CITEPH Project

Simulation of extreme waves impacts on a FLNG

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Context of the study

- Strong wave impacts knowledge => structural design

- Hydrodynamics loads — ~ms, ~mm
- Induced by waves — ~s, ~m
- Strongly nonlinear
- multiphysics — Gas compressibility, hydroelasticity

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Experimental setup

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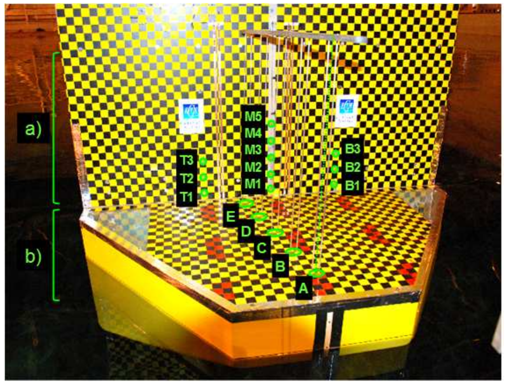
Experimental setup

Experimental Wave Tank ECN

- 50x30x5 m
- Multiflap wave generator

Simplified FNLG model

- 1.1m width



Instrumentation

- Wave probes in tank
- Wave probes on deck
- Pressure probes on breakwater

Water waves

- Regular waves
- Wavelength=7.3m
- Amplitude = 0.44m

Wave-Forcing procedure

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Forcing procedure

- Main algorithm

Complete problem through direct simulation

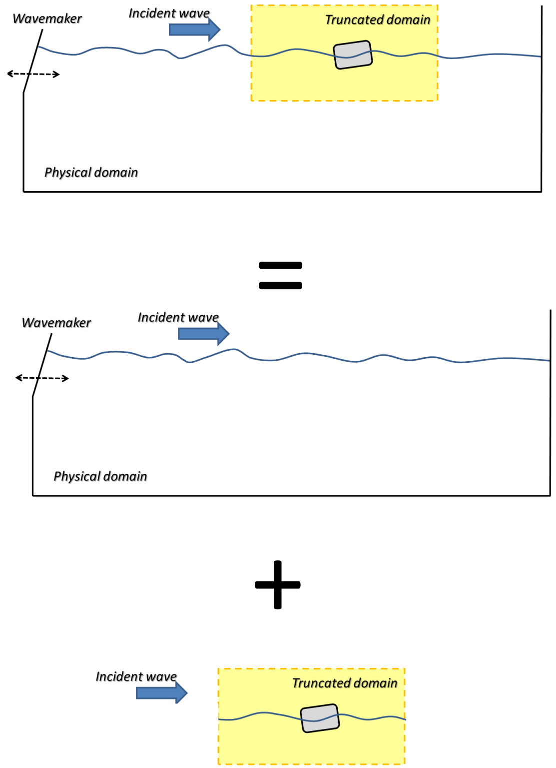
- ➢ Wave generation
- ➢ Wave propagation from generator to structure
- ➢ Impacts
- ➢ High cpu time consuming
- ➢ Numerical methods not adapted

Wave generation/propagation

- ➢ Spectral methods
- ➢ No dissipation
- ➢ No structure
- ➢ Low cpu time
- ➢ Computed <u>once</u> before SPH computation

Impact

- ➢ SPH method
- ➢ Inlet/outlet wave boundaries



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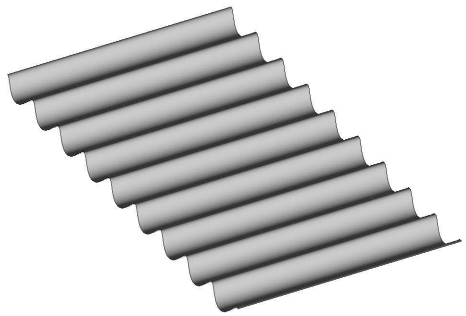
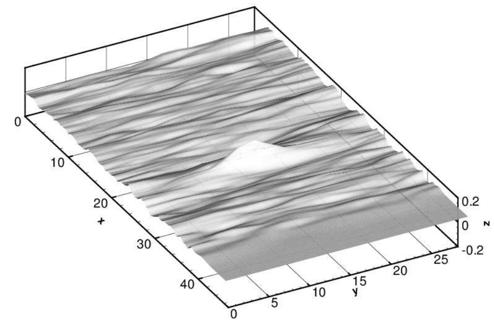
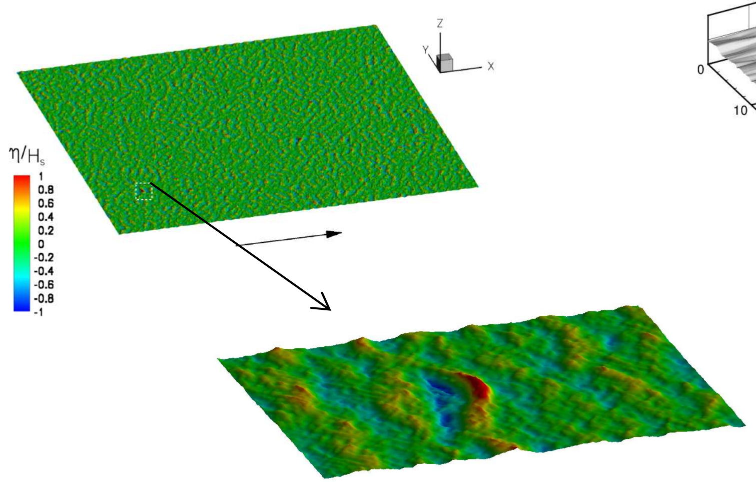
Forcing procedure

- Incident wave models: potential spectral methods
  - Rienecker & Fenton
    - ★ Monochromatic regular waves
    - ★ Bidimensional
    - ★ Fully nonlinear
  - HOS (Higher Order Spectral)
    - ★ Irregular waves
    - ★ Multidimensional
    - ★ Fully nonlinear
    - ★ Applications: focused waves, states, etc.







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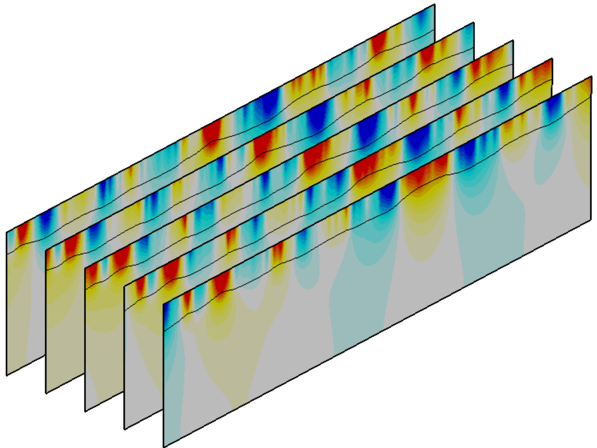
Forcing procedure

- Incident wave solution

File storage

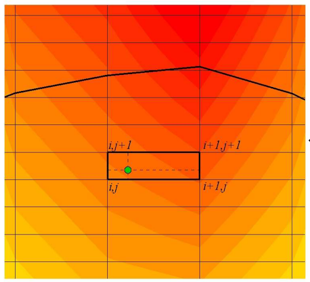


- HOS solution computed once
- File storage of a set of cartesian grids covering the impact area, at various instants

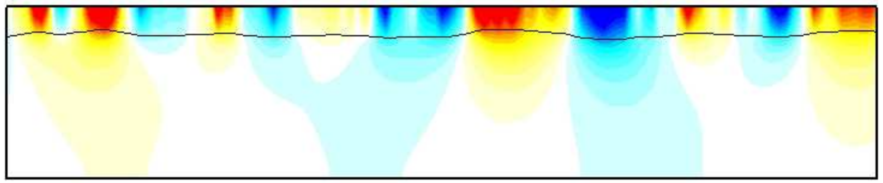
Linear interpolation in time

Bilinear interpolation in space

V, p at particle position

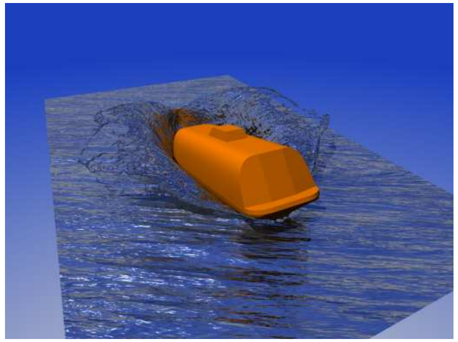


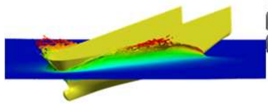
Cartesian grid at time t

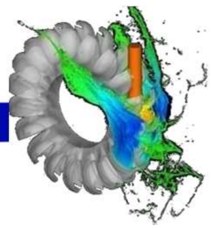


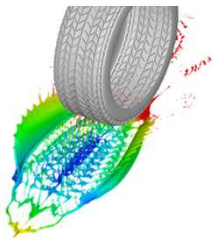
Forcing procedure

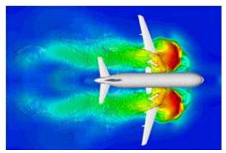
- SPH-flow solver
  - Developed by ECN and HydrOcean
  - Improved SPH solvers
    - ★ Riemann solvers for stability
    - ★ Renormalization for accuracy
  - High Parallel efficiency
    - ★ domain decomposition (MPI comm.)
    - ★ Efficient scalability (linear scalability up to 40000 cores / 1 billion particles)
    - ★ Variable-h capability
    - ★ 3D complex geometries/domains











Forcing procedure

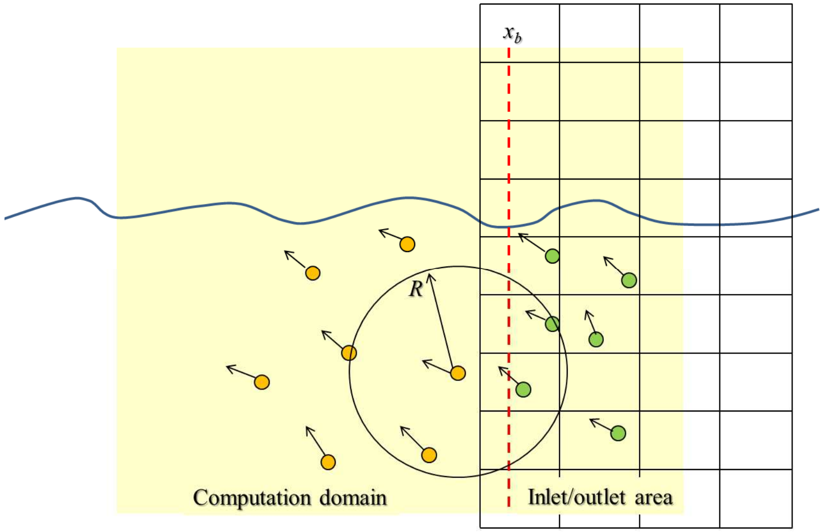
- Imposition of incident field

Free standard particles

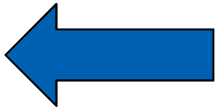
- ➢ Standard SPH scheme
- ➢ Standard flux interactions with dummy particles

Dummy particles in the inlet/outlet area

- ➢ Pressure, velocity from potential solution
- ➢ Position updated with incident velocity



Incident waves



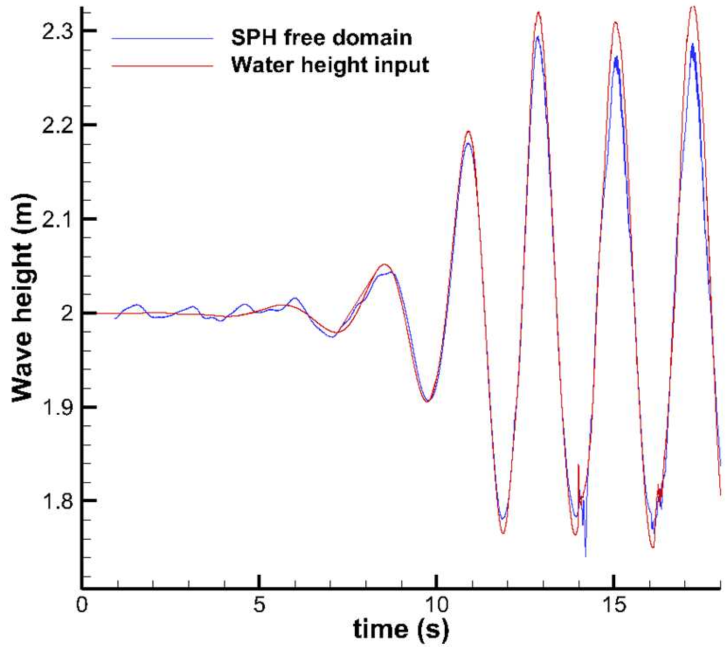
★ No remeshing

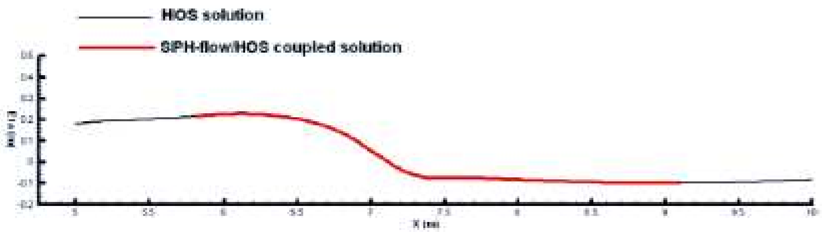
★ Enough particles at start time in the buffer zone is required

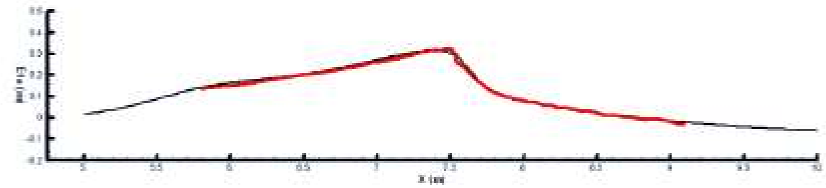
★ Vitalization/unvitalization of particles through inlet/outlet boundary

Numerical simulation of Greenwater event

- Free surface elevation
  - Reproduction of HOS signal along the ship in the undisturbed area
  - No phase shifting of SPH/reference HOS
  - Small damping



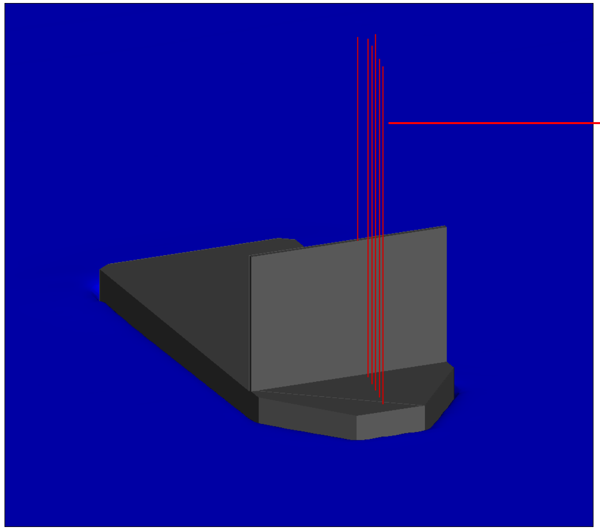




Numerical Simulation of a Greenwater event

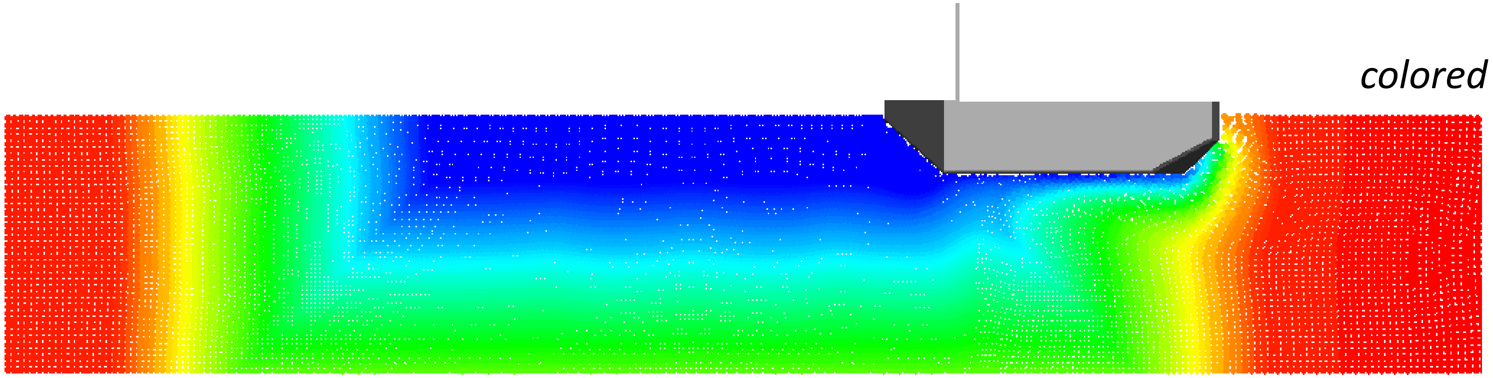
Numerical simulation of Greenwater event

- Numerical Set-up
  - dx = 0.01 m
  - ~ 250 neighbours
  - L/dx ≈ 100 (L = deck width)
  - λ/dx ≈ 750 (λ = wave length)
  - ~ 1.5 millions particles
  - h-variable discretisation
  - Use of 512 cores



wave probes

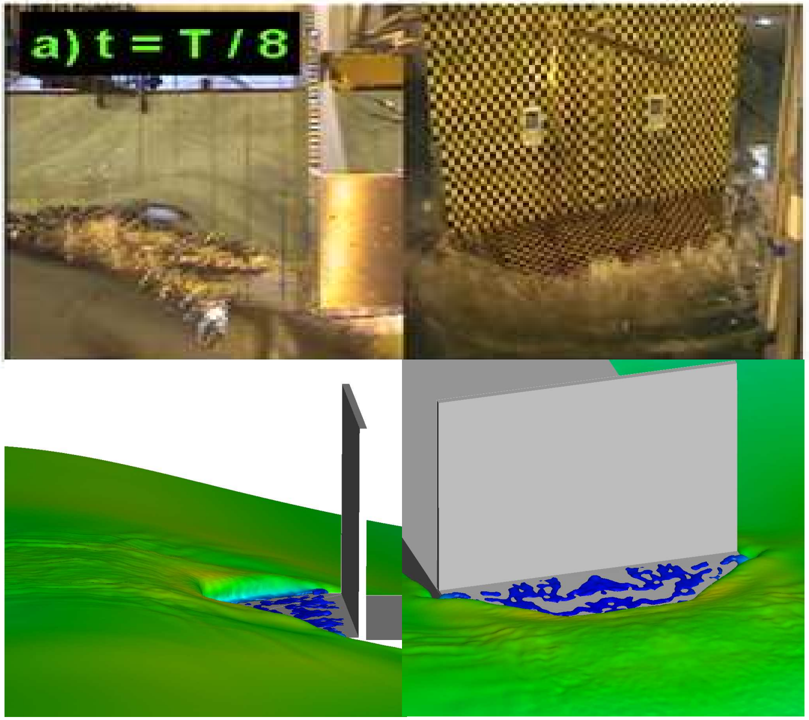
colored according to h



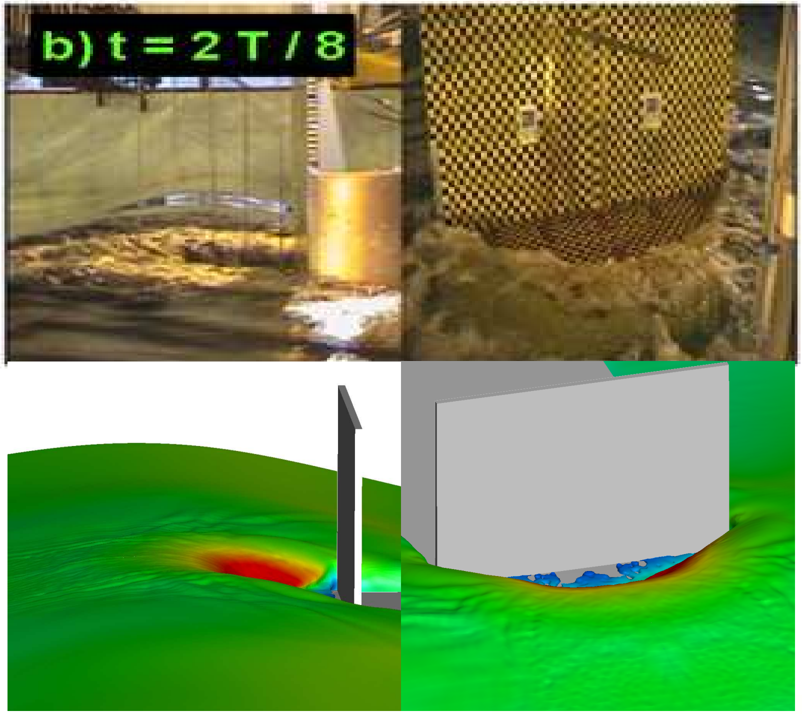
Numerical simulation of Greenwater event

- Qualitative description

Incident wave exceeding freeboard



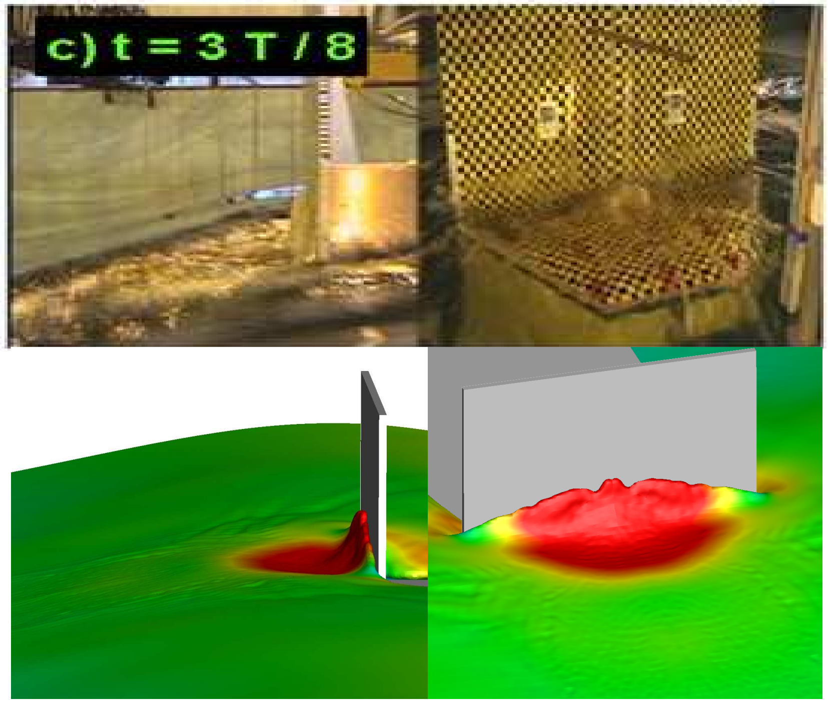
Impact of the plunging jet, Flooding of lateral flows



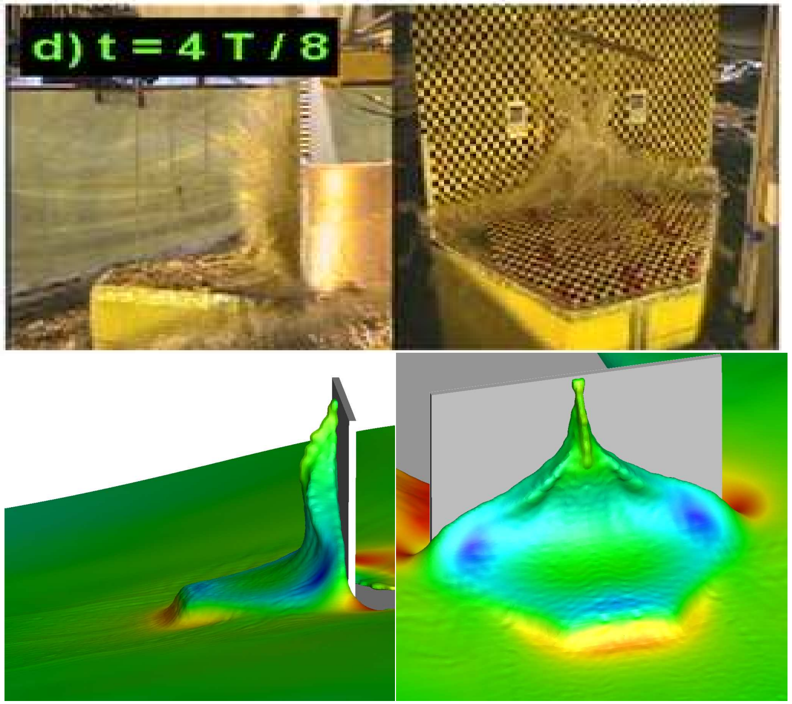
Numerical simulation of Greenwater event

- Qualitative description

Converging flow impacts the wall



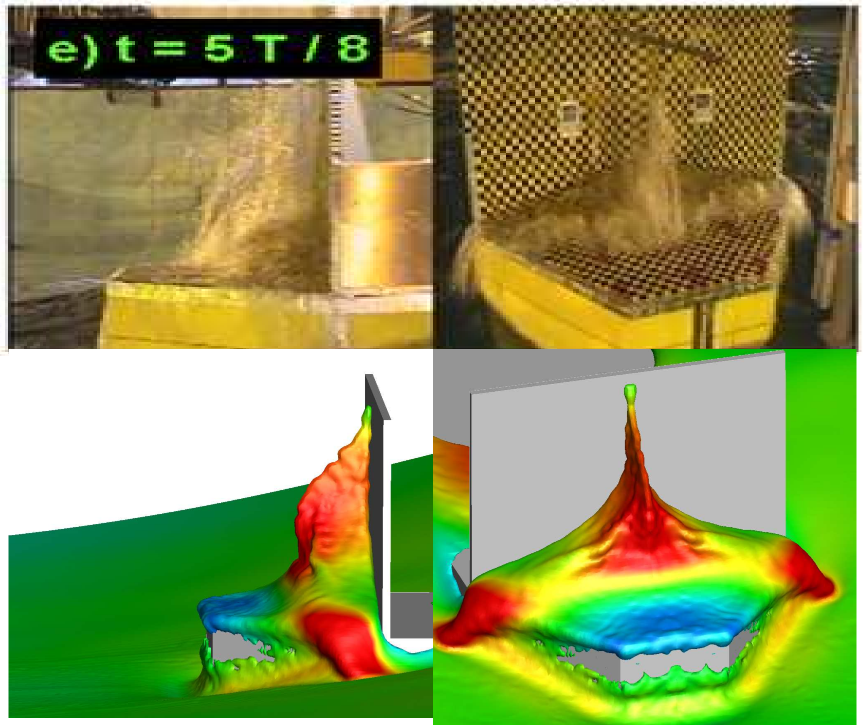
Flow is deviated vertically



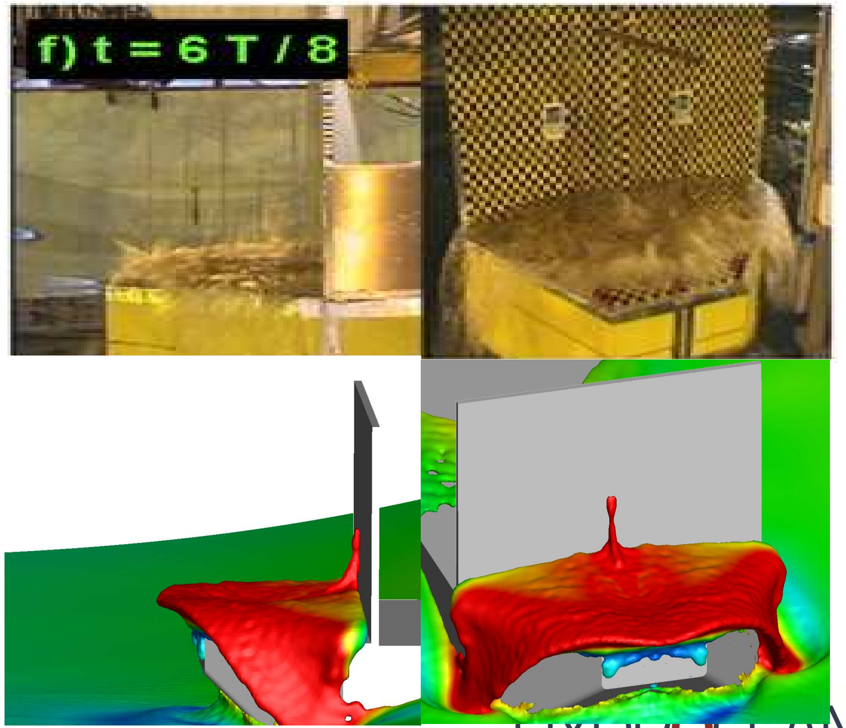
Numerical simulation of Greenwater event

- Qualitative description

Collapse of the water column

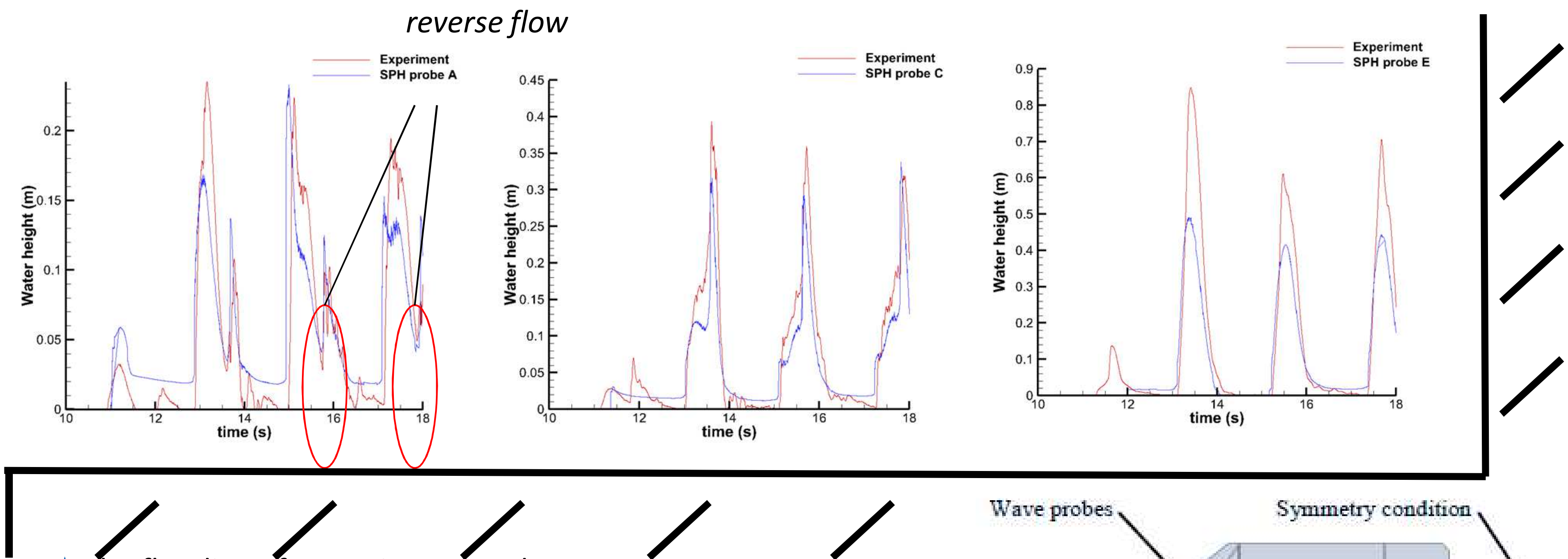


Water escape



Numerical simulation of Greenwater event

- Water elevation on deck



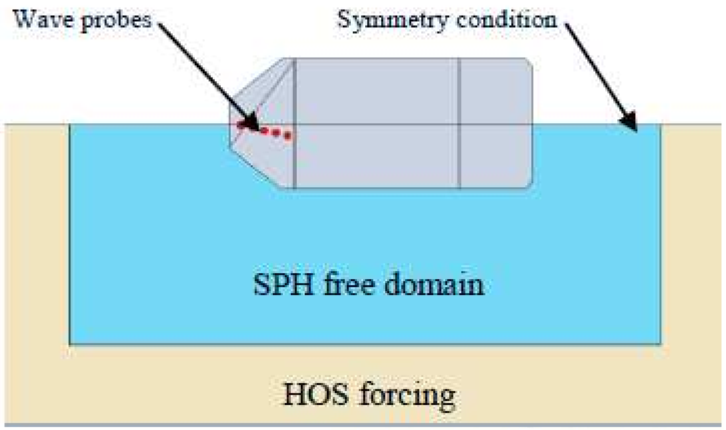
★ The flooding of water is captured

★ Impact time occurrences well captured

★ Good estimation of water elevation near the ship fore

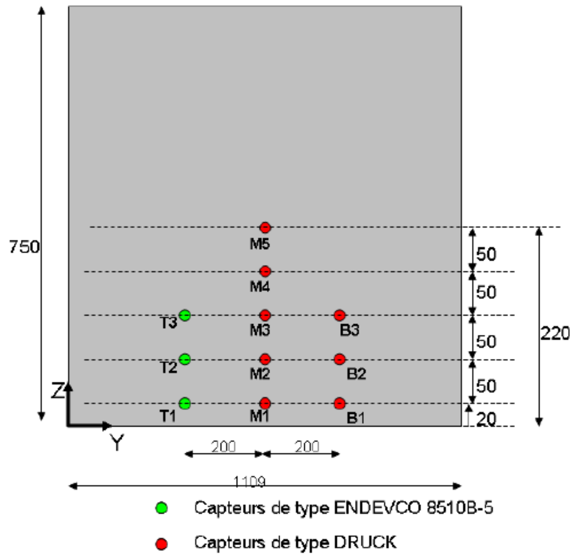
★ Progressive damping of the water elevation on deck

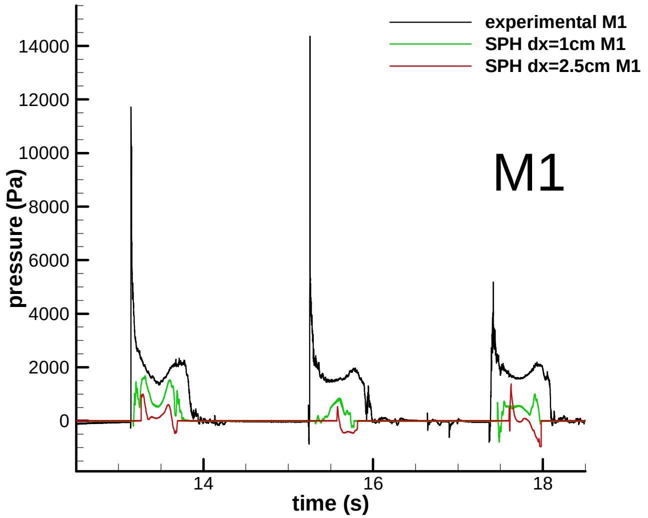
★ Initial conditions for wall impact not met

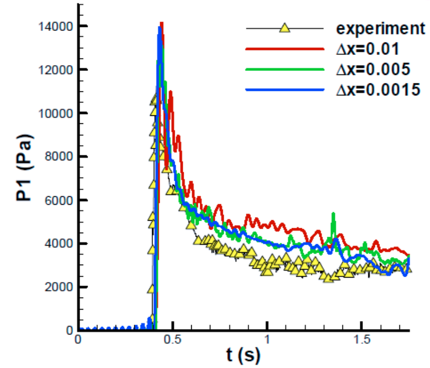


Numerical simulation of Greenwater event

- Pressure probes on breakwater

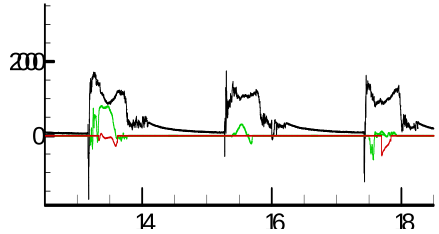




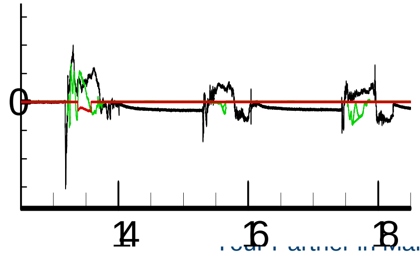


Dam break on an obstacle

M3



M4



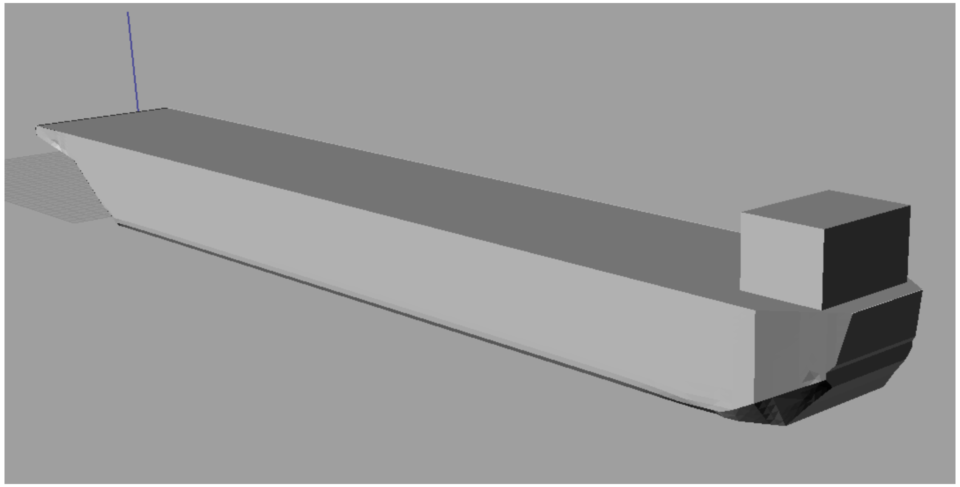
-Good synchronisation
-Impact pressures not captured
-Need of higher refinement

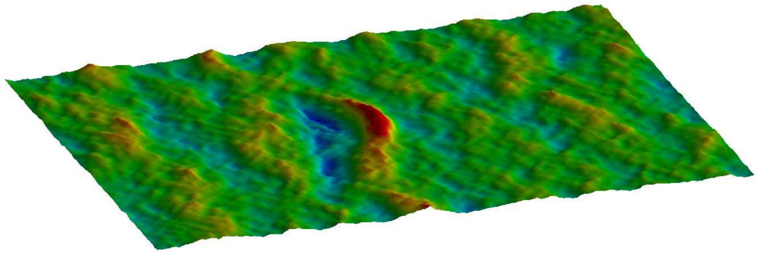
Industrial application

Industrial application

- Selection of greenwater event

  - Irregular sea state statistically described as (Hs, Tp)
  - How to determine most severe conditions?
  - Not possible with CFD
  - Use of 'old' linear potential solvers





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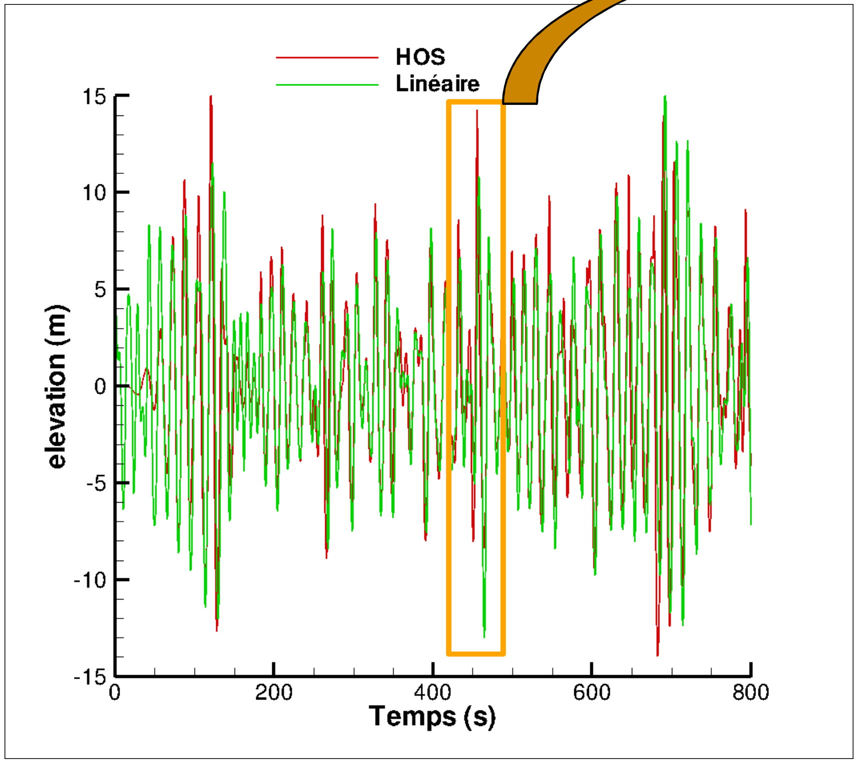
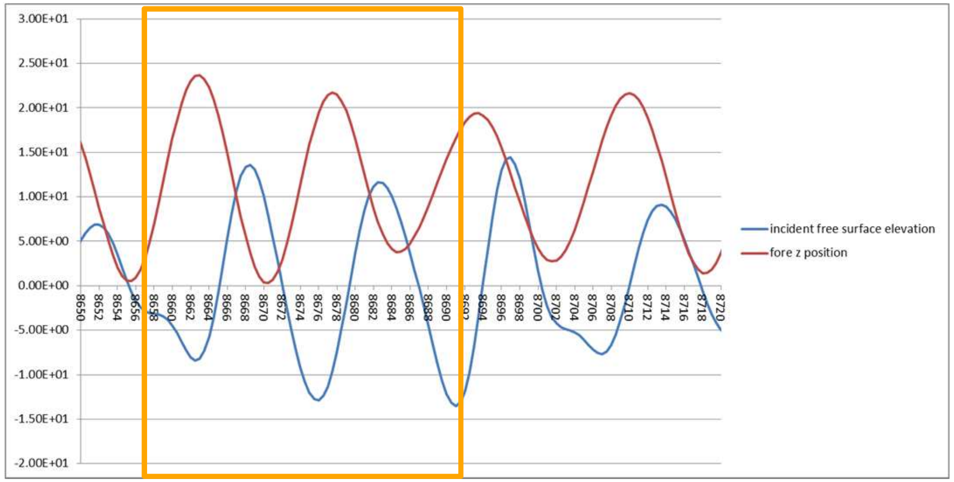
Industrial application

- Selection of greenwater event



Linear seakeeping solver



HOS/SPH-flow

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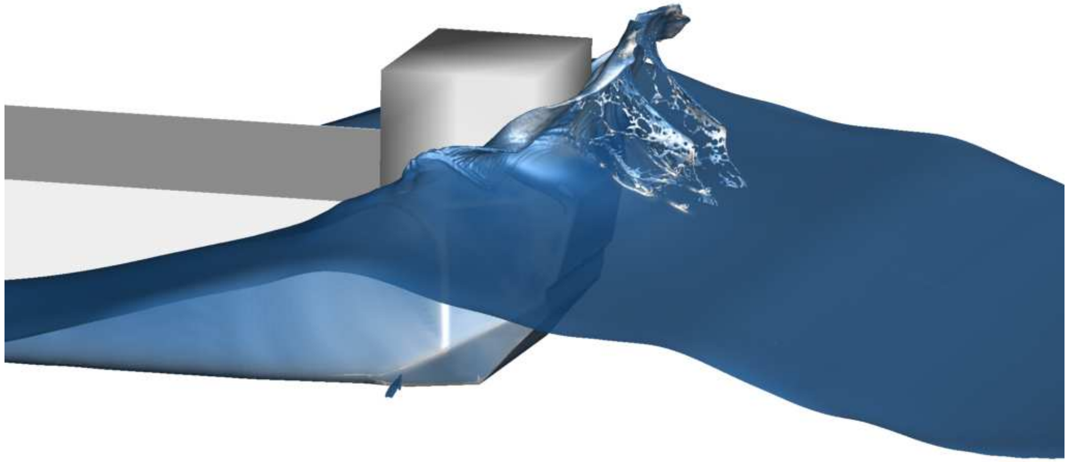
Industrial application

- Selection of greenwater event



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Conclusions and perspectives

Conclusions

- wave-structure interactions simulation
  - forcing procedure between non-linear potential flows and SPH is effective
  - uses the advantages of each solver, without drawbacks for simulations with no diffracted field at open boundaries

- Numerical simulation of greenwater events:
  - propagation phase: no phase shifting, small damping
  - Qualitative behaviour of deck flooding is captured
  - Kinematics OK, dynamics (pressure) not => Need of higher refinement => local refinement
  - Still a very demanding problem in terms of CPU