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

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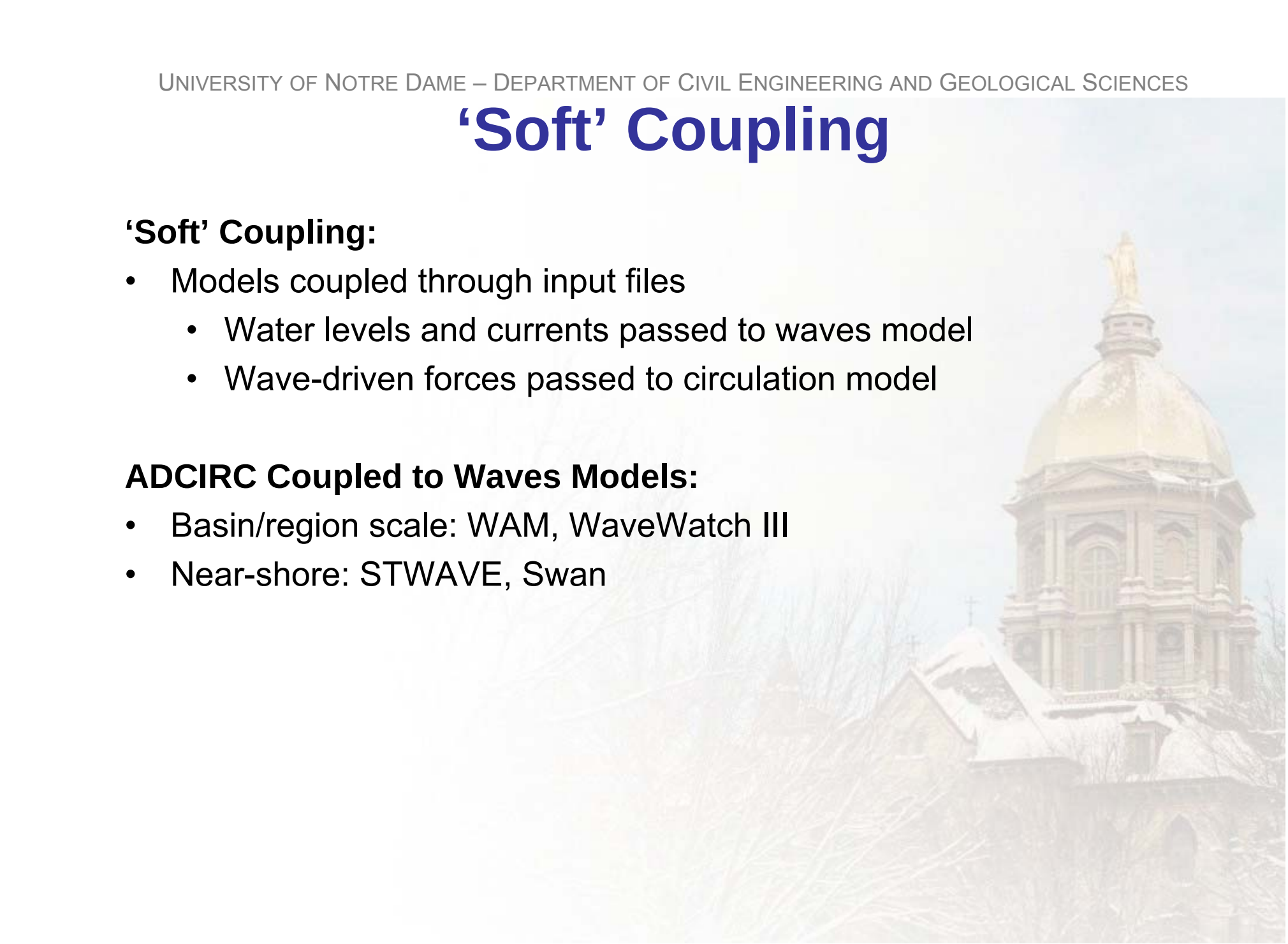
'Soft' Coupling

'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:

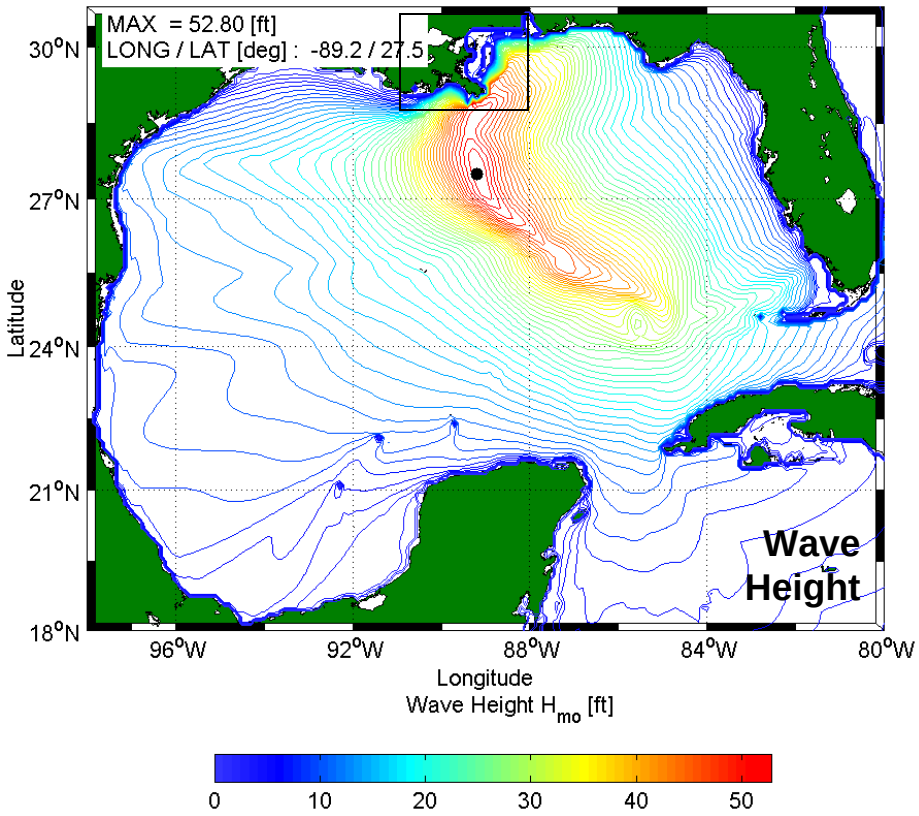
- Basin/region scale: WAM, WaveWatch III
- Near-shore: STWAVE, Swan



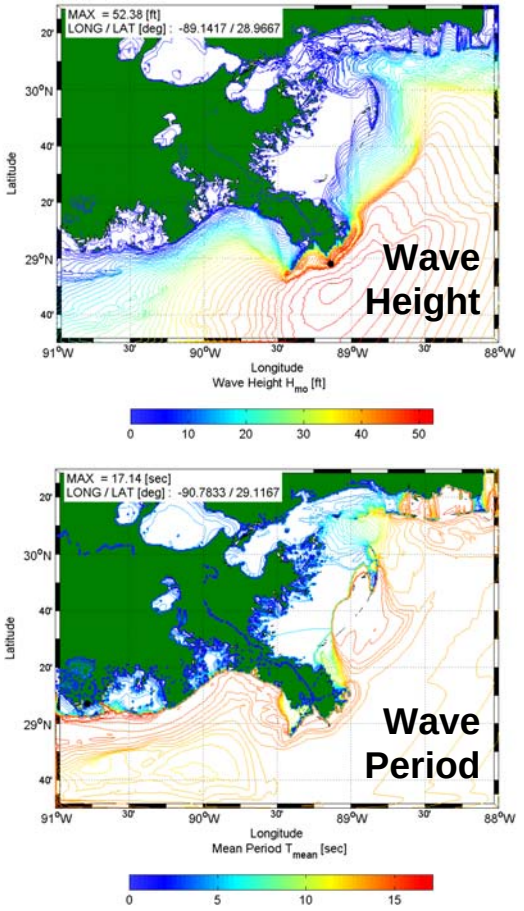
'Soft' Coupling

Example: Louisiana Storm Surge Modeling:

Basin-Scale WAM Model



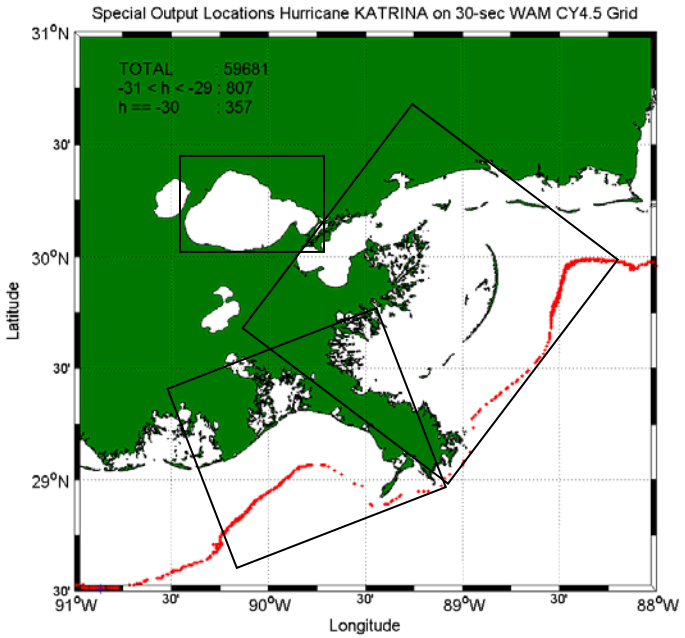
Region-Scale WAM Model

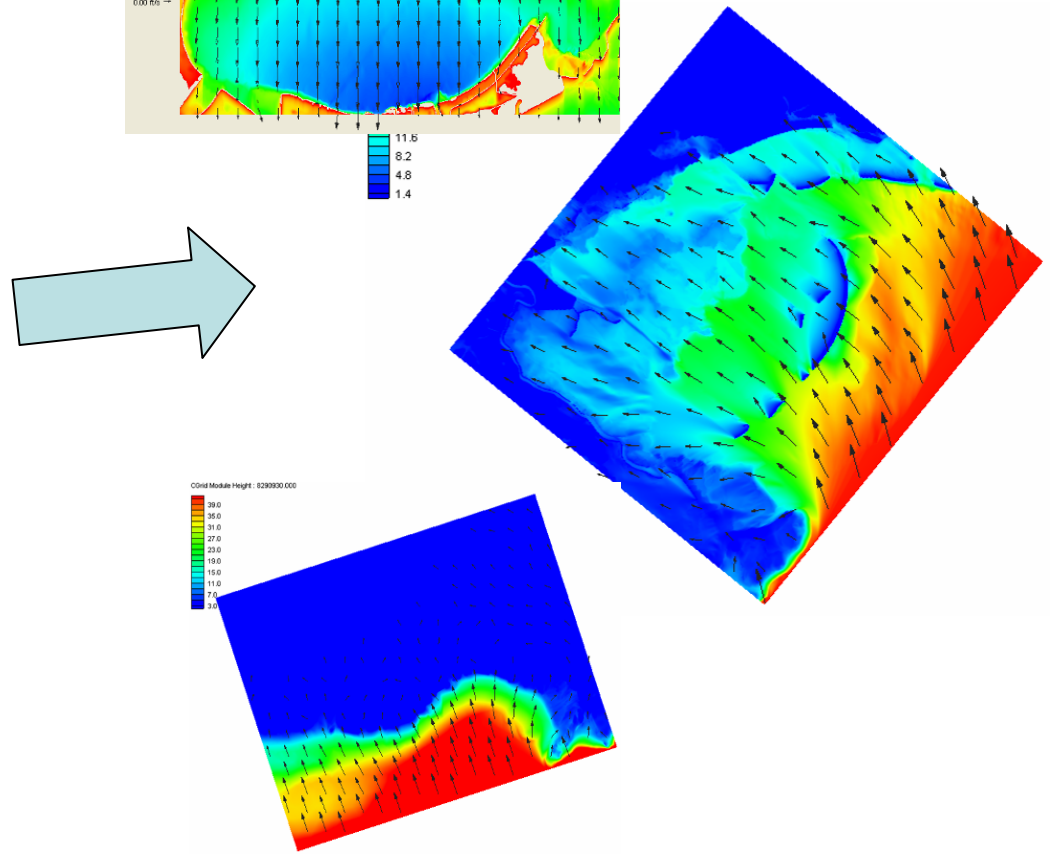


‘Soft’ Coupling

Example: Louisiana Storm Surge Modeling:

Near-Shore STWAVE Model

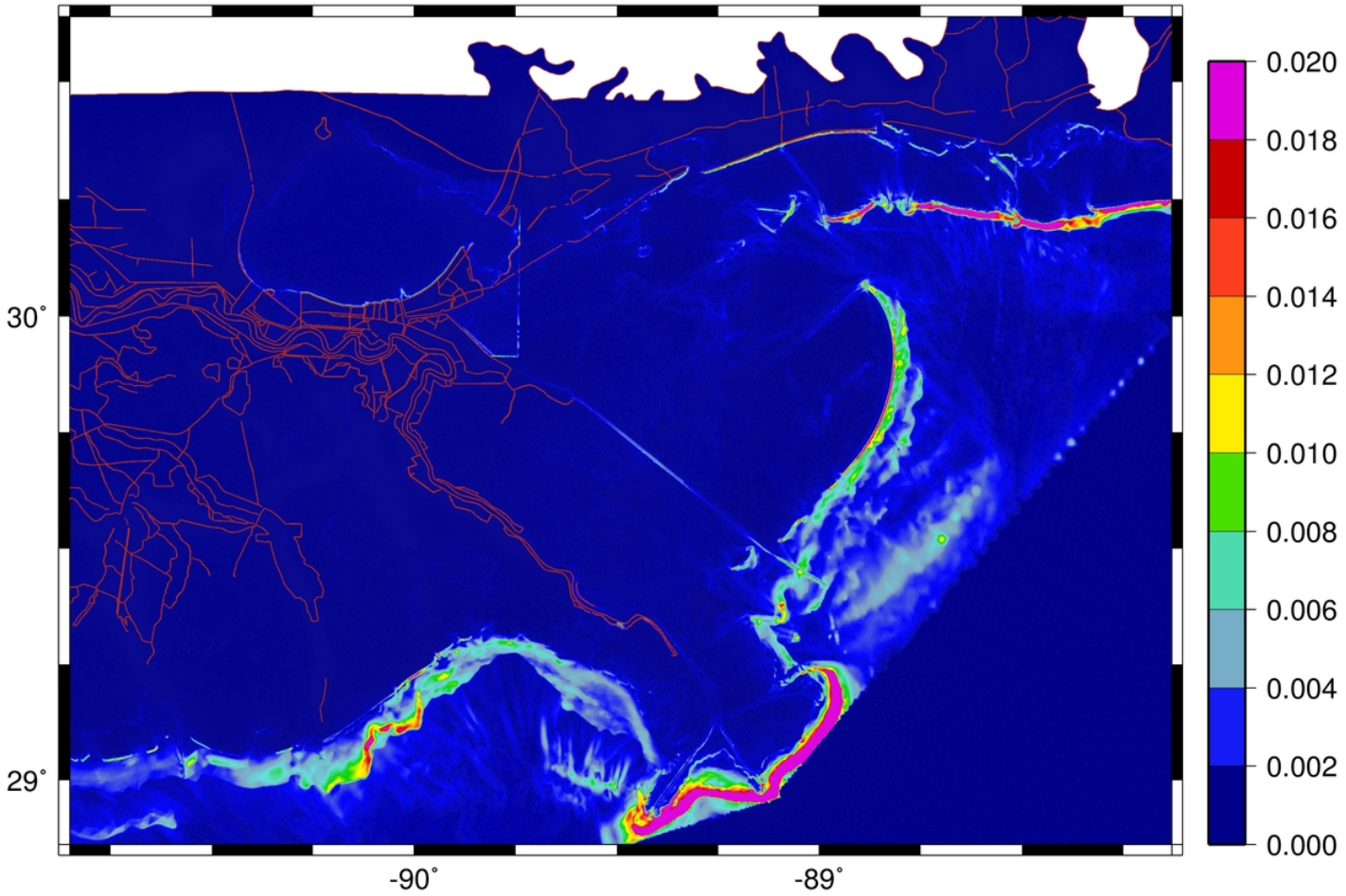




‘Soft’ Coupling

It Works!

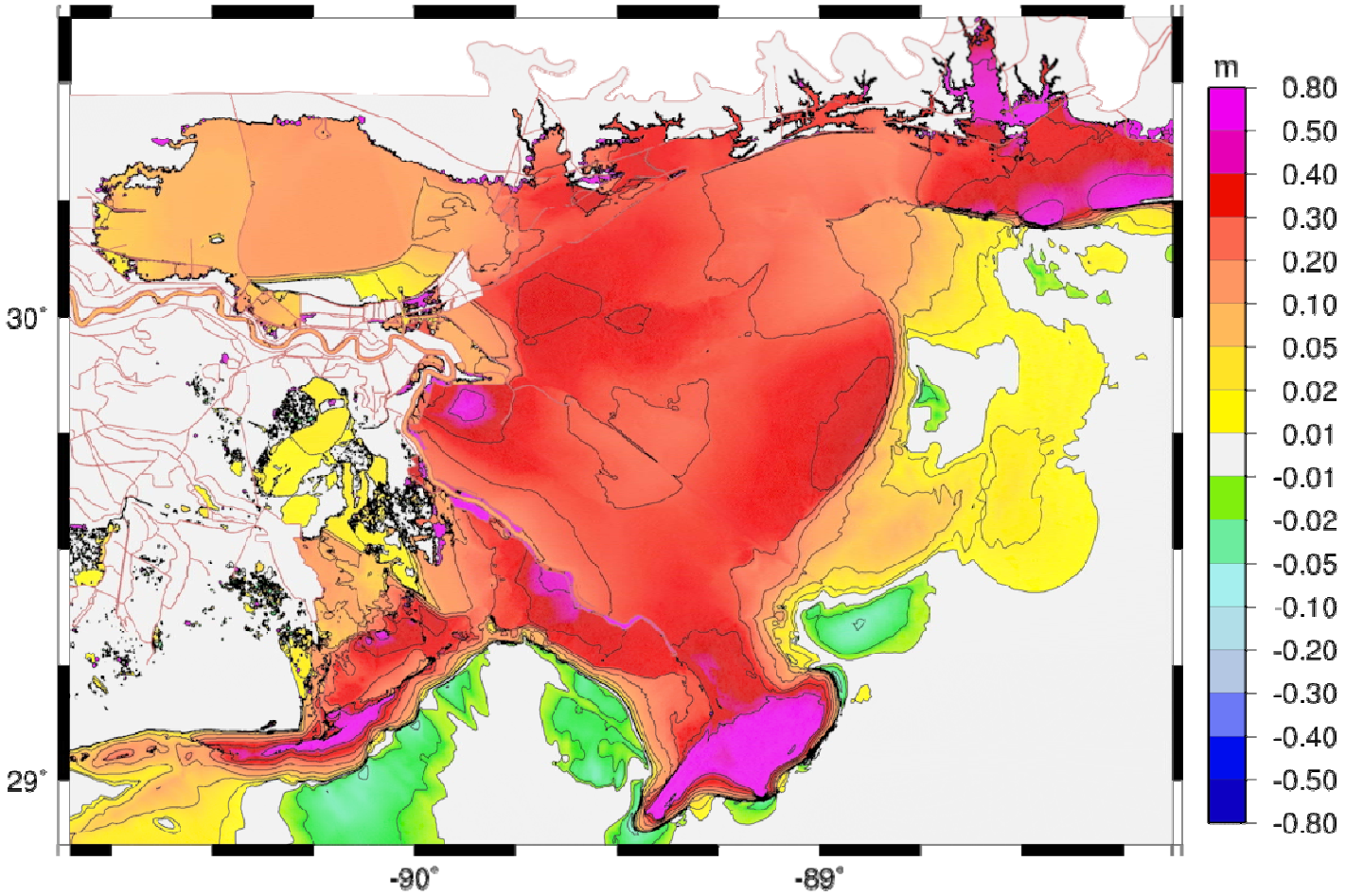
- Maximum wave-driven forces in Hurricane Katrina



'Soft' Coupling

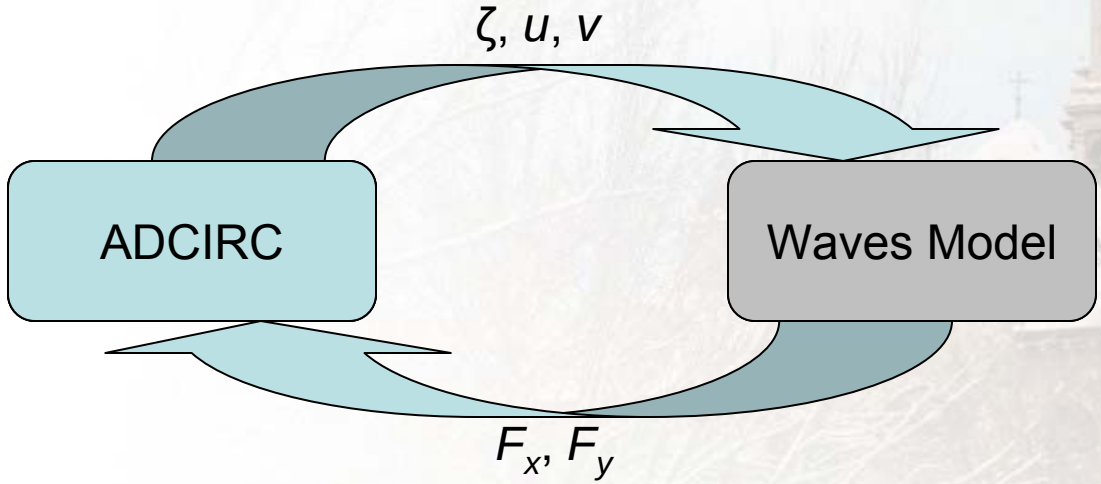
It Works!

- Effect of waves during Hurricane Katrina



Disadvantages of 'Soft' Coupling

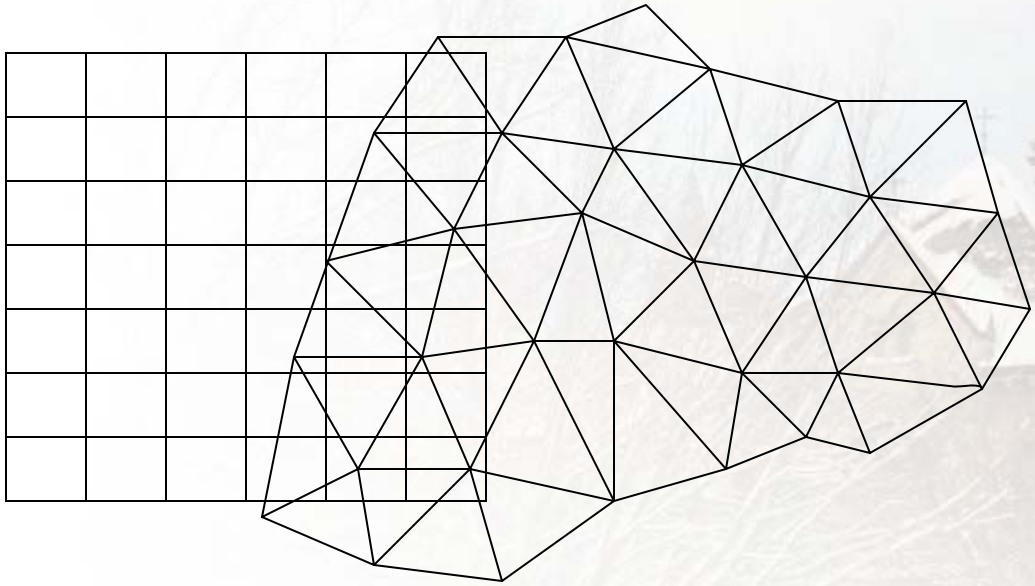
1. **Iteration:**
   - Models coupled through input files
     - Water levels and currents passed to waves model
     - Wave-driven forces passed to circulation model
   - Process can be automated, but is still inefficient



Disadvantages of 'Soft' Coupling

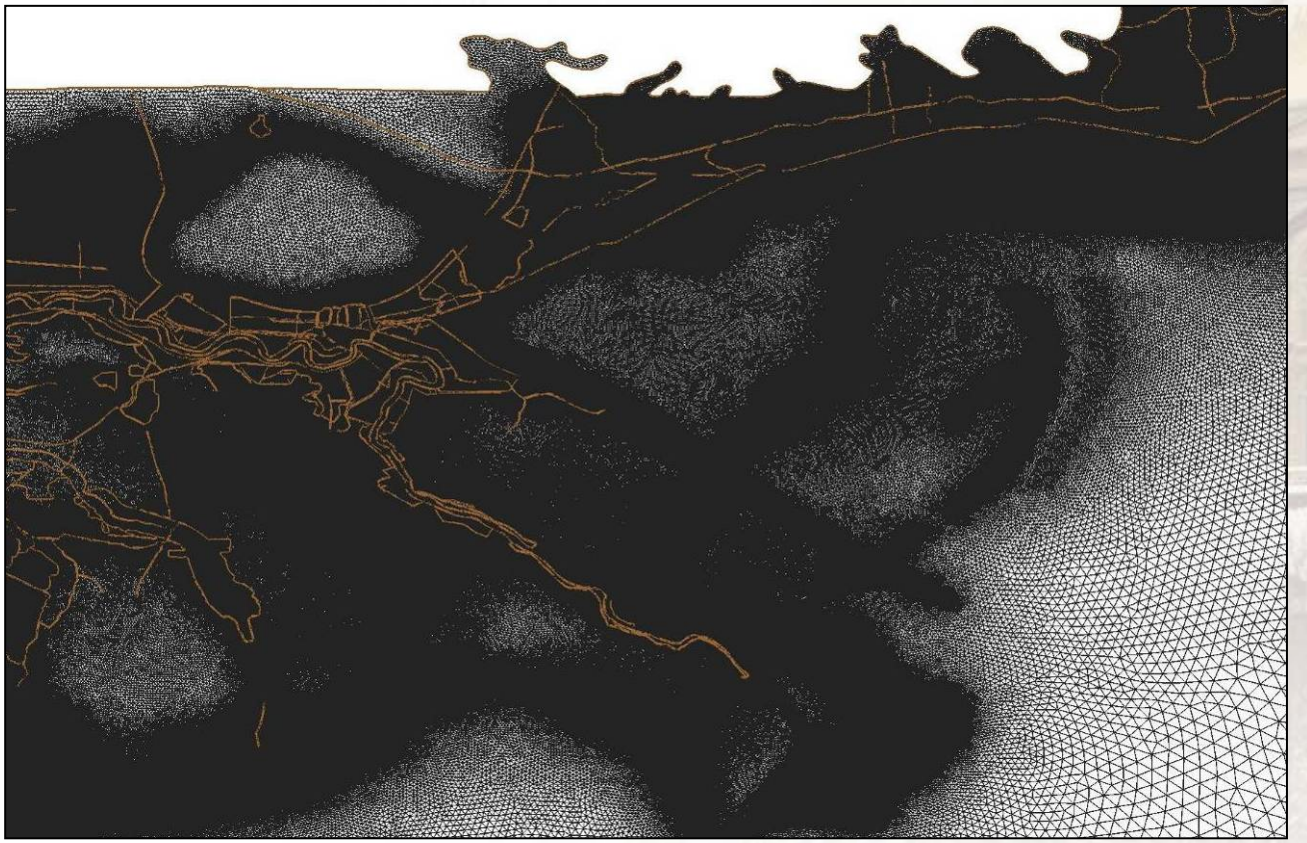
2. Interpolation:

- 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

'Hard' Coupling:

- Models coupled into the same executable
- Each processor splits time between waves and circulation
  - Alternate between ADCIRC and wave model
  - Run both models on the same unstructured mesh
  - Pass information through memory – no files

Advantages:

1. No nesting of meshes
2. No overlapping of meshes
3. No need for directionality in waves model
4. Ability to increase resolution in breaking zones on the fly

'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)

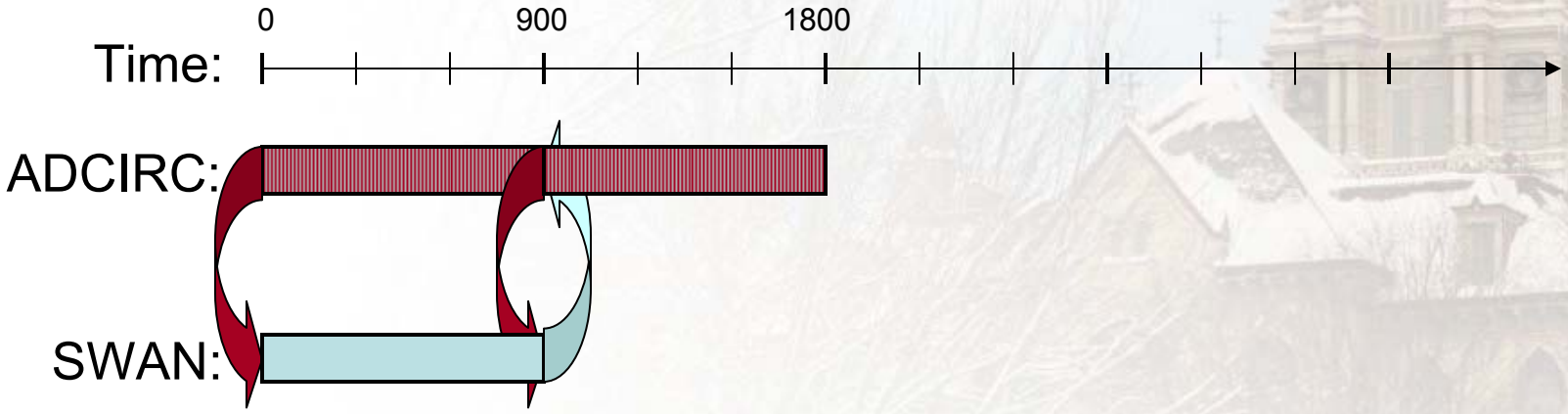
Progress:

- SWAN converted to unstructured meshes (UnSWAN?)
- ADCIRC and SWAN compiled into AdcSwan
- Initial attempts at coupling in serial

'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

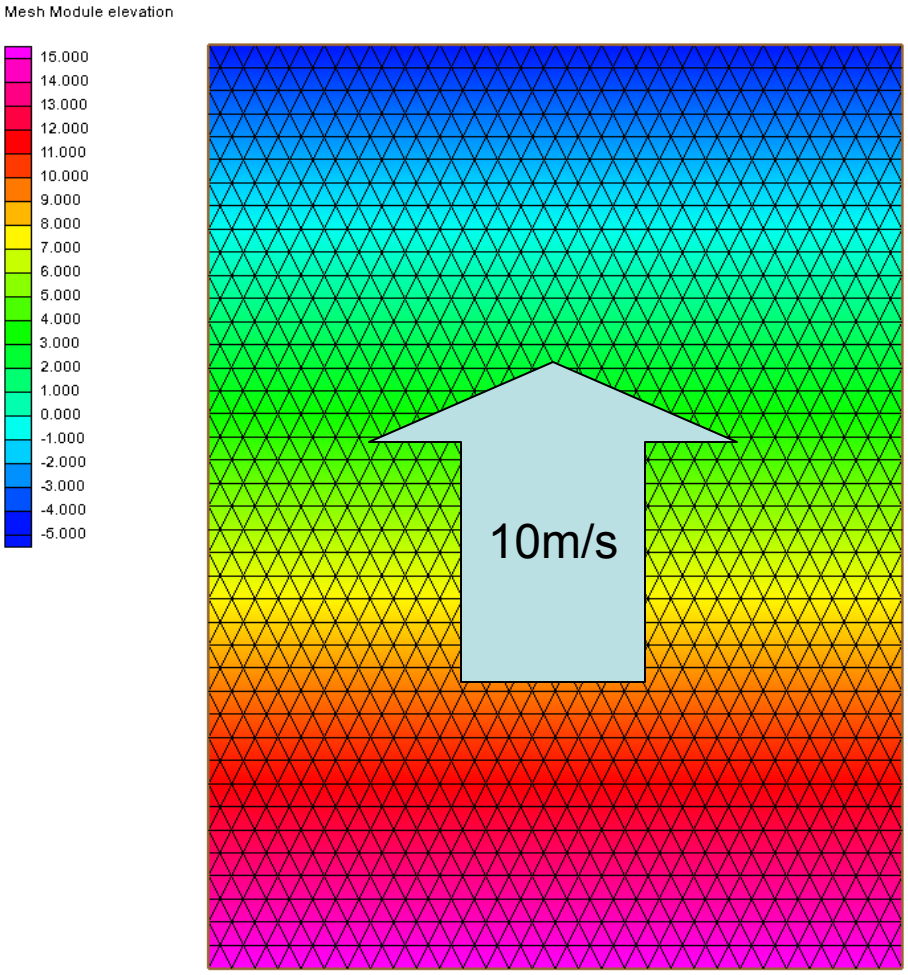


- SWAN is always interpolating, and ADCIRC is always extrapolating

Preliminary Results

Wind-Driven Waves and Set-up:

- Bathymetry of Test Domain:



1,291 Nodes

30km x 40km

1km Mesh Spacing

Linear Sloping Bathy

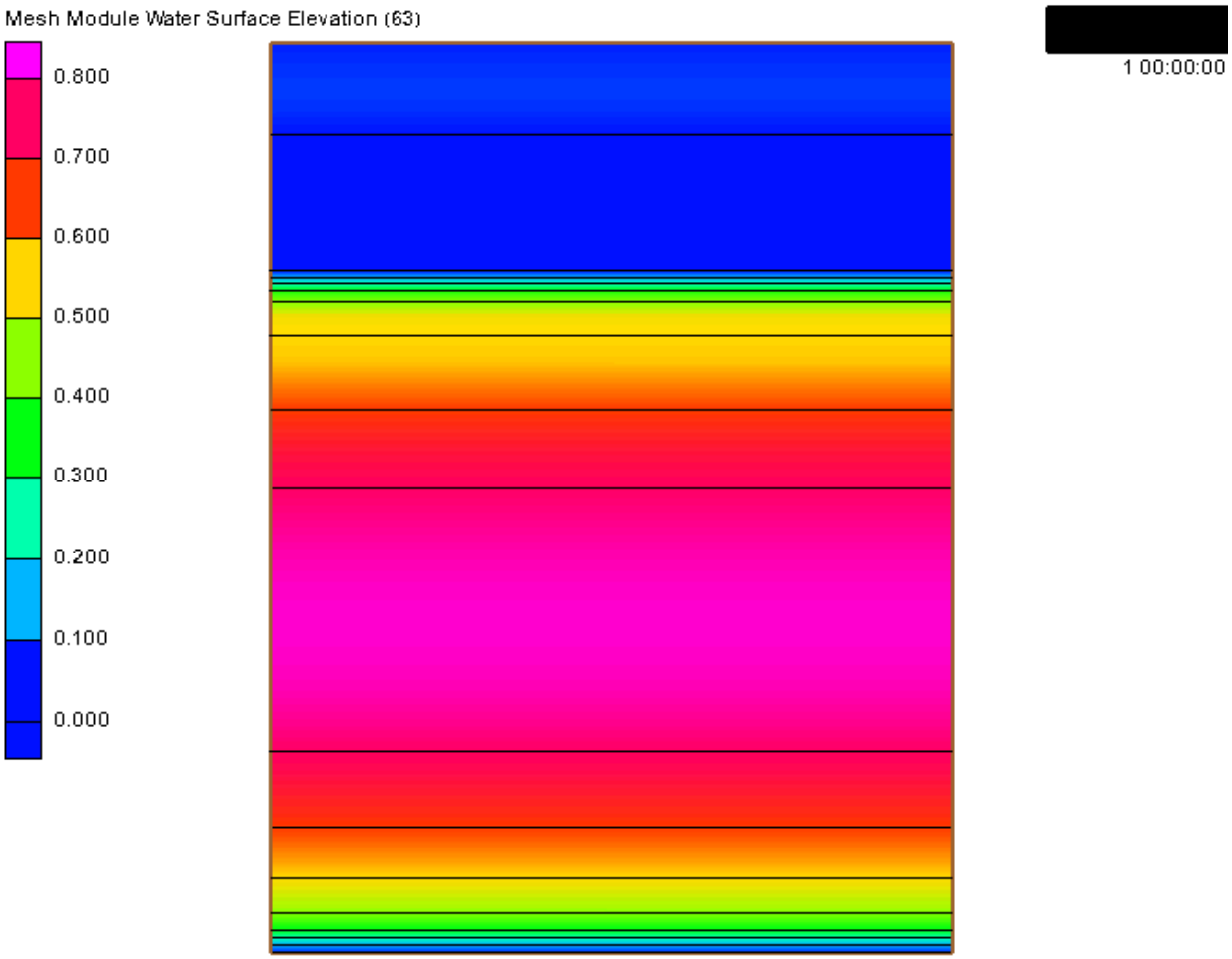
15m at South (Ocean)

-5m at North (Land)

Preliminary Results

Wind-Driven Waves and Set-up:

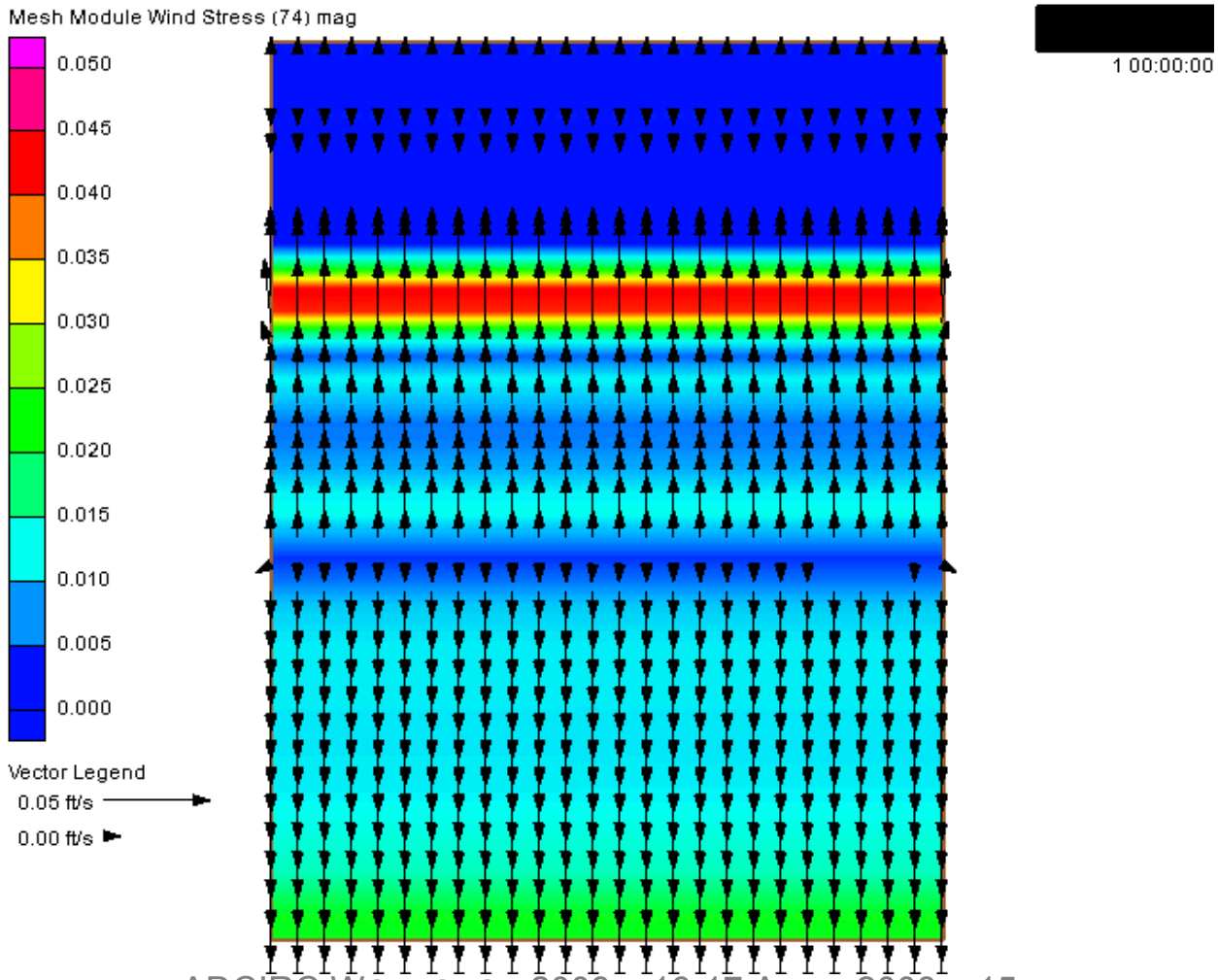
- Significant Wave Heights:



Preliminary Results

Wind-Driven Waves and Set-up:

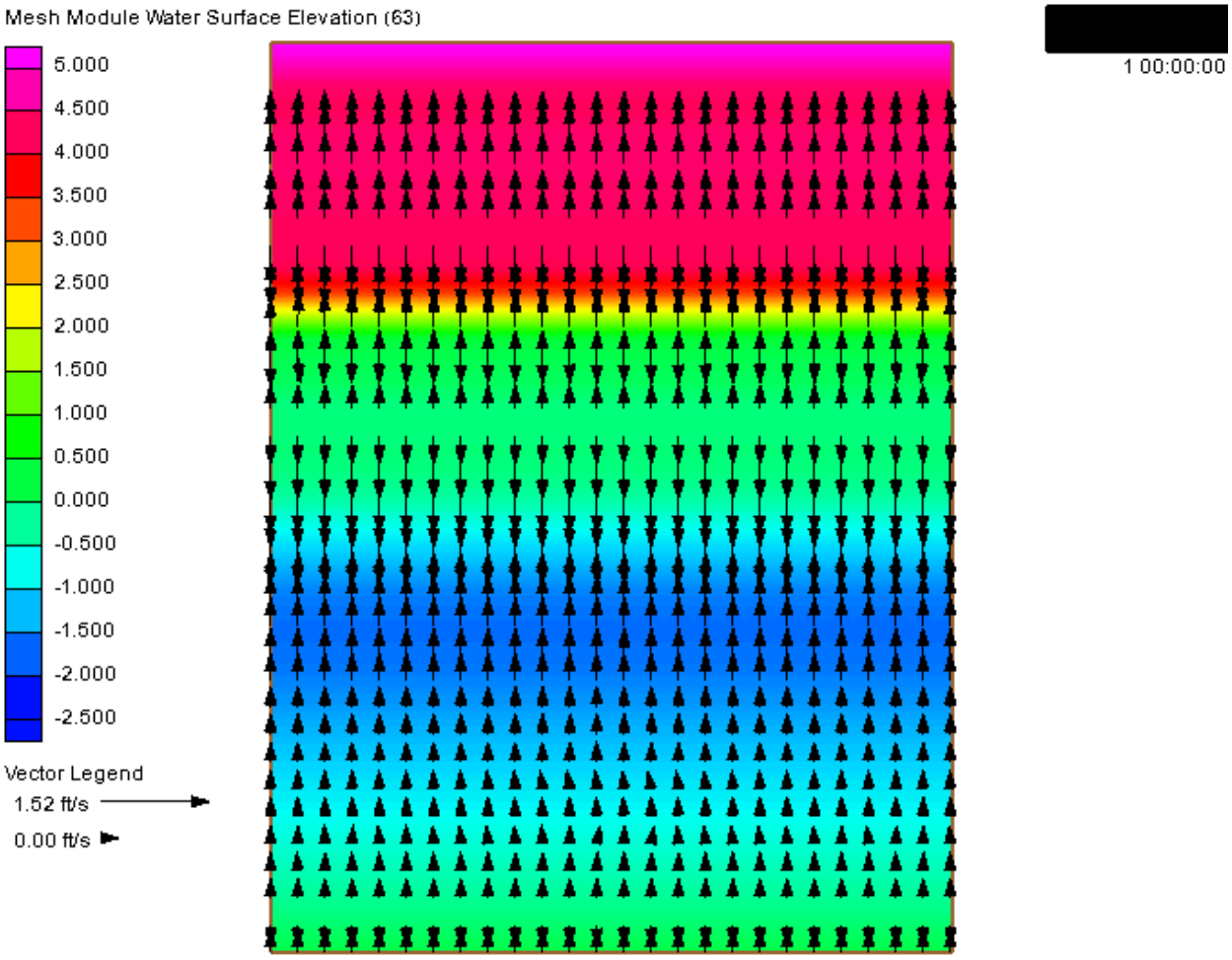
- Wave-Driven Forces:



Preliminary Results

Wind-Driven Waves and Set-up:

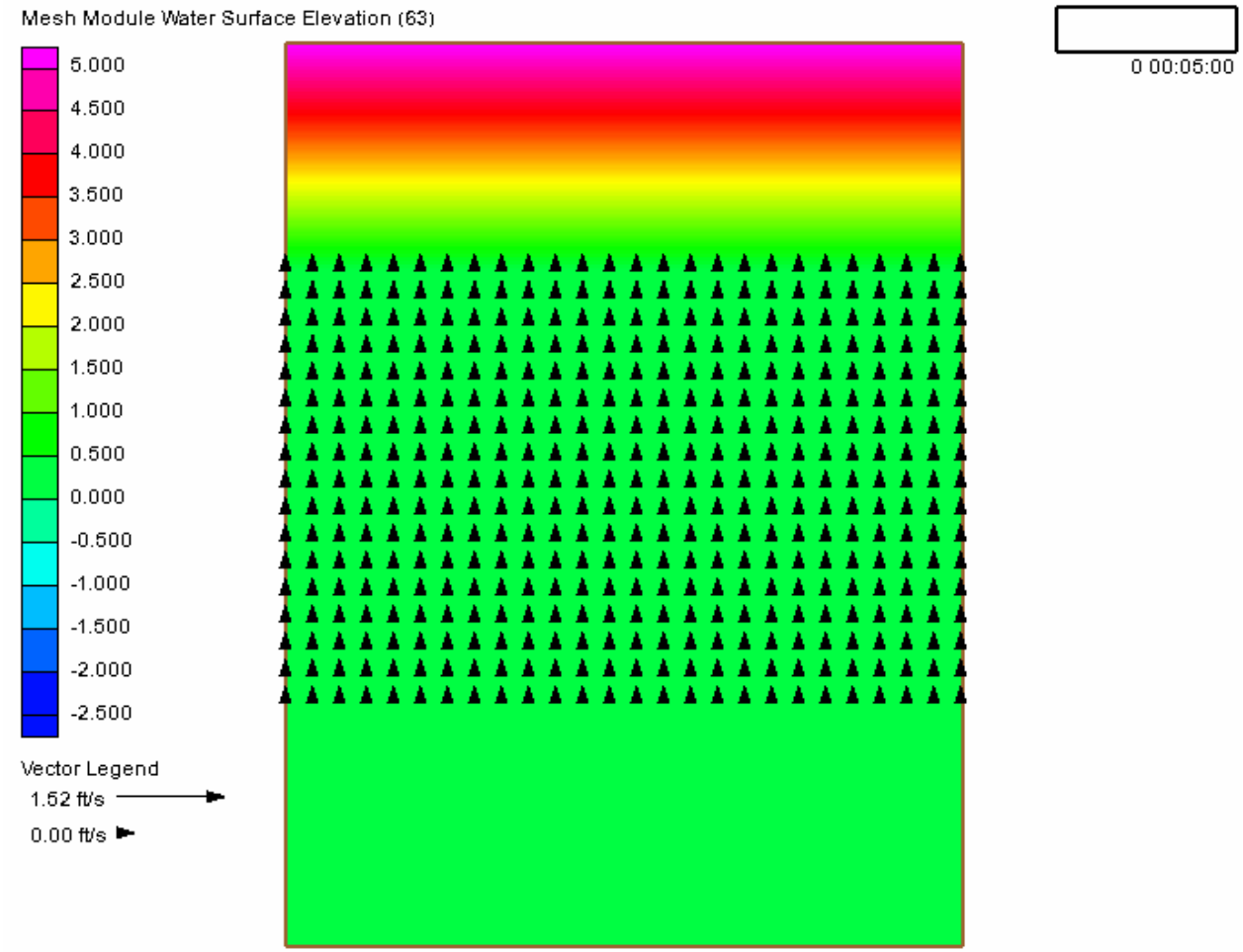
- Water Levels and Currents:



Preliminary Results

Wind-Driven Waves and Set-up:

- Water Levels and Currents:



Future Work

SWAN:

- Parallelize the unstructured SWAN model (PUnSwan?)

AdcSWAN:

- Validate against simple waves studies (Bowen 1968, etc.)
- Consider overlapping time-stepping scheme
- Study convergence in Δx, $\Delta\theta$, $\Delta\sigma$
- Apply to large-scale hurricane storm surge simulations
- Implement in DG and increase resolution on the fly