SEASONAL FLOWS ON COOL SLOPES ON MARS (COMPARISON OF FOUR DISTINCT SLOPE PROCESSES)

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Abstract Not only warm slopes are capable to exhibit seasonal flows of probably liquid water or brine origin on Mars, but cool slopes in the polar regions too. The characteristic patterns observed in the vicinity of the dark dune spots (DDSs) at the Southern Polar Region of Mars since the MOC images of the MGS showed developing and extending dark narrow patches on the frost covered dark dunes. Their emanation from the dark dune spots were the first observed as seepage process in 2000. In this paper we compare four types of recently active seasonal flow-like processes on Mars.

Introduction: There are several flow-like features on Mars which might be produced by ongoing water or brine related processes today (Mohlmann, 2010), although there are other models that interpret some of them by dry mass movements (Hansen, et al. 2011a, *Science,* **331,** pp. 575-578; Hansen, et al., 2010, *41st LPSC*. #2029, Hansen et al, 2011b, *Mars Polar Science* #6023). In this work we first review and compare these different flow-like features. After the detailed description of the flow features on warm slopes (McEwen), and studies of mass movements on cold dune slopes (Hansen) we focus on the flows we observed to develop on cool slopes in the Southern Polar Regions of Mars.

The geographical arrangement of the four slope flow typesis visible in Fig. 1.. From bottom to top the following features are indicated: **A) DDS seepages, B) Slope streaks, C) Recurring Slope Lineae, D) Northern Slope Activities.**

Methods: Since 2001 we have been analyzing MOC, HRSC, HiRISE images, topographic data and also reviewed the published results from other authors in peer-reviewed journals and the LPSC and EPSC conferences to identify the various possible flow-like features on Mars. Those features were taken as flow-like ones in this work, which are: 1. present on slopes, 2. show at least one morphological signature of fluid movement (meandering path, anabranching structure, accumulated pond-like feature at their termination), 3. forming on Mars today and their changes could be identified on different images acquired in the last years, 4. differ in albedo from their surroundings. Beyond the above mentioned data, CRISM and TES based spectral and temperature values were also analyzed where it was possible – although their lower resolution did not make possible to do comprehensive analysis.

Regarding the *nomenclature* the various terms used in this work are relevant only for the morphological description, and do not necessarily mean the same as they are sometimes used in classical Earth sciences. For identifying the features we used the terms slope streak, gully on dunes, DDS-seepage, recurring slope lineae and Northern Slope activities.

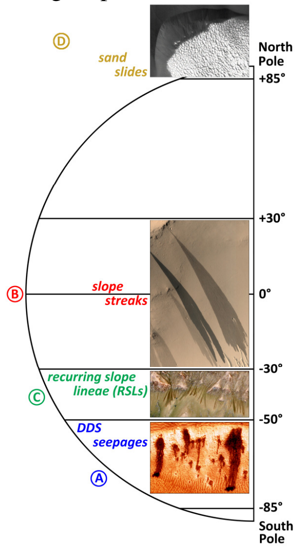

Fig. 1. The four flow types we are comparing. DDS seepages (A), Slope streaks (B), Recurring slope lineae (C), and Northern slope activities (D).

DDS-seepages (A): Beyond the general morphology, the most important feature of these flows are the accumulated pond-like features at the end of the flow [4,5,6,7,8]. The existence of the ponds prove the collecting downslope flow liquid at the bottom of the slope, where there is no preferred direction to continue moving of the liquid material.

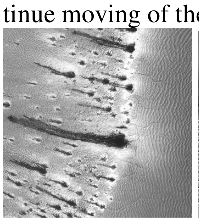
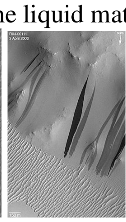
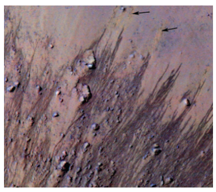

Fig. 2. (A) Fig. 3. (B) Fig. 4. (C)

Slope streaks (B) are low latitude flow-like features on dust covered terrains, that show anabranching pattern and usually darker than their surroundings. Based on Kreslavsky and Head and other author's work [9,10,11,12, 13, 14] they might form by the seepage of dense brines.

Recurring Slope Lineae (RSL, formerly TSL) (C): relatively dark albedo markings with sharp margins. They extend downslope on steep slopes. The narrow, some meters wide streaks have lengths up to 100s of meters. [15,16,17] at the southern middle latitudes.

Northern slope activities (D, Fig. 6.): These are relatively dark albedo signatures extending downslope on steep northern dune slopes, similar to DDS seepages, however, after defrosting the surface exhibits gully like valleys and the transported material is visible on the front floor of the dune. Hansen et al writes: „along dune crests spring cracks form, bands of sand flow down dune slipfaces" http://www.lpi.usra.edu/meetings/polar2011/pdf/6023.pdf.

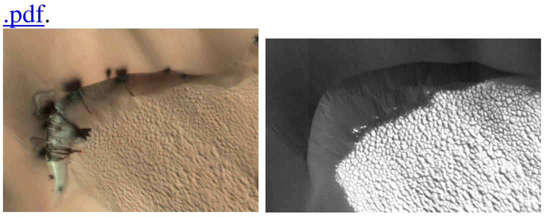

Fig. 6. (D)

In the last case of Northern slope activities the images presented by (Hansen et al. 2011) show various active processes that may or may not be related to each other. In our selection the dark band of sand flow is considered in our study. We suggest that the formation of the other two surface features is not related to the wet downslope processes. These are the diffuse fan-like streaks and the dust avalanches.

The diffuse fan-like streaks emanate from dark spots. Outbursting is forced by jets, caused by the sublimation of the CO_2 ice cover from its bottom, and can be explained by Kieffer model (3, 4). Although these different features may originate at the same location, they are not necessarily similar in origin. As shown previously (5) diffuse and confined slope streaks have different characteristics and they form at different times during local spring.

The "cloud of dust" observed near some short dark streaks and probably caused by a sudden dust avalanche. However, it can be argued that that cloud could have been the dust directly ejected by CO_2 jets, just during the imaging process. In our analysis of the diffuse and confined streaks in the southern hemisphere revealed that they form at different times and are morphologically different (Fig. 2.), suggesting an independent origin (5).

References: [1] Mohlmann (2010) *Int. J. Astrobiol.* 9, 45–49. [2] Hansen, et al. (2011a) *Science,* **331,** pp. 575-578. [3] Hansen, et al. (2010*) 41st LPSC.* #2029, [4] Hansen, et al. (2011b): Hansen, C. J.; Bourke, M.; Bridges, N.; Byrne, S.; Diniega, S.; Dundas, C.; McEwen, A.; Mellon, M.; Pommerol, A.; Portyankina, G.; Thomas, N (2011b) *Fifth International Conference on Mars Polar Science and Exploration,* LPI Contribution No. 1623, p. #6023.

Table 1. Spatial characteristics of the flow-like structures

Name	**Location (latitude)**	**Steepness (degree)**	**Surface type**	**Duration of presence**	**Occurrence (Ls)**	**Source**
DDS-seepages	65°-80° N+S	21 [3], 7 -16 [4]	seasonal frost covered basaltic dunes	months	N: 14°-65° [7] S: 210°-248°[6]	from Dark Dune Spots
Slope streaks	<30°N+S	steep dune slopes	dust rich terrains	years	all seasons [16]	no visible
Transient slope lineae	32°-48°S	>20° (equator, E, W facing)	debris slopes	months	260°-20°	bedrock outcrops, boulders

Table 2. Physical parameters of the flow-like structures

Name	**Morphology**	**Average velocity of flow**	**Albedo, contrast to surroundings**	**Temperature (K)**	**Thermal inertia**	**Possible origin**
DDS-seepages	10-100 m, branching	1.4 m/sol	darker, 0.2-0.3	180-220	200-400	brine flow
Slope streaks	few km long, sinuosing	?	usually darker, >0.25	>275	<100	dust avalanche / brine flow
Transient slope lineae	~100 m long, small channel	0.6 m/sol [8]	<0.20	250-300	180-340	brine flow