# Mapping and modeling Earth Science Data

*Segment II: Making maps with GMT, an introduction*

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# The problem

- Produce publication quality plots (including $x - y$) and geographic maps
- Achieve flexibility and automated processing (which requires modularity and script based operation)
- Do it the open source way (low cost, high transparency, high portability, high robustness)

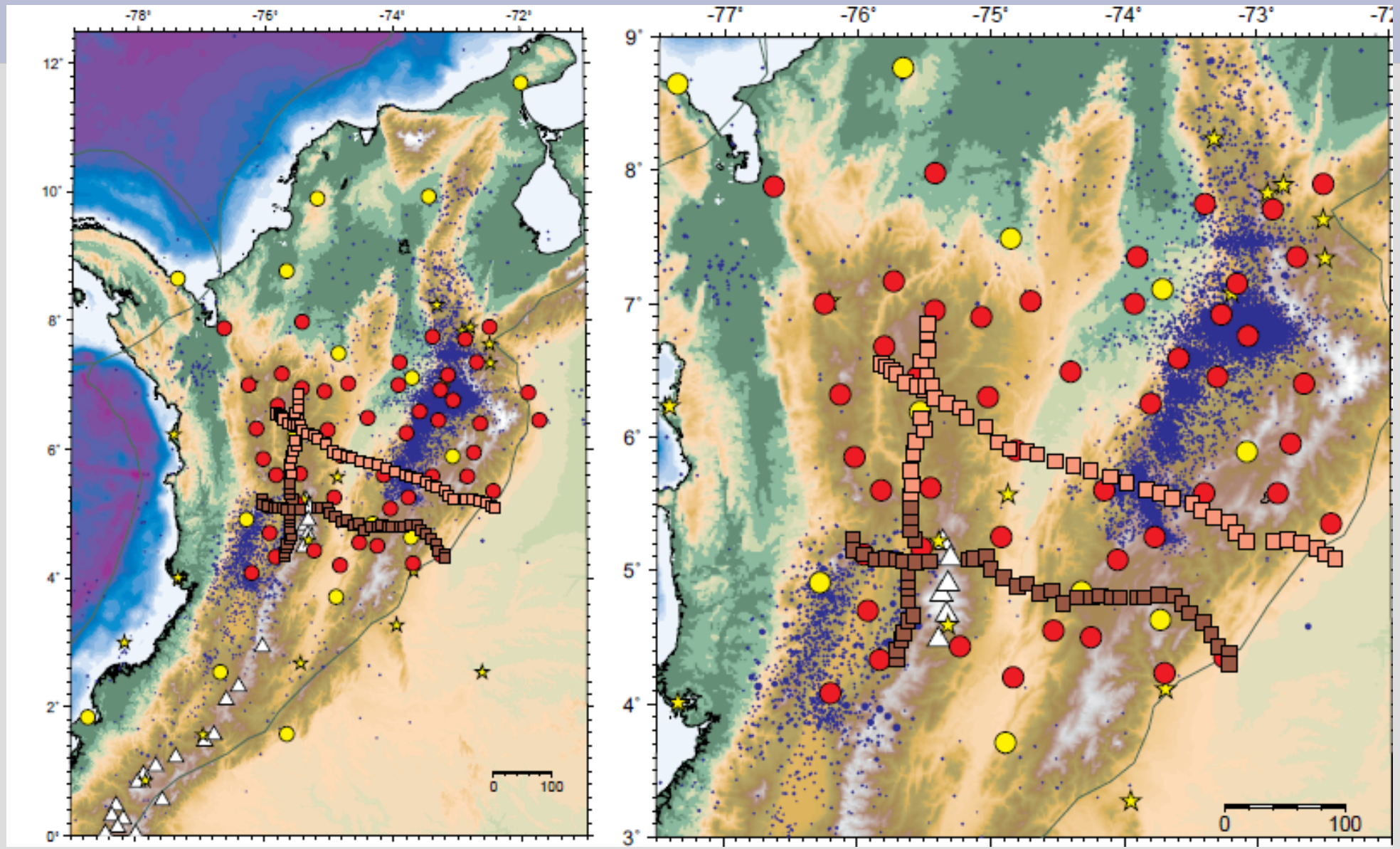
# The solution

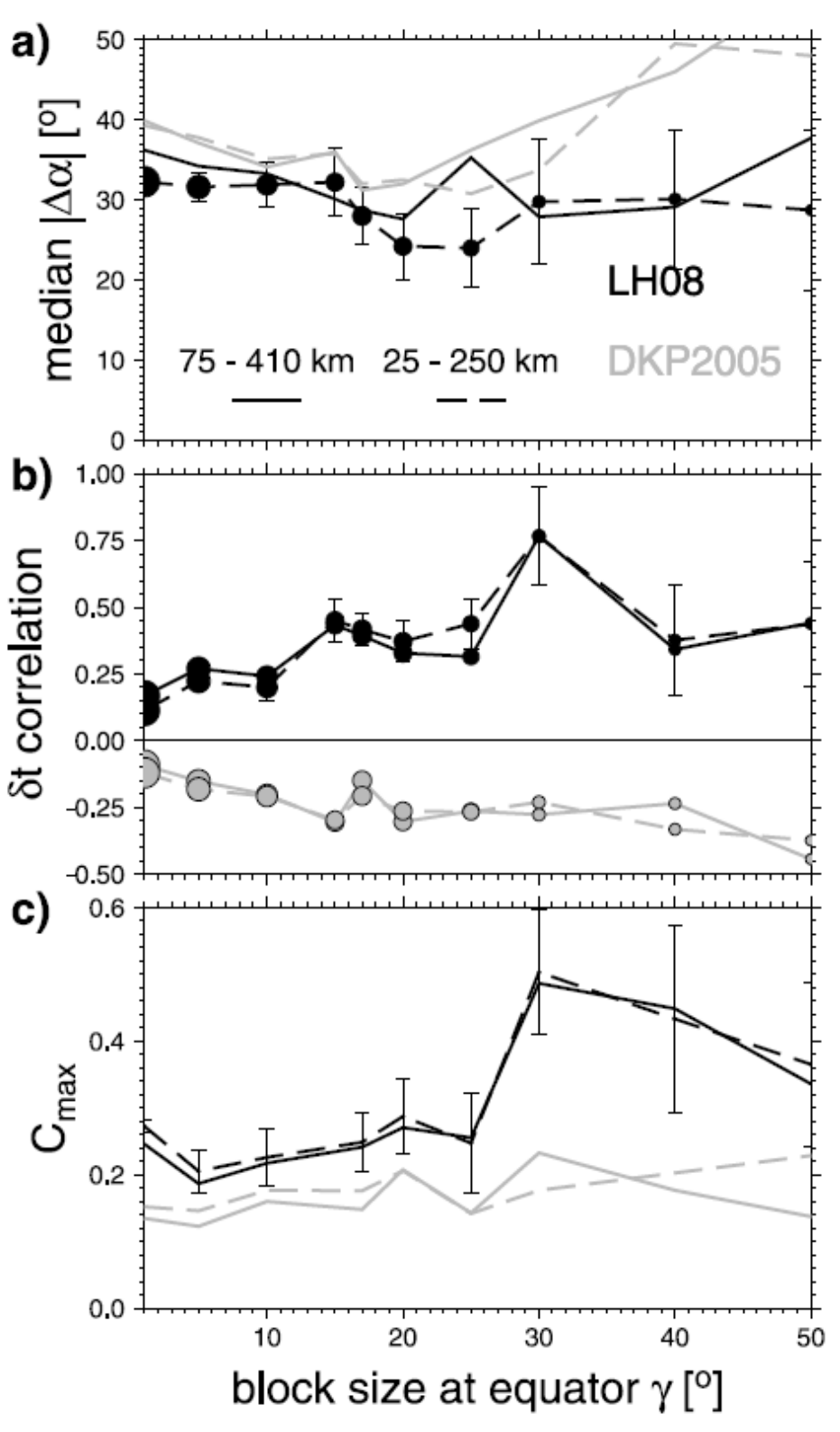
- The *Generic Mapping Tools* (GMT)
  - "~65 tools for manipulating geographic and Cartesian data sets (including filtering, trend fitting, gridding, projecting, etc.) and producing Encapsulated PostScript File (EPS) illustrations"
  - It has a somewhat steep learning curve, and no graphical user interface
- *i*GMT: a GMT GUI and script generator

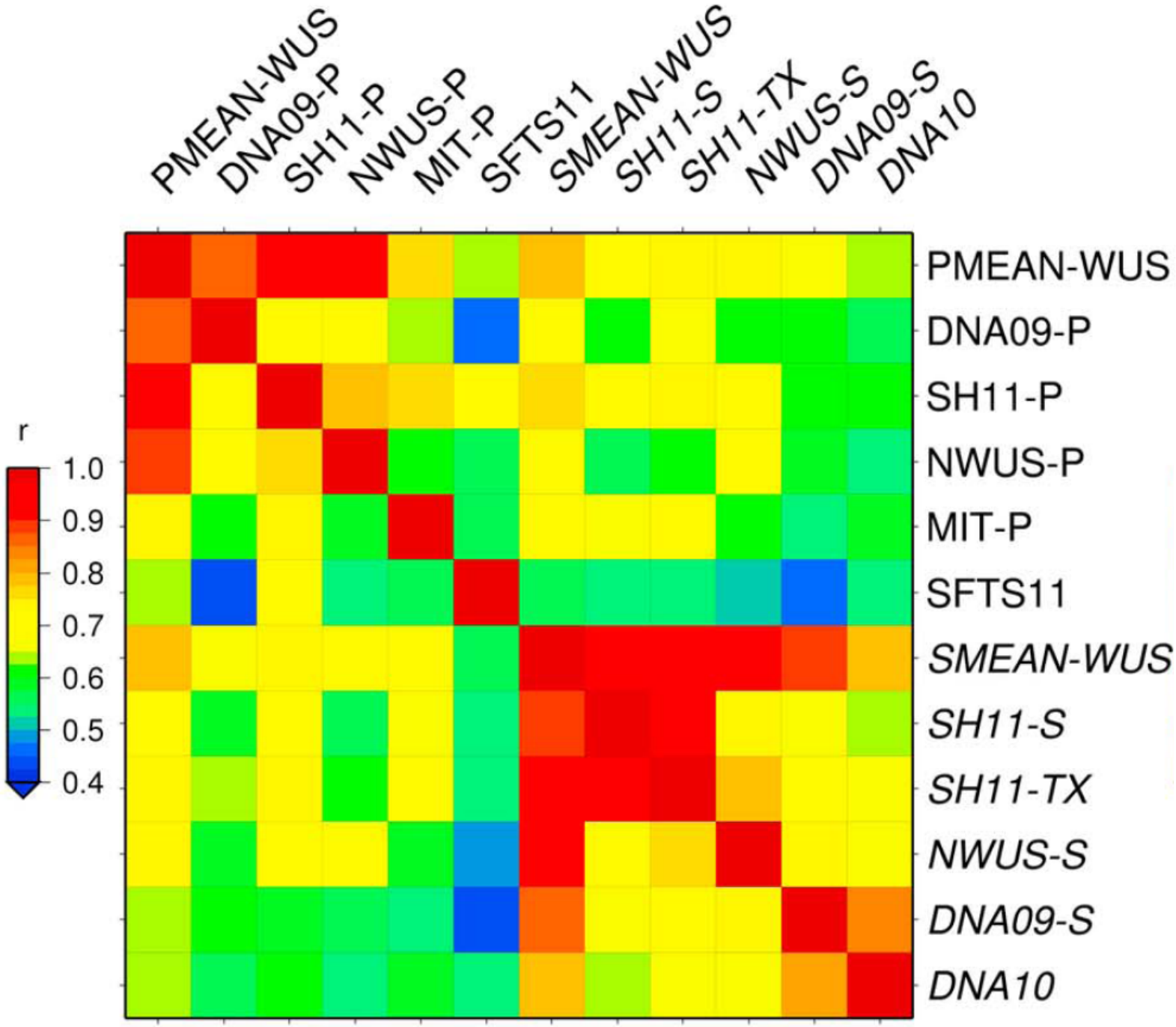
# GMT

- Written by Paul Wessel and Walter Smith
- Version 4 is at 4.5.8, version 5 is beta (under development) (as of 06/2012)
- UNIX based, C language, command line tool, GPLed
- ASCII, NetCDF data input is projected, and produces a PS
- Data processing, plotting, projections, etc.
- Flexible, powerful, complicated
- http://gmt.soest.hawaii.edu/

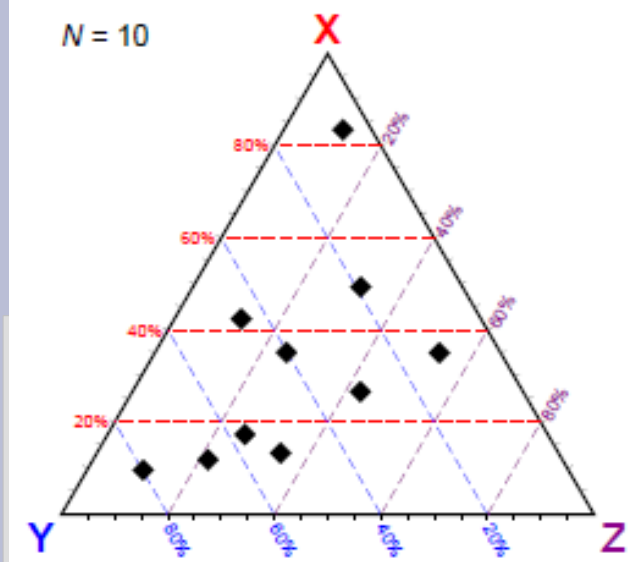
# GMT produced examples

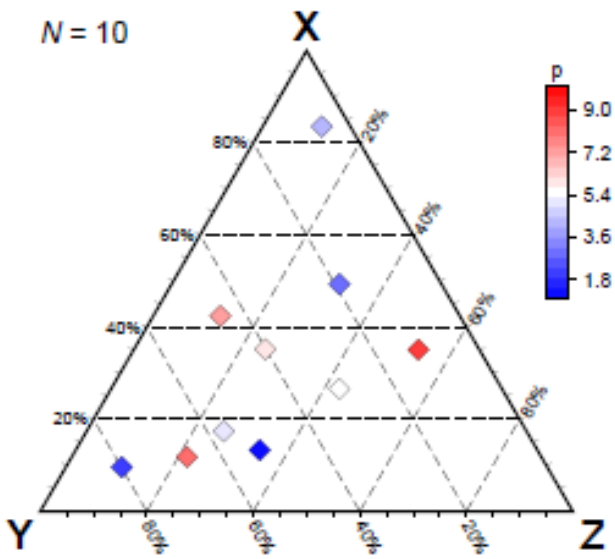


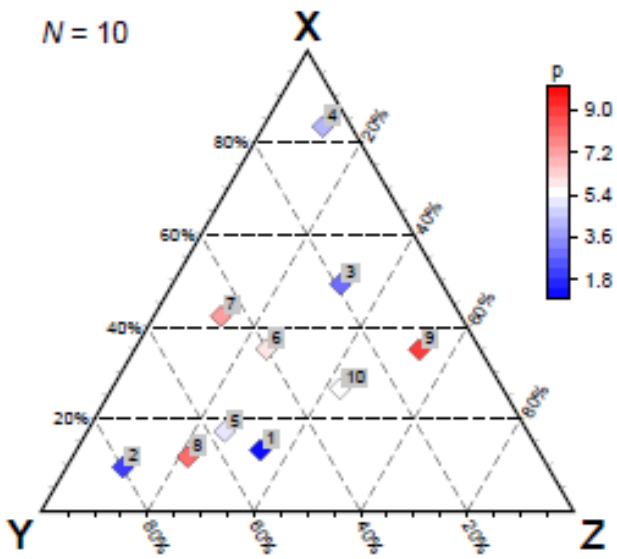

a)
median |Δα| [°]
LH08
75 - 410 km
25 - 250 km
DKP2005
b)
δt correlation
c)
$C_{max}$
block size at equator γ [°]

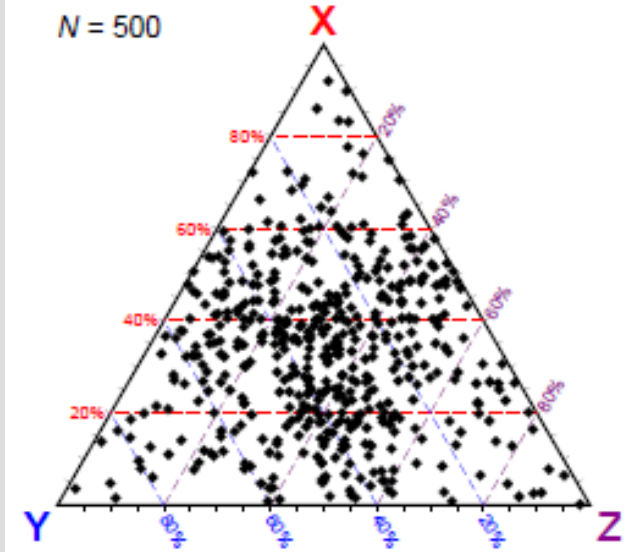


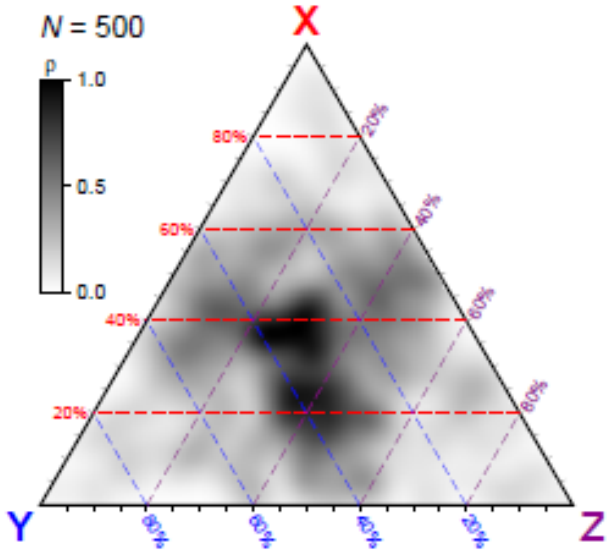

original parameterization

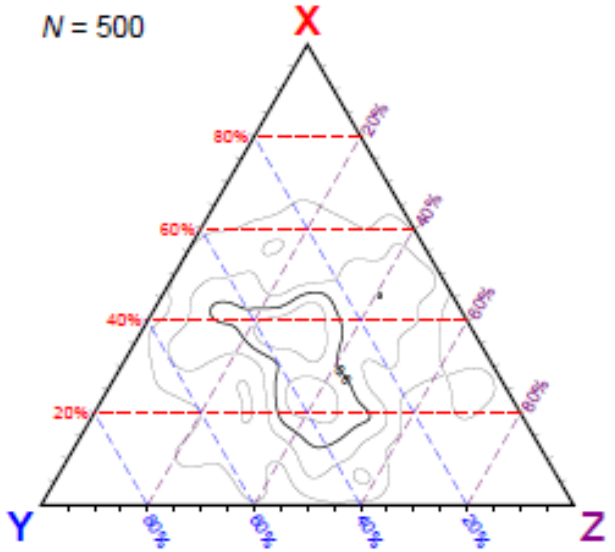


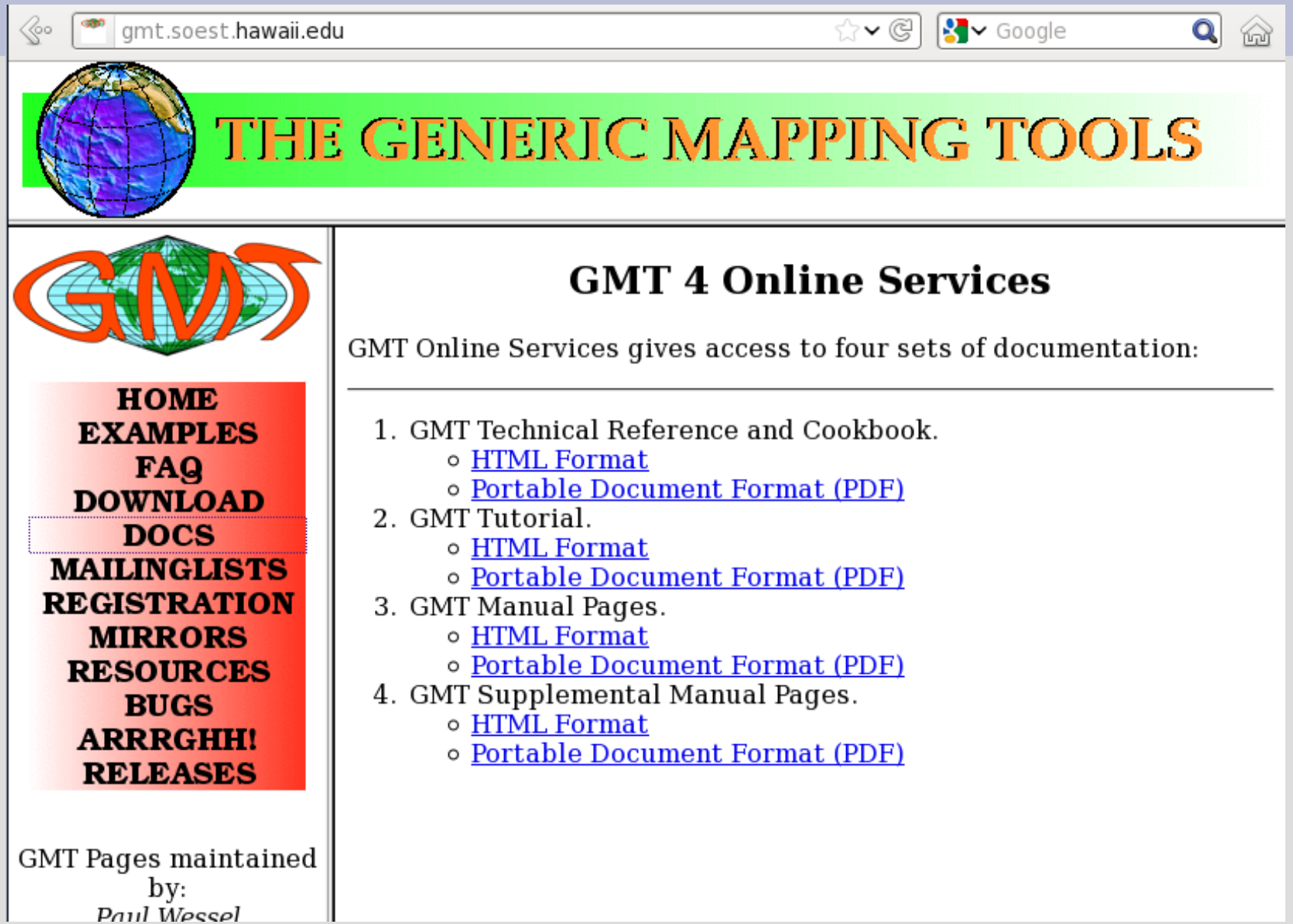




GMT script to plot these ternary diagrams

# How to get it?

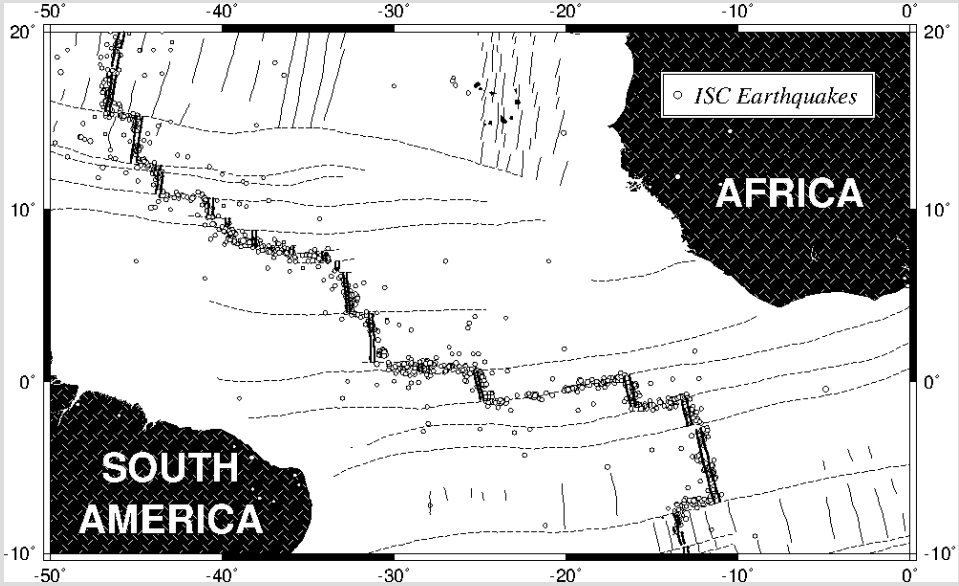
- Download from GMT web page and install
  - Requires Linux or OS-X
  - Prerequisites:
    - compilers
    - NetCDF
    - PS viewer
- Install via package manager (yum, fink)
- USC Geodynamics Earth Science Computing Environment

# GMT documentation



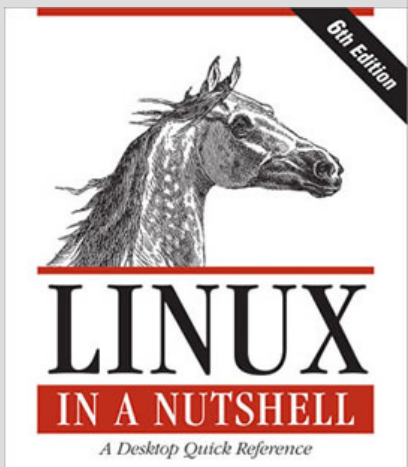
# Running GMT

```
#!/bin/bash
#               GMT EXAMPLE 07
# Purpose:      Make a basemap with earthquakes and isochrons etc
# GMT progs:    pscoast, pstext, psxy
# Unix progs:   $AWK, echo, rm
ps=../example_07.ps
pscoast -R-50/0/-10/20 -JM9i -K -GP300/26 -Dl -Wthinnest -B10 -U~Example 7 in Cookbook~ > $ps
psxy -R -J -O -K -m fz.xy -Wthinner,- >> $ps
$AWK '{print $1-360.0, $2, $3*0.01}' quakes.xym | psxy -R -J -O -K -H1 -Sci -Gwhite -Wthinnest >> $ps
psxy -R -J -O -K -m isochron.xy -Wthin >> $ps
psxy -R -J -O -K -m ridge.xy -Wthicker >> $ps
psxy -R -J -O -K -Gwhite -Wthick -A >> $ps << END
-14.5   15.2
 -2     15.2
 -2     17.8
-14.5   17.8
END
psxy -R -J -O -K -Gwhite -Wthinner -A >> $ps << END
-14.35  15.35
 -2.15  15.35
 -2.15  17.65
-14.35  17.65
END
echo ~-13.5 16.5~ | psxy -R -J -O -K -Sc0.08i\
          -Gwhite -Wthinner >> $ps
echo ~-12.5 16.5 18 0 6 LM ISC Earthquakes~ | \
         pstext -R -J -O -K >> $ps
pstext -R -J -O -Sthin -Gwhite >> $ps << END
-43 -5 30 0 1 CM SOUTH
-43 -8 30 0 1 CM AMERICA
 -7 11 30 0 1 CM AFRICA
END
rm -f .gmt*
```



# What is happening here?

- UNIX uses shell/shell script interactions with the OS system, traditionally
- This is a good thing, but can take some time to get used to
- This is why we spent time talking about UNIX

# Getting data into GMT

- `cat data_file.xy | psxy -Rw/e/s/n -Jxw/yh -Sa0.1 -P > tmp.ps`
- Binary via NetCDF grd files
- Tools for import/export/handling
  - `grdinfo, grdmath`
  - `xyz2grd, grd2xyz`
  - `surface, nearneighbor`
  - Converters: `kml2ascii, etc.`

# Some GMT things

- Region:
  - `-R125/130/20/30`
- Projection:
  - `-JM7i`
  - `-JH127.5/6c`
- Line styles:
  - `-W2,45/50/50`
  - `-Wthick,black,-`
- Boundary annotation:
  - `-Ba10f1`
  - `-Ba5f.5g1:"x":/a10f1:"y"::."plot title":WeSn`

```
> gmtdefaults -L | more
#
#       GMT-SYSTEM 4.5.7 [64-bit] Defaults file
#
#-------- Plot Media Parameters ------------
PAGE_COLOR              = white
PAGE_ORIENTATION        = landscape
PAPER_MEDIA             = letter+
#-------- Basemap Annotation Parameters ------
ANNOT_MIN_ANGLE         = 20
ANNOT_MIN_SPACING       = 0
ANNOT_FONT_PRIMARY      = Helvetica
ANNOT_FONT_SIZE_PRIMARY = 14p
ANNOT_OFFSET_PRIMARY    = 0.075i
ANNOT_FONT_SECONDARY    = Helvetica
ANNOT_FONT_SIZE_SECONDARY       = 16p
ANNOT_OFFSET_SECONDARY  = 0.075i
DEGREE_SYMBOL           = ring
HEADER_FONT             = Helvetica
HEADER_FONT_SIZE        = 36p
HEADER_OFFSET           = 0.1875i
LABEL_FONT              = Helvetica
LABEL_FONT_SIZE         = 24p
LABEL_OFFSET            = 0.1125i
OBLIQUE_ANNOTATION      = 1
PLOT_CLOCK_FORMAT       = hh:mm:ss
PLOT_DATE_FORMAT        = yyyy-mm-dd
PLOT_DEGREE_FORMAT      = +ddd:mm:ss
Y_AXIS_TYPE             = hor_text
#-------- Basemap Layout Parameters ---------
BASEMAP_AXES            = WESN
BASEMAP_FRAME_RGB       = black
BASEMAP_TYPE            = plain
FRAME_PEN               = 1.25p
FRAME_WIDTH             = 0.075i
GRID_CROSS_SIZE_PRIMARY = 0i
GRID_PEN_PRIMARY        = 0.25p
GRID_CROSS_SIZE_SECONDARY       = 0i
GRID_PEN_SECONDARY      = 0.5p
MAP_SCALE_HEIGHT        = 0.075i
POLAR_CAP               = 85/90
TICK_LENGTH             = 0.075i
TICK_PEN                = 0.5p
X_AXIS_LENGTH           = 9i
Y_AXIS_LENGTH           = 6i
X_ORIGIN                = 1i
Y_ORIGIN                = 1i
UNIX_TIME               = FALSE
UNIX_TIME_POS           = BL/-0.75i/
UNIX_TIME_FORMAT        = %Y %b %d %
#-------- Color System Parameters --
COLOR_BACKGROUND        = black
COLOR_FOREGROUND        = white
COLOR_NAN               = 128
COLOR_IMAGE             = adobe
COLOR_MODEL             = rgb
HSV_MIN_SATURATION      = 1
HSV_MAX_SATURATION      = 0.1
HSV_MIN_VALUE           = 0.3
HSV_MAX_VALUE           = 1
#-------- PostScript Parameters ----
CHAR_ENCODING           = Standard+
DOTS_PR_INCH            = 300
GLOBAL_X_SCALE          = 1
GLOBAL_Y_SCALE          = 1
N_COPIES                = 1
PS_COLOR                = rgb
PS_IMAGE_COMPRESS       = none
PS_IMAGE_FORMAT         = ascii
PS_LINE_CAP             = butt
PS_LINE_JOIN            = miter
PS_MITER_LIMIT          = 0
PS_VERBOSE              = FALSE
TRANSPARENCY            = 0
#-------- I/O Format Parameters ----
D_FORMAT                = %lg
FIELD_DELIMITER         = tab
GRIDFILE_FORMAT         = nf
GRIDFILE_SHORTHAND      = FALSE
PS_LINE_JOIN            = miter
PS_MITER_LIMIT          = 0
PS_VERBOSE              = FALSE
TRANSPARENCY            = 0
#-------- I/O Format Parameters ------------
D_FORMAT                = %lg
FIELD_DELIMITER         = tab
GRIDFILE_FORMAT         = nf
GRIDFILE_SHORTHAND      = FALSE
INPUT_CLOCK_FORMAT      = hh:mm:ss
INPUT_DATE_FORMAT       = yyyy-mm-dd
IO_HEADER               = FALSE
N_HEADER_RECS           = 1
NAN_RECORDS             = pass
OUTPUT_CLOCK_FORMAT     = hh:mm:ss
OUTPUT_DATE_FORMAT      = yyyy-mm-dd
OUTPUT_DEGREE_FORMAT    = +D
XY_TOGGLE               = FALSE
#-------- Projection Parameters ------------
ELLIPSOID               = WGS-84
MAP_SCALE_FACTOR        = default
MEASURE_UNIT            = inch
#-------- Calendar/Time Parameters ----------
TIME_FORMAT_PRIMARY     = full
TIME_FORMAT_SECONDARY   = full
TIME_EPOCH              = 2000-01-01T12:00:00
TIME_IS_INTERVAL        = OFF
TIME_INTERVAL_FRACTION  = 0.5
TIME_LANGUAGE           = us
TIME_UNIT               = d
TIME_WEEK_START         = Sunday
Y2K_OFFSET_YEAR         = 1950
#-------- Miscellaneous Parameters ----------
HISTORY                 = TRUE
INTERPOLANT             = akima
LINE_STEP               = 0.01i
VECTOR_SHAPE            = 0
VERBOSE                 = FALSE
```

# GMT problems and solutions

- K-O

  1) Some-GMT-command -K > tmp.ps
  2) Some-other-command -O -K >> tmp.ps
  3) Yet-another-command -O -K >> tmp.ps
  4) Some-last-command -O >> map.ps

- RTFM, the cookbook, or the tutorial
- Join the GMT help list (and google if someone has experienced the same problem before)
- Get a working script and modify
- *i*GMT

# Some nitty gritty stuff that matters

- PS bounding box can be off – `modifybb`
- PDF is more portable (but sometimes Illustrator chokes nonetheless) -
  - `epstopdf`
  - `ps2pdf`
  - `eps2eps` (...)
- PNG is sometimes more useful (but cannot edit anymore)
  - `convert -density 150 file.ps file.png`

# Some GMT caveats

- There are bugs, sometimes (e.g. supp packages)
- Not necessarily spherical (`surface` vs. `sphtriangulate`)
- Hidden parameters in .gmtdefaults file
- Wrong scaling (-Jx100) will kill your machine
- Non interactive, not fully 3D
- However, it's the best and there's a large user community

# Worked GMT examples: Example 1

- Plot point data on an overview map
- From the files in `examples.tgz` go to

  `examples/gmt/example_1`

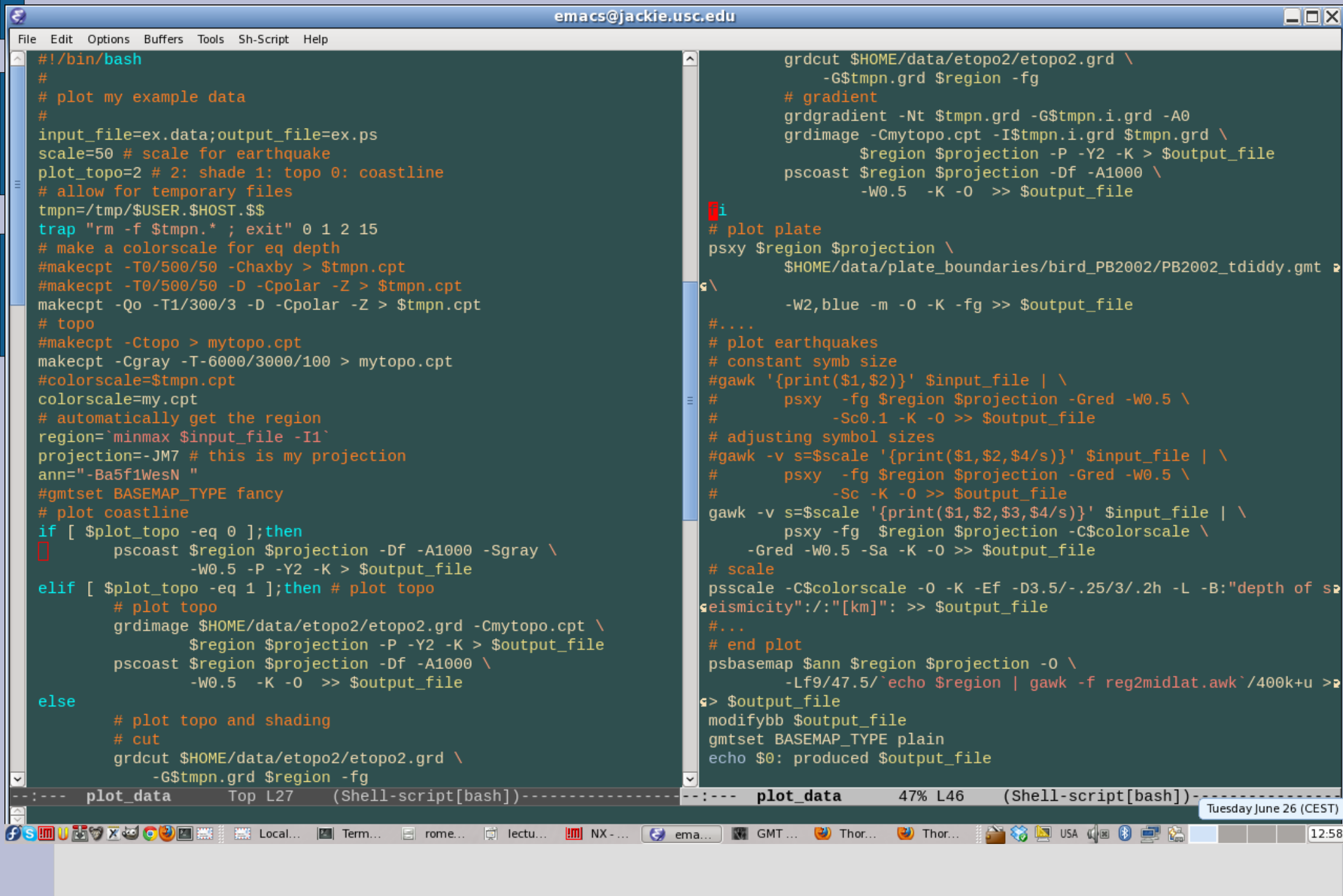
  and check out `ex.data`
- My solution from today is in

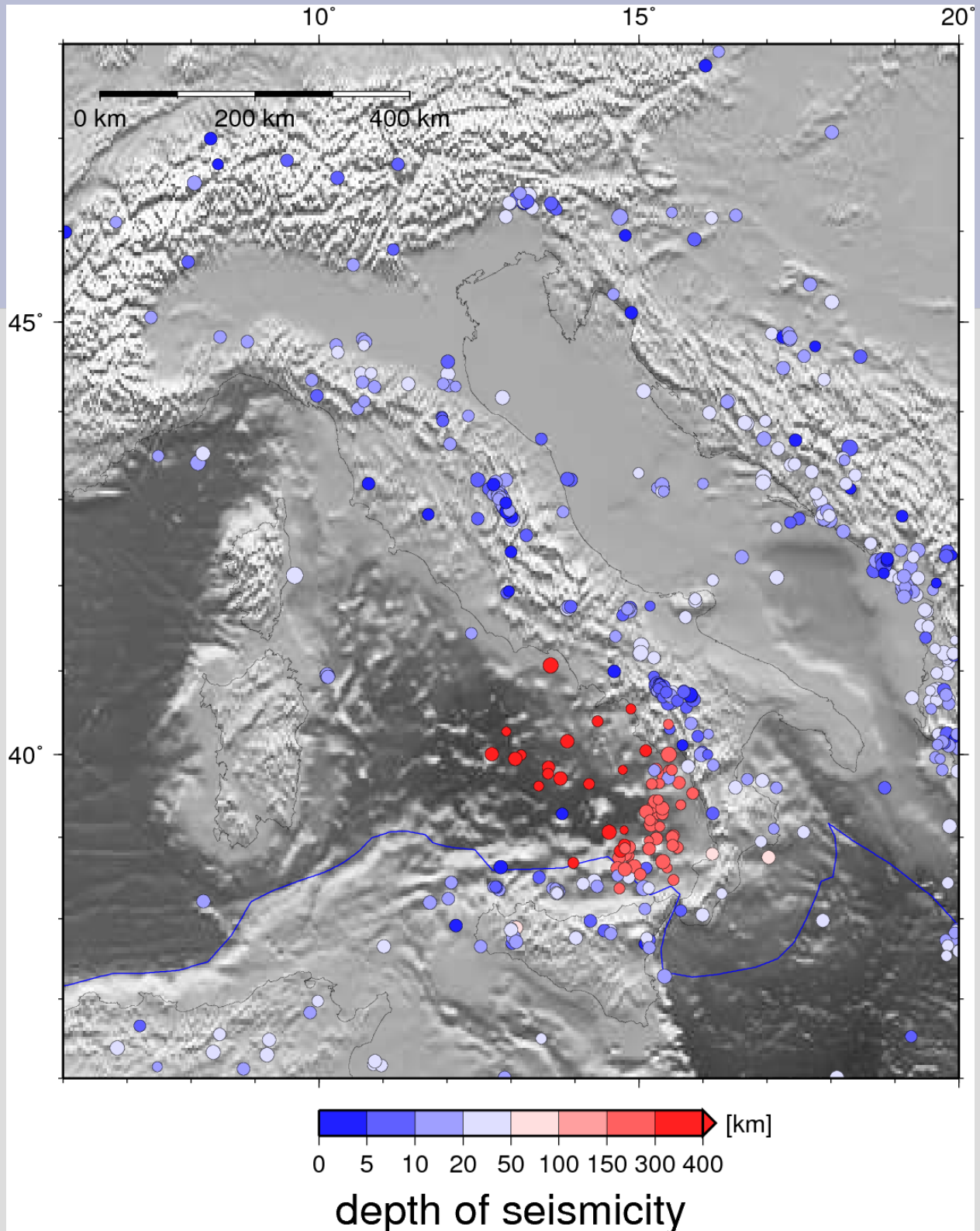
  `examples/gmt/example_1/plot_data`

# Worked GMT examples: Example 2

- Plot point data on an overview map, and add ETOPO2 topography in background
- My solution from today is in

```
examples/gmt/example_1/plot_data
```

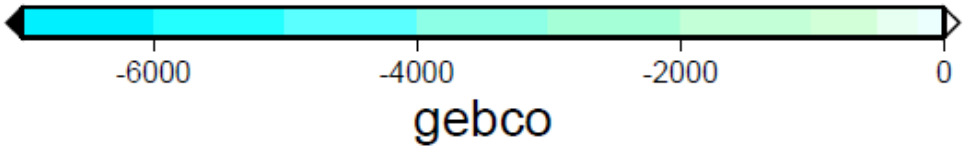

emacs@jackie.usc.edu
File Edit Options Buffers Tools Sh-Script Help
#!/bin/bash
#
# plot my example data
#
input_file=ex.data;output_file=ex.ps
scale=50 # scale for earthquake
plot_topo=2 # 2: shade 1: topo 0: coastline
# allow for temporary files
tmpn=/tmp/$USER.$HOST.$$
trap "rm -f $tmpn.* ; exit" 0 1 2 15
# make a colorscale for eq depth
#makecpt -T0/500/50 -Chaxby > $tmpn.cpt
#makecpt -T0/500/50 -D -Cpolar -Z > $tmpn.cpt
makecpt -Qo -T1/300/3 -D -Cpolar -Z > $tmpn.cpt
# topo
#makecpt -Ctopo > mytopo.cpt
makecpt -Cgray -T-6000/3000/100 > mytopo.cpt
#colorscale=$tmpn.cpt
colorscale=my.cpt
# automatically get the region
region=`minmax $input_file -I1`
projection=-JM7 # this is my projection
ann="-Ba5f1WesN "
#gmtset BASEMAP_TYPE fancy
# plot coastline
if [ $plot_topo -eq 0 ];then
pscoast $region $projection -Df -A1000 -Sgray \
-W0.5 -P -Y2 -K > $output_file
elif [ $plot_topo -eq 1 ];then # plot topo
# plot topo
grdimage $HOME/data/etopo2/etopo2.grd -Cmytopo.cpt \
$region $projection -P -Y2 -K > $output_file
pscoast $region $projection -Df -A1000 \
-W0.5 -K -O >> $output_file
else
# plot topo and shading
# cut
grdcut $HOME/data/etopo2/etopo2.grd \
-G$tmpn.grd $region -fg
--:--- plot_data Top L27 (Shell-script[bash])----------
grdcut $HOME/data/etopo2/etopo2.grd \
-G$tmpn.grd $region -fg
# gradient
grdgradient -Nt $tmpn.grd -G$tmpn.i.grd -A0
grdimage -Cmytopo.cpt -I$tmpn.i.grd $tmpn.grd \
$region $projection -P -Y2 -K > $output_file
pscoast $region $projection -Df -A1000 \
-W0.5 -K -O >> $output_file
fi
# plot plate
psxy $region $projection \
$HOME/data/plate_boundaries/bird_PB2002/PB2002_tdiddy.gmt \
-W2,blue -m -O -K -fg >> $output_file
#....
# plot earthquakes
# constant symb size
#gawk '{print($1,$2)}' $input_file | \
# psxy -fg $region $projection -Gred -W0.5 \
# -Sc0.1 -K -O >> $output_file
# adjusting symbol sizes
#gawk -v s=$scale '{print($1,$2,$4/s)}' $input_file | \
# psxy -fg $region $projection -Gred -W0.5 \
# -Sc -K -O >> $output_file
gawk -v s=$scale '{print($1,$2,$3,$4/s)}' $input_file | \
psxy -fg $region $projection -C$colorscale \
-Gred -W0.5 -Sa -K -O >> $output_file
# scale
psscale -C$colorscale -O -K -Ef -D3.5/-.25/3/.2h -L -B:"depth of se
ismicity":/:"[km]": >> $output_file
#...
# end plot
psbasemap $ann $region $projection -O \
-Lf9/47.5/`echo $region | gawk -f reg2midlat.awk`/400k+u >>
$output_file
modifybb $output_file
gmtset BASEMAP_TYPE plain
echo $0: produced $output_file
--:--- plot_data 47% L46 (Shell-script[bash])----------
Tuesday June 26 (CEST)
Local... Term... rome... lectu... NX - ... ema... GMT ... Thor... Thor... USA 12:58

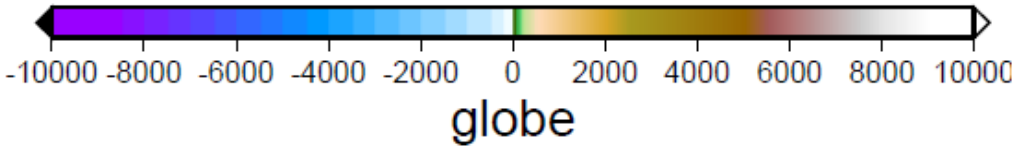

10˚
15˚
20˚
45˚
40˚
0 km
200 km
400 km
[km]
0 5 10 20 50 100 150 300 400
depth of seismicity

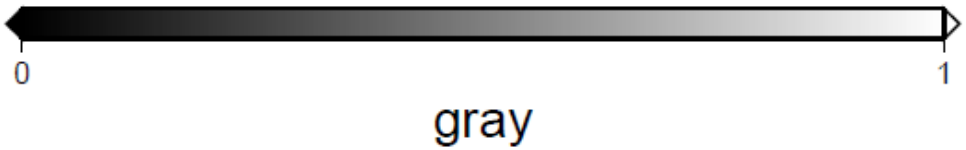
# Colormaps

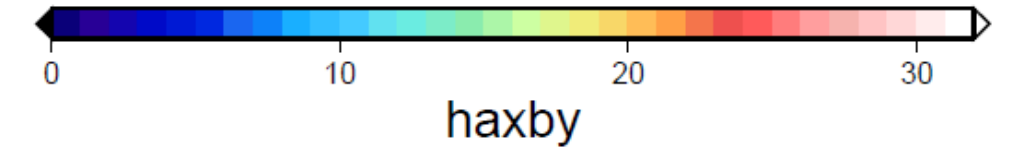
- `grdimage` and `grdview` to plot grd files
- Check out cpt-city and my PDF for GMT colorscales





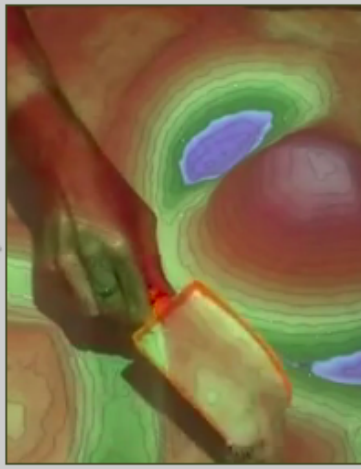



## An archive of colour gradients

For cartography, technical illustration and design. The archive supports several formats and is organised by author.

- Art gradients by Blackheartedwolf
- Colour schemes by Cynthia Brewer
- Obesity scales from CalorieLab
- Selected five-colour palettes from COLOURlovers
- Subtle gradients from Crumblingwalls
- Palettes for positive functions by Duncan Agnew
- Dave Green's cubehelix for astronomical intensity images
- Gradients by Diane Simoni
- DS9 colour scales for astronomical visualisation
- A DEM palette by Erika Mackay
- Toning samples by Eric R. Jeschke
- Themed art gradients by ElvenSword
- Selected legends from the European Soil Database
- ESRI colour ramp collection
- Vista login button gradients by Fused Graphics
- The DEM palettes from drawmap, by Fred M. Erickson
- Felix von Luschan skin-colour scales
- A seismic amplitude scheme by Gery
- GIMP gradients
- Palettes from the graphics packages GIST and Yorick
- Generic Mapping Tools palettes
- Two-colour glossy gradients from GoSquared
- Gradients from GIMP Paint Studio
- GRASS colour ramps
- Colour tables from the h5utils package
- Spectral gradients by Hult



Elevation in the UC Davis augm
reality sandbox with the mby s