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Possible water lubricated grain movement in the circumpolar region of Mars

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ABSTRACT

In this work we evaluate a new model on the possibility, could microscopic liquid water supported grain movement on Mars happen at the circumpolar region (in Richardson crater) today, combined with the analysis of new HiRISE ESP images. We confirmed earlier (PSP images based) findings on the morphology, sequential growth and two separate phased formation method of flow features emanate from Dark Dune Spots (1: gas-jet driven streaks toward different directions, 2: flow-like streaks downward). We also identified that the gas-jet ejected and back fallen grains surrounded by water ice produce local enrichment of H_2O, forming local water ice layer.

Several model scenarios were developed and evaluated to exploit the possibilities of liquid supported flow, including the increased thickness of interfacial liquid layer by salts and impurities, the collapse and movement of loose stratum of air-fallen dust–salt mixture with interbedded liquid layers, the mechanical force to kick-off the movement by hydration/dehydration cycles, and the migrating phase change plus the seeping of thin liquid film around interconnected grains. Selecting the most relevant elements among them, which are also compatible to our current knowledge of Mars, a comprehensive model was built that could be tested. This best model contains four interconnected and subsequent elements: 1. deposition of airfall dust in autumn and winter producing a loose surface layer, 2. spatial concentration of H_2O ice by gas-jet activity during the CO_2 sublimation phase, 3. mechanical kick-off by daily expansion/contraction cycles to mix the components, 4. engulfed hygroscopic salts and dust grains to enlarge the ratio of liquid to support the flow. The emerged self-amplifying process could produce daily movement in theory. The scenario contains realistic elements; it is in agreement with the observations, and also being testable by laboratory modelling. The analyzed locations are important because of the joint occurrence of concentrated water ice, elevated temperature and moving flow-features; and it also provides insight into the possible current action of liquid water on Mars.

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1. Introduction

The aim of this work is to evaluate the possibility of the movement of certain dark streaks in Richardson crater on the top of seasonal water ice cover, supported by thin liquid interfacial water on Mars. For this aim we survey new HiRISE images (recorded during the Extended Science Phase – ESP) to complete earlier analyzed PSP (primary science phase) images, improve the observation based data on these features, and evaluate model scenarios on the joint existence of water ice, elevated temperature and flow-like features together, to provide a realistic possibility of liquid supported movement. The new contribution of this work to the field is the analysis of new images, confirmation of earlier findings, identification of flow-features that firmly move on/in water ice, and to evaluate four realistic models scenarios on their origin. Such analysis is of high importance as there are several observations from different authors that suggest the flow of liquid water or brine is possible on Mars today. Among these indicators there are the Recurring Slope Lineae (RSL, formerly TSL, McEwen et al., 2011), low latitude slope streaks occasionally with anastomosing morphology (Kreslavsky and Head, 2007, 2009; Miyamoto et al., 2004; Yakolev, 2011; de Mijolla et al., 2011), and the flow-like features emanating from Dark Dune Spots (DDSs, Kereszturi et al., 2010) which are further discussed in this work.

In recent years Recurring Slope Lineae (RSL) were targeted by many detailed observations (McEwen et al., 2014), where low albedo features move downward on slopes during southern

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summer. The liquid volume was estimated to be in the order of m^3 (Ferris et al., 2002) at these structures. They resemble in appearance to the Antarctic water tracks (Levy, 2012). Laboratory data suggest the formation of RSL's is compatible with a solution having freezing point around 223 K (Chevrier and Rivera-Valentin, 2012), but because of local elevated afternoon temperature (Stillman et al., 2014) they also might form without freezing point depression. Spectral signature of water has been identified there (Ojha et al., 2015) during their active period, and spectral signature that indicates enhanced abundances or distinct grain sizes of ferric and ferrous minerals probably connected to the sorting by the flow process is also present (Ojha et al., 2013). There is an ongoing debate on whether the above listed flow-like features formed by the contribution of liquid water/brine or not (Ferris et al., 2002; Dobrovolskis, 2014; Schorghofer et al., 2002). This work extends the related discussion with presenting elements and scenarios that are possible and compatible with the observations, and selecting the best of them to build a comprehensive model for their formation.

The flow-like structures analyzed here are present at the southern hemisphere of Mars (Mohlmann and Kereszturi, 2010), where H_2O ice and temperature are close to the threshold limit of interfacial liquid water formation (Kereszturi and Rivera-Valentin, 2012). Liquid water/brine could be present at the landing site of Phoenix lander (Rennó et al., 2009), and also at Curiosity rover in Gale crater (Martín-Torres et al., 2015). Here we synthesize chains of observational evidences (Section 3) and theoretical arguments for these flow-like dark streaks definitely move on/in water ice with elevated temperature. Although it is also possible that dry mass movement produce the observed flow-like features (Hansen et al., 2010, 2011), observations till now were not able to firmly identify the formation mechanism.

2. Material and methods

We analyzed Richardson crater on the southern hemisphere of Mars (72 °S 179 °E), where springtime ephemeral surface features called Dark Dune Spots (DDSs) appear (Ganti et al., 2003). The H_2O frost starts to condense at $Ls=0°$ in autumn there, CO_2 starts to condense around $Ls=20–30°$, and after the winter the CO_2 ice sublimates between $Ls=200°$ and $270°$, even later H_2O ice sublimates around $Ls=270–290°$.

During the analysis we used HiRISE optical images (Table 1) recorded during the ESP with suitable resolution to show the target features that have not been analyzed in detail for this purpose. This work also uses earlier results on compositional and thermal data as well as including PSP images, which can be read in Kereszturi and Appere (2014). Spectral data of these previous works used CRIST FTR images (Murchie et al., 2007), analyzed by CAT-ENVI software (Morgan et al., 2009), the corresponding details on the spectral work can be read on Kereszturi et al. (2011). For temperature data TES (Thermal Emission Spectrometer, onboard Mars Global Surveyor, Christensen et al., 2004) measurements were applied. Beside the measurements model calculations based values were used by solving the one-dimensional thermal diffusion equation with a finite element approach (Rivera-Valentin et al. 2011; Rivera-Valentin, 2012; Ulrich et al. 2010), assuming a homogenous ice-cemented soil column, also considering the atmospheric water vapour pressure influenced sublimation rate (see details in Kereszturi and Rivera-Valentin, 2012).

The temporal evolution of certain surface features was followed by the above mentioned optical, spectral images and thermal information together, and the findings served as the bases to develop the model scenarios. The new contribution in this work is the analysis of the recently released and previously not surveyed

Table 1
HiRISE images analyzed in this work beside the earlier surveyed PSP images (details can be found in the cited publications). In the last column the "flow-features" marks the appearance of the growing flow-like features, while the "diffuse streaks" marks the gas-jet driven phase before the emergence of flow-like features at an earlier seasonal phase.

Image id. number	Local time	Solar longitude (deg)	Date	Phenomena
ESP_011640_1080_RED	16.2489	194.229	2009.01.19	Flow-features
ESP_011706_1080_RED	16.367	197.258	2009.01.24	Flow-features
ESP_011772_1080_RED	16.482	200.310	2009.01.29	Flow-features
ESP_011851_1080_RED	16.2523	203.992	2009.02.04	Flow-features
ESP_011917_1080_RED	16.3647	207.092	2009.02.10	Flow-features
ESP_012273_1080_RED	16.1709	224.140	2009.03.09	Flow-features
ESP_012774_1080_RED	15.7042	248.755	2009.04.17	Flow-features
ESP_012840_1080_RED	15.7724	252.020	2009.04.22	Flow-features
ESP_012906_1080_RED	15.8373	255.284	2009.04.28	Flow-features
ESP_013829_1080_RED	15.0405	299.935	2009.07.09	–
ESP_019710_1080_RED	16.0549	161.697	2010.10.10	Diffuse streaks
ESP_020132_1080_RED	16.1446	179.698	2010.11.12	Diffuse streaks
ESP_020277_1080_RED	16.0766	186.120	2010.11.23	Diffuse streaks
ESP_023033_1080_RED	14.7788	317.602	2011.06.26	–
ESP_024668_1080_RED	14.9747	023.153	2011.10.31	–
ESP_028611_1080_RED	16.1911	165.232	2012.09.02	–
ESP_029112_1080_RED	16.1278	186.967	2012.10.11	Diffuse streaks
ESP_029745_1080_RED	16.178	216.393	2012.11.30	Flow-features
ESP_029824_1080_RED	15.9301	220.195	2012.12.06	Flow-features
ESP_030602_1080_RED	15.4832	258.416	2013.02.05	–
ESP_030747_1080_RED	15.2624	265.564	2013.02.16	–
ESP_031248_1080_RED	14.7583	289.864	2013.03.27	–
ESP_031749_1080_RED	14.4539	313.109	2013.05.05	–
ESP_031881_1080_RED	14.6649	319.009	2013.05.15	–
ESP_032870_1080_RED	14.8861	000.083	2013.07.31	–
ESP_033015_1080_RED	14.8882	005.674	2013.08.12	–
ESP_033371_1080_RED	15.0457	019.013	2013.09.08	–
ESP_037551_1080_RED	16.1768	170.458	2014.07.31	Diffuse streaks
ESP_037617_1080_RED	16.2977	173.285	2014.08.05	Diffuse streaks
ESP_037683_1080_RED	16.4197	176.138	2014.08.10	Diffuse streaks
ESP_038105_1080_RED	16.4037	194.967	2014.09.12	Flow-features
ESP_038250_1080_RED	16.2487	201.663	2014.09.23	Flow-features

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