Global mapping of neutrons from the Moon by LEND instrument onboard LRO M.L. Litvak[1], I. G. Mitrofanov[1], A. B. Sanin[1], W. V. Boynton[2], G. Chin[3], J. B. Garvin[3], D. Golovin[1], G. Droege[2], L. G. Evans[4], K. Harshman[2], A.S. Kozyrev[1], A. Malakhov[1], T. McClanahan[3], G. Milikh[5], M. Mokrousov[1], R. Sagdeev[5], R. Starr[6], J. Trombka[5], [1]**Space Research Institute, RAS, Moscow, 117997, Russia, litvak@mx.iki.rssi.ru,** [2]University of Arizona, Tucson, AZ USA **,** [3]NASA Goddard Space Flight Center, Greenbelt, MD USA, [4]Computer Science Corporation, Greenbelt, MD USA, [5]University of Maryland, College Park, MD USA, [6]Catholic University, Washington DC, USA,

Introduction: The Lunar Exploaration Neutron Detector (LEND) was flown onboard Lunar Reconainsane Orbiter (LRO) to provide global mapping of Moon neutron albedo in different energy ranges and to derive the distribution of hydrogen at the polar regions of the Moon with spatial resolution ~ 10 km [1,2,3].

The observation of the neutron leakage spectrum may provide details about the Moon itself as well as about the space environment. Regional variations of neutron flux in the thermal energy range correlate with concentrations of major and minor soil forming elements (like Fe, Ti, K, Gd, Sm) having large macroscopic absorption cross sections. The intensity of epithermal (neutrons with energies from 0.4 eV up to 100 keV) neutron flux is sensitive to the abundance of hydrogen. Even a small amount (~100 ppm) of H causes significant depression of epithermal neutron flux. Fast neutrons (neutrons with energies from 100 keV up to 15 MeV) can be used to analyze the average composition of lunar regolith via correlation of intensity of fast neutron flux and average atomic mass of the lunar soil.

More than 10 years ago, the first global remote sensing observations were accomplished by Lunar Prospector Neutron Spectrometer (LPNS). LPNS was able to create global maps of lunar thermal, epithermal and fast neutrons [4,5]. LPNS revealed vast polar regions of extended neutron suppression (4-5% lower in comparison with low latitude areas) of epithermal neutrons at both the north and south poles (interpreted presumably as water ice rich areas, [6]). The best spatial resolution of LPNS (~45 km at altitude of 30 km) was too poor to resolve local areas with highest H abundance leaving open the question whether the hydrogen was uniformly distributed within extended suppression territory or localized in permanently shadowed regions. LPNS global maps of thermal and fast neutrons also have shown significant regional variations of neutron flux across the surface closely related with non-homogeneity of soil composition (caused by enhanced abundance of Fe-oxides in mares and South Polar Atkin basin, see for example [4,5]).

LEND is similar to LPNS in the global monitoring of thermal, epithermal and fast neutrons by omni-directional neutron detectors with spatial resolution strongly defined by the altitude but also having the significant additional advantage of being able to measure epithermal neutron flux with much better spatial resolution (at least 5 times better) than was done before [1,2,3]. At an altitude of 50 km LEND's resolution is comparable with the size of large Permanently Shadowed Regions (PSR) providing the possibility to reanalyze polar areas to better localize regions of neutron suppression and hydrogen abundance inside them. LEND latest observations during the more then 1 year of mapping phase allowed to create global maps of Moon neutron flux in different energy ranges with various spatial resolution.

In our analysis we have created LEND global maps showing regional variations of thermal, epithermal and fast neutron fluxes and have compared it with variances of soil elemental composition. The second task of investigation was analysis of signals from different LEND detectors to estimate amplitude of neutron signal measured by LEND collimated sensors and compare it with spacecraft background. Finally, the third task was to compare LEND global mapping with previous results accomplished by Lunar Prospector Neutron Spectrometer (LPNS).

Results: We have presented the latest results of data reduction and analysis of lunar neutron flux measured by the LEND instrument onboard LRO mission. Three energy ranges, thermal (<0.015 eV), epithermal (0.4-100 eV) and fast (>0.7 MeV) have been studied in our analysis.

The largest regional variations of factors of 3-4 are seen in the LEND thermal neutrons map between the mare basaltic terrains on the nearside and highlands on the farside of the Moon. This coincides with results from LPNS data analysis and is explained by significantly higher abundance of iron within the maria (Figure 1).

The variation of epithermal neutron flux across the lunar surface is much smaller (~10%) and most evident in the extended neutron suppression poleward of 70S and 70N, clearly visible in both LEND and LPNS data (Figure 2). In addition to the analysis of global maps based on comparison of data from omni-directional detectors, LEND can map epithermal neutrons with significantly higher spatial resolution than previously reported using counting collimated sensors. The data reduction procedures may be used to remove the fast neutron component of background in the collimated sensors, leaving only the epithermal neutrons recorded in the collimator field of view. The last one was estimated as 1.7 counts per second (from the total counting rate about 5 counts per second). The resulting map reveals new local neutron suppression areas not visible before, associated both with partially sunlit and permanently shadowed areas [7,8].

The fast neutron flux changes by 25% across the lunar surface from maria to the highlands, with the largest value of fast neutron flux observed in mare terrains. This result is consistent with the LPNS argument that mare basalts are rich in iron thus producing more fast neutrons in comparison with Al-rich highlands (Figure 3). The latitude band profile of fast neutron flux does not show significant polar extended neutron suppression effect as observed in the epithermal neutron range. One may distinguish only small areas around poles with neutron suppression less than 1%. This may lead to a model where the hydrogen distribution at the lunar poles, on average is depth dependent with higher weight fraction of H beneath a relatively hydrogen poor regolith.

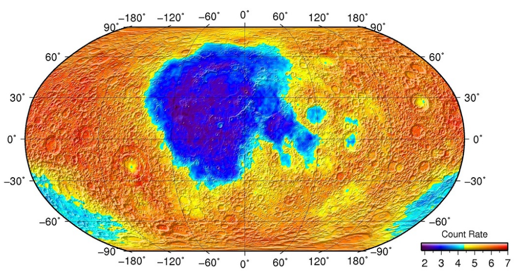

Figure 1. Smoothed map 1°x1° of thermal neutron flux from lunar surface measured as a difference in counting rate between the pair of LEND Doppler detectors.

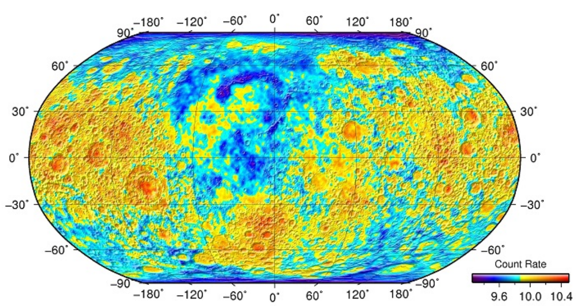

Figure 2. Smoothed map 1°x1° of epithermal neutron counting rate measured by LEND detectors.

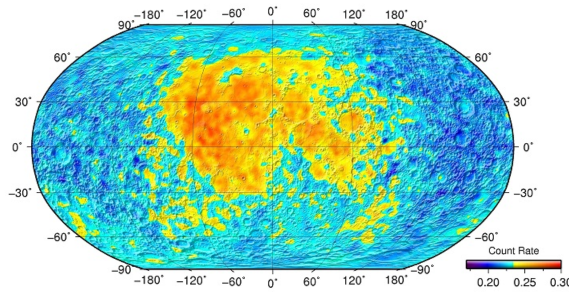

Figure 3. Smoothed map 1°x1° of fast neutron flux from the lunar surface measured by LEND fast neutron sensor.

References:

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