Monday, October 13, 2003
Morning Session I
SETTING THE STAGE
8:15 a.m.   Victoria Room

WELCOME, INTRODUCTIONS, AND IMPORTANT ANNOUNCEMENTS

Clifford S. *   Parker T.
A Brief Summary of Important Issues in the Hydrologic and Climatic Evolution of Mars

McCleese D. *   [INVITED]
Future Exploration of Mars: Opportunities for Polar Investigations

THE LATEST FROM MARS: GRS

Boynton W. V. *   Chamberlain M.   Feldman W. C.   Prettyman T.   Hamara D.   Janes D.   Kerry K.
GRS Team   [INVITED]
Ice in the Polar Regions of Mars: Evidence for Wet Periods in the Recent Past **[#8133]**

Feldman W. C. *   Maurice S.   Prettyman T. H.   Mellon M. T.   Squyres S. W.   Karunatillake S.
Elphic R. C.   Funsten H. O.   Lawrence D. J.   Tokar R. L.
Association of Measured Distribution of Near-Surface Hydrogen at High Northerly Latitudes with Surface Features on Mars **[#8101]**

Litvak M. L. *   Mitrofanov I. G.   Kozyrev A. S.   Sanin A. B.   Tretyakov V.   Boynton W. V.
Hamara D. K.   Shinohara C.   Saunders R. S.   Drake D.
Comparison Between North and South Near Polar Regions of Mars from HEND/Odyssey Data **[#8020]**

GENERAL DISCUSSION

10:15 – 10:30 a.m.   BREAK

ICE IN THE POLAR REGIONS OF MARS: EVIDENCE FOR WET PERIODS IN THE RECENT PAST.

W. V. Boynton[1,2], M. Chamberlain[1], W. C. Feldman[3], T. Prettyman[3], D. Hamara[1], D. Janes[1], K. Kerry[1] and the GRS Team. [1]Lunar and Planetary Lab, Univ. of Arizona, Tucson AZ 85721, [2]Department of Planetary Science, Univ. of Arizona, Tucson AZ 85721, [3]Los Alamos National Laboratory, Los Alamos N.M 87545.

Introduction: In our earlier work [1] we showed that the south polar region of Mars had high contents of subsurface ice. This conclusion was based on a preliminary analysis of data from the Mars Odyssey Gamma-Ray Spectrometer instrument suite. Subject to the assumptions made at the time, the GRS observations in the south-polar region could be fit to a two-layer model consisting of a “dry” upper layer with low hydrogen content and an ice-rich lower layer. The upper layer ranged in H content, expressed as H_2O, from 2% near -45° latitude to 3% near -75°. The thickness of the upper layer, expressed as column density, ranged from >100 g/cm^2 at -55° latitude to 40 g/cm^2 near -75°. The ice content of the lower layer was inferred to be 35 ± 15% with the higher end of the range preferred.

Several necessary assumptions were made in this work, the most significant of which was that we needed to make a normalization for the absolute flux of both gamma rays and neutrons. We now know that both of these assumptions were incorrect, and we have determined better normalization values. For the neutrons, we normalize to the case of the thick CO_2 seasonal frost in the north overlying the water-ice residual cap [3]. For the gamma rays, we normalize to the frost-free northern residual cap [4]. The effect of these re-normalizations is to increase the amount of subsurface ice compared to the earlier work.

Results: The results are shown in the first two maps in fig. 1. In these maps, the gamma-ray flux has been converted to equivalent amount of H_2O assuming that the hydrogen is evenly distributed with depth, *i.e.* there is not an overlying ice-free layer. This assumption is clearly incorrect, but it serves to provide a firm lower limit to the amount of H_2O in the soil. If, as seems clear, the ice-rich regolith is covered by an H_2O-poor layer, the H_2O content in the lower layer must be substantially higher because the overlying layer will attenuate the gamma-ray flux. In both polar regions, away from the residual cap, this lower limit to the H_2O content is around 40%. A similar analysis based on the epithermal neutron flux, again assuming the H_2O is uniformly distributed with depth, shows a minimum limit of around 60% H_2O in the polar regions [5].

Another interesting result is to look at the limit on the thickness of the upper “dry” layer in the case of a two-layer model (fig. 1). These maps have been made by assuming the ice-rich layer is pure ice, and that the gamma-ray signal is attenuated by the overburden of the dry layer (here assumed to be 3% H_2O). Again for both polar regions, we see that the maximum thickness the upper layer could have is about 20 g/cm^2. This result is inconsistent with the results of the data from the GRS Neutron Spectrometer, as the thermal neutron flux clearly shows a minimum in the south around 70 deg latitude [2,1], and this minimum occurs when the H_2O-rich layer is buried by around 50 g/cm^2 of dry material, a result that is nearly independent of the amount of H_2O in the lower layer.

Discussion: We are drawn now to the conclusion that the simple two-layer model does not describe the observations. This result is not surprising considering that the footprint of the GRS is large, about 550 km, and a variety of different H_2O contents and depths could co-exist in our footprint.

Nevertheless, one of the important observations is still the very large quantity of ice found in the polar regions. The minimum amount, about 60% by mass, requires that an emplacement mechanism other than vapor diffusion to fill pore spaces was responsible for depositing the ice in the polar regions. This conclusion follows from consideration of the data in Table 1, which shows the relationship between volume percent and weight percent assuming a bulk grain density of 2.5 g/cm^3. The column “Ice-free density” is the density of the soil without ice assuming the ice was completely filling the pore space. If we allow for some experimental uncertainty on the GRS results, it is still clear that the minimum H_2O content is conservatively between 50% and 65% by mass. When converted to volume %, we require unreasonably low-density soils to have sufficient pore space to accommodate the high concentration of ice found by the GRS.

One mechanism that could emplace with a high ice/dust ratio is the deposition ice in the form of snow or frost directly onto the surface in the polar regions. In this case the deposition rates of ice and dust would determine the bulk ice/dust ratio. Obviously for this mechanism to satisfy the GRS observations, the rate of ice deposition would have to be higher than the rate of dust deposition.

Table 1. *Relationship between ice content and ice-free soil density.*

Weight % ice	**Volume % ice**	**Ice-free density**
35%	59%	1.01
50%	73%	0.67
65%	84%	0.41

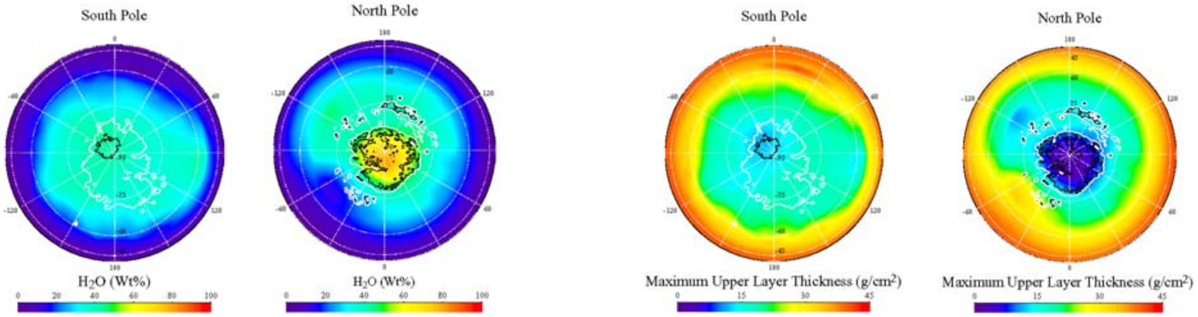
Presumably the dust and ice could be deposited at different times over the course of a Mars year, but the ice would have to be present on the surface year round. Any significant seasonal sublimation of ice would leave behind a lag deposit of dust which would dilute the snow or frost deposited the next year. Clearly in order to build up the regolith with a high ice/dust ratio, the lag deposit cannot be greater than the layer of ice which is deposited in any given season.

The current Mars epoch is clearly not conducive to the deposition of snow or frost on the surface to survive throughout the year, but if this kind of process is responsible for emplacing the ice with a high ice/dust ratio, an important question is how long ago did this happen. Even though the amount of ice seems to be inconsistent with its emplacement by vapor deposition, it seems clear that that the process of vapor deposition and ice sublimation [6,7] is operating on Mars. This conclusion is based on the observation that the line marking the beginning of the ice-rich region in the south [1] precisely matches the predictions for where subsurface ice should be stable under current martian conditions. Even though the high content of ice could not be emplaced by vapor deposition, once emplaced under the appropriate wet conditions, it can subsequently sublime away to its stable depth leaving a lag deposit above it when the climate changes to one more like the present.

Since the deposition/sublimation mechanism appears to be viable now, it must also work under other conditions with different obliquities. Under such conditions, the depth to the frost point will change [7]. Because the high ice content is within about 20 g/cm^2 of the surface and because vapor deposition cannot re-emplace ice in the high concentrations observed, it would appear that the maximum depth to the frost point has never exceeded this value of around 20 g/cm^2 after the ice was emplaced in the form of snow or frost. If, as seems likely, conditions in the past were such that the lag deposit could have gotten much thicker, the observation of the near-surface ice-rich deposit implies that the wet conditions for snow or frost deposition occurred more recently.

References: [1] Boynton *W. V. et al.*, (2002) *Science, 297,* 81. [2] Feldman W. C. *et al.*, (2002) *Science, 297,* 75. [3] Feldman W. C. *et al.*, (2003) *GRL*, submitted [4] Boynton W. V. *et al.*, (2002) 6th Mars Conf. Abstract #3259. [5] Feldman W. C. *et al.*, (2002) 6th Mars Conf. Abstract #3218. [6] Leighton R. B. and Murray B. C. (1966) *Science, 153,* 136. [7] Mellon M. T. and Jakosky B. M. (1993) *JGR, 98,* 3345..

Fig. 1. *Polar stereographic views of the minimum H_2O content inferred from the Mars Odyssey GRS (left) and maximum thickness of the upper layer. The dark contour is the residual cap; the light contour is the layered terrain.*



Association of Measured Distribution of Near-Surface Hydrogen at High Northerly Latitudes with Surface Features on Mars.

W.C. Feldman[1], S. Maurice[2], T.H. Prettyman[1], M. T. Mellon[3], S.W. Squyres[4], S. Karunatillake[4], R.C. Elphic[1], H.O. Funsten[1], D.J. Lawrence[1], and R.L. Tokar[1], [1]Los Alamos National Laboratory, Los Alamos, New Mexico, [2] Observatoire Midi-Pyrenees, Toulouse, France, [3] LASP, University of Colorado, Boulder, CO, [4]Cornell University, Ithaca, NY

Introduction: Lower-limit estimates of the global abundance of hydrogen on Mars reveal a remarkable surface distribution [1]. Three discrete reservoirs are apparent. Two of the reservoirs fill large areas that cover much of the northern and southern high-latitude regions, and the third has several components at equatorial to mid latitudes. A map of water-equivalent hydrogen, M_{H2O}, north of +50^o latitude derived from epithermal-neutron counting rates measured between areocentric longitudes of 100^o and 181^o (when the seasonal CO_2 frost cover was completely absent) [1], is shown in Figure 1. M_{H2O} is seen to maximize at 100% by mass, at the north-polar residual cap. This maximum is a component of a generally water-rich region that covers much of the surrounding high-latitude terrain. This region has a local minimum that overlies Olympia Planitia, a secondary maximum that follows a narrow arc at about +75^o latitude that connects 100^o to 180^o east longitude, and a pronounced secondary maximum that is centered at about +70^o latitude and –135^o east longitude. Whereas the arc-shaped maximum overlies a similar arc of surface water ice that is apparent in visible images of Mars, the secondary maximum has no apparent surface feature. Another feature of the enhanced reservoir of hydrogen at high northerly latitudes is that it is pinched off on one side by a relatively low H_2O-abundance region that is centered on –45^o longitude.

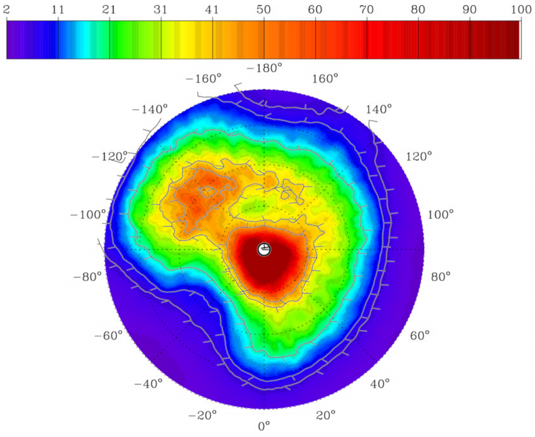


Fig. 1. Map of lower-limit abundances of M_{H2O}, shown in orthographic projection north of +50^o latitude. The contours correspond to 7%, 10%, 20%, 40% and 50% M_{H2O}, progressing inward from the outside.

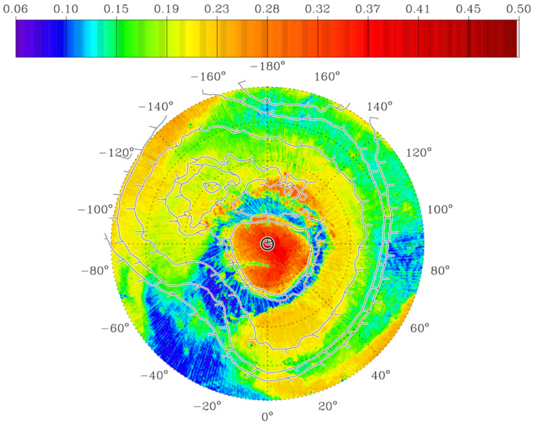


Fig. 2. Map of albedo shown in orthographic projection north of +50^o latitude. Contours of mass % H_2O are the same as in Fig. 1.

Intercomparison with Surface Features: In an attempt to search for physical properties of the Martian surface that are associated with the foregoing hydrogen abundance features, we overlayed contours of M_{H2O} onto maps of thermal inertia, albedo, and rock abundance [2,3,4]. Starting first with the albedo (shown in Fig. 2), we see that the highest albedo, which corresponds to surface water-ice deposits, overlies the central maximum in M_{H2O} and the outlying arc of high M_{H2O}. Additionally, the secondary maximum in M_{H2O} lies within an extended region of relatively high albedo. An extended region of low albedo that is centered on –45^o longitude at the mouth of Chasma Boreale, is coincident with the pinched-off portion of the high-latitude, high M_{H2O} terrain. Extension of this region to lower latitudes is shown in Fig. 3, which intercompares M_{H2O} with rock abundance and albedo. Inspection shows that most regions of high rock abundance and low albedo overlie regions of relatively low M_{H2O}. However, the inverse is not true. There are regions of low rock abundance (and high albedo) that are coincident with regions of low M_{H2O}. In addition, there is a region just south of Arabia Terra, and between

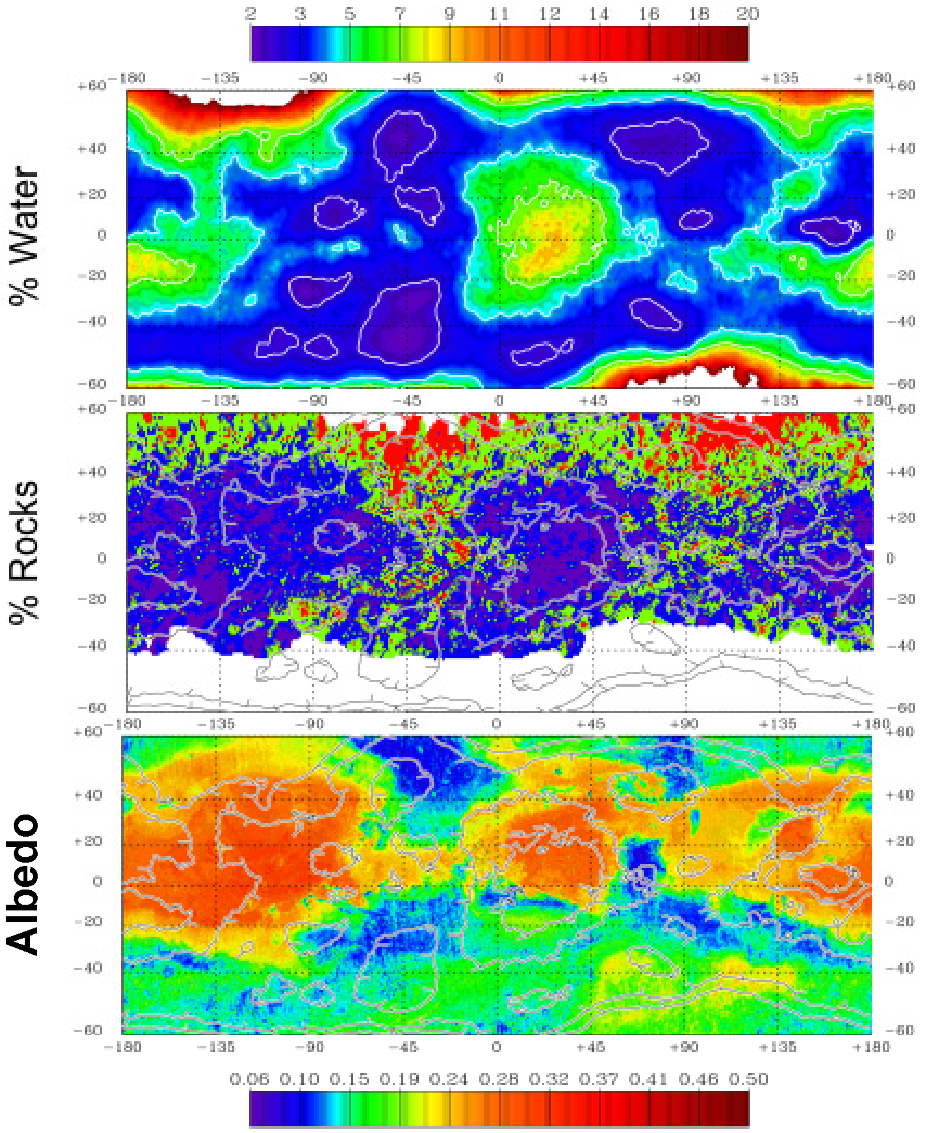


Fig. 3. Maps of $M_{H2O,}$, percent abundance of rocks [4], and albedo [2,3] all in cylindrical projection between ±60°. Contours of M_{H2O} corresponding to 3%, 5%, and 7% are overlayed on all three maps. The colors in the middle panel correspond to 0%-5% [purple], 5%-10% [blue], 10%-17% [green], and >17% [red] rock abundance, respectively.

–20° and –40° latitude near 180° east longitude where the albedo is not high, the rock abundance is low, and M_{H2O} is relatively high. Altogether, these associations suggest that no single process can explain all of the observed structure of enhanced M_{H2O} deposits on Mars. For example, contributing factors could be the physical structure of subsurface soils (such as porosity and permeability), the mineral and chemical composition of these soils, the time dependence of the partial pressure of water vapor in the atmosphere, and the time-dependence of, and insulating properties of the overlying dust cover.

References: **[1]** Feldman, W.C., et al., J.G.R., submitted, 2003, [2] Mellon, M.T., et al., LPSC, XXXIII, Houston, TX, 2002, [3] Christensen, P.R., et al., J. G.R., 106, 23823-23871, 2001, [4] Christensen, P.R., Icarus, 68, 217-238, 1986.

COMPARISON BETWEEN NORTH AND SOUTH NEAR POLAR REGIONS OF MARS FROM HEND/ODYSSEY DATA.

M.L. Litvak[1], I.G. Mitrofanov[1], A.S. Kozyrev[1], A.B. Sanin[1], V. Tretyakov[1], W.V. Boynton[2], D.K. Hamara[2], C. Shinohara[2], R. S. Saunders[3], D. Drake[4], [1]Space Research Institute, RAS, Moscow, 117997, Russia, max@cgrsmx.iki.rssi.ru, , [2]University of Arizona, Tucson, AZ 85721, USA, [3]Jet Propulsion Laboratory, Pasadena, CA 91109, USA, [4]Lansce 3, Los Alamos Nat'l Lab. Los Alamos, NM and TechSource Inc, Santa Fe, NM 87594, USA.

Introduction: The two years of neutron mapping measurements onboard Mars Odyssey spacecraft are presented based on High Energy Neutron Detector (HEND) observations. HEND instrument is a part of GRS suite responsible for registration of epithermal and fast neutrons originating in Mars subsurface layer [1,2]. The scattering of fast neutrons in Mars surface caused by primary cosmic rays is strongly sensitive to presence of hydrogen atoms. Even several percents of subsurface water significantly depress epithermal and fast neutron flux [3,4]. It turns orbit neutron spectroscopy into one of most efficient methods for finding distribution of subsurface water.

There is direct correspondence between energy of registered neutron and depth where it was produced. The production rate of fast neutrons has maximum at depths less than tens of centimeters while the epithermal neutrons originate in layer placed 1-3 m below the surface. Combining measurements in epithermal energy range with measurements above 1 MeV one may reconstruct the water abundance distribution at different depths starting from thin subsurface layer and going down to several meters depths. It allows to check simple model describing layered structure of regilith.

It is known that North and South near polar regions are affected by global redistribution of atmospheric CO_2. The maximal thickness of CO_2 snow depth may be as high as 1 m at latitudes close to martian poles[5]. It explains why neutron flux above martian poles significantly varies from summer to winter seasons. It occurs because CO_2 frost hides upper surface layer from the orbit observations. This fact was used to estimate thickness of CO_2 deposit at different latitudes[6,7]. Here we suggest to make comparison between martian near polar regions in both ways as in terms of subsurface regolith structure as in terms of distribution of CO_2 deposits.

Data Analysis. To realize this approach we split our study in two steps. On first one the summer data were processed when surface was free from seasonal CO_2 frost. It helps us to find best fit parameters describing regolith structure in given region. To do it two layers model was applied to the data. It consists of relative dry (~2% of water) upper soil layer covering the bottom water ice rich layer. The thickness of upper layer and content of water in bottom layer were used as free parameters. To convert orbital measurements to real values of neutron flux near Mars surface we should to take into account atmosphere thickness above observed region. The orbital measurements are accumulated each ~ 20 sec and gathered from large surface area. The sizes of this footprint area may be as large as 600 km x 600 km. To avoid complicated model-dependent analysis how neutron flux is distributed inside footprint area we split Mars near polar regions into large areas with sizes which are more than HEND footprint. The thickness of martian atmosphere was taken from Ames Global Climate Model.

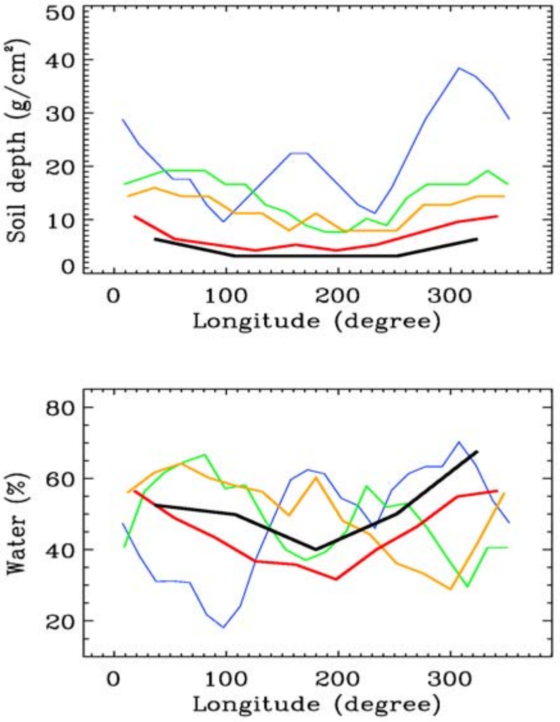


Fig 1. The content of water ice and thickness of soil deposit above it are shown for North region. Black color corresponds to 80°-90° latitude belt. The red, yellow, green and blue colors correspond to 75°-85°, 70°-80°, 65°-75°, 60° -70° latitude belts.

In this study we restrict ourselves by studying regions near Mars poles above 60 degrees for each hemisphere. It was done by two reasons. At first, observation of these regions demonstrates presence of enormous amount of water in subsurface layer [1,2,8,9]. At second, The south and north regions are highly affected by seasonal CO_2 global circulation process. The CO_2 snow depth varied from tens of cm up to ~1m at the selected latitudes.

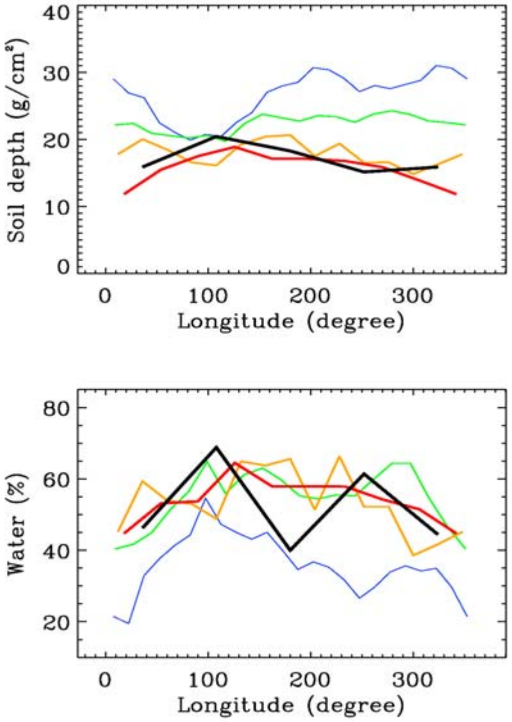


Fig 2. The content of water ice and thickness of soil deposit above it are shown for South region. Black color corresponds to 80°-90° latitude belt. The red, yellow, green and blue colors correspond to 75° -85°, 70° -80°, 65° -75°, 60° -70° latitude belts .

On second step of our study we fixed best fit parameters for each selected area and implemented additional layer of neutron production which should simulate CO_2 deposit. Fitting the HEND data for different winter seasons we tried to find the best fit thickness of this layer.

Conclusions: Comparison between north and south regolith structures show that south and north near polar regions contain comparable content of subsurface water ice. But on south the ice rich layer is placed significantly deeper in comparison with north areas (see fig 1 and fig 2). The minimal depth of bedding of water ice for North was founded equal ~ 3 g/cm². For south region this value was estimated more then 10 g/cm².

Model estimations of winter CO_2 deposit shows that thickness of snow layer may achieve up to 1 meter on South while snow depth on North do not exceed 80-85 cm. The distribution of south CO_2 deposit also shows more complicated and irregular behavior then on north.

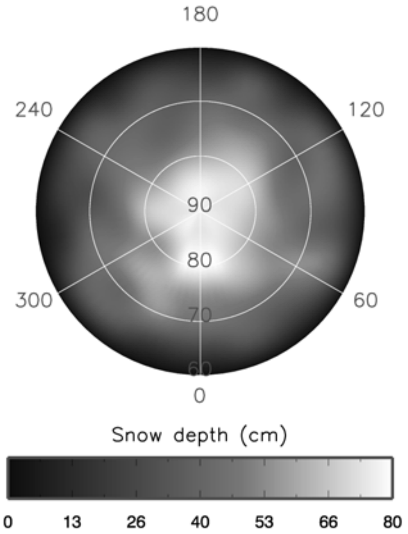


Fig 3. The Map of CO_2 deposit are shown for north region of Mars.

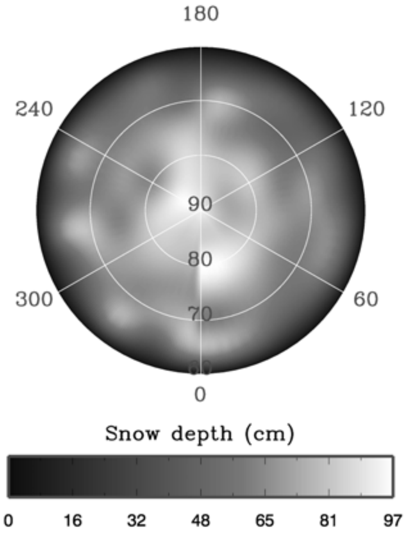


Fig 4. The Map of CO_2 deposit are shown for south region of Mars.

References:

[1] Mitrofanov I.G. et al. (2002) *Science*, 78-81. [2] Mitrofanov I.G. et al. (2003) *LPS XXXIV*, Abstract # 1104. [3] Drake D.M. et al. (1988) *JGR*,V.93, 6353-6368. [4] Feldman W.C. et al. (1993) *JGR*, V.98, 20855-20870. [5] Smith D.E. et al. (2001) , 294, 2141-2146. [6] Mitrofanov I.G. et al. (2003) *Science*, 2081-2084. [7] Litvak M.L. et al. (2003), 6th conference on Mars, Pasadena 2003. [8] Boynton W. et al. (2002) *Science*, 81-85 [9] Feldman W.C. et al (2002) *Science*, 75-78