IISEE Lecture for Seismology and Tsunami Course

Computer
- GMT -

Lecturer
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(This lecture was originally written by Y. Yagi and modified by Y. Fujii)

Why GMT?

GMT stands for Generic Mapping Tools, which was developed by Paul Wessel and Walter Smith. GMT is freely available for use.

Advantage

GMT can create location maps, plot data in numerous formats (x-y plots, map plots, contour plots, and so on) and do simple data processing (filtering, smoothing, etc.).

GMT provides a complete database of coastlines, national boundaries, rivers, lakes, and so on with reasonably high resolution, and allows the creation of simple maps with different geographic projections using this database.

The output form of GMT is postscript. Postscript is a language that is used and interpreted by other programs (like ghostscript, gv, ggv, ghostview, and so on) to plot images on a computer screen and print them.

Weaknesses

You cannot manipulate images easily once the postscript is created.

The GMT commands are cryptic, and the interface is non-intuitive.

Preparation for Lecture

Go to home directory

```
$ cd
```

Make “GMT” directory

```
$ mkdir  GMT
```

(We use this directory for today’s lecture.)

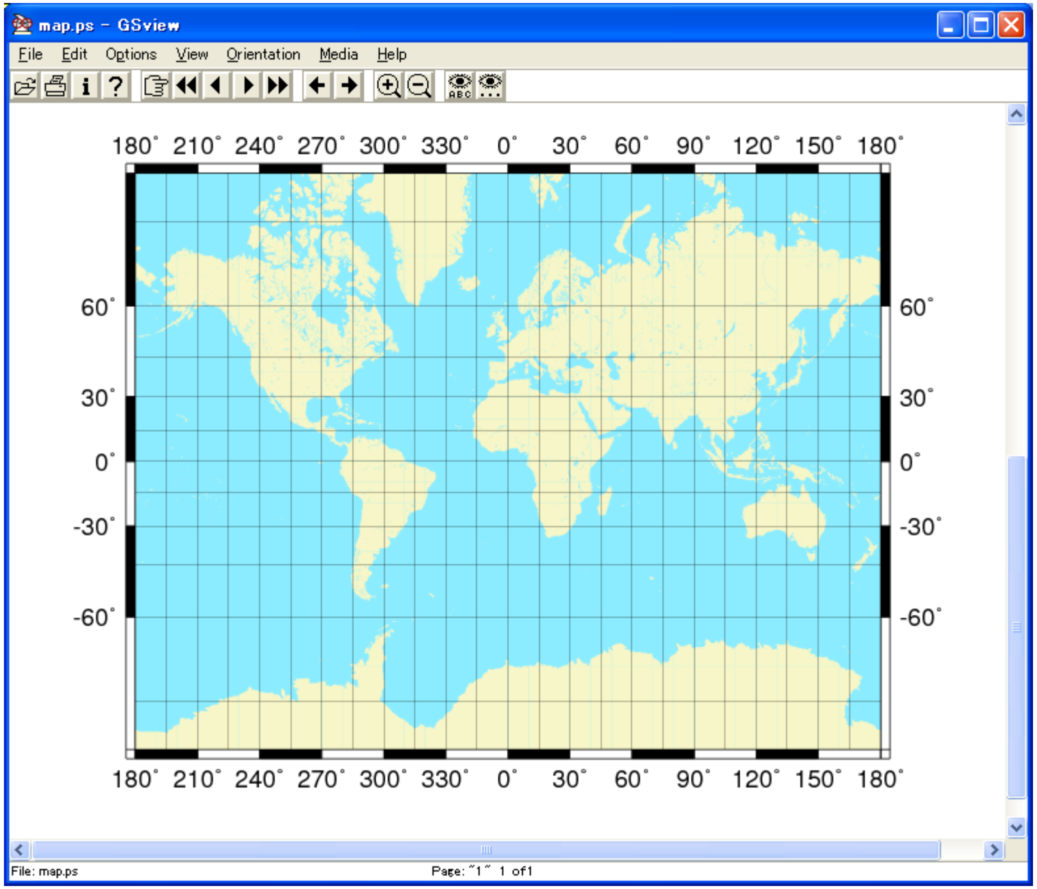
Go to “GMT” directory

```
$ cd  GMT
```

Creating Maps (1)

The syntax of the GMT command is similar to a UNIX command. Using options, we can set the plot area, projection type, size, and so on. In the shell prompt, type

```
$ pscoast  -R-180/180/-80/80  -JM15c  -Ba30g15  -G245/245/200  -S140/235/255  -P  > map.ps
$ gs  map.ps
```



Creating Maps (1)

pscoast: This is a GMT command that indicates a postscript file with GMT showing coastlines will be generated. Generally, the GMT commands begin with “ps”.

-R-180/180/-80/80: This indicates the region that will be plotted. The scale is degrees. The syntax is -R(min x or longitude value)/(max x or longitude value)/(min y or latitude value)/(max y or latitude value).

-JM15c: This controls the map projection and size. In this case, a Mercator projection is applied and the total width of the map is 15 cm.

-Ba30g15: This labels the axes every 30 degrees of latitude and longitude and draws a grid line every 15 degrees of latitude and longitude.

-G245/245/200: This controls the color of the continents and other land areas. The numbers are in the (red)/(green)/(blue) scheme.

-S140/235/255: This controls the color of the seas, rivers, and lakes.

> map.ps: This mean outputting to map.ps.

Creating Maps (1)

----------------------------- Useful option for pscoast ------------------------------------

-Dl: This controls the density of the coast lines. (-Df: full; -Dh: high; -Di: intermediate; -Dl: low)

-W(*numbers***)**: This controls the thickness of the coast line.

-N(*numbers***)**: This draws the boundary. [-N1 = National boundaries; -N2 = State boundaries within the Americas; -N3 = Marine boundaries; -Na = All boundaries (1-3)]

-P: This implies the portrait page orientation.

-Lf<lon0>/<lat0>/<slat>/<length>: This draws a simple map scale centered on <lon0>/<lat0>. The scale is calculated at latitude <slat>. The <length> is in kilometers.

Exercise (1)

1. Please create a map that covers Japan with a high-density coast line and save it as “japan.ps”.

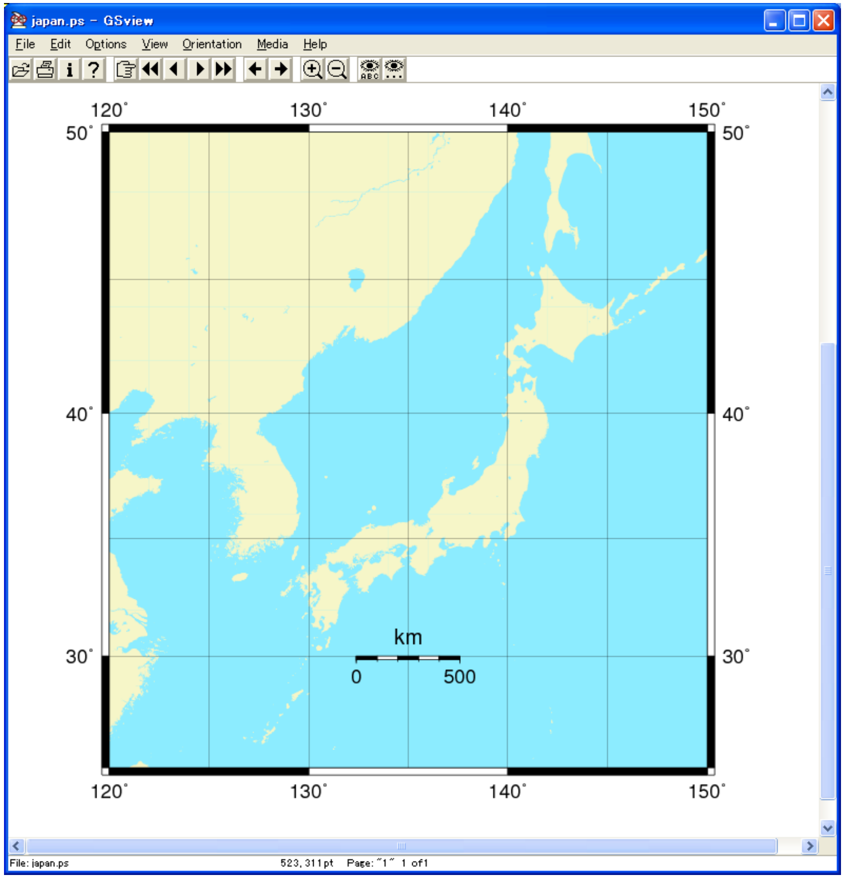
2. Please create a map that covers your country with a high-density coast line and save it as “country.ps”.

Exercise (1)

1. Type

```
$ pscoast  -R120/150/25/50  -JM15c  -Ba10g5  -G245/245/200  -S140/235/255  -Dh
        -Lf135/30/30/500+lkm  -P  >  japan.ps
$ gs  japan.ps
```

2. Please refer to 1.

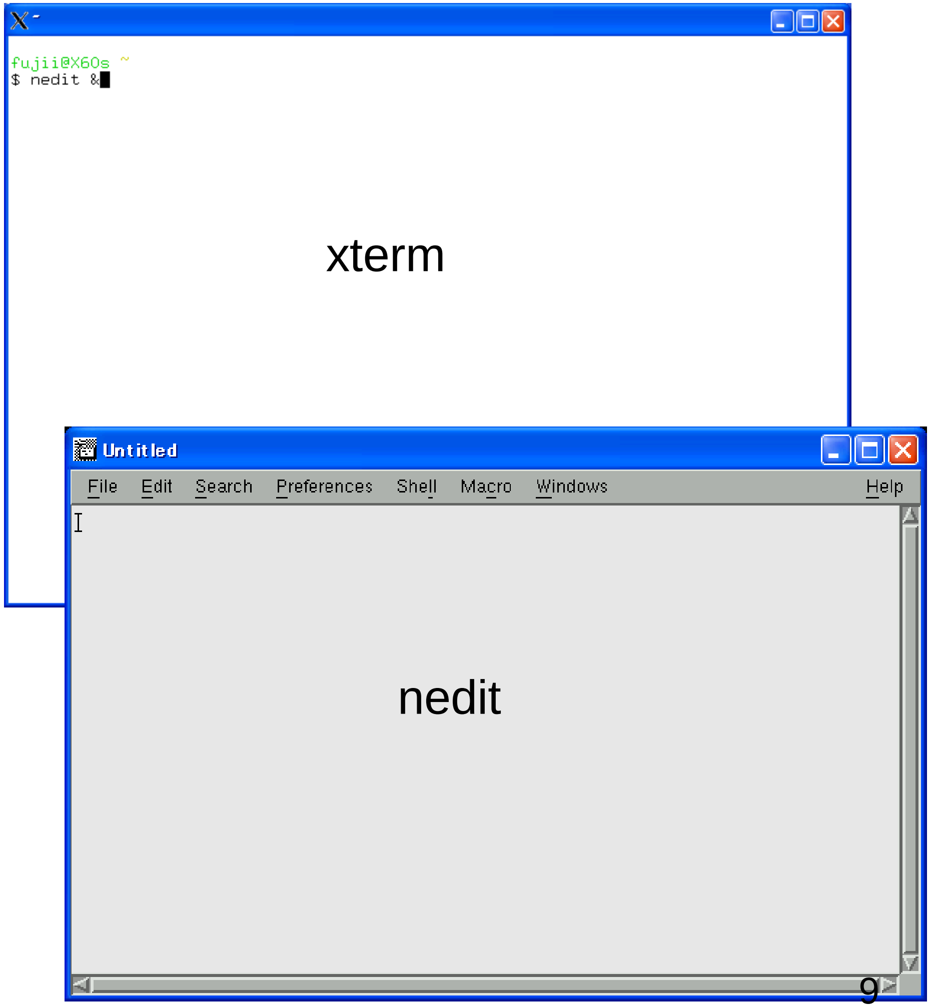


Creating Maps (2)

Shell script is useful for automation and customization. In this section, we run some GMT commands using the csh script.

Please open nedit:

$ nedit &



```
fujii@X60s ~
$ nedit &
```

Creating Maps (2)

Write the following in the nedit window:

```
#!/bin/csh  -f
pscoast  -R-180/180/-80/80  -JM15c  -Ba30g30  -G245/245/200  -S140/235/255  -Dl
      -W1  -P  >  map2.ps
```

Save as “**cm2.csh**”; change to the execute mode; run csh script.

```
$ chmod   u+x   cm2.csh
$ ./cm2.csh
```

You can get the postscript file (map2.ps).

Next, we will plot text on the map. Modify the following lines in the nedit window:

```
#!/bin/csh -f
pscoast  -R-180/180/-80/80  -JM15c  -Ba30g30  -G245/245/200  -S140/235/255  -Dl
      -N1  -W1    -P  -K  >  map2.ps
pstext  -R  -JM  -P  -O  << EOF >>  map2.ps
135   35   18   0   1   LT   Japan
EOF
```

Note: -K and -**O** options are important for combinations of GMT commands.

The text is overwritten on an existing plot (therefore, the **-O** argument is used) and more postscripts will be added (therefore, the **-K** argument is used).

-K: This allows more plot codes to be appended later.

-O: This implies the overlay plot mode.

Creating Maps (2)

```
pstext  -R  -JM  -P  -O  << EOF >>  map2.ps
135   35   18   0   1   LT   Japan
EOF
```

pstext: This is a GMT command that indicates that a postscript file with text will be generated.

-R: This indicates the region that will be plotted. When the region is not defined, this value is defined by the previous value.

<< EOF: This is a csh option that indicates the inputting of parameters using the **EOF** prompt.

(135 35 18 0 1 LT Japan):

This indicates (x coordinate, y coordinate, size of font, angle of text, font, justify, text), respectively.

EOF: This indicates the end of the input prompt.

Creating Maps (2)

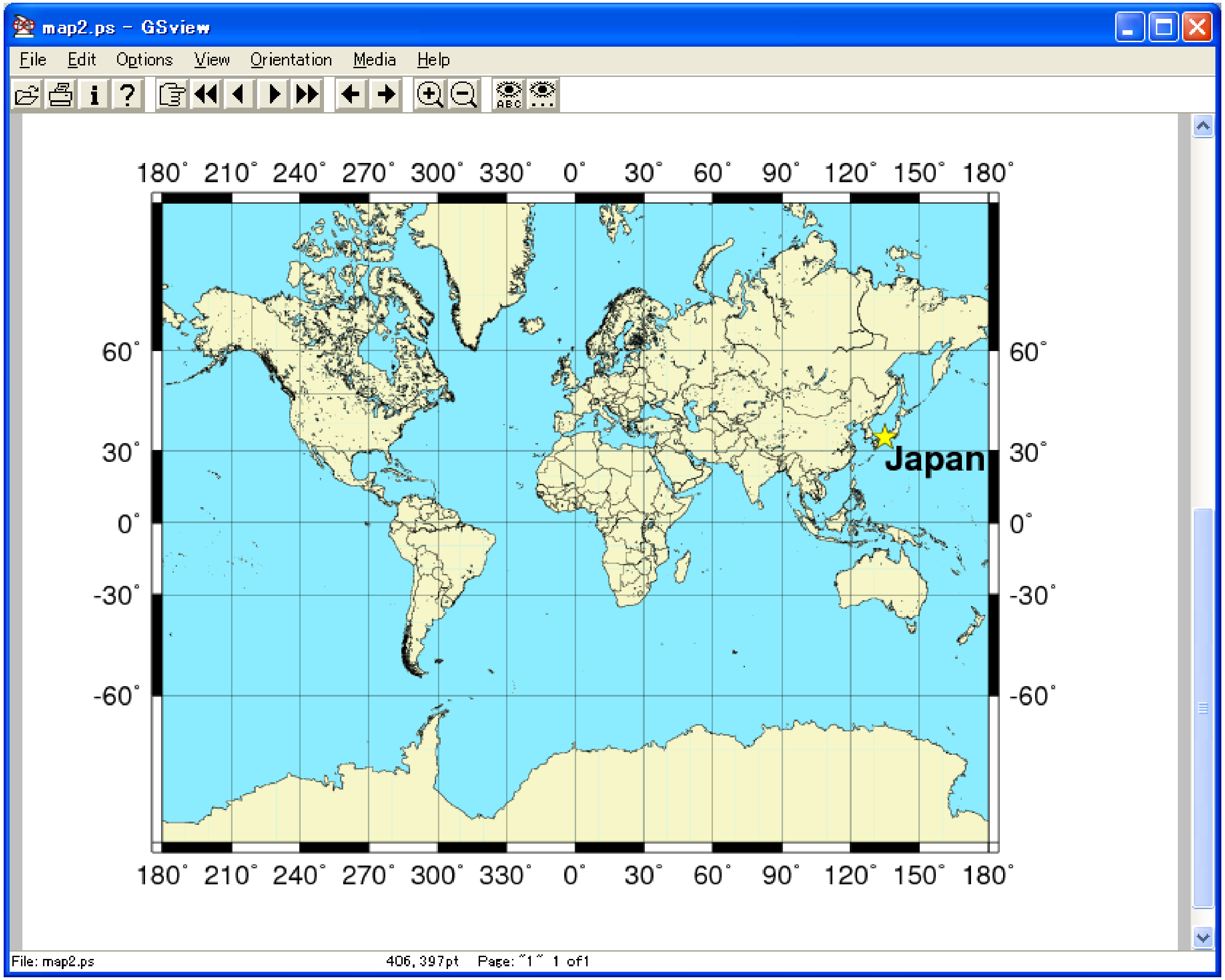
We will plot points (e.g., station locations) on the map. Modify the following lines of “cm2.csh” in the “nedit” window:

```
#!/bin/csh  -f
pscoast  -R-180/180/-80/80  -JM15c  -Ba30g30  -G245/245/200  -S140/235/255  -Dl
          -N1  -W1  -P  -K  >  map2.ps
pstext  -R  -JM  -P  -O  -K  << EOF >>  map2.ps
135   35   18   0  1   LT   Japan
EOF
psxy  -R  -JM  -Sa0.5c  -G255/255/0  -W1  -P  -O  << EOF >>  map2.ps
135   35
EOF
```

psxy: This command reads (x,y) pairs from the standard input or file and creates a postscript code that will plot lines or symbols at the specified locations on a map.

-S: This option can select the type and size of the symbol. (-Sa: type of symbol is star) and no symbol size is given, then psxy will interpret the third column of the input data as the symbol size.

Creating Maps (2)



Exercise (2)

1. Please create a map that covers Japan with the country name and save it as “japan2.ps”.

2. Please create a map that covers your country with the country name and save it as “country2.ps”.

Exercise (2)

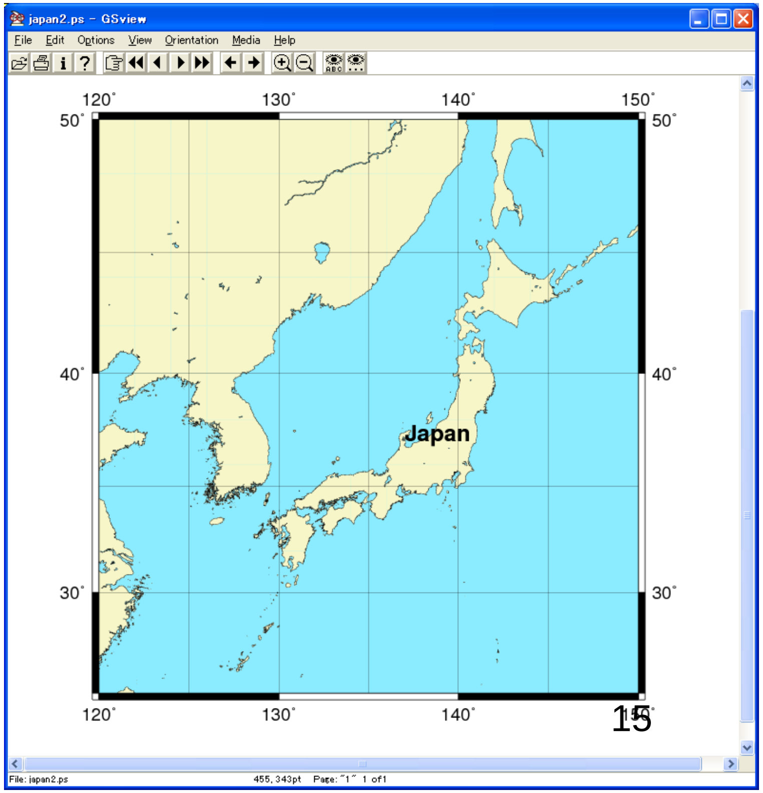
1. **Write the following lines in the nedit window and save it as “ex2.csh”.**

```
#!/bin/csh  -f
pscoast  -R120/150/25/50  -JM15c  -Ba10g5  -G245/245/200  -S140/235/255  -Dh  -W1
        -P   -K  >  japan2.ps
pstext  -R  -JM  -P  -O  <<EOF>>  japan2.ps
137  38   18   0   1   LT   Japan
EOF
```

Change it to the execute mode to run the csh script.

```
$ chmod   u+x   ex2.csh
$ ./ex2.csh
```

2. **Please refer to 1.**



Creating Maps (3)

We will plot many symbols on the location maps (in this case, the epicenter locations).
Copy cm2.csh to cm3.csh.

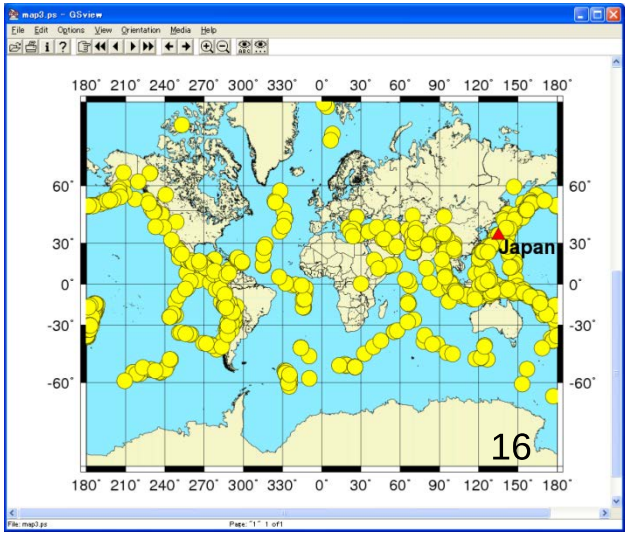
```
$ cp   cm2.csh   cm3.csh
```

Modify the following lines of “cm3.csh” in the nedit window:

```
#!/bin/csh -f
pscoast  -R-180/180/-80/80  -JM15c  -Ba30g30  -G245/245/200  -S140/235/255  -Dl  -K  -N1
    -W1  -P  >  map3.ps
psxy  ../UNIX/cmt.gmt  -R  -JM  -Sc0.5c  -G255/255/0  -W1  -P  -O  -K   >>  map3.ps
pstext  -R  -JM  -P  -O  -K  << EOF >>  map3.ps
135   35   18   0  1   LT   Japan
EOF
psxy  -R  -JM  -St0.5c  -G255/0/0  -W1  -P  -O  << EOF >>  map3.ps
135   35
EOF
```

-Sc0.5c: We select the type and size of the symbol as a circle and 0.5 cm, respectively.

cmt.gmt: We have created this file in the previous UNIX lecture.



Creating Maps (3)

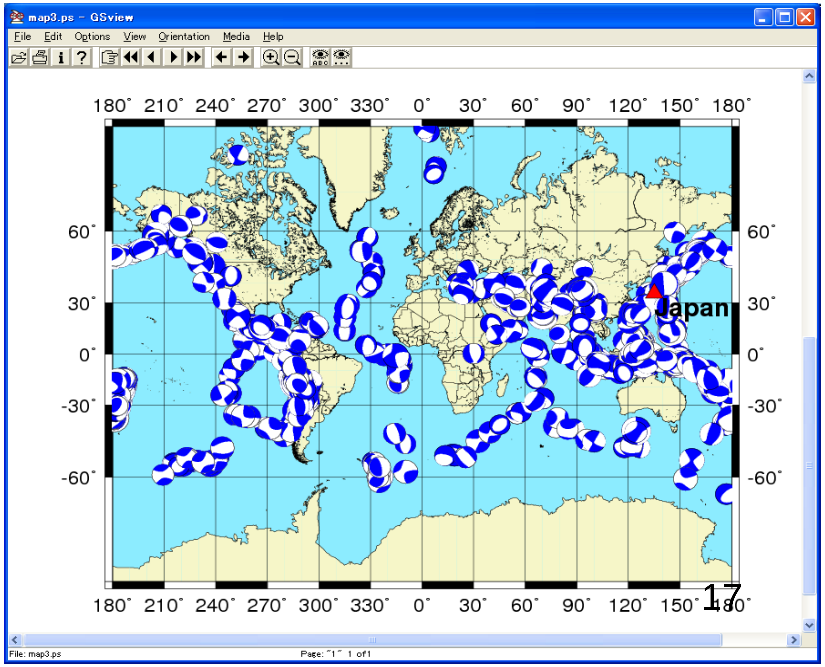
We will plot the moment tensor solution on the location maps.
Edit the following lines of “cm3.csh” in the nedit window:

```
#psxy  ../UNIX/cmt.gmt  -R  -JM  -Sc0.5c  -G255/255/0  -W1  -P  -O  -K  >>  map3.ps
psmeca  ../UNIX/cmt.gmt  -R  -JM  -Sm0.5c/-1  -G0/0/255  -P  -O  -K  >>  map3.ps
```

#: The line beginning with this letter is recognized as a comment by C shell (csh).

psmeca: This command reads (x, y, and information of the focal mechanism) from the standard input or file and creates the postscript code that will plot the focal mechanism at those locations on the map.

-Sm0.5c: We select the same data format as that in the Global CMT Catalog.
(format: please refer to page 34 of the UNIX lecture notes)



Creating Maps (3)

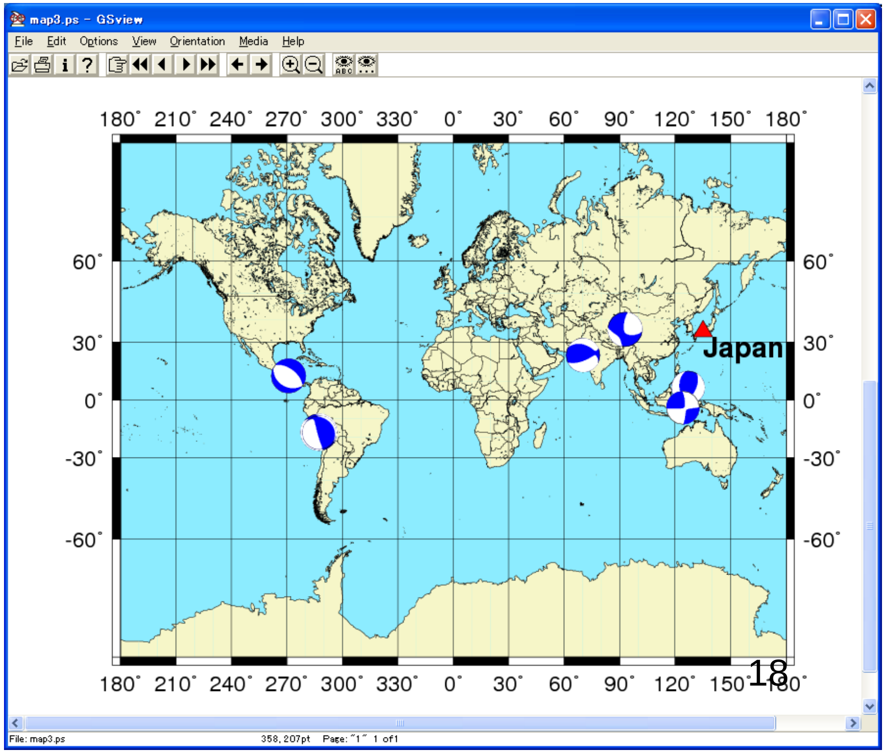
We will select large earthquakes using “awk” and remove text.
Modify the following lines of “cm3.csh” in the nedit window:

```
#psmeca  ../UNIX/cmt.gmt  -R  -JM  -Sm0.5c/-1  -G0/0/255  -P  -O  -K  >>  map3.ps

awk  '$10  >=  27 {print $0}'  ../UNIX/cmt.gmt  |  psmeca  -R  -JM  -Sm0.5c/-1  -G0/0/255
    -P  -O  -K >>  map3.ps
```

Note: awk “$10 >= 27 {print $0}”

If $10 (size of the earthquake) is larger than 27, awk prints all the columns of
($1, $2, $3, $4, $5, $6, $7, $8…).



Creating Maps (3)

psmeca: This command is useful to plot the focal mechanisms on the map.

--------------------------- Useful option for psmeca ------------------------------

-Sa: If you have a value of (strike, dip, slip) for the earthquake, you can plot the focal mechanism using the "-Sa" option.

e.g.,

```
psmeca  -R  -JM  -Sa0.5c/-1  -G255/0/0  -P  -O  -K  <<EOF>>  map3.ps
150.0   40.0   15.0   210.0   20.0   -90.0   7   0   0   test
EOF
```

(150.0	40.0	15.0	210.0	20.0	-90.0	7	0	0	test)
longitude,	latitude,	depth (km),	strike,	dip,	slip,	magnitude,	X,	Y,	text

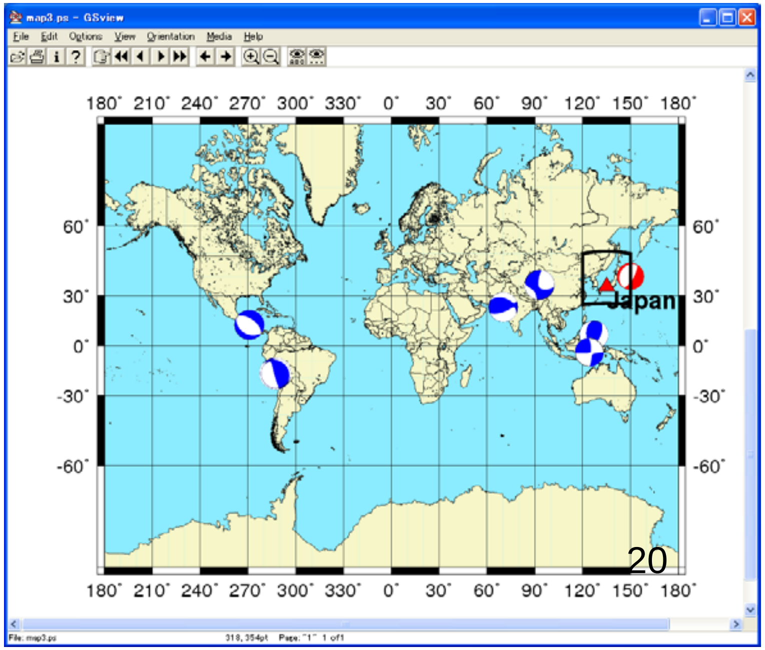
X,Y: the longitude and latitude at which the beach ball is placed. Entries in these columns are required to be inputted using the -C option. Here, 0,0 in columns 8 and 9 will plot the beach ball at the longitude and latitude given in columns 1 and 2.

Creating Maps (3)

We will plot complicated outlines (polygons) on maps using the “psxy” command. Modify the following lines of “cm3.csh” in the nedit window.

```
psxy  -R  -JM  -St0.5c  -G255/0/0  -W1  -P  -O  -K  << EOF >>  map3.ps
135  35
EOF

psxy  -R  -JM  -W10.0  -P  -O  << EOF >>  map3.ps
120   25
150   25
150   50
120   50
120   25
EOF
```



Exercise (3)

1. Please plot the Global CMT solutions on the map near Japan and save it as “japan3.ps”.

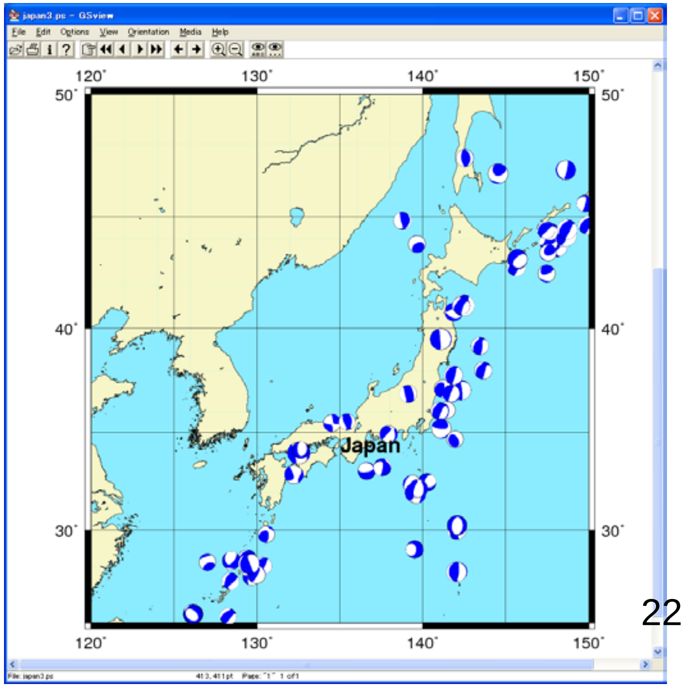
2. Please plot the Global CMT solutions on the map near your country and save it as “country3.ps”.

Exercise (3)

1. **Copy “ex2.csh” to “ex3.csh” and modify the following line in the nedit window.**

```
#!/bin/csh  -f
pscoast  -R120/150/25/50  -JM15c  -Ba10g5  -G245/245/200  -S140/235/255  -Dh  -K
        -W1  -P  >  japan3.ps
psmeca  ../UNIX/cmt.gmt  -R  -JM  -Sm0.5c/-1  -G0/0/255  -P  -O  -K  >>  japan3.ps
pstext  -R  -JM  -P  -O  << EOF >>  japan3.ps
135  35  18  0  1  LT  Japan
EOF
```

2. **Please refer to 1.**



Creating Histograms

We will plot the histogram of earthquakes using the “pshistogram” command.
Write the following in the new nedit window and save it as “ch.csh”.

```
#!/bin/csh -f
awk  '{print $3}'  ../UNIX/cmt.gmt  |  pshistogram  -R0/800/0/800  -JX10c  -W50  -L1.0
    -G0/0/255  -Ba100:"depth (km)":/a100:"Number of earthquake":WSne  -P  >  hist.ps
```

pshistogram: This command reads the first column from the file [or standard input] and calculates the histogram parameters based on the bin-width provided. Using these parameters, scaling, and optional range parameters, it will generate the postscript code that plots a histogram.

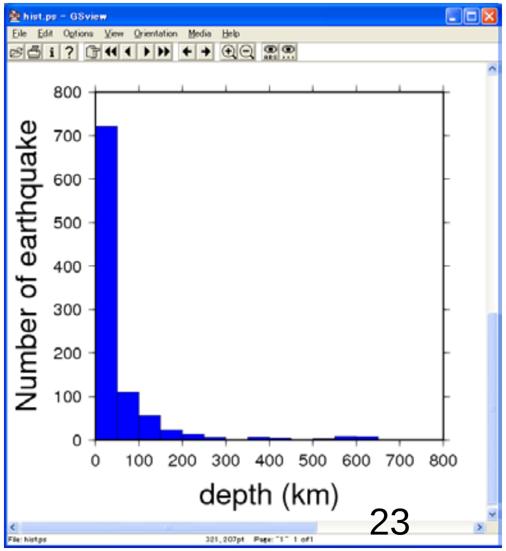
-W(number): Sets the width (number) used for histogram calculations.

-L(number): Draws the bar outline using the pen thickness.

-Ba100:"depth":/a100:"Number of earthquakes":WSne

(:"depth":), (:"Number of earthquakes":): Labels for each axis can be added by surrounding them with colons.

WSne: Upper case (WS) means drawing the axis/tick marks and annotate it, whereas lower case (e.g., ns) will only draw the axis/tick marks.



Single Script for Two Figures

We will correlate the map with the histogram.
Modify the following lines of “ch.csh” in the new nedit window.

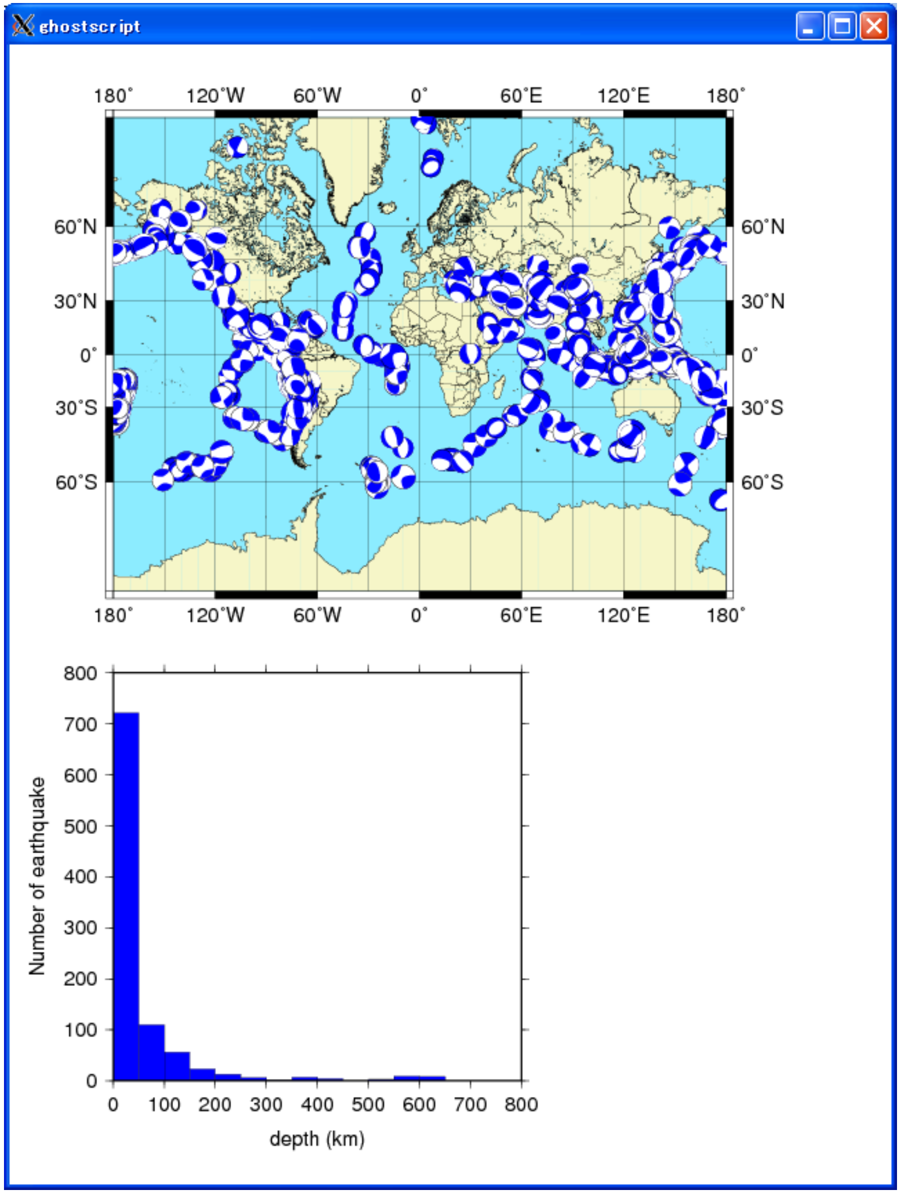
```
#!/bin/csh  -f
gmtset  LABEL_FONT_SIZE  14p
gmtset  ANOT_FONT_SIZE  14p
gmtset  PLOT_DEGREE_FORMAT  F

awk   '{print $3}'   ../UNIX/cmt.gmt   |  pshistogram  -R0/800/0/800  -JX10c  -W50
         -L1.0  -G0/0/255    -Ba100:"depth (km)":/a100:"Number of earthquake":WSne
         -P  -K  >  hist.ps
pscoast  -R-180/180/-80/80  -JM15c  -Ba60g30/a30g30  -G245/245/200
                             -S140/235/255  -Dl   -N1  -W1  -P  -O  -K  -Y12c  >>  hist.ps
psmeca  ../UNIX/cmt.gmt  -R  -JM  -Sm0.5c/-1  -G0/0/255  -P  -O  >>  hist.ps
```

gmtset: This command sets the value of the GMT environment.
“gmtset LABEL_FONT_SIZE 20p” means that we set “LABEL_FONT_SIZE” as “20p”

-X or -Y: This option shifts the origin of the drawing pen.
“-X10c -Y12c” means that we set the origin to (10 cm, 12 cm).

Single Script for Two Figures



Using Color Palette File (1)

In the previous figures, we cannot illustrate the depth of the hypocenters. In this section, we will explain the depth of the hypocenters using the color palette and option “-C” (for psxy) or “-Z” (for psmeca).

Write the following in the new nedit window:

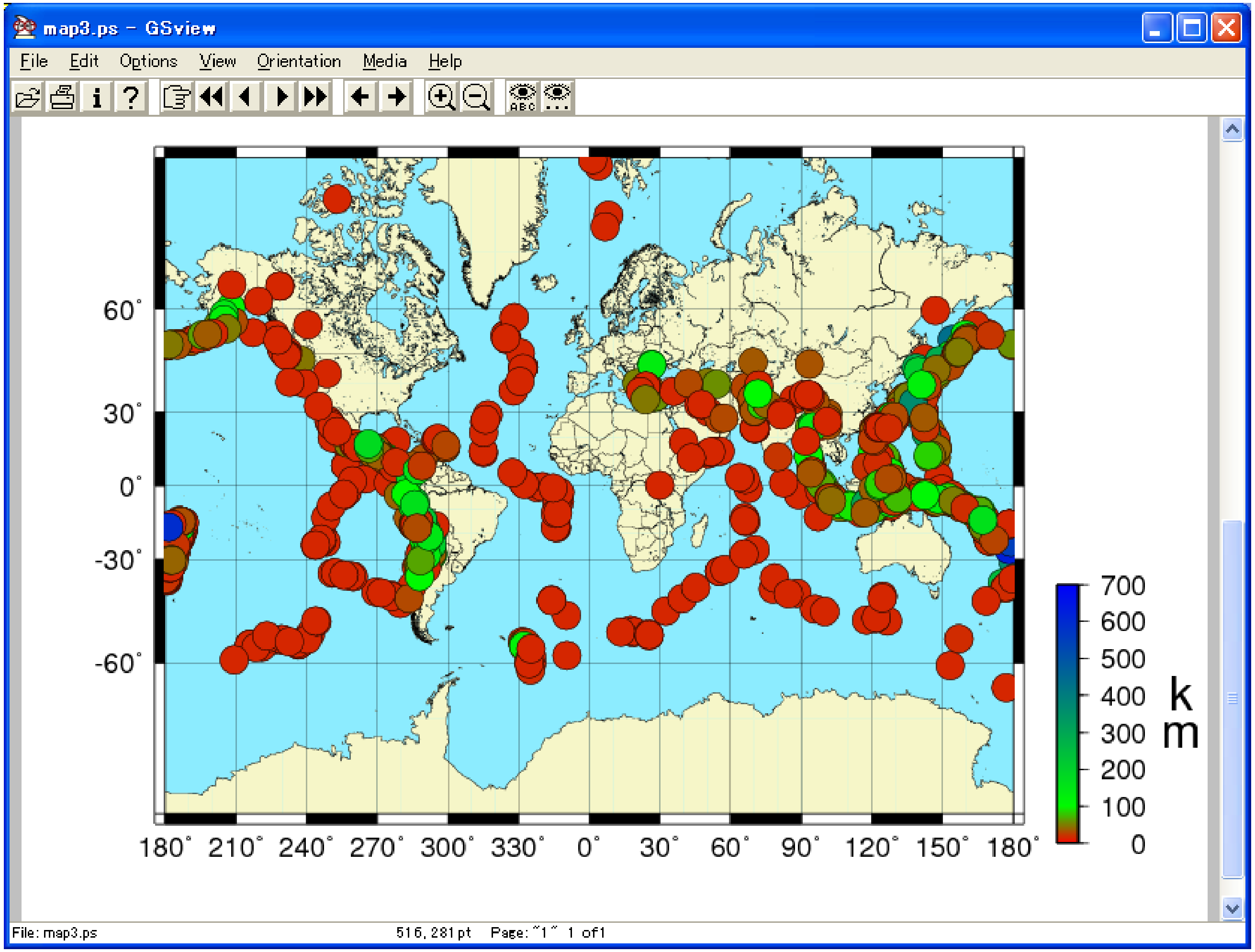
```
  0      255    0   0        100      0  255    0
100        0  255   0        700      0    0  255
#(depth(small)  color (r/g/b),  depth (large)  color (r/g/b)
```

and save it as “depth.cpt”.

Copy “cm3.csh” to “cp1.csh” and modify the following lines in the nedit window:

```
#!/bin/csh  -f
pscoast  -R-180/180/-80/80  -JM15c  -Ba30g30nSeW  -G245/245/200  -S140/235/255
    -Dl  -N1  -W1  -P  -K  >  map3.ps
psxy  ../UNIX/cmt.gmt  -R  -JM  -Sc0.5c  -W1  -Cdepth.cpt  -P  -O  -K  >>  map3.ps
psscale  -Cdepth.cpt  -D0/0/5c/0.5c  -B100:km:  -O  -X16c  -Y2c  >>  map3.ps
```

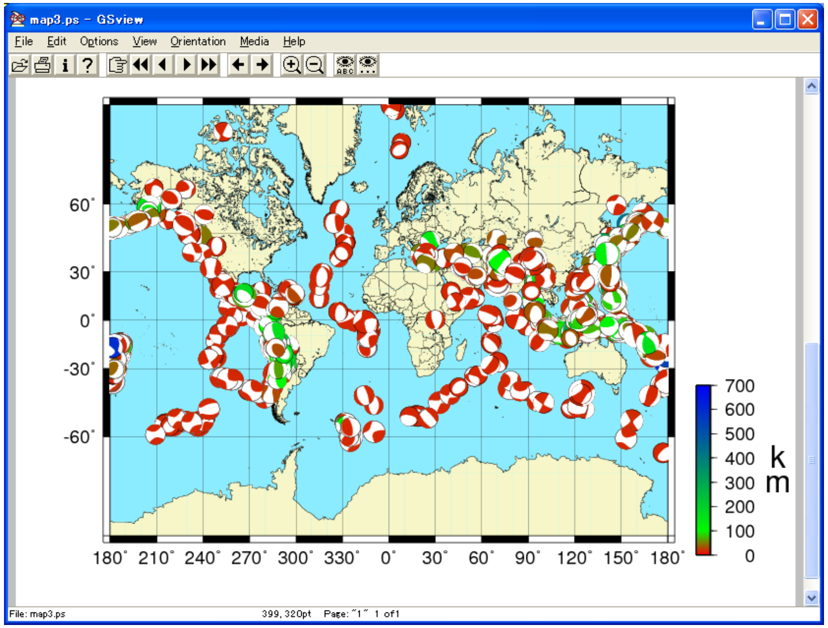
Using Color Palette File (1)



Using Color Palette File (2)

Copy “cp1.csh” to “cp2.csh” and modify the following lines in the nedit window:

```
#!/bin/csh -f
pscoast  -R-180/180/-80/80  -JM15c  -Ba30g30nSeW  -G245/245/200  -S140/235/255
   -Dl  -N1  -W1  -P  -K  >  map3.ps
psmeca  ../UNIX/cmt.gmt  -R  -JM  -Sm0.5c/-1  -Zdepth.cpt  -P  -O  -K  >>  map3.ps
psscale  -Cdepth.cpt  -D0/0/5c/0.5c  -B100:km:  -O  -X16c  -Y2c  >>  map3.ps
```



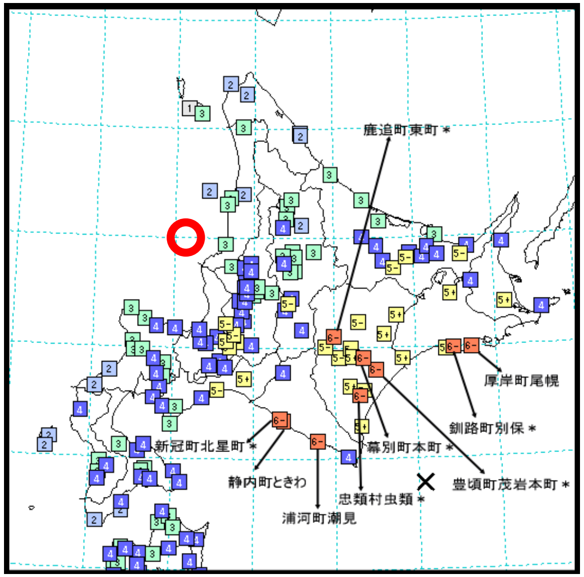
Exercise (4)

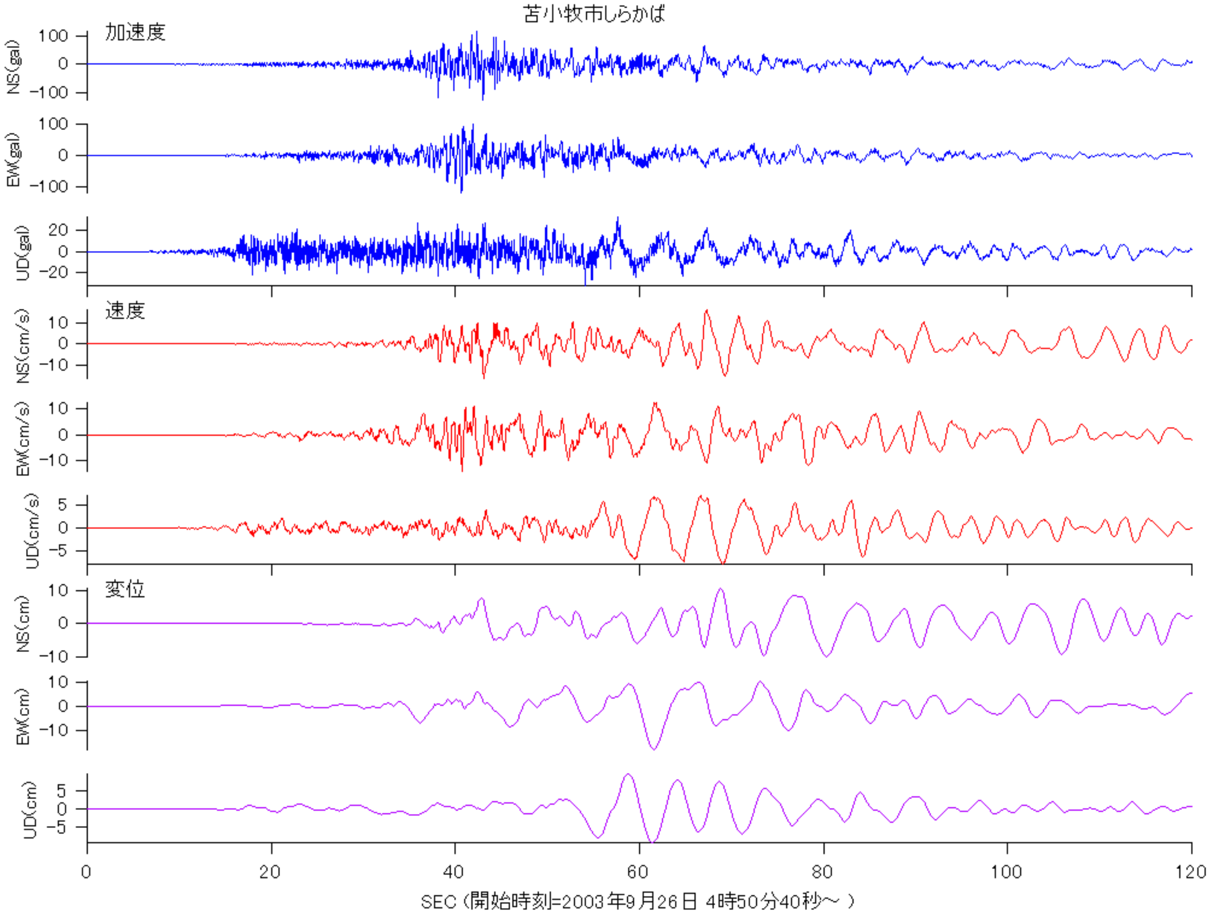
1. Please download information on the CMT solutions in 2002 from the Global CMT website, and plot the CMT solutions on a map.

2. Please discuss the depths of the hypocenters.

3. Please discuss the mechanism of earthquakes near your country.

Plotting Waveforms





Source: http://www.seisvol.kishou.go.jp/eq/kyoshin/jishin/030926_tokachioki/index.htm
(Japan Meteorological Agency’s Web site)

Plotting Waveforms

We will plot the seismic waveforms using “awk” and “psxy”.
Copy waveform data from “earth” or “ocean”.

```
$ scp  earth2:/home/fujii/GMT/wave.dat  .
```

Write the following in the nedit window:

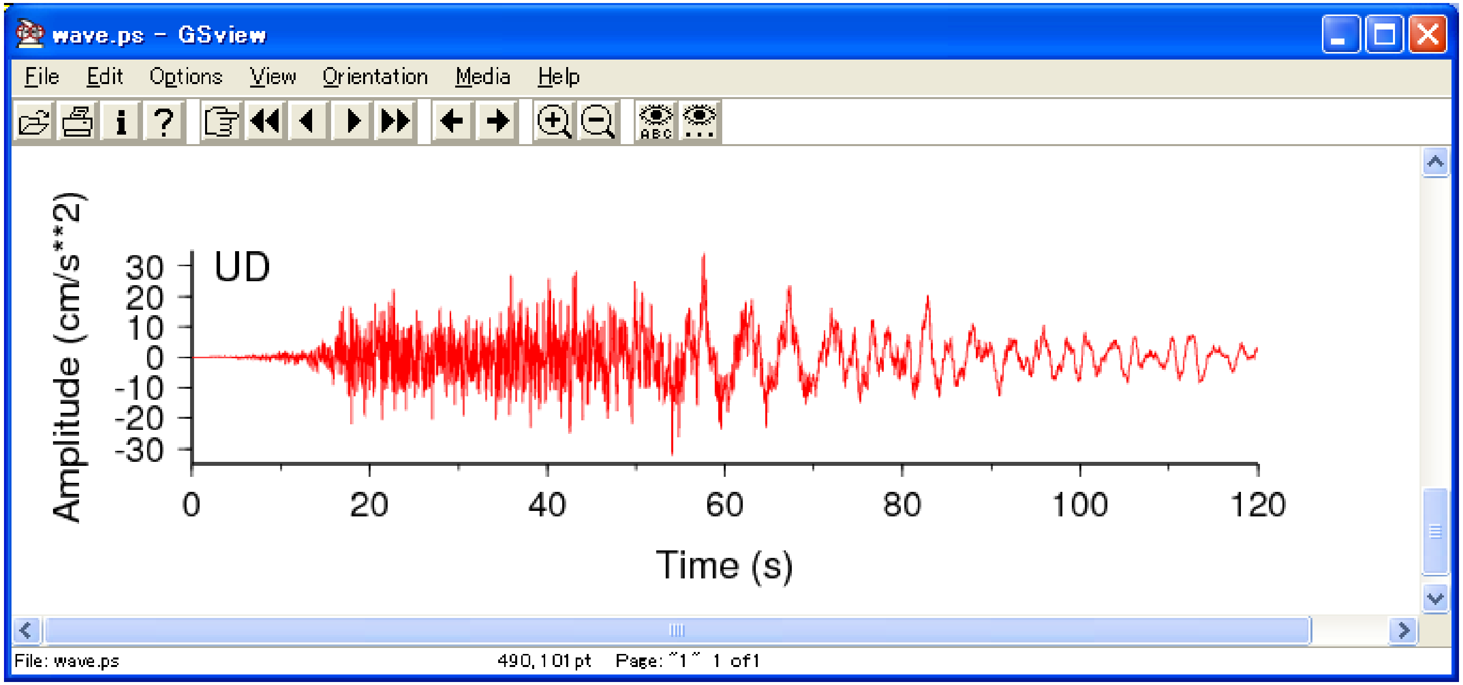
```
#!/bin/csh  -f
gmtset  LABEL_FONT_SIZE 15p
set  datafile  =  wave.dat
set  psfile  =  wave.ps
set  size  =  15.0c/3.0c
set  range  =  0/120/-35/35

psbasemap  -JX$size  -R$range  -Ba20f10:"Time (s)":/a10f10:"Amplitude (cm/s**2)":SW -P  -K  > $psfile
awk  '{ print $1, $4 }'  $datafile  |  psxy  -W2/255/0/0  -JX$size  -R$range  -P  -O  -K  >> $psfile
pstext  -JX$size  -R0/10/0/4  -P  -O  << EOF >>  $psfile
0.2   4.0  16   0   0   LT   UD
EOF
```

Plotting Waveforms

Save it as “**pw.csh**”; change to the execute mode; run csh script.

```
$ chmod   u+x   pw.csh
$ ./pw.csh
$ gs  wave.ps
```



Grid Data (Topography)

Topography data can be downloaded from the website of GEBCO

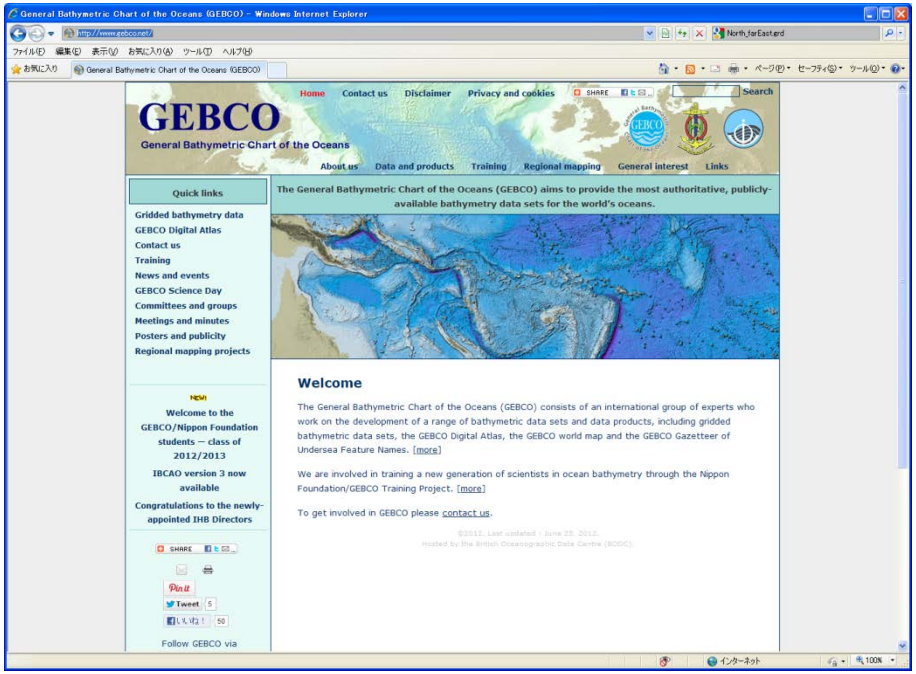
http://www.gebco.net/

You can find the topography data that has already been prepared on “earth2” or “ocean”.

/home/fujii/GMT/GEBCO_japan.grd

To copy the grid file to your local PC, type

```
$ scp  earth2:/home/fujii/GMT/GEBCO_japan.grd  .
```



The General Bathymetric Chart of the Oceans (GEBCO) aims to provide the most authoritative, publicly-available bathymetry data sets for the world’s oceans.

Welcome to the GEBCO/Nippon Foundation students – class of 2012/2013

IBCAO version 3 now available

Congratulations to the newly-appointed IHB Directors

Welcome

The General Bathymetric Chart of the Oceans (GEBCO) consists of an international group of experts who work on the development of a range of bathymetric data sets and data products, including gridded bathymetric data sets, the GEBCO Digital Atlas, the GEBCO world map and the GEBCO Gazetteer of Undersea Feature Names. [more]

We are involved in training a new generation of scientists in ocean bathymetry through the Nippon Foundation/GEBCO Training Project. [more]

To get involved in GEBCO please contact us.

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Hosted by the British Oceanographic Data Centre (BODC).

Drawing the Grid Data (1)

Write the following in the nedit window:

```
#!/bin/csh  -f
set  REGION  =  128/148/30/48
set  SIZE  =  M18c
set  AXIS  =  f1a5g5WSne
set  grdfile  =  GEBCO_japan.grd
set  cptfile  =  color.cpt
set  psfile  =  japan_topo.ps
makecpt  -Cglobe  -Z  >  $cptfile
grdimage  $grdfile  -R$REGION  -J$SIZE  -C$cptfile  -K  -P  >  $psfile
pscoast  -R$REGION  -J$SIZE  -B$AXIS  -Dh  -W2,150  -P  -O  >>  $psfile
```

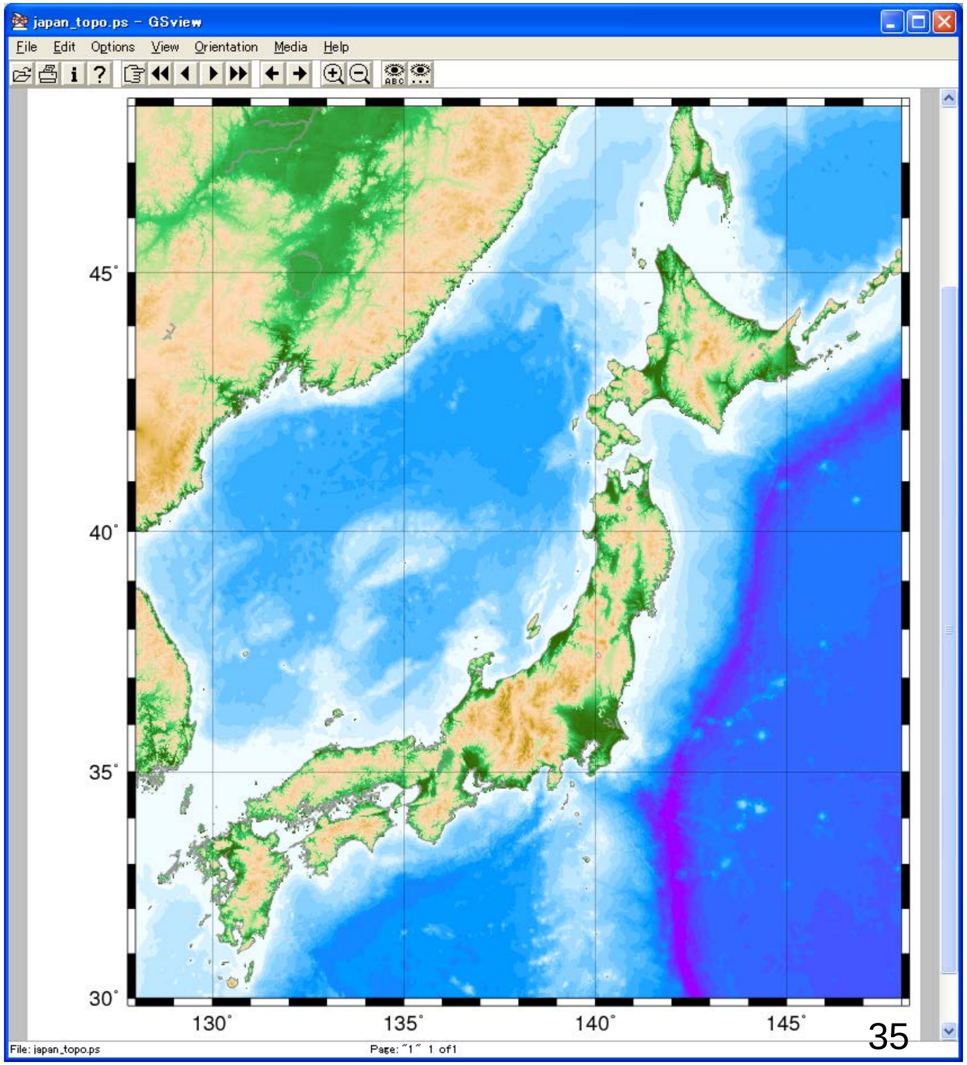
Save it as “**topo.csh**”; change to the execute mode; run csh script.

```
$ chmod   u+x   topo.csh
$ ./topo.csh
```

Drawing the Grid Data (1)

makecpt: This command is useful to create a color palette.

grdimage: This command draws the map using grid data written in the NetCDF format.



How to make the Grid Data (1)

Topography data around Mt. Fuji are prepared in xyz ASCII format on “earth2” or “ocean”.

/home/fujii/GMT/Mt_Fuji.xyz

To copy the xyz data to your local PC, type

```
$ scp  earth2:/home/fujii/GMT/Mt_Fuji.xyz  .
```

To convert the xyz data to NetCDF grid format, write the following in the nedit window.

```
#!/bin/csh  –f
set  REGION  =  138/140/34/36
set  xyzdat  =  Mt_Fuji.xyz
set  grdfile  =  Mt_Fuji.grd
xyz2grd  $xyzdat  -I5m  -R$REGION  -G$grdfile  -V
```

And save as “**make_grd.csh**”; change to the execute mode; run csh script.

```
$ chmod  u+x  make_grd.csh
$ ./make_grd.csh
```

Drawing the Grid Data (2)

Copy “**topo.csh**” to “**Mt_Fuji.csh**” and edit it in the nedit window:

```
#!/bin/csh  –f
set  REGION  =  138/140/34/36
set  AXIS  =  f10ma30mWSne
set  SIZE  =  M16c

set  grdfile  =  Mt_Fuji.grd
set  psfile  =  Mt_Fuji.ps

set  cptfile  =  color.cpt
makecpt  -Cglobe  -Z  >  $cptfile

grdimage  $grdfile  -R$REGION  -J$SIZE  -C$cptfile  -K  -P  >  $psfile
grdcontour  $grdfile  -R$REGION  -J$SIZE  -A500  -K  -P  -O  >>  $psfile
pscoast  -R$REGION  -J$SIZE  -B$AXIS  -Df  -W2,150  -P  -O  >>  $psfile
```

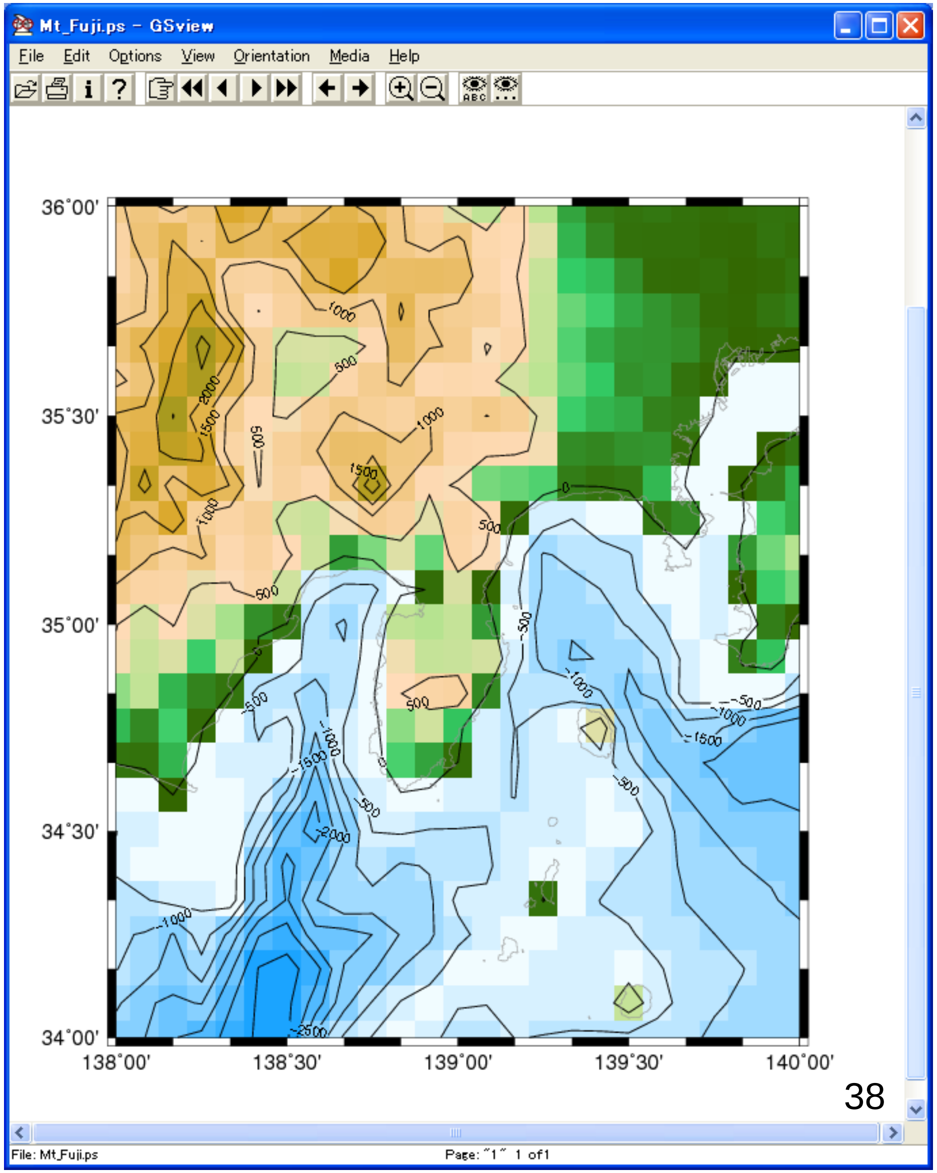
Overwrite save and run the shell script.

```
$ ./Mt_Fuji.csh
```

Drawing the Grid Data (2)

xyz2grd: reads a z or xyz table and creates a binary grid file.

grdcontour: reads a 2-D grid file and produces a contour map by tracing each contour through the grid.



How to make the Grid Data (3)

If you need to make a finer grid, in another words, if you only have sparse xyz data, write the following to convert the xyz data.

```
#!/bin/csh  –f
set  REGION  =  138/140/34/36
set  xyzdat  =  Mt_Fuji.xyz
set  grdfile  =  Mt_Fuji.grd

#xyz2grd  $xyzdat  -I1m  -R$REGION  -G$grdfile  -V
   (Commnet out, because this command will not work well for a fine grid size.)

blockmedian  $xyzdat  -R$REGION  -I1m  -V  |  ¥
surface   -R$REGION  -I1m  -C1  -T0.35   -V  -G$grdfile
```

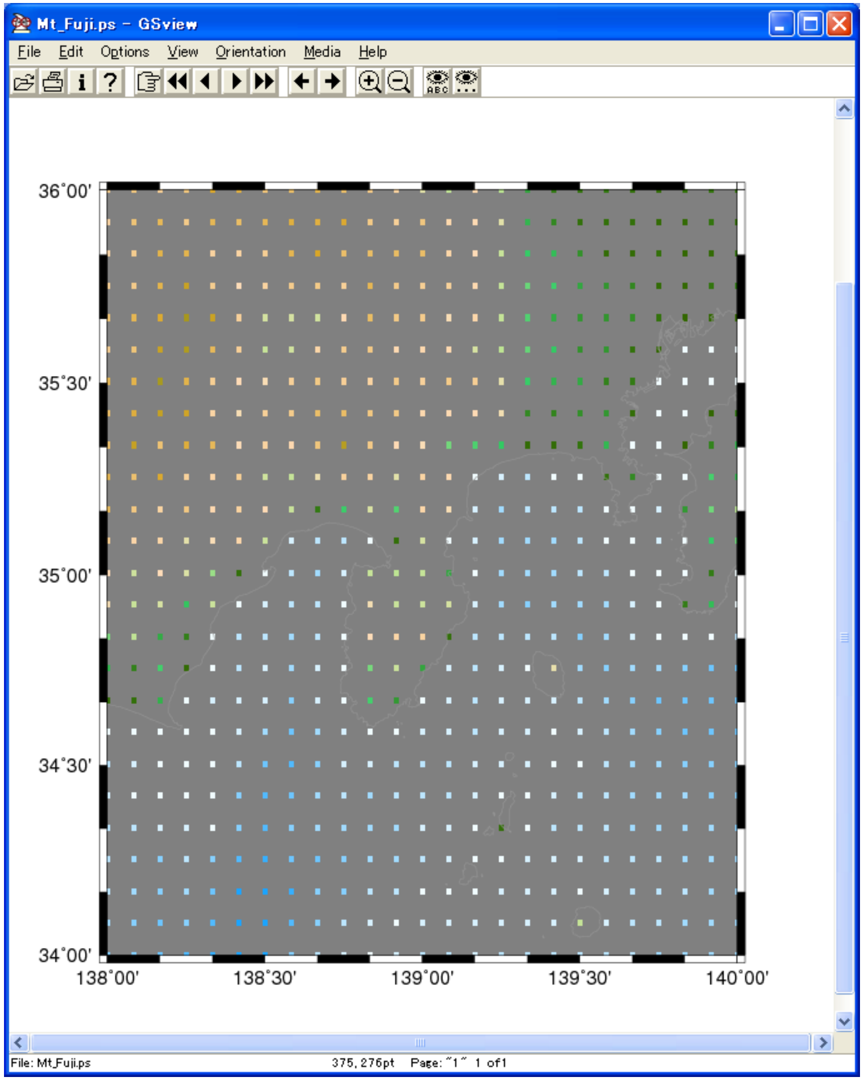
Save and run the shell script.

```
$ ./make_grd.csh
```

Drawing the Grid Data (3)

Original xyz data has a resolution of 5 arc-minute.

However, we have tried to convert the xyz data with a finer grid size of 1 arc-minute, by using **xyz2grd** command.



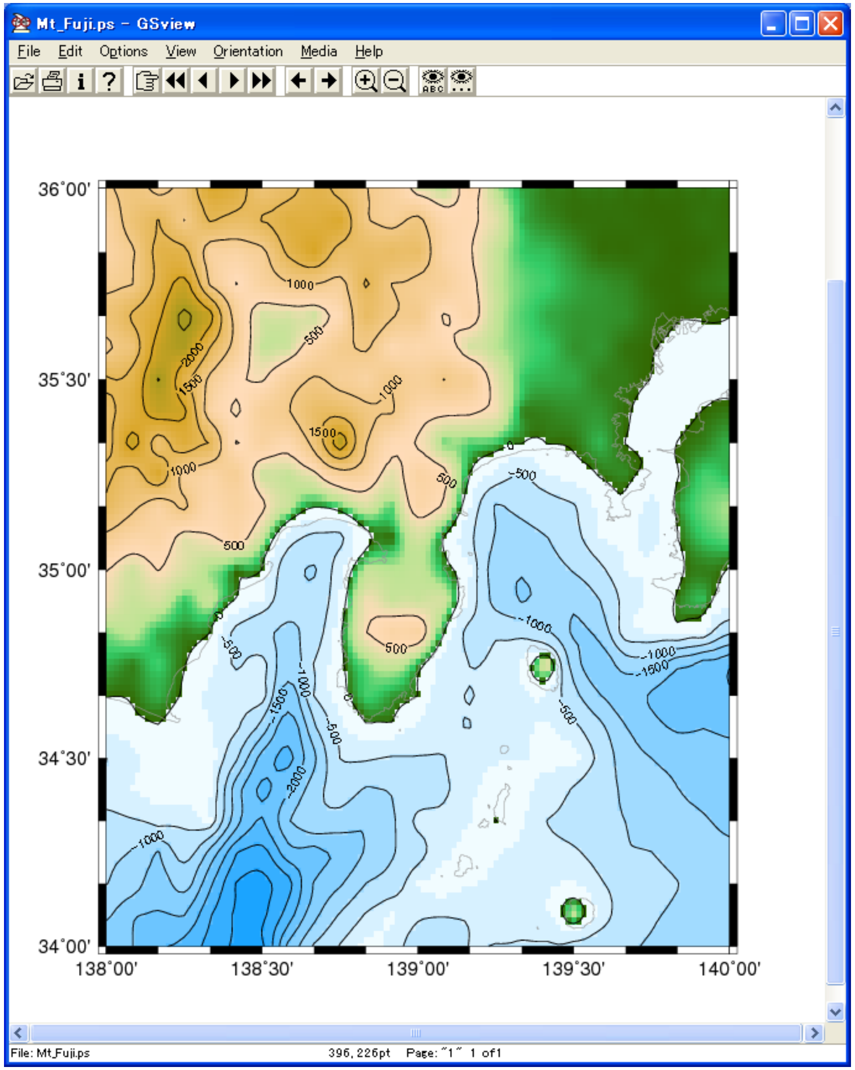
Drawing the Grid Data (3)

blockmedian: reads arbitrarily located (x,y,z) triples from standard input [or xyz files] and writes to standard output a median position and value for every non-empty block in a grid region defined by the -R and -I arguments.

surface: reads randomly-spaced (x,y,z) triples from standard input [or xyz file] and produces a binary grid file by solving:

(1 - T) * L (L (z)) + T * L (z) = 0

where T is a tension factor between 0 and 1, and L indicates the Laplacian operator.



References

For more information, we recommend you to bookmark the following address:

C:¥programs¥GMT4¥doc¥html¥index.html

including

- GMT Technical Reference and Cookbook
- GMT Tutorial
- GMT Manual Pages
- GMT Supplemental Manual Pages