



U.S. ARMY®



# OVERVIEW OF THE SMS (V13.1), COASTAL MODELING SYSTEM, AND USER RESOURCES

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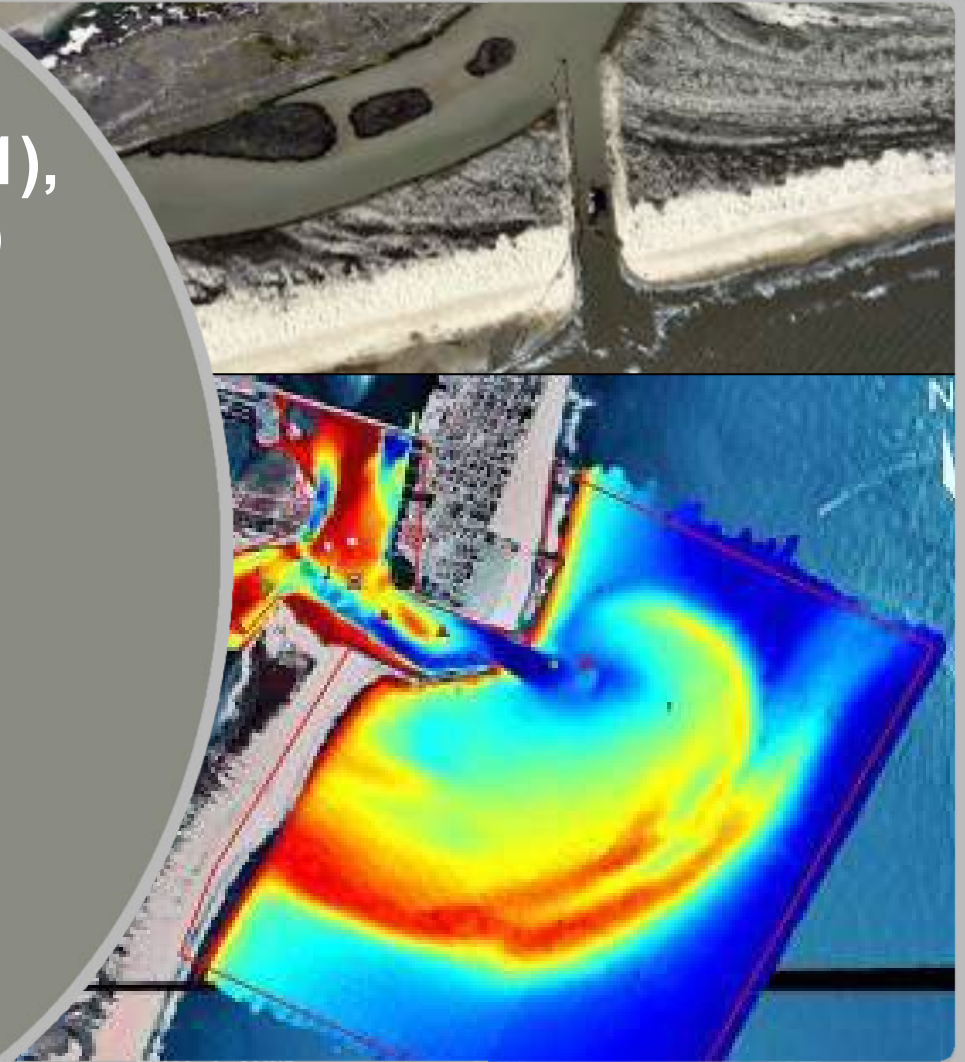
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CMS/GenCade SAD Workshop,  
Mobile, Alabama  
19-23 September 2022



US Army Corps  
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# CHL

COASTAL &  
HYDRAULICS  
LABORATORY



# ERDC

ENGINEER RESEARCH & DEVELOPMENT CENTER

# Outline

- CMS Overview
- Review of Features and Capabilities
- Overview of User Interface
- Recent accomplishments and features
- Upcoming developments and improvements
- Questions





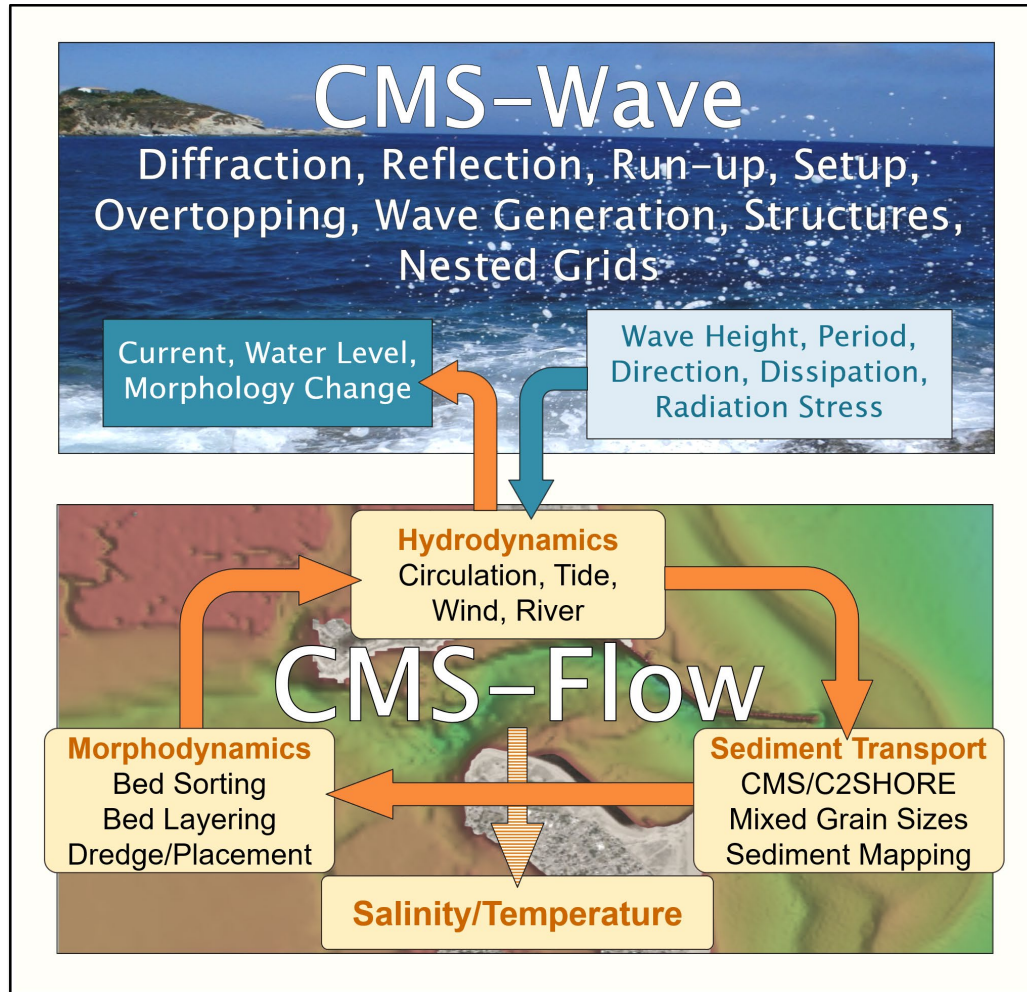


# Overview of Presentation

- Introduction to the Surface-water Modeling System (SMS v.13.1)
  - What is it?
  - Tools, Modules, Data Tree, Images, etc.
  - CMS Models interface
- Introduction to the Coastal Modeling System (CMS)
  - CMS-Flow – Hydrodynamics, Sediment Transport, Morphology Change
  - CMS-Wave – Half-plane waves and Full-plane wind forcing.



# CMS Overview



CMS Framework

Since 1997...

- >75 workshops
- Districts can independently run the CMS!

Advantages...

- Robust
- Physics-based
- Integrated SYSTEM
- In SMS
- User-friendly



# What is the SMS?



- **A Pre-Processor**
  - Organize and create input files for Corps of Engineers' numerical models
- **A Post-Processor (visualize results)**
  - Create plots
  - Create film loops
  - Data calculator
  - Dataset creation
- **Connect with outside tools**
  - Import/export CAD data
  - Import/export GIS data
  - Import/export tabular ASCII data
  - Import/export image data



# Overview of the SMS interface



The SMS interface is modular. Separate [modules](#) pertaining to each data type. As the user switches from one module to another, the [menus](#) and [tools](#) change. Inside the modules, the user associates a numerical model with a mesh or grid. When that grid is active, the tools and menus for the associated model are also enabled.

The SMS screen includes several [toolbars](#), [edit fields](#), and [menus](#). Some of these change as the user switches [modules](#) or [numerical models](#). The principal components include:

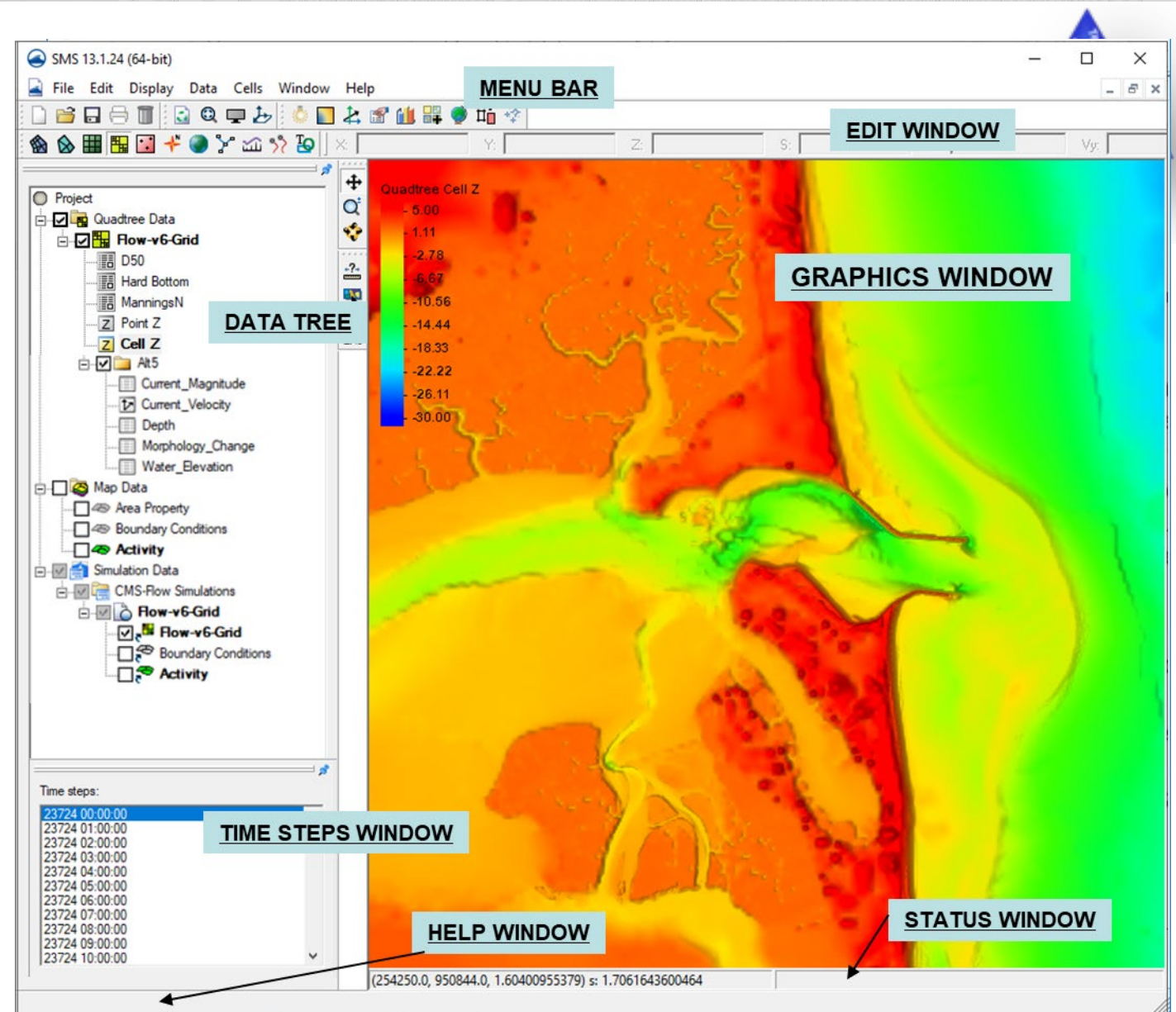
- [Menu Bar](#) - Menu to issue commands. These change as the module and model change.
- [Edit Window](#) - Fields directly below the menu bar showing the coordinates and function values for selected entities.
- [Graphics Window](#) - Display panel to show the data being manipulated.
- [Project Explorer \(Data Tree\)](#) - Tree representation of data currently referenced through SMS.
- [Time Step Window](#) – Appears if transient data are available.
- [Toolbars](#) - Several toolbars can be displayed. For more information on each toolbar, see the [Toolbars](#) article.
- [Help or Status Window](#)

The toolbars, project explorer, time steps window, and edit window are dockable windows. Dockable windows may be positioned by the user.

# SMS Modeling Suite

The Data Tree (also referred to as the “Project Explorer”) is a dockable window that appears by default on the left side of the SMS screen.

This window displays a hierarchical tree structure representing all data currently being managed in an SMS simulation.





# Toolbars

- Static Toolbar
- Dynamic Toolbar



- ▶ Grid
  - ▶ CMS-Flow
  - ▶ CMS-Wave
- ▶ Scatter
- ▶ Annotation



- Data Toolbar
- Optional Toolbars



- ▶ Macro



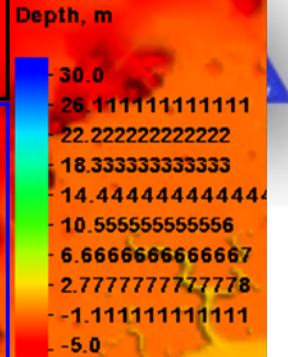
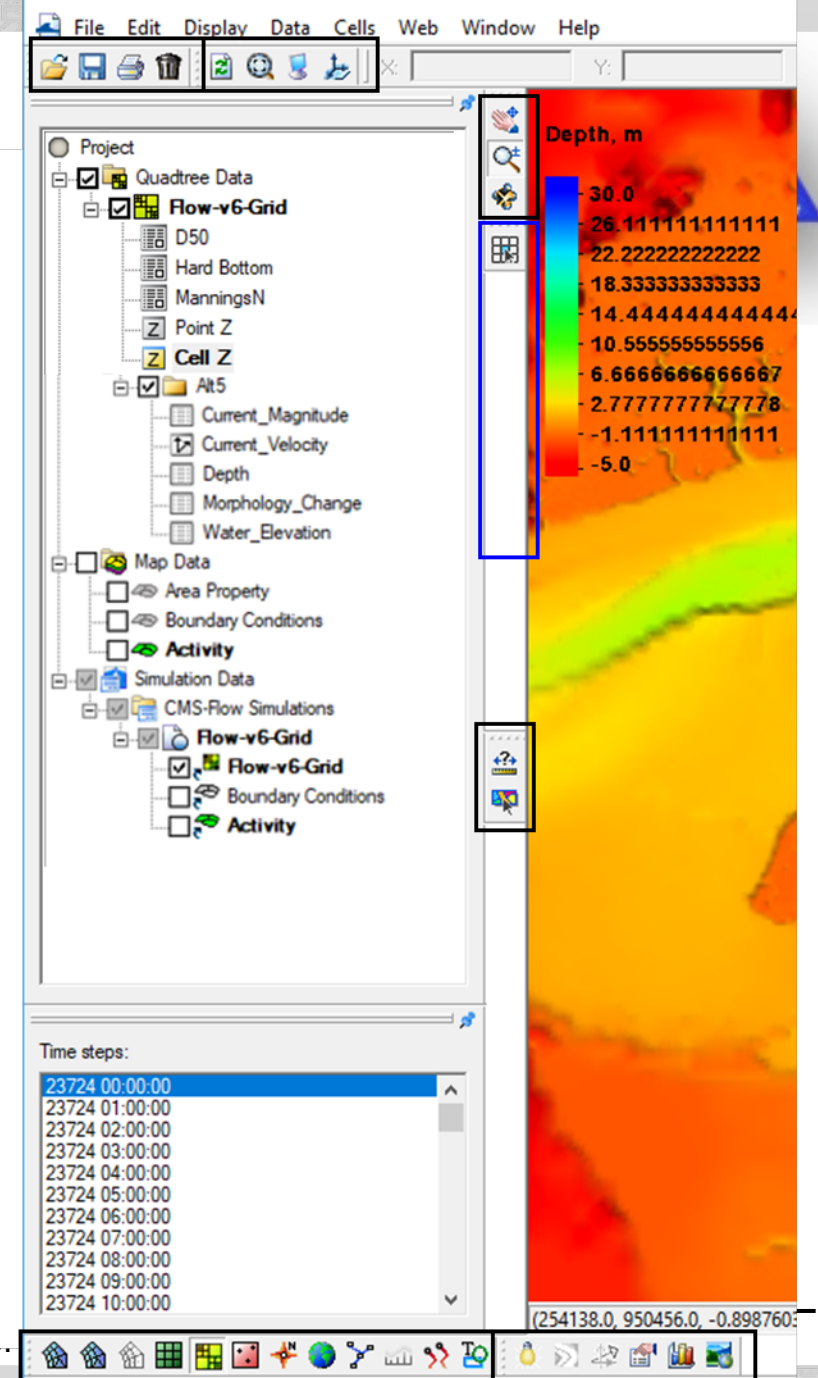
- ▶ File



- ▶ Display



- Module Toolbar



Time steps:

23724 00:00:00  
23724 01:00:00  
23724 02:00:00  
23724 03:00:00  
23724 04:00:00  
23724 05:00:00  
23724 06:00:00  
23724 07:00:00  
23724 08:00:00  
23724 09:00:00  
23724 10:00:00

(254138.0, 950456.0, -0.898760)



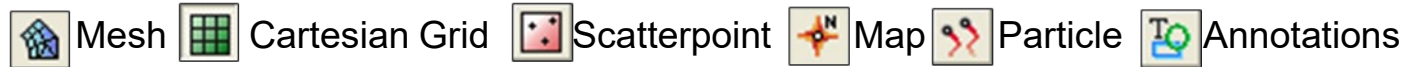
# Tools

## Individual Tools

- Static Toolbar



- Module Toolbar



- Data Toolbar



- Optional Toolbars

- Macro



- File



- Display

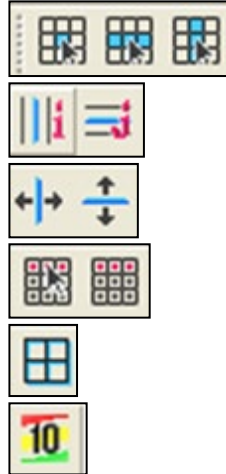




# Dynamic Toolbar

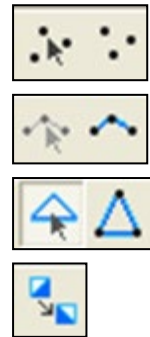
## Cartesian Grid / Quadtree tools

- Select Cell, Row, and Column
- Split Column and Row
- Move Column and Row Edges
- Select and Create Cellstrings
- Create Grid Frame
- Apply Contour Labels



## Scatter Data tools

- Select and Create Point
- Select and Create Breakline
- Select and Create Triangle
- Flip Triangle Edge



## Map Data Tools

- Select Feature Node
- Create Feature Node
- Select Vertex
- Add Vertex
- Select Feature Arc
- Create Feature Arc
- Select Feature Polygon
- Create 2-d Grid Frame
- Select 2-d Grid Frame



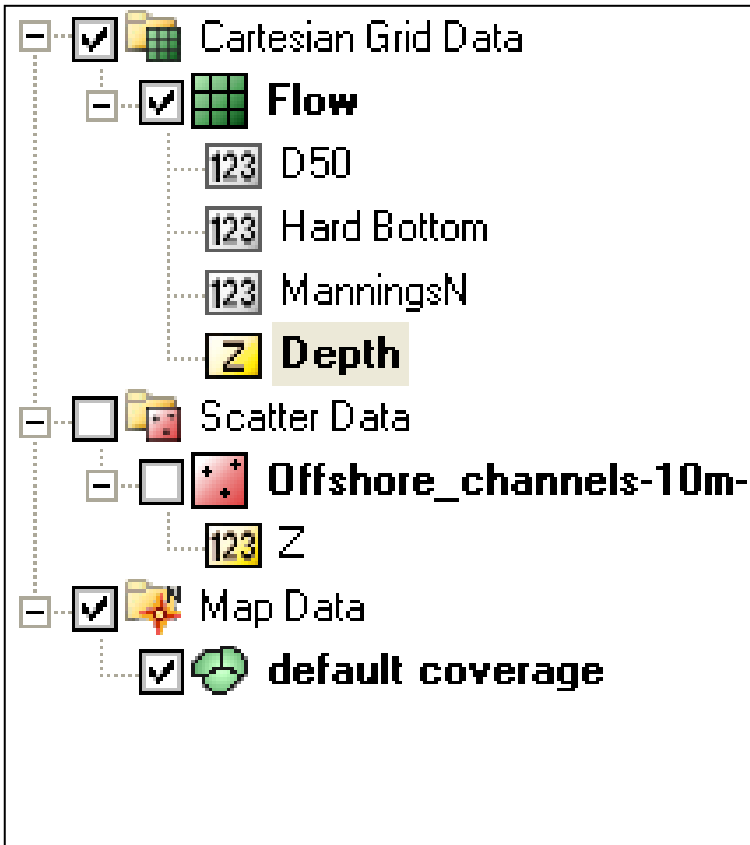
**Selection** tools usually have an arrow that points to the specific type of element.

**Creation** tools are identical to selection tools, only they do not have the arrow.





# Data Tree Components



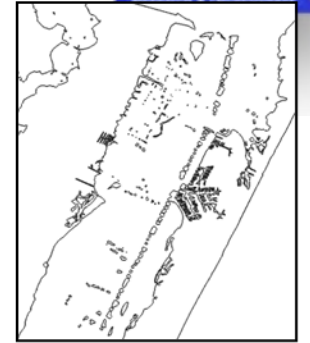
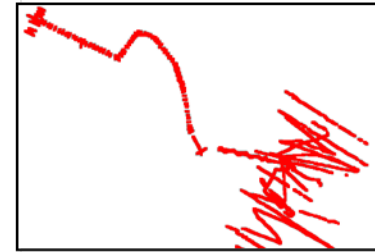
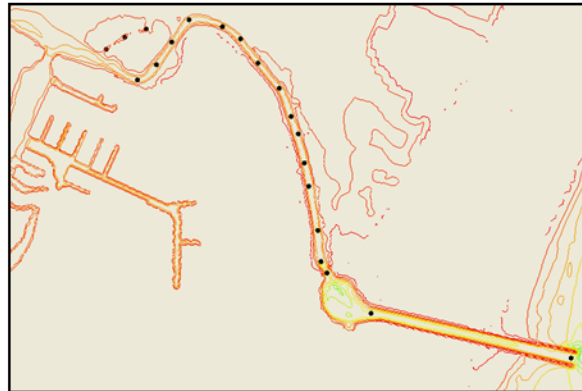
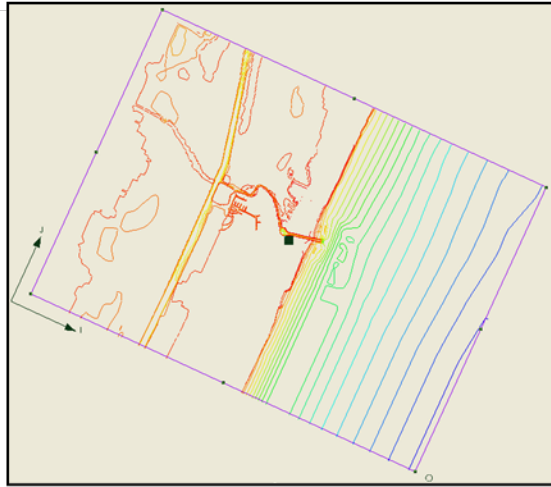
- The Data Tree makes selection of loaded datasets easy. Simply click on a dataset to make it active, and the graphics window updates accordingly.
- There are several “right-click” options available depending on the type of dataset activated, and within which module it is located. A few of these are:
  - Basic Dataset Information
  - Dataset-specific contour options
  - Export to file
  - Metadata Information
- The display of each asset in the Data Tree can be turned off by unchecking the display box next to the dataset name.

# SMS – a complete modeling interface

Build a CMS model from start to finish – all within SMS

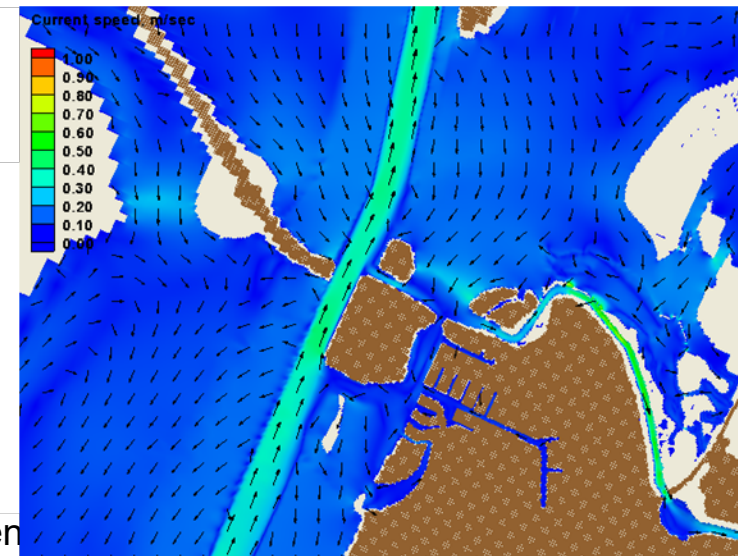
## Import Background Data

- Topographic & bathymetric data – numerous formats supported
- Images – maps & aerial photos
- CAD, GIS & spreadsheet data



## Create Conceptual Model

- Delineate CMS model domain
- Define areas of finer resolution



## Generate & Run CMS Models

- Automatically generate grid
- Interpolate depths from background data
- Utilize built-in interfaces to define model-specific parameters and boundary conditions
- Run model and visualize results

US Army Corps of Engineers • Engineer Research and Development

# SMS – Data Processing – Import Wizard



**File Import Wizard - Step 2 of 2**

SMS data type:  
 Scatter Set Filter Options

☐ No data flag -999.0

Name: Imported Data

Mapping options  
☒ Triangulate data ☐ Delete long triangles  
 Maximum edge length: 100000.0  
 Merge duplicate points within tolerance: 0.0000100

File preview

| Type   | X       | Y        | Z       | Scalar data | Vector X | Vector Y |
|--------|---------|----------|---------|-------------|----------|----------|
| Header | XYZ     | (2697    | points) | WSE         | Velocity | Velocity |
|        | 105.074 | -286.841 | 50.750  | 53.318      | 1.260    | -0.706   |
|        | 104.575 | -287.898 | 49.607  | 53.368      | 1.308    | -0.412   |
|        | 104.076 | -288.955 | 48.464  | 53.418      | 1.577    | -0.712   |
|        | 103.612 | -290.029 | 48.464  | 53.376      | 2.096    | -0.604   |

First 20 lines displayed.

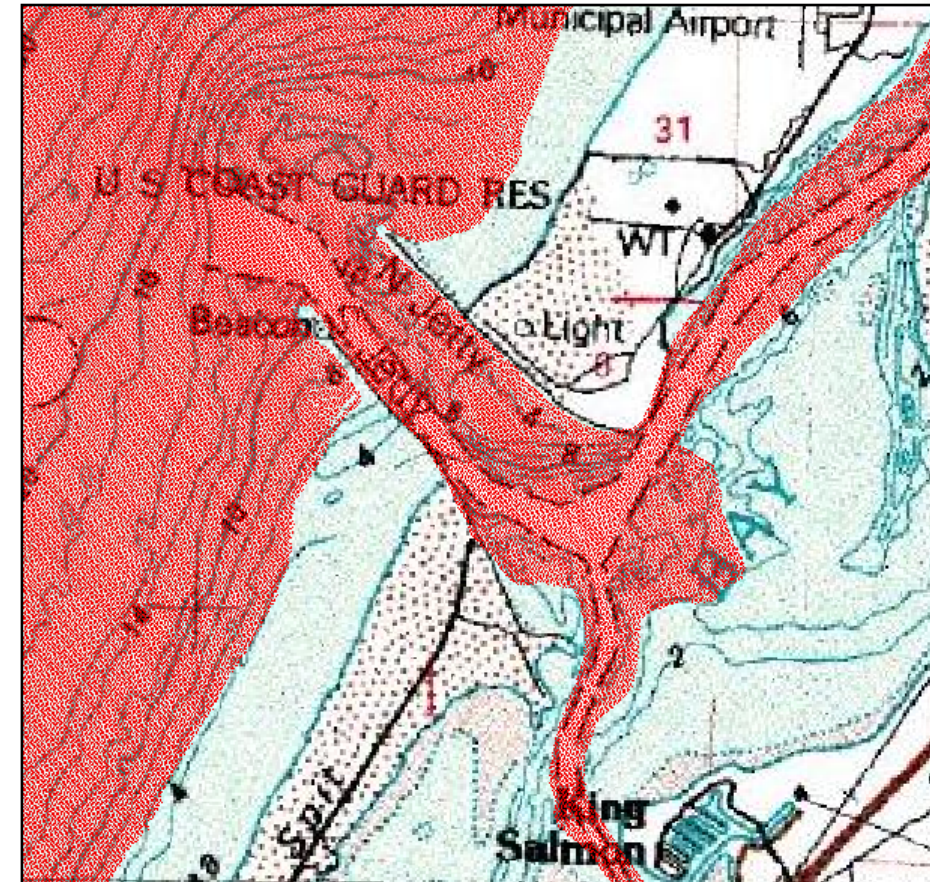
Help < Back Finish Cancel



# Scattered Data (TINs)

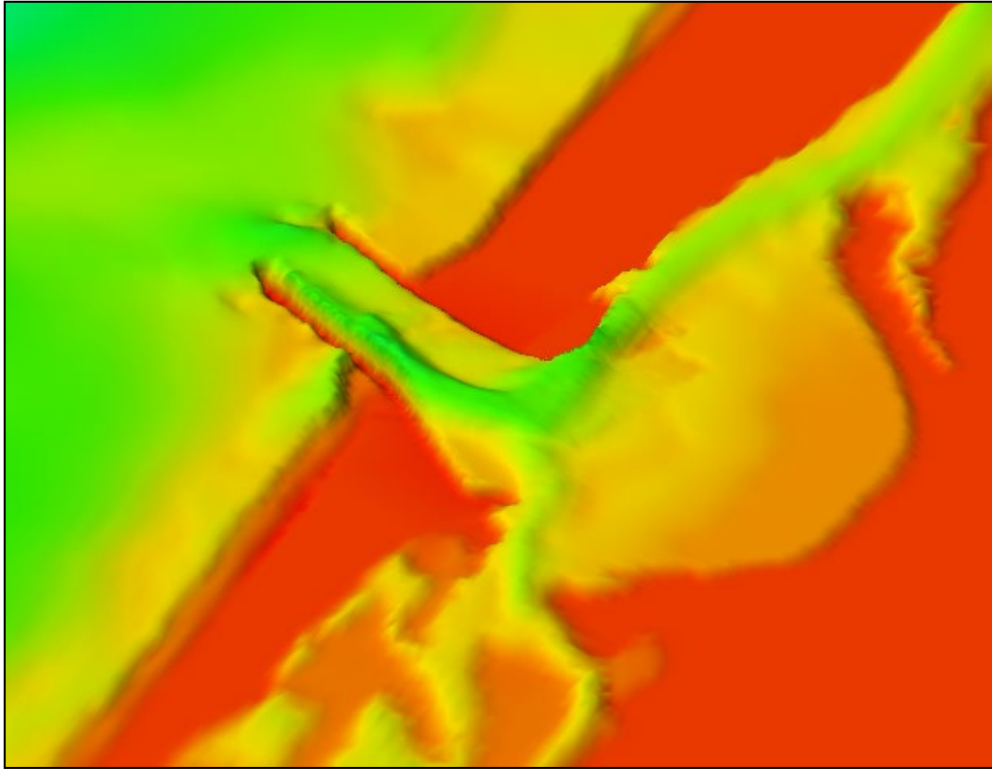


- **Stores spatially varied data**
  - ▶ Bathymetric data most common
  - ▶ Interpolates from one grid/mesh to another
  - ▶ Allows combination of data sources
  - ▶ Facilitates data thinning or filtering





# Visualization of Scattered Data



***Humboldt Bay, CA***  
*Oblique view*  
*Z-magnification 5x*

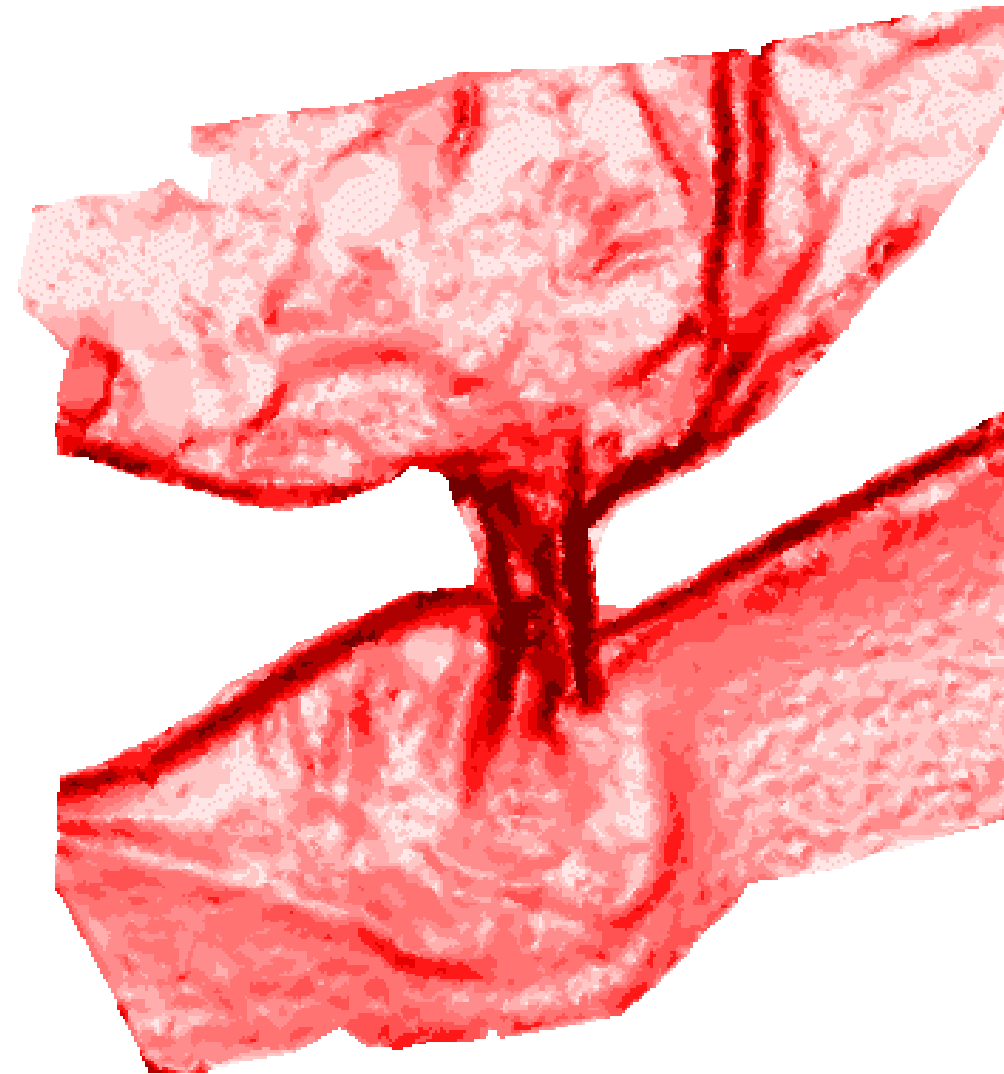
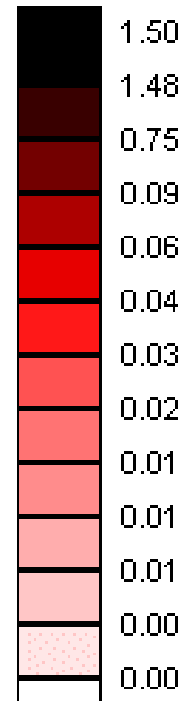
## ■ Options

- Magnify in Z direction
- Oblique or plan views
- Fill with contours options
- Shading

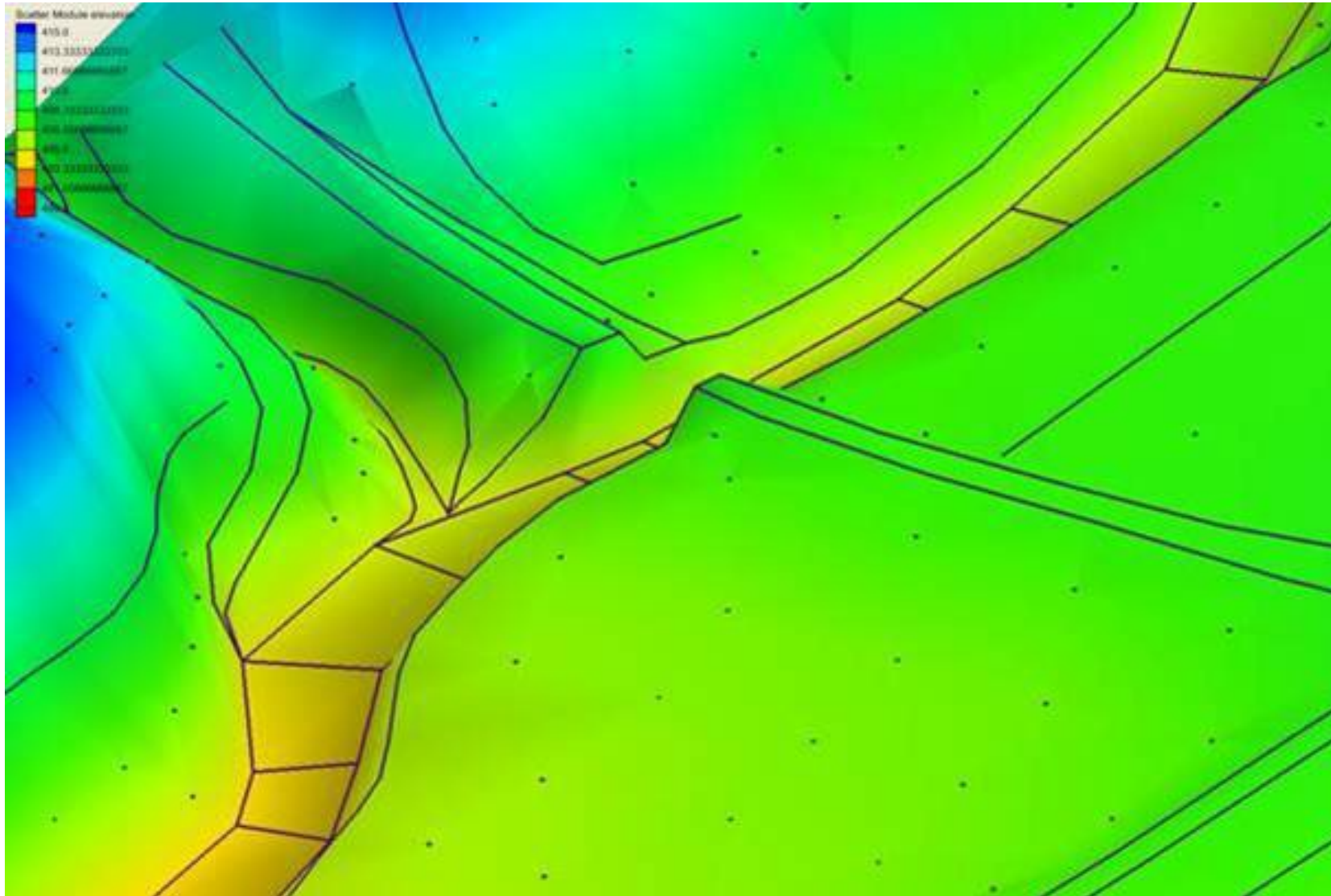
# LIDAR Surveys



Gradient



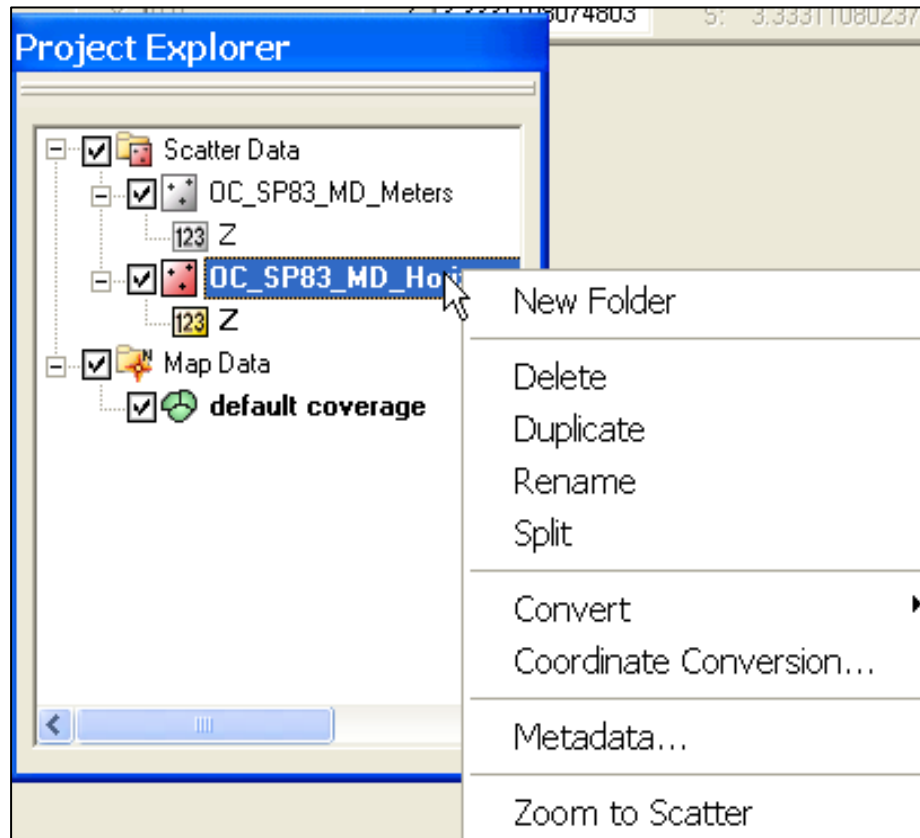
# Breaklines



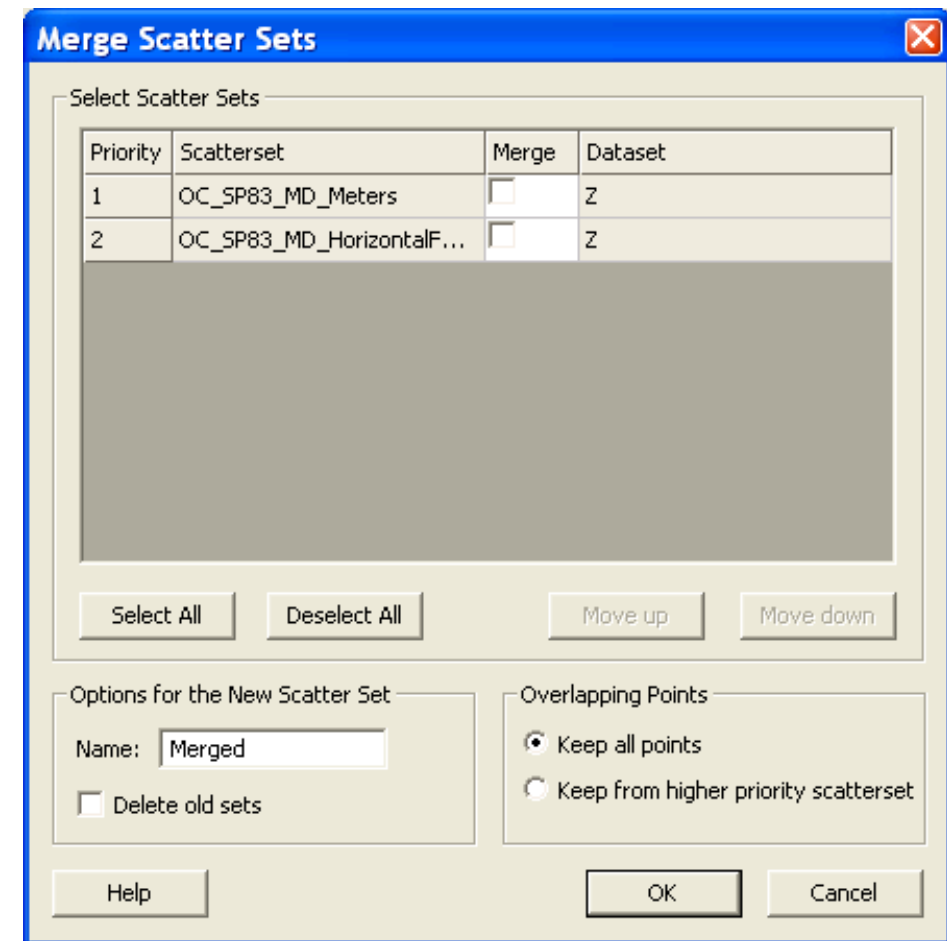


# Operating with Scatter Sets

## Right Click Menu



## Merge



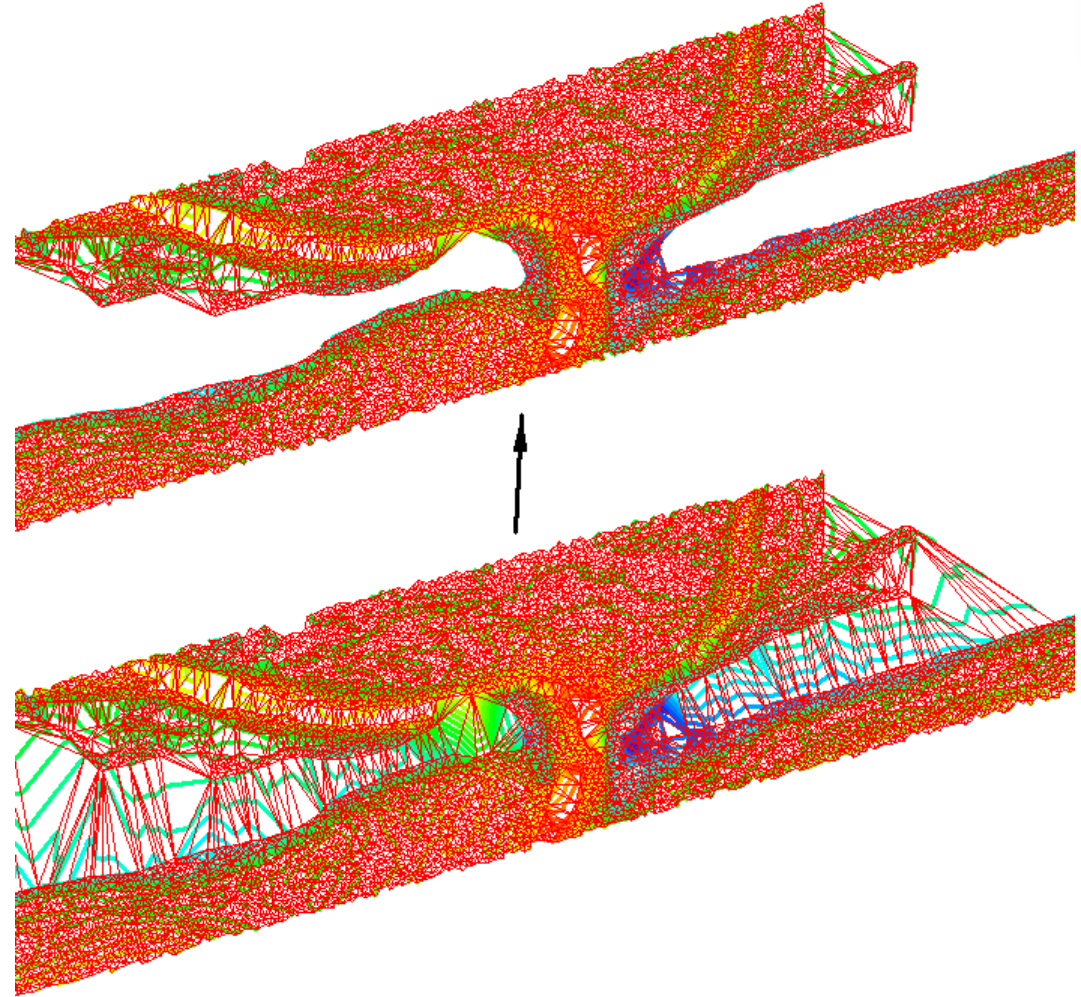


# Points and Triangles

User can delete points or triangles to change extents of a set.

User can swap edges to alter shape of surface

- Used in linear interpolation

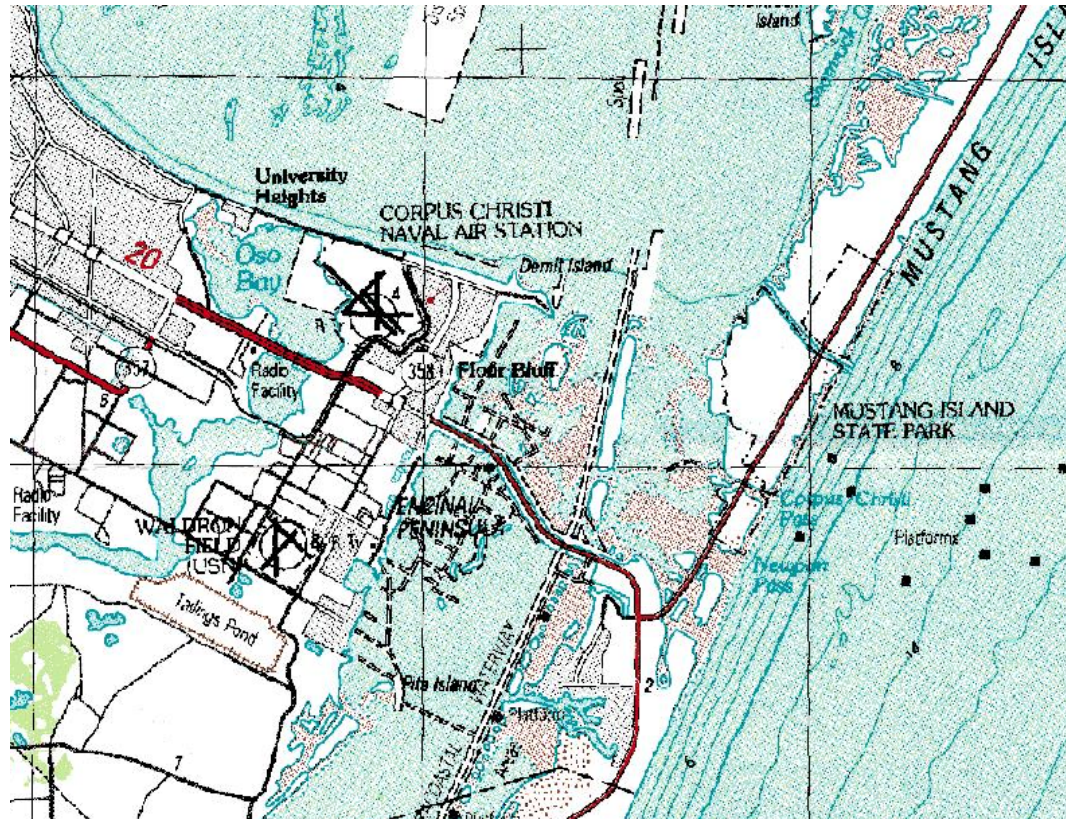




# Images



## Topo Maps



## Aerial Photos

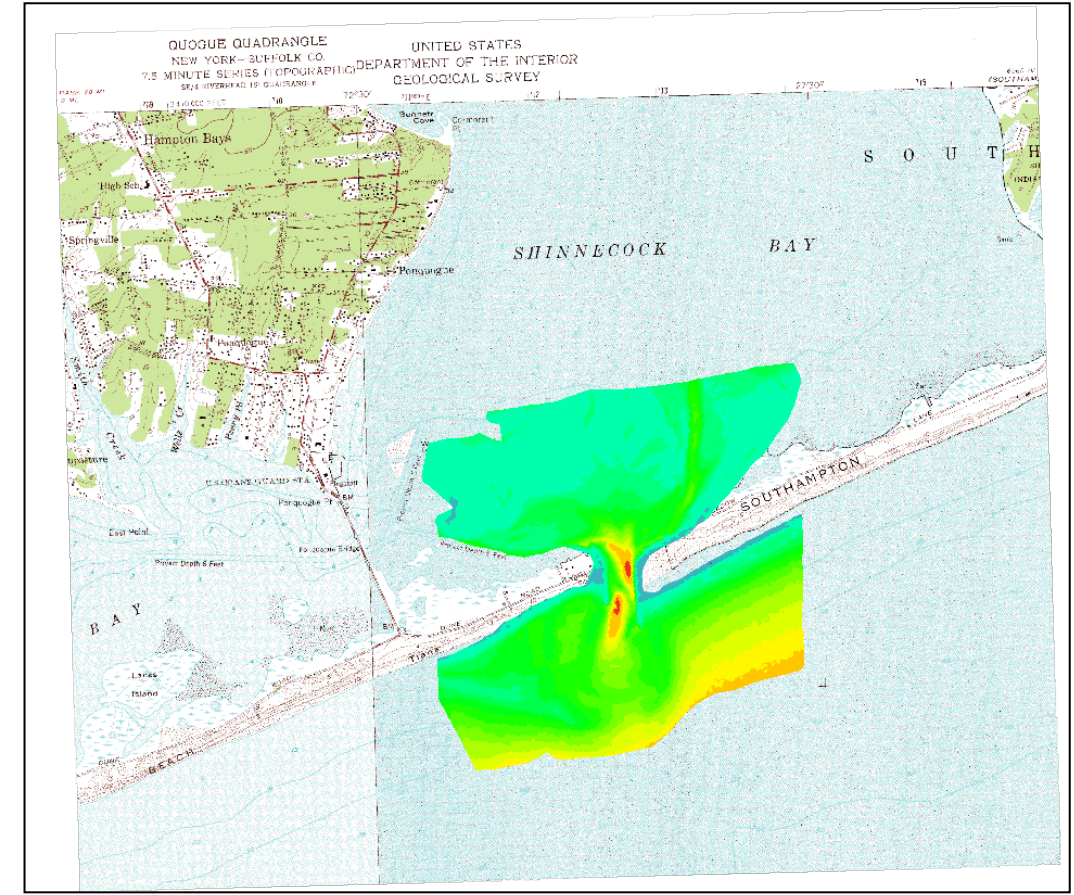
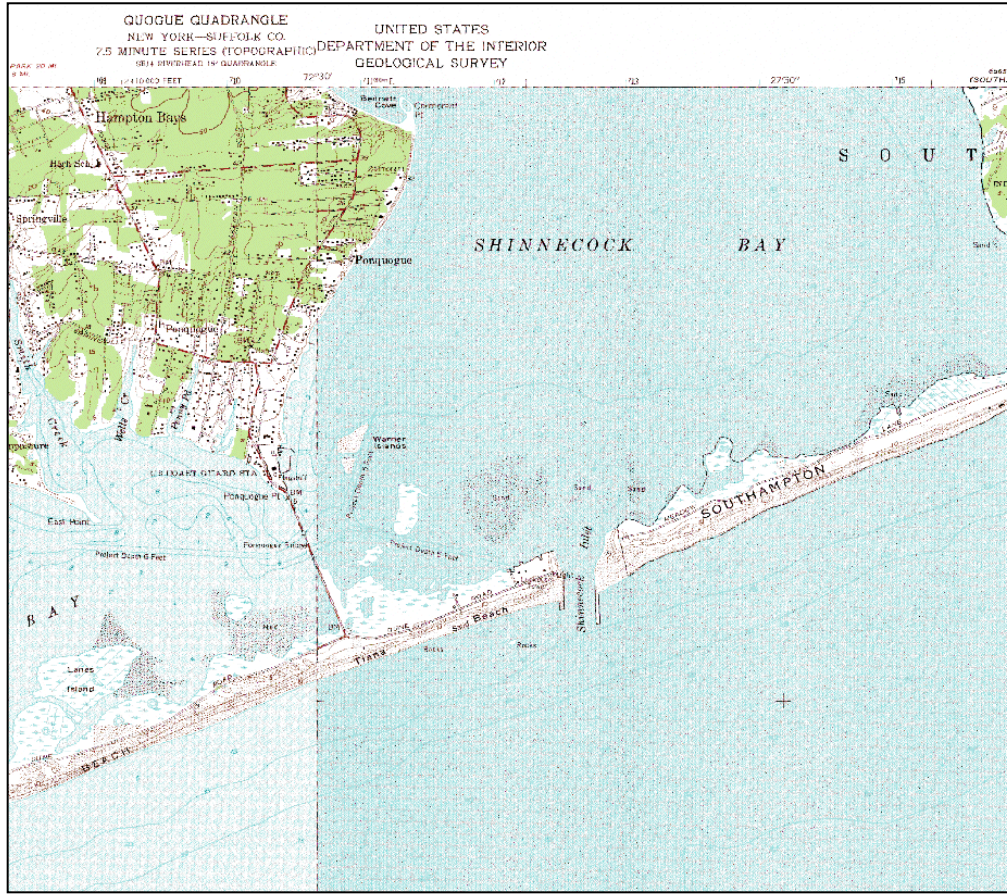




# Image Data

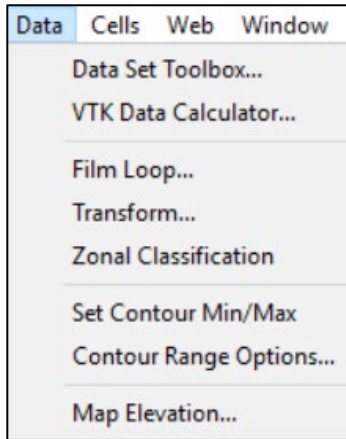


## Overlay data over images



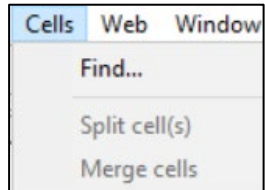


# CMS-Flow Interface: Pull-down menus

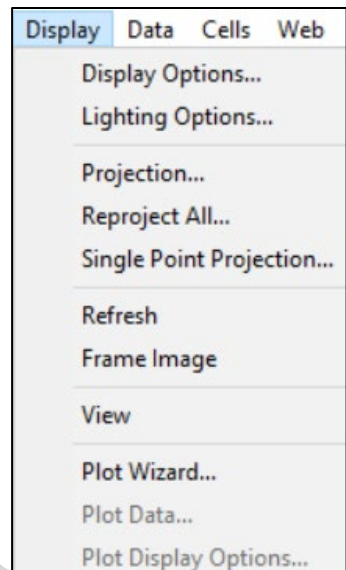


The Data pull-down menu contains many items – here are a few:

- Dataset Toolbox – Dataset-based operations (includes Calculator)
- Vector/Contour Options – Change appearance of data within the Graphics Window
- Film Loop – Generate animations based on loaded data/solutions
- Transform – manually changes geometry properties
- Map Elevation – Define a dataset to be the “Z” (Depth) dataset for a grid



The Cells pull-down menu contains options for finding specific cells and manipulating one or many selected cells.



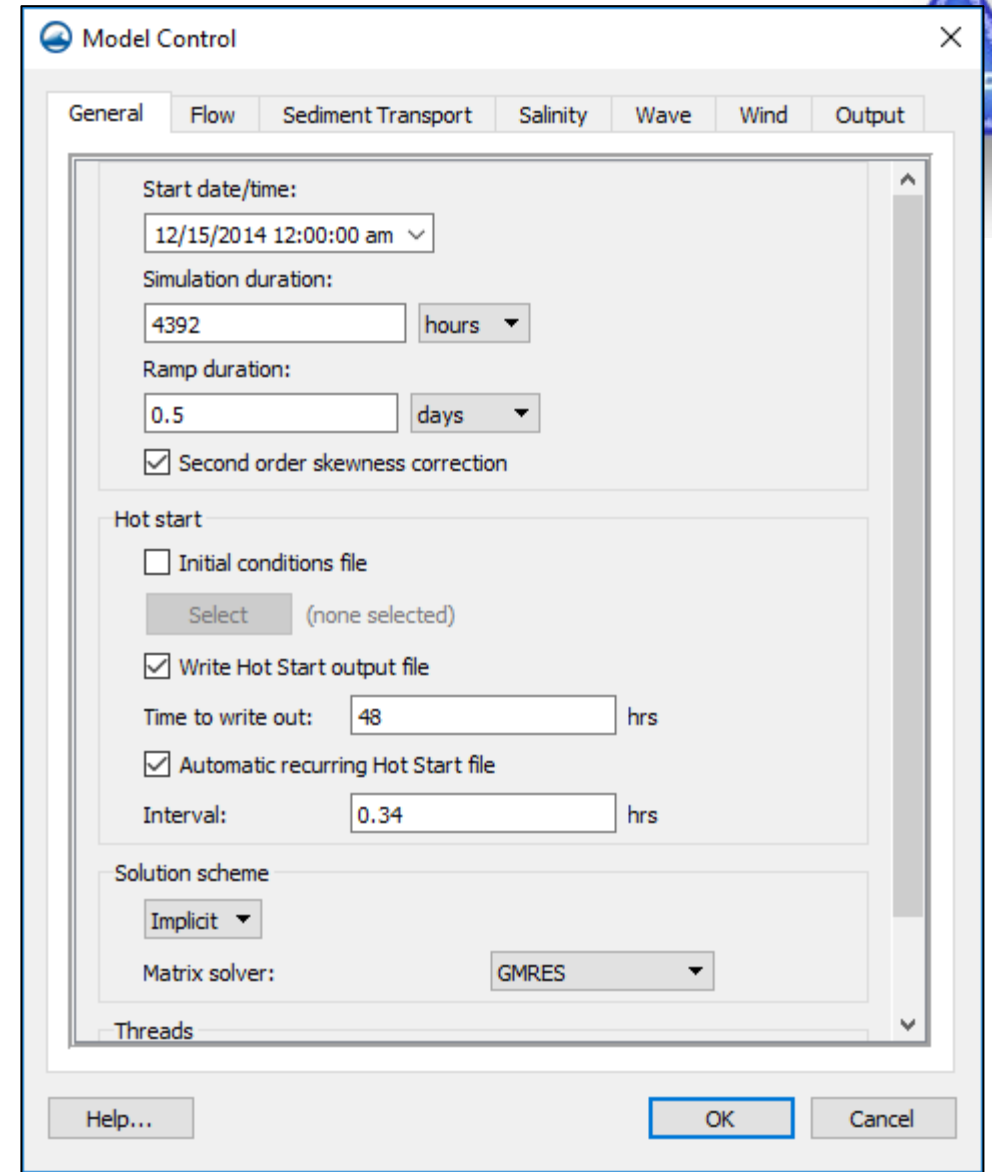
The Display pull-down menu contains commands to manipulate what and how data is viewed inside the interface.

- Display Options – Affect visibility of various options
- Lighting Options – Enable and modify an “external light source”
- Projection – Set the default display projection for items loaded into SMS
- View – get information on various selections for later reproducibility.
- Plot Wizard – View loaded data in various graphical charts and plots.

# CMS-Flow Model Control

## Parameter Specification and File I/O

- Time Control
- Auxiliary Files
- Parameters
  - Wet/Dry depth
  - Flags
- Process sections to Include
  - Flow
  - Sediment Transport
  - Wind
  - Waves
  - Salinity
  - Output options



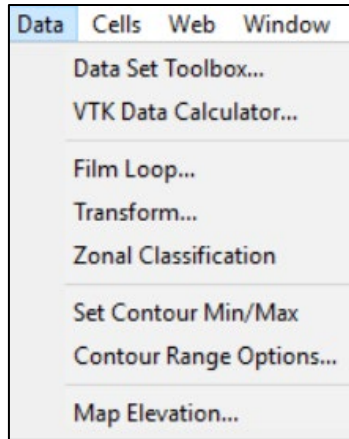
The screenshot shows the 'Model Control' dialog box with the 'General' tab selected. The dialog has tabs for General, Flow, Sediment Transport, Salinity, Wave, Wind, and Output. The General tab contains the following settings:

- Start date/time:** 12/15/2014 12:00:00 am
- Simulation duration:** 4392 hours
- Ramp duration:** 0.5 days
- ☒ Second order skewness correction
- Hot start**
  - ☐ Initial conditions file
  - Select (none selected)
  - ☒ Write Hot Start output file
  - Time to write out: 48 hrs
  - ☒ Automatic recurring Hot Start file
  - Interval: 0.34 hrs
- Solution scheme**
  - Implicit
  - Matrix solver: GMRES
- Threads**

Buttons at the bottom: Help..., OK, and Cancel.

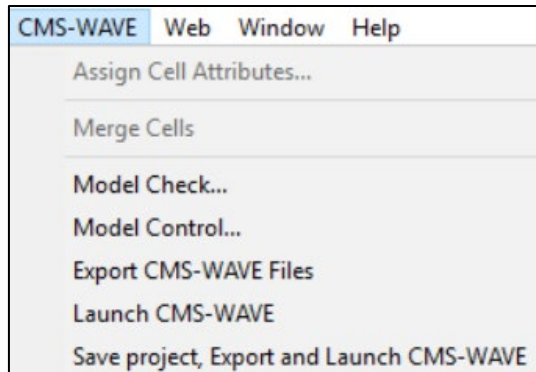


# CMS-Wave Interface: Pull-down Menus



The Data pull-down menu uses most of the items as for CMS-Flow:

- Dataset Toolbox – Dataset-based operations (includes Calculator)
- Vector/Contour Options – Change appearance of data within the Graphics Window
- Film Loop – Generate animations based on loaded data/solutions
- Transform – manually changes geometry properties
- Map Elevation – Define a dataset to be the “Z” (Depth) dataset for a grid



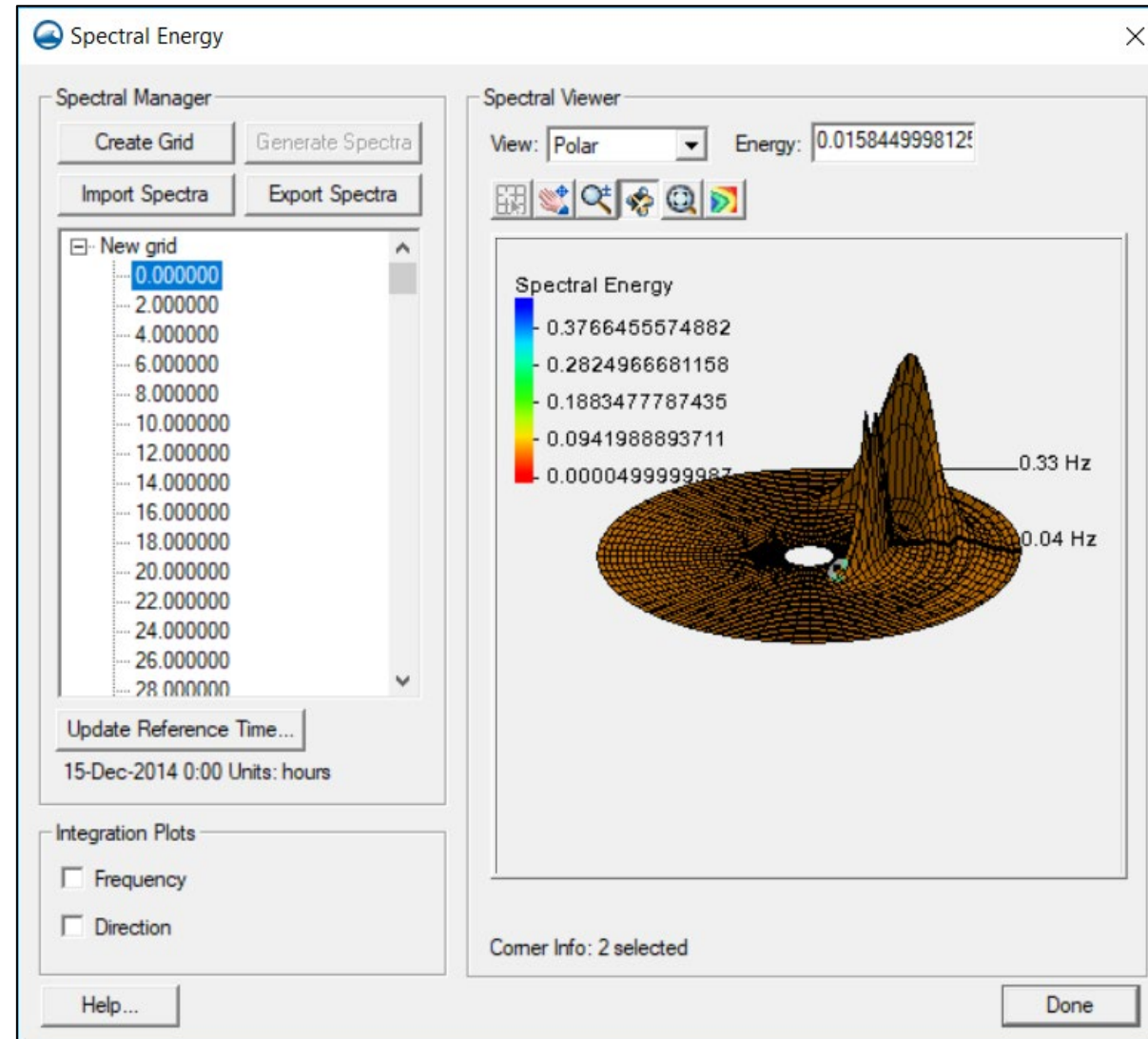
The CMS-Wave menu contains commands to operate the model.

- Model Control – Set up the parameters and running options for a CMS-Wave simulation
- Model Check – Analyze present wave grid and modeling parameters for errors before run commences.
- Export CMS-Wave files – Writes all the CMS-Wave information out to the correctly formatted files.
- Launch CMS-Wave – Runs CMS-Wave with assigned options
- Save project, Export, and Launch – Saves the project and then both exports the files and launches the model, all in one step.

# Spectral Energy Menu



## Example of Imported Spectra from Wave Gauge





# Generate Spectra from Bulk Criteria

Generate Spectra

Parameter Settings

Generation Method: **TMA (Shallow Water)**

☒ Replace Old Spectra

Directional Spreading Distribution:

☐ Wrapped Normal

☒ Cosine Power

Seaward boundary Depth:

☒ Specify once for all spectra

30.0 m

☐ Specify for each spectrum

Angle Settings

Projection: **Shore Normal**

Spectral Parameters

|   | Time Offset (hrs)/Index | Angle (deg) | Hs (m) | Tp (s) | Gamma | nn |
|---|-------------------------|-------------|--------|--------|-------|----|
| 1 | 1.0                     | 30.0        | 2.0    | 10.0   | 3.3   | 4  |
| 2 |                         |             |        |        |       |    |

Import Import from GenCode Export Spectral Defaults >>

Help... Generate Cancel

Select from several types of generation methods.

Observe the direction relative to the created wave grid.



# CMS-Wave Model Control



- Turn on Wetting & Drying of Cells
- Turn on Reflection (FWD, BWD)
- Choose Bed Friction type
- Set parameters
- Choose Output Datasets
- Choose Wave Source

CMS-WAVE Model Control

**Input Forcing**

Currents:

Water level:

**Spectra**

Source:

Plane type:

Interpolation type:

Date Format:

**Wind**

Source:

**Settings**

**Bed Friction**

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

**Matrix Solver**

Number of threads:

Forward reflection:

Backward reflection:

Muddy bed:

Wave breaking formula:

☒ Allow wetting and drying

☒ Infragravity wave effect

☒ Diffraction intensity:

☐ Non-linear wave effect

☐ Run up

☒ Fast-mode run

**Output**

☐ Radiation stresses

☐ Sea/swell

☒ Wave breaking

☒ Indices

☐ Energy dissipation

Format:

**Input Datasets**

Format:



# Dataset Toolbox

## Mathematical Operations

- Comparisons
- Data Calculator

## Spatial Operations

- Spacing
- Gradients/Derivatives
- Smoothing

## Temporal Operations

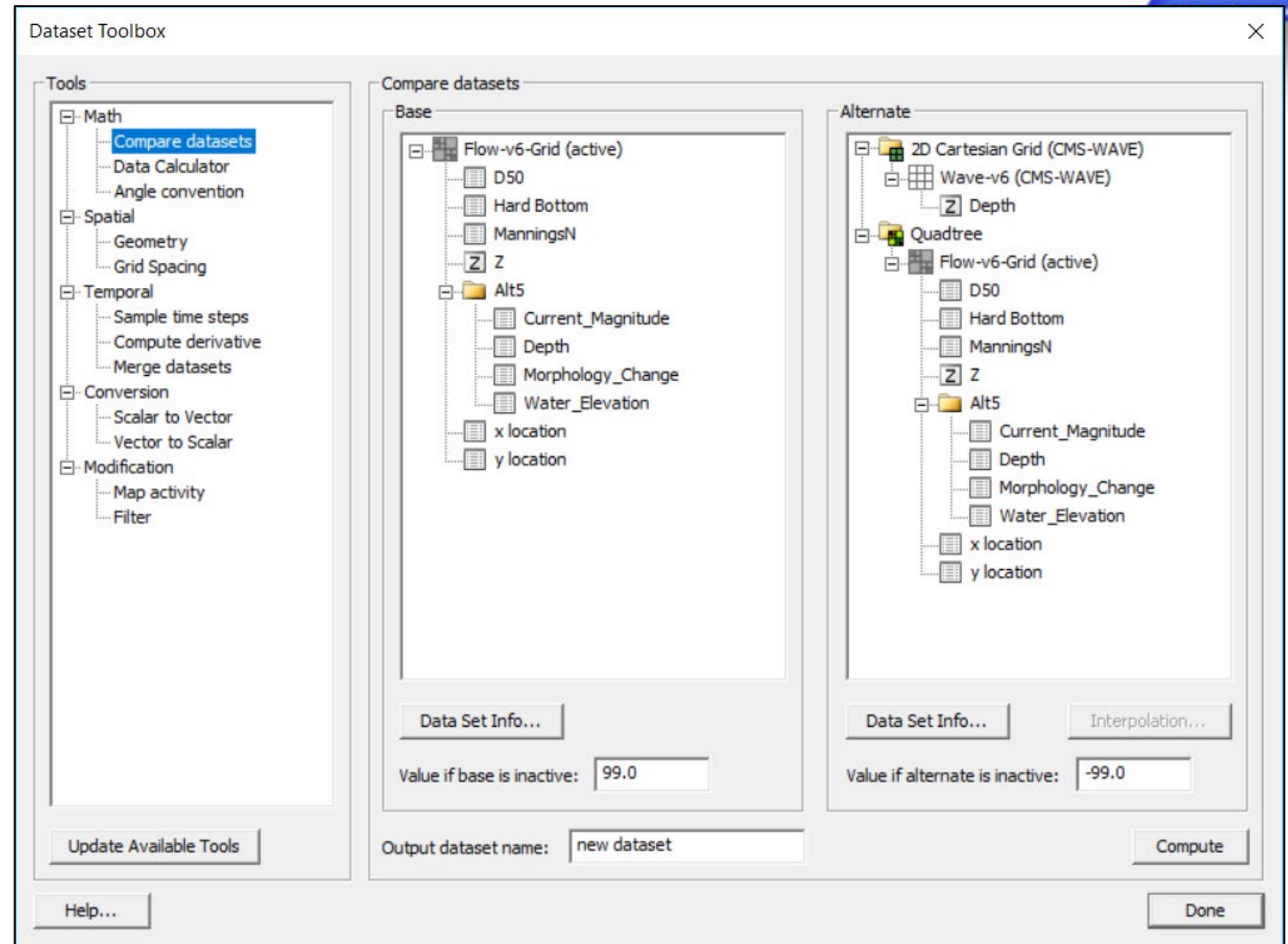
- Sample times
- Temporal derivatives

## Conversions

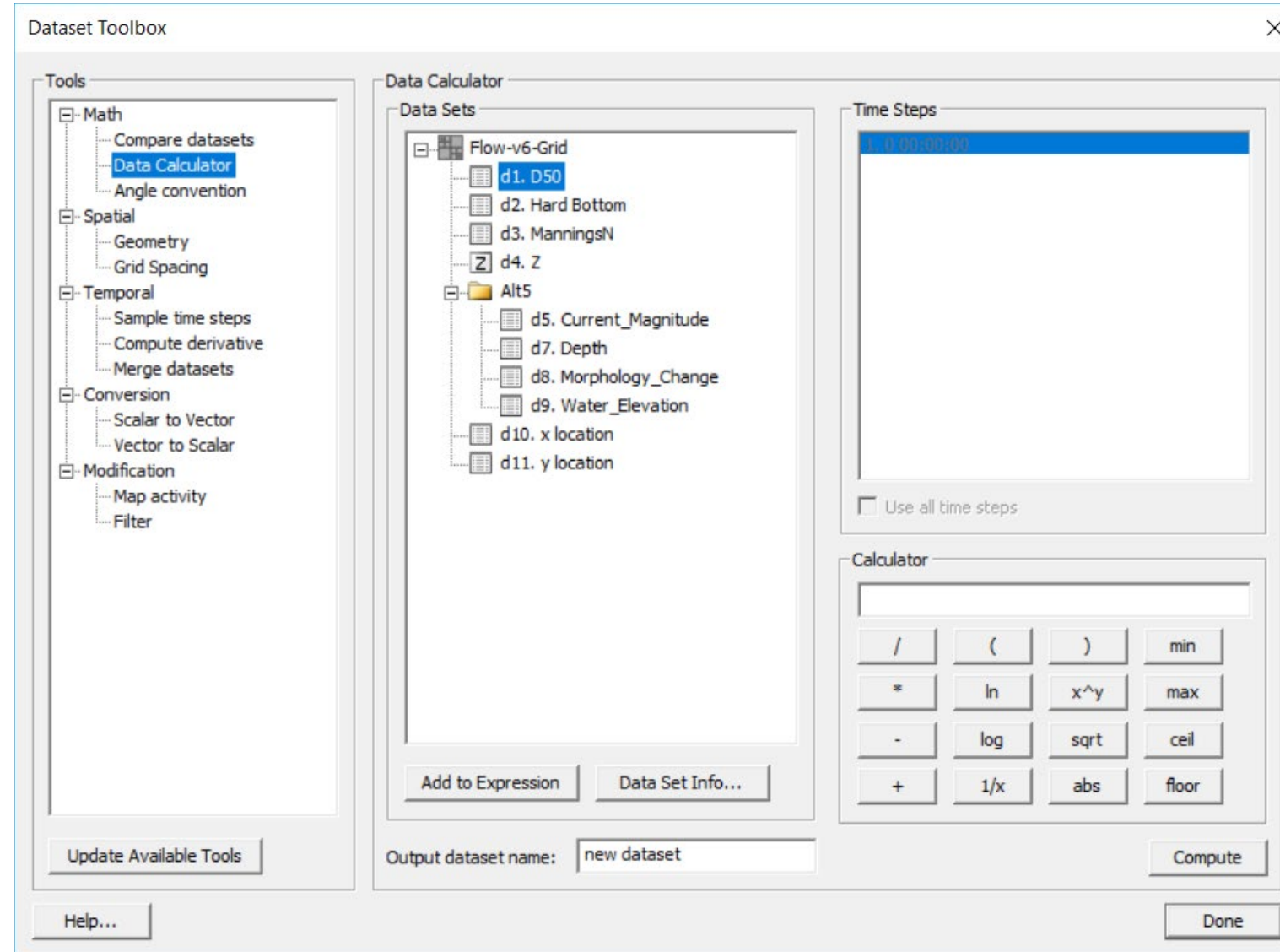
- Vector <-> Scalars

## Activity Mapping

- Map activity
- Value filtering



# Dataset Calculator







# Coordinate Projections

- All major datums
- Project
  - Point
  - Object
  - Entire project
- Support for projection files
- Automatic detection of projections
  - Images
  - CAD
  - GIS

A screenshot of a "Display Projection" dialog box. The dialog has a title bar with a close button. It is divided into two main sections: "Horizontal" and "Vertical". In the "Horizontal" section, there are two radio buttons: "No projection" and "Global projection". The "Global projection" radio button is selected. To the right of the "Global projection" radio button is a "Units:" label followed by a dropdown menu showing "Meters". To the right of the "Global projection" radio button is a "Set Projection..." button. Below these is a text area containing the following text: "Projection name: NAD 1983 StatePlane New Jersey FIPS 2900 (Meters)", "WKT: PROJCS[\"NAD\_1983\_StatePlane\_New\_Jersey\_FIPS\_2900\",GEOGCS[\"GCS\_North\_American\_1983\",DATUM[\"D\_North\_American\_1983\",SPHEROID[\"GRS\_1980\",6378137.0,298.257222101]],PRIMEM[\"Greenwich\",0.0],UNIT[\"Degree\",0.0174532925199433]],PROJECTION[\"Transverse\_Mercator\"],PARAMETER". In the "Vertical" section, there are two labels: "Datum:" and "Units:". The "Datum:" label is followed by a dropdown menu showing "Local". The "Units:" label is followed by a dropdown menu showing "Meters". At the bottom of the dialog are three buttons: "Help...", "OK", and "Cancel".

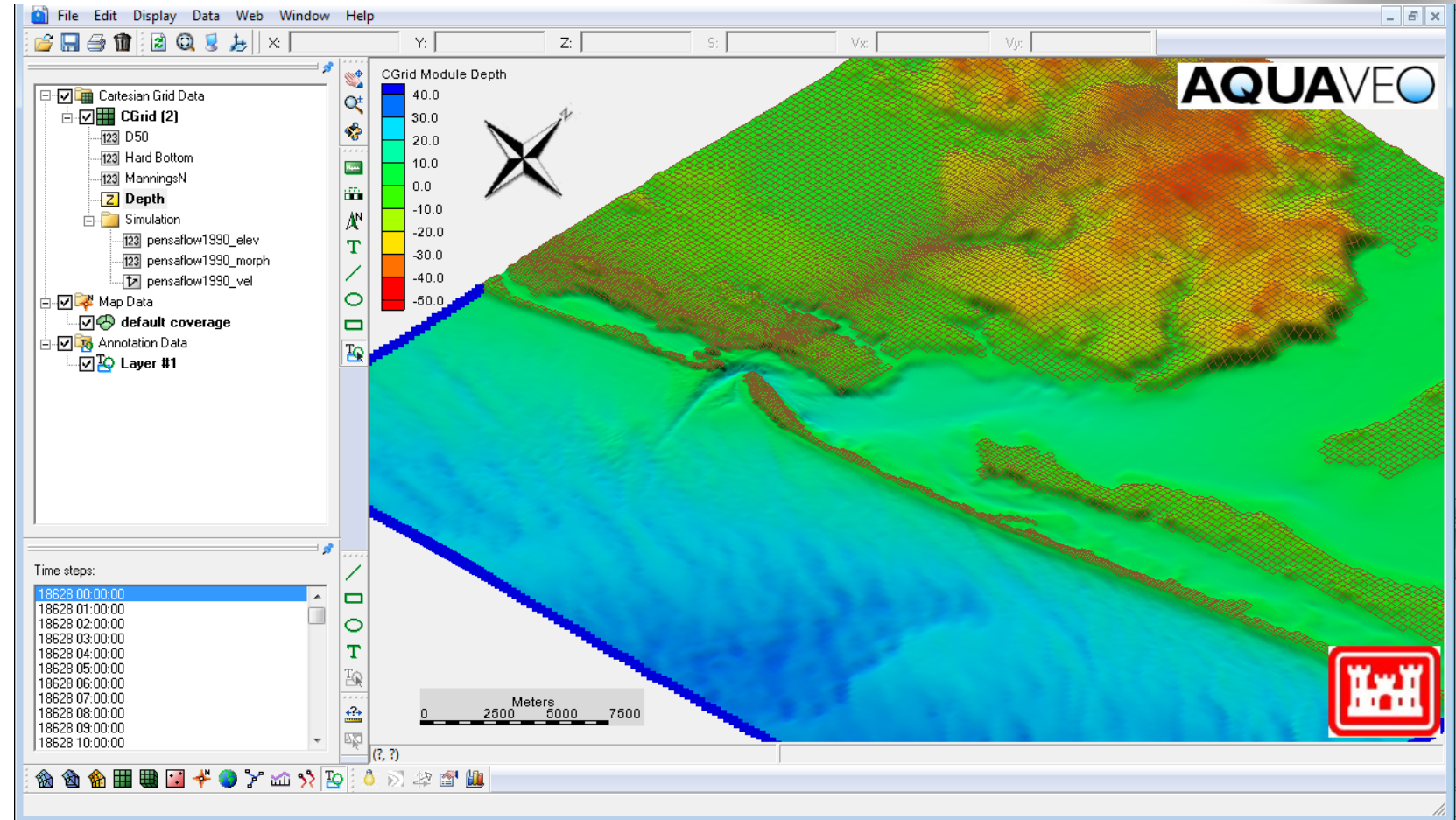
# SMS – Post Processing



- **Annotations**
- **Graphic images**
- **Animations**
  - .avi filmloops
  - .kmz – Google Earth Exports
- **2D Plots**
  - Time series
  - Profiles and Cross sections – both steady state and transient

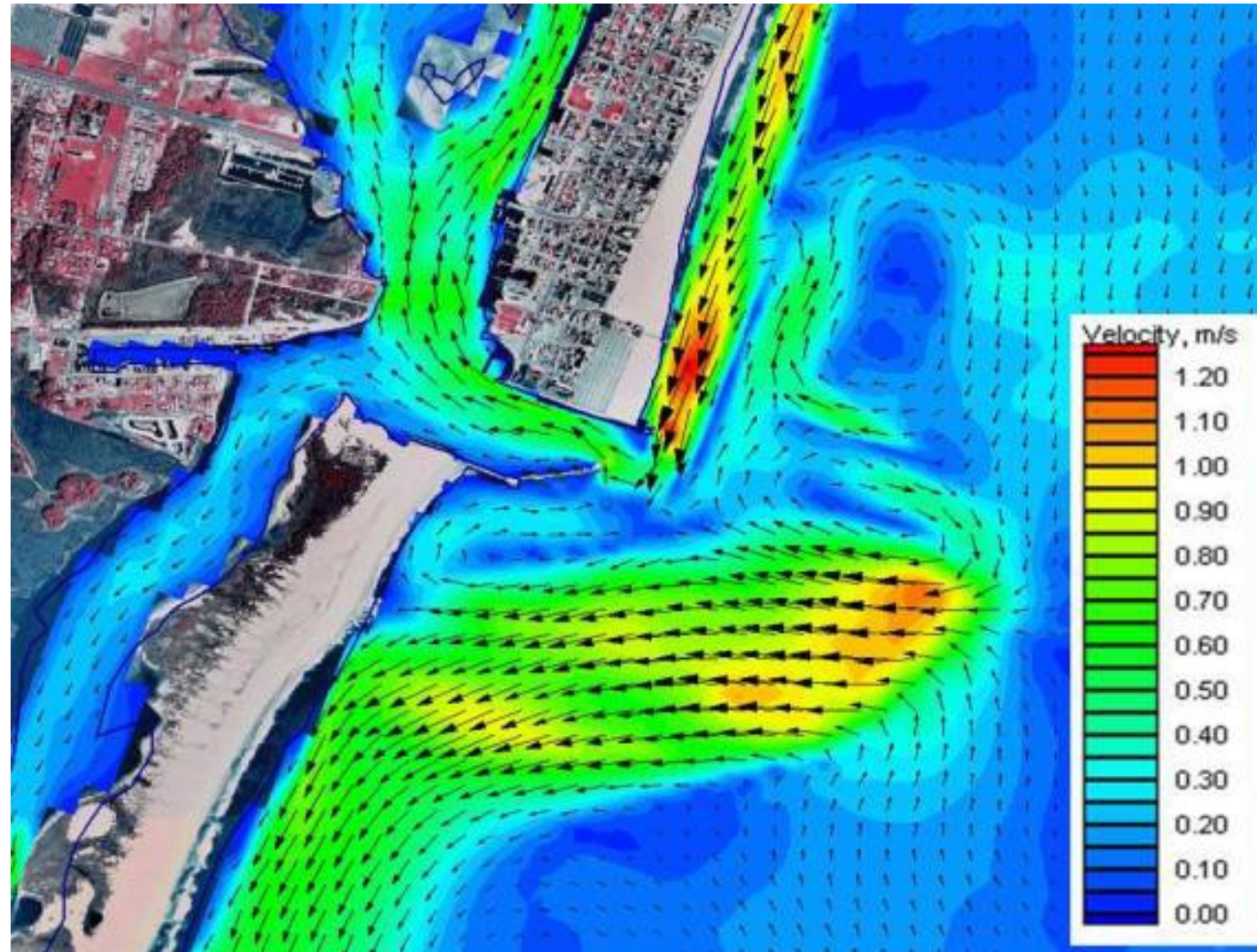
# Annotation Layers

- Replaces Drawing Objects
- New Objects
  - Screen space images (logos)
  - Scale bars
  - North Arrows
- Organizes entities into layers
- Anchored to either world or screen



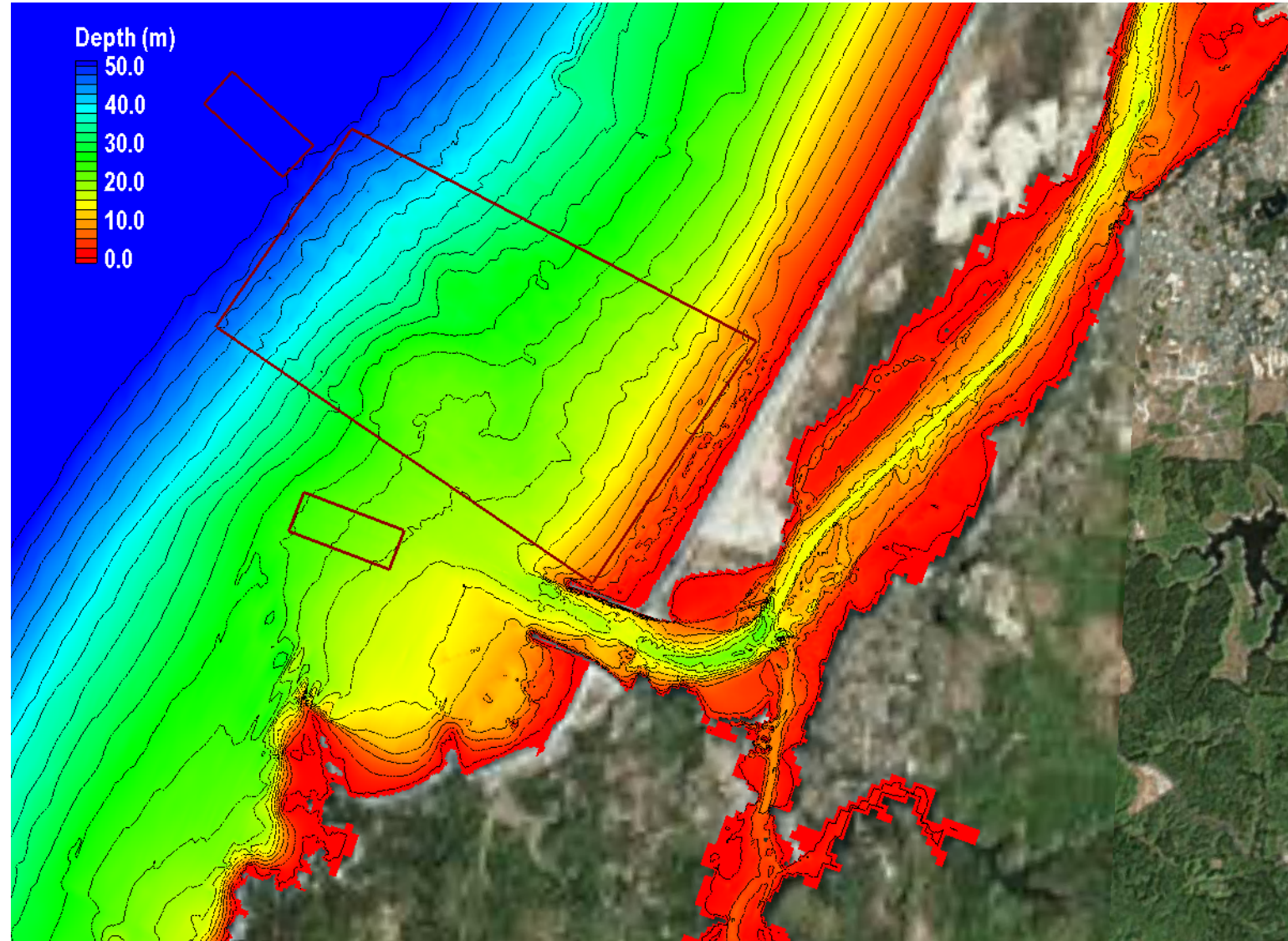


# Contour/Vector Plots





# Google Earth KML Overlay



# Obtaining and Activating SMS



<https://cirp.usace.army.mil/products/SMS.php>

## USACE District and ERDC staff –

Contact [sms@usace.army.mil](mailto:sms@usace.army.mil) and request a password for any version of SMS. If no response in one business day, contact [mitchell.e.brown@usace.army.mil](mailto:mitchell.e.brown@usace.army.mil) to facilitate.

## Others –

Visit [https://www.aquaveo.com/password\\_request](https://www.aquaveo.com/password_request) for a temporary password. Contact Aquaveo sales at [sales@aquaveo.com](mailto:sales@aquaveo.com) or call (801) 302-1400. Request evaluation version from within the SMS registration form.





# Overview of Presentation

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  - What is it?
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- Introduction to the Coastal Modeling System (CMS)
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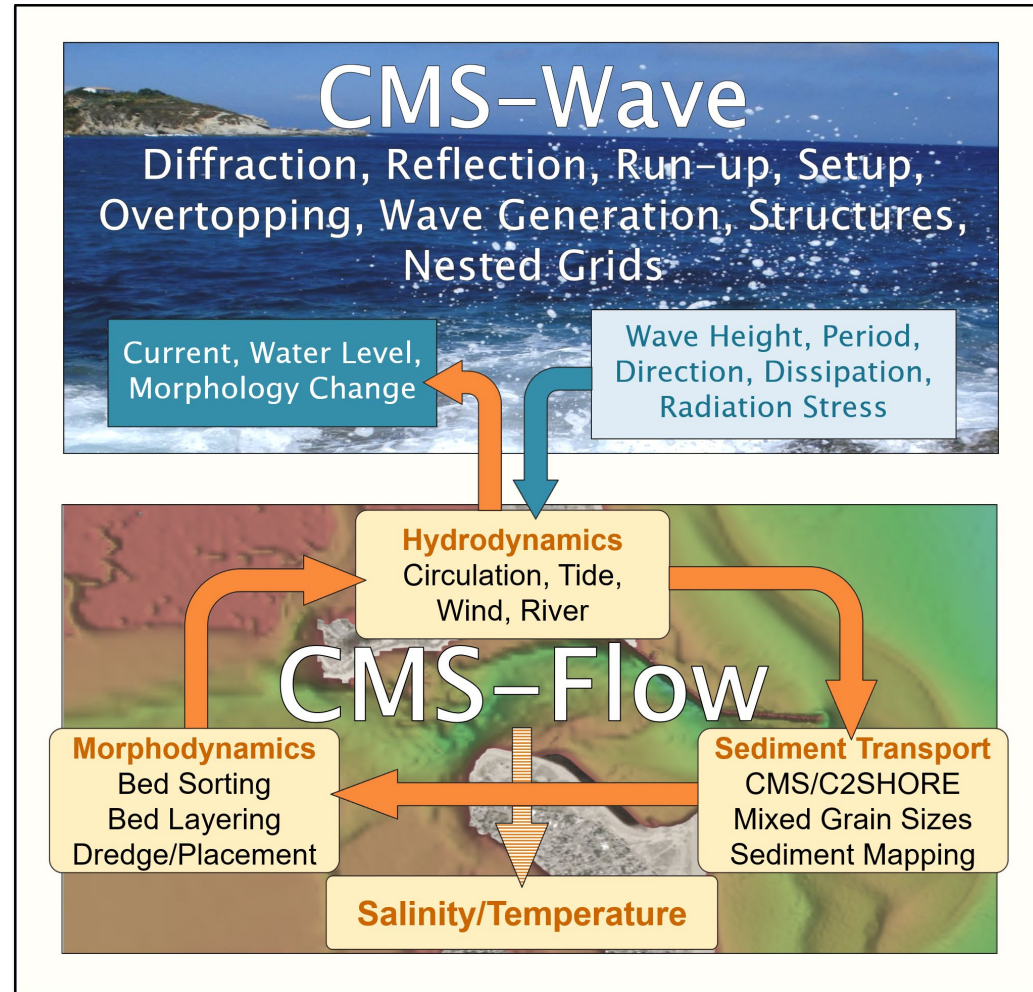
# Objective

**Deliver** to District engineer's desktops **integrated** advanced models that can be used as a **practical** engineering tool for **coastal** shoaling and erosion problems in reduction of O&M costs.

- Integrated: All relevant processes, models efficiently coupled together
- Practical: PC-based, user-friendly interface, fast, robust, and accurate
- Deliver: Manuals, tech reports, journal papers, Wiki, workshops, phone help, etc.



# Coastal Modeling System



CMS Framework

## What is the CMS?

- Integrated wave, current, and morphology change model in the Surface-water Modeling System (SMS).

## Why CMS?

- Operational at ERDC, several Districts and many consulting companies
- Validated with real applications
- Robust and user-friendly
- Easy to set up and fast to get results quickly

## Types of Applications

- **Channels:** Deepening, widening, lengthening, realigning
- **Jetties:** Lengthening, raising, rehabbing
- **O&M:** Placement areas – berms, wetlands
- **Processes:**  
 Navigability – waves and currents;  
 Environmental – circulation and sediment transport



# Coastal Modeling System

## Availability

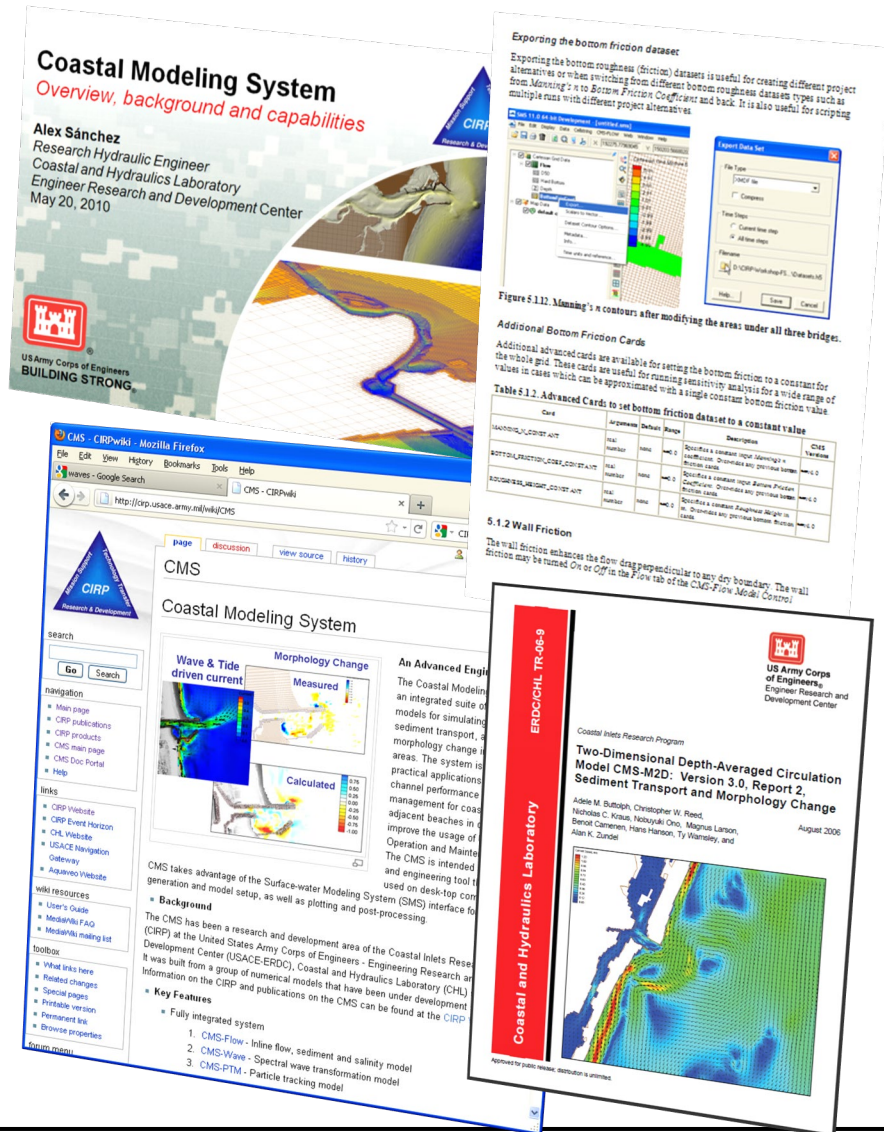
- ▶ Comes with SMS installation package
- ▶ CIRP website (under Products)
- ▶ CMS is **Free** and interface is relatively inexpensive
- ▶ POC's:
  - [Honghai.Li@usace.army.mil](mailto:Honghai.Li@usace.army.mil)
  - [Mitchell.E.Brown@usace.army.mil](mailto:Mitchell.E.Brown@usace.army.mil)
  - [Lihwa.Lin@usace.army.mil](mailto:Lihwa.Lin@usace.army.mil)

## Documentation

- ▶ Several TR's, CHETN's and journal papers
  - <https://cirp.usace.army.mil/pubs/>
- ▶ CIRP Wiki
  - <https://cirpwiki.info/wiki/CMS>
- ▶ New User's Guide will be available in early FY23

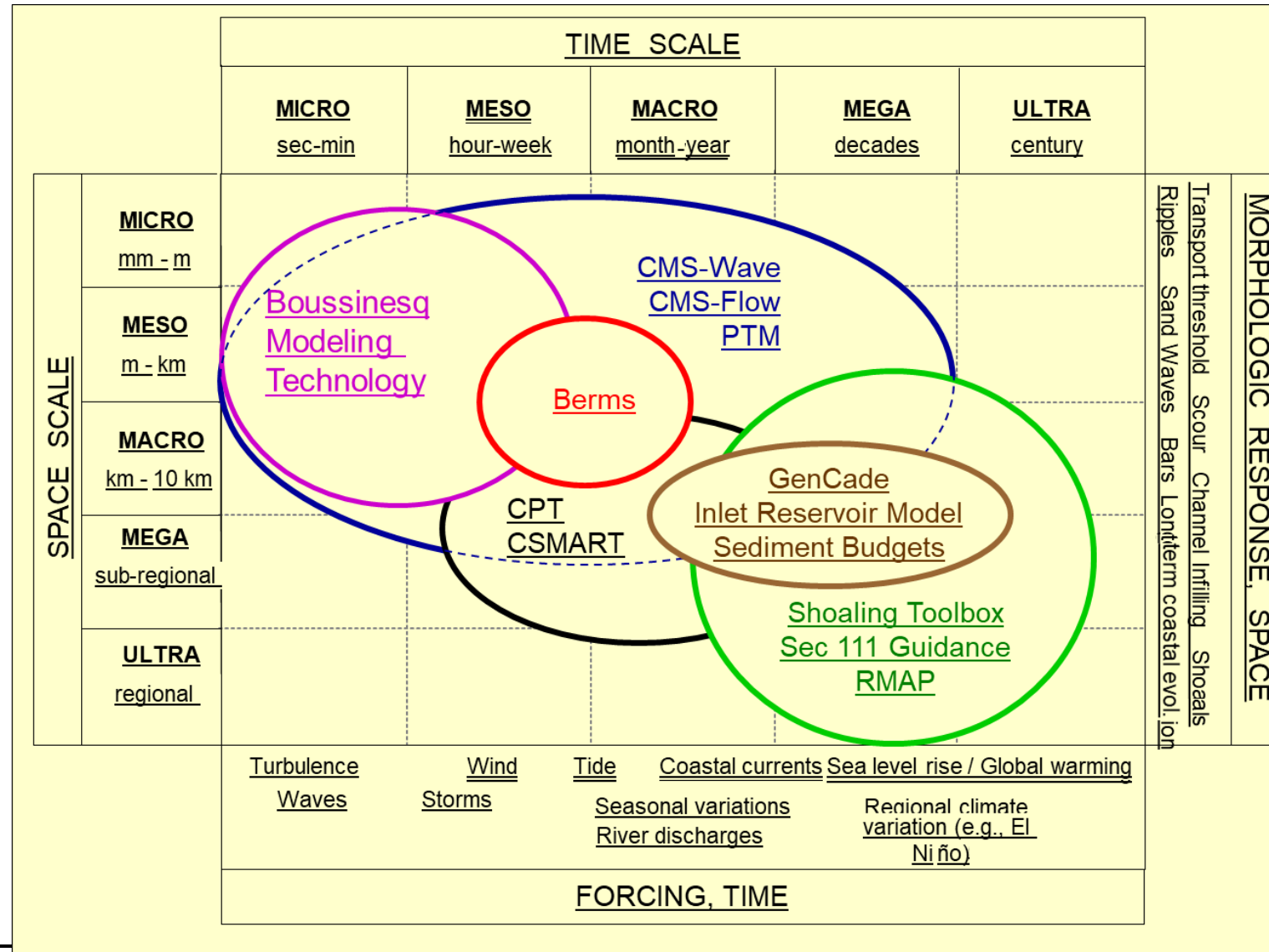
## Training and Support

- ▶ Many annual and individual workshops and webinar series
- ▶ CMS instructional webinars and videos on CIRP website





# Scales of Coverage



# CMS-Flow: Key Features

## Finite Volume Method

- Conserves mass
- Stable

## Inline sediment transport and morphology change

- Non-equilibrium total load
- Multiple-sized transport
- Bed sorting and layering

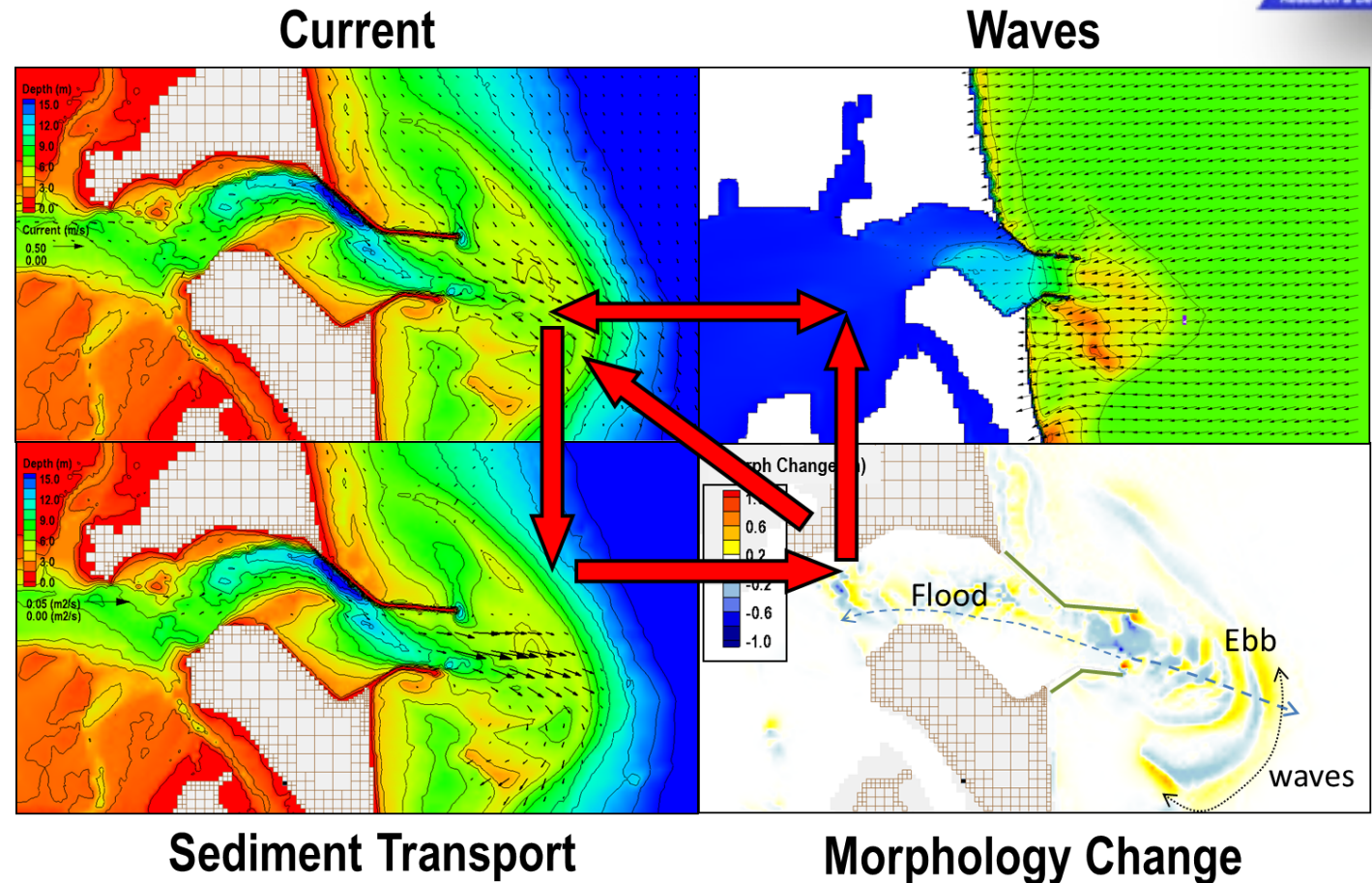
## Inline CMS-Wave model

- Wave-current interactions

## Nesting capability

## Forcing

- Tidal constituents or water level, river flux, wind, atmospheric pressure, waves, etc.





# CMS-Flow: Key Features

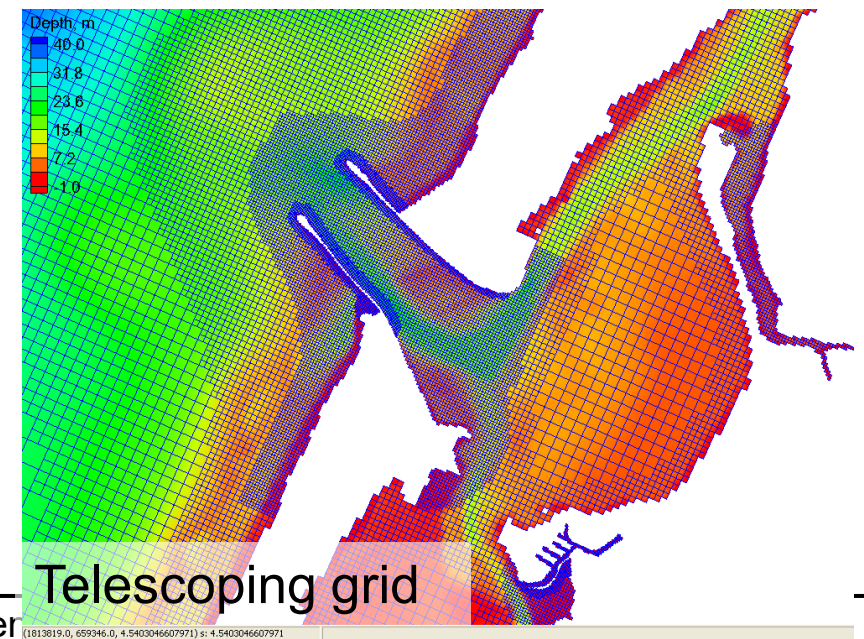
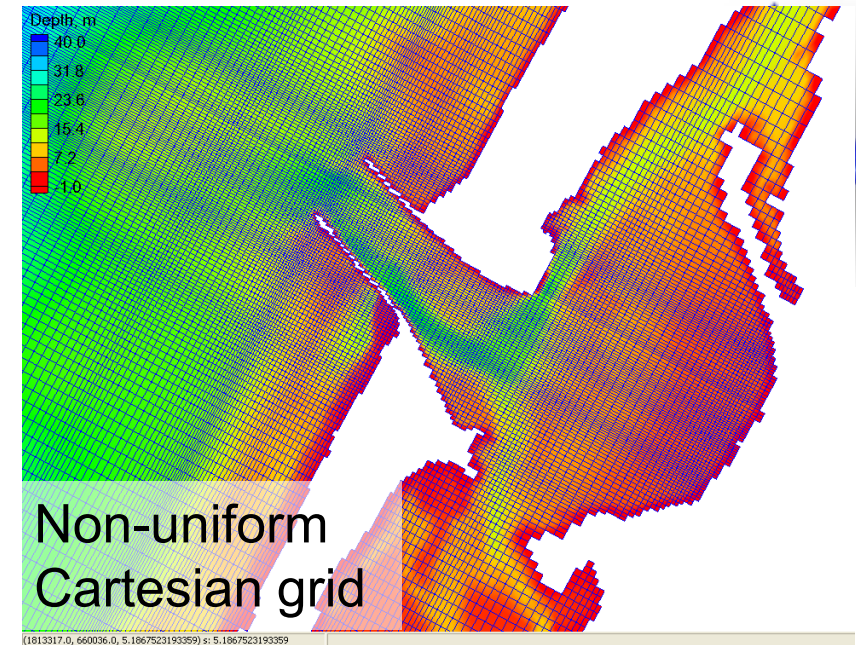
## Grid type

- Non-uniform Cartesian grid: Easy to setup
- Telescoping grid: Efficient, easy, flexible

## Solver options

- Implicit: Tidal flow, long-term morphology change:  
10+ **minute** time step
- Explicit: Flooding, breaching, super-critical flow:  
~ 1 **second** time step

Increased efficiency using multiple processors/threads.





# Overview of Governing Equations

## Hydrodynamics

- Conservative form of depth-averaged shallow water equations.
- Includes Coriolis, wave and wind forcing, bottom and wave friction, and turbulent diffusion

## Sediment

- Non-Equilibrium (AD Total Load)
- Equilibrium Total Load (Exner equation)
- Eq. Bed Load + Advection-Diffusion Suspended Load

## Salinity (simple)

- Advection-Diffusion equation
- **No density effects for sediment transport.**

## Waves

- Wave-action balance equation with diffraction



# Hydrodynamics

## Conservative form of the depth-averaged shallow water equations in Cartesian coordinates

$$\frac{\partial h}{\partial t} + \frac{\partial(hU_j)}{\partial x_j} = S, \quad j = 1, 2 \quad h = \zeta + \eta$$

$$\frac{\partial(hU_i)}{\partial t} + \frac{\partial(hU_iU_j)}{\partial x_j} - \varepsilon_{ij3}f_c hU_j = -gh \frac{\partial \eta}{\partial x_j} + \frac{\partial}{\partial x_j} \left( \nu_t h \frac{\partial U_i}{\partial x_j} \right) + \frac{1}{\rho} (\tau_{Si} + \tau_{wi} - \tau_{bi})$$

Depth - averaged current velocity

Total water depth

Still water depth

Water surface elevation

Gravity

Atmospheric Pressure

Precipitation / Evaporation

Coriolis

Turbulent eddy viscosity

Bottom stress (including waves)

Wave stress (forcing)

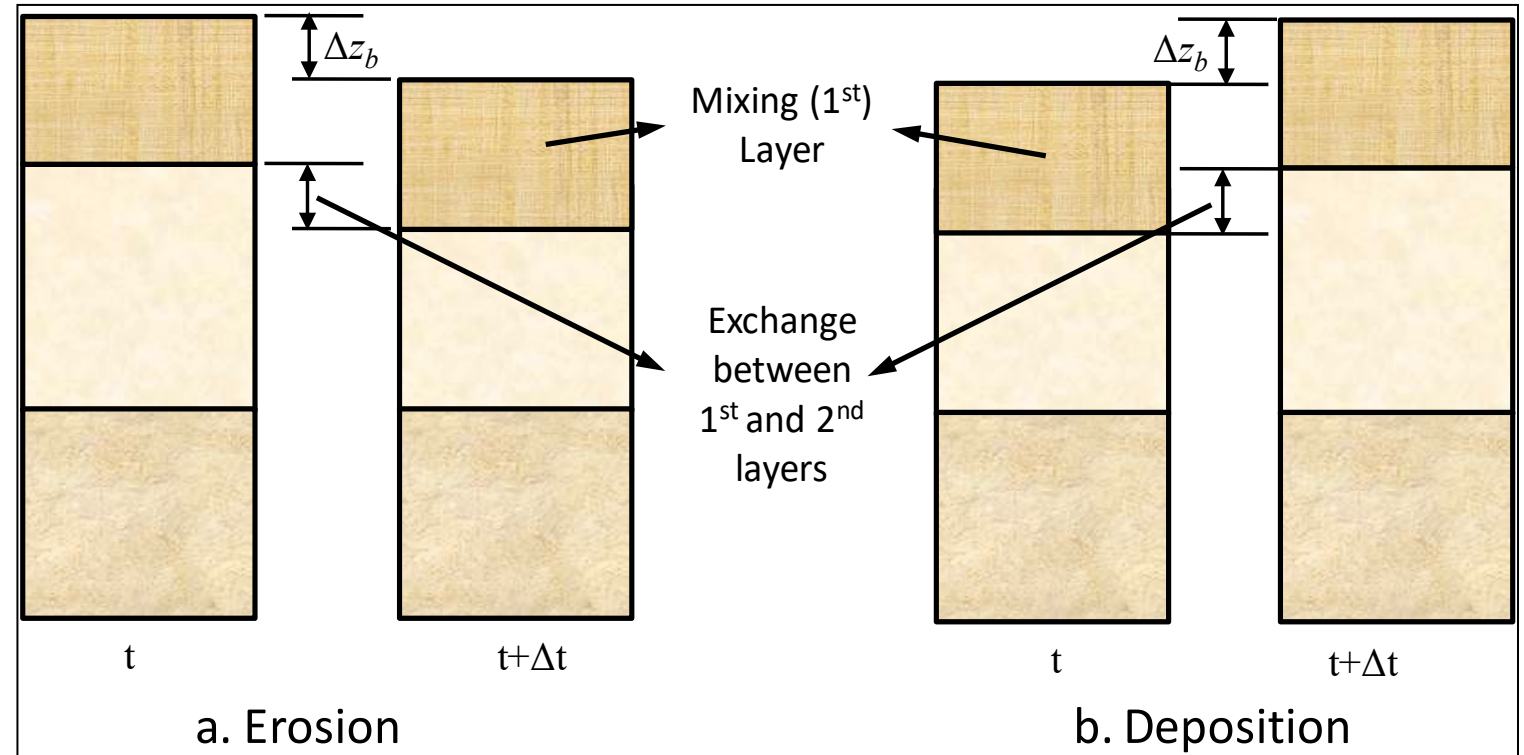
Wind stress



# Sediment Transport: Multiple Size Classes

## Bed Sorting and Gradation

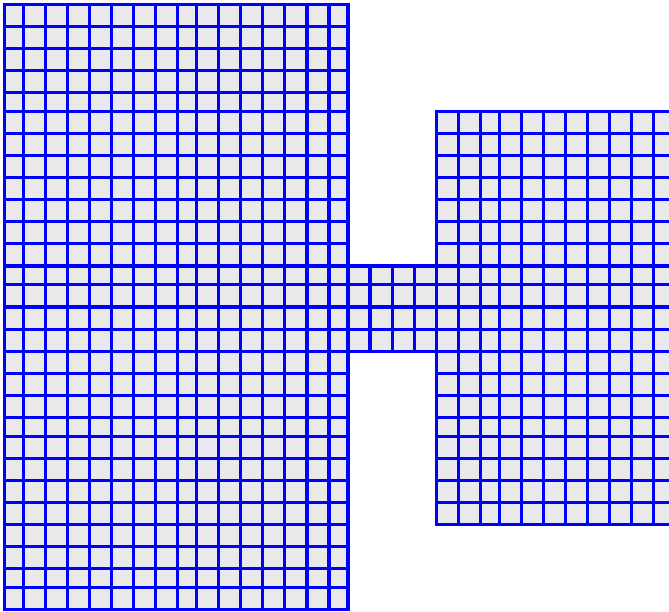
- First layer  
(active or mixing layer)
- Second layer
- Thickness of first layer determined based on bed characteristics
- Fixed number of layers
- Layers merge and split
  - Min and max layer thickness



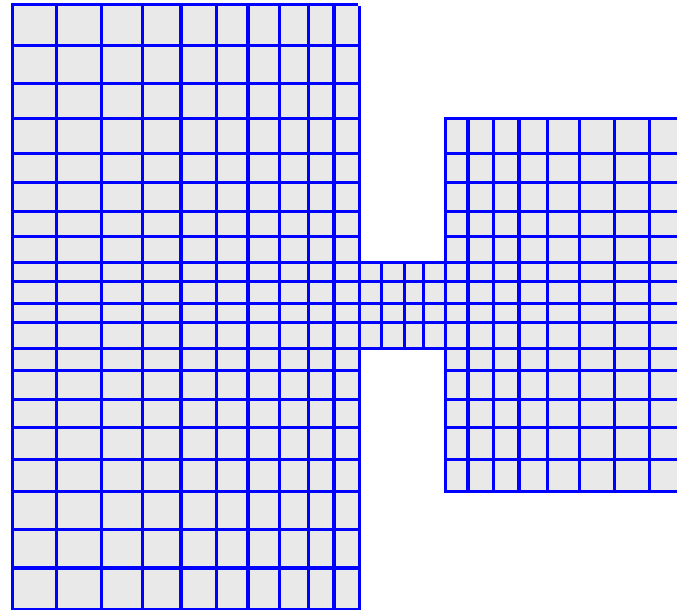
# Grid Options in the Surface-water Modeling System



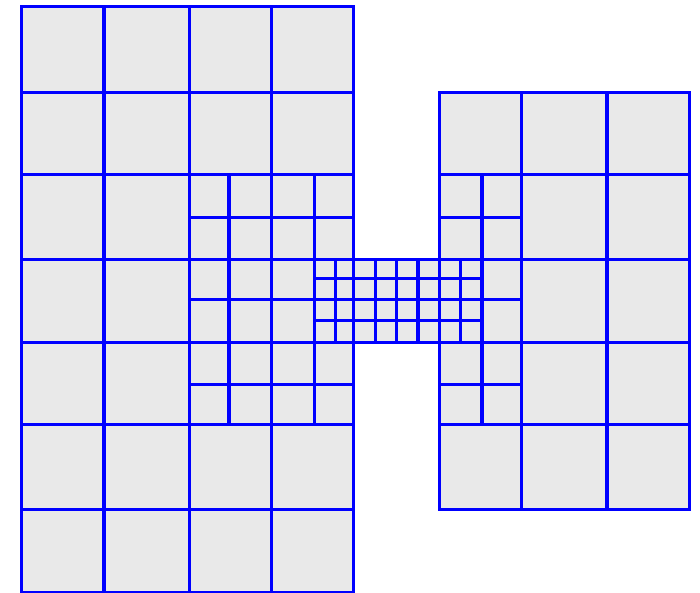
Regular Cartesian  
(squares)



Nonuniform Cartesian  
(rectangles)



Telescoping / Quadtree  
(non-conforming squares)



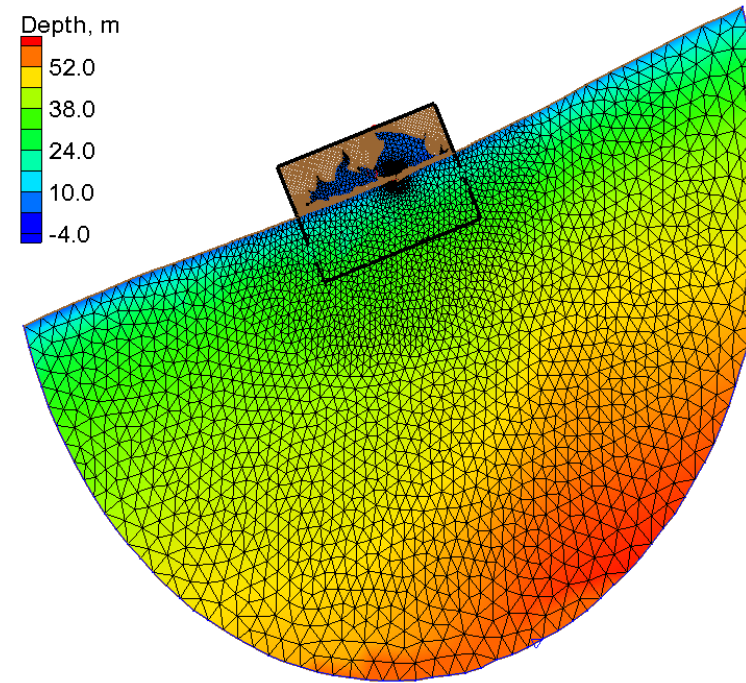
# Forcing and Boundary Conditions

## Forcing

- Spatially constant and variable wind fields
- Atmospheric pressure gradients
- Wave and roller stresses

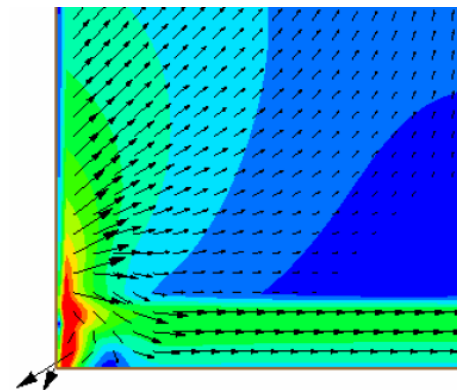
## Boundary Conditions (BC)

- Closed (wall) BC
- River Flux BC
- Water level time series
- One-way nesting
- Tidal database boundary extraction
- Wind and wave-adjusted water level boundary conditions

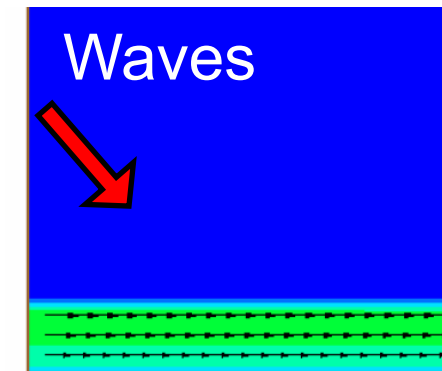


Nested –  
forcing from  
within other  
models

Non-adjusted BC



Adjusted BC

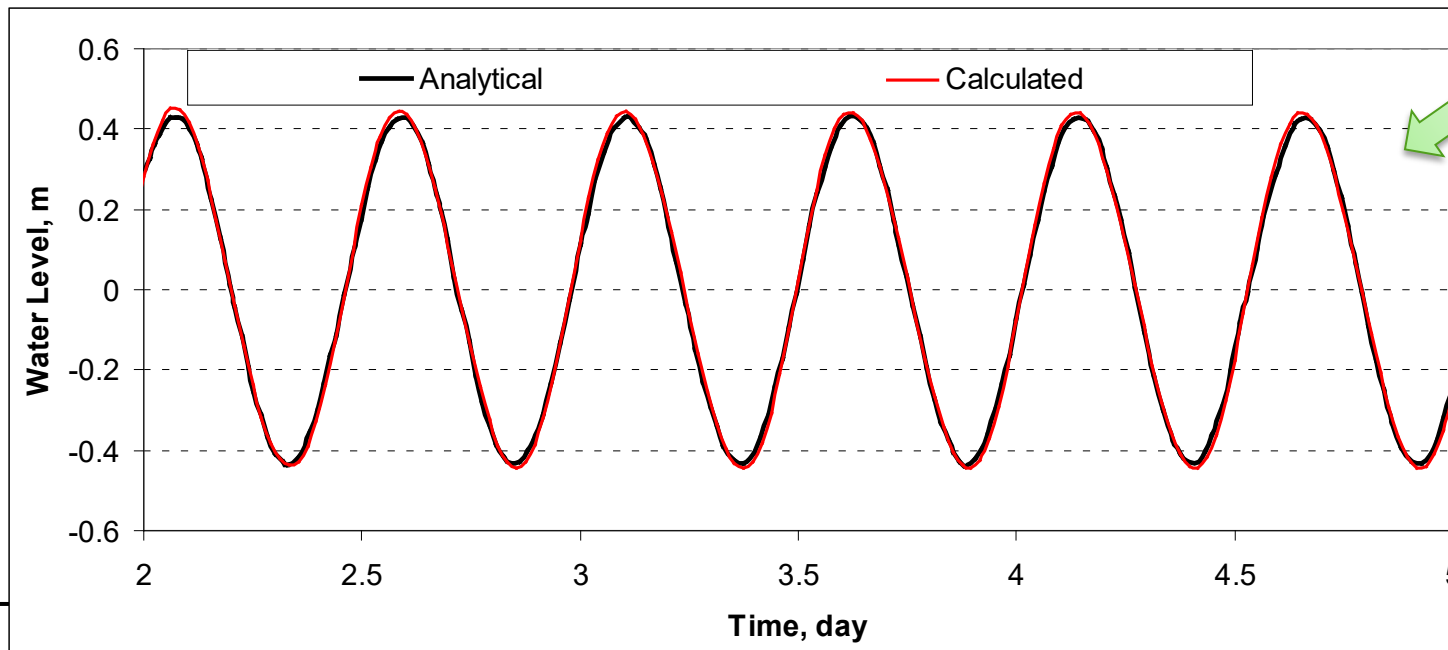
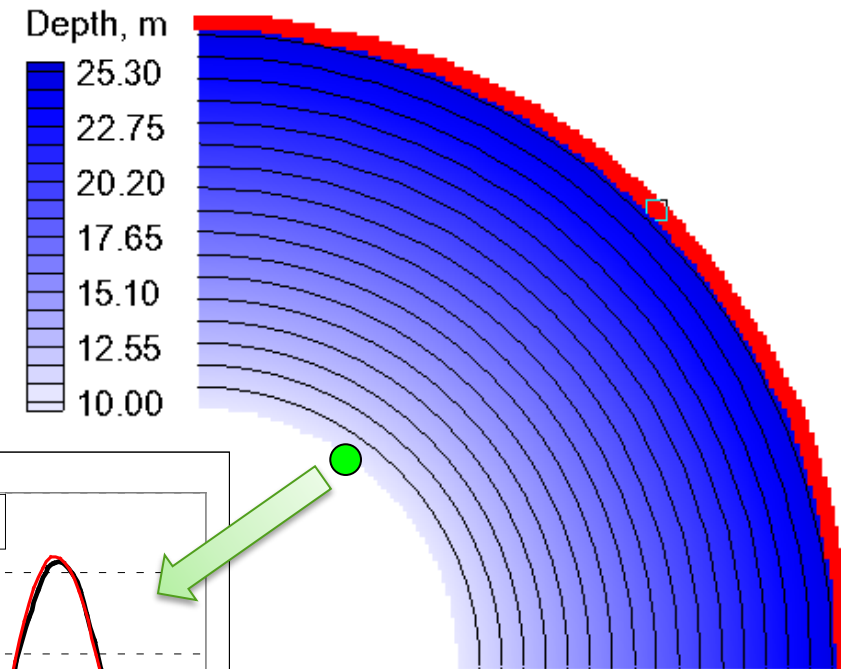




# Validation: Tidal propagation

- M2 Tide
- No Bottom friction
- No viscosity
- Time step: 10 min

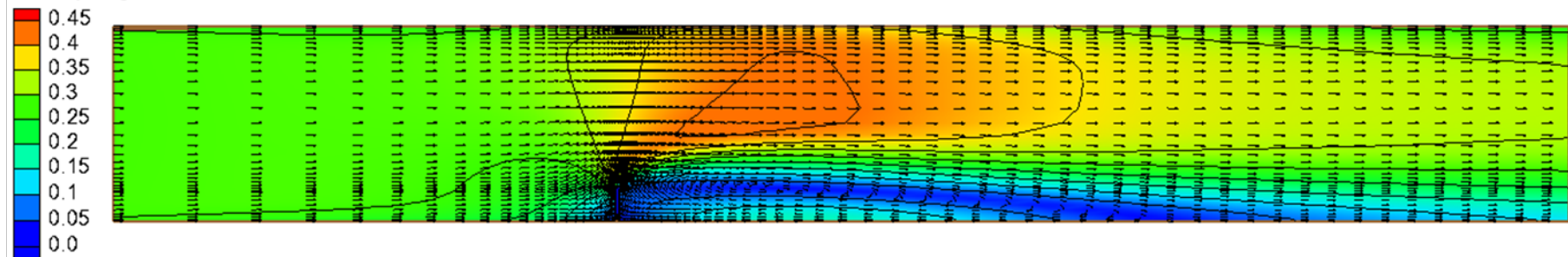
Quarter Annulus  
Analytical solution



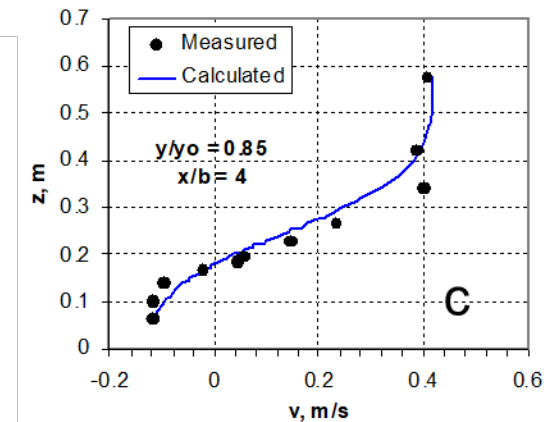
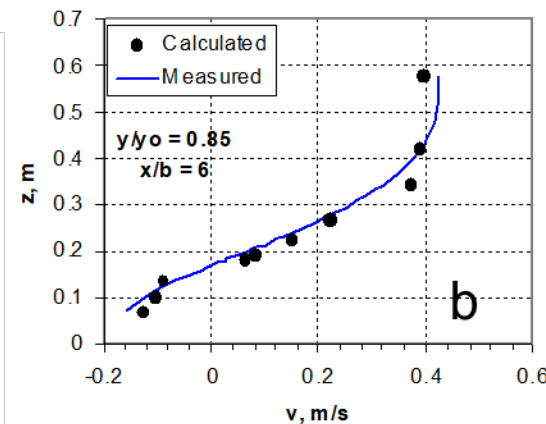
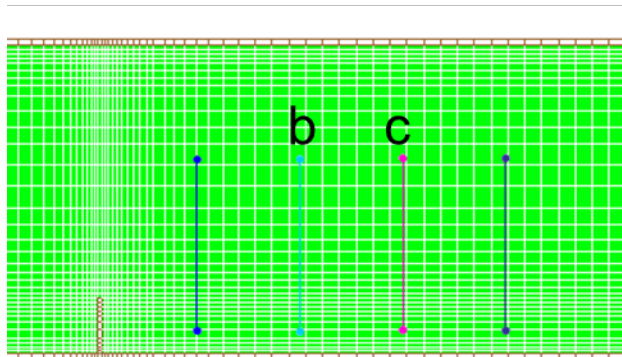
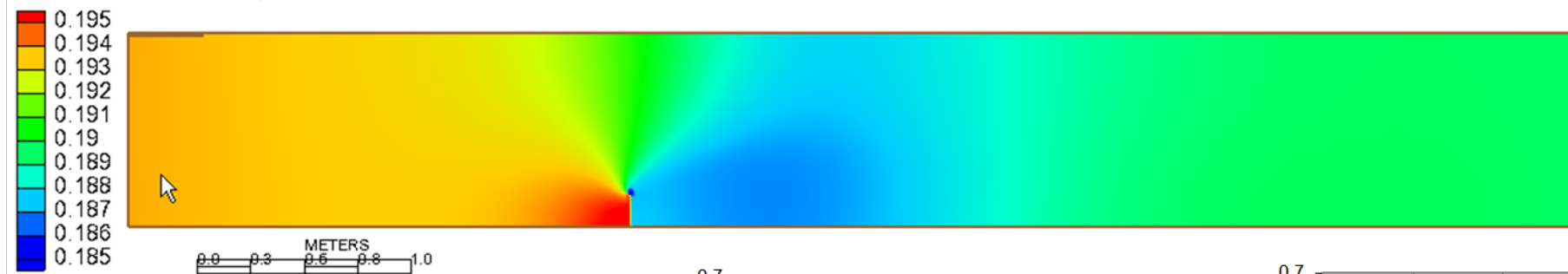
ter •

# Validation: Spur dike case

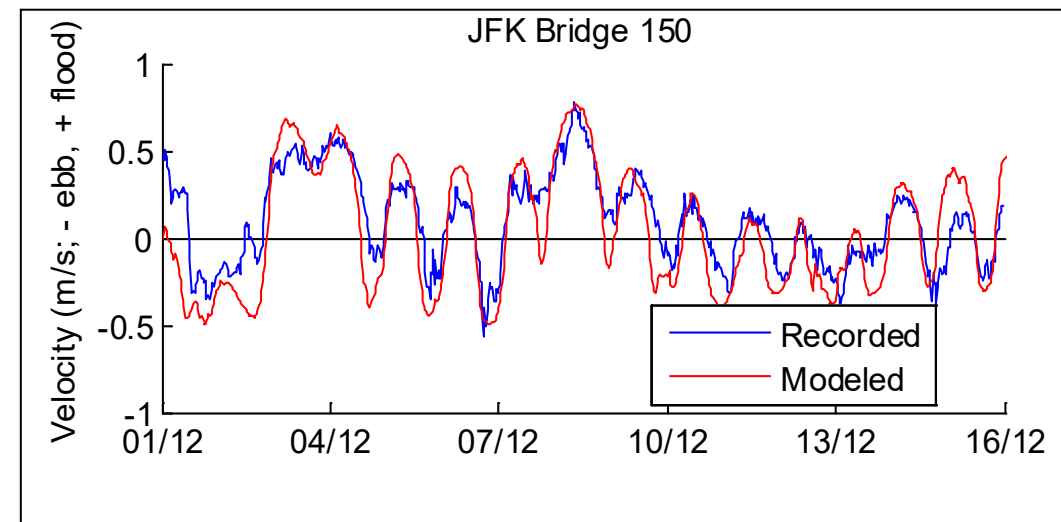
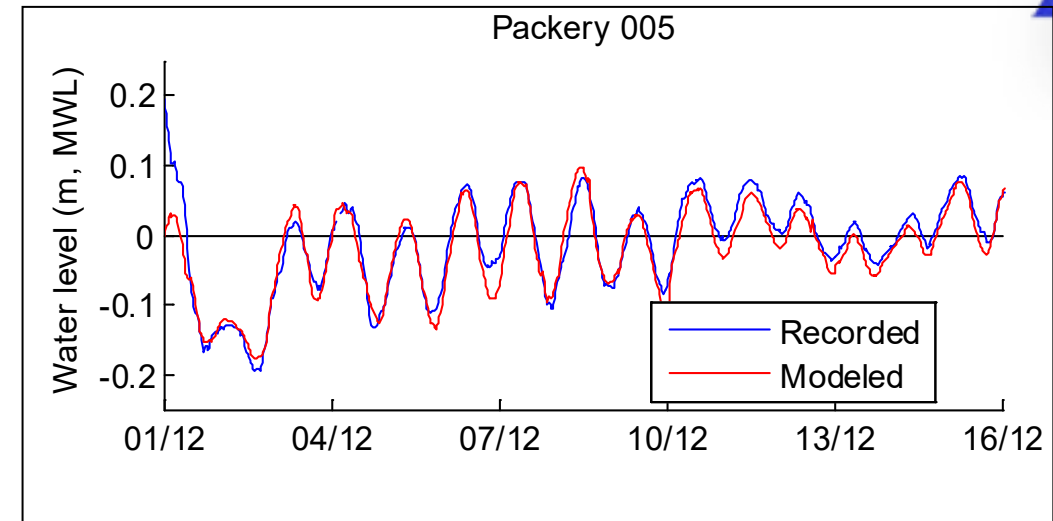
Velocity Magnitude, m/sec



Water Surface Elevation, m



# Validation: Packery Channel, TX

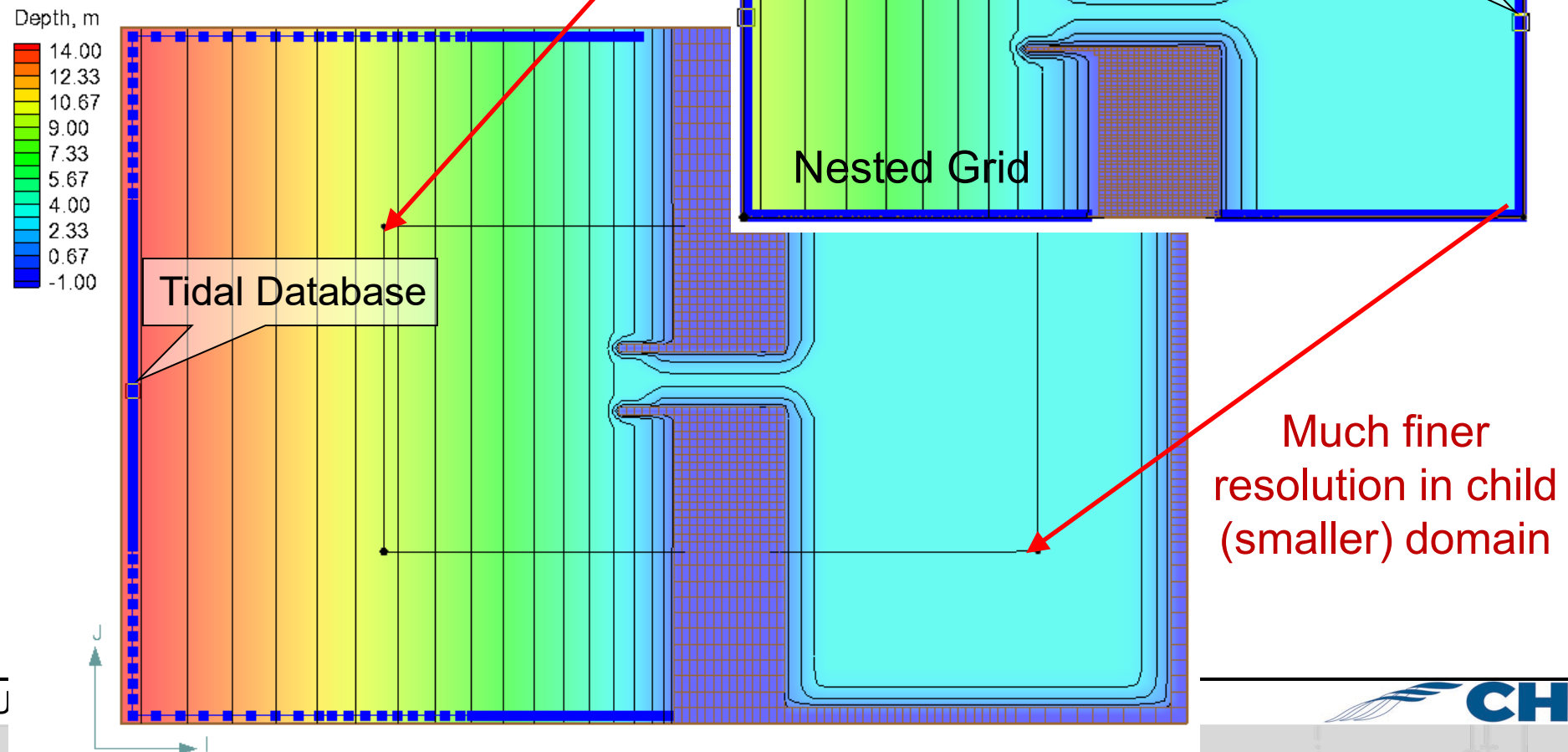




# Validation: Nested Grid Capability

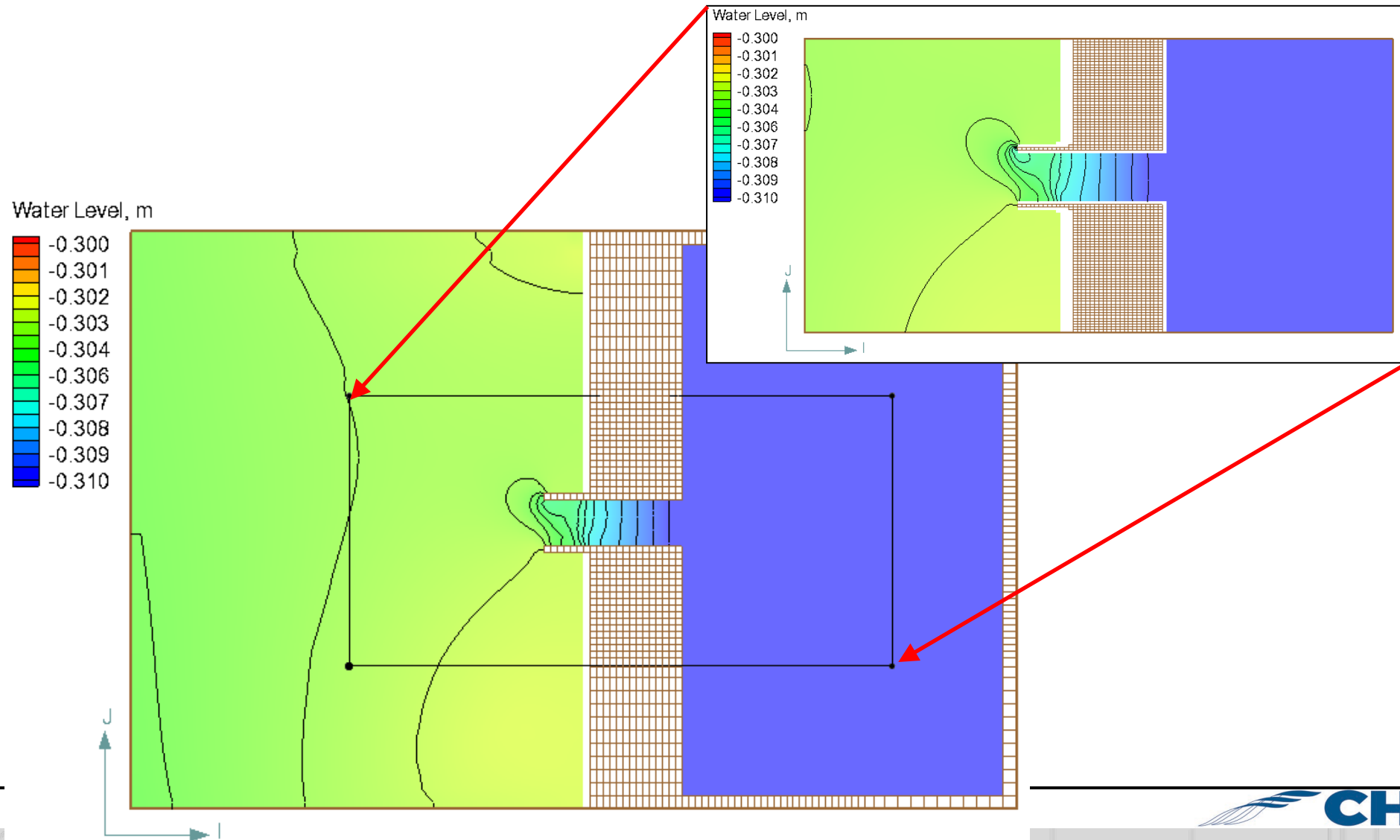
Can obtain forcing information from:

- Larger domain (CMS, ADCIRC)
- Tidal Constituent Databases  
(LeProvost, ADCIRC Atlantic & Pacific, others)



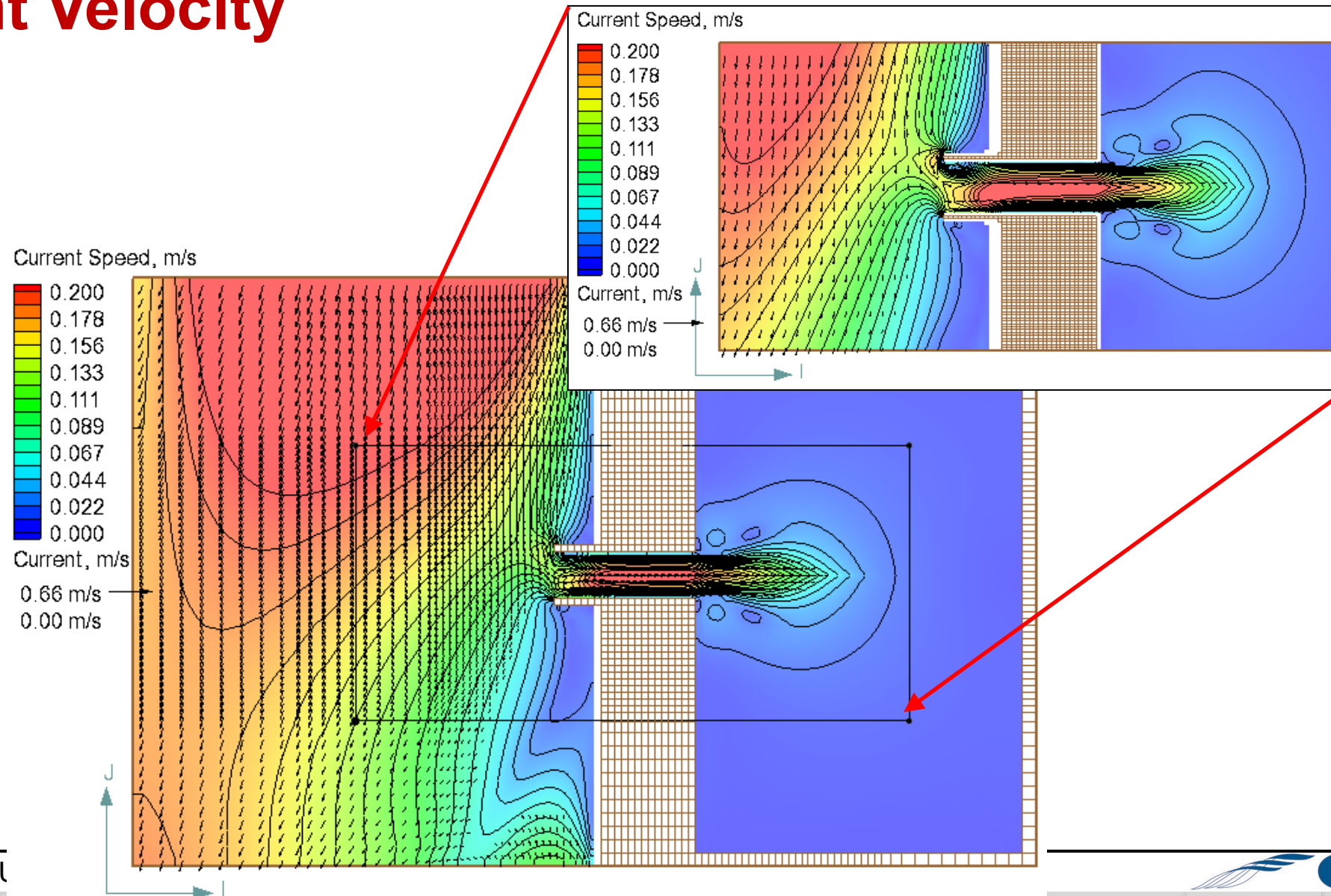
# Validation: Nested Grid Capability

## Water Elevation



# Validation: Nested Grid Capability

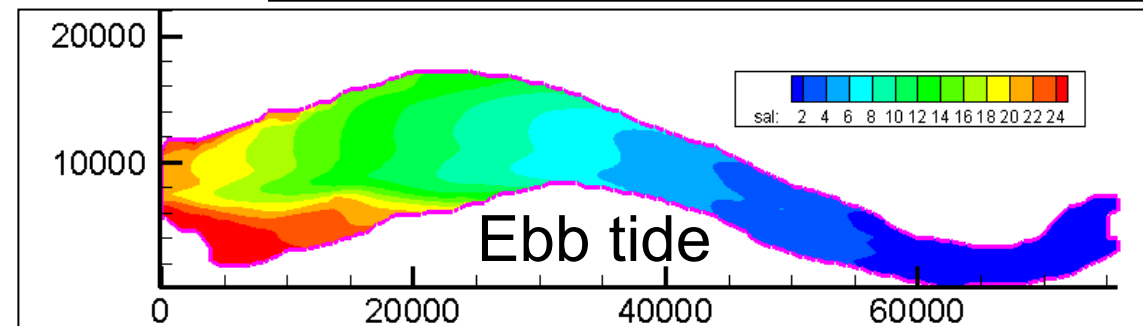
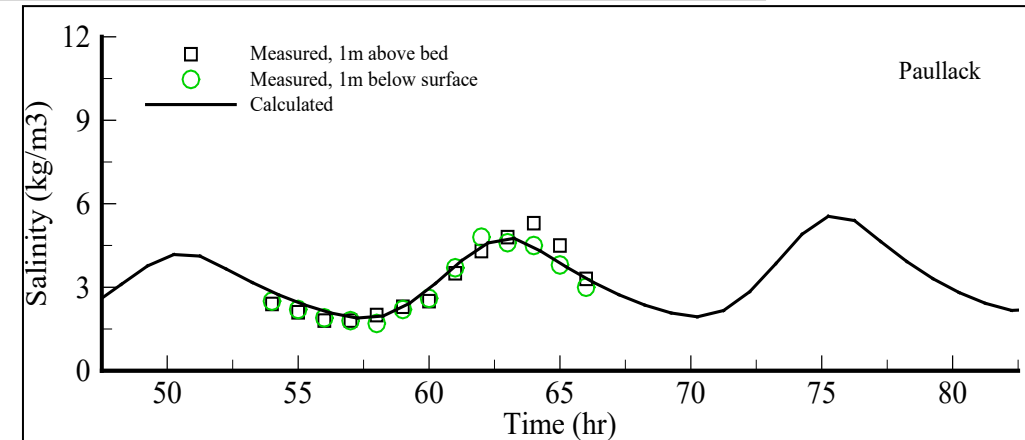
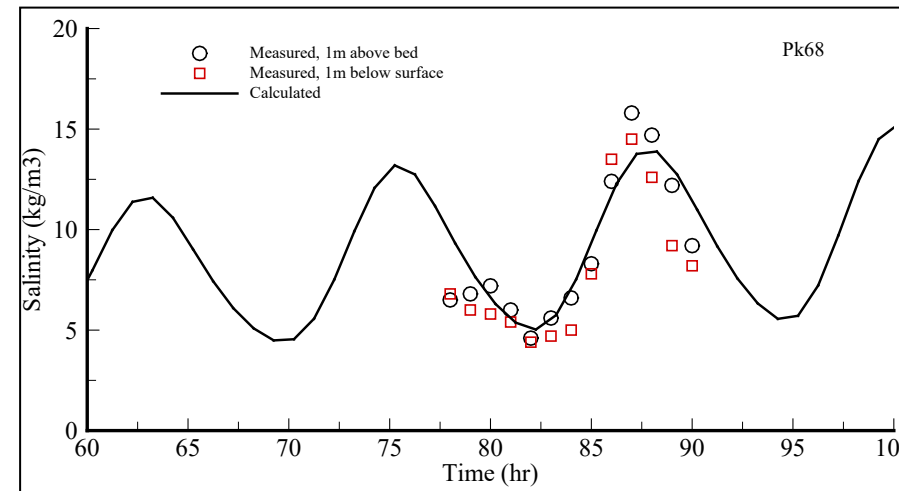
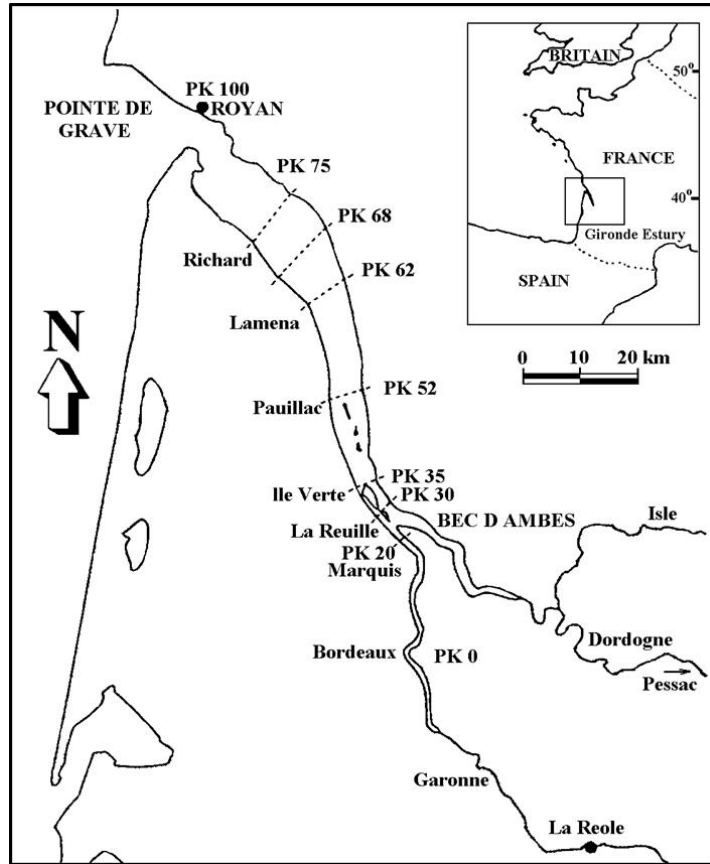
## Current Velocity





# Validation: 2D Salinity Gironde Estuary, FR

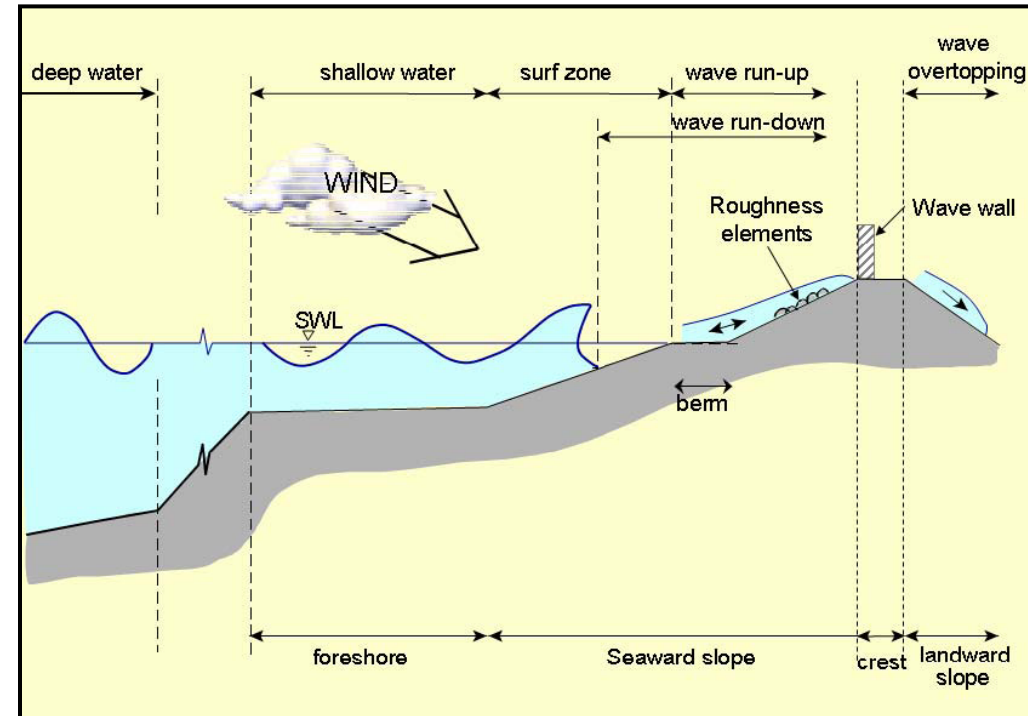
UNCLASSIFIED



UNCLASSIFIED

# CMS-Wave : Key Features

- Shoaling, refraction, diffraction, reflection
- Bottom friction
- White capping
- Wave breaking (4 options)
- Wind generation
- Wave-current, and wave-wave interactions
- Transmission, runup, and overtopping
- Muddy bottom
- Automatic grid rotation
- Non-uniform Cartesian grid with nesting capability
- Simplified Formulation “Fast Mode” for non-production runs
  - Reduces run time between 5-7x



# CMS-Wave: Governing Equation

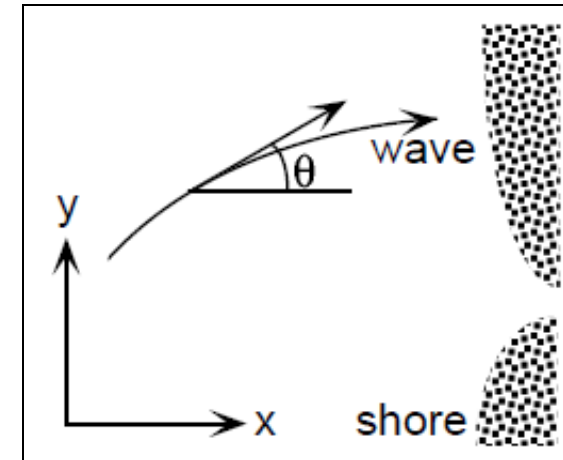
## Wave-Action Balance Equation with Diffraction

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

↖ Diffraction intensity factor

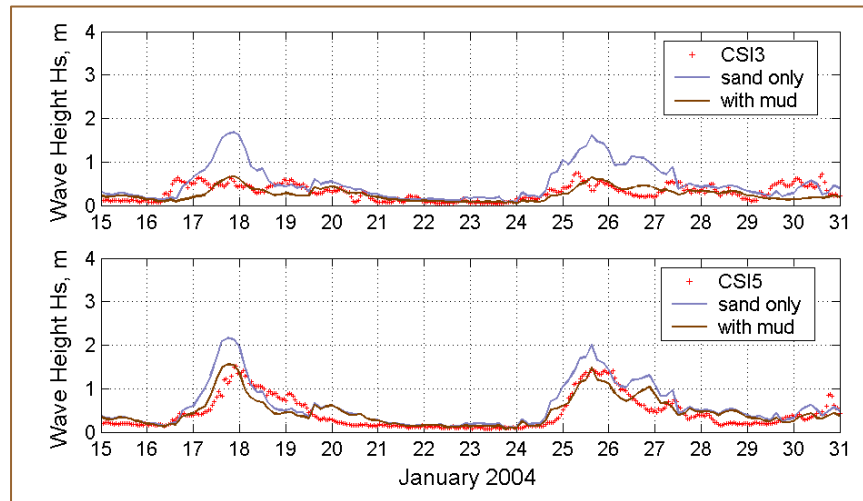
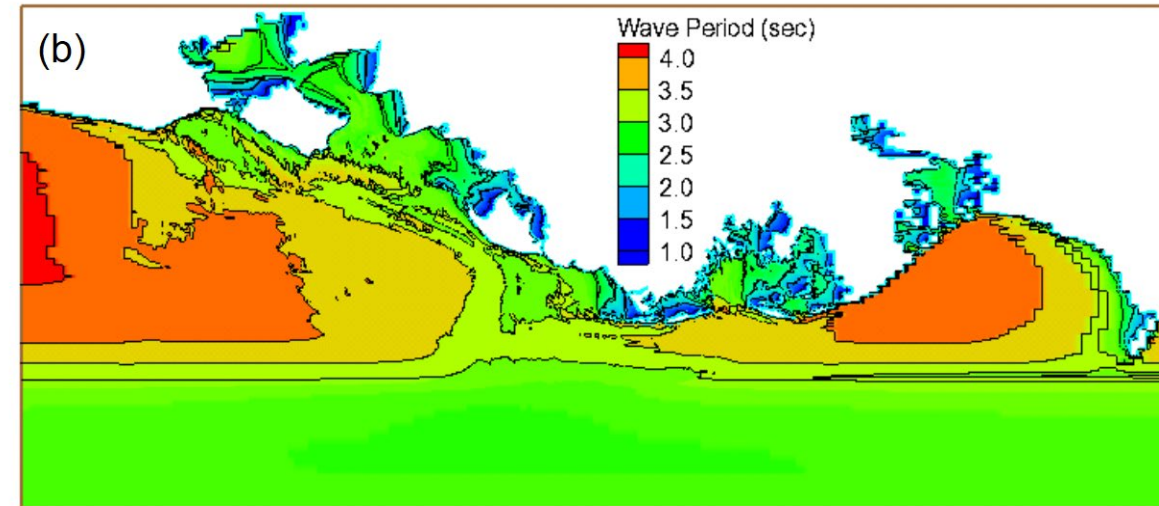
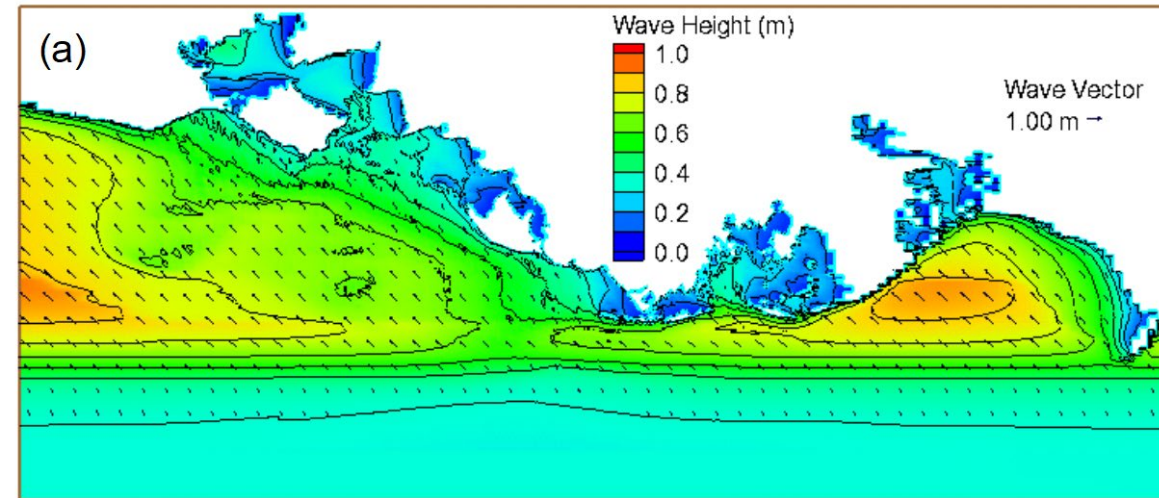
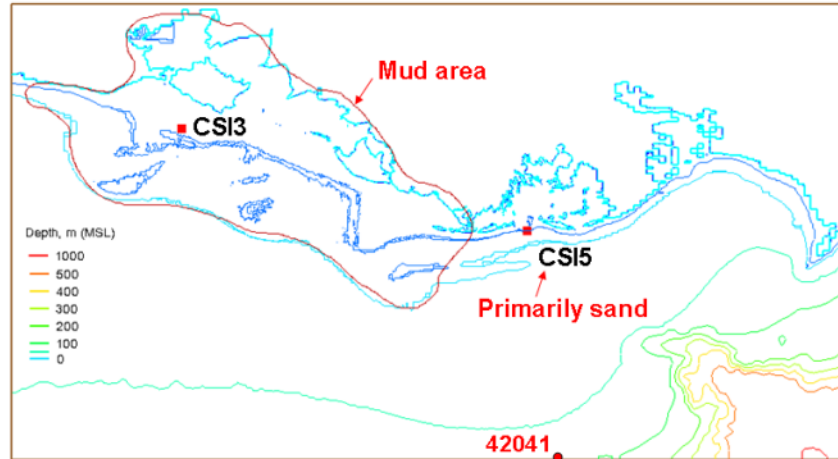
where  $A = E / \sigma$  , wave-action spectrum  
and  $E = E(\sigma, \theta)$  , wave directional spectrum

Note:  $x$  is normal to the  
offshore boundary;  
 $y$  is parallel to the  
offshore boundary

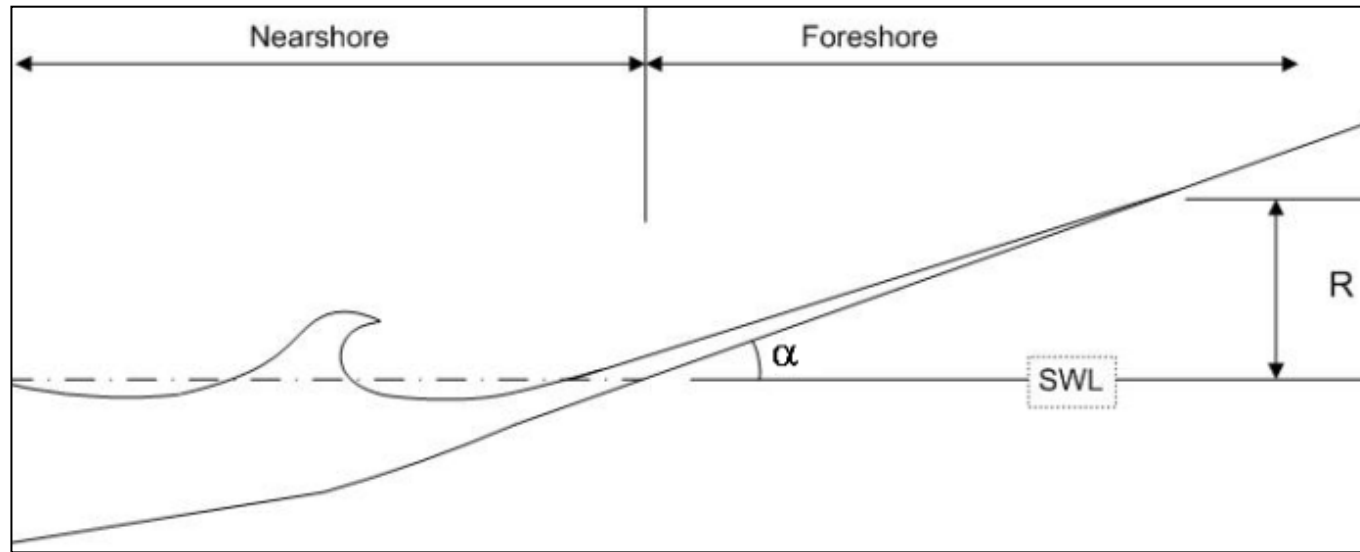




# Validation: Louisiana Muddy Coast

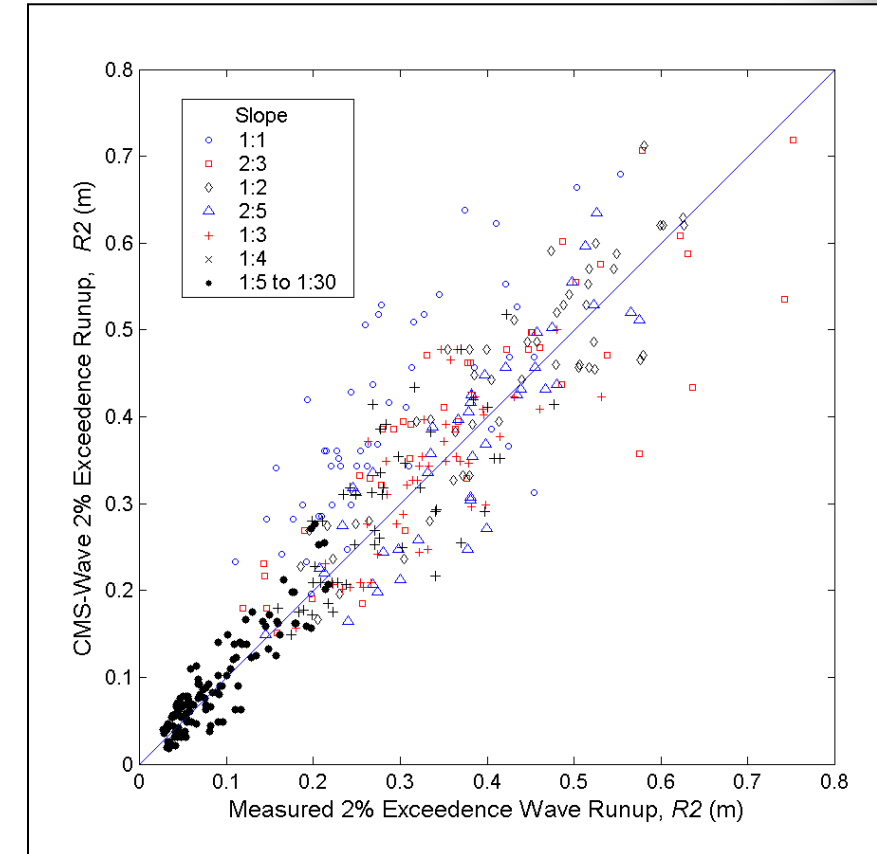


# Validation: Wave Run-up



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

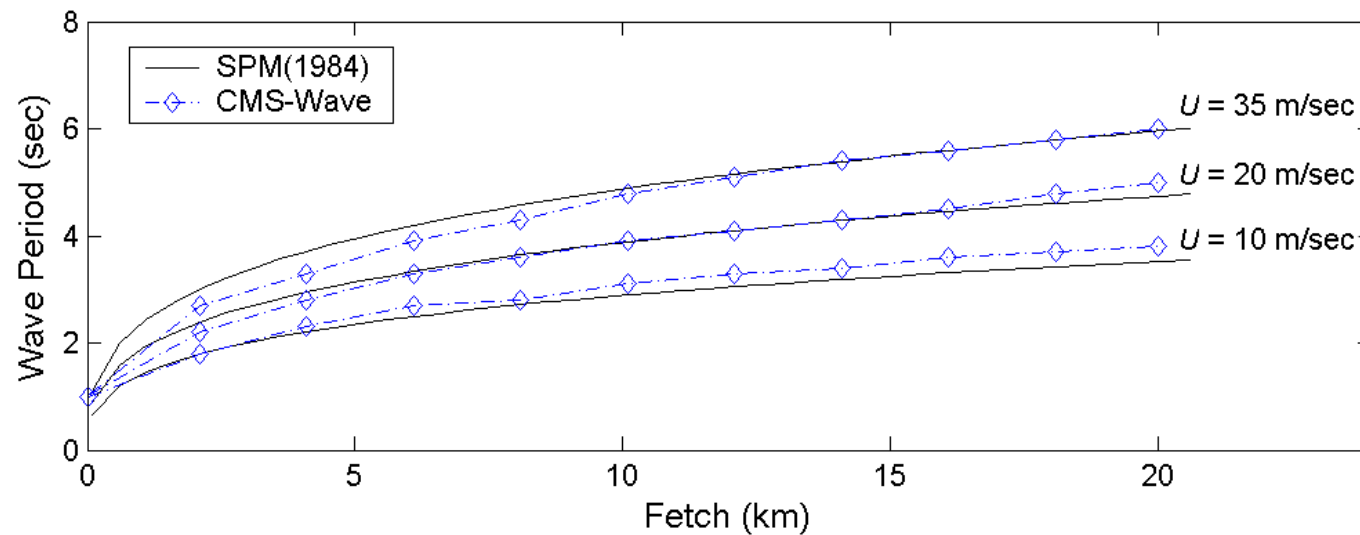
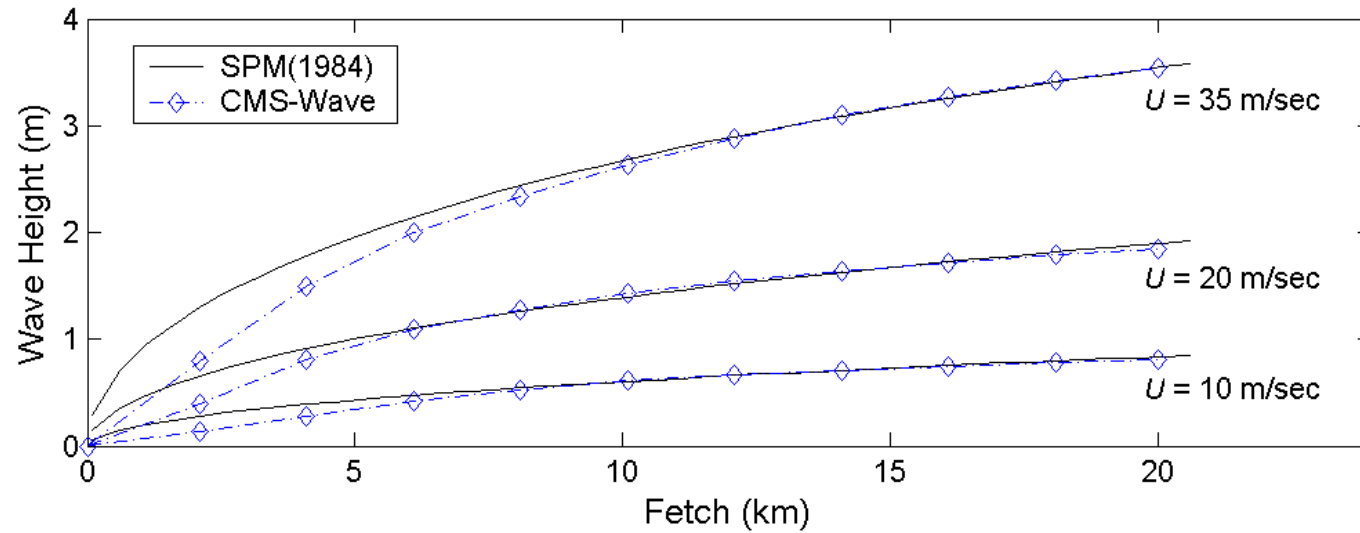
**Two-percent run-up,  $R_2$  : the vertical up-rush level exceeded by 2-percent of the larger run-up height**



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

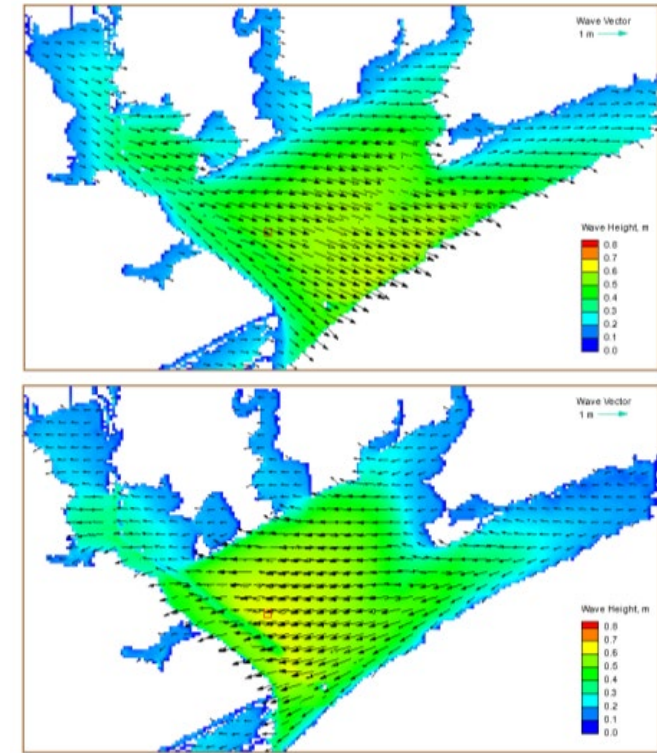
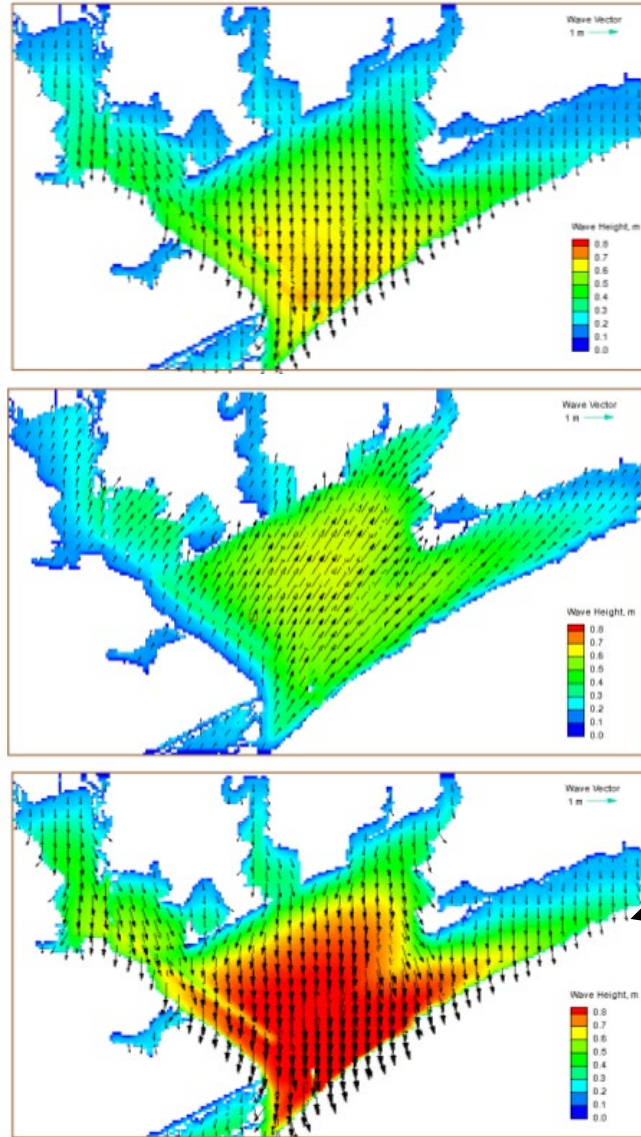
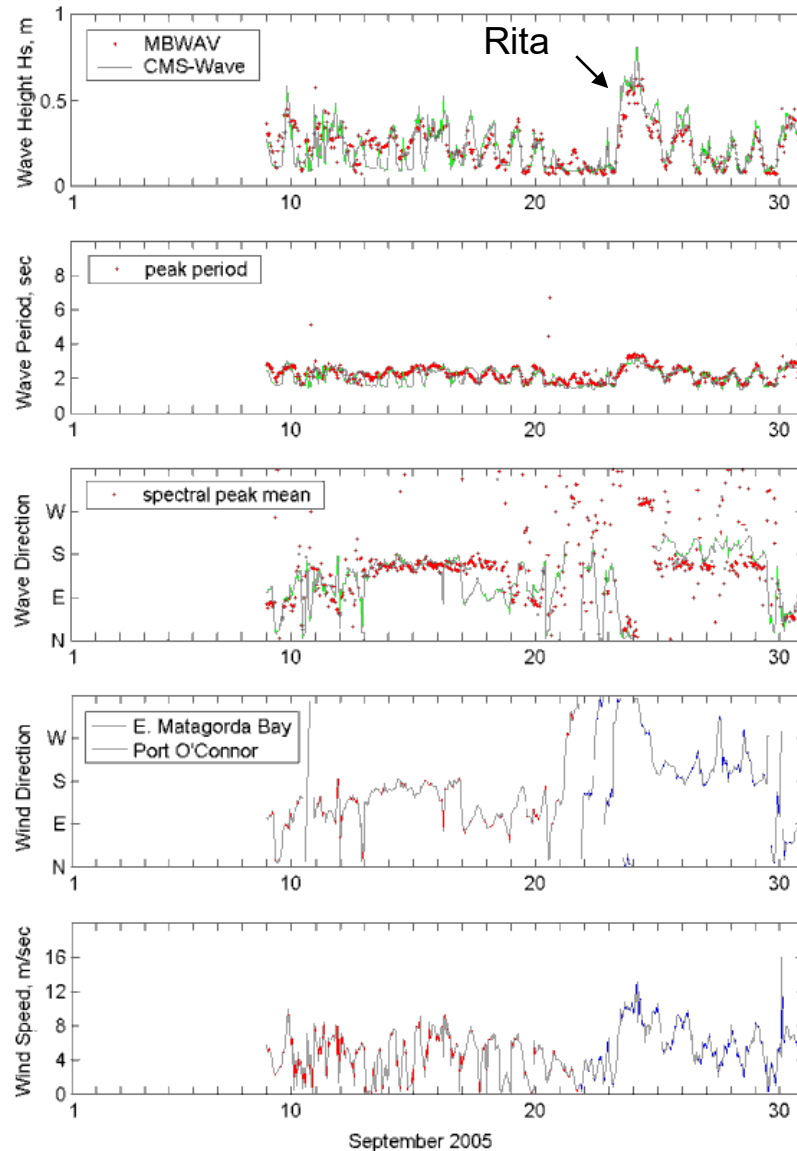


# Validation: Wind-Wave Generation





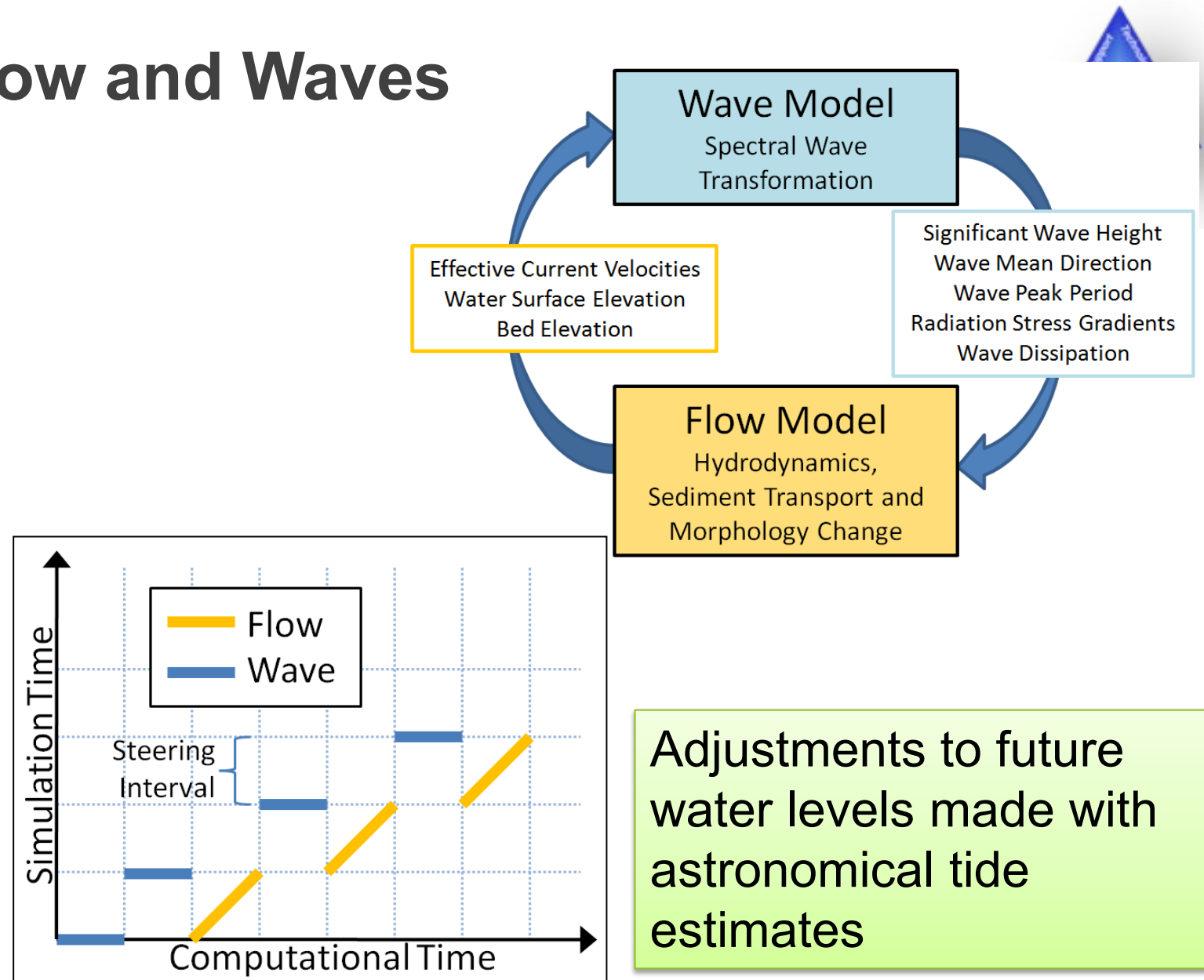
# Validation: Wave Generation at Matagorda Bay, TX



**Hurricane Rita**  
0400 UTC, 24 September 2005

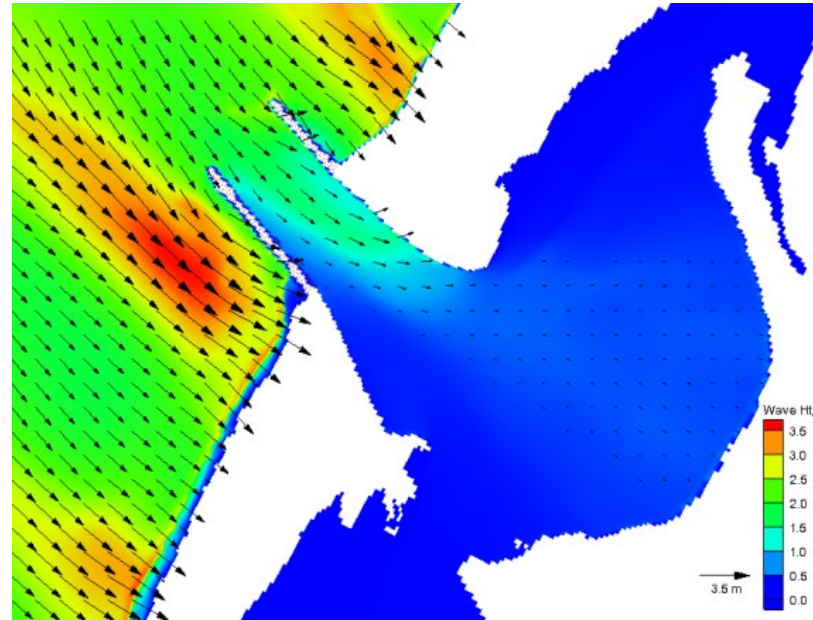
# Coupling between Flow and Waves

- Steering process
  - Roller included in wave model
  - Sediment transport and morphology change included in flow model
- Flow and Wave models may have the same or different grids

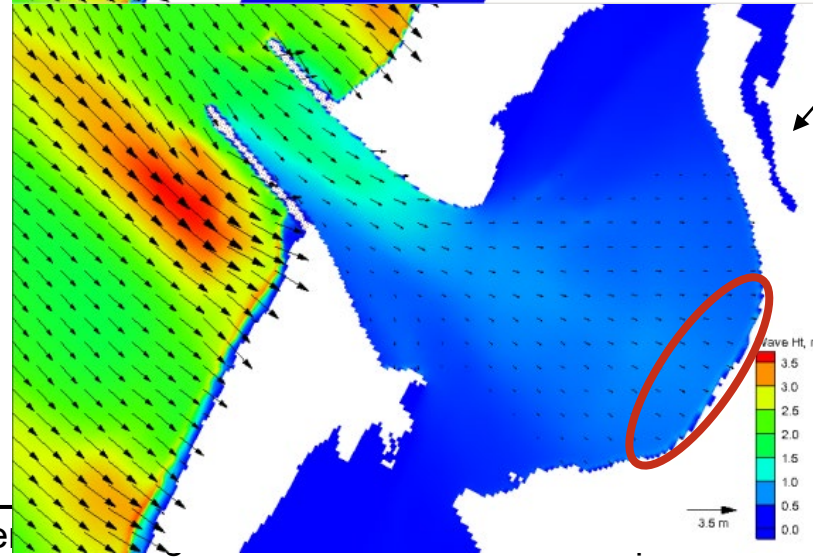




# Infra-gravity Waves at Humboldt Bay, CA



Incident wave:  
2 m, 15 sec  
from NE





# Sediment Transport: Key features

## Three Sediment transport models

- Non-Eq. (AD Total Load) -- **default**
- Equilibrium Total Load (Exner equation)
- Eq. Bed Load + AD Suspended Load

## Four sediment transport formulas

- Lund-CIRP -- **default**
- Van Rijn
- Watanabe
- Soulsby-van Rijn

Hard-bottom

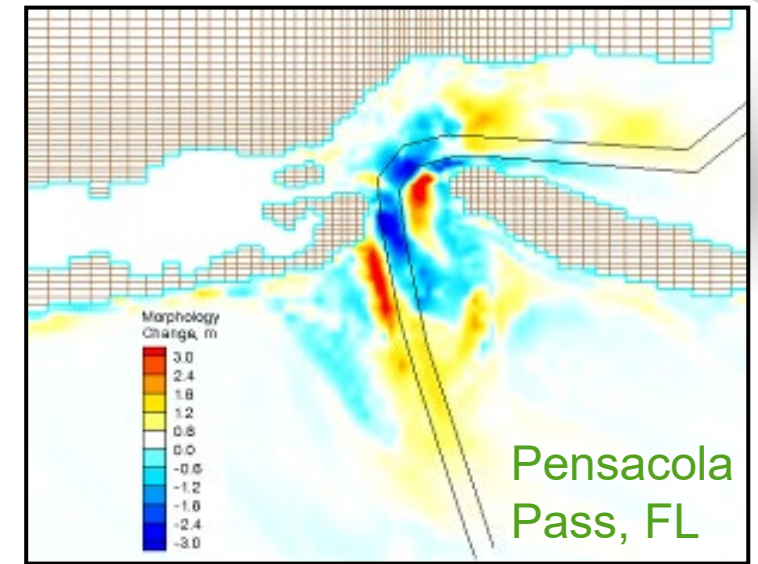
Avalanching

Bed slope influence on bed load

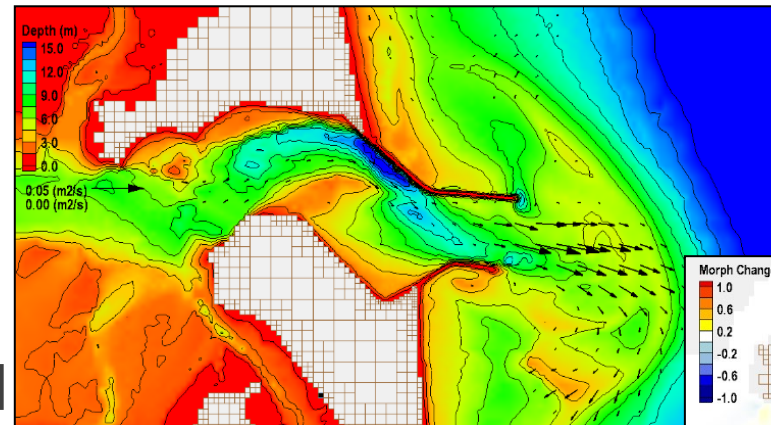
Multiple-sized sed. transport

Bed Layering

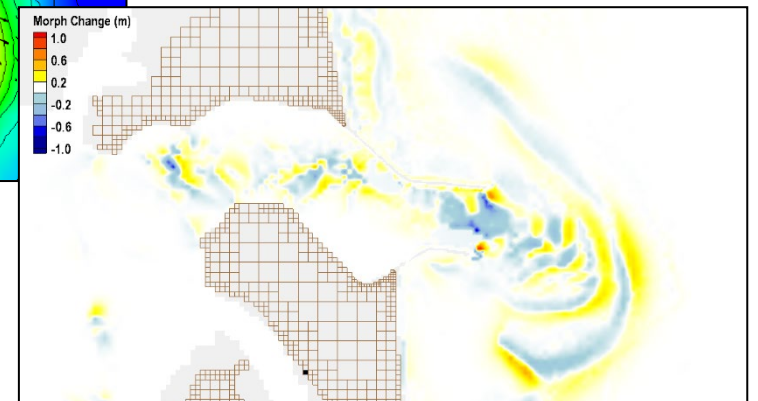
Eulerian Tracking (via Class Fractions)



Channel Infilling ~700,000 cu m



Merrimack Inlet, MA





# Sediment Transport

## Equilibrium Total-Load Transport Model

- Assumes both the bed and suspended loads are in local equilibrium at all times.
- Solves the Exner Equation (sediment mass balance equation)

$$(1 - p'_m) \frac{\partial \zeta}{\partial t} = \frac{\partial q_{t*j}}{\partial x_j} + \frac{\partial}{\partial x_j} \left[ D_s |q_{t*}| \frac{\partial \zeta}{\partial x_j} \right]$$

$D_s \rightarrow$  Bed-slope coefficient

$p'_m \rightarrow$  Sediment porosity

$q_{t*} \rightarrow$  Equilibrium total load sediment transport

$\zeta \rightarrow$  Still water depth



# Sediment Transport

## Non-equilibrium Sediment Transport Model

### Adopts

- Adaptation concept

### Solves

- AD equation for total load concentration

$$\frac{\partial}{\partial t} \left( \frac{hC_t}{\beta_t} \right) + \frac{\partial (hU_j C_t)}{\partial x_j} = \frac{\partial}{\partial x_j} \left[ Kh \frac{\partial (r_s C_t)}{\partial x_j} \right] + \alpha_t \omega_f (C_{t*} - C_t)$$

- Sediment balance equation for bed change rate

$$(1 - p'_m) \frac{\partial \zeta}{\partial t} = \alpha_t \omega_f (C_{t*} - C_t) + \frac{\partial}{\partial x_j} \left[ D_s |q_b| \frac{\partial \zeta}{\partial x_j} \right]$$

$C_t \rightarrow$  Total load concentration

$\beta_t \rightarrow$  Transport correction factor

$r_s \rightarrow$  Fraction of suspended load

$\alpha_t \rightarrow$  Adaptation coefficient

$\omega_f \rightarrow$  Fall velocity

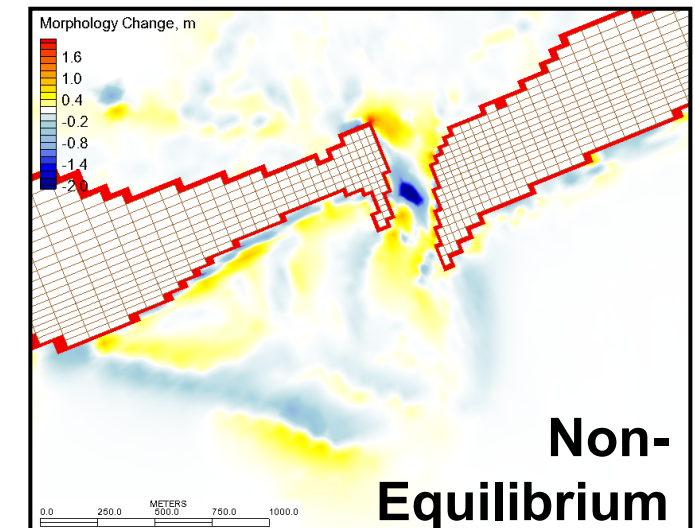
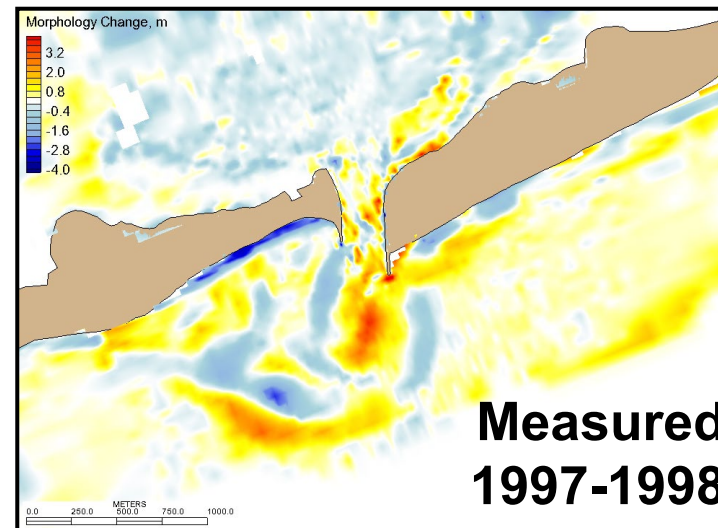
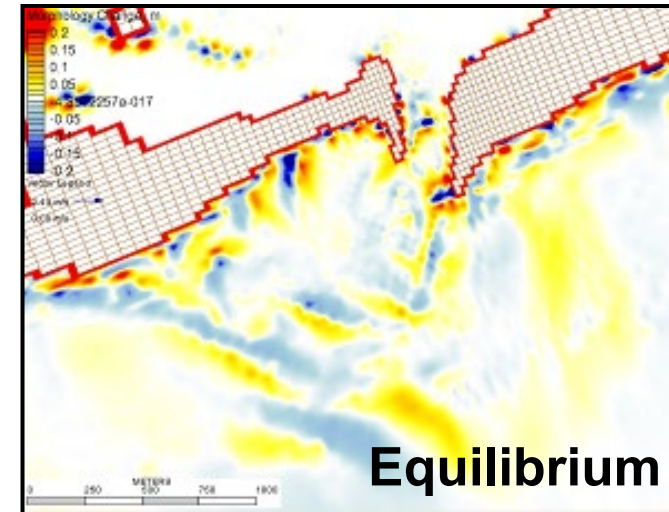


# Non-Equilibrium Transport (NET)

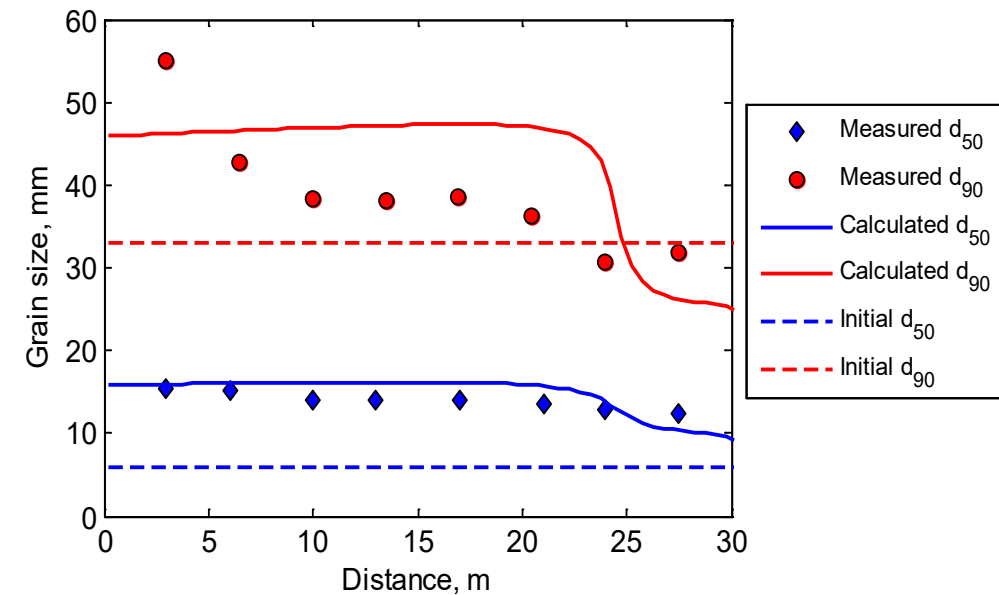
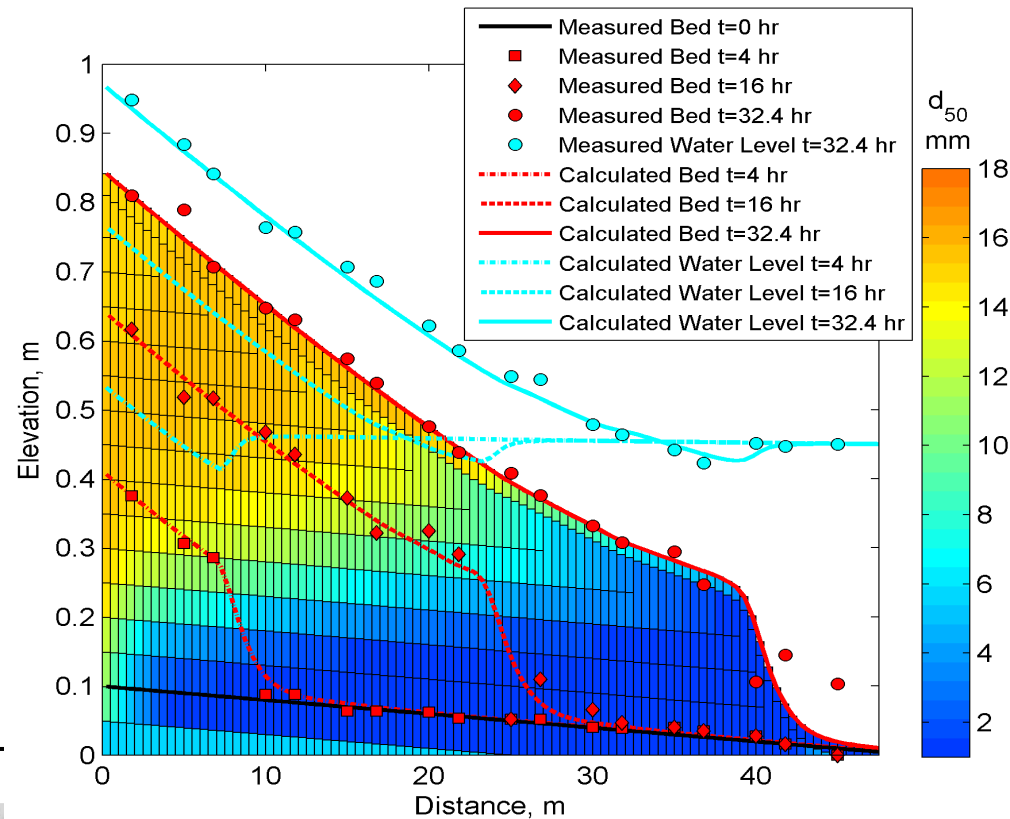
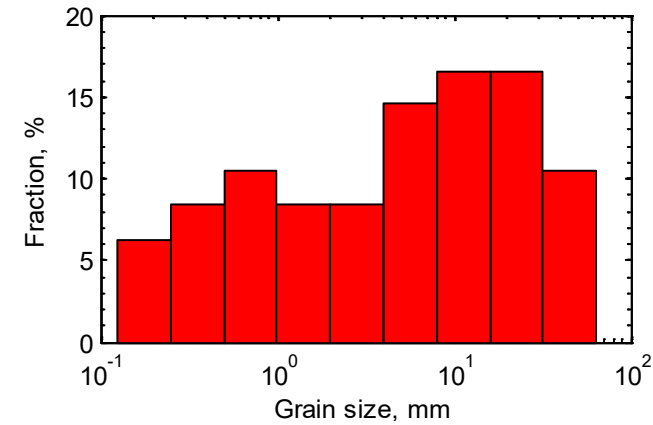
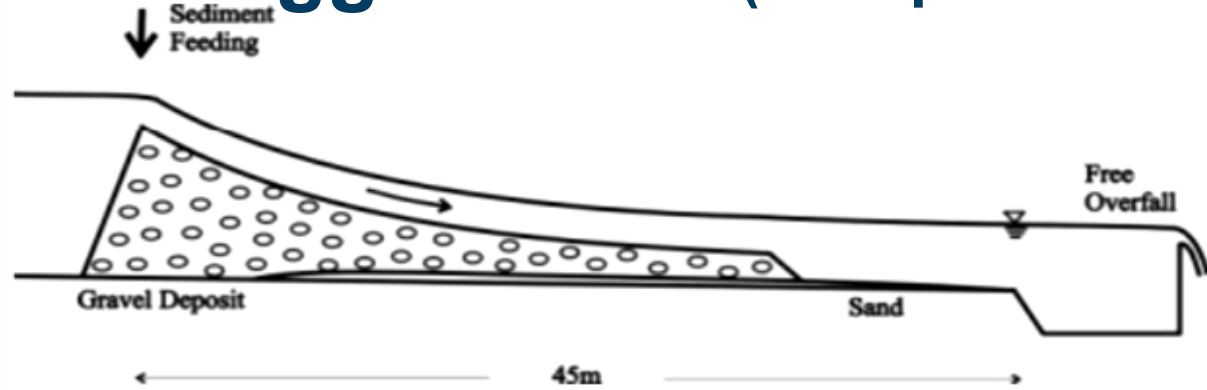
## Advantages of NET

- Accounts for temporal and spatial lags between flow and sediment transport (typically reduces transport and smooths it in a physically correct way)
- Hard-bottom automatically represented
- Realistic results
- More stable

## Shinnecock Inlet, NY



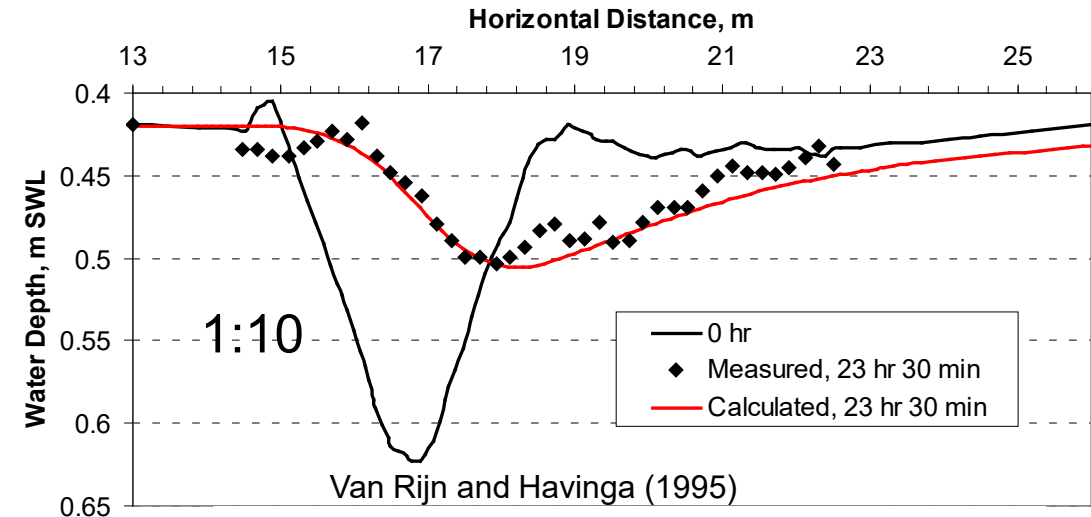
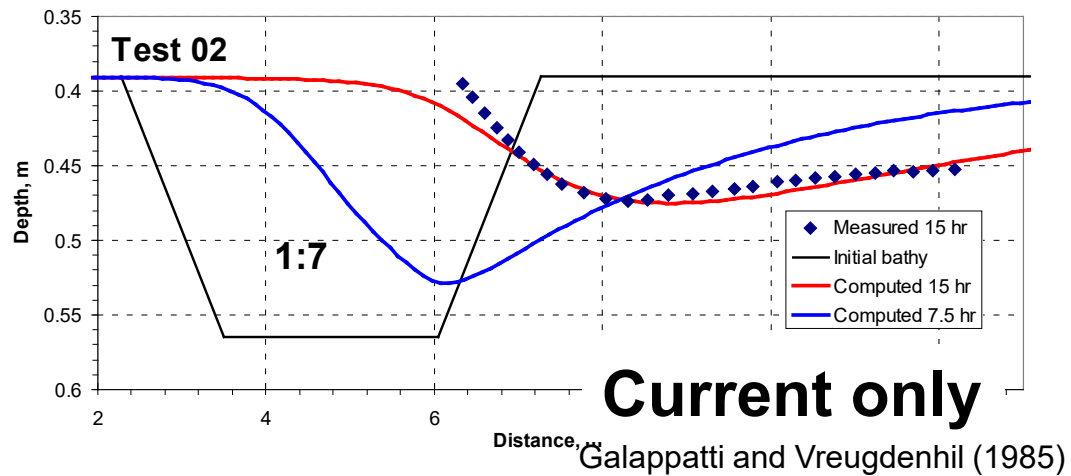
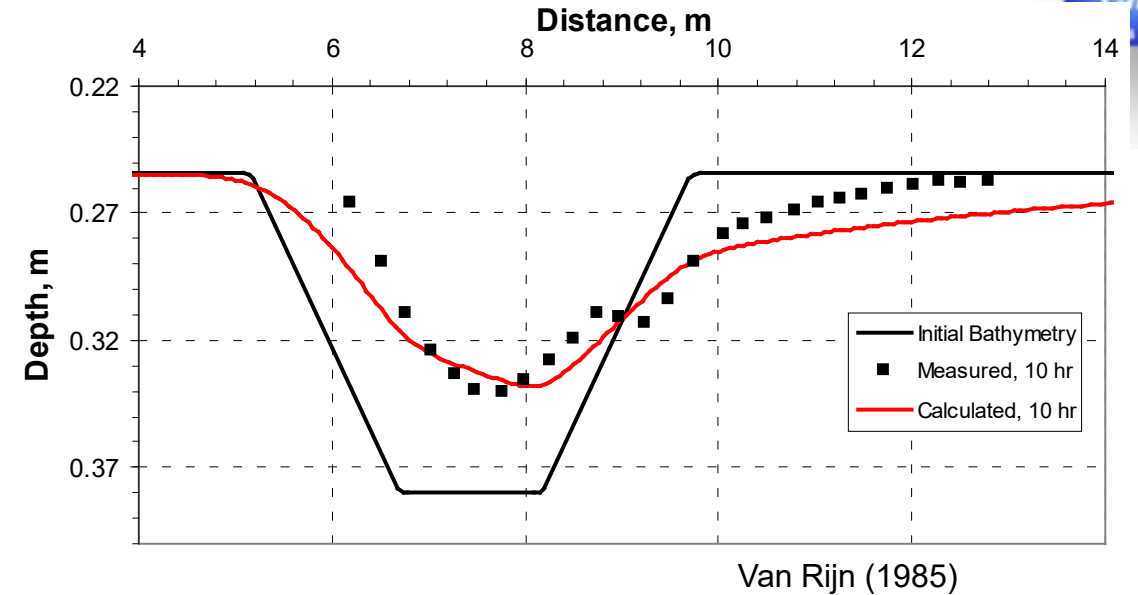
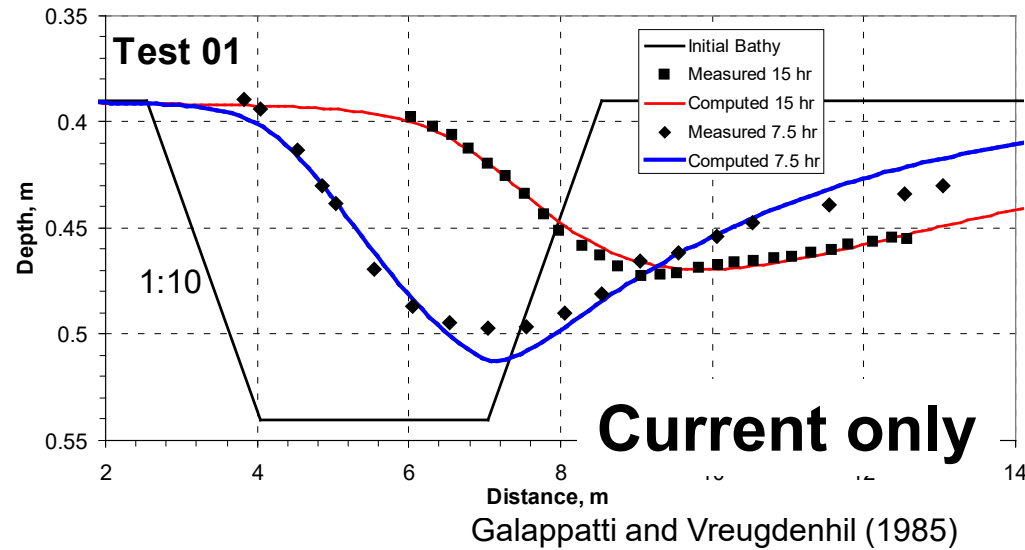
# Bed Aggradation (Multiple-sized sediments)



# Validation: Channel Infilling



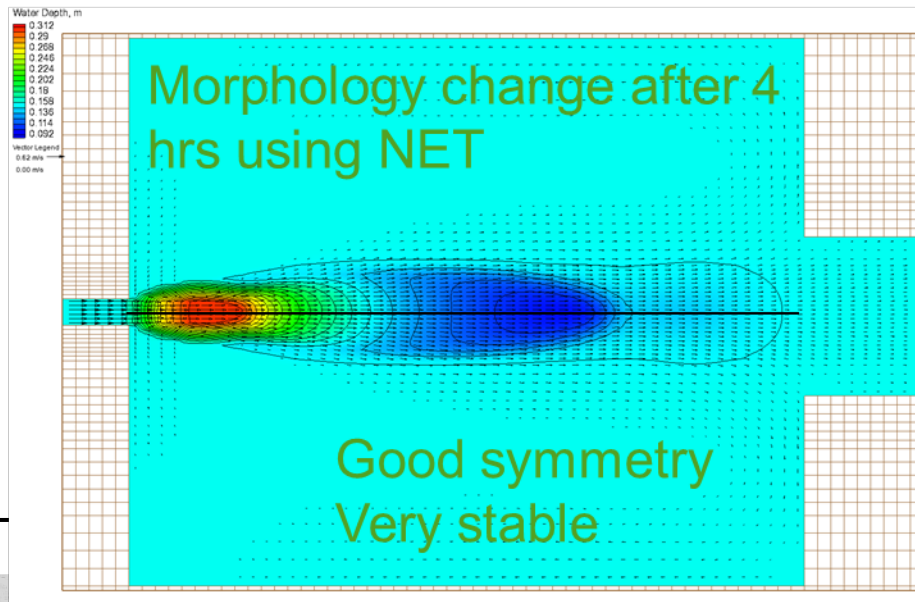
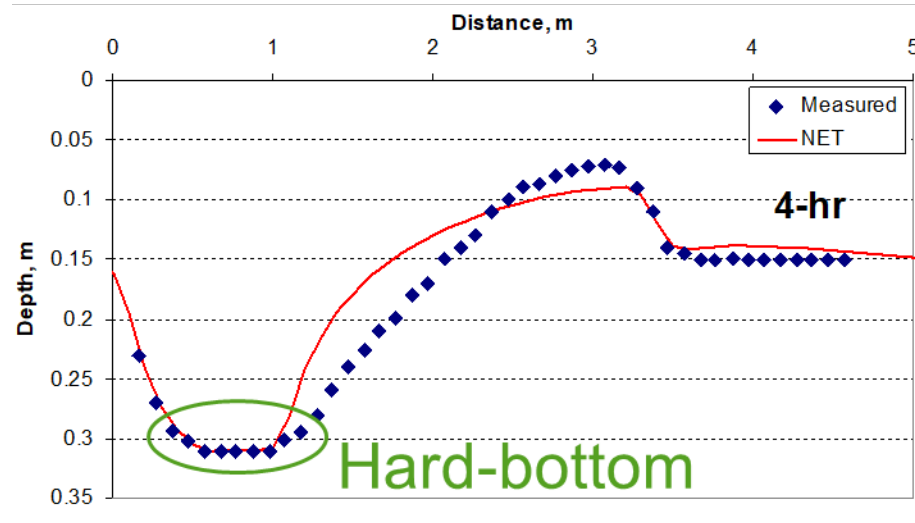
## Waves parallel to flow



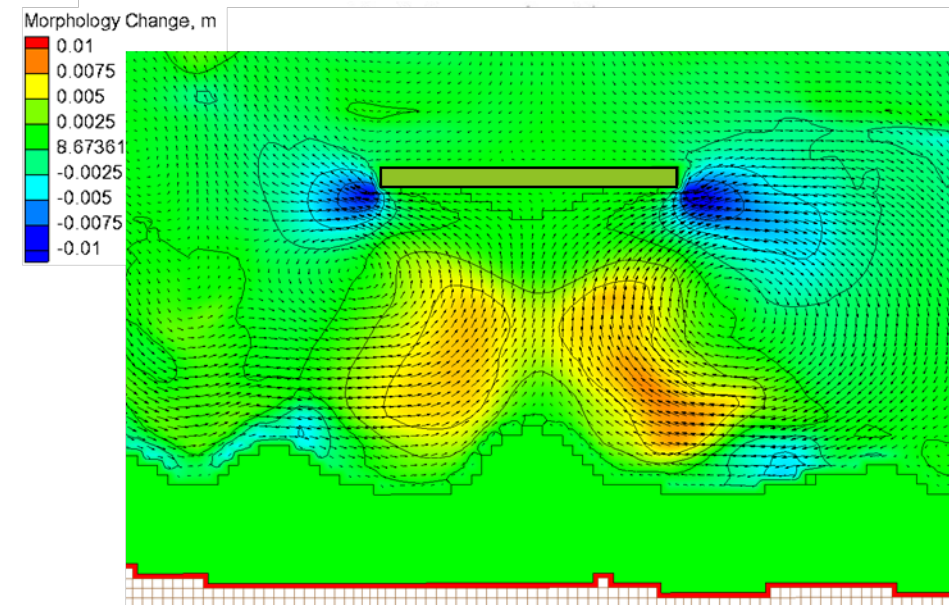
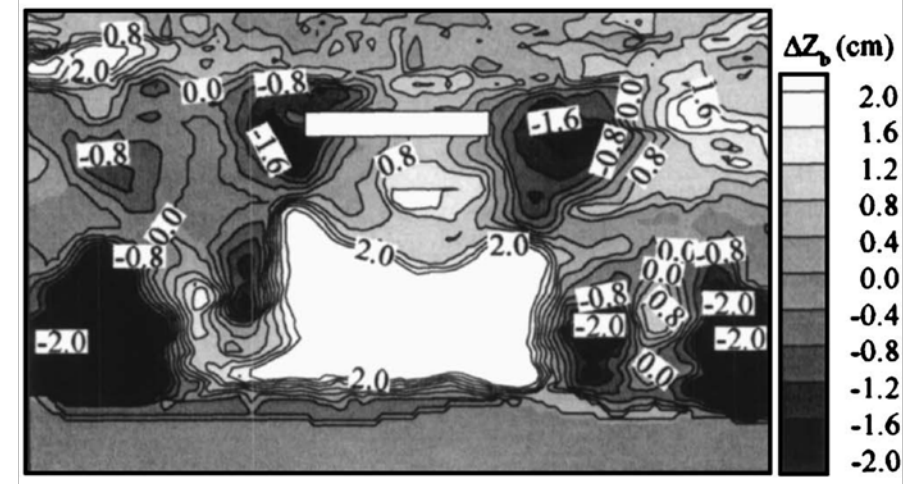


# More Validation

## Clear-water Jet (Thuc 1991)

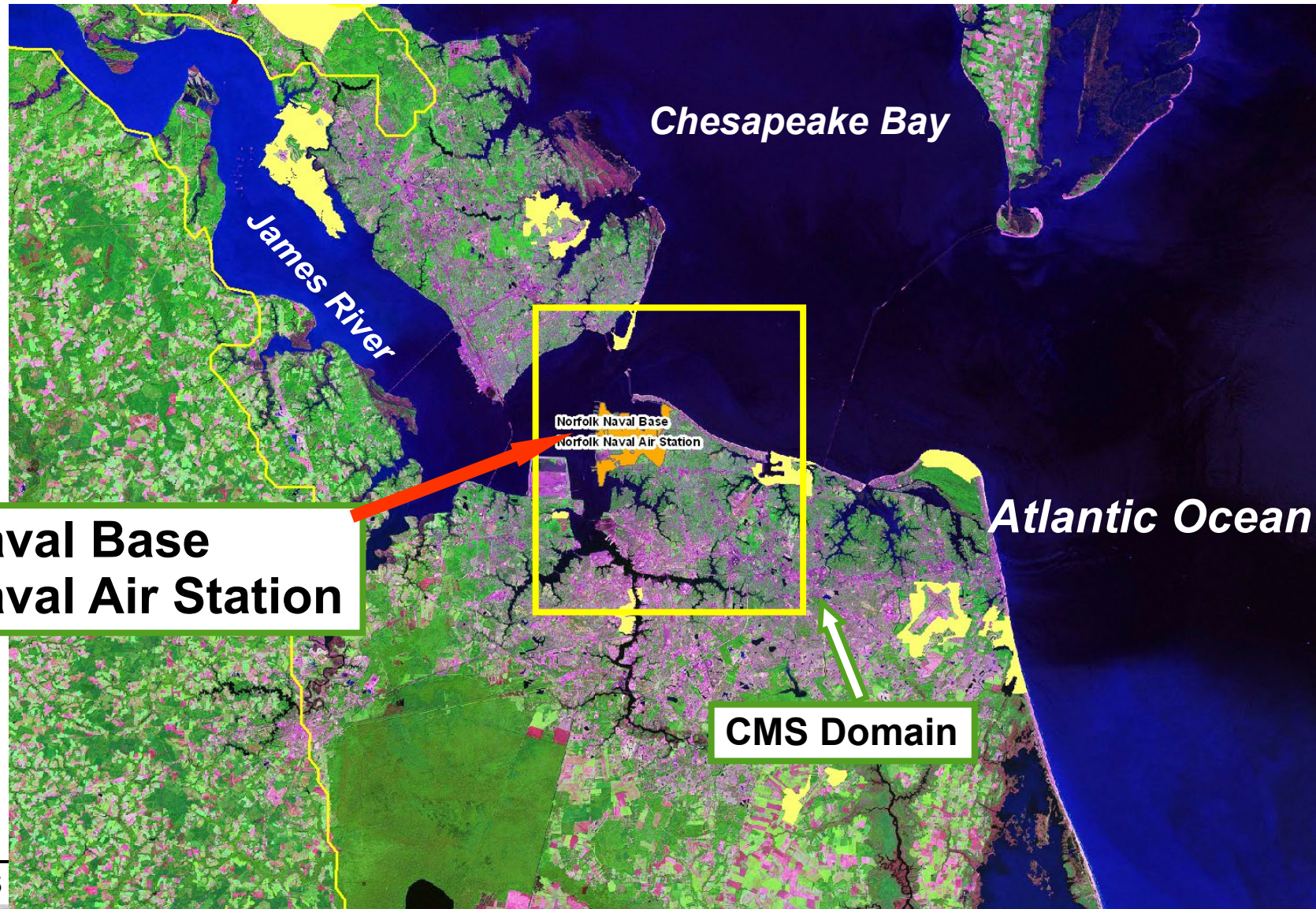


## Detached breakwater (Mimura 1983)





# Chesapeake Bay: Storm Surge Flooding (Hurricane Isabel)



US

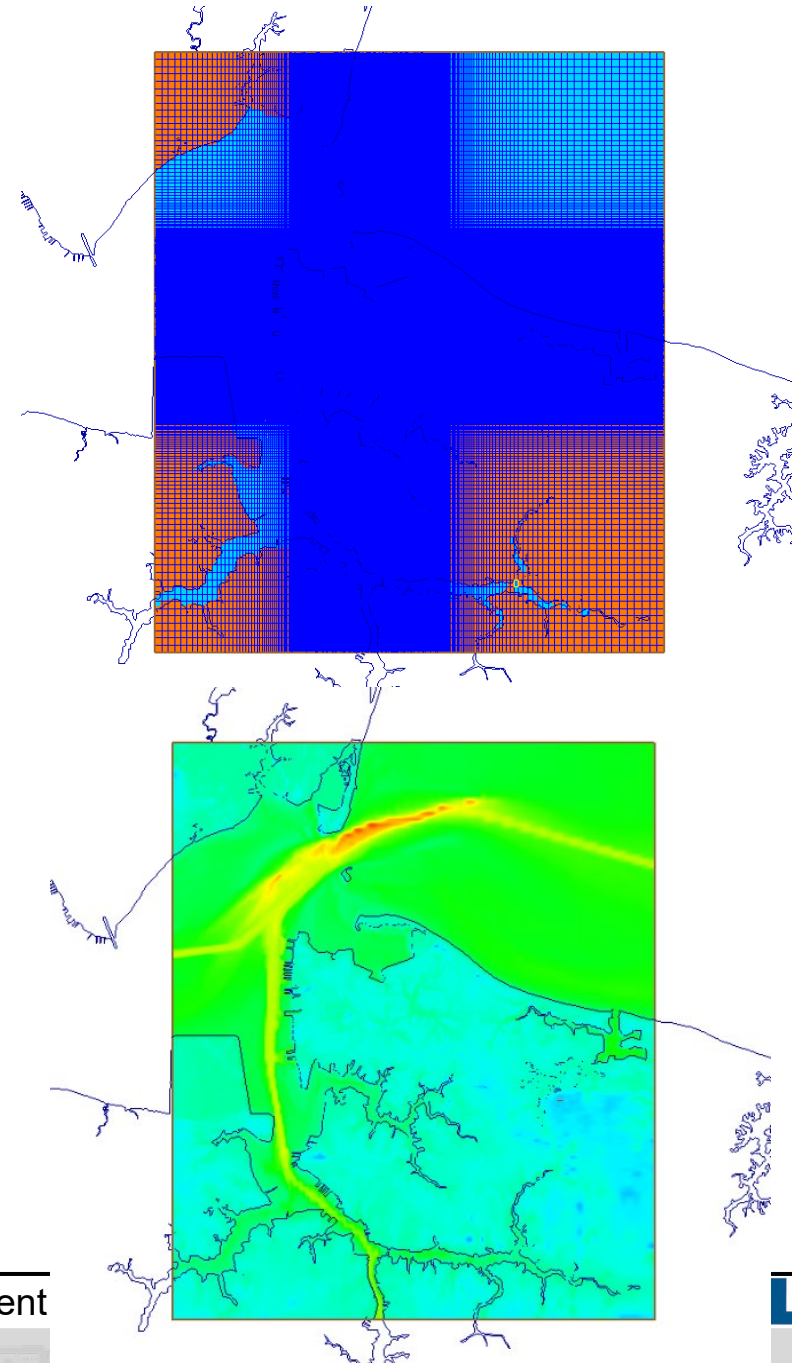


# Hurricane Isabel Simulation

## 17-21 Sep 2003

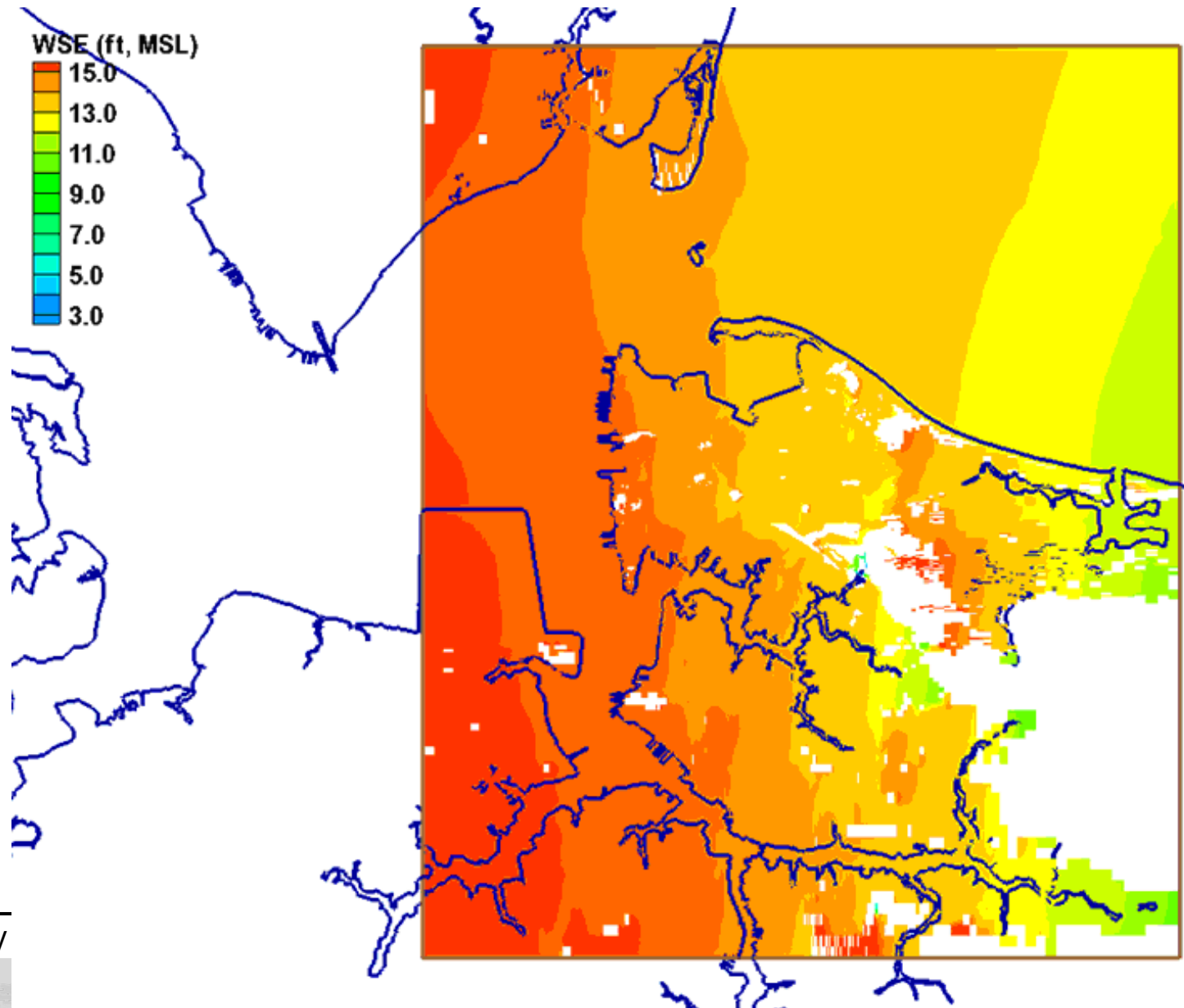
- Domain Size: 20 x 24 km
- 530k cells (rectilinear grid)
- 10-300 m resolution
- WSE from regional ADCIRC model
- Wind and atmospheric pressure from PBL model

**Norfolk Naval Base**  
**Norfolk Naval Air Station**



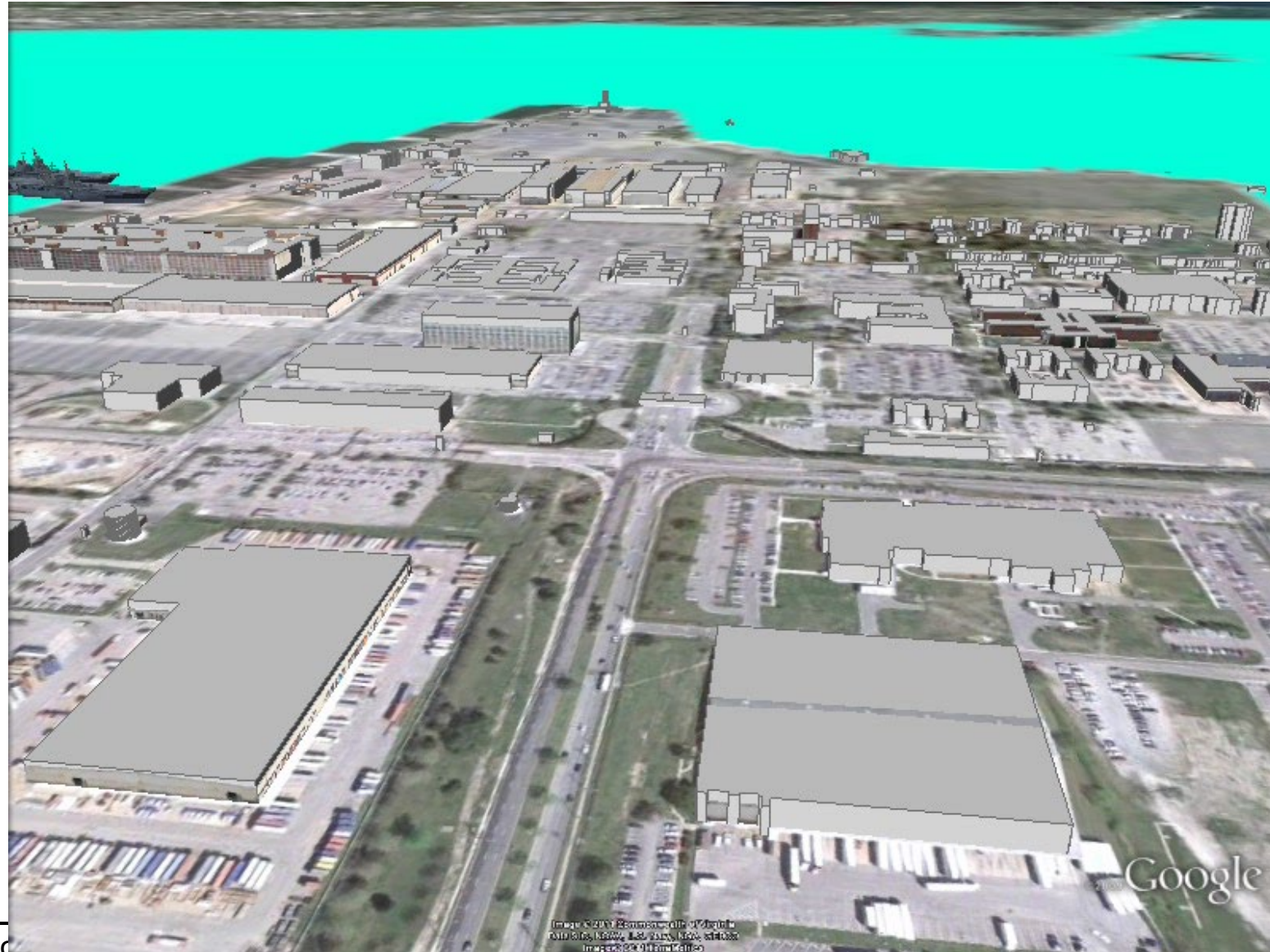


# Norfolk Air Force Base



Example water level

# Animation based on CMS Results



US Army Corps of Engineers Engineer Research and Development Center



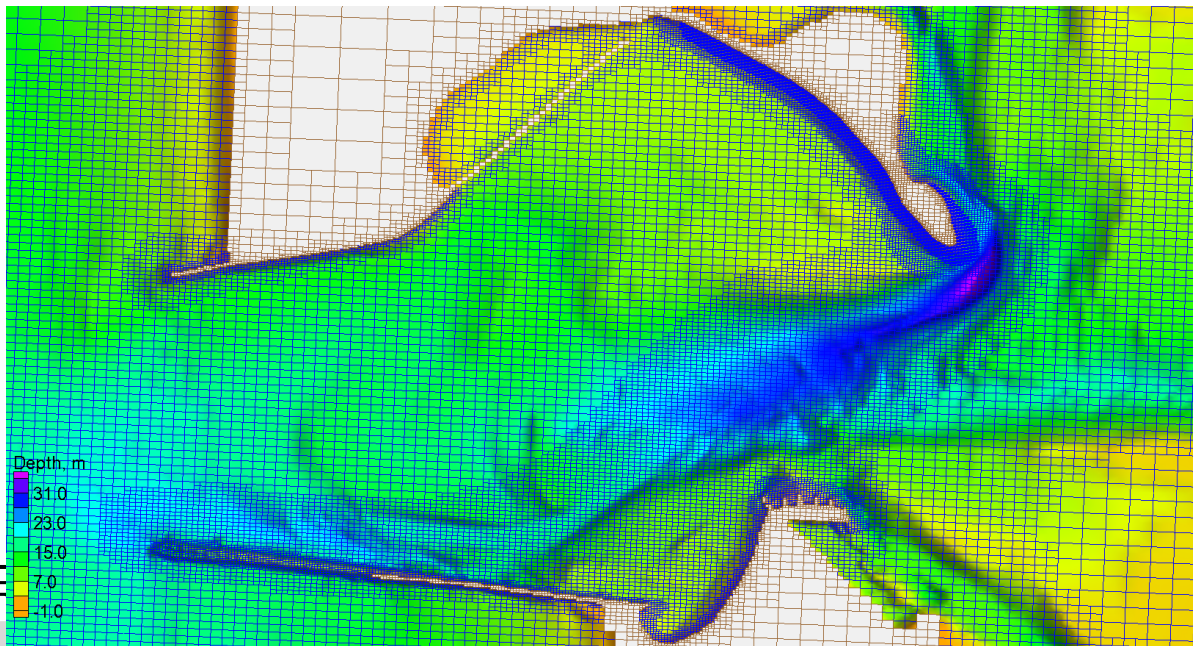
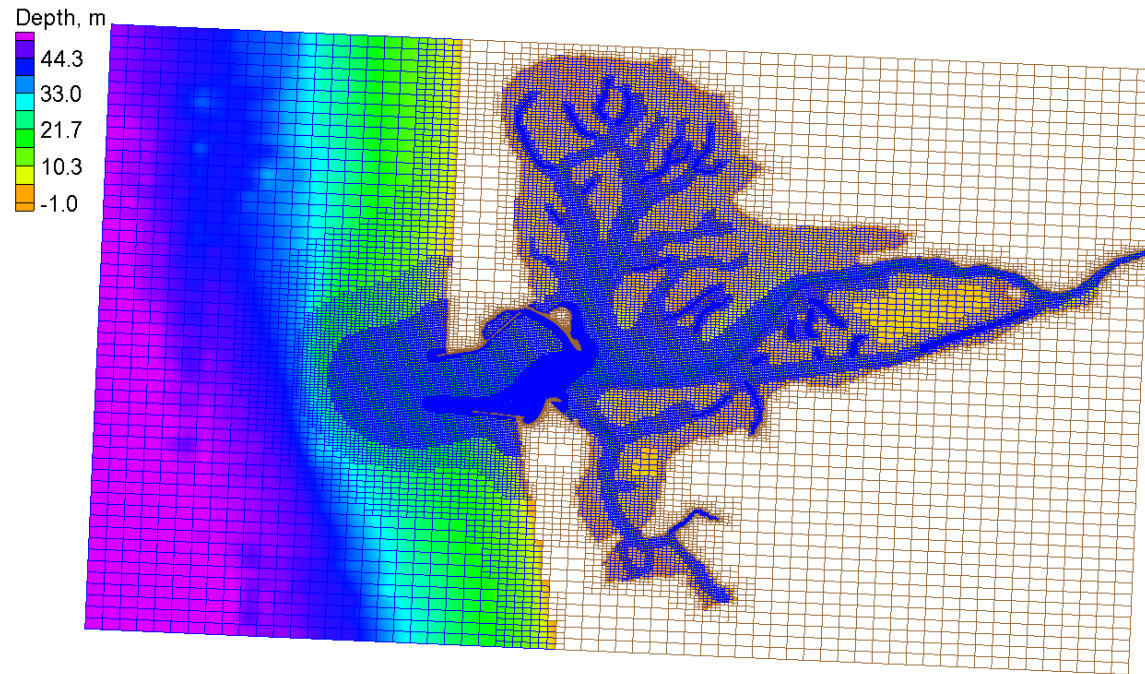
# Grays Harbor, WA

## Objective

- Determine if growing spit will affect adjacent navigation channel

## Result

- Cause and prediction of spit growth determined
- Spit does grow and was not expected to significantly impact nav. channel in next 3 years





# Extreme Wetting/Drying: Bahia Grande, TX



- Remediation, restoration project
- Wind-blown sand is hazardous to power line transformers and human health
- 1:1500 slope
- Circulation dominated by wind



# Wind Generated Flow in Bahia Grande, TX

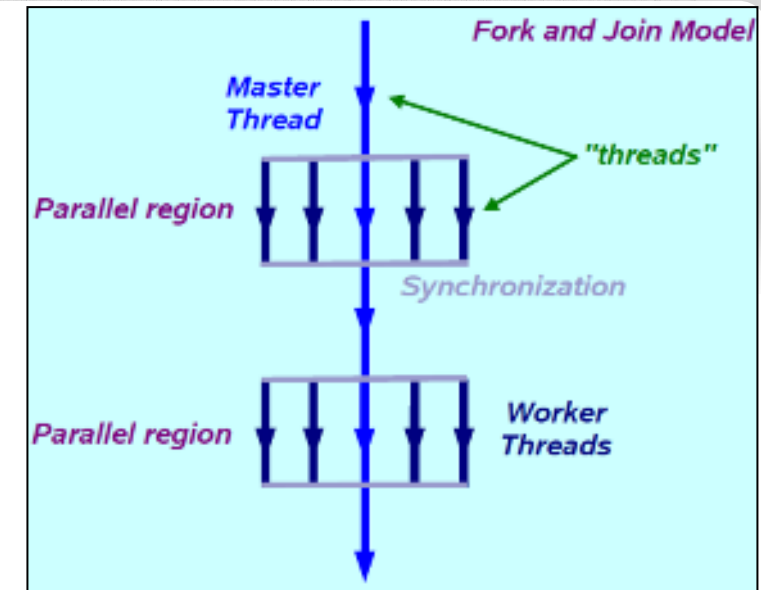
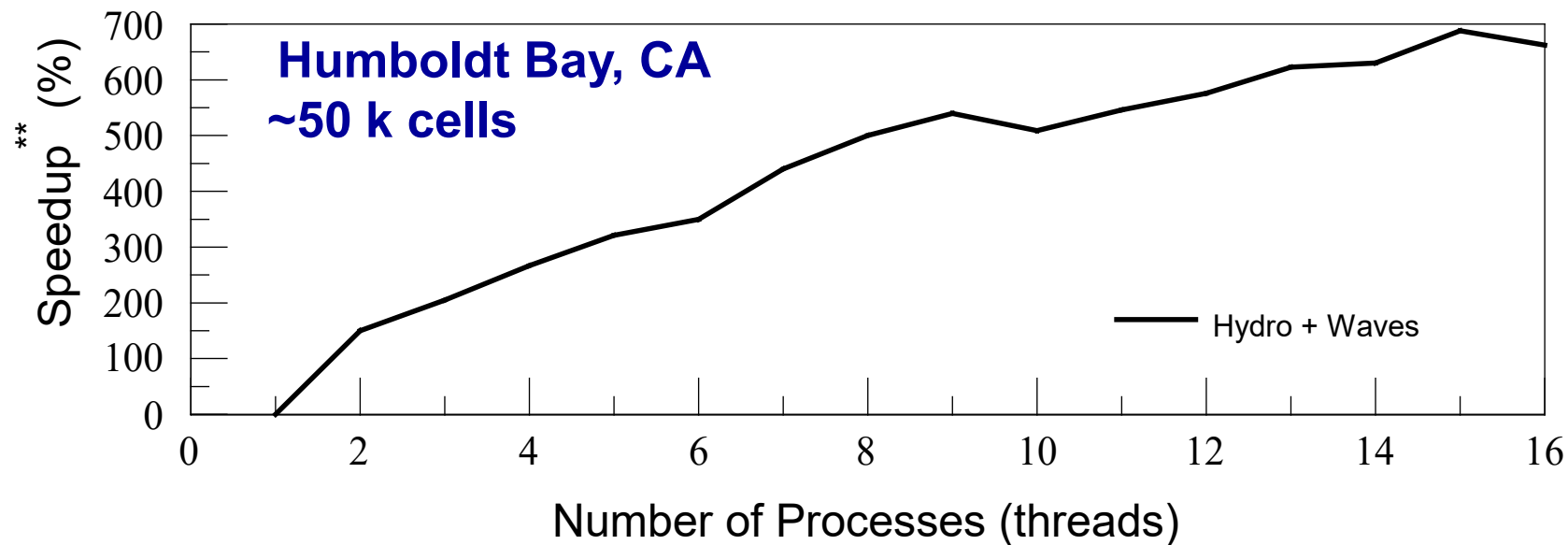
Animation



# Parallel Processing

- **CMS-Flow parallelized using OpenMP**
  - Implicit Solution Scheme – Upper limit = 4
  - Explicit Solution Scheme – Upper limit = # of procs on Machine

Speedup for CMS-Flow **Explicit** using multiple processors

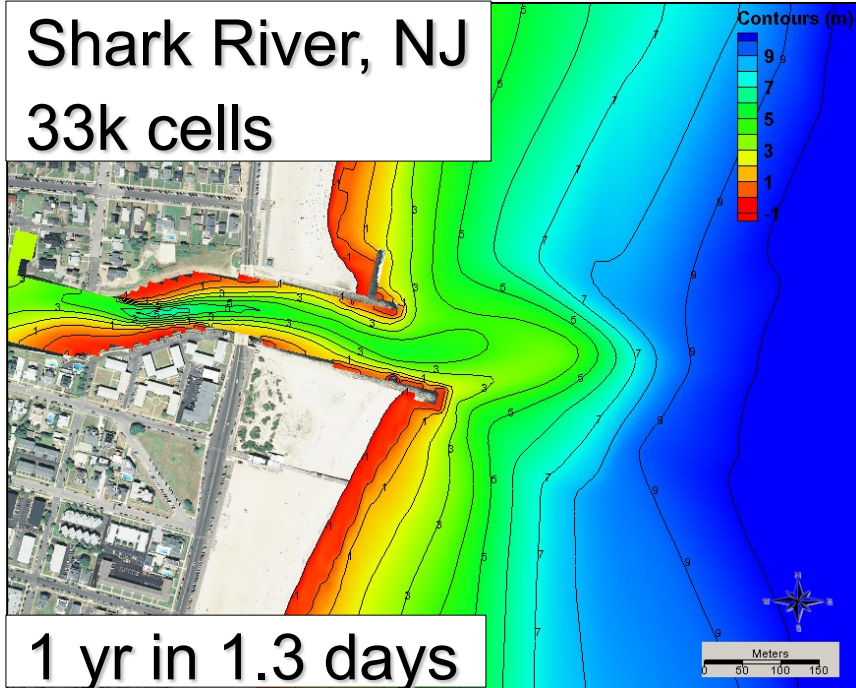


$$\text{speed up} = 100 \frac{\text{Serial Run time}}{\text{Parallel Run time}}$$



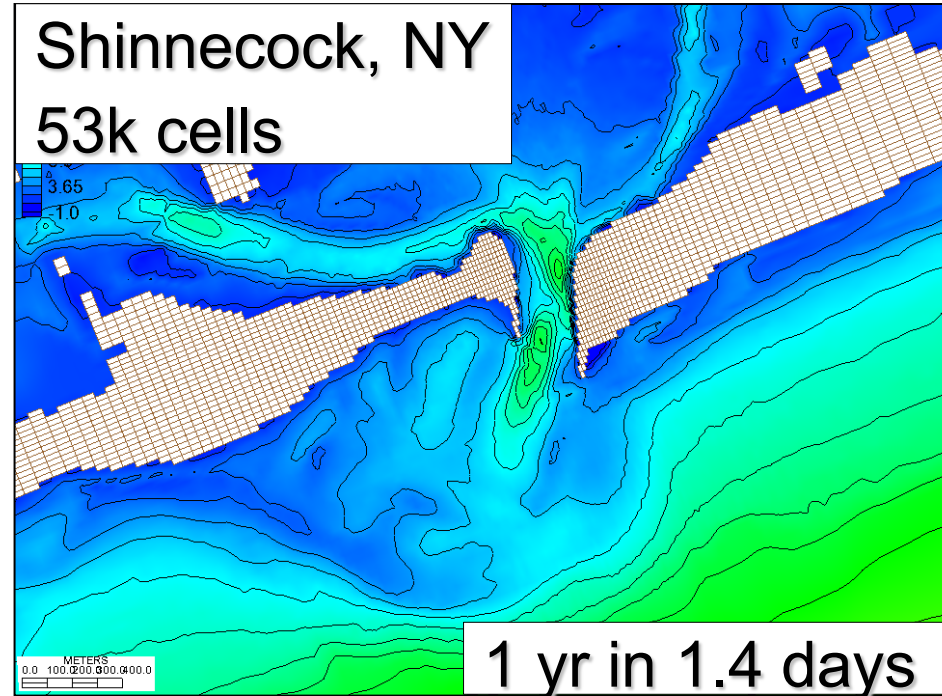
# Computational Speed (Implicit)

Shark River, NJ  
33k cells



1 yr in 1.3 days

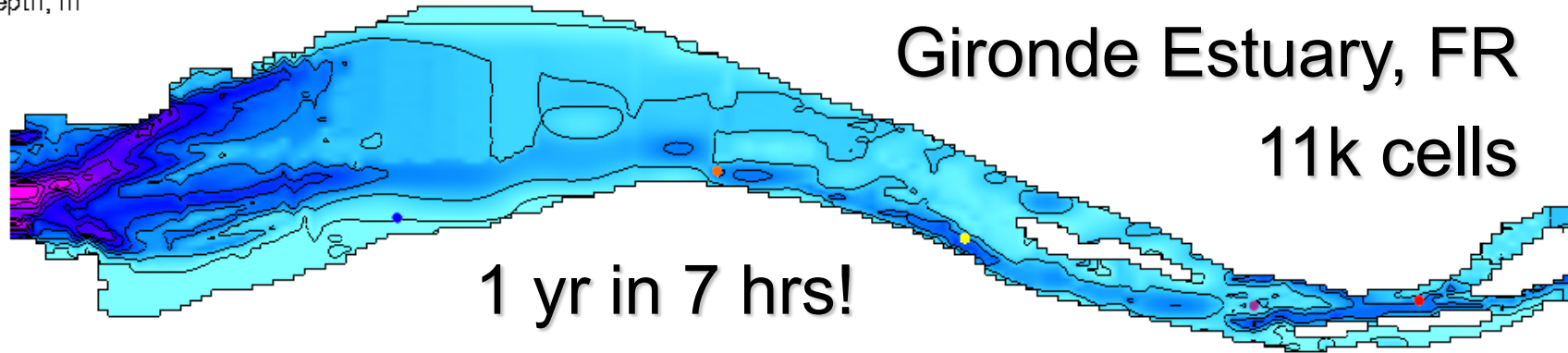
Shinnecock, NY  
53k cells



1 yr in 1.4 days

Water Depth, m

32.0  
28.8  
25.6  
22.4  
19.2  
16.0  
12.8  
9.6  
6.4  
3.2  
0.0

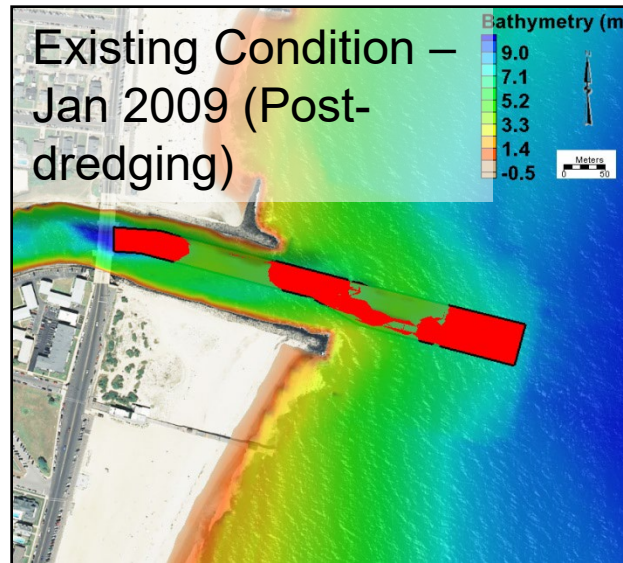


1 yr in 7 hrs!

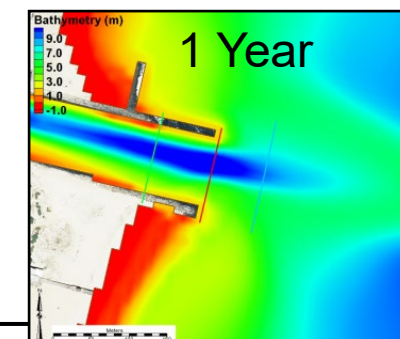
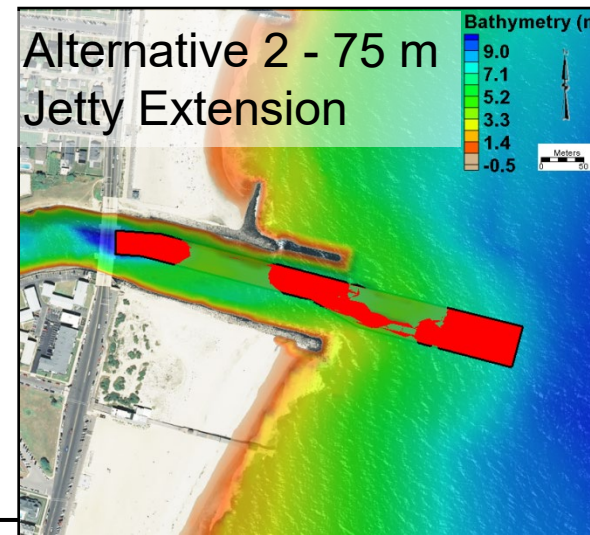
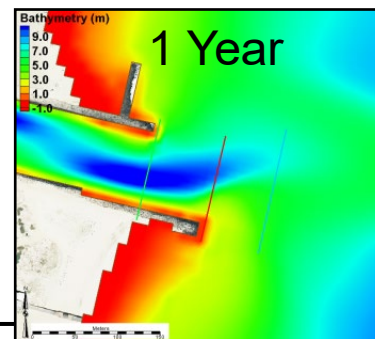
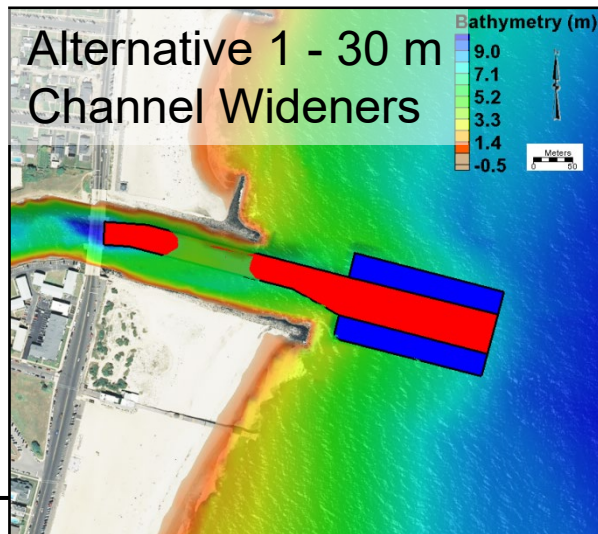
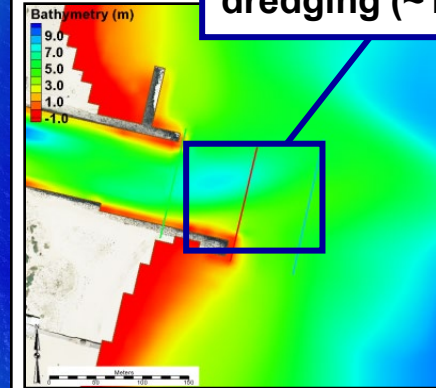
Gironde Estuary, FR  
11k cells



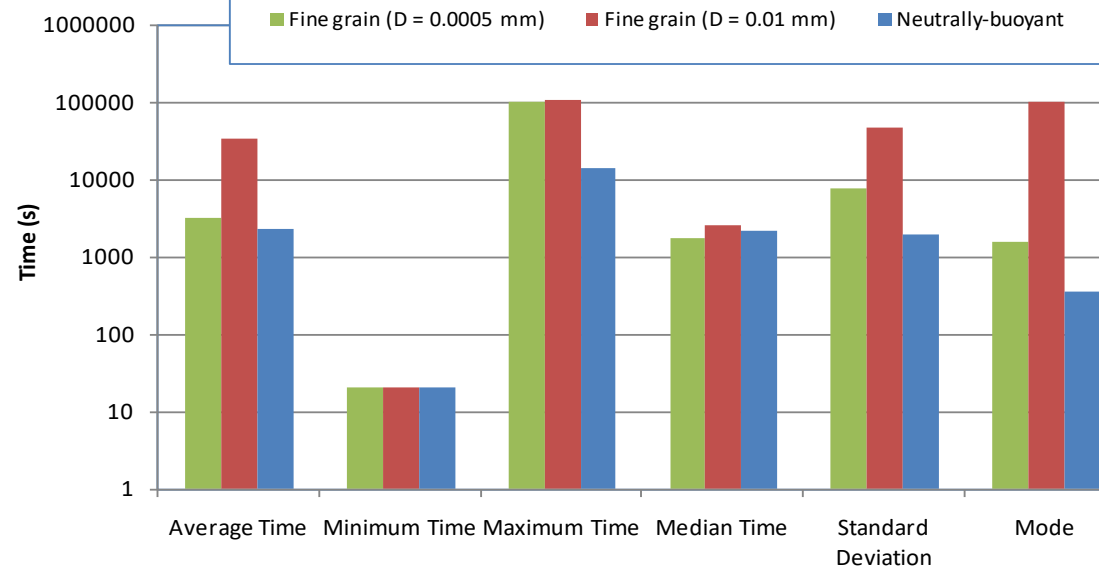
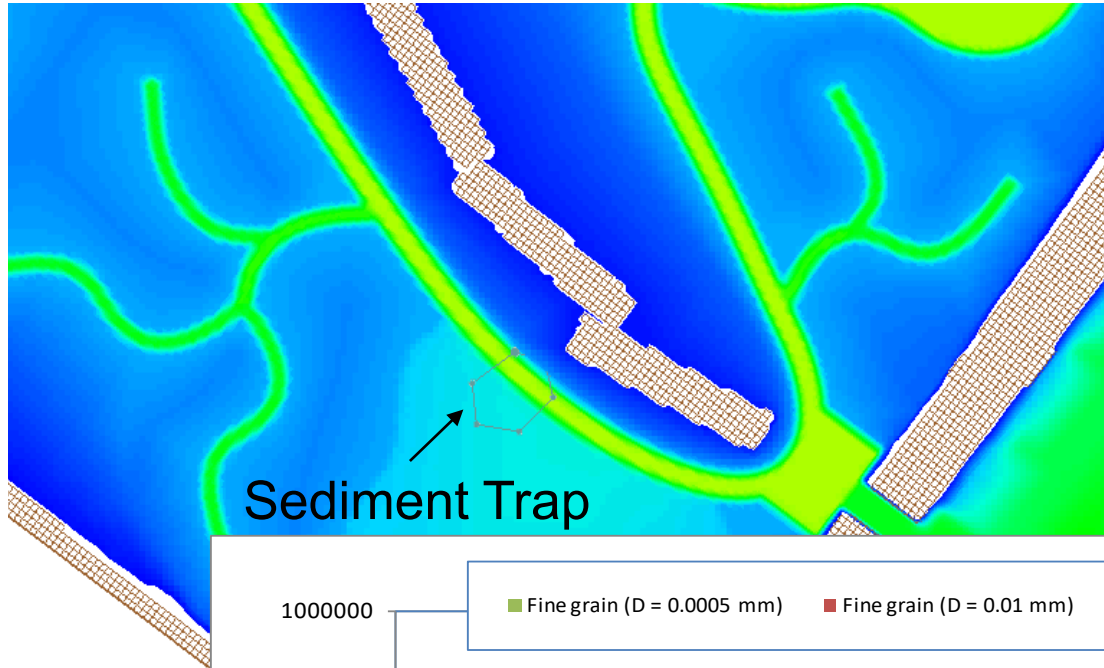
# Shark River Inlet, NJ Application



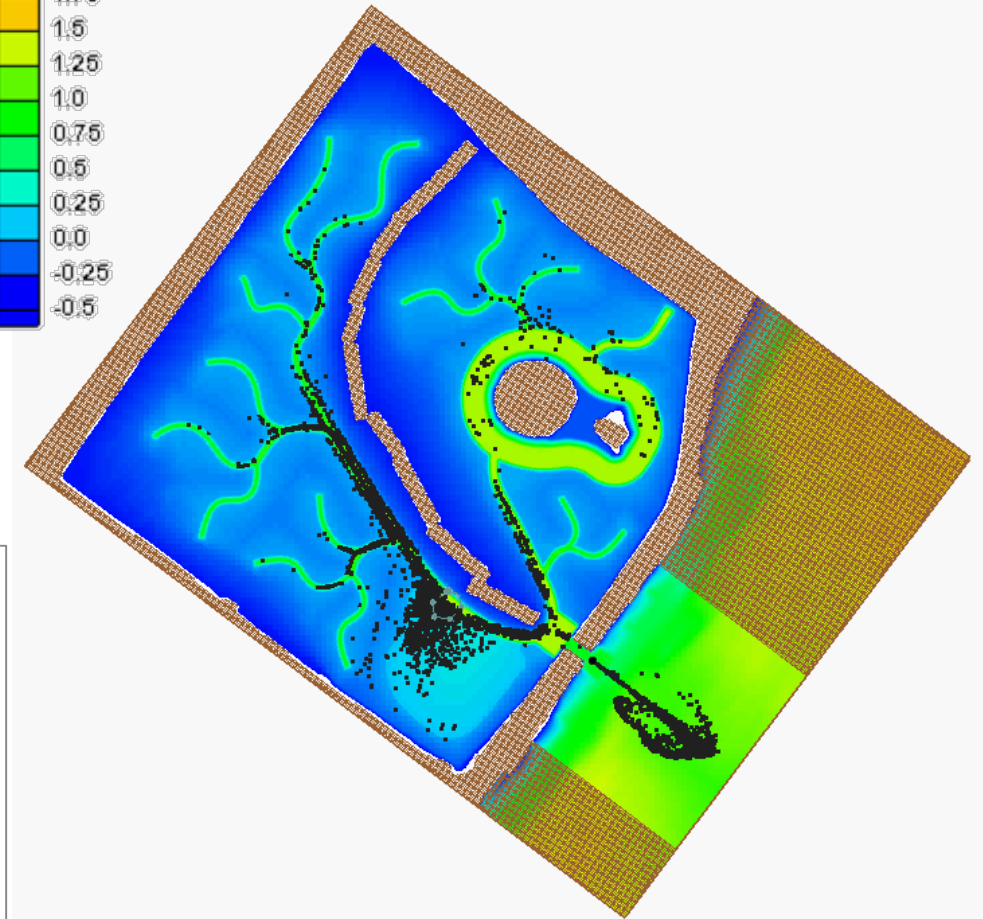
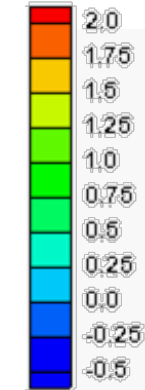
Consistent with volume removed during the next dredging (~10k m<sup>3</sup>)



# CMS/PTM Application: Poplar Island, MD



CGrid Module Depth



## Residence Times

ent Center •



# Poplar Island, Cell 1A (CMS/PTM)

## Animation

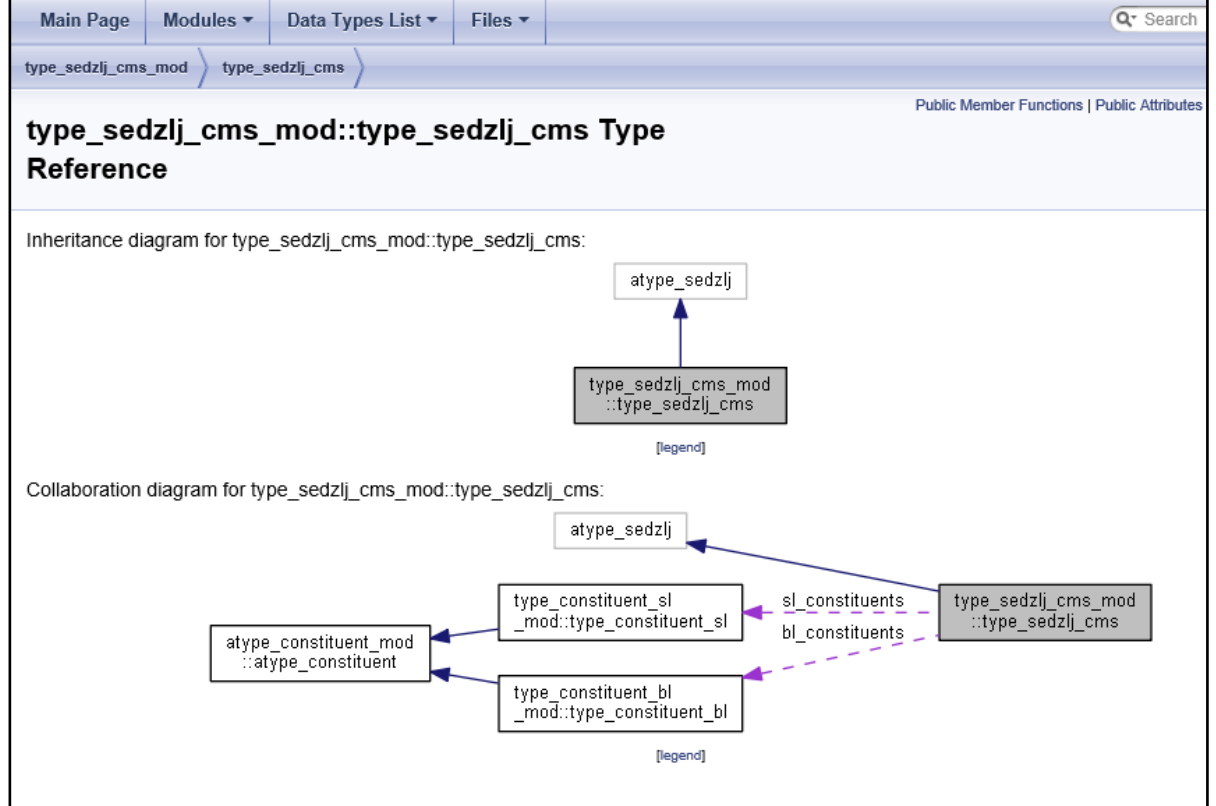


# Mixed Sediment Transport Model (SEDZLJ) – in process

- Incorporate the SEDZLJ into CMS via CORSED libraries
- Add the capability of simulating the cohesive sediment transport in CMS
- Compare SEDZLJ with CMS-sediment transport and with LIDAR surveys



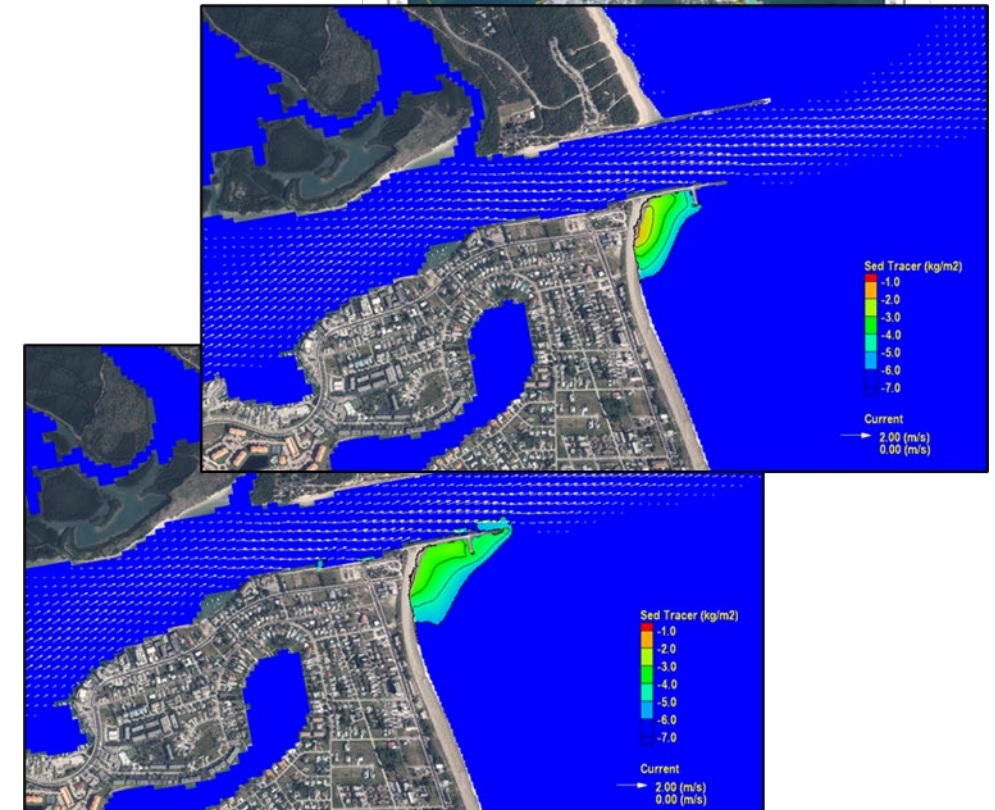
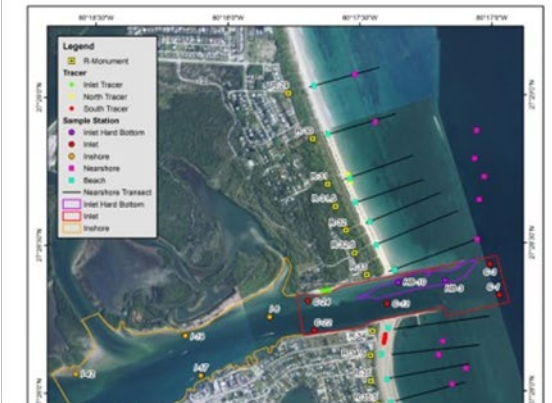
## CMS-SEDLIBJ Integration



# Sediment Mapping

## (Coos Bay, Oregon and Ft. Pierce, Florida)

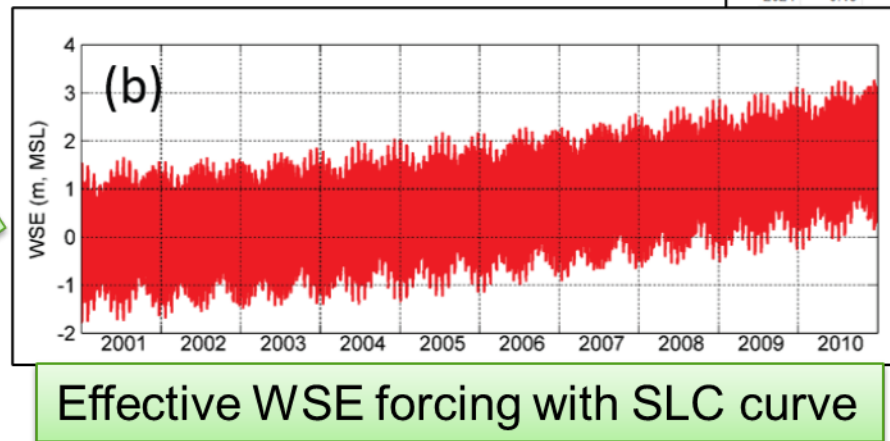
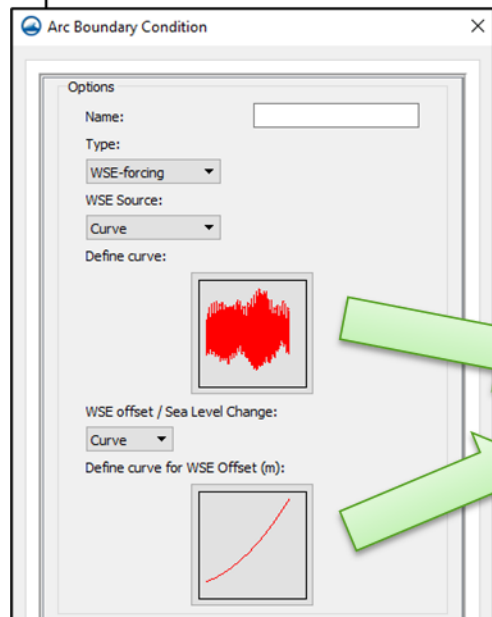
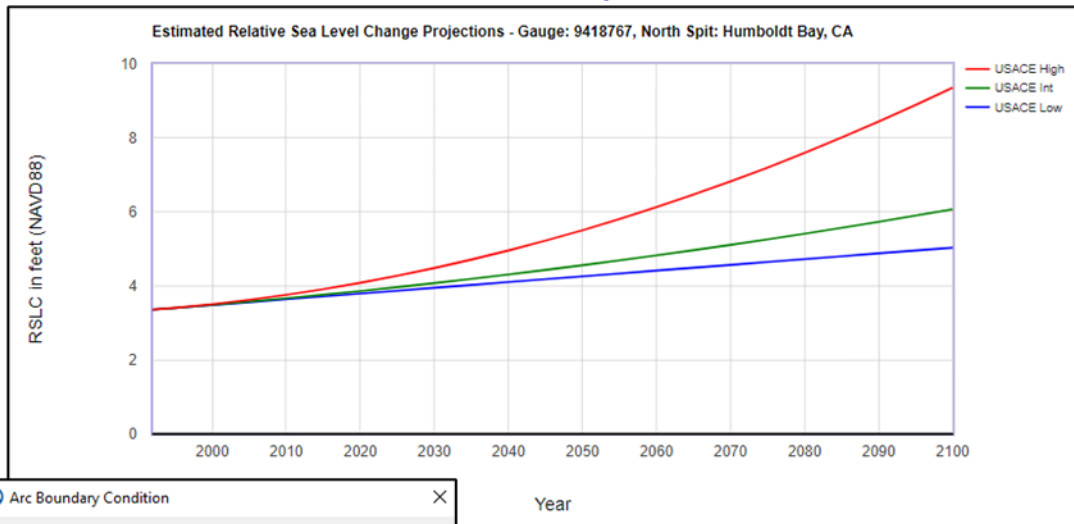
- Conduct data analysis, examine sediment transport, and identify sand pathways
- Model development for sediment mapping simulations (Ft Pierce inlet system and adjacent beaches)
- Conduct mid- to long-term simulations to cover the period of sediment tracer deployment and sampling
- Build CMS/SMS model control dialog for Sediment Mapping





# Implementation of Sea-level change interface in SMS 13.0+

[https://cwbi-app.sec.usace.army.mil/rccslc/slcc\\_calc.html](https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html)



Print Curves

Long-term Morphology Simulation  
9418767, North Spit: Humboldt Bay, CA  
NOAA's Regional Rate: 0.00513 meters/yr  
All values are expressed in meters relative to MSL

| Year | USACE Low | USACE Int | USACE High |
|------|-----------|-----------|------------|
| 2000 | 0.04      | 0.04      | 0.05       |
| 2001 | 0.05      | 0.05      | 0.06       |
| 2002 | 0.05      | 0.05      | 0.06       |
| 2003 | 0.06      | 0.06      | 0.07       |
| 2004 | 0.06      | 0.07      | 0.08       |
| 2005 | 0.07      | 0.07      | 0.09       |
| 2006 | 0.07      | 0.08      | 0.09       |
| 2007 | 0.08      | 0.08      | 0.10       |
| 2008 | 0.08      | 0.09      | 0.11       |
| 2009 | 0.09      | 0.10      | 0.12       |
| 2010 | 0.09      | 0.10      | 0.13       |
| 2011 | 0.10      | 0.11      | 0.14       |
| 2012 | 0.10      | 0.11      | 0.15       |
| 2013 | 0.11      | 0.12      | 0.16       |
| 2014 | 0.11      | 0.13      | 0.17       |
| 2015 | 0.12      | 0.13      | 0.18       |
| 2016 | 0.12      | 0.14      | 0.19       |
| 2017 | 0.13      | 0.14      | 0.20       |
| 2018 | 0.13      | 0.15      | 0.21       |
| 2019 | 0.14      | 0.16      | 0.22       |
| 2020 | 0.14      | 0.17      | 0.23       |
| 2021 | 0.15      | 0.17      | 0.24       |
| 2022 | 0.15      | 0.18      | 0.26       |
| 2023 | 0.16      | 0.19      | 0.27       |
| 2024 | 0.16      | 0.19      | 0.28       |
| 2030 | 0.20      | 0.23      | 0.36       |
| 2031 | 0.20      | 0.24      | 0.37       |
| 2032 | 0.21      | 0.25      | 0.39       |
| 2033 | 0.21      | 0.26      | 0.40       |
| 2034 | 0.22      | 0.26      | 0.42       |
| 2035 | 0.22      | 0.27      | 0.43       |
| 2036 | 0.23      | 0.28      | 0.44       |
| 2037 | 0.23      | 0.29      | 0.46       |
| 2038 | 0.24      | 0.29      | 0.48       |
| 2039 | 0.24      | 0.30      | 0.49       |
| 2040 | 0.25      | 0.31      | 0.51       |
| 2041 | 0.25      | 0.32      | 0.52       |
| 2042 | 0.26      | 0.32      | 0.54       |
| 2043 | 0.26      | 0.33      | 0.56       |
| 2044 | 0.27      | 0.34      | 0.57       |
| 2045 | 0.27      | 0.35      | 0.59       |
| 2046 | 0.28      | 0.36      | 0.61       |
| 2047 | 0.28      | 0.36      | 0.62       |
| 2048 | 0.29      | 0.37      | 0.64       |
| 2049 | 0.29      | 0.38      | 0.66       |
| 2050 | 0.30      | 0.39      | 0.68       |
| 2051 | 0.30      | 0.40      | 0.70       |
| 2052 | 0.31      | 0.41      | 0.72       |
| 2053 | 0.31      | 0.41      | 0.73       |
| 2054 | 0.32      | 0.42      | 0.75       |
| 2055 | 0.32      | 0.43      | 0.77       |
| 2056 | 0.32      | 0.43      | 0.78       |
| 2057 | 0.33      | 0.44      | 0.80       |
| 2058 | 0.33      | 0.44      | 0.81       |
| 2059 | 0.33      | 0.45      | 0.83       |
| 2060 | 0.33      | 0.45      | 0.84       |
| 2061 | 0.34      | 0.46      | 0.86       |
| 2062 | 0.34      | 0.46      | 0.87       |
| 2063 | 0.35      | 0.47      | 0.89       |
| 2064 | 0.35      | 0.47      | 0.90       |
| 2065 | 0.35      | 0.48      | 0.92       |
| 2066 | 0.38      | 0.53      | 1.00       |
| 2067 | 0.39      | 0.54      | 1.02       |
| 2068 | 0.39      | 0.55      | 1.04       |
| 2069 | 0.40      | 0.56      | 1.07       |
| 2070 | 0.40      | 0.56      | 1.09       |
| 2071 | 0.41      | 0.57      | 1.11       |
| 2072 | 0.41      | 0.58      | 1.13       |
| 2073 | 0.42      | 0.59      | 1.16       |
| 2074 | 0.42      | 0.60      | 1.18       |
| 2075 | 0.43      | 0.61      | 1.20       |
| 2076 | 0.43      | 0.62      | 1.23       |
| 2077 | 0.44      | 0.63      | 1.25       |
| 2078 | 0.44      | 0.64      | 1.28       |
| 2079 | 0.45      | 0.65      | 1.30       |
| 2080 | 0.45      | 0.66      | 1.33       |
| 2081 | 0.46      | 0.67      | 1.35       |
| 2082 | 0.46      | 0.68      | 1.38       |
| 2083 | 0.47      | 0.69      | 1.40       |
| 2084 | 0.47      | 0.70      | 1.43       |
| 2085 | 0.48      | 0.71      | 1.45       |
| 2086 | 0.48      | 0.72      | 1.48       |
| 2087 | 0.49      | 0.73      | 1.51       |
| 2088 | 0.49      | 0.74      | 1.53       |
| 2089 | 0.50      | 0.75      | 1.56       |
| 2090 | 0.50      | 0.76      | 1.59       |
| 2091 | 0.51      | 0.77      | 1.62       |
| 2092 | 0.51      | 0.78      | 1.65       |
| 2093 | 0.52      | 0.79      | 1.68       |
| 2094 | 0.52      | 0.80      | 1.71       |
| 2095 | 0.53      | 0.81      | 1.74       |
| 2096 | 0.53      | 0.82      | 1.77       |
| 2097 | 0.54      | 0.83      | 1.80       |
| 2098 | 0.54      | 0.84      | 1.83       |
| 2099 | 0.55      | 0.85      | 1.86       |
| 2100 | 0.55      | 0.86      | 1.89       |

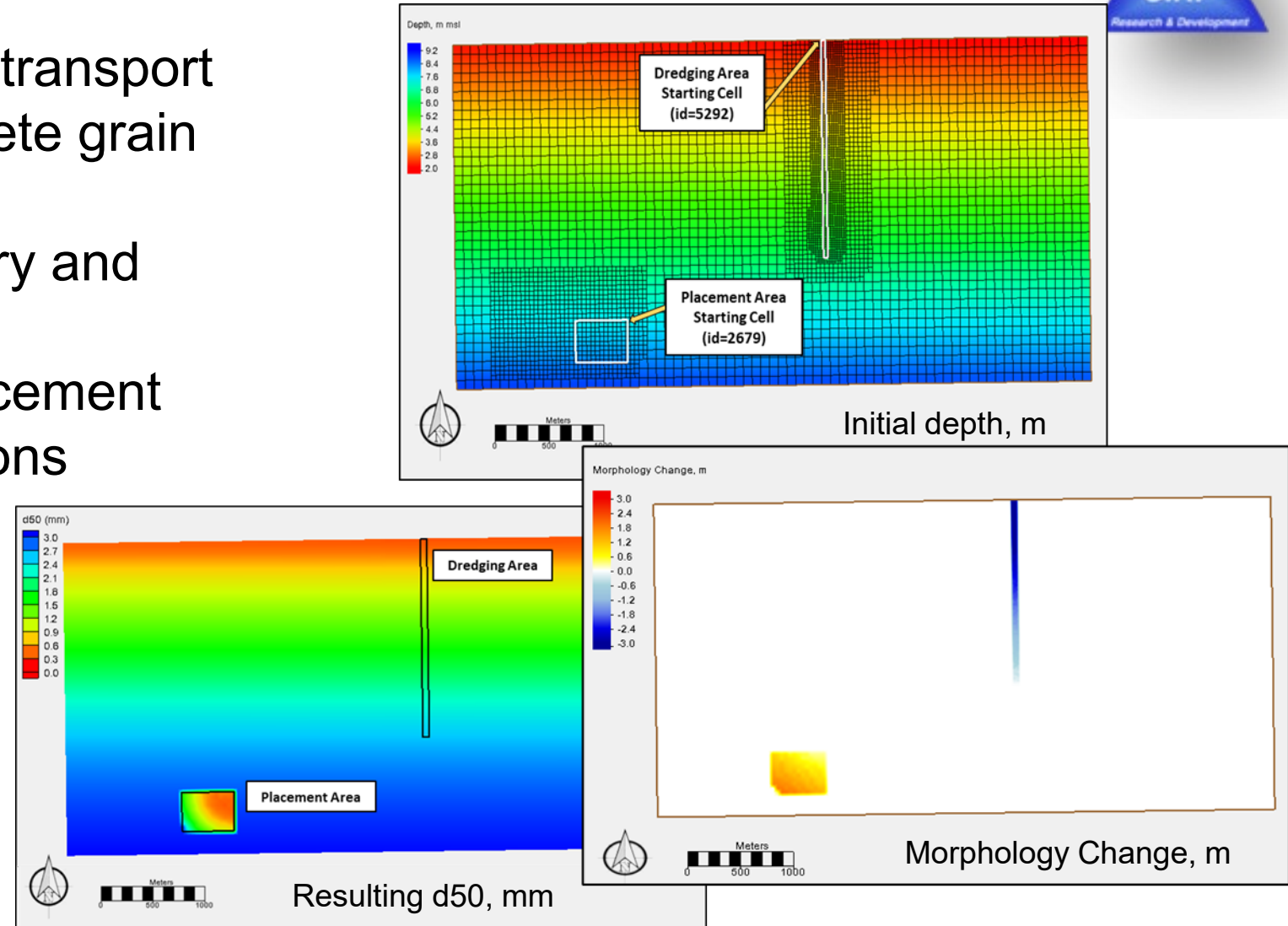
- SLC is incorporated in the CMS through application of a constant value or a time-series curve within the SMS framework.

- Presently, this model capability is applicable to the *WSE-forcing* open boundary type specified as a *WSE Curve* or by *Tidal Constituents* in the CMS.

# Implementation of Dredge Module interface into SMS 13.0+



- Single- or multiple-grain size transport
- Represent sediment by discrete grain size classes
- Dynamically adjust bathymetry and construct islands
- Options for dredging and placement operations DURING simulations
- Evaluate the morphologic changes and estimate future dredging requirements



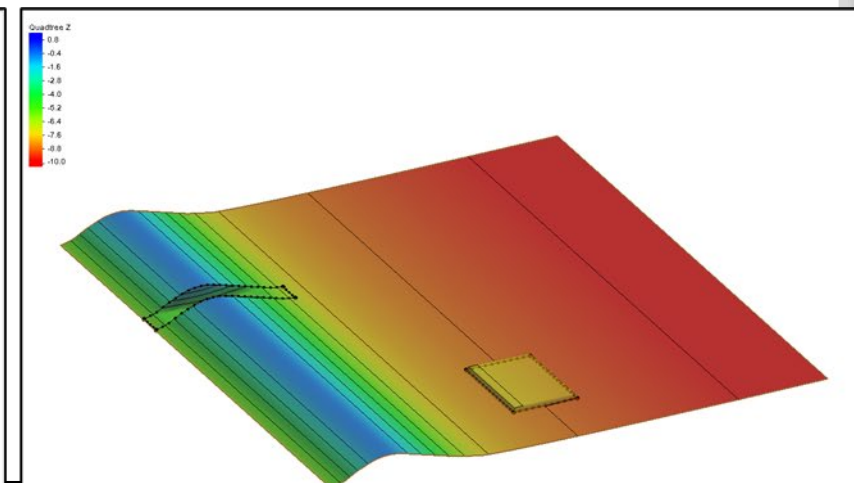
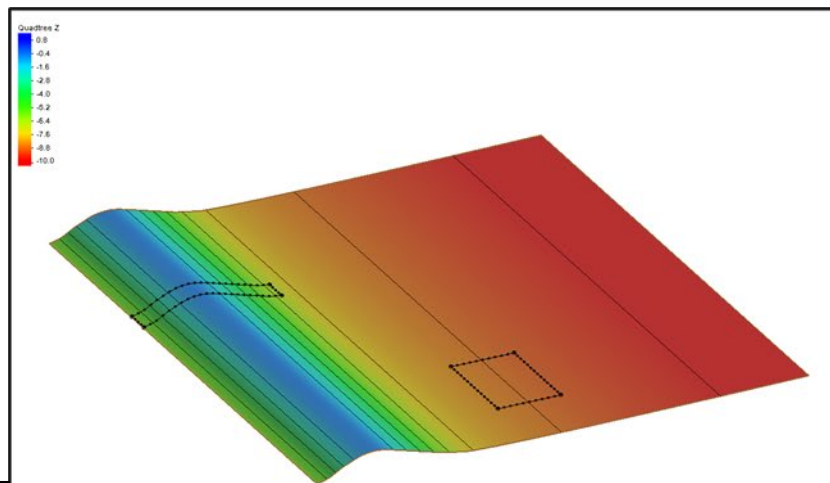
# Implementation of Sediment Volume tool interface into **SMS 13.1+**



- Define mining and placement zones
- SMS generates new alternative grids based on multiple setups
- More accurate than modifying depths cell by cell to reach desired volume of material.

Mass Balance Table

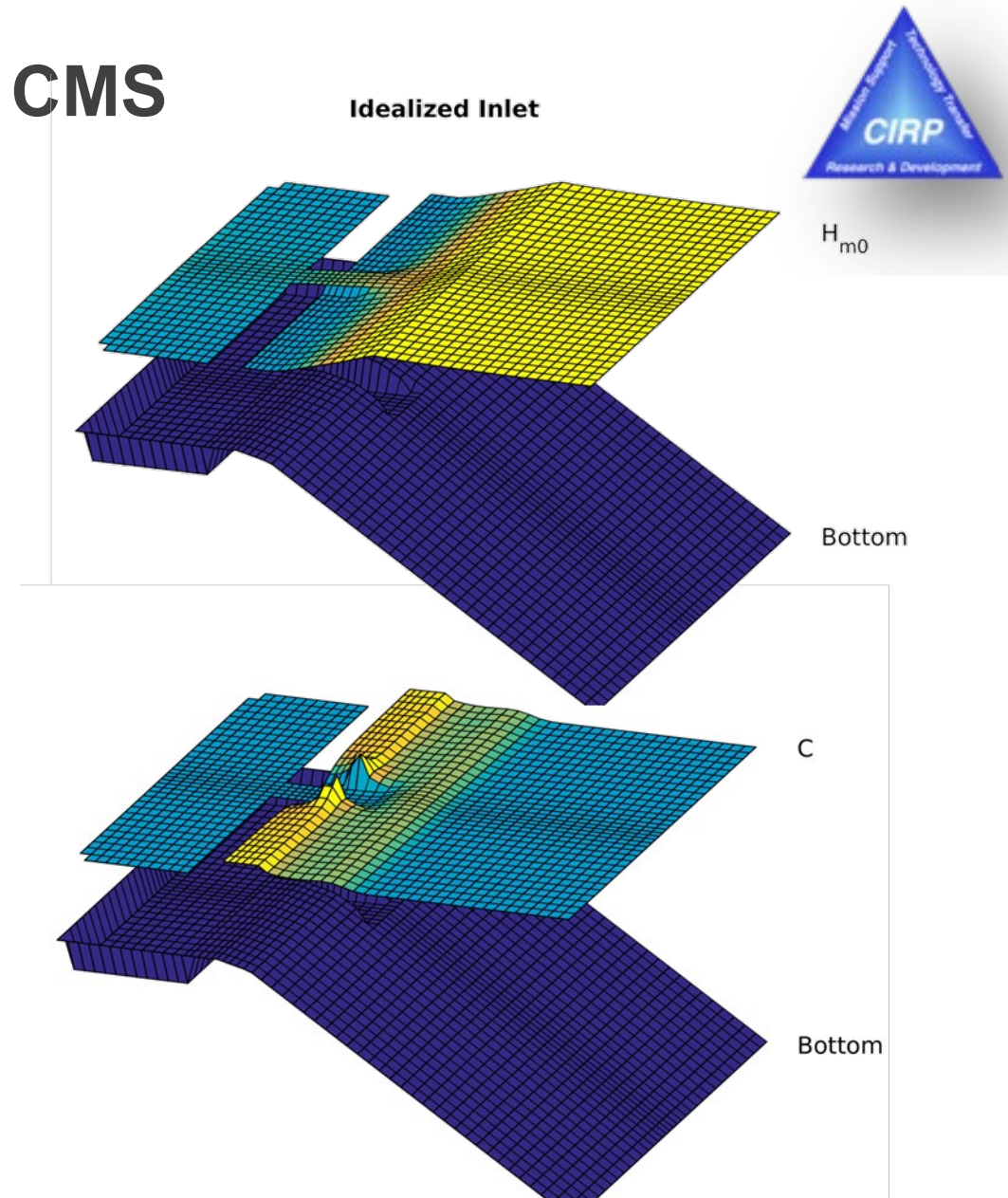
| Mass Balance Table |           |    |                         |                          |       |          |            |       |
|--------------------|-----------|----|-------------------------|--------------------------|-------|----------|------------|-------|
|                    | Name      | ID | Polygon type            | Cut / fill type          | Value | Priority | Priority % | Total |
| 1                  | Channel   | 2  | Specified cut region ▼  | Constant elevation (m) ▼ | -5    |          |            | 1.03  |
| 2                  | Placement | 1  | Available fill region ▼ | Relative thickness (m) ▼ | 5     | 1 ▼      | 100        | 3.78  |
| 3                  |           |    |                         |                          |       |          |            |       |
| 4                  |           |    |                         |                          |       |          |            |       |





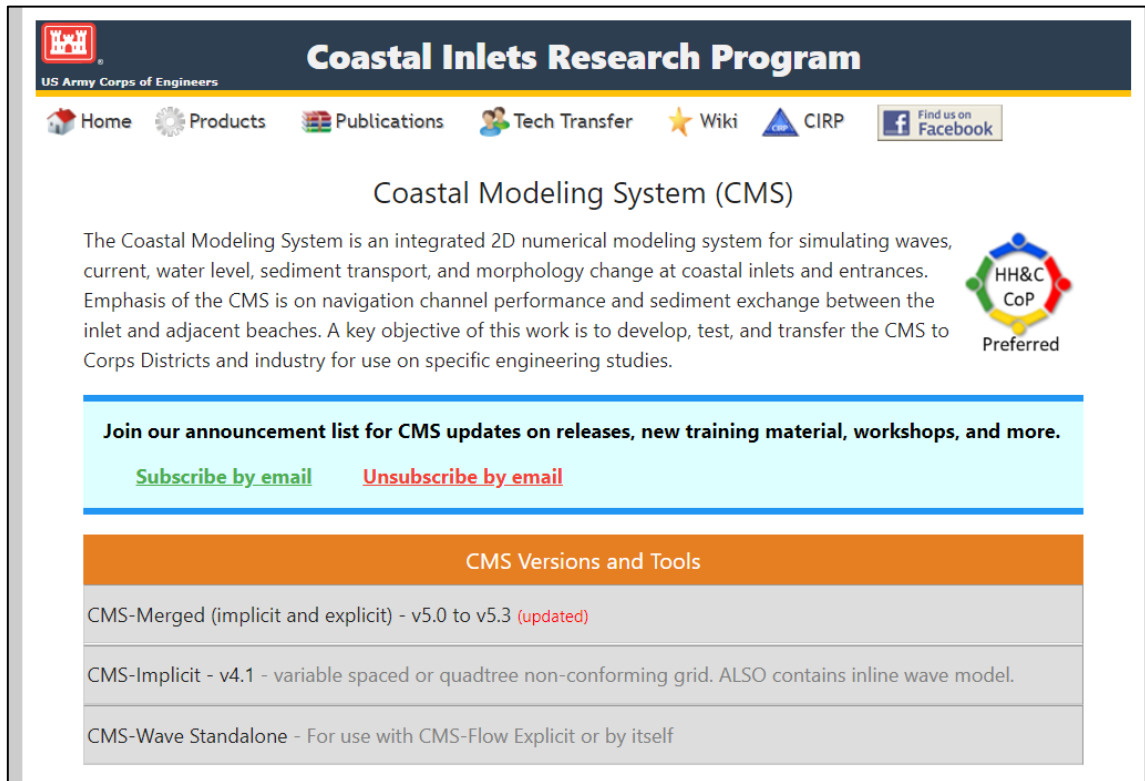
# Validation and Testing of CSHORE in CMS

- CSHORE sediment transport option is implemented
- Dependencies on waves, currents are satisfied with CMS wave, flow module solutions
- The computed concentration field and sediment transport has been verified with the theoretical CSHORE basis
- A comparison of the new implementation vs LSTF data is ongoing.
- Brad Johnson is working on this part of the code.



# Documentation

## CIRP website



**Coastal Inlets Research Program**

US Army Corps of Engineers

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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, 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.

**Join our announcement list for CMS updates on releases, new training material, workshops, and more.**

[Subscribe by email](#) [Unsubscribe by email](#)

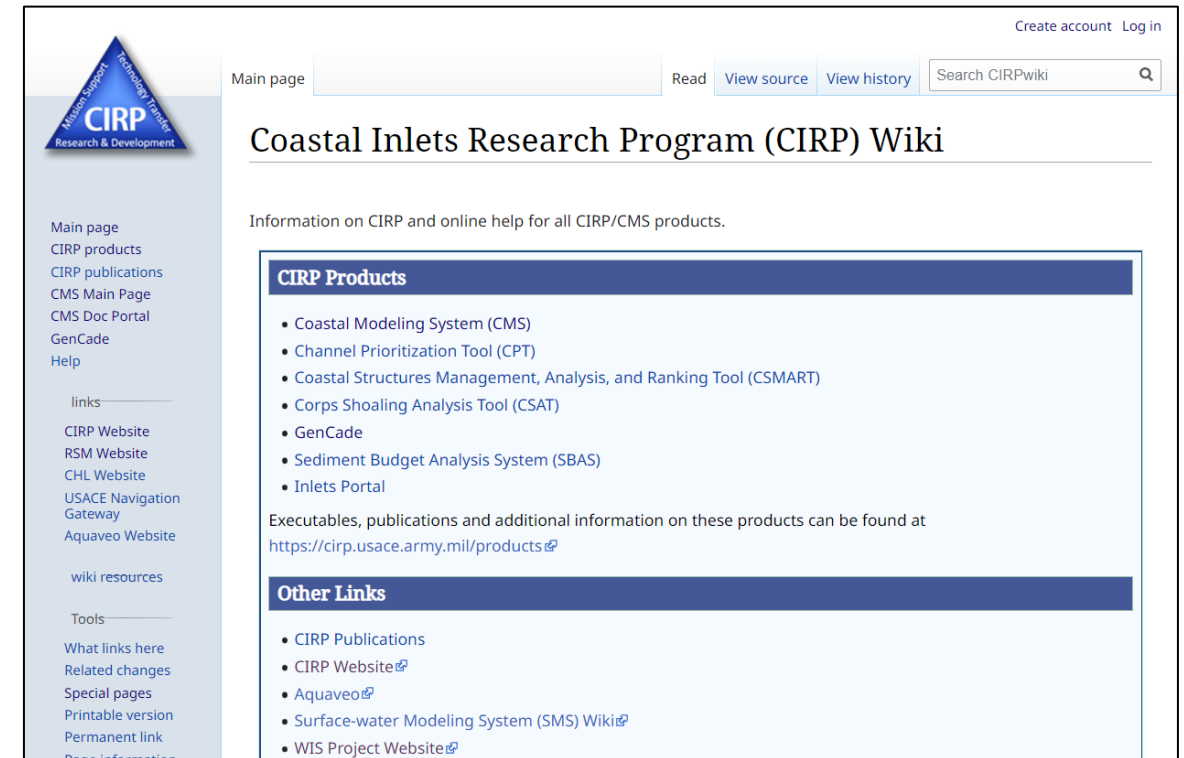
#### CMS Versions and Tools

|                                                                                                         |
|---------------------------------------------------------------------------------------------------------|
| CMS-Merged (implicit and explicit) - v5.0 to v5.3 <a href="#">(updated)</a>                             |
| CMS-Implicit - v4.1 - variable spaced or quadtree non-conforming grid. ALSO contains inline wave model. |
| CMS-Wave Standalone - For use with CMS-Flow Explicit or by itself                                       |

<https://cirp.usace.army.mil/>



## CIRP Wiki



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Main page Read View source View history Search CIRPwiki

### Coastal Inlets Research Program (CIRP) Wiki

Information on CIRP and online help for all CIRP/CMS products.

#### CIRP Products

- Coastal Modeling System (CMS)
- Channel Prioritization Tool (CPT)
- Coastal Structures Management, Analysis, and Ranking Tool (CSMART)
- Corps Shoaling Analysis Tool (CSAT)
- GenCade
- Sediment Budget Analysis System (SBAS)
- Inlets Portal

Executables, publications and additional information on these products can be found at <https://cirp.usace.army.mil/products>

#### Other Links

- CIRP Publications
- CIRP Website
- Aquaveo
- Surface-water Modeling System (SMS) Wiki
- WIS Project Website

<https://cirpwiki.info>

# Documentation – Website ([cirp.usace.army.mil](http://cirp.usace.army.mil))

- Products
  - CMS
  - GenCade
  - Others
- Publications
  - Technical Reports
  - CHETNS
  - Journal Articles
  - Others
- Tech Transfer
  - Webinars
  - Workshops
  - Video Clips

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CHL Navigation R&D Collaboration Video  
Brochures  
Posters

The Coastal Inlets Research Program (CIRP) is hosting a Tech Transfer Workshop from 19 - 23 September 2022. The workshop will be held at the US Army Corps of Engineers' Mobile District Area Office, located in Mobile, Alabama.

The focus of this workshop is on the Surface-Water Modeling System (SMS) Version 13.1, Coastal Modeling System (CMS) Version 5.2, and GenCade Version 1.1.8.

Note: This will be a hybrid workshop with **very limited** seating availability at the Mobile District. Otherwise, the workshop will be conducted via Webex. Contact Mitchell Brown, [mitchell.e.brown@usace.army.mil](mailto:mitchell.e.brown@usace.army.mil), to see if there is room to attend in person.

Webex connection information:  
<https://usace1.webex.com/join/CIRP>. For audio, choose to have the system call you.

| Time        | Mon, 19 Sep | Tue, 20 Sep                                            | Wed, 21 Sep                                         | Thu, 22 Sep                                                             | Fri, 23 Sep                                                                     |
|-------------|-------------|--------------------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| 0830 - 1200 |             | CMS (v5.2)<br>Flow grid creation<br>Flow model control | CMS (v5.2)<br>Steering<br>Post-processing<br>Hydro- | GenCade (v1.1.8)<br>Introduction to GenCade<br>Simple Example Walk-Thru | CMS (v5.2)<br>Multiple Sediment Grain Sizes<br>Advanced Topics<br>SMS 13.2 demo |



# Documentation – Wiki (<https://cirpwiki.info>)



## ■ CMS

- Documentation Portal
- Tutorials
- Technical Info (Equations)
- Validation Cases

## ■ Gencode

- Information
- User Guide

### GenCode Users Guide

#### 1. Getting Started

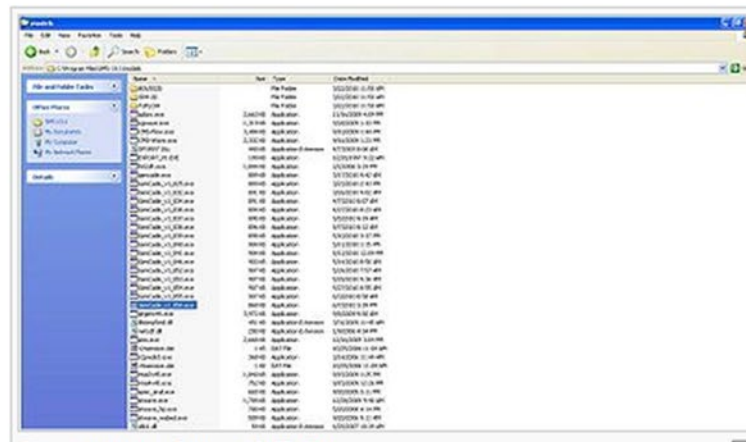
This GenCode guide was last updated in November 2010. Most of the screenshots used in this guide were created with the August 25, 2010, build of the SMS. This guide refers to GenCode\_v1\_070.exe as the most recent executable. Developers are constantly upgrading the SMS and GenCode executables, so the graphics in a future version may look slightly different than the visuals included in this user guide.

A very simple example can be found [here](#). This example shows all steps necessary to produce results and includes a zip file with all of the input and output files that can be used to reproduce the results on another computer.

#### 1.1 Setup GenCode in the SMS

GenCode is available in the SMS (Surface-water Modeling System) interface. To use GenCode, a working version of SMS 10.1 and executable for SMS 11.0 Development are necessary. The SMS 11.0 Development executable is copyrighted, so a registration code is necessary before using.

First, locate the GenCode executable on the machine. As of November 2010, the most recent GenCode executable is GenCode\_v1\_070.exe. Drop the executable into the models folder under SMS 10.1 as shown in Figure 1.



# Summary



## Depth-integrated and wave-averaged

- Hydrodynamic and
- Sediment transport and morphology change models

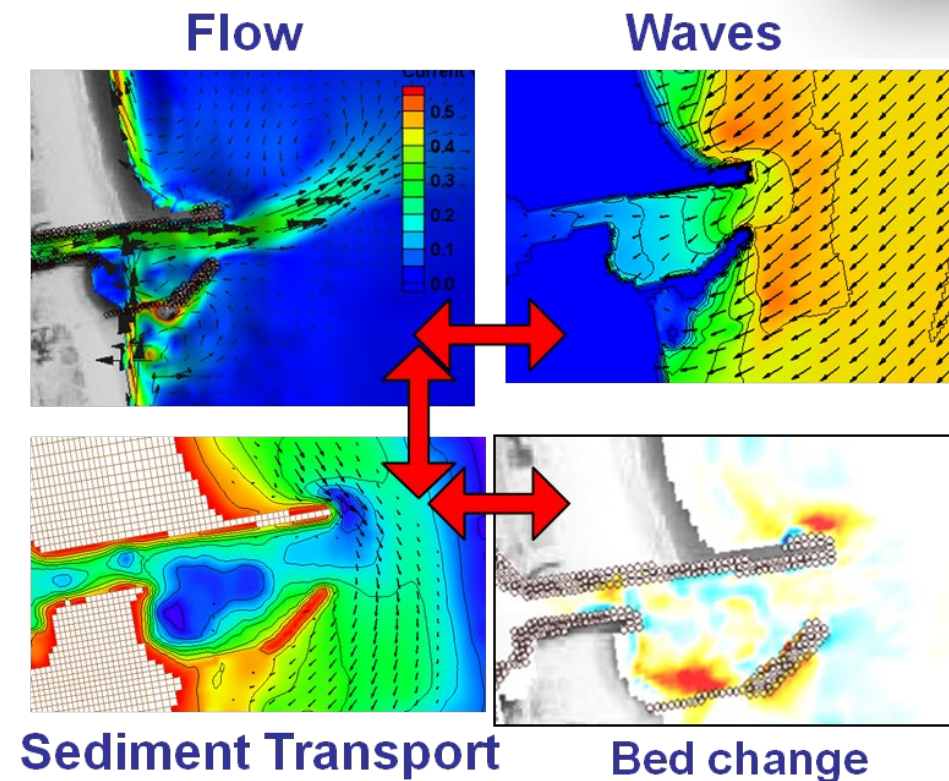
## Coupled to

- Spectral wave model
- Roller model

Model extensively verified and tested with analytical, laboratory, and field test cases

Field applications demonstrate the model capability for engineering projects

Improvements in stability and new features each year.





# Questions?

**Mitch Brown**

**[Mitchell.E.Brown@usace.army.mil](mailto:Mitchell.E.Brown@usace.army.mil)**

**601-634-4036**

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**601-634-2704**