Overview of Benchmark Workshop **Objectives**,

- Construct a set of model validation tests for tsunami-like nearshore currents and evaluate existing models against these tests
  - Goal is to get a handle on model accuracy and variability, not to advance a “standard”
  - Ideally tests include both offshore and onshore (overland flow) currents, and are taken from both analytical/lab and field datasets
  - Identify any gaps in our modeling ability of these processes

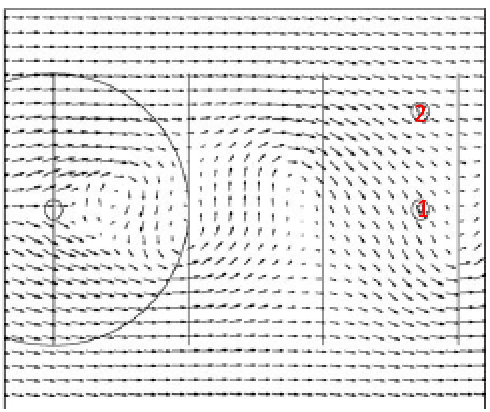
Overview of Datasets – Benchmark #1

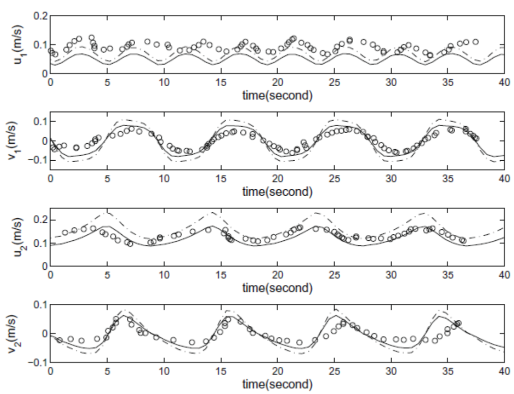
- A steady inflow case, to test a model's ability to properly generate a wake
- Steady inflow with a submerged conical island (no moving boundary)
- Wake / separation generated through spatial gradients of bottom friction
- Data to compare:

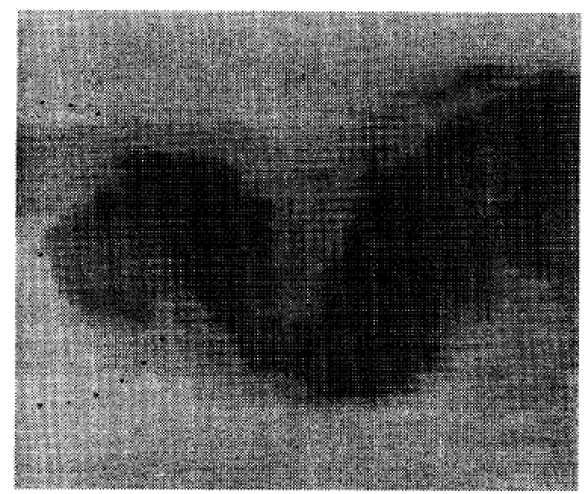
SHALLOW-WATER FLOW AROUND MODEL CONICAL ISLANDS OF SMALL SIDE SLOPE. II: SUBMERGED

By Peter M. Lloyd[1] and Peter K. Stansby[2]

ABSTRACT: Experiments have been conducted to study the unsteady wakes of submerged conical islands. The islands used in the tests have side slopes ranging from 8.0 to 33.1°. Experiments in a shallow-water channel with a steady, subcritical free stream showed vortex shedding to occur in the wake when the water depth above the island apex was relatively small. Flow separation from positions near the island apex was found to be important in producing this unsteady wake. As the water depth was increased the shedding was observed to become less vigorous and eventually stop. All islands tested produced similar results with the angle of the island side slope exerting relatively little influence on the process. The results of wind tunnel visualization studies, which used a rigid top plate to produce the effect of fluid depth, support the results from the water channel. Pictures of the surface flow patterns produced on the islands by the wind action are presented. Two-dimensional (2D) and three-dimensional (3D) shallow-water numerical models with the hydrostatic pressure assumption have been run for comparison with the laboratory measurements. The complex 3D flow observed in the near wake provides a severe test for the models. Although both models were found to reproduce gross features of the submerged island wakes their mode of generation could be quite different in model and experiment.







- Time series of velocity components in the wake
- Can the model get magnitude and frequency of the vortex shedding correct?

Not a wave, but best way to test wake generation, role of numerical dissipation in wake generation

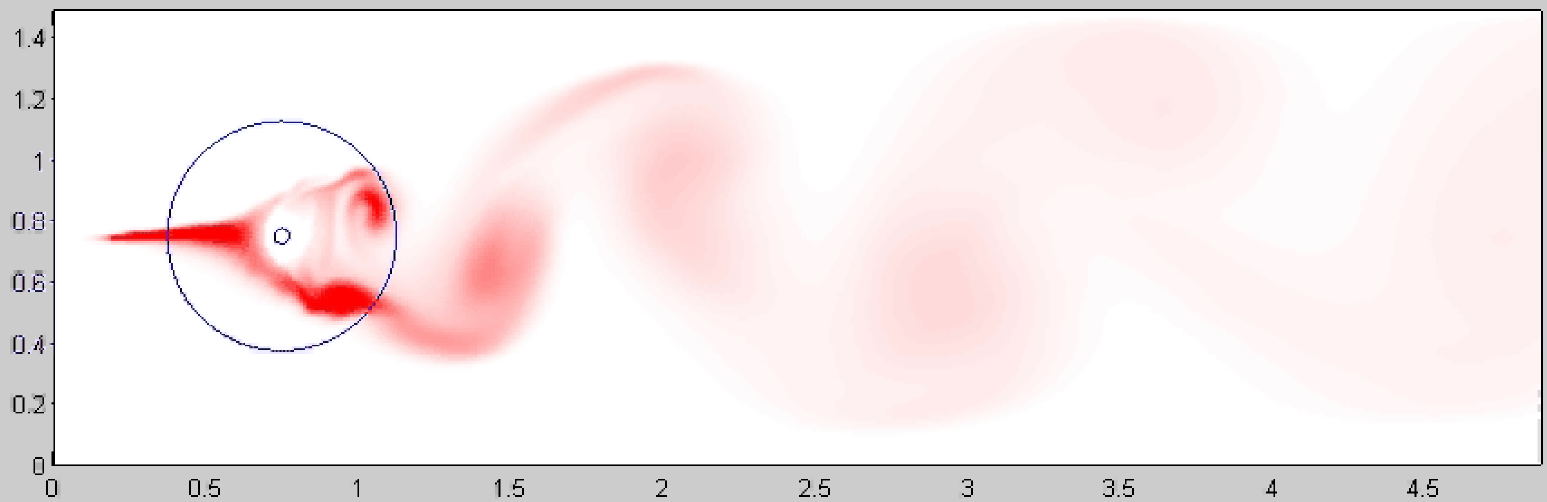
Overview of Potential Datasets – Finalists

MODELERS ASKED TO PRESENT RESULTS FOR THREE DIFFERENT CONFIGURATIONS:

1) Simulation result with dissipation sub-models included, using the roughness information included in the paper to best determine the friction factor. In the papers, the friction factor is estimated to be 0.006 (as a dimensionless pipe-flow-like drag coefficient) or a Mannings n value of 0.01 $s/m^{1/3}$. If a RE-dependent friction factor formulation is used, then a roughness height, k_s, of ~$1.5e^{-6}$ m should be used.

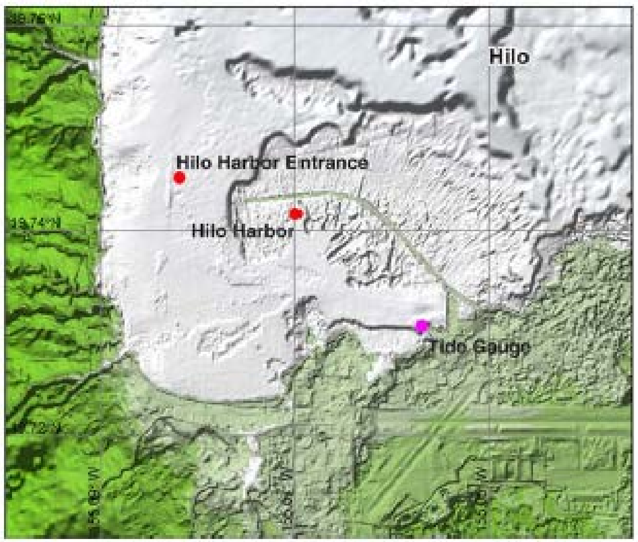
2) Simulation results with optimized agreement based on tuning of dissipation model coefficients (e.g. friction factor). Note that this simulation can be skipped if the modelers do not wish to optimize their comparisons.

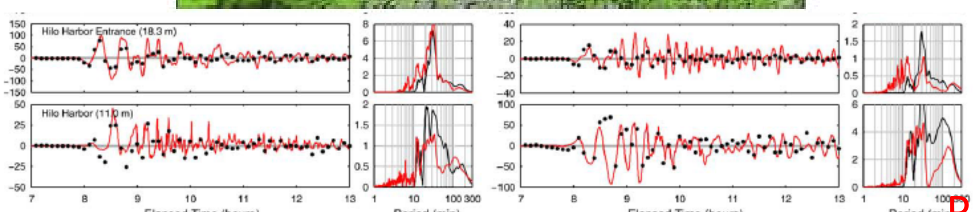
3) Simulation result with ALL dissipation sub-models NOT included (e.g. a physically inviscid simulation). The purpose of this test is to understand the relative importance of physical vs numerical dissipation for this class of comparison.



Overview of Datasets – Benchmark #2

- Hawaii ADCP network & Pawlak data, 2001
- A number of good candidates; many gages are in relatively deep water (>20 m) and so currents are both tidally affected and linear (wrt water wave)
- Hilo Harbor is a challenging location:





- Low data sampling rate (6 min), many current oscillations not resolved

JOURNAL OF GEOPHYSICAL RESEARCH: OCEANS, VOL. 118, 5703–5719, doi:10.1002/jgrc.20413, 2013

Surges around the Hawaiian Islands from the 2011 Tohoku Tsunami

Kwok Fai Cheung,[1] Yefei Bai,[1] and Yoshiki Yamazaki[1]

Received 6 June 2013; revised 19 August 2013; accepted 22 September 2013; published 22 October 2013.

[1] The 2011 Tohoku tsunami devastated the northeastern Japan coasts and caused localized damage to coastal infrastructure across the Pacific. The tsunami resulted in strong currents around the Hawaiian Islands that led to closure of harbors and marinas for up to 38 h after its arrival. We utilize a nonhydrostatic model to reconstruct the tsunami event from the seismic source for elucidation of the physical processes and inference of the coastal hazards. A number of tide gauges, bottom pressure sensors, and ADCPs provided point measurements for validation and assessment of the model results in Hawaii. Spectral analysis of the computed surface elevation and current reveals complex flow patterns due to multiscale resonance. Standing waves with 33–75 min period develop along the island chains, while oscillations of 27 min or shorter are primarily confined to an island or an island group with interconnected shelves. Standing edge waves with periods 16 min or shorter, which are able to form nodes on the reefs and inside harbors, are the main driving force of the observed coastal currents. Resonance and constructive interference of the oscillation modes provide an explanation of the impacts observed in Hawaii with implications for emergency management in Pacific island communities.

Citation: Cheung, K. F., Y. Bai, and Y. Yamazaki (2013), Surges around the Hawaiian Islands from the 2011 Tohoku Tsunami, *J. Geophys. Res. Oceans*, *118*, 5703–5719, doi:10.1002/jgrc.20413.

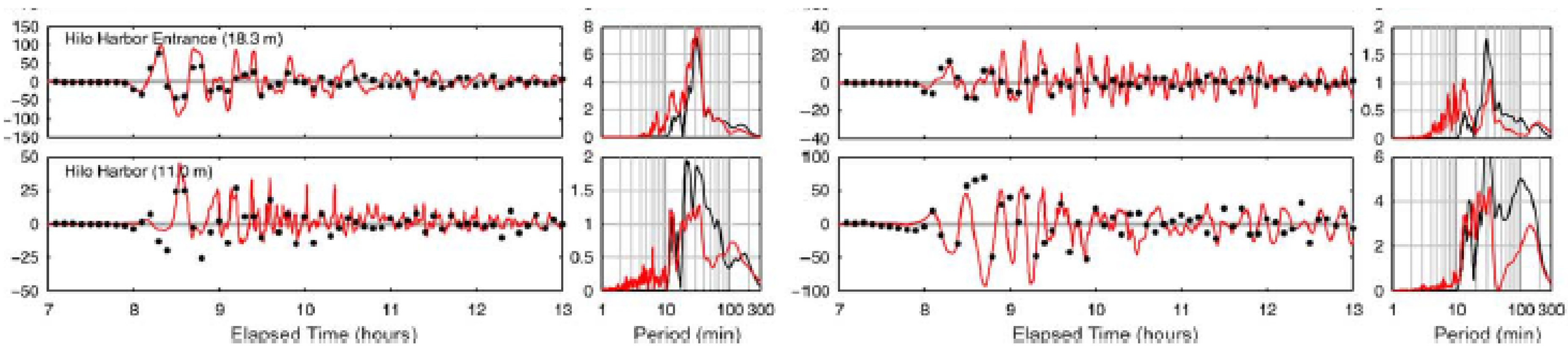
- **What level of precision can we expect from a model with regard to modeling currents on real bathymetry?**
- **Will a model converge with respect to speed predictions and model resolution?**
- **What is the variation across different models, using the same wave forcing, resolution, and bottom friction?**

Probably most comprehensive current dataset for a tsunami; data at most interesting & challenging locations not ideal

Overview of Datasets – Benchmark #2

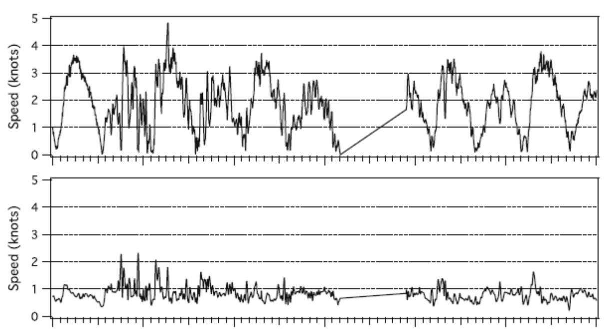
Modelers asked to provide results for at three different numerical configurations:

- 1) Simulation result at ~20 m resolution (2/3 arcsec, de-sample the input bathymetry), using a Mannings n coefficient of 0.025 (or approximate equivalent if using a different bottom stress model)
- 2) Simulation result at ~10 m (1/3 arcsec) resolution using a Mannings n coefficient of 0.025 (or approximate equivalent if using a different bottom stress model)
- 3) Simulation result at 5 m resolution (1/6 arcsec, or the lowest resolution possible; use bi-linear interpolation), using a Mannings n coefficient of 0.025 (or approximate equivalent if using a different bottom stress model)
- Modelers are encouraged to compare simulation results both locally (required by the benchmark) as well as to examine statistical measures of spatial variability between the different resolutions.



Overview of Datasets – Benchmark #3

- New Zealand ADCP / Tauranga Bay
- ADCP in the main channel, five nearby tide stations



- Data sampled at 2 min; resolution good
- Clear tidal modulation of the tsunami signals
  - Tides important
- Models can be forced with water elevation from Abeacon gage
  - No need to specify EQ source, a bit more control

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Pure and Applied Geophysics

Observations, Effects and Real Time Assessment of the March 11, 2011 Tohoku-oki Tsunami in New Zealand

Jose C. Borrero,[1,2,8] Rob Bell,[3] Claudia Csato,[1] Willem DeLange,[4] Derek Goring,[5] S. Dougal Greer,[1,8] Vernon Pickett,[6] and William Power[7]

Abstract—The great Tohoku-oki earthquake of March 11, 2011 generated a devastating tsunami in the near field as well as substantial far-field effects throughout the Pacific Ocean. In New Zealand, the tsunami was widely observed and instrumentally recorded on an extensive array of coastal tidal gauges and supplemented by current velocity data from two sites. While the tsunami's first arrival was on the morning of March 12 in New Zealand, the strongest effects occurred throughout that afternoon and into the following day. Tsunami effects consisted primarily of rapid changes in water level and associated strong currents that affected numerous bays, harbors, tidal inlets and marine facilities, particularly on the northern and eastern shores of the North Island. The tsunami caused moderate damage and significant overland flooding at one location. The tsunami signal was clearly evident on tide gauge recordings for well over 2 days, clearly illustrating the extended duration of far field tsunami hazards. Real time analysis and modelling of the tsunami through the night of March 11, as the tsunami crossed the Pacific, was used as a basis for escalating the predicted threat level for the northern region of New Zealand. A comparison to recorded data following the tsunami shows that these real time prediction models were accurate despite the coarse near-shore bathymetry used in the assessment, suggesting the efficacy of such techniques for future events from far-field sources.

Key words: Tsunami, New Zealand, Japan, tide gauge, field survey, numerical modeling.

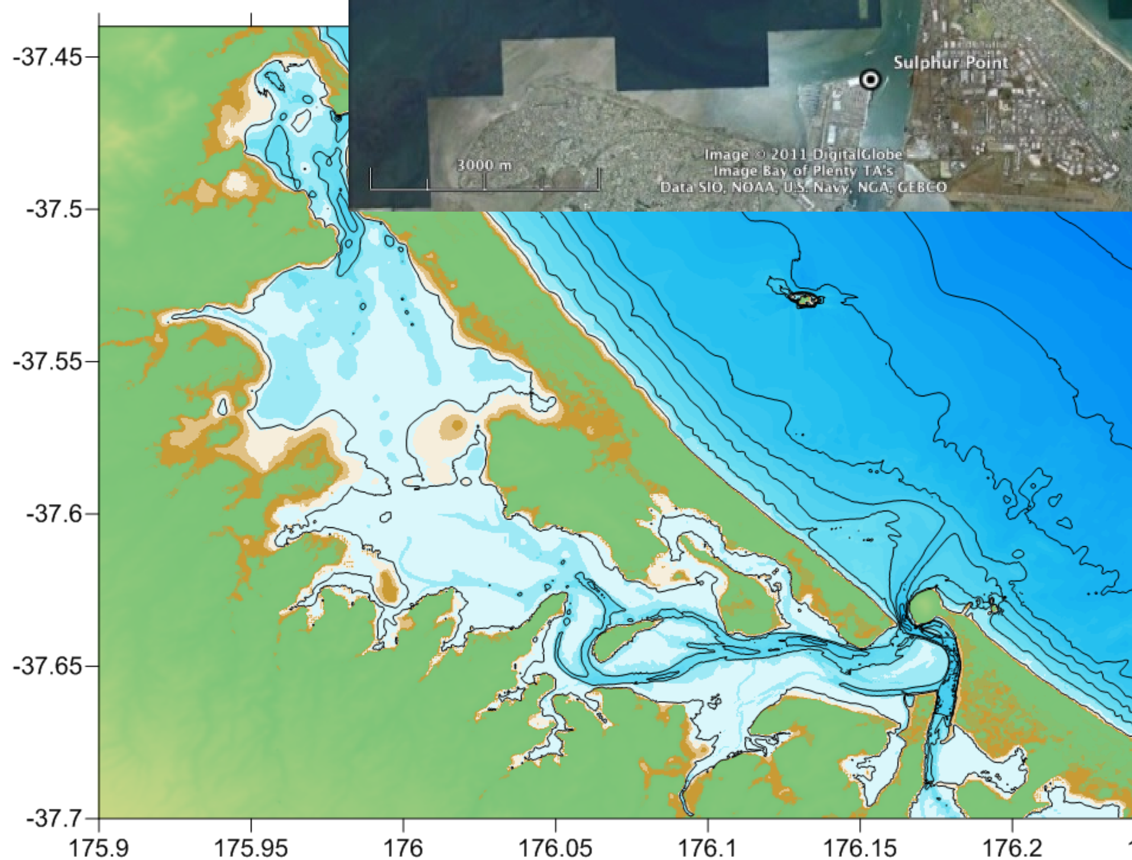
1. Introduction

The great Tohoku-oki earthquake ($M_w = 8.9$, USGS) of March 11, 2011 (0546 UTC), occurred along the northern east coast of Honshu Island in Japan, generated a devastating tsunami with the strongest effects observed in the near field close to the earthquake source and ultimately resulted in nearly 20,000 casualties and billions of dollars in damage (IOC/UNESCO, 2011). The first warning message from the Pacific Tsunami Warning Center (PTWC) was issued 9 min after the event (0555 UTC), and listed the earthquake as a Magnitude 7.9. The message established a tsunami warning for the region close to the earthquake source and put the

If we want to include a case where the tides may play a role, this is likely the best option

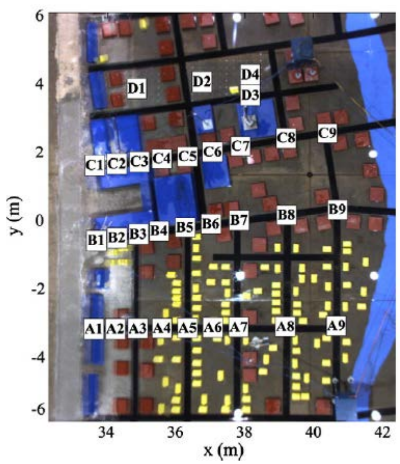
Overview of Datasets – Benchmark #3

- Drive simulations with measured free surface elevation @ A Beacon
  - ~20 m depth
  - No source modeling / propagation needed
- Tsunami-only simulation
  - Estuary is large wrt to tsunami
  - Small domain (900 by 600 w/ 10m resolution)
  - 12 hours simulation time
  - Drive with tsunami signal extracted from ABeacon
- Tsunami+Tide simulation
  - Estuary is intermediate wrt to tides (need to model entire bay to get tidal entrance velocity signal correct)
  - Large domain (3000 by 3000 w/ 10 m resolution)
  - 60+hours simulation time (need at least one tidal cycle to “warm up” estuary

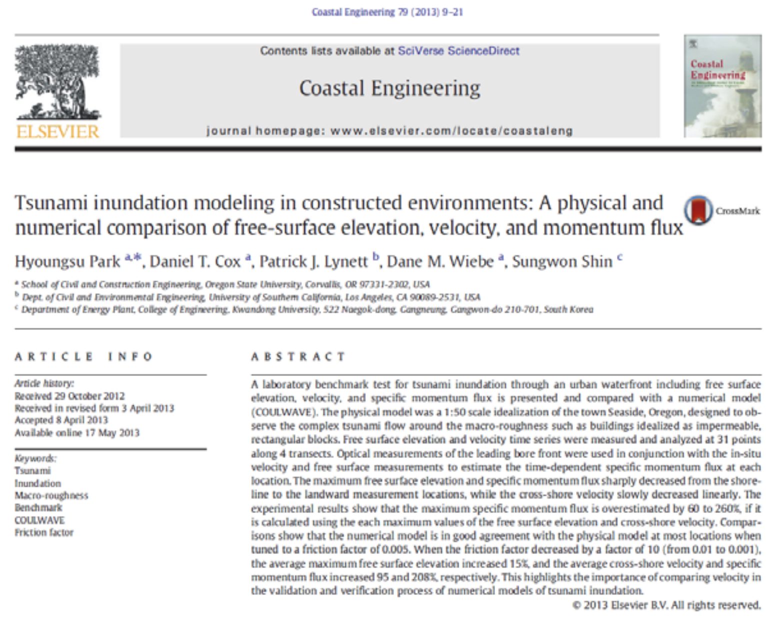


Overview of Datasets – Benchmark #4

- Flow through built environment
- Seaside model built at OSU
- Model needs to be able to resolve buildings (including overtopping of buildings) in the topo surface
- Compare with time series of velocities and elevations (some co-located) through "streets"



- Capturing the bore front and getting bottom friction "right" are important to the velocity comparisons
- Incident wave condition defined by a free surface time series (not a solitary wave)



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Tsunami inundation modeling in constructed environments: A physical and numerical comparison of free-surface elevation, velocity, and momentum flux

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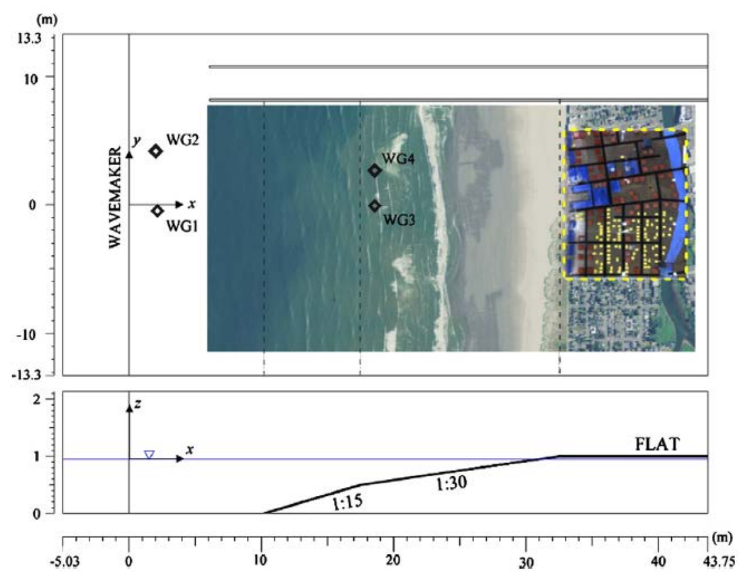
ABSTRACT

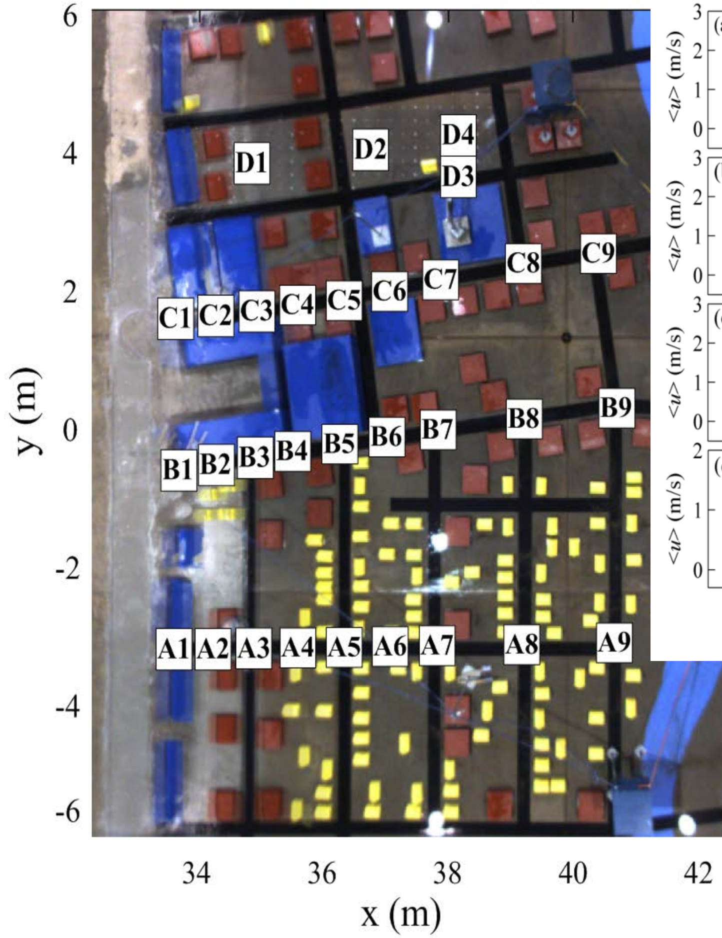
A laboratory benchmark test for tsunami inundation through an urban waterfront including free surface elevation, velocity, and specific momentum flux is presented and compared with a numerical model (COULWAVE). The physical model was a 1:50 scale idealization of the town Seaside, Oregon, designed to observe the complex tsunami flow around the macro-roughness such as buildings idealized as impermeable, rectangular blocks. Free surface elevation and velocity time series were measured and analyzed at 31 points along 4 transects. Optical measurements of the leading bore front were used in conjunction with the in-situ velocity and free surface measurements to estimate the time-dependent specific momentum flux at each location. The maximum free surface elevation and specific momentum flux sharply decreased from the shoreline to the landward measurement locations, while the cross-shore velocity slowly decreased linearly. The experimental results show that the maximum specific momentum flux is overestimated by 60 to 260%, if it is calculated using the each maximum values of the free surface elevation and cross-shore velocity. Comparisons show that the numerical model is in good agreement with the physical model at most locations when tuned to a friction factor of 0.005. When the friction factor decreased by a factor of 10 (from 0.01 to 0.001), the average maximum free surface elevation increased 15%, and the average cross-shore velocity and specific momentum flux increased 95 and 208%, respectively. This highlights the importance of comparing velocity in the validation and verification process of numerical models of tsunami inundation.

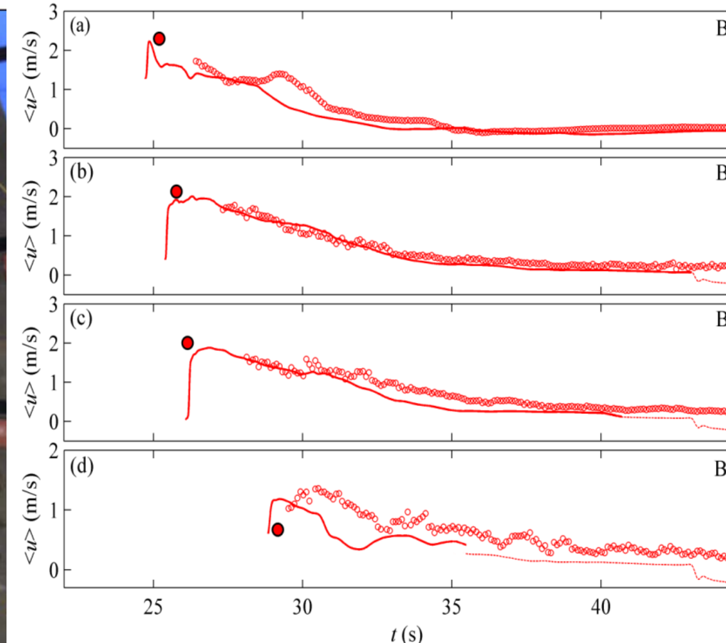


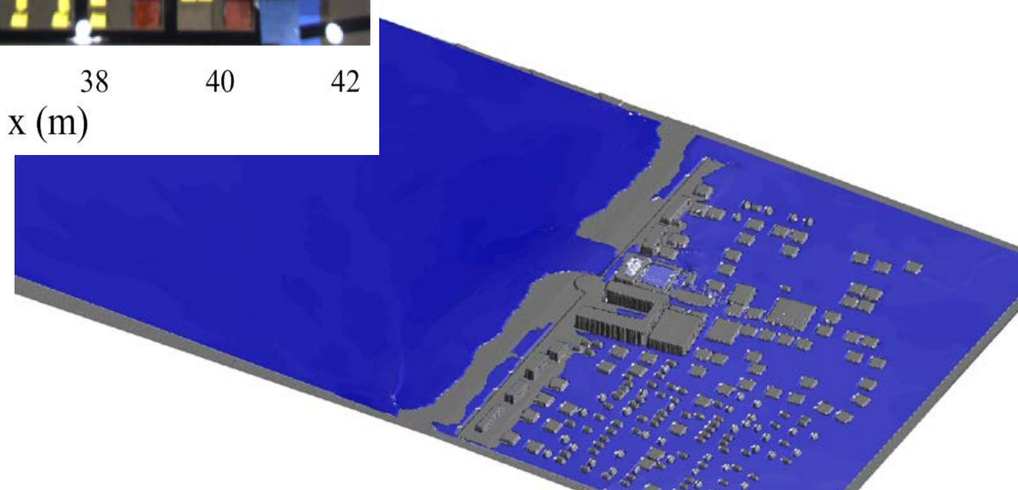
Very nice dataset

Overview of Datasets – Benchmark #4

- Wavemaker or near-wave maker free surface elevation time series (not solitary wave or other "known" wave solution)
- Requires moving shoreline
- Breaking model
- Lateral vertical walls
- Need to be able to handle structures either as vertical walls or an approximate steep slope



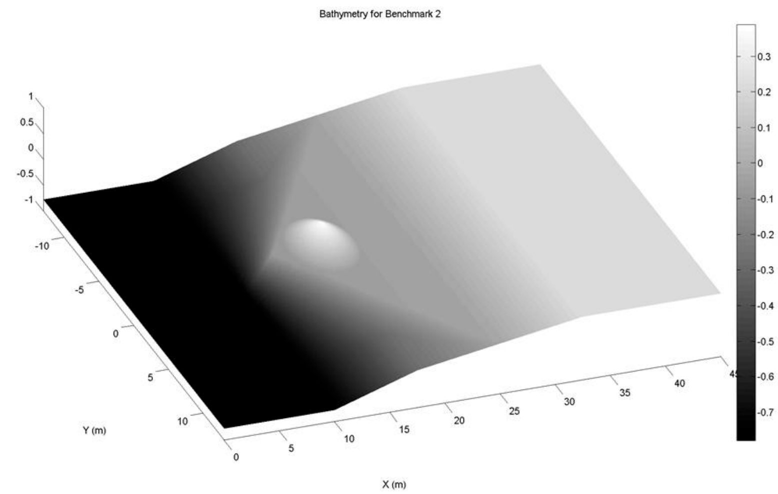


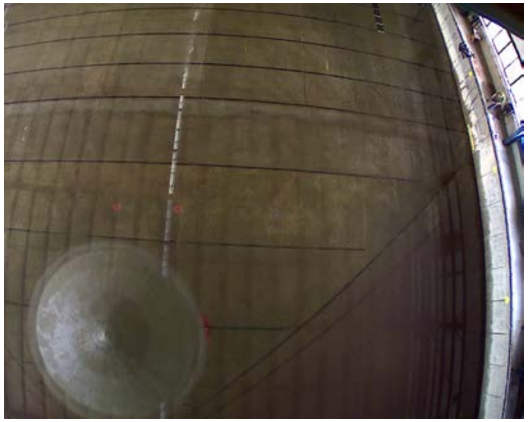


Overview of Datasets – Benchmark #5

- Breaking solitary wave past a conical obstacle
- Used in the 2009 "ISEC" workshop at OSU
  - See videos here
  - https://www.youtube.com/watch?v=I4uTHWBpaZg
  - https://www.youtube.com/watch?v=p8LPXs5sz1Y
- Compare with free surface and velocity measurements on the shelf
- PIV derived velocity time series in the wake behind the island
  - See video here:
  - https://www.youtube.com/watch?v=iUQo8G-ZMRQ

- Similar to L&S (steady flow), except with a wave, breaking, overtopping – MUCH more complex





Overview of Datasets – Benchmark #5

- Wavemaker or solitary wave initial condition
- Requires moving shoreline
- Breaking model
- Lateral vertical walls
- Would probably use the same data points used for the ISEC workshop in 2009
- May be additional velocity data available in lee of bump