NEUTRON SPECTROSCOPY OF MARS ONBOARD MARS ODYSSEY: 1.5 MARTIAN YEARS OF OBSERVATIONS FROM HIGH ENERGY NEUTRON DETECTOR. M. L. Litvak[1], I. G. Mitrofanov[1], A.S. Kozyrev[1], A.B. Sanin[1], W. Boynton[2], C. Shinohara[2], D. Hamara[2], R. S. Saunders[3]; [1]Institute for Space Research, RAS, Moscow, 117997, Russia; [2]University of Arizona, Tucson, AZ 85721, USA; [3]Jet Propulsion Laboratory, Pasadena, CA 91109, USA.

Abstract. More then 2 years ago 2001 Mars Odyssey spacecraft was inserted into circular orbit around Mars and global mapping of planet in neutrons (HEND, NS), gamma-rays (GRS), visible and infrared bands (THEMIS) was started. It was first attempt to use neutron spectroscopy of Mars to get new information about structure and composition of planet's subsurface. In this study we pay attention to the distribution of water in polar and equatorial regions of Mars, estimation of mass and density of CO_2 frost, annual variations in Mars's seasonal cycle. All these results are based on deconvolution of observational data of orbital neutron flux registered by Russian High Energy Neutron Spectrometer (HEND).

Observations. The High Energy Neutron Detector (HEND) is part of the Gamma-Ray Spectrometer (GRS) on the Mars Odyssey Mission. HEND has three ^{3}He proportional counters for measuring epithermal neutrons in broad energy range from 0.4 eV up to 100 keV and organic scintillator for measuring fast neutrons with energy more then 1 MeV [1,2]. Basically the whole strategy of HEND observations may be divided into two independents ways: observation of summer surface (CO_2 frost free) and observation of seasonal changes cuased by redistribution of atmospheric CO_2 between martian poles.

Data analysis. The analysis of the summer data allows to deconvolve distribution of water ice and chemically bounded water in martian subsurface. To do it we have used model dependent technique based on numerical simulation of orbital flux and suggestion the model of martian regolith. In this analysis we applied two different structure models of martian soil: homogeneous model and double layered model. According the first one the water ice/chemically bounded water is homogeneously distributed trough the subsurface. The single parameter of the model is a varied content of water. The second regolith model consists of the water ice layer which is placed beneath dry layer with small content of water. This model is described by two free parameters (thickness of dry layer and content of water in the bottom layer). The special fitting procedure was created and tested to find best correspondence between real data and model parameters. It was found that northern polar regions may be described by homogenous model [3]. On fig 1 we present distribution of water ice in this region. On the contrary, HEND data processing showed that southern polar regions are not compatible with homogeneous model and requires the double layered model of regolith [3]. On fig 2 and fig 3 we present distribution of water ice in these regions.

In addition to water ice rich polar territories HEND observations also revealed equatorial regions (Arabia Terra and Memnonia) with significant abundance of water. The estimation of water content in Arabia shows that its average percantage may be equal to ~ 10% by weight. But there are particular moisture spots where content of water may be found as high as 16% (see Fig 4). It is close or even higher than upper limit of chemically bounded water extracted from geochemistry. So the question what we see at Arabia Terra - chemically bounded water or remnants of water ice is still open.

It was also found that neutron flux depends on the seasonal changes of martian climate. The neutron flux (registered above the polar regions of planet) increases up to 10 times during the polar winter and drops back at the summer time. The model processing of HEND data allows to estimate column density (g/cm^2) of CO_2 frost for given seasonal interval and create 4-dimensional model of seasonal deposit. By help this model we may follow the dynamics of CO_2 thickness at different parts of seasonal caps [4,5]. The estimation of CO_2 frost column density is a direct way to get mass of seasonal deposit. It may be estimated as production of column density C_d, g/cm^2 to surface area S, cm^2 covered by CO_2 frost. On fig 5 we present results of such estimation.

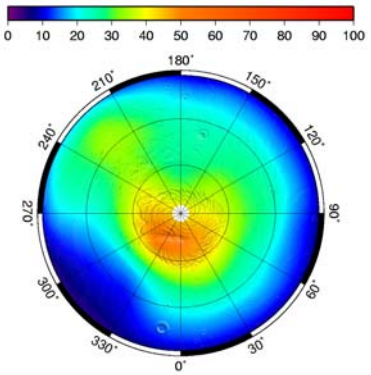

Fig 1. The distribution of the water-ice content (mass %) over the northern "ice permafrost" region (according to the homogeneous model)

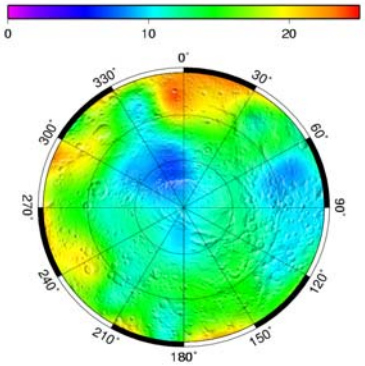

Fig 2. The distribution of the surficial density of the upper dry layer (g/cm^2) in the southern ice permafrost region on Mars according to the two-layer model

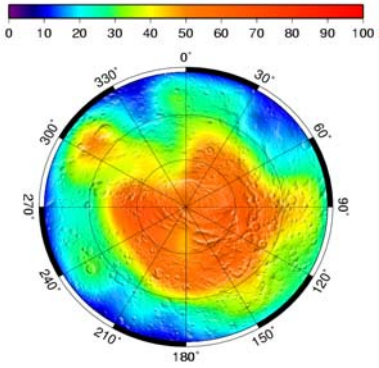

Fig 3. The distribution of the water-ice content (mass %) over the southern "ice permafrost" region on Mars according to the two-layer model

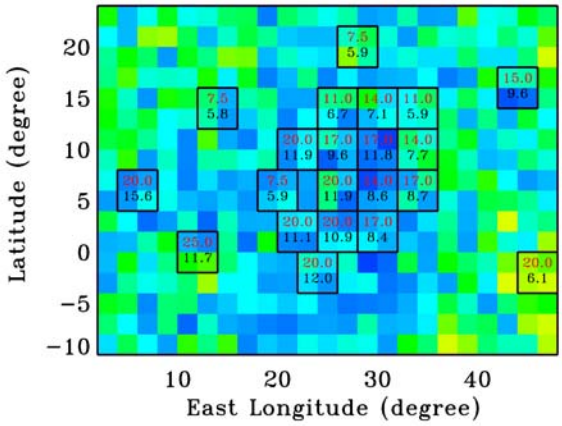

Fig 4. The estimations of water content (mass %, digits shown by black color) and surficial density of the upper dry layer (g/cm^2, digits shown by red color) for selected regions (black frames). These estimations are drawn above a map of epithermal neutron flux in Arabia Terra. The blue and cayan pixels corresponds to regions with significant abundance of subsurface water (>7-8%). The yellow and green pixels corresponds to relative dry regions (<6%).

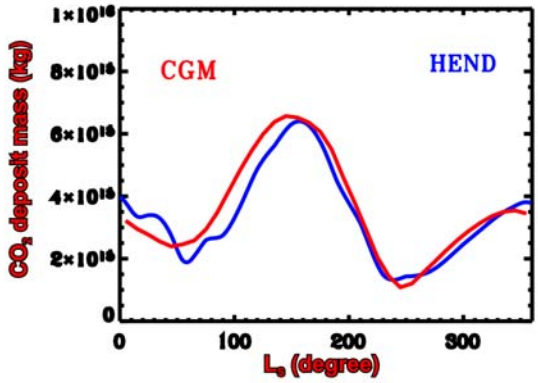

Fig 5. The estimations of total condensed mass by General Circulation Model (red line) and by HEND data processing (blue line).

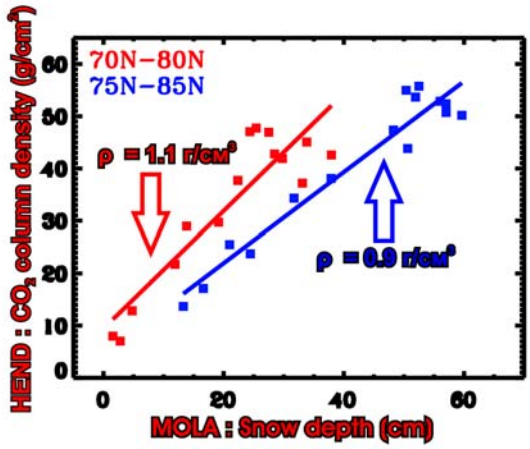

Fig 6. The estimations of volume density from comparative analysis between HEND and MOLA data.

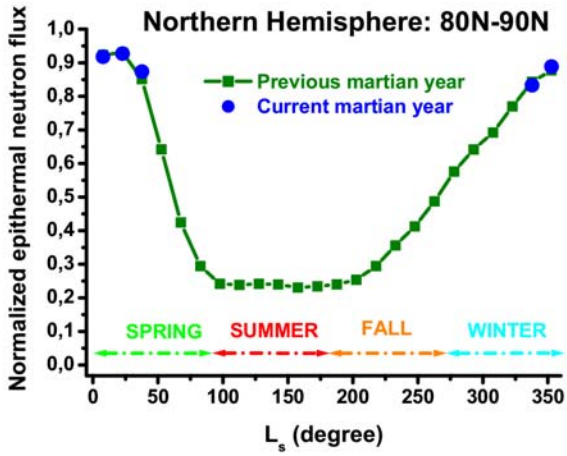

Fig 7. Seasonal variations of neutron flux observed in northern hemisphere for two successive martian years.

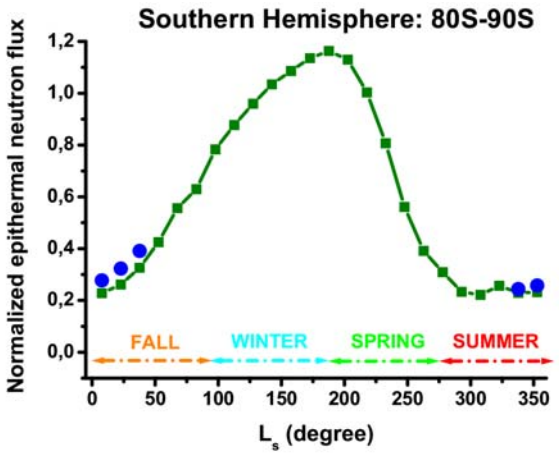

Fig 8. Seasonal variations of neutron flux observed in northern hemisphere for two successive martian years.

Another important result which should be evaluated from 4-dimensional model of CO_2 frost concerns the estimation of volume density (g/cm^3) of seasonal deposit. The comparative analysis between HEND CO_2 column density and linear thickness of CO_2 frost estimated by MOLA/MGS [6] give us possibility to calculate the volume density of CO_2 deposit. The first step in this direction has already done and preliminary estimations of CO_2 density at northern polar latitudes are found (see Fig 6).

The continuous observation of Mars in HEND experiment lasts more than 1 martian year that allows searching annual variations of martian seasonal cycle. The first results of such study presented at figures 7,8. It is seen that northern seasonal curves repeat the seasonal variations founded for previous martian year. On south the situation is a bit different and significant differences between seasonal curves obtained for two successive martian year are observed.

References: 1) Mitrofanov et al., Science, 297, 2002, 78-81. 2) Mitrofanov et al., Solar System Research, 5, 366-377, 2003 3) Mitrofanov et al., Solar System Research, 4, 253-257, 2004 4) Litvak et al. Solar System Research, 5, 378-386, 2003, 5) Litval et al., Solar System Research, 3, 167-177, 2004. 6) Smith et al., 2001, Science, 294 , 2141–2146 2001.