

GTOPO30 Documentation ReadMe

Table of Contents

1.0 Introduction.....	2
2.0 Data set Characteristics.....	2
3.0 Data Format	2
3.1 DEM File (.DEM).....	4
3.2 Header File (.HDR).....	4
3.3 World File (.DMW).....	5
3.4 Statistics File (.STX).....	5
3.5 Projection File (.PRJ).....	5
3.6 Shaded Relief Image (.GIF).....	6
3.7 Source Map (.SRC).....	6
3.8 Source Map Header File (.SCH).....	7
4.0 Data Distribution.....	7
4.1 Obtaining Data	8
4.2 File Sizes.....	8
5.0 Notes and Hints for GTOPO30 Users.....	9
6.0 Data Set Development	9
6.1 Data Sources.....	9
6.1.1 Digital Terrain Elevation Data	10
6.1.3 USGS Digital Elevation Models	10
6.1.4 Army Map Service Maps.....	10
6.1.5 International Map of the World.....	11
6.1.6 Peru Map	11
6.1.7 New Zealand DEM.....	11
6.1.8 Antarctic Digital Database	11
6.2 Data Processing	11
6.2.1 Raster Source Processing	11
6.2.2 Vector Source Processing	12
6.2.3 DEM Merging	12
6.2.4 Global Product Assembly.....	13
7.0 Accuracy	13

8.0 GTOPO30 Caveats.....	14
8.1 Grid Spacing and Resolution.....	14
8.2 Topographic Detail and Accuracy.....	15
8.3 Production Artifacts	16
9.0 Summary	16
10.0 References.....	16
11.0 Disclaimers	17

1.0 Introduction

GTOPO30 is a global digital elevation model (DEM) resulting from a collaborative effort led by the staff at the U.S. Geological Survey's [EROS Data Center](#) in Sioux Falls, South Dakota. Elevations in GTOPO30 are regularly spaced at 30-arc seconds (approximately 1 kilometer). GTOPO30 was developed to meet the needs of the geospatial data user community for regional and continental scale topographic data. This release represents the completion of global coverage of 30-arc second elevation data that have been available from the EROS Data Center beginning in 1993. Several areas have been updated and the entire global data set has been repackaged, so these data supersede the previously released continental data sets. Comments from users of GTOPO30 are welcomed and encouraged.

2.0 Data set Characteristics

GTOPO30 is a global data set covering the full extent of latitude from 90 degrees south to 90 degrees north, and the full extent of longitude from 180 degrees west to 180 degrees east. The horizontal grid spacing is 30-arc seconds (0.0083333333333333 degrees), resulting in a DEM having dimensions of 21,600 rows and 43,200 columns. The horizontal coordinate system is decimal degrees of latitude and longitude referenced to WGS84. The vertical units represent elevation in meters above mean sea level. The elevation values range from -407 to 8,752 meters. In the DEM, ocean areas have been masked as "no data" and have been assigned a value of 9999. Lowland coastal areas have an elevation of at least 1 meter, so in the event that a user reassigns the ocean value from -9999 to 0 the land boundary portrayal will be maintained. Due to the nature of the raster structure of the DEM, small islands in the ocean less than approximately 1 square kilometer will not be represented.

3.0 Data Format

To facilitate electronic distribution, GTOPO30 has been divided into 33 smaller pieces, or tiles. The area from 60 degrees south latitude to 90 degrees north latitude and from 180 degrees west longitude to 180 degrees east longitude is covered by 27 tiles, with each tile covering 50 degrees of latitude and 40 degrees of longitude. Antarctica (90 degrees south latitude to 60 degrees south latitude and 180 degrees west longitude to 180 degrees east longitude) is covered by 6 tiles, with each tile covering 30 degrees of latitude and 60 degrees of longitude. The tiles names refer to the longitude and latitude of the upper-left (northwest) corner of the tile. For example, the coordinates of the upper-left corner of tile E020N40 are 20 degrees east longitude and 40 degrees north latitude. There is one additional tile that covers all of Antarctica with data in a polar

stereographic projection. The following table lists the name, latitude and longitude extent, and elevation statistics for each tile.

Tile	Latitude		Longitude		Elevation			
	Min	Max	Min	Max	Min	Max	Mean	Std Dev.
W180N90	40	90	-180	-140	1	6098	448	482
W140N90	40	90	-140	-100	1	4635	730	596
W100N90	40	90	-100	-60	1	2416	333	280
W060N90	40	90	-60	-20	1	3940	1624	933
W020N90	40	90	-20	20	-30	4536	399	425
E020N90	40	90	20	60	-137	5483	213	312
E060N90	40	90	60	100	-152	7169	509	698
E100N90	40	90	100	140	1	3877	597	455
E140N90	40	90	140	180	1	4588	414	401
W180N40	-10	40	-180	-140	1	4148	827	862
W140N40	-10	40	-140	-100	-79	4328	1321	744
W100N40	-10	40	-100	-60	1	6710	375	610
W060N40	-10	40	-60	-20	1	2843	212	168
W020N40	-10	40	-20	20	-103	4059	445	298
E020N40	-10	40	20	60	-407	5825	727	561
E060N40	-10	40	60	100	1	8752	1804	1892
E100N40	-10	40	100	140	-40	7213	692	910
E140N40	-10	40	140	180	1	4628	549	715
W180S10	-60	-10	-180	-140	1	2732	188	297
W140S10	-60	-10	-140	-100	1	910	65	124
W100S10	-60	-10	-100	-60	1	6795	1076	1356
W060S10	-60	-10	-60	-20	1	2863	412	292
W020S10	-60	-10	-20	20	1	2590	1085	403
E020S10	-60	-10	20	60	1	3484	893	450
E060S10	-60	-10	60	100	1	2687	246	303
E100S10	-60	-10	100	140	1	1499	313	182
E140S10	-60	-10	140	180	1	3405	282	252
W180S60	-90	-60	-180	-120	1	4009	1616	1043
W120S60	-90	-60	-120	-60	1	4743	1616	774
W060S60	-90	-60	-60	0	1	2916	1866	732
W000S60	-90	-60	0	60	1	3839	2867	689
E060S60	-90	-60	60	120	1	4039	2951	781
E120S60	-90	-60	120	180	1	4363	2450	665
ANTARCPS	-90	-60	-180	180	1	4748	2198	1016

The 27 tiles that individually cover 50 degrees of latitude and 40 degrees of longitude each have 6,000 rows and 4,800 columns. The 6 Antarctica tiles that individually cover 30 degrees of

latitude and 60 degrees of longitude each have 3,600 rows and 7,200 columns. There is no overlap among the tiles so the global data set may be assembled by simply abutting the adjacent tiles.

The tile named ANTARCPS includes the same data as the 6 geographic tiles covering Antarctica, but is presented in a polar stereographic projection. The horizontal grid spacing is 1,000 meters, and the tile has 5,400 rows and 5,400 columns. The projection parameters used for the polar stereographic projection are: 0 degrees for the longitude of the central meridian, 71 degrees south for the latitude of true scale, and 0 for the false easting and false northing.

Data for each tile are provided in a set of 8 files. The files are named with the tile name and a file name extension indicating the contents of the file. The following extensions are used:

Extension	Contents
DEM	digital elevation model data
HDR	header file for DEM
DMW	world file
STX	statistics file
PRJ	projection information file
GIF	shaded relief image
SRC	source map
SCH	header file for source map

The simple format should allow for easy ingest into most popular image processing and geographic information systems packages. Further information on the contents of the files is provided below.

3.1 DEM File (.DEM)

The DEM is provided as 16-bit signed integer data in a simple binary raster. There are no header or trailer bytes imbedded in the image. The data are stored in row major order (all the data for row 1, followed by all the data for row 2, etc.).

3.2 Header File (.HDR)

The DEM header file is an ASCII text file containing size and coordinate information for the DEM. The following keywords are used in the header file:

BYTEORDER	byte order in which image pixel values are stored M = Motorola byte order (most significant byte first)
LAYOUT	organization of the bands in the file BIL = band interleaved by line (note: the DEM is a single band image)
NROWS	number of rows in the image
NCOLS	number of columns in the image
NBANDS	number of spectral bands in the image (1 for a DEM)
NBITS	number of bits per pixel (16 for a DEM)
BANDROWBYTES	number of bytes per band per row (twice the number of columns for a 16-bit DEM)
TOTALROWBYTES	total number of bytes of data per row (twice the number of columns for a single band 16-bit DEM)

BANDGAPBYTES	the number of bytes between bands in a BSQ format image(0 for a DEM)
NODATA	value used for masking purposes
ULXMAP	longitude of the center of the upper-left pixel (decimal degrees)
ULYMAP	latitude of the center of the upper-left pixel (decimal degrees)
XDIM	x dimension of a pixel in geographic units (decimal degrees)
YDIM	y dimension of a pixel in geographic units (decimal degrees)

Example header file (W100N40.HDR):

BYTEORDER	M
LAYOUT	BIL
NROWS	6000
NCOLS	4800
NBANDS	1
NBITS	16
BANDROWBYTES	9600
TOTALROWBYTES	9600
BANDGAPBYTES	0
NODATA	-9999
ULXMAP	-99.99583333333334
ULYMAP	39.99583333333333
XDIM	0.00833333333333
YDIM	0.00833333333333

3.3 World File (.DMW)

The world file is an ASCII text file containing coordinate information. It is used by some packages for georeferencing of image data. The following is an example world file (W100N40.DMW) with a description of each record:

0.00833333333333	x dimension of a pixel (decimal degrees)
0.00000000000000	rotation term (will always be zero)
0.00000000000000	rotation term (will always be zero)
-0.00833333333333	negative y dimension of a pixel (decimal degrees)
-99.99583333333334	longitude of the center of the upper-left pixel
39.99583333333333	latitude of the center of the upper-left pixel

3.4 Statistics File (.STX)

The statistics file is an ASCII text file which lists the band number, minimum value, maximum value, mean value, and standard deviation of the values in the DEM data file.

Example statistics file (W100N40.STX):

```
1 -9999 6710 -6078.8 5044.2
```

3.5 Projection File (.PRJ)

The projection information file is an ASCII text file which describes the projection of the DEM and source map image.

Example projection file (W100N40.PRJ):

```
Projection    GEOGRAPHIC
Datum        WGS84
Zunits       METERS
Units        DD
Spheroid     WGS84
Xshift       0.0000000000
Yshift       0.0000000000
Parameters
```

3.6 Shaded Relief Image (.GIF)

A shaded relief image is provided as an overview of the data in each tile. The images were derived from a generalized version of GTOPO30 with a horizontal grid spacing of 240-arc seconds (approximately 8 kilometers), so many small islands and features will not be visible. The images are meant to provide a convenient way for users to view the general topographic features portrayed in each tile. The shaded relief images are provided as GIF images which can be displayed by many popular image display programs and World Wide Web browsers. An image size 750 rows by 600 columns is used for the tiles covering 50 degrees of latitude by 40 degrees of longitude. An image size 450 rows by 900 columns is used for the Antarctica tiles which cover 30 degrees of latitude by 60 degrees of longitude each. The Antarctica polar stereographic tile is portrayed by a shaded relief image having 675 rows by 675 columns.

3.7 Source Map (.SRC)

The source map is a simple 8-bit binary image which has values that indicate the source used to derive the elevation for every cell in the DEM. The source map is the same resolution and has the same dimensions and coordinate system as the DEM. Like the DEM, it has no header or trailer bytes and is stored in row major order. These codes are used in the source map image:

Value	Source
-----	-----
0	Ocean
1	Digital Terrain Elevation Data
2	Digital Chart of the World
3	USGS 1-degree DEM's
4	Army Map Service 1:1,000,000-scale maps
5	International Map of the World 1:1,000,000-scale maps
6	Peru 1:1,000,000-scale map
7	New Zealand DEM
8	Antarctic Digital Database

More information on each of these sources is provided in section 6.1 (Data Sources). The cells with value 0 (ocean) in the source map can be used as an ocean mask (the ocean cells match exactly all the cells masked as "no data" in the DEM with a value of -9999). Likewise, the cells

with values 1-8 together constitute a global land mask. Every cell in the DEM with an elevation has a corresponding cell in the source map with a value in the range 1-8.

3.8 Source Map Header File (.SCH)

The source map header file is an ASCII text file containing size and coordinate information, similar to the DEM header file. The following keywords are used in the source map header file:

BYTEORDER	byte order in which image pixel values are stored M = Motorola byte order (most significant byte first)
LAYOUT	organization of the bands in the file BIL = band interleaved by line (note: the source map is a single band image)
NROWS	number of rows in the image
NCOLS	number of columns in the image
NBANDS	number of spectral bands in the image (1 for the source map)
NBITS	number of bits per pixel (8 for the source map)
BANDROWBYTES	number of bytes per band per row (the number of columns for an 8-bit source map)
TOTALROWBYTES	total number of bytes of data per row (the number of columns for a single band 8-bit source map)
BANDGAPBYTES	the number of bytes between bands in a BSQ format image (0 for the source map)
NODATA	value used for masking purposes
ULXMAP	longitude of the center of the upper-left pixel (decimal degrees)
ULYMAP	latitude of the center of the upper-left pixel (decimal degrees)
XDIM	x dimension of a pixel in geographic units (decimal degrees)
YDIM	y dimension of a pixel in geographic units (decimal degrees)

Example source map header file (W100N40.SCH):

BYTEORDER	M
LAYOUT	BIL
NROWS	6000
NCOLS	4800
NBANDS	1
NBITS	8
BANDROWBYTES	4800
TOTALROWBYTES	4800
BANDGAPBYTES	0
NODATA	-9999
ULXMAP	-99.995833333333334
ULYMAP	39.995833333333333
XDIM	0.008333333333333
YDIM	0.008333333333333

4.0 Data Distribution

Data for each GTOPO30 tile are distributed electronically as a compressed tar file. The 8 files for each tile have been combined into one file with the Unix "tar" command, and the tar file has been compressed with GNU "gzip" utility. To use the GTOPO30 data files, the tar file must first be decompressed and then the individual data files extracted from the tar file

4.1 Obtaining Data

[EarthExplorer](#) can be used to search, preview, and download Global 30 Arc-Second Elevation (GTOPO30). The collection is located under the Digital Elevation category.

4.2 File Sizes

After decompression and extraction from the tar files, the following filesizes are present for each of the 3 sizes of tiles:

Tile size -----	File ----	Size (bytes) -----
50 degrees latitude by 40 degrees longitude	DEM	57600000
30 degrees latitude By 60 degrees longitude	Source map	28800000
Antarctica polar stereographic data (5,400 km x 5,400 km)	DEM	51840000
	Source map	25920000
	DEM	58320000
	Source map	29160000

For each tile, the total for all the other file types (HDR, DMW, STX, PRJ, GIF, and SCH) is well under 1 megabyte.

The global 16-bit DEM (21,600 rows by 43,200 columns) has a size of 1.74 gigabytes. The global 8-bit source map of the same dimensions has a size of 889.9 megabytes.

Through the use of the gzip compression utility the total size of the global data set is reduced about 90% from almost 2.72 gigabytes to under 290 megabytes. The list below shows the compressed size for each tile. The sizes range from less than 1 megabyte to about 25 megabytes, with the average at about 8 megabytes. Decompressed, the tar file for each tile can be as large as 84 megabytes.

File ----	Size (bytes) -----
antarcps.tar.gz	10538463
e020n40.tar.gz	26124072
e020n90.tar.gz	16992230
e020s10.tar.gz	8262946
e060n40.tar.gz	17935016
e060n90.tar.gz	22402428
e060s10.tar.gz	113591
e060s60.tar.gz	5308336
e100n40.tar.gz	14175303
e100n90.tar.gz	24994154
e100s10.tar.gz	4361555
e120s60.tar.gz	6131365
e140n40.tar.gz	1140685
e140n90.tar.gz	9222752
e140s10.tar.gz	4059027
w000s60.tar.gz	5080091
w020n40.tar.gz	16938044

w020n90.tar.gz	8844434
w020s10.tar.gz	2927056
w060n40.tar.gz	3721100
w060n90.tar.gz	6820815
w060s10.tar.gz	6738966
w060s60.tar.gz	3558292
w100n40.tar.gz	11330238
w100n90.tar.gz	15656539
w100s10.tar.gz	9575882
w120s60.tar.gz	5677801
w140n40.tar.gz	6497682
w140n90.tar.gz	17031379
w140s10.tar.gz	89706
w180n40.tar.gz	131975
w180n90.tar.gz	5477564
w180s10.tar.gz	116231
w180s60.tar.gz	3500153

5.0 Notes and Hints for GTOPO30 Users

Because the DEM data are stored in a 16-bit binary format, users must be aware of how the bytes are addressed on their computers. The DEM data are provided in Motorola byte order, which stores the most significant byte first ("big endian"). Systems such as Sun SPARC and Silicon Graphics workstations use the Motorola byte order. The Intel byte order, which stores the least significant byte first ("little endian"), is used on DEC Alpha systems and most PCs. Users with systems that address bytes in the Intel byte order may have to "swap bytes" of the DEM data unless their application software performs the conversion during ingest. The statistics file (.STX) provided for each tile gives the range of values in the DEM file, so users can check if they have the correct DEM values stored on their system.

Users of ARC/INFO or ArcView can display the DEM data directly after simply renaming the file extension from .DEM to .BIL. However, if a user needs access to the actual elevation values for analysis in ARC/INFO the DEM must be converted to an ARC/INFO grid with the command IMAGEGRID. IMAGEGRID does not support conversion of signed image data, therefore the negative 16-bit DEM values will not be interpreted correctly. After running IMAGEGRID, an easy fix can be accomplished using the following formula in Grid:

```
out_grid = con(in_grid >= 32768, in_grid - 65536, in_grid)
```

The converted grid will then have the negative values properly represented, and the statistics of the grid should match those listed in the .STX file. If desired, the -9999 ocean mask values in the grid could then be set to NODATA with the SETNULL function.

6.0 Data Set Development

GTOPO30, completed in late 1996, was developed over a 3 year period through a collaborative effort led by staff at the U.S. Geological Survey's EROS Data Center (EDC). The following organizations participated by contributing funding or source data: the National Aeronautics and Space Administration (NASA), the [United Nations Environment Programme/Global Resource Information Database \(UNEP/GRID\)](#), the U.S. Agency for International Development (USAID), the [Instituto Nacional de Estadística Geográfica e Informática \(INEGI\)](#) of Mexico, the [Geographical Survey Institute \(GSI\)](#) of Japan, [Manaaki Whenua Landcare Research](#) of New Zealand, and the [Scientific Committee on Antarctic Research \(SCAR\)](#).

6.1 Data Sources

GTOPO30 is based on data derived from 8 sources of elevation information, including vector and raster data sets. The following table lists the percentage of the global land surface area derived from each source (a full description of each source is provided below):

Source -----	% of global land area -----
Digital Terrain Elevation Data	50.0
Digital Chart of the World	29.9
USGS 1-degree DEM's	6.7
Army Map Service 1:1,000,000-scale maps	1.1
International Map of the World 1:1,000,000-scale maps	3.7
Peru 1:1,000,000-scale map	0.1
New Zealand DEM	0.2
Antarctic Digital Database	8.3

6.1.1 Digital Terrain Elevation Data

[Digital Terrain Elevation Data \(DTED\)](#) is a raster topographic data base with a horizontal grid spacing of 3-arc seconds (approximately 90 meters) produced by the [National Geospatial-Intelligence Agency \(NGA\)](#) (formerly the Defense Mapping Agency, formerly known as the National Imagery and mapping Agency (NIMA)). DTED was used as the source for most of Eurasia and large parts of Africa, South America, Mexico, Canada, and Central America. DTED coverage for Mexico was provided by INEGI.

6.1.2 Digital Chart of the World

[Digital Chart of the World \(DCW\)](#) is a vector cartographic data set based on the 1:1,000,000-scale Operational Navigation Chart (ONC) series, which is the largest scale base map source with global coverage (Danko, 1992). The DCW and the ONC series are products of NGA.

The topographic information of interest for generating DEM's is contained in several DCW hypsography layers. The primary contour interval on the source ONC's is 1,000 feet (305 meters), and supplemental contours at an interval of 250 feet (76 meters) are shown in areas below 1,000 feet in elevation. In limited areas of higher elevation supplemental contours at 500-foot (152-meter) intervals. The DCW drainage layers were also used as input to the DEM generation process; this information included stream networks, lake shorelines, lake elevations, and ocean coastlines. The DCW was used as the primary source for filling gaps in the DTED coverage, including all of Australia, most of Greenland, and large areas of Africa, South America, and Canada.

6.1.3 USGS Digital Elevation Models

[USGS 1-degree DEM's](#) with a horizontal grid spacing of 3-arc seconds (approximately 90 meters) were used as the source data for the continental United States, Alaska, and Hawaii. The topographic information content is similar to that of DTED. The "1-degree" designation refers to the unit of data distribution.

6.1.4 Army Map Service Maps

Paper maps at a scale of 1:1,000,000 produced by the Army Map Service (AMS), a predecessor of DMA and NIMA, were acquired and digitized by GSI of Japan. Contours (with intervals of 100, 150, 300, and 500 meters), spot heights, drainage lines, and coastlines for some islands of southeast Asia

and some small areas in South America were delivered to EDC as digital vector cartographic data sets.

6.1.5 International Map of the World

Paper maps from the 1:1,000,000-scale International Map of the World (IMW) series were digitized by GSI to provide source data for the Amazon basin. The International Map of the World includes national maps produced to a United Nations specified standard for 1:1,000,000-scale mapping. The maps used for this project had a 100-meter contour interval.

6.1.6 Peru Map

Small areas of a 1:1,000,000-scale map from the Peruvian government were digitized to fill gaps in source data for South America. The map had a contour interval of 1,000 meters.

6.1.7 New Zealand DEM

Manaaki Whenua Landcare Research contributed a DEM with a 500-meter horizontal grid spacing for New Zealand. The DEM was derived from elevation information on 1:63,360-scale maps with a 100-foot (30-meter) contour interval.

6.1.8 Antarctic Digital Database

The [Antarctic Digital Database \(ADD\)](#) was produced under the auspices of the Scientific Committee on Antarctic Research. Digital contours and coastlines from the ADD were used as source material for Antarctica. The ADD vector data were compiled from maps ranging in scale from 1:200,000 to 1:5,000,000. The detail, density, and interval of the contours in the ADD vary widely, with the more detailed data near the coastline and very generalized data in the interior of the continent. Detailed metadata provided in the ADD identifies the map scale from which each contour line was extracted.

6.2 Data Processing

GTOPO30 was developed over a 3 year period during which continental and regional areas were produced individually. As such, processing techniques were developed and refined throughout the duration of the project. Although the techniques used for the various continental areas are very similar, there were some differences in approach due to varying source material. More details about data development for several of the continental areas are reported by [Verdin and Greenlee \(1996\)](#), [Bliss and Olsen \(1996\)](#), and [Gesch and Larson \(1996\)](#).

Data processing was accomplished using commercially available geographic information system software, public domain image processing software, vector-to-raster gridding software, and utilities developed specifically for this project. To more efficiently handle the numerous input data sets and to standardize the proper sequence of processing steps, the production procedures were automated to a great extent by employing preset parameter values, scripted command files, and consistent naming schemes for input and output data files.

6.2.1 Raster Source Processing

Processing of the raster source data, including DTED, USGS DEM's, and the New Zealand DEM, involved generalizing the higher resolution data to the 30-arc second horizontal grid spacing. Because the DTED and USGS DEM's were already in a geographic "projection" they only required a sampling of the full resolution 3-arc second data. One representative elevation value was selected to represent the area covered by 100 full resolution cells (a 10 by 10 matrix). As the project progressed, several methods of generalization were used. Selection of the representative 30-arc second value was accomplished by systematic subsampling for North and South America, by calculation of the median value for Eurasia, and by the breakline emphasis approach ([Gesch and Larson, 1996](#)) for Africa. The 500-meter New Zealand DEM was generalized to 30-arc seconds by reprojecting it from the New Zealand National Grid projection to geographic coordinates using bilinear resampling.

6.2.2 Vector Source Processing

The topographic information from the vector cartographic sources, including the DCW, the ADD, and the Army Map Service, International Map of the World, and Peru 1:1,000,000-scale maps, was converted into elevation grids through a vector-to-raster gridding approach. Contours, spot heights, stream lines, lake shorelines, and ocean coastlines were input to the [ANUDEM](#) surface gridding program developed at the Australian National University ([Hutchinson, 1989](#)). ANUDEM, specifically designed for creating DEM's from digital contour, spot height, and stream line data, employs an approach known as drainage enforcement to produce raster elevation models that represent more closely the actual terrain surface and contain fewer artifacts than those produced with more general purpose surface interpolation routines. Drainage enforcement was performed for all areas covered by vector source data except Antarctica and Greenland.

A significant amount of preprocessing was required to prepare and format the vector source data for input to ANUDEM. This processing included editing and updating the vector stream lines so that the direction of each was oriented downstream (a requirement of ANUDEM). Further preprocessing involved detection and correction of erroneous contour and point elevations ([Larson, 1996](#)). Ocean coastlines were assigned an elevation of zero for input as contours. Also, shorelines of lakes for which the DCW included elevations were tagged and used as contour input. The output from ANUDEM was an elevation model grid referenced in the same horizontal coordinate system as the generalized raster source data. The output grid spacing of 30-arc seconds has been shown to be appropriate for the information content present in the DCW hypsography layers ([Hutchinson, 1996](#); [Shih and Chiu, 1996](#)).

6.2.3 DEM Merging

Prior to merging with the generalized raster data, lakes for which the DCW did not indicate an elevation were updated on the DCW grid with the lowest grid cell elevation found along the shoreline. When each of the vector sources was gridded, an overlap area with the adjacent raster sources was included so that smoothing could be performed to minimize the elevation discrepancies among the sources. Also, additional point control was input into the ANUDEM gridding process so interpolated elevations in the overlap region would more closely match the raster source elevations. The additional control was derived from the generalized raster sources within a 1-degree buffer surrounding the vector source areas.

Merging of the generalized raster sources and the gridded vector sources was accomplished by mosaicking the data sets. The generalized raster sources had the highest priority so coverage of the data with the greater topographic detail and accuracy was maximized. The grid derived from DCW data had the highest priority among the vector sources, and the other digitized map data was used when DCW hypsography was unavailable. The merging procedure including blending of the generalized raster sources and the vector-derived grids within an approximate 1-degree overlap area along the irregular boundaries. The blending algorithm computes a weighted average with the weights

for each data source determined on a cell-by-cell basis according to the cell's proximity to the edges of the overlap area ([Franke, 1982](#)).

A final processing step performed on the mosaicked and blended product involved "clipping out" the land (as defined by vector coastline data) and setting the ocean areas to a constant background value. Use of vector coastline data resulted in a more consistent portrayal of the land/ocean interface, especially in areas where raster source data (which had an implied coastline) met with vector source data. The DCW coastline was used to clip the following areas: Africa, Eurasia, South America, Australia, New Zealand, Greenland, and isolated ocean islands. The [World Vector Shoreline \(WVS\)](#), a vector shoreline data set from NIMA, was used for North America, including Hawaii, the Caribbean islands, and Central America. The islands of Borneo and Sulawesi in southeast Asia were clipped with the coastline digitized from the 1:1,000,000-scale map source. Antarctica was defined by the coastline as portrayed in the ADD.

6.2.4 Global Product Assembly

The global product was assembled from the continental and regional DEM's. Several areas of overlap due to different production stages of the project were addressed and eliminated, most notably between the Africa and Eurasia data sets. The global source map was generated from masks of source data coverage, and was verified to register with the DEM precisely. Finally, the entire data set was packaged into tiles for easier electronic distribution.

7.0 Accuracy

The absolute vertical accuracy of GTOPO30 varies by location according to the source data. Generally, the areas derived from the raster source data have higher accuracy than those derived from the vector source data. The full resolution 3-arc second DTED and USGS DEM's have a vertical accuracy of + or - 30 meters linear error at the 90 percent confidence level ([Defense Mapping Agency, 1986](#); [U.S. Geological Survey, 1993](#)). If the error distribution is assumed to be Gaussian with a mean of zero, the statistical standard deviation of the errors is equivalent to the root mean square error (RMSE). Under those assumptions, vertical accuracy expressed as + or - 30 meters linear error at 90 percent can also be described as a RMSE of 18 meters. The areas of GTOPO30 derived from DTED and USGS DEM's retain that same level of accuracy because through generalization a representative elevation value derived from the full resolution cells is chosen to represent the area of the reduced resolution cell (although the area on the ground represented by that one elevation value is now much larger than the area covered by one full resolution cell).

The absolute vertical accuracy of the DCW, the vector source with the largest area of coverage, is stated in its product specification as + or - 650 meters linear error at the 90% confidence level ([Defense Mapping Agency, 1990](#)). Experience has shown that the grids derived from DCW data should in many areas be much more accurate than the 650-meter specification. To better characterize the accuracy of the areas of GTOPO30 derived from DCW vector hypsography, the DCW grid was compared to 30-arc second DTED, which had been aggregated by averaging. By aggregating, the comparison could be done at the 30-arc second cell size of the DCW grid. The comparison was done for portions of southern Europe and the Mideast, and all of Africa. Eliminated from the comparison were those areas of the DCW grid for which supplemental DTED point control had been included in the gridding process. If the averaged DTED are thought of as the reference data set, the RMSE of the DCW grid is 95 meters. To get an idea of the overall absolute accuracy of the DCW grid, the relative error between the DCW and DTED can be combined with the known error of the DTED itself in a sum of squares. The root of that sum of squares is 97 meters. Using the assumptions about the error distribution cited above, a RMSE of 97 meters can be expressed as + or - 160 meters linear error at 90 percent confidence. This number compares favorably with an expected vertical accuracy (linear error at 90 percent) of one-half of the primary contour interval of 1,000 feet (305 meters) for the topographic maps on which the DCW is based.

The accuracy of the areas of GTOPO30 based on the other sources can only be estimated based on that which is known about each source. Using certain assumptions, the vertical accuracy of each source (and the derived 30-arc second grid) can be estimated from the contour interval. One assumption is that the original map sources meet the commonly used accuracy standard which states that 90% of the map elevations are within + or - one-half of the contour interval. It is unknown if any of these maps actually meet this standard. Also, map digitizing and elevation surface interpolation errors are unknown and therefore not included. The table below lists the estimated absolute vertical accuracy for the areas of GTOPO30 derived from each source, with the method of estimating the accuracy also identified. The RMSE numbers were calculated using the assumptions about the error distribution cited above (a Gaussian distribution with a mean of zero).

Source	Vertical accuracy (meters)		Estimation method
	L.E. at 90%	RMSE	
DTED	30	18	product specification
DCW	160	97	calculated vs. DTED
USGS DEM	30	18	product specification
AMS maps	250	152	estimated from 500-meter interval
IMW maps	50	30	estimated from 100-meter interval
Peru map	500	304	estimated from 1,000-meter interval
N.Z. DEM	15	9	estimated from 100-foot interval
ADD	highly variable	wide range of scales and intervals	

Local differences among DEM grid cells are often analyzed to calculate slope and other land surface parameters. The relative vertical accuracy (or point-to-point accuracy on the surface of the elevation model), rather than the absolute accuracy, determines the quality of such parameters derived from local differencing operations. Although not specified for this data set, for many areas the relative accuracy is probably better than the estimated absolute accuracy.

8.0 GTOPO30 Caveats

As with all digital geospatial data sets, users of GTOPO30 must be aware of certain characteristics of the data set (resolution, accuracy, methods of production and any resulting artifacts, etc.) in order to better judge its suitability for a specific application. A characteristic of GTOPO30 that renders it unsuitable for one application may have no relevance as a limiting factor for its use in a different application. Because only the end user can judge the applicability of the data set, it is the responsibility of the data producer to describe the characteristics of the data as fully as possible, so that an informed decision can be made by the user.

8.1 Grid Spacing and Resolution

For any application, the horizontal grid spacing (which limits the resolution) and the vertical accuracy of GTOPO30 must be considered. The 30-arc second grid spacing equates to about 1 kilometer, although that number decreases in the east/west (longitudinal) direction as latitude increases. The table below lists the approximate distance covered by 30-arc seconds at different latitudes. Thus, at high latitudes there is an unavoidable redundancy of data in order to keep the 30-arc second spacing consistent for the global data set. This is particularly true for the geographic version of Antarctica where the ground distance for 30-arc seconds of longitude converges to zero at the South Pole.

Latitude (degrees)	Ground distance (meters)	
	E/W	N/S

Equator	928	921
10	914	922
20	872	923
30	804	924
40	712	925
50	598	927
60	465	929
70	318	930
73	272	930
78	193	930
82	130	931

The variation in ground dimensions for one 30-arc second cell should be especially considered for any application that measures area of or distance across a group of cells. Derivative products, such as slope maps, drainage basin areas, and stream channel length, will be more reliable if they are calculated from a DEM that has been first projected from geographic coordinates to an equal area projection, so that each cell, regardless of latitude, represents the same ground dimensions and area as every other cell.

Users should maintain the distinction between grid spacing and resolution. Even though the global data set has a consistent 30-arc second grid spacing, not all topographic features that one would expect to be resolved at that spacing will be represented. The level of detail of the source data determines whether the 30-arc second sampling interval is truly appropriate for resolving the important topographic features represented in the source. Certainly, a 30-arc second grid spacing is appropriate for the areas derived from higher resolution DEM's (DTED, USGS DEM's, and the New Zealand DEM), and 30-arc seconds has been shown to be suitable as the cell spacing for grids derived from DCW hypsography ([Hutchinson, 1996](#); [Shih and Chiu, 1996](#)). However, coverage of DCW contours is not complete, and there are areas for which elevations were interpolated based only on very sparse DCW point data and/or distant contours. Small areas of this nature are located in Africa, South America, and islands of southeast Asia, while Australia and Greenland contain larger such areas. Also, the quality of the contours from the ADD for the interior of Antarctica does not realistically support a 30-arc second (or even 1-kilometer) grid spacing, although such data are provided for completeness and consistency of the global product.

8.2 Topographic Detail and Accuracy

Differences in topographic detail among the sources are evident in GTOPO30. This change in level of topographic information is especially evident at the boundary between areas derived from DTED and DCW in regions of higher relief. The mosaicking techniques that were used resulted in a smoothing of the transition areas, but the change in detail between the two sources remains very noticeable. Even if the same topographic feature (ridge, stream valley, lake, etc.) is represented in the data derived from the two sources, the elevations across the feature may change somewhat abruptly due to the varying accuracy of the sources. Derived products, such as slope maps, for the source transition areas also emphasize the differences in topographic information derived from the varying sources.

Users are reminded that the accuracy levels described above are estimates, and that the accuracy for specific locations within the overall area derived from any one source can vary from the estimate. For instance, approximately 30% of the DTED 1-degree by 1-degree tiles (the production and distribution unit for full resolution DTED) have an absolute vertical accuracy worse than the product specification of + or - 30 meters at 90% confidence. Also, the actual accuracy for some areas derived from the vector contour sources may be better or worse than the estimate. When the map source had multiple

contour intervals, the largest interval was used for a conservative estimate. In contrast, some areas may be worse than the estimate because no contour coverage was available for those specific locations.

8.3 Production Artifacts

Artifacts due to the production method are apparent in some areas of GTOPO30. While the magnitude of the artifacts in a local area are usually well within the estimated accuracy for the source, users are nonetheless made aware because the effects are plainly visible and they may affect some applications of the DEM. Some areas derived from DTED, especially in Africa and the Mideast, exhibit a striping artifact, most likely due to the production method of the DTED. The artifact is very evident in the full resolution data, but remains noticeable even in the generalized 30-arc second version. Generally, the pattern is more noticeable in low relief areas, while in higher relief areas it is masked by the actual terrain variation. Another pattern seen in some areas derived from DTED is a blocky appearance, which is reflection of the 1-degree tiling structure of the full resolution DTED. These areas derived from contiguous DTED 1-degree tiles appear blocky because of vertical offsets among the tiles in the original full resolution DTED. The artifacts in the DTED areas may or may not be visible, depending on the method used to display the data. For instance, when viewing the DEM data as an image either in shades of gray or color, the artifacts may be hidden, depending on the number of shades or colors used. If the data are displayed as a shaded relief image the appearance of the artifacts will vary depending on the direction of illumination, vertical exaggeration applied, and the scale of the display. Generally, none of the artifacts will be visible on a small scale portrayal of the global data set.

Some production artifacts are also present in the areas derived from the vector sources. Small artificial mounds and depressions may be present in localized areas, particularly where steep topography is adjacent to relatively level areas, and the hypsography data were sparse. Additionally, a "stair step" (or terracing) effect may be seen in profiles of some areas, where the transition between contour line elevations does not slope constantly across the area but instead is covered by a flat area with sharper changes in slope at the locations of the contour lines. When a histogram of elevations is presented there are sharp peaks at elevations that are multiples of the contour interval of the source. This effect is common in DEM's produced by gridding of contour data in which the interpolation process favors elevations at or near the contour values, thus leading to a greater frequency of those elevations. Every effort to reduce these effects has been made by careful selection of parameters for the interpolation process, but some level of these conditions inevitably remain due to the nature of vector-to-raster surface generation.

9.0 Summary

GTOPO30 provides a new level of detail in global topographic data. Previously, the best available global DEM was the [ETOPO5](#) data set, and its successor [TerrainBase](#), with a horizontal grid spacing of 5-arc minutes (approximately 10 kilometers) ([Row, Hastings, and Dunbar, 1995](#)). GTOPO30 data are suitable for many regional and continental applications, such as climate modeling, continental-scale land cover mapping, extraction of drainage features for hydrologic modeling ([Danielson, 1996](#); [Verdin and Greenlee, 1996](#)), and geometric and atmospheric correction of medium and coarse resolution satellite image data ([Gesch, 1994](#); [Jet Propulsion Laboratory, 1997](#)).

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11.0 Disclaimers

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