PhotoSat
1188 West Georgia Street, Suite 580
Vancouver, British Columbia, Canada, V6E 4A2
Tel: +1 (604) 681 9770

PhotoSat Pleiades-1B stereo satellite surveying accuracy study, Asmara, Eritrea, 74 GCP, RMSE 26cm

- **189km^2 surveyed using 74 ground reference survey points**
- **This Pleiades-1B satellite elevation surveying accuracy is accurate to 26cm RMSE, determined by 1,677 survey checkpoints**
- **March, 2013 Pleiades-1B stereo satellite photos processed by PhotoSat in October, 2016**

Gerry Mitchell, P. Geo, Geophysicist, President PhotoSat
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A 1m grid of elevation values, covering an area of 189 square kilometres, was produced over the PhotoSat test area in Eritrea. The elevation grid was made using geophysical processing of 50cm ground resolution stereo satellite photos taken by the CNES Pleiades-1B satellite. The stereo satellite elevation processing was referenced to 74 ground survey points. The elevation surveying accuracy was measured with over 1,000 survey checkpoints.

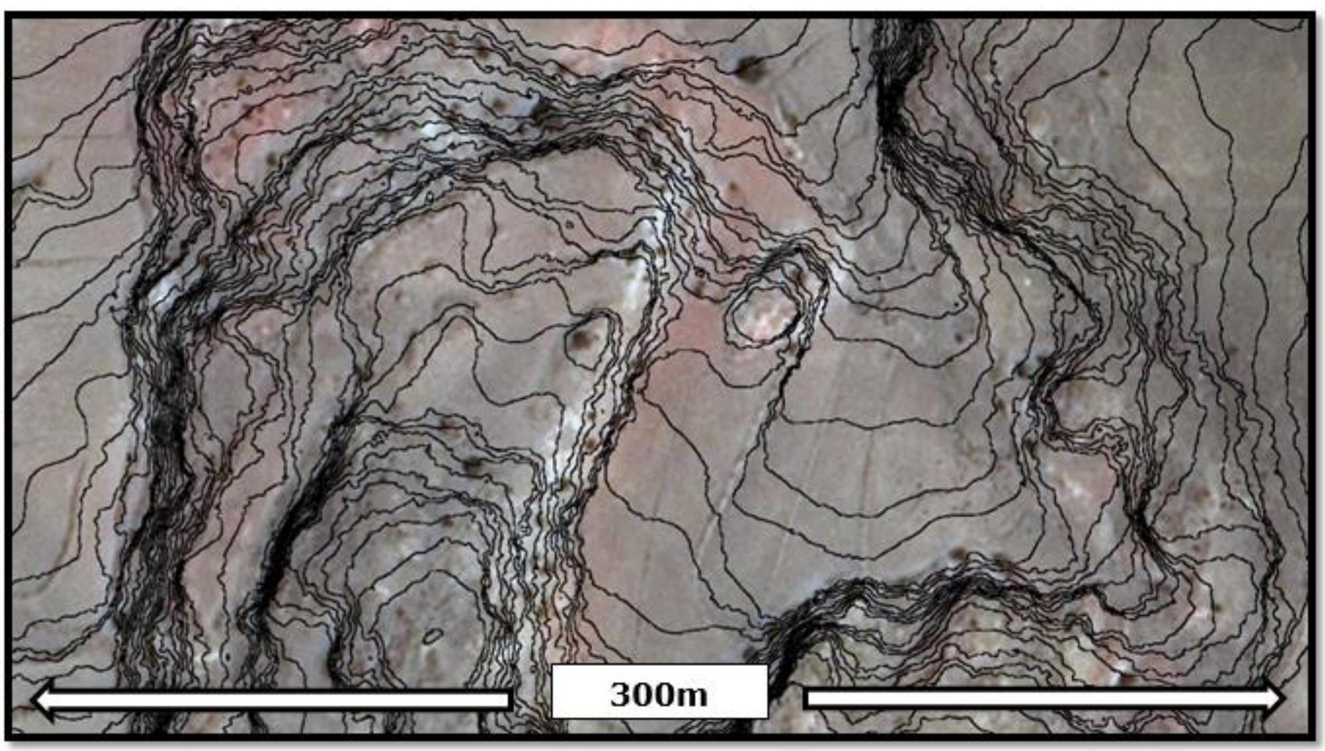

Figure 1. Pleiades-1B colour image with 50cm contours from the PhotoSat Pleiades-1B survey of the Eritrea test area.

Stereo satellite photos:

PhotoSat satellite surveying uses high quality stereo satellite photos. These photos are taken by the satellite as it passes over the survey area along a north to south satellite orbit. The process of taking the stereo photos is illustrated in Figure 2.

The satellite photographs the same ground area within a minute or two. The ground conditions are close to identical on the two photos. The difference in appearance of ground features on the photos is due to the different look directions of the satellite camera.

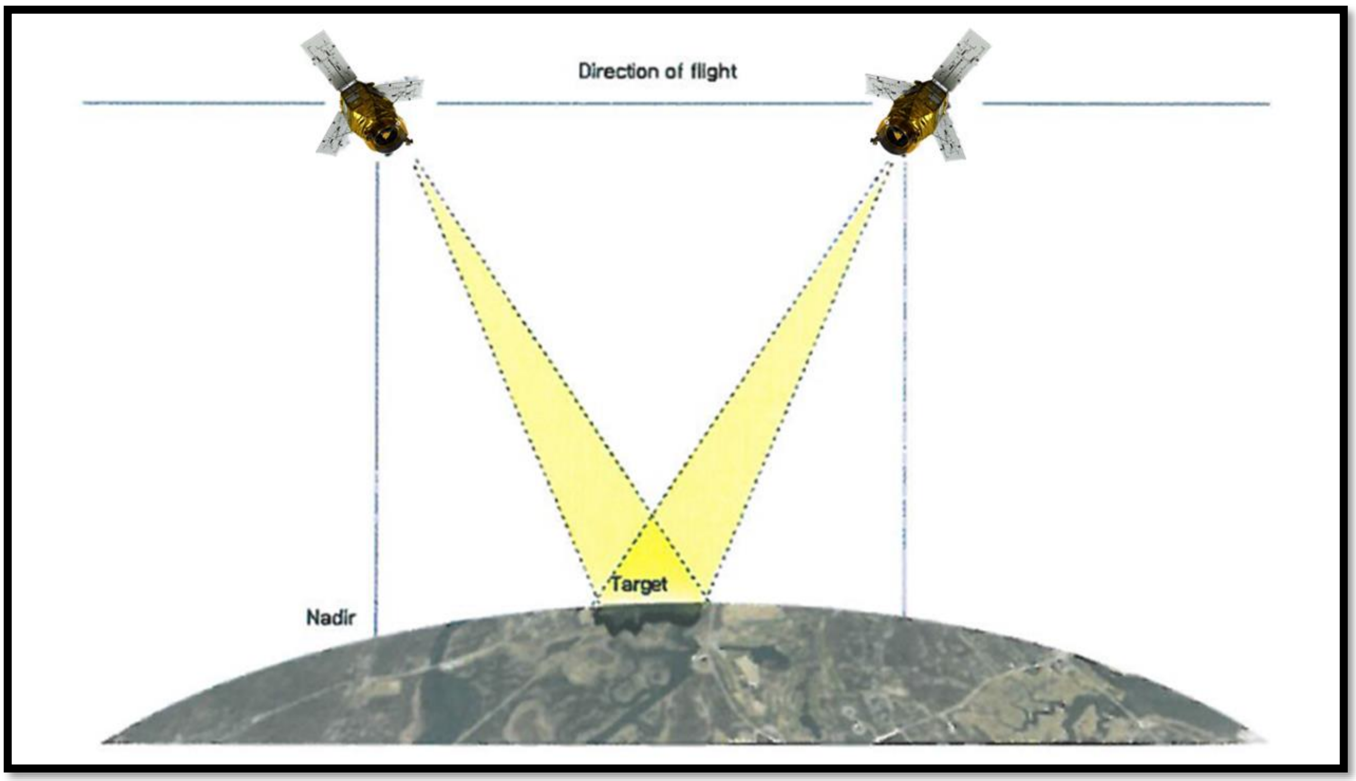

Figure 2. Illustration showing the process of taking satellite stereo photos. The satellite points forward to take the first photo. About one minute later, and 300km further along its orbital track, the satellite rotates to take the second photo looking backwards along the track. Hundreds of km^2 can be accurately surveyed with a single pair of stereo satellite photos.

PhotoSat geophysical stereo satellite processing system:

Survey coordinates of ground features are determined by measuring the apparent shift in location of the features between the two satellite photos. PhotoSat uses a proprietary geophysical processing system to generate survey coordinates from stereo satellite photos. This system is described in a PhotoSat white paper published at a 2010 ASPRS conference.

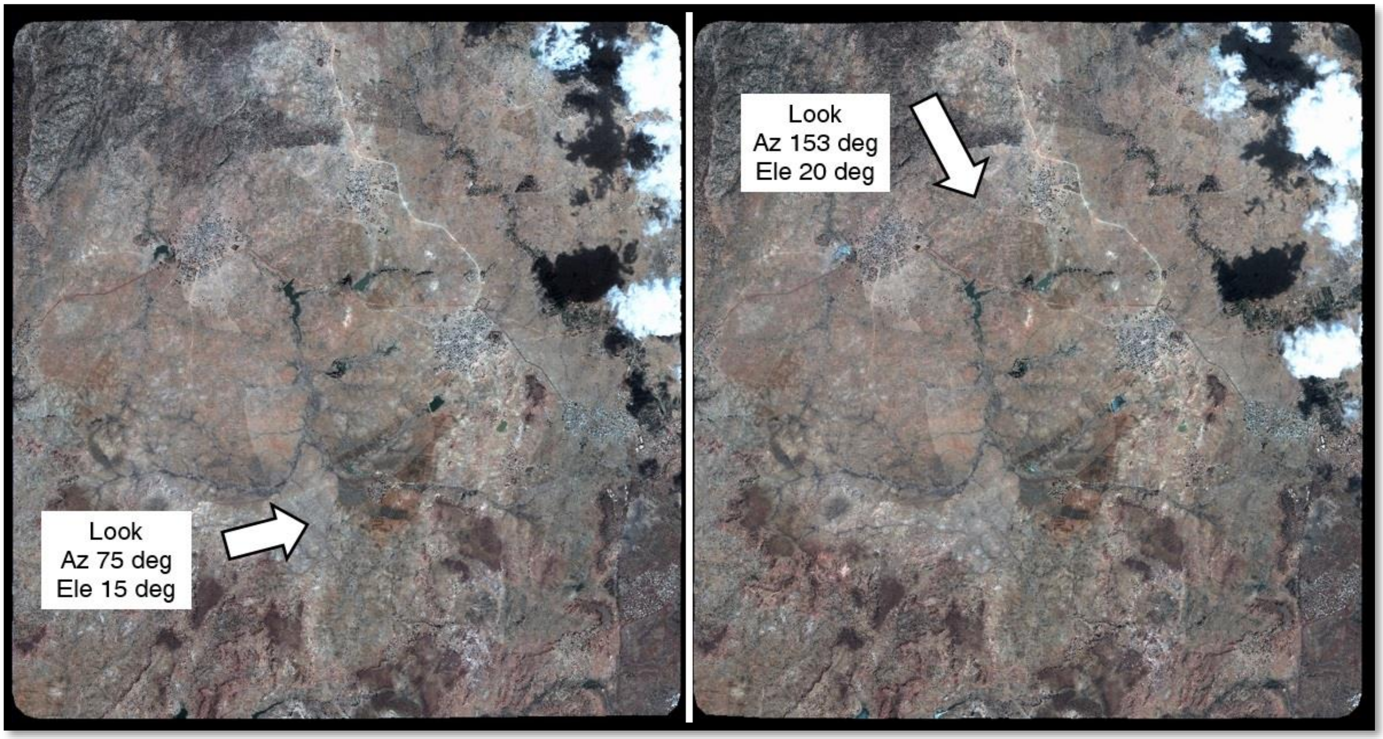

Figure 3. Pleiades-1B satellite photos of PhotoSat's Eritrea test area taken on March 10, 2013 at approximately 11:10 AM local time. The photo on the left was taken looking at an azimuth of 75 deg and angle from vertical of 15 deg. The photo on the right was taken looking at an azimuth of 153 deg and angle from vertical of 20 deg. The arrows on the photos indicate the satellite look direction. The lengths of the arrows are proportional to the look angles from vertical. This stereo pair has a convergence angle of 22 deg, a bisector azimuth of 121 deg and bisector angle of 14 deg from vertical.

Eritrea satellite photos:

The pair of stereo Pleiades-1B satellite photos over the Eritrea test area are shown in Figure 3. The photos were taken on March 10, 2013 at approximately 11:10 AM local time. The stereo satellite photo look directions, convergence angle, bisector azimuth and bisector angle from vertical are shown in the figure caption. The convergence angle of 22 deg is optimum for surveying elevations in level to moderate terrain.

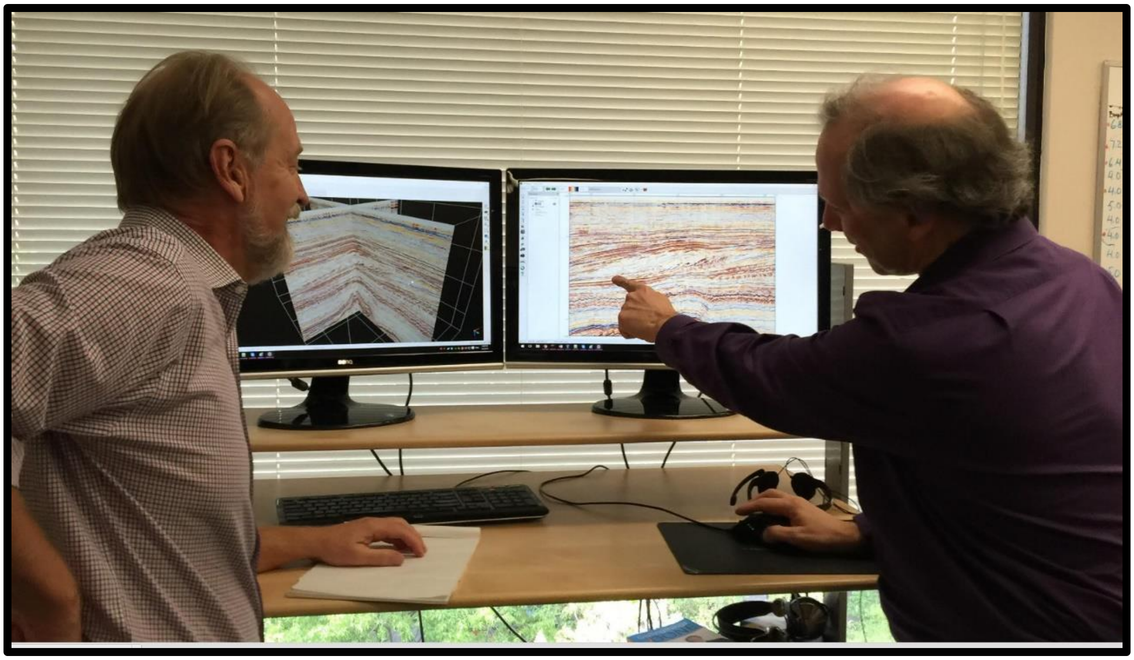

Figure 4. Gerry Mitchell, left, and Michael Ehling with an Oil and Gas seismic processing workstation. This technology is the basis for the PhotoSat geophysical stereo satellite processing system named the PhotoSat Process Manager.

Figure 5. Michael, Gerry and Jayda Akatsuka with the PhotoSat Process Manager.

Eritrea elevation grid:

PhotoSat produced a 1m grid of elevations over the entire project area. We processed the stereo Pleiades-1B photos with our geophysical stereo satellite processing system in October, 2016. An image of the 1m elevation grid is shown in Figure 7.

Ground reference points:

With this accuracy study we are demonstrating that we can produce highly accurate Pleiades-1B surveys with 74 ground reference points. Having as little as 74 reference points for a 189km^2 satellite surveying project is not uncommon in mining exploration projects.

The locations of the ground reference points are shown in Figure 6. The ground reference point was determined by fitting the satellite elevation grid to a dense set of ground survey points around a topographic high. This fit was within 25 cm horizontal and 5 cm vertical.

Global shift of stereo satellite survey to match ground reference:

The Pleiades ortho photo and elevation grid needed a constant shift of -4.45m E, -2.4m N and -2.0m in elevation to match the ground surveying. The global accuracy of most Pleiades-1B stereo satellite photos is better than 3m.

Accuracy evaluation checkpoints:

The accuracy of the PhotoSat 1m survey grid was evaluated with 1,677 ground survey checkpoints. These points were originally surveyed for a large mining exploration gravity survey conducted between 2004 and 2008 by MWH Geophysics. The distribution of the elevation checkpoints is shown in Figure 8.

The elevation checkpoints were surveyed to an accuracy of 2cm using Real Time Kinematic GPS survey equipment. One of the MWH Geophysics survey teams and their equipment are shown in Figure 9. The accuracy checkpoints consist of a 250m by 250m regional grid of points.

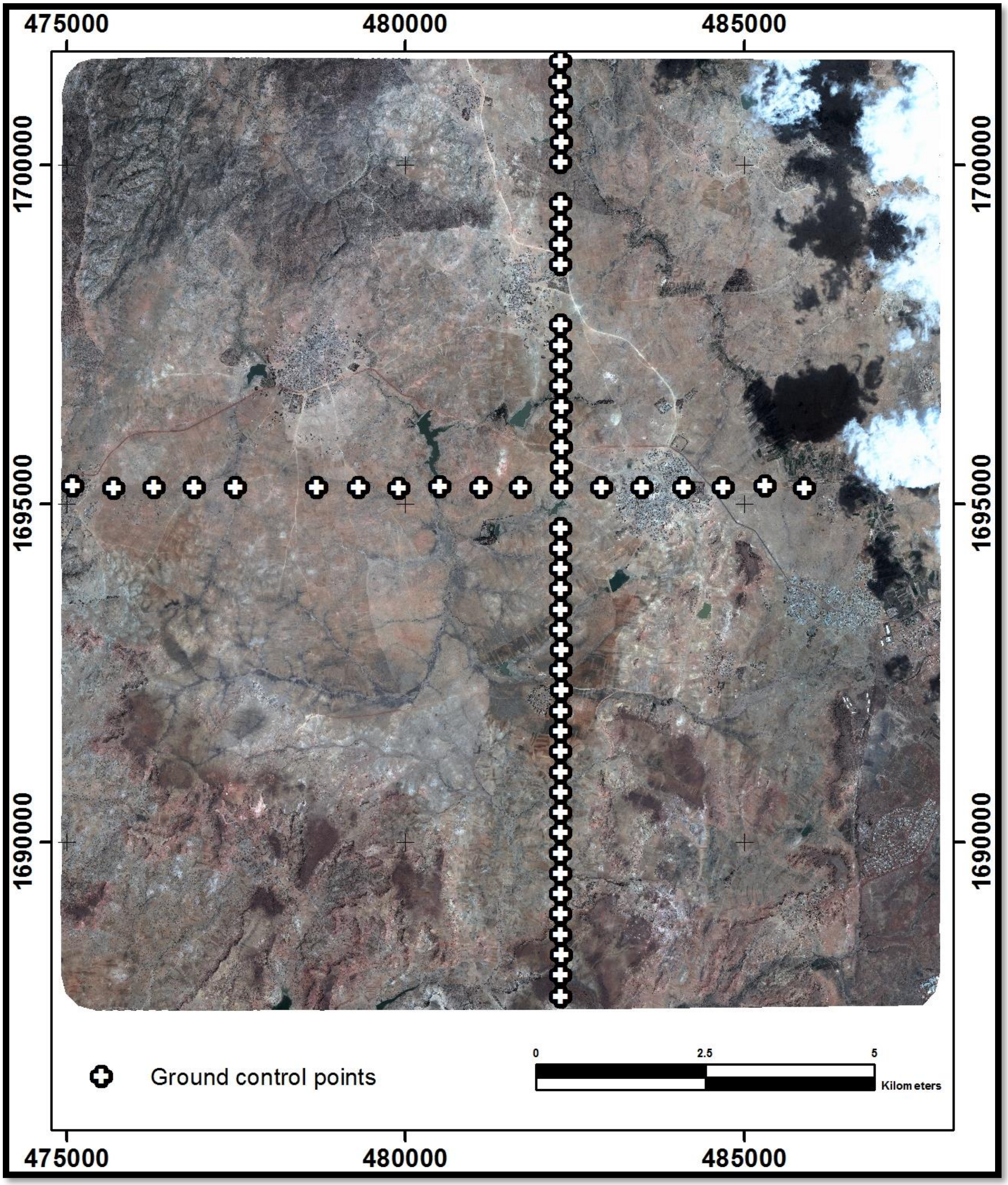

Figure 6. Pleiades-1B 50cm stereo satellite photo. Asmara, Eritrea.

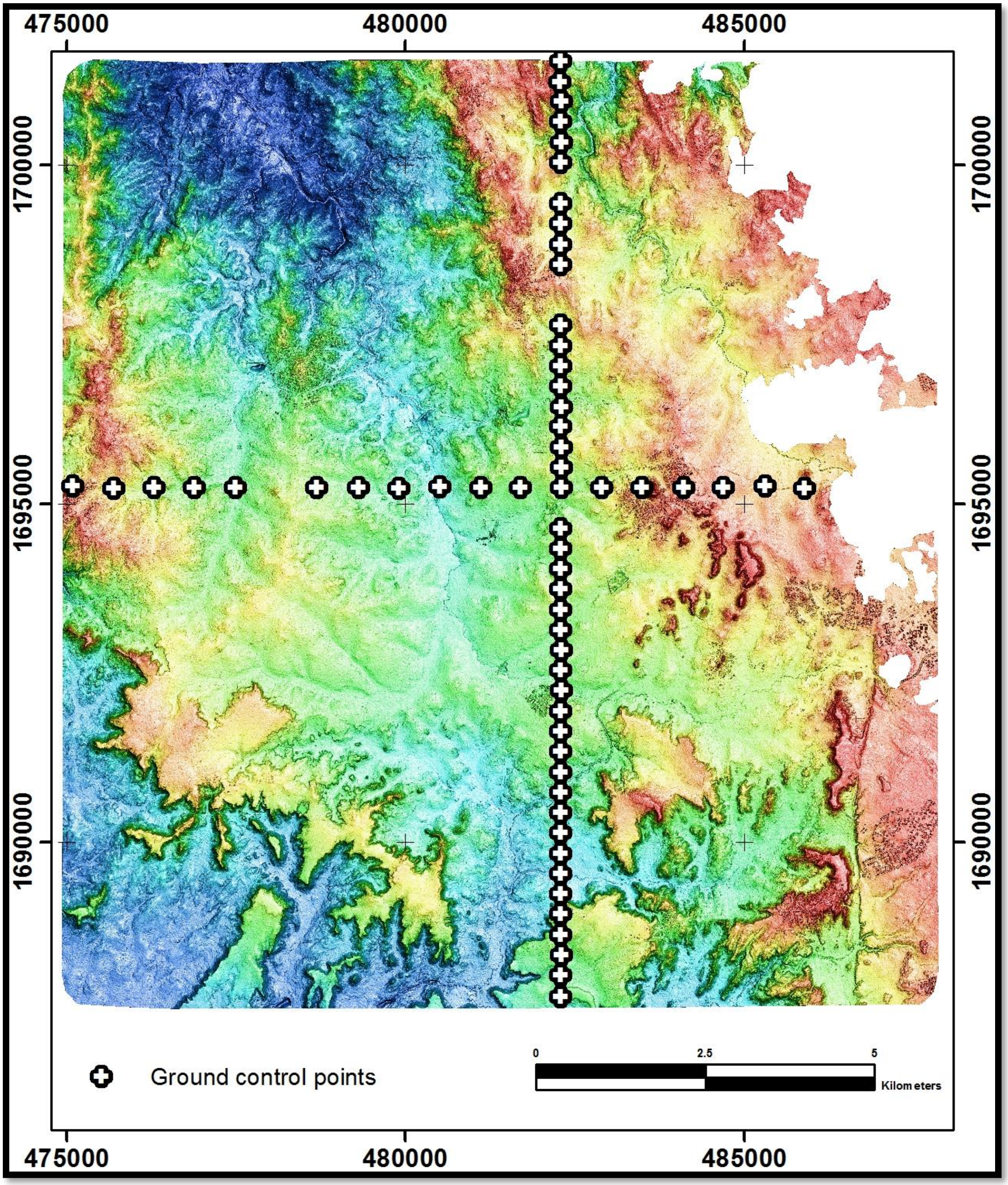

Figure 7. Stereo Pleiades-1B elevation image created from the 1m PhotoSat Asmara, Eritrea satellite survey grid. The figure shows the location of the ground control points.

Elevation survey accuracy statistics:

The *Guidelines for Digital Elevation Data* of the US National Digital Elevation Program (NDEP) recommends that elevation checkpoints should be chosen in areas with slopes less than 20% grade. 1,677 elevation checkpoints with slopes less than 20% grade have an RMSE of 26cm as shown in Figure 10.

A histogram of the elevation differences between the PhotoSat WorldView survey grid and all 1,908 ground survey checkpoints is shown in Figure 11. The RMSE using all of the points is 27cm.

The points on slopes over 20% grade have an RMSE of 40cm as shown in Figure 12.

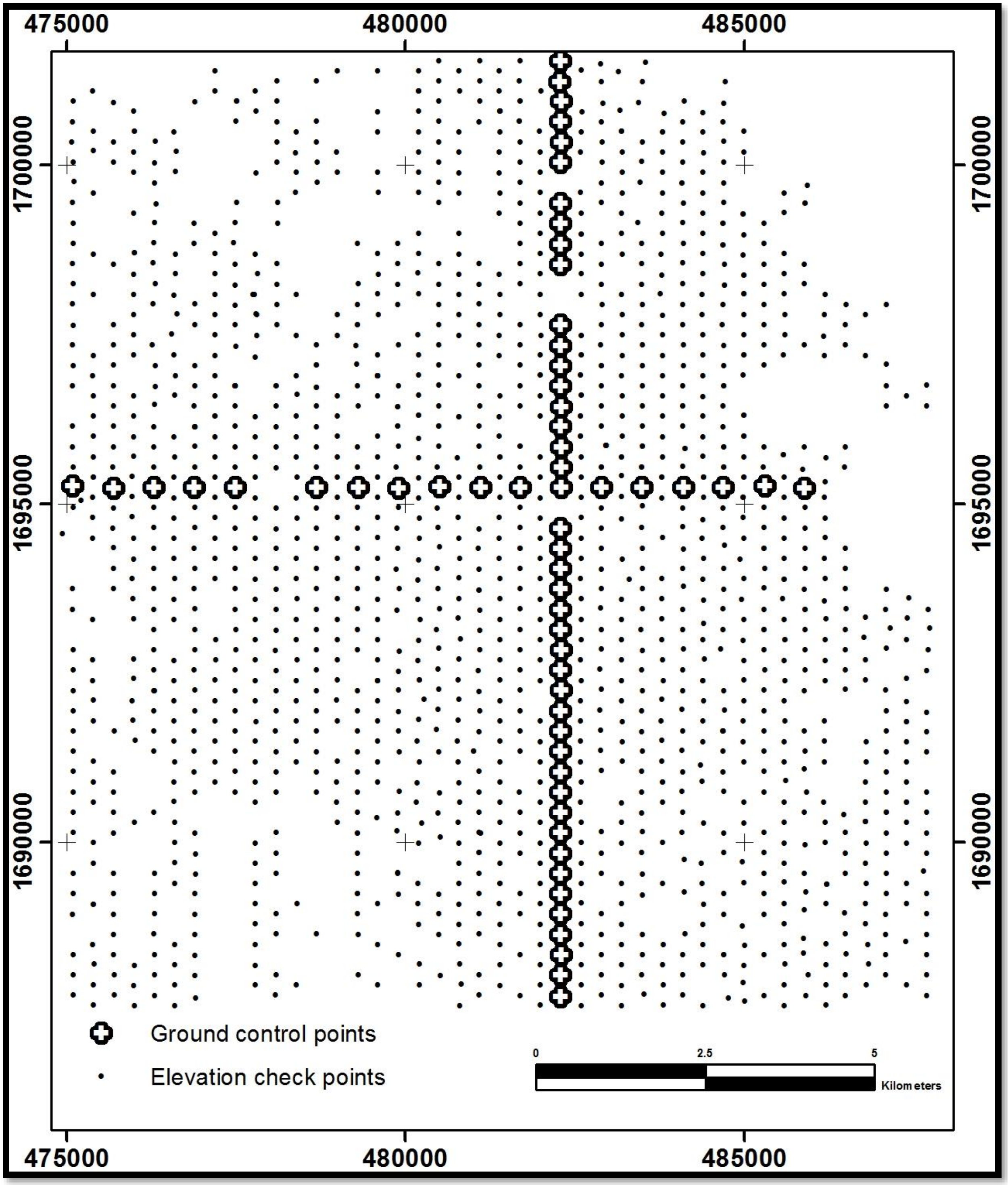

Figure 8. Area of the 14.4km by 13km Eritrea Stereo Pleiades-1b 1m elevation grid showing the 74 ground control points and the 1,677 gravity survey stations used as elevation checkpoints to determine the accuracy of the stereo satellite survey

Figure 9. Asmara Project, Eritrea. MWH Geo-Survey differential GPS survey crew and equipment*.* The Magellan RTK base with a ProMark^{TM} 500 GPS rover are shown in this photo.

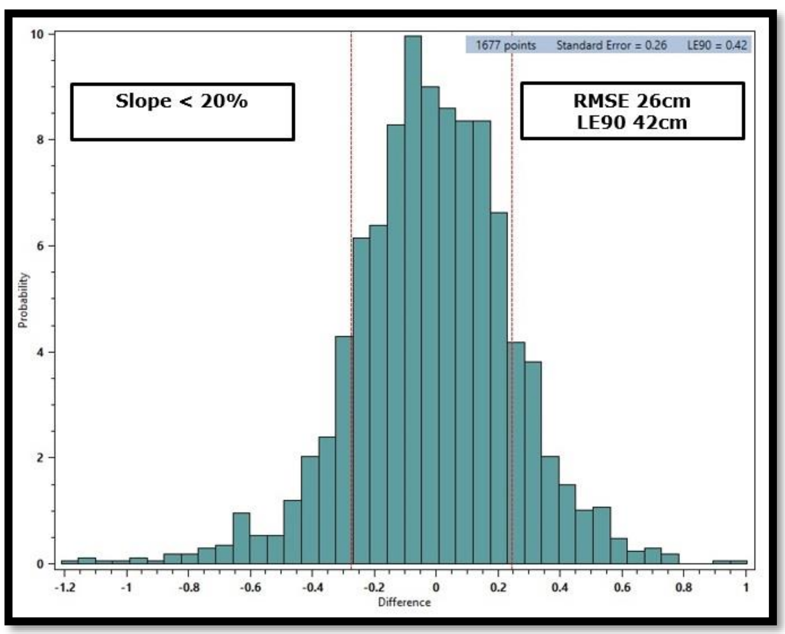

Figure 10. Histogram of the elevation differences between the Pleiades-1B stereo satellite elevations for the 14.4km by 13km area and the 1,677 elevation checkpoints with slopes less than 20% grade. The *Guidelines for Digital Elevation Data* of the US National Digital Elevation Program (NDEP) recommends that elevation checkpoints should be chosen in areas with slopes less than 20% grade. RMSE 26cm, LE90 42cm.

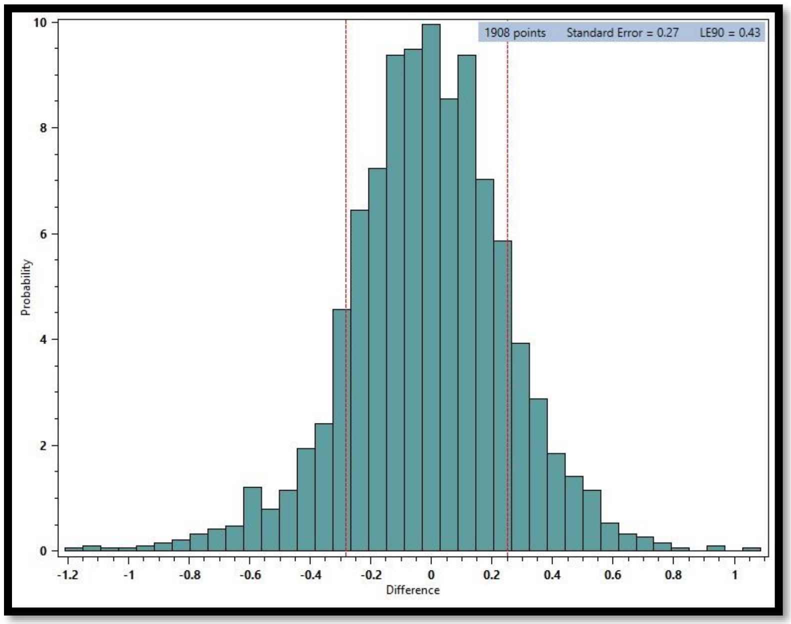

Figure 11. Histogram of the elevation differences between the Pleiades-1B stereo satellite elevations for the 14.4km by 13km area and all 1,908 elevation checkpoints. RMSE 27cm, LE90 43cm.

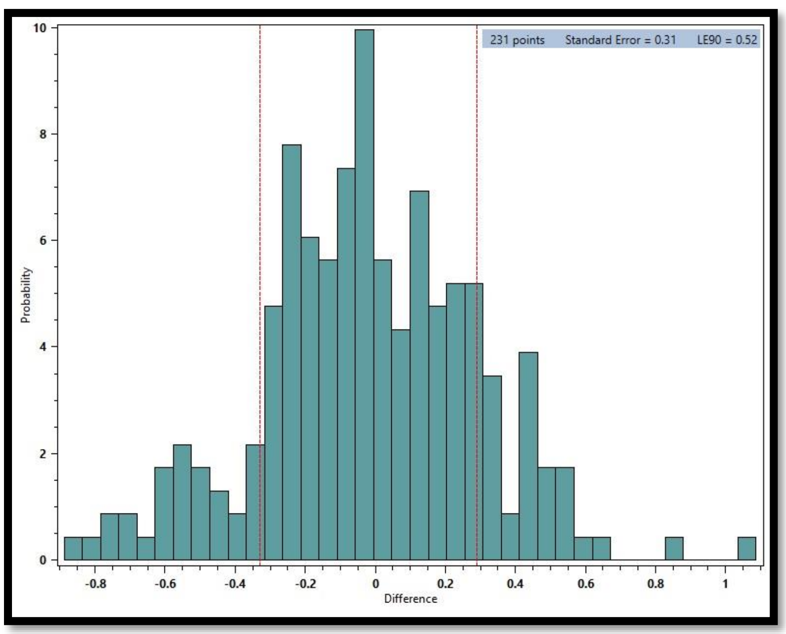

Figure 12. Histogram of the elevation differences between the Pleiades-1B stereo satellite elevations for the 14.4km by 13km area and the 231 elevation checkpoints with slopes between 20% and 100% grade. RMSE 31cm, LE90 52cm.

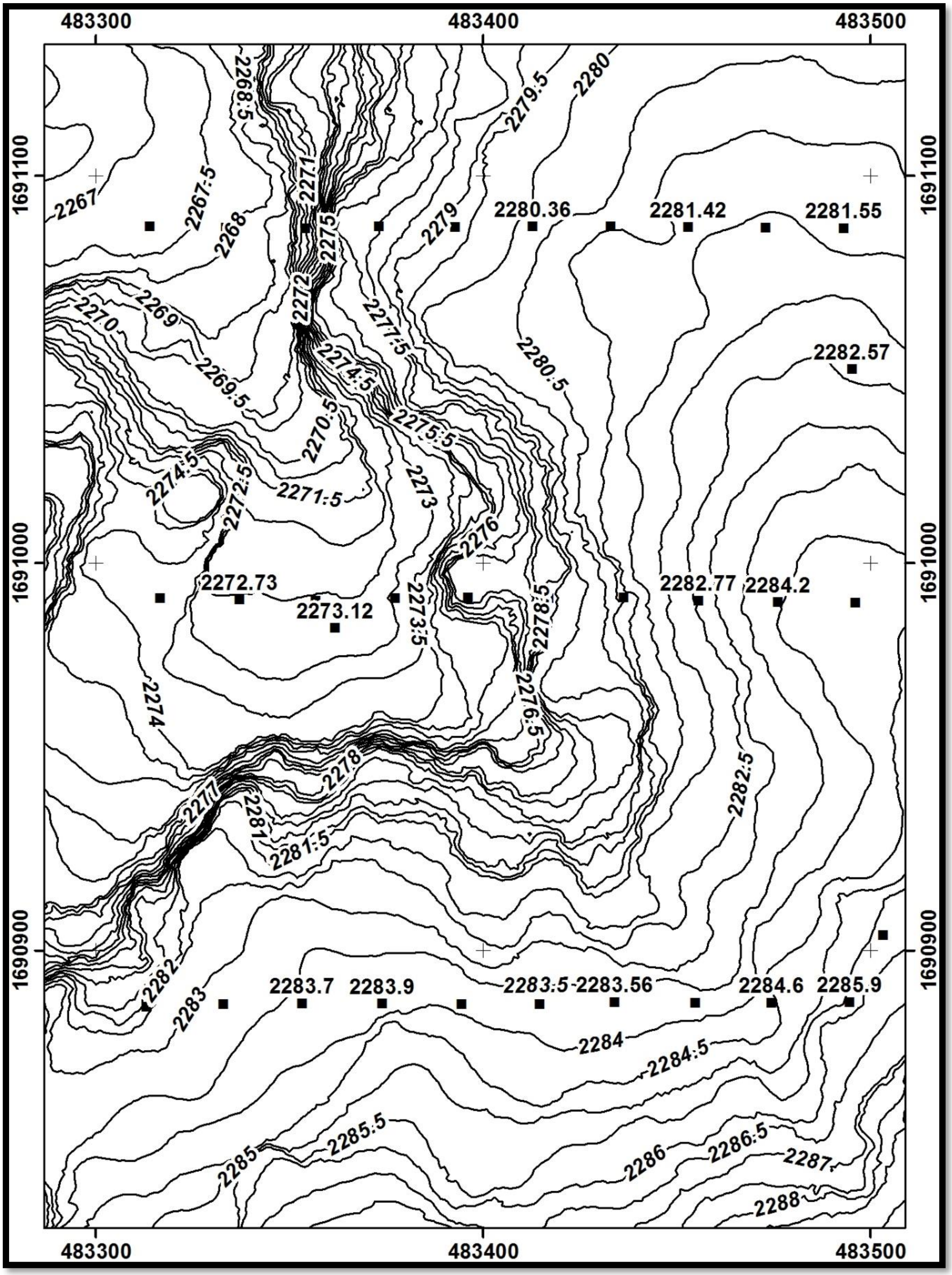

Figure 13. 50cm contours from the stereo Pleiades-1B elevation survey showing the elevations of some of the elevation checkpoints used to determine the stereo satellite elevation surveying accuracy of better than 30cm RMSE.

Comparison between elevation checkpoints and 50cm PhotoSat contours:

The very close agreement between the satellite survey elevations and the ground survey checkpoints can be seen in Figure 13. Labeled 50cm contours are shown with the posted elevations of the ground survey points. This figure is typical of the agreement between the PhotoSat survey and the ground survey over the entire survey area.

Cautionary Statement:

This is an accuracy assessment for elevation surveying from a single stereo pair of Pleiades-1B satellite photos. While in our experience these results are typical for most Pleiades-1B stereo photos, these results may not apply to any specific pair of Pleiades-1B stereo photos.

References:

A Geophysical Stereo Satellite Elevation Mapping System, Mitchell G & Ehling M, ASPRS 2010 Annual Convention, San Diego, California, USA
http://www.photosat.ca/pdf/asprs_geophysical_mapping_system_2010.pdf

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http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf