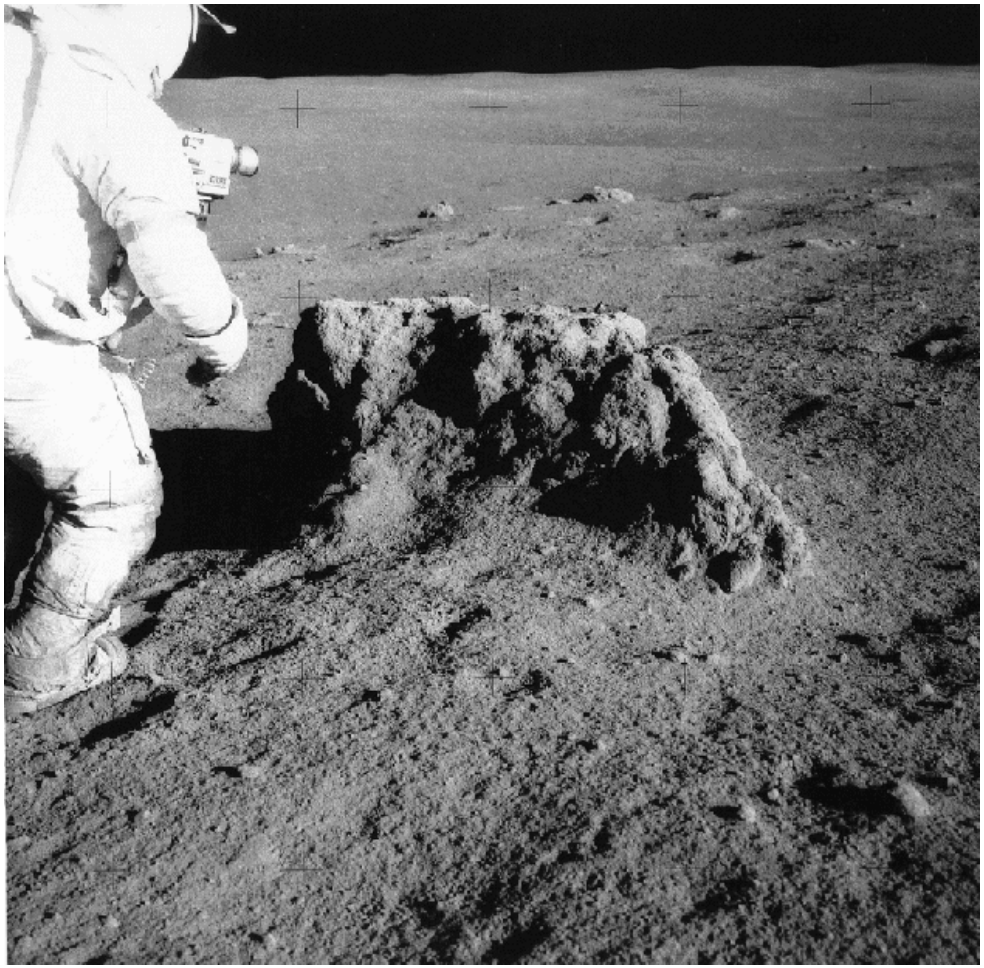
A New Method for Mapping the Rock Size Frequency Distribution on the Moon using Diviner Infrared Measurements

Catherine Elder,[1] P. Hayne,[1] S. Piqueux,[1] J. Bandfield,[2] J.-P. Williams,[3] R. Ghent,[4] D. Paige[3]

[1]Jet Propulsion Laboratory, California Institute of Technology, [2]Space Science Institute, [3]UCLA, [4] University of Toronto

© 2016. All rights reserved.

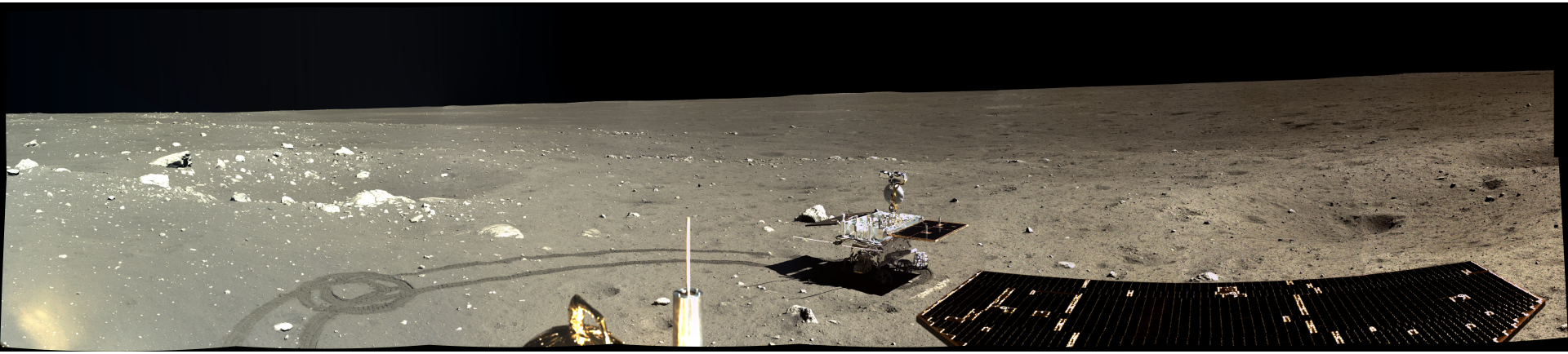
Motivation



Apollo 14 – “Big Rock” 1.5 m wide, 0.6 m high

- Landing site selection (MSL)
  - Mars Science Laboratory required: <0.5% chance of landing on a rock taller than 0.55 m

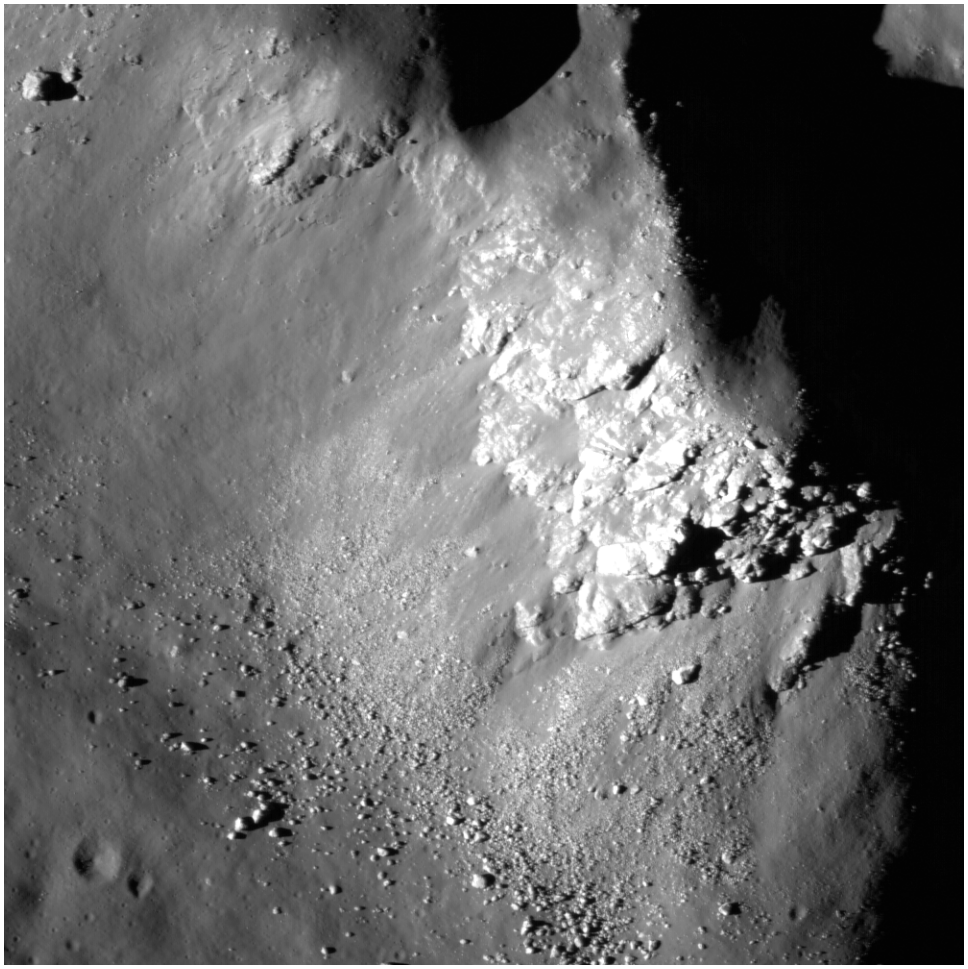
Motivation



Chang'e 3 lander panorama

- Sample acquisition planning

Motivation



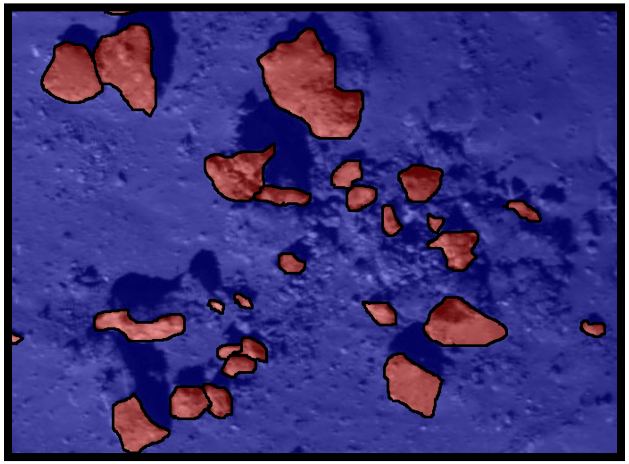
Lunar Reconnaissance Orbiter Camera (LROC) image of the central uplift in Copernicus crater

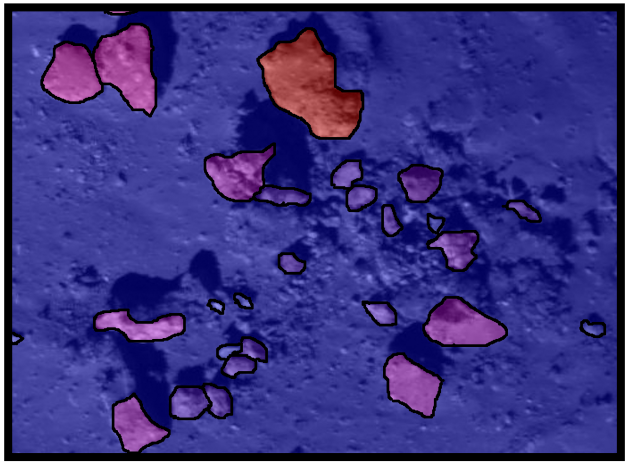
- Understand geologic processes and ages

Previous approaches

1. Counting rocks in visible imagery
   - Requires better than 0.5 m/pixel resolution
2. Multispectral thermal infrared data
   - Rocks have higher thermal inertia than regolith
     → Multiple temperatures within a pixel
   - Warm temperatures have a stronger influence at short wavelengths
   - Can detect subpixel rocks
   - Assume rock temperature from a 1D model
     → Only detect large rocks (>1 m)

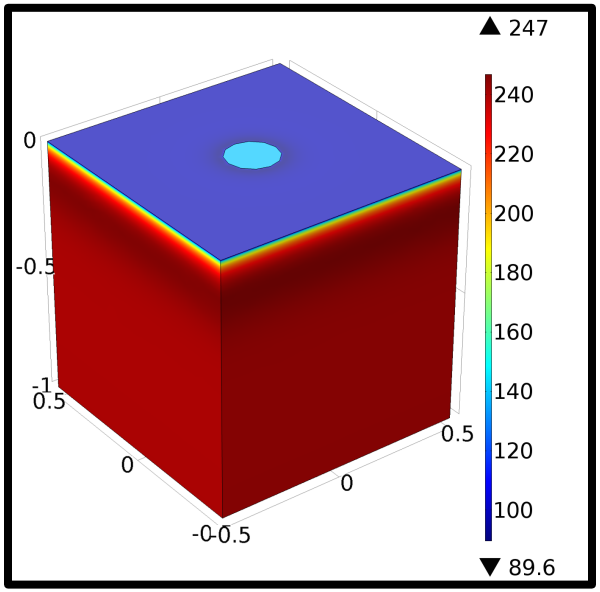
Improved approach

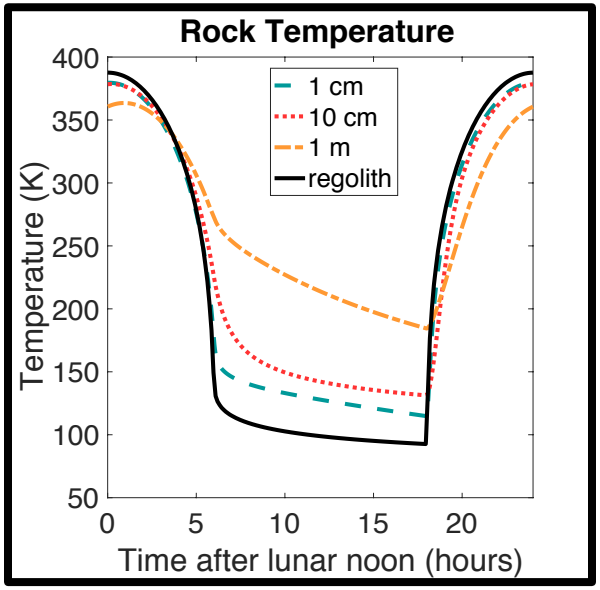




- Real rocks vary in size
  → Different temperatures and cooling rates
- 3D thermal modeling of different sized rocks allows the detection of smaller rocks

3D COMSOL modeling



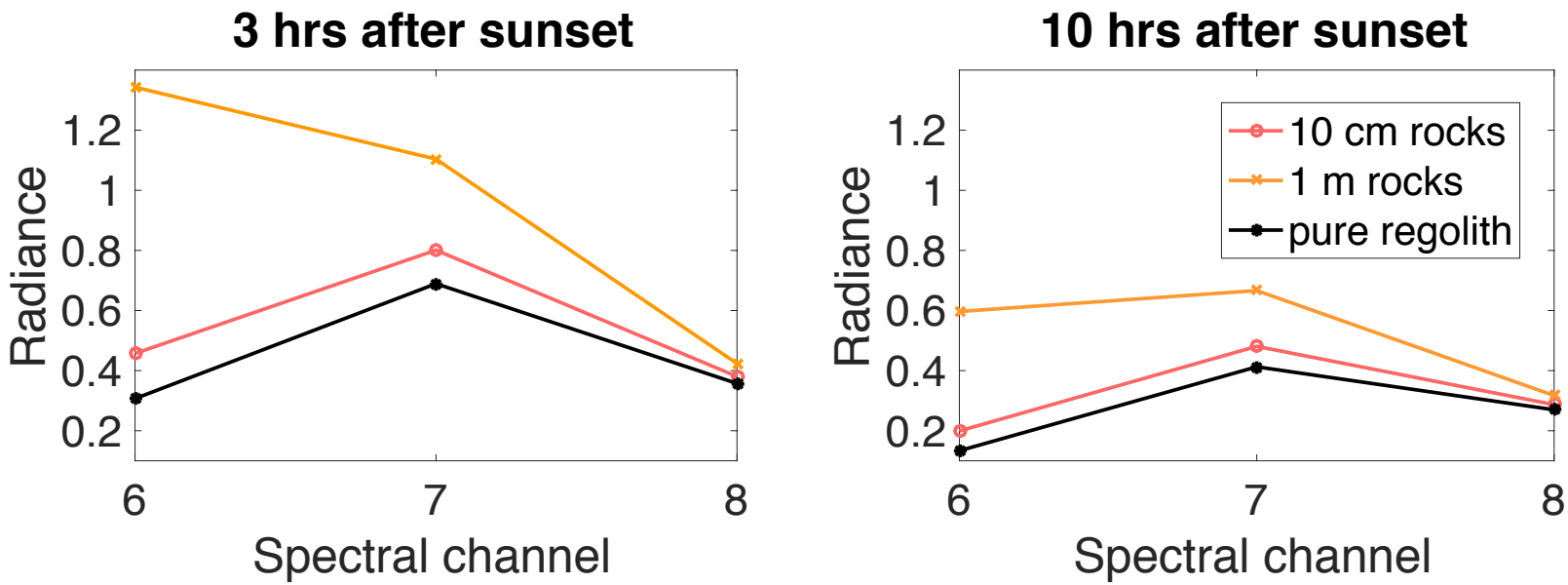


- COMSOL Multiphysics – finite element commercial software
- Half hemisphere of rock embedded in regolith, flat surface
- Different sizes and latitudes

Observations

- Data from the Lunar Reconnaissance Orbiter (LRO) Diviner radiometer
- 9 spectral channels 0.3 to 400 microns (we use 3 channels from 13-100 microns)
- Global coverage including diurnal variability

Model radiance



- Model of expected radiance for 10% rock coverage by 10 cm rocks and 1 m rocks compared to no rocks

Size Frequency Distribution

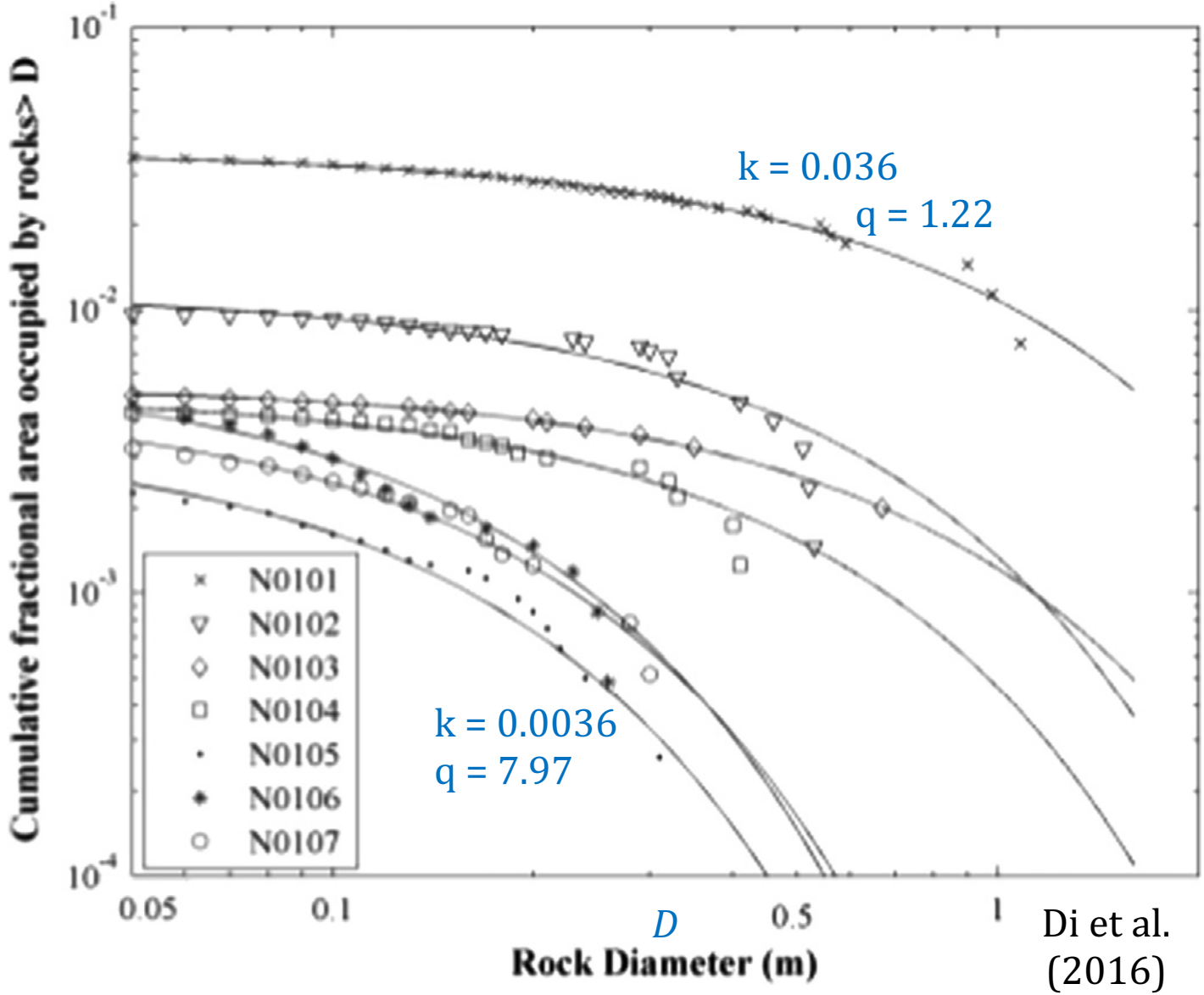
- An exponential function is a good fit to rock distributions on the Earth and Mars, related to fracture theory (Golombek and Rapp, 1997)

$$F(D) = ke^{-qD}$$

F	cumulative fractional area covered by rocks of size D or larger
k	total fractional area covered by rocks
q	governs rate of drop-off at large rock sizes

Chang'e 3 site

$$F(D) = ke^{-qD}$$



High q:
Not many
large rocks

Di et al.
(2016)

Size Frequency Distribution

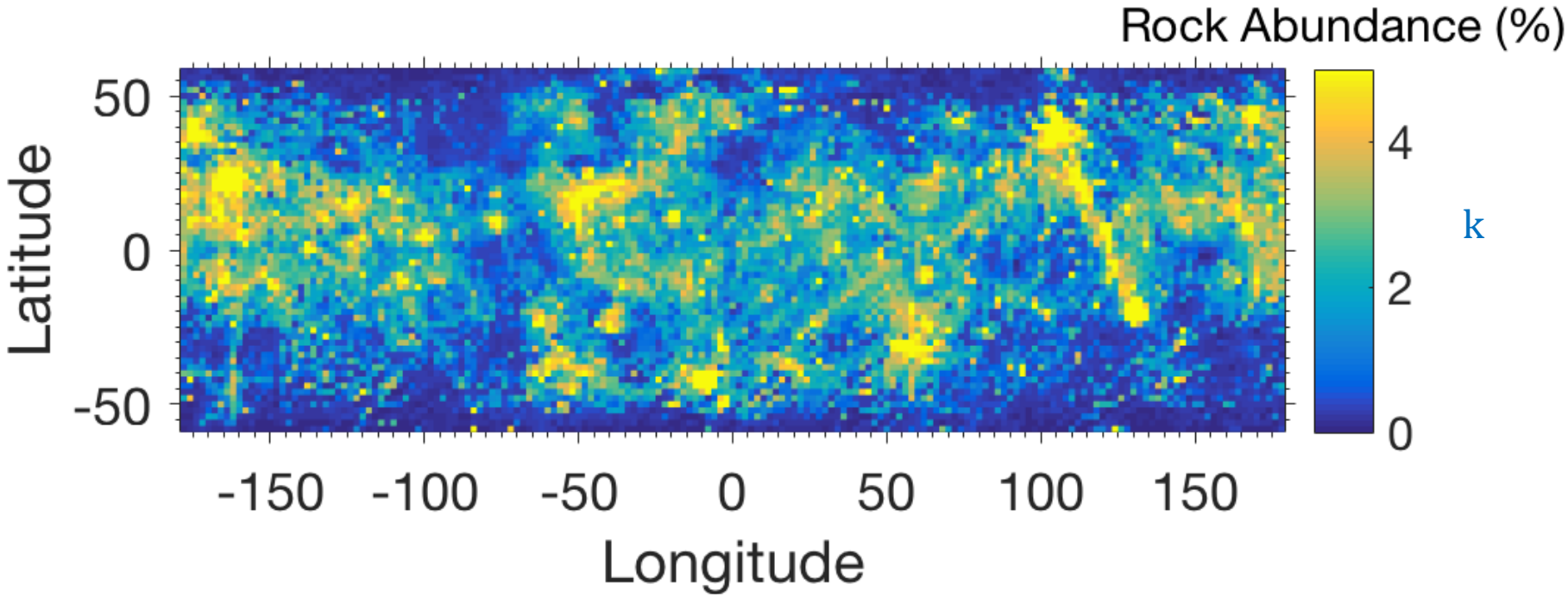
- Rock size frequency distribution and model temperatures → model radiance
- Compare to Diviner radiance at multiple times and channels 6, 7, 8

$$F(D) = ke^{-qD}$$

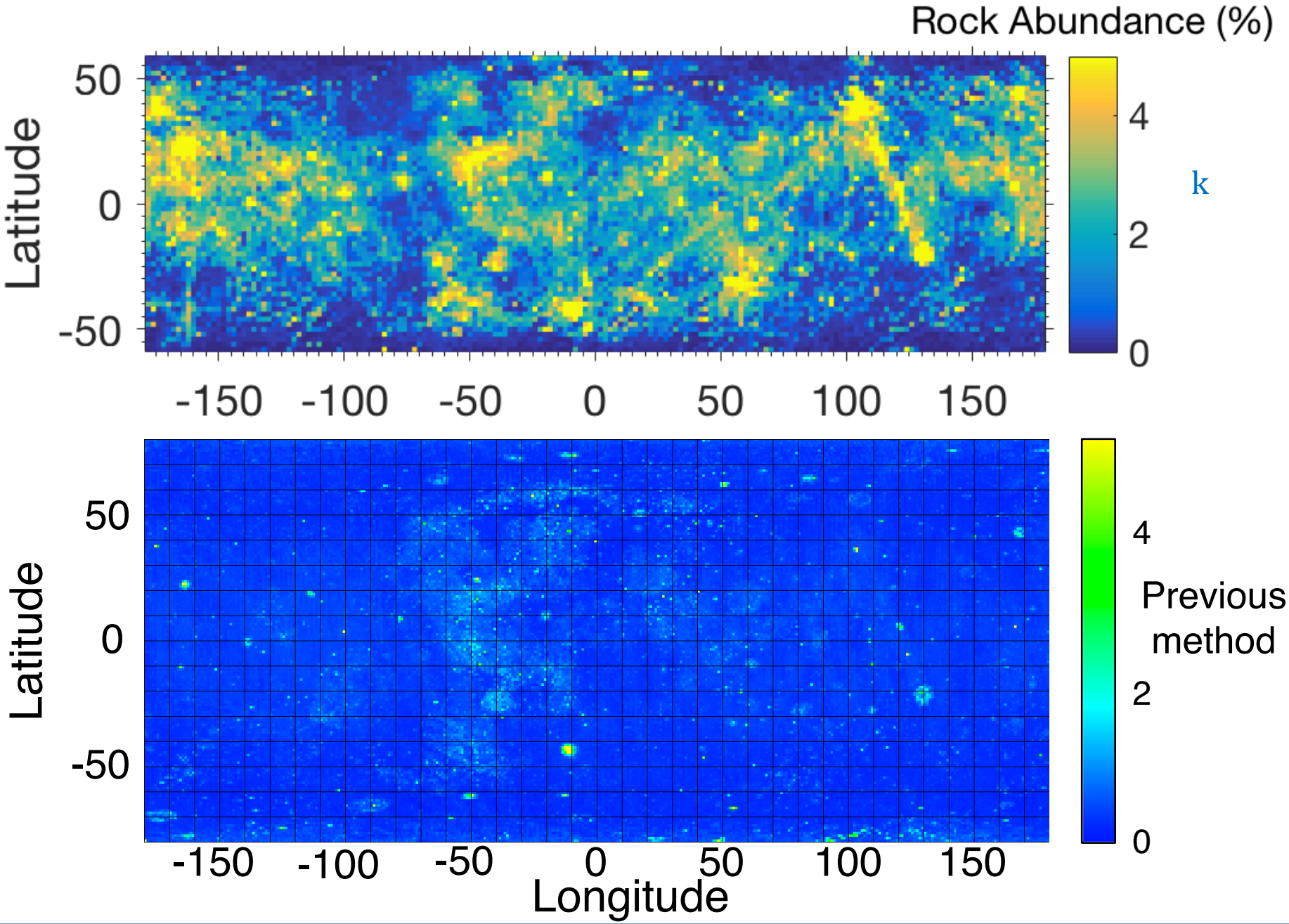
F cumulative fractional area covered by rocks of size D or larger

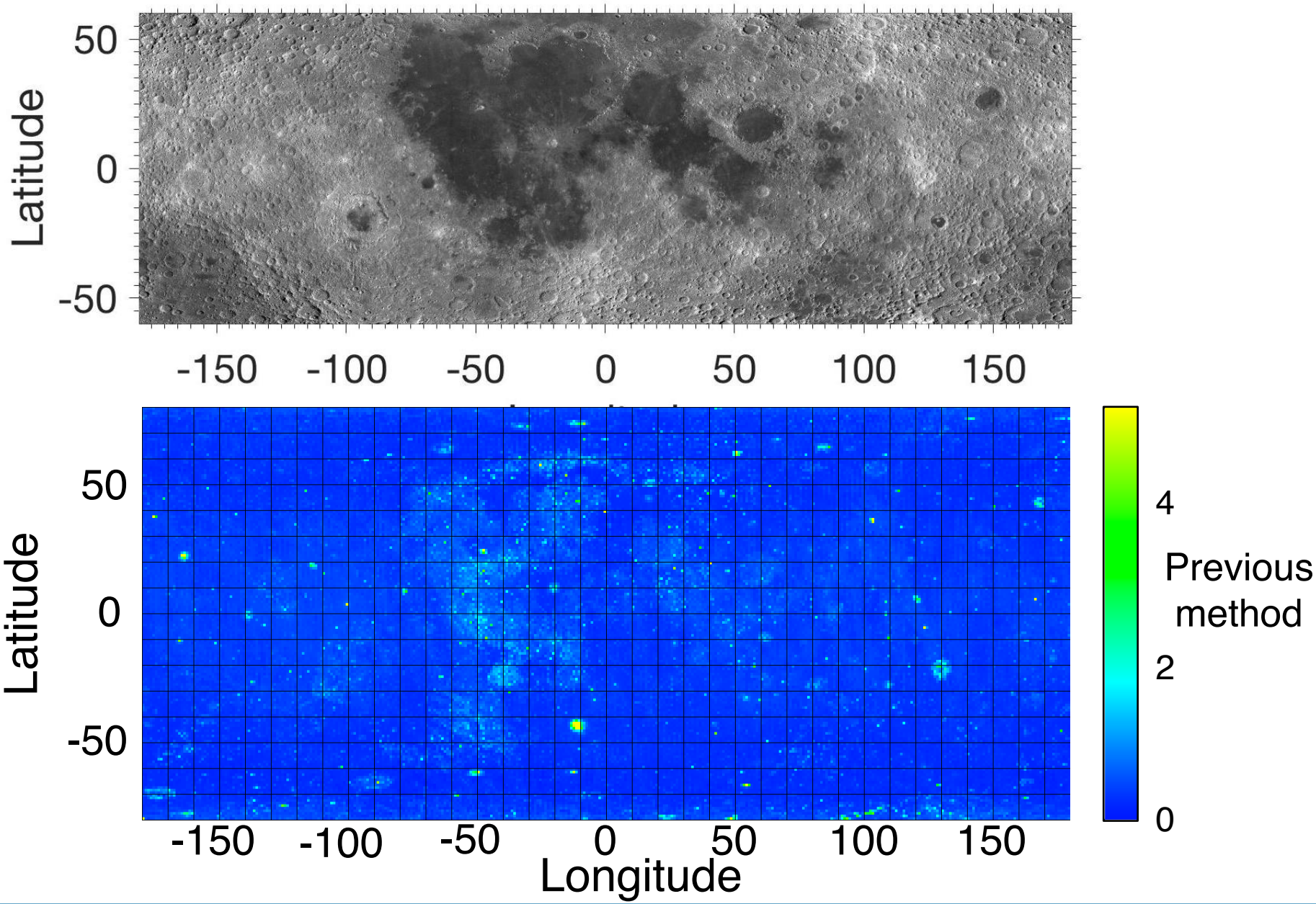
k total fractional area covered by rocks

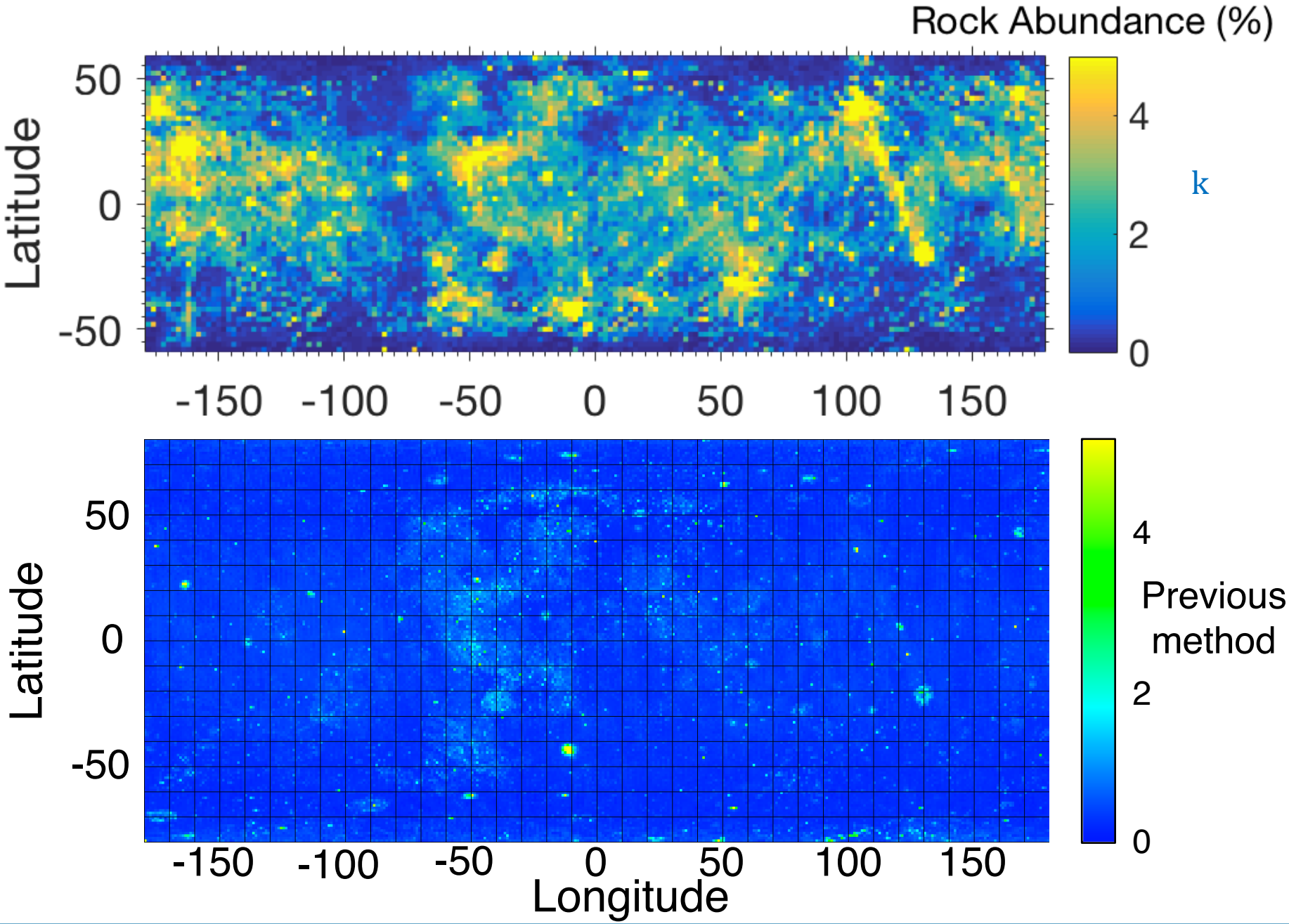
q governs rate of drop-off at large rock sizes

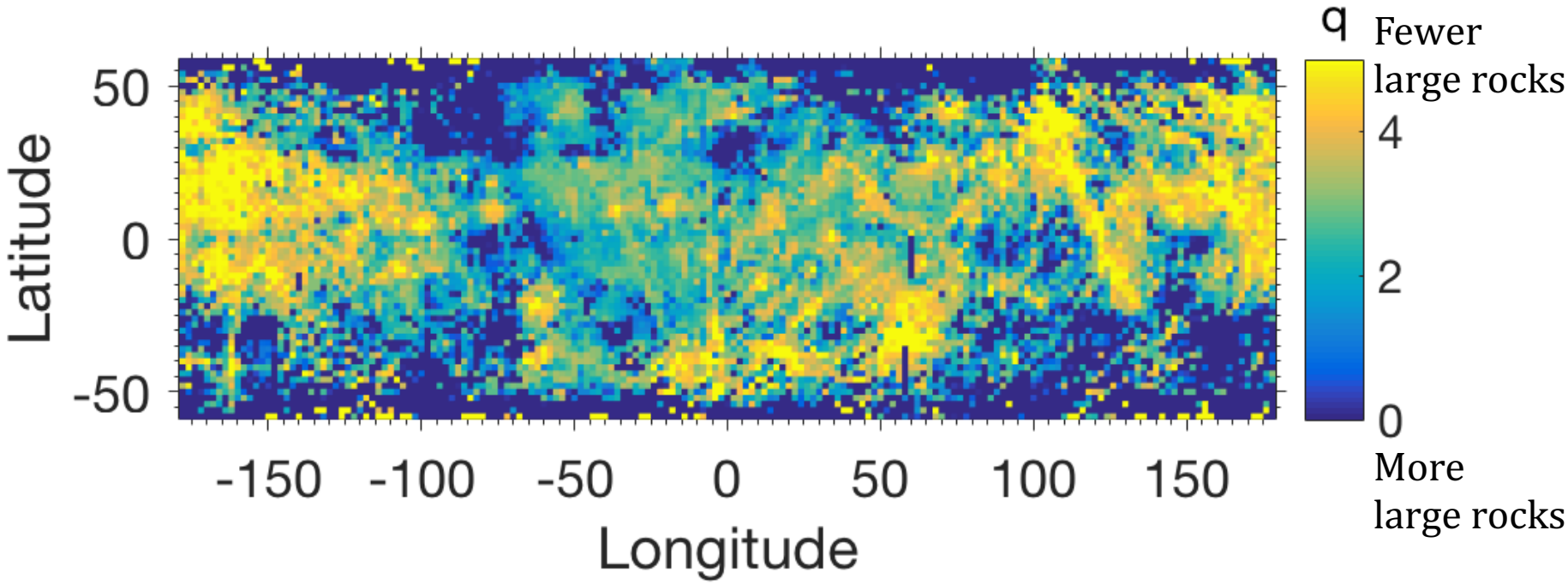


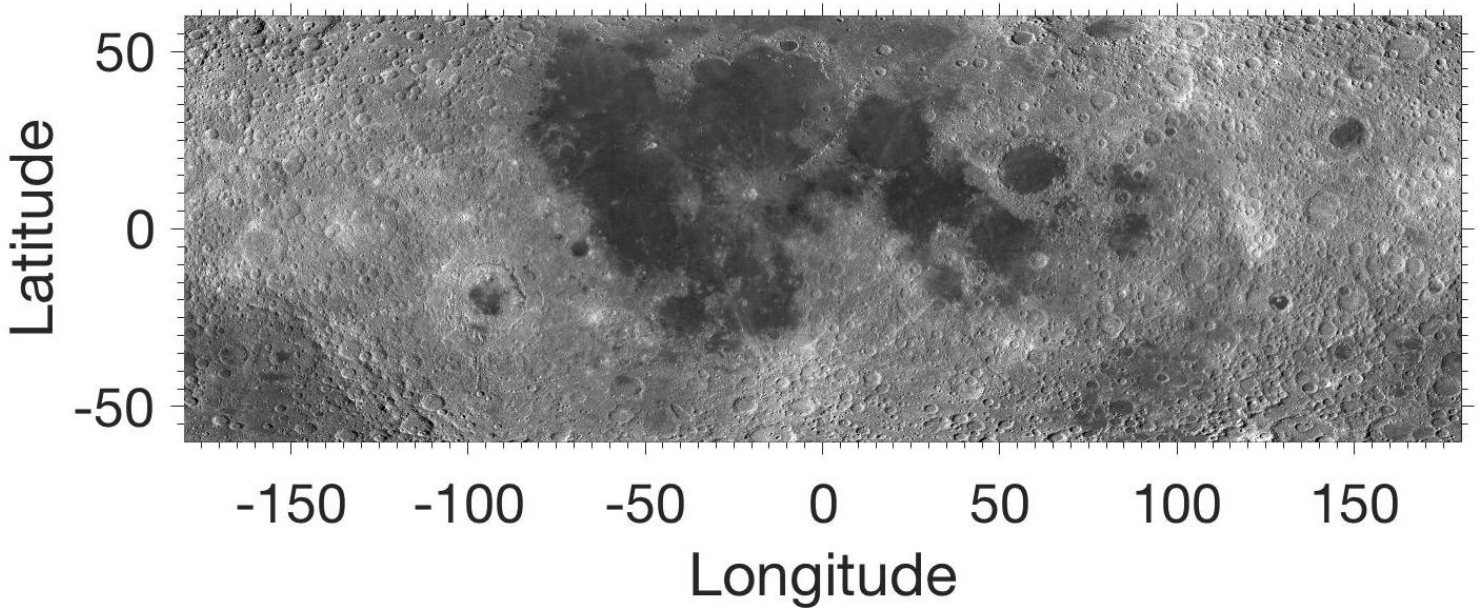
Note: Final full resolution maps will be 128 pixels per degree


Rock Abundance (%)
Latitude
50
0
-50
-150
-100
-50
0
50
100
150
4
2
0
k
Latitude
50
0
-50
-150
-100
-50
0
50
100
150
Longitude
4
2
0
Previous method


Latitude
50
0
-50
-150
-100
-50
0
50
100
150
Latitude
50
0
-50
-150
-100
-50
0
50
100
150
Longitude
4
Previous method
2
0


Rock Abundance (%)
Latitude
50
0
-50
-150
-100
-50
0
50
100
150
4
2
0
k
Latitude
50
0
-50
-150
-100
-50
0
50
100
150
Longitude
4
2
0
Previous method


q
Fewer large rocks
4
2
0
More large rocks
50
0
-50
Latitude
-150
-100
-50
0
50
100
150
Longitude


50
0
-50
Latitude
-150
-100
-50
0
50
100
150
Longitude

Future work

- Model diurnal temperature curves for more rock sizes and latitudes.
- Validate the method by counting rocks in high resolution images from the Lunar Reconnaissance Orbiter Camera (LROC) and landing sites.
- Apply algorithm to full resolution Diviner data to produce higher resolution global maps.
- Produce global maps of rocks in different size ranges.

Conclusions

- We detect rocks orders of magnitude smaller than previous work
- There are local areas of high rock abundance in both highlands and maria
- The lunar maria have more large rocks relative to the lunar highlands
  - → Consistent with the highlands older age