ESTIMATION AND MAPPING OF THE WINTER-TIME INCREASE OF THE WATER ICE AMOUNT IN THE MARTIAN SURFACE SOIL BASED ON THE TES TI SEASONAL VARIATIONS ANALYSIS.
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Introduction: Since the surface materials on Mars in the current period are characterized regionally by both unchanged structure and a chemical composition, their thermal inertia values may to be changeable mostly due to influence of two climatic factors: at the high atmospheric dust opacity (resulted to reduction of the surface temperature amplitude) and at increase of the thermal conductivity values due to appearance of the water ice (or frost) in the soil porosity volume during winter. Investigation of the second factor represents important step for understanding of the seasonal redistribution of the water's phases between the regolith and atmosphere. In the work we presents the preliminary results of new method for estimation and mapping of the winter-time increase of the water ice amount (in vol. %) in the surface layer of the Martian soil equal to daily skin depth (3-10 cm). The method had been developed based on the TES TI seasonal variations analysis.

Methodical approach and results: Conducted recently analysis of the TES TI seasonal variations [1, 2] shown that the concrete summer-time TES TI values, located on the different latitudes of the planet are becoming consecutively higher in the autumn-winter period (Ls=200°-360°). The time range of such intense increase of the TI value coincides with season of strong atmospheric dust loading [3], which represents a repeatable process in each Martian year. The dust loading results in an increase of the atmospheric temperature at the 10-40 km altitudes and reduces the diurnal temperature oscillations on the surface [3]. This reduction in the amplitude of the temperature oscillation results in a higher apparent TI. In addition, during the autumn-winter seasons the surface temperature on the middle and high latitudes reach the values at or below the water vapor freezing point which may result in ice (or frost) appearance in the surface soil and in the way to cause an increase in TI values. To investigate the order of the winter-time increase of the water ice amount within the Martian surface layer (3-10 cm in thickness) we compared the results of the summer- (Ls=120°-150°) and winter-time (Ls=300°-310°) TES TI mapping in three sectors of Mars (Fig.1) within the latitude range ±50° where the seasonal cover of CO_2 ice is absent. Three Martian years observations of the TES were used for the TI mapping. At that, we consider that the summer-time and the winter-time TI values are characteristic of the dry and icy soils correspondingly.
To exclude the influence of the atmospheric dust opacity on the thermal inertia determination, the both analyzed

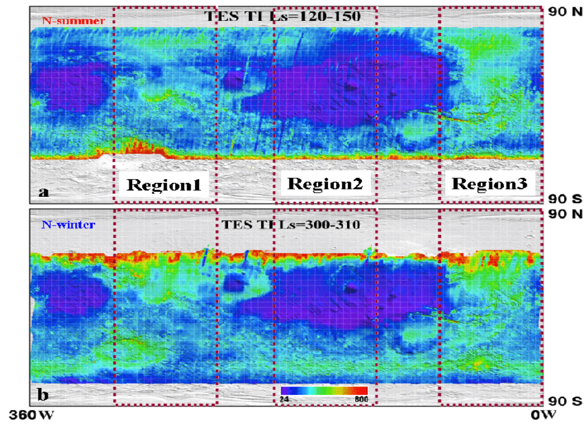

Figure1. ***The global TES TI maps created for the different seasons: a - N summer / S-winter; b – N-winter / S-summer. Dotted box marks the studded regions of Mars.***

seasonal ranges were selected in this way to have similar lowest values of the dust opacity (Fig.2a). As one can see from the mapping results (Fig.1), the values of the TI on the latitudes 30°-50°N and 40°-50°S during winter season are becoming notably higher compared with summer-time values, while on the low latitudes the TI value were mostly constant during both seasons. It is notably that for the same seasonal ranges the similar tendency is observing for the TES albedo: its values increases remarkably during winter (with regard to the summer-time values) on the latitudes > 30° (N,S) and are mostly invariable on the low latitudes (Fig.2b).

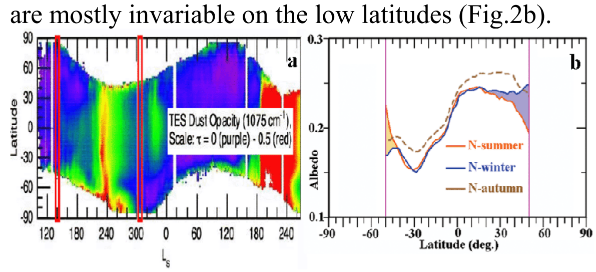

Figure2. ***The TES dust opacity (a) versus Ls and the latitudes (from* [3]*). Red box shows selected Ls ranges for the TES TI mapping. b - zonally averaged TES albedo for N-summer (red), N-winter (blue) and N-autumn (brown) in the region 2. Painted area shows albedo increase during winter season.***

The observing simultaneous increase of the TES TI and albedo values during winter serves as reliable indicator of the water ice (or frost) appearance within the surface soil in the season. To estimate the possible ice content in the Martian soil (in volume fraction) at which the observed winter-time TI values could be achieved with regard to it's the summer-time value (TI dry soil) we used the nomograms for ice content determination. The nomograms have been compiled (see [1, 2]) based on relationship between the TI $_{\text{dry soil}}$ and the TI $_{\text{icy soil}}$ values (computed for different soil's ice content from 0% to 10%). Zonally averaged (in 5° latitude belts) the

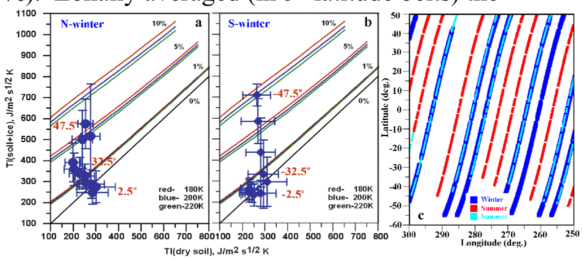

Figure3. ***Example of the nomograms used for estimation of the winter-time ice amount in the soil of the studded region 3. Vertical and horizontal bars represent the standard deviation. Red numbers indicates the latitude value. c- Example of the coincided winter- and summer-time TES TI surface footprints (dark and light blue).***

summer-time and winter-time TES TI values were plotted on the nomograms (Fig.3a,b). The location of the plotted points relatively of the drawn curves of the nomograms let to define what average water ice amount corresponds to the TI values within the latitude belts in the winter. As seen from Figure 3a,b, the zonally averaged winter-time TI values are consistent with a soil ice content of 1-8 vol. % regionally for latitude ranges 30°-50°N and 40°-50°S values are consistent with much less soil ice content (mostly < 1 vol. % and up to dry soil). To compile the map of the winter-time ice distribution within surface layer in the studded sector of Mars we fulfilled next procedure. 1 - From all mapped TES TI data we extracted only that the summer and winter TES TI surface footprints (Fig.3c.), which have longitude location coincidence at accuracy <0.05°. 2- Two-component mixture (soil+ice) are characterized by next thermal parameters: $\rho c = \varepsilon\, \rho_{ice}\, c_{ice} + \rho_{dry}\, c_{dry}$ and $k = \varepsilon\, k_{ice} + I^2_{\ dry}/(\rho_{dry}\, c_{dry})$, where ε is the ice volume part. These two expressions has been substituted into formula of the thermal inertia ($I^2 = k\rho c$). 3 - Solving of the received quadratic equation $a\varepsilon^2 + b\varepsilon + c = 0$ for each coincided footprint (where $a = \rho_{ice}\, c_{ice}\, k_{ice}$, $b = \rho_{dry}\, c_{dry}\, k_{ice} + \rho_{ice}\, c_{ice}\, k_{dry}$, and $c = I^2_{dry} - I^2$) relatively unknown parameter (ε). I_{dry} and I represent the mapped thermal inertia values for summer and winter seasons respectively. 4 - Having the values of ε for each coincided TES TI footprint (φ,λ) we compiled the map of the winter-time ice amount in the surface layer within the studded regions of Mars (Fig.4.)

Summary: Results of the TES TI seasonal variation analysis are indicative on existence of the notable winter-time increase of the water ice (or frost) in the surface soil layer with thickness equal to daily skin depth (3-10 cm). Comparison of the mapped winter-time TES TI values with computed values of the TI icy soil for different ice content shows that the mapped winter-time TES TI values in the latitude range 40°-50° (N, S) are well consistent with the presence of the water ice amount in the soil from 4 up to 10 vol. % (regionally) whereas on the lower latitudes - with ice content < 1 vol. % (up to dry soil).

References: [1] Kuzmin R.O. et all., (2007), *VII Mars Conference*, # 3022. [2] Kuzmin R.O. et all., (2007), European Mars Science and Exploration Conference: Mars Express & ExoMars, #1120023. [3] Smith, M.D., (2006) Second workshop on Mars atmospheric modeling and observations. Granada, Spain, 2006.

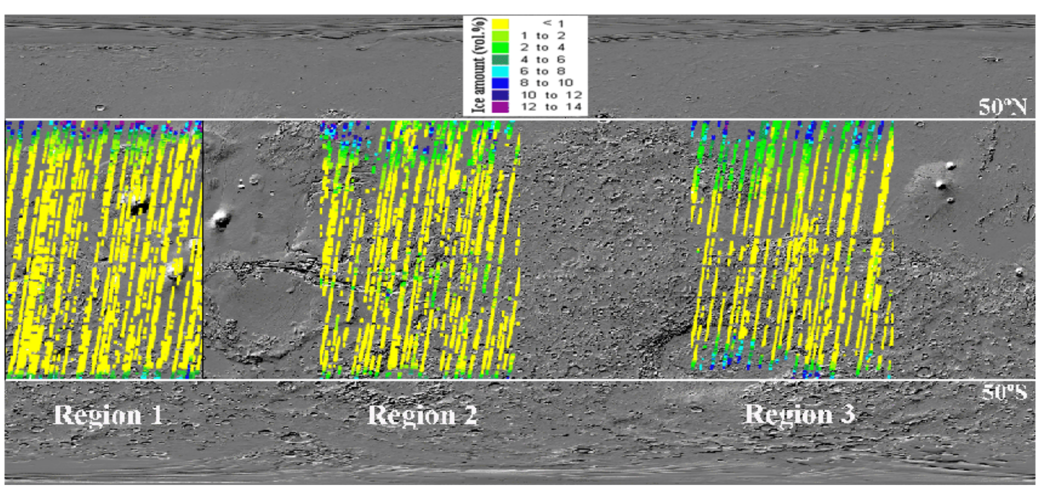

Figure4. ***The map of the water ice amount distribution in the surface soil of Mars during the winter-time in both hemispheres.***