GMT and gridded data sets

- GMT can be used to calculate and display **gridded data sets**
- A gridded data set is an array of regularly spaced points in space
- You can think of it as a matrix (or as a spreadsheet):
  - Rows and columns correspond to y and x axis (for instance latitude and longitude)
  - The value in each cell represents the measured quantify (for instance elevation)

GMT and gridded data sets

- Gridded data sets in GMT are stored in net-CDF format: a binary format with a header followed by the data
- `grdinfo` allows you to check the contents of a GMT grid file
- Download `etopo5.grd` from the class web site and type `grdinfo etopo5.grd` to get:

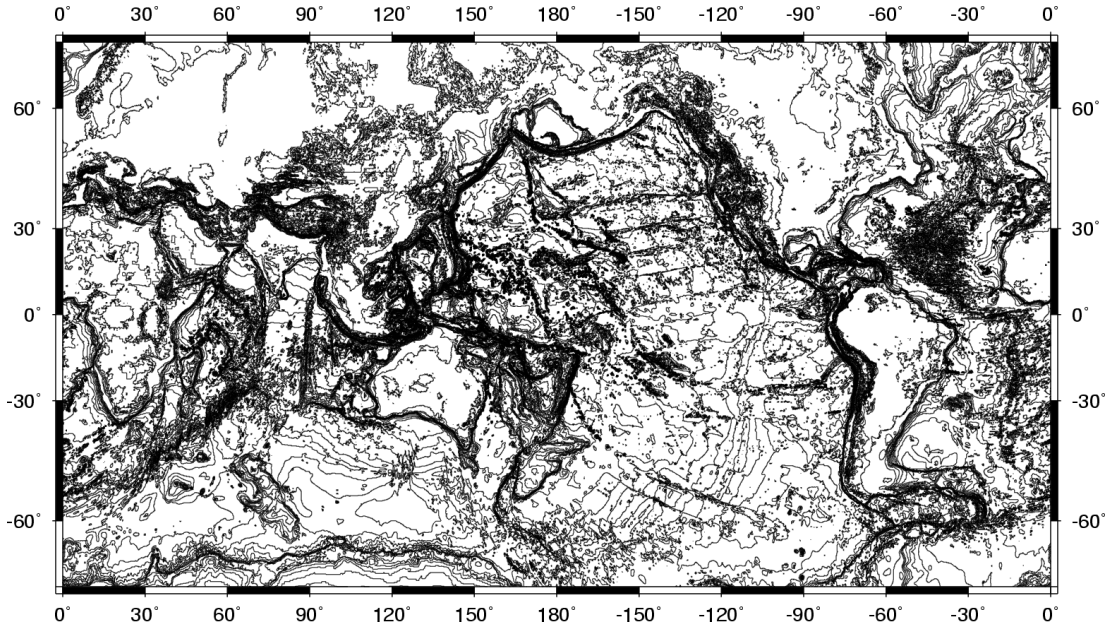
```
etopo5.grd: Title: TOPO world
etopo5.grd: Command: grdmath etopo5.grd 1000 x = etopo5km.grd
etopo5.grd: Remark:
etopo5.grd: Normal node registration used
etopo5.grd: grdfile format # 0
etopo5.grd: x_min: 0 x_max: 360 x_inc: 0.0833333 units: degree nx: 4321
etopo5.grd: y_min: -90 y_max: 90 y_inc: 0.0833333 units: degree ny: 2161
etopo5.grd: z_min: -10741 z_max: 7833 units: km
etopo5.grd: scale_factor: 1 add_offset: 0
```

- This file contains the world topography and bathymetry with a grid step of 5 minutes (about 10 km)

Contouring gridded data sets

- Gridded data sets can be displayed as contour maps
- For instance:

```
grdcontour etopo5.grd -R0/360/-70/70 -JM7i \
          -C500 -P -B30 > etopo5_cont.ps
```



Contouring gridded data sets

Other contouring options:

- Annotate contours with `-A2000` (every 2000 unit)
- Add smoothing with `-S4`
- Tick highs and lows with `-T`
- Skip small features with `-Q100` (skip if contour defined by less than 100 points)

Contouring gridded data sets

Customize your contours:

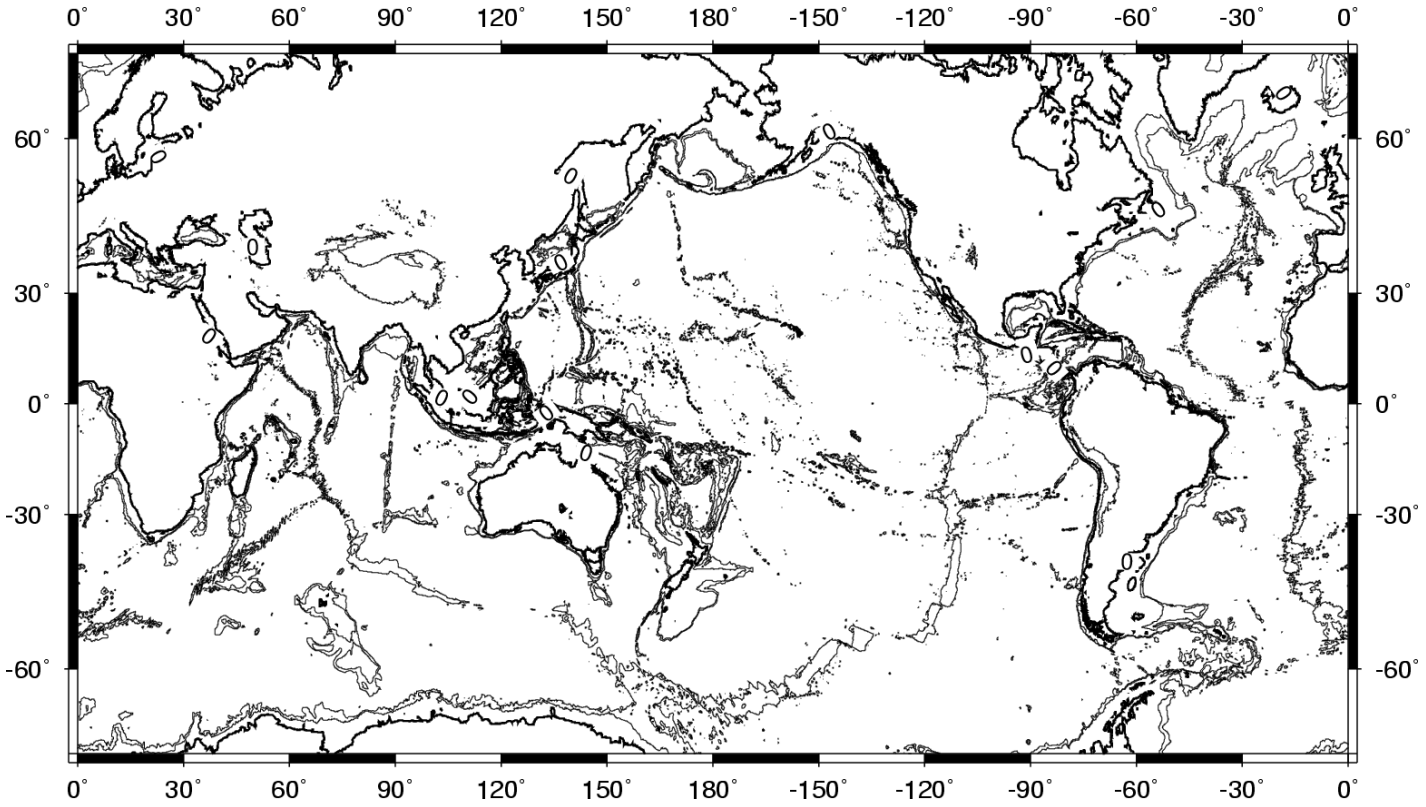
- Create a contour file (`cont.lev`), with for instance the following 5 contour levels (note that contour 0 will be annotated):

```
-8000 C
-3000 C
-2000 C
0     A
3000  C
```

- Use `-Ccont.lev` to plot those contours:

```
grdcontour etopo5.grd -R0/360/-70/70 -JM7i \
          -Ccont.lev -P -B30 > etopo5_cont.ps
```

Contouring gridded data sets



Color image of gridded data sets

- Before you can display your gridded data set as a color image, you need to creat a color map = a table that links your data range (e.g., elevation) with colors

- There are two ways to create a color map:
  - `makecpt -Ctopo -T-12000/8000/2000 -Z > etopo5.cpt`

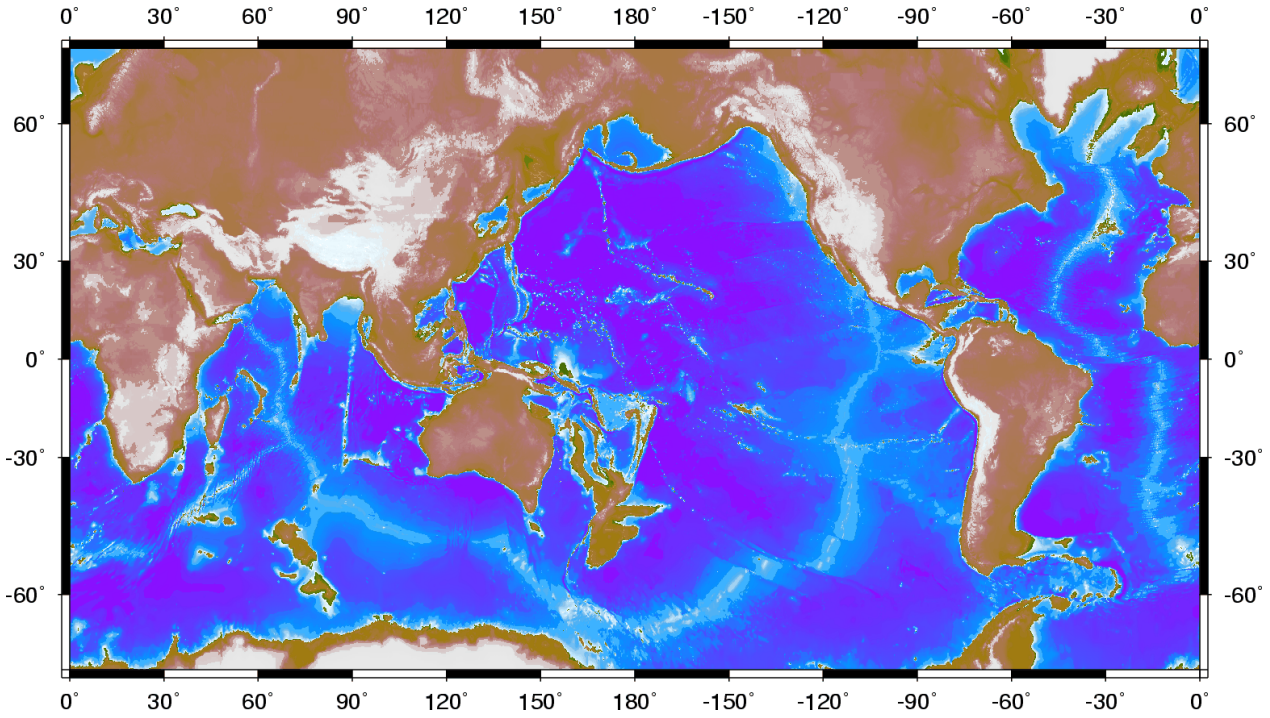
```
-12000  201     119     217     -10000  201     119     217
-10000  138     162     230     -8000   138     162     230
-8000   138     243     207     -6000   138     243     207
-6000   189     243     133     -4000   189     243     133
-4000   240     176     134     -2000   240     176     134
-2000   116     163     179     0       116     163     179
0       220     214     142     2000    220     214     142
2000    246     232     202     4000    246     232     202
4000    255     249     245     6000    255     249     245
6000    255     252     250     8000    255     252     250
B       236     140     255
F       255     255     255
N       128     128     128
```

  - `grd2cpt etopo5.grd -Cglobe -Z > etopo5.cpt`

Color image of gridded data sets

Once you have a color map (`etopo5.cpt`), plot the image with `grdimage`:

```
grdimage etopo5.grd -R0/360/-70/70 -JM7i \
        -Cetopo5.cpt -P -B30 > etopo5_map.ps
```



Add illumination

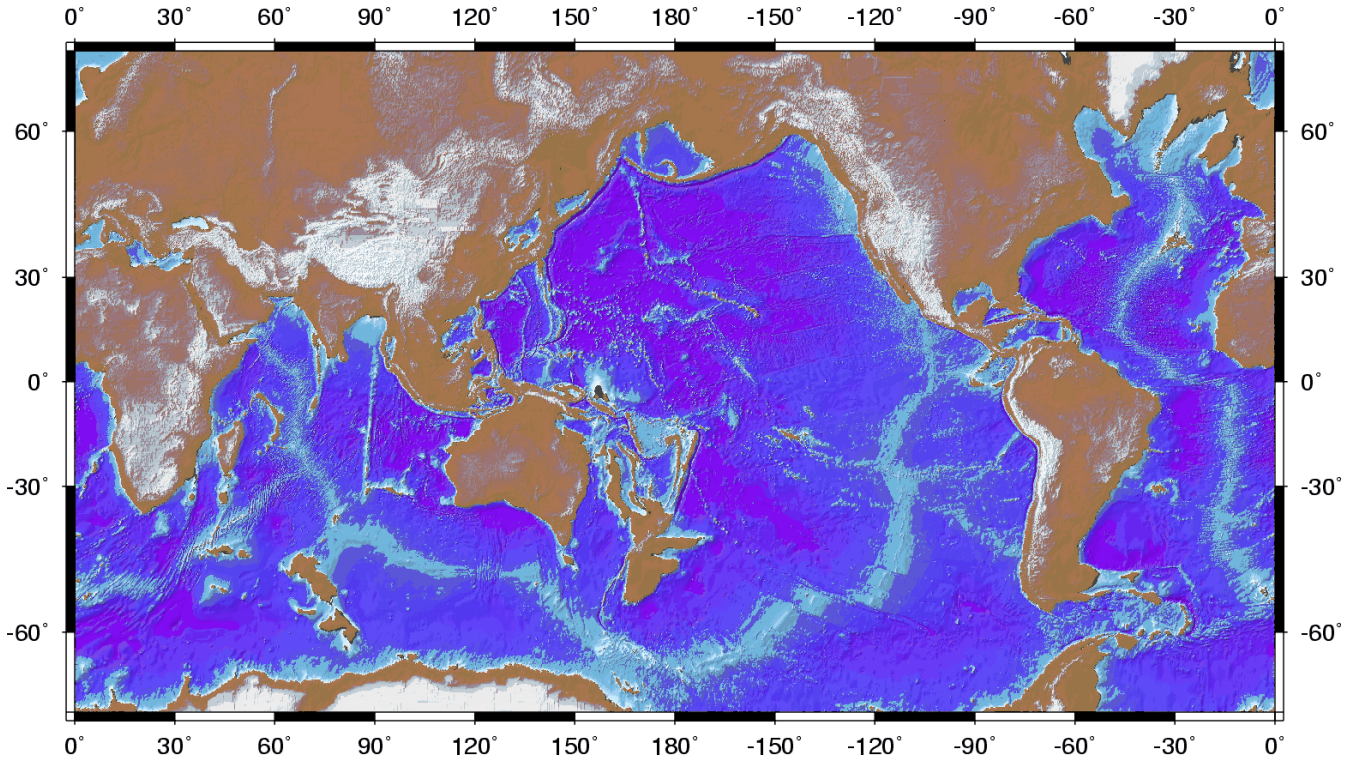
- Illumination (= shading) can be added to the color image
- But a grd file that contains the illumination data must be created first
- Illumination will be a function of the spatial gradient of the elevation in the direction of illumination $\Rightarrow$ use `grdgradient`
- Then illumination needs to be normalized between -1 and +1 $\Rightarrow$ use `grdhisteq` and `grdmath`
- The recipe is:

```
grdgradient etopo5.grd -A300 -Getopo5.grad -Nt
grdhisteq etopo5.grad -Getopo5.hist -N
grdinfo etopo5.hist
grdmath etopo5.hist 4.41977 / = etopo5.norm
```

Add illumination

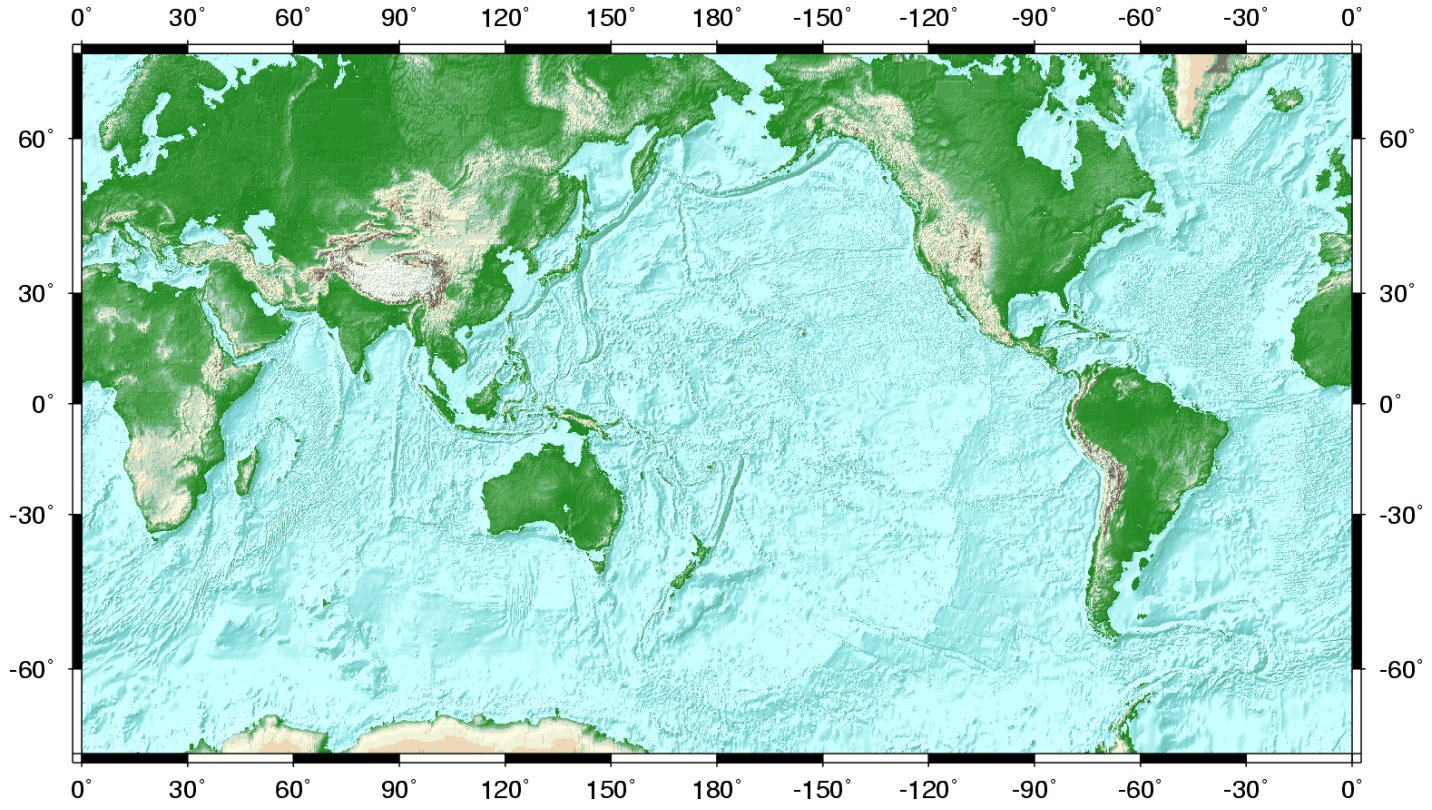
Add illumination with `-I`:

```
grdimage etopo5.grd -Ietopo5.norm -R0/360/-70/70 \
        -JM7i -Cetopo5.cpt -P -B30 > etopo5_map.ps
```



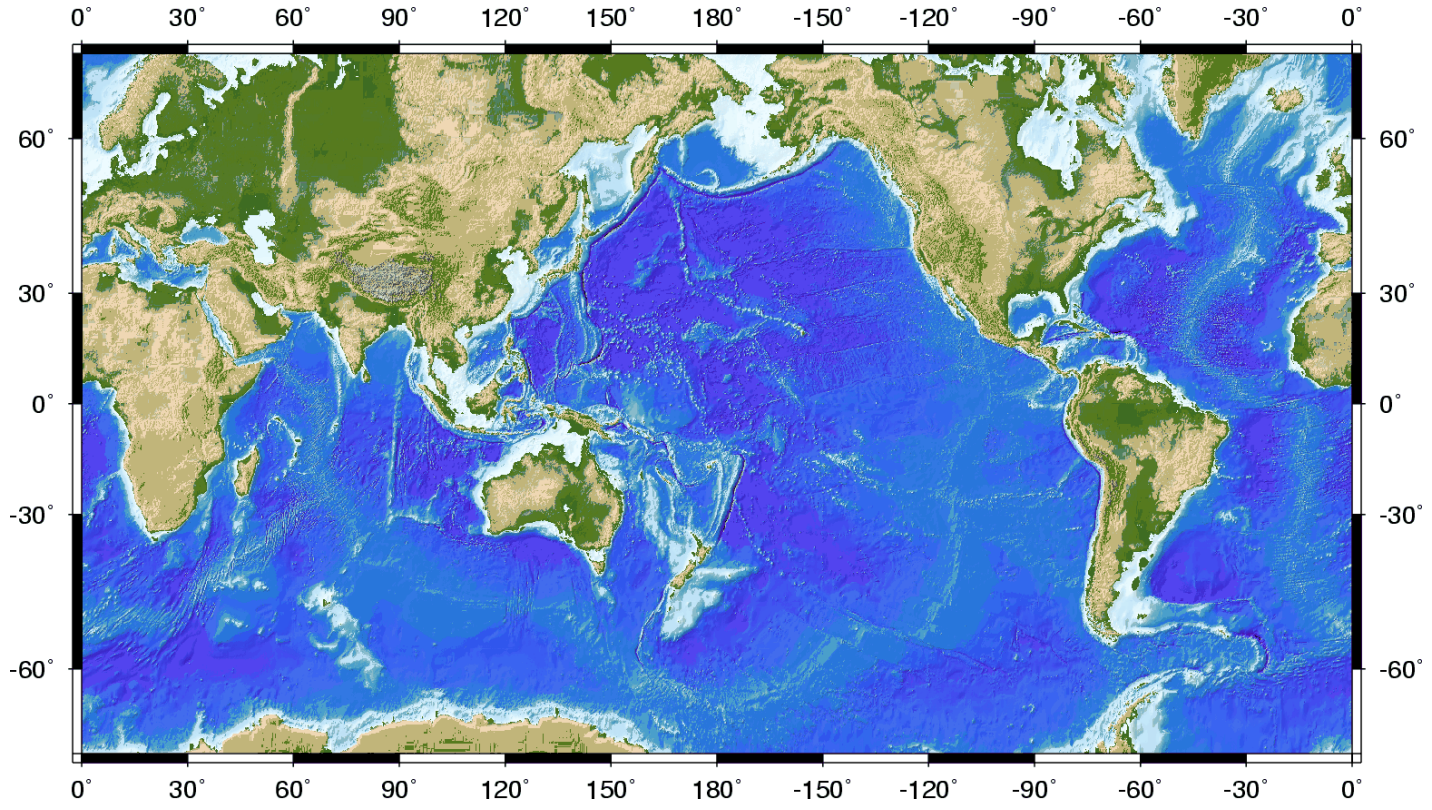
Try different color maps

Download `rob2.cpt` from the class web site and produce:



Try different color maps

Download `myglobe.cpt` from the class web site and produce:



Global Digital Elevation Models

- ETOPO5: global bathymetry and topography, grid spacing = 5 minutes (about 10 km)
- GTOPO30: global topography only
  - Horizontal grid spacing = 30 arc seconds (approximately 1 km).
  - http://edcdaac.usgs.gov/gtopo30/gtopo30.html
- SRTM: global topography only
  - Horizontal grid spacing = 1 arc second (30 m) for continental U.S., 3 arc seconds (90 m) for rest of the world
  - http://www2.jpl.nasa.gov/srtm/
  - http://edc.usgs.gov/products/elevation.html
  - http://edcsgs9.cr.usgs.gov/pub/data/srtm/

Global Digital Elevation Models

- Log on to
  `http://edcdaac.usgs.gov/gtopo30/gtopo30.html`
- Download north-east Africa: `E020N40.tar.gz`
- Uncompress with `gunzip E020N40.tar.gz`
- Untar with `tar xvf E020N40.tar`
- Keep `E020N40.DEM` but delete `E020N40.tar` and the all other archive files (to save space)
- Reminder: to monitor your disk quota: `quota -v username`

Converting a DEM into GMT grd format

- Most DEMs do not come in GMT format: they need to be converted into netCDF format before they can be used and displayed with GMT
- `grdraster` performs this conversion from any binary format to netCDF
- `grdraster` reads a file called `grdraster.info` that describes the format of the file to be converted
- By default, GMT looks for `grdraster.info` in directory `$GMTHOME/share/dbase`
- If you do not have write permissions in `$GMTHOME/share/dbase` (which is most likely), then you need to set an environement variable to the directory that contain your `grdraster.info` file:

```
setenv GMT_GRIDDIR my_directory
```

Converting a DEM into GMT grd format

- `grdraster.info` file contains one line per file to be converted, for instance:

```
17 "GTOPO30 NE AFRICA" "m" -R20/60/-10/40 -I0.5m P i 1 0 -9999 E020N40.DEM B
18 "SRTM LEVEL 3"      "m" -R38/39/7/8    -I3c   G i 1 0 -9999 N07E038.hgt B
```

- Format of `grdraster.info` is (for file 17):
  - `17` = file number
  - `GTOPO30 NE AFRICA` = comment
  - `m` = unit (meters)
  - `-R20/60/-10/40` = boundaries of binary data file
  - `-I0.5m` = horizontal sampling in binary file
  - `P/G` = pixel versus grid registration
  - `1` = scale to apply to binary file in conversion
  - `0` = offset to apply to binary file in conversion
  - `-9999` = values to use if data is NaN
  - `E020N40.DEM` = binary file name
  - `B/L` = big/little endian computer

Converting a DEM into GMT grd format

- Convert `E020N40.DEM` into GMT format using:

```
grdraster 17 -R20/60/-10/40 -Gne_africa.grd
```

- To produce a smaller file, center on the Afar depression:

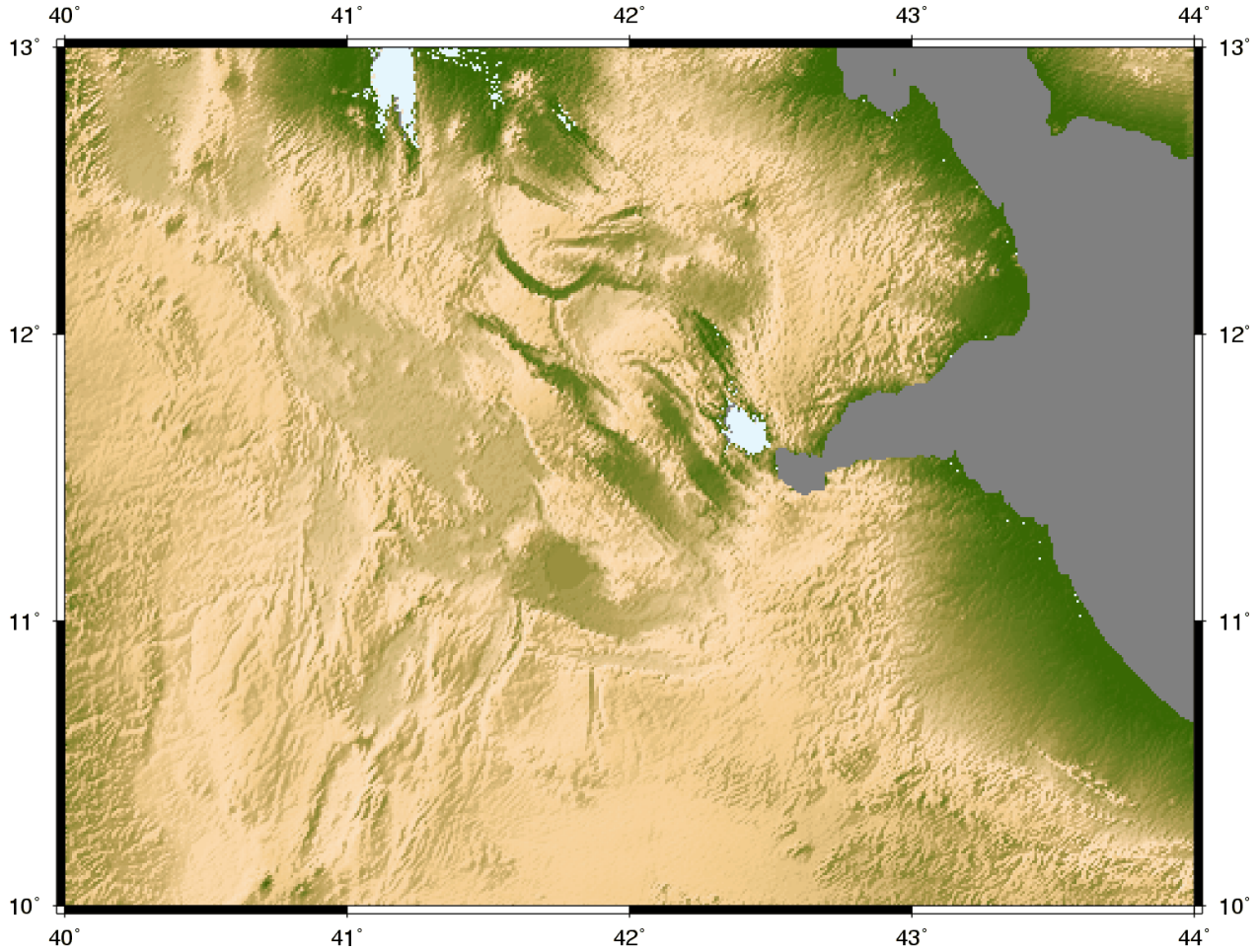
```
grdcut ne_africa.grd -Gne_africa_sub.grd -R40/44/10/13
```

- Or directly from the `grdraster` command:

```
grdraster 17 -R40/44/10/13 -Gne_africa_sub.grd
```

- Then plot:

```
grdimage ne_africa_sub.grd -Ine_africa_sub.norm -R40/44/10/13
        -JM7i -Cmyglobe.cpt -P -B1 > ne_africa_sub.ps
```

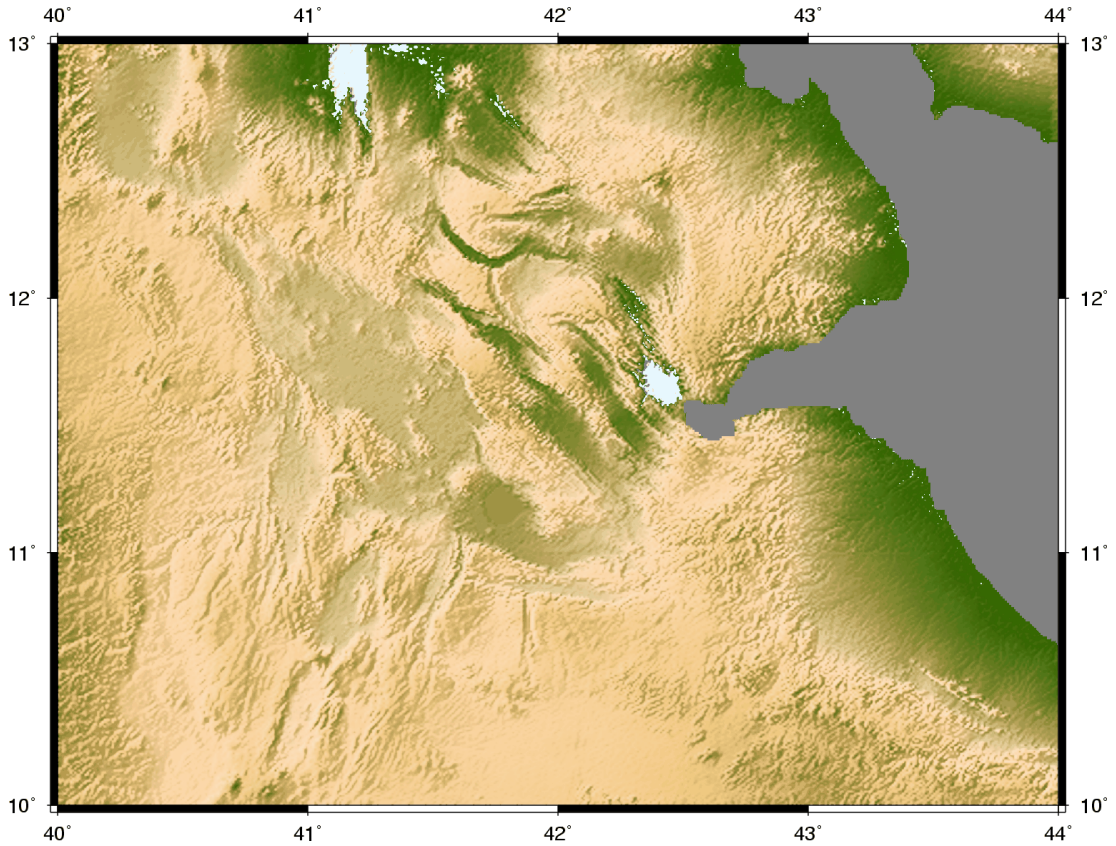


It starts to show pixels...

More on displaying gridded files

Let's resample the grd files every 0.1 minutes:

```
grdsample ne_africa_sub.grd -Gne_africa_sub_resampled.grd -I0.1m
grdsample ne_africa_sub.norm -Gne_africa_sub_resampled.norm -I0.1m
grdimage ne_africa_sub_resampled.grd -Ine_africa_sub_resampled.norm \
        -R40/44/10/13 -JM7i -Cmyglobe.cpt -P -B1 > ne_africa_sub.ps
```



Merging bathymetry and topography from different files

- Plot bathymetry first:

```
grdimage -R35/60/0/20 -JM7i etopo5.grd -Cmyglobe.cpt -P -K -Y1.5 >! all.ps
```

- Cut the topography grid over land:

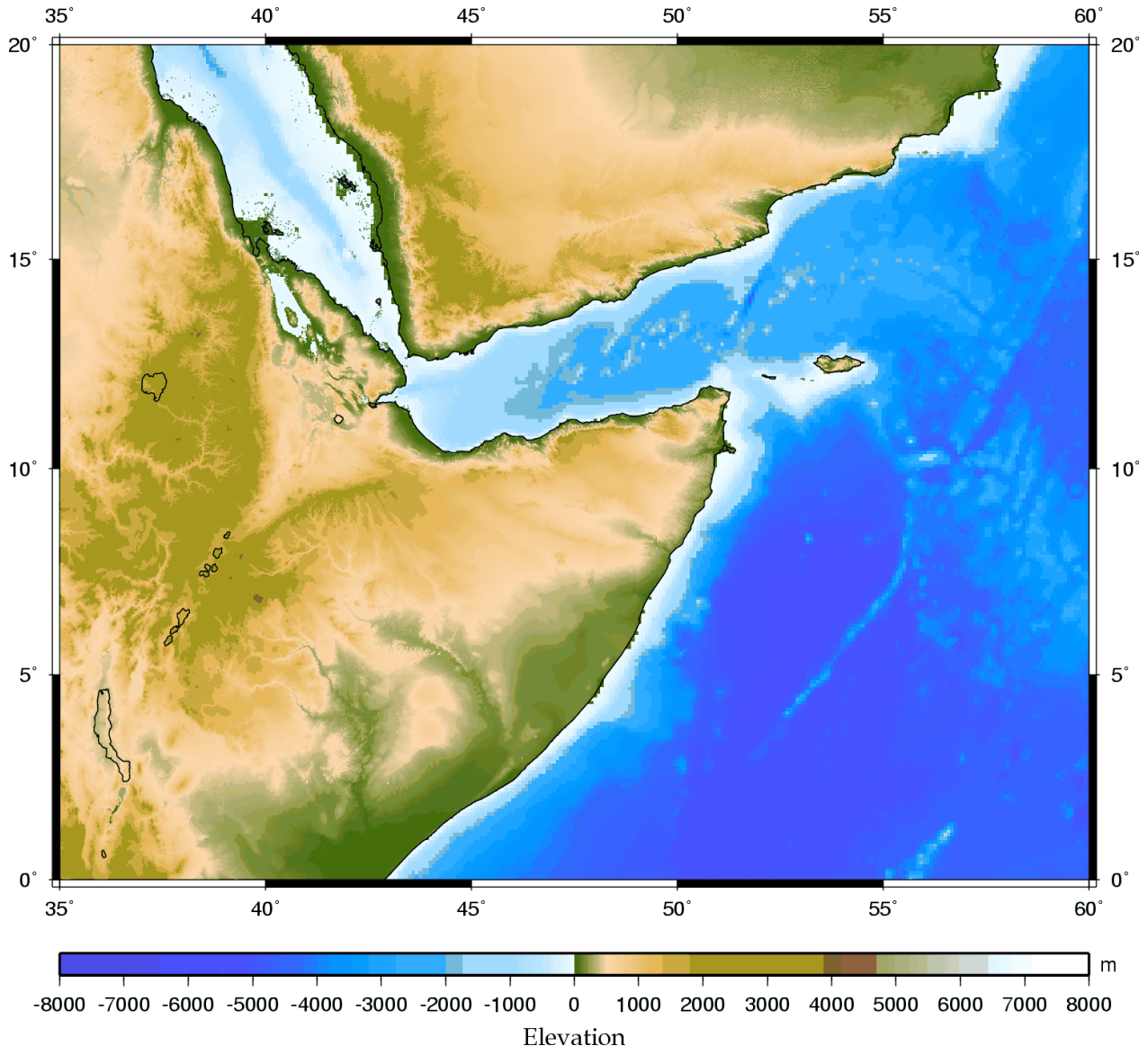
```
pscoast -R -JM -Dh -Gc -K -O >> all.ps
grdimage -R -JM ne_africa.grd -Cmyglobe.cpt -K -O >> all.ps
pscoast -Q -O -K >> all.ps
```

- Plot coastlines:

```
pscoast -R -JM -B5 -Di -W2/0 -A100 -O -K >> all.ps
```

- Note that your could `grdcut` etopo5.grd and resample the resulting file at a higher resolution with `grdsample`
- Add a color scale:

```
psscale -D3.5/-0.5/7/0.15h -Ba1000:Elevation:/:m: -Cmyglobe.cpt -O >> all.ps
```


35°
40°
45°
50°
55°
60°
20°
15°
10°
5°
0°
m
-8000 -7000 -6000 -5000 -4000 -3000 -2000 -1000 0 1000 2000 3000 4000 5000 6000 7000 8000
Elevation

Grid files in 3D

- First, let's cut the large etopo grid into a smaller subset:

```
grdcut etopo5.grd -R-76/-55/9/23 -Gnecar.grd
grdcut etopo5.norm -R-76/-55/9/23 -Gnecar.norm
```

- Then, let's use `grdview` to plot:

```
grdview necar.grd -JM8.5i -Cmyglobe.cpt -Qs -JZ1i
        -E70/20 -Wc -B1a2 -Inecar.norm > necar.ps
```

  - `-Qm/s/i`: plot mesh, surface, or image
  - `-JZ`: vertical scale
  - `-E`: view point azimuth/elevation

A 3D view of the NE Caribbean plate boundary