IMPROVEMENT OF EXTERIOR ORIENTATION OF MARS EXPRESS HRSC IMAGERY USING A PHOTOGRAMMETRIC BLOCK. M. Spiegel[1], R. Schmidt[2], U. Stilla[1], G. Neukum[3], [1]Photogrammetry and Remote Sensing, Technische Universitaet Muenchen, Arcisstr. 21, 80333 Muenchen, Germany, spiegel@bv.tum.de, [2]Institute of Photogrammetry and GeoInformation, Leibniz Universitaet Hannover, Nienburger Str. 1, 30167 Hannover, Germany, schmidt@ipi.uni-hannover.de, [3]Institut fuer Geologie, Geophysik und Geoinformatik, Freie Universitaet Berlin, Malteserstr. 74-100, 12249 Berlin, Germany.

Introduction: Since January 2004 the High Resolution Stereo Camera (HRSC) on board the ESA Mission Mars Express is imaging the surface of planet Mars in color and stereoscopically in high resolution. The Institute of Photogrammetry and GeoInformation (IPI) of the Leibniz University of Hannover and the Department Photogrammetry and Remote Sensing (FPF) of the Technische Universitaet Muenchen are jointly processing the data of the HRSC to improve the exterior orientation of the orbiter. This will be accomplished by registration of the HRSC data to the Mars Observer Laser Altimeter (MOLA) data using single strips or neighboring strips forming a block. With the result of the processing chain, high quality products such as Digital Terrain Models (DTMs), ortho image mosaics and shaded reliefs can be derived from the imagery.

Input Data: ESA and the German Aerospace Center (DLR) delivers image strips of the HRSC and observed exterior orientation of the Mars Express spacecraft. The MOLA instrument acquired more than 640 million observations by measuring the distances between the orbiter and the surface of Mars which cover the entire surface of the planet. In addition to the surface described by the original, irregularly spaced MOLA track points NASA distributed a grid-based global DTM which is derived from these MOLA points [1].

Concept: IPI uses the HRSC data as input for the automatic extraction of image coordinates of tie points via digital image matching. The software delivers a large number of automatically measured tie points between multiple stereo strips or between neighboring strips building a block [2].

After this, the bundle adjustment approach estimates the parameters of the exterior orientation only at a few selected orientation points. The mathematical model for photogrammetric point determination with a three-line camera is based on the well known collinearity equations. These equations describe the fundamental geometrical condition between object points and image coordinates. In a first step, the aproach does not use the MOLA DTM as control information. This step is only established to search for blunders in the image coordinates. In a second step the aproach is extended to use the MOLA DTM as control information. At locations where HRSC points are available a local surface is derived from the MOLA data. The constraint is that HRSC points have to lie on this local surface defined by four neighboring DTM grid points, which enclose the HRSC point. The distance of the HRSC point to the surface defined by the four DTM points is minimized. This is ensured by one additional condition equation for each HRSC point. After this second step the HRSC points are fitted optimally to the MOLA reference and with the HRSC point cloud also the exterior orientation of HRSC imagery is registered to the global reference frame provided by MOLA data [3].

Results: Here, the results of the bundle adjustment will be discussed for three cases:

Using the nominal exterior orientation (Case A): Figure 1 (left) shows the average displacements in planimetry between neighboring strips. The average displacements are in the range of 150 m up to 200 m in planimetry. The height differences between the HRSC object points and the MOLA DTM are irregularly distributed over the whole area (Figure 2 (left)).

Improved exterior orientation with single strips (Case B): The Figure 1 (middle) shows the average displacements between strips, again. But, in this case the average displacements are smaller (only 15 m up to 40 m) as in case A. Also, the height differences are much smaller as in the case discussed before (Figure 2 (middle)).

Improved exterior orientation adjusted in a block (Case C): The best results are achieved in this case. The average displacements in planimetry are lower than 10 m (Figure 1 (right)). The improvement of the height differences between the HRSC object points and the MOLA DTM is in this case only small because of the very good results in case B.

Conclusion: The improvement of the exterior orientation is absolutely necessary. The best result is reached with the bundle adjustment of a block. But also, the adjustment of single strips leads to good results.

References: [1] Neumann, G.A. et al. (2003) LPS XXXIV, Abstract #1978. [2] Heipke, C. et al. (2004) *IntArchPhRS, Vol. 35 Part B4*, 846–851. [3] Spiegel, M. et al. (2006) *IntArchPhRS, Vol. 36 Part 4*.

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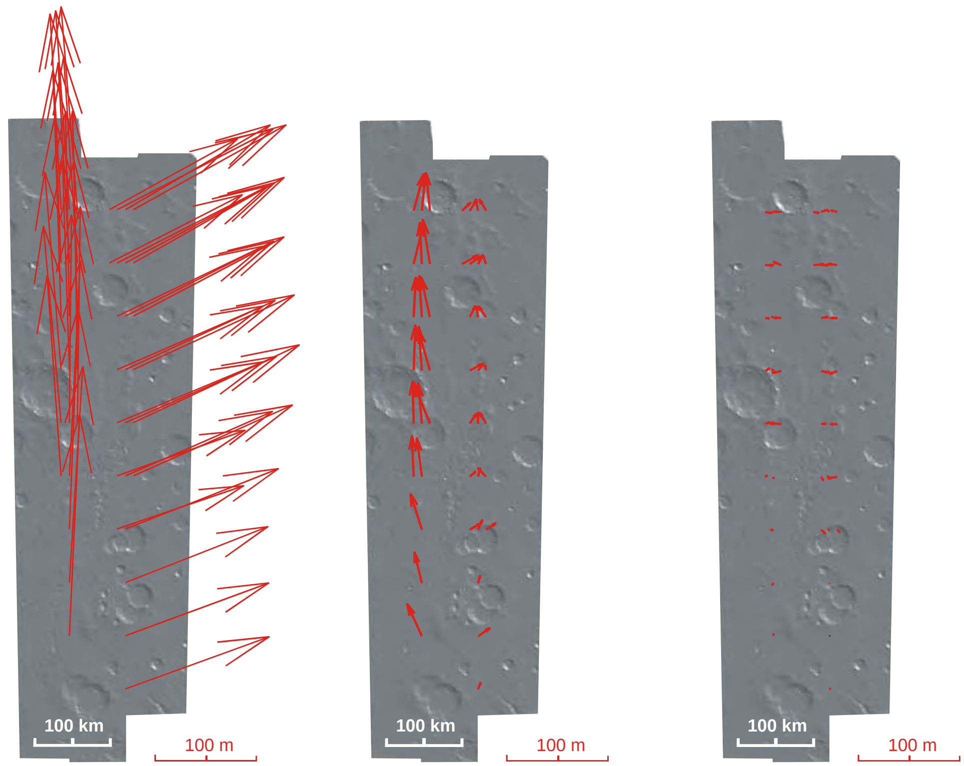

Figure 1: Average displacements between strips in planimetry. Before (left, case A), adjusted as single strips (middle, case B), and after a full bundle adjustment within a block (right, case C). Scale for right bar refers to the length of the arrows.

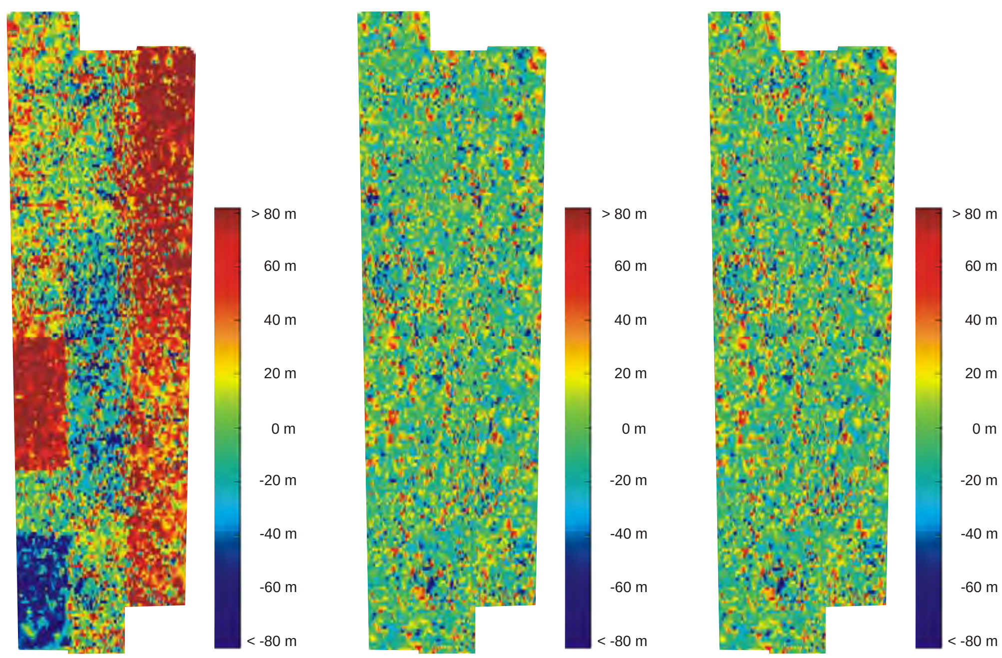

Figure 2: Differences between HRSC object points and MOLA DTM. Before (left, case A, average difference 90 m), adjusted as single strips (middle, case B, average difference 36 m), and after a full bundle adjustment within a block (right, case C, average difference 35 m).