EROSION RATE AND SEASONALITY OF BLOCK FALLS AT THE NORTH POLE OF MARS BASED ON HIRISE IMAGES. L. Fanara[1,2], K. Gwinner[1], E. Hauber[1], J. Oberst[1,2], [1]Institute of Planetary Research, DLR, Rutherfordstr. 2, 12489, Berlin, Germany (lida.fanara@dlr.de), [2]Department of Geodesy and Geoinformation Science, Technical University of Berlin, Straße des 17. Juni 135, 10623, Berlin, Germany.

Introduction: The layered structures of dusty ice at the poles of Mars hold important information about past climatic changes of the planet. While Mars is currently at the end of an ice age with ice still accumulating at the poles [1], parts of the margin of the north polar ice cap are eroding, due to avalanches and block falls which are very common at these steep scarps [2,3]. It has been suggested that avalanches scour dust off the scarps, which leads to block falls, induced by thermal stress, that steepen the scarps as a competing effect to viscous flow [4,5].

In its 10 years of operation in Mars orbit, the High Resolution Imaging Science Experiment (HiRISE) has captured many such surface processes at the margin of the north polar ice cap. Its ground pixel size of up to 0.25m makes it the only instrument that can resolve blocks as small as a metre across (diameter), while it has a high coverage frequency of the north polar region (up to 7 times in a month).

Russell et al. [6] analysed the landslide erosion of a long scarp by manually identifying the mass wasting events. We developed an automated change detection process to obtain quantitative estimates of the frequency and total volume of block displacements, and we analyse the seasonality of the events to ultimately improve our understanding of the present-day evolution of the north pole.

Test area: We investigate one of the most imaged and active scarps of the north pole at 83.8°N, 124.6°E over a length of 11 km. Its slope drops from ~60° to ~20° at the contact between the North Polar Layered Deposits (NPLD) and the Basal Unit (BU) while the total height of the scarp is 500-700m.

Block falls have been found along the whole scarp, either as single-block events or events involving multiple blocks. The blocks follow a path either from the NPLD or the BU towards the foot of the steep scarps [7]. The blocks come to rest within a distance of 700m downslope as measured from the border between BU and NPLD. The diameters of the blocks vary from less than a metre to 5 metres. While the shapes of most blocks are ellipsoidal, we also find blocks with very elongated shapes and some with clear angular shapes. The source of the blocks is sometimes clearly visible, but most of the time it is hard to identify it unambiguously.

Change detection: Figure 1 shows a result of our change detection method. The detection of small changes, such as these blocks, requires accurately co-registered images obtained at different times. To this end, we ortho-rectify the images using HiRISE Digital Terrain Models (DTMs) that we produce using the Ames Stereo Pipeline [8]. As we observe residual offsets between overlapping orthoimages, horizontal shift values are determined and applied to allow for best possible co-registration within a local area. The co-registered images are the inputs for the change detection.

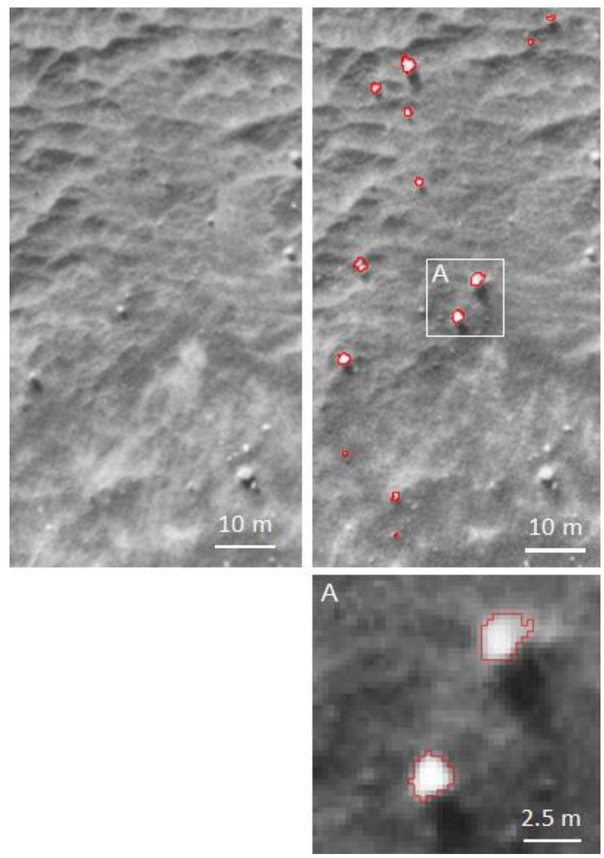

Figure 1: Left: part of HiRISE image before the block fall event. Right: image after the block fall event with change detection result, red: new blocks.

HiRISE images the north pole of Mars only in northern spring and summer, as in winter the pole is not illuminated by the sun. For the automatic change detection we only select summer images, when the area is clear of the seasonal CO_2 ice cap.

The images are first subtracted from each other and the difference image is classified using a thresholding technique, providing us with the largest differences between them. In order to distinguish between blocks and other surface changes we then check block candidates for consistency with a simple bright ellipsoidal object model accompanied by a dark shadow. We also apply filtering to the difference image to retrieve the most prominent boundaries of changed regions and then check whether block candidates from the previous step are located in these regions. On this basis, the algorithm classifies whether the feature will be defined as a new block or not. In order to evaluate our results, we test our algorithm on areas where we have manually identified the displaced blocks.

Erosion rate: Over 11 km of the scarp's length, our algorithm identified approximately 9300 displaced blocks during a period spanning the summer of Mars Year (MY) 28 to the summer of MY 32. Figure 2 demonstrates where most of the events occurred. Assuming that the blocks are spherical objects, we derived a volume of approximately 60,000 m^3. If we further assume that all of the blocks have been detached either from the NPLD or the BU, the estimated erosion rate is ~15,000 m^3/MY with the scarp retreating by ~1m/kyr. Currently, we are mapping the source of the blocks where possible. We also attempt to identify blocks that were already at the foot of the scarp but have moved from one location to another.

Seasonality: By comparison of two summer images, one MY apart, we obtain a map of all displaced blocks for that year. We searched 5km along the length of the scarp through all available images of MY 30 to determine the exact timing of each event. During the imaging period of HiRISE (L_s 29 - L_s 145), the scarp was more active in the summer (L_s 87 - L_s 145) than in the spring (L_s 29 - L_s 87). However, a large number of events occurred between the last image of MY 29 (L_s 141) and the first image of MY 30 (L_s 29). We are currently analysing other parts of the scarp over the years to gain an improved perspective about the seasonality of block falls.

Discussion: We set up a systematic procedure for co-registering HiRISE images and automatic detection of block displacements at the foot of north polar scarps. Our method retrieves the locations, shapes and sizes of the new blocks between images taken in the summer, when the area is clear of the seasonal CO_2 ice cap. We applied our method to an 11 km long scarp and estimated its erosion rate at ~15000 m3/MY, which corresponds to a back wasting rate of ~1m/kyr. The spatial distribution of new blocks and the correlation with topographic information is important for understanding their kinematics and the associated dynamics.

We have also narrowed down the time interval within which each event occurred in Mars Year 30 by using the information on the available HiRISE temporal coverage of the region and we found that block falls were more frequent during the summer than in the spring. However, a large number of events occurred between the last image of MY 29 (L_s 141) and the first image of MY 30 (L_s 29). More data from other years need to be analysed to determine the early spring and late summer behaviour of the scarp.

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References: [1] Smith I. B. et al. (2016) *Science, 352,* 1075-1078. [2] Russell et al. (2008) *Geophys. Res. Lett., 35,* L23204. [3] Russell et al. (2008) *LPS XXXIX,* Abstract #1391. [4] Sori M. M. et al. (2016) *GRL,* 43, 541–549. [5] Byrne S. et al. (2016) *6th Mars Polar Sci. Conf.,* Abstract #6022. [6] Russell et al. (2014) *AGU,* Abstract #P33A-4024. [7] Russell et al. (2014) *8th Intern. Conf. on Mars,* Abstract #1791. [8] Moratto et al. (2010) *LPS XLI,* Abstract #1533.

Figure 2: Density map of block fall events that occurred between MY 28 and MY 32.