OVERVIEW OF THE SMS (V13.3), COASTAL MODELING SYSTEM, AND USER RESOURCES

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CMS Basics Webinar Series
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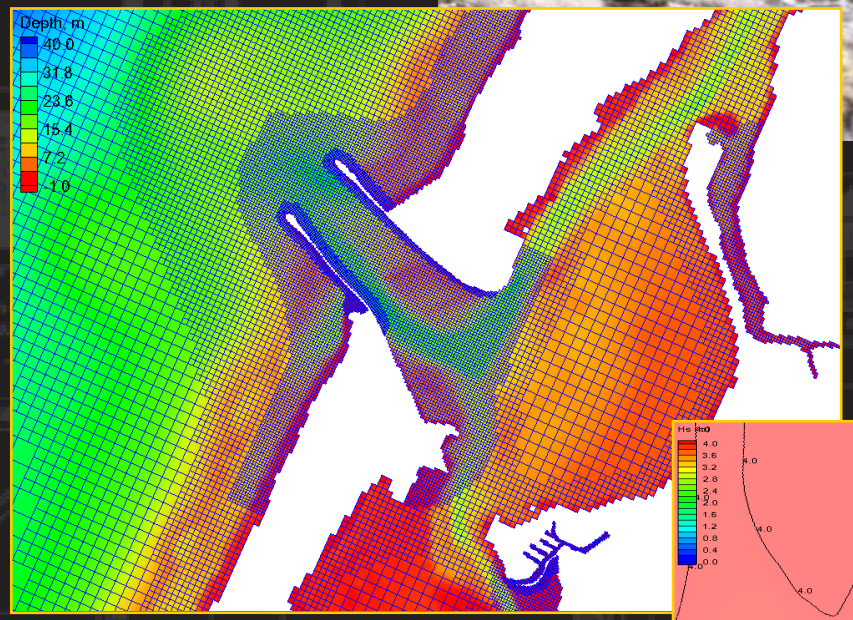

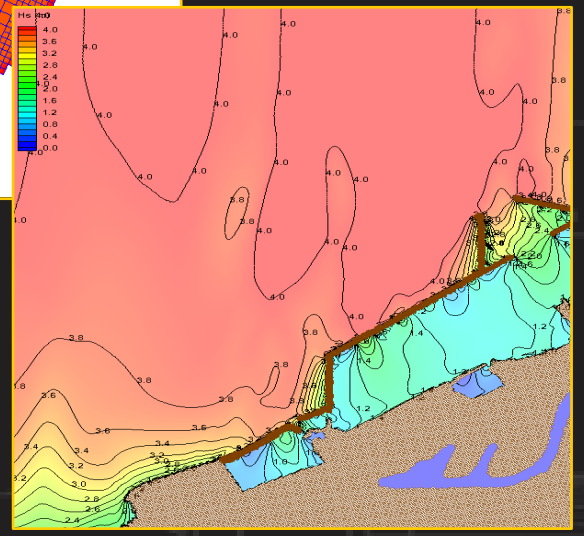

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OVERVIEW OF PRESENTATION

- Introduction to the Surface-water Modeling System (SMS v.13.3)
  - 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.

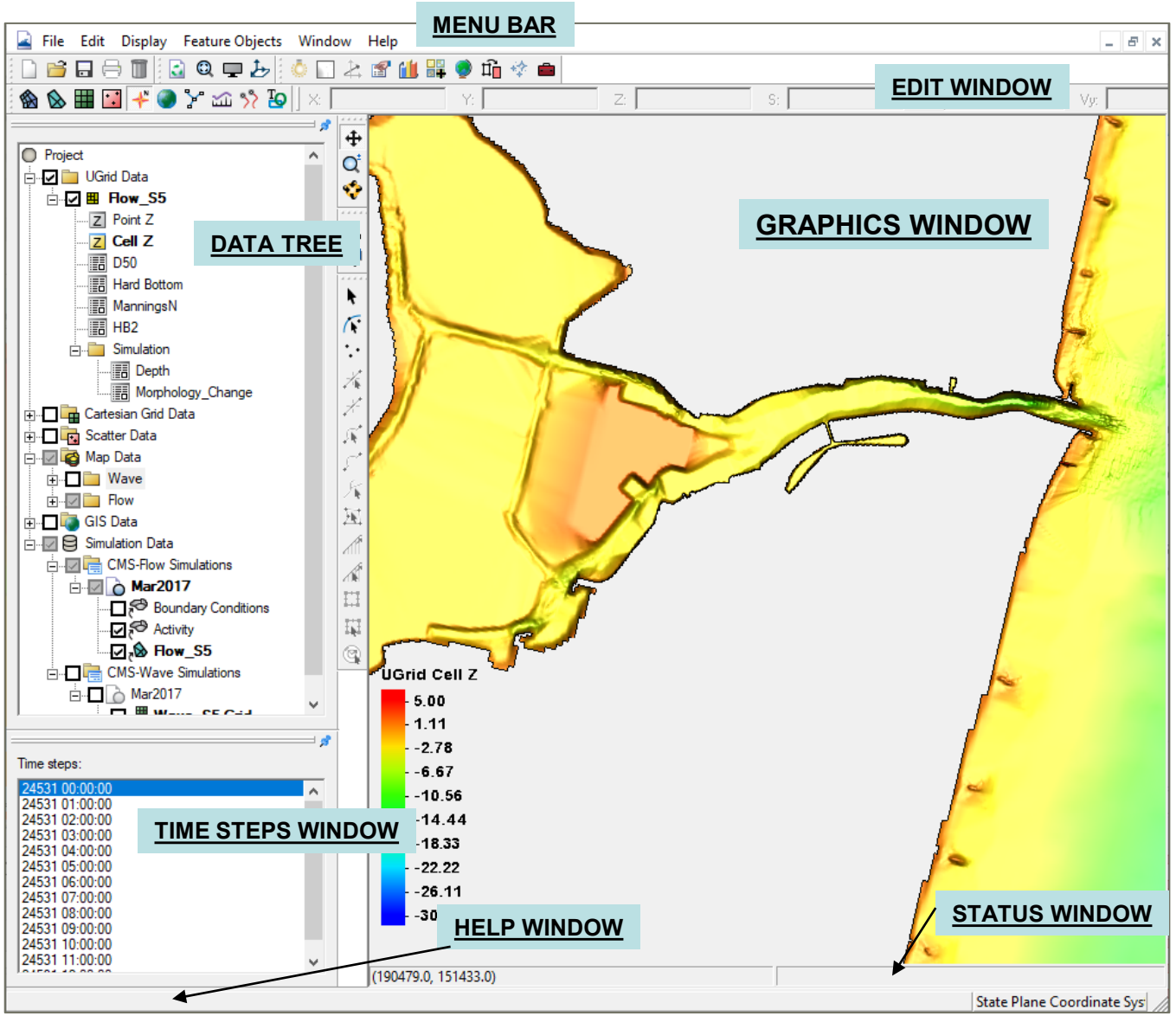
WHAT IS THE SMS?

- 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

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.



DYNAMIC TOOLBAR

Cartesian Grid tools

- Select Cell, Row, and Column 
- 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 Any Object
- 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

UGrid Tools (for telescoping)

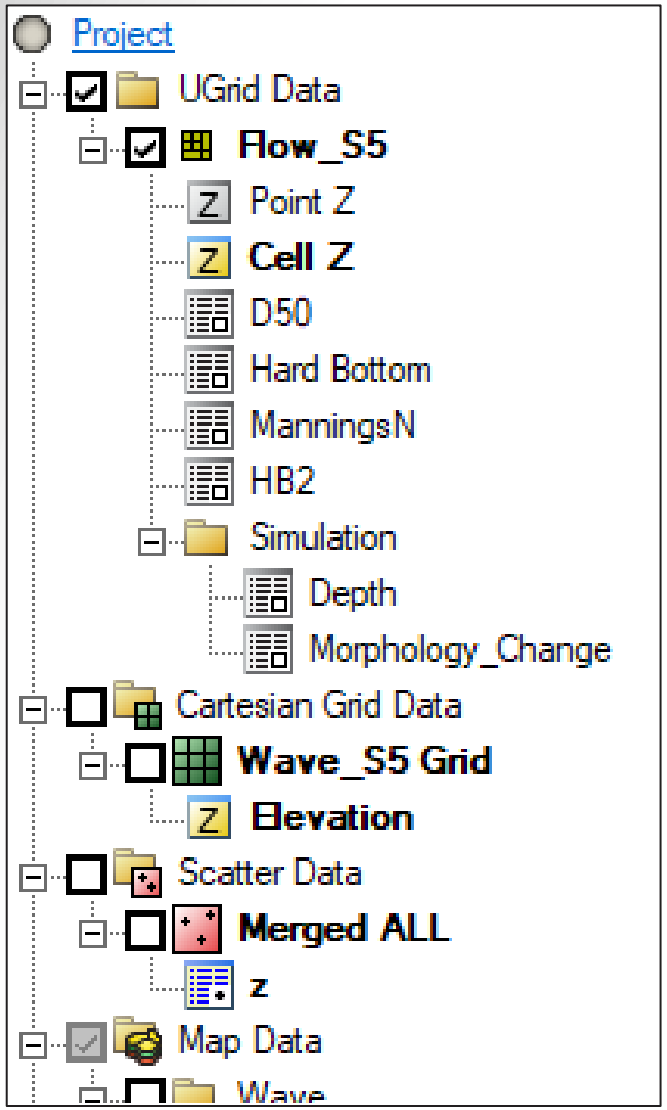
- Select Point
- Select Cell
- Create Nodestring**
- Create Cross Section**

** Not Presently used for CMS

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



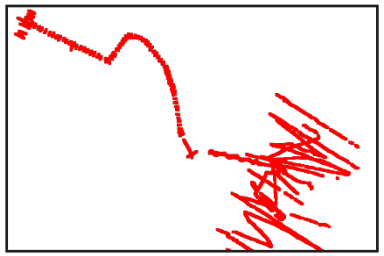
- The Data Tree makes selection of loaded datasets easy. Simply click on a dataset to make it active, and the graphics window updates accordingly.
- There are several "right-click" options available depending on the type of dataset activated, and within which module it is located. A few of these are:
  - 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.

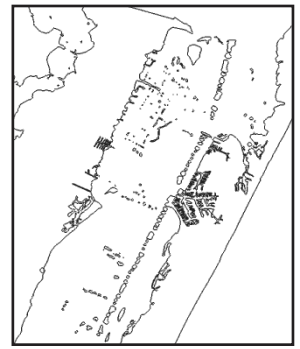
SMS – A COMPLETE MODELING INTERFACE

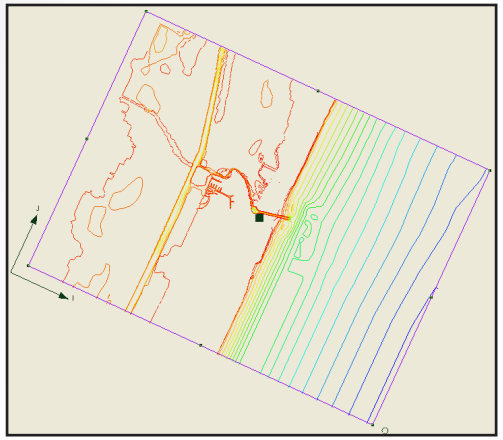
Build a CMS model from start to finish – all within SMS

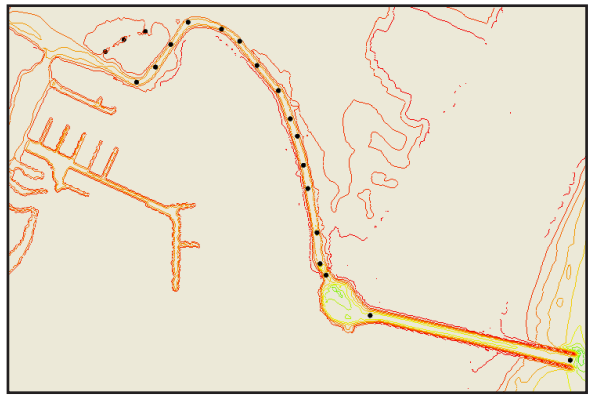
Import Background Data

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



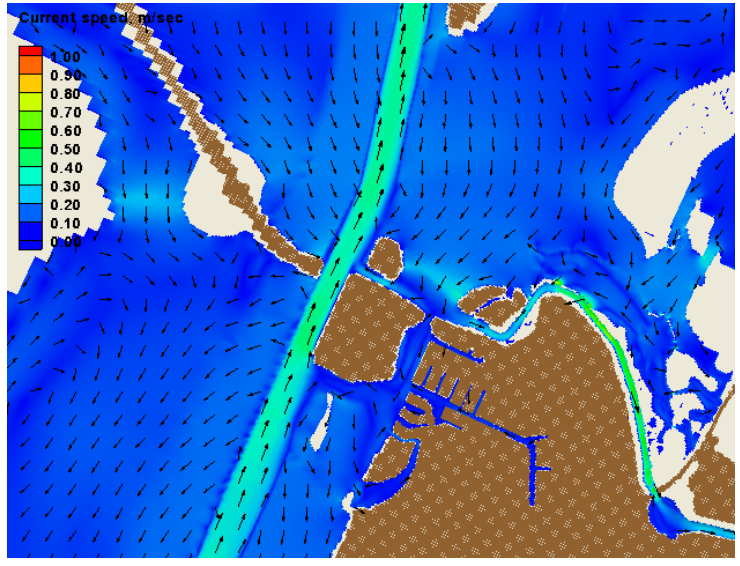






Create Conceptual Model

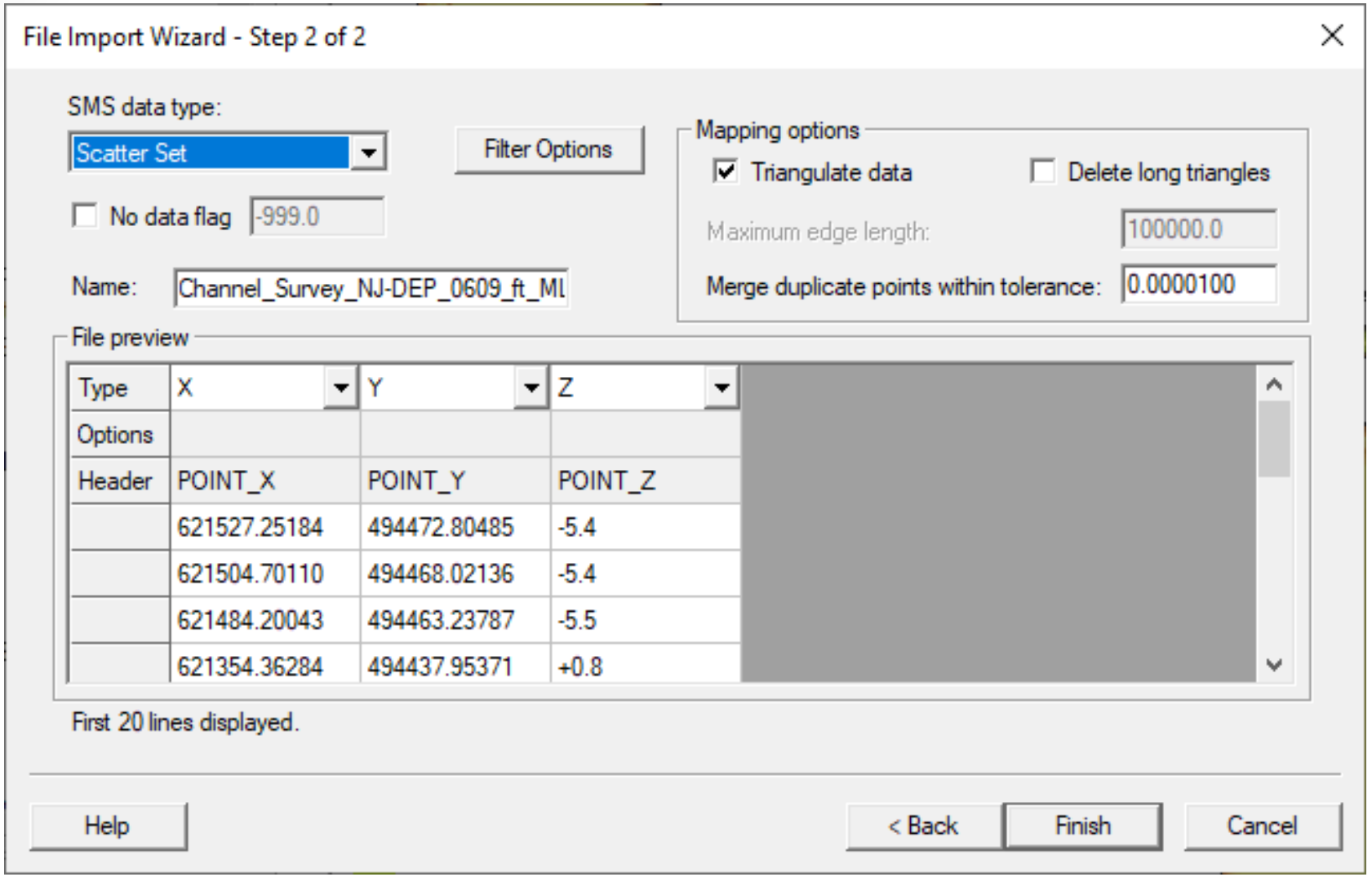
- Delineate CMS model domain
- Define areas of finer resolution



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

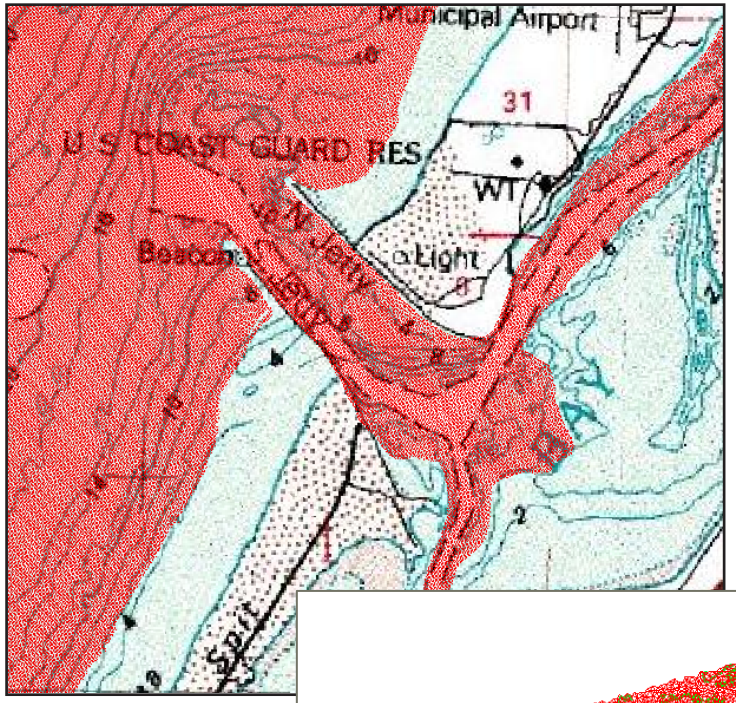
SMS – DATA PROCESSING – IMPORT WIZARD

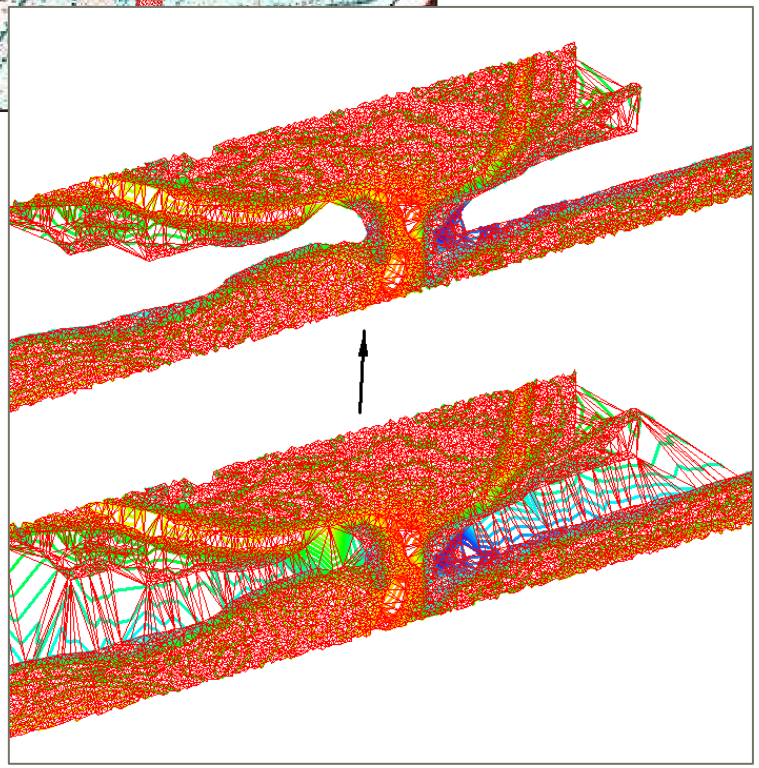


SCATTERED DATA (TINS)

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



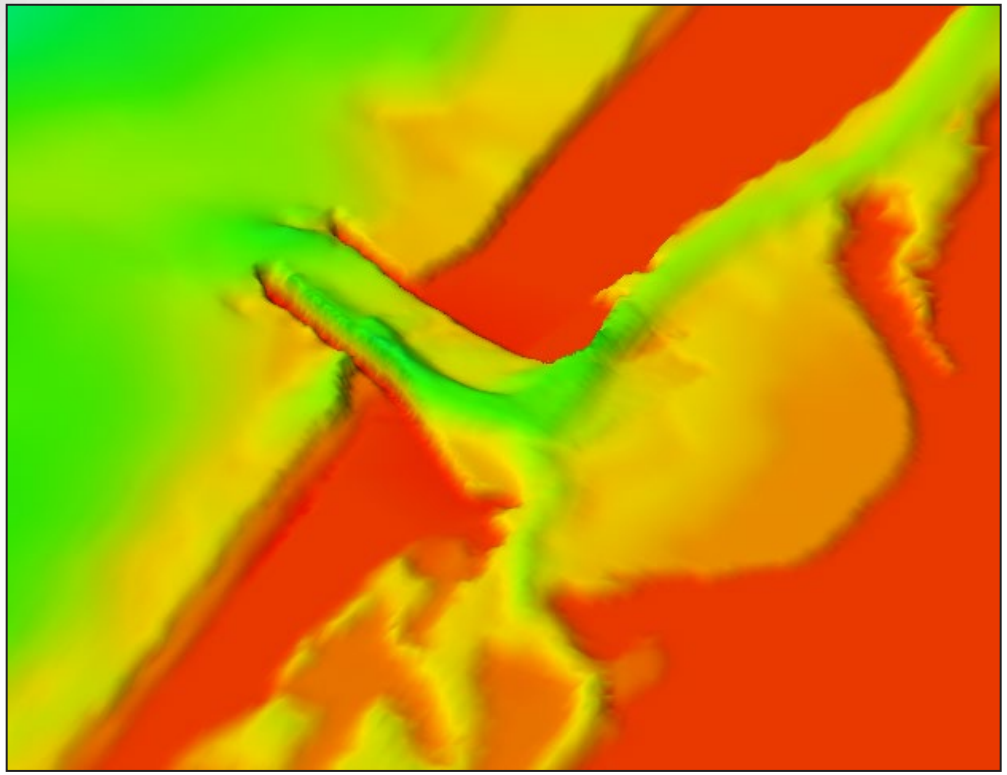


User can delete points or triangles to change extents of a set.

User can swap edges to alter shape of surface

- Used in linear interpolation

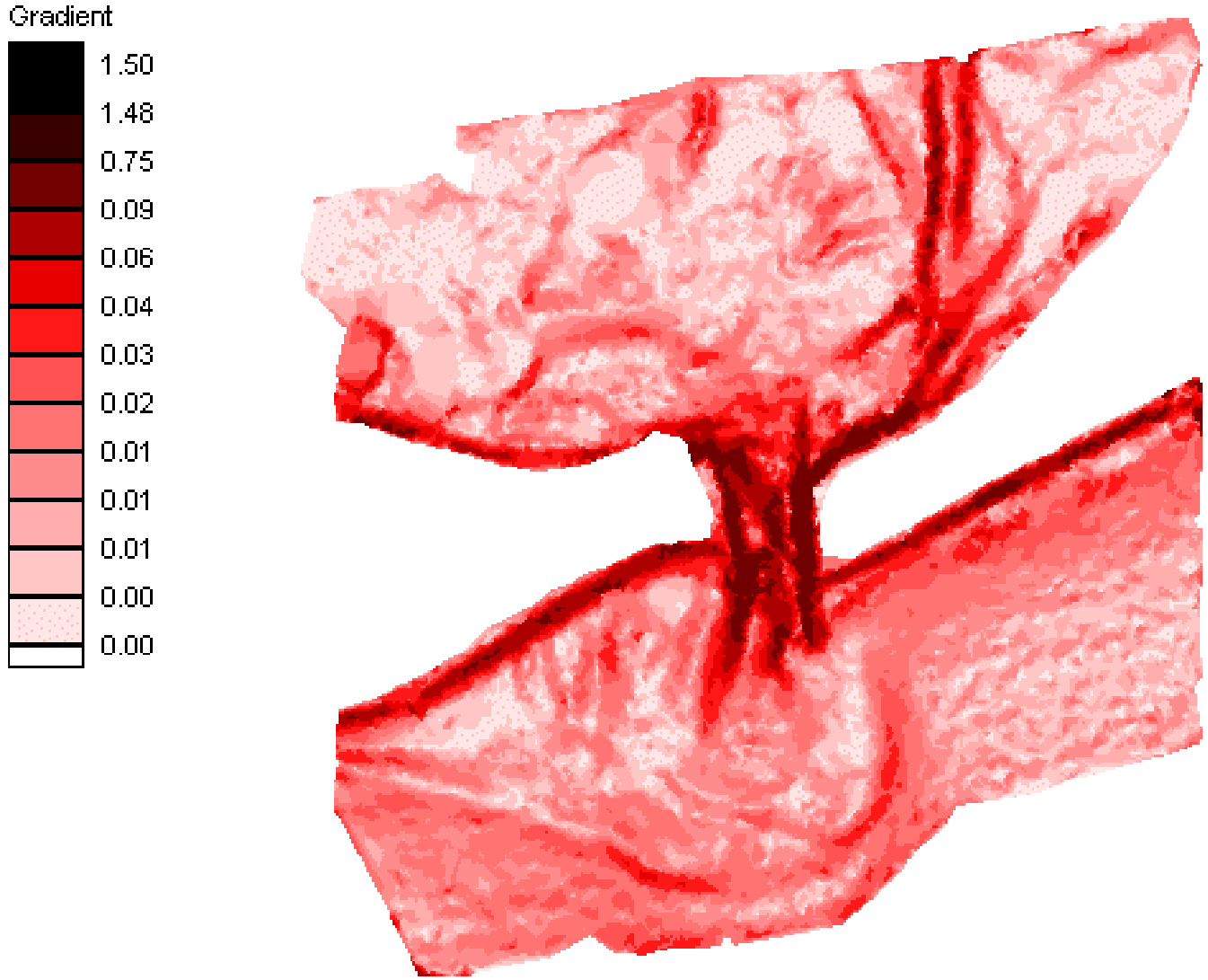
VISUALIZATION OF SCATTERED DATA



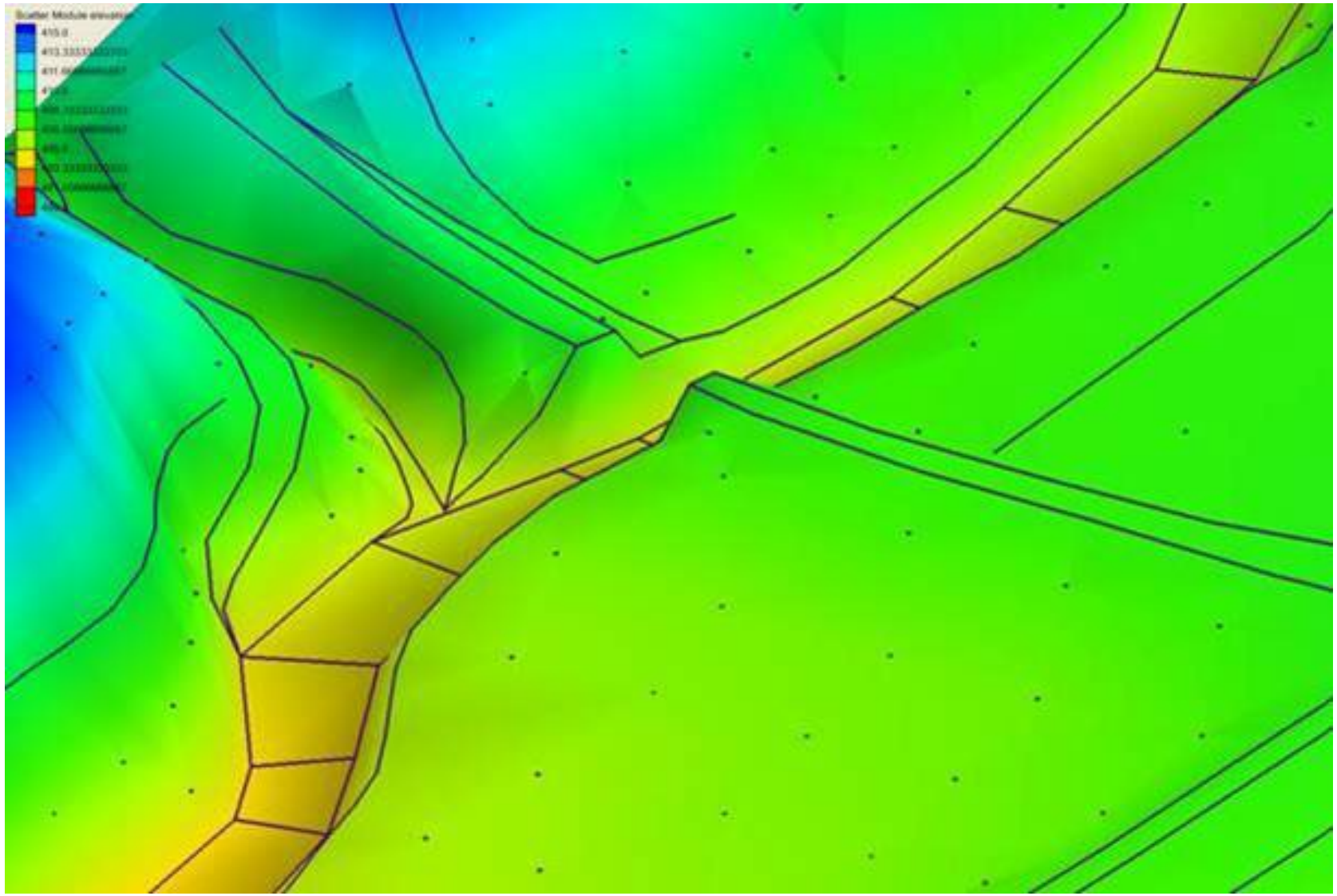
Humboldt Bay, CA
Oblique view
Z-magnification 5x

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

LIDAR SURVEYS

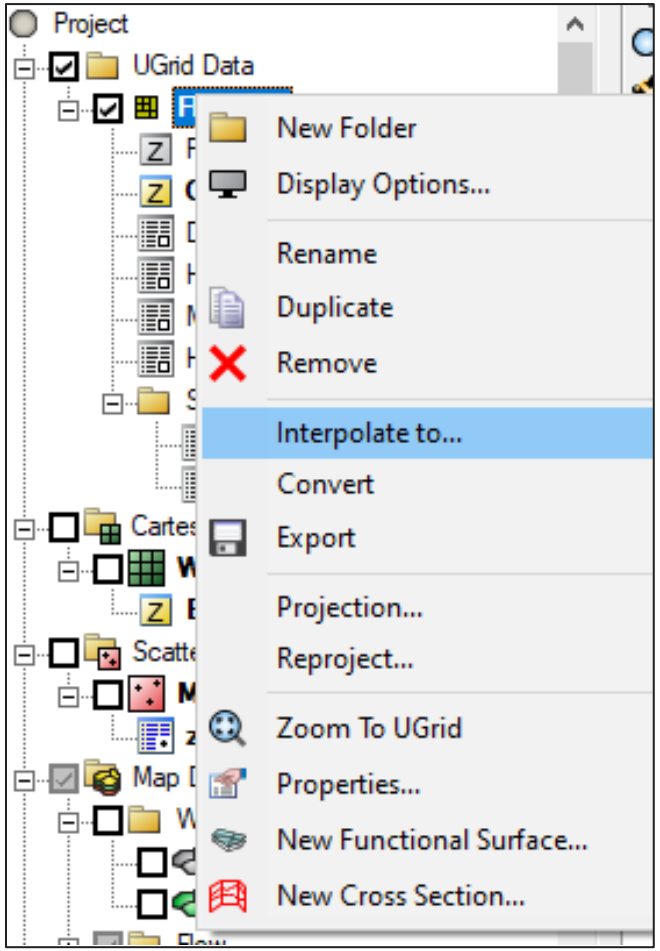


BREAKLINES

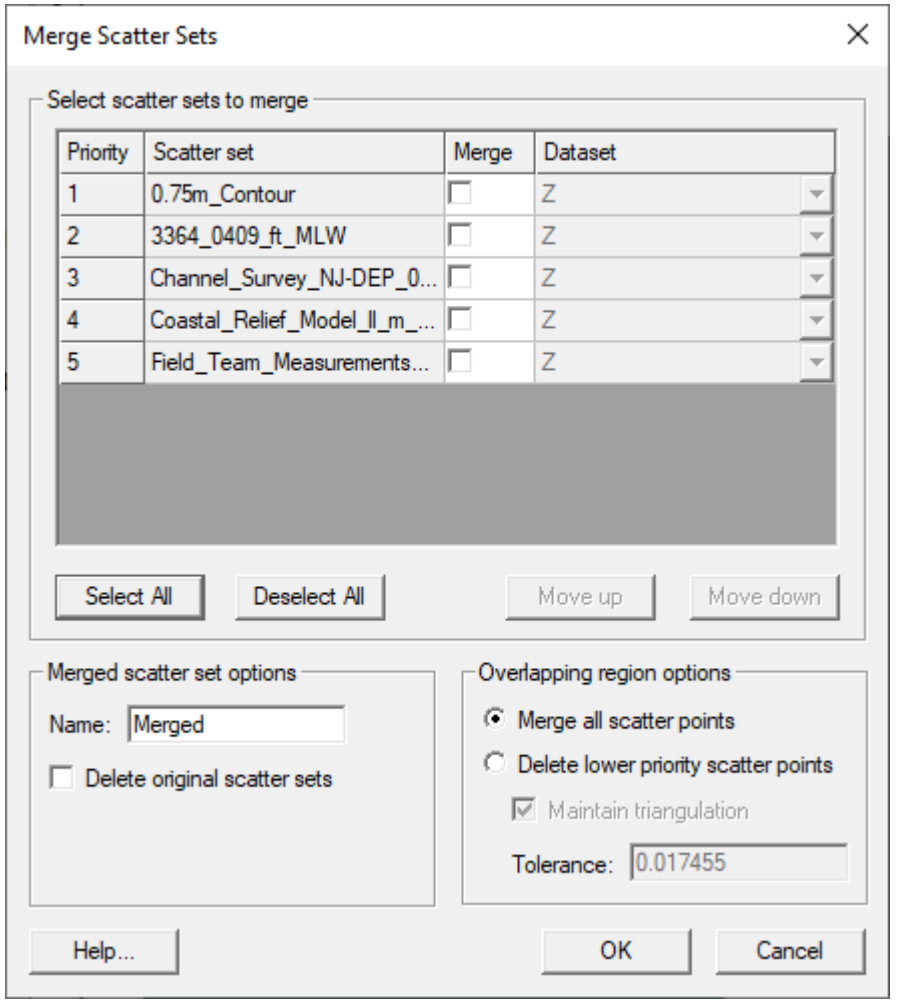


OPERATING WITH SCATTER SETS

Right Click Menu

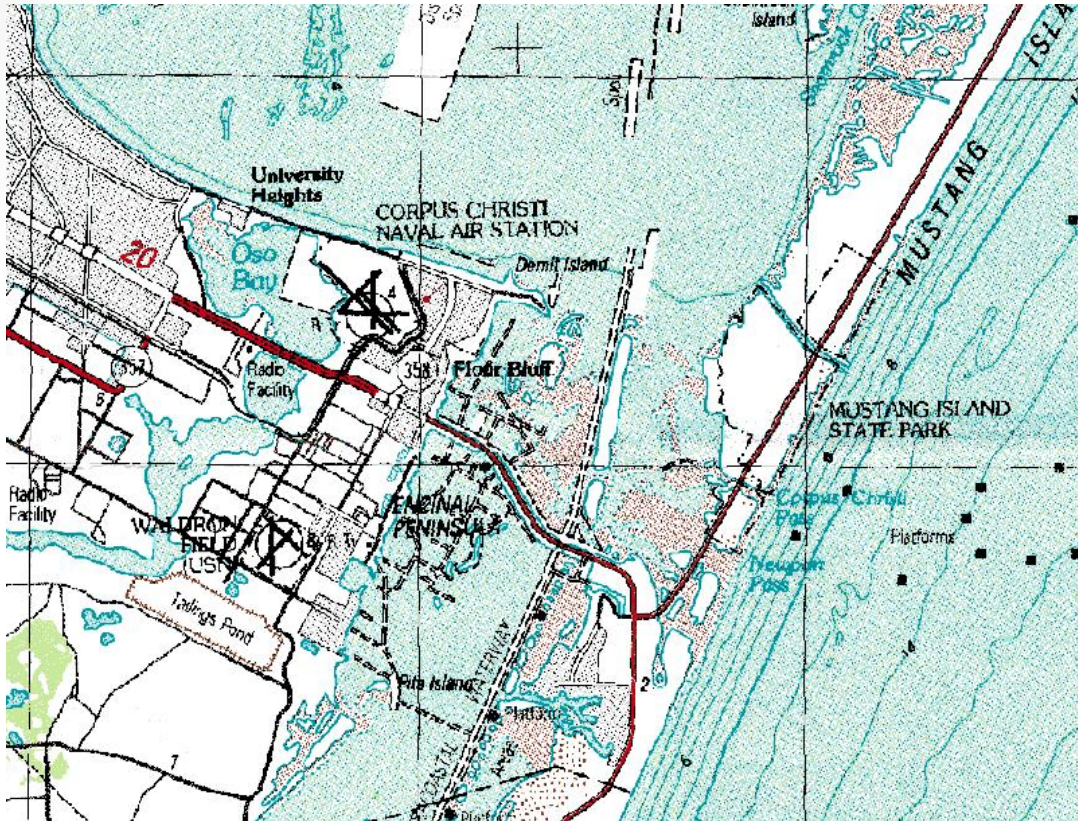


Merge



IMAGES

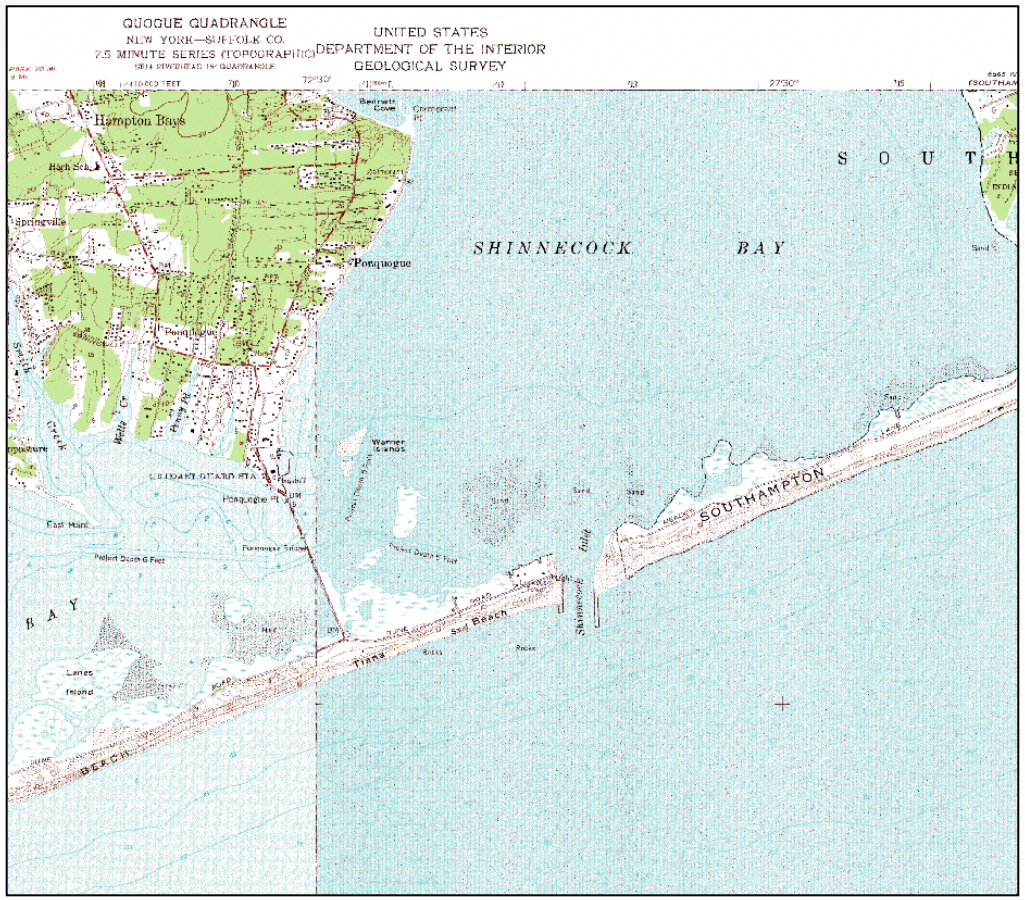
Topo Maps

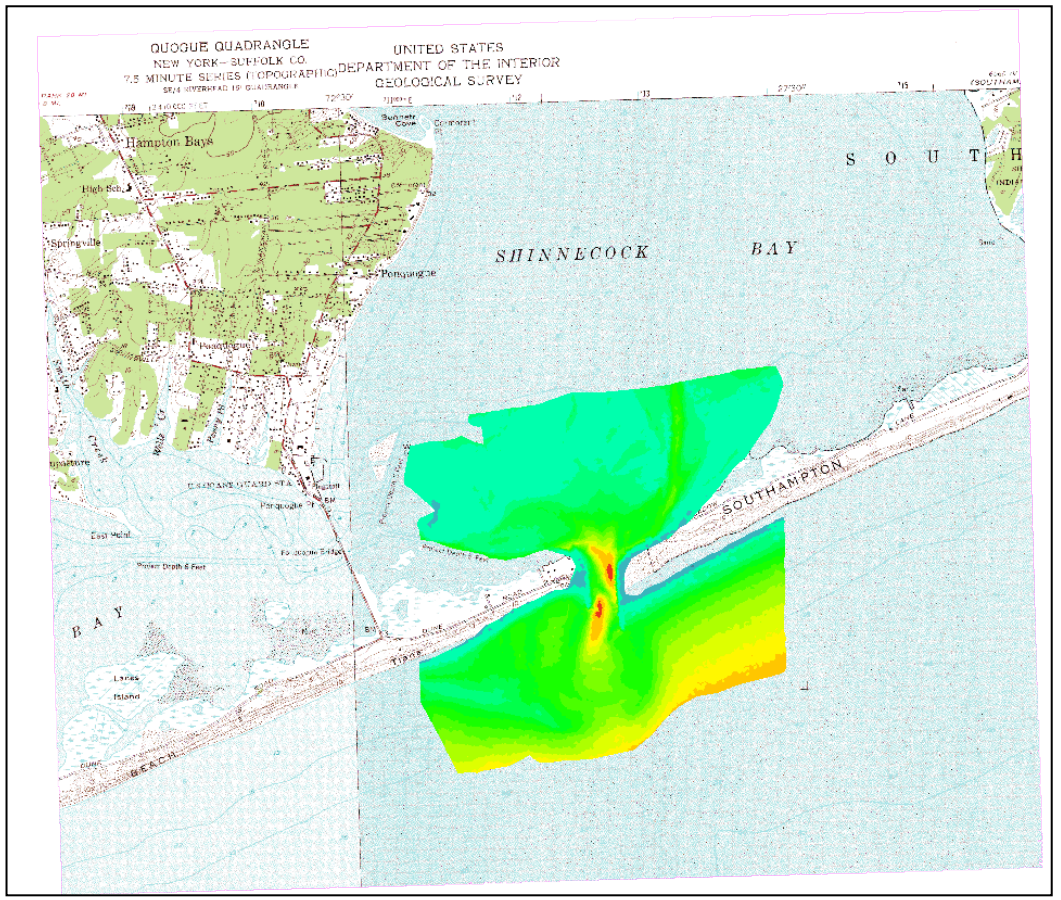


Aerial Photos

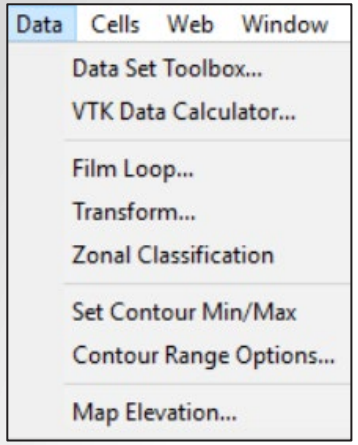
IMAGE DATA

Overlay data over images



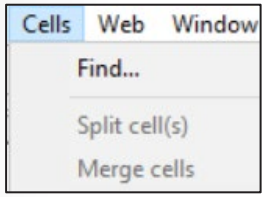


GENERAL SMS INTERFACE: PULL-DOWN MENUS

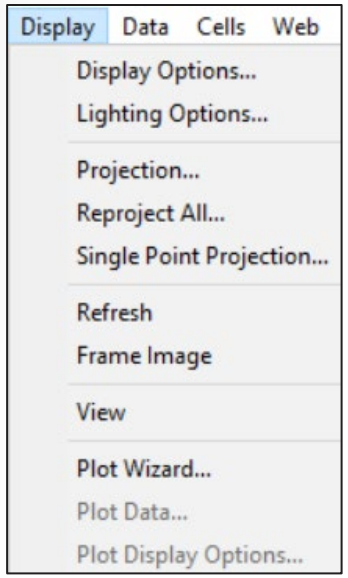


The Data pull-down menu contains many items – here are a few:

- 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.

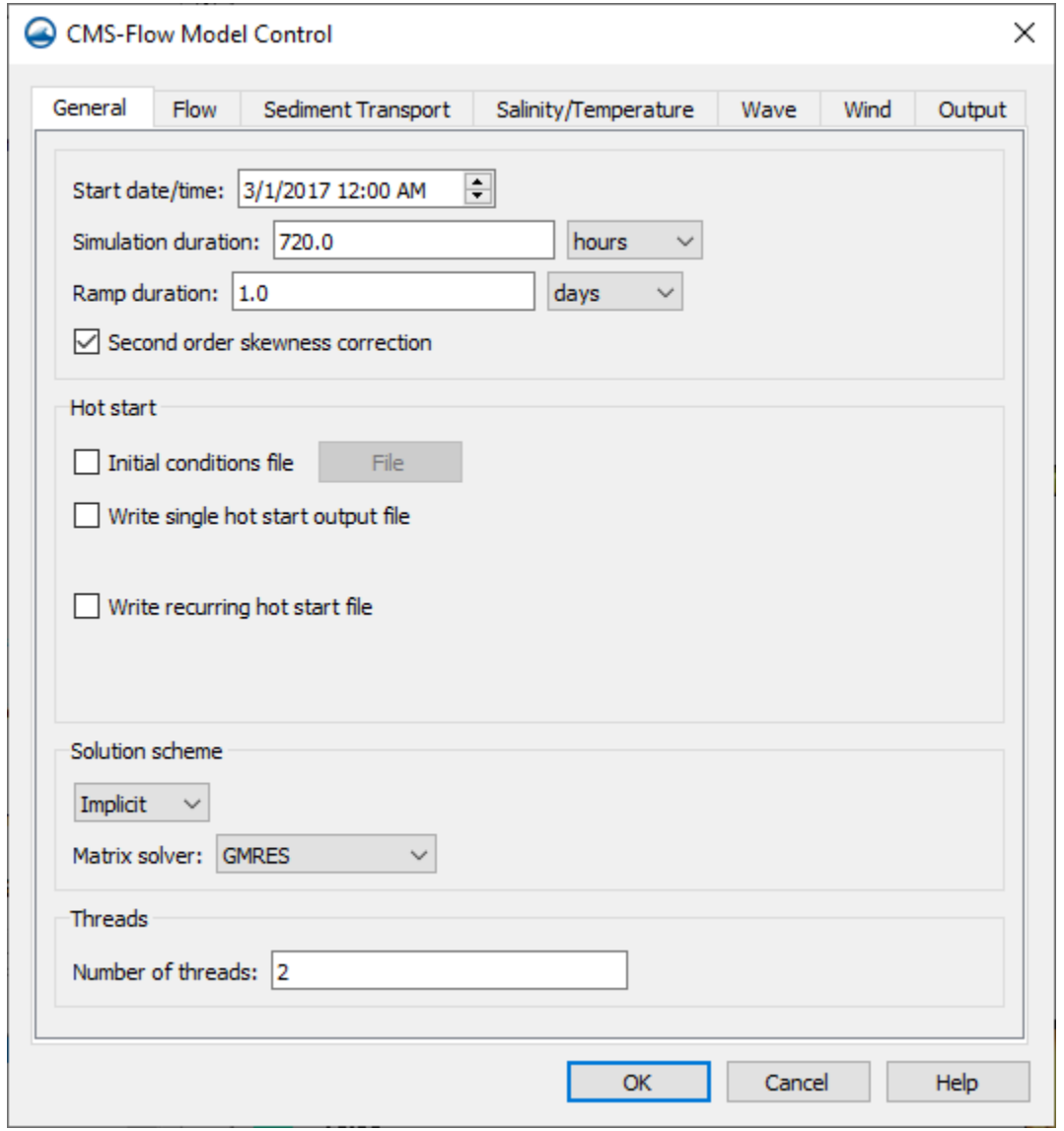


The Display pull-down menu contains commands to manipulate what and how data is viewed inside the interface.

- 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.

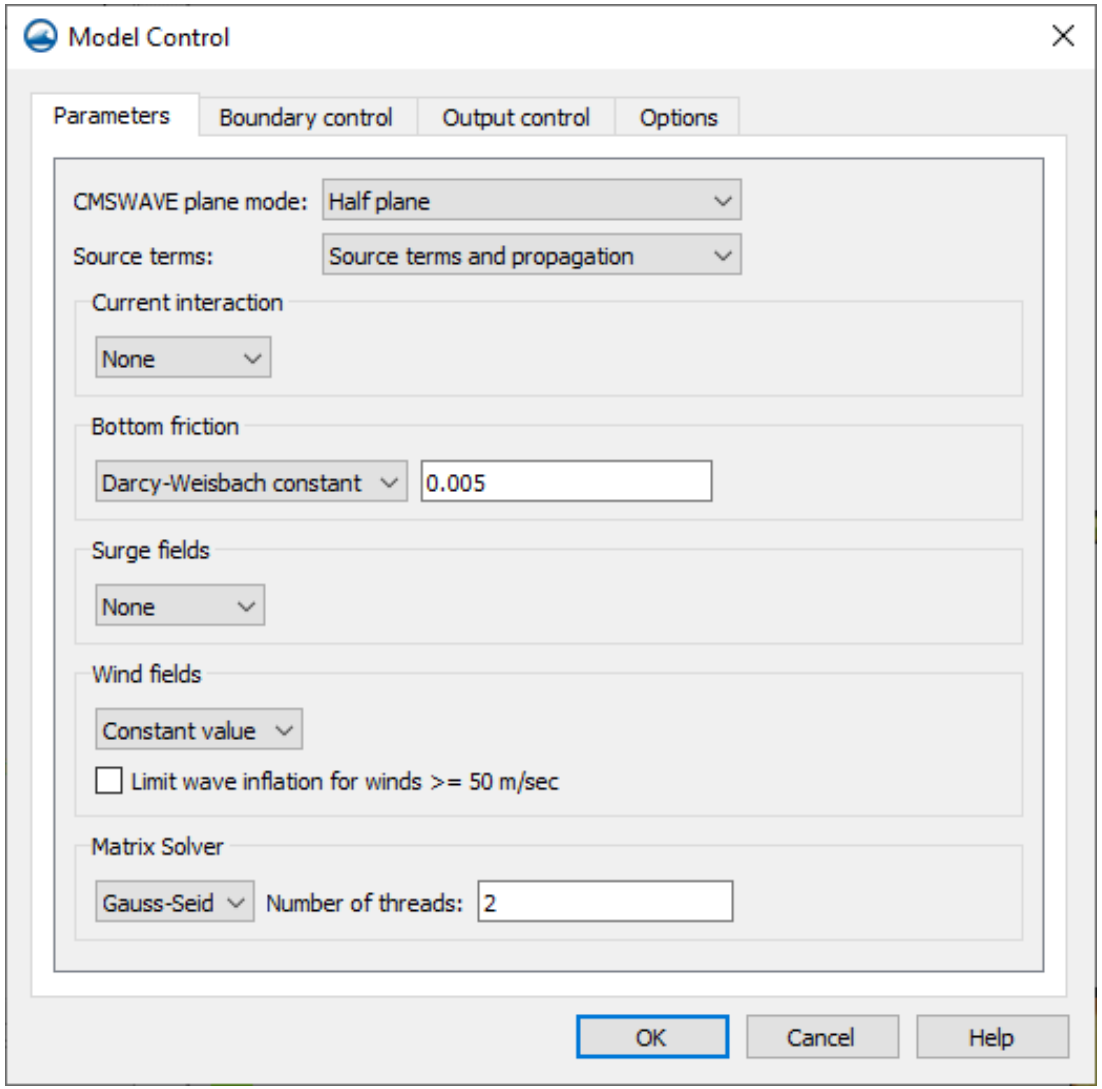
CMS-FLOW MODEL CONTROL
PARAMETER SPECIFICATION AND FILE I/O

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



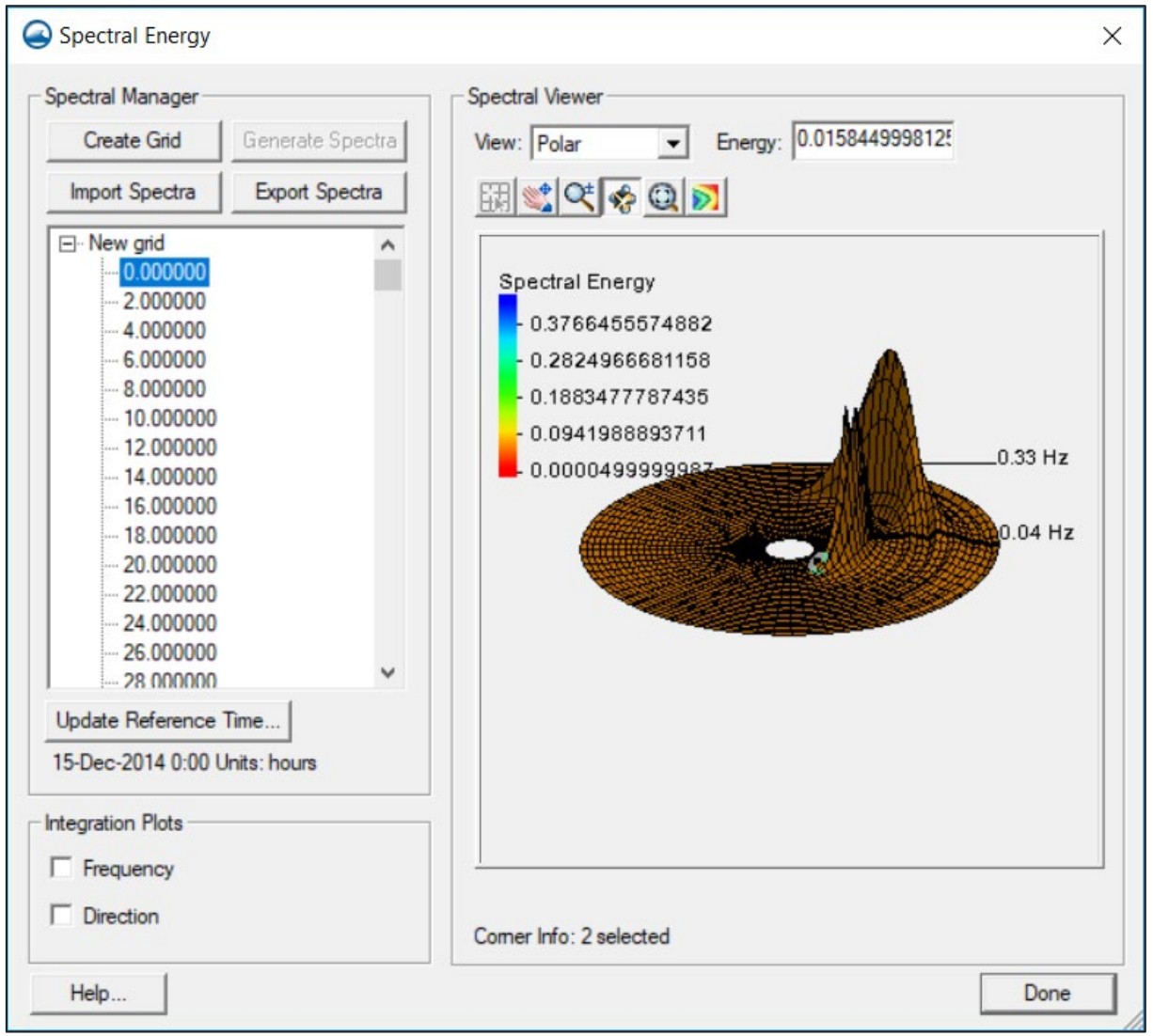
CMS-WAVE MODEL CONTROL

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

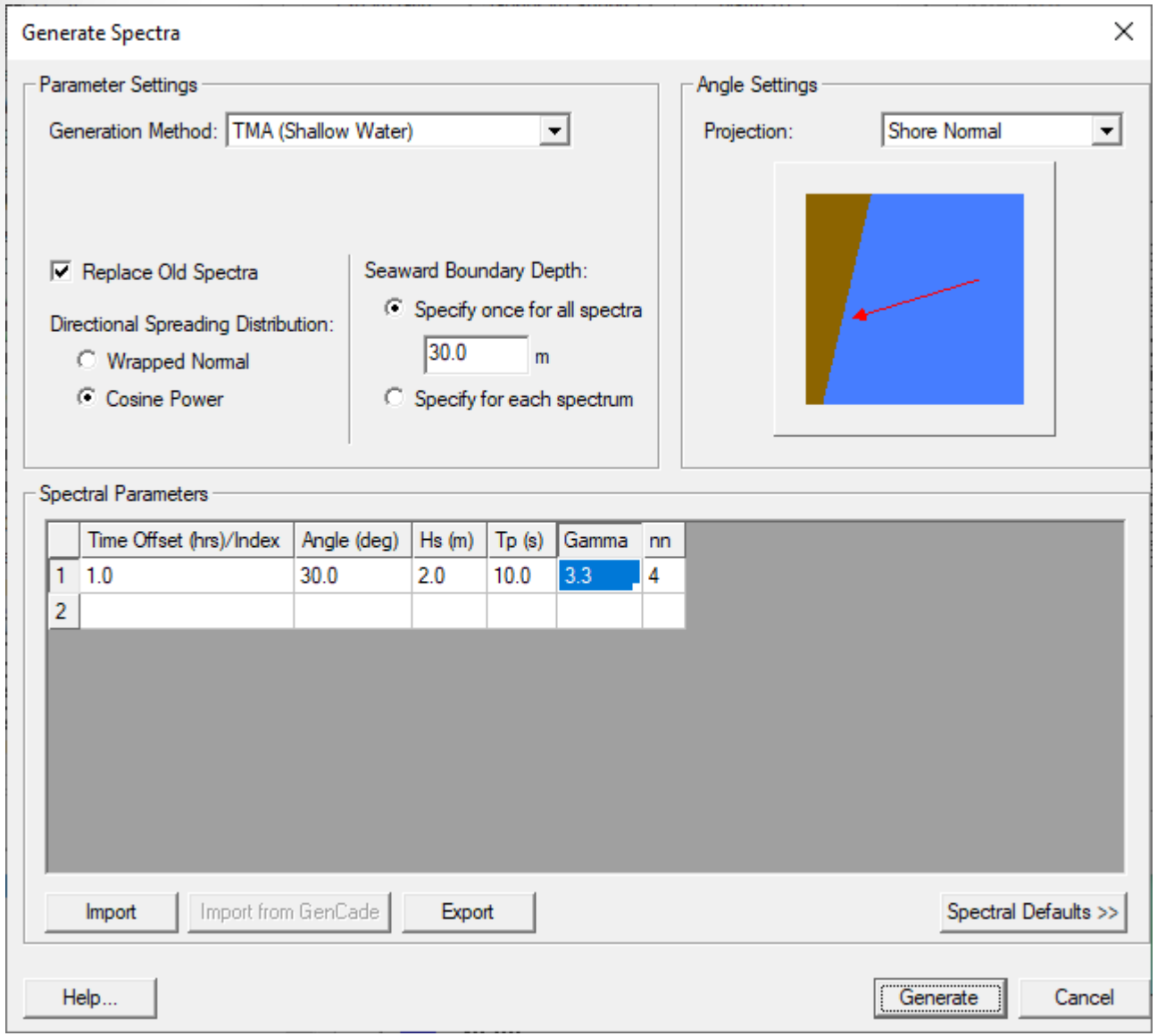


SPECTRAL ENERGY MENU

Example of Imported Spectra from Wave Gauge



GENERATE SPECTRA FROM BULK CRITERIA



Select from several types of generation methods.

Observe the direction relative to the created wave grid.

DATASET TOOLBOX

Mathematical Operations

- Comparisons
- Data Calculator

Spatial Operations

- Spacing
- Gradients/Derivatives
- Smoothing

Temporal Operations

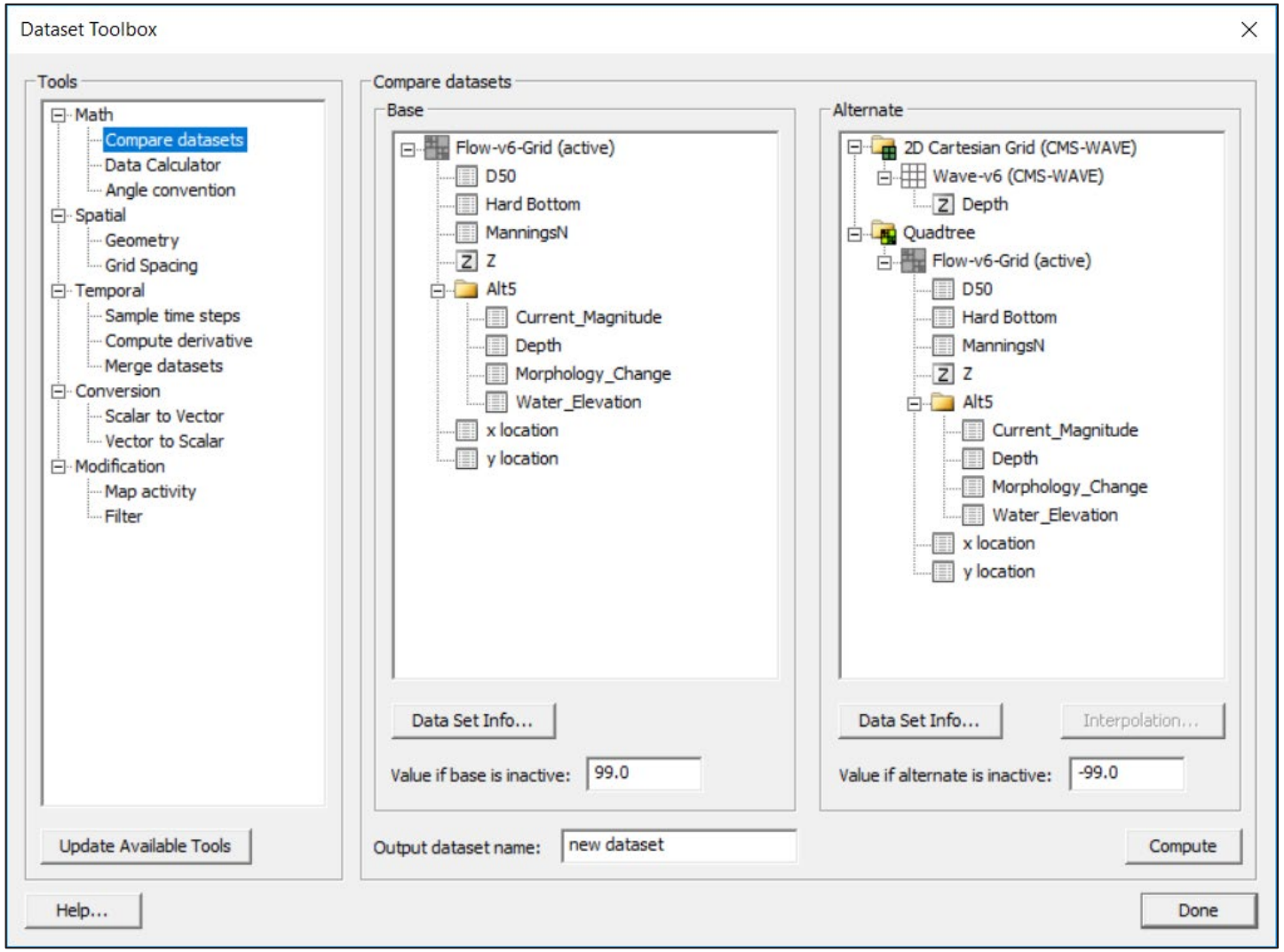
- Sample times
- Temporal derivatives

Conversions

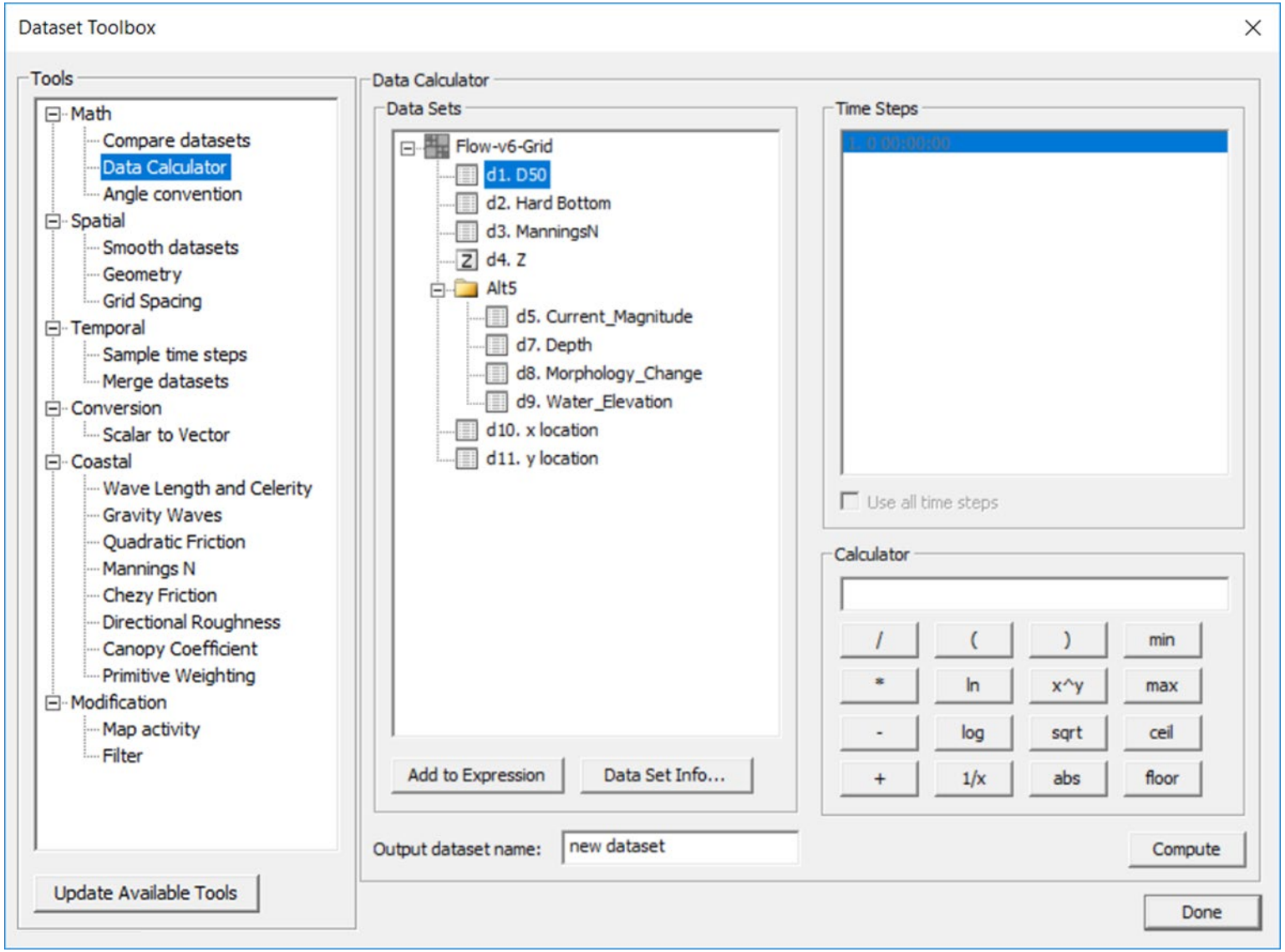
- Vector <-> Scalars

Activity Mapping

- Map activity
- Value filtering

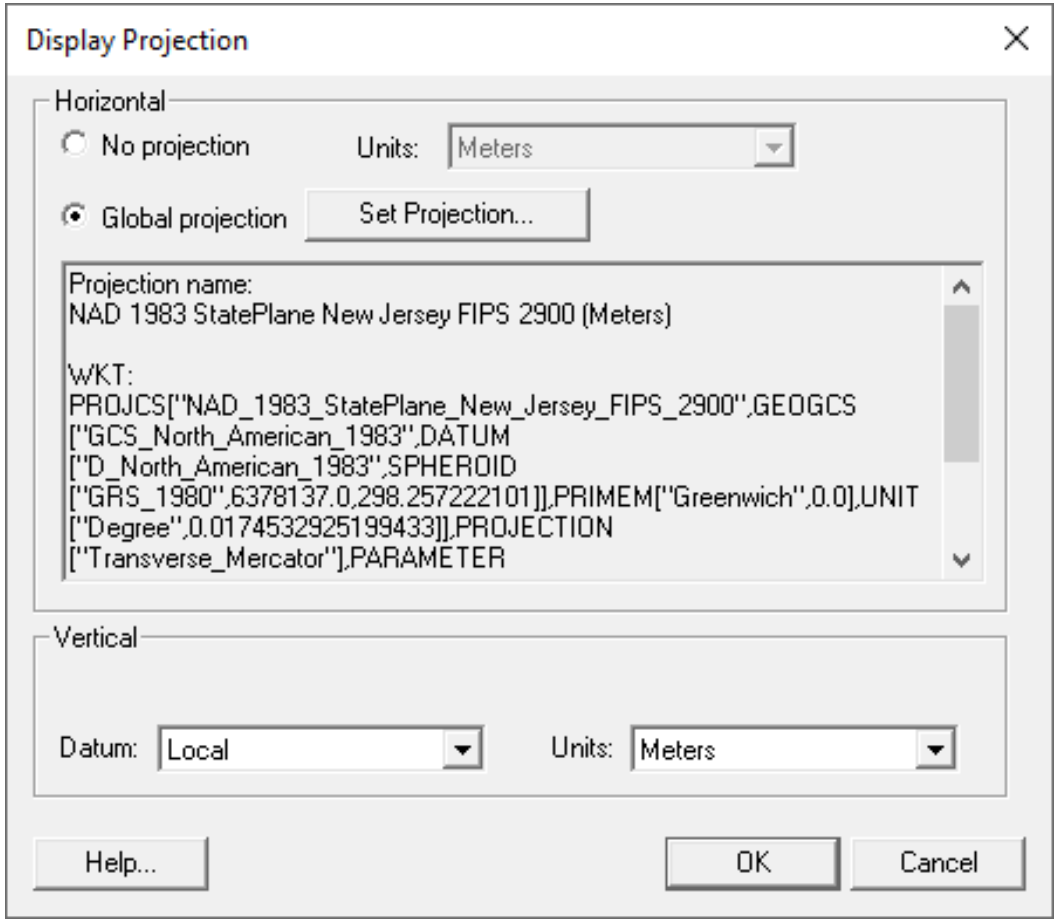


DATASET CALCULATOR



COORDINATE PROJECTIONS

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

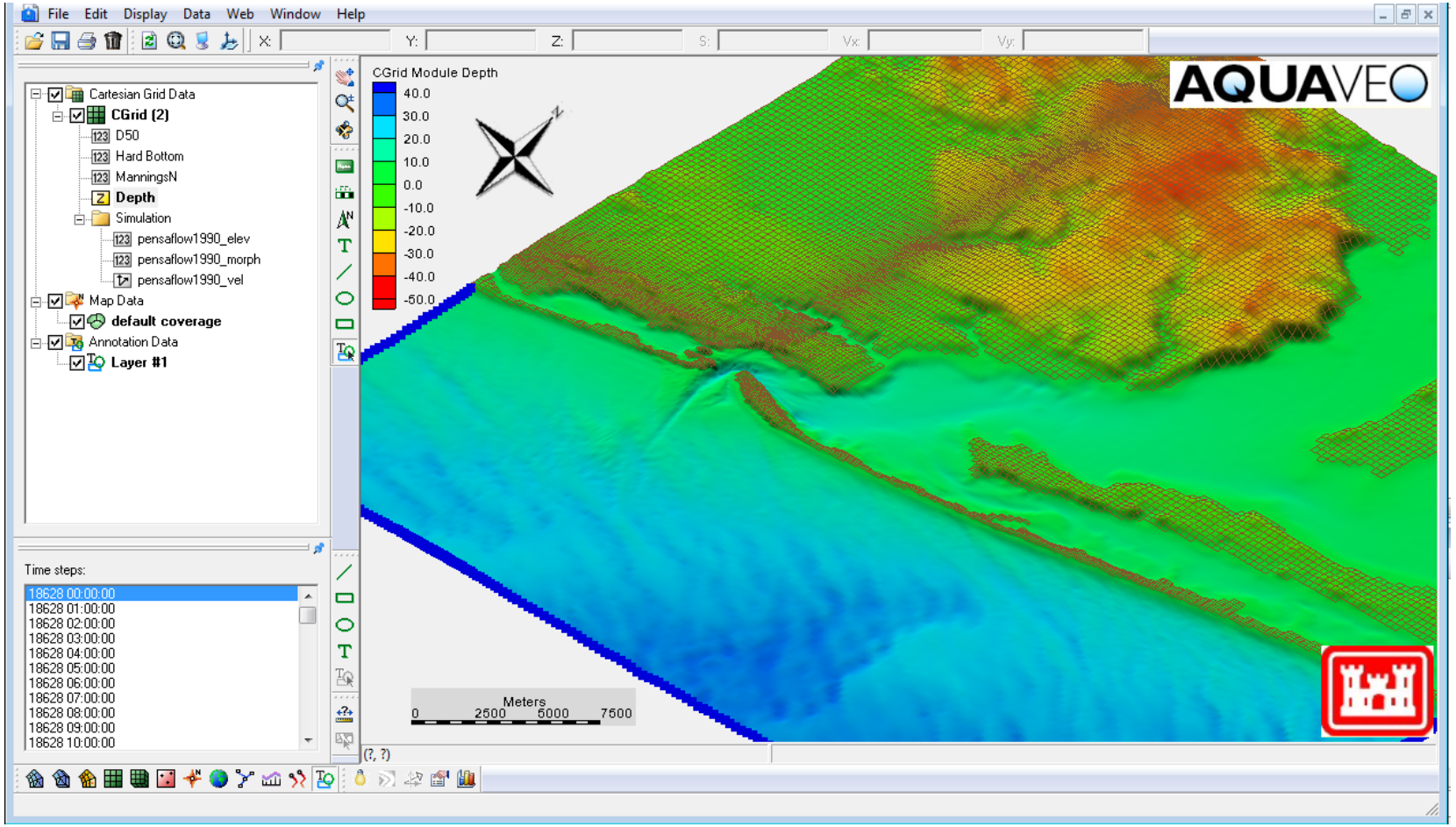


SMS – POST PROCESSING

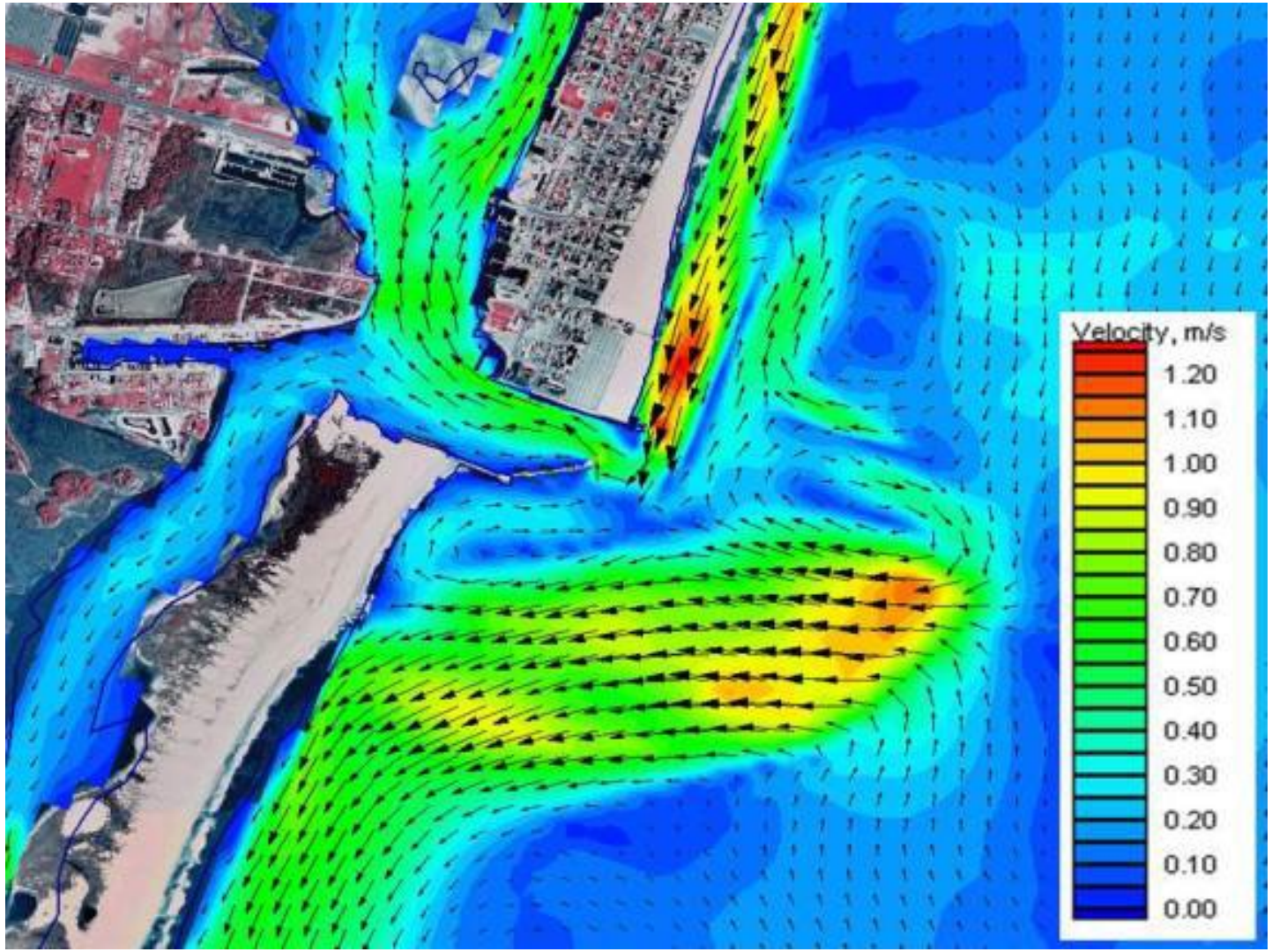
- Annotations
- Graphic images
- Animations
  - .mp4 film loops
  - .kmz – Google Earth Exports
- 2D Plots
  - Time series
  - Profiles and Cross sections – both steady state and transient

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



OBTAINING AND ACTIVATING SMS

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

USACE District and ERDC staff –

Contact 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 to facilitate.

Others –

Visit https://www.aquaveo.com/password_request for a temporary password.

Contact Aquaveo sales at sales@aquaveo.com or call (801) 302-1400.

Request evaluation version from within the SMS registration form.

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- Introduction to the Surface-water Modeling System (SMS v.13.2)
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  - CMS-Flow – Hydrodynamics, Sediment Transport, Morphology Change
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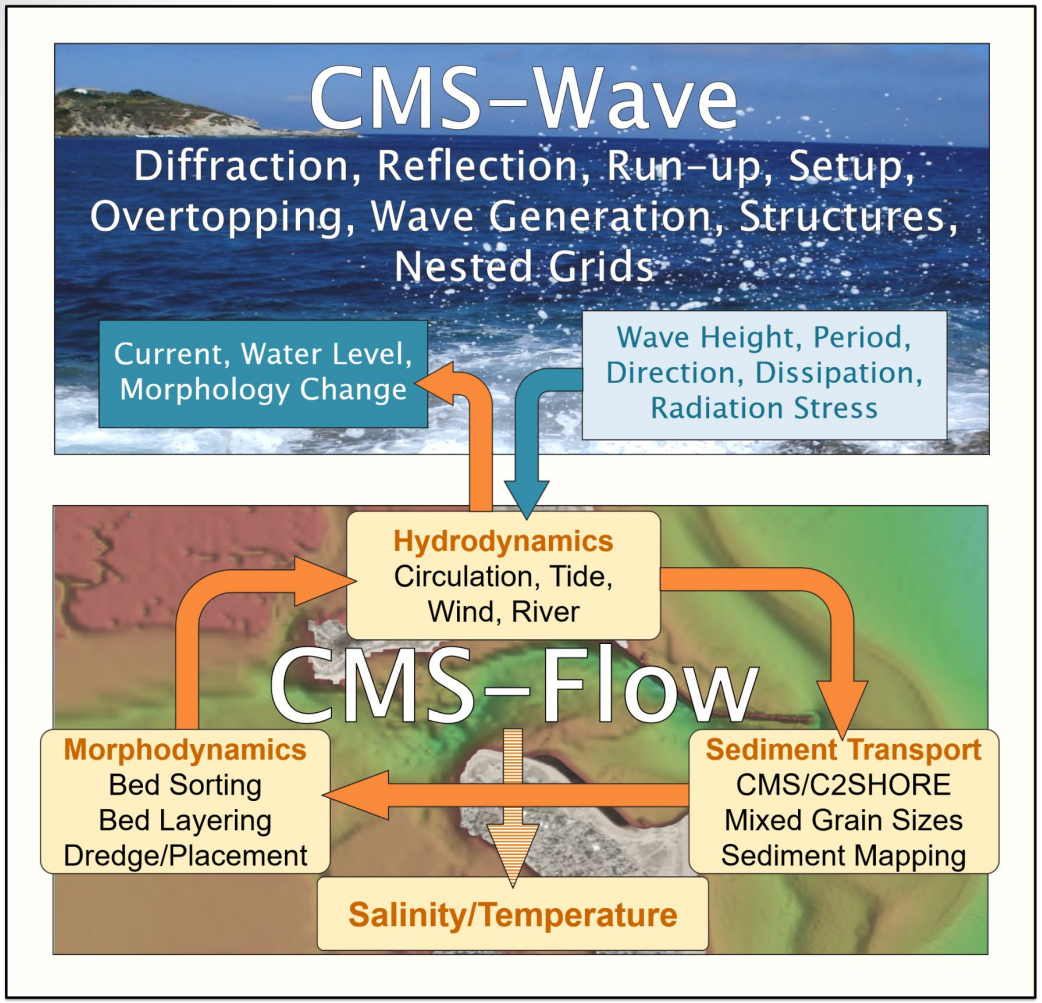
MISSION STATEMENT

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).

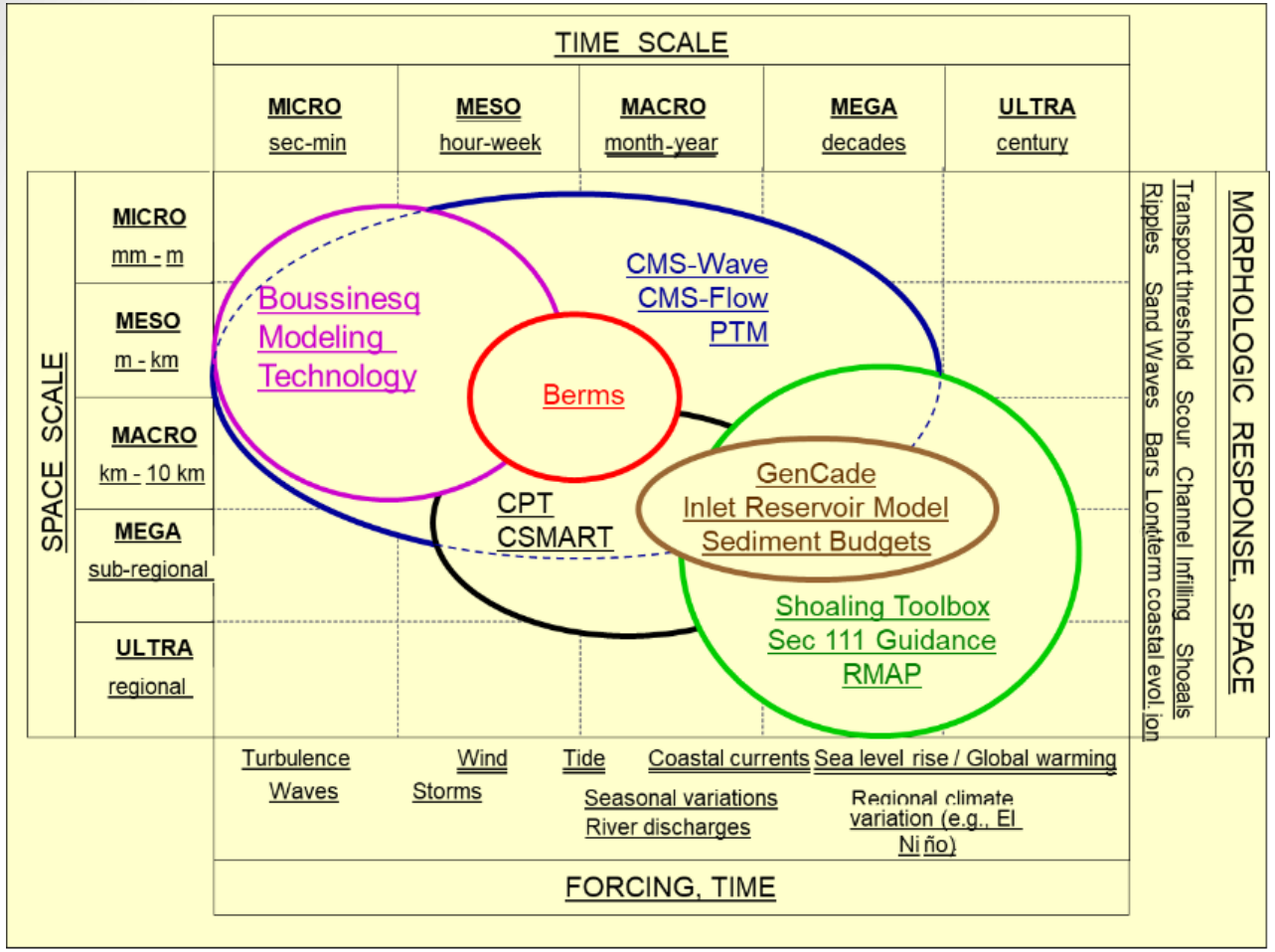
Why CMS?

- 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

WHEN IS CMS THE RIGHT TOOL?



Capability	Intended application	Presently Not available
Flow	WSE and depth-averaged currents	
Waves	Nearshore, phase-averaged	Offshore (deep water); phase-resolving
Sediment transport	Sand, multiple grain sizes; dunes via coupling with Aeolis	Fine grains (silt, mud)
Vegetation	Wave, flow drag	Sediment dynamics (under development)
Salinity, temperature	Scalar concentration advection and diffusion	Multi-phase flow; salt wedge dynamics
Speed	Desktop-friendly (hrs-days)	HPC
Grid cell size	Regional to macro (km-m)	Fine scale (cm-mm)
Numerics	Structured, non-uniform (quadtree); implicit and explicit in time	Unstructured (triangular)

CMS-FLOW

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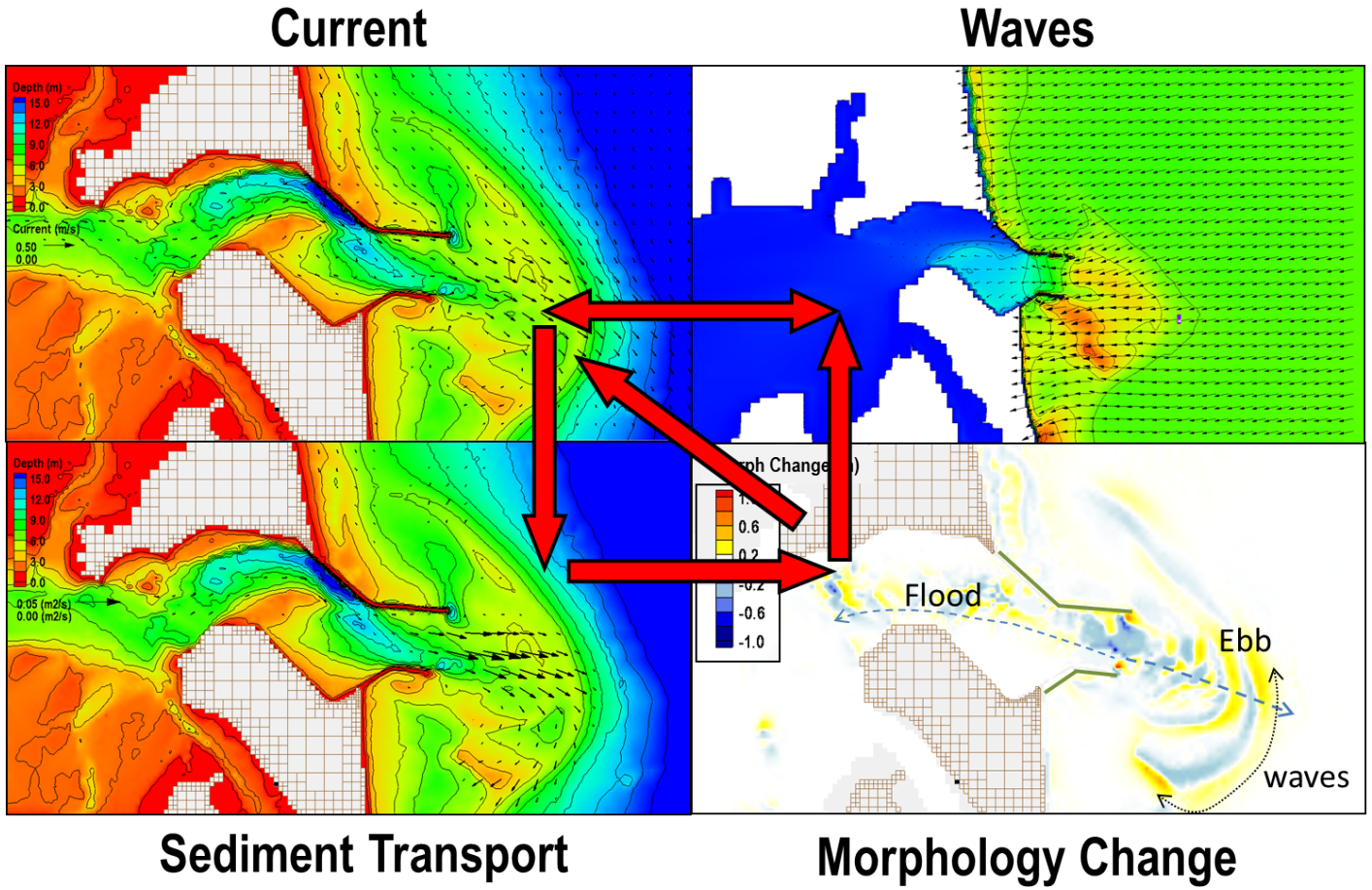
CMS-FLOW: KEY FEATURES

- 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 options

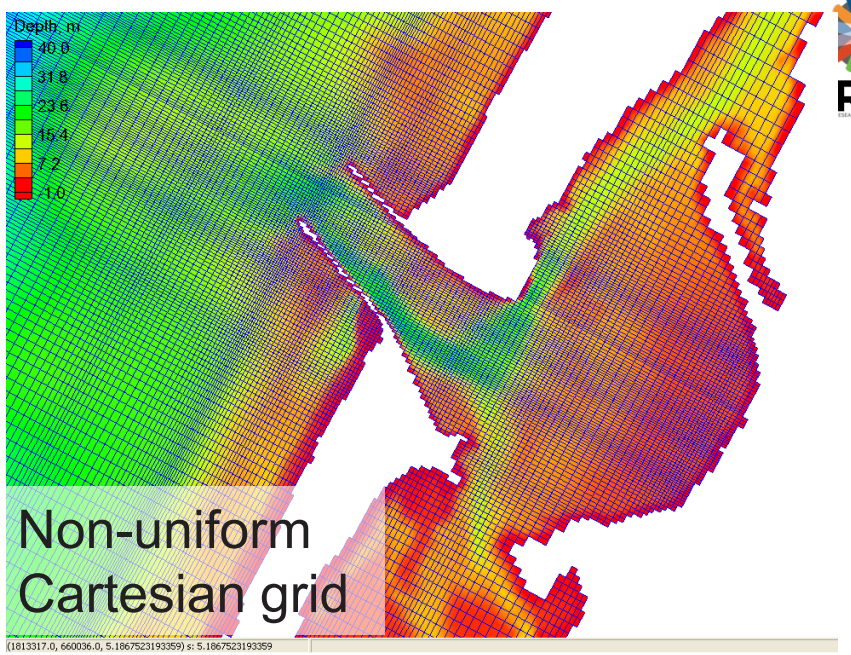
– Non-uniform Cartesian grid: Easy to setup
– Telescoping grid: Efficient, easy, flexible

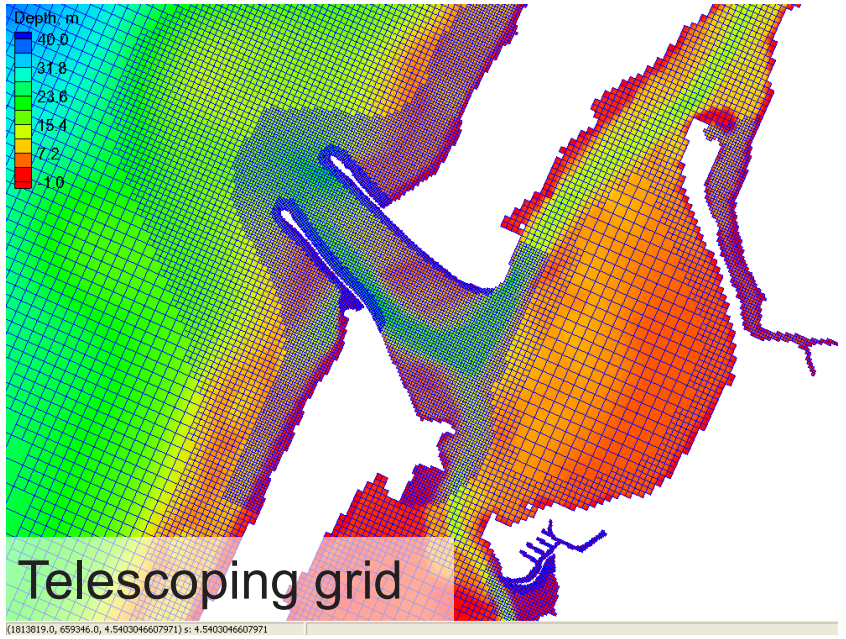
Solver options

– Implicit: Tidal flow, long-term morphology change: ~10+ min time step
– Explicit: Flooding, breaching, super-critical flow: ~ 1 sec time step

Increased efficiency with OpenMP Parallel processing

– No MPI (domain decomposition) …yet

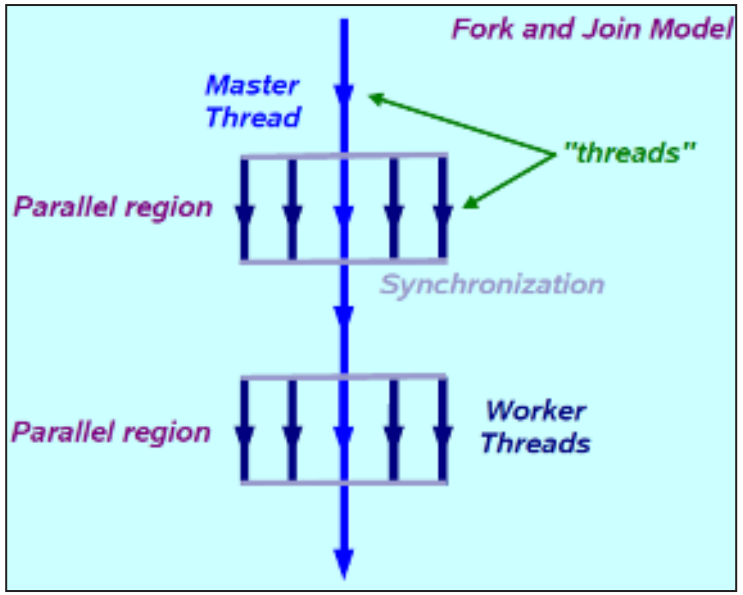




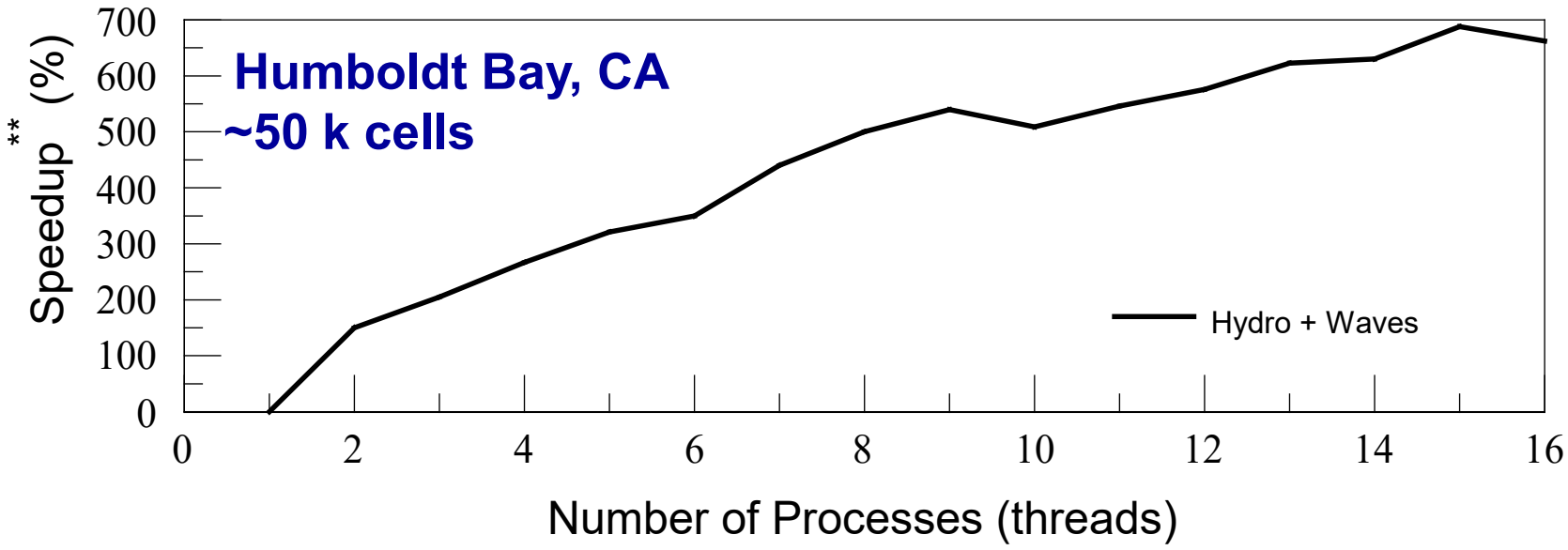
PARALLEL PROCESSING

- **CMS-Flow parallelized using OpenMP**

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



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



For **Implicit**, using 4 processors shows best speed improvement.

Future work will include optimizing the implicit scheme for more processors.

HYDRODYNAMICS

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

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

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

$U \rightarrow$ Depth-averaged current velocity

$h \rightarrow$ Total water depth

$\zeta \rightarrow$ Still water depth

$\eta \rightarrow$ Water surface elevation

g $\rightarrow$ Total water depth

$f_c \rightarrow$ Coriolis

$\nu_t \rightarrow$ Turbulence eddy viscosity

$\tau_b \rightarrow$ Bottom stress (including waves)

$\tau_S \rightarrow$ Wave stress (forcing)

$\tau_w \rightarrow$ Wind stress

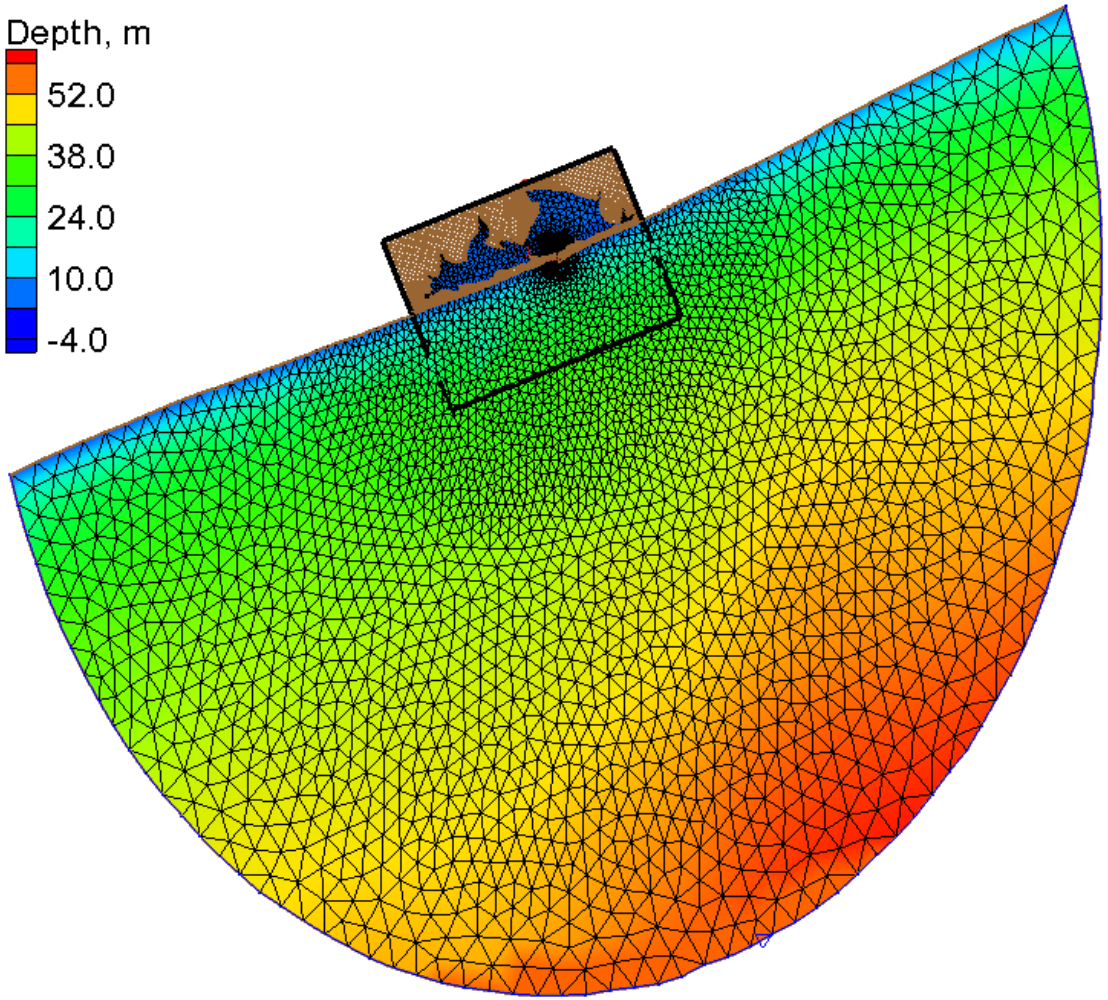
FORCING AND BOUNDARY CONDITIONS

Forcing

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

Boundary Conditions (BC)

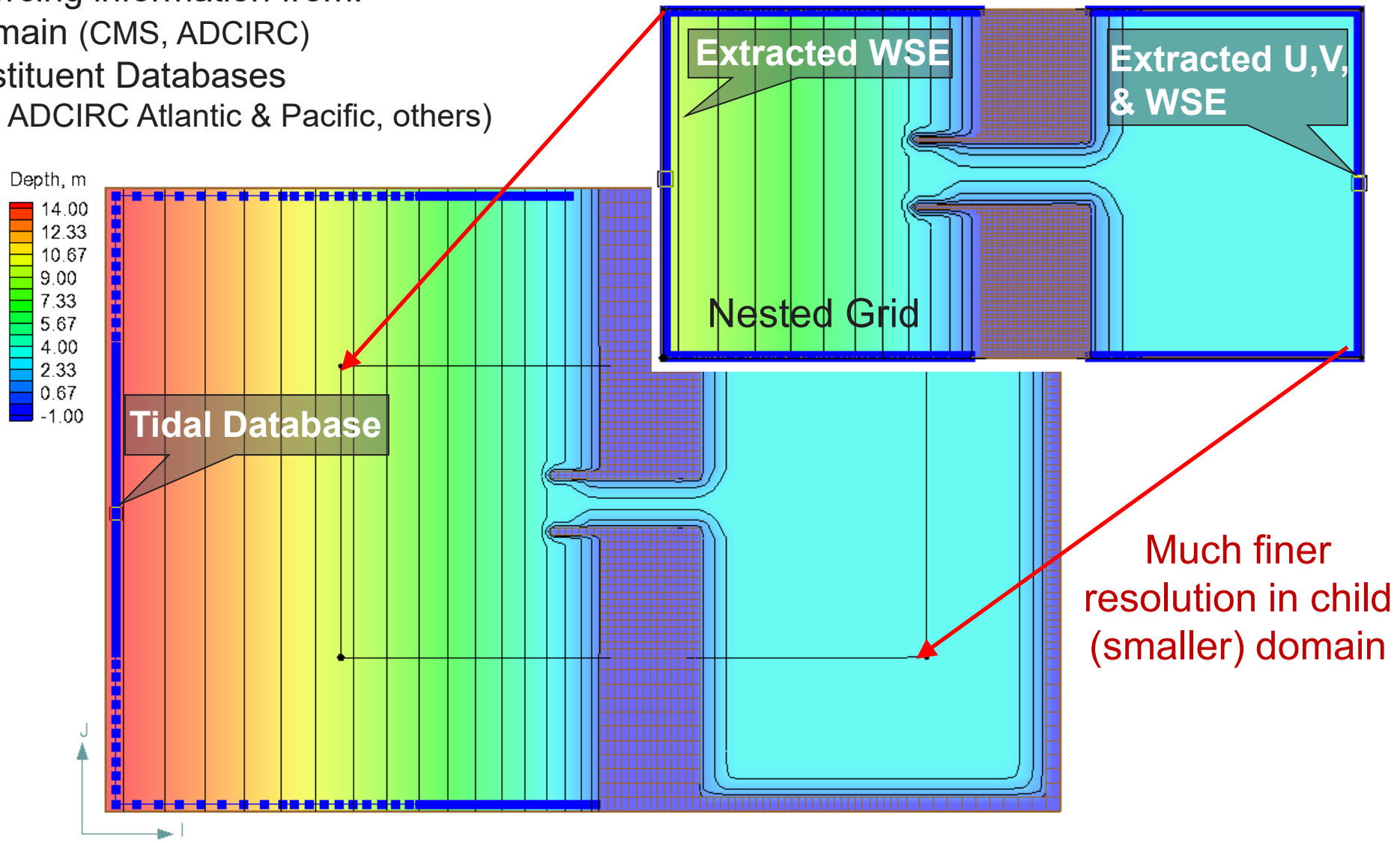
- Closed (wall) BC
- River Flux BC
- Water level time series
- One-way nesting
- Tidal database boundary extraction
- Wind and wave-adjusted water level boundary conditions



NESTED GRID CAPABILITY

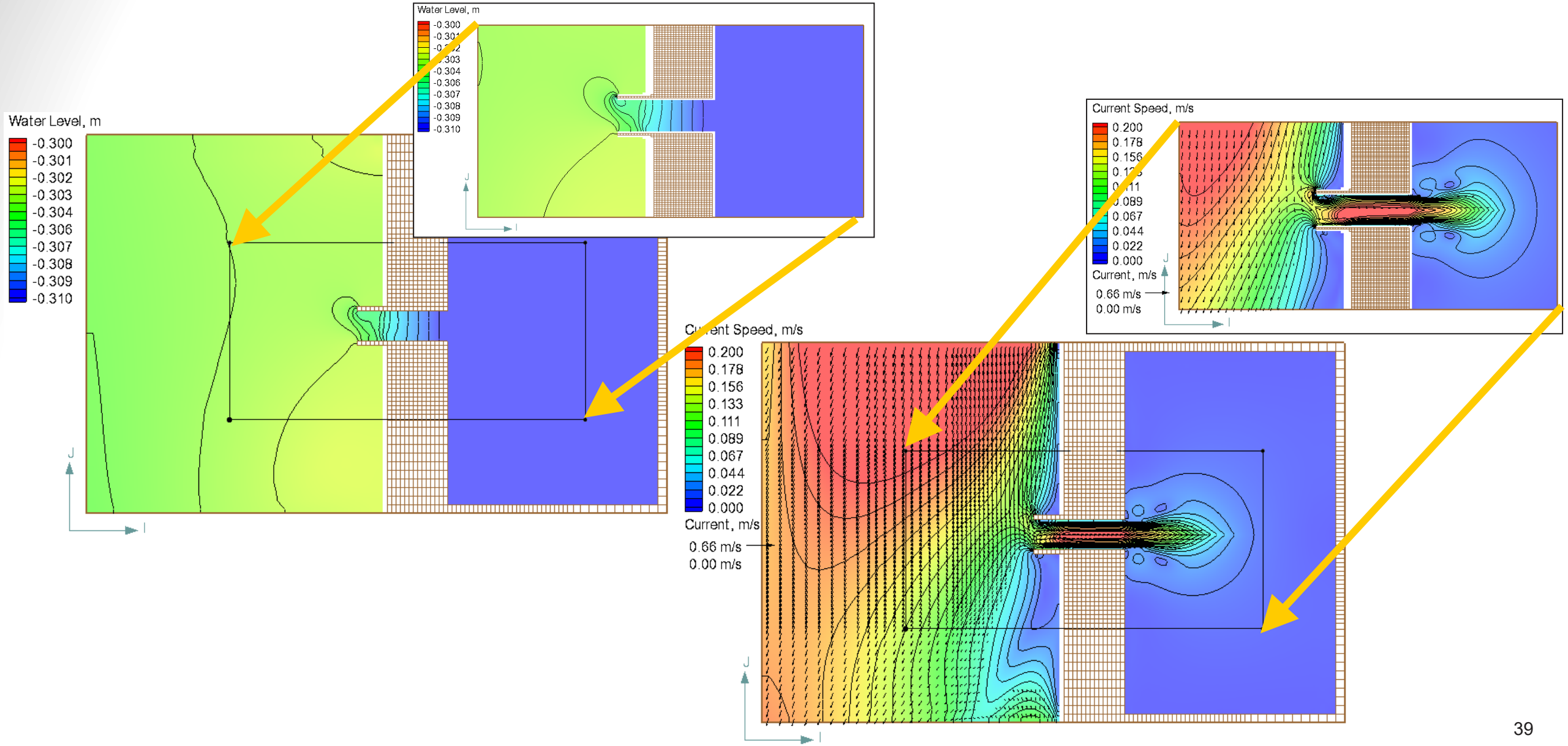
Can obtain forcing information from:

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



Much finer resolution in child (smaller) domain

NESTED GRID CAPABILITY



CMS-WAVE

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CMS-WAVE: GOVERNING EQUATION

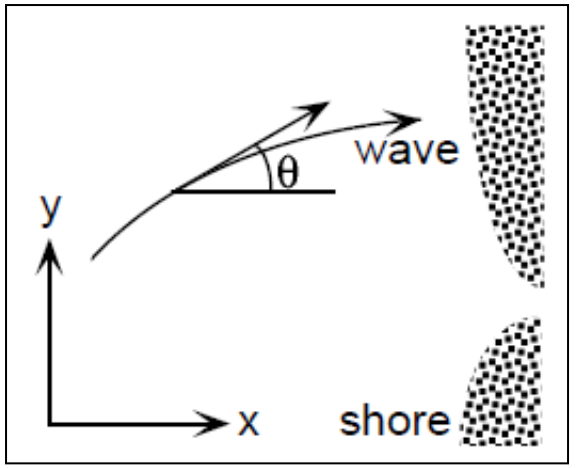
Wave-Action Balance Equation with Diffraction

- Phase-averaged approach

Diffraction intensity factor, range of 0 – 4 (default)

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

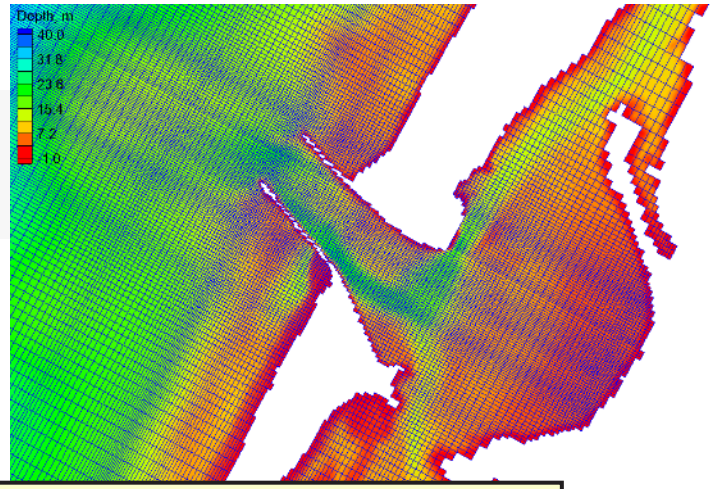
where $A=E/\sigma$, wave-action spectrum
and $E=E(\sigma,\theta)$, wave directional spectrum

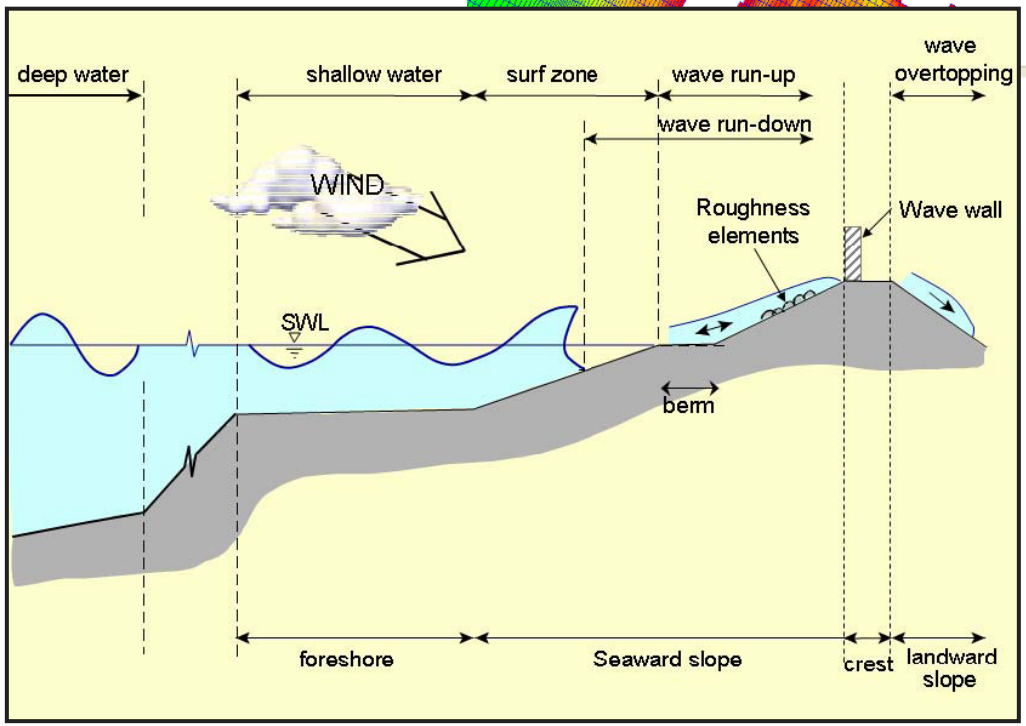


CMS-WAVE : KEY FEATURES

- Grid options
  - Non-uniform Cartesian grid: Easy to setup
    - » Telescoping grid is not available
- Processes
  - Shoaling, refraction, diffraction, reflection, and bottom friction
  - White capping
  - Wave breaking (4 options)
  - Wind-wave generation, wave-current, and wave-wave interactions (e.g., reflection)
  - Wave transmission, run up, and overtopping
  - Waves over Muddy bottom
  - Simplified Formulation “Fast Mode” for non-production runs
    - Reduces run time between 5-7x
- OpenMP parallel processing

Non-uniform Cartesian grid



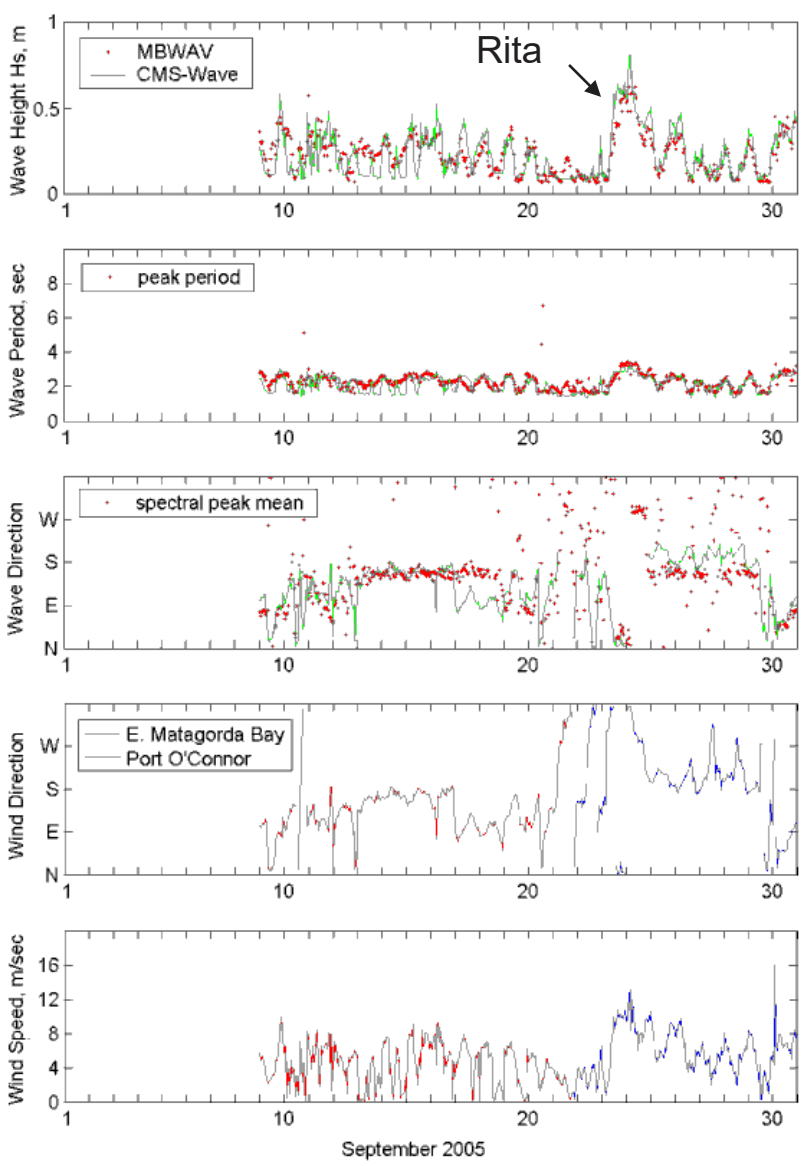


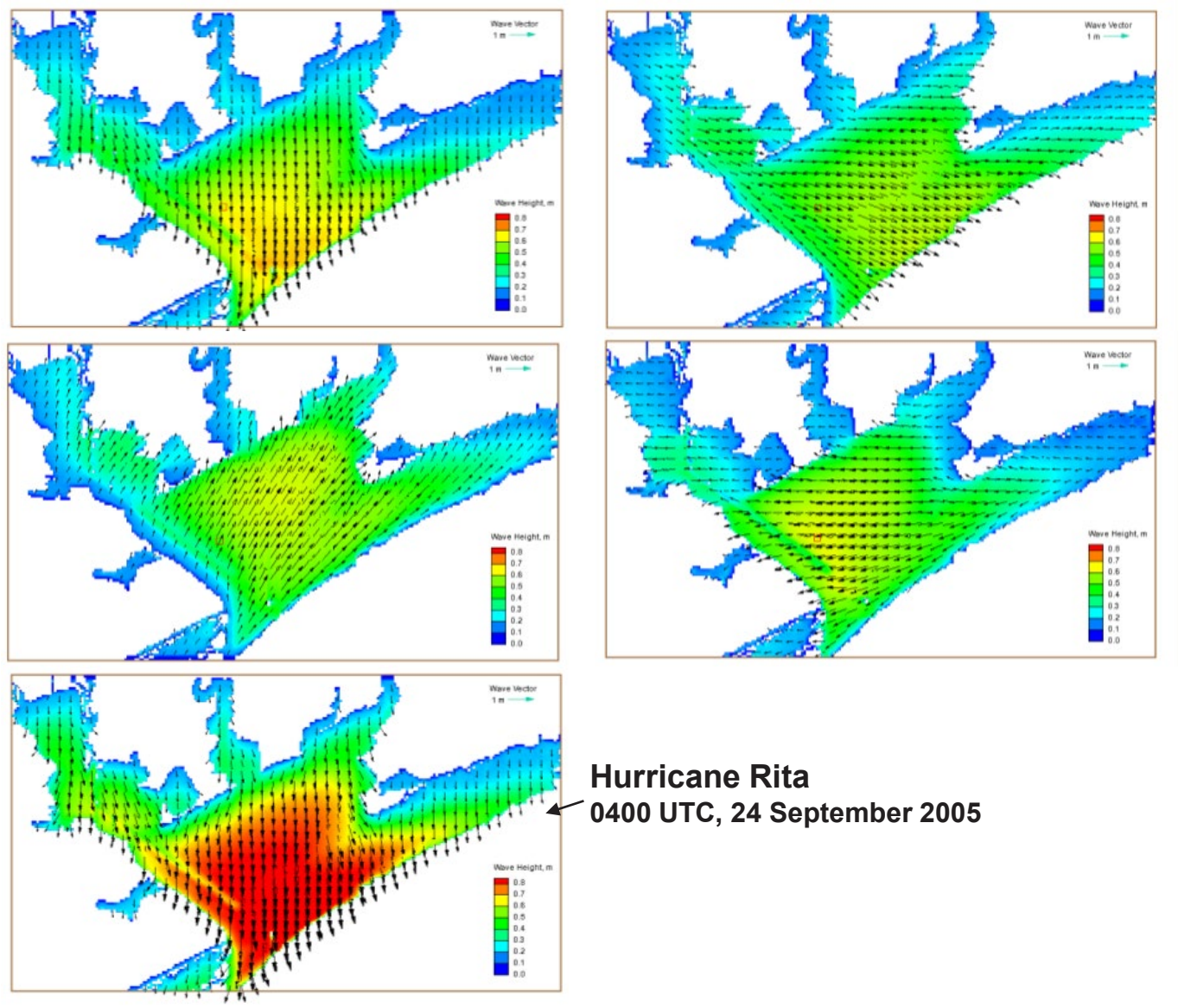
CMS-WAVE CAPABILITY

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

Structures

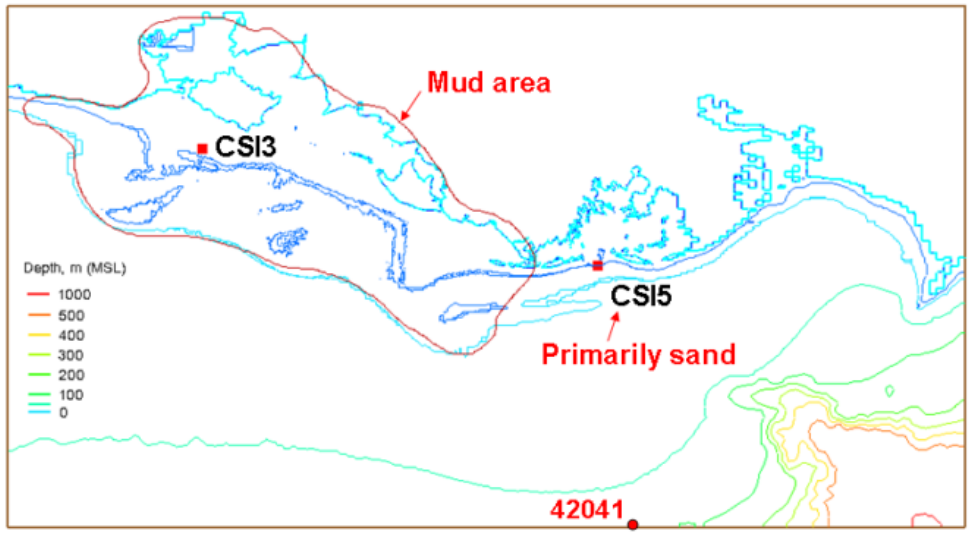
WAVE GENERATION AT MATAGORDA BAY, TX

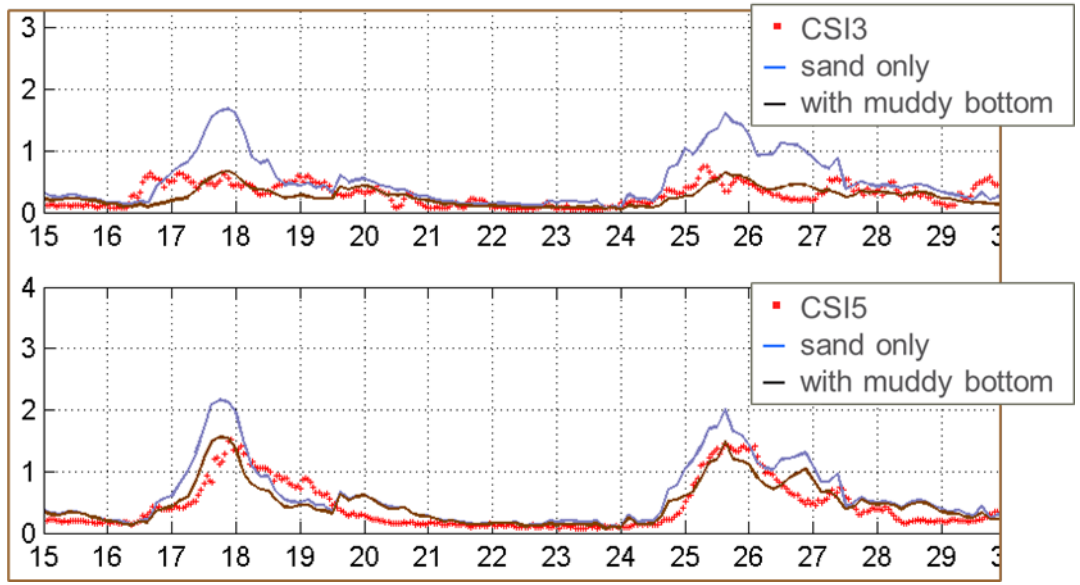


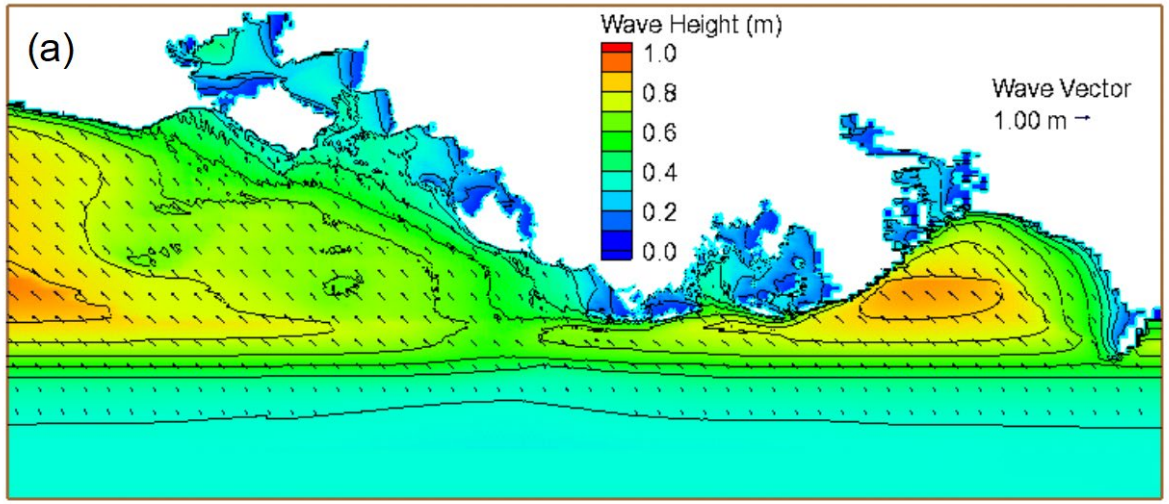


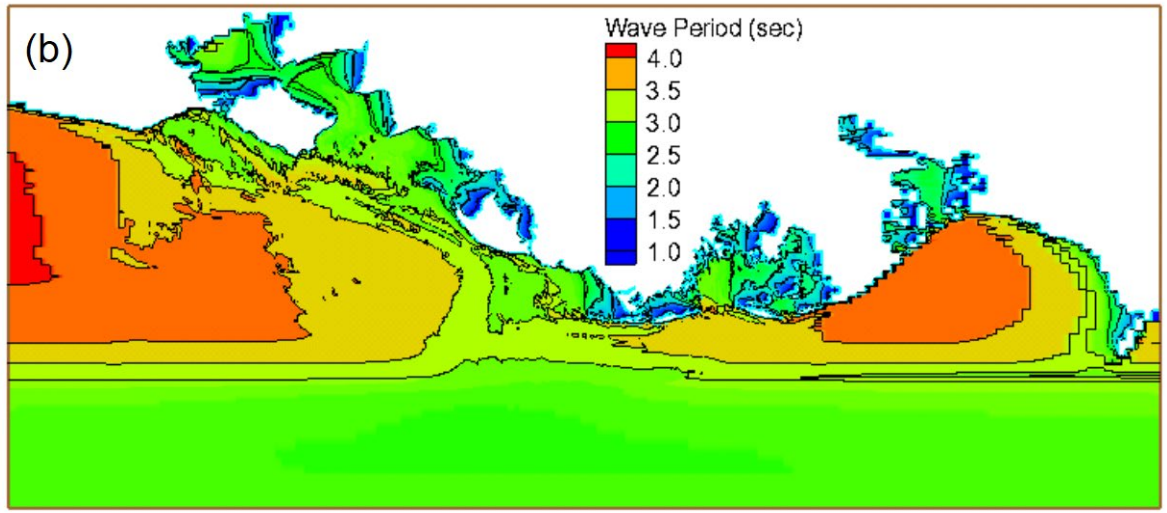
Hurricane Rita
0400 UTC, 24 September 2005

WAVES OVER MUDDY BOTTOM



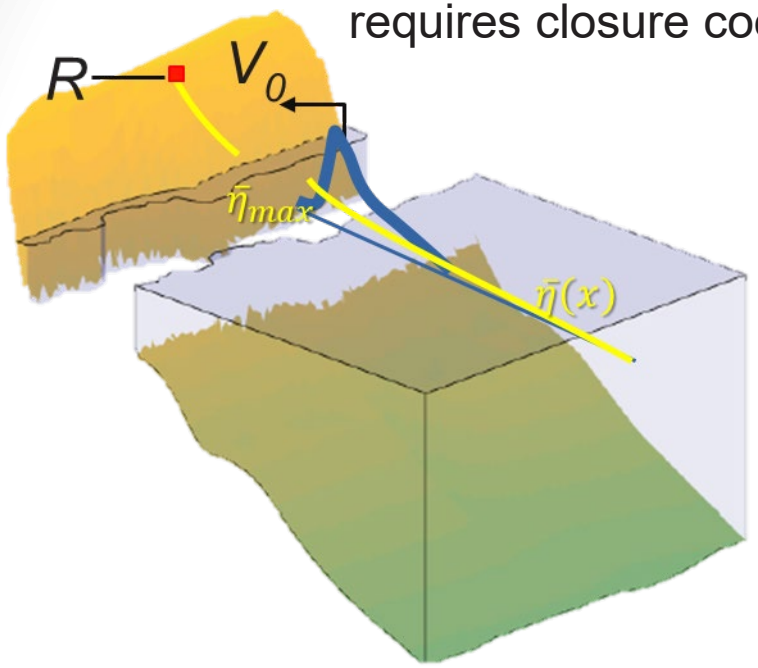






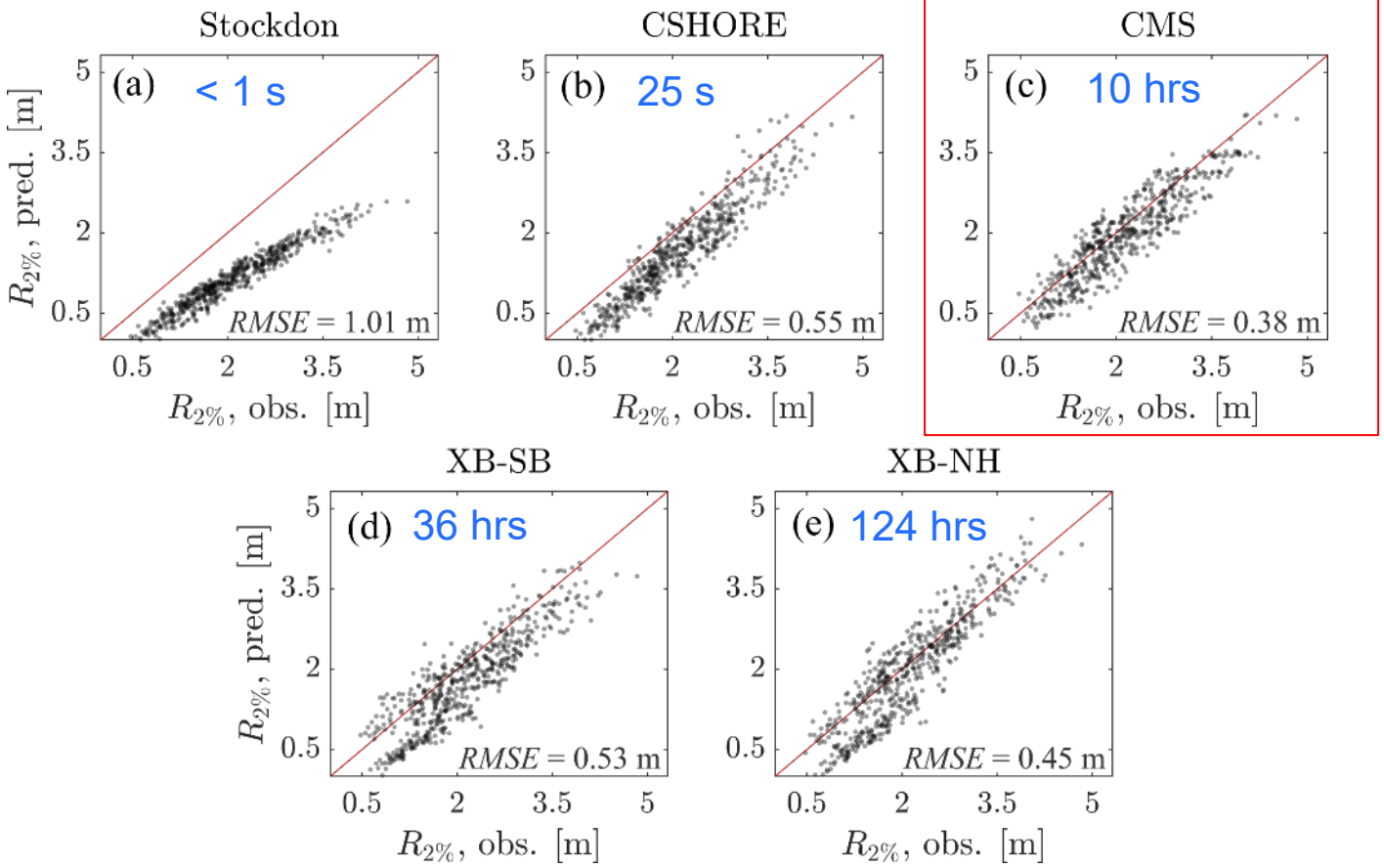
WAVE RUN UP

Bore-type swash solution
requires closure coefficient A_0



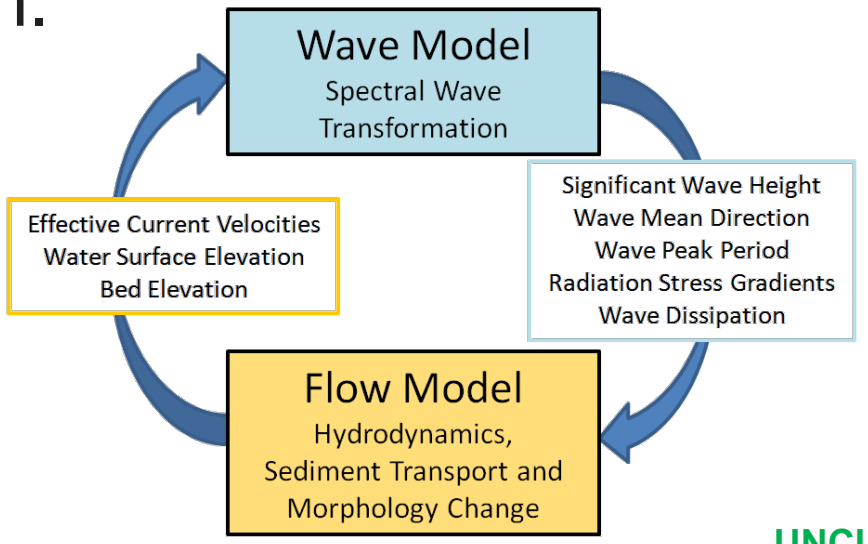
$$\frac{\partial M}{\partial x} = \frac{\partial}{\partial x}\{A_0 g h^2\} = -g\bar{h}\frac{\partial z_b}{\partial x} - c_f\overline{|U|U}$$

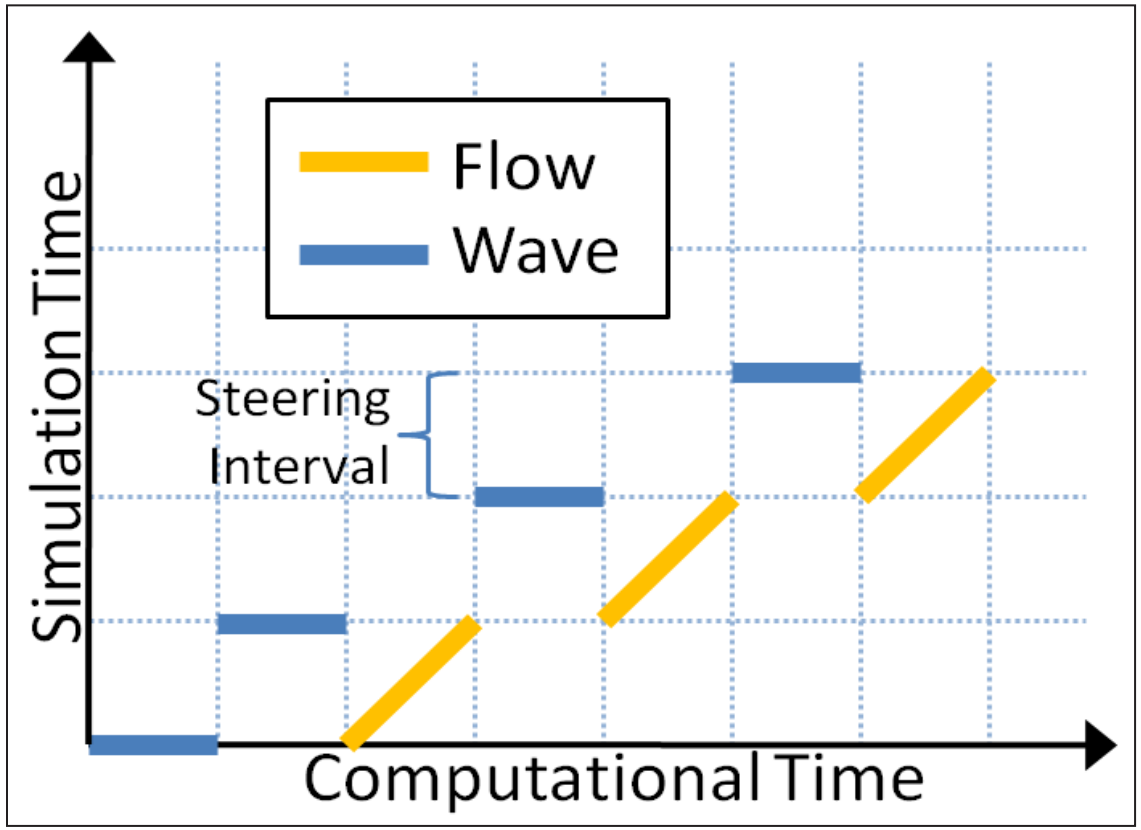
$$M \cong A_0 g \bar{h}^2$$



COUPLING BETWEEN FLOW AND WAVES

- Steering process
  - Roller included in wave model
  - Sediment transport and morphology change included in flow model
- Separate Flow and Wave grids with the same or different domain definition.





Adjustments to future water levels made with astronomical tide estimates to reduce the effect of a time lag in response.

SEDIMENT TRANSPORT

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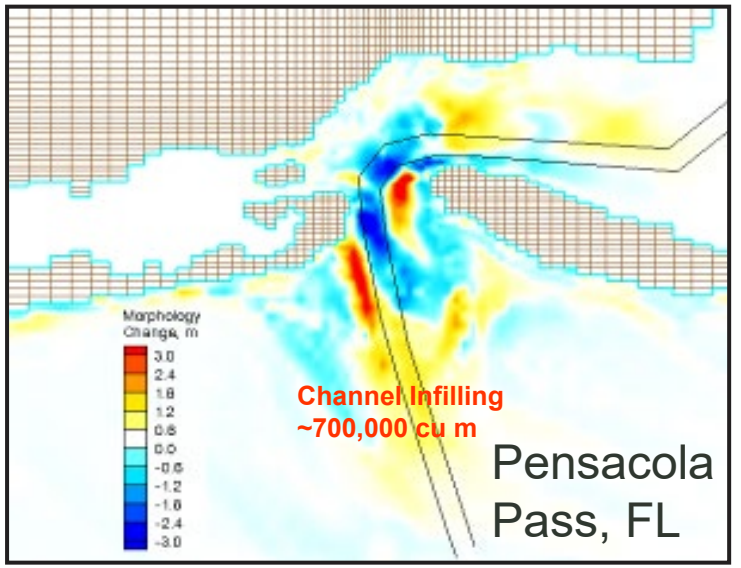
SEDIMENT TRANSPORT: KEY FEATURES

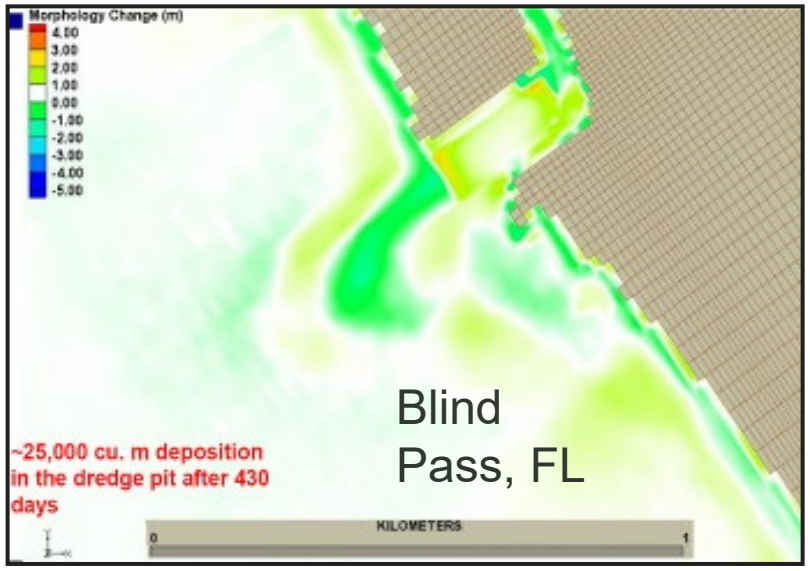
- Choice of morphology model
  a) Non-equilibrium total load (AD + total load)
  b) Equilibrium (i.e., Exner's equation)
  c) Eq. bedload and Advection-Diffusion (AD) suspended load

  Available for Explicit only and no longer recommended**

- Choice of sediment transport formulation
  - Lund-CIRP (2006)
  - van Rijn (1984, 2007)
  - Watanabe (1987)
  - Soulsby-van Rijn (1997)
  - C2SHORE (available in SMS 13.2+)

- Hard bottom (non-erodible layer)
- Avalanching due to slope
- Bed slope influence on bed load
- Multiple-sized sediment transport





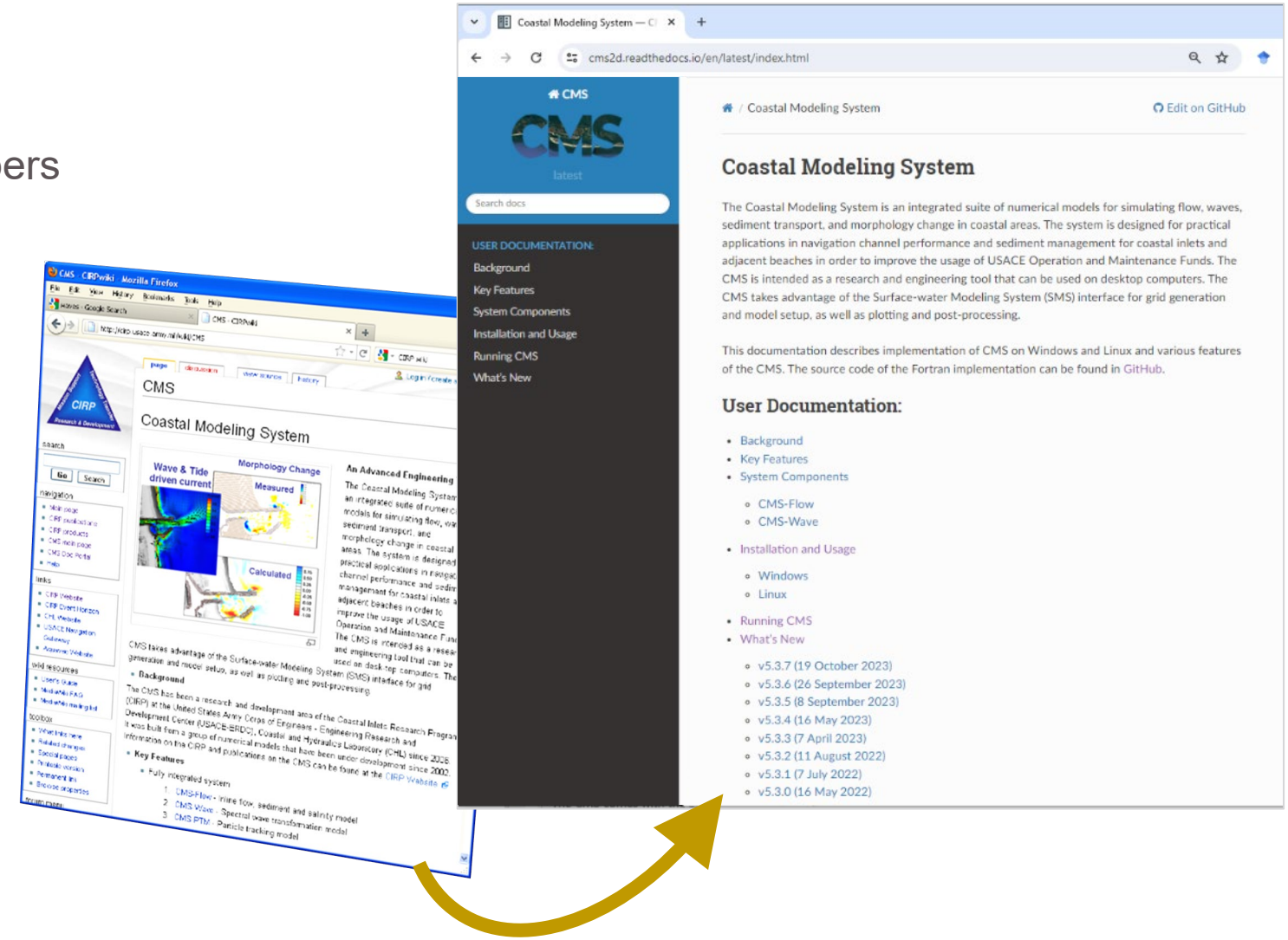
COASTAL MODELING SYSTEM

Documentation

- Several TR's, CHETN's and journal papers
  - https://cirp.usace.army.mil/pubs/
- CIRP Wiki
  - https://cirpwiki.info/wiki/CMS

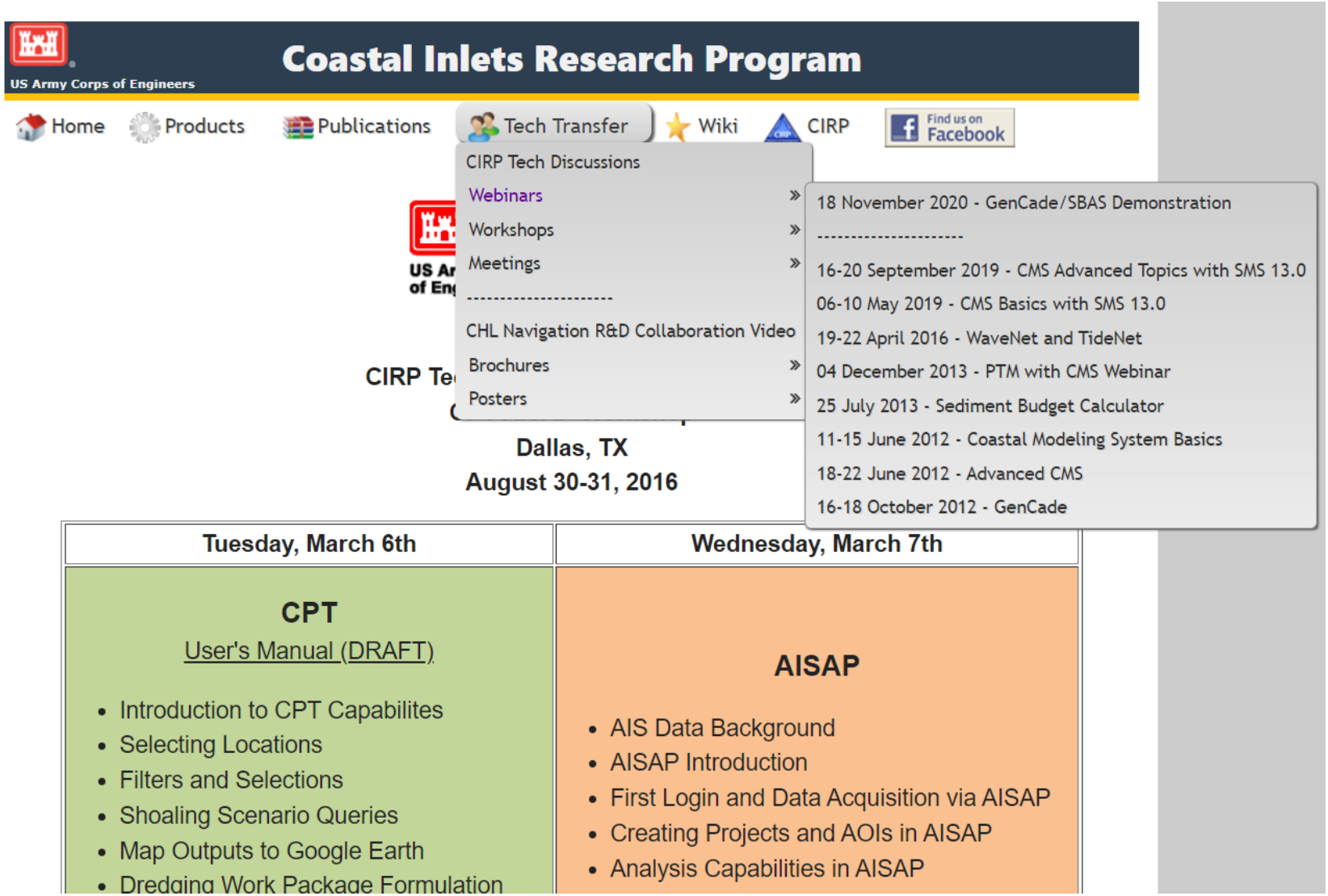
We're growing!

New information on CMS related to the source code, compiling, installing is being added to: https://cms2d.readthedocs.io



DOCUMENTATION - WEBSITE (https://cirp.usace.army.mil)

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



DOCUMENTATION - WIKI (https://cirpwiki.info/wiki/CMS)

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

Rubble Mound Tests

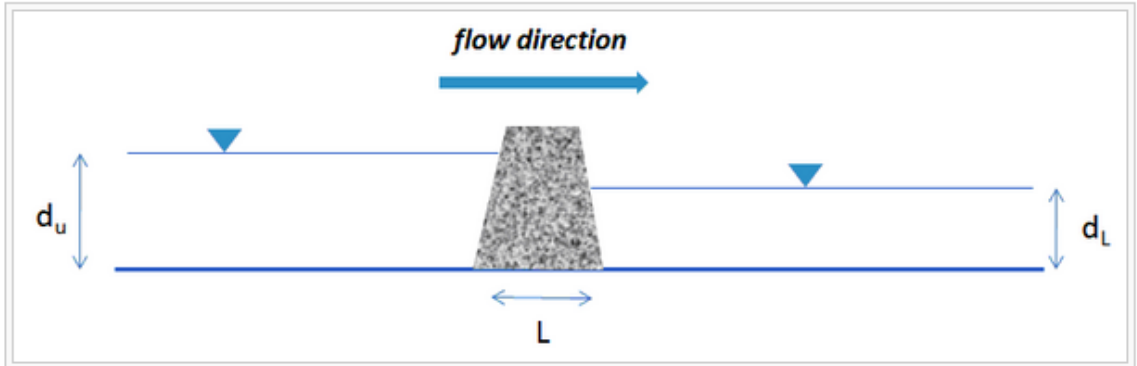


Figure 1. Schematic of the model configuration for validation and numerical grid independence test.

A model test case was developed to both verify the model code and to determine the sensitivity to the grid resolution used to represent the rubble mound. A schematic of the test case is shown in Figure 1. Water levels are held constant at the upstream and downstream values, creating the gradient across the rubble mound. The gradient creates a flow that is dependent on Δh, L and the resistance parameters a and b. Five CMS grids were constructed to represent the test case, each using a different number of cells to represent the rubble mound. For each grid scenario, a simulation was made sufficiently long to reach steady conditions. Then the flow rate through the mound was compared to an analytical solution. Analytical solutions can be readily obtained from the resistance formula for the test case configuration if either a or b is set to zero.

$$q_x = \begin{cases} \frac{h_u^2 - h_L^2}{2La}, b=0 \\ \frac{\sqrt{h_u^3 - h_L^3}}{3Lb}, a=0 \end{cases} \quad (1)$$

The results for the 5 test grids are shown in Table 1 for b=0, and in table 2 for a=0. For all of the simulations, d_u was set to 2.0 m, d_L was set to 1.5 m, L ~16 m and the values for a and b were 1.0 and 1.0. The total

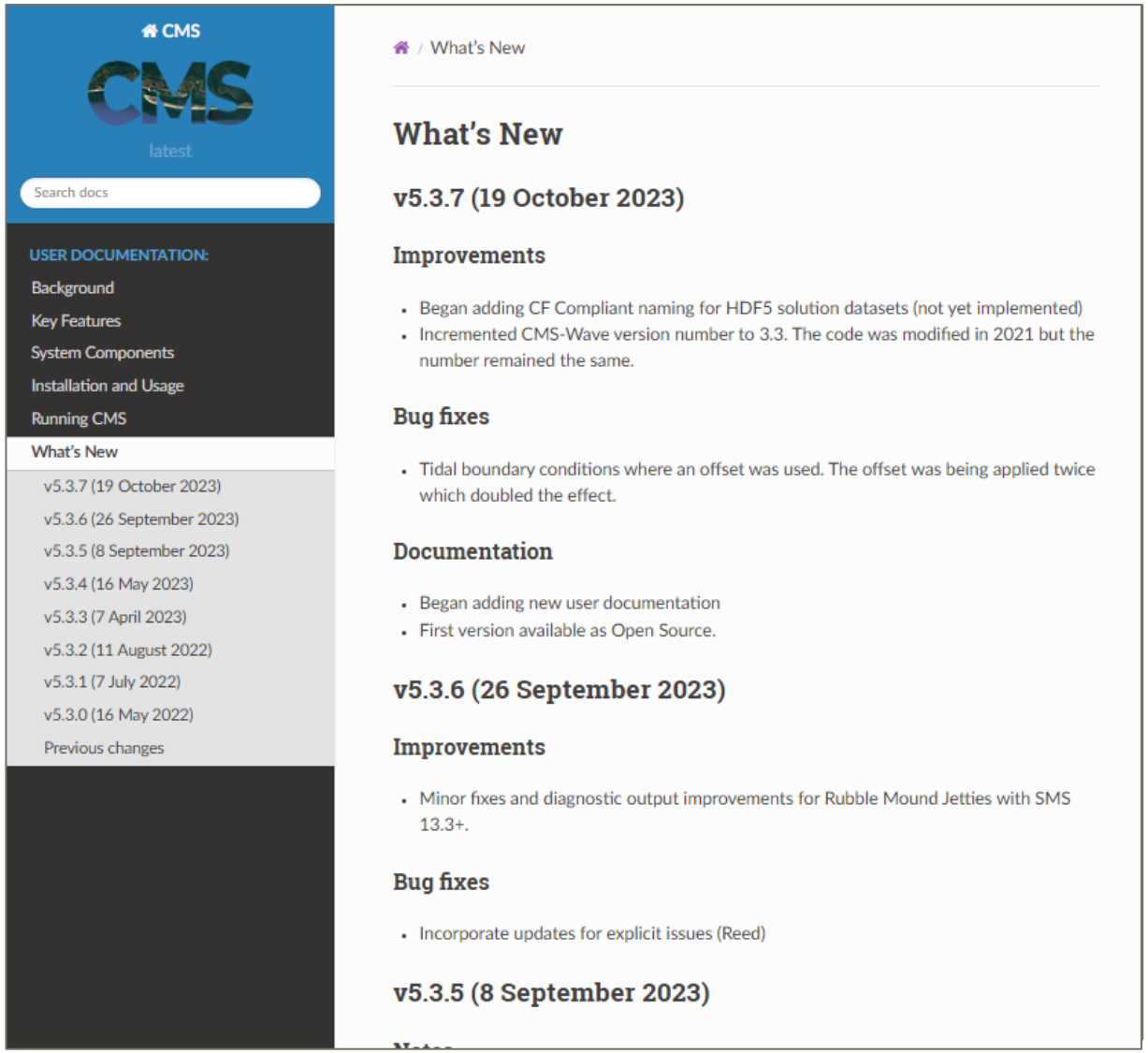
2. Salinity Calculation at Humboldt Bay, CA

In this section, the salinity

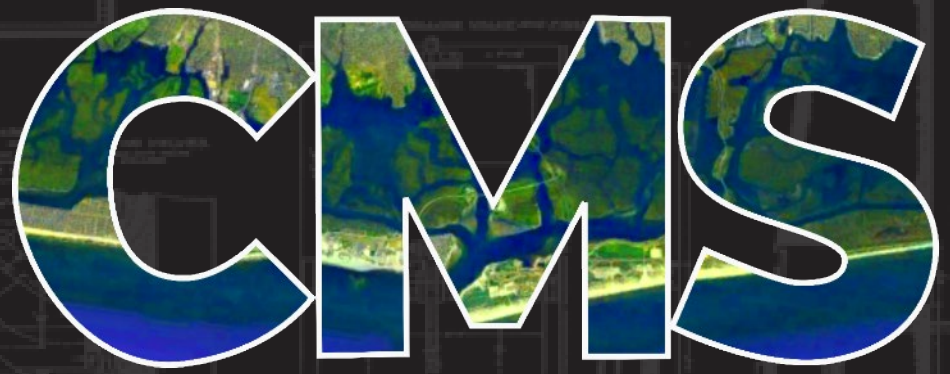
DOCUMENTATION – OPEN-SOURCE (CMS2D.READTHEDOCS.IO)

CMS

- Background
- Installation and Usage
- Compiling on Windows and Linux (no HPC yet)
- What's New
- Links to Repository



CONNECT WITH US



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