PhotoSat GeoEye-1 Stereo Satellite DEM Comparison to a LiDAR DEM over the Garlock Fault in Southeast California.

Gerry Mitchell, Geophysicist, President PhotoSat
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In December 2009, a study was conducted to measure the elevation mapping accuracy and resolution of PhotoSat's GeoEye-1 stereo satellite digital elevation models (DEMs) compared to LiDAR DEMs. For this comparative study, GeoEye, the owner of the GeoEye-1 satellite, provided a GeoEye-1 stereo satellite photo pair over a 10km section of the Garlock Fault in southeast California.

The Garlock Fault was mapped with a LiDAR survey in April 2008 by OpenTopography. The Garlock Fault LiDAR DEM data is available on the OpenTopography website www.opentopography.org. The location of the Garlock Fault LiDAR survey and the area of the comparison with the GeoEye-1 stereo satellite DEM is shown in figure 1. The comparisons of the LiDAR and stereo GeoEye-1 DEMs are shown in figures 2 through 9.

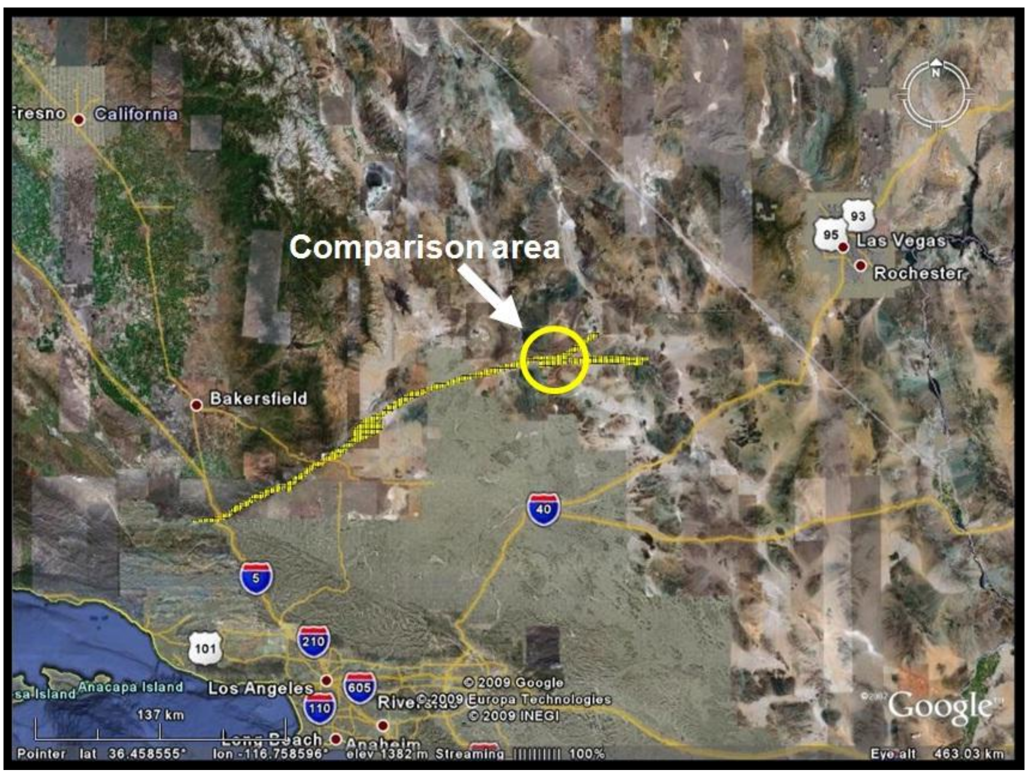

Figure 1. The Garlock Fault Opentopography LiDAR survey shown on Google Earth. The Garlock Fault LiDAR survey was flown in April 2008. The location of the GeoEye-1 stereo satellite photos, acquired November 30, 2009, is shown by the circle.

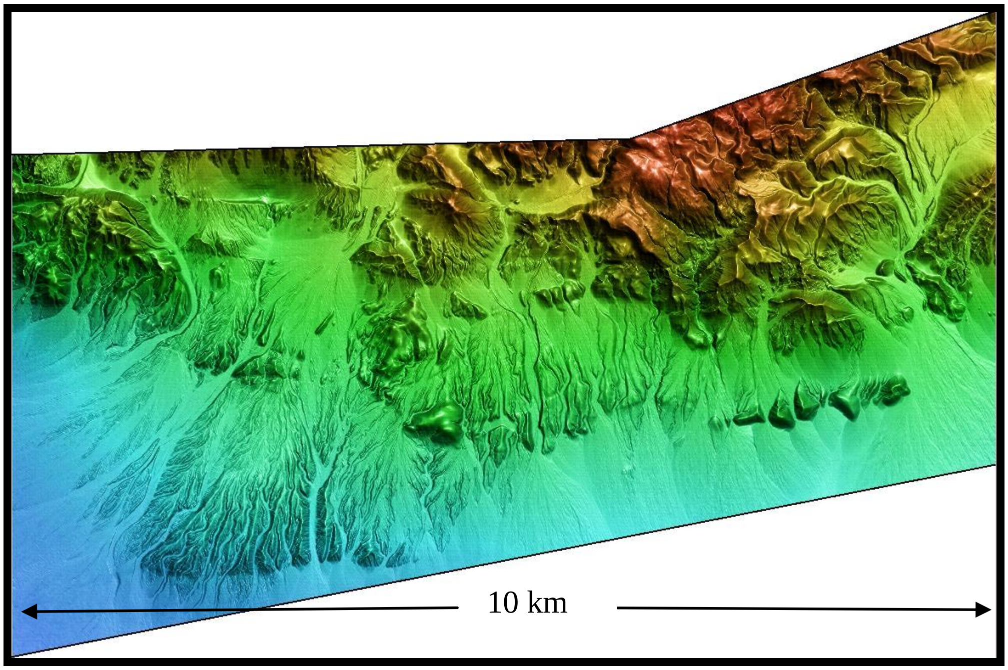

Figure 2. An image showing a portion of the Garlock Fault Opentopography LiDAR DEM. The dimensions of the area are 10 km east - west by 5km north – south. Lower elevation are blue and higher elevations are red.

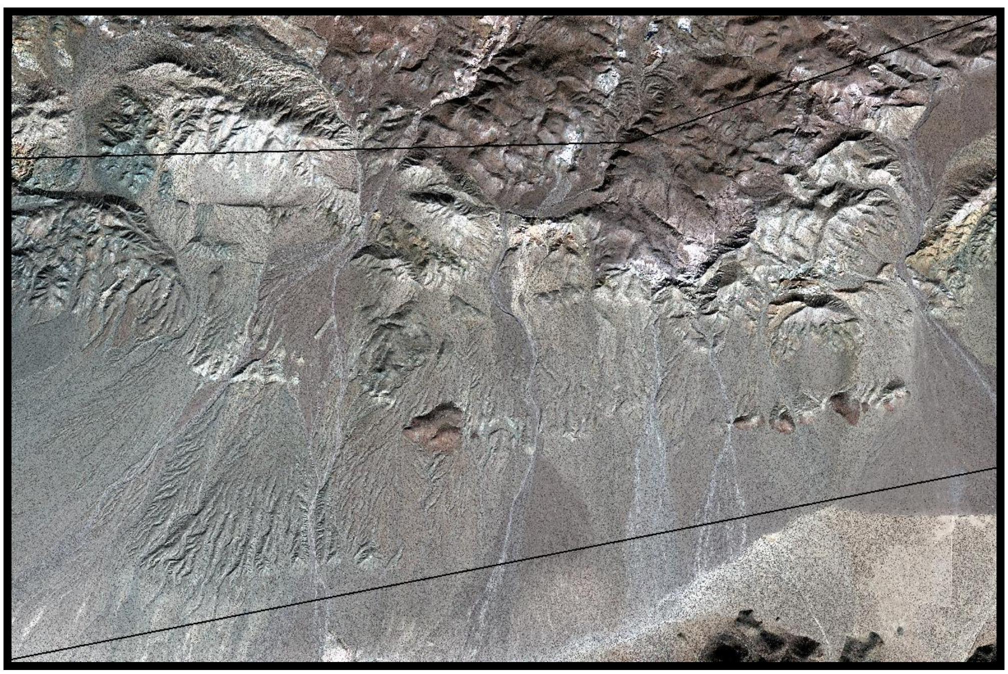

Figure 3. GeoEye-1 50cm resolution orthophoto, created from the GeoEye-1stereo photos, for the area of the Garlock Fault LiDAR survey used in this study.

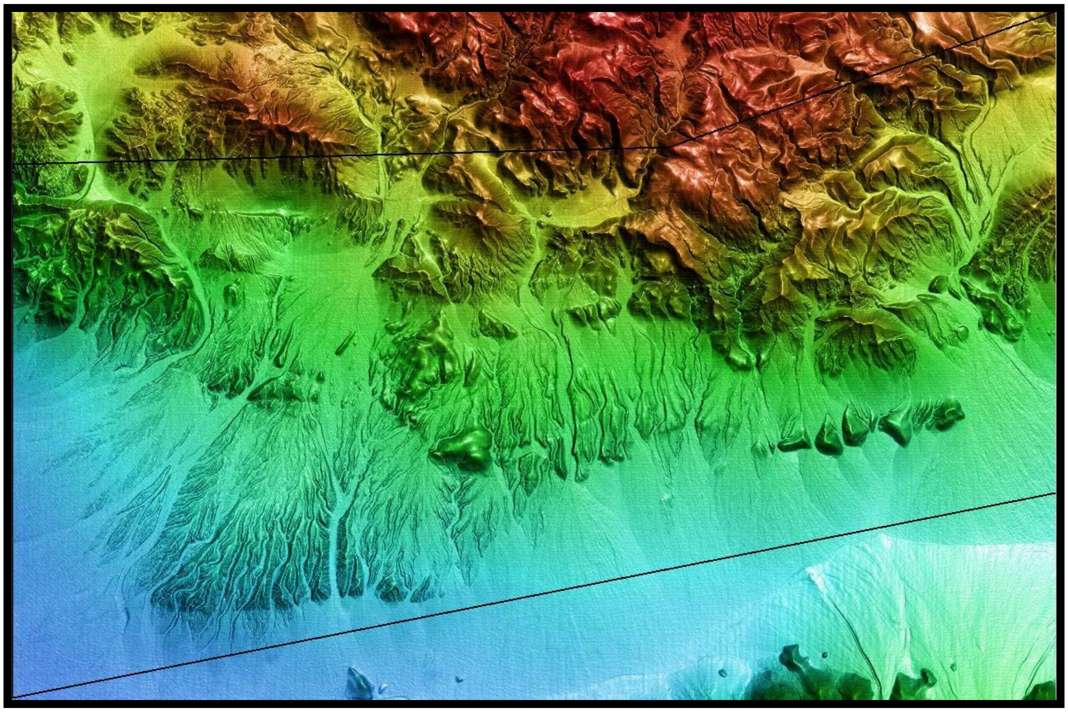

Figure 4. Stereo GeoEye-1 DEM image covering the area of the LiDAR image in figure 2. This DEM has an elevation point every meter. At this scale the LiDAR and GeoEye-1 images are identical. Lower elevation are blue and higher elevations are red.

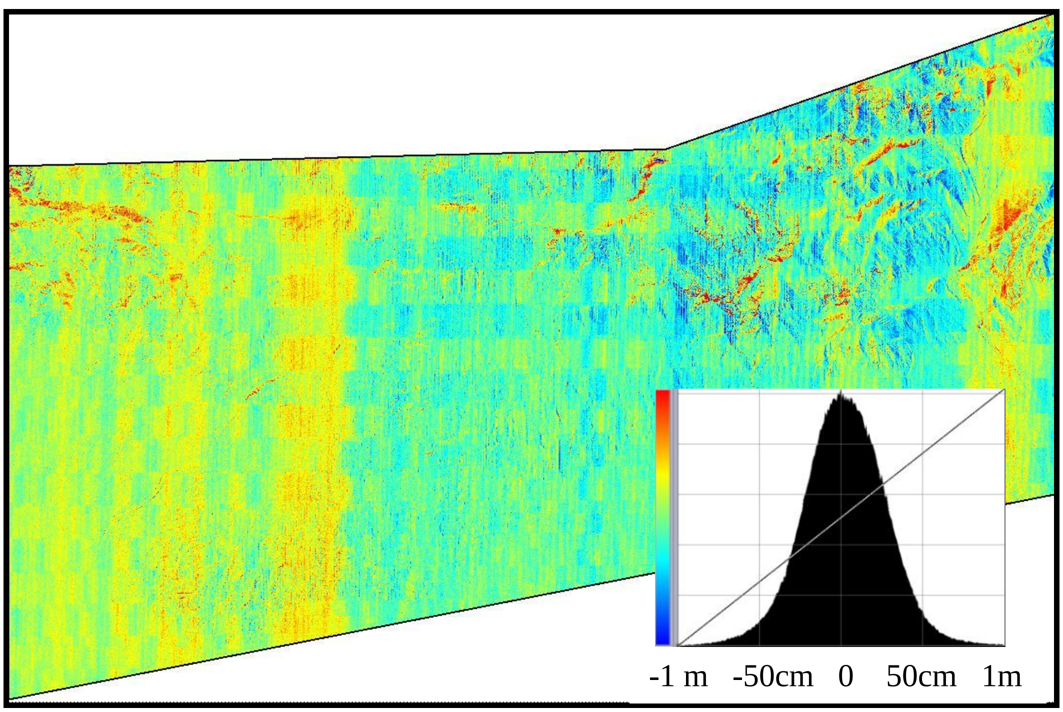

Figure 5. Image of the elevation differences between the GeoEye-1 and LiDAR DEMs displayed as blue, for -1m, to red, for +1m, differences. The image and histogram were created in ERMapper. The standard deviation of the elevation differences is 25cm.

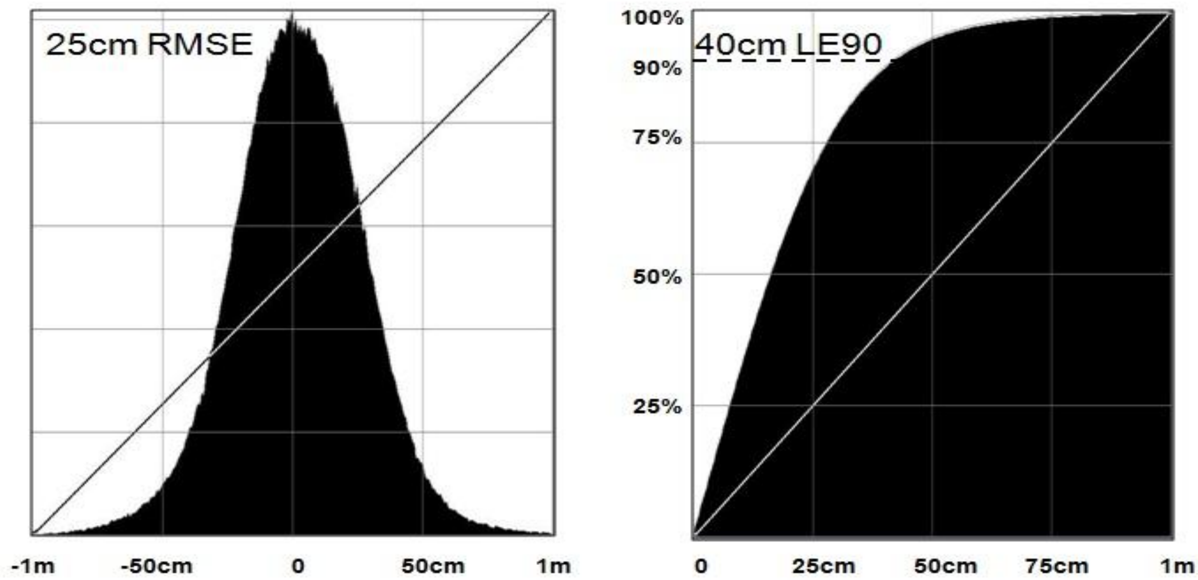

Figure 6. The elevation differences between the GeoEye-1 and LiDAR DEMs are shown in a standard histogram on the left and a cumulative histogram on the right. These histograms were created in ERMapper. If we assume that the LiDAR DEM is perfect, the GeoEye-1 DEM elevations have a Root Mean Square Error (RMSE) of 25cm. Ninety percent of the stereo GeoEye-1 elevations are within 40cm of the LiDAR elevations giving a 90% Linear Error (LE90) of 40cm.

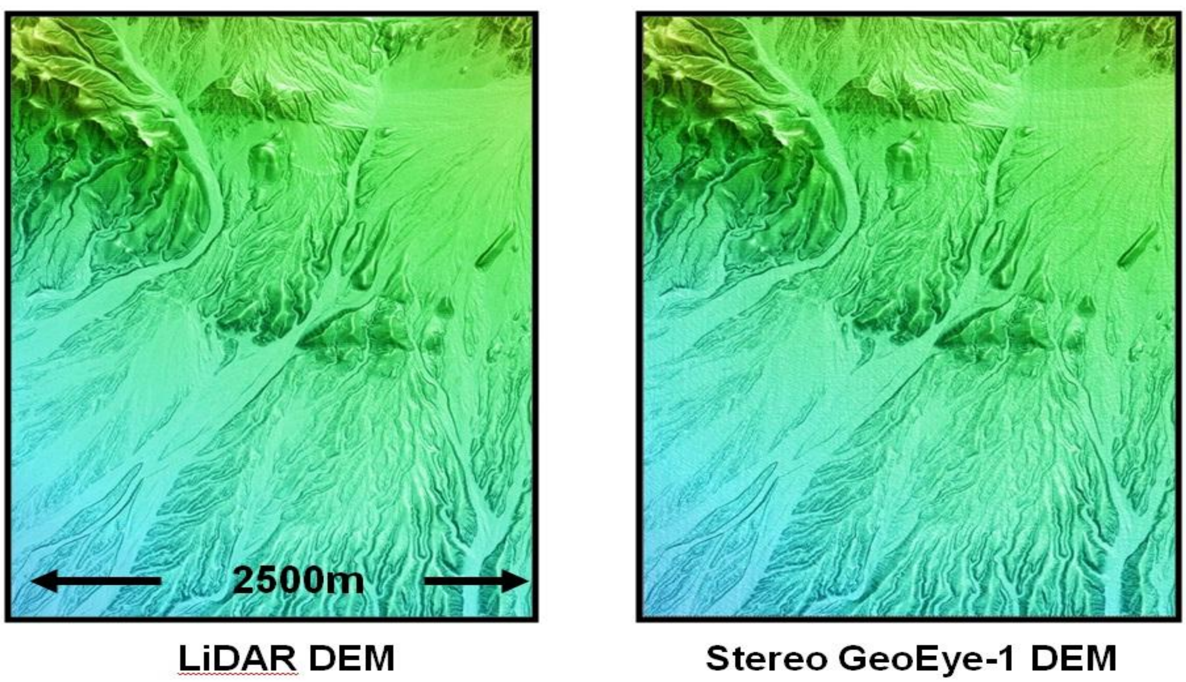

Figure 7. Comparison of the LiDAR and GeoEye-1 DEMs for a 2,500m wide area. Minor differences between the DEMs are visible at this scale.

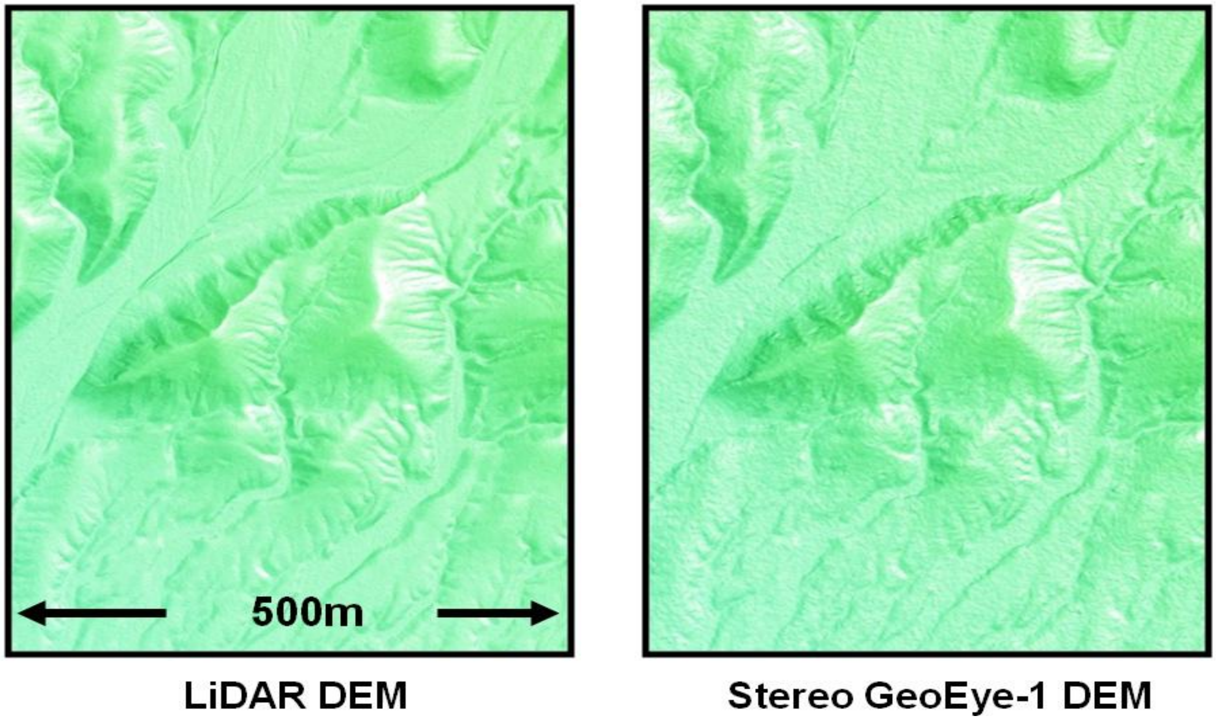

Figure 7. Images of the LiDAR and GeoEye-1 DEMs for a 500m wide area. At this scale, fine topographic features are much clearer on the LiDAR DEM.

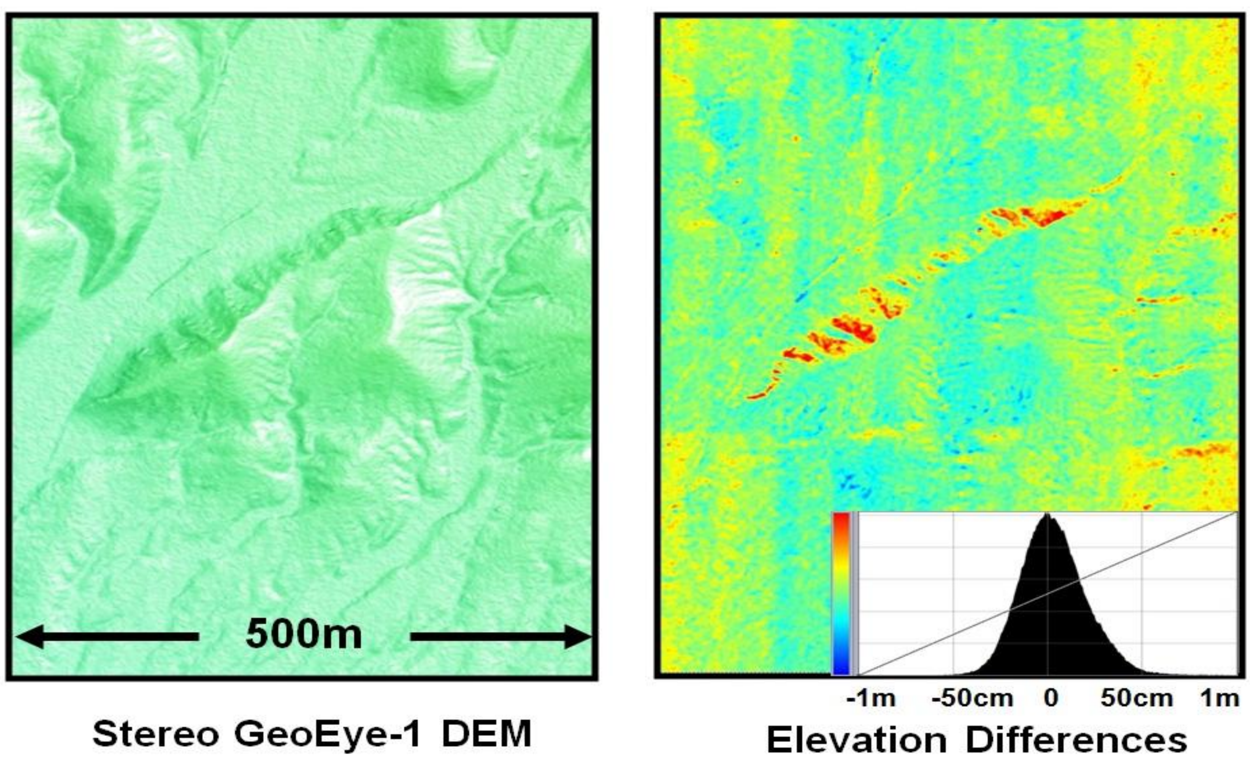

Figure 8. Image of the elevation differences between the GeoEye-1 and LiDAR DEMs. There are elevation differences, shown in red, of up to 1m on the steep NW facing slope. The standard deviation of the elevation differences is 18cm.

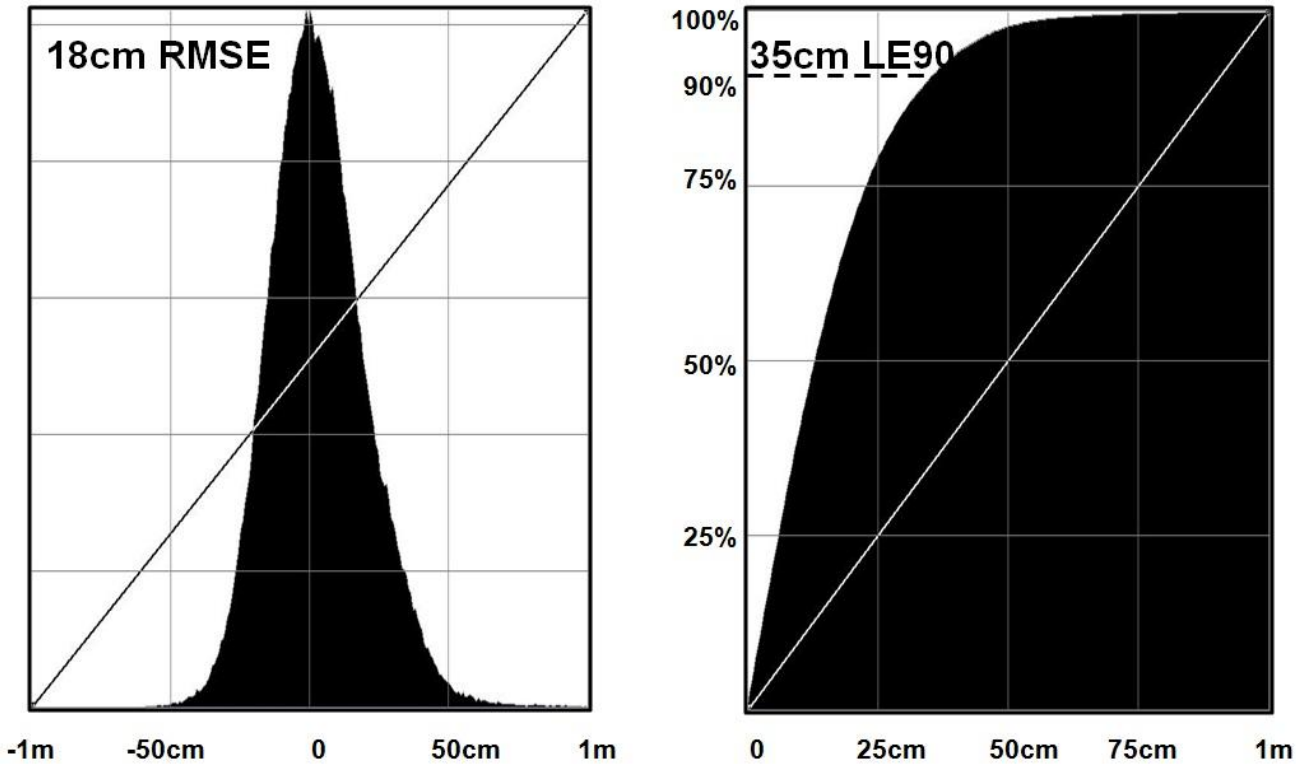

Figure 9. The elevation differences between the GeoEye-1 and LiDAR DEMs for the 500m wide area are shown in a standard histogram on the left and a cumulative histogram on the right. If we assume that the LiDAR DEM is perfect, the GeoEye-1 DEM elevations have an RMSE of 18cm. Ninety percent of the stereo GeoEye elevations are within 35cm of the LiDAR elevations giving a 90% Linear Error (LE90) of 35cm for this area.

Discussion:

PhotoSat is processing 50cm GeoEye-1 stereo satellite photos to 1m Digital Elevation Models (DEMs) with vertical accuracies of better than 50cm RMSE, as determined by thousands of ground survey points on mapping projects in Eritrea and Mexico. For more information on these accuracy studies, please refer to the following reports:

http://www.photosat.ca/pdf/eritrea_wv2_topographic_mapping_accuracy_report_july2014.pdf

http://www.photosat.ca/pdf/WV_accuracy_chihuahua.pdf

To measure PhotoSat's GeoEye DSMs to LiDAR DEMs, GeoEye provided PhotoSat with stereo GeoEye-1 photos over an area of southeast California with a publicly available LiDAR DEM by OpenTopography. The high quality OpenTopography LiDAR DEM has spectacular resolution and accuracy. When we make the conservative assumption that the OpenTopography LiDAR DEM is perfectly accurate and use it to measure the accuracy of the GeoEye stereo DEM we get the following elevation accuracy results for the 1m GeoEye DEM:

Entire 50 km^2 area	GeoEye DEM	25cm RMSE	40cm LE90
500m x 650m area	GeoEye DEM	18cm RMSE	35cm LE90

Advantages of Stereo Satellite DEMs:

Some advantages of stereo satellite DEMs are as follows:

- Large areas of stereo satellite photos can be acquired and processed quickly.
- Mapping projects may be anywhere in the world as the satellites have global coverage.
- No government survey permits are required, so there are no mapping project delays due to government bureaucracy.
- No charges for aircraft standby and crew waiting for favourable survey weather.
- No in country presence is required.

References:

NCALM LiDAR, Southern California Fault System LiDAR Survey (April 2 – April 26, 2008, Processing Report. (undated preliminary report)

Fraser C. and Ravanbakhsh M. Georeferencing Accuracy of GeoEye-1 ImageryPE&RS 75(6): 634 - 638