BEYOND THE EQUILIBRIUM PARADIGM – GLACIAL DEPOSITS IN THE EQUATORIAL REGION OF MARS.

J. Helbert[1] and J. Benkhoff[1,2], [1]Institute for Planetary Research, German Aerospace Center DLR, (Rutherfordstr. 2, Berlin-Adlershof, Germany, joern.helbert@dlr.de), [2]Research and Scientific Support Department, ESTEC, (Keplerlaan1, 2201AZ Noordwijk ZH, The Netherlands).

Introduction: While Mars has been considered for a long time a dry place except for the early Noachian, this view has changed in recent years. This started mainly after the MOC imagery showed features like the gullies and morphological features which can be associated with glacial activity. Now the motion was discussed that at least small amounts of water or ice had been present in the recent past on Mars. Still, the common notion was that Mars today is a dry place. With the excellent dataset of the Gamma and Neutron spectrometer (GRS and HEND) on board of Mars Odyssey this view had to be corrected. The instrument detected water abundance of at least 8wt% in the equatorial regions of Mars and this water is found within the first 2m below the surface, the penetration depth of the instrument.

Recent results by MarsExpress: Since January 2004 the High Resolution Stereo Camera (HRSC) on MarsExpress reports mounting evidence for very recent glacial activity in the equatorial regions of Mars. At the same time the Planetary Fourier Spectrometer reports localized enhancements in the near surface atmospheric water abundance. We will dicusss scenarios which can explain these observations based on the assumption of longtime stable equatorial ice deposits.

Water on Mars: There are three main explanations for the observed amount of water which are not mutually exclusive. Some of the water measured is most likely adsorbed water. While it is still unclear how much water the Martian soil can adsorb, this mechanism can not explain the high abundances measured in some place. We might see highly hydrated minerals. Some of the suggested minerals are indeed capable of holding large quantities of water. The last and maybe most exciting possibility are near surface ice deposits. However if it is ice, the question is, how did it survive close to the surface under the hyper-arid conditions we encounter on present day Mars. And how much ice is there really on present day Mars?

Ice on Mars: Until today we have seen ice only at the polar caps and only this year did we get the first direct measurements of ice abundances by the PFS and OMEGA instrument on Mars Express. We do not have any direct evidence for ice at lower latitudes. From the GRS and HEND measurements we know that the polar caps extend under the surface much further than previously expected. One might assume therefore that near surface ice deposits we see at low latitudes are literally only the tip of an iceberg and the Mars might have a global ice reservoir in shallow depths. If this would be the case, Mars would be a wet planet which is just temporarily frozen. Another less dramatic scenario is the assumption that ice deposits at low latitudes are remnants of the last Martian ice age. The change in the obliquity of Mars can lead to a redistribution of ice across the planet. So maybe we observe today a transition state, in which we only see the dwindling remains of equatorial glaciers. If the ice within the top 2m has survived until today, this would however imply that these regions have been covered by large amounts of ice during the last ice age. Both ice related scenarios would imply that Mars has, or at least had in the very recent past, large quantities of ice on or close to the surface. It implies further that Mars is not in a steady stat, but has a active climate with global variations on several different time scales.

The Berlin Mars near Surface Thermal model: Over the recent years we have developed the Berlin Mars near Surface Thermal model (BMST) to address this question [1]. Most models used up to now assume a thermophysical steady state for the Martian soil. Under such conditions ice could not be stable close to the surface in equatorial regions. However modelling shows that the obliquity of Mars changes dramatically over time [2]. There are observational evidences showing at least two climatic cycles on Mars. There is a long term cycle in the order of 5-10 Mio. years as shown evidence of glaciation in equatorial regions [3] and a medium term cycle in the order of 100-300ka as shown for example by the layering in the polar caps [4].

The BMST is focused on studying the stability of recently deposited ice. Our model is based on a layered structure of the subsurface material, in which each layer can have different physical and thermo-physical properties. The main features of the BMST are a high lateral resolution down to the centimeter range, the realistic treatment of the thermal properties of ice-rock mixtures, a detailed treatment of gas flux within the surface and into the atmosphere and a variable temporal resolution which allows to study daily as well as annual variations. Using the model we can study the redistribution of volatiles with the subsurface over time. This allows to predict limits for the burial depth of ice assuming non-equilibrium conditions.

Terra Arabia: The SWC channel of the PFS instrument on MarsExpress has detected an enhancement in the atmospheric water vapour content close to the surface over Terra Arabia [5]. Interestingly this is one of the equatorial areas in which GRS on Mars Odyssey reports an increased water content in the soil [6]. The HEND instrument of the GRS instrument suite reports a water abundance of 12 wt% below an at least 19cm thick layer of dry soil [7]. We will show a scenario in which ice placed in Terra Arabia during a recent ice age in Mars is indeed stable within 1m below the surface over several 10ka. GCM calculations as done for example by [8] show, that during phases of higher obliquity larger amounts of high can be deposited in this area. The ice deposit is protected until present time by a lag deposit consisting of a layer of very fine, bright dust with a very low thermal conductivity. We find this dust layer in one of the area which geographical coincides with the areas showing the highest content of water in the soil in GRS measurements. While such a long time stable ice deposit would explain the GRS observations, it contradicts the observations by PFS. However we have identified adjacent areas in which ice might have migrated downward after deposition on or close to the surface. This downward migration can lead to the formation of an ice lens within the first few meters below the surface. The modelling shows that a destruction of this ice lens by sublimation can lead to a significant increase of water vapour being released in the atmosphere. This might by observed by PFS right now.

Hecates Tholus: An analysis of data obtained by the HRSC camera on MarsExpress revealed morphological evidence for the existence of glacial deposits on the flank of Hecates Tholus [3]. Their ages derived from crater counts are about 5 to 24 million years. We have studied the stability of glacial remenants from the last Martian ice age in this area.

Summary: We will show, that even in the equatorial regions of Mars ground ice deposits can be stable over long periods of time. The main assumption we have to do is, that the near surface layer of Mars is not in an equilibrium state.

There are mounting evidences of Martian climate cycles on different time scales. One of the shortest time scales indicated by the layering in the polar caps is in the order of only several 10ka.

References: [1] Helbert and Benkhoff, JGR, 2003 [2] Laskar et al., Icarus, 2004. [3] Hauber et al., Nature 2004. [4] Milkovich et al. 2004 [5] Formisano et al. 2004 [6] Boynton et al. 2003 [7] Mitrofanov et al. 2003 [8] Haberle et al. 2004

Additional Information: This work was supported by the German Research Council (DFG) under grant BE 1630/2.