Tsunami current modeling in Alaska: Validation and verification of a numerical model

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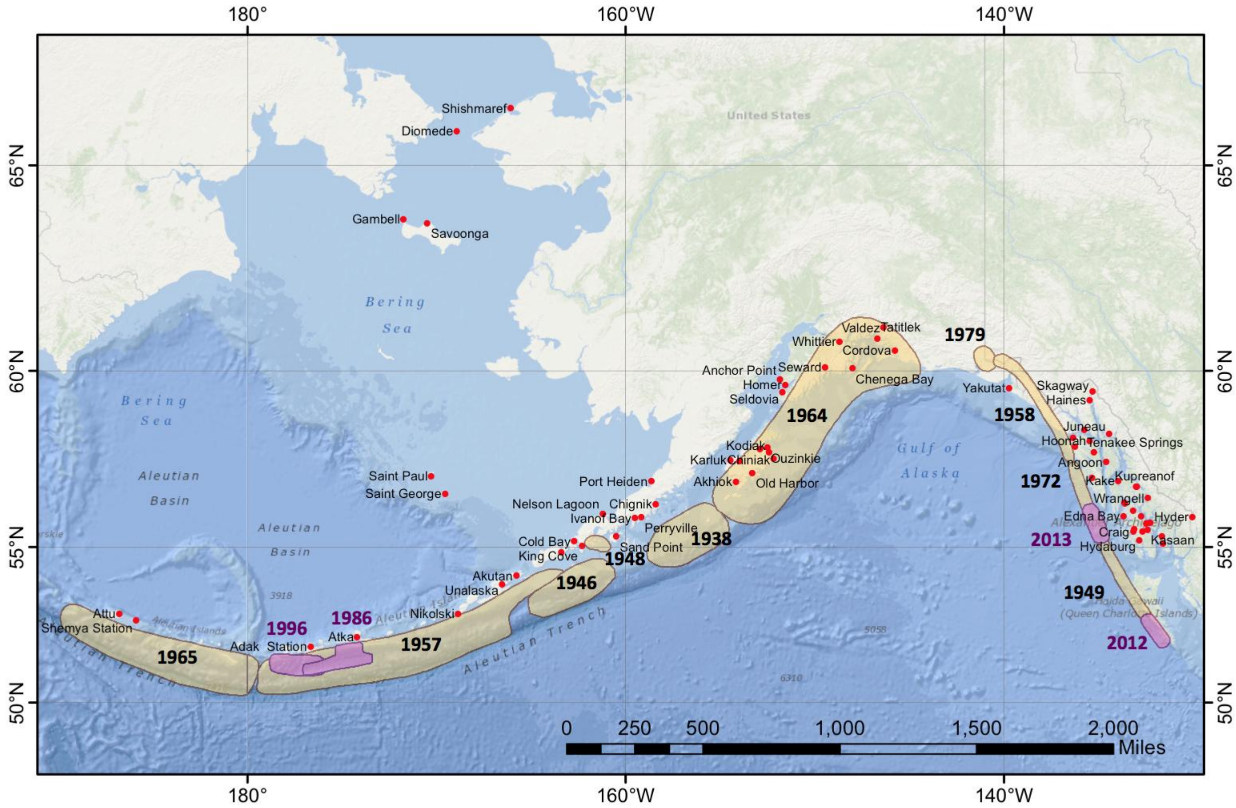
NTHMP Model Validation Workshop

Portland, February 2015

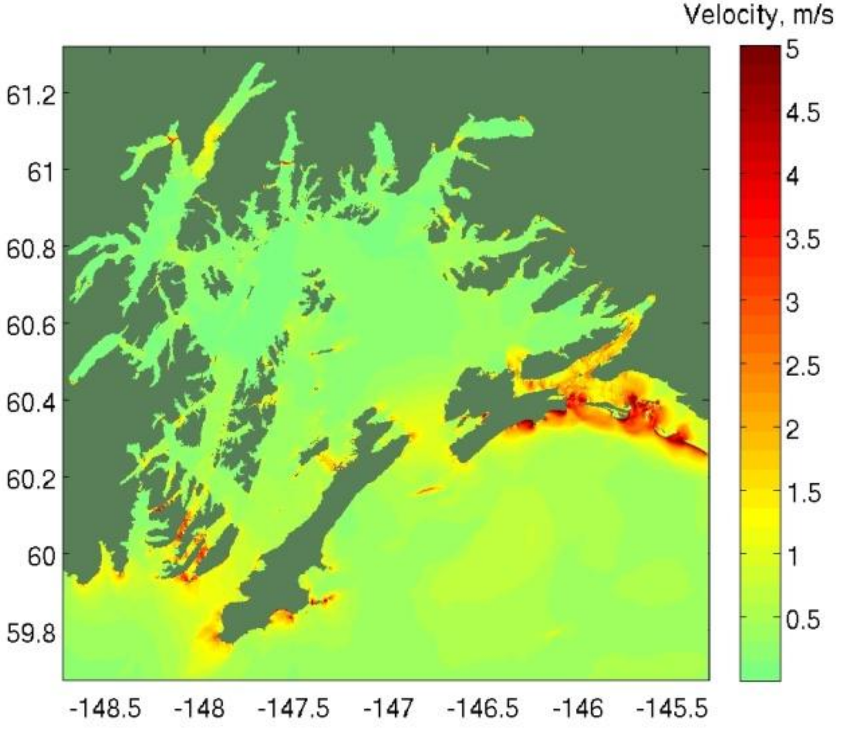
Alaska coastal communities at risk of tsunamis



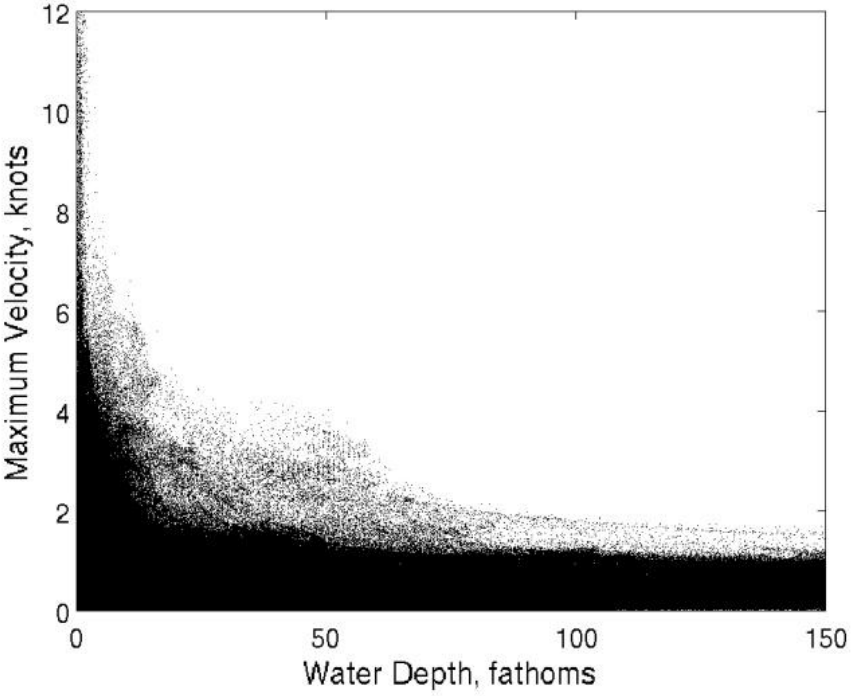
- The Alaska coastline has the greatest tsunami potential in the US. The Great Alaska earthquake of March 28, 1964, generated a major **local tectonic** tsunami (**25** fatalities) and **local landslide** tsunamis (**81** fatalities).
- Tsunami inundation mapping in Alaska requires an understanding of **both tectonic and landslide** tsunami potential for many coastal communities.

Modeling a M_w9.1 Cascadia event in Prince William Sound

Maximum velocity



Maximum velocity



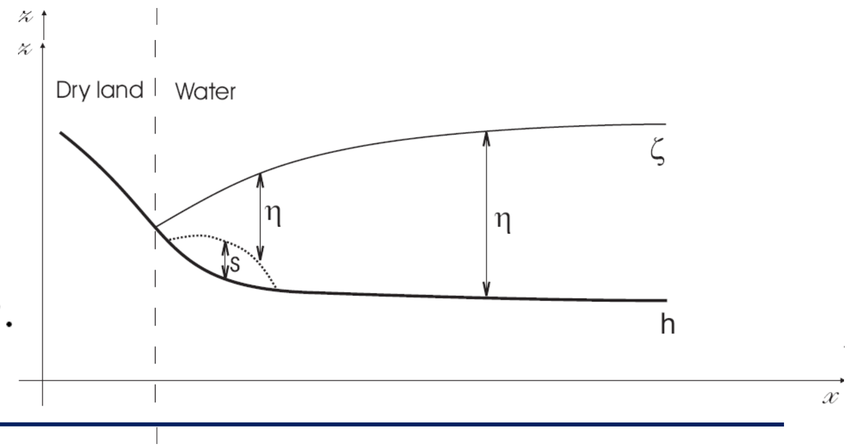
Modeling of the tsunami currents reveals some hazardous currents forming in narrow passages and near the tip of the narrow peninsulas.

Model description

Governing equations:

$$\frac{\partial \zeta}{\partial t} + \nabla \cdot \boldsymbol{V} = 0, \quad \zeta = h + \eta$$

$$\frac{\partial \boldsymbol{V}}{\partial t} + \nabla \cdot (\boldsymbol{V} \boldsymbol{v}) = -g\eta \nabla \zeta - f\,(\boldsymbol{e}_r \times \boldsymbol{V}) + \eta \boldsymbol{\tau}.$$



$\boldsymbol{v} = (v, u)$ is the horizontal water velocity,
$\boldsymbol{V} = \eta \boldsymbol{v}$ is the water flux,
η is the water depth,
h is the bathymetry,
g is the acceleration of gravity,
f is the Coriolis parameter,
$\boldsymbol{e}_r$ is the outward unit normal vector
$\boldsymbol{\tau}$ represents the bottom friction:

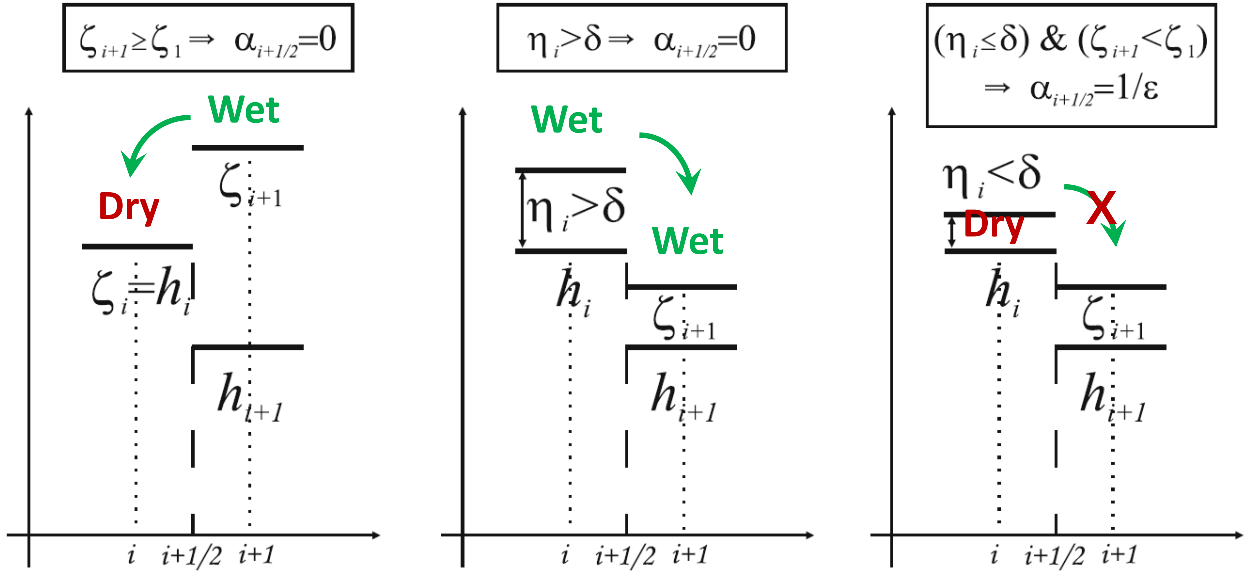
$$\boldsymbol{\tau} = \frac{\nu}{2\eta} \boldsymbol{v} \|\boldsymbol{v}\|, \qquad \mu^2 = \frac{\nu}{2g} \eta^{1/3}.$$

The constants ν and μ are the friction coefficient and Manning's roughness, respectively.

Solve the system in the spherical coordinates by finite differences on Arakawa C-grid, using a semi-implicit in time scheme

Runup and its numerical implementation

Computation of the runup and backwash



Benchmarking: March 2011, Galveston, TX

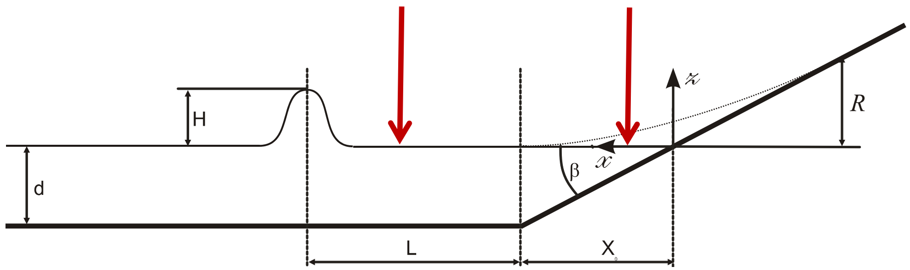
Basic considerations

- Convergence and conservation

Benchmarking

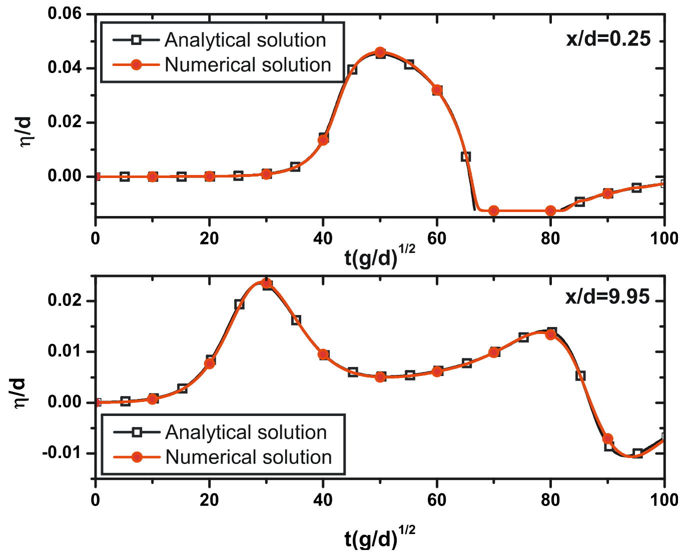
- Analytical benchmarking (*Canonical and composite beaches)*
- Laboratory benchmarking *(Cylindrical island, Monai Valley)*
- Field data benchmarking *(Hokkaido-Nansei-Oki 1993 earthquake)*

BM #1, Analytical. Single wave on simple beach

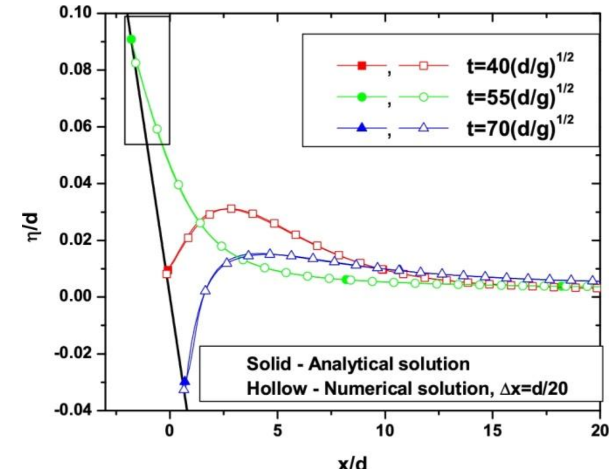


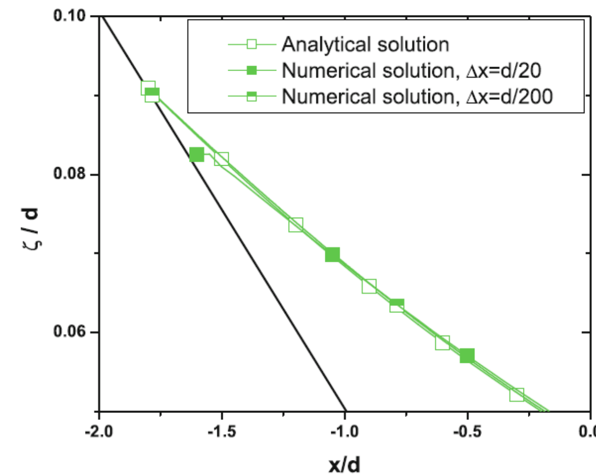
Canonical beach bathymetry and the initial wave surface profile, Synolakis (1987).

***CASE H/d*=0.019**



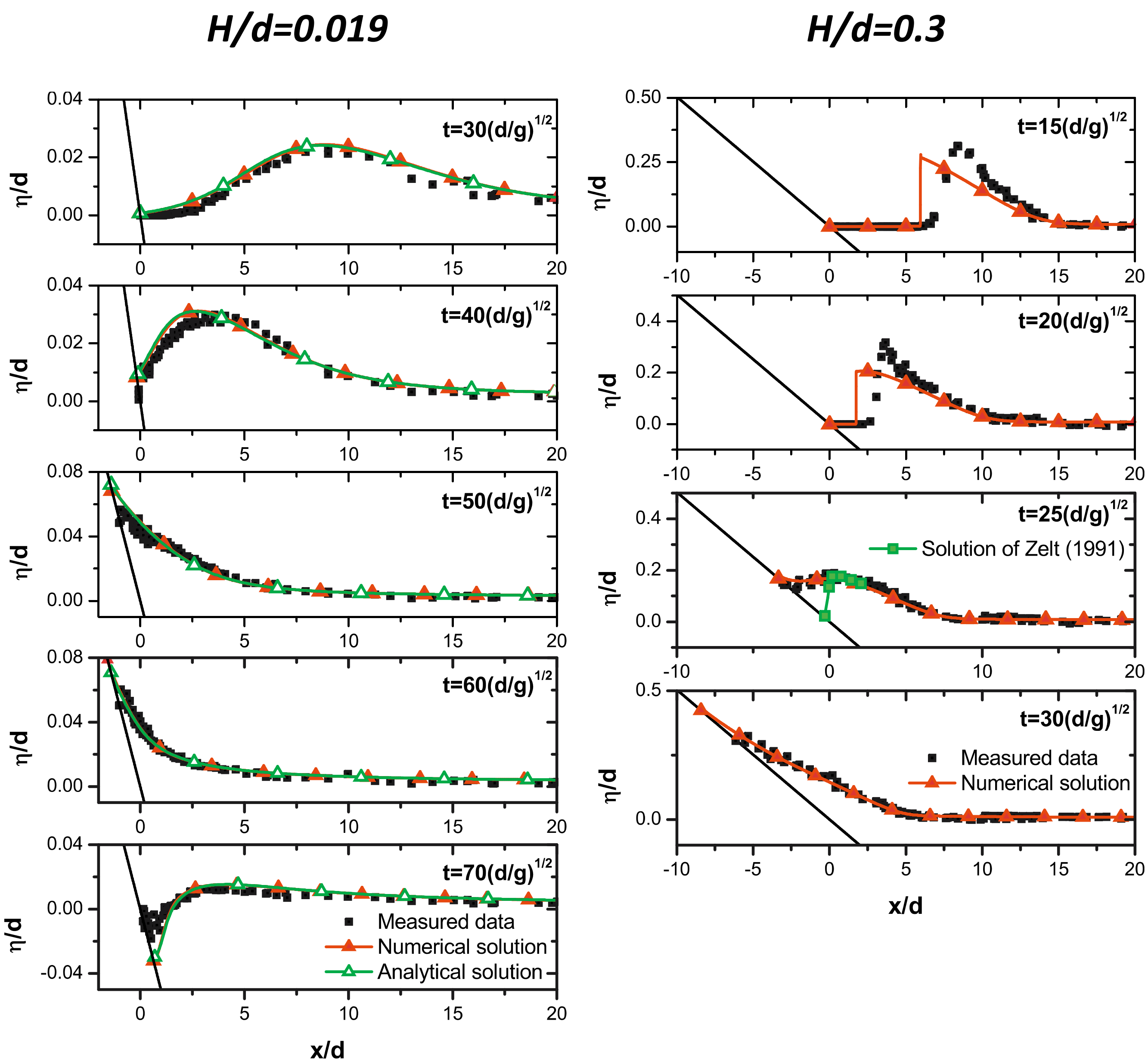
Comparison of analytically and numerically computed water level dynamics at x/d = 0.25 and x/d = 9.95





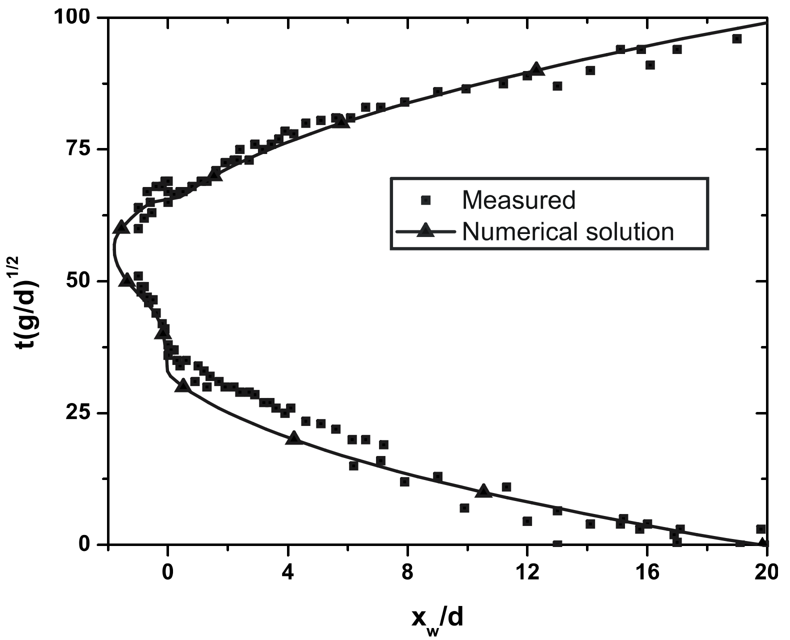
Bottom plot is an enlarged version of the top plot within the rectangle region. Two numerical solutions are computed on grids with Δx/d=20 and Δ x/d=200 are shown at $t=55(d/g)^{1/2}$. The numerical solution converges to the analytical one.

BM #4, Laboratory. Single wave on simple beach

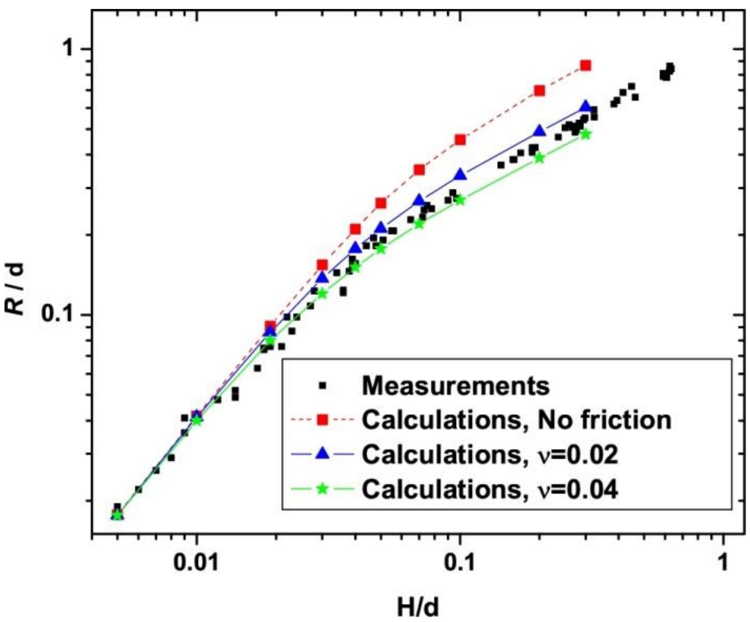


BM #4, Laboratory. Single wave on simple beach

Comparison of the numerical solution to observations



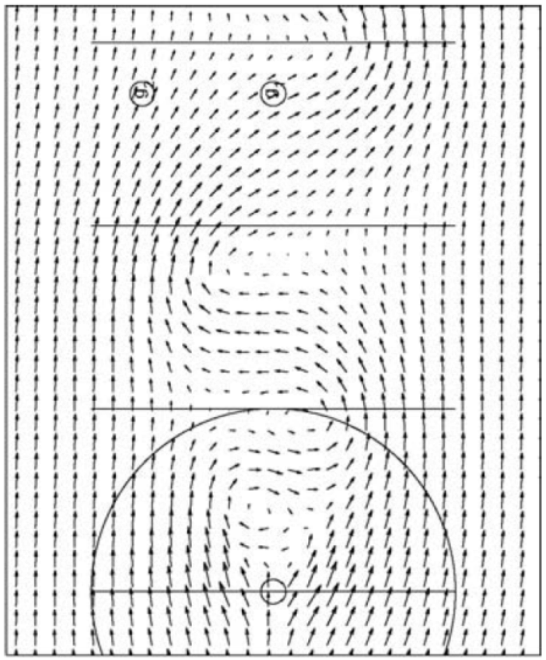
Comparison of the computed and measured waterfront location, *H/d=0.019*.
The measurements are by Synolakis (1986).



Non-dimensional maximal run-up of solitary waves on the beach versus the height of the initial wave.

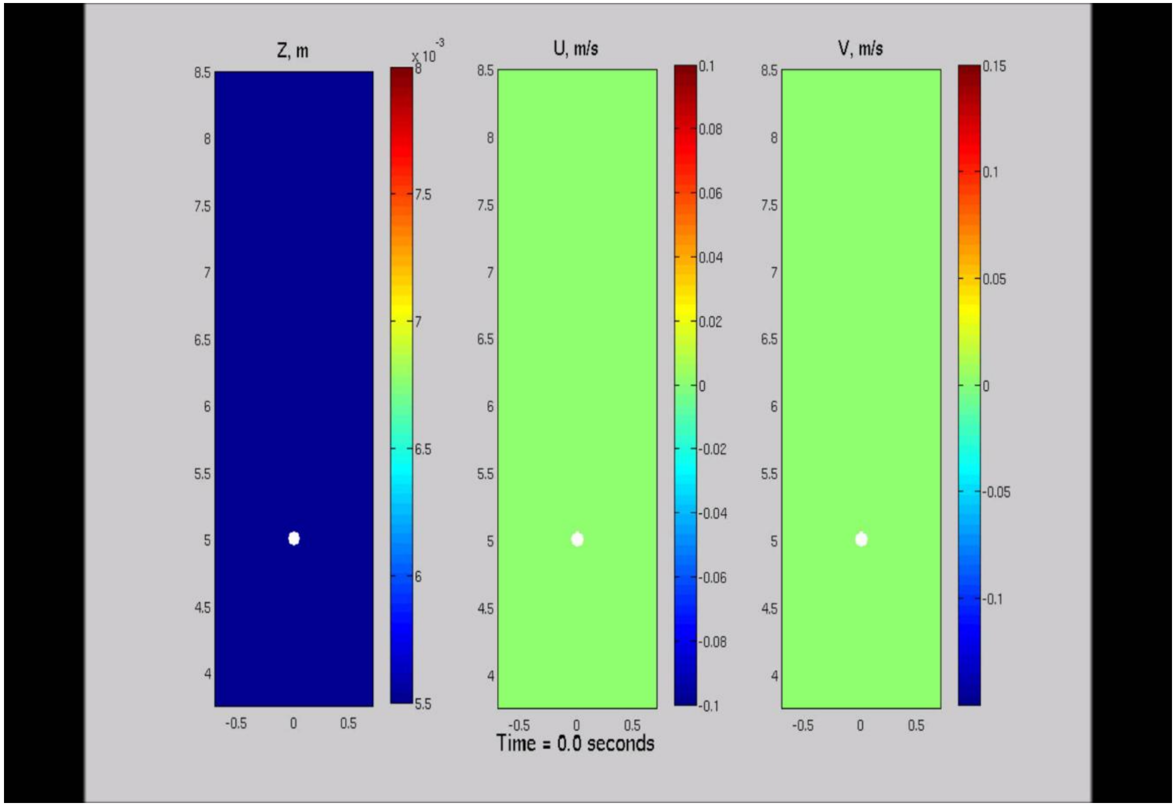
BP 1: Flow around the submerged conical island

Schematic view on the submerged island from above



The discharge velocity is U = 0.115 m/s, and the water depth is h = 0.054 m.

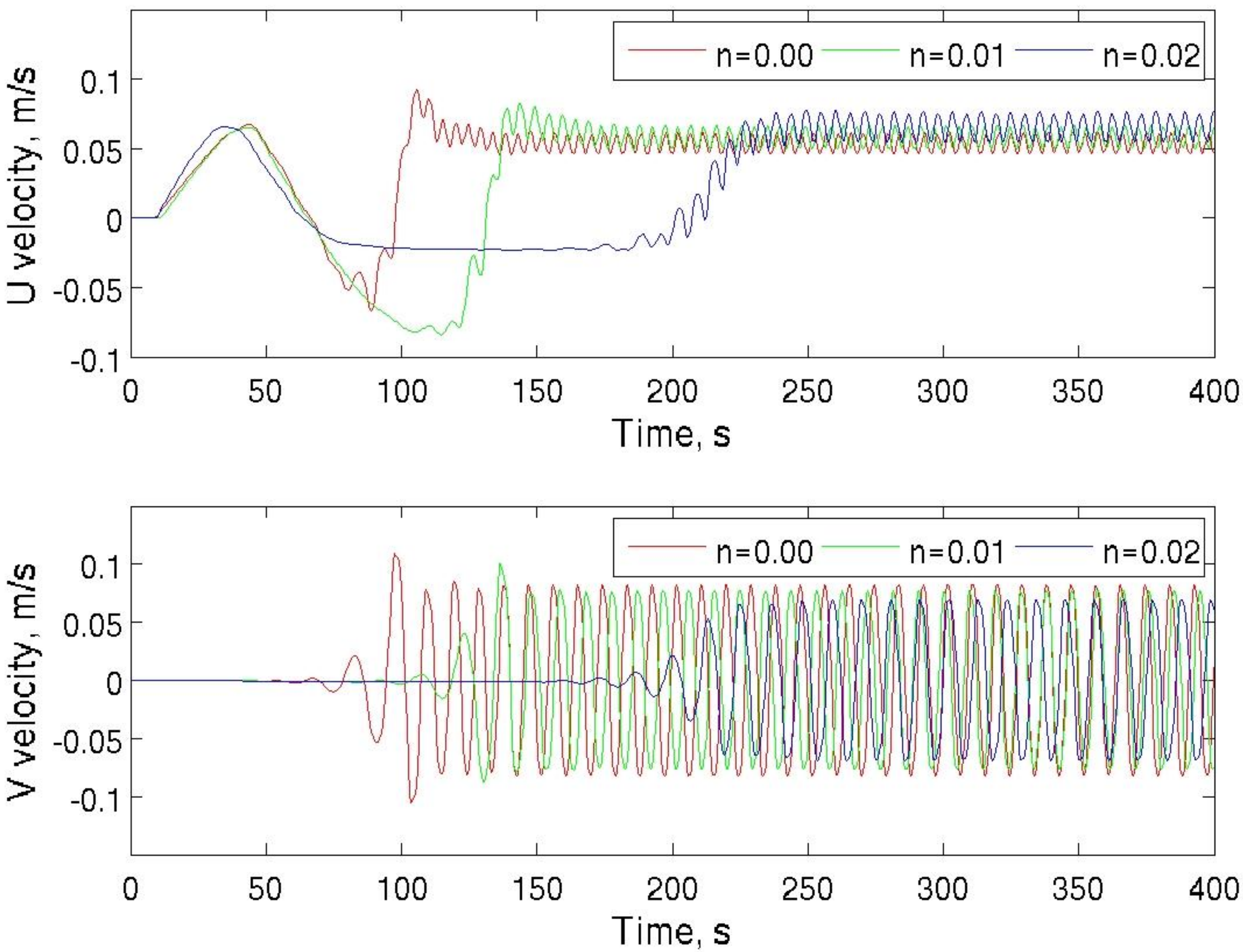
Modeled vortex past the island, n=0.01



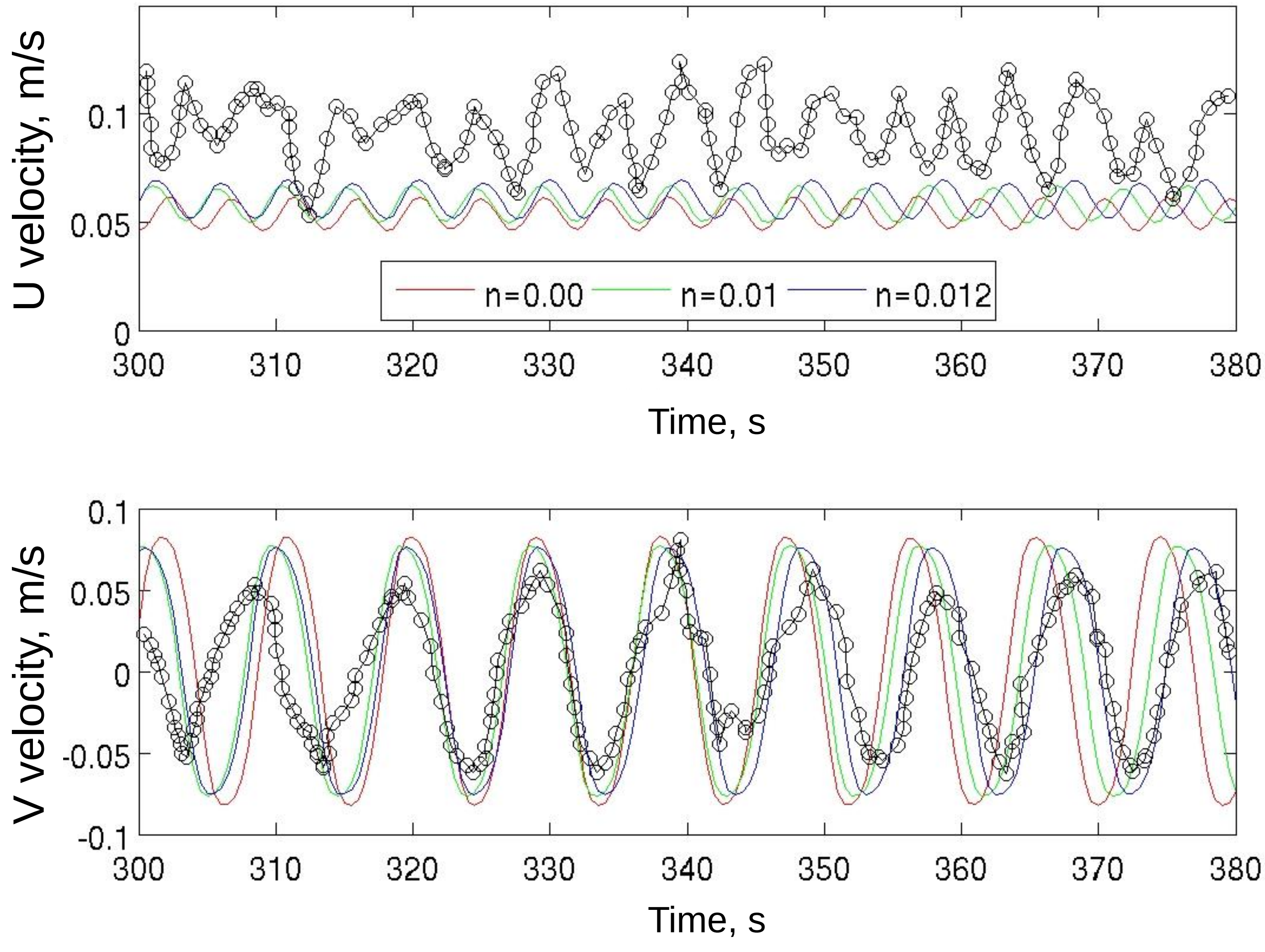
Spatial resolution, dx=dy=0.01m

The simulated flow pattern is stable and does not significantly depend on the spatial resolution and time step.

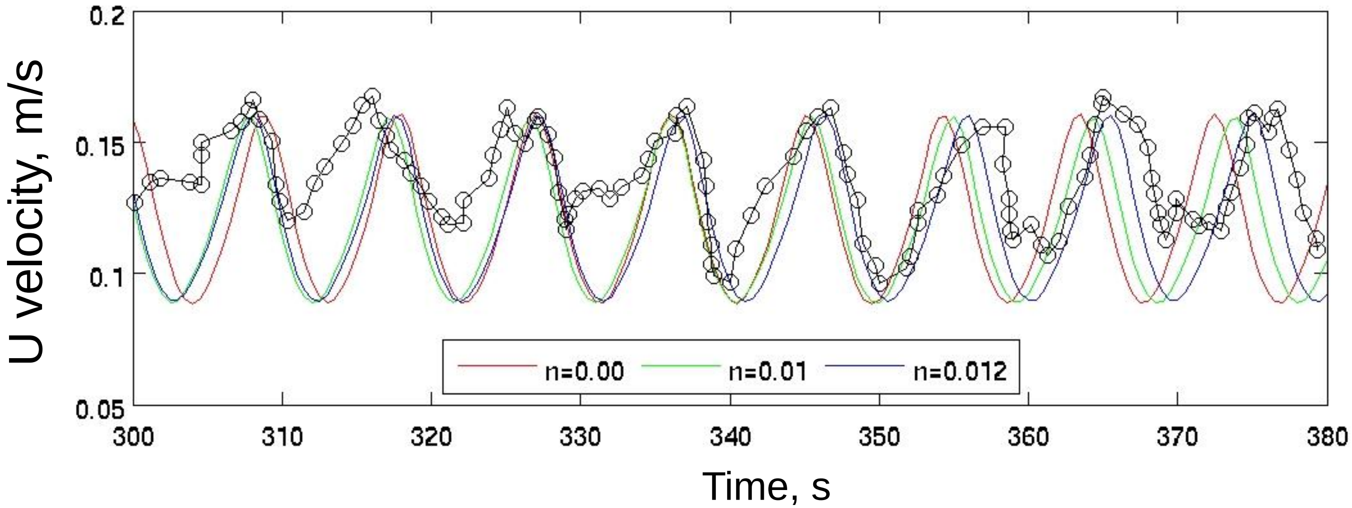
BP 1: Modeled water velocities behind the island

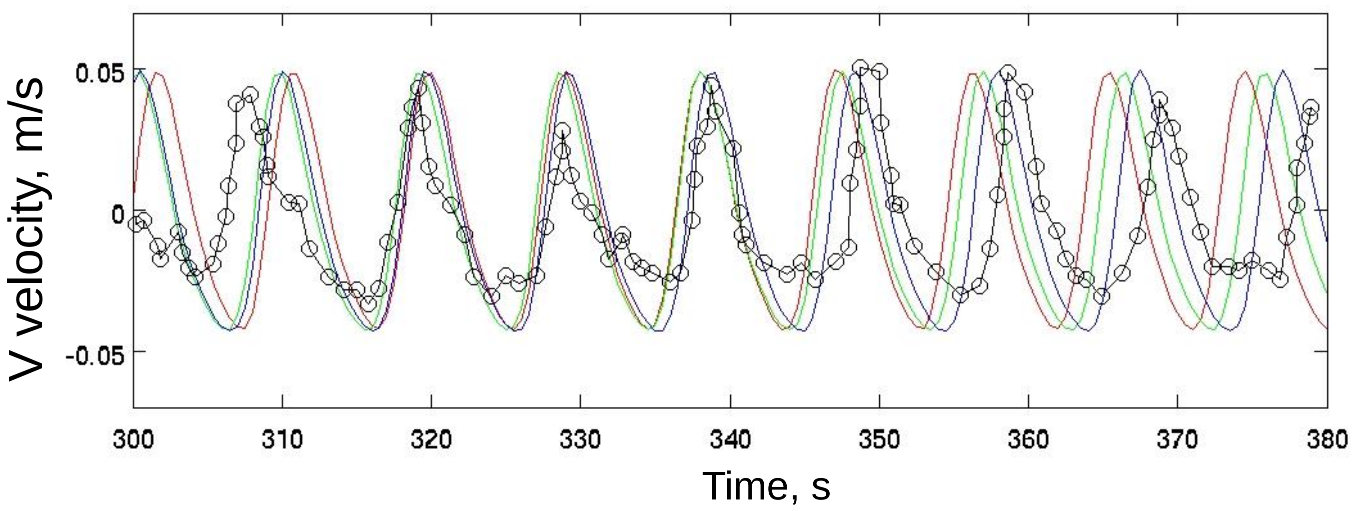


BP 1: Comparison of the modeled water velocities behind the island, Point 1



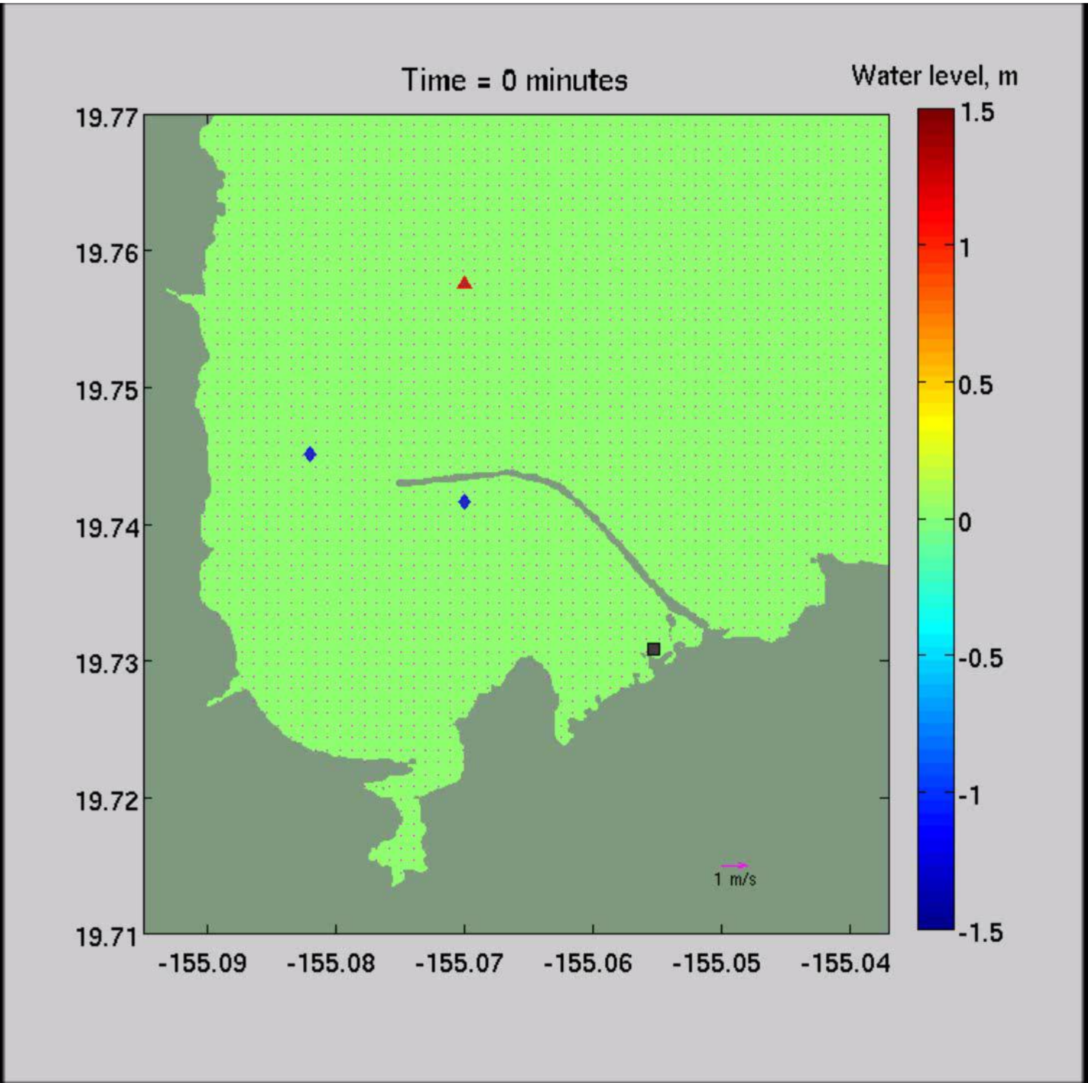
BP 1: Comparison of the modeled water velocities behind the island, Point 2



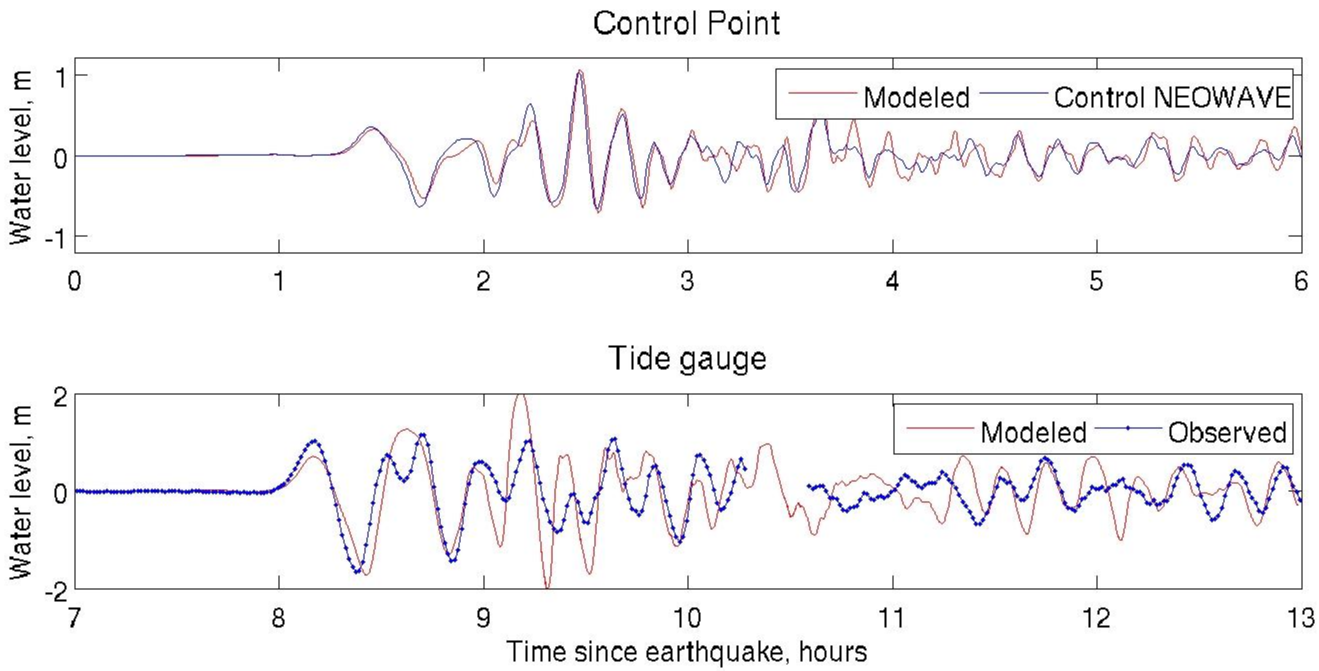


BP 2: Modeling the Japan 2011 tsunami in Hilo Harbor

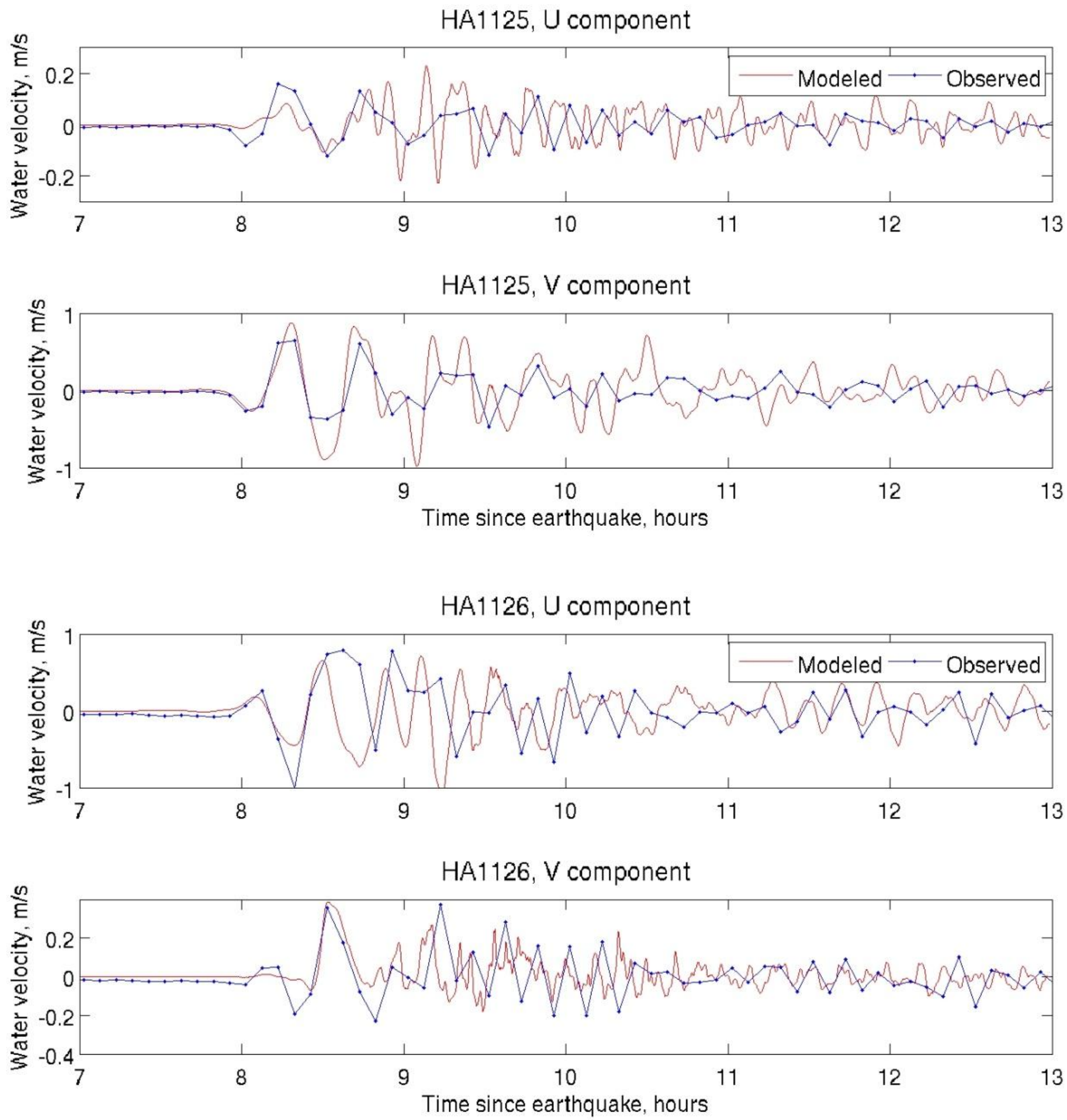
The model is forced through a segment of the northern boundary, n =0.025



BP 2: Comparison at the Control Point and Tide Gauge



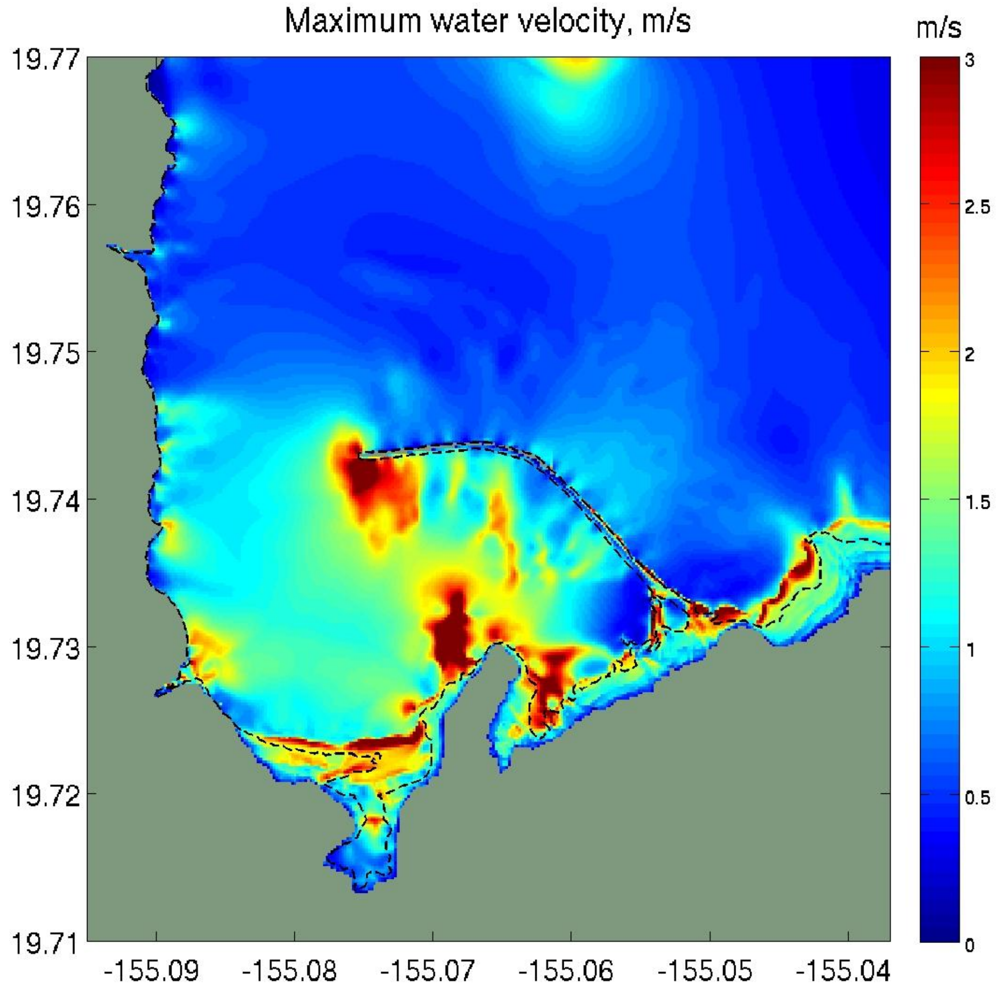
BP 2: Comparison at the ADCP locations



Spatial resolution 5m

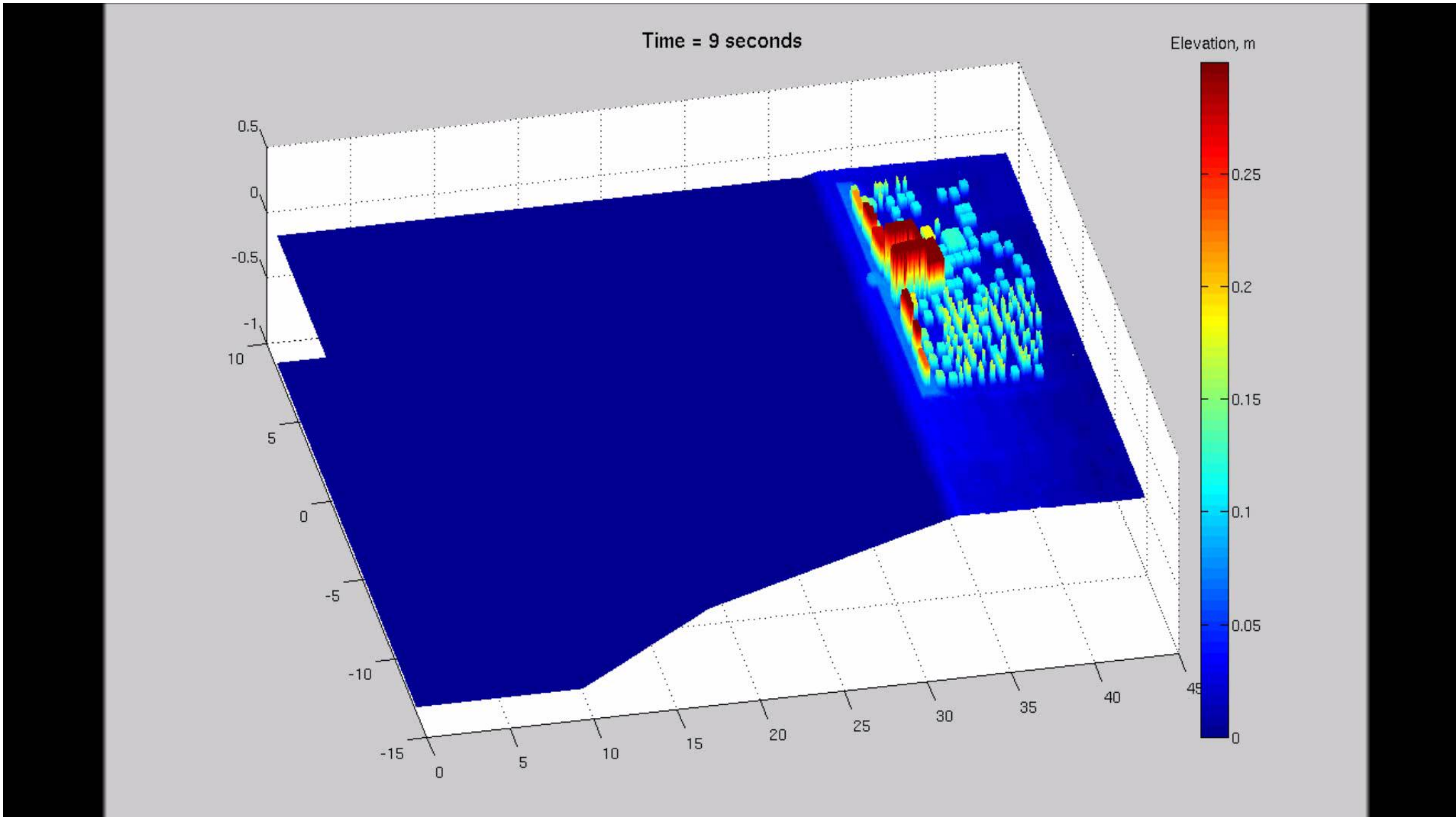
BP 2: Comparison of the computed maximum tsunami current maps

Resolution 20 m



Finer the spatial resolution, more details around jetties.

BP 4: A small-scale model of the town of Seaside, Oregon

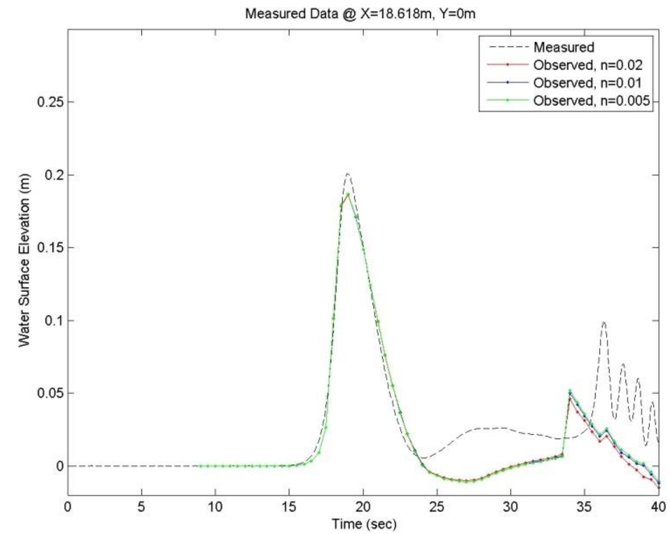


Coarse spatial resolution: 0.04 m, n=0.02

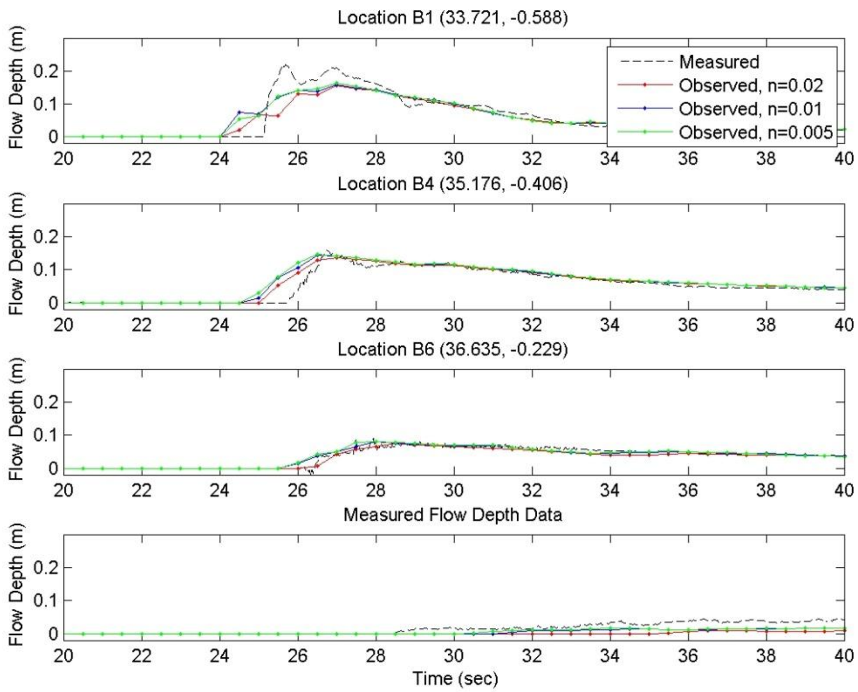
BP 4: Comparison with observations

Spatial resolution: 0.04 m

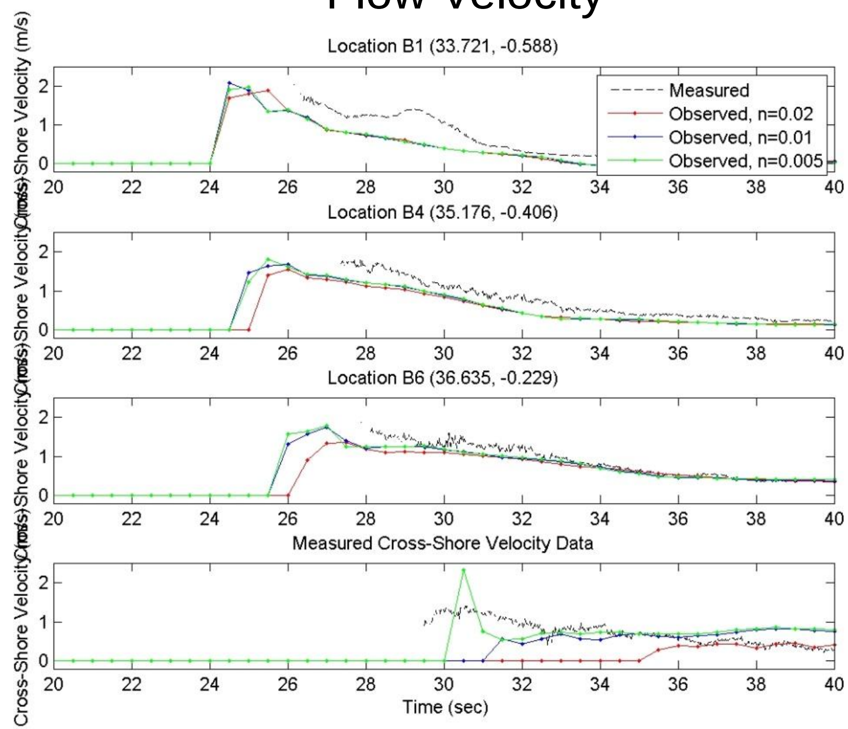
Control Point



Flow Depth



Flow Velocity



Conclusions

- BM 1 and 2 are completed; BP 4 is in progress
- Results are good, but there is always room for improvement