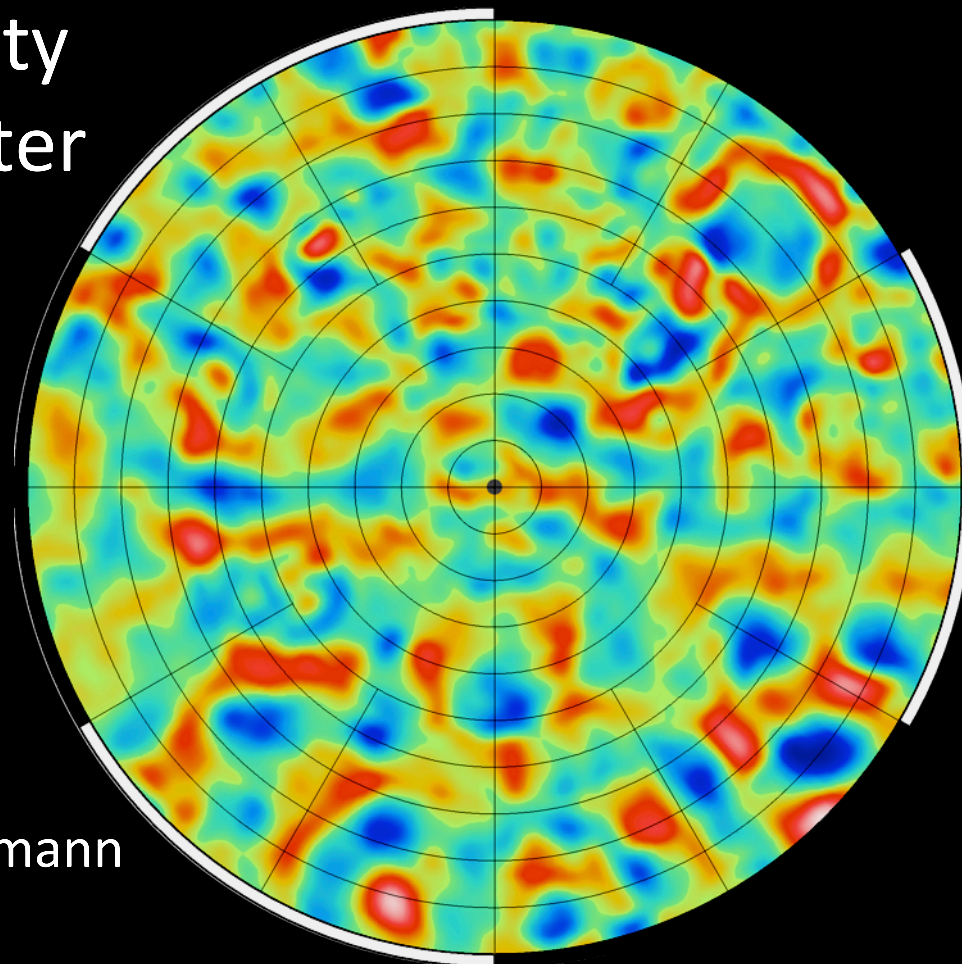
Lunar South Pole Gravity and the Search for Water



David E. Smith, Maria T. Zuber
Department of Earth, Atmospheric and Planetary Sciences
Massachusetts Institute of Technology

Sander Goossens
CRESST
University of Maryland, Baltimore County

Erwan Mazarico, Gregory A. Neumann
Solar System Exploration Division
NASA/Goddard Space Flight Center

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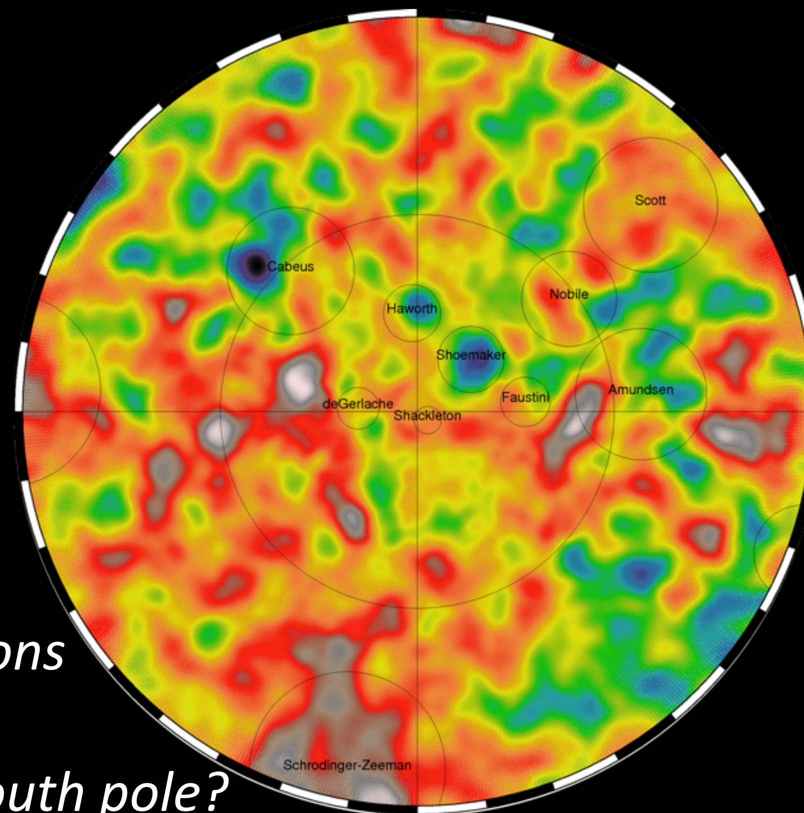
Investigate the crustal structure of the lunar south pole, including the possible presence of water ice, by asking:



1. What is the relationship of PSRs and LEND data?
Is it true that LEND does not support the Idea that the "ice is in the permanently shadowed regions"?

2. Are the LEND neutron suppression regions associated with the locations of crustal Bouguer gravity anomalies at the lunar south pole?

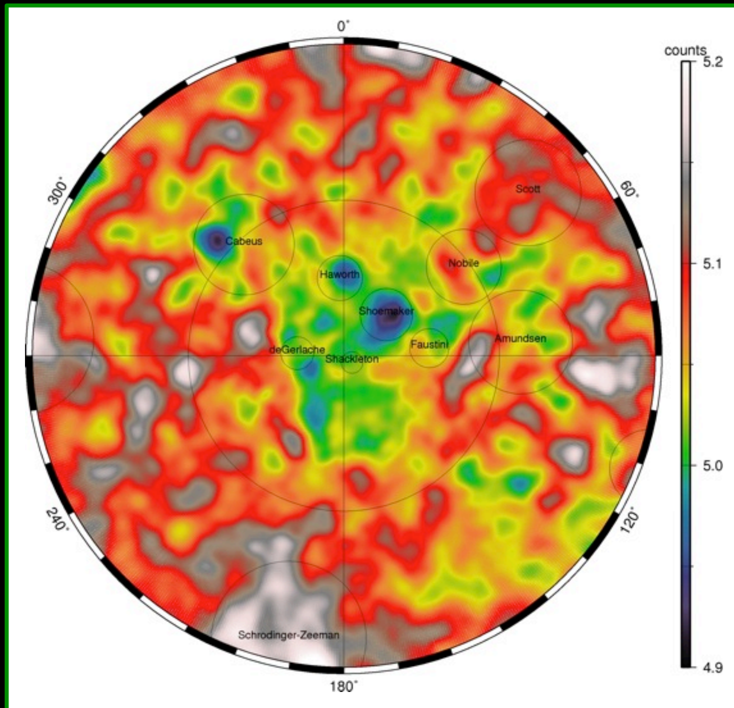
3. What does it take to create a gravity anomaly from a density contrast in the crust, and how does it vary with depth?

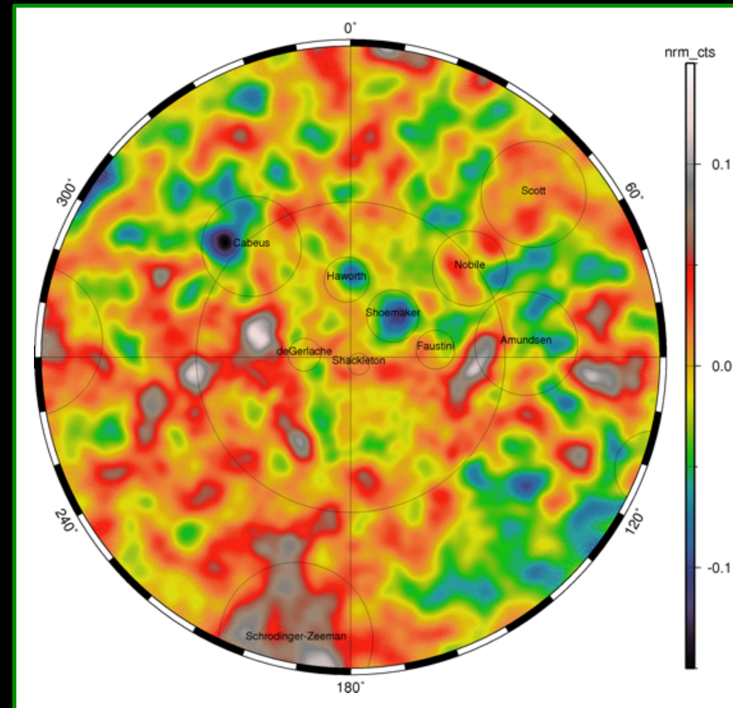
Question # 1

What is the relationship of PSRs and LEND data?

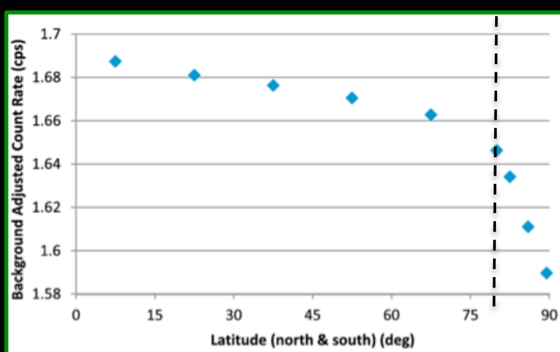
Is it true that LEND does not support the idea that the "ice is in the permanently shadowed regions"?

LEND Epithermal Neutrons from the Collimated Detectors





LEND dataset shows a latitude trend



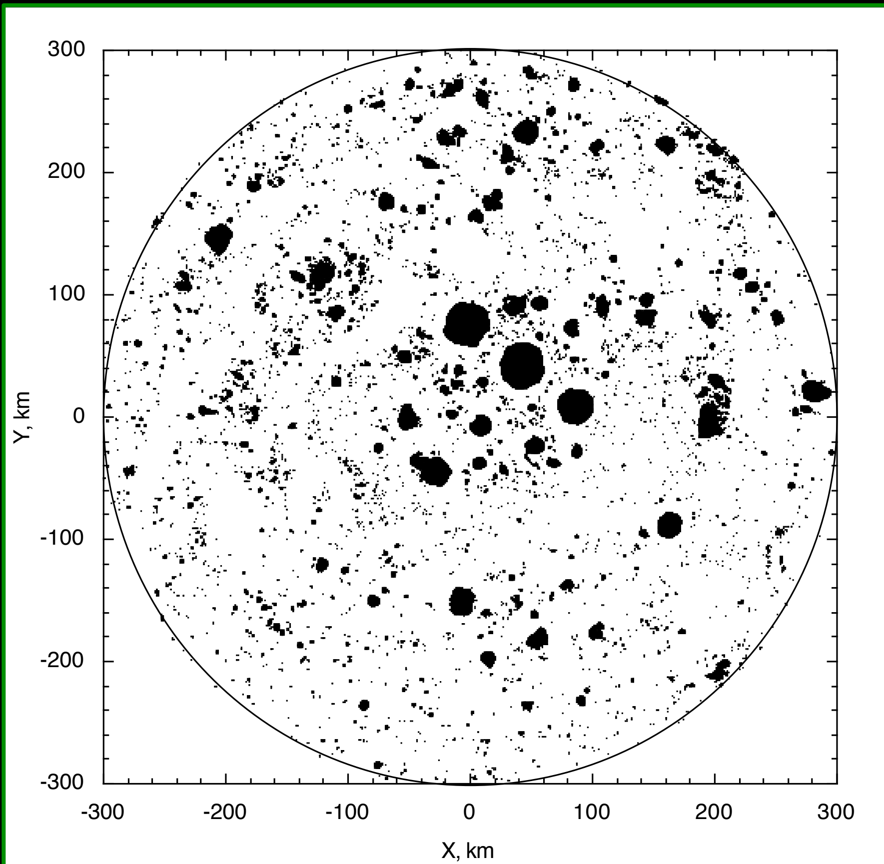
Boynton et al: JGR, VOL. 117, E00H33, doi: 10.1029/2011JE003979, 2012

LEND dataset with quadratic latitude trend removed, and used in this analysis

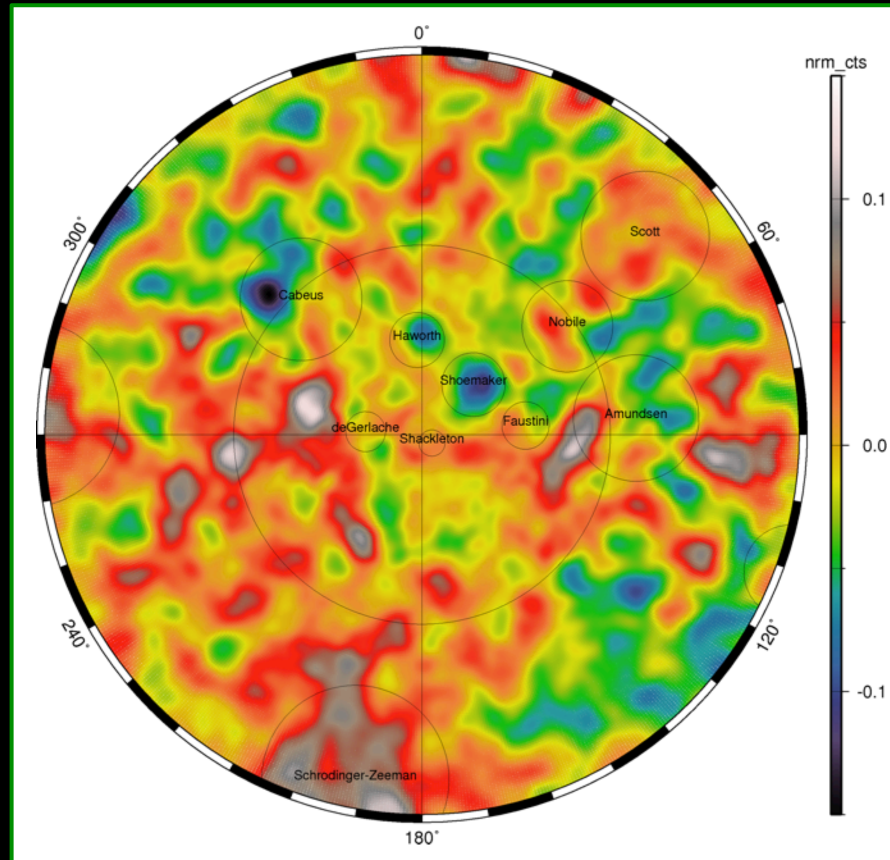
The cause is of the trend in latitude is not clear.
Could it be the result of a crustal density variation in crust, incl. H_2O?

Comparing the Neutron Data Locations with the PSRs

PSR Dataset



LEND Dataset



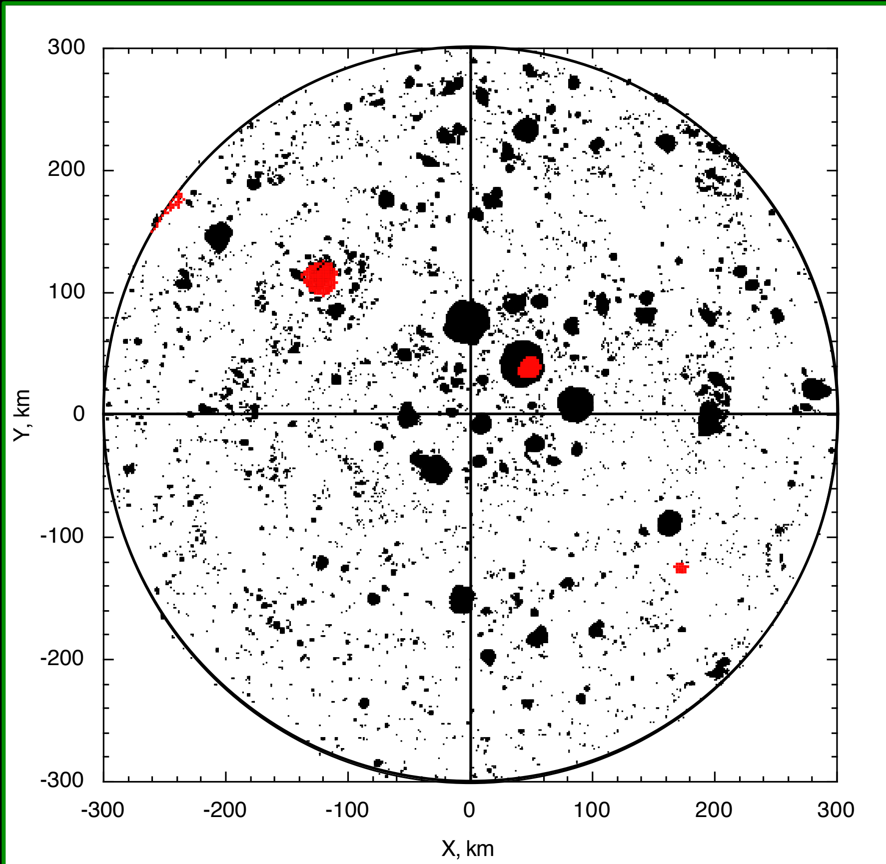
The PSRs derived from LOLA Topography; 400 m pixel resolution.

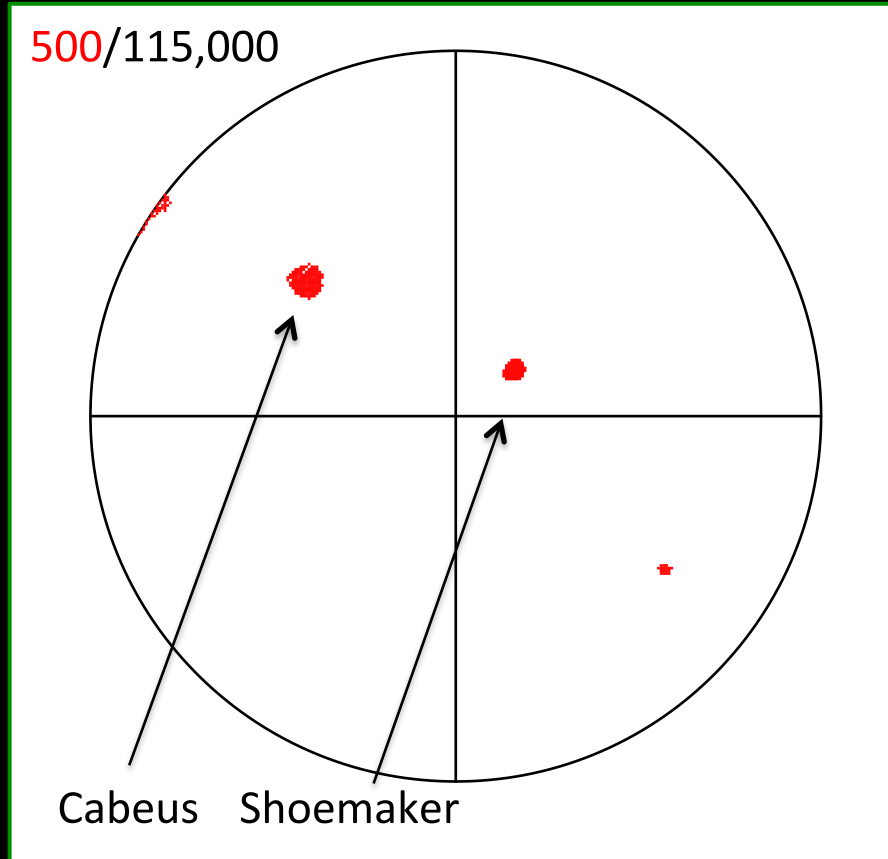
(Mazarico et al)

LEND data with resolution 5 km

(Mitrofanov et al)

Comparing the "Strongest" Neutron Suppression Regions with PSR locations

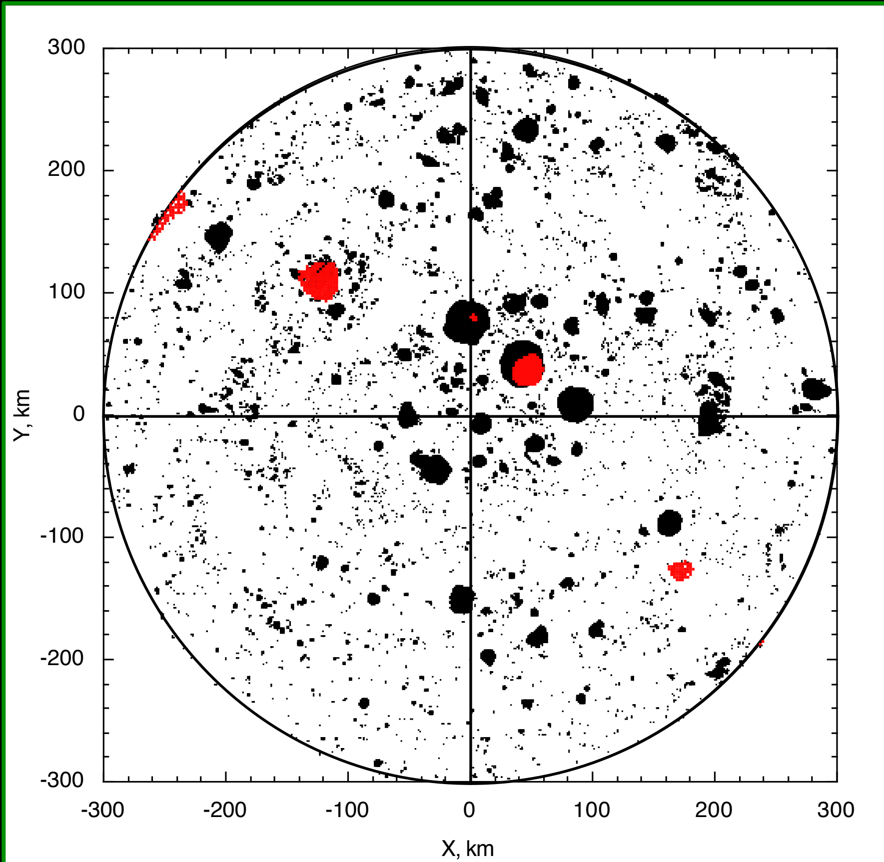


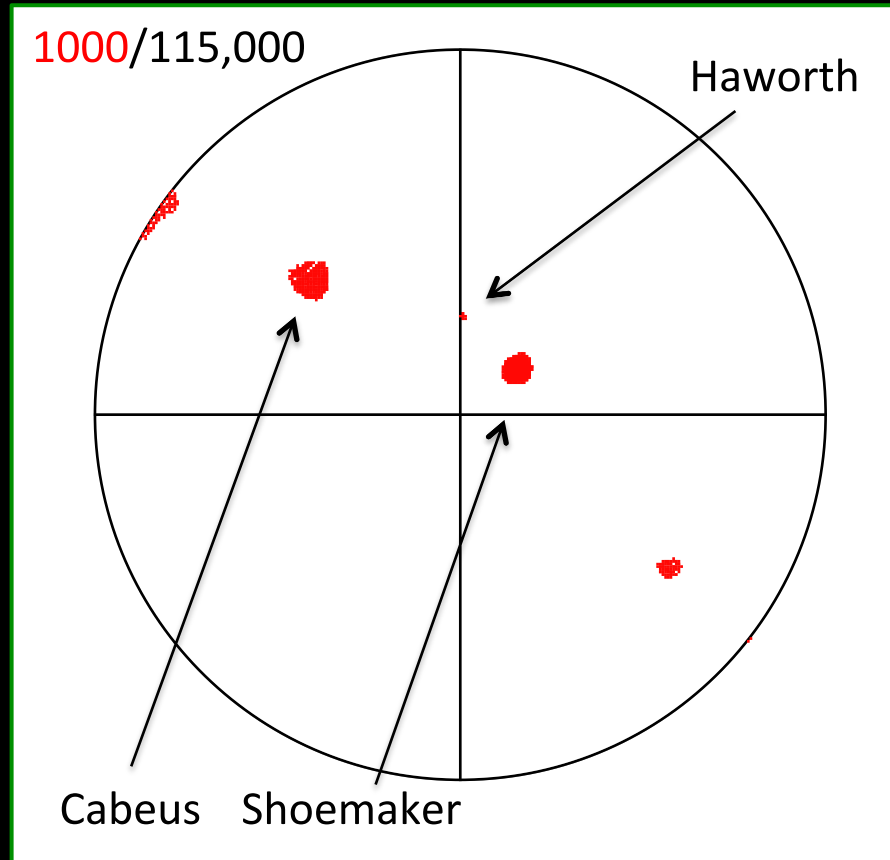


LEND data are organized "low" to "high" counts.

Right figure shows locations of the 500 highest strongest suppression regions.
Left figure shows suppression region overlain on PSRs.

Comparing the "Strongest" Neutron Suppression Regions with PSR locations





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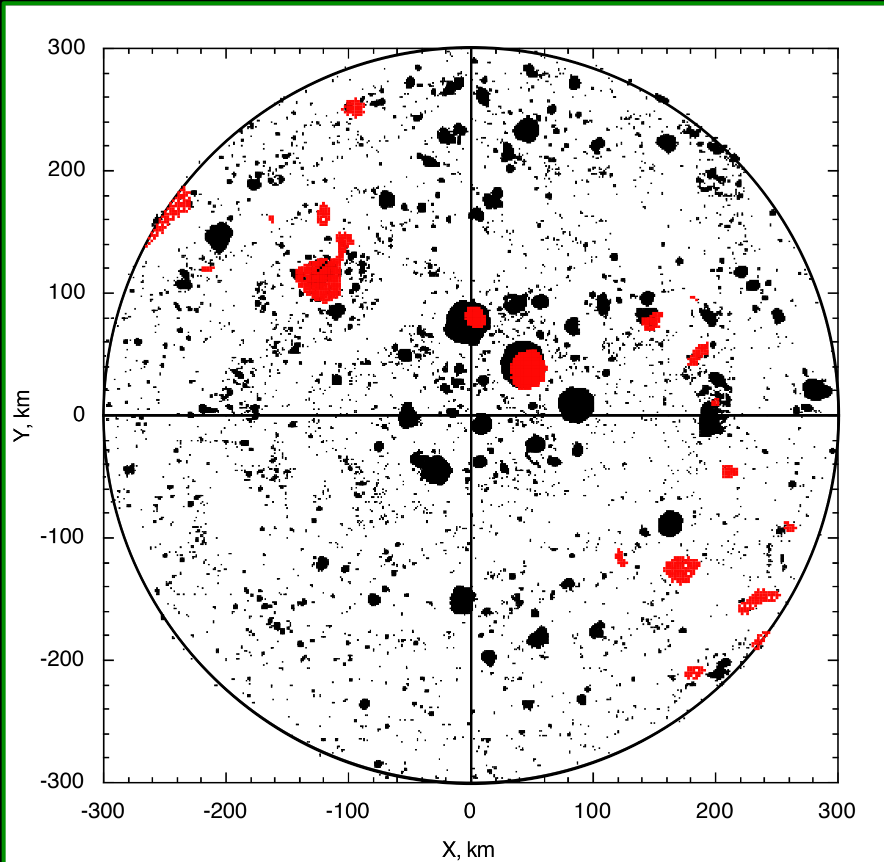
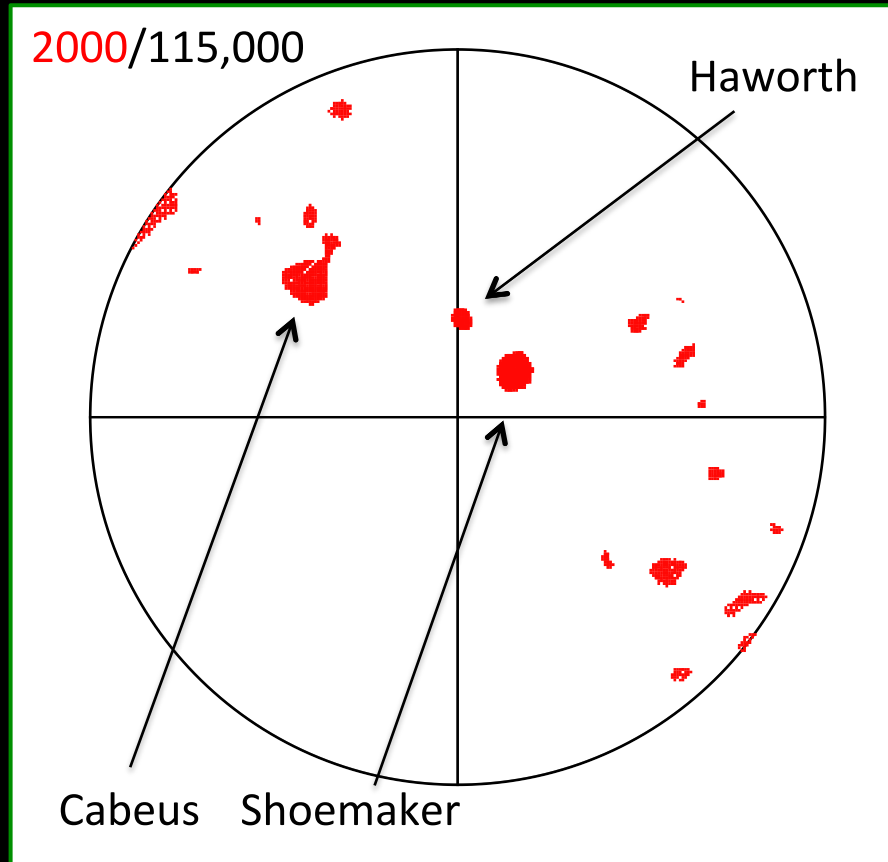
Comparing the "Strongest" Neutron Suppression Regions with PSR locations





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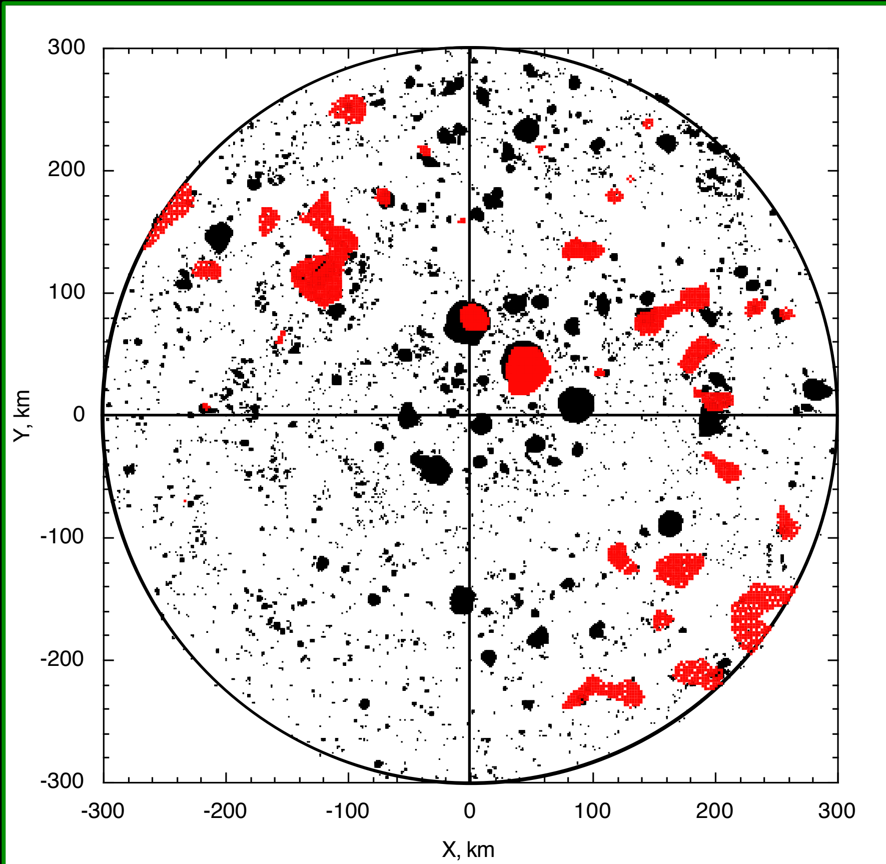
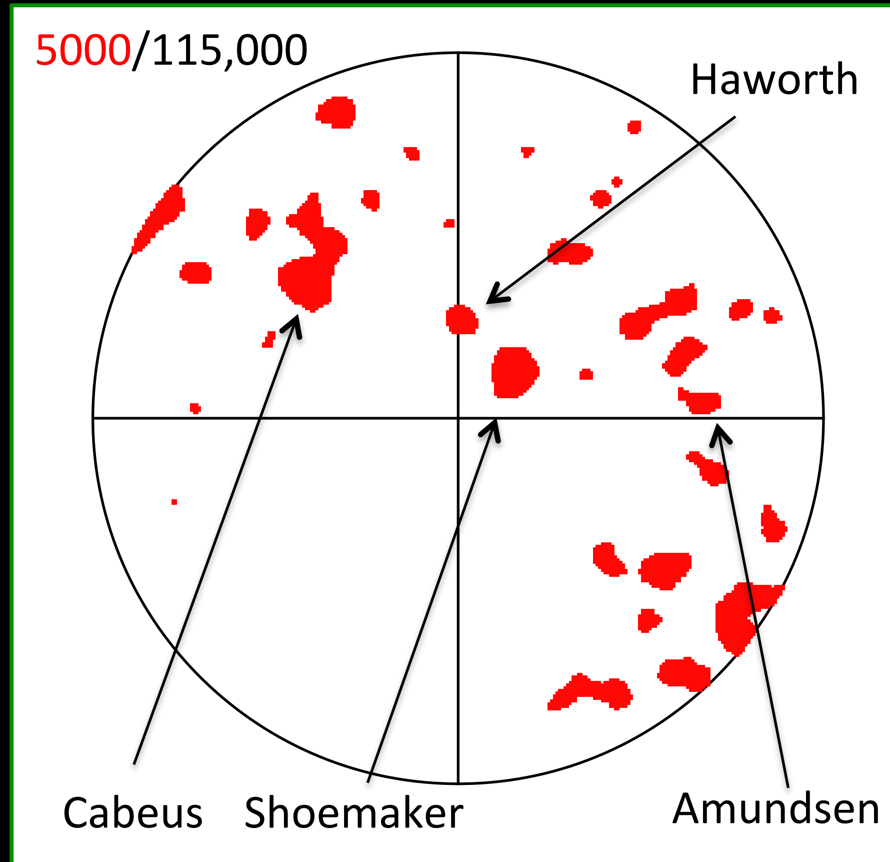




LEND data are organized "low" to "high" counts.

Right figure shows locations of the 5000 highest strongest suppression regions.
Left figure shows suppression region overlain on PSRs.

Conclusion: Question # 1

1. There is some overlap of neutron suppression regions and PSRs but the suppression regions are larger than the PSRs indicating that the suppression region is not limited to the PSR alone.

2. There are numerous suppression regions that have almost no, or very small, areas that are in shadow.

3. A few large craters, notably Cabeus, Shoemaker and Haworth, are strong neutron suppression areas.

4. <u>A PSR is not necessarily, or in general, a neutron suppression region.</u>

5. <u>A neutron suppression area is not in general a PSR.</u>

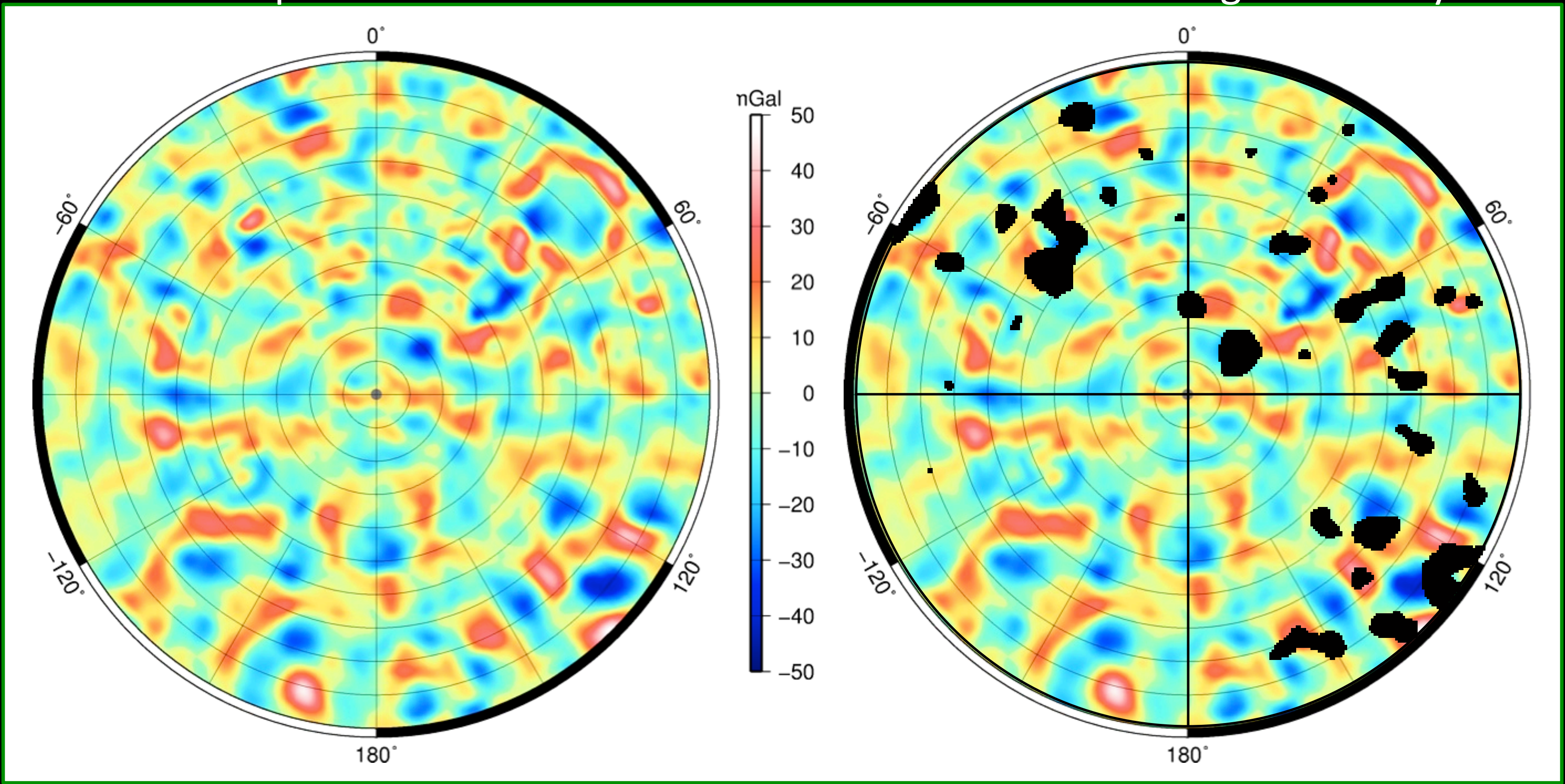
Question # 2

Are the LEND neutron suppression regions associated with the locations of crustal Bouguer gravity anomalies at the lunar south pole?

Bouguer Gravity and Neutron Suppression Regions

Bouguer Gravity of the Crust: Depth 10-45 km

LEND Observations overlain on Bouguer Gravity



Quick answer: No obvious visual correlation of LEND with gravity.

Conclusion: Question # 2

There is no correlation of LEND data with GRAIL crustal Bouguer anomalies - but if the crust were the source of the water and the PSRs are the recipients of the water then the two do not need to be coincident.

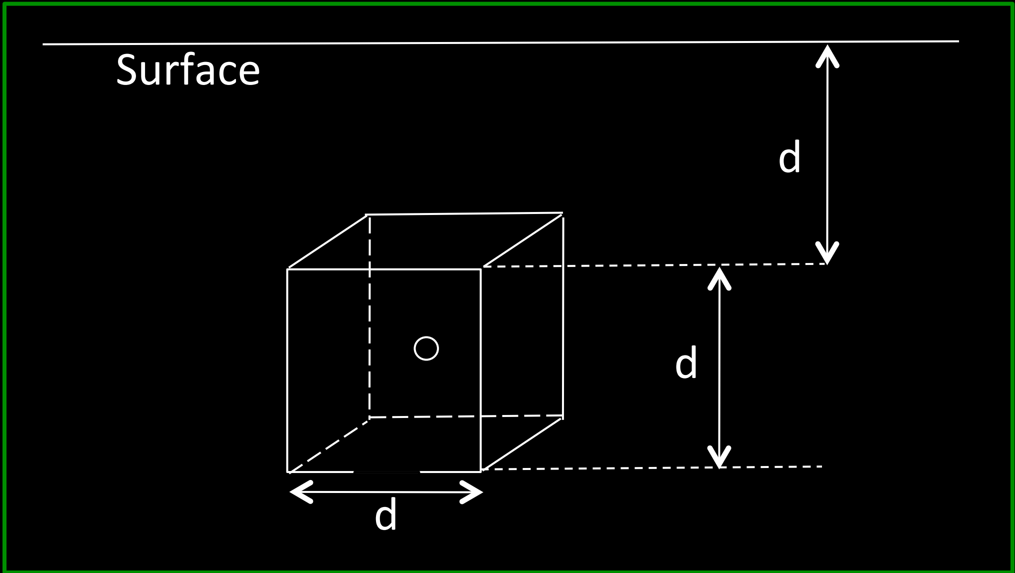
Question # 3

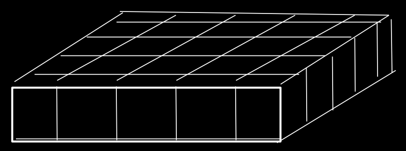
What does it take to create a gravity anomaly from a density contrast in the crust?

What are the options for explaining the observed gravity at the surface?

Modeling the Surface Gravity from a Crustal Density Contrast

We consider a cube of dimension “d” whose top surface is at depth “d”. This relationship of block depth and size makes it possible to approximate the center of mass of the cube at its geometric center, 1.5d below the surface.

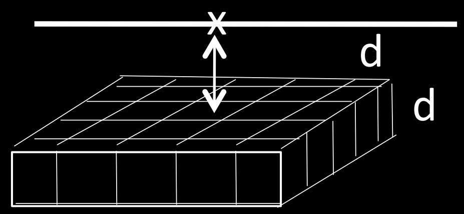




We form a layer of 25 identical cubes.
Each cube has a density contrast of dρ

We calculate the gravity anomaly at the surface above the center block for various depths in the crust and various density contrasts.

Magnitude of Gravity Anomaly at the Surface



3 density contrasts used representing a layer:

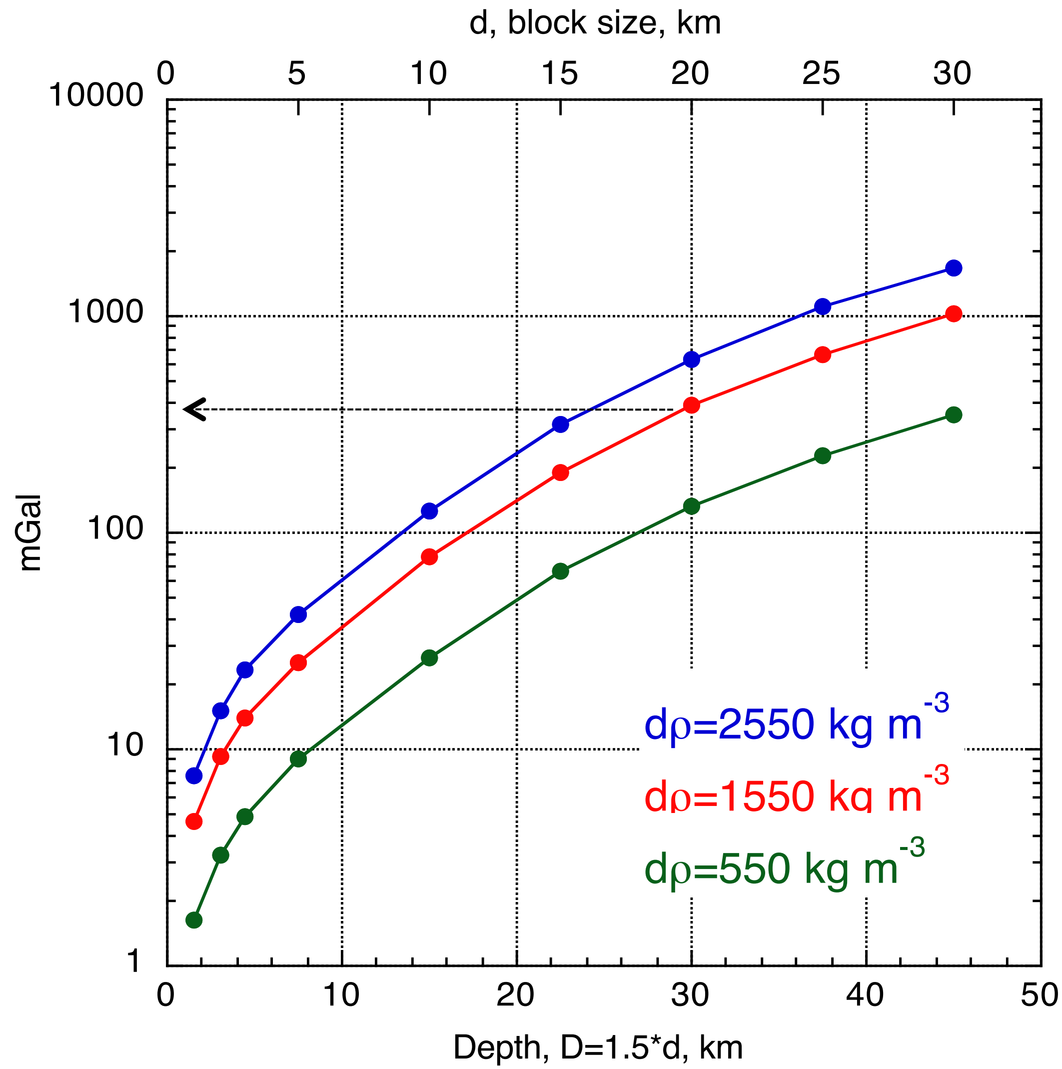
(1) empty

(2) filled with water

(3) Filled with a slightly less dense crustal material

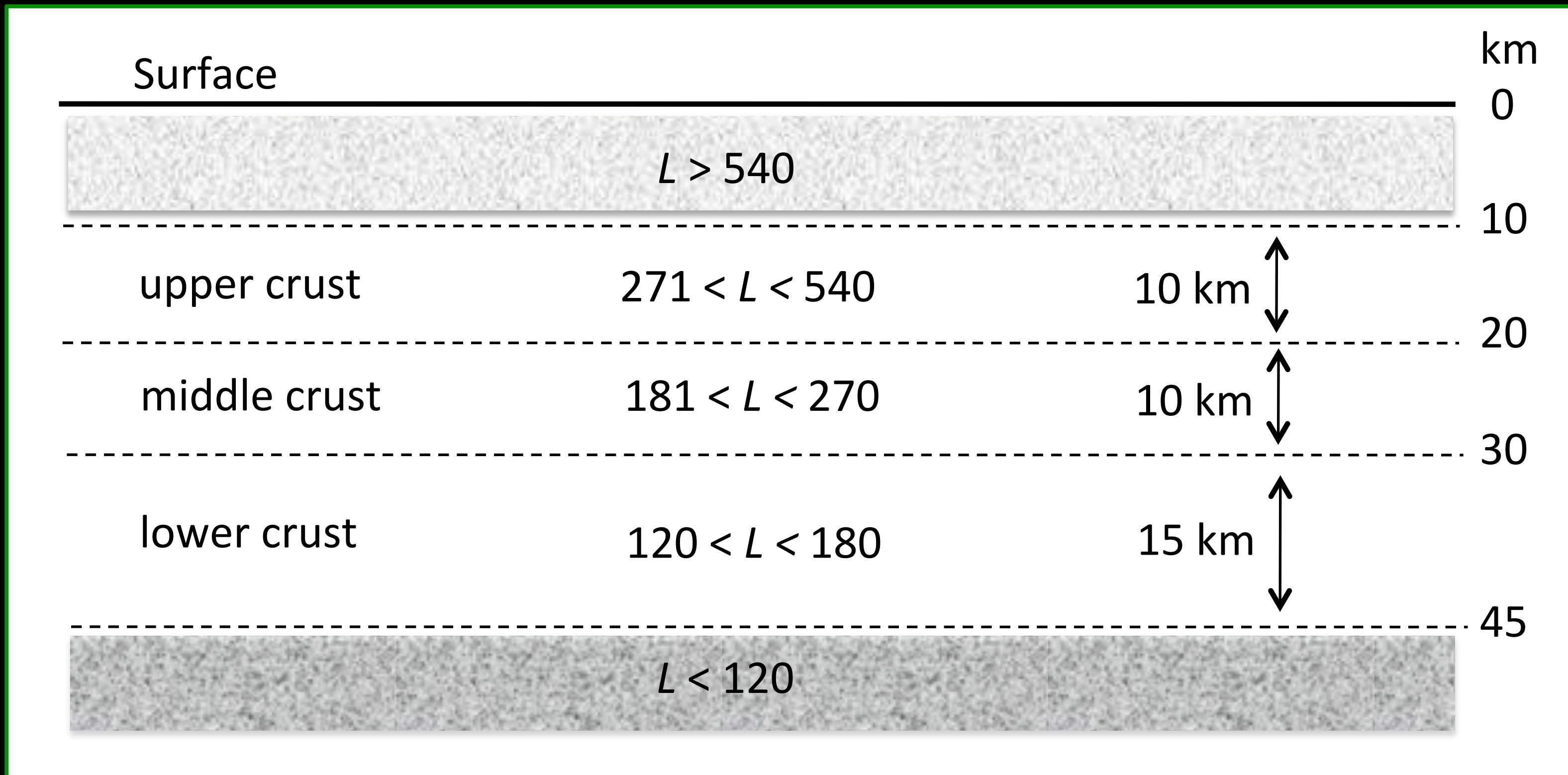
Depths ranging from 1.5 km to 45 km of the center of the block, with corresponding block sizes of 1 km to 30 km

Example: A 20 km cube with center at 30 km depth creates a gravity anomaly of 389 mGal if 100% H_2O



dρ = 2550: density is zero (porosity bubble)
dρ = 1550: density is same as water ice
dρ = 550: density is 2000 kg/m^3

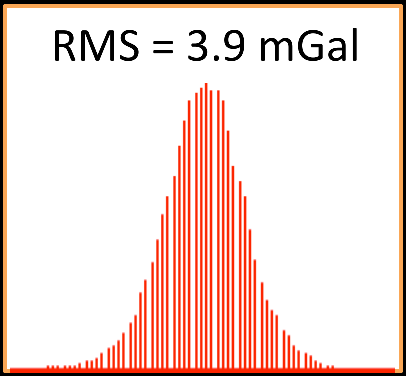
Model of Layered Crust



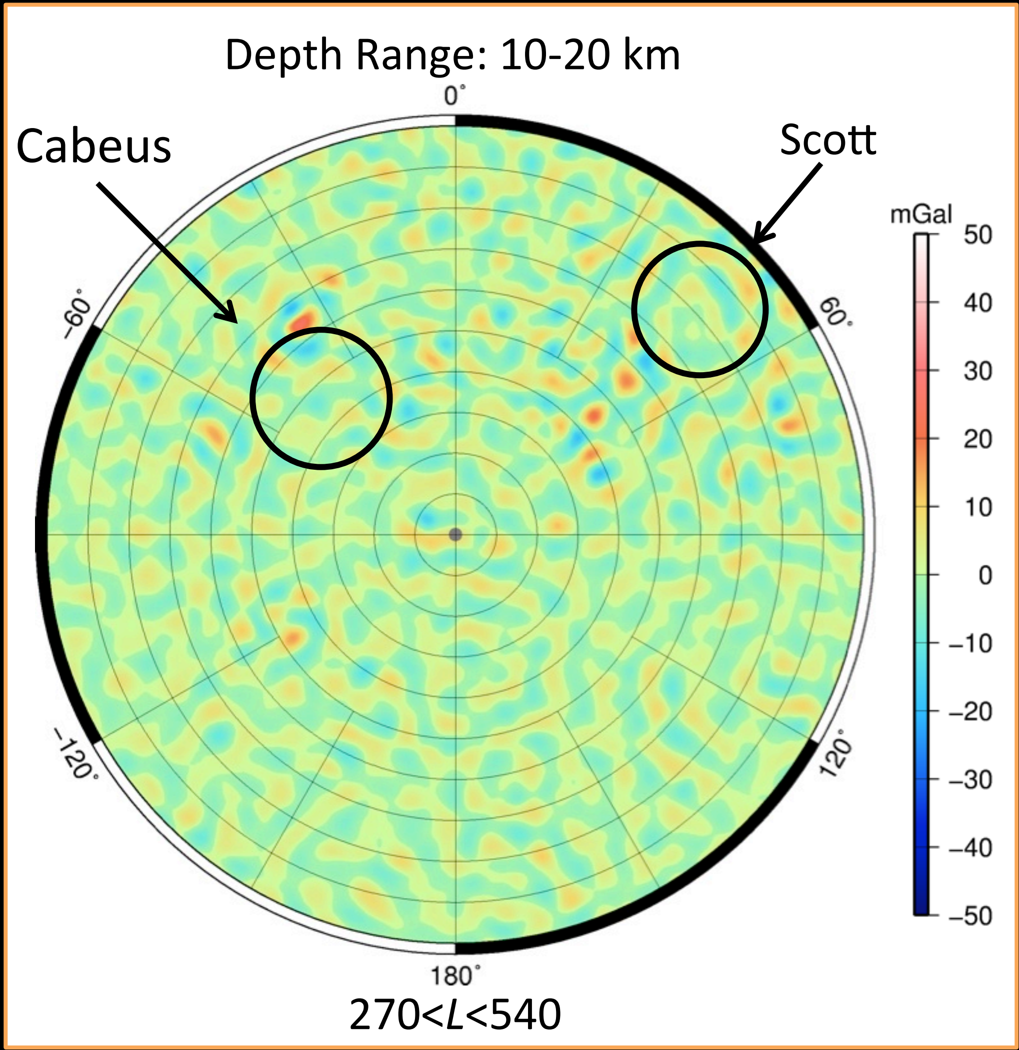
The crust is layered according to the degree range of the gravity field using depth = (180/L)*30 km

Bouguer Gravity between 10 and 20 km Depth

Min: -18.9 mGal, (323.9, -83.1)
Max: 24.8 mGal, (323.5, -83.7)



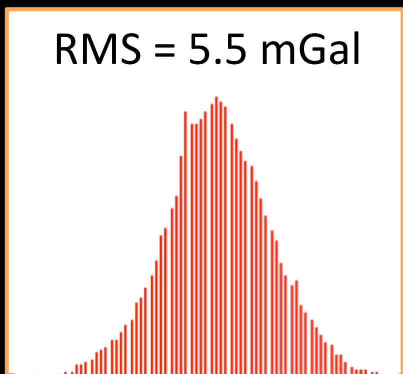
- At 10 to 20 km depth the gravity anomalies are randomly distributed. 99% within ± 12 mGal.
- The max/min values are situated in Cabeus crater. Scott is the only large crater evident at this depth.

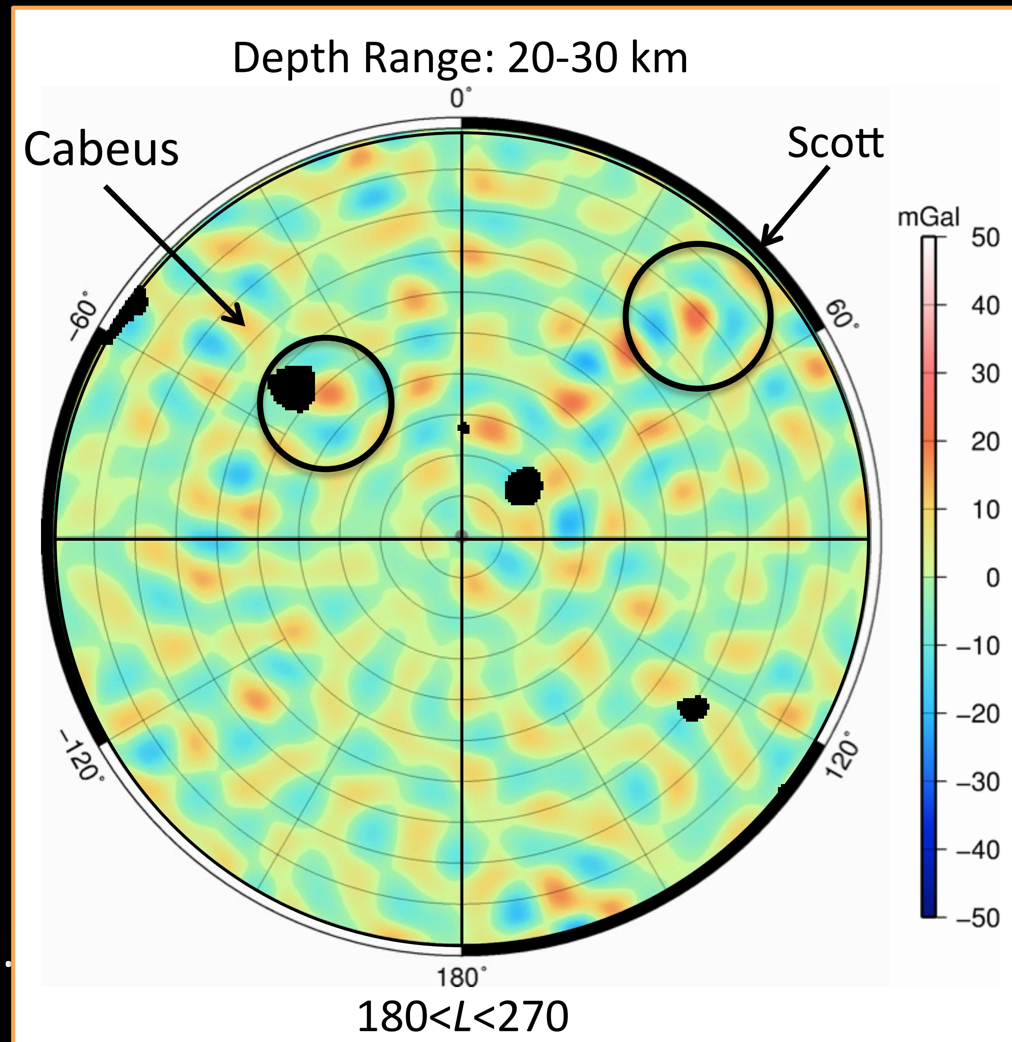


RMS of gravity anomalies can be explained by: (1) 3% porosity contrast; or (2) 5% H_2O; or (3) 15% density contrast (500 kg/m^3)

Bouguer Gravity between 20 and 30 km Depth

Min: -22.2 mGal, (36.6, -84.7)
Max: 21.5 mGal, (49.9, -82.2)



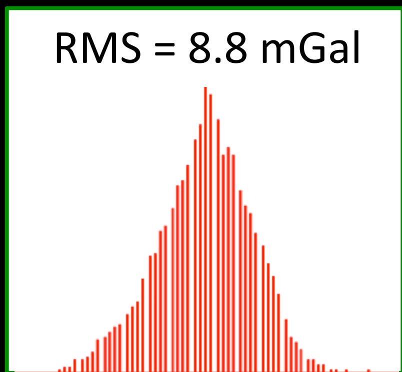


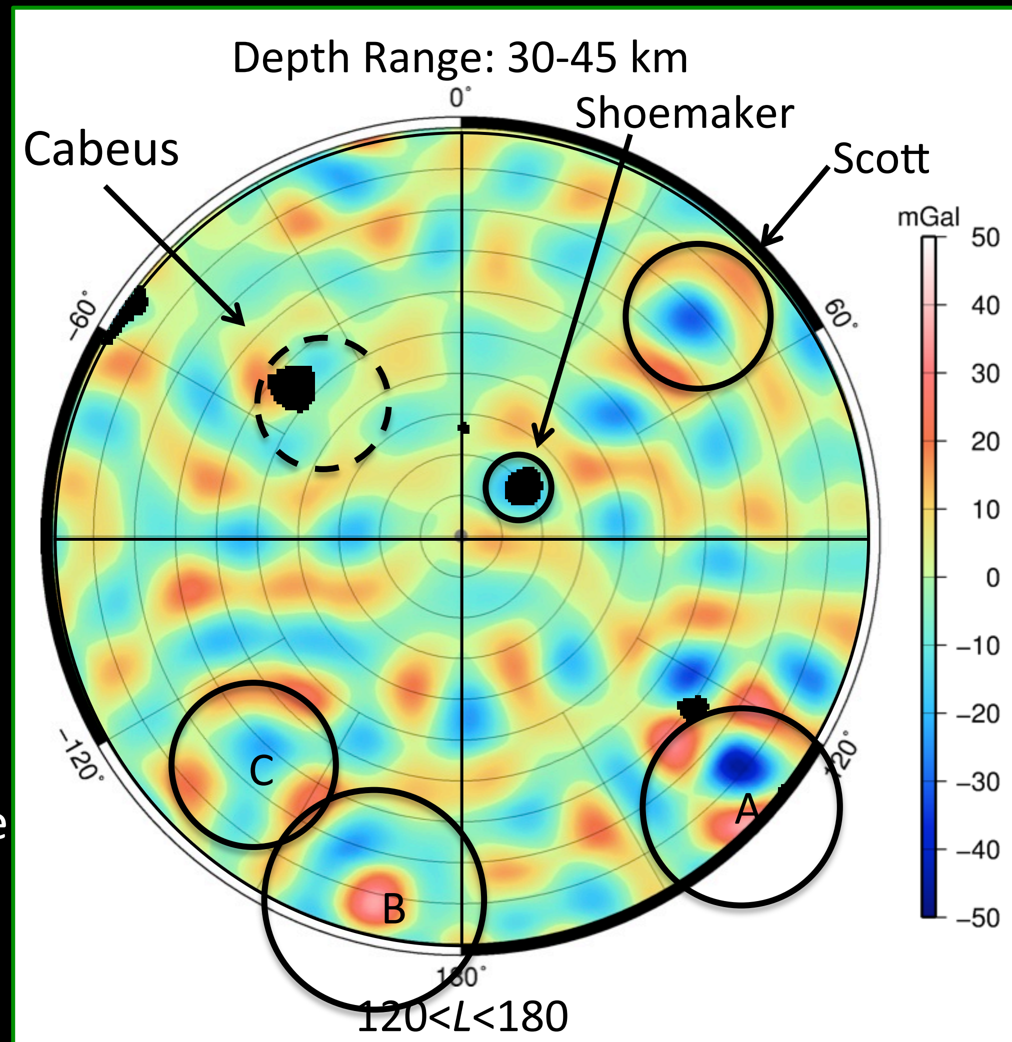
- At 20 to 30 km depth gravity anomalies are larger. 99% within ± 17 mGal.
- Feature near Cabeus disappeared, a central high has appeared.
- Scott crater central high is evident.

RMS of gravity anomalies can be explained by: (1) 1.5% porosity contrast; or (2) 2.3% H_2O; or (3) 6.6% density contrast (500 kg/m^3)

Bouguer Gravity between 30 and 45 km Depth

Min: -45.6 mGal, (129.7, -81.2)
Max: 36.4 mGal, (135.2, -80.0)



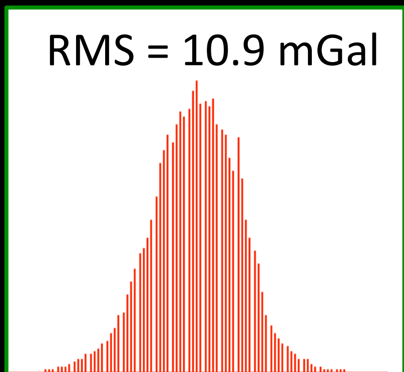


- At 30 to 45 km depth the gravity anomalies are much larger.
99% within ± 26 mGal.
- Scott crater central anomaly is –ve
- Craters A, B, & C appear at this depth only. (A&C show crater rims; B a central high)

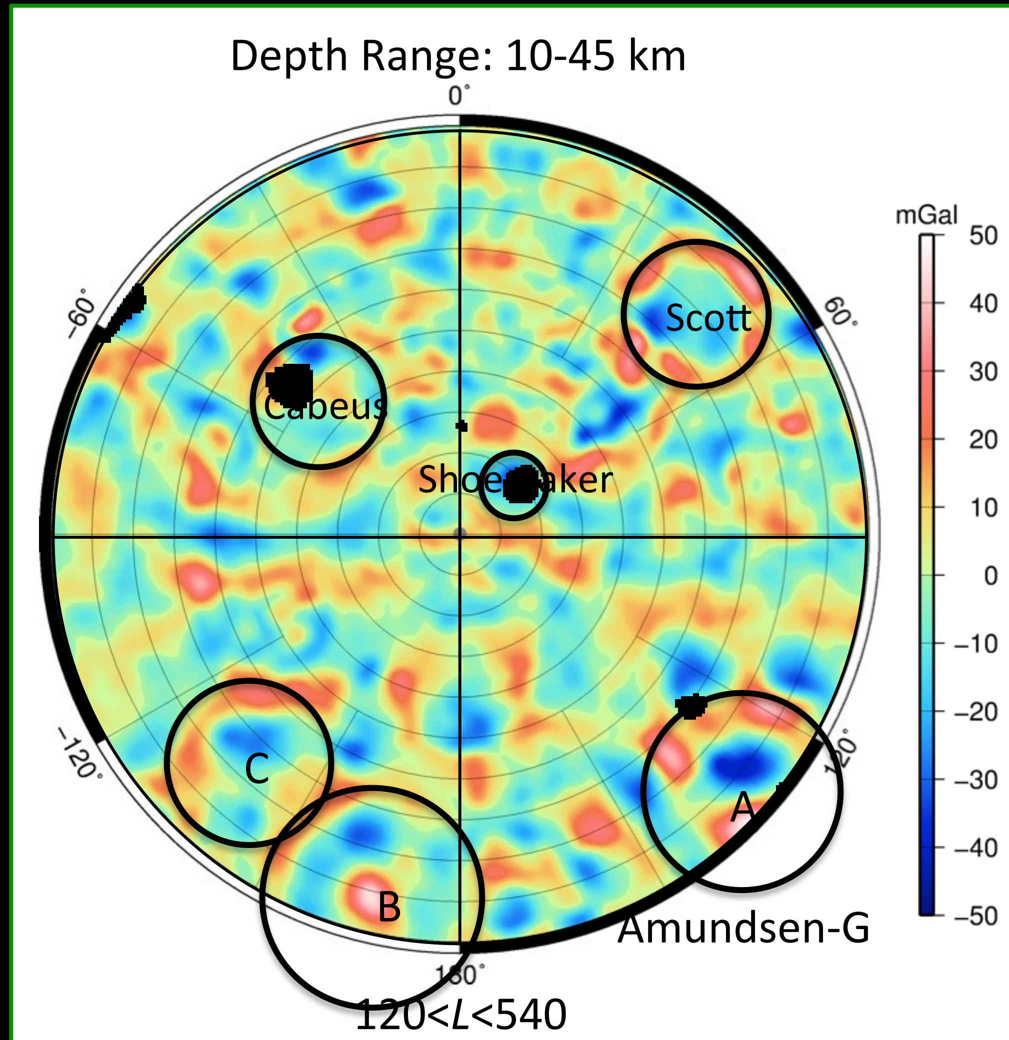
RMS of gravity anomalies can be explained by: (1) <u>0.8% porosity contrast</u>; or (2) <u>1.3% H_2O</u>; or (3) <u>3.9% density contrast</u> (500 kg/m^3)

Bouguer Gravity of the Crust, 10 and 45 km Depth

Min: -40.7 mGal, (129.7, -81.0)
Max: 47.9 mGal, (135.2, -80.0)



- Cabeus: Shallow, -ve anomaly <20 km, possible connection to LEND
- Scott: Rim extends through crust, 10-45 km
- Craters A, B & C: only seen at >30 km depth
- Shoemaker: only seen at > 30 km, so gravity anomaly not related to LEND observations

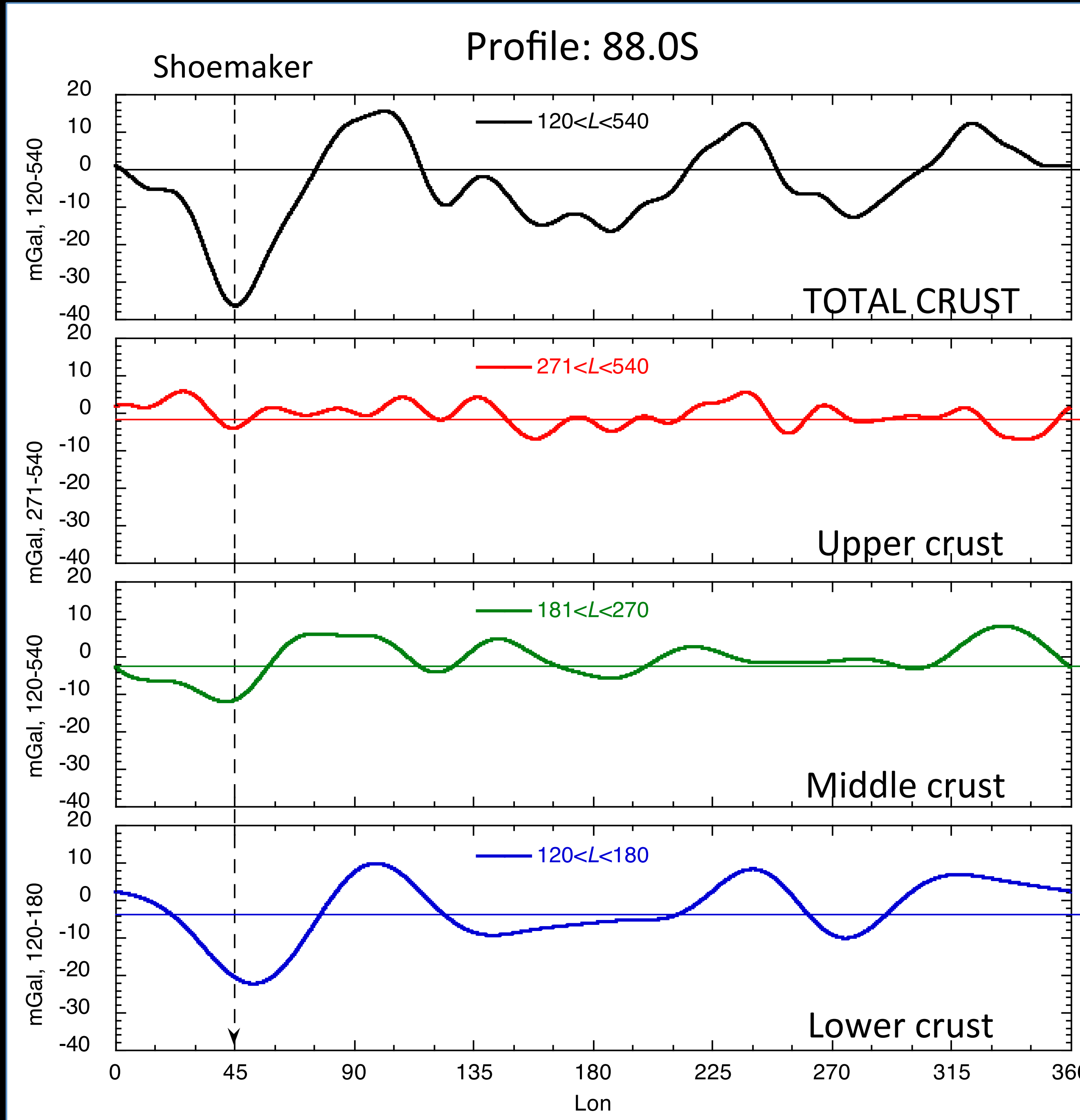


Latitude profile 88.05S

Only feature of significance is the gravity anomaly under Shoemaker.

Hardly visible in the upper crust but the largest feature in the middle and lower crust.

Conclusion: Shoemaker anomaly is primarily a result of a density anomaly in the middle and lower crust.

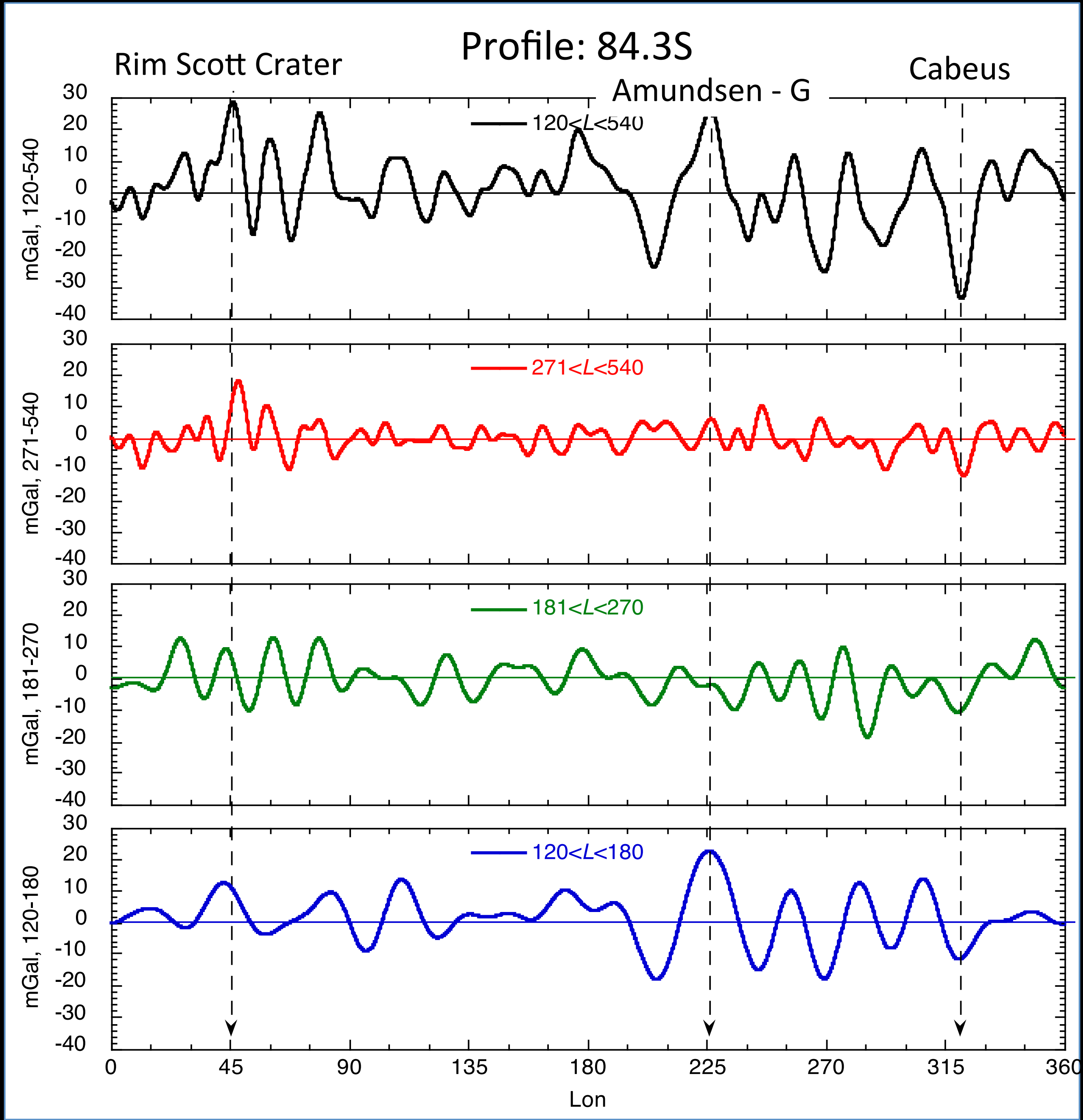


Latitude profile 84.30S

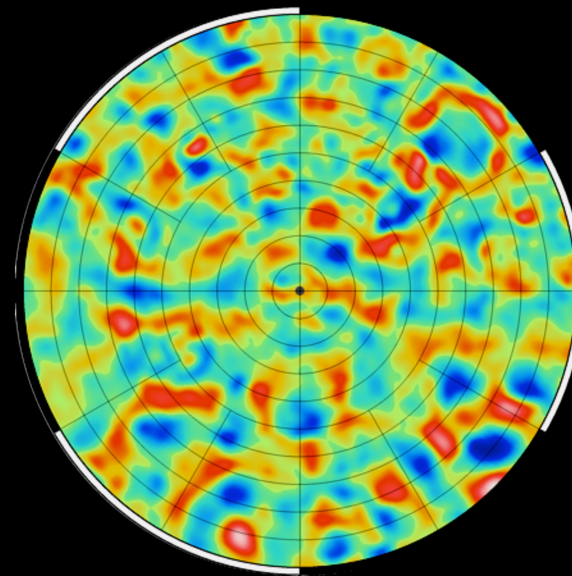
Significant features include the rim of Scott crater, rim of Amundsen-G, and low in Cabeus.

Scott rim and Cabeus identifiable in all 3 crustal levels.

Amundsen-G crater north rim only seen in the lower crust.

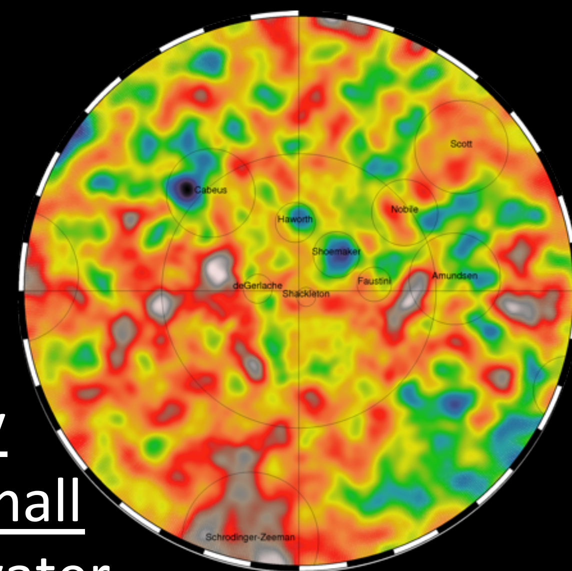


CONCLUSIONS



1. A PSR is not necessarily, or in general, a neutron suppression region; a neutron suppression area is not in general a PSR.

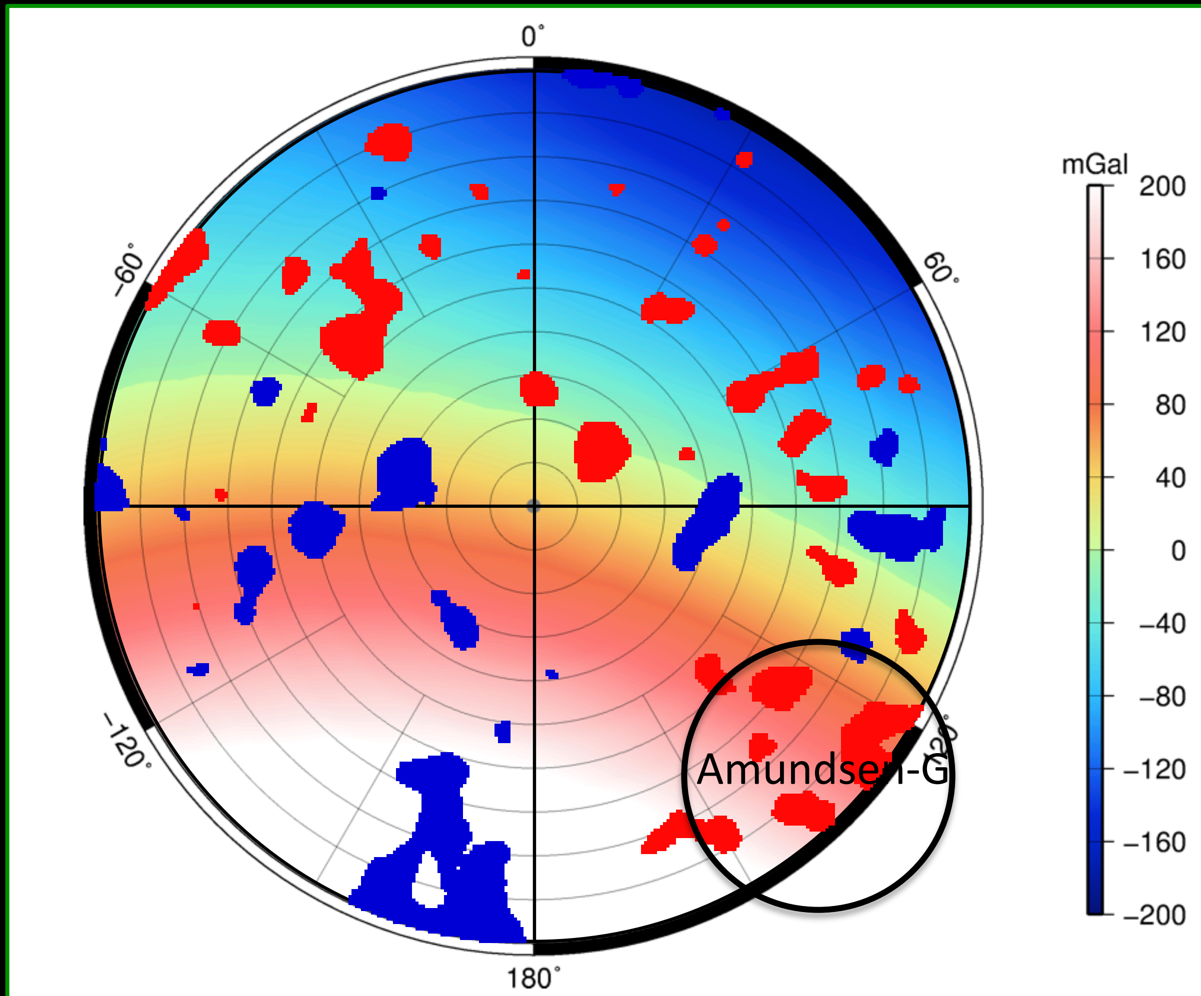
2. There is no general correlation of LEND data with GRAIL crustal Bouguer anomalies with exception of Cabeus.



3. The Bouguer anomalies in the upper crust are consistent with impact-related crustal fracturing/homogenization.

4. The RMS Bouguer signal can be explained by small variations in crustal porosity and/or small amounts of water ice, but the presence of water ice is not required.

LEND High (blue) and Low (red) Neutron Counts (±5000) over Low Degree Bouguer Gravity (2<*L*<10)



The low neutron counts over Schrodinger appear anomalous with regard to a SP-A explanation

Thank you