EPSC Abstracts
Vol. 5, EPSC2010-555, 2010
European Planetary Science Congress 2010

Variations of the water ice and the bound water in the surficial soil layer of the Martian seasonal permafrost

R.O. Kuzmin (1, 2), E.V. Zabalueva (1), P.H. Christensen (3), N.A. Evdokimova (2), M.L. Litvak (2), I.G. Mitrofanov (2)
(1)Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, 19 Kosygin str., Moscow 119991, Russia (rok@geokhi.ru), (2) Space Research Institute, Russian Academy of Sciences, Profsoyuznaya str. 84/32, Moscow, 117810, Russia; (3) School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, USA

1. Introduction

The particularities of the seasonal variations of both the water ice and the bound water in the surficial layer of the Martian regolith (outside of the seasonal polar caps) represents one of the key objectives for understanding of the modern water cycle on Mars. The variations are provoked by the processes condensation/sublimation of the H_2O-ice and hydration/dehydration of the salts minerals in the surface regolith under influence of seasonally changeable surface temperatures, atmospheric humidity and a relative humidity in the surficial layer of the soil. The processes directly related with the seasonal permafrost (SP) layer which is forming in the surficial regolith during the autumn-winter period [1]. In the work we reports the mapping results of the wintertime amounts of the H_2O-ice and the bound water (BW) amounts variations in the surficial soil layer of the SP in the northern hemisphere of Mars. The results were received on the basis of the TES, the HEND and the OMEGA instruments data analysis.

2. TES and OMEGA observations

The TES data were used for mapping of the H_2O-ice amount within surficial layer of the SP (based on the thermal inertia data (TI)) and the bound water distribution (based on the 6.1 μm index) during the winter season (Ls=300°-310°). The OMEGA data were used for mapping of both the H_2O-ice on the surface (1.5 μm band index) and the bound water distribution (1.93 μm band index) during winter time in the Northern hemisphere of Mars. As it was shown recently [2,], the strong increase of the thermal inertia of the Martian soil during the winter season in the area adjoining to the edge of the seasonal polar caps is indicative on the increase of the H_2O-ice amount in the surface layer (equal to daily thermal skin depth in 2-10 cm) due to formation of the SP layer. Comparison of the mapping results shown that the most intensive hydration process on the Martian surface takes place closely to the latitude belt with the high concentration of the temporally stable H_2O-ice within surficial soil of the SP (see fig.1 and 2).

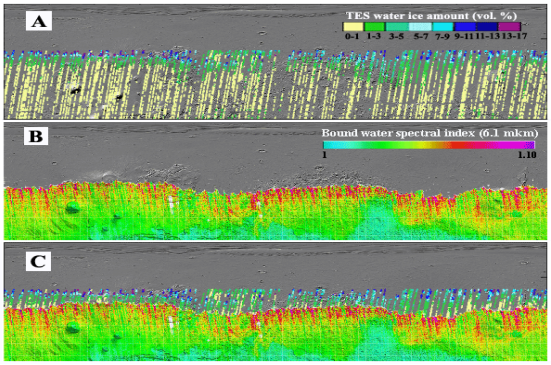

Figure 1: The maps of both the wintertime water ice amount (vol. %) in the surficial layer of the Martian soil (A) and the 6.1 μm bound water index areal distribution (B) derived from TES data. C – Combination of both maps (A+B).

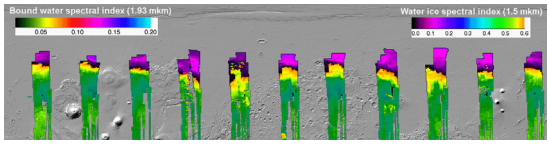

Figure 2: The map of both the water ice index (1.93 μm) and bound water index (1.5 μm) on the surface of Mars in the winter season (Ls=300°-320°), derived from the OMEGA data.

Such relationship maybe provoked by appearance in the surface soil of the temporally stable water ice which assists to the water vapor saturation conditions that intensifies the hydration process of the salts minerals in the soil. In the direction to lower latitudes (with decreasing of the H_2O-ice amount in the soil) the BW spectral index values are becoming gradually lower. Recent experimental studies of the $MgSO_4$-H_2O system at low temperatures [3] show that at the existence of ice, low surface temperatures, and the

high sulfate content of surface soil on Mars such magnesium sulfate phase as $MgSO_4 \cdot 11H_2O$ may represent a possible mineral species near the surface at high latitudes or elsewhere in the subsurface. At that, the phase boundary for epsomite - $MgSO_4 \cdot 11H_2O$ at the temperature < 220K exist at the relative humidity range 27-50% [3], being parallel to kieserite-epsomite dehydration boundary. We suppose that the zone with the highest values of the 6.1 μm bound water index (seen on the figure 1b) is related with appearance of the phase $MgSO_4 \cdot 11H_2O$ in the immediate proximity to the latitude zone with water ice-reached soil (seen on the figure 1a).

3. HEND observations

The seasonal variations of the water equivalent content in the Martian soil (water ice + bound water) within the thicker surface layer of SP (up to depth 20-30 cm) we analysed based on the HEND fast neutrons flux data (with energy range 2.5-10 Mev (FN2)) collected during the third Martian years of the observations. To convert the mapped variations of fast neutrons flux (normalized to the flux observed above Solis Planum area - the driest place with minimal water content ~2 wt. %) we did numerical simulations based on MCNPX program [4], taking into account soil composition of major soil forming elements (derived from Mars Pathfinder and MER data [5, 6]) and atmosphere thickness as a function of place and the Martian seasons (taken from Ames General Circulation Model [7]). Best correspondence between data and simulations gave us best estimation of water content. We found that distribution of the water equivalent content in the surficial layer of the SP shows notable seasonal differences (figure 3a). During the winter the water equivalent in the surface soil on the latitudes 30° N is becoming higher than during the summer on ~7 wt. % and on the latitude 55°-60°N – on 17-20 wt. %.. If the averaged wintertime TES H_2O-ice amount in the soil layer (in 2-10 cm) to add to the averaged summertime HEND water equivalent in the soil layer (in 20-30 cm), we will receive the amount of the water that is almost equal to the amount of the HEND water equivalent, accumulated during the winter season (see the figure 3b). This is means that the HEND fast neutrons flux is quite well sensitive to the wintertime increase of the water ice in the shallower surface soil layer (thickness 2-10 cm), derived from the TES TI data.

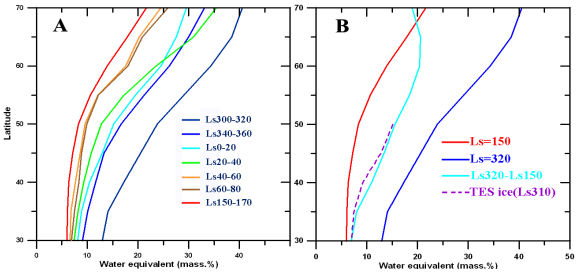

Figure 3: A – Seasonal dynamics of the HEND water equivalent amount (mass %) in the surface soil layer (thickness ~20-30 cm) versus the latitude. B -The HEND water equivalent amount in the surface soil layer versus the latitude for summer (red) and winter (dark blue) seasons the water equivalent amount accumulated during the winter season (blue). The sum of the TES wintertime water ice amount with the summertime HEND water equivalent amount is shown by dotted line.

6. Summary

The joint analysis of the TES, HEND and OMEGA data demonstrates the existence of the strong seasonal effect of the H_2O-ice amount (as well as the bound water) variations in the surficial soil of SP. The potential wintertime amount of the water ice within surface layer (2-10 cm) of the SP is quite significant and approaches in average 4-7 vol. % on the latitude 45°-50°N and 1-2 vol. % on the latitude 30°-35°N. In the deeper surface soil layer of the SP (20-30 cm) the seasonal variations of the water equivalent amount are larger. The zonally averaged water equivalent amount during the winter on the latitudes 30°N is higher than during the summer on ~7 wt. % and on the latitude 55°-60°N – on 17-20 wt. %. In winter season the portion of the H_2O-ice accumulation in the HEND water equivalent amount approaches 25% on the latitudes 30°-35°N and 50% on the latitude 40°-50°N.

Acknowledgments:
This study was supported by the Russian Foundation for Basic Research (project № 10-2-00464-a)

References:

[1] Kuzmin R.O. et al., *Solar System Reseach*, 3, 1, 1-11, 2004; [2] Kuzmin R.O. et al., *JGR,* 114, E04011, 2009; [3] Peterson R.C. and R. Wang, *Geology*, 34, 11, 957-960, 2006; [4] Waters, L.S., MCNPX User's Guide (document LA-UR-99-6058). Los Alamos National Laboratory, 1999; [5] Foley C.N. et al., *JGR,* 108, E12, ROV 37-1 through 37-21, 2003; [6] Brückner J.G. et al., *JGR*, 108, E12,ROV 35-1, through 35-18; [7] Haberle, R.M., et al., *JGR*, 98, E2, 3093-3123, 1993.