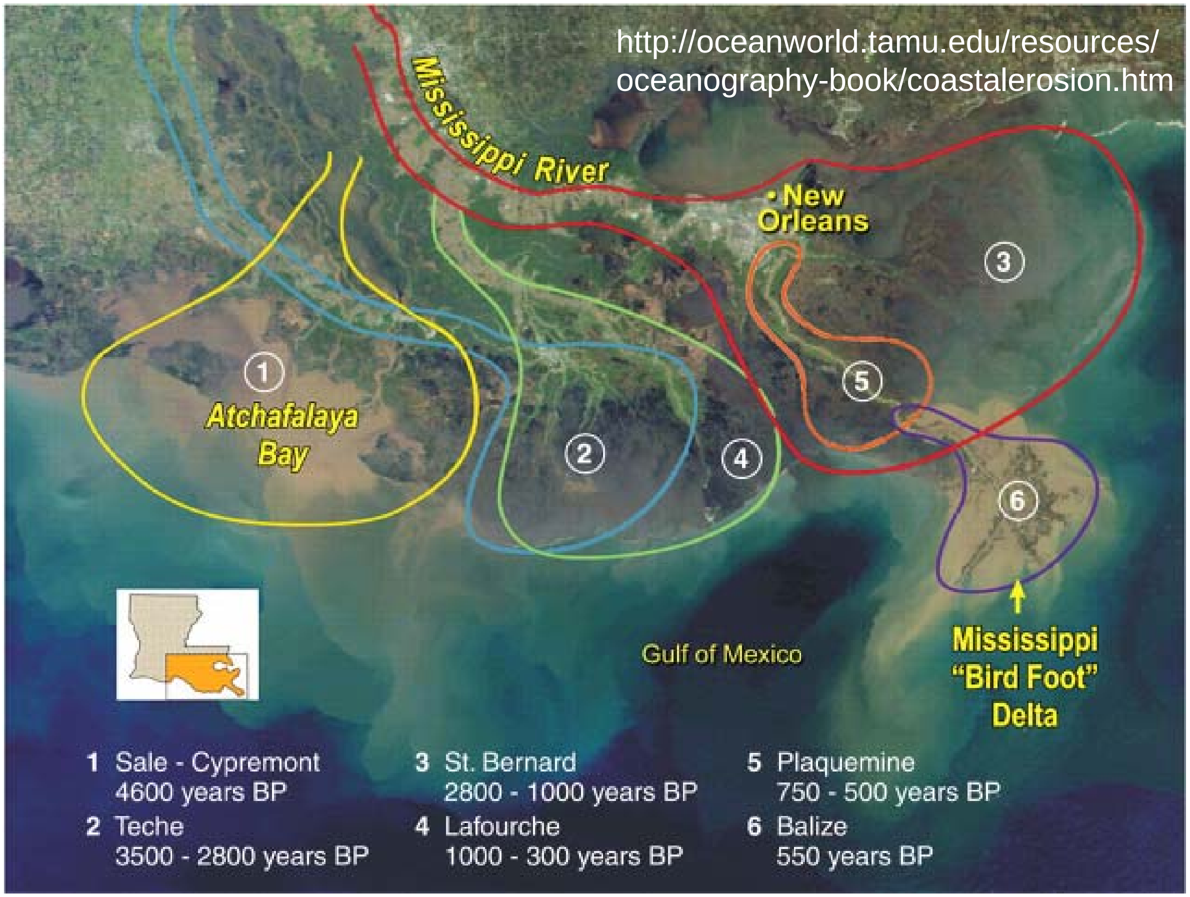
CMS-Wave Demonstrations to Louisiana (Levees & Muddy coast)



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Outline

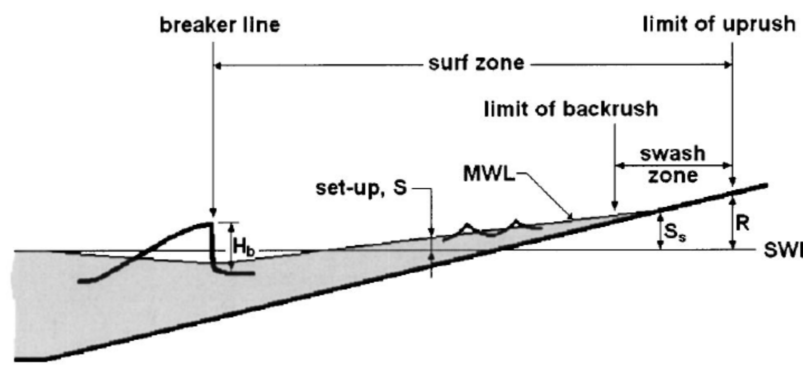
1. Definitions of wave run-up & setup
2. Wave run-up formulas
3. Advantages of CMS-Wave run-up
4. Ahrens & Titus experiments (1981)
5. Mase & Iwagaki experiments (1984)
6. Examples run-up & overtopping
7. Idealized single-breakwater
8. Goda wave transmission experiments (2000)
9. Hughes wave-overtopping levee experiments (2008)
10. Muddy coast comparisons

1. Definition of Wave Run-up & Setup

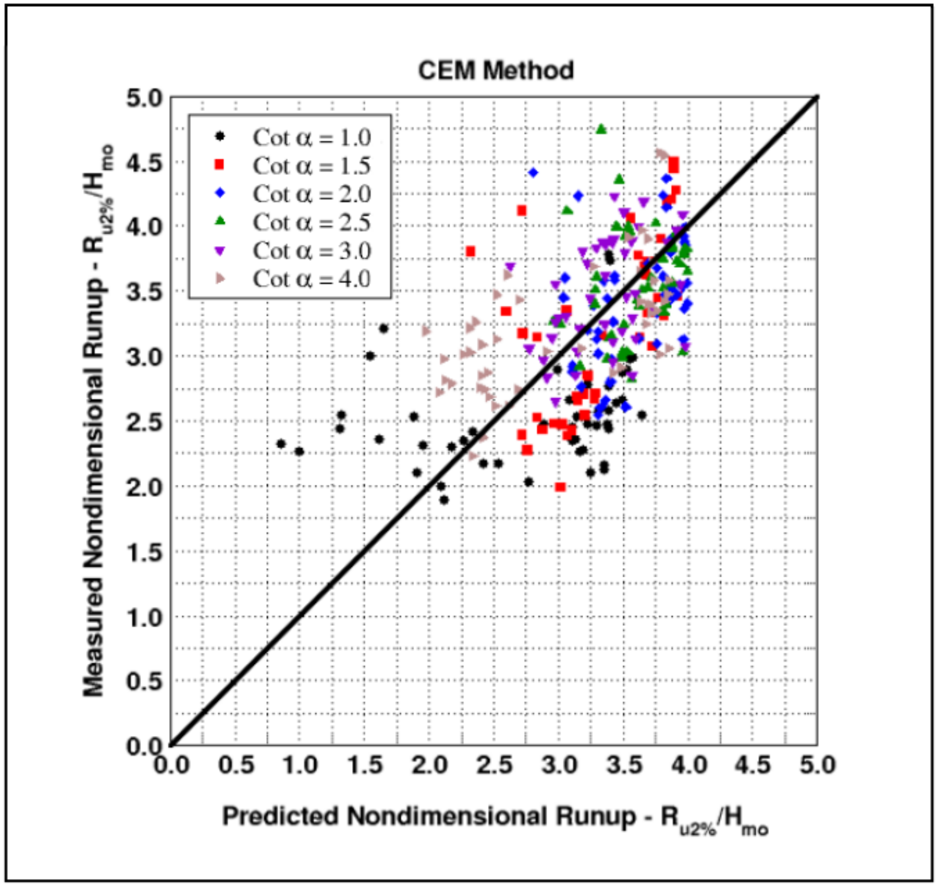
Definitions:

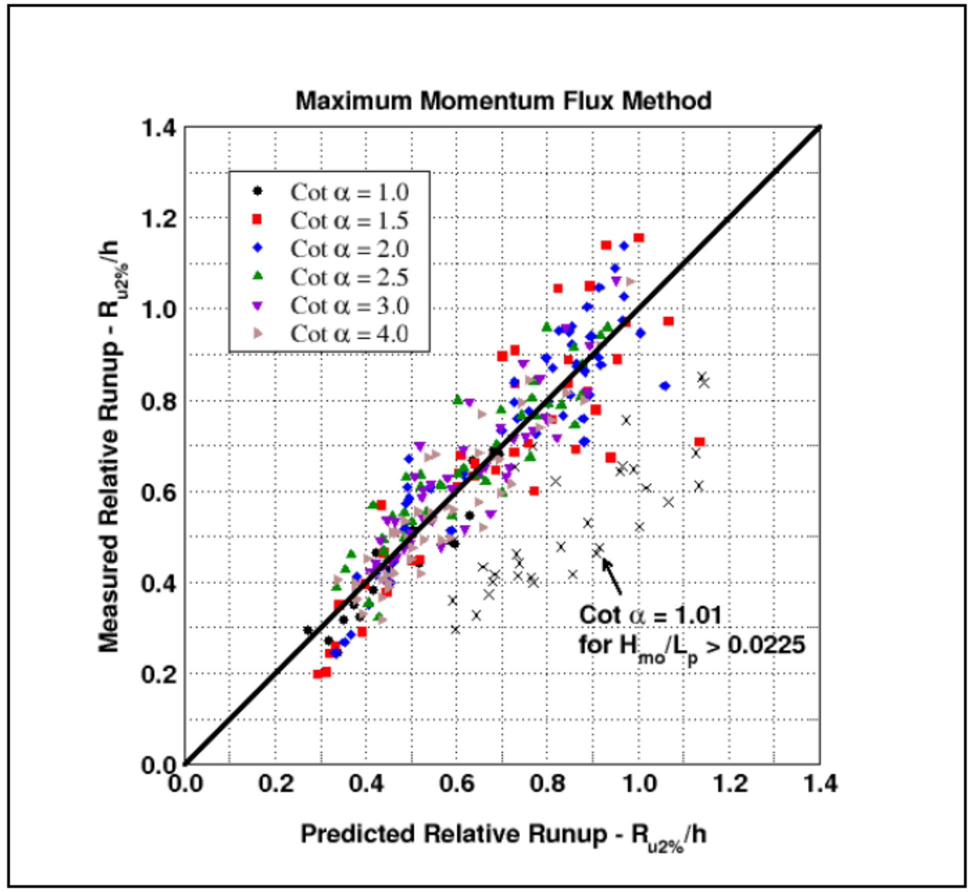
- **Wave Run-up**: maximum vertical extent of wave uprush on a beach or structure above the still-water level (SWL)

- **Wave Setup**: rise of mean water level above the SWL caused by wave breaking on a beach or structure



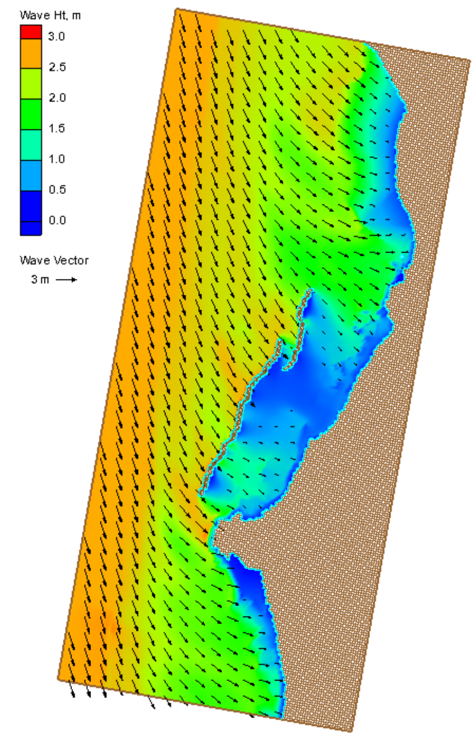
2. Wave Run-up Formulas

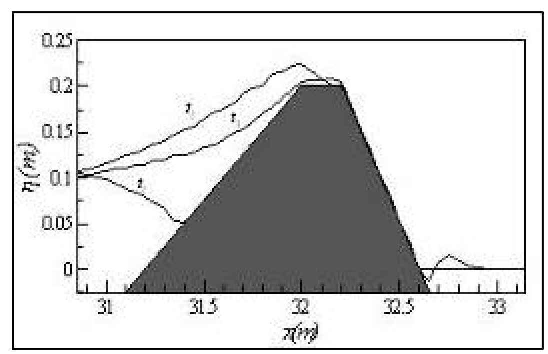




3. Advantages of CMS-Wave Run-up

- Computationally efficient – users can specify structures and areas for wave run-up calculations
- Essential for calculation of coast erosion, barrier island breaching, wave overtopping, and coastal flooding during storms
- CMS-Wave calculates wave run-up and setup to determine the maximum water level (surge + tide + wave run-up + wave setup)
- Can be coupled with CMS-Flow





4. Ahrens and Titus Run-up Experiments (1981)

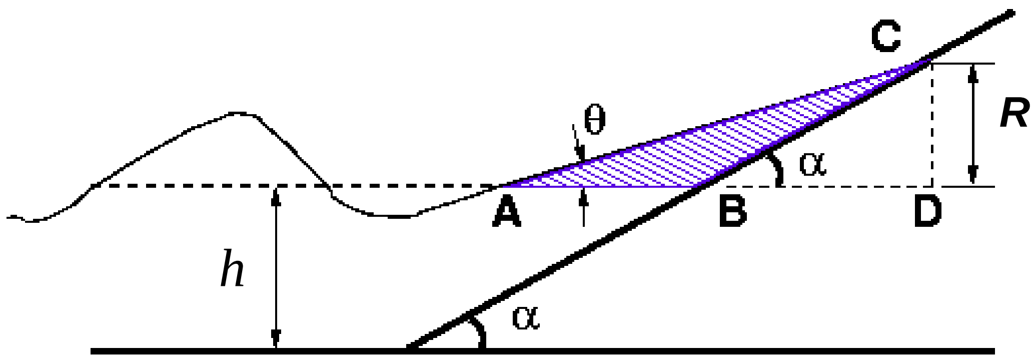
- 275 Laboratory experiments (in 1.2 m x 4.6 m wave tank)
- Irregular wave run-up on plane, smooth slopes
- 6 different slopes: 1:1 (steep), 2:3, 1:2, 2:5, 1:3, and 1:4 (moderate)
- 8 different water levels: 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8 m
- A wide range of incident spectra (varying spectral width)

Input Wave Parameters & Run-up Measurements

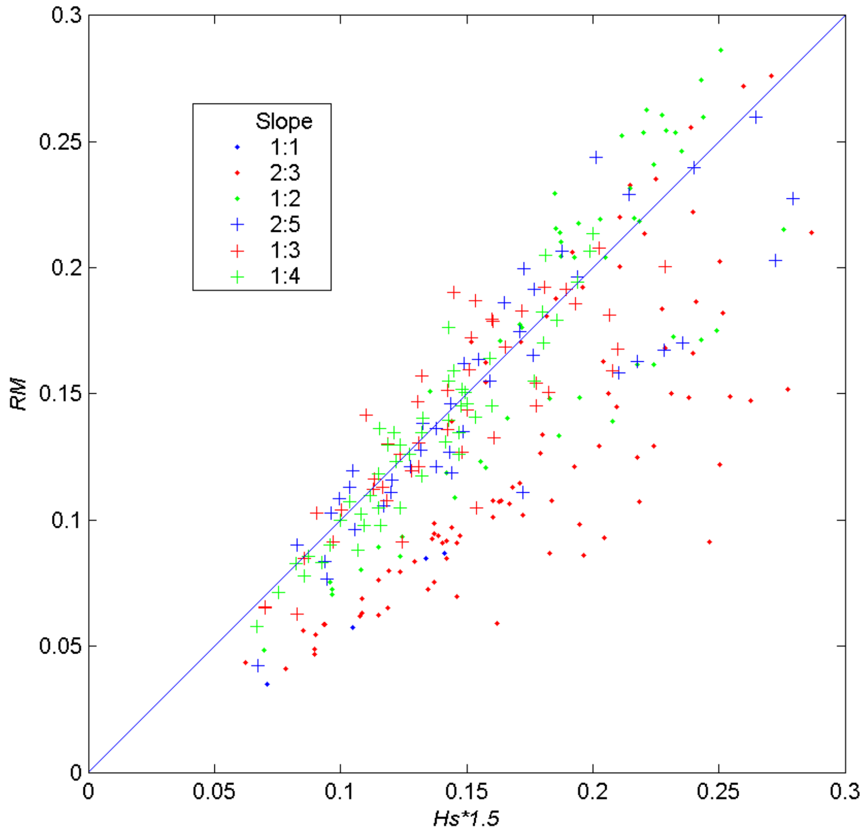
- Incident wave parameters: *Hs*, *Tp*, *Qp* (wave group parameter)

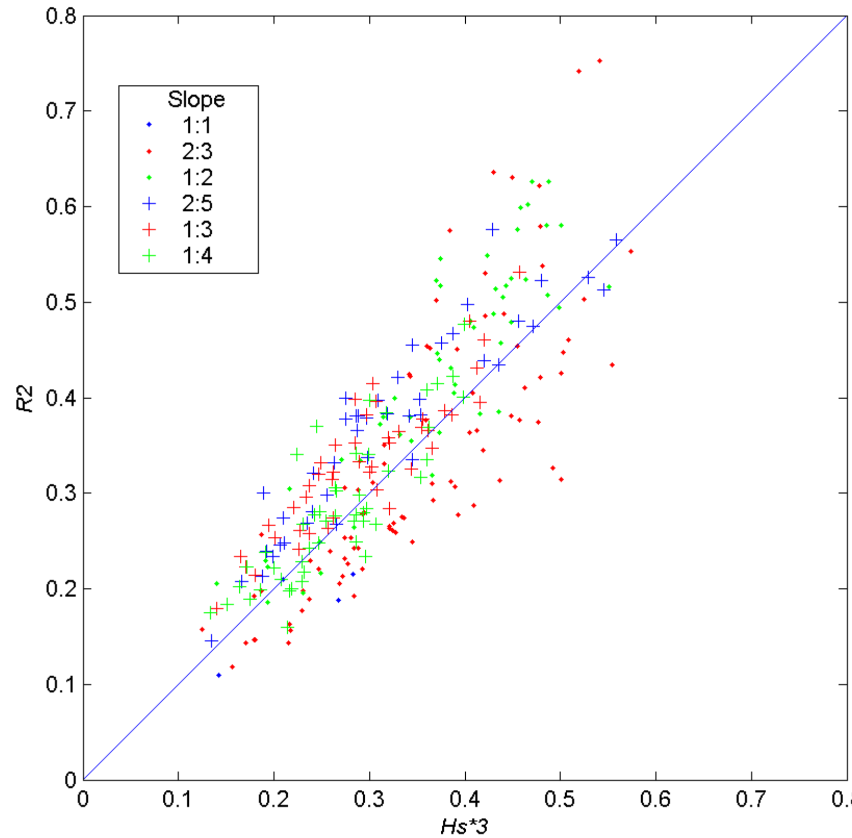
$$Qp = \frac{2\int f\,S^2(f)\,\mathrm{d}f}{\left(\int S(f)\,\mathrm{d}f\right)^2}, \quad \text{(Goda, 1970)}$$

- Wave run-up data: *R2* (total run-up by 2% exceedance) and *RM* (average elevation of total run-ups)



Ahrens and Titus Run-up Data





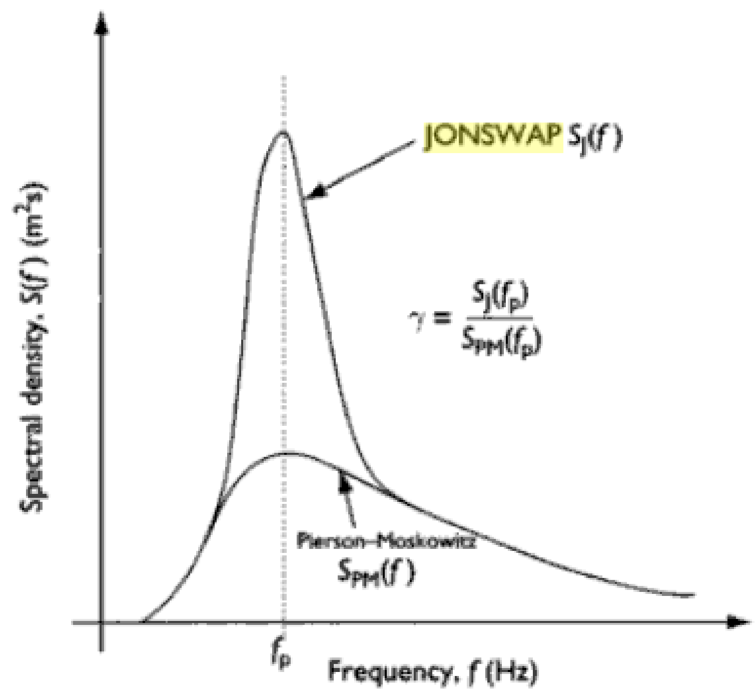
Relationship between *Qp* & *JONSWAP* γ

$$Qp^* = \frac{(\gamma - 3)}{2} + 3 \quad \text{or} \quad \gamma = 2\ (Qp^* - 3) + 3 \quad (\gamma \geq 1)$$

JONSWAP spectrum (Hasselmann et al., 1973)

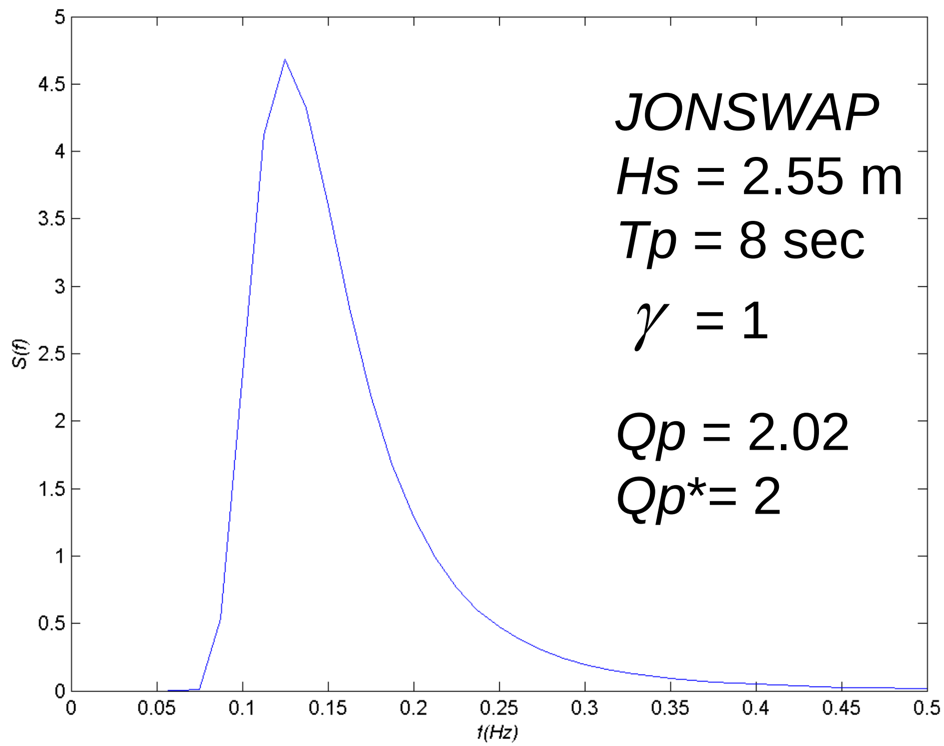
$$S(f) = \frac{\alpha g^2}{(2\pi)^4 f^5} \exp\left[-1.25\left(\frac{f_p}{f}\right)^4\right] \gamma^q$$

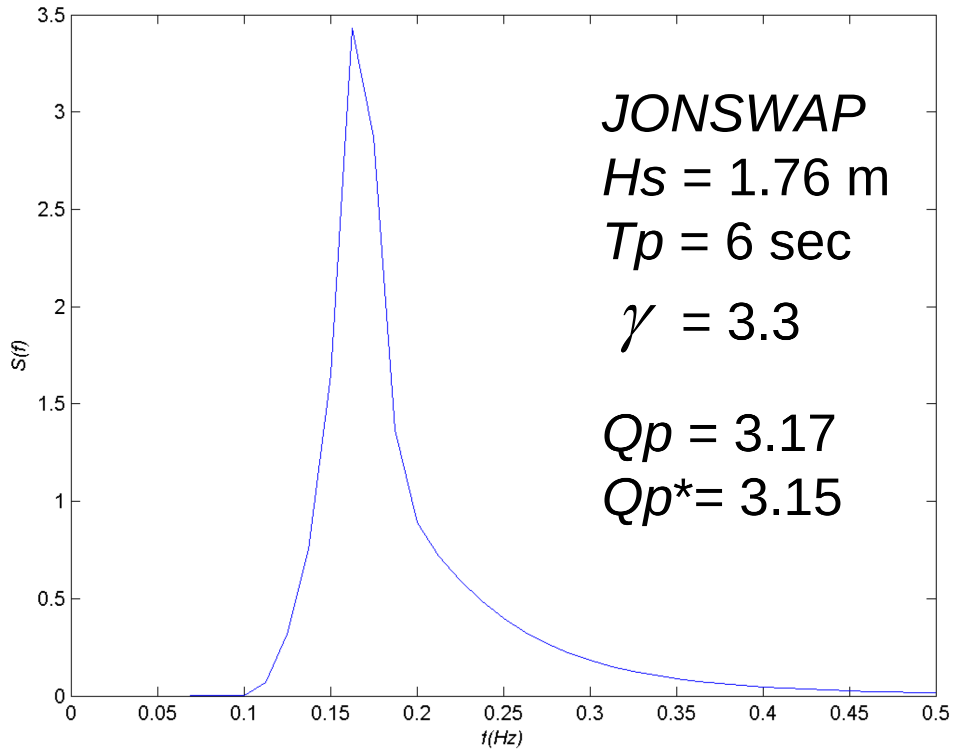
$$\text{with} \quad q = \exp\left(-\frac{(f - f_p)^2}{2\sigma^2 f_p^2}\right) \quad \text{and} \quad \sigma = \begin{cases} 0.07 & f \leq f_p \\ 0.09 & f > f_p \end{cases}$$



Pierson–Moskowitz and JONSWAP frequency spectra.

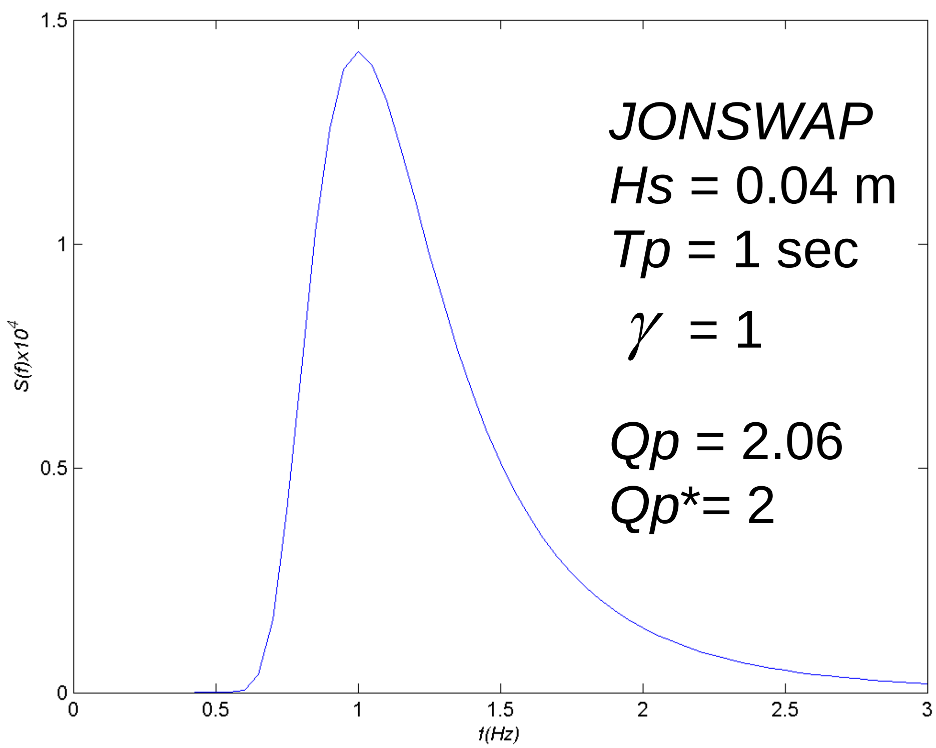
Relationship between *Qp* & JONSWAP γ
Examples 1 & 2

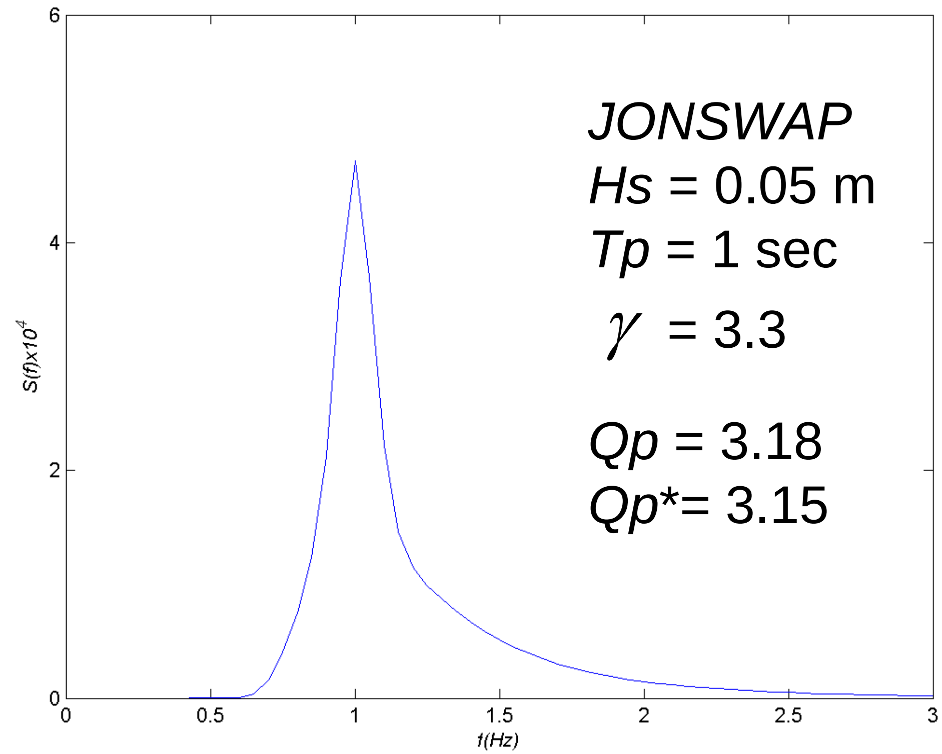




Prototype scale

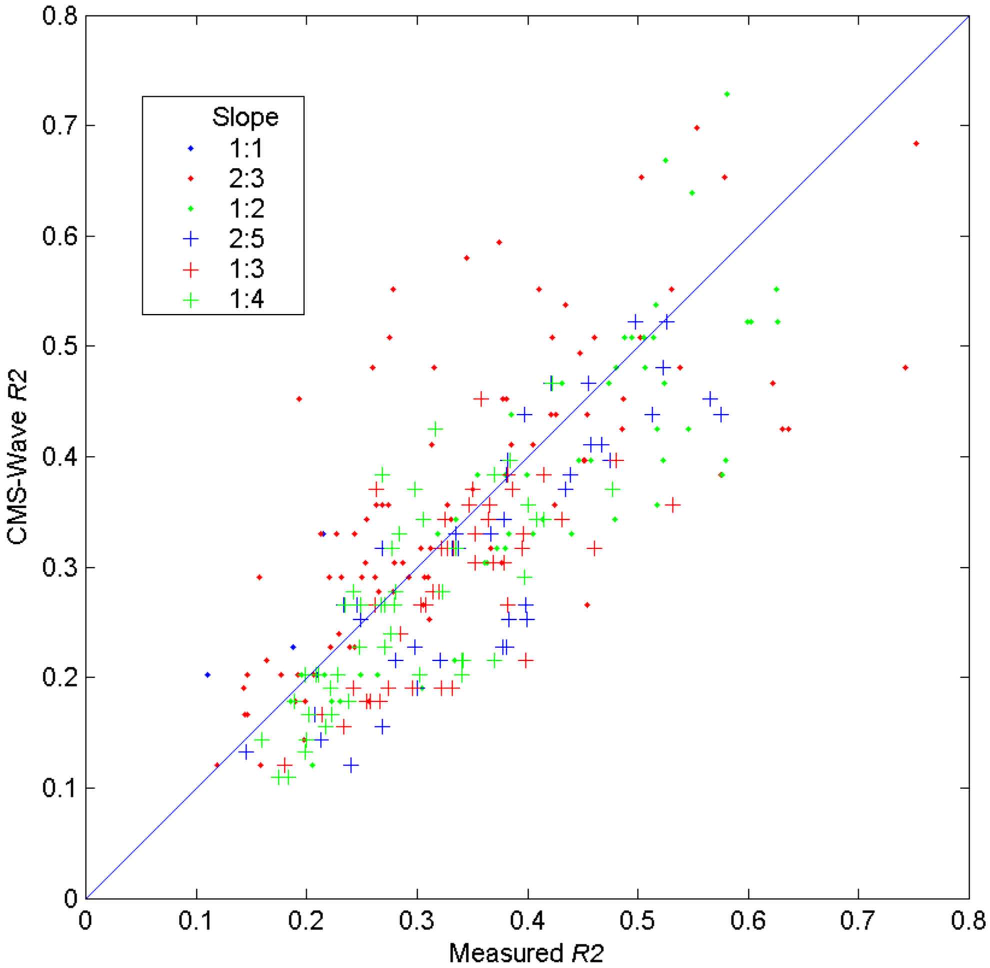
Relationship between *Qp* & JONSWAP γ
Examples 3 & 4





Laboratory scale

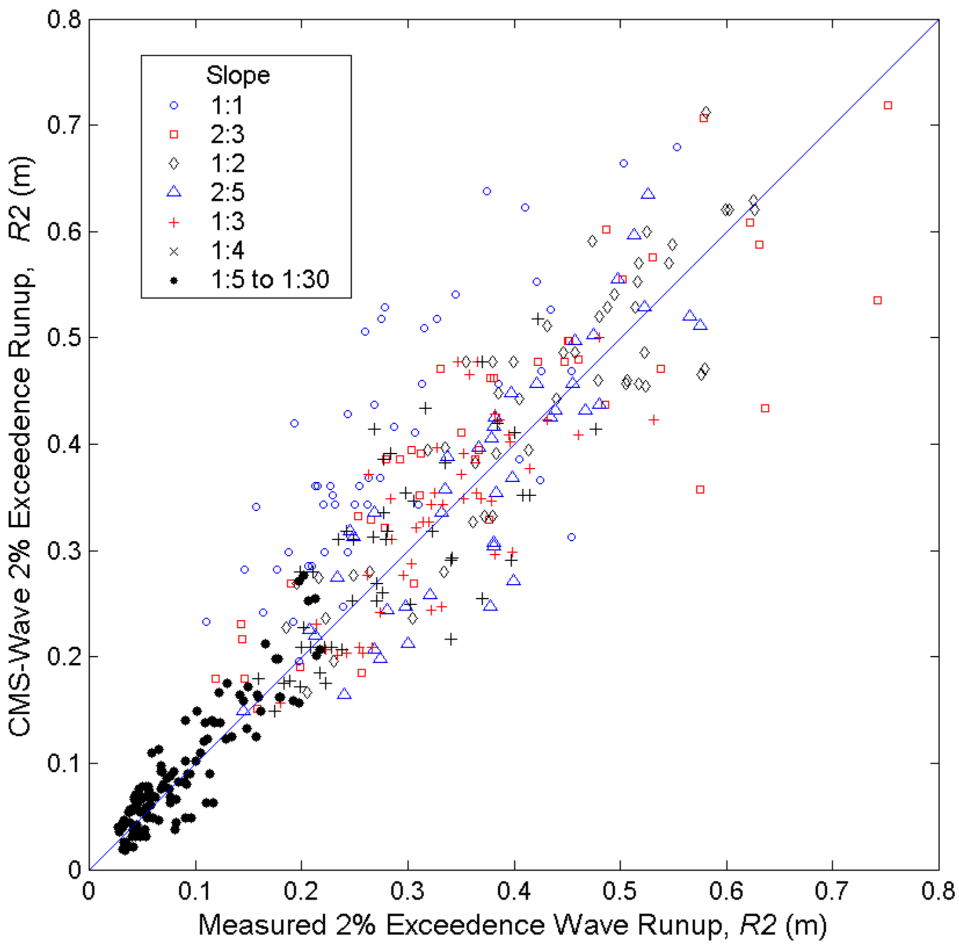
CMS-Wave Calculated Runup *R2*



5. Mase and Iwagaki Experiments (1984)

- 120 Laboratory experiments (in 0.5 m x 27 m wave tank)
- Irregular wave run-up on plane, smooth slopes
- 4 different slopes: 1:5 (moderate), 1:10, 1:20, and 1:30 (mild)
- 2 water levels (flat bottom section): 0.45 m for 1/5, 1/10 and 1/20 slope; 0.43 m for 1/30 slope
- Incident spectra (varying wave energy): Pierson-Moskowitz type

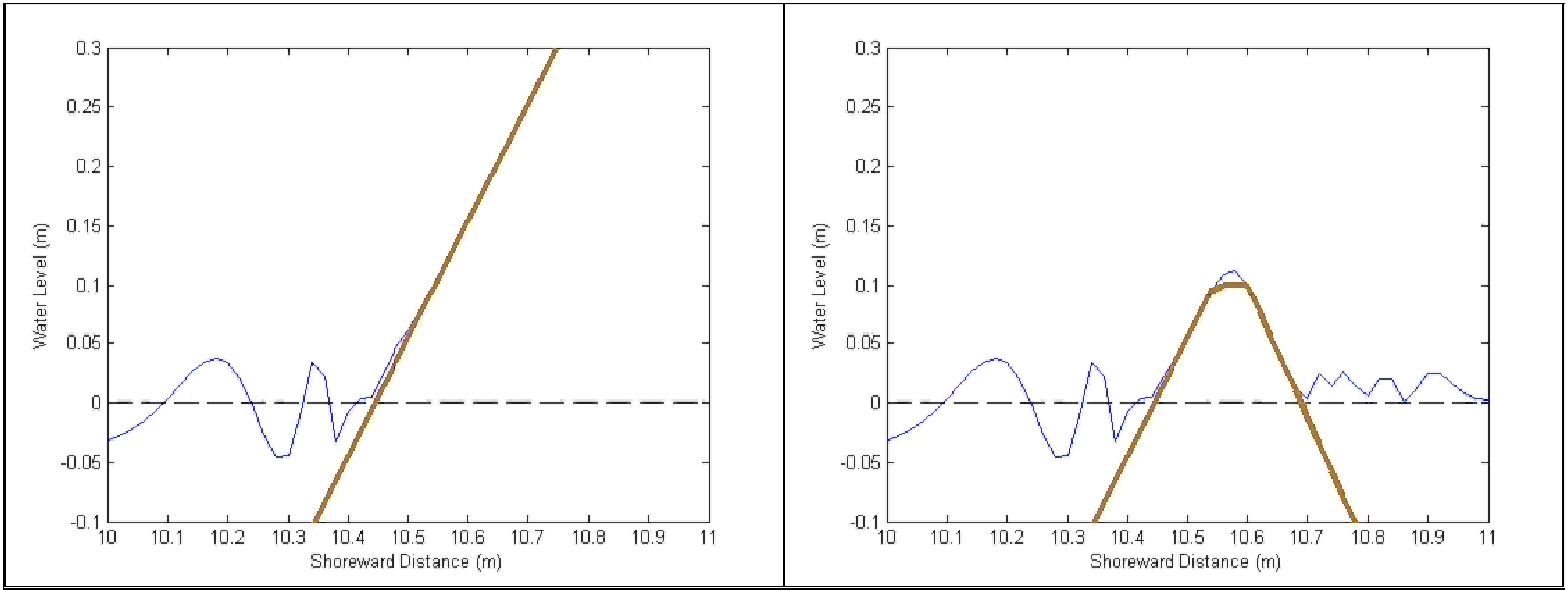
CMS-Wave Calculated Run-up *R2*



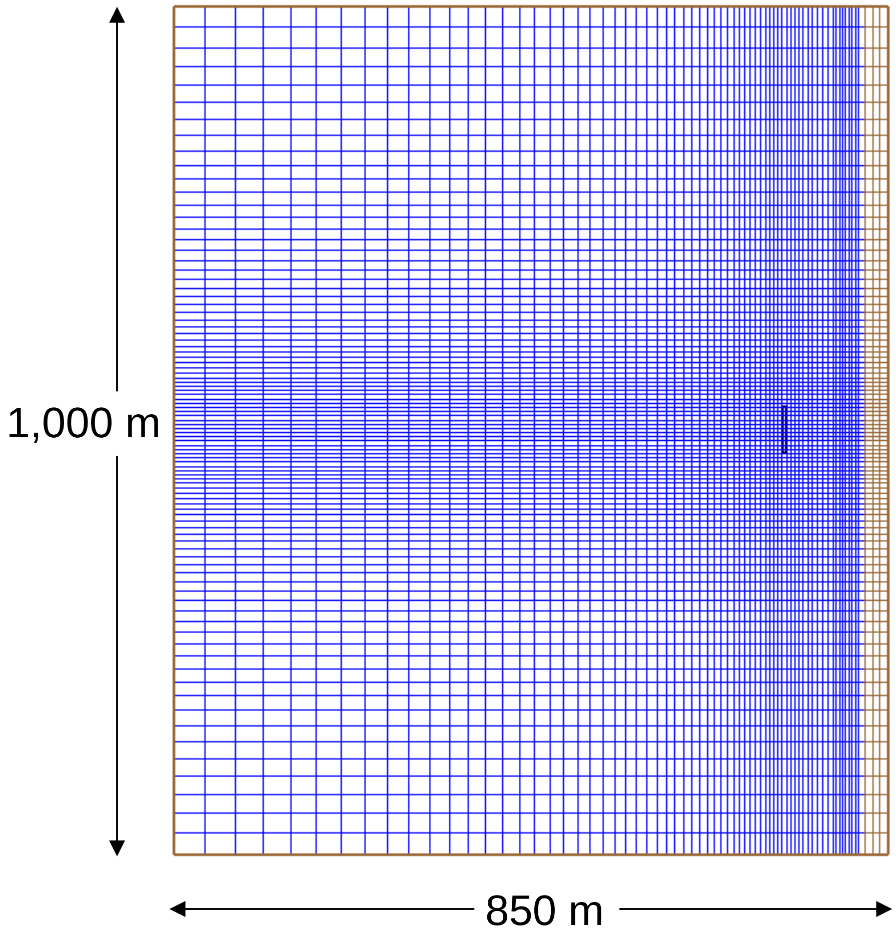
Slope	Correlation Coefficient
1:1	0.74
2:3	0.86
1:2	0.90
2:5	0.88
1:3	0.79
1:4	0.72
1:5 - 1:30	0.91

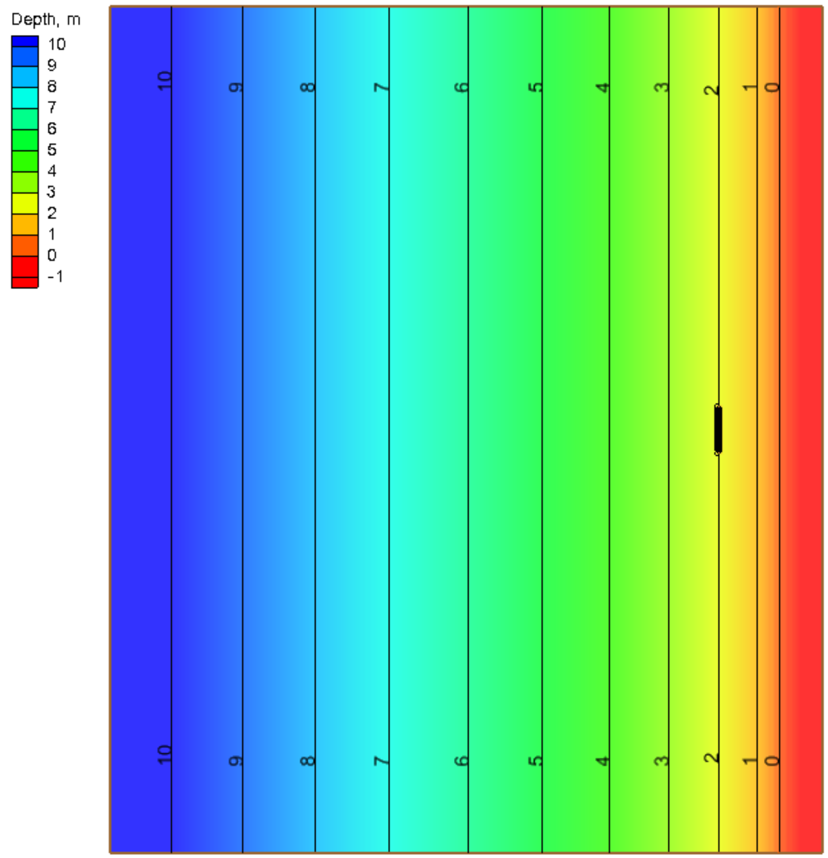
6. Example CMS-Wave Run-up & Overtopping

Run-up Overtopping



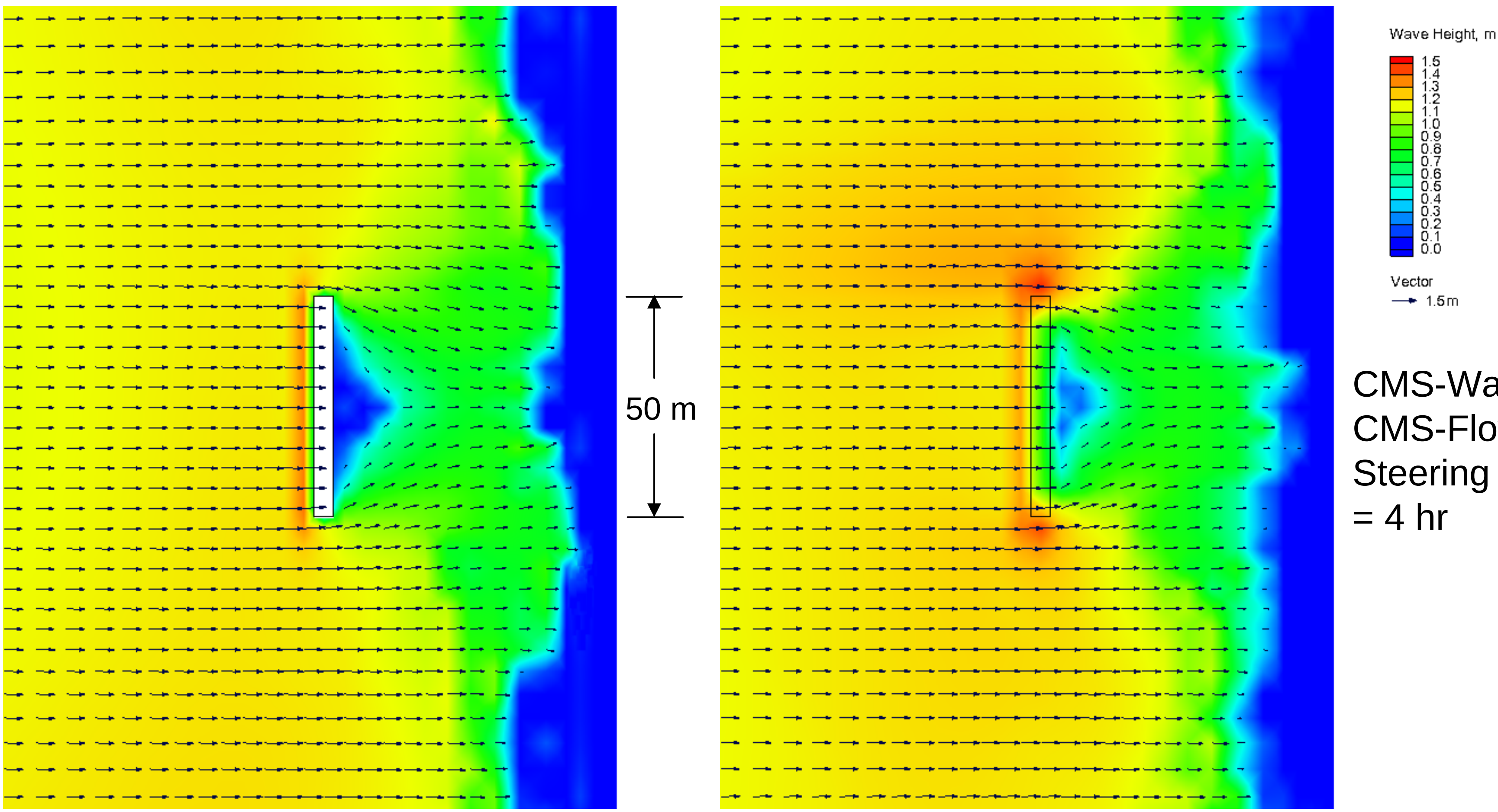
7. Example Idealized Single-Breakwater *CMS Grid*





Breakwater length = 50 m,
width = 5 m, elevation = 1 m MSL

Calc. Wave Fields after 10-day Simulation
Incident Wave: 1-m, 8-sec, 0-deg

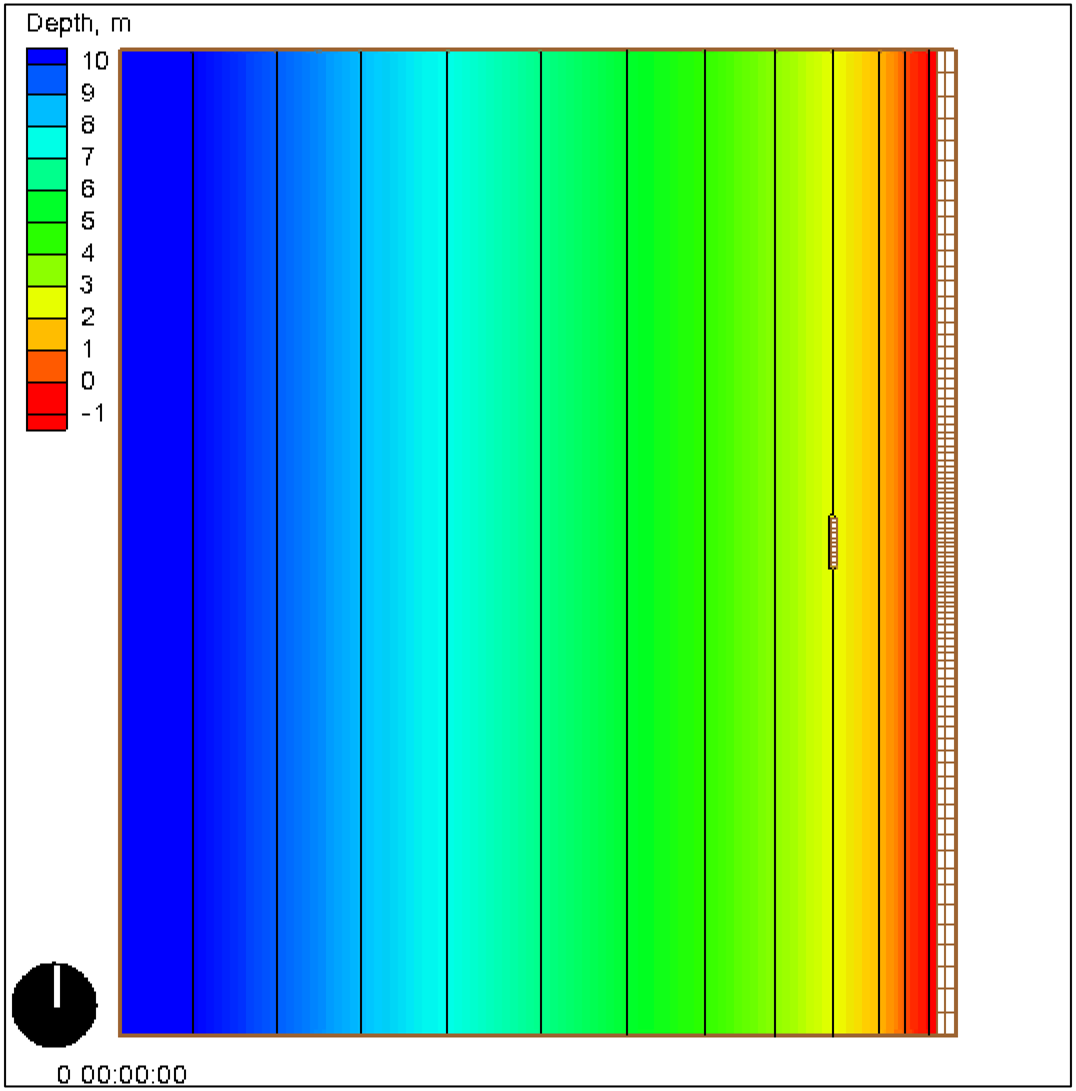


CMS-Wave & CMS-Flow Steering interval = 4 hr

NO wave run-up
NO wave overtopping

Wave run-up
Wave overtopping

Calc. Morphology: 30-day Animation *with Wave Diffraction & Overtopping*



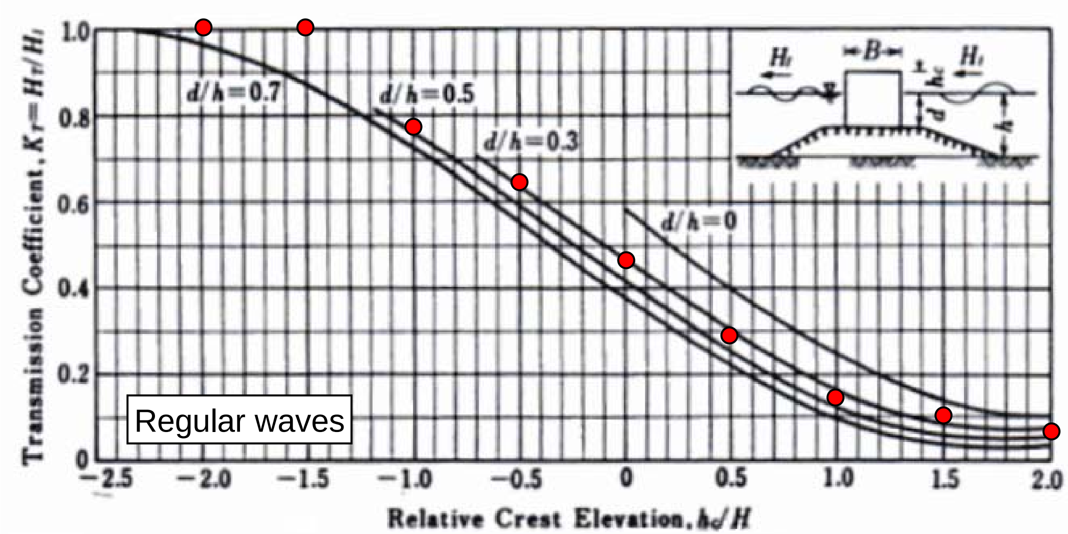
CMS
Steering Interval
= 4 hr

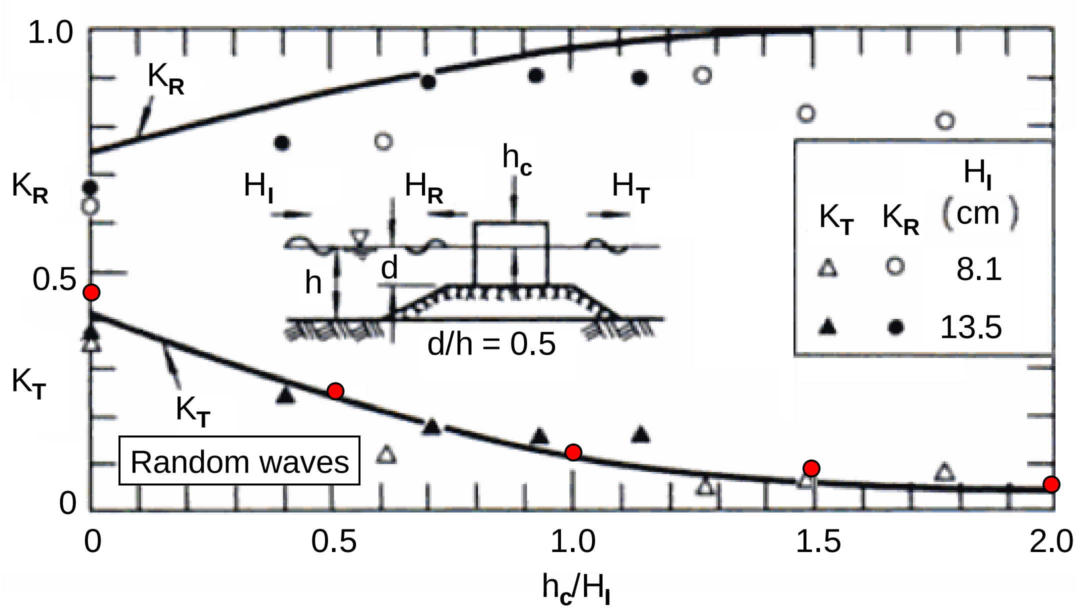
Grain Size
= 0.18 mm

Hydro time step
= 0.25 sec

Transport and
morphology
calc time step
= 9 sec

8. Goda Wave Transmission Experiments (2000)





Transmission coefficients k_t
H_i = 1 m, Tp = 6 sec (monochromatic wave)
h = 10 m, d = 5 m, B = 80 m

h_c (m)	CMS-Wave		Equations	
	Vertical wall ●	Rubble mound	Vertical wall	Rubble mound
-2.0	1.02	1.02		
-1.5	1.03	1.03		
-1.0	0.78	0.78		
-0.5	0.63	0.63		
0.0	0.46	0.34	0.45	0.33
0.5	0.27	0.18	0.30	0.18
1.0	0.15	0.04	0.15	0.03
1.5	0.10	0.024		
2.0	0.07	0.018		

9. Hughes Wave-Overtopping Levee Experiments (2008)

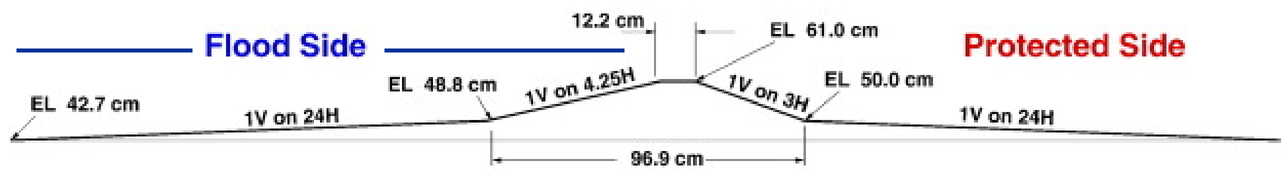


Fig. 1. Tested levee cross section (model-scale units).

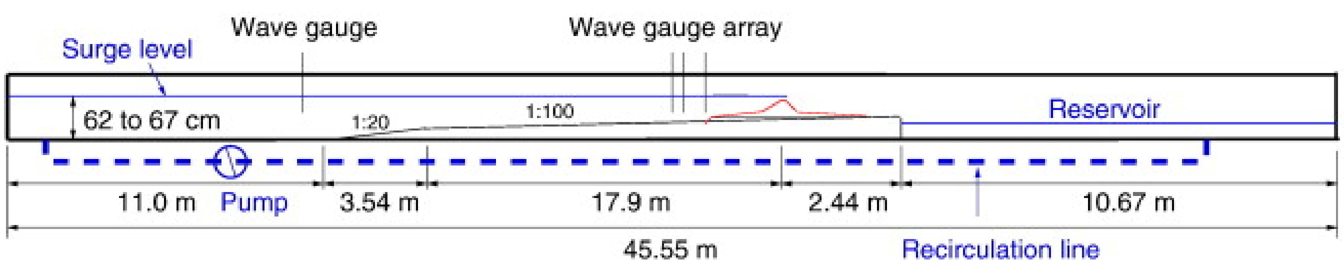


Fig. 2. Profile view of wave flume (model-scale units).

Experiment number	Prototype-scale H_{m0} (m)	Prototype-scale T_p (s)	Average overtopping discharge q_s (m^3/s/m)	Average overtopping discharge q_{ws_ave} (m^3/s/m)
Surge level = + 0.29 m above levee crown				
R128	0.82	6.07	0.266	0.378
R129	1.67	5.94	0.308	0.492
R130	2.54	5.94	0.287	0.520
R104	1.00	10.51	0.259	0.297
R105	1.89	10.51	0.241	0.492
R131	2.83	10.51	0.240	0.728
R107	0.79	13.66	0.247	0.351
R108	1.68	13.66	0.259	0.551
R109	2.48	13.66	0.261	0.696
Surge level = + 0.81 m above levee crown				
R110	0.77	5.69	1.155	1.181
R111	1.46	5.94	1.213	1.098
R112	2.40	5.94	1.180	1.061
R113	0.88	10.12	1.125	1.094
R132	1.91	10.12	1.601	1.620
R115	2.66	10.51	1.248	1.432
R116	0.75	14.37	1.173	1.250
R117	1.63	14.37	1.250	1.450
R118	2.42	14.37	1.237	1.508
Surge level = + 1.3 m above levee crown				
R119	0.64	6.07	2.453	2.576
R120	1.17	6.07	2.525	2.657
R121	2.30	6.07	2.546	2.670
R122	0.86	10.12	2.629	2.621
R123	1.79	10.12	2.529	2.770
R124	2.74	10.12	2.587	2.758
R125	0.74	14.37	2.417	2.585
R126	1.50	14.37	2.475	2.734
R127	2.31	14.37	2.538	2.839

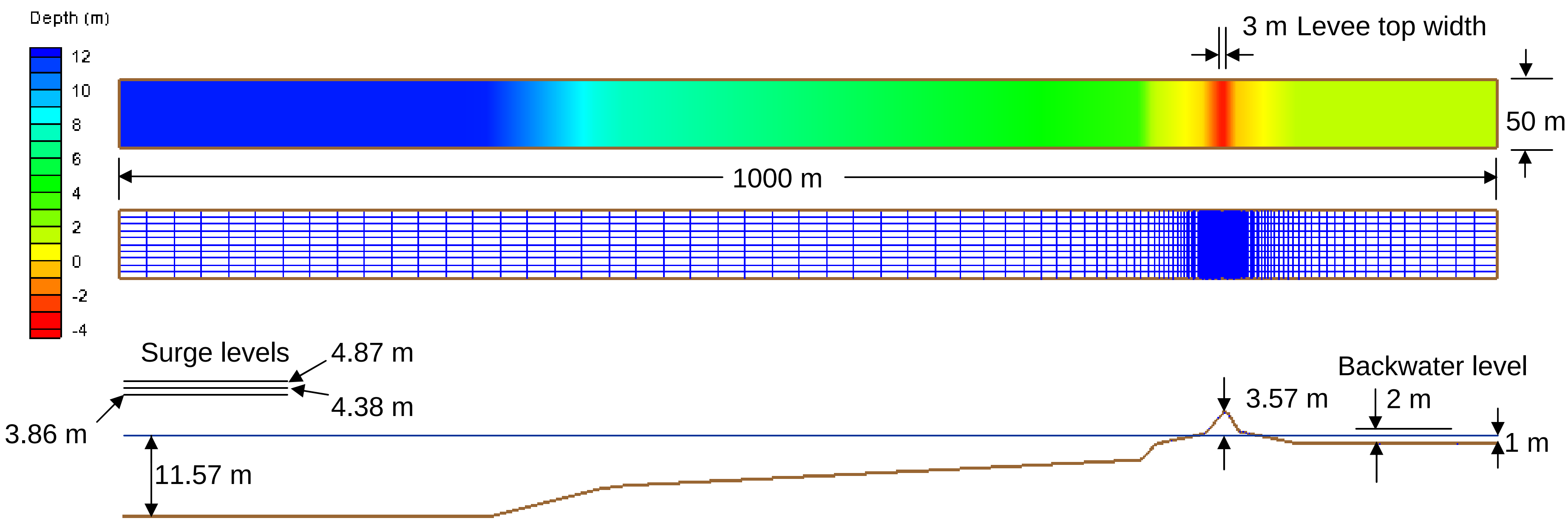
27 experiments:
Prototype-to-model length scale = 25:1

Design condition:
3 surge elevations (0.29, 0.81, 1.3 m above levee crest)

3 sig. wave heights (0.9, 1.8, 2.7 m)

3 peak wave periods (6, 10, 14 sec)

CMS Grid (Prototype)



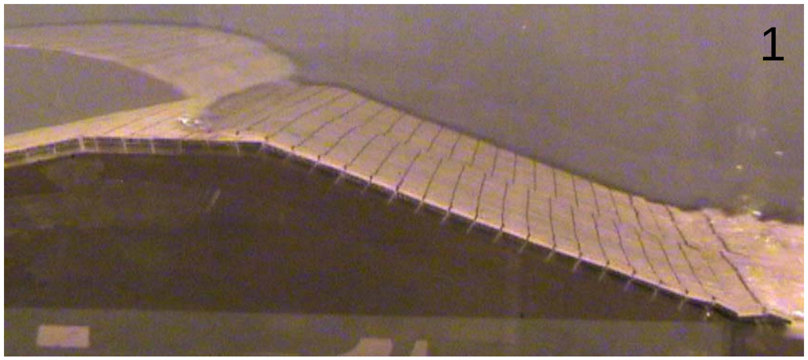
Model domain: 50 m x 1000 m (10 x 152 cells);
a constant 5-m spacing along y axis & variable 0.5 - 20-m spacing along x axis

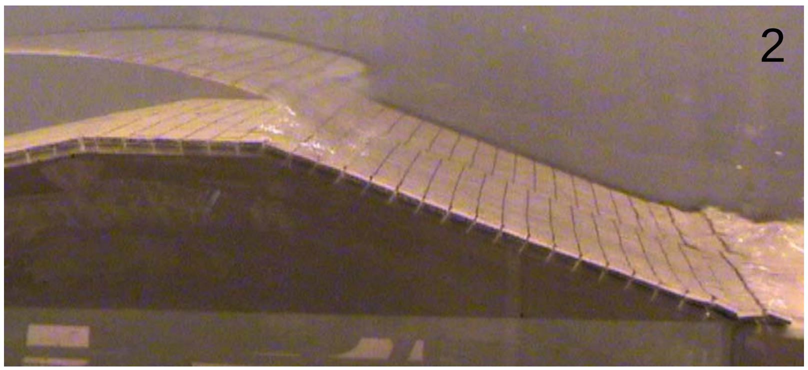
Simulation duration = 5 hrs, Wave input interval= 0.5 hr, Hydro time step = 0.05 sec
CMS-Wave bottom friction $c_f = 0.005$
CMS-Flow Manning's $n = 0.05$ for levee and $n = 0.025$ elsewhere

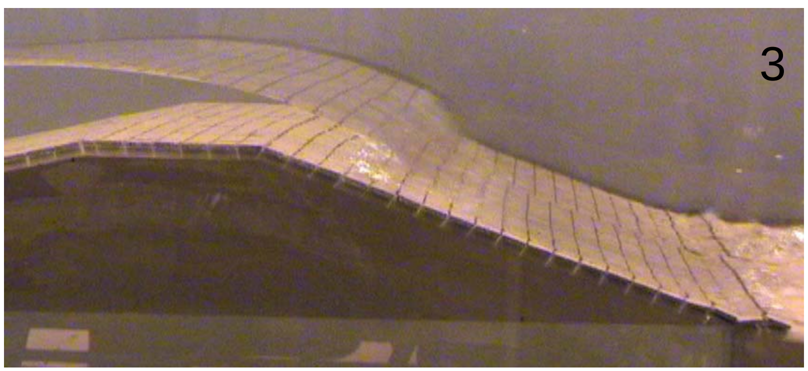
Measured & Calculated Overtopping Rate

Case number	Surge level (m)	Wave height (m)	Wave peak period (sec)	Overtopping rate (m^2/sec)		
				Measured	CMS-Flow	CMS-Wave
R128	0.29			0.27	0.28	
	0.29	0.82	6.1	0.38	0.38	0.39
R109	0.29			0.26	0.28	
	0.29	2.48	13.7	0.70	0.85	0.92
R121	1.3			2.55	2.57	
	1.3	2.30	6.1	2.67	2.93	2.76
R127	1.3			2.54	2.57	
	1.3	2.31	14.4	2.84	2.98	2.81

R113: Surge level = 0.81 m (3 ft)
H_s = 0.88 m, T_p = 10.1 sec



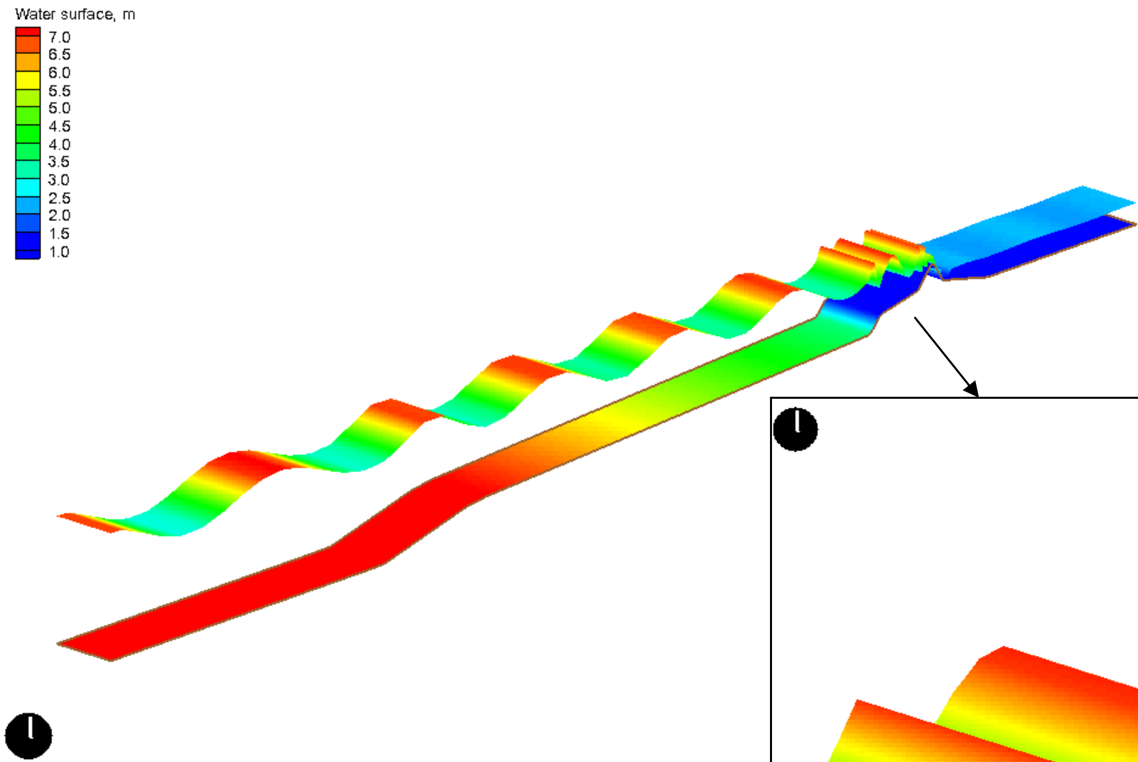


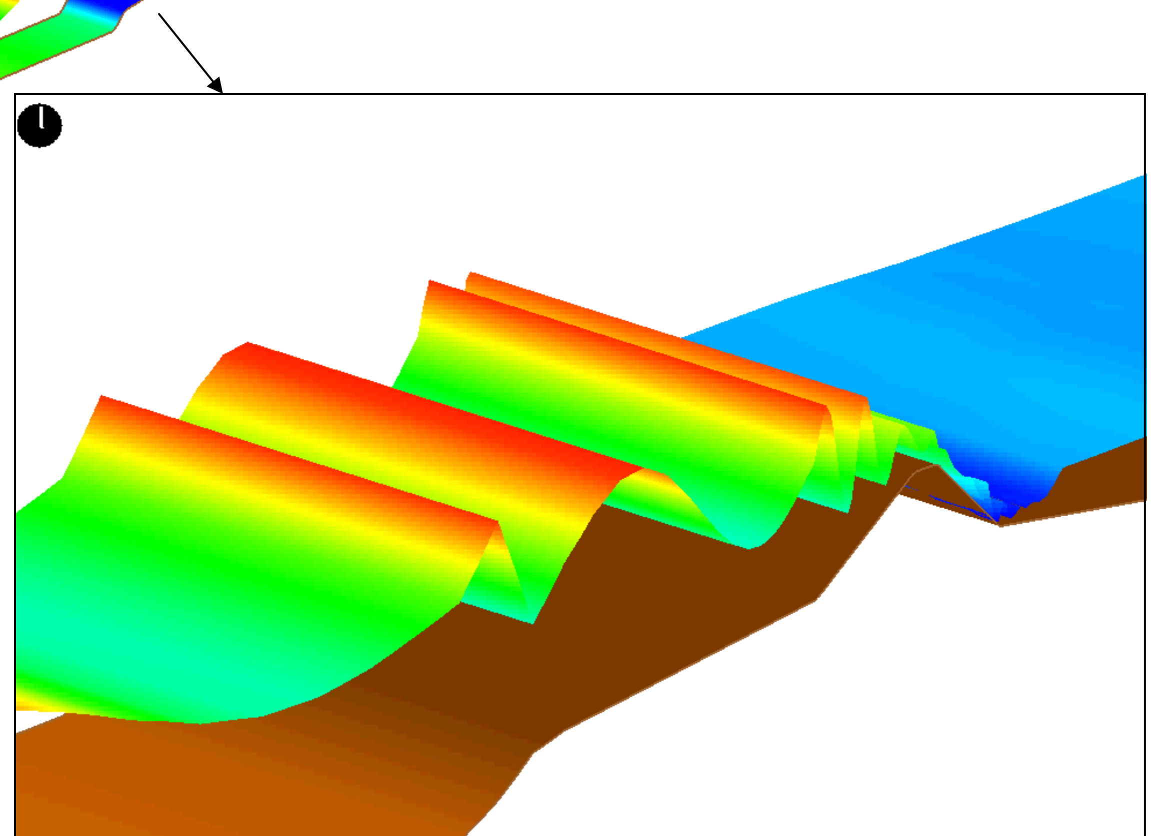


ERDC/CHL TR-08-10

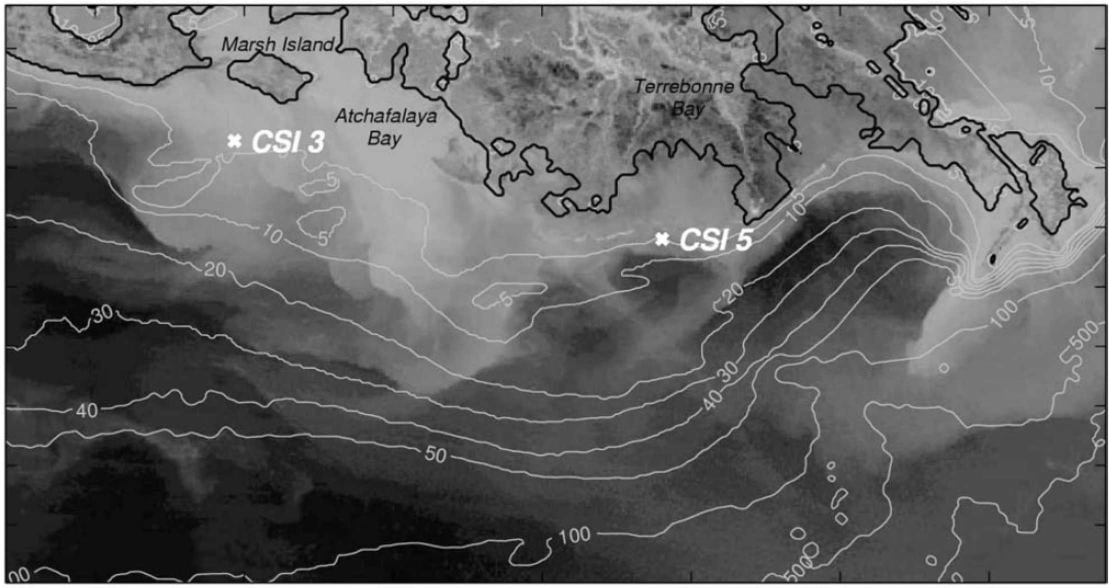
Calculated Wave Overtopping R127
Surge level =1.3 m, H_s =2.3 m, T_p =14 sec

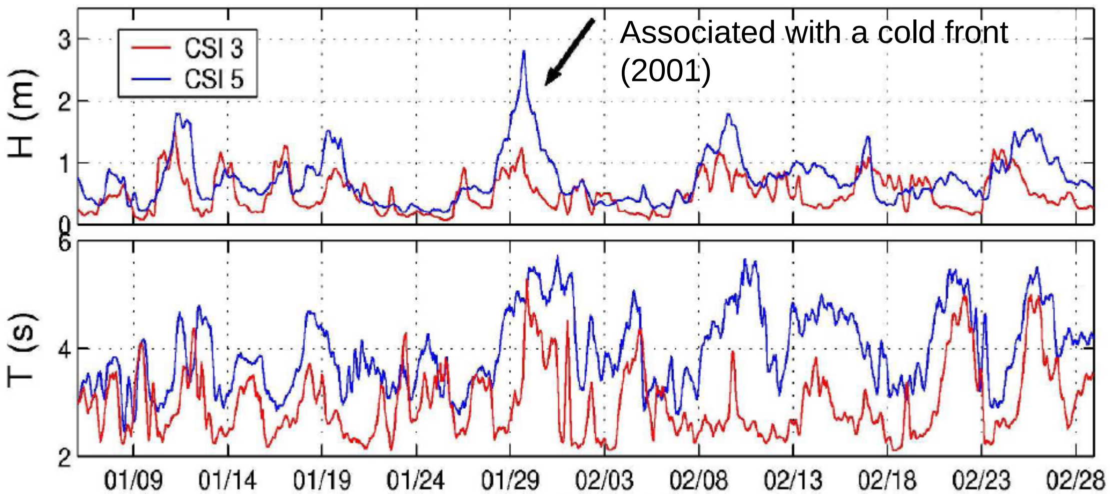
Animation by SMS





10. Louisiana Coast Wave Simulation





Wave-Current Information System
Coastal Studies Institute (CSI)
Louisiana State University
(Image by Earth Scan Laboratory, CSI)

CSI 3 – fine silt cohesive sediment

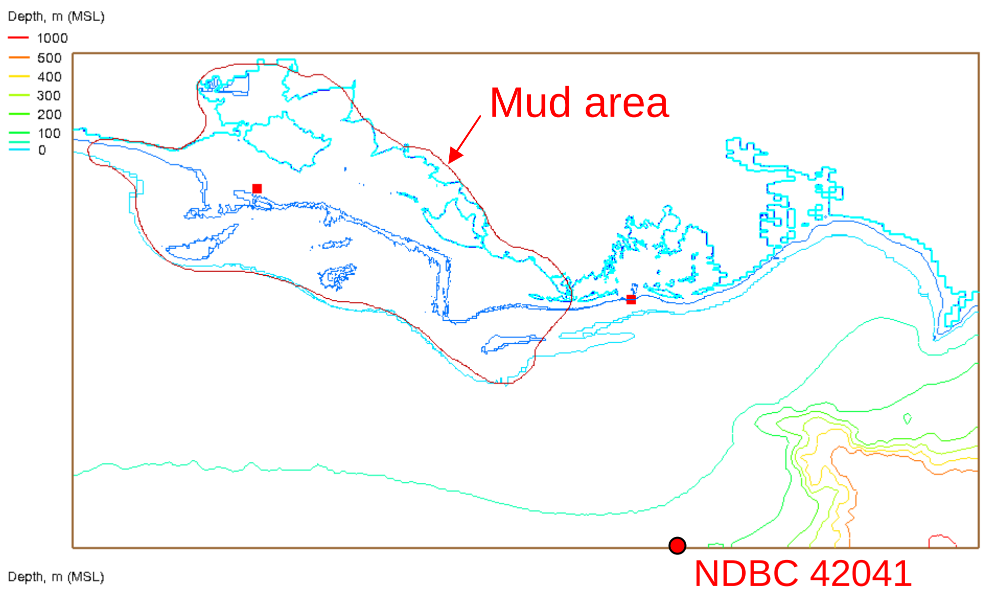
CSI 5 – fine quartz sand

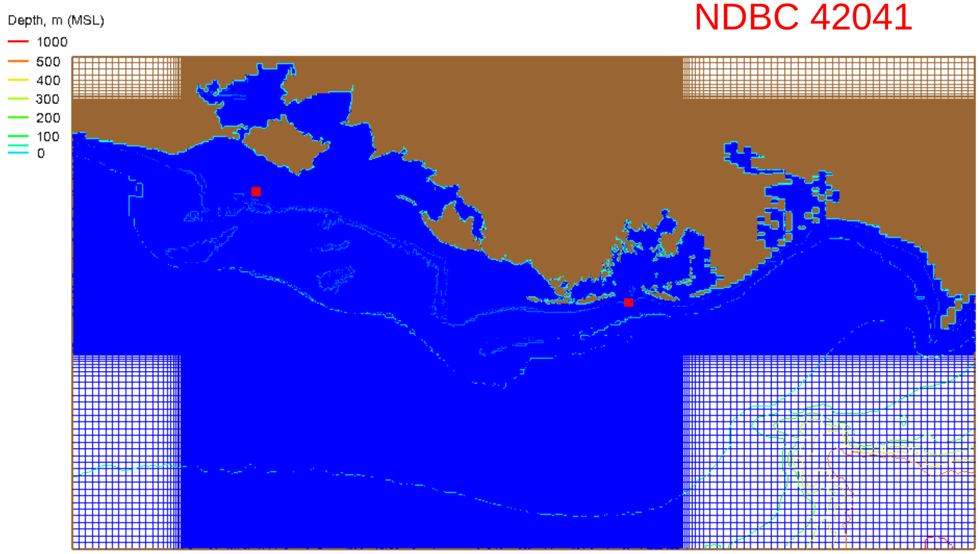
Refs:

Sheremet, A. and Stone, G.W. 2003. Wave dissipation due to heterogeneous sediments on the inner Louisiana shelf. Proceedings. Of Coastal Sediments'03, Clearwater Beach, FL.

Sheremet, A, Meta, A.J., Liu, B. and Stone, G.W. 2005. Wave-Current interaction on a muddy inner shelf during Hurricane Claudette. Estuarine, Coastal and Shelf Science 63.

CMS-Wave Louisiana Coast Simulation





Model domain: 180 m x 330 km
(500 x 1000 cells)

largest cell ~ 2.5 km x 2.5 km
smallest cell ~ 200 m x 200 m

$$S_{dp} = -4(\nu_k + \nu_t)k^2 E$$

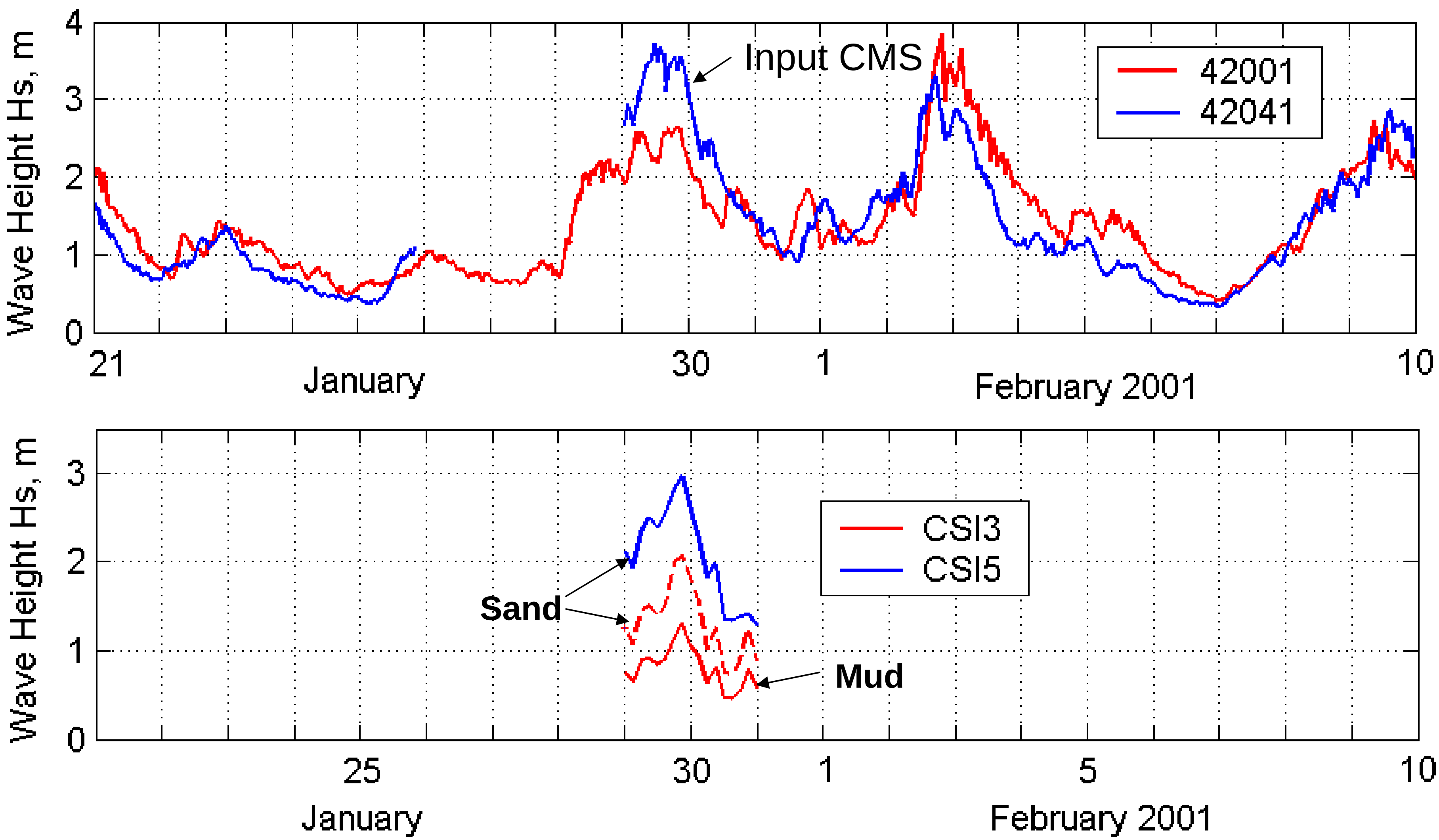
where

$$\nu_t = \nu_{t,breaking} \frac{H_s}{h}$$

$\nu_{t,breaking}$ = 0.04 m²/sec

ν_k ~ 0

CMS-Wave Grid



References & Contacts

1. Lin, L., Z. Demirbilek, H. Mase, J. Zheng., and F. Yamada. 2008 "CMS-Wave: A Nearshore Spectral Wave Processes Model for Coastal Inlets and Navigation Projects," ERDC/CHL TR-08-13.

2. Hughes, S. 2003 "Estimating Irregular Wave Run-up on Smooth, Impermeable Slopes," ERDC/CHL CHETN-III-68.

3. Headquarters, U.S. Army Corps of Engineers. 2003 Coastal Engineering Manual, EM-1110-1100, Washington, DC.

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