Physical and Numerical Modeling of Waves over Fringing Reefs

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Volker Roeber & Kwok Fai Cheung
Department of Ocean and Resources Engineering, University of Hawaii

Marcelo Kobayashi
Department of Mechanical Engineering, University of Hawaii

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O. H. HINSDALE WAVE RESEARCH LABORATORY
OREGON STATE UNIVERSITY

Goals after conduction of experiments:

- Data analysis of OSU experiments used for validation of numerical

3 slopes, 3 reef crests, 3 water levels, 6 Solitary wave

-Development of numerical model for wave propagation over fringing reef

- Parameterization of energy dissipation and surf similarity for waves over reefs

Current Findings:

Numerical model has to include:

- Dispersion
- Wave breaking
- Friction
- Conservative variables and conservative scheme!

Energy dissipation is function of:

- Conjugate depths near breaking point (⇨bore height, speed)
- Reef crest height
- Slope
- Type of wave breaking

Numerical Model

Based on Nwogu's Boussinesq equations with conservative variables:

Continuity Equation:

$$H_t + M_x + \left[\left(\frac{z^2}{2} - \frac{h^2}{6} \right) h \left(\frac{M}{H} \right)_{xx} + \left(z + \frac{h}{2} \right) h \left(h \frac{M}{H} \right)_{xx} \right]_x = 0$$

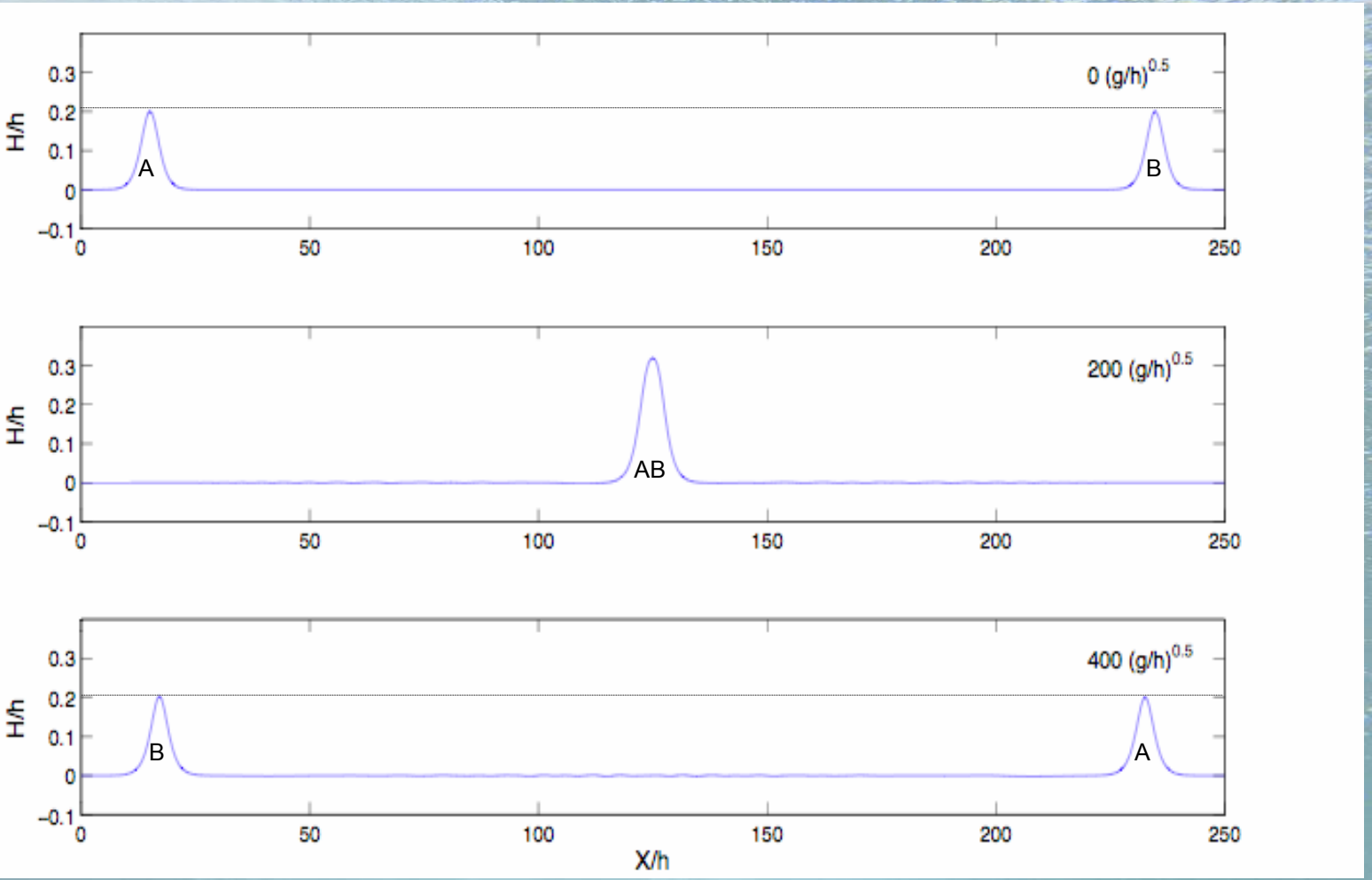
$$M = HU$$

Momentum Equation:

$$M_t + \left(\frac{M^2}{H} \right)_x + \frac{M}{H} \left[\left(\frac{z^2}{2} - \frac{h^2}{6} \right) h \left(\frac{M}{H} \right)_{xx} + \left(z + \frac{h}{2} \right) h \left(h \frac{M}{H} \right)_{xx} \right]_x$$
$$+ H \left[g(H_x - h_x) + z \left(\frac{z}{2} \left(\frac{M}{H} \right)_{xxt} + \left(h \left(\frac{M}{H} \right)_t \right)_{xx} \right) \right] + \tau_x + R_{Bx} = 0$$

- Finite volume MUSCL scheme with 2nd order predictor and 3rd order corrector
- Novel exact Riemann solver for wet-dry beds (no iterations needed)
- Novel wave breaking term; eddy viscosity concept depending on momentum gradients
- Stable and accurate even when used outside of its range of applicability
- Volume and energy conservative, very little numerical dissipation

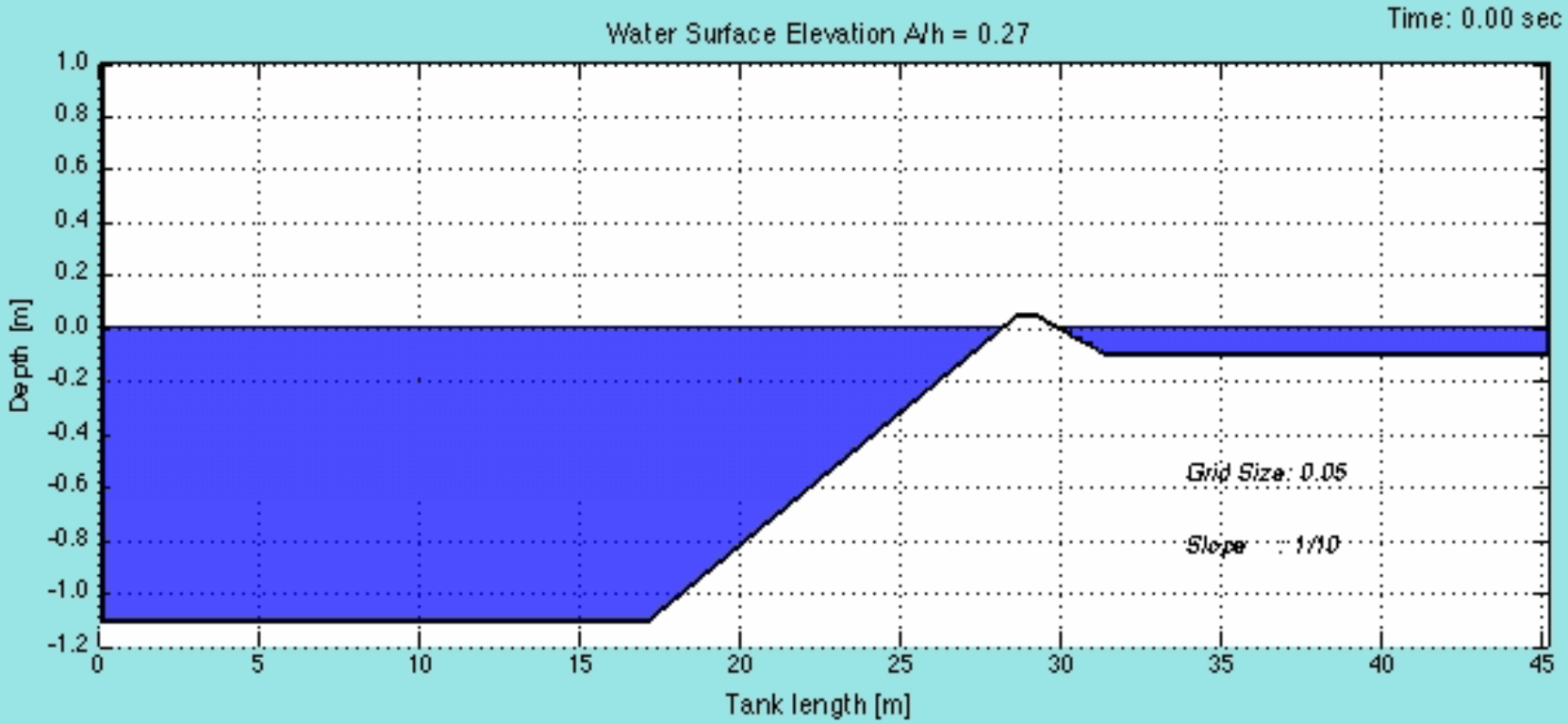
Soliton Collision (dispersion test)



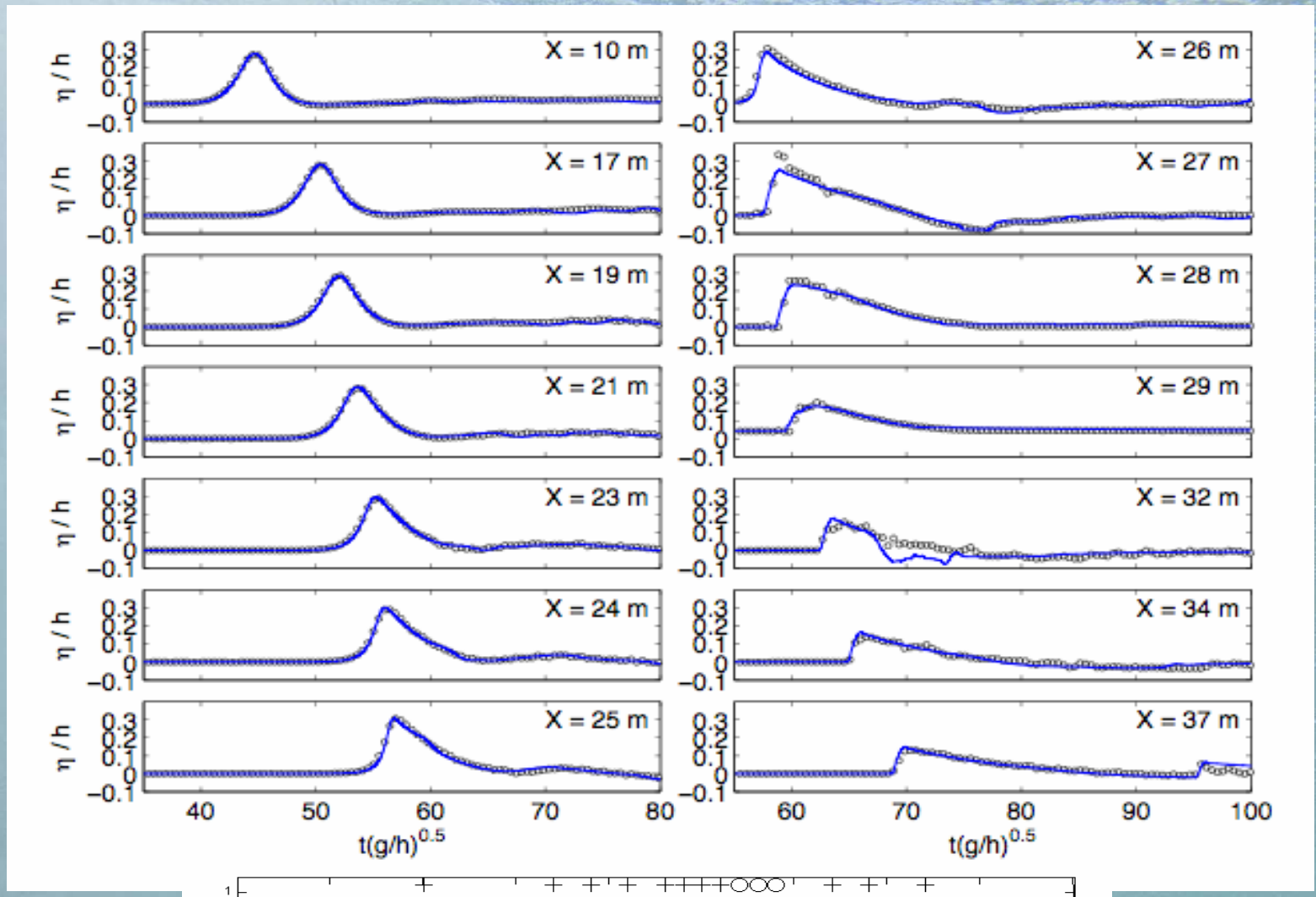
OSU: 30-cm solitary wave over exposed reef crest

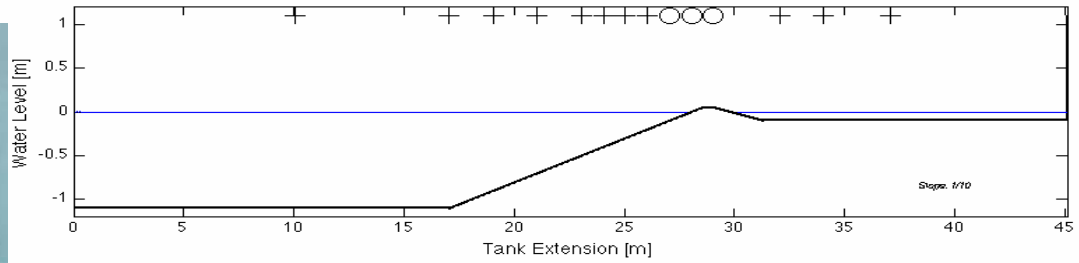
0.30-cm solitary wave
1.10-m water depth
0.05-m reef crest
Cr = 0.4
dx = 0.05-m

Animation

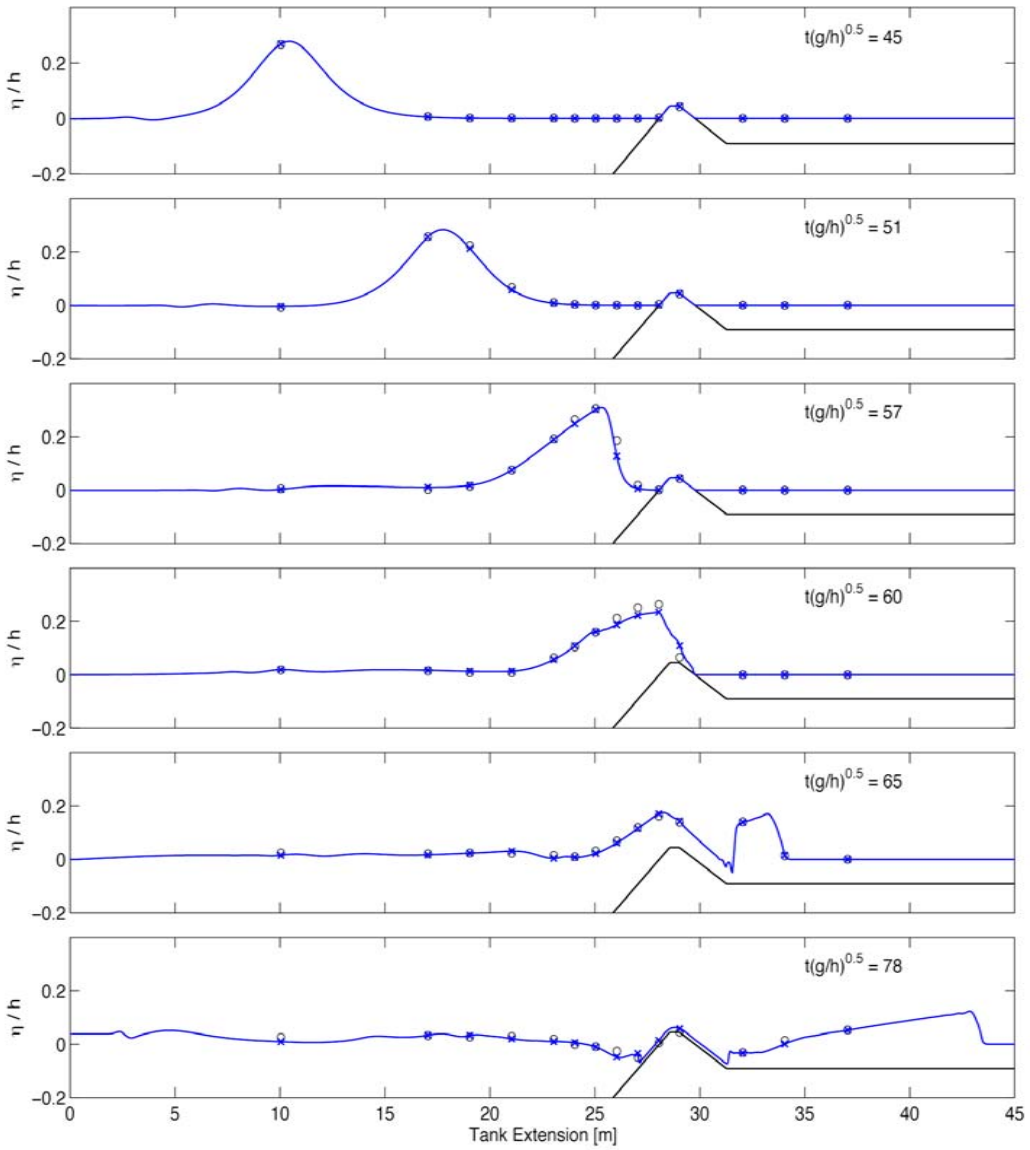


30-cm solitary wave over exposed reef crest: *Time-series*





30-cm solitary wave over exposed reef crest: *Time-snapshots*



Propagation

Shoaling

Before breaking (start at 27.4-m)

During breaking (end at 28.9-m)

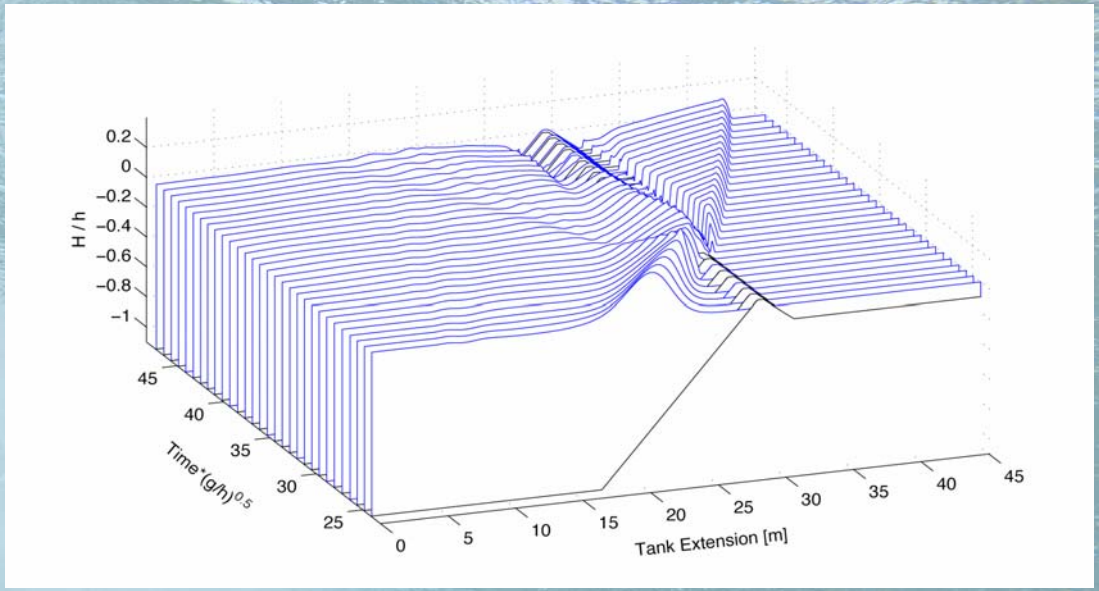
Second hydraulic jump

Bore propagation & reef exposure

Energy Dissipation over reef

Wave propagation over reef (obstacles) involves:

- Energy Reflection
- Energy Dissipation throughout wave breaking
- Energy Transmission



Energy dissipation involves:

- Wave height and shape
- Reef height and width
- Slope
- Breaker type

Continuing Work

Parametric Study:

Since model has been validated by experimental data,
use model in a parametric study to characterize nearshore wave conditions (different slopes, crests, water levels, waves).

Surf Similarity:

Since depth integrated model cannot simulate wave overturning,
OSU experiments help finding surf similarity parameter.

Tool:

Produce a validated tool to provide nearshore wave conditions for Performance Based Tsunami Engineering.

THANK YOU!