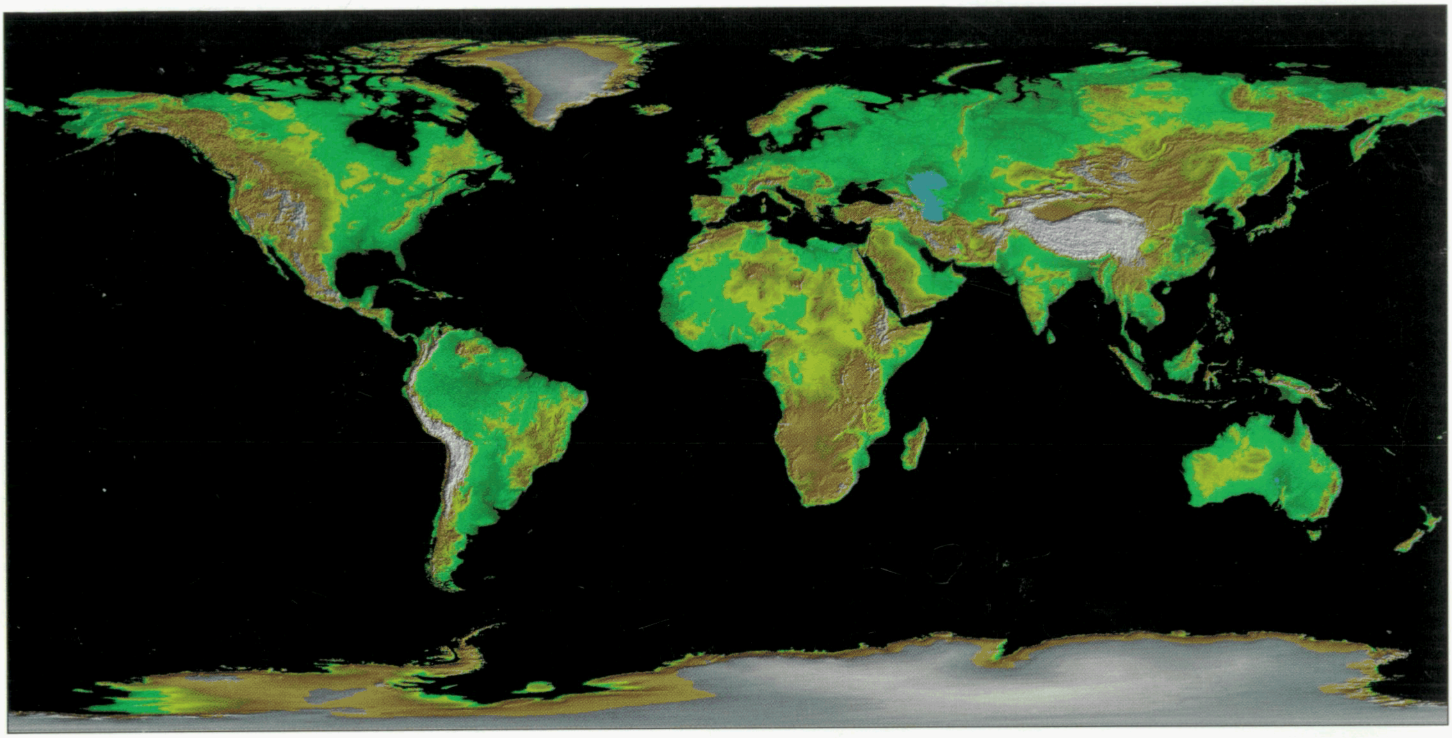
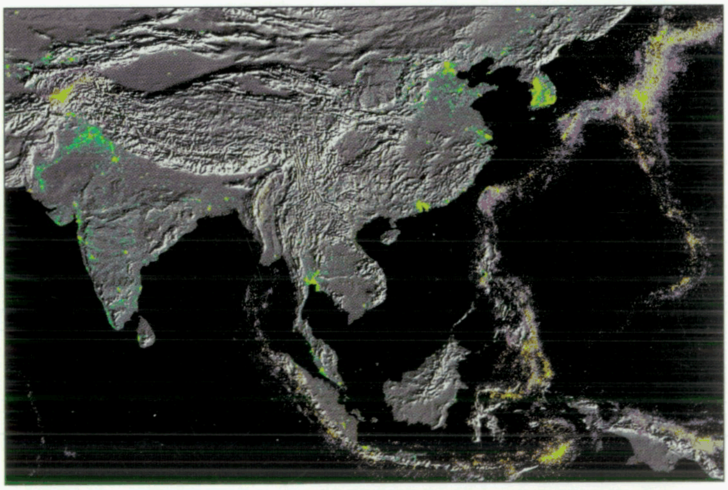
Global Land One-kilometer Base Elevation (GLOBE)





Key to Geophysical Records Documentation No. 34
May 1999

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
National Geophysical Data Center
Boulder, Colorado 80303-3328

Front Cover

Upper Image: Color image showing the GLOBE digital elevation model. Black denotes areas flagged as ocean in GLOBE.

Lower Image: Shaded-relief image of southern and eastern Asia. Earthquake depths are shown in purple (shallow earthquakes) and pink (deeper earthquakes). Nighttime lights (from NOAA's archive of Defense Meteorological Satellite Program imagery) is shown in greens (less intense) and yellows (most intense). The nighttime lights are primarily settled areas, plus industrial features such as gas flares in petroleum fields.

Back Cover

GLOBE data come from eighteen combinations of source/lineage, described in Section 5A. This summary map shows the distributions of data by these sources/ lineages.

Global Land One-kilometer Base Elevation (GLOBE)

Digital Elevation Model, Version 1.0
Documentation Version 1.0

Edited by
David A. Hastings
Paula K. Dunbar
for the GLOBE Task Team of the Committee on Earth Observation Satellites

NGDC Key to Geophysical Records Documentation No. 34
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Trademark Acknowledgments

Publication Citation

The Global Land One-kilometer Base Elevation (GLOBE) was developed on behalf of the GLOBE Task Team, created by the Committee on Earth Observation Satellites (CEOS), Working Group on Information Systems and Services (WGISS), Data Subgroup (DS). GLOBE also coordinates with the International Geosphere-Biosphere Programme's Data and Information System, and International Society of Photogrammetry and Remote Sensing (ISPRS) Working Group IV/6 on Global Databases in Support of Environmental Monitoring. The data base citation is found on page 8. The documentation manual should be cited as follows:

> Hastings, David A., and Paula K. Dunbar, 1999. *Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Documentation, Volume 1.0.* Key to Geophysical Records Documentation (KGRD) 34. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80303, U.S.A.

Contents

1. Executive Summary

This is the first version of documentation for the Global Land One-kilometer Base Elevation (GLOBE) data set. GLOBE is an internationally designed, developed, and independently peer-reviewed global digital elevation model (DEM), at a latitude-longitude grid spacing of 30 arc-seconds (30"). This report describes the history of the GLOBE project, the candidate data sets, data compilation techniques, organization, and use of the data base. The data are available on CD-ROM and the World Wide Web.

The previous standards for global digital elevation models (DEMs) are ETOPO5 (NGDC, 1988) and TerrainBase (Row and Hastings, 1994; Row and others, 1995), which were at 5 arc-minute (5') gridding. Higher resolution DEMs exist for parts of the world (Gittings, 1997). However, when GLOBE was conceived, no DEM of higher resolution was known that covered more than two-thirds of Earth's land surface. That DEM (NIMA, various dates) and most higher-resolution DEMs outside the United States are restricted by copyright or other limitation on their distribution.

Two global DEMs have been produced at 30" gridding during the design and development of GLOBE. The Jet Propulsion Laboratory, a Federally-funded Research and Development Center operated by the California Institute of Technology for the National Aeronautics and Space Administration (NASA), developed a DEM from Digital Terrain Elevation (DTED) and other sources, for internal use in support of NASA satellite missions. Separately, the U.S. Geological Survey developed a DEM called GTOPO30. Both of these data sets have provided important pieces of GLOBE Version 1.0. However, GLOBE Version 1.0 differs from such projects:

- Additional contributions have been made directly to GLOBE, and to the National Oceanic and Atmospheric Administration's (NOAA's) long-standing program in international digital elevation data. Eighteen (18) combinations of data source/lineage have been mosaicked and described.
- GLOBE is an ongoing program of data collection, with enhancement of the data base and documentation for as long as the data are useful.
- GLOBE is an active program to enhance access to the data. This includes evolving improvements to the GLOBE Web site, and to CD-ROM and other possible distributions of GLOBE data. This also includes plans to make available many source DEMs, not just the final GLOBE mosaic, plus documentation.

GLOBE data are suitable for many regional and continental applications, such as:

- Design for communications infrastructure (such as cellular communications networks and radio/television broadcast antenna systems) in the absence of higher-resolution data. For example, the U.S. Federal Communications Commission certified 30" data for the conterminous United States for such purposes. The data have been distributed for almost two decades by NOAA's National Geophysical Data Center (NGDC).

- Logistical design for other civil works in remote areas, in the absence of higher-quality data.
- Development of flight safety systems (navigational aids, terrain avoidance aids, etc.). Note that such critical applications require careful adaptation of DEMs with current levels of quality.
- Processing of satellite data such as geometric and atmospheric correction of medium and coarse resolution satellite image data (Gesch, 1994; Jet Propulsion Laboratory, 1998, in press), as well as initial geometric correction of higher-resolution satellite data.
- Various forms of environmental study, such as climate modeling, continental-scale land cover mapping, and extraction of drainage features for hydrologic modeling (Danielson, 1996; Verdin and Greenlee, 1996).
- "Validation" of future global DEMs (especially when the candidates for GLOBE are also used) and of future regional DEMs lacking better, available regional DEMs for the same region.

Caveats: Note that GLOBE Version 1.0, like other digital topographic data, are insufficiently accurate over their full global extent to be taken too literally for mission-critical applications. They must always be interpreted with extreme caution. They should not be used exclusively in mission-critical or life-critical applications. Nevertheless, GLOBE Version 1.0, with its present 30" gridding, multiple sources, and documentation designed to inform users of the character of such data, is a remarkable improvement over previously available data and ancillary materials. It greatly exceeds the original expectations of its developers. This document contains discussions about data quality; caveats are concentrated in Sections 6 and 12.

GLOBE remains in active development. Peer review continues to be an integral part of the GLOBE process; please see our peer review site on the World Wide Web linked from http://www.ngdc.noaa.gov/seg/topo/globe.shtml. Future versions of GLOBE should be even more valuable, as they are expected to include:

- Additional improved elevation data
- Global bathymetric coverage
- Multiple indices (such as quasi-maximum and quasi-minimum elevations as well as representative values) where available
- Multiple source files and documentation designed so that the user may be able to develop custom DEMs
- Visualizations, such as NGDC provides for other DEMs that it distributes. (See Web sites http://www.ngdc.noaa.gov/seg/topo/state.html and http://www.ngdc.noaa.gov/mgg/image/images.html for examples.)

GLOBE has been creative in negotiating ways to release new DEMs to the public:

- The GLOBE project negotiated the first public release of the previously restricted Digital Terrain Elevation Data (DTED) from the Defense Mapping Agency (now the National Imagery and Mapping Agency). DTED Level 0 was initiated as a joint DMA/GLOBE design, and was contributed to NGDC for GLOBE.

- The GLOBE project negotiated development of non-copyright derivations from copyright DEMs. This has involved joint design of a DEM with lower horizontal and/or vertical resolution or a different datum or map projection than is subject to local copyright requirements or desires. The resultant DEM is still valuable as part of the GLOBE compilation.

- GLOBE has developed creative licensing agreements with sources of high-resolution data, allowing high-quality data that must be kept under copyright to still be accessible.

GLOBE cites sources of data, and can mention, when appropriate, that certain sources can directly supply higher quality data. We hope you will contact the GLOBE Secretariat about the benefit to yourselves (and the public) from contributing to the GLOBE data base. Please contact:

David Hastings, Secretary of GLOBE
National Oceanic and Atmospheric Administration
National Geophysical Data Center
325 Broadway
Boulder, Colorado 80303, U.S.A.

Tel: (+1-303) 497-6729
Fax: (+1-303) 497-6513
email: dah@ngdc.noaa.gov

Participants in the GLOBE Task Team are noted in Section 2.C and in Appendix A.

Note: The Web-based version of this documentation will receive more frequent updates than the printed version. Go to http://www.ngdc.noaa.gov/seg/topo/report/.

2. Introduction

2.A. What GLOBE Is

The Global Land One-kilometer Base Elevation (GLOBE) project is several things.

- **GLOBE is a data base.** It is a unique, global, digital elevation model (DEM) designed, openly peer-reviewed, implemented, and documented while being coordinated by a global consortium of scientists and organizations. During GLOBE's development, at least two global DEMs were developed by other groups supporting various objectives. However, GLOBE's objectives (as noted here) are broader than merely the development of the data base.

- **GLOBE is a file format.** GLOBE began with the conceptual opening of a two-dimensional thirty-arc-second (30") latitude-longitude digital data array, and the hope to populate it with both the Best Available Data (*B.A.D.*), and the Globally Only Open-Access Data (*G.O.O.D.*). The former could include copyright data that might be made available for distribution by GLOBE with minimal restrictions, while the latter could not contain any restricted data. Allowing for both options has enabled GLOBE, for example, to work with the Australian Surveying and Land Information Group to develop a DEM much better than could otherwise be included while respecting the intellectual property rights of the Australian government.

- **GLOBE is a data management philosophy.** GLOBE's original array actually was a nested grid that allowed multiple overlapping coverage at various grid spacings, but all in latitude-longitude projection. The design followed the raster data model of the Geographic Resources Analysis Support System (GRASS), a scientific geographic information system. This concept was used in NGDC's TerrainBase (Row and Hastings, 1994), which was a prototype of GLOBE at lower resolution. The concept proved stable throughout the 8 years of GLOBE's development.

- **GLOBE is a working environment.** GLOBE was never a source for funding DEM data creation. Rather, GLOBE was (and is) an *ad-hoc* group that meets to share information on data sources and development techniques. Semiannual to annual GLOBE meetings were attached to other assemblies to allow for synergy between GLOBE participants and other scientists. The simultaneous development of increased cooperation between agencies in several countries, and between certain military and civilian institutions, led to increased public access to a major military DEM. In addition, that climate led to an agreement for joint development of a dedicated Space Shuttle mission designed to create an almost-global DEM (between 60° North and South latitudes, the orbital coverage of the Space Shuttle). The currently funded U.S. Department of Defense/NASA Shuttle Radar Topography Mapper mission hopes to provide publicly-available 3 arc-second digital elevation data during 2001–2002.

2.B. A Brief History of GLOBE

GLOBE was initially spearheaded in 1990 by Gunter Schreier of the Deutsches Fernerkundungsdatenzentrum (DFD, the German Remote Sensing Data Center), part of the Deutsches Zentrum für Luft- und Raumfahrt (DLR, the German Aerospace Center). Schreier was interested in improved regional and global DEMs for satellite data processing. His goal was to create a diplomatic environment among:

- U.S. Geological Survey (USGS), which was experimenting with contour-to-grid conversions of Digital Chart of the World (DCW) hypsography to DEMs
- University College London (UCL), which was experimenting with several techniques of creating DEMs
- National Geophysical Data Center (NGDC), with its long-standing program of increased access to international and global digital terrain data
- Others who might be interested in such cooperation and data development

GLOBE began as an *ad-hoc* group, though Schreier hoped to affiliate GLOBE with the Committee on Earth Observation Satellites (CEOS) Working Group on Data (WGD, later largely reformed into the Working Group on Information Systems and Services, WGISS), and the International Geosphere-Biosphere Programme's (IGBP) Data and Information System (DIS). Formal affiliation with CEOS/WGD came in 1993. GLOBE is also an official project within Focus 1 of IGBP-DIS (http://www.cnrm.meteo.fr:8000/igbp/frame/activities/activity_13/index2.html).

GLOBE held meetings at DLR, USGS, and NGDC, and participated in meetings of the CEOS-WGD, the CEOS-WGISS, and the CEOS Working Group on Calibration and Validation. In addition, a Digital Elevation Model Science Working Group (DEM/SWG) formed later by NASA to support objectives of its Earth Observing System, had significant common interests with GLOBE participants and mission. The distribution of these meetings allowed various specialists in topography to share their expertise with the GLOBE Task Team (as CEOS-WGD named the group). Gunter Schreier was the first head (and only "officer") of the GLOBE Task Team.

The original concept opened an empty 30 arc-second latitude-longitude array, and began listing possible sources of DEMs that could populate that array. Initial plans were to encourage experiments by USGS to convert DCW hypsography to 30" grids, and to seek additional contributions of DEMs. NGDC's ETOPO5, or possibly its TerrainBase (then being conceived) would be over-sampled for use as filler wherever better data were not made available.

1992: DMA published DCW. Prototypes had been evaluated for several years prior to 1992, but this year marked the availability of DCW's full global coverage.

1993: Techniques for converting DCW were well underway by USGS with participation by UCL. UCL's J.-P. Muller determined that SPOT imagery, by nature of pricing and restrictions on the data, would not be feasible for GLOBE. Also in 1993, a change in Schreier's duties made it difficult for him to continue as Secretary of GLOBE; David Hastings of NGDC succeeded him in late 1993.

1994: Hastings was able to negotiate, in cooperation with Gerald Elphingstone and others at the Defense Mapping Agency (DMA), the design and development of a 30" DEM derived by DMA for contribution to GLOBE. This became the prototype for DTED Level 0, which is now available on the National Imagery and Mapping Agency's (NIMA, DMA's successor) Web site and on CD-ROM from NGDC. This became the single largest contribution to GLOBE by coverage area.

1995: The Geographical Survey Institute (GSI) of Japan created an unrestricted DEM for the international scientific community, contributing it to the GLOBE project. This became an example for some other sources of copyright DEMs to derive publicly releasable versions to the scientific community. The first contribution by DMA was released on CD-ROM by NGDC as GLOBE Prototype Version 0.1.

1996: The Australian Surveying and Land Information Group (AUSLIG) negotiated to have NGDC create a 30" DEM of Australia from AUSLIG source materials. This data set remains the property of AUSLIG, but is licensed to NGDC for distribution with GLOBE. AUSLIG also became a distributor of GLOBE by this agreement. Also in 1996, DTED Level 0 was placed on NIMA's Web site.

1997: Several DEMs were brought to the GLOBE project's attention. Several of these are still under consideration.

1998: GLOBE Version 1.0 neared completion.

1999: GLOBE Version 1.0 was completed and released. Work on updated releases are in progress.

2.C. Major Collaborators in GLOBE

The members of the GLOBE Task Team, with representative contributions, are summarized below, in time-sequential order. Acronyms are defined in Appendix B.

Before 1993:

DLR (Gunter Schreier and Achim Roth): initial coordinator (Schreier), design considerations, quality control

NOAA/NGDC (David Hastings and Paula Dunbar): later coordinator (Hastings); prototype construction in the form of NGDC's TerrainBase; DEM collection, creation, and conversion; coordinating GLOBE review, compilation, documentation, and access

UCL (Jan-Peter Muller): Design considerations, DCW conversion prototyping, quality control testing

USGS/EDC (Susan Jenson and Dean Gesch): DCW conversion, DEM collection and conversion, construction of USGS's GTOPO30

1993:

CEOS-WGD (via Gunter Schreier): design and distribution considerations

1994:

DMA (now NIMA; Gerald Elphingstone): developing publicly releasable DTED prototype, design considerations

GSI (Hiroshi Murakami, later Hiromichi Maruyama): DEM of Japan, quality control, digitizing

IGBP-DIS (John MacDonald): design and distribution considerations

1995:

JPL (Nevin Bryant): design and distribution considerations, development of MISR DEM

1996:

AUSLIG (Peter Holland): data from which to create a DEM of Australia

1997:

ISPRS Working Group IV/6 (Ryutaro Tateishi): design considerations

2.D. Contributions Invited for Future Enhancements to GLOBE

GLOBE remains an active project. Contributions are still valuable. If you have a DEM that could be appropriately formatted to 30" latitude-longitude projection, World Geodetic System-84 horizontal datum, and Mean Sea Level vertical datum, please contact the GLOBE Secretariat.

If your data are proprietary or copyright, we would still like to discuss cooperation with you. Several holders of proprietary or copyright data have found it useful to adapt their data for distribution with GLOBE (or the similarly designed TerrainBase). If your data are of higher resolution, for example, a 30" "sampler" in GLOBE, with proper source citation, could help bring attention to your data.

3. Citation of GLOBE and Copyright Information

3.A. Citation of GLOBE

The GLOBE data base should be cited as follows:

> GLOBE Task Team and others (Hastings, David A., Paula K. Dunbar, Gerald M. Elphingstone, Mark Bootz, Hiroshi Murakami, Hiroshi Maruyama, Hiroshi Masaharu, Peter Holland, John Payne, Nevin A. Bryant, Thomas L. Logan, J.-P. Muller, Gunter Schreier, and John S. MacDonald), eds., 1999. *The Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0.* National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80303, U.S.A. Digital data base on the World Wide Web (URL: http://www.ngdc.noaa.gov/seg/topo/globe.shtml) and CD-ROMs.

This documentation manual should be cited as follows:

> Hastings, David A., and Paula K. Dunbar, 1999. *Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Documentation, Volume 1.0.* Key to Geophysical Records Documentation (KGRD) 34. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80303, U.S.A.

Some other editorial efforts of the National Geophysical Data Center, such as the Global Ecosystems Database (NOAA and EPA, 1992) and TerrainBase (Row and Hastings, 1994), are edited as symposium volumes. In those efforts, individual constituents are treated as chapters in the symposium volumes, and are separately citable.

GLOBE is somewhat different. GLOBE contains a combination of data sets, derived from a different combination of sources, and reprocessed through a still different combination of lineages. Some sources are not fully cited. In addition, several processing methods are not fully cited. For example, Digital Terrain Elevation Data come from "best available sources," which are not cited, and are derived by methods which are also not cited. Thus, full citability of GLOBE components is not currently possible, and will not be possible until some sources of data for GLOBE are better documented. Our alternative for GLOBE is to cite the entire data set as above, and to cite individual parts of GLOBE by source and lineage, as described in Sections 5 and 11.E.

Each individual data set used in GLOBE may be cited separately, using the asterisked (*) citation for that data set (Sections 5.A.i through 5.A xi).

If you're planning to use GLOBE for research or development issues, please cite GLOBE in your bibliography as noted above. GLOBE is a peer-reviewed formal scientific publication. In addition, please read Sections 6 and 12 if you plan to develop anything from GLOBE, or plan to redistribute GLOBE (or any derivation of GLOBE).

3.B. Copyright and Redistribution Information

Though an improvement over previous global DEMs, GLOBE data are imperfect. See the caveats and disclaimers in Sections 6 and 12 of this document.

3.B.i. Copyright Information

For the most part, these data are not copyright, nor are they restricted in any way. This is true of all data files and information, except for selected data within the *B.A.D.* (*B*est *A*vailable *D*ata) data files. (See Section 11.A for the file-naming convention.) In GLOBE version 1.0 the only area with *B.A.D.* GLOBE coverage is Australia, with data copyright AUSLIG.

The documentation, source/lineage, and *G.O.O.D.* files (*G*lobally *O*nly *O*pen-access *D*ata) files are all unrestricted. (See Section 11.A for the file-naming convention.). However, these are scientific data, and should be cited accordingly. The citation of the full *G.O.O.D.* files should be made as noted in Section 3.A. If you want more detailed citation of geographic parts of GLOBE, you should refer to the source/lineage map, and its legend (given in Section 11.E).

3.B.ii. Redistribution Information

If you repackage and/or redistribute *G.O.O.D.* GLOBE files in any way, please be aware of the disclaimers in Section 12, and others throughout this document.

The copyright data in *B.A.D.* GLOBE files may not be repackaged or reproduced in any way without permission of the copyright holders. The distribution of copyright data (contained only in files with ???B pattern names) is shown in the source files with the ???T pattern names. Contact names and addresses are in Appendix A.

4. General Characteristics of GLOBE

The Global Land One-Kilometer Base Elevation (GLOBE) digital elevation model (DEM) is a global data set covering 180° West to 180° East longitude and 90° North to 90° South latitude. The horizontal grid spacing is 30 arc-seconds (0.008333... degrees) in latitude and longitude, resulting in dimensions of 21,600 rows and 43,200 columns. At the Equator, a degree of latitude is about 111 kilometers. GLOBE has 120 values per degree, giving GLOBE slightly better than 1 km gridding at the Equator, and progressively finer longitudinally toward the Poles (see Section 6.A).

The horizontal coordinate system is seconds of latitude and longitude referenced to World Geodetic System 84 (WGS84). The vertical units represent elevation in meters above Mean Sea Level. The elevation values range from -407 to 8,752 meters on land. In GLOBE Version 1.0, ocean areas have been masked as "no data" and have been assigned a value of -500.

Besides the GLOBE DEM, associated files include a source/lineage file. This source/lineage file provides a mask of ocean coverage (by using category 0 of the source/lineage file), so that the user may reassign the -500 flag values for ocean coverage to 0, then later re-separate those values from 0 values on land.

Due to the nature of the raster structure of the DEM, small islands in the ocean less than approximately 1 square kilometer (specifically, those that are not characterized by at least one 30" grid cell and/or do not have coastlines digitized into Digital Chart of the World or World Vector Shoreline) may not be represented.

Though an improvement over previous global DEMs, GLOBE data are imperfect. See the caveats and disclaimers contained in Sections 6 and 12 of this document.

5. Data Set Development

Six gridded DEMs, and five cartographic sources, were adapted for use in GLOBE. Several of these sources were processed in more than one way (sometimes involving several different organizations) to create 30" grids. This resulted in 18 combinations of source/lineage used in GLOBE.

The source materials are discussed immediately below, followed by discussions of regional quality control assessments and merges of the data. Thirty histograms showing distribution values for all source/lineage combinations are presented.

5.A. DEM Sources and Processing

GLOBE version 1.0 has 11 broad sources of information. Many of these sources themselves have multiple sources, such as different series of imagery, maps, cadastral surveys, etc. In addition, some of these 11 broad sources of information have been reprocessed in various ways, by various organizations, before being combined into GLOBE Version 1.0.

GLOBE is not monolithically uniform in its characteristics. In fact, no monolithically uniform DEM of any great coverage area has yet been demonstrated to the GLOBE Task Team.

GLOBE cites data sources by original source and subsequent lineage. The importance of this for data stewardship is apparent.

Besides DTED Levels 1–5, distributed only by NIMA, and DTED Level 0, distributed via NIMA's Web site and on CD-ROM by NGDC, several other data sets developed from DTED or its precursors are distributed by other organizations. For example:

- The USGS's 3 arc-second DEMs for the conterminous United States and Alaska are actually an embryonic version of DTED that was transferred to USGS in the 1970s for public distribution.
- Similarly, some 30" and 5' DEMs distributed by NGDC since the early 1980s were derived by DMA and contributed to NGDC for public distribution.
- Subsequently, many DTED cells for the same area have been updated, beyond the versions originally contributed to USGS and NGDC.
- USGS used some of its 3" data in its GTOPO30 compilation that contributed significantly to GLOBE Version 1.0.
- Data from the NGDC version was added to GLOBE, as appropriate.

We thus prefer to cite the full lineage of the data in GLOBE documentation, including source and intermediate steps in the lineage of the data.

When citation of original source plus subsequent lineage is done, the contribution of the National Imagery and Mapping Agency and its predecessors (via DTED, Digital Chart of the World, and their derivatives) is noteworthy. A preponderance of the data began at this source. In addition, several previously copyright DEMs have been adapted for inclusion on an unrestricted or highly open basis. Also, GLOBE borrowed procedures, and in some cases data, from previous global DEM efforts, listed in Appendix A. The GLOBE project is indebted to these initiatives.

Various combinations of data source and lineage have resulted in subtle differences in georegistration and the actual type of elevation values used in different parts of GLOBE. The decisions that led to these differences were often based on scientific/technical analyses by diverse teams of data producers. However, some decisions may appear arbitrary to the user of GLOBE data. Considering the wide variety of possible influences on a DEM, the variety of georeferencing and sampling techniques incorporated into GLOBE is far from its greatest possible source of error.

Table 1. Percentage of the Global Land Surface Derived from Each Source

Source	% of global 30" grid cells	appx. % of global area	number of 30" grid cells
Oceanic coverage	66.8	71.1	623,579,513
Land coverage	33.1	29.9	309,525,237
Source	**% of non-oceanic 30" grid cells**	**appx. % of land area**	**number of 30" grid cells**
Digital Terrain Elevation Data*	46.6	57.5	144,162,669
Digital Chart of the World	16.5	22.6	51,368,537
Australian DEM**	3.2	5.2	10,031,254
Antarctic Digital Database	28.1	8.3	86,945,078
Brazil 1:1,000,000-scale maps	2.0	3.5	6,027,490
DEM for Greenland	2.6	1.0	7,344,478
AMS 1:1,000,000-scale maps	0.67	1.1	2,088,224
DEM for Japan	0.18	0.26	556,763
DEM for Italy	0.16	0.21	490,585
DEM for New Zealand	0.14	0.18	419,894
Peru 1:1,000,000-scale map	0.03	0.05	90,625

*This line shows percentages of GLOBE derived from DTED sources, by all intermediate steps used. This includes DTED Level 0, and other 30" derivations from DTED and its prototypes distributed by the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey.

**There are two versions of GLOBE. One version is completely unrestricted, and uses a DEM developed from Digital Chart of the World (DCW). Another version contains a licensed DEM from the Australian Surveying and Land Information Group. The figure given for Australia covers the area of that country/continent. If you are using the version of GLOBE that incorporates the DCW-based DEM for Australia, the total percentage of global land area with DCW source combines this line with the line above, for a total of 27.7% of the global land surface, 19.6% of non-oceanic 30" grid cells, and 60,666,875 total 30" grid cells. The unrestricted (G.O.O.D.) version of GLOBE has slightly less land area than the best available (B.A.D.) version of GLOBE in Australia. Table 1 shows the B.A.D. version.

Note that in source/lineage category 13, the blend between categories 12 and 14 contains 1,435,022 grid cells. Half this number (717,511 grid cells) has been assigned *each* to categories 12 (JPL model for Greenland) and 14 (DCW). This is because Table 1 treats *sources,* and the blending process used to make category 13 is dominated by category 12 in half its area, and by category 14 in the other half of its area.

5.A.i. Digital Terrain Elevation Data (DTED)

Primary Developer:	National Imagery and Mapping Agency (NIMA, formerly Defense Mapping Agency (DMA); prior to DMA, the Army Map Service).
Title:	Digital Terrain Elevation Data Levels 1 and 0
Publication Dates:	Regular releases since the 1960s
Bibliographic Citations:**	National Imagery and Mapping Agency, 1996. *Digital Terrain Elevation Data Level 0.* National Imagery and Mapping Agency, Fairfax, Virginia. (Partly *in* GLOBE Task Team and others, 1999.) National Imagery and Mapping Agency, various dates. *Digital Terrain Elevation Data Level 1* and derivations (*in* USGS, ed., 1997, and partly *in* GLOBE Task Team and others, 1999).
Post-processing:	Defense Mapping Agency (versions described below contributed to U.S. Geological Survey and National Geophysical Data Center), U.S. Geological Survey (for GTOPO30), and NOAA/National Geophysical Data Center (for GLOBE). DTED Level 0 is the outcome of joint GLOBE/DMA design and DMA/NIMA implementation. Its prototype was contributed directly to the GLOBE project, as was a copy of DTED Level 0.
Bibliographic Citation * for Post-processed DEMs:	NIMA, USGS, and NGDC, 1997. *30"-gridded DEM from DTED, Precursors, and Derivatives.* National Geophysical Data Center, Boulder, Colorado (*in* GLOBE Task Team and others, 1999).
Source/Lineage Categories:	1–7

* Primary reference citation for all data from this source
** Primary reference citation for DTED Level 0

DTED is a raster topographic data base provided by NIMA and its predecessors: (1) between 1 July 1972 and 30 September 1996 by the DMA, (2) between September 1968 and June 1972 by the U.S. Army Topographic Command (USATC), and (3) before September 1968 by the Army Map Service (AMS), which was formed in May 1942. The earliest digital antecedents to DTED were developed in the 1950s by AMS.

DTED was used as the source for most of Eurasia and large parts of Africa and the Americas.

DTED Level 0, a new NIMA data base, is the result of a joint GLOBE/DMA initiative, which resulted in the joint design and DMA production (just before DMA was reorganized into NIMA) of DTED Level 0.

5.A.i.a. Source Characteristics

DTED Level 1 is produced in 3 arc-second gridding, on a latitude-longitude projection. DTED Level 1 data files have the following characteristics:

- They cover 1° by 1° of latitude-longitude, and are called "DTED cells."
- DTED files have their origin in the southwestern corner of the DTED cell. The grid cell registration is centered on that corner. Thus the first 3" DTED grid cell in the file continuing north from 40°N latitude and east from 40°E longitude would be centered at exactly that location.
- Grid cell sequencing begins at the southwestern corner (the origin of the file just noted), then continues upwards (column-wise) to the northwestern corner. Successive eastward columns are presented. The final value in the file is the value of the northeastern corner.
- DTED files have 1201 columns by 1201 rows, overlapping at their edge columns and rows with neighboring DTED cells.

DTED Level 1 data are created from a variety of "best-available" sources. These may be:

- cartographic: maps containing elevation contours and/or point values created by national, local, or non-U.S. agencies, or by NIMA itself or its predecessors
- imagery: aerial photography or satellite imagery, from U.S. or non-U.S. sources
- other possible sources such as Global Positioning Survey measurements or satellite altimetry

Sources are not publicly cited. However, certain characteristics of resultant DEMs help interpret general source characteristics. For example, analysis of shaded-relief images digitally derived from DEMs often detect blockiness, striping, or other patterns symptomatic of various data development techniques. Some of these are discussed below, and explicitly illustrated on the GLOBE Web site's public Beta Test area (linked to the GLOBE Home Page at http://www.ngdc.noaa.gov/seg/topo/globe.shtml).

Common artifacts in DTED Level 1 data include:

- Vertical offsets between many 1° by 1° DTED files. These may be seen as vertically offset blocks in shaded-relief or slope maps derived from the data. These offsets may be caused by discontinuities in cartographic source materials, such as topographic contour lines that fail to match across map boundaries. They may also be caused by inadequately documented geodetic models, such as incorrect or missing information on projection or datum. Edge "feathering" as an attempt to provide continuity between 1° by 1° DTED cells also contributed artifacts of its own.
- Directional biases in resolution. These may be seen as striped patterns in shaded-relief, slope,

or aspect maps derived from such data. Such anisotropies in DEMs may be caused by stereoprofiling techniques (often involving oversampling between stereoprofiles to make the final grid). These techniques were sometimes used to create DEMs from analog stereoscopic imagery or undeterminable satellite source sensor characteristics.

The artifacts are common to other DEMs derived by similar techniques from similar sources.

Prototype correction techniques have been developed at the Jet Propulsion Laboratory, Pasadena, California. Presentations at GLOBE Task Team meetings (Nevin Bryant, California Institute of Technology, 1995, verbal communication; see also Ritter and Bryant, 1997) have demonstrated the contribution that such techniques might make toward rectifying some artifacts in DTED. However, in the absence of a more substantial study, the GLOBE Task Team decided not to attempt such repairs for GLOBE Version 1.0.

Between 50° North and South latitudes, DTED Level 1 data are 3x3 arc-second grids. Outside these latitudes the longitudinal gridding gets coarser:

latitude range (N & S)	seconds of latitude	seconds of longitude
0°–50°	3	3
50°–70°	3	6
70°–75°	3	9
75°–80°	3	12
80°–90°	3	18

Stated accuracy objectives are within 50m horizontal (at 90% circular error; twice the standard deviation), and 30m vertical (at 90% linear error; two sigma). However, areas lacking source materials that meet these standards may still have DTED created for them, if adequate alternatives are not envisaged.

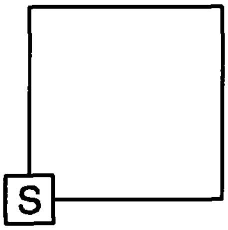
DTED seeks to use World Geodetic System 84 (WGS84) for horizontal reference, and Mean Sea Level as vertical reference. However, this may not always be the case as cartographic sources may not be completely or accurately described, and materials from such sources may not be accurately converted to WGS84 and Mean Sea Level.

5.A.i.b. Derivation of the 30" DEM from Source Materials

In 1994, NGDC and DMA jointly designed a 30" DEM which DMA would contribute to NGDC for GLOBE. In the original design, a 10x10 array of 3" DTED Level 1 grid cells was processed to determine the minimum, maximum, and mean of 3" values in each available 30" GLOBE grid cell. The data were restructured at NGDC for more convenient processing in raster geographic information systems (GIS), and released to the public as GLOBE Prototype Version 0.1 in 1995.

NIMA added a discrete (spot) 3" value to the data collection. This compilation is available at NIMA's

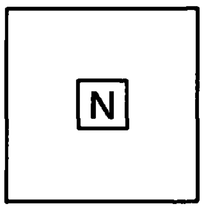
Web site (http://www.nima.mil) at the time of writing this document, and also on CD-ROM from NGDC as GLOBE Prototype Version 0.5. The latter version has the files restructured for greater ease of use in a GIS.



Southwestern corner 3" value assigned to 30" grid cell.

Graphic describing georeferencing and sampling for DTED Level 0 discrete (spot) data (source/lineage category 1).

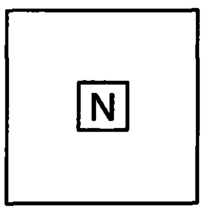
In addition, DMA had contributed coverage for most of the United States from an early precursor of DTED to USGS for public distribution. USGS calls these data "USGS 3 arc-second data." USGS resampled these data to 30" by nearest-neighbor techniques, for incorporation into GTOPO30. These data form GLOBE 1.0 source/lineage category 5.



Cell-centered registration, nearest-neighbor 3" value used.

Graphic describing georeferencing and sampling for DMA/USGS 3 arc-second data to 30" for the U.S.A. (source/lineage category 5).

Similarly, DMA provided 30" grids for the conterminous U.S. (from an early version of DTED) for public distribution by NGDC in the early 1980s. This 30" DEM included mean and spot (nearest-neighbor from 3") values. The spot data form GLOBE 1.0 source/lineage category 4.

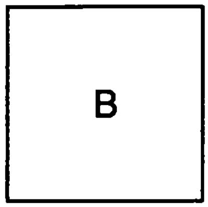


Cell-centered registration, nearest-neighbor 3" value used.

Graphic describing georeferencing and sampling for DMA/USGS 30" spot data for the conterminous U.S.A. and vicinity (source/lineage category 4).

As noted previously, USGS developed a 30" global DEM, called GTOPO30. GTOPO30 development involved specific groups assembling data for the different continents. Decisions made by these groups resulted in the following resampling methods:

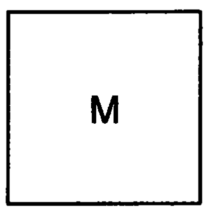
- For Africa (the first continent attempted), the resampling of 3" data used a "breakline" approach that favored ridges and valleys (Gesch and Larson, 1996). This was done to best fit with the ANUDEM-based methods (Hutchinson, 1989, 1996; Danielson, 1996) used for Digital Chart of the World gridding for Africa. *(See next page for graphic.)*



Cell-centered registration, breakline value computed.

Graphic describing georeferencing and sampling for DTED for Africa (source/lineage category 6).

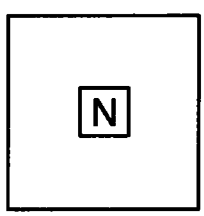
- For Eurasia, the resampling consisted of computing median values of non-oceanic locations within each 30" arc-second grid cell.



Cell-centered registration, 10x10 median value computed.

Graphic describing georeferencing and sampling for DTED for Eurasia (source/lineage category 2).

- For the Americas, the resampling consisted of taking a ("nearest-neighbor") 3" value nearest the center of each respective 30" grid cell. Due to the georeferencing of the 30" GLOBE grid compared to that of 3" DTED Level 1 data, there is a 3" DTED Level 1 grid cell-centered directly at the center of a 30" GLOBE cell. That value was used in the Americas.



Cell-centered registration, nearest-neighbor 3" value used.

Graphic describing georeferencing and sampling for DTED for the Americas (source/lineage category 3).

- The DEMs for Eurasia and Africa were mosaicked along 39°N latitude, and 59°E longitude. The data were linearly blended along a 2-degree-wide zone centered along these lines. Thus at 40°N, median derivations were used, at 38°N (west of 58°E) breakline methods were used exclusively, and at 39°N (west of 59°E) 50% weighting of both of these methods was used. This blending is category 7 in the source/lineage map.

Thus, data originally from DTED sources have been contributed to GLOBE directly from NIMA. In addition, data were previously contributed by DMA for public distribution to USGS and NGDC at various times during the past 20 years. The source/lineage map (on the back cover of this publication) shows where different versions of these data were used in GLOBE Version 1.0.

5.A.i.c. Extracts from Prototype NIMA Documentation of DTED Level 0

The following text is from NIMA's provisional description of DTED Level 0 (http://www.nima.mil/geospatial/products/DTED/dted.html) at the time of release of DTED Level 0:

> "In support of military applications, the National Imagery and Mapping Agency (NIMA) has developed a standard digital dataset (Digital Terrain Elevation Data (DTED) Level 0) which may be of value to scientific, technical, and other communities. This DTED product is a uniform matrix of terrain elevation values which provides basic quantitative data for systems and applications that require terrain elevation, slope, and/or surface roughness information. DTED Level 0 elevation post spacing is 30 arc-second (nominally one kilometer). In addition to this discrete elevation file, a separate binary file provides the minimum, maximum, and mean elevation values computed in 30 arc-second square areas (organized by one degree cell). Finally, DTED Level 0 contains the NIMA Digital Mean Elevation Data . . . providing minimum, maximum, and mean elevation values and standard deviation for each 15 minute by 15 minute area in a one degree cell. This initial prototype release is a "thinned" data file extracted from the NIMA DTED Level 1 holdings in combination with other publicly releasable data. As such, this version of DTED Level 0 is a step toward a worldwide digital terrain dataset. Efforts to fully populate a worldwide DTED Level 0 dataset continue . . . The current DTED Level 0 and subsequent releases will be updated consistent with established NIMA production maintenance procedures.
>
> Support from select international mapping organizations was instrumental in the generation of the Level 0 dataset. The following nations have contributed data to this effort: Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, and the United Kingdom. In many cases, higher resolution terrain data of the above listed nations is available for public sale. If you are interested in obtaining such data over any of the above listed countries, please contact the civil mapping authorities of the individual nation directly.
>
> This data set may be freely copied, manipulated, adapted or combined with other geospatial information as desired by the user. It allows a gross representation of the Earth's surface for general modeling and assessment activities. Such reduced resolution data is not intended and should not be used for automated flight guidance or other precision activity involving the safety of the public.
>
> The data contained in DTED Level 0 is a derivative set only, and does not represent the entire Department of Defense (DOD) archive of terrain data. In making this data available to the general public, the NIMA in no way alters the controlled status of the remaining archives. Technical support or general assistance with respect to DTED Level 0 is available only to U.S. Government users. The NIMA requests that products developed using DTED Level 0 credit the source with the following statement, 'This product was developed using DTED Level 0, a product of the National Imagery and Mapping Agency.'"

5.A.i.d. Characteristics of 30" DEMs from DTED

Analysis of Histograms: Histograms showing distribution of values for all source/lineage combinations are presented in this Section (Section 5) on data set development. Some histograms are presented with two linear axes, while others have logarithmic vertical axes (ordinates). The abscissa (horizontal axis) values are meters of elevation. The ordinate (vertical axis) values are normalized to percentages by source/lineage for an individual elevation value (in meters).

Plate 1 shows the overall distribution of elevation values in GLOBE. It is shown here for comparison with Plates 2 through 30, which show distributions of elevation values for individual parts of GLOBE. Plate 1 is discussed in Section 5.B.ii.

The NIMA discrete (spot) data encompass about forty percent of GLOBE Version 1.0. In order to initiate discussions on the major components of GLOBE, this analysis dissects the NIMA discrete data into regions:

- **Africa/Europe:** Plate 2 covers DTED discrete data for 40°S to 60°N latitude and 18°W to 60°E longitude. There is a relatively linear decline (on the semi-logarithmic plot) between about 1100m and 4000m. There is a broad, low, peak about 1000–1100m (much of Africa is high plains of this altitude), several small spikes, and an apparently large spike at -400m. This spike is an artifact of the semi-logarithmic plot, and involves less than 200 square kilometers around the Dead Sea. The largest spike in this region occurs at -28m, corresponding

[text continues on page 34]

Plate 1. GLOBE Version 1.0 DEM

Source/Lineage Categories 1 through 18

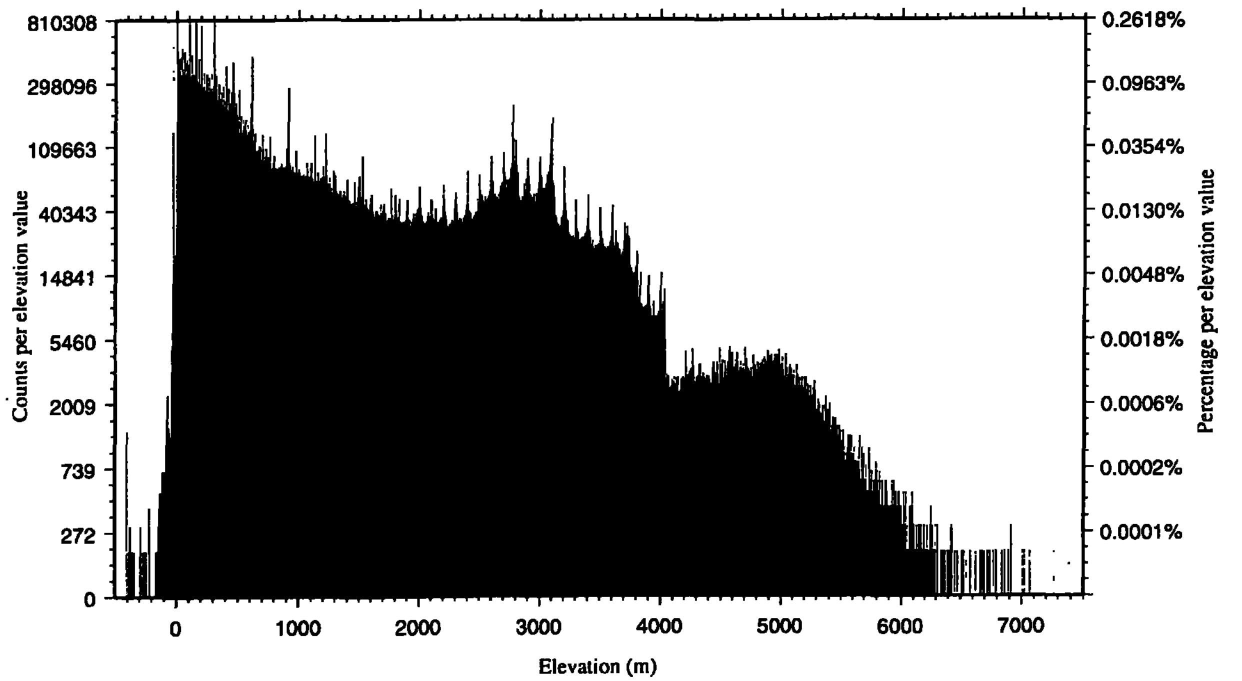


Plate 2. DTED Discrete DEM: Parts of Africa and Europe (semi-logarithmic plot)

Part of Source/Lineage Category 1

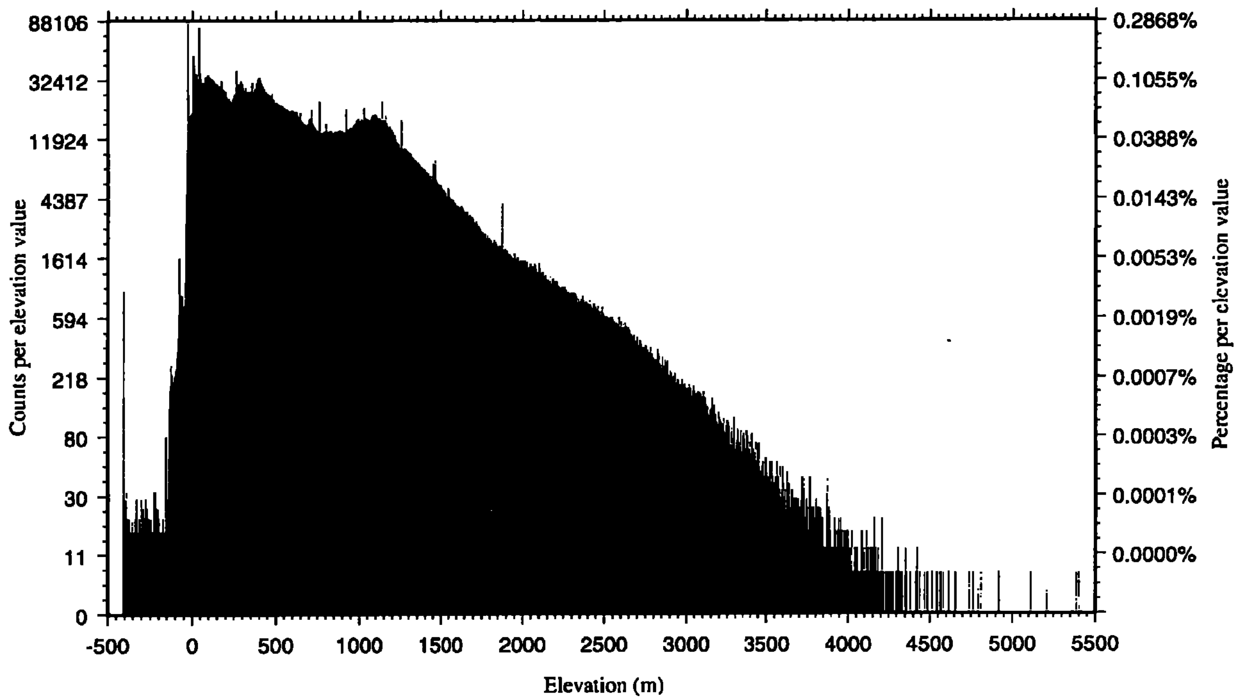


Plate 3. DTED Discrete DEM: Parts of Asia (semi-logarithmic plot)

Part of Source/Lineage Category 1

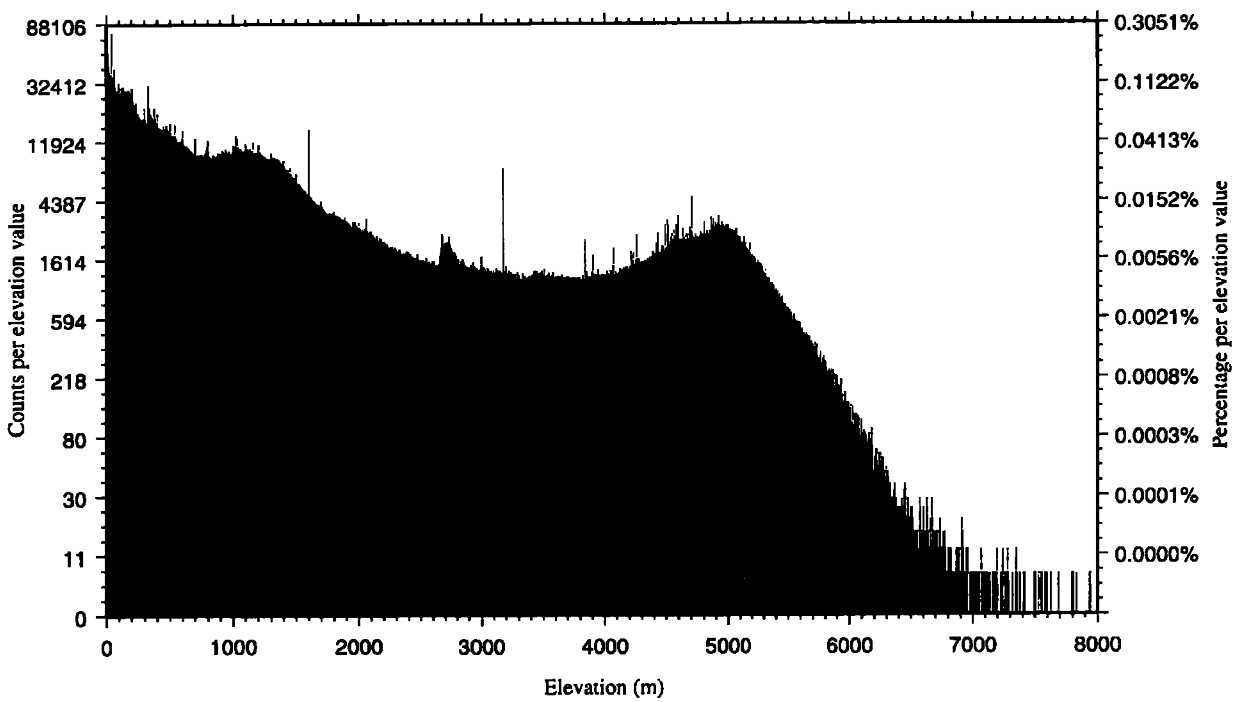


Plate 4. DTED Discrete DEM: Parts of North America (semi-logarithmic plot)

Part of Source/Lineage Category 1

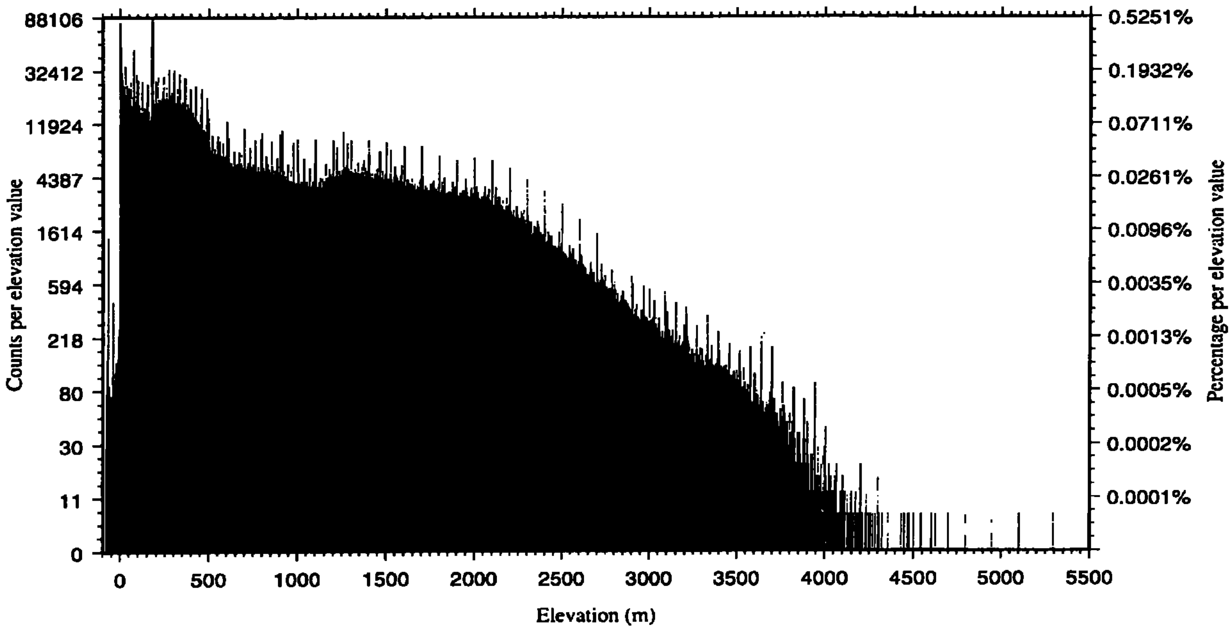


Plate 5. DTED Discrete DEM: Parts of South America (semi-logarithmic plot)

Part of Source/Lineage Category 1

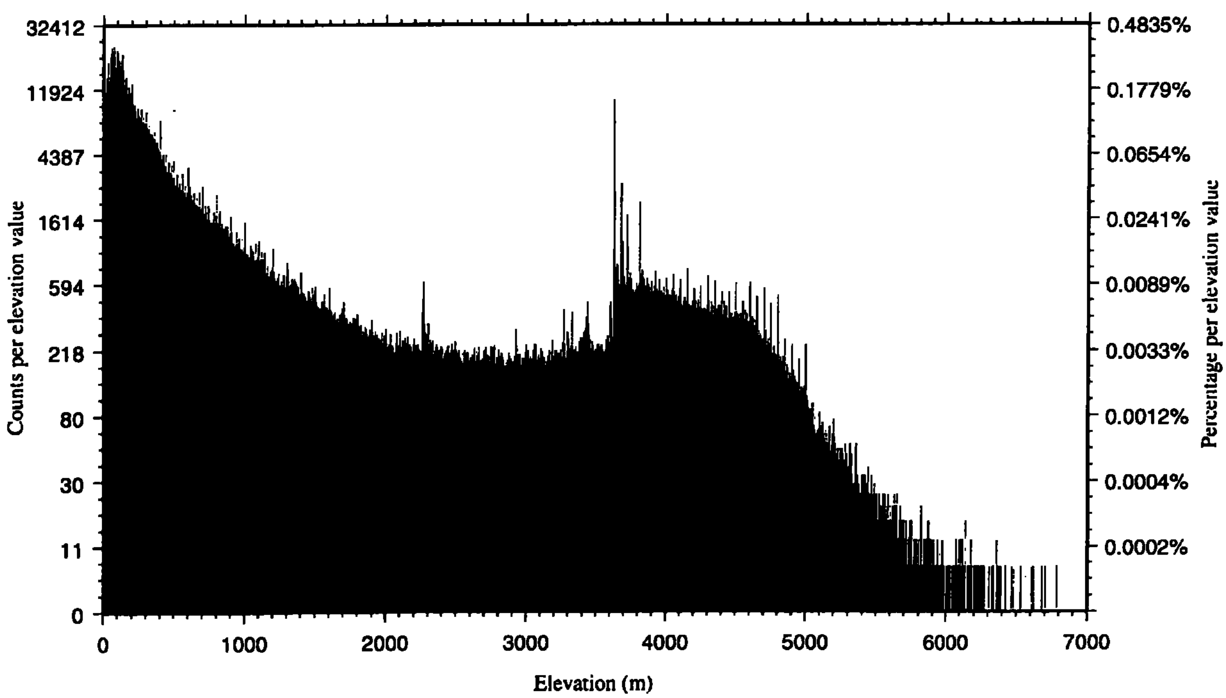


Plate 6. DTED Median DEM: Parts of Eurasia (semi-logarithmic plot)

Source/Lineage Category 2

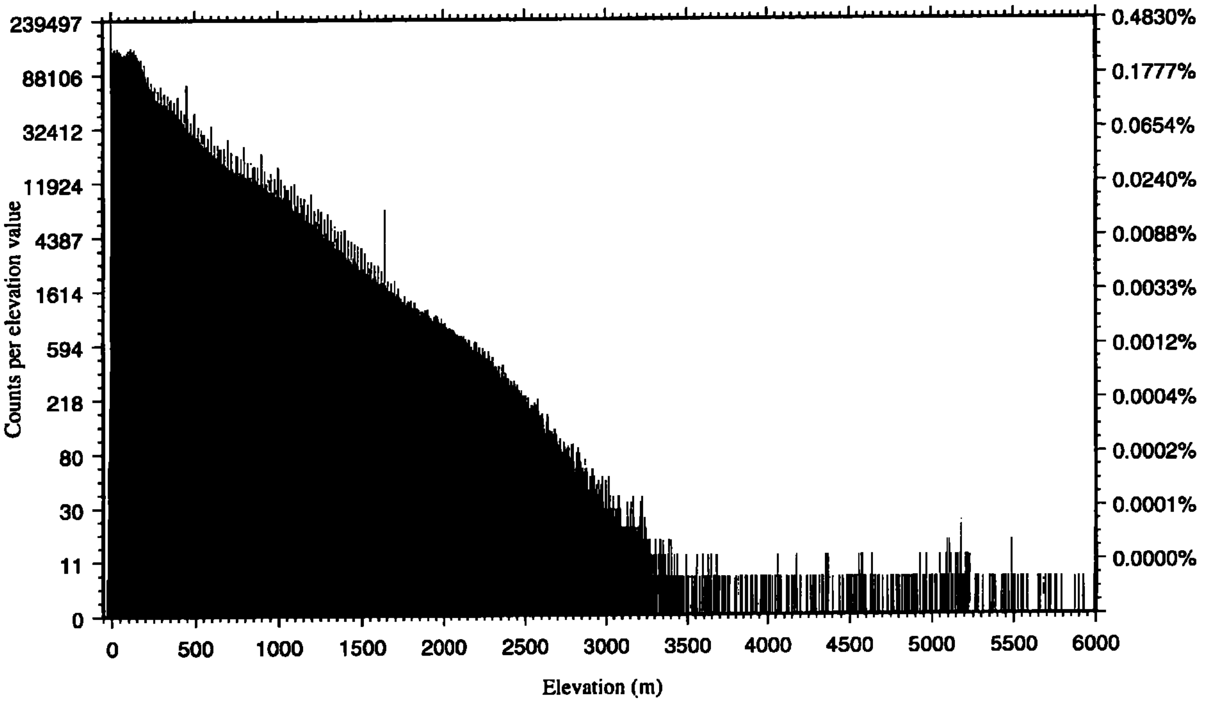


Plate 7. DTED Nearest Neighbor DEM: Parts of the Americas (semi-logarithmic plot)

Source/Lineage Category 3

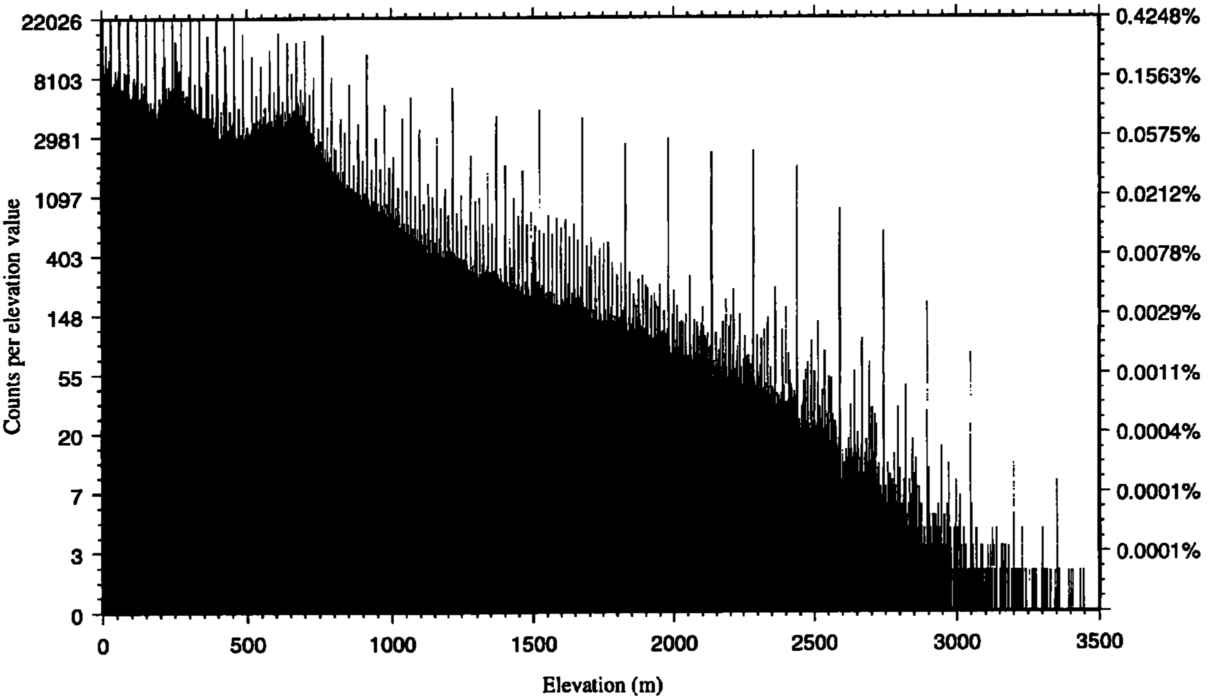


Plate 8. DTED Breakline DEM: Parts of Africa/Asia/Europe (linear plot)

Source/Lineage Category 6

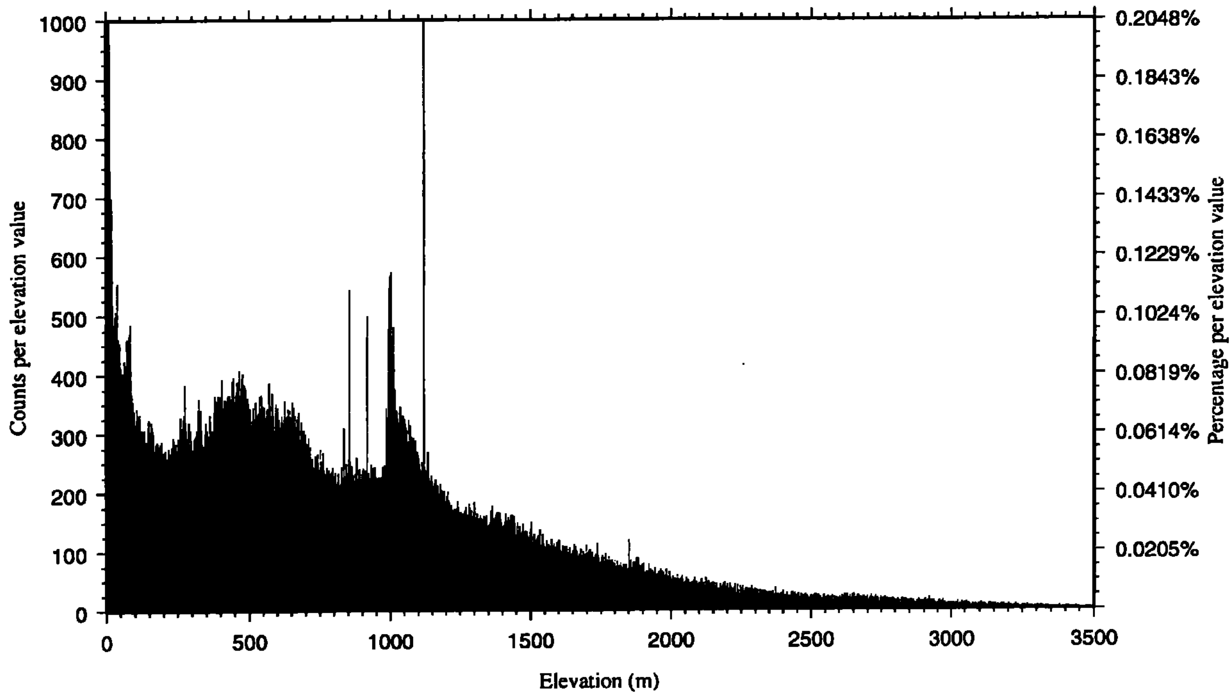


Plate 9. Blend of DTED Breakline and Median DEMs: Parts of Turkey (linear plot)

Source/Lineage Category 7

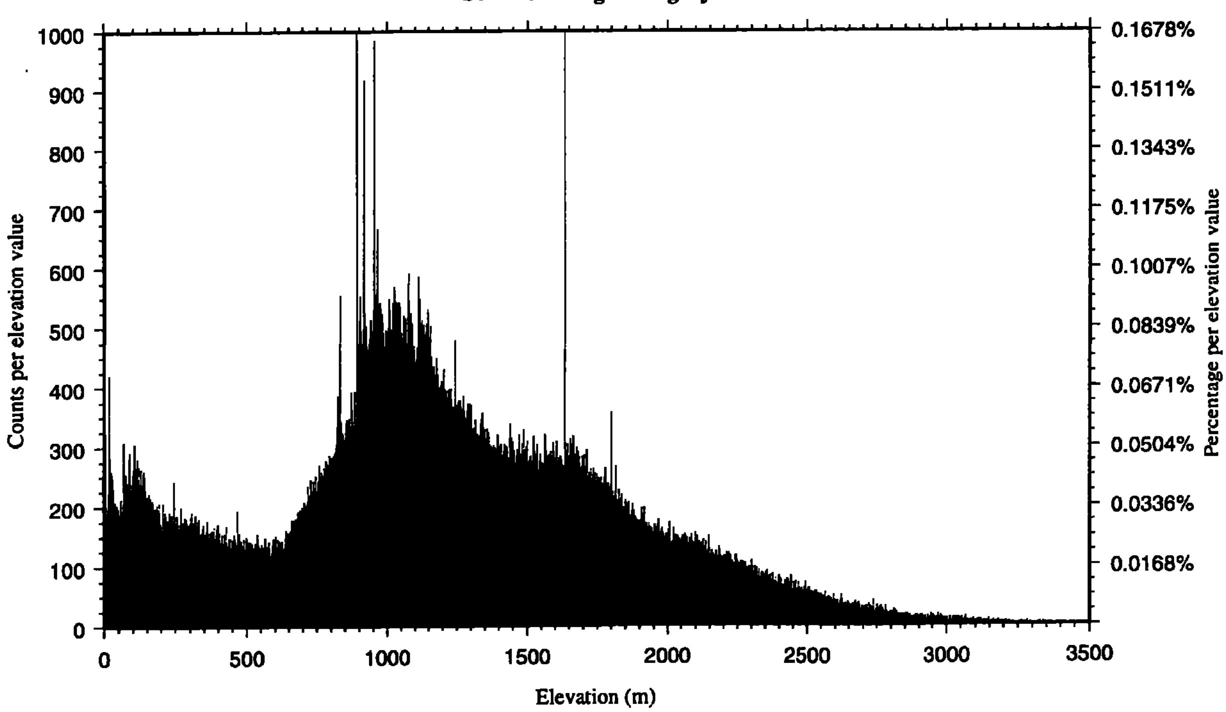


Plate 10. DTED/NGDC DEM: Parts of North America (linear plot)

Source/Lineage Category 4

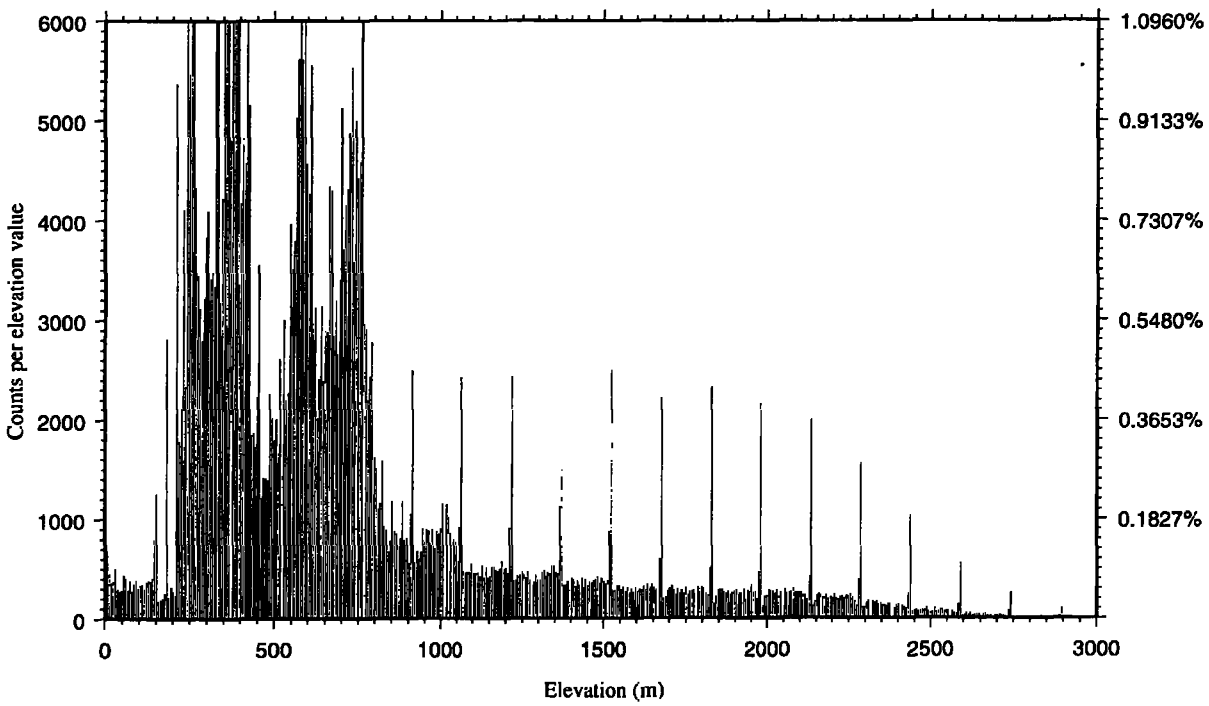


Plate 11. DMA/USGS DEM: Parts of North America (semi-logarithmic plot)

Source/Lineage Category 5

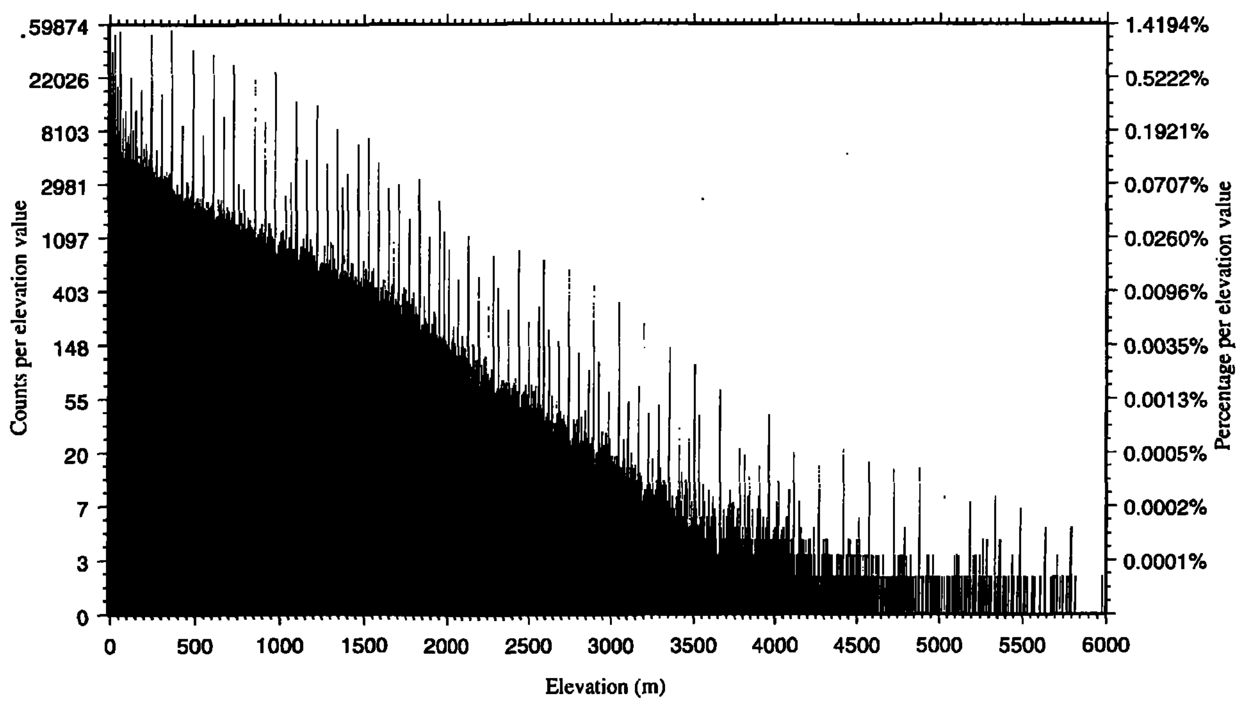


Plate 12. AUSLIG/NGDC DEM: Australia (semi-logarithmic plot)

Source/Lineage Category 8

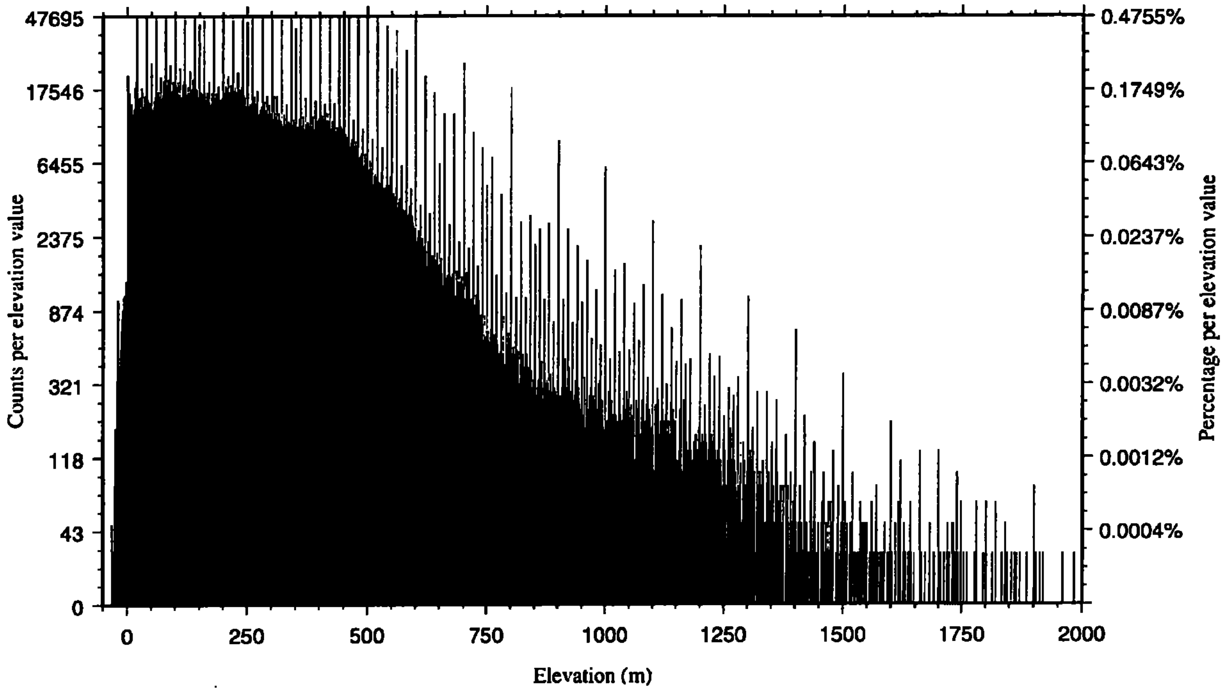


Plate 13. DCW-based DEM: Australia (semi-logarithmic plot)

Part of Source/Lineage Category 14

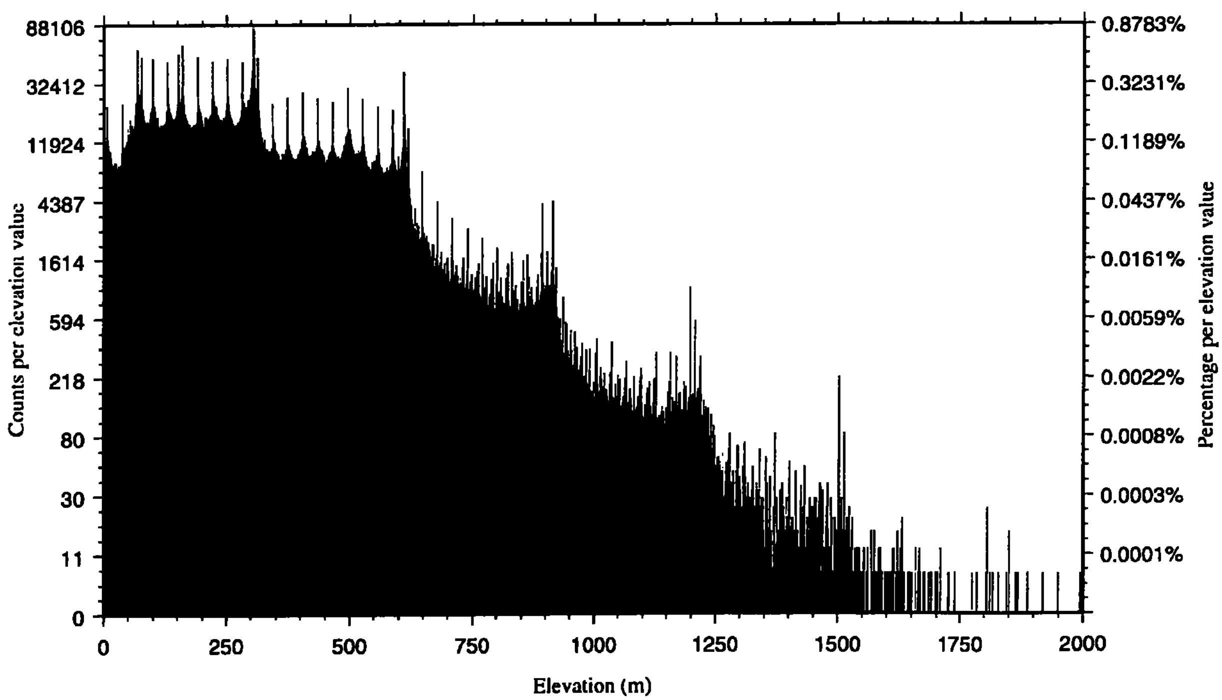


Plate 14. GSI DEM: Japan (linear plot)

Source/Lineage Category 9

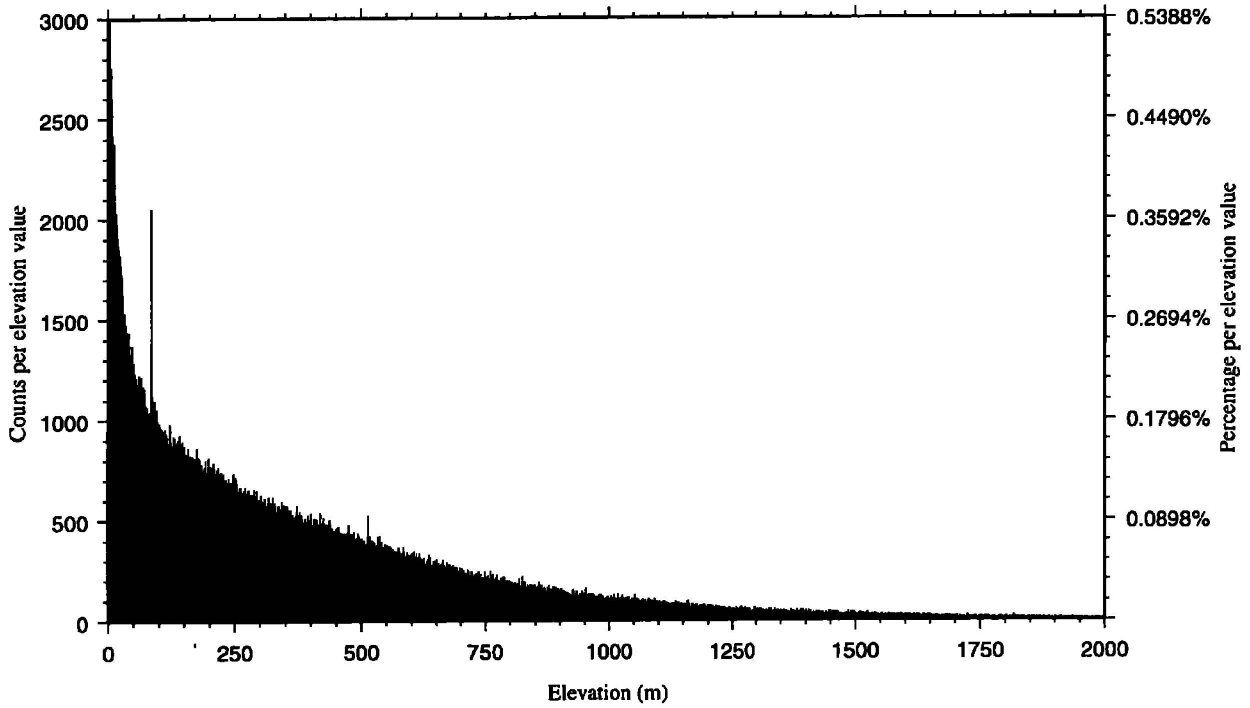


Plate 15. GSI DEM: Japan (semi-logarithmic plot)

Source/Lineage Category 9

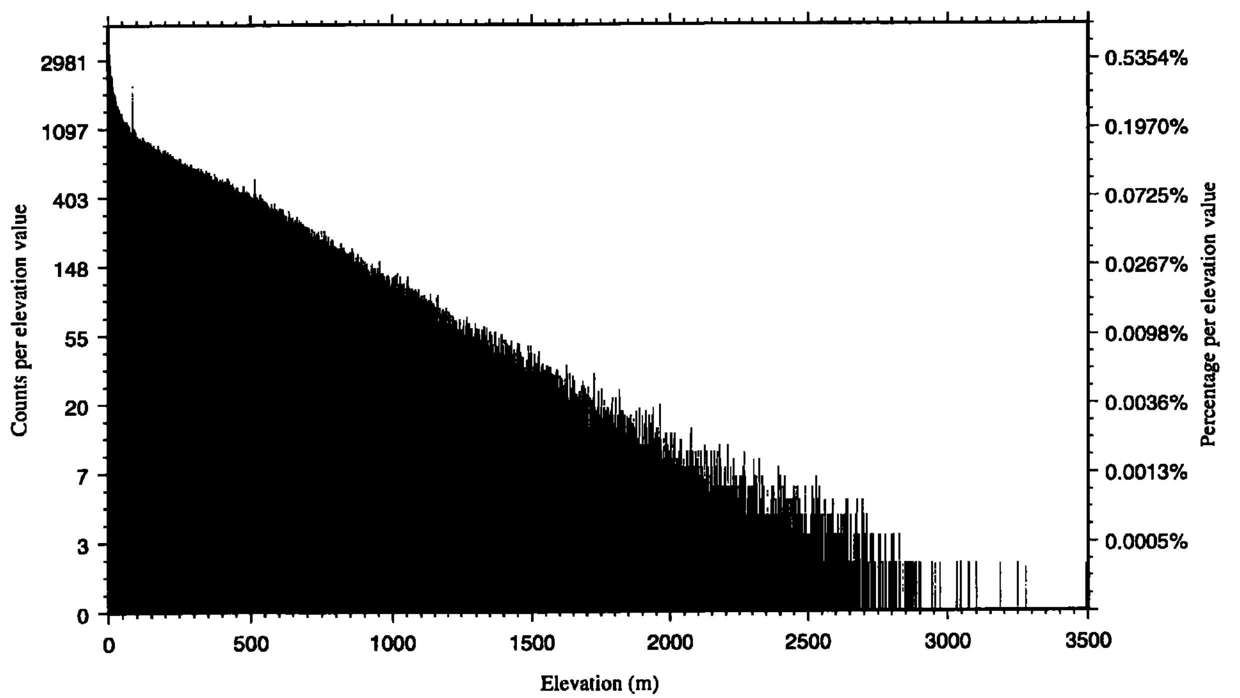


Plate 16. SGN/NGDC DEM: Italy (linear plot)

Source/Lineage Category 10

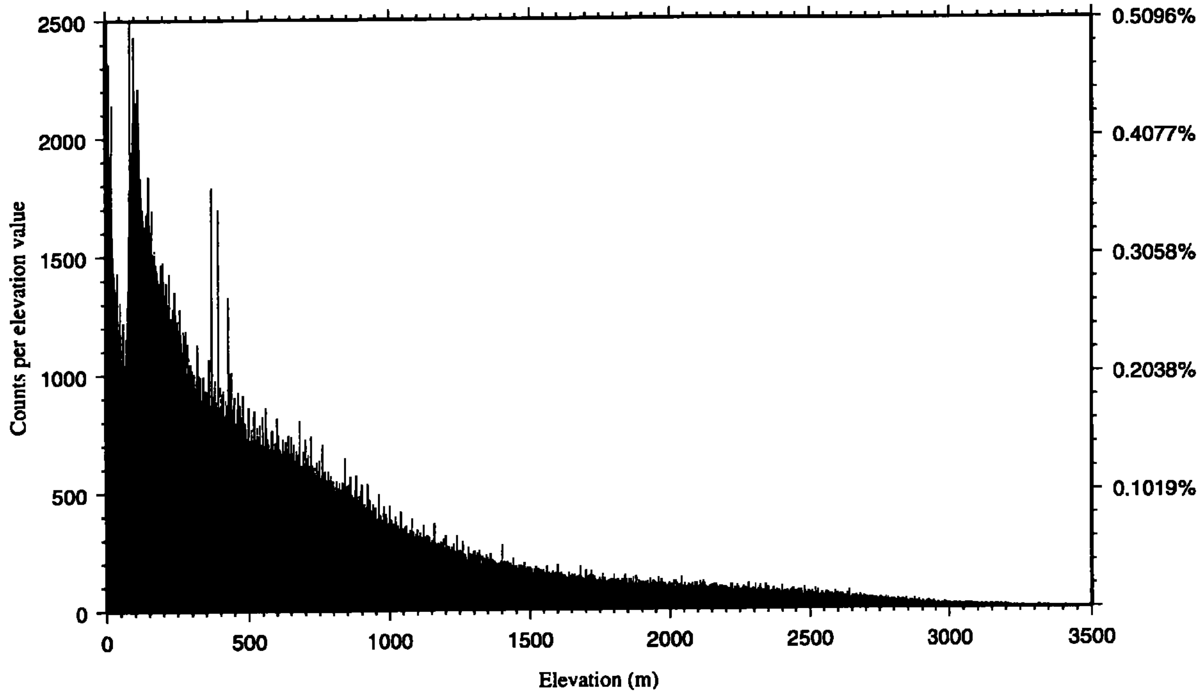


Plate 17. SGN/NGDC DEM: Italy (semi-logarithmic plot)

Source/Lineage Category 10

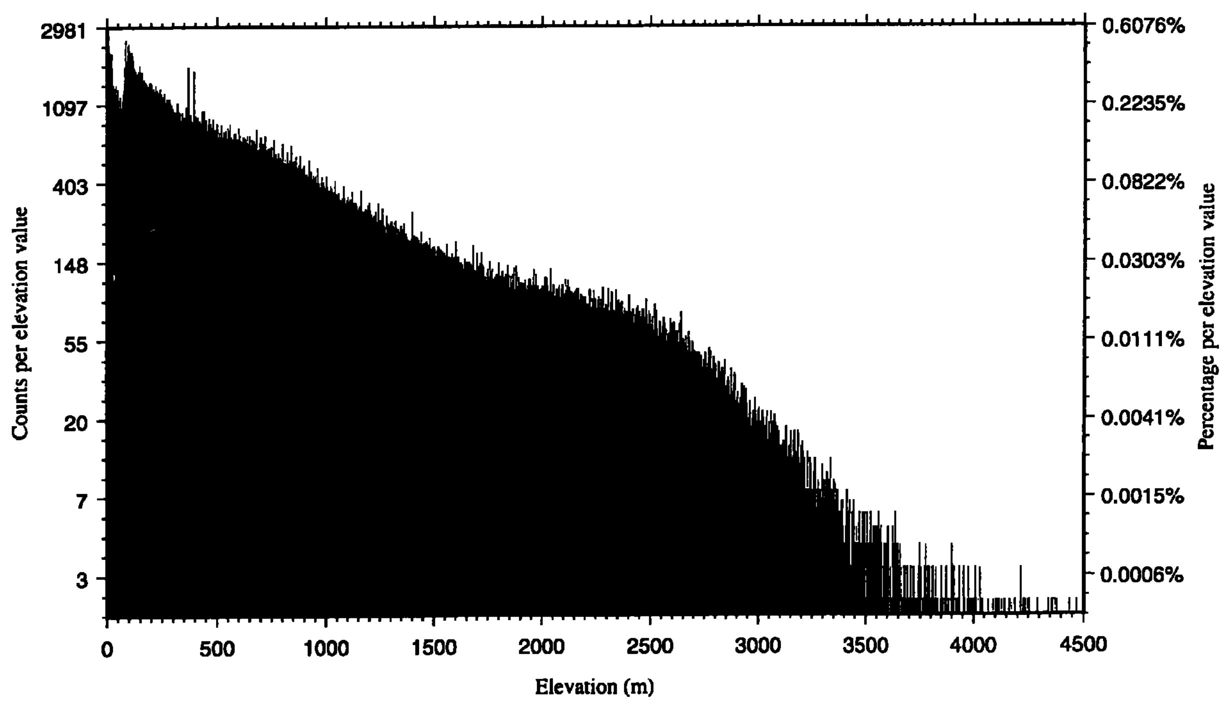


Plate 18. LCR DEM: New Zealand (linear plot)

Source/Lineage Category 11

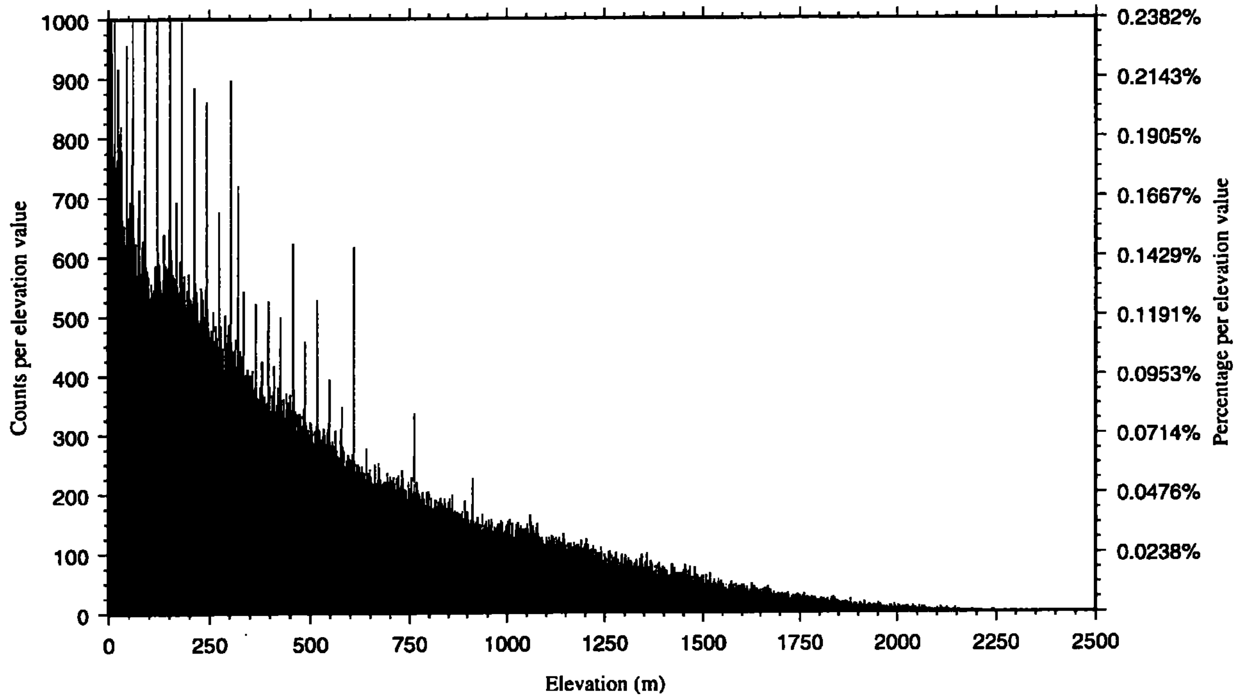


Plate 19. LCR DEM: New Zealand (semi-logarithmic plot)

Source/Lineage Category 11

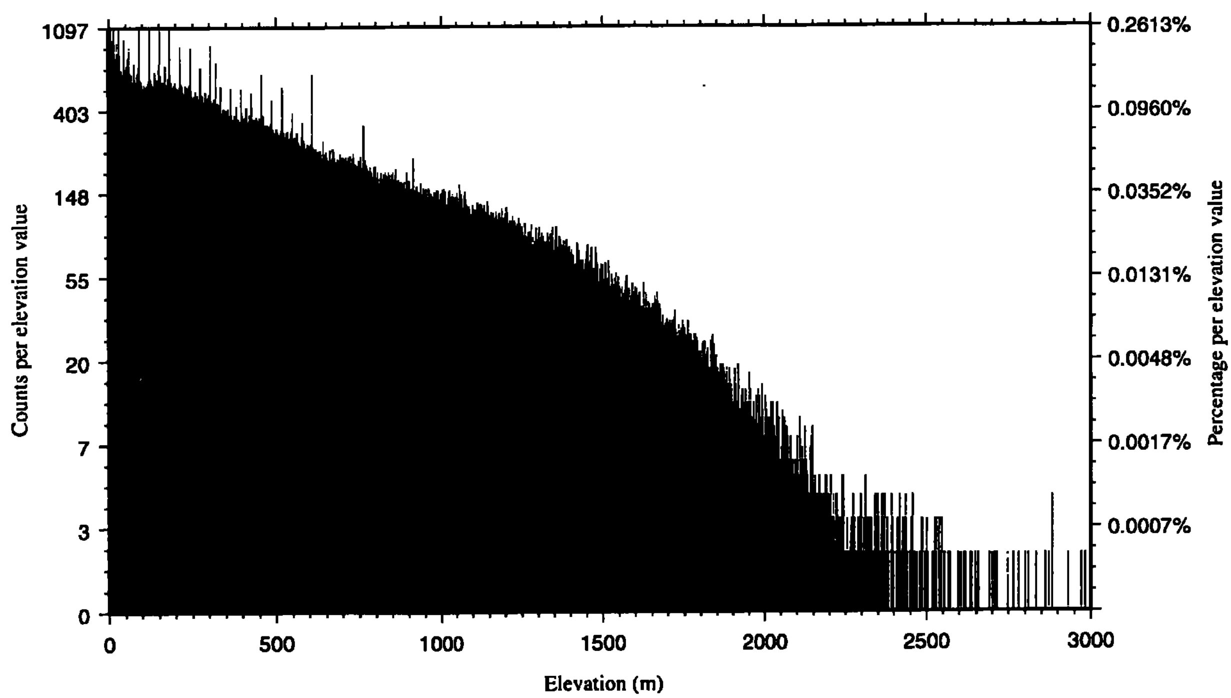


Plate 20. Zwally and others/NSIDC/JPL DEM: Parts of Greenland (linear plot)

Source/Lineage Category 12

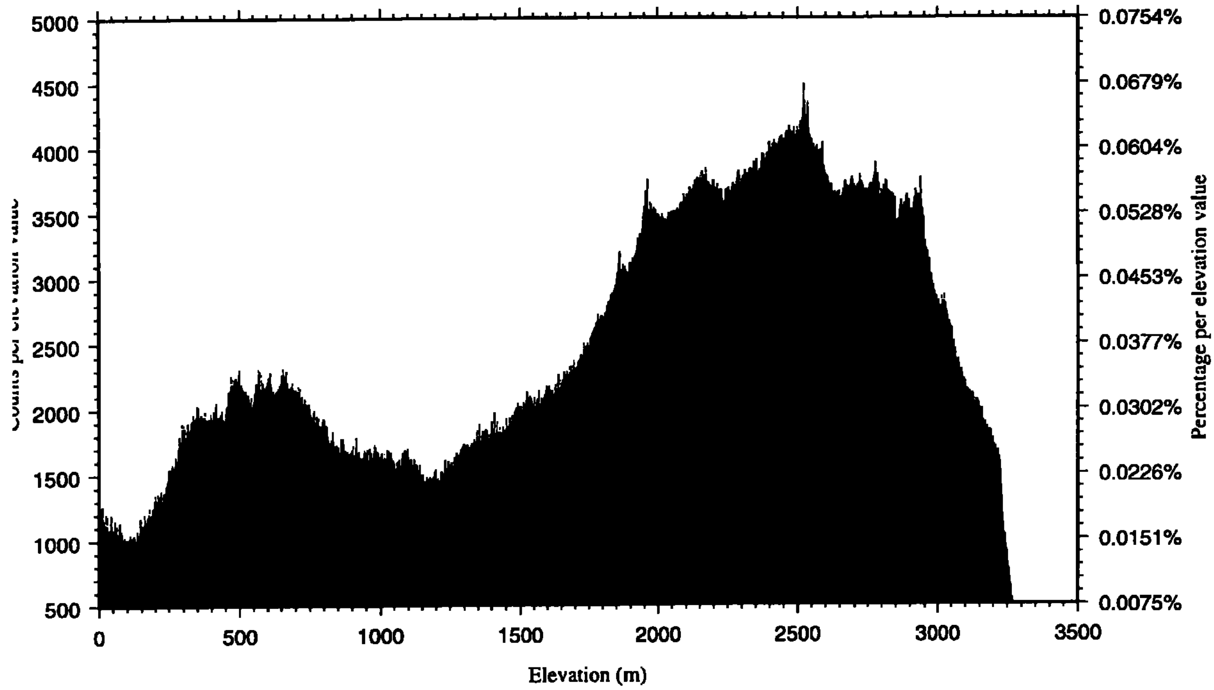


Plate 21. DEM Blend Zone in Greenland (linear plot)

Source/Lineage Category 13

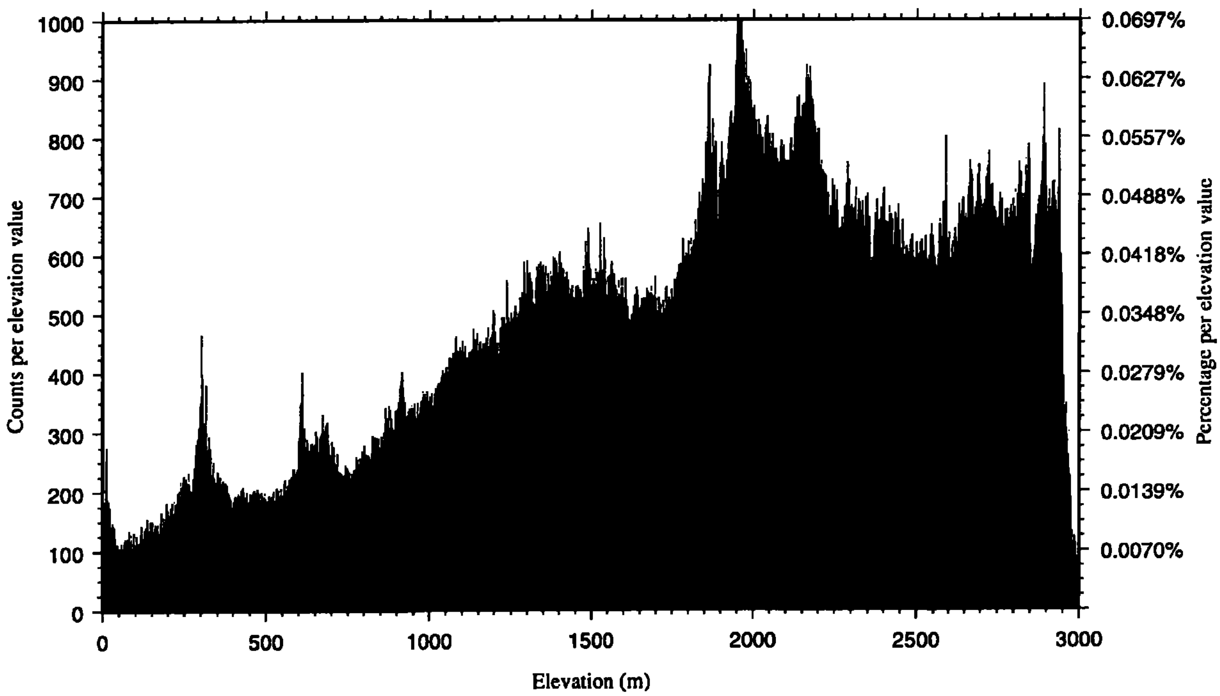


Plate 22. DCW-based DEM: Parts of Africa and Europe (semi-logarithmic plot)

Part of Source/Lineage Category 14

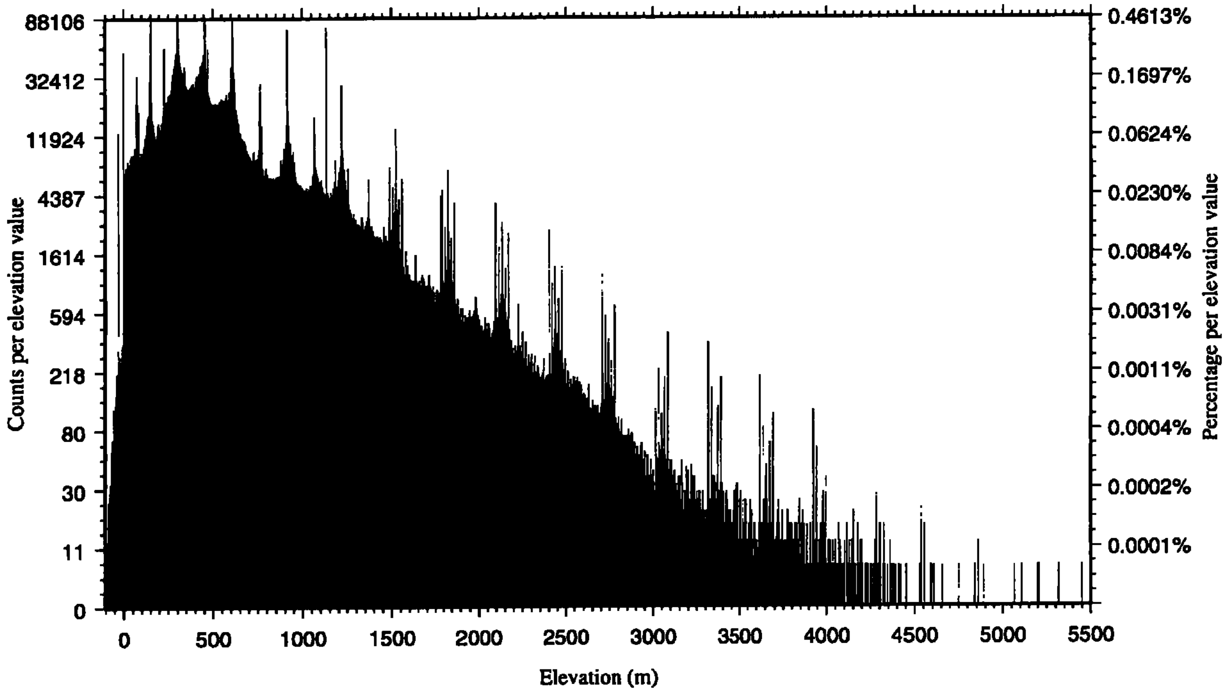


Plate 23. DCW-based DEM: Parts of Asia (semi-logarithmic plot)

Part of Source/Lineage Category 14

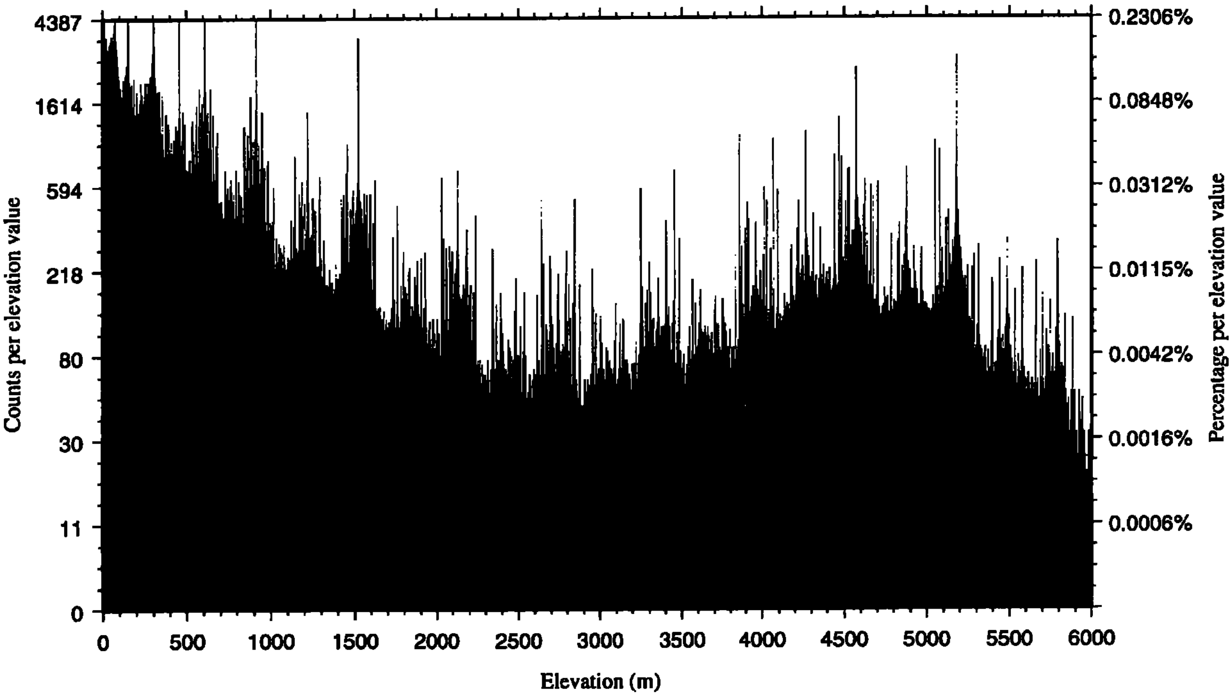


Plate 24. DCW-based DEM: Parts of North America (semi-logarithmic plot)

Part of Source/Lineage Category 14

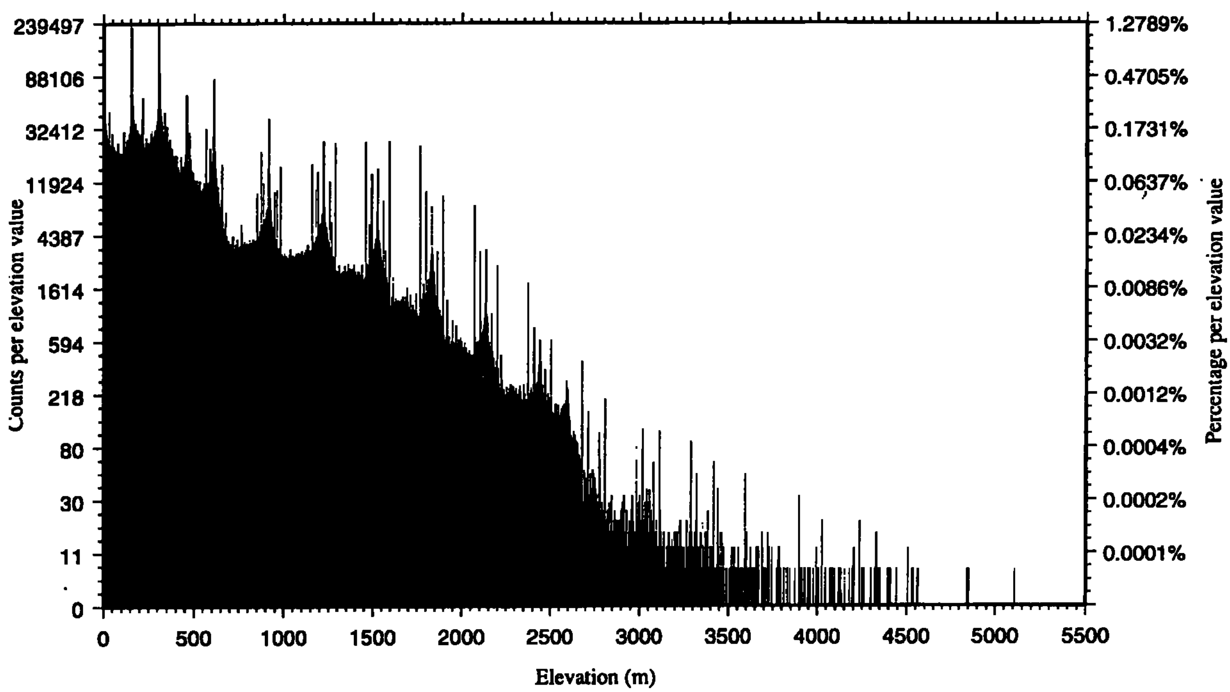


Plate 25. DCW-based DEM: Parts of South America (semi-logarithmic plot)

Part of Source/Lineage Category 14

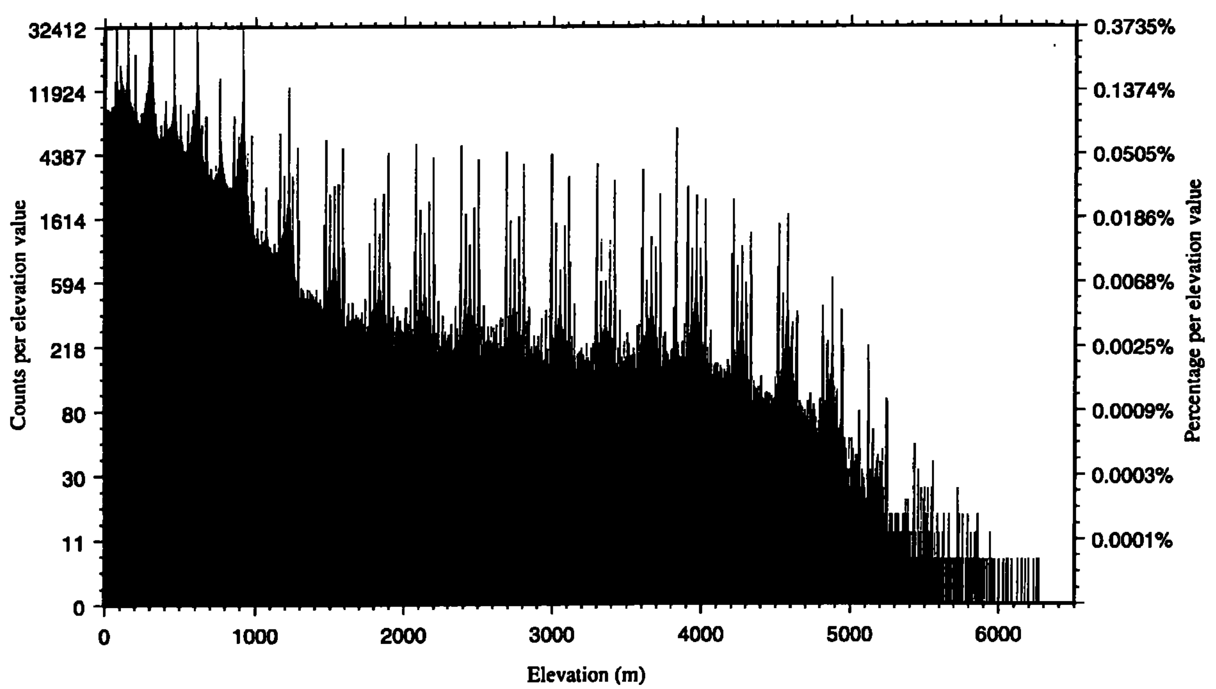


Plate 26. DEM Derived from AMS Maps: Parts of South America (linear plot)

Part of Source/Lineage Category 15

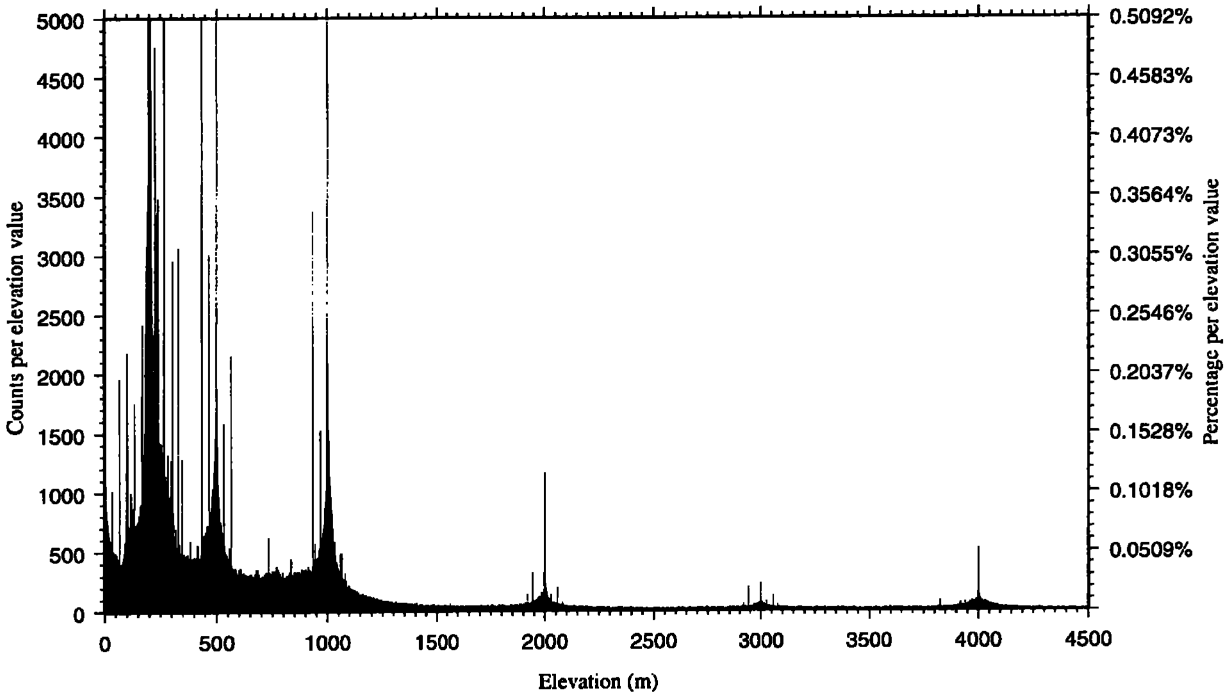


Plate 27. DEM Derived from AMS Maps: Parts of Southeast Asia (linear plot)

Part of Source/Lineage Category 15

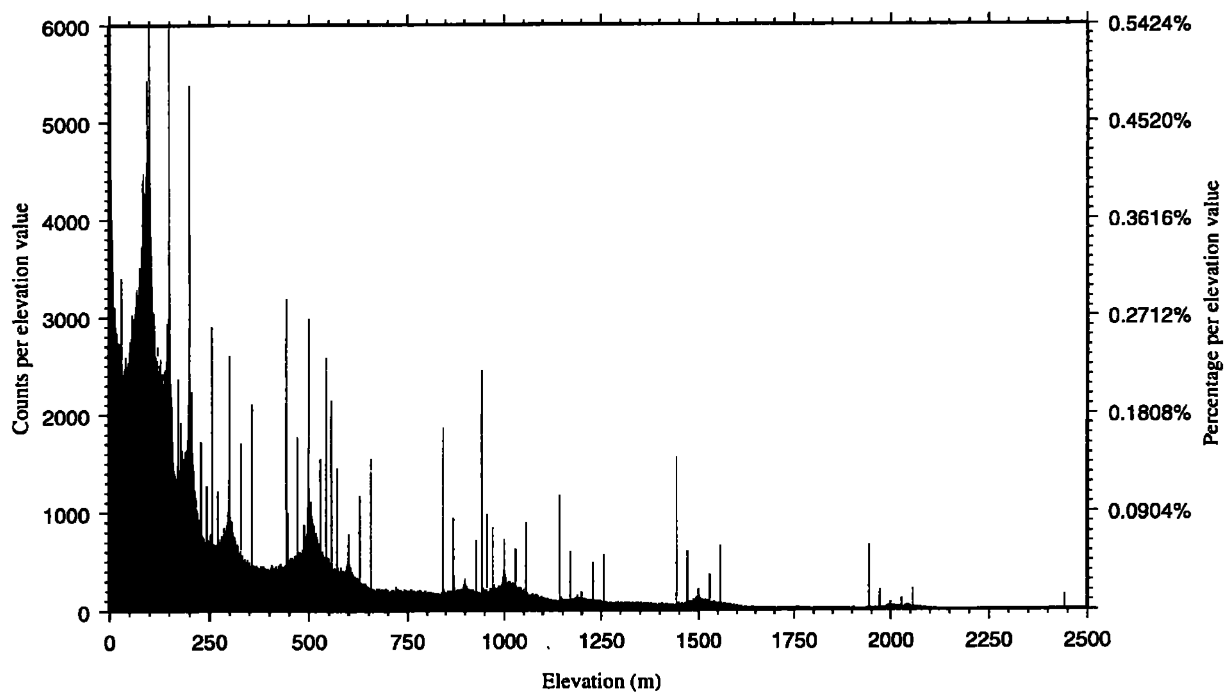


Plate 28. DEM Derived from Maps: Part of Brazil (semi-logarithmic plot)

Source/Lineage Category 16

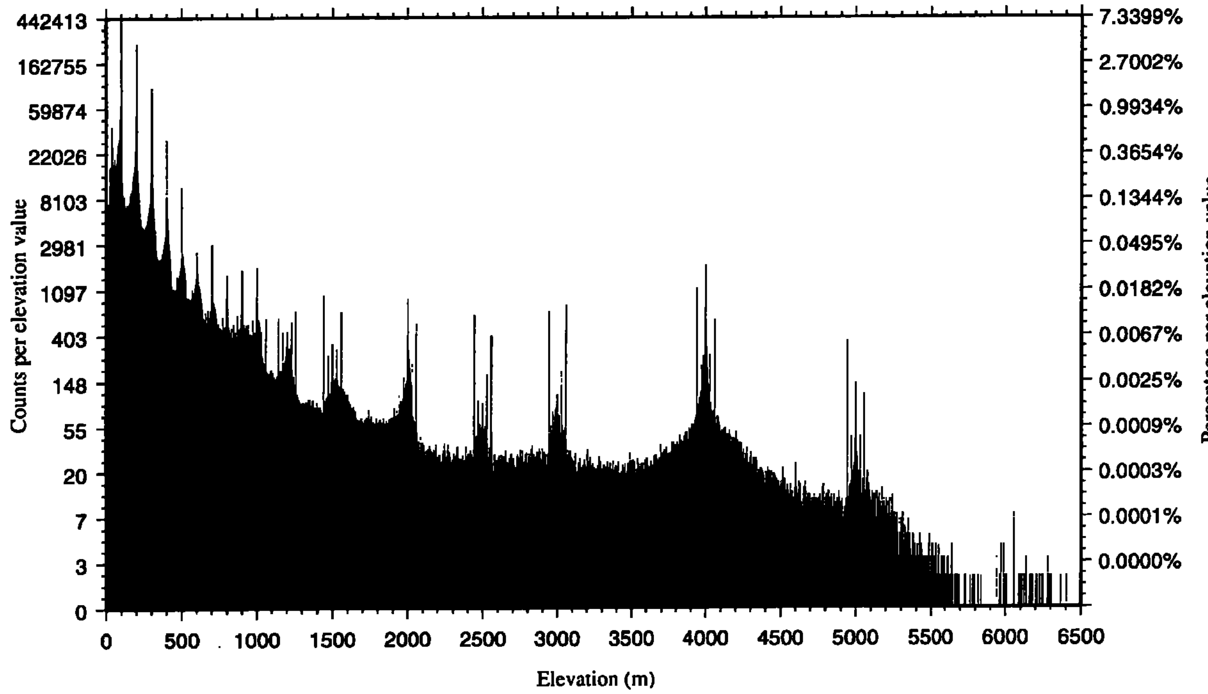


Plate 29. DEM Based on Maps: Part of Peru (linear plot)

Source/Lineage Category 17

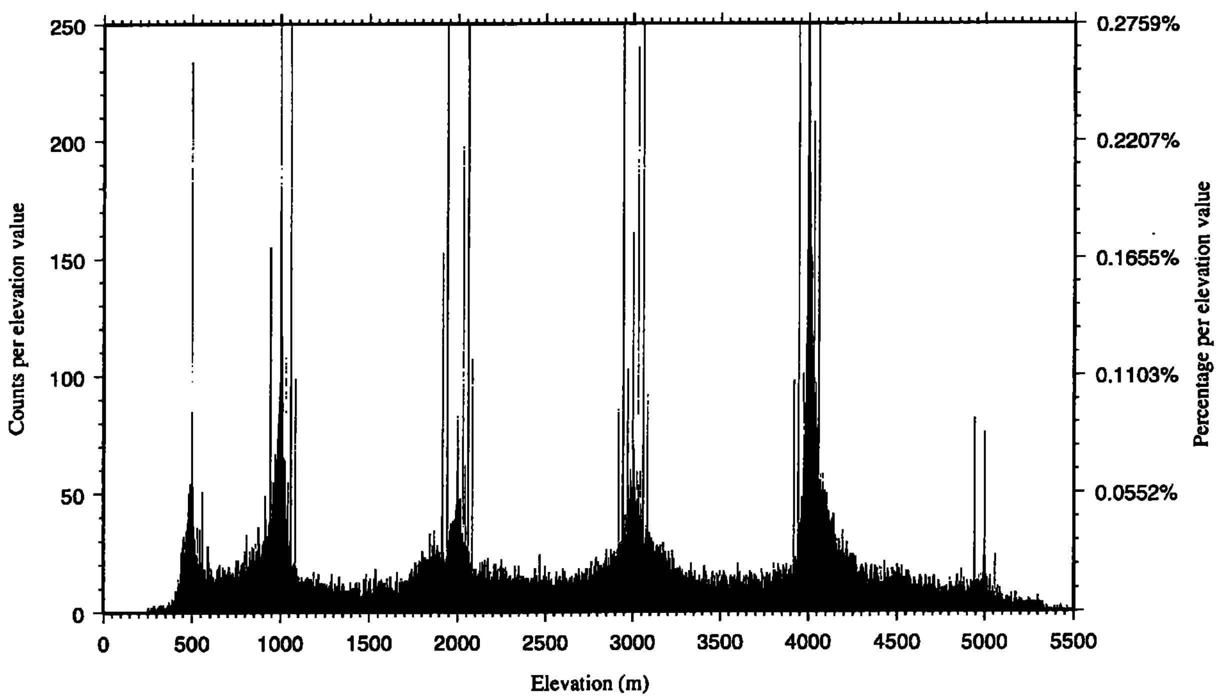
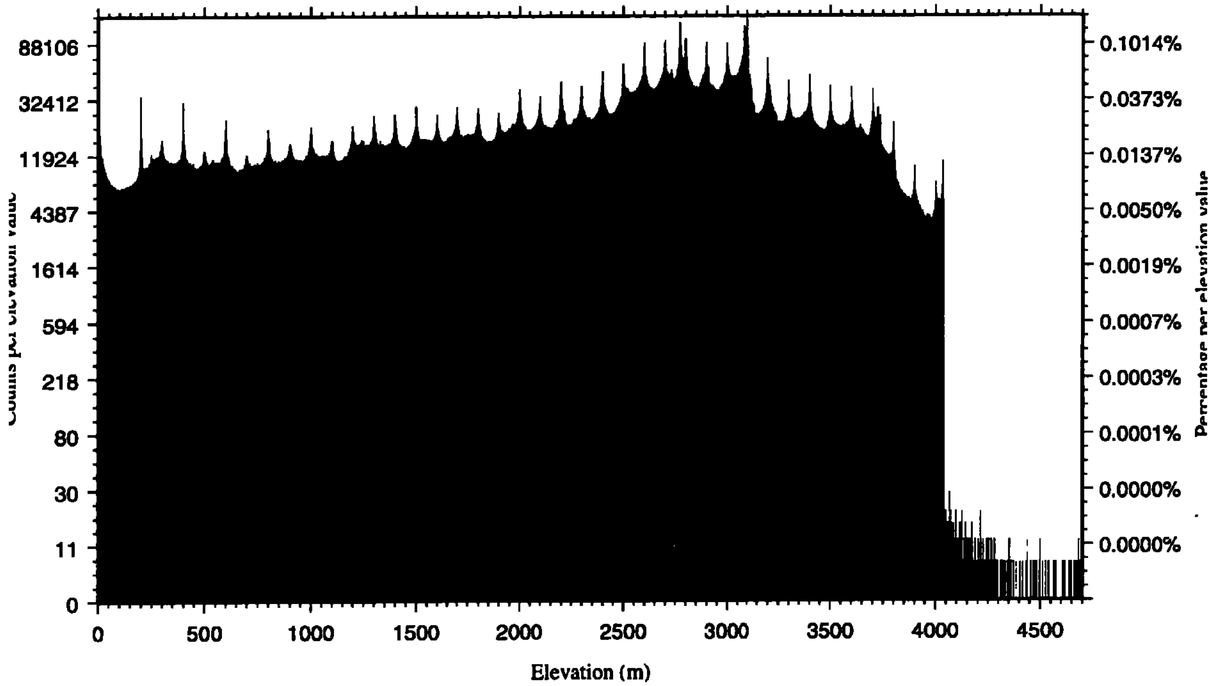


Plate 30. DEM Based on Antarctic Digital Database (semi-logarithmic plot)

Source/Lineage Category 18



to the surface of the Caspian Sea. Another large spike at 1875m corresponds to Lake Sevan in Armenia. The DEM is generally smooth, with few (or no) spikes characteristic of cartographic source materials.

- **Asia:** Plate 3 covers DTED discrete data for 0° to 50°N latitude and 60° to 150°E longitude. There is a gradual decline in the semi-logarithmic plot to 4000m, with a broad peak about 1000m elevation (corresponding to large areas in central Asia), a small peak about 2700m, and a large and relatively sharp peak at 5000m (corresponding to the Qinghai-Tibetan Plateau), with a much steeper quasi-linear drop off between 5000m and 7000m. A small area in Asia extends to over 8000m in elevation. There are few large spikes in this data set. Most notable are one at 1601m, corresponding to Lake Issyk-Kul south of Alma-Aty, and another at 3176m, corresponding to Lake Qinghai in Qinghai Province, China. The relatively low occurrence of spikes, and the large areas of Asia with banded shaded relief images, suggest that imagery was the major source of DTED in this area.

- **North America:** Plate 4 (covering DTED discrete data for 15° to 50°N latitude and 15° to 180°W longitude) shows considerable effect of spiking at various contour intervals. Though these spikes are not as prominent as those in DEMs derived from DCW, the histogram suggests that cartographic source materials may be more common in North America than in (for example) Asia. The overall histogram has a modest trough below 300m (and a significant trough for elevations below sea level), then a roughly linear decline from 300m to about 4500m, with additional troughs about 700m and 1100m.

- **South America:** Plate 5 covers DTED discrete data for 55°S to 15°N latitude and 20° to 95°W longitude. There is a modest trough below 100m elevation, then a curved decline in numbers of elevation values between 100m and 3000m. This curve continues slightly upward to about 3600m, where a spike marks a discontinuous increase in area at 3600m to 4600m, followed by a relatively rapid dropoff to 6000m. A few elevations occur to about 6800m. A spike at 2300m corresponds to the Salazar de Atacama, east of Antofagasta, Chile. Spikes between 3600m and 3800m correspond to elevations of the Altiplano, with 3810m being the elevation of Lake Titicaca. Surrounding high plains and lower reaches of the Andes range between 4000m and 5000m.

The data from DTED sources poleward of 50° (North or South) latitude (and in a few other areas where NIMA discrete data were unavailable) were selected from GTOPO30. Those data used three different sampling methods, plus a fourth type where two types were blended:

- **Eurasia:** Plate 6 primarily covers Eurasia north of 50°N latitude, plus a few areas not covered by NIMA discrete data, such as France. The semi-logarithmic plot shows an almost linear decrease between 600m and 3500m, with very modest bulges around 1000m and 2300m (suggesting slight concentrations of elevations at those heights). Spiking is modest below 1700m, with one prominent spike at 1640m, corresponding to Lake Hovsgol in western Mongolia. Above 1800m elevation, significant spiking is largely absent from the histogram. There is a prominent spike at 1m, partly resulting from GTOPO30's forcing sea level areas on land to a nominal one meter elevation.

- **Americas:** Plate 7 has significant, narrow spikes at approximately 150m (500ft) intervals, with secondary spikes at several lesser intervals. This suggests that a variety of contour intervals was available in the DEM source maps. The semi-logarithmic plot is not linear as are a few other semi-log plots of other DEMs. Modest peaks (broader than spikes) in the histogram occur between 250–300m (just short of 1000ft), and 650–700m (just above 2000ft). Between 700m and 1200m the histogram is relatively smooth, with superimposed spikes. Modest peaks occur around 1200m and above, at similar values to those of spikes. This suggests that vertical granularity of the data is coarsest at 1200m (4000ft) and above. At such higher elevations, major spikes occur at approximately 300m (1000ft) intervals. Such spikes exist at lower elevations, but they are less prominent.

- **Africa:** Plate 8 is also somewhat similar to that for the median and nearest-neighbor resamplings (source/lineage categories 2 and 3). This linear plot shows a granularity, but at about 500m and 1000m, with a subsidiary peak at about 100m. The sharp spike at 1121m is caused by Lake Beysehit in Turkey. These data appear in limited areas in GLOBE as they were overwritten by DTED discrete (source/lineage category 1) data in most areas.

- **Africa-Eurasia blend:** Plate 9 shows data used only in a small portion of GLOBE. The data were overwritten by DTED discrete (source/lineage category 1) data in most areas. The Anatolian Plateau dominates the data set, with elevations about 1000 meters. The major spikes in the data set represent lakes and playas in Turkey. For example, the spike at 892m (2055 grid cells, compared to 300–600 grid cells for similar elevations) corresponds to Lake

Tuzand. The spike at 1634m (5455 grid cells, compared to 300–320 cells for similar elevations) corresponds to Lake Van.

Two additional DTED derivations were used in North America:

- **DMA/NGDC:** Plate 10 shows spikes about every 150m (500ft), with broader peaks about 300m and 600m. As with other DEMs for North America, a cartographic lineage appears to dominate these data.
- **DMA/USGS:** Plate 11 shows an almost linear decline in frequency of occurrence below about 3500m of elevation, with superimposed spikes denoting concentrations of elevation values at various intervals. The major increments (shown by the most prominent spikes) are about every 300m (1000ft), with lesser intervals at about 150m (500ft) and 75m (250ft). Below 250m, smaller subsidiary contour intervals appear to have been included in the source materials for this DEM.

Other Assessments: DTED Level 0 (the .dt0 and .mmm files on NIMA's Web site) generally contains four values of elevation for each 30" grid cell where 3" data are available. The following countries have 3" DTED coverage: United Kingdom, France, Greece, Turkey, Cyprus, Israel, South Korea, and Iceland. However, permission had not been received in time to place DTED Level 0 coverage at NIMA's Web site by October 1996: Subsequent permission allowed USGS to derive 30" DEMs for all these countries but the United Kingdom.

DTED Level 0 data were produced by NIMA at consistent *decimation rates*, rather than for consistent grid spacings. USGS resampled DTED to constant 30" grid spacings poleward of 50° latitude, where permissible. Thus, poleward of 50° North and South latitudes, DTED Level 0 resolution is less than GTOPO30's.

In order to maintain consistent cell-centered georegistration, an 11x11 array of 3" DTED Level 1 grid cells should have been sampled to arrive at DTED Level 0 values. Thus there is a very slight misregistration implied by the 10x10 array actually used to make DTED Level 0. Considering the other variabilities in current global DEM compilation, this should be of minor consequence.

DTED Levels 1 and 0 are integer values, as are other DEMs used here, resulting in some artifacts in low-lying areas.

Peer review encouraged by NGDC resulted in the discovery that DTED Level 0 "mean" data were frequently lower than DTED Level 0 "minima." Further investigations at NGDC suggest that this pattern varies by location—some areas experience this phenomenon more than others. To date, NIMA has not updated these data. Discussions with peer reviewers led to the consensus that NIMA discrete (spot) sample values, though displaced to the southwestern corners of the 30" grid cells, were the most globally consistent and desirable candidate data for their areas of coverage, between 50° North and South latitude, when other national sources were not better. Where USGS and NGDC have 30" data with cell-centered nearest-neighbor georeferencing, NIMA discrete (spot) data may have less desirable georeferencing. However, NIMA includes several updates and improvements not available in the older versions available through NGDC and USGS.

In addition to these observations, original characteristics of DTED, noted in Section 5.A.i.a still apply to DTED Level 0, with minor alterations due to the different resolution of the 30" data.

The median, nearest-neighbor, and "breakline" versions within GTOPO30 are not shown in the GTOPO30 source map available from USGS. As these may affect applications of the data, we have attempted to illustrate where each version is located. We have modified our source map for GTOPO30 data, as well as our source map for GLOBE data, to reflect these different derivations, based on descriptions of the process from USGS scientists. USGS's blend between breakline and median data processing is also depicted on GLOBE's source/lineage map (back cover), where such data are used.

5.A.ii. DEM for Australia

Primary Developers:	Australian Surveying and Land Information Group (AUSLIG) and the National Geophysical Data Center (NGDC)
Title:	30" DEM for Australia
Publication Date:	1998
Bibliographic Citations:	Australian Surveying and Land Information Group, 1996. *Point Elevation Data File for Australia.* Australian Surveying and Land Information Group, Belconnen, ACT, Australia.
*	AUSLIG and NGDC, 1998. *30 Arc-second Digital Elevation Model for Australia* (*in* GLOBE Task Team and others, 1999).
Post-processing:	None. The original development was directly for GLOBE.
Source/Lineage Category:	8

* Primary reference citation for all data from this source

In 1996, NGDC and the Australian Surveying and Land Information Group (AUSLIG) signed an agreement to provide access to high-quality Australian elevation information for GLOBE. AUSLIG offered access to a data base of 5,190,624 point elevations, from which NGDC would derive a 30" gridded DEM for use in GLOBE. The original data base was proprietary to AUSLIG; the resultant DEM would be owned by AUSLIG and any other providers of data. AUSLIG would license the data to NGDC for distribution with GLOBE.

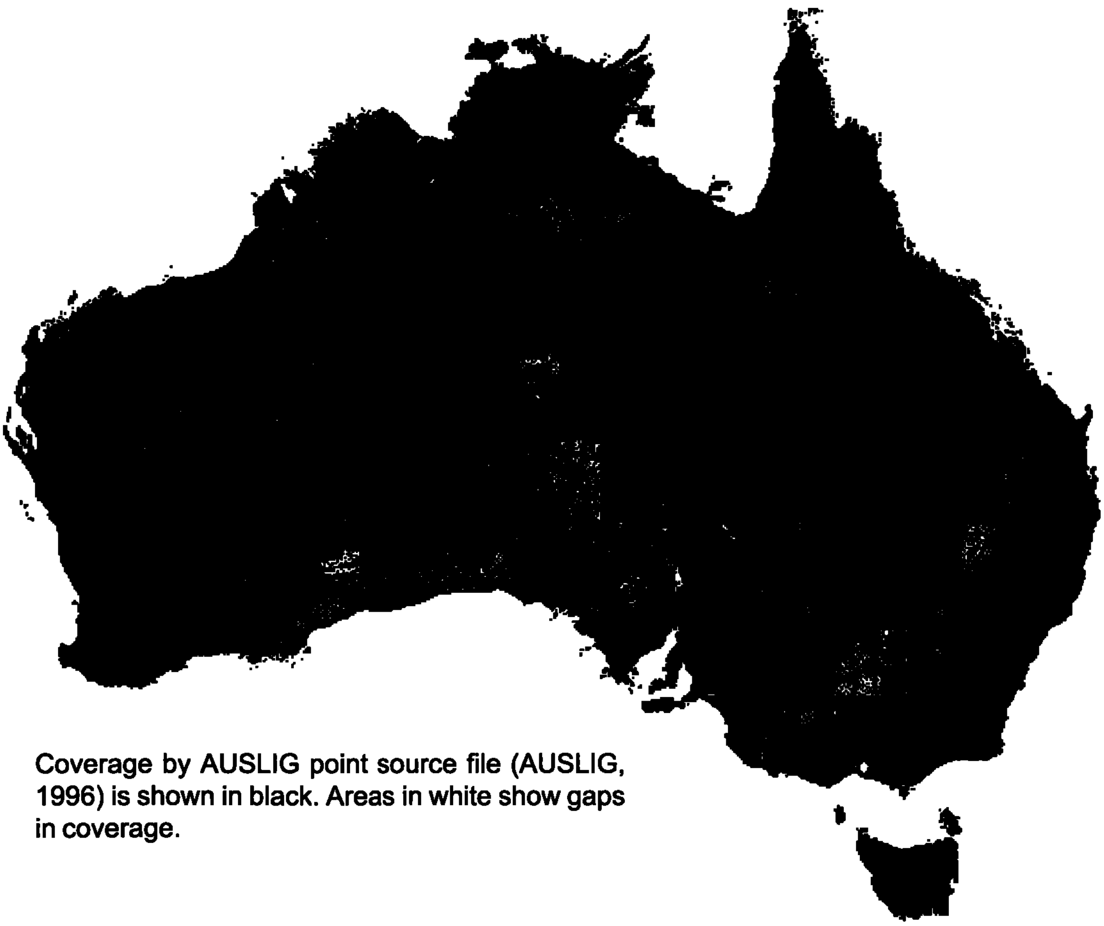
Inspection of the data base (AUSLIG, 1996) by NGDC suggested that it consisted primarily of digitized contours from topographic maps, supplemented by coastlines, and point elevations. AUSLIG describes the data as follows (John Payne, AUSLIG, 1998, written communication):

> "The elevation data in the relief theme supplied by AUSLIG had been derived from AUSLIG's published 1:100,000 scale topographic maps and unpublished 1:100,000 scale map compilation material. The elevation data are point elevations captured at an irregular interval spacing to best portray the terrain. The spot elevation feature

contains either spot heights on the source material or points selected from contours. Spot heights are individual point elevations in the source material. They are generally located at local high points such as sand ridges, hills and mountain tops or at the low points in depressions. These points were observed directly by stereoplotter in the map production process."

Inspection of the source data found that topographic contour intervals tended to range from 10 meters upwards. In some areas, data density averaged one value per 30" grid cell (sometimes slightly more, sometimes less). More commonly, data were almost this dense in areas of high topographic relief and high population—less than this in areas of low population and topographic relief. Of course, in areas of low relief, one might expect fewer topographic contours. Overall data density may be inferred from over five million elevation values for about ten million 30" grid cells for Australia (a 1/2 ratio). In the view of NGDC scientists, this source data set was appropriate for the task of interpolating a 30" grid. A map showing coverage in AUSLIG (1996) is shown below.

NGDC experimented with various options of surface generation: the Generic Mapping Tools' interpolation routines, Arc/INFO's Triangular Irregular Network module, the Geographic Resources Analysis Support System (GRASS)' functions s.surf.idw, s.surf.tps, r.surf.idw, and r.surf.idw2. Several



Coverage by AUSLIG point source file (AUSLIG, 1996) is shown in black. Areas in white show gaps in coverage.

of the packages had difficulty in handling the volume of data required for this surface generation. In the end, s.surf.idw in GRASS was selected as the smoothest running, yet appropriate for data distributions as provided. Quality control at NGDC, University College London, and elsewhere, determined that this DEM was of relatively high quality.

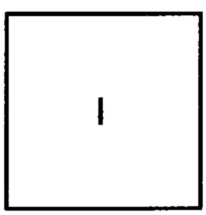
The surface generation was run in GRASS, within a mask derived as follows. Kent Lethcoe of USGS's EROS Data Center provided a 30" gridded mask of oceans (derived from World Vector Shoreline [WVS]) and lakes (derived from Digital Chart of the World) vectors. Every 30" grid cell containing at least one point of zero or higher elevation in the AUSLIG point data base was added to the land area in this mask.

AUSLIG notes (John Payne, AUSLIG, 1998, written communication) that:

> "In the AUSLIG data, all points which coincided with the coastline were derived by selecting representative points on the waterline feature in the framework layer, and assigning an elevation of 0 metres. Because the framework layer is 1:250,000 scale source data, their accuracy is considerably different to the rest of the elevation data contained in the relief theme. Zero values in the interior, and subzero elevations for Australia, are well inland around Lake Eyre."

The land mask for Australia provided by USGS was enlarged to include all 30" grid cells containing point elevations in AUSLIG (1996). In so doing, we accepted the Australian source materials as adding detail to the land mask previously based only on WVS coastlines. Areas on land (not counting lakes and oceans) received interpolated elevations, where point elevations did not exist. The output interpolated elevations were the inverse-distance-weighted mean of the three closest point elevations.

Elevations for each lake in the mask were taken to be the lowest DEM value around that lake. These were determined as follows. Lake areas were "spread" one grid cell into adjacent shore areas, using the GRASS function r.grow. The lowest elevation for each lake shore was determined by finding the lowest non-zero value in each of the "spread" lake areas. These lowest shoreline values were then assigned to their respective lakes as the highest water level that could be contained in the catchment area.



Cell-centered registration, value interpolated from points.

Graphic describing georeferencing and sampling for AUSLIG/NGDC's model for Australia.

Analysis of Histograms: Plate 12 has spikes about every 20 and 50 meters, probably corresponding to contour values on AUSLIG source maps. This histogram shows a few elevations below sea level to about -30m, a modest trough above sea level to 60m, then a relative steady decline in frequency of occurrence beyond 3500m, punctuated by spikes at apparent contour values in cartographic source materials. These spikes are relatively high; likely the result of a high density of source point values at contour values, leaving relatively fewer gaps for the interpolation routine to populate with other values.

Plate 13 shows spikes at approximately 30m (100ft) intervals, corresponding to contour values in the source Digital Chart of the World. The largest spike in USGS's DCW-derived DEM occurs at 304m, corresponding to 1000ft elevation. Subsidiary contour intervals of 30m (100ft) below 600m (and to a lesser degree to 1200m) are suggested by the histogram. There is a modest trough in this histogram below 60m, then a plateau between 60m and 300m. There is a sharp drop to a lower plateau at 300–600m, another sharp to a lower level (more a decay curve than a plateau) at 600–900m, and then more gradual drops to 2400m. Finally, there is a slightly steeper drop to 3600m, after which there are few elevations in Australia. This DEM has no elevations below sea level.

The spikes are more pronounced in the AUSLIG/NGDC DEM than in the DCW/USGS DEM, probably a result of the "minimalist" approach to interpolation and the relatively dense network of points in the AUSLIG source data set. Where a 30" grid cell had an elevation assigned from the AUSLIG source file, NGDC's procedure accepted that value. Since there are over five million source data points for ten million square km of Australia, slightly over half of the 30" grid cells were already assigned elevation values (usually in multiples of 20 or 50 meters).

Local histograms are smoother in areas with coarser-spaced AUSLIG source points, where interpolated points are more numerous than source points. The contour interval is coarser in the DCW/USGS DEM, consistent with the coarser scale of the DCW source materials.

Other assessments: Australia is unique in GLOBE Version 1.0. It has two DEMs: a completely unrestricted DEM derived (as described in Section 5.A.vii) from Digital Chart of the World contours, and a DEM derived by NGDC and licensed by AUSLIG from its source materials. Comparing the two DEMs to Operational Navigation Charts (ONCs, the source materials for DCW) yields some interesting features.

For example, in South Australia, west of Port Augusta, the ONC graphically depicts (via shading patterns) a large dune field. However, the dune field has only a very modest influence on the topographic contours in that area, as the contour interval is rather course on ONCs. The DCW DEM almost completely misses the dune field. The AUSLIG DEM shows the dune field in good detail since contour intervals and supplemental point elevations are of sufficient resolution. However, individual dunes within the dune field, sketched (probably slightly stylistically) on the ONC, appear to be too subtle for the contour interval on the AUSLIG maps used to make the point data base. This suggests that the 30" GLOBE DEM is of appropriate resolution for the AUSLIG source materials.

5.A.iii. DEM for Japan

Primary Developer:	Geographical Survey Institute (GSI)
Title:	30" DEM for Japan
Publication Date:	1995
Bibliographic Citation: *	Geographical Survey Institute, 1995. *30 Arc-second Digital Elevation Model of Japan*. Geographical Survey Institute, Tsukuba, Japan (*in* GLOBE Task Team and others, 1999).
Post-processing:	None
Source/Lineage Category:	9

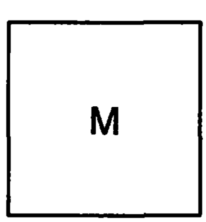
* Primary reference citation for all data from this source

The Geographical Survey Institute (GSI) of Japan has two series of DEMs: a 50-meter grid based on 1:25,000-scale maps (in progress), and a 250-meter grid also based on 1:25,000-scale maps (completed). The data are in Japan's standard projection. The horizontal datum is the Tokyo datum; the vertical datum is mean sea level of Tokyo Bay. Both versions are copyright, based on the Survey Law in Japan.

The Digital Map 250m Grid Elevation data set was produced by manually measuring elevation values at approximately 250m intervals from 1:25,000 scale topographic maps. The actual intervals were 11.25 arc-seconds of longitude and 7.5 arc-seconds in latitude. These intervals correspond to a 40 x 40 division of one 1:25,000-scale GSI Topographic Map sheet, which covers 7.5 minutes in longitude and 5 minutes in latitude. The contour interval of these source maps is 10 meters. The source maps were derived from 1:40,000-scale stereoscopic aerial photographs, using 9 inch (23cm) film size and a lens of 6-inch (150mm) focal length, and using traditional stereoplotting techniques. Japan has large amounts of mountainous terrain, and about 65% of the land surface is forested. However, experienced operators are skilled at recreating the ground surface elevation despite these obstacles.

GSI reprojected and resampled the Digital Map 250m Grid Elevation data to WGS84 horizontal datum, with vertical datum kept at mean sea level (for Tokyo Bay), and averaged the resultant 11.25" x 7.5" data to a 30" latitude-longitude grid. It considers the vertical accuracy to be 5–10m RMSE.

GSI contributed these data for unrestricted use by the international scientific community, giving a copy to NGDC for GLOBE.



Cell-centered registration, mean of source 7.5" x 11.25" grid cells in output 30" cell.

Graphic describing georeferencing and sampling for the DEM for Japan.

Plates 14 and 15 both show the DEM for Japan; with linear and semi-logarithmic scaling, respectively. Surprisingly, for data derived from cartographic sources, a histogram of this DEM is almost unnaturally smooth, and is linear between 200m and 2900m. It shows only one prominent spike, at 85m. This spike corresponds to Lake Biwa, just northeast of Kyoto. This suggests a very dense distribution of contours, little "artistic license" taken in creating the original map contours from source materials, and highly appropriate "contour-to-grid" conversion techniques in making the DEM from the cartographic source.

There appear to be a few, very subtle, breaks in topographic style in a pattern that suggests edge effects in source maps, or in contour-to-grid creation of the DEM. These may reflect subtle discontinuities in horizontal or vertical datum that affected the data when reprojected. GSI notes that slight initial discrepancies occur during the production of topographic maps, but that these are adjusted to ensure continuity between sheets (and thus in DEMs derived from them).

5.A.iv. DEM for Italy

Primary Developers:	Servizio Geologico Nazionale (SGN) and National Geophysical Data Center (NGDC)
Title:	30" DEM for Italy
Publication Date:	1994
Bibliographic Citations:	Carrozzo, M.T., D. Luzio, C. Margiotta, T. Quarta, F. Zuanni, A. Chirenti, and A.M. Tundo, 1985. Data base of mean height values for the whole Italian landmass and surrounding areas: determining and statistical analysis. *Bollettino di Geodesia e Science Affini*, No. 1, 1985, pp. 38–56.
*	Servizio Geological Nazionale and Row, L.W., 1994. *30 Arc-second Digital Elevation Model for Italy, in* Row and Hastings, 1994 (*in* GLOBE Task Team and others, 1999).
Post-processing:	None. This DEM was originally created for TerrainBase.
Source/Lineage Category:	10

* Primary reference citation for all data from this source

The DEM for Italy was derived at NGDC, from a 7.5x10-second DEM developed by the Servizio Geologico Nazionale (SGN) of Italy. This section summarizes documentation prepared by Row and others (1995, pp. 4-91 through 4-95) for TerrainBase (Row and Hastings, 1994), and is also described by Carrozzo and others (1985).

The 7.5x10-second DEM developed by SGN was developed for use in gravity terrain corrections. Organizations involved with either developing, analyzing, or financing the data set included AGIP (a major petroleum company in Italy), the National Research Council, National Group of Solid Earth Geophysicists (GNGTS), Ministry of Education (MPI), and the University of Lecce. Source materials included several topographic map sources cited in Row and others (1995), at scales of 1:25,000 to 1:50,000 for land, plus hydrographic maps at 1:100,000.

Mean height values were manually extracted from the topographic maps at regular grid intervals. The size of the grid was selected to maximize the amount of reliable detail obtainable from the source maps, while keeping the resolution from becoming so fine as to overly burden the developers. Grid spacings of 7.5x10 seconds were used for 1:25,000 scale maps, 15x20 seconds for 1:50,000 maps, and 30x40 seconds for the 1:100,000 scale maps. A map of sources is presented in Carrozzo and others (1985), and reproduced in Row and others (1995, p. 4-94).

Grid lines were printed on transparent acrylic sheets in 20-minute latitude sections, and overlain on the maps to guide data collection. For each grid cell, a mean height was manually estimated from the contours and point heights that appeared within and adjacent to each cell.

The 6,210,000 elevation values were derived from 3450 maps, 1,878,000 heights in coastal regions from 130 coastal maps, and 3,456,000 depth values from 120 maps. The coarser grids were then interpolated to 7.5x10-second gridding by an undocumented technique. SGN then tiled the data into 20x30-minute areas.

Data were analyzed for errors by SGN using the following procedures:

1. SGN checked that data were expressed in proper metric terms, and that they were intrinsically valid. SGN verified that the data fell within a predetermined range of values for the area under consideration.

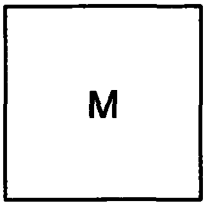
2. SGN checked the slope at each cell by testing whether the difference between each cell and its neighbors did not exceed a threshold value as determined by the type of local terrain.

3. SGN spot-checked data by independently collecting data from various cells twice. SGN then verified that the two values did not differ beyond predetermined values, based on the local terrain.

4. SGN generated contour maps from the gridded data in each area, and overlaid these on the source maps for comparison.

5. SGN generated contour maps from several adjacent areas, and overlaid these on 1:100,000-scale source maps, to confirm proper edge matching between processed areas.

SGN and NGDC jointly developed a method for compiling these proprietary data into an unrestricted 30" grid. According to this method, NGDC computed the mean value of all 7.5x10-second grid values contained in each 30" output grid cell. Areas containing significant errors were removed from the model (these were filled by NIMA DTED Level 0 discrete values during the patching process making GLOBE Version 1.0).



Cell-centered registration, mean of source 7.5" x 10" grid cells in an output 30" grid.

Graphic describing georeferencing and sampling for the DEM for Italy.

Plates 16 and 17 are histograms for the DEM of Italy, on linear and semi-logarithmic scales, respectively. There is a trough in the histogram for elevations below 80m in the SGN DEM, a broad peak at about 70m to 200m (the elevations of the lakes in the Italian Alps), and modest spikes at about 400m and 440m. Otherwise, the histogram is relatively smooth. The semi-logarithmic plot shown is not quite linear between 100m and 2000m elevation. Then a modest bulge occurs at about 2500m, with a rapid diminution of elevation values above about 2800m. This DEM is not quite so smooth as the GSI DEM for Japan. Nevertheless, it is unusually free of spikes, considering its cartographic source.

5.A.v. DEM for New Zealand

Primary Developer:	Manaaki Whenua Landcare Research, Ltd. (LCR)
Title:	DEM for New Zealand
Publication Date:	1996
Bibliographic Citation: *	Manaaki Whenua Landcare Research, 1996. *500-metre Digital Elevation Model for New Zealand.* Manaaki Whenua Landcare Research, Ltd., Lincoln, New Zealand (*in* USGS, 1997; also *in* GLOBE Task Team and others, 1999).
Post-processing:	U.S. Geological Survey (for GTOPO30).
Source/Lineage Category:	11

* Primary reference citation for all data from this source

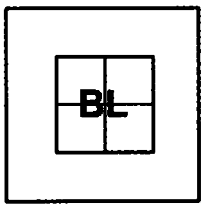
Manaaki Whenua Landcare Research, Ltd. (LCR), contributed a DEM with a 500m horizontal grid spacing for New Zealand to USGS for GTOPO30. This map was in New Zealand's national projection. The DEM was adapted from elevation information on 1:63,360-scale maps (e.g. 1 inch = 1 mile scale). The source maps have a 30m (100ft) contour interval.

The original projection is described as follows:

Method of projection: Modified Cylindrical. A sixth-order conformal modification of a Mercator using the International spheroid.
Points of tangency: 41°00' South, 173°00' East.

Linear graticules: None.
Properties:
Shape: Conformal. Local shapes are correct.
Area: Minimal distortion, less than 0.04 percent for New Zealand.
Direction: Minimal distortion within New Zealand.
Distance: Scale is within 0.02 percent of true scale for New Zealand.
Limitations: Projection not useful for areas outside New Zealand.

USGS reprojected the data to 30" latitude-longitude projection using bilinear resampling.



Cell-centered registration, bilinear resampling of source 500m grid.

Graphic describing georeferencing and sampling for the DEM for New Zealand.

Plates 18 and 19 show spikes at approximately 30m (100ft) intervals below 606m (2000ft). There are additional spikes at about 750m (2500ft) and 900m (3000ft). Above that elevation, the histograms are relatively smooth. This suggests that the vertical granularity of the source maps may be more appropriate at higher elevations than for lower elevations. Nevertheless, the DEM is of relatively high quality for one apparently derived from cartographic sources. There is a modest trough in values between 100m and 150m.

5.A.vi. DEM for Greenland

Primary Developers: H. Jay Zwally and Robert A. Bindschadler (NASA Goddard Space Flight Center), Anita Brenner and John DiMarzio (Hughes STX) for the Oceans and Ice Branch of the Laboratory for Hydrospheric Physics, NASA/Goddard Space Flight Center.

Title: DEM for Greenland from GEOSAT Altimetry

Publication Date: 1997

Bibliographic Citations: National Snow and Ice Data Center (NSIDC), 1997. *SEASAT and GEOSAT Altimetry Data for the Antarctic and Greenland Ice Sheets.* University of Colorado, National Snow and Ice Data Center, Boulder, Colorado. (CD-ROM)

** Zwally, H. Jay, Anita C. Brenner, John DiMarzio, and Robert A. Birndschadler, 1997. DEM of Greenland from GEOSAT Altimetry (*in* NSIDC, 1997).

Zwally, H. Jay, A.C. Brenner, J.A. Major, T.V. Martin, and R.A. Bindschadler, 1990. Satellite radar altimetry over ice. *Volume 1, Processing and Corrections of SEASAT Data over Greenland.* NASA Reference Publication 1:1233.

Zwally, H. Jay, Judith A. Major, Anita C. Brenner, Robert A. Bindschadler, and Thomas V. Martin, 1990. Satellite radar altimetry over ice. *Volume 2, Users' Guide for Greenland Elevation Data from SEASAT.* NASA Reference Publication 2:1233.

Post-processing: Jet Propulsion Laboratory (JPL) for the Multiangle Imaging Spectro-Radiometer DEM.

Post-processing (Step 2): National Oceanic and Atmospheric Administration (for GLOBE).

Bibliographic Citation * for Post-processed DEM: Bryant, Nevin, Richard Fretz, Niles Ritter, and Rafael Alanis, 1995. *JPL/MISR 30 Arc-second Digital Elevation Model.* Jet Propulsion Laboratory, Pasadena, California.

Source/Lineage Category: 12 (and partly 13)

Note: The best current DEM for Greenland is a hybrid of this DEM, DTED, and DCW-based contours as described below and in Section 5.B.i.d.

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* Primary reference citation for all data from this source
** Definitive citation of GEOSAT data source

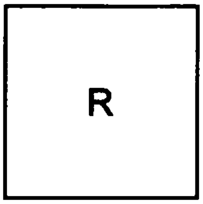
There is only limited DTED coverage for Greenland. Where available, these data were used.

For other areas, several DEMs have been created using SEASAT, GEOSAT, and ERS-1 satellite altimetry. These data provide closely spaced spot measurements of the distance between the satellite platform carrying the altimeter. These measurements undergo various corrections and calibrations to produce spot measurements of elevation. Statistical processes may be used to reduce noise where measurement densities are sufficiently high. The resultant spot measurements are then interpolated into elevation grids (e.g. DEMs). The only version of such data that we have evaluated enough to use is this contribution based on GEOSAT data (see two paragraphs below). Further improvements of altimetry-based data are anticipated.

Alternatively, Operational Navigation Charts, upon which DCW was based, provide topographic contours south of about 72°N latitude. North of that latitude, contours exist in some coastal areas, with inland areas having only a sparse collection of point elevations apparently collected on traverses. USGS used DCW to create its DEM of Greenland, except where DTED was available.

Another DEM was created from GEOSAT altimetry by Zwally and others (NSIDC, 1997; see list under "Primary Developers," above). This was provided to the MISR/JPL DEM project, in support of the NASA EOS Multiangle Imaging SpectroRadiometer mission, by GLOBE Task Team member J.-P. Muller. The original DEM had 10 km gridding, but was resampled to 30" by JPL for use in the

MISR mission. (Further documentation is available from NSIDC at http://www-nsidc.colorado.edu.) North of 72°N latitude, JPL used Digital Chart of the World contours to create a gridded DEM.



Cell-centered registration at lower resolution; value replicated from 10km grid for Greenland.

Graphic describing georeferencing and sampling for the Zwally (and others)/NSIDC/JPL data for Greenland

Plate 20 only incorporates data for the area of the original Zwally (and others)/NSIDC/JPL DEM ultimately used in GLOBE. As that area is dominated by the Greenland Ice Sheet, it is not surprising that the histogram is dominated by elevations of 2000–3000m. Note that this DEM is dissimilar from other DEMs in GLOBE, as are its sources. Further assessment may follow in future versions of GLOBE, after other candidate DEMs from altimetric sources are assembled and analyzed.

Plate 21 shows the two-degree wide blend zone between the data contributed by JPL and those from DCW and DTED in Greenland. The histogram shows that dominant elevations are about 2000m in this area off the center of the ice cap.

NGDC's assessment of NIMA DTED, USGS, and Zwally (and others)/NSIDC/JPL DEMs suggested that NIMA DTED were preferred where available. The USGS model was preferred in many coastal areas in the south, southeast and southwest, where DCW hypsography was relatively detailed. However, in the interior, even south of 72° latitude where DCW contours were fairly detailed, the Zwally (and others)/NSIDC/JPL DEM appeared preferable.

It was suggested by J.-P. Muller of University College London (Geomatic Engineering Department) that even where DCW contours existed on the Greenland Ice Sheet, that they were not necessarily very accurate compared to the NSIDC model. Inspection at NGDC for terrain-like characteristics in the two DEMs supported this assessment. The Zwally (and others)/NSIDC/JPL DEM was thus preferred primarily at higher latitudes and inland. At these latitudes, this DEM appeared to overrun coastlines in some areas, perhaps because the satellite altimetry gave readings on ice features (and thus considered land by that model, whereas World Vector Shoreline (WVS) coastlines considered some of these areas to be oceanic).

Therefore, NGDC mosaicked a DEM for Greenland based on the following priorities:

1. DTED-based 30" data where available.
2. USGS/GTOPO30 data based on DCW, where DCW contained sufficient detail (generally southerly near-coastal areas not characterized by substantially permanent ice).
3. Zwally (and others)/NSIDC/JPL data in other areas (generally in the interior of Greenland, and in northerly coastal areas characterized by substantially permanent ice).
4. NGDC performed a linear transition between the Zwally (and others)/NSIDC/JPL DEM and

the DCW-based DEM, over a two-degree wide zone. This transition is category 13 in the source/lineage map.

5. In some northern coastal areas characterized by substantially permanent ice, USGS/GTOPO30 values sometimes extended oceanward of the limit of Zwally (and others)/NSIDC/JPL coverage. In this case, the USGS/GTOPO30 data were used. In some other areas, Zwally (and others)/NSIDC/JPL values sometimes extended oceanward of USGS/GTOPO30 data coverage, which was limited by a selection of DCW and WVS coastlines. In such cases, the coastlines used by USGS/GTOPO30 were accepted, thus masking out Zwally (and others)/ NSIDC/JPL elevations in areas considered oceanic by USGS/GTOPO30.

5.A.vii. Digital Chart of the World

Primary Developer:	Defense Mapping Agency (now National Imagery and Mapping Agency)
Title:	Digital Chart of the World
Publication Date:	1992
Bibliographic Citation:**	Defense Mapping Agency (DMA), 1992. *Digital Chart of the World.* Defense Mapping Agency, Fairfax, Virginia. (Four CD-ROMs.)
Post-processing:	U.S. Geological Survey (USGS) for GTOPO30.
Bibliographic Citation * for Post-processed DEM:	DMA and USGS, 1996. *30" DEM from Digital Chart of the World* (*in* USGS, ed., 1997).
Source/Lineage Category:	14

* Primary reference citation for all data from this source
** Primary reference citation for Digital Chart of the World

Digital Chart of the World (DCW) is a vector cartographic data set based largely on the 1:1,000,000-scale Operational Navigation Chart (ONC) series of aircraft navigation charts. ONC has been cited as the largest scale base map source with global coverage (Danko, 1992). ONCs were products of the Army Mapping Service (AMS), then DMA, now National Imagery and Mapping Agency (NIMA). They were based on photogrammetric analyses of Department of Defense Corona imagery acquired in the 1960s.

ONCs contain vector base map information such as political boundaries, transportation infrastructure, waterways, and coastlines, as well as raster-like shading for selected categories of land cover type. The objective of this information is to facilitate navigation by pilots. In addition, for much (but not all) of the world, ONCs contain topographic contours. The primary contour interval is 1000ft (305m), with supplemental contours at 250ft (76m) intervals in areas below 1000ft elevations. Limited supplemental contours at 500ft (152m) intervals exist above 1000ft elevations.

Point elevations also appear in ONCs, often at airports, cities, or topographic features such as selected mountain peaks. In addition, some lake surfaces are labeled with typical elevations. In many areas lacking topographic contours, sparse point elevations are still available.

ONCs (and DCW, which is derived from ONCs) use World Geodetic System 84 (WGS84) for horizontal reference, and Mean Sea Level as vertical reference. However, this may not always be the case, as cartographic sources (for example) may not be completely or accurately described, and materials from such sources may not be accurately converted to WGS84 and Mean Sea Level.

In the late 1980s, DMA instigated a design and contracting process to digitize the contents of ONCs. The work was contracted to a private company. The resultant data base occupies four CD-ROMs, which is distributed by USGS for DMA.

Absolute horizontal accuracy of the DCW hypsography is reported to be 2040m rounded to the nearest 5m at 90% circular error. Vertical accuracy is considered to be 610m for contours, and 30m for spot elevations (DMA, 1990).

Errors can exceed such figures locally. For example, the ONC for northern Greenland contains notices such as: "CAUTION: Arctic Institute of North America Project Nord (Control Data Corp.) indicates position discrepancies in excess of 11 nautical miles (Nov. 68)."

Topographic contours and point elevations are the primary data for deriving DEMs from DCW. Supplementary data include drainage information. Streams were used to guide the contour-to-grid process using the ANUDEM program of Hutchinson (1989, 1996). Lake shorelines and ocean coastlines provide further guidance.

DCW was used as the primary source for filling gaps in the DTED coverage, including all of the unrestricted DEM for Australia, and large areas of Africa, South America, and Canada. University College London was active in early development of DCW conversion techniques. The Jet Propulsion Laboratory used contour-to-grid techniques to make much of its 30" DEM noted in Section 1 and in Section 5.A.vi. However, all of DCW contour-to-grid data used in GLOBE were produced by USGS.

The following is USGS, 1997b, description of its vector data processing techniques. These apply to DCW, as well as the other cartographic source materials listed in Sections 5.A.viii to 5.A.xi:

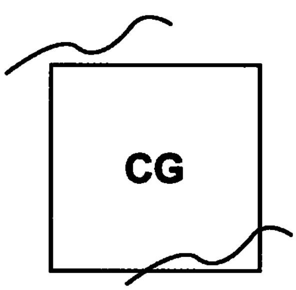
> "The topographic information from the vector cartographic sources, including the DCW, the ADD [Antarctic Digital Database], and the Army Map Service, International Map of the World, and Peru 1:1,000,000-scale maps, was converted into elevation grids through a vector-to-raster gridding approach. Contours, 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 [*sic*] 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)."

The following passage is from another part of USGS (1997b):

"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."



Cell-centered registration; contour-to-grid value computed.

Graphic describing georeferencing and sampling for DCW conversion.

Analysis of Histograms: As the Digital Chart of the World was the source for about 23% of GLOBE, we performed histogram analyses on DEMs from DCW for the same areas as NIMA discrete data. Note that only data used in GLOBE were run through the histogramming process, so DTED- and DCW-based histograms *should be* different.

- **Africa/Europe:** Plate 22 plots DCW coverage of Africa and Europe (0° to 60°N latitude and 0° to 60°E longitude) is largely similar to that of DTED discrete data for the same region. A similar trough at low elevations (including some elevations below sea level), peak about 450m, and gradual quasi-linear decline to 4500m is apparent. The DCW-based DEM is, however, punctuated by spikes at approximately 300m (1000ft) intervals, with subsidiary spikes at lower elevations, as might be expected from its source, Operational Navigation Charts. A spike at 1200m is superimposed upon the broader peak at the same elevation that is more apparent in the histogram of DTED discrete for Africa and Europe. However, that elevation appears to exhibit a slightly more pronounced peak around 1200m in the DCW-derived DEM, as well.

- **Asia:** Plate 23 plots DCW coverage for Asia (between 0° to 90°N latitude and 60° to 180°E longitude) shows a similar pattern of steady decrease in frequency of occurrence, with a broad peak about 5000m elevation. As for Asia, the DCW-based DEM shows prominent spikes at 300m increments, with spikes at subsidiary contour intervals for lower elevations.

- **North America:** A similar broad pattern to that shown for DTED discrete data for North America is apparent in Plate 24. Spiking at contour intervals in source maps (with associated broader peaks probably derived in gridding) is typical of this series of DCW-based DEMs. There appear to be fewer higher elevations than in Plate 4, as might be expected considering the coverage of these data.

- **South America:** In Plate 25, the DCW-based DEM has a similar pattern to that of DTED discrete data, with the superposition of more spikes (at about 300m increments, with intermediate spikes at lower elevations). The broad peak at 4000–5000m apparent in the DTED-based data is not so apparent in the DCW-based DEM. This is because the Altiplano is covered more by DTED (and, to a lesser degree, by AMS and Peruvian maps) than by DCW.

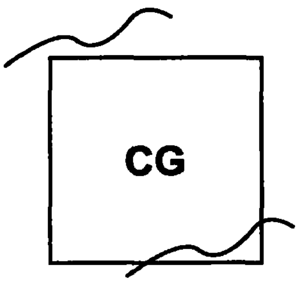
5.A.viii. Maps for Parts of Asia and South America

Primary Developer:	Army Map Service (now National Imagery and Mapping Agency)
Title:	Maps
Publication Date:	1950s and 1960s
Bibliographic Citations:	Army Map Service (AMS), various dates. South America 1:1,000,000. World (South America) 1:1,000,000. World (South Pacific) 1:1,000,000. East Indies 1:1,000,000. Army Map Service, Washington, D.C. (Map series, with global coverage but various regional names, consistent with International Map of the World specifications.)
	U.S. Army Topographic Command (USATC), various dates. World (South America) 1:1,000,000. U.S. Ar.ny Topographic Command, Washington, D.C. (Map series consistent with International Map of the World specifications.)

	Defense Mapping Agency (DMA), various dates. World (Asia) 1:1,000,000. Defense Mapping Agency Topographic Center, Washington, D.C. (Map series consistent with International Map of the World specifications.)
Post-processing:	Geographical Survey Institute (GSI, Japan) and U.S. Geological Survey (for GTOPO30).
Bibliographic Citation * for Post-processed DEM:	AMS, GSI, and USGS, 1997. *30"-gridded DEMs from AMS Maps.* USGS, EROS Data Center, Sioux Falls, South Dakota.
Source/Lineage Category:	15

* Primary reference citation for this source

Paper maps at a scale of 1:1,000,000 produced by the Army Map Service (AMS) were acquired and digitized by the Geographical Survey Institute 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 USGS as digital vector cartographic data sets. USGS used ANUDEM-based contour-to-grid techniques to create DEMs from these digitized map areas. That procedure is described in Section 5.A.vii.



Cell-centered registration; contour-to-grid value computed.

Graphic describing georeferencing and sampling for AMS map conversion.

Histogram analysis of AMS maps divides the source into maps for South America (Plate 26) and for Asia (Plate 27). Plate 26 shows prominent sharp spikes and broader peaks at about 150m, 200m, 500m, and 1000m increments. This suggests relatively sparse contour information.

Plate 27 shows prominent sharp spikes and broader peaks at approximately 300m and 500m increments, plus at 100m, 150m, and 200m. This suggests a combination of contour values in 1000ft and 500m increments, with subsidiary contour values at lower elevations. It also suggests relatively sparse contour information.

5.A.ix. Maps for Part of Brazil

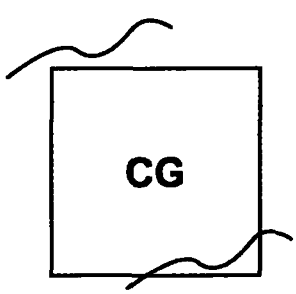
Primary Developer:	Instituto Brasiliero de Geografia e Estatistica
Title:	Maps for the International Map of the World on the Millionth Scale
Publication Date:	Various, 1970s and 1980s.
Bibliographic Citation:	Instituto Brasiliero de Geografia e Estatistica (IBGE), various dates. *Carta Internacional do Mundo, ao Milionesimo.* Instituto Brasiliero de Geografia e Estatistica, Rio de Janeiro, Brazil. (Physical, including topographic, maps of the world on a scale of 1:1,000,000; sheets covering Brazil.)
Post-processing:	Geographical Survey Institute (GSI, Japan), and U.S. Geological Survey (USGS) for GTOPO30.
Bibliographic Citation * for Post-processed DEM:	IBGE, GSI, and USGS, 1997. *30"-gridded DEMs from IBGE Maps.* USGS, EROS Data Center, Sioux Falls, South Dakota.
Source/Lineage Category:	16

* Primary reference citation for this source

The International Map of the World (IMW) on the Millionth Scale project was created in 1913, when a number of national and other cartographic agencies joined to form the Central Bureau of the IMW. In 1953, IMW activities were transferred to the Secretariat of the United Nations (UNO, 1973).

The IMW project sets standards for presentation of such maps, to increase uniformity of content and presentation. Actual maps are produced by many public (and a few private) organizations. The maps used in this instance were produced by Instituto Brasiliero de Geografia e Estatistica (IBGE), the Brazilian Institute of Geography and Statistics, which has a program for 10-yearly updates to maps in this series. This forms Brazil's 1:1,000,000 topographic map series, designed to be compatible with IMW standards.

Paper maps from this series were adapted for digitizing, then digitized by the Geographical Survey Institute of Japan to provide source data for the Amazon basin and adjacent areas. The maps used for this project had a 100-meter contour interval. USGS used ANUDEM-based contour-to-grid techniques to create DEMs from these digitized map areas. That procedure is described in Section 5.A.vii.



Cell-centered registration; contour-to-grid value computed.

Graphic describing georeferencing and sampling for IMW map conversion.

Plate 28 shows sharp spikes and broader peaks occurring at 100m increments below 1000m. There is also a separate spike at 1200m, spikes at 500m increments to 3000m, and at 1000m increments above 3000m, suggesting these are contour values in the original source maps. The histogram shows a proportionately large amount of coverage around 4000m elevation.

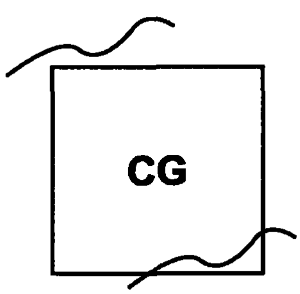
5.A.x. Map for Part of Peru

Primary Developer:	Ministerio de Guerra, Peru
Title:	Mapa Fisico Politico del Peru
Publication Date:	1984
Bibliographic Citation:	Ministerio de Guerra, 1984. *Mapa Fisico Politico del Peru.* Ministerio de Guerra, Lima, Peru.
Post-processing:	Geographical Survey Institute (GSI, Japan) and U.S. Geological Survey (USGS) for GTOPO30.
Bibliographic Citation * for Post-processed DEM:	Ministerio de Guerra, GSI and USGS, 1997. *30"-gridded DEM from Peruvian Maps.* USGS, EROS Data Center, Sioux Falls, South Dakota.
Source/Lineage Category:	17

* Primary reference citation for this source

Small areas of a 1:1,000,000-scale map, entitled *Ministerio de Guerra Mapa Fisico Politico del Peru,* produced in 1984, were adapted for digitizing to fill gaps in source data for South America. The map had a contour interval of 1000 meters. Digitizing was done by the Geographical Survey Institute of Japan.

USGS used ANUDEM-based contour-to-grid techniques to create DEMs from these digitized map areas. That procedure is described in Section 5.A.vii.



Cell-centered registration; contour-to-grid value computed.

Graphic describing georeferencing and sampling for Peru map conversion.

Plate 29 has broad peaks and sharp spikes at increments of 1000m, with a subsidiary peak/spike at 500m, and few values below 400m. The latter is consistent with the coverage of this data set, which includes no coastal areas.

5.A.xi. Antarctic Digital Database

Primary Developer:	Scientific Committee for Antarctic Research
Title:	Antarctic Digital Database
Publication Date:	1993
Bibliographic Citation:	Scientific Committee for Antarctic Research, 1993. *Antarctic Digital Database on CD-ROM.* Scott Polar Research Institute, Cambridge, England.
Post-processing:	U.S. Geological Survey (for GTOPO30); NOAA/National Geophysical Data Center (for GLOBE).
Bibliographic Citation * for Post-processed DEM:	USGS, 1996b. *30 Arc-second-gridded Digital Elevation Model Derived from the Antarctic Digital Database (SCAR, 1993).* USGS, EROS Data Center, Sioux Falls, South Dakota. (*In* USGS, 1997; also *in* GLOBE Task Team and others, 1999.)
**	Hastings, David A., and Paula K. Dunbar, 1999. *Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Documentation, Volume 1.0.* KGRD 34, NOAA, National Geophysical Data Center, Boulder, Colorado, pp. 55-56.
Source/Lineage Category:	18

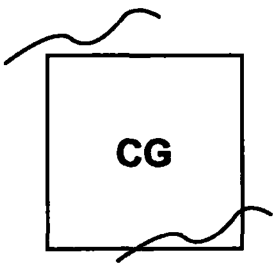
* Primary reference citation for this source
** Reference citation noting repairs to data from this source

The Antarctic Digital Database (ADD) was produced under the auspices of the Scientific Committee on Antarctic Research (SCAR). This project compiled topographic contour maps from eleven nations into one collection. 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 ADD vary widely, with the more detailed data near the coastline and very generalized data in the interior of the continent. The coastline was updated using 1:1,000,000-scale satellite images. Detailed documentation and metadata provided in ADD identifies the map scale from which each contour line was extracted. The data base is available on CD-ROM.

Digital contours and coastlines from ADD were used as source material for Antarctica. They were converted to DEMs at USGS, using contour-to-grid techniques. That procedure is described in Section 5.A.vii.

GLOBE quality control detected edge-effect errors in the USGS adaptation of ADD. The westernmost column bordering on 180°W longitude, easternmost two columns, and southernmost row bordering on the South Pole contained nominal flag values instead of actual elevations. These errors were corrected by NGDC for GLOBE.



Cell-centered registration; contour-to-grid value computed.

Graphic describing georeferencing and sampling for ADD conversion.

Plate 30 shows a broad peak about 3000m elevation, typical for ice caps. The precipitous drop in the histogram at 4050m, with very few elevation values trailing off to about 4700m is notable, as is the modest trough in values between 0 and 200m elevation. Spikes at every 100m of elevation from 200m through 4000m suggests 100m contour intervals for significant parts of the map. However, the data base is documented as having various horizontal scales and levels of contour detail.

There are several DEMs and spot elevation data sets derived from satellite altimetry for Antarctica. Several of these are being evaluated for future versions of GLOBE.

5.B. Assembly of GLOBE Version 1.0

DEMs from various sources were merged several times during the life of the GLOBE project:

1. Twenty-six DEMs and Digital Bathymetric Models from various sources were merged at NGDC to form TerrainBase. TerrainBase was primarily a lower-resolution data set. However, DEMs for the U.S. and environs, and for Italy, were available at 30" gridding for GLOBE.

2. DEMs for various sources were merged at JPL for its MISR DEM. The JPL contribution to GLOBE consists of coverage of Greenland, where DTED are not available.

3. DEMs from many sources were merged by USGS, during the creation of its GTOPO30. These merges included USGS's selection of its preferred raster-derived DEMs, then its selection of preferred DEMs from cartographic sources. The following text is USGS's (1997b) description of its process of "learning as the project progresses":

   > "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."

The following is USGS's (1997b) description of its merging of raster- and vector-derived DEMs within GTOPO30:

"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."

The following is USGS's (1997b) description of its final data assembly to make GTOPO30:

"The global product was assembled from the continental and regional DEMs. 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."

Categories 2, 3, 5–7, 11, and 14–18 in the GLOBE source/lineage map were originally compiled by USGS into GTOPO30. (GTOPO30's source map does not differentiate lineage, thus does not differentiate its various methods of handling data from DTED-based sources.) NGDC reassembled the USGS/GTOPO30 tiles before assembling GLOBE. In addition, it edited the USGS/GTOPO30 source file to represent the various methods of resampling used in GTOPO30 (that were not all documented in USGS's source file). This last editing is representational, to help make users aware of these resampling techniques. The actual boundaries depicted between resampling techniques are estimates, based on verbal descriptions by USGS scientists.

4. The MISR and GTOPO30 DEMs were made by their creators to meet their own objectives. Finally, NGDC selected and merged available data into GLOBE. This effort used DEMs generated by Zwally (and others)/NSIDC/JPL for Greenland. Many parts of GTOPO30 were used, including the DEM contribution for New Zealand, the SCAR vector data, and the maps cooperatively selected and converted to DEMs by GSI and USGS. Additional input data came from AUSLIG, GSI, NIMA, and SGN. The merging process is described below.

Please note that peer review for this merging continues. Future versions of GLOBE will incorporate peer review comments. If appropriate, substitutions of data will be made.

5.B.i. Quality Assessment

5.B.i.a. Japan

Data coverage for Japan was available from GSI, NIMA and USGS/GTOPO30. The peer review Web site for GLOBE notes that the data are all of relatively high quality. However, inspection of the data for Japan helped to confirm independent peer review comments that the NIMA (DTED Level 0) "mean" values are sometimes lower than the "minima." Actual data values for all candidates tended to disagree by very little. Shaded relief, slope, and aspect images appear nearly identical, as a rule. However, the histograms of the GSI data were notably smooth, lacking the spikes common in DEMs generated from cartographic sources (and which had typical spike patterns in the GTOPO30 and NIMA versions). This suggests that a common artifact in DEMs developed from cartographic sources was addressed more thoroughly in the GSI DEM of Japan than in any other DEM from such sources ever seen by ourselves. The result is a DEM that has the smoothest distribution of elevations, and the least "binning" favoring contour values of source maps, of any candidate DEM. Thus, the GSI DEM was selected for Japan.

5.B.i.b. Italy

Data coverage for Italy was available from SGN/NGDC, NIMA and USGS/GTOPO30. (The latter candidate had high-resolution SGN source materials, reprocessed as described in Section 5.A.iv by NGDC to 30".)

Again, data from all candidates were of relatively high quality. However, histograms of the SGN data showed significantly less spiking than those for NIMA and GTOPO30. Similarly, slope, aspect, and shaded relief analyses showed that the SGN data were of somewhat higher quality at higher elevations, but of much higher quality at lower elevations. This probably reflects a more detailed scale of SGN's source materials, with smaller contour intervals than may have been used by NIMA to make DTED Level 1 data. In the areas of the SGN/NGDC DEM that contained holes (see Section 5.A.iv), DTED Level 0 discrete values were inserted. Thus, the SGN/NGDC DEM was selected for Italy, supplemented where it had holes by DTED Level 0 discrete values.

5.B.i.c. Australia

Data coverage for Australia was available from AUSLIG/NGDC, USGS/GTOPO30, and JPL. The AUSLIG data (see Section 5.A.ii) contain considerably higher level of detail, so were selected for the "Best Available Data" (*B.A.D.*) version.

However, this version contains data copyrighted by, and licensed for, GLOBE distribution from AUSLIG. As this version may present some difficulties for some users, an unrestricted "*G*lobally *O*nly *O*pen-access *D*ata" (*G.O.O.D.*) alternative from GTOPO30 (see Section 5.A.vii) is also available. Although accuracy assessments by University College London suggested that the JPL version may have slightly greater overall absolute accuracy, that version contained specific areas with considerable artifacts. It is possible that future versions of GLOBE may contain mosaics of JPL and USGS data.

Note that the land areas covered in the *B.A.D.* and *G.O.O.D.* versions of GLOBE differ slightly. This is because the AUSLIG data coverage extends slightly into areas considered oceans by World Vector Shoreline, which defined the limits of contour-to-grid conversion in the USGS DEM. Thus the AUSLIG/NGDC DEM for Australia exhibits slightly greater land area in some areas than does the USGS DEM for Australia.

The process that modified the land mask for the AUSLIG-based data is described in Section 5.A.ii.

5.B.i.d. Greenland

Data coverage for Greenland was available from Zwally (and others)/NSIDC/JPL and DCW, with very limited NIMA coverage. A review by J.-P. Muller of University College London determined that the JPL version compared much more favorably with available point elevation control (Muller and Mandanayake, 1998a; Muller and others, 1998b). NGDC's assessment of the DEMs suggested that the Zwally (and others)/NSIDC/JPL DEM was best in the interior and northerly coastal areas characterized by permanent ice. DCW (or DTED where available) was preferred in southerly coastal areas.

NGDC scientists inspected Zwally (and others)/NSIDC/JPL, DCW, and DTED DEMs, to determine which sources were preferable for which areas. Using inspection, a two-degree wide zone for linear blending was created. The two DEMs were used equally in the middle of the zone. Weighting was adjusted 4 percent every 5 minutes throughout the zone.

In very limited areas, the DCW coverage extends oceanward from the mosaicked DTED and Zwally (and others)/NSIDC/JPL data. This is because of different interpretations of coastlines between the three candidate DEMs in this area. Such differences in interpretation of coastline are common. They are especially common in polar areas where the edge seasonal or "permanent" ice may be accepted as coastline in some data sets when it overlaps coasts onto the ocean, whereas other data sets discount such ice features and attempt to determine the "dry land" coastline below such ice. In such areas, the DCW data were patched into GLOBE Version 1.0.

In other limited areas, the Zwally (and others)/NSIDC/JPL DEM extended oceanward of the limits of DCW or DTED coverage. In these cases, the coastal mask used in GTOPO30 data was honored by GLOBE, so any Zwally (and others)/NSIDC/JPL DEM coverage coincident with this ocean mask was not used in GLOBE.

Note that several alternative candidate data sets are available for Greenland. These are still under evaluation, with further development being pursued. This may (or may not) result in improved coverage for Greenland in a future version of GLOBE.

5.B.i.e. Antarctica

Data coverage for Antarctica was available from SCAR/USGS, via USGS/GTOPO30, and several other candidates. The SCAR/USGS data set was originally compiled from various sources by SCAR, then converted to 30" DEM grid by USGS as described in Section 5.A.xi. The data from other candidates were not ready for peer review in time for GLOBE Version 1.0.

Though the quality assessment noted that improved alternatives are under development (e.g. Muller and Mandanayake, 1998a), there was no assurance that such data would soon be available for public distribution.

Quality assessment of the candidates favored the SCAR/USGS model, but also found edge effects in that model (see Section 5.A.xi for discussion). The SCAR/USGS DEM, as repaired by NGDC, was selected for Antarctica.

5.B.i.f. Conterminous United States and Vicinity

Data coverage for the conterminous United States and some neighboring areas was available from AMS/DMA/NIMA sources, with several lineages:

- One 30" version was contributed directly from NIMA to NGDC for GLOBE. This version (DTED Level 0) includes spot, minimum, mean, and maximum 3" values for each 30" grid cell. However, independent peer review led to the discovery that the "mean" values were frequently lower than the "minimum" values, and that the spot values appeared to be the most accurate representative elevation values. These data are the newest and sometimes contain revisions to source data since DMA contributed data to NGDC and to USGS.
- A second version for the conterminous U.S. was previously reprocessed to 30" by DMA and contributed to NGDC for public distribution. This version was contributed to NGDC before DTED Level 0 (noted above) was designed, but after the 3" (noted below) data were contributed

to USGS. Thus, this DMA/NGDC data set may have benefited from enhancements to the topographic data since DMA's contribution to USGS. Both discrete (spot, nearest-neighbor) and average data were contributed to NGDC. As the other data in the region used nearest-neighbor resampling, the spot version of the DMA/NGDC data were considered more appropriate for use in GLOBE Version 1.0.

- A third version at 3" gridding for most of the U.S. except Hawaii was contributed by DMA to USGS for public distribution. (USGS calls this version "USGS 3-arc-second DEMs.") This was a pioneering DEM, perhaps the first gridded DEM ever developed. USGS resampled these 3" data to 30" for inclusion into GTOPO30, using a nearest-neighbor technique. DMA/NGDC data may have received editorial improvements, while NIMA/DTED Level 0 data clearly (according to peer review input) have many such enhancements.

Because of the lineage of enhancements, NIMA/DTED Level 0 were selected where available. Second priority went to DMA/NGDC data. Where neither of these data were available, DMA/USGS data were used.

In several cases in coastal areas, NIMA discrete (spot) grid cells had values of 0 (sea level) where NGDC or USGS data had values above zero. Inspection of these areas led to the observation that the single 3" value sampled to make DTED Level 0 discrete data may have been zero, but the samples used to make the NGDC and/or USGS versions were non-zero. In such cases, NGDC or USGS non-zero values were allowed to replace sea level DTED Level 0 discrete values. A mask was built to prevent inland values of zero elevation from being overwritten by subsequent non-sea-level values. Non-sea-level values were allowed to overwrite values of zero elevation in near-coastal areas. Inspection of the three candidate data sets in near-coastal and inland areas suggested this as the most appropriate procedure for this version of GLOBE. The order of priority was (1) DTED Level 0 discrete value, (2) NGDC value if DTED Level 0 discrete value was zero or ocean mask value, and (3) USGS/GTOPO30 value if the previous two sources were both zero or ocean mask values.

5.B.i.g. DTED within 50° of the Equator

Besides the areas noted above, DEMs within 50° of the Equator were available from NIMA (via NIMA/DTED Level 0) and Manaaki Whenua Landcare Research, Ltd. (LCR) (via USGS/GTOPO30). The coverage for New Zealand from LCR was the only one available at that resolution for New Zealand, so was used in GLOBE. For areas where NIMA/DTED Level 0 data were available, the discrete (spot) values were determined by independent review to be the most consistent and representative values. Thus these were selected, where available, outside of coverage of Japan (GSI) and Italy (SGN).

5.B.i.h. DTED Poleward of 50° North and South Latitudes

Besides areas noted above, DEMs poleward of 50° North and South latitude were available from NIMA, via NIMA/DTED Level 0 and USGS/GTOPO30. DTED Level 0 was decimated at consistent 1/10 ratio from the original spatial resolution of DTED Level 1. (See the table in Section 5.A.i.a for specifics.) Data used in GTOPO30 were resampled to a consistent 30" by 30" grid spacing. Thus the latter carry greater resolution poleward of 50° and were selected for GLOBE Version 1.0.

5.B.i.i. DCW vs. Other Cartographic Sources

Several analyses of DCW-generated 30" DEMs were conducted by USGS and UCL (see Muller and others, 1998c), including comparisons with higher-resolution DEMs, and with other DEM candidates for GLOBE. These analyses tended to show that DCW produced a less-than-ideal DEM. This was largely due to the large contour interval in the source Operational Navigational Charts (ONC). The stylization of ONC contours also contributed to artifacts in derived DEMs. Nevertheless, DCW-based DEMs were determined to be generally much more useful at 30" than regridded ETOPO5 or TerrainBase data (whose source data have grid spacings as coarse as 10').

DCW lacks contours for many parts of the world. In some cases other DEMs were contributed to GLOBE or GTOPO30. In other areas, GSI and USGS located cartographic sources that could be used to supplement DCW.

For parts of Indonesia, Brazil and neighboring South American countries, GSI and USGS located maps for GSI adaption to digital contours, and subsequent USGS contour-to-grid conversion to 30" DEMs.

This effort was only done when DCW contours were lacking or troublesome. Thus, for every area where other cartographic sources were used, those other sources were automatically preferred. DCW-based DEMs are unavailable for such areas.

5.B.ii. Global Data Set Assembly

GLOBE's final assembly was created in GRASS' r.patch module. This module combines data of various grid spacings and coverage areas into a resultant data set of defined coverage area and grid spacing. GRASS lets one work within a defined mask. It first inserts the highest-priority data set into the output grid, then replaces all remaining areas with a "0" value with values from the next-highest priority data set, *ad infinitum*. Working masks can be changed at any point in the sequence; this requires restarting r.patch.

The first task was to determine the priority of patching. The second task was to determine the mask(s) to be applied at each stage of patching. As GRASS version 4.1x uses zero as its "no-data" mask, and cannot distinguish between numerical zeros and areas of "no data," one must design masks to compensate for this characteristic of the software. Subsequent versions of GRASS, currently under development, are not subject to this characteristic. However, GLOBE Version 1.0 was managed under GRASS 4.1.4, which does have this characteristic.

The following patching sequence was used:

a. Insert Japan-GSI. (No mask applied during the patch.)

b. Insert Italy-SGN. (Japan-GSI coverage mask applied, but this is trivial.)

c. Insert Australia-AUSLIG/NGDC to *B.A.D.* GLOBE. Insert Australia-DCW/USGS/GTOPO30 to *G.O.O.D.* GLOBE. (Mask accounting for previous steps applied, but this is trivial.)

d. Insert Antarctica-SCAR/USGS/GTOPO30 as repaired by NGDC. (Mask accounting for previous steps applied, but this is trivial.)

e. Insert for conterminous U.S. and vicinity:

   i. NIMA spot data. (Mask accounting for previous steps applied, but this is trivial.)

   ii. DMA/NGDC data.(Mask accounting for previous steps applied, now nontrivial. This mask prevents overwriting of inland areas at sea level, but allows non sea-level values in DMA/NGDC data to overwrite sea-level values in NIMA spot data in coastal areas.)

   iii. DMA/USGS/GTOPO30 data. (Mask accounting for previous steps applied. This mask acts as the previous mask, allowing coastal zeros to be overwritten by coastal non-zeros.)

f. Insert NIMA spot data within 50° of the Equator. (Mask accounting for previous steps applied.)

g. Insert NIMA/GTOPO30 data poleward of 50° of the Equator. (Mask accounting for previous steps applied.)

h. Insert DEM for Greenland, including Zwally (and others)/NSIDC/JPL-DCW blend. (Mask accounting for previous steps applied.)

i. Insert DEMs from cartographic sources. (Mask accounting for previous steps applied. This allows DEMs from cartographic sources to line some coastal areas, such as limited areas in Greenland.)

Plate 1 (page 19) is a histogram of elevation distributions in GLOBE. Prominent features in this histogram can be traced to features within individual sources of data. Histograms of these data are plotted in Plates 2–30 and discussed in Section 5.A. For example:

- Spiking is more prominent at elevations of 4000m and below, as few data from cartographic sources appear to cover areas with elevations higher than 4000m.
- The abrupt falloff in values above 4000m visible in the Antarctic Digital Database (Plate 30) is prominent in Plate 1.
- The bulge in elevation values around 5000m visible in DTED discrete coverage of Asia (Plate 3) is visible in Plate 1.
- The bulge in elevation values around 2500–3000m visible in ADD (Plate 30), and Greenland (Plates 20 and 21) is visible in Plate 1.

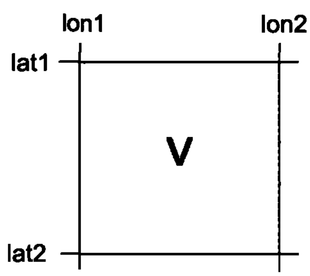
Inspection of the resultant DEM shows a relatively good fit between pieces, though there seems to be a modest disagreement between DCW-derived grids and DTED over vertical datum. In addition, the forcing of 0 elevations to 1 in categories used in GTOPO30 may cause difficulties for some users. However, discrepancies appear to be in this order of subtlety.

5.B.iii. Georeferencing of GLOBE

Individual source materials used by GLOBE have a variety of internal georeferencing schemes. This may raise questions of how to georeference the entire GLOBE DEM in one's application.

Each GLOBE grid cell is bounded by integer increments of 30 arc-seconds of latitude and longitude. Feed this information through your software's georeferencing conventions. For example:

- If your software uses the center of grid cells for reference, you probably would use 179°59'45" West longitude, 89°59'45" North latitude as the center of the first grid of Tile A.
- If your software uses the outside edges of extreme cells for your reference, you may use something like 50°N–90°N and 180°W–90°W as the edges of tile A.
- For more information, contact the support personnel for your software.



Grid cell edges, lon1, lon2, lat1, and lat2 are integer increments of 30". Internal georeferencing varies by source. (See Sections 5.A.i through 5.A.xi.)

Graphic describing georeferencing for the entire GLOBE grid.

5.B.iv. Comparison of GLOBE with Other Available DEMs

GLOBE has considerably higher resolution than earlier predecessors ETOPO5 and TerrainBase. Although TerrainBase was originally considered a candidate for filling GLOBE with areas lacking higher-resolution data, GLOBE ultimately found 30" data from other sources for all areas but Antarctica and Greenland. (The converted SCAR data base, and several other candidates for supplementing GLOBE coverage of Antarctica, are considered better than ETOPO5/TerrainBase; the Greenland GEOSAT-based DEM was converted to 30" by JPL.) GLOBE is a likely source for updating the next version of TerrainBase, which will be regularly updated until user interest indicates that it should be discontinued.

The TerrainBase management philosophy of soliciting contributions, and proactively offering to participate in the design and development of unrestricted regional DEMs for the global compilation, will be continued in the GLOBE project. TerrainBase and GLOBE served as prototypes for each other during TerrainBase's design and development. TerrainBase's efforts at data compilation led to the SGN DEM for Italy which has since been adapted to GLOBE.

JPL's DEM at 30" was developed for internal support of NASA's Multiangle Imaging Spectro-Radiometer (MISR) mission. The project had permission to reprocess DTED Level 1 data to 30" gridding, but not to share those data with the general public. In addition, JPL used contour-to-grid techniques to convert DCW to 30" DEMs in many areas; but not to the level of effort of USGS's effort with GTOPO30. JPL's effort was largely crafted to meet its mission. Nevertheless, J.-P. Muller's comparison of GTOPO30 and the MISR DEM favored the MISR version for Greenland. As that data set was largely unrestricted, the GLOBE project has incorporated unrestricted coverage for the Greenland Ice Sheet into GLOBE.

The USGS/GTOPO30 effort was also developed partially for NASA, for more general support of NASA's Earth Observing System science community. It worked extensively to develop DCW contour-to-grid procedures. It also acquired and processed several gridded DEMs, and worked cooperatively with GSI to adapt several printed topographic maps to DEMs. Much of its data were incorporated into GLOBE.

The GLOBE project added several data sets, including the first public release from DTED, the AUSLIG/NGDC DEM, and DEMs from GSI and SGN. GLOBE uses the DTED Level 0 discrete values where available between 50° North and South latitudes, where GTOPO30 uses several inconsistent sampling methods for different areas. The GLOBE project also added the public peer review site, enhanced documentation, and enhanced features on its Web site. Periodic enhancements to data and documentation are anticipated.

5.B.v. GLOBE's Development as Additional DEMs Are Created

GLOBE plans to continue seeking additional data, continue enhancing data quality and documentation, and continue maintaining GLOBE products until the U.S. Department of Defense/NASA Shuttle Radar Topography Mapper (SRTM) mission or other projects produce DEMs that exceed GLOBE's standards and capabilities.

It is hopeful that the SRTM mission, currently scheduled for launch in late 1999, will achieve its objective of a publicly unrestricted 3" DEM for 60° North to South latitudes by 2001–2002, possibly supplemented by similar data for higher latitudes. It is also hopeful that at least some areas of the world will see 1"-gridded data released to the public from SRTM and from other high-resolution imaging satellites being developed by several companies.

However, while SRTM is currently funded, there is no guarantee of its successful completion. Beyond completion of its DEM mapping task, SRTM data must receive a thorough quality assessment which could be a worthwhile contribution provided by an independent effort like GLOBE's.

GLOBE may be put to rest after the full global SRTM (with enhancements) 3" DEM is complete. However, it is possible that GLOBE coverage may remain the best widely-accessible data for parts of the world well after completion of the SRTM mission.

6. Imperfections in Digital Elevation Data

As with all digital geospatial data sets, users of GLOBE 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 GLOBE 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.

6.A. Grid Spacing and Resolution

For any application, the horizontal grid spacing (which limits the resolution) and the vertical accuracy of GLOBE 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	Ground distance (meters)	
(degrees)	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
74	256	930
78	193	930
82	133	931
86	64	931
89	16	931
90	0	931

Resolution is defined as the minimum distance between two objects that can be separated in the image. Many people mistakenly equate "resolution" to "pixel" or grid cell size, when resolution is actually approximately 2.83 times grid cell size. Thus, the numbers above should be multiplied by 2.83 to get an estimate of horizontal resolution.

Users should maintain this distinction between grid spacing and resolution. Even though the global data set has a consistent 30 arc-second grid spacing, not all topographic features will be resolved at that spacing. 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.

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.

Certainly, a 30 arc-second grid spacing is appropriate for the areas derived from higher resolution DEMs (DTED, Japan-GSI, Italy-SGN, 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 (the *G.O.O.D.* version from DCW) contains larger such areas. Australia (the *B.A.D.* version from AUSLIG sources) also has variable source point distribution, though distribution tends to be higher in areas of higher relief, tending to lead to higher horizontal resolution where needed. The quality of the contours from the Antarctic Digital Database 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.

6.B. Topographic Detail and Accuracy

Differences in topographic detail among the sources are evident in GLOBE. 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 noticeable. Seams within data from "a single source" are sometimes apparent. Examples include DMA/USGS data in the Seward Peninsula of Alaska and DTED coverage near Cordoba and Mendoza, Argentina.

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 half of the 1°x1° DTED cells (the production and distribution unit for full resolution DTED) have an absolute vertical accuracy worse than the product specification of ± 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.

6.C. Production Artifacts

Artifacts due to the production method are apparent in some areas of GLOBE. While the magnitude of the artifacts in a local area are usually well within the estimated accuracy for the source, they may affect some applications of the DEM.

Some areas derived from DTED exhibit a striping artifact, most likely due to the production method of the DTED (see Section 5.A.i.a for more information). 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 a reflection of the 1° tiling structure of the full resolution DTED from source data with certain characteristics (Section 5.A.i.a). These areas derived from contiguous DTED 1°x1° cells appear blocky because of vertical offsets among the tiles in the original full resolution DTED.

The artifacts in the DTED areas may be visible or obscured, depending on the method used to display the data. For instance, when viewing the DEMs as an image either in shades of gray or color, the artifacts may be subdued or 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 course-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 are sparse. Additionally, a "stair step" (or terracing) effect may be seen in profiles of some areas. Here 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. Histograms of elevations show sharp peaks at elevations that are multiples of the source's contour interval. This effect is common in DEMs 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. However, some level of these conditions inevitably remain due to the nature of vector-to-raster surface generation.

7. Accuracy

GLOBE's accuracy can be subdivided into horizontal and vertical accuracy, and again into absolute and relative accuracy.

7.A. Horizontal Accuracy

Horizontal accuracy can be affected by errors in horizontal positioning of features, or errors in recording horizontal datum. Horizontal accuracy may differ between sources. In some cases, it may also differ within sources, if multiple sources were used. For example, DTED Level 1 data contained data from various cartographic sources, as well as from various types of imagery. If individual map sources had errors in recorded horizontal datum, or had misplaced contour lines (as could happen during compilation or in printing), the resultant DEM would be misplaced horizontally, in an undocumented fashion. If individual sources of imagery had errors in image navigation, resultant DEMs could be mislocated if these errors were not corrected during development of respective DEMs.

7.A.i. Data from Raster Data Sources

In most cases, data from DTED Level 1 3" source materials (source/lineage categories 2–7) can be expected to have 15" or better horizontal accuracy. Thus, nearest-neighbor resamplings to 30" gridding for the MISR DEM, GTOPO30, and GLOBE should remain within the appropriate 30" grid cell. This would make no measurable horizontal error for such data.

In the case of DTED Level 0 discrete (spot) data (source/lineage category 1), the reference location is at the southwestern corner of each 30" grid cell. Errors as small as 100m in horizontal datum might misplace a DTED discrete value into an adjacent 30" grid cell, making for a maximum anticipated absolute horizontal error of one 30" grid cell. Relative horizontal inaccuracy from such data could be comparatively high—on the order of one grid cell relative error on (probably rare) occasions.

Source/lineage categories 9–11 probably have horizontal errors of less than 30" for almost all parts of the world.

Data from satellite altimetry, such as were used for part of Greenland (source/lineage categories 12 and 13) may be mislocated due to inaccurate determination of the satellite's location in space. As these data were originally gridded at larger than 30" intervals, oversampling to 30" for the MISR DEM might have permitted horizontal errors of more than 30" in source/lineage categories 12 and 13 in GLOBE. We currently have no formal estimate of the horizontal accuracy of such data, other than to assign the GEOSAT gridded DEM grid cell size of 10km to the likely horizontal locational accuracy.

7.A.ii. Data from Cartographic Sources

Topographic contour lines in maps at 1:1,000,000 scale used for DCW and source/lineage categories 15–17) can be stylized so as to be 30" (one GLOBE grid cell) off. The SCAR data base (source/lineage category 18) could be mislocated by a greater amount, owing to the relatively pioneering status of current mapping of Antarctica. However, errors can exceed such figures locally. For example, the ONC for northern Greenland contains notices such as: "CAUTION: Arctic Institute of North America Project Nord (Control Data Corp.) indicates position discrepancies in excess of 11 nautical miles (Nov. 68)."

In addition, surface generation algorithms might impose horizontal errors at least 30" off in areas without much control by contour lines. This is because interpolated surfaces may be misguided by patterns in point or contour data sources, especially where such data are stylized or scarce.

Similarly, the AUSLIG/NGDC data (source/lineage category 8) may be shifted horizontally by the interpolation process, in areas with relatively low density of source data. Due to the high density of source data points, this problem should be unusual. Stylization of source maps should have little effect on horizontal accuracy in GLOBE, as these have relatively high resolution.

7.B. Vertical Accuracy

The absolute vertical accuracy of GLOBE varies by location according to the source data. Generally, areas derived from raster source data have higher accuracy than those derived from vector source data. However, some data that were delivered to GLOBE (or to the MISR or GTOPO30 DEMs) as rasters came from cartographic sources, thus complicating assessment of their accuracy.

7.B.i. Absolute Accuracy: Data from Raster Sources

Digital Terrain Elevation Data (DTED): The full resolution 3" DTED have a vertical accuracy of ± 30 meters (two-sigma) linear error at the 90 percent confidence level (Defense Mapping Agency, 1986), where they meet specifications. 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 these assumptions, vertical accuracy expressed as ± 30 meters linear error at 90 percent can also be described as a RMSE of 18 meters.

The areas of GLOBE derived from DTED might be interpreted to retain (or slightly improve upon) the level of vertical accuracy found in the source 3" data. This is because the representative value computed during compositing to 30" is either a simple value (as in nearest-neighbor or spot sampling) at the same vertical accuracy as the source data, or is a computation (as a mean or median) that should reduce some of the random error in a sample of source 3" values.

A visual inspection of DMA's (1995) map, *Available DTED1 Cells by Accuracy Range*, suggests that about half of DTED coverage meets specifications, while the other half fails to meet horizontal, vertical, or both horizontal and vertical specifications. About 25% of DTED has 30–50 meter vertical accuracy and 0–50 meter horizontal accuracy; about 15% has 0–50 meter vertical and 50–131 meter horizontal accuracy. Ten percent has either (1) 50–9999 meter vertical and 0–131 meter horizontal accuracy, or (2) 0–9999 meter vertical and 131–9999 meter horizontal accuracy. Specific accuracy information for each 1°x1° DTED cell is contained in DTED Level 0 header information on NIMA's Web site.

Shaded-relief images produced from DTED sources show two fairly common shading patterns suggestive of vertical errors:

1. Striping apparently caused by stereoprofiling techniques or use of satellite scanner imagery. The amplitude of these errors is usually small, in the 0–20 meter range. These appear to be within NIMA's tolerances for DTED.
2. Blocking around the edges of individual 1°x1° DTED Level 1 tiles (DTED cells). These appear to be edge effects due to subtle de-facto disagreements about (most likely) vertical or (possibly) horizontal datum between DTED tiles. These also appear to be well within vertical accuracy specifications set by NIMA for DTED for their respective DTED tiles.

Note that NIMA allows for vertical errors as great as 9999 meters, for some areas. This appears to be an extremely conservative figure.

Other Raster Data Sources: Data for Italy, Japan, and New Zealand were supplied as raster data. However, their documentation notes that they were derived from cartographic sources. These are discussed below. Zwally (and others)/NSIDC/JPL data for Greenland were derived from satellite altimetry. Assessment of vertical accuracy of this data set is not yet complete.

7.B.ii. Absolute Accuracy: Data from Cartographic Sources

Digital Chart of the World (DCW): The absolute vertical accuracy of the DCW, the vector source with the largest area of coverage, is stated in its product specification as ± 650 meters linear error at the 90% confidence level (Defense Mapping Agency, 1990). USGS's (1997b) experience while converting DCW to grids 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 areas derived from DCW vector hypsography, USGS compared its DCW grid to 30 arc-second DTED, which had been aggregated by averaging in selected areas of overlap with DCW coverage. 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. Those areas of the DCW grid for which supplemental DTED point control had been included in the gridding process were eliminated from the comparison.

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 ± 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 (USGS, 1997b).

AUSLIG Source Data: The accuracy of AUSLIG spot elevations in its source relief layer varies with the type of source material from which they were captured. AUSLIG provided the following table, giving estimates of vertical accuracy applicable to each source of point determination in terms of its standard deviation in meters:

Spot height	5
Spot height inside depression contour	5
Spot height on sand ridge	5
Point captured from 20m contour	10
Point captured from 40m contour	20
Waterline (edge of sea)	25

NGDC's estimate of 10m linear error at the 90% confidence level from histogram analysis can be considered as an overall empirical estimate for the DEM derived from these sources, weighted by the volume of data from the various sources. The estimate was derived from the dominant implied contour interval in the grid of 20m, plus the dense coverage of source data compared to the 30" output grid.

Other Sources: The accuracy of the areas of GLOBE 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 ± 1/2 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. However, histogram analysis of DEMs derived from cartographic sources of undocumented contour interval can often be used to estimate contour intervals from those original cartographic sources.

Table 2 (next page) lists the estimated absolute vertical accuracy for the areas of GLOBE 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).

7.B.iii. Relative Accuracy

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.

Table 2. Estimated Absolute Vertical Accuracy for Areas of GLOBE

Source	Vertical accuracy (meters) L.E. at 90%	RMSE	Estimation method
DEM for Japan	10	6	estimated from histogram analysis of DEM*
DEM for Australia	10	6	estimated from histogram analysis of DEM
DEM for Italy	13	8	estimated from 25-meter contour interval**
DEM for New Zealand	15	9	estimated from 100-foot contour interval
DTED	30–200	18–120	product specification for lower figure; higher figure estimated from DMA DTED coverage map categorizing horizontal and vertical accuracy by location
Maps for Brazil	50	30	estimated from 100-meter contour interval
DEM for Greenland	150	91	estimated from histogram analysis of DEM
DCW	160	97	calculated vs. DTED
Maps for Asia and S. America	250	152	estimated from 500-meter contour interval
Map for Peru	500	304	estimated from 1000-meter contour interval
SCAR/USGS	500	304	estimated from histogram analysis of DEM

* Here is a description of our method of estimating vertical accuracy from histogram analysis of the DEM. Since traditional contour map production goals include vertical accuracy of 1/2 of the contour interval, the estimates above by USGS for contour maps equate 1/2 of the source map's contour interval to vertical accuracy. Histogram analyses of DEMs can often determine the likely contour values of source maps. These interpreted contour intervals were halved to estimate vertical accuracy of DEMs. In many cases, more than one contour interval appears to exist in DEMs, perhaps because the DEMs were produced from various types of maps, or perhaps because of supplemental contour intervals. In such cases, vertical accuracy was estimated conservatively.

** Just outside of Italy, but included in the Italian DEM, some sources had somewhat coarser contour intervals. In addition, histogram analyses within Italy suggests that different supplemental contour intervals were used (to 5 meters in low-gradient areas (Salvi, 1995)), and that some contour lines were decimated in mountainous terrain, especially in northern Italy. Nevertheless, the estimates noted above are probably reasonably accurate.

7.B.iv. Summary: How to Use These Assessments

If you are developing critical applications, the accuracy figures estimated here should only be a starting point for your own assessments. For example, areas of rugged topography can be expected to have different (probably coarser) absolute and relative accuracies than areas of subdued topography. Also, mixtures of map and imagery scales (and types) may have been used in developing some DEMs. In the United States, for example, areas in the mountainous West may have contour intervals of about 60m (200ft), whereas in parts of North Dakota, 2m (5ft) supplemental contours exist in places. The figures in Table 2 are an attempt to provide information, and are certainly not a commitment to such levels of accuracy anywhere in the data base.

7.C. Additional Accuracy Assessments by Peer Reviewers

University College London: J.-P. Muller of UCL performed accuracy assessments of GTOPO30 and the JPL/MISR DEMs, as well as the AUSLIG/NGDC DEM (Muller and others, 1998a, 1998b, 1998c). This was done by compiling a large number of point elevation values, such as from the commercial Jeppesen airport data base, and various geophysical data bases from NGDC, such as the elevations of gravity observation stations. He found that the JPL/MISR DEM was slightly more accurate than GTOPO30, with Australia and Greenland particularly better. However, the AUSLIG/NGDC DEM was preferred over the other two available compilations in Australia.

One outcome of this study was the concern over the general quality control of the point elevation data used in the comparisons. One airport elevation appeared to be several thousand meters off and other values seemed unreasonable. Muller noted that "what constitutes the control" and "what constitutes the data set being tested against the control" was unclear. Muller used statistical techniques to reject point data that disagreed with the DEMs by more than 300m, based on the estimated "worst case" RMSE shown in Table 2 (previous page). This served as an attempt to remove point elevation values with significant unknown errors that might have crept into point data bases without quality control.

J.-P. Muller (1997; Muller and others, 1998b) used a global compilation of ERS-1 (Earth Resources Satellite) radar altimetry data at 5' (Bamber and others, 1997; Bamber and Muller, 1999) to compare with other DEMs. The MISR DEM was slightly higher quality than GTOPO30, and the AUSLIG/NGDC DEM was best for Australia by a factor of 2 compared to the other options.

National Oceanic and Atmospheric Administration: Dru Smith of NOAA's National Ocean Service performed comparisons between full-resolution DTED Level 1 data, other DEMs and geodetic models, and DTED Level 0 means, maxima, minima, and discrete (spot) values. He found that the DTED Level 0 mean values tended to be considerably lower than corresponding derivations made directly from DTED Level 1 data. They also were lower than other DEMs and geodetic models available to him. He was concerned that DTED Level 0 might have had a production bug. However, he found the DTED Level 0 discrete values to be reasonable.

De Montfort University: P.A.M. Berry of De Montfort University (United Kingdom) compared ERS-1 and ERS-2 altimetry with DTED Level 0 means and discrete values. The satellite altimetry should have a longer spatial wavelength view of topography than DTED Level 1, though perhaps shorter wavelength than DTED Level 0. Initial comparisons with DTED Level 0 means also noted a significant discrepancy with ERS-1 and ERS-2 altimetry-derived elevations. DTED Level 0 means seemed significantly lower than ERS-derived elevations produced by Berry. Later comparisons between ERS-derived elevations and DTED Level 0 discrete values in the central United States suggested much better overall agreement. Berry plans further assessments, including the development of a map showing differences in the geographic distribution of GLOBE and her ERS-derived elevations.

Geographical Survey Institute: Hiroshi Murakami of the Geographical Survey Institute of Japan compared DEMs of Japan produced by GSI with others produced by USGS from DCW. This study suggested that DCW for Japan did not use Mean Sea Level as vertical datum, but rather had used the

Japanese national datum. In short, it appeared that DCW had been mislabeled as to vertical datum for Japan. This mislabeling could have been caused by inaccurate or inaccurately interpreted source material documentation for the Operational Navigation Charts upon which DCW was based.

Use of These Studies in GLOBE: The studies by Muller helped in the selection of candidates for GLOBE. The independent studies by Smith and by Berry helped NGDC select the DTED Level 0 discrete values as preferable for GLOBE, where available between 50° North and South latitude. These values might also have been selected where available poleward of 50° latitude. However, their lower horizontal resolution made the GTOPO30 versions preferable at such higher latitudes, as noted in Section 5.B.i.h. The study by Murakami suggests modest caution when using elevations derived from DCW.

7.D. Additional Comments on Accuracy

Note that various methods for measuring the terrain surface do not necessarily measure the same objective. In-situ surveys (such as Global Positioning System or cadastral surveys) tend to measure at a location above the ground surface, then compute the ground elevation below the "known" ground clearance of the measurement. Stereo-optical imagery may measure the top of tree canopy—which may or may not be converted to the elevation of the ground surface when the DEM is made. This could be considered an issue of "attribute accuracy." That is, are DEMs measuring what they purport to measure? In most cases, the source data sets for GLOBE have not been able to address this issue.

In addition, misrepresentations or errors in vertical datum could lead to 100+m errors in a DEM. This may happen when information is missing from a map and an analyst makes an incorrect assumption about the map. For example, the analyst may assume a particular ellipse in reprojecting data, when another ellipse, or a sphere, had been used but not documented (or incorrectly documented).

8. Visualizations of GLOBE and Ancillary Data

8.A. Visualizations of GLOBE

The GLOBE Web site contains a Gallery of GLOBE Images at http://www.ngdc.noaa.gov/seg/topo/globegal.shtml At the time of writing this document, the Gallery contains 5 arc-minute colored views of the world and (separately) for each continent. It also includes shaded-relief images, and shaded-relief images with earthquake hypocenters superimposed, for the same areas as the collection of colored views. In addition, selected smaller areas are shown as full-resolution views, of similar type. These images can be used to illustrate the character of GLOBE data (see also Hastings and Dunbar, 1998). They can also be used as base map illustrations, for anyone seeking digital images of any part of the land surface.

8.B. Ancillary Data

The GLOBE Task Team originally expressed a desire to include "ancillary" data with the GLOBE DEM. Original discussions centered around a registered, full-resolution source file, ocean mask, slope, aspect, shaded relief, bathymetry, and possibly other data.

ETOPO5 included bathymetry, to make the first integrated global surface relief model. TerrainBase used the bathymetric data from ETOPO5 to do the same. The GLOBE Task Team decided to forego resampling these data and to exclude bathymetric data until better bathymetric data might appear.

8.B.i. Source/Lineage File (with Contained Ocean Mask)

A source/lineage file accompanies GLOBE Version 1.0. It is tiled in the same manner as the DEM. Its file naming convention is "?10S", where "?" is the tile letter ranging from A to P (see diagram in Section 11.A).

The source/lineage file not only identifies the original source data set, but also certain important details of processing used to make the 30" DEM. In some cases, it goes back earlier in the history of a data set than source maps in other compilations (for example, noting that NIMA was the designer of DCW, and that DMA originated certain DEMs distributed by NGDC and USGS). In other cases, it notes subsequent processing that might be important, such as who might have adapted printed maps to digital format, and who might have converted the digital vector lines to 30" raster grids.

The legend for the source/lineage map of GLOBE Version 1.0 is given in Section 11.E. Refer to the back cover of this publication for a visual representation of the source/lineage map. For a higher resolution image, go to the online GLOBE documentation at http://www.ngdc.noaa.gov/seg/topo/report/.

8.B.ii. Slope and Aspect Data (Why Aren't They Provided?)

Although the GLOBE Task Team originally hoped to have slope and aspect data as ancillary data sets, we currently consider the data at too early a stage of development to justify this. Users may compute their own slope and aspect data, with the caveat that considerable care should go into the derivation of such products. The DEMs still contain significant artifacts. Such artifacts are within individual DEMs from individual sources/lineages. There are also discontinuities or steep gradients at seams between data sources/lineages (caused by or incidental to the mosaicking process). Until additional artifact removal is performed, the GLOBE Task Team believes that users be fully responsible for the results of their own slope and aspect maps.

9. Upcoming Improvements

We anticipate additional improvements for GLOBE. Here are some of the possibilities.

9.A. Integration with Other Data

NGDC has access to two new bathymetric models of higher resolution than the Digital Bathymetric Data Base 5-minute (DBDB5) that was used in ETOPO5 and TerrainBase. Neither is quite ready for release. When a digital bathymetric model has been released that is compatible with the GLOBE DEM, we anticipate combining it with GLOBE.

There are two options for incorporating elevations and bathymetry:

1. Blend the two data sets together. In this option, all 16 GLOBE compressed tiles on the GLOBE FTP and Web site will contain both elevations and bathymetry. Each tile will be much larger than at present.

2. Have two versions of GLOBE: (1) a dry GLOBE having only land elevations, and (2) a wet/dry GLOBE having both elevations and bathymetry.

Comments on these options would be appreciated. Our address and email contact information is given in Section 1.

GLOBE Version 1.0 makes useful and fascinating reference data for analysis and presentation of other data. For example, Stable Lights data sets from the Defense Meteorological Satellite Program's Operational Linescan System (OLS) (http://www.ngdc.noaa.gov/dmsp/dmsp.html) make dramatic illustrations of human impact on the global environment, when plotted on base map color or shaded-relief illustrations of GLOBE 1.0 data. The Gallery of GLOBE Images on the GLOBE Web site contains examples of such data integration (http://www.ngdc.noaa.gov/seg/topo/globegal.shtml).

9.B. Additional Contributions of Land Elevation Data

Several elevation models have been made available to the GLOBE Task Team. Others are still being discussed with their developers. We hope to add updates periodically. If you have DEMs that could be adapted for GLOBE, we would appreciate your contributions. Contact information is given in Section 1.

10. Data Distribution

- GLOBE data are distributed at no cost from the GLOBE Web site (http://www.ngdc.noaa.gov/seg/topo/globe.shtml). Follow the link to "Get GLOBE Data." You can get the individual files, or select your own customized area for downloading.

- GLOBE data are also distributed no cost from NGDC's anonymous FTP site:

  ```
  FTP: ftp.ngdc.noaa.gov
  USERID: anonymous
  PASSWORD: [your email address]
  : dir
  : cd GLOBE_DEM/data/elev
  : binary
  : get [filename] or mget [filespecpattern]
  : bye
  ```

  The GLOBE source data are on the ftp site in the GLOBE_DEM/data/source directory.

  These files are compressed with the GZIP utility. GZIP is widely used freeware, available for most computer platforms. Go to http://www.gzip.org to download the version you need to uncompress the data.

- The data are also available at modest cost-of-reproduction on CD-ROMs. If you are interested in all GLOBE data, or don't have fast Internet access, this may be the best source of the data. Contact:

  GLOBE DEM Project (E/GC1)
  NOAA/National Geophysical Data Center
  325 Broadway
  Boulder CO 80303

  Tel: 303-497-6277
  Fax: 303-497-6513
  Email: keh@ngdc.noaa.gov (ordering information)
  Email: dah@ngdc.noaa.gov (technical information)

Possibly in the future, GLOBE data and documentation (including updates) may be distributed by other organizations. Check the GLOBE DEM project's Web site for possible developments of this type.

11. Data Format and Importing GLOBE Data

11.A. Data and Source File-Naming Convention

To facilitate handling, GLOBE has been divided into 16 smaller pieces, or tiles.

One option for file naming would have been to include latitudes and longitudes in each tile. However, we wanted to include the version number of each data file. We also wanted to identify the *G.O.O.D.* versions of GLOBE (unrestricted data) and *B.A.D.* versions (best available data, but with noted restrictions). Both may exist for any given tile. In addition, we wanted to allow for the GZIP process which takes two characters from DOS (traditional PC 8.3 character) file names.

Finally, we wanted to be prepared for the Spatial Data Transfer Standard (SDTS), a set of standards designed for improved transfer of spatial data between computer systems. (Currently a developing standard in the U.S., it is being considered by the International Standards Organization for worldwide use.) SDTS only allows the data developer to use the first four characters of a file name. The other characters are reserved for naming the SDTS "modules" (that is, the transfer files).

In order to be SDTS compliant, we restricted the tile name to four characters. The file naming convention for the data and source files is as follows:

- First, a letter that fits the following tiling diagram:

	180°W – 90°W	90°W – 0°	0° – 90°E	90°E – 180°E
North Pole 90°N – 50°N	A	B	C	D
50°N – Equator 0°	E	F	G	H
Equator 0° – 50°S	I	J	K	L
50°S – South Pole 90°S	M	N	O	P

- Second, the 2-digit version number. This refers to the version of the tile. For example, if Tile A of GLOBE Version 1.0 is revised with new or corrected data, that first revision would create Version 1.1 for that tile, which would then be named A11G. A major revision of GLOBE (for example, the addition of bathymetric data to all tiles) might create GLOBE Version 2.0 (and the A tile would have file name A20G until revised again).

- Third, the data file naming convention (to the left of the dot in the file name):

  G *G.O.O.D.* GLOBE data (unrestricted GLOBE data)
  B *B.A.D.* GLOBE data (restricted GLOBE data)
  S Source/lineage data (for *G.O.O.D.* GLOBE data)
  T Source/lineage data (for *B.A.D.* GLOBE data)

- Fourth, the file extensions (to the right of the dot) identifying data format.

  (no extension) uncompressed data or source/lineage file (from CD-ROMs containing uncompressed data)
  .gz gzip-compressed data or source/lineage file (from the Web site or source file directory on the CD-ROM containing compressed data)

Note that all of the filenames on the CD-ROMs are stored in lowercase.

11.B. Metadata File-Naming Convention and Directory Structure

Metadata, including headers and associated files, are also found on GLOBE Volume 1 and on the GLOBE Web site, according to the directory structure listed below. The prefixes of all the metadata file names are the same as the associated data or source file. The file extensions, listed in parentheses next to he directory name, vary according to the type of file. As an example, "a10g.clr" would be tile A, version number 1.0, *G.O.O.D.* data, Arc/INFO (and ArcView) palette file. The file would be found in directory /data/elevation/esri/clr. All of the filenames on the CD-ROM are stored in lowercase.

\data, raster data directory

- **elevation,** Global Land One-km Base Elevation Data
  - **esri,** ESRI support files
    - **clr,** Palette files (.clr extension)
    - **hdr,** Header files (.hdr extension)
  - **geovu,** GeoVu support files
    - **fmt,** Format files (.fmt extension)
    - **hdr,** Header files (.hdr extension)
    - **lst,** Histogram files (.lst extension)
    - **pal,** Palette files (.lst extension)
  - **grass,** GRASS support files
    - **cellhd,** Header files (no extension)
    - **colr,** Palette files (no extension)
    - **grasstar,** UNIX tar file containing GRASS database (.tar extension)
  - **idrisi,** Idrisi support files
    - **doc,** Header files (.doc extension)

- **pal,** Palette files (.pal extension)
- **smp,** Palette files (.smp extension)

- **source,** Global Land One-km Base Source Data

  - **esri,** ESRI support files
    - **clr,** Palette files (.clr extension)
    - **hdr,** Header files (.hdr extension)
  - **geovu,** GeoVu support files
    - **fmt,** Format files (.fmt extension)
    - **hdr,** Header files (.hdr extension)
    - **lst,** Histogram files (.lst extension)
    - **pal,** Palette files (.lst extension)
  - **grass,** GRASS support files
    - **cellhd,** Header files (no extension)
    - **colr,** Palette files (no extension)
    - **grasstar,** UNIX tar file containing GRASS database (.tar extension)
  - **idrisi,** Idrisi support files
    - **doc,** Header files (.doc extension)
    - **pal,** Palette files (.pal extension)
    - **smp,** Palette files (.smp extension)

11.C. Elevation Data File Sizes, Regional Extent, and Statistics

Table 3 (next page) lists the name, latitude and longitude extent, elevation statistics, and file sizes for each tile. There is no overlap among the tiles; the global data set may be assembled by abutting the adjacent tiles.

11.D. Digital Elevation Data File Format

Files ?10G and ?10B ("?" is the wildcard notation for tile letters "A" through "P") are provided as 16-bit signed integer data in a simple binary raster. There are no header or trailer bytes embedded 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.). All files have 10800 columns, and either 4800 or 6000 rows (see Table 3, next page). The following diagram depicts the organization of the files:

```
bytes1/2 ........................................ bytes21599/21600
bytes21601/21602 ................................ bytes43199/43200
..........................................................
etc.
.........................................(last byte-1)/(last byte)
```

(text continues on page 84)

Table 3. Tile Definitions

Tile	Latitude Min.	Latitude Max.	Longitude Min.	Longitude Max.	Elevation Min.*	Elevation Max.	Data Grid Columns	Data Grid Rows
A10G	50	90	-180	-90	1	6098	10800	4800
B10G	50	90	-90	0	1	3940	10800	4800
C10G	50	90	0	90	-30	4010	10800	4800
D10G	50	90	90	180	1	4588	10800	4800
E10G	0	50	-180	-90	-84	5443	10800	6000
F10G	0	50	-90	0	-40	6085	10800	6000
G10G	0	50	0	90	-407	8752	10800	6000
H10G	0	50	90	180	-63	7491	10800	6000
I10G	-50	0	-180	-90	1	2732	10800	6000
J10G	-50	0	-90	0	-127	6798	10800	6000
K10G	-50	0	0	90	1	5825	10800	6000
L10G	-50	0	90	180	1	5179	10800	6000
L10B**	-50	0	90	180	-34	5179	10800	6000
M10G	-90	-50	-180	-90	1	4009	10800	4800
N10G	-90	-50	-90	0	1	4743	10800	4800
O10G	-90	-50	0	90	1	4039	10800	4800
P10G	-90	-50	90	180	1	4363	10800	4800

Tile	DEM Uncompressed	DEM GZIP-Compressed	Source/Lineage Uncompressed	Source/Lineage GZIP-Compressed
A10G	103,680,000	20,396,907	51,840,000	257,343
B10G	"	18,034,782	"	340,035
C10G	"	24,837,828	"	210,981
D10G	"	32,145,400	"	127,663
E10G	129,600,000	17,229,934	64,800,000	142,904
F10G	"	19,044,848	"	295,485
G10G	"	59,373,436	"	379,860
H10G	"	27,920,006	"	310,809
I10G	"	165,724	"	71,873
J10G	"	21,275,017	"	195,611
K10G	"	16,211,780	"	159,950
L10G	"	11,642,180	"	250,180
L10B*	"	14,374,075	"	237,682
M10G	103,680,000	6,145,510	51,840,000	66,737
N10G	"	8,521,837	"	109,433
O10G	"	9,071,480	"	59,916
P10G	"	9,247,144	"	67,790

* Note: This "minimum" shows the minimum elevation on land. Every tile contains values of -500 for oceans, with no values between -500 and the minimum value for land noted here.

** Note: This tile contains the AUSLIG/NGDC DEM, and is the only GLOBE Version 1.0 tile containing enhanced/restricted *B.A.D.* data.

Also NOTE: If using a UNIX workstation, Apple Macintosh or some other computer, your file names may appear in lower case after reading files from the CD-ROMs or Web site.

The data are in little-endian byte order (that is, for IBM-compatible PCs, Digital Equipment VAXes, etc.). UNIX workstations using big-endian byte order can swap bytes using the command:

```
dd if=inputfilename of=outputfilename conv=swab
```

where "inputfilename" and "outputfilename" are replaced with the user's selection of input and output file names. Alternatively, NGDC's public domain GeoVu software, which runs on IBM-compatible PCs, Sun and Silicon Graphics UNIX workstations, and Apple Macintoshes, may be used for this and other purposes. See http://www.ngdc.noaa.gov/seg/geovu/geovu.shtml for more information about GeoVu.

11.E. Source/Lineage Map

The "?10S" files (and single "L10T" file) are a tiled source map; these files also contain lineage information denoting post-source processing. Each file is a simple 8-bit (byte) binary image which has values that indicate the source used to derive the elevation for every cell in the DEM, plus the subsequent lineage of processing used to derive the DEM. The source/lineage 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:

Code	Source/Lineage (with section of this document that describes source/lineage)
0	Ocean.
1	DTED Level 0 discrete (spot) 30" DEM, sampled from the southwestern corner of the 30" GLOBE grid cell. (More information in Section 5.A.i.)
2	DTED-based 30" median DEM from USGS/GTOPO30. (More information in Section 5.A.i.)
3	DTED-based nearest-neighbor (to center of 30" GLOBE grid cell) DEM from USGS/GTOPO30. (More information in Section 5.A.i.)
4	DTED resampled to 30" by NIMA, provided to NGDC for public distribution in the 1980s. Spot (nearest-neighbor) version used. (More information in Section 5.A.i.)
5	DTED provided to USGS for public distribution in the 1970s, regridded to 30" by nearest-neighbor techniques by USGS. (More information in Section 5.A.i.)
6	DTED-based 30" "breakline" DEM from USGS/GTOPO30. (More information in Section 5.A.i.)
7	DTED-based DEM. Linear blending between classes 2 and 6 at their suture. (More information in Section 5.A.i.)
8	DEM for Australia. AUSLIG point elevation data base for Australia, converted to 30" DEM by NGDC (copyright 1998 by AUSLIG, licensed to NGDC for distribution with GLOBE). (More information in Section 5.A.ii.)
9	DEM of Japan, from GSI. (More information in Section 5.A.iii.)
10	DEM for Italy at high resolution from SGN, converted to 30" gridding by NGDC (for SGN). (More information in Section 5.A.iv.)

11 DEM of New Zealand at 500m gridding by LCR, reprojected to 30" by USGS. (More information in Section 5.A.v.)

12 DEM of Greenland at 90" by Zwally (and others)/NSIDC, converted to 30" by JPL. (More information in Section 5.A.vi.)

13 Zwally (and others)/NSIDC/JPL and DCW blended DEM. Linear blending between classes 12 and 14 at their suture. (More information in Sections 5.A.vi. and 5.B.i.d.)

14 Digital Chart of the World. Developed by DMA from 1:1,000,000-scale maps, converted to 30" grid by USGS. (More information in Section 5.A.vii.)

15 Maps for parts of southeast Asia and South America at 1:1,000,000 scale by AMS, digitized by GSI, gridded at 30" by USGS. (More information in Section 5.A.viii.)

16 Maps for part of Brazil. Produced at 1:1,000,000 scale by the Fundacao Instituto Brasiliero de Geografia e Estatistica of Brazil as part of the International Map of the World series, adapted to digital vectors by GSI, gridded at 30" by USGS. (More information in Section 5.A.ix.)

17 Map for part of Peru. Produced at 1:1,000,000 scale by the Ministerio de Guerra of Peru, adapted to digital vectors by GSI, gridded at 30" by USGS. (More information in Section 5.A.x.)

18 SCAR Antarctic Digital Database, converted to 30" DEM by USGS, subsequently repaired by NGDC. (More information in Section 5.A.xi.)

The cells with code 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 -500. Likewise, the cells with codes 1–18 together constitute a global land mask. Every cell in the DEM with an elevation has a corresponding cell in the source map with a code in the range 1–18.

Refer to the back cover of this publication for a visual representation of the source/lineage map. For a higher resolution image, go to the online GLOBE documentation at http://www.ngdc.noaa.gov/seg/topo/report/.

11.F. Header Files and Associated Files

GLOBE's Web site and CD-ROM version contain header files for NGDC's GeoVu, GRASS, Idrisi, Arc/INFO, and ArcView formats, plus metadata in the formats of the Global Change Master Directory .dif, and Federal Geographic Data Committee (FGDC). Each header is a separate file. The GeoVu, .dif, and FGDC files describe the entire data base, and have their own naming conventions. The other headers are different for each tile, and have the same naming convention as described in Sections 11.A and B. The FGDC metadata information for GLOBE Version 1.0 is contained in Appendix C. The Global Change Master Directory .dif file is also given in Appendix C.

11.F.i. Information about GeoVu Headers and Associated Files

Section 11.G.iv describes how to import GLOBE data into GeoVu. All GeoVu header files have a .hdr extension. On the next page is the GeoVu header file a10g.hdr, as an example:

```
file_tile                   =  Tile A Elevation
number_of_display_colors =  256
palette                     =  TOPO_LAND_256
data_type                   =  image
data_byte_order             =  little_endian
upper_map_y                 =  90.0
lower_map_y                 =  50.0
left_map_x                  =  -180.0
right_map_x                 =  -90.0
number_of_rows              =  4800
number_of_columns           =  10800
grid_size(x)                =  0.00833333
grid_size(y)                =  0.00833333
grid_unit                   =  degrees
grid_origin                 =  upperleft_x
grid_cell_registration      =  upperleft
map_projection              =  lat/lon
elevation_unit              =  Meter
missing_flag                =  -500
elevation_max               =  8752
elevation_min               =  -432
comment1 = actual elevation max  = 6098
comment2 = actual elevation min  = 1
```

Note that all of the GeoVu elevation header files have the same maximum elevation of 8752m and minimum elevation of -432m. The actual maximum and minimum elevations for the file are also listed as comments at the end of the header file. This was done to standardize the display colors for all 16 elevation files.

The GeoVu header files are stored in the /data/elev/geovu/hdr and /data/source/geovu/hdr directories of GLOBE Volume 1 and the GLOBE Web site.

Format files are also required for accessing the data with GeoVu. GeoVu format files have a .fmt extension. These files are stored in the /data/elev/geovu/fmt and /data/source/geovu/fmt directories.

If you are accessing the data from the CD-ROMs, you will need the GeoVu menu files. They are stored in the directory containing the GeoVu installation files for your particular platform. For example, the menu files for the PC are found in the software/geovu/pc directory.

If you are accessing the data from the CD-ROMs using a GeoVu menu file, you do not need to copy the header or format files onto your local machine. If you downloaded the data from the GLOBE Web site, therefore are not using a GeoVu menu file, you must copy the header and format files to the same directory as the data file.

Color palette files are provided for viewing the data in GeoVu. The files are stored in the /data/elev/geovu/pal and /data/source/geovu/pal directories. If you are accessing the data from the CD-ROMs using a GeoVu menu file, you need to copy the globe1.lst palette file from GLOBE Volume 1 to the GeoVu directory on your local machine.

If you downloaded the data from the GLOBE Web site, therefore are not using a GeoVu menu file, you need to copy the geopal.lst to the GeoVu directory on your local machine. This file supersedes the geopal.lst that is included with the GeoVu installation files.

11.F.ii. Information about Idrisi Headers and Associated Files

Section 11.G.v describes how to import the data into the Idrisi geographic information system.

Listed below is the Idrisi 4.x and Idrisi-for-Windows header file a10g.doc. Idrisi normally requires its header files to have a .doc file extension, unless you have modified this information in your Idrisi.env file.

```
file title   :    Tile A Elevation
data type    :    integer
file type    :    binary
columns      :    10800
rows         :    4800
ref. system  :    lat/long
ref. units   :    deg
unit dist.   :    0.0083333
min. X       :    -180.0000000
max. X       :    -90.0000000
min. Y       :    50.0000000
max. Y       :    90.0000000
pos'n error  :    unknown
resolution   :    unknown
min. value   :    1
max. value   :    6098
value units  :    meters
value error  :    unknown
flag value   :    -500
flag def'n   :    none
legend cats  :    0
```

The Idrisi header files are stored in the /data/elev/idrisi/doc and /data/source/idrisi/doc directories of GLOBE Volume 1 and the GLOBE Web site.

Color palette files are provided for viewing the data in Idrisi. Palette files with .pal extensions are ASCII files which may be used in Idrisi-for-DOS or Idrisi-for Windows. They are stored in the /data/elev/idrisi/pal and /data/source/idrisi/pal directories.

Palette files with .smp extensions are binary files usable only in Idrisi-for-Windows. They are stored in the /data/elev/idrisi/smp and /data/source/idrisi/smp directories.

Idrisi header and palette files should be placed in the same directory as the binary data.

11.F.iii. Information about GRASS Headers and Associated Files

Section 11.G.vi describes how to import GLOBE data into GRASS.

Listed below is an example of a GRASS header file (a10g):

```
proj:        3
zone:        0
north:       90N
south:       50N
east:        90W
west:        180W
cols:        10800
rows:        4800
e-w resol:   0:00:30
n-s resol:   0:00:30
format:      1
compressed:  0
```

The GRASS header files are stored in the /data/elev/grass/cellhd and /data/source/grass/cellhd directories of GLOBE Volume 1 and GLOBE Web site.

Color palette files are provided for viewing the data in GRASS. These files are stored in the /data/elev/grass/colr and /data/source/grass/colr directories.

In GRASS, the header files should be placed in your "cellhd" directory (parallel to the "cell" directory containing the data). The palette files should be placed in your "colr" directory (parallel to the "cell" directory containing the data).

In addition, a fuller GRASS directory structure (containing cellhd, colr, and associated files) is available to facilitate use of GLOBE data in GRASS (see Section 11.G.vi). That directory structure is stored in the identical /data/elev/grass/grasstar/ and /data/source/grass/grasstar/ files on GLOBE Volume 1 and the GLOBE Web site.

The process for importing GLOBE data into GRASS, described in Section 11.G.vi, can be automated by scripting the procedure. A sample script is provided in the /data/elev/grass/script directory.

11.F.iv. Information about Arc/INFO (and ArcView) Headers and Associated Files

Section 11.G.viii describes how to import GLOBE data into Arc/INFO. Section 11.G.ix describes how to import GLOBE data into ArcView.

The Arc/INFO (and ArcView) header file a10g.hdr is shown on the next page. Note: Arc/INFO and ArcView use the same header and palette files.

```
BYTEORDER      I
LAYOUT         BIL
NROWS          4800
NCOLS          10800
NBANDS         1
NBITS          16
BANDROWBYTES   21600
TOTALROWBYTES  21600
BANDGAPBYTES   0
NODATA         -500
ULXMAP         -179.995833333
ULYMAP         89.995833333
XDIM           0.00833333
YDIM           0.0083333
```

The Arc/INFO (and ArcView) header files are stored in the /data/elev/esri/hdr and /data/source/esri/hdr directories of GLOBE Volume 1 and GLOBE Web site.

Color palette files are provided for viewing the data in Arc/INFO and ArcView. ArcView palette files have a .clr extension. In Arc/INFO one specifies the name of a palette file. The same palette files can be used in both ESRI products. The color palette files are stored in the /data/elev/esri/clr and /data/source/esri/clr directories.

The Arc/INFO (and ArcView) header and palette files should be placed in the same directory as the binary data file.

11.G. Obtaining and Importing GLOBE Data

11.G.i. Obtaining the Data

See Section 10.

11.G.ii. GUNZIP the Compressed Data from the Web Site

Any data with a .gz extension must be uncompressed with GUNZIP. The command syntax may be one of these:

```
gunzip inputfilename
gzip -d inputfilename
```

This will uncompress the data, remove the .gz file extension, and delete the compressed .gz file. Note that you must have enough hard disk space to uncompress a file. Compressed and uncompressed file sizes are given in Table 3 (page 83). If you are not familiar with GUNZIP, go to http://www.gzip.org.

11.G.iii. Which Computer Are You Using?

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 IBM PC-compatible byte order, which stores the least significant byte first ("little endian"). Systems such as Digital Equipment VAXes and Alpha workstations, as well as computers using most Intel-compatible central processing units (CPUs) use this byte-ordering scheme.

For Apple Macintosh computers and most popular UNIX workstations, the typical byte order is most significant byte first ("big endian"). Some UNIX GIS applications provide an option to swap the bytes when importing the data (e.g. ERDAS/IMAGINE) or the information can be specified in header files (e.g. Arc/INFO and ArcView). If the application does not provide this option (e.g. GRASS), users with systems that use big-endian byte ordering have to "swap bytes" of the DEM data. This is easily done on most UNIX workstations, using the `dd` command. Check how this command works on your UNIX workstation, probably by running the command `man dd`. Typically, the command is executed as follows:

```
dd if=inputfilename of=outputfilename conv=swab
```

11.G.iv. Importing into NGDC's GeoVu

The CD-ROM version of GLOBE data, as well as data obtained from the GLOBE Web site, are accessible with NGDC's GeoVu utility. This utility may be useful for browsing, viewing, subsetting, and reformatting the data. Software and documentation are provided for Apple Macintosh, IBM-compatible PCs, and Sun and Silicon Graphics UNIX workstations.

11.G.iv.a. Accessing GLOBE Data on the CD-ROM

GeoVu can be found in the /software/geovu directory of GLOBE Volume 1.

You may want to print documentation found in the software/geovu/documnt directory. Read the readme.1st file in the directory for an overview of the documentation enclosed in that directory. Then go to the directory designated for your computer system of choice (for example, PC). In that computer system-related directory, read the readme.1st file, and follow its directions for installing and running GeoVu. This information is also provided on NGDC's GeoVu Web site at http://www.ngdc.noaa.gov/seg/geovu/geovu.shtml.

Importing and displaying the northwestern tile (a10g) with GeoVu is presented as an example.

- First, install GeoVu. Next, copy the GLOBE GeoVu color palette file (globe1.lst) and GeoVu menu files (globe1_1.men, globe1_2.men, globe1_3.men, and globe 1_4.men) to your GeoVu directory. The color palette and menu files (described in Section 11.F.i) are found in the directory containing the GeoVu installation files for your particular platform. For example, the palette and menu files for the PC are found in the software/geovu/pc directory.

- Insert GLOBE Volume 1 into the appropriate CD-ROM drive.

- Start GeoVu. From the GeoVu screen, select **File/Set Data**. In the Main List of Data Sources screen that appears, highlight **GLOBE 1.0 1999, Northern Hemisphere, 1 of 4** and enter the CD-Drive letter and click >>Next.

- An introduction screen will then appear. After reading the information, click >>Next. In the Main Menu that appears, highlight **Data: Tile A(50-90N, 90-180W)** and click OK to display the file with the default options.

- In addition to displaying the file with the defaults, you can also specify a subset of the region and/or select a different color palette. The option to write to disk is also provided. To specify a subset of the region, select **Search/Create.** A Data Source Selections screen will appear. Highlight **Tile A Elevation** and click OK. An Image Search Parameters screen will appear. Click on Set Search Parameters Limits to change the region. Click OK to display the subset of the tile.

11.G.iv.b. Accessing GLOBE Data Obtained from the GLOBE Web Site

The GLOBE Web site contains links to GeoVu support files for online GLOBE data, as well as to GeoVu software. NGDC's GeoVu Home Page is at http://www.ngdc.noaa.gov/seg/geovu/geovu.shtml. To access a GLOBE data tile with GeoVu, you will need a header file, a format file, and a color palette file (described in Section 11.F.i). All of these associated GeoVu files are available on the GLOBE Web site.

Importing and displaying the northwestern tile (a10g) with GeoVu is presented as an example.

- First, install GeoVu. Next, copy the geopal.lst file from the GLOBE Web site to your GeoVu directory. This file supersedes the geopal.last file included in the GeoVu installation files.

- Download the GLOBE data and the associated header and format files to the same directory (a different directory from the GeoVu directory). For example, copy the **a10g** data tile, **a10g.fmt**, and **a10g.hdr** to the same directory.

- Rename the data file, **a10g**, to **a10g.bin.**

- To display the file **a10g.bin**, start GeoVu. From the GeoVu screen, select **File/Set Data/ Other Disk Files** and then click OK. A dialog box will appear that allows you to navigate to the **a10g.bin** file. After selecting the **a10g.bin** file, select **Search/Create**. An Image Search Parameters screen will appear. Click OK to display the file with the default options. In addition to displaying the file with the defaults, you can also specify a subset of the region and/or select a different color palette. The option to write to disk is also provided.

11.G.v. Importing into Clark University's Idrisi

Users of Idrisi may import the DEM and source/lineage files (GUNZIP decompressed) using the following procedure. Importing the northwestern tile of GLOBE (file a10g) into Idrisi is presented as an example.

- Copy the **a10g.doc** (IDRISI DOC file described in Section 11.F.ii), **globedat.smp** (IDRISI color palette file described in Section 11.F.ii), and **a10g** (elevation data) files into same disk location. Rename the file a10g to **a10g.img**.
- Start Idrisi for Windows. Click on display and enter **a10g**. Under Palette Options click on **User Defined** and enter **globd256** (or double click and select this palette). Confirm that the **Autoscale image for display** option has been activated (this should happen by default for integer data). Click OK to get the display.
- To standardize the display colors, the number 8752 must be substituted for the actual maximum elevation for a tile in its .doc file. This may be done by hand editing the a10g.doc file, or by running Document. On the top line of Idrisi for Windows, click on File, then on Document. Enter **a10g** and click OK. Replace the actual maximum value for the file with **8752**. Click OK.
- Display the data as shown above. This will autoscale the display colors uniformly for all data sets. The zero and negative values are all displayed as black, but if queried, the correct value is displayed.
- To replace 8752 with the actual maximum value for the file, run Document on the a10g file. Next to the window for maximum value click on the button to **Calculate**. This puts the actual maximum and minimum back in their appropriate boxes.

The files can also be imported by running Document, specifying the data type (integer for DEMs, byte for source/lineage files), grid cell size of 0.00833333, and coordinate range for the specific GLOBE tile. You can have Idrisi automatically find the maximum and minimum values for the DEMs, or you can enter the values from Table 3 (page 83) to avoid waiting for Idrisi to check each large file for maximum and minimum value.

Idrisi for DOS color palette files are also available: globd16.pal is for the COLOR module; glob256.pal is for the COLOR85 module. See documentation for Idrisi versions 3.x or 4.x regarding the use of user-defined palettes in these modules.

11.G.vi. Importing into the U.S. Army Corps of Engineers' GRASS

Two procedures are presented for importing the DEM and source/lineage files (GUNZIP decompressed) into GRASS: (1) importing GLOBE data using a sample GRASS data base, and (2) importing GLOBE data into your own GRASS data base.

11.G.vi.a. Importing GLOBE Data Using a Sample GRASS Data Base

For convenience, a sample GRASS data base for GLOBE is provided. This data base is in a global 30" latitude-longitude "projection." It contains GRASS cell header (cellhd), cell miscellaneous (cell_misc), and color (colr) directories and files for GLOBE data and source tiles. It also contains an empty cell directory, into which GLOBE tiles may be placed.

- Copy the grasglob.tar file from /data/elev/grass/grasstar/ or data/elev/grass/grasstar/ (the files are identical) to a directory on your Unix workstation. To "un-tar" the file, run the following command (or similar for your environment):

  ```
  tar -xvf grass.tar
  ```

- Copy data from the GLOBE Web site or CD-ROMs into the grass/user/cell directory. You may wish to "mv" the directory structure so that the "user" becomes your login name, thus making a grass/yourlogin/cell directory. Go to that directory.

- GUNZIP any data files containing a .gz extension (see Section 11.G.ii).

- To keep track of your files, rename all data tiles with a .pc extension. For example, "mv a10g a10g.pc".

- Byte-swap the data for most Unix workstations.

  ```
  dd if=a10g.pc of=a10g.ux conv=swab
  ```

- Delete the a10g.pc file. For example, "rm a10g.pc".

- Start GRASS. Make sure that there is no mask, by interactively executing the **r.mask** command and removing the current mask (if any).

- Set the GRASS region to the region of the data file by executing the following GRASS command:

  ```
  g.region rast=a10g.ux
  ```

- GRASS' multibyte format handles signed integers differently from traditional 16-bit integers used in GLOBE. Therefore, if you are importing a DEM file such as the a10g.file, the following command must be executed:

  ```
  r.mapcalc 'a10g=if(a10g.ux-32768,a10g.ux-65536,a10g.ux,a10g.ux)'
  ```

  where **a10g** is the final name for this GLOBE DEM file. *This step is not necessary when importing source/lineage files.*

- If you are importing a DEM file such as the a10g file, remove the temporary file by executing the following GRASS command:

  ```
  g.remove a10g.ux
  ```

- If you are importing a source/lineage file such as the a10s file, uncompress the files (which are compressed on the CDs and the Web site) in your grass/yourlogin/cell directory using one of the following:

```
unzip a10s.gz
gzip -d a10s.gz
```

  where **a10s** is the final name for this GLOBE source/lineage file.

- You may want to GRASS-compress the DEM and source/lineage files to reduce the sizes of the files. To shrink the file without changing its name, execute the following GRASS command:

```
r.compress a10g
r.compress a10s
```

- You can now display the a10g and a10s files using the GRASS color palette files provided.

- NOTE: You can automate the ingest of many GLOBE DEM files by scripting this procedure. Sample scripts are provided in the /data/elev/grass/script/ and /data/source/grass/script/ directories.

11.G.vi.b. Importing GLOBE Data Into Your Own GRASS Data Base

- Copy the **a10g.ux** and **a10s** GRASS cell header files (described in Section 11.F.iii) into your GRASS cellhd directory. Also copy the **a10g** and **a10s** color palette files (described in Section 11.F.iii) into your GRASS colr directory.

- Follow the same procedures described in the previous section except omit the first step (untarring the grasglob.tar file).

11.G.vii. Importing into ERDAS

Users of ERDAS may import the DEM files (GUNZIP decompressed) using the following procedure. Importing the northwestern (file a10g) tile of GLOBE into ERDAS is presented as an example.

- Start ERDAS. Click on the Import button. In the Import/Export template that appears, select Generic Binary for Type and the appropriate response for Media. Enter **a10g** as the input filename. The default output filename is **a10g.img**. Click OK and Close.

- The Import Generic Binary Data template is displayed next. Enter **10800** for the number of columns and **4800** for the number of rows. (The number of columns is always **10800**. The number of rows is **4800** for tiles that cover 50° to 90°N or 50° to 90°S latitude and **6000** for tiles that cover 0° to 50°N or 0° to 50°S latitude.) For Data Type use **Unsigned 8 bit** (the default) if importing a source/lineage file, and **Signed 16 bit** if importing a GLOBE DEM file. The data format type is **BIL**. If you are running UNIX ERDAS, click on **Swap Bytes** and click OK to begin the import. When the import is complete, click OK again. Close the Import/Export template window.

- Select Image Information from the Tools pulldown menu. The ImageInfo template is then displayed. Click Open from the File pulldown menu and select **a10g.img** and click OK. Select Change Map Model from the Edit pulldown menu. Enter the appropriate x (longitude) and y (latitude) coordinates for the imported data set; for tile **a10g** the x coordinate is **-180** and the y coordinate is **90**. This information is found in Table 3 (page 83). Next, enter **0.00833333** for x and y pixel sizes. Set the Projection to **Geographic (lat/lon)**. The Units should automatically change to **Degrees**. Click OK. When a confirmation window pops up, click OK again. Leave the ImageInfo window open.

- In the ImageInfo template, select Compute Statistics from the Edit pulldown menu. The Statistics Generation Option template is then displayed. Change the Skip Factor to **1** and the Skip Factor Y to **1**. Change the Bin Function to **Linear**. Then click OK. After the statistics are computed, confirm that the information in the ImageInfo window is correct and close the window.

Your data should now be in ERDAS, in latitude/longitude projection. The file can be displayed as a raster layer. Some ERDAS processes (such as computing shaded relief images) may want you to reproject the data, or at least signify to ERDAS that the data are in a projection other than Geographic.

ERDAS adds header and footer information to GLOBE's binary raster grids as part of the procedure described above for importing new files. Earlier versions of ERDAS performed this task with the functions FIXHEAD and BSTATS. FIXHEAD details the numbers of columns and rows, georeferencing, number of bytes, etc. This information is provided in Table 3 (page 83). BSTATS is run after FIXHEAD, appending statistical information to the end of the file.

11.G.viii. Importing into ESRI's Arc/INFO

Users of Arc/INFO can import GLOBE DEM and source/lineage files (GUNZIP decompressed) by converting the DEM to an Arc/INFO grid with the command IMAGEGRID. Importing the northwestern (file a10g) tile of GLOBE into Arc/INFO is presented as an example.

- Copy **a10g.hdr** (Arc/INFO header file described in Section 11.F.iv), **a10g.clr** (Arc/INFO color palette file described in Section 11.F.iv), and **a10g** (elevation data) files into your Arc/INFO workspace. Rename the file a10g to **a10g.bil**. You should now have the following files in your ArcInfo working directory: a10g.bil, a10g.hdr, and a10g.clr.

- Next, from within Arc/INFO run IMAGEGRID:

```
IMAGEGRID a10g.bil a10gaig
```

- To add projection information to a10gaig, at the Arc prompt type the following:

```
projectdefine grid a10gaig
```

This begins an interactive dialog for entering projection information for the data set. At the Project prompt, enter the following information. The word "parameters" completes the projection definition.

```
projection geographic
units dd
datum wgs84
zunits meters
parameters
```

- IMAGEGRID does not support conversion of signed image data, therefore the negative 16-bit DEM values will not be interpreted correctly. After running IMAGEGRID and adding the projection information, this can be fixed by using the following formula in **GRID**:

```
a10gconv = con(a10gaig >= 32768, a10gaig - 65536, a10gaig)
```

where a10gaig is the file created by IMAGEGRID, and a10gconv is the converted signed integer grid. The converted grid will then have the negative values properly represented, and the statistics of the grid should match those listed in Table 3 (page 83). This process creates a georeferenced Arc/INFO GRID file called a10gconv. You can use the resultant GRID file in Arc/INFO's GRID module. *This step is not necessary when importing source/lineage files.*

- If desired, the -500 ocean mask values in the grid could then be set to NODATA with the SETNULL function in **GRID**:

```
a10gnull = setnull(a10gconv == -500, a10gconv)
```

- To display the file with the color palette provided, copy the **a10g.clr** file (color palette file) to your Arc/INFO workspace. Then use the following commands in **ARCPLOT**:

```
display 9999
mape a10gnull
gridpaint a10gnull # # # a10g.clr
```

The zero and negative values are all displayed as black.

11.G.ix. Importing into ESRI's ArcView

An Arc/INFO coverage created using the procedure described in Section 11.G.viii can be displayed in ArcView. In addition, the GLOBE data and source/lineage files (GUNZIP decompressed) can be displayed after renaming the file by adding a .bil extension. Importing the northwestern tile of GLOBE (file a10g) in ArcView is presented as an example.

- Copy the **a10g.hdr** (Arc/INFO header file described in Section 11.F.iv), **a10g.clr** (Arc/INFO palette file described in Section 11.F.iv), and **a10g** (elevation data) files into your ArcView working directory. Rename the file a10g to **a10g.bil**. You should now have the following files in your ArcView working directory: a10g.bil, a10g.hdr, and a10g.clr.

- Start ArcView. You should either open an existing project with a view in a geographic (latitude-longitude) projection, which covers the area(s) you want to work with; or start a new view. If you start a new view, choose Properties from the View pulldown menu. In the View Properties window, click on the Projection button and select **Projections of the World** as the Category and **Geographic** as the Type. Click OK in the View Projections window. In the View Properties window select **Kilometers** or **Miles** as the Distance Units. Click OK.

- Add the **a10g.bil** file to the View as an **Image Data Source** theme. After you add the a10g.bil image, your project should show the data file in your legend. To display the a10g.bil theme in the View window, click on the raised box to the left of the theme name (a10g.bil) to make a check mark. Un-"check" all other data that you may have in this project.

ArcView does not correctly interpret negative values. Therefore, the zero and negative values are all displayed as black. The values in the image displayed cannot be queried with ArcView, unless you have the ArcView extension Spatial Analyst.

11.G.x. Importing into Adobe Photoshop

Users of Photoshop can display GLOBE DEM and source/lineage files (GUNZIP decompressed) after renaming the file by adding a .raw extension. Importing the northwestern tile of GLOBE (file a10g) into Photoshop is presented as an example.

- Copy the **a10g** (elevation data) files onto your hard drive. Rename the file a10g to **a10g.raw**.

- Start Photoshop. Select Open from the File pulldown menu and select **Raw** for Files of Type. Find the file on your disk and highlight it. Click OK. The Raw Options window is then displayed. Enter **10800** for Width and **4800** for Height. Under Channels, make sure that the Count is **1**. For Depth select **16 bits**. For Byte Order select **IBM PC**. For Header keep **0** bytes. Click OK to open and display the image (which will probably initially display in black and white).

Note: The width is **10800** for all tiles, but the height is **4800** for tiles that cover 50° to 90°N or 50° to 90°S latitude and **6000** for tiles that cover 0° to 50°N or 0° to 50°S latitude. This information is also found in Table 3 (page 83).

Photoshop Version 4 imports 16-bit data, but does not allow you to work with the data until saved to an 8-bit version. Photoshop Version 5 handles 16-bit data directly, but in a limited way. You will probably have to save the data to an 8-bit version before you can do much with the data in Photoshop Versions 4 or 5.

11.G.xi. Importing into Other Software Packages

Sections 11.G.iv through 11.G.x give specific examples for representative geographic information systems, image processing systems, and a graphics program. If you are using a different application, we hope that:

- The examples may still give you an idea of how to import GLOBE data into your particular application.
- The header files for the given examples may be useful for importing into your application. For example, some applications use GRASS, Idrisi, or other headers to help import GLOBE data.

Although we cannot describe how to ingest GLOBE data into every available GIS, we are happy to post methods for ingestion into other software packages if you submit them to us (with your name, postal address, and email address and/or fax number). We regret that we will not be able to support users of other systems which we may not have. However, the support personnel for your particular software package should be able to help you, as the structure of GLOBE data is typical of many raster gridded data.

11.H. Projection Information

Listed below is the projection information for each data file in GLOBE:

```
Projection         Geographic (latitude/longitude)
Datum              WGS84
Zunits             Meters above mean sea level
Hunits             30 arc-seconds of latitude and longitude
Spheroid           WGS84
Xshift             0.0000000000
Yshift             0.0000000000
Cell Referencing   Each cell is nominally bound by 30" intervals of latitude
                   and longitude, beginning with any whole degree (e.g.
                   0.0000 degrees)
Parameters         NONE other than those above
```

11.I. Georeferencing in GLOBE

See Section 5.B.iii. Georeferencing conventions of several software packages are shown in Sections 11.F.i through 11.F.iv, and 11.H.

12. Disclaimers

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government nor the GLOBE Task Team.

The user accepts full responsibility for use or misuse of these data. Please read the following warnings, extracted from elsewhere in this document (Section 1):

> Note that GLOBE Version 1.0, like other digital topographic data, are insufficiently accurate over their full global extent to be taken too literally for mission-critical applications. They must always be interpreted with extreme caution. They should not be used exclusively in mission-critical or life-critical applications.

The following passage was provided by NIMA:

> "The data contained in DTED Level 0 is a derivative set only, and does not represent the entire Department of Defense archive of terrain data. In making these data available to the general public, NIMA in no way alters the controlled status of the remaining archives. Technical support or general assistance with respect to DTED Level 0 is available only to U.S. Government users. NIMA requests that products developed using DTED Level 0 credit the source with the following statement: "This product was developed using DTED Level 0, a product of the National Imagery and Mapping Agency."
>
> Warranty Disclaimers and Requirements:
>
> a. Under 10 U.S.C. 456, no civil action may be brought against the United States on the basis of the content of data prepared or disseminated by either the former Defense Mapping Agency (DMA) or NIMA.
>
> b. DTED Level 0 was developed to meet only the internal requirements of the DOD. DTED Level 0 is provided "as is," and no warranty, express or implied, including but not limited to the implied warranties of merchantability and fitness for particular purpose or arising by statute or otherwise in law or from a course of dealing or usage in trade, is made by NIMA as to the accuracy and functioning of the product.
>
> c. Neither NIMA nor its personnel will be liable for any claims, losses, or damages arising from or connected with the use of DTED Level 0. The user agrees to hold harmless the U.S. National Imagery and Mapping Agency. The user's sole and exclusive remedy is to stop using DTED Level 0.
>
> d. For any products developed using DTED Level 0, NIMA requires a disclaimer that use of DTED Level 0 does not indicate endorsement or approval of those products by either the Secretary of Defense, the former Defense Mapping Agency, or the National Imagery and Mapping Agency. Pursuant to the United States Code, 10 U.S.C.

445, the name of the Defense Mapping Agency, the initials "DMA," the seal of the Defense Mapping Agency, the name of the National Imagery and Mapping Agency, the initials "NIMA," the seal of the National Imagery and Mapping Agency, or any colorable imitation thereof shall not be used to imply approval, endorsement, or authorization of a product without prior written permission from the U.S. Secretary of Defense."

The following passage was posted on USGS's GTOPO30 Web site:

"Please note that some U.S. Geological Survey (USGS) information contained in this data set and documentation may be preliminary in nature and presented prior to final review and approval by the Director of the USGS. This information is provided with the understanding that it is not guaranteed to be correct or complete and conclusions drawn from such information are the sole responsibility of the user."

The above-noted disclaimers are applicable, as adapted by including the appropriate data source(s) and processor(s) to all portions of GLOBE, from all sources. In addition, they are applicable to the entire GLOBE data set, associated data files (such as source/lineage data), and documentation.

The following passage applies to the AUSLIG/NGDC DEM for Australia:

"The AUSLIG/NGDC DEM for Australia [see Section 5.A.ii for extent of these data] is Commonwealth Copyright, AUSLIG, Australia's national mapping agency (1998). All rights reserved. These data have been reproduced with the permission of the General Manager, Australian Surveying and Land Information Group, Department of Industry, Science and Tourism, Canberra, ACT.

The Commonwealth of Australia is the owner of the data.

The data are licensed to NOAA/NGDC for distribution with GLOBE.

AUSLIG is the custodian of the copyright of the maps and data products it produces on behalf of the Australian Government, ie. the Commonwealth. This custodianship has been devolved to AUSLIG by the Australian Government Publishing Service.

AUSLIG has a statutory responsibility to administer the Commonwealth Copyright of all its products. AUSLIG does not give away copyright. Rather it grants a right to use its products as specified in any application to use its products, ie., a license.

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NOAA's standard disclaimer reads as follows:

> "While every effort has been made to ensure that these data are accurate and reliable within the limits of the current state of the art, NOAA cannot assume liability for any damages caused by any inaccuracies in the data or as a result of the failure of the data to function on a particular system. NOAA makes no warranty, expressed or implied, nor does the fact of distribution constitute such a warranty. The user must be cautious when using these data. None of the data represented here are perfect. As in many complex scientific endeavors, error can be expected."

Also, see Sections 6 and 7.

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The U.S. Geological Survey frequently participated in GLOBE meetings, and hosted one GLOBE meeting, but does not consider itself a member of the GLOBE Task Team.

GLOBE has been affiliated with the following international efforts:

- Committee on Earth Observation Satellites (CEOS)
  Working Group on Information Systems and Services (WGISS)
  Data Subgroup
  (The GLOBE Task Team reports to the CEOS-WGISS Data Subgroup)

- International Council of Scientific Unions (ICSU)
  International Geosphere-Biosphere Programme (IGBP)
  Data and Information System (IGBP-DIS)
  (GLOBE is a part of Focus I of IGBP-DIS)

- International Society of Photogrammetry and Remote Sensing
  Commission IV: Mapping and GIS
  Working Group IV/6: Global Databases Supporting Environmental Monitoring

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Some of this text is taken verbatim (or with modest modification) from USGS (1997b), especially some of the descriptions of USGS procedures in developing USGS/GTOPO30. Other text is based on TerrainBase documentation (Row and others, 1995). In addition, this project is indebted to its six previous and concurrent efforts at developing global digital elevation data sets:

1. ETOPO5 (1984–1985), developed by Margo Edwards of Washington University (St. Louis) for NGDC
2. ELEVBATHY (1984–1985), developed by David Hastings at the EROS Data Center for NASA MAGSAT data analysis
3. TerrainBase (1991–1994), developed by Lee Row and David Hastings at NGDC
4. JPL/MISR DEM (1994–1995), developed by Nevin Bryant, Richard Fretz, Niles Ritter and Rafael Alanis of the Cartographic Applications Group at JPL for the MISR mission
5. GTOPO30 (1993–1997), developed by a team led by Susan Greenlee at the EROS Data Center
6. DTED Level 1, under development for many years at the National Imagery and Mapping Agency, formerly the Defense Mapping Agency; and DTED Level 0 (1994–1996), initially designed in conjunction with the GLOBE Task Team, later released to the public as well as to GLOBE

The histograms shown in Plates 1–30 (pages 19–34) were developed with the Generic Mapping Tool (GMT), by Paul Wessell and Walter Smith (http://www.soest.Hawaii.edu/gmt/). The figure showing coverage of the AUSLIG/NGDC DEM for Australia (page 38) was developed in the Geographic Resources Analysis Support System (GRASS) GIS (http://www.baylor.edu/~grass and http://sunsite.unc.edu/LDP/HOWTO/mini/GIS-GRASS.html).

Appendix B. Glossary of Acronyms

ADD	Antarctic Digital Database (of SCAR)
AGIP	Azienda Generale Italiana Petroli (an Italian petroleum company)
AMS	Army Map Service, 1946–1968
ANUDEM	Australian National University digital elevation modeling software package
AUSLIG	Australian Surveying and Land Information Group
B.A.D.	Best Available Data (better than *G.O.O.D.* GLOBE data, but with noted restrictions)
BSTATS	An ERDAS function
CALTECH	California Institute of Technology
CEOS	Committee on Earth Observation Satellites
DCW	Digital Chart of the World
DEM	Digital elevation model. This is used in the generic sense of a raster data set attempting to represent the elevation of the dry land surface. It does not imply any particular data format or collection methodology. It also does not include other forms of digital elevation data, such as digitized points or contours.
DFD	Deutsches Fernerkundungsdatenzentrum (German Remote Sensing Data Center)
DIS	Data and Information System
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DMA	Defense Mapping Agency, 1972–1996
DOD	U.S. Department of Defense
DTED	Digital Terrain Elevation Data (NIMA DEMs)
EDC	EROS Data Center
EOS	Earth Observing System (a NASA program)
EPA	Environmental Protection Agency
ERDAS	Earth Resources Data Analysis System (a software package)
EROS	Earth Resources Observation Systems
ERS	Earth Resources Satellite (European Space Agency satellite series)
ESRI	Environmental Science Research Institute, Inc.
ETOPO5	5-minute global DEM (the first global DEM, which also included bathymetry)
FGDC	Federal Geographic Data Committee
FIXHEAD	An ERDAS function
FTP	File Transfer Protocol
GIS	Geographic information system
GLOBE	Global Land One-kilometer Base Elevation project
GMT	Generic Mapping Tool
GNGTS	Gruppo Nazionale di Geofisica della Terra Solida (Italy)
G.O.O.D.	Globally Only Open-access Data (unrestricted GLOBE data)
GRASS	Geographic Resources Analysis Support System GIS
GSFC	Goddard Space Flight Center
GSI	Geographical Survey Institute, Japan
GTOPO30	USGS's name for its global 30" DEM

GZIP	A software utility
IBGE	Instituto Brasiliero de Geografia e Estatistica
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
IMW	International Map of the World
ISPRS	International Society of Photogrammetry and Remote Sensing
JPL	Jet Propulsion Laboratory (a NASA research center administered by the California Institute of Technology)
LCR	Manaaki Whenua Landcare Research, Ltd., New Zealand
MISR	Multiangle Imaging SpectroRadiometer
MPI	Ministerio della Publica Instruziane (Italian Ministry of Public Instruction)
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite, Data, and Information Service
NGDC	National Geophysical Data Center
NIMA	National Imagery and Mapping Agency
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
ONC	Operational Navigation Chart
OLS	Operational Linescan System
RMSE	Root-mean-square error
SCAR	Scientific Committee on Antarctic Research
SDTS	Spatial Data Transfer Standard
SGN	Servizio Geologico Nazionale (National Geological Service (Italy))
SRTM	Shuttle Radar Topography Mapper mission
UCL	University College London
UNO	United Nations Organization
URL	Uniform Resource Locator (Web address)
USATC	U.S. Army Topographic Command
USGS	U.S. Geological Survey
WGD	Working Group on Data
WGISS	Working Group on Information Systems and Services
WGS	World Geodetic System
WVS	World Vector Shoreline
WWW	World Wide Web

Appendix C.
Federal Geographic Data Committee Metadata, and Global Change Master Directory .DIF for GLOBE

Below are the Federal Geographic Data Committee (FGDC) metadata for GLOBE Version 1.0. Global Change Master Directory .dif file contents begin on page 130.

Federal Geographic Data Committee Metadata

We adapted answers to several FGDC metadata fields:

- **Publication_Date:** "Varies" is not allowed, but accurately describes several GLOBE source data fields. Where "varies" is the correct answer, "Unknown" (an FGDC-allowable but technically incorrect answer) is used.
- **Source_Scale_Denominator:** Only an integer value is allowed in this field. "Varies" is not allowed, but accurately describes several GLOBE source data sets, especially when sources include maps and imagery of varying scales. Some sources, such as those used to make DTED, are undocumented. In these cases, 99999999 is used.

The following is the FGDC metadata for GLOBE Version 1.0:

1 Identification_Information:
  1.1 Citation
      1.1.8.1 Originator: National Geophysical Data Center (editor)
      1.1.8.2 Publication_Date: 1998
      1.1.8.4 Title: GLOBE: Global Land One-km Base Elevation 30-sec. DEM
      1.1.8.5 Edition: Version 1.0
      1.1.8.6 Geospatial_Data_Presentation_Form: Model
      1.1.8.7 Series_Information:
        1.1.8.7.1 Series_Name: Key to Geophysical Records Documentation (KGRD) 34
        1.1.8.7.2 Issue_Identification: Hastings, David A., and P. K. Dunbar. Global Land One-km Base Elevation (GLOBE) Digital Elevation Model Documentation, National Oceanic and Atmospheric Administration, National Geophysical Data Center, Publication KGRD 34, Boulder, Colorado, 1999.
      1.1.8.8 Publication_Information:
        1.1.8.8.1 Publication_Place: Boulder, CO
        1.1.8.8.2 Publisher: National Geophysical Data Center
      1.1.8.10 Online_Linkage: http://www.ngdc.noaa.gov/seg/topo/globe.shtml
  1.2 Description:
    1.2.1 Abstract:
      GLOBE is a project to develop the best available 30-arc-second (nominally 1 kilometer) global digital elevation data set. This Version 1.0 of GLOBE contains data from 11 sources, and 18 combinations of source and lineage. It continues much in the tradition of the National Geophysical Data Center's TerrainBase (DIF 1090), as TerrainBase served as a generally lower-resolution prototype of GLOBE data management and compilation techniques.

The GLOBE mosaic has been compiled onto CD-ROMs for the international user community. It is also available from the World Wide Web and via anonymous FTP. Improvements to the global model are anticipated, as appropriate data and/or methods are made available. In addition, individual contributions to GLOBE (several areas have more than one candidate) should become available at the same Web site.

GLOBE may be used for technology development, such as helping plan infrastructure for cellular communications networks, other public works, satellite data processing, and environmental monitoring and analysis. GLOBE prototypes (and probably GLOBE itself after its release) has been used to help develop terrain avoidance systems for aircraft. In all cases, GLOBE data should be treated as any potentially useful but guaranteed imperfect data set. Mission- or life-critical applications should consider the documented artifacts, as well as likely undocumented imperfections, in the data.

1.2.2 Purpose: Provide Topographic Data for Scientific, Technical, and other Applications
1.2.3 Supplemental_Information:
1.2.3.1 Entry_ID: FE01180
1.2.3.2 Sensor_Name: ALTIMETERS
1.2.3.2 Sensor_Name: ECHO SOUNDERS
1.2.3.2 Sensor_Name: CAMERAS
1.2.3.2 Sensor_Name: IMAGING RADIOMETERS
1.2.3.3 Source_Name: AIRCRAFT
1.2.3.3 Source_Name: SATELLITES, MISCELLANEOUS
1.2.3.3 Source_Name: FIELD SURVEYS
1.2.3.3 Source_Name: SHIPS
1.2.3.3 Source_Name: MODELS
1.2.3.5 Originating_Center: National Geophysical Data Center
1.2.3.6 Storage_Medium: 3480 Cartridge
1.2.3.6 Storage_Medium: CD-ROM
1.2.3.6 Storage_Medium: Online
1.2.3.9 NOAAServer URLs:
1.2.3.9.1 Moreinfo: http://www.ngdc.noaa.gov/seg/topo/globe.shtml
1.3 Time_Period_of_Content:
1.3.1 Currentness_Reference: Publication date
1.3.1.3 Range_of_Dates/Times:
1.3.1.3.1 Beginning_Date: 1975-01-01
1.3.1.3.3 Ending_Date: Publication date
1.4 Status:
1.4.1 Progress: Complete
1.4.2 Maintenance_and_Update_Frequency: Irregular
1.5 Spatial_Domain:
1.5.1 Bounding_Coordinates:
1.5.1.1 West_Bounding_Coordinate: -180.0
1.5.1.2 East_Bounding_Coordinate: 180.0
1.5.1.3 North_Bounding_Coordinate: 90.0
1.5.1.4 South_Bounding_Coordinate: -90.0
1.6 Keywords:
1.6.1 Theme:
1.6.1.1 Theme_Keyword_Thesaurus: Uncontrolled Keywords as used in GCMD DIF
1.6.1.2 Theme_Keyword: EARTH SCIENCE > LAND SURFACE > Topography > Landforms
1.6.1.2 Theme_Keyword: EARTH SCIENCE > LAND SURFACE > Topography > Relief

1.6.1.2 Theme_Keyword: EARTH SCIENCE > LAND SURFACE > Topography > Surface Roughness

1.6.1.2 Theme_Keyword: EARTH SCIENCE > LAND SURFACE > Topography > Terrain Elevation

1.6.1.2 Theme_Keyword: EARTH SCIENCE > OCEANS > Coastal Processes > Coastal Elevation

1.6.1.2 Theme_Keyword: INFOTERRA > Environmental Monitoring > Environmental Measurements > Elevation

1.6.1.2 Theme-Keyword: CIESIN > ENVIRONMENTAL PROTECTION > GEOGRAPHY AND LAND COVER > TOPOGRAPHIC DATA

1.6.1.2 Theme-Keyword: CIESIN > ENVIRONMENTAL PROTECTION > MODELING > GEOGRAPHIC INFORMATION SYSTEMS

1.6.1.2 Theme-Keyword: CIESIN > ENVIRONMENTAL PROTECTION > MODELING > MODELING

1.6.1.2 Theme-Keyword: CIESIN > ENVIRONMENTAL PROTECTION > MODELING > RESEARCH AND DEVELOPMENT > MODELS

1.6.1.1 Theme_Keyword_Thesaurus: None

1.6.1.2 Theme_Keyword: DEM

1.6.1.2 Theme_Keyword: Digital elevation model

1.6.1.2 Theme_Keyword: Elevations

1.6.1.2 Theme_Keyword: Topography

1.6.2 Place:

1.6.2.1 Place_Keyword_Thesaurus: Uncontrolled Keywords GCMD

1.6.2.2 Place_Keyword: Location: Global

1.6.4 Temporal:

1.6.4.1 Temporal_Keyword_Thesaurus: None

1.6.4.2 Temporal_Keyword: Generally current (no special instant in time)

1.7 Access_Constraints: None

1.8 Use_Constraints: None for one (G.O.O.D.) version of GLOBE. Copyright restrictions on derivation/reproduction or redistribution of another (B.A.D.) version of GLOBE, as described in GLOBE documentation.

Recommend: Cite GLOBE as a scientific publication: GLOBE Task Team and others (Hastings, David A., Paula K. Dunbar, Gerald M. Elphingstone, Mark Bootz, Hiroshi Murakami, Hiroshi Maruyama, Hiroshi Masaharu, Peter Holland, John Payne, Nevin A. Bryant, Thomas L. Logan, J.-P. Muller, Gunter Schreier, and John S. MacDonald), eds., 1999. The Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80303, U.S.A. Digital data base on the World Wide Web (URL: http://www.ngdc.noaa.gov/seg/topo/globe.shtml) and CD-ROMs.

1.9 Point of Contact:

1.9.10.2 Contact_Organization_Primary

1.9.10.2.1 Contact_Organization: NOAA/NESDIS/NGDC > National Geophysical Data Center

1.9.10.2.2 Contact_Person: David A. Hastings

1.9.10.4 Contact_Address

1.9.10.4.1 Address_Type: mailing address

1.9.10.4.2 Address: NOAA/NESDIS/NGDC (E/GC1) 325 Broadway

1.9.10.4.3 City: Boulder

1.9.10.4.4 State_or_Province: CO

1.9.10.4.5 Postal_Code: 80303

1.9.10.4.6 Country: USA

1.9.10.5 Contact_Voice_Telephone: (303) 497-6729

1.9.10.6 Contact_TDD/TTY_Telephone: (303) 497-6958
1.9.10.7 Contact_Facsimile_Telephone: (303) 497-6513
1.9.10.8 Contact_Electronic_Mail_Address: Email: Internet > dah@ngdc.noaa.gov

2 Data_Quality_Information
2.1 Attribute_Accuracy
2.1.1 Attribute_Accuracy_Report: Some of the methods used to measure elevation do not actually measure that of the ground surface. See Section 6 of GLOBE documentation (KGRD 34).
2.1.2 Quantitative_Attribute_Accuracy_Assessment:
2.1.2.1 Attribute_Accuracy_Value: variable may range +/- 10 to +/- 250 meters or more
2.1.2.2 Attribute_Accuracy_Explanation: statistical and histogram analysis
2.2 Logical_Consistency_Report: GLOBE documentation discusses logical consistency implicitly in its quality control and accuracy assessments. Adjacent data files have no gaps between themselves. A few land areas of 30 arc-seconds in size may be missing. Most smaller areas are missing. Bathymetry is not included in GLOBE Version 1.0. (See NGDC's TerrainBase or ETOPO5 for lower-resolution bathymetric data. GLOBE Version 2.0 may include bathymetric data.)
2.3 Completeness_Report: GLOBE has full global coverage of the land surface within the context of its 30-arc-second gridding. (Smaller features are usually not seen.)
2.4 Positional_Accuracy:
2.4.1 Horizontal_Positional_Accuracy:
2.4.1.1 Horizontal_Positional_Accuracy_Report: Arc-seconds of latitude and longitude
2.4.1.2 Quantitative_Horizontal_Positional_Accuracy_Assessment:
2.4.1.2.1 Horizontal_Positional_Accuracy_Value: 18.0
2.4.1.2.2 Horizontal_Positional_Accuracy_Explanation: Few elevation values should be more than about 18 arc-seconds from their implied location in the 30 arc-second grid.
2.4.2 Vertical_Positional_Accuracy:
2.4.2.1 Vertical_Positional_Accuracy_Report: Vertical accuracy varies by source materials used in GLOBE. Values may range from 10 meters to 250 meters (and in rare cases, to over 500 meters in elevation).
2.4.2.2 Quantitative_Vertical_Positional_Accuracy_Assessment:
2.4.2.2.1 Vertical_Positional_Accuracy_Value:
2.4.2.2.2 Vertical_Positional_Accuracy_Explanation: Methods of assessing vertical accuracy include statistical analyses of high-resolution DEM sources by their producers, assessments of contour intervals in some source maps, histogram analyses of DEMs lacking in more detailed assessments. (Histograms often show "spikes" suggesting contour intervals of source maps.)
2.5 Lineage:
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: National Imagery and Mapping Agency
2.5.1.1.1.2 Publication Date: 1996
2.5.1.1.1.4 Title: Digital Terrain Elevation Data
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: model
2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: magnetic tape
2.5.1.3 Type_of_Source_Media: CD-ROM
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: 1975

2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1996
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: DTED
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: Australian Surveying and Land Information Group
2.5.1.1.1.2 Publication Date: 1996
2.5.1.1.1.4 Title: Australian Point Elevation File
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: Magnetic tape
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1996
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: AUSLIG elevation point file
2.5.1.6 Source_Contribution: Point elevations
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: Geographical Survey Institute of Japan
2.5.1.1.1.2 Publication Date: 1995
2.5.1.1.1.4 Title: 30 arc-second DEM of Japan
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 200000
2.5.1.3 Type_of_Source_Media: Disc
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1995
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: DEM for Japan
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: Servizio Geologico Nazionale (Italy)
2.5.1.1.1.2 Publication Date: 1985
2.5.1.1.1.4 Title: Italian DEM for gravity terrain corrections
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: model

2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: Magnetic tape
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1985
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: Italian DEM for gravity terrain corrections
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: Manaaki Whenua Landcare Research, Ltd. (NZ)
2.5.1.1.1.2 Publication Date: 1995
2.5.1.1.1.4 Title: 500-metre DEM for New Zealand
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 63360
2.5.1.3 Type_of_Source_Media: Magnetic tape
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1995
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: 500-metre DEM for New Zealand
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: H.J. Zwally and others
2.5.1.1.1.2 Publication Date: 1997
2.5.1.1.1.4 Title: DEM for Greenland
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: Magnetic tape
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: 1985
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1986
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: DEM for Greenland
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:

2.5.1.1 Source_Citation:
  2.5.1.1.1 Citation_Information:
    2.5.1.1.1.1 Originator: Defense Mapping Agency (now NIMA)
    2.5.1.1.1.2 Publication Date: 1992
    2.5.1.1.1.4 Title: Digital Chart of the World
    2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Atlas
2.5.1.2 Source_Scale_Denominator: 1000000
2.5.1.3 Type_of_Source_Media: CD-ROM
2.5.1.4 Source_Time_Period_of_Content:
  2.5.1.4.1 Time_Period_Information:
    2.5.1.4.1.3 Range_of_Dates/Times:
      2.5.1.4.1.3.1 Beginning_Date: 1987
      2.5.1.4.1.3.2 Beginning_Time: Unknown
      2.5.1.4.1.3.3 Ending_Date: 1992
      2.5.1.4.1.3.4 Ending_Time: Unknown
  2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: DCW
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
  2.5.1.1.1 Citation_Information:
    2.5.1.1.1.1 Originator: Army Map Service (U.S. Army, now part of NIMA)
    2.5.1.1.1.2 Publication Date: Unknown
    2.5.1.1.1.4 Title: Various maps
    2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Atlas
2.5.1.2 Source_Scale_Denominator: 1000000
2.5.1.3 Type_of_Source_Media: Paper
2.5.1.4 Source_Time_Period_of_Content:
  2.5.1.4.1 Time_Period_Information:
    2.5.1.4.1.3 Range_of_Dates/Times:
      2.5.1.4.1.3.1 Beginning_Date: Unknown
      2.5.1.4.1.3.2 Beginning_Time: Unknown
      2.5.1.4.1.3.3 Ending_Date: Unknown
      2.5.1.4.1.3.4 Ending_Time: Unknown
  2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: AMS maps
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
  2.5.1.1.1 Citation_Information:
    2.5.1.1.1.1 Originator: Fundacao Instituto Brasiliero de Geografia e Estatistica (Brazil), published under the International Map of the World series
    2.5.1.1.1.2 Publication Date: Unknown
    2.5.1.1.1.4 Title: Various maps
    2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Atlas
2.5.1.2 Source_Scale_Denominator: 1000000
2.5.1.3 Type_of_Source_Media: Paper
2.5.1.4 Source_Time_Period_of_Content:
  2.5.1.4.1 Time_Period_Information:
    2.5.1.4.1.3 Range_of_Dates/Times:
      2.5.1.4.1.3.1 Beginning_Date: Unknown

2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: Unknown
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: IMW maps
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: Ministerio de Guerra (Peru)
2.5.1.1.1.2 Publication Date: 1984
2.5.1.1.1.4 Title: Mapa Fisico Politico del Peru
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Map
2.5.1.2 Source_Scale_Denominator: 1000000
2.5.1.3 Type_of_Source_Media: Paper
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1984
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: Peru map
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: Scientific Committee on Antarctic Research
2.5.1.1.1.2 Publication Date: 1994
2.5.1.1.1.4 Title: Antarctic Digital Database
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Atlas
2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: CD-ROM
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1994
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: ADD
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: National Oceanic and Atmospheric Administration (National Geophysical Data Center)
2.5.1.1.1.2 Publication Date: Unknown
2.5.1.1.1.4 Title: Digital Topographic Data

2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: CD-ROM
2.5.1.3 Type_of_Source_Media: Magnetic tape
2.5.1.3 Type_of_Source_Media: Online
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: Unknown
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: NGDC Topographic Data
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: GLOBE Task Team of the Committee on Earth Observation Satellites, via the National Oceanic and Atmospheric Administration (National Geophysical Data Center)
2.5.1.1.1.2 Publication Date: 1999
2.5.1.1.1.4 Title: Global Land One-km Base Elevation Digital Elevation Model
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: CD-ROM
2.5.1.3 Type_of_Source_Media: Online
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1999
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: GLOBE
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: U.S. Geological Survey
2.5.1.1.1.2 Publication Date: Unknown
2.5.1.1.1.4 Title: Digital elevation models
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 250000
2.5.1.3 Type_of_Source_Media: Magnetic tape
2.5.1.3 Type_of_Source_Media: Online
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown

2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1970
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: USGS DEMs
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: U.S. Geological Survey
2.5.1.1.1.2 Publication Date: 1997
2.5.1.1.1.4 Title: GTOPO30
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: CD-ROM
2.5.1.3 Type_of_Source_Media: Online
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1996
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: USGS GTOPO30
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: National Oceanic and Atmospheric Administration (National Geophysical Data Center)
2.5.1.1.1.2 Publication Date: 1997
2.5.1.1.1.4 Title: AUSLIG/NGDC DEM for Australia
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: CD-ROM
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1996
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: DEM for Australia
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: National Oceanic and Atmospheric Administration (National Geophysical Data Center)

2.5.1.1.1.2 Publication Date: 1994
2.5.1.1.1.4 Title: DEM for Italy
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: CD-ROM
2.5.1.3 Type_of_Source_Media: Online
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1984
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: DEM for Italy
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: Jet Propulsion Laboratory
2.5.1.1.1.2 Publication Date: 1996
2.5.1.1.1.4 Title: Zwally (and others)/NSIDC/JPL DEM for Greenland
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 99999999
2.5.1.3 Type_of_Source_Media: File transfer
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1994
2.5.1.4.1.3.4 Ending_Time: Unknown
2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: Zwally (and others)/NSIDC/JPL DEM for Greenland
2.5.1.6 Source_Contribution: Elevation data
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
2.5.1.1.1 Citation_Information:
2.5.1.1.1.1 Originator: U.S. Geological Survey
2.5.1.1.1.2 Publication Date: 1996
2.5.1.1.1.4 Title: DEM for New Zealand
2.5.1.1.1.6 Geospatial_Data_Presentation_Form: Model
2.5.1.2 Source_Scale_Denominator: 63360
2.5.1.3 Type_of_Source_Media: Online
2.5.1.4 Source_Time_Period_of_Content:
2.5.1.4.1 Time_Period_Information:
2.5.1.4.1.3 Range_of_Dates/Times:
2.5.1.4.1.3.1 Beginning_Date: Unknown
2.5.1.4.1.3.2 Beginning_Time: Unknown
2.5.1.4.1.3.3 Ending_Date: 1996
2.5.1.4.1.3.4 Ending_Time: Unknown

2.5.1.4.2 Source_Currentness_Reference: Publication date
2.5.1.5 Source_Citation_Abbreviation: DEM for New Zealand
2.5.1.6 Source_Contribution: Elevation data
2.5.2 Process_Step:
2.5.2.1 Process_Description: DTED has had several processing runs at the Defense Mapping Agency (now NIMA), the U.S. Geological Survey (USGS), and the National Geophysical Data Center (NGDC), before being mosaicked into GLOBE Version 1.0. Generally, DTED Level 1 data were resampled to 30 arc-second gridding by different methods at different times, mosaicked from 1x1 degree DTED cells, quality-checked, then blended by USGS and/or NGDC into regional or GLOBAL DEMs. The latter were used for the final blending into GLOBE. GLOBE documentation gives more detail.
2.5.2.2 Source_Used_Citation_Abbreviation: DTED
2.5.2.3 Process_Date: 1997
2.5.2.5 Source_Produced_Citation_Abbreviation: USGS DEMs
2.5.2.5 Source_Produced_Citation_Abbreviation: NGDC topographic data
2.5.2.5 Source_Produced_Citation_Abbreviation: GTOPO30
2.5.2.6 Process_Contact:
2.5.2.6.2 Contact_Organization_Primary
2.5.2.6.2.1 Contact_Organization: NOAA/NESDIS/NGDC > National Geophysical Data Center
2.5.2.6.2.2 Contact_Person: David A. Hastings
2.5.2.6.4 Contact_Address
2.5.2.6.4.1 Address_Type: Mailing address
2.5.2.6.4.2 Address: NOAA/NESDIS/NGDC (E/GC1) 325 Broadway
2.5.2.6.4.3 City: Boulder
2.5.2.6.4.4 State_or_Province: CO
2.5.2.6.4.5 Postal_Code: 80303
2.5.2.6.4.6 Country: USA
2.5.2.6.5 Contact_Voice_Telephone: (303) 497-6729
2.5.2.6.6 Contact_TDD/TTY_Telephone: (303) 497-6958
2.5.2.6.7 Contact_Facsimile_Telephone: (303) 497-6513
2.5.2.6.8 Contact_Electronic_Mail_Address: Email: Internet > dah@ngdc.noaa.gov
2.5.2 Process_Step:
2.5.2.1 Process_Description: The AUSLIG elevation point file was interpolated to a 30 arc-second grid file using the GRASS-GIS function s.surf.idw (using 3 nearest points). This work was done at the National Geophysical Data Center, under an agreement with AUSLIG, to produce a model for use in GLOBE.
2.5.2.2 Source_Used_Citation_Abbreviation: AUSLIG elevation point file
2.5.2.3 Process_Date: 1997
2.5.2.5 Source_Produced_Citation_Abbreviation: DEM for Australia
2.5.2.6 Process_Contact:
2.5.2.6.2 Contact_Organization_Primary
2.5.2.6.2.1 Contact_Organization: NOAA/NESDIS/NGDC > National Geophysical Data Center
2.5.2.6.2.2 Contact_Person: David A. Hastings
2.5.2.6.4 Contact_Address
2.5.2.6.4.1 Address_Type: Mailing address
2.5.2.6.4.2 Address: NOAA/NESDIS/NGDC (E/GC1) 325 Broadway
2.5.2.6.4.3 City: Boulder
2.5.2.6.4.4 State_or_Province: CO
2.5.2.6.4.5 Postal_Code: 80303

2.5.2.6.4.6 Country: USA
2.5.2.6.5 Contact_Voice_Telephone: (303) 497-6729
2.5.2.6.6 Contact_TDD/TTY_Telephone: (303) 497-6958
2.5.2.6.7 Contact_Facsimile_Telephone: (303) 497-6513
2.5.2.6.8 Contact_Electronic_Mail_Address: Email: Internet > dah@ngdc.noaa.gov
2.5.2 Process_Step:
2.5.2.1 Process_Description: The Italian DEM for gravity terrain corrections was resampled to 30" gridding by the National Geophysical Data Center (NGDC), following a joint design by NGDC and the Servizio Geologico Nazionale of Italy.
2.5.2.2 Source_Used_Citation_Abbreviation: Italian DEM for gravity terrain corrections
2.5.2.3 Process_Date: 1994
2.5.2.5 Source_Produced_Citation_Abbreviation: DEM for Italy
2.5.2.6 Process_Contact:
2.5.2.6.2 Contact_Organization_Primary
2.5.2.6.2.1 Contact_Organization: NOAA/NESDIS/NGDC > National Geophysical Data Center
2.5.2.6.2.2 Contact_Person: David A. Hastings
2.5.2.6.4 Contact_Address
2.5.2.6.4.1 Address_Type: Mailing address
2.5.2.6.4.2 Address: NOAA/NESDIS/NGDC (E/GC1) 325 Broadway
2.5.2.6.4.3 City: Boulder
2.5.2.6.4.4 State_or_Province: CO
2.5.2.6.4.5 Postal_Code: 80303
2.5.2.6.4.6 Country: USA
2.5.2.6.5 Contact_Voice_Telephone: (303) 497-6729
2.5.2.6.6 Contact_TDD/TTY_Telephone: (303) 497-6958
2.5.2.6.7 Contact_Facsimile_Telephone: (303 497-6513
2.5.2.6.8 Contact_Electronic_Mail_Address: Email: Internet > dah@ngdc.noaa.gov
2.5.2 Process_Step:
2.5.2.1 Process_Description: The 500-m DEM for New Zealand was reprojected from the New Zealand national projection and datum to latitude-longitude 30" gridding by the U.S. Geological Survey.
2.5.2.2 Source_Used_Citation_Abbreviation: 500-m DEM for New Zealand
2.5.2.3 Process_Date: 1996
2.5.2.5 Source_Produced_Citation_Abbreviation: DEM for New Zealand
2.5.2.6 Process_Contact:
2.5.2.6.2 Contact_Organization_Primary
2.5.2.6.2.1 Contact_Organization: U.S. Geological Survey
2.5.2.6.2.2 Contact_Person: Susan K. Greenlee
2.5.2.6.4 Contact_Address
2.5.2.6.4.1 Address_Type: Mailing address
2.5.2.6.4.2 Address: USGS EROS Data Center
2.5.2.6.4.3 City: Sioux Falls
2.5.2.6.4.4 State_or_Province: SD
2.5.2.6.4.5 Postal_Code: 57198
2.5.2.6.4.6 Country: USA
2.5.2.6.5 Contact_Voice_Telephone: (605) 594-6011
2.5.2.6.7 Contact_Facsimile_Telephone: (605) 594-6589
2.5.2.6.8 Contact_Electronic_Mail_Address: Email: Internet > sgreenlee@usgs.gov
2.5.2 Process_Step:
2.5.2.1 Process_Description: The NSIDC DEM for Greenland was resampled to 30 arc-seconds