CMS-Wave Background and Capabilities

Developed for coastal and inlet applications

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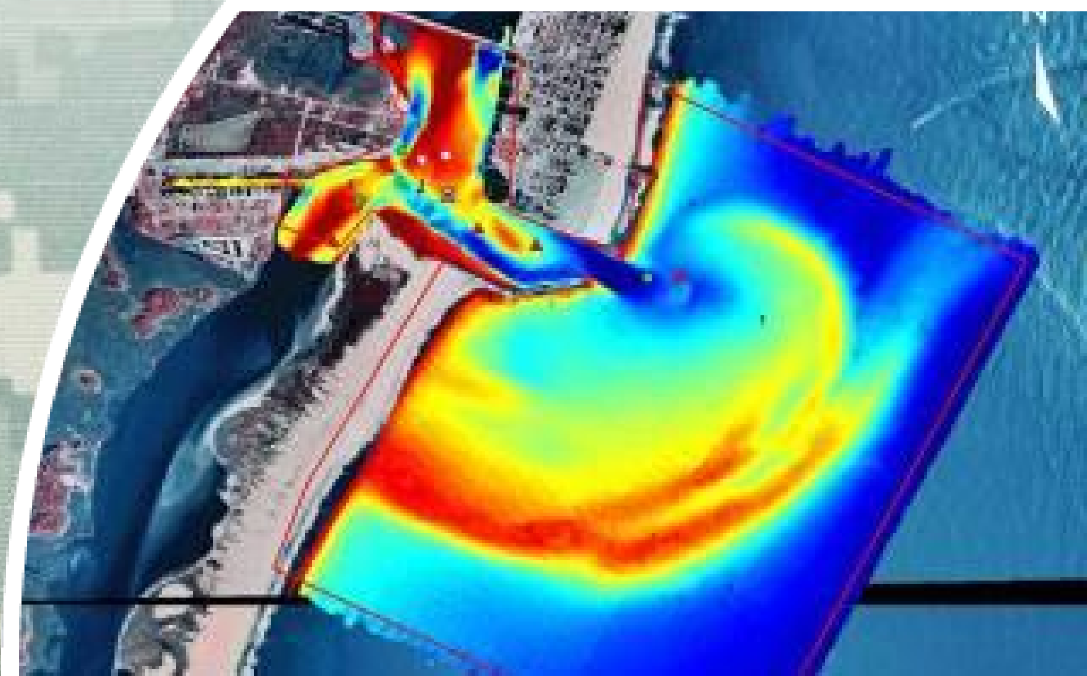

US Army Corps of Engineers
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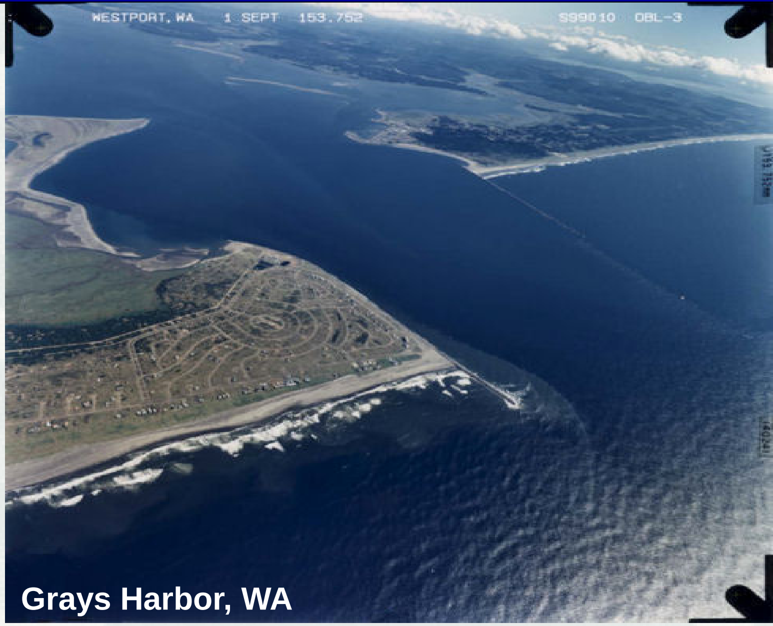
Outline


Grays Harbor, WA

- Overview of CMS-Wave
- Capability
- Governing equations
- Incident wave spectrum
- Wave-current interaction
- Diffraction and reflection
- Wind input and wave dissipation
- Wave run-up, overtopping, & new features
- Coupled operation and future development
- Conclusions

1. Overview of CMS-Wave

- Steady-state (time-independent), half-plane, two-dimensional spectral transformation solved by finite-difference, forward-marching implicit scheme
- PC-based efficient model, stand-alone or coupled to CMS-Flow, a circulation and sediment transport model, through the SMS interface
- Emphasis on wave-structure-land interactions for practical coastal engineering projects

2. Capabilities

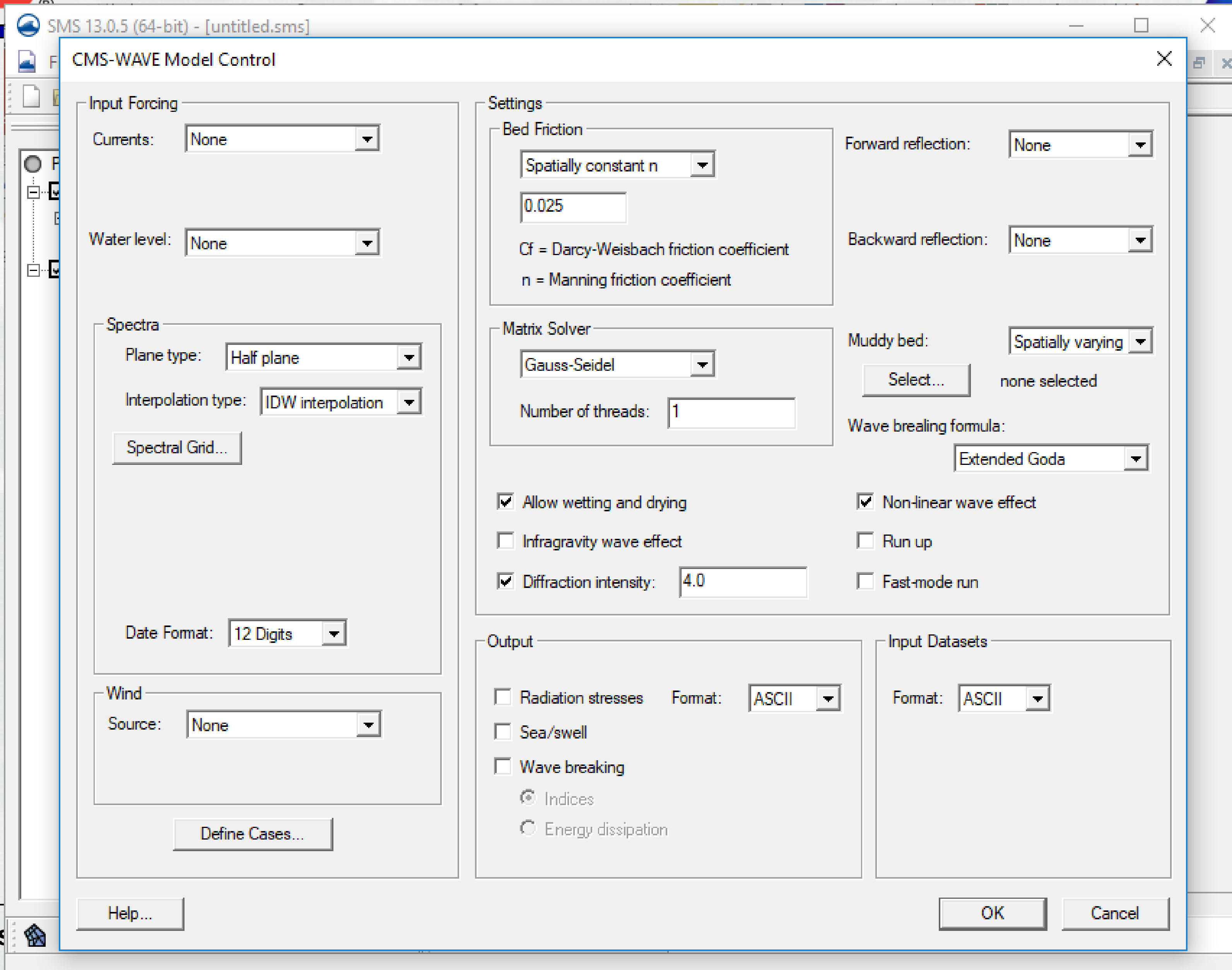
- Wave diffraction, reflection (forward & backward), breaking, bottom friction dissipation
- Wind input, wave-current interaction
- Wave transmission at structures
- Wave run-up, overtopping, overland flow
- Variable grids with nesting
- Nonlinear wave-wave interaction & infra-gravity waves
- "Fast mode" for quick calculations & prelim runs

CMS-Wave capabilities

Capability	CMS-Wave
Spectrum transformation	Directional
Refraction & shoaling	Represented
Depth-limited wave breaking	Choice among four formulas
Roller	Represented
Diffraction	**Theory**
Reflection	**Represented**
Transmission	**Formulas**
Run-up and setup	**Theory**
Wave-current interaction	Theory
Wave-wave interaction	Theory
Wind input	Theory
White capping	Theory
Bottom friction	Theory

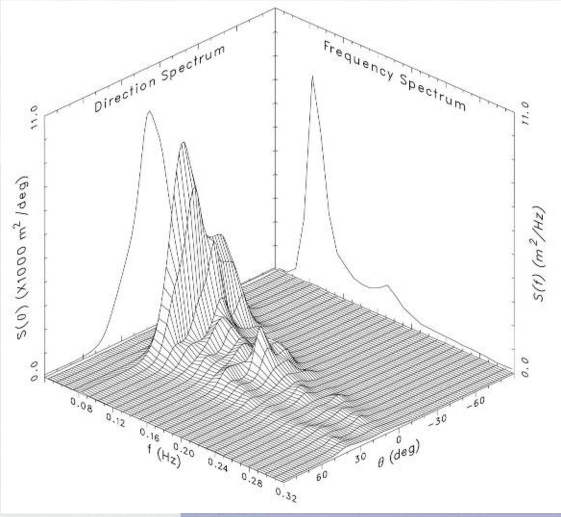
Structures (Diffraction, Reflection, Transmission, Run-up and setup)

CMS-Wave SMS 13.0 Interface

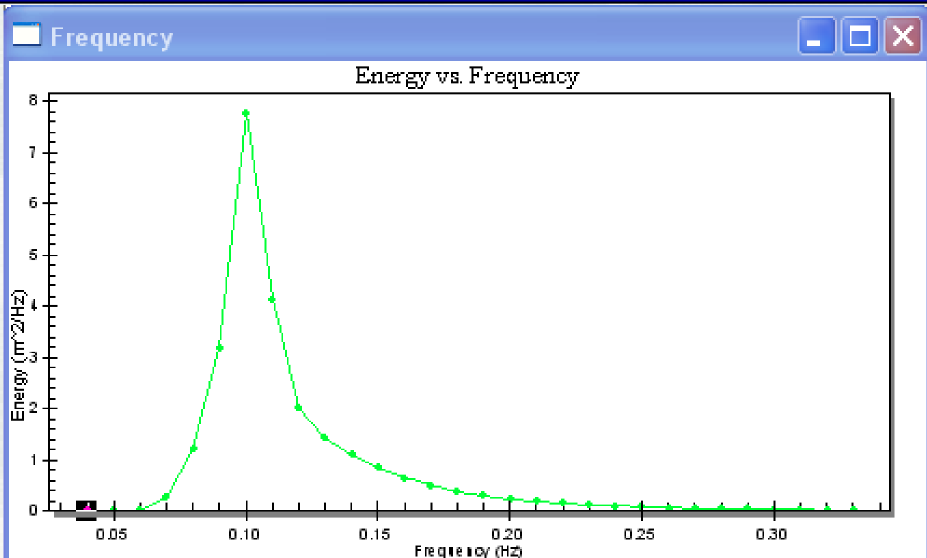


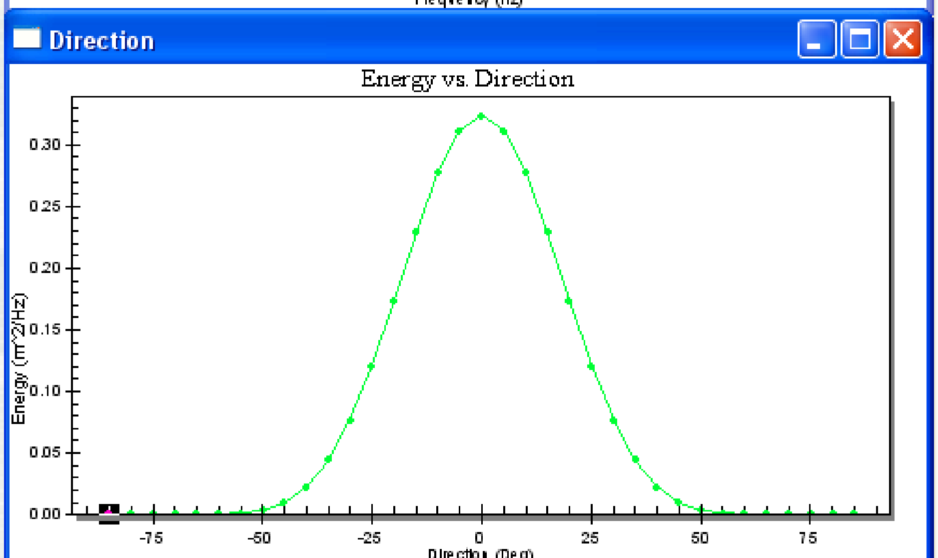
4. Incident Wave Spectrum

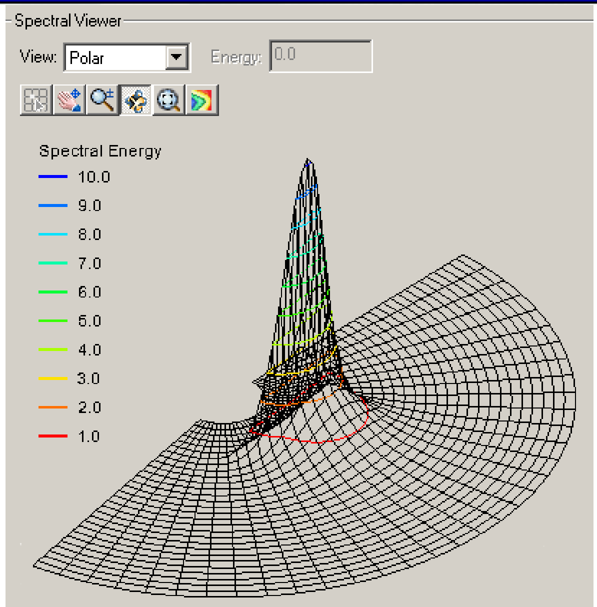
- NDBC/NOAA Ocean Buoys
- CDIP Coastal Buoys
- Project specific measurements (ADCP)
- Theoretical spectra (SMS)

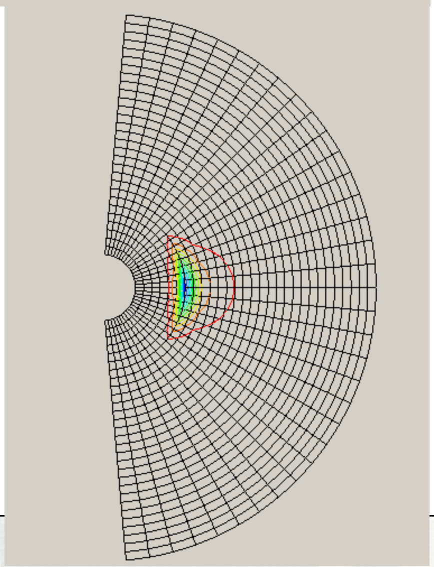


SMS Wave Spectrum Display

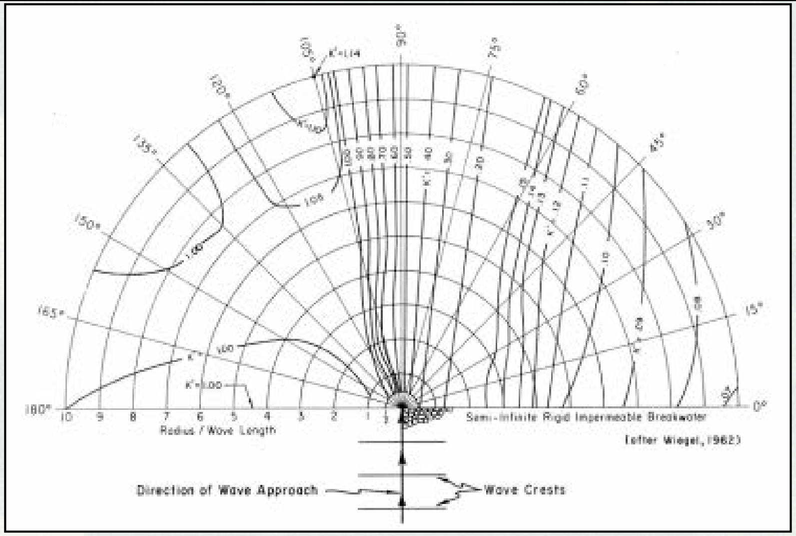


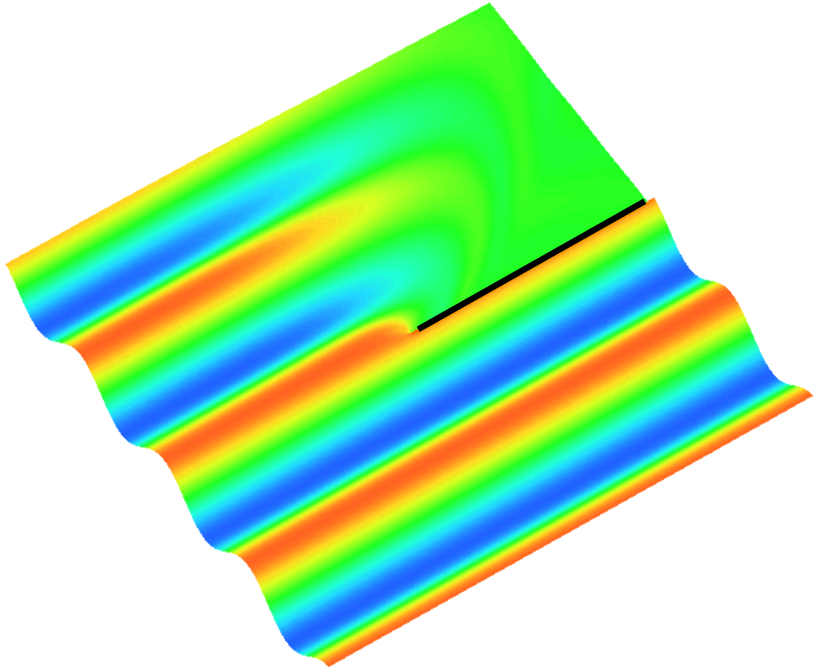


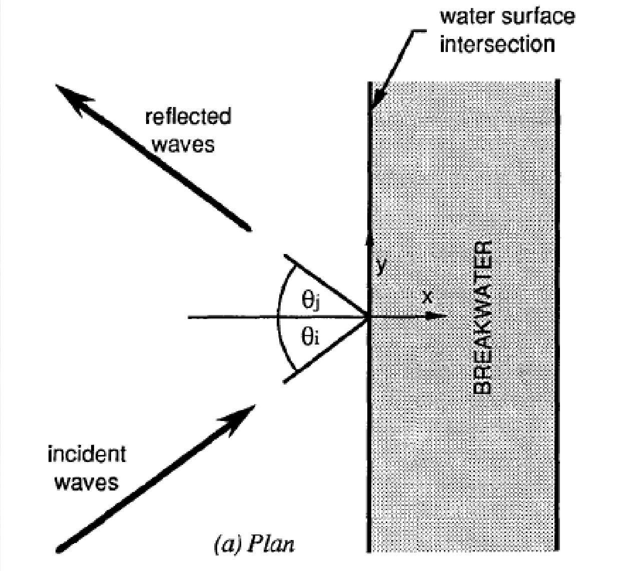


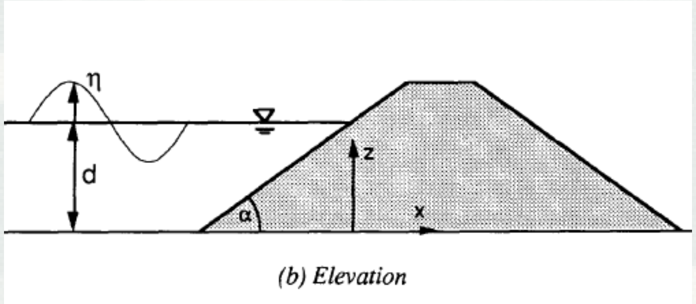


6. Jetty Breakwater Wave Diffraction and Reflection

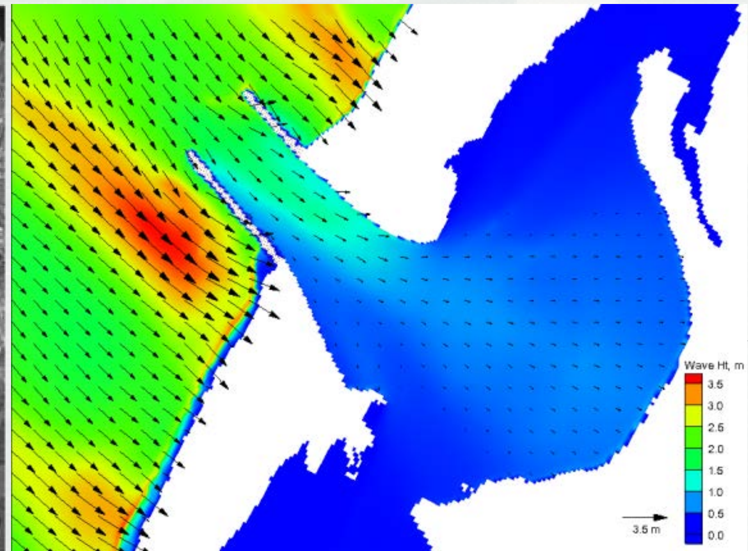


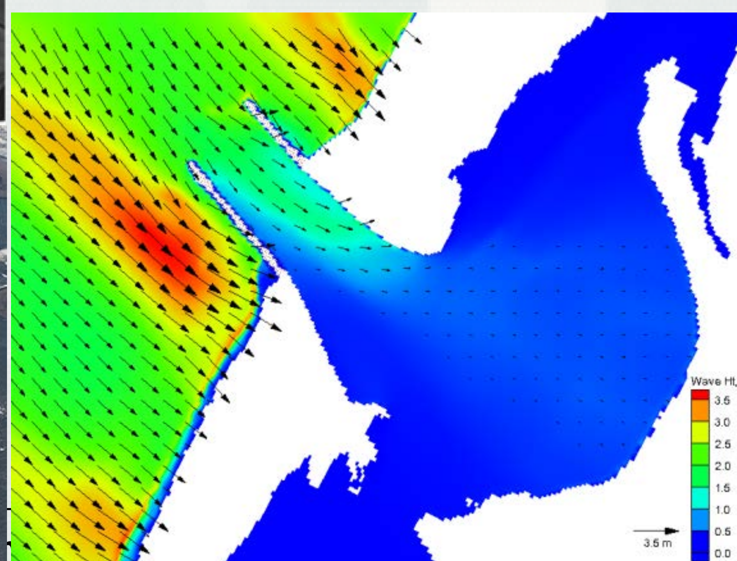






Infra-gravity Waves at *Humboldt Bay, CA*



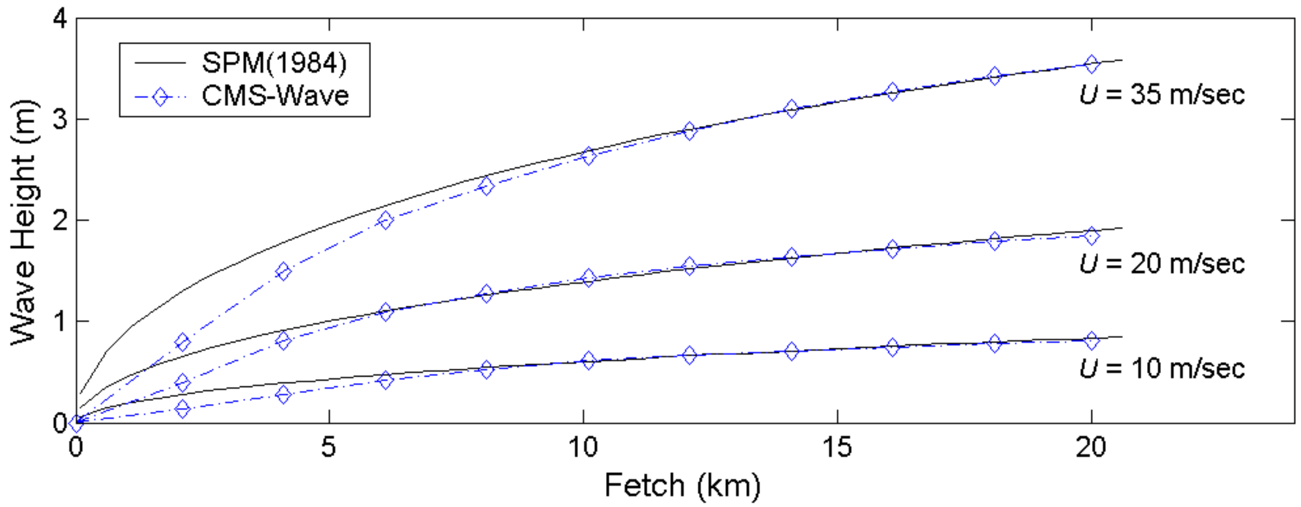


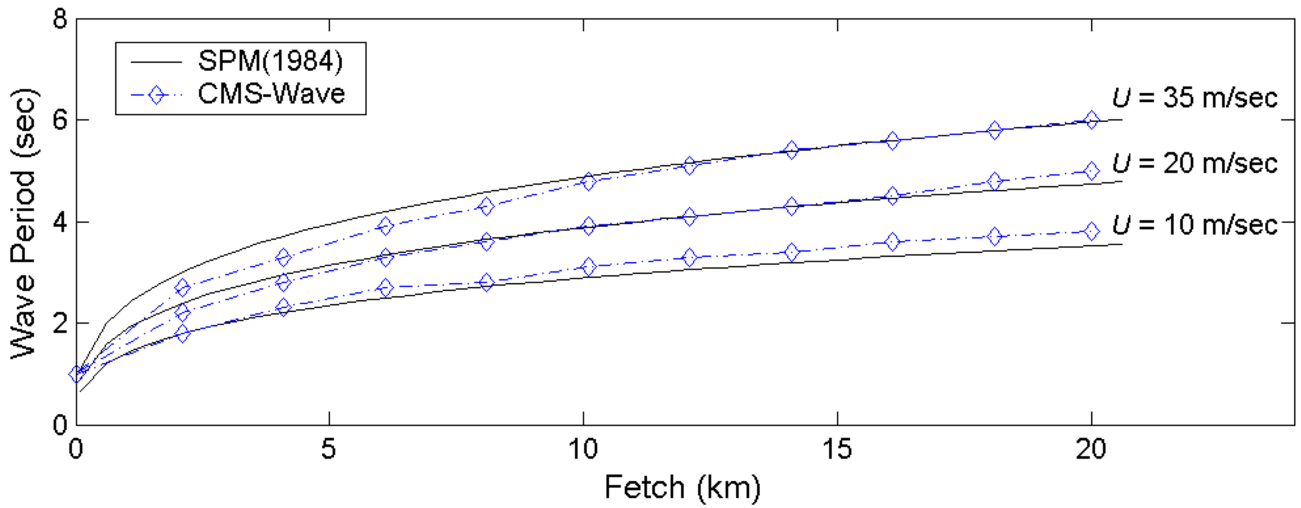
Incident wave:
2 m, 15 sec
from NE

with infra-gravity wave

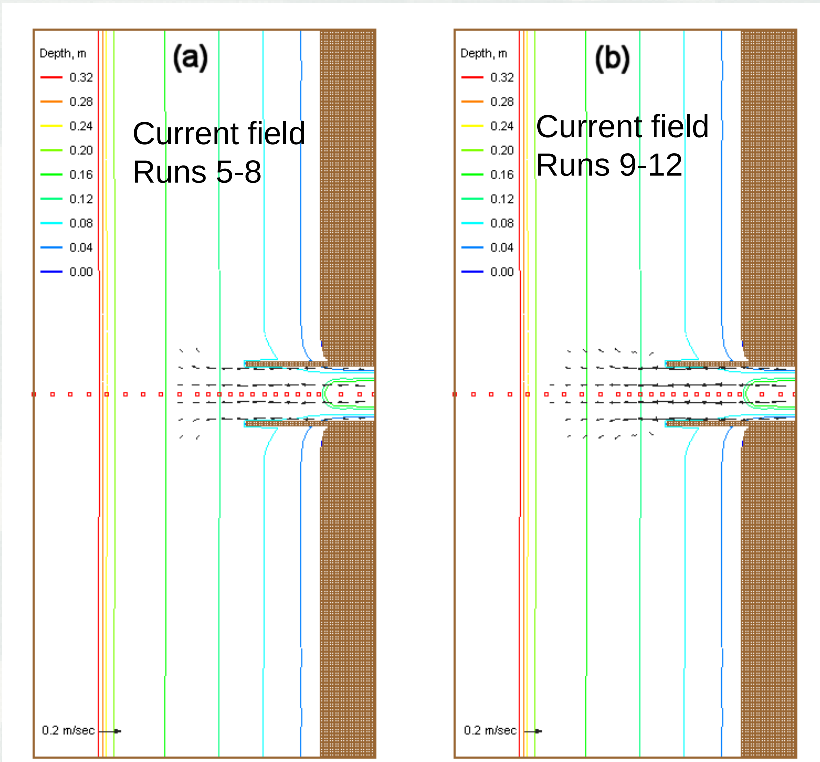
without infra-gravity wave

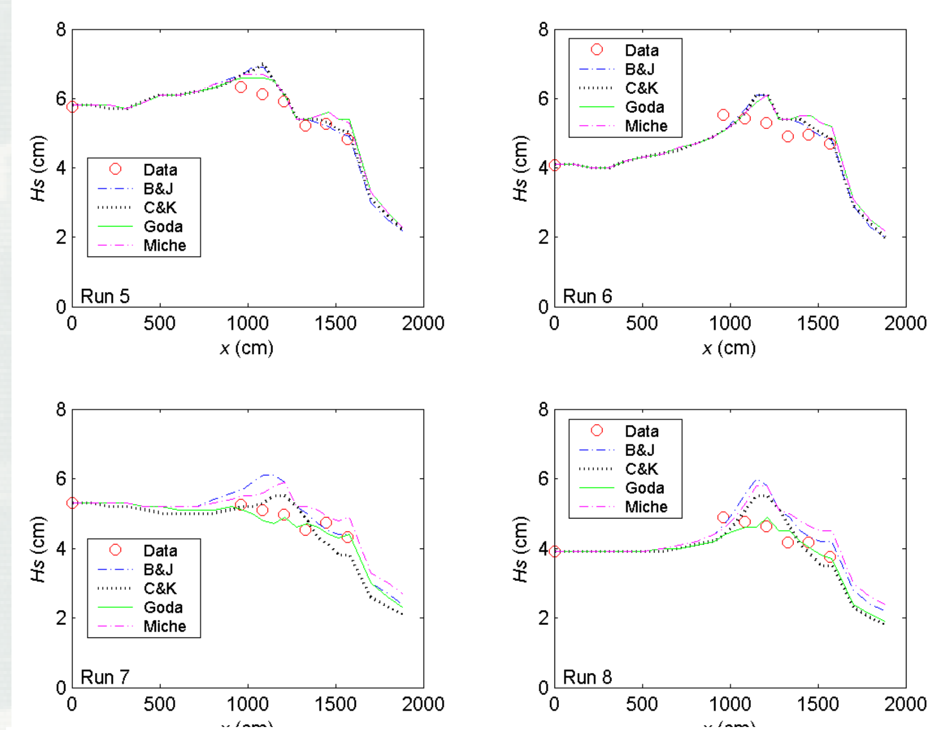
7. Wind-Wave Generation

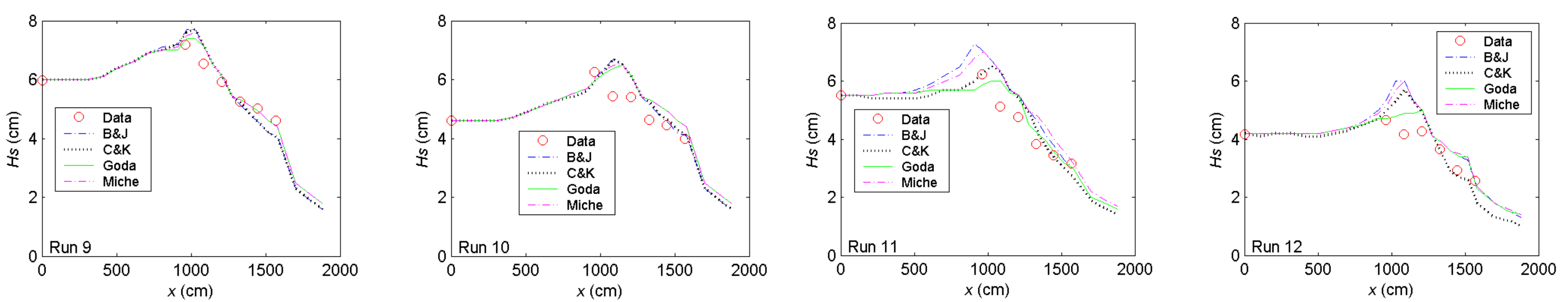




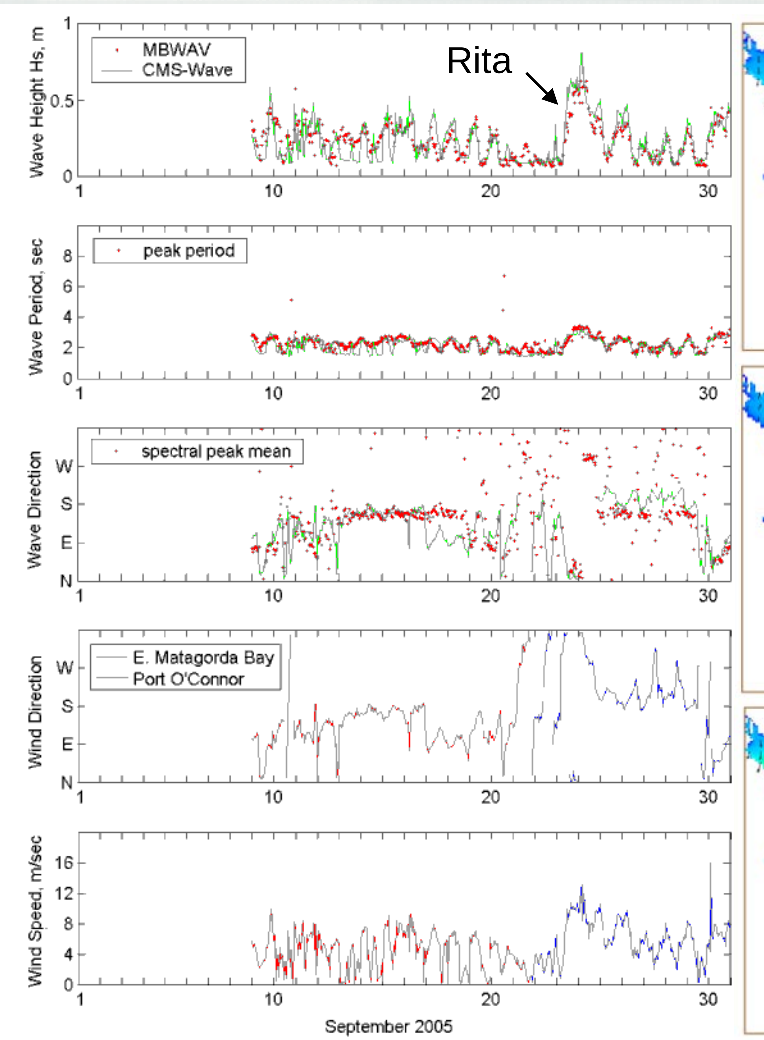
Wave Breaking Formulas

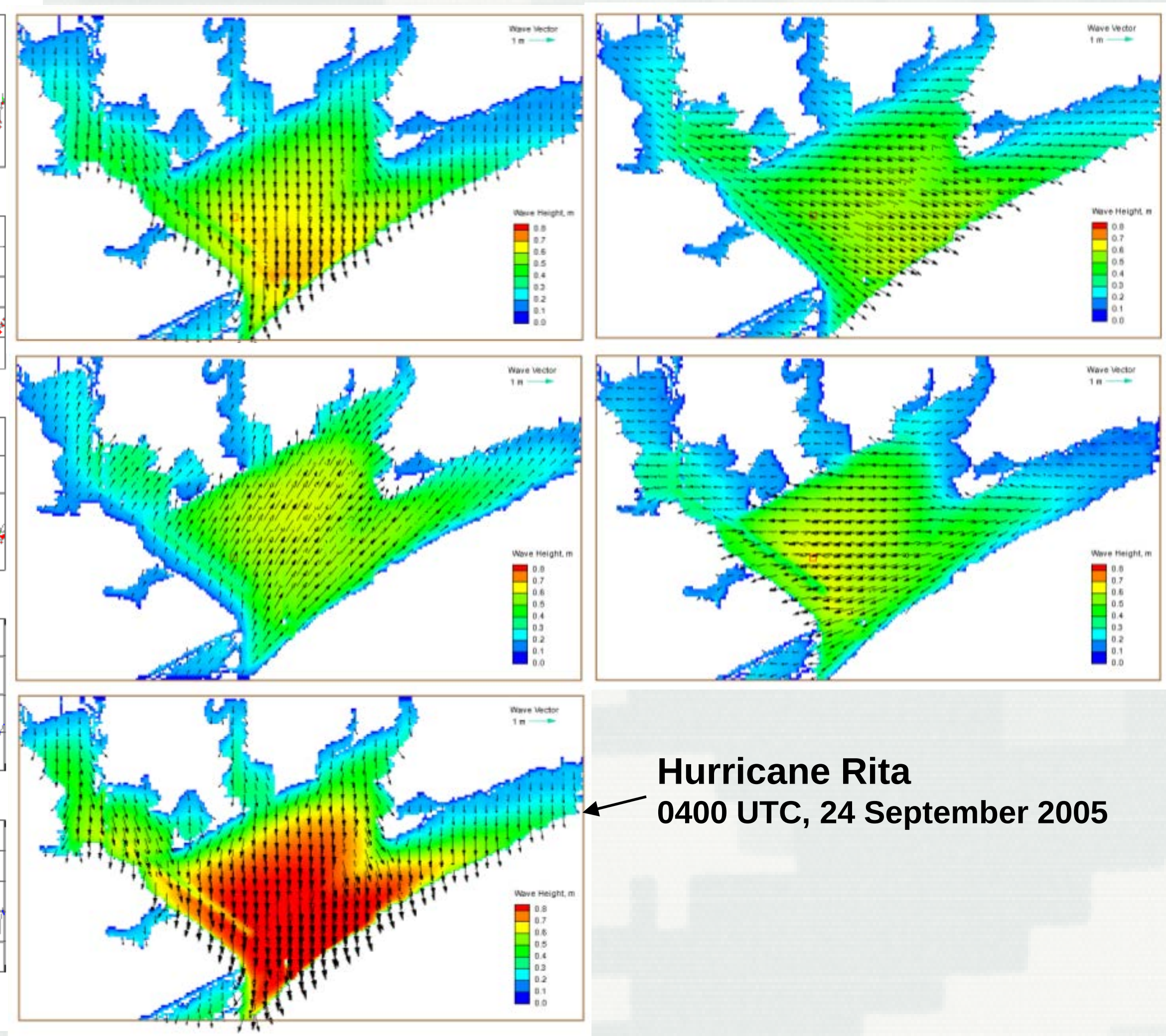






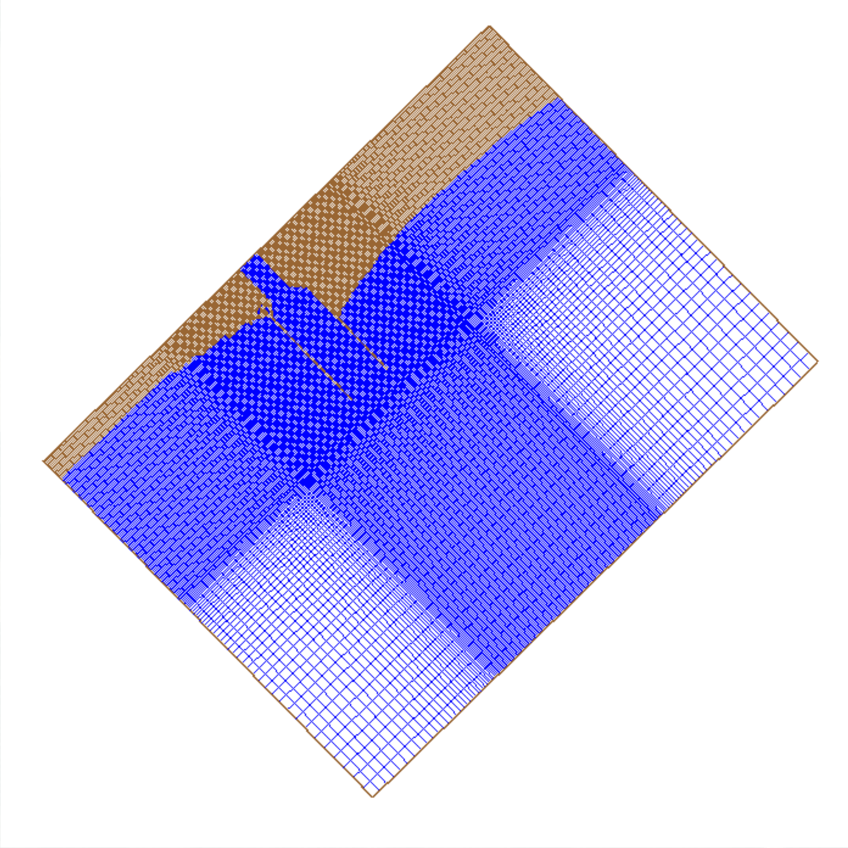
Wave Generation in *Matagorda Bay, TX*



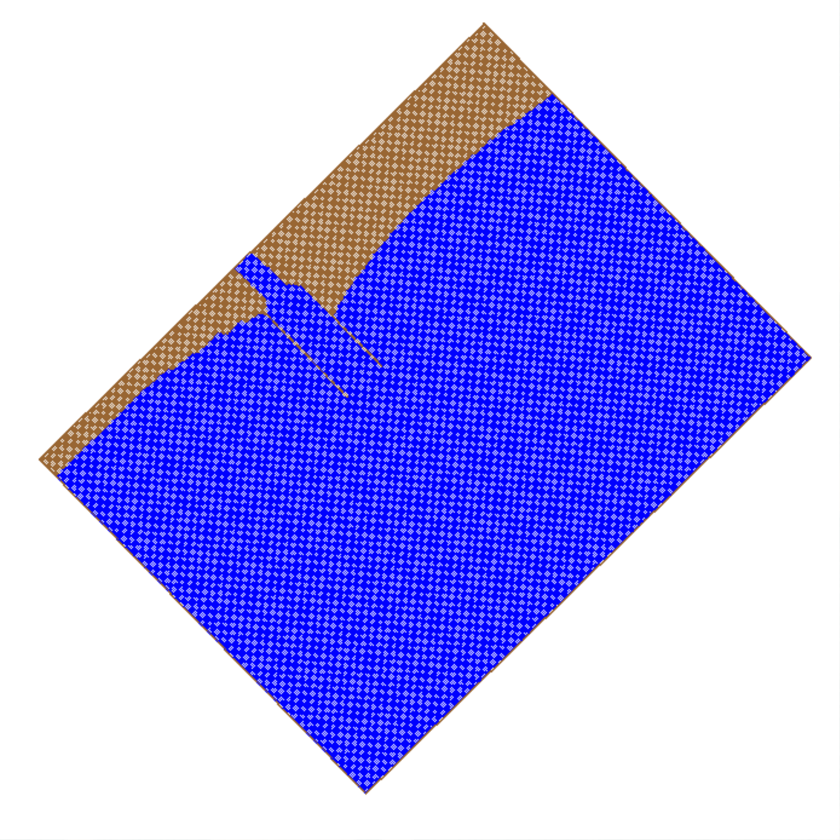


Hurricane Rita
0400 UTC, 24 September 2005

Variable Rectangular-Cell Grids

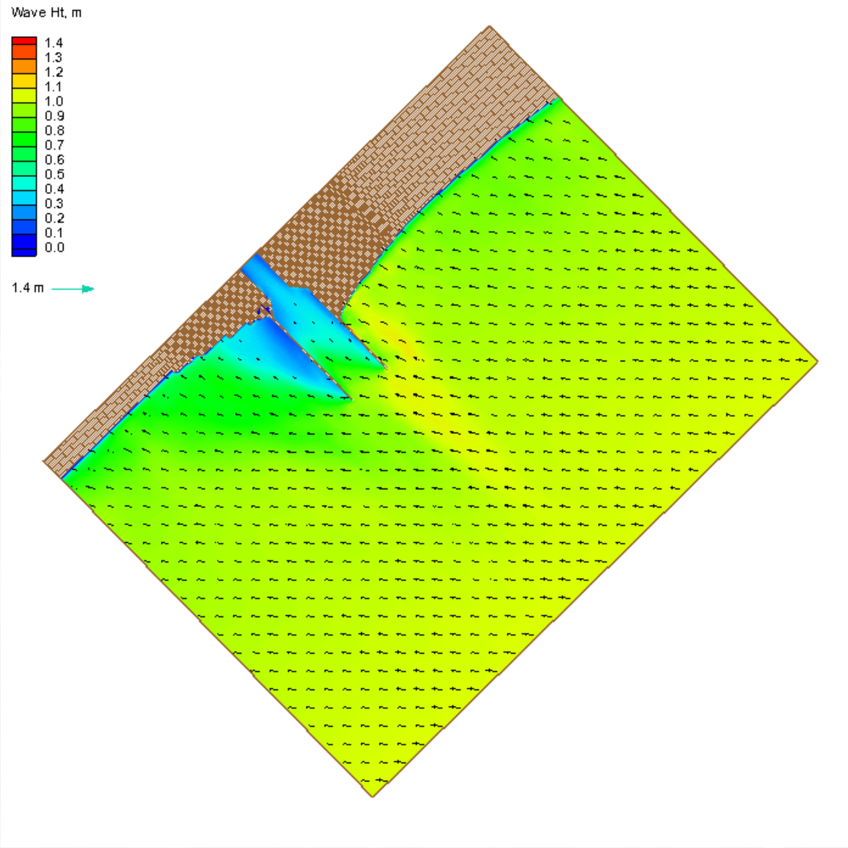


Variable-rectangular cells
Total 223 x 172 cells

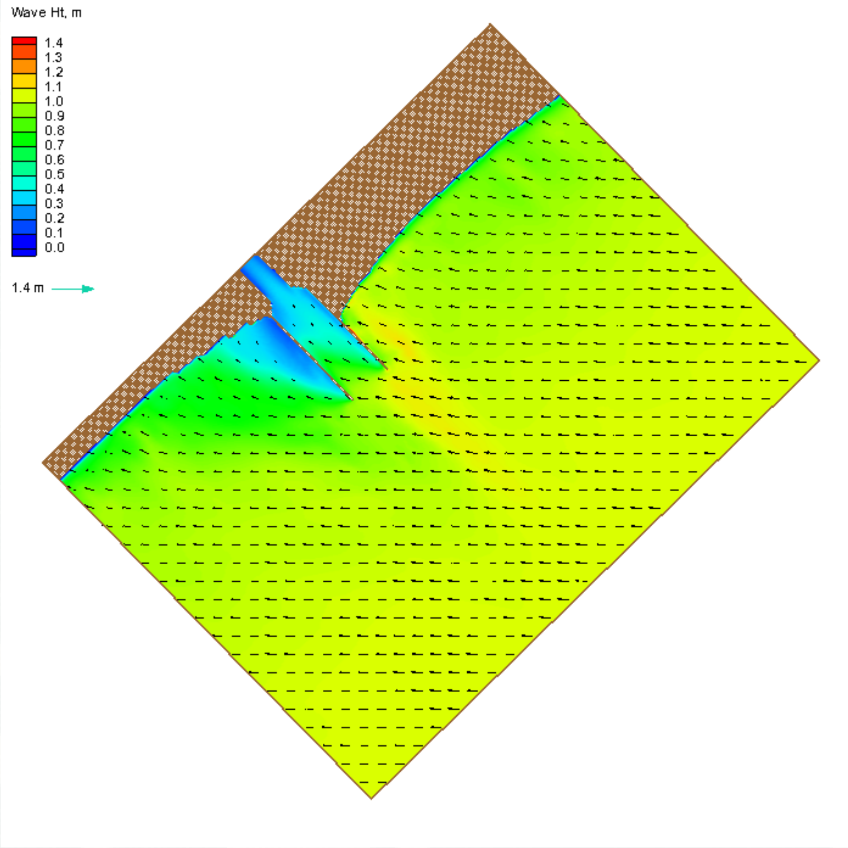


Square (20 m x 20 m) cells
Total 316 x 426 cells

CMS-Wave on Variable Grids

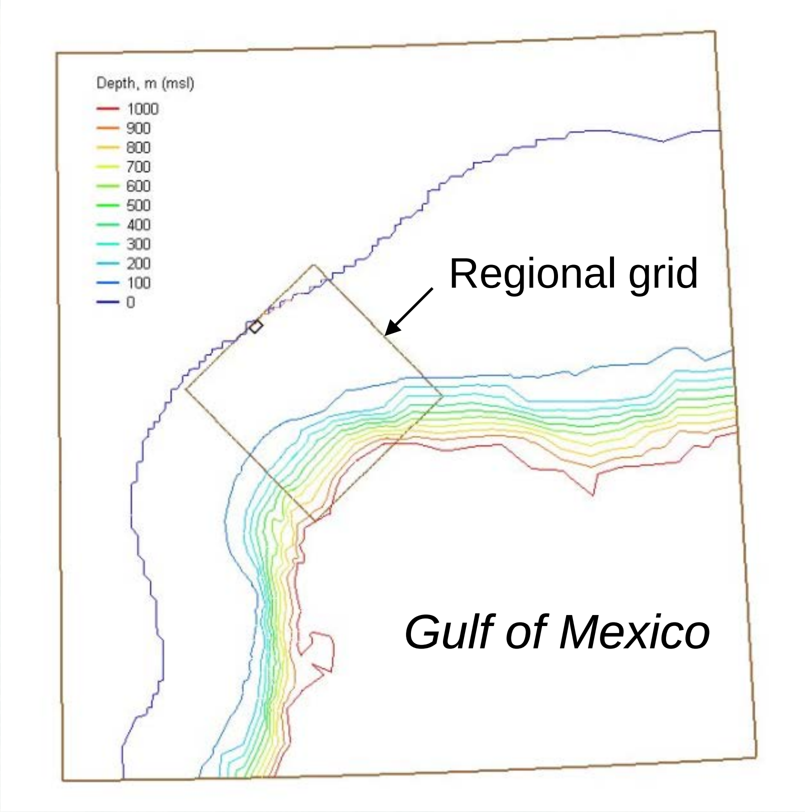


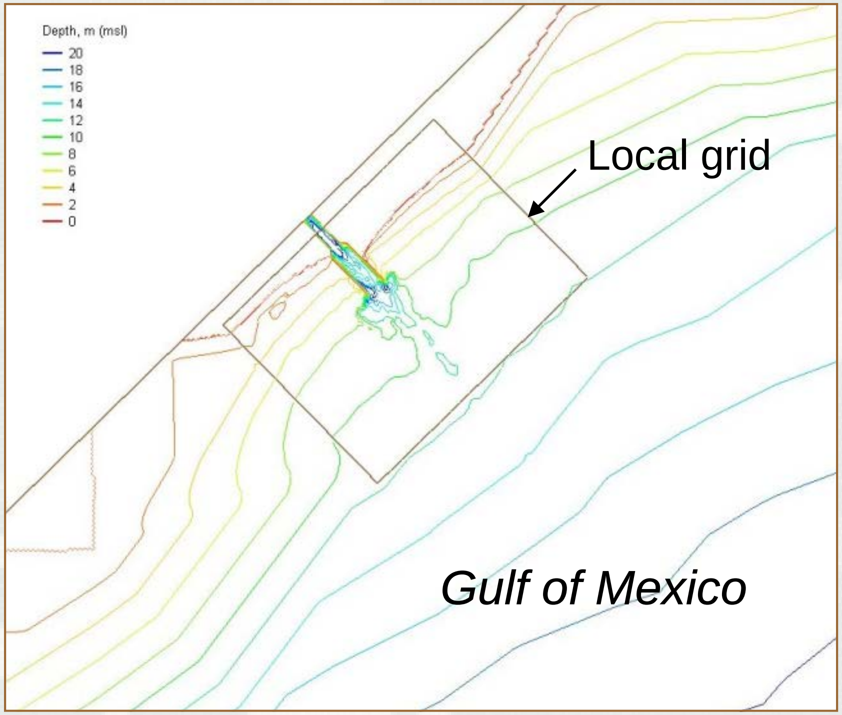
Variable-rectangular cells
Total 223 x 172 cells



Square (20 m x 20 m) cells
Total 316 x 426 cells

Grid Nesting

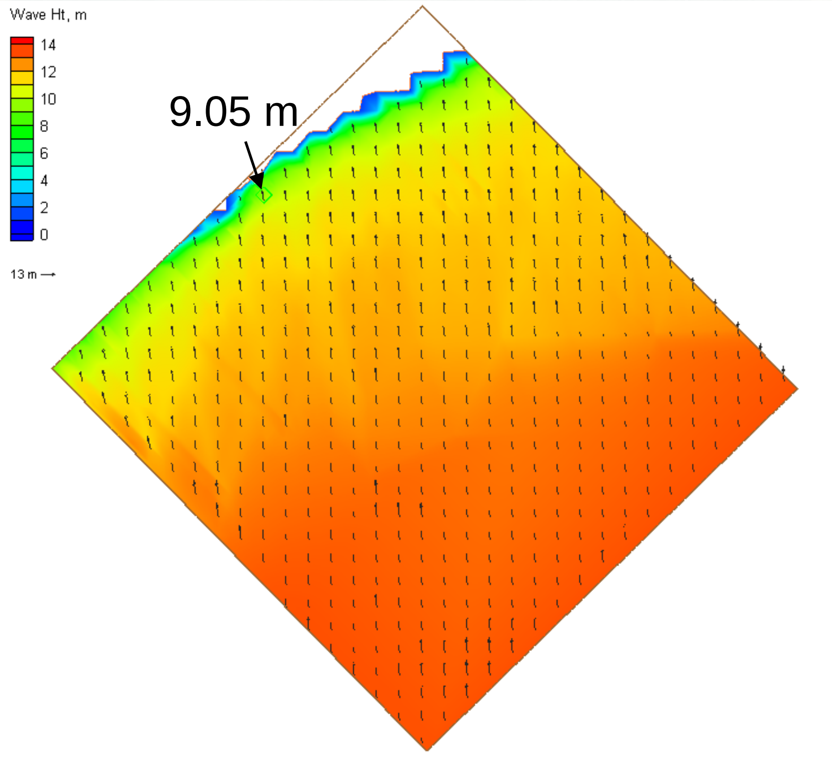




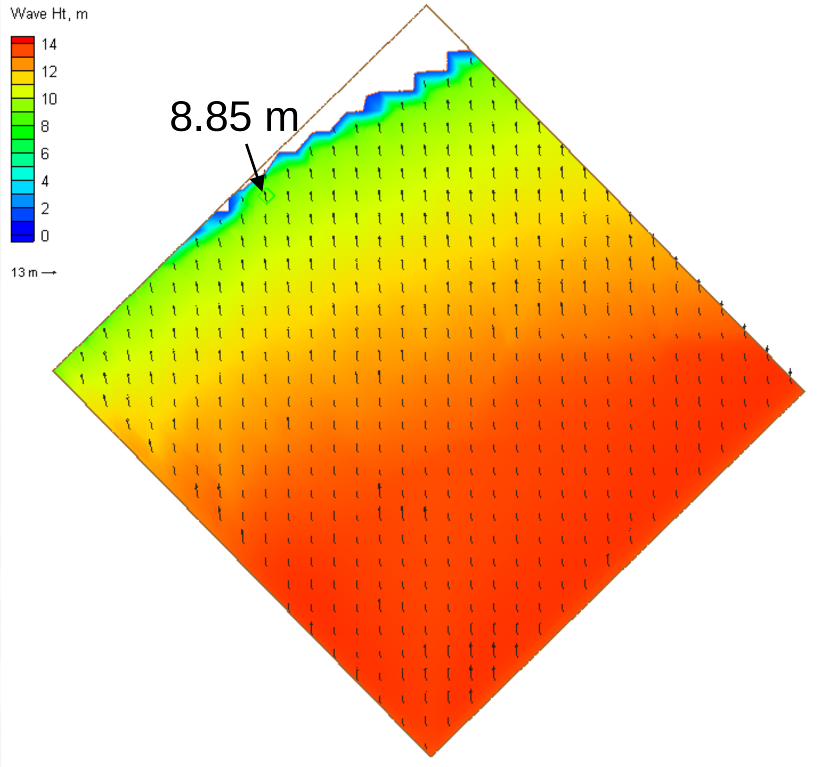
Regional Wave Generation

Incident Waves: 12.9 m, 13.8 sec, from S

Max Surge: 3.5 m (Return Period = 50 yrs)

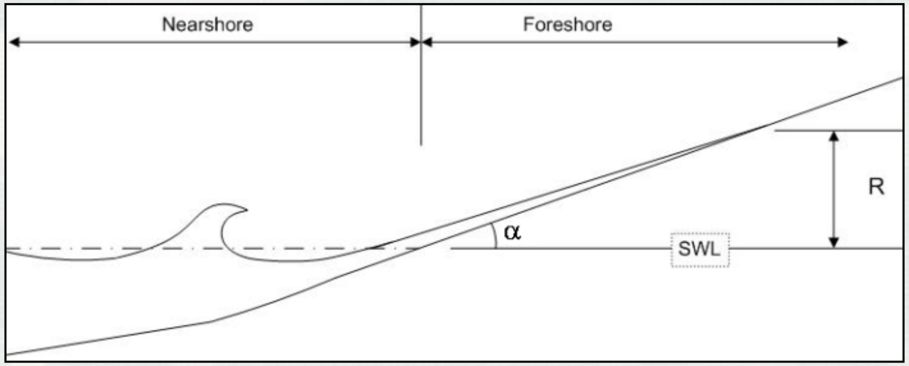


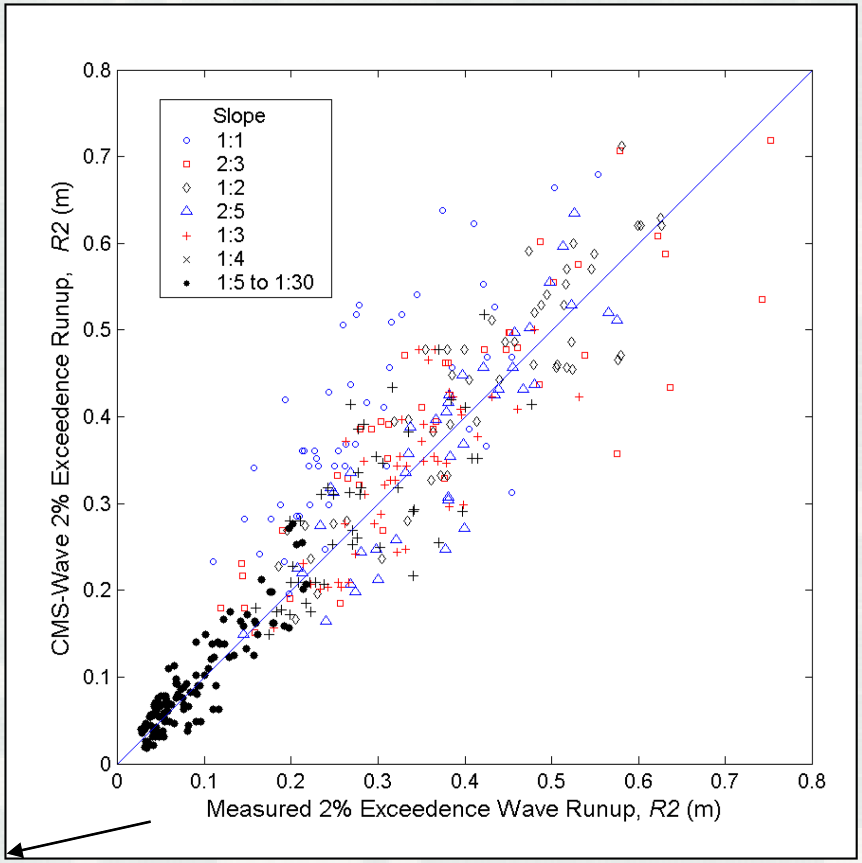
Without wind



With wind (27 m/sec, from S)

8. Wave Run-up





Wave run-up: rush of waves up a slope or structure

Two-percent run-up, *R2* : the vertical up-rush level exceeded by 2-percent of the larger run-up height

Ahrens & Titus (1981), Mase & Iwagaki (1984) ~ 400 laboratory experiments

Floating Breakwater

An analytical formula of the transmission coefficient for a rectangle floating breakwater of width *B* and Draft *D* (Macagno 1953):

$$K_t = \left[1 + \left(\frac{kB \sinh \frac{kh}{2\pi}}{2 \cosh k(h-D)} \right)^2 \right]^{-\frac{1}{2}}$$

Bottom-Mound Breakwater

Vertical wall breakwater (Kondo and Sato, 1985):

$$K_t = 0.3\ (1.5 - \frac{h_c}{H_s}), \quad \text{for} \quad 0 \le \frac{h_c}{H_s} \le 1.25$$

Composite or rubble-mound breakwater:

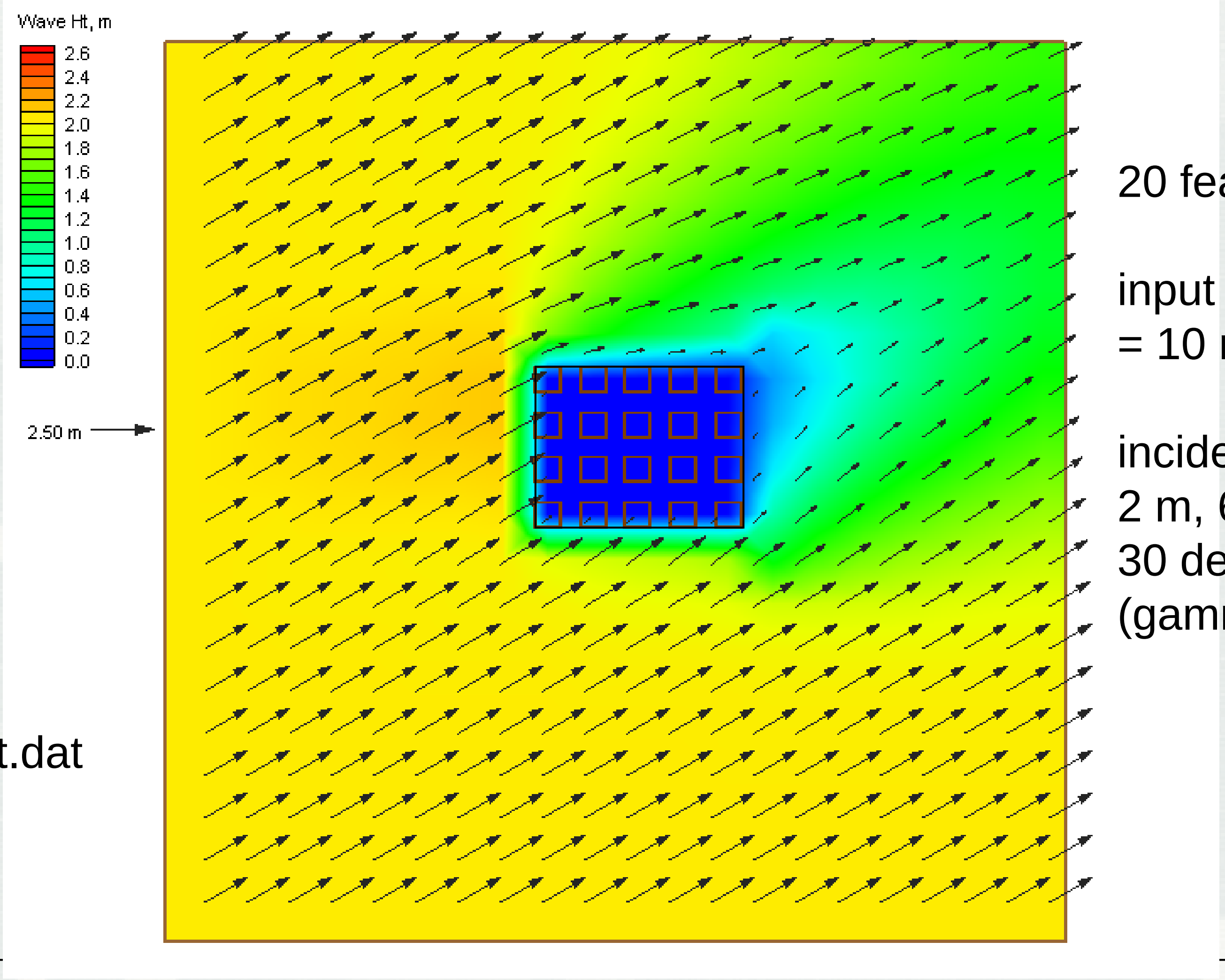
$$K_t = 0.3\ (1.1 - \frac{h_c}{H_s}), \quad \text{for} \quad 0 \le \frac{h_c}{H_s} \le 0.75$$

where h_c is the crest height (above mean water level) and H_s is the incident wave height.

Idealized Island Example

```
20
 9 10
10 10
11 10
12 10
13 10
 9 11
10 11
11 11
12 11
13 11
 9 15
10 15
11 15
12 15
13 15
 9 16
10 16
11 16
12 16
13 16
```

struct.dat



20 feature cells

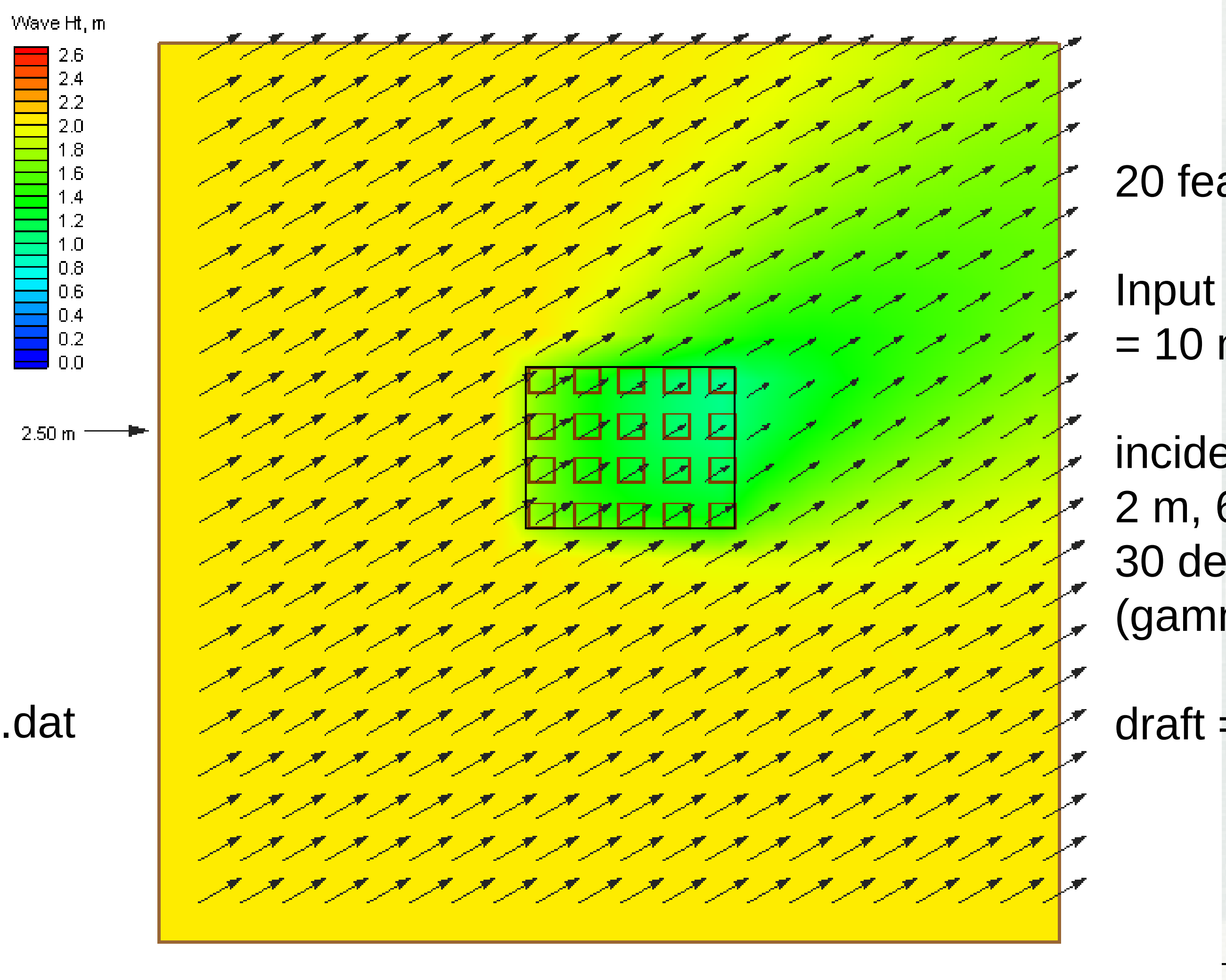
input depth = 10 m

incident wave: 2 m, 6 sec, 30 deg oblique (gamma = 4)

Idealized Floating Breakwater

20
9 10 3 2
10 10 3 2
11 10 3 2
12 10 3 2
13 10 3 2
9 11 3 2
10 11 3 2
11 11 3 2
12 11 3 2
13 11 3 2
9 15 3 2
10 15 3 2
11 15 3 2
12 15 3 2
13 15 3 2
9 16 3 2
10 16 3 2
11 16 3 2
12 16 3 2
13 16 3 2

struct.dat



20 feature cells

Input depth = 10 m

incident wave:
2 m, 6 sec,
30 deg oblique
(gamma = 4)

draft = 2 m

Idealized Platform

20
9 10 4 1
10 10 4 1
11 10 4 1
12 10 4 1
13 10 4 1
9 11 4 1
10 11 4 1
11 11 4 1
12 11 4 1
13 11 4 1
9 15 4 1
10 15 4 1
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12 15 4 1
13 15 4 1
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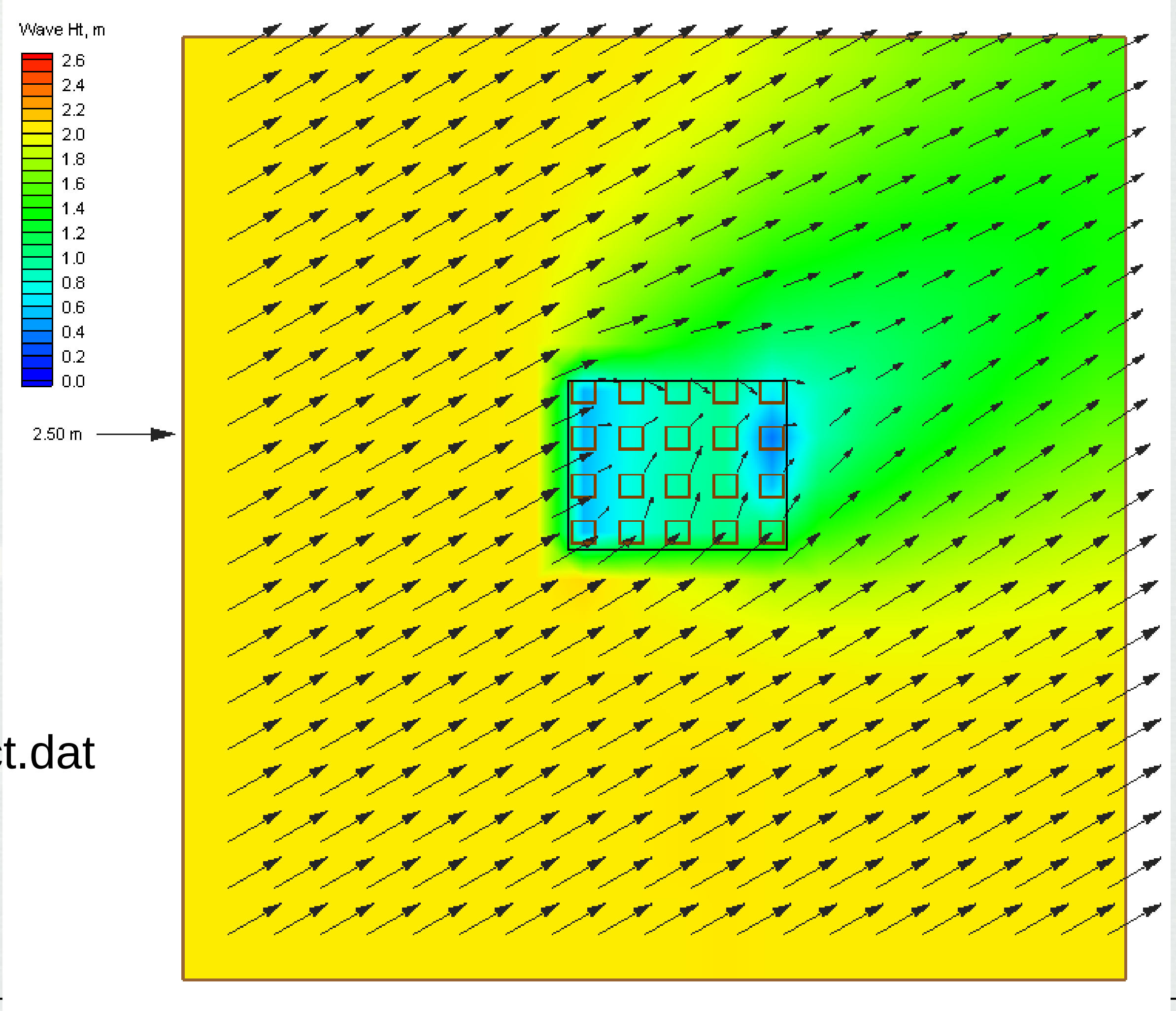
11 16 4 1
12 16 4 1
13 16 4 1

struct.dat



20 feature cells

input depth
= 10 m

incident wave:
2 m, 6 sec,
30 deg oblique
(gamma = 4)

platform elev.
= 1 m (mwl)

Submerged Platform

```
20
 9 10 4 -2
10 10 4 -2
11 10 4 -2
12 10 4 -2
13 10 4 -2
 9 11 4 -2
10 11 4 -2
11 11 4 -2
12 11 4 -2
13 11 4 -2
 9 15 4 -2
10 15 4 -2
11 15 4 -2
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10 16 4 -2
11 16 4 -2
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13 16 4 -2
```
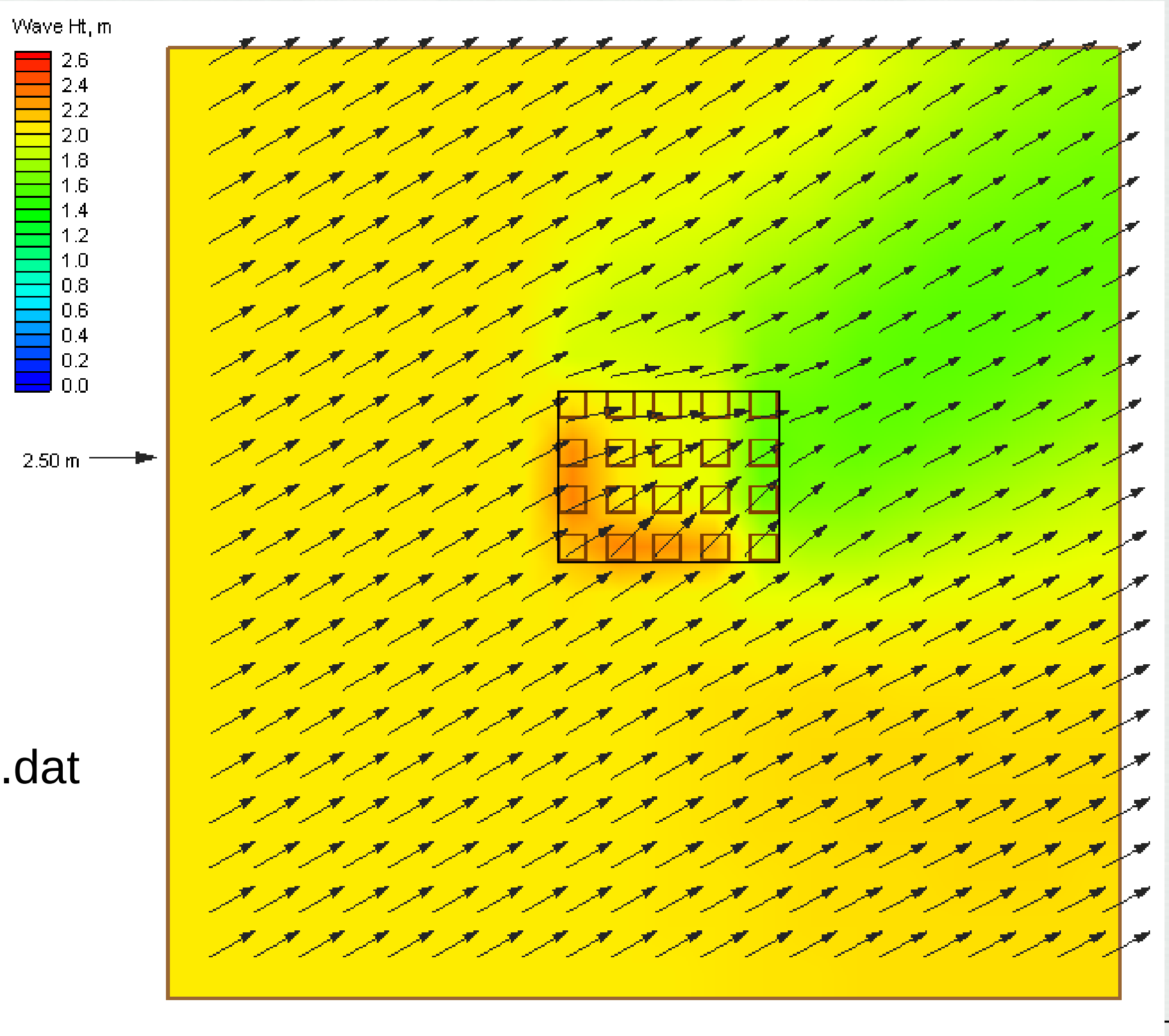

struct.dat



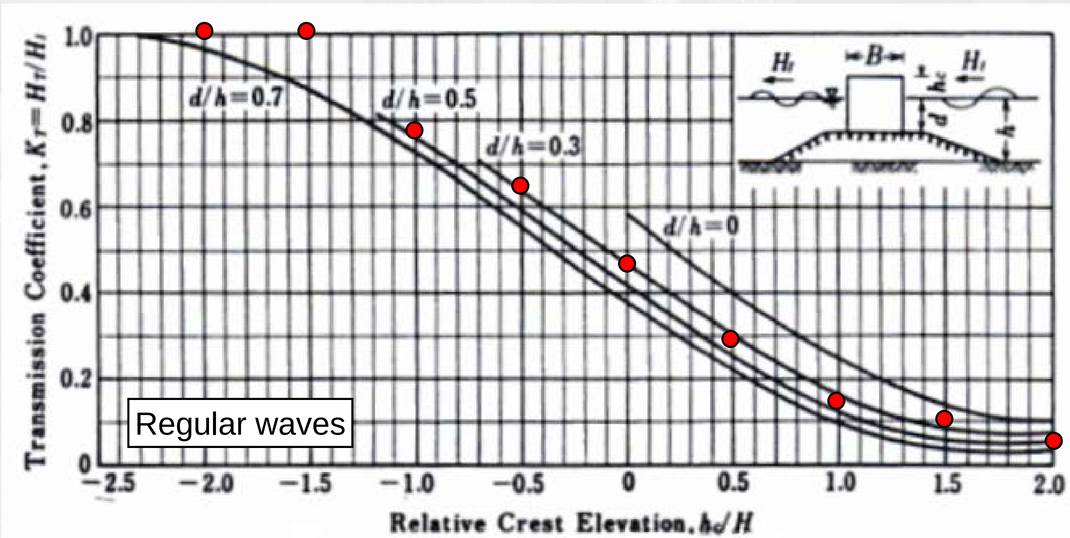
20 feature cells

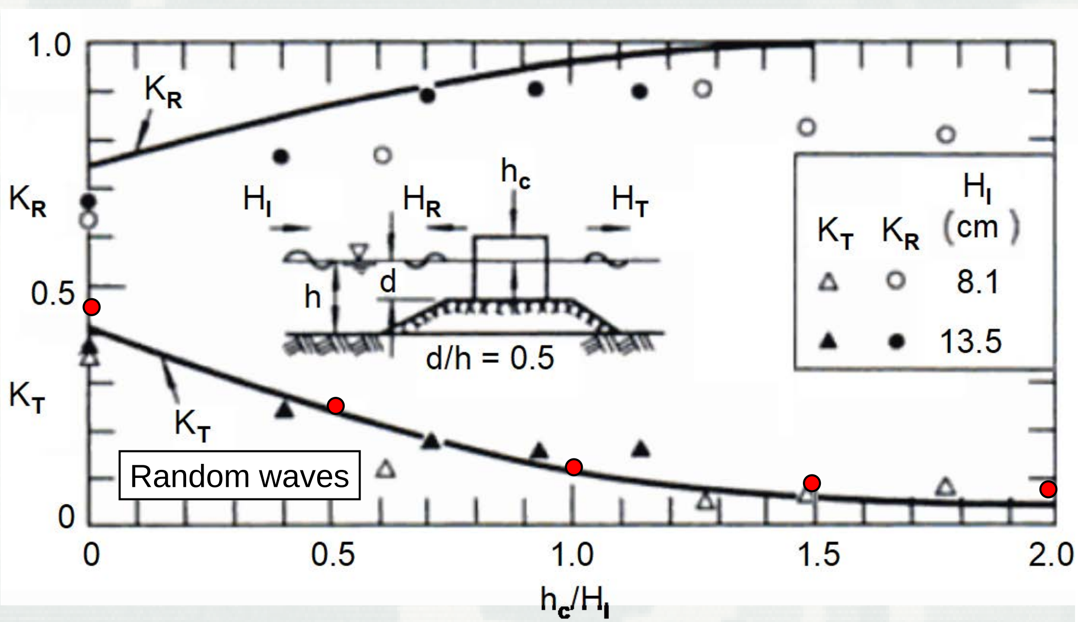
input depth = 10 m

incident wave: 2 m, 6 sec, 30 deg oblique (gamma = 4)

platform elev. = -2 m (mwl)

Wave Transmission Experiment (Goda, 2000)

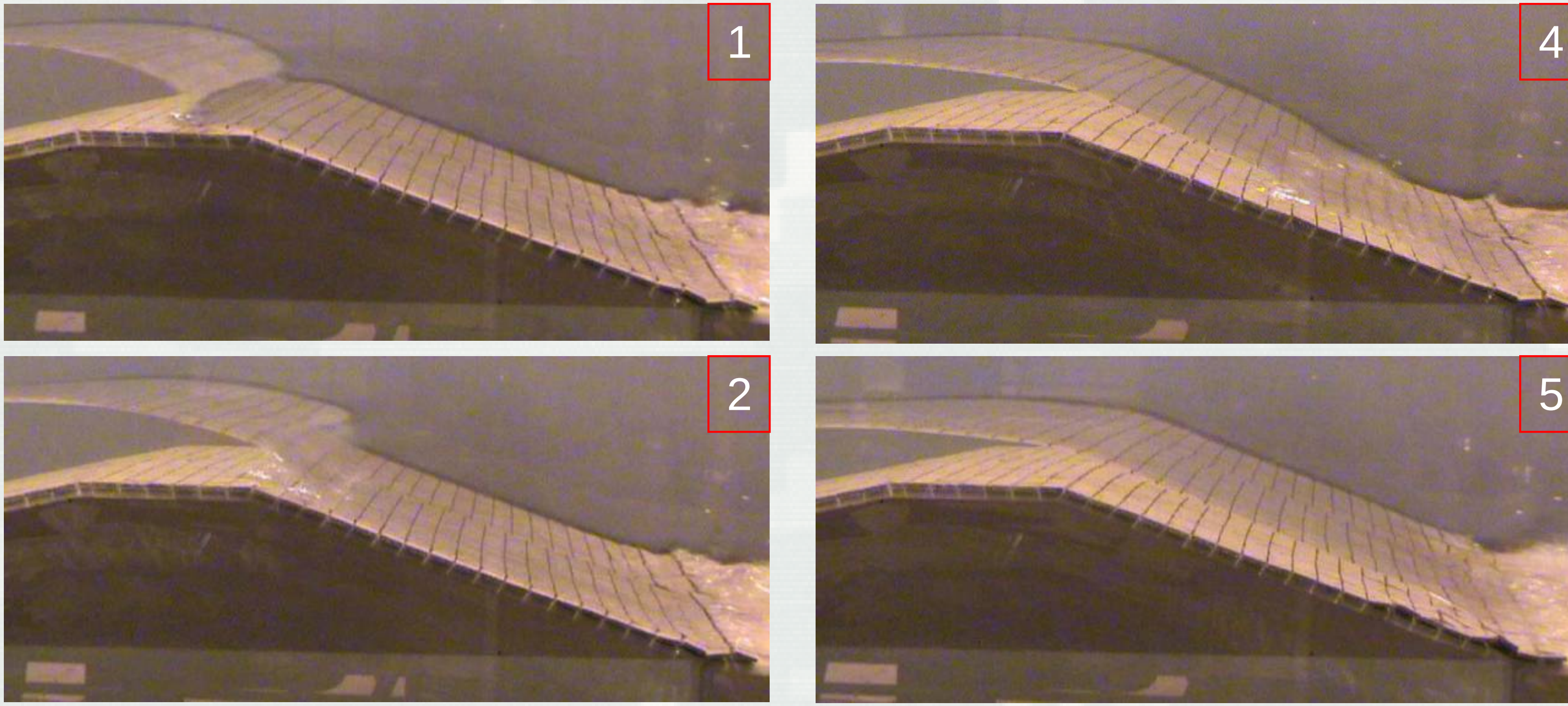


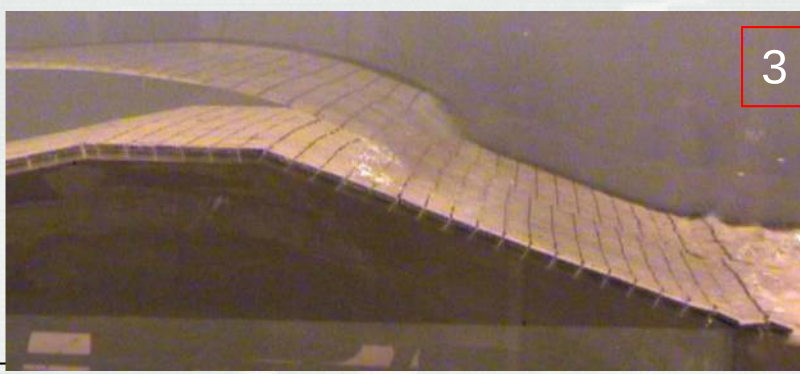


Transmission coefficients k_t
H_i = 1 m, Tp = 6 sec (monochromatic wave)
h = 10 m, d = 5 m, B = 80 m

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		

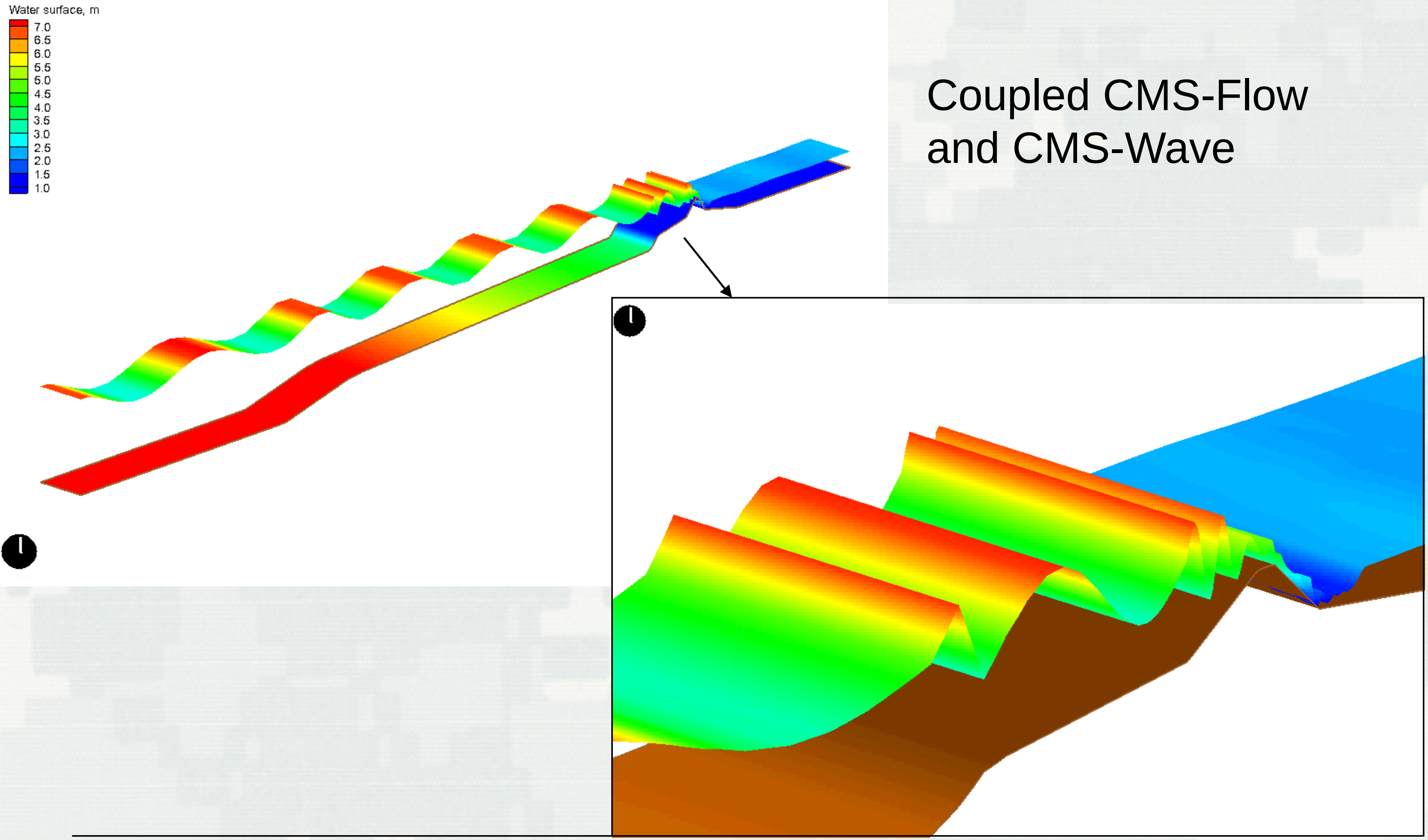
Wave overtopping: Surge level = 0.81 m (3 ft)
Hs = 0.88 m, *Tp* = 10.1 sec (Hughes, 2008)





ERDC/CHL TR-08-10
by Hughes (2008)

Calculated Wave Overtopping R127
Surge level =1.3 m, *Hs* =2.3 m, *Tp* =14 sec



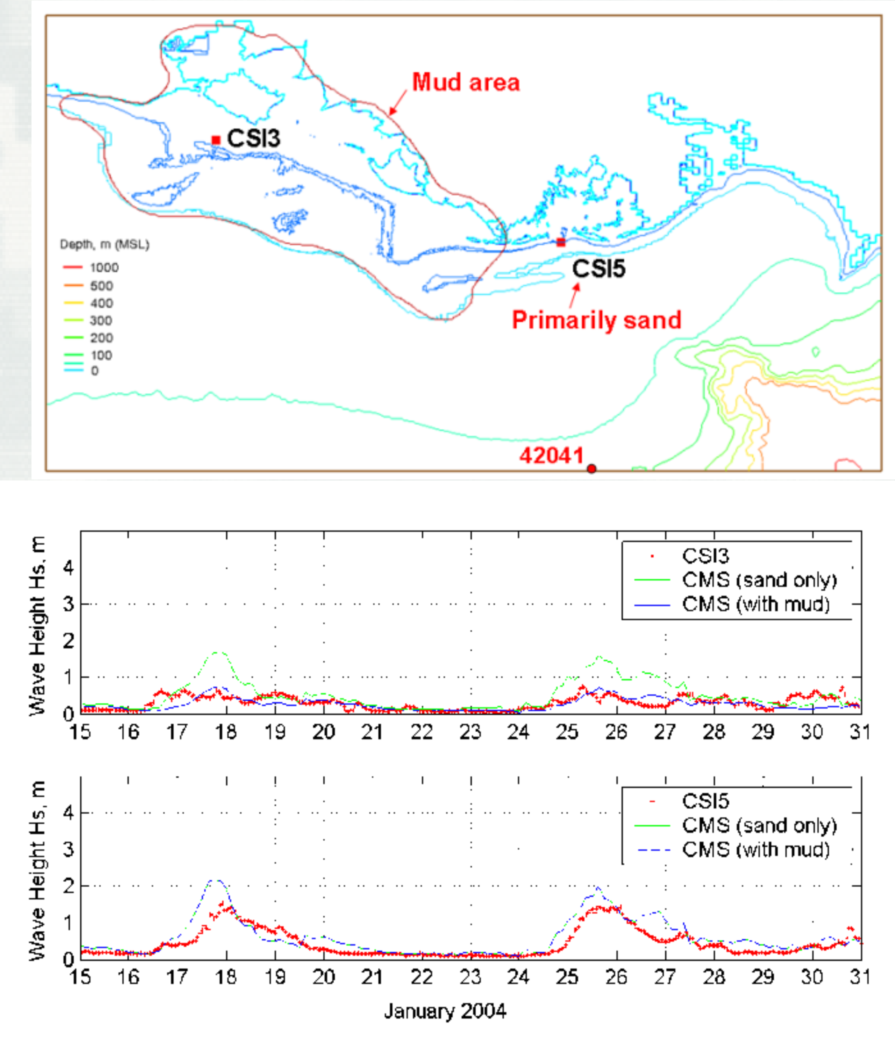
Coupled CMS-Flow and CMS-Wave

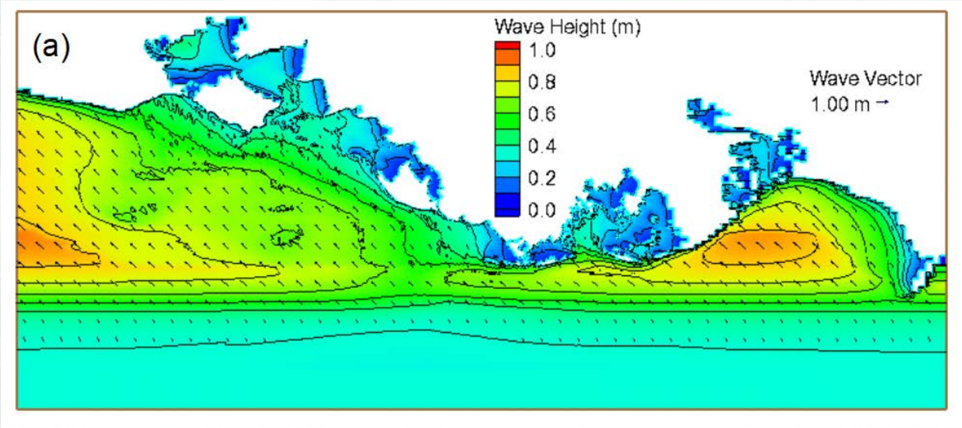
Calculated Wave Overtopping Rate

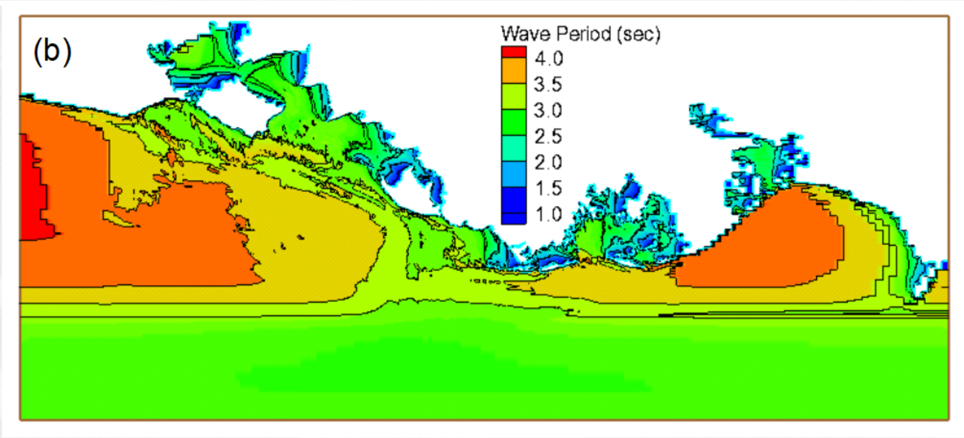
Case number	Surge level (m)	Wave height (m)	Wave peak period (sec)	Overtopping rate (m^2/sec)		
				Measured	CMS-Flow	CMS-Wave
R128	0.29			0.27	0.28*	
	0.29	0.82	6.1	0.38	0.38	0.39
R109	0.29			0.26	0.28*	
	0.29	2.48	13.7	0.70	0.85	0.92
R121	1.3			2.55	2.57*	
	1.3	2.30	6.1	2.67	2.93	2.76
R127	1.3			2.54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

* Calibration ☐ With wave overtopping

Louisiana Muddy Coast Simulation



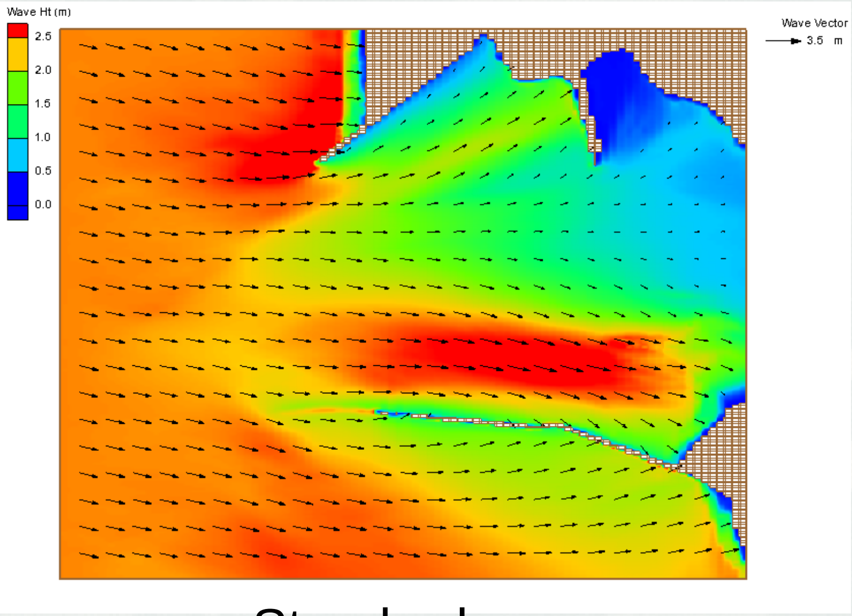




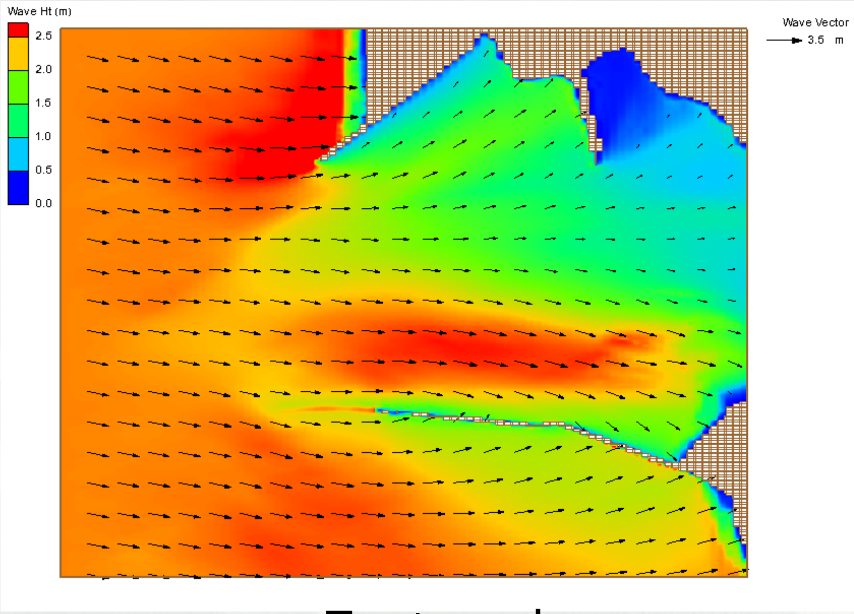
CMS-Wave Fast Mode

- Fast mode uses 5 to 7 directional bins with spectral calculations (Standard runs with 35 directional bins)

- Ideal for quick applications, prelim runs, time-pressing project



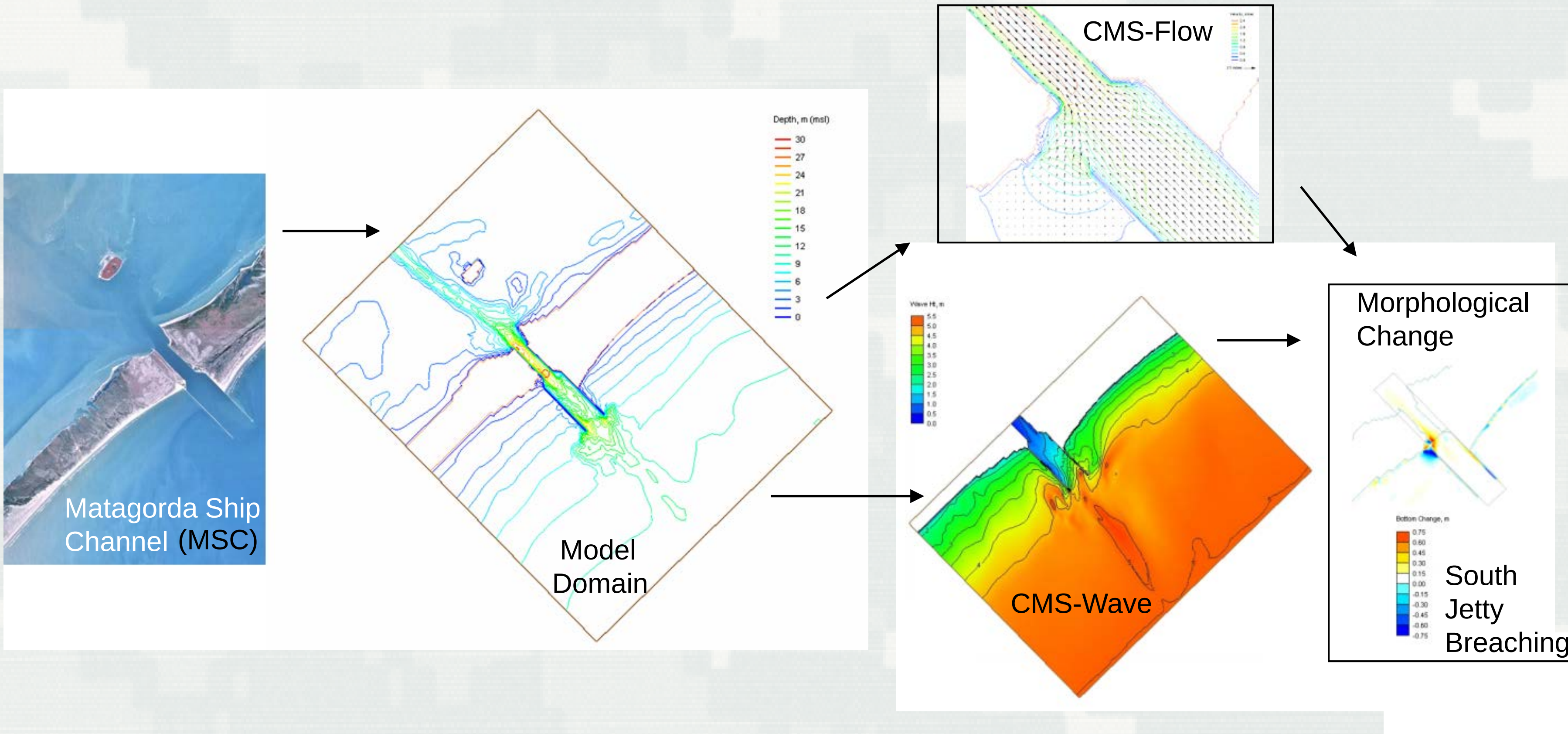
Standard run



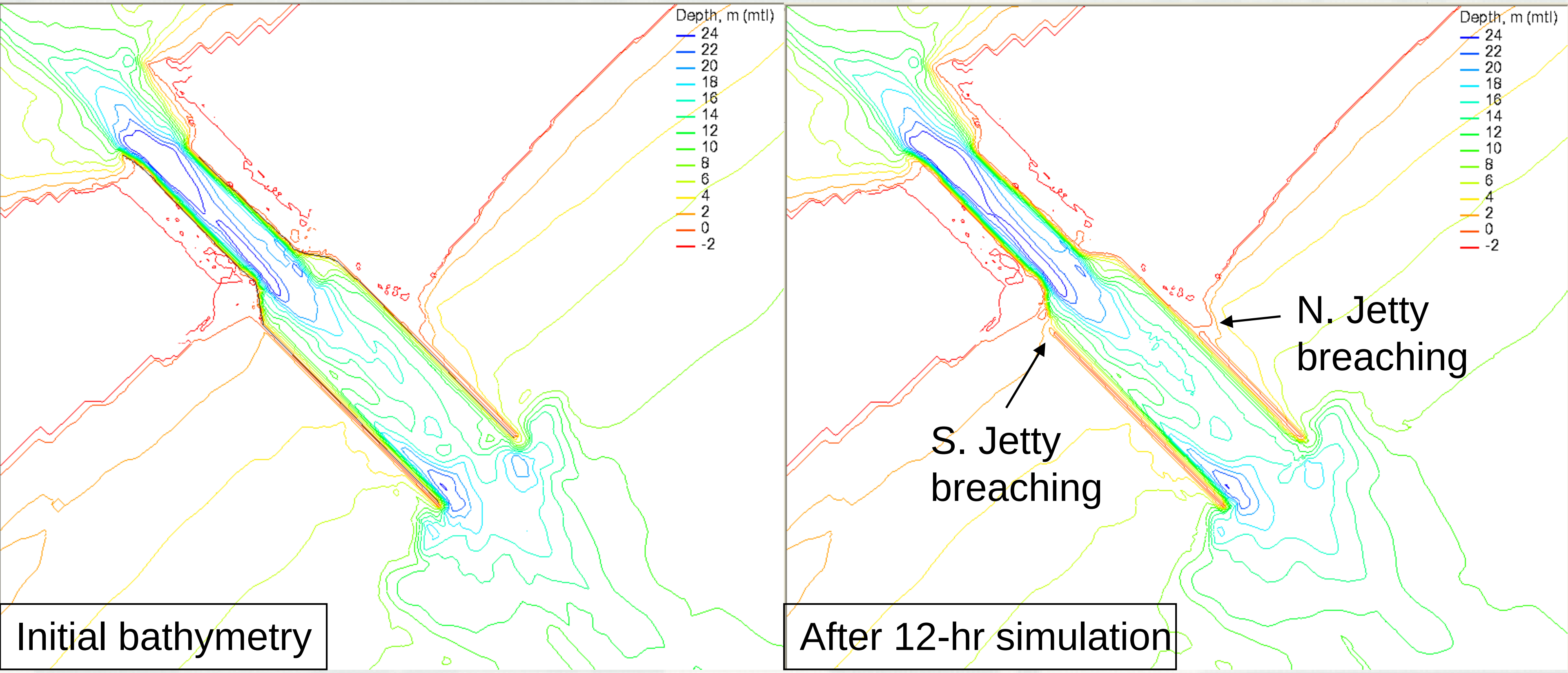
Fast mode

9. Coupling with CMS-Flow

Breaching at Jetty, Simulation at Matagorda Ship Channel, TX



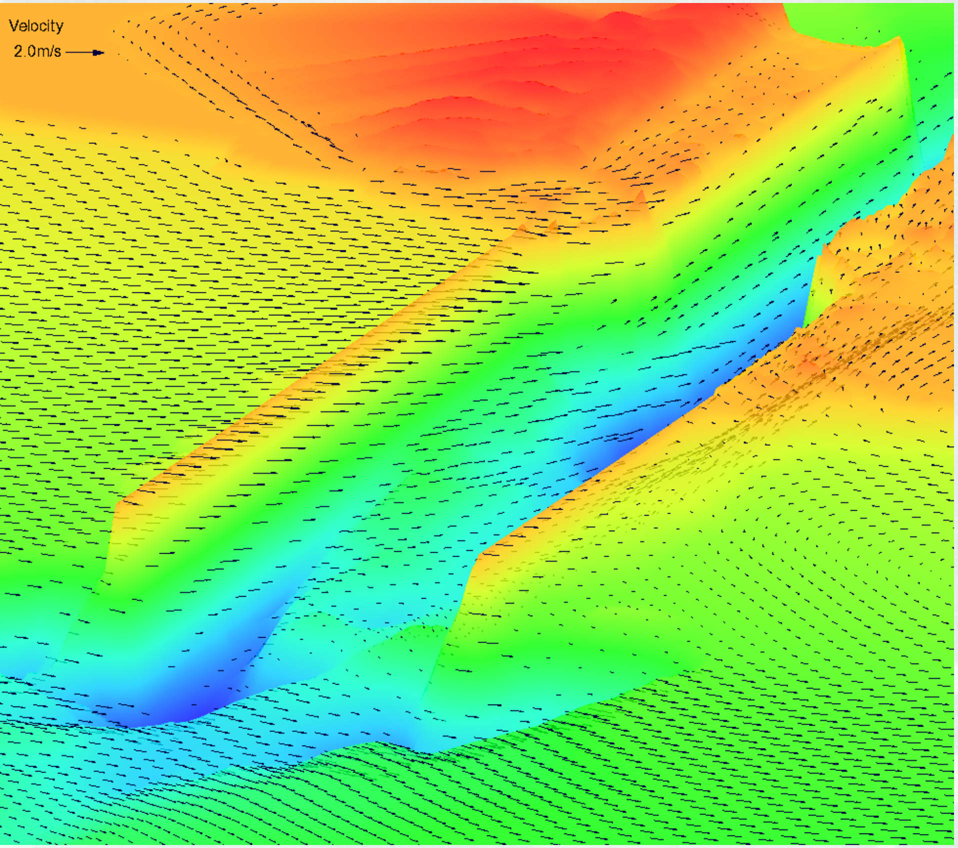
MSC Jetty Wave Run-up & Breaching
Cat 3 Hurricane (50-Yr Life-Cycle)



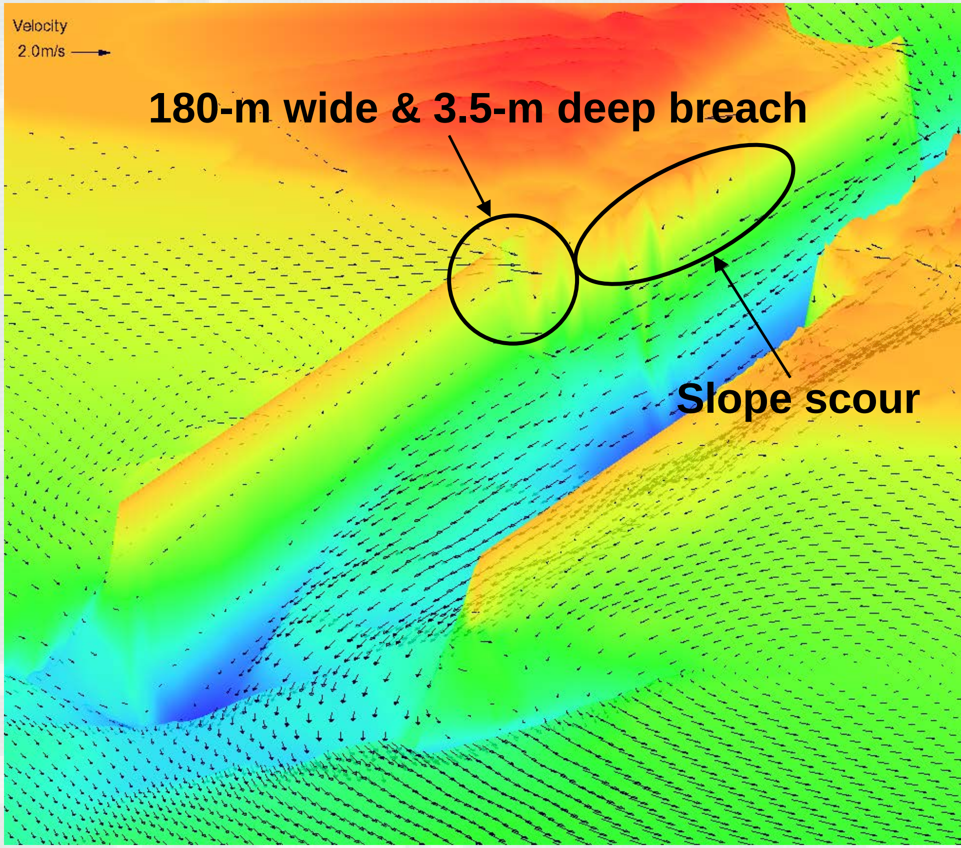
- Peak storm surge level reaches 3.5 m between Hrs 4 and 8
- Incident offshore wave is 7.6 m, 14.3 sec, from south

MSC Jetty Wave Run-up & Breaching
Cat 3 Hurricane (50-Yr Life-Cycle)

Storm surge over the initial bathymetry

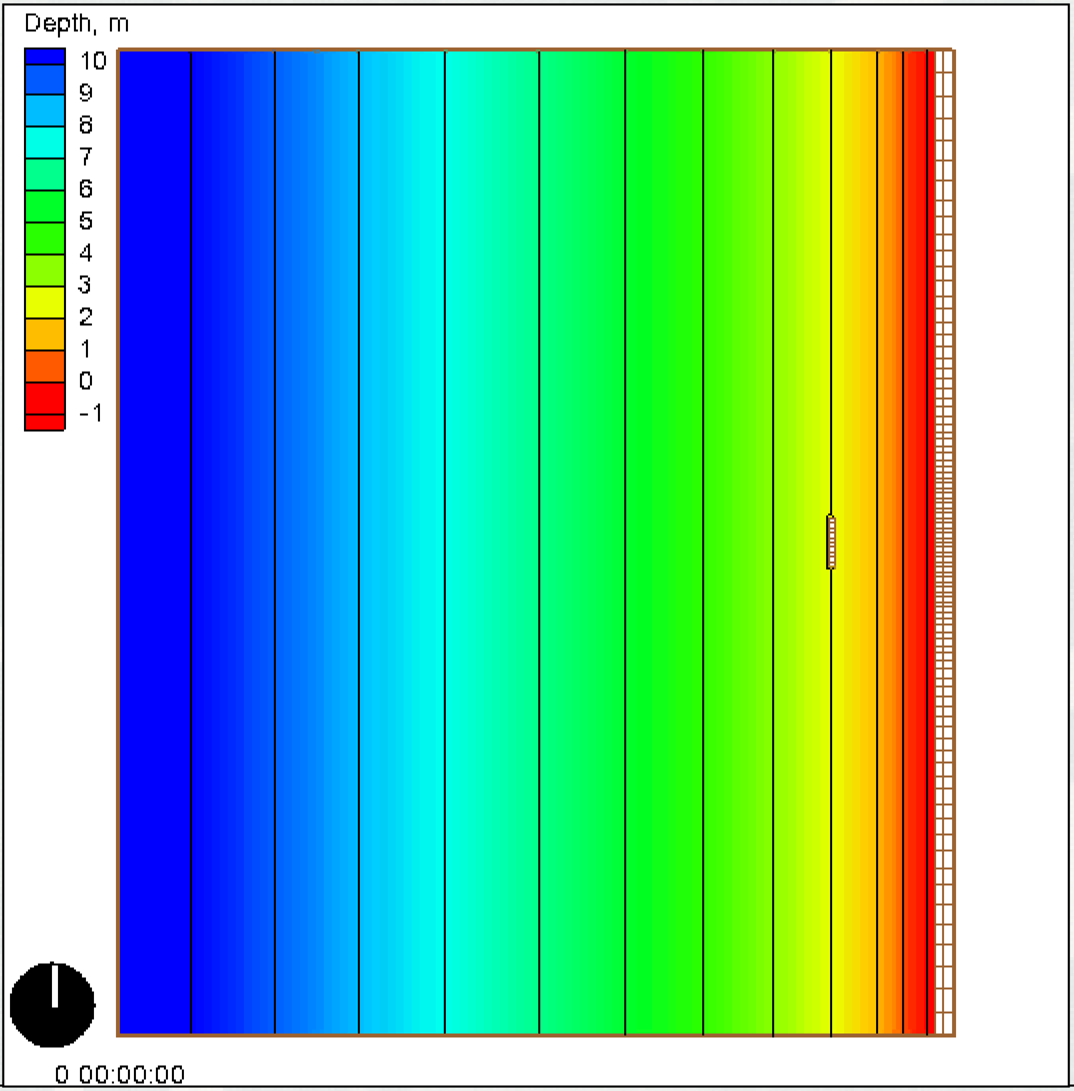


South Jetty breach in 12-hr simulation



- Peak storm surge level reaches 3.5 m between Hrs 4 and 8
- Incident offshore wave is 7.6 m, 14.3 sec, from south

Calculated 30-day Morphology Change Tombolo Development



CMS
Steering Interval = 4 hr

Grain Size = 0.18 mm

Hydro time step = 0.25 sec

Transport and morphology calc time step = 9 sec