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DMG dipartimento di matematica e geoscienze

The DMG Quick Reference Manuals

Quick LSO Optimization and Plotting

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Quick LSO Optimization and Plotting

In the following the procedure for quick LSO Optimization and plotting of results is shown.

Required input files

Required input files can be found in **/XDST/Examples/LSO_Example**. Copy them into a directory dedicated to the computations.

Here is what you should have in the directory before you run *`Lso.sh`*:

```
drwxr-xr-x  110 vaccari  dstguest  3774 Nov  6 09:10 CELLE
drwxr-xr-x    2 vaccari  dstguest    68 Nov  6 09:15 CELLE_fixLayer
drwxr-xr-x    2 vaccari  dstguest   306 Feb  7 11:52 PLOT
drwxr-xr-x    2 vaccari  dstguest   170 Feb  7 11:43 SMOOTH_fixLayer
drwxr-xr-x    2 vaccari  dstguest    68 Nov  6 09:14 VELw_fixLayer
-rwxrwxrwx    1 vaccari  dstguest   167 Jan  8  2019 depth_step_list
-rwxr-xr-x    1 vaccari  dstguest    82 Nov 25  2009 run_tmpL
```

and the content of directories:

```
./CELLE
drwxr-xr-x  2 vaccari  dstguest   646 Jun 28  2019 E10.25N39.25
drwxr-xr-x  2 vaccari  dstguest   646 May  3  2019 E10.25N39.75
drwxr-xr-x  2 vaccari  dstguest   510 Jun  3  2019 E10.25N40.25
drwxr-xr-x  2 vaccari  dstguest   476 Jun 28  2019 E10.25N40.75

...
...

drwxr-xr-x  2 vaccari  dstguest   442 Apr  8  2011 E9.75N45.75
drwxr-xr-x  2 vaccari  dstguest   782 Mar  8  2011 E9.75N46.25
drwxr-xr-x  2 vaccari  dstguest   816 Mar  8  2011 E9.75N46.75
-rw-r--r--  1 vaccari  dstguest  1340 Oct 14 10:36 list


./CELLE_fixLayer
Empty


./PLOT
-rw-r--r--  1 vaccari  dstguest   1382 Jul  4  2019 BLOCK_COLOR
-rw-r--r--  1 vaccari  dstguest    711 Jun 12  2019 Lista_etichette.txt
-rw-r--r--  1 vaccari  dstguest   3352 Sep  9 11:13 block
-rw-r--r--  1 vaccari  dstguest    540 Jun 12  2019 flags_gmt_1
-rwxrwxrwx  1 vaccari  dstguest   1159 Mar 16  2010 makeblock1
-rw-r--r--  1 vaccari  dstguest    316 Jan 22 17:00 optiModelArea.par
-rw-r--r--  1 vaccari  dstguest  27557 Sep  9 11:13 table.txt


./SMOOTH_fixLayer
-rw-r--r--  1 vaccari  dstguest  1301 May 28  2019 fixed_comb
-rw-r--r--  1 vaccari  dstguest    29 May 28  2019 fixed_start_cell
-rw-r--r--  1 vaccari  dstguest  1004 Feb  7 11:43 lso.par


./Velw_fixLayer
Empty
```

⚠️➡It is highly suggested that you store in a dedicated directory (usually named `Base`) a copy of the input files used for each run, so that you can easily retrieve them later to repeat the computation or to use them as a starting point for a modified configuration of the modelling.⬅⚠️

Description of input files

Lso.sh

This is the script that launches in the correct order all the programs necessary to perform LSO Optimization and prepares the input file for plotting results.

If, for some strange reason, someone wants to perform the process step by step by himself the running order of executables is specified in the script and some explanation word will be dedicated in the next section. Good luck anyway!

Depth_step_List

This is the file that specifies the correct layering for converting the Hedgehog solutions to a format ready to be used by Lso (where all the solutions in all the considered cells must have the same layering).

If you are working with regional Hedgehog where solutions describe the upper 350 kilometers the suggested layering is the following one. In other cases the best thing is to ask Enrico Brandmayr, or Davide Bisignano or, best of all, to remember that hic sunt leones.

```
depth_range(km)  step(km)    No.of_layers
  0    1         0.05   20
  1    3         0.1    20
  3    5     0.2    10
  5   10     0.5    10
 10   40         1          30
 40  360         2     160
```

run_tmpL

It is just a service script, don't lose you mind wondering what it does.

In folder ./CELLE/

./E10.25N39.25/

Your folder ./CELLE/ shall contain subfolders of this kind (with longitude and latitude values of the centre of the cell) for all the cells for which you want to perform the optimization.

Each folder ElonNlat shall contain the solutions (1model, 2model, ...) and the input file (E10.25N39.25.inp) of the Hedgehog inversion.

When you fill these folders with the results of your hedgehog inversion pay attention not to copy other files, in particular those with name starting with a number, in fact this could create some problem for the Lso run.

At the moment you can use both 1°x 1° and 0.5° x 0.5° cells.

List

You will not be surprised that this file contain a list of the cells that are in the directory ./CELLE

The correct form is the following

```
E10.25N39.25
E10.25N39.75
E10.25N40.25
...
E11.25N40.75
E11.25N41.25
E11.25N41.75
E11.75N39.25
```

You can create this file with the following line command (in folder ./CELLE/)

```
   ls -d * >> list
```

(In this way at the end of the file also the file "list" itself will appear, this is not a problem)

In folder ./SMOOTH_fixLayer/

lso.par

Is the file that contains the parameters for the run of Lso

```
/tmpXDST/bisi/2019/LSO/Lso_Nuovo/LSO_example                PATH
VELw_fixLayer                                               DATADIR
SMOOTH_fixLayer                                             DATAWORK
cell_orig                                                   DATAORIG
NEW_2R                                                      METH
8.25                                                        LONMIN
13.75                                                       LONMAX
39.25                                                       LATMIN
46.75                                                       LATMAX
0.5                                                         STEP
50                                                          SIZE
40                                                          MAXNS
1000                                                        NL
250                                                         NLAY
1                                                           nf
```

The lines the you have to correct for your run are the following.

- PATH is the path of the folder where you run the script Lso.sh.
- LONMIN, LONMAX, LATMIN, LATMAX are the values of the center of the cells on the border of the zone you are going to explore.(*)
- STEP is the size of the cells involved in the computation. As written before it can be 1°x 1° or 0.5°x 0.5 °.
- The meaning of other parameters are beyond the scope of this manual, eventually we can discuss them in osmiza.

(*) Lso works on rectangular (and simply connected) domains but is not necessary that you have hedgehog solution for all the cells in your domain. It can afford empty cells as we'll see in the next part.

fixed_start_cell

In normal LSO procedure the starting cell is chosen ad the one with the minimum difference among the hedgehog solution.

In some cases thought can be useful to choose by yourself the starting cell. This can happen for example when you have cell already studied or cell with particular information, or maybe also if you want to understand how the chosen solutions in all cells change varying the starting cell.

If you want to choose by yourself the starting cell this file is necessary and he has the following form.

```
3    4 45.75  8.75  8 250
```

(Pay attention because this part is quite tangled!)

Domain for Lso computation is built considering the rectangle between maximum and minimum longitudes and latitudes in pars.par plus 2 columns and 2 lines at the external border.

In this way the third line from top is the maximum latitude for which we have hedgehog solution and the third column from left is the minimum longitude.

But complications doesn't stop here, in fact we you have to consider column and row index you have to start count from 0.

So t first two numbers in file start_cell are the column and the row index of the chosen starting cell, that in this case is indeed that in the fourth column and in the fifth row.

Then we have latitude and longitude of the starting cell (Yes, I know that would be more logical to write them in the same order of column and row index but that's what we have, imagine it like some sort of chiasmus, maybe code developers like it).

Then we have the number of hedgehog solutions for the chosen shall (8 in this case).

The last number is the number of layers of the solution, it is decided in pars.par but, as written before, the advice is to do not change it.

fixed_comb

Is the file where you can fix a chosen solution in some cell.

That can be useful for example when a part of the domain has already been processed or when there are reliable information from literature for some cell.

Obviously this operation has to be done very carefully following the indication exposed before about relationship with position on the matrix domain and geographical coordinates.

This file has the following format.

```
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1   7   6  12  14  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1   6   6  11  13  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1   8   8   4   3  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  12  10  13  13  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1   0   0   0   0  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1   0   0   0   0  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1   0   0   0   0  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1   0   0   0   0  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1   0   0   0   0   0   0  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1   0   0   0   0   0   0  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1   0   0   0   0   0   0   0   0  -1  -1  -1  -1  -1  -1
  -1  -1   0   0   0   0   0   0   0   0  -1  -1  -1  -1  -1  -1
  -1  -1   0   0   0   0   0   0   0   0   0   0   0   0  -1  -1
  -1  -1   0   0   0   0   0   0   0   0   0   0   0   0  -1  -1
  -1  -1   0   0   0   0   0   0   0   0   0   0   0   0  -1  -1
  -1  -1   0   0   0   0   0   0   0   0   0   0   0   0  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
```

- -1 means that in that cell there is no hedghog solution so it will be not considered in the computation.
- 0 appears in the cells where the Lso process has to be performed.
- The other numbers represent the number of the solution fixed by the user in chosen cells.

To be clear in this example the minimum longitude is E8.25 and the maximum latitude is 46.75 and for the corresponding cell we have chosen the solution number 7.

./CELLE_fixLayer/

This folder shall be empty before the run of LSO.

It will be filled in the first part of the run with the same contents of folder ./CELLE/ but with all models corrected with the same layering (specified in Depth_step_list)

./Velw_fixLayer./

Also this folder shall be empty before the run of LSO.

It will be filled in the first part of the run with files containing information on velocity and thickness of all the solutions.

These files have name like

```
VT43.750000_9.750000_1
```

and are the correct form of the input also for GSO and GFO.

In folder ./PLOT/

Lista_etichette.txt

This file contains a list of labels used to identify each cell (or quarter cell) in the studied zone.

It has the following form

```
f-2-IV
f-2-I
f-1-IV
f-1-I
f-2-III
f-2-II
f-1-III
f-1-II
e-2-IV
e-2-I
e-1-IV
e-1-I
```

As we'll see in the next part this column will be pasted (along with the next file "flags_gmt") to that contains the coordinates and the chosen solution for each cell to plot the results.

So these labels shall be written in the right order that is (following the order of LSO results format) row by row from left (west) to right (est) starting for the upper (northest) row.

The correct organization of these labels on the map can be found, for example, in Brandmayr Phd Thesis.

flags_gmt_1

This file contains a list of flags that the GMT script will use for plotting.

It has the following form

```
wesn
wesn
Wesn
Wesn
wesn
wesn
wesn
wesn
wEsn
wEsn
wesn
wesn
wesn
```

Capital letter referred to a cardinal point in GMT commands means that a certain information (in this case depth) is printed at corresponding side the plotted cell.

So essentially you have to put a capital W for the cells on the western board of your domain and the capital E on the eastern ones.

optiModelArea.par

Is the par file for the two GMT_area2 scripts.

```
0.5             #step
Cor_Sar_Tirr    #output name
7.5             #minlon of general map
14.5            #maxlon of general map
38.5            #minlat of general map
43.5            #maxlat of general map
19.0            #horizontal position of general map
14.5            #vertical position of general map
```

By this file you can control the boundaries of the general map view in the figure in relation to the cells you have to plotted. In fact while the boundaries of the plotted "pillars" are given in file "lista" those of the general map view can be changed depending on the dimension of the plotted zone. (Don't worry if this part sounds tangled, everything will be clear when you will see the plot). To do this last check you have to properly modify the values of minlon, maxlon, minlat and maxlat in this file, while to change also the position of the general view map (it could be necessary) you have to properly modify the last two parameters.

makeblock1

Is an operative script for the color selection in the plotting procedure.

BLOCK_COLOR

Is the file that contains the rgb codes of the colors assigned to different Vs values.

Two (or more) words shall be spent on this topic...

This particular choice of color scale for mantle and crust has been prepared specifically for Tirreno region, where we can image there can be a very soft mantle magma, but for other regions cannot be the best choice.

If you are working in zones like Tirreno or anyway you are satisfied by color choice you are quite lucky and you can jump to the next section.

If you want to manage colors (both color scales and mantle/crust choice) you have to look carefully in sources.

```
model2cptWrite.c
model2cptRead.c
```

and in file

```
BLOCK_COLOR.
```

Model2cptWrite.c (and the counterpart "read" as well) assign an index to vs values of every layer.

There are 3 possible situations:

- we are sure to be in the mantle
- we are sure to be in the crust
- we have to choose where we are

This choice is taken in the if-statement at line 176 of model2cptWrite.c

```
if((iter==0) || ((iter>0) && (v<3.25 || v>4.05)) || (i<=5) || (i>=11) )
    fprintf(out,"%s\n",v_color[(int)((500-v*100)/5)]);
          else if (iter>0)
            {
            if((i>5) && (i<11))
                if((v>=3.25) && (v<=4.05))
```

If Vs < 3.25 or Vs > 4.05 and we are in the first 5 layers or in the layers after the 11th of the structure the choice between crust and mantle is fixed.

In the case the program assign to the velocity the index v_color that is referred to a specified line of file block_color.

If instead Vs is the interval 3.25-4.05 and the layer is between the 6th and the 10th the choice between crust and mantle is made by the user.

This choice, from the operative point of view is determined by the index "ans" in the source file.

Ans = 0 is for the crust and ans = 1 is for mantle.

Once that this choice has been made (have patience and we'll discover how in the next lines) the correspondent index colors are assigned in line 186

```
 fprintf(out,"%s\n",sp_col[(int)((v*100-330)/15)][ans]);
```

This index correspond to RGB values specified in the first lines of the source where you can find the set of colors both for crust (ans=0) and mantle (ans=1).

(Quite complicated...lucky me that I had to discover everything by myself...)

So if you want to change in someway the color scale you have to manage these concepts.

For what concerns the layers for which the mantle-crust choice shall be made the user has to set the value of the index "ans".

In the run of GMT_area2_Write this index is automatically set to 1 while for GMT_area2_Read is read from the file crostamant, produced in the GMT_area2_Write run, and properly modified by the user.

Commands execution

Running Lso script

As written before there is some option in running LSO.

You can run it without fixing anything in this way

```
    Lso.sh 0 0.
```

You can run it fixing just the starting cell in this way

```
    Lso.sh 1 0,
```

or you can run it fixing both starting cell and the solution in chosen cells

```
    Lso.sh 1 1,
```

or you can also fixed the solution in chosen cells but not fixing the starting cell, in this case

you can you can launch it like this

```
    Lso.sh 0 1.
```

Obviously when you selected option with fixed starting cell and fixed solution in some cell you have to prepare carefully the files fixed_start_cell and fixed_comb as seen before.

Some detail inside the script.

The script, following its own script nature, does the most of the work for you but nonetheless is better for you to understand what happens inside it (especially if you have to use it for you master or phd thesis), because if something goes wrong (you won't believe but it can happen...sometimes) you have to get your hands dirty inside it.

It performs the following main commands.

```
  mdl2slices
```

Running mdl2slices the original models of all cells will be sampled at depths and layers specified in the file depth_step_list. The program creates a directory CELLE_fixLayer similar to the directory CELLE but with sampled models.

The program creates also the directory VELw_fixLayer similar to that created by matching program of B.Farina and necessary for the following LSO (and in GFO/GSO if in some other point in the spacetime it will work)

The programme creates the file elenco (the same created by matching of B.F.) that is necessary for LSO.

The file "elenco" is then copied in folder ./SMOOTH_fixLayer/ and now we following it for important part.

```
  StartCel_New
```

It read file elenco and produces:

- average_cell that contains the computation of the average norm of the difference vectors of all possible combinations in every cell.
- minmatrix that contains, for each cell, the mean value of the norm as explained in the previuos point
- start_cell that is a file of one string containing the information of the chosen starting cell (the one with minimum average norm) as seen before when the file fixed_start_cell has been explained.

CreSetCel

It read file elenco and produces file

```
set_cell
```

that is a map indicating for each cell the number of hedgehog solutions. It puts 0 for the part of the domain without hedgehog solutions (remember that the domain of Lso shall be rectangular).

BestScell1new

It reads files start_cell (or fixed_start_cell if you have chosen to fix it) and set_cell and gives as output file

```
combNEW_2R_1.out
```

that contains the best solution for starting cell and its neighbor cells.

It contains 5 string each one indicating the matrix coordinates (in the complicated way seen before, remember!) and the number of chosen solution.

(The strange name of the file is due to the "method name" and the possibility of choose more than one combination but for what we know at the moment there is just one method and it is better to find just one combination)

MatrixSol1New

It reads file start_cell (or fixed_start cell if you have chosen to fix it) and combNEW_2R_1.out and gives as output file

```
NEW_2RSolI_1.out
```

that contains the matrix indicating the chosen solution of the starting cell, 0 for the cells for which a solution has to be chosen and -1 for the elements without hedgehog solution.

BestSolNEW2R1

It read file start_cell (or fixed start cell if you have chosen to fix it), minmatrix, set_cell and NEW_2RSolI_1.out (or fixed_comb if you have chosen to fix the solution in some cell) and produces the files

```
#SolC_1.out and #SolT_1.out
```

that are exactly the same and originally where produced for a better form of control (melius abundare quam deficiere, anyway it should be quite easy to fix the code avoiding this waste).

Now we have to be grateful to an engineer, thank you Matteo, because thanks to him now this program produce also the file

```
test.out
```

that is the human readable translation of the two files above and contains a string for each cell with latitude, longitude and chosen solution, like this:

```
46.750000 8.250000    7
46.750000 8.750000    6
46.750000 9.250000   12
46.750000 9.750000   14
46.250000 8.250000    6
46.250000 8.750000    6
46.250000 9.250000   11
46.250000 9.750000   13
45.750000 8.250000    8
45.750000 8.750000    8
45.750000 9.250000    4
```

```
45.750000 9.750000    3
45.250000 8.250000   12
45.250000 8.750000   10
45.250000 9.250000   13
45.250000 9.750000   13
```

This last file is then copied in folder ./PLOT/ and if you have prepared in the proper way files

`Lista_etichette.txt`

and

`flags_gmt_1`

the script will paste them together in file

`lista_all`

that is in the correct form for the GMT scripts:

```
46.750000 8.250000    7         f-2-IV  wesn
46.750000 8.750000    6         f-2-I   wesn
46.750000 9.250000   12         f-1-IV  Wesn
46.750000 9.750000   14         f-1-I   Wesn
46.250000 8.250000    6         f-2-III wEsn
46.250000 8.750000    6         f-2-II  wESn
46.250000 9.250000   11         f-1-III wesn
46.250000 9.750000   13         f-1-II  wesn
45.750000 8.250000    8         e-2-IV  wesn
45.750000 8.750000    8         e-2-I   wesn
45.750000 9.250000    4         e-1-IV  Wesn
45.750000 9.750000    3         e-1-I   Wesn
45.250000 8.250000   12         e-2-III wEsn
45.250000 8.750000   10         e-2-II  wEsn
45.250000 9.250000   13         e-1-III wesn
45.250000 9.750000   13         e-1-II  wesn
44.750000 8.250000    9         d-2-IV  wesn
44.750000 8.750000    3         d-2-I   wesn
```

Plotting results

If everything worked correctly now in folder ./PLOT/ you should have the file lista_all, seen before, that is ready to be read by GMT scripts.

However often could be better to do not plot the results for all the studied domain, or at least, to do not plot all of them in the same image.

So what you have to do is to select the zone you want to plot in the file lista_all and copy the relative lines in a file call lista that will be read by GMT scripts.

For example in this case we have performed LSO from latitude 47 to latitude 39 but we want to plot the cells just from latitude 42 so we eliminate the first 32 lines in lista_all with this command

```
   sed '1,32d' lista_all >> lista.
```

After that you have to check the par file optiModelArea.par, normally the boundaries of general map should be 0.5° larger than those of the selected cells but it can depend on the geographical features you want to enlighten or on the size of the map. Also the position of the general map depends on the geographical features of the plotted cell. (Don't worry if it sound complicated, once you see the plot everything will be clearer).

Now you have to launch the first script with the proper depth, for example 50 km.

```
   plotOptiAreaWrite.sh 50
```

Remember that at this stage you just want to have a general image of your results to select in the proper way if some ambiguous layer is crust or mantle so the choice of the depth has to be made in a way that highlights these layers.

If everything has worked now you should have the ps file

```
Cor_Sar_Tirr50.ps
```

and file

```
crostamant
```

that has the following form

```
1 6 4 ../CELLE/E10.25N42.75
1 6 4 ../CELLE/E10.75N42.75
1 6 3.7 ../CELLE/E10.25N42.25
1 6 3.7 ../CELLE/E10.75N42.25
1 6 4 ../CELLE/E9.25N40.75
1 8 4 ../CELLE/E9.25N40.75
1 6 4 ../CELLE/E9.75N40.75
1 8 4 ../CELLE/E12.25N40.75
1 8 4 ../CELLE/E12.75N40.75
1 6 3.8 ../CELLE/E13.25N40.75
1 6 3.8 ../CELLE/E13.75N40.75
```

where the first column is the crust-mantle index, the second is the layer's number, the third is Vs value and the fourth is the cell where the ambiguous layer is present.

In the first column 1 stands for mantle (and its own color palette) and 0 for crust (and its own color palette), before running the final script you have to choose which layers are crust and which layers are mantle and modify the index where necessary.

Now you can run plotOptiAreaRead.sh at every depth you need for your result (just remember that our inversions are made down to 350 Km). You have to launch it one time for each selected depth. For example.

```
   plotOptiAreaRead.sh 100
```

will gives you the result for 100 Km depth

```
Cor_Sar_TirrP100.ps.
```

(Output name "Cor_sar_Tirr" is related to this particular case and can be changed in line 14 of GMT scripts, "P" stands for "processed").

Note: the procedure for plotting hypocenters at the moment is not working with 0.5°x 0.5° cell, it have to be corrected because now it puts all the hypocenters of the western parts of cells (E**..25) in the western part of the quarter cell and all the hypocenters of the eastern parts of the cells (E**.75) in the eastern part of the quarter cell. The location procedure has to be reviewed.