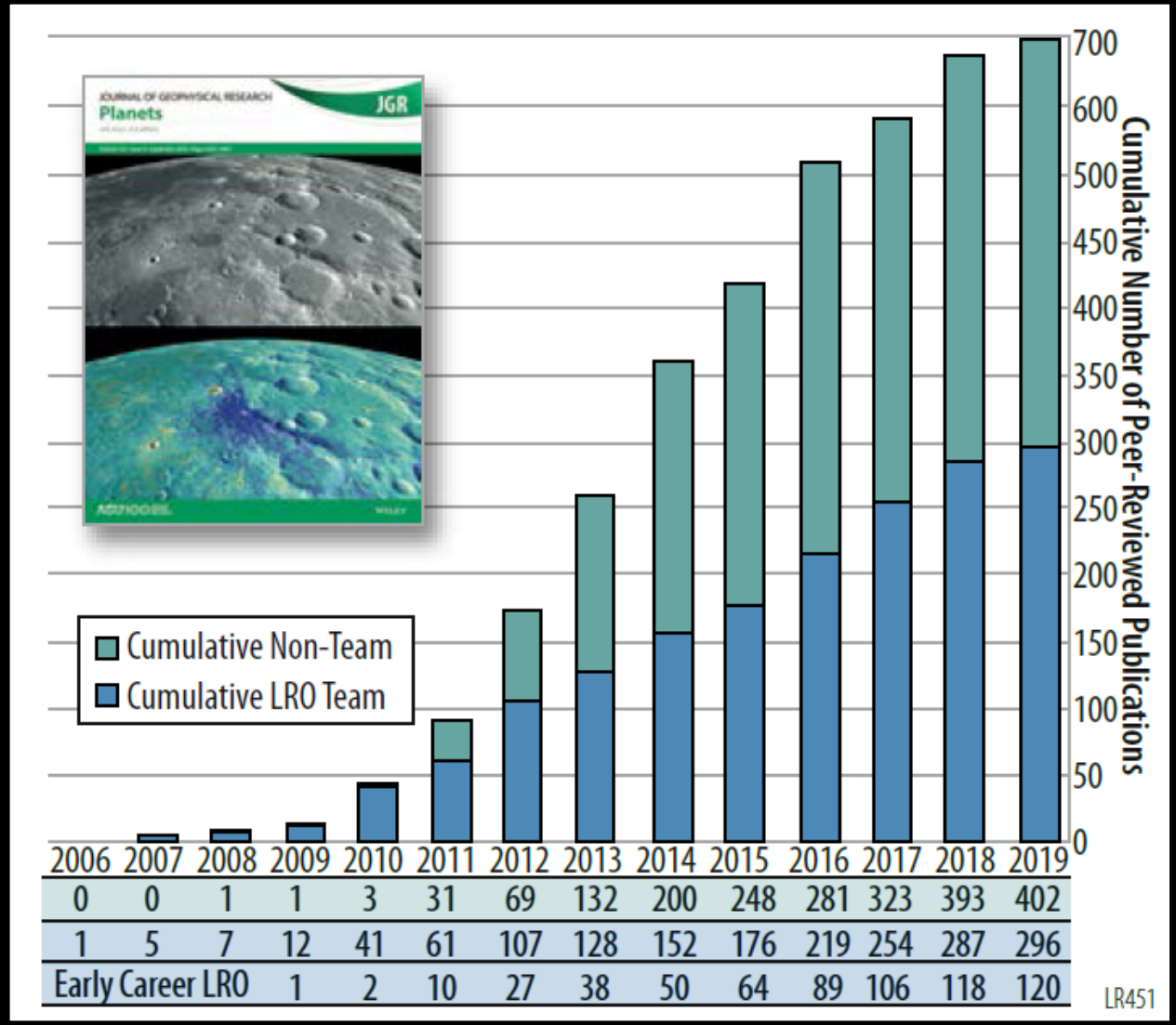
NGLO will support Artemis landing site validation and active surface operations and address open lunar Strategic Knowledge Gaps.

- NGLO will provide color stereo imagery of Artemis landing sites, enhancing safety and science.
- NGLO will support polar operations with high temporal resolution coverage of Artemis landing sites.
- NGLO will address open SKGs related to polar and pyroclastic resource distribution and potential.



A long-term mission will support continue to support the lunar science community and develop the next generation of leaders in lunar science and exploration.

- NGLO will provide color stereo imagery of Artemis landing sites, enhancing safety and science.
- Equity, diversity, and inclusion should be considered at all stages of mission development and execution.
- Establish formal and informal mentoring programs within the team for early career scientists.



NGLO offers several advantages over smallsats and cubesats.

- Orbital maintenance is difficult with small satellites. Maintaining a 50 km orbit for 2 years requires more fuel than is available for a small satellite mission.
- A long duration orbital mission would provide high temporal resolution measurements of the lunar surface over the course of the Sun’s activity cycle.
- Some instruments have large masses and require high power use and data downlink volumes to maximize science return. This prohibits their use on small satellites.
- A large satellite bus provides a stable platform for simultaneous high spatial resolution measurements from multiple instruments.

Summary and Recommendation

- NGLO would address all NRC-SCEM and ASM-SAT science questions.
- NGLO would provide critical support to the Artemis human exploration program.
- NGLO has several advantages over single or multiple small satellite or cube satellite missions (although those are very valuable).
- NGLO would support the lunar community and develop the next generation of lunar science and exploration leaders.
- We recommend that an NGLO concept study be performed to constrain cost and evaluate trades in orbit and instrument options.