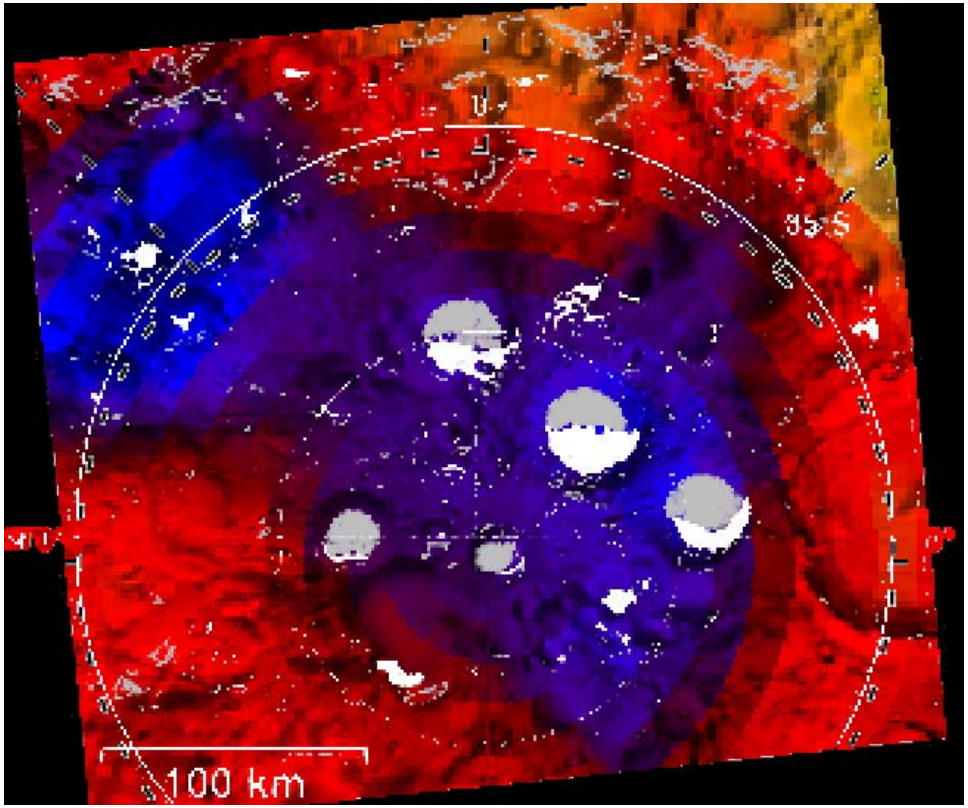
Relationship between Hydrogen-enriched Areas and Permanently Shadowed Regions near the Lunar South Pole

William Boynton, Jerry Droege, Igor Mitrofanov, and the LEND team

LEAG meeting, 9/15/2010

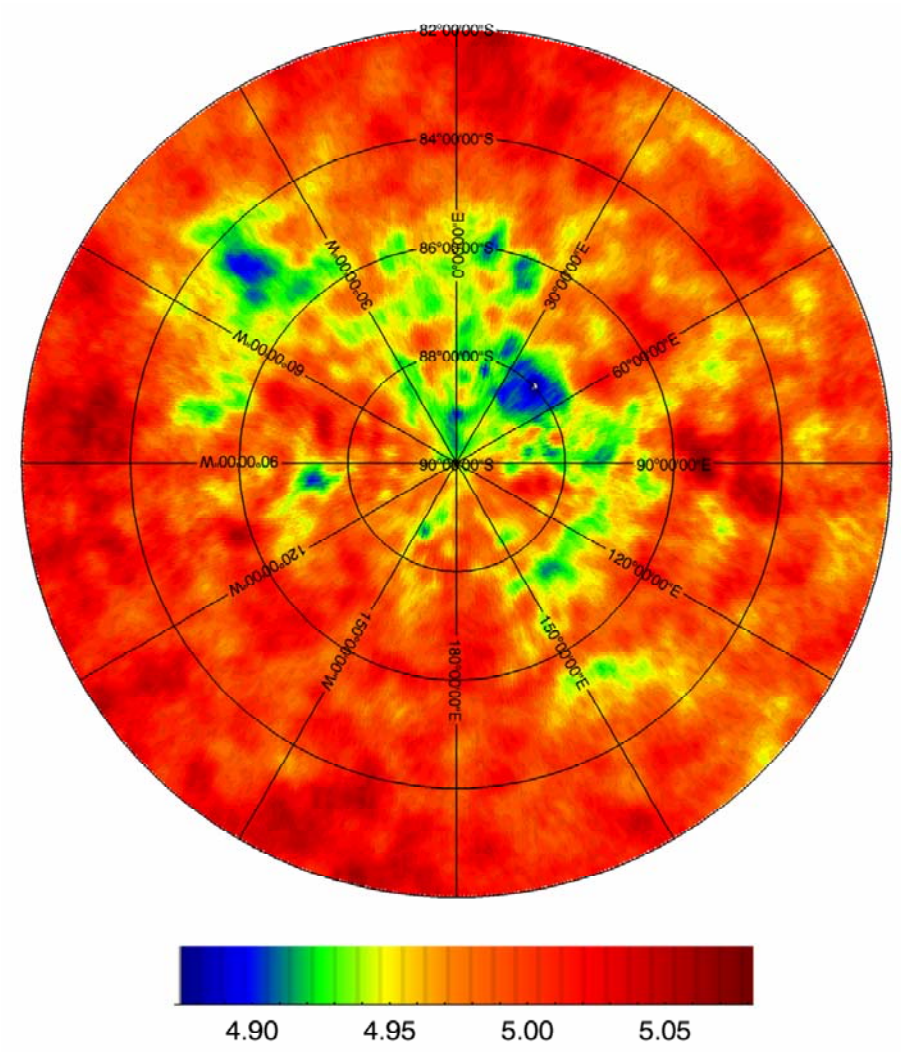
The view of the south pole before LEND

- Concept of PSRs were known before Lunar Prospector and thought the could be places of H enrichment.
- Data from the Lunar Prospector Neutron Spectrometer were consistent with the H being located in the PSR's with much lower amounts outside the PSRs.
- But the spatial resolution of the LPNS was not sufficient, even with Pixon "image enhancement" to have confidence that the H was really located there.
- LEND now has sufficiently good spatial resolution to address the question of the location of the H enrichment.



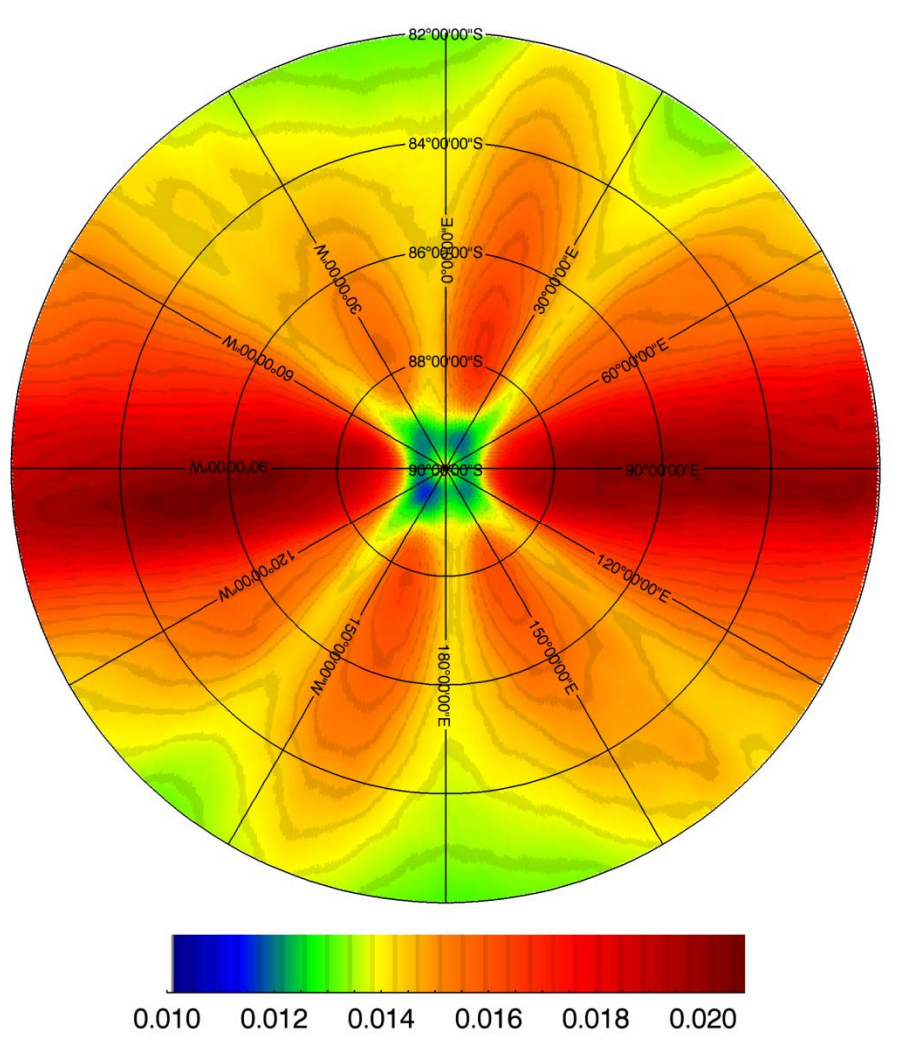
South Polar map of LEND epithermal-neutron count rates

- All maps will go to -82° latitude.
- The average count rates show some clear depressions in neutron flux
- Depressions in epithermal neutron flux are due to increases in H content
- Two important questions:
  - Are the depressions real or noise?
  - Are they associated with Permanently Shadowed Regions (PSRs)?
- Data are smoothed to reduce noise, but at the expense of spatial resolution.



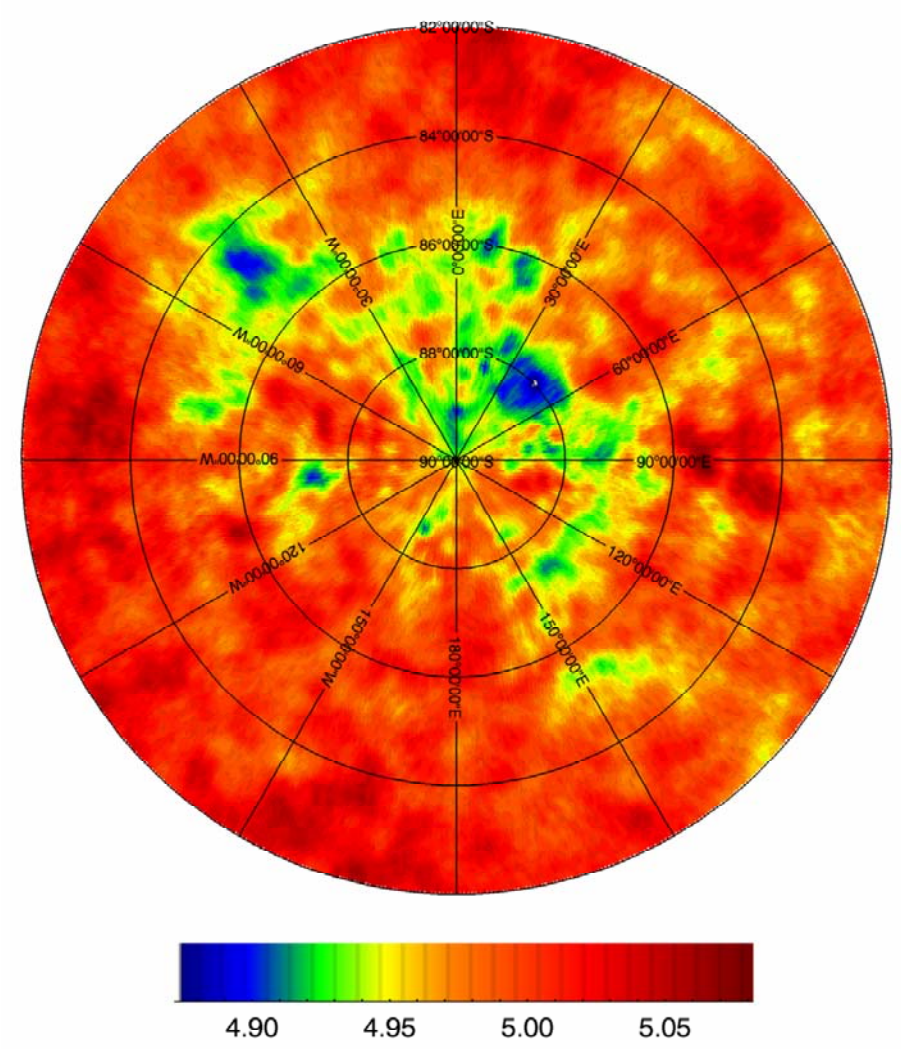
Uncertainties in count rates are well known

- The uncertainty in the count rate is sqrt(number of counts) / time
- Uncertainties are smaller closer to the poles because we have more data near the poles
- Uncertainties are larger at 90°E and 90°W where the instrument is turned off for orbital trim maneuvers.
- For much of the region, the uncertainties are on the order of 0.015 cps.

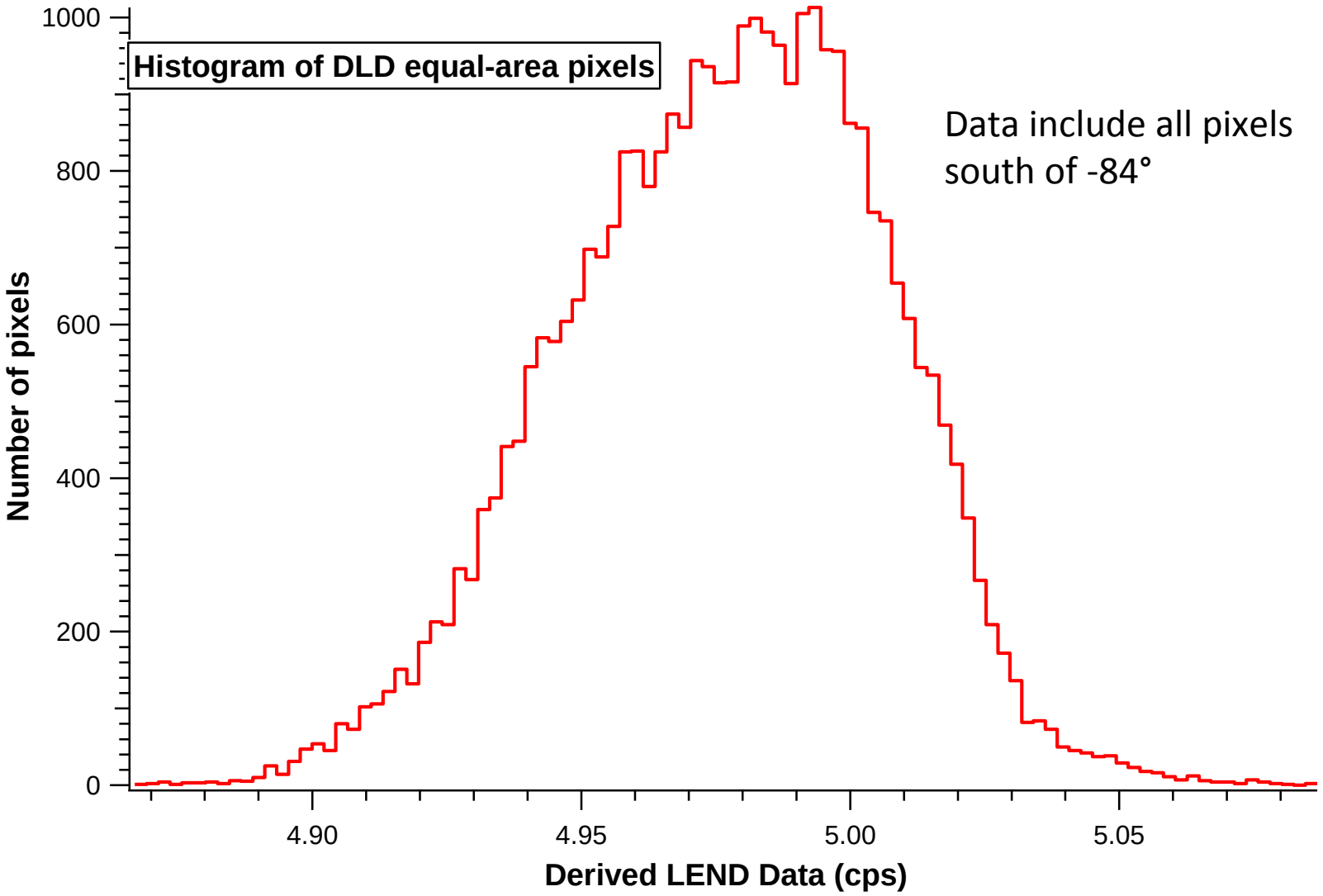


Now that we know the uncertainties on this map, what next?

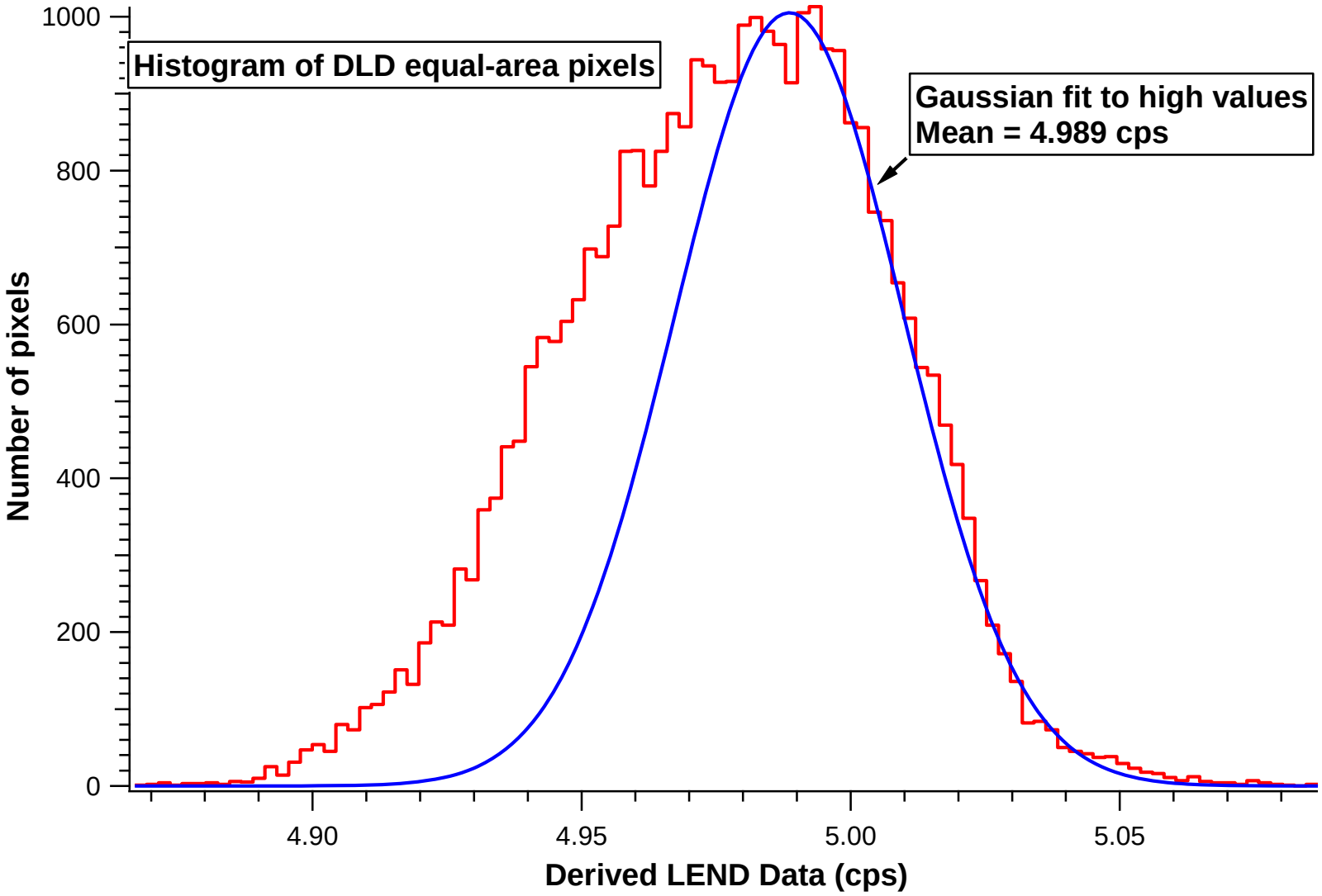
- We know the uncertainties are on the order of 0.015 cps, but is a minimum of 4.90 cps real or not?
- We need to know what is the comparison value.
- What is a good “typical” value from which we determine the depression of the neutron count rate?
- We need a way to get a good “average” value of the “typical” region.
- If the depressions are just noise, a histogram of count rates should show a Gaussian distribution.



Histogram of DLD values is skewed to low values

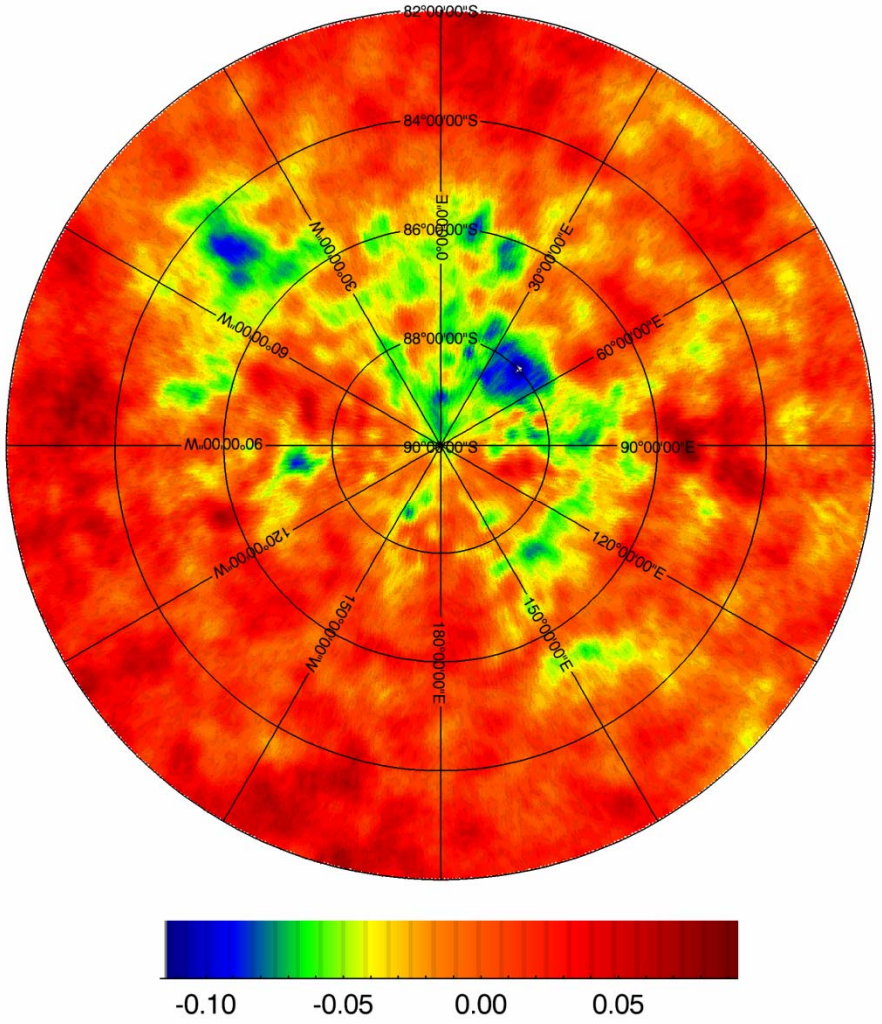


Gaussian fit to high values shows a normal distribution



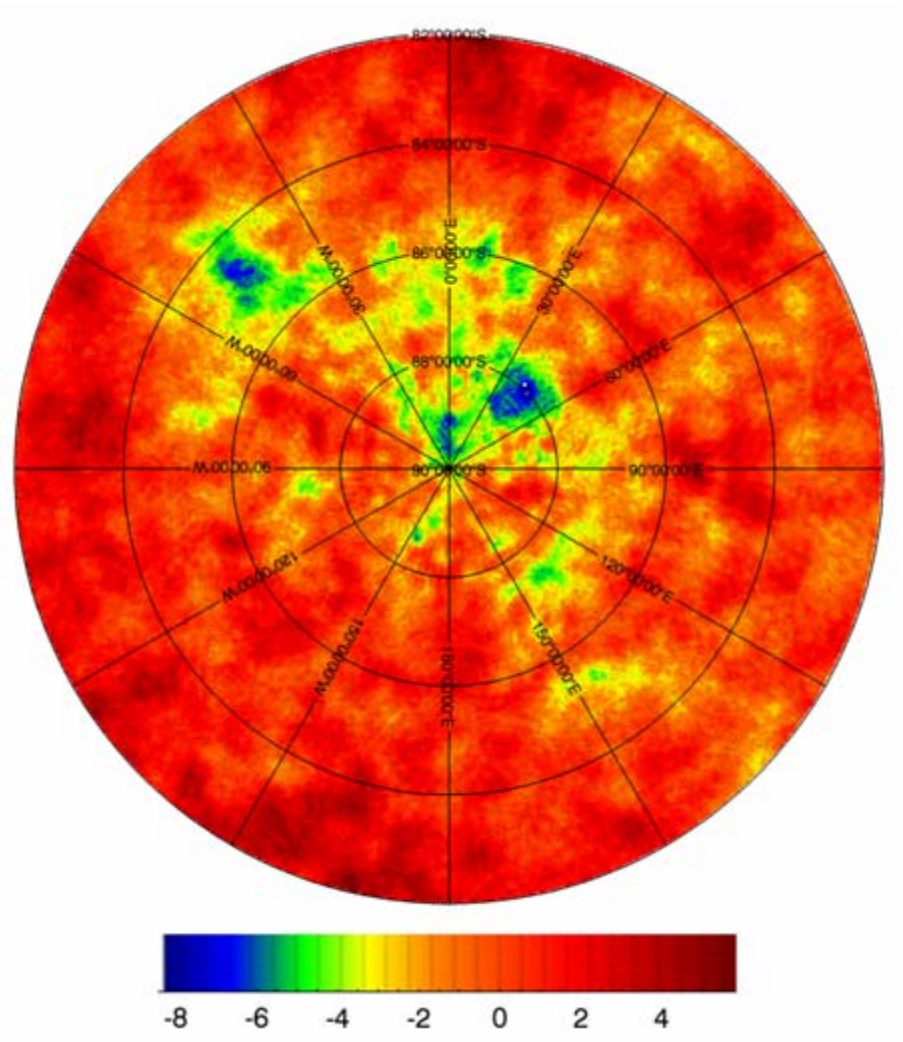
LEND count rate difference map

- By subtracting 4.989 from the earlier map, we can make a count rate difference map
- Now we can ask if the depressions are significant relative to the average typical non-depressed region.
- Since typical uncertainties are on the order of 0.015 cps, a depression of -0.10 is clearly significant (more than 6 σ)



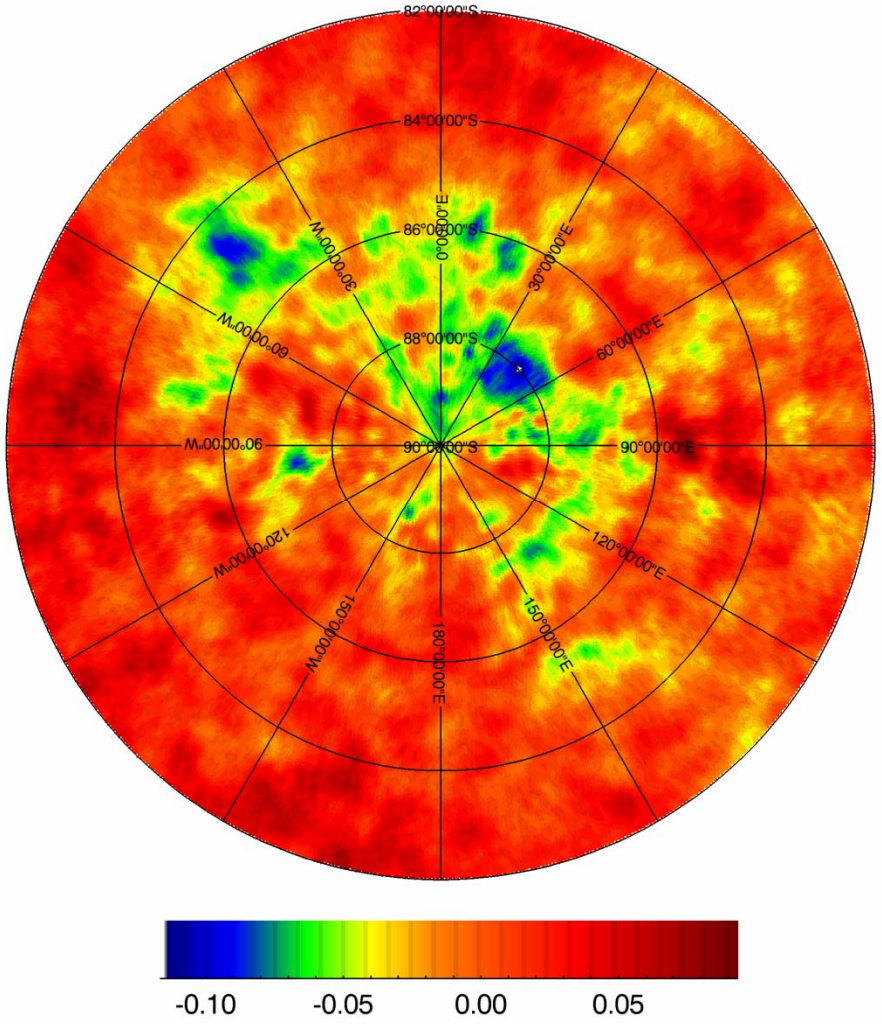
LEND count rate / uncertainty

- Generally values that are 3 σ from the mean are considered significant.
- On this map all green and blue and most of yellow is significant at the 3-σ level.
- Some positive values north of -84° are significant, but represent gradual trend of less H with decreasing latitude.



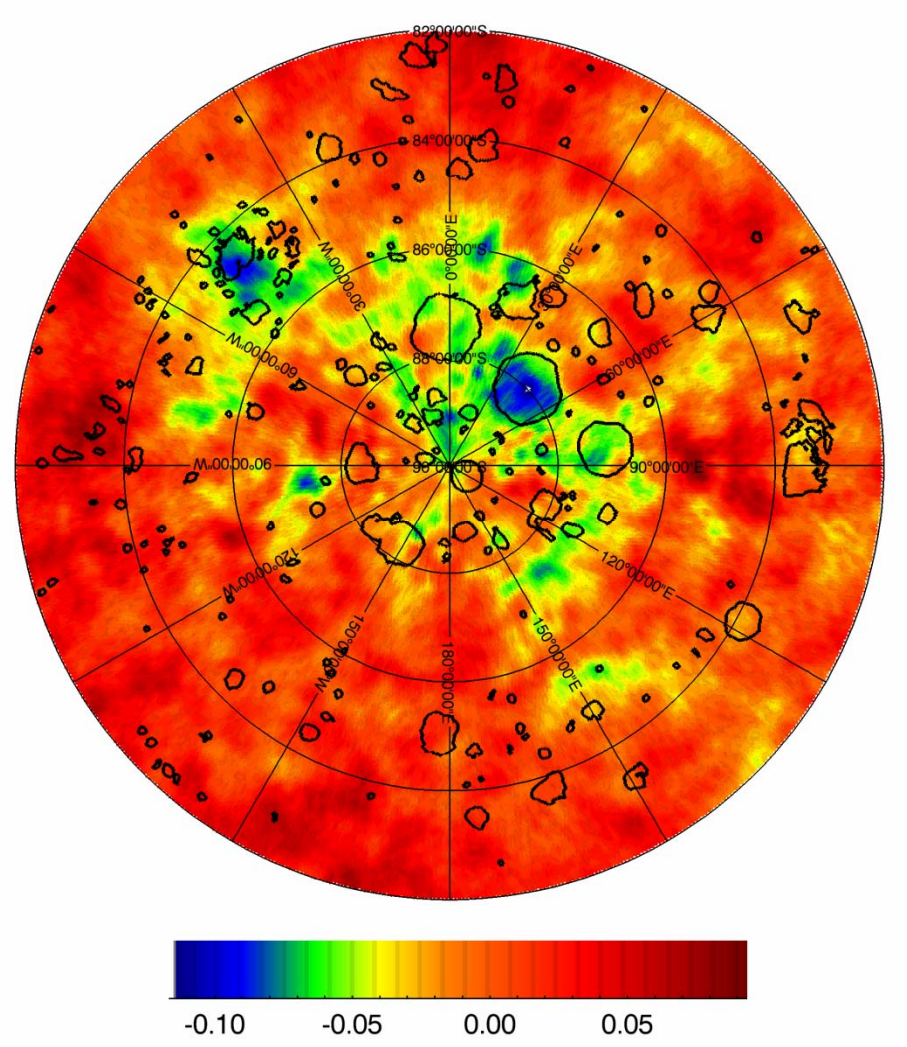
Flux depressions are not noise, but what about PSRs?

- We need to see to what extent the flux depressions are related to the PSRs (permanently shadowed regions).



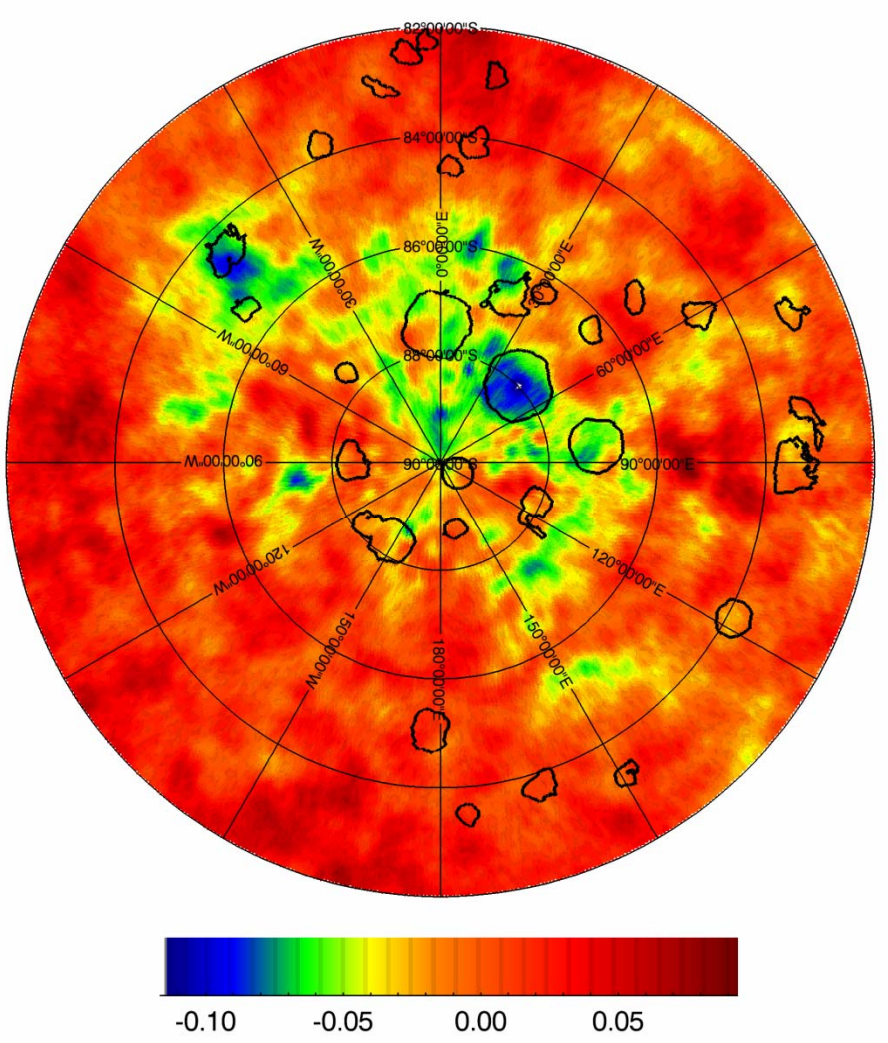
All PSRs > 5 km² in area

- We define a *Neutron Suppressed Region* (NSR) as a region where the neutron flux is suppressed by <0.04 cps and the results are significant at 3 σ or more.
- On this map, all of the blue, green, and much yellow is in NSRs.
- We will compare PSRs with NSRs.
- Many of these PSRs, however, are too small for LEND to see them even if they were enriched in H.



All PSRs > 100 km² in area

- Most of these PSRs are big enough that if they had a significant amount of H enrichment, LEND would see them.
- For most of them there is not even a hint of a count rate depression.
- Two PSRs are associated with NSRs: Shoemaker and Cabeus.
- Shoemaker is virtually identical to the greatest flux depression.
- Cabeus PSR is a little offset from greatest flux depression of nearby NSR.
- What about other PSRs and NSRs.
  - Based on the map, it sure doesn't look like any relationship between them.



Evidence for still a modest relationship between PSRs and NSRs

	All PSR's	Without Cabeus and Shoemaker
% of map that is a PSR	4.9	4.0
% of NSR's that are in PSRs	19.8	8.4
% of map that is an NSR	7.2	7.2
% of PSR's that are in NSRs	29.2	15.0

Summary and final thoughts

- A significant fraction of H-enriched regions are not associated with PSRs.
- A significant fraction of PSRs are not associated with H enrichment.
- Shoemaker and Cabeus are the only exceptions
- This observation suggests a much more complex mechanism for H enrichment.
- Observation of H enrichment in areas of sunshine implies H is buried to some substantial depth.
- H enrichment is mostly in one hemisphere
  - Implications?
- Can’t assume all PSRs are good landing sites for water.
  - Most are not!