INTERMAP®

GeoSoluciones

Technical Review

NEXTMap® World 10™ Digital Elevation Model

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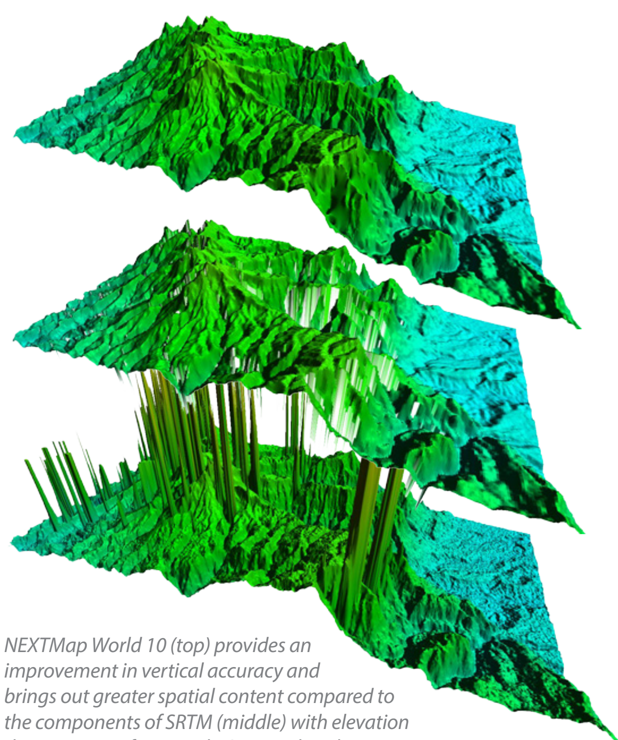


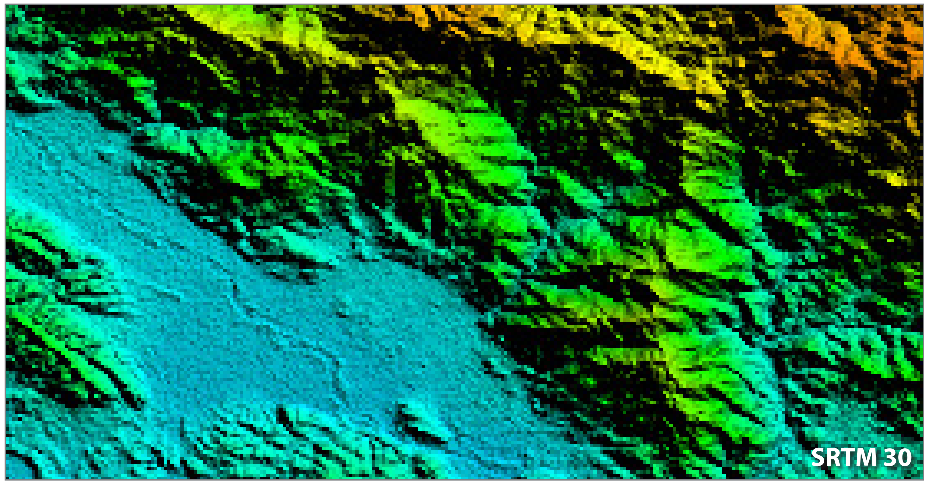
NEXTMap World 10 (top) provides an improvement in vertical accuracy and brings out greater spatial content compared to the components of SRTM (middle) with elevation depression artifacts, and ASTER with spikes in elevation artifacts (bottom).

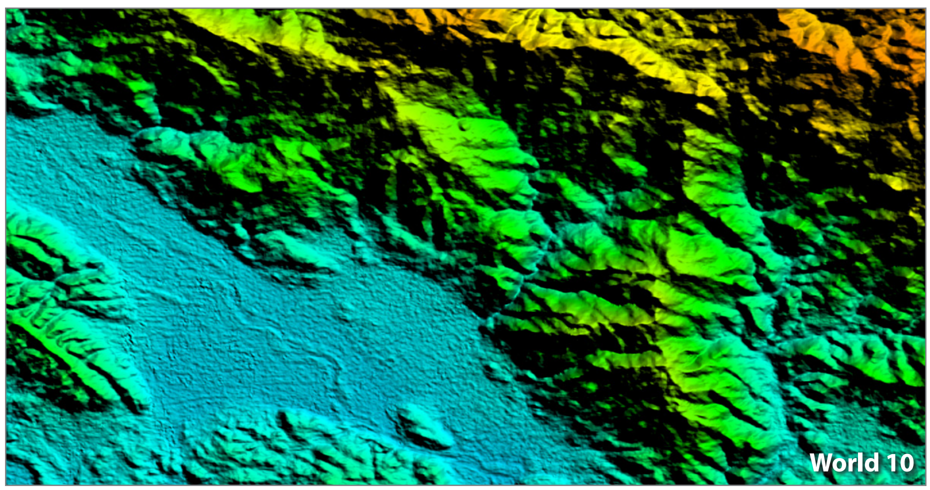
Summary

The NEXTMap® World 10™ Digital Elevation Model (DEM) by Intermap Technologies® is a fused data model using corrected public data as the input source. This model provides seamless, best available elevation data with a 10-meter ground sampling distance (GSD) covering all land mass over the entire planet.

NEXTMap World 10 DEM is a combination of 90-meter and 30-meter Shuttle Radar Topographic Mission (SRTM) v2.1 data, 30-meter ASTER Global DEM v2, and 1-kilometer GTOPO30 data, all of which have been ground controlled using LiDAR data from NASA's Ice, Cloud and Land Elevation Satellite (ICESat) collection. Based on internal testing with airborne LiDAR datasets, Intermap believes the ICESat data, when restricted to flat un-obstructed terrain, has an accuracy of 25 centimeters.

Intermap applies a proprietary algorithm when fusing datasets into the World 10 DEM. Our approach involves a sequence of steps designed to optimize the vertical and spatial integrity of the final product. The data is pre-conditioned through the application of a sophisticated varying vertical correction. Data fusion to the pixel level is then done with a complex weighting schema designed to retain higher value data content. A non-linear blending is then passed over the boundary between datasets to ensure a smooth and continuous model. The result is a product that is specifically designed to generate, in Intermap's view, the best worldwide DEM available today.





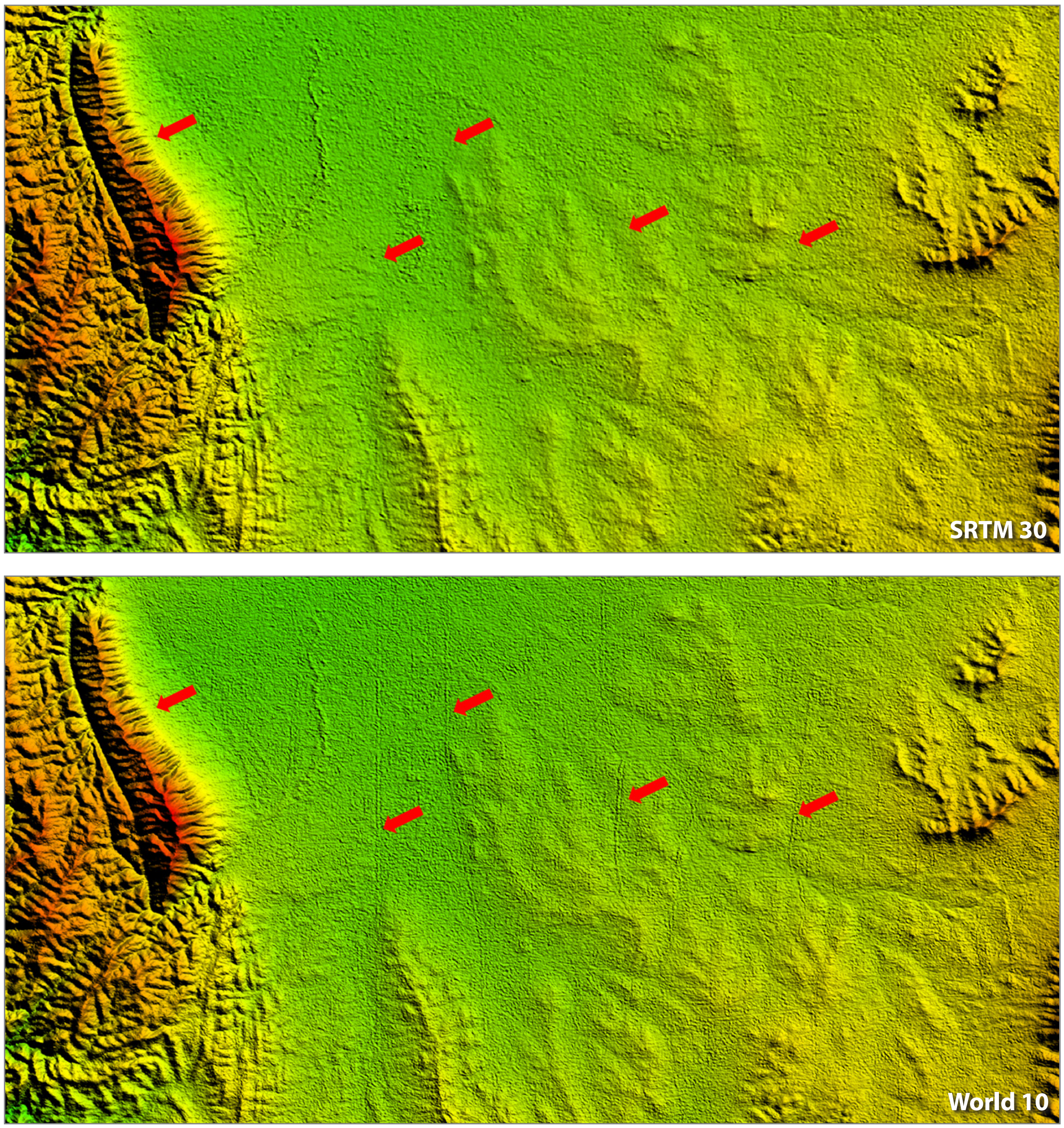
World 10 Inputs

World 10 DEM uses the following dataset inputs:

- **SRTM90 v2.1: Ninety-meter posted digital surface model (DSM), IFSAR collection conducted in February of 2000.** The data extends from 60 degrees north to 56 degrees south, and it has a claimed vertical accuracy of 14 meters LE95. Known issues include varying levels of vertical accuracy and significant numbers of data voids.
- **SRTM30: Thirty-meter posted DSM, IFSAR collection conducted in February of 2000.** The data extends from 60 degrees north to 56 degrees south, and it has a claimed vertical accuracy of 14 meters LE95. Known issues include varying levels of vertical accuracy and significant numbers of data voids.
- **ASTER 30 v2.0: Thirty-meter posted DSM, optical satellite collection spanning from 2005 to 2011.** The data extends from 83 degrees north to 83 degrees south, and it has a claimed vertical accuracy of 20 meters LE95. Known issues include poor vertical accuracy, data voids, and extensive spike blunders.
- **ICESat: LiDAR points from a Geoscience Laser Altimeter System (GLAS) Satellite.** The collection spanned from 2003 to 2010, and it was conducted as a direct nadir pulse collected in a polar orbital path. Known issues include unreliable vertical elevations due to cloud returns and anomalies.
- **GTOPO30: Thirty-meter posted DSM, derived from eight raster and vector sources by the USGS in 1996.** The DSM is known to exclude ridgelines and valleys due to course resolution.

Process

The NEXTMap World 10 DEM is primarily composed of SRTM 90 v2.1, SRTM30, and ASTER fused together at the pixel level through Intermap's proprietary Data Fusion process. GTOPO30 was incorporated along with ASTER in the polar regions. To improve upon the SRTM data, Intermap corrected all voids inherent in SRTM public data with high frequency ASTER data through its proprietary terrain filter. The resulting data was fused together at the pixel level and upsampled to 10 meters. To improve the vertical accuracy, Intermap first ran a proprietary filter process on the ICESat LiDAR points to remove all non-ground anomalies. The resulting ICESat data had dense global coverage and a 25 centimeter RMSE, well suited for use as a ground control dataset. With the ICESat as a control set, Intermap built a correction model for the SRTM surface and applied the correction to the z values of the DEM.



World 10 brings out spatial content like roads, erosion, and mountain definition.

SRTM Hydro Enforcement

Major waterways as defined by SRTM editing standards also received additional hydro enforcement edits to correct elevations based on ICESat control points. These adjustments to the surface model were all made without compromising the SRTM hydro edits.

The resulting corrected DEM model had vertical adjustments from -5 to +10 meters and the overall mean error was improved by four meters. The final output was then upsampled to a 10-meter post using a bicubic interpolation.

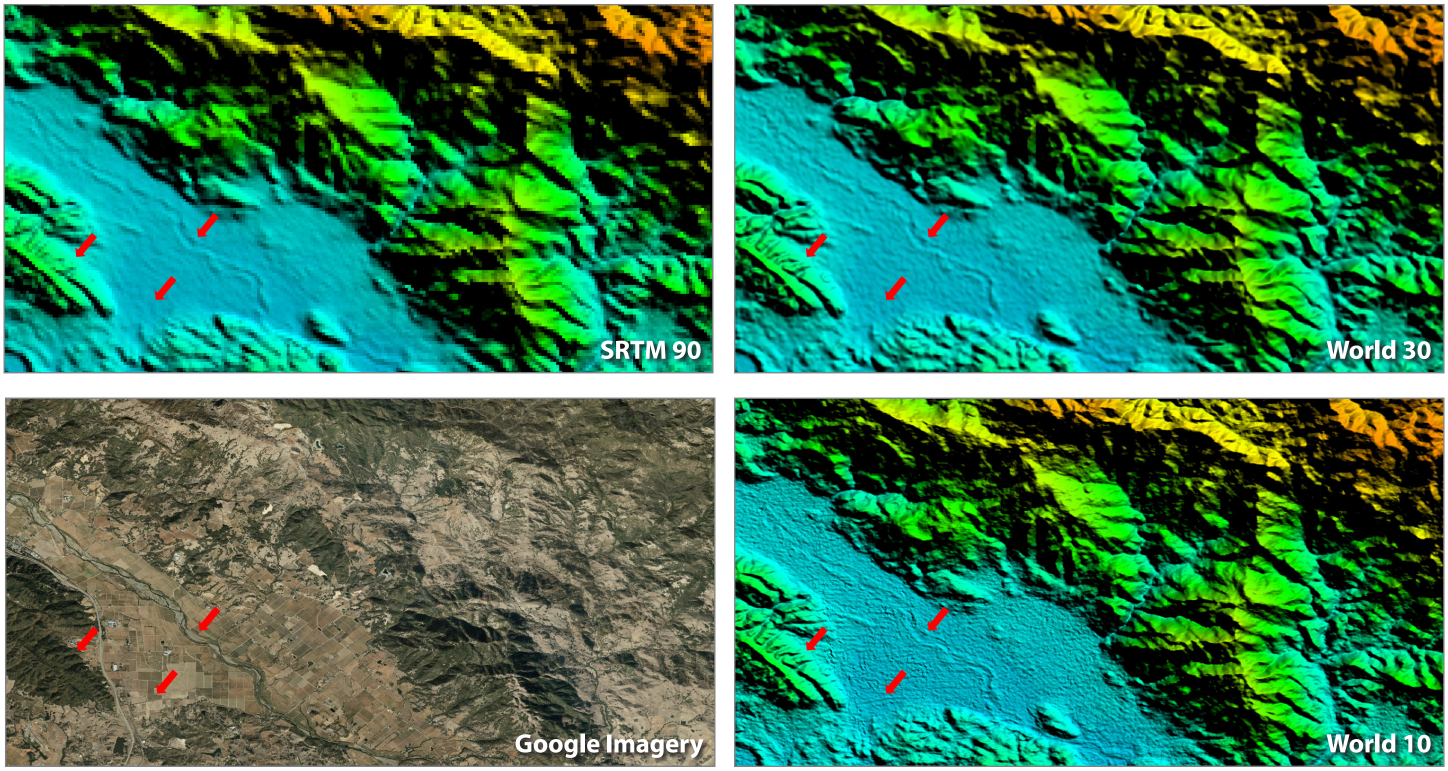
ASTER and GTOPO in the Polar Regions

With an improved vertical accuracy of the DEM complete, Intermap then focused on infilling the voids left in the terrain model from the SRTM. Using ASTER 30 as the infill data source, Intermap used its proprietary fusion process to adjust the vertical values and perform a planar tilt of the data for each infill piece of ASTER data. The result was a seamless void filled dataset where the infilled ASTER matched all the surrounding edges of the master surface model. If any anomalies were detected in the input ASTER, they were removed before being added to the World 10 DEM. In instances where both SRTM and ASTER had voids over the same geography, GTOPO30 was used as the infill data.

The final component of the World 10 build was the addition of ASTER and GTOPO30 DSM models to the northern and southern latitudes allowing for full global coverage. Just as the SRTM surface was corrected using the filtered ICESat control points, so too was the ASTER surface model.

The ASTER surface model correction was significantly more extensive than the SRTM correction and resulted in adjustments to the z value that ranged from -23 meters to +23 meters. With the ASTER data vertically corrected, it could be merged to the World 10 model at 60 degrees north latitude with coverage up to 89 degrees north latitude. The remaining last one degree of polar data was covered using the GTOPO30 data upsampled to a 10-meter post. The intersecting datasets had very similar vertical values at their lines of intersection since both were corrected using the same ground control set. However, due to the texture detail differences of the varying DSM native posts, it was important to blend the data using a proprietary smoothing technique that extended 200 kilometers into both datasets.

For the southern latitudes the same process of correction and blending was used with ASTER and GTOPO30. Thus, the resulting dataset extended from pole to pole.



Roads, rivers, and mountain definition become more clear with World 10.

Frequency Fusion: The End Result is Far Greater than the Sum of the Parts

Each data set has its own advantages and disadvantages. The engineers at Intermap Technologies worked hard analyzing the strengths and weaknesses of each dataset, and only used high frequency content in the fusion process. The end result is a model far improved from the individual inputs. By leveraging this proprietary fusion process, Intermap's World 10 DEM reveals terrain features like roads and dry creek beds hidden in the various input data sources. It also dramatically reduced noise and increased accuracy in the polar regions. The result is additional available terrain information that can be used to more accurately perform analysis.

Terrain Filter

Intermap uses a proprietary terrain filter to identify spikes and voids inherent in input data sources like SRTM and ASTER, and fills in those areas with accurate data. With the removal of these artifacts, World 10 provides a consistent, realistic terrain.

Improved Polar Regions

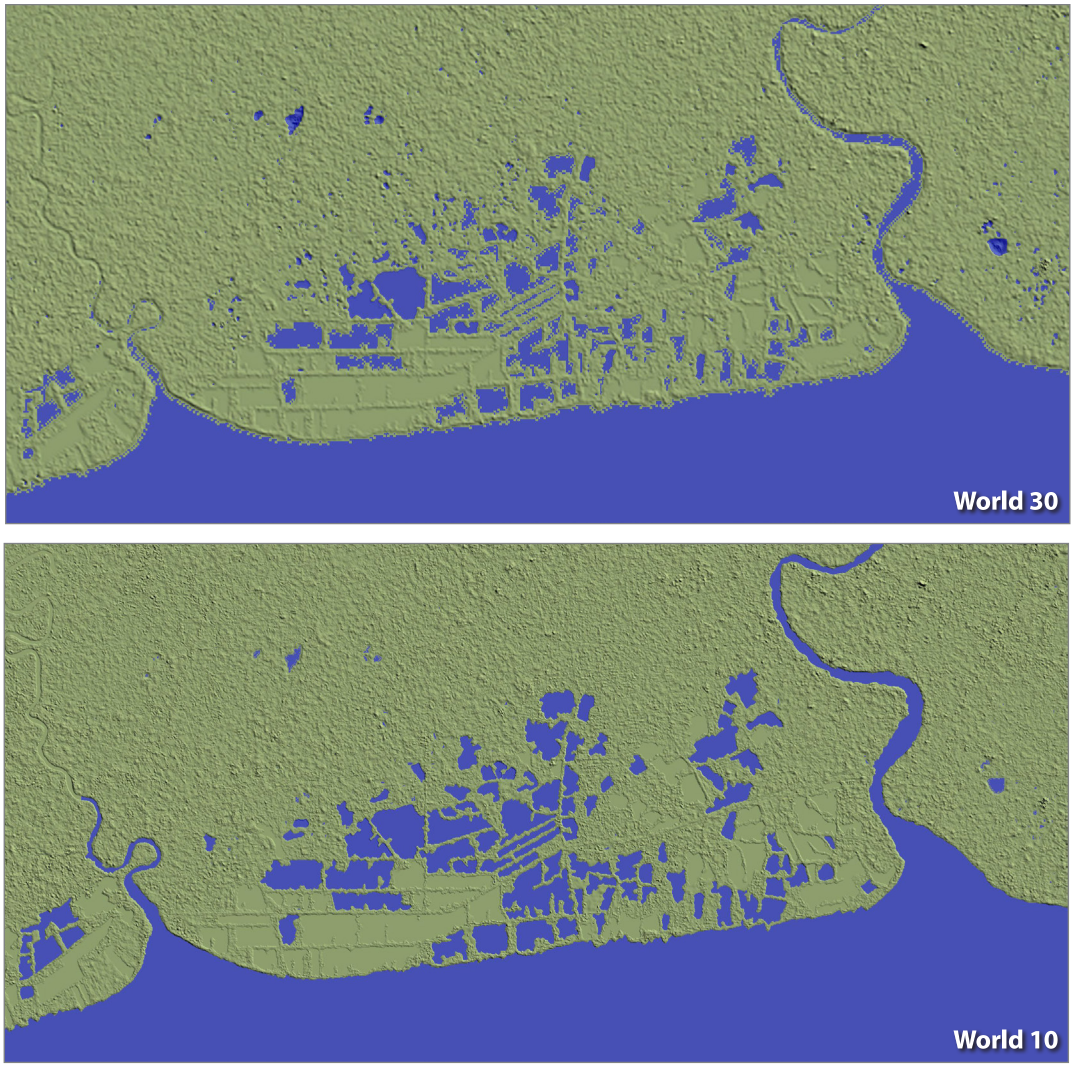
The occurrence of ice, lack of ground control points (GCPs), and poor quality of data from free data sources have hindered efforts at improving data in the polar regions up until now. Intermap applied its proprietary terrain filter to the ASTER data layer to flatten spikes and remove noise from the data. By filling in voids, removing noise spikes, and normalizing and blending the best aspects of ASTER and GTOPO, elevation accuracies are vastly improved along with revealing terrain features that were invisible in the raw public data. Intermap has also leveraged GCPs from its work performed in polar regions like Alaska and Canada to improve accuracies north of the 60th parallel.

Improved Coastal Areas

With free datasets, coastal areas are inherently "trouble" areas for elevation data. Depending on the type of technology used, water reflects poorly and produced errors in the data. Fluctuations of 10 feet or more are common over large bodies of water at sea level, throwing off land elevation nearby. Intermap focused on these areas for improvement. World 10 leverages ICESat processing around coastal areas to improve elevation accuracies on both land and water. By identifying and filtering ICESat points located over oceans and in coastal areas, these points could then be corrected to zero elevation. These improved accuracies make World 10 a valuable data source for natural resource management and other analyses tied to coastal data.

Ten-Meter Post

In order to allow customers to leverage the new terrain features and improved accuracies of World 10, the dataset has been up-sampled to a 10 meter post using a bicubic interpolation.



World 10 coastal areas are improved from World 30.

Validation and Edits

The World 10 data was validated using automated elevation comparisons to verify that no outstanding differences were detected. The data was also subjected to a slope identification process that flagged all areas containing slopes over 80 degrees. Areas identified to have high slopes were manually edited to make sure the identified slope was not an anomaly, and, if so, edited using infill data.

Accuracy Assessment

Intermap conducted three accuracy assessments on the World 10 DEM.

1. First, World 10 elevations were compared to the filtered ICESat LiDAR ground control points that have a vertical accuracy of 25 centimeter RMSE.
2. For the second assessment, the World 10 DEM was compared to survey and validated Intermap ground control points as well as external ground control points from government programs.
3. The final accuracy assessment was performed using Intermap's NEXTMap five-meter posted IFSAR DSM data.

The following are World 10 accuracy test results:

a. RMSE: 5 meter
b. LE95: 10 meter

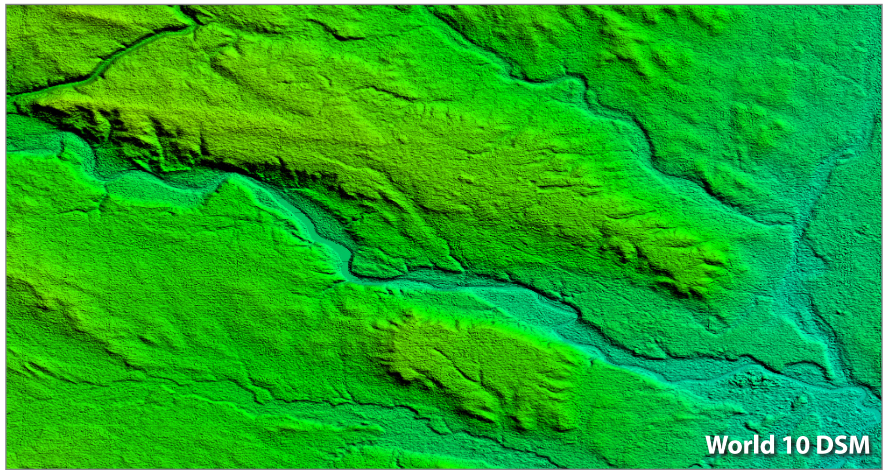
Age of World 10 Data

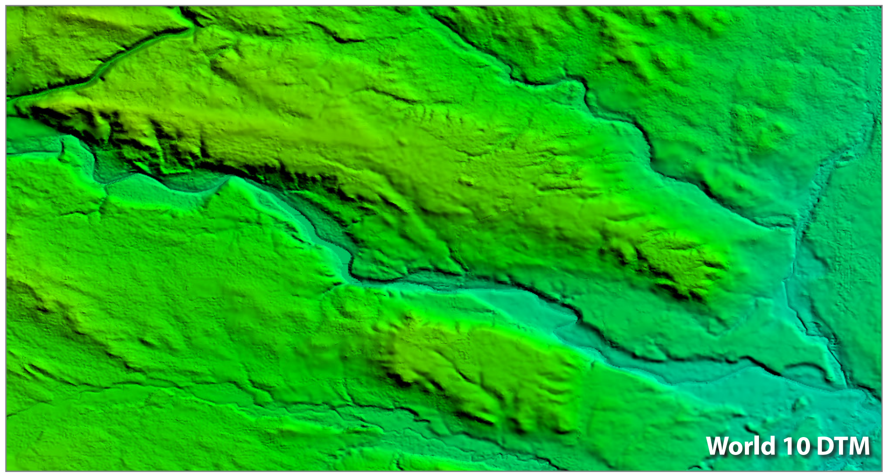
World 10 is comprised of four data sources (SRTM 90, SRTM 30, ASTER, and GTOPO30) fused together to produce the final DEM. Many of the input datasets were acquired over multiple years with layers of data combined to form the final dataset. Because of this fusion of various datasets at each pixel, it is not possible to derive a definitive acquisition date for any given area. The best estimate of the data's age is from 2005 through 2011.

World 10 DTM Process

World 10 is the only worldwide Digital Terrain Model (DTM). The DTM has vegetation, buildings, and other cultural features digitally removed, leaving just the underlying terrain. This is achieved using Intermap's proprietary software, which derives terrain elevations based on measurements of bare ground contained in the original data as well as manually reviewing and editing every tile. The key feature of the DTM is that it infers the terrain characteristics that may be hidden in the DSM. In the following figure, you can see how the buildings and trees in the previous DSM figure are no longer visible. Other tools, such as Google satellite imagery, are further used to aid in the editing process.

Please note that World 10 DTMs are made-to-order. Please see your Intermap Partner for turnaround times.





The World 10 DTM has vegetaion and cultural features that are visible in the DSM digitally removed.

DTM Hydro Enforcement

Hydro enforcement is performed to ensure a more accurate water-land elevation with proper water flow. Water features are individually edited to include flattening water elevation, and removing and/or correcting defects, imperfections, and anomalies to ensure proper water flow based on elevation. Single line drains and double line drains are flattened and match the DSM, and saddles greater than 10m are removed.

FITS (Fully Integrated Terrain Solution) Editing Process

Intermap's proprietary FITS process is a key contributor to the nuances in our DTM. FITS utilizes existing ancillary data from many sources as an input to the DTM process. The practice reduces any bias, tips, and or tilts in the ancillary data. This process is performed in a localized manner to ensure a best fit adjustment. The FITS steps are carried out in an automated session prior to the data review by one of our trained 3D editing staff members. Three levels of manual and visual operator checks are performed on every data pixel to ensure they conform to product specifications.

NEXTMap World 10 DEM Specifications

- Worldwide coverage digital elevation model (both DTM and DSM)
- A fusion of SRTM90, SRTM30, ASTER, GTOPO30, using ICESat for vertical control
- Format: bil, hdr, row major starting in upper left corner
- 1/3 arc second postings (~10 meter)
- 1°x1° cell (~50MB)
- File dimensions 3601 x 3601
- Pixel size IEEE 32 bit floating point
- Geographic Projection
- WGS84 Horizontal Datum
- WGS84 Vertical Datum
- EGM96 Geoid
- No data value -10000.0
- Date range: 2005-2011
- RMSE: 5m / LE95: 10m accuracy