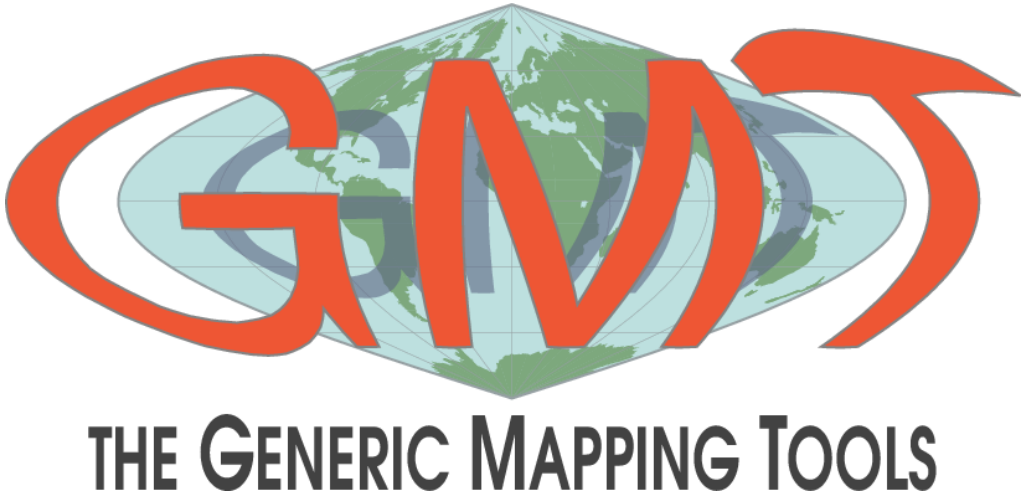
Visualizing Geospatial Data with GMT



Generic Mapping Tools (GMT)

- The **objective** of this session is to introduce you to geospatial visualization using GMT

- Introduction ~30 min
  - What are GMT?
  - Why create maps using GMT?
  - Examples of GMT maps/uses
- Part 1 - Getting Started ~60 min
  - Basic Syntax and commands
  - Map Projections/Coordinate Systems
- Part 2 - Advanced Topics ~60 min
  - Gridding and contouring datasets
  - Color/Illumination/Intensities
  - Using Photoshop to create animations

What are GMT?

- The Generic Mapping Tools are an open source collection of tools for manipulating geographic and Cartesian data sets (including filtering, trend fitting, gridding, projecting, etc.) and producing PostScript illustrations ranging from simple x–y plots via contour maps to artificially illuminated surfaces and 3D perspective views.
- It makes publication quality maps and figures.

Why Geospatial Visualization? When is geography important?

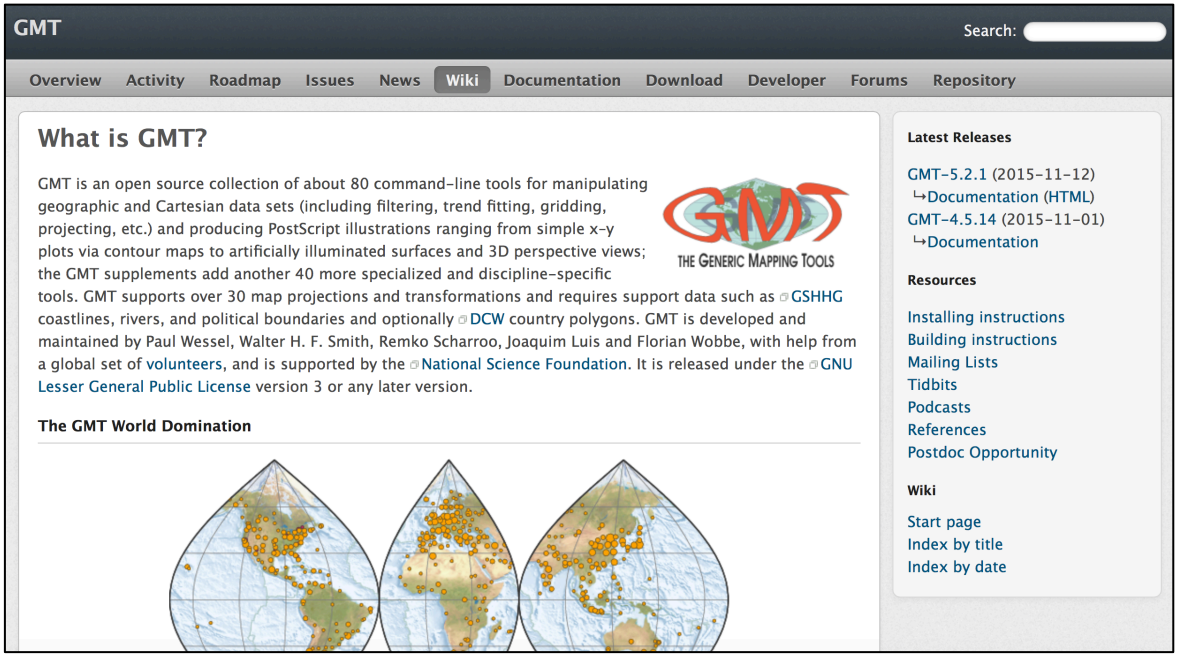
- Communicate geospatial information in ways that allow for informed decision making
  - Mineral and Resource Exploration
  - Earthquakes and Natural Hazards
  - Water Resource Management
  - Fire Fighting
  - Art History
  - Forestry
  - Archeology
  - Environmental Studies
  - Urban Planning
  - Social Services
  - Utility Mapping

Why GMT?

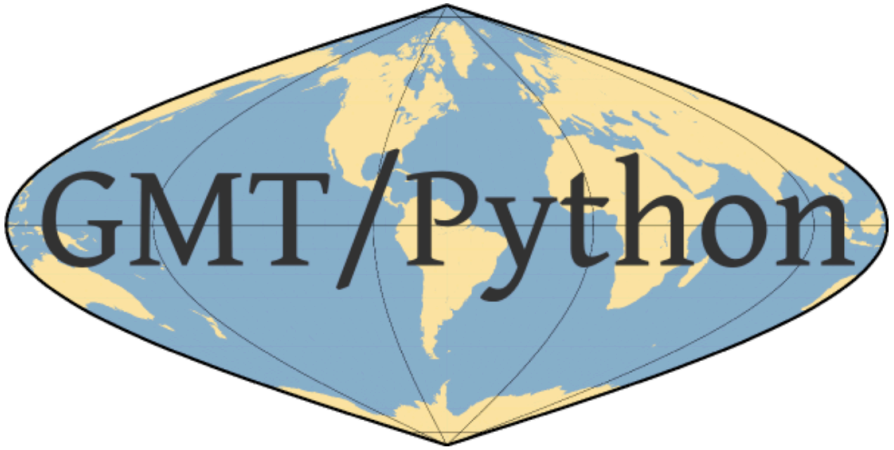
- PROS
  - Open Source (free!)
  - Powerful, flexible, and robust
  - High quality (.ps) output suitable for publication
- CONS
  - Steep learning curve
  - Not user friendly

Resources

- GMT web page – http://gmt.soest.hawaii.edu
  - Documentation and man pages
  - Discussion forum
  - Examples (included on box)
  - Tutorial
  - GMT Technical Reference and Cookbook
  - Podcast



Python API



A Python interface for the Generic Mapping Tools

- Coming Soon!
- Package is still in early stages of design and implementation
- Goal is modern API for Python programmers who want to use GMT
- Requires development version of GMT and Python 3

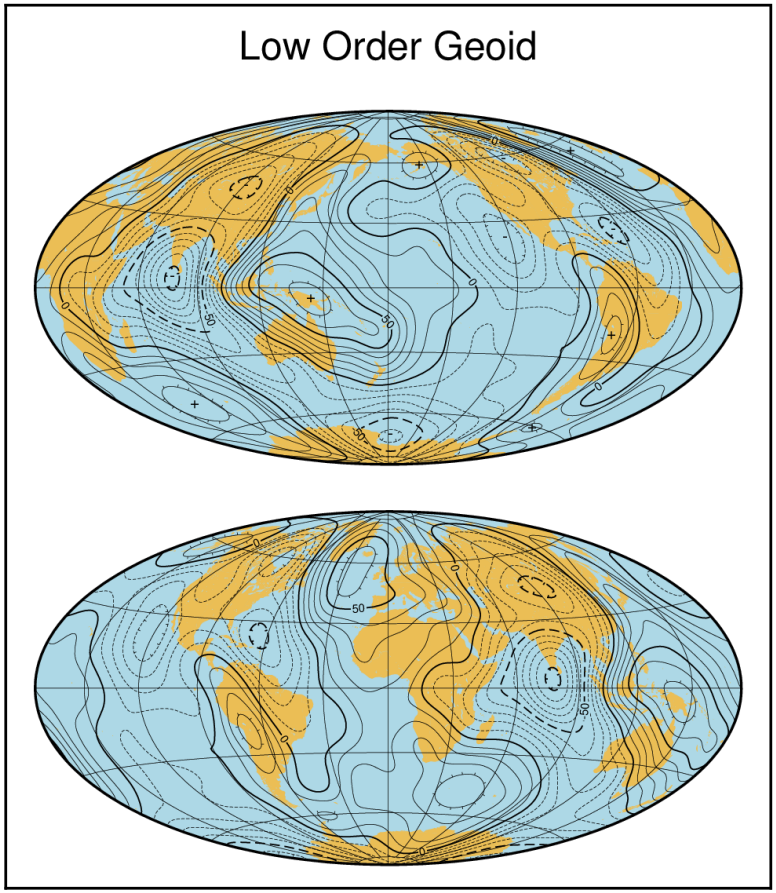
https://genericmappingtools.github.io/gmt-python/index.html

GMT Output

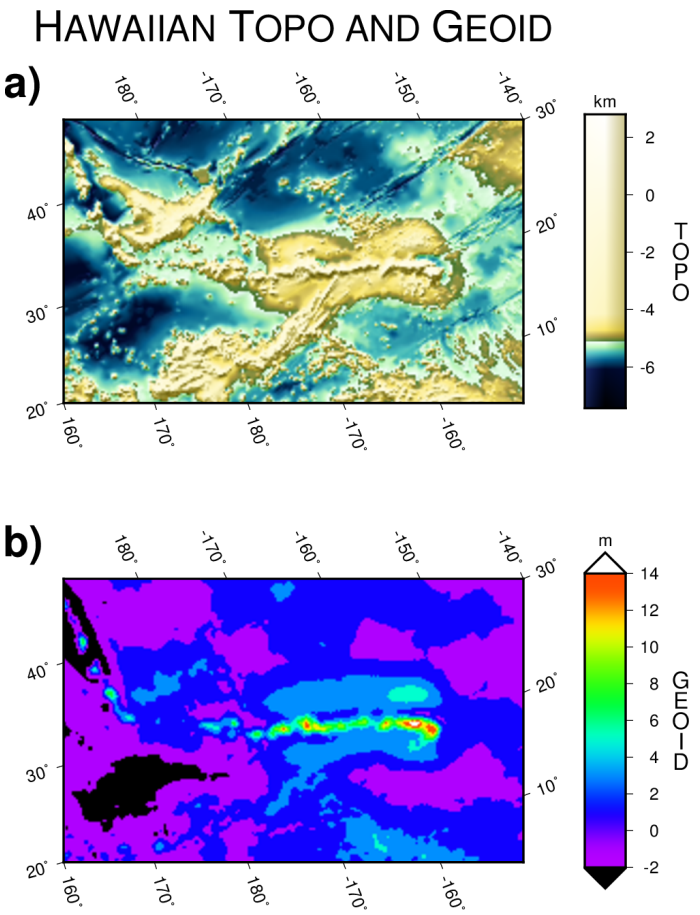
1. PostScript plot(s).
2. Data Table(s).
3. Gridded data set(s).
4. Statistics & Summaries.
5. Warnings and Errors, written to *stderr*.
6. Exit status (0 means success, otherwise failure).

GMT Examples

Contour Maps

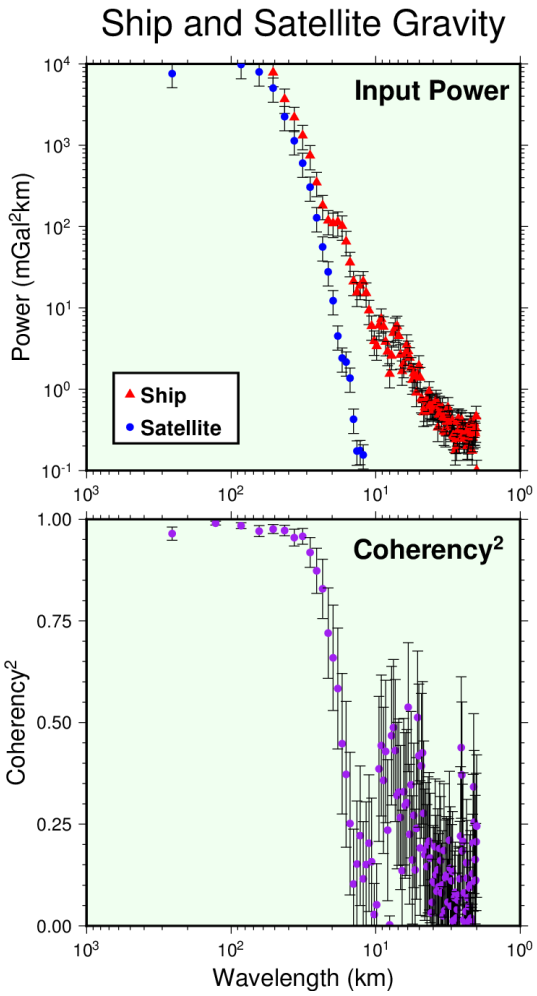


Topo and Geoid Maps



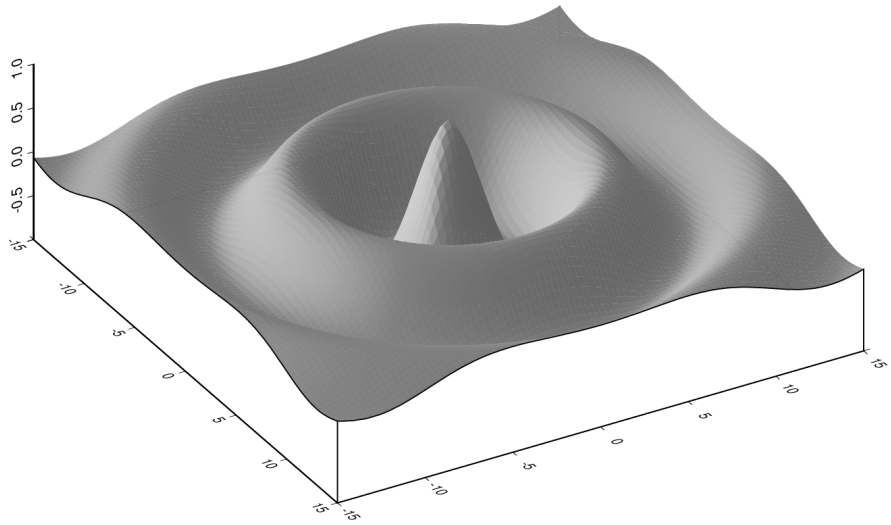
GMT Examples

Spectral Estimation and xy plots



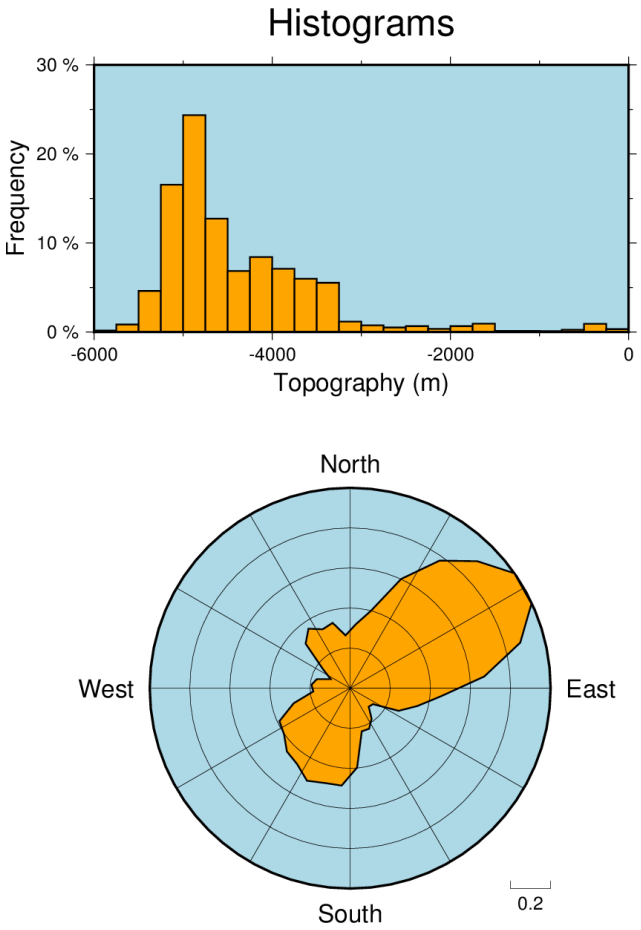
3D Perspective Mesh Plot

$$z(r) = \cos(2\pi r/8) \cdot e^{-r/10}$$

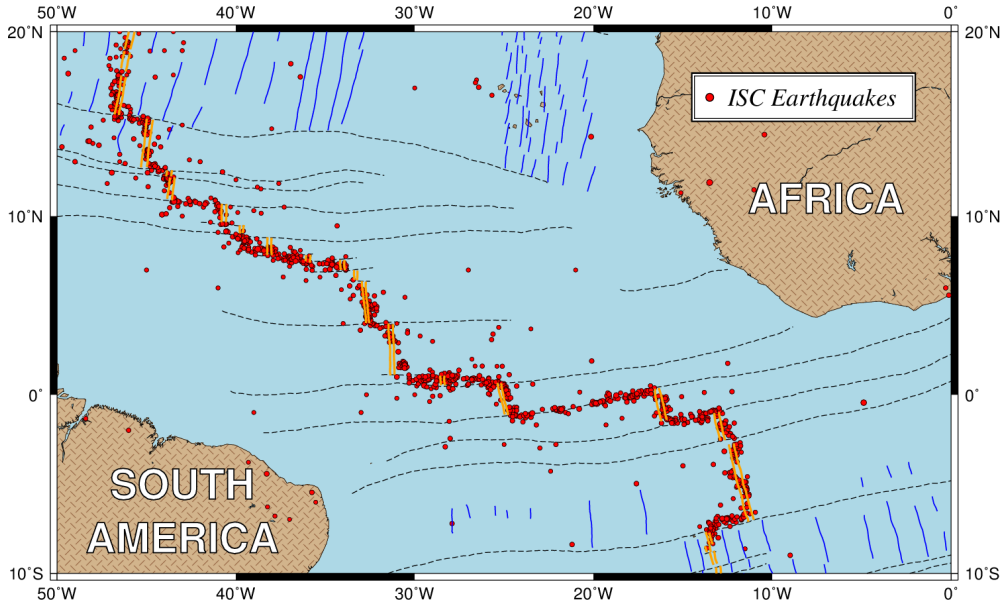


GMT Examples

Plotting of Histograms

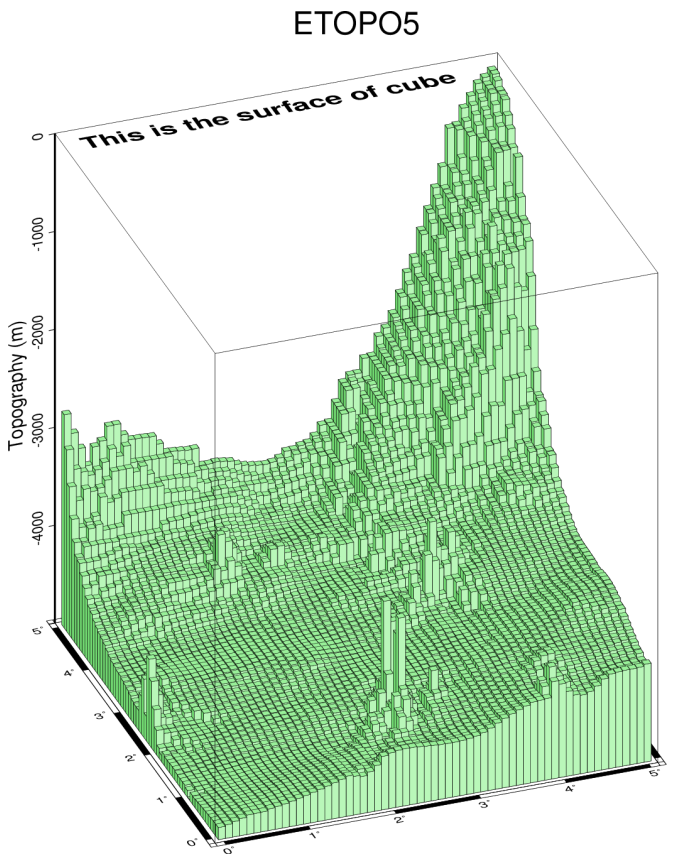


A Simple Location Map

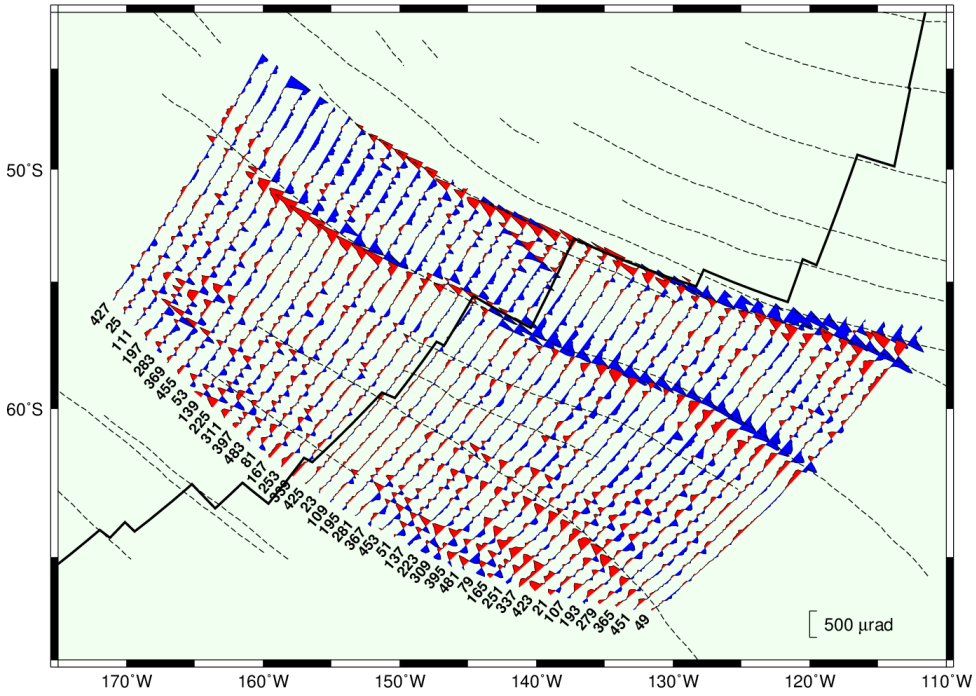


GMT Examples

3D Histogram

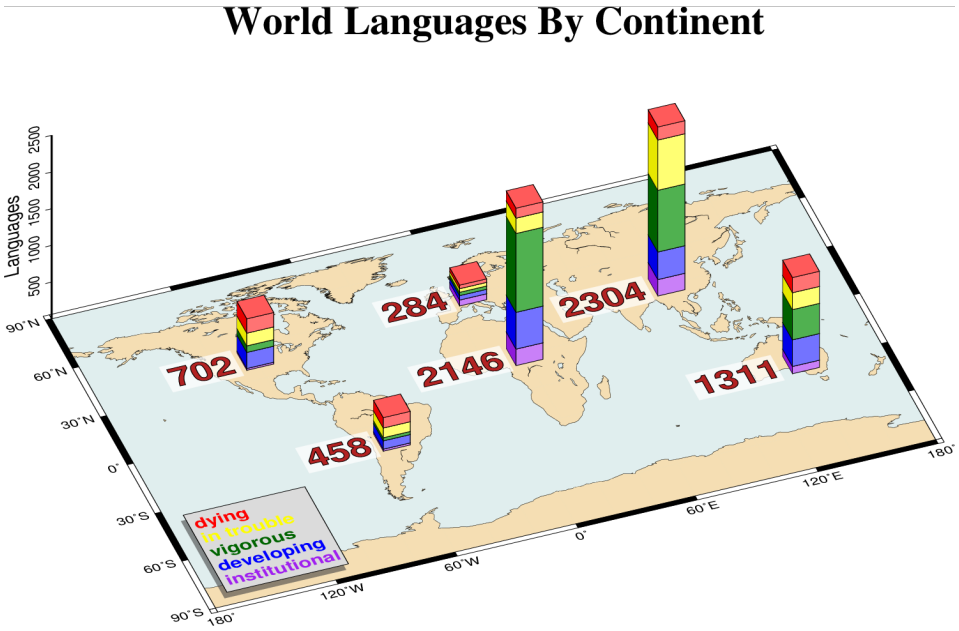


Time Series Along Tracks

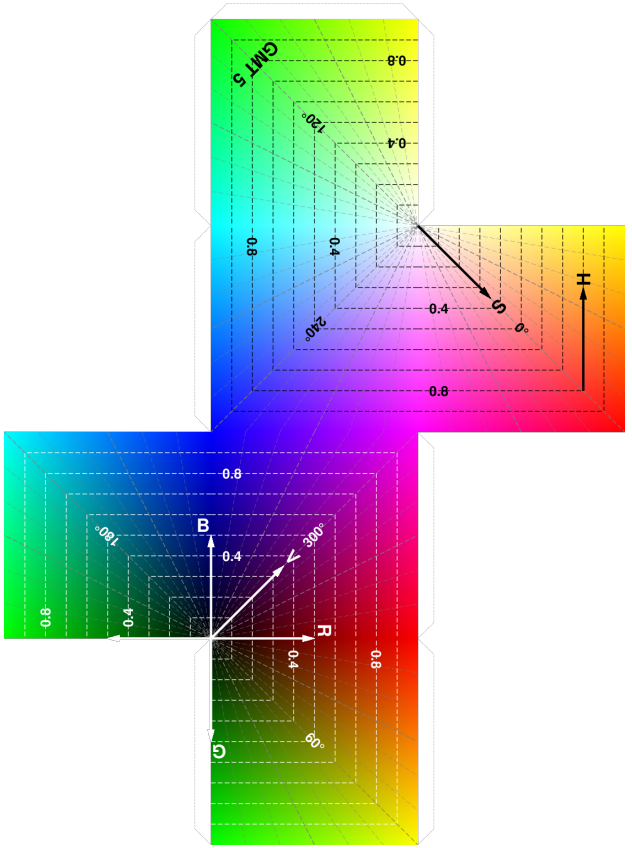


GMT Examples

Geographical Bar Graph Plot

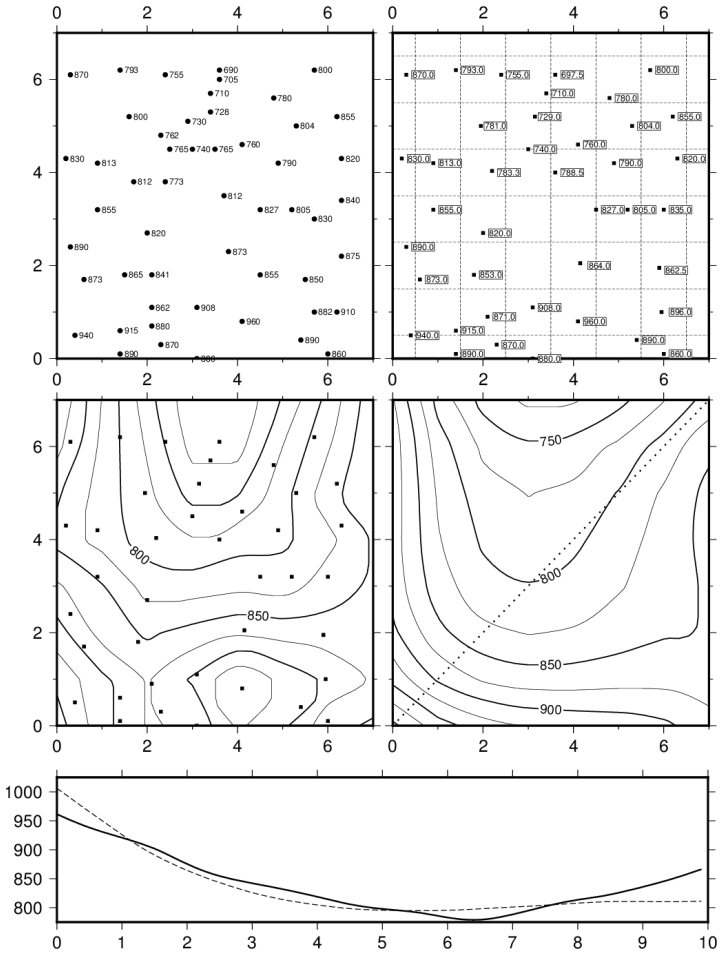


A 3D RGB Color Cube

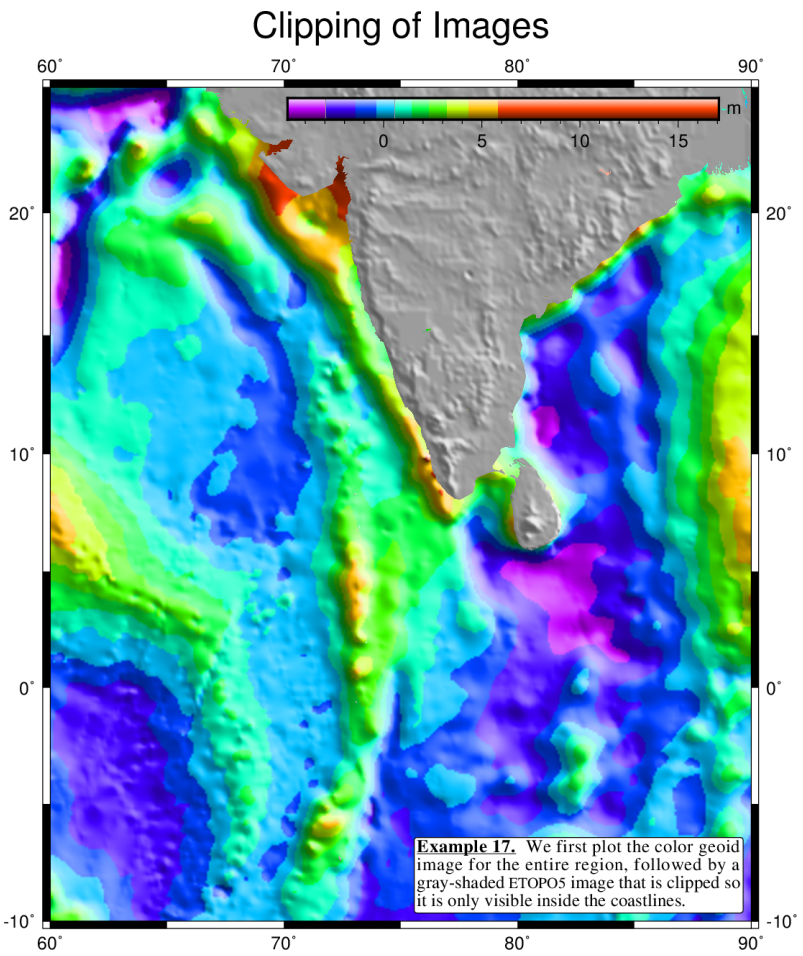


GMT Examples

Gridding of Data and Trend Surfaces

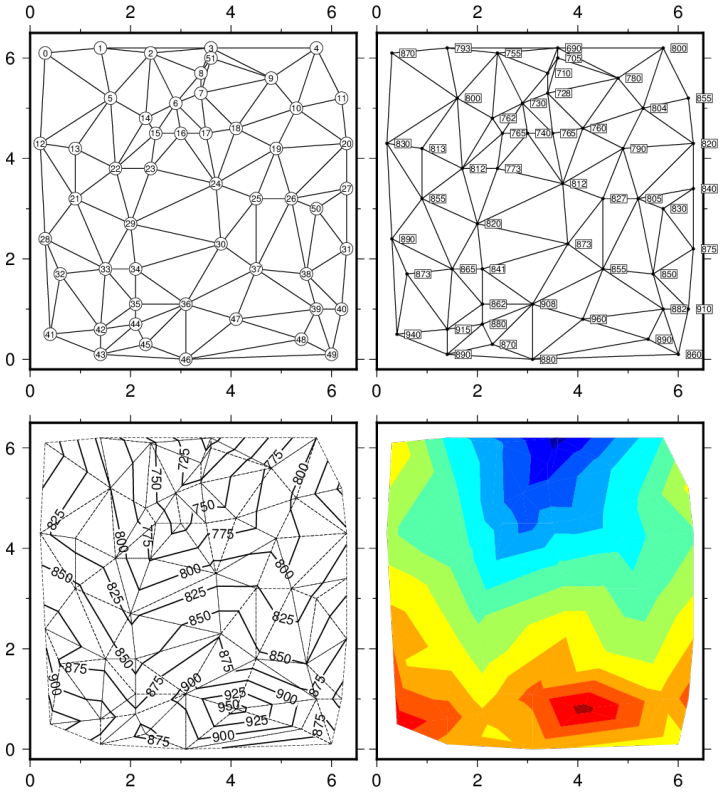


Images Clipped by Coastlines



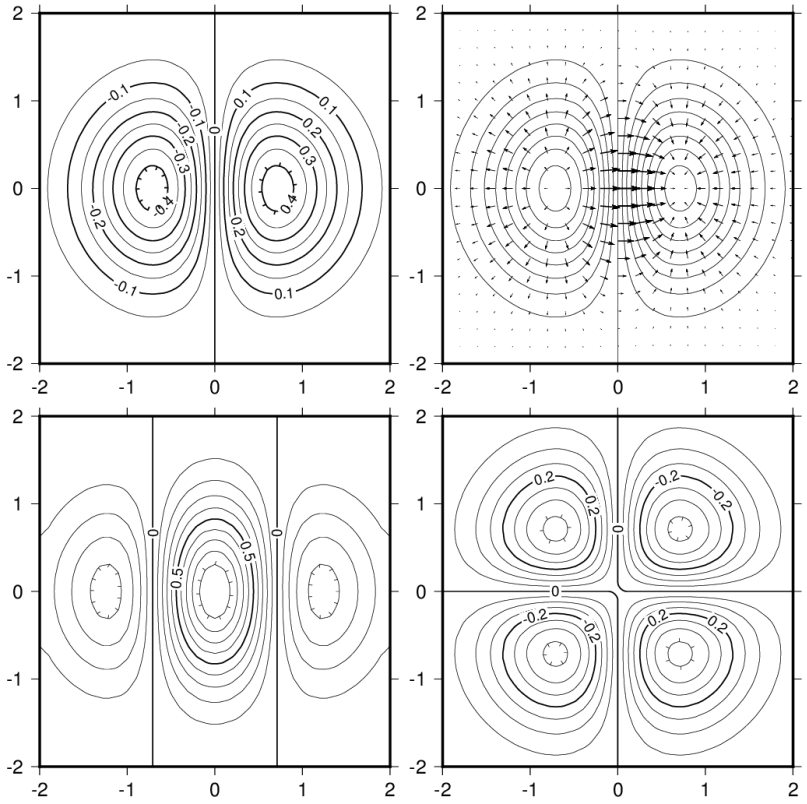
GMT Examples

Optimal Triangulation of Data



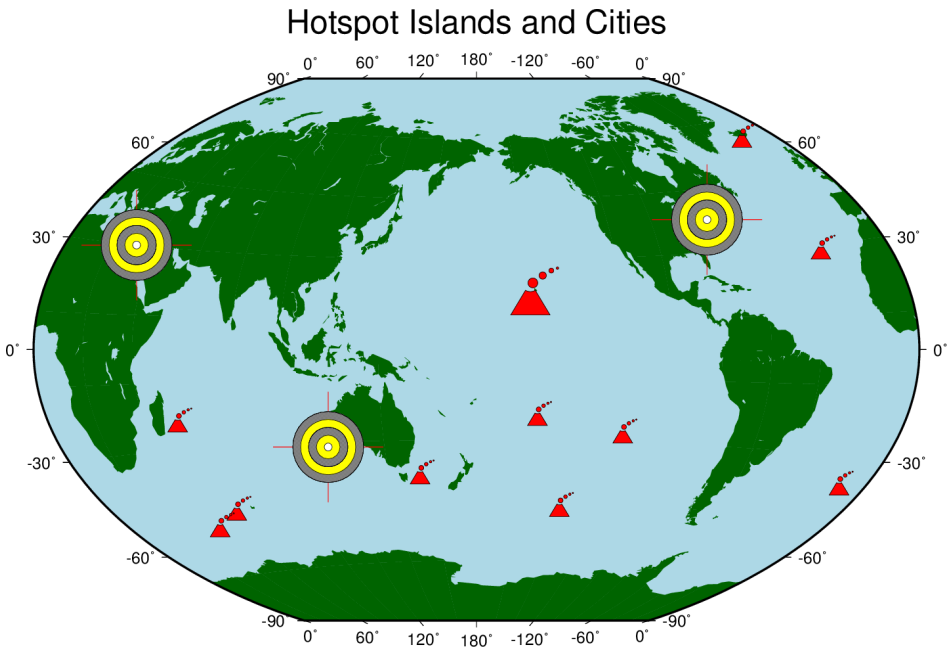
Plotting of Vector Fields

$$z(x,y) = x \cdot exp(-x^2-y^2)$$

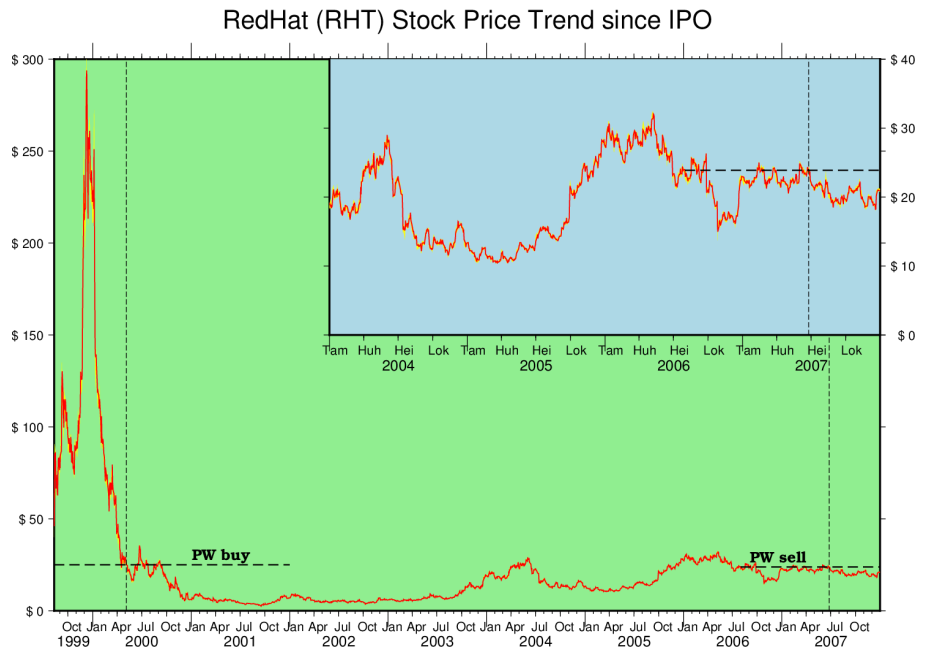


GMT Examples

Custom Plot and Symbols

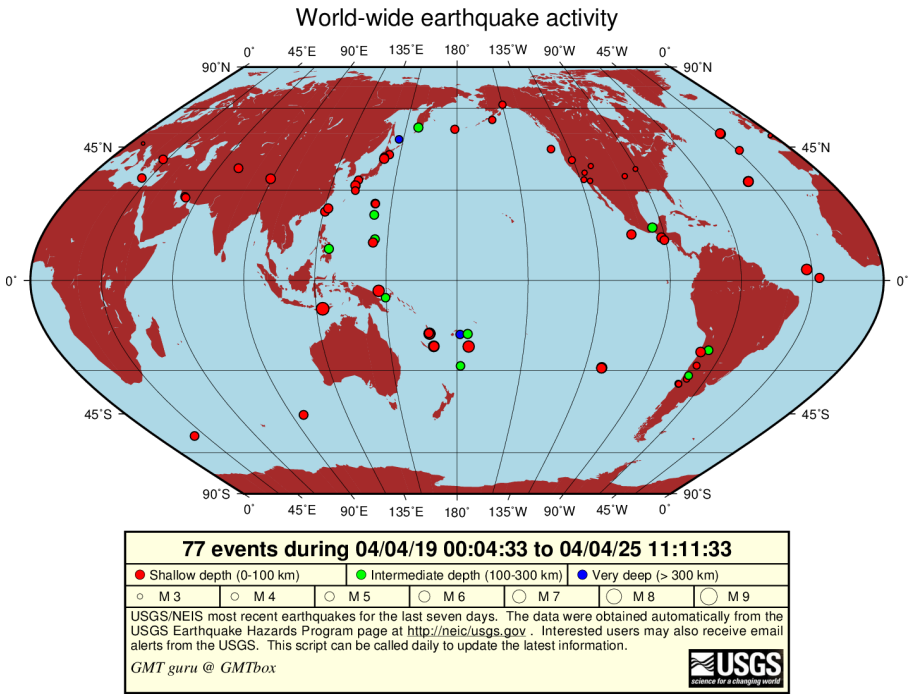


Time Series of Red Hat Stock Price

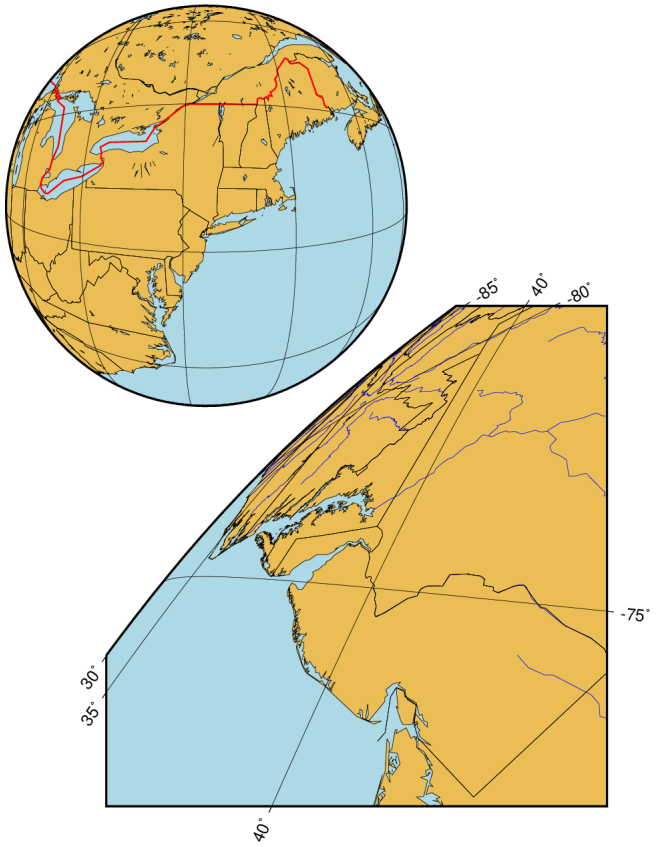


GMT Examples

Worldwide Seismicity Last 7 days

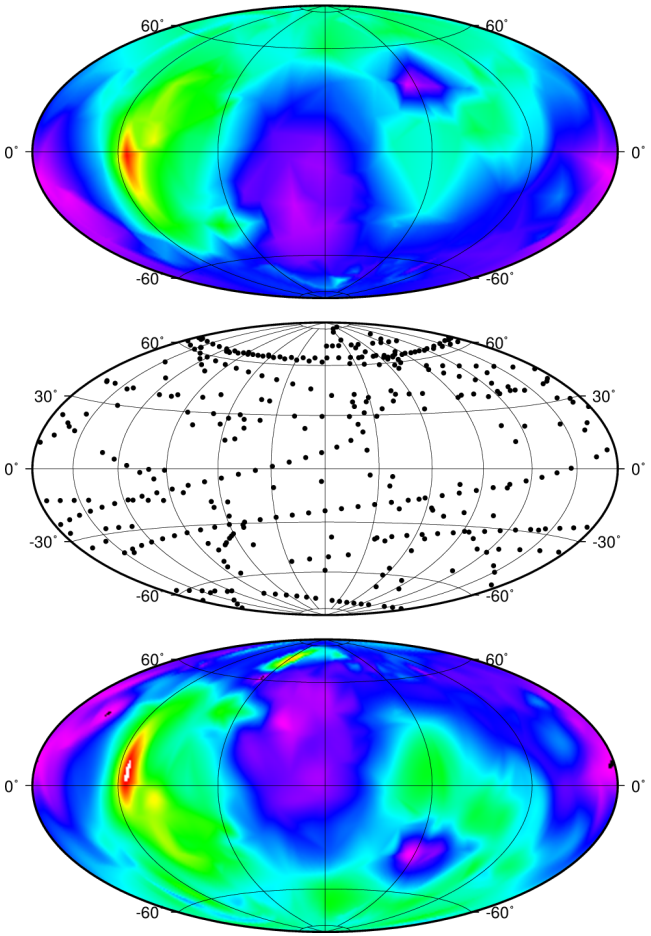


General Vertical Perspective Projection

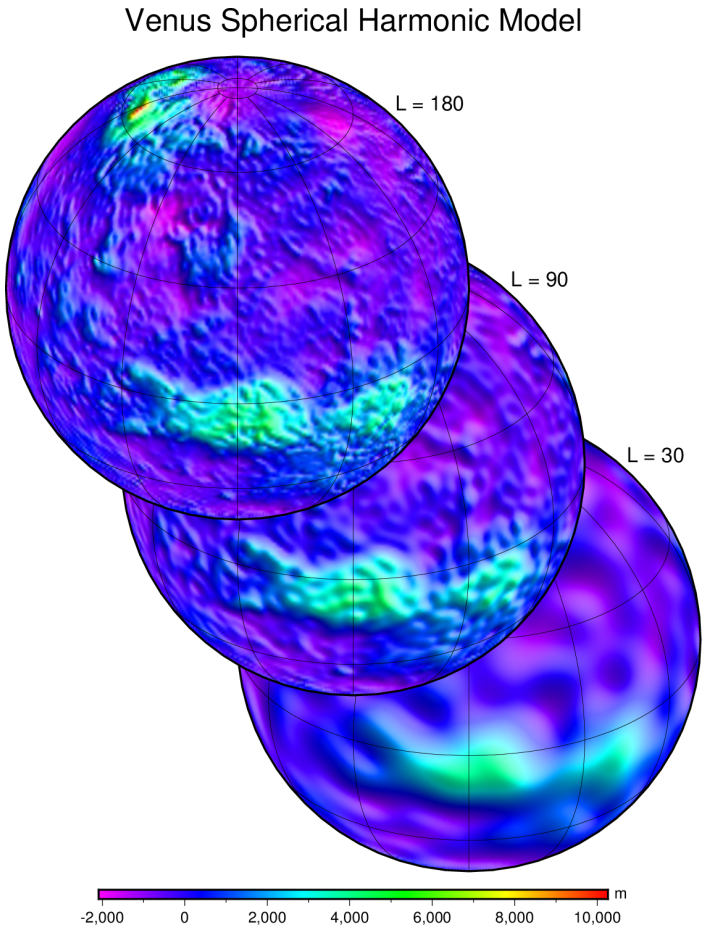


GMT Examples

Spherical Gridding using Renka's Algortihm



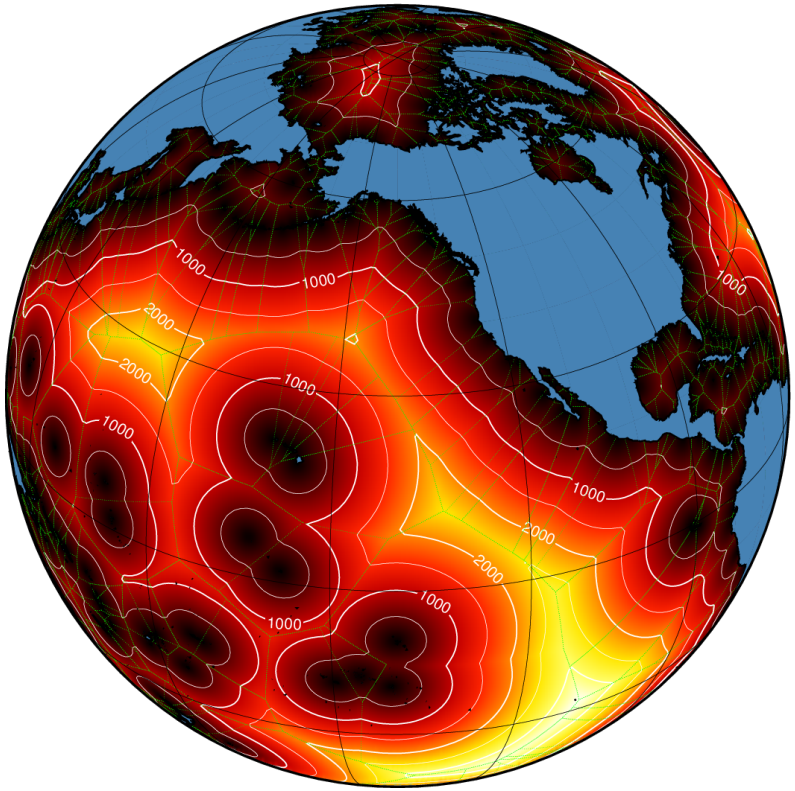
Evaluation of Spherical Harmonics Coefficients



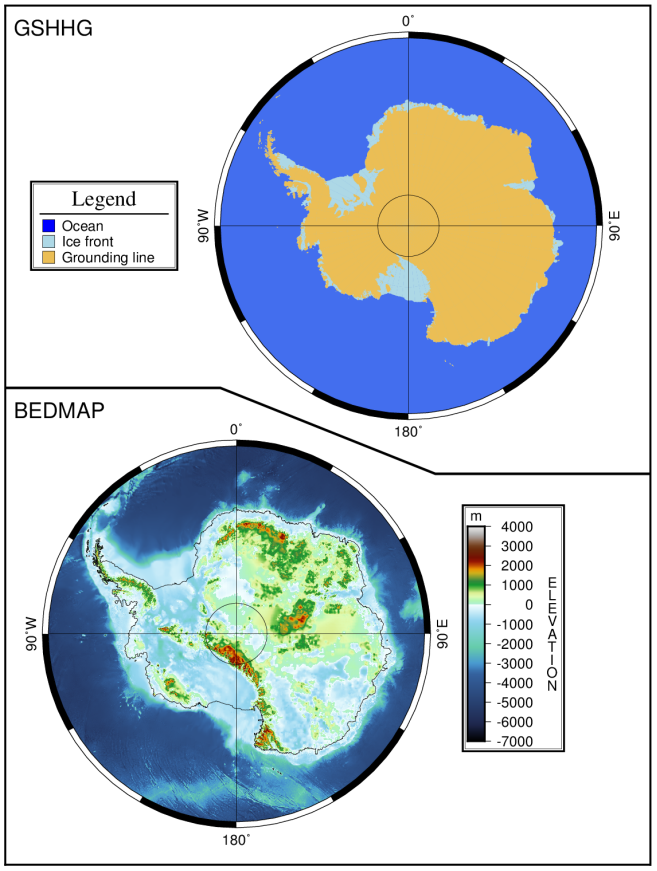
GMT Examples

Spherical Triangulation and Distance Calculations

Distances from GSHHG crude coastlines

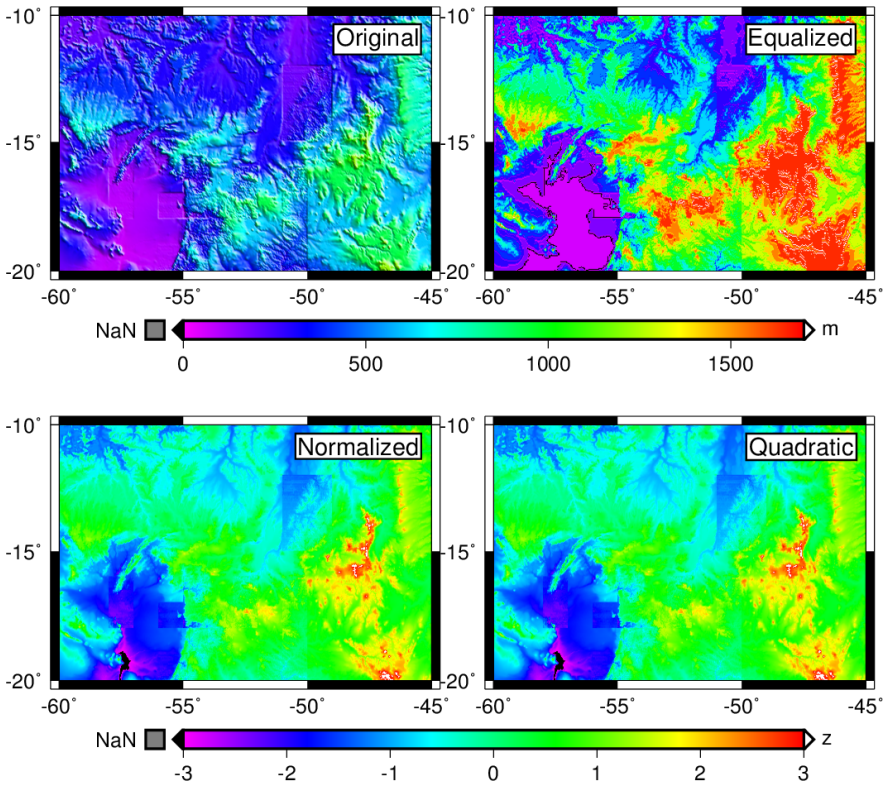


Antarctica and Stereographic Projections

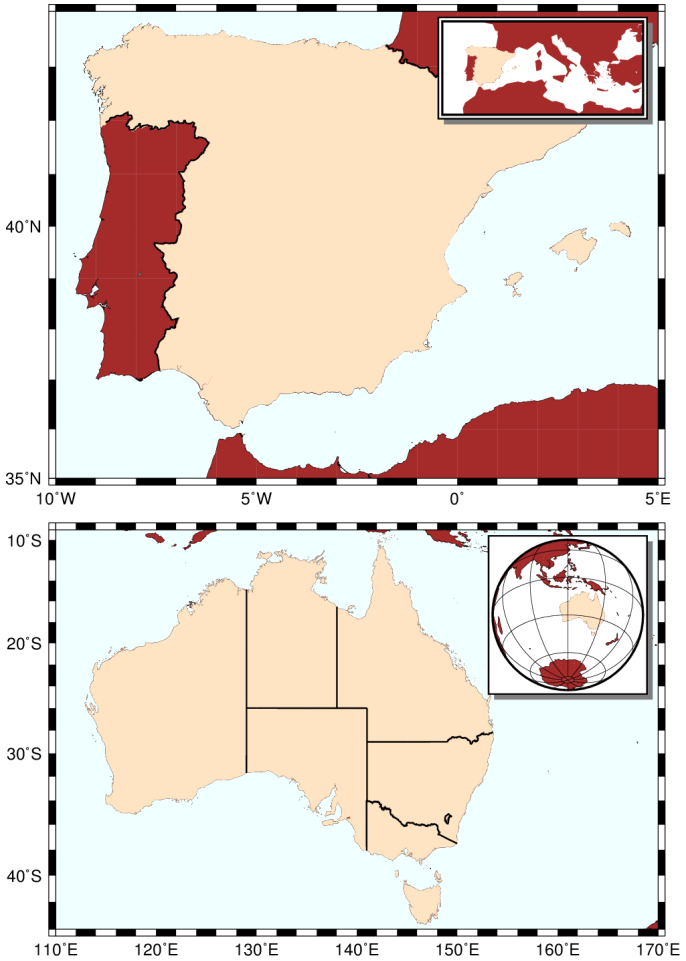


GMT Examples

Histogram Equalization of Bathymetry Grids

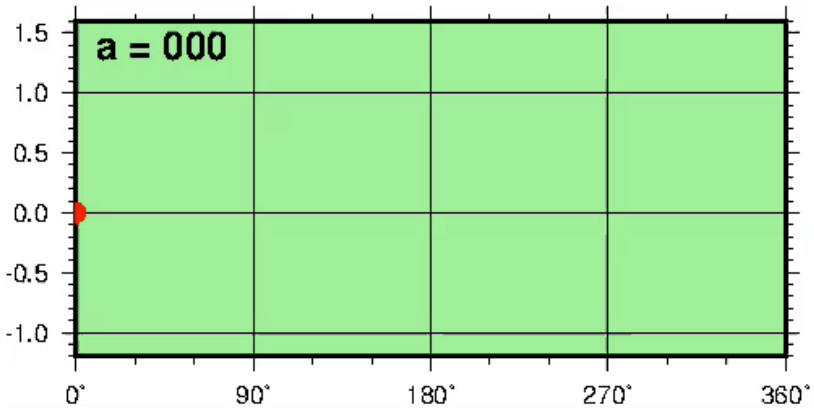


Map Insets

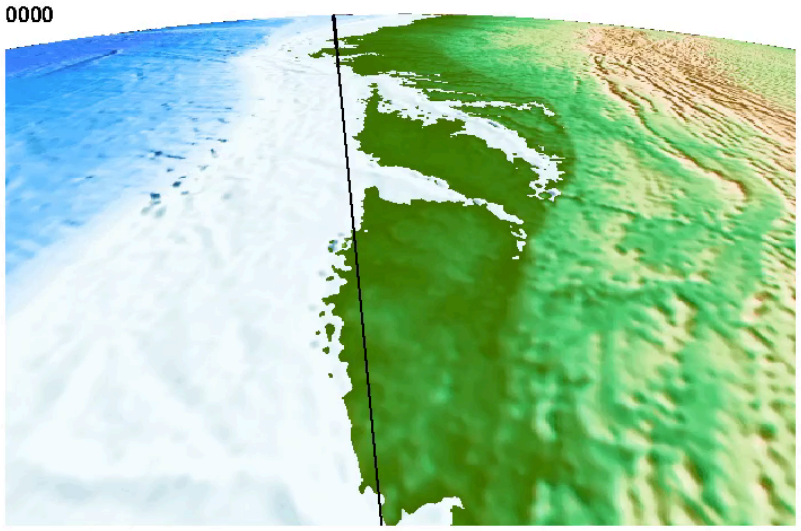


GMT Examples

Animation of Sine Function



Topography Flyover

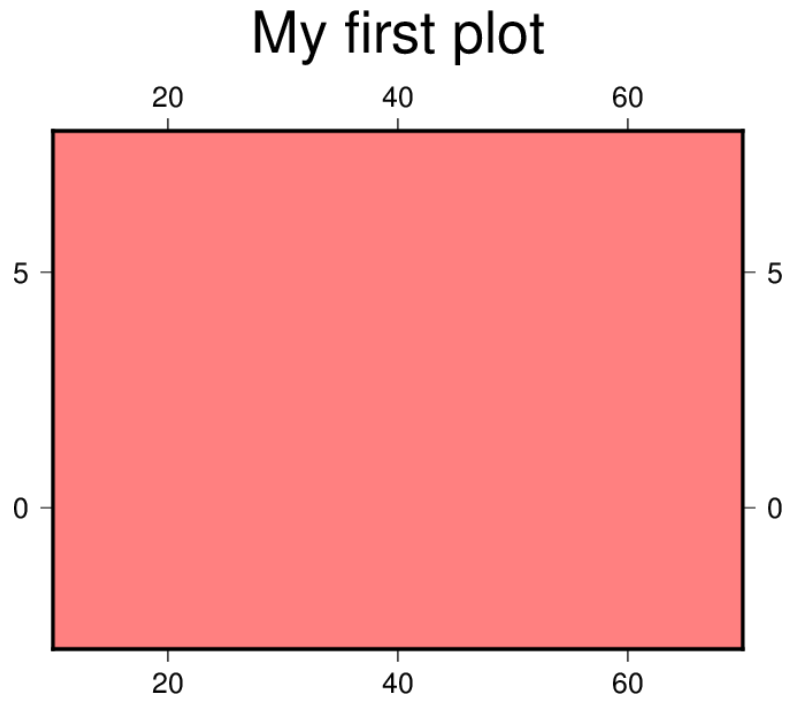


GMT Basics

- Run GMT commands through bash script on the command line
  - Create new text file with favorite text editor
  - Type `#!/bin/bash` on first line of file
  - Save and make executable

Linear Projection

gmt psbasemap -R10/70/-3/8 -JX4i/3i -Ba -B+glightred+t"My first plot" -P > GMT_tut_1.ps



Exercises:

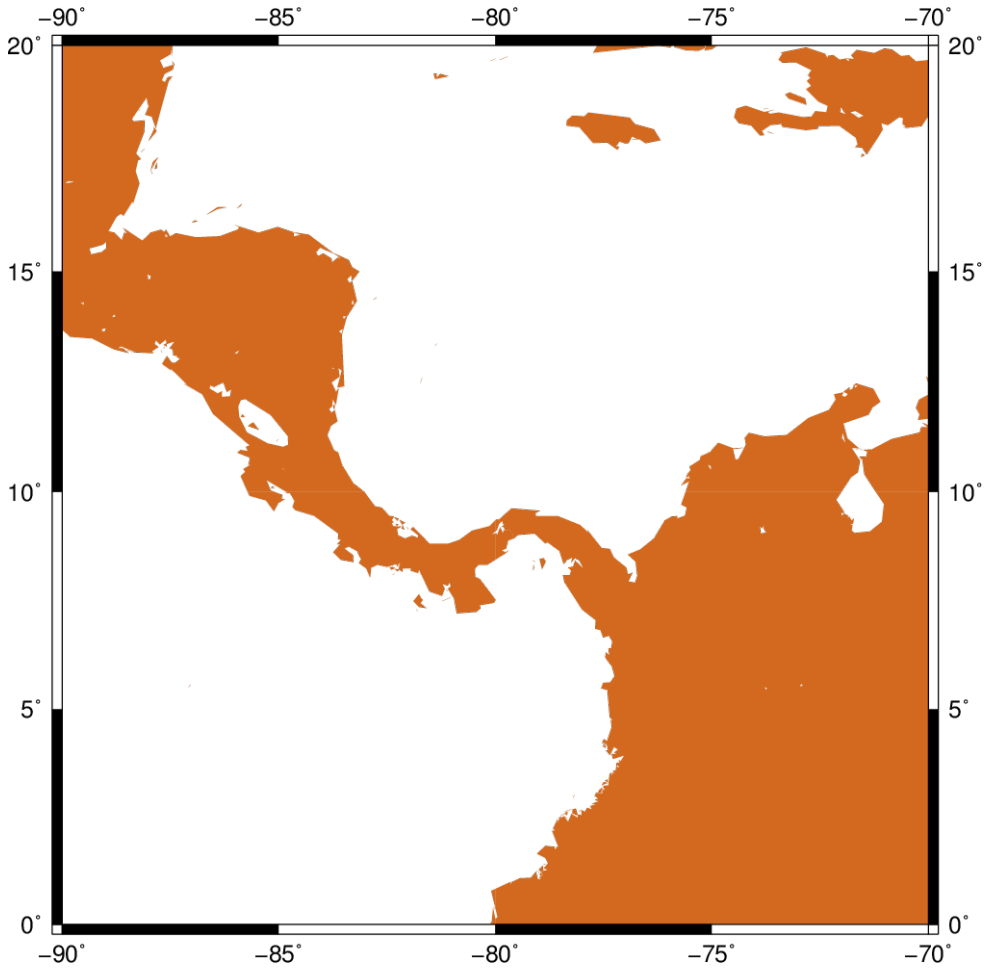
1. Try change the **-JX** values.
2. Try change the **-B** values.
3. Omit the **-P**.
4. Change title and canvas color.

Mercator Projection

gmt pscoast -R-90/-70/0/20 -JM6i -P -Ba -Gchocolate > GMT_mercator.ps

Exercises:

1. Add the **-V** option.
2. Pick another region and change land color.
3. Pick a region that includes the north or south poles.
4. Try **-W**0.25**p** instead of (or in addition to) **-G**.



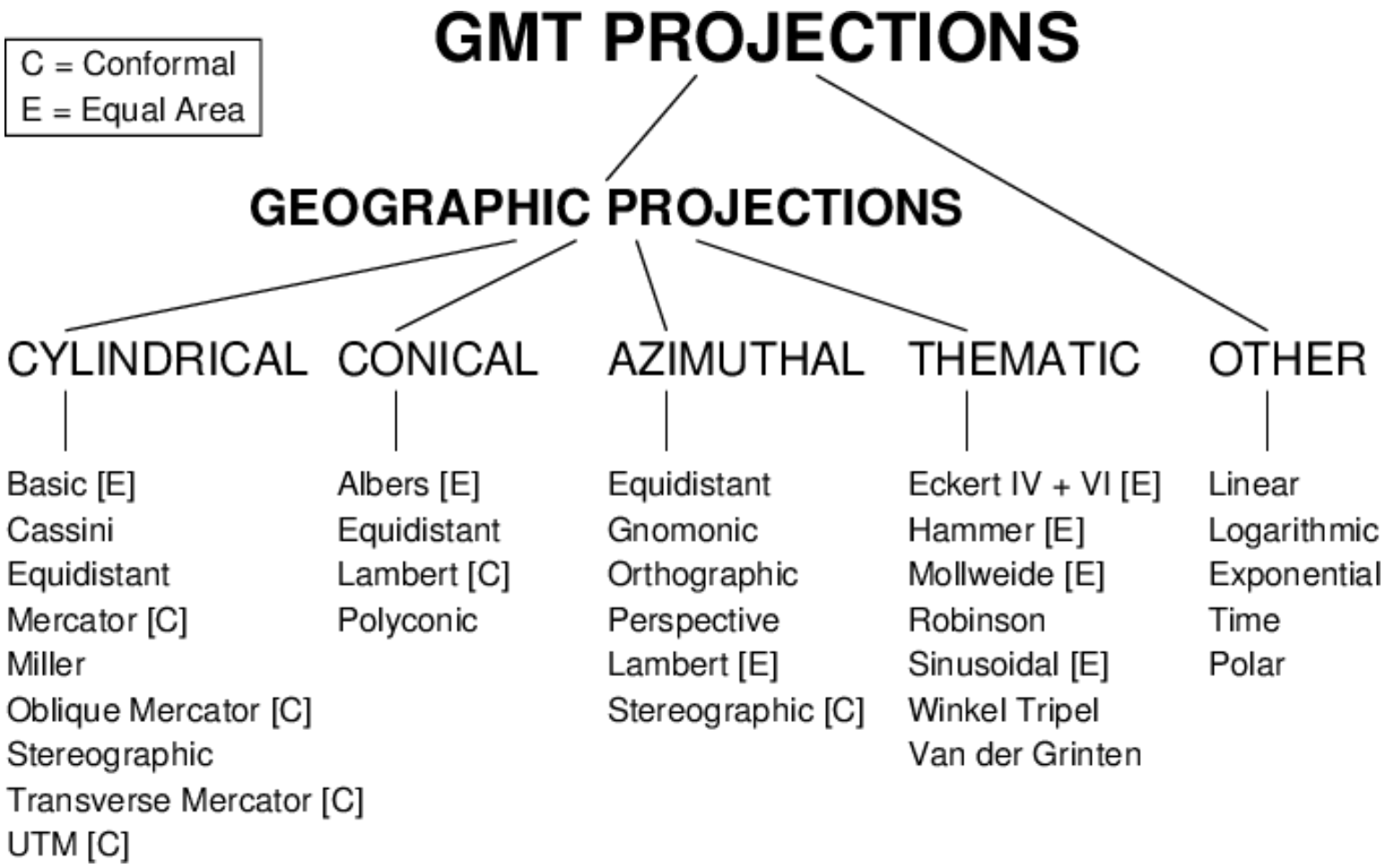
Orthographic Projection

gmt pscoast -Rg -JG280/30/6i -Bag -Dc -A5000 -Gwhite -SDarkTurquoise -P > GMT_tut_5.ps

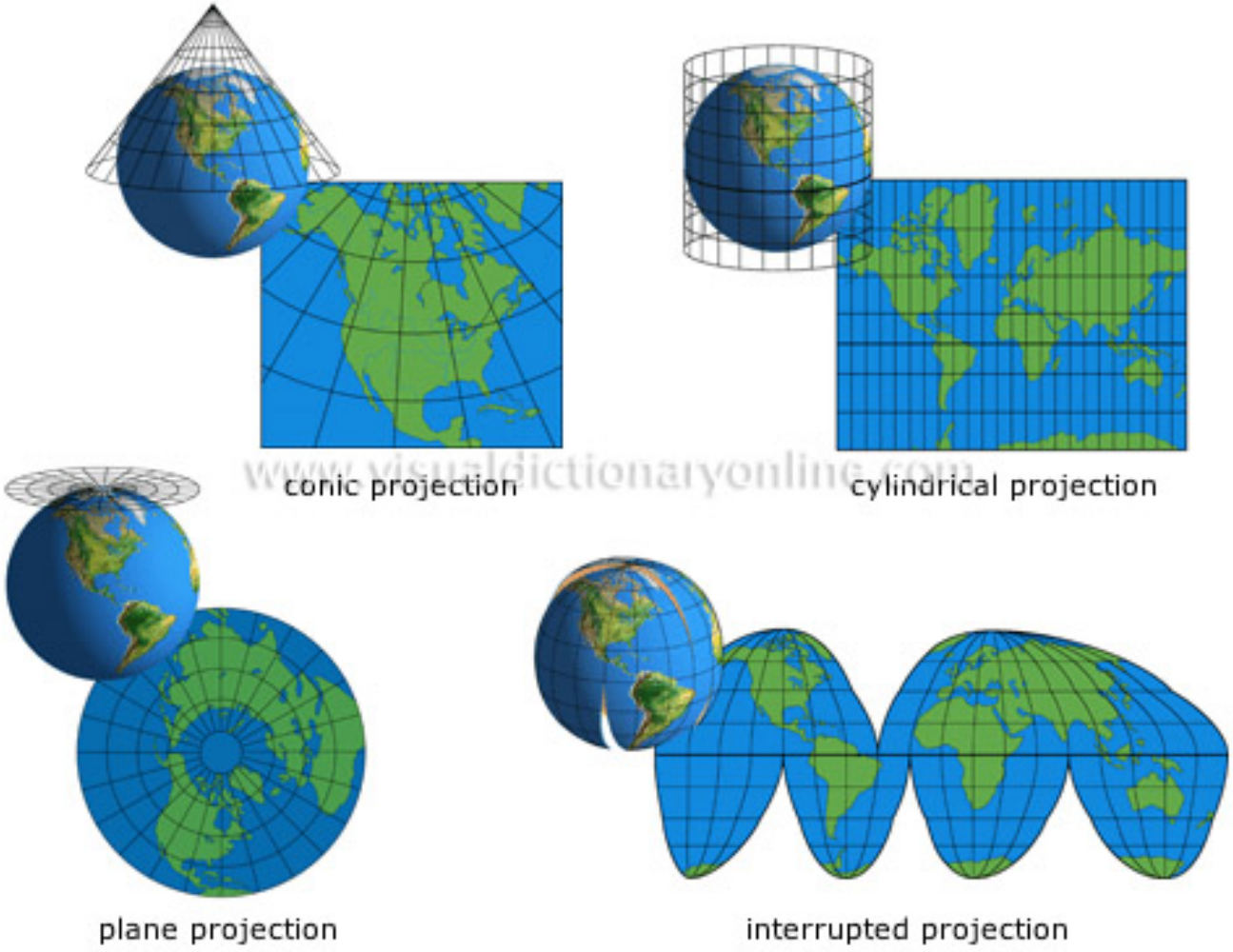
Exercises:

1. Use the rectangular option in **-R** to make a rectangular map showing the US only.

Available GMT projections



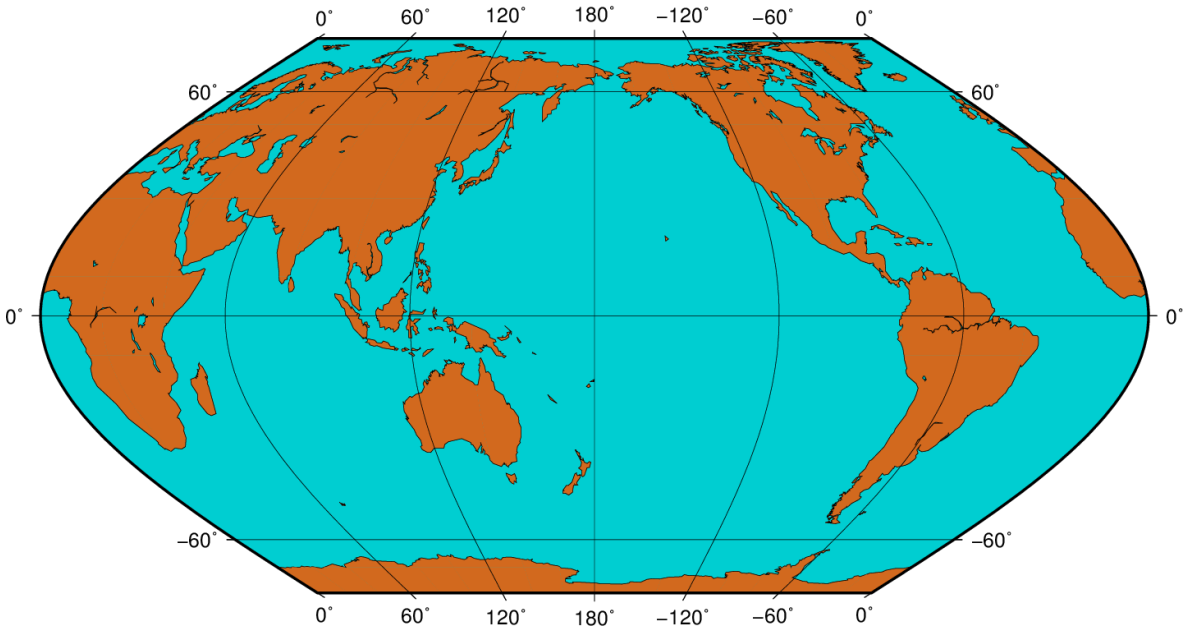
Map Projections



https://en.wikipedia.org/wiki/List_of_map_projections

Eckert VI Projection

gmt pscoast -Rg -JKs180/9i -Bag -Dc -A5000 -Gchocolate -SDarkTurquoise -Wthinnest > GMT_tut_6.ps



Exercises:

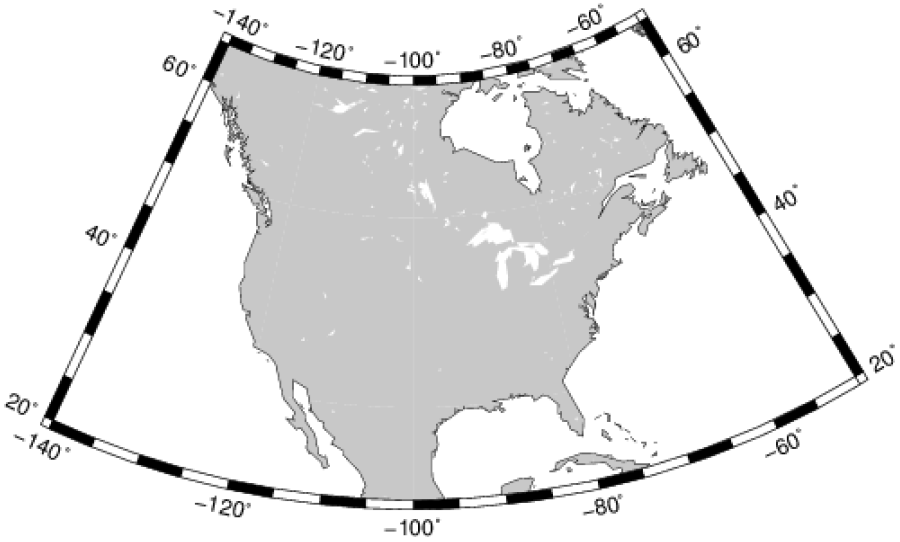
1. Center the map on Greenwich.
2. Add a map scale with **-L**.

Albers Projection

gmt pscoast -R-140/-50/20/65 -JB-100/35/33/45/6i -Ba20f5/a20f5 -Dc -Ggray -W1/0 -P > GMT_alpers.ps

Change/add the following features to your map:

- Longitudinal interval marks every 20º
- Latitudinal interval marks every 10º
- Light brown land masses
- Light blue oceans
- Intermediate resolution coastlines
- 1500 km long map scale in bottom right corner
- 7.5 inches wide
- All major rivers in blue pen
- State boundaries in dashed black pen
- Country borders in solid red
- Solid green star showing your favorite city
- Text annotation of your favorite city
- Map Title



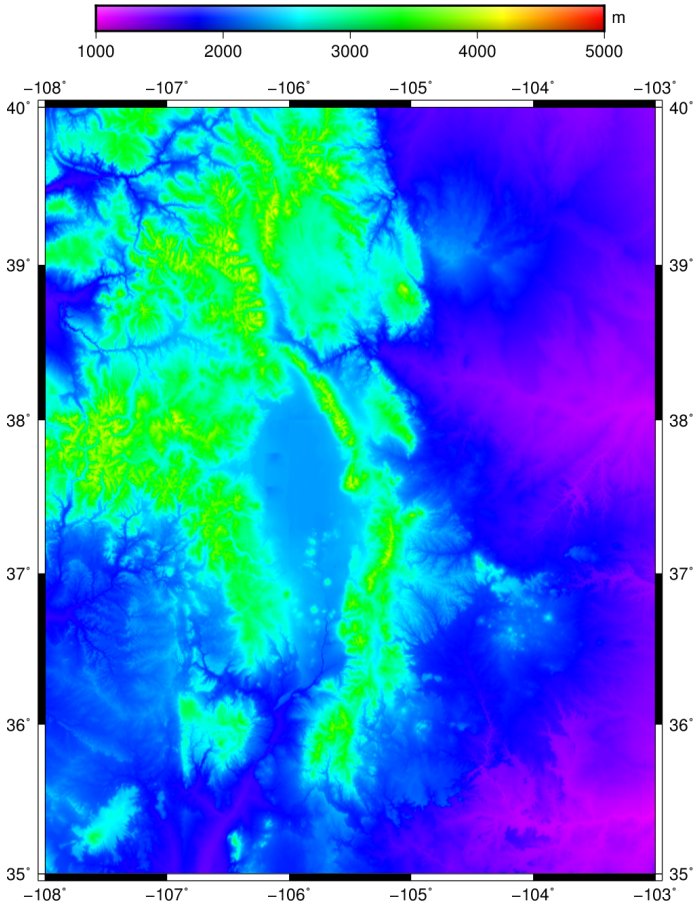
Postscript File handling Best Practices

- -K and -O options
  - Important when using multiple commands to create postscript file
  - **-K** Allow more plot code to be appended to this plot later (every command except the last)
  - **-O** Allow this plot code to be appended to an existing plot (every command except first)

- > and >> options
  - Use > for first command of script
  - Use >> for every subsequent command

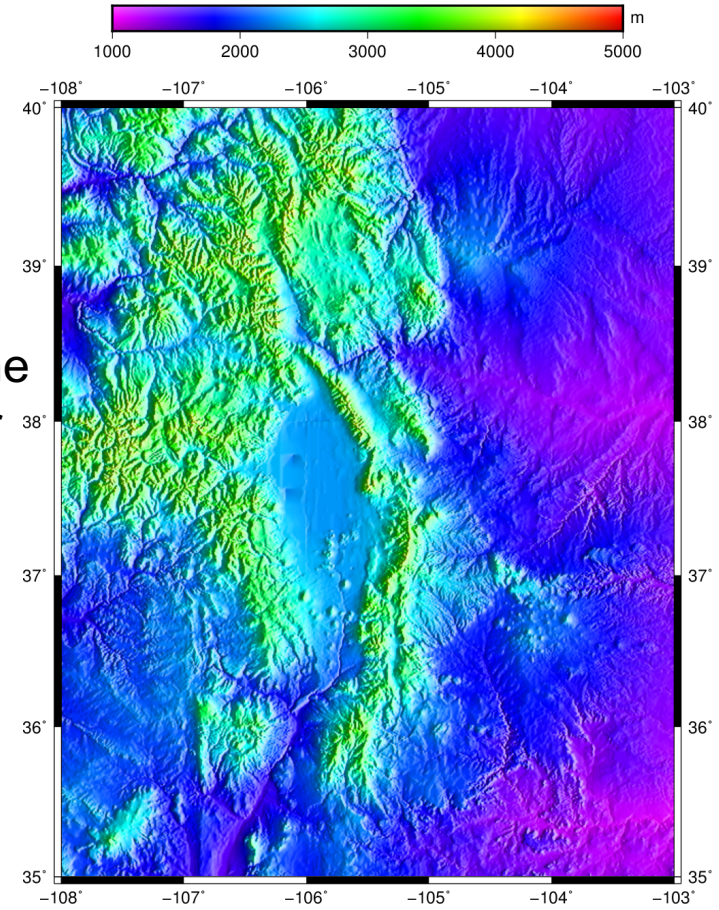
Color Images – USA topography

```
gmt makecpt -Crainbow -T1000/5000/500 -Z > topo.cpt
gmt grdimage us.nc -JM6i -P -Ba -Ctopo.cpt -V -K > GMT_tut_15.ps
gmt psscale -DjTC+w5i/0.25i+h+o0/-1i -Rus.nc -J -Ctopo.cpt -I0.4 -By+lm -O >>
GMT_tut_15.ps
```



Color Images – USA topography

```
gmt grdgradient us.nc -Ne0.8 -A100 -fg -Gus_i.nc
gmt grdimage us.nc -Ius_i.nc -JM6i -P -Ba -Ctopo.cpt -K > GMT_tut_16.ps
gmt psscale -DjTC+w5i/0.25i+h+o0/-1i -Rus.nc -J -Ctopo.cpt -I0.4 -By+lm -O >>
GMT_tut_16.ps
```

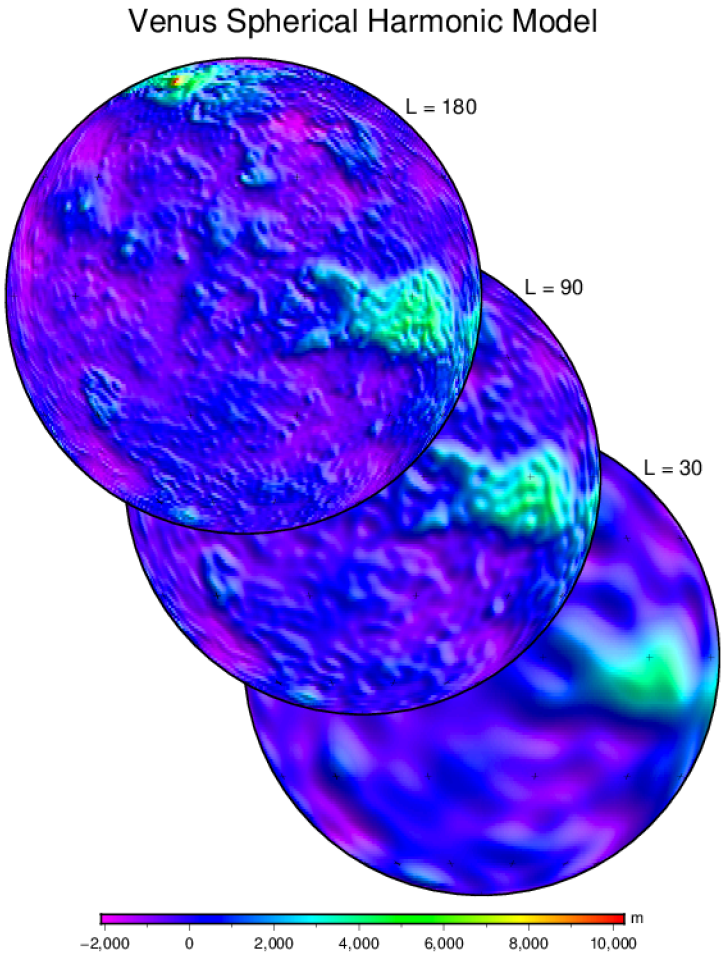


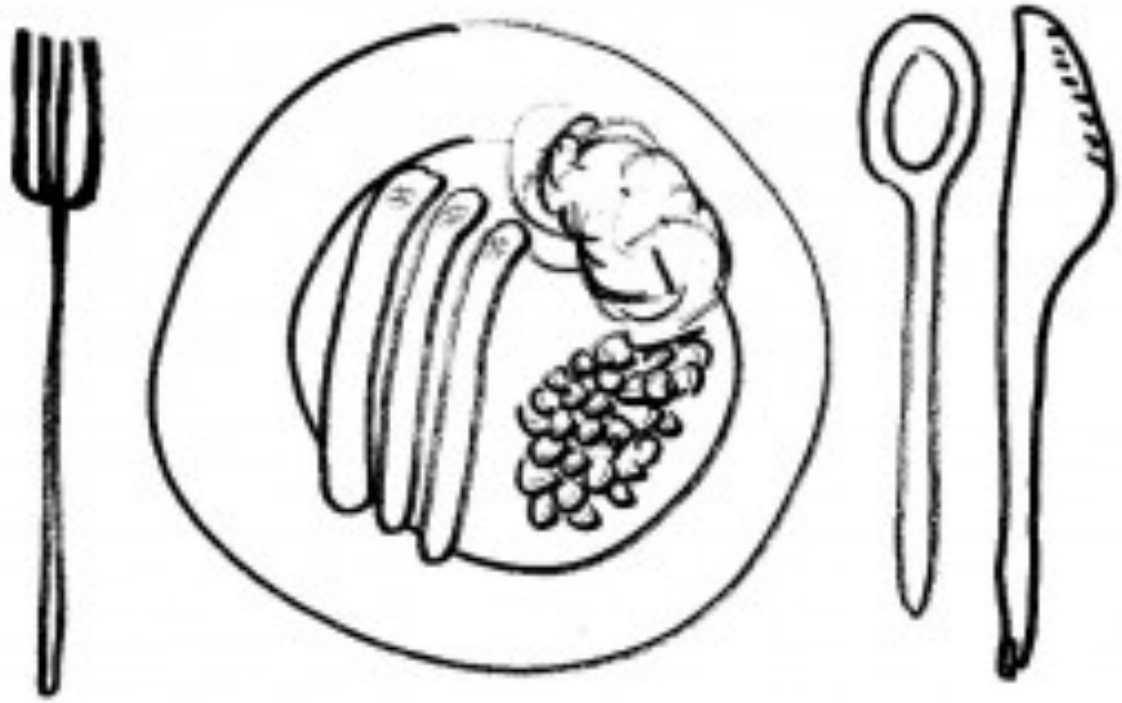
Exercises:

1. Force a gray-shade image. Compare the topographic features. Is rainbow the best colorbar? Try a few different color bars. Which one works the best and why?
2. Rerun *grdgradient* with **-N**1.
3. Change the illumination azimuth and rerun. What azimuth is best and why?

Venus topography

- Use the script venus.sh to complete the exercise
- Try changing the order of the spherical harmonic topographic model by adjusting the sph2grd filter options (-F)
- Try changing the azimuth of the gridded image. What happened?
- Create a movie of Venus as a revolving planetary body
    1. Uncomment the while loop and associated lines in venus.sh
    2. Run script to create a series of tif images over a range of azimuths that will be used as frames for the animation.
    3. Follow the attached instructions to use Adobe Photoshop to make the movie.





out for lunch

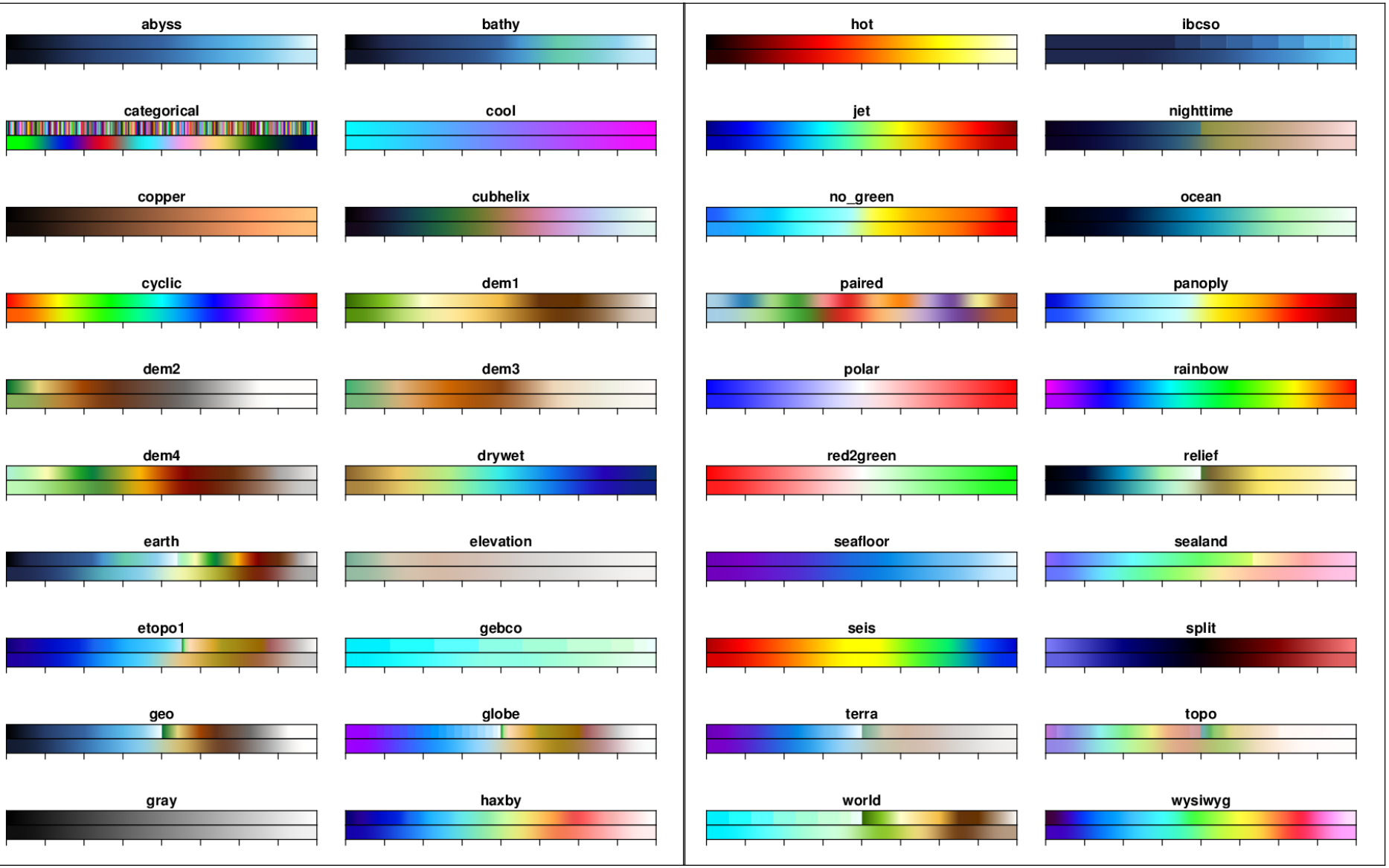
LIGO data exercises

- Plot L1 data
- Plot H1 data
- Plot L1 data overlaid on H1 data
- Plot L1 and H1 station locations on a map showing their geospatial relationship
- Plot observed data as inset on map
- Plot line connecting Hanford and Livingstone stations. Is it straight? What if you change the map projection?
- Add topography to your map
- Plot an animation of

Example Datasets

- Global topography/bathymetry data
  - https://www.ngdc.noaa.gov/mgg/global/
- LIGO data
  - https://losc.ligo.org/data/
- Planetary Data
  - http://pds-geosciences.wustl.edu

Some Usefule References


abyss
bathy
hot
ibcso
categorical
cool
jet
nighttime
copper
cubhelix
no_green
ocean
cyclic
dem1
paired
panoply
dem2
dem3
polar
rainbow
dem4
drywet
red2green
relief
earth
elevation
seafloor
sealand
etopo1
gebco
seis
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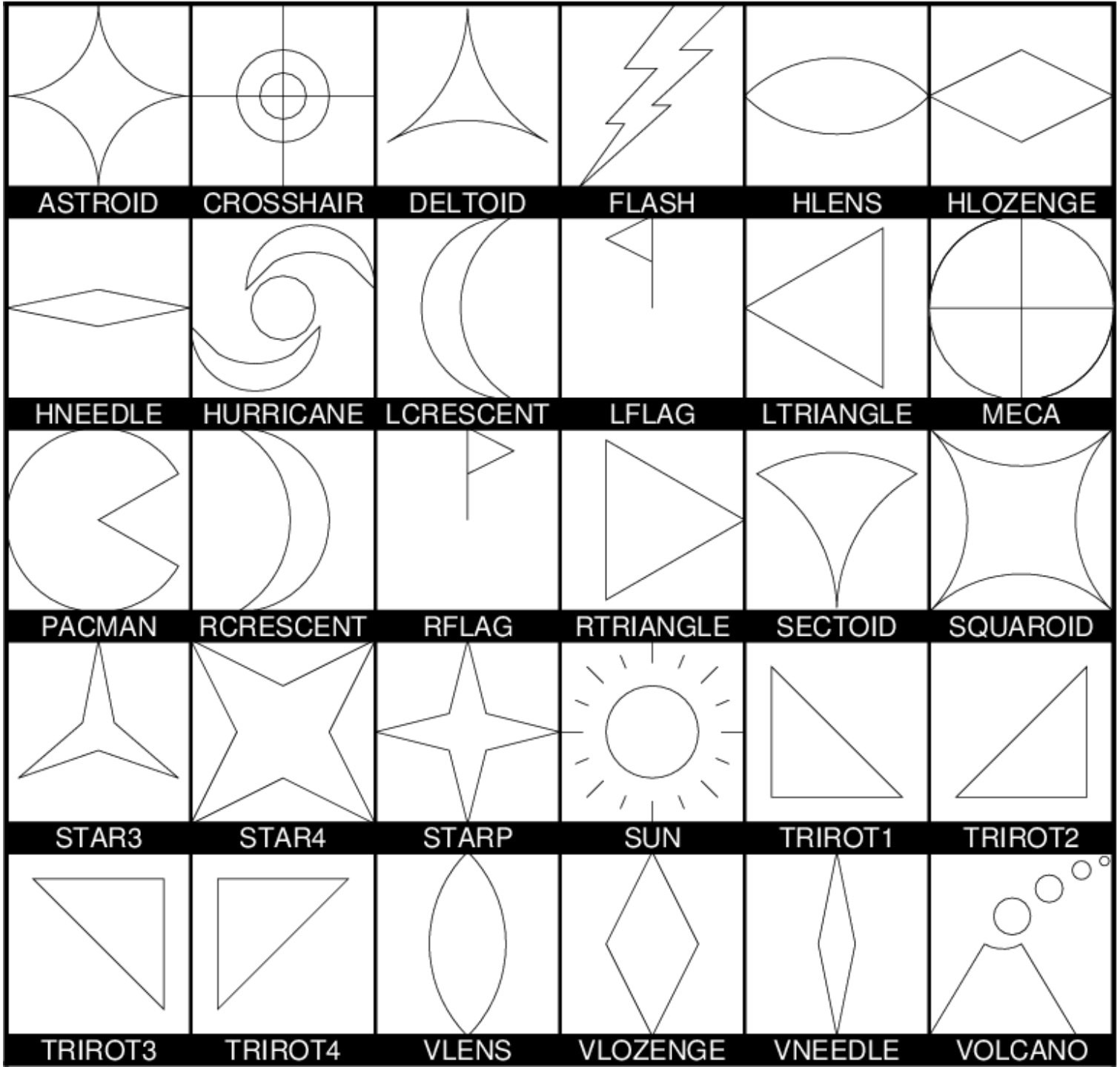
geo
globe
terra
topo
gray
haxby
world
wysiwyg


ASTROID
CROSSHAIR
DELTOID
FLASH
HLENS
HLOZENGE
HNEEDLE
HURRICANE
LCRESCENT
LFLAG
LTRIANGLE
MECA
PACMAN
RCRESCENT
RFLAG
RTRIANGLE
SECTOID
SQUAROID
STAR3
STAR4
STARP
SUN
TRIROT1
TRIROT2
TRIROT3
TRIROT4
VLENS
VLOZENGE
VNEEDLE
VOLCANO

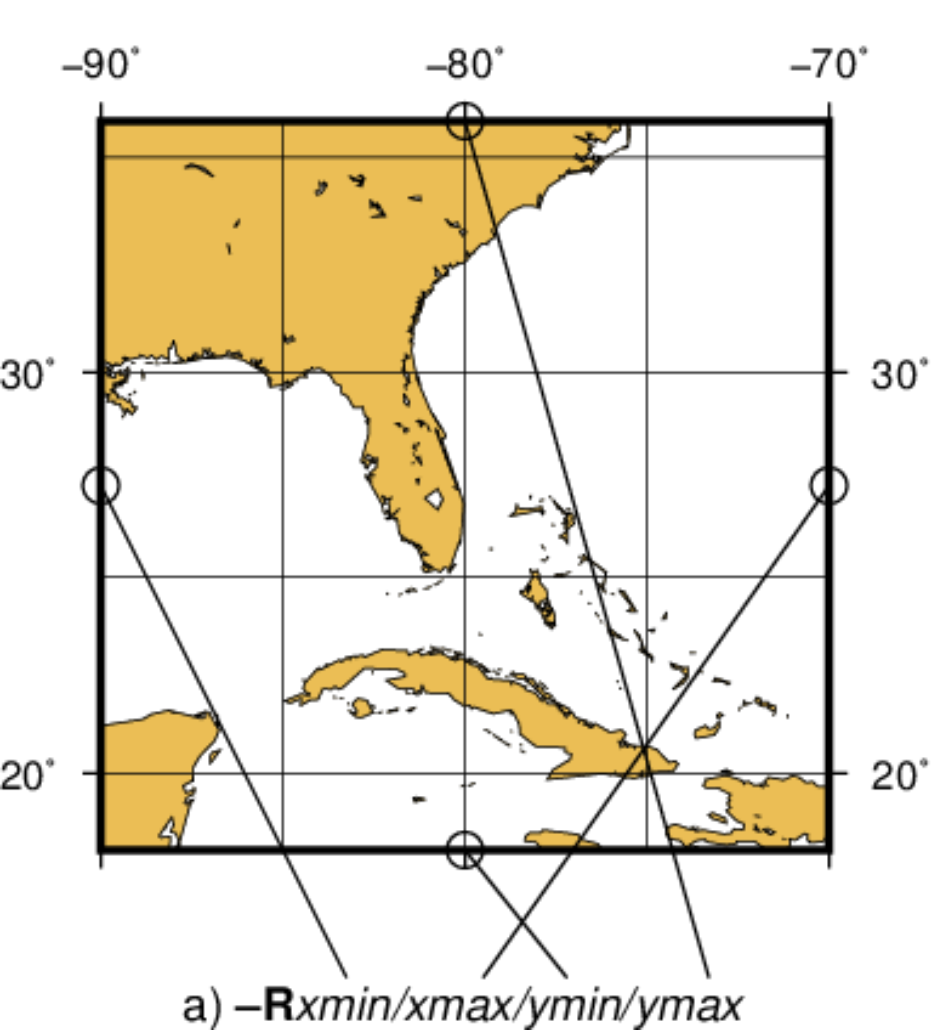
Standardized Command Line Options

-B	Define tick marks, annotations, and labels for basemaps and axes
-J	Select a map projection or coordinate transformation
-K	Allow more plot code to be appended to this plot later
-O	Allow this plot code to be appended to an existing plot
-P	Select Portrait plot orientation [Default is landscape]
-R	Define the extent of the map/plot region
-U	Plot a time-stamp, by default in the lower left corner of page
-V	Select verbose operation; reporting on progress
-X	Set the *x*-coordinate for the plot origin on the page
-Y	Set the *y*-coordinate for the plot origin on the page
-a	Associate aspatial data from OGR/GMT files with data columns
-b	Select binary input and/or output
-c	Specify the number of plot copies
-d	Replace user *nodata* values with IEEE NaNs
-f	Specify the data format on a per column basis
-g	Identify data gaps based on supplied criteria
-h	Specify that input/output tables have header record(s)
-i	Specify which input columns to read
-n	Specify grid interpolation settings
-o	Specify which output columns to write
-p	Control perspective views for plots
-r	Set the grid registration to pixel [Default is gridline]
-s	Control output of records containing one or more NaNs
-t	Change layer PDF transparency
-x	Set number of cores to be used in multi-threaded applications
-:	Assume input geographic data are (*lat,lon*) and not (*lon,lat*)

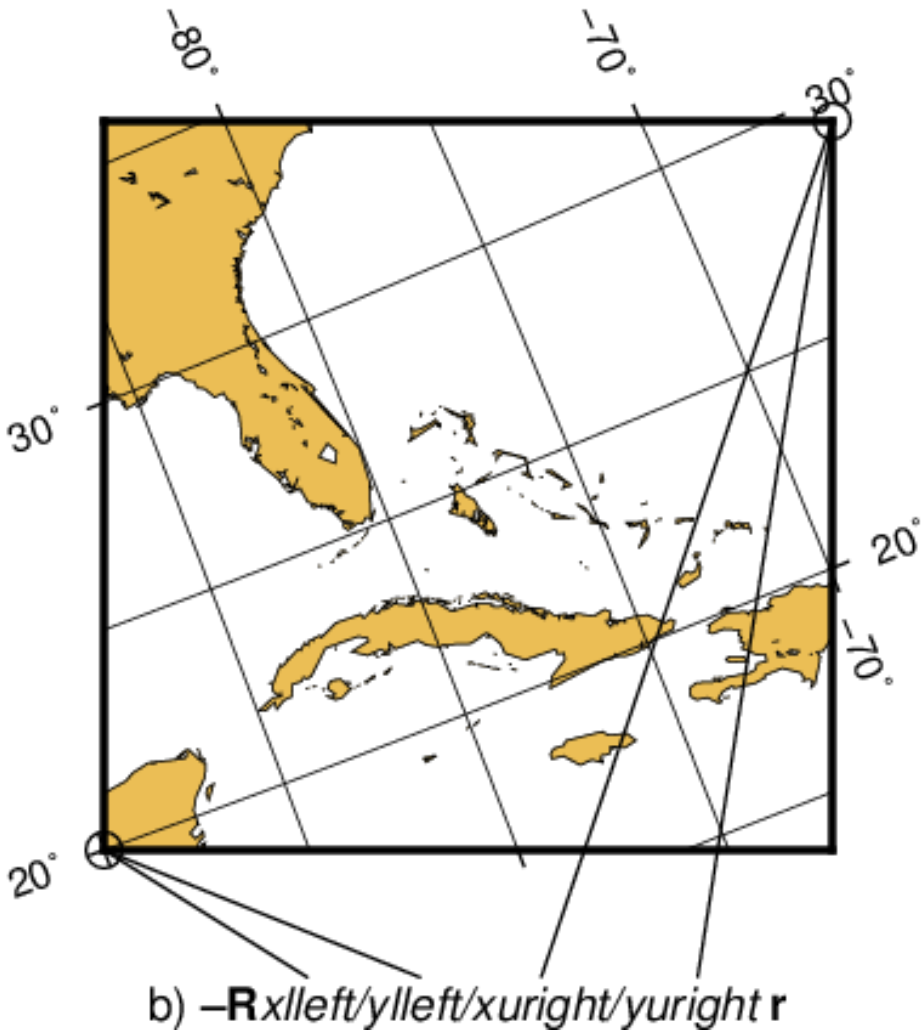
pscoast Command Line Options

Option	Purpose
-A	Exclude small features or those of high hierarchical levels (see Appendix K)
-D	Select data resolution (**b**ull, **h**igh, **i**ntermediate, **l**ow, or **c**rude)
-G	Set color of dry areas (default does not paint)
-I	Draw rivers (chose features from one or more hierarchical categories)
-L	Plot map scale (length scale can be km, miles, or nautical miles)
-N	Draw political borders (including US state borders)
-S	Set color for wet areas (default does not paint)
-W	Draw coastlines and set pen thickness

Map Region: the –R option

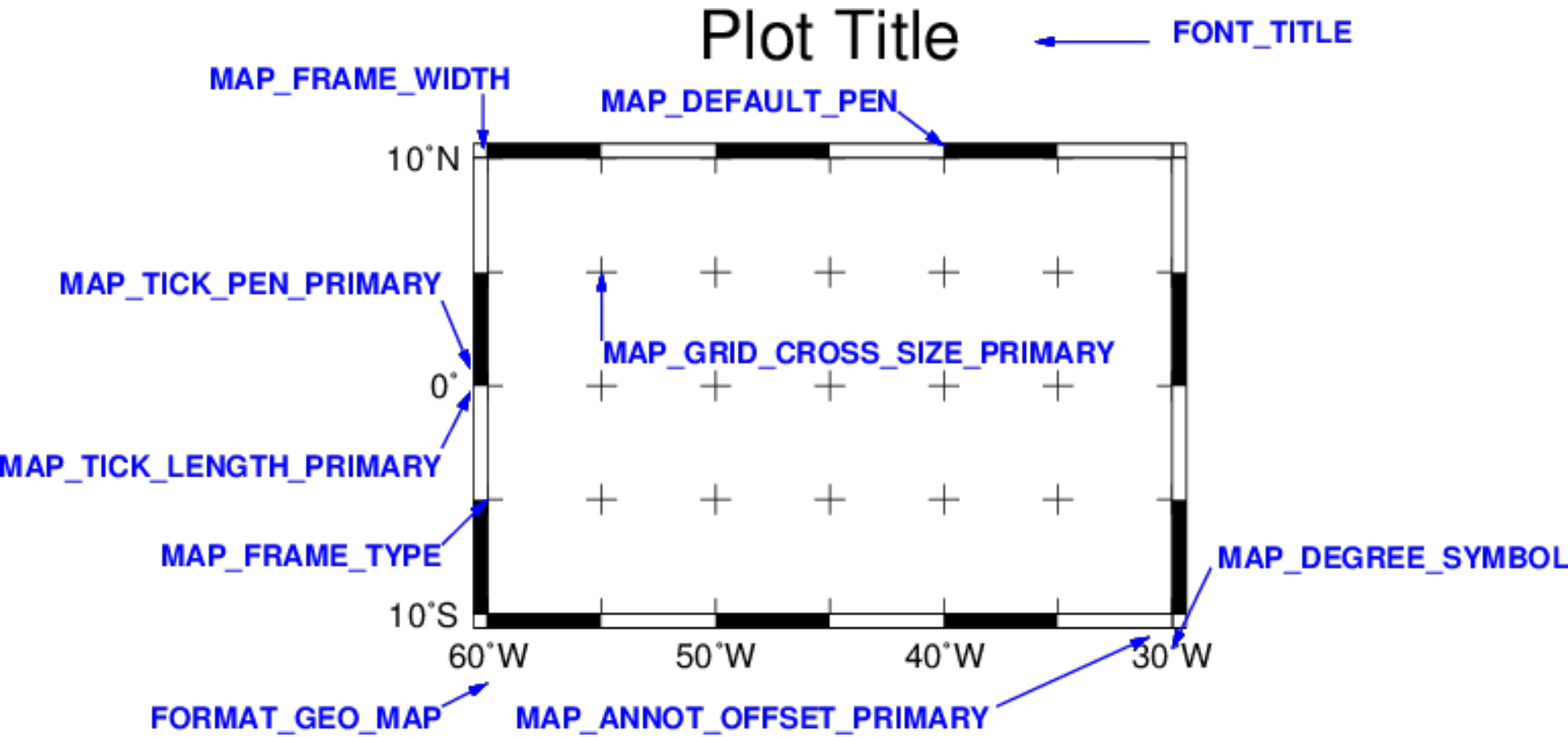


a) –**R***xmin/xmax/ymin/ymax*

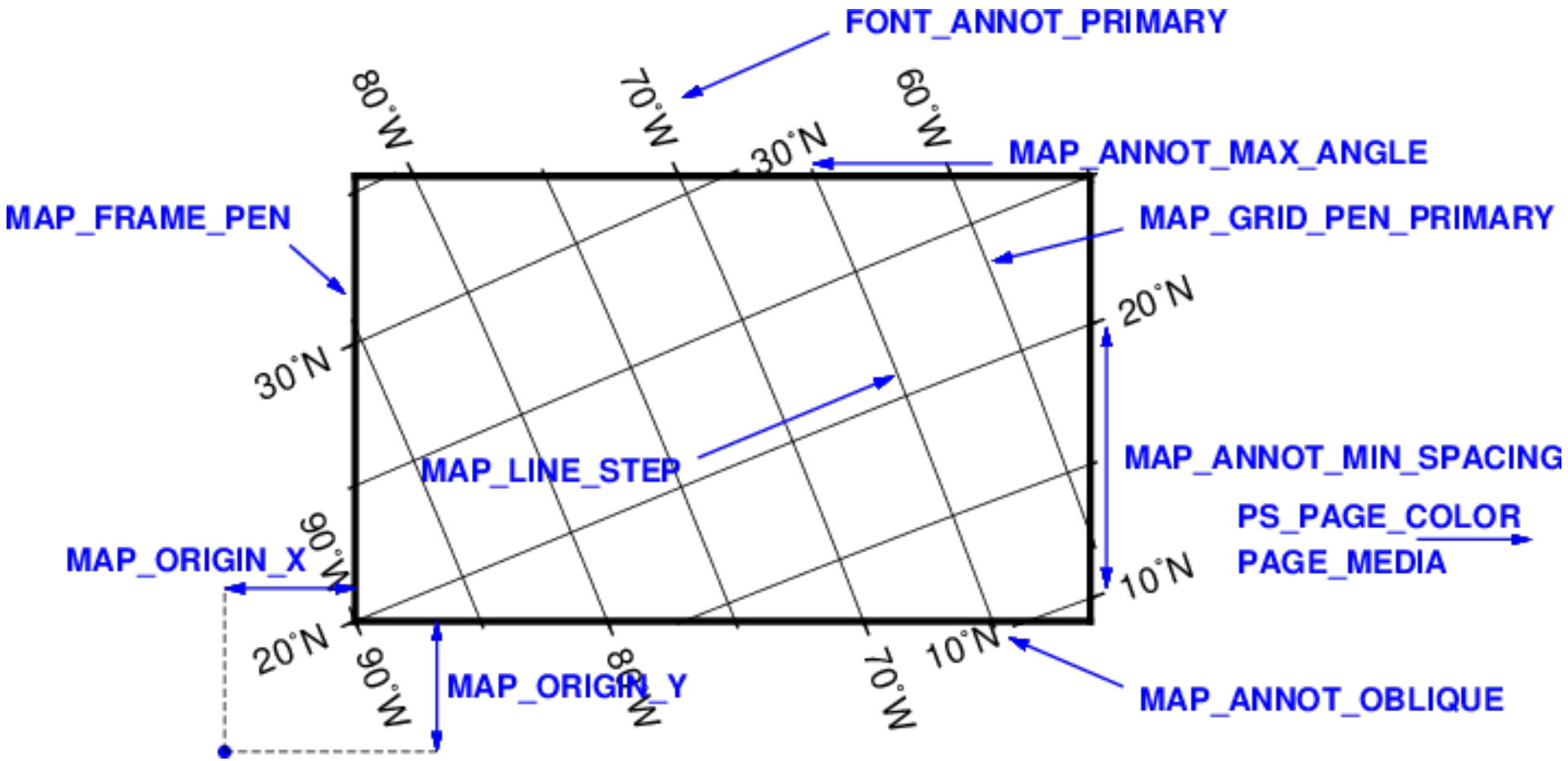


b) –**R***xlleft/ylleft/xuright/yuright* **r**

GMT defaults



GMT defaults



GMT defaults