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Erosion rate of the north polar scarps of Mars based on automated detection of block falls in HiRISE images

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Abstract

We automatically detected ice block falls in high resolution satellite images of the north polar region of Mars, with the aim of understanding their role in erosion processes and the morphological evolution of the region. Our change detection method is based on the combination of Binary Large OBjects (BLOB) detection and machine learning and we aim to extend our investigation to all steep scarps of the margin of the north polar ice cap where suitable high resolution data exist.

1. Introduction

Based on radar measurements, ice is currently accumulating at the North Polar Layered Deposits (NPLD) [1], while modelling has shown significant viscous flow of the outmost scarps [2], which are nevertheless very steep. After the CO_2 ice layer sublimates in spring, temperature oscillations lead to fracturing of both the NPLD and the underlying Basal Unit (BU) [3]. This results in block falls that are responsible for the scarp retreat [4].

High Resolution Imaging Science Experiment (HiRISE) was the camera to reveal how dynamic this area is, with frequent avalanches [5] and block falls [6]. It has been imaging the scarps regularly for the past 10 years making change detection possible. Manual investigation for block falls for estimating their volume and the erosion rate costs a lot of time. We have developed a change detection method to amend this.

Wagstaff et al. [7], Di et al. [8] and Xin et al. [9] have presented methods for detecting large-scale changes that commonly occur in regions of Mars with a stable background. Block falls, however, are very small changes occurring in a variable environment and therefore require a process-specific approach with high geometric accuracy.

2. Change Detection

Using Ames Stereo Pipeline (ASP) [10] we produce HiRISE Digital Terrain Models (DTM) at the locations along the outmost scarps of the north polar ice cap for which stereo pairs exist. We then ortho-rectify all images of a location onto the respective DTM and co-register them to each other locally based on Enhanced Correlation Coefficient Maximization (ECC) [11] to reach subpixel accuracy.

To highlight the changes we first subtract the co-registered images of different times (Fig. 1). We then identify the block falls amongst all changes of the region by modelling them as bright objects accompanied by a shadow. We combine thresholding and BLOB detection with a Support Vector Machine (SVM) trained on Histogram of Oriented Gradients (HOG) [12] of thousands of blocks as well as other changes to recognise all the pairs of newly appeared blocks and shadows. We then refine their shape by combining edge detection with watershed and the volume of each block is estimated from an assumed ellipsoid around the long axis of a fitted ellipse to the shape of the block.

We also run the algorithm with the reverse order of the images to find the blocks that have disappeared. In some cases these have simply rolled further down or large blocks disintegrate into smaller pieces while moving downslope. In other cases blocks seem to sublimate over the years.

We validate our method by manually identifying block falls and comparing this to the result of the automated detection in several test areas. The validation shows a precision and sensitivity of over 70%.

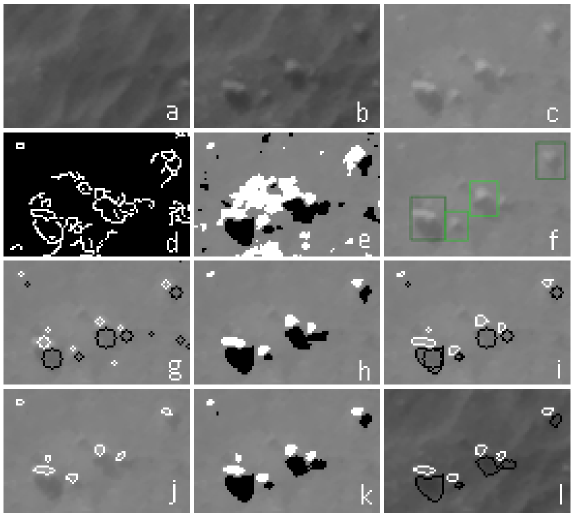

Figure 1: Change detection example. a) "before" image, b) "after" image, c) difference image, d) threshold image, e) edge detection, f) SVM-HOG detections, g) and h) BLOB bright and dark areas, i) candidate blocks and shadows, j) updated shape of candidate blocks from edges, k) shape of candidate blocks and shadows after watershed, l) final pairs of blocks and shadows.

3. Summary and Conclusions

Our study provides a systematic procedure for producing accurately co-registered HiRISE images and for detecting block falls between images of different times with a high confidence level. We apply this method to all scarps of the margin of the north polar ice cap where at least one HiRISE stereo pair exists to estimate the erosion rate of the steep icy scarps and we assess how and where erosion affects the current morphology of the north polar ice cap.

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