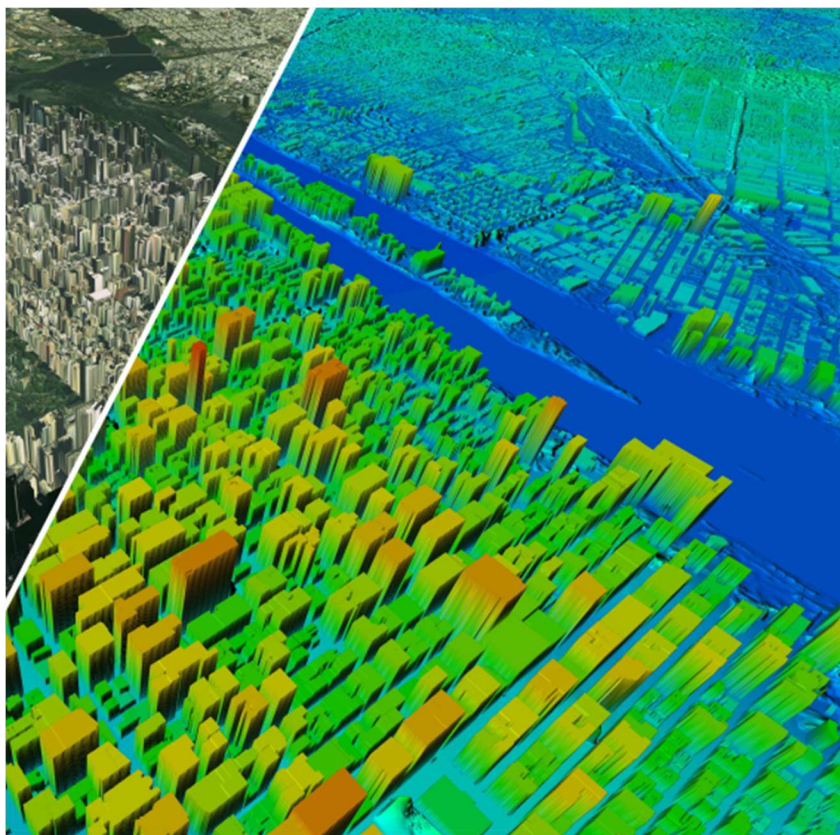




白皮书

NEXTMap One™ 数字高程模型 垂直精度验证

Intermap Technologies, Inc.®
8310 South Valley Highway, Suite 400
Englewood, CO 80112



NEXTMap One DSM 产品，美国纽约市

介绍

NEXTMap One is Intermap’s next generation 3D terrain dataset that provides seamless data at one meter resolution for precise spatial analysis. The Digital Surface Model (DSM) contains first-surface elevations from terrain, vegetation and cultural features such as buildings and infrastructure. The Digital Terrain Model (DTM) provides elevations of the bare earth with the surface features removed. Examples of the NEXTMap One DSM and DTM products are shown in Figure 1. Both DSM and DTM are ideal for supporting sectors such as telecommunication, aviation, geology, forestry, natural resources, infrastructure planning and emergency response and enabling applications like orthorectification, 3D visualization, watershed analysis, land cover, environmental risk analysis and cartography.

The NEXTMap One DSM and DTM were created using Intermap’s Intelligent Resolution Improvement System (IRIS™), that combines the best features from multiple sensors resulting in a seamless global dataset that is both highly accurate and spatially rich. IRIS utilizes new collection and archive satellite, airborne and ground control data to build the NEXTMap One DSM and DTM products. NEXTMap One is built to a global specification, however a regional specification is used for areas where additional airborne and ground control data are available. A description of both specifications is provided in Table 1. The coverage of NEXTMap One regional specification products is shown in Figure 2. The purpose of this paper is to validate the absolute vertical accuracy of the NEXTMap One DSM and DTM at both specifications.

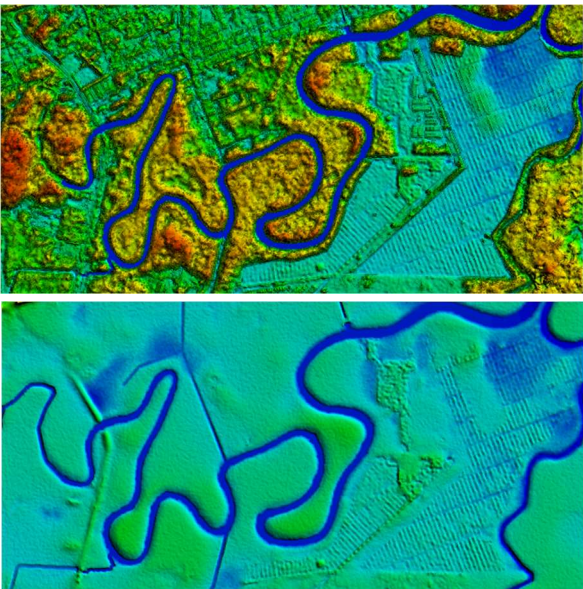


图 1. NEXTMap One DSM (上图) 和 DTM (下图) 样例

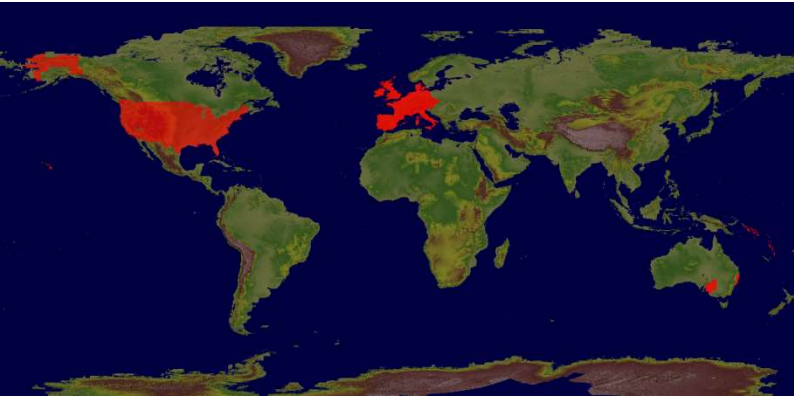


Figure 2. Coverage of NEXTMap One regional specification products (红色)

Table 1. Specifications for NEXTMap One elevation models

| Specifications | NEXTMap One DSM/DTM |
|----------------------------|--|
| Posting | 1.0m |
| Absolute Vertical Accuracy | 1.0m LE90* (Regional) 3.0m LE90* (Global) |
| Projection | Geographic |
| Horizontal Datum | WGS84 |
| Vertical Datum | WGS84 |
| Geoid | EGM2008 |

*in unobstructed areas with slope less than 10 degrees

Validation Methodology

The validation process was performed by Intermap and then repeated and independently verified by The Digital Photogrammetry Research Group at Purdue University. The approach to this effort was to compare NEXTMap One elevation data to high accuracy LiDAR reference data in a variety of land cover and terrain slope conditions. The reference LiDAR DSM and DTM were first generated from the point cloud data using only the first return points and the ground points respectively. The resulting reference DSM and DTM have the same horizontal and vertical datum as the NEXTMap One DSM and DTM and have the same post spacing of one meter. Next, a difference surface was created by subtracting the LiDAR DSM or DTM from the corresponding NEXTMap One DSM or DTM. The elevation errors were categorized using slope information and surface height information and were then assessed within each category. The terrain slope was derived from the LiDAR DTM resampled to five meters to ensure that only the true terrain slopes are represented. The surface height was calculated as the difference between the LiDAR-derived DSM and the LiDAR-derived DTM and represents the relative obstruction height from the ground, such as building height and tree height. The elevation errors are grouped to the following three terrain classes: Low Slope (<10°), Medium Slope (10~20°), and High Slope (>20°) and to the following four obstruction levels: No Obstruction (<0.3m), Low Obstruction (0.3~1.5m), Medium Obstruction (1.5~5.0m), and High Obstruction (>5.0m).

Test Sites

Three test sites were selected in the USA. Sufficient data were available at these sites to build the NEXTMap One product to global and regional specification. Both specifications were built in these areas to facilitate the validation effort. These study sites were selected because they exhibit a wide range of terrain and land cover types and because of the availability of high accuracy LiDAR-derived elevation data. Table 2 provides a description of each test site and Figure 3 shows an overview of the terrain of the first test site.

Table 2. Test site information

| Test Site | Location | Elevation Range | Terrain | Land Coverage |
|-----------|---------------------------------|-----------------|--------------------------|--|
| 1 | Perry, Oklahoma, USA | 250~400m | flat to moderate terrain | mostly agricultural fields with one small town |
| 2 | Bradly Gardens, New Jersey, USA | 0~100m | flat to moderate terrain | mix of rural township and forests |
| 3 | Salem, Utah, USA | 1370~2640m | flat to mountainous | agricultural, residential and forested |

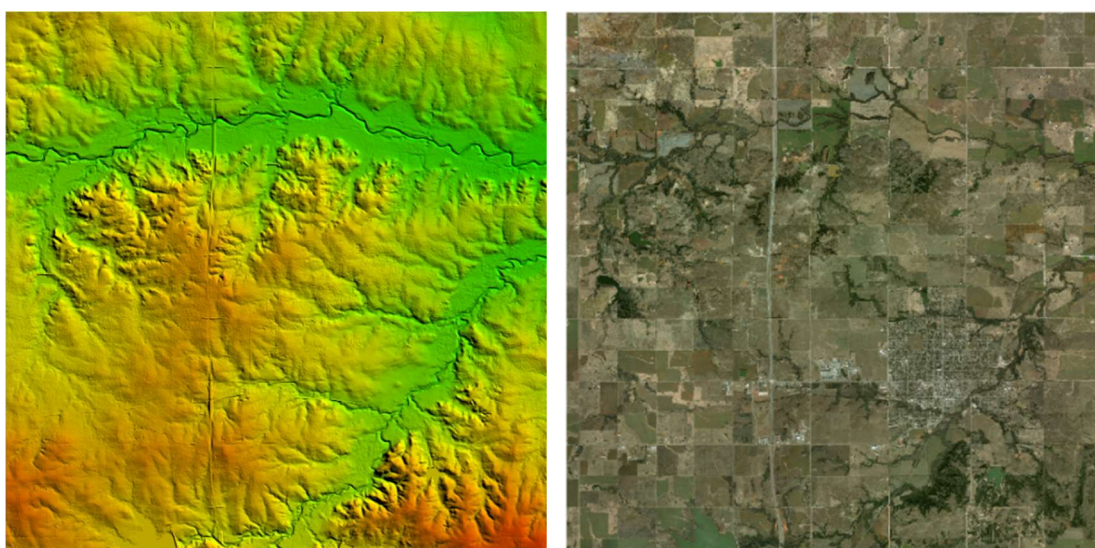


Figure 3. LiDAR DTM terrain (left) and satellite imagery showing land cover (right) providing an overview of Test Site 1.

Reference Data

Airborne LiDAR-derived DSMs and DTMs are used as ground truth in this validation. The LiDAR data were obtained from the United States Geological Survey (USGS)¹ as point clouds in LAS format with a nominal point density that ranges from 0.5 pts / m² to 10.9 pts / m². The approximate acquisition date for the three sites and the expected absolute vertical accuracy are listed in Table 3. The expected absolute vertical accuracy adheres to the required accuracy for USGS Quality Level 1 specifications for Site 3 and Quality Level 3 specifications for Sites 1 & 2 as published in USGS's latest Lidar Base Specification².

Table 3. Reference data information

| Test Site | Location | Approx. Acquisition Date | Nominal Pulse Density (pls/m ²) | Expected Abs Vertical Accuracy (cm, RMSE) |
|-----------|---------------------------------|--------------------------|---|---|
| 1 | Perry, Oklahoma, USA | 2012-12 ~ 2012-12 | 0.6 | 20 |
| 2 | Bradly Gardens, New Jersey, USA | 2006-11 ~ 2007-02 | 0.5 | 20 |
| 3 | Salem, Utah, USA | 2013-10 ~ 2014-05 | 10.9 | 10 |

¹ <https://earthexplorer.usgs.gov/>

² USGS Lidar Base Specification V1.2, Nov. 2014, <https://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf>

Results: Regional Specification Products

The resulting absolute vertical accuracy from all three test sites for each terrain and land cover group are summarized in Table 4 for the regional specification products. The results have shown that the absolute vertical accuracy of NEXTMap One regional products are well within the posted specification of 1.0m (LE90) for both its digital surface model (DSM) and its digital terrain model (DTM) for low slope and unobstructed areas. The elevation errors increase as terrain slope increases and/or obstruction level increases. In areas with medium slope and medium obstruction level, the obtained accuracy is approximately 2.0m (LE90) for both DSM and DTM, while in areas with high slope and high obstruction level, the accuracy is approximately 7.0m (LE90). Figure 4 & Figure 5 display the difference surfaces between the NEXTMap One and LiDAR DSM and DTM respectively, along with the corresponding histograms for Test Site 1. There are no systematic errors observed in the difference surface or in the elevation error histogram. The validation results are consistent among each of the test sites.

Table 4. Absolute vertical accuracy (regional products): LE90 (in meters)

| | NEXTMap One DSM | | | NEXTMap One DTM | | |
|--------------------|-----------------|--------------|------------|-----------------|--------------|------------|
| | Low Slope | Medium Slope | High Slope | Low Slope | Medium Slope | High Slope |
| No Obstruction | 0.78 | 1.59 | N/A | 0.73 | 2.07 | N/A |
| Low Obstruction | 1.45 | 2.58 | 2.17 | 1.33 | 2.80 | 2.74 |
| Medium Obstruction | 1.75 | 1.99 | 2.18 | 1.40 | 2.18 | 2.37 |
| High Obstruction | 6.04 | 6.50 | 7.64 | 2.05 | 4.28 | 6.30 |

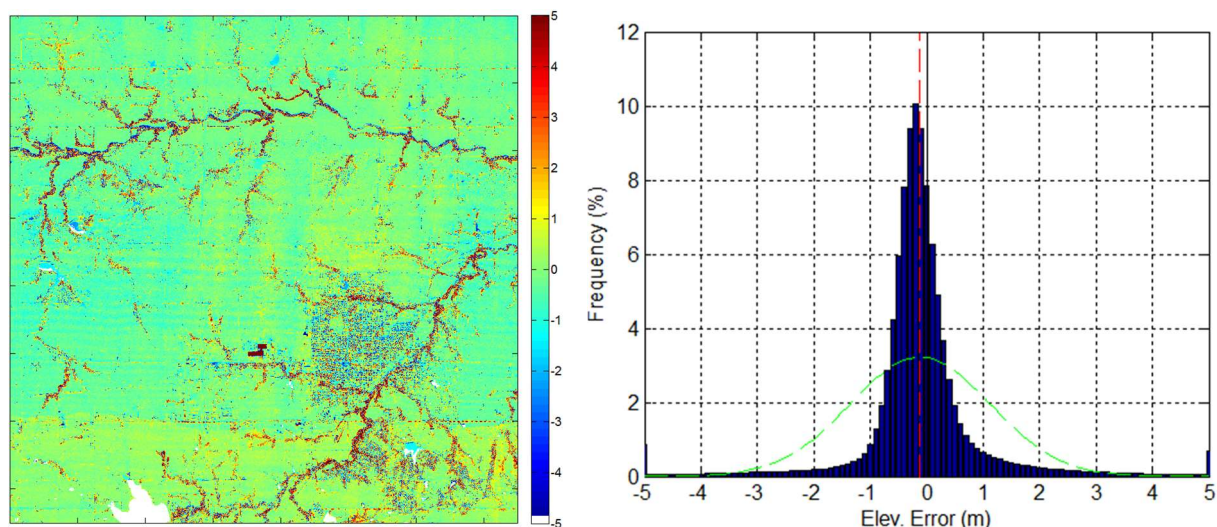


Figure 4. Difference surface for NEXTMap One DSM (regional) minus LiDAR DSM (left) and the corresponding error histogram (right) from Site 1

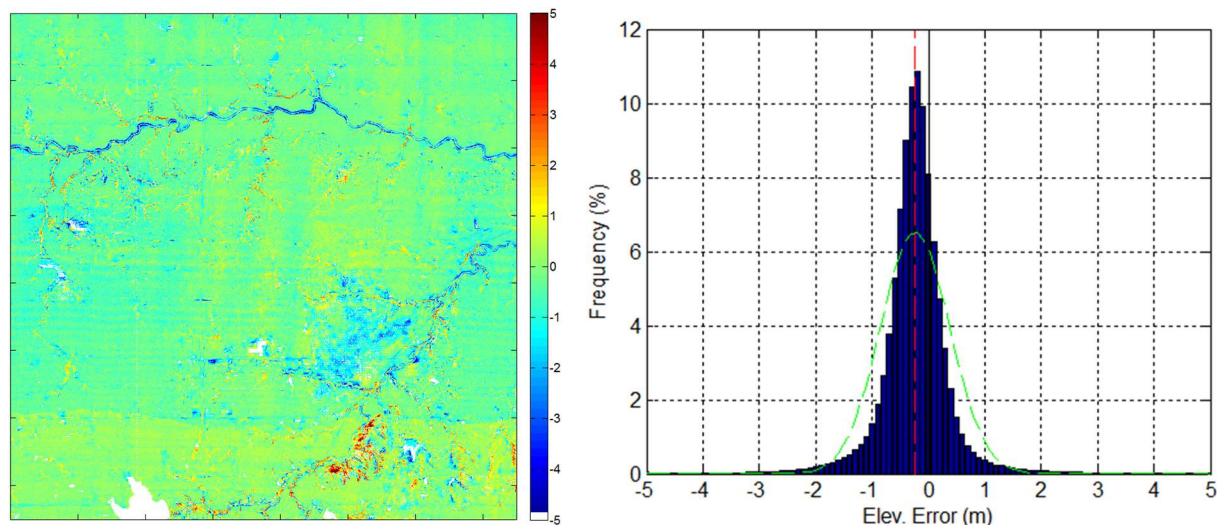


Figure 5. Difference surface for NEXTMap One DTM (regional) minus LiDAR DTM (left) and the corresponding error histogram (right) from Site 1

Results: Global Products

An overview of the obtained accuracy results for the NEXTMap One DSM global products is provided in Table 5. The absolute vertical accuracy for low slope and unobstructed areas is well within the posted specification of 3.0m (LE90). In areas with medium slope and medium obstruction level and areas with high slope and high obstruction level, the obtained accuracy is approximately 4.3m (LE90) and 11.7m (LE90) respectively. The difference surface between NEXTMap One DSM (global) and LiDAR DSM and the corresponding histogram for Test Site 1 are shown in Figure 6. No systematic error is observed in the difference surface or in the elevation error histogram.

Table 5. Absolute vertical accuracy (global products): LE90 (in meters)

| | NEXTMap One DSM | | |
|--------------------|-----------------|--------------|------------|
| | Low Slope | Medium Slope | High Slope |
| No Obstruction | 1.77 | 3.18 | N/A |
| Low Obstruction | 2.41 | 4.74 | 8.05 |
| Medium Obstruction | 2.51 | 4.26 | 9.36 |
| High Obstruction | 7.13 | 8.92 | 11.67 |

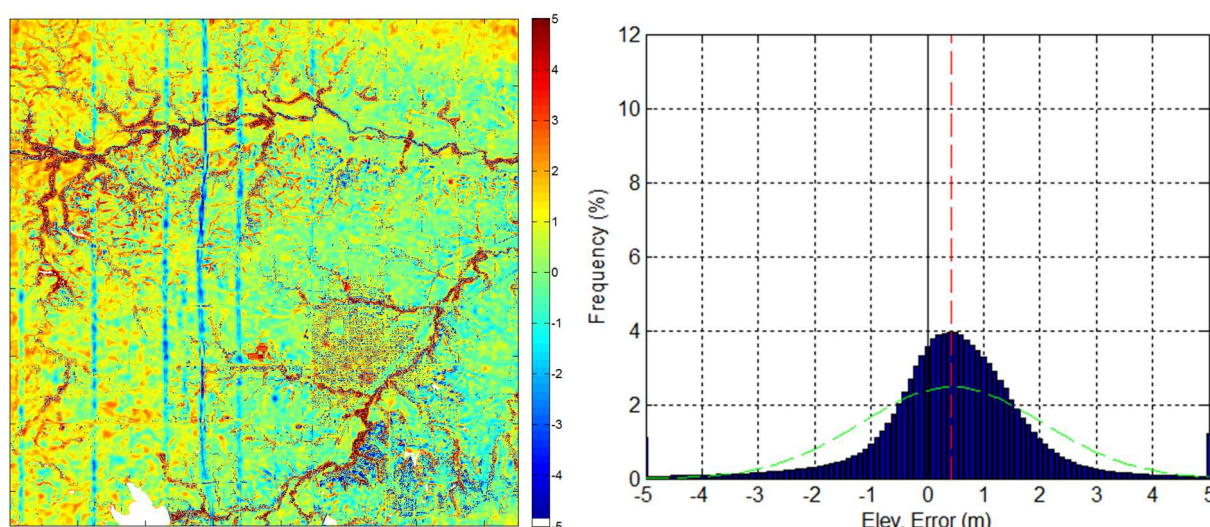


Figure 6. Difference surface of NEXTMap One DSM (global) minus LiDAR DSM (left) and the corresponding error histogram (right) from Site 1

Conclusions

The validation results from the three test sites show that the elevation errors of NEXTMap One DEMs increase with increasing terrain slope and surface height. In low slope and unobstructed areas, the obtained accuracy for regional products is better than 80cm (LE90) for both DSM and DTM, which is well within the posted specification of 1.0m (LE90). The obtained accuracy for the global DSM product is approximately 1.7m (LE90) for low slope and unobstructed areas and meets the posted specification of 3.0m (LE90). The results of this validation were independently verified by the Digital Photogrammetry Research Group at Purdue University. Our next step is to expand the validation to include other regions around the world, including Europe, Asia, Africa, South America and Arctic regions and to better understand the accuracy variations for different terrain and different land cover conditions.