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Seasonal redistribution of the water ice in the surficial soil layer of Mars

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Introduction: The character of the seasonal redistribution of the water ice in the surface layer of the Martian regolith outside of the seasonal polar caps represents one of the key objectives for understanding the modern water cycle on Mars.

The potential formation of a seasonal subsurface ice layer on Mars (seasonal permafrost) to latitudes of ~30° in both hemispheres was proposed on the basis of theoretical considerations [1, 2]. In the work we report the results of determination of the seasonal permafrost (SP) external boundaries and the estimation and mapping of the water ice content within the surficial soil layer of the SP. The results were received on the basis of the TES and HEND data analysis.

TES observations: To define the order of the winter-time increase of the water ice within the Martian surface layer corresponding to the daily thermal skin depth (2-10 cm in thickness) we compared the difference between the TI values mapped separately for the N-summer- (Ls=120°-150°) and the N-winter (Ls=300°-310°) in the latitude range ±50° out of the seasonal CO_2 ice cover. The water ice volume part was estimated for all coincided summer and winter TES TI surface footprints by solving of the quadratic equation, received at inclusion of the thermal parameters for two-component mixture (soil+ice) into formula of thermal inertia [3]. The estimated wintertime amount of the water ice in the Martian soil was globally mapped within the latitude belt ±50° (Fig. 1a). As it well seen from Figure 1a, the notable asymmetry of the SP in both Martian hemispheres can be observed on the basis of the areal distribution of the water ice amount >1vol %: the distribution area is broader in the northern hemisphere than in the southern one. This asymmetry is seen especially distinctively on the plot of the zonally averaged water ice amount versus latitude (Fig.1b): the values of the water ice amount in the surface soil on the latitude 40°-50°N approaches the 2-6.5 vol. % while on the latitude 40°-50° S only 1-4 vol. % . We suggest that the external boundary of the area with the mapped water ice amount >1 vol. % (in both hemispheres) represents the external boundary of the SP on Mars.

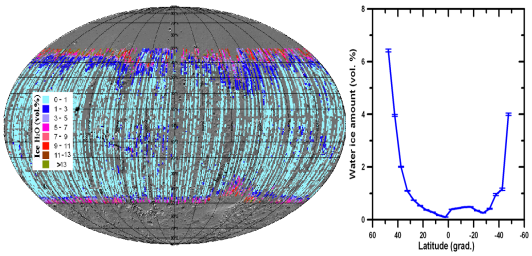

Fig.1. *a-The map of the wintertime water ice increase in the surficial layer of the Martian soil in both hemispheres in the latitude range ±50° derived from TES TI data; b- zonally averaged (in the 5° latitude belt) water ice amount versus latitude.*

To understand how the TES TI is sensitive to the water condensation and sublimation processes around the edge of the retreating Northern seasonal polar cap, we analyzed temporal and spatial changes of the parameter during the period from Ls=340° to Ls=70° through the time interval in the 20°Ls [4]. The mapped TI values were compared with their summer-time values. We found that very distinct annulus (5°-7° in the width) of the high TI (HTI) arises around the cap's edge at each stage of the seasonal cap recession (Fig.2). Besides, the HTI annulus moves in the northern direction on the ~4°-6° in the Ls range ~20°. With each next stage of the seasonal polar cap recession the area of the previous HTI annulus disappears completely during indicated Ls range and the values of the thermal inertia within the area are decreased subsequently, approaching to the summer-time values. The water ice amount in the surface soil layer (thickness 2-10 cm) within

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the HTI annulus was estimated by the same method as for the estimation of the winter-time increase of water ice [3] in the surface soil outside of the seasonal CO_2 ice caps. The average water

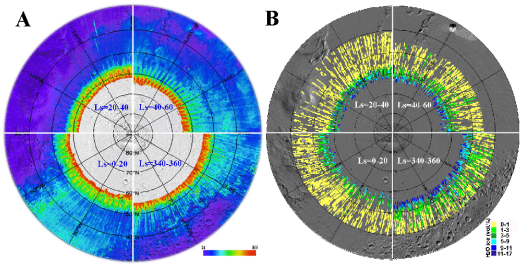

Fig.2 *The HTI annuluses around the Northern seasonal polar cap during different stages of the cap's retreat (a) and the water ice amount (vol. %) in the surface soil within the HTI annulus derived from the TES TI data.*

ice amount in the surface soil layer within the 5°-width HTI annulus varies from 5 to 7 vol. %. We suppose that the mapped HTI annulus represents the remnant of the sublimating SP layer exposing from under the recessing CO_2 ice cap.

HEND observations: The seasonal variations of the water ice amount within thicker surface layer of the SP (up to depth 20-30 cm), we analyzed based on the HEND fast neutrons flux data (with energy range 2.5-10 Mev (FN2)) collected during the first Martian years of the observations [5]. We found that distribution of the water equivalent content in the surface soil (corresponding to the mapped normalized fast neutrons flux) shows notable seasonal differences (Fig.3): during the winter the water equivalent in the surface soil on the latitudes > 40° N,S is higher than during the summer (on 2-7 wt.%).

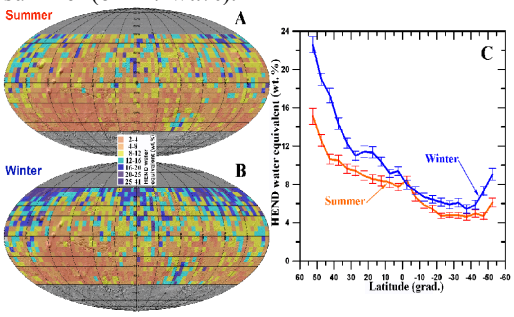

Fig.3. *The maps of the summer- (a) and the wintertime (b) water equivalent (wt.%) in the surface soil layer (with thickness 20-30 cm) derived from HEND fast neutrons flux (FN2) data; c- zonally averaged (in the 5° latitude belt) water equivalent versus latitude for the summer and winter seasons. Vertical bars – mean error.*

Observing difference 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 [3]. Besides, the picture of the winter-time water equivalent distribution (in both hemispheres) has visible similarity with one of the winter-time distribution of the water ice derived from the TES TI data (see Fig.1a). Mapping results show that the latitudinal trend of the zonally averaged difference values between the winter and the summer the HEND water equivalent in the surface soil is very similar with one of the zonally averaged values of the TES water ice amount (Fig.4).

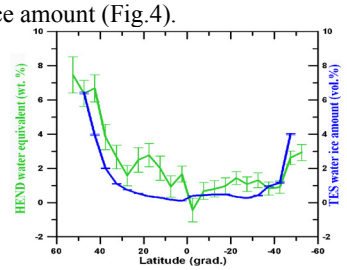

Fig.4. *Zonally averaged (in the 5° latitude belt) both the HEND water equivalent difference (green) between the winter and summer seasons and wintertime water ice increase in the surficial soil (blue) derived from TES TI data. Vertical bars – mean error.*

Conclusion: The joint analysis of the TES, HEND data demonstrates the existence of the strong seasonal effect of the water ice amount variations in the surficial soil layer thickness from the 2-10 cm up to 20-30 cm. The potential wintertime amount of the water ice within surface layer of the SP is quite significant and approaches in average 4-6.5 vol. % on the latitude 40°-50°N and 1-4 vol. % on the latitude 40°-50°S. The average water ice amount in the surface soil of the SP remnant layer (exposing from under the recessing CO_2 ice cap) varies from 5 to 7 vol. % on the latitude > 50°N. In according with our results the Northern and the Southern hemispheres are characterized by distinctive asymmetry of the SP area on the basis of the water ice amount distribution in the surface soil layer and the extent of its external boundaries.

References: [1] Farmer C.B. and Doms P.E., (1979) *JGR,* 84, 2881-2888; [2] Schorghofer N. and Aharonson O., (2005) *JGR,*110, E05003; [3] Kuzmin R.O. et al., (2009) *JGR,* 114, E04011; [4] Kuzmin R.O. et al., (2009) *LPSC XXXX,* #1917; [5] Litvak M.L. et al., (2007), *Solar System Reseach,* 41, 385-397.