FLARE
FLOODING ACCIDENT RESPONSE

Webinar on
Numerical flooding simulation tools in realistic large-scale flooding scenarios

Validation of numerical tools against model tests: a benchmark study

3 March 2022

The project has received funding from the European's Horizon 2020 research and innovation programme (Contract No.: 814753)

FLARE benchmark study: structure

Flooding fundamentals up/down flooding and progressive flooding in captive model tests	
Cruise ship: Transient and progressive flooding in calm water	**Ropax:** Transient flooding in calm water
Transient and progressive flooding in beam seas	Transient and gradual flooding in beam seas

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Contributors

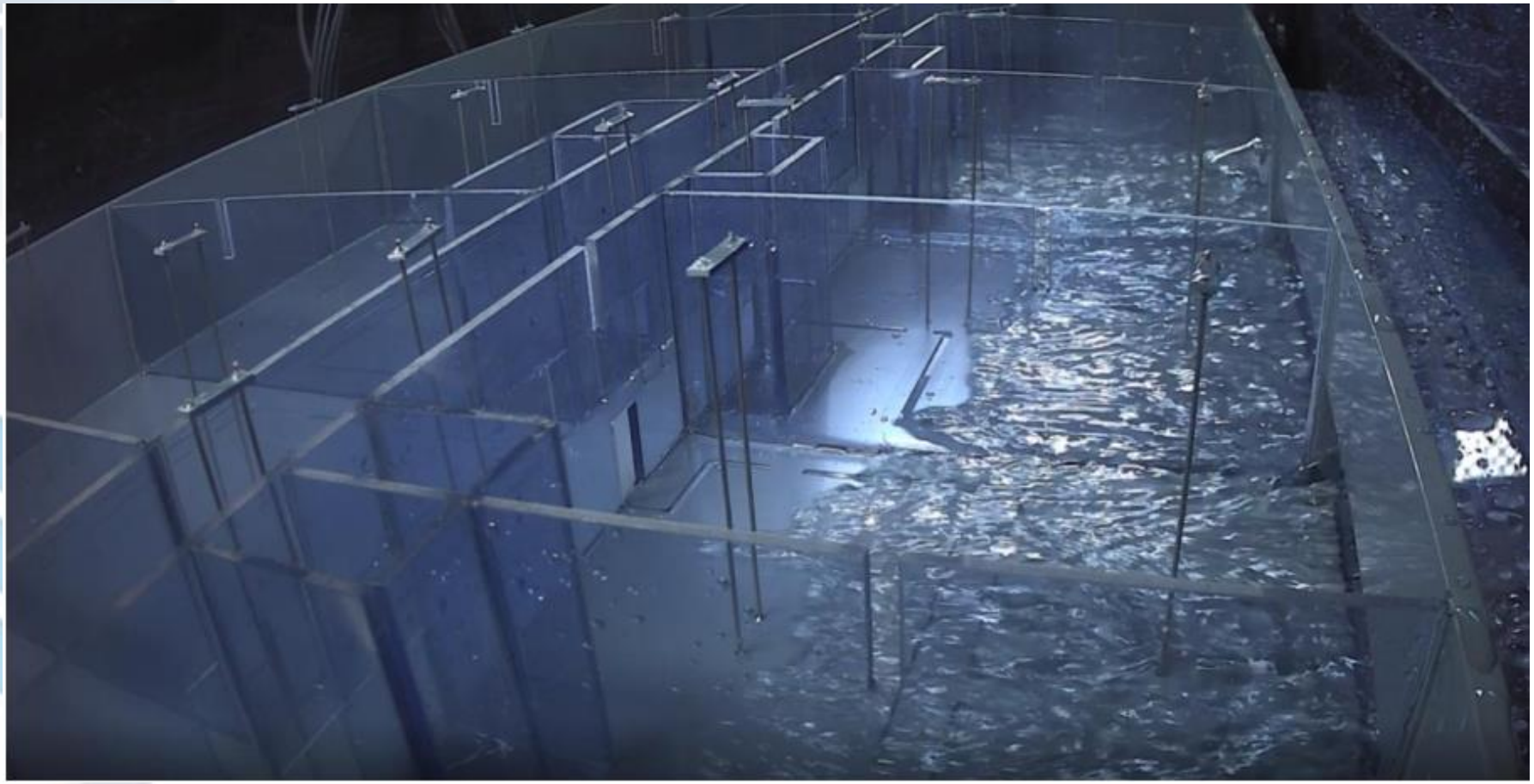
- Pekka Ruponen & Markus Tompuri, NAPA, Finland
- Rinnert van Basten Batenburg, Henry Bandringa & Riaan van't Veer, MARIN, The Netherlands
- Luca Braidotti, UNITS, Italy
- Shuxia Bu, CSSRC, China
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- Gyeong Joong Lee, KRISO, Korea
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- Alistair Murphy, BROO, UK
- Maria Acanfora & Gennaro Rosano, UNINA, Italy
- Eivind Ruth, DNV, Norway
- Petri Valanto, HSVA, Germany

11 institutions from 8 different countries have contributed, at least to some parts of the benchmark study, using 12 codes

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Flooding fundamentals

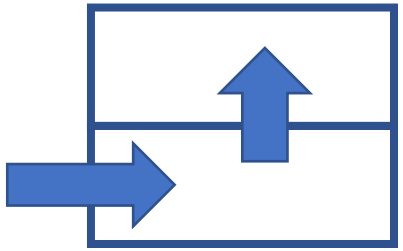




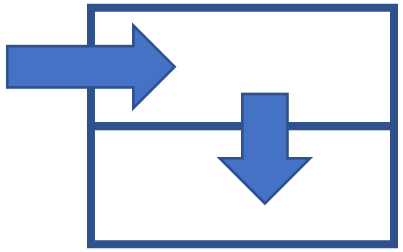
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Flooding fundamentals

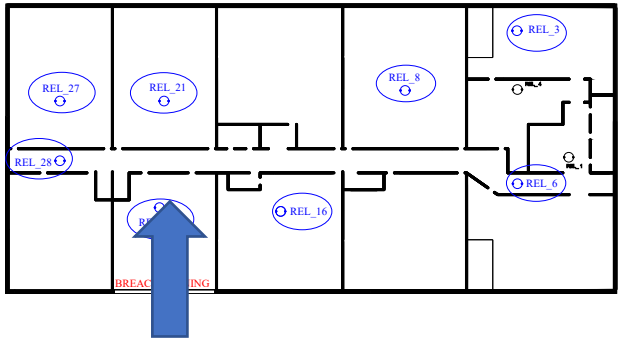
Up-flooding:



Down-flooding:



Progressive flooding on a deck of a cruise ship:



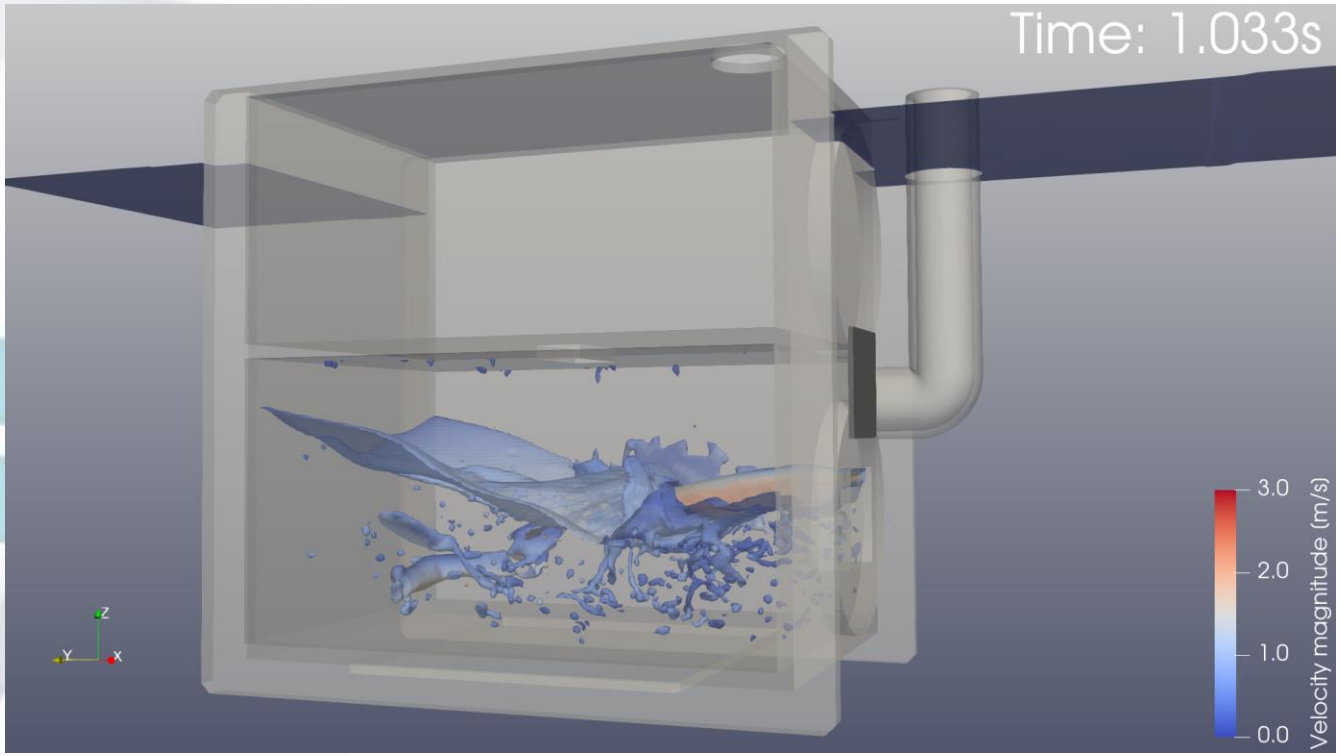
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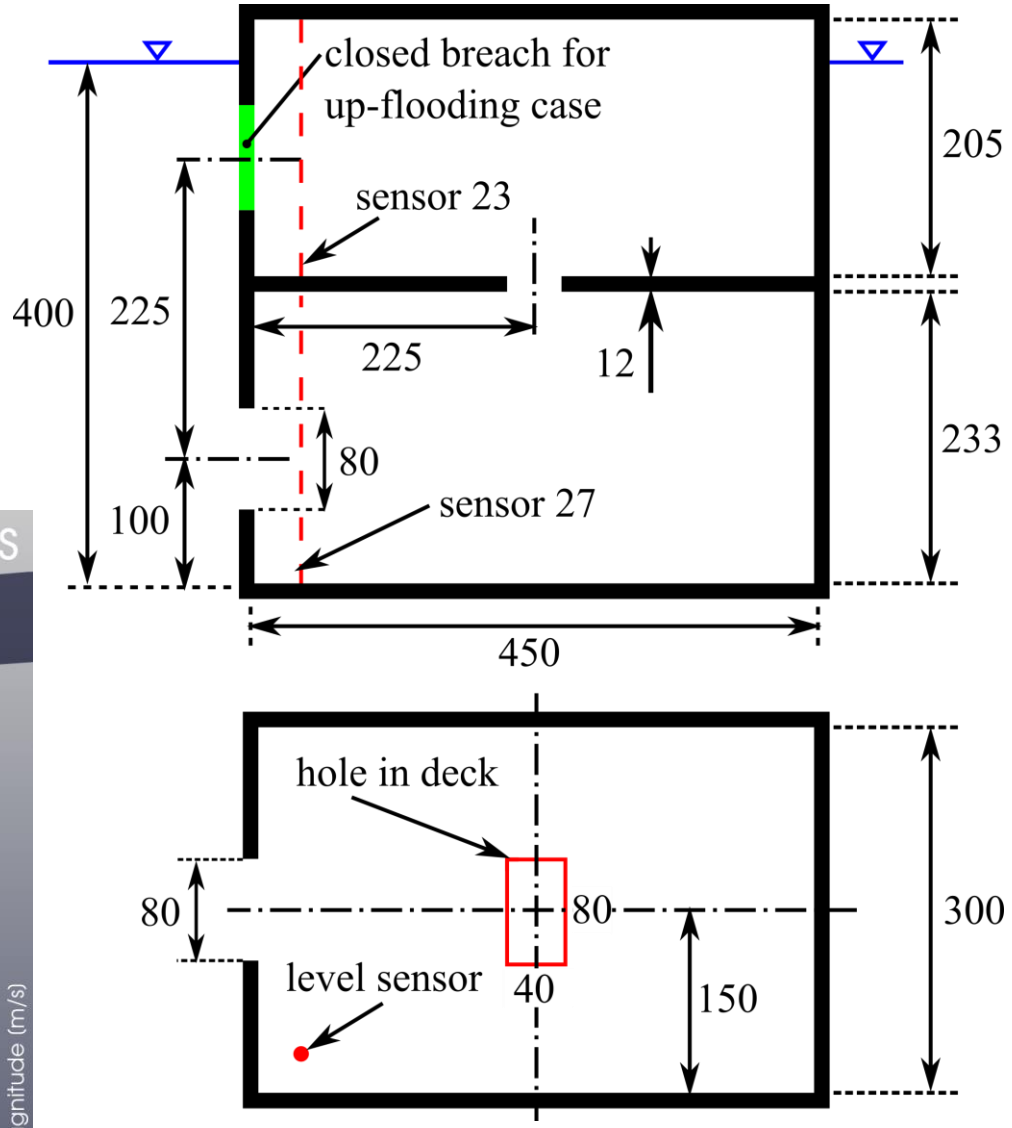
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Up-flooding

Fixed floating position; Draft 400 mm

Snapshot from ComFLOW simulation by MARIN:

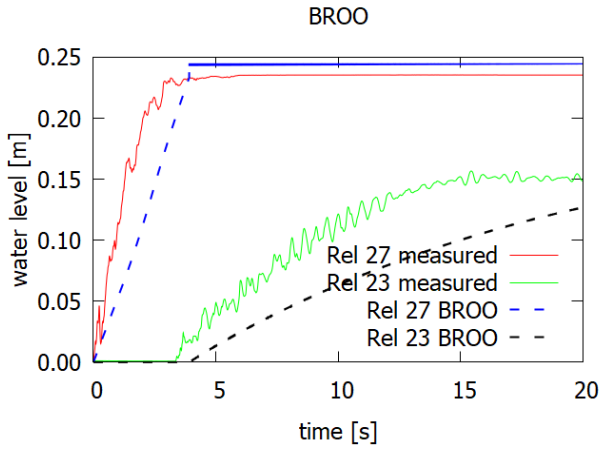


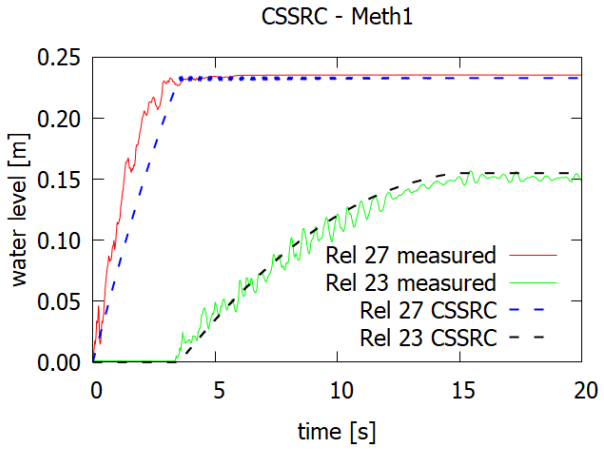


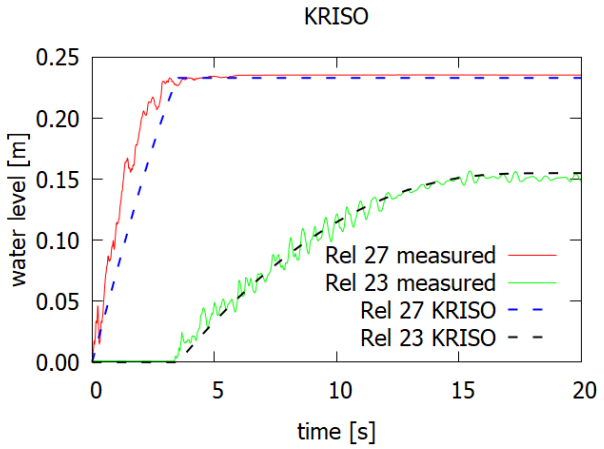
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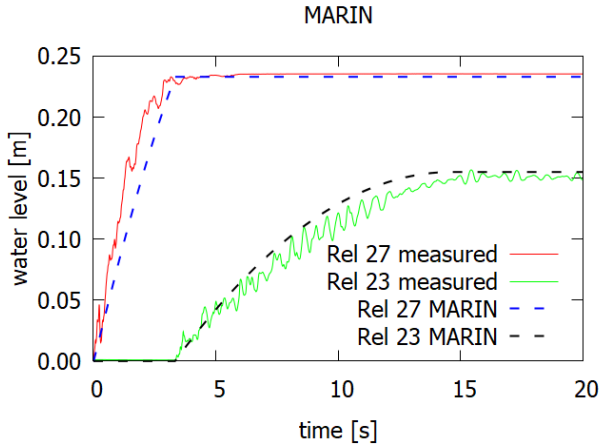
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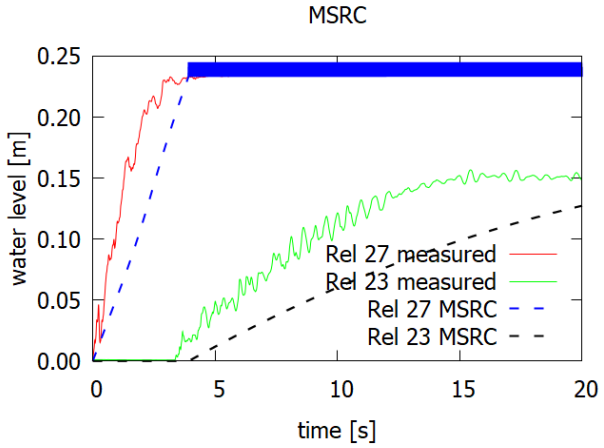
Up-flooding results

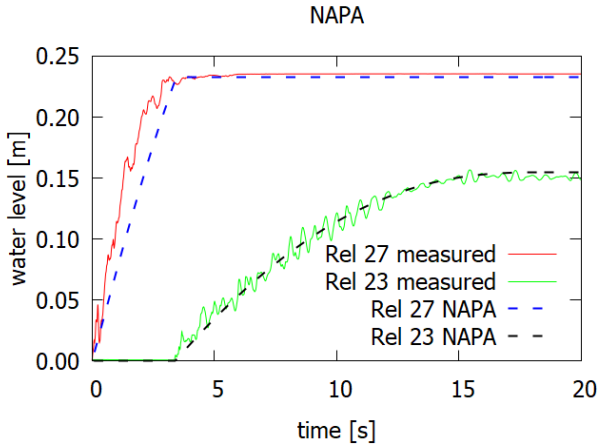


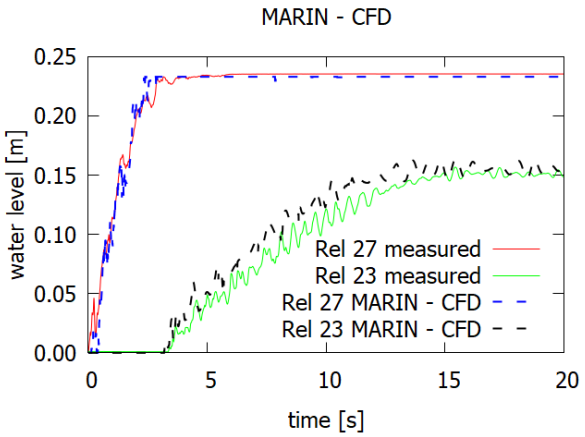


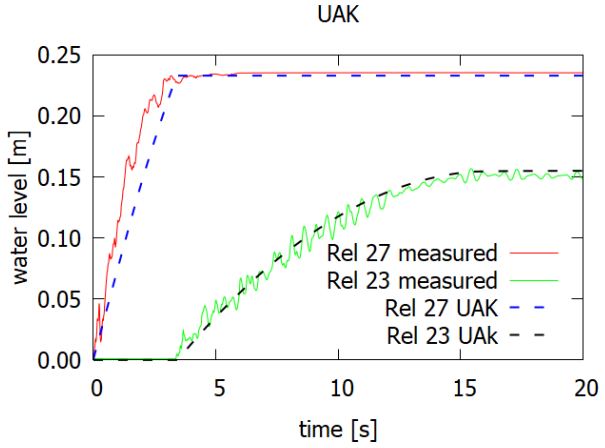


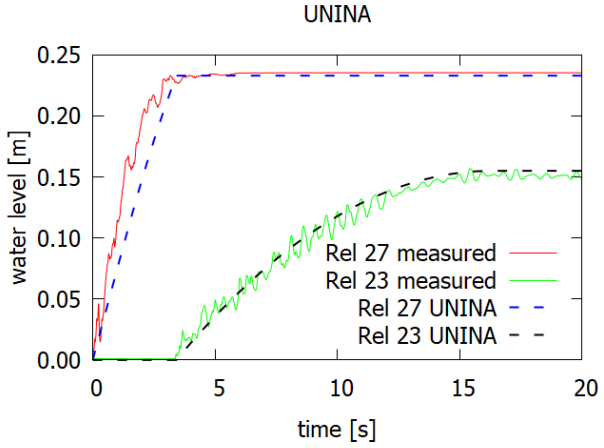


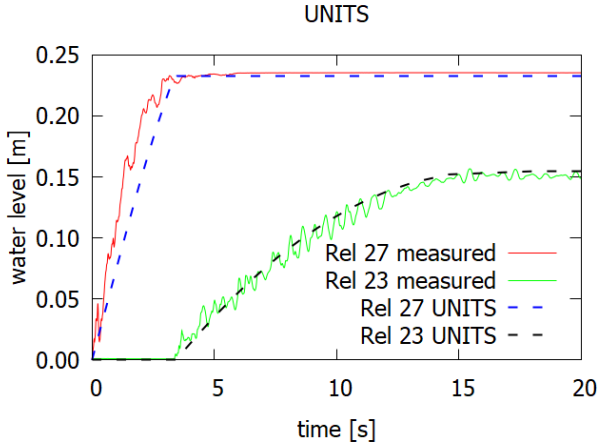












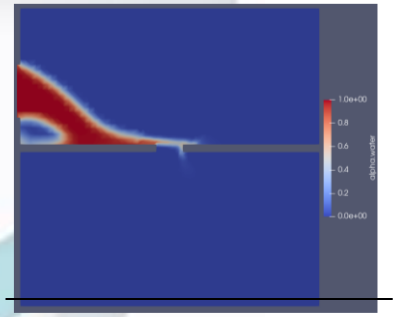
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Down-flooding

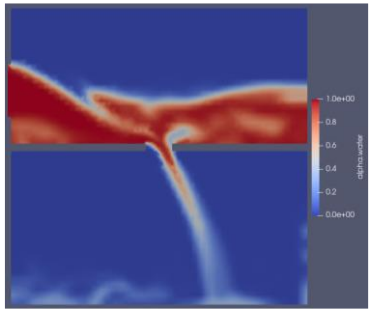
Same compartment geometry

Hole in the tween deck is smaller 40 mm x 40 mm

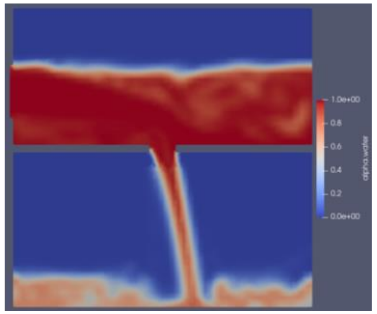
Time = 0.2 s



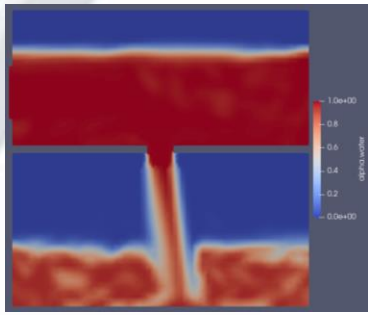
Time = 2.0 s



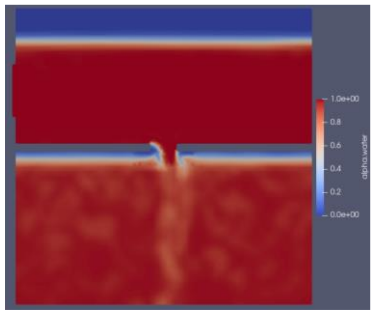
Time = 4.0 s



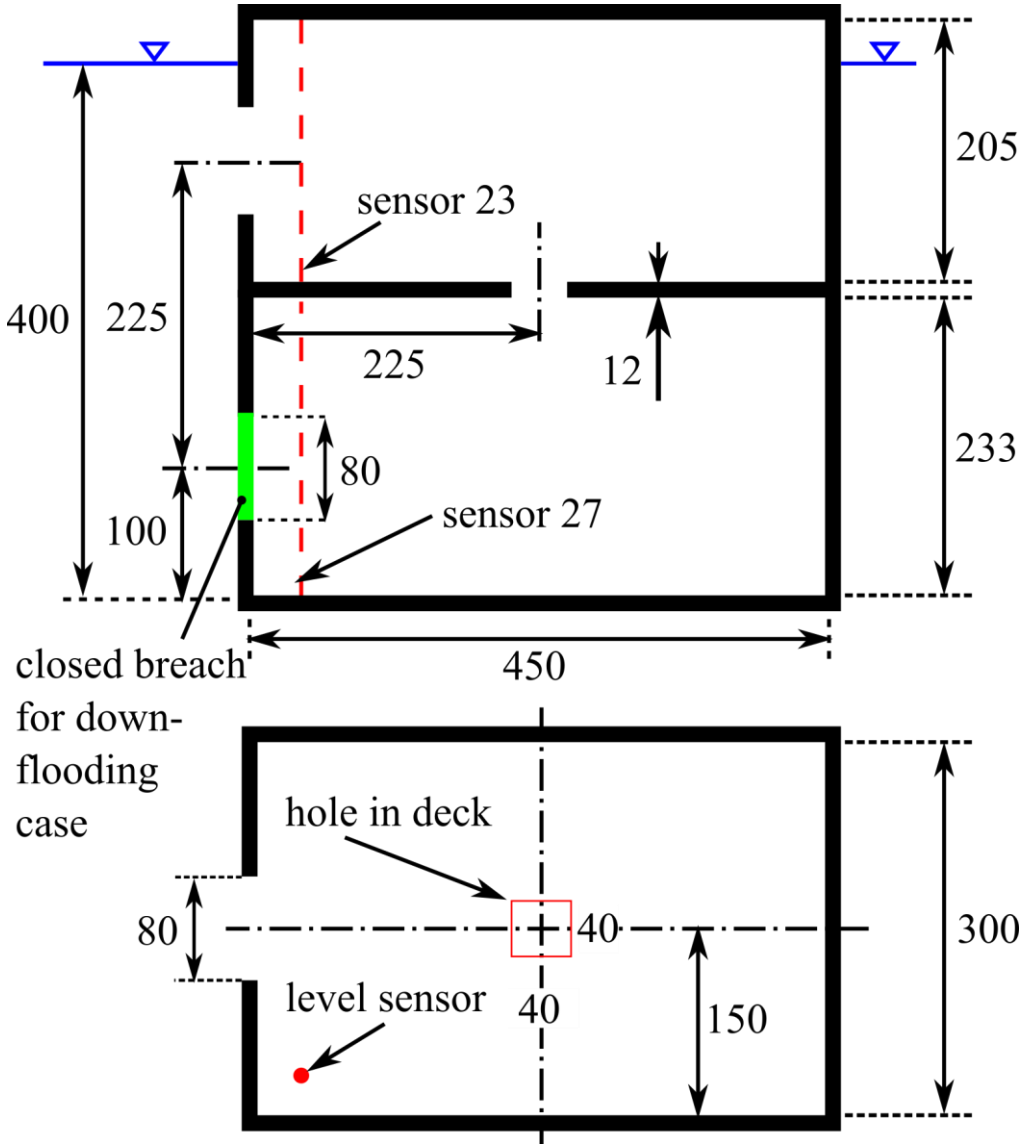
Time = 8.0 s



Time = 20.0 s

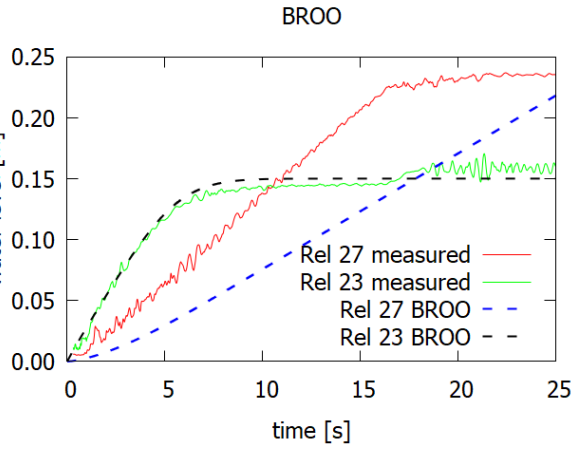


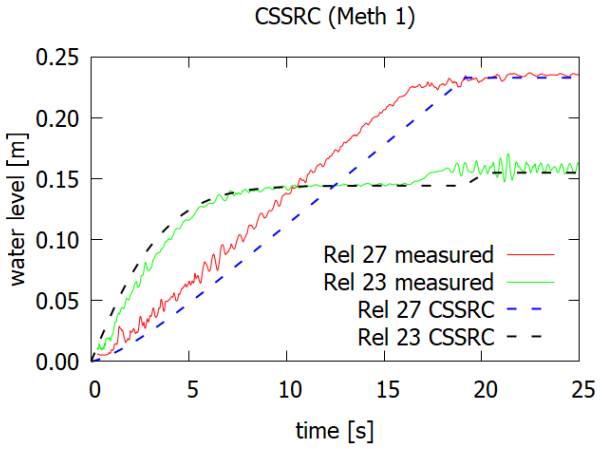
OpenFOAM CFD simulation results from DNV

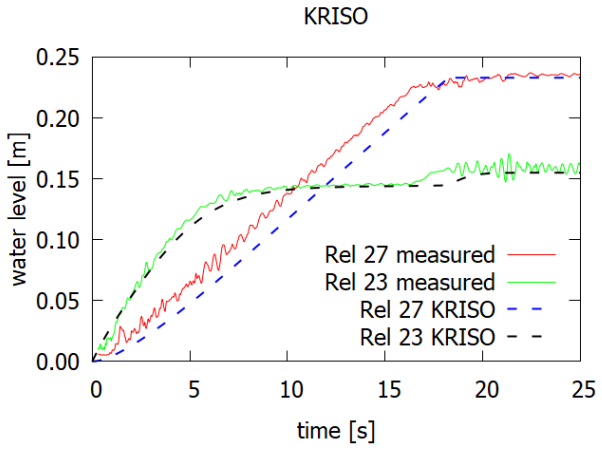


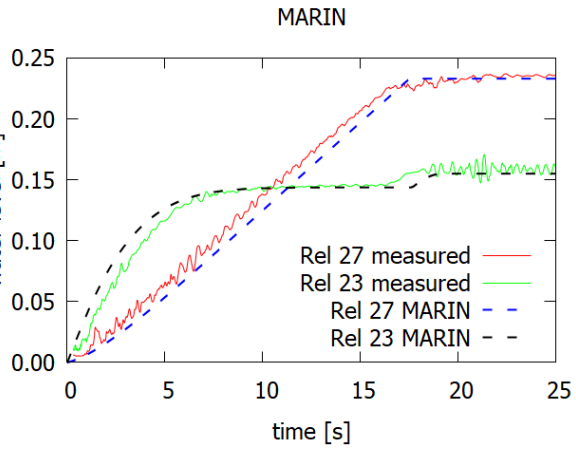
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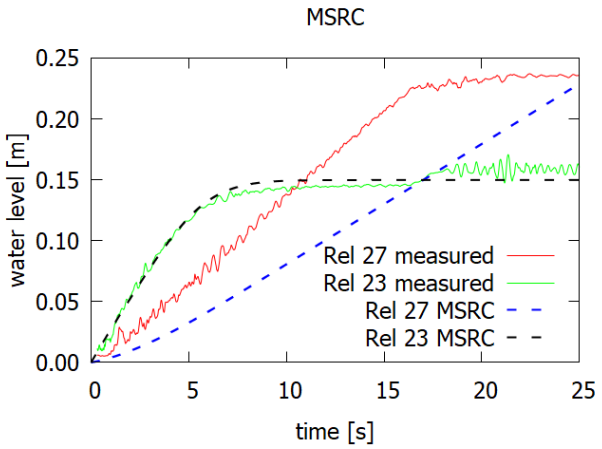
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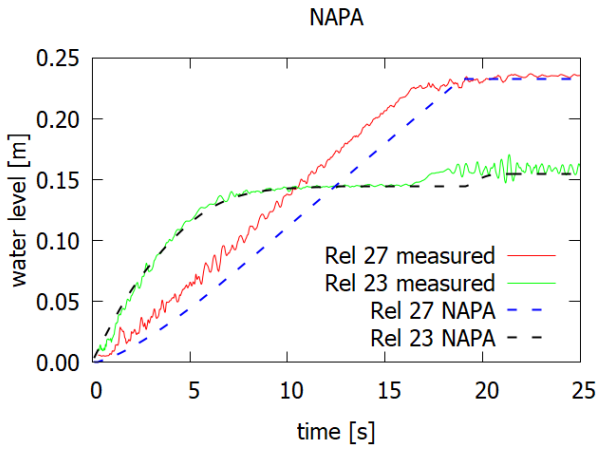


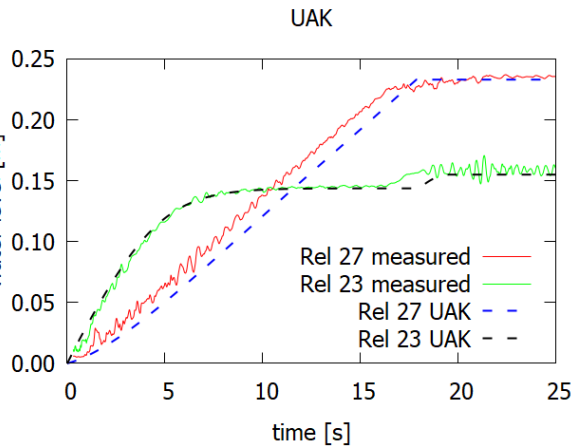


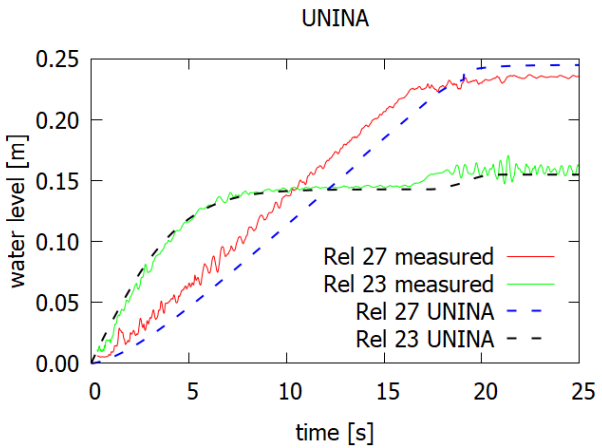


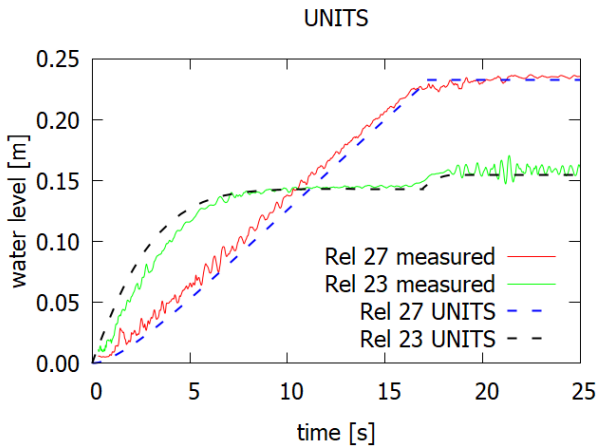












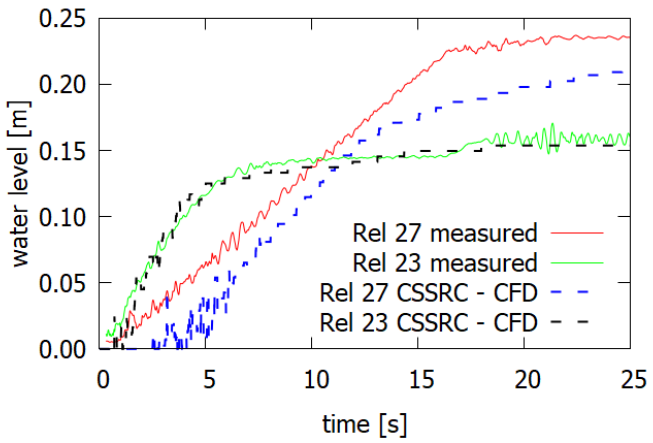
Down-flooding results:

Bernoulli-based codes

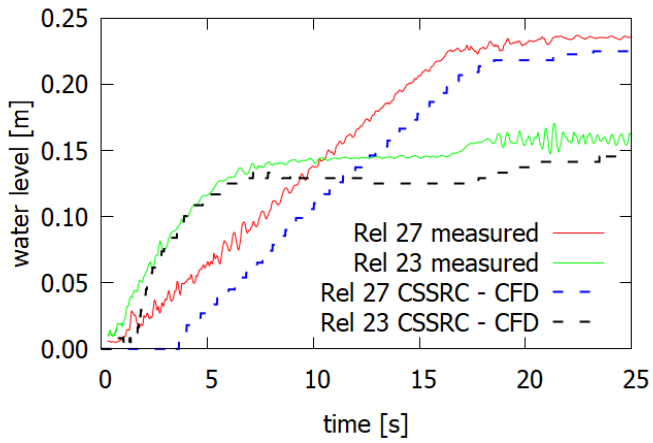
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Down-flooding results: CFD codes

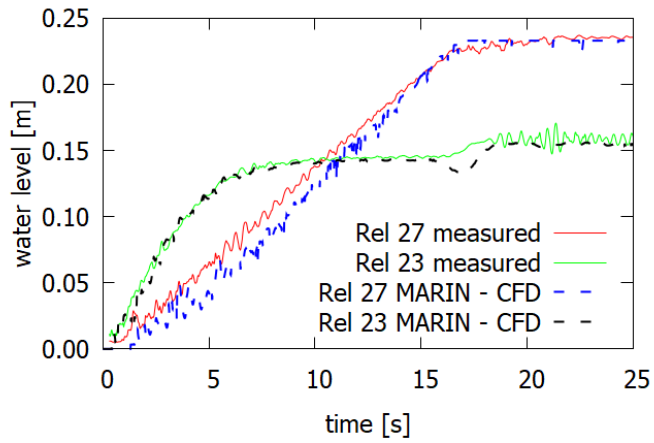
CSSRC - CFD (noslip)



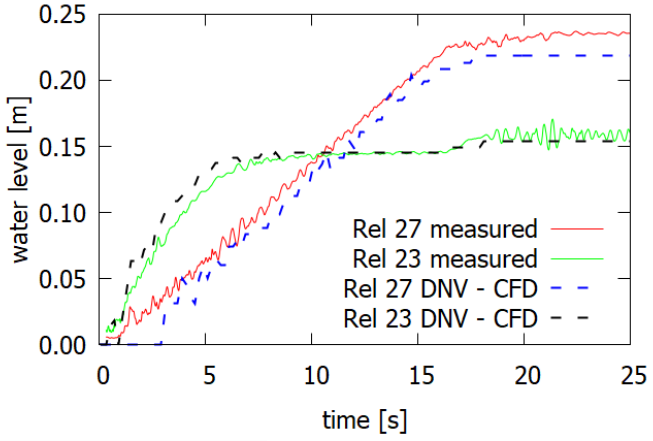
CSSRC - CFD (slip)



MARIN - CFD



DNV - CFD



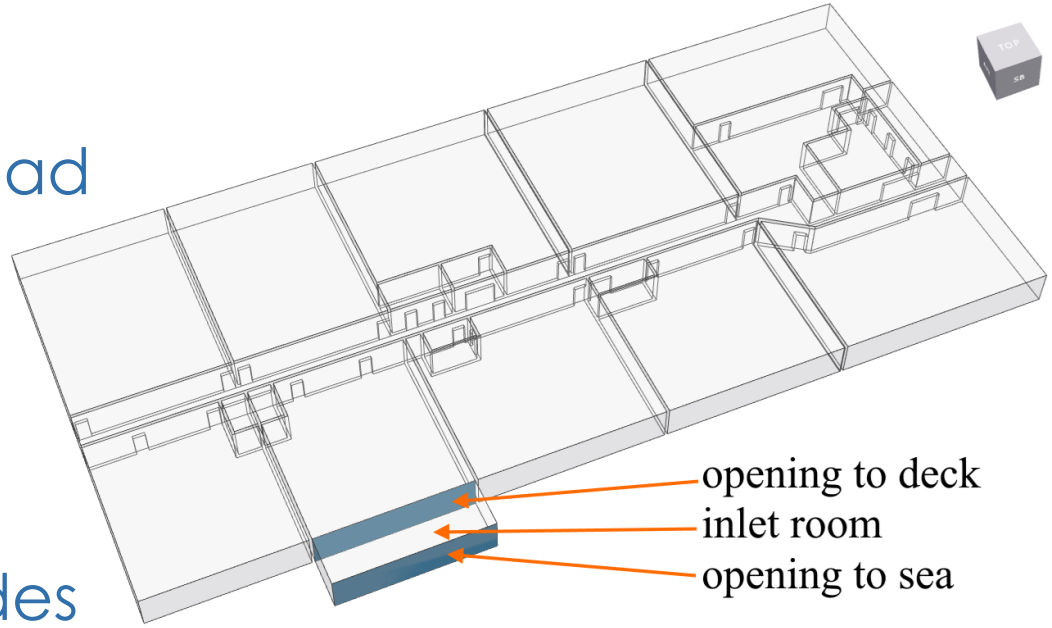
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Deck flooding

Typical arrangement on the bulkhead deck for cruise ships

Characterized by the long service corridor



With Bernoulli-based simulation codes a unified modelling was adopted

- Corridor divided into 5 rooms
- Discharge coefficient 1.0 used for artificial openings along the corridor

Model tests by MARIN in scale 1:60 with external water level 30 mm above the deck level

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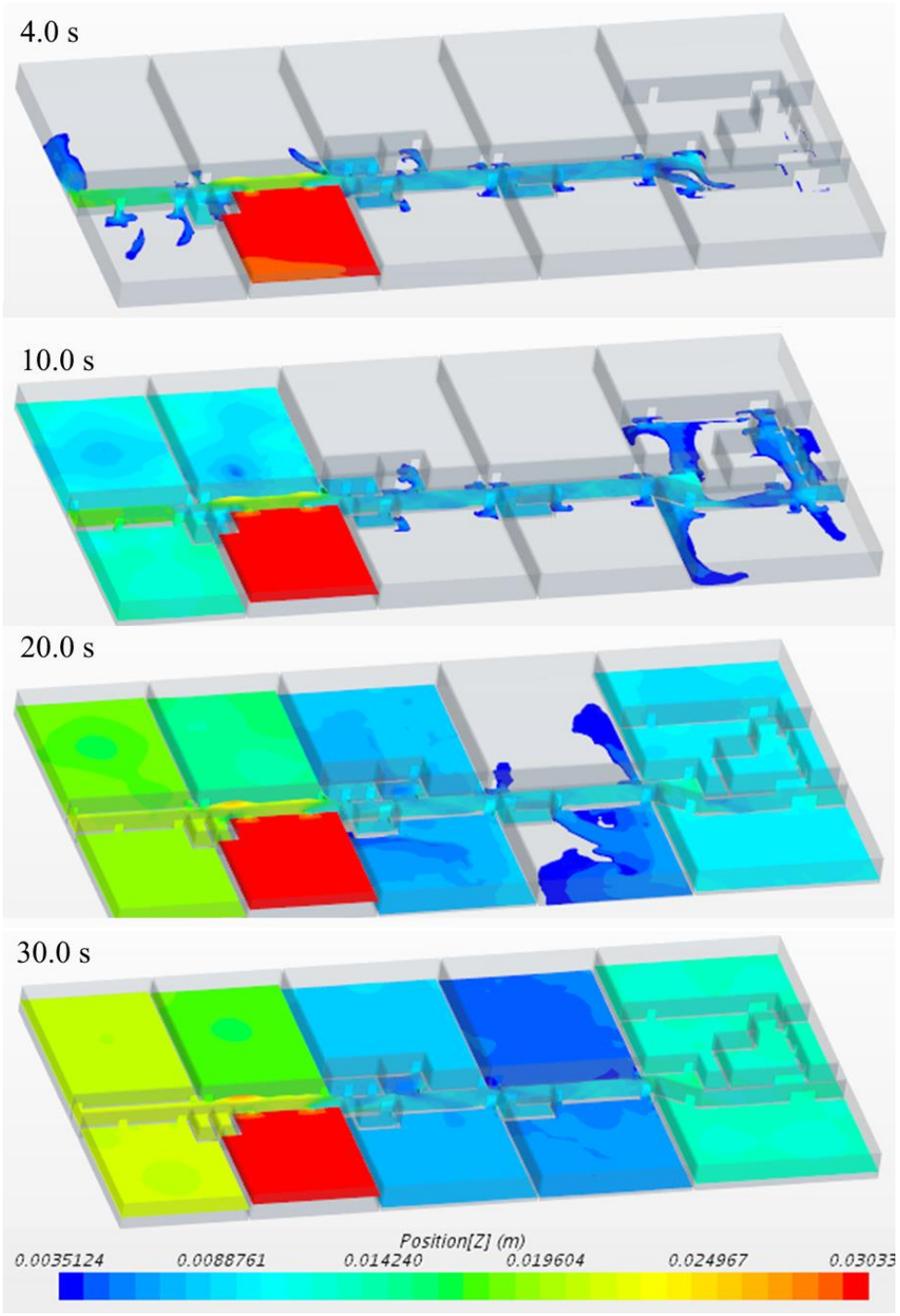
Deck flooding

Flooding propagates along the long corridor

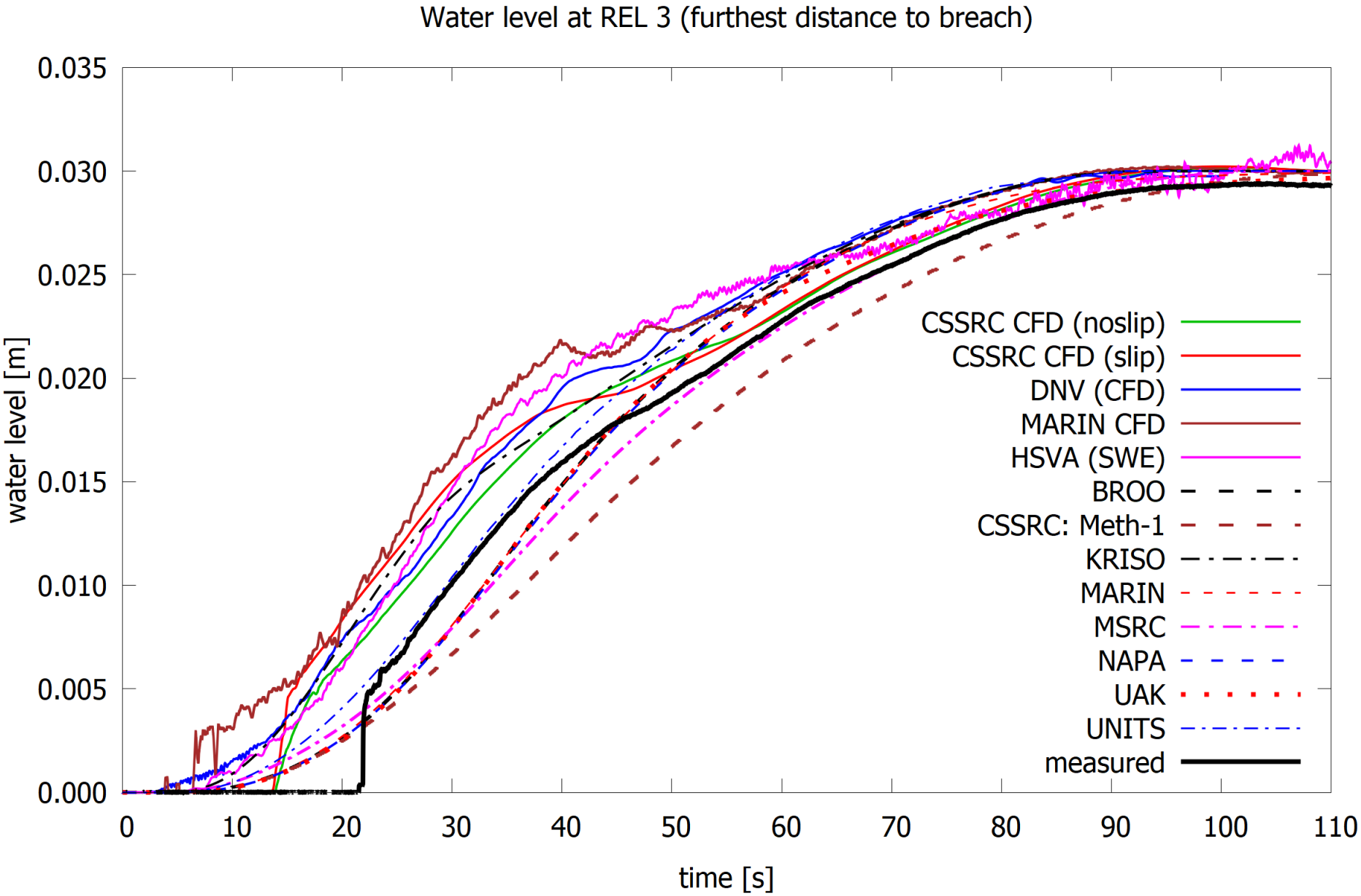
Rooms in the forward and aft ends are flooded first

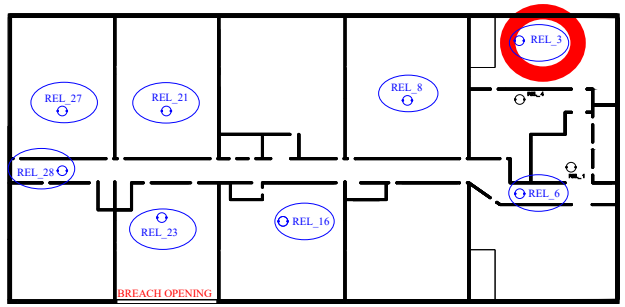
Flooding to rooms in the middle is delayed

- Visualized in the CFD results from CSSRC using Star-CCM+



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Example of results

Large differences with Bernoulli-based codes, although same geometry and input values are used

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Conclusions – flooding mechanisms

Most participants could correctly simulate both up- and down-flooding processes

In the deck flooding case, notable variation in results for was observed

- Also between Bernoulli-based methods using the same modelling practices and discharge coefficients

CFD tools can capture details of the flooding process

- However, the computational performance does not allow for practical applications in ship design

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Cruise ship flooding



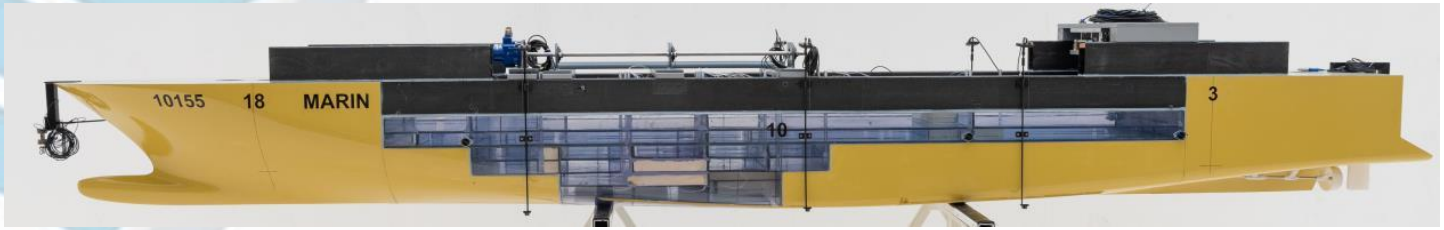
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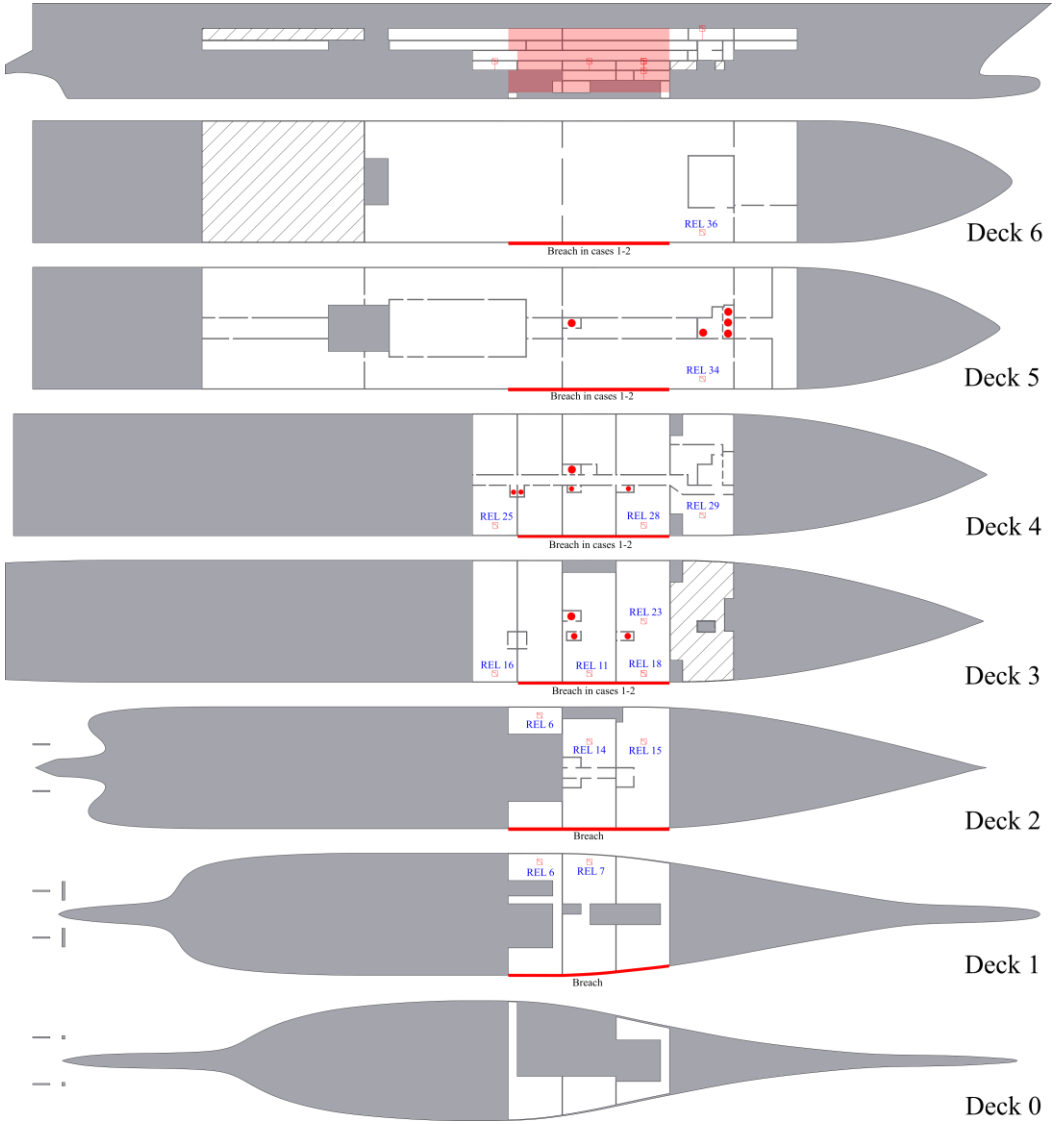
Cruise ship flooding

Transient and progressive flooding

Calm water and beam seas with significant wave height of 4 m

Model tests by MARIN

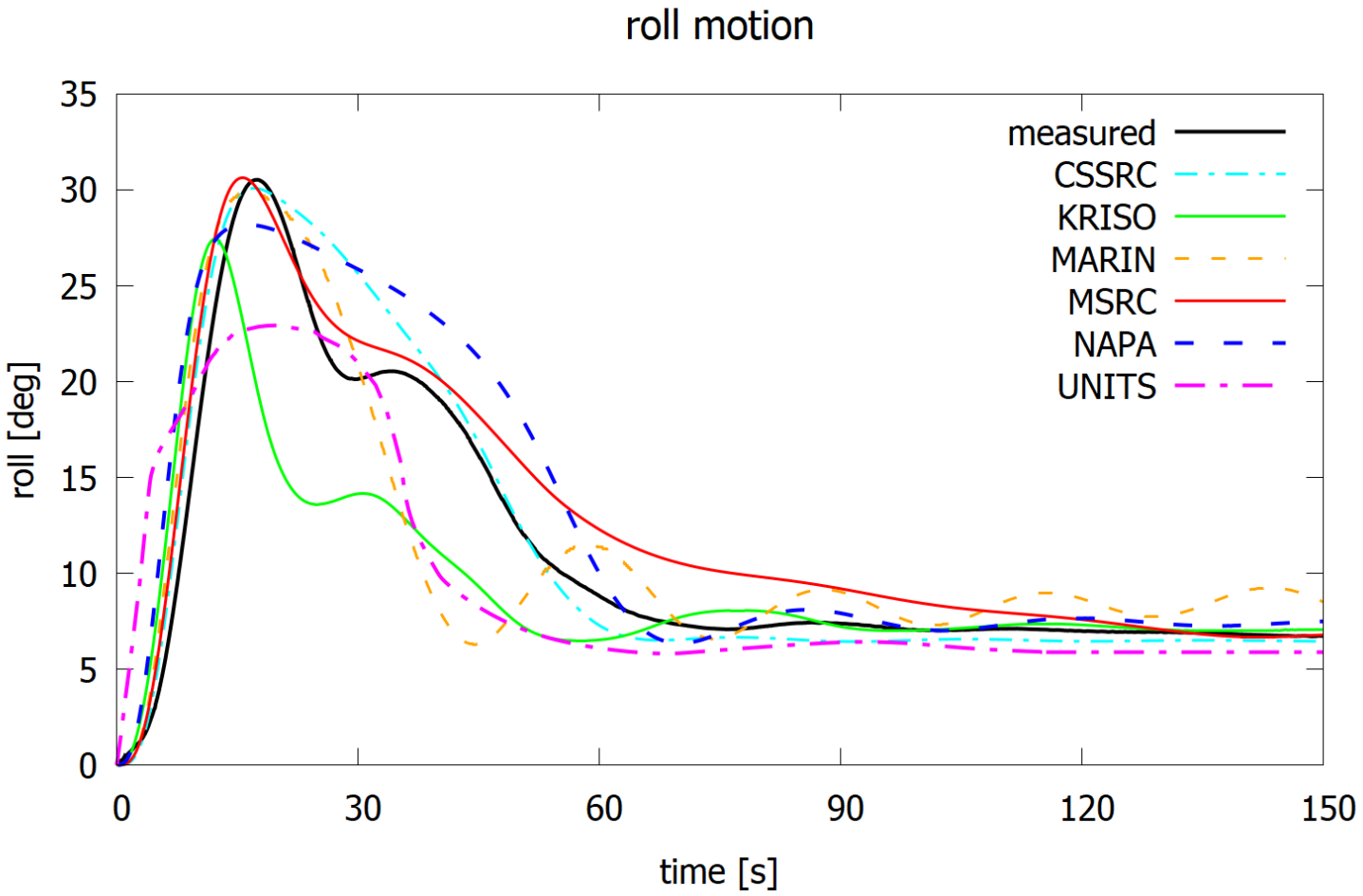




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Cruise ship: transient flooding in calm water

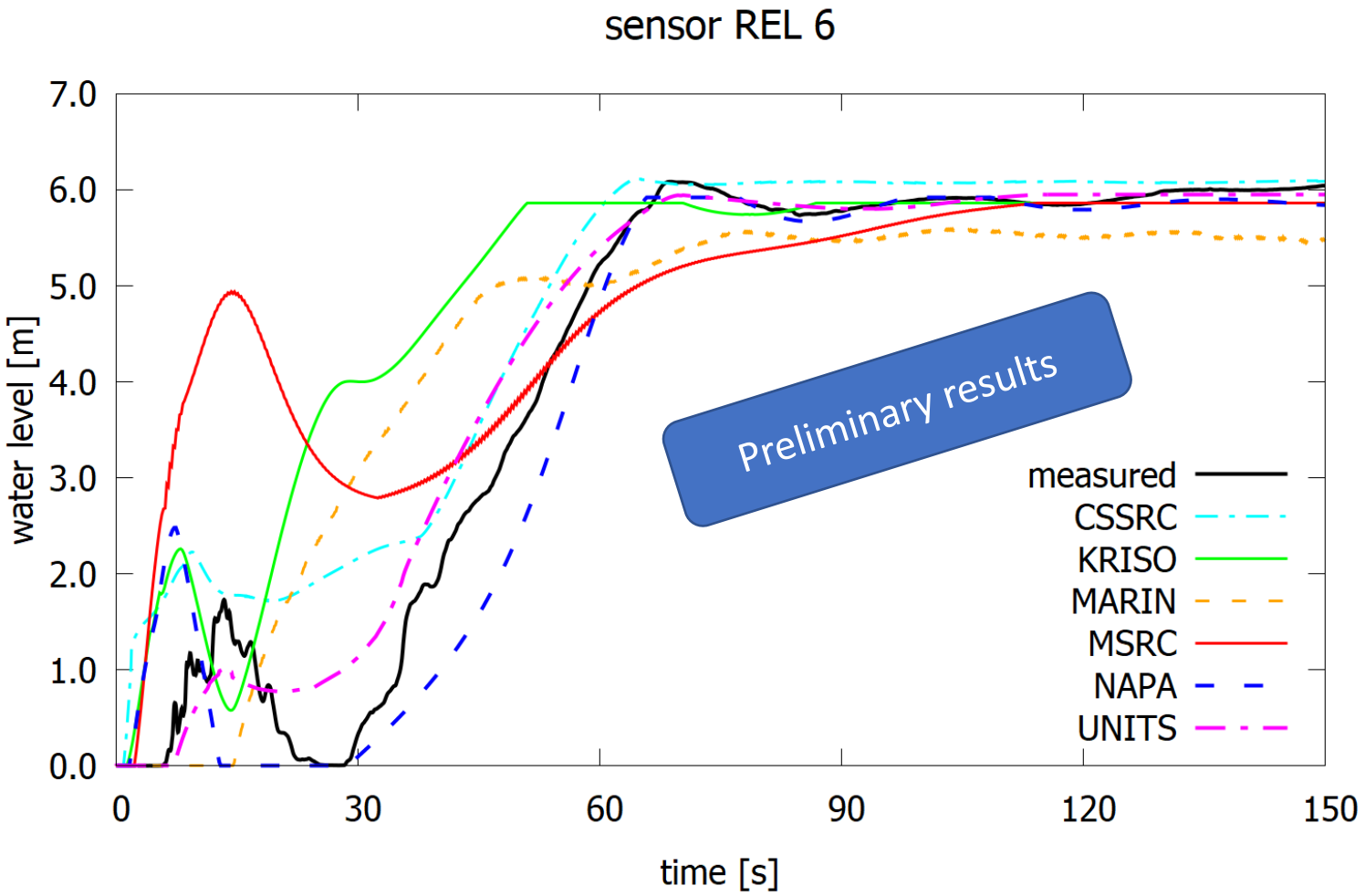


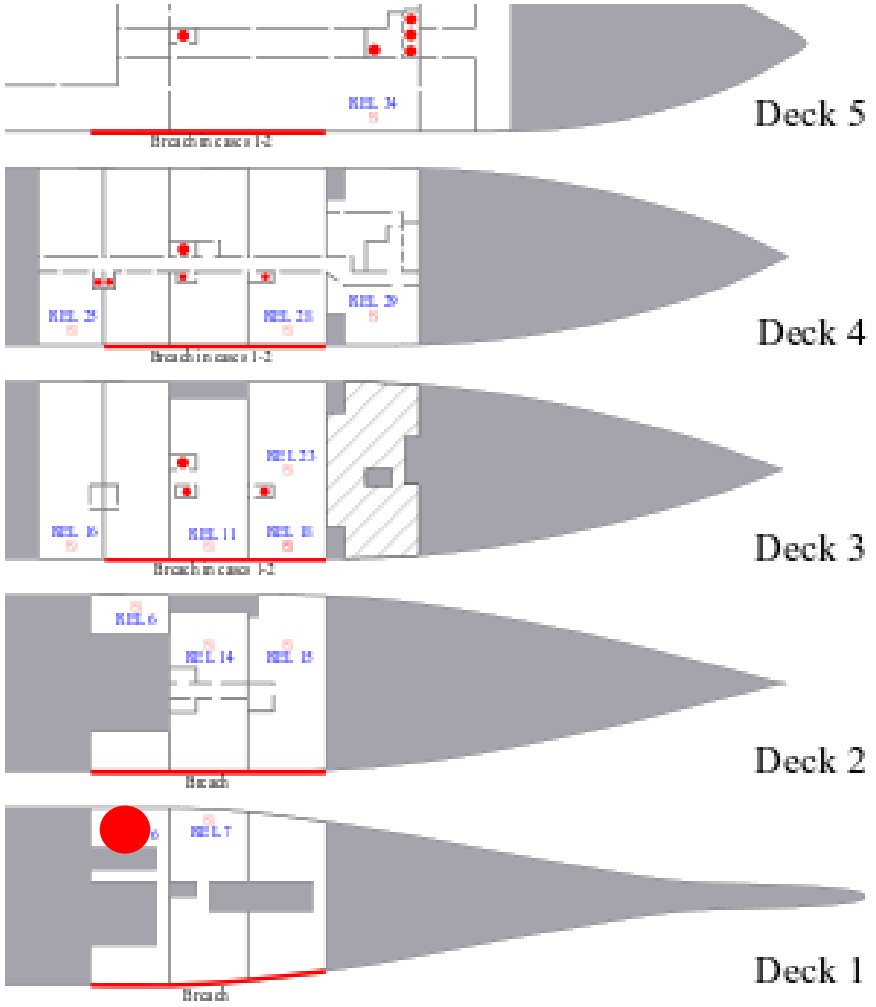
Preliminary results

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Cruise ship flooding: water levels

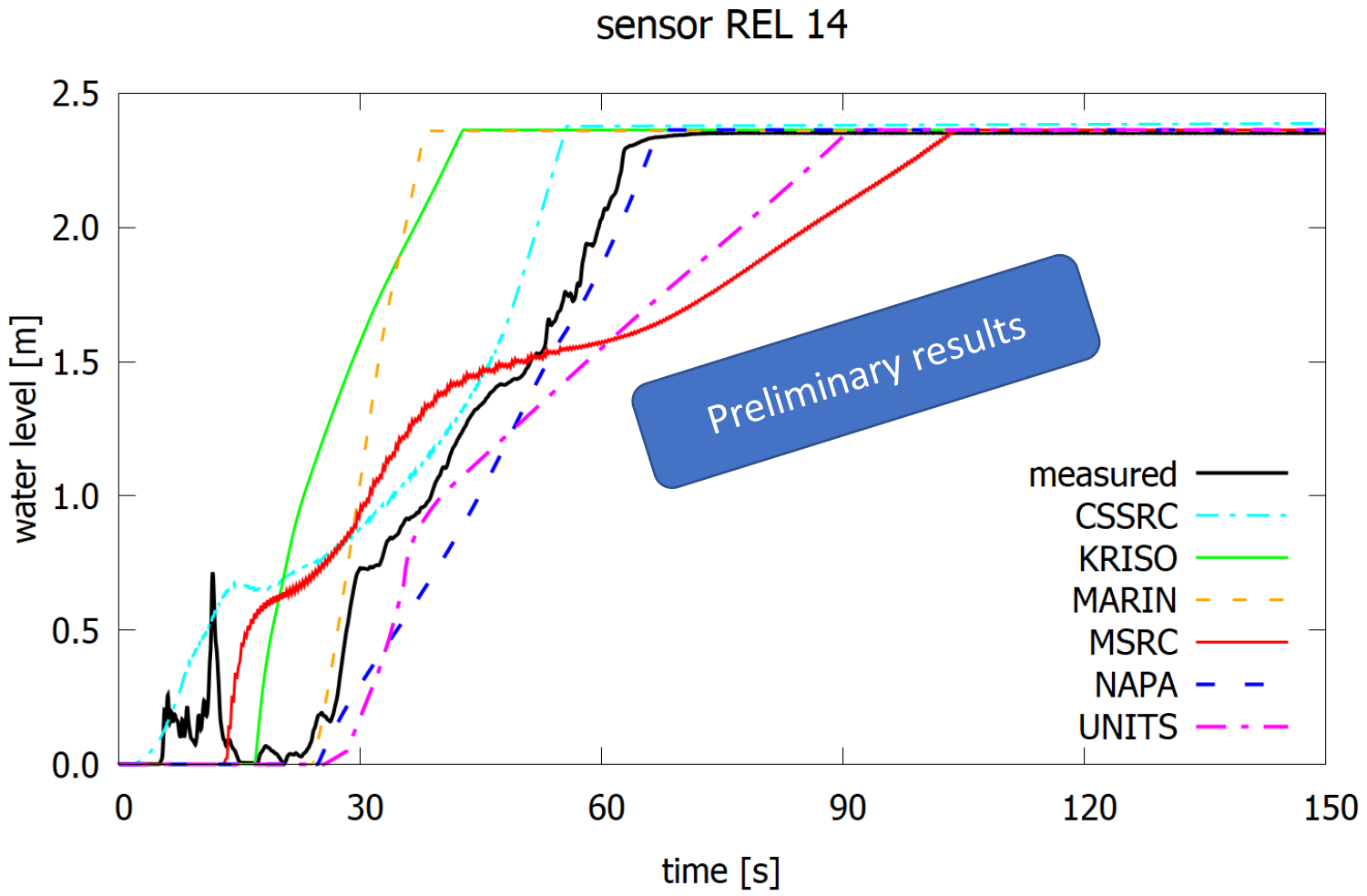


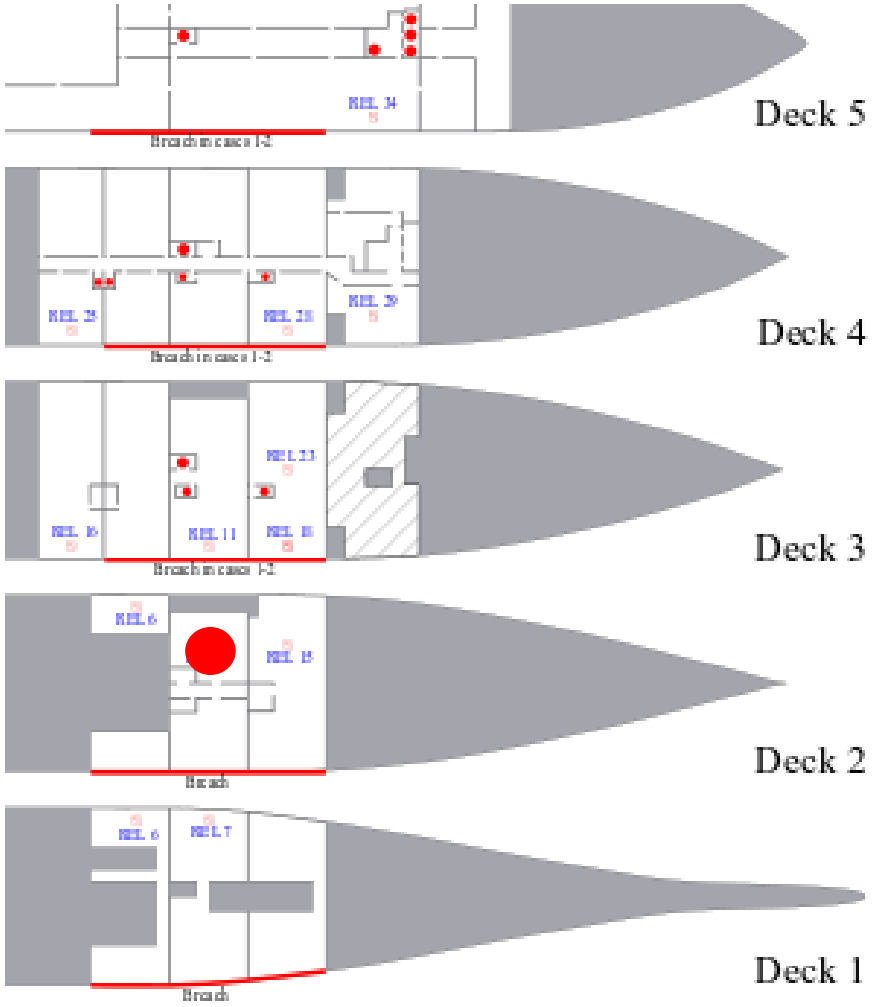


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Cruise ship flooding: water levels



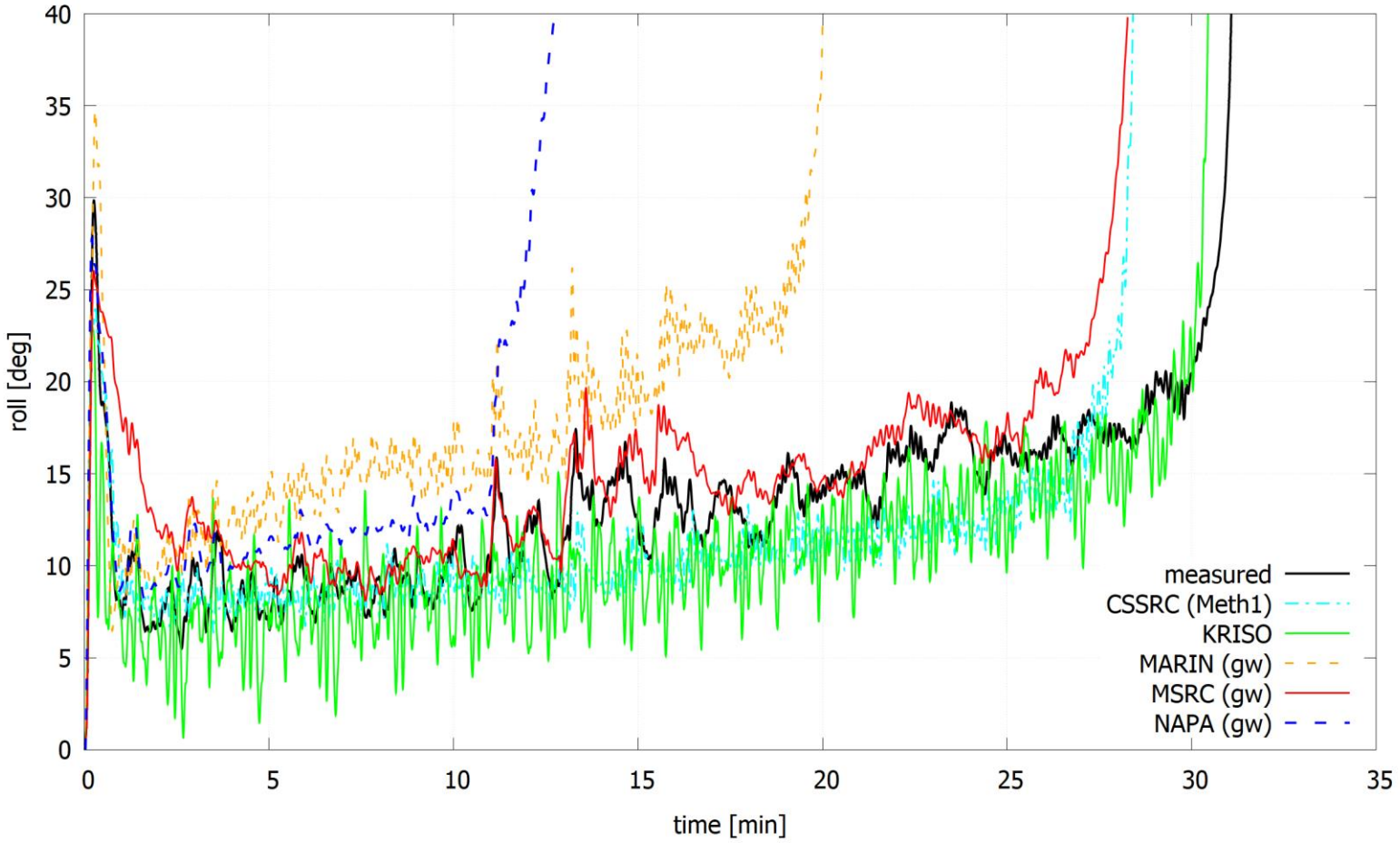


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Cruise ship flooding in waves

Preliminary results



Same 3-comp. breach

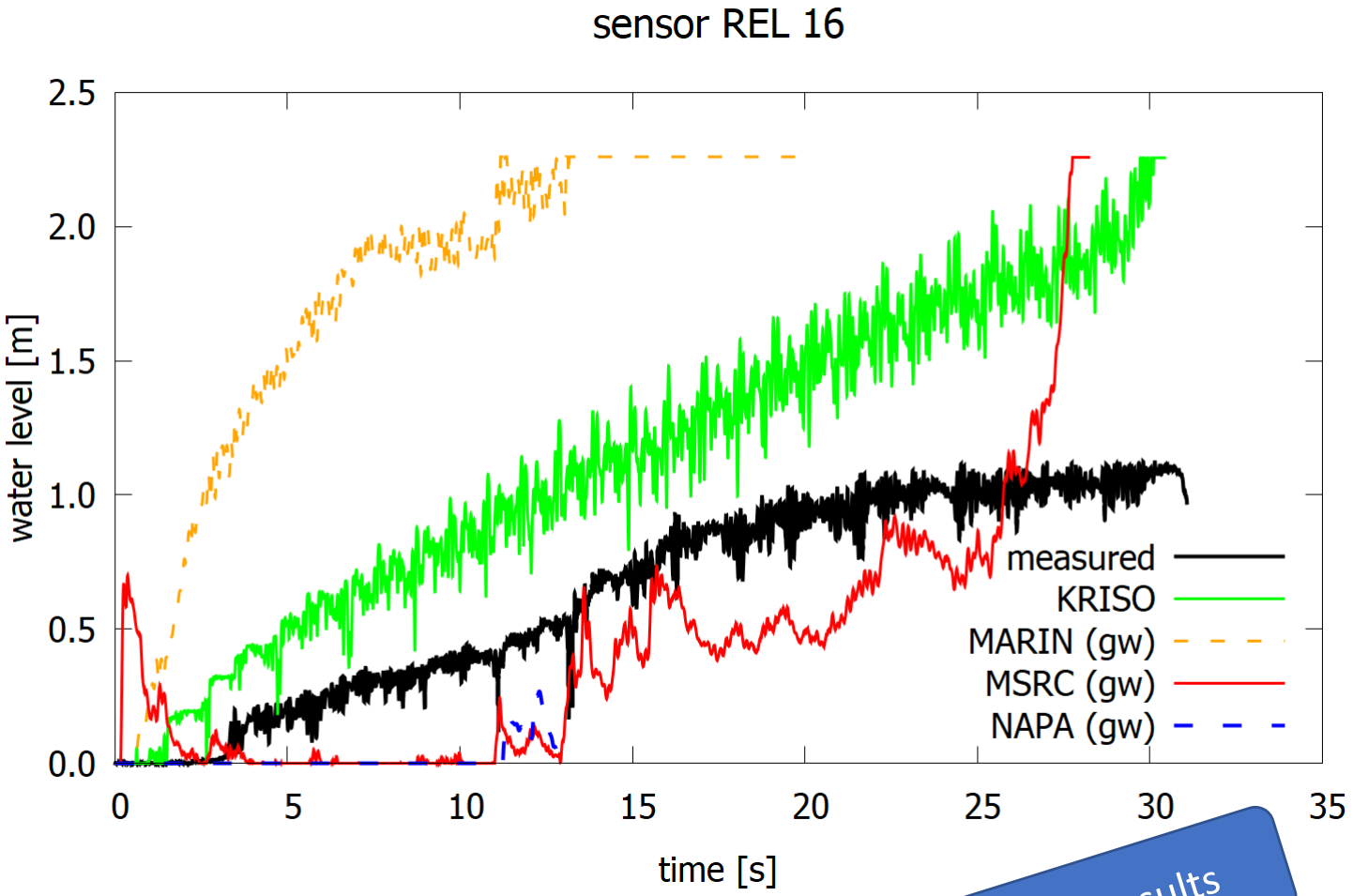
Beam seas, Hs = 4 m

Participants denoted with **(gw)** used the measured wave train, for others best match out of 20 random wave realizations

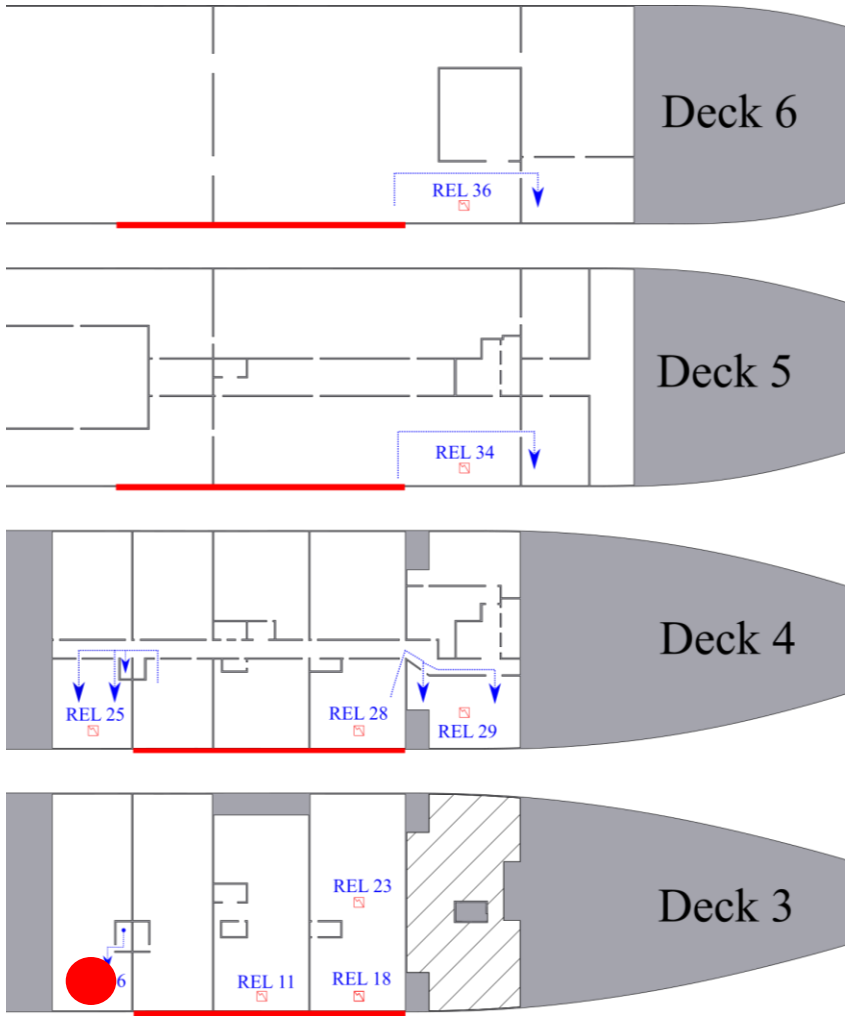
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Cruise ship flooding in waves: water levels



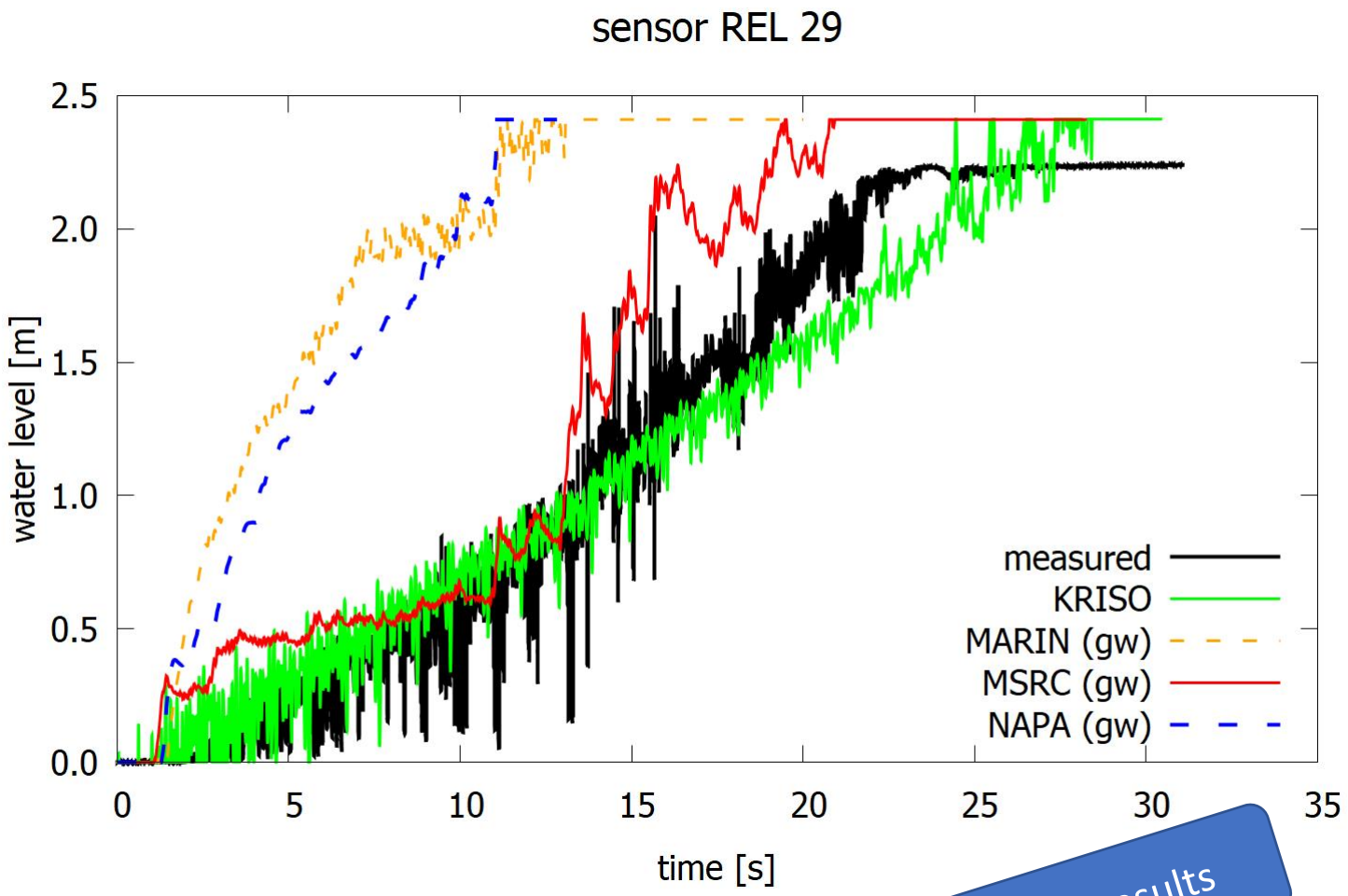
Preliminary results



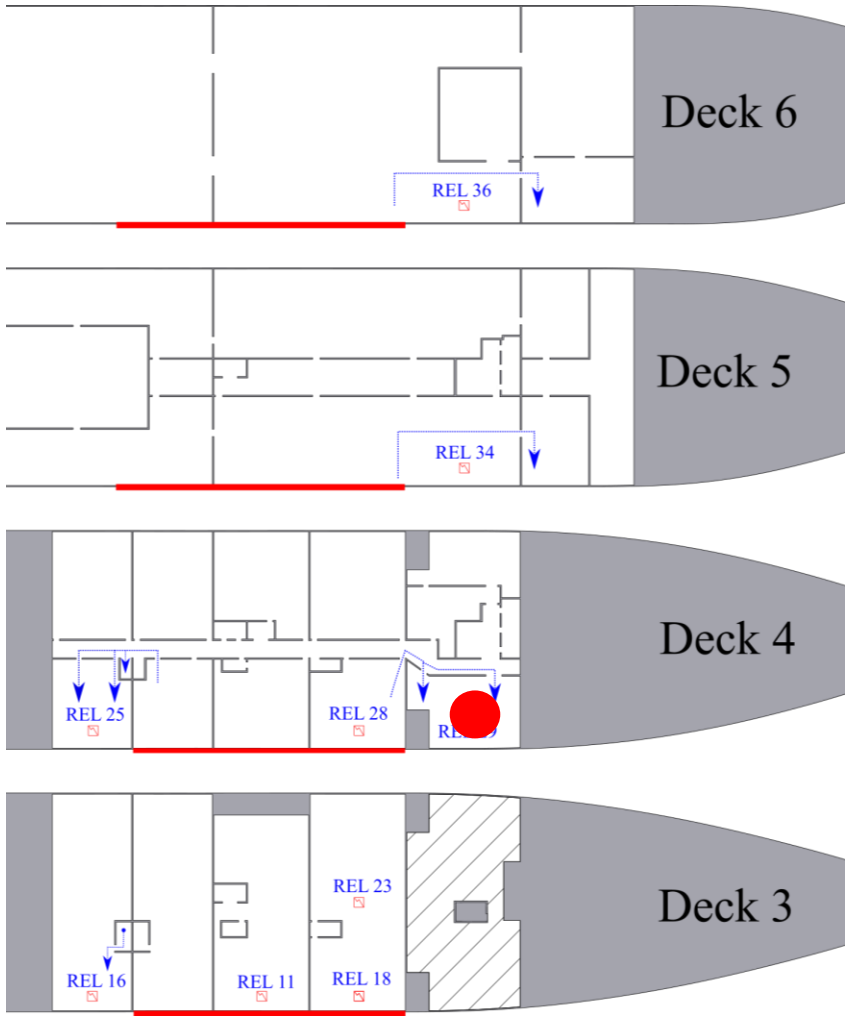
The project has received funding from the European's Horizon 2020 research and innovation programme (Contract No.: 814753)

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Cruise ship flooding in waves: water levels



Preliminary results



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Ropax flooding



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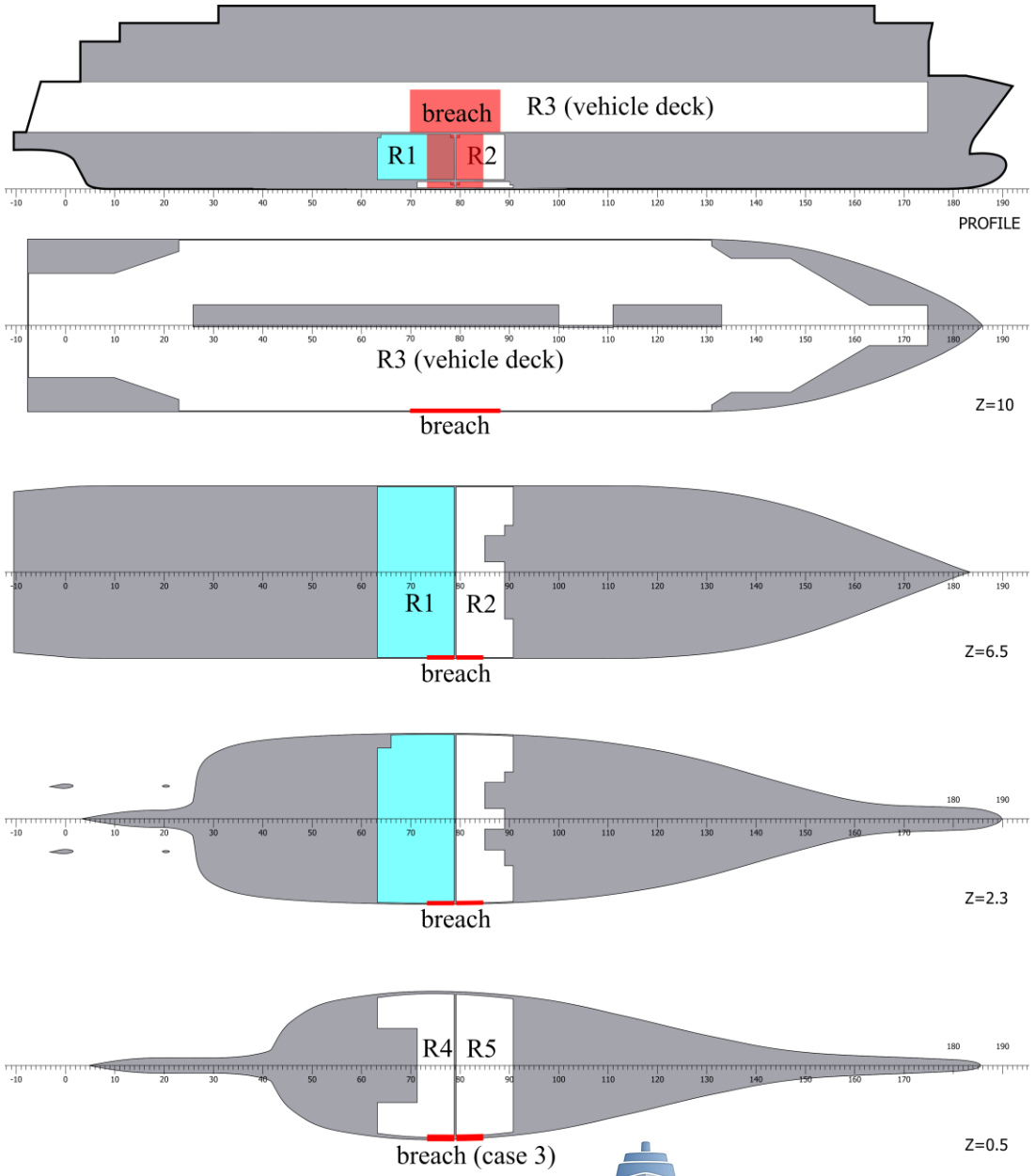
Ropax

Transient flooding in calm water and in beam seas

2-compartment damage

Model tests by HSVA

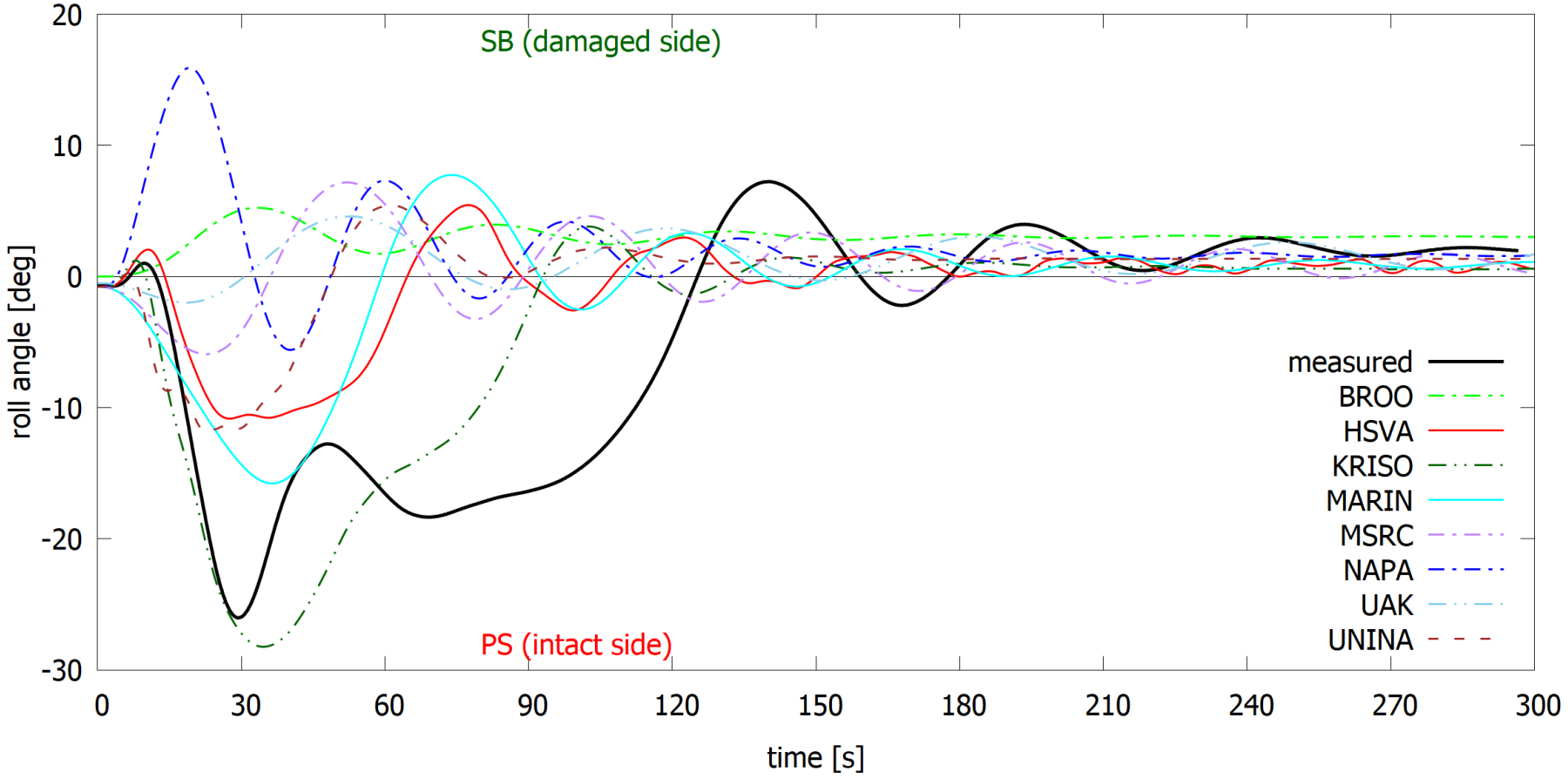
Results shown in full ship scale

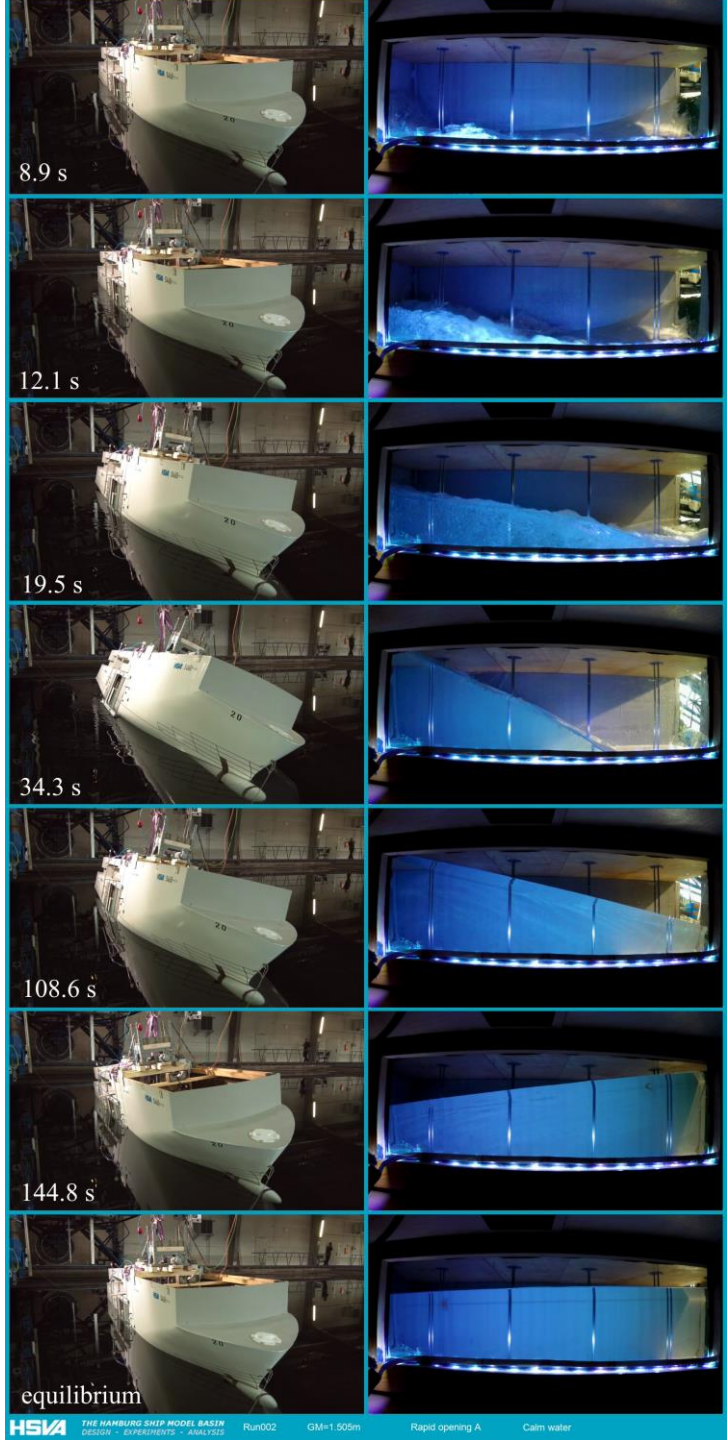


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Transient flooding in calm water

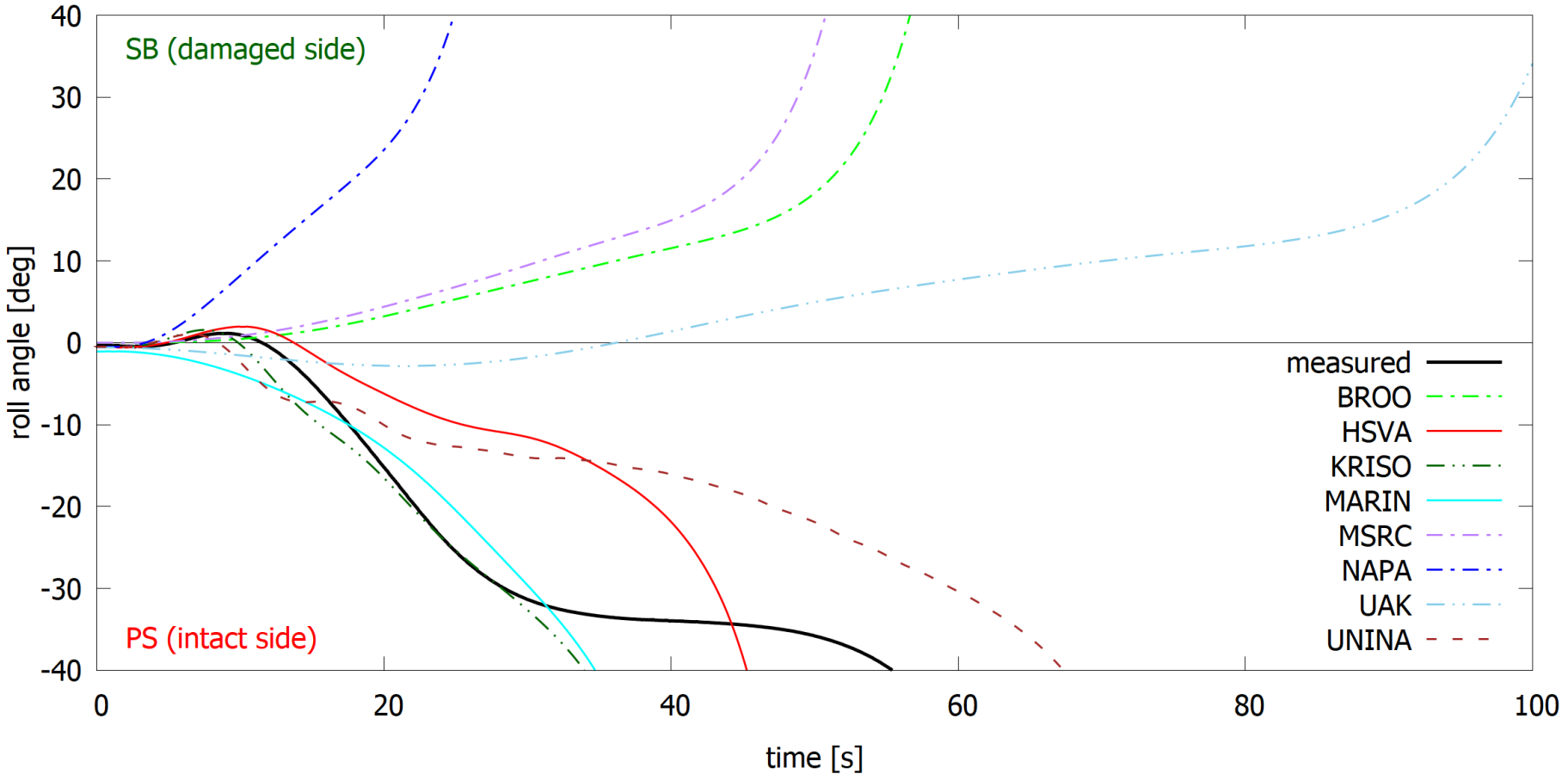




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Ropax: capsize in calm water

Lower initial GM



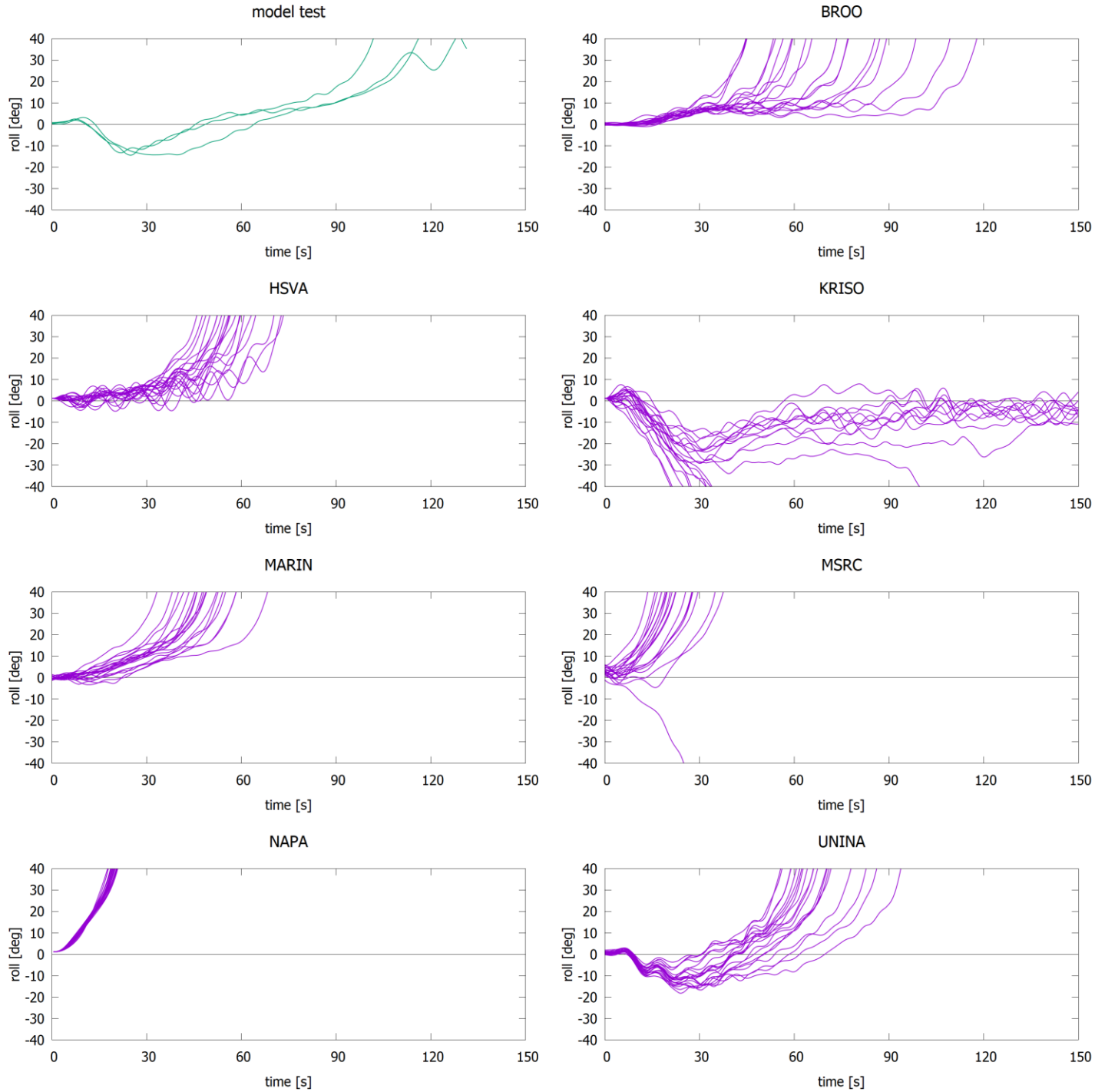
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Transient flooding in beam seas

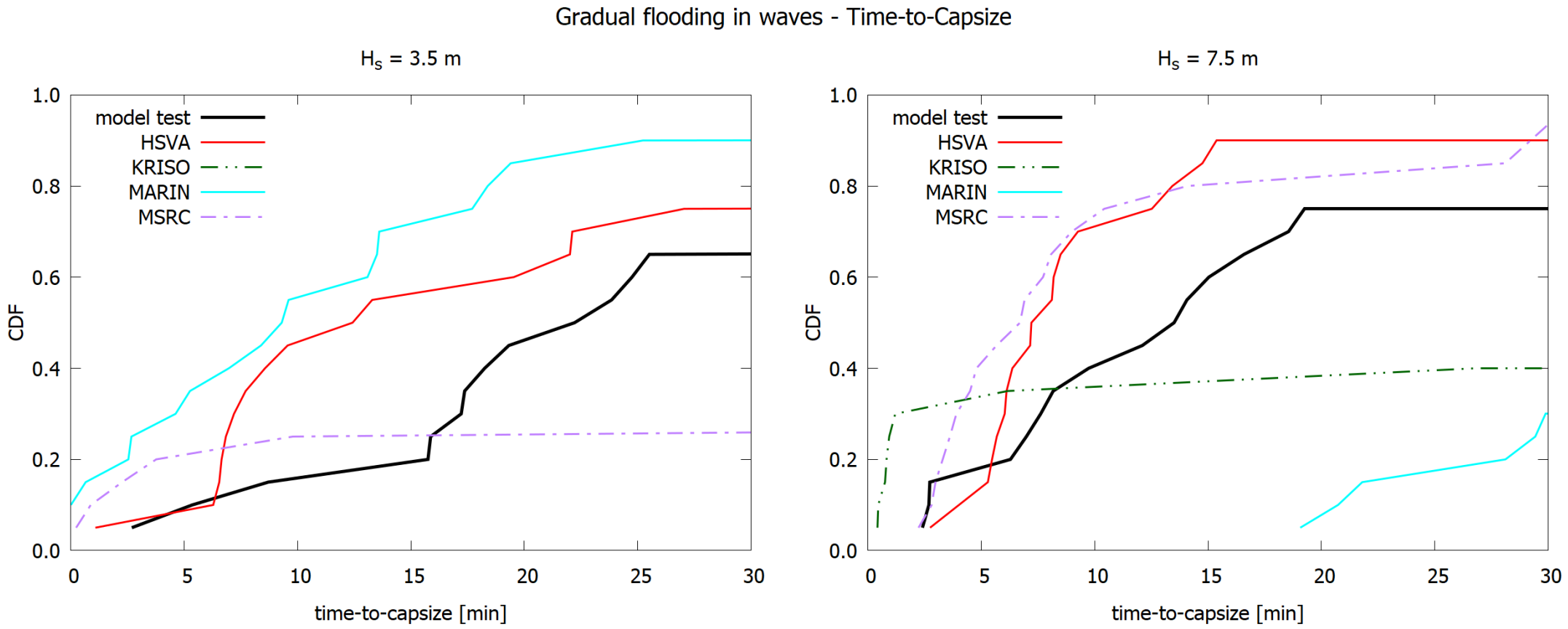
Relatively low initial GM of 1.425 m is applied

JONSWAP wave spectrum ($\gamma = 3.3$) with $H_s = 4.0$ m and $T_p = 10.0$ s is used, with waves facing the damage.



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Ropax: gradual flooding in Waves



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Conclusions – ship flooding cases

Qualitative result (survival or capsize) was in general well predicted for:

- Transient flooding of the ropax
- Transient and progressive flooding of the cruise ship

Significant scatter in the results for gradual flooding of the ropax in waves

Capsize of the cruise ship in waves was correctly captured, but notably different flooding mechanisms were observed between the codes

Further research and development of the simulation codes still needed

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Publications

1. **Benchmark Study on Simulation of Flooding Progression,** Proceedings of the 1st International Conference on the Stability and Safety of Ships and Ocean Vehicles, 7-11 June 2021, Glasgow, Scotland, UK.
2. **International benchmark study on numerical simulation of flooding and motions of a damaged ropax ship**, manuscript under review
3. Paper on cruise ship flooding cases is being prepared, hopefully with some additional and updated contributions

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Thank you!

DNV

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