

A Rogue Bore-Soliton-Splash

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"Mathematics of Computational Science", University of Twente
[International Workshop on Rogue Waves](#)



Fluid Fascinations 2010

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



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Splashing
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Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

Creation of:

- *Hele-Shaw beach* at Art & Science show **Fluid Fascinations** in honour of the late D. Howell Peregrine.
- Bore-Soliton-Splash.

1 Motivation

2 Splashing Results

3 Mathematical Challenges

4 Relation to Tohoku Tsunami

5 Discussion

1. Motivation

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

History of The Splash:

- *Request:* Create a soliton in the wave channel at the opening of the Research & Education Plaza at University of Twente, see photo.
- *My response:* Making solely a soliton is too boring given the opaque cement channel walls.
- *The show:* Create instead a water feature for opening of Education Plaza.
- *The science:* Create the highest splash possible in water channel using bores and solitons; *and, control it.*
- *The method:* Combine theoretical insights on solitons, bores and flow through contractions into a splash.
- *Self-imposed constraint:* cause no structural damage.

Wave Channel

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

Water wave channel:

- Two sluice gates, one removable by excavator.
- Uniform channel section.
- Channel linearly converging at one end:



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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

Phenomenon:

- Main/side solitons generated by removing sluice gate: 2.52m/s.
- Front soliton breaks quickly into a bore.
- It crashes 14s later into linearly converging closed narrows.
- Bore reflects, draws a trough . . .
- . . . in which the unbroken second soliton crashes,
- resulting in a 3.5-4m vertical jet at 15-17s.
- *Surprise*: This *reproducible* result is very sensitive to initial wave heights. Why?
- *Highest wave*: ratio of 10 of the incoming wave of 0.35m vs. the splash height of 3.5m. *Truly rogish*.

Relevance?

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

What started as a ‘bit of fun’ might have relevance.

- **Tsunami run-up** highest vertically in converging bays/valleys.
- **Nonlinear rogue waves** highest where bottom topography and waves of different directions locally “resonate”.
- Waves creating crevices on rocky coasts, and subsequent splashes, **causing erosion and displacing boulders**.

2. Splashing Results

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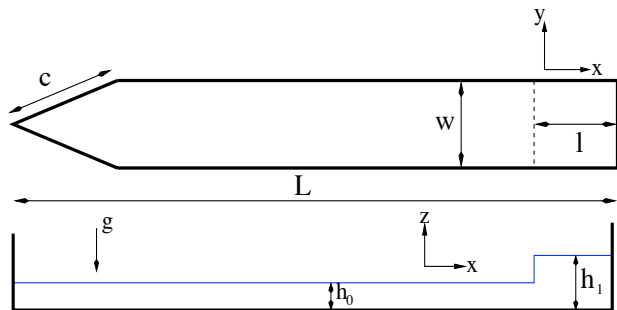
Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



Domain sketch: $L = 43.63 \pm 0.2\text{m}$, $c = 2.7 \pm 0.1\text{m}$,
 $l = 2.63 \pm 0.1\text{m}$, $w = 2\text{m}$.

Scale

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

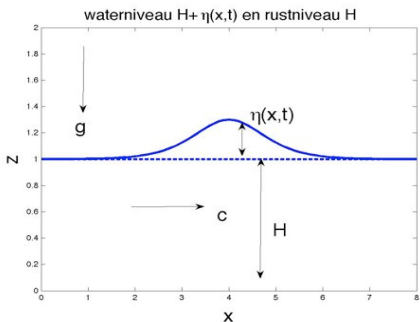
Channel at research/education plaza is not really meant for research:



Making the scale.

Procedure

- Make two still water levels in sluice and main channel segments.
- Open sluice gate and create a head soliton with lower solitons on one side.



Classical soliton.

Procedure

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

- Main soliton breaks into bore.
- Bore and second large soliton travel trough channel.



Procedure

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

- Bore dissipates energy and can become soliton again close to narrows.
- Convergence in narrows.
- Various possibilities regarding reflection and interaction of reflected & incoming waves.

Runs

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

Case	h_0 (m)	h_1 (m)	Comments
1	0.32	0.67	bore
2	0.38	0.74	good splash
3	0.41	0.9	Bore Soliton Splash, like cases 6 & 8
4	0.47	1.0	bore
5	0.41	1.02	low BSS
6	0.41	0.9	BSS like cases 3 & 8
7	0.45	0.8	good splash
8	0.41	0.9	<i>BSS</i> & (highest?) splash
9	0.43	0.9	2 solitons & tiny splash

Table 1: Experiments 1 to 7: 27-09-2010; 8 & 9: 30-09-2010.
Sluice gates levels $h_{0,1}$.

Sensitivity

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Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

- Cases 3, 6, & 8 with highest (recorded) splash are repeats with $h_0 = 0.41\text{m}$ and $h_1 = 0.9\text{m}$.
- Case 9 differs 0.02m: $h_0 = 0.43\text{m}$ and $h_1 = 0.9\text{m}$ resulting in no wave breaking and no significant splash.

Sensitivity: case 8

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Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



Case 8 with $h_0 = 41\text{cm}$: the bore.

Sensitivity: case 8

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



Sensitivity: case 9

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



Case 9 with $h_0 = 43\text{cm}$: only solitons.

Sensitivity: case 9

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



Sensitivity: case 9

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Splash

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



Sensitivity: case 9

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Splash

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



Sensitivity: case 9

Bore-Soliton-
Splash

Onno
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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



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Bore-Soliton-
Splash

Onno
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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



Sensitivity: case 9

Bore-Soliton-
Splash

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion



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Bore-Soliton-
Splash

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

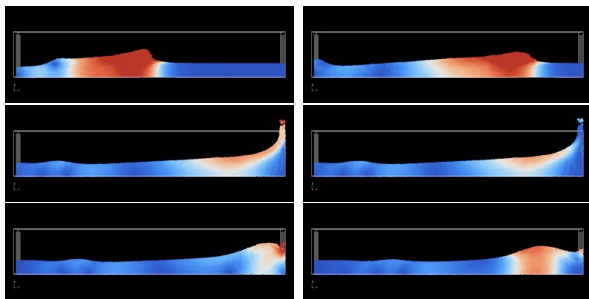
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3. Mathematical Challenges

Brute force:

- Brute-force SPH calculation.
- Problems: dof too high because of wave height decrease.
- Semi-2D channel part coupled to 3D contraction part.



Velocity field at times $t = 1.53, 2.55, 3.57, 3.64, 4.08, 4.50$ s in finite 11m 2D channel. Maximum splash about 1.2m at $t \approx 3.64$ s.

Compatible Modelling

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Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

Compatible modelling:

- Air-water mixture theory.
- Based on extension of Luke's variational principle.
- Compatible variational discretizations.
- 2D straight channel part; 3D contraction and splash part.
- Alternatively, Hamiltonian potential flow⁺⁺ model with vertical vorticity & bores; see poster Elena Gagarina.

Idealized Models

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

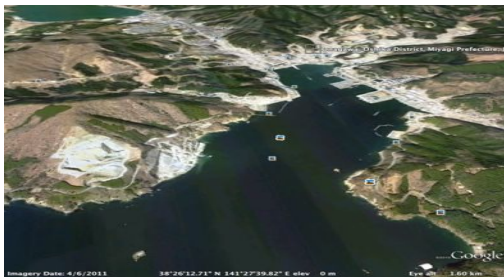
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Decomposition into semi-analytic components:

- Formation bore-soliton compound.
- Propagation of compound in channel.
- Convergence in channel.
- Model of upward movement and jet.
- This week: patch solutions of KP-equation together; discussions with Kodama.

4. BSS and Tohoku Tsunami

- “Critical run-up factors and impact ... Tohoku Tsunami” by Lekkas et al. 2011.
- Vertical run-up Tohoku tsunami highest in Onagawa Bay: 42m for rough estimate of 7.5m incoming waves.
- Ratio run-up/wave height is thus circa 5.5.
- Ratio BSS/incoming wave height is 10.



5. Discussion

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

- Small-scale portable *Bore-Soliton-Splash* also works:
 - scope for **high-tech version** with fully automatized measurements
 - scope for **optimization theory** to determine when highest splash occurs . . .
 - given (data of) brute-force numerics, air-water mixture theory, or idealized model of bore-soliton and jet.
- Extensions to contraction with initially dry land and slanted walls, relevant for tsunami hazard mitigation.
- Design of measures to 'break' the rogue splash.

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Bore-Soliton-
Splash

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

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- Zweers 2010: Bore-Soliton-Splash webpage, via www.utwente.nl/~bokhoveo
- Movies of BSS:
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- Cotter & B. 2010: Variational water wave model with accurate dispersion and vorticity. *J. Eng. Mech.* **67**.
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Fluid Fascinations

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Motivation

Splashing
Results

Mathematical
Challenges

Relation to
Tohoku
Tsunami

Discussion

