BOUNDARIES OF MARTIAN PERMAFROST AT NORTH AND SOUTH HEMISPHERE, AS SEEN BY FREND NEUTRON TELESCOPE.

D. V. Golovin[1], I. G. Mitrofanov[1], A. B. Sanin[1], M. L. Litvak[1], M. V. Djachkova[1], S. Yu. Nikiforov[1], [1]Space Research Institute of the Russian Academy of Sciences, Profsoyuznaya st. 84/32, 117997, Moscow, Russia, golovin@np.cosmos.ru.

Introduction: Fine Resolution Epithermal Neutrons Detector (FREND) is a neutron telescope installed onboard the ESA's Trace Gas Orbiter [1]. Its epithermal neutron flux measurements from orbit allow to map the ground water content in the subsurface of Mars down to 1 meter in depth. The instrument's major component is its neutron collimator that narrows significantly the field of view allowing for mapping with high spatial resolution of 60-200 km [1].

We present below the resolved boundaries of Martian polar permafrost at northern and southern hemispheres, which are thought to be associated with the isoline of the content of water (as WEH) about 15 wt.%. Due to statistical nature of measurements, we also present the uncertainty width for the found permafrost boundaries in this study.

Methodology: In previous studies [2] we presented the water content maps for the latitudes belt from -50º up to +50º. The map was produced from data between May 2018 and November 2021 and smoothed with a 12° filter. This filter corresponds to the 600 km / pixel spatial resolution. To avoid the influence CO_2 deposits for derived water content we excluded measurement at seasons when such deposits are presented on the Martian surface corresponding to the Mars Climate Database [3].

The typical upper value of content of chemically bounded water in Martian soil is thought to be about 10 wt% [4]. We have tested different values of WEH for water isolines from 10 up to 20 wt%, which might be associated with a boundary of the ground free ice water in the shallow subsurface. It was found that 15 wt% of WEH content is thought to be most likely value for definition of permafrost boundary. From one side it is higher than chemically bound water and less then values around 20 wt% when permafrost line goes to polar latitudes of Mars (>73º) which are not covered by the FREND data due to TGO orbit inclination.

To evaluate statistical uncertainty of the found boundaries we have simulated the number of 10^4 maps with random statistical noise for neutron counts using the Monte Carlo method. Each artificial map was transferred to the map for WEH values by the same procedure as the observed one. The isolines of 15 wt% were derived for each map at the north and south hemispheres. The latitude distributions of the number of isolines for all 360 longitudinal segments with the width of 1º were found. The mean latitude was selected, as the most probable latitude of boundary at each particular longitudinal segment, and the sample variance for all other latitudes of the totality of isolines were used, as the measure for uncertainty of the such boundary.

Results: Figure 1 shows the derived permafrost boundaries in correspondence with 15 wt% isoline for water content in the subsurface for both hemispheres of Mars.

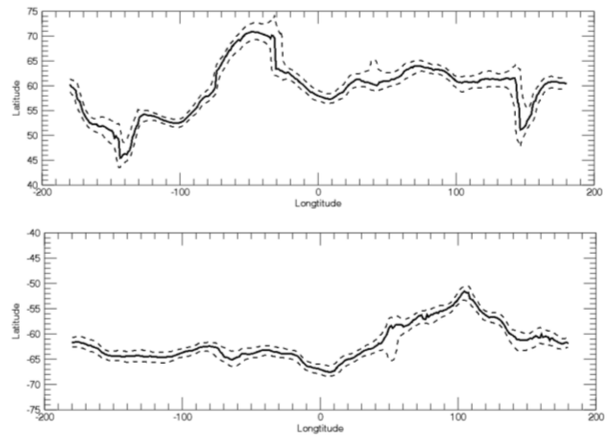

Figure 1. The boundaries of Martian ground water ice permafrost are presented, as associated with 15 wt% isolines of water content for north hemisphere (top panel) and south hemisphere (bottom panel). Dashed lines indicates 1σ statistical uncertainties of the boundaries.

Average latitude of permafrost is found to be about 60º for both Martian hemispheres. Permafrost boundary is located in latitudes from 45ºN up to 70ºN in northern hemisphere and only from 52ºS up to 68ºS in southern hemisphere. The longitudinal behavior of 15 wt% water isolines for north and south is quite different. Further studies are necessary to correspond the shape of these boundaries with such physical parameters as morphology, relief, temperature seasonal variations, atmosphere thickness and others.

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References: [1] I. Mitrofanov, et al. (2018) SSR, 214, 86. [2] A. Malakhov, et al. (2022) JGR, 127, 5, e07258. [3] F. Forget, et al. (1999) JGR, 104, E10. [4] Wang et al. (2013) JGR, 226, 1, 980-991.