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Tsunami Inundation Simulation in Urban Topography

DPRI-KU

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Backgrounds 1/2

- Tsunamis have complex behavior especially in urban area inundation.
- The structural damage is dependent on not only the inundation height but also the momentum.
- Numerical simulations which capture the local behavior are required to minimize casualties and damages.

Backgrounds 2/2

- Only inundation heights are used for evaluation of tsunami damages.
- Buildings are often replaced with roughness and wave diffraction and dispersion around them are neglected.
- It's important to take account of micro topography with the land structures.

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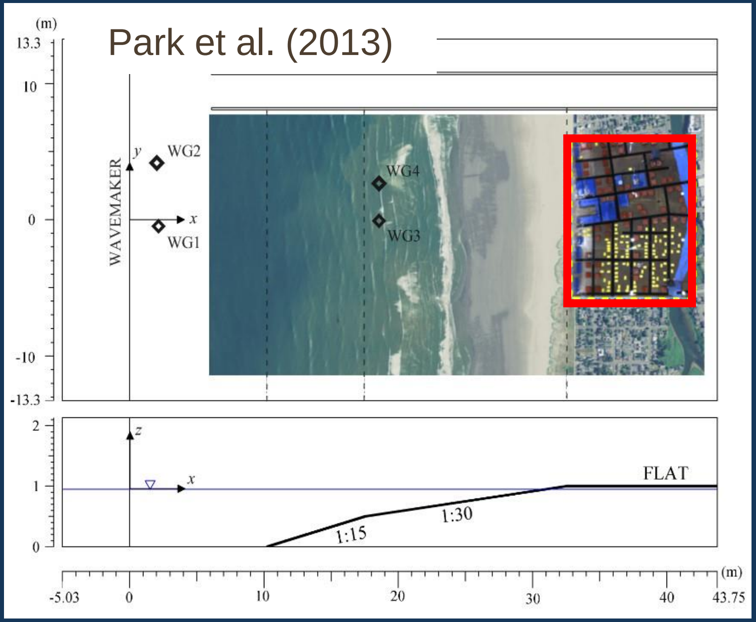
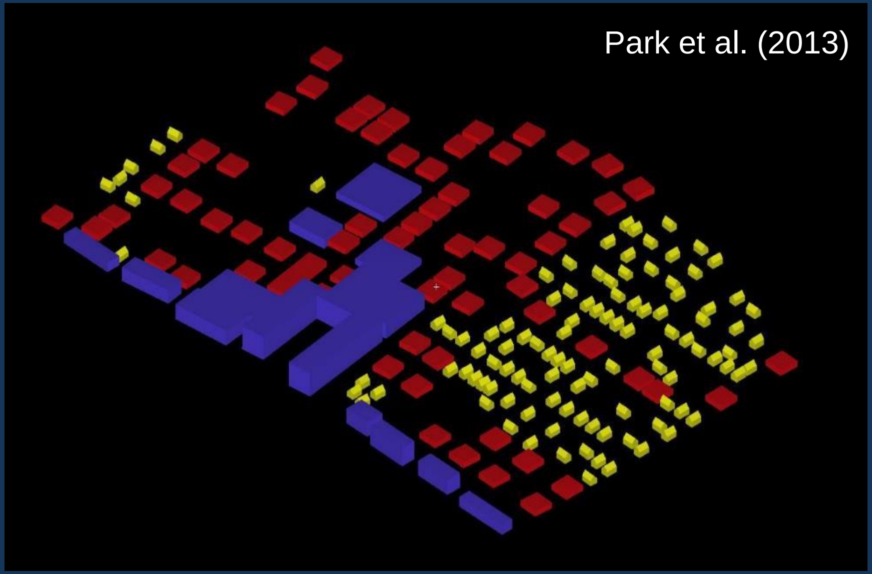
- This study aims to understand :
  - Validity of quasi-3D model simulations on city scale
  - Difference between 2D and quasi-3D model when simulating urban areas

Outlines of numerical simulation

Benchmark: a physical experiment Park et al. (2013)



Seaside city, Oregon

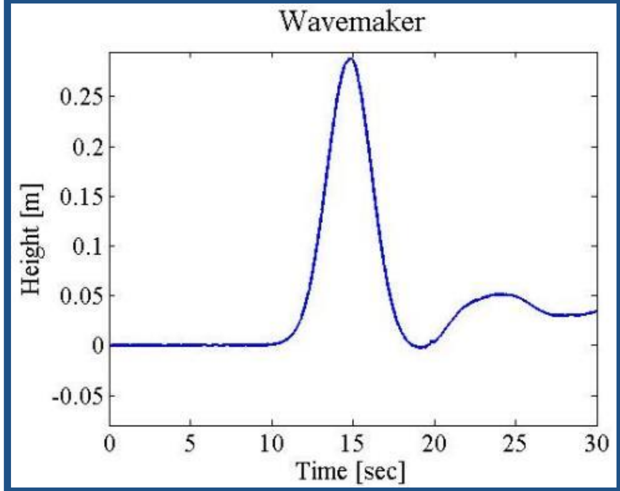


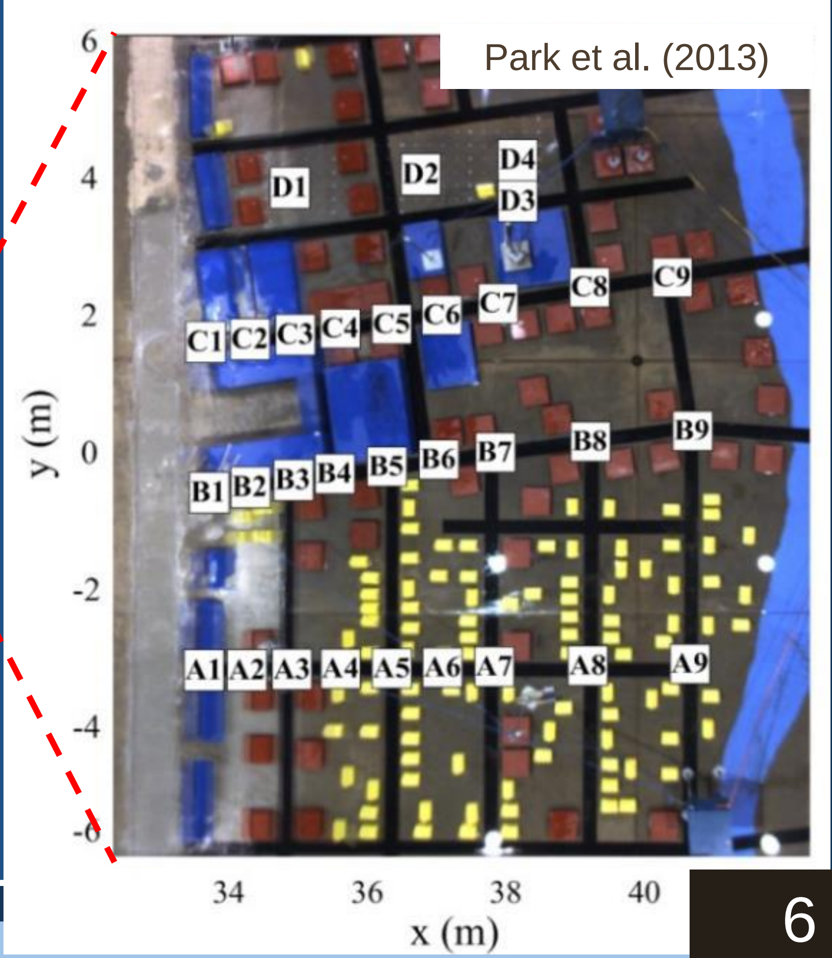
1/50 scale
Length : 48.8m
Width : 26.5m

Maximum depth : 1m
Slopes: 0 - 1/15 - 1/30 - 0

Benchmark: a physical experiment

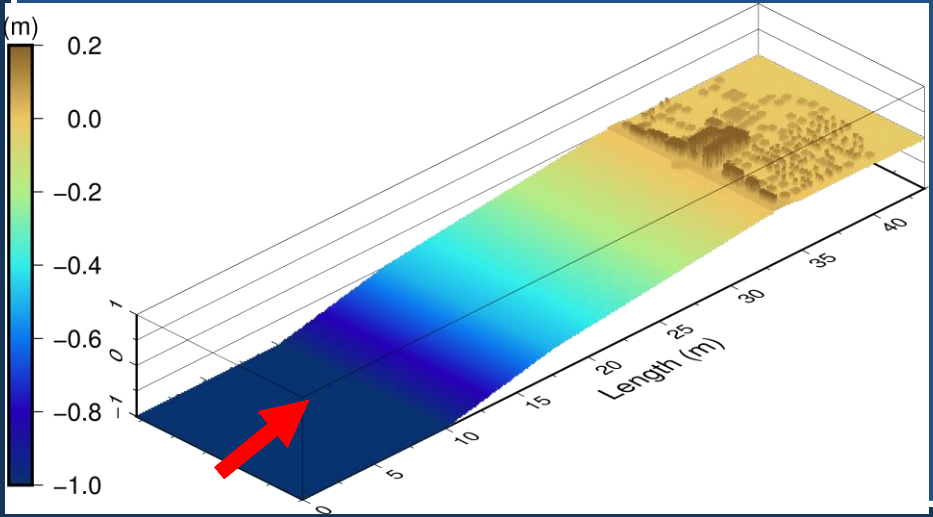
- 31 points for sampling along the streets
  - A1 - A9, B1 - B9, C1 - C9, D1 - D4
- Instruments (Frequency 50Hz)
  - Surface elevation
  - Cross-shore velocity u

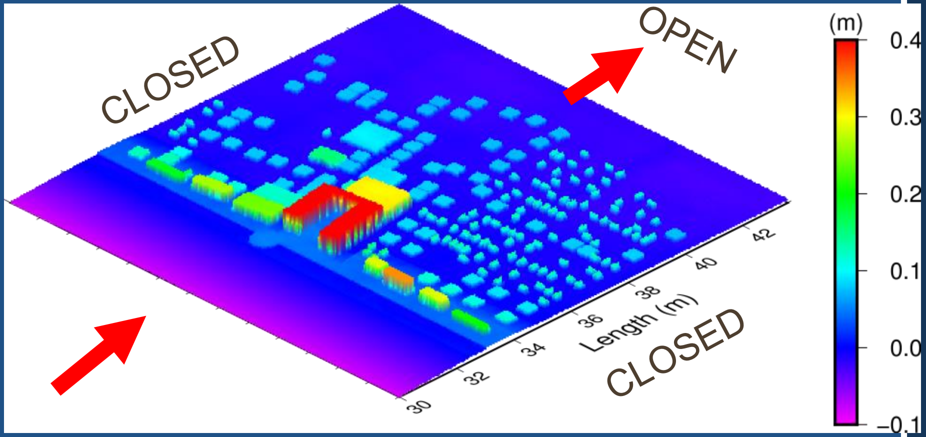




Numerical Simulation: Quasi-3D and 2D model

- Regional Ocean Modeling System (ROMS)
  - Shchepetkin and McWilliams(2003)
- The hydrostatic primitive equations for momentum
- σ - coordinate system
- Bottom friction : quadratic friction law
- 2D model is basically the same as quasi-3D, different from the number of the layers



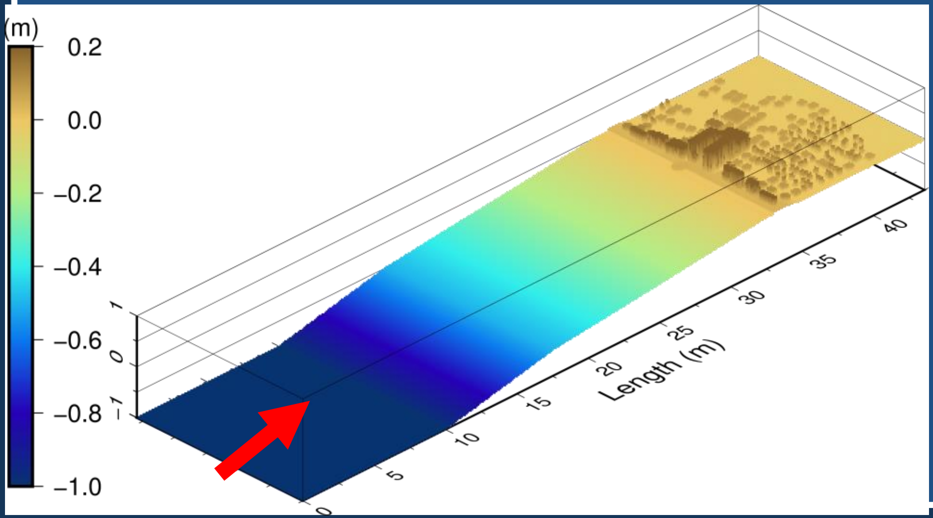


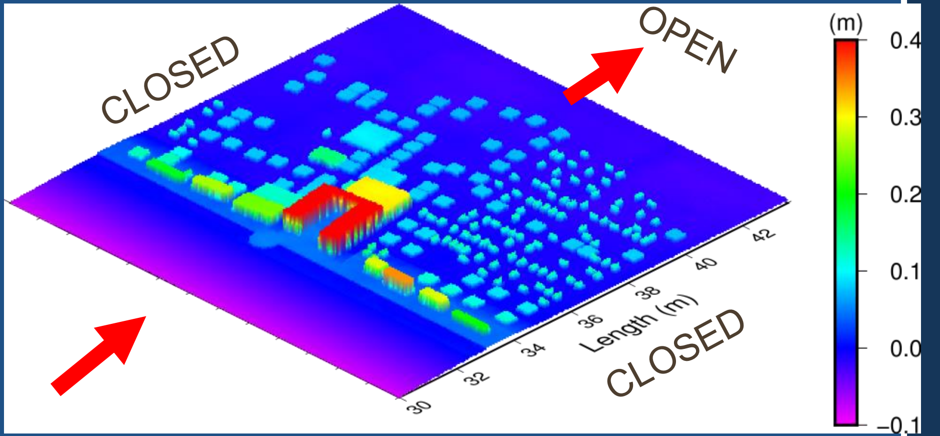
Numerical Simulation: Quasi-3D and 2D model

- Coordinate systems
  - Vertical : σ coordinate
    - quasi-3D: 20 layers
    - 2D: single layer
  - Horizontal: Rectangular
    - $\Delta x, \Delta y$: 0.04 m
  - The minimum building has 4 × 6 grids

- Δt : 0.002~0.010 s

- Lateral boundaries
  - North and South : closed
  - East and West : open

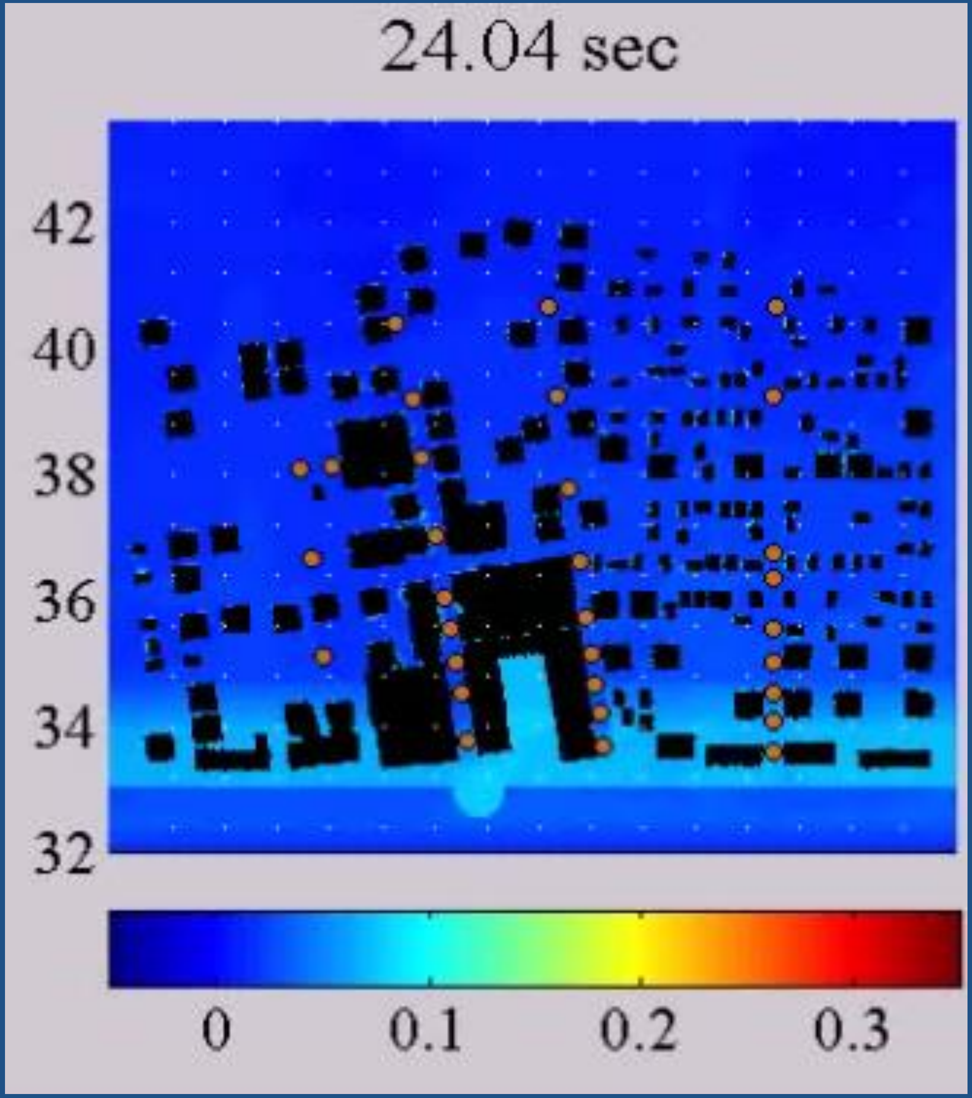




Results and Discussion

1. Quasi-3D model simulation
2. Comparison of quasi-3D and 2D model

Result of Simulation by quasi-3D Model



- Verification

  inundation height η

  velocity u and $\bar{u}$

- Color

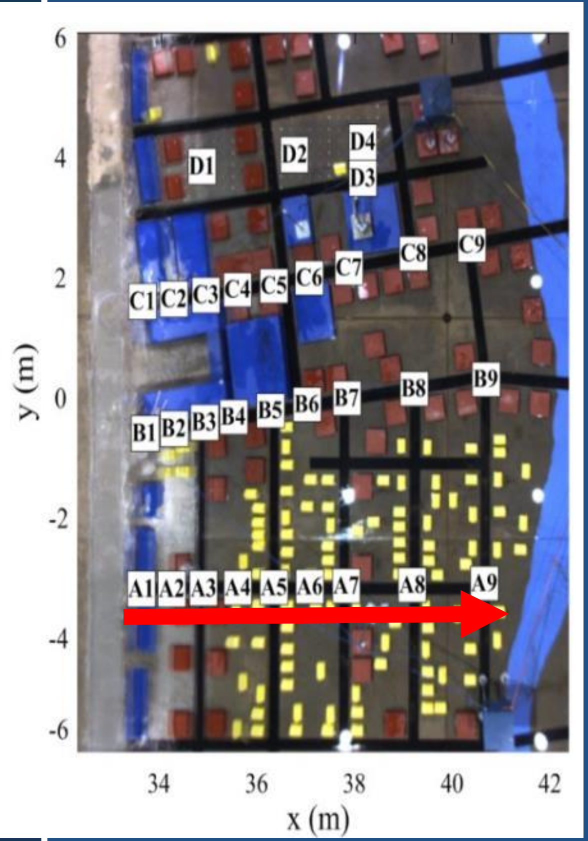
  surface elevation

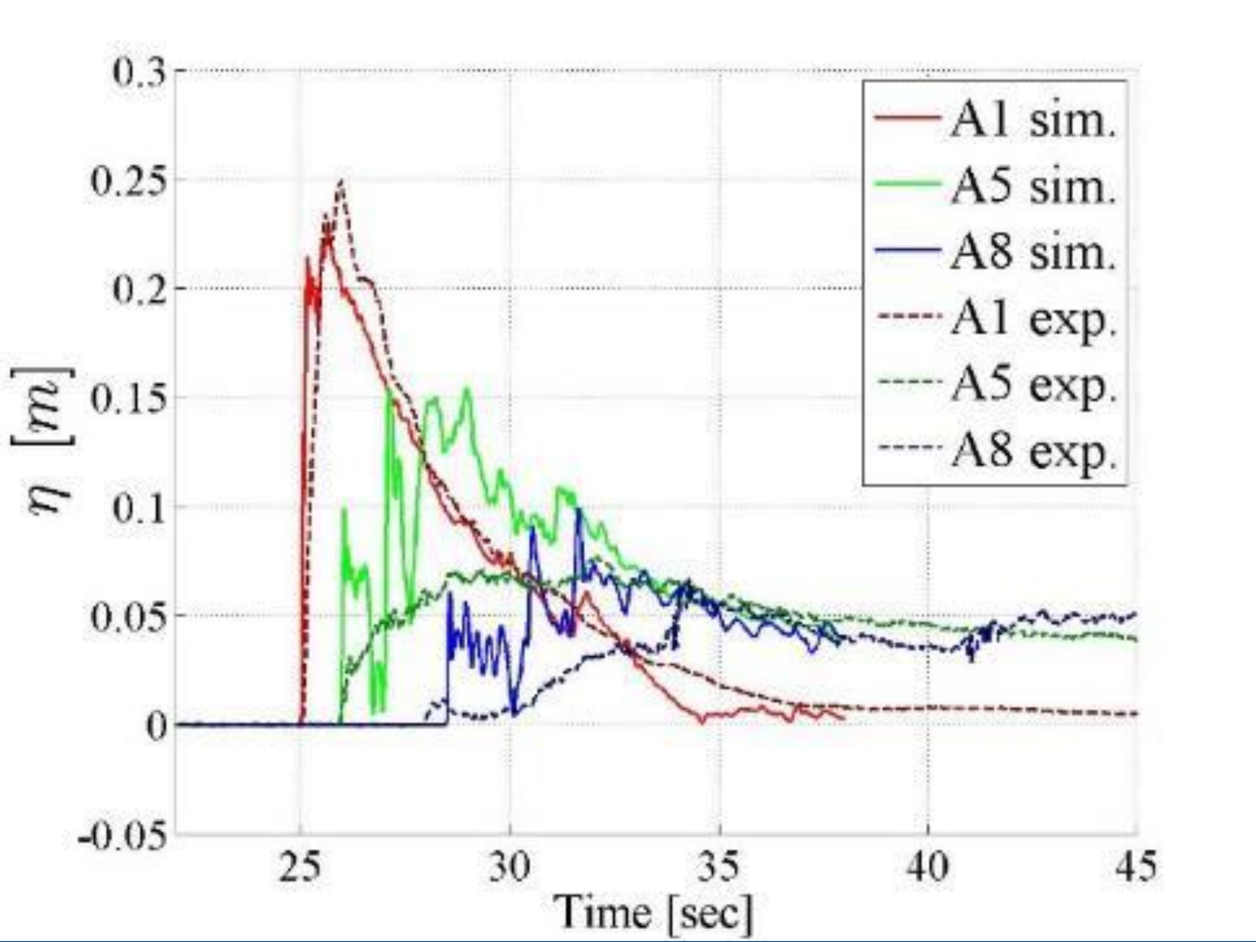
- Arrow

  magnitude and direction of the velocity

Q3D: Inundation height (Main street)

Measurement locations

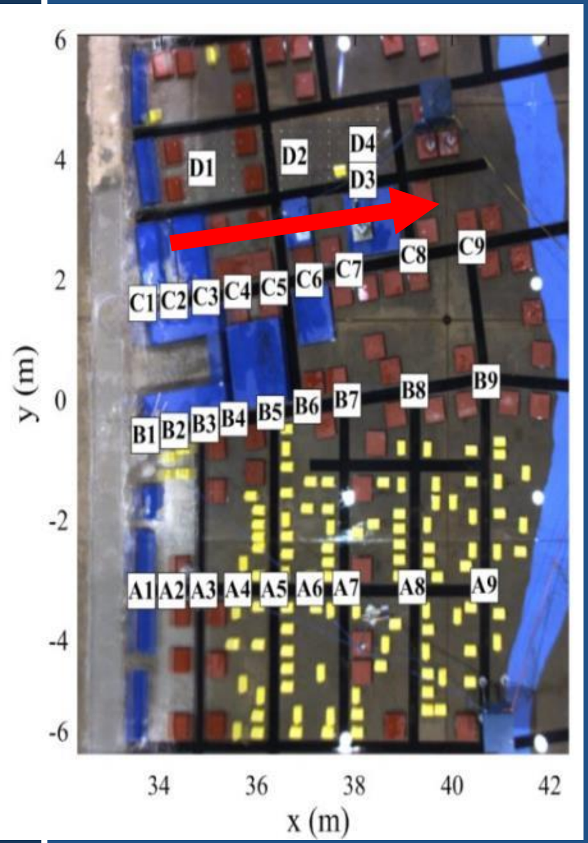


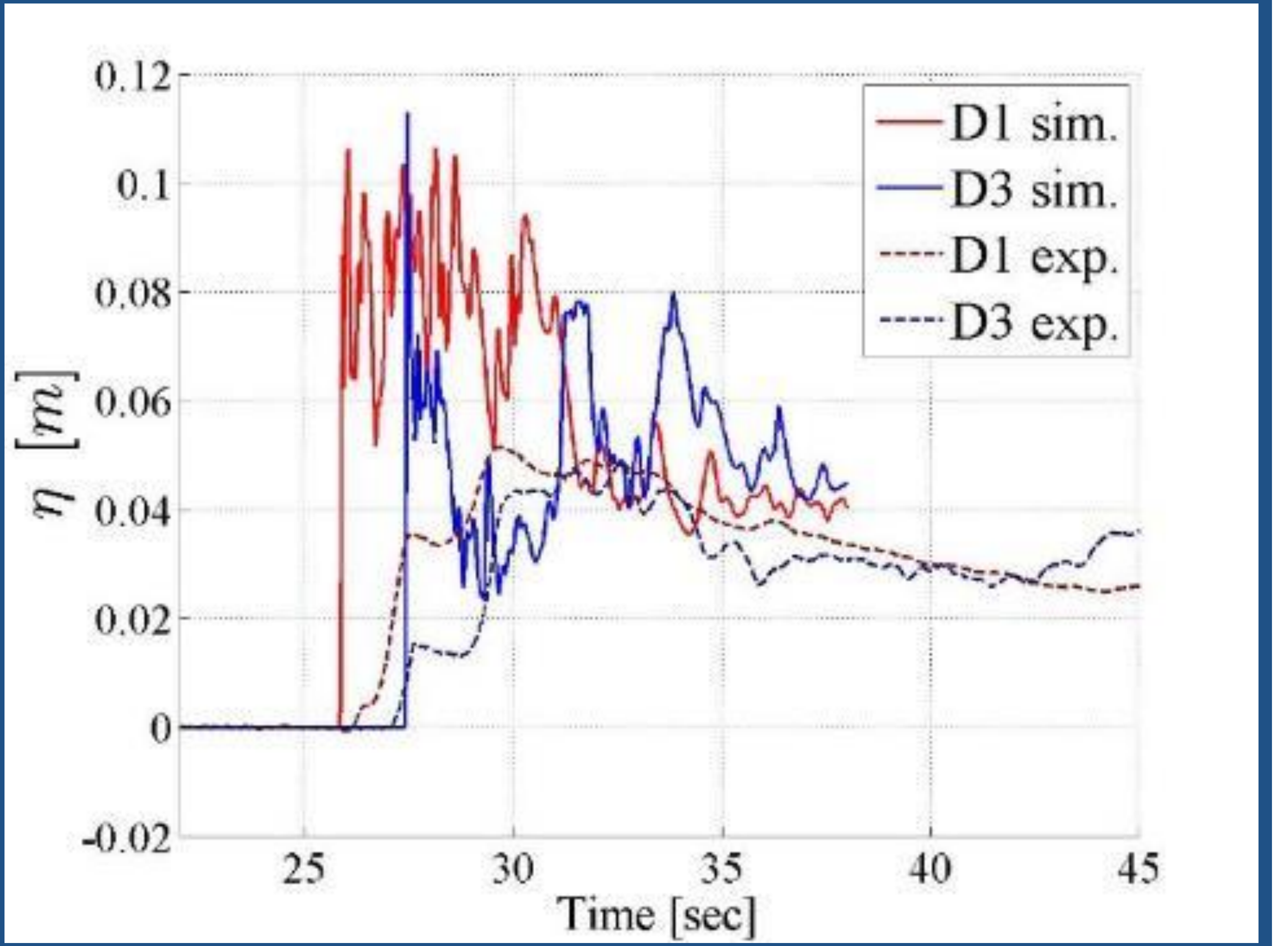


- The simulation tended to overestimate in in the middle of the line.
- The arrival time at A8 was delayed

Q3D: Inundation height (Behind of buildings)

Measurement locations

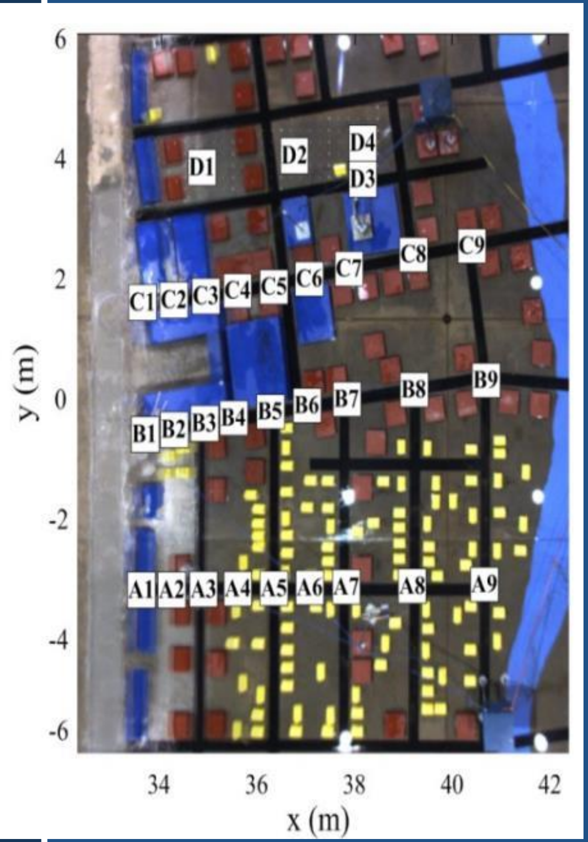


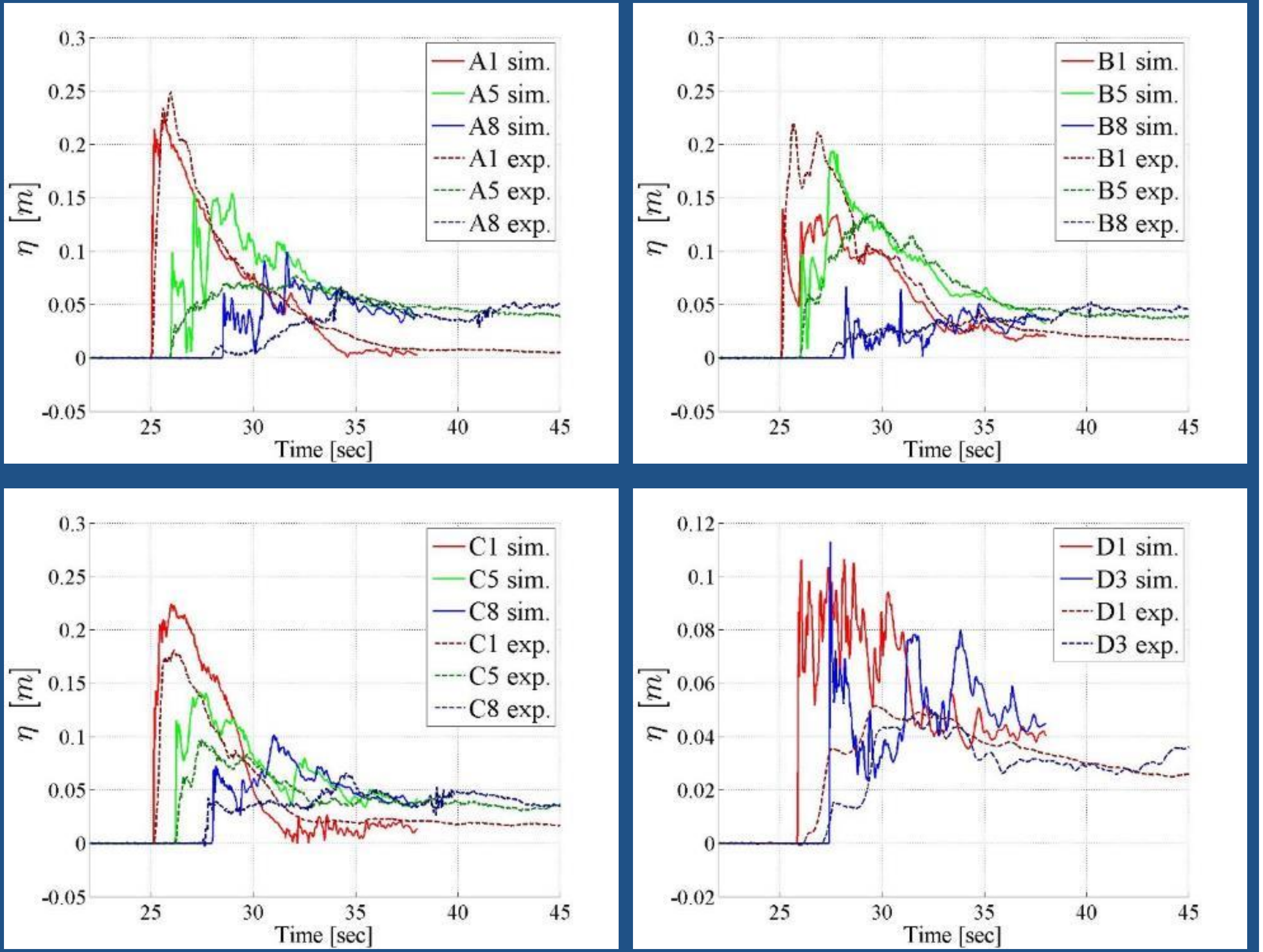


There is fluctuation in the simulation due to the reflection of the wall and wave interference.

Q3D: Inundation height

Measurement locations

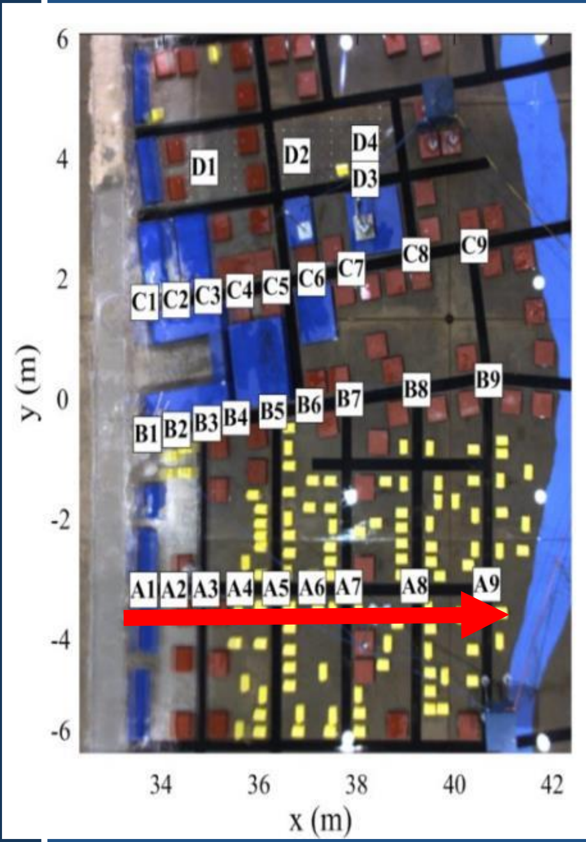


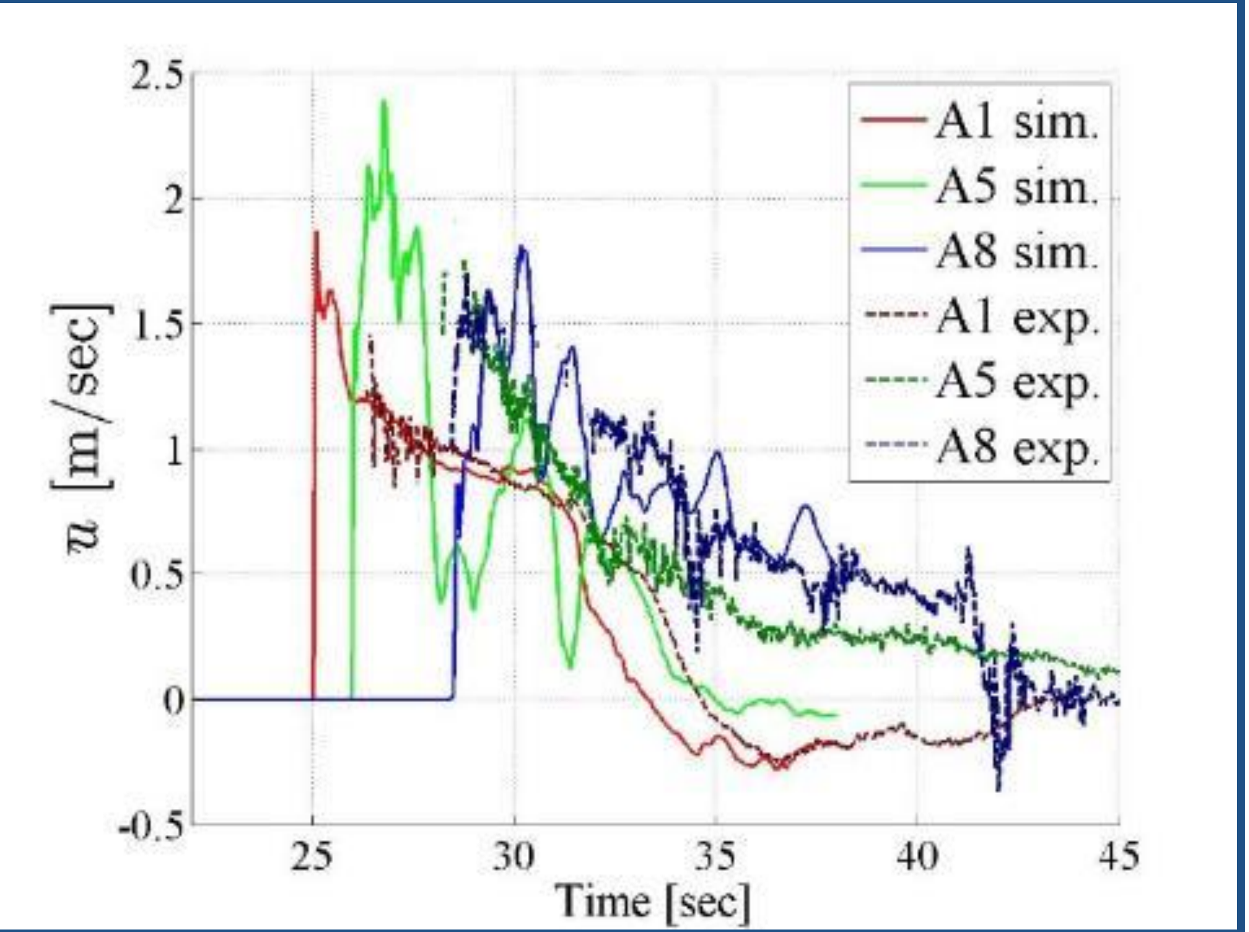


- The trends of line B and C were similar to A line.
- D line was independent of the others and its error is large.

Q3D: Cross-shore velocity

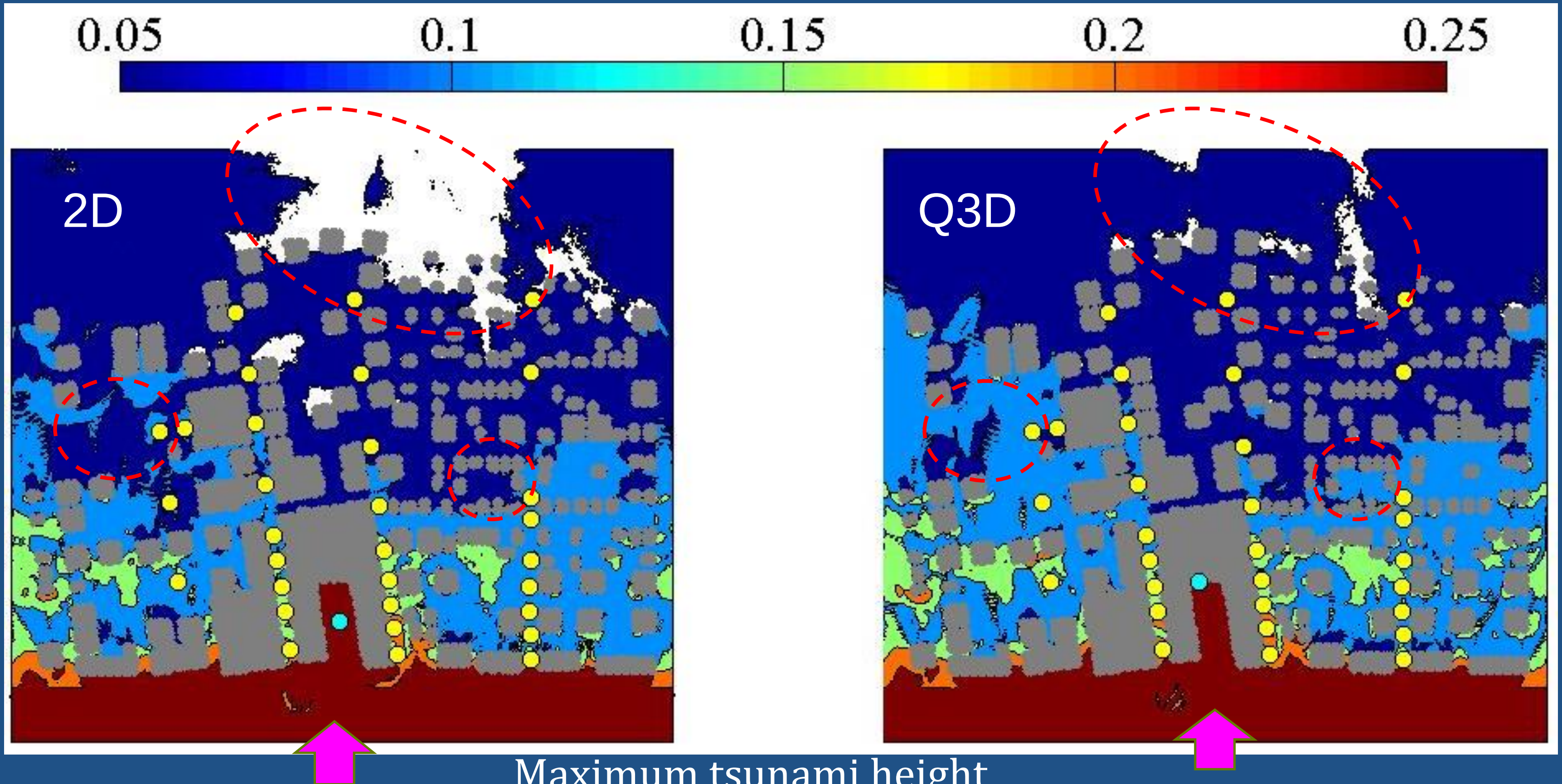
Measurement locations





Except for when experimental data was not available, the quasi-3D simulation agreed well with experiment results.

2D vs Quasi-3D

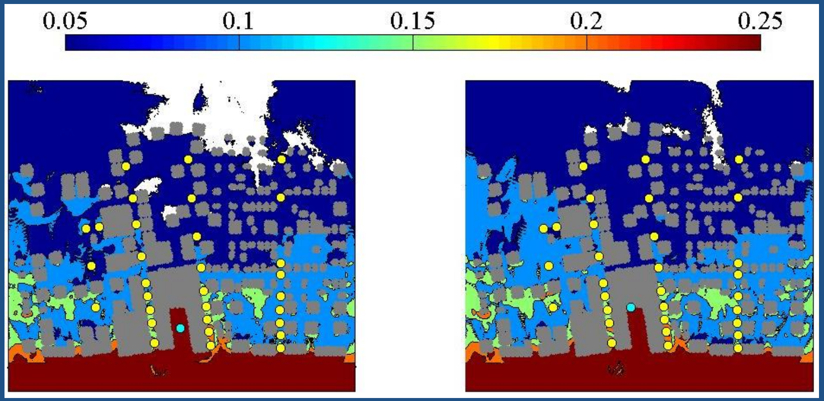


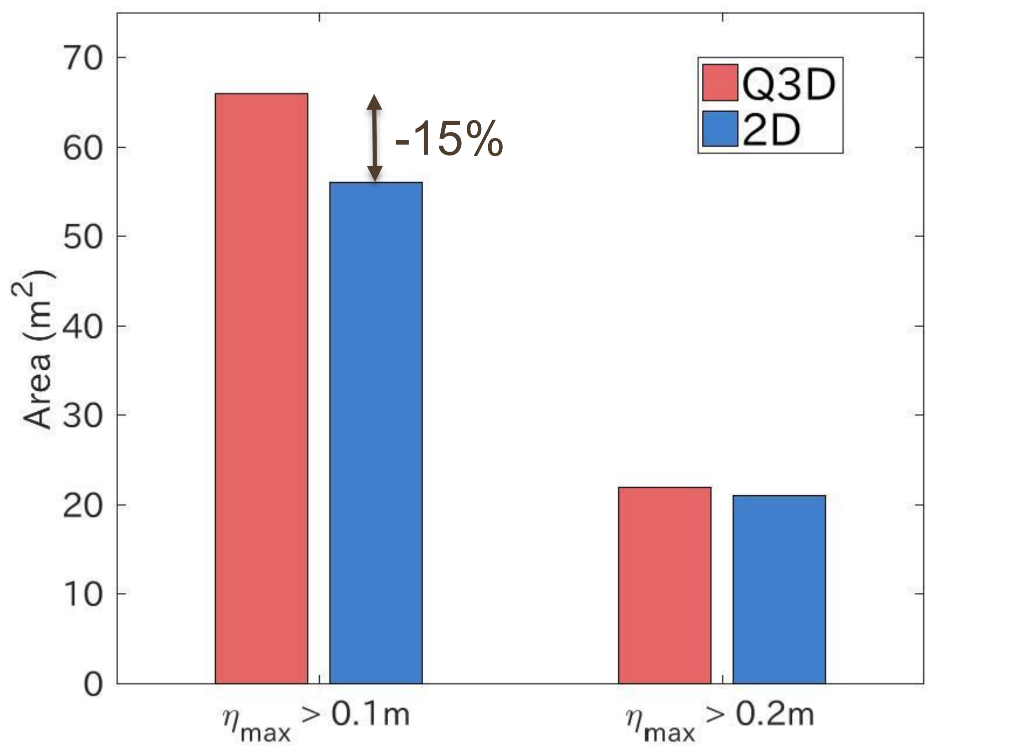
Maximum tsunami height

- Little difference from the shoreline to the middle
- The differences can be seen at region surrounded by the small houses and buildings at the inland.

2D vs Quasi-3D

- The areas of tsunami over the certain heights were calculated.
- Area of over 0.10m (5.0m in actual scale) in the 2D model is significantly smaller than that in the the quasi-3D.
- This comes from the difference of the total energy dissipation due to vertical viscosity and bottom friction.
- The 2D model may underestimate the tsunami damage, especially in urban areas.





Actual scale 5 m 10 m

Conclusions

- Characteristics of tsunami inundation by Q3D/2D model was compared and validated against physical model.

- The Q3D model agreed well with the experiment on the straight streets from the shoreline, but it differed with the experimental data at the points behind large buildings.

- The 2D simulation tended to be smaller in comparison with the Q3D model, because the 2D model assumes the vertical velocity profile.