

# Spherical Multiple-Cell (SMC) grid utility tools

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## 1. Introduction

This SMC grid tool package consists of SMC grid generating and test programs in Python and Fortran languages and Linux shell scripts. They are classified by language types and collected in self-explained sub-directories. Tool programs are designed to be as simple as possible so that no extra software is needed except for the essential Linux operation system, Python and Fortran compiler. The package is uploaded to Github for public access under the BDS license. Interested users can download the SMCGTools full package from the web site at:

<https://github.com/ww3-opentools/SMCGTools>

You need to copy the whole `SMCGTools/*` to your disk space and modify the paths inside some program files before you use it. A possible improvement is to set up a working path to `SMCGTools/` and pass it as the default top directory.

Step by step guides to use this tool package are given, using an example grid SMC61250 for demonstration. Users may modify their input files to change the spatial resolution for your specified requirements. Starting with preparation of your own bathymetry file, which is too large to be stored on Github site, you may go through all the steps for generating the grid cell array, trimming the cell array, creating the face arrays, and running the propagation test.

Users' feedback about the tool package is welcome and improvement of any of the tool programs or other contribution will be added to the tool package and properly acknowledged.

## 1. Prepare a bathymetry file

One global bathymetry data, GEBCO\_2022, are available for download from:

[https://www.gebco.net/data\\_and\\_products/gridded\\_bathymetry\\_data](https://www.gebco.net/data_and_products/gridded_bathymetry_data)

The data set was published in June 2022 and is a global terrain model for ocean and land, providing elevation data, in meters, on a 15 arc-second interval grid. It consists of 43200 rows x 86400 columns, giving 3,732,480,000 data points. The GEBCO\_2022.nc file is provided in NetCDF 4 format and is about 7.5 Gb in unpressed form. It should be quoted as

GEBCO Compilation Group (2022) GEBCO 2022 Grid.  
(doi:10.5285/e0f0bb80-ab44-2739-e053-6c86abc0289c)

For SMC grid generating, the bathymetry data must be firstly reduced to the required size-1 cell resolution. For the following example grid, the size-1 cell length will be set at  $\Delta\lambda = 0.087890625^\circ$  and  $\Delta\phi = 0.05859375^\circ$ . The longitude resolution is chosen so that the total number of points along one longitude parallel circle is  $4096 = 2^{12}$ , which eases the longitudinal merging at high latitudes for a global grid including the Arctic. The full latitude range from 90S to 90N will cover 3072 size-1 cells. This latitude cell length is roughly 6 km, so this reduced bathymetry is also referred as global 6 km bathymetry. It has equal number of size-1 cells on the north and south hemispheres so the Equator could be used as the reference point for cell latitude indices.

As the GEBCO\_2022 bathymetry data are quite large and awkward to handle on a desktop machine, a first step reduction is done by just average a fixed number of points into one along both directions. For instance, a factor of 20 is chosen for the longitude direction and it reduces the 15 second resolution to 5 minutes with 4320 points in one parallel circle. For the latitude direction a factor of 12 is used and it reduces the 15 second resolution to 3 minutes or 3600 points along the latitude range. The temporary data are then interpolated to the required size-1 resolution in the longitude direction (from 4320 to 4096 points) and the latitude direction (from 3600 to 3072).

The first reduction step could be done with a Python program with the command line after modifying the input file `configreduce.txt` to point to your `GEBCO_2022.nc` file.

```
SMCGTools/PySMCs/ python reduce_interp.py configreduce.txt
```

Which created the temporary bathymetry in `tmpfls/` and it is renamed by

```
SMCGTools/tmpfls/ mv GEBCO_reduced_20_12.nc ../Bathys/Bathy083_050.nc
```

The interpolation step could be done with the following command lines:

```
PySMCs/ python reduce_interp.py configinterp.txt  
tmpfls/ mv Bathy_interpolated_*.nc ../Bathys/Bathy088_059deg.nc
```

The final bathymetry file `Bathys/Bathy088_059deg.nc` will be used for generating the SMC61250 grid. The advantage of this netCDF bathymetry file over the ASCII one is that it has merged both the elevation and the obstruction arrays into the same file, apart from the increase spatial resolution.

## 2. Generate and trimming SMC61250 grid

A sample 4-level (6-12-25-50 km) grid, SMC61250, is generated with the Python program, `SMC61250Cells.py`, which uses the bathymetry file, `Bathy088_059deg.nc`, created in section 1. The water depth is derived by the difference from the bathymetry elevation to the mean sea level height. As a results, some inland lakes, like the Caspian Sea and the Great Lakes, do not have the correct water depth because their lake surface levels are different from the mean sea level. To rectify the water depths for these inland water bodies, a separate Python program is used to create their local cells with their specified water surface levels. Cell array files will be saved in a temporary sub-directory `SMCGTools/tmpfls/`, including an Arctic part cell array file as this is a full global grid.

The Python program, `Lakes625Cells.py`, created the 3-level (6-12-25 km) Caspian Sea and Great Lakes cells with the same bathymetry file but different water surface heights for different lakes. The `smcellgen.py` has a named parameter `wlevel = 0.0` for dry cell specification. This parameter defines the water depth reference point and uses the sea

level altitude as the default value. For inland lakes, the wlevel parameter could be assigned the actual water level elevation so that true water depth for the given lake could be derived. The depmin = 0.0 parameter is used to define the elevation of cell expanding domain, which could include dry cells if it is assigned a value above the water level. By definition, depmin should be at least equal to wlevel so it is reset to be equal to wlevel if it is given a value lower than wlevel. The dshalw = 0.0 parameter is used to define the refined shallow water area. It should be smaller than depmin for any refinement and it is reset to be equal to depmin if it is assigned a value higher than depmin.

Note all elevations or bathymetry input are assumed to be positive above sea level. Cell depth is calculated as  $\text{depth} = \text{wlevel} - \text{bathymetry}$ , so it is positive if bathymetry is below water level elevation. If the depth is negative, it means the cell floor is above the water level or it is a dry cell. Cells with depth = 0 are just at the water level and they are turned to be dry cells in the updated ww3\_grid program. For tsunami model, these cells are sensitive to coastal inundation.

The individual lake cells are trimmed with awk scripts (stored in Linuxs/zTrimming/) to remove isolated cells or overlapping areas. First to remove the count/header line from each individual lake file and move it into Linuxs/zTrimming/, then use the Linux command line, taking the Ontario Lake cell array for example:

```
Linuxs/zTrimming/ awk -f awkSuperior Supr6125Cels.dat > Supr6125Cels.d
```

The trimmed Caspian Sea cells are saved in Casp6125Cels.dat and the trimmed Great Lakes are merged into a single file GtLk6125Cels.dat. The global SMC61250 cell array, SMC61250Cels.dat, is also edited to remove its count/header line and renamed SMC61250Cels.d. Then it is trimmed and merged with the individual lakes by the following Linux command lines:

```
Linuxs/zTrimming/ ls awkAmazon awkAustralia awkCaspiaNo awkGtLakeNo \
awkBlackSea awkMeditern awkTurpBngl | ../trimtempcels ./SMC61250Cels.d
Linuxs/zTrimming/ cat GtLk6125Cels.d Casp6125Cels.d >> tempcels.dat
Linuxs/zTrimming/ ../countcell61v tempcels.dat
Linuxs/zTrimming/ mv New_tempcels.dat ../../DatGMC/SMC61250Cels.dat
```

The first line trims the, SMC61250Cels.d, which is created by the Python program, SMC61250Cells.py, and edited to remove the first count/header line. The second line append the trimmed Great Lakes and Caspian Sea cells into the trimmed global cell array. The third command line sorts the trimmed global cell array and add a new count/header line. The final Linux command line moves the new cell array to replace the old one in DatGMC/.

Note the Python programs must be executed within the PySMCs sub-directory because some called library files are store there. This may be changed by setting up a Python path so that you may run the Python program outside the SMCGTools/PySMCs/ sub-directory.

The trimming scripts, awk\*, are created manually by zooming local areas with Linux awk command and Python viewing programs, latlon2ijs.py and smcviewdep.py. How to create the trimming scripts will be demonstrated later in Part II when boundary cells are trimmed because they share the same trimming techniques.

One Python program smcellgen.py called by the SMC61250Cells.py program could be used separately to read a netCDF bathymetry data and created a SMC grid with specified resolution levels. This program may be adapted by advanced Python users to generate a different SMC grid. Details of its usage will not be discussed here.

### 3. Visualise the global grid and zoom in selected regions.

The SMC61250 grid could be viewed by drawing the grid in a stereographic projection, which uses projection point 4 times of the sphere radius from the projection plane so that the Equatorial area distortion by the standard stereographic projection (2 radius from the projection plane) is mitigated. The projection is specified in the `PySMCs/steromap.py` and the grid plot can be generated by running the Python program, `SMC61250Grids.py`, on a Linux command line:

```
SMCGTools/PySMCs/ python SMC61250Grids.py
```

It will require a choice number for either a global view (0) or a regional view (1 for Euro-Arctic region or 2 for West-Pacific region). The program will save the projection polygons for the selected view before drawing the grid plot.

The plot is saved in ps format in `SMCGTools/tmpfls/`. You may view the ps plot with Linux `gv` command or convert the ps file into a gif format for a quick view with Linux `xv`.

```
SMCGTools/tmpfls/ ls smc61250grdGlob.ps | ../Linuxs/convps2gif90r
```

The above global view plot is in landscape format while regional plot may be in portrait format and could be converted into gif format with `Linuxs/convps2gif`.

If you like a different regional view other than the two provided ones, you may modify one of the regional view option inside the program `SMC61250Grids.py` (or insert an extra option) by specifying a new set of parameters as below:

```
if( pltype == 'Pacific'):  
## West Pacific regional plot  
    plon= 138.0  
    plat= 18.0  
    pangle=33.0  
    clrbxy=[-13.6, 7.5, 7.5, 0.8]  
    sztpxy=[ 15.0, 10.0, -10.0, 7.0]  
    rngsxy=[-15.0, 15.0, -10.0, 10.0]  
    papror='landscape'
```

where `plon` and `plat` are the longitude and latitude of your new regional centre and `pangle` is the spanning angle from the centre to the edge of your selected region (at the default 10 unit radius). As the projection is similar to the orthogonal projection, the maximum spanning angle is 90 degree to cover one hemisphere. If your spanning angle is less than 90 degree, the hemisphere is projected larger than the default circle of 10 unit radius. You may use the `rngsxy` range parameters to select your plotting area in this case. The above example selects a plotting area from -15 to 15 units in the x-axis and -10 to 10 units along the y-axis.

The `clrbxy` parameters specify the colour key box position and size in plotting units. It automatically chooses a horizontal or vertical colour bar by the x and y sizes of the colour box. The above colour box is a horizontal one, 7.5 unit long and 0.8 unit high and its SW corner is at the point (-13.6, 7.5) in the plot. You may position your colour key inside the plot over a blank land area or simply put it at the edge of the plot.

The `sztpxy` first two parameters specify the ps plot x/y-sizes in inches and the last two parameters specify where your text messages are printed in plotting units.

The last parameter `paper='landscape'` tells the program to draw the ps plot in landscape orientation. This is for printing convenience. You may use portrait orientation for all plots if you like.

#### 4. Generate face arrays.

SMC grid face arrays are generated with a FORTRAN program in `SMCGTools/F90SMC/`. The program `SMCGSideMP.f90` could be run in OpenMP mode with 2 threads or run as a single processor program without OpenMP. In this example, the program is compiled with OpenMP on a Linux machine:

```
SMCGTools/F90SMC/ ifort -r8 -qopenmp SMCGSideMP.f90
SMCGTools/F90SMC/ mv a.out SMCGSideMP
```

You need to work out the FORTRAN compiler on your system and create the executable with correct OpenMP option. The executable is renamed as `SMCGSideMP` for later use.

Before running the program to generate your face arrays, a few parameters are needed for input to the program. An example input file is given in `Linuxs/SideMPInput.txt`, which contains the following lines:

```
SMC61250
 260000   300000   4   ##   NCL,   NFC,   MRL
   4096     3072   0   ##   NLon, NLat, NPol
'../DatGMC/SMC61250Cels.dat'
.FALSE.
```

The first line `'SMC61250'` is the grid name, and the second line specifies the cell number `NCL`, face number `NFC` and number of resolution levels `MRL`. The cell and face numbers should be larger than the actual cell and face numbers for memory allocation purpose. The cell number could be derived by counting the cell array file. The exact face number is not known yet so here an estimated face number about 10% more than the cell number is used. If the program failed because the face number was smaller than the exact face number, you could increase the `NFC` value and run the program again.

The 3rd line specifies a rectangular domain in size-1 cells. Here `SMC61250` is a global grid, it covers 4096 size-1 cells in the longitude direction and 3072 size-1 cells in the latitude direction. The 3rd number on the 3rd line is the number of polar cells in the grid. For this `SMC61250` grid global part, there is no polar cell.

A Linux run script is provided in `SMCGTools/Linuxs/runSMCSideMP` to run the face generating program. You need to modify the paths to your directories before you run it. In Linux system, issuing the command line:

```
SMCGTools/Linuxs/ ./runSMCSideMP SideMPInput.txt
```

which will generate the face arrays for the global part in the `SMC61250` grid. The face array files are saved in `SMCGTools/tmpfls/SMC61250[IJ]Sid.dat` and they need to be moved out of this temporary directory to `DatGMC/`.

```
SMCGTools/tmpfls/ mv SMC61250ISid.dat SMC61250JSid.dat ../DatGMC/
```

Face arrays for the Arctic part are created with a similar job script and input files (Linuxs/runSMCSideMPArc and SideMPInputArc.txt). Modify the paths inside the script before you run it. The Arctic part face arrays are saved as SMC61250A[IJ]Sd.dat in tmpfls/ and they need to be moved into DatGMC/ as well.

```
SMCGTools/Linuxs/ ./runSMCSideMP SideInputArc.txt
SMCGTools/tmpfls/ mv SMC61250AISid.dat ../DatGMC/SMC61250AISd.dat
SMCGTools/tmpfls/ mv SMC61250AJSid.dat ../DatGMC/SMC61250AJSd.dat
```

## 5. Run propagation model to test the cell and face arrays

There are two propagation test models available in SMCGTools/F90SMC/PropOMP and PropHyb/. The OpenMP version PropOMP model stores wave spectra in one memory block for all spatial points for shared memory machines. The PropHyb test is for distributed memory machines in hybrid mode (MPI-OpenMP). It distributes spatial sea points among MPI ranks for wave spectral storage as in WW3 and calculates spatial propagation in spectral component parallelization mode.

The PropOMP model can be run on multi-core desktop machines with a Fortran compiler. To speed up the model, a single frequency bin can be used with a few directional bins (24 or 36). Total wave height is output at selected time intervals as text files and visualized with a Python program. The following steps demonstrate how the model is run and results are checked:

- i) Copy the whole subdirectory SMCGTools/F90SMC/PropOMP/ to your desk space and modify the Makefile for your local Fortran compiler and OpenMP option.
- ii) Compile the Fortran PropOMP model in Linux system with the make command.
- iii) Change to sub-directory SMCGTools/Linuxs/ and modify the PropInput.txt file for your model grid. The sample file is for the SMC61250 grid and parameters are explained by the comments following the # marks.
- iv) Modify the Linux script runSMCGProp for your directory paths and run it.

```
SMCGTools/Linuxs/ ./runSMCGProp PropInput.txt
```

- v) Move the output files to a storage directory (OutDat/ for instance) and select files to be visualised into cfiles.txt, such as for selecting all files

```
ls C* > cfiles.txt
```

Note that the first line in cfiles.txt will be skipped so you can put anything on the first line (some comments for instance). The above Linux command line puts the CMesgs.txt file on the first line.

- vi) Modify the SMCGTools/PySMCs/SMC61250Props.py for your directory paths and draw the SWH plots for your selected files. The plots will be saved in SMCGTools/tmpfls/ in ps format. You may view them directly with Linux gv or convert them into gif with Linuxs/convps2gif(90r) for xv viewer.

The global propagation test demonstrates an initialised wave field propagating over the SMC61250 grid. Wave will travel as far as it reaches coastlines. If any premature energy loss appears, it may indicate something wrong with your cell or face arrays.

Obstruction ratios for the SMC61250 grid is generated with `SMC61250Obstr.py`, which uses the obstruction ratios saved in the bathymetry file `Bathy088_059deg.nc`. This obstruction ratio file is not used in the propagation test but it will be required for the WW3 wave model propagation scheme.

## 6. Prepare input files for WW3 model to use your SMC grid.

Apart from the cell and face arrays for your SMC grid, WW3 also requires a few input files for its model configuration. A full list of WW3 input files for the SMC61250 grid is available on our Cray X40 machine.

```
WW3Vn7/inp650/ ls -l
-rw-r--r-- 1 mo_users      21634 Oct 17  2018 SMC61250AISd.dat
-rw-r--r-- 1 mo_users      27826 Oct 17  2018 SMC61250AJSd.dat
-rw-r--r-- 1 mo_users      11920 May  4  2021 SMC61250BArc.dat
-rw-r--r-- 1 mo_users    6669105 May  4  2021 SMC61250Cels.dat
-rw-r--r-- 1 mo_users    14231888 May 17 14:11 SMC61250GISd.dat
-rw-r--r-- 1 mo_users    15123437 May 17 14:11 SMC61250GJSd.dat
-rw-r--r-- 1 mo_users     1190920 May 17 14:36 SMC61250Obst.dat
-rw-r--r-- 1 mo_users    62733319 Jul 27 16:28 mod_def.ww3
-rw-r--r-- 1 mo_users      28235 May 17 14:57 ww3_grid.inp
-rw-r--r-- 1 mo_users      3572 Oct 30  2018 ww3_ounf.inp.template
-rw-r--r-- 1 mo_users      2799 May 21 16:17 ww3_outf.inp.template
-rw-r--r-- 1 mo_users      7177 Sep 19  2016 ww3_outp.inp.template
-rw-r--r-- 1 mo_users     18425 May 21 16:17 ww3_shel.inp.template
-rw-r--r-- 1 mo_users      3401 Dec 20  2012 ww3_strt.inp
```

SMC grid also uses the sub-grid partial blocking ratios for unsolved small islands. The sub-grid obstruction ratios are generated with `SMCGTools/PySMCs/SMC61250Obstr.py`, which uses pre-calculated obstruction ratios on the same latitude-longitude grid at about 6 km as the bathymetry data (`SMCGTools/Bathys/Glob6kmObstr.dat`) and converts them onto the SMC grid cells. Note that only cells in the global part of the SMC61250 grid are assigned obstruction ratios. The Arctic part will assume all obstruction ratios to be zeros as it is in the central Arctic Ocean around the N Pole. This also makes it convenient to drop the Arctic part (for cold seasons) without modifying the obstruction ratio file.

The `SMC61250Obstr.py` also calls a Python function `global50km.py` to work out the regular 50 km grid parameters. As SMC grid shares some output settings with a regular grid at its base resolution, these parameters are required for WW3 input files. These parameters are saved in a text file `S61250Regul.txt`, in addition to the obstruction ratio file `SMC61250Obst.dat`.

A Python program `SMC61250RInfo.py` is also provided here to generate regular grid information for the SMC61250 grid. Users may modify the parameters inside to tuning your regular grid coverage area, instead of using the one fixed by `global50km.py`.

Instructions for preparing other WW3 input files and run the WW3 wave model are available in the WW3 user guide and will not repeat here.

## 7. Visualise SWH output from WW3 model on SMC grid.

The WW3 output file `out_grd.ww3` could be converted into sea point only SWH at the pre-set output interval in ASCII file if you choose the type 4 option in the `ww3_outf.inp` file for postprocessing with `ww3_outf`.

These text SWH output files are named as `ww3.yymmddhh.hs` and can be visualised with the Python program `SMCGTools/PySMCs/SMC61250SWHts.py`, which read the input file `strendat` in the same directory for selection of plotting times:

```
SMCGTools/PySMCs/ cat strendat
16090106 16093018 12H
```

The above `strendat` tells `SMC61250SWHts.py` to draw one month from (20)16090106 hr to (20)16093018 hr at 12 hr interval.

The `SMC61250SWHts.py` needs to be modified for your storage paths and SWH plots are saved as ps file in `SMCGTools/tmpfls/`. You may view them with `gv` or convert them into gif for `xv` viewer just as your view the grid plot. In fact, the `SMC61250SWHts.py` uses the exact grid projection polygons of the grid plot to draw the SWH plots.



## Part II: SMC sub-grids for multi-grid run

### 1. Splitting a global SMC61250 grid into 3 sub-grids

The `SMCGTools/PySMCs/Sub61250Splt3.py` program is used to split the SMC61250 global grid into 3 sub-grids. It uses three prescribed dividing lines to split the global grid and the dividing lines are defined by lists of latitude-longitude pairs, which are stored in the file `Bathys/Subgrdline3.dat`. You may modify these dividing lines for a different sub-grid configuration. The 3 sub-grids cell arrays are saved in `tmpfls/` along with their boundary cells. You need to modify the program for your paths before you run it. This path update applies to all subsequently mentioned programs and this reminder will not be repeated.

Use the `Linuxs/runSub3CountCell` script to sort the cell arrays into final form and move the `tmpfls/*61250*.dat` files into `DatSub/`.

Note that the Arctic part in the SMC61250 grid will be appended to the `Atln61250` sub-grid and its cell and face arrays in `DatGMC/` can be used directly with the sub-grid cell and face arrays.

The sub-grids can be visualised with `SMCGTools/PySMCs/Sub61250Grid3.py` by selecting individual sub-grid or a full global view of all sub-grids together. The individual sub-grid option will also generate their boundary cell id list for use in the WW3 model run. A list of the boundary cell lon-lat positions are also saved for a global model to generate boundary conditions for each sub-grid if it need to run as an independent model.

A Python program `smcelsplit.py` is also provided here for a more general splitting job. Advanced users may adapt the program for your use. Details will not be explained here.

Once you see the sub-grid plots, you may find that some cells are isolated after the splitting and other cells may be better moved into its neighbouring sub-grid. These flaws are the results of the rough splitting lines, which must be single-valued functions of latitudes. If you could find a more flexible splitting method, these flaws may be removed. For the time being, some manual tuning with Linux `awk` editor is used to adjust the sub-grid cell array. This is the same method used to tuning boundary cells, which will be discussed later.

### 2. Generate face arrays and obstruction ratios for sub-grids

Use the `Linuxs/runSub3SideMP` to generate face arrays for the 3 sub-grids. Face array files are saved in `tmpfls/*61250[IJ]Sid.dat` and they need to be moved into `DatSub/` for later use.

Obstruction ratios for the 3 sub-grids are generated with `PySMCs/Sub61250bstr3.py` and saved in `tmpfls/*61250Obst.dat`. Move these files into `DatSub/` as well.

### 3. Other input files required for WW3 multi-grid run

Apart from the sub-grid cell and face arrays, WW3 multi-grid model also requires some extra input files. An example list of input files required for WW3 model multi-grid run on the Sub61250 sub-grids is listed here:

```

-rw-r--r-- 1      2460 Oct  7 10:52 Atln61250Blst.dat
-rw-r--r-- 1 1752832 Oct  7 15:01 Atln61250Cels.dat
-rw-r--r-- 1 3942279 Oct  7 15:15 Atln61250ISid.dat
-rw-r--r-- 1 4211380 Oct  7 15:15 Atln61250JSid.dat
-rw-r--r-- 1  313015 Oct  7 15:59 Atln61250Obst.dat
-rw-r--r-- 1    9520 Oct  7 10:55 Pacf61250Blst.dat
-rw-r--r-- 1 2965850 Oct  7 15:01 Pacf61250Cels.dat
-rw-r--r-- 1 6229376 Oct  7 15:14 Pacf61250ISid.dat
-rw-r--r-- 1 6608227 Oct  7 15:14 Pacf61250JSid.dat
-rw-r--r-- 1  529625 Oct  7 15:59 Pacf61250Obst.dat
-rw-r--r-- 1   21639 Oct  6 16:44 SMC61250AISd.dat
-rw-r--r-- 1   26855 Oct  6 16:44 SMC61250AJSd.dat
-rw-r--r-- 1   11921 Oct  6 10:40 SMC61250BArc.dat
-rw-r--r-- 1   12480 Oct  7 10:58 Soth61250Blst.dat
-rw-r--r-- 1 2018944 Oct  7 15:01 Soth61250Cels.dat
-rw-r--r-- 1 4226706 Oct  7 15:13 Soth61250ISid.dat
-rw-r--r-- 1 4478350 Oct  7 15:13 Soth61250JSid.dat
-rw-r--r-- 1  360535 Oct  7 15:59 Soth61250Obst.dat
-rw-r--r-- 1   28251 Oct 11 11:14 ww3_grid_Atln.inp
-rw-r--r-- 1   28071 Oct 11 11:24 ww3_grid_Pacf.inp
-rw-r--r-- 1   28071 Oct 11 11:28 ww3_grid_Soth.inp
-rw-r--r-- 1   5064 Sep 13 11:04 ww3_multi.inp.template
-rw-r--r-- 1   3610 May 11 2021 ww3_ounf.inp.template
-rw-r--r-- 1   2799 Nov  2 2018 ww3_outf.inp.template
-rw-r--r-- 1   7177 Jan 27 2021 ww3_outp.inp.tempAtln
-rw-r--r-- 1   7177 Oct  6 2020 ww3_outp.inp.tempPacf
-rw-r--r-- 1   7177 Feb 16 2021 ww3_outp.inp.tempSoth
-rw-r--r-- 1  17861 May 21 16:24 ww3_shel.inp.tempAtln
-rw-r--r-- 1  16550 May 21 16:25 ww3_shel.inp.tempPacf
-rw-r--r-- 1  16630 May 21 16:26 ww3_shel.inp.tempSoth
-rw-r--r-- 1   3401 Dec 20 2012 ww3_strt.inp

```

Instructions for generating those extra input files and running the multi-grid model are available in the WW3 user guide.

#### 4. Postprocessing of multi-grid model output and visualisation of SWH field

Visualization of the multi-grid SWH field is like the single SMC grid case except for that there are choices to draw individual sub-grid field or merge them together like a single global output. The individual sub-grid output files `out_grd.[Atln/Pacf/Soth]` are converted into ASCII files with the postprocessing program `ww3_outf` type 4 conversion. The ASCII SWH output are transferred to our desktop machine for visualisation. They can be drawn with the Python program `SMCGTools/PySMCs/Sub61250SWHts.py`, which reads the same input file `PySMCs/strendat` for selection of model times as for single grid SWH plots.

#### 5. Tuning sub-grid boundary cells

The sub-grid boundary cells generated by the splitting program `Sub61250Splt3.py` may not be perfect. For instance, some boundary cells near coastlines are isolated by land and they would not affect the sub-grid boundary conditions. These redundant boundary cells may be deleted from the boundary cell list, reducing the model communication load. On the other hand, some small islands within boundary zones may reduce the effective width of the boundary line and the boundary line is better to be widened around the small islands. These fine tunings of the sub-grids and their boundary cells are not automatized so far and must be done manually on cell-by-cell bases. To aid for the viewing of boundary cells, a few

programs are developed for selecting some cells for a specified area. The following steps illustrate how these tools are used.

- i) First specify your interested area by the latitude-longitude pairs for the SW and NE corners of the area and save them in a text file: Slatlons.dat. These lat-lon pairs may be retrieved from Google Map by clicking on these points. You may simply work them out from a world atlas.
- ii) Run the python script, PySMCs/latlon2ijs.py, to convert you lat-lon pairs into corresponding cell index values:

```
SMCGTools/PySMCs/ python latlon2ijs.py Slatlons.dat 8
Input argvs = ['Slatlons.dat', '8']
Read grid info from Gridinfo.dat
Input file zlon zlat dlon dlat =
[0. 0. 0.08789062 0.05859375]
Read lat-lon pairs from Slatlons.dat
[[ 33.6 -7.5]
 [ 37.4 -4. ]
 [-16. 115.5]
 [-1. 138.6]]
Total number of lat-lon pairs = 4
SMC grid zlon, zlat, dlon, dlat = [0. 0.
0.08789062 0.05859375]
i, j indexes will be rounded to nearest multiple of k = 8
352.500 33.600 4008 576
356.000 37.400 4048 640
115.500 -16.000 1312 -272
138.600 -1.000 1576 -16
xlon ylat and converted i j's are saved in Slatlons.dat_ijs
Cells in area of the first two lines could be selected with
awk -f awktemp Cell_file > tempcels.dat
```

This program gets the SMC grid zlon, zlat, dlon, dlat values from the default file: Gridinfo.dat and converts your (lat, lon) pairs into corresponding (i, j) indexes to the nears multiple of size-8 cells. The converted results are also saved in the file, Slatlons.dat\_ijs. The sample area specified by the first two pairs are for the Gibraltar Strait area and an awk script file, awktemp, is produced for selection cells in the area.

```
SMCGTools/PySMCs/ cat awktemp
## awk script to select cells for area specified by
## SW corner: 352.500 33.600 4008 576
## NE corner: 356.000 37.400 4048 640
## Usage: awk -f awktemp Cell_file > tempcels.dat
```

```
{ if ((( $1 >= 4008 && $1 < 4048 ) &&
      ( $2 >= 576 && $2 < 640 ))) print $0 }
```

- iii) Run the Linux awk command to select cells in your specified area:  
SMCGTools/PySMCs/ awk -f awktemp ../DatSub/Atln61250Cels.dat \  
> tempcels.dat

Here the sub-grid Atln61250 is chosen for illustration.

- iv) The selected cells can be viewed with  
SMCGTools/PySMCs/ python smcviewwrap.py  
Input argvs = []  
Read cells from tempcels.dat  
Total number of cells = 197  
Cel i, j range = 4006 4047 574 642

```

Figure size = 4.1 6.8
Read table from  rgbspectrum.dat
136  colors with depth marks at  [1 10 100 1000 10000]

```

The png format diagram is used for viewing the cells within the selected area and may help make the decision whether any cell needs to be edited. Removing a boundary cell can be done by simply locating the cells in the boundary cell list file and deleting the cell line.

The awk command script file, `awktemp`, may be modified for selecting cells in a particular area specified by the `i` and `j` ranges as `$1` and `$2`. You may delete these cells by simply reversing (adding logical not ! at the beginning of) the awk script condition, such as

```

{ if (!( $1 >= 4008 && $1 < 4048 ) &&
    ( $2 >= 576 && $2 < 640 )) print $0 }

```

Another linux script, `removecell`, is also available for removing a list of cells from a given cell list. For instance, if you like to remove all the cells listed in `tempcels.dat` from the original cell list file, `../DatSub/Atln61250Cels.dat`, you may simply issue the command line:

```

SMCGTools/PySMCs/ cat tempcels.dat | ../Linuxs/removecell \
    ../DatSub/Atln61250Cels.dat

```

A new `templist` file will be created and it should be the same as `Atln61250Cels.dat` except that those cells listed `tempcels.dat` have been removed. To confirm the removal is done properly, you may compare the new list with the original one.

Further automatization of trimming cells could be achieved by saving those `awktemp` scripts with different names and do all the trimming in one go with the script:

```

SMCGTools/Linuxs/trimtempcels

For example, the following line combines all the listed awk* scripts to trim the given input file:
ls awkCaspian awkBaikal awkVictoria | trimtempcels \
    ../DatSub/Atln61250Cels.dat

```

This script may be used later to repeat the above trimming if the input cell array is updated.

## 6. Mixed resolution multi-grid option

The SMC multi-grid option treats each sub-grid as an independent 'regional' model so different resolution SMC sub-grids may be used in one multi-grid configuration. For instance, a refined European area at 3-6-12-25 km resolutions may be used with the 6-12-25-50 km sub-grids in the rest areas, if their boundary conditions are set up properly. As the present SMC multi-grid option uses a simplified 1-1 spectral swapping boundary condition, it would be ideal if boundary cells are identical cells in their donor sub-grids. These can be done by adding duplicated cells in donor sub-grids. If the donor sub-grid has different resolution levels from the receiving grid, the boundary cell location indexes and size numbers must be adjusted before adding to the donor grid cell array. The Python program `smcupalevel.py`, for instance could change the cell array up a resolution level by simply doubling the first 4 indexes of each cell in the given cell array file:

```
python smcupalevel.py tempcels.dat
```

which will write the modified cell array in the file `tempcels.dat_New`.

Other tools for generating mixed resolution sub-grids are still in development stage and the guide will be updated when they are added to the package.

## **Appendix: Users of the SMCGTools package outside UK Met Office**

Yudai Aoki from Niigata University, Japan, used the SMCGTools package to set up his own SMC grid wave model. Some questions are answered as well.

Emilio Echevarria (MetOcean Solutions, New Zealand) set up their global SMC grid wave forecasting model with an earlier version of the SMC grid tools and presented a poster in Wave 2023 titled:

Flexible Spherical Multiple Cells grids for improved global to coastal wind-wave modelling  
Emilio Echevarria, Jorge Perez, Henrique Rapizo and Saulo Meirelles

Fang Hou from NMEFC created their 6-level SMC grid forecasting model with help from CMA visitors who were trained in the UK Met Office for 6 months in 2008 for the SMC grid technique. He also developed a flexible SMC grid generating software which is available on request to him or MNEFC. The SMCGTools package is also passed to him.

Stefan Zieger (BoM) updated their SMC grid global wave forecasting model and they reported it in Wave 2023 as well. BoM is the 4th weather centre to adopt the SMC grid forecasting model. Their talk title is:

Recent Upgrade to the Bureau's Operational Wave Model

Aihong Zhong, Robert Greenwood, Stefan Zieger, Jessica Sweeney, Tony Hirst and Charles Sanders.

Passing the SMCGTools package to Lucy Bricheno (NOC Liverpool) for generating a SMC grid for their AMM15 domain refined (500 m) grid.

Passing the SMCGTools package to Breogan Gomez's ex-colleague in Spain for generating a test SMC grid for their wave forecasting model.

Passing the SMCGTools package to Nadao Kohno (JMA) for refining their wave climate model grid.

Passing the SMCGTools package to Rajesh Kumar (CCRS, Meteorological Service Singapore) for refining their regional and global wave climate model grids.

Passing the SMCGTools package to Alexander Babanin (University of Melbourne, Australia) and Qingxiang Liu (Ocean University of China) for their collaborated research project.