ANALYSIS OF THE SEASONAL VARIATIONS OF THE WATER EQUIVALENT OF HYDROGEN AMOUNT IN THE SUBSURFACE REGOLITH ON MARS BASED ON THE HEND DATA ACCUMULATED DURING FIVE THE MARTIAN YEARS. R. O. Kuzmin [1,2], M. L. Litvak[1], I. G. Mitrofanov[1], E. V. Zabalueva[2], [1] *Space Research Institute, RAS, Moscow, 117997, Russia,* rkuzmin@yahoo.com, [2] *V. I. Vernadsky Institute for Geochemistry and Analytical Chemistry, RAS, Russia.*

Introduction: Global mapping of the neutrons albedo of Mars by the instrument HEND on board of the orbiter Mars Odyssey has been continued for more than the five Martian years. Such a long period of the observations not only let us study the seasonal variations of the water amount in a surface regolith during seasonal cycle, but also compare a seasonal cycles of different years. The main goal of our work was analysis of the water seasonal variations within the subsurface regolith in the middle latitudes of Mars. For the analysis we used the multiyear HEND observations of the fast and the epithermal neutrons fluxes with different energy ranges (2.5-10 MeV, 1-2.5 MeV, 10 eV-1 MeV, 10 eV-10 keV, and 0.4 eV-1 keV). As the neutrons of each energy range are characterized by definite generation depth, it is possible to estimate the water equivalent of the Hydrogen (WEH) amount at different depths of the surficial regolith.

Methodology: In our analysis of the seasonal variations we have estimated the WEH amount in subsurface regolith in the latitude belt 30ºN-50ºN which is located outside of seasonal polar cap caver composed from CO_2 snow. To exclude the influence of both Galactic Cosmic Rays (GCR) variations and seasonal variations of the Martian atmosphere thickness, it is necessary to conduct normalization of the measured neutrons fluxes. For the normalization procedure the equatorial belt (0º-10ºN by latitude and 120ºE-240ºE by longitude) has been chosen. Likely to the studied latitude belt, the equatorial belt is characterized by similar both atmosphere thickness and its relative oscillations from one season to other. The Martian seasonal cycle has been divided on 24 intervals (by length in 15º L_s) and the neutrons flux in each of the intervals has been normalized to the averaged neutrons flux measured in the equatorial belt.

Analysis of seasonal plots of the normalized fast neutrons fluxes (measured in each of the five Martian years) shows that local variations of the neutrons flux may be as large as 10-15%. At that, the plots (averaged over all five years of observations) show systematic deficit of the fast neutrons (~7% and ~10% for neutrons with energy 1-2.5 MeV and 2.5-10 MeV respectively) during autumn-winter period in the northern hemisphere. Such effect is most likely related with redistribution of atmospheric water from the southern hemisphere to the northern one in the season with succeeding condensation and accumulation of the water in subsurface regolith layer. To estimate the effect's value, we have used data of numeric modeling of instrument HEND and converted related variations of the neutrons flux to relative variations of the WEH amount. For the estimation of the WEH amount absolute value we have used content of water in the equatorial belt region derived from Gamma-Ray-Spectrometer (GRS) measurements on board of the Mars Odyssey orbiter [1]. The value of the water absolute content in the region is equal to ~4.7%. We may collate measured values with numeric calculations and determine the water content in the studied latitude belt using following expression:

$Flux_{30°N50°N}/Flux_{norm}=F_{num}(W\%)/F_{num}(4.7\%)$,

where $Flux_{30°N50°N}$ and $Flux_{norm}$ – measured values in the latitude belt 30ºN-50ºN and the equatorial belt (used for the normalization); F_{num} is taken from numerical calculations, W – is unknown value of the water content. The amounts of the WEH, received by such method, are shown on the fig.1 as the individual plots of a seasonal water contents for each Martian year of observations and averaged one over all five years.

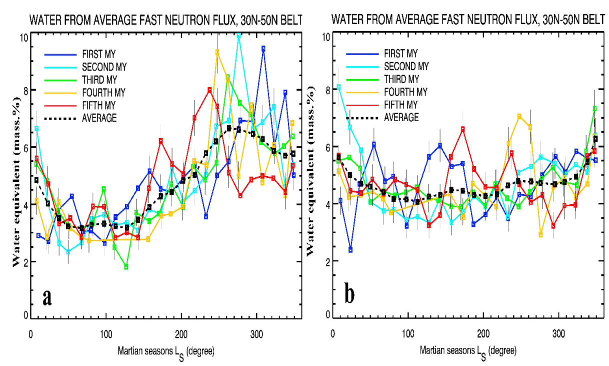

Figure 1. *Plots of seasonal variations of WEH amount in subsurfacel soil layer of Mars for different years of observations estimated based on mapping data of the fast neutrons with the energy 2.5-10 MeV (a) and 1-2.5 MeV (b). Dotted line shows plots averaged over all five the Martian years.*

For more detailed study of dependence of seasonal variations of the WEH amount in the Martian soil versus depth, we have also analyzed the HEND data gathered by the detectors SD, MD and LD (which are sensitive to the different energy ranges of epithermal neutrons). It gives us possibility to study effect of seasonal variations of subsurface water st different depths. The studied latitude belt is characterized by a sufficiently high amount of the physically and chemically bonded water in the subsurface soil layer [1,2] with maximum amount in 10-15 mass.%. Therefore in our analysis we have considered a simple model of two-layer soil – upper dry layer with the water amount 2 mass.% and lower wet layer with water amount 15 mass.%. By using numerical modeling, we have changed the depth location of lower layer and inspected how measured signal has been changed in each of the detectors. It has been found that when the location of the wet layer is close to the surface the neutrons flux decreases essentially. At consecutive increasing of the wet layer depth the neutrons flux is increasing and it approaches the saturation on the depth > 1 m. In the case of the detector LD (detects the neutrons in the energy range 10eV-1MeV) the leakage neutrons flux is close to the saturation level of 95% at depths approaching to the ~50 cm, while in the case of the detectors SD and MD (detect the neutrons with energy < 10keV) it is happen at the depths > 60 cm only.

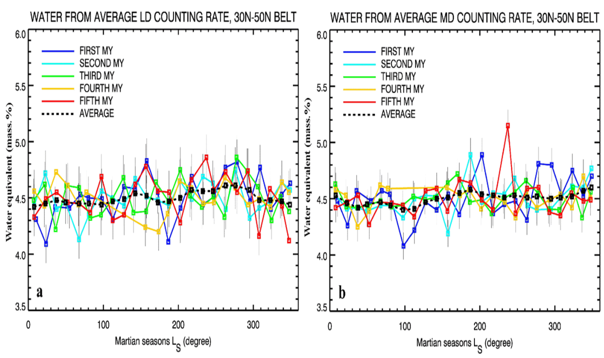

Figure 2. *Plots of seasonal variations of the WEH amount in subsurface soil layer of Mars for different years of observations estimated based on the data from the detector LD (a) and MD (b). Dotted line shows seasonal variations of the WEH amount averaged over all five years of observations.*

Results: As well seen from the fig.1, the average increasing of the WEH amount (averaged over all the five Martian years) for autumn-winter season approaches 3.5 mass.% (in the soil layer with thickness ~20 cm, corresponds to the neutrons measured in the energy range 2.5-10 MeV) and 2 mass.% (in the soil layer with thickness ~40 cm, corresponds to the neutrons measured in the energy range 1-2.5 MeV). Averaging of the WEH amount over all five years (based on the data from the detectors SD and MD) shows that the WEH amount during the seasonal cycle is relatively stable at the depths > 60 cm. Based on the data from the detector LD (fig.2), the averaged wintertime increasing of the WEH amount approaches up to 0.3 mass.% at the depth of 50 cm. Following to the results of conducted analysis, the most significant seasonal variations of the WEH amount in the studied latitude belt (30ºN-50ºN) are related with subsurface regolith layer with ~20 cm of thickness (see fig.3). With increasing of a regolith depth the seasonal variations of the WEH amount are becoming weaker and die down completely at the depths > 60 cm.

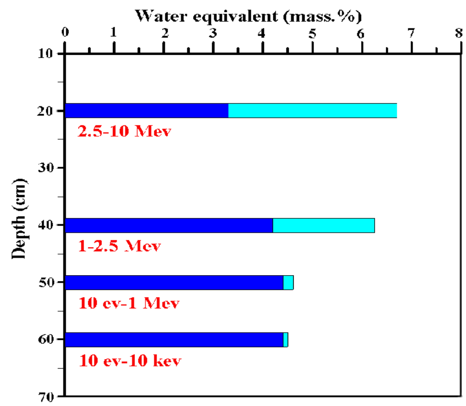

Figure 3. *The values of the WEH amount in summertime (dark blue) and the increasing values of the WEH amount in wintertime (blue) versus the depth. The energy ranges of measured neutrons are shown by red.*

References: **[1]** Boynton W.V. et al., *J. Geophys. Res.* 2007. V. 112. № E12. **[2]** Mitrofanov, I. G. et al.,*Solar Syst. Res.* 38, 253–65, 2004.