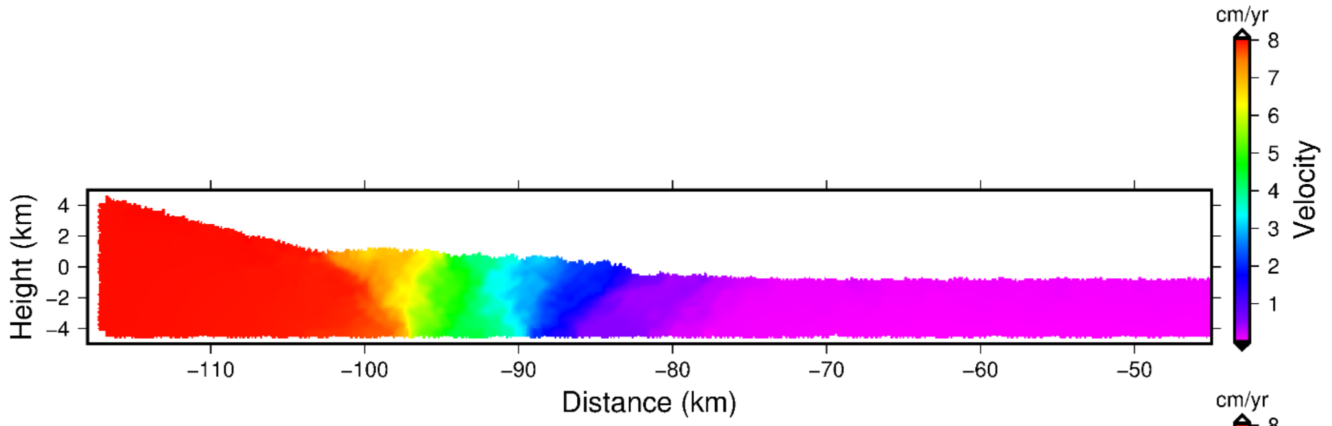
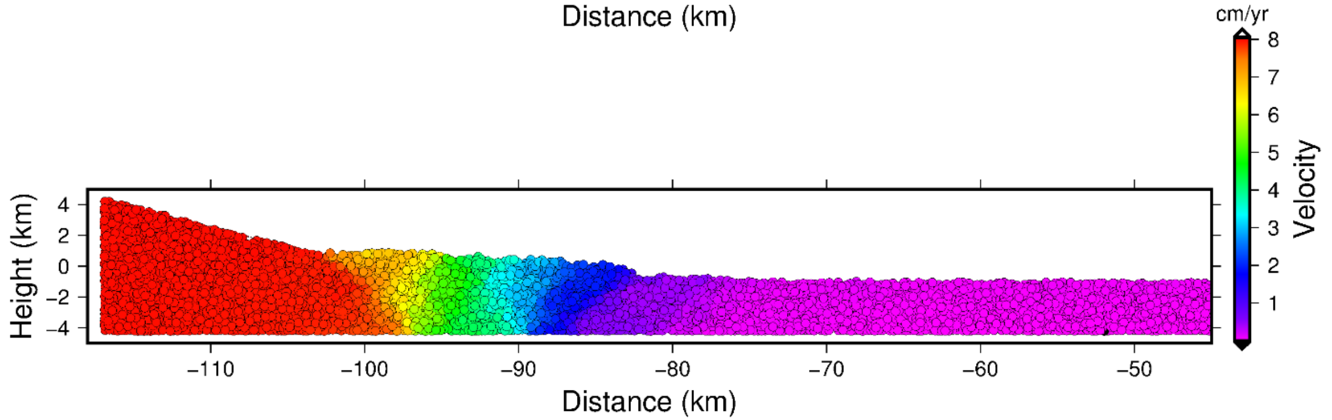
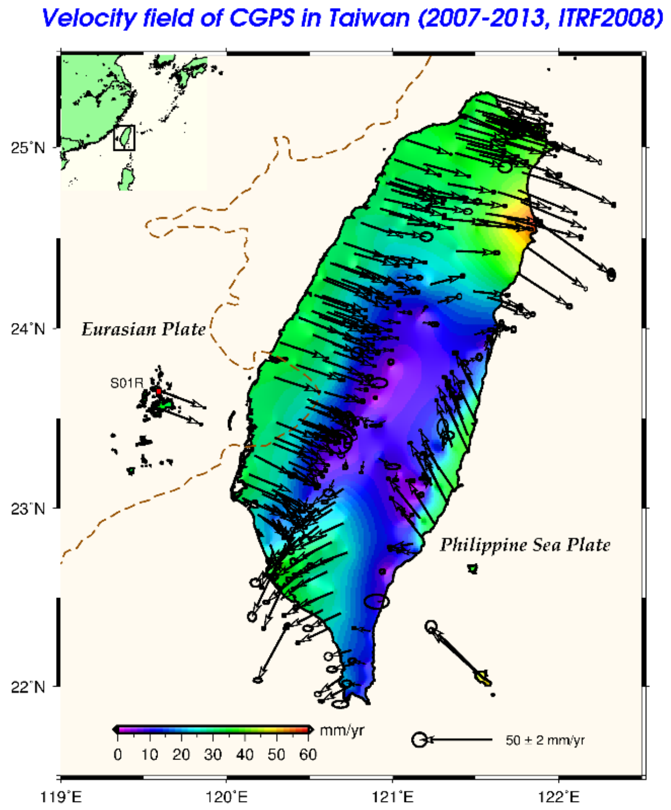
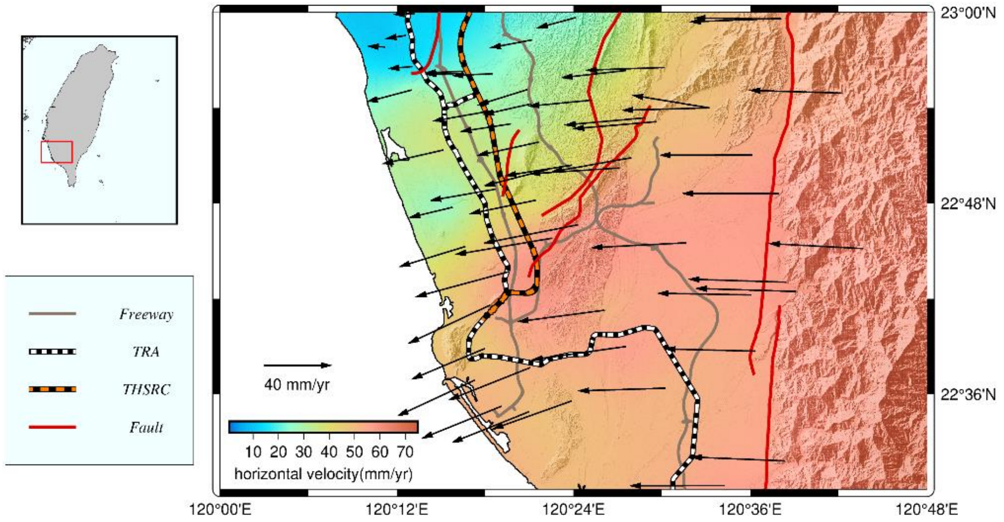
GMT Lect09 : Making Grid File & Drawing Geodetic Data

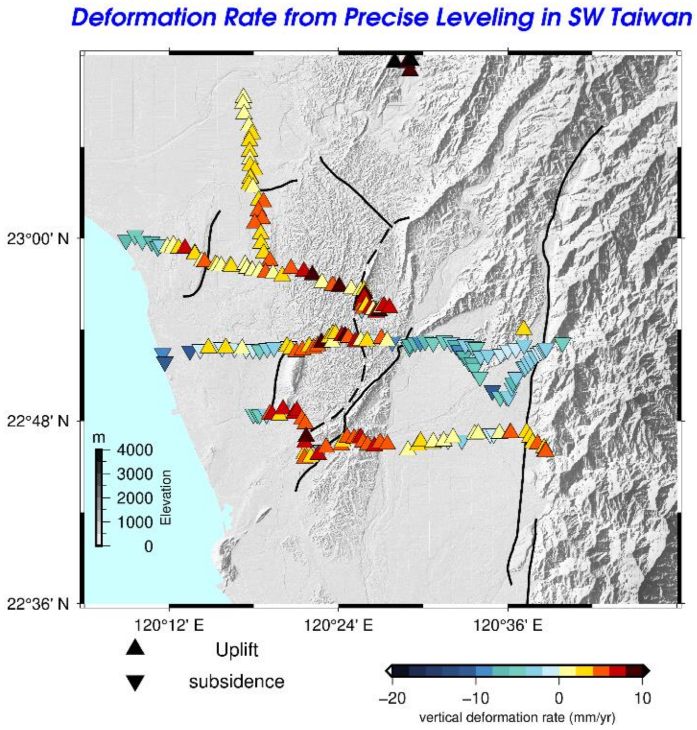






胡植慶　國立臺灣大學地質科學系
Jyr-Ching HU, Dept. of Geosciences, NTU



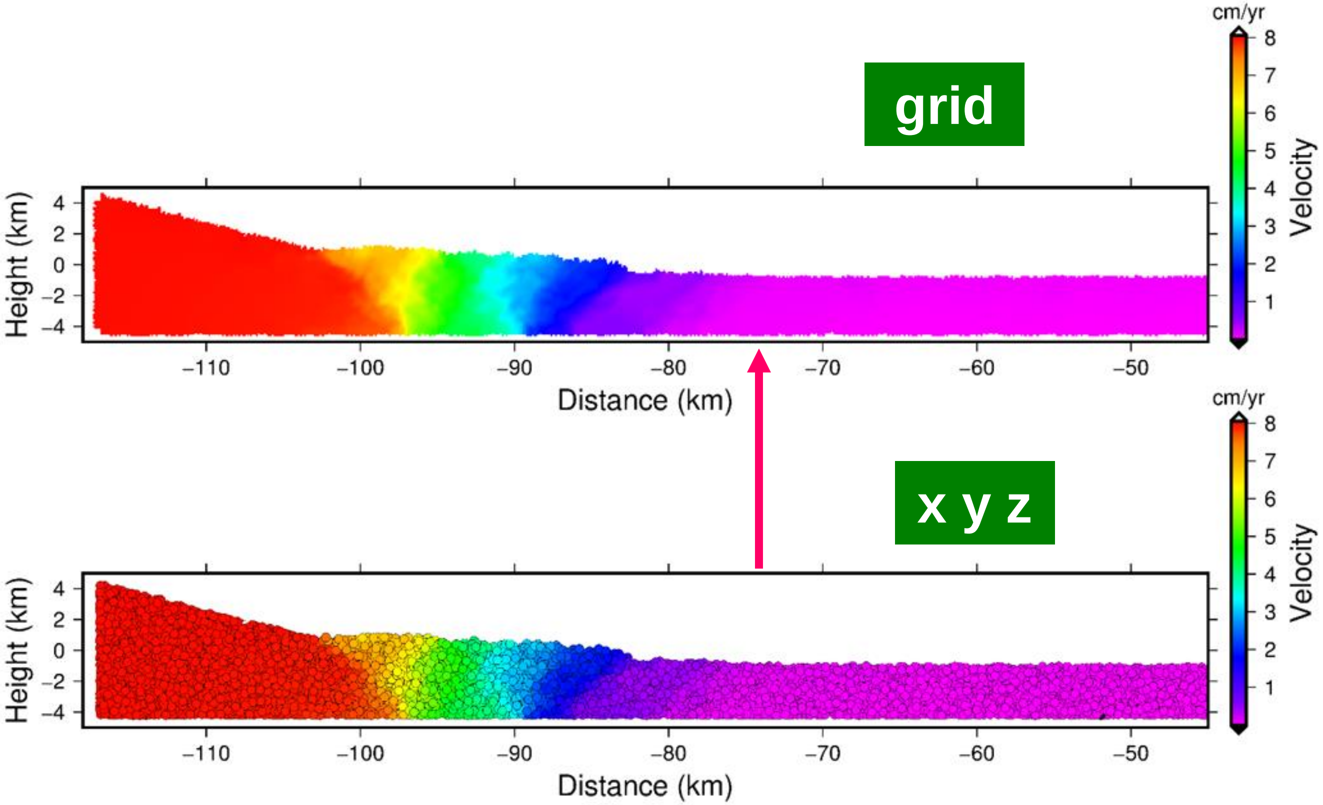


gmt commands

- nearneighbor: Grid table data using a “Nearest neighbor” algorithm (使用最鄰近搜尋演算法對數據進行網格化)
- blockmean: Block average (x,y,z) data tables by L_2 norm (用L_2 範數的方法將輸入檔案過濾成區塊平均資料)
- surface: Grid table data using adjustable tension continuous curvature splines (連續不規則曲線的曲率)
- xyz2grd: Convert table to 2-D grd file (將XYZ資料轉成網格文件)

Convert table to 2-D grd file

Data: 2-D distinct element（分離元素）modeling for accretionary prism (增積楔)



Data: Wang Fang-Lin
Numerical sandbox

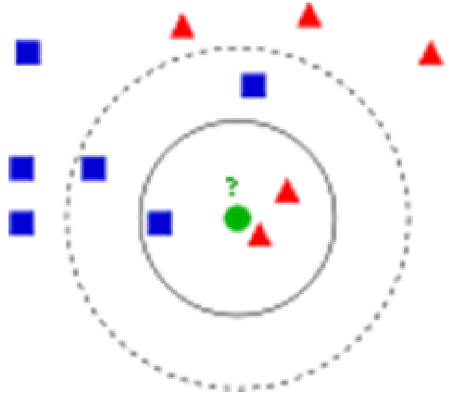
Input file: pinfo.txt

```
32498.000000 -33.571409  -2.900410  0.002882  0.016874
32496.000000 106.981891 -1.391961 -0.000964  0.043271
```

Nearneighbor

Grid table data using a "Nearest neighbor" algorithm

- nearneighbor reads arbitrarily located (x,y,z[,w]) triples [quadruplets] from standard input [or table] and uses a nearest neighbor algorithm to assign an average value to each node that have one or more points within a radius centered on the node.
- The average value is computed as a weighted mean of the nearest point from each sector inside the search radius.
- The weighting function used is $w(r) = 1 / (1 + d^2)$, where $d = 3 * r / search\_radius$ and r is distance from the node. This weight is modulated by the observation points' weights [if supplied].



Nearneighbor

*gmt nearneighbor [**table**] -**G**out_grdfile -**I**increment -**N**sectors[+mmin_sectors] -Rregion -**S**search_radius[unit] [-**E**empty] [-V[level]] [-W] [-bibinary] [-dinodata] [-eregexp] [-fflags] [-hheaders] [-iflags] [-nflags] [-rreg] [-:[i|o]] [--PAR=value]*

Example 01: To create a gridded data set from the file **seaMARCII_bathy.lon_lat_z** using a 0.5 min grid, a 5 km search radius, using an octant search, and set empty nodes to -9999:

```
gmt nearneighbor seaMARCII_bathy.lon_lat_z -R242/244/-22/-20 -I0.5m -E-9999 -Gbathymetry.nc -S5k -N8+m8
```

-G*out_grdfile*: Give the name of the output grid file.

-I*xinc[unit][+e|n][/yinc[unit][+e|n]]*: *x_inc* [and optionally *y_inc*] is the grid spacing

-N*sectors*[+m*min_sectors]*: The circular area centered on each node is divided into *sectors*. Average values will only be computed if there is at least one value inside at least *min_sectors* of the sectors for a given node.

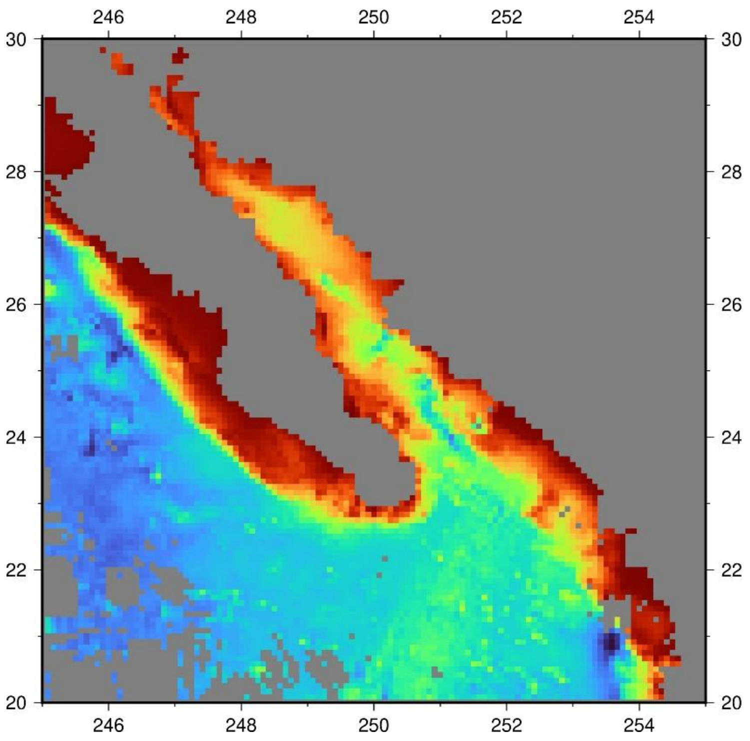
-S*search_radius[unit]* : Sets the *search_radius* that determines which data points are considered close to a node. Append the distance unit.

-E*mpty*: Set the value assigned to empty nodes [NaN].

Nearneighbor

gmt nearneighbor [**table**] **-G**out_grdfile **-I**increment **-N**sectors[+mmin_sectors] -Rregion **-S**search_radius[unit] [**-E**empty] [-V[level]] [-W] [-bibinary] [-dinodata] [-eregexp] [-fflags] [-hheaders] [-iflags] [-nflags] [-rreg] [-:[i|o]] [--PAR=value]

Example: To grid the data in the remote file **@ship_15.txt** at 5x5 arc minutes using a search radius of 15 arch minutes, and plot the resulting grid using default projection and colors, try Nearneighbor.bat or Nearneighbor.sh

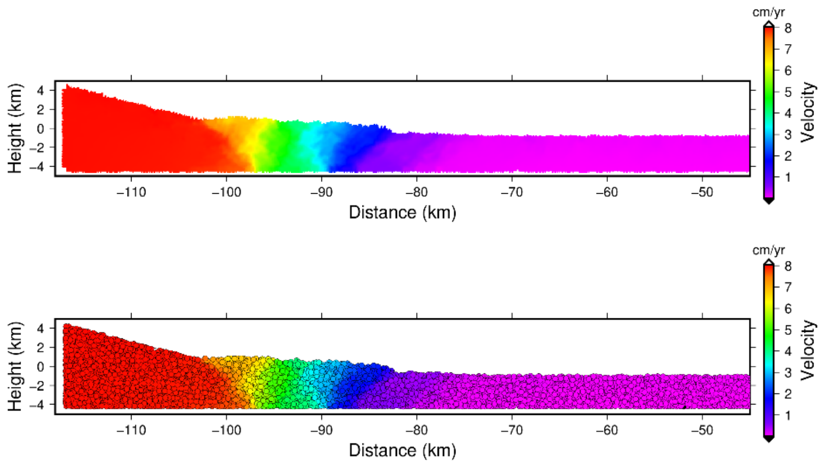



```
gmt begin map jpg
gmt nearneighbor @ship_15.txt -R245/255/20/30 -I5m -Ggrid.nc -S15m
gmt grdimage grid.nc -B
gmt end
```

Please open **ship_15.txt**

245.00891	27.49555	-636.0
245.01201	27.49286	-655.0
245.01512	27.49016	-710.0

Lecto9a



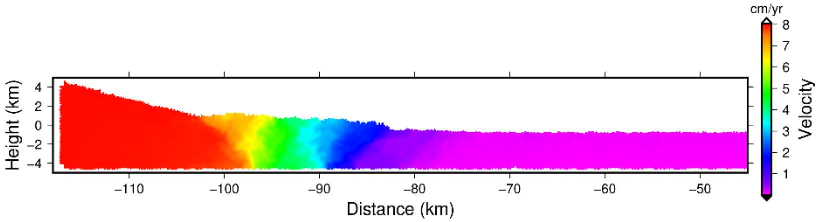

```
gawk "{print $2, $3, sqrt($4*$4+$5*$5)}" pinfo.txt | gmt
nearneighbor -Gxy.grd -R-118/-45/-5/5 -I0.1/0.1 -N4 -S0.48 -
ENaN –V
gmt grdinfo xy.grd  > xy.grd.info
more xy.grd.info
gmt grd2cpt xy.grd  -Crainbow -Fr -N -Z > xy.cpt
echo N 255  255  255 >> xy.cpt
gawk "{print $2, $3, sqrt($4*$4+$5*$5)}" pinfo.txt | gmt plot -
Jx0.12 -R-118/-45/-5/5 -Sc0.07 -W0.01 –Cxy.cpt -
Bx10+l"Distance (km)" -By2+l"Height (km)" -BWeSn
```

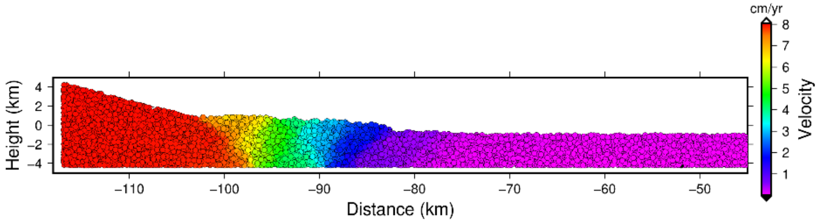
-S*search_radius[unit]*: Sets the search_radius in same units as the grid spacing

-N*sectors[+mmin_sectors]* : The circular area centered on each node is divided into *sectors* sectors. Average values will only be computed if there is at least one value inside at least *min_sectors* of the sectors for a given node.

- Nodes that fail this test are assigned the value NaN
- Default is a quadrant search with 100% coverage, i.e., sectors = min_sectors = 4
- Note that only the nearest value per sector enters into the averaging; the more distant points are ignored.
- ***-E****empty*: Set the value assigned to empty nodes [NaN].

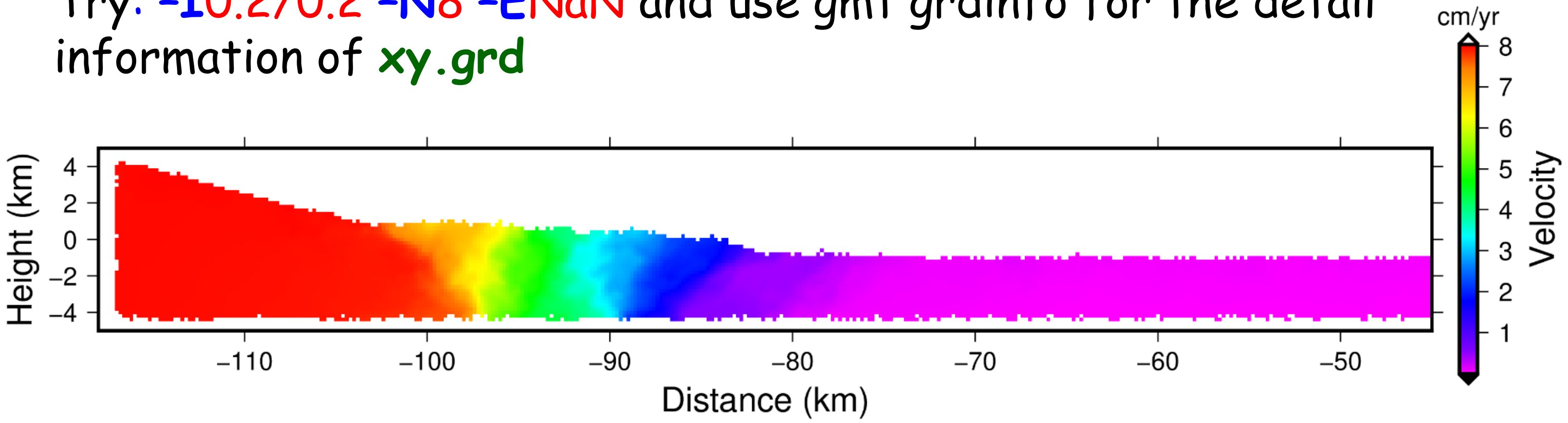
Lect09A





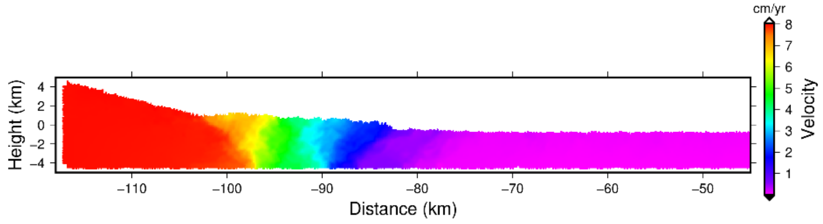

```
gawk "{print $2, $3, sqrt($4*$4+$5*$5)}" pinfo.txt | gmt nearneighbor -Gxy.grd -R-118/-45/-5/5 -I0.1/0.1 -N4 -S0.48 -ENaN –V
gmt grdinfo xy.grd  > xy.grd.info
more xy.grd.info
gmt grd2cpt xy.grd  -Crainbow -Fr -N -Z > xy.cpt
echo N 255  255  255 >> xy.cpt
gawk "{print $2, $3, sqrt($4*$4+$5*$5)}" pinfo.txt | gmt plot -Jx0.12 -R-118/-45/-5/5 -Sc0.07 -W0.01 –Cxy.cpt -Bx10+l"Distance (km)" -By2+l"Height (km)" -BWeSn
```

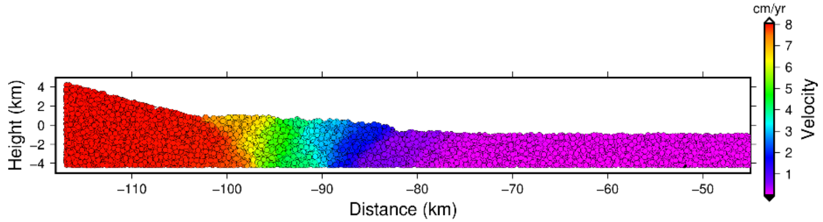
Try: –I0.2/0.2 –N8 –ENaN and use gmt grdinfo for the detail information of **xy.grd**



Try: –I0.1/0.1 –N8 –E-9999 and use gmt grdinfo for the detail information of **xy.grd**

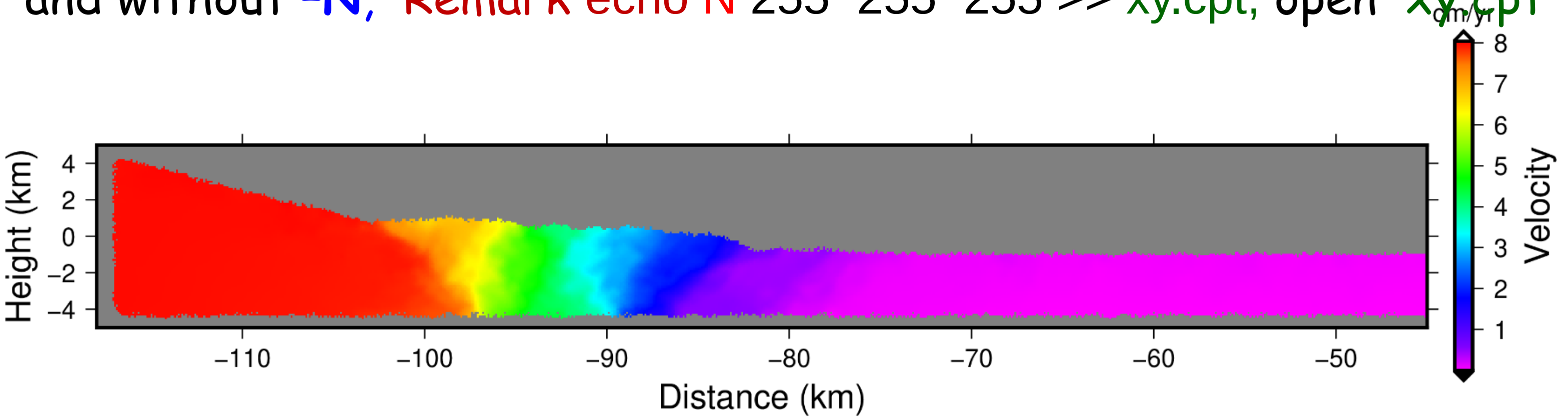
Lect09A






```
gawk "{print $2, $3, sqrt($4*$4+$5*$5)}" pinfo.txt | gmt nearneighbor -Gxy.grd -R-118/-45/-5/5 -I0.1/0.1 -N4 -S0.48 -ENaN –V
gmt grdinfo xy.grd  > xy.grd.info
more xy.grd.info
gmt grd2cpt xy.grd  -Crainbow -Fr -N -Z > xy.cpt
echo N 255  255  255 >> xy.cpt
gawk "{print $2, $3, sqrt($4*$4+$5*$5)}" pinfo.txt | gmt plot -Jx0.12 -R-118/-45/-5/5 -Sc0.07 -W0.01 –Cxy.cpt -Bx10+l"Distance (km)" -By2+l"Height (km)" -BWeSn
```

Try: –Fr and without –N, Remark echo N 255 255 255 >> xy.cpt, open xy.cpt



- **-F**[R|r|h|c]: Force output cpt file to written with r/g/b codes, gray-scale values or color name (R, default) or r/g/b codes only (r), or h-s-v codes (h), or c/m/y/k codes (c).
- **-N**: Do not write out the background, foreground, and NaN-color fields [Default will write them].

Try: -Fh, -Fc and open xy.cpt

Blockmean

Block average (x,y,z) data tables by L2 norm (使用 L_2 範式對(x,y,z)資料做區塊平均)

L_p norm of vectors x and y = $[\Sigma|x_i-y_i|^p]^{1/p}$

（歐基理德距離，也就是計算每個對應元素差值的平方和，再開平方）

- blockmean reads arbitrarily located (x,y,z) triples [or optionally weighted quadruples (x,y,z,w)] from standard input [or table] and writes to standard output a mean position and value for every non-empty block in a grid region defined by the -R and -I arguments.
- Either blockmean, blockmedian, or blockmode should be used as a pre-processor before running surface to avoid aliasing short wavelengths
- These routines are also generally useful for decimating or averaging (x,y,z) data

Blockmean

*gmt blockmean [**table**] –**I**increment -Rregion [-**A**fields] [-C] [-**E**[+p|P]] [-**G**[grdfile]] [-**S**[m|n|s|w]] [-V[level]] [-W[i|o][+s]] [-aflags] [-bbinary] [-dnodata] [-eregexp] [-fflags] [-hheaders] [-iflags] [-oflags] [-rreg] [-:[i|o]] [--PAR=value]*

- **table**: 3 [or 4, see -W] column ASCII data table file(s) [or binary, see -bi] holding (x,y,z[,w]) data values. [w] is an optional weight for the data. If no file is specified, blockmean will read from standard input.
- **-I**xinc[unit][=|+][/yinc[unit][=|+]]: grid spacing. Optionally, append a suffix modifier.
- Geographical (degrees) coordinates: Append m to indicate arc minutes or s to indicate arc seconds.
- If one of the units e, f, k, M, n or u is appended instead: the increment is assumed to be given in meter, foot, km, Mile, nautical mile or US survey foot, respectively.
- Converted to the equivalent degrees longitude at the middle latitude of the region (the conversion depends on PROJ_ELLIPSOID)
- **-S**[*m*|*n*|*s*|*w*]: Use **-S**n to report the number of input points inside each block, **-S**s to report the sum of all z-values inside a block, **-S**w to report the sum of weights [Default (or **-S**m reports mean value].

Example: blockmean

```
REM To find 5 by 5 minute block mean values from the ASCII data in ship_15.txt
gmt blockmean @ship_15.txt -R245/255/20/30 -I5m > ship_5x5.txt
REM To determine how many values were found in each 5x5 minute bin
gmt blockmean @ship_15.txt -R245/255/20/30 -I5m -Sn > ship_5x5_count.txt
REM To determine the mean and standard deviation per 10 minute bin
REM and save these to two separate grids called field_z.nc and field_s.nc
gmt blockmean @ship_15.txt -I10m -R-115/-105/20/30 -E -Gfield_%%s.nc -Az,s
```

Please open **ship_15.txt**

245.00891	27.49555	-636.0
245.01201	27.49286	-655.0
245.01512	27.49016	-710.0

Please open **ship_5x5.txt**

245.888876667	29.9787066667	-384
246.96821	29.97529	-94.6666666667
245.87457	29.92127	-426

Please try: **-S**s, **-S**m

Please open **ship_5x5_count.txt**

245.888876667	29.9787066667	3
246.96821	29.97529	3
245.87457	29.92127	5

Example: blockmean

```
REM To determine the mean and standard deviation per 10 minute bin
REM and save these to two separate grids called field_z.nc and field_s.nc
gmt blockmean @ship_15.txt -I10m -R-115/-105/20/30 -E -Gfield_%%s.nc -Az,s
gmt grdinfo field_s.nc > field_s.nc.info
type field_s.nc.info
```

- ***-E**[+p|P]*: Provide Extended report which includes s (the standard deviation about the mean), l, the lowest value, and h, the high value for each block. Output order becomes x,y,z,s,l,h[,w]. [Default outputs x,y,z[,w]. If **-E**+p|P are used then input data uncertainties are expected and s becomes the propagated error of the weighted (+p) or simple (+P) z mean.
- ***-A**field*: Select which fields to write to individual grids. Requires **-G**. Append comma-separated codes for available fields: z (the mean data z, but see -S), s (standard deviation), l (lowest value), h (highest value) and w (the output weight; requires -W). Note s|l|h requires **-E** [Default is just z].
- ***G**[grdfile]*: Write one or more fields directly to grids; no table data are written to standard output. If more than one fields are specified via **-A** then grdfile must contain the format flag %s (for shell script, %%s for batch file) so that we can embed the field code in the file names.

Please open: **field_s.nc.info** and **field_z.nc.info**

Surface

*gmt surface [table] **-G**outputfile.nc **-I**increment -Rregion [-Aaspect_ratio|m] [**-C**convergence_limit[%]] [-Llower] [-Lupper] [-Mmax_radius[u]] [-Nmax_iterations] [-Q] [-Ssearch_radius[m|s]] [**-T**[i|b]tension_factor] [-V[level]] [-Zover-relaxation_factor] [-aflags] [-bibinary] [-dinodata] [-eregexp] [-fflags] [-hheaders] [-iflags] [-rreg] [-:[i|o]] [--PAR=value]*

- surface reads randomly-spaced (x,y,z) triples from standard input [or table] and produces a binary grid file of gridded values z(x,y) by solving:

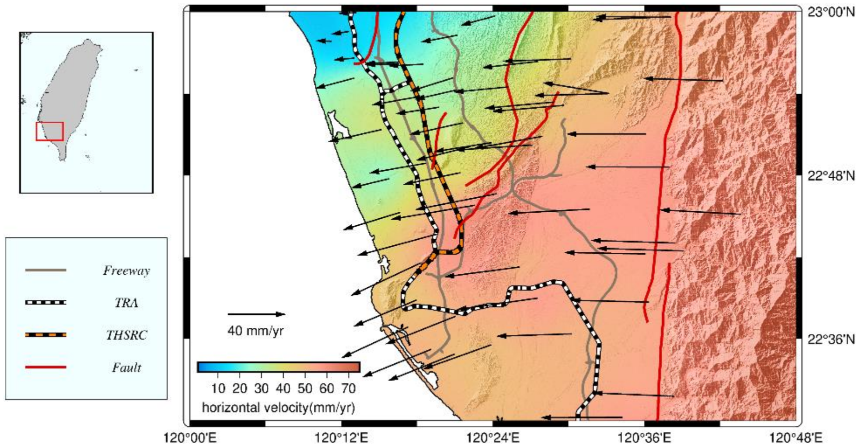
$$(1 - T) * L (L (z)) + T * L (z) = 0$$

- where T is a tension factor between 0 and 1, and L indicates the Laplacian operator (拉普拉斯算子). T = 0 gives the "minimum curvature" solution.
- Minimum curvature can cause undesired oscillations and false local maxima or minima (See Smith and Wessel, 1990, Smith-Wessel-1990.pdf), and you may wish to use T > 0 to suppress these effects.

-T[i|b]*tension_factor*: These must be between 0 and 1. Default = 0 for both gives minimum curvature solution. Experience suggests:

1. T ~ 0.25 usually looks good for potential field data; 2. T should be larger (T ~ 0.35) for steep topography data; 3. T = 1 gives a harmonic surface (no maxima or minima are possible except at control data points).

Lect09B



Copy subtle.cpt to c:/programs/gmt6/share/cpt

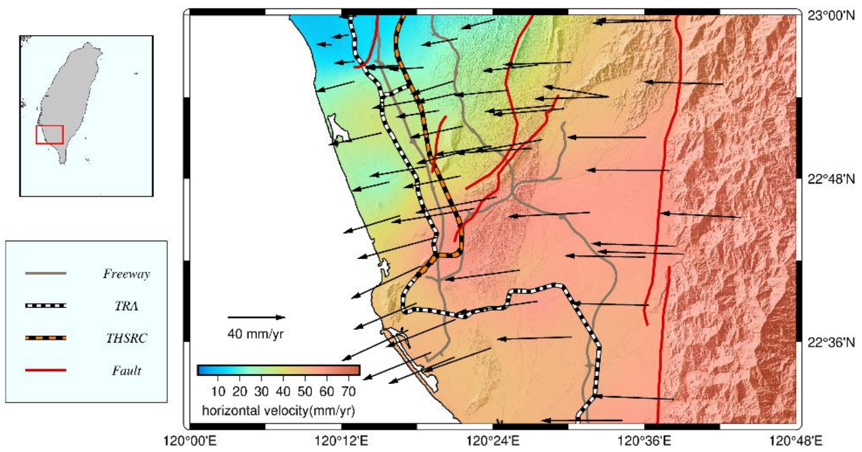
```
set GPS=cGPS-2018_S01R.gmt
gawk "{print $2, $3, sqrt($4*$4+$5*$5) }" %GPS% | gmt blockmean -R%range% -I0.01 > GPS.xy
gmt surface GPS.xy -R%range% -T0.05 -I0.01 -GGPS.grd –V
gmt grdgradient %topo% -A300 -G temp_shade.nc -Ne0.5 -V
```

```
gmt grdcut temp_shade.nc -RGPS.grd -Gtemp_cut.nc
gmt grdsample GPS.grd -Rtemp_cut.nc –GGPS_temp.grd –V
gmt makecpt -Csubtle -T0.68/75/0.1 -Z  > velocity.cpt
gmt makecpt -Cvelocity.cpt -A50 > velocity50.cpt
```

- gmt makecpt **-A***transparency[+a]*: Sets a constant level of transparency (0-100) for all color slices.
  - Prepend +a to also affect the fore-, back-, and nan-colors
  - Default is no transparency, i.e., 0 (opaque)

Please try: different normalization for **-N**e or **-N**t and level of transparency

Lect09B




```
gmt begin %prefix% tif A+m0.5c
gmt basemap -Bxa0.2f0.1 -Bya0.2f0.1 -BwESn -R%range% -JM121.0/7.5 -V
REM gmt draw inland image
gmt coast -Gc -Df -V
gmt grdimage GPS_temp.grd -Cvelocity50.cpt -Itemp_cut.nc
gmt coast -Q -V
```

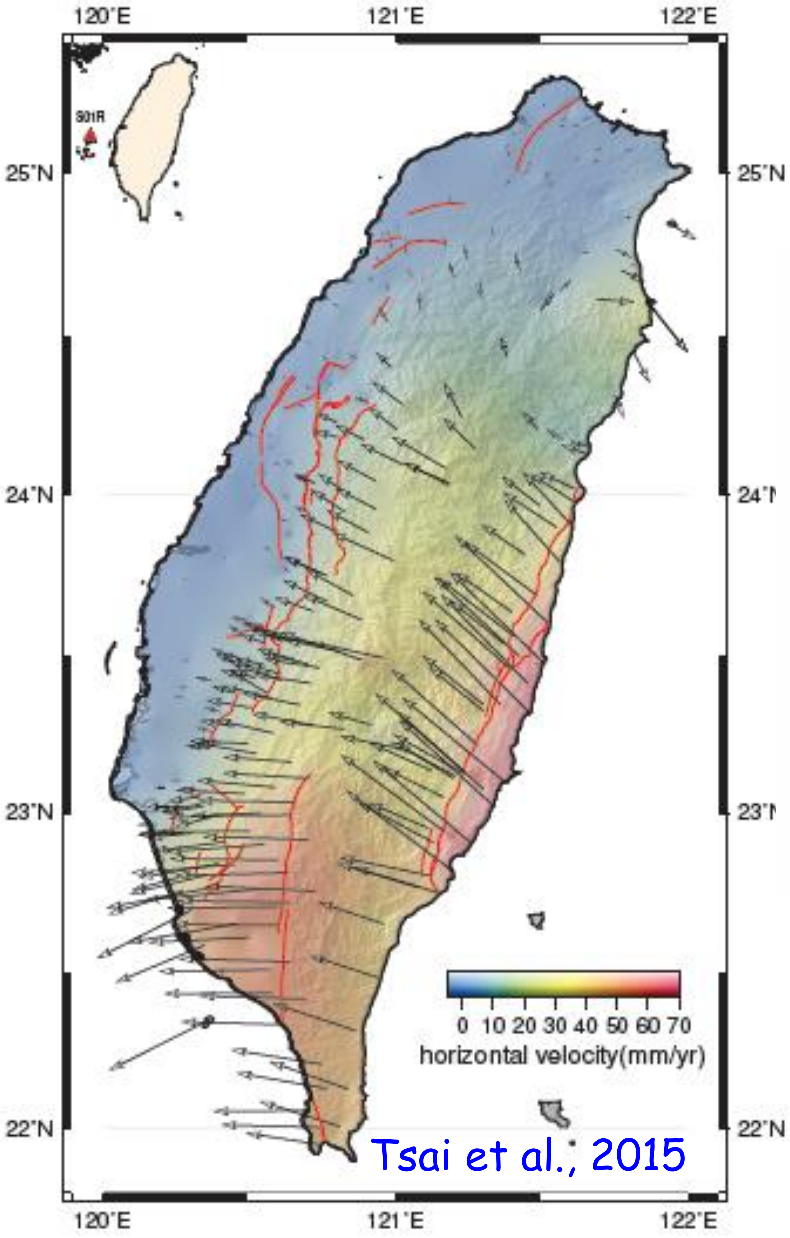
```
gawk "{print $2, $3, $4, $5, 0, 0, 0 }" %GPS% | gmt velo -Se.018/0.95/0 -A0.12i+a30+e -W1p,black -Gblack
REM ====== Add colorbar ==========
gmt colorbar -Cvelocity50.cpt -Dx0.1/0.6+w2.0/0.12+h -N -Bx10+l"horizontal velocity(mm/yr)" -V
```

Please open cGPS-2018_S01R.gmt

8118	120.553	23.463	-14.9	4.1	3.7	0	0	0.1
AKND	120.3573	22.8033	-39.2	-8.1	2.5	0	0	0
ALIS	120.8133	23.5082	-28.4	5.9	2.3	0	0	0.1

- S01R: GNSS (Global Navigation Satellite system) station located at Paisha, Penghu (澎湖白沙站)
- https://scweb.cwb.gov.tw/geophysics/GPSContent.aspx?lan=tw (中央氣象局地球物理觀測平台)

Abnormal deformation across active structures



Tsai et al., 2015

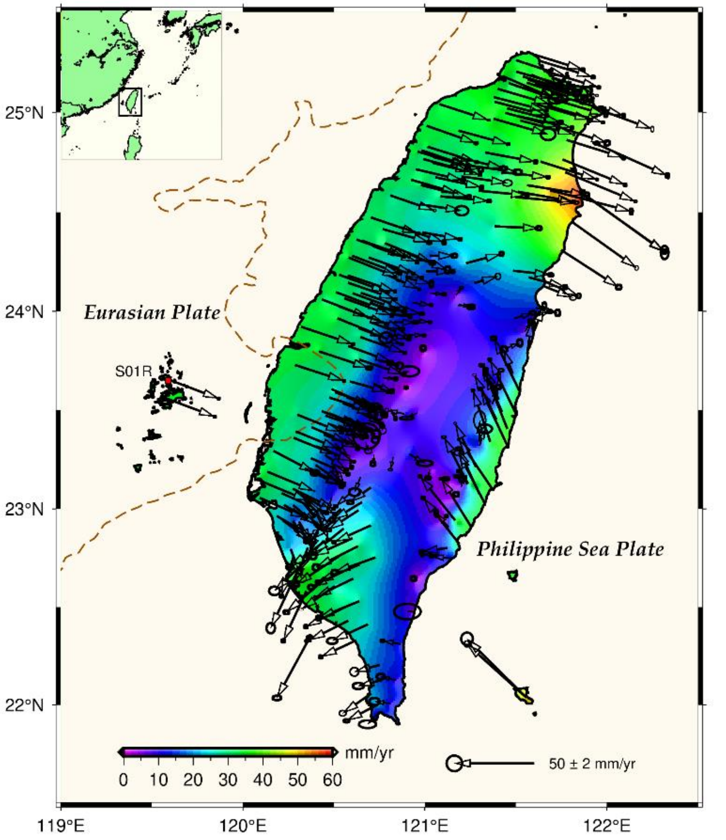
nd fill elevated Tienliao III Bridge to the

https://www.youtube.com/watch?v=TE6s9MTSHUI

Lect09c

```
gmt gmtset FONT_TITLE 18p,16,blue MAP_TITLE_OFFSET 2p
```

Velocity field of CGPS in Taiwan (2007-2013, ITRF2008)



Q: Why $2, $3, $4, $6, $5, $7, 0, $1?

```
gawk "{print $2, $3, $4, $6, $5, $7, 0, $1}" CGPS_ITRF2008.dat > CGPS_ITRF2008.gmt
gawk "{print $1, $2, sqrt($3^2+$4^2)}" CGPS_ITRF2008.gmt > CGPS_ITRF2008_Vect.gmt
```

Open CGPS_ITRF2008.gmt

Lon.(°)	Lat.(°)	Ve	Vn	(mm/yr)	(mm/yr)	0	Site
120.55298	23.46298	16.4	-7.7	0.4	0.5	0	8118
120.35726	22.80331	-8	-21.6	1	0.3	0	AKND

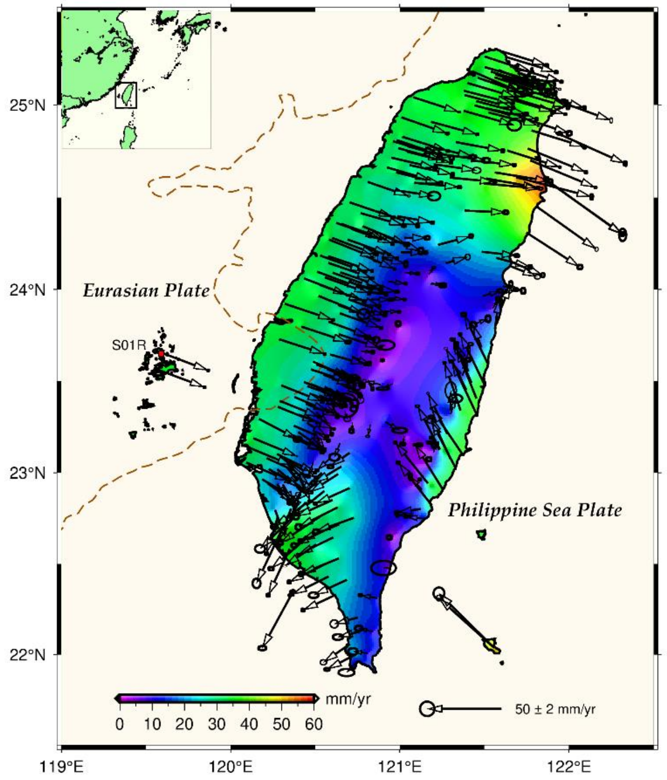
- ITRF: International Terrestrial Reference Frame (國際地球參考系統) (http://itrf.ensg.ign.fr/)
- Continuous GPS data: Dr. Min-Chien Tsai (蔡旻倩博士），Seismological Center, Central Weather Bureau, Taiwan, ROC)

Open CGPS_ITRF2008.dat (From Table 1 of Tsai et al., TAO, 2015)

Site	Lon.(°)	Lat.(°)	Ve (mm/yr)	Vn (mm/yr)	Vu (mm/yr)	Period (year)
8118	120.55298	23.46298	16.4 0.4	-7.7 0.5	1 3	2007~2014
AKND	120.35726	22.80331	-8 1	-21.6 0.3	3.2 1.4	2007~2014

Lect09c

Velocity field of CGPS in Taiwan (2007-2013, ITRF2008)

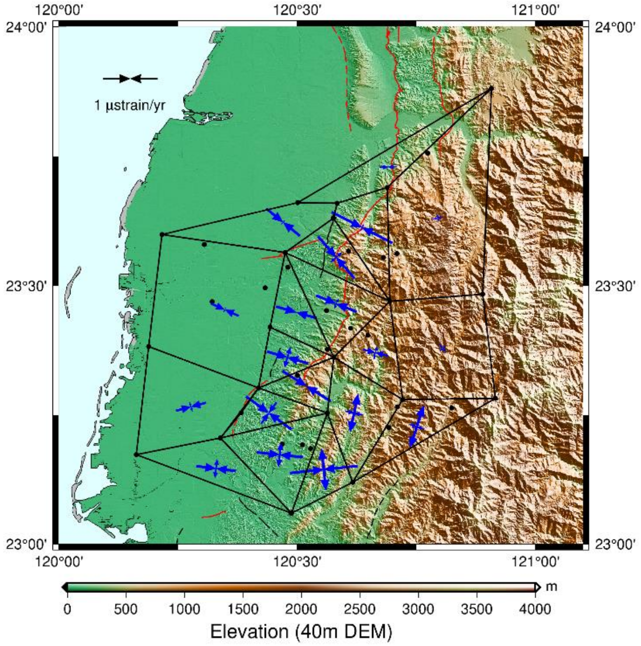



```
gmt blockmean CGPS_ITRF2008_Vect.gmt -R -I0.01 -h1 > cgps_mean.xy
gmt surface cgps_mean.xy -R -T0.35 -I0.01 -Gcgps_mean.xy.grd -V
gmt makecpt -Crainbow -T0/60/2 > cgps.cpt
gmt grdimage cgps_mean.xy.grd -I+a315+ne0.3 -Ccgps.cpt -B –V
gmt coast -Df -W1.5p -V -Sfloralwhite
```

```
gmt velo CGPS_ITRF2008.gmt -J -R -Se.015/0.95/0 -A0.15i+a30+e -W1.5p,Black -h1 -V
REM Plot legend
gmt set PS_CHAR_ENCODING Standard+
echo 121.60 21.70 -50 0 2 2 0 | gmt velo -Se.015/0.95/10 -A0.15i+a30+e -W1.5p,black
echo 121.92 21.70 10,0 0 MC 50 \234 2 mm/yr | gmt text -F+f+a+j -V
```

-A: Vector Attributes

+aangle: sets the angle of the vector head apex [30].
+e: places a vector head at the end of the vector path [none]. Optionally, append t for a terminal line, c for a circle, or a for arrow [Default].



Lect09d

```
gmt velo Strain.txt -R -Jm -Sx0.8  -W2p,blue -A+a45+n1.0 -V
echo 120.15 23.90 -1 0 180 | gmt velo -Sx0.8 -W1p,0/0/0 -A+a45+n1.0  -V
echo 120.15 23.85 12 0 0 MC 1 @~m@~strain/yr | gmt text -Jm –R -F+f+a+j -V
```

- *nnorm*: Scales down vector attributes
- @~m@~: @~ (tilde,波浪號) toggles between the selected font and Greek (Symbol) (打開/關閉Symbol字體)

-Sx*cross_scale*: Gives Strain crosses. Cross_scale sets the size of the cross in inches (unless c, i, or p is appended). Parameters in the following columns:

1,2: longitude, latitude, of station

3: eps1 (ε_{11}), the most extensional eigenvalue of strain tensor, with extension taken positive (應變張量的主值，正值為伸張變形)

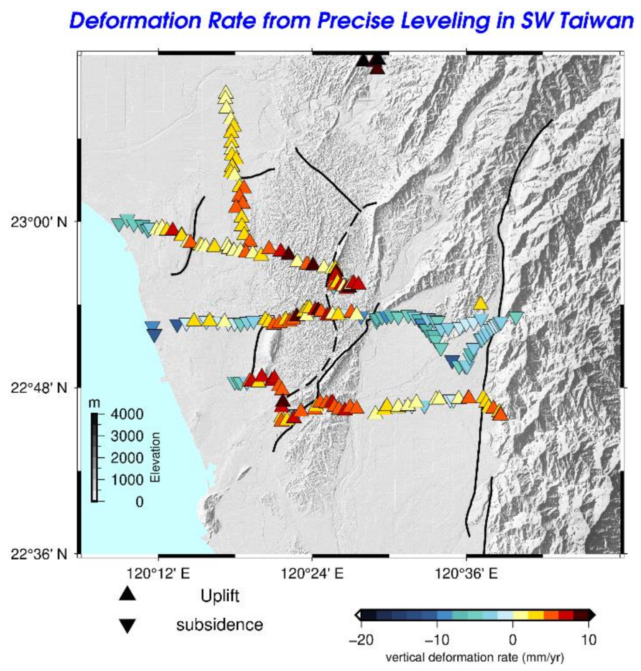
4: eps2 (ε_{22}), the most compressional eigenvalue of strain tensor (負值為壓縮變形)

5: azimuth of eps2 in degrees CW from North.

Open Strain.txt

120.6915	23.7296	-0.05	-0.31	88
120.4708	23.6229	0.10	-0.79	129
20.3487	23.4537	0.10	-0.55	114

Lectoge




```
gmt makecpt -Cbathy -T-20/0/2 -N > vertical.cpt
gmt makecpt -Chot -T0/10/2 -I >> vertical.cpt
gmt plot leveling_s.txt -Si -Cvertical.cpt -W0.2p,gray0 -V
gmt plot leveling_u.txt -St -Cvertical.cpt -W0.2p,gray0 –V
gmt colorbar -Cvertical.cpt -Dx8c/-1.9c+w6.5c/0.3c+h+e -B10+l"vertical deformation rate (mm/yr)" -V
```

- **-N**: Do not write out the background, foreground, and NaN-color fields [Default will write them]

- **-I**: Reverse the sense of the color progression (翻轉顏色的順序)

Open leveling_s.txt (subsidence)

```
> 7新竹-五峰
120.9283 24.8428   -5.99058   0.2i
120.9334 24.8417   -6.13536   0.2i
120.9396 24.8383   -6.26684   0.2i
```

Open leveling_u.txt (uplift)

Open vertical.cpt

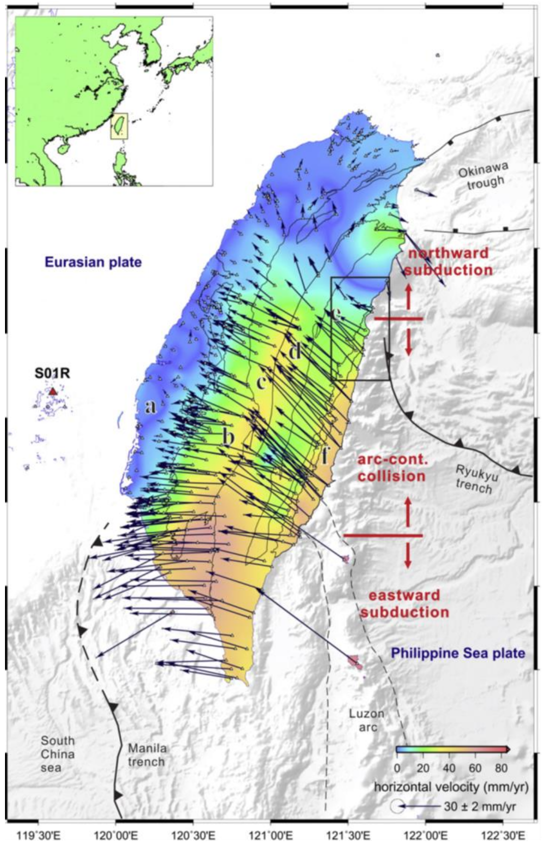
```
-20  12.4/16/31.6          -18   12.4/16/31.6
-18  32.4/44/84.4          -16   32.4/44/84.4
-16  38/60/106             -14   38/60/106
-----
-4   135.8/209.33/229.8    -2    135.8/209.33/229.8
-2   203.4/237/248.6        0    203.4/237/248.6
0    255/255/153            2    255/255/153
2    255/221/0              4    255/221/0
-------
8    68/0/0                 10   68/0/0
B    white
F    black
N    127.5
```

Exercise 09

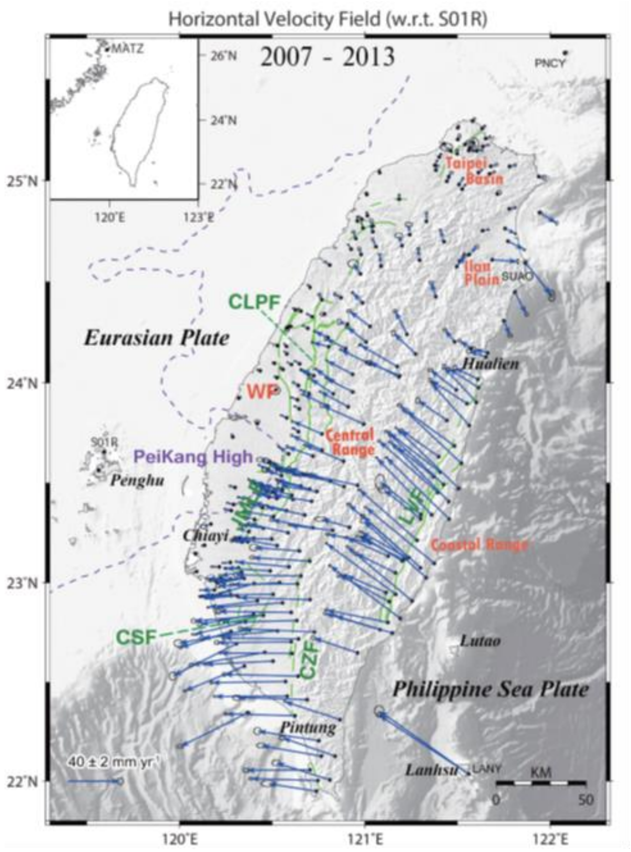
- Using Lect09c.bat or Lect09c.sh as a template
- Using blockmean and surface to get horizontal velocity field (see Chen et al., 2014) based on the data (Table 2) published from Tsai et al. (2015).
- Using gmt inset to draw a locality map shown in Chen et al., 2014 or Tsai et al. 2015

- Superimpose GPS velocity field on 40 m DEM (Taiwan40m_WGS84.nc) by adjusting transparency and bathymetry around Taiwan (Taidp200m.nc)

See paper:
Tsai, M.C., et al., 2015. Velocity Field Derived from Taiwan Continuous GPS Array (2007 - 2013), Terr. Atmos. Ocean. Sci., 26(5), 527-556



Chen et al., 2014



Tsai et al., 2015

Final Report

- Part I (60%): Basemap of your study area with all commands learned with various dataset including DEM, active faults, seismicity, sampling locations, GPS velocity field, etc. The more data you use, the higher grade you gain!
- Part II (40%): topic “Energy and Environment” in Our World in Data (https://ourworldindata.org/)

Suggested subtopics: Climate Change, Access to Energy, Energy, Renewable Energy, Fossil Fuels, CO_2 and Greenhouse Gas Emissions, Natural Disasters

- Give a brief introduction of motivation of your study (Part 1) and how you are interested in the topic associated with Energy and Environment (Part II)
- Detailed explanation of your data used for GMT
- Highlight the new commands or arguments used for drawing
- Feedback for improvement of the course

Our World in Data: Energy and Environment