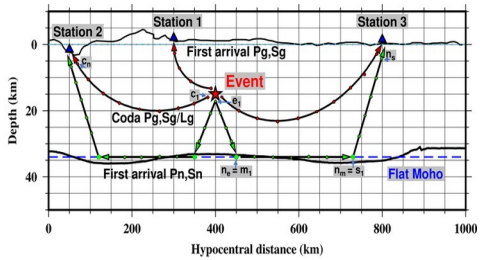
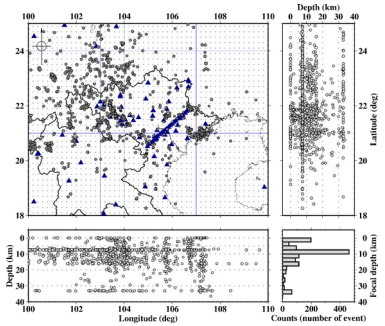
1D Ppn relocation package user guide

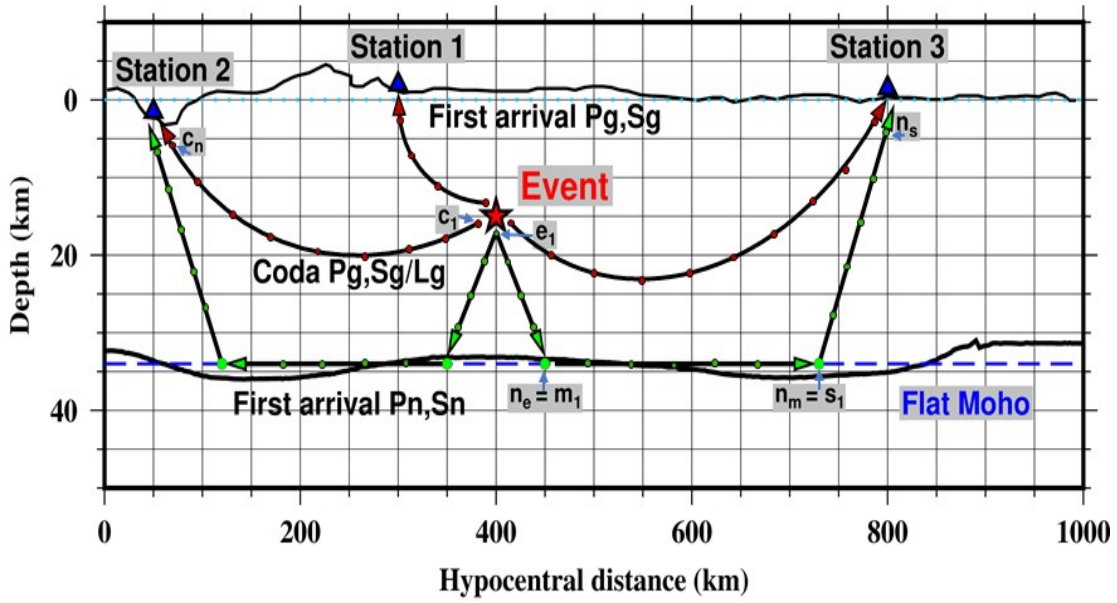




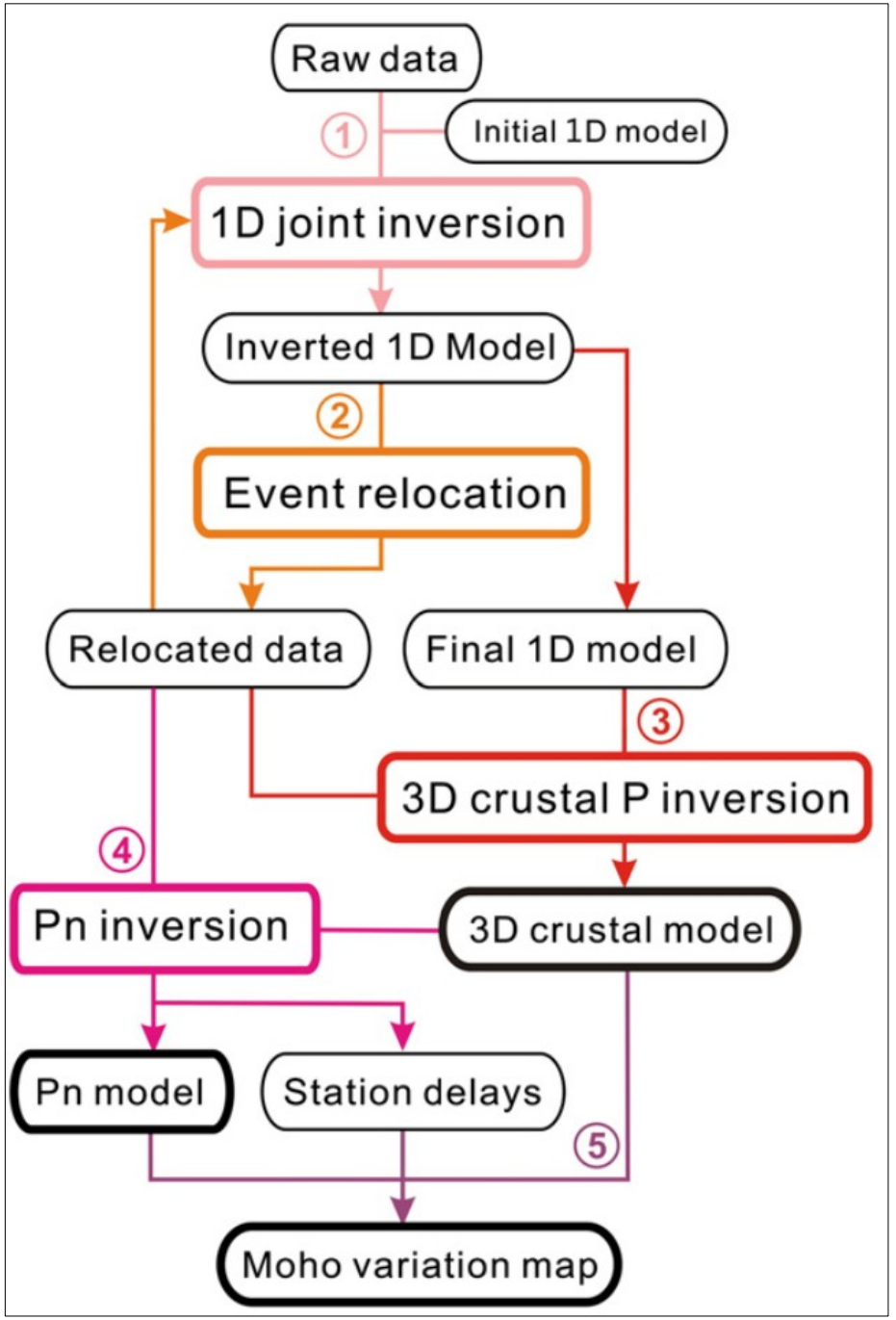
Ha Vinh Long

December, 27th 2022

Idea



Conceptual diagram of direct and refracted wave on the crust



Huang et. al, 2013

WORKING DIRECTORY: reloc

```
[longhv@omori 1.relocPS]$ ls
00_1Dmod                   00.plotrms.sh              distazsub.c   input                output_data      producerayfile      reloc           run.log      s3dloc.out  surfpath.o
00.compare_phases_cut.sh   00.reloc_compare_cata.sh   distazsub.o   lsqr.log             output_data_cut  producerayfile.f90  reloc2inv1d.f90 s3dloc.chk   s3dloc.rms  TDplot
00.compare_phases.sh       00.residual.bash           err_check     make3dmod_combined   para.inp         ray_path_001        reloc2inv1d.o   s3dloc.cor   s3dloc.tt   topo.grd
00_evt                     00_sta                     fault_lv1.txt Makefile             pbr.f90          ray_path_002        residual_001    s3dloc.err   src         topo.shd
00_evt_cut.out             00_sta.out                 func.f90      makeinput            pbr.o            ray_path_003        residual_002    s3dloc.f90   subr.f90    utilities
00_evt.out                 00_tt                      func.o        MOD3D                pn_path.f90      ray_path_004        residual_003    s3dloc.lis   subr.o
00.phases.sh               00_tt_full                 init_data     outputcatalog.f90    pn_path.o        readme              residual_004    s3dloc.o     surfpath.c
```

- Initial data: (00_evt | 00_sta | 00_tt)
- Initial model: MOD3D
- Output files (main): s3doc.***
- Output files (plot and check): ray_path*** | residual***
- Program files and tool: make3dmod_combined | **src** | utilities
- Plot files: *.sh

Input data preparation

➢ Station file

```
[longhv@omori 1.relocPS]$ head 00_sta
TDV    21.4647   105.6457    1200.0    0.0    0.0
BGV    21.2902   106.2275      15.0    0.0    0.0
DHV    21.6268   105.1838      70.0    0.0    0.0
HNV    20.9382   105.6888      50.0    0.0    0.0
HBV    20.7962   105.3387      54.0    0.0    0.0
PLV    20.8060   106.6302      90.0    0.0    0.0
TQV    21.8283   105.2083      20.0    0.0    0.0
KMI    25.1233   102.7400    1975.0    0.0    0.0
CHTO   18.8140    98.9443     316.0    0.0    0.0
QIZ    19.0290   109.8445     240.0    0.0    0.0
```

➢ Column contents
+ **col 1**: station name (max 4 characters)
+ **col 2**: station latitude (deg)
+ **col 3**: station longitude (deg)
+ **col 4**: station elevation (m)
+ **col 5**: station residual 1 (sec)
+ **col 6**: station residual 2 (sec)

➢ Event list file

```
[longhv@omori 1.relocPS]$ head 00_evt
  19960928   13141660 19.601 102.860    7.50 5.4 0.0 0.0 1.2          4
  19961221   17510600 20.423 100.168    7.50 5.3 0.0 0.0 1.9          5
  19970109   09425780 24.019 103.940   33.00 3.7 0.0 0.0 1.3          6
  19970113   16083780 23.971 103.820    7.50 2.5 0.0 0.0 1.5          7
  19971024   09304140 22.519 101.625    7.50 4.2 0.0 0.0 1.1          8
  19971119   06515500 21.994 101.717    7.40 3.8 0.0 0.0 0.8          9
  19980210   08180419 21.125 104.809   22.80 3.2 0.0 0.0 0.4         10
  20200727   05144850 20.939 104.709    7.00 5.1 0.0 0.0 1.0       1262
  20200727   05395610 20.921 104.711   15.00 2.8 0.0 0.0 0.8       1263
  20200727   08522510 20.929 104.704   13.20 3.0 0.0 0.0 0.8       1264
```

➢ Column contents
+ **col 1**: event date (YYYYMMDD)
+ **col 2:** event time (MMHHmmSS)
+ **col 3**: event latitude (deg)
+ **col 4**: event longitude (deg)
+ **col 5**: event depth (km)
+ **col 6**: event magnitude
+ **col 7**: station residual 2 (sec)
+ **col 8~10**: not use
+ **col 11**: event id (no duplicate required)

➢ Traveltime file (absolute value)

```
[longhv@omori 1.relocPS]$ head 00_tt
#           1
TDV     3.70   0.0 Pg
BGV     9.90   0.0 Pg
DHV    10.20   0.0 Pg
HNV    12.20   0.0 Pg
PLV    21.20   0.0 Pg
#           2
TDV     4.33   0.0 Pg
BGV    10.53   2.0 Pg
TQV    10.88   1.0 Pg
```

➢ Column contents
Section 1: **# *…ith*:** event id (match with event file)
Section 2:
+ **col 1**: station name (match with station file)
+ **col 2**: traveltime
+ **col 3**: phase weighted
+ **col 4**: phase name (Pg, Pn, Sg, Sn)

Input model preparation

- Create 3D model from 1D

Using the make3dmod_combined directory to make the 3D model

```
 1. 11
-10.000  -2.500   0.000   5.000  10.000  20.000  30.000  40.000  50.000  60.000 660.000
  5.241   5.741   5.841   5.874   5.881   5.883   5.925   5.925   5.925   5.925   5.925
 8.065
34.517
```

- **Row 1: model parameters**
  + **col 1**: not use
  + **col 2**: number of layers
- Row 2: Depth value
- Row 3: Velocity value at the depth
- Row 4: Mantle velocity (at Moho)
- Row 5: Moho depth

Notice: This example model calculate from 1D inversion from Pg and Pg phases

Input model preparation

- Create 3D model from 1D

Using the make3dmod_combined directory to make the 3D model

```
[longhv@omori make3dmod_combined]$ cat 3dmod.params
*       ============= Parameter file for make 3D model from 1D model =======
*       Any line start with * character will be ignore.
*       ------------------- Start the parameter ----------------------------
* Start long - end long
100.0   110.0
* Start lat - end lat
17.5    25.5
* Horizontal grid (grdxy)
0.25
*   Span boudary of the model
3.0
* number of models: nmod (1=P, 2=S, 3= P&S)
3
* Input 1st models (if nmod=1, it P mod or S mod)
output_005P
* Input 2nd model
output_005S
*
```

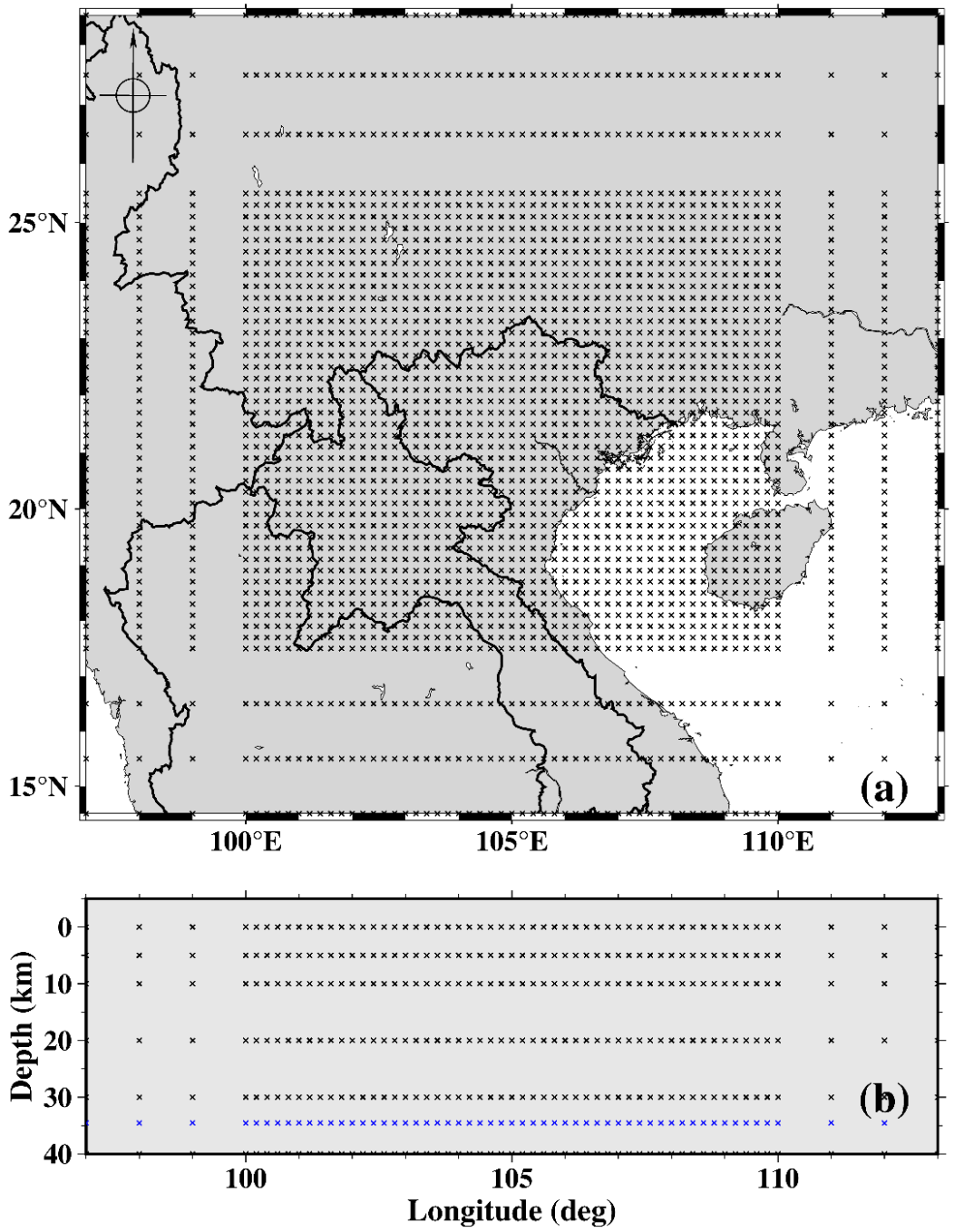
Change the setting file 3dmod.params

Run:

> Make clean

> Make

```
[longhv@omori make3dmod_combined]$ make clean
rm -f *.o make3dmod MOD.ini MOD3D
[longhv@omori make3dmod_combined]$ make
gfortran -O3 -mcmodel=medium -I../ -c make3dmod.f90
gfortran -O3 -mcmodel=medium -I../ -o make3dmod *.o
./make3dmod
 This version make the model for P, S or both P-S wave speed
 Reading the paramter file 3dmod.params
 nlon,nlat          43          35
 read 1D model for P wave in file: output_005P
 read 1D model for S wave in file: output_005S
 3D models build up
 Write the output model on ...MOD3D file
 writing the P wave model
 writing the S wave model
 Done!
```



Input model preparation

```
[longhv@omori 1.relocPS]$ head MOD3D
0.20  71  61  20  20
0.20 1.00  71  61   9  20  20
  90.00  91.00  92.00  93.00  94.00  95.00  96.00  97.00  98.00  99.00 100.00 100.20 100.40 100.60 100.80 101.00 101.20 101.40 101.60 101.80 102.00 102.20 102.40 102.60 102.80 103.00 103.20
103.40 103.60 103.80 104.00 104.20 104.40 104.60 104.80 105.00 105.20 105.40 105.60 105.80 106.00 106.20 106.40 106.60 106.80 107.00 107.20 107.40 107.60 107.80 108.00 108.20 108.40 108.60 1
08.80 109.00 109.20 109.40 109.60 109.80 110.00 111.00 112.00 113.00 114.00 115.00 116.00 117.00 118.00 119.00 120.00
   7.50   8.50   9.50  10.50  11.50  12.50  13.50  14.50  15.50  16.50  17.50  17.70  17.90  18.10  18.30  18.50  18.70  18.90  19.10  19.30  19.50  19.70  19.90  20.10  20.30  20.50  20.70
 20.90  21.10  21.30  21.50  21.70  21.90  22.10  22.30  22.50  22.70  22.90  23.10  23.30  23.50  23.70  23.90  24.10  24.30  24.50  24.70  24.90  25.10  25.30  25.50  26.50  27.50  28.50
29.50  30.50  31.50  32.50  33.50  34.50  35.50
  90.00  91.00  92.00  93.00  94.00  95.00  96.00  97.00  98.00  99.00 100.00 100.20 100.40 100.60 100.80 101.00 101.20 101.40 101.60 101.80 102.00 102.20 102.40 102.60 102.80 103.00 103.20
103.40 103.60 103.80 104.00 104.20 104.40 104.60 104.80 105.00 105.20 105.40 105.60 105.80 106.00 106.20 106.40 106.60 106.80 107.00 107.20 107.40 107.60 107.80 108.00 108.20 108.40 108.60 1
08.80 109.00 109.20 109.40 109.60 109.80 110.00 111.00 112.00 113.00 114.00 115.00 116.00 117.00 118.00 119.00 120.00
   7.50   8.50   9.50  10.50  11.50  12.50  13.50  14.50  15.50  16.50  17.50  17.70  17.90  18.10  18.30  18.50  18.70  18.90  19.10  19.30  19.50  19.70  19.90  20.10  20.30  20.50  20.70
 20.90  21.10  21.30  21.50  21.70  21.90  22.10  22.30  22.50  22.70  22.90  23.10  23.30  23.50  23.70  23.90  24.10  24.30  24.50  24.70  24.90  25.10  25.30  25.50  26.50  27.50  28.50
29.50  30.50  31.50  32.50  33.50  34.50  35.50
 -20.00   0.00  10.00  20.00  30.00  40.00  50.00  60.00 660.00
   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.0
15   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8
.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015
   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.0
15   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8
.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015
   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.0
15   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8
.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015   8.015
```

Row 1: grid size | *i*lat inner | *k*long inner | *n*lat outer | *m*long outer (**for Moho**)
Row 2: grid size inner | grid size outer | *i*lat inner | *k*long inner | *k*dep | *n*lat outer | *m*long outer (**for Crust**)
Row 3: Latitude coordinates for Moho (total *i* values)
Row 4: Longitude coordinates for Moho (total *k* values)
Row 5: Latitude coordinates for Crust (total *i* values)
Row 6: Longitude coordinates for Crust (total *k* values)
Row 7: Depth coordinates for Crust (total *k* values)
Row 8~: velocity for Pn – Pg – Sn - Sg

Input parameters file preparation

```
[longhv@omori 1.relocPS]$ cat input
00_evt
00_sta
00_tt_full
MOD3D
34.552
```

Row 1: event file name
Row 2: station file name
Row 3: traveltime file name
Row 4: Model file name
Row 5: 1D Moho depth value

parameters file

```
[longhv@omori 1.relocPS]$ cat para.inp
!-CONTROL SETTING
    real*8 Ws2p,damp,rmscut,adjcut,cut_off
    integer maxitr,maxirs,maxevt,maxsta,maxrds,maxnlat,maxnlon,maxndep,ilatdeg,ilondeg,idepkm,&
            maxtrpts,maxcoef,maxgrid,maxcor,iluck
    parameter(Ws2p=0.5)  ! Phase weight of S wave corresponded with P wave
    parameter(damp=0.05) ! model damping
    parameter(maxcor=1)  ! station correlation (=1 if no corr)
    parameter(maxitr=4)  ! Number of relocate iterations
    parameter(maxirs=5)  ! Number of lottery search
    parameter(rmscut=0.01)
    parameter(adjcut=0.5)  ! km unit
    parameter(cut_off=50.0)  ! not use the ray over cut_off sec residual with observed ray
    parameter(iluck=0) ! Set parameter for play role the lottery = 1 or not = 0
    parameter(iluflag=0) ! location uncertainty accumulation flag (0= no sum the error over iterations, 1 = yes)
    parameter(imod=2) ! The wave type used. 1 for P wave only, 2 for P & S wave
    parameter(ijoint=1) ! Joint Pg, Pn or not (0 = no, 1 = yes)
    parameter(iforcedepth=0) ! use force the depth to 0 when the depth become negative (0 = no, 1 = yes)
```

Notice: Change the relocation options before recompile the program

Other parameters below this need fully understand with the program!!!

Now we can run!

Run:
> Make clean
> Make

```
[longhv@omori 1.relocPS]$ make clean
rm -f *.o ray_p* fort* *.err *.cor *.chk *.out s3*.rms s3*.tt *.tt residual_* *_data err_* *.log temp* tmp*
[longhv@omori 1.relocPS]$ make
gfortran  -c func.f90
gfortran  -c subr.f90
gfortran  -c pbr.f90
gfortran  -c pn_path.f90
gfortran  -c s3dloc.f90
gcc -Wall -c distazsub.c
gcc -Wall -c surfpath.c
surfpath.c: In function ‘surfpath_’:
surfpath.c:12:49: warning: variable ‘plon’ set but not used [-Wunused-but-set-variable]
  double x1,x2,x,y1,y2,y,z1,z2,z,px,py,pz,p,plat,plon;
                                                 ^
surfpath.c:12:44: warning: variable ‘plat’ set but not used [-Wunused-but-set-variable]
  double x1,x2,x,y1,y2,y,z1,z2,z,px,py,pz,p,plat,plon;
                                            ^
gfortran  -c reloc2inv1d.f90
gfortran -o reloc *.o
./reloc < input
 input event data file name:
 00_evt
 input station data file name:
 00_sta
 input absolute travel time file name:
 00_tt_full
 input velocity model file name:
 MOD3D
 input the moho depth:
   34.552000000000000
 nevt:          20 nsta:         134 nray:         669
********************************
Run the reloction with station correction number >    1
-------------------------------------------------
 # event:      1     #id:      4
Input location:102.860 19.601  7.500
 --> itr:            1
nray used:     23 rms: 0.33390116
Update the location:    102.834    19.572     8.398
```

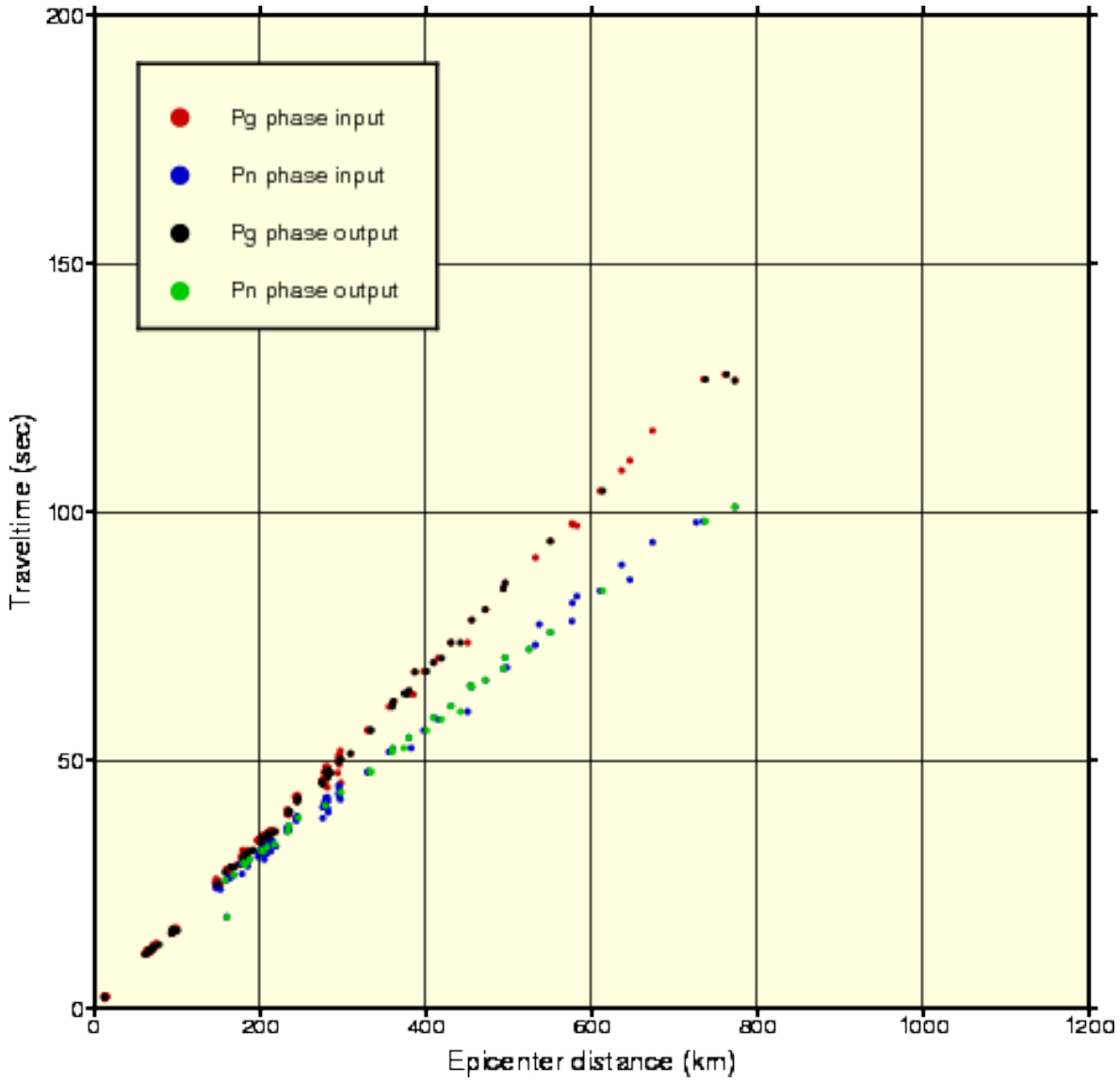
Notice: The print on the screen also can read on the file run.log

Now we can run!

Signal of finish

```
Iteration number - nresidual - RMS
     1     20      0.607
     2      9      0.331
     3      9      0.331
     4      9      0.330
Station number - nray used to correction - correction value

 process!! read the relocated event file: <- s3dloc.lis

 process!!!,reading updated station file: s3dloc.cor


 write to --> output file: -> 00_evt.out

 write to output file: -> 00_sta.out

 produce T-D data
 produce T-D data
rm: cannot remove `*.ps': No such file or directory
makecpt: Warning: Making a continuous cpt from a discrete cpt may give unexpect
psbasemap: Constructing basemap
pslegend: Generate temporary legend script GMT380830.bat
pslegend: Use temporary input file pslegend_380830.txt
pslegend: Executing and removing legend script
pslegend: Done
9 00_evt.out
[longhv@omori 1.relocPS]$
```

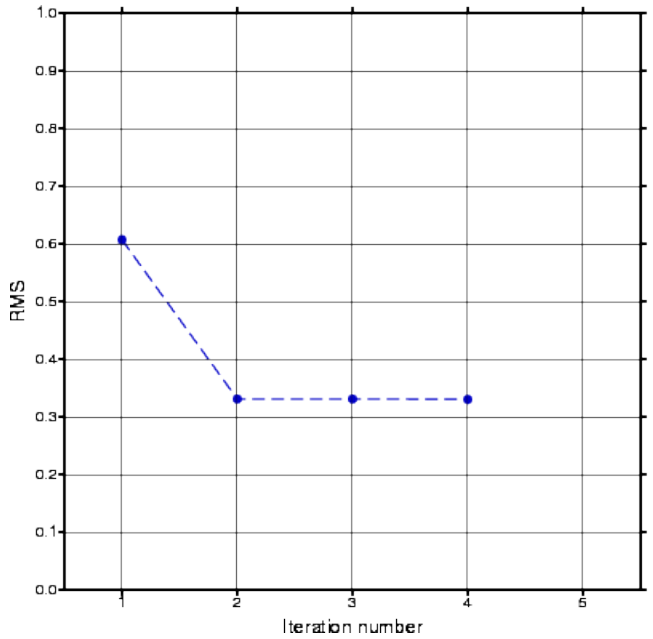
OUTPUT: 00_evt.out | 00_sta.out | 00_evt_cut.out (more sorely)

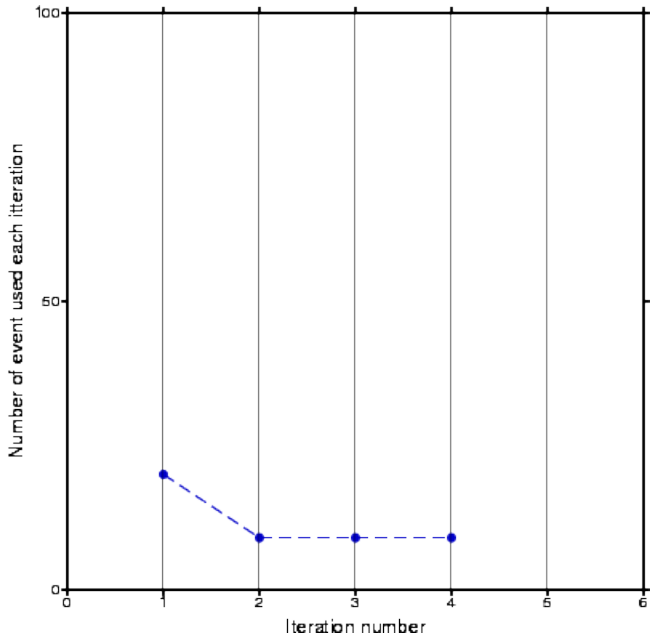


TD diagram of Phase before and after relocation

Some code to check!

> sh 00.plotrms.sh



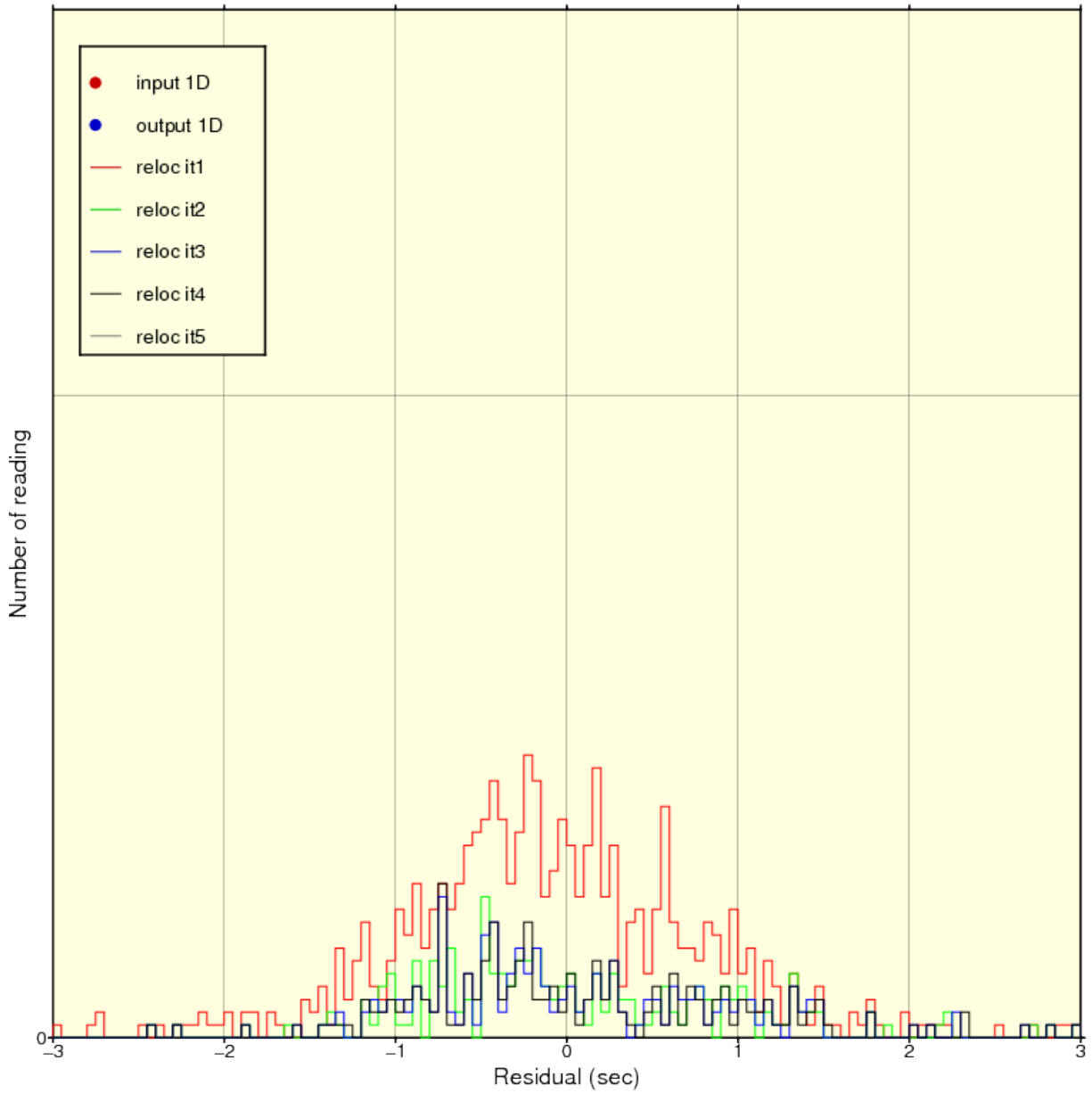


RMS reduction and the number of event use for each iteration

Some code to check!

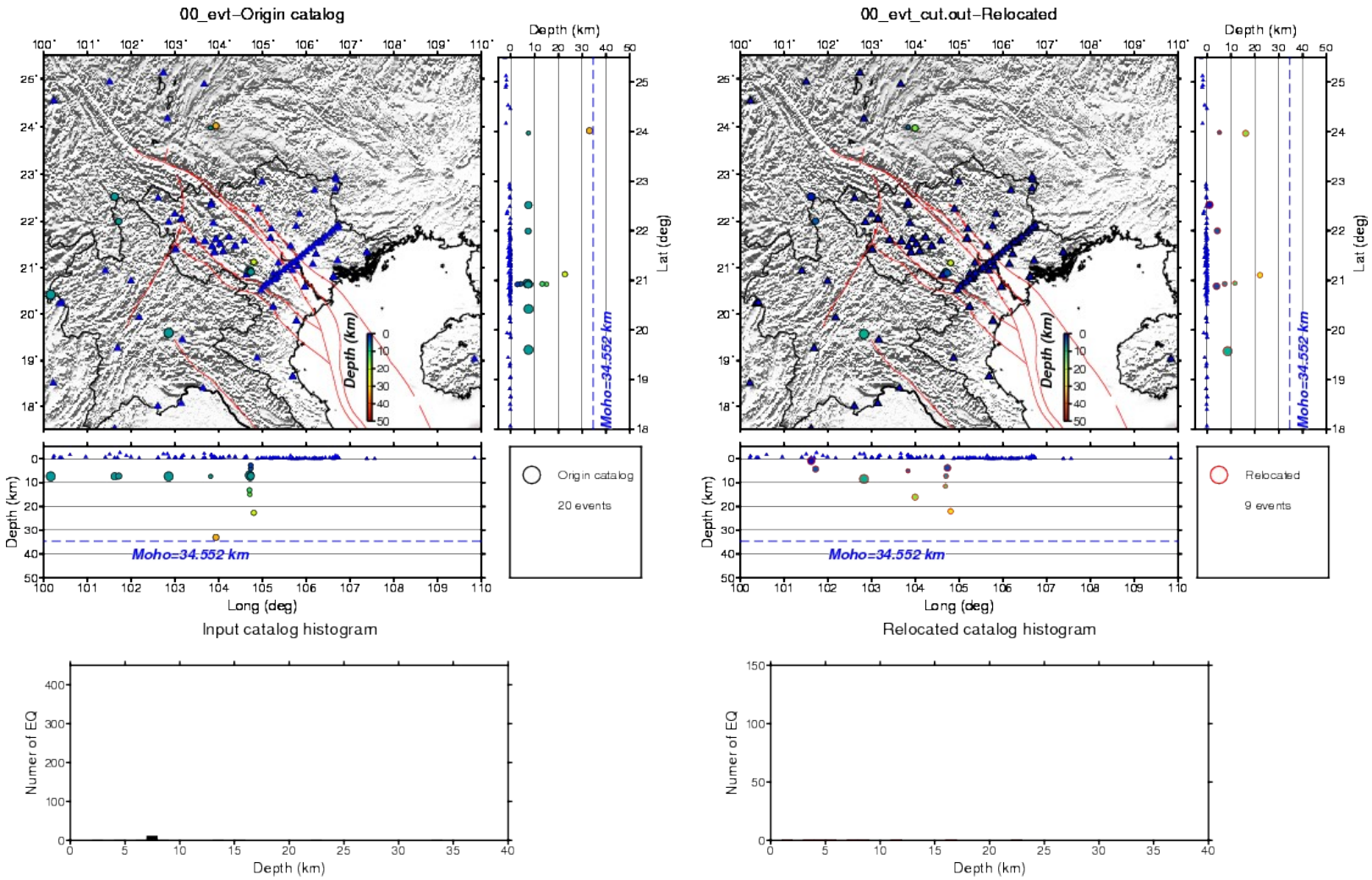
> sh 00.residual.bash

Residual distribution each iteration



Some code to check!

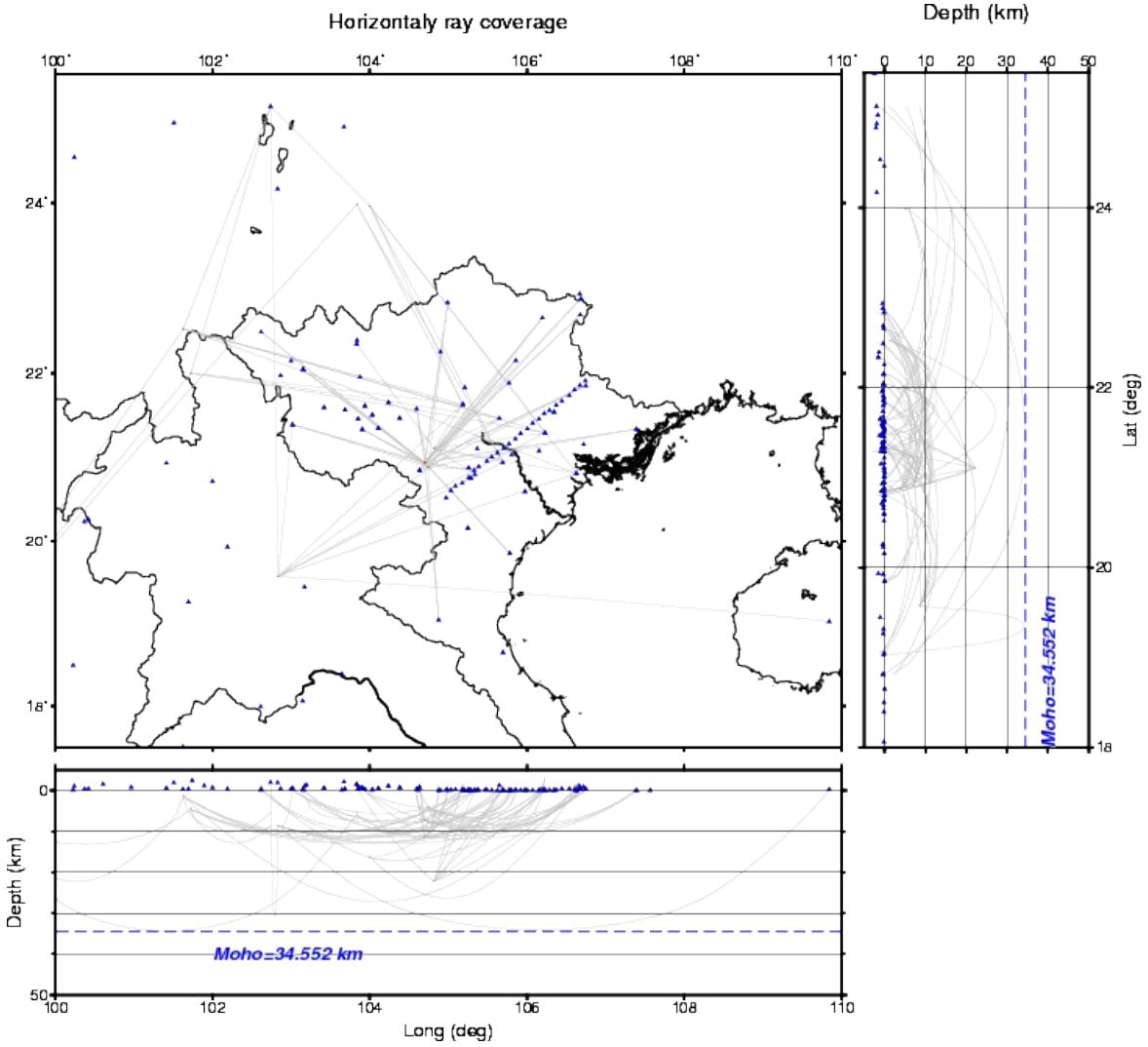
> sh 00.reloc_compare_cata.sh

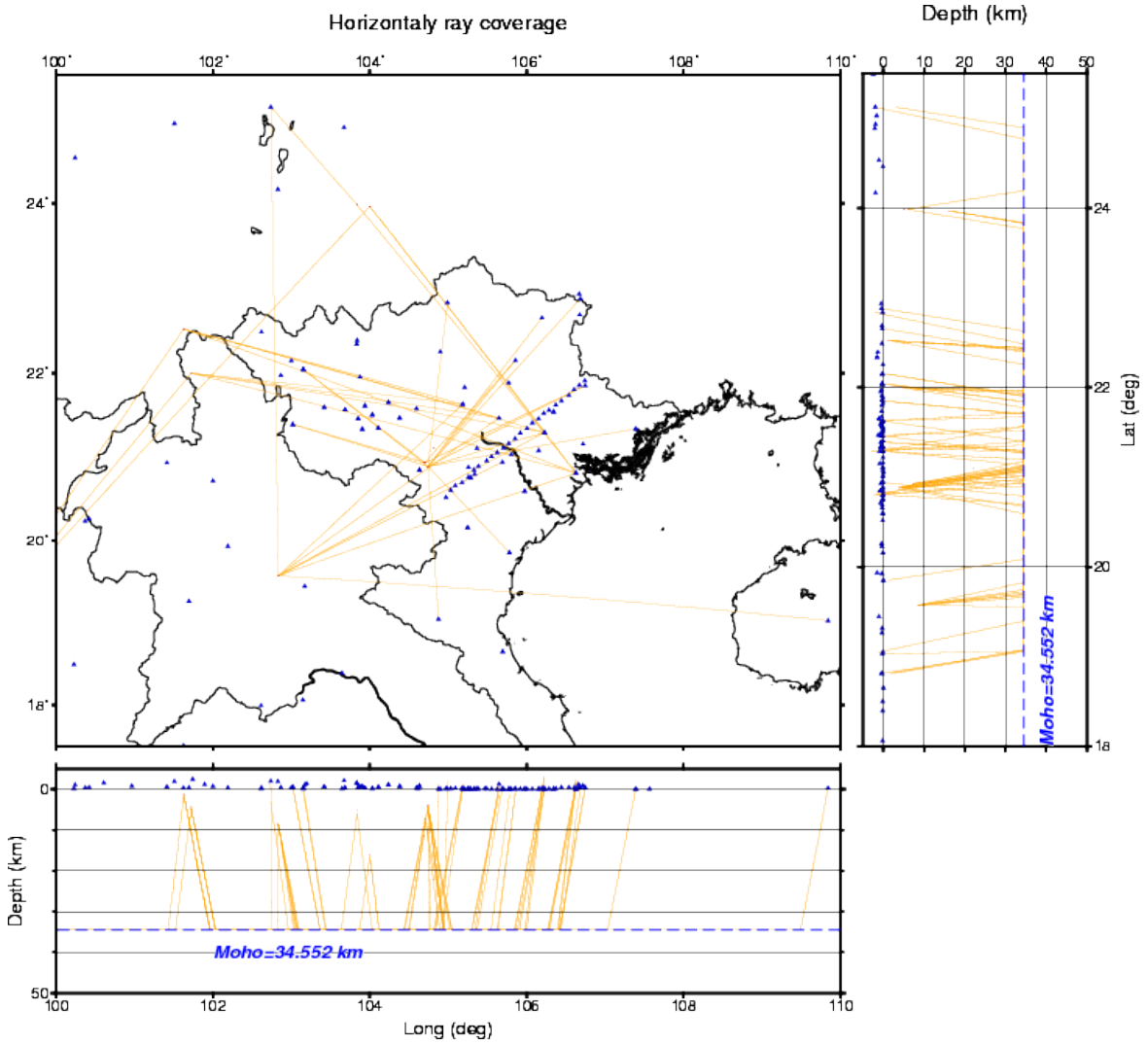


Initial (left) and output data (right)

Some code to check!

> sh 00.reloc_compare_cata.sh





Raytracing


THAT'S ALL
FOLKS !