ESSC4140 Seismology
Introduction to GMT (Tutorial #1)

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TA office hour: Thursday 16:00-17:30

Venue for tutorial: SC329

Some useful links

GMT Homepage:

https://www.soest.hawaii.edu/gmt/

Online GMT Tutorial:

http://gmt-tutorials.org/en/index.html

Installation on personal computer:

Git: https://git-scm.com/downloads

GMT: https://docs.gmt-china.org/6.0/install

Objective of this series of tutorials

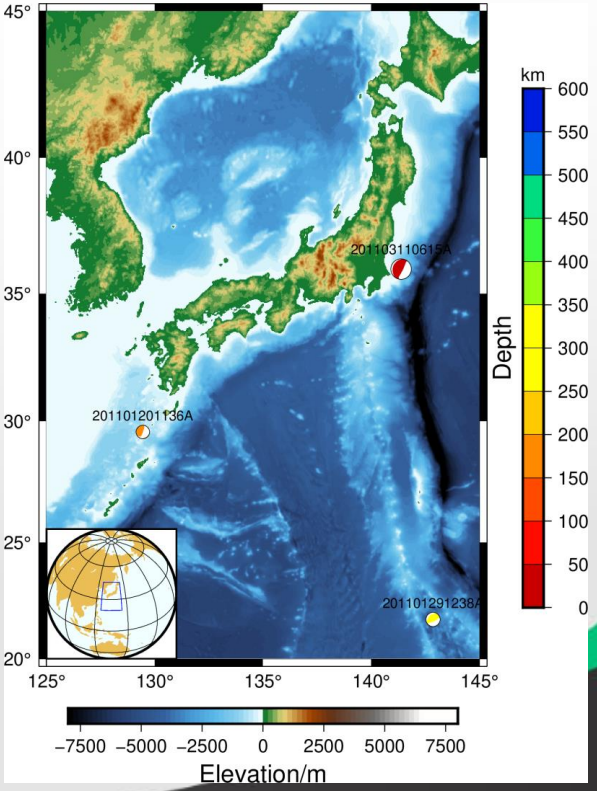
Cartesian, geographic and various data sets

GMT

Creating simple x-y plots or more complex graphics

142.906449088	20.4706618719	-2629.97607422
142.941667124	20.4706618719	-2749.20556641
142.97688516	20.4706618719	-2900.71630859
143.012103196	20.4706618719	-3173.2487793
143.047321232	20.4706618719	-3515.28955078
143.082539268	20.4706618719	-3785.9375
143.117757304	20.4706618719	-3882.34960938
143.152975341	20.4706618719	-3849.13476563
143.188193377	20.4706618719	-3768.56298828
143.223411413	20.4706618719	-3648.87768555
143.258629449	20.4706618719	-3633.97753906
143.293847485	20.4706618719	-3602.37329102
143.329065521	20.4706618719	-3683.31542969
143.364283557	20.4706618719	-3858.42016602
143.399501593	20.4706618719	-4020.11914063
143.434719629	20.4706618719	-4041.34277344
143.469937665	20.4706618719	-3989.51831055

GMT



129.45 29.56 159 -0.28 0.60 -0.32 2.51 7.49 2.02 23 X Y 201101201136A
142.85 21.71 319 1.52 -1.05 -0.47 1.16 0.29 -0.92 24 X Y 201101291238A
141.38 35.92 29 4.39 -0.31 -4.07 3.17 6.34 -1.97 27 X Y 201103110615A

Basic Unix commands

$ pwd (present working directory)

$ ls (list)

$ cd (change directory)

- . (the current directory)
- .. (one level up from the current directory)
- path/to/the/directory

$ mkdir/touch (make a directory/file)

$ cp/rm/mv (copy/remove/move)

$ cat/less/more (concatenate/read file)

$ echo (like 'print')

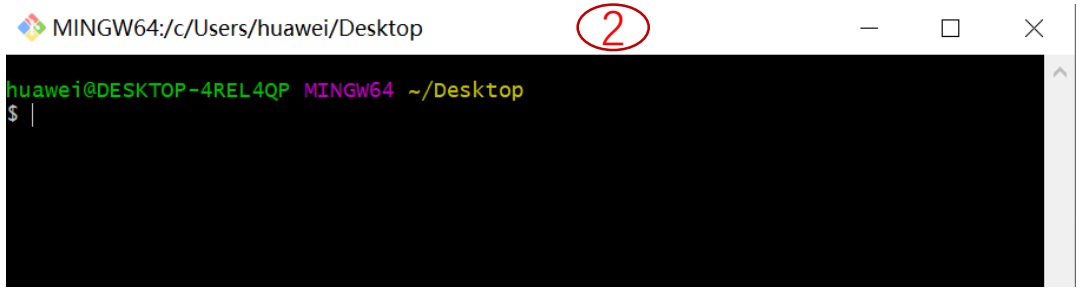
> (redirect output to and overwrite a file, use >> to append)

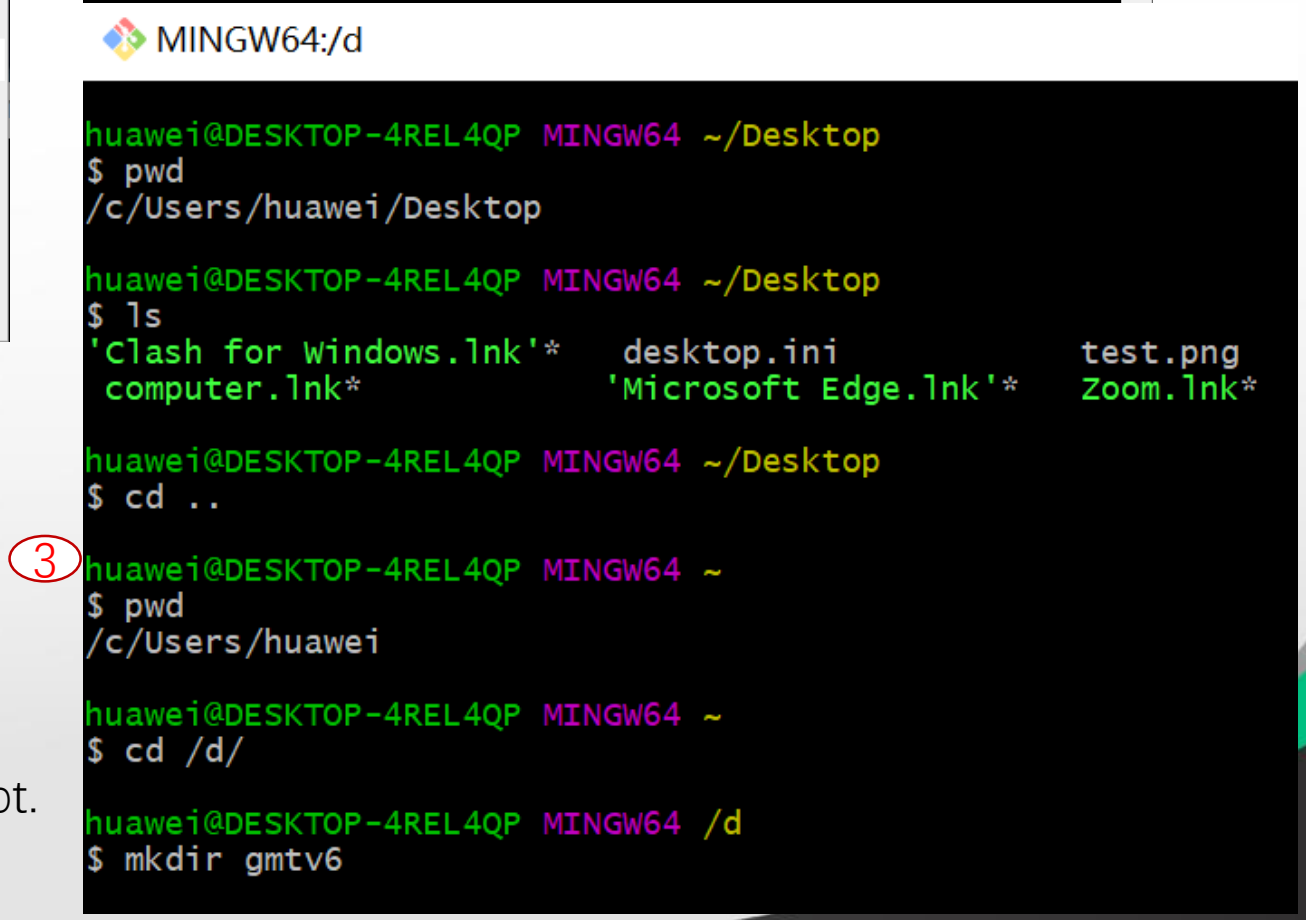
* represents a string of arbitrary length

? represents exactly one character

Note that: '$ command --help' is very useful

Open the command prompt and the command always follows $





After creating the working derectory named "gmtv6", close the command prompt.

MINGW64:/d/gmtv6 ④

```
huawei@DESKTOP-4REL4QP MINGW64 ~/Desktop
$ cd /d/gmtv6/

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6
$ touch first.txt

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6
$ ls
first.txt

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6
$ cp /c/Users/huawei/Downloads/GMT.zip .

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6
$ ls
first.txt  GMT.zip

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6
$ rm first.txt
```

```
huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6
$ mv first.txt ~/Desktop/
```

" . " means the present working directory

"rm" will delete the file inreversibly

Uncompress the zip file using mouse or using command-unzip like step 5

⑤

```
huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6
$ unzip GMT.zip
Archive:  GMT.zip
   creating: GMT/
  inflating: GMT/colombia.cpt
  inflating: GMT/colorbar.sh
  inflating: GMT/eq.dat
  inflating: GMT/final.sh
  inflating: GMT/inset.sh
  inflating: GMT/Japan.grd
  inflating: GMT/meca_depth.sh
  inflating: GMT/section1.sh
  inflating: GMT/source.txt

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6
$ ls
GMT/  GMT.zip
```

⑥

```
huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6
$ cd GMT

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ ls
colombia.cpt  eq.dat     inset.sh*  meca_depth.sh  source.txt
colorbar.sh*  final.sh*  Japan.grd  section1.sh*

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ cat source.txt
129.45 29.56 159 -0.28 0.60 -0.32 2.51 7.49 2.02 23 X Y 201101201136A
142.85 21.71 319 1.52 -1.05 -0.47 1.16 0.29 -0.92 24 X Y 201101291238A
141.38 35.92 29 4.39 -0.31 -4.07 3.17 6.34 -1.97 27 X Y 201103110615A
huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ echo "Hello"
Hello

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ echo "hello" > temp

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ cat temp
hello
```

⑦

```
huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ ls colo?b*
colombia.cpt  colorbar.sh*

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ less --help
```

Basic Unix commands

awk (a unix command to organize, find and extract infomation in text files)

$ less eq.dat

(Press q to quit)

$ awk '{print $3,$1}' eq.dat

$ awk '{print $0}' eq.dat

| (the pipe operator takes the result of last command and passes it to the next command)

usage: **command 1 | command 2**

e.g.

echo 'hello world *' | awk '{print $3}' | ls

```
huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ echo 'hello world *' > temp

huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ cat temp
hello world *
```

```
huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ awk '{print $3}' temp
*
```

```
huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ ls *
colombia.cpt  eq.dat     inset.sh*  meca_depth.sh  source.txt
colorbar.sh*  final.sh*  Japan.grd  section1.sh*   temp
```

```
huawei@DESKTOP-4REL4QP MINGW64 /d/gmtv6/GMT
$ echo 'hello world *' | awk '{print $3}' | ls
colombia.cpt  eq.dat     inset.sh*  meca_depth.sh  source.txt
colorbar.sh*  final.sh*  Japan.grd  section1.sh*   temp
```

Run commands automatically

Now let's try to write a simple shell script named 'simple.sh'

$ touch simple.sh

```
#!/bin/sh
pwd
echo contains
# list all files and directories
ls *
echo done
```

Then run it:

$ ./simple.sh or $ sh simple.sh

The first line always starts with: #!/bin/sh to tell the default shell to use the interpreter located at /bin/sh
And use **the pound sign # to add comments**

GMT commands

First, view the basic syntax of GMT commands by typing:

$ gmt

usage: **gmt <module name> [<module-options>]**

Then, check the available GMT modules by typing:

$ gmt --help

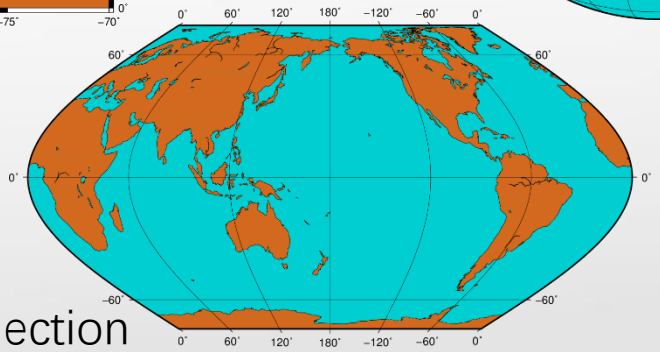
section 1	**section 2**	**section 3**
basemap	grdimage	project
plot	makecpt	data download
text	colorbar	Q&A
coast	meca	
	inset	

GMT Map Projections (-J)

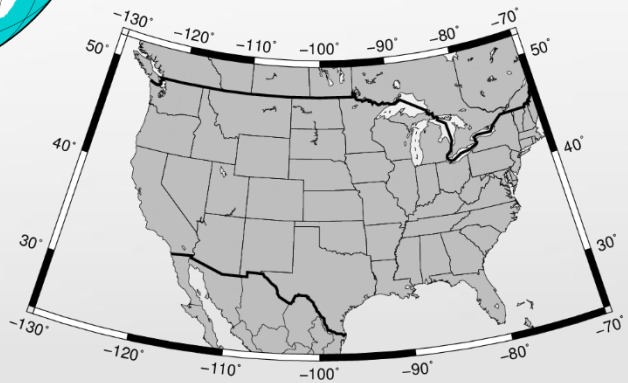
GMT plots the spherical Earth on a flat surface, therefore, **projection is needed**

Mercator projection

Orthographic projection



Eckert VI projection



Albers projection

GMT supports more than 30 different projections, if you are interested, please refer to:
https://en.wikipedia.org/wiki/List_of_map_projections
https://www.generic-mapping-tools.org/GMT.jl/v0.8.0/proj_examples.html

basemap

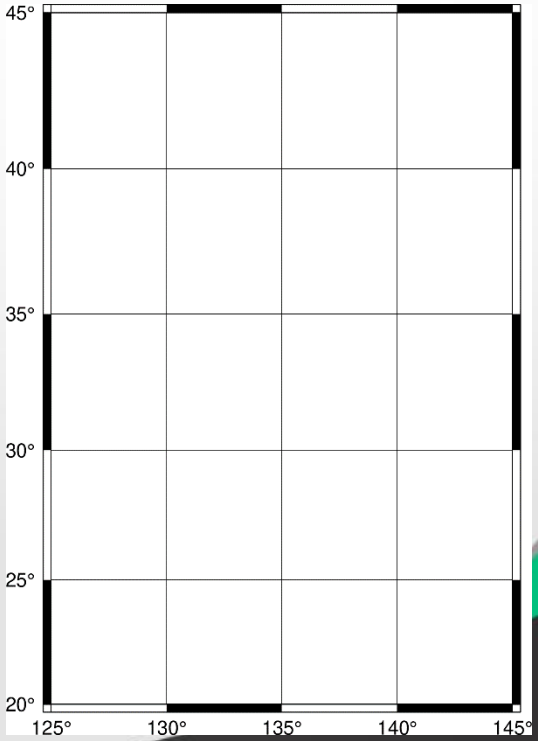
gmt basemap -JM10c -R125/145/20/45 -Bxa5g5 -Bya5g5 -BWeSn -png Japan

- Use the module named basemap to generate a new figure
- Option: -JM10c

-JM indicates Mercator projection, upper case 'M' means it followed by width (the height is further determined by -R), and lower case 'm' means followed by scale;
10c is 10 cm, another unit usually used is i (inch).

- Option: -R125/145/20/45

-R specifies the data region with min/max coordinates
125/145/20/45 corresponds to xmin/xmax/ymin/ymax, here actually is west/east/south/north



basemap

gmt basemap -JM10c -R125/145/20/45 -Bxa5g5 -Bya5g5 -BWeSn -png Japan

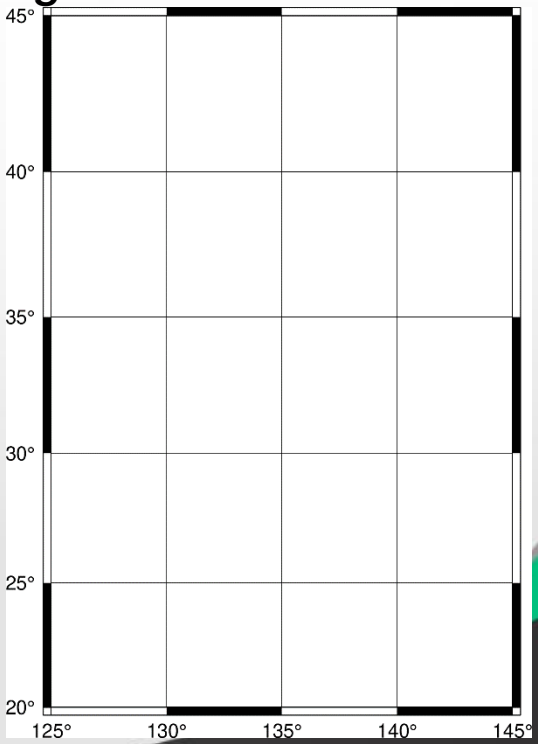
Exercise:
Change the -Bx/-By values e.g. -Bxa2g5
Change -BWeSn e.g. -BWESN

- Options: -Bxa5g5 -Bya5g5 -BWeSn

-B specifies the boundary settings
x/y indicates the axis
a is annotation, use a5 to plot annotation every 5 degree
g is grid, use g5 to plot gridlines every 5 degree

-BWeSn
Take the left side for instance,
W indicates annotation exits for this side;
w indicates no annotation;
l indicates no annotation and ticks;
if omit W/w/l, then the left side would disappear.

-png and Japan are the format and name of the figure, respectively



plot

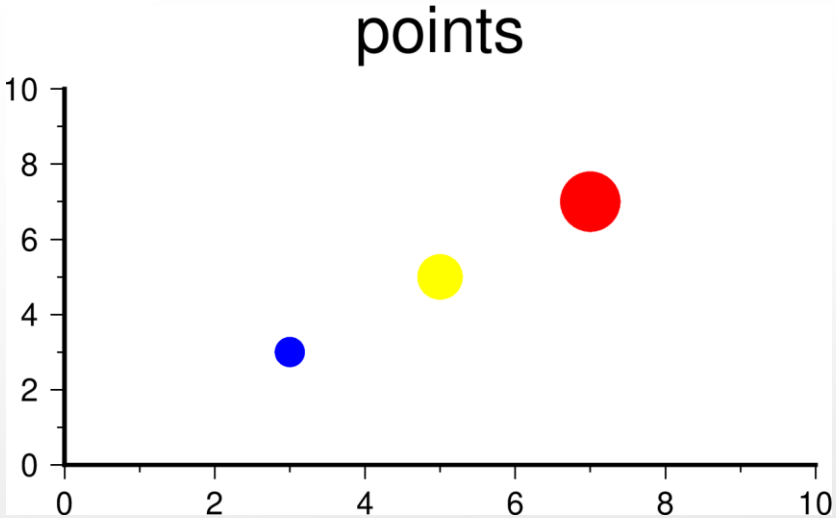
```
echo -e "3 3 0 0.4 \n 5 5 1 0.6 \n 7 7 2 0.8" | gmt plot -JX10c/5c -R0/10/0/10
-Ba2f1 -BWS+t"points" -Sc -Cblue,yellow,red  -png point
```

- Use the module named plot to add symbol or lines
- Option: -JX10c/10c

-JX means using linear projection
10c/10c corresponds to width/height

- Option: -Ba2f1 -BWS+t"points"

f1: plot ticks with the interval of 1;
no gridline here
+t"points": add a title



Input lines:
3 3 0 0.1
5 5 1 0.2
7 7 2 0.3

1st and 2nd column specify x and y position of symbol's center
3th column controls the color of symbol
4th column controls the size of symbol

plot

```
echo -e "3 3 0 0.4 \n 5 5 1 0.6 \n 7 7 2 0.8" | gmt plot -JX10c/5c -R0/10/0/10
-Ba2f1 -BWS+t"points" -Sc -Cblue,yellow,red  -png point
```

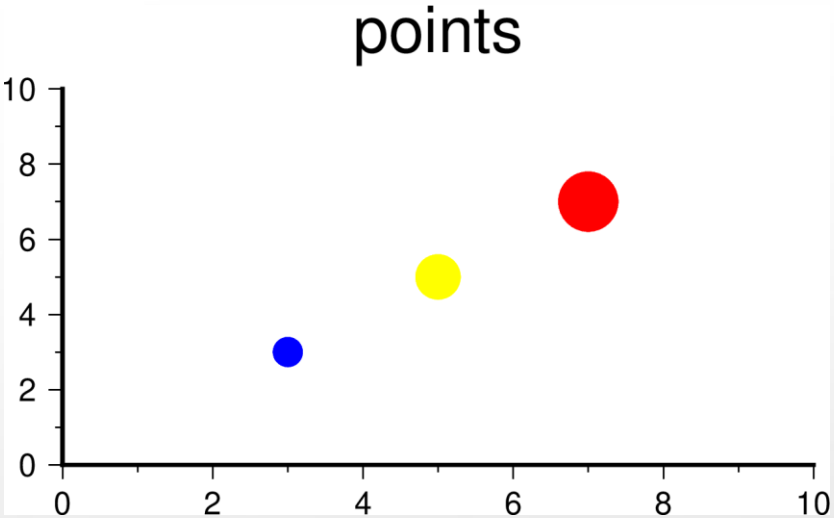
- Option: -Sc

-Sc defines the shape of symble as circle

- Option: -Cblue,yellow,red

This option specifies the color range of different points, you can either use a list of colors or a cpt file which will be introduced later

here blue corresponds to value 0;
yellow corresponds to value 1;
red corresponds to value 2; and the like...



Exercise:

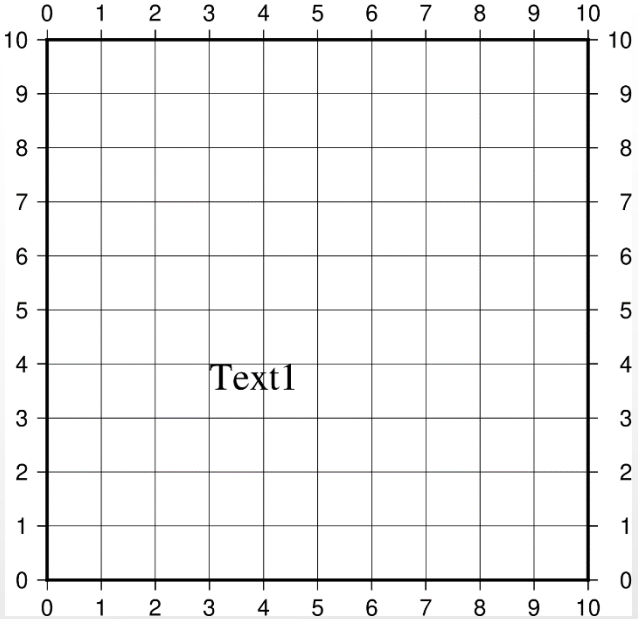
1. Change the -S option and try different symbols

2. Use this command to plot a line

(Tips: at least two points, remove -S, -C options)

text

echo "3 4 Text1" | gmt text -JX10c/10c -R0/10/0/10 -Ba1g1 -F+f20p,4+jTL -png text



- Use the module named text to add text

- Option: -F+f20p,4+jTL

-F specifies the value of text attributes

+f20p,4 sets the size to be 20p (the default unit is point, 1 point ≈0.04cm), sets the font to be 4, which corresponds to Times-Roman, there are 35 types of font totally.

+jTL set the topleft of text relative to given x,y coordinate.

Exercise: try +f30p,4 / +f20p,10 / ...

try +jBL / +jMC and observe the position of text

coast

gmt coast -JM10c -R125/145/20/45 -Ba5 -BWeSn+t"Map of Japan" -Da -Gyellow -Slightblue -W0.5 -L128/22+c22+w200k+u -png shoreline

- Use the module named coast to plot coastline, river and borders with the included datasets.

- Option: -Da

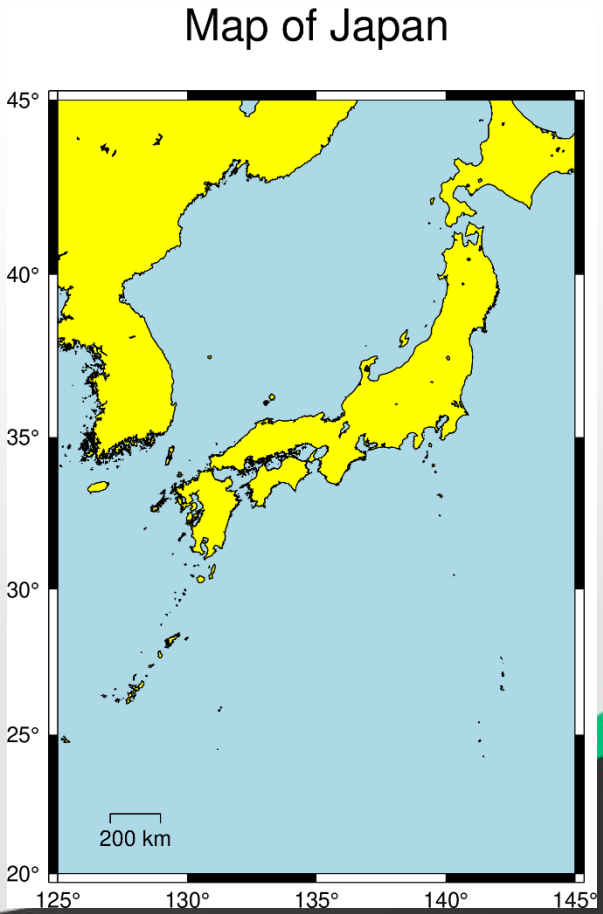
Choose the resolution of shoreline from a (auto selection given map scale), f (full resolution), h (high resolution), i (intermediate resolution), l (low resolution) and c (crude resolution).

- Option: -Gyellow

Paint the dry area with yellow

- Option: -Slightblue

Paint the wet area with lightblue



coast

gmt coast -JM10c -R125/145/20/45 -Ba5 -BWeSn+t"Map of Japan" -Da -Gyellow -Slightblue -W0.5p -L128/22+c22+w200k -png shoreline

- Option: -W0.5

-W controls the width, color and style of the shorelines

0.5p sets the pen width to be 0.5 point

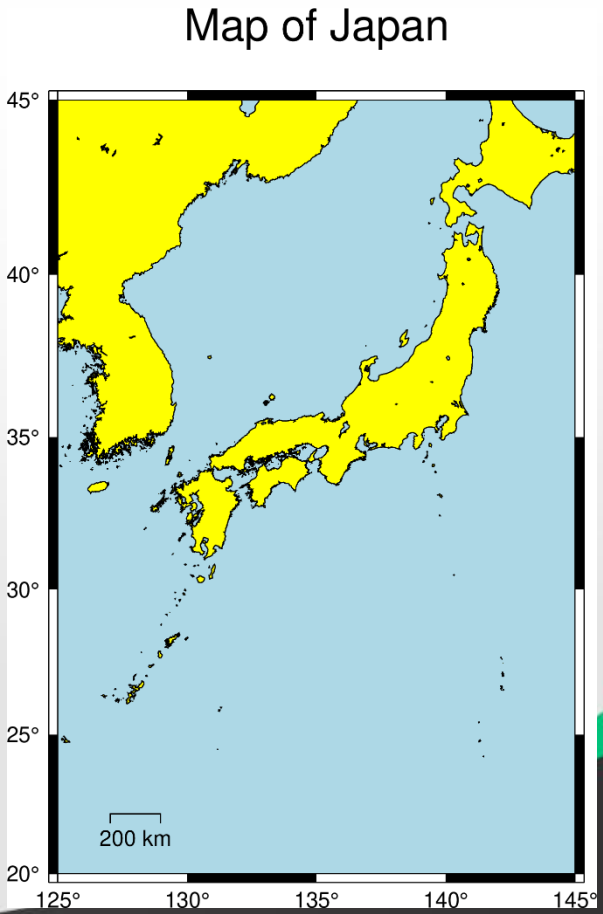
- Option: -L128/22+c22+w200k

-L indicates the addition of a map scale

128/22 is the x/y coordinate of a reference point, if not specified, it's the center of the map scale

+c22 means the the scale will be calculated along the latitude line of N22°

+w200k gives the realistic length of the map scale which is 200 km

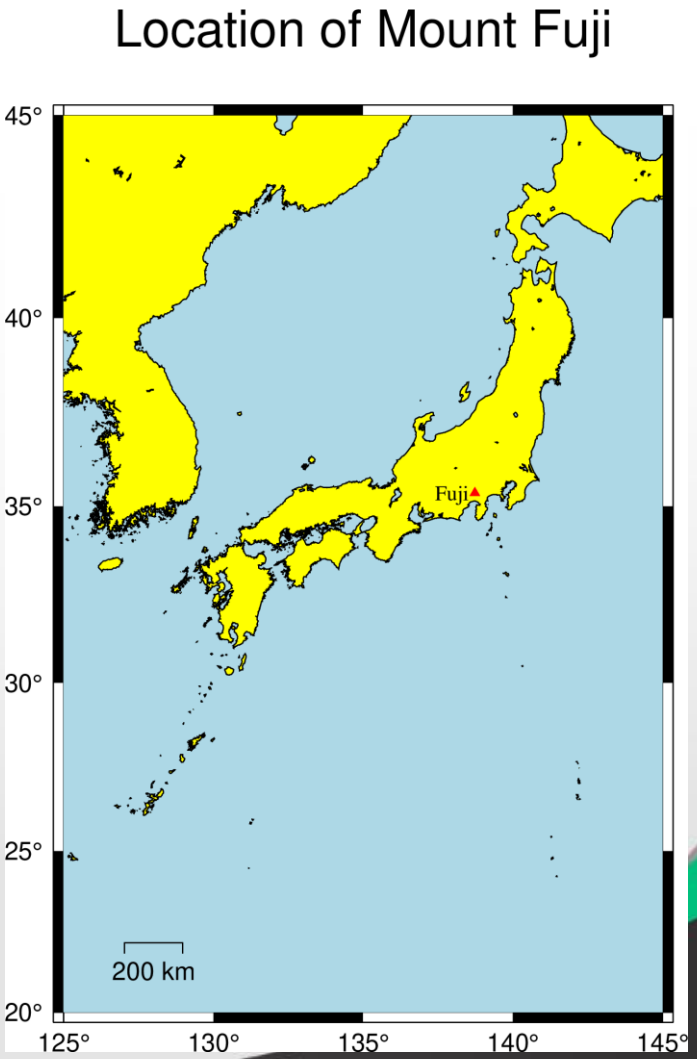


Exercise:

- Try different colors for dry and wet areas
- Try different resolutions of shoreline
- Add a new map scale with different center positions and lengths

Run a script to over the section 1

```
#!/bin/sh

gmt begin MountFuji png

gmt basemap -JM10c -R125/145/20/45 -Ba5
-BWeSn+t"Location of Mount Fuji"

gmt coast -Da -Gyellow -Slightblue -W0.5p
-L128/22+c22+w200k

echo 138.729050 35.360638 | gmt plot -
St0.2c -Gred

echo 138.729050 35.360638 Fuji | gmt text -
F+f10p,4+jMR -D-0.1/0

gmt end show
```



Exercise：

Try another type of projection: -JC10c

Add another place of interest

But the color of this map looks bad...
Now let's move to the second section and see how to solve this.

Topography map

- topography data consists of coordinates in three columns:

  longitude latitude elevation(m)

  ……

- GMT can use the topography datasets and plot them with different color palettes

- These topography datasets are in a NetCDF format and generally with an extension of .grd

- Color palette file is used to link grid values such as elevation with colors and have an extension of .cpt

grdimage

gmt grdimage Japan.grd -Cgeo -JM10c -R125/145/20/45 -Ba5 -BWeSn -png topo01

- Use the module named grdimage to plot a color image with grids or NetCDF file

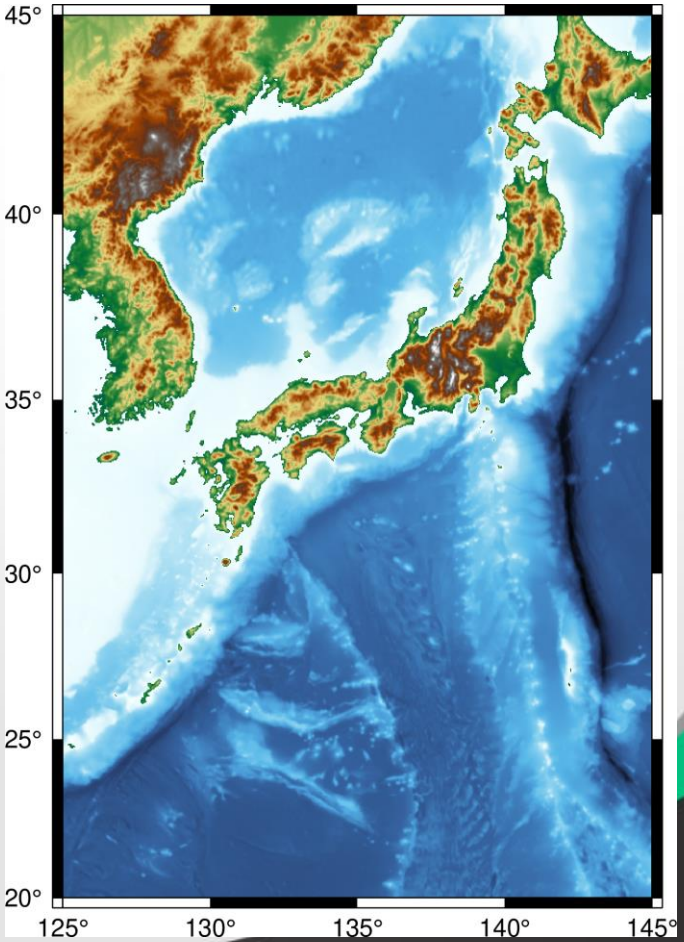
- Japan.grd

It's a NetCDF file in binary format and includes the elevation information over the region of "-R125/145/20/45".

See the last several slides about how to download and convert topography datasets for a specific region.

- Option: -Cgeo

-Cgeo indicates GMT will use the built-in color palette named "geo" and assign continuous colors over the elevation data range



makecpt

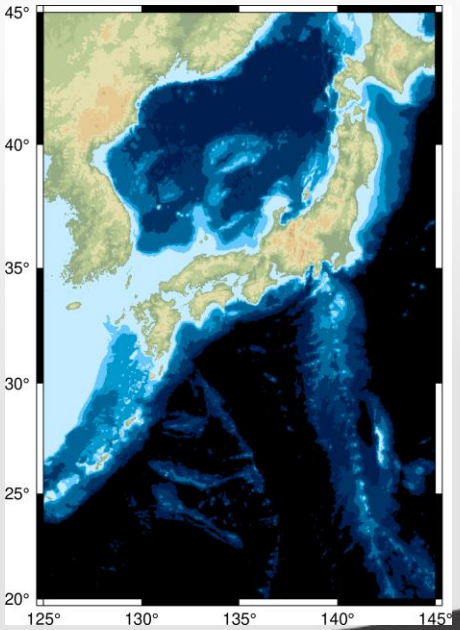
If you don't want to directly use the built-in cpt files, try two other methods to produce better or more specialised topography map's look.

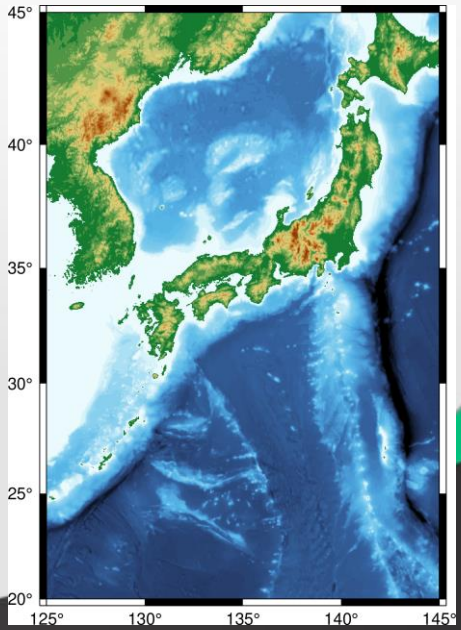
1. use makecpt command to creat a cpt file, -T-8000/8000/200 is -Tz_min/z_max/z_inc

```
gmt makecpt -Cgeo -T-8000/8000/200 > geo_1.cpt
gmt grdimage Japan.grd -Cgeo_1.cpt -JM10c -R125/145/20/45 -Ba5 -BWeSn -png topo01
```

2. use a custom cpt file.

```
# colombia.cpt
# GMT colour palette by Shadowxfox
# http://fr.wikipedia.org/wiki/Fichier:Colombia_Mapa_Relieve.svg
# licence: http://creativecommons.org/licenses/by-sa/3.0/deed.fr
# COLOR_MODEL = RGB
-4000   0  30  80  -3000   0  30  80
-3000   0  51 102  -2000   0  51 102
-2000   0 102 153  -1000   0 102 153
-1000   0 153 205  -500    0 153 205
-500  100 200 255  -200  100 200 255
-200  198 236 255  0     198 236 255
0     148 171 132  100   148 171 132
100   172 191 139  200   172 191 139
200   189 204 150  500   189 204 150
500   228 223 175  1000  228 223 175
1000  230 202 148  2000  230 202 148
2000  205 171 131  3000  205 171 131
3000  181 152 128  4000  181 152 128
4000  155 123  98  5000  155 123  98
```





Exercise:

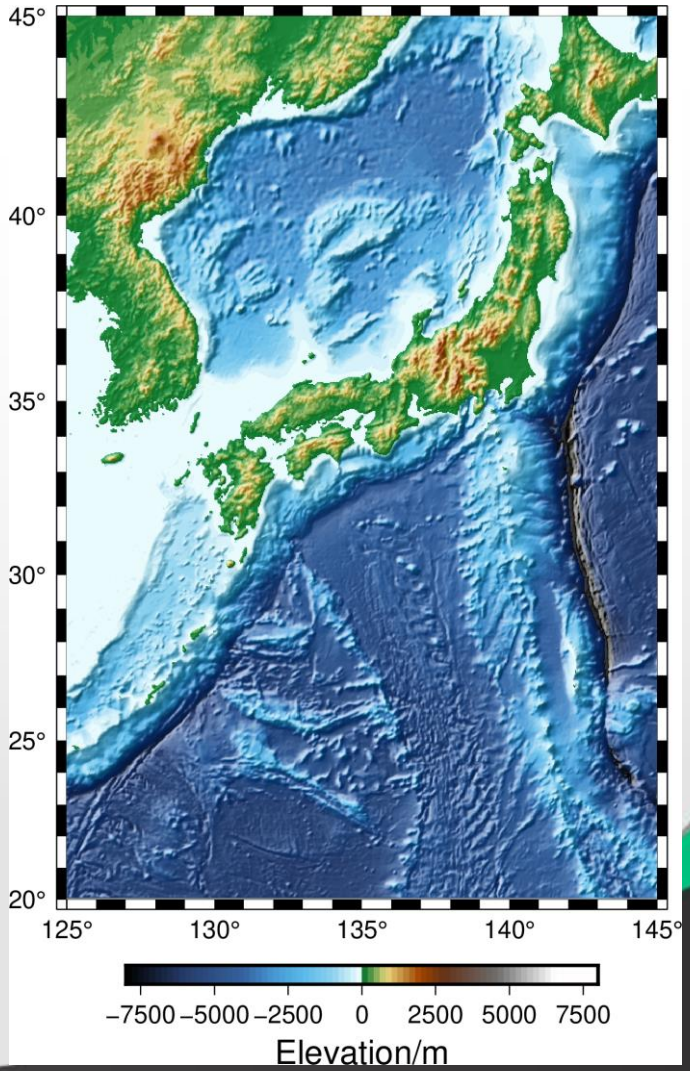
- Try one or more built-in cpt. e.g. -Ctopo/-Crainbow
- Try to make one or more custom cpt file according to "colombia.cpt"
- Download the elevation data and plot a new topography map for the region of your interest.

colorbar

```
#!/bin/sh
gmt begin topo02 png
gmt basemap -JM10c -R125/145/20/45 -Baf -BWSen
gmt makecpt -Cgeo -T-8000/8000/200
gmt grdimage Japan.grd -I+d
gmt colorbar -Bxa2500+l"Elevation/m"
gmt end show
```

- Use **-I+d** to apply the default directional illumination and make the topography map look like 3D, it's not required.
- Use the module named colorbar to add a color scale bar
- Option: -Bxa2500+l"Elevation/m"

-Bxa2500 is a annotation setting option
Use +l"Elevation/m" to add a label which descrips the z value and its unit



meca

gmt meca source.txt -JM10c -R125/145/20/45 -Ba5 -Sm0.2c -png beachball_mag

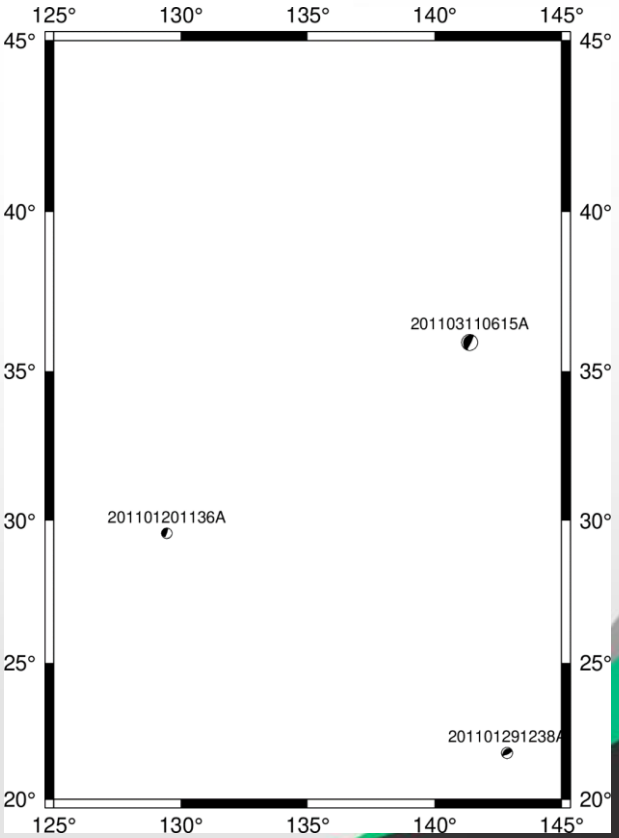
- Use the module named meca to plot focal mechanism

- -Sm0.2c

-Sm corresponds to the format of seismic moment tensor data in the "source.txt" file. (There are different types of format to descrip the focal mechanism of an earthquake, discuss it in the section 3)

0.2c determines the beachball diameter of a magnitude 5 earthquake, and the size of other beachballs will be calculated using the equation:

$$size = M / 5 * 0.2c$$



You can add the option -M to fix the scale for all beachballs

meca

```
gmt makecpt -Cseis -T0/600/50 > dep.cpt
gmt begin beachball_dep png
gmt meca source.txt -JM10c -R125/145/20/45 -Ba5 -Sm0.3c -M -Zdep.cpt
gmt colorbar -Cdepth.cpt -Bx+l"Depth" -By+l"km" -DjTL+w5c/0.5c+ml+o0.8c/1c
gmt end show
```

If we want use the color to represent the depth, then the first step would be creat a custorm cpt file. (recall the makecpt command)

- When plotting the focal mechanisms, make sure to add the -Z<cptfile> option.

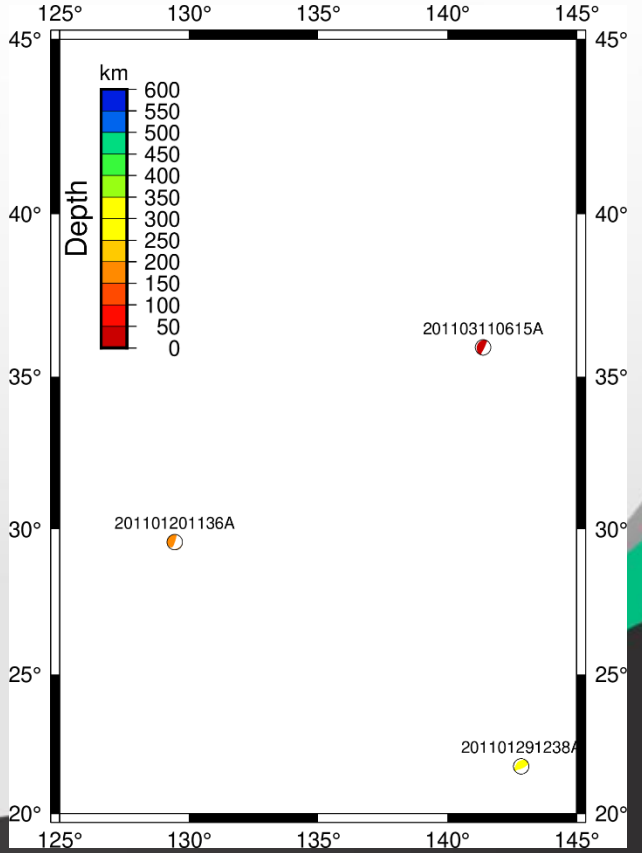
And then plot a color bar and adjust its scale and position using the option -D:

- -DjTL+w5c/0.5c+ml+o0.8c/1c

jTL means the position is at the topleft, use +o0.8c/1c to move it along the x and y axes.

+w5c/0.5c sets the length and width of color bar

use +ml to put the annotation at the left side, try +mr



Exercise:

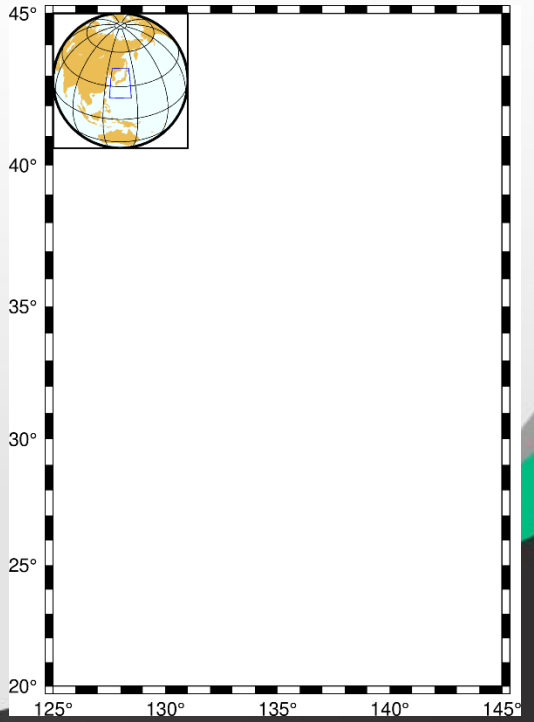
- Download other types of focal mechanism and choose the related -S option
- Make a higher resolution CPT file and plot it again.

  e.g. -T0/600/20
- Adjust the position, length, width and annotation of colorbar.

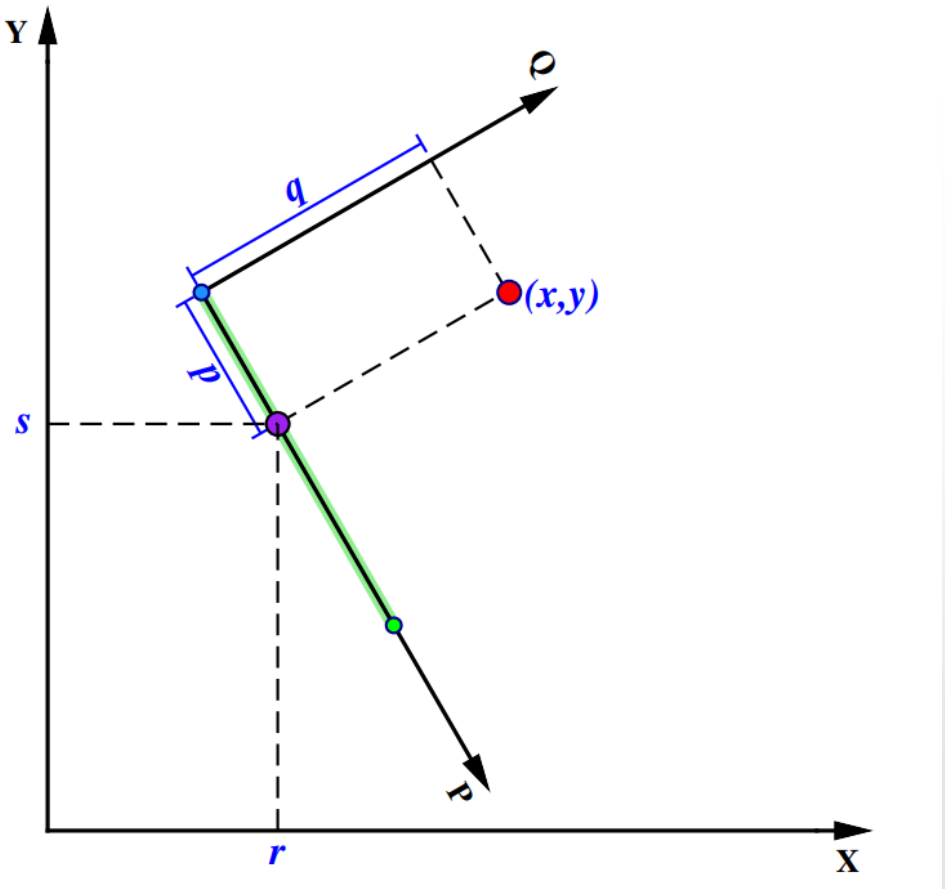
inset

```
#!/bin/sh
gmt begin inset png
gmt basemap -JM10c -R125/145/20/45 -Baf -BWSen
    gmt inset begin -DjTL+w3c -F+gwhite+p1p
        gmt coast -JG135/35/? -Rg -Bg -Glightbrown -Sazure1 -A10000
        echo -e "125 20\n145 20\n145 45\n125 45\n125 20" | gmt plot -W0.3p,blue
    gmt inset end
gmt end show
```

- -DjTL+w3c defines the justification and width/height of the inset box
- -F+gwhite+p1p uses white to fill the inset box and sets the frame width to be 1 point
- -A10000 means the borders of lake or island that smaller than 10000 km² won't be shown



project



If we know the position of a line and a point, then we can use the command **project** to derive:

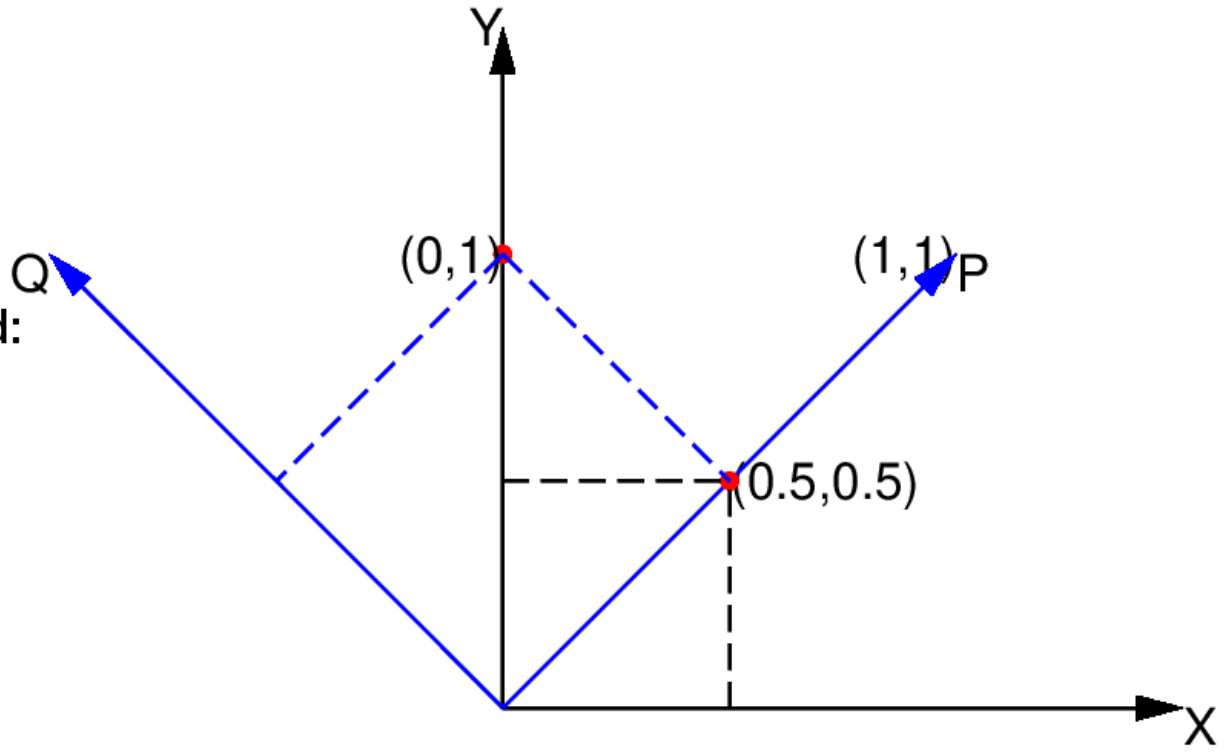
1. the position of this point in P-Q coordinate system, which is (p, q)

2. the position of the project point in X-Y coordinate system, which is (r, s)

A simple example:

echo 0 1 99 | gmt project -C0/0 -E1/1 -Fxyzpqrs

The starting point of line:
(0,0)
The end point of line:
(1,1)
The point being projected:
(0,1)
z=99
p=?
q=?
r=?
s=?

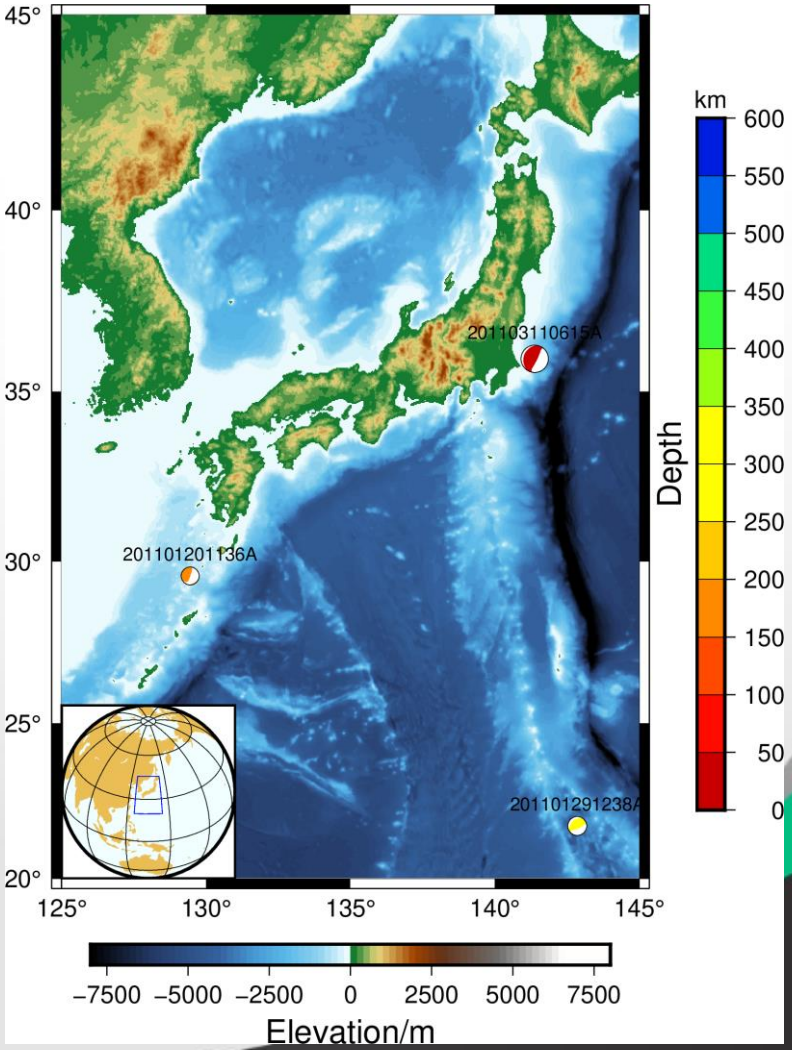


The output is specified by -F:

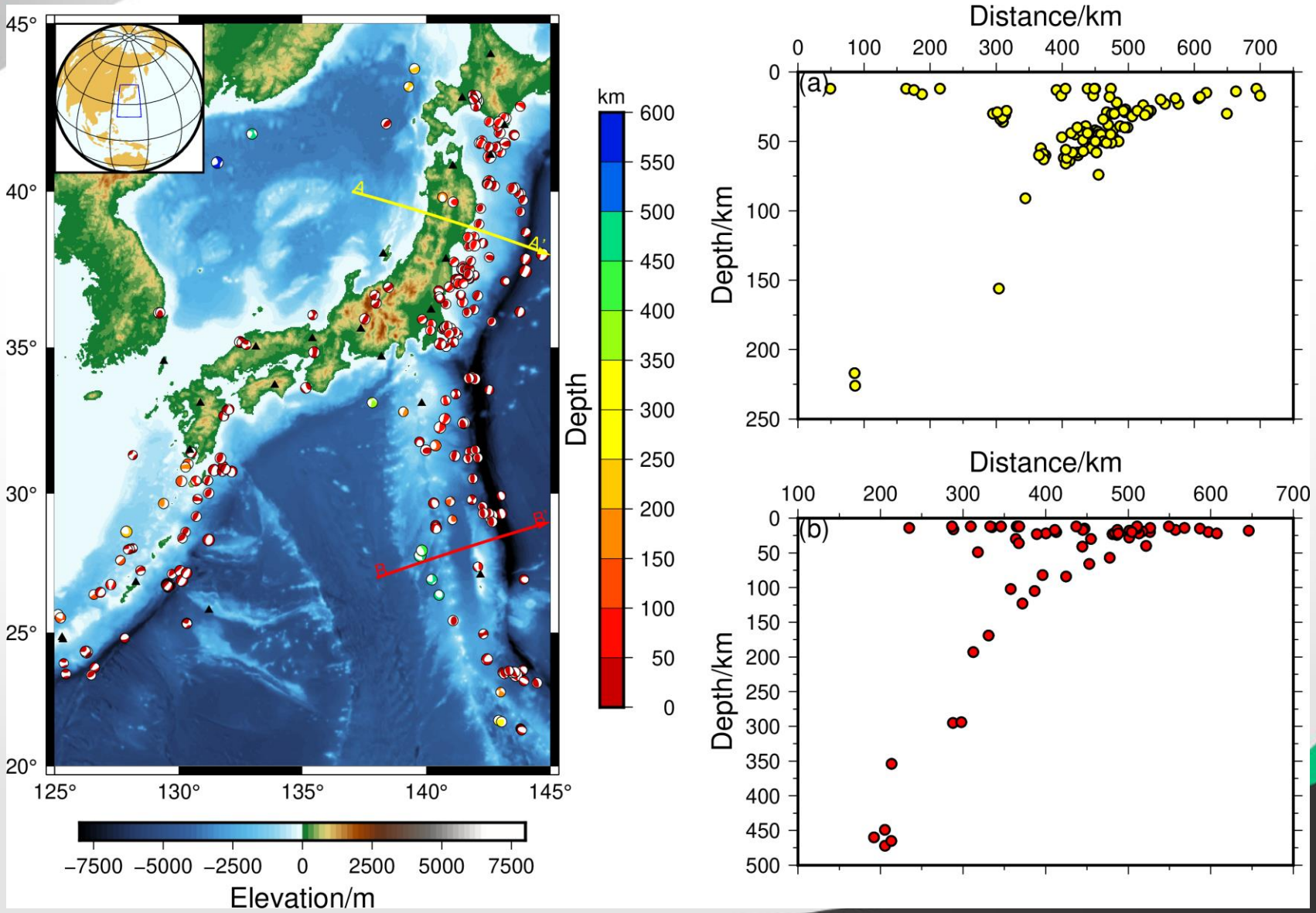
```
huawei@DESKTOP-4REL4QP MINGW64 /d/Courses@CUHK/Term02/ESSC4140/gmt_working-folde
r
$ echo 0 1 99 | gmt project -C0/0 -E1/1 -Fxyzpqrs
0       1       99      0.707196528995  0.707034975064  0.500038074276  0.500095195479
```

A better map

```
#!/bin/sh
gmt makecpt -Cseis -T0/600/50 > dep.cpt
gmt begin final png
gmt basemap -JM10c -R125/145/20/45 -Ba5 -BWeSn
gmt makecpt -Cgeo -T-8000/8000/200
gmt grdimage Japan.grd
gmt colorbar -Bxa2500+l"Elevation/m" -DjBC+w9c+o0c/-1.5c+m
gmt meca source.txt -Sm0.3c -C+s0.5p -Zdep.cpt
gmt colorbar -Cdep.cpt -DJMR+w12c+o1c/-0.3c+ml -Bx+l"Depth" -By+l"km"
    gmt inset begin -DjBL+w3c -F+gwhite+p1p
        gmt coast -JG135/35/? -Rg -Bg -Glightbrown -Sazure1 -A10000
        echo -e "125 20\n145 20\n145 45\n125 45\n125 20" | gmt plot -W0.3p,blue
    gmt inset end
gmt end show
```

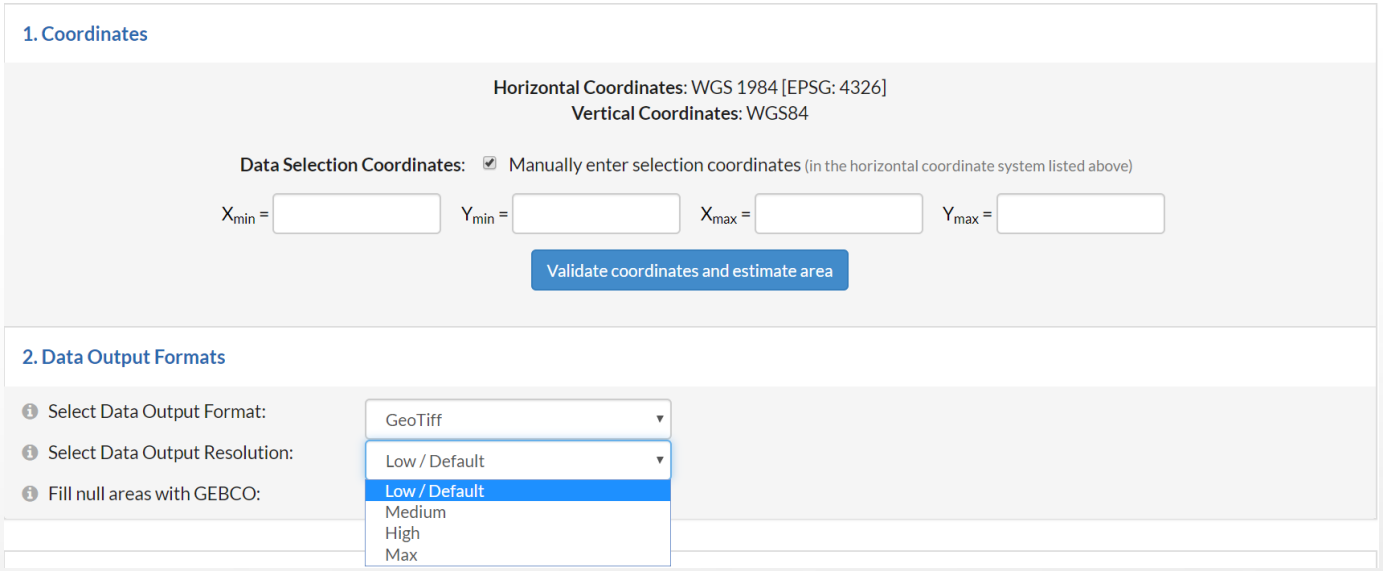


Another figure



Data download and conversion

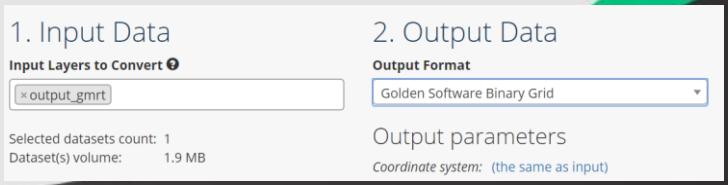
- Download the topography data:
http://opentopo.sdsc.edu/raster?opentopoID=OTGMRT.112016.4326.1



Or go to http://srtm.csi.cgiar.org/srtmdata/ https://earthexplorer.usgs.gov/

- Convert the data from GeoTiff format to NetCDF format online:
https://mygeodata.cloud/converter/tiff-to-grd

Choose Binary Grid format and click convert now button



Data download and conversion

- Download the earthquake catalog:

https://earthquake.usgs.gov/earthquakes/search/

or http://ds.iris.edu/wilber3/find_event

- Download the focal mechanism data:

https://www.globalcmt.org/CMTsearch.html

Output type:

- Standard
- List of event names
- GMT psvelomeca input
- GMT psmeca input
- CMTSOLUTION format
- Full format

Done Reset

The option -S of gmt meca command supports these format. If you download the other formats, don't forget to change "-Sm" to "-S?"

Output in GMT psmeca (GMT v>3.3) format
Columns: lon lat depth mrr mtt mpp mrt mrp mtp iexp name

```
75.16 39.44 12 2.88 -3.26 0.38 0.15 -0.34 0.02 23 X Y 201101010156A
-63.21 -27.02 586 -2.47 -0.12 2.59 -1.76 2.98 -0.77 26 X Y 201101010956A
121.67 -49.08 13 0.02 -1.91 1.90 -1.25 0.01 -4.03 23 X Y 201101011837A
167.73 -19.26 18 -3.52 -1.22 4.74 0.21 0.57 -1.33 23 X Y 201101012335A
68.89 36.35 29 1.98 0.14 -2.11 -0.33 0.43 0.05 23 X Y 201101020336A
```

Exercise and Q&A

Try to complete the last question in homework No. 1

If you have questions about this tutorial,

ask me or google it.

Email address: sjh2019@link.cuhk.edu.hk

This tutorial was completed mainly based on:

https://docs.gmt-china.org/latest/

And some ideas are from Zhu Gaohua and Matthew Herman's great works