# Circulation Model M2D: Capabilities for Model Coupling and Sediment Transport

# Overview of M2D

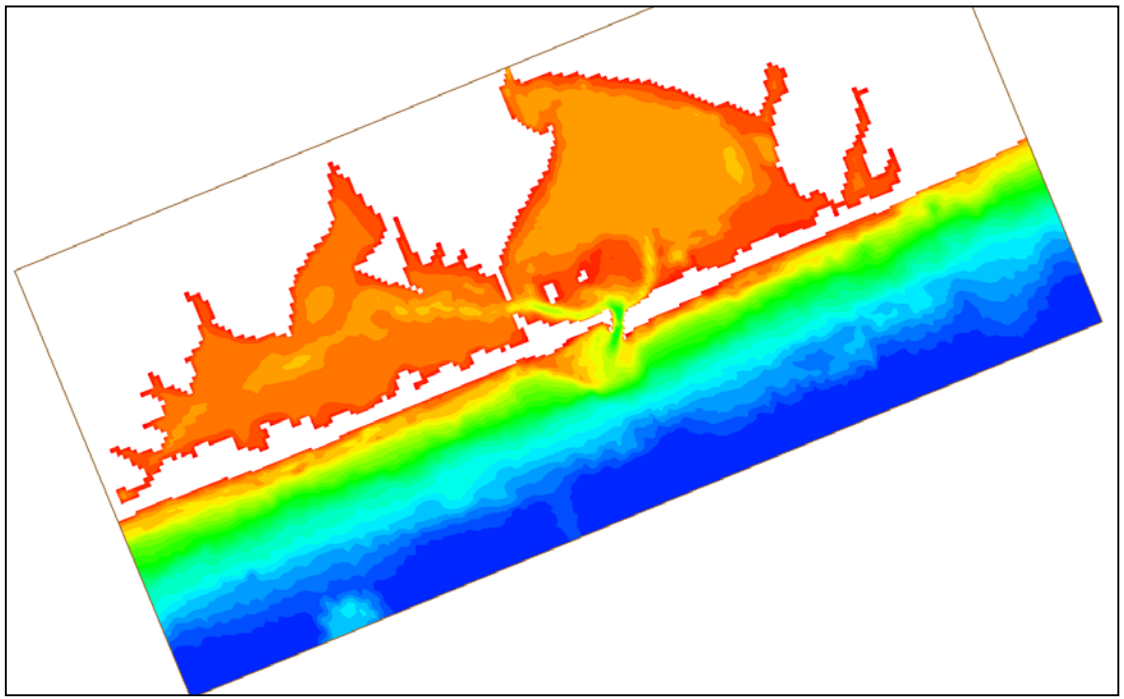
- 2D horizontal circulation model (water level & current)
- Rectilinear grid, variable cell size
- Multiple types of forcing:
  - Water level, wind, waves, flow rate, tidal constituents
- Efficient calculations, no matrix solutions
- Efficient storage in memory
- Easy to configure & run

# Topics

1. Capabilities & Features of M2D
2. Coupling w/ ADCIRC
3. Coupling w/ STWAVE thru Steering Module
4. Sediment Transport

# Present Features

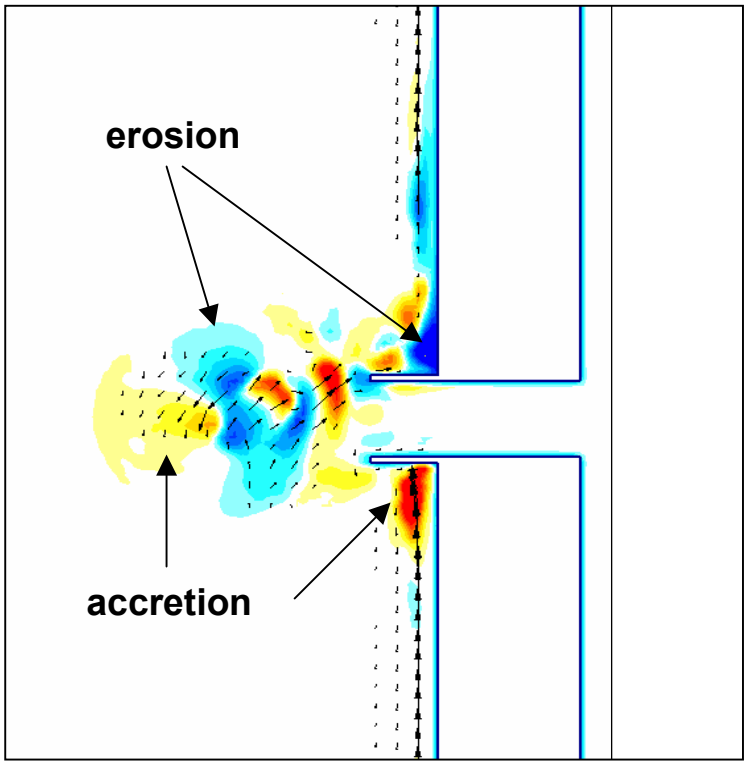
- Multiple types of boundary conditions
- Wind forcing
- Wave forcing
- Variable cell size
- Wetting & drying
- Spatially - variable friction coefficient



**M2D domain for Shinnecock Inlet, NY**

# Sediment Transport*

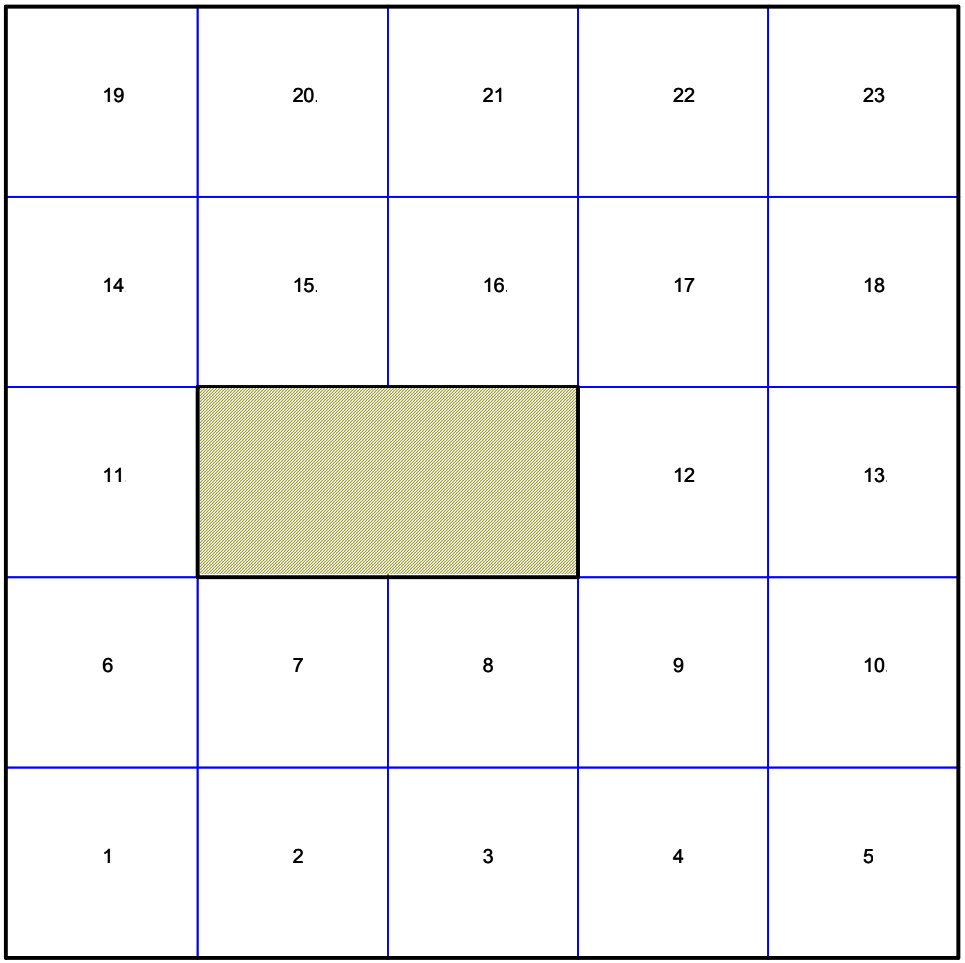
- Sediment Transport
  - Watanabe Total Load formulation (in place, under testing)
  - Update of bathymetry (in place)
  - Sediment transport rates output as global vectors (in place)
  - Non-erodable bottom (in progress)




Transport vectors and change in depth
Tide + waves

* Capability is in progress, release expected Fall 2003

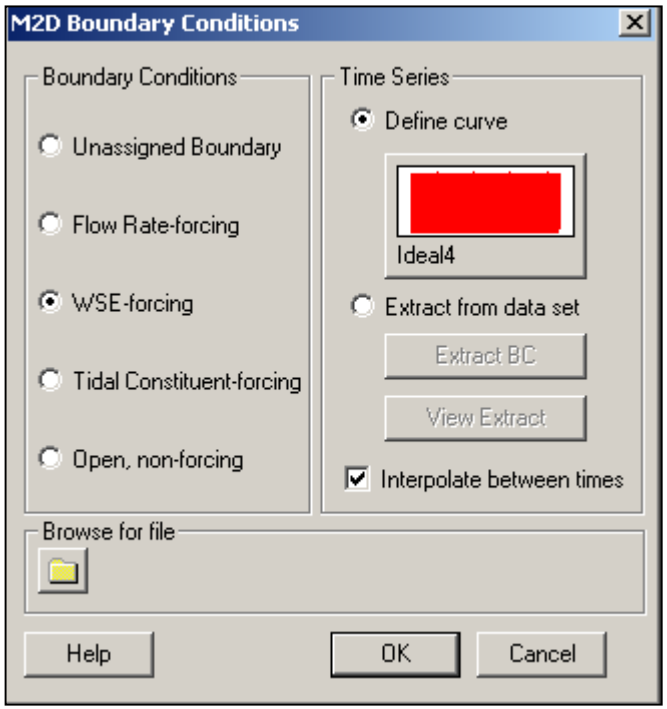
# Grid Storage




- Cells given unique identification numbers
- Never-wetted areas are not stored
- Calculations point to neighbor cells
- No matrix indexing
- Reduces memory requirements for complex shorelines

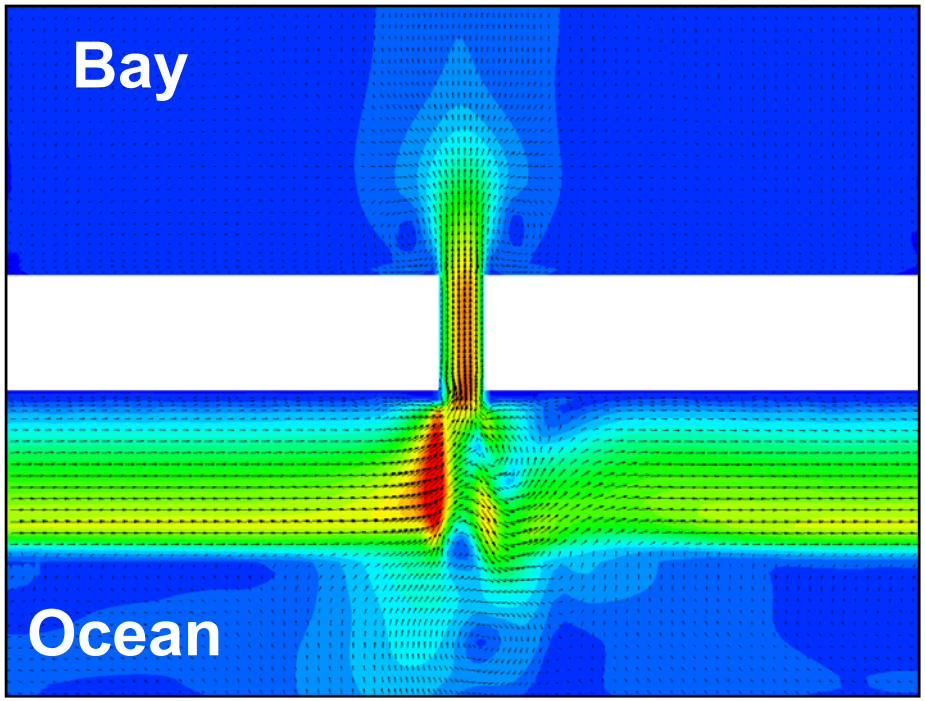
# Boundary Conditions

- Water-level time series
  - Provided by user
  - Extracted from ADCIRC or other models, automated in SMS
  - Generated in SMS
- Tidal constituents
- Flow rate
- Passive open boundary
  - Lets water move in & out of boundary (not forced)
  - Needed nearshore w/ waves, wind



# Wave Forcing

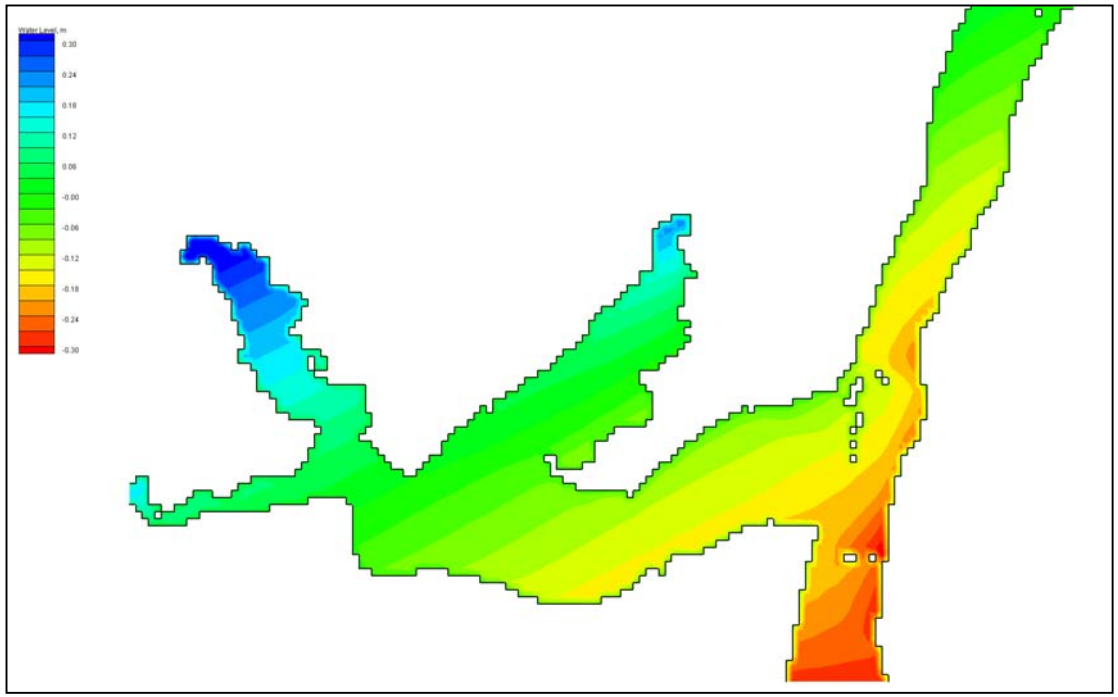
- Calculate wave-driven currents, setup, & set down
- Wave stresses implemented into momentum equations
- Input: time series of radiation-stress gradient fields
- Auto coupling w/ STWAVE in SMS Steering Module




**Wave-induced current, idealized inlet**

# Wind Forcing

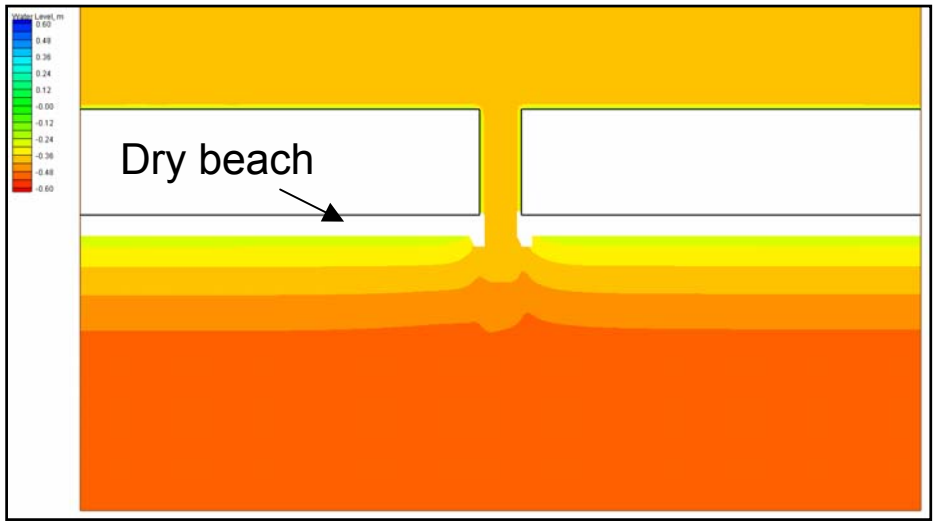
- Calculate wind-generated currents, setup, set down
- Time varying, spatially homogenous
- Wind-stress coefficient (Hsu 1988)
  - Wind speed dependent
  - Developed for shallow water
- Specify anemometer height in M2D control file
- Wind input: time series of speed & direction

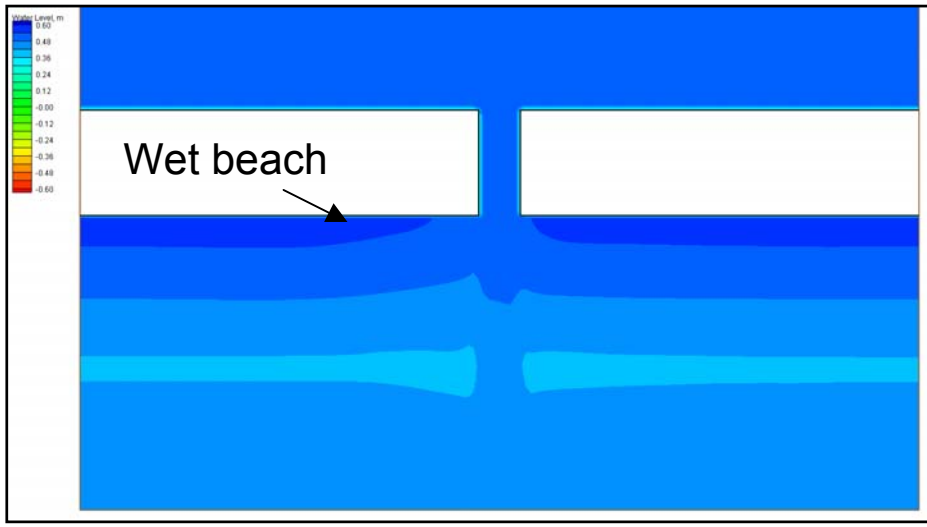



**Wind setup & set down, Baffin Bay, TX**

# Wetting & Drying

- Represents inundation & exposure of cell bottom w/ variation in water level
- Beaches, shoals, tidal flats

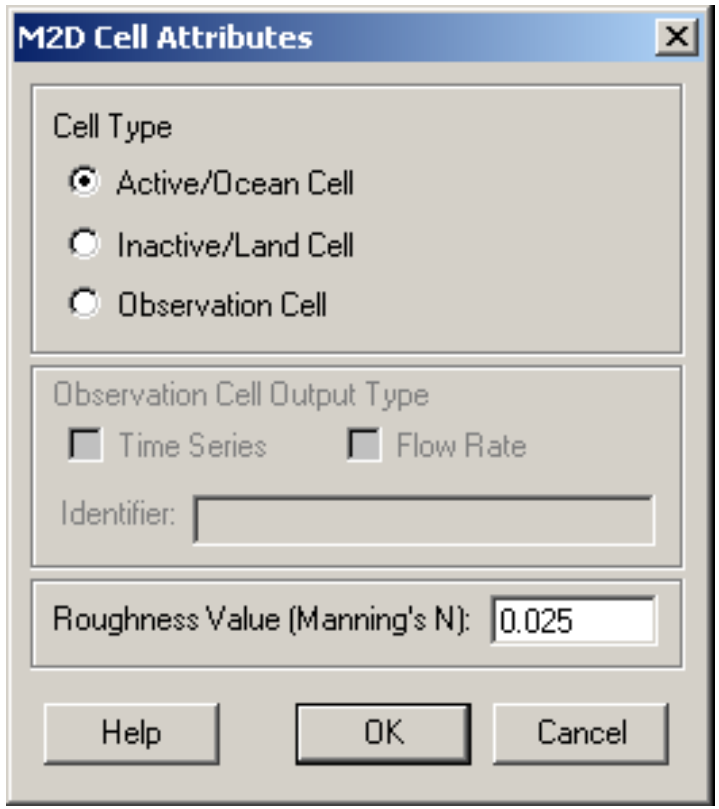



**Wetting & drying on a beach, idealized inlet**

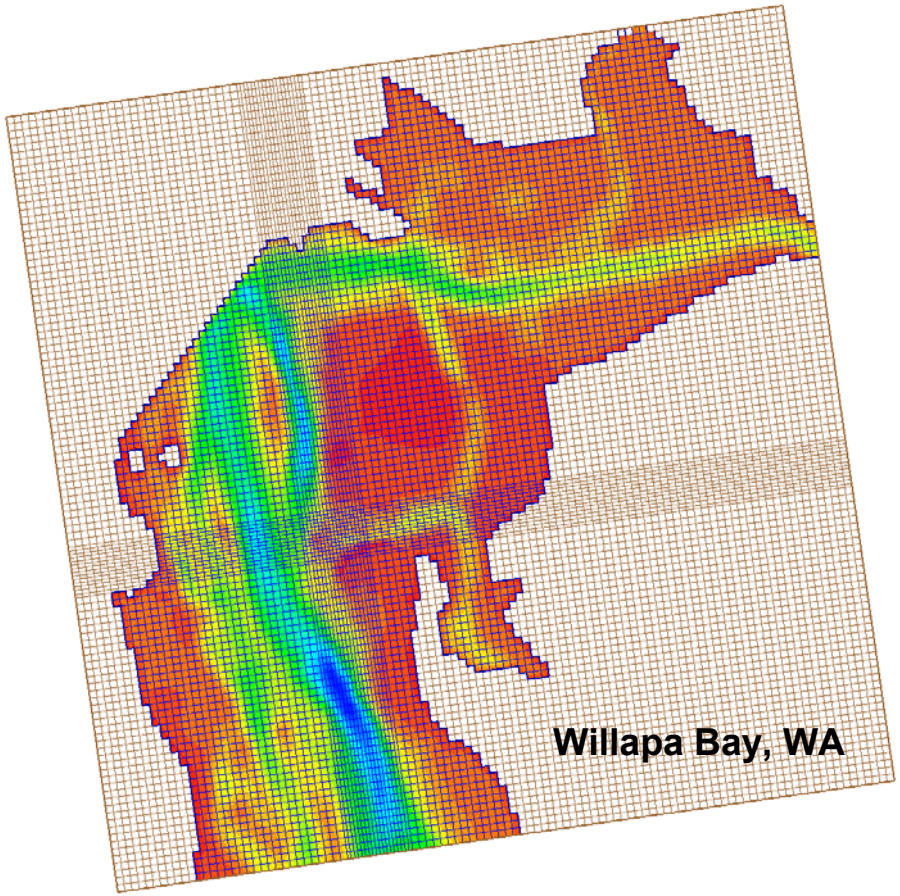
# Bottom Friction Coefficient

- Specified as Manning's roughness coefficient *n*
- Spatially variable
- Scaled exponentially in shallow water
  - Depths > 0.2 m, no significant scaling
  - Maximum scaled $C_f = 2C_f$



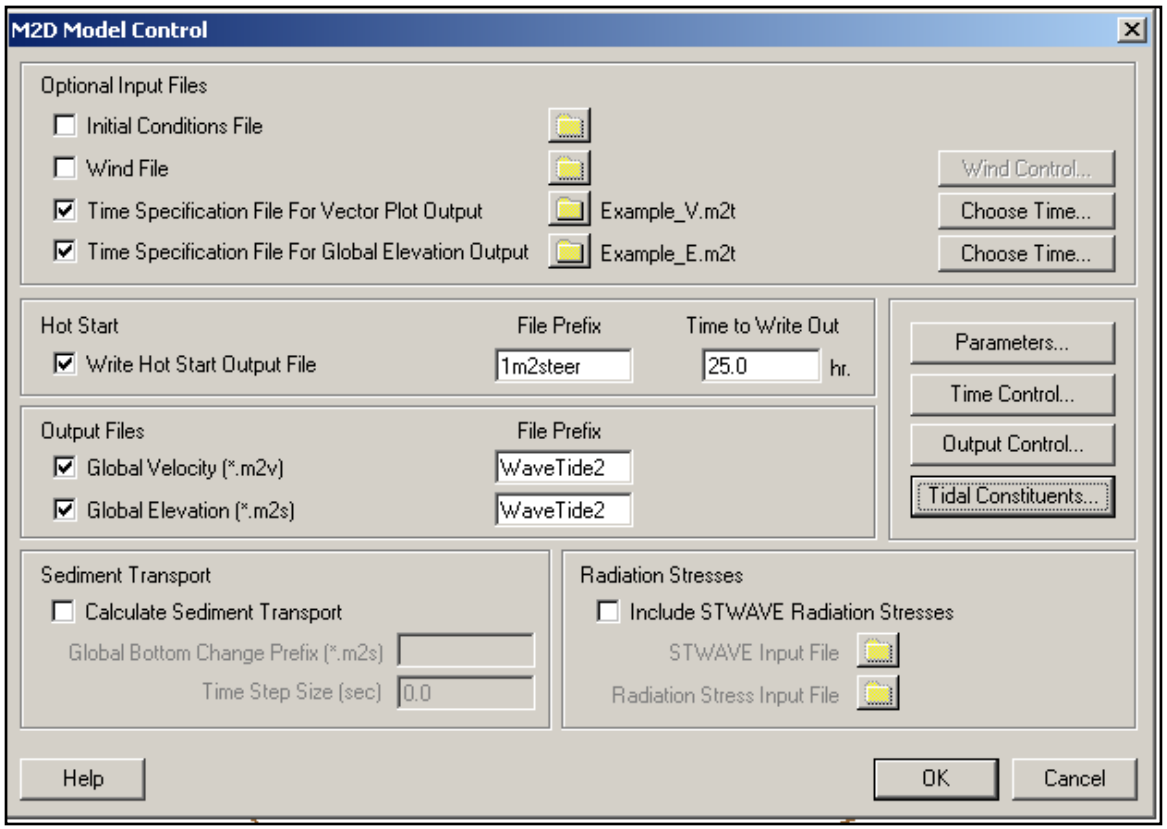
# Grid Development

- Domain & discretization
- Bathymetric data
- Manning's *n*
  - Spatially variable
  - Dependent on properties of material
- Latitude
  - Coriolis calculation
  - Spatially variable or constant
  - For no Coriolis, set latitude to zero



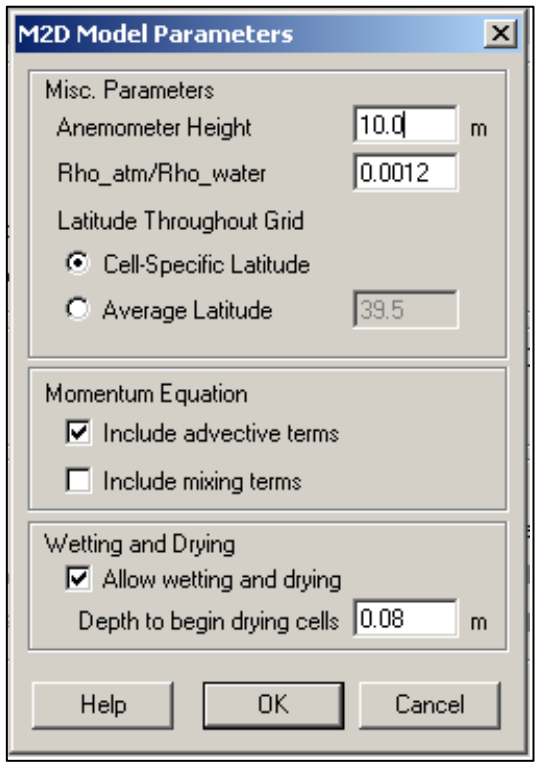
# Model Control

- Parameter settings
- Run options
- Time control
- Station output specifications
- Global output specifications
- Hot start option
- Tide forcing option



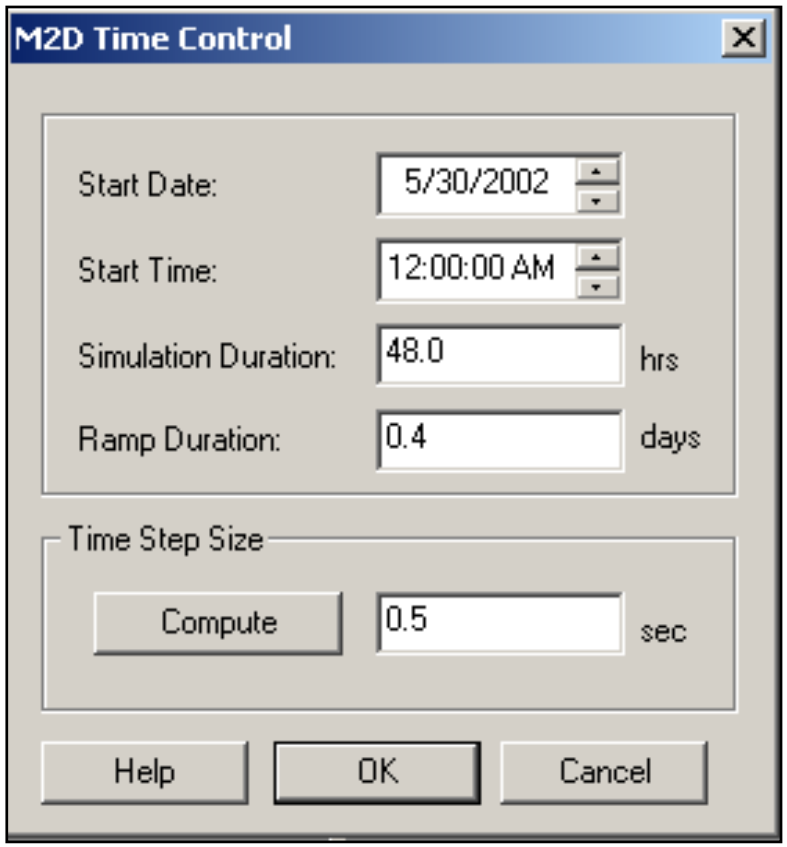
# Parameter Settings & Run Options

- Atmospheric parameters
  - Anemometer height, typically 10 m
  - Density ratio, typically 0.0012
- Latitude
  - Constant or variable over grid
- Momentum equation
  - Advective terms
  - Mixing terms
- Wetting & Drying
  - Enable
  - Depth at which cells are treated as dry



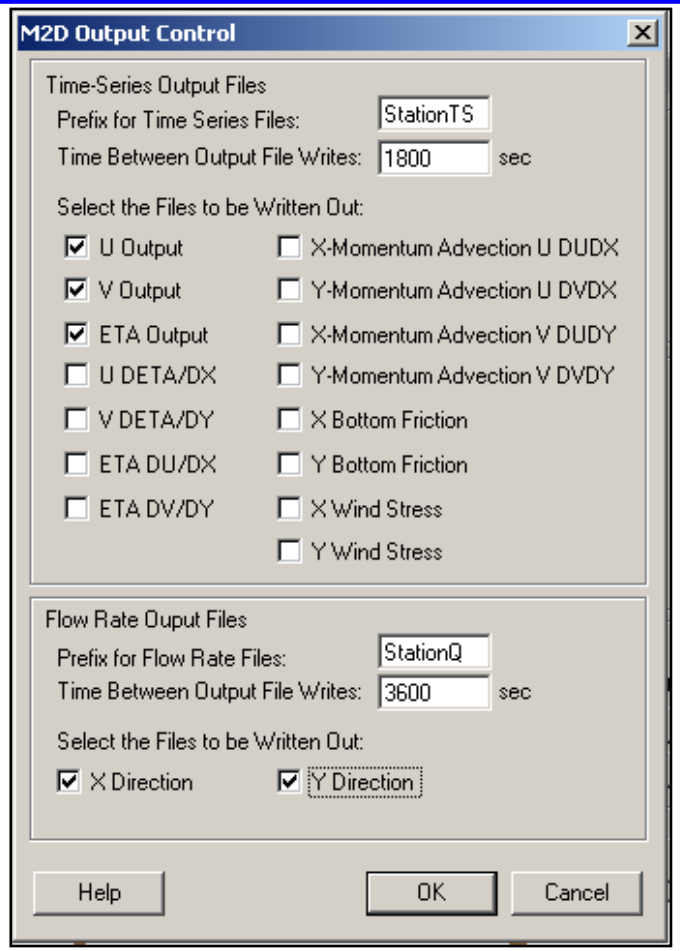
# Time Control

- Start date & time
- Length of simulation (hr)
- Ramp duration (day)
- Time step (sec)
  - SMS has option to compute max time step based on Courant condition
  - M2D requires time step smaller than calculated max



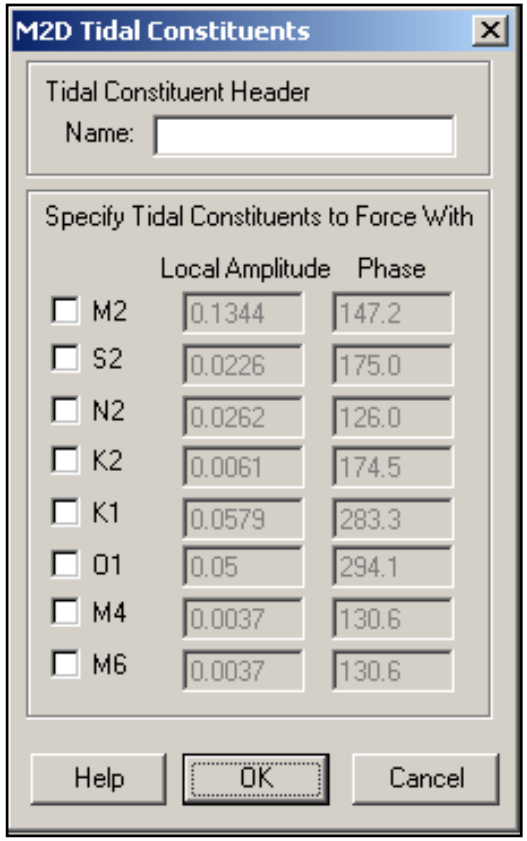
# Station Output

- Variable output
  - File name prefix
  - Time interval for output
  - Variables or terms to be written
- Flow rate output
  - File name prefix
  - Time interval for output
  - $Q_x$ and/or $Q_y$ output



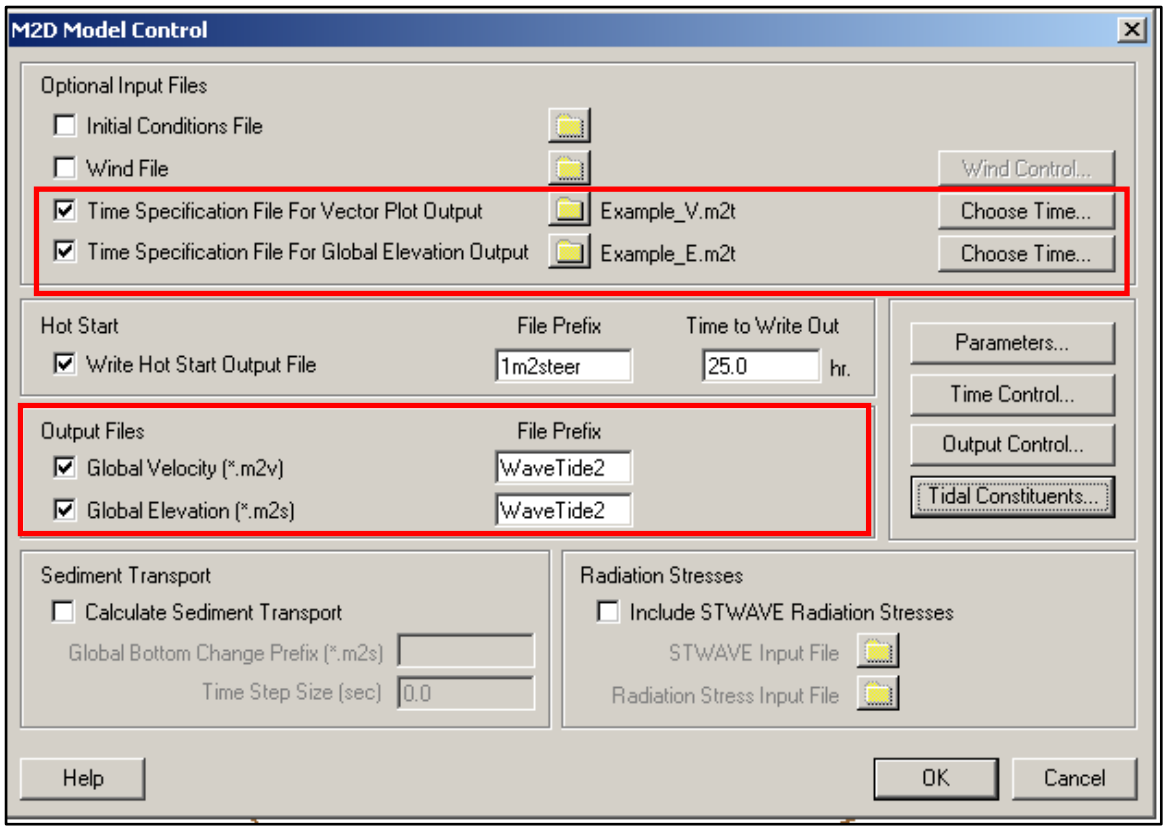
# Tidal Constituent Forcing

- Header line
  - Text description, 1 line
- Select constituents for forcing
  - Constituent
  - Specify amplitude
  - Specify phase



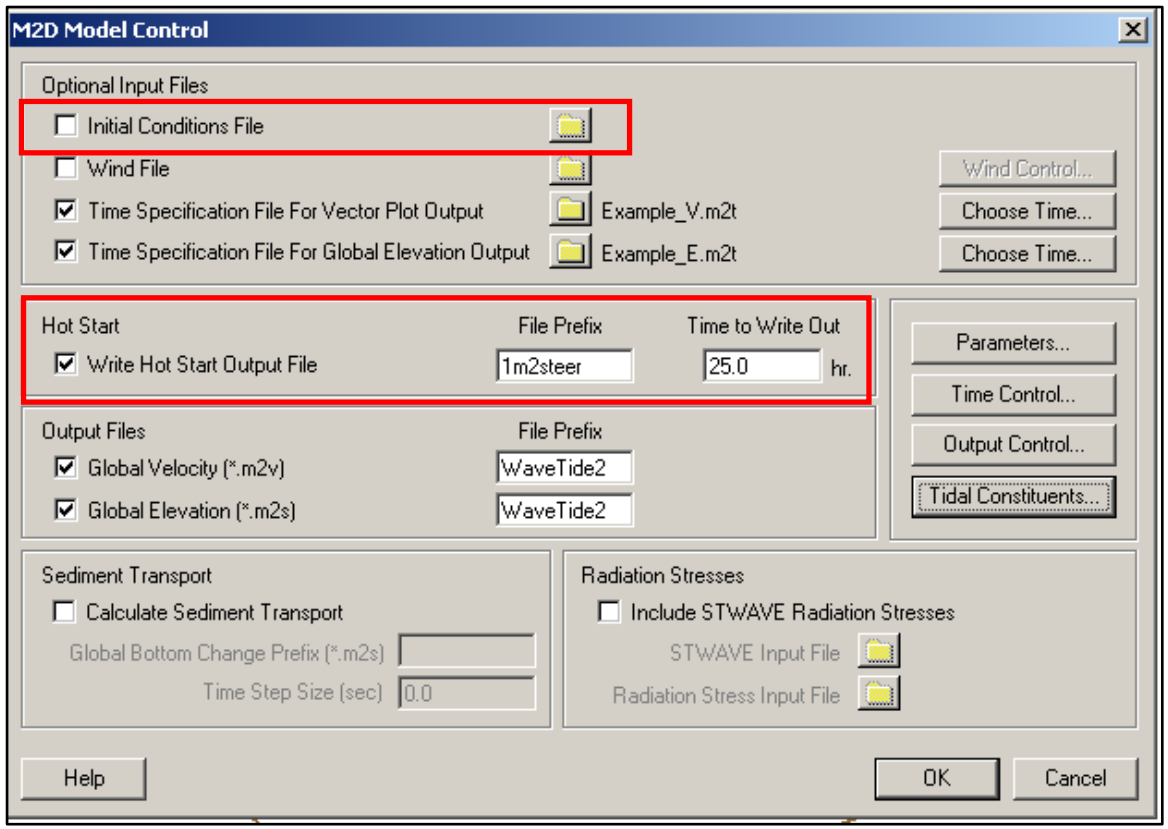
# Global Output

- Water level, u, v
- Times for global output
  - Constant or variable time increments (hr)
  - Time increment generator in SMS
- Global output file prefix



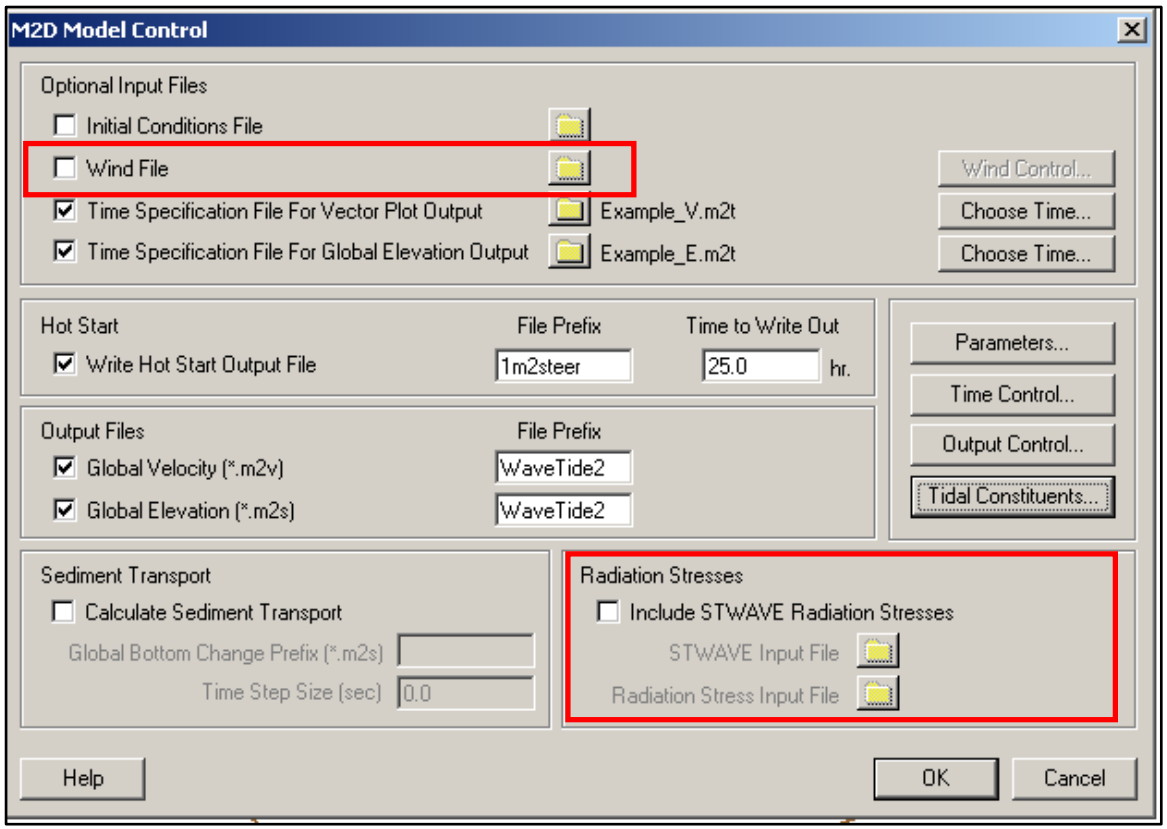
# Hot Start & Initial Conditions

- Initial conditions file:
  - Hot starts
  - Numerical tests
- Save hot start file
  - Saves at 1 time
  - File name prefix

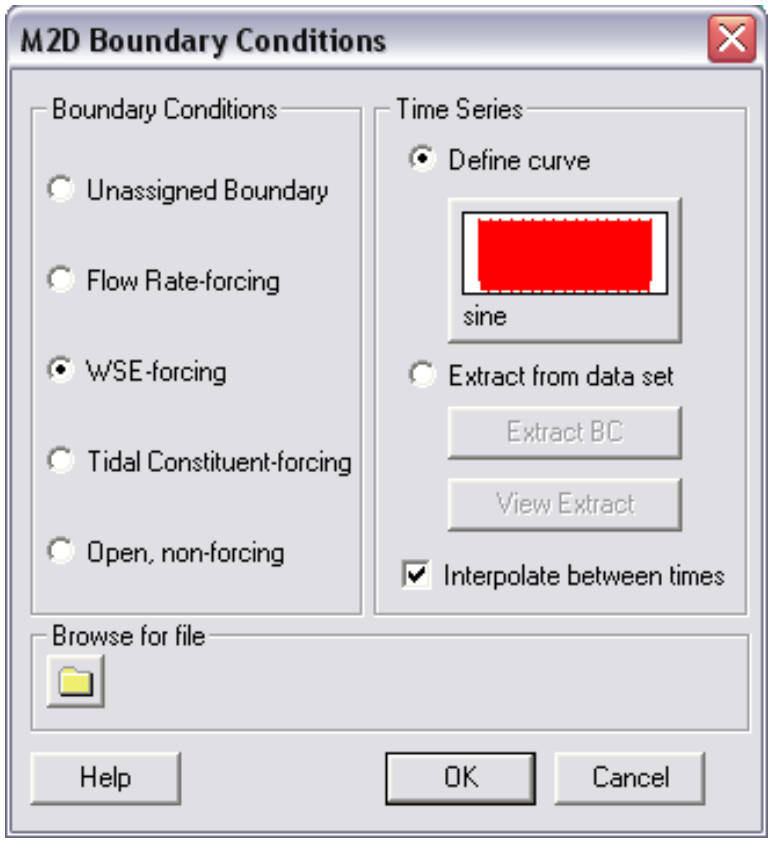


# Wind & Wave Forcing

- Wind forcing
  - File containing times series of wind speed & direction
- Wave forcing
  - Use this dialog when not invoking Steering Module, wave stress file already present
  - Parameters automatically set when using Steering Module



# Water Level Forcing Options

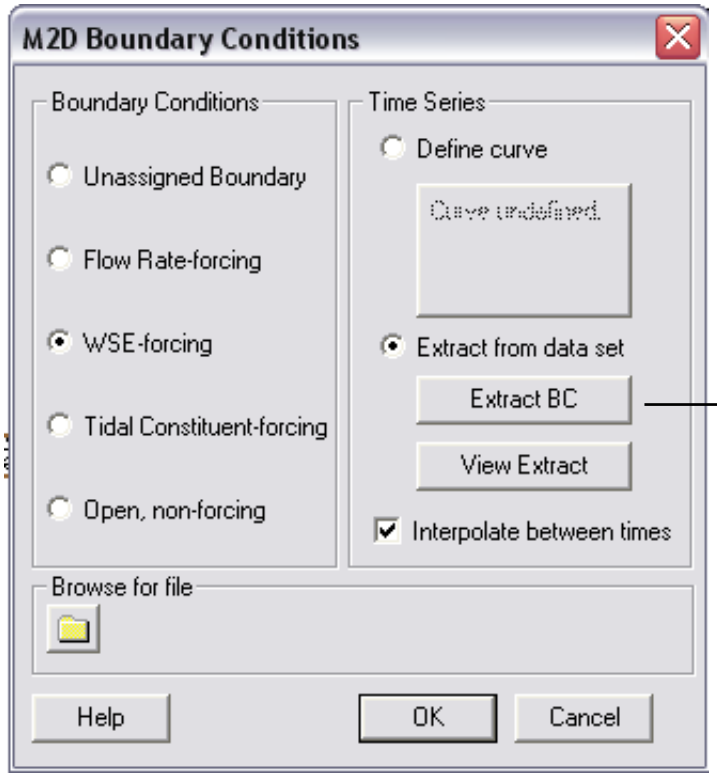


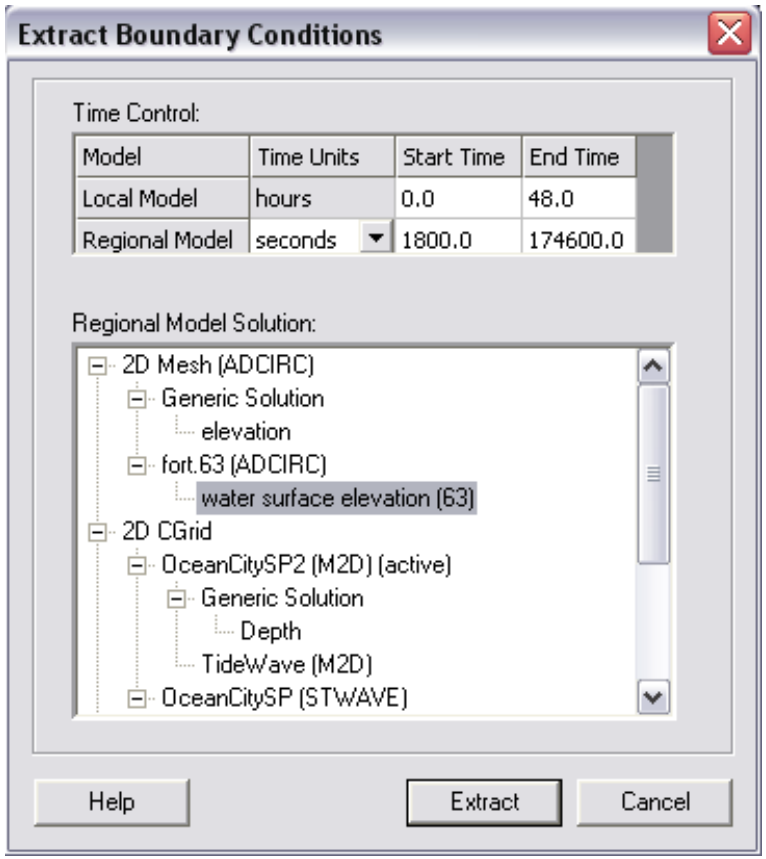

Define wsel curve w/in SMS

Extract wsel values from ADCIRC or other model

Load existing file

# Extracted Water Levels Coupling w/ ADCIRC



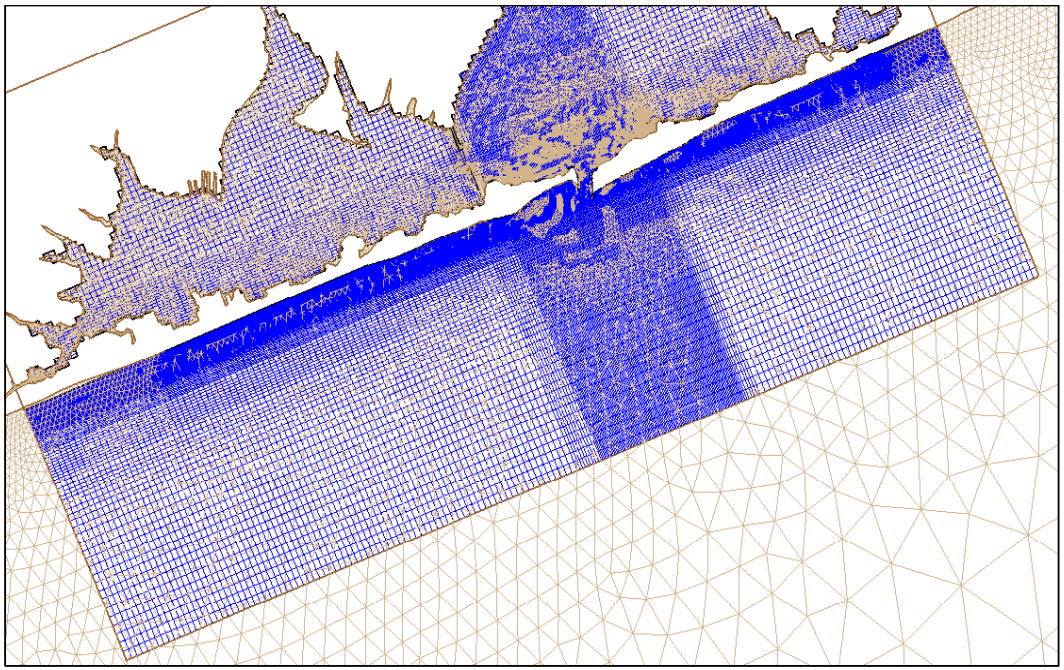



# Model Coupling

- Rectilinear M2D can serve as a convenient local model for representing coastal processes on the same scale as the wave model.
- M2D can then be driven by the regional oceanographic model ADCIRC, together with local forcing of wind and tributary discharge.
- Considerations for coupling M2D with ADCIRC & STWAVE are presented.

# Coupling with ADCIRC

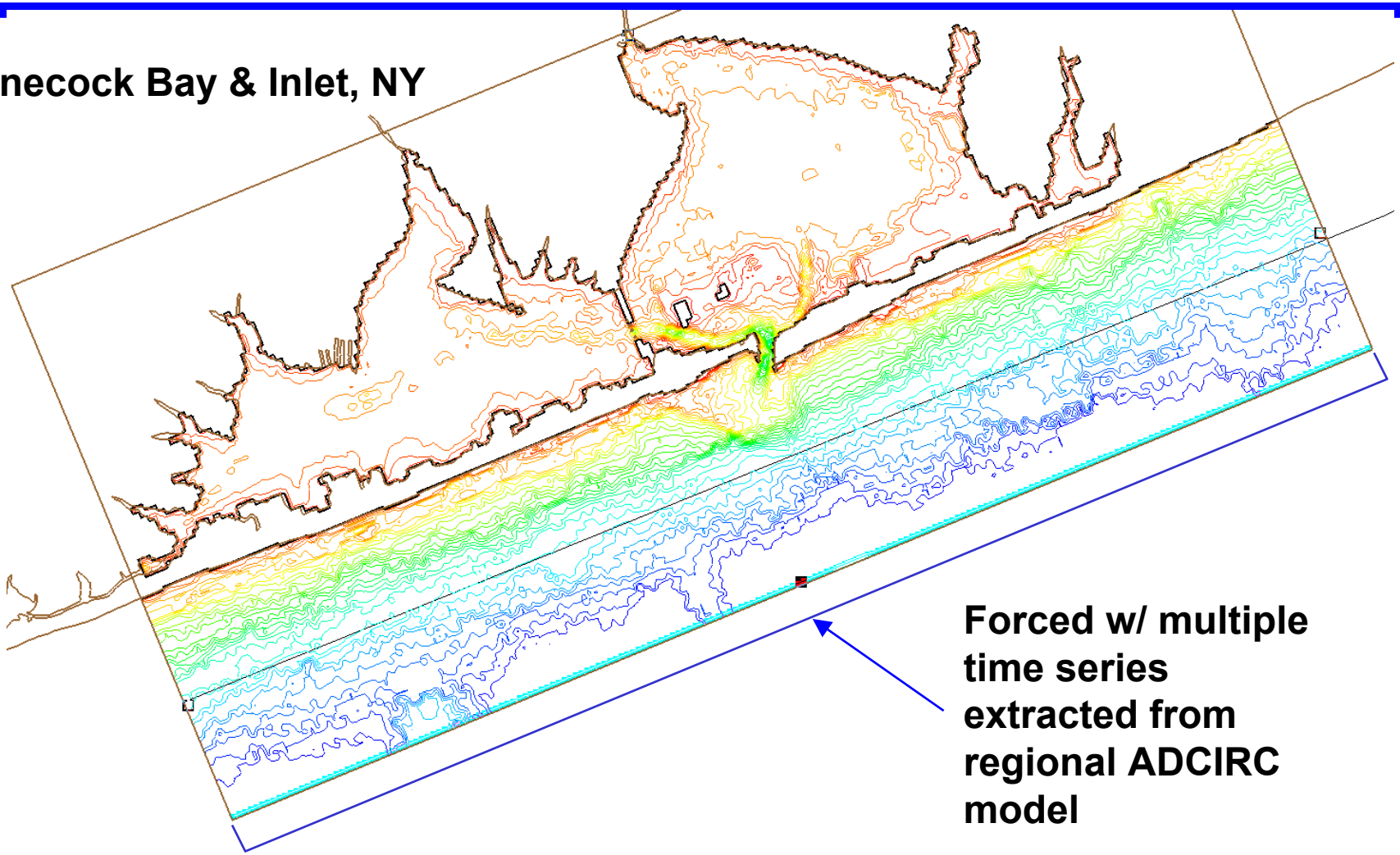
- SMS automates coupling of ADCIRC & M2D
- ADCIRC water levels & interpolated onto M2D boundary cells
- Time series of water level saved as forcing for M2D simulation
- CHETN available



M2D grid & ADCIRC mesh at Shinnecock Inlet

# Example

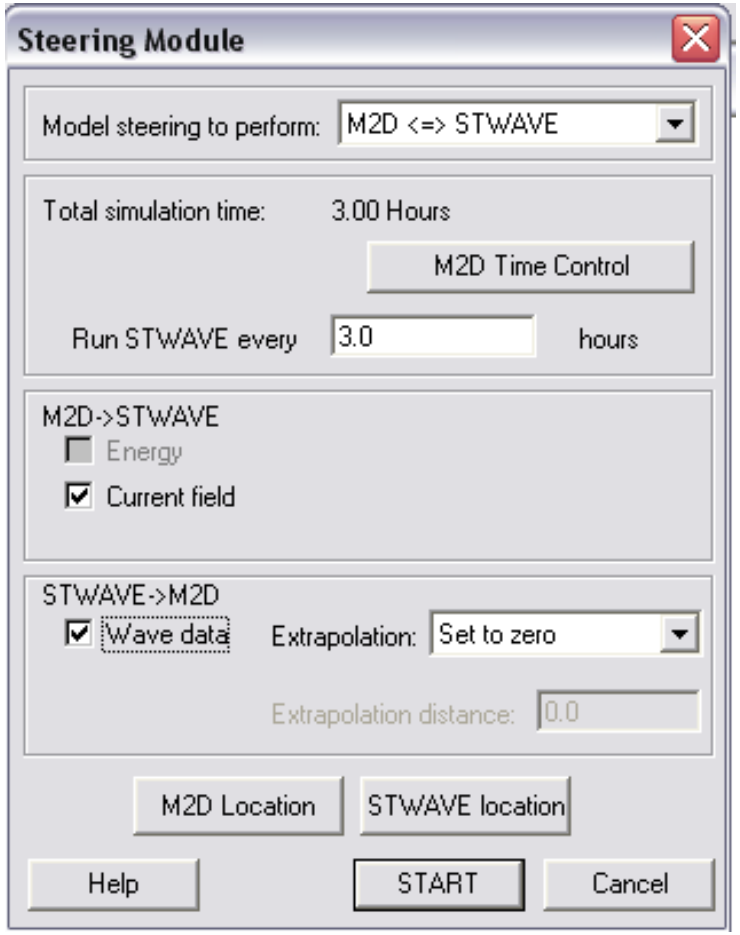
**Shinnecock Bay & Inlet, NY**



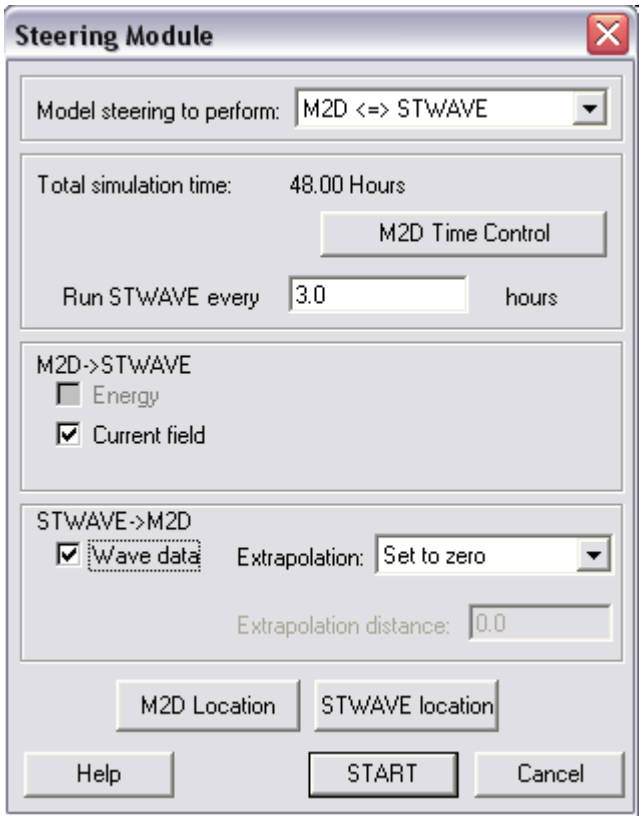
**Forced w/ multiple time series extracted from regional ADCIRC model**

# Steering Module Coupling with STWAVE

- Automated in SMS thru the Steering Module
- Radiation-stress gradients from STWAVE mapped to M2D grid
- Water depths & current from M2D mapped to STWAVE grid
- Coupling frequency defined by user
- 1- or 2-way coupling



# Steering Module Dialog




Access to M2D timing parameters

Steering Interval

Pass currents to STWAVE

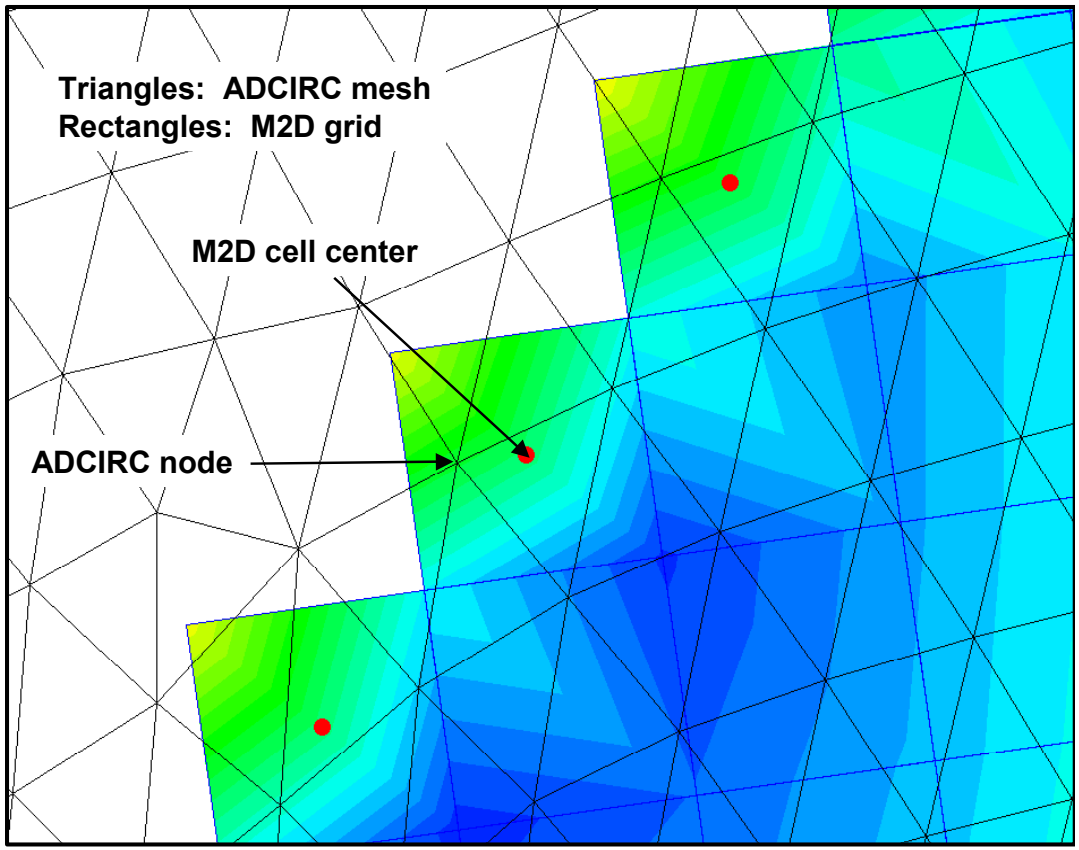
Pass wave information to M2D

# Coupling Considerations

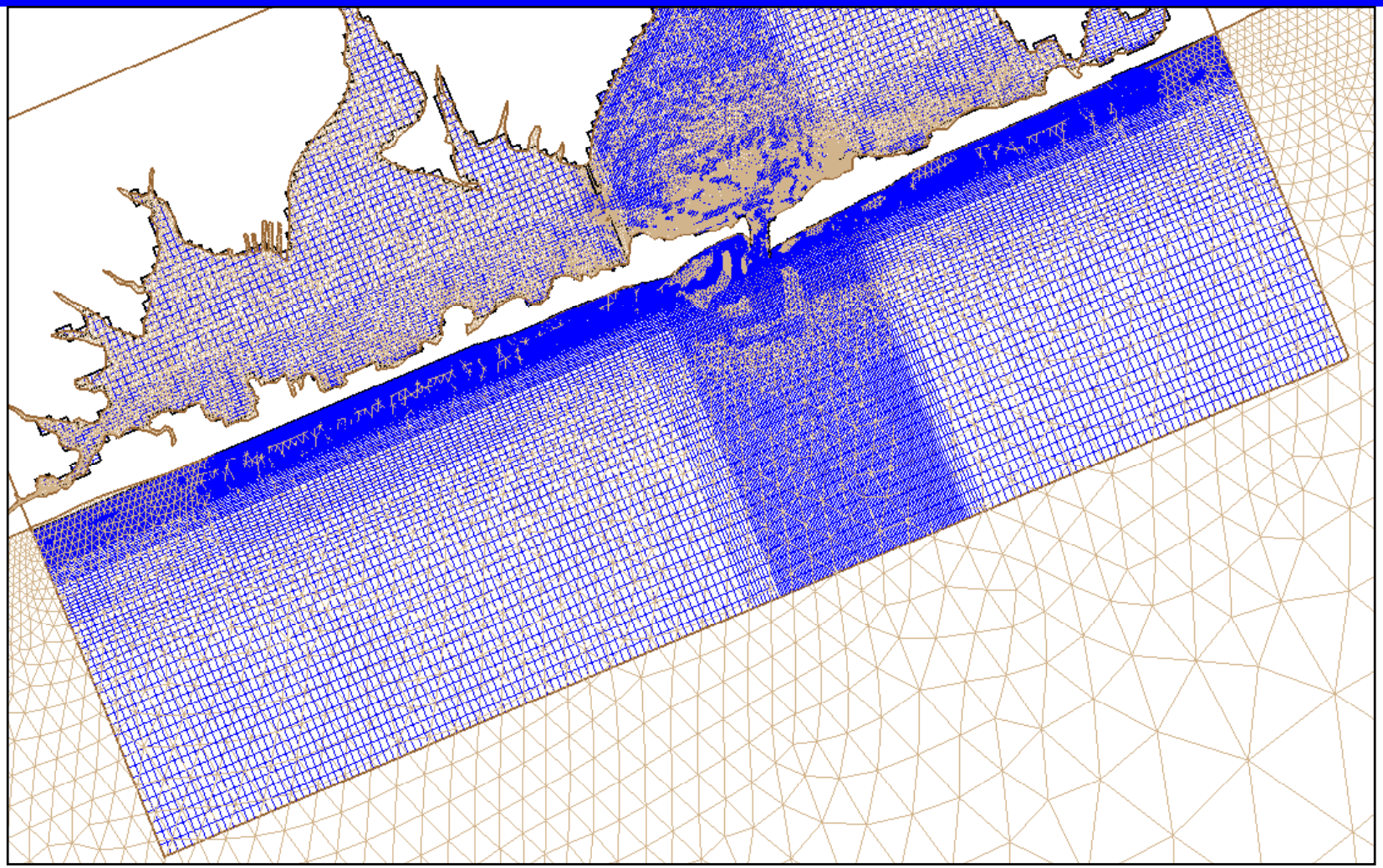
- M2D & ADCIRC
  - ADCIRC mesh resolution near M2D boundary
  - ADCIRC output frequency
- M2D & STWAVE
  - M2D vs. STWAVE grid conventions
  - Grid resolution
  - Coupling interval
- General considerations

# M2D & ADCIRC
# Mesh Resolution Near M2D Boundary

- ADCIRC node spacing similar to M2D cell dimension
  - Near M2D boundary
  - Accuracy in interpolation to M2D cell centers
- Preserves water-level distribution
  - Wind setup/down
  - Tidal phase

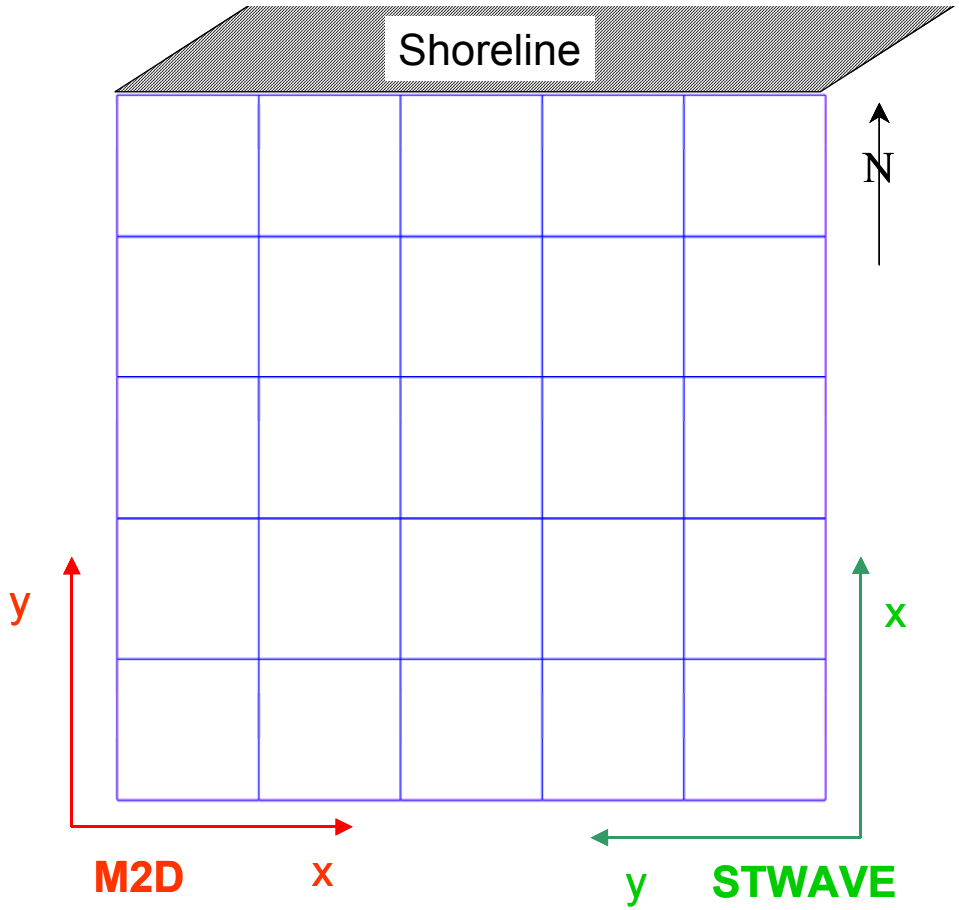


# Example M2D & ADCIRC Resolution



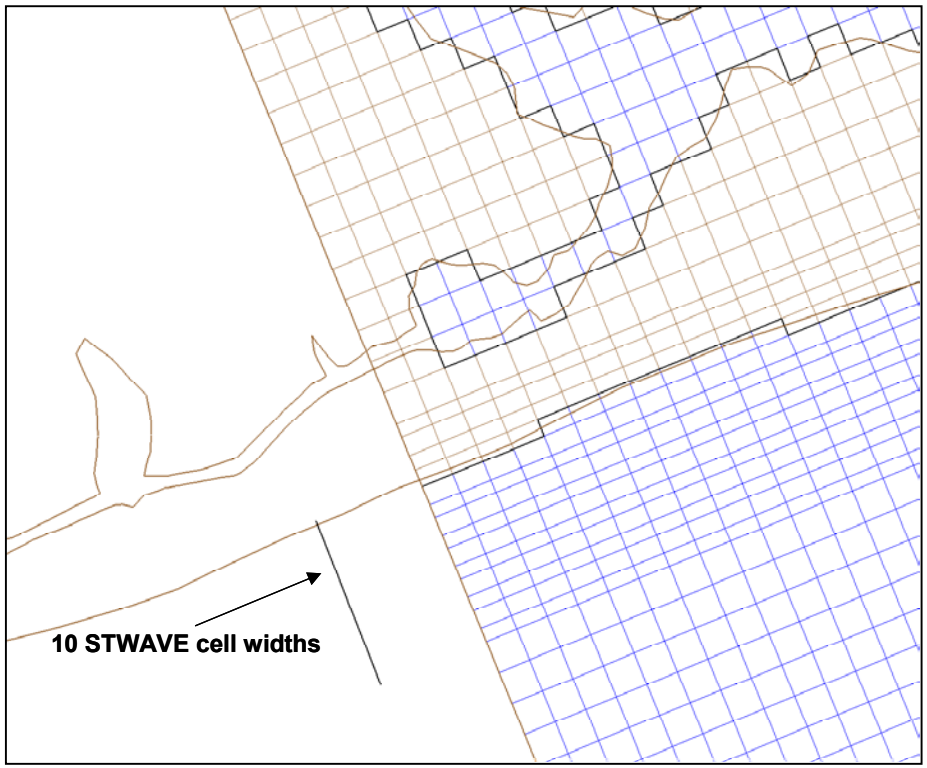
# M2D & STWAVE Grid Conventions

- M2D: relative to geographic
  - Aligned w/ geographic
    - **x**: E-W parallel
    - **y**: N-S parallel
  - Rotated +/- 45 deg w/ respect to geographic
- STWAVE: relative to shoreline
  - x: shore normal
  - y: shore parallel



# M2D & STWAVE
# Grid Resolution

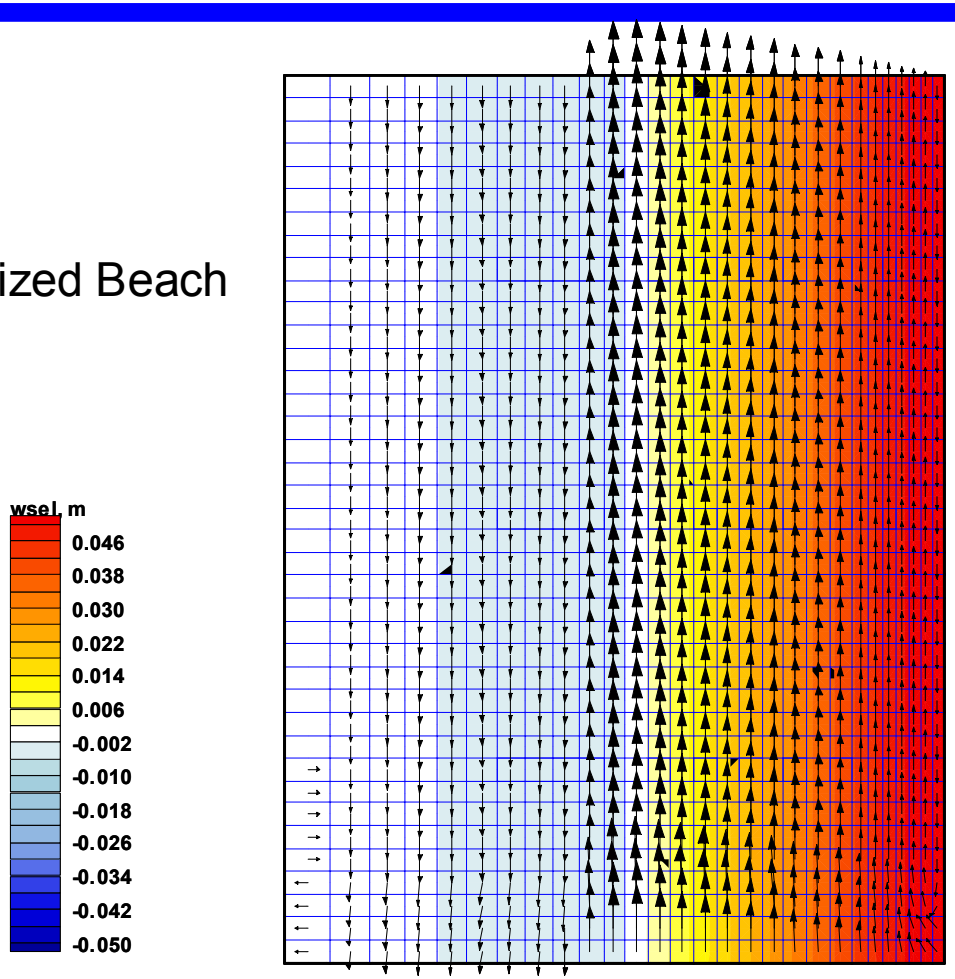
- Similar resolution nearshore (surf zone)



# M2D & STWAVE Coupling Interval

- Time scales of processes being calculated
  - Changes in water level, waves, wind
- Model run time
  - Greater frequency of coupling increases run time
- Strength of interactions
  - Greater frequency if interactions strongly dependent on time-varying conditions
  - Current & water level in an inlet modify wave propagation

Idealized Beach



# General Considerations

- Each application will require judgment calls on aspects of the model configuration & couplings
- Model response is dependent on:
  - Physical & forcing properties (bathymetry, tide range, wave properties, etc.)
  - Grid properties (size, resolution, boundary conditions)
  - Coupling settings (frequency of coupling, 1- or 2-way interaction)

# Sediment Transport

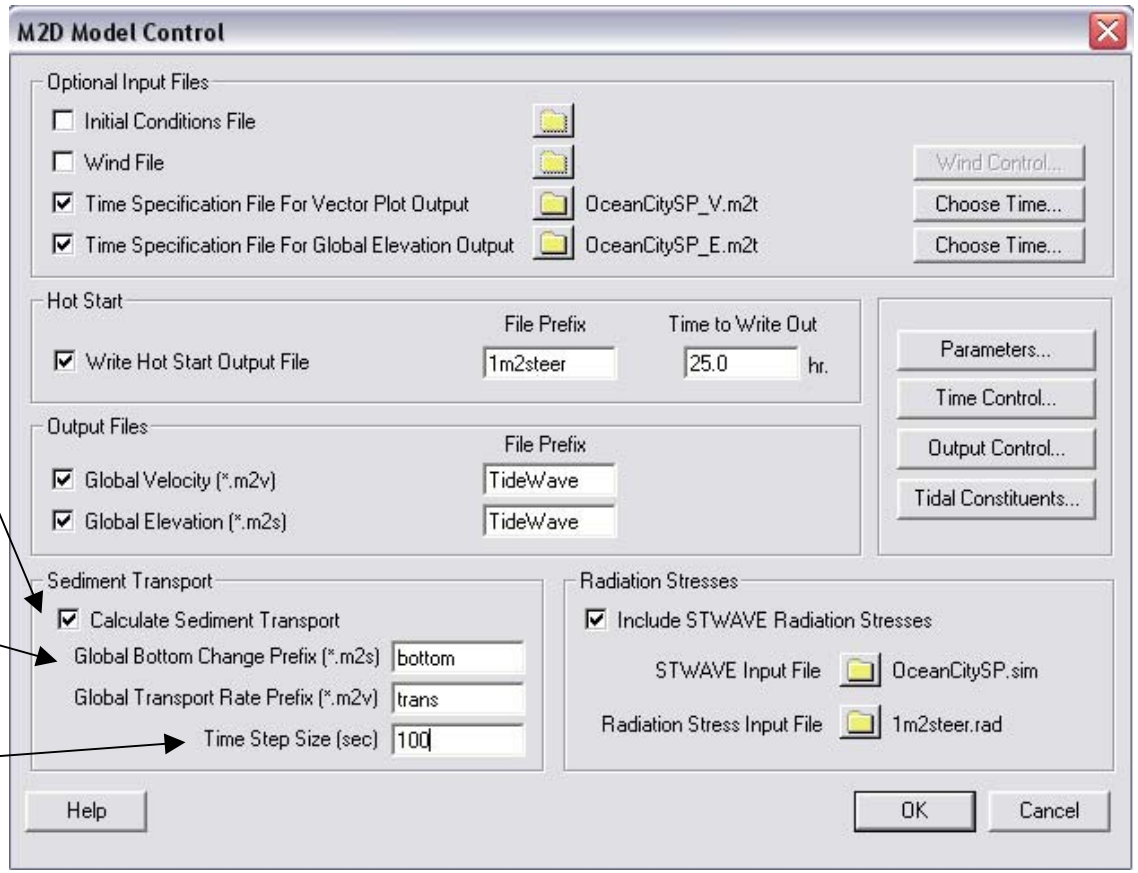
- Transport code embedded w/in M2D
  - Watanabe (1987)
  - More formulations presently being implemented
- Couple circulation & sed transport at user-defined intervals
- Transport rates & depth change are calculated
- Depth change fed back to circulation model
- Output global transport rates & depth

# SMS Options

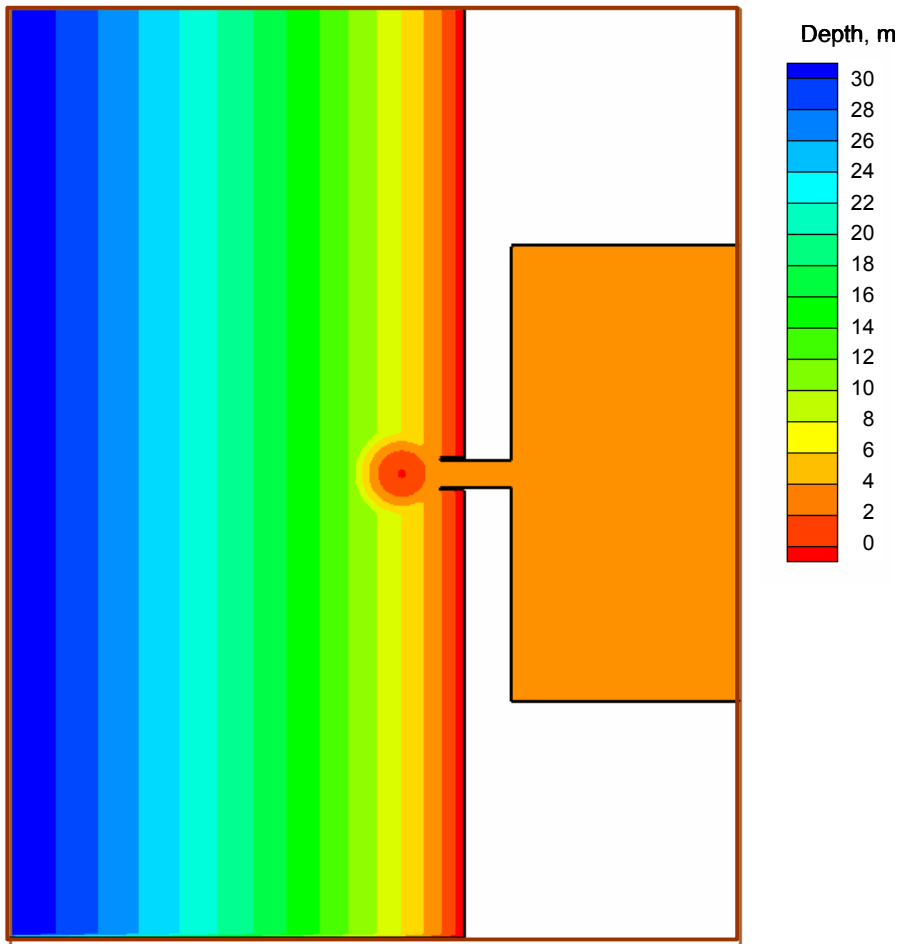
Turn on sed transport

Sed transport output files

Sed transport calc time step

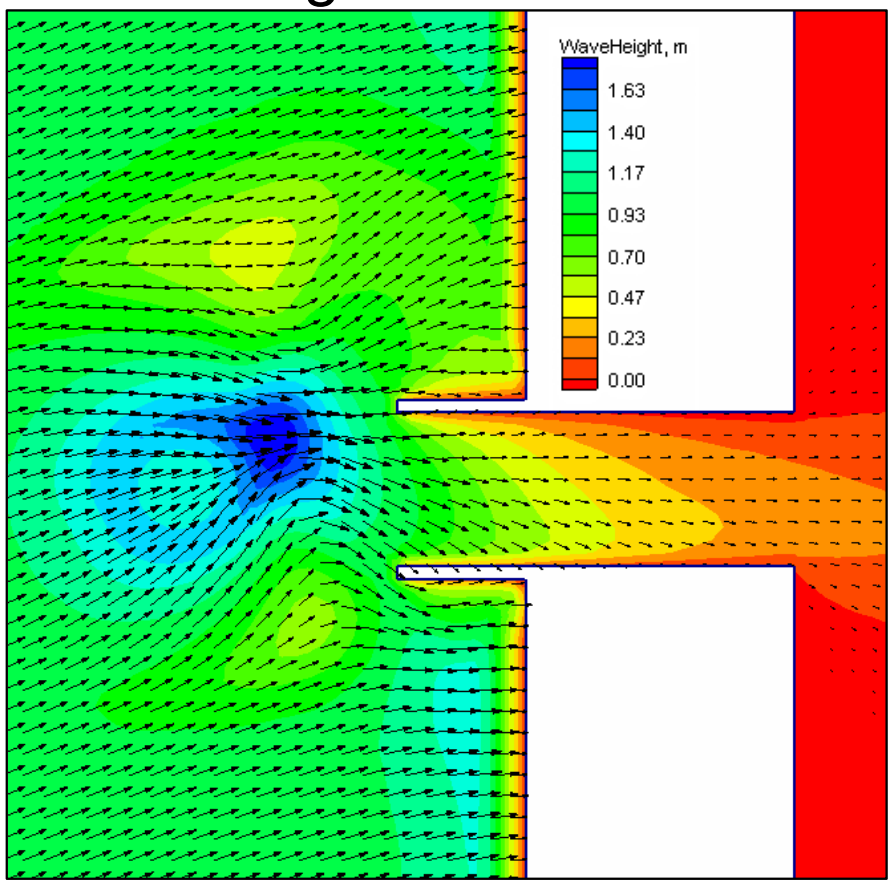


# Example
# Idealized Inlet & Ebb Shoal

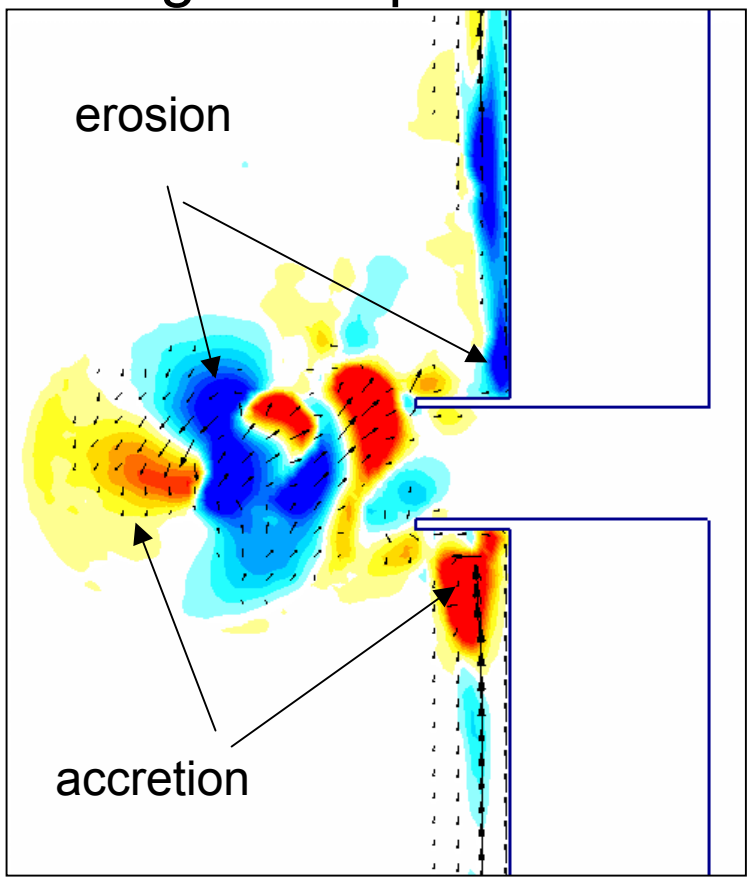


# Example Results
# Forcing by Waves

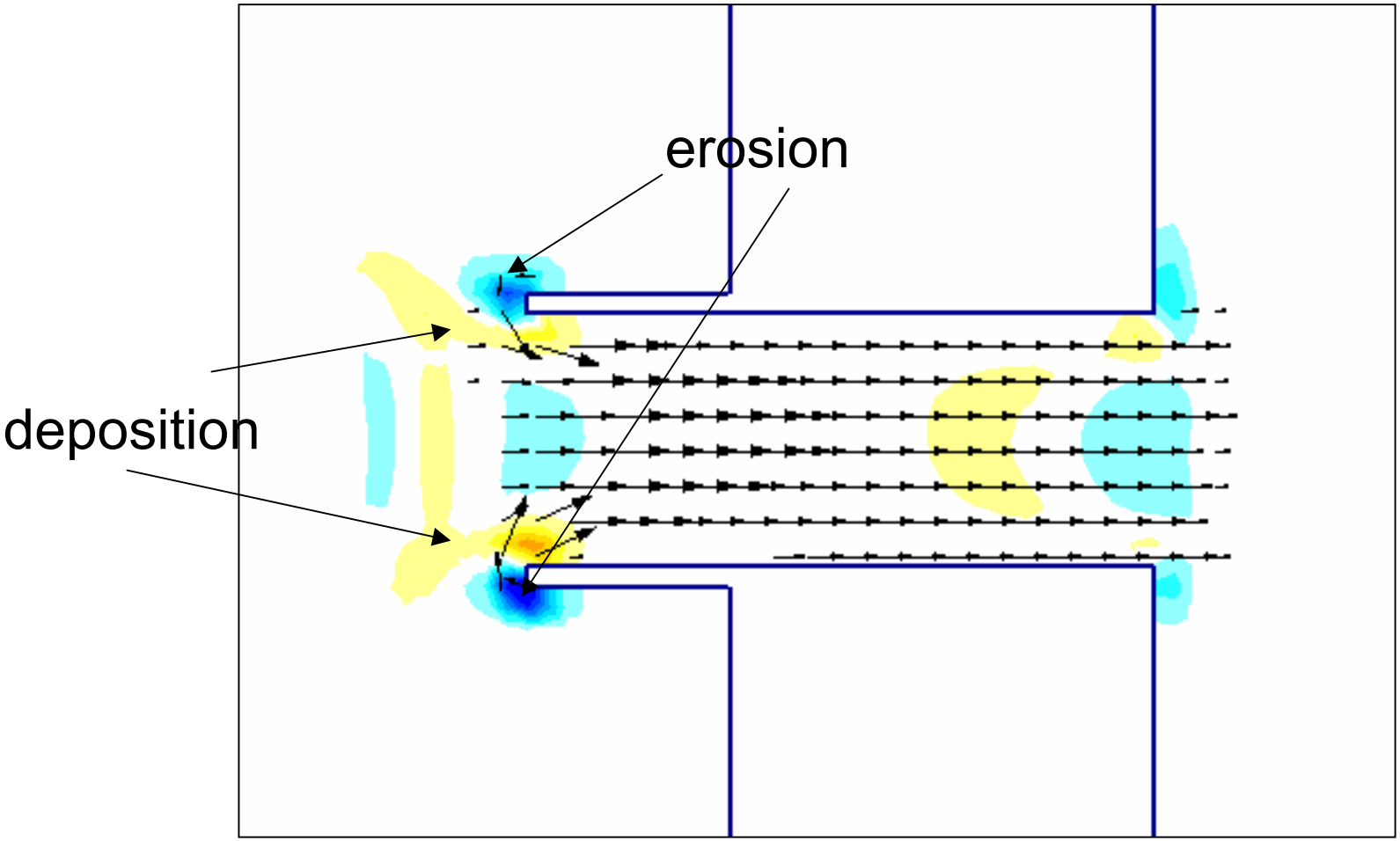
## Wave height & direction




## Change in depth



# Example Results
# Forcing by Tide



# Future Capabilities

- Sediment Transport
  - Range of sediment transport formulations
    - Selected by user
    - Selected by model
    - Function of hydrodynamic regime (current strength, wave properties, etc.)
    - Multiple sediment transport formulations applied within a single simulation
      - Spatially variable
      - Temporally variable based on changes in hydrodynamics
  - Spatially-variable grain sizes