GRASS 4.0 Tutorial:
DTED and DEM Elevation Data Extraction

Stuart Bradshaw
Mary Martin
Chester Kos
Scott Tweddale

U.S. Army Corps of Engineers
Construction Engineering Research Laboratory
Environmental Division
Spatial Analysis Systems Team
P.O. Box 9005
Champaign, IL 61826-9005

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1. INTRODUCTION

1.1. Background

This document describes the means by which users can convert digital elevation data produced by the Defense Mapping Agency and the U.S. Geological Survey into GRASS raster format. GRASS (the Geographic Resources Analysis Support System) is a public domain, image processing, and geographic information system (GIS) originally developed by researchers in the Environmental Division of the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (USACERL-EN) in Champaign, Illinois. The system is used to input, manipulate, analyze, and output geographic data by users in both military and non-military and public and private agencies based in North America, Europe, and other parts of the world. Elevation data are employed in a variety of GRASS applications.

Although most GRASS development has been conducted at USACERL, system integration, development, testing, distribution, training, and support is performed by numerous publicly- and privately-operated sites throughout the world. GRASS version 4.0 implemented significant additions and modifications to system libraries and programming code. Mechanisms are needed to transfer current technology and information about GRASS to user and development sites.

This document reflects modifications made to GRASS version 4.0 and guides the user through the importation of digital elevation data into GRASS.

1.2. Objective

The objective of this work is to transfer knowledge of GRASS version 4.0 data input and conversion functions to the field. This document guides the user through the process of using a number of GRASS and UNIX programs to extract different forms of elevation data and import these into a GRASS database.

1.3. Approach

Current GRASS elevation data file extraction and import functions are examined in this report.

1.4. Scope

This document discusses the 4.0-release version of GRASS elevation data file extraction and import programs, completed in Summer of 1991. Some elements of this document will be dated and inaccurate for post-4.0 software releases.

1.5. Mode of Technology Transfer

The information in this report will aid the technical transfer of USACERL's GRASS image processing and geographic information system. GRASS is being transferred to the field through the following mechanisms: training programs, hands-on experience, a user support center, newsletters, extensive documentation, institutional structures at the Army and interagency levels, communication networks, and other forums.

User feedback on GRASS program capabilities, documentation, and other technology transfer mechanisms is important to the development of the system. Users are encouraged to communicate such feedback to GRASS development staff at USACERL, via existing electronic communication networks and via the GRASS Information Center at USACERL, P.O. Box 9005, Champaign, IL 61826-9005; phone 217-373-7220; fax 217-373-7222; or e-mail: grassbug@zorro.cecer.army.mil.

2. ELEVATION DATA IN GRASS

Elevation data are employed in a variety of GRASS applications. Before such data can be used, however, they must be converted to a raster format usable within GRASS. This tutorial describes the means by which users can convert digital elevation data produced by the Defense Mapping Agency (DMA) and the U.S. Geological Survey (USGS) into GRASS raster format.

This process involves: (1) extracting the elevation data from magnetic tape, and (2) importing the data into GRASS in raster form. This tutorial also explains how to generate slope and aspect GRASS raster files from the imported elevation data, and how to rescale the elevation data.

The USGS produces a digital elevation product called Digital Elevation Model (**DEM**) data. The process by which DEM data are extracted from tape is fairly simple and is explained in section 1 of this tutorial. The DMA produces two types of elevation data, called Digital Terrain Elevation Data Levels 1 & 2 (**DTED-1**, and **DTED-2**). The tape extraction process for DTED data is slightly more complex and is explained in section 2.

This tutorial assumes use of the spearfish sample database distributed to users along with their GRASS code (i.e., it assumes the user is working in LOCATION: *spearfish*, and MAPSET: *sample*). This location and mapset were used to enable the user to replicate the examples in this tutorial. However, you may substitute your own location and mapset for these if you wish. Similarly, for the purposes of this tutorial, the full pathname leading to our spearfish sample database is: **/usr/grass.data/spearfish/sample** (i.e., $GISDBASE/spearfish/sample). Your database may be installed in a different location on your system. If you install your database in a path other than this one, change the pathnames appropriately where they are used throughout this tutorial.

Commands to be entered by the user will appear in **bold** type. Variables that the user should specify (i.e., file names, pathnames, device names, etc.) will appear in *italics*.

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1. Extracting DEM Data and Generating Appropriate Map Layers
2. Extracting DTED Data and Generating Appropriate Map Layers
3. Generating Slope and Aspect Map Layers
4. Rescaling Elevation Data

3. EXTRACTING DEM DATA AND GENERATING APPROPRIATE MAP LAYERS

The USGS produces 7.5-minute Digital Elevation Model (DEM) data and distributes it on 1/2-inch, 9-track magnetic tapes. These data are referenced using the Universal Transverse Mercator (UTM) coordinate system. The following steps guide the user through the process of extracting DEM data from magnetic tape and generating GRASS raster files.

3.1. Setting Up the User's Environment

Place a map with UTM coordinates of the area of interest beside you. An index of the 1:24,000 topographic maps of the relevant state by your side will also be useful. If you ordered DEM data, then you probably identified the quad(s) with this index. Start running GRASS version 4.0, by typing:

grass4.0

Choose an appropriate *location* and *mapset*.

Load the DEM tape onto a tape drive. You should be familiar with the tape drive used. Assuming that the tape is physically loaded, you now need to set the tape density. On Concurrent (a.k.a., Masscomp) machines, enter either of the following two commands (which is dependent on your system set-up):

assign 1600 or **assign 1600x**

If you are working on a Sun Microsystems machine, the tape density will be set automatically. (The appropriate tape density will generally be 1600 bpi unless a different value is written on the tape spool.)

3.2. Examine the DEM Tape

Check the contents of the tape using the GRASS command **m.dem.examine**. This command scans each file and displays information to the terminal screen.

Type the following command, specifying the appropriate parameters:

m.dem.examine input=*name* **blocksize=***tape_block_size*

where *name* is the input file (e.g., /dev/rmt0) and *tape_block_size* is the physical block size of the data on your tape. (If you do not know the physical block size, use the GRASS command **m.examine.tape** to discover it.) The block size associated with a DEM tape is usually 10,240. For example, if you have a tape containing DEM data for the spearfish sample data set, the command line:

m.dem.examine input=/dev/rmt0 blocksize=10240

will examine the files on tape and print the following information to the screen:

```
DEADWOOD NORTH

min elevation:    1061.0
max elevation:    1676.0

ns_res:     30.00
ew_res:     30.00

# of columns in file = 375

file north UTM = 4928112.0
file south UTM = 4914068.0
file east  UTM = 609546.125
file west  UTM = 599375.1875
-----------------------------------------------------------------
```

```
-----------------------------------------------------------------
    SPEARFISH

    min elevation:    1079.633545
    max elevation:    1841.247803

    ns_res:     30.00
    ew_res:     30.00

    # of columns in file = 339

    file north UTM = 4927952.5
    file south UTM = 4913923.5
    file east  UTM = 599587.375
    file west  UTM = 589437.6875
-----------------------------------------------------------------
```

Information about each file on the tape will appear. In this case, two reports appear since there are two files on the tape.

3.3. Choosing a Region

The tape extraction program only extracts DEM data that fall within the boundaries of the current region. Run the GRASS programs *g.region* to set your region large enough to encompass all of the desired data. In general, the default region can be used. However, to create an elevation raster file covering only a single quad, it is necessary to identify the UTM coordinates bounding the four edges of the quad. For example, to create a raster file for only the Deadwood North quad using the example DEM tape above, record the UTMs provided through *m.dem.examine*, run the GRASS program *g.region*, and enter the coordinates of the desired region and the resolution of the resultant raster file.

Note that it is important to set the region correctly to ensure that all desired elevation data desired are properly extracted. Type

g.region

to identify the region.

3.4. Extract the Data

The GRASS program *m.dem.extract* extracts DEM data and creates a raster file.
The format in which it is used is stated below. The user should specify relevant parameters.

m.dem.extract input=*tapedev* **output=***raster_file* **blocksize=***block_size*

input=*tapedev*	Tape device name (*input file*).
output=*raster_file*	Resultant raster file name (*output file*); this file will always be placed into the "cell" directory under the user's current GRASS mapset.
blocksize=*block_size*	Tape *block size*.

For example, the following command:

m.dem.extract input=/dev/rmt0 output=dem_elevation blocksize=10240

will extract DEM data from a tape having a block size of 10,240, and convert it into a raster-format file named "dem_elevation." The *m.dem.extract* program will report to the screen the UTM coordinates defining the region into which these data will fall, the number of rows and columns in the resultant raster file, and the resolution of the raster file being created. This output is simply a description of the current region.

rows:	# of rows in raster file
cols:	# of cols in raster file
north:	north edge of raster file
south:	south edge of raster file
east:	east edge of raster file
west:	west edge of raster file
ns_res:	north-south resolution
ew_res:	east-west resolution

Type the command:

m.dem.extract input=*tape_device_name* **output=***output_file_name* **blocksize=10240**

The extraction of a single quad will take about one-half hour. If you are extracting more than one quad and are communicating with the computer through a network, place the extraction program in the "background." This will preserve the execution of the program if the network goes down and will also allow you to execute other GRASS programs while waiting. To place this process in the background, type:

^Z <RETURN>
bg

When the program has finished running, check to see that the output raster file was created. List the files present in your directory with the command:

ls /usr/grass.data/*your_LOCATION/your_MAPSET***/cell**

The output file created by the extract program should be listed in this directory. If the raster file is present, you have successfully developed an elevation map layer.

The DEM file created is still not in a form directly usable within GRASS. You now need to run the GRASS command **r.support**.

4. EXTRACTING DTED AND GENERATING APPROPRIATE MAP LAYERS

The process of generating elevation files from DMA data consists of three steps:

1. Extracting Data from Tape(s): Data are extracted from magnetic tape and stored in an output file on the user's system.
2. Rotating the Data: The output file resulting from Step 1 is rotated to an orientation usable within GRASS.
3. Importing the Data to Raster Files: The rotated data are referenced using the UTM map coordinate system, and imported into GRASS raster form.

The Defense Mapping Agency produces Digital Terrain Elevation Data levels 1 and 2 (DTED-1, and DTED-2). Although both the DMA and the USGS distribute this data, each distributes it in a different tape format. The program you use to extract DTED data from tape will therefore depend upon your source of the data (DMA or USGS). DTED data obtained from the *DMA* are extracted using the GRASS program *m.dted.extract*. DTED data obtained from the *USGS* are extracted using the program *m.dmaUSGSread*. Determine the distribution source of your DTED before you begin the extraction process.

4.1. Setting Up the User's Environment

Place a map with latitude and longitude as well as UTM coordinates of the geographic area of interest beside you. Invoke GRASS by typing:

grass4.0

Choose an appropriate *location* and *mapset*.

Note that several files which consume large amounts of computer memory and disk space are created during this extraction process. These files are placed in your current working directory and must be manually removed by you later (e.g., using the UNIX **rm** command).

DTED data come on 1/2-inch magnetic tape. Load the tape onto a tape drive. Assign the appropriate tape density. On Concurrent machines, use either of the following two commands (which is dependent on your set-up):

assign 1600 or **assign 1600x**

If you obtained your data from the USGS, then continue with section 2.2. If you obtained your data from the DMA, proceed to section 2.3.

4.2. Extracting DTED from USGS tapes

The program *m.dmaUSGSread* is used to extract DTED data from tapes purchased from the USGS. The format for the command is:

dd [if=*tape_drive_name***] ibs=***input_block_size* **| m.dmaUSGSread top=***value* **bottom=***value* **left=***value* **right=***value* **output=***name* **logfile=***name*

The user should substitute specific items for those which are italicized on the command line shown above.

tape_drive_name = Name of the tape drive [default /dev/rmt0]
input_block_size = Input block size; usually written on the tape spool
value = Beginning or ending row and column numbers of the data
output *name* = Name of output file to hold the extracted DTED data
logfile *name* = Name of file to hold related information about the extracted data

The number of rows and columns of data for each DTED file supplied by the USGS is 1201, with the row-column origin in the southwest corner. It is easiest to extract all 1201 rows and columns, since this will ensure that your area of interest will be completely extracted.
For example, given the following parameters,

if	=	/dev/rmt0
ibs	=	10240
top	=	row SW (1)
left	=	col SW (1)
bottom	=	row NE (1201)
right	=	col NE (1201)

the command line:

dd if=/dev/rmt0 ibs=10240 | m.dmaUSGSread top=1 bottom=1201 left=1 right=1201 output=dted.data logfile=dted.logfile

will extract DTED data from the input file (tape drive) /dev/rmt0, and place them into an output file named "dted.data" in the user's current working directory. Once the data have been extracted, the file "dted.data" should be rotated 90 degrees. This procedure is discussed in section 2.4.

4.3. Extracting DTED from DMA tapes

Examine the contents of your tape using the program *m.dted.examine*. This program reads the header file and prints to the screen information describing the data. Enter the command:

m.dted.examine input=*tape_drive_name*

The *m.dted.extract* program is used to extract DTED data from tapes obtained from the DMA. The format for this command with all its arguments is:

m.dted.extract [-fq] input=*name* **output=***name* **header=***name* **north=***lat* **south=***lat* **east=***lon* **west=***lon*

-f Read the entire tape in all cases.

-q Run quietly, without displaying messages on program progress to standard output.

input=*name* The name of a tape drive on which the DMA *input file* will be mounted. If the user does not specify a tape drive on the command line, this program will assign input to be taken from the tape drive /dev/rmt0, by default.

output=*name* The name and location (expressed by the full pathname) of the *output file* into which the DMA data extracted from the tape (the input file) will be placed (for example, of = /tmp/dma.out).

header=*name* The name and location (full pathname) of a *header file* describing the new output file (i.e., hf = /tmp/dma.hd) should be placed in the same directory as the output file.

north,south,east,west The north, south, east, and west latitude and longitude coordinates of a region completely encompassing the user's area of interest within the database named in the user's LOCATION. These coordinates should be slightly larger than the area described by the UTM coordinate boundaries of the actual area of interest to ensure that no areas for which DMA data are available are lost. Only data that fall within this region will be extracted from tape. Data outside this region will be ignored. The format for these variables is: ddd.mm.ss{N|S|E|W}, where *ddd* are degrees, *mm* are minutes, *ss* are seconds, and either N, S, E, or W is appended to represent north, south, east, or west (e.g., 104.00.00N).

For example, given the following parameters,

```
input   =   /dev/rmt0
output  =   dma.out
header  =   dma.hd
north   =   37.30.00N
south   =   37.13.00N
east    =   103.30.00W
west    =   103.45.00W
```

the following command will extract the data from the tape for the designated region:

m.dted.extract input=/dev/rmt0 output=dma.out header=dma.hd north=37.30.00N south=37.13.00N east=103.30.00W west=103.45.00W

If the command is executed correctly, the following will appear:

```
initializing dma.out

SW    37.00.00N  105.00.00W
NE    38.00.00N  104.00.00W
SW    37.00.00N  104.00.00W
NE    38.00.00N  103.00.00W
```

The screen above indicates the program has been successfully started. The above parameters are latitude and longitude coordinates describing the corners of the data contained on the tape.

The output files created by this program which we have called ‘‘dma.out" and ‘‘dma.hd," should now appear in your current directory.

Examine the header file before proceeding. It contains the following information, some of which is required as input to the GRASS programs *m.rot90* and *r.in.ll*.

1. The latitude and longitude coordinates of the extract region
2. The resolution of the latitude and longitude
3. The number of bytes per column (bpc) (generally 2 on DMA tapes)
4. The number of rows and columns

4.4. Rotating the Data

Geographic data in GRASS are oriented toward true north and are stored in data files row by row. However, when DTED data are read from a tape, data are extracted column by column, moving from the southwesternmost corner to the northeasternmost corner. In relation to the way in which GRASS data are stored in raster files, the DTED data extracted from tape are rotated 90 degrees. The extraction programs discussed above simply extracted elevation data from a tape without altering its orientation. We now must *rotate* each column of data (in the file "dma.out") 90 degrees to make it correspond with the GRASS data storage format.

The GRASS program *m.rot90* rotates the extracted data 90 degrees, putting true north at the top of the file. The use of this command is stated below:

m.rot90 [-q] input=*name* **output=***name* **rows=***value* **cols=***value* **bpc=***value*

where:

-q	Run quietly, without displaying messages on program progress to standard output (the user's terminal screen).
input=*name*	The *full pathname* of the file created by either of the GRASS programs *m.dmaUSGSread* or *m.dted.extract*, identifying the file to be rotated.
output=*name*	The name of an *output file* to contain the rotated data.
rows=*value*	The number of *rows* in the input file.
cols=*value*	The number of *columns* in the input file.
bpc=*value*	The number of *bytes per cell* (bpc) -- i.e., bytes per data value.

Given the below parameters,

input	=	dma.out
output	=	rot.out
rows	=	301
cols	=	358
bpc	=	2

the following command will rotate the data in the file "dma.out" 90 degrees, and place the output in the new file "rot.out."

m.rot90 input=dma.out output=rot.out rows=301 cols=358 bpc=2

Enter the command along with the proper parameters. When the GRASS prompt returns, list out the files present in your current working directory. You should now find the output file named "rot.out," in addition to the output "dma.out" and header "dma.hd" files already created by the *m.dem.extract* program.

4.5. Importing the Data to a Raster File

The program *r.in.ll* converts the above rotated file from latitude and longitude coordinates to UTM coordinates, and creates a raster file. Note that *r.in.ll* will create the new raster file based on the current region. It is therefore important that you check the boundaries of the current region *before* you create the new raster file, to ensure that the current region is sufficiently large to encompass the extracted data. Only data falling into the current region will be converted to raster form. Set the current region by running the GRASS command:

g.region

The command **r.in.ll** with all its arguments is:

r.in.ll [-s] input=*name* **output=***name* **bpc=***value* **corner=***corner,lat,lon*
dimension=*rows,cols* **res=***latres,lonres* **spheroid=***name*

where:

-s	Signed data (high bit means negative value).
input=*name*	The full pathname of an existing *input raster file*.
output=*name*	The name of an *output file* into which the resulting raster file will be placed.
bpc=*value*	Number of *bytes per cell*.
corner=*corner,lat,lon*	The latitude and longitude coordinates of any *one corner* of the input file. Format: {nw|ne|sw|se},dd:mm:ss{N|S},ddd:mm:ss{E|W}. The latitude and longitude are specified as **dd.mm.ssH** where dd is degrees, mm is minutes, ss is seconds, and H is the hemisphere. (e.g., to specify the southwest corner: **corner**=sw,46N,120W). Note: the latitude and longitude specified are for the center of the corner cell.
dimension=*rows,cols*	Number of *rows* and *columns* in the input file.
res=*latres,lonres*	The *resolution* of the latitude and longitude in arc-seconds (taken from the header file).
spheroid=*name*	*Spheroid* of local datum (spheroid of projection). Options: airy, australian, bessel, clark66, everest, grs80, hayford, international, krasovsky, wgs66, wgs72, wgs84.

It is important to recall that the output file ‘‘rot.out" created by *m.rot90* contains the *rotated* data. This means that the data contained in **rows** in the file ‘‘dma.out" (the input file to *m.rot90*) are now in **columns** in the file ‘‘rot.out" (the *m.rot90* output file); similarly, what were **columns** in the file *dma.out* are now **rows** in the file *rot.out*" *Therefore, the numbers of rows and columns must be switched. You need to tell r.in.ll* the numbers of rows and columns present in the input file to this program (i.e., the numbers of rows and columns in *rot.out*). You must therefore remember here to reverse the numbers of rows and columns you earlier input to the *m.rot90* program.

The number of bytes per column, the resolutions of the latitude and longitude, and the latitude/longitude coordinates describing any single corner of your input file, are all available in the header file stored in *dma.hd*. The spheroid of local datum refers to the spheroid projection to be used. Currently, the following spheroid projections are available:

airy	everest	krasovsky
australian	grs80	wgs66
bessel	hayford	wgs72
clark66	international	wgs84

The spheroid of local datum (projection) commonly used for most map sources within the United States currently is *clark66.*

You must input your request to the *r.in.ll* program using this format. In this example these variables are assigned the following values:

input = rot.out
output = import.out
bpc = 2
corner = sw,37.13.00N,103.45.00W
rows = 358

cols = 301
latres = 3
lonres = 3
spheroid = clark66

The following line is the correct format utilizing the above parameters.

r.in.ll input=rot.out output=import.out bpc=2 corner=sw,37:13N,103:45W dimension=358,301 res=3,3 spheroid=clark66

List the files present in the directory with the command:

ls /usr/grass.data/*your_LOCATION/your_MAPSET***/cell**

The output file created by this program which we have called ‘‘import.out" should now be listed in this directory.

You may now rescale your data if so desired (see section 4). If you desire to produce aspect and slope raster files, continue with section 3 before going to section 4.

5. GENERATION OF SLOPE AND ASPECT MAP LAYERS

Slope and aspect raster files are derived from unrescaled elevation data using the GRASS program *r.slope.aspect*. Slope and aspect layers should only be created from elevation files that represent true elevation (i.e., not with rescaled elevation files). To generate slope and aspect map layers type the command:

r.slope.aspect

You will be asked to input the name of the elevation raster file to be used, a name for the new slope map layer, and a name for the new aspect map layer.

6. RESCALING THE ELEVATION DATA

Throughout the GIS world, it is customary to rescale data into the range 0-255. Prior to release of GRASS version 3.0, this was also done in GRASS. All GRASS 3.0 and GRASS 4.0 programs now comfortably handle raster files having more than 256 categories.

It is sometimes desirable to rescale raster files into 256 categories. However, do not destroy your true value file. There are several programs in GRASS that require the use of true value raster files to perform accurate calculations.

To find the category value range of a raster file, use the GRASS command *r.describe*:

r.describe -r map=import.out

r.describe will evaluate the raster file and report the range of elevation values within it.

The rescaling of elevation data is done using the GRASS command *r.rescale*. Let us rescale the spearfish elevation file with which we have been working. The elevation range of the DEM data for the spearfish data set is 1066-1840 meters. Type the command:

r.rescale

You will be asked for the name of the map to be rescaled and for the name of the new, rescaled raster map:

This program allows you to rescale a data layer so that all the data fall with in a range that you choose

Enter the data range to be rescaled (data outside the range you specify will become 0)
min: 1066____
max: 1840____

Enter the resultant data range

min: 1_____
max: 255____

When finished, an elevation raster file which may be used and displayed will exist in your mapset. At this point, if you are satisfied with the new data layer, remove any files created during this session which are no longer needed; i.e., the large files created by the DMA extraction and conversion processes.

7. CONCLUSIONS AND RECOMMENDATIONS

This manual is part of an ongoing process to document Geographic Resources Analysis Support System (GRASS) program functions. It is one of many technology transfer mechanisms being implemented to explain current, and future, GRASS program capabilities to resource managers and system users.

Documentation, along with training programs, hands-on use, a user-support center, newsletters, institutional structures at the Army and interagency levels, communication networks, and other forums, can be used to aid this on-going technology transfer effort.

User feedback on GRASS program capabilities, documentation, and other technology transfer mechanisms is also needed. Users are encouraged to communicate such feedback to GRASS development staff at USACERL, via existing electronic communication networks and via the GRASS Information Center at USACERL, P.O. Box 9005, Champaign, IL 61826-9005; phone 217-373-7220; fax 217-373-7222; or e-mail grassbug@zorro.cecer.army.mil.

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