Coupled, Unstructured Grid, Wave and Circulation Models: Preliminary Results

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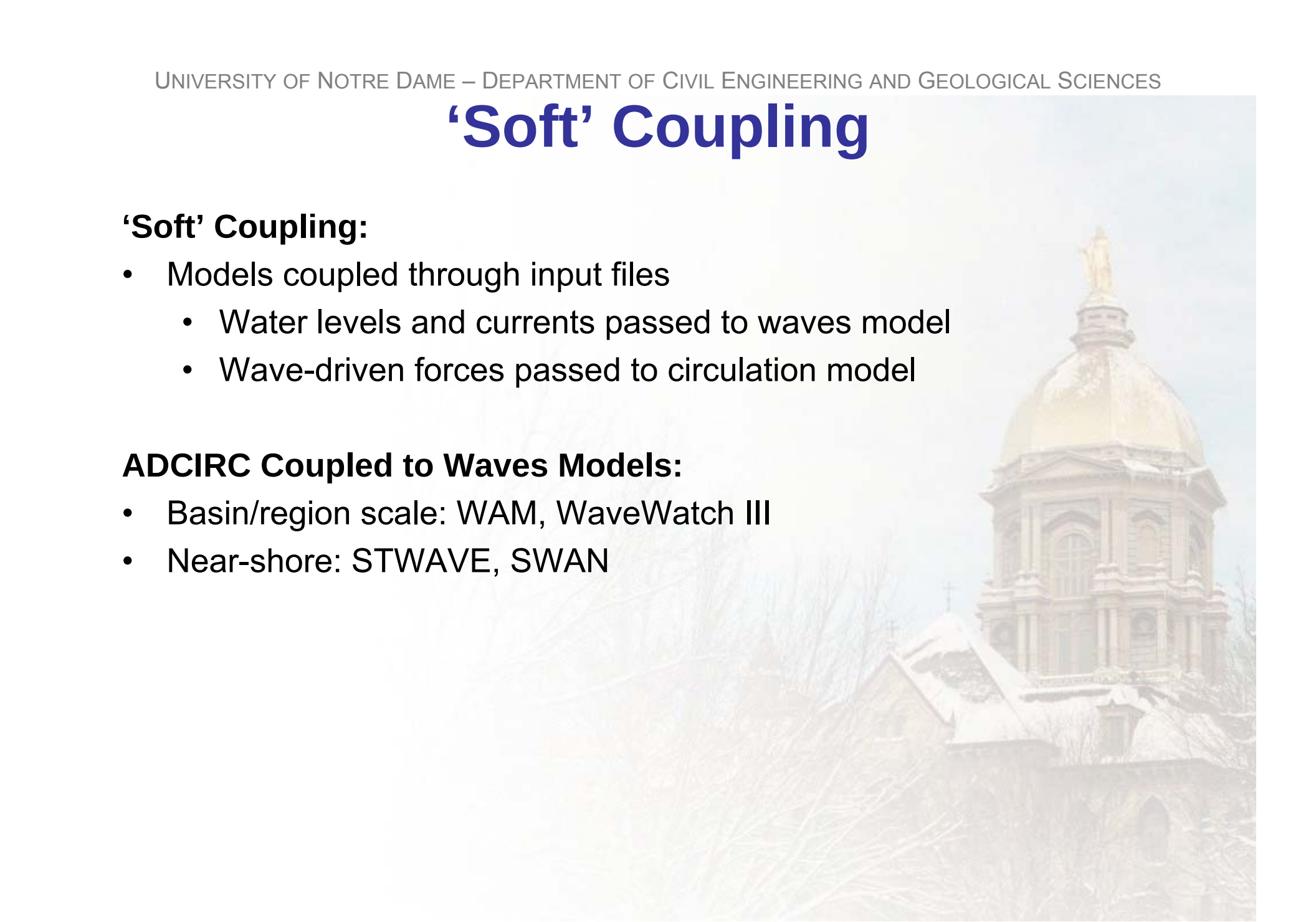
'Soft' Coupling

'Soft' Coupling:

- Models coupled through input files
  - Water levels and currents passed to waves model
  - Wave-driven forces passed to circulation model

ADCIRC Coupled to Waves Models:

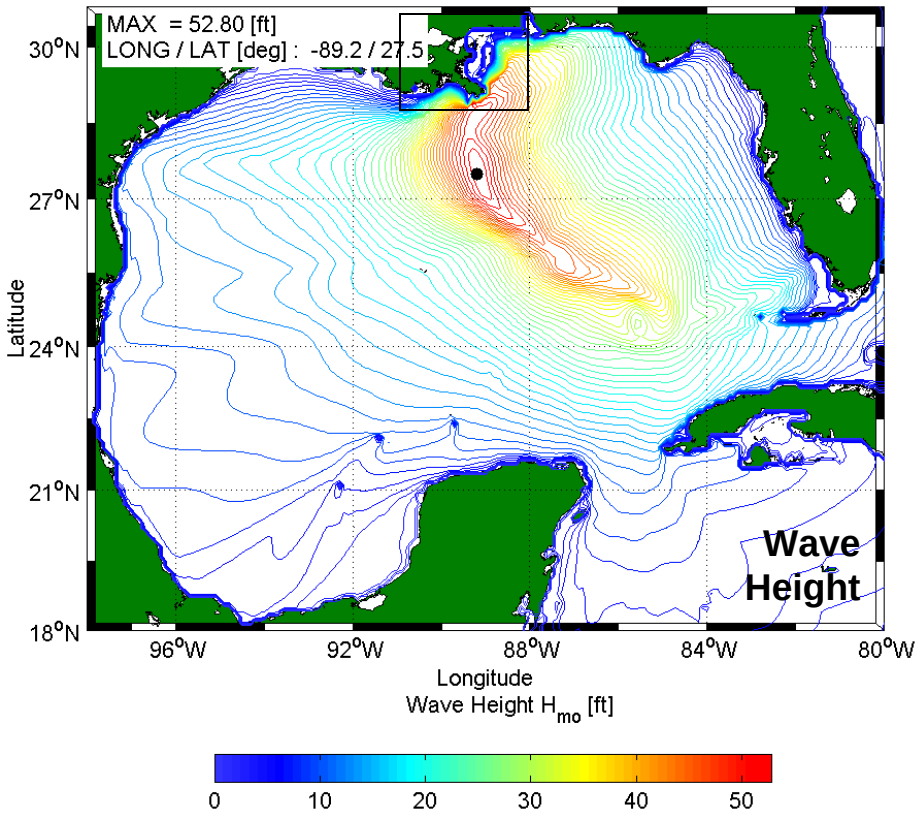
- Basin/region scale: WAM, WaveWatch III
- Near-shore: STWAVE, SWAN



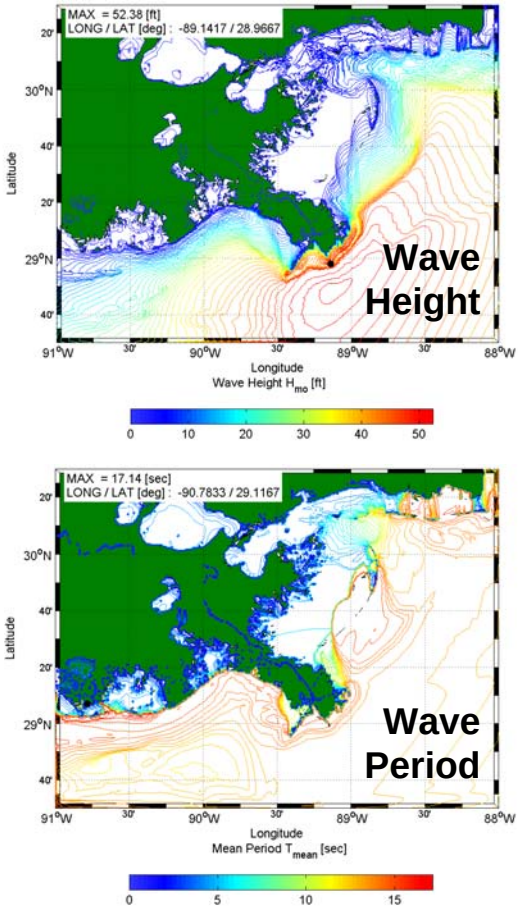
'Soft' Coupling

Example: Louisiana Storm Surge Modeling

Basin-Scale WAM Model



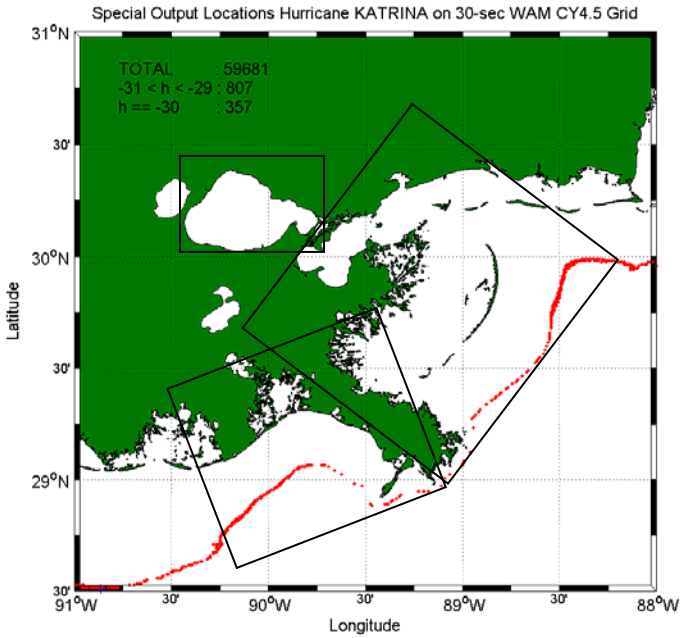
Region-Scale WAM Model

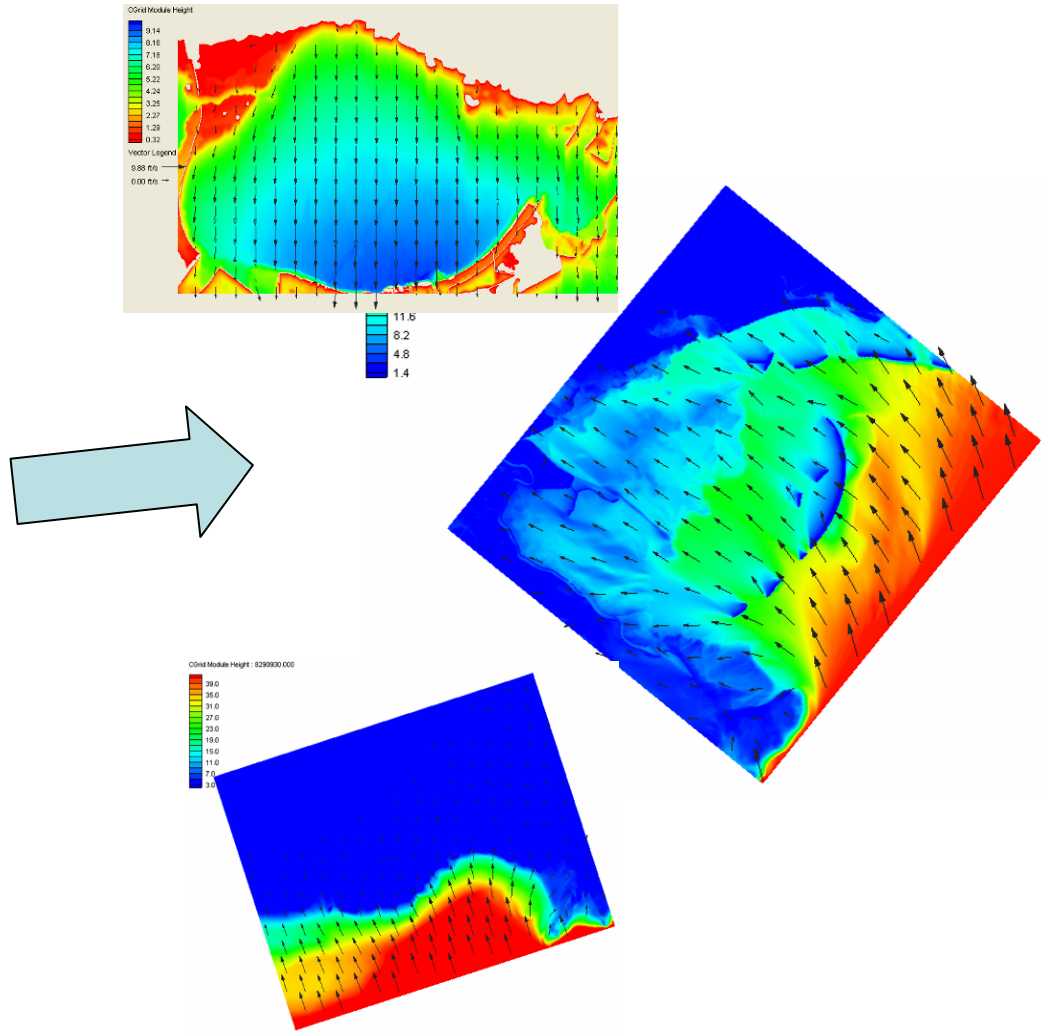


‘Soft’ Coupling

Example: Louisiana Storm Surge Modeling

Near-Shore STWAVE Model

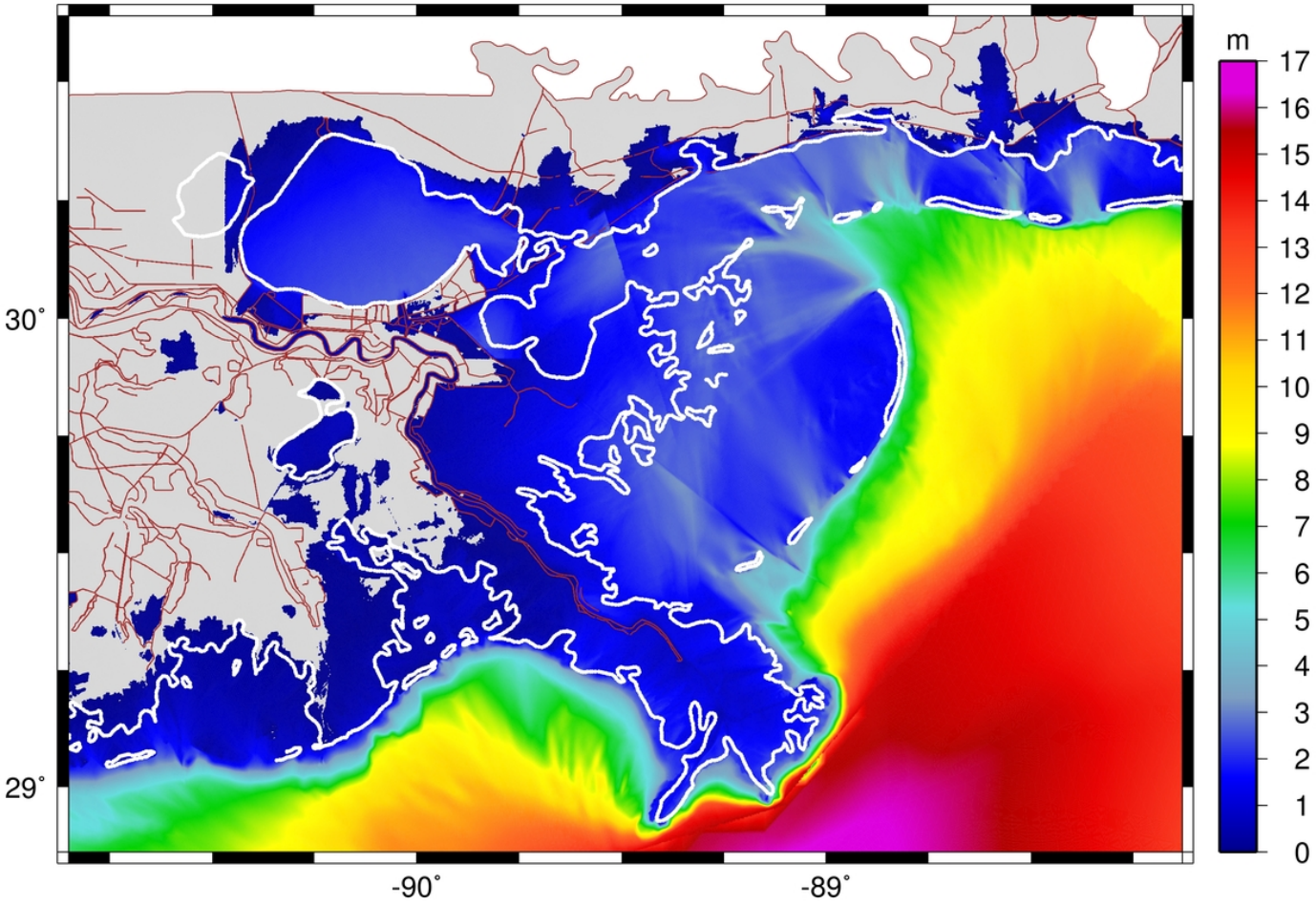




‘Soft’ Coupling

It Works!

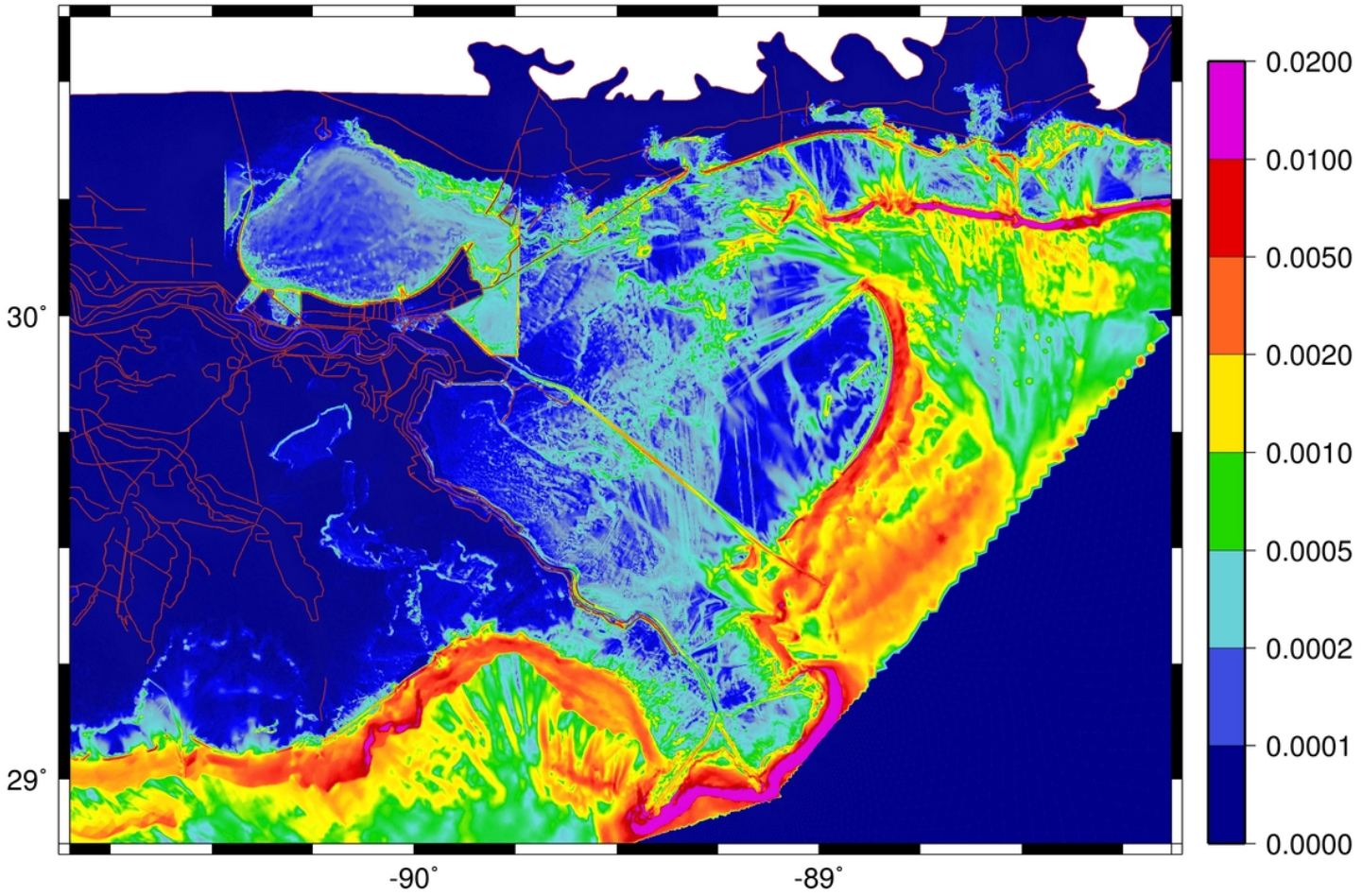
- Maximum significant wave heights in Hurricane Katrina



‘Soft’ Coupling

It Works!

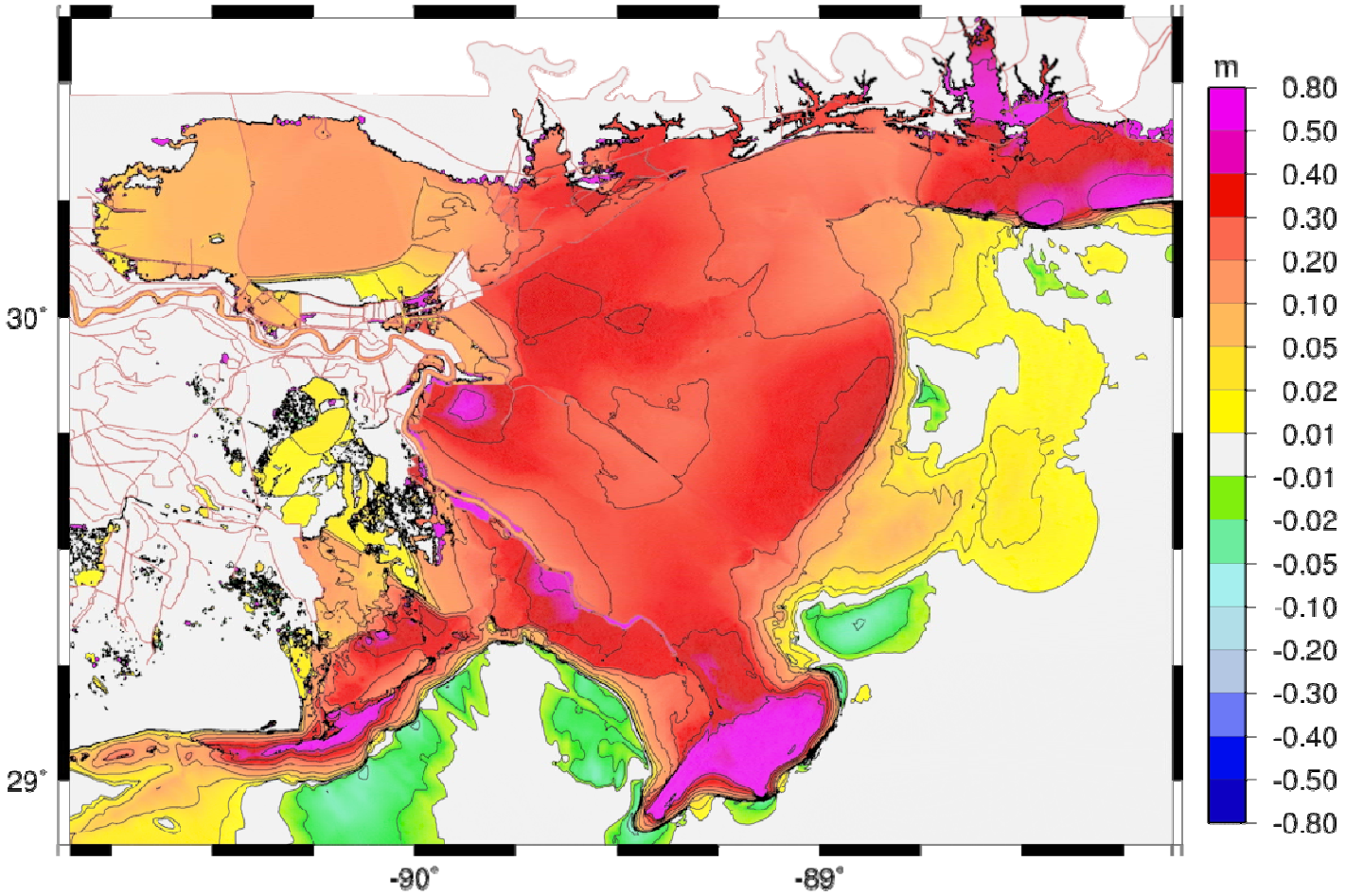
- Maximum wave-driven forces in Hurricane Katrina



‘Soft’ Coupling

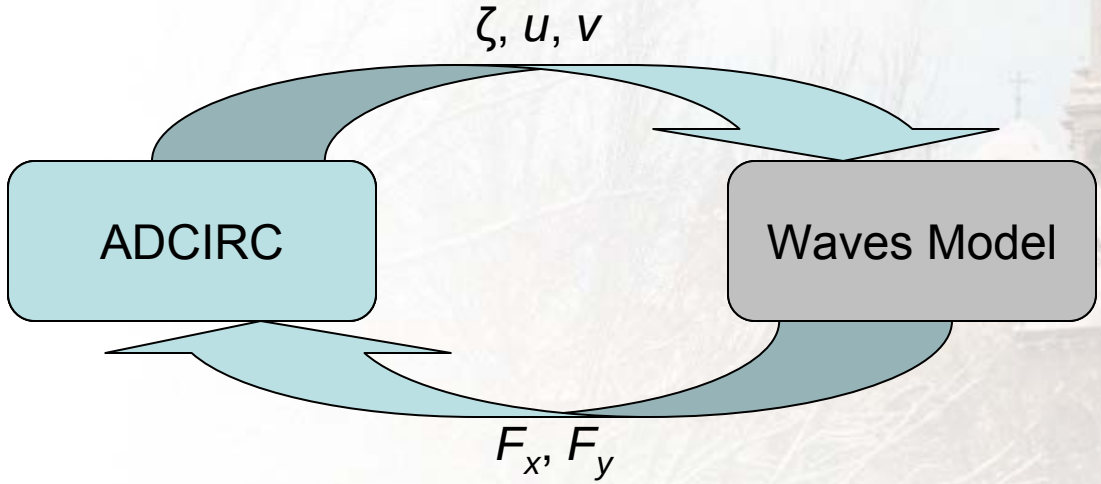
It Works!

- Effect of waves during Hurricane Katrina



Disadvantages of 'Soft' Coupling

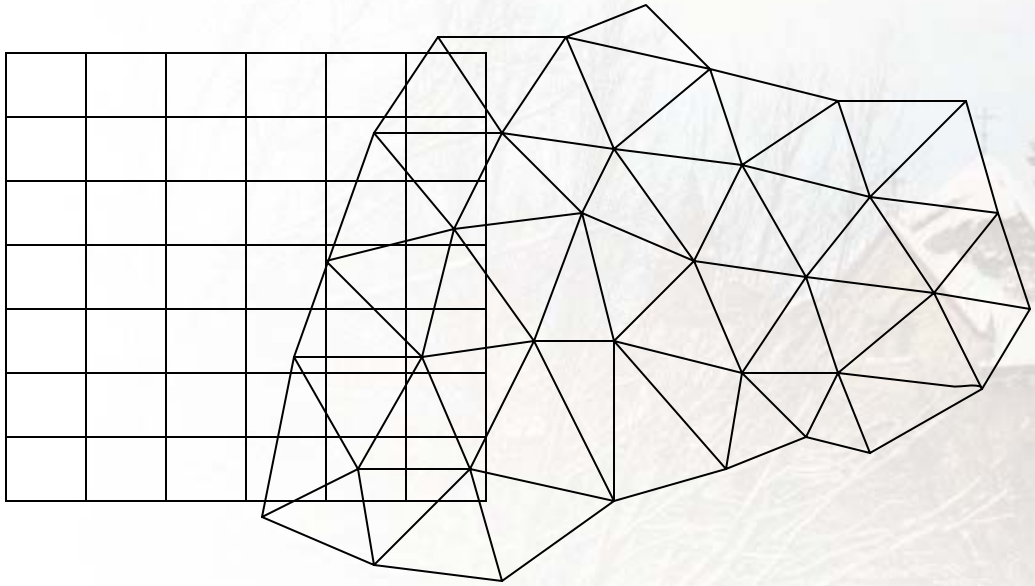
1. **Iteration:**
   - Models coupled through input files
     - Water levels and currents passed to waves model
     - Wave-driven forces passed to circulation model
   - Process can be automated, but is still inefficient



Disadvantages of 'Soft' Coupling

2. Interpolation:

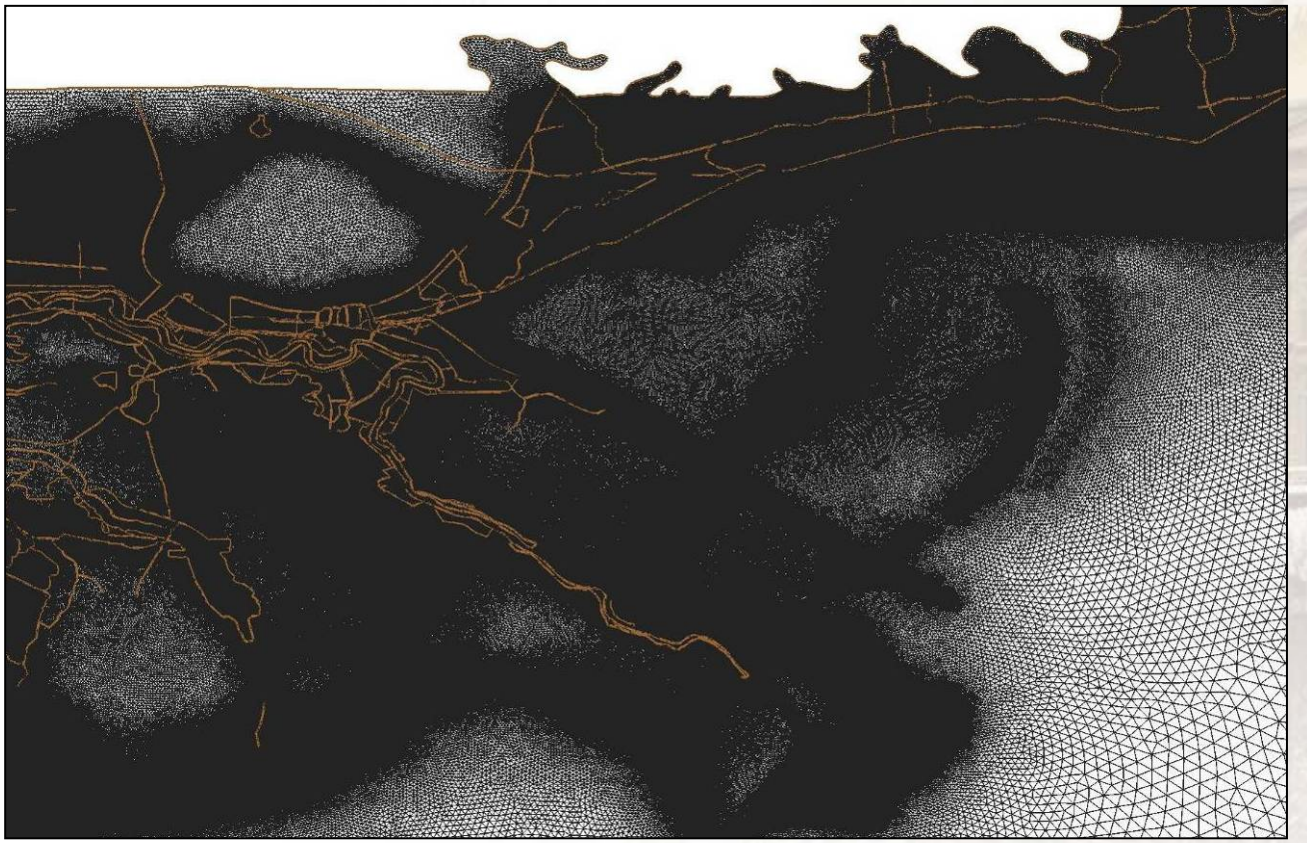
- Wave and circulation models run on different grids
  - Wave models on structured meshes
  - ADCIRC on unstructured, finite element mesh
- Results must be interpolated onto each mesh



Disadvantages of 'Soft' Coupling

3. Resolution in wave breaking zones:

- Circulation model has no knowledge of wave breaking
- Must over-resolve these zones



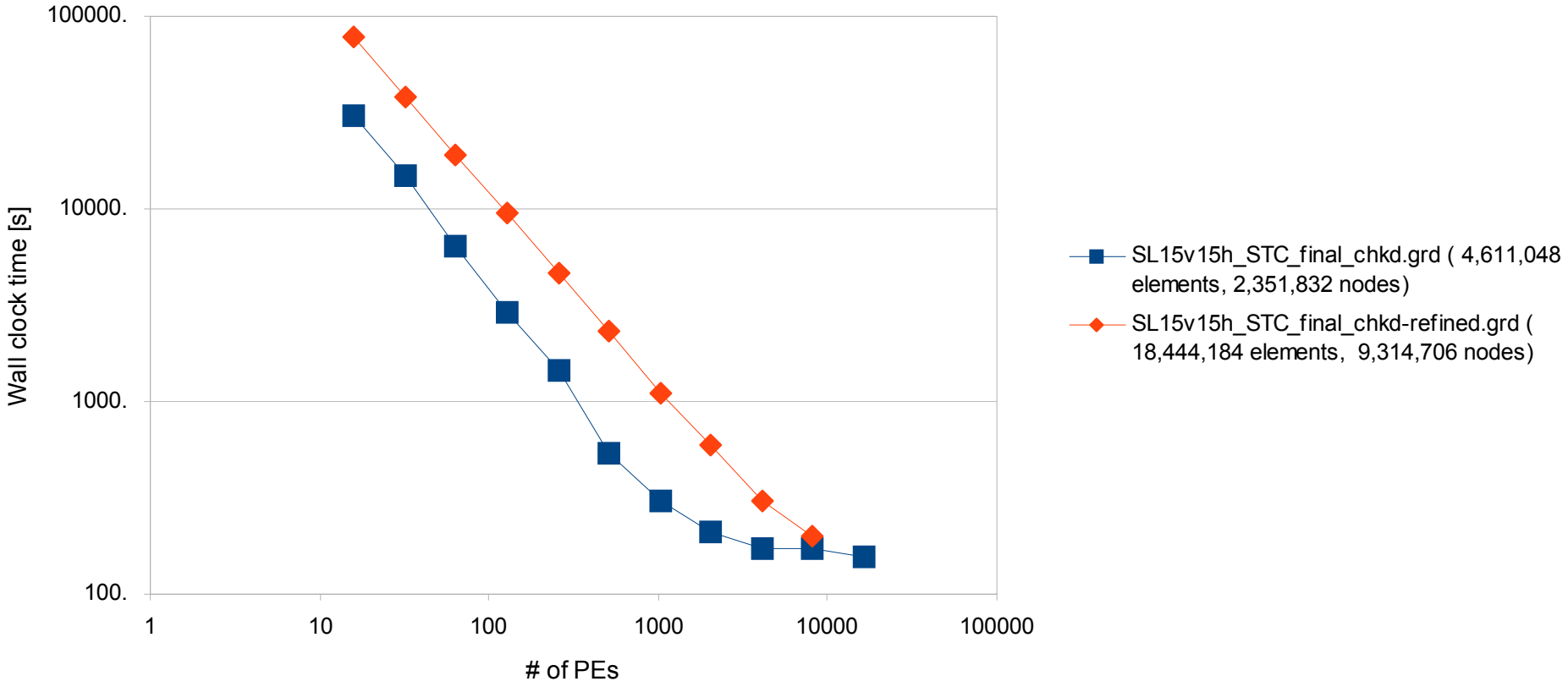
'Hard' Coupling

Advantages:

- ADCIRC and waves model run on the same mesh
  - No nesting of meshes
  - No overlapping of meshes
- ADCIRC and waves model run on the same processor
  - No interpolation
  - No global message passing
  - Information is passed through memory
- Optimization of physics
  - No need for directionality in waves model
  - Dynamic *h*- and *p*-adaptivity
- Optimization of code
  - No overhead for coupling modeling framework
  - Utilize shared memory on multi-core processors

'Hard' Coupling

Maintain our Scaling:



'Hard' Coupling

Introducing … AdcSwan! (Or SwAdcirc?)

- ADCIRC coupled to Simulating WAves Near-shore (SWAN)
- SWAN:
  - Developed by Booij, Holthuijsen, Zijlema at Delft University
  - Non-phase-resolving, wave energy propagation model
  - Solves for wave directions (θ) and frequencies (σ)

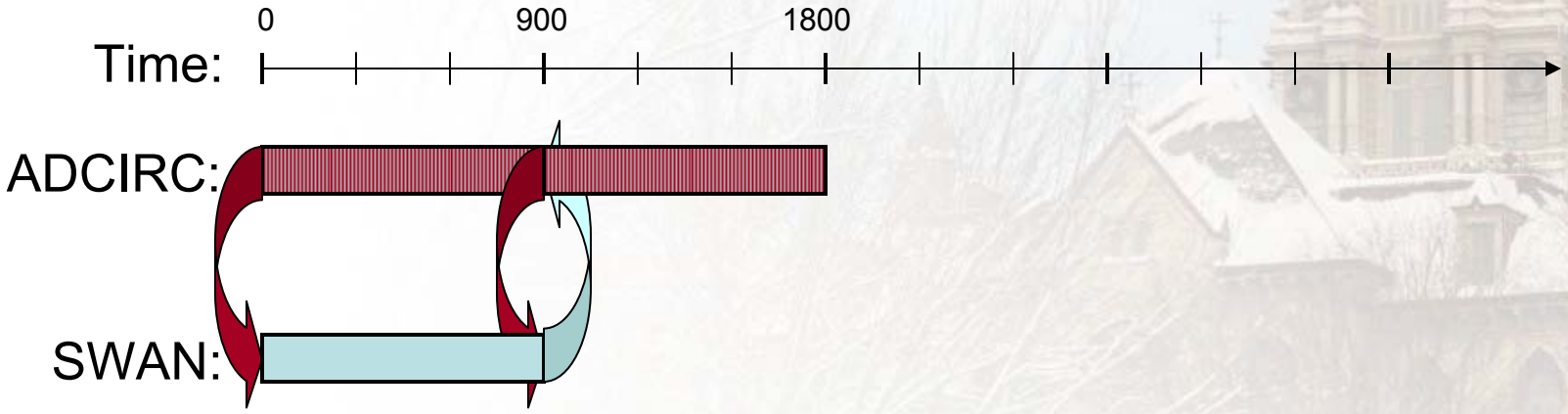
Progress:

- SWAN converted to unstructured meshes (UnSWAN)
- UnSWAN implemented in parallel (PUnSWAN)
- ADCIRC and PUnSWAN compiled into PAdcSwan
- Initial attempts at coupling in parallel

'Hard' Coupling

First Attempt at Coupling:

- ADCIRC is run for 900 seconds (Δt = 1 sec)
- Water levels (ζ) and currents (*u,v*) are passed to Swan
- SWAN is run for 900 seconds (Δt = 900 sec)
- Radiation stresses (S_{xx}, S_{xy}, S_{yy}) and wave-driven forces (F_x, F_y) are computed; forces are passed to ADCIRC
- Repeat

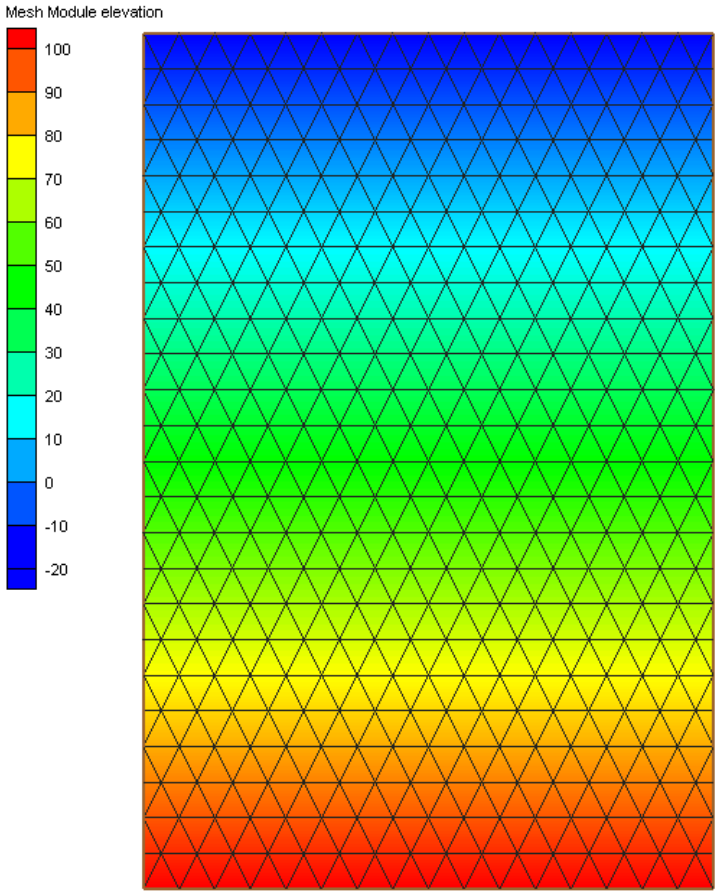


- SWAN is always interpolating, and ADCIRC is always extrapolating

Preliminary Results

Example #1: Waves and Set-up:

- Bathymetry of Test Domain



437 Nodes

4km x 6km

250m Mesh Spacing

Linear Sloping Bathy

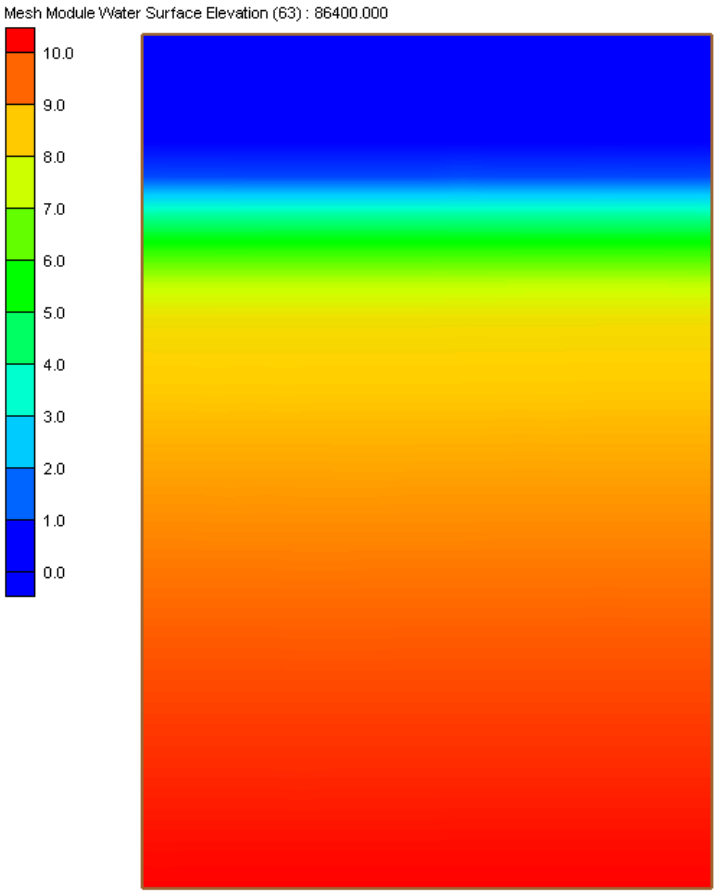
100m at South (Ocean)

-20m at North (Land)

Preliminary Results

Example #1: Waves and Set-up:

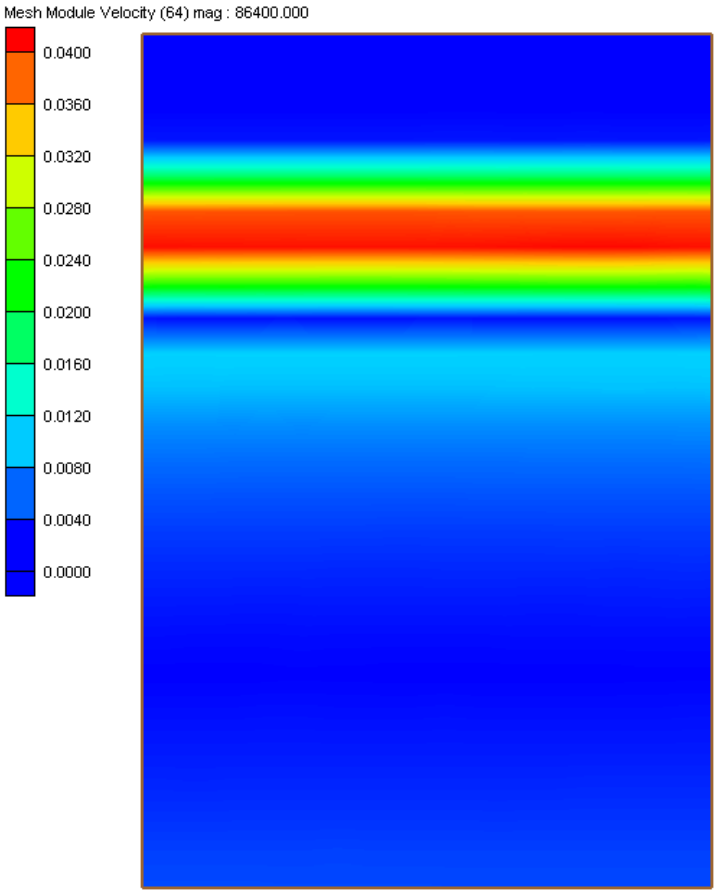
- Significant Wave Heights



Preliminary Results

Example #1: Waves and Set-up:

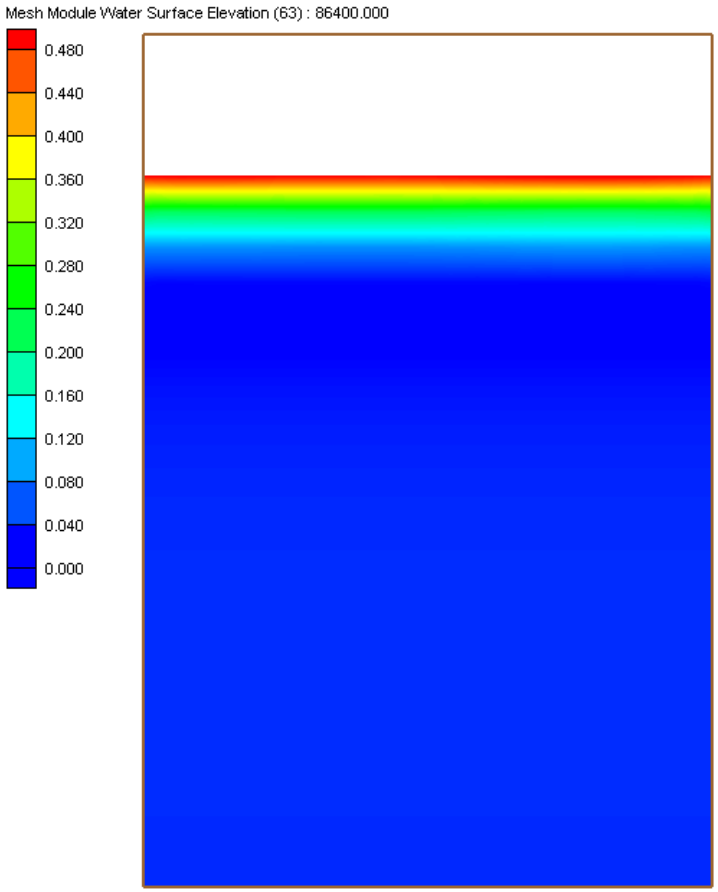
- Wave-Driven Forces



Preliminary Results

Example #1: Waves and Set-up:

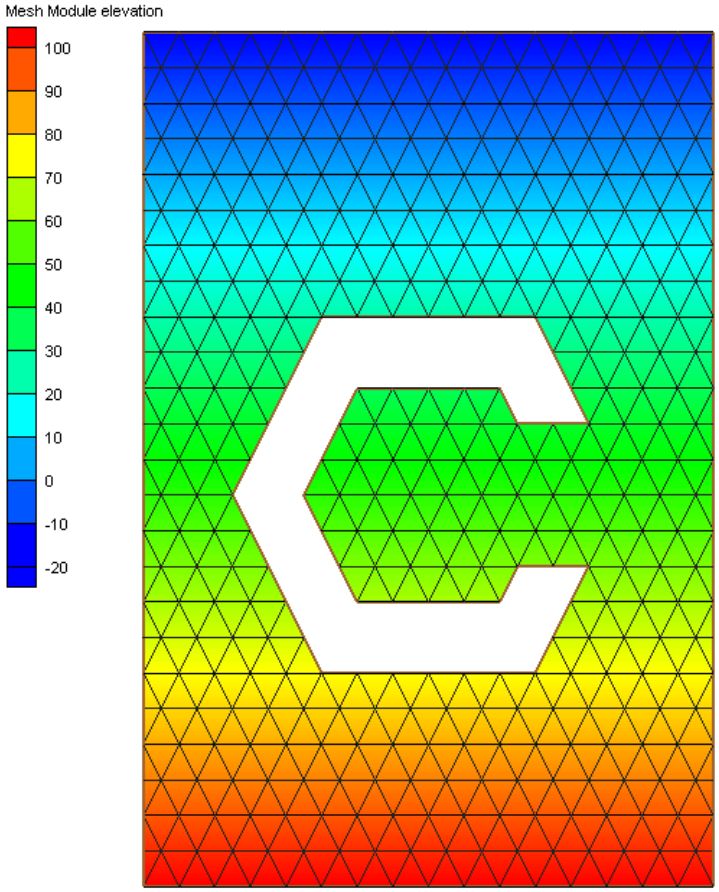
- Water Levels



Preliminary Results

Example #2: Waves and Set-up:

- Bathymetry of Test Domain



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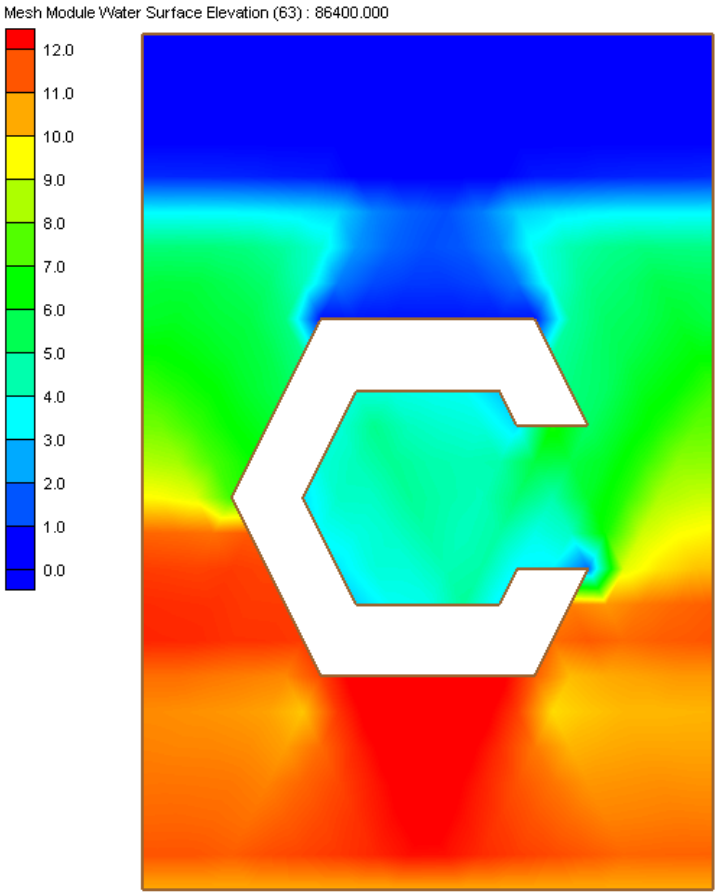
- Significant Wave Heights



Preliminary Results

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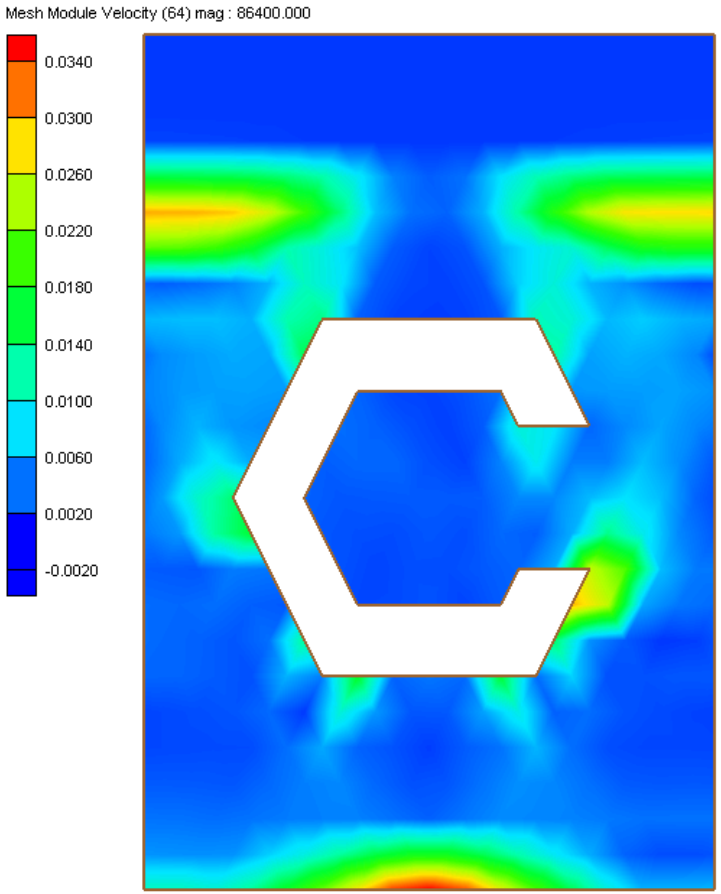
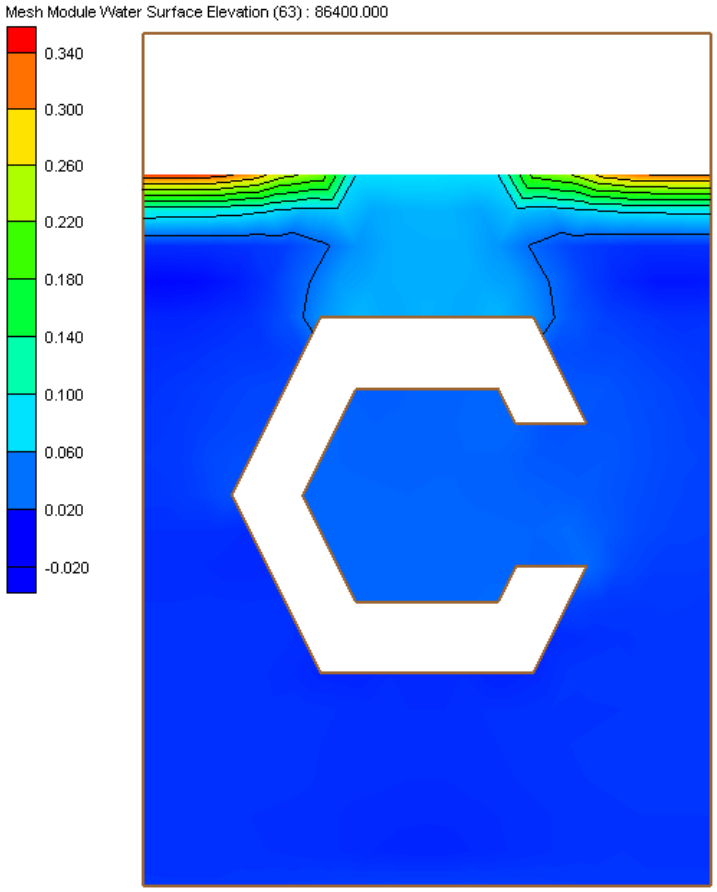


Preliminary Results

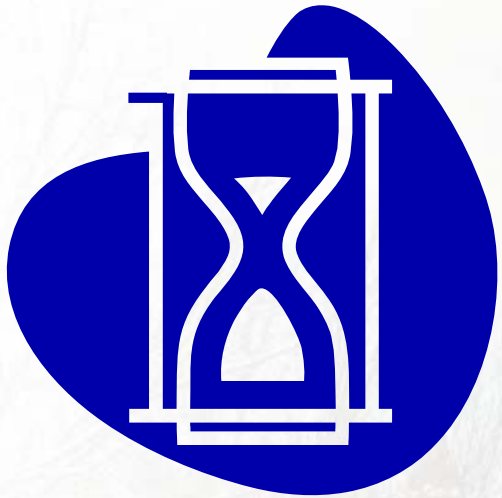
Example #2: Waves and Set-up:

- Water Levels



Preliminary Results

Example #3: Katrina Hindcast:



Future Work

Validation:

- Idealized cases with analytical solutions
- Lab cases with measured data
- Hurricane hindcasts

Convergence Tests:

- Idealized cases that represent actual flow conditions
- Optimal or Required mesh spacing?

Optimization:

- Coding – Shared memory?
- Numerics – Dynamic mesh refinement?