Icarus 238 (2014) 66–76

Contents lists available at ScienceDirect

Icarus

journal homepage: www.elsevier.com/locate/icarus

Searching for springtime zonal liquid interfacial water on Mars

Akos Kereszturi [a,b,*], Thomas Appéré [c,d]

[a] Konkoly Thege Miklos Astronomical Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Astrophysical and Geochemical Laboratory, Konkoly Thege M. 15-17, H-1121 Budapest, Hungary
[b] New Europe School for Theoretical Biology and Ecology, Hollos Korvin str. 5, H-1038 Budapest, Hungary
[c] Laboratoire AIM, CEA-Saclay, DSM/IRFU/SAp, 91191 Gif-sur-Yvette, France
[d] Institut de Planétologie et d'Astrophysique de Grenoble, Université J. Fourier, CNRS/INSU, Grenoble, France

ARTICLE INFO

Article history:
Received 18 March 2013
Revised 28 April 2014
Accepted 4 May 2014
Available online 17 May 2014

Keywords:
Mars
Astrobiology

ABSTRACT

We analyzed the spatial and temporal characteristics of the surface temperature at the northern water ice annulus on Mars that is left behind the receding seasonal carbon dioxide cap in springtime. Using OMEGA hyperspectral images we show that water ice without carbon dioxide ice coverage lasts for 10–30 days between 55° and 70°N. The longest water ice coverage without CO_2 ice is observed between 40–55°N and 300–330°E and lasts 80–110 days in ideal case. Using TES temperature data, we show that thin interfacial liquid water may be present at the water ice annulus. Higher spatial resolution THEMIS temperature data shows that the above mentioned finding is relevant to a spatial scale of 100 m. Although the exact near surface water vapor concentration is not known, beside the average 10 pr-μm we used two elevated values and corresponding threshold temperatures for interfacial liquid water formation: 190 and 199 K beside the average 180 K. While the area of interfacial liquid water is substantially smaller in the case of higher threshold temperature values, even for 199 K terrains exist at THEMIS and OMEGA scale of resolution where such thin interfacial liquid water could be present on the surface. Summarizing: good chance exists for the presence of liquid interfacial water in the warmest part of the day on at the northern hemisphere of Mars at extended areas – although firm evidence requires better targeted future observations.

1. Introduction

The dry atmosphere of Mars and low temperature of its surface prevent the persistence of liquid water in pure and macroscopic form today. Better chances are present in the microscopic scale or bulk salty solutions. Here we investigate the possibility of microscopic scale interfacial water along the contact surface of seasonal water frost and minerals during northern spring. In our earlier work we presented spectral and modelling evidences on the probable presence of such interfacial liquid water in the southern hemisphere at Richardson crater on Mars (Kereszturi et al., 2011) at possible flow-like features (Möhlmann and Kereszturi 2010). Here we study the evidence for similar features in the northern hemisphere. In this work we first analyze the general possibilities using low spatial resolution, global datasets (OMEGA and TES, see details in Section 3). Then we present targeted, higher spatial resolution analyses of the best regions for the appearance of possible interfacial liquid water. The rationality of this work relies on the chemical and even possible biological consequences of such thin microscopic water layer that are mostly unexplored for Mars. The identification of the temporal and spatial characteristics of this interfacial liquid water could be a first step toward this direction.

Here we analyze TES based annual temperature trends and correlate them to OMEGA based spatial and temporal changes of the water ice annulus at the northern hemisphere. First we consider global trends then we focus on the two longitudinal bands where the extension of the water ice ring is the widest and the narrowest respectively, as it might give insight on differences in water ice accumulation and time of its presence on the surface. We complete the analysis by studying pairs of overlapping OMEGA and THEMIS images in order to investigate the distribution of surface temperature in the water ice annulus at higher spatial resolution.

In this work we use the term of liquid interfacial water for the thin, undercooled liquid layer between solid water ice and minerals. Beside this, resembling quasi-liquid layer might exist on mineral surfaces without ice cover under ideal conditions (regarding the temperature and atmospheric vapor content, see Bryson et al., 2008; Fouchet et al., 2007; Möhlmann, 2008), called

* Corresponding author at: Konkoly Thege Miklos Astronomical Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Astrophysical and Geochemical Laboratory, Konkoly Thege M. 15-17, H-1121 Budapest, Hungary.
E-mail address: kereszturi.akos@csfk.mta.hu (A. Kereszturi).

http://dx.doi.org/10.1016/j.icarus.2014.05.001
0019-1035/

adsorbed water. It is also important to clarify the difference between hydrated martian regolith and the above mentioned H_2O types: interfacial water exists only where mineral surfaces and solid ice are in physical contact, while ice is not necessary regarding adsorbed water and hydrated regolith. Moreover, the H_2O molecules are loosely attached to the mineral surfaces regarding adsorbed water, while for hydrated material these molecules are embedded in the structure of the minerals and are more difficult to extract – a higher temperature input is needed. Here we analyse only the first case, i.e. liquid interfacial water, where solid ice layer on the surface can be definitely observed from orbit.

2. Overview of current knowledge

Below we summarize our current knowledge on the spatial and temporal changes and occurrence of water ice at the northern hemisphere. Such overview provides the context for the interpretation of the possible liquid interfacial water at the seasonal polar cap.

2.1. Northern seasonal water ice annulus

Using TES data, a relatively warm and bright ring was observed during northern spring lagging a few degrees of latitude behind the receding boundary (Giuranna et al., 2007) of regions at CO_2 ice sublimation temperature, interpreted as H_2O ice (Kieffer and Titus, 2001). Using THEMIS data, Wagstaff et al. (2008) determined that this moderately cold annulus has an average temperature of 182 K. The characteristics of this water ice annulus were analyzed in detail using OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité) near-infrared hyperspectral observations (Appéré et al., 2011) (see Fig. 1). This analysis shows that the water ice annulus surrounding the sublimating CO_2 ice deposits extends over 6° of latitude at L_s = 320° of martian year 27, decreasing to 2° at L_s = 350° and gradually increasing to 4.5° at L_s = 50° of martian year 28 (martian years (MY) defined by Clancy et al. (2000) began with MY 1 starting at the 1955 northern spring equinox, L_s = 0°, where L_s is the aerocentric longitude of the Sun). This annulus first consists of a thin layer of water frost as observed by the Viking Lander 2 (Jones et al., 1979; Hart and Jakosky, 1986; Svitek and Murray, 1990) deposited on the surface and then trapped by CO_2-rich ice layer deposited later. The water frost layer hided below the CO_2 ice is exposed when the surface warms up in spring and CO_2 ice sublimates. By L_s = 50°, H_2O ice spectrally dominates most of the deposits while surface temperature indicates abundant CO_2 ice. This apparent contradiction is caused by the fact that H_2O ice embedded in seasonal CO_2 ice is released at CO_2 ice sublimation and gradually overlies CO_2 ice, hiding its near-infrared spectral signature (Appéré et al., 2011). Some water vapor from the atmosphere is also cold-trapped on top of CO_2 ice and contributes to the gradual building of a top optically thick layer of H_2O ice.

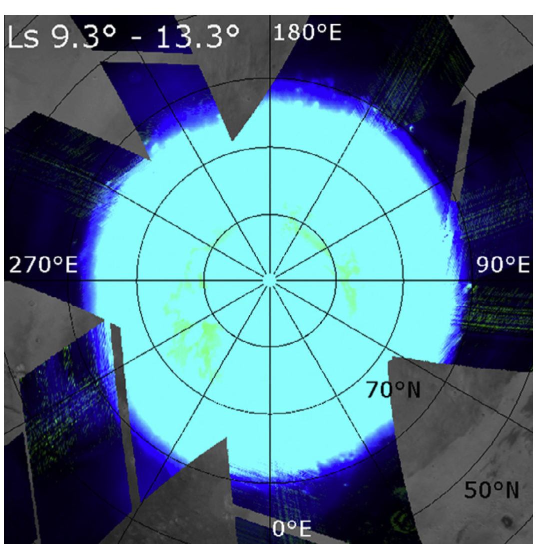

Fig. 1. Map of the northern seasonal ices centered on the north pole of Mars from OMEGA observations acquired between L_s 9.3° and 13.3° during martian year 28. Regions in light blue are covered by CO_2 ice contaminated by H_2O ice and dust particles. These CO_2-rich ice deposits are surrounded by a H_2O ice annulus in medium blue. Dark blue indicates H_2O ice clouds surrounding the H_2O ice annulus. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2.2. Threshold temperature for interfacial water formation

The threshold temperature for interfacial water formation along the mineral–water ice interface depends on the water vapor partial pressure at the surface (Möhlmann, 2008). Using Eq. (27) of Möhlmann (2008), we computed this threshold temperature as a function of the water vapor partial pressure at the surface (Fig. 2).

The knowledge of the water vapor partial pressure at the surface during northern winter and spring is very restricted. Therefore the average column abundance is often used as an indicator of the value above the surface. It relies on the assumption that water vapor is uniformly distributed in the atmospheric column with a scale height of 10.8 km (Rapp, 2006). We analyze possible deviations from this assumption in Section 5, calculating finally with three possible threshold temperature values.

TES instrument has measured the evolution of the water vapor column abundance at the latitude of the water ice annulus during northern spring. It increases from 7 μm-pr at L_s = 20–25° to 40 μm-pr at L_s = 70–75° (Pankine et al., 2010), which corresponds to an increase of water vapor partial pressure from 0.066 to 0.376 Pa. The corresponding threshold temperature for interfacial water formation varies from 187 K to 199 K (see Fig. 2). During northern spring, surface temperature along the seasonal CO_2 and H_2O ices boundary increases from 150 K to 200 K (Kieffer and Titus, 2001; Wagstaff et al., 2008). The surface temperature during the presence of the seasonal water ice cover thus may be close to the threshold temperature for interfacial water formation along the mineral–water ice interface.

We studied three threshold temperatures for the interfacial water formation: (i) a temperature of 180 K corresponding to a very low water vapor column abundance of 2 μm-pr, typical of the dry northern winter atmosphere (Smith, 2004); (ii) a temperature of 190 K corresponding to a water vapor column abundance of

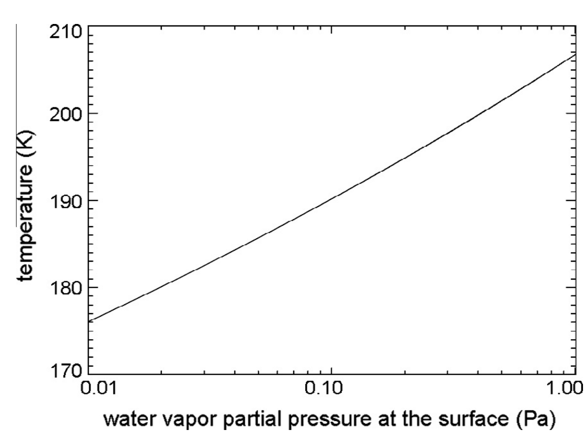

Fig. 2. Threshold temperature of interfacial water formation as a function of the water vapor partial pressure at the surface according to Eq. (27) of Möhlmann (2008).