Coastal Modeling System (CMS) for Integrated Calculation of Waves, Flow, Sediment Transport, and Morphology Change

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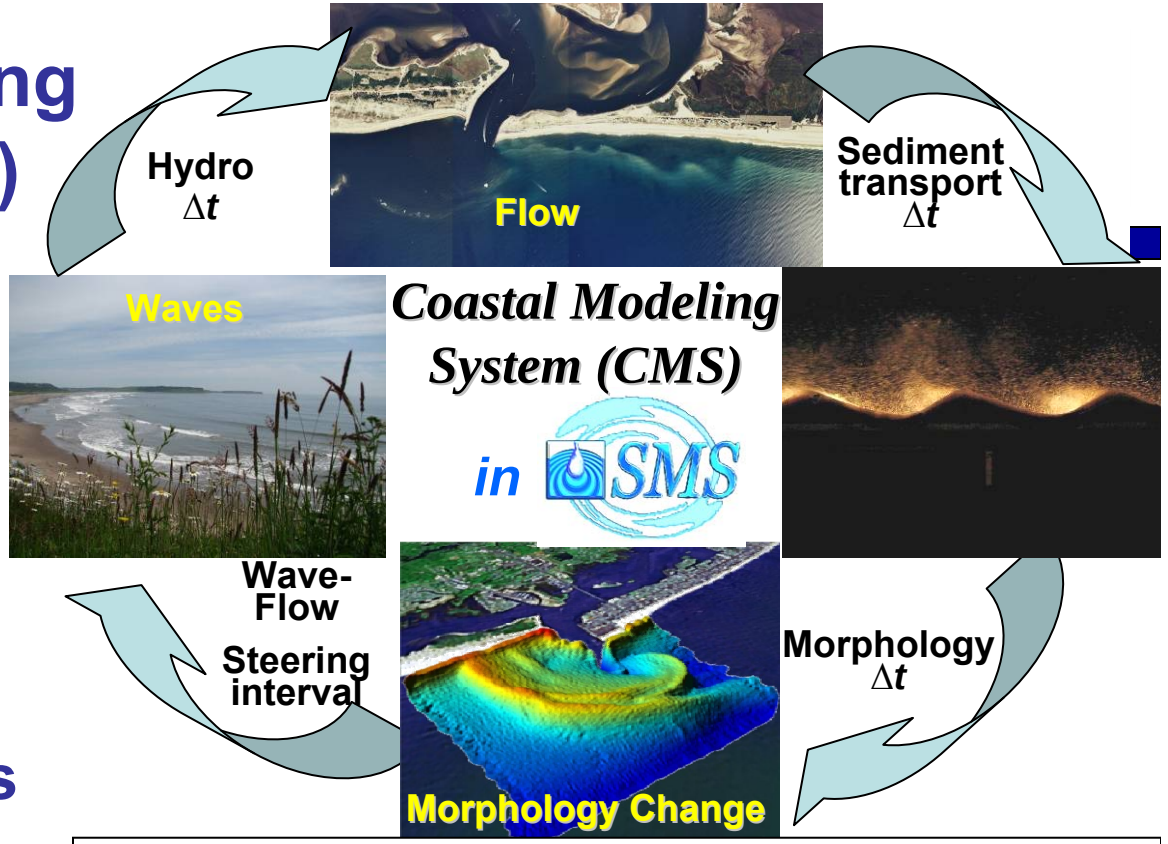
Coastal Modeling System (CMS)

CMS is a CIRP flagship product

- Interactive calculation of waves, current, sediment transport, and morphology change (shore term – storms, and long term – decades)
- Channels, jetties, and levees represented.
- 2D version – Non-Equilib sediment Transport (NET), Rapid Assessment of Morphology (RAM).
- Represents sediment motion by waves and horizontal gradients in current – vertical structure starting in FY10.
- Shoreline change & breach representation (as near jetties) underway.
- Vegetation module underway.
- Long been fully integrated in the SMS.
- Quick to setup and build efficient grids, given good bathymetry/forcing data.
- *Scores of person-years at CHL, at SMS developers, and by academia and consultants.*

Coastal Modeling System (CMS)

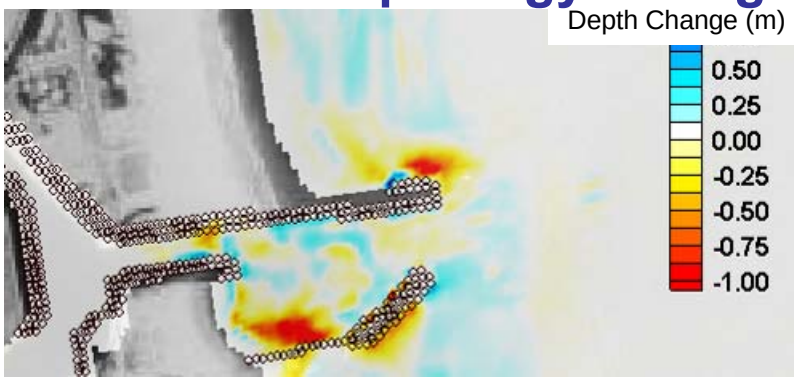


2-D and 3-D Numerical modeling at local- to regional-scale coastal projects including:

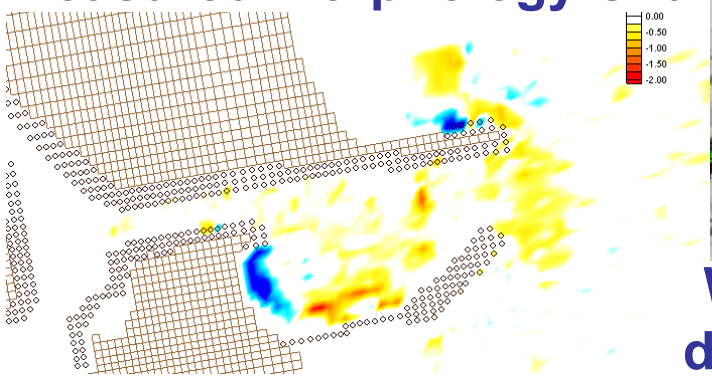
- **Inlets**
- **Navigation channels**
- **Coastal structures**

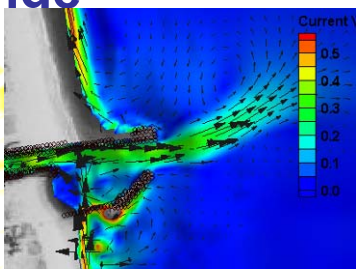
Dynamic feedback between waves, flow, sediment transport, & morphology change

Calculated Morphology Change



Measured Morphology Change





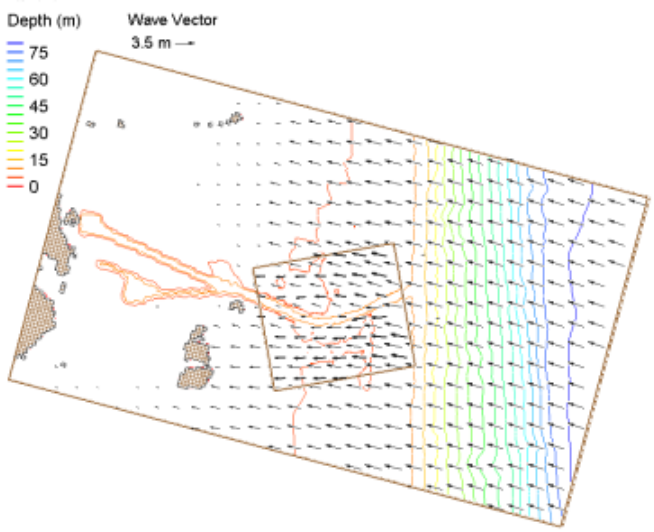
Wave & Tide driven current

Available processes/features in CMS-Wave

- Directional Spectrum transformation
- Refraction / Shoaling
- Depth-limited Wave breaking
- Diffraction
- Reflection (forward/backward)
- Transmission
- Run-up and set-up/set-down
- Wave-current interaction
- Wind
- White capping
- Bottom Friction
- Muddy Coast

Recent additions to CMS-Wave

- Wave run-up calculation
- Four different wave-breaking formulas
  - Extended Goda
  - Extended Miche (New)
  - Battjes and Janssen (New)
  - Chawla and Kirby (New)
- Ability to specify feature cells for wave transmission, wave run-up and setup on beach face, and wave overtopping structures
- Grid nesting capability
- “Fast mode” (Simplified Formulation) run capability



Available processes/features in CMS-Flow

- WL/Tide/Flux forcing
- Wind forcing (spatially constant at present)
- Wave forcing
- Sediment transport (Equilibrium and Non-Equilibrium, Total Load and Advection-Diffusion)
- Wetting/Drying
- Bottom friction (spatially variable)
- Hard-bottom representation (non-erodible layer)
- Basic variable grain size
- Basic 2-d Salinity transport
- Parallel Processing on PC using OpenMP

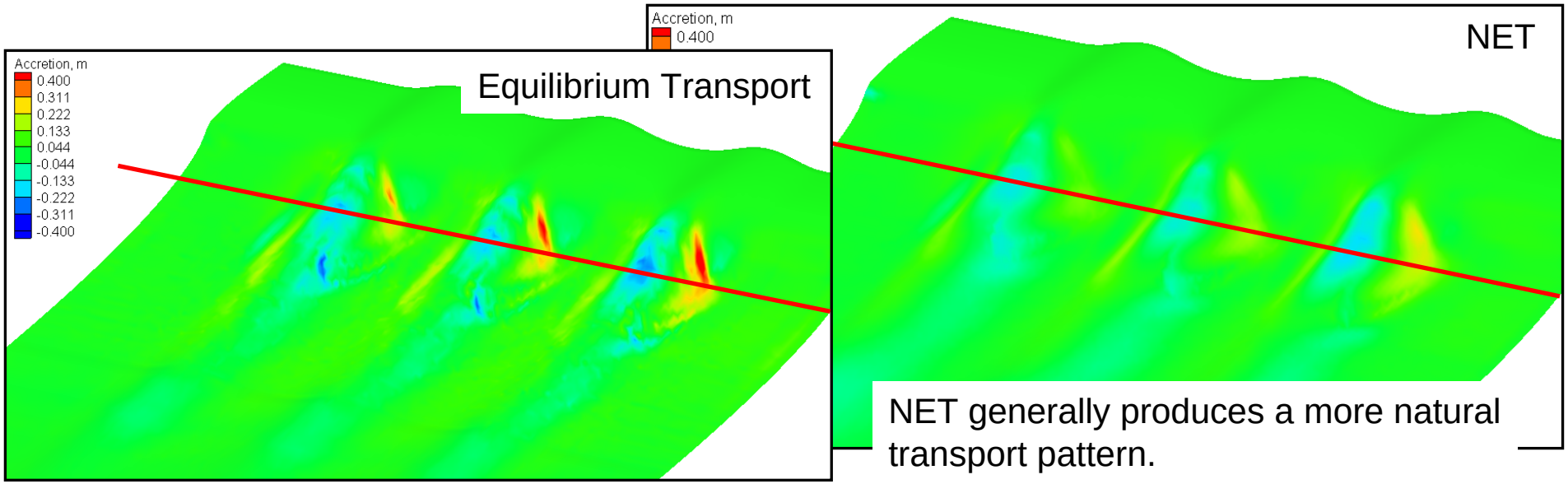
Recent Changes to CMS-Flow

- **Increased Speed -** An optimization of the coding structure for CMS-Flow has created a 500 to 1,000 percent increase in simulation speed depending on user's selections.
- **Additional Sediment Transport Algorithm** - A Non-equilibrium (NET) version of the advection diffusion sediment transport algorithm in CMS-Flow.
- **OpenMP Parallelization** - Use multiple processors on PCs to reduce runtime.
- **2D Salinity Transport** - Can specify a default global salinity concentration as well as introduce a different sediment sources at boundaries.
- **Variable Grain Size** (Phase 1) – Can specify zones of grain size for sediment transport calculations.
- **Improved Stability and Better Error Diagnostics.**

Quick Intro to a Few Features

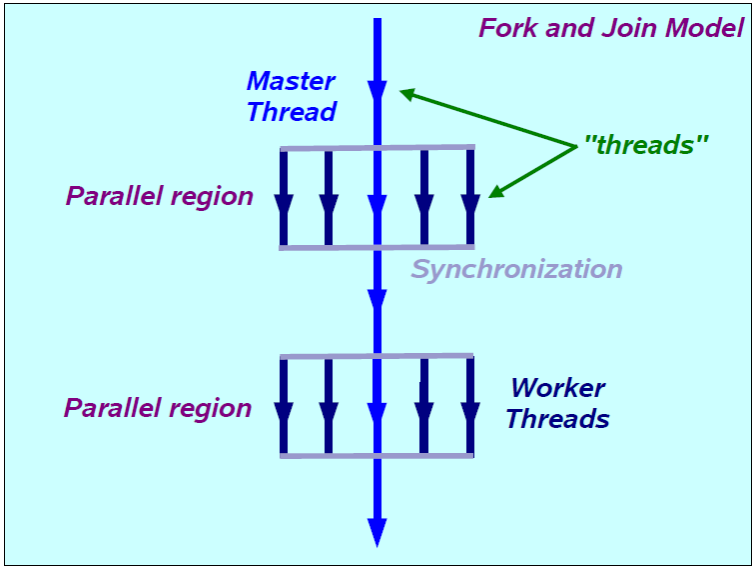
Non-Equilibrium Sediment Transport (NET)

- Accounts for temporal and spatial lags between flow and sediment transport
- Can easily handle constrained sediment loading (over- or under-loading)
- Hard-bottom (non-erodible bottom) automatically computed
- Can simulate suspended and bed load separately or combined as bed-material or total load
- Much more stable than equilibrium (standard) sediment transport



Parallel Processing

- **CMS-Flow has been parallelized using the OpenMP parallelization method. Routines parallelized are:**
  - Initialization
  - Hydrodynamics
  - Morphology
  - Sediment Transport (ongoing)
  - Salinity
- **SMS interface implementation is underway.**
  - Workaround: Access via "**Advanced**" tab in model control
  - Add card "OPENMP_PROCESSORS <white space> #"



- **On some newer computers (Intel and AMD) there are sometimes two "threads" per processor. This is called Hyper-threading (HT)**
  - CMS will determine if the computer has HT capability and adjust the number of threads accordingly.
  - **If User specifies 1 processor and HT is available, CMS-Flow will operate with 2 threads !!**
- **Works best on grids with more than 20,000 cells.**
- **At some point, adding more processors will no longer speed up the run down and cause unnecessary use of processors (see next slide).**

Parallel Processing

Time comparison from 1 interval of steering run

- Flow grid ~42,000 cells
- Hydro Timestep – 0.5 sec
- Transport Timestep – 10 sec
- Morphology update – 0.5 hr

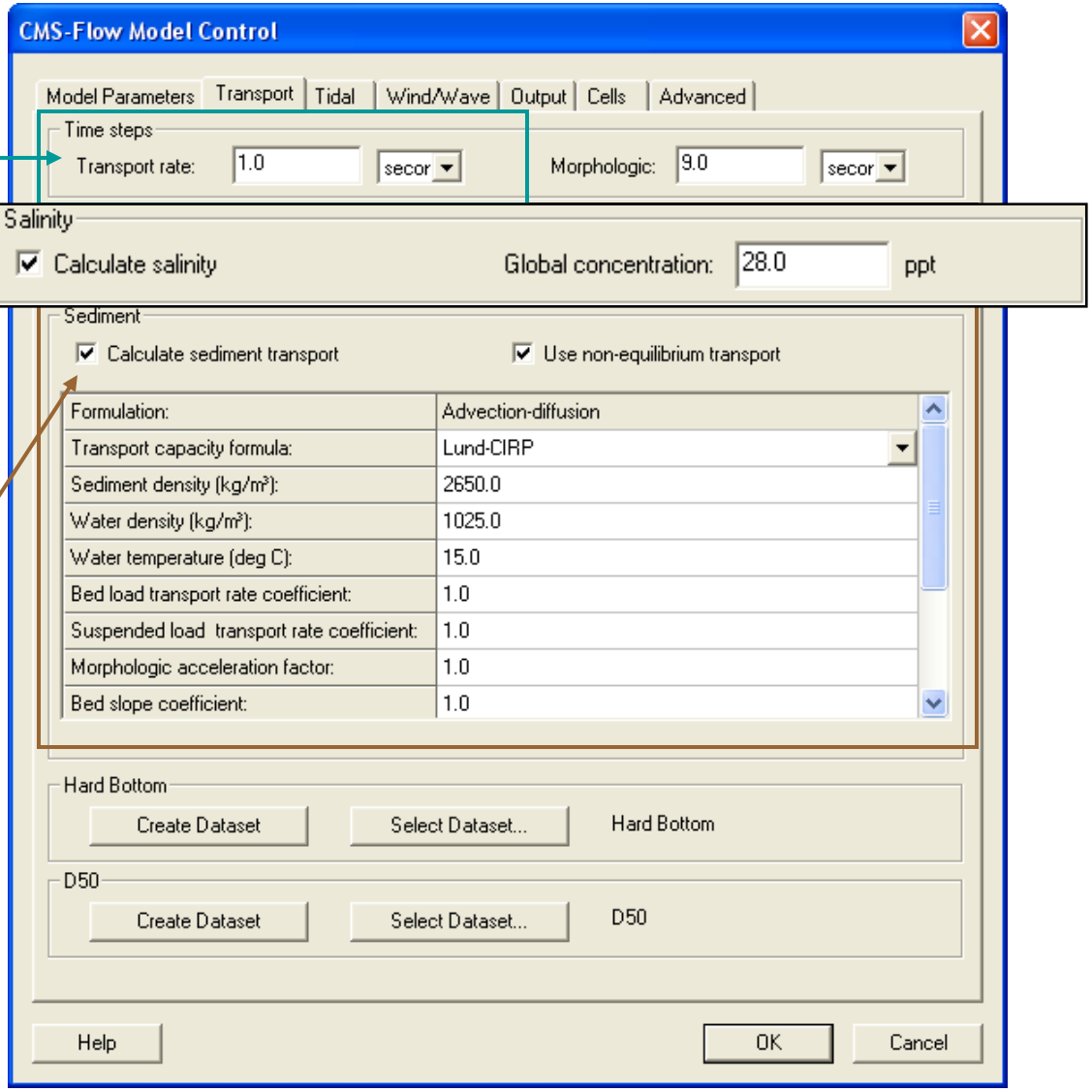
	Serial 1 Processor	**Parallel** 1 Processor (2 Threads)	**Parallel** 2 Processors (4 Threads)	**Parallel** 3 Processors (6 Threads)	**Parallel** 4 Processor (8 Threads)
Hydro + Waves only	12 m 52 sec	8 m 23 sec ~1.5x faster	4 m 29 sec **~2.8x faster**	6 m 6 sec ~2.1x faster	5 m 4 sec ~2.5x faster
Hydro + Waves + ST : Total Load – Lund CIRP	15 m 46 sec	8 m 37 sec ~1.8x faster	5 m 10 sec **~3.0x faster**	6 m 37 sec ~2.4x faster	6 m 34 sec ~2.4x faster
Hydro + Waves + ST : NET – LundCIRP capacity	17 m 28 sec	11 m 15 sec ~1.5x faster	7 m 17 sec **~2.4x faster**	7 m 50 sec ~2.2x faster	7 m 15 sec ~2.4x faster

Salinity

Presently, a combined transport timestep for both salinity and sediment.

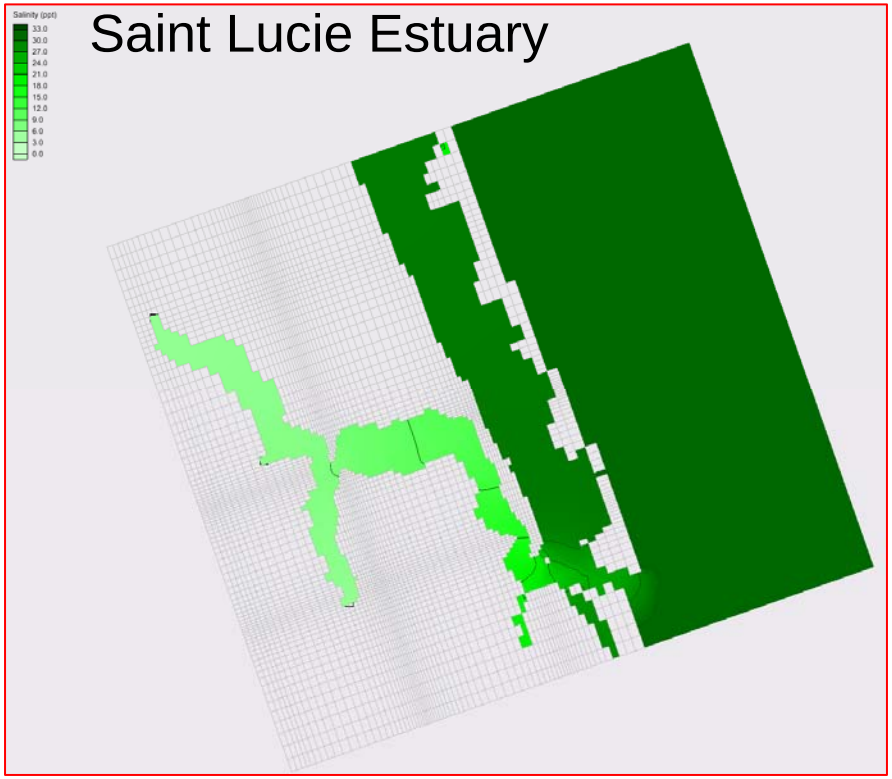
- Activate salinity transport.
- Assign default global salinity concentration.
- Salinity concentration boundary conditions are enabled

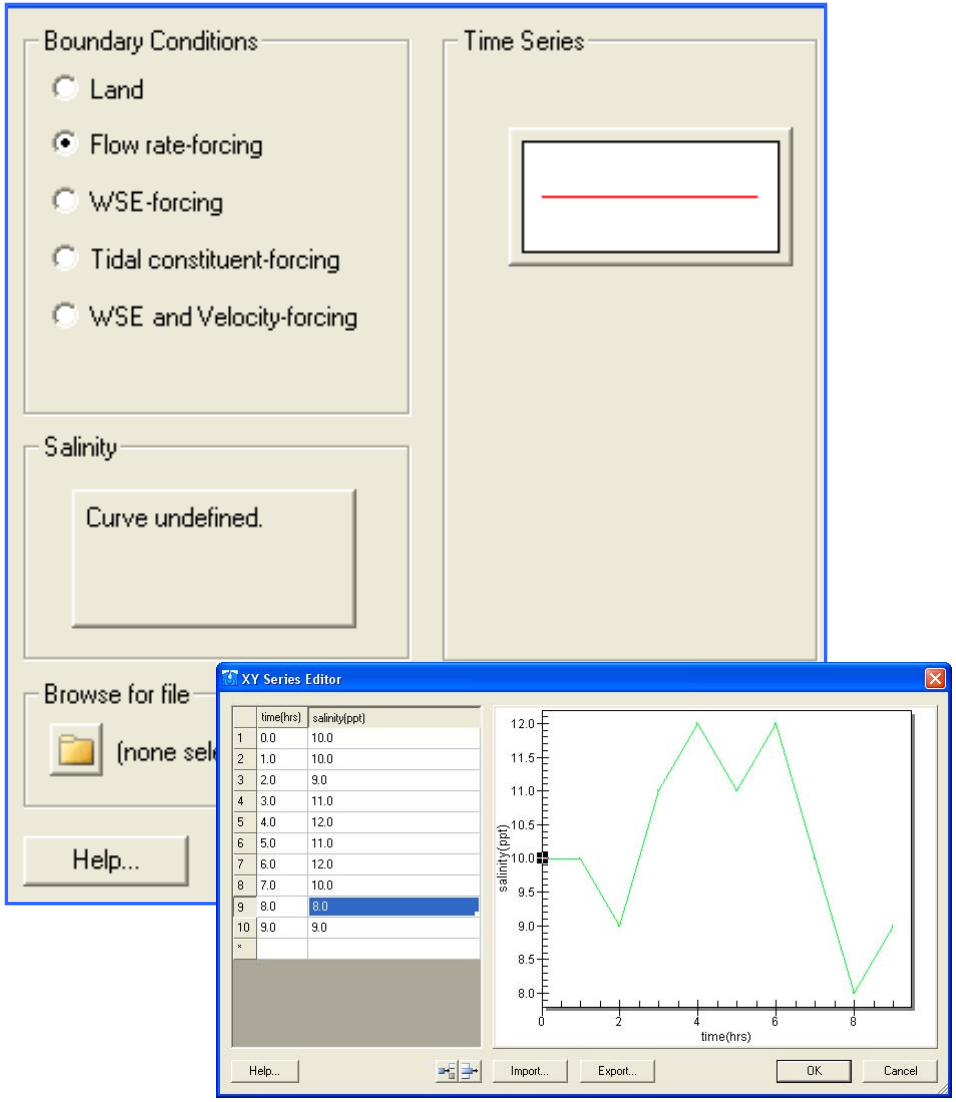
- Activate sediment transport.
- Choice of fundamental type of equations (Equilibrium or Non-equilibrium).
- Assign various sediment parameters, coefficients, and formulations.



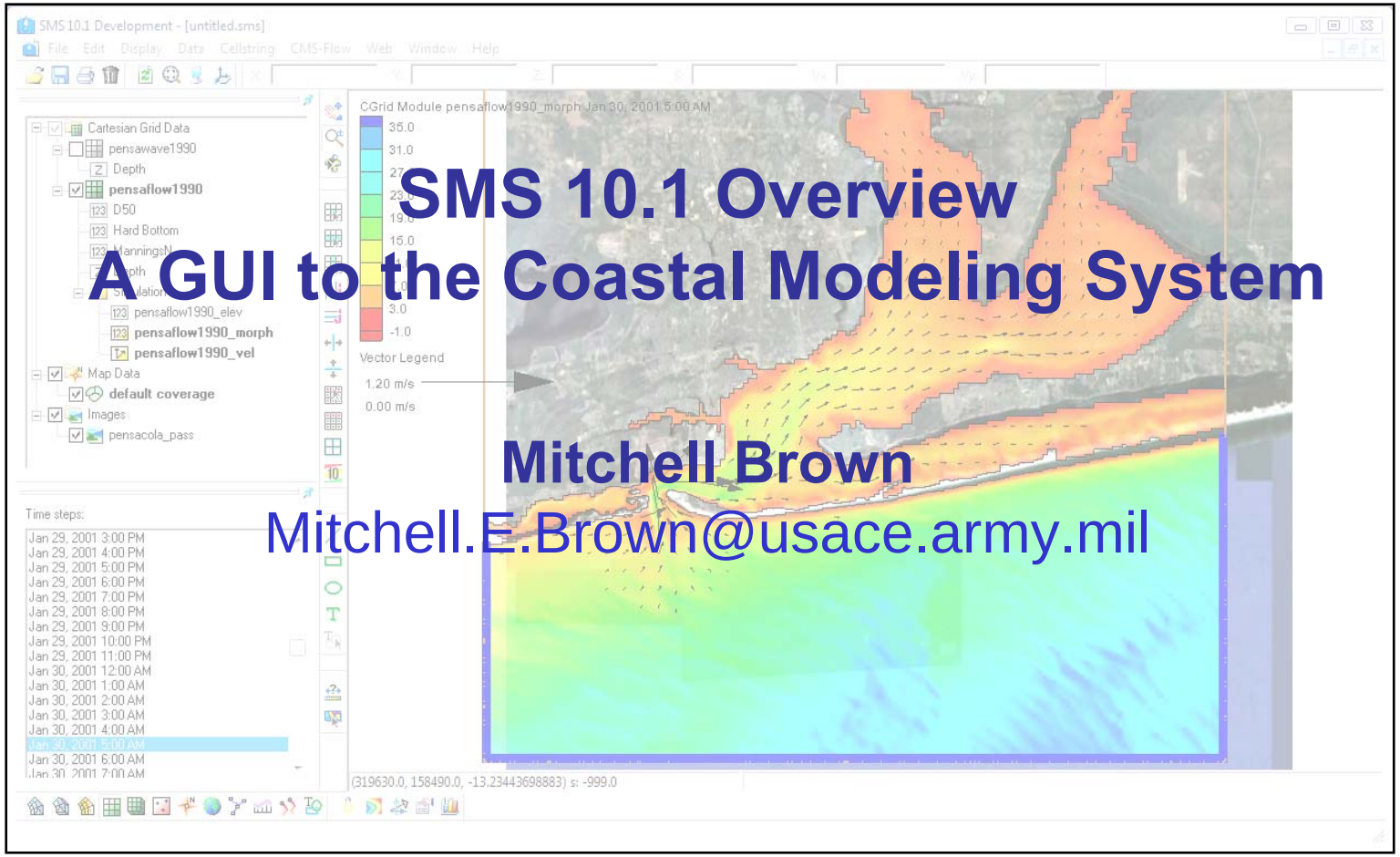
Salinity

- Select cellstrings to assign salinity boundary forcing curves.
- Pull-down menu has option for “Assign BC”
- Cellstring has new “Salinity” option to assign concentration forcing information.





Introduction to the SMS



SMS 10.1 Overview
A GUI to the Coastal Modeling System

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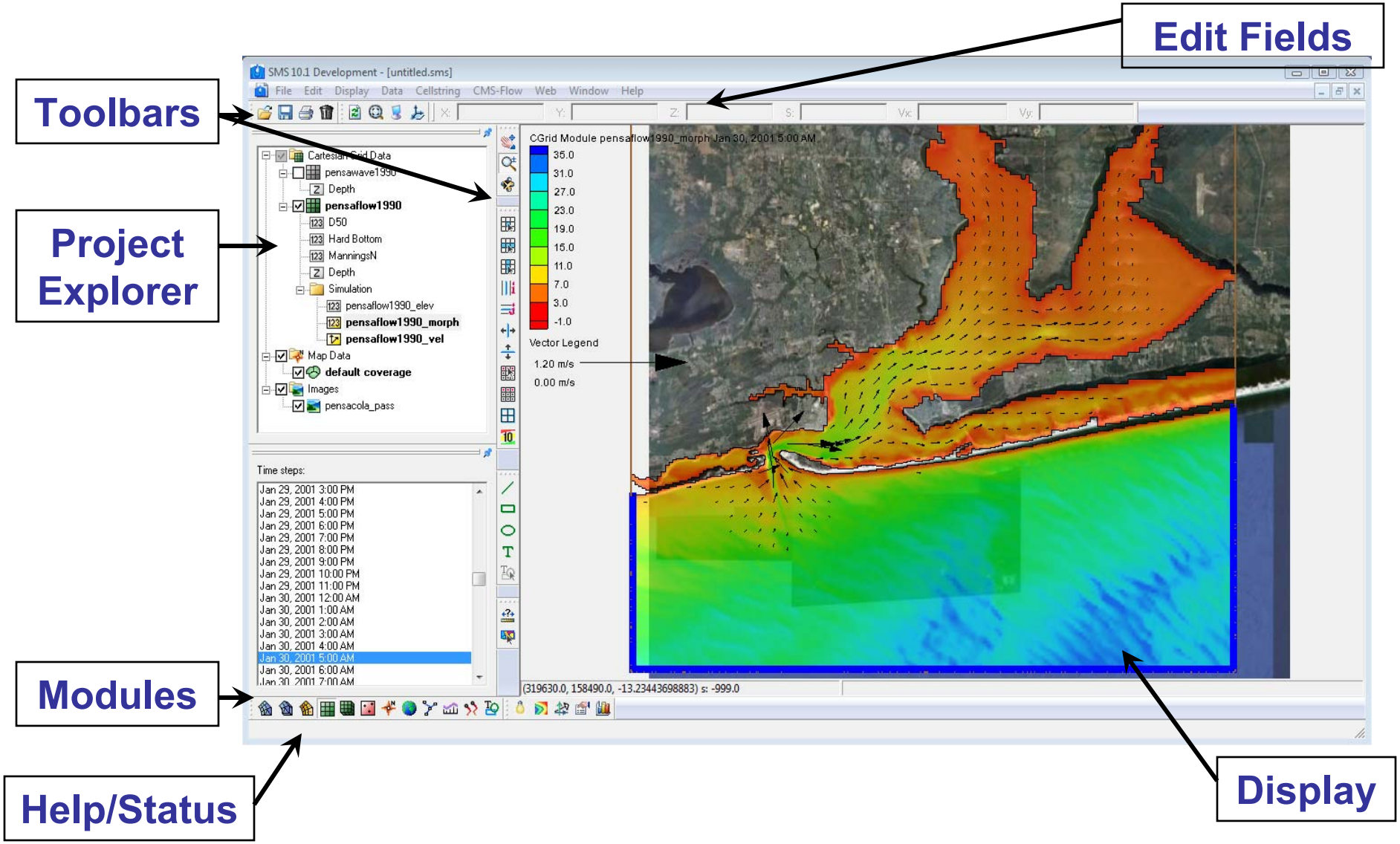
What is the SMS?

- **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
  - Data set creation
- **Connect with outside tools**
  - Import/export CAD data
  - Import/export GIS data
  - Import/export tabular ASCII data
  - Import/export image data

SMS Interface

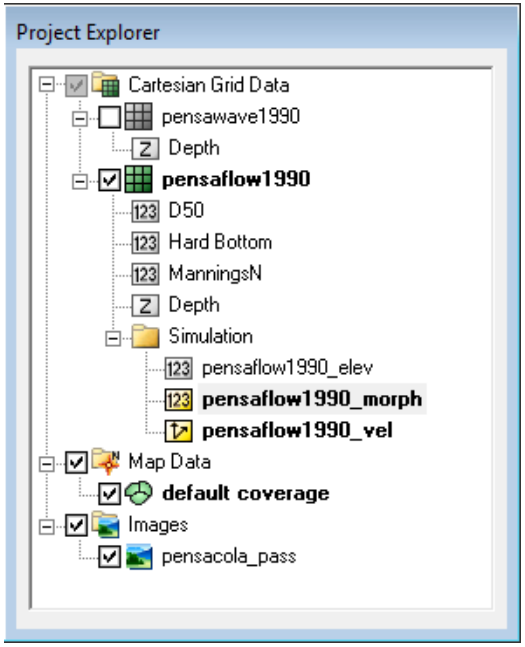


Major Functionality

- Manage/Transform/Edit/Optimize data
- Construct model domain (grids)
- Simplify model parameter specification
- Format data (File I/O)
- Solution review/Post-processing
  - Visualization
  - Data set creation
  - Plots and reports

SMS Modules

- **Separate Commands for Separate Data Types**
  - Scattered Data
  - Conceptual/Map Data
  - Finite Difference Data



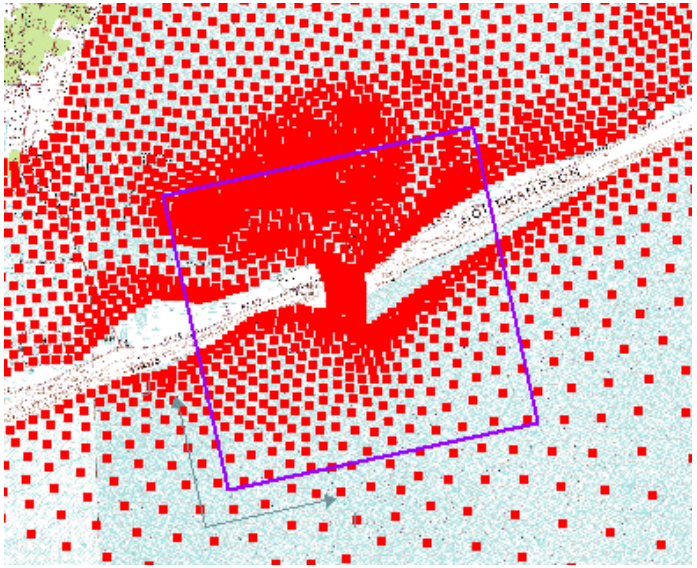
- **Project Explorer (Data Tree)**
  - Geometric objects in base level of the tree
  - Functional data sets organized below

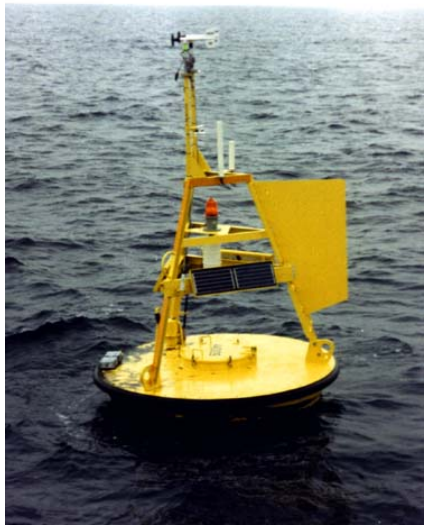
SMS Tools

- Toolbars
  - Toolbar switches which current geometric object.
  - Controls effects of mouse activity in graphics window
  - Arrow in icon indicates “select” tool
  - Dependent on current module and model
- Macro Bars 
  - Display settings set in preferences (Edit|Preferences)
  - Menu command equivalents 
  - Available at all times

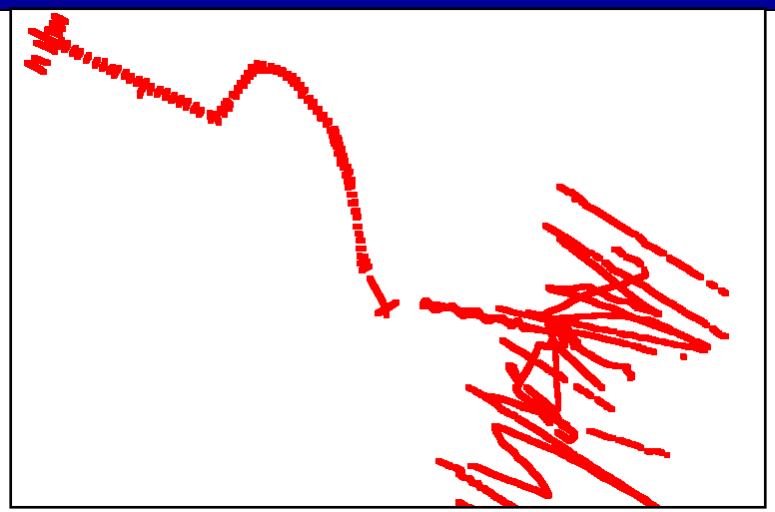
Data In SMS

- **Images**
- **Map Module**
  - Coastlines
  - Field data
- **Scatter Module**
  - Scattered depth data



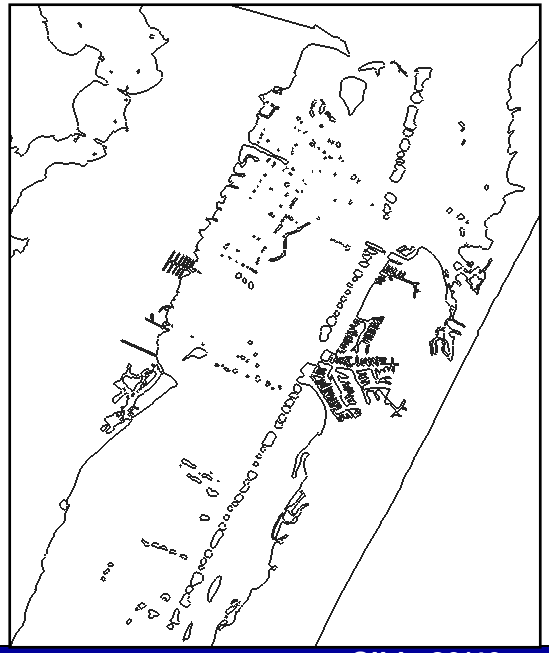


Data Types



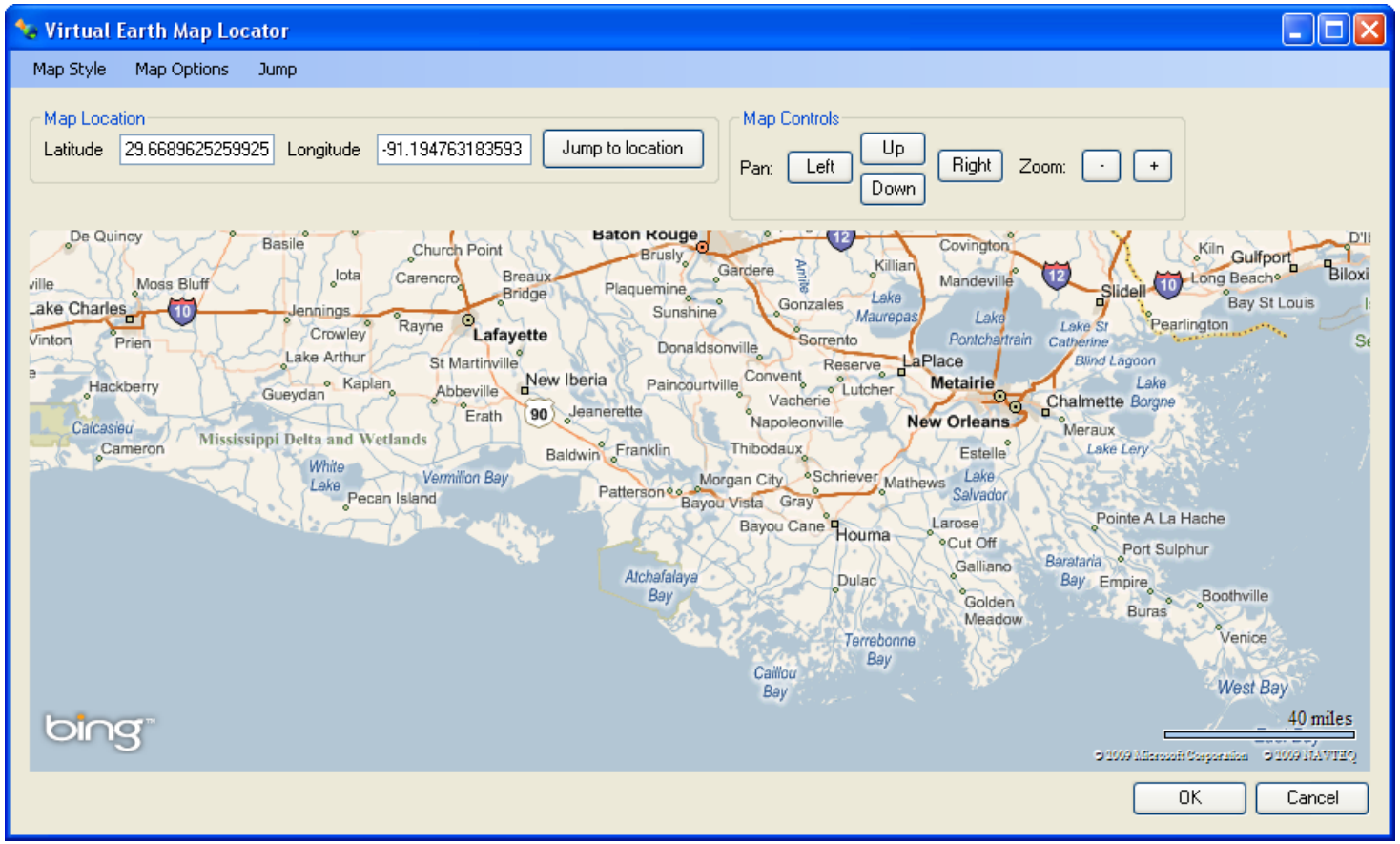
Bathymetry

Aerial Photos or other plan-view images



Coastline

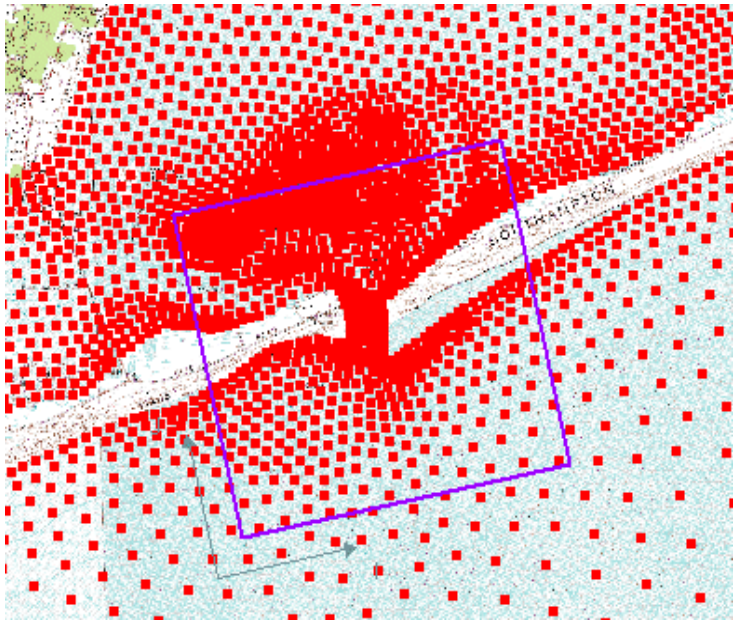
Download Images



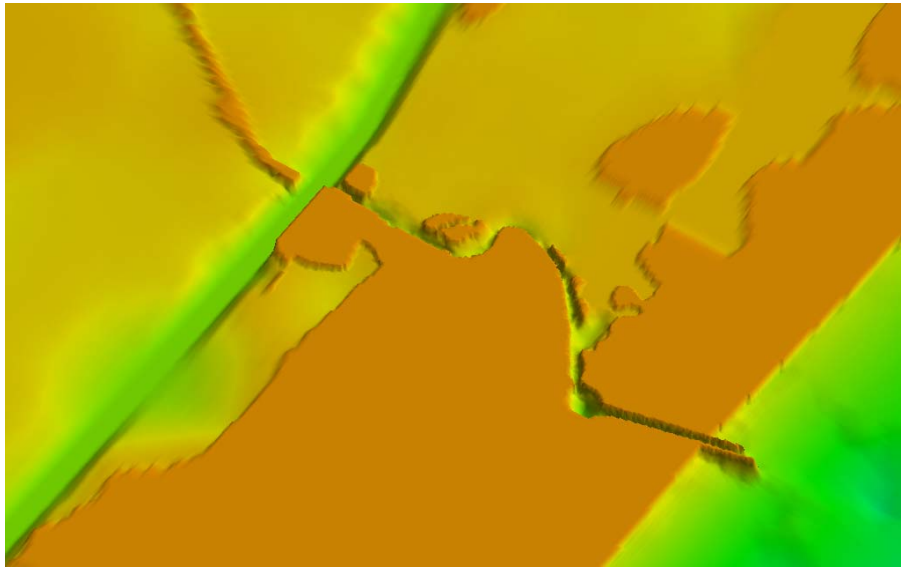
- Virtual Earth to locate site from inside SMS
- USGS as image source

Scatter Data (TINs)

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



Visualization of Scattered Data

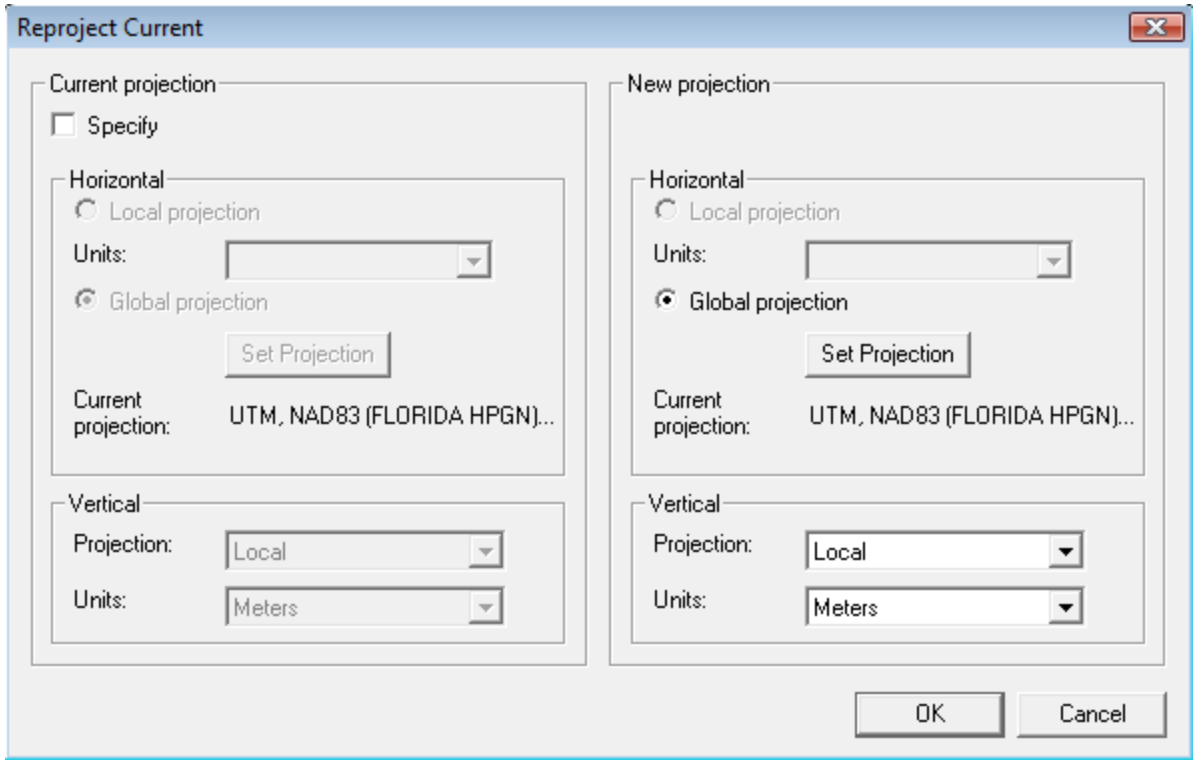


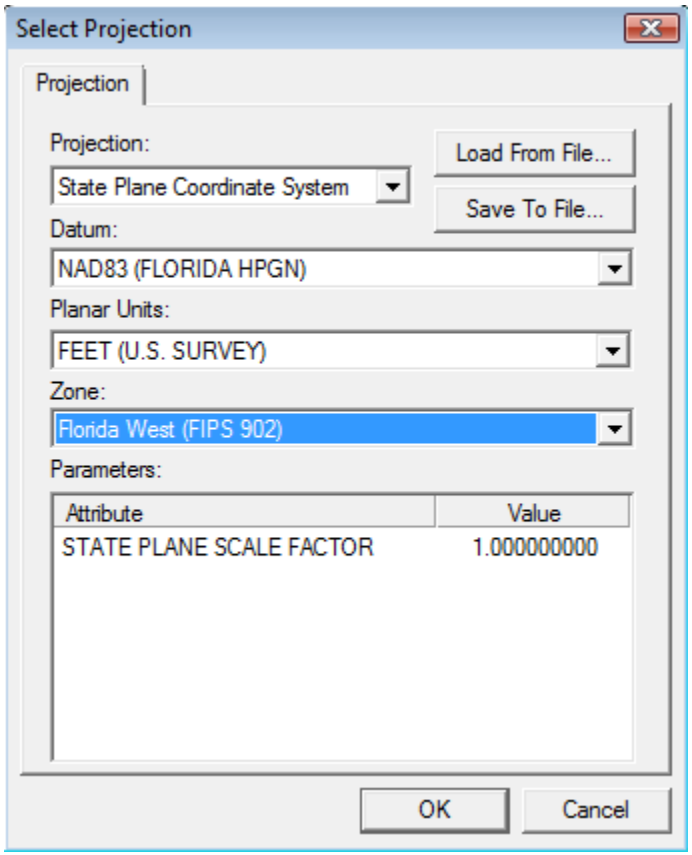
Packery Channel, TX
Oblique view

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

Coordinate Systems

- Projection defined by user (or projection file)
- Conversion or reprojection supported

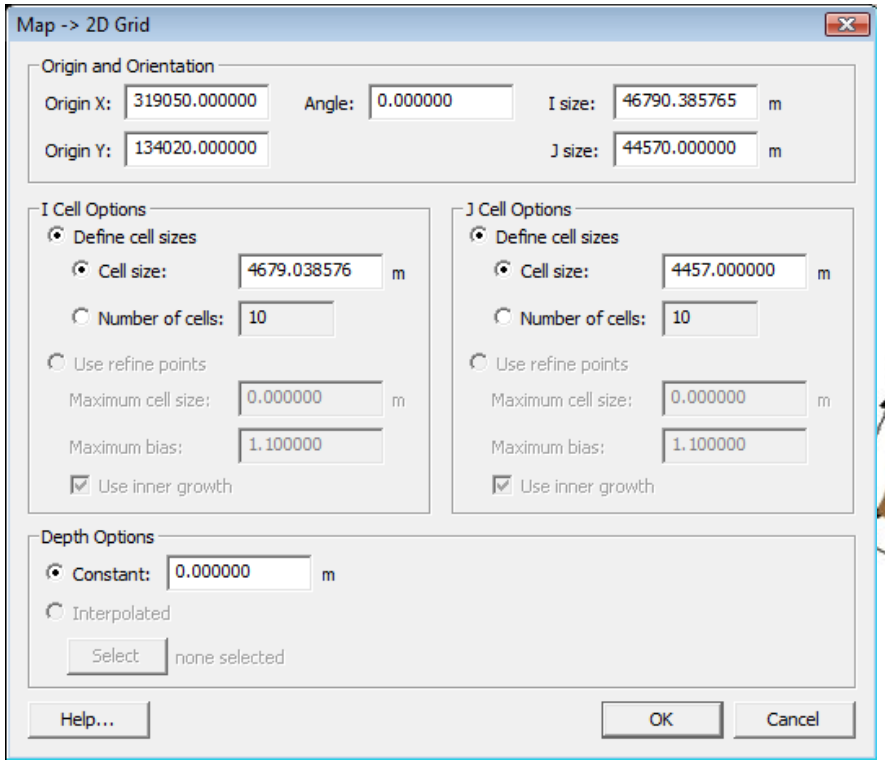


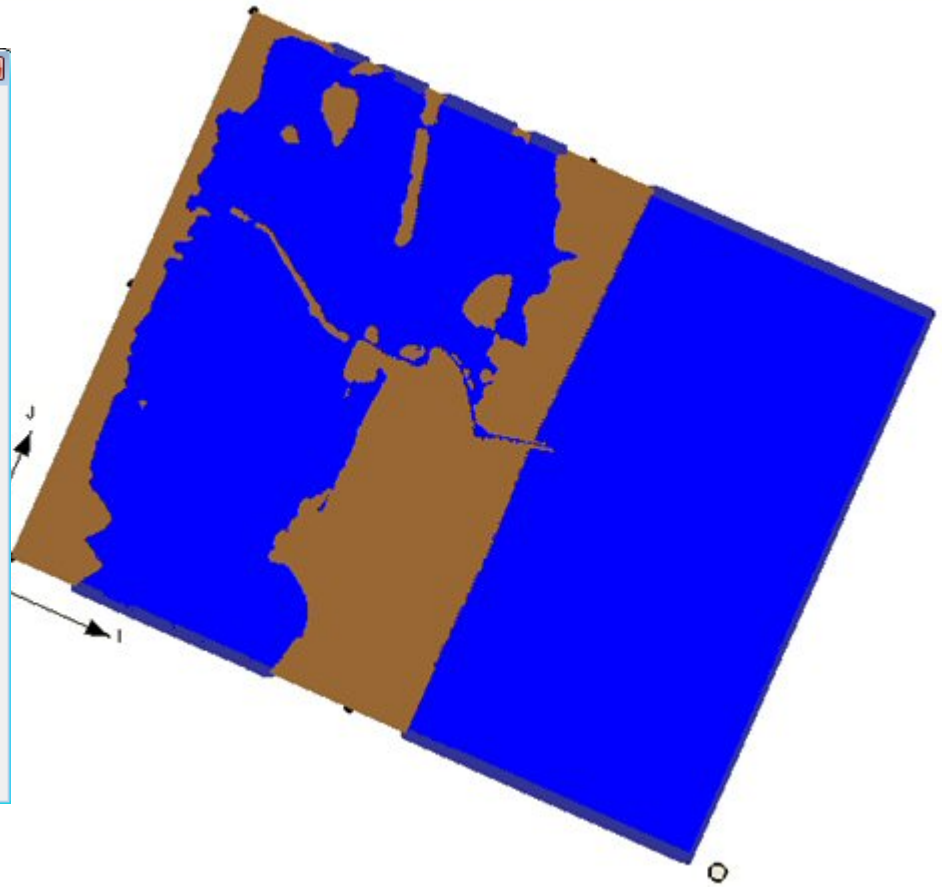


Major Functionality

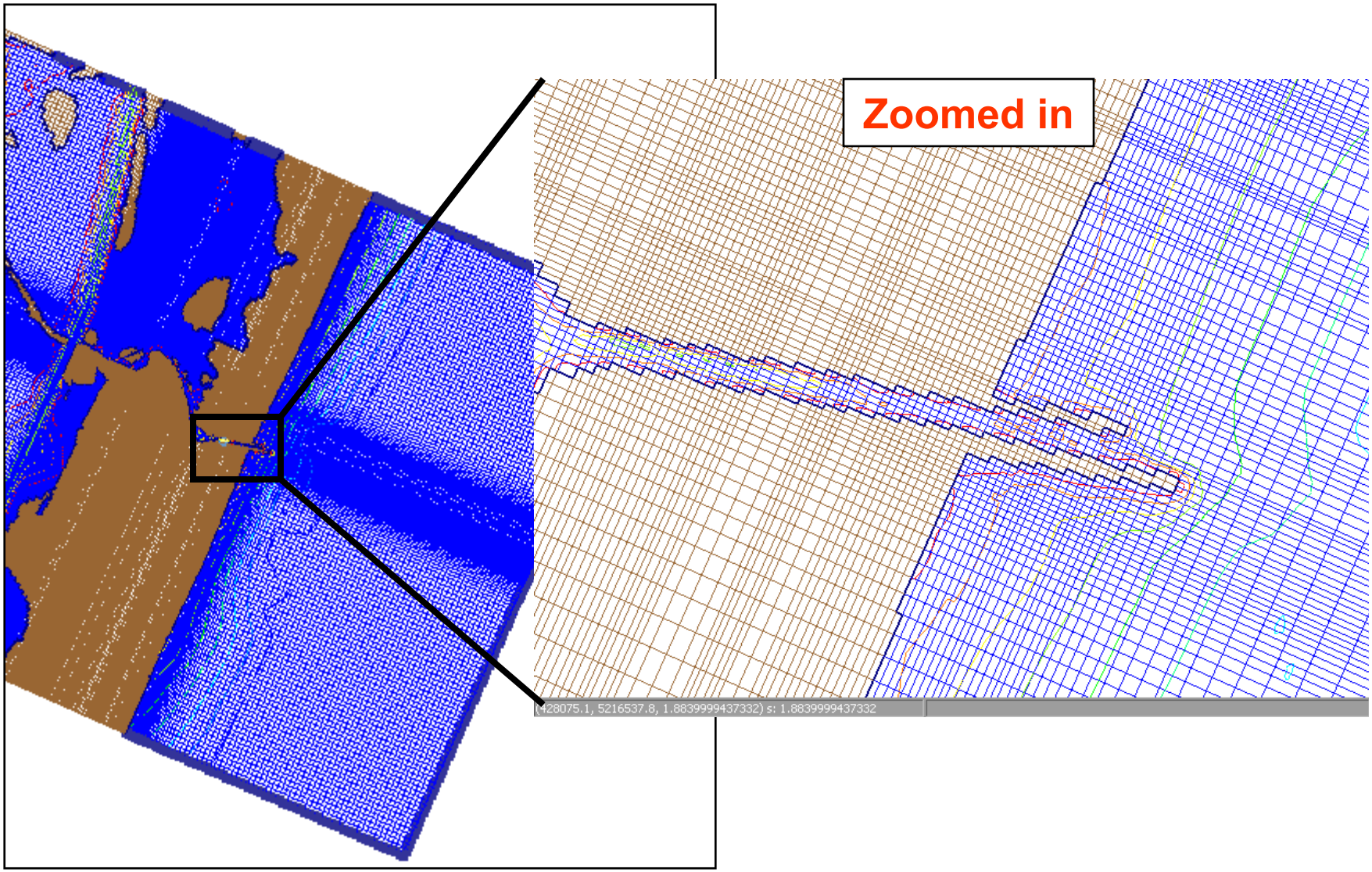
- Manage/Transform/Edit/Optimize data
- Construct model domain (grids)
  - CMS-Flow/CMS-Wave/PTM
- Simplify model parameter specification
- Format data (File I/O)
- Solution review/Post-processing
  - Visualization
  - Data set creation
  - Plots and reports

Map Grid Frame to Grid Constant Cell Size





Map Grid Frame to Grid Variable Spacing



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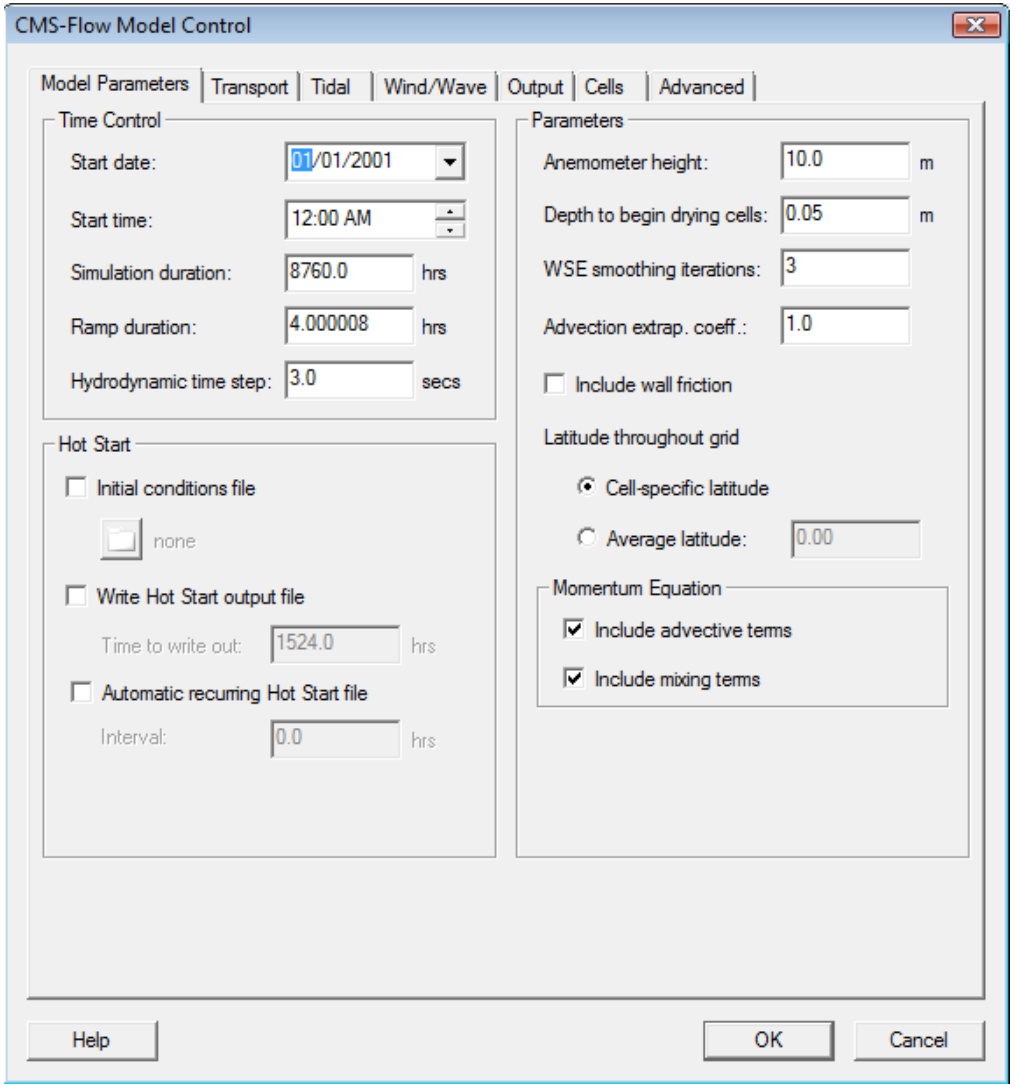
Parameter Specification and File I/O

- Time Control
- Auxiliary Files
- Parameters
  - Solver type
  - Flags
  - …



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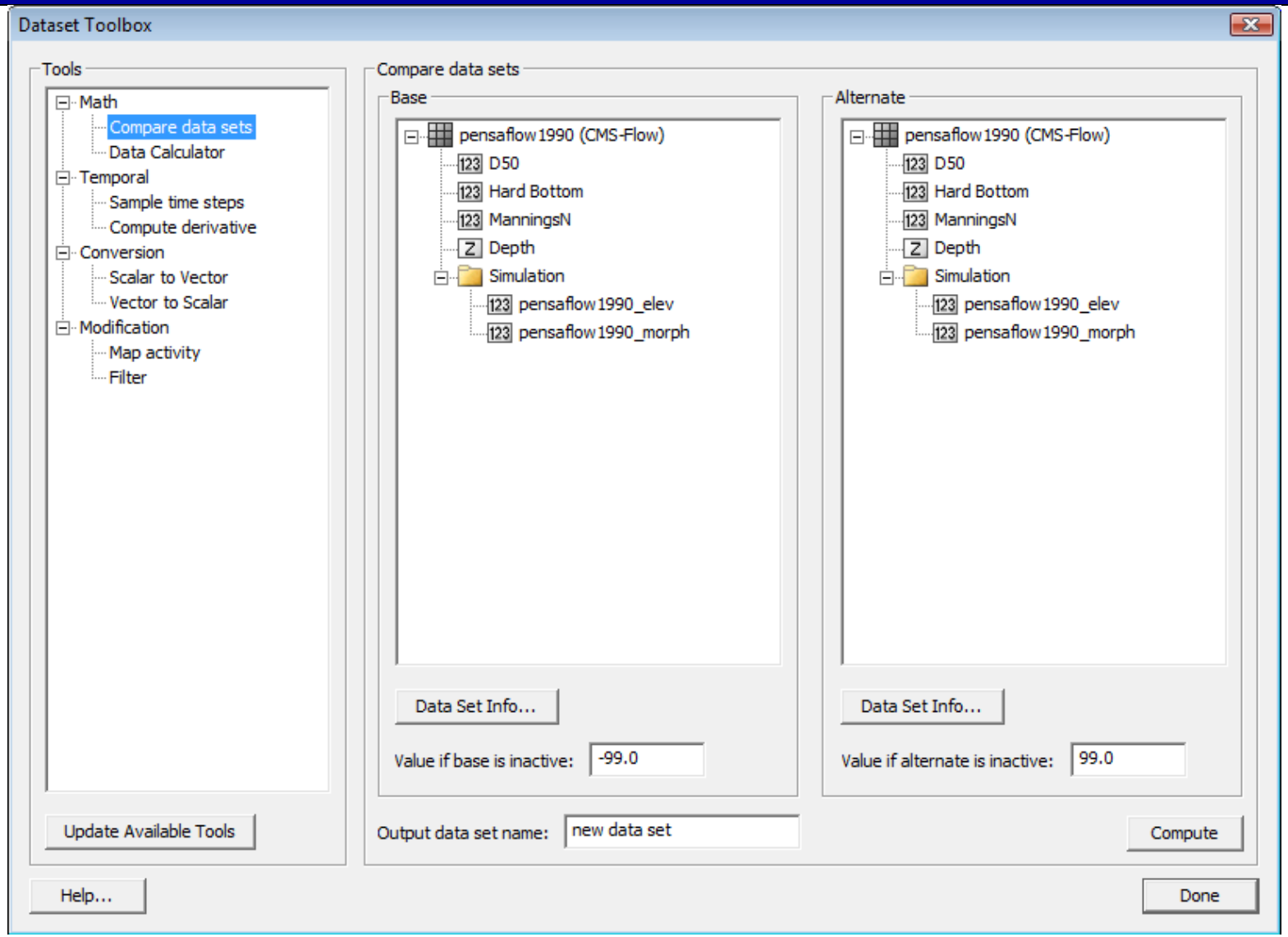
What's New in SMS 10.1

- Dataset Toolbox
- Grid duplication/rotation tools
- Web Menu
- Spatial Data Coverages
  - Data types
  - Plot types
  - Compass plots

What's New in SMS 10.1

- Coordinate Projections
  - More projections
  - Automatic reprojection of data with projection file
    - Images
    - CAD Data
- Annotation Layers
  - North Arrows
  - Legends
  - Screen Space Images

Dataset Toolbox

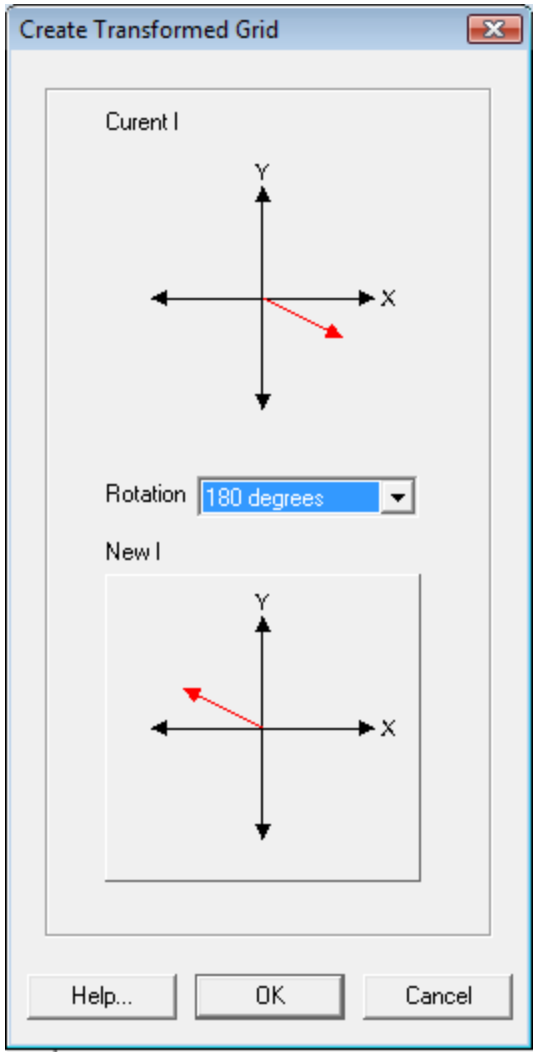


Dataset Toolbox

- Temporal Operations
  - Sample times
  - Temporal derivatives
- Mathematical Operations
  - Comparisons
  - Data Calculator
- Spatial Operations
  - Spacing
  - Gradients/Derivatives
  - Smoothing
- Conversions
  - Vector <-> Scalars
- Coastal Functions
  - Wavelength/Celerity
  - Courant number
- Activity Mapping
  - Map activity
  - Value filtering

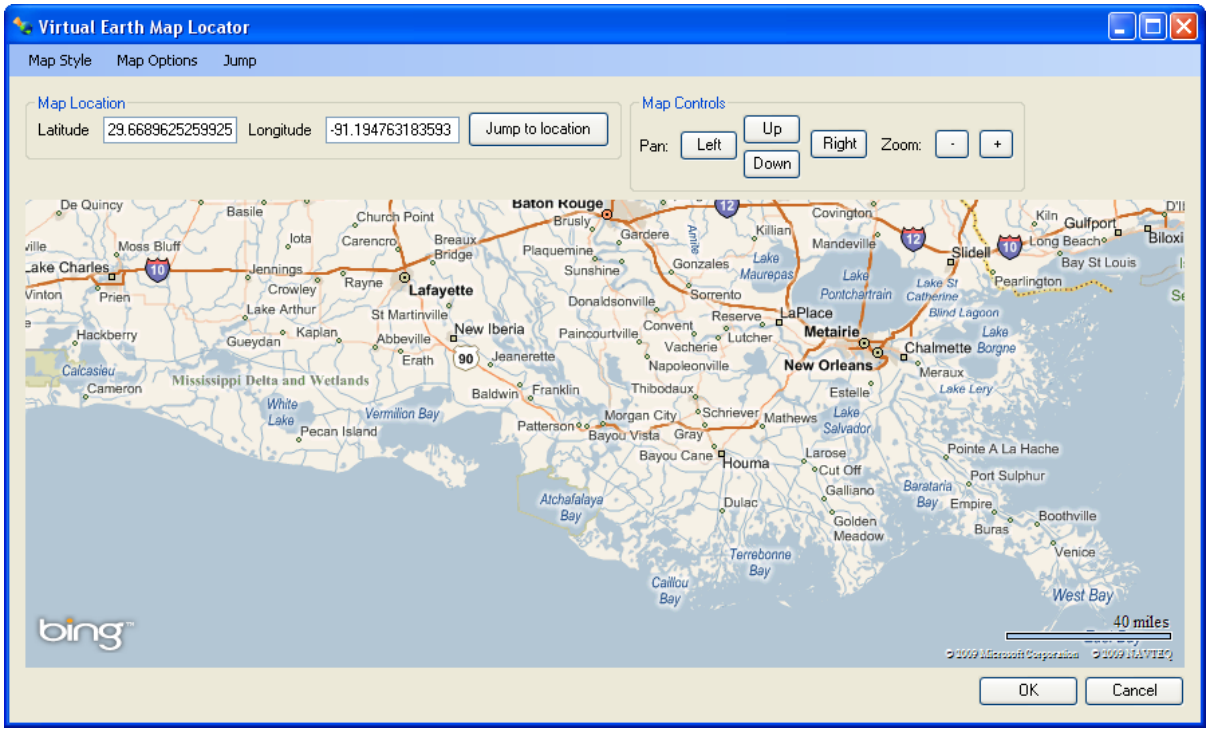
Duplicate/Rotate Grid

- Accessed by Right Click on Grid in Project Explorer
  - Duplicate Flow grid for Wave model or vice-versa
  - Rotate Wave grid to appropriate orientation



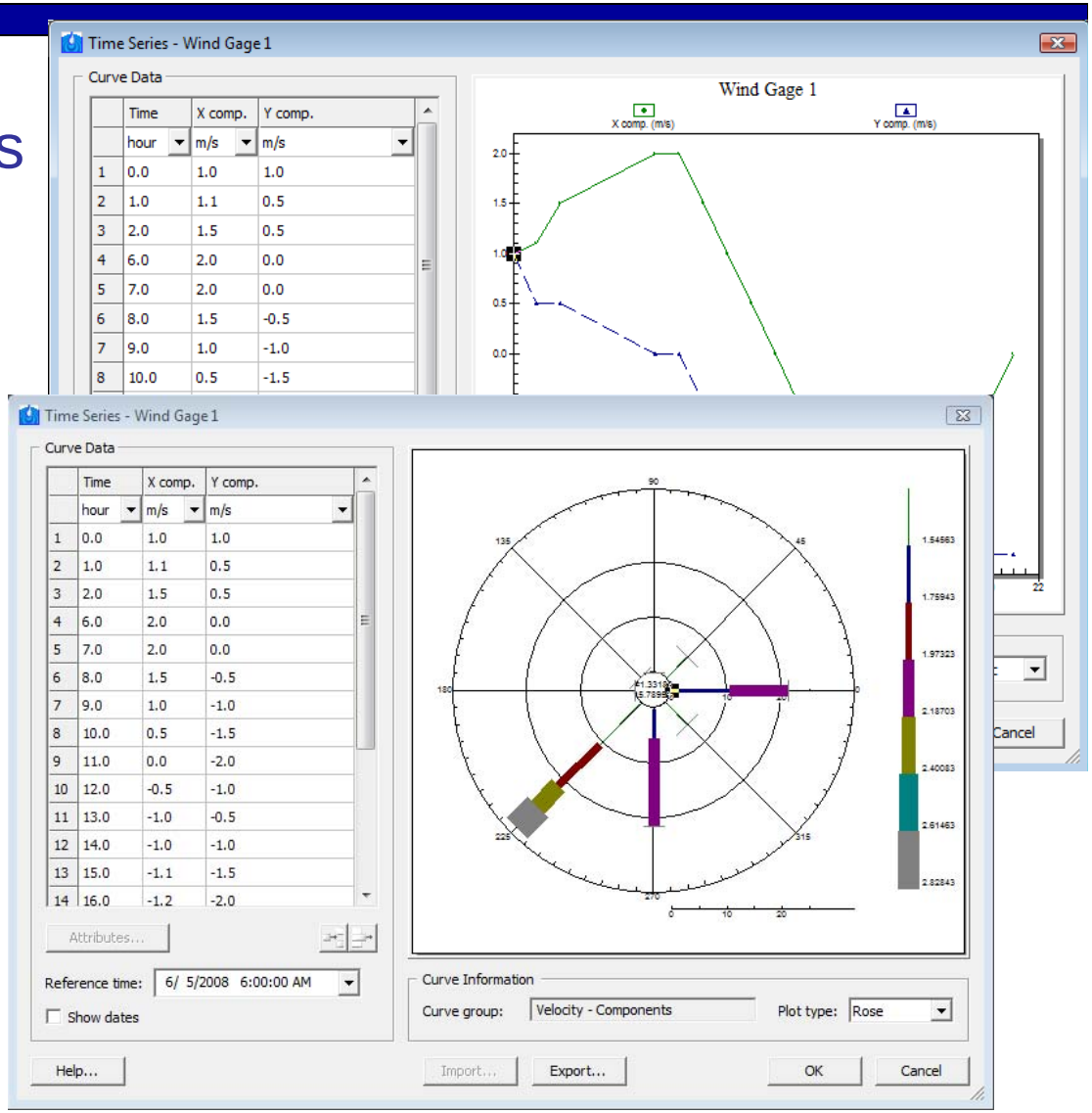
Web Menu

- Import data from web …
  - Virtual Earth
  - Image data
  - Elevation data
- Find Data
  - Links to useful web sites
- Tidal Data
  - Links to coastal filtering tools



Spatial Data Coverages

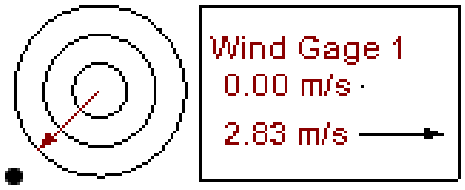
- Create nodes at locations of interest (gauges)
- Associate temporal data with the location
  - Scalar data
  - X/Y vector data
  - Mag/dir vector data
- Plot types
  - Scientific
  - Multi-axis
  - Rose plots

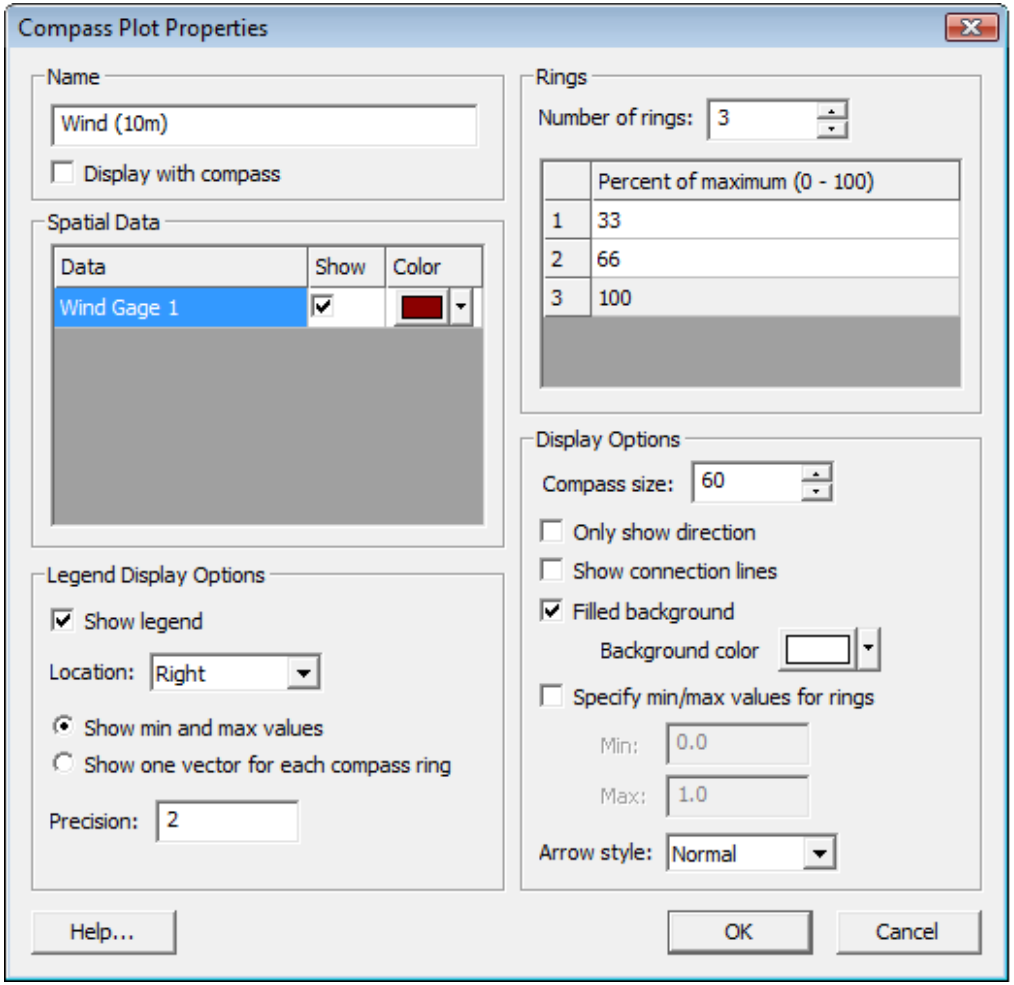


Spatial Data Coverages

Compass plot

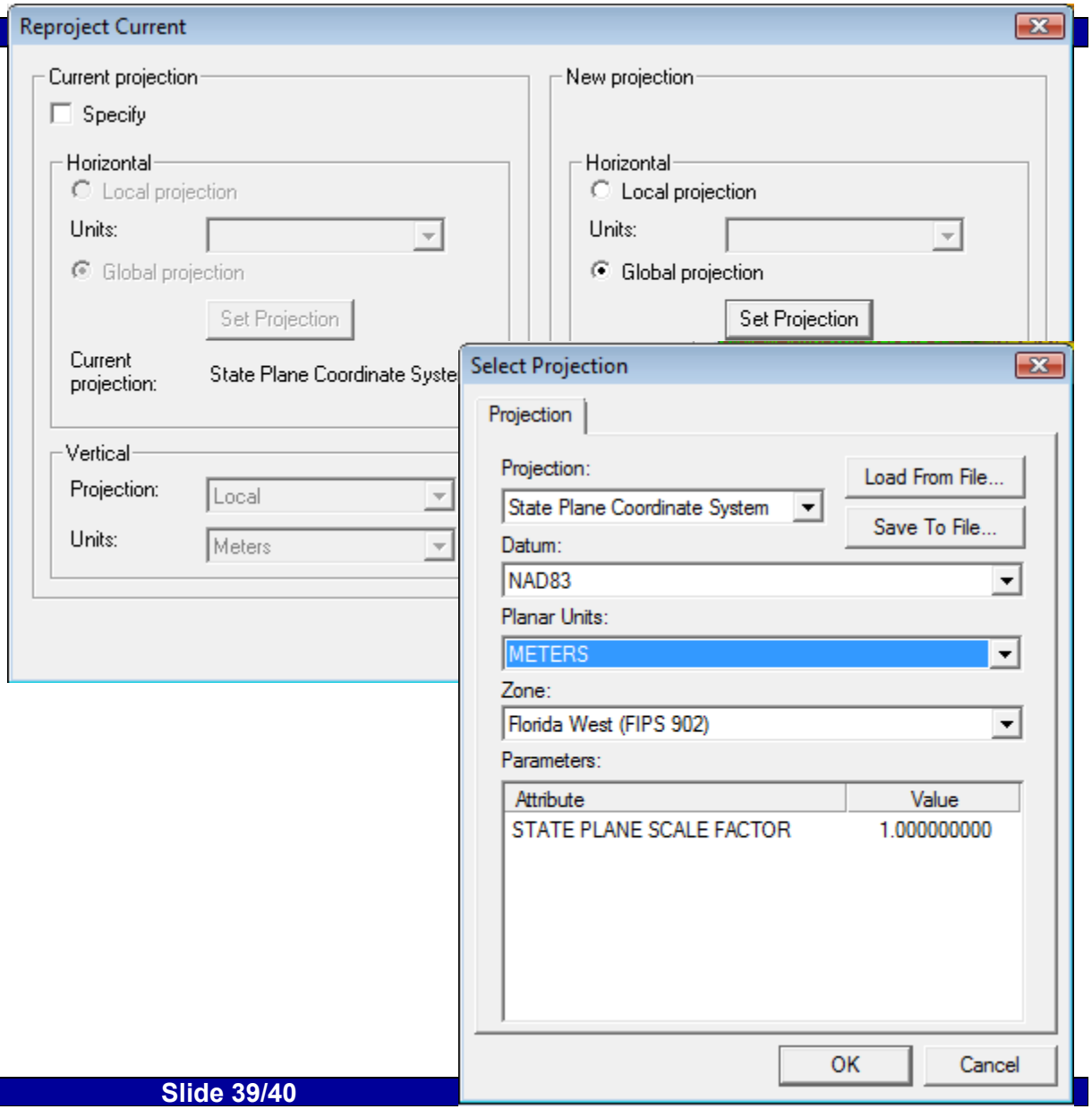
- Displayed on graphics window
- Updates with dates
- User managed





Coordinate Projections

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



Annotation Layers

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