Running WWATCH on triangular meshes

Fabrice Ardhuin

The friends of WAVEWATCH III Team
Marine Modeling and Analysis Branch
NOAA / NWS / NCEP / EMC

ardhuin@ifremer.fr
NCEP.list.waves@NOAA.gov
Covered in this lecture:

- Why triangles?
- Grid structure & running ww3_grid
- Time integration & grid optimization
- Numerical schemes: spatial advection
- Post-processing
- Triangles + squares in 2-way nested runs

What is not covered:

- Hands-on tutorial on grid generation
- for this: search for “tutorial” on Ifremer's wiki (using Polymesh)


Next course at UMD or at Ifremer!

One paper with specific numerics (for coastal reflection):
Ardhuin & Roland (JGR 2012)

Some other papers with just application:
Ardhuin & al. (JPO 2009: Stokes drift; JPO 2012: wave-current)

All these are at:
http://wwz.ifremer.fr/iowaga (just google IOWAGA)

And you can find forecasts and hindcasts there:
http://www.previmer.org/en/forecasts/waves
Minimizing number of nodes …

- 1) Because we really need high resolution in some places
- 2) Because we want to use crazy expensive physics

Extreme case: only 900 nodes, to use exact non-linear interactions (Ardhuin et al. JPO 2007)

And better shoreline orientation

From Roland et al. (JGR 2012)
Why triangles

There are other alternatives

● 1) Nesting regular grids
● 2) Curviliear grids
● 3) Quad-trees or “SMC” grids
● 4) Hexagons …

● It is a matter of taste (and practicality and CPU time)…
● but I do not know how to help you with those. So let's go back to the simplest grid element: a triangle
The grid structure

Basic triangle stuff

The image shows a grid structure with a triangle labeled as "Triangle" and a node labeled as "Coastline Node". The grid is marked with latitude and longitude coordinates, and various cells are highlighted, including a median dual cell. The grid is used for basic numerical solution techniques in the context of triangles.
The grid structure

The input file: built on “Gmsh” format

- 1) Nodes
- 2) Elements
  - Active boundary points (element type 15)
  - Triangles (element type 2)

- The input file was kept to a minimum, we did not include further info: neighbour lists...
- That extra info is recomputed when running ww3_grid and stored in mod_def.ww3
- … which can take minutes with more than 100K nodes!
- Internal storage in WWATCH is unchanged, we just have NY = 1
- This carries into output files from ww3_outf & ww3_ounf
The grid structure

Running **ww3_grid** for triangles

- Only a few things in **ww3_grid.inp** are different from other grids:

  - 1) You have to tell **ww3_grid** that your grid is a triangle mesh:
    ```
    $ Define grid .................................................................$
    'UNST' T F ! NB: T T for a global grid... never tried yet!
    ```

  - 2) Define the depth threshold and scale factor + mesh file name
    ```
    4.0 0.30 20 -1.4 1 '(20f10.2)' 'NAME' 'hawaii_v5.msh'
    ```

- That's it! Nothing else
  ```
  $ 4 Limiting bottom depth (m) to discriminate between land and sea
  $ points, minimum water depth (m) as allowed in model, unit number
  $ of file with bottom depths, scale factor for bottom depths (mult.),
  $ IDLA, IDFM, format for formatted read, FROM and filename.
  ```
The grid structure

Defining list of input boundary points

OK, but listing the active input points (MAPSTA=2) is very cludgy!
You can do it … but you can also tell ww3_grid to figure it out.

- Otherwise, just add these two namelist parameters near the top of
  ww3_grid.inp

&UG UGOBCAUTO = T, UGOBCDEPTH = -20. ! or any other depth
- This means that ww3_grid will turn boundary points into active
  boundary points if the local depth (before water level added) is more
  than 20 m (yes, z is positive up in ww3_grid.inp)
Time integration and grid optimization

Time integration

Because it is not so simple to define the proper advection **time step**, in the case of 'UNST' grid, the time step is **not set** to the value defined in ww3_grid.inp but instead it is **dynamically adjusted** (for explicit schemes). This time step will be different for each spectral component and will vary with current speed and water level.

So if your grid has **just one** very flat or very tiny triangle this time step could well be **0.1 s** (instead of 10 or 20 s) and the run grinds to a halt!

So how do I know about it?

Option 1) check the CFL numbers in the model output (not so easy)

Option 2) – my choice - Run a version of the code compiled with the “T” switch (for test output). The screen output (or, in the future, some file fort.994) will list the “bad guys”, the nodes that cause the time step to be so small.
Time integration and grid optimization

Test output to find the bad guys
This test output comes from w3profsmd.ftn

```
617 !/T      DO IP = 1, NX
618 !/T      DMAXEXP = SI(IP)/MAX(DBLE(1.0E-10),KKSUM(IP))
619 !/T      IF (DTMAX.EXP.LT.DMAX*1.3.AND.IK.EQ.1) WRITE(6,'(A,3I8,2F8.3,3F10.4)') 'DTMAX: ', IK, ITH, IP, &
620 !/T      REAL(DMAXEXP), REAL(DMAXGL), XYB(IP,1), XYB(IP,2), XYB(IP,3)
621 !/T      END DO ! IP
```

```
DTMAX:  1  1  15504  0.629  0.629  -1.0199  44.5647  0.0000  
DTMAX:  1  2  15504  0.622  0.622  -1.0199  44.6457  0.0000  
DTMAX:  1  3  15504  0.661  0.661  -1.0199  44.6457  0.0000  
DTMAX:  1  4  15504  0.759  0.759  -1.0199  44.6457  0.0000  
DTMAX:  1  5  15457  1.131  0.929  -2.3814  47.5000  -2.2883  
DTMAX:  1  5  15457  1.131  0.929  -2.3814  47.5000  -2.2883  
DTMAX:  1  6  15504  0.990  0.990  -1.0199  44.6457  0.0000  
DTMAX:  1  7  15449  1.354  1.142  -5.1328  48.4594  0.0000  
DTMAX:  1  7  15469  1.408  1.142  0.1134  49.4831  -1.9901  
DTMAX:  1  7  15504  1.142  1.142  -1.0199  44.6457  0.0000  
DTMAX:  1  7  15508  1.458  1.142  -3.0863  48.8736  0.0000  
DTMAX:  1  7  24622  1.444  1.142  -3.0862  48.8738  0.0000  
DTMAX:  1  8  15449  1.105  1.105  -5.1328  48.4594  0.0000  
DTMAX:  1  8  15469  1.415  1.105  0.1134  49.4831  -1.9901  
DTMAX:  1  8  15508  1.308  1.105  -3.0863  48.8736  0.0000  
DTMAX:  1  8  24622  1.304  1.105  -3.0862  48.8738  0.0000  
```
I know what you think … this ought to be easier. This is why Aron Roland is trying to get the ww3_shel interacting with Polymesh via a GUI.
**Numerical schemes**

**General principles :**
**Contour Residual Distribution**

Advection equation:

\[ \frac{\partial N}{\partial t} + \nabla_x (c_x N) = 0 \]

Discrete form:

\[ \int_T \frac{\partial N}{\partial t} dA = - \int_T c_x \nabla N dA = \Phi_T \]

Update of spectrum = sum on dual cell

\[ N_i^{n+1} = N_i^n + \frac{\Delta t}{S_i} \sum_{T,i \in D_i} \Phi_{i,T} \]
Numerical schemes

4 schemes implemented:


2) «Positive Streamline Invariant» EXPFSPSI (Abgrall 2001)
   CPU cost of full model: 15

   (Lax-Wendroff kind of scheme)

4) Implicit N scheme: IMPFSIMP

Higher order = more expensive and less numerical diffusion
Numerical schemes

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Example applications

with currents & water levels

Ardhuin & al. (2012):

Important code change: «refraction filter» on total refraction (now PR3 only)

In the pipeline:
- use of tidal constituents (saves disk space!!) : OK in tide branch
Example applications

with currents & water levels

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Example applications

Coastal reflection: Hawaii grid used in tutorial

Ardhuin & Roland (JGR 2012):

Shoreline orientation is easier to define: reflection AT shoreline nodes
Different with regular grid: shoreline BETWEEN nodes
Coastal reflection: Hawaii grid used in tutorial validation at Waimea buoy 51201
Example applications

Hawaii grid used in tutorial

Boundary conditions from Ifremer's hindcast

http://tinyurl.com/iowagaftp/HINDCAST/GLOBAL/2008_ECMWF/
Example applications

Hawaii grid used in tutorial
Summary

- Advection schemes in WWATCH taken straight from WWM II
  - several validation and comparison study
  - 2 year of routine forecasts
  - 20 year hindcast for test area, now expanding to full France

- 4 different schemes to chose from. Personally the N scheme works great. If you are a daredevil, maybe the IMP is for you