DualSPHysics: APPLICATIONS TO TSUNAMI ENGINEERING PROBLEMS

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Nils Goseberg
Ludwig-Franzius-Institut
Leibniz Universität Hannover, Germany

: @nilsgoseberg
: goseberg@lufi.uni-hannover.de
: www.nilsgoseberg.de

And collaborators:
M. Heunecke, H. von Häfen, J. Stolle, I. Nistor

© D. J. Phillip , Hurricane Katrina, Gulfport, US.

Presentation outline

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1. Introduction and Objective

2. Assessing Means of Generating Long Waves

3. Simulation of Debris Dynamics in Harbours

4. Conclusions and Outlook


Sendai, Japan. www.bbc.co.uk

Sri Lanka, Getty Images

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Introduction and Objective

Hazards involving extreme hydrodynamic flows I

- Natural disasters (tsunami), extreme weather (flashfloods)
  - Extreme hydrodynamic flows
- Characteristics of these flows:
  - High energy, high momentum
  - Significant debris entrainment and displacement
- Disruption of public safety or traffic infrastructure

Braunsbach, Germany May, 30th, 2016

Example of Extreme Hydrodynamic Flow: Tsunami On-land Flow

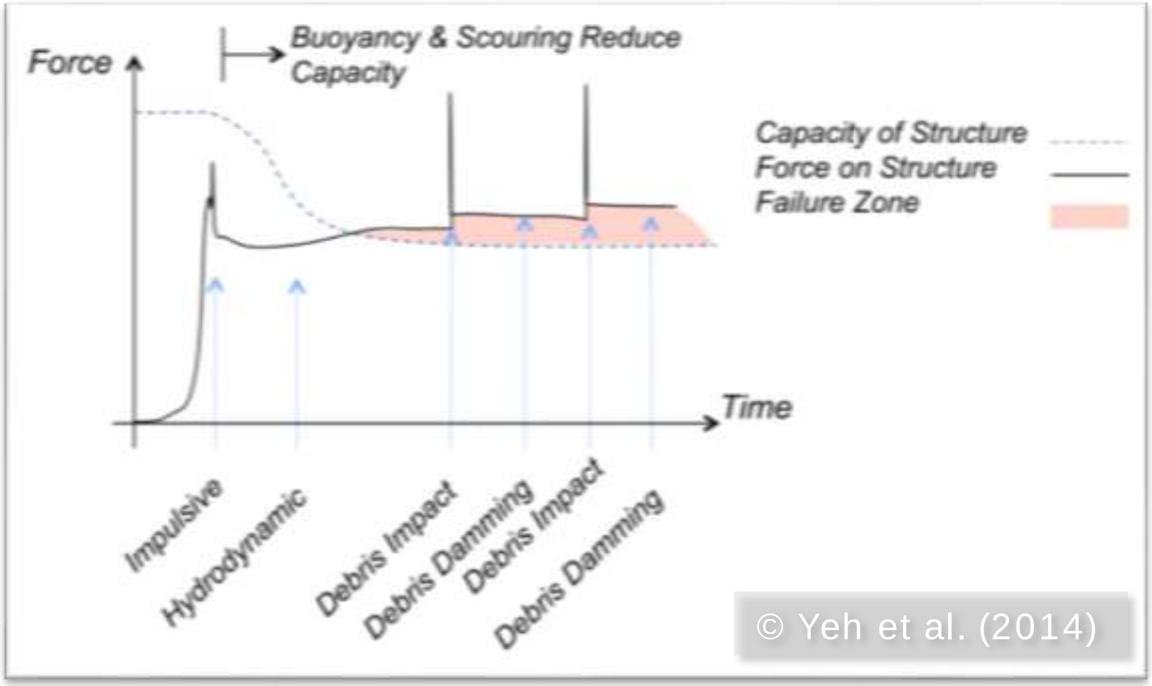
- Example: 2011 Tohoku Earthquake and Tsunami
- Debris entrained by the on-land flow are difficult to detect due to:
  - Partial submergence
  - Agglomeration and damming of flow-entrained debris
- Concern: Impact loads onto vertical structures by multiple debris items

Miyako harbor, Japan, on Mar., 11th, 2011

Introduction and Objective

Tsunami Engineering: Forces Exerted on Vertical Structure

- Typical force time-history on building as a result of tsunami attack
  - Combination of static and transient forces
  - Results in complex processes
  - Buoyancy and scouring may reduce capacity
- ASCE 7 (2017), FEMA P646, Japanese guidelines
  - Prescriptions for various force components – incomplete!



Objective

- Long-term perspective
  - Facilitate elaboration of guidelines and standards to
    - ❑ Reliably predict **effects** of extreme flows
    - ❑ Improve **load** estimates on structures
  - Extend experimental and numerical research
    - ❑ Collapsing structures in hydraulic engineering
    - ❑ Fully accounting for the complex dynamics of processes

EUROCODES BUILDING THE FUTURE

ASCE AMERICAN SOCIETY OF CIVIL ENGINEERS

JSCE

- Short-term perspective
  - Investigate usefulness of SPH-method in the field of tsunami engineering
  - Develop novel experimental methods to track debris in flows
  - Study debris in extreme hydrodynamic flows
    - ❑ Impacts
    - ❑ Damming

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Assessing Means of Generating Long Waves

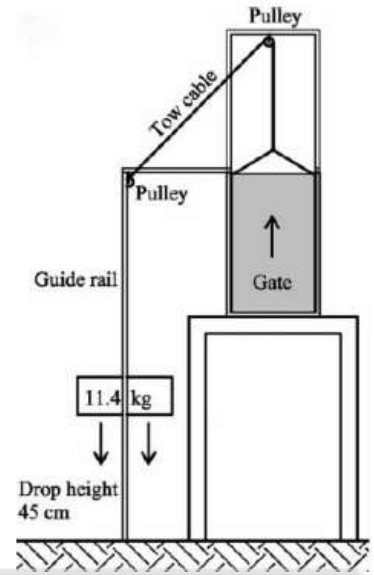
Dam - break gates

- Lift and swing gates used in literature to study various problems

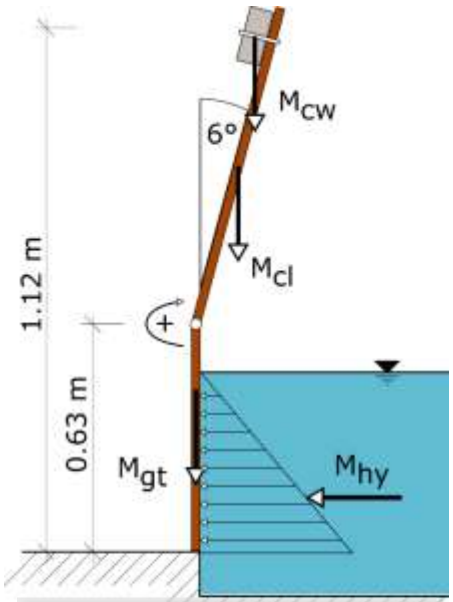
- Opening criterion exists for lift gates only!
  - Lauber (1997) and Lauber & Hager (1998) define max. opening time t_{open}

$$t_{open}\sqrt{\frac{g}{d_0}} \leq 1,25$$

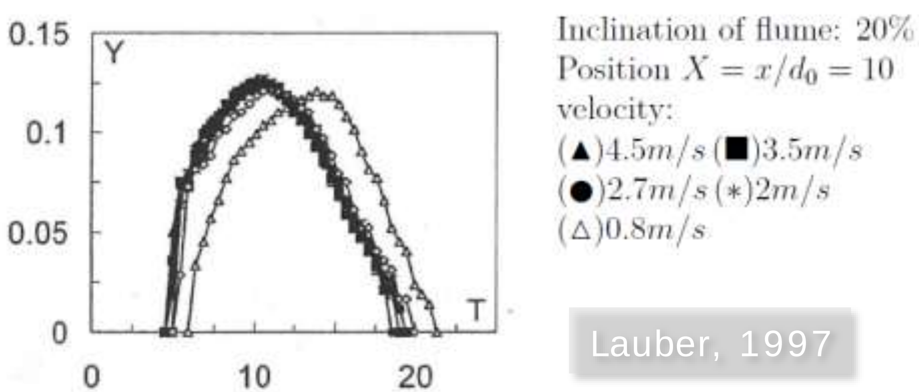
- Definition based off a point measurement ($X=x/d_0=10$) downstream of gate mechanism



Oertel & Bung, 2012



Goseberg et al. 2017



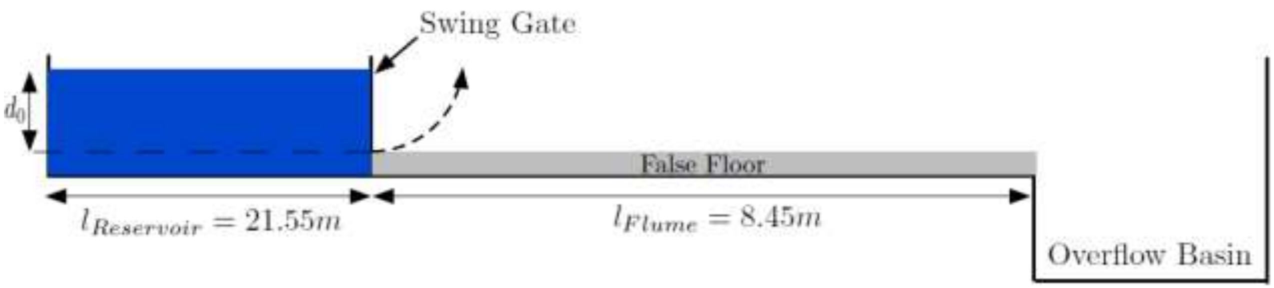
Lauber, 1997

Assessing Means of Generating Long Waves

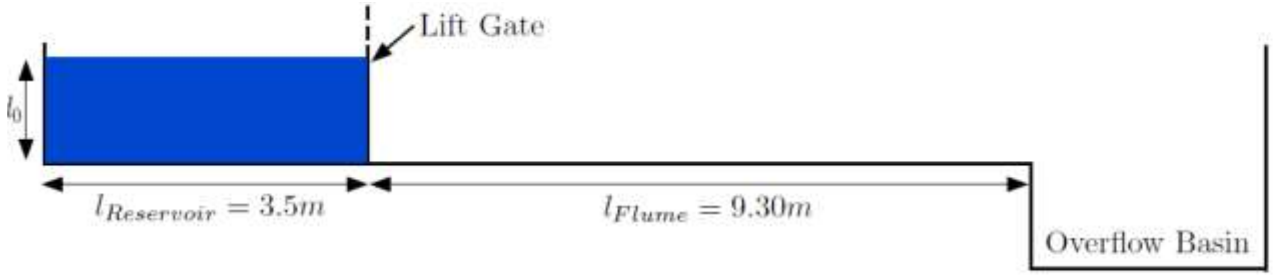
Investigating gate opening time (von Häfen et al, 2017)

- Calling for larger scale experiments makes gate construction very costly
- Research questions
  - Opening times for swing gates
  - Spatial variation of free-surface elevation error downstream

- Numerical method: Smoothed particle hydrodynamics (SPH)
  - Implementation: DualSPHysics (Crespo, 2008; Canelas et al., 2016)



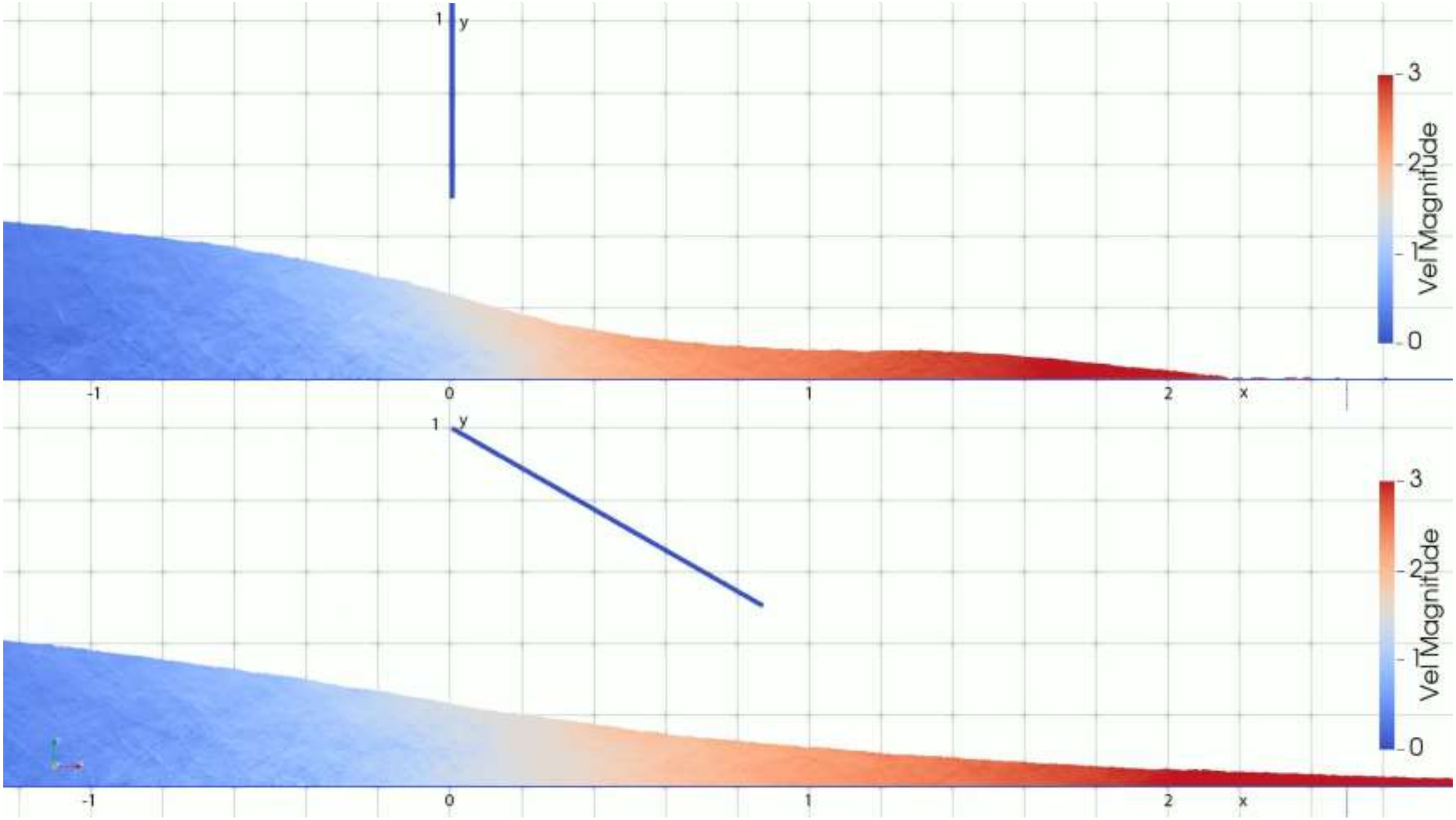
For testing University of Ottawa experiments



For testing Khankandi et al. (2012) experiments

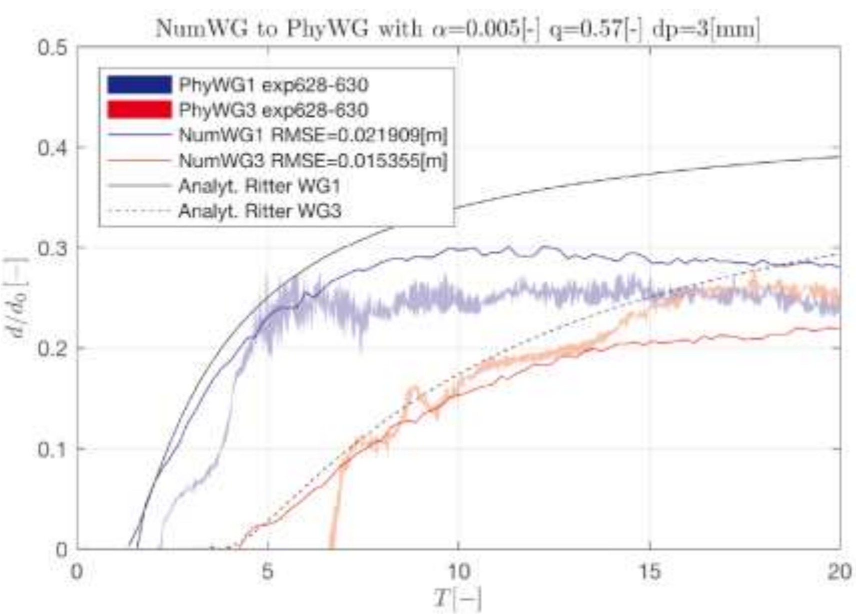
Comparison of Lift and Swing Gate

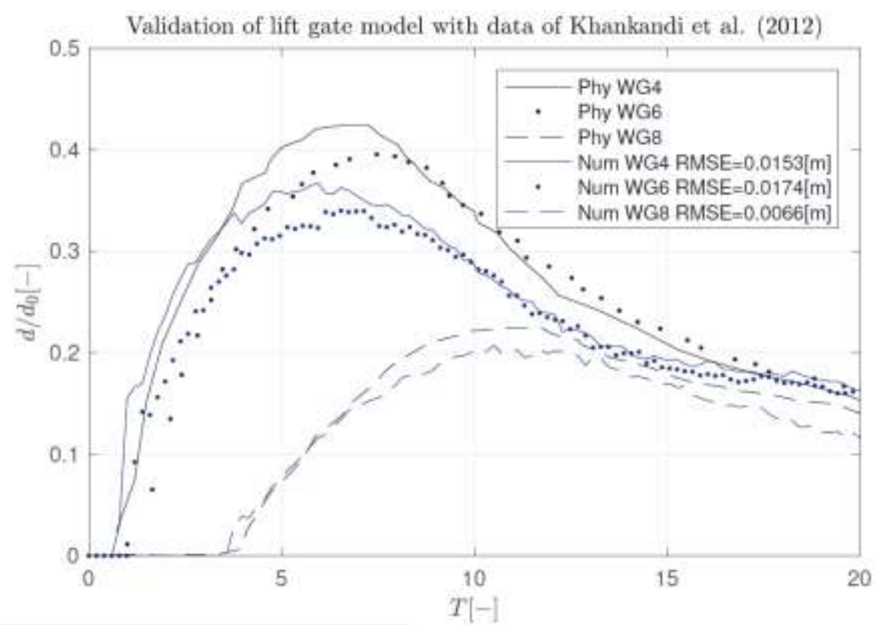
- Near - gate dynamics, color - coded by the velocity field



Validation of the numerical model (von Häfen et al, in prep.)

- Swing and lift gate experiments were compared to numerical results
  - Good agreement
  - SPH model reproduces dynamics at the wave front
  - Reasonable RMSE
- Calibrated and validated model allows for prognostic purposes





von Häfen, 2017. Seminar thesis, LUH

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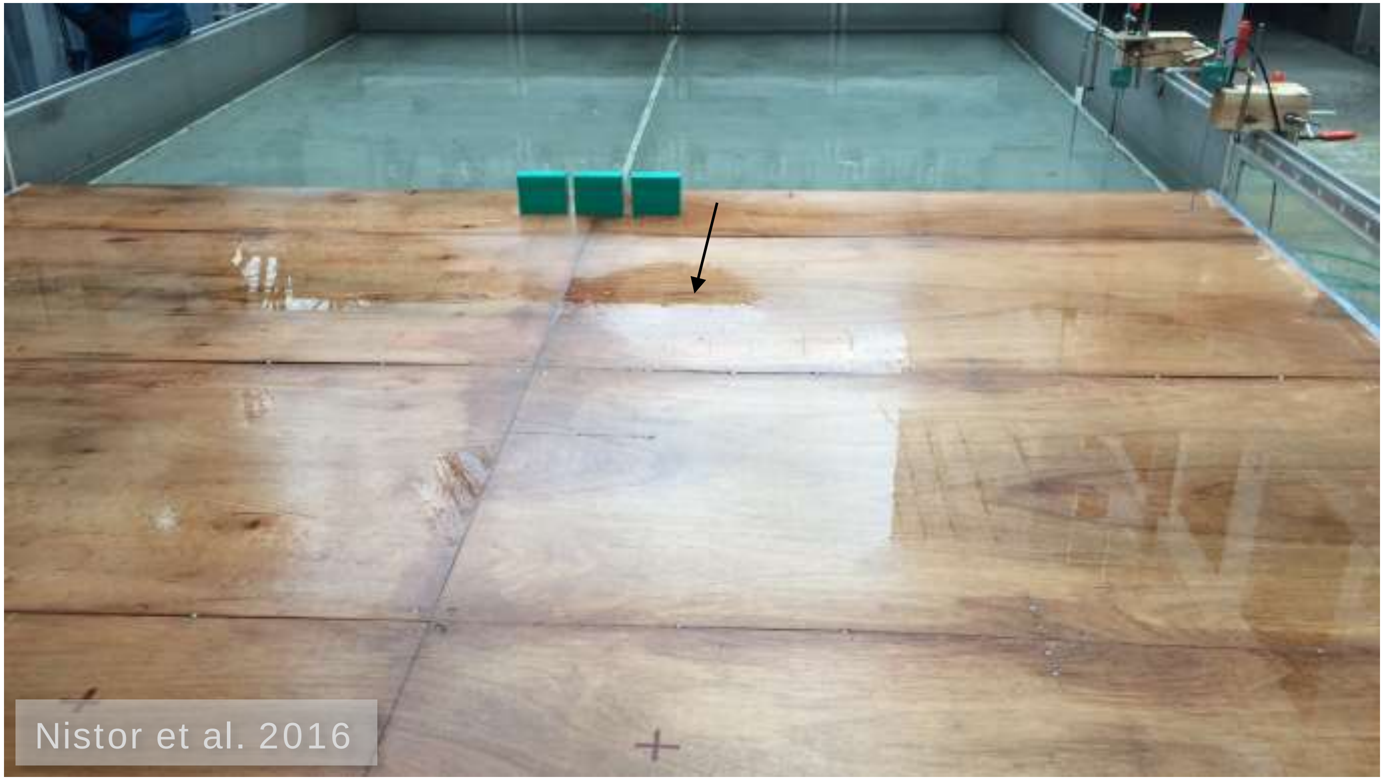
Simulation of Debris Dynamics in Harbours

Experimental testing of debris dynamics

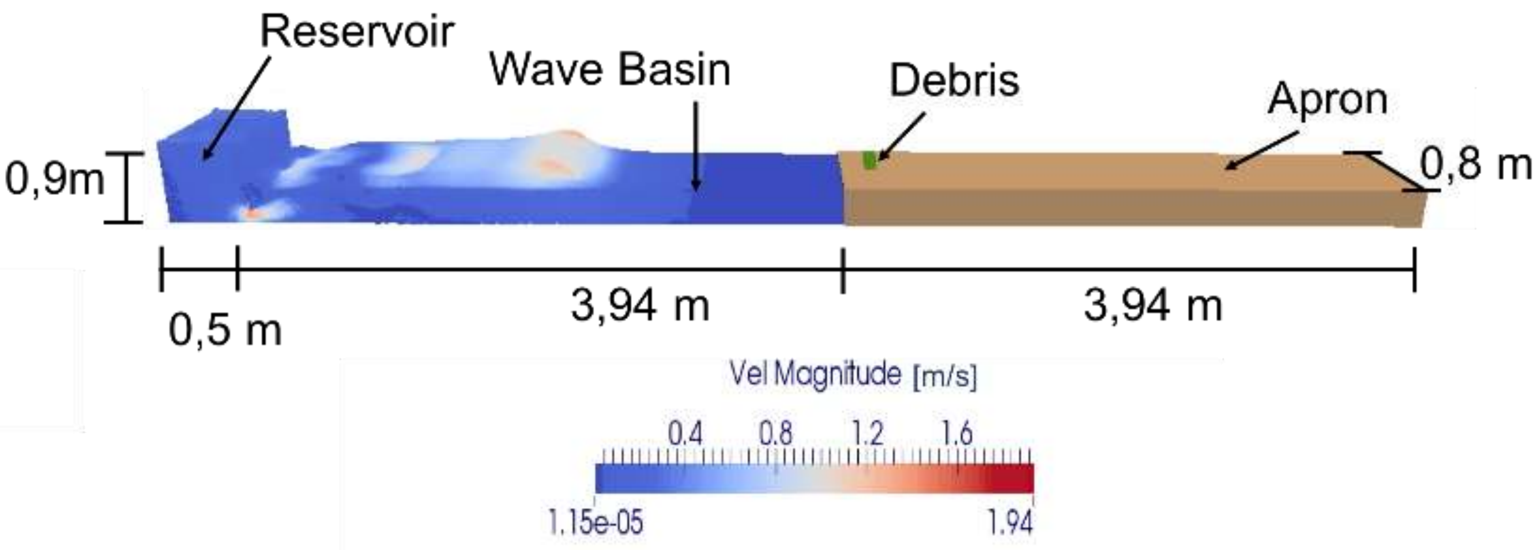
- Model of a harbour – Collaboration Waseda Univ., Japan (Prof. Shibayama)
  - Horizontal apron, sea bed and quay wall
  - Tsunami-like inflow condition
  - 1:40 scaled-down shipping containers (*"smart" debris*)



Nistor et al. 2016

Model Setup

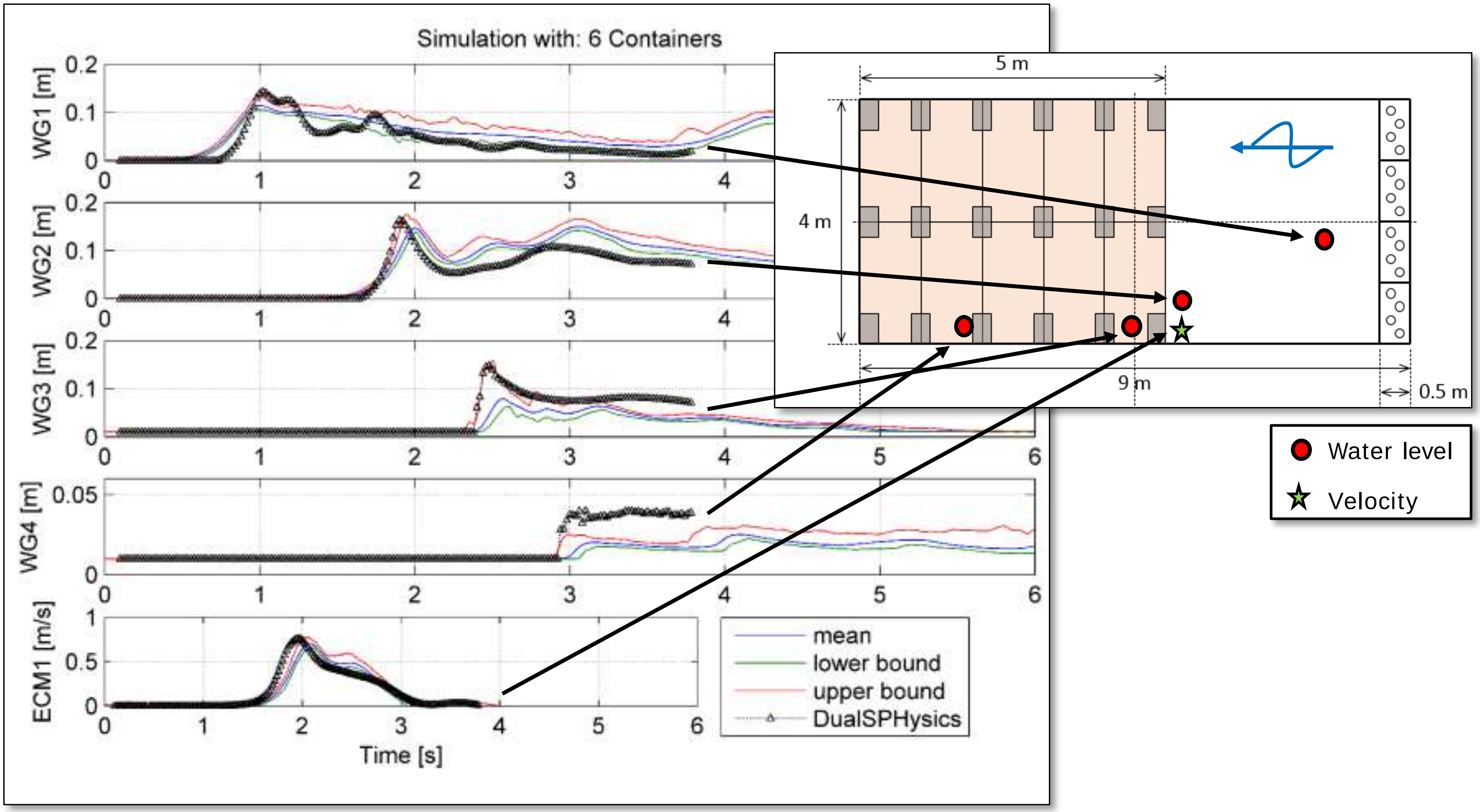
- DualSPHYsics V4.0 with support for solid objects through DEM
- Modelling a 0.8 m wide section of the basin
  - Dropping water column in the wave-maker, instantaneous
  - Simulating the first few seconds, t<5 s
  - Particle spacing: ~5 mm



Debris dynamics in harbours

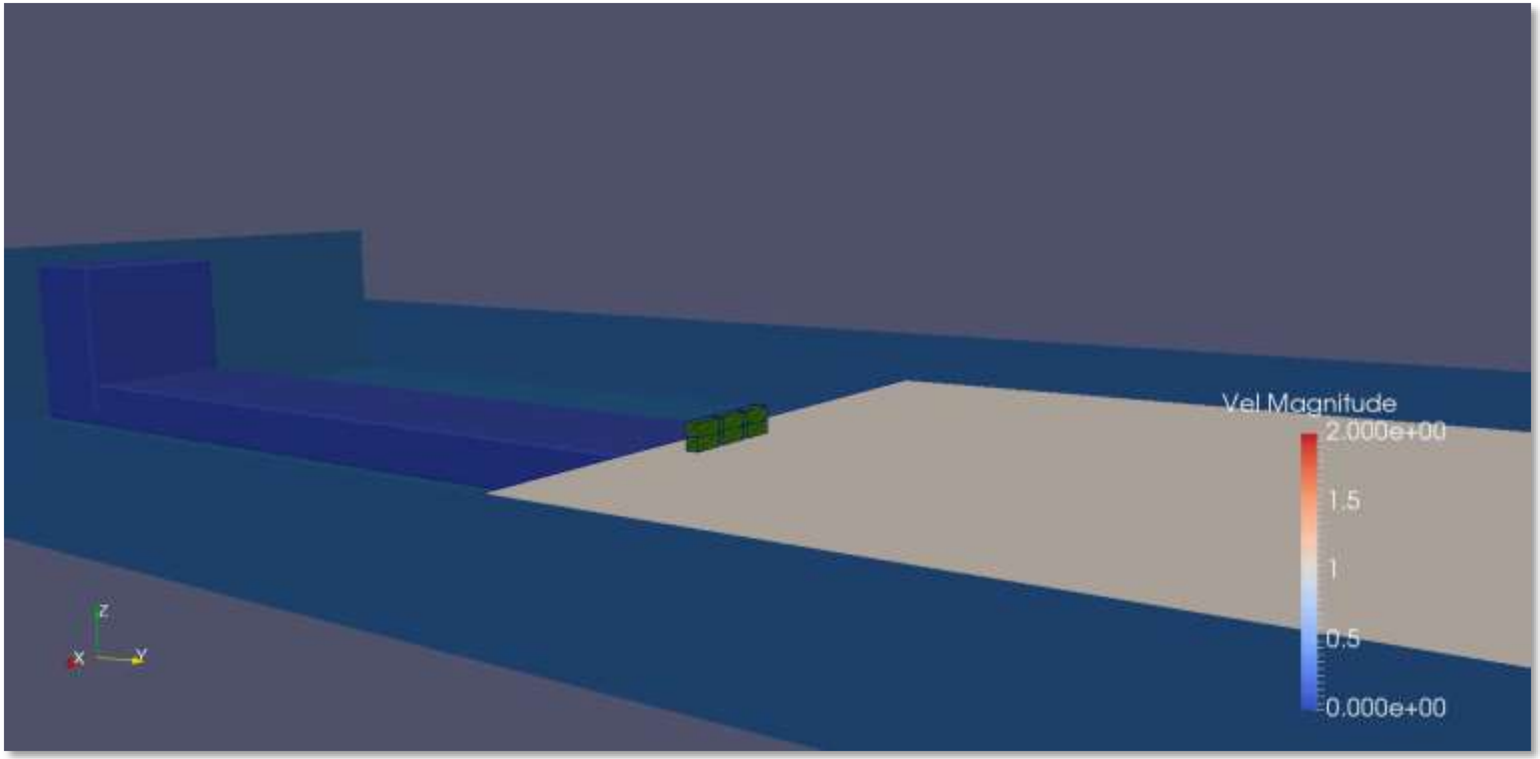
Numerical modelling of debris dynamics I

- Validation of water levels and velocity with experimental data (DualSPHysics)



Numerical modelling of debris dynamics II

- Simulating debris dynamics on the harbor apron
  - 6 shipping containers, 3x2 side-by-side arrangement
  - Key numbers
    - 10 mio. Particles, initial particle spacing dp = 5 mm
  - But: Difficulties stabilizing current numerical scheme



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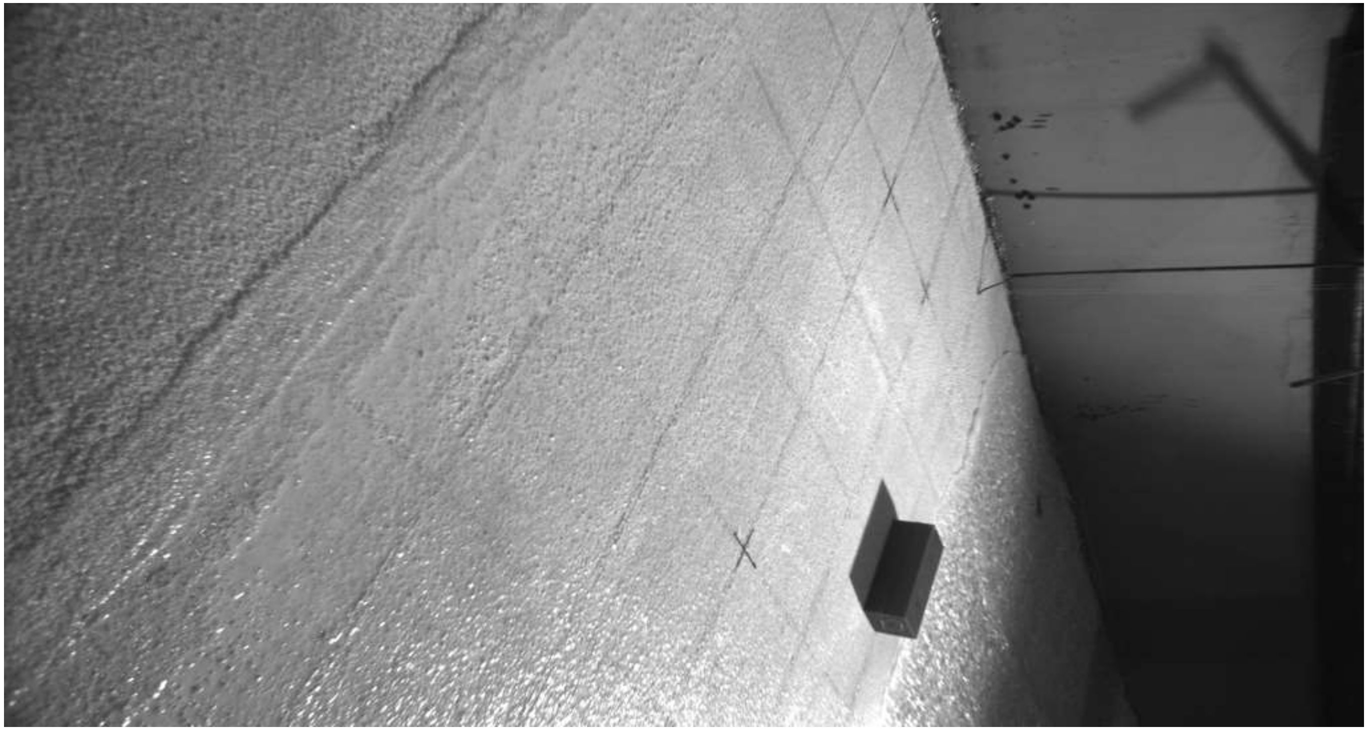
Conclusions and Outlook

Conclusions and Outlook

- Investigate usefulness of SPH-method in the field
  - SPH indeed a useful tool
    - Delivers very realistic hydrodynamics
    - Allows to investigate dam-break gate dynamics and evolving surge wave
- Study debris in extreme hydrodynamic flows
  - Debris dynamics
    - SPH deems useful
    - Limitations: Performance vs. resolution, instabilities of SPH-DEM
- Future research / interests involving SPH
  - Collapsing structures
  - Determination of impact loads on vertical structures
  - Less-than-rigid/elastic structures with SPH?
  - Tsunami scour with realistic soil models?
  - Air entrainment of bores striking (elastic) structures
  - Aquaculture installation for shellfish/seaweed

Thank you for your attention!



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Thanks for your attention!