CORRELATION OF LUNAR SOUTH POLAR EPITHERMAL NEUTRON MAPS: LUNAR EXPLORATION NEUTRON DETECTOR AND LUNAR PROSPECTOR NEUTRON DETECTOR. T.P. McClanahan[1], I.G. Mitrofanov[2], W.V. Boynton[3], R. Sagdeev[4], J.I. Trombka[1,4], R.D. Starr[1,5], L.G. Evans[1,6], M.L. Litvak[2], G. Chin[1], J. Garvin[1], A. B. Sanin[2], A. Malakhov[2], G.M. Milikh[4], K. Harshman[3], M.J. Finch[3], G. Nandikotkur[4], [1]Space Science Exploration Division, NASA Goddard Space Flight Center, Greenbelt, MD, USA., [2]Institute for Space Research, Moscow, Russia, [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA., [4]Space Physics Department, University of Maryland, College Park, MD, USA, [5]Catholic University, Washington , DC, USA, [6]Computer Sciences Corporation, Glenn Dale, MD, USA..timothy.p.mcclanahan@nasa.gov

Introduction: The Lunar Reconnaissance Orbiter's (LRO), Lunar Exploration Neutron Detector (LEND) was developed to refine the lunar surface hydrogen (H) measurements generated by the Lunar Prospector Neutron Spectrometer [1,2]. LPNS measurements indicated a ~4.6% decrease in polar epithermal fluxes equivalent to (1.5+/-0.8)% H concentration and are direct geochemical evidence indicating water /high H at the poles [3]. Given the similar operational and instrumental objectives of the LEND and LPNS systems, an important science analysis step for LEND is to test correlation with existing research including LPNS measurements. In this analysis, we compare corrected low altitude epithermal rate data from LPNS available via NASA's Planetary Data System (PDS) with calibrated LEND epithermal maps using a cross-correlation technique.

Background: Accumulations of H have long been assumed to occur in permanent shadow regions (PSR)'s in topographic lows near the poles [4]. In these regions, low illumination and temperatures < 100° K are postulated to mitigate H sublimation [5]. Analysis of orbital Clementine UVVIS and earth ground based radar measurements identified numerous small scale PSR's with (< 50 km) diameter [6]. PSR results determined from illumination modeling of digital elevation models (DEM) from Kaguya Laser Altimetry have since confirmed the existence of numerous PSR's > 0.5 km^2 poleward of +/- 85° [7]. LPNS uncollimated footprint is stated to be ~55 km FWHM [8]. Given the areal disparity between the larger LPNS footprint and many PSRs, some localized H concentrations may exceed present LPNS estimates. This possibility is due to the effective blurring incurred by convolving different rate regions within each footprint [9].

To enhance surface signals on LEND, four co-aligned surface pointing epithermal neutron detectors are implemented in a passive neutron collimator, as well as a total of six detectors positioned internal and external to the detector system [10]. These detectors monitor the energy spectrum of low (thermal), medium (epithermal) and high (fast) energy neutrons emitted from the lunar surface and near the spacecraft (background). The collimator contains neutron absorbing materials, ^{10}B and polyethylene to effectively discriminate surface emission positions to within +/- 5.6° of the instrument bore site. From 50 km altitude, this configuration yields a field of view subtending a ~10km diameter surface footprint [10]. LPNS measurements were sampled at 0.05 Hz and corrected for cosmic ray variation and spacecraft spin [11]. LEND samples at a 1 Hz rate and nominally points nadir. A consequence of LEND's collimation and discrimination of surface neutrons is that the LEND integral calibrated count rates, ~5 cps are approximately a factor of four lower than epithermal count rates encountered by LPNS, ~20cps.

Methods: To derive a comparable resolution epithermal count rate maps, corrected low altitude (30+/-15 km) south polar LPNS epithermal samples were mapped using a convolutional approach with 1 km^2 map pixel resolution [-78,-90]° latitude [LPNS PDS]. LEND epithermal maps used south polar (30-50 km) data collected June 30 to November 20, 2009. A circular uniform intensity mapping disc 55 km in diameter is used for both mapping systems, with 1 km^2 pixels approximating the LPNS point spread function (PSF). Each sample's PSF is scaled by the integral epithermal counts detected. The disc is added to the counts accumulation map, centered at the latitude, longitude boresight intersection coordinate at the time of detection. Similarly, an integration time scaled disc is added to the time accumulation map. Counts maps are finally time normalized yielding epithermal emission rate maps of the surface.

LPNS and LEND maps have higher uncertainties towards mid-latitudes due to polar tracking i.e. less accumulated coverage moving off pole. To account for this factor, maps were decomposed as a function of latitude, where map pixel sets **x**, **y** were derived in each 2° latitude band [-78,-90]°. Cross correlation of pixel sets was performed for each latitude band yielding a correlation coefficient, $\rho_{x,y} = \mathrm{cov}(\mathbf{x},\mathbf{y})/\sigma_x\sigma_y$, where cov is the latitude band covariance between maps: $1/|\mathbf{x}| \sum(\mathbf{x}-\mu_x)(\mathbf{y}-\mu_y)$, σ's are pixel standard deviations in each map band.

Results: Figure 1a,b illustrates south pole centered a) LPNS and b) LEND maps [-78:-90]°. Map rate ranges were thresholded as a function of respective mean count rates +/- 3σ. Maps indicate a large quasi-elliptical depression in epithermal rates centered at [-87.6°, 325.8°] lat/lon, principle axis between extents [-81.1°,308.7°], [-86.7°, 104.8°] = 363 km. Map epithermal minima positions indicative of high H concentration occur in both maps in permanent shadow within the Cabeus crater: LPNS[-84.18°, 309.24°, 18.42 cps], LEND[-84.06°, 312.97°, 4.75 cps]. Distance between minima positions ~12 km or 1.2 LEND footprint extents. Epithermal band [-84:-86°], μ, σ = LPNS[19.16, 0.215], LEND[4.94,0.044] respectively. For Cabeus minima differences and significances relative to the -84:-86 band moments: LPNS = [-0.74, -3.44σ], LEND = [-0.18, -4.32σ] indicating statistically significant > 3σ epithermal rate differences in these locations. Importantly, though both maps have been equivalently blurred using the 55km PSF, LEND indicates a more statistically significant minima in this location relative to LPNS. This may infer a higher H concentration than was established with the lower resolution LPNS measurements supporting the LPNS PSR blurring hypothesis.

Figure 2, cross-correlation of map latitude band pixels yields a correlation coefficient, $\rho_{x,y}$. Increasingly positive $\rho_{x,y}$0:1 indicate map pixels that have increasing agreement in map relative intensities vs. latitude band means. $\rho_{x,y}$ ~0 indicate independent or randomly related map pixel intensities. $\rho_{x,y}$ 0:-1 indicates inverse pixel relationship. Results indicate highest correlation near the pole [-88:-90]°, $\rho_{x,y}$ = 0.59 and decreasing moving towards mid-latitudes. This is consistent with the lower coverage and increased uncertainties inherent in both LPNS and LEND maps. Correlation coefficient for the entire map area = 0.47.

References: [1] Chin *et al.* (2007) *Sp. Sci. Rev.*, 129 4, 391-419 [2] Mitrofanov *et al*, (2009) *Astrobiology* #8 4, 793-804 [3] Feldman et al (1999) *Science, 90,* 1151–1154. [4] Maurice *et al*, .[4] Arnold J. (1979) *JGR* #84 5659-5658 [5] Crider *et al* (2003) *Adv. Sp. Res.* #30 8, 1869-1874 [6] Bussey B.J. (2003) *Geo. Phys. Res. Lett.* Vol 30 #6, 1278 [8] Noda *et al*, (2008) *GRL* Vol 35, L24203, [9] Feldman *et al* (1999) *WS on New Views of the Moon* [10] Mitrofanov *et al*, (2010a), *Science*, (in press) [11] Mitrofanov *et al*, (2010b), *Sp.. Sci. Rev.* (in press) [12] Maurice *et al*, (2004), *JGR*, 109 E07S04.

Figure 1a: LPNS epithermal rate map, -78:-90°

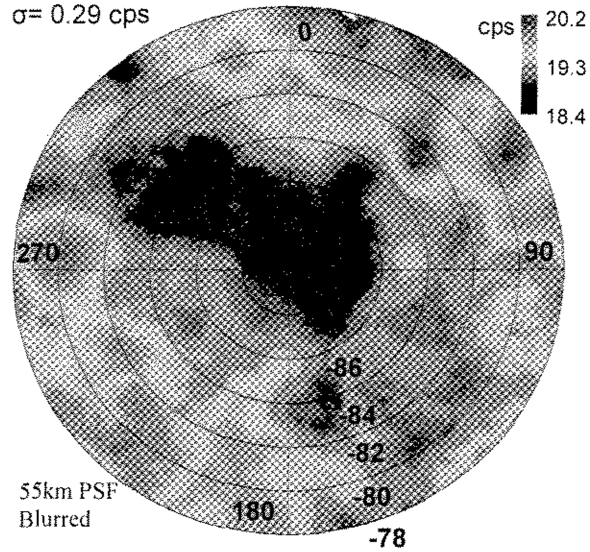
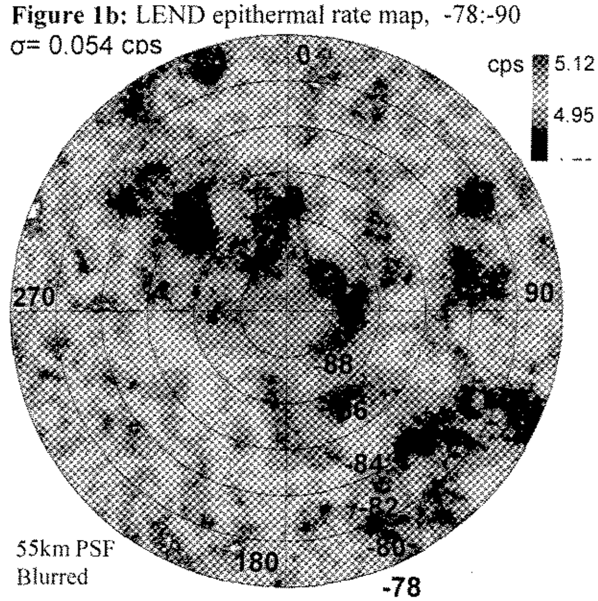


Figure 1b: LEND epithermal rate map, -78:-90



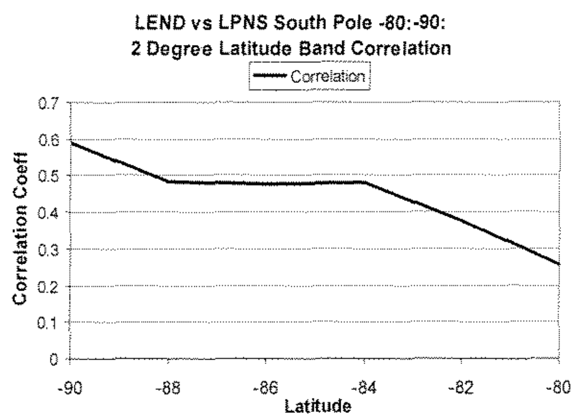


Figure 2:LEND,LPNS map correlation / 2° lat-bands