Visualizing Geospatial Data with GMT

THE GENERIC MAPPING TOOLS

Generic Mapping Tools (GMT)

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

- Introduction ~30 min
  - What are GMT?
  - Examples of GMT maps/uses
- Part 1 - Getting Started ~60 min
  - Basic Syntax and commands
  - Map Projections/Coordinate Systems
  - Gridding and contouring datasets
  - Color/Illumination/Intensities
- Part 2 - Independent Mapping Project ~60 min

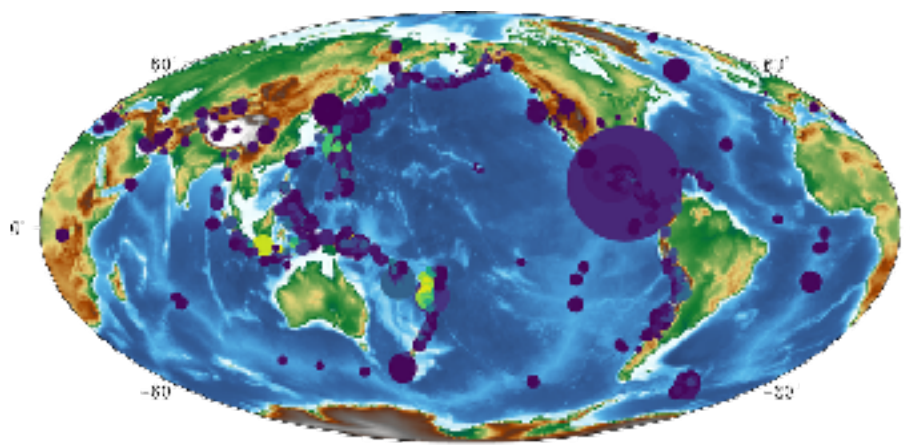
THE GENERIC MAPPING TOOLS

What are GMT?

- GMT is an open source collection of about 80 command-line 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 GMT?

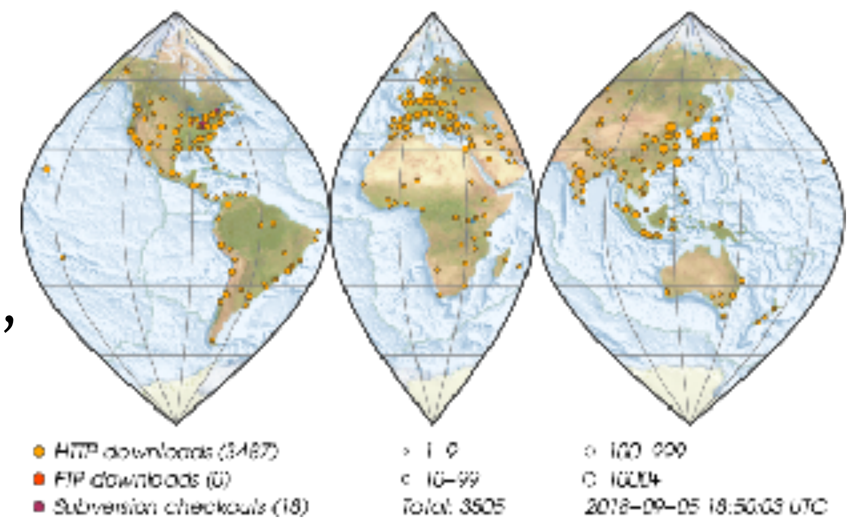
- PROS
  - Open Source (free!)
  - Powerful, flexible, and robust
  - High quality (.ps) output suitable for publication
- CONS
  - Steep learning curve
  - Not user friendly



Who uses GMT?

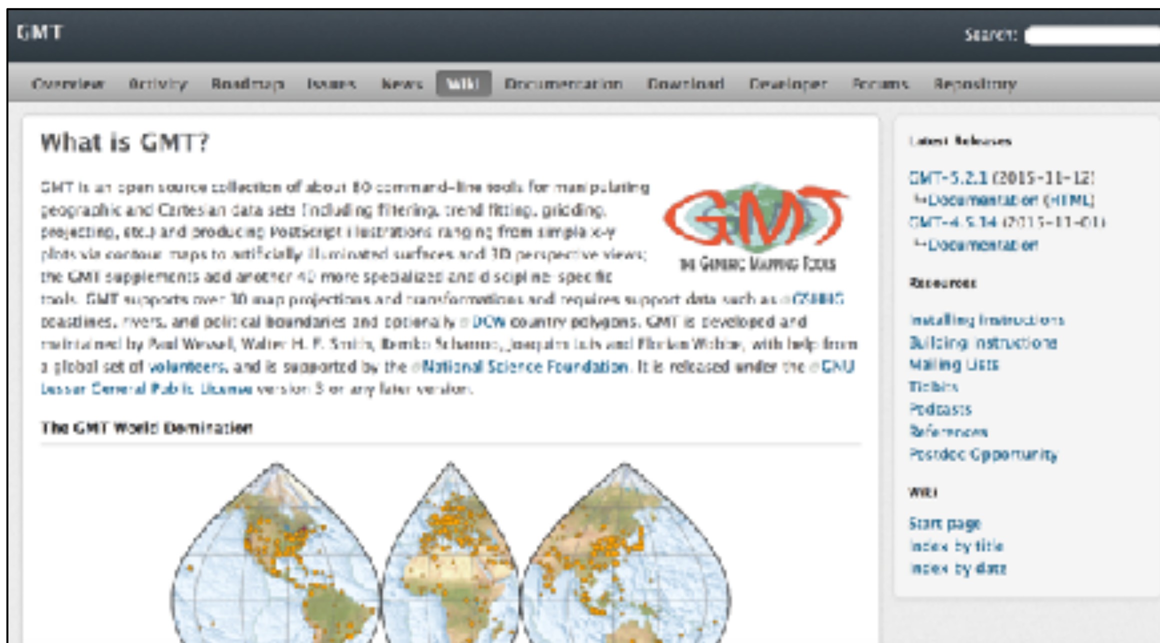
- Most users are Earth, ocean or planetary scientists

- Also used in
  - medical research,
  - engineering,
  - physics,
  - mathematics,
  - social and biological sciences,
- And by
  - geographers,
  - fisheries institutes,
  - oil companies,
  - a wide range of government agencies,
  - innumerable hobbyists.



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

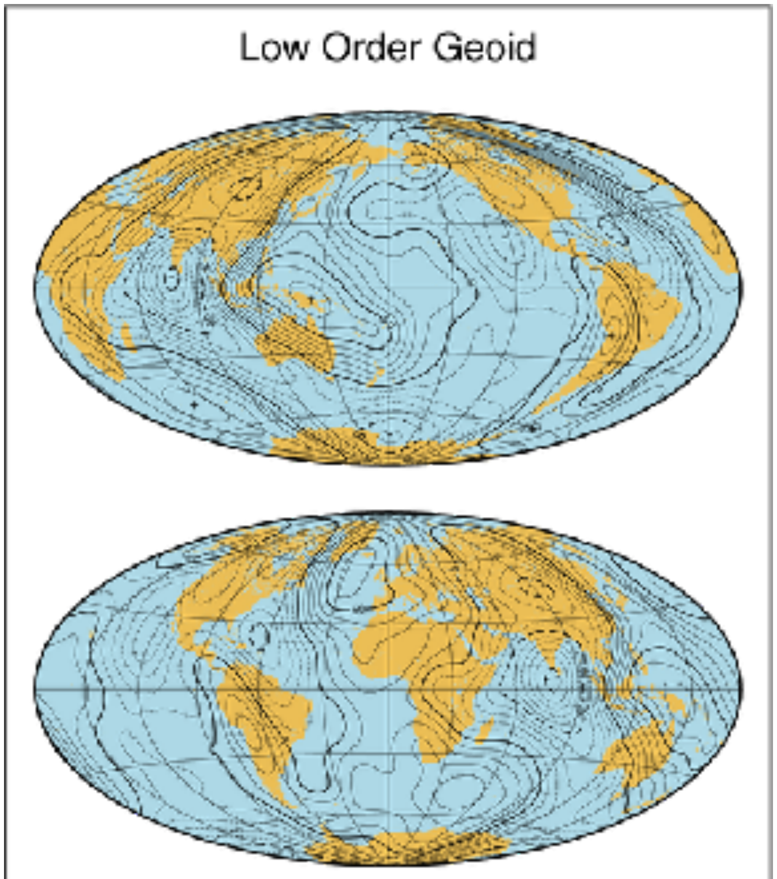


Python API - www.gmtpython.xyz

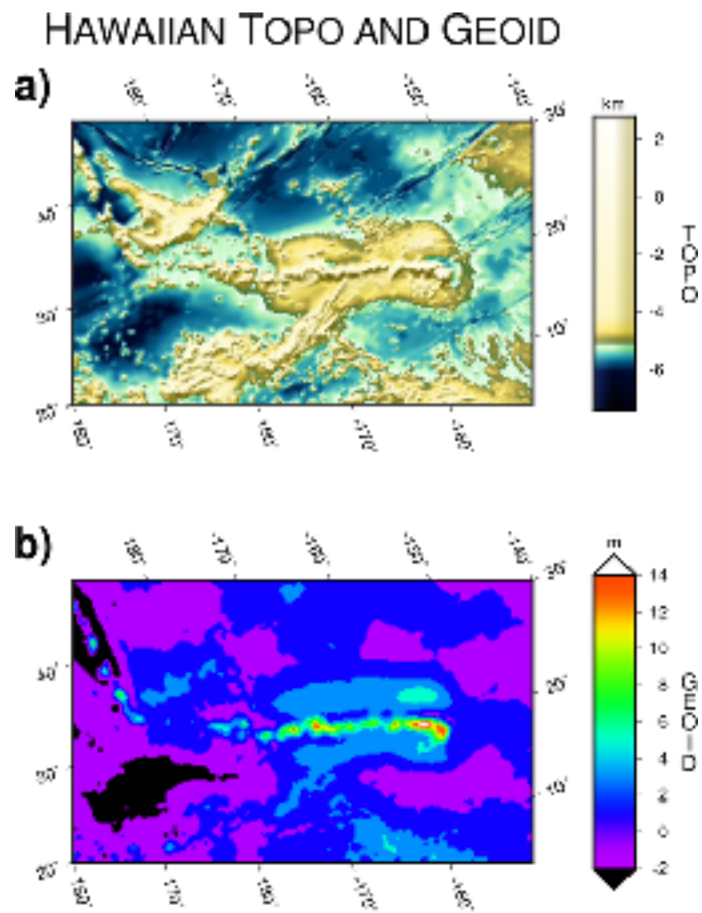
- Goal is modern API for Python programmers who want to use GMT
- Package is still in early stages of design and implementation
- This course will be taught using the Python API even though it is incomplete
  - Seamless integration
  - Only an introduction
  - The future of GMT
- Use distribution version for full functionality

GMT Examples

Contour Maps

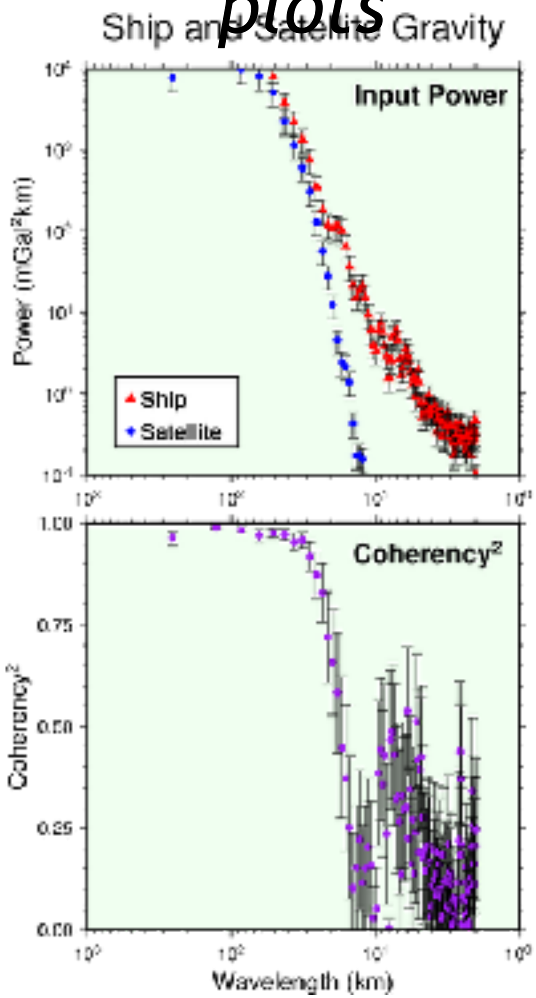


Topo and Geoid Maps



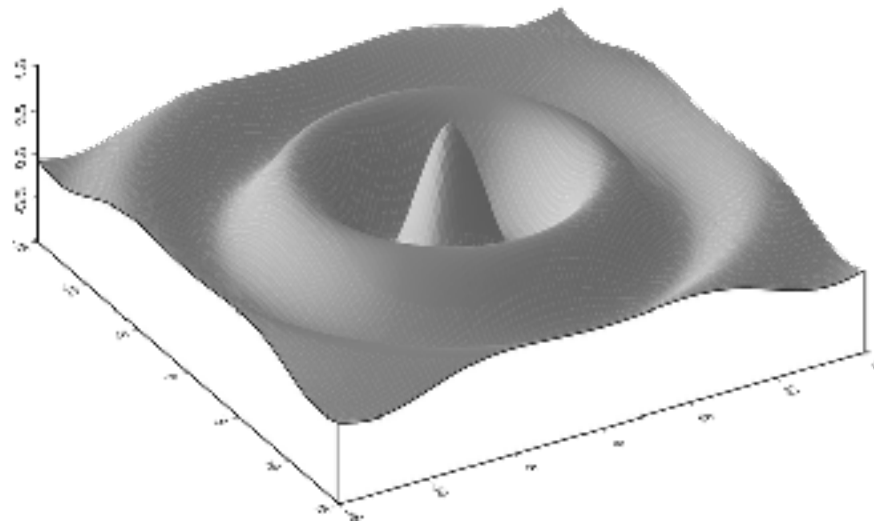
GMT Examples

Spectral Estimation and xy plots



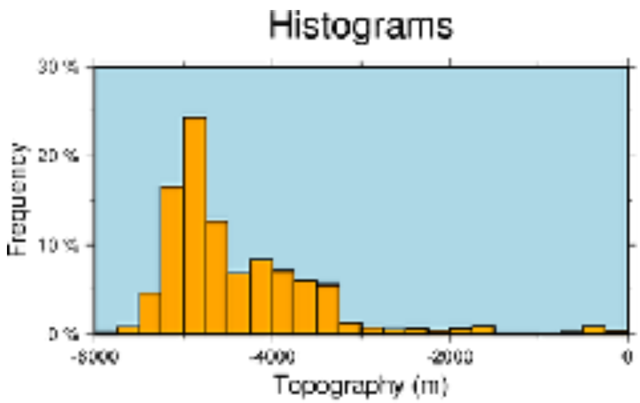
3D Perspective Mesh Plot

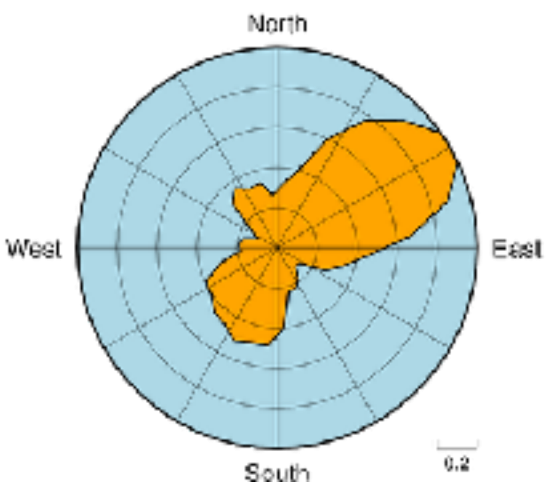
$$z(r) = \cos\,(2\pi r/8) \cdot e^{-r/10}$$



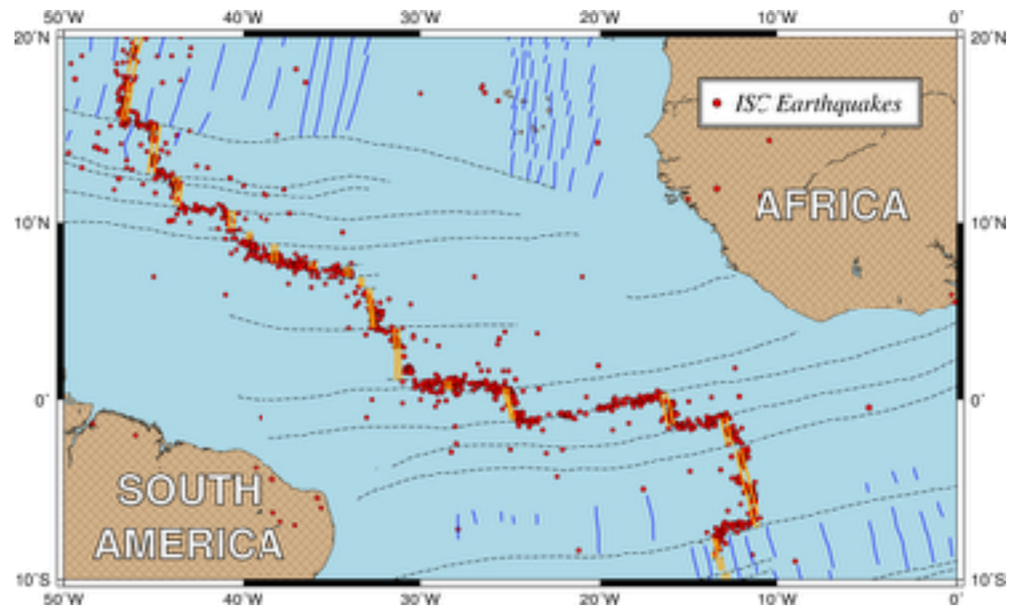
GMT Examples

Plotting of Histograms



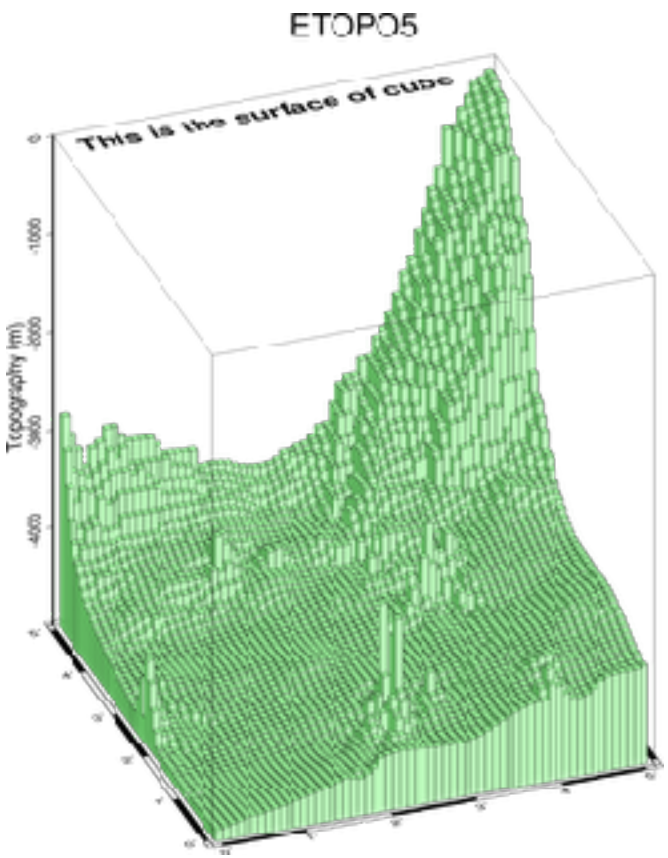


A Simple Location Map

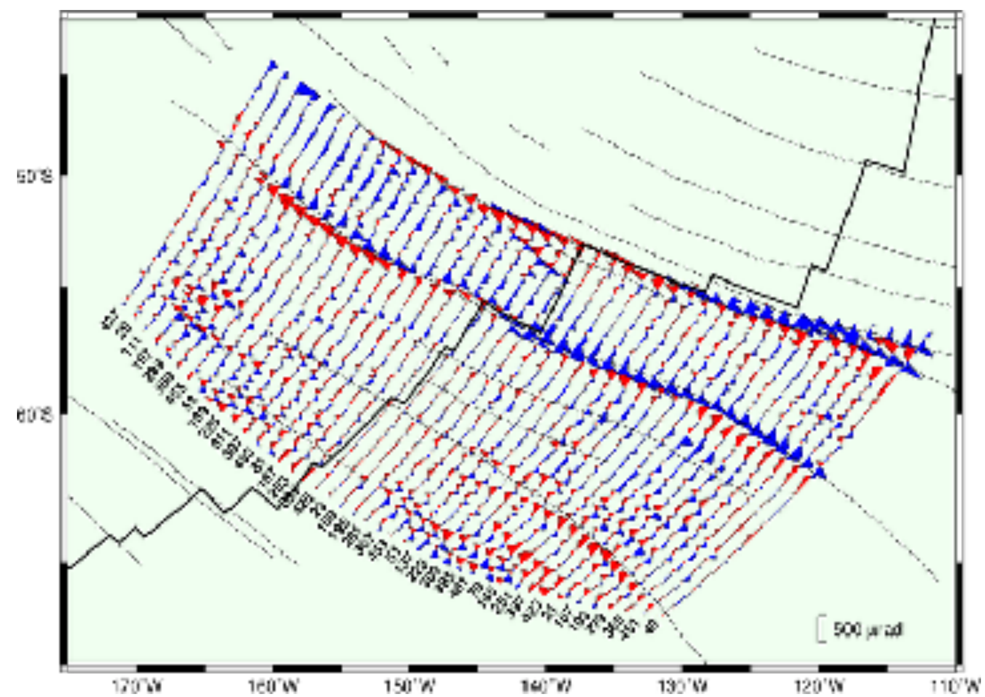


GMT Examples

3D Histogram

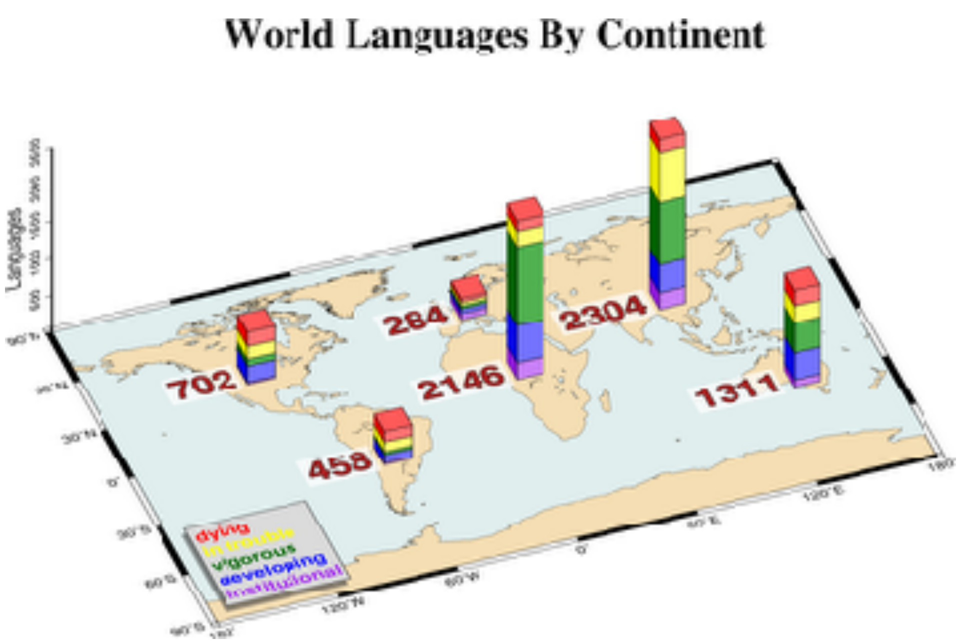


Time Series Along Tracks

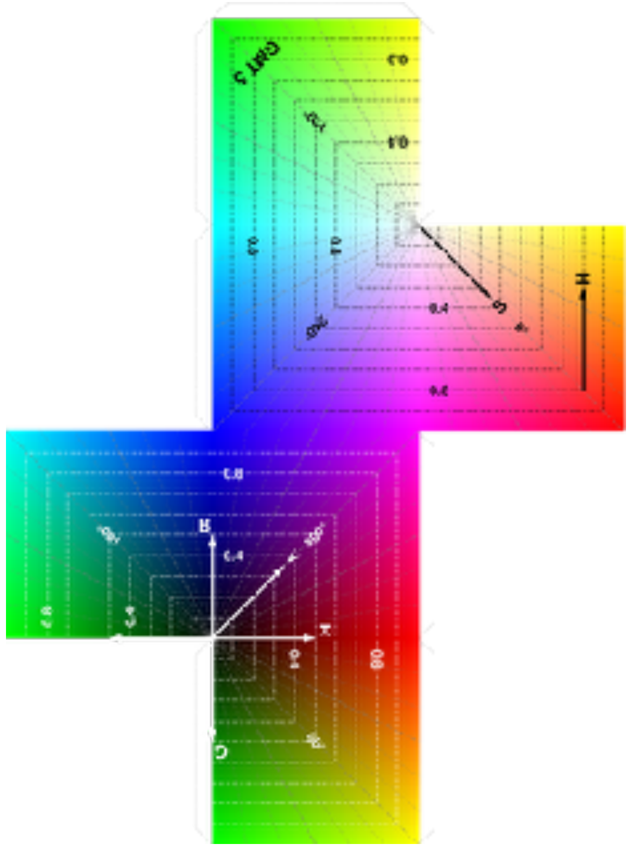


GMT Examples

Geographical Bar Graph Plot

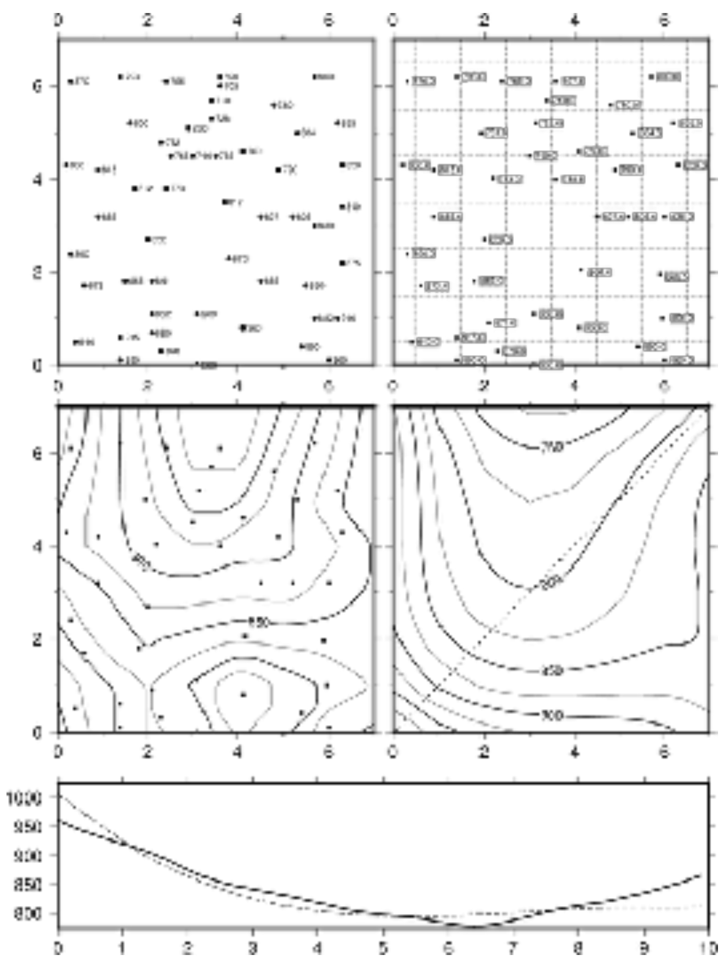


A 3D RGB Color Cube

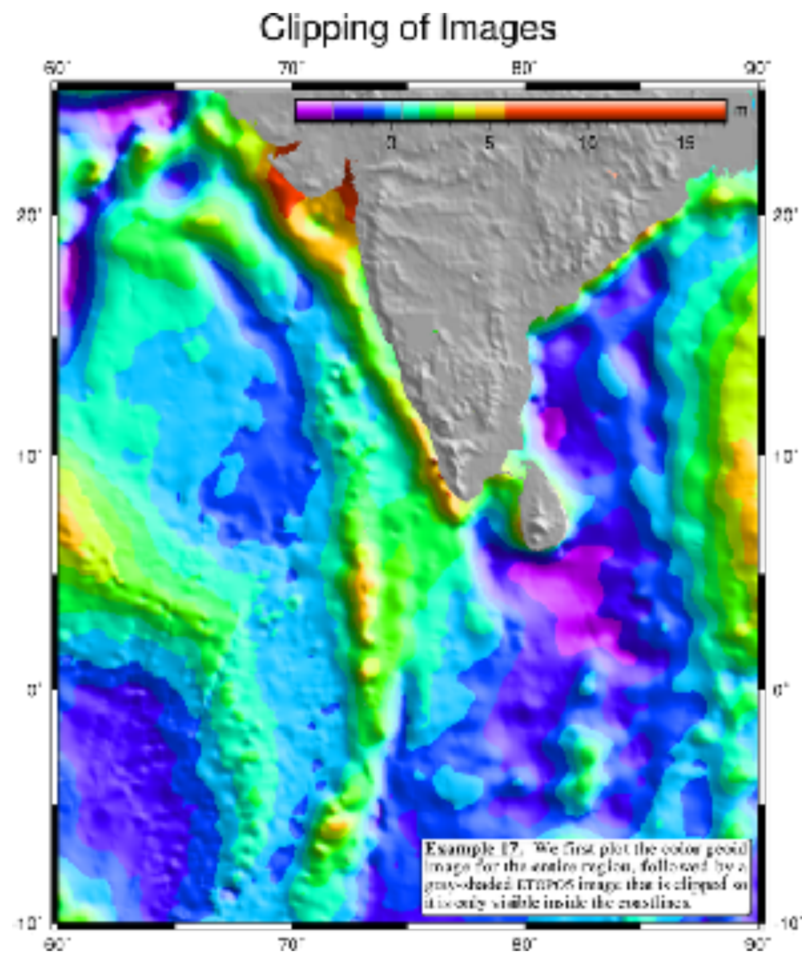


GMT Examples

Gridding of Data and Trend Surfaces

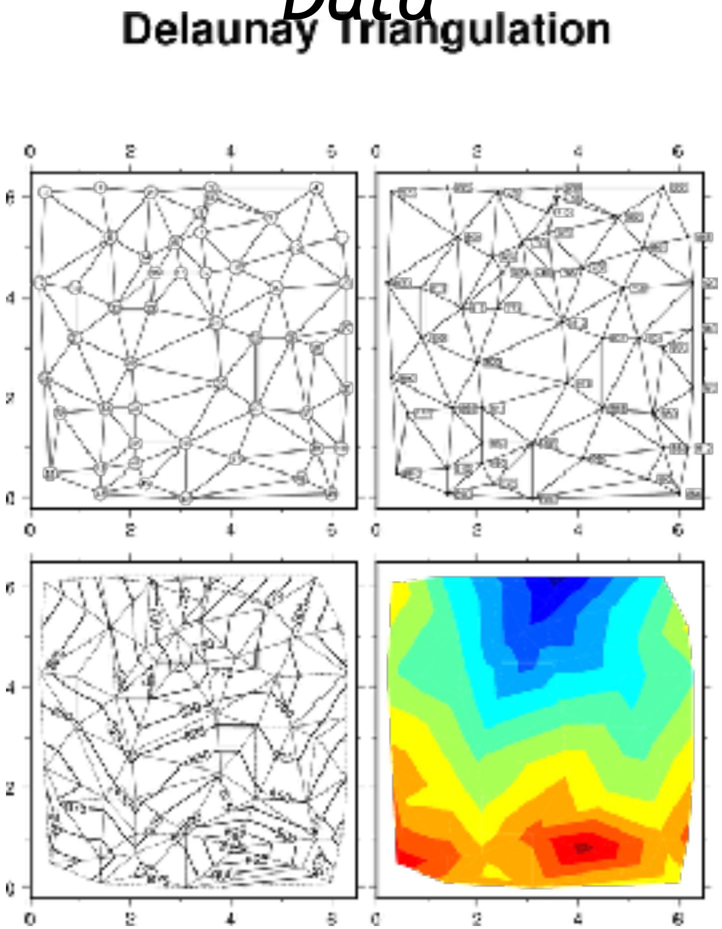


Images Clipped by Coastlines

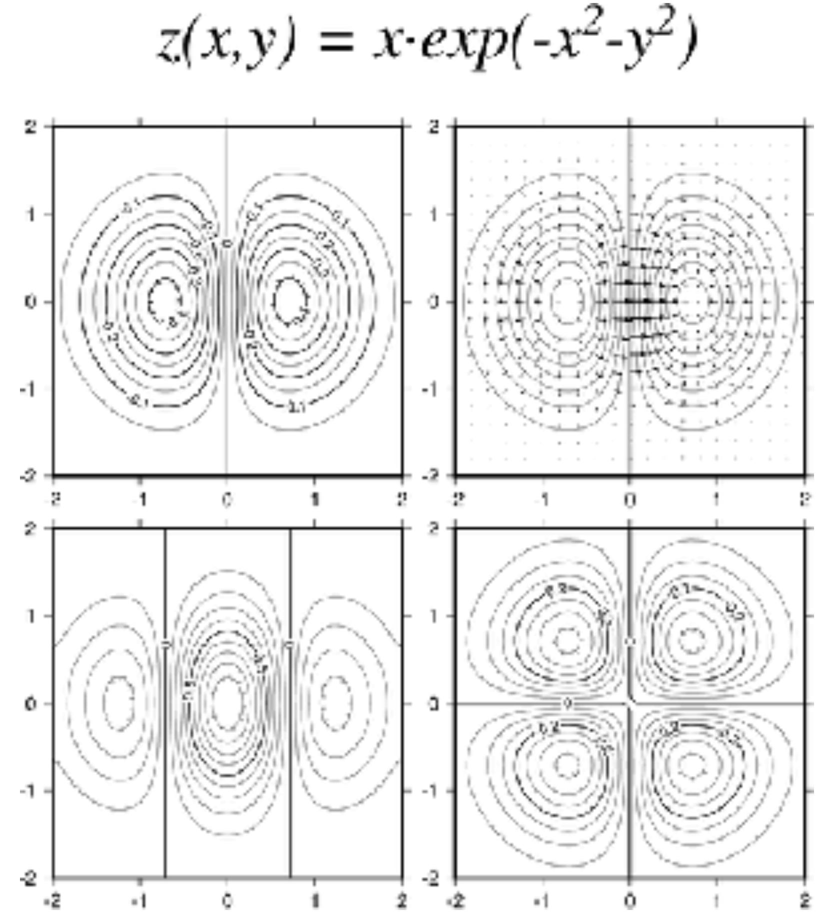


GMT Examples

Optimal Triangulation of Data

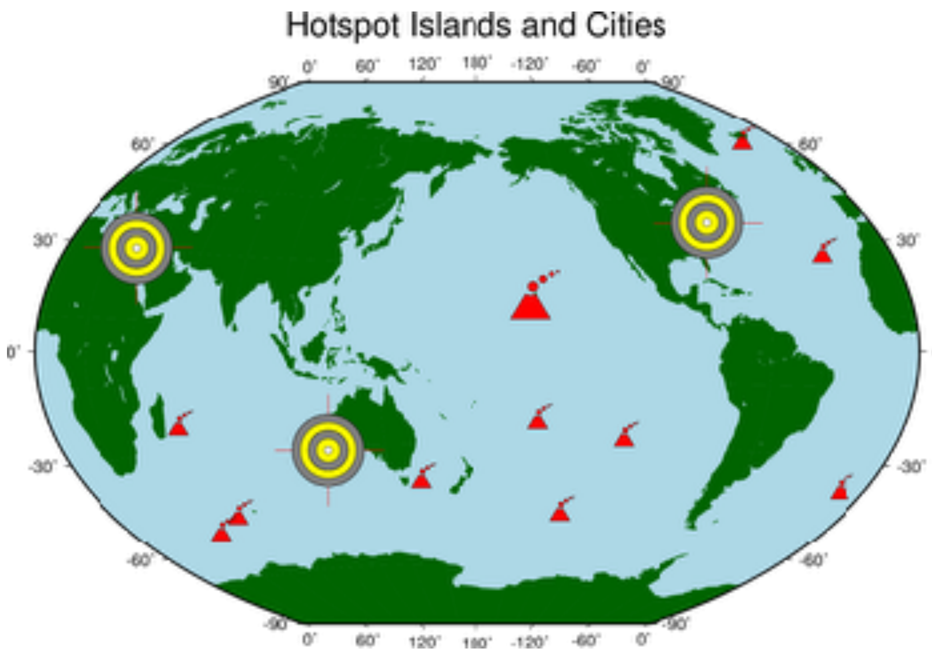


Plotting of Vector Fields

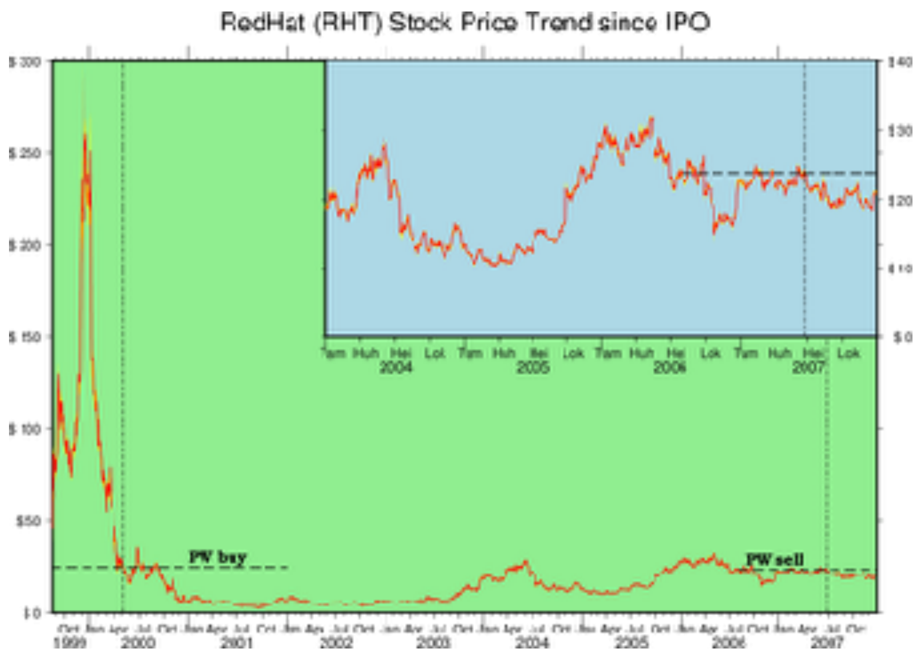


GMT Examples

Custom Plot and Symbols

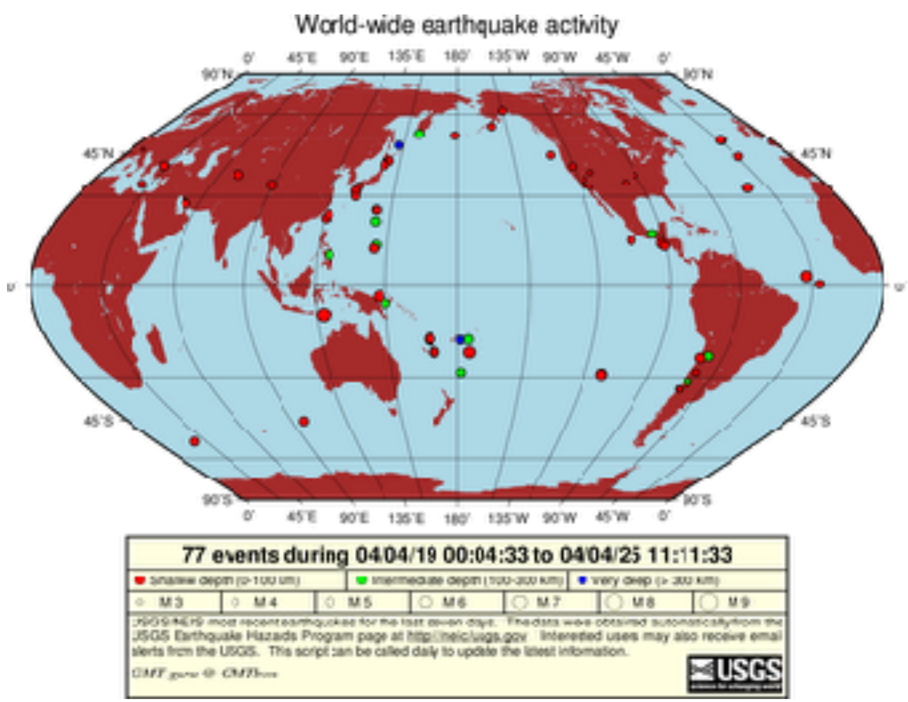


Time Series of Red Hat Stock Price

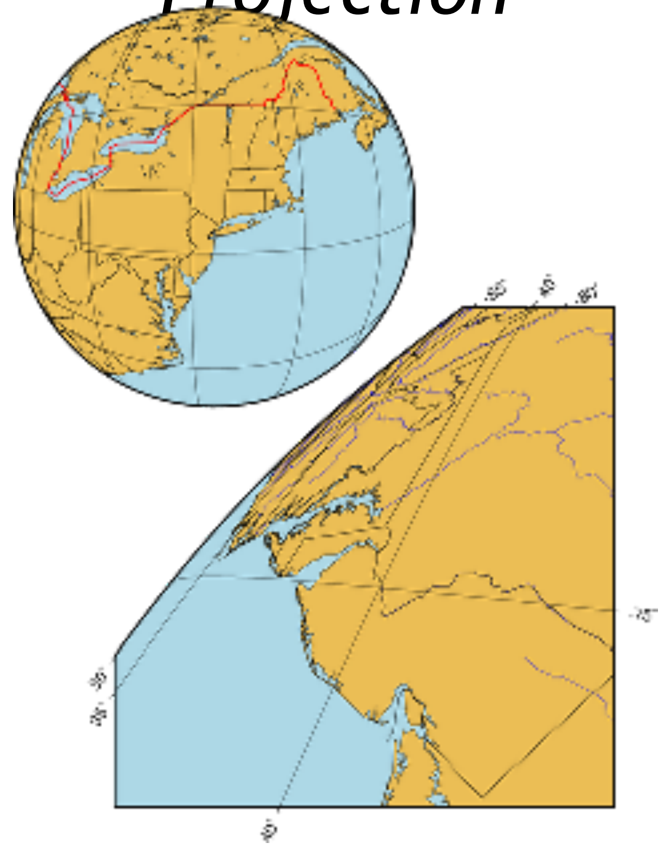


GMT Examples

Worldwide Seismicity Last 7 days

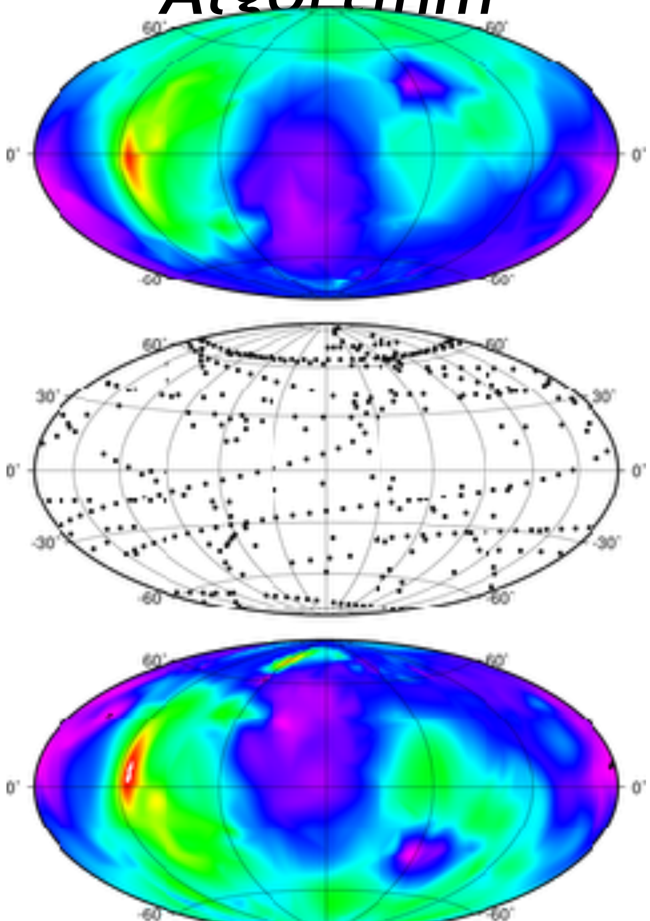


General Vertical Perspective Projection

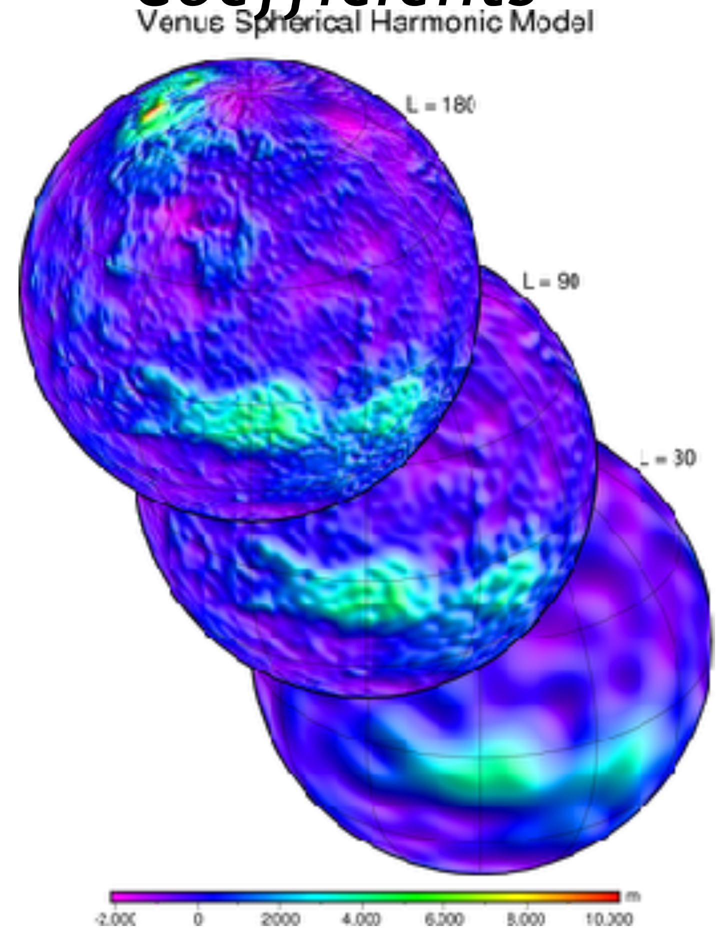


GMT Examples

Spherical Gridding using Renka's Algortihm

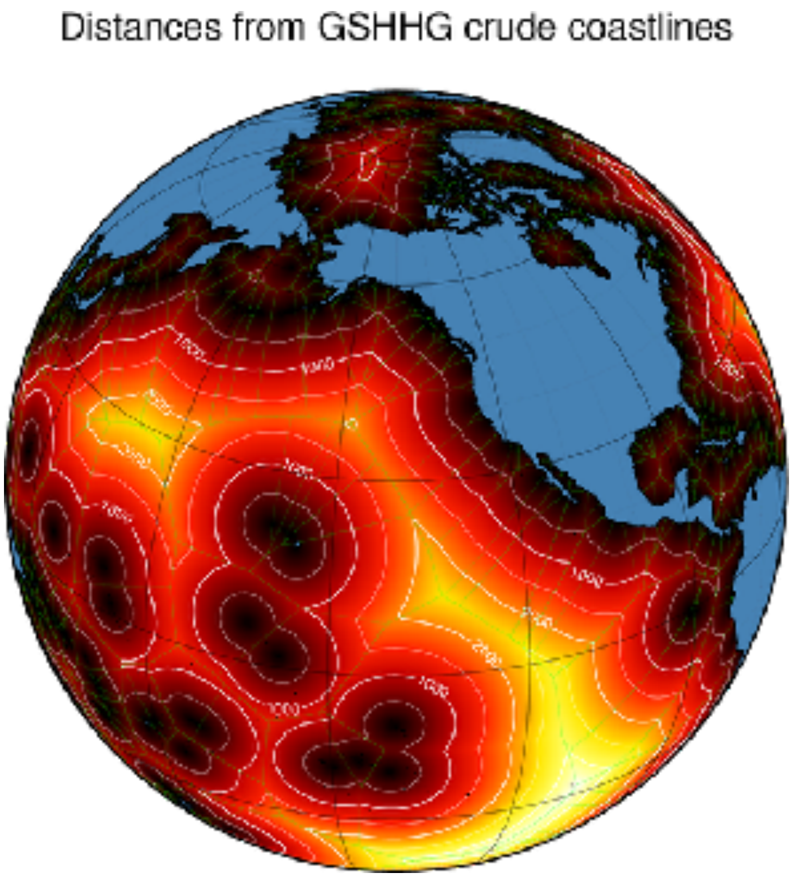


Evaluation of Spherical Harmonics Coefficients

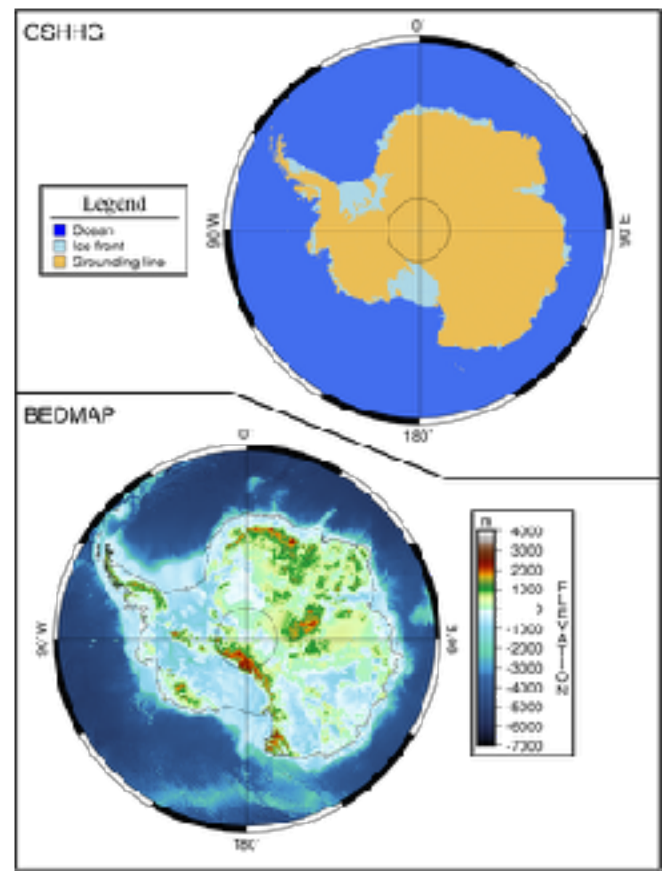


GMT Examples

Spherical Triangulation and Distance Calculations

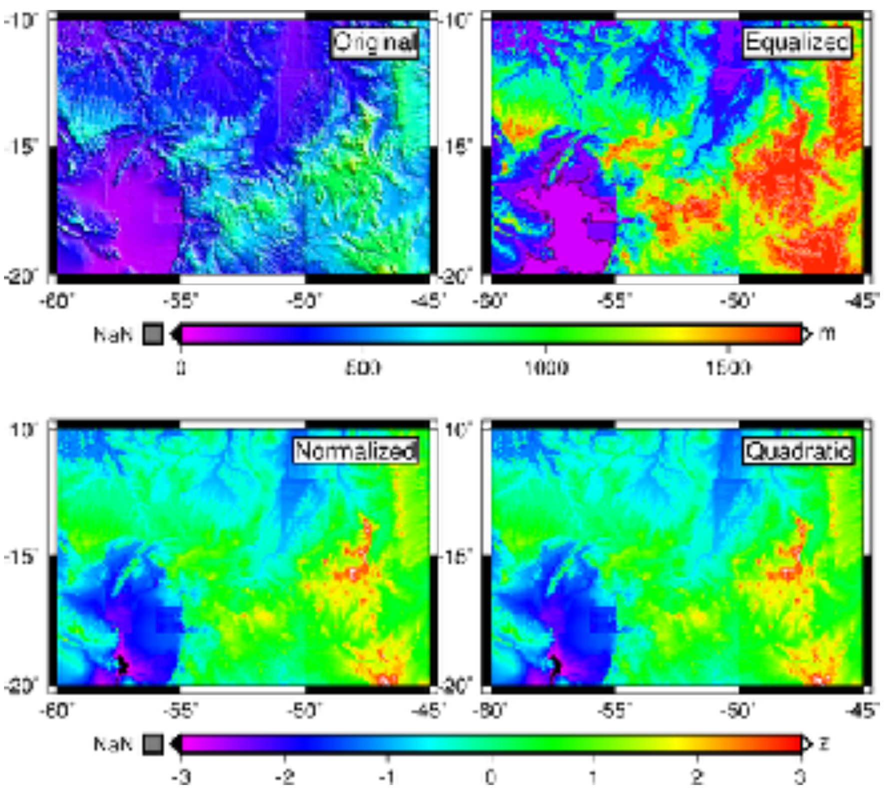


Antarctica and Stereographic Projections

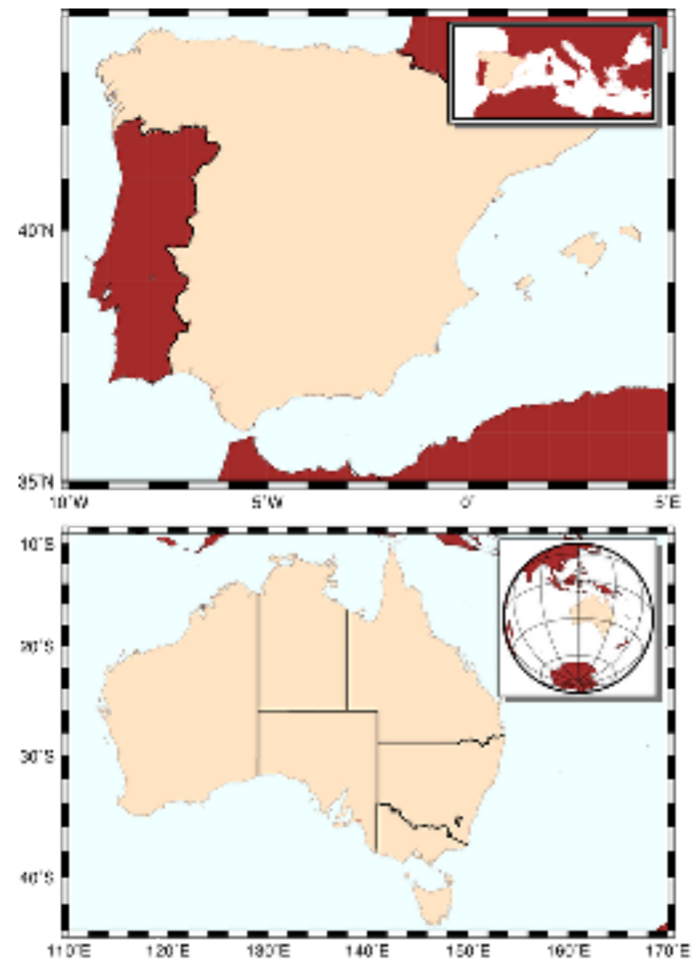


GMT Examples

Histogram Equalization of Bathymetry Grids



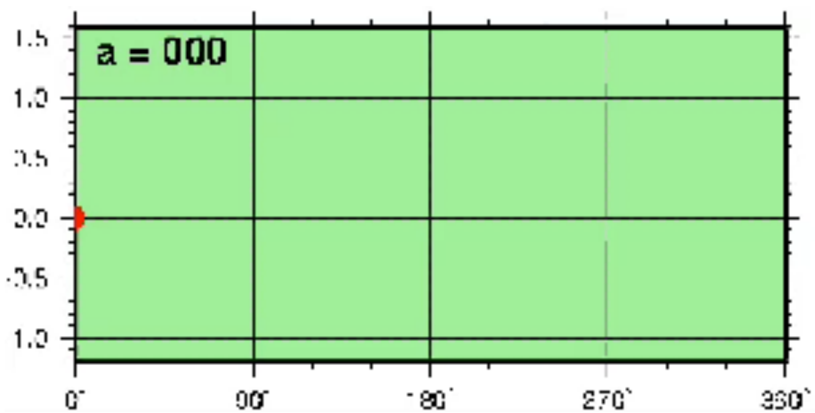
Map Insets

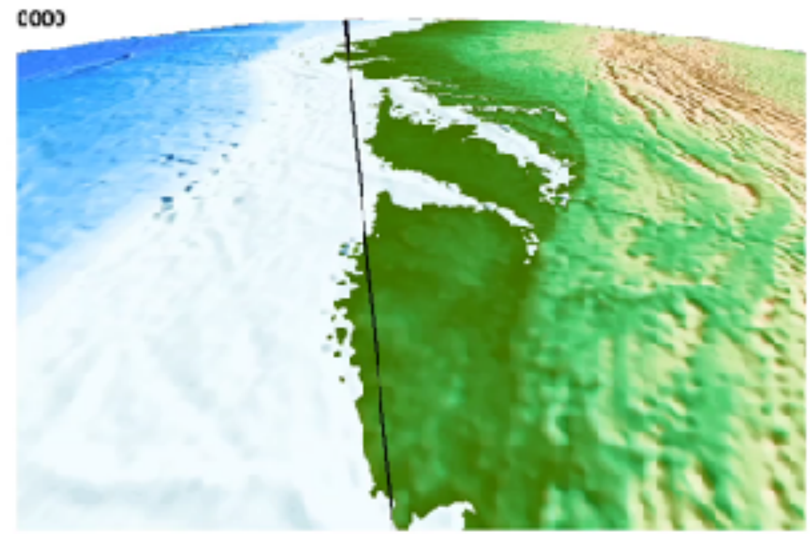


GMT Examples

Animation of Sine Function

Topography Flyover





Getting Started w/ GMT

- Run GMT API through Python
- Type ‘source activate gmt-python’ from a terminal window
- Type ‘jupyter-notebook’ to launch Jupyter
- Open the notebook ‘first-steps.ipynb’ available on the git repository

My first map

GMT command line syntax

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

GMT Python API syntax

fig.coast(region=[-90, -70, 0, 20], projection='M6i', land='chocolate', frame=True)

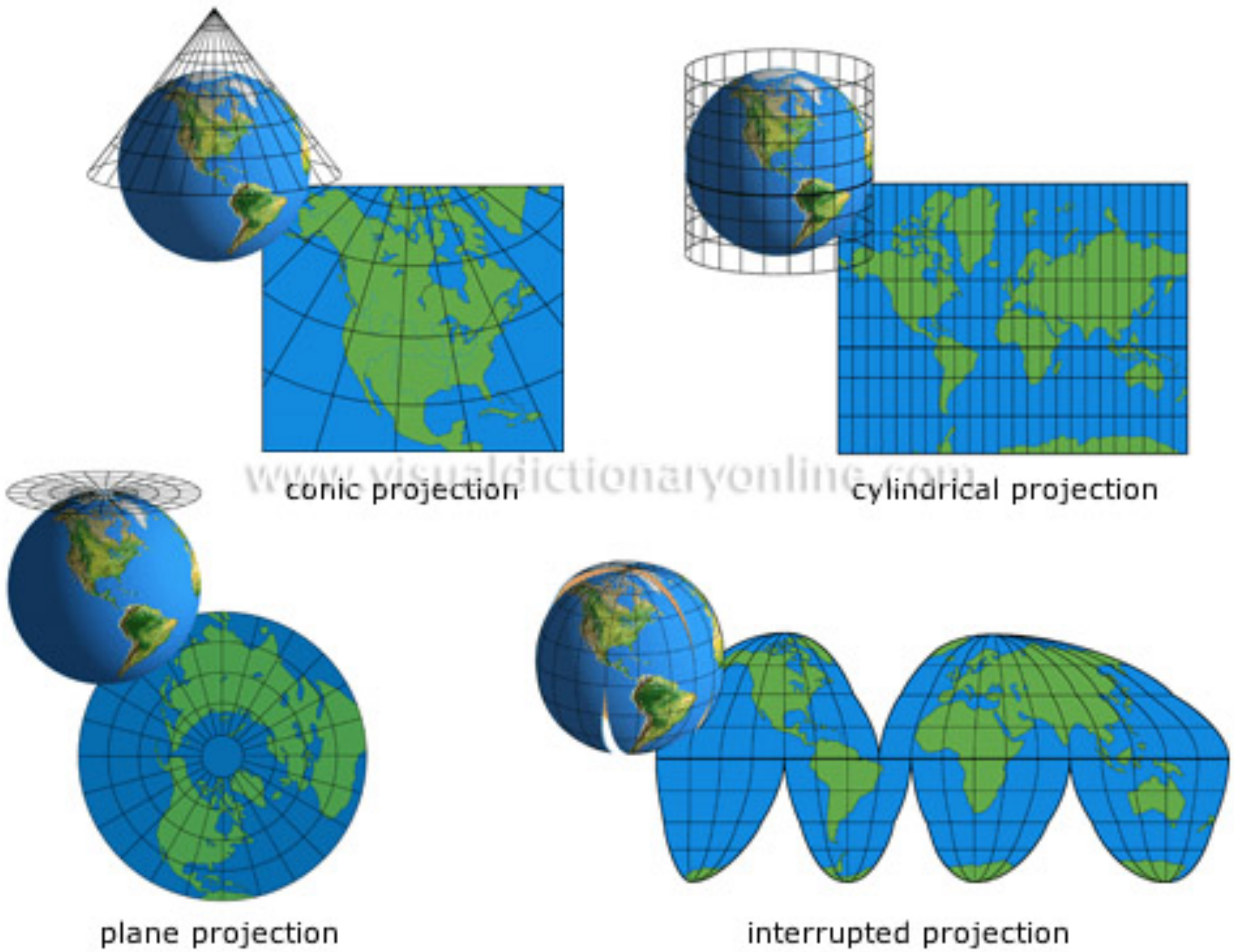
GMT Python API using command line syntax

fig.coast(R='-90/-70/0/20', J='M6i', G='chocolate', B=True)

Exercises:

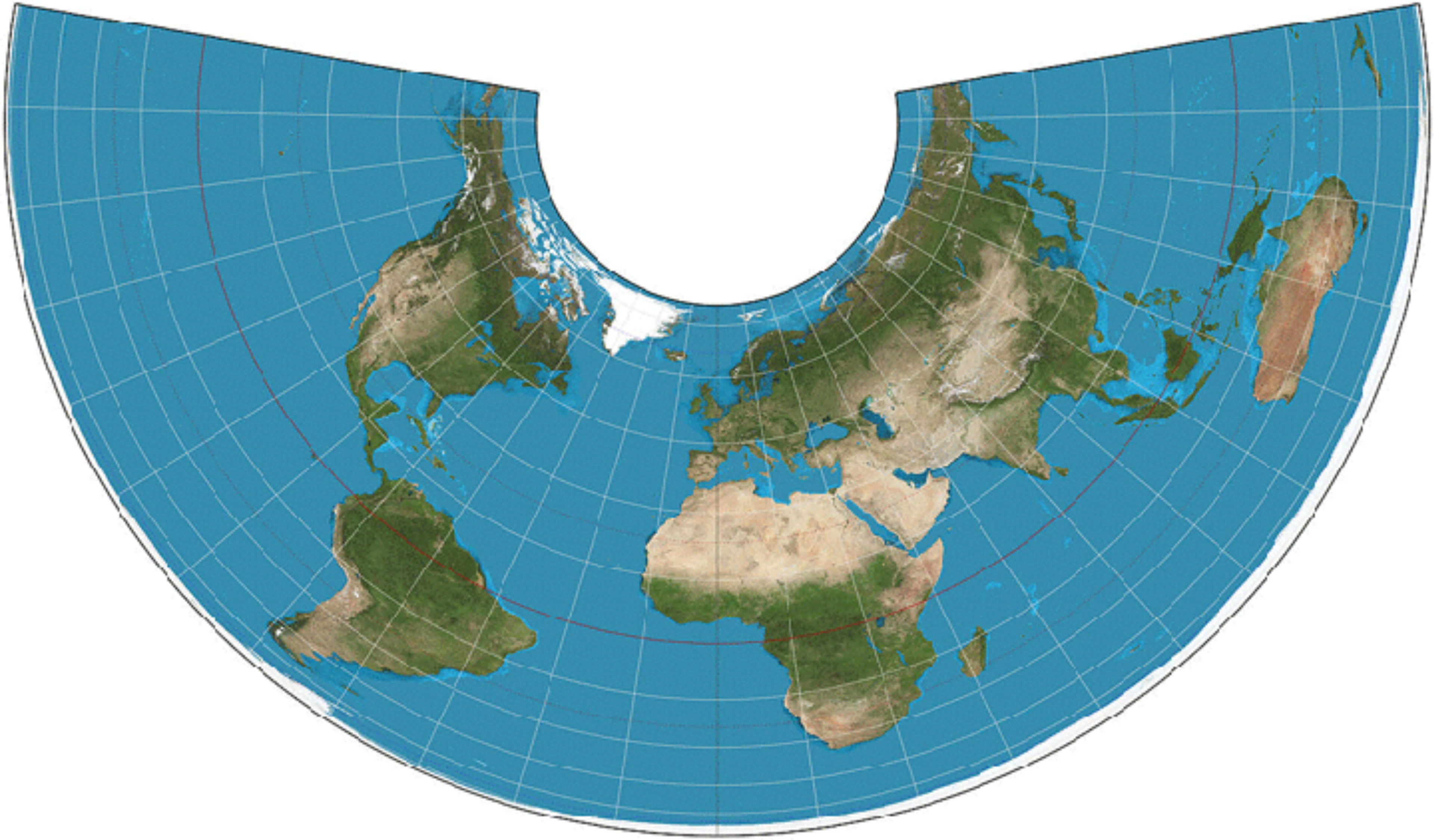
1. Pick another land color
2. Pick another water color
3. Pick a region that includes the north or south poles.
4. Try **-W**0.25**p** instead of (or in addition to) **-G**. This is the pen alias in GMT.
5. What is the map projection?

3 Basic Types of Map Projections

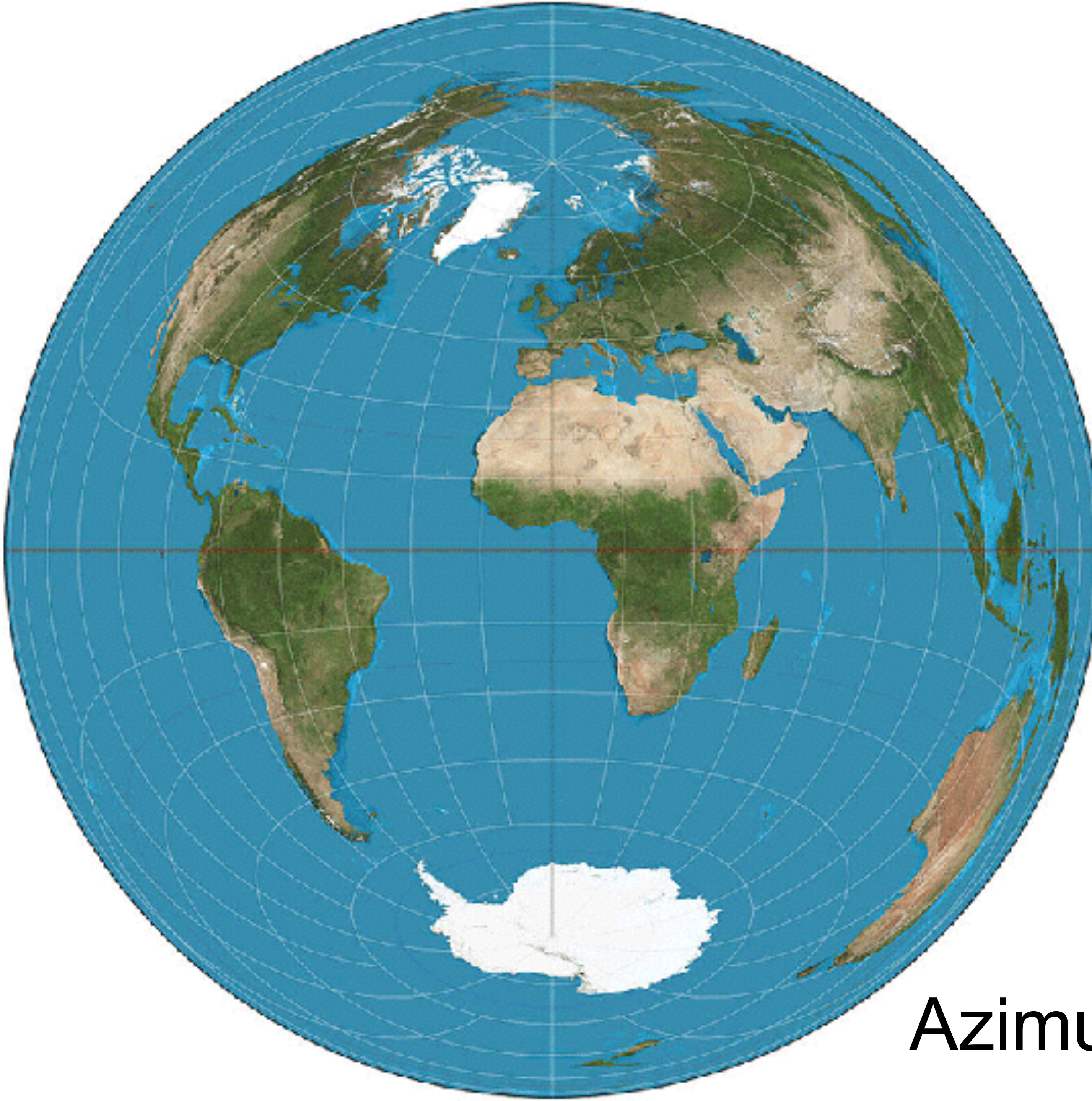


https://en.wikipedia.org/wiki/List_of_map_projections


Cylindrical

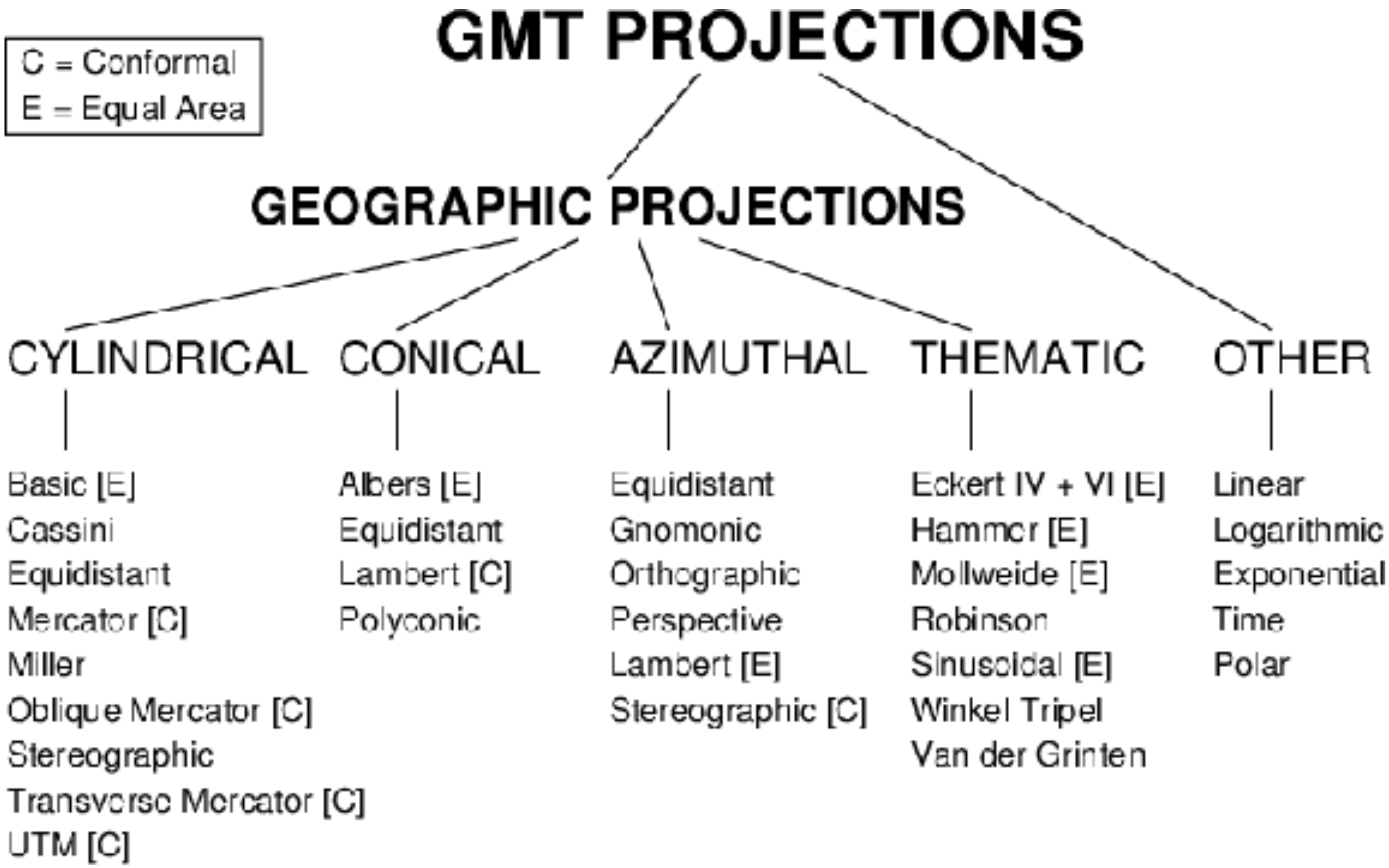


Conical



Azimuthal

Available GMT projections



Map Projections

- https://www.jasondavies.com/maps/transition/

Orthographic Projection

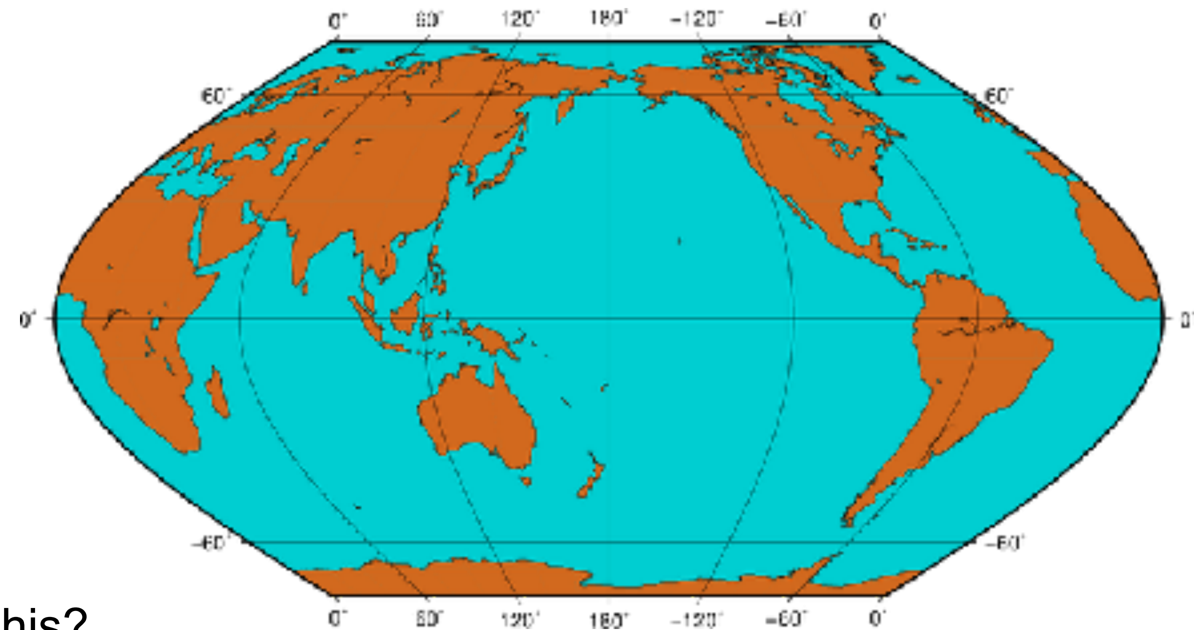
gmt pscoast -Rg -JG280/30/6i -Bag -Dc -A5000 -Gwhite -SDarkTurquoise -P > GMT_tut_5.ps

Exercises:

1. What type of map projection is shown?
2. Write this command and create this map using Python GMT
3. Use the rectangular option in **-R** to make a rectangular map showing the US only.

Eckert VI Projection

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



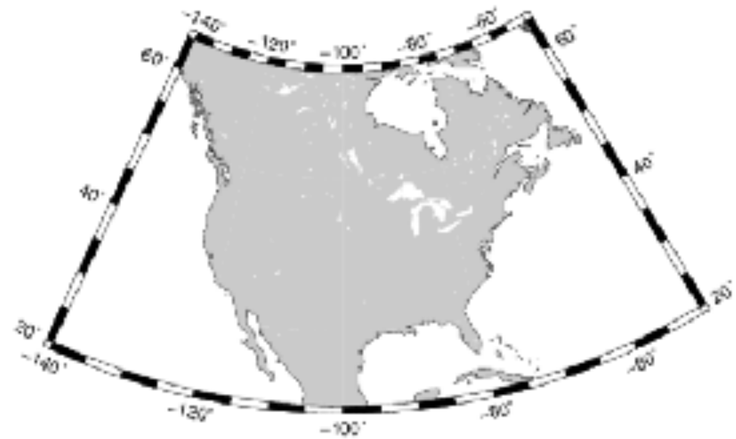
Exercises:

1. What type of projection is this?
2. Rewrite the command in Python GMT
3. Center the map on Greenwich.
4. 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

What is the map projection?



Rewrite thecommand in GMT Python and add the following features to your map:

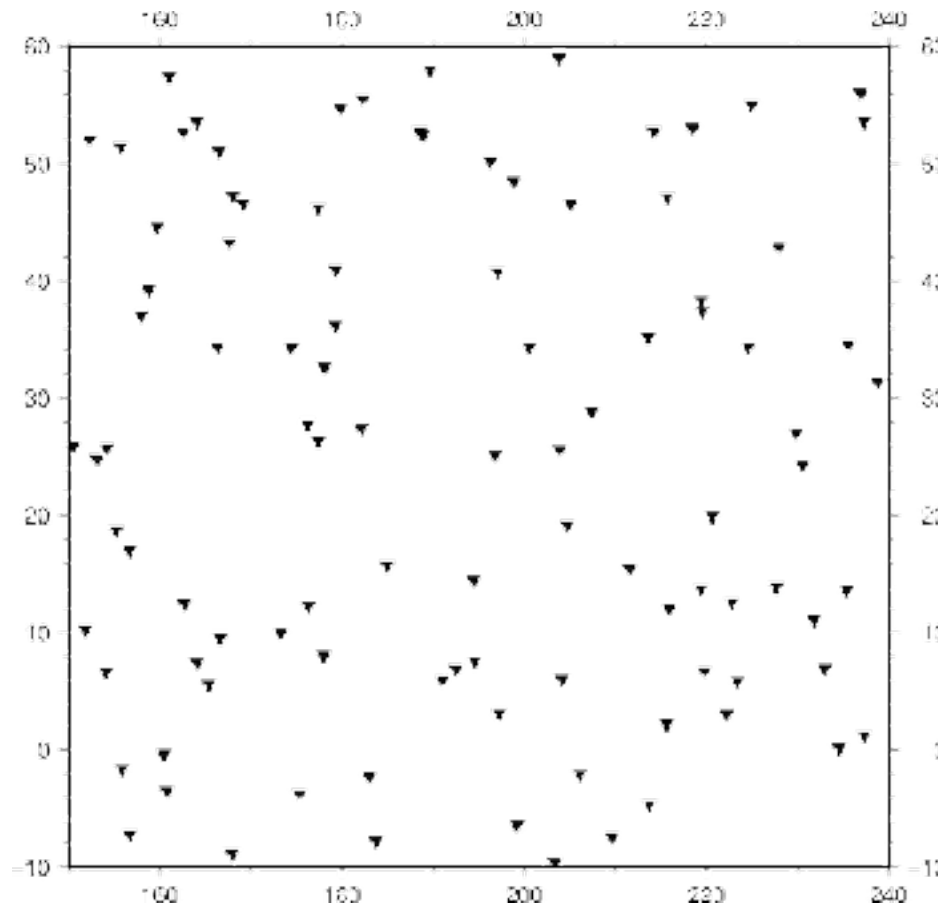
- Longitudinal interval marks every 20º
- Latitudinal interval marks every 10º
- Light brown land masses
- Light blue oceans
- Intermediate resolution coastlines
- 1500 km long map scale in bottom right corner
- 7.5 inches wide
- All major rivers in blue pen
- State boundaries in dashed black pen
- Country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

Linear Projection for XY plots

1. Can you recreate this plot in matplotlib? How?

2. Try plotting your example dataset from Tuesday’s matploblib tutorial.

3. Which is easier?



Independent Mapping Project

1. Pick your favorite continent, country, or region.
2. Create a map that shows the topography/bathymetry of your area.
3. Plot some point data on your map
    - Earthquakes
    - Volcanoes
    - Airport locations
    - Beaches
    - Lightning strikes
4. Save your map for upload to the git repository
5. Display your map on a Nasa WorldWind globe

Be prepared to say what map projection you choose and why.

Some ideas include plot recent seismicity on Hawaii, plot volcano locations in Alaska, plot LIGO data on a map etc.

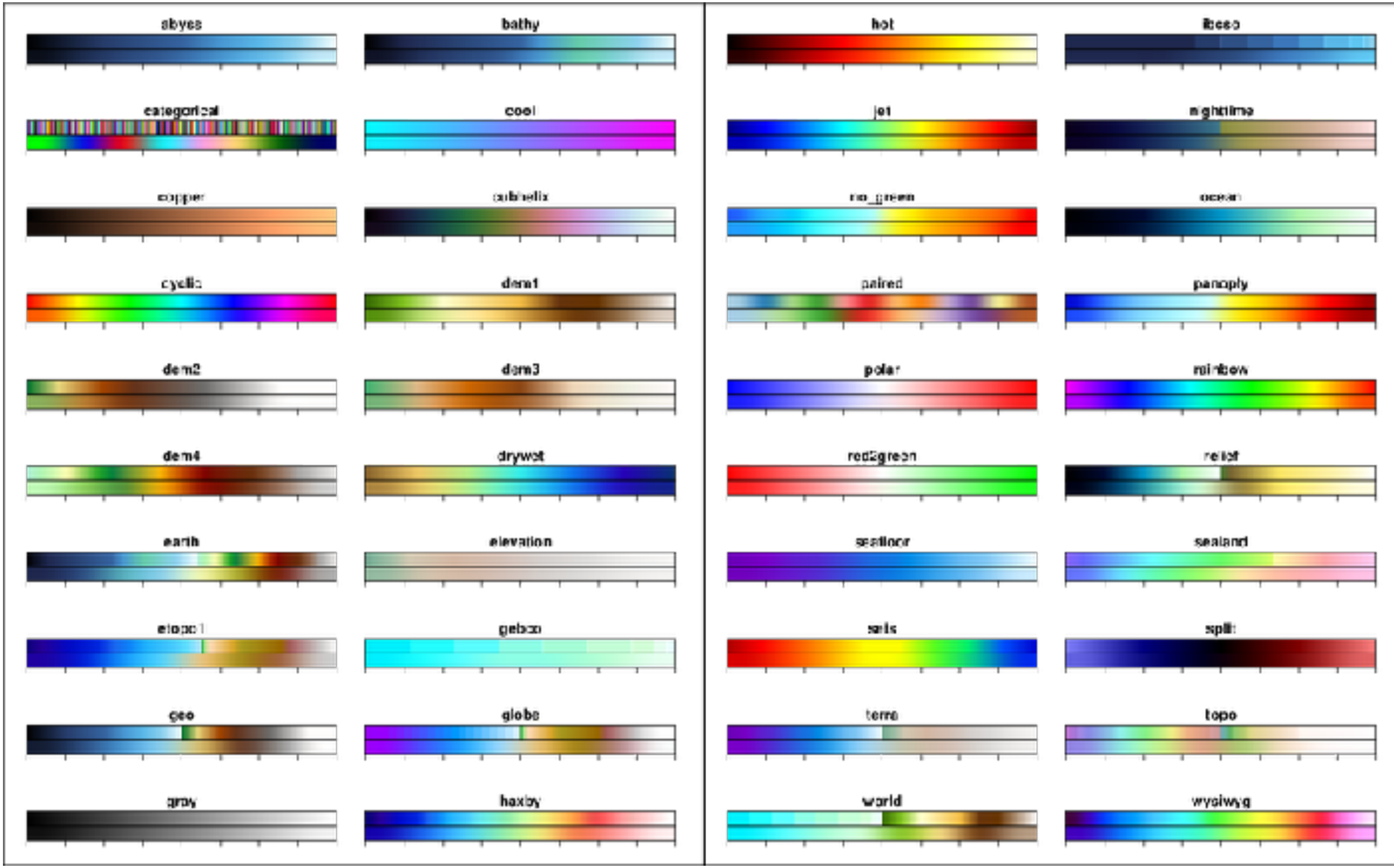
LIGO data exercises

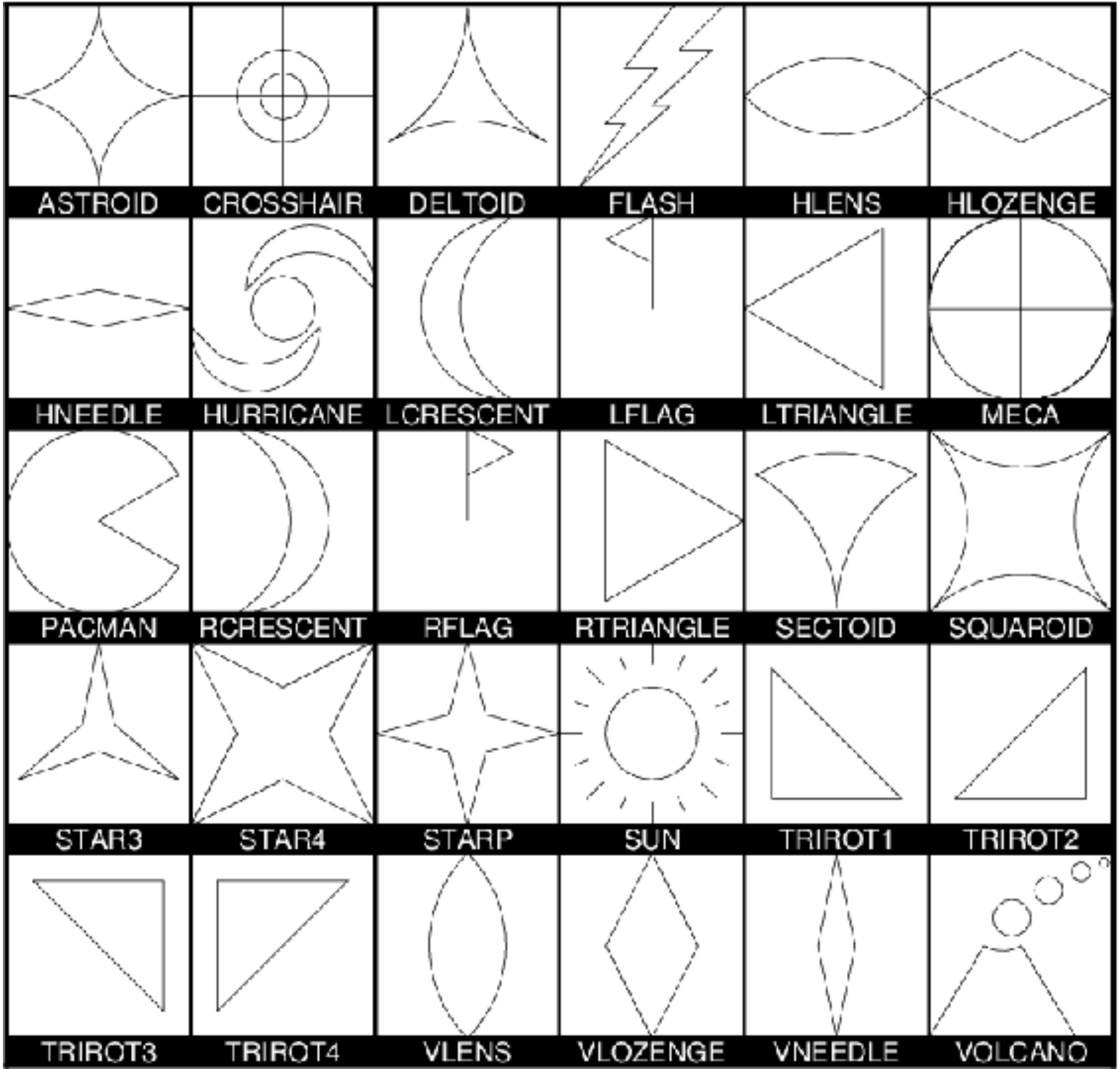
- Plot L1 data
- Plot H1 data
- Plot L1 data overlaid on H1 data
- Plot L1 and H1 station locations on a map showing their geospatial relationship
- Plot observed data as inset on map
- Plot line connecting Hanford and Livingstone stations. Is it straight? What if you change the map projection?
- Add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

Example Datasets

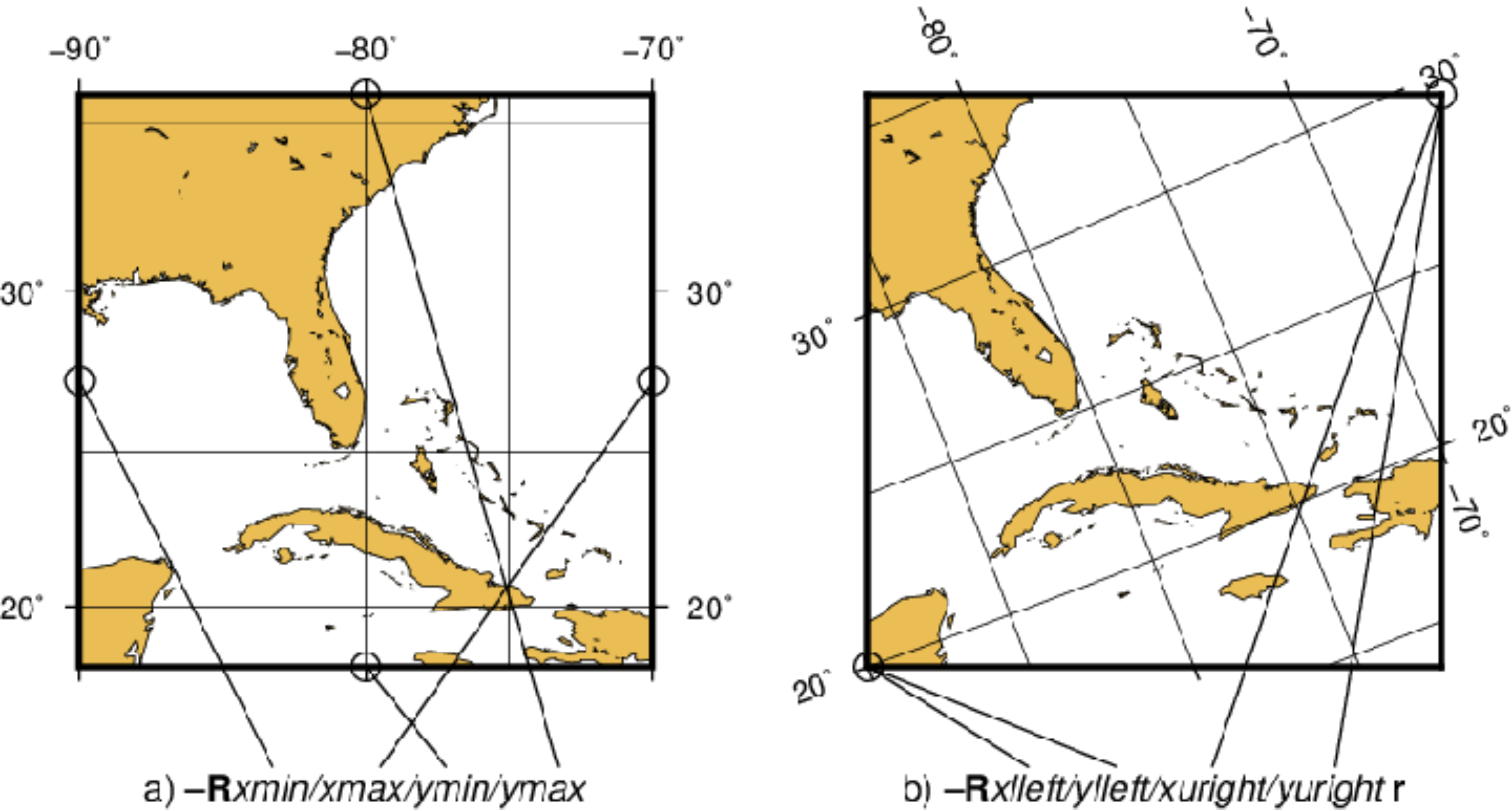
- Global topography/bathymetry data
  - https://www.ngdc.noaa.gov/mgg/global/
- LIGO data
  - https://losc.ligo.org/data/
- Earthquakes
  - https://earthquake.usgs.gov/earthquakes/search/
- Volcanoes
  - https://sos.noaa.gov/datasets/volcano-locations/

Some Useful References

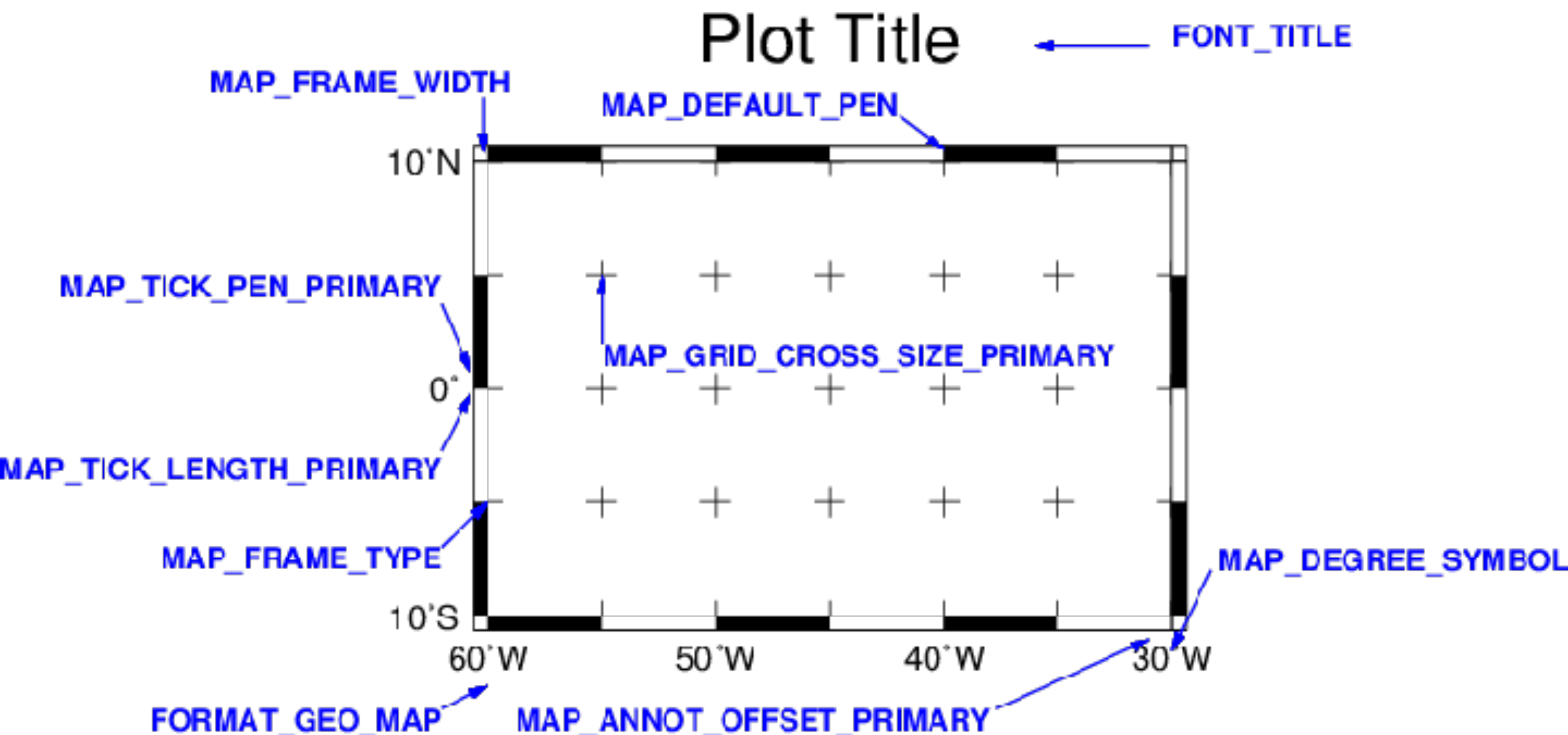



ASTROID
CROSSHAIR
DELTOID
FLASH
HLENS
HLOZENGE
HNEEDLE
HURRICANE
LCRESCENT
LFLAG
LTRIANGLE
MECA
PACMAN
RCRESCENT
RFLAG
RTRIANGLE
SECTOID
SQUAROID
STAR3
STAR4
STARP
SUN
TRIROT1
TRIROT2
TRIROT3
TRIROT4
VLENS
VLOZENGE
VNEEDLE
VOLCANO

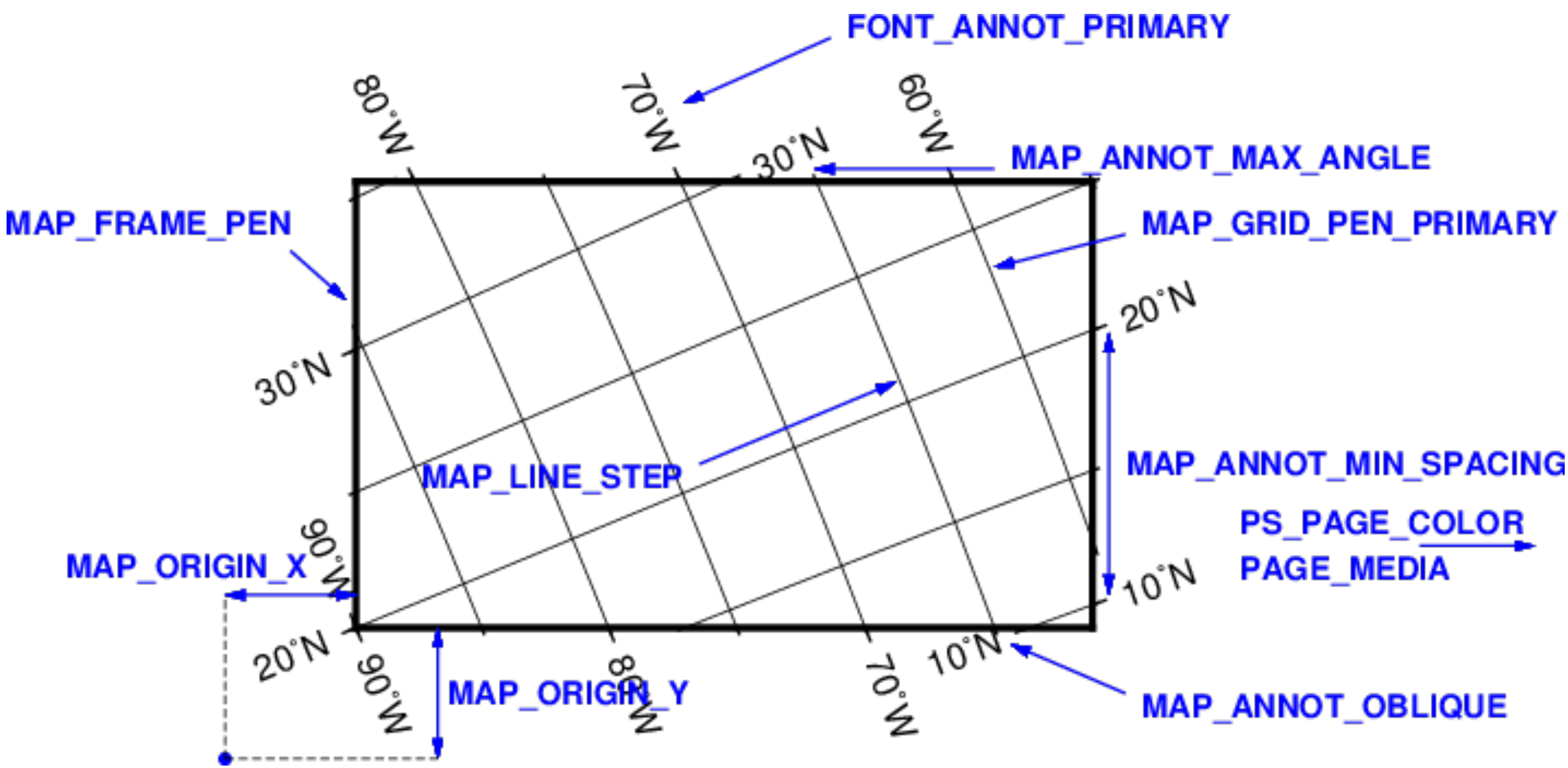
Map Region: the –R option



GMT defaults



GMT defaults



GMT defaults