WW3 Tutorial 1.2: Lake Victoria.

Purpose

In this tutorial exercise we will go through the steps of setting up a realistic, single-grid wave model. This model can then be used to explore a wide range of aspects of running WAVEWATCH III ® (WW3). First, we will go through the setup manually. Subsequently, and automated script can be used to explore WW3. The model set up for Lake Victoria in central Africa. The exercise material was developed for a capacity building workshop of JCOMM[1] – TPC[2], in Nairobi, Kenya, in November 2012. The grids for this model were developed by Deanna Spindler, using survey data provided by Ali Mafimbo from the Kenya Meteorological Department (KMD). A report on the development of these grids is in preparation. Winds for this model is taken from the Climate Forecast System Reanalysis (CFS, CFSR) data base from NOAA/NCEP.

Input files

Files needed to be able to run the Lake Victoria models are found in the directory `day_1/tutorial_LV`, and consist of

```
switch              (switch file, copy to ~/wwatch3/bin and recompile
                    using w3_make)
clean.sh            (auxiliary scripts)
LV.sh
ww3_grid.LV_xx      (input files)
LV_xx.bot           (grid data for large, medium and small grids,
LV_xx.mask               xx='lg', 'md' and 'sm', respectively)
LV_xx.obst
ww3_strt.inp        (more input files)
ww3_prep.inp
ww3_shel.const.inp
ww3_shel.CFS.inp
ww3_outf.inp
ww3_outp.inp
gx_outf.inp
gx_outp.inp
wind.200911.data    (CFSR wind data fro November 2009)
map_LV.gs           (GrADS scripts)
spec.gs
source.gs
1source.gs
cbarn.gs
colorset.gs
figs                (directory with selected model results)
```

[1] Joint Committee on Oceanography and Marine Meteorology (UNESCO).
[2] Tropical Cyclone Program, UNESCO, World Meteorological Organization.

Setting up the model (interactive)

There are three model versions available, with resolutions of 5', 2.4' and 1.2', respectively. To expedite setting up the model, we will use the smallest model here, identified in the files as 'LV_sm'. Normally. A significant part of the effort of setting up a model is defining the grid. Making grids will be addressed in great detail in day 2 of this WW3 winter school. Here, the grids have been prepared already, with bottom depths (LV_sm.bot), obstruction grids (LV_sm.obst) and a grid mask (LV_sm.mask). The corresponding input file for the grid preprocessor (ww3_grid.LV_sm) set up to use these data, and is reproduced below.

```
$ -------------------------------------------------------------------- $
$ WAVEWATCH III Grid preprocessor input file                           $
$ -------------------------------------------------------------------- $
  'Lake Victoria (small)         '
$
   1.1  0.06623  29  24  0.5
   F T T T F T
    900.  675.  450.  60.
$
  &MISC FLAGTR = 4 /
END OF NAMELISTS
$
  'RECT' T 'NONE'
    49     51
     5.00   5.00     60.00
    31.00  -3.20      1.00
  -0.10   0.50  20 -0.001000  1  1 '(....)'  'NAME' 'LV_sm.bot'
                30  0.010000  1  1 '(....)'  'NAME' 'LV_sm.obst'
                40            1  1 '(....)'  'NAME' 'LV_sm.mask'
$
     0.    0.    0.    0.       0
$ -------------------------------------------------------------------- $
$ End of input file                                                    $
$ -------------------------------------------------------------------- $
```

The first active line (line not starting with '$', defines the grid name. The next line defines the discrete spectrum, with a frequency increment of 10%, and 24 directions. The lowest frequency of 0.066Hz is a little larger than for typical ocean models, which is feasible here due to the enclosed nature and weak winds of Lake Victoria. The following flags switch on (2D) spatial propagation, refraction, and source terms, and the four model time steps follow (15min overall time step). The following active line defines this grid as a rectilinear and spherical grid, without closure in longitudes (i.e., it is a regional rather than global grid). The discrete grid size is 49x51, with spatial increments of 5/60 degrees (5'), and a lower left corner at 31°E and 3.2°S. The next three lines hook up the external data files as identified above.

The model definition file mod_def.ww3 for this grid/model can be generated by using the program ww3_grid and the prepared input file ww3_grid.LV_sm.

```
ln -s ww3_grid.LV_sm ww3_grid.inp
ww3_grid
```

The full output of the grid preprocessor is reproduced in the `figs/ww3_grid.const.out`. Only part is reproduced here. The output starts with

```
                    *** WAVEWATCH III Grid preprocessor ***
                ===============================================

  Comment character is '$'

  Grid name : Lake Victoria (small)


  Spectral discretization :
 --------------------------------------------------
       Number of directions        :  24
       Directional increment (deg.):  15.0
       First direction       (deg.):   7.5
       Number of frequencies       :  29
       Frequency range        (Hz) :   0.0662-0.9551
       Increment factor            :   1.100


  Model definition :
 --------------------------------------------------
       Dry run (no calculations)   :  ---/NO
       Propagation in X-direction  :  YES/--
       Propagation in Y-direction  :  YES/--
       Refraction                  :  YES/--
       Current-induced k-shift     :  ---/NO
       Source term calc. and int.  :  YES/--
 . . .
```

Note that the first direction is rotated by half a discrete direction, and that the discrete spectrum runs up to nearly 1Hz. Note (on-screen) the print plot of the map of the grid. The output of the grid preprocessor ends with

```
 . . .
  Writing model definition file ...


  Summary grid statistics :
 --------------------------------------------------
       Number of longitudes      :        49
       Number of latitides       :        51
       Number of grid points     :      2499
       Number of sea points      :       768 (30.7%)
       Number of input b. points :         0
       Number of land points     :      1731
       Number of excluded points :         0


  End of program
 ========================================
         WAVEWATCH III Grid preprocessor
```

This small grid of only 768 grid points is easily run on a single processor desktop, or laptop, and hence does not need an MPI implementation of the code to run effectively. After the grid preprocessor is run, the model definition file `mod_def.ww3` is found in the directory. This file is used by every subsequent WW3 executable. The next step is to generate initial conditions for the model. This is done with the code `ww3_strt`, and an input file `ww3_strt.inp` is prepared and reproduced here

```
$ -------------------------------------------------------------------- $
$ WAVEWATCH III Initial conditions input file                          $
$--------------------------------------------------------------------- $
    3
$ -------------------------------------------------------------------- $
$ End of input file                                                    $
$ -------------------------------------------------------------------- $
```

The input file simply request initial condition type 3, which means that the initialization is based on fetch limited growth based on the local wind speed and direction, as well as on the discrete spatial grid size. Note that generating initial conditions is not strictly necessary, but does provide a cleaner model behavior (less warning messages) and a faster model spin-up. Executing the program

```
ww3_strt
```

results in the following (self-explanatory) output

```
                    *** WAVEWATCH III  Initial conditions ***
                 ===============================================

  Comment character is '$'

  Grid name : Lake Victoria (small)


  Initial field ITYPE = 3
 --------------------------------------------------
       Fetch-limited JONSWAP spectra based on local
       wind speed (fetch related to grid increment).

       Writing restart file  ...


  End of program
 =========================================
         WAVEWATCH III Initial conditions
```

and in the generation of the file `restart.ww3`. With the model definition file and the initial conditions file the wave model can already be run, as `ww3_shel` can be run with homogeneous wind fields defined in its input file `ww3_shel.inp`. A proper input file for such a run is provided as the file `ww3_shel.const.inp`, and is reproduced here

```
$ -------------------------------------------------------------------- $
$ WAVEWATCH III shell input file                                       $
$ -------------------------------------------------------------------- $
   F F     Water levels
   F F     Currents
   T T     Winds
   F       Ice concentrations
   F       Assimilation data : Mean parameters
   F       Assimilation data : 1-D spectra
   F       Assimilation data : 2-D spectra.
$
   20091111 000000
   20091112 000000
$
   1
$
   20091111 000000  3600  20091112 000000
     T F T F T  F T T T T  T T T T T  T T T T T  T T T T T  F F F F F
     F F F F F  F F F F F  F F F F F  F F F F F  F F F
   20091111 000000  3600  20091112 000000
    33.00 -1.00 'Center    '
     0.0   0.0  'STOPSTRING'
   20091111 000000     0  20091112 000000
   20091112 000000     1  20091112 000000
   20091111 000000     0  20091112 000000
   20091111 000000     0  20091112 000000
$
   'WND' 20091101 000000    9.5   145.    2.0
   'STP'
$ -------------------------------------------------------------------- $
$ End of input file                                                    $
$ -------------------------------------------------------------------- $
```

The first block of input data consists of flags for different types of model input. For the first three inputs, a second flag identifies if the input is homogeneous, and defined at the bottom of the input file. The next two input lines give the starting and ending time of the model run, in `yyyymmdd hhmmss` format. The following line is irrelevant for the single-processor model version used here and will be discussed elsewhere. The next block sets all output requests. For all six output types, a first line gives starting time (`yyyymmdd hhmmss`), time increment (seconds), and ending time. If the increment is 0, the output type is switched off. Hourly grid output is requested, with flags as identified in the fully documented input file provided with WW3 (and in the manual). Hourly point output is requested for a point in the middle of Lake Victoria. A single restart file is requested at the end of the model run. The other three output types are switched off with a time increment set to 0. The model can be run with this input file by executing

```
ln –s ww3_shel.const.inp ww3_shel.inp
ww3_shel
```

Full output of this model run is captured in `figs/ww3_shel.const.out`, and the model generates the raw output files `out_grd.ww3`, `out_pnt.ww3` and `restart001.ww3`. Also produced is a log file `log.ww3`, which is reproduced here as the file `figs/log.const.ww3`.

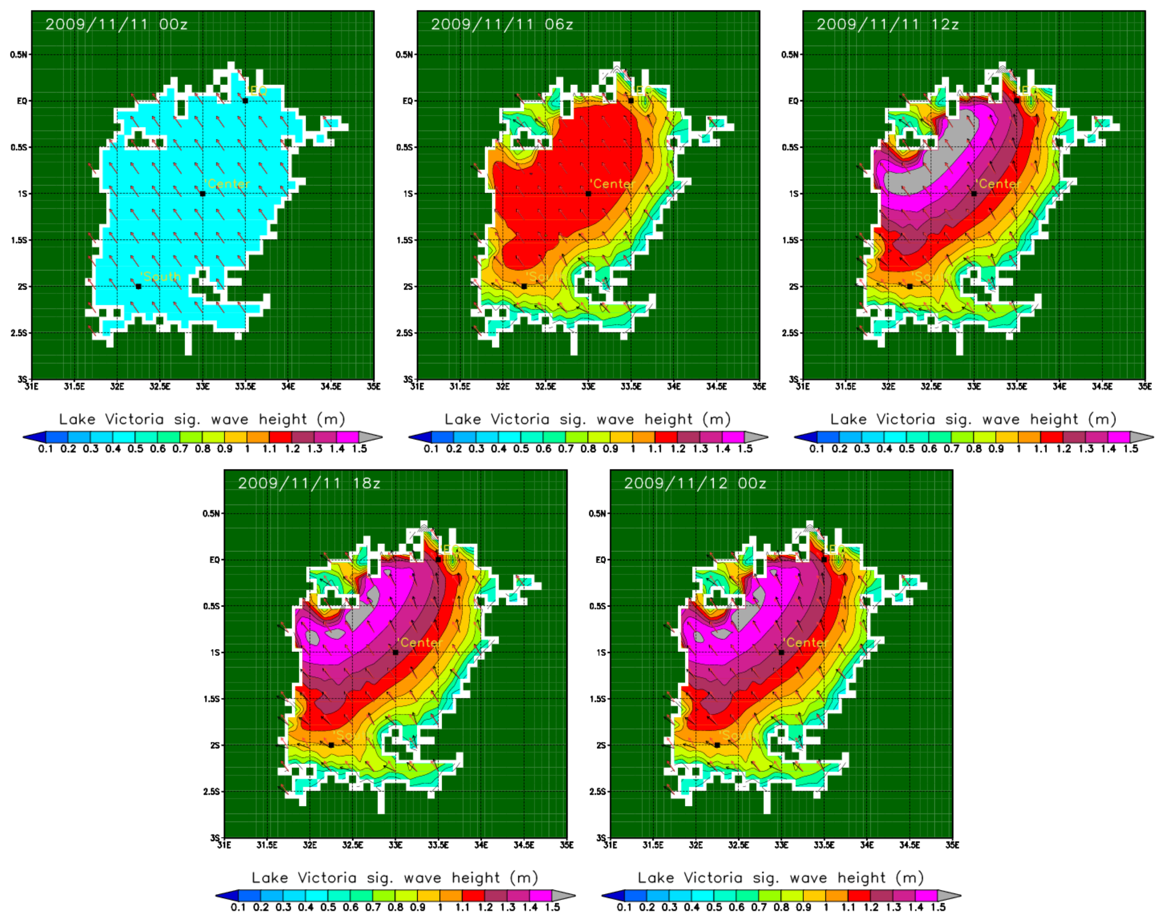
The raw model output cannot be assessed easily, but needs to be post-processed. The easies postprocessing is done with the programs `ww3_outf` (for field output) and `ww3_outp` (for point output). Input files for these programs are provided, and the programs are executed interactively by typing

```
ww3_outf
ww3_outp
```

The text output of these programs is rather lengthy, and therefore not reproduced here. Instead, the output can be found in the files `figs/ww3_outf.const.out` and `figs/ww3_outp.const.out`. Graphical output using GrADS can similarly be produced by running the corresponding WW3 output programs, and the GrADS script provided here. Wave height plots can be produced by executing

```
gx_outf
grads -pc "run map_LV"
```

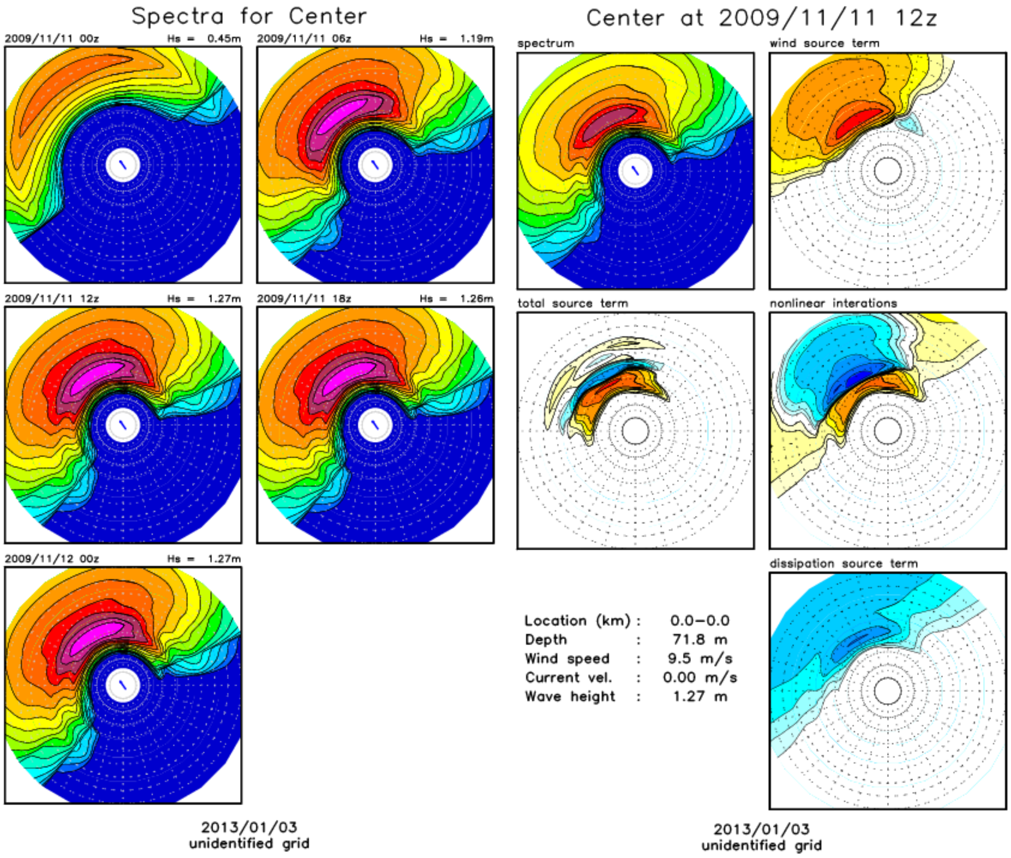
Wave heights for model integration at 6h intervals are presented below.



The graphics show the course model resolution, the output points called 'Central' and a gradually building wind sea associated with a constant wind from the south-east, reaching a steady-state solution after 18h. Similarly spectral output can be generated for the output point by executing

```
gx_outp
grads -pc "run spec"
grads -pc "run source"
```

A subset of the graphics this produced are presented below, showing a growing winds sea and its source terms.



Whereas the programs executed so far prove the concept of this wave model, they are not yet complete, since they do not use realistic wind fields. Using realistic winds requires two additions/adaptations. First, wind data needs to be prepared. Second,t he wave model needs to use these winds instead of the previous homogeneous winds.

With this test case, a subset of the CFSR winds is provided in file `wind.200911.data`. This file consists of hourly data on a 29x29 grid with a 0.5° resolution centered on Lake Victoria. The file is human-readable and for each wind field contains a time stamp,a field of wind eastward wind speed components, a field of northward components, and a field of air-sea temperature differences in °C. An input file for the WW3 input preprocessor (`ww3_prep.inp`) is provided and reproduced below.

```
$ -------------------------------------------------------------------- $
$ WAVEWATCH III Field preprocessor input file                          $
$ -------------------------------------------------------------------- $
   'WNS' 'LL' T T
$
    26.0   40.0   29   -8.0   6.0   29
$
  'NAME' 2 1 '(..T..)' '(..F..)'
  20 'wind.200911.data'
$ -------------------------------------------------------------------- $
$ End of input file                                                    $
$ -------------------------------------------------------------------- $
```

The first line in the input file defines the input data to be processed as wind including air-sea temperature differences on a regular grid. The second line defines the grid of the input field with range and steps west-to-east and south-to-north, respectively. The remaining data identifies where and how the wind data is stored. The wind data is preprocessed by executing

```
ww3_prep
```

the output of which command is reproduced in `figs/ww3_prep.out`. Note that the WW3 wind file `wind.ww3` contains more than 700 hourly wind fields, covering all of the month November of 2009. The wave model will attempt to read this file if the wind input flag in `ww3_shel.inp` is `T`, and the homogeneous flag for wind input is `F`, as is done in the file `ww3_shel.CFS.inp`.

```
F F     Currents
T F     Winds
F       Ice concentrations
```

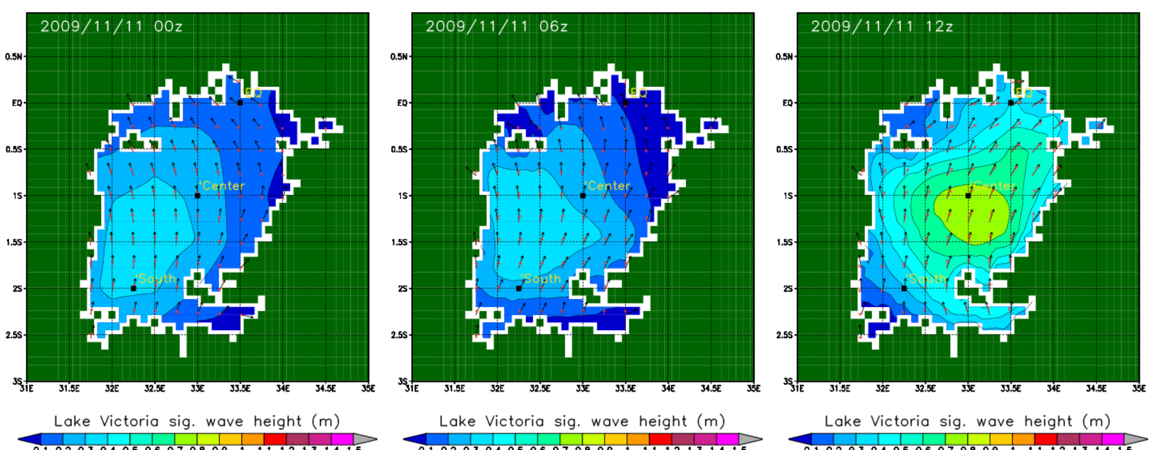
This changed flag is the only difference compared to the file `ww3_shel.const.inp`. Note that the homogeneous wind data at the end of this file is still present, but will now be ignored.With the wind field preprocessed, the model can now be run with the CFS winds by executing

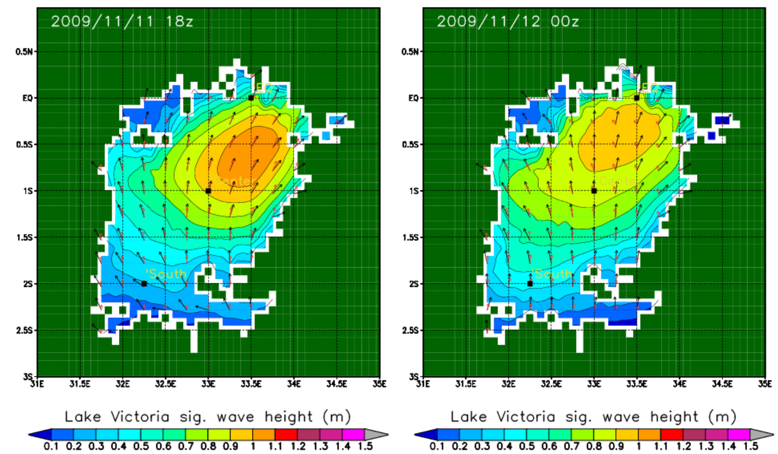
```
ln -sf ww3_shel.CFS.inp ww3_shel.inp
ww3_shel
```

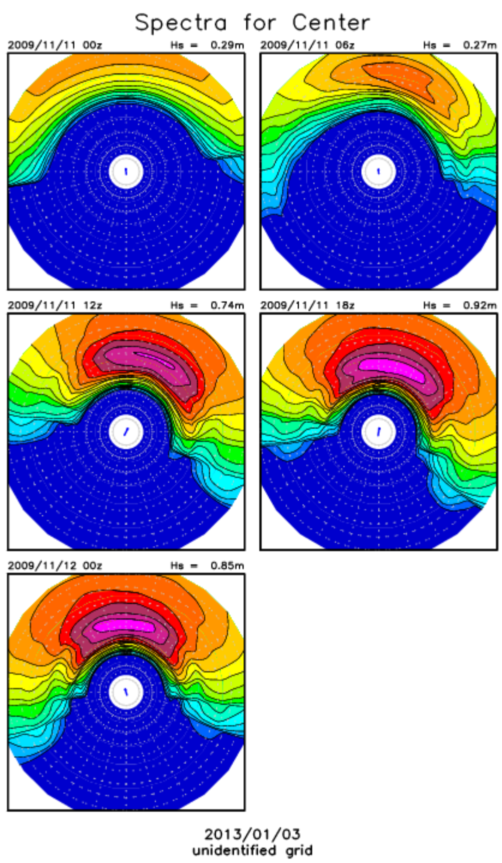
The full output of the latte command can be found in `figs/ww3_shel.CFS.out`. Output con be generated as was done above for the homogeneous winds by executing

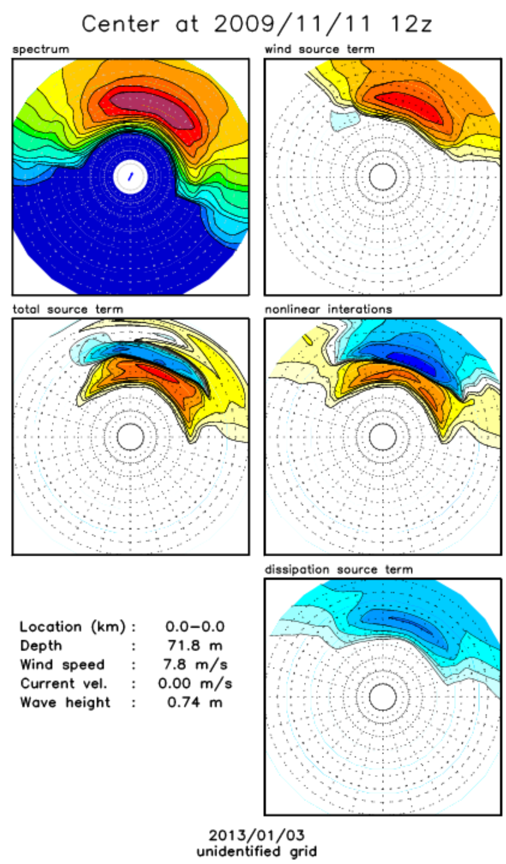
```
gx_outf
grads -pc "run map_LV"
gx_outp
grads -pc "run spec"
grads -pc "run source"
```

resulting in the corresponding graphics presented below.









This completes the setup and interactive running of the basic Lake Victoria model.

Running the model (scripted)

So far, the Lake Victoria model has been set up in an interactive way. If such a model is to be run regularly, is will need to be automated in a scripted form. Such a script is provided with the script `LV.sh`. This script can run both the constant and CFS wind cases, and has several additional options set in the top of the script

```
. . .
# 0. Preparations -----------------------------------------------------------

  set -e

  grid='LV_sm'               # Choose one of the three grids
  wind='yes'                 # Yes: run with CFS winds data
                             # No : run with homogeneous winds

  t_beg='20091111 000000'  # Starting time of run
  t_end='20091112 000000'  # Ending time of run
  t_rst='20091112 000000'  # Time for restart file, if empty no restart file
# t_rst=                   # Time for restart file, if empty no restart file

cat > buoy.all << EOF
    33.50  0.00 'EQ        '
    33.00 -1.00 'Center    '
    32.25 -2.00 'South     '
EOF

# 0.a Process restarting
. . .
```

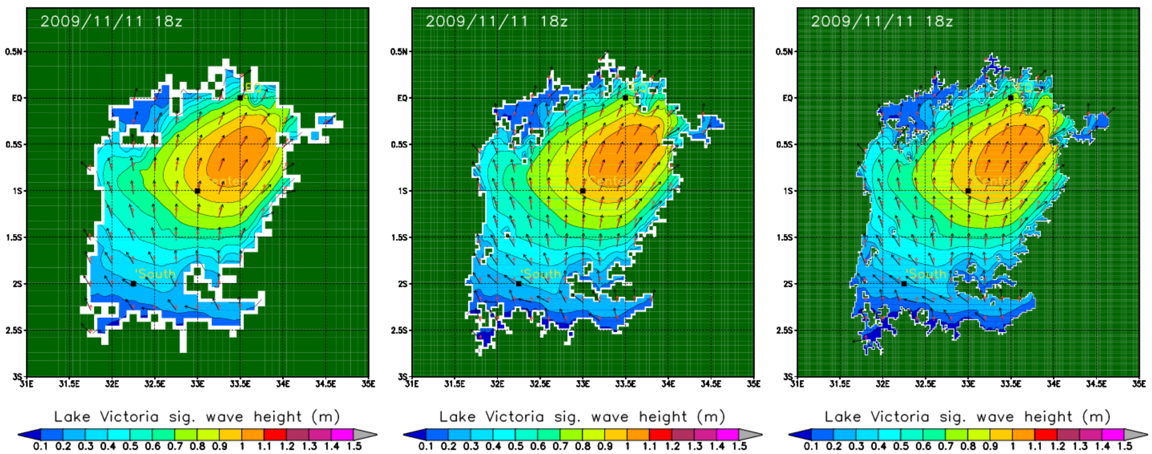
The options that can be set in this part of the script include

- Selection of any of the three grids.
- Selection of CFS or constant winds. If constant winds are to be changed, or to be made variable in time, additional changes need to be made further down in the script, where the file `ww3_shel.inp` is constructed.
- Selection of a start and end time of the run. These should be in November 2009.
- An option to generate a restart file. If this file is generated, it is saved in a new directory `restarts`. This directory is removed be executing `clean.sh all`, but not be `clean.sh` only.
- A list of output points is defined here in the file `buoy.all`, to be used in both `ww3_shel.inp` and `map_LV.gs`.

Note , furthermore, that

- The script runs all output postprocessors, but not the GrADS scripts.
- All raw output files from `ww3_shel` are retained in the directory, so that post-processors can be run interactively after `LV.sh` has been run.

As an example of results obtained with the script, equivalent model results for 18z November 11 for all three grid resolutions are presented below, showing a drastically better resolved coastal area and islands in the larger grids (with a more detailed wave field), but near-identical results in the center of the lake, away from islands.



The script can be the basis of additional experimentation with this fairly simple model set up. Rather than guiding additional model experiments, suggestions are made for things to do with this script. The students are encouraged to pick, choose and experiment. Some suggestions are

- Start with browsing the script to see how I have "automated" the model. Some preset files are used, other files are generated on the fly.
- Run the model for consecutive days, using a hot start from the restart file from the previous day.
- Work with the other two grids (if you have the patience ☺).
- Change compile-time model options (propagation scheme, physics packages) and look at the impact on the model results.
- Play with the mean water level as a homogenous input.
- Experiment with output options that have not been used yet.
  - Addition options in the postprocessors.
  - Additional fields to be analyzed.
  - Add output points.
- For after day 4's training on MPI: Modify the script to run the model under MPI, so that the large grid can be turned around quickly.

*** HAVE FUN ! ***

References

The manual.

More information:
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