Introduction to SWASH model: theory and hands-on session Ourense, 9th May 2014

Tomohiro Suzuki

Flanders Hydraulics Research

SWASH model

- SWASH : Simulating WAves till SHore
- Wave-flow model
- Time domain
- Based on non-linear shallow water equation with non-hydrostatic pressure (fully non-linear)

Easy-to-use

- Open source, available at Sourceforge.net
- Accessible:

  - Fortran 90

  - Parallel computing

  - Simple data structure, easy-to-understand

  - Easy to install
- The same ”touch and feel” as SWAN

  SWAN : spectrum domain wave model

  ~almost the same input

Input is simple; Just 50 lines in this case (Wenduine case)

```
$*************HEADING*****************************************
$
$ Wenduine physical model, Test_125
$
PROJ 'WEN_125_INC' '01'
$
$***********MODEL INPUT**********************************
$ Water level
SET LEVEL 6.92
MODE NONST ONED

$ Coordinates (1D)
CGRID 0. 0. 0. 1300.0 0. 2600 0 ! Flume physical total:64 m, SWASH: 52 m,  NGrid 2600 (dx=0.5 m)
VERT 1 ! 1 layer

$ Bottom (1D)
INPGRID BOTTOM 0. 0. 0. 2600 0 0.5 0.
READINP BOTTOM -1. 'WEN_125.bot' 1 0 FREE ! Slope 1/35, depth -16.88 m

$ Initial state
INIT zero

$ Wave conditions
BOU SIDE W CCW BTYPE WEAK CON SERIES 'WEN_125_INC.bnd'
BOU SIDE E CCW BTYPE RADIATION

$ Physics
FRIC MANN 0.01
Break
NONHYDROSTATIC

$ Numerics
DISCRET UPW MOM
TIMEI 0.1 0.5
$

$************* OUTPUT REQUESTS **************************
$
POINTS 'WG'    FILE 'out_wg.loc'     ! Wave gauges
TABLE  'WG'    NOHEAD 'WEN_125_INC_OUT.tbl' TSEC WATL OUTPUT 000000.000 0.2 SEC
POINTS 'LAYER' FILE 'out_layer.loc'  ! Overtopping layer depth and speed
TABLE  'LAYER' NOHEAD 'WEN_125_INC_OUT.ltn' TSEC DIST BOTL WATL OUTPUT 000000.000 0.2 SEC
TABLE  'LAYER' NOHEAD 'WEN_125_INC_OUT.lsp' TSEC DIST BOTL VEL  OUTPUT 000000.000 0.2 SEC
POINTS 'WGO'   FILE 'out_surf.loc'   ! Water surface
TABLE  'WGO'   NOHEAD 'WEN_125_INC_OUT.sur' TSEC WATL OUTPUT 031355.000 0.2 SEC

$
TEST 1 0
COMPUTE 000000.000 0.02 SEC 032355.000
STOP
```

Basic philosophy

- Provide an efficient and robust model that allows a wide range of time and space scales of surface waves and shallow water flows in complex environments

  -> NS model (e.g. VOF mode) is too expensive to simulate in 3D domain and number of waves (e.g. 1000 waves)

Most of the coastal application, one layer calculation is enough (kh<1)

Principle behind non-hydrostatic wave-flow modeling

- Simplest modeling for wave transformation: NLSW
- NLSW-type models are able to deal with breaking/bore capturing
- Non-hydrostatic pressure enable to model many other wave phenomena (dispersion, surf beat, triads, etc.).
- Water depth can be divided into a number of layers: improvement of dispersion relation

Main uses

- Predicting wave transformation
  - Offshore to beach
  - Agitation in ports and harbor
  - Transmission over porous structure
  - Overtopping over a dike (e.g. Wenduine)
- Predicting flow
  - Rapidly changing topography, typically found in coastal flooding (e.g. dike breaks, tsunamis and flood waves)
- Others
  - Ocean circulation, tides and storm surges

Physics

- Propagation, frequency dispersion, shoaling, refraction, reflection and diffraction,
- flooding, wave run-up,
- nonlinear wave-wave interactions (surf beat, triads),
- wave-induced currents and wave-current interaction,
- wave breaking,
- bottom friction, and
- subgrid turbulence and vertical mixing.

Numerics

- Staggered grid in space and time
- Time stepping is done in combination with second order projection method
- Either SIP (depth-averaged mode) or (M)ILU-BiCGSTAB (multi-layered mode) iterative solver is employed for the solution of the pressure Poisson equation.

Comparison with Boussinesq model

- SWASH improves its frequency dispersion by increasing this number of layers rather than increasing the order of derivatives of the dependent variables
- SWASH is more robust and faster than Boussinesq-type wave model.
- SWASH does not have any numerical filter nor dedicated dissipation mechanism to eliminate short wave instabilities.
- Wave breaking in SWASH is not artificial
- Fully non-linear in SWASH

Computations

- SWASH computations can be made on a regular and an orthogonal curvilinear grid in a Cartesian or spherical coordinate system.
- SWASH runs can be done serial, i.e. one SWASH program on one processor, as well as parallel, i.e. one SWASH program on more than one processor using an MPI protocol.

Boundary conditions

- Wave boundary (weakly reflective)
  - Regular waves by means of Fourier series or time series
  - Irregular unidirectional waves by means of 1D spectrum (Defined spectrum, Pierson-Moskowitz, Jonswap or TMA).
  - Irregular multidirectional waves by means of 2D spectrum. (Defined spectrum, Pierson-Moskowitz, Jonswap or TMA) while the directional spreading can be expressed with the well-known cosine power or in terms of the directional standard deviation.
- Velocity or discharge
- Sommerfeld or radiation condition
- Sponge layers
- Periodic boundaries

Output (ASCII or binary Matlab files)

- water surface elevation
- depth-averaged velocity magnitude and direction
- layer-averaged velocity magnitude and direction
- vertical distribution of horizontal velocity
- turbulence quantities (k, ε and ν_t)
- time-averaged turbulence quantities
- transport constituents (salt, heat and suspended sediment)
- time-averaged transport constituents
- layer-averaged pressure
- vertical distribution of pressure
- non-hydrostatic pressure
- significant wave height
- wave-induced setup
- maximum horizontal runup or inundation depth

etc

```
$*************HEADING******************************************
$
$ Wenduine physical model, Test_125
$
PROJ 'WEN_125_INC' '01'
$
$***********MODEL INPUT**********************************
$ Water level
SET LEVEL 6.92
MODE NONST ONED

$ Coordinates (1D) 
CGRID 0. 0. 0. 1300.0 0. 2600 0 ! Flume physical total:64 m, SWASH: 52 m,  NGrid 2600 (dx=0.5 m)
VERT 1 ! 1 layer

$ Bottom (1D)
INPGRID BOTTOM 0. 0. 0. 2600 0 0.5 0.
READINP BOTTOM -1. 'WEN_125.bot' 1 0 FREE ! Slope 1/35, depth -16.88 m

$ Initial state
INIT zero

$ Wave conditions
BOU SIDE W CCW BTYPE WEAK CON SERIES 'WEN_125_INC.bnd'
BOU SIDE E CCW BTYPE RADIATION

$ Physics
FRIC MANN 0.01
Break
NONHYDROSTATIC

$ Numerics
DISCRET UPW MOM
TIMEI 0.1 0.5
$

$************ OUTPUT REQUESTS *************************
$
POINTS 'WG'    FILE 'out_wg.loc'     ! Wave gauges
TABLE  'WG'    NOHEAD 'WEN_125_INC_OUT.tbl' TSEC WATL OUTPUT 000000.000 0.2 SEC
POINTS 'LAYER' FILE 'out_layer.loc'  ! Overtopping layer depth and speed
TABLE  'LAYER' NOHEAD 'WEN_125_INC_OUT.ltn' TSEC DIST BOTL WATL OUTPUT 000000.000 0.2 SEC
TABLE  'LAYER' NOHEAD 'WEN_125_INC_OUT.lsp' TSEC DIST BOTL VEL  OUTPUT 000000.000 0.2 SEC
POINTS 'WGO'   FILE 'out_surf.loc'   ! Water surface
TABLE  'WGO'   NOHEAD 'WEN_125_INC_OUT.sur' TSEC WATL OUTPUT 031355.000 0.2 SEC

$
TEST 1 0
COMPUTE 000000.000 0.02 SEC 032355.000
STOP
```

Examples

http://swash.sourceforge.net/

Check a11stwav case

input

a11stwav.sws -> SWASH input file

a11stwav.bot -> bathymetry file

a11stwav.wlv -> incident wave file

Exercise

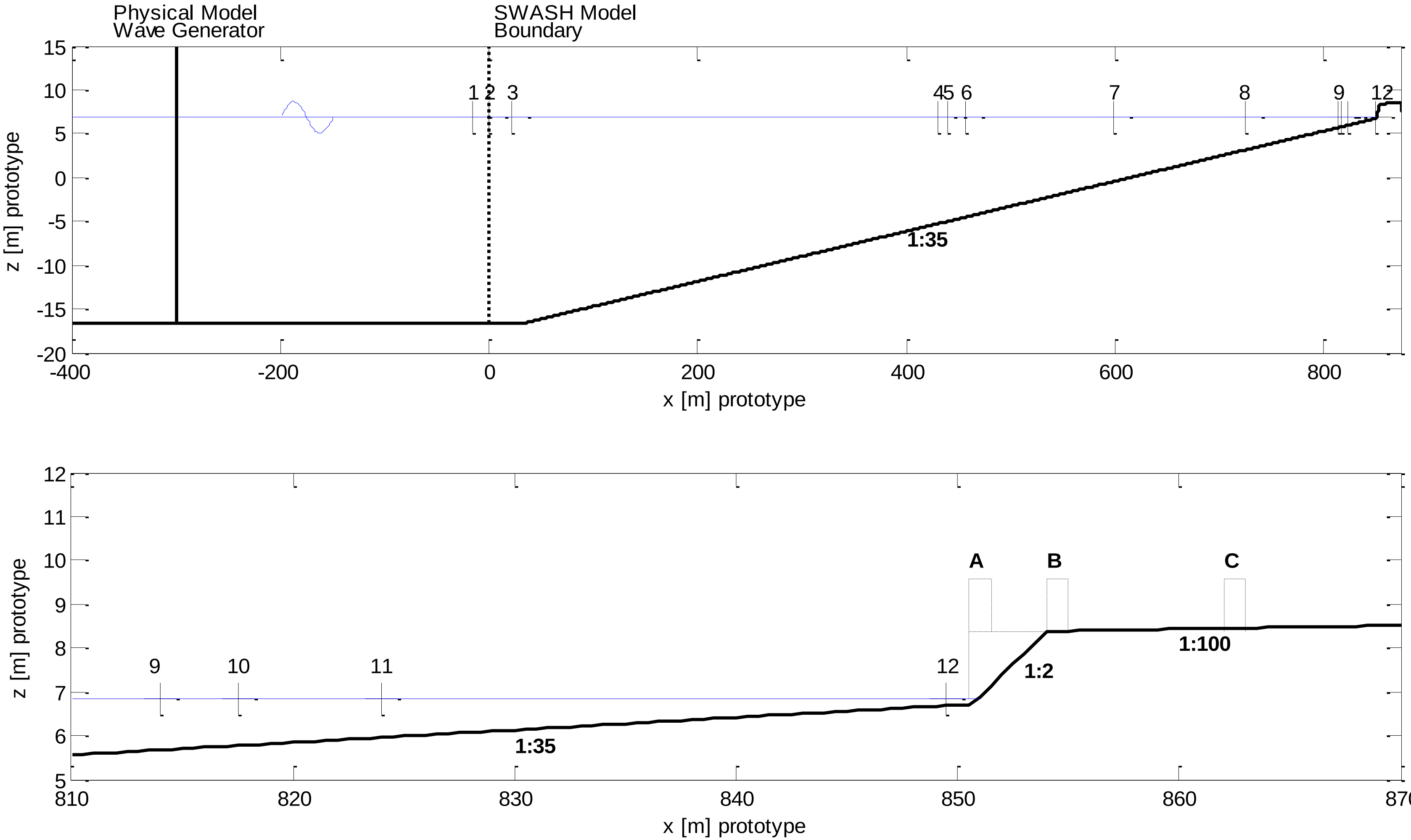
Case 1: a11stwav

Run a11stwav case

output
a11stw01.tbl -> output water surface
a11stw01.prt -> log file

SWASH run + mkplot (matlab file)

Case 2: Wenduine wave overtopping calculation



```
$*************HEADING******************************************
$
$ Wenduine physical model, Test 125
$
PROJ 'WEN_125_INC' '01'
$
$***********MODEL INPUT**********************************
$ Initial setting
SET LEVEL 6.92                          ! Water level
MODE NONST ONED                         ! 1D

$ Computation grid
CGRID 0. 0. 0. 1300.0 0. 2600 0         ! x0,y0,dir,x_total,y_total,x_ngrid,y_ngrid
VERT 1                                  ! 1 layer

$ Bottom file read
INPGRID BOTTOM 0. 0. 0. 2600 0 0.5 0.   ! x0,y0,dir,x_ngrid,y_ngrid,dx,dy
READINP BOTTOM -1. 'WEN_125.bot' 1 0 FREE ! -1:coefficient, 1:idla, 0:n_header

$ Initial state
INIT zero                               ! Starting from zero (no velocity)

$ Wave conditions
BOU SIDE W CCW BTYPE WEAK CON SERIES 'WEN_125_INC.bnd'  ! west boundary Input incident wave time series / wave condition
BOU SIDE E CCW BTYPE RADIATION                          ! east boundary Sommerfeld

$ Physics
FRIC MANN 0.01                          ! Bottom friction manning
Break                                   ! Breaking on

$ Numerics
NONHYDROSTATIC                          ! when VERT>6 then 'NONHYDROSTATIC standard'
DISCRET UPW MOM                         ! Up-wind
TIMEI 0.1 0.5                           ! Explicit
$

$************ OUTPUT REQUESTS ************************
$
POINTS 'WG'    FILE 'out_wg.loc'                                                  ! Wave gauge locations
TABLE  'WG'    NOHEAD 'WEN_125_INC_OUT.tbl' TSEC WATL OUTPUT 000000.000 0.2 SEC        ! initial time 000000.000; dt 0.2 SEC  hhmmss format
POINTS 'LAYER' FILE 'out_layer.loc'                                               ! Overtopping layer depth and speed output locations
TABLE  'LAYER' NOHEAD 'WEN_125_INC_OUT.ltn' TSEC DIST BOTL WATL OUTPUT 000000.000 0.2 SEC  ! initial time 000000.000; dt 0.2 SEC
TABLE  'LAYER' NOHEAD 'WEN_125_INC_OUT.lsp' TSEC DIST BOTL VEL  OUTPUT 000000.000 0.2 SEC  ! initial time 000000.000; dt 0.2 SEC
POINTS 'WGO'   FILE 'out_surf.loc'                                                ! Water surface output locations
TABLE  'WGO'   NOHEAD 'WEN_125_INC_OUT.sur' TSEC WATL OUTPUT 000000.000 0.2 SEC        ! initial time 000000.000; dt 0.2 SEC
$
TEST 1 0                                                                          ! error check
COMPUTE 000000.000 0.02 SEC 001000.000                                            ! Computation initial dt 0.02 SEC Endtime 001000.000
STOP
[EOF]
```

SWASH run + matlab (SWASH_ANA, SWASH_VIS)

Case 3: Coupling with SPH (WISE)

- Incident wave analysis (Wavelab) to make .bnd (incident wave time series) file

  *without bandpass
- Make .bot (bathymetry) file
- Run and check SWASH result represents physical model
- Modify .bot (bathymetry) file at WG X
- Run SWASH with the new bathymetry
- Pass calculated result to SPH