DUALSPHYSICS MODELLING SEA WAVES. NEW DEVELOPMENTS, CAPABILITIES AND PRACTICAL EXAMPLES

Dr. Corrado ALTOMARE (Flanders Hydraulics Research - Ghent University)

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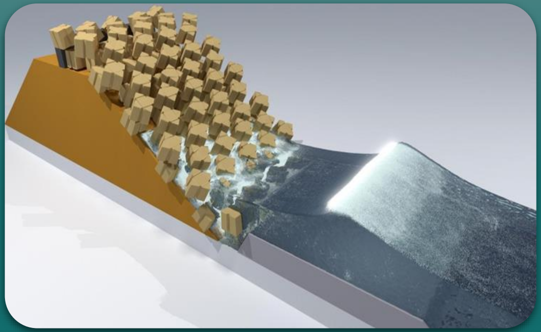
200 YEARS
GHENT
UNIVERSITY

OUTLINES



Waves

Coupling

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Wave generation/absorption in DualSPHysics

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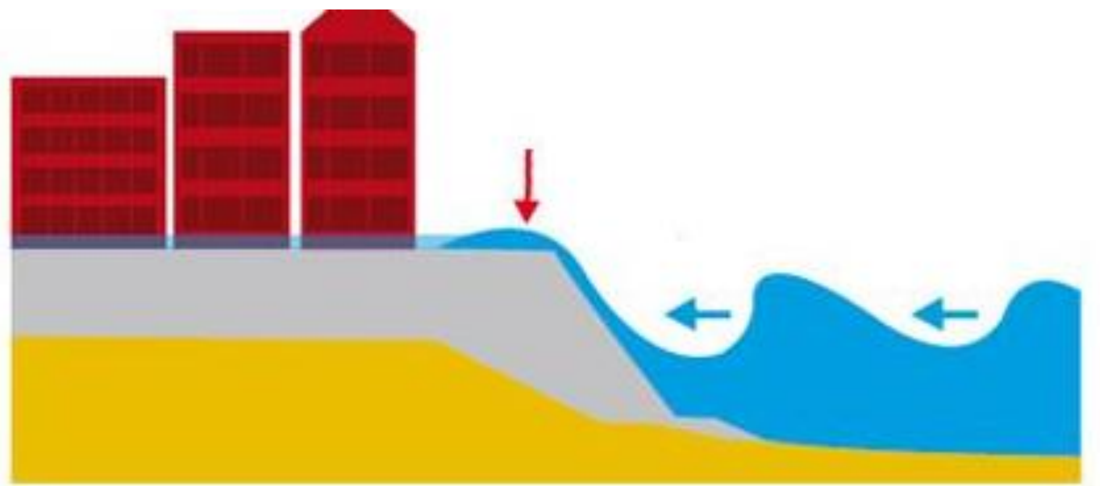
What do we want to model?

Keys for successful numerical simulation for coastal structure design:

- Good wave generation
- Good wave transformation
- Reasonable computational cost
- etc, etc..



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Wave generation/absorption in DualSPHysics

stand-alone model

coupling framework

Piston- & Flap-type wavemakers

MULTI-LAYERED piston

Relaxation Zone

Open Boundary Conditions

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Wave generation and wave absorption

The wave generation in DualSPHysics mimics the conditions of physical wave facilities.

- The wave-maker (**piston**, **flap**, **flap** with **variable draft**) consists of a rigid body formed by boundary particles.
- The motion of the wave generator is prescribed controlling its position (linear or angular) at each instant of time.
- AUTOMATIC WAVE GENERATION:
  - Regular & Irregular
  - 1^{st} and 2^{nd} Order

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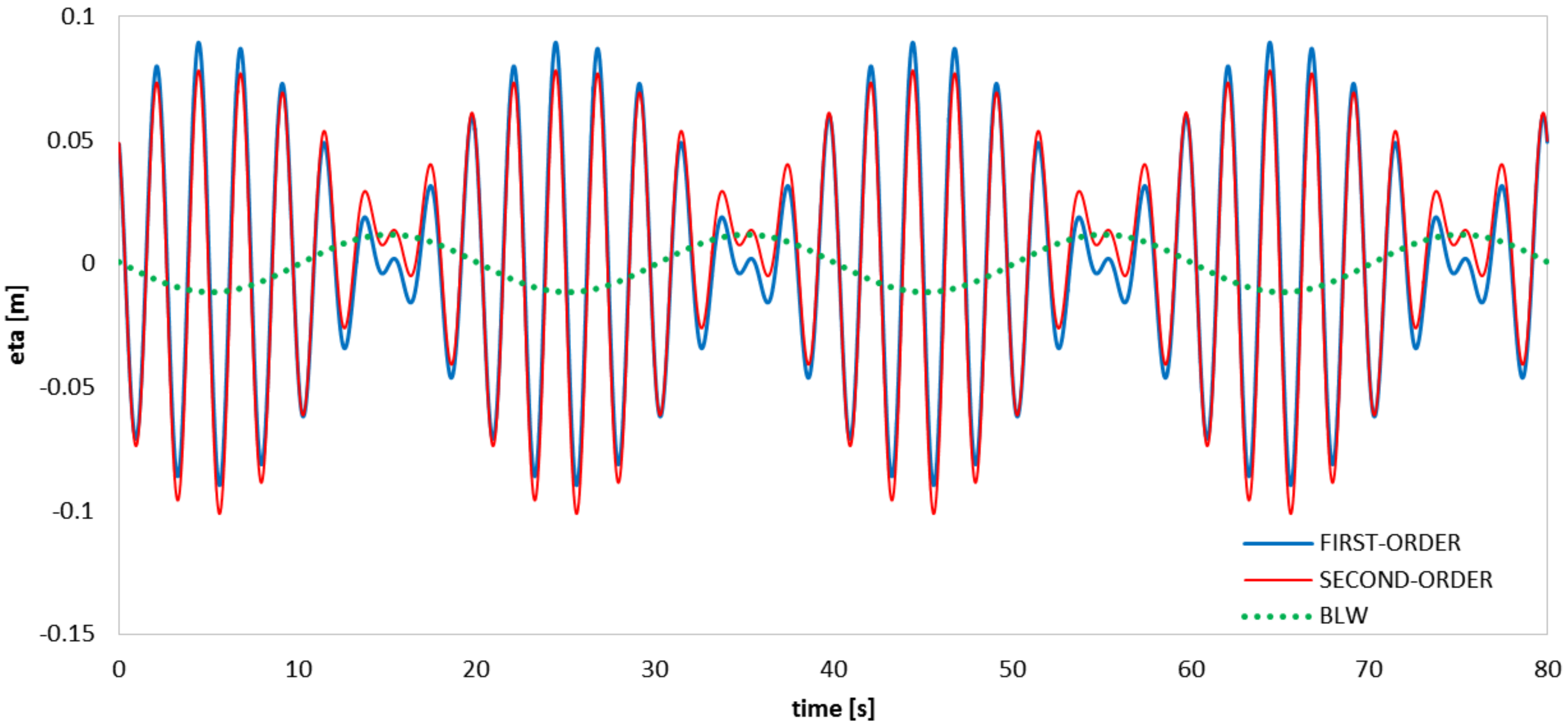
Wave generation and wave absorption

PISTON-type wavemaker, IRREGULAR waves, 2nd Order BOUND LONG waves (Hughes, 1993)

Bound long waves (BLW) refer to the set-down of the water level that is generated by wave groups



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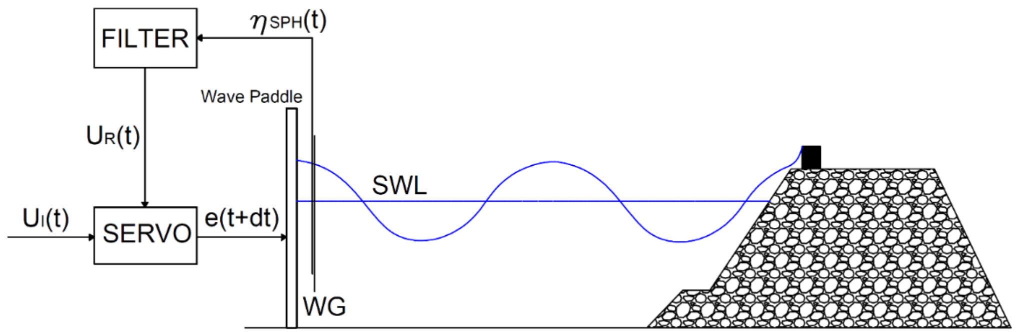
Wave generation and wave absorption

Active wave absorption



$$\eta_R(t) = \eta_{SPH}(t) - \eta_I\,(t)$$

Reflected wave at $\mathbf{4} * \boldsymbol{h}$ from the piston → FILTER

$$U_R(t) = \eta_R(t)\sqrt{g/d}$$

Velocity correction (uniform velocity field)

+

$$U_I(t) = \omega\frac{S_0}{2}\sin(\omega t + \delta)$$

Theoretical wave maker velocity

↓

$$U_C(t+dt) = U_I(t) - U_R(t)$$

Corrected wave maker velocity → SERVO

$$e(t+dt) = e(t) + (U_C(t+dt) + U_C(t))\frac{dt}{2}$$

Wave maker position at $\boldsymbol{t} + \boldsymbol{dt}$

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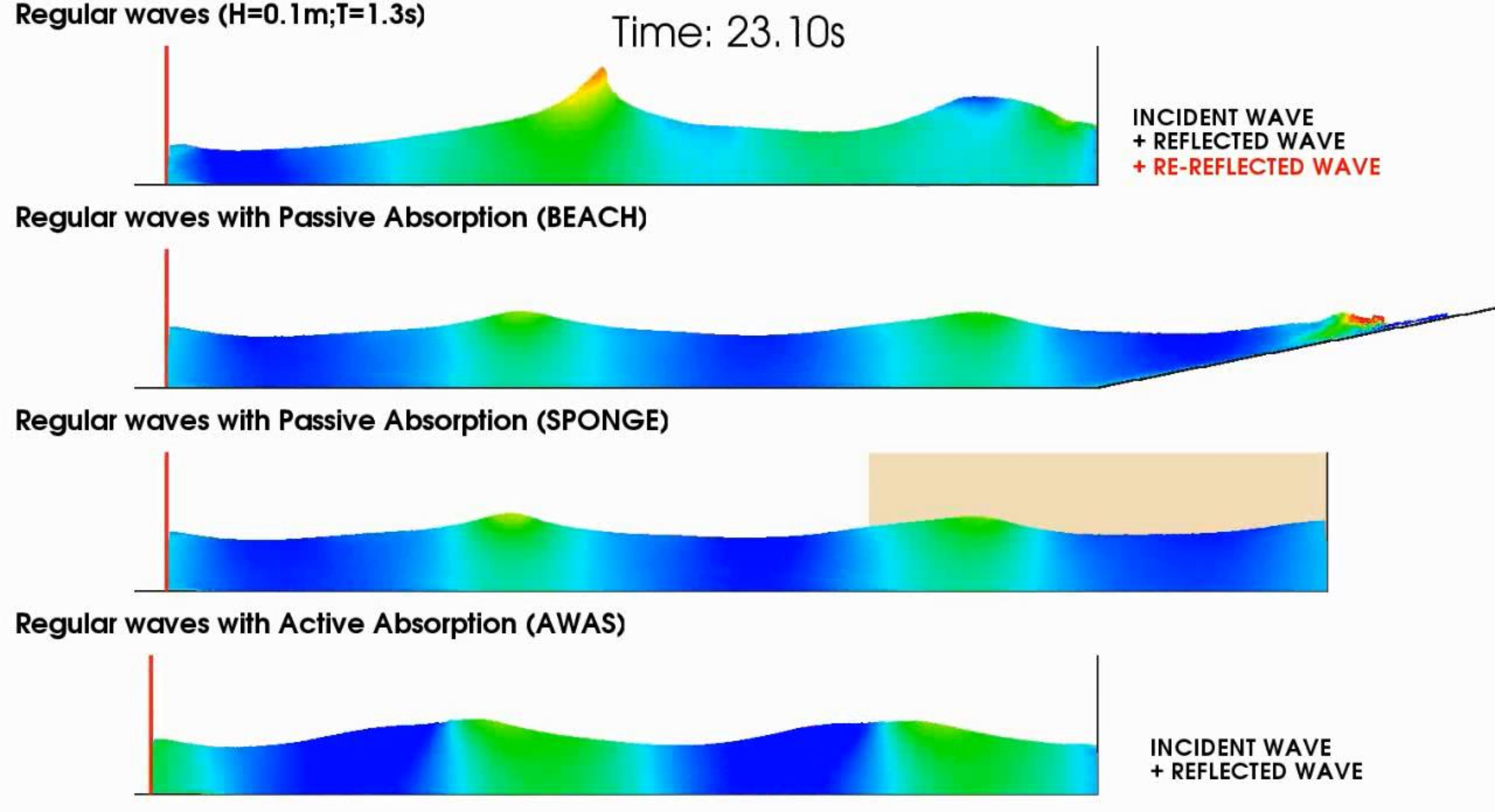
(Shaffer and Klopman , 2000)

Wave generation and wave absorption

Wave generation and wave absorption (passive and active)
AWAS system in SPH models



Wave generation and wave absorption

Generation

_FmtXML_WavePaddles.xml

AWAS

_FmtXML_WavePaddlesAwas.xml

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```xml
<!-- *** Example for PISTON to create IRREGULAR waves *** -->
<special>
    <wavepaddles>
        <piston_spectrum>
            <mkbound value="12" comment="Mk-Bound of selected particles" />
            <depth value="50" comment="Water depth (default=0)" />
            <start value="0" comment="Start time (default=0)" />
            <duration value="0" comment="Movement duration, Zero is the end of simulation (default=0)" ,
            <pistondir x="1" y="0" z="0" comment="Movement direction (default=(1,0,0))" />
            <spectrum value="jonswap" comment="Spectrum type: jonswap,pierson-moskowitz" />
            <discretization value="stretched" comment="Spectrum discretization: regular,random,stretche
            <waveorder value="1" comment="Order wave generation 1:1st order, 2:2nd order (default=1)" /
            <waveheight value="1.5" comment="Significant Wave Height (Hs)" />
            <waveperiod value="9.5" comment="Peak Period" />
            <gainstroke value="1" comment="Gain factor to amplify/reduce the paddle stroke (default=1)"
            <peakcoef value="3.3" comment="Peak enhancement coefficient (default=3.3)" />
            <waves value="3" comment="Number of waves to create irregular waves (default=50)" />
            <randomseed value="2" comment="Random seed to initialize a pseudorandom number generator" /
            <serieini value="0" autofit="true" comment="Initial time in irregular wave serie (default=0
            <ramptime value="0" comment="Time of ramp (default=0)" />
            <savemotion time="10" timedt="0.02" xpos="0.1" zpos="-0.5" comment="Saves motion data. xpos
            <saveserie timemin="0" timemax="300" timedt="0.05" xpos="0" comment="Saves serie data (opti
            <saveseriewaves timemin="0" timemax="1000" xpos="0" comment="Saves serie heights" />
            <calcserielength timemax="1000" comment="Calculates serie length (optional)" />
        </piston_spectrum>
    </wavepaddles>
</special>
<!---------------------------------------------------------------------------------->
```

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```
<!-- *** Example for AWAS (only for Piston) with regular and irregular waves *** -->
<special>
    <wavepaddles>
        <piston>
            ...
            <awas_zsurf>
                <startawas value="0" comment="Time to start AWAS correction (default=start+ramp*waveperiod)" />
                <swl value="0.266" comment="Still water level (free-surface water)" />
                <elevation value="2" comment="Order wave to calculate elevation 1:1st order, 2:2nd order (default=2)" />
                <gaugex value="0.05" comment="Position in X from piston to measure free-surface water (default=5*Dp)" />
                <_gaugex valueh="3" comment="Position in X from piston to measure free-surface water (according H value)" />
                <_gaugex valuedp="5" comment="Position in X from piston to measure free-surface water (according Dp value)" />
                <gaugey value="1" comment="Position in Y to measure free-surface water" />
                <gaugezmin value="0.05" comment="Minimum position in Z to measure free-surface water, it must be in water (default=domain l:
                <gaugezmax value="0.5" comment="Maximum position in Z to measure free-surface water (default=domain limits)" />
                <gaugedp value="0.25" comment="Resolution to measure free-surface water, it uses Dp*gaugedp (default=0.1)" />
                <_coefmasslimit value="0.4" comment="Coefficient to calculate mass of free-surface (default=0.5 on 3D and 0.4 on 2D)" />
                <savedata value="1" comment="Saves CSV with information 1:by part, 2:more information, 3:by step (default=0)" />
                <limitace value="2" comment="Factor to limit maximum value of acceleration, with 0 disabled (default=2)" />
                <correction coefstroke="1.8" coefperiod="1" powerfunc="3" comment="Drift correction configuration (default=no applied)" />
            </awas_zsurf>
        </piston>
        <piston_spectrum>
            ...
            <awas_zsurf>
                ...
            </awas_zsurf>
        </piston_spectrum>
    </wavepaddles>
</special>
```

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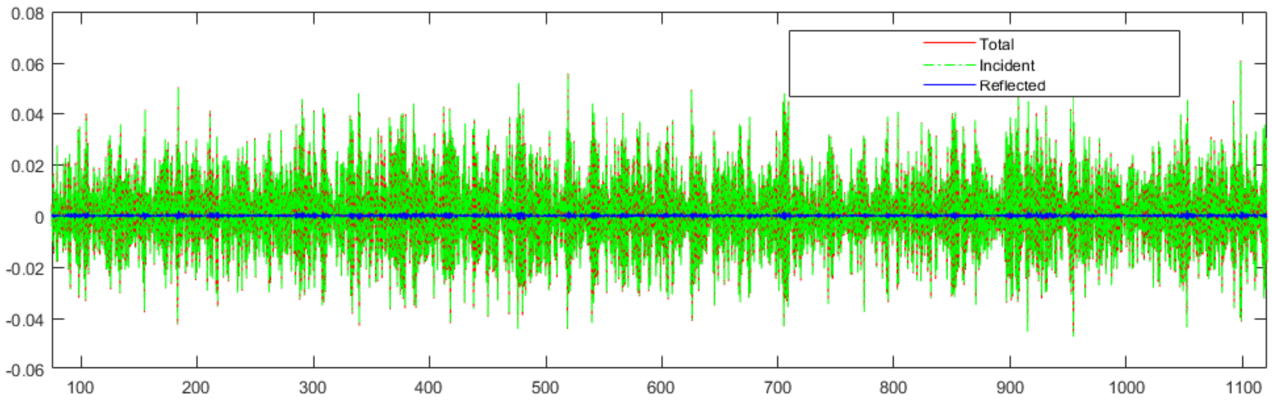
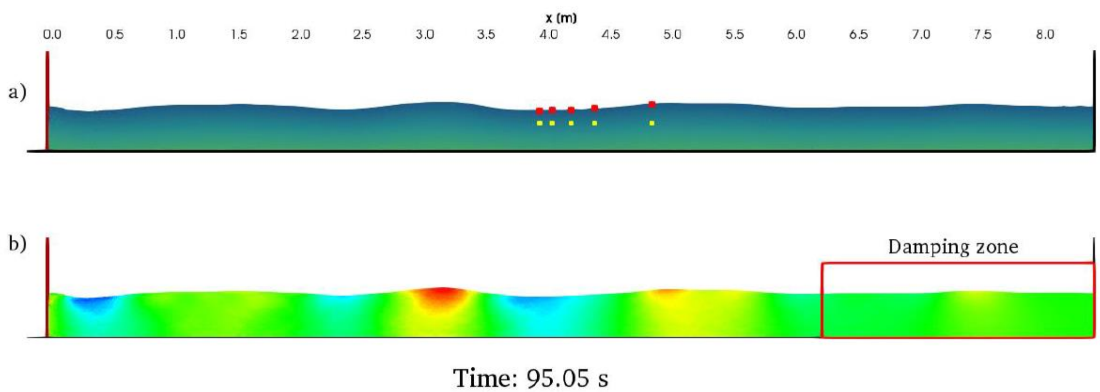
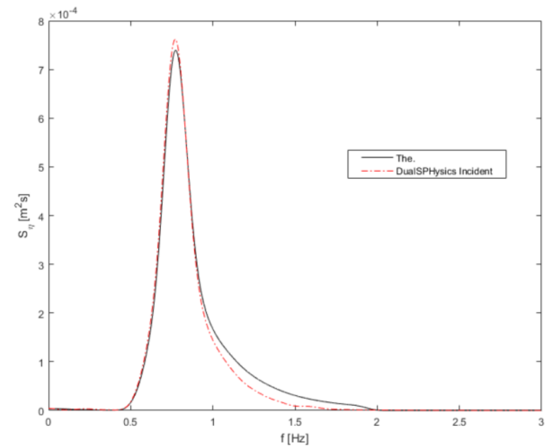
Wave generation and wave absorption

Long events: 1000 waves



23.6h runtime (on Tesla K20c) for 82,541 fluid particles





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Err (wave height)=-3.5%, Err (spectral period)= +4.7%

Wave generation/absorption in DualSPHysics

stand-alone model

coupling framework

Piston- & Flap-type wavemakers

MULTI-LAYERED piston

Relaxation Zone

Open Boundary Conditions

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COUPLING techniques

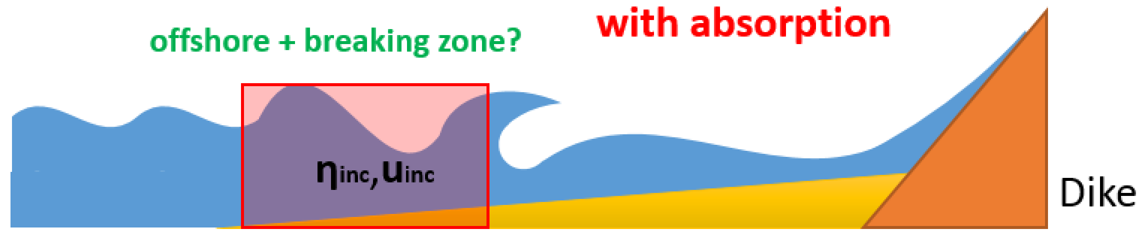
Altomare et al. (2015)

Multi-layered piston

1-way offline

Altomare et al. (2018)

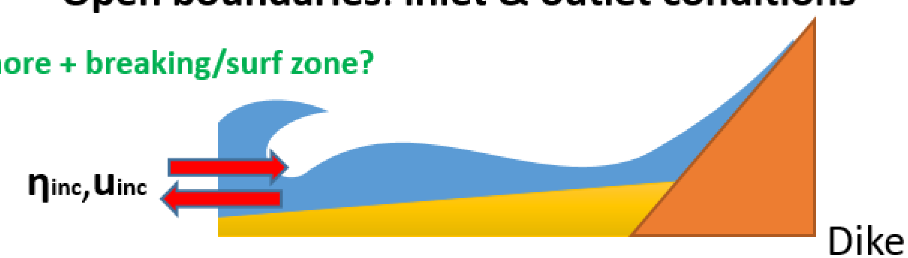
Relaxation Zone technique



Verbrugghe et al. (under review)

2-ways

Open boundaries: inlet & outlet conditions



Wave generation/absorption in DualSPHysics

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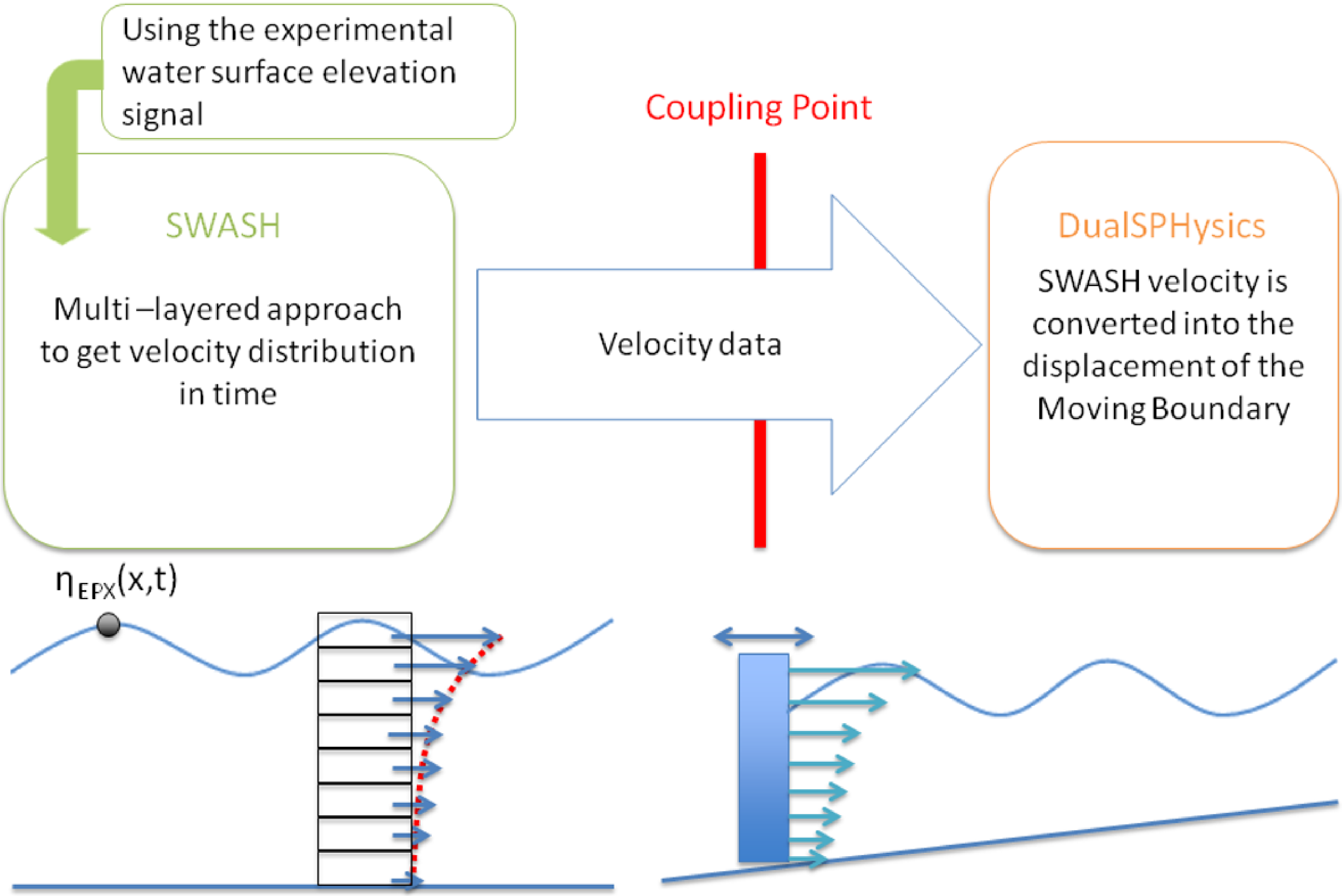
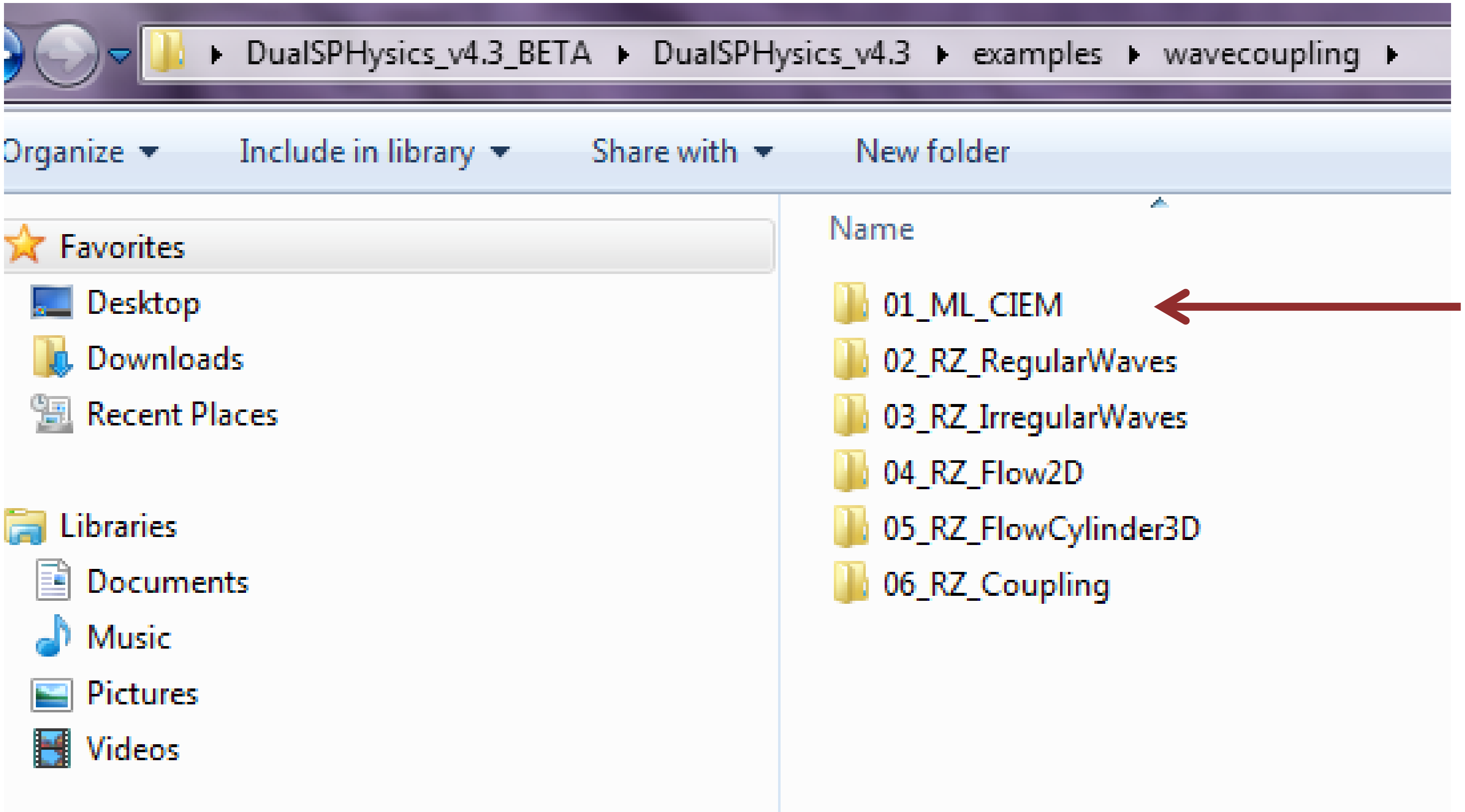
Multi-layered piston

Altomare et al (2015)





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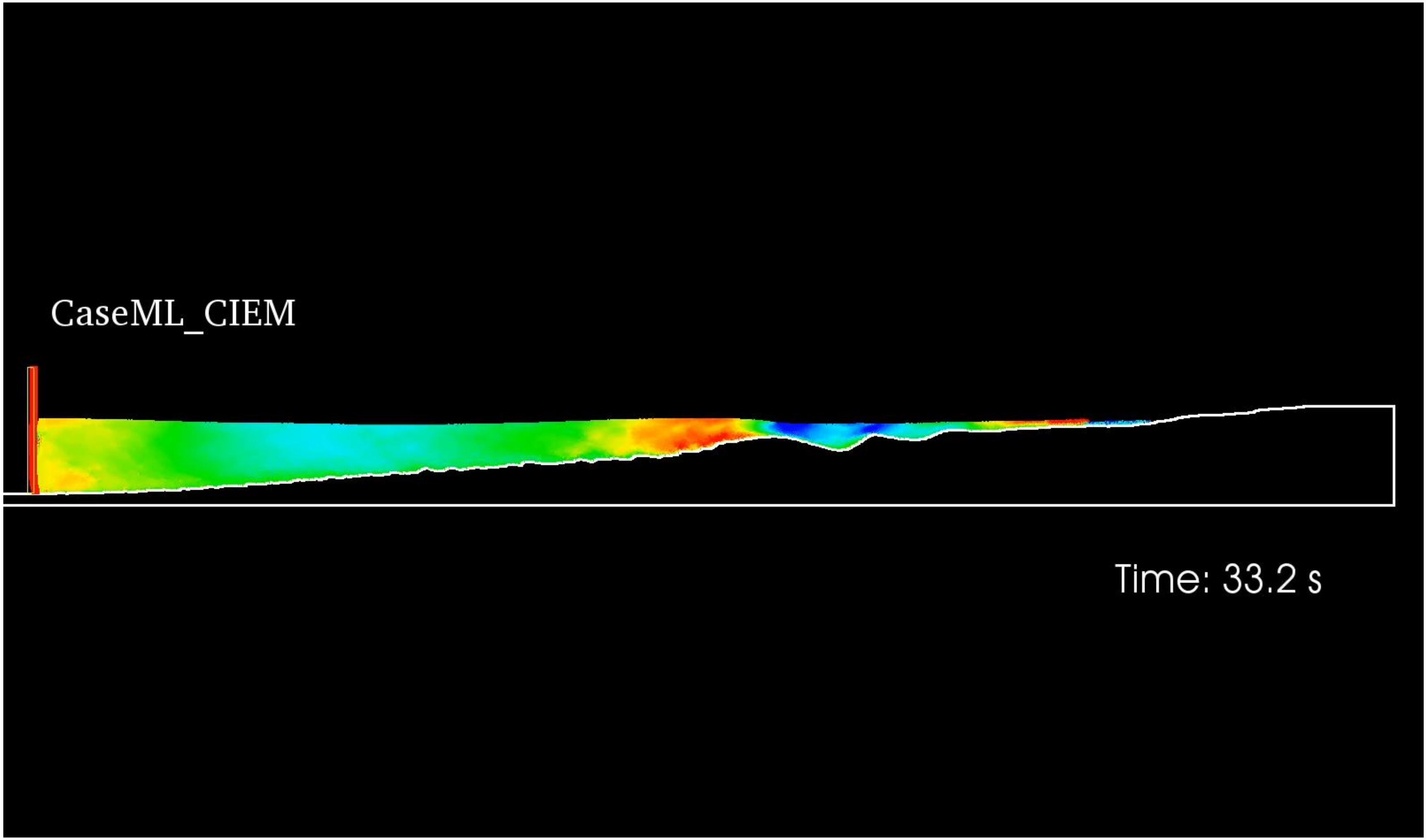
MULTI-LAYERED PISTON for COUPLING with wave propagation model (i.e. SWASH)

```xml
    <special>
    <!--MOVEMENT OF MULTI-LAYER PISTON WAVEMAKER FROM EXTERNAL FILE CREATED AFTER SWASH SIMULATION -->
<mlayerpistons>
    <piston1d>
        <mkbound value="10" comment="Mk-Bound of selected particles" />
        <filevelx value="CIEM_SWASH_corr_velx_x09_y00.csv" comment="File name with X velocity" />
        <incz value="0" comment="Z offset (def=0)" />
        <timedataini value="16" comment="Time offset (def=0)" />
        <smooth value="0" comment="Smooth motion level (def=0)" />
    </piston1d>
</mlayerpistons>
    </special>
```


CaseML_CIEM
Time: 33.2 s

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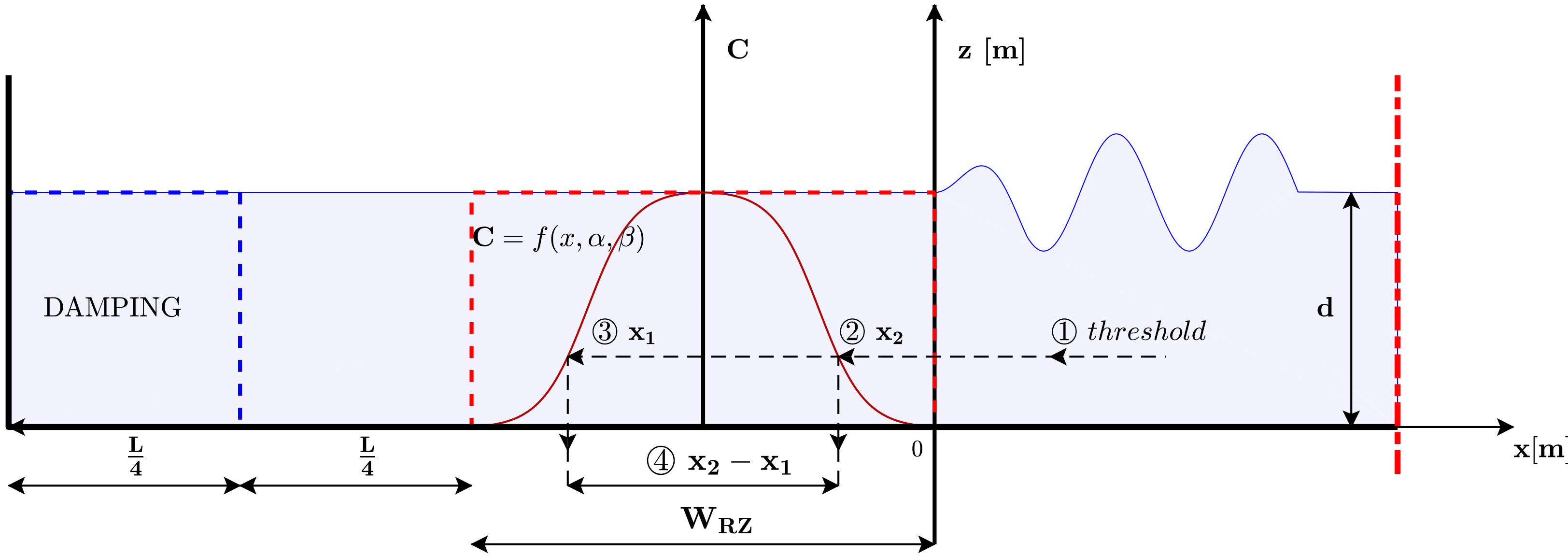
MULTI-LAYERED piston

Relaxation Zone

Open Boundary Conditions

Relaxation Zone

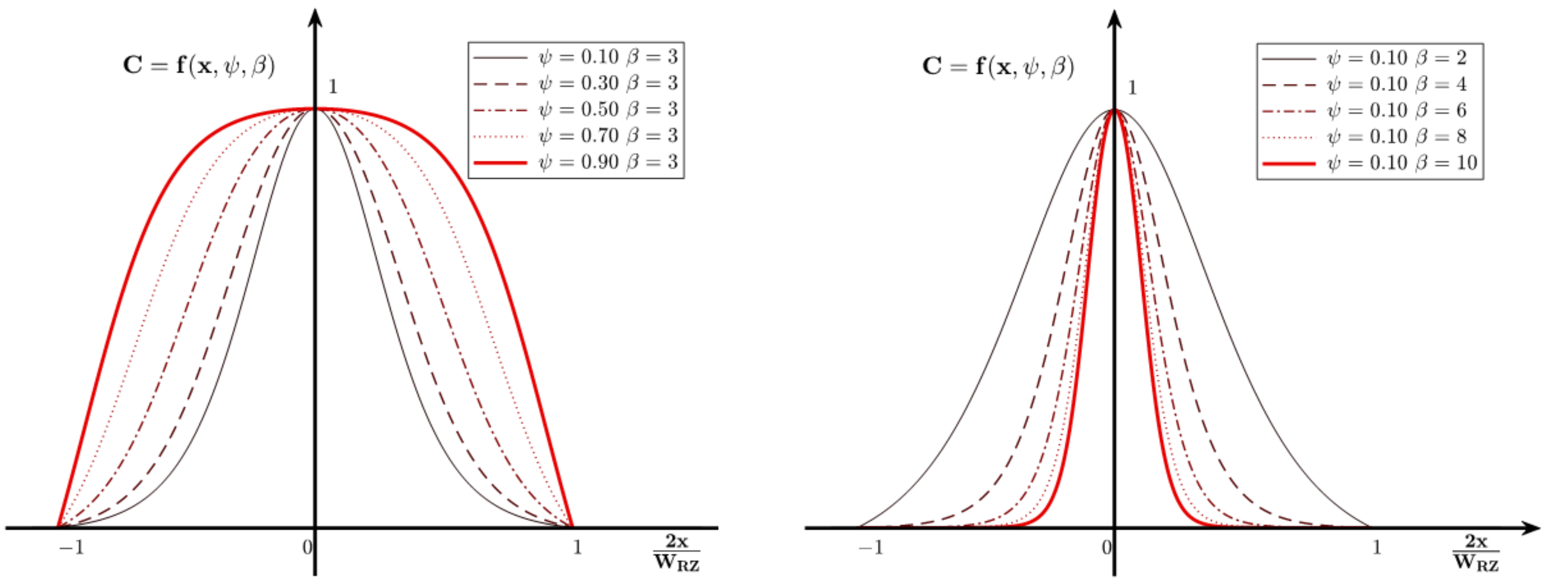
Altomare et al. (2018)



$$\boldsymbol{v}(x,z,t)_{RZ} = C(x)\boldsymbol{v}_c + (1- C(x))\, \boldsymbol{v}_p$$

Relaxation Zone

Altomare et al. (2018)



$$C(x,\psi,\beta) = \frac{\left\{tanh\left(\left(\frac{2x}{W_{RZ}}+\psi\right)\beta\right) - tanh\left(\left(\frac{2x}{W_{RZ}}-\psi\right)\beta\right)\right\} - \left\{tanh\big((1+\psi)\beta\big) - tanh\big((1-\psi)\beta\big)\right\}}{\{tanh(\psi\beta) - tanh(-\psi\beta)\} - \left\{tanh\big((1+\psi)\beta\big) - tanh\big((1-\psi)\beta\big)\right\}}$$

$$with\ -1 \leq \frac{2x}{W_{RZ}} \leq 1$$

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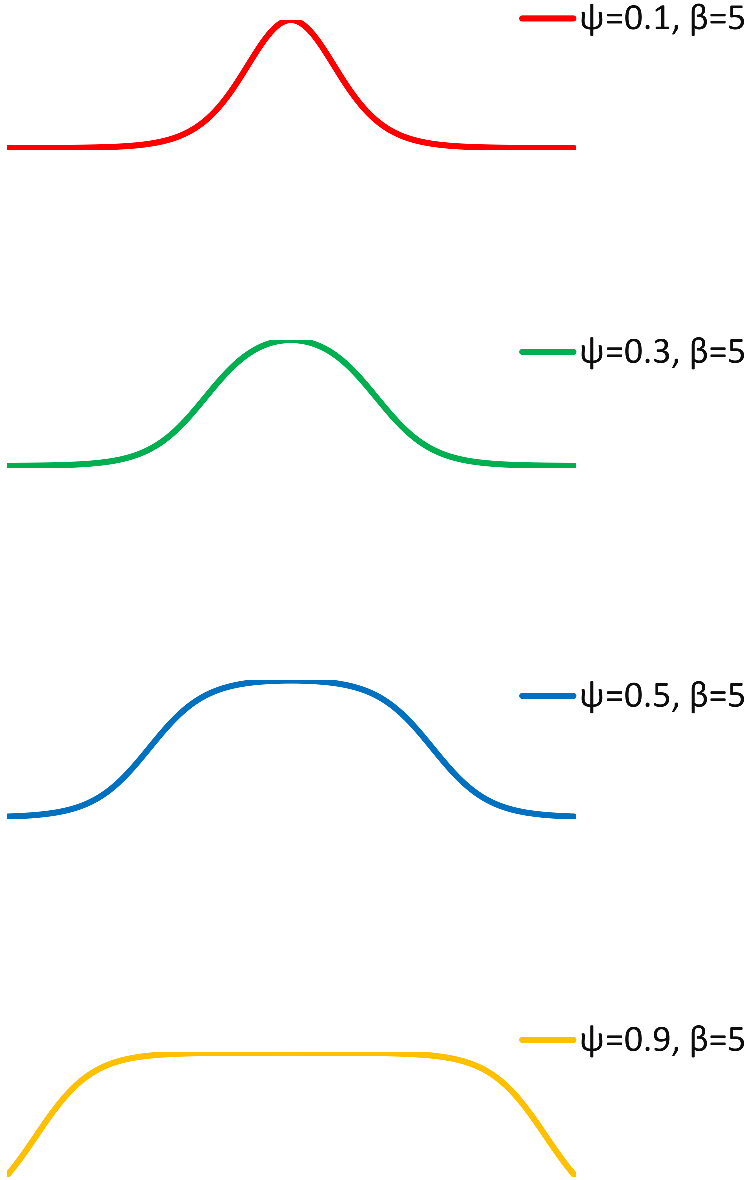
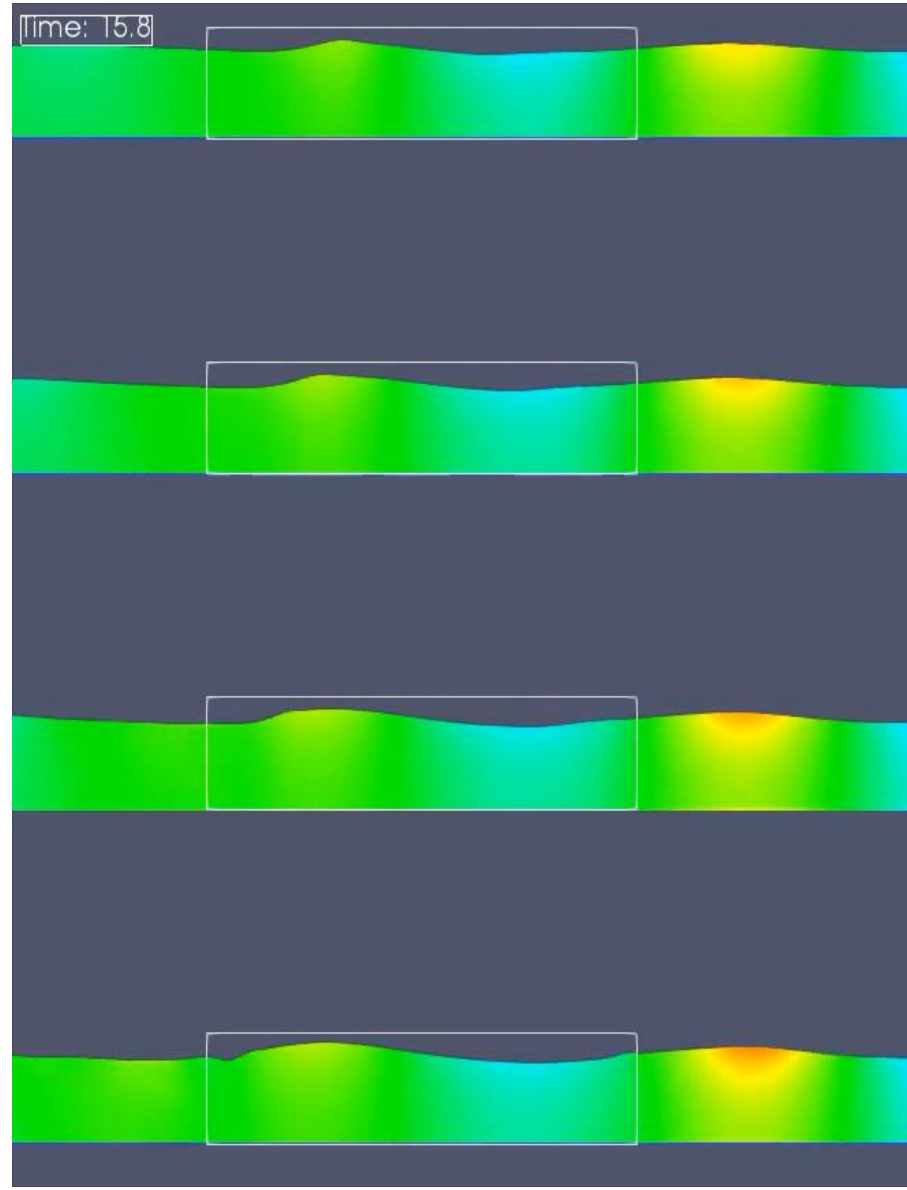
Relaxation Zone

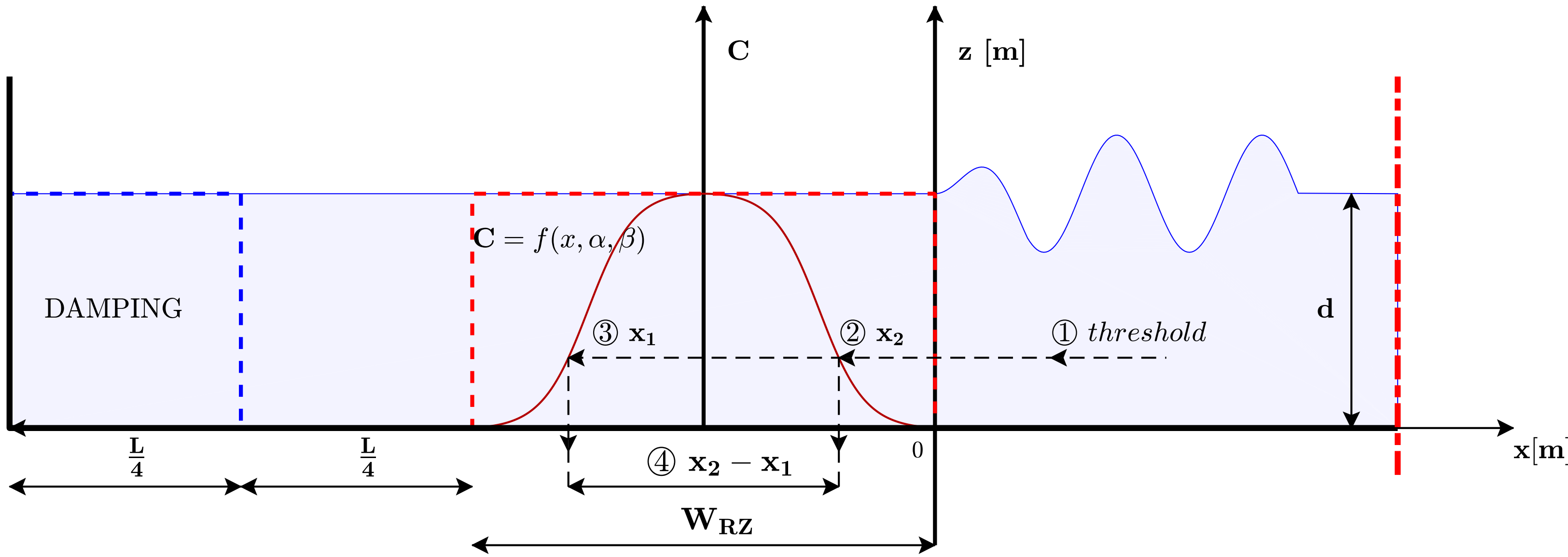
Altomare et al. (2018)





Relaxation Zone

Altomare et al. (2018)



$$W_{eff} = (x_2 - x_1) W_{RZ} \; [m]$$

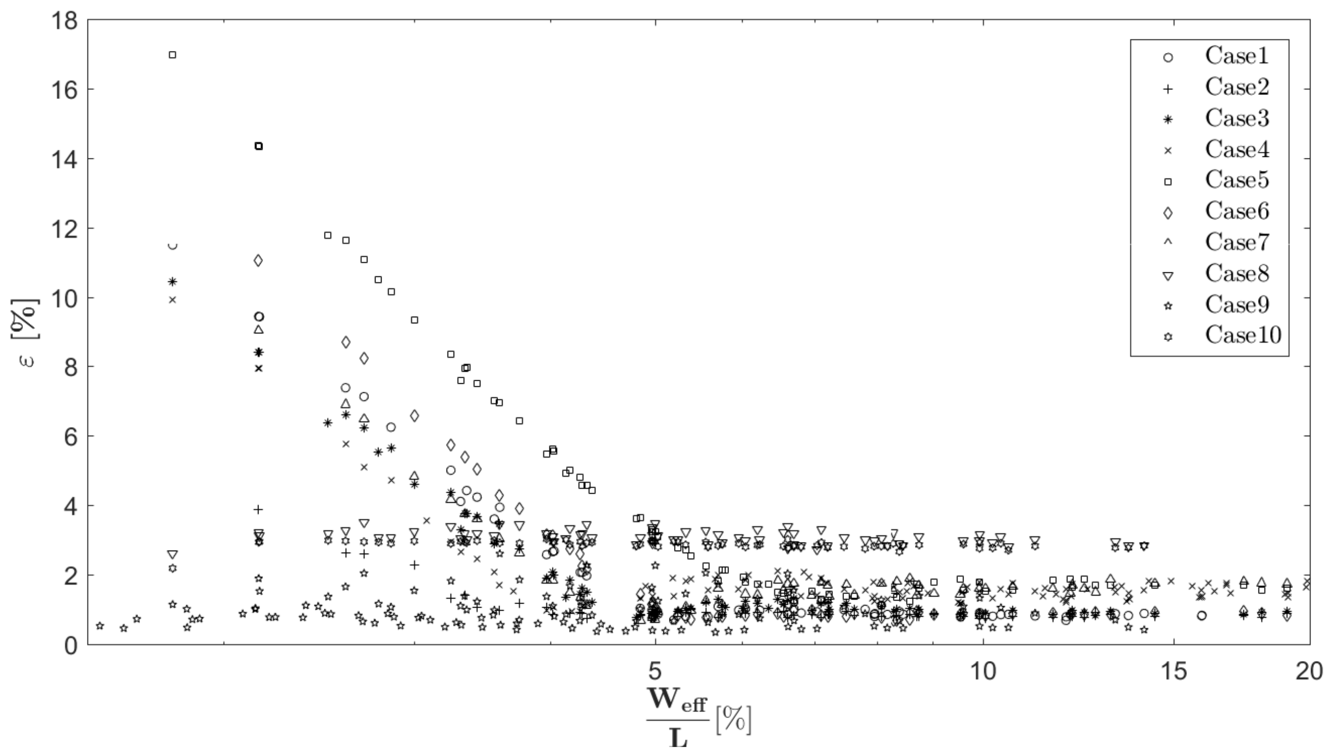
where

$$x_1 \; \| C(x, \psi, \beta) = threshold \cup \frac{2x}{W_{RZ}} \ni [-1,\; 0]$$

$$x_2 \; \| C(x, \psi, \beta) = threshold \cup \frac{2x}{W_{RZ}} \ni [0,1]$$

Relaxation Zone

Altomare et al. (2018)



1 Calculate L, wavelength, based on wave period and water depth.
2 Determine the effective size of the RZ, as $W_{eff} \geq 0.08 \bullet L$
3 Select the isoline in the abacus ($k_{eff} \in [0.80,0.90]$ is suggested)
4 Then, calculate $W_{RZ} = W_{eff}/k_{eff}$
5 According to your choice of k_{eff}, fix the value of ψ (or β) to determine from the abacus the right value of β (or ψ).

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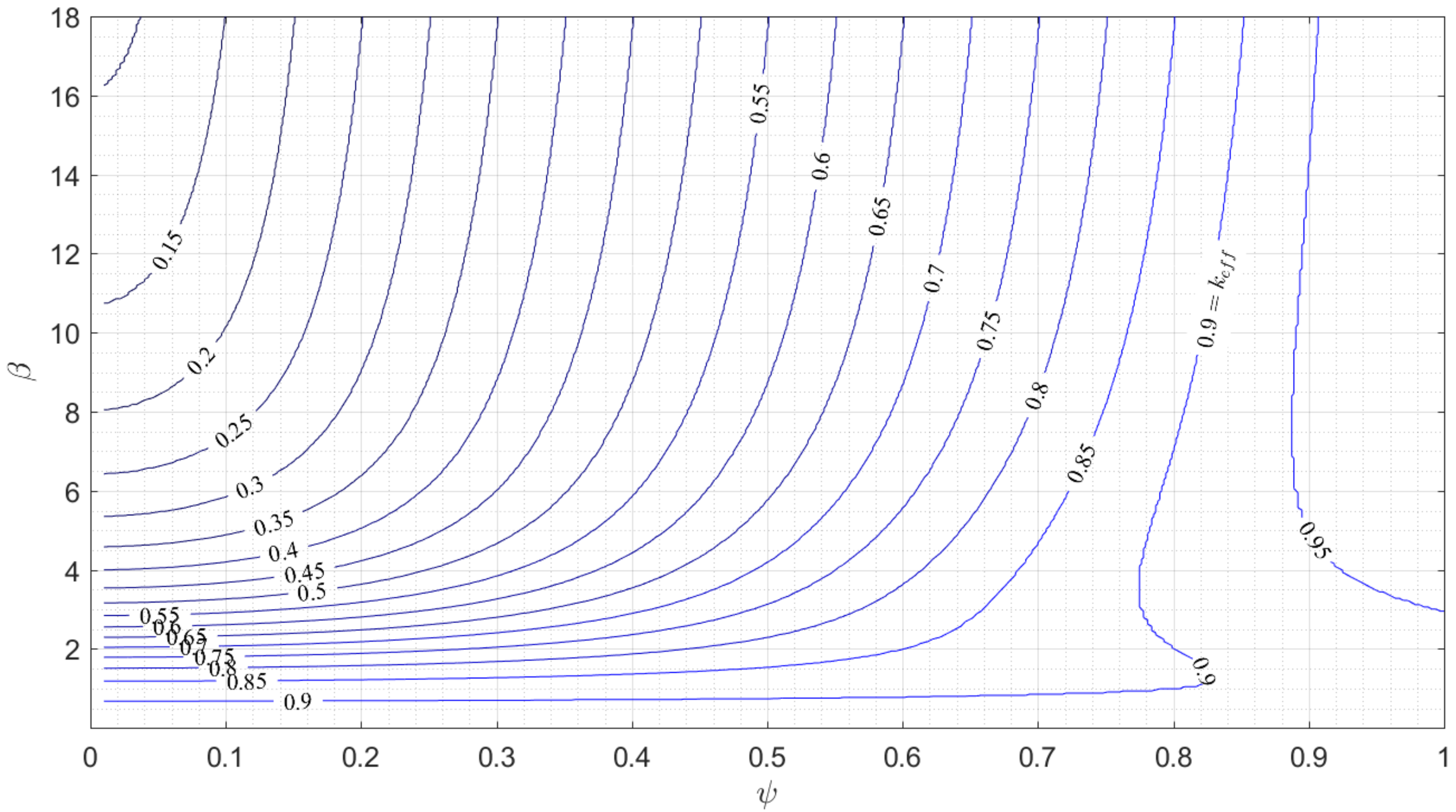
Relaxation Zone

Altomare et al. (2018)



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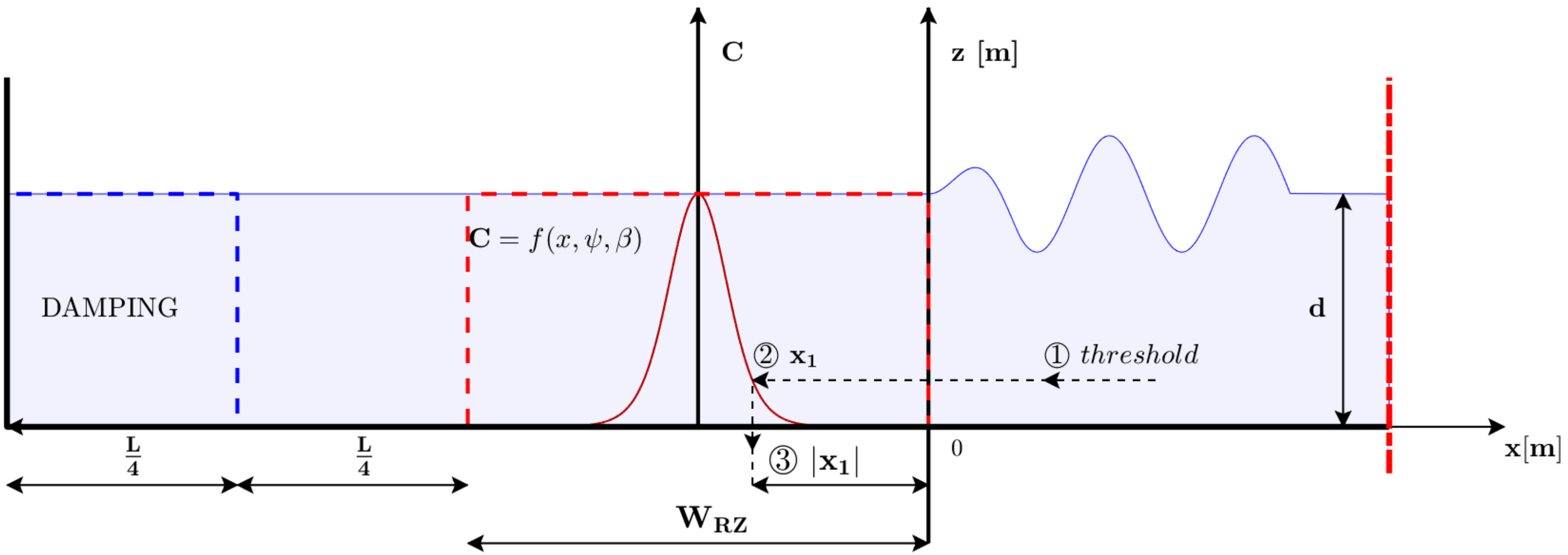
Relaxation Zone

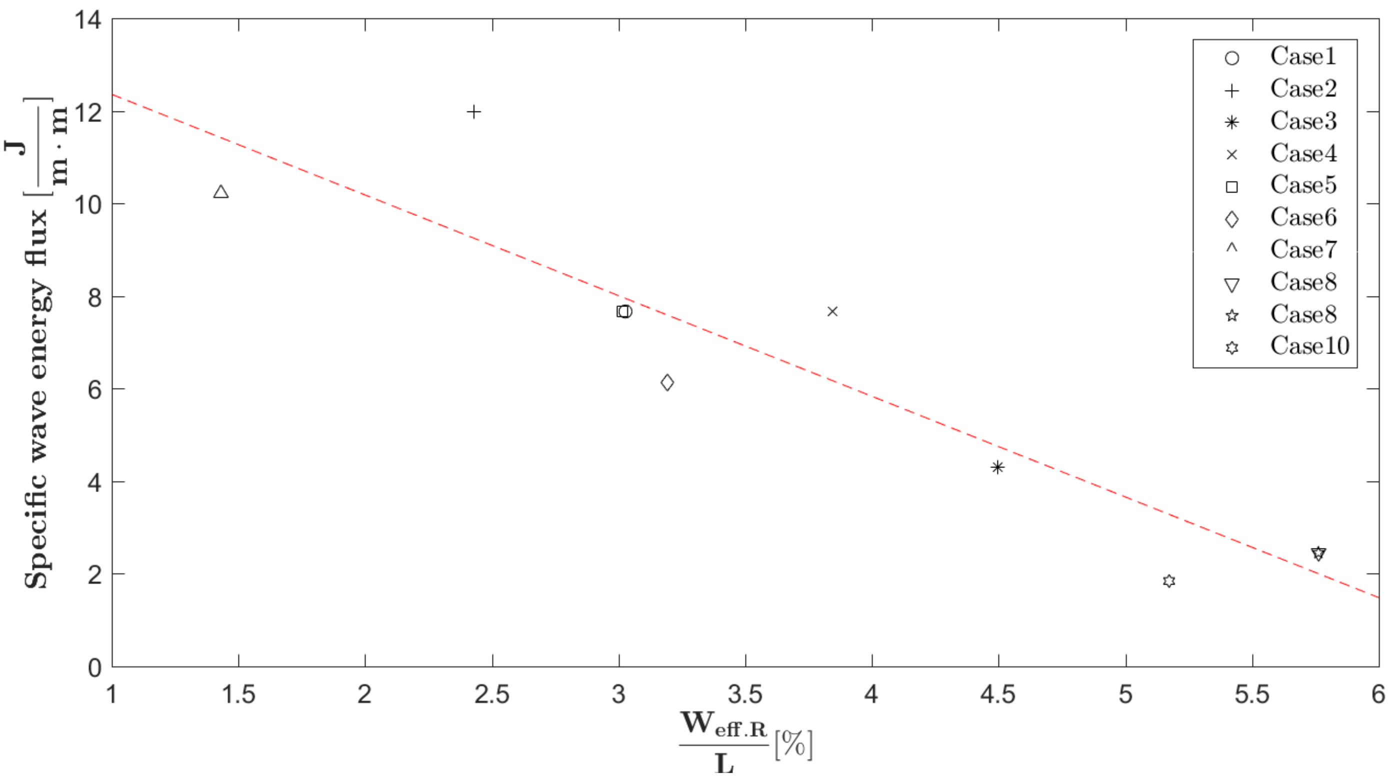
Altomare et al. (2018)



$$W_{RZ} = \frac{W_{eff.R}}{1 - |x_1|}$$

Relaxation Zone

Altomare et al. (2018)



$$W_{RZ} = \frac{W_{eff.R}}{1-|x_1|}$$

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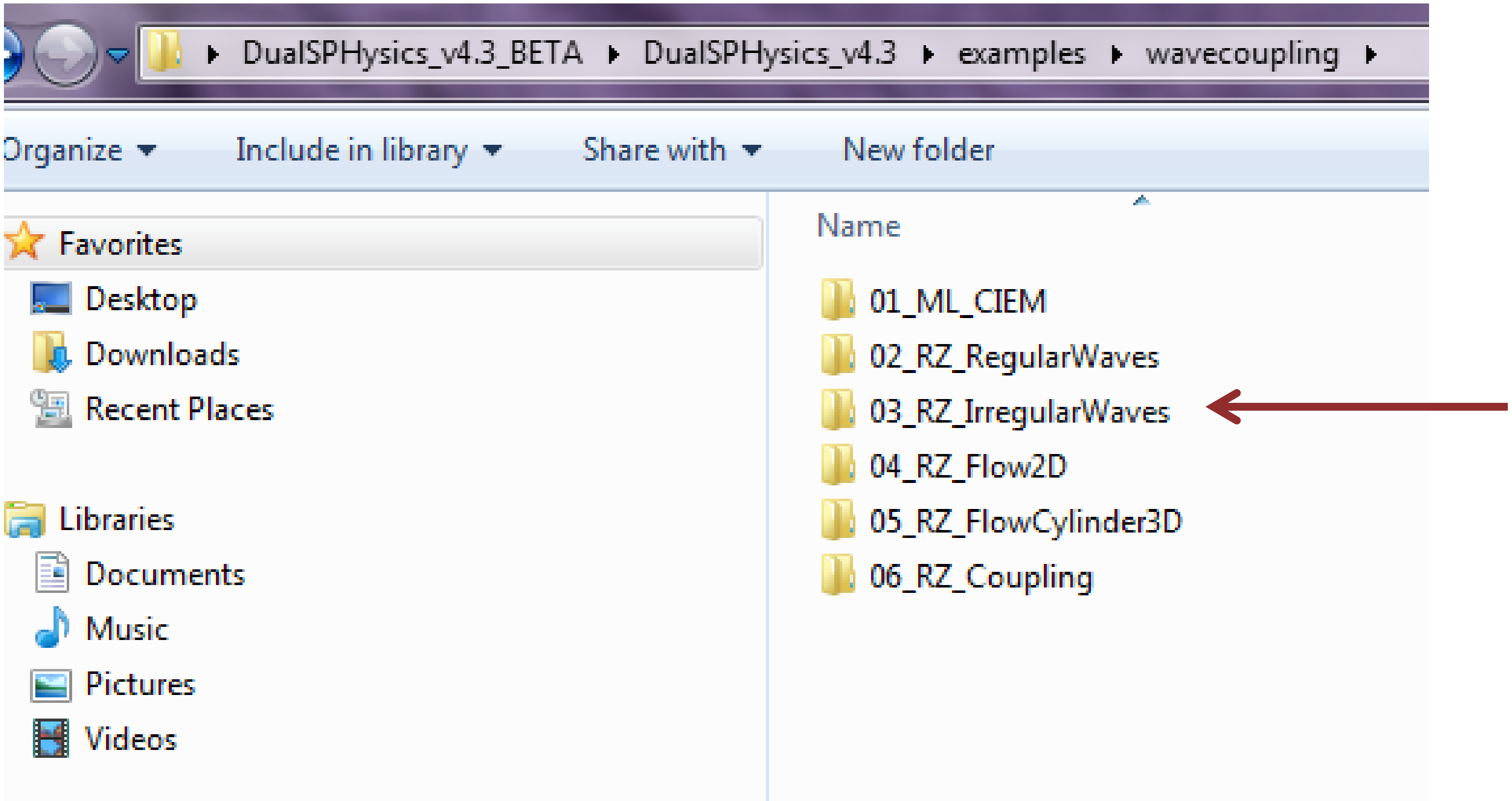
Relaxation Zone

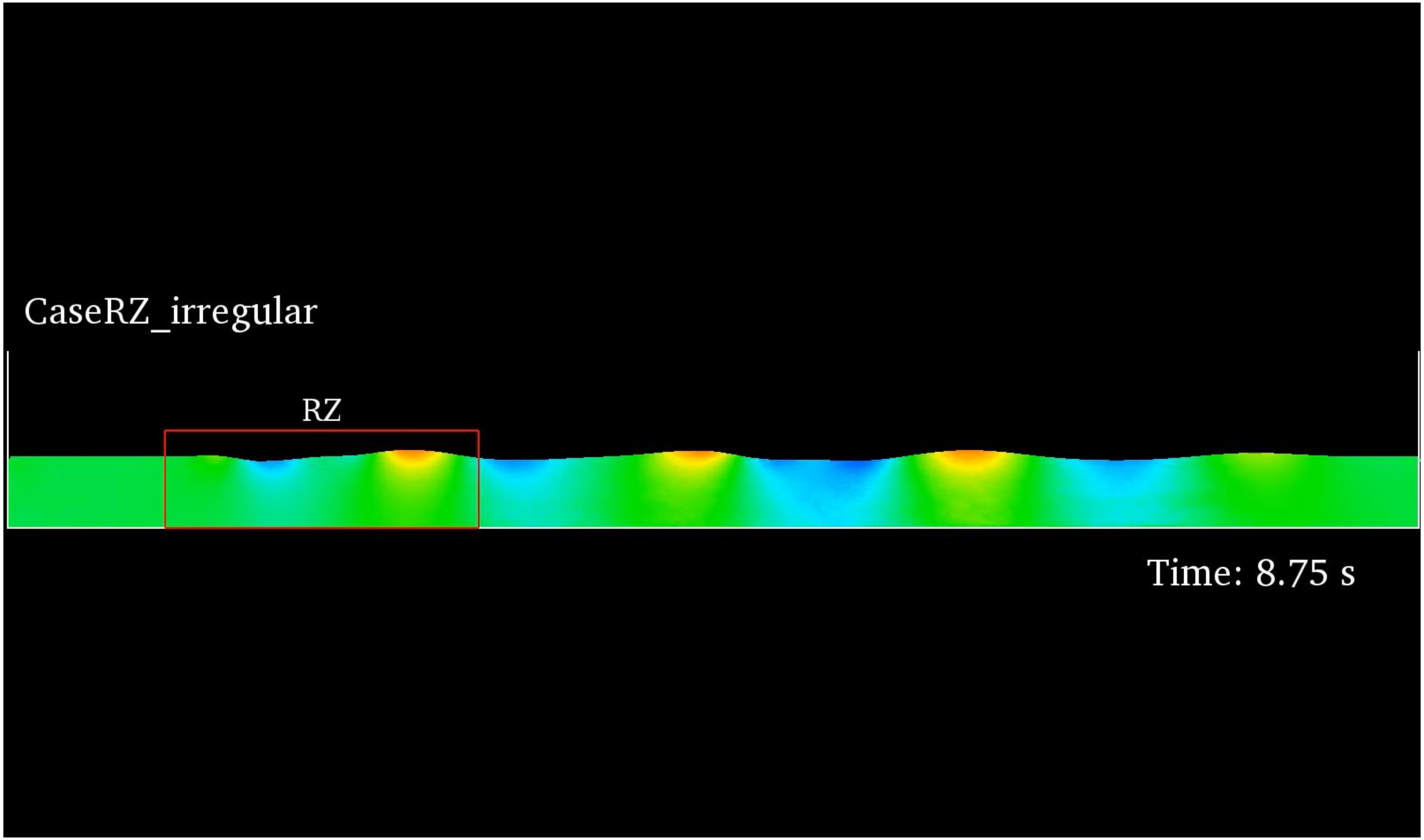
Altomare et al. (2018)



```
<special>
<!--APPLICATION OF RELAXATION ZONE FOR IRREGULAR WAVE GENERATION -->
    <relaxationzones>
        <rzwaves_spectrum>
            <start value="0" comment="Start time (def=0)" />
            <duration value="0" comment="Movement duration, Zero is the end of simulation (def=0)" />
            <peakcoef value="3.3" comment="Peak enhancement coefficient (default=3.3)" />
            <spectrum value="jonswap" comment="Spectrum type: jonswap,pierson-moskowitz" />
            <discretization value="stretched" comment="Spectrum discretization: regular,random,stretched,cosstretched (defa
            <waveorder value="1" comment="Order wave generation 1:1st order, 2:2nd order (default=1)" />
            <waveheight value="0.10" comment="Significant Wave Height" />
            <waveperiod value="1.6" comment="Peak Period" />
            <waves value="64" comment="Number of waves to create irregular waves (default=50)" />
            <randomseed value="2" comment="Random seed to initialize a pseudorandom number generator" />
            <depth value="0.8" comment="Water depth for wave generation" />
            <swl value="0.8" comment="Still water level (free-surface)" />
            <center x="-1.775853" y="1.000000" z="0.000000"  comment="Central point of application" />
            <width value="3.551707"comment="Width for generation" />
            <ramptime value="0" comment="Time of initial ramp (default=0)" />
            <serieini value="0" comment="Initial time in irregular wave serie (default=0)" />
            <savemotion time="50" timedt="0.1" xpos="14" zpos="-0.5" comment="Saves motion data. xpos and zpos are optional
            <saveserie timemin="0" timemax="100" timedt="0.1" xpos="0" comment="Saves serie data (optional)" />
            <saveseriewaves timemin="0" timemax="1000" xpos="0" comment="Saves serie heights" />
            <_calcserielength timemax="1000" comment="Calculates serie length (optional)" />
            <coefdir x="1" y="0" z="0" comment="Coefficients for each direction (default=(1,0,0))" />
            <coefdt value="1000" comment="Multiplies by dt value in the calculation (using 0 is not applied) (default=1000)
            <function psi="0.5" beta="6" comment="Coefficients in funtion for velocity (def. psi=0.9, beta=1)" />
            <driftcorrection value="1.0" comment="Coefficient of drift correction applied in velocity X. 0:Disabled, 1:Full
        </rzwaves_spectrum>
    </relaxationzones>
    <damping>
    <!--PASSIVE ABSORPTION (i.e. DAMPING AREA) BEFORE THE RZ -->
        <dampingzone>
            <limitmin x="-5.327560" y="0" z="0" comment="Location where minimum reduction is applied" />
            <limitmax x="-3.551707" y="0" z="0" comment="Location where maximum reduction is applied" />
            <overlimit value="1" comment="The scope of maximum reduction over limitmax (def=0)" />
```

Relaxation Zone

Altomare et al. (2018)



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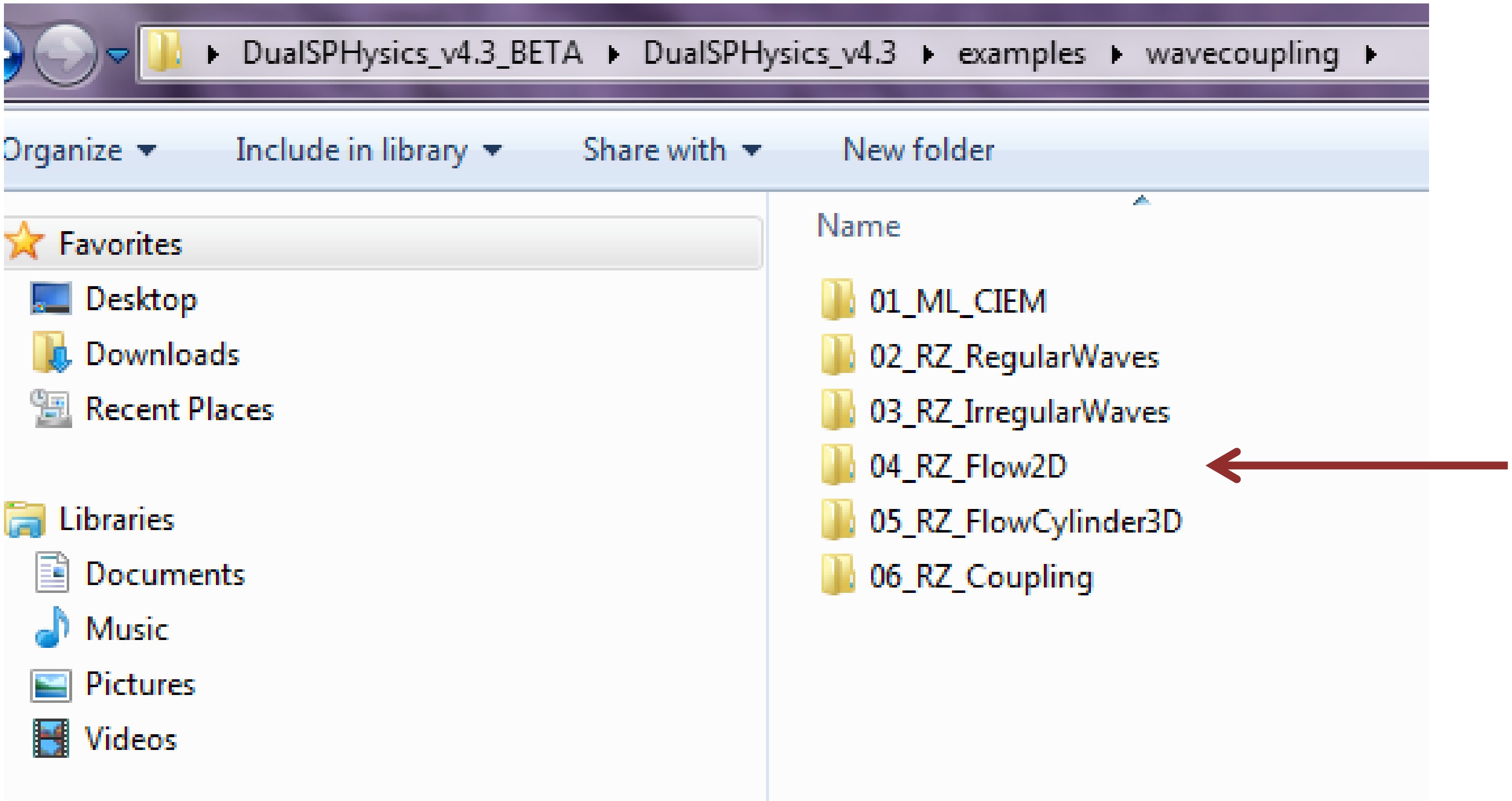
Relaxation Zone

Altomare et al. (2018)



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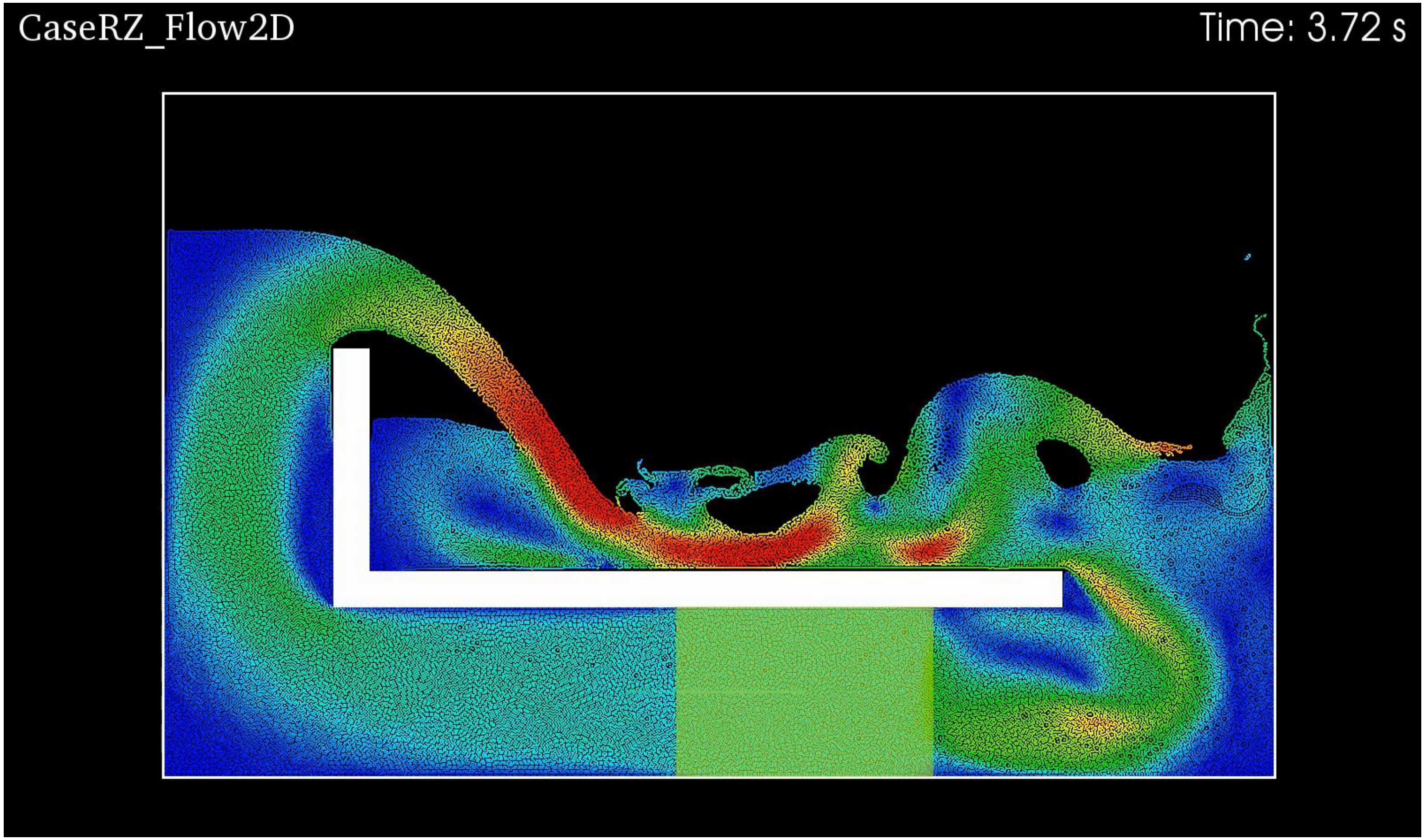
UNIFORM VELOCITY FIELD IN X- DIRECTION

```
<special>
<!--APPLICATION OF RELAXATION ZONE TO CREATE A UNIFORM VELOCITY FIELD IN X- DIRECTION -->
    <relaxationzones>
        <rzwaves_uniform>
            <start value="0" comment="Start time (default=0)" />
            <duration value="0" comment="Duration, Zero is the end of simulation (default=0)" />
            <domainbox>
                <point x="0.6" y="-0.05" z="0" />
                <size x="0.3" y="0.1" z="0.2" />
                <direction x="-1" y="0" z="0" />
                <_rotateaxis angle="-45" anglesunits="degrees">
                    <point1 x="0.3" y="0" z="0" />
                    <point2 x="0.3" y="1" z="0" />
                </_rotateaxis>
            </domainbox>
            <velocitytimes comment="Uniform velocity in time">
                <timevalue time="0.0" v="0" />
                <timevalue time="1.0" v="0.3" />
                <timevalue time="3.0" v="0.4" />
                <timevalue time="6.0" v="0.7" />
                <timevalue time="8.0" v="0.2" />
            </velocitytimes>
            <coefdt value="1000" comment="Multiplies by dt value in the calculation (using 0 is nc
            <function psi="0.7" beta="3" comment="Coefficients in funtion for velocity (def. psi=0
        </rzwaves_uniform>
    </relaxationzones>
</special>
```

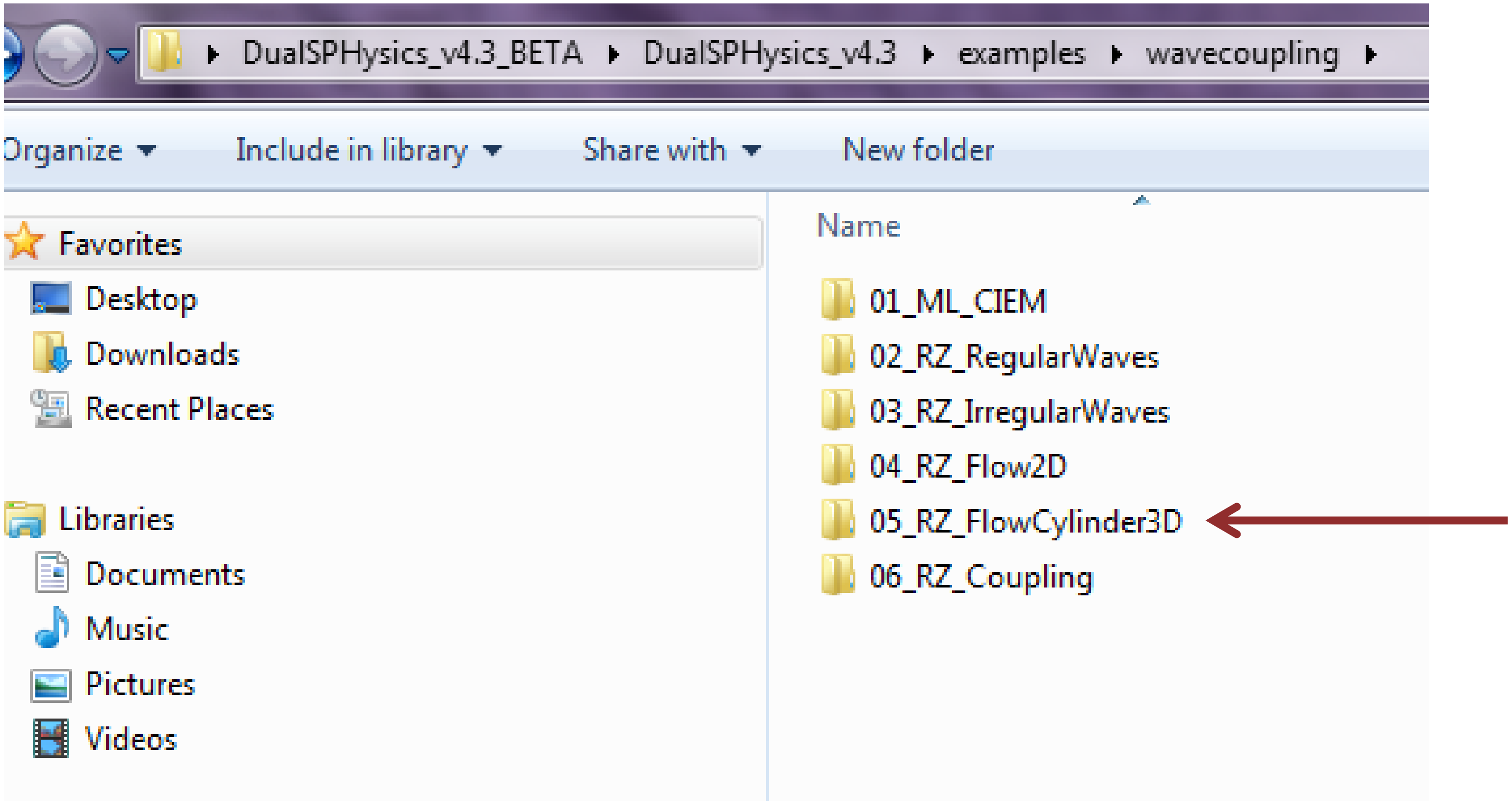
Relaxation Zone

Altomare et al. (2018)



Relaxation Zone

Altomare et al. (2018)



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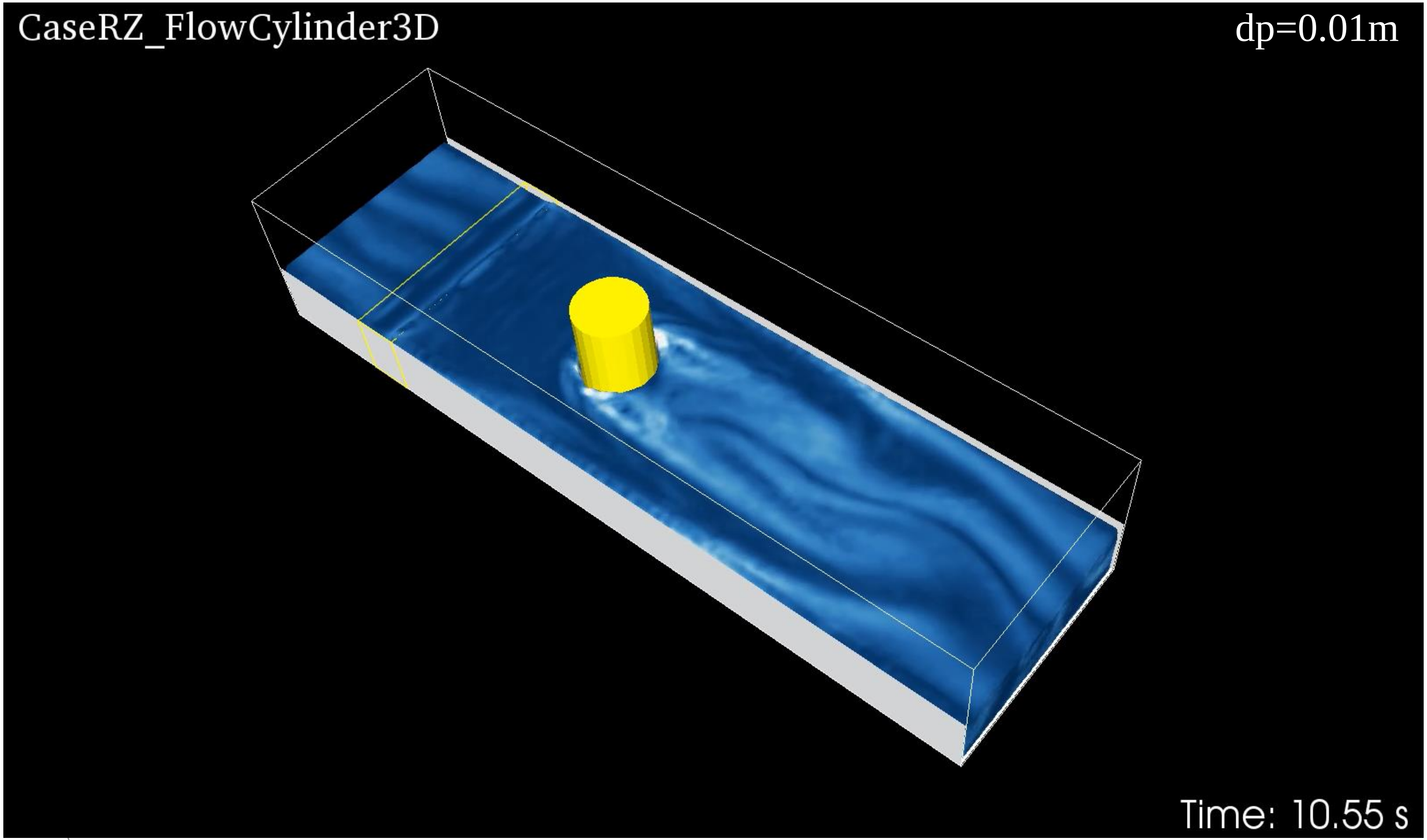
UNIFORM VELOCITY FIELD IN X- DIRECTION

Relaxation Zone

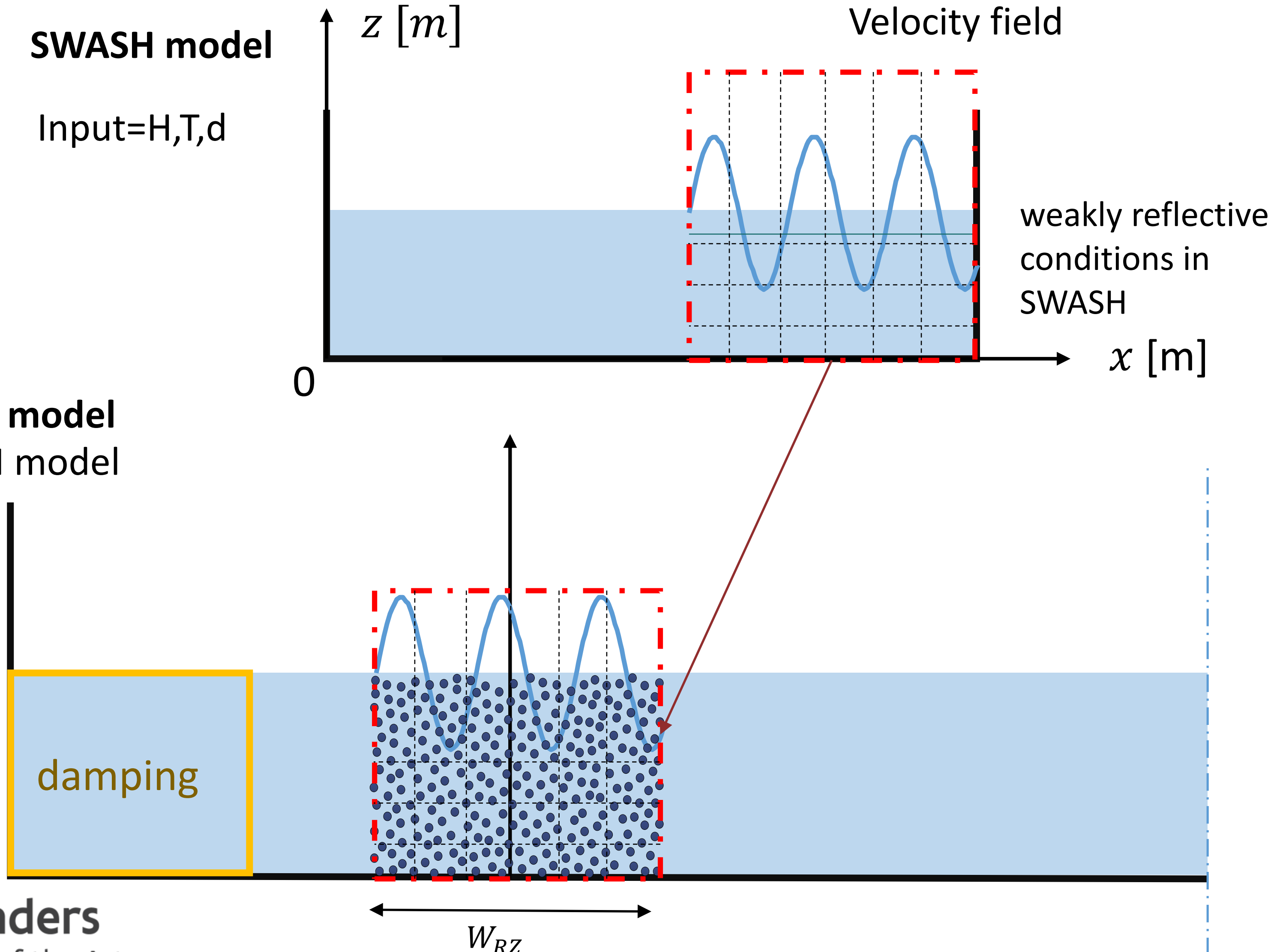
Altomare et al. (2018)



Relaxation Zone *for Coupling*

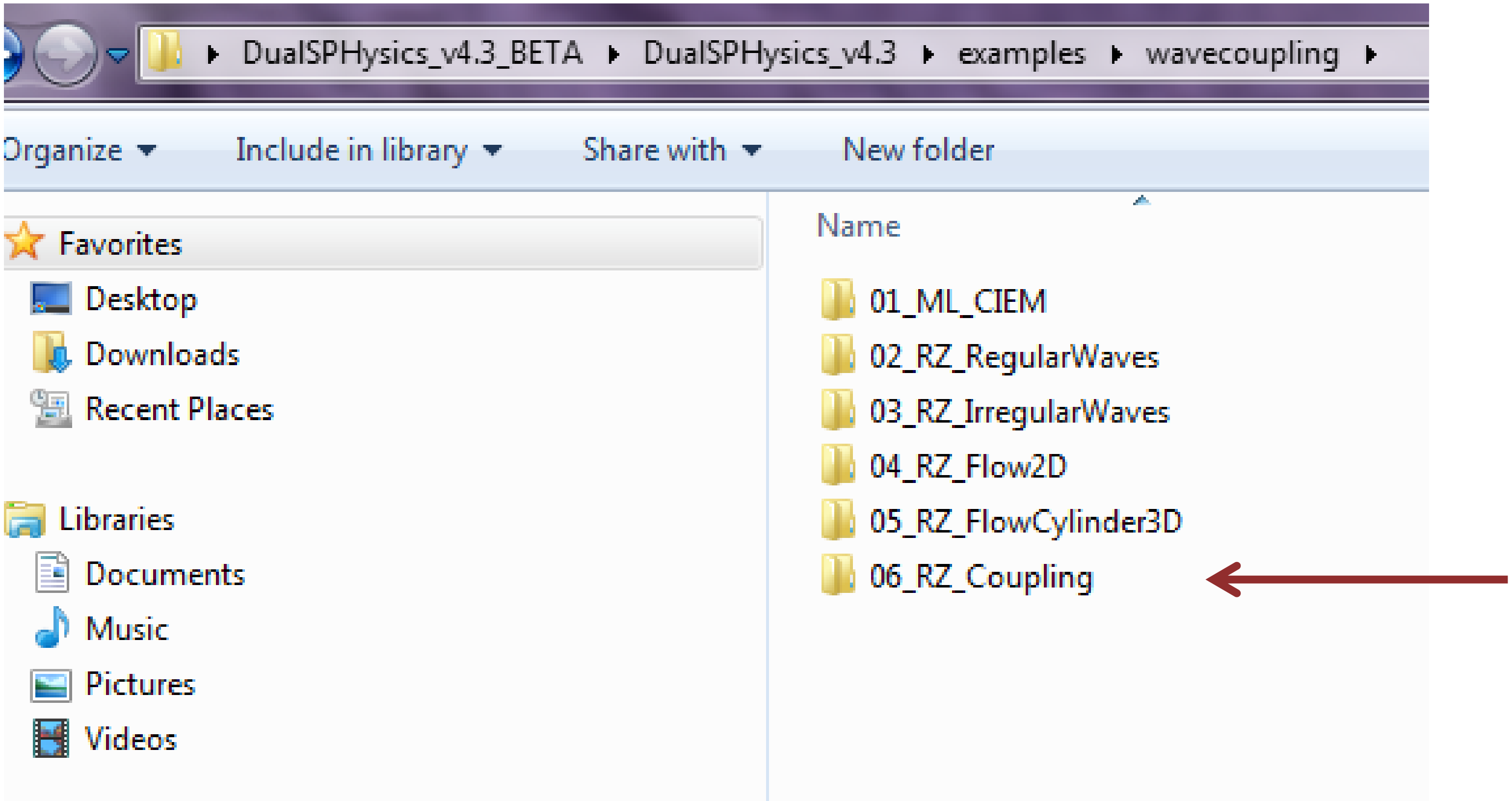
Altomare et al. (2018)

DualSPHysics model
Input=SWASH model



Relaxation Zone

Altomare et al. (2018)

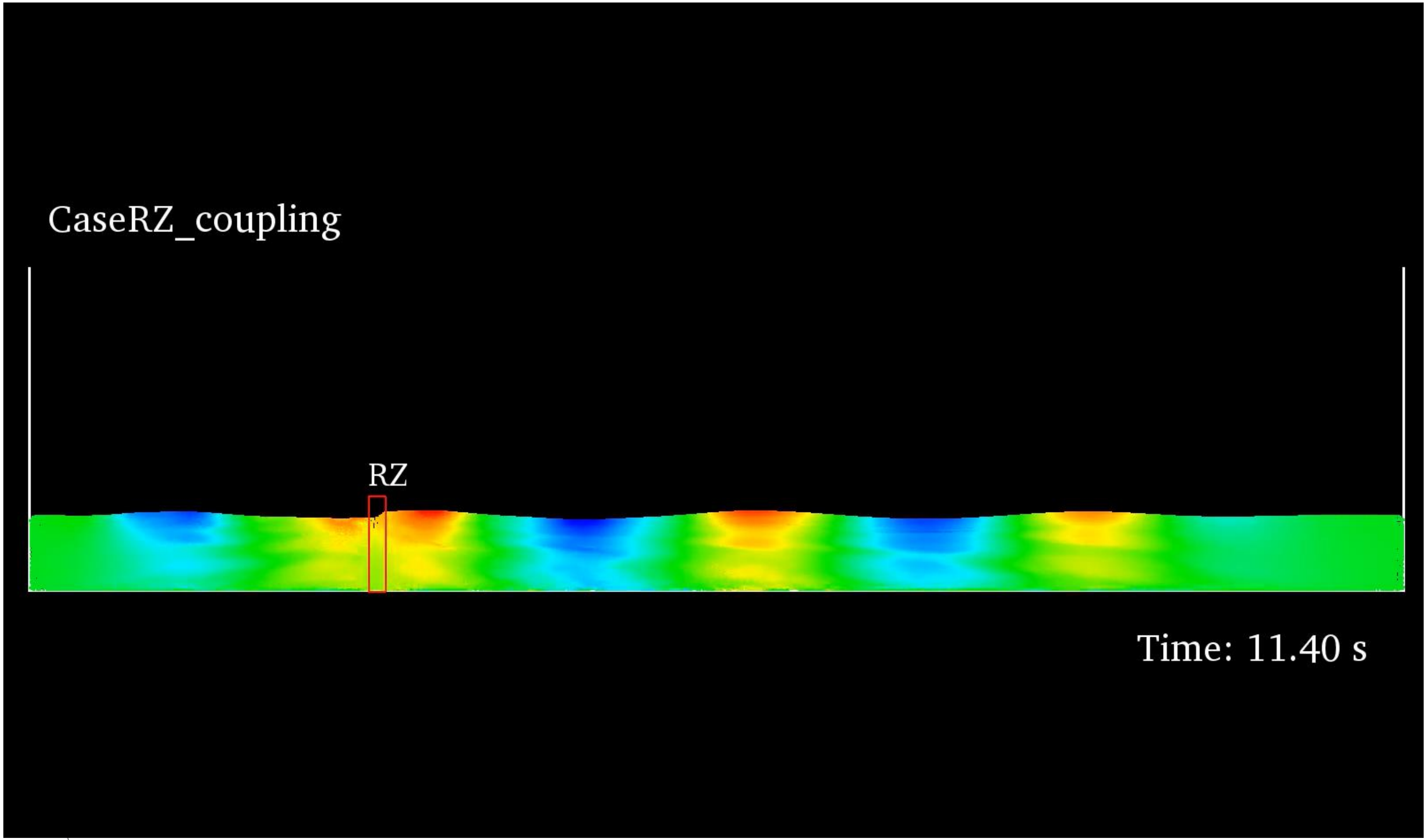


RZ COUPLING WITH WAVE PROPAGATION MODEL

```xml
<special>
<!--APPLICATION OF RELAXATION ZONE WAVE GENERATION USING VELOCITY DATA FROM WAVE PROPAGATION MODEL (e.g. SWASH)-->
    <relaxationzones>
        <rzwaves_external_1d>
            <start value="0" comment="Start time (def=0)" />
            <duration value="0" comment="Movement duration, Zero is the end of simulation (def=0)" />
            <depth value="0.8" comment="Water depth. It is necessary for drift correction (def=0)" />
            <swl value="0.8" comment="Still water level (free-surface). It is necessary for drift correction (def=0)" />
            <filesvel value="Case_SWASH_8L_corr" comment="Main name of files with velocity to use" />
            <filesvelx initial="0" count="5" comment="First file and count to use" />
            <usevelz value="false" comment="Use velocity in Z or not (def=false)" />
            <movedata x="-0.177585" y="1" z="0.8" comment="Movement of data in CSV files" />
            <dpz valuedp="1" comment="Distance between key points in Z (def=2)" />
            <smooth value="10" comment="Smooth motion level (def=0)" />
            <center x="-0.088793" y="1" z="0" comment="Central point of application" />
            <width value="0.177585" comment="Width for generation" />
            <coefdir x="1" y="0" z="0" comment="Coefficients for each direction (default=(1,0,0))" />
            <coefdt value="1000" comment="Multiplies by dt value in the calculation (using 0 is not applied) (default=100
            <function psi="0.9" beta="0.9" comment="Coefficients in funtion for velocity (def. psi=0.9, beta=1)" />
            <driftcorrection value="0.1" comment="Coefficient of drift correction applied in velocity X. 0:Disabled, 1:Fu
            <driftinitialramp value="8" comment="Ignore waves from external data in initial seconds (def=0)" />
        </rzwaves_external_1d>
    </relaxationzones>
    <!--PASSIVE ABSORPTION (i.e. DAMPING AREA) BEFORE THE RZ -->
    <damping>
        <dampingzone>
            <limitmin x="-1.953439" y="0" z="0" comment="Location where minimum reduction is applied" />
            <limitmax x="-3.729292" y="0" z="0" comment="Location where maximum reduction is applied" />
            <overlimit value="1" comment="The scope of maximum reduction over limitmax (def=0)" />
            <redumax value="20" comment="Maximum reduction in location limitmax (def=10)" />
            <factorxyz x="1" y="1" z="1" comment="Application factor in components (def x=1,y=1,z=1)" />
        </dampingzone>
```

Relaxation Zone

Altomare et al. (2018)



Wave generation/absorption in DualSPHysics

stand-alone model

coupling framework

Piston- & Flap-type wavemakers

MULTI-LAYERED piston

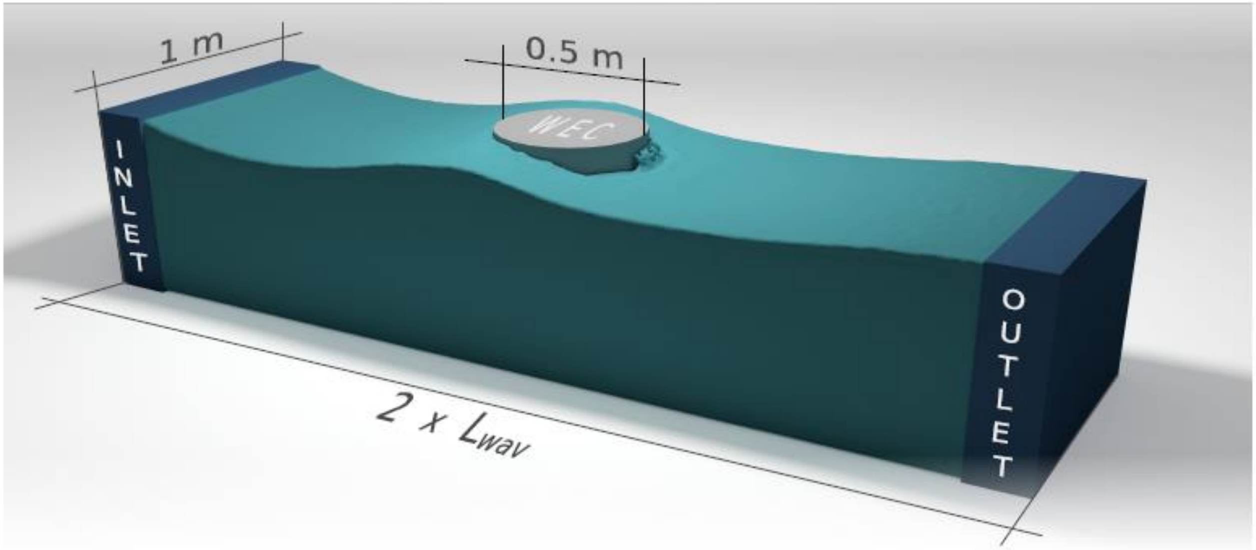
Relaxation Zone

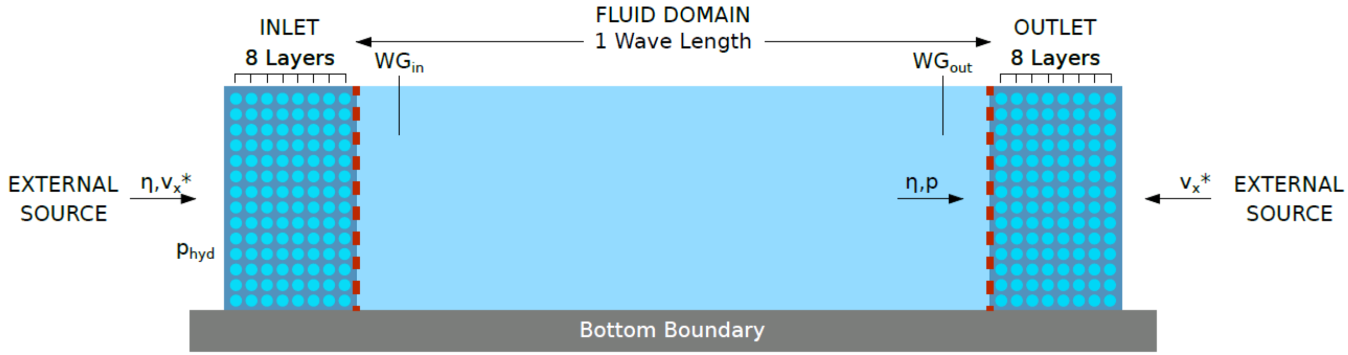
Open Boundary Conditions

Open Boundary Conditions

Day 2, 14:45 - 15:00

Tim Verbrugghe:
"Application of open boundaries within a coupled DualSPHysics-OceanWave3D model"

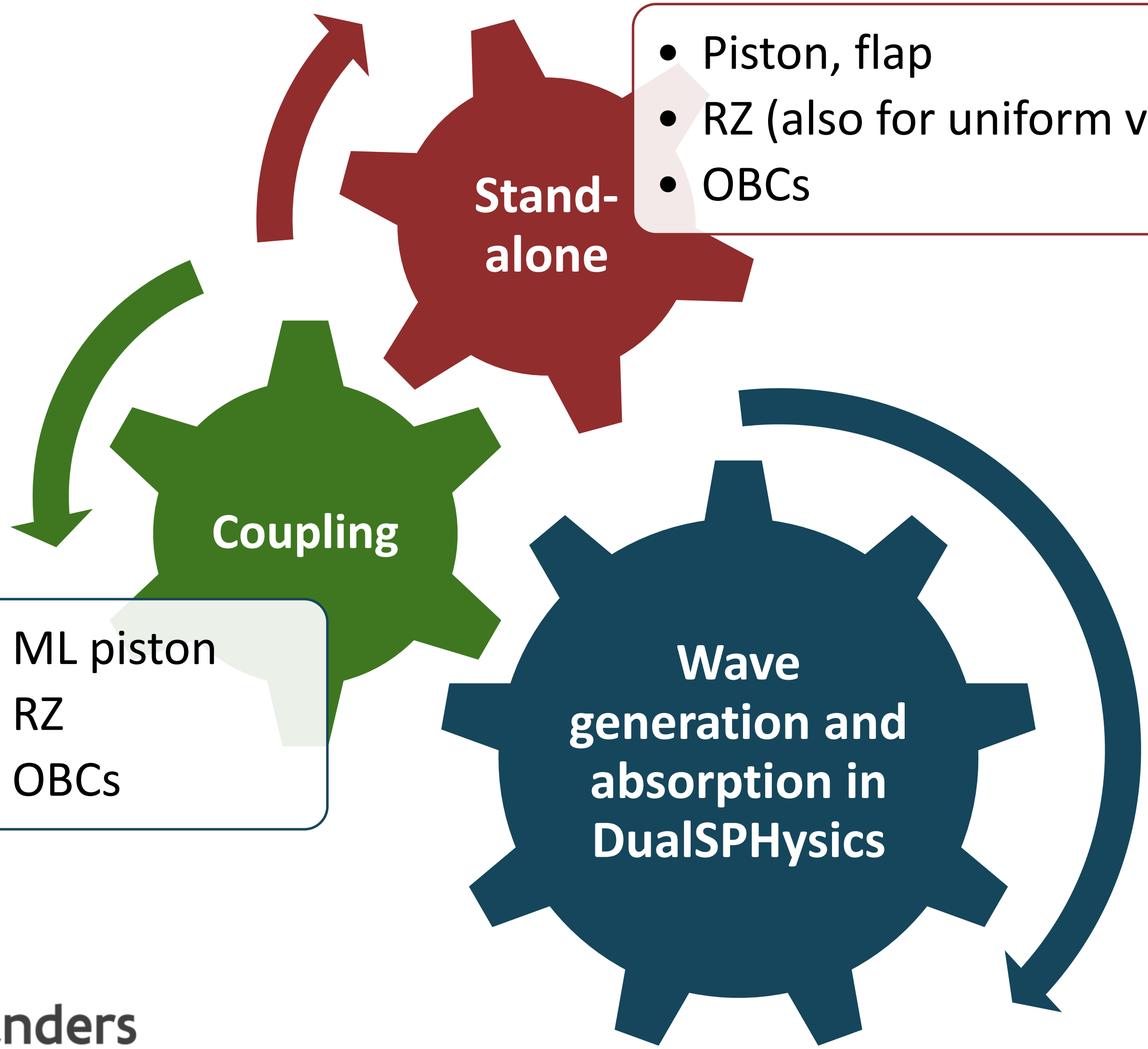




Flanders
State of the Art

Conclusions

In a nutshell…



- Piston, flap
- RZ (also for uniform velocity profiles)
- OBCs

- ML piston
- RZ
- OBCs