SEARCHING FOR WATER ICE IN THE DARK DUNE SPOTS OF MARS USING CRISM DATA.
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Introduction: Flow-like features [1] emanate from Dark Dune Spots [2] were observed in the Polar Regions of Mars, which may be formed with the help of interfacial water [3,4] or brines. Here we discuss the possibility of water ice inside the large, easily observable spots at this terrain.

Methods: We analyzed CRISM spectral data [5], with CAT-ENVI software [6] in Richardson crater (72°S, 179°E). During the work FRT hyperspectral images acquired in the long infrared region were used. After the photometric correction, default volcano scan 61C4 and New McGuire 2-wavelength (2007/1980) [7] filtering methods were used. Surface temperatures were derived from TES as average annual values with 3x8 km spatial resolution [8].

Table 1. Absorption lines for H_2O and CO_2

absorption band (μmeter)	component	Characteristics
1.25	H_2O ice	Large-grained old water ice mainly, barely detectable for frost and cloud
1.5 (deepest)	H_2O ice	Wide min. between 1.38-1.8 with smll asymmetry where the rise is steeper at the shorter wavelength [9]
2 (deepest)	H_2O & CO_2 ice	Wide between 1.9-2.1
2.2-2.5	H_2O ice	Desrease in reflectivity toward the longer wavelength [11]
3	H_2O ice	saturates when the path length of photons within H_2O ice exceeds a few micrometers
1.44	CO_2 gas	[9, 10]
1.435	CO_2 ice	[12, 13]
2.281	CO_2 ice	[12, 13]
2.29 – 2.35	CO_2 ice	characteristic doublet absorption of CO_2 ice

Water ice identification: A few μm of pure water ice at the surface of Mars creates characteristic near-IR absorption features several % deep (Table 2.). When mixed with other component (CO_2 ice, dust), the contrast of H_2O signatures is reduced: as little as 1% mixing concentration of water ice within CO_2 ice is however enough to be detectable in near-IR data [14]. When water ice is detected, it is however difficult to confirm the presence of surface water ice because atmospheric water ice particles in clouds may also produce resembling absorption feature. Significant spectral lines are listed in Table 1. analyzed images are listed in Table 2.

Table 2. The analyzed images of Richardson crater

image no.	surf. temp. (K)	solar long. (deg.)	atm. H_2O cont. (pr μm)	local solar time
FRT000052BC	170	213.61	?	16.2
FRT000054E5	180	217.5	?	16.0
FRT00005FF6	266	248.72	11	15.7
FRT00007A6A	230	312.97	17	14.7

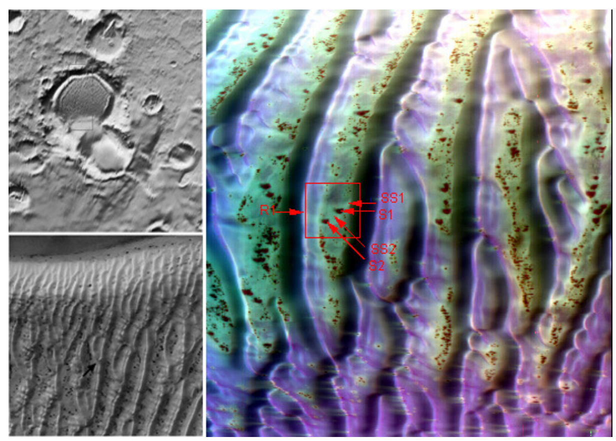

Fig. 1. Overview (left) and the analyzed locations (right) in Richardson crater

The range of Martian surface H_2O grain sizes is between 10 μm (frost) and 100 μm and even up to 1 mm (perennial ice cap) [15, 16] , while atmospheric H_2O ice grains are smaller between 1 and 4 micrometer [17]. Based on published results we found that the best features to identify moderate grain size and as a result surface water ice particles are the following (the largest grains producing the 1.25 micrometer line are not expected at the analyzed location as frost rather than perennial ice is more likely there):

- shape and size of the broad absorption between about 1.4 and 1.8 (deepest at 1.5) micrometer. Unfortunately this region overlapped from CO_2 lines by a sharp and deep line at 1.4 and a more complex set of lines close to each other between about 1.55 and 1.65. The depth of this band can be calculated with relative to two wavelength out of this H_2O-CO_2 complex: relative to 1.385 and 1.772 micrometer. There still can be problematic cases, because larger than 100 micrometers H_2O ice grains produce an absorption that extend beyond 1.77 µm – but such large grins are supposed to be absent in the seasonal cap [10].

- 1.65 micrometer band depth (a narrow feature within the broader 1.5 µm band). The boundary between the optical filters in CRISM detector may produce artifact here with various shapes and at somewhat different location, very close to the possible water ice line [5].

Discussion: The analyzed locations are in Richardson crater (Fig. 1.), with two dark spots (S1, S2) and their bright surrounding (SS1, SS2) and a bright average point on the ridge of a dune (R). Sample spectra of the analyzed locations (R, S1, S2, SS1, SS2) are visible in Fig. 2. at the end of southern winter on the CRISM image acquired at Ls=213.61.

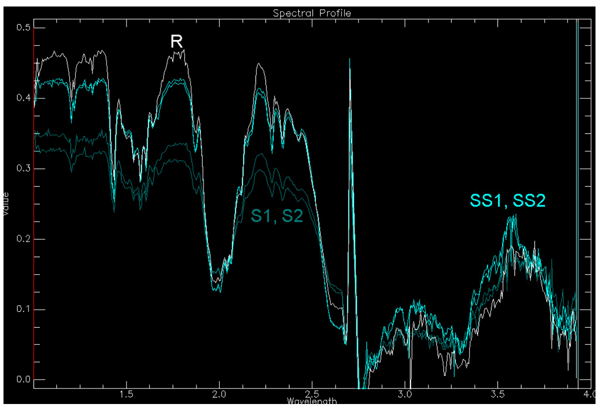

Fig. 2. Spectra of R, S1, S2, SS1, SS2 locations on the CRISM image FRT000052BC_07_IF163L between 1 and 4 micrometer

Analyzing the change of spectra as the season passes by is visible in Fig. 3. for the spot S2 in the period Ls=213-312.

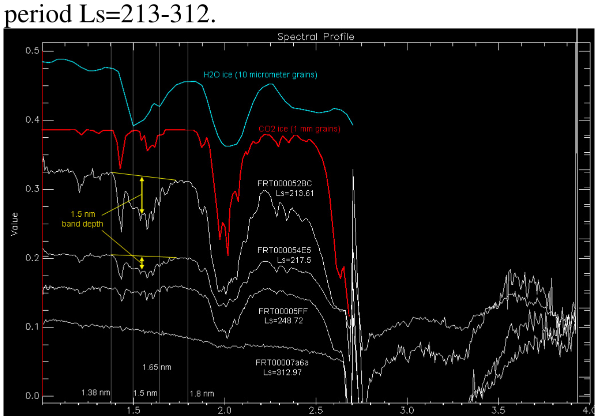

Fig 3. Changes of spectral shapes of the spot no. S1 and reference spectra of pure H_2O (blue) and CO_2 (red)

The curves in Fig. 2. are resembling to each other in shape. Characteristic difference is in the global reflectance level (vertical axis), where the spots (S1, S2) are substantially darker than the other terrains. Regarding the numerical results:

- We calculated the band for H_2O ice centered at 1.5 µm normalized to 1.385 µm and 1.772 µm according to [9]. A strong absorption around 1,4 µm is also present both inside the spots and on the bright terrain too. At this region two lines are very close to each other. The band values do not differ much inside and outside the spots (Table 3.), and decreased as time passed by toward summer.

Table 3. Changes of H_2O band depth

Ls	213.61	217.5	248.72	312.97
S1	0.1240	0.0974	0.0190	0.0123
SS1	0.1303	0.1170	0.0185	0.0143

- CO_2 ice is also present inside the spots with large grain size (typically 1 mm) as suggested by strong bands depth around 2.3 microns. The translucent slab ice state may be present.until Ls=217.5.

Conclusion: We found H_2O ice in the spectra of Dark Dune Spots are present at the same order as their surrounding ice cover. The strength of H_2O ice features decreased as the season progressed toward summer. It is difficult to find out if H_2O ice is on the surface or in the atmosphere. Based on [18] atmospheric vapor content in pr-micrometers is below the limit of detection when the 1.5 band is deep, and elevated when the band is not present. This is compatible with the idea, that surface water ice produces the actual band depth, although the effect of clouds can not be excluded. The work is going on to separate atmospheric and surface components of water ice. Also, surface CO_2 ice act as a cold trap for atmospherical H_2O vapor. Thus, CO_2 frost is likely covered by a thin layer of water ice [19].

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