**BOUMUST User’s Manual**

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The third-order Runge\_Kutta scheme with strong stability preserving property was applied for time stepping.

* 1. **Numerical treatment of wet-drying and wave breaking**

We used the hydrostatic construction technique proposed by Wang et al. (2011) to treat wet-drying boundaries.

We proposed a combination of two criteria for triggering wave breaking modeling within our shock-capturing scheme, namely, the ration of wave height to water depth criterion(*e.g.*, Fang et al., 2013; Shi et al., 2012; Tonelli and Petti, 2010)and the local slope angle criterion(is the critical front face angle at the initiation of breaking; see Kazolea, Delis and Synolakis, 2014). Local wave slope criterion is introduced herein to consider steady jumps, which cannot be captured by the first criterion since (Kazolea, Delis and Synolakis, 2014). In the computation, the ratio of wave height to water depthand the local wave angle  are computed at each computation cell. If at least one of the criteria is satisfied, the cells are labeled as breaking cells, and dispersive terms are deactivated. Dispersive terms can only be reactivated oncereduces to below a certain threshold, *i.e.* , this ensures the stable computation(Tonelli and Petti, 2011) and is quite necessary for fully nonlinear Boussinesq equations, otherwise instability tends to occur due to sharply deactivating or reactivating dispersive terms

* 1. **Boundary conditions and wavemaker**

We implemented various boundary conditions including wall boundary condition, absorbing boundary condition following Kirby et al. (1998) and periodic boundary condition following Chen et al. (2003).

Wavemaker implemented in this study include Wei and Kirby’s (1999) internal wavemakers for regular waves and irregular waves. For the irregular wavemaker, an extension was made to incorporate an alongshore periodicity into wave generation, in order to eliminate a boundary effect on wave simulations. The technique exactly follows the strategy in Chen et al. (2003), who adjusted the distribution of wave directions in each frequency bin to obtain alongshore periodicity. This approach is effective in modeling of breaking wave-induced nearshore circulation such as alongshore currents and rip currents.

1. **User’s Manual**

**4.1 Program outline and flow chart**



**4.2 Subroutine and function descriptions**

*Still being written*

**4.3 Installation and compilation**

BouMust is distributed in a compressed file. To install the programs, first, unzip the package. The source code was written using Fortran 90 with Compaq Visual Fortran 6.6(CVF can work on Windows 7, but windows XP is best ). For users, running the executable file named BouHybrid.exe under the release folder is the simplest way, and users need input files ready for their cases( NOTE: BouMust was developed with Windows XP. which means that there may be compatibility issues if BouMust works in other operating systems including higher versions of Windows). Besides, we used Compaq Array Visualizer(CAV) in BouMust to view and analyze array data graphically, which requires the installation of CAV. Of course, users can choose to switch that function off. Both CVF and CAV are not distributed with BouMust, and users can get them from Internert We also provide users source codes (main.f90, mod\_global.f90, mod\_param.f90, mod\_util.f90) to compile and run. however, we still recommend users compile these files under CVF.

**4.3 Input**

Following are descriptions of parameters in input.txt (NOTE: all parameter names are capital sensitive)

**PROJECTNAME:** name of your project, used for log file and project folder.

**SPECIFICATION OF EQUATION**

EqID: governing equation

EqID=23: GN equation.

EqID=1: nonlinear shallow water equation.

**SPECIFICATION OF DIMENSION**

Mglob: global dimension in  direction.

Nglob: global dimension in  direction.

SPECIFICATION OF GRID SIZE

DX: grid size(m) in  direction.

DY: grid size(m) in  direction.

**SPECIFICATION OF TIME**

TOTAL\_TIME: simulation time in seconds

PLOT\_INTV\_SNAPSHOT: output interval in seconds (Note, output time is not exact because adaptive dt is used.)

PLOT\_INTV\_GAGE: time interval (s) of gauge output.

SCREEN\_INTV: time interval (s) of screen print.

**SPECIFICATION OF BATHYMETRY**

DEPTH\_TYPE: depth input type.

DEPTH\_TYPE=DATA: from a depth file (depth.txt).

The program includes several simple bathymetry configurations such as

DEPTH\_TYPE=FLAT: flat bottom, need DEPTH\_FLAT.

DEPTH\_TYPE=SLOPE: plane beach along  direction. It needs three parameters: slope, SLP, slope starting point, Xslp and depth of flat part, DEPTH\_FLAT.

DEPTH\_FILE: bathymetry file if DEPTH\_TYPE=DATA, the file name must be ‘depth.txt’, and file dimension should be  with the first point as the south-west corner. The read format in the code is shown below.

DO J=1, Nglob

READ(1,\*) (Depth(I,J), I=1,Mglob)

ENDDO

DEPTH\_FLAT: water depth of flat bottom if DEPTH\_TYPE=FLAT or DEPTH\_TYPE=SLOPE (flat part of plane beach).

SLP： slope if DEPTH\_TYPE=SLOPE

Xslp: starting (m) of a slope, if DEPTH\_TYPE=SLOPE

**SPECIFICATION OF INITIAL CONDITION**

INT\_UVZ: logical parameter for initial condition, default is FALSE.

INI\_U: logical parameter for initial , default is FALSE, the name of file must be U.txt, data format is the same as depth data.

INI\_V: logical parameter for initial , default is FALSE, the name of file must be V.txt, data format is the same as depth data.

INI\_Z: logical parameter for initial , default is FALSE, the name of file must be Z.txt, data format is the same as depth data.

**SPECIFICATION OF WAVEMAKER**

WAVEMAKER: wavemaker type.

WAVEMAKER=LEF\_SOL: left boundary solitary, need AMP, DEP and LAGTIME.

WAVEMAKER=INI\_SOL: initial solitary wave, WKN B solution, need AMP, DEP and XWAVEMAKER.

WAVEMAKER=INI\_REC: initial rectangular hump, need XC, YC and WID.

WAVEMAKER=WK\_REG: Wei and Kirby 1999 internal wave maker, need XC\_WK, Tperiod,, AMP\_WK, DEP\_WK, Theta\_WK, and Time\_ramp(factor of period).

WAVEMAKER=WK\_IRR: Wei and Kirby 1999 TMA spectrum wavemaker, need XC\_WK, DEP\_WK, Time\_ramp, Delta\_WK, FreqPeak, FreqMin, FreqMax, Hmo, GammaTMA, ThetaPeak

WAVEMAKER=WK\_TIME\_SERIES: fft time series to get each wave component and then use Wei and Kirby’s (1999) wavemaker. Need input WaveCompFile (including 3 columns: per,amp,pha) and NumWaveComp,PeakPeriod,DEP\_WK,Xc\_WK,Ywidth\_WK.

WAVEMAKER=WK\_SRC\_SERIES:

AMP: amplitude (m) of initial , if WAVEMAKER = INI REC, WAVEMAKER = INI SOL,

WAVEMAKER = LEF SOL.

DEP: water depth at wavemaker location, if WAVEMAKER = INI SOL, WAVEMAKER = LEF SOL.

LAGTIME, time lag (s) for the solitary wave generated on the left boundary, e.g., WAVEMAKER

= LEF SOL.

XWAVEMAKER:  (m) coordinate for WAVEMAKER = INI SOL.

Xc:  (m) coordinate of the center of a rectangular hump if WAVEMAKER = INI REC.

Yc:  (m) coordinate of the center of a rectangular hump if WAVEMAKER = INI REC.

WID: width (m) of a rectangular hump if WAVEMAKER = INI REC.

Time ramp: time ramp (s) for Wei and Kirby (1999) wavemaker.

Delta WK: width parameter δ for Wei and Kirby (1999) wavemaker. δ = 0.3 ∼ 0.6

DEP WK: water depth (m) for Wei and Kirby (1999) wavemaker.

Tperiod: period (s) of regular wave for Wei and Kirby (1999) wavemaker.

AMP WK: amplitude (m) of regular wave for Wei and Kirby (1999) wavemaker.

Theta WK: direction (degrees) of regular wave for Wei and Kirby (1999) wavemaker. Note: it

may be adjusted for a periodic boundary case by the program. A warning will be given if

adjustment is made.

FreqPeak: peak frequency (1/s) for Wei and Kirby (1999) irregular wavemaker.

FreqMin: low frequency cutoff (1/s) for Wei and Kirby (1999) irregular wavemaker.

FreqMax: high frequency cutoff (1/s) for Wei and Kirby (1999) irregular wavemaker.

Hmo: Hmo (m) for Wei and Kirby (1999) irregular wavemaker.

GammaTMA, TMA parameter *γ* for Wei and Kirby (1999) irregular wavemaker.

ThetaPeak: peak direction (degrees) for Wei and Kirby (1999) irregular wavemaker.

Sigma\_Theta: parameter of directional spectrum for Wei and Kirby (1999) irregular wavemaker.

SPECIFICATION OF PERIODIC BOUNDARY CONDITION

(Note: only south-north periodic condition was implemented)

PERIODIC: logical parameter for periodic boundary condition, T-periodic, F-wall boundary condition.

**SPECIFICATION OF SPONGE LAYER**

SPONGE\_ON: logical parameter, T – sponge layer, F – no sponge layer.

Sponge west width: width (m) of sponge layer at west boundary.

Sponge east width: width (m) of sponge layer at east boundary.

Sponge south width: width (m) of sponge layer at south boundary.

Sponge north width width (m) of sponge layer at north boundary

R sponge: decay rate in sponge layer. Its values are between 0.85 *∼* 0.95.

A sponge: maximum damping magnitude. The value is ∼ 5.0.

**SPECIFICATION OF PHYSICS**

DISPERSION: logical parameter for inclusion of dispersion terms. T – calculate dispersion, F-no dispersion terms

Gamma1: parameter for linear dispersive terms. 1.0 – inclusion of linear dispersive terms, 0.0 – no linear dispersive terms.

Gamma2: parameter for nonlinear dispersive terms. 1.0 – inclusion of nonlinear dispersive terms, 0.0 – no nonlinear dispersive terms.

Gamma1=1.0, Gamma2=1.0 for the fully nonlinear Boussinesq equations.

Gamma3: parameter for nonlinear shallow water equations(Gamma3=1.0).

Cd:

**SPECIFICATION OF NUMERICS**

FLUX\_TYPE: options for numerical flux, HLL(c), MUSTA or CENTRAL

MUSCL\_ORDER: options for flux reconstruction, SECOND for the second-order, FOURTH for the fourth-order

LIMITTER\_YPE: options for flux limiter, MINMOD and VANLEE

Regularization: logical parameter, T - , F –

SHORELINE\_SKILL:

Time\_Iteration: stepping option, SSPRK2 for the second-order Strong Stability-Preserving(SSP) Runge-Kutta scheme, SSPRK3 for the third-order Strong Stability-Preserving(SSP) Runge-Kutta scheme

CFL: CFL number, CFL~0.25

**SPECIFICATION OF TREAT WAVE BREAKING**

SHOCK\_TYPE: options for wave breaking.

SHOCK\_TYPE=NONE: no wave breaking

SHOCK\_TYPE=RULE1: local hybrid epsilon() and slope()

SHOCK\_TYPE=RULE2: local hybrid  and slope()

SHOCK\_TYPE=RULE3: empirical eddy viscosity term is applied

GAMMA\_1: critical value of  for switching from Boussinesq to NSWE, the default is 0.8

GAMMA\_2:

ApplyFroude: logical parameter for consideration of Froude number, ApplyFroude=T, wave breaking is modeled by switching from Boussinesq to NSWE at cells where the Froude numbers exceeds a certain threshold, the default is F.

FroudeCap: cap for Froude number in velocity calculation for efficiency. The value could be 5~10.0

**SPECIFICATION OF WET\_DRY**

MinDepth: minimum water depth(m) for wetting and drying scheme. Suggestion: MinDepth=0.001 for lab scale and 0.01 for field scale

MinDepthFrc: minimum water depth(m) to limit bottom friction value. Suggestion: MinDepthFrc =0.01 for lab scale and 0.1 for field scale.

**SPECIFICATION OF MIXING**

MIXING: logical parameter for smagorinsky mixing, T of FALSE

T\_INTV\_mean: averaging time interval(s), the default is 20.0

C\_smg: smagorinsky coefficient.

**SPECIFICATION OF OUTPUT**

NumberStations: number of station for output. If NumberStations > 0, need input i, j in stat.txt

ETASCALE: scale factor for output *η*, only used in gauge output, the default is 1.0

USCALE: scale factor for output *u*, only used in gauge output, the default is 1.0

VSCALE: scale factor for output *v*, only used in gauge output, the default is 1.0

TSCALE: scale factor for output *t*, only used in gauge output, the default is 3600.0

TOFFSET: offset for output *t*, only used in gauge output, the default is 0.0

OUT\_RUNUP: logical parameter for output right-hand runup, only worked for 1D case. T of F.

CAL\_MEAN: logical parameter for output statistic wave height, only worked for 1D case. T or F.

TIMEBEG: start time of eta time series.

TIMEEND: end time of eta time series

HTYPE: options for output statistic wave height

HTYPE=1: average height

HTYPE=2: the difference between maximum and minimum of eta

HTYPE=3: significant wave height

DEPTH OUT: logical parameter for output depth. T or F.

U: logical parameter for output *u*. T or F.

V: logical parameter for output *v*. T or F.

ETA: logical parameter for output *η*. T or F.

BED: logical parameter for output bed elevation. T of F.

HMAX: logical parameter for output of recorded maximum surface elevation . T or F.

Umean: logical parameter for output mean *u*, T of F

Vmean: logical parameter for output mean *v*, T of F

ETAmean: logical parameter for output mean *η*, T of F

MASK: logical parameter for output wetting-drying MASK. T or F.

MASK9: logical parameter for output MASK9 (switch for Boussinesq/NSWE). T or F.

SXL: logical parameter for output of wave speed of left value at *x*-interface. T of F.

SXR: logical parameter for outoput of wave speed of right value at *x*-interface. T of F.

SYL: logical parameter for outoput of wave speed of left value at *y*-interface. T of F.

SYR: logical parameter for outoput of wave speed of right value at *y*-interface. T of F.

SourceX: logical parameter for output source terms in *x* direction. T or F.

SourceY: logical parameter for output source terms in *y* direction. T or F.

P: logical parameter for output of momentum flux in *x* direction. T or F.

Q: logical parameter for output of momentum flux in *y* direction. T or F.

Fx: logical parameter for output of numerical flux F in *x* direction. T or F.

Fy: logical parameter for output of numerical flux F in *y* direction. T or F.

Gx: logical parameter for output of numerical flux G in *x* direction. T or F.

Gy: logical parameter for output of numerical flux G in *y* direction. T or F.

AGE: logical parameter for output of breaking age. T or F.

1. **Examples**