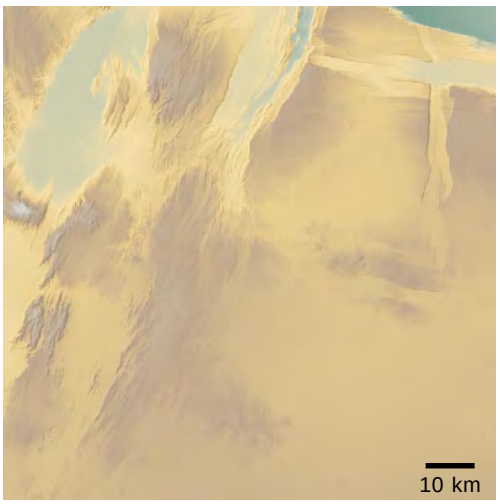
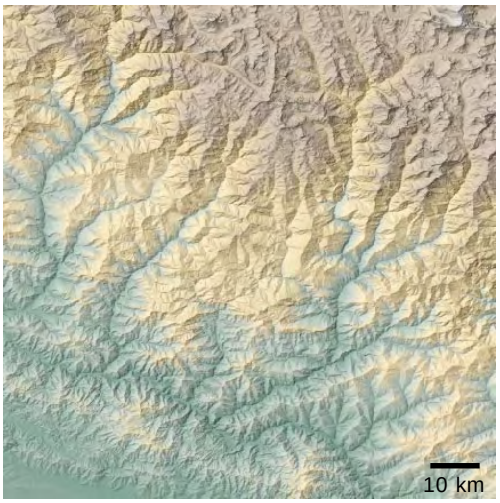
JPEG2000 Compression for Global ASTER DEM

The Global Digital Elevation Model (GDEM) derived from ASTER imagery consists of 22,600 1°-by-1° tiles covering land surfaces between 83°N and 83°S latitude (see the Technical Guide entitled *ASTER Global Elevation Data*). These tiles are distributed as uncompressed GeoTIFF files 24.8 MB in size. The total uncompressed size of the complete set of ASTER GDEM tiles is thus 547 GB. When you directly view these ASTER GDEM tiles in TNTmips, the pyramid tiers created to provide fast viewing at any zoom level increase the required disk storage by about 37%, for a total stored size of 750 GB.

DEM data generally compress very efficiently because contiguous cells have similar values. The stored size of ASTER GDEM tiles and mosaics can be dramatically reduced without loss or with insignificant loss of detail by using JPEG2000 compression. JPEG2000 provides both lossless and lossy compression schemes that are based on a pyramided representation of the raster, reducing the need for additional pyramid tiers for fast viewing. TNTmips allows you to apply JPEG2000 compression to raster objects stored in TNT Project Files or to export linked GeoTIFF files to GeoJP2 files using JPEG2000 compression.



ASTER Global DEM tile N10E041, northern Ethiopia, shown with color relief-shading. The extensive low-relief areas in this tile result in efficient JPEG2000 compression (see table below).



ASTER Global DEM tile N27E086, Nepal. This tile spans the foothills and crest of the Himalaya Mountains. The topographic complexity in this tile results in less efficient JPEG2000 compression (see table below).

MicroImages has converted a sample of ASTER GDEM tiles and tile mosaics to GeoJP2 files with lossless and lossy JPEG2000 compression. The GDEM samples include different types of terrain from several continents. The results of these tests are discussed below and on the reverse.

Lossless JPEG2000 Compression

Lossless JPEG2000 compression preserves all of the original elevation values. In our tests lossless JPEG2000 compression reduced the 24.8 MB ASTER GDEM tiles to sizes ranging from 4.1 to 2.4 MB, or a range of compression ratios from 6:1 to about 10:1 (see table to the right). The differences in these compression ratios are related to variations in the topographic complexity and local relief of the terrain represented in the tiles, as illustrated above. JPEG2000 lossless compression is able to achieve higher compression for areas with smoother, less complex topography.

Assuming an average lossless compression ratio of 8:1, we estimate that the stored size of the complete ASTER GDEM could be reduced from 547 GB to about 68 GB using lossless JPEG2000 compression (see table below right).

Lossy Best Quality JPEG2000 Compression

The Lossy Best Quality option for JPEG2000 applies the minimum possible lossy compression. As with lossless compression, the amount of compression achieved is directly related to the local topographic complexity of the tile. In our tests Lossy Best Quality compression reduced the size of the 24.8 MB ASTER GDEM tiles to sizes ranging from 2.5 MB to 0.9 MB. These compressed sizes correspond to compression ratios ranging from 10:1 to 27:1 (see table above right).

ASTER GDEM Tile (24.8 MB Uncompressed)	**JPEG2000 Lossless Compression**	**JPEG2000 Lossy Best Quality Compression**
N10E041 Northern Ethiopia low to moderate local relief	2.4 MB 10:1 ratio	952 KB 27:1 ratio
N38W106 Colorado, USA moderate to high local relief	3.0 MB 8:1 ratio	1.4 MB 18:1 ratio
N27E086 Nepal very high local relief	4.1 MB 6:1 ratio	2.5 MB 10:1 ratio

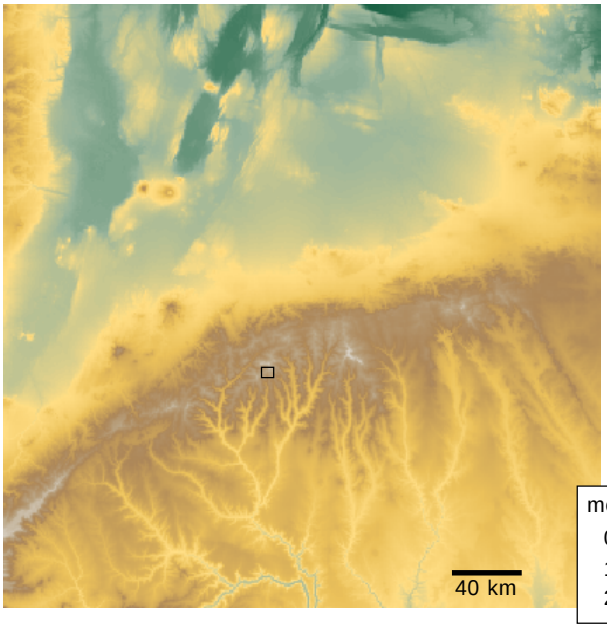
Table with sample variations in compressed size and compression ratio for ASTER GDEM tiles with varying topographic complexity and local relief when compressed using JPEG2000 Lossless and Lossy Best Quality compression.

ASTER GDEM GeoTIFF	**JPEG2000 Lossless Compression**	**JPEG2000 Lossy Best Quality Compression**	**JPEG2000 Lossy 80:1 Compression**
547 GB	68 GB	30 GB	6.9 GB

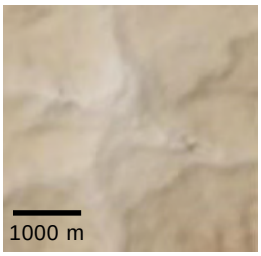
Table comparing stored size of the complete ASTER GDEM data set with estimated sizes using JPEG2000 compression.

To assess the quality and fidelity of the lossy-compressed ASTER GDEM, we exported a mosaic of 9 tiles to GeoJP2 using

(over)

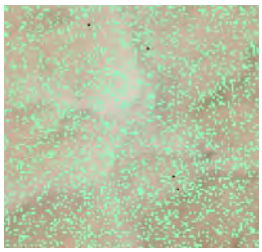


Left, mosaic of 9 GDEM tiles in northern Ethiopia. Below are detailed color-shaded relief views of the small area enclosed by the black box that compare the original and Lossy Best Quality surfaces. The loss of spatial detail with Lossy Best Quality JPEG2000 compression is negligible.

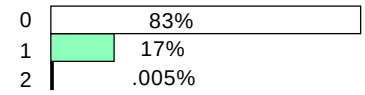


Original uncompressed

Lossy Best Quality JPEG2000 Compression



Color overlay indicates cell value changes (m); green = 1, black = 2.



Histogram of elevation difference (m) between JPEG2000 Lossy Best Quality (19:1) compressed ASTER GDEM and original. The maximum elevation deviation is 2 meters.

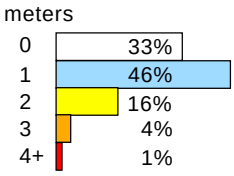
Lossy Best Quality JPEG2000 compression. The mosaic covers terrain with varied relief in Ethiopia (see illustration above). The uncompressed size of the set of GDEM tiles for this area is 223 MB. The exported GeoJP2 file of the mosaic with Lossy Best Quality JPEG2000 compression is 12 MB in size (about 19:1 compression ratio). As shown in the graph above, 83% of the cells in the lossy-compressed mosaic retain the same value as in the original DEM, and nearly all the rest differ by only 1 meter. The maximum deviation from the original is 2 meters. This deviation is well below the stated vertical accuracy of 20 meters for the ASTER GDEM data, and causes no visual loss of detail in the compressed DEM in comparison to the original.

Assuming an average compression ratio of 18:1, the stored size of the complete ASTER GDEM set could be reduced to about 30 GB using JPEG2000 Lossy Best Quality Compression with only insignificant loss of spatial detail.

Lossy 80:1 JPEG2000 Compression

In order to investigate the effect of lossy compression at higher compression ratios, we exported the ASTER GDEM mosaic discussed above to a GeoJP2 file with 80:1 lossy JPEG2000 compression. This 80:1 compression reduced the stored size of the DEM from 223 MB for the original GeoTIFF tiles to 2.8 MB.

As shown in the illustrations at the bottom of this page, even with this large degree of compression, the loss of spatial detail in the compressed version is barely noticeable. A histogram of the change in cell value from the original DEM to the lossy-compressed version is shown below. The histogram shows that 79% of the cells in the compressed raster have unchanged value or are only 1 meter above or below the elevation of the original. Only 1% of the cells differ by 4 meters or more from the original, and the maximum deviation is 20 meters. Therefore no cell in the 80:1 compressed DEM differs from its original value by more than the stated vertical accuracy of 20 meters for the ASTER GDEM data. Using 80:1 lossy JPEG2000 compression, the size of the complete set of ASTER GDEM tiles could be reduced to 6.9 GB, small enough to fit on a double-layer DVD. This compressed data would be adequate for 3D and stereo visuallization and many other uses.

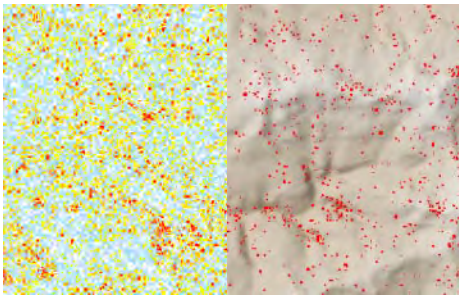


Histogram of elevation difference (m) between 80:1 JPEG2000 lossy compressed ASTER GDEM and original. The maximum elevation deviation is 20 meters, but 95% of cells have values within 2 meters of the original GDEM.

Original uncompressed

Lossy 80:1 JPEG2000 Compression

Above, color-shaded relief views of a sample area in the Ethiopia mosaic comparing the original uncompressed surface to the surface with 80:1 lossy JPEG2000 compression. Loss of spatial detail with lossy compression is barely noticeable.



Above left, raster indicating change in cell value with lossy compression over west side of sample area. Color values shown in histogram above. Above right, cells that changed by 4 m or more are shown over the color-shaded east part of the area.