

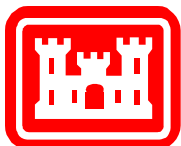
Introduction to CMS-Wave



Grand Isle, LA

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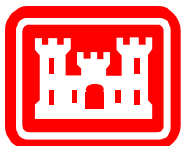


Outline



1. Overview of CMS-Wave
2. Capability
3. Governing Equations
4. Incident Wave Spectrum
5. Wave-Current Interaction & Radiation Stress Calculation
6. Diffraction and Reflection
7. Wind Input Function
8. Wave Dissipation
9. Variable Rectangular-Cell Grid
10. Wave Run-up & Other New Features
11. CMS Steering Operation
12. Future Improvement



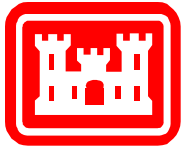


1. Overview of CMS-Wave



Objective: CMS-Wave is designed for accurate spectral transformation affecting operation and maintenance of coastal inlet navigation projects as well as the reliability assessment of shipping in inlets and harbors.

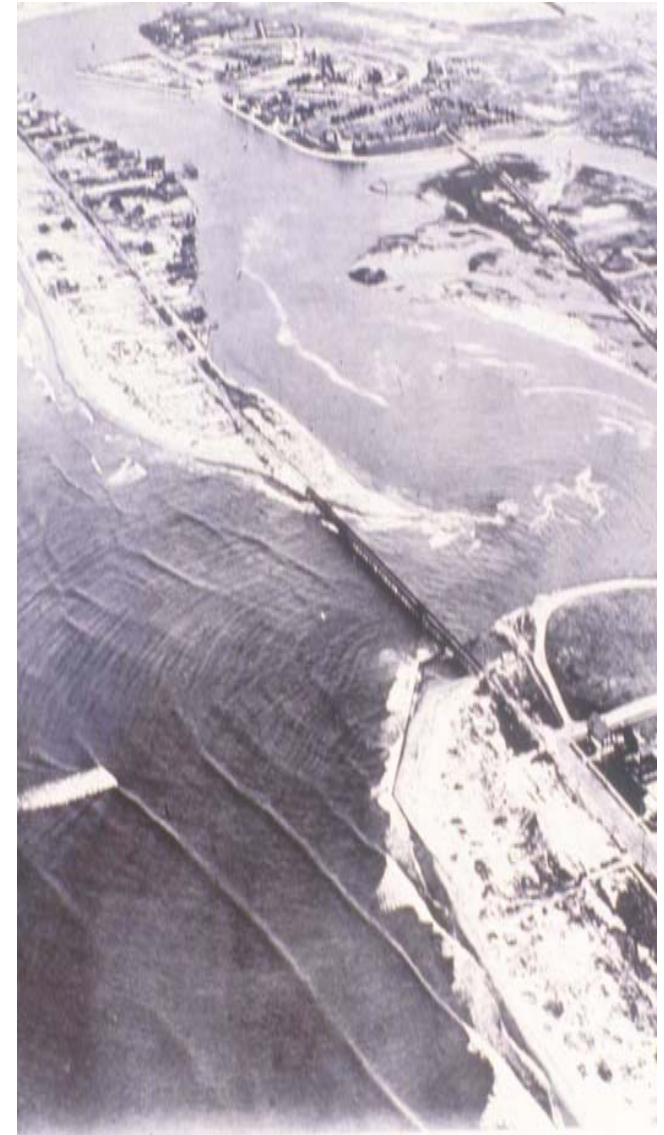
- Introduced to Coastal Modeling System (CMS) in 2005. Fully operational in Surface Modeling System (SMS)
- Based upon **WABED** (Wave-Action Balance Equation with Diffraction) developed by Mase (2001)
- Steady-state (time-dependent), half-plane, two-dimensional spectral transformation model using a finite-difference, forward-marching implicit scheme

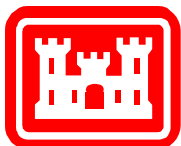


Overview of CMS-Wave (Continue)



- Mathematically consistent treatment of wave refraction; diffraction, reflection, & transmission at structures; wave run-up, wave setup, shoaling, bottom friction, wind input, and wave-current interaction
- Can be operated standalone or coupled to CMS-Flow, a circulation and sediment transport model, through the SMS interface



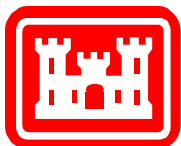


2. CMS-Wave Capability



CMS-Wave and STWAVE (half-plane) Comparison, 31 Mar 09

Capability	CMS-Wave	STWAVE	
Spectrum transformation	Directional	Directional	
Refraction & shoaling	Represented	Represented	
Depth-limited wave breaking	Choice among four formulas	One formula	
Roller	Represented	None	
Structures {	Diffraction	Theory	Smoothing
	Reflection	Represented	None
	Transmission	Formulas	None
	Run-up and setup	Theory	None
Wave-current interaction	Theory	Theory	
Wave-wave interaction	Theory	Semi-empirical	
Wind input	Theory	Semi-empirical	
White capping	Theory	Semi-empirical	
Bottom friction	Theory	Theory	



Sample CMS-Wave SMS 10.1 Interface



SMS 10.1 Development - [untitled.sms]

File Edit Display Data CMS-Wave Web Window Help

Y: Z: S: Vx: Vy:

CMS-Wave Model Control

Grid Definition

X origin: 0.0000 m Cell size: 50.000000 m
Y origin: 0.0000 m Columns: 10
Angle: 0.0000 deg Rows: 10

Settings

Allow wetting and drying

Forward reflection
• Spatially constant: 0.5
• Spatially varied: none selected

Backward reflection
• Spatially constant: 0.3
• Spatially varied: none selected

Bed friction
• Spatially constant Cf: 0.005
• Spatially varied Cf: none selected
• Spatially constant n: 0.005
• Spatially varied n: none selected

Diffraction intensity: 4.0

Currents
• Single timestep: none selected
• All timesteps: none selected

Wave Source

Spectra
 Wind
 Spectra and wind
 Simplified formulation

Parameters...

Output

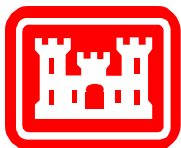
Radiation stresses

Breaking
Function: Extended Goda

Indices
 Energy dissipation

Help... OK Cancel

Cf = Darcy-Weisbach friction coefficient
n = Manning friction coefficient



3. Governing Equation

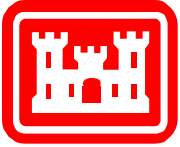


Wave-Action Balance Equation with Diffraction

$$\frac{\partial[(c_{gx} + u)A]}{\partial x} + \frac{\partial[(c_{gy} + v)A]}{\partial y} + \frac{\partial[c_{g\theta}A]}{\partial \theta} = \frac{\kappa}{2\sigma} \{ (cc_g \cos^2 \theta A_y)_y - \frac{1}{2} cc_g \cos^2 \theta A_{yy} \} + S_{in} + S_{dp}$$

where $A = E / \sigma$ is the wave-action spectrum
and $E = E(\sigma, \theta)$ is the wave directional spectrum.

Note: x is normal to the offshore boundary, y is parallel to the offshore boundary



4. Incident Wave Spectrum



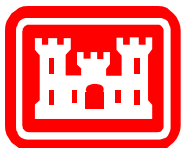
A single input spectrum applied along the seaward boundary, e.g., a JONSWAP type:



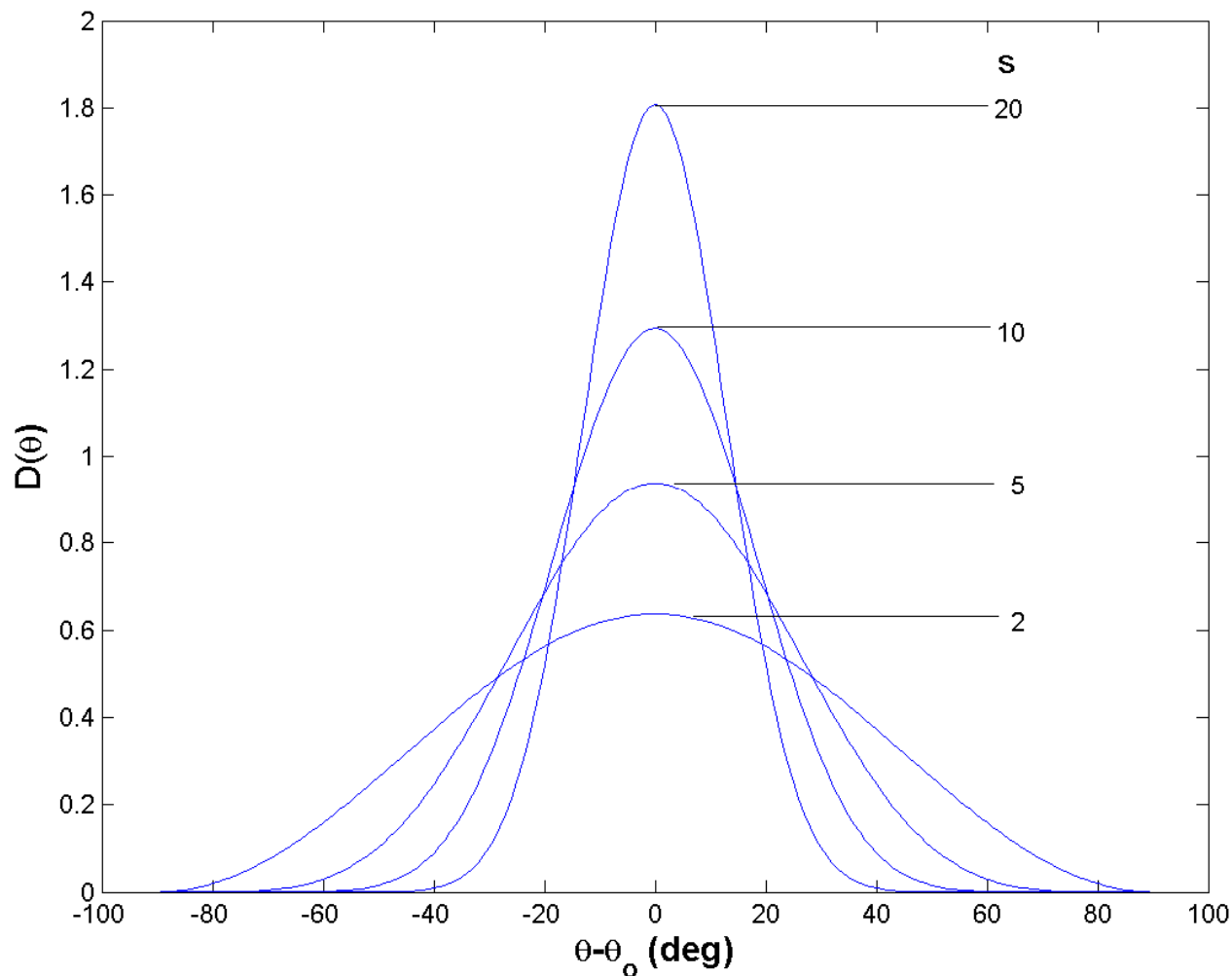
$$E = \frac{\alpha g^2}{\sigma^5} \exp(-0.74 \frac{\sigma_0^4}{\sigma^4}) \gamma^a D(\sigma, \theta)$$

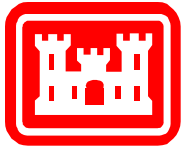
where $D(\theta) = \frac{2^s}{\pi} \frac{\Gamma(s/2 + 1)}{\Gamma(s + 1)} \cos^s(\theta - \theta_o)$ for $|\theta - \theta_o| < \pi/2$

and s is the directional spreading parameter.



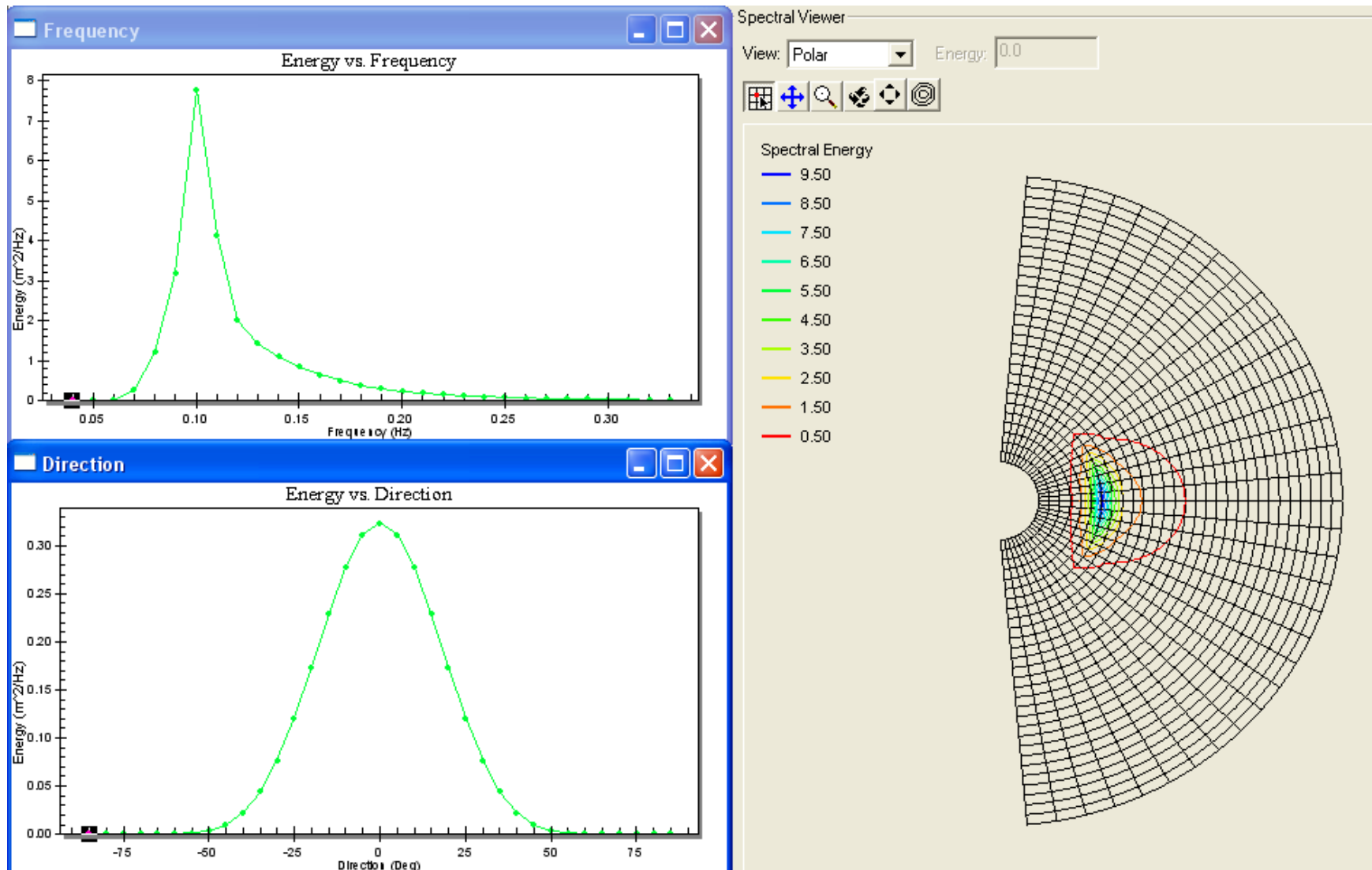
Idealized Directional Distribution

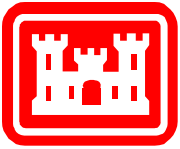




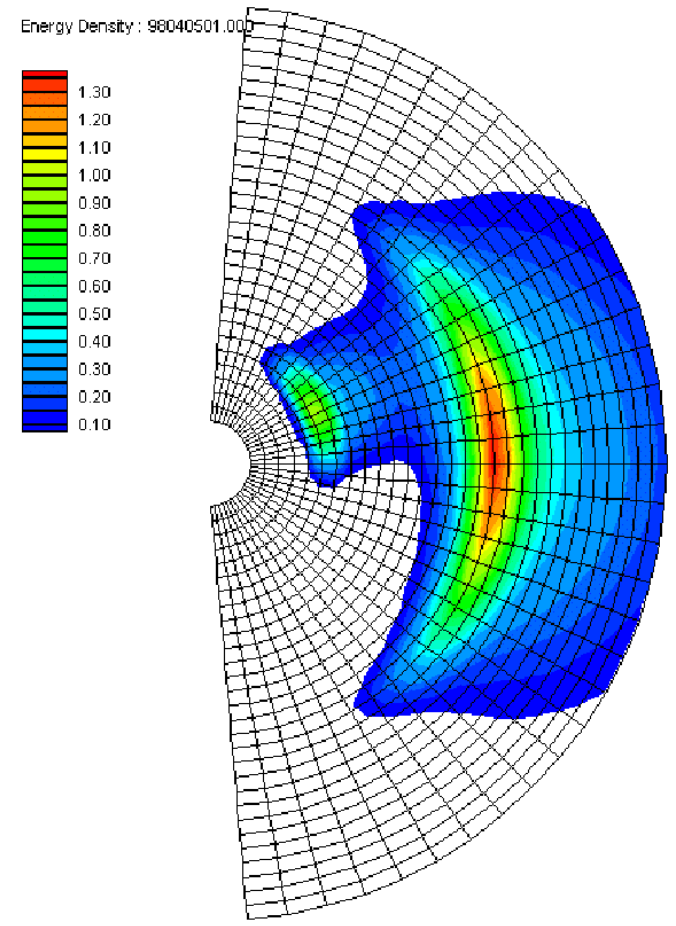
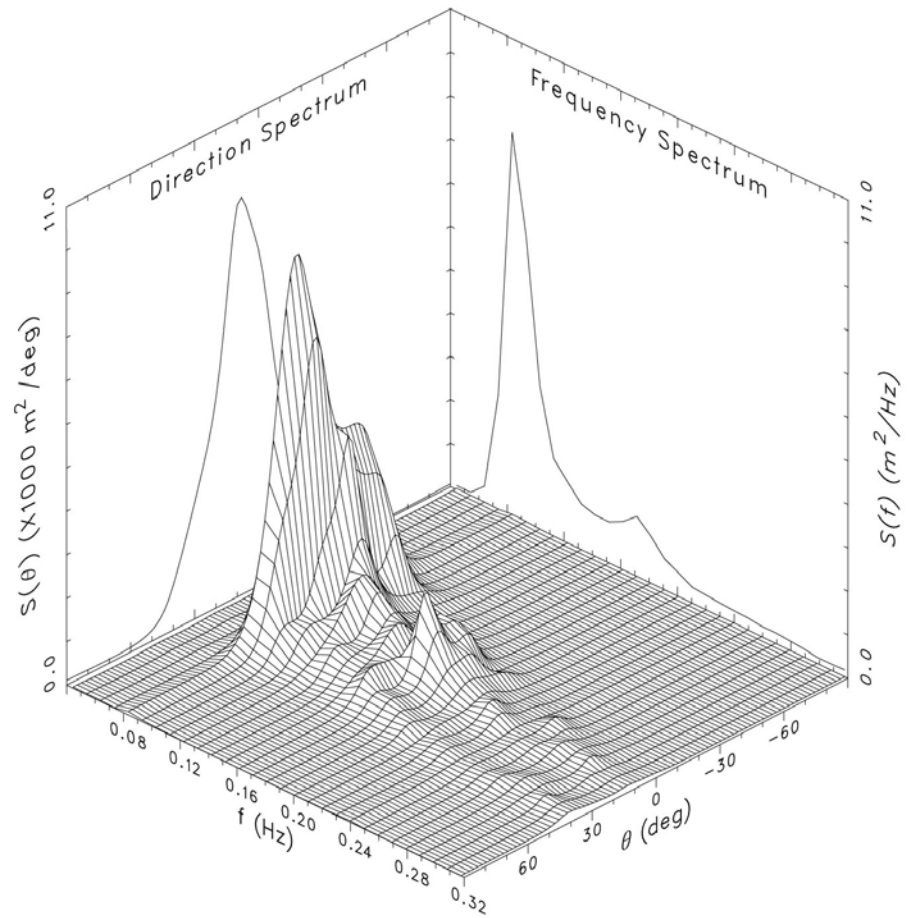
JONSWAP Spectrum

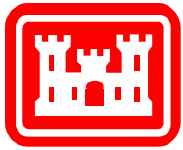
$H = 2\text{ m}$, $T = 10\text{ sec}$, $S = 10$





Input Measured Spectrum





5. Wave-Current Interaction & Radiation Stress Calculation



- Solving wave number k in dispersion equation with a current:

$$\sigma = \sqrt{gk \tanh kh} + ku \cos \theta + kv \sin \theta$$

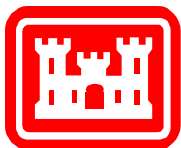
- Computing wave radiation stresses:

$$S_{xx} = E \left[n(\cos^2 \theta + 1) - \frac{1}{2} \right],$$

$$S_{yy} = E \left[n(\sin^2 \theta + 1) - \frac{1}{2} \right],$$

$$S_{xy} = E \frac{n}{2} \sin 2\theta, \quad \text{where } n = \frac{1}{2} + \frac{kh}{\sinh 2kh}$$





6. Diffraction and Reflection

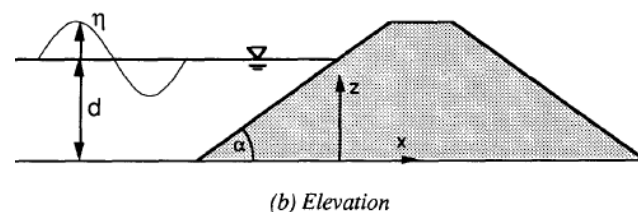
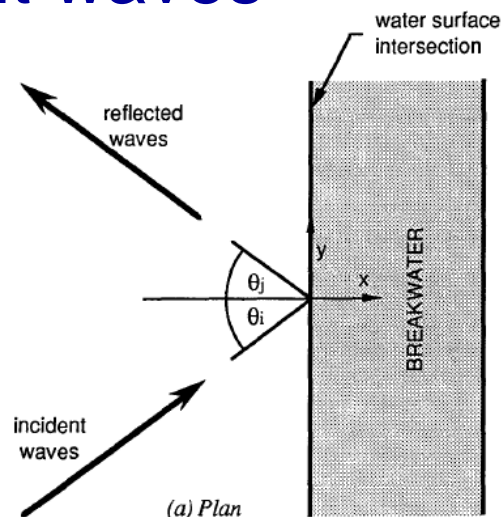


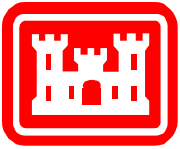
- Diffraction included in the governing equation

$$\frac{\partial[(c_{gx} + u)A]}{\partial x} + \frac{\partial[(c_{gy} + v)A]}{\partial y} + \frac{\partial[c_{g\theta}A]}{\partial \theta} = \frac{\kappa}{2\sigma} \left\{ (cc_g \cos^2 \theta A_y)_y - \frac{1}{2} cc_g \cos^2 \theta A_{yy} \right\} + S_{in} + S_{dp}$$

↙ Diffraction intensity factor

- Reflection computed as the mirror image of incident waves

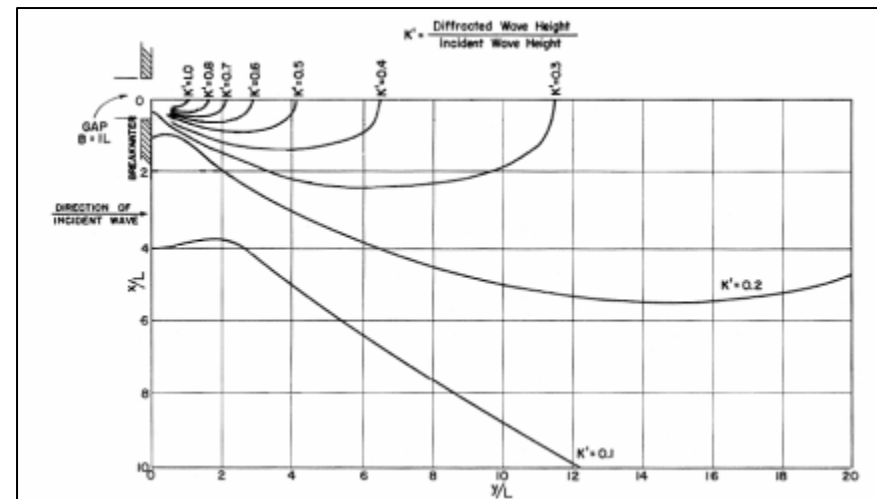
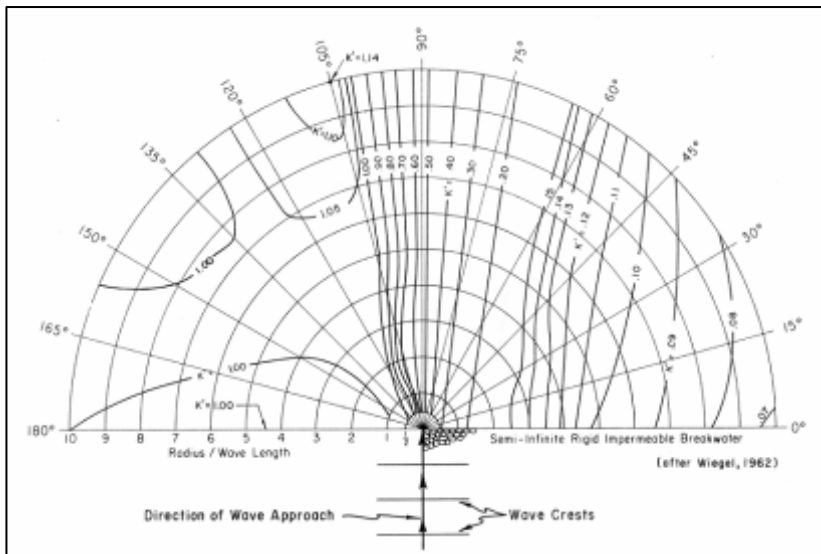
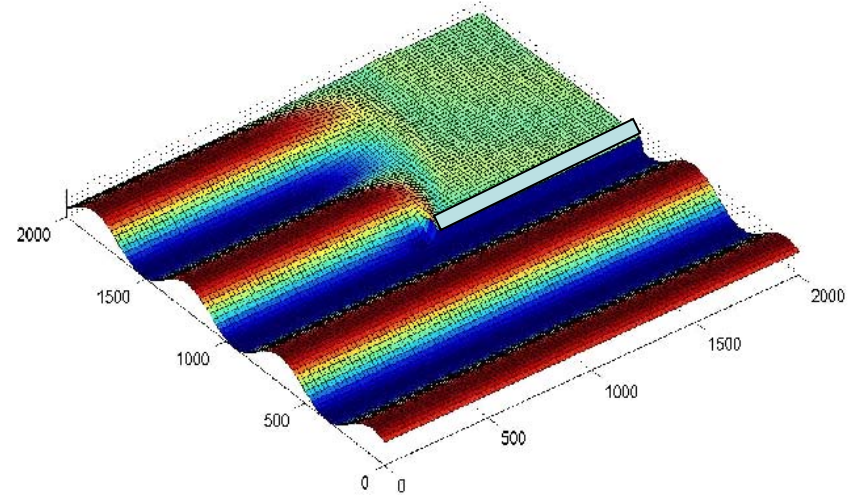


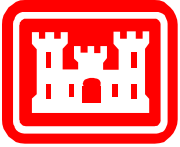


Jetty and Breakwater Wave Diffraction



Humboldt Bay, CA





7. Wind Input Function

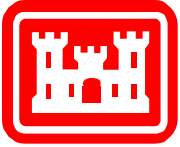


$$S_{in} = \frac{a_1 \sigma}{g} F_1(\bar{w} - \bar{c}_g) F_2\left(\frac{c_g}{w}\right) E_{PM}^*(\sigma) \Phi(\theta) + \frac{a_2 \sigma}{g} F_1(\bar{w} - \bar{c}_g) F_2\left(\frac{c_g}{w}\right) F_3\left(\frac{c_g}{w}\right) E$$

where $F_1(\bar{w} - \bar{c}_g) = \begin{cases} w \cos(\theta_{wind} - \theta) - c_g(\sigma, \theta), & \text{if } c_g < w \\ 0, & c_g \geq w \end{cases}$

$$F_2\left(\frac{c_g}{w}\right) = \begin{cases} \left(\frac{c_g}{w}\right)^{1.2}, & \text{if } c_g < w \\ 1, & c_g \geq w \end{cases} \quad \text{and} \quad F_3\left(\frac{c_g}{w}\right) = \begin{cases} \log_{10}\left[\left(\frac{c_g}{w}\right)^{-1}\right], & \text{if } c_g < w \\ 0, & c_g \geq w \end{cases}$$

$$E_{PM}^*(\sigma) = \frac{g^2}{\sigma^5} \exp\left(-0.74 \frac{\sigma_0^4}{\sigma^4}\right), \quad \sigma_0 = g/w, \quad \text{and} \quad \Phi(\theta) = \frac{8}{3\pi} \cos^4(\theta - \theta_{wind})$$



8. Wave Dissipation



- White capping

$$S_{dp} = -C_{ds} (ak)^{1.5} \frac{\sigma}{g} c_g(\sigma, \theta) F_4(\vec{w}, \vec{u}_{current}, \vec{c}_g) F_5(kh) E$$



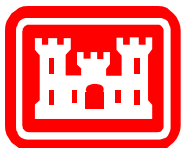
where $F_4(\vec{w}, \vec{u}_{current}, \vec{c}_g) = \left| \frac{u + w}{\vec{w} + \vec{u}_{current} + \vec{c}_g} \right|$, $F_5(kh) = \frac{1}{\tanh kh}$

and $a = \sqrt{E(\sigma, \theta) d\sigma d\theta}$ is wavelet calculated for each grid cell

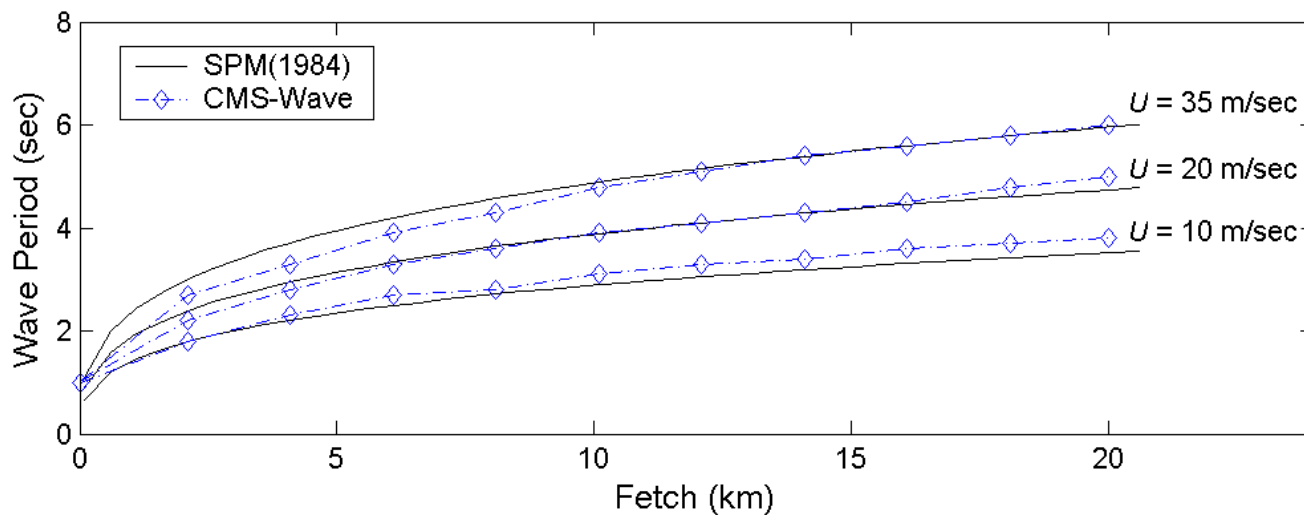
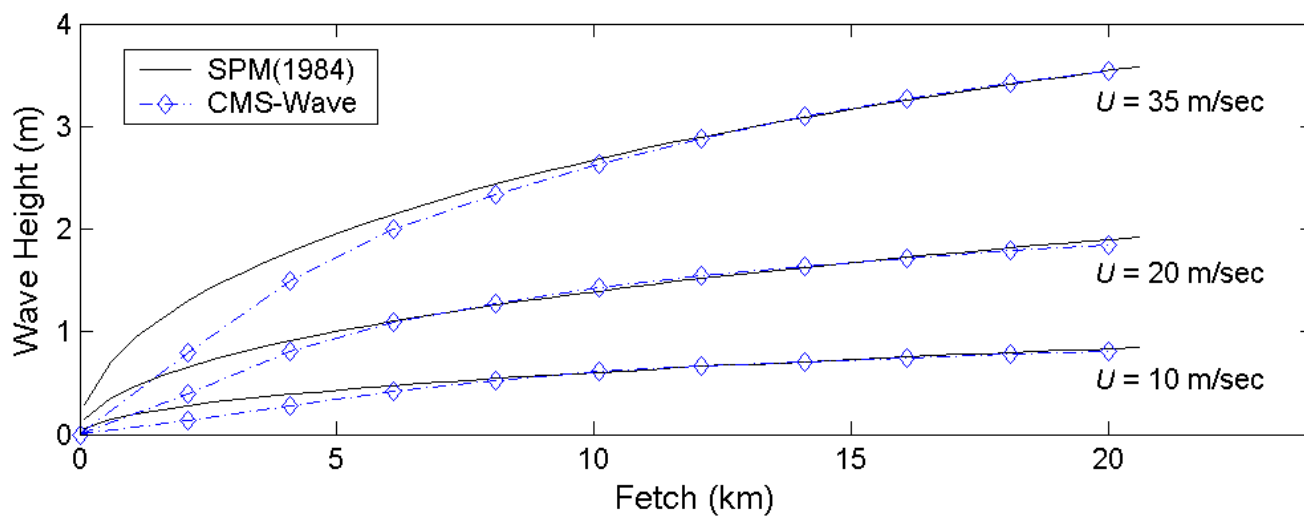
- Depth-limited Breaking

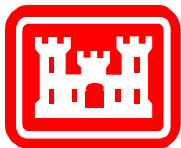
$$S_{dp} = -\varepsilon_b A$$

Can select from formulas of Goda (default), Miche, Battjes and Janssen, Chawla and Kirby

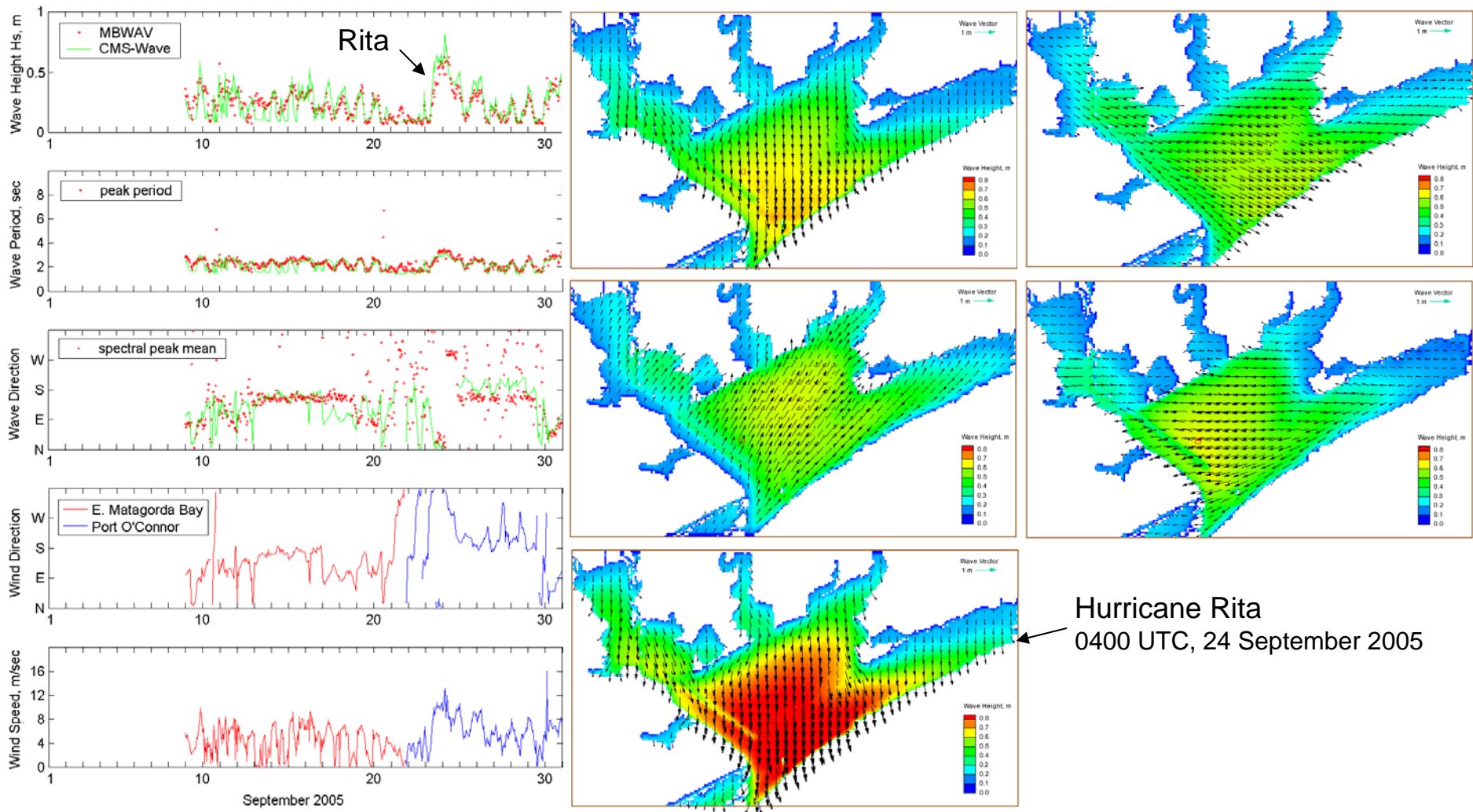


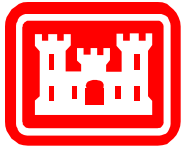
Fetch-limited Wind-wave Growth



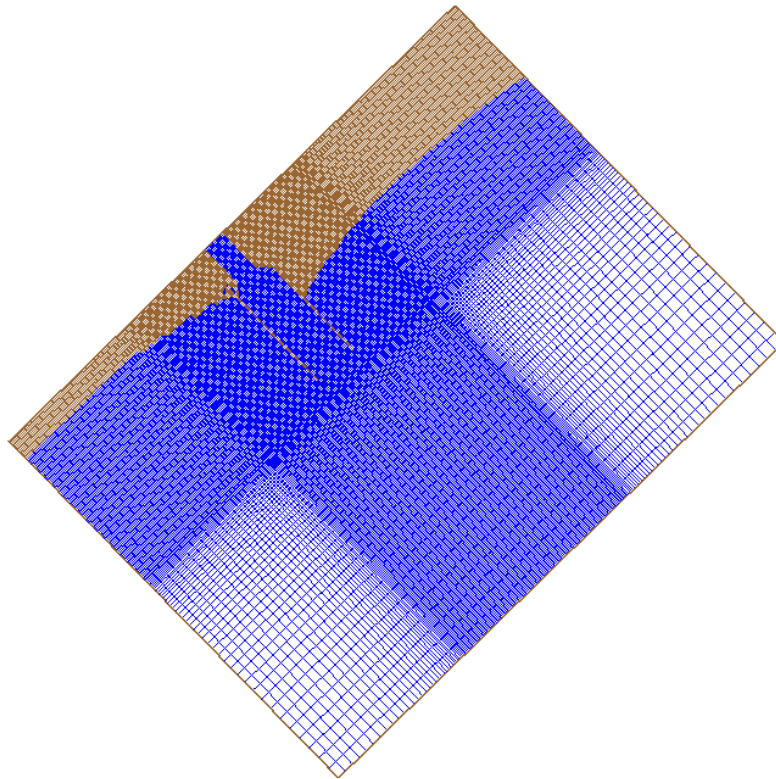


Wave Generation with Arbitrary Wind Direction Matagorda Bay, TX

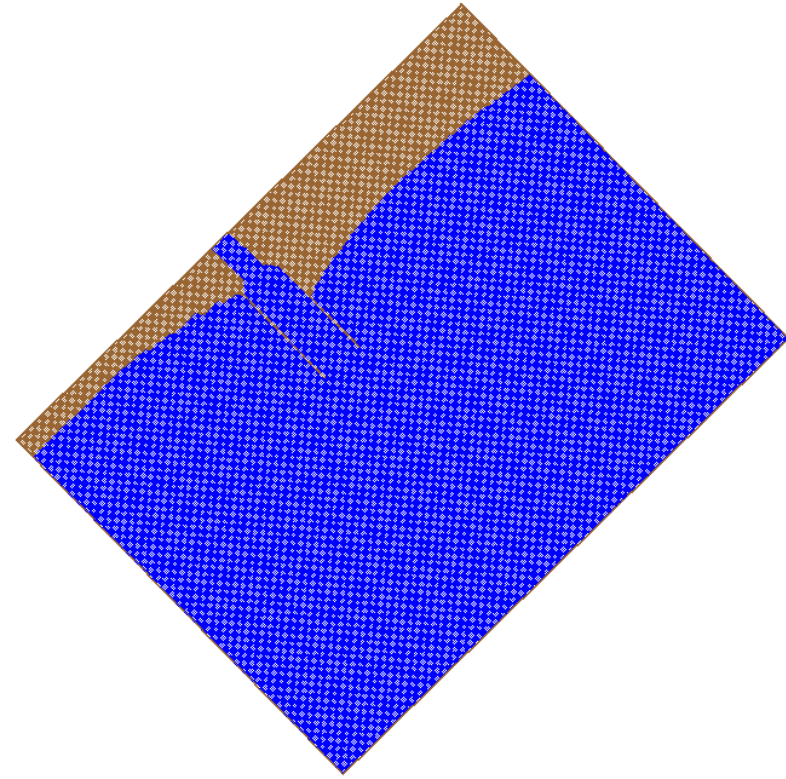




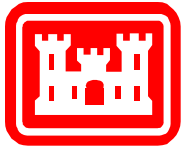
9. Variable Rectangular-Cell Grid (saves time)



Variable-rectangular cells
Total 223 x 172 cells



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

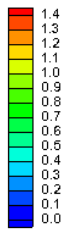


CMS-Wave Simulation

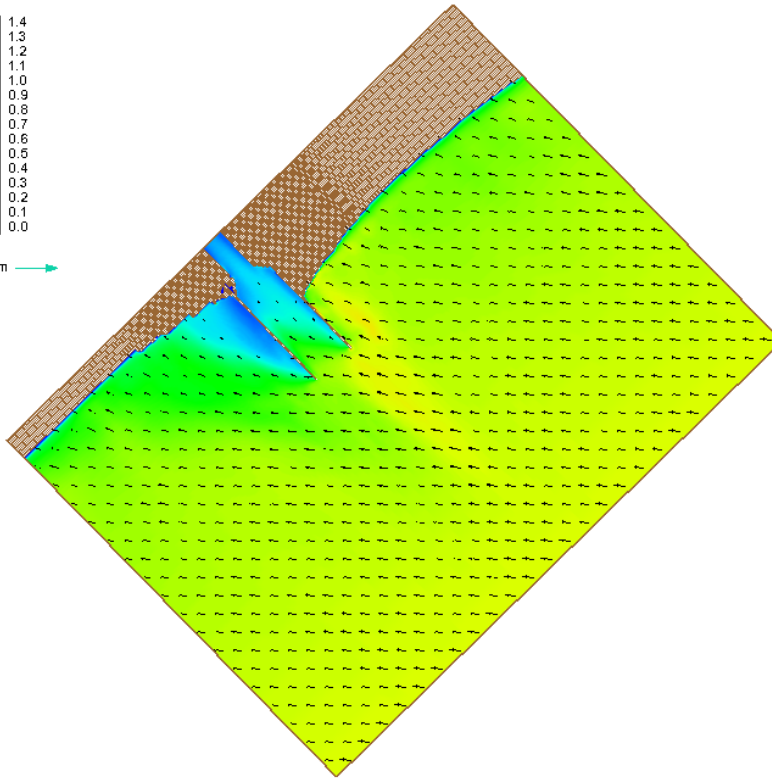
$H_s = 3\text{ m}$, $T_p = 6\text{ sec}$, $\text{Surge} = 2.9\text{ m}$



Wave Ht, m

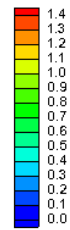


1.4 m →

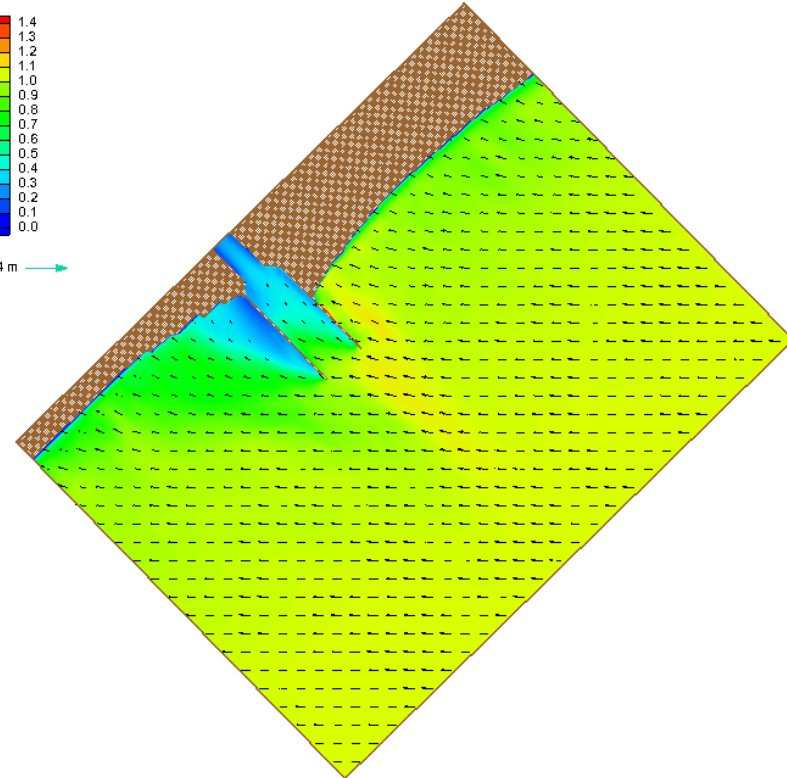


Variable-rectangular cells
Total 223 x 172 cells

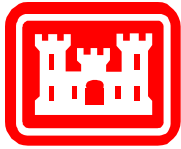
Wave Ht, m



1.4 m →



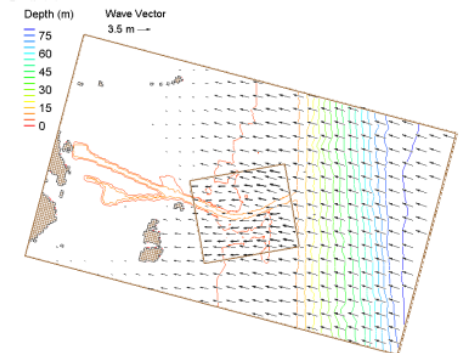
Square (20 m x 20 m) cells
Total 316 x 426 cells

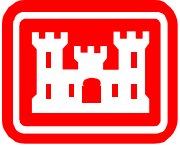


10. Wave Run-up & Other New Features

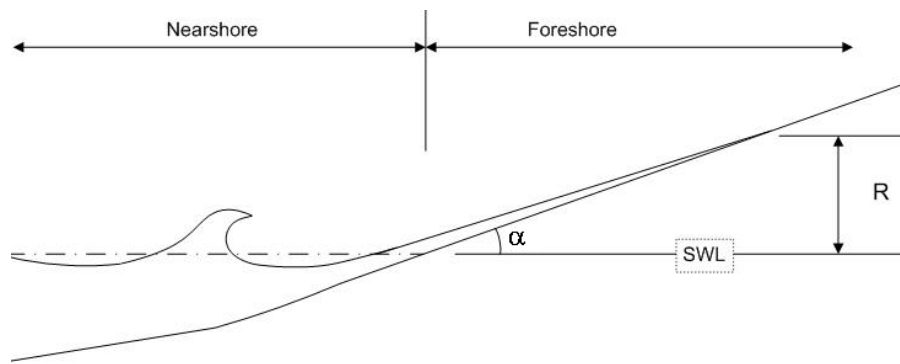


- A. Wave Run-up Calculation
- B. Four different wave-breaking formulas
- C. Specify feature cells for wave run-up, setup wave transmission & overtopping structures.
- D. Muddy coast
- E. Grid nesting capability
- F. “Fast mode” run capability



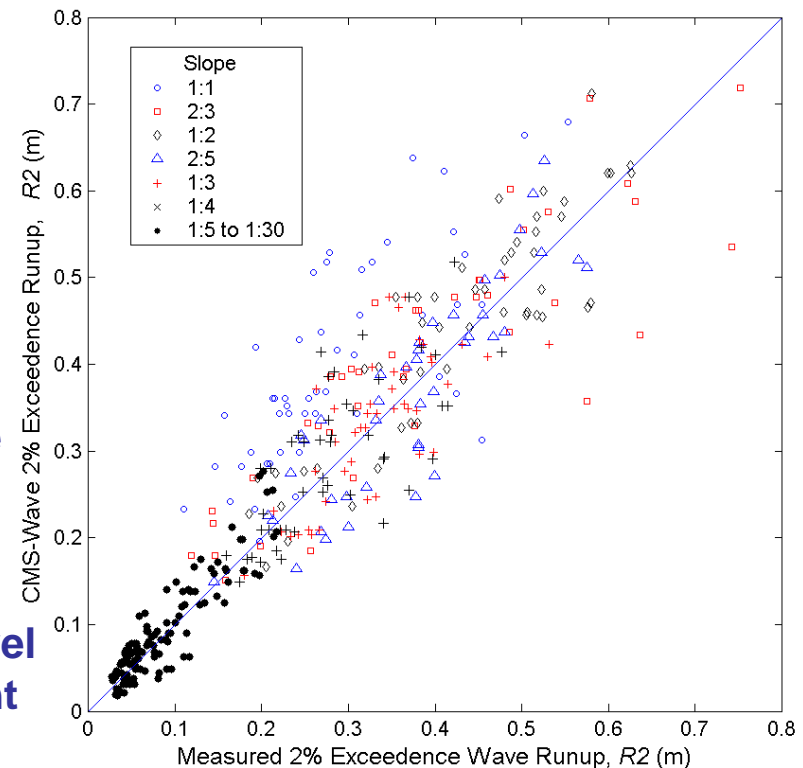


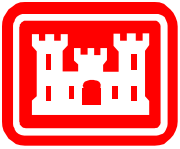
A. Wave Run-up Calculation



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

- **Mean run-up, R_M : average run-up of all waves**
- **Two-percent run-up, R_2 : the vertical up-rush level exceeded by 2-percent of the larger run-up height**





Wave Run-up Calculation



Total run-up $R2 = \text{wave setup} + 2\% \text{ exceedance of swash level}$

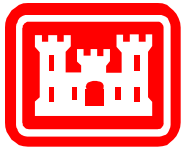
$$\text{Wave setup: } \frac{\partial \eta}{\partial x} = -\frac{1}{\rho gh} \left(\frac{\partial S_{xx}}{\partial x} + \frac{\partial S_{xy}}{\partial y} \right), \quad \frac{\partial \eta}{\partial y} = -\frac{1}{\rho gh} \left(\frac{\partial S_{xy}}{\partial x} + \frac{\partial S_{yy}}{\partial y} \right)$$

$$\text{Max setup (Guza and Thornton, 1981): } \eta_{\max} = 0.17 H_0$$

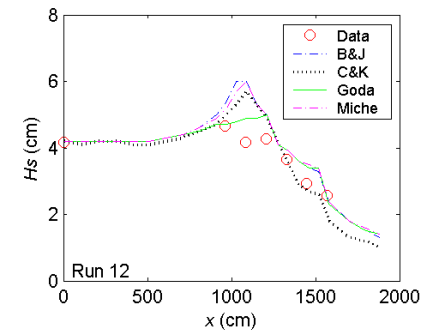
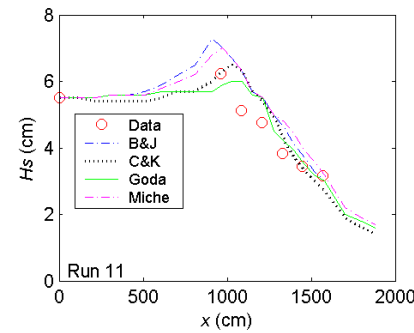
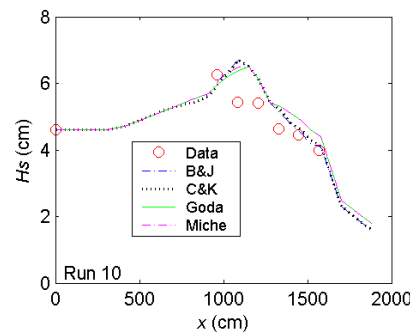
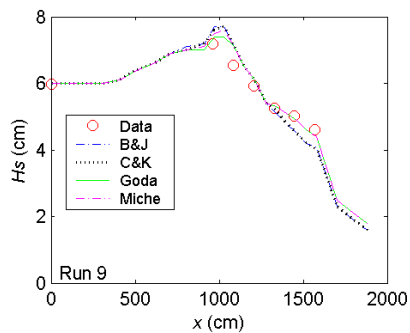
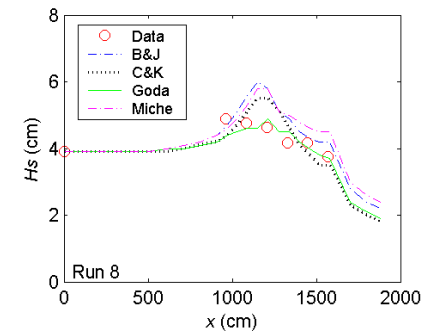
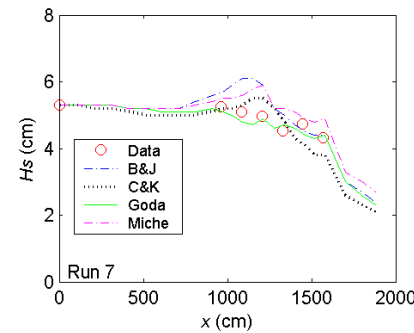
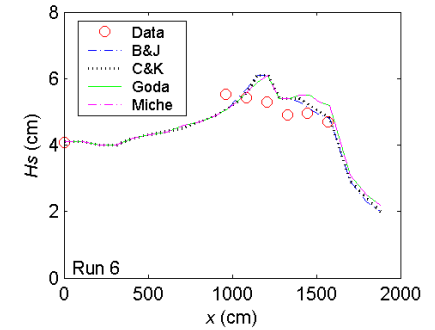
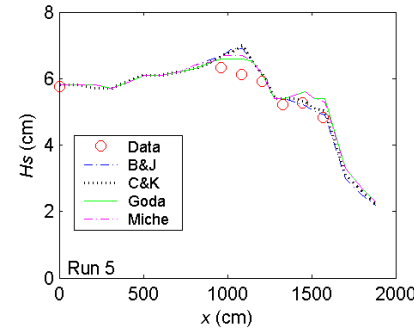
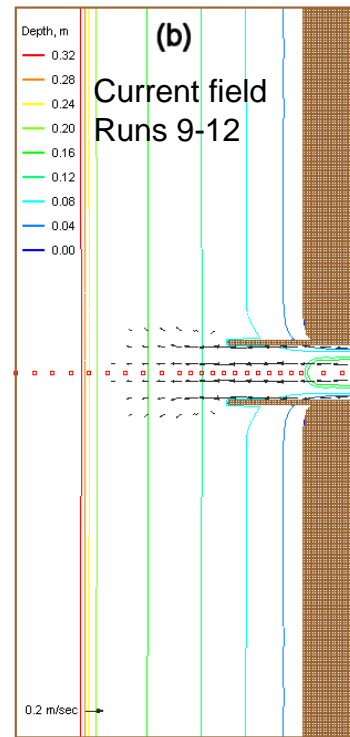
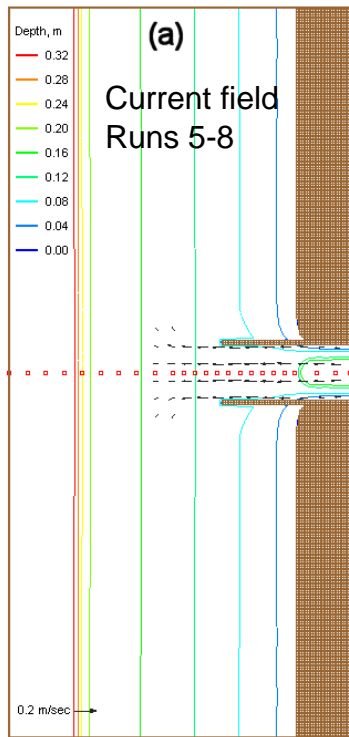
$$\text{Total runup } R2 \text{ (2\% exceedance)} = 2 \eta_{\max} \quad (\text{Komar, 1998})$$

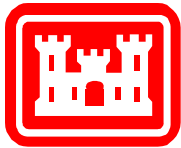
$$\text{Max water level} = \max \left(\eta + H_s / 2, R2 \right)$$

* Wave setup and max water level field are saved in setup.wav



B. Four Different Wave-Breaking Formulas

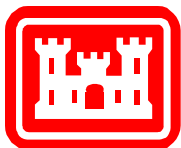




C. Specify Feature Cells in SMS10.1



The screenshot displays the SMS 10.1 Development interface. The main window shows a bathymetry map with depth contours and a grid of cells. A red arrow points from the 'Assign Cell Attributes...' option in the left-hand menu to a specific cell on the map. A 'Cell Attributes' dialog box is open, showing the 'Structure' radio button selected and a dropdown menu with 'Wave runup' chosen. The dialog also includes options for 'Use', 'Elev', 'Monitoring station', 'Nesting output', and 'Genesis monitoring station'. The status bar at the bottom indicates 'Cell info: 1 selected; Area = 248.048 m²; Volume = 10.5939 m³; id = 21051; i = 186; j = 108; di = 4.97212; dj = 49.8877.'

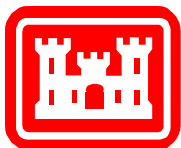


Floating Breakwater



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



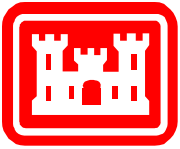
Vertical wall breakwater (Kondo and Sato, 1985):

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

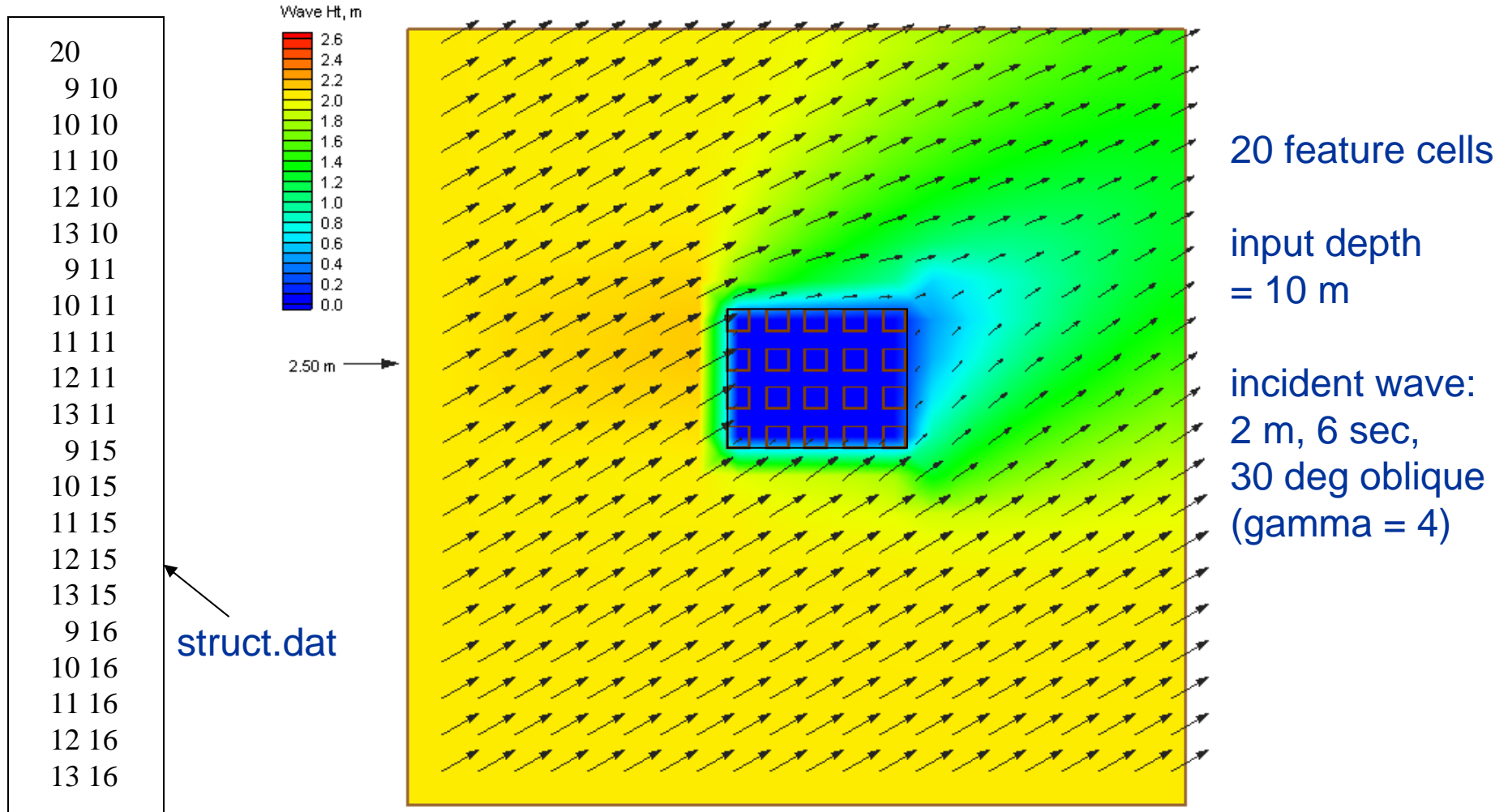
Composite or rubble-mound breakwater:

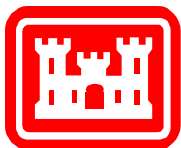
$$K_t = 0.3 \left(1.1 - \frac{h_c}{H_s}\right), \quad \text{for } 0 \leq \frac{h_c}{H_s} \leq 0.75$$

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

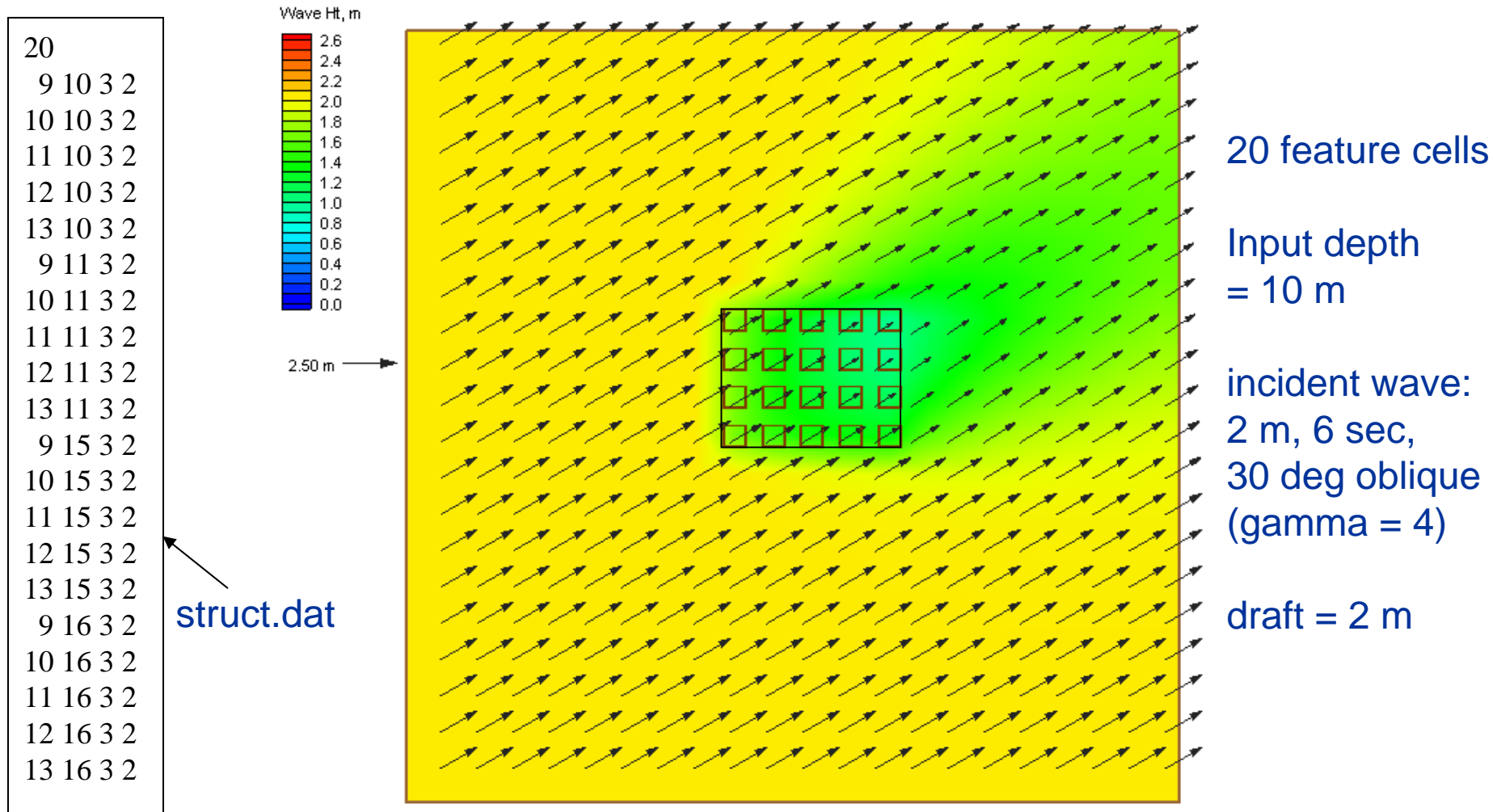


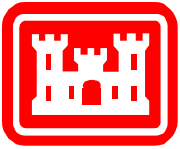
Idealized Island Example





Idealized Floating Breakwater



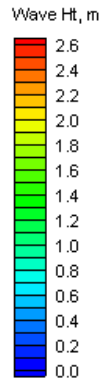


Idealized Platform

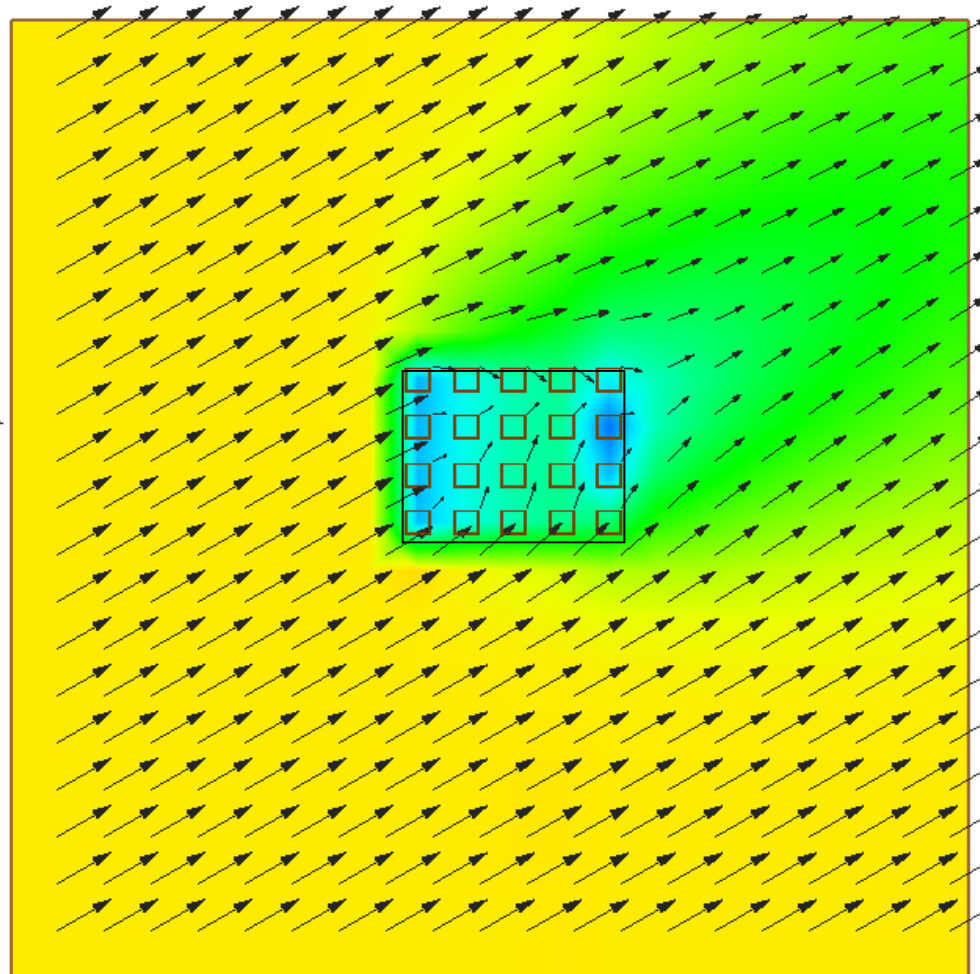


```
20
 9 10 4 1
10 10 4 1
11 10 4 1
12 10 4 1
13 10 4 1
 9 11 4 1
10 11 4 1
11 11 4 1
12 11 4 1
13 11 4 1
 9 15 4 1
10 15 4 1
11 15 4 1
12 15 4 1
13 15 4 1
 9 16 4 1
10 16 4 1
11 16 4 1
12 16 4 1
13 16 4 1
```

struct.dat



2.50 m →

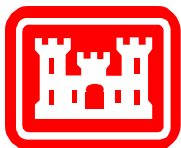


20 feature cells

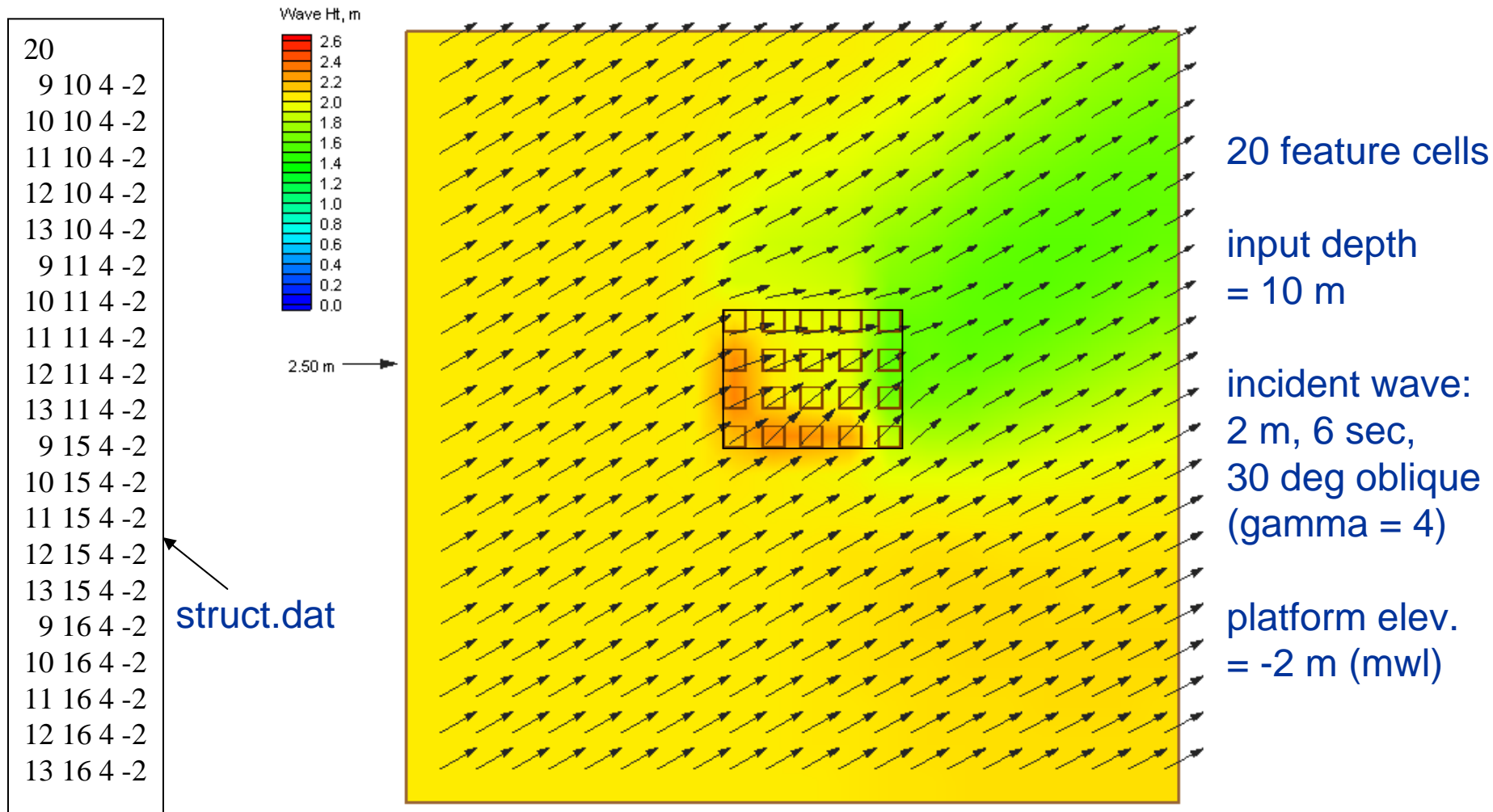
input depth
= 10 m

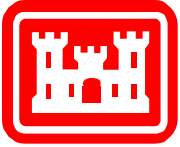
incident wave:
2 m, 6 sec,
30 deg oblique
(gamma = 4)

platform elev.
= 1 m (mwl)



Submerged Platform





D. Muddy Coast



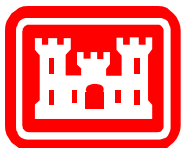
Wave dissipation by damping (Lamb, 1932):

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

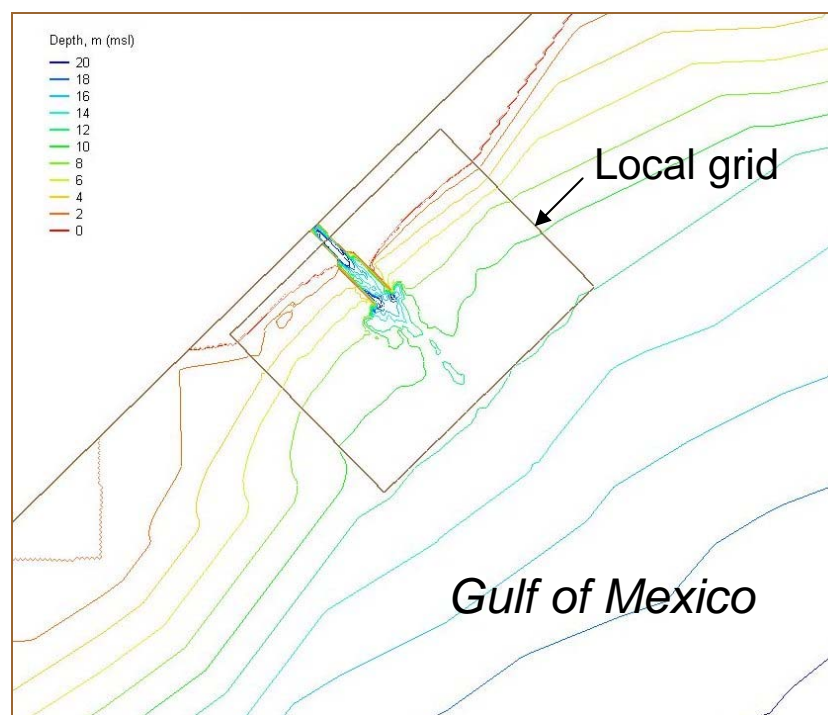
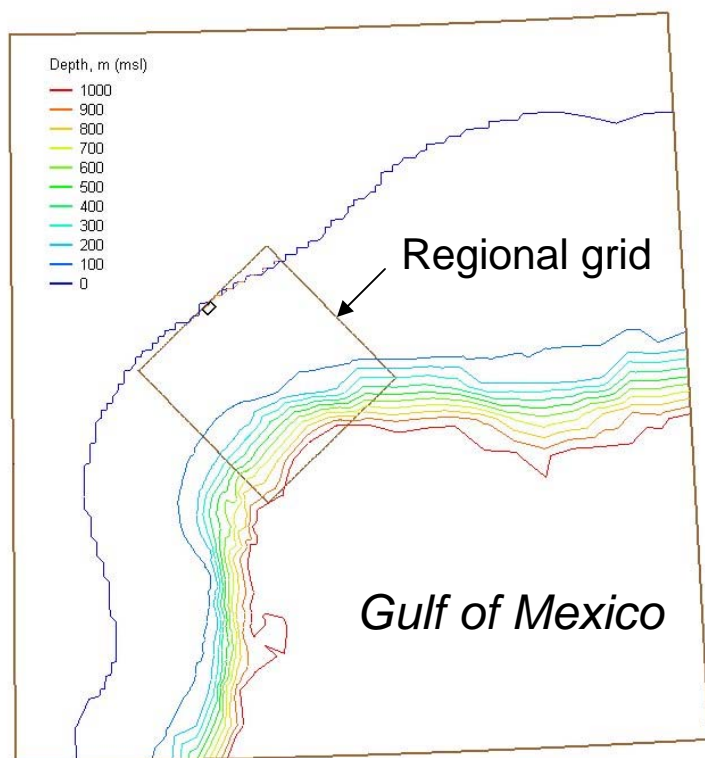
where ν_k is the kinematic viscosity of sea water,

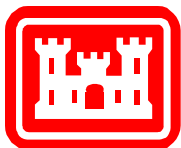
and ν_t is the turbulent eddy viscosity:

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



E. CMS-Wave Grid Nesting



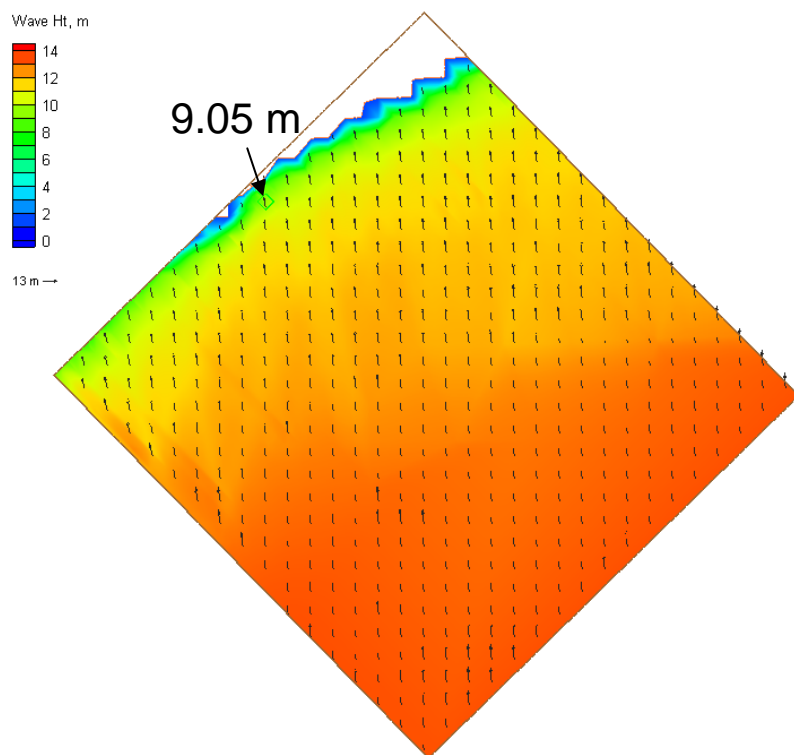


Regional Wave Generation

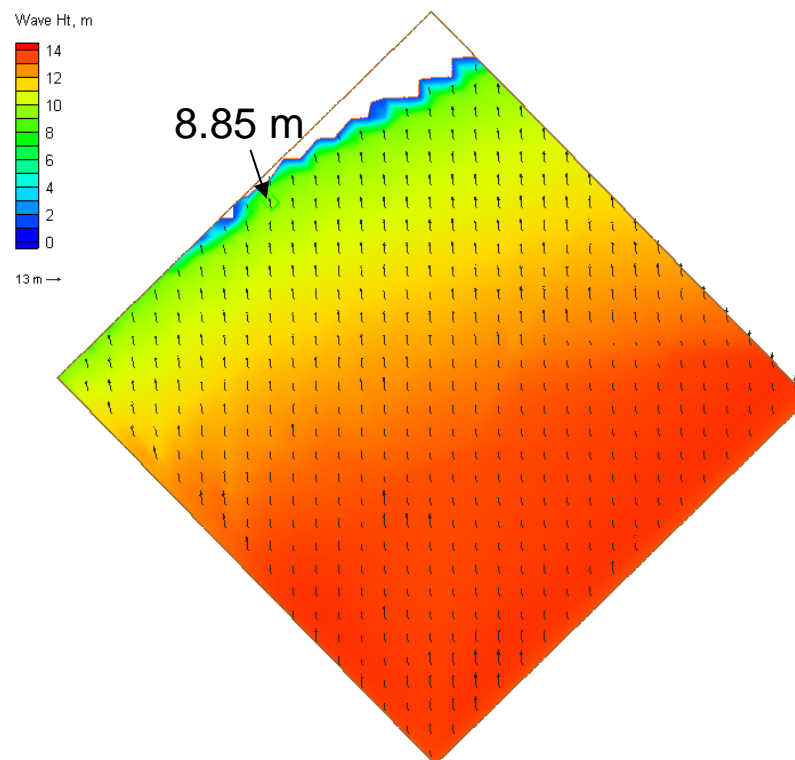
Incident Waves: 12.9 m, 13.8 sec, from S



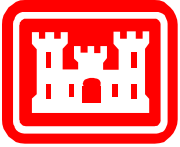
Max Surge: 3.5 m (Return Period = 50 yrs)



Without wind



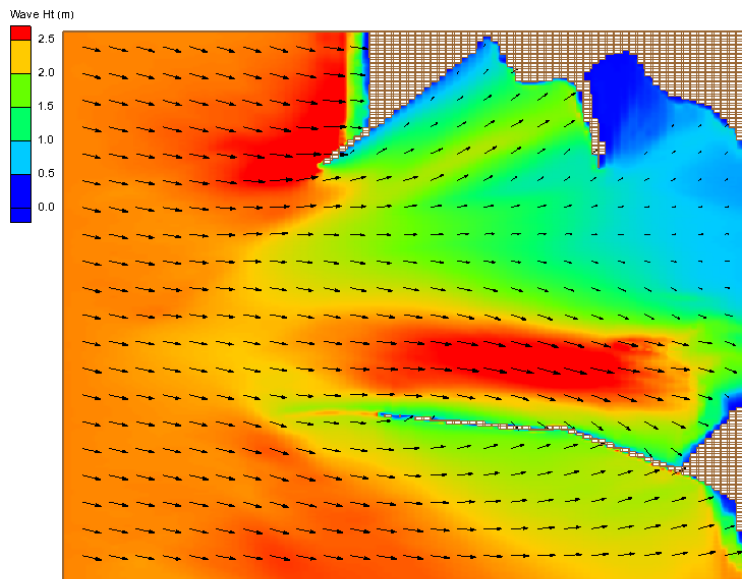
With wind (27 m/sec, from S)



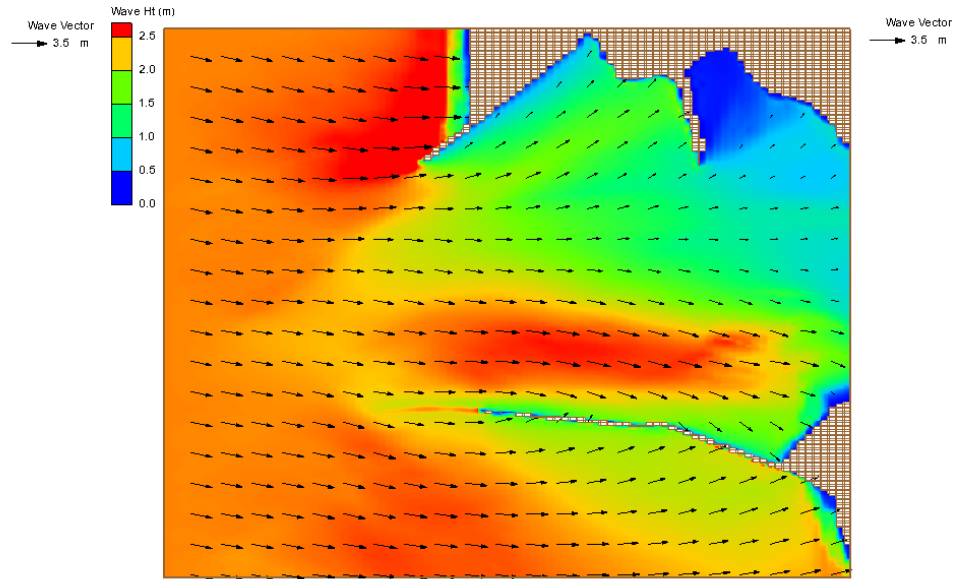
F. CMS-Wave Fast Mode



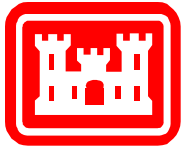
- Use 5 to 7 directional bins in spectral calculations (Normal runs on 35 directional bins)
- Ideal for a quick application or time-pressing run



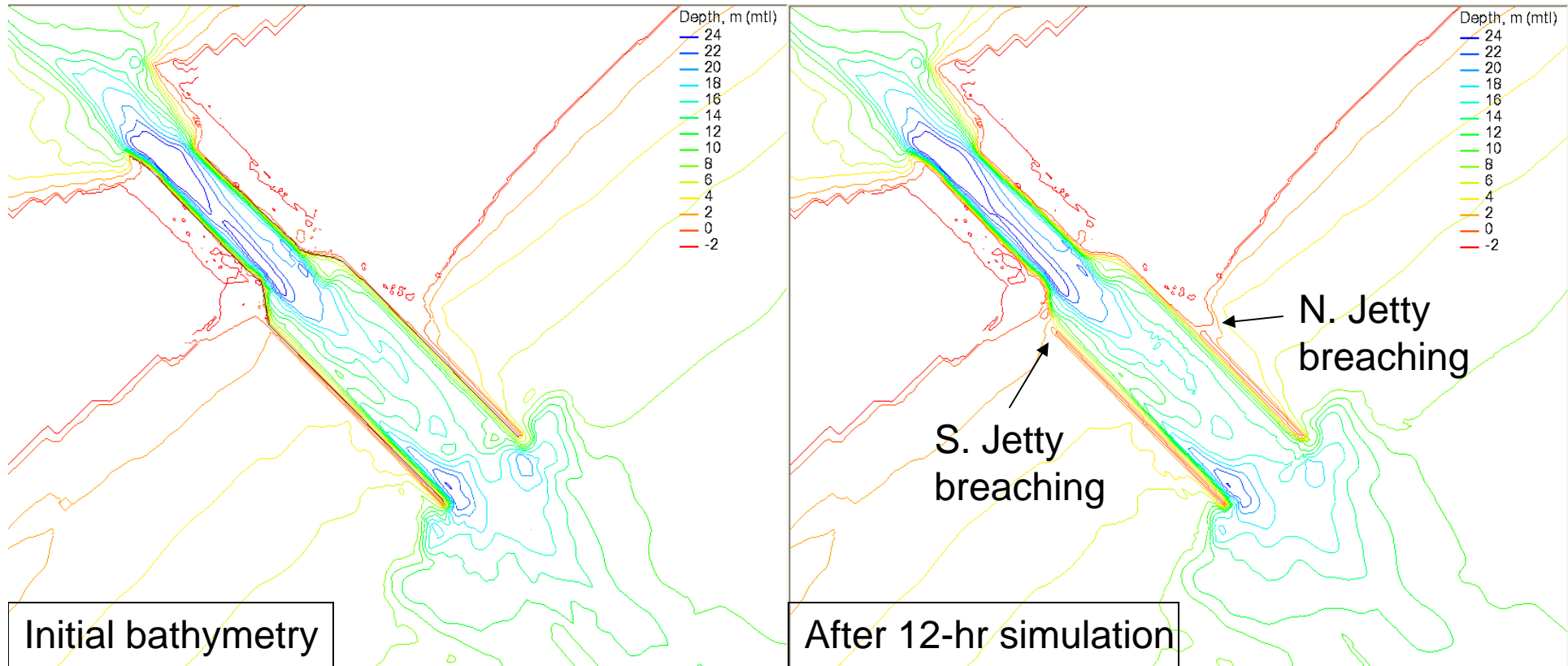
Normal run



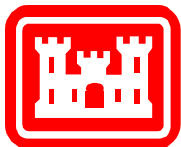
Fast mode



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



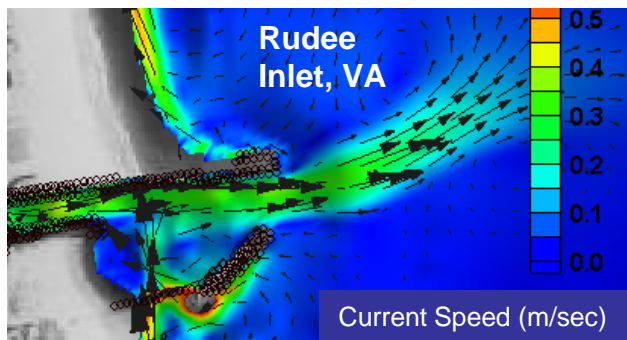
- Peak storm surge level reaches 3.5 m between Hrs 4 and 8
- Incident offshore wave is 7.6 m, 14.3 sec, from south direction



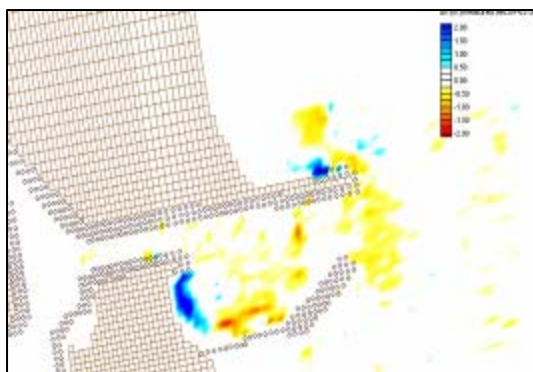
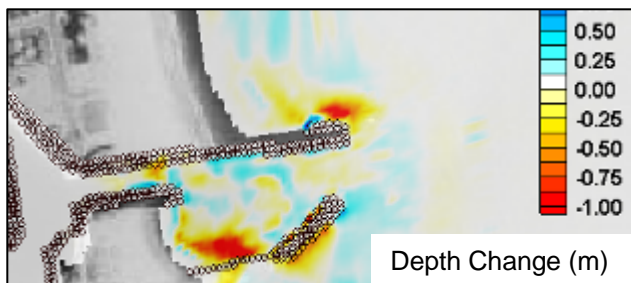
Sample CMS Steering Applications



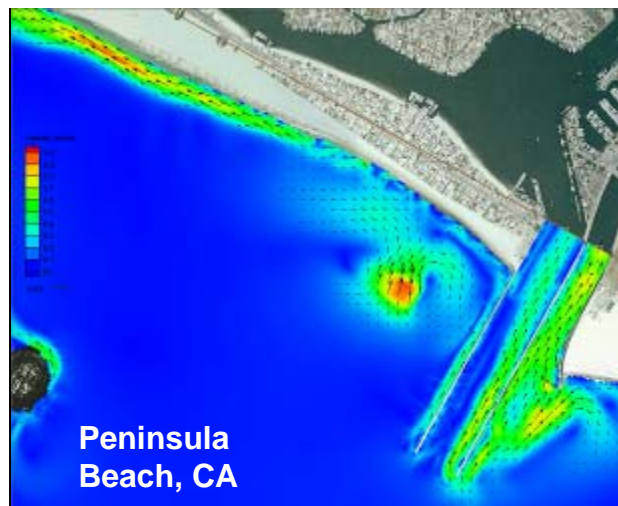
Wave & Tide-driven current



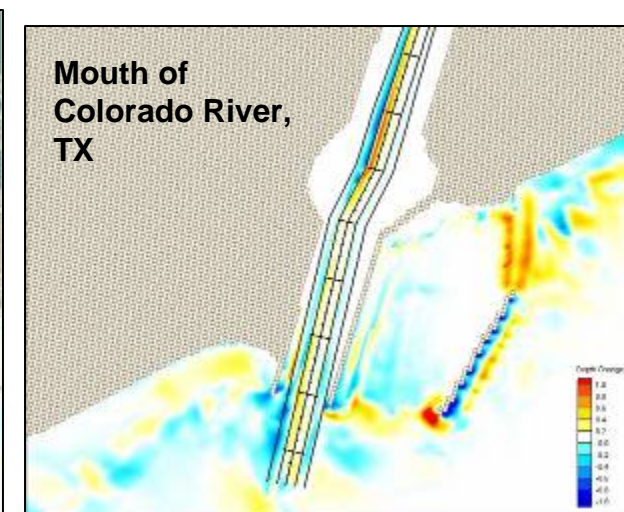
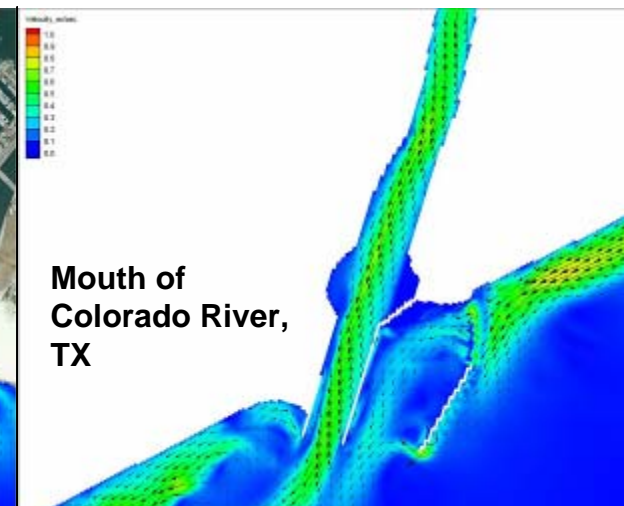
Morphology Change

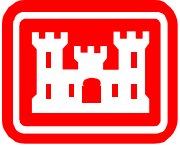


Wave-driven current



Wave & Tide-driven current





12. Future Improvement



Physics

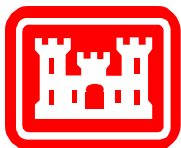
- Non-linear wave-wave interaction

Speed increases

- Inline code: CMS-Wave & CMS-Flow
- XMDF (binary format) for CMS-Wave
- Implementation of Open MPI
- Unstructured and telescoping grids

Functionality

- Full-plane transformation



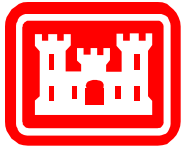
References & Contacts



1. Lin, L., H. Mase, F. Yamada, and Z. Demirbilek. 2006. "Wave-Action Balance Equation Diffraction (WABED) Model: Tests of Wave Diffraction and Reflection at Inlets." ERDC/CHL CHETN-III-73.
2. Zheng, J., H. Mase, Z. Demirbilek, and L. Lin. 2008. "Implementation and evaluation of alternative wave breaking formulas in a coastal spectral wave mode." *Ocean Engineering*. Vol. 35., pp.1090-1101.
3. 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.

[CMS-Wave](#)

Lihwa.Lin@usace.army.mil



CIRP - Coastal Inlets Research Program - Mozilla Firefox

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Coastal Modeling System (CMS)

The Coastal Modeling System is an integrated 2D numerical modeling system for simulating waves, current, water level, and sediment transport, and morphology change at coastal inlets and entrances. Emphasis of the CMS is on navigation channel performance and sediment exchange between the inlet and adjacent beaches. A key objective of this work is to develop, test, and transfer the CMS to Corps Districts and industry for use on specific engineering studies. The models CMS-Flow and CMS-Wave are included and linked in the CMS through a Steering Module developed within the Surfacewater Modeling System (SMS) version 10.0 and higher.

Choose a model below to expand the information:

CMS-Flow Hydrodynamic and Transport Model

CMS-Wave Model

Version Release (chronological, latest first)

CMS-Wave - 2.00 – November 2008

- **Interface** – Surface Modeling System (SMS) version 10.0+ (10.1 recommended)
- **Variable rectangle cells** – allow wider spacing cells in the offshore where the wave property variation is small and away from the area of interest to save the computational time.
- **Full-plane wave generation capability** – simulate local wave generation by wind in a lake or bay, neglecting swell from the ocean. This feature is automatically activated in the case of wind forcing only, with zero wave energy input at the sea boundary.
- **Newly implemented structural features** – calculate wave run-up on beaches, wave transmission of submerged reefs and floating breakwater, and wave overtopping over breakwaters.
- **Optional fast-mode** – minimize computer simulation time by automatically reducing directional bins in spectral transformation calculations. This option is ideal for a long or time-pressing simulation when looking for a quick and easy application.

The latest version of CMS-Wave v2 – [executable Documentation](#) on using CMS-Wave with SMS10.1 – CMS-Wave: A nearshore spectral wave processes model for coastal inlets and navigation projects, ERDC/CHL TR-08-13, Aug 2008

The latest version of SMS 10.1 (see SMS10.0/10.1 panel on our website)

Done

start 10th-CIRP-WH... Auto Clicker CIRP_Worksho... Intro-CMS-Wa... aCMSWAVE_T... CIRP - Coastal ... 6:27 PM