Data Processing and Plotting Using Generic Mapping Tools

Maria Seton and Kara Matthews
EarthByte Group
School of Geosciences, University of Sydney

Course Information

- Course will consist of lectures with practical exercises imbedded
- Two sessions:
  - 10am-12:30pm - Maria
  - 1:30pm-4pm - Kara

Assessment

- Assessment is a final practical assignment to be handed in by 5pm Friday 12th April, 2013 via email or Large File Transfer
- Any questions:
  - Maria (Rm 400) email maria.seton@sydney.edu.au
  - Kara (Rm 414) email kara.matthews@sydney.edu.au
  - Course Notes: ftp.earthbyte.org/earthbyte/Teaching/SUCOGG_GMT_Course

Lecture Outline

- What is GMT?
- What can it do?
- Examples of GMT output
- Basic unix knowledge that you need in order to use GMT
- GMT default settings
- GMT file formats

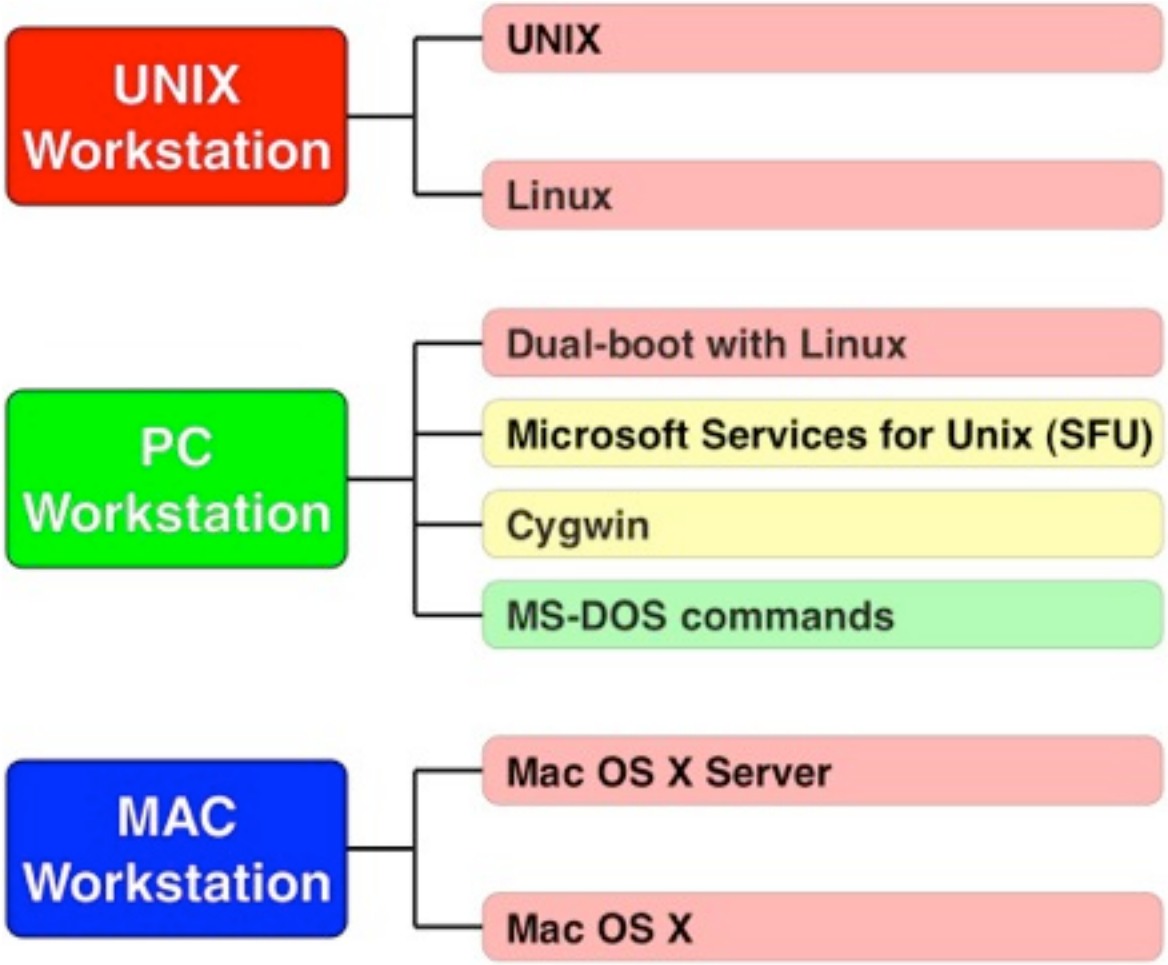
What is GMT?

- Stands for Generic Mapping Tools
- GMT does data processing and visualisation

- Raw data → processing → illustration

- It is open source, platform independent and free to download and use
- GMT is jointly developed by Paul Wessel (UH) and Walter H. F. Smith (NOAA)
- It is very popular, used by ~15,000 people

GMT Platform Scenarios



Why is GMT popular?

- Free
- Easy to install on all platforms
- Architecture-independent file formats
- Quality PostScript graphics
- Extensible
- Developers are scientists and users

What is GMT?

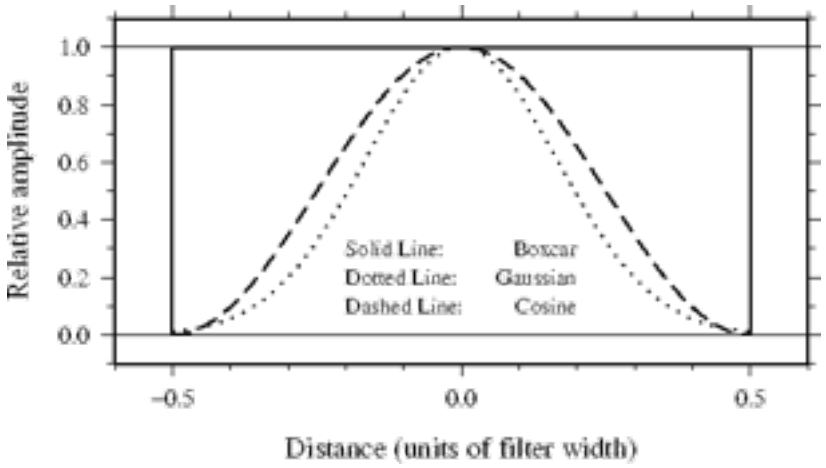
- GMT consists of 60+ individual programs
- Written in POSIX C
- GMT has a command line interface
- GMT consists of small modules which focus on limited tasks
- But modules can be combined in many ways to achieve complex tasks
- There is a seamless integration with UNIX OS and tools

What Can GMT Do?

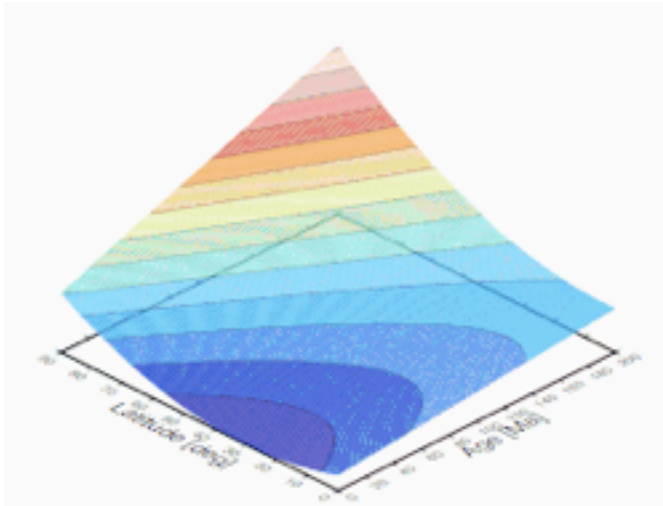
- GMT can process and manipulate data
- GMT can generate a postscript plot of your data
- However, remember that GMT is not a GIS or image processing package

GMT can ….

Filter time-series and 2D data



Do trend fitting of data

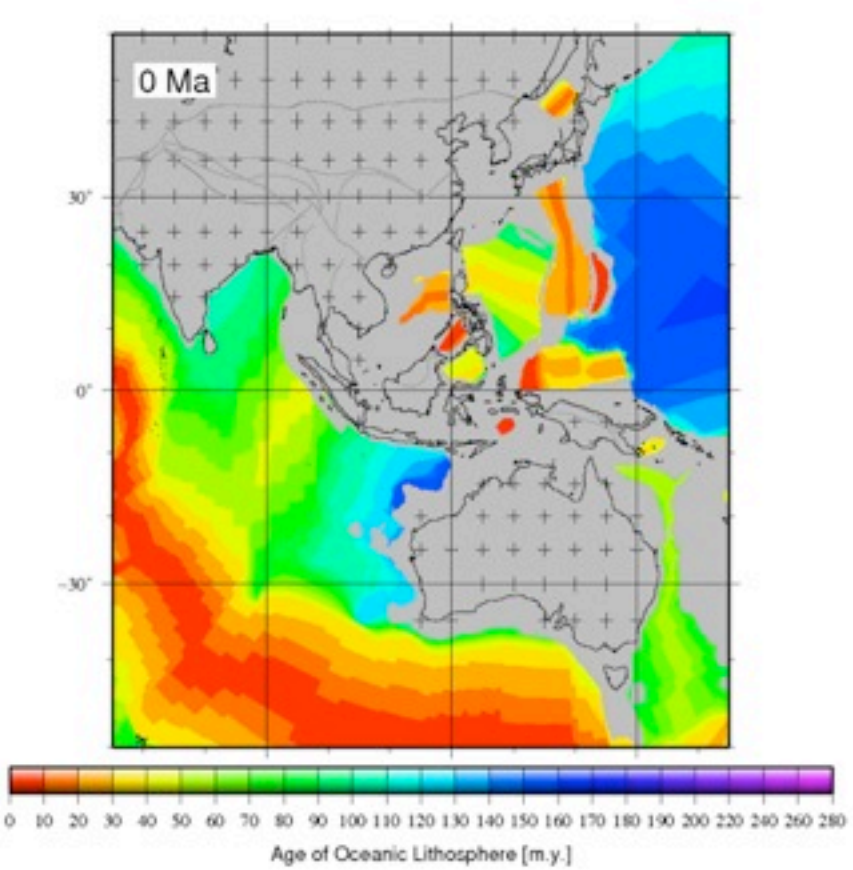


GMT can ….

- Grid xyz data

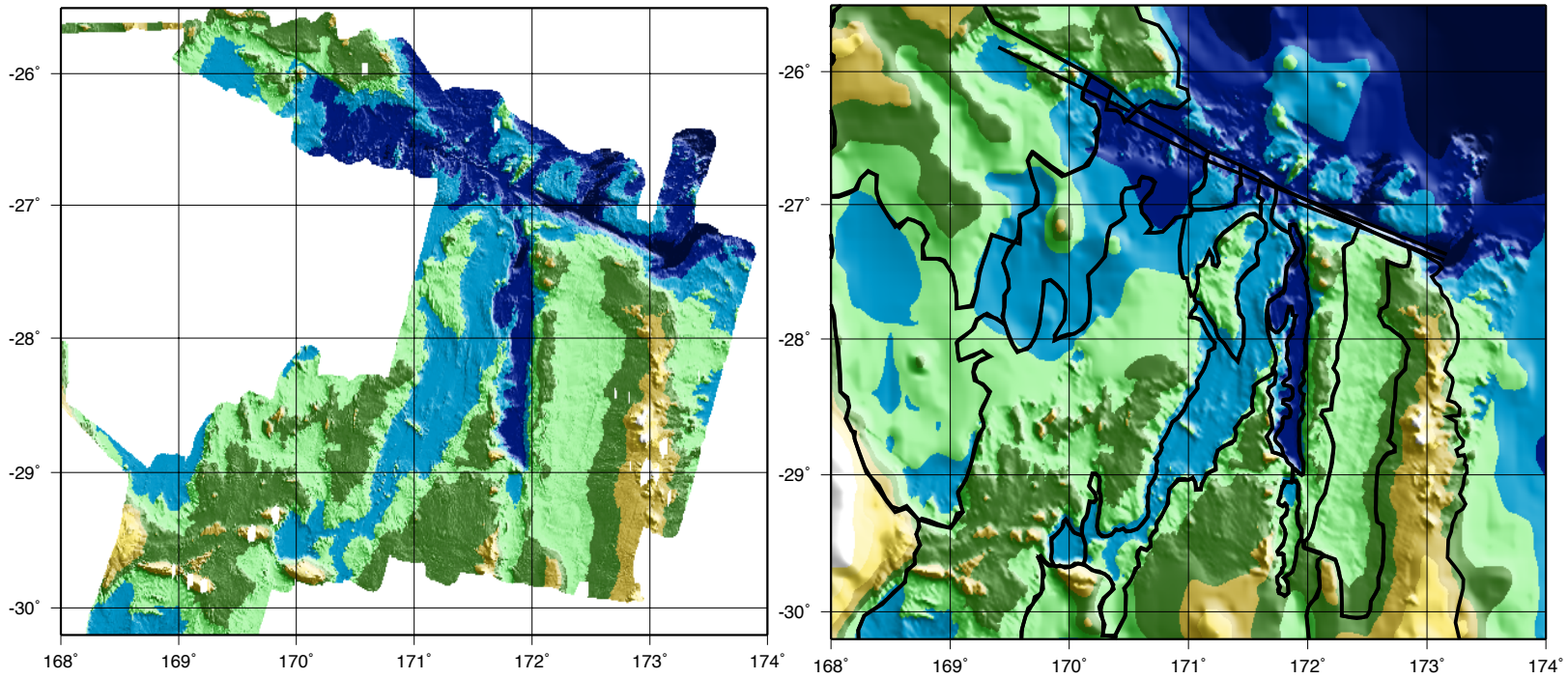
long	lat	age
110.94	20.11	66.27
110.97	21.21	50.73
111.11	21.99	23.34
112.09	22.54	60.23
112.64	22.68	67.76

.....



GMT can ....

Cut, paste and blend grids

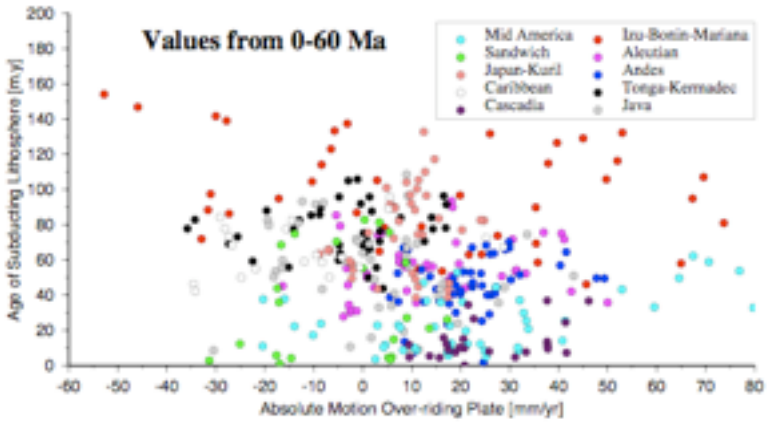


GMT can ….

- Resample a data set
- Do arbitrary math operations
- Calculate directional derivatives
- Grid masking
- Data projections
- Optimal triangulations
- Subset extraction

GMT can ….

- Plot x-y diagrams of lines, polygons and symbols
- Plot text and labels



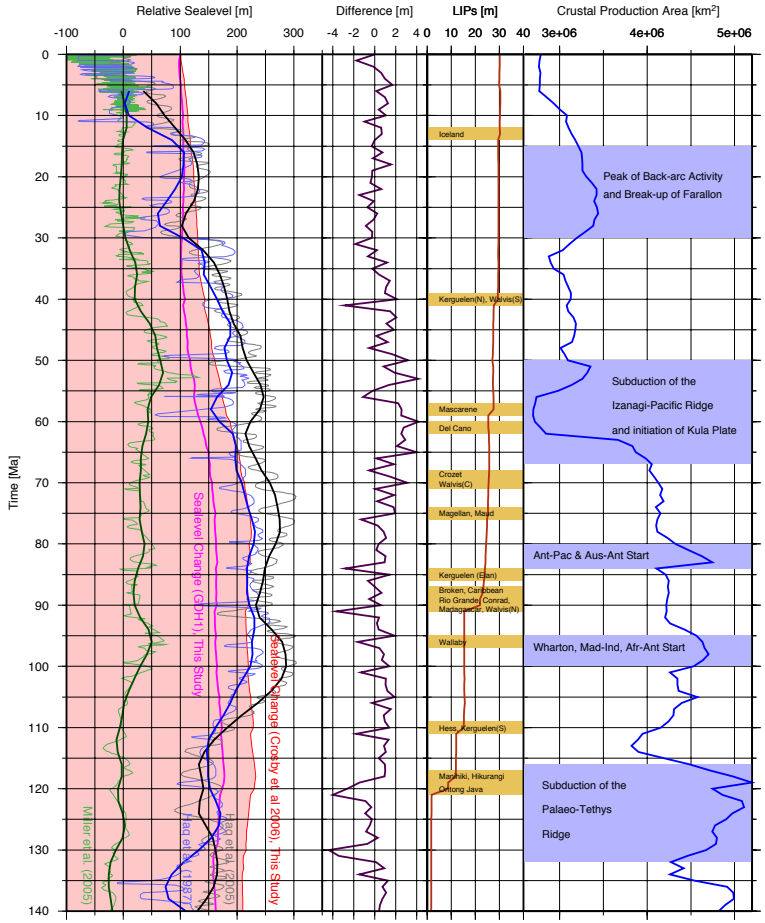
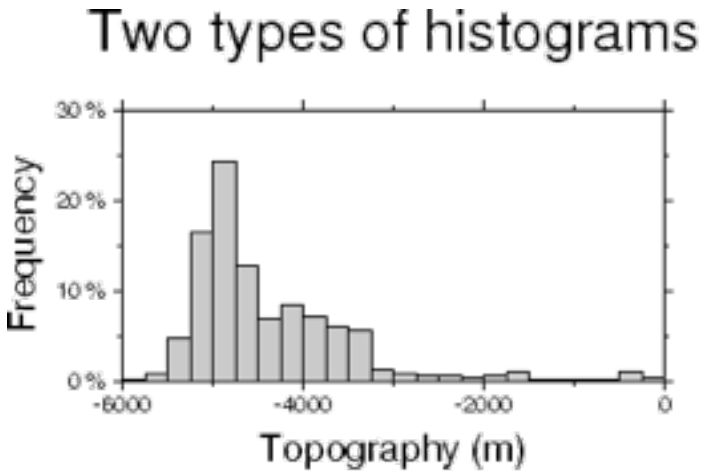
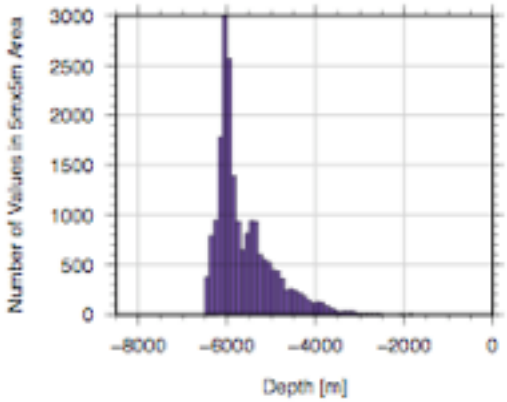


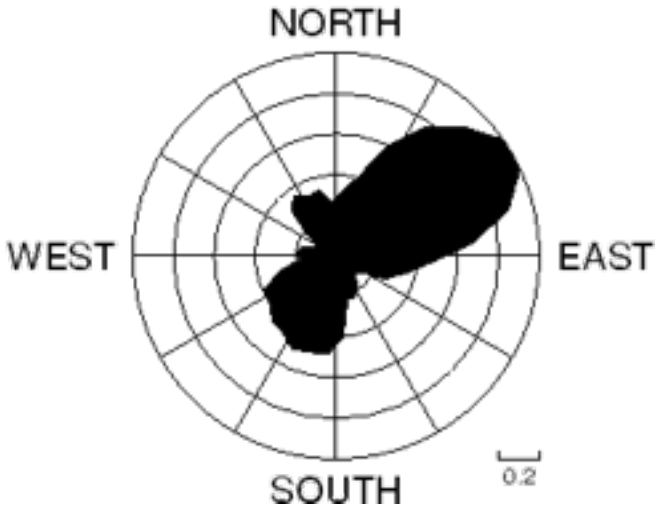
Figure 6: Muller et. al.

GMT can ….

- Plot rectangular or polar histograms

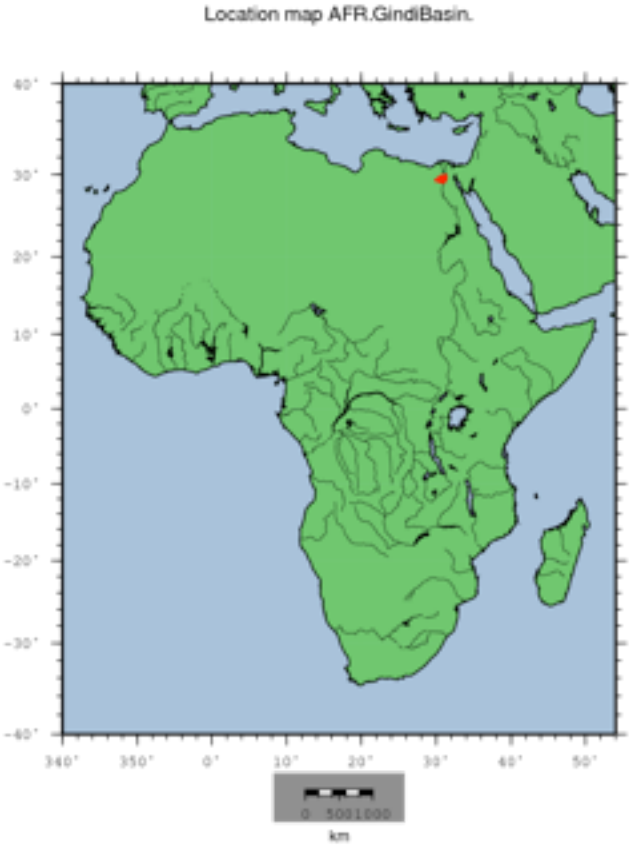


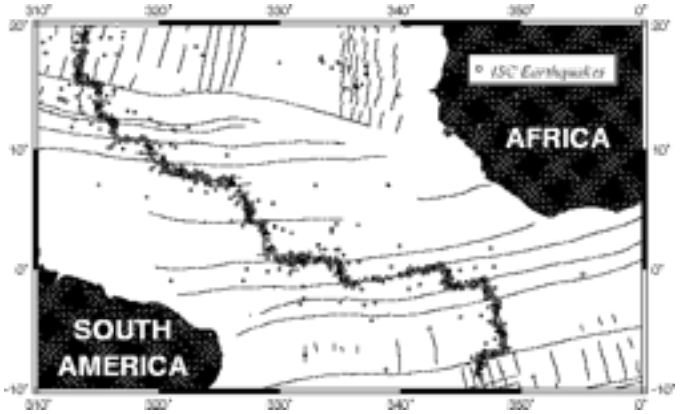




GMT can ….

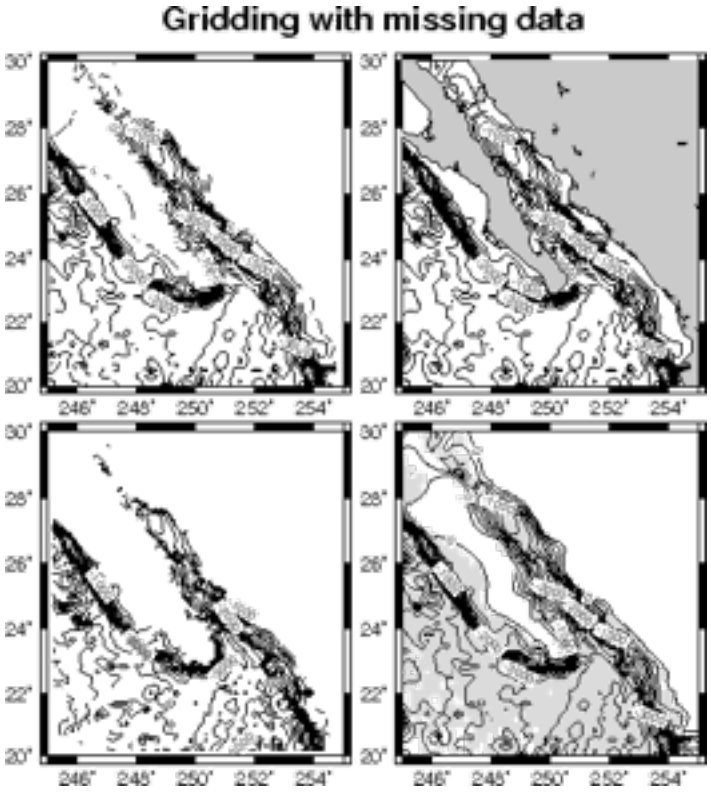
- Plot basemaps with coastlines, rivers and borders

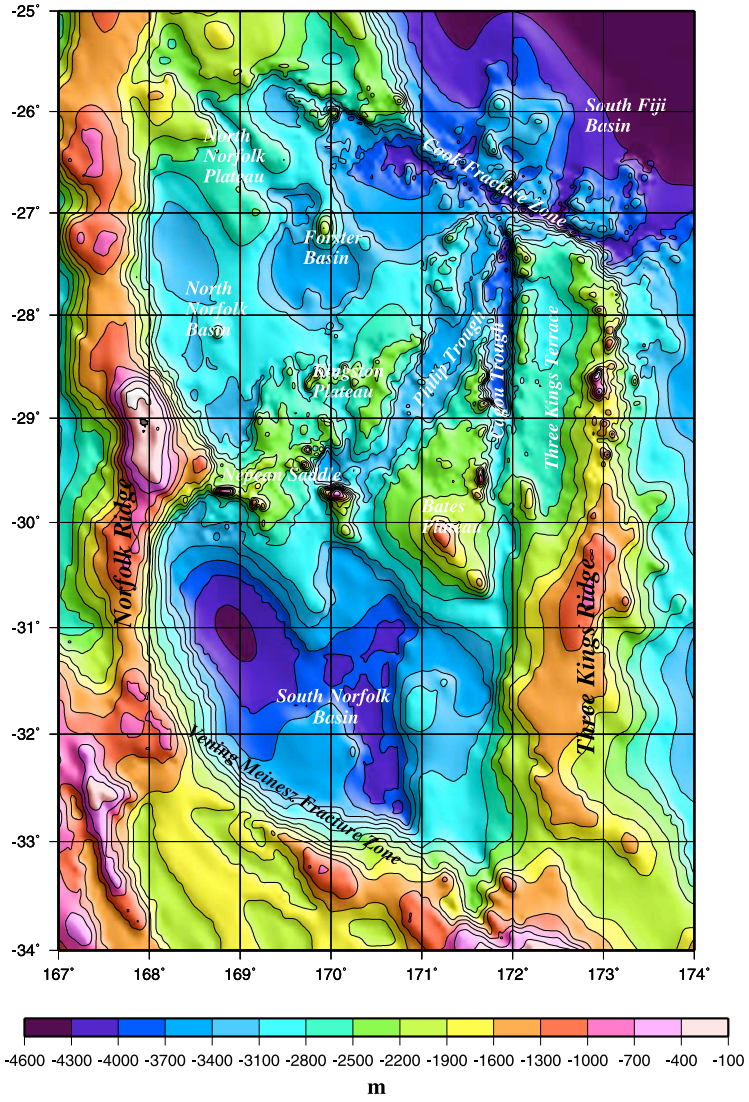




GMT can ....

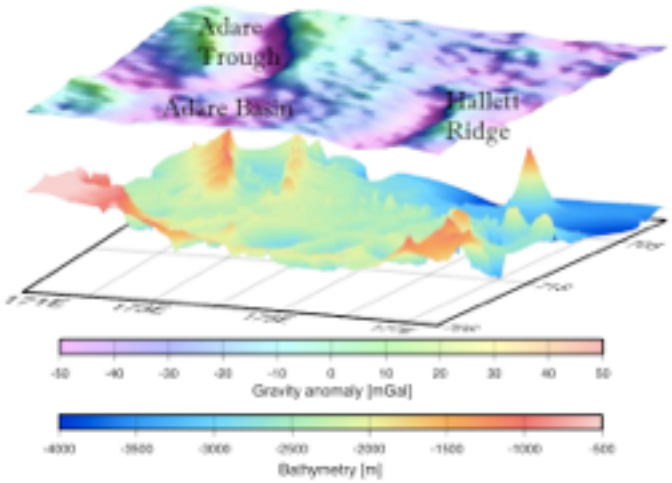
- Plot contour maps

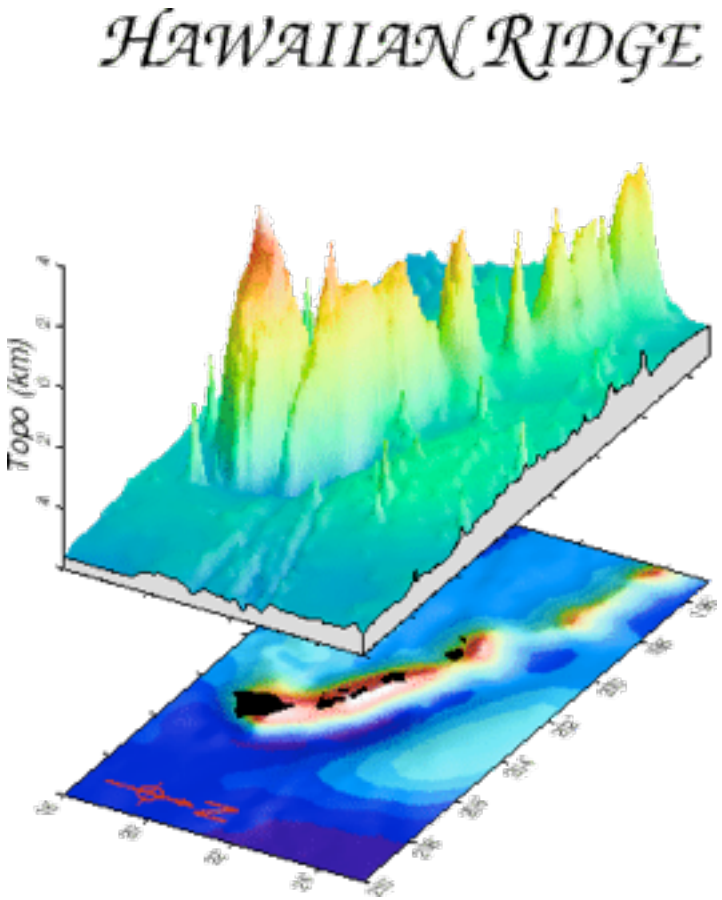




GMT can ….

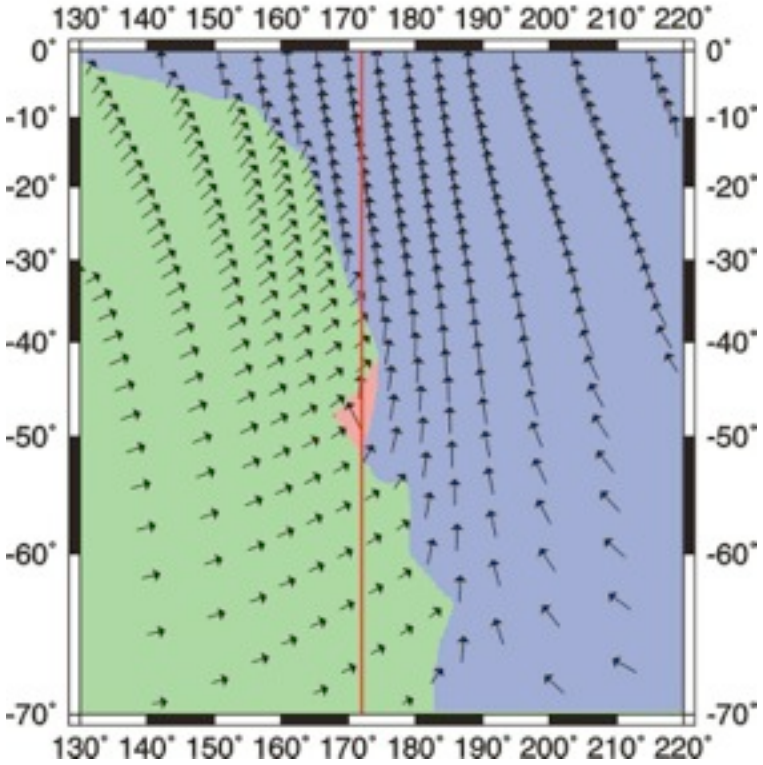
- Plot perspectives views with illumination

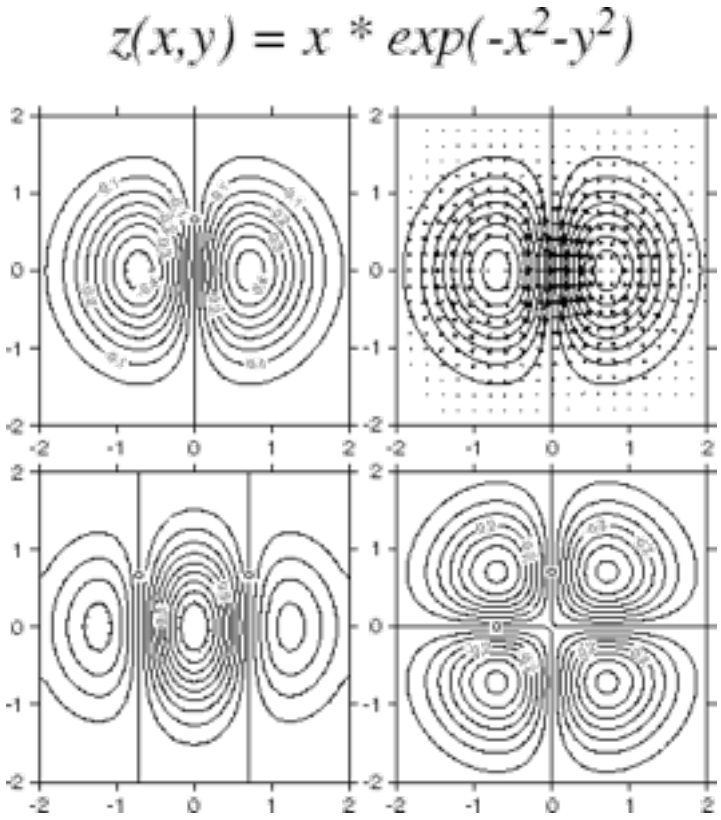




GMT can ….

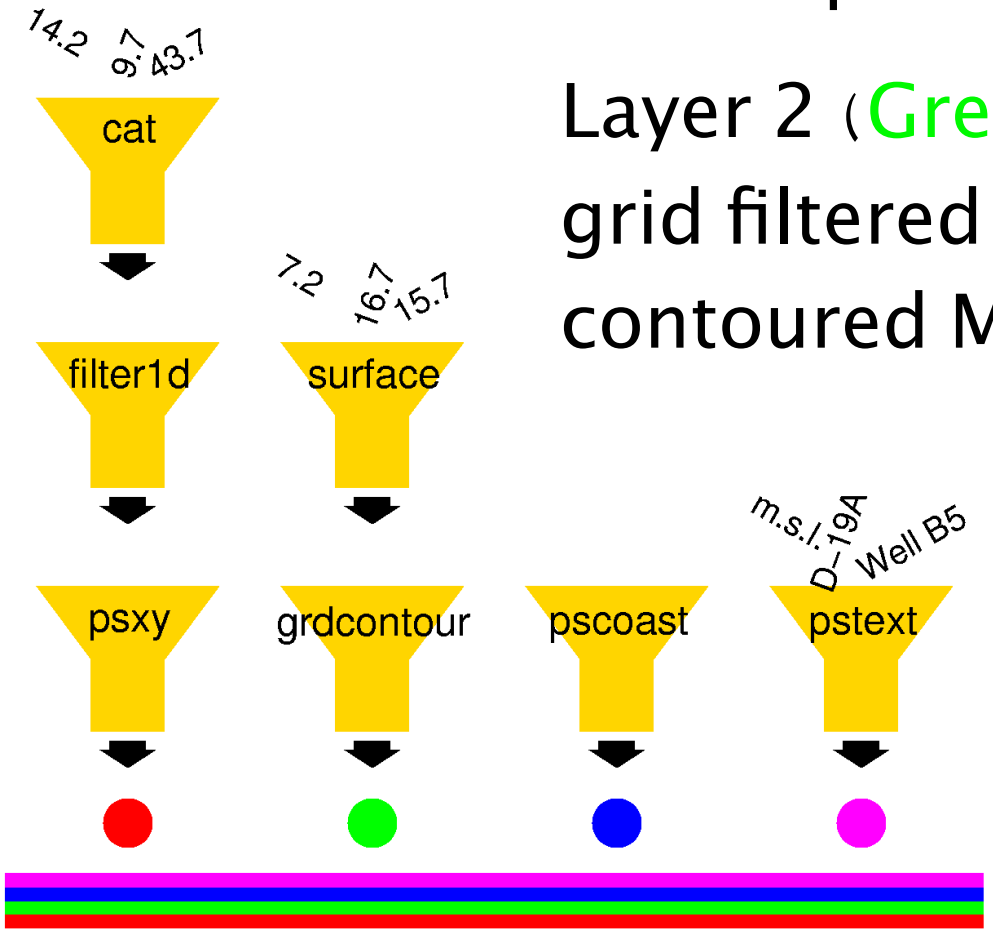
- Plot vectors and vector fields





All GMT tools work together

Layer 1 (Red): create ascii file, Filter ascii data and plot

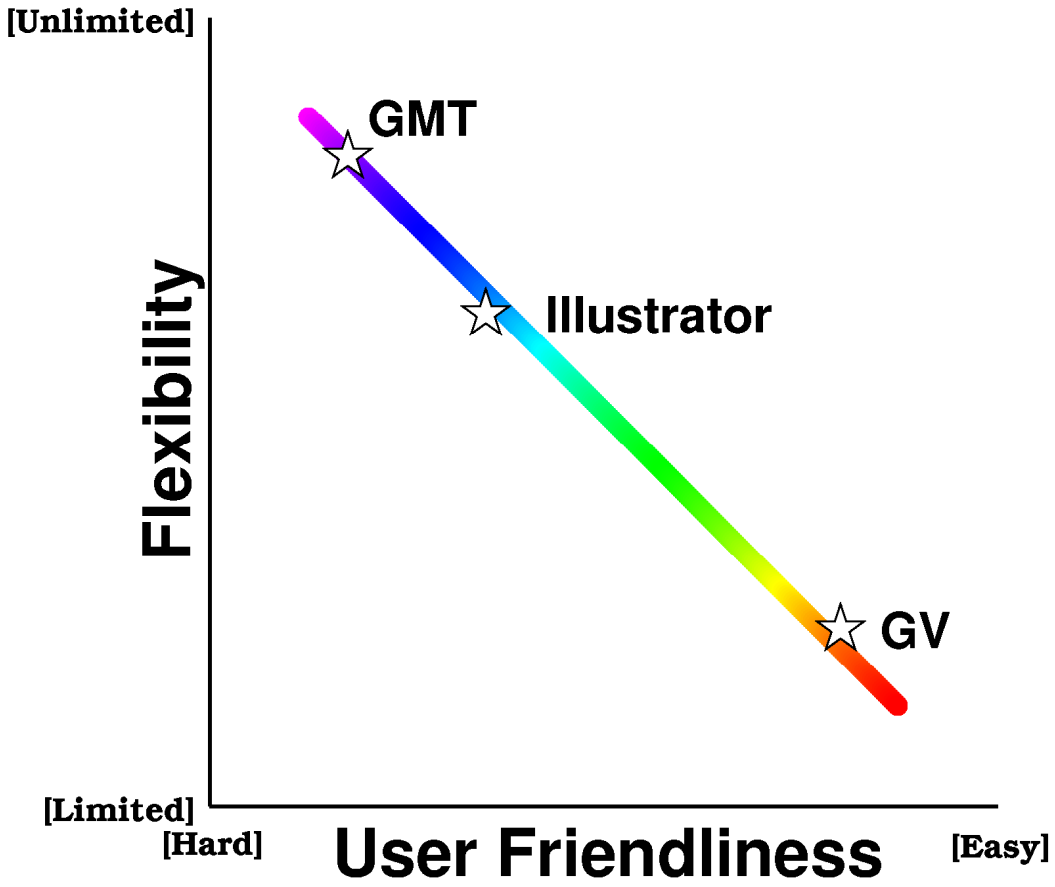


Layer 2 (Green): Interpolate and grid filtered data and make a contoured Map

Layer 3 (Blue): Plot coastlines on top of map

Layer 4 (Pink): Plot labels on top of map

The Learning Curve



- GMT is very flexible but it is initially not so user friendly
- Its flexibility is its greatest asset

Unix and shell Environment

- Login
- Using stdin, stdout, and stderr
- I/O redirection
- Pipes
- Wild cards
- File permissions
- Command history
- UNIX tools
- UNIX man pages

Class Exercise – Login

- USyd students – use your unikey and password
- Non-USyd students – get login from me
- Use your unikey and password to login to a computer (running windows)
- Go to Start – Programs – Putty – Putty
- Type in 129.78.236.17 under hostname, then connect
- Username is gmt-user, password wel0veGMT
- Have an active linux terminal

Input/Output

- UNIX initialises 3 file handles:
  - stdin: Standard input [keyboard]
  - stdout: Standard output [screen]
  - stderr: Standard error [screen]
- These can all be redirected so that read (or write) instead takes place from (or to):
  - files on the disk
  - a process (e.g., another UNIX program)

Redirection examples

- GMTprogram inputfile > outputfile
- GMTprogram inputfile >> outputfile
- Notes:
  - The last example appends to an existing file
  - If no input file is given the program reads stdin

Piping and other plumbing

- Pipes are used to connect the output of one program to the input of another:
  - program1 | program2 < results.dat
  - program3 inputfile | lp
  - cat inputfile | program4 | lp

Notes:

1. lp is the printing program
2. cat sends contents of file to stdout

UNIX Wild cards

- Wild cards allow many files to be addressed one by one at the same time
- Four kinds of UNIX wild cards exist:

*	Matches anything (even nothing)
?	Matches any single character
[list]	Matches any one character in list
[range]	Matches any one character in range

Wild card examples

- Print all files beginning with “data__” and ending in “.d”:
  - lp data__*.d
- Process files beginning with “line__” followed by any single character and ending in “.d”:
  - crunchjob line__?.d ›› final.d

UNIX File Permissions

- File permissions may be any combination of read (r), write (w), and execute (x)
- This combination may be set differently for the user (u), the group (g), or others (o)
- To see a file's permission, use "ls -l":
  - ls -l myfile
  - The permission is printed [d]rwxrwxrwx
  - - means a permission is not given
  - a leading d indicates a directory

Output may look like this:

```
-rw-r--r--  1 marias  marias  15597 Aug 26 12:15 myfile
```

Executable k shell scripts

- A script is a file with one or more ksh or UNIX commands in it
- Scripts must start with magic line:
  - #!/bin/ksh
- Add comments by starting lines with #
  - # This script makes Fig 7 in Thesis
- Save script to a filename (e.g., fig7.sh)
- Make executable
  - chmod +x fig7.sh

Command History

- The command "history n" will show the last n commands you have issued
- To repeat a previous command, try:
  - !n, where n is the command number
    - !203 (will run command # 203 once more)
  - !prefix, where prefix is the beginning of a command string:
    - !progra
  - !! will repeat the previous command

UNIX and Windows Tools

- terminal (for entering commands)
  - Terminal, xterm
- editor (for writing scripts)
  - gedit, vi, emacs, textmate – we will use notepad on windows
- PostScript previewer
  - ghostview (or gv), preview – we will use Acrobat
- UNIX utilities
  - ksh, awk, grep, sed, wc, head, tail, sort

Useful UNIX commands

- pwd (print working directory)
- cd dir (changes directory to dir)
- mkdir dir (makes the directory dir)
- rm file(s) (removes the given files)
- rmdir dir (removes an empty directory)
- cp a b (copies file a to file b)
- mv old new (moves old to new)

Class Exercise – Create a directory

- Go to your linux terminal
- Type pwd – this prints your working directory
- Now we want to create a directory called yourname
- Type mkdir yourname
- View the contents of that directory by typing
  cd yourname
  pwd
  ls *

Class Exercise – Create a directory

- Do the same to create a directory called GMT_Course

GMT General Features

- Default settings
- Measurement units
- Standardized command line switches
- Table data formats
- Grid file formats
- Color palette tables
- Pens and Fills
- Character escape sequences

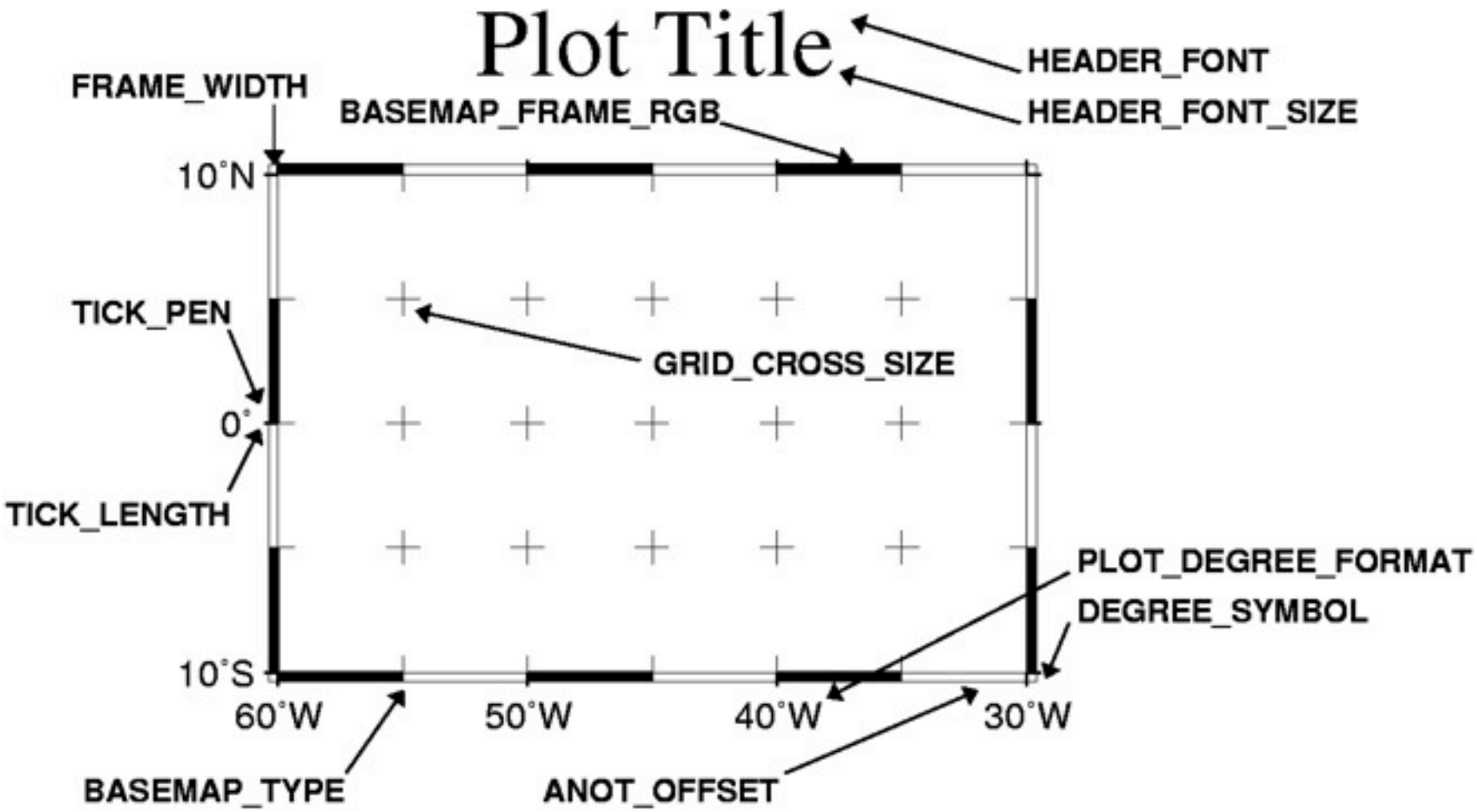
GMT Default parameters

- More than 100 parameters
- Stored in .gmtdefaults4 files (ASCII)
- Affect many aspects of GMT operations
- GMT searchers for .gmtdefaults4 in
  - The current directory
  - The home directory
  - Defaults to the GMT install settings

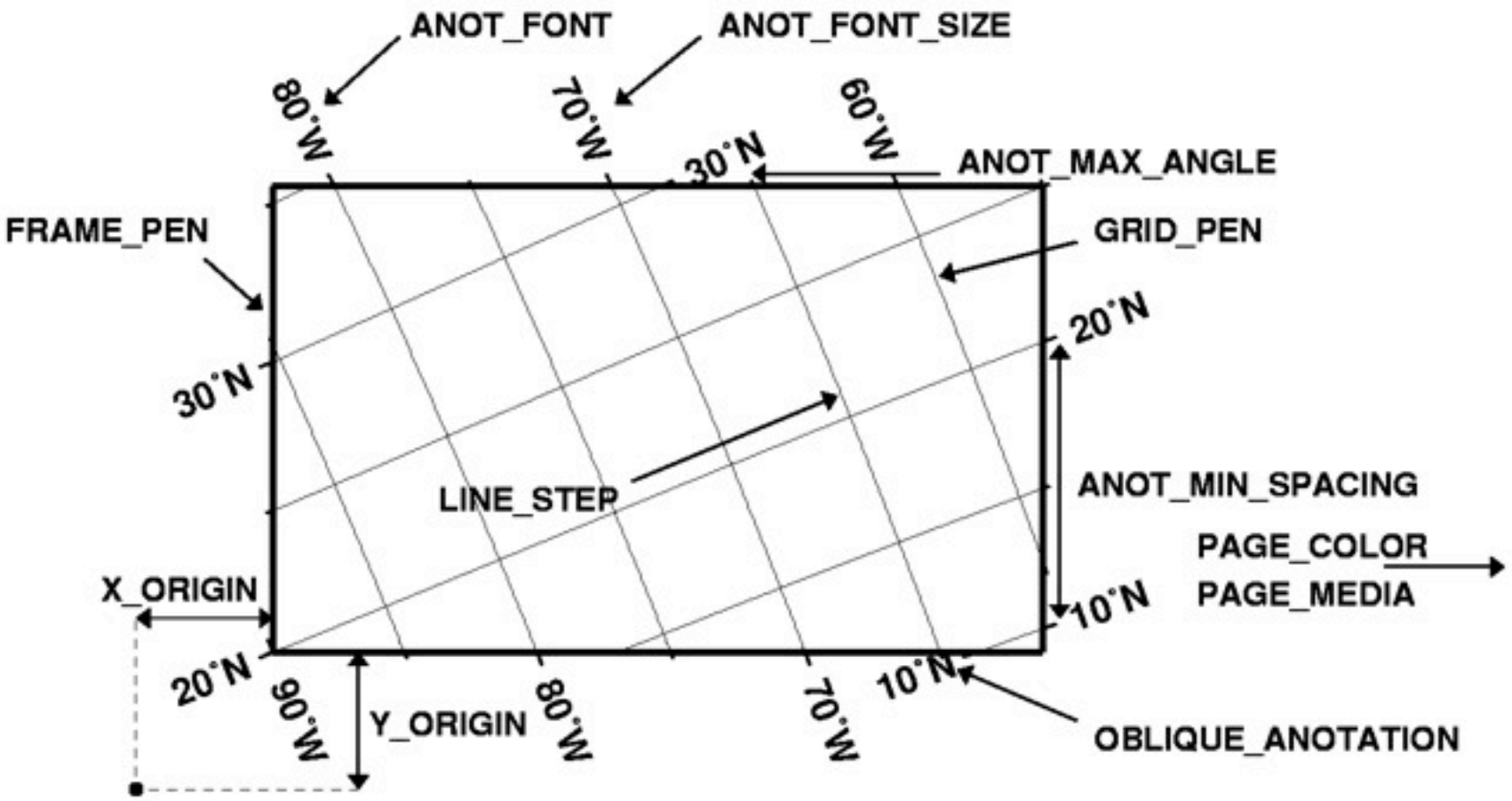
Class Exercise – Make a .gmtdefaults4 file

- In the GMT_Course directory, type
  gmtdefaults -D > .gmtdefaults4
- The defaults file is a systems file (. at the beginning) so it will not display if you type ls
- Type ls -all
- Type vi .gmtdefaults4 to see what the file looks like
- Type :q to close the file

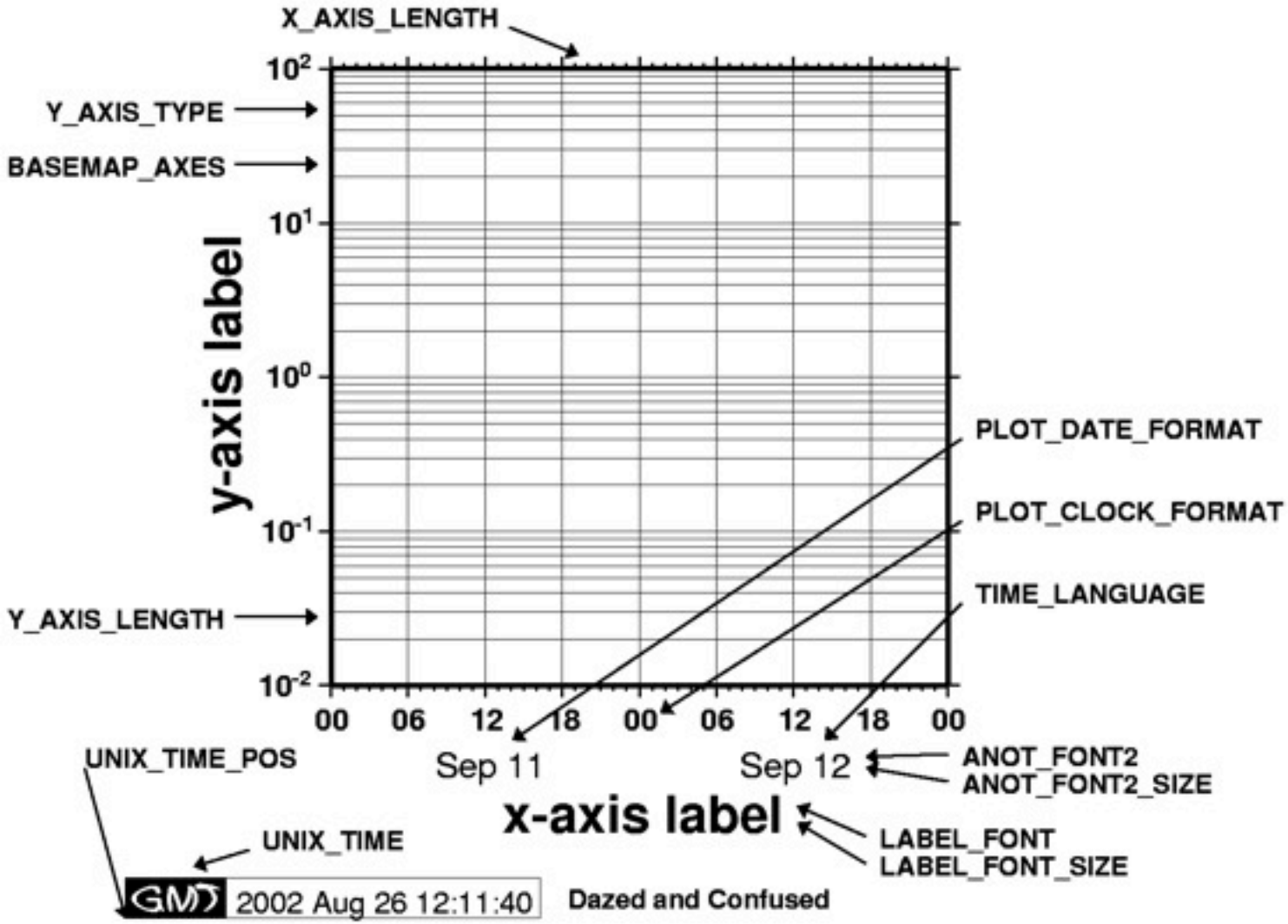
GMT Defaults Parameters（1）



GMT Defaults Parameters（2）



GMT Defaults Parameters (3)



GMT Measurement Units

Can accept cm, inch, meter, or point

- Append unit abbreviation to value:
  - 4c, 3.5i, 18p
- Set MEASURE_UNIT to desired unit
  - Values without trailing unit imply the default unit

Common Command Line Options

OPTION	MEANING
–B	Define annotation-, tick-, and grid-intervals, axes labels, and title
–H	Indicate that ASCII tables have header record(s)
–J	Sets the current map projection or coordinate transformation
–K	Allows more plot code to be appended to current plot
–O	Overlay more plot code on current plot
–P	Select Portrait orientation [Default is landscape]
–R	Define the world coordinates domain
–U	Plot time-stamp on the plot
–V	Run program in verbose mode
–X	Set x-coordinate for plot origin
–Y	Set y-coordinate for plot origin
–b	Selects binary input or output
–c	Specify number of plot copies
–f	Specify data format on a per column basis
–:	Input geographic data are (lat, lon) rather than (lon, lat)

GMT file formats

- Data tables
  - ASCII (slow but human readable)
    - Single segment (default)
    - Multi-segment with internal headers
    - May have header records
    - fields can be separated by tabs, space or commas
  - Binary (faster for larger files)
    - Single segment (default)
    - Multi-segment (internal headers)

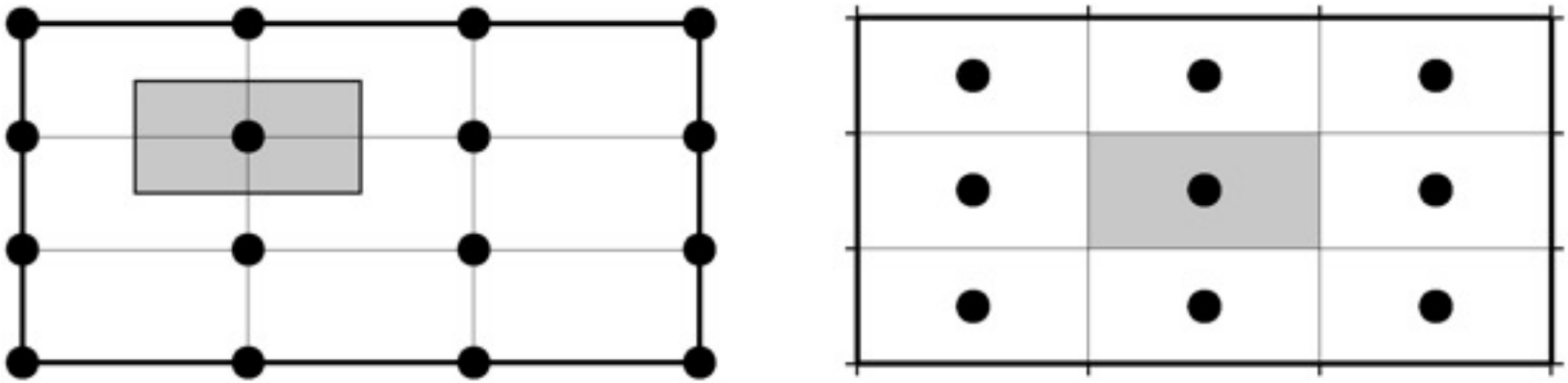
Example：ASCII data table with 1 line header record

```
> time (Ma), conv. rate (mm/yr), angle, abs.rate (mm/yr), abs.rate.normal (mm/
yr), strike 2.5         37.8        -46.6       34.4        31.1893  9
7.5         41.6        -49.0       32          35.2788  9
12.5        52.4        -53.2       28.8        45.9185  8
17.5        53.4        -52.5       29.5        46.477   8
22.5        51          -60.6       21.4        47.4838  8
27.5        61.2        -54.2       27.8        54.1364  8
30          nan         90.0        9           nan      9
17.5        51.8        -54.5       26.5        46.3576  9
7.5         41.6        -49.0       34          34.488   7
12.5        52.4        -53.2       29.8        45.4709  7
17.5        53.4        -52.5       30.5        46.011   7
22.5        51          -60.6       22.4        47.1518  7
27.5        61.2        -54.2       25.8        55.0995  10
30          nan         90.0        -0          nan
17.5        51.8        -54.5       -0          51.8
7.5         41.6        -49.0       -0          41.6
```

GMT file formats

- Gridded data sets, z(x,y)
  - Rectangular domain with equidistant grid spacing Δx and Δy
  - x and y-coordinates implied and not stored
  - Contain comments and header info
  - Gridline- or pixel-registration possible
  - Architecture-independent netCDF format
  - Other native binary formats available
  - Custom formats can be accommodated

Grid file registrations

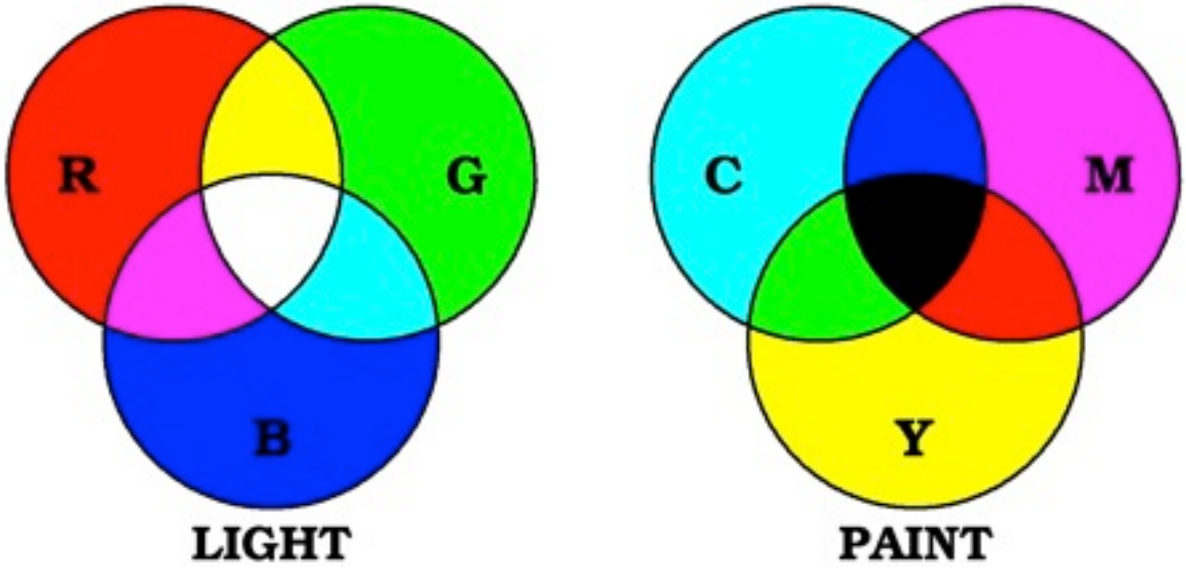


- Gridline registration has 1 row/column more than pixel registration
- Gridline registration has nodes at gridline intersections whereas pixel registration has nodes centered on the grid boxes

GMT file formats

- Colour palette tables
  - ASCII table with optional comments
  - Commonly use the r/g/b system
  - Each record defines colour as a function of z between slice z_0 to z_1
  - Any number of slices allowed; z must be monotonically increasing with no gaps
  - Colour may be constant or change linearly from z_0 to z_1

How does color work?



- Computer monitors mix light to make colors
  - RGB is always end-product
- Printers mix paint to make colors
  - Black (K) is used as 4th paint
  - CMY are reduced given the amount of K present

Specifying Color

- Color is specified in one of four ways:
  - Color names: Give standard X11 names such as red, green, violet, etc.
  - RGB system: Give r/g/b where each integer indicates intensity of light from 0 to 255. If r = g = b we have gray and only r needs to be specified.
  - HSV system: Give h-s-v for hue, saturation, and value.
  - CMYK system: Give c/m/y/k values, each in the 0-100% range.

Colour palette table

```
#       cpt file created by makecpt on Fri Mar  9 17:26:19 2001
#       No input V1.0 shade table was given; a gray scale was made.
#       Contours were made using a mid-value of -3500 and a contour interval of 1000
#
-6500   15      15      15      -5500   15      15      15
-5500   47      47      47      -4500   47      47      47
-4500   79      79      79      -3500   79      79      79
-3500   111     111     111     -2500   111     111     111
-2500   143     143     143     -1500   143     143     143
-1500   175     175     175     -500    175     175     175
-500    207     207     207     500     207     207     207
B       0       0       0
F       255     255     255
```