PhotoSat
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PhotoSat Prism stereo satellite mapping accuracy study, Asmara, Eritrea, 3 GCP, RMSE 1.19m

- **2,300km^2 mapped using only three ground reference survey point**
- **This ALOS PRISM satellite elevation mapping accuracy is accurate to 1.19m RMSE, determined by 7,469 survey checkpoints**
- **October 2007 PRISM stereo satellite photos processed by PhotoSat in October 2016**

Gerry Mitchell, P. Geo, Geophysicist, President PhotoSat
November, 2016

A 5m grid of elevation values, covering an area of 2,300 square kilometres, was produced over the PhotoSat test area in Eritrea. The elevation grid was made using geophysical processing of 2.5m ground resolution stereo satellite photos taken by the PRISM satellite. The stereo satellite elevation processing was referenced to three ground map point. The elevation mapping accuracy was measured with over 7,000 survey checkpoints.

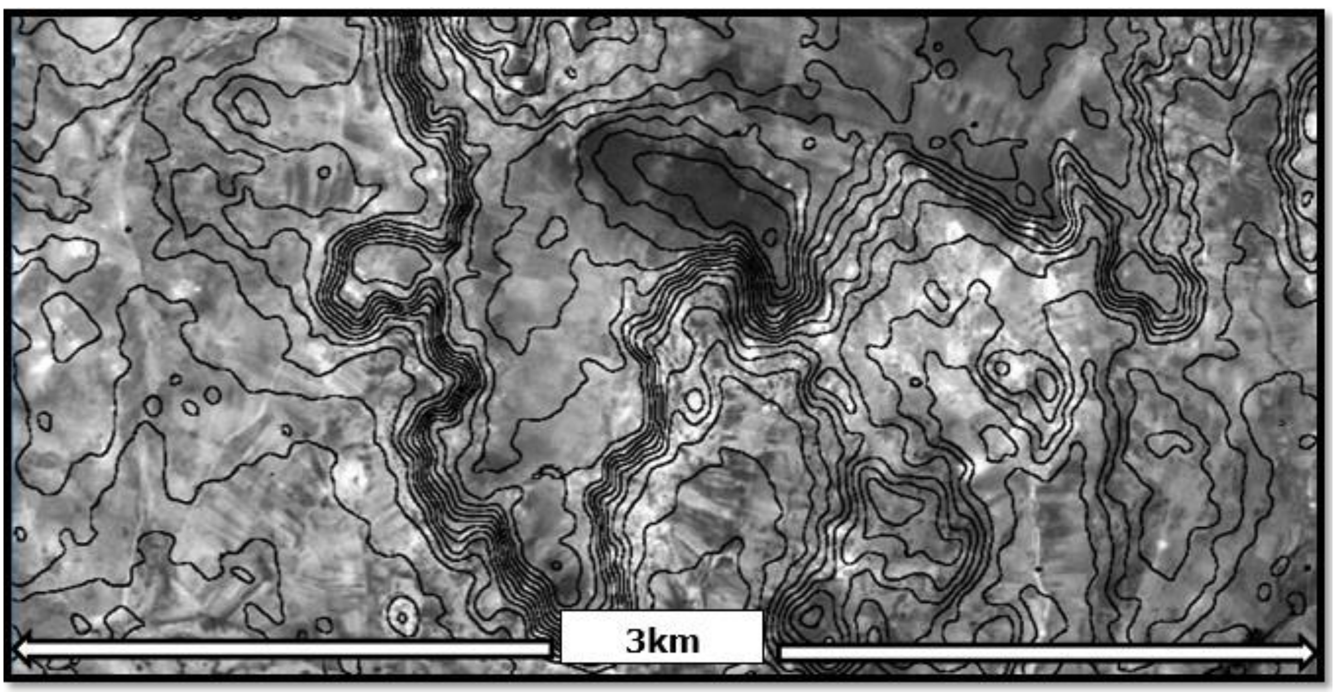

Figure 1. PRISM colour image with 5.0m contours from the PhotoSat PRISM map of the Eritrea test area.

Stereo satellite photos:

PhotoSat satellite mapping uses high quality stereo satellite photos. These photos are taken by the satellite as it passes over the mapping area along a north to south satellite orbit. The satellite photographs the same ground area within a minute or two, so the ground conditions are close to identical on each photo. The difference in appearance of ground features on the photos is due to the different look directions of the satellite camera.

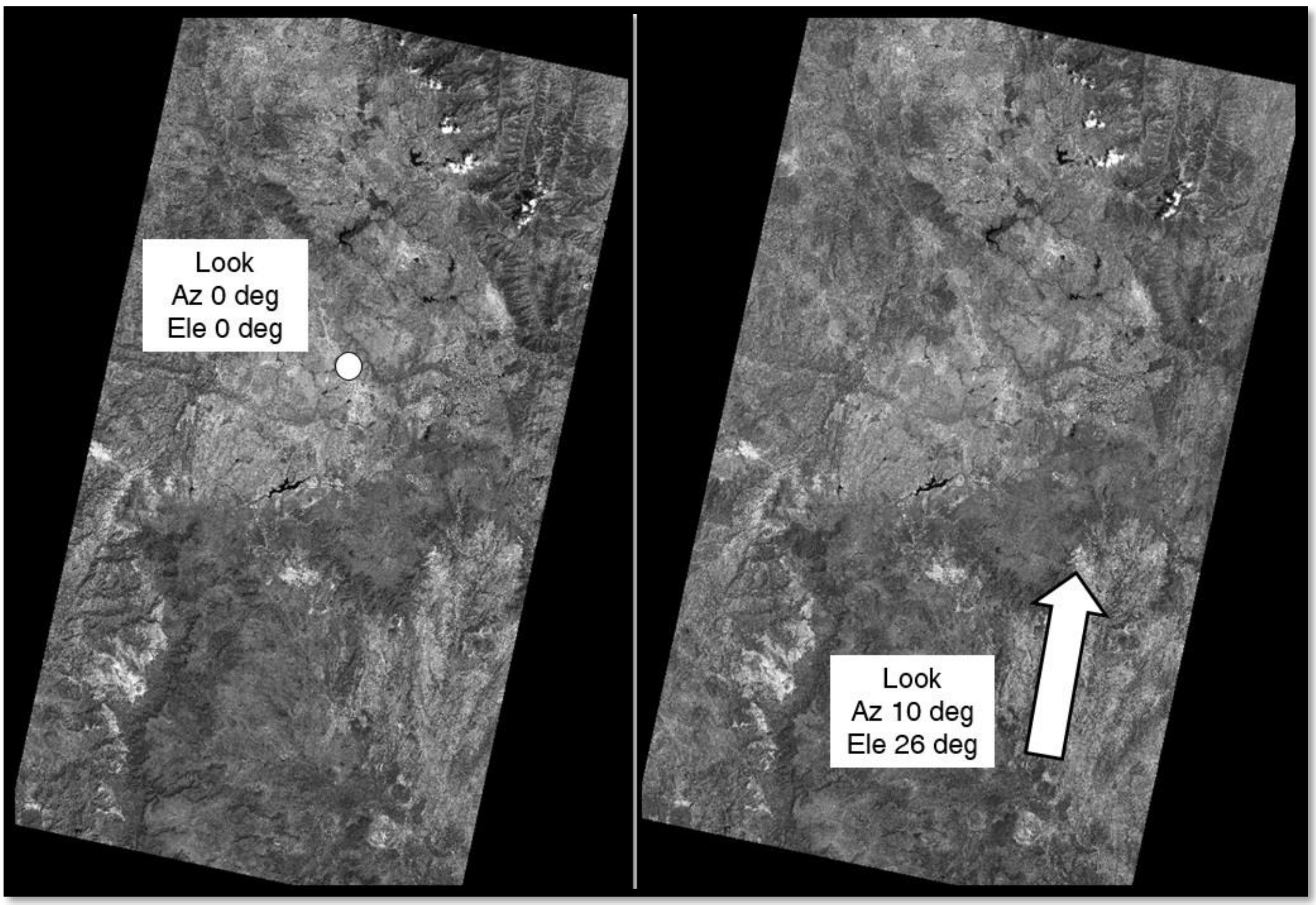

Figure 2. PRISM satellite photos of PhotoSat's Eritrea test area taken on October 24, 2007 at approximately 10:30 AM local time. The photo on the left was taken looking straight down. The photo on the right was taken looking at an azimuth of 10 deg and angle from vertical of 26 deg. The arrows on the 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 26 deg, a bisector azimuth of 10 deg and bisector angle of 13 deg from vertical.

PhotoSat geophysical stereo satellite processing system:

Elevations 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 map coordinates from stereo satellite photos. This system is described in a PhotoSat white paper published at a 2010 ASPRS conference.

Eritrea satellite photos:

The pair of stereo PRISM satellite photos over the Eritrea test area are shown in Figure 2. 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 26 deg is optimum for mapping elevations in level to moderate terrain.

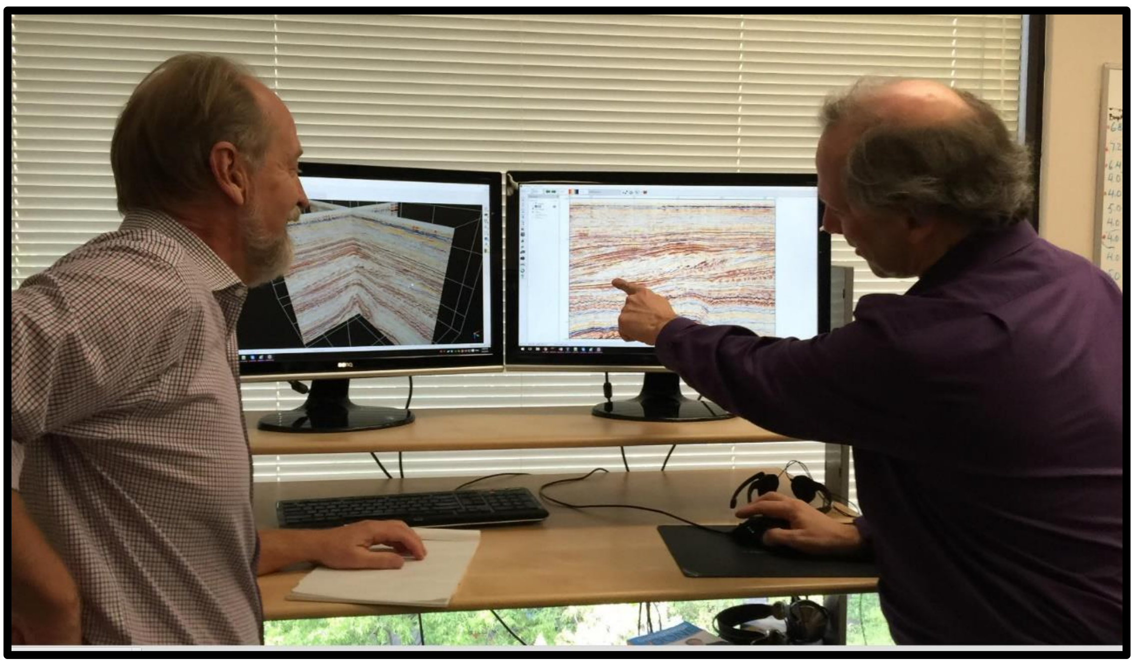

Figure 3. Gerry Mitchell, left, and Michael Ehling with an Oil and Gas seismic processing workstation. This technology is the basis for the PhotoSat geophysical stereo satellite processing system named the PhotoSat Process Manager.

Figure 4. Michael, Gerry and Jayda Akatsuka with the PhotoSat Process Manager.

Eritrea elevation grid:

PhotoSat produced a 5m grid of elevations over the entire project area. We processed the stereo PRISM photos with our geophysical stereo satellite processing system in October 2016. An image of the 5m elevation grid is shown in Figure 6.

Ground reference points:

With this accuracy study we are demonstrating that we can produce highly accurate PRISM mapping with only three ground reference point. Having as little three ground reference points for a 2,300km^2 satellite mapping project is not uncommon in mining exploration projects.

The location of the ground reference points is shown in Figure 5.

Global shift of stereo satellite map to match ground reference:

The WorldView ortho photo and elevation grid needed a constant shift of
0.25m E, -5.25m N and -11.98m in elevation to match the ground surveying. The global accuracy of most PRISM stereo satellite photos is better than 25m.

Accuracy evaluation checkpoints:

The accuracy of the PhotoSat 5m map grid was evaluated with 7,469 ground survey checkpoints. These points were originally surveyed for a large mining exploration gravity map conducted between 2004 and 2008 by MWH Geophysics. The distribution of the elevation checkpoints is shown in Figure 7.

The elevation checkpoints were surveyed to an accuracy of 2cm using Real Time Kinematic GPS map equipment. One of the MWH Geophysics survey teams and their equipment are shown in Figure 8. The accuracy checkpoints consist of a 250m by 250m regional grid of points.

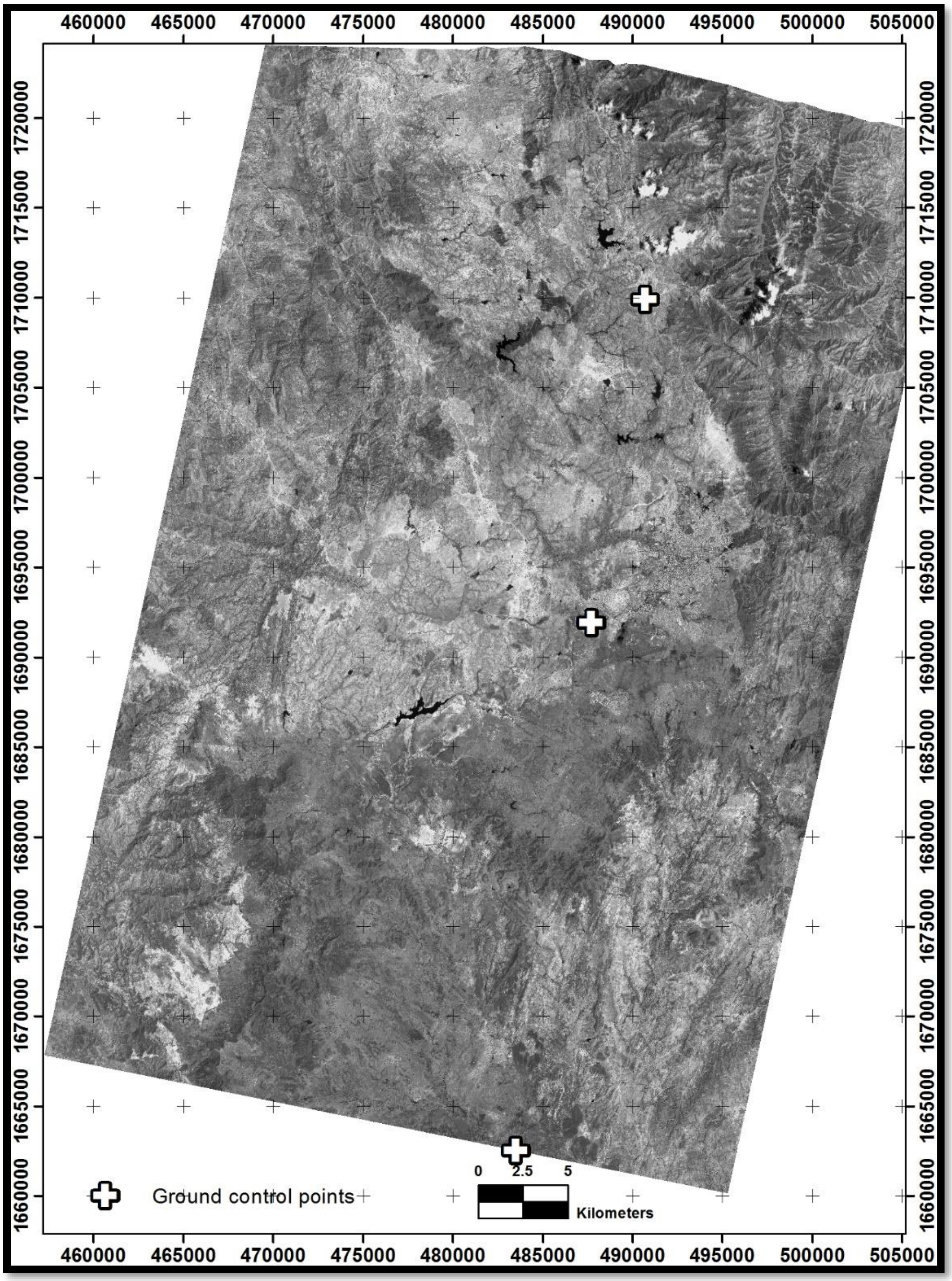

Figure 5. PRISM 2.5m stereo satellite photo. Asmara, Eritrea.

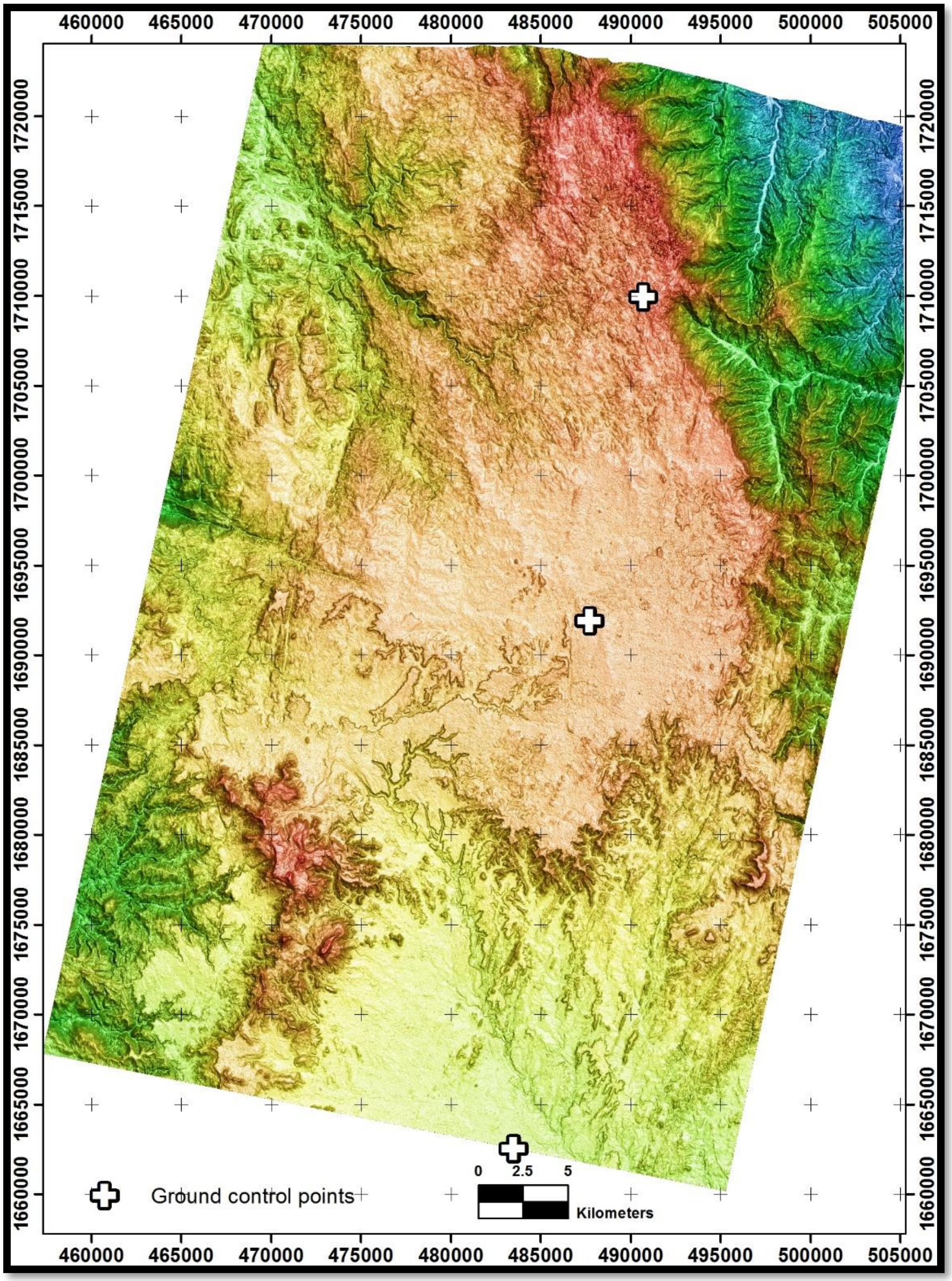

Figure 6. Stereo PRISM elevation image created from the 5m PhotoSat Asmara, Eritrea satellite elevation grid.

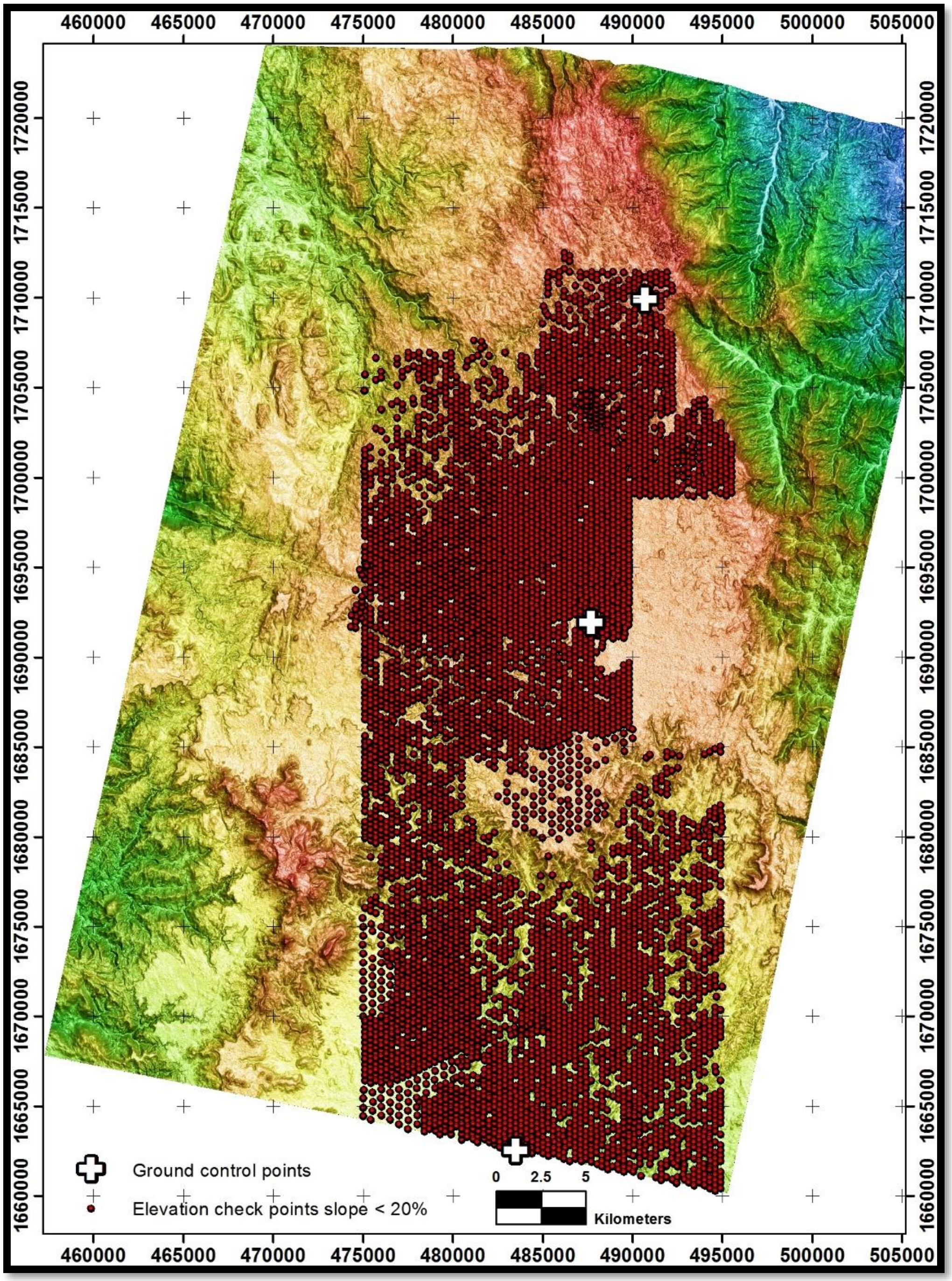

Figure 7. Stereo PRISM elevation image showing the location of the ground control point and the 7,469 elevation checkpoints.

Elevation mapping 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. The 7,469 elevation checkpoints with slopes less than 20% grade have an RMSE of 1.19m as shown in Figure 9.

A histogram of the elevation differences between the PhotoSat PRISM survey grid and all 9,087 ground survey checkpoints is shown in Figure 10. The RMSE using all of the points is 1.68m.

The points on slopes over 20% grade have an RMSE of 3.03m as shown in Figure 11.

Figure 8. Asmara Project, Eritrea. MWH Geo-Maps differential GPS map crew and equipment. The Magellan RTK base with a ProMark^{TM} 500 GPS rover are shown in this photo.

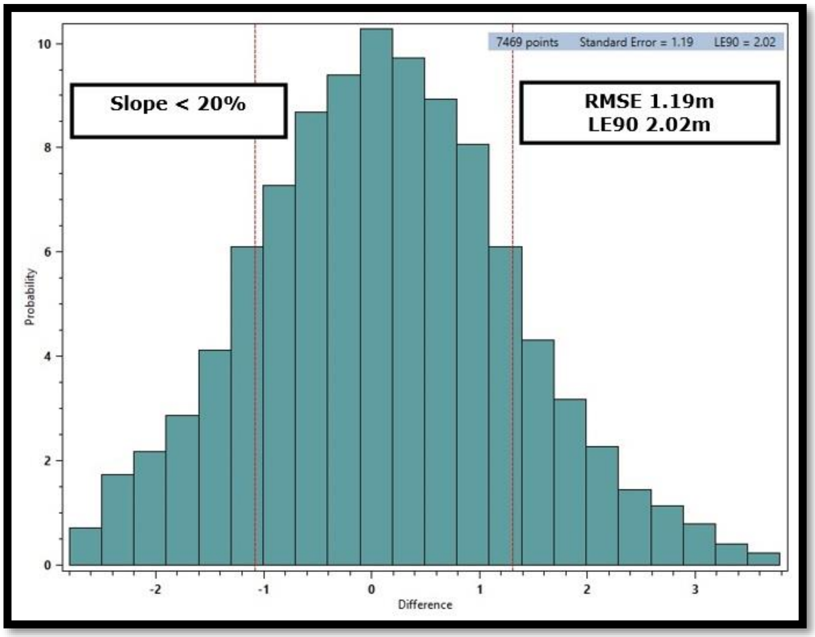

Figure 9. Histogram of the elevation differences between the PRISM stereo satellite elevations for the 60km by 40km area and the 7,469 elevation checkpoints with slopes less than 20% grade. The *Guidelines for Digital Elevation Data* of the US National Digital Elevation Program (NDEP) recommends that elevation checkpoints should be chosen in areas with slopes less than 20% grade. RMSE 1.19m, LE90 2.02m.

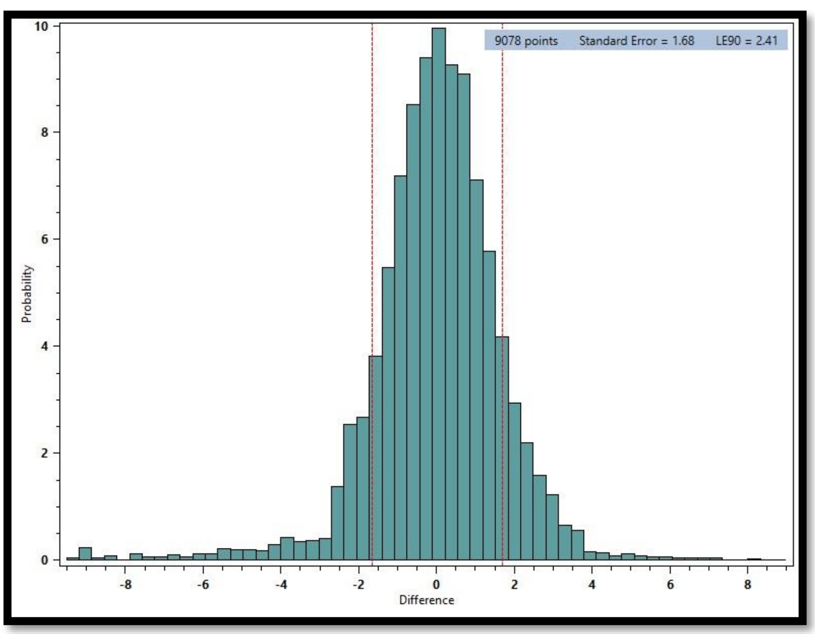

Figure 10. Histogram of the elevation differences between the PRISM stereo satellite elevations for the 60km by 40km area and all 9,078 elevation checkpoints. RMSE 1.68m, LE90 2.41m.

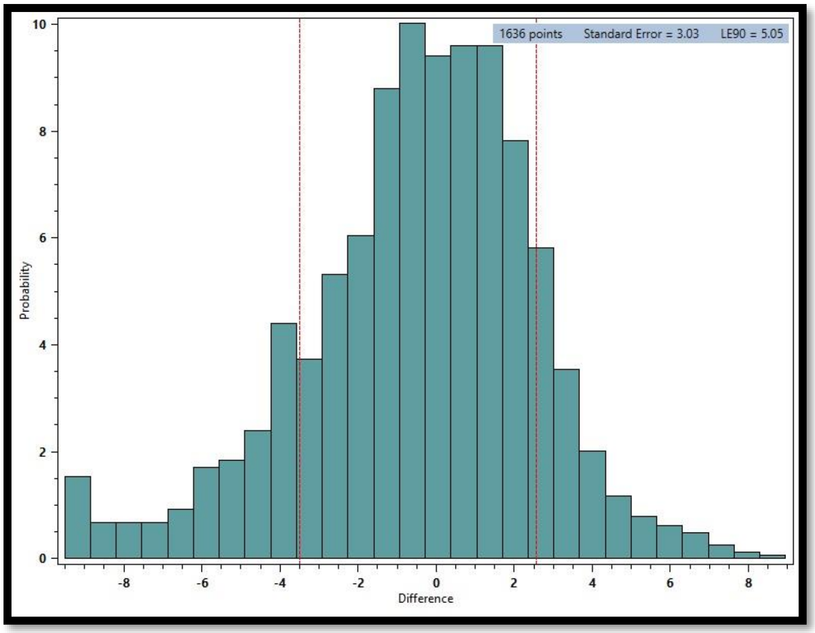

Figure 11. Histogram of the elevation differences between the PRISM stereo satellite elevations for the 60km by 40km area and the 1,636 elevation checkpoints with slopes between 20% and 100% grade. RMSE 3.03m, LE90 5.05m.

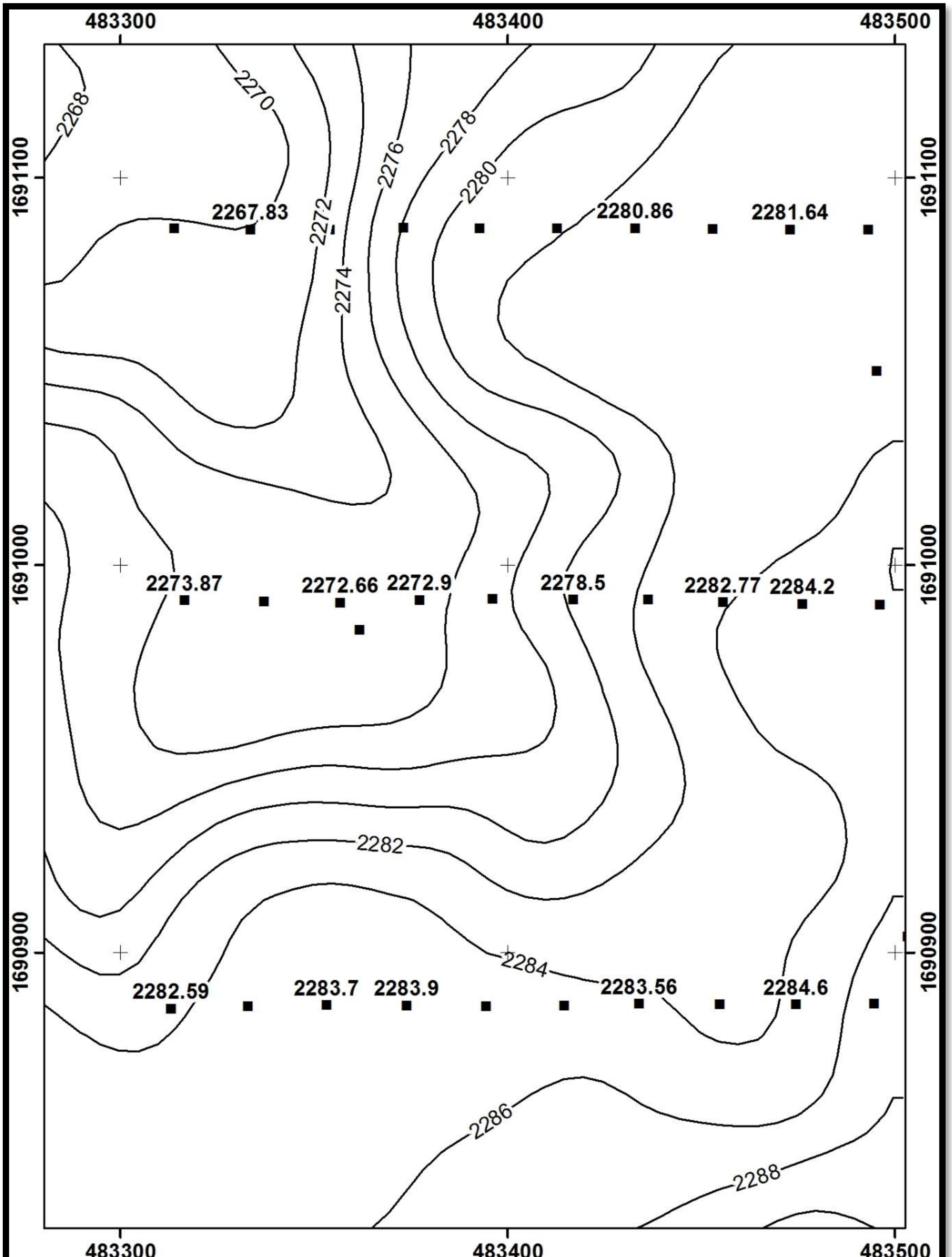

Figure 12. 2m contours from the stereo PRISM elevation map showing the elevations of some of the elevation checkpoints used to determine the stereo satellite elevation mapping accuracy of better than 2.5m RMSE.

Comparison between elevation checkpoints and 1.5m PhotoSat contours:

The very close agreement between the satellite map elevations and the ground map checkpoints can be seen in Figure 12. Labeled 2m contours are shown with the posted elevations of the ground map points. This figure is typical of the agreement between the PhotoSat map and the ground map over the entire map area.

Cautionary Statement:

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

NDEP Guidelines for Digital Elevation Data.
http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf