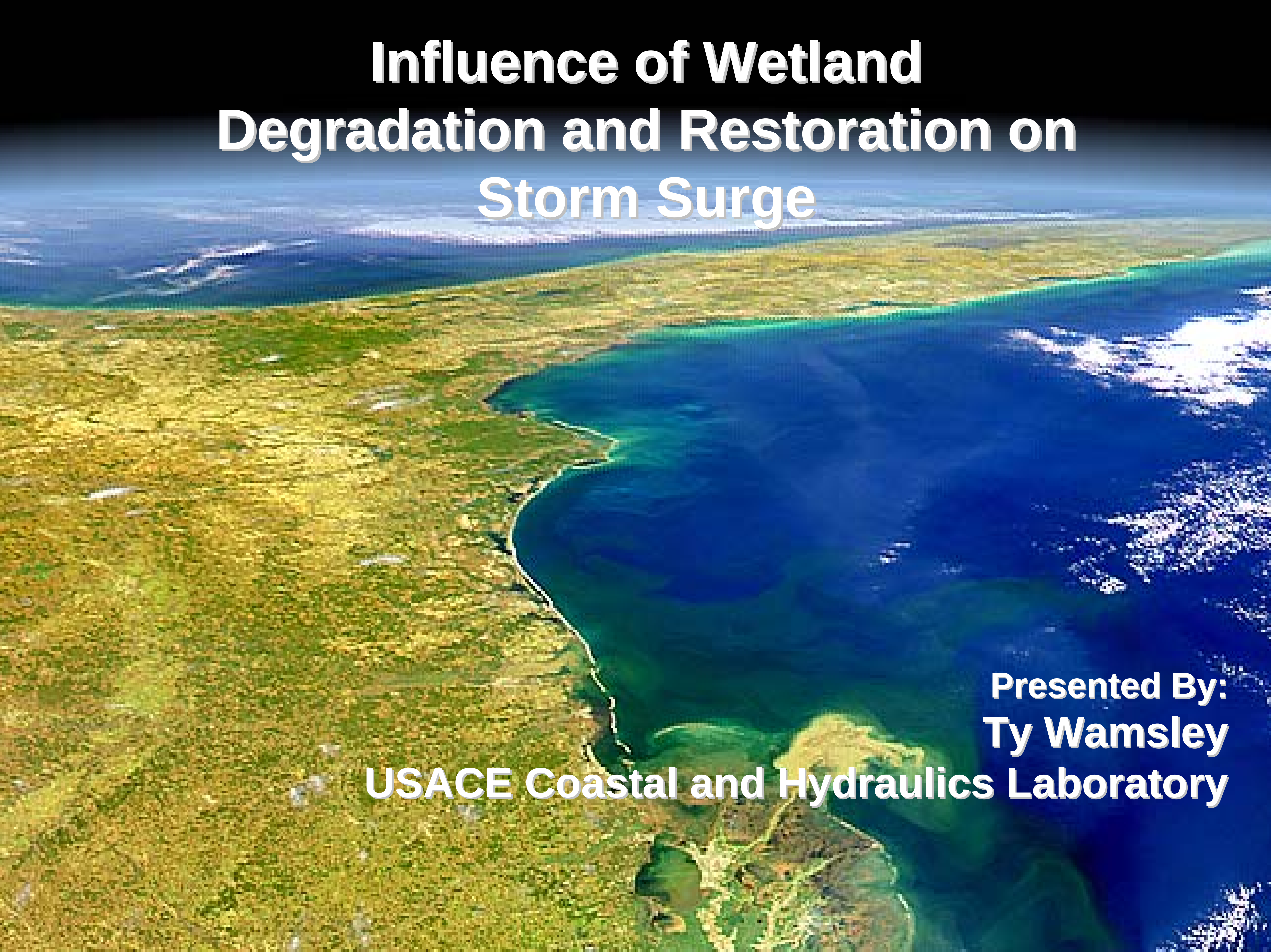
Influence of Wetland Degradation and Restoration on Storm Surge



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Team Effort

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Purpose/Motivation

- Complicated Dynamics preclude application of simple “rules of thumb” (i.e. X miles of marsh reduces surge by Y feet)
  - Storm track
  - Storm intensity
  - Surrounding topography/bathymetry
  - Vegetation type

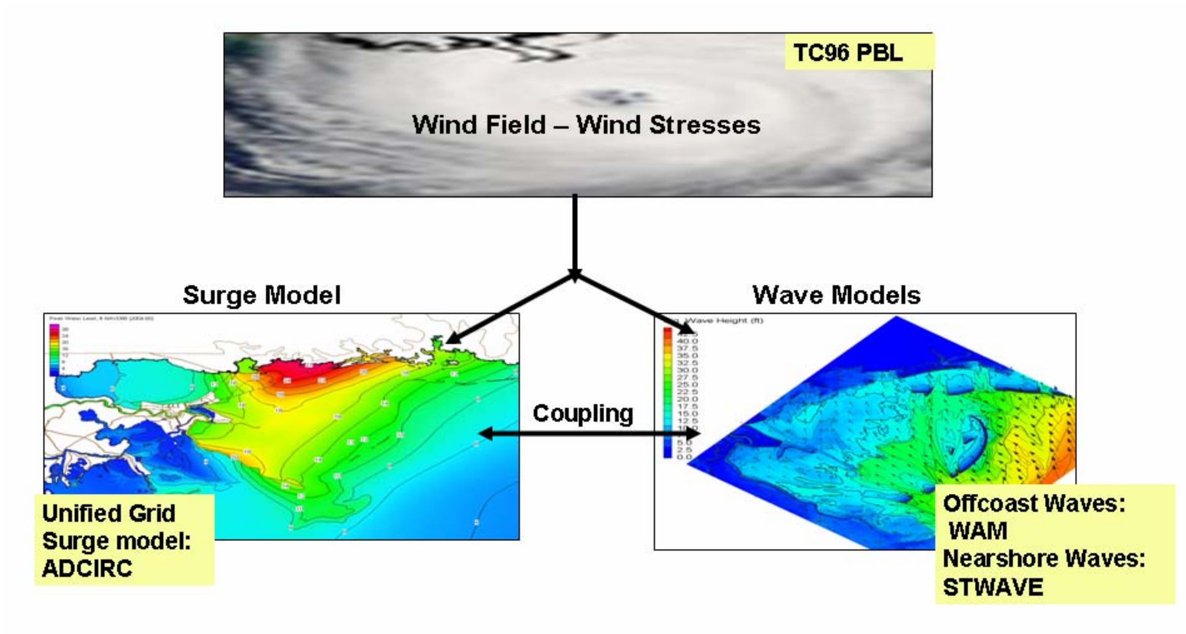
- Apply numerical models to assess the potential of wetland features for reducing storm surge.

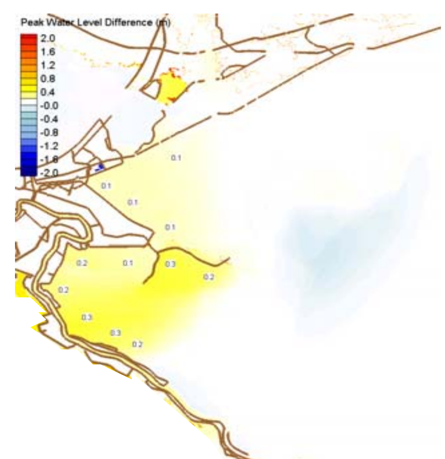
- Trends and relative performance.

- Modeling is a tool for qualitative and/or semi-quantitative evaluation of the surge reduction

Methodology

- Apply integrated modeling system.
- Modify bathymetry and friction fields to represent wetland degradation and restoration.
- Compute statistical surfaces with JPM-OS methodology.
- Compare results to base condition.





Summary of Conclusions

- Simulations indicate that vegetated landscape features do have surge reduction potential.
- Can not apply a simple “rule of thumb” to quantify surge reduction potential of wetlands.
- Impact can be amplified in areas with levee “pockets”.
- Large continuous restorations provide maximum benefit.
- More research and data is needed.

Storm Surge and Wetlands

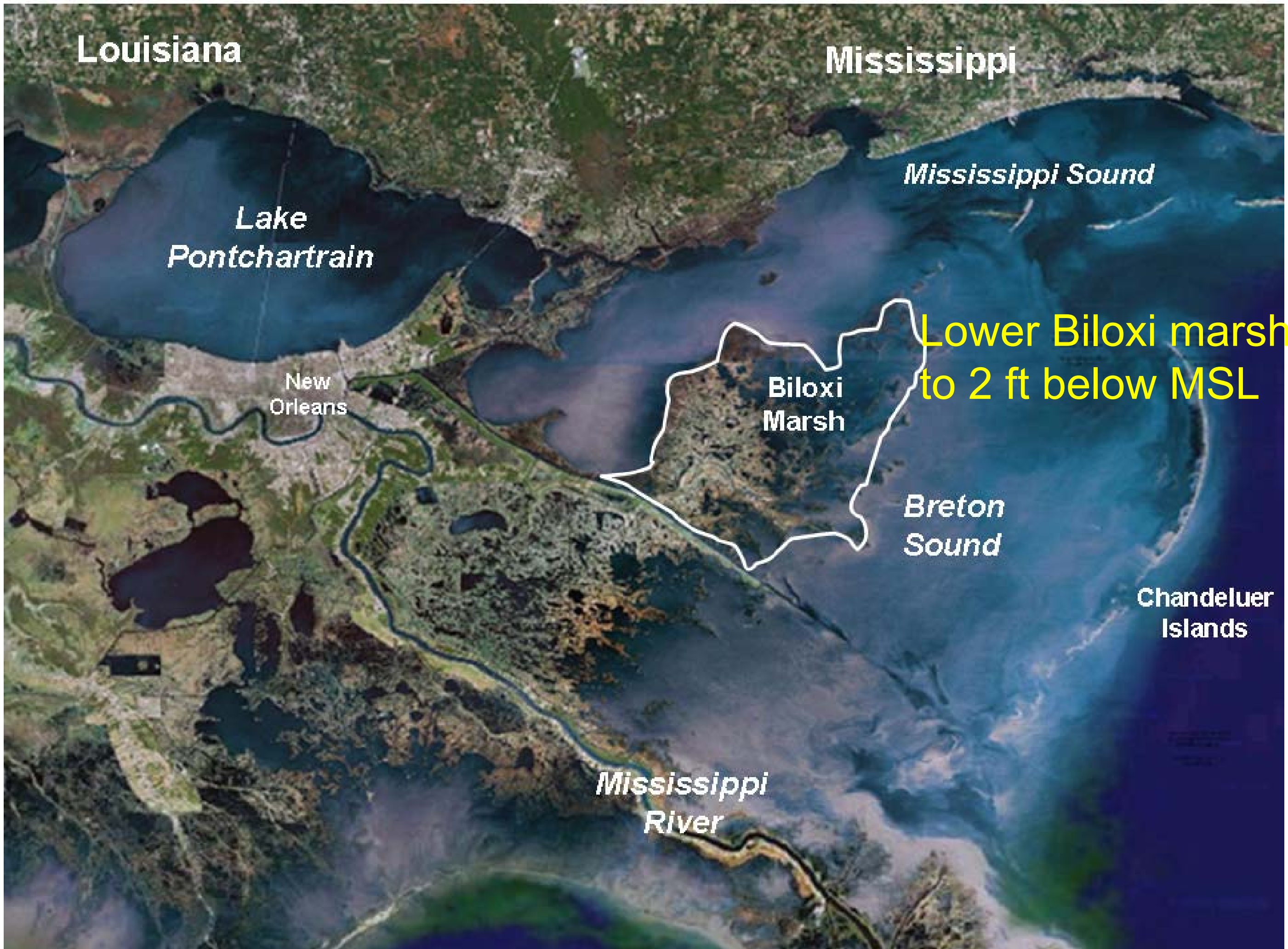
- Considered:
  - Bathymetry and topography act as physical barrier and create bathymetric resistance.
  - Vegetation reduces surface winds and slows surge propagation .
- Not Considered:
  - Changes to the landscape that occur during storms passage (ie vegetation stripped, land mass eroded)
  - Changes in the structure of the hurricane itself due to landfall infilling phenomenon that may be influenced by landscape features

Wetland Changes - Model

- Restoration/Degradation impacts on surge:
  - Depth
  - Wind (surface roughness and canopy)
  - Bottom Friction (through simple Manning formulation)

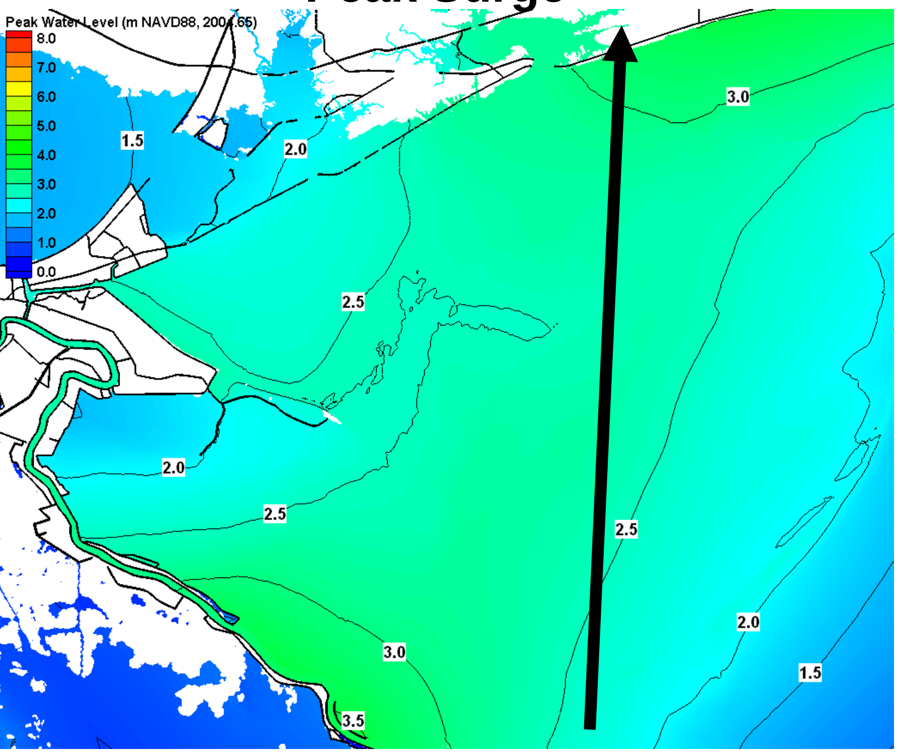
- Codes and methodologies developed to modify the ADCIRC grid and input friction files directly.

Sensitivity Demonstration



Sensitivity Demonstration

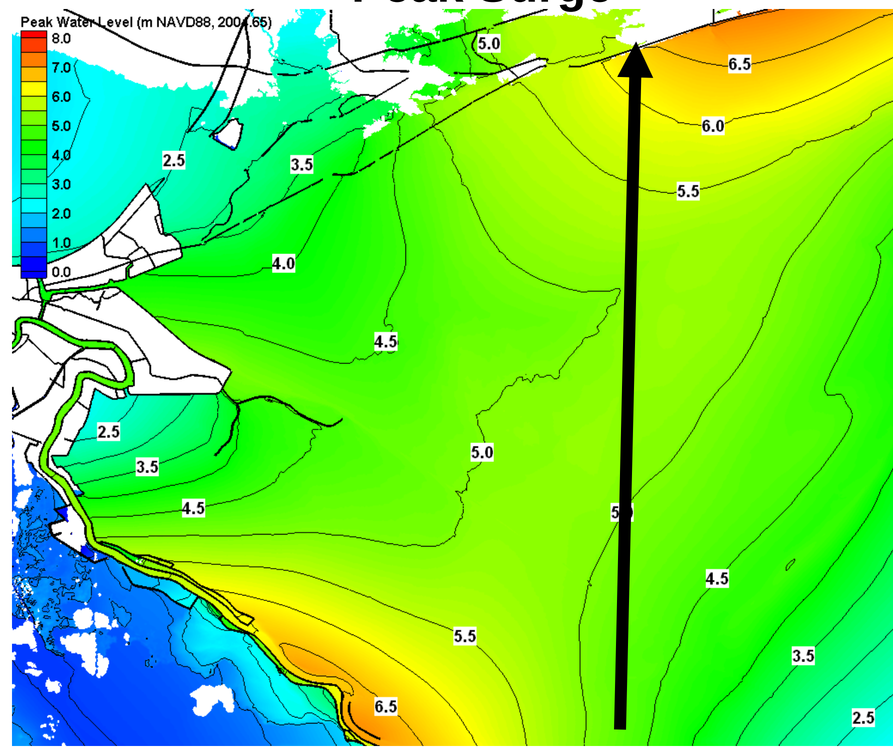
Peak Surge



HUR1 (Hurricane Hilda-like)

- **Central Pressure: 960 mb**
- **Rmax: 22 nm**
- **Forward Speed: 11 knots**

Peak Surge

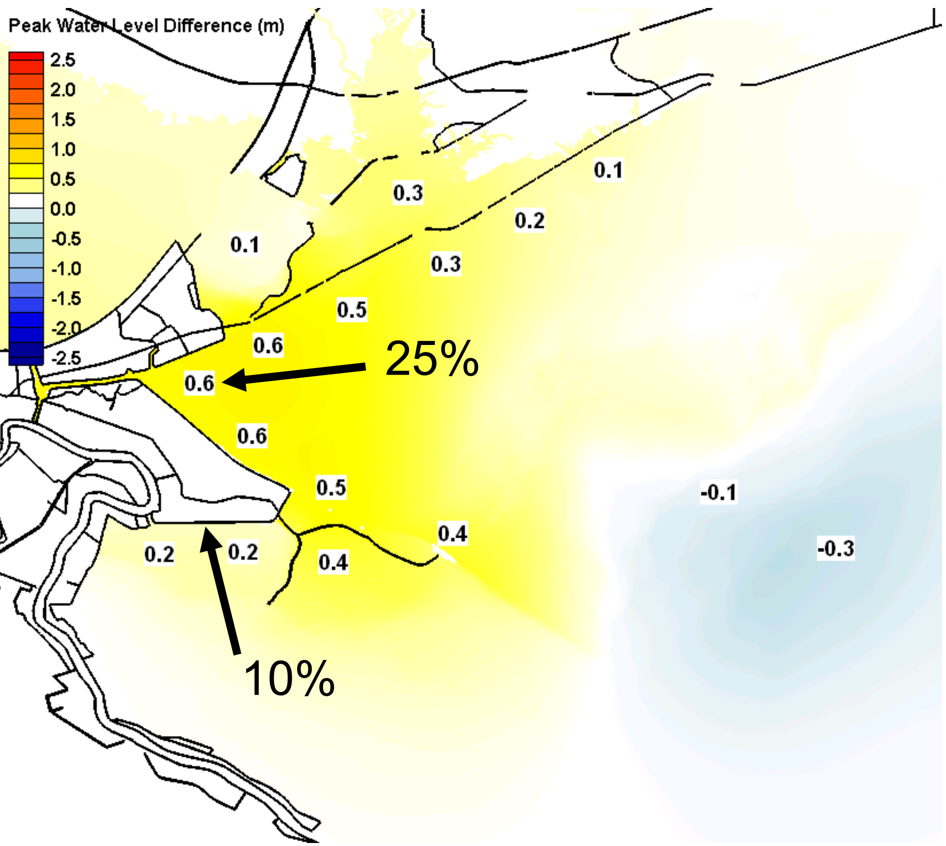


HUR2 (Hurricane Katrina-like)

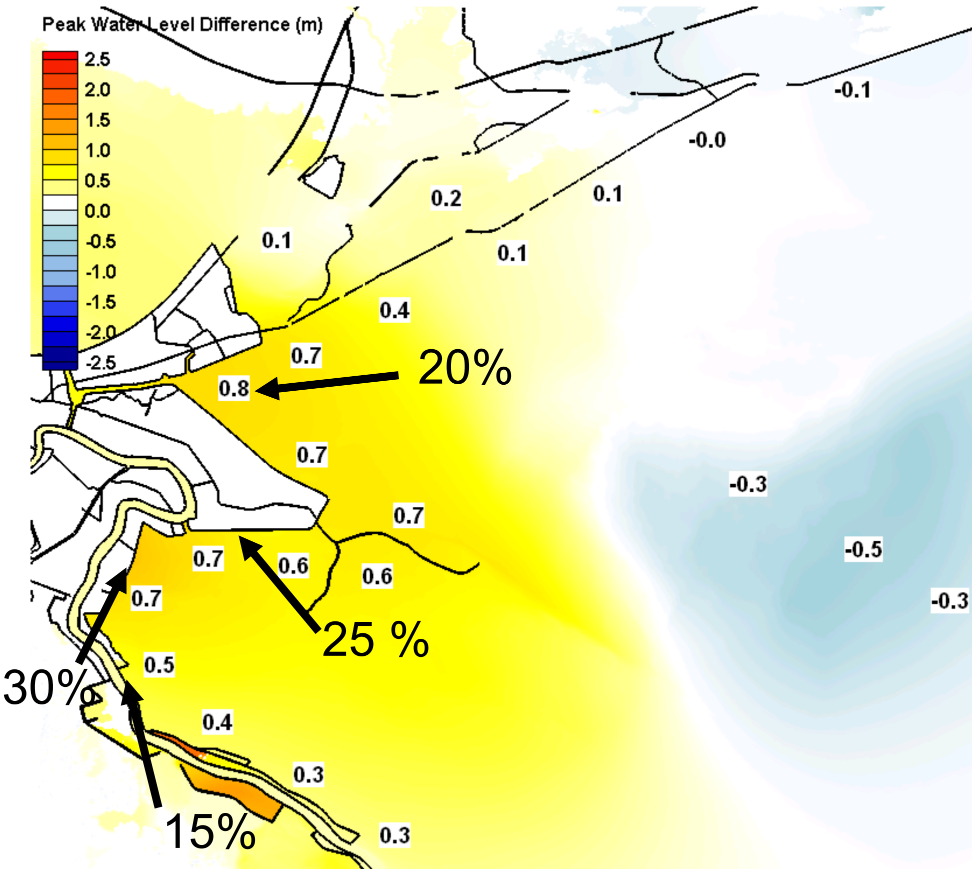
- **Central Pressure: 900 mb**
- **Rmax: 22 nm**
- **Forward Speed: 11 knots**

Biloxi Degradation

Surge: Degraded - Base



HUR1



HUR2

Wetland Change Scenarios

- Future “Degraded”: Based on 50-year “No Increased Action” landscape prediction from the Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) model.
- Restored: Based on plan developed by Federal and State interests.

Future No Increased Action Coastal Landscape
CLEAR Output => ADCIRC

Bathy/Topo

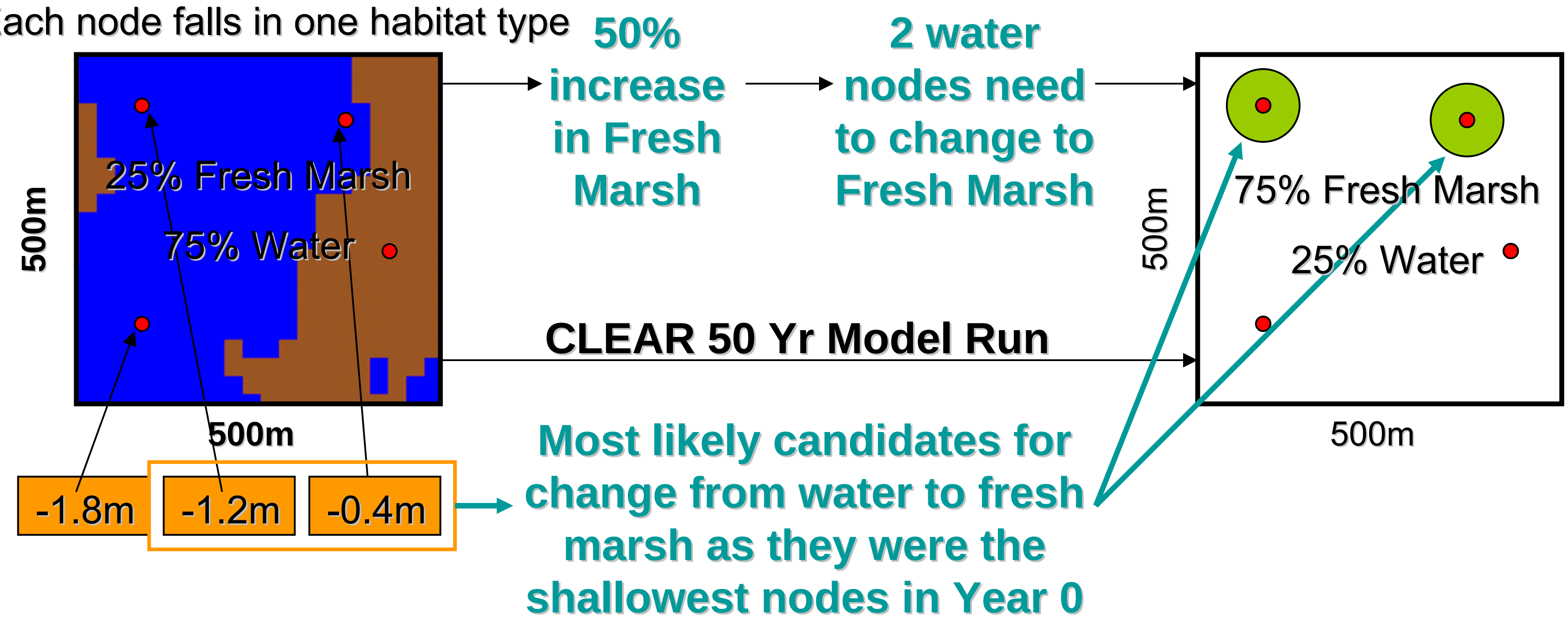
CLEAR Input Cell Year 0

•LULC Data at 25m Res

•Each node falls in one habitat type

CLEAR Output Cell Year 50

•Spatial uncertainty



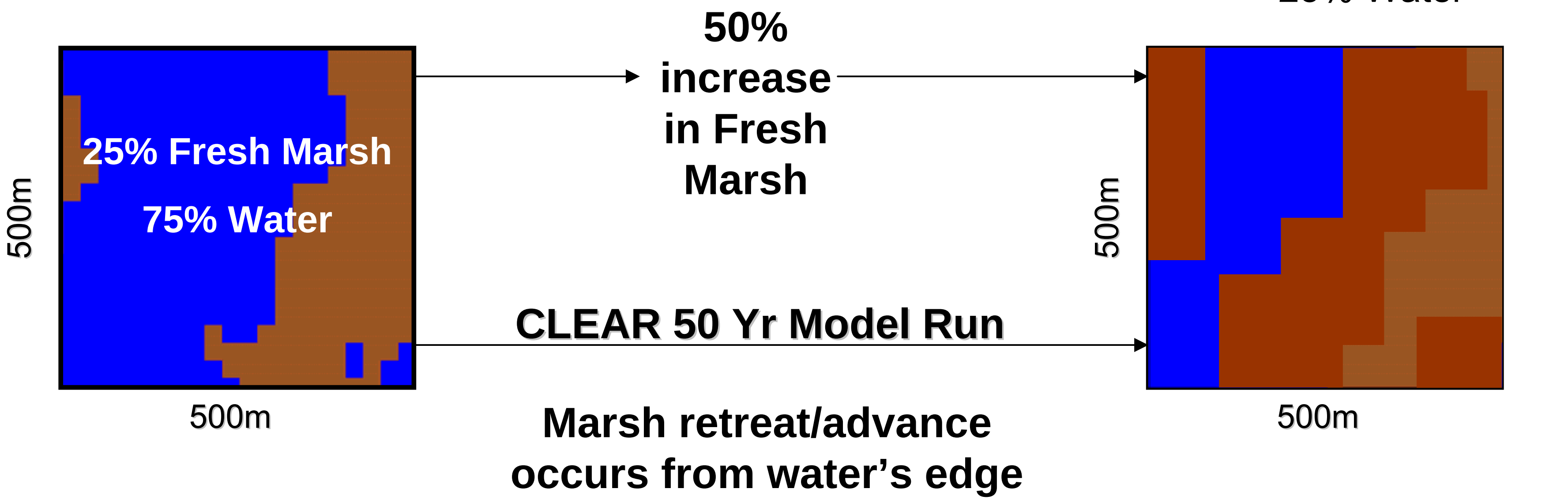
Credit: Brady Couvillon, USGS National Wetlands Research Center

NLCD/GAP Source Datasets Updated for Manning-n and z0

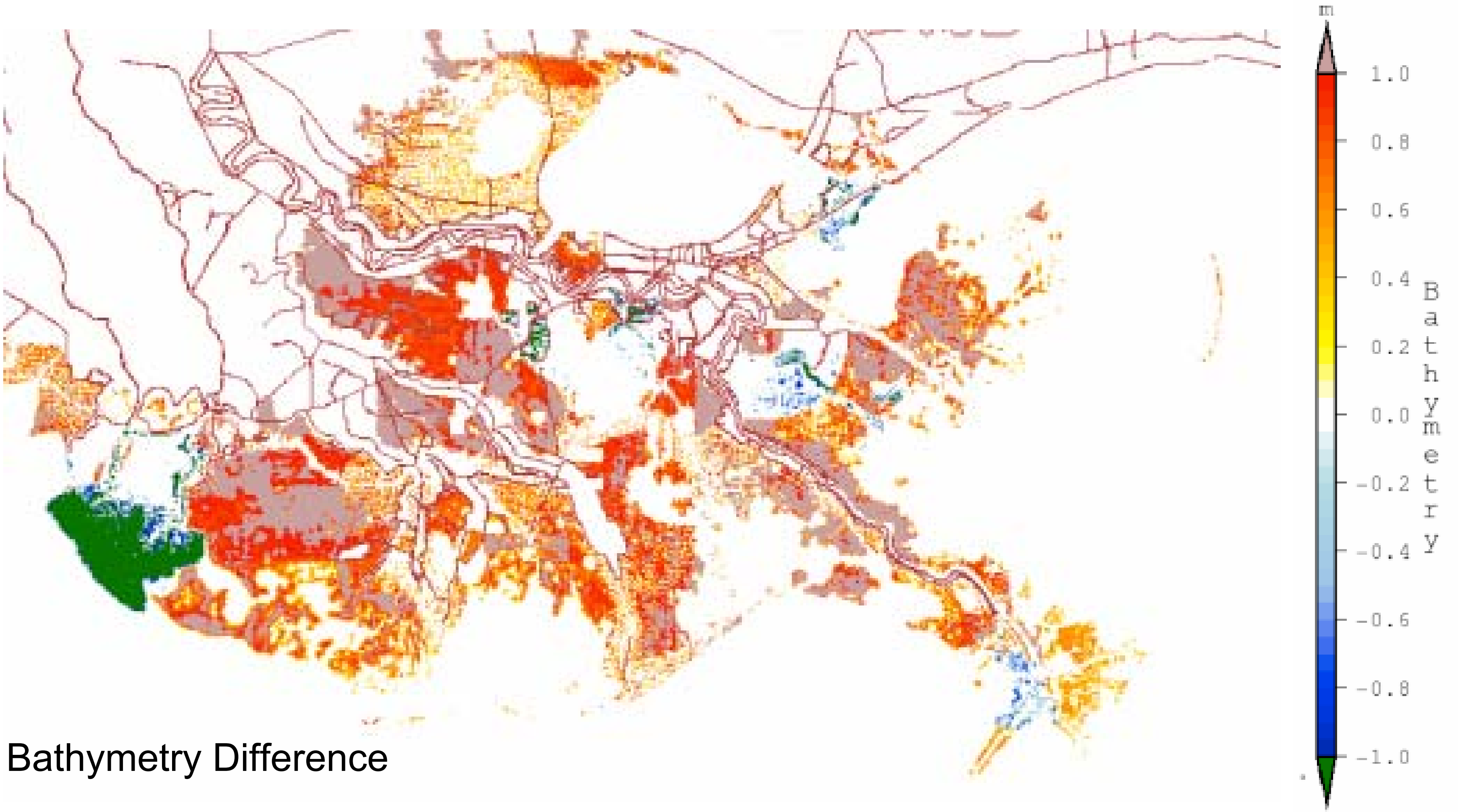
NLCD/GAP Data Year 0

CLEAR Output Cell Year 50

Spatial uncertainty - 75% Fresh Marsh
25% Water

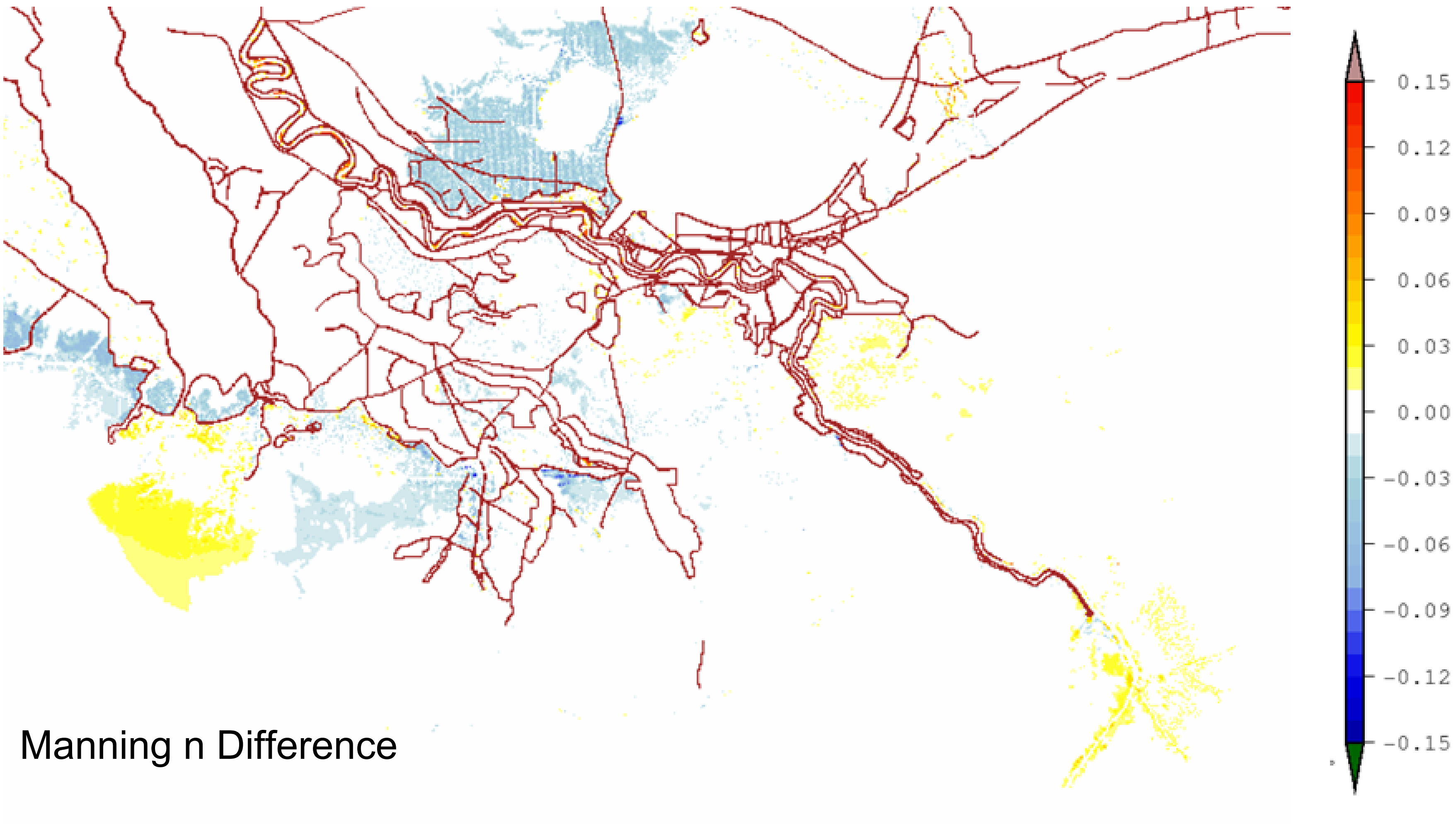


Future Degraded Landscape Changes



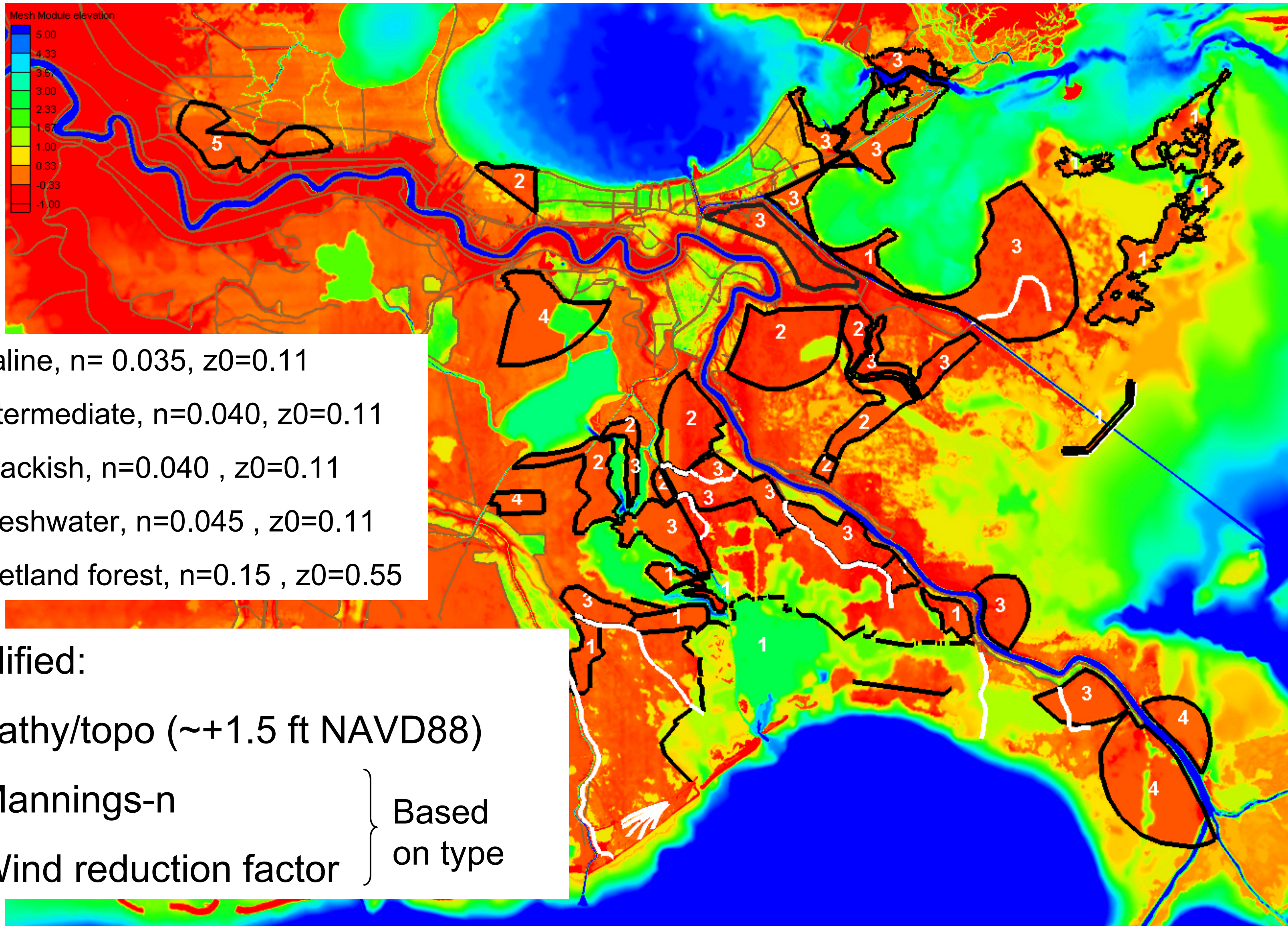
Bathymetry Difference

Future Degraded Landscape Changes



Manning n Difference

Restored Landscape



1-Saline, n= 0.035, z0=0.11

2-Intermediate, n=0.040, z0=0.11

3-Brackish, n=0.040 , z0=0.11

4-Freshwater, n=0.045 , z0=0.11

5-Wetland forest, n=0.15 , z0=0.55

Modified:

- bathy/topo (~+1.5 ft NAVD88)
- Mannings-n
- Wind reduction factor

} Based on type

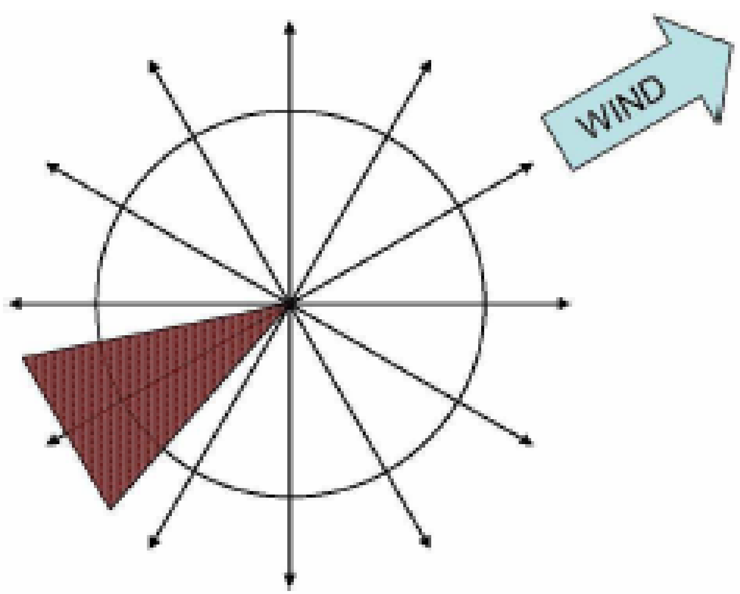
Restored Marsh

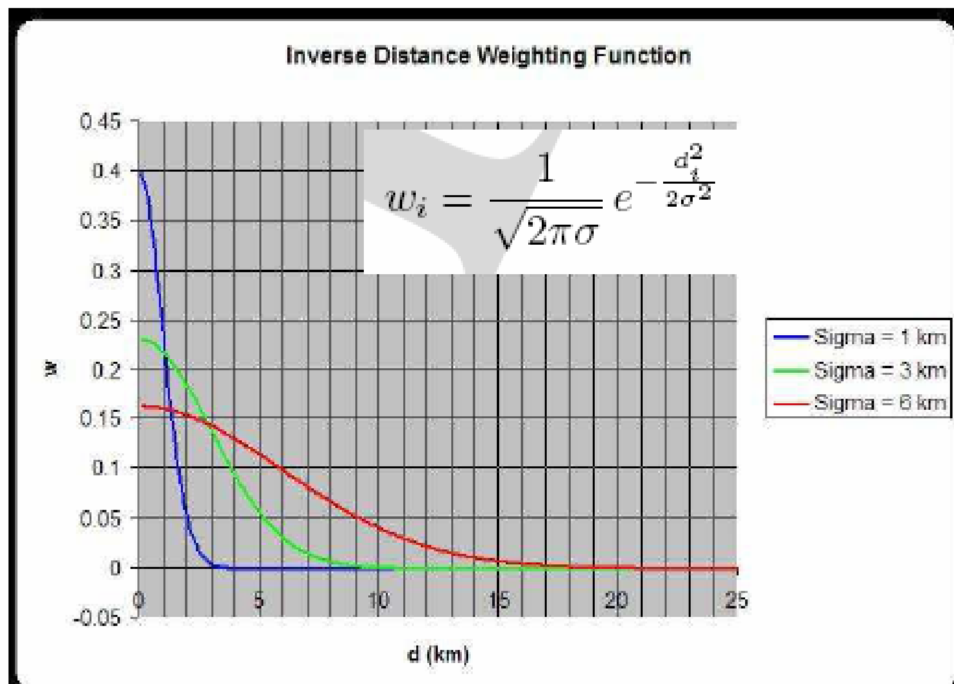
- Procedure
  - Spatial extent of wetland restoration determined
    - Constructed – given
    - Sediment Diversions
      - "Volume" of land created and diversion location is given and the marsh is built radially outward until given volume is achieved.
  - Bathy/topo raised to healthy marsh level
  - Manning n updated
  - Canopy updated
  - Directional roughness lengths calculated

(Bathy/topo raised to healthy marsh level; Manning n updated; Canopy updated: Local)

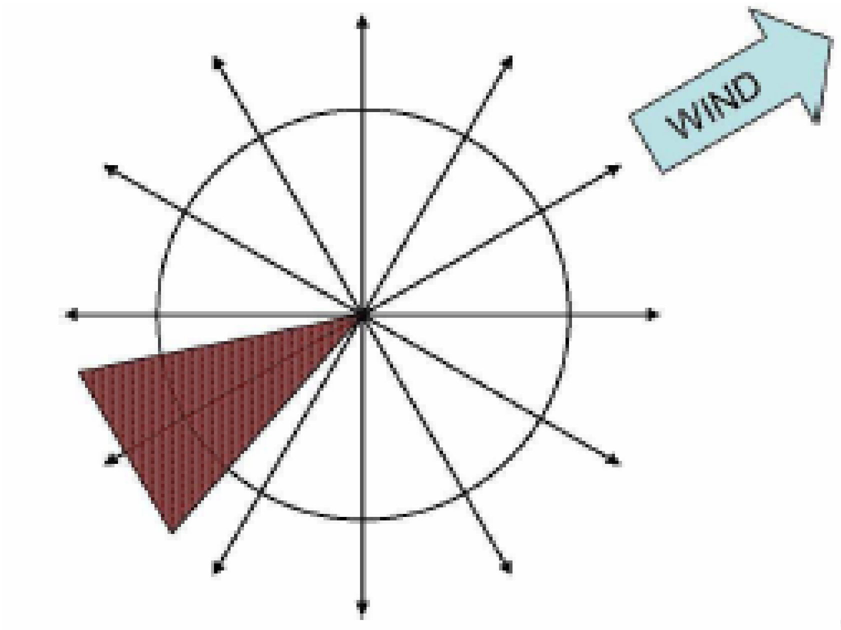
Directional Roughness Lengths

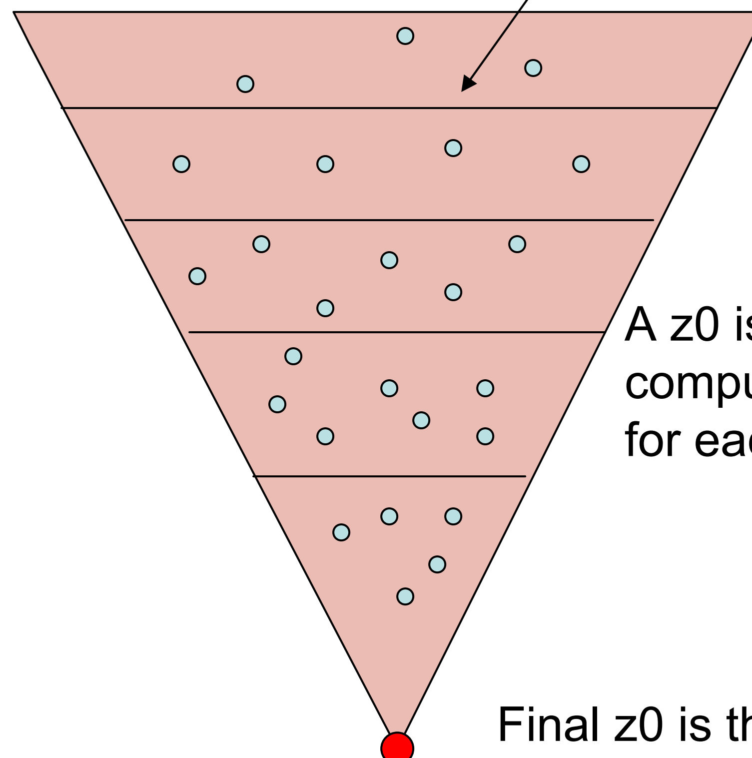
- Wind Reduction
  - Winds are reduced to account for higher surface roughness through a directional land masking procedure





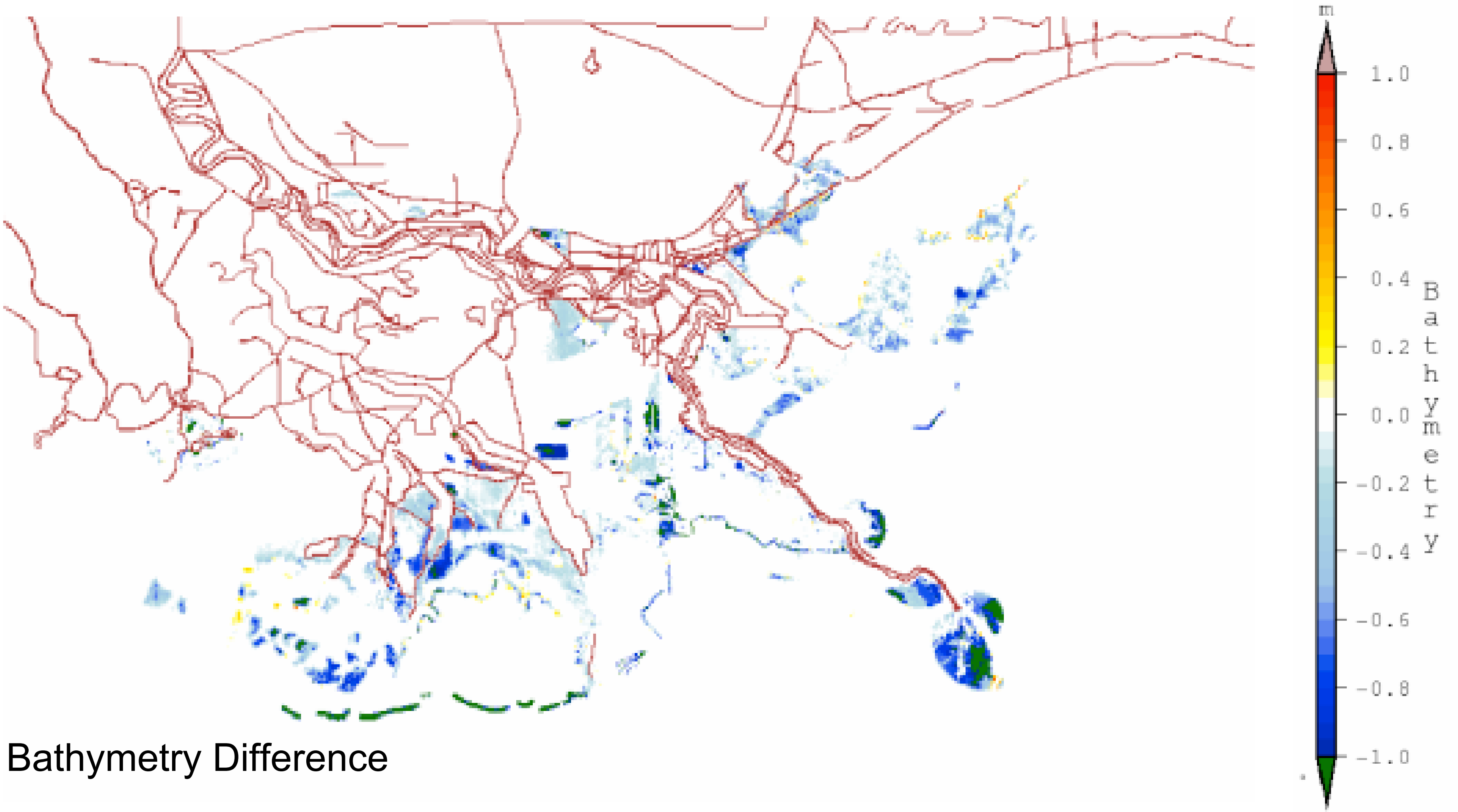
Directional Roughness Lengths





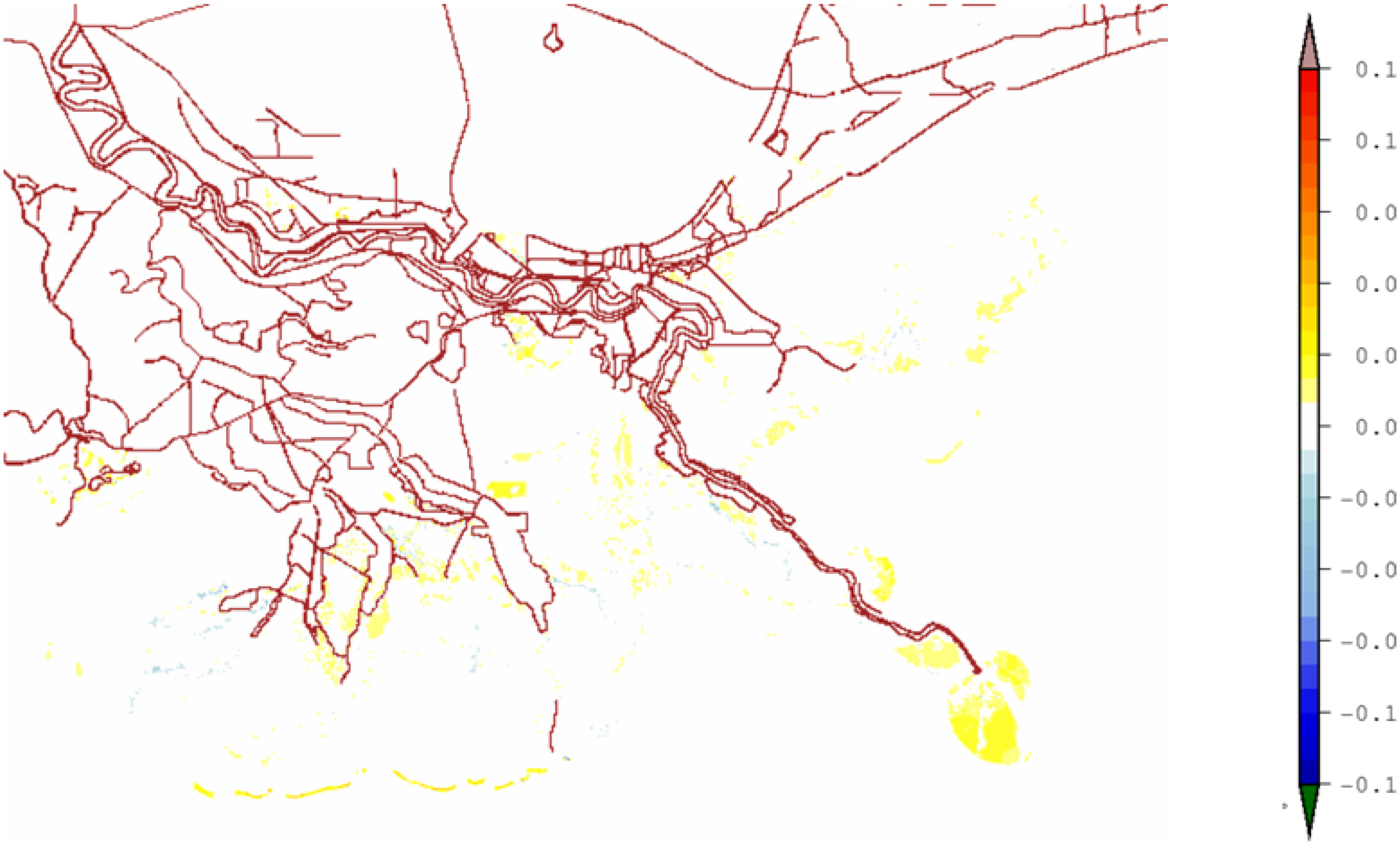
Because nodes are not equally distributed on the unstructured grid, an area weighted average method is used to compute the final inversed distance weighted z0

Restored Landscape Changes



Bathymetry Difference

Restored Landscape Changes



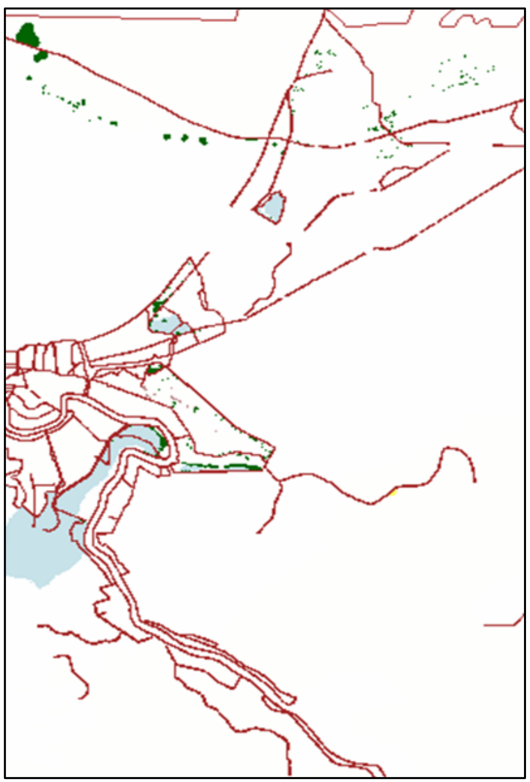
Manning n Difference

Storm Simulations

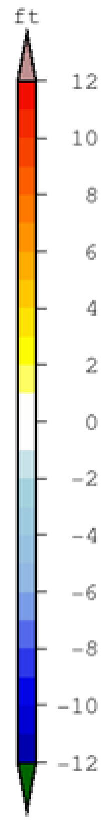
- Future No Increase Action
  - 152 storms, statistical analysis performed
- Restored Landscape
  - 24 storms simulated

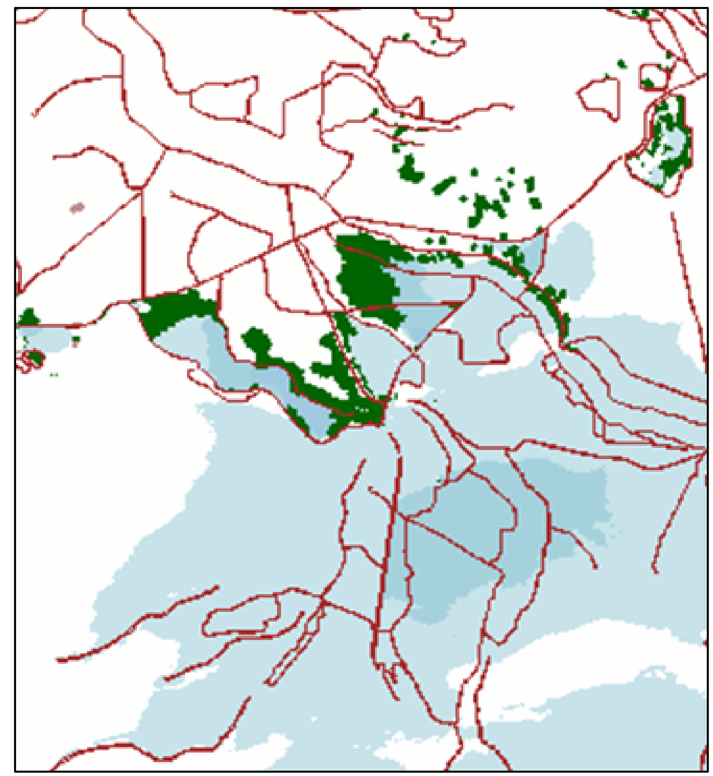
Restored Landscape

Peak of Peak Difference Plots



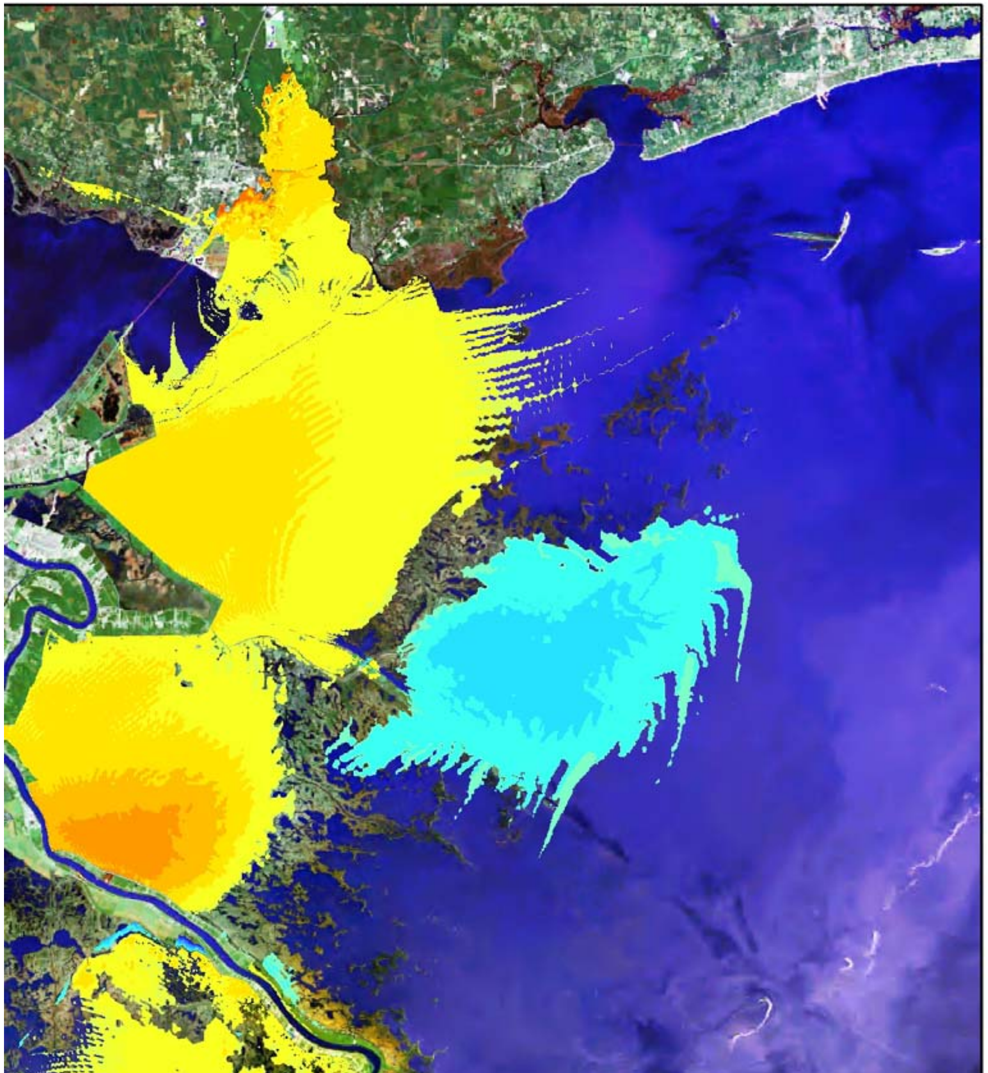
Less than 0.5 ft change east of river



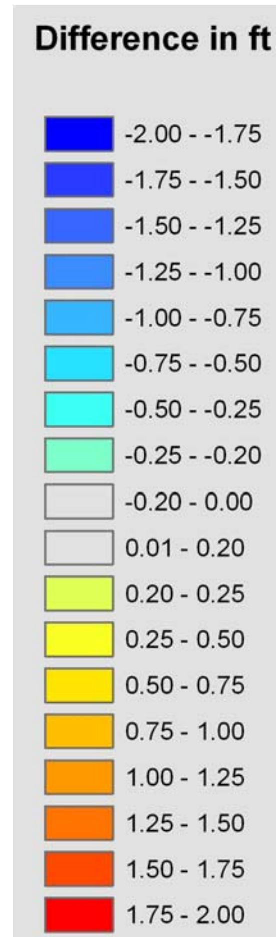


1 to 2 ft change in the Houma area

Future Degraded Landscape

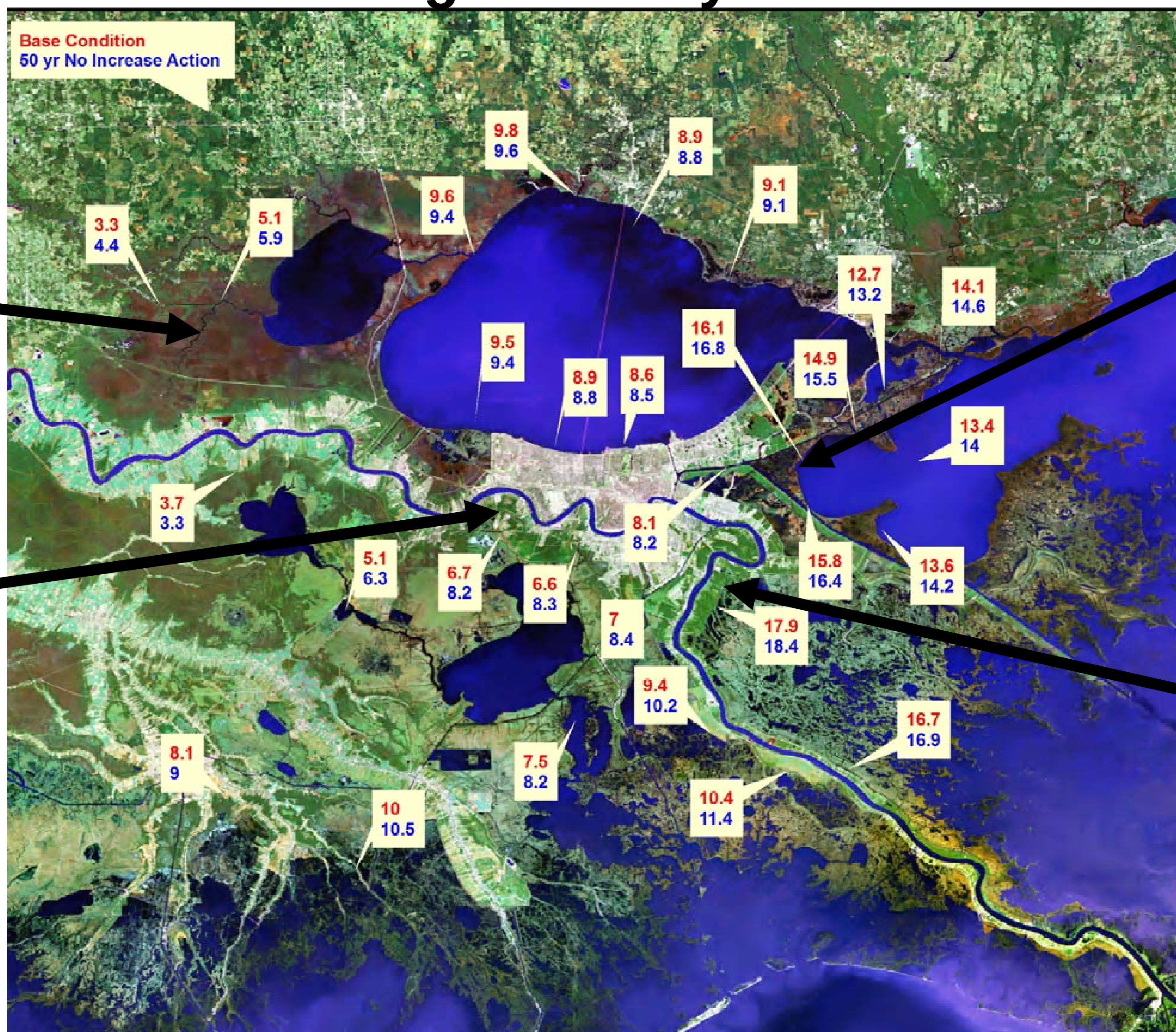


Change in 100-yr level



Future Degraded Landscape

Change in 100-yr level



Little change in Ponchartrain

Marepaus ~1 ft

Funnel ~0.75 ft

West Bank ~1 to 1.5 ft

Caernarvon ~0.5 ft

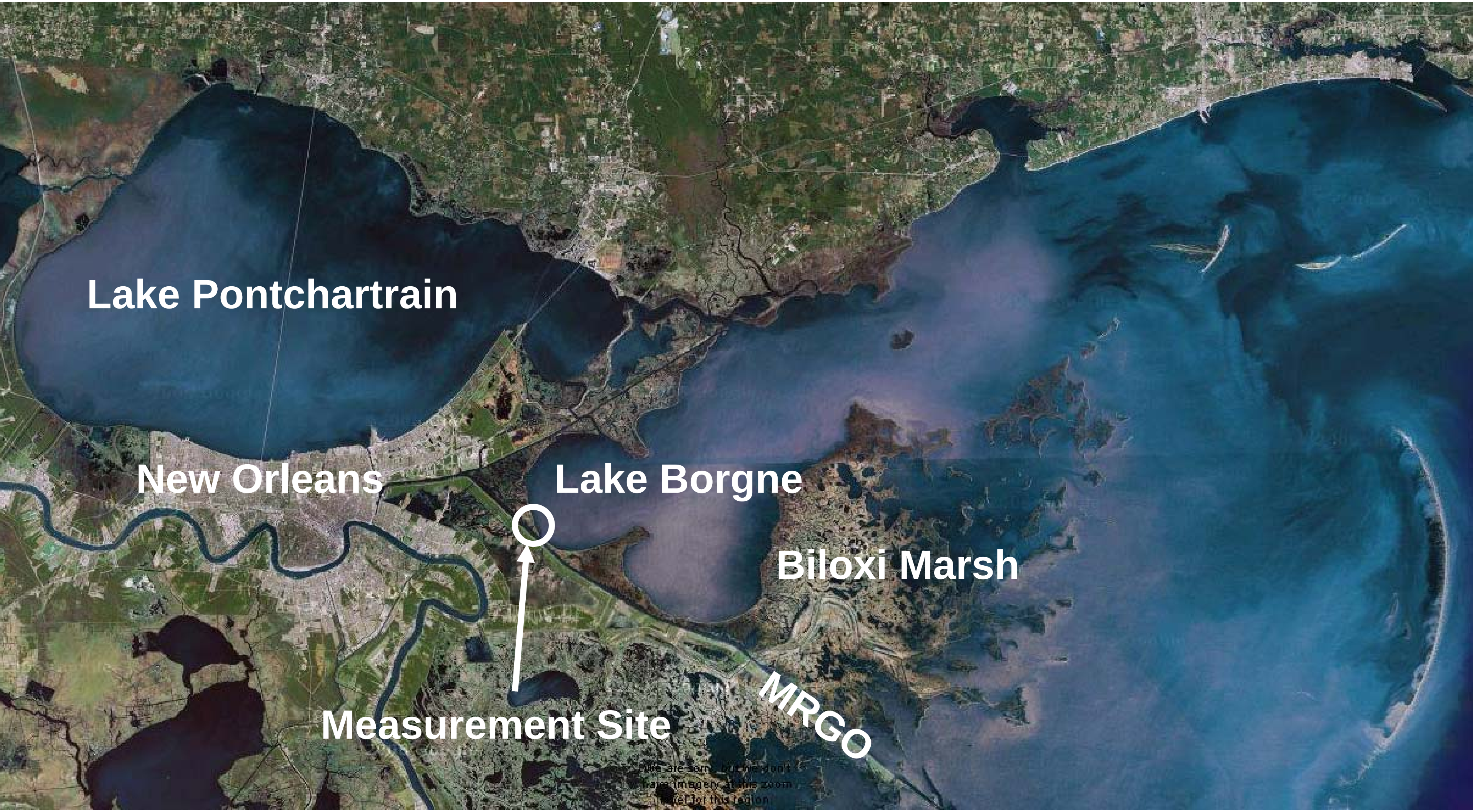
Summary

- Simulations indicate that vegetated landscape features do have surge reduction potential.
- Based on these simulations, 100-yr levels are increased for the future degraded condition by as much as 1.5 ft at the West Bank, otherwise differences are generally 0.5 ft or less.
- Impact can be amplified in areas with levee “pockets”, indicating that these may be the best area for targeted restoration activities.
- Large continuous restorations provide maximum benefit, significant change would require restoration efforts at the landscape scale.
- Lesson: Keep what you have.
- More data and research is needed.

Lake Borgne Measurements

- Measure wave attenuation and water levels across wetlands
  - Four non-directional wave/water level gauges
  - Anemometer
  - Characterization of wetland (elevation, plant type, plant density, plant height, …)

Lake Borgne Field Site



Lake Borgne Deployment

1000-2000 ft of wetland lake-ward of Gauges 2, 3, and 4.

Gauge 1 is reference.

End

Parameterizations of Frictional Resistance

- Wind Reduction
  - Winds in ADCIRC and STWAVE are reduced to account for higher surface roughness through a directional land masking procedure

Roughness length scales

$$f_r = \left(\frac{z_{0_{marine}}}{z_{0_{land}}} \right)^{0.0706}$$

Varies w/land cover and quantified by FEMA-HAZUS study (NLCD)

$$z_{0_{marine}} = \frac{\alpha_c C_d W_{10}^2}{g}$$

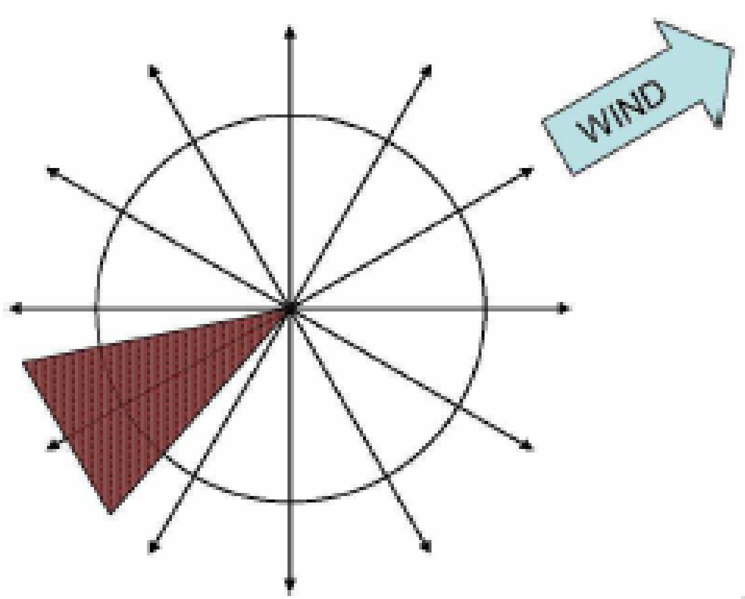
α_c=0.18 (Charnock parameter)

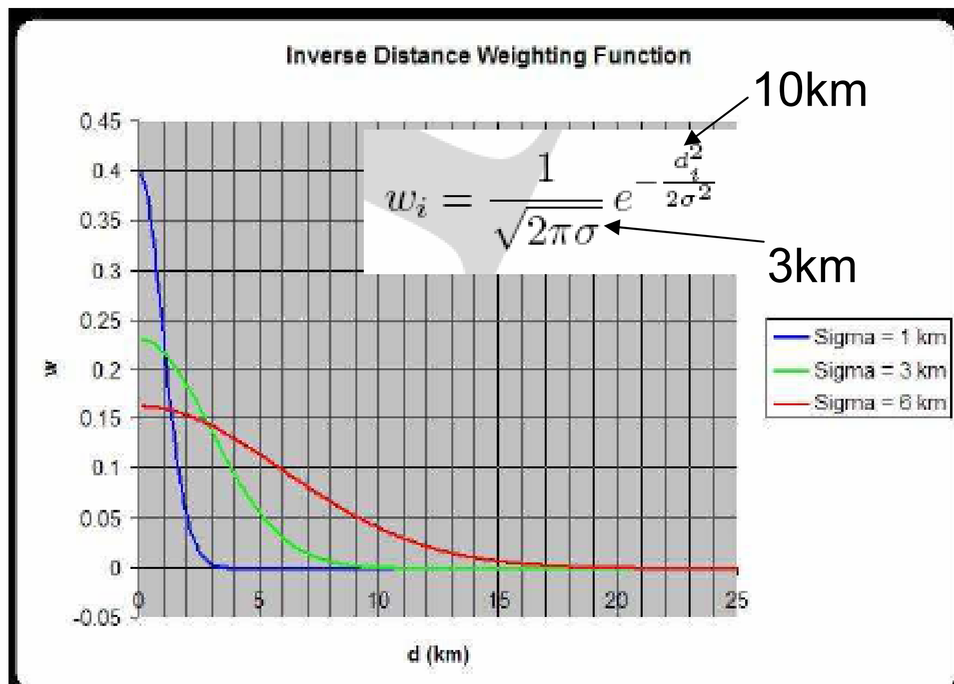
As inundation takes place, roughness is reduced

$$z_0' = z_{0land} - \frac{d}{30} \quad \text{for} \quad z_0' \geq z_{0_{marine}}$$

Parameterizations of Frictional Resistance

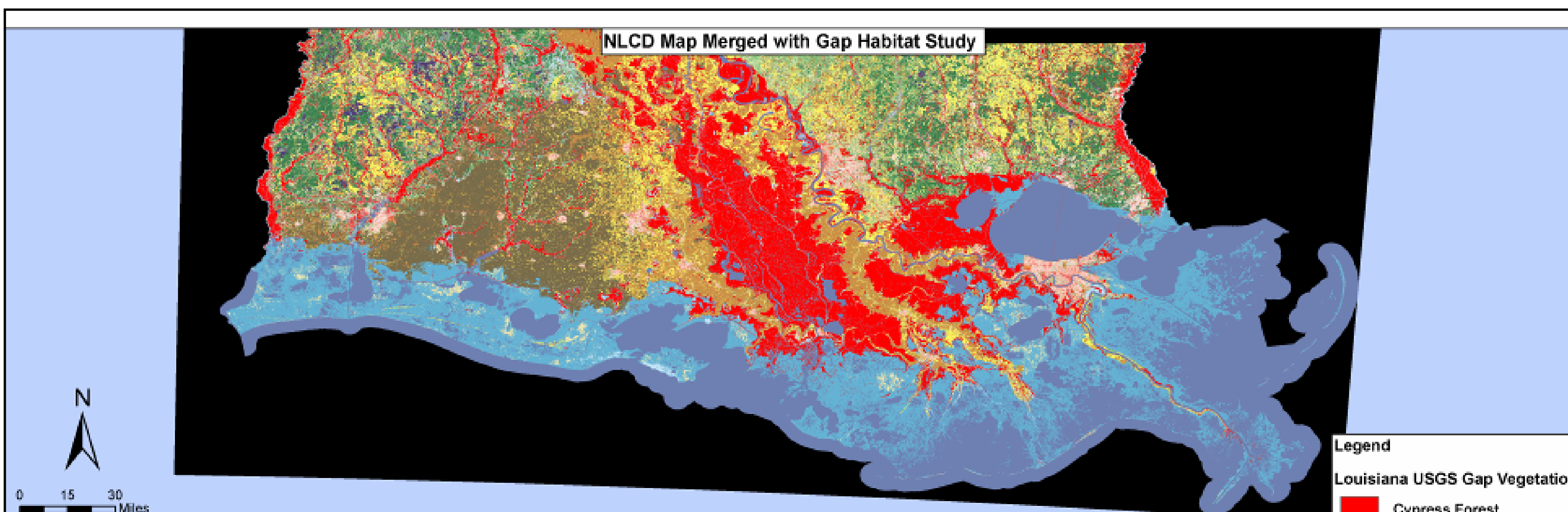
- Wind Reduction
  - Winds in ADCIRC and STWAVE are reduced to account for higher surface roughness through a directional land masking procedure





Parameterizations of Frictional Resistance

- Wind Reduction
  - A canopy is applied to areas classified as NLCD/GAP forest precluding momentum transfer from the wind fields to the water column



Parameterizations of Frictional Resistance

- Manning-n scalar parameterization used to approximate flow resistance from a variety of physical mechanisms, including form drag, skin friction, and secondary currents.

Manning-n values for Louisiana GAP classes (FEMA 2005):

n = 0.055	! fresh marsh
n = 0.050	! intermediate marsh
n = 0.045	! brackish marsh
n = 0.035	! saline marsh
n = 0.15	! wetland forest - mixed
n = 0.17	! upland forest - mixed
n = 0.18	! dense pine thicket
n = 0.020	! water

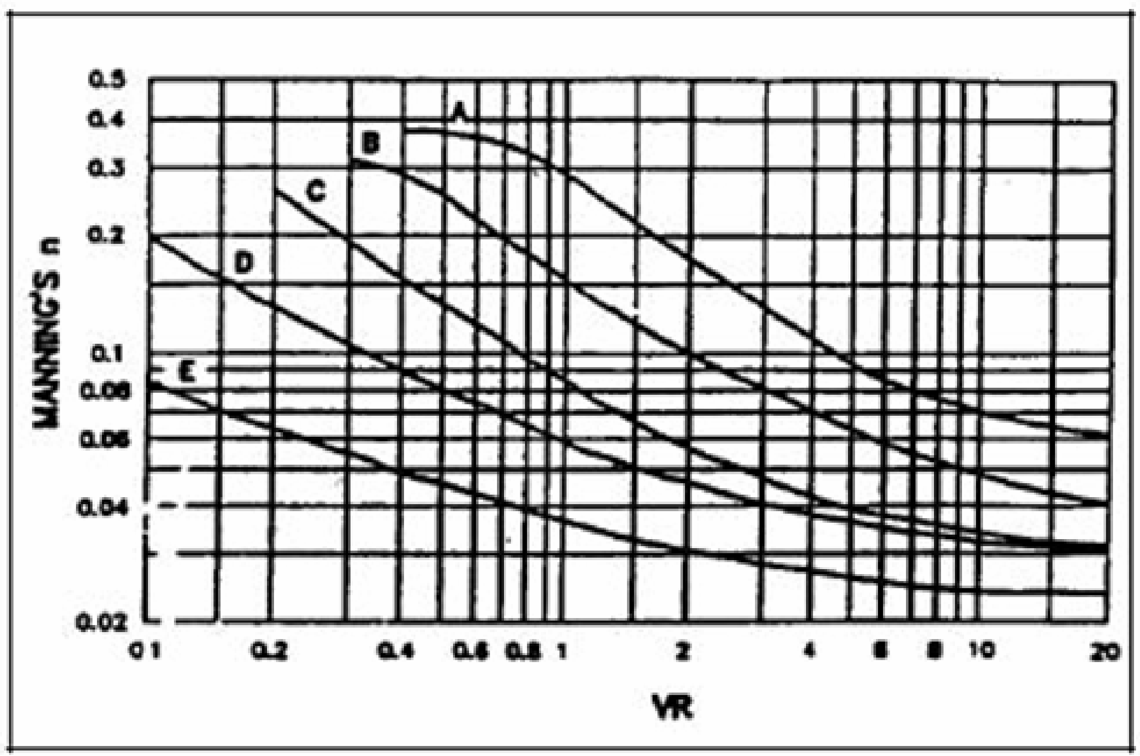
-defined at appropriate grid scale

-published values

-validated against hindcasts of hurricanes Katrina and Rita

Parameterizations of Frictional Resistance

- Factors influencing Manning-n value.



Turbulence ↑ => n ↓

Veg "damage" ↑ => n ↓

Modeling a 3D process with a depth-integrated model?? => n ↓

More data needed!

STWAVE

- Restoration impacts on nearshore waves:
  - Depth (refraction, shoaling, **breaking**)
    - Still-water depth
    - Surge
  - Wind (generation)
  - Friction (through Manning formulation, dissipation is a function of water depth and vegetation type)

$$S_{bf} = \frac{-1}{g}\left(\frac{gn^2}{d^{1/3}}\right)\frac{\sigma^2}{\sinh^2 kd}E(f,\alpha)u_{rms}$$

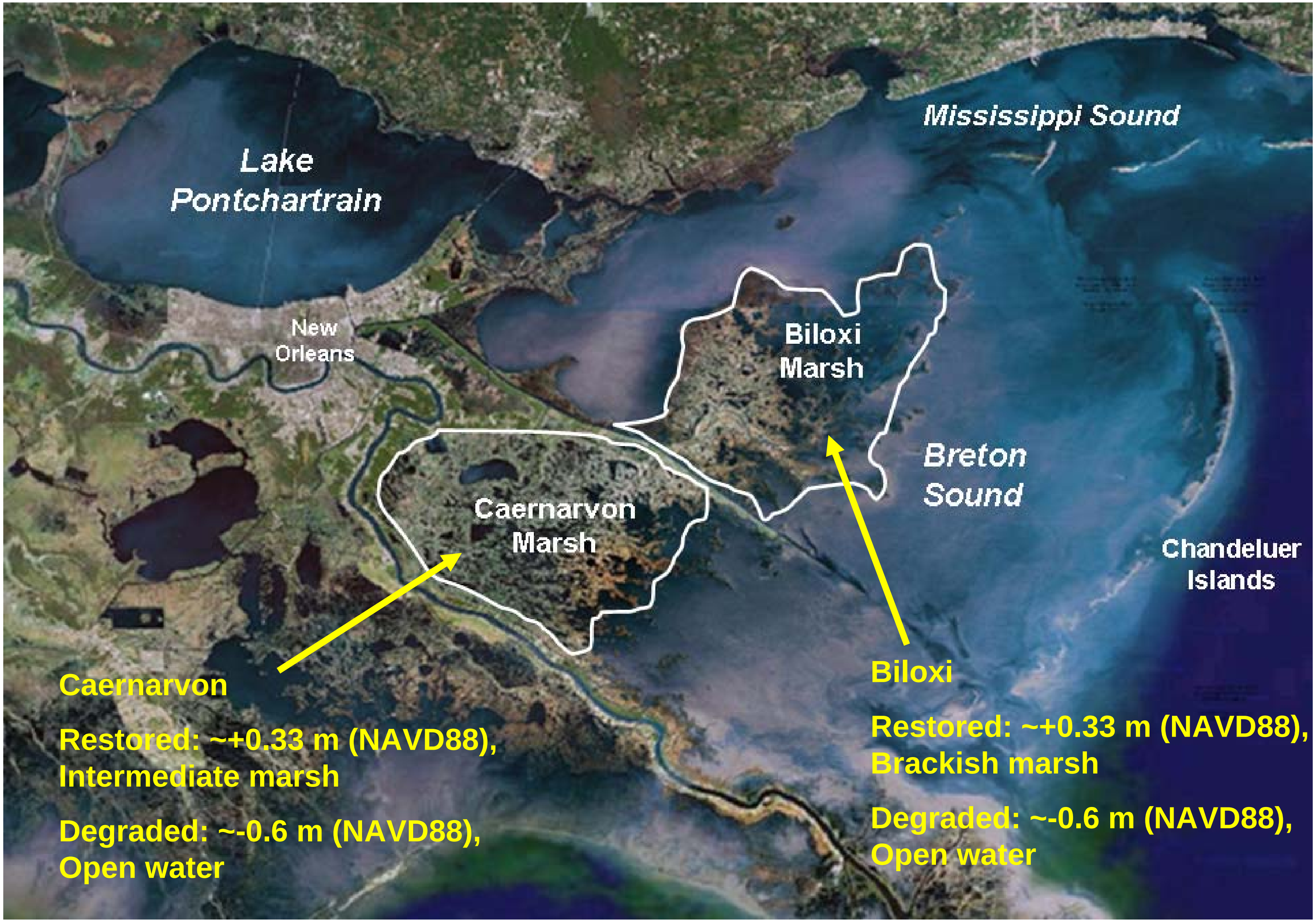
Spectral-based dissipation source term

Holtuijsen (2007)

Wetland Conditions

- Base Condition
- Caernarvon marsh restoration and deterioration
- Biloxi marsh restoration and deterioration
- Coast-wide restored marshes
- Future No Increased Action coastal landscape.

Wetland Restoration/Degradation

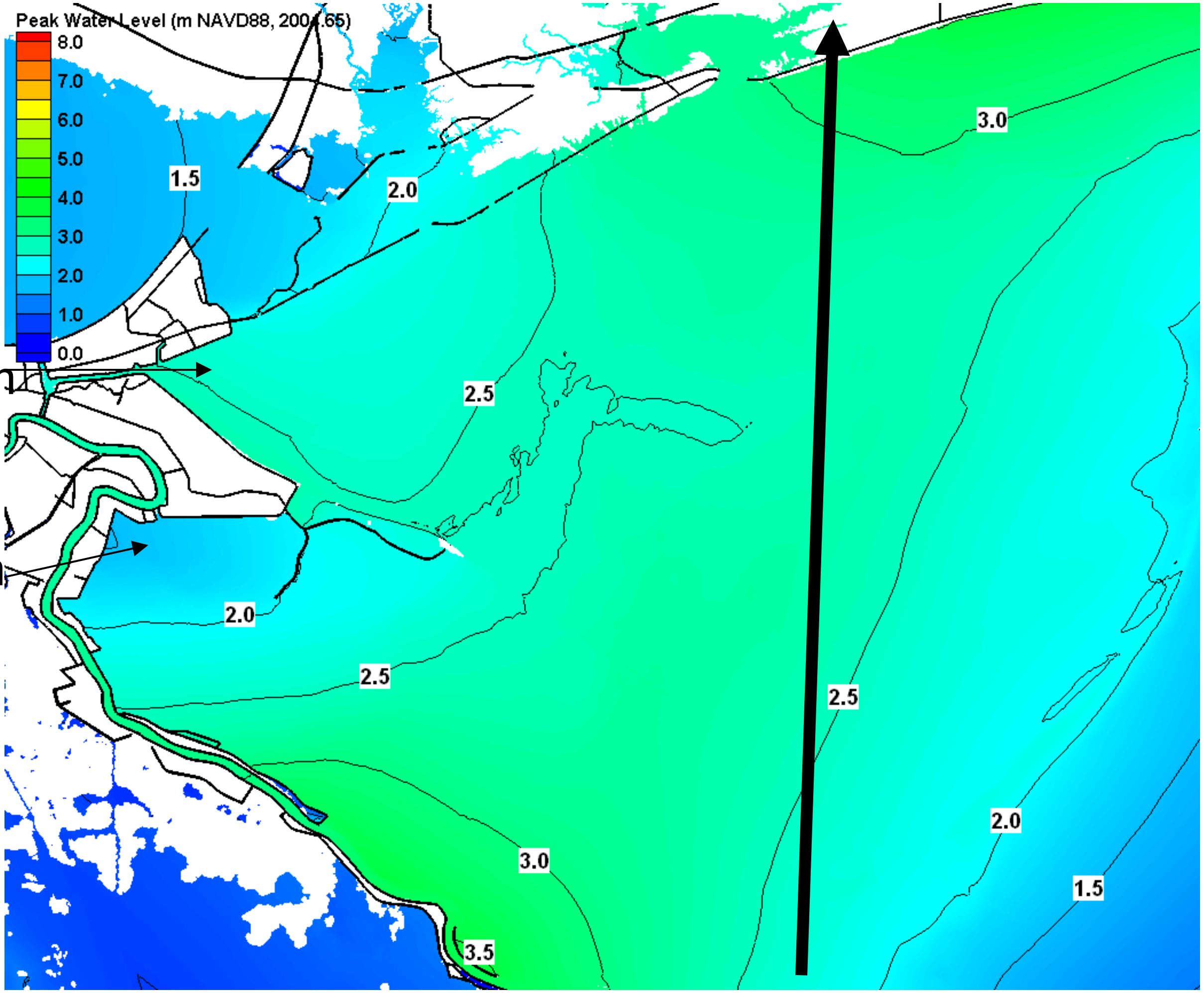


Storm HUR1

HUR1 (Hurricane Hilda-like)

- **Central Pressure: 960 mb**
- **Rmax: 22 nm**
- **Forward Speed: 11 knots**

Peak Surge



2.5 m

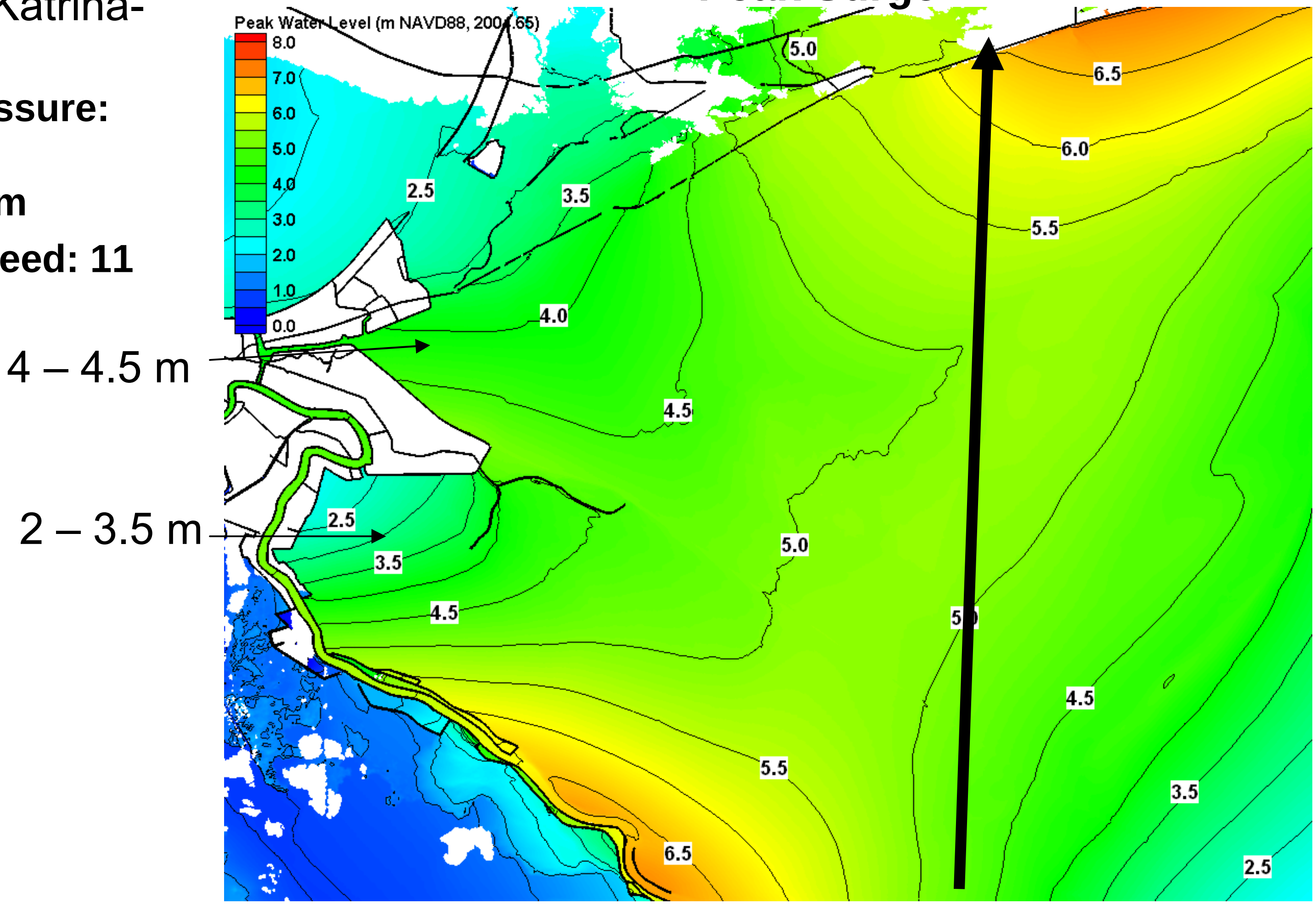
1.5 - 2 m

Storm HUR2

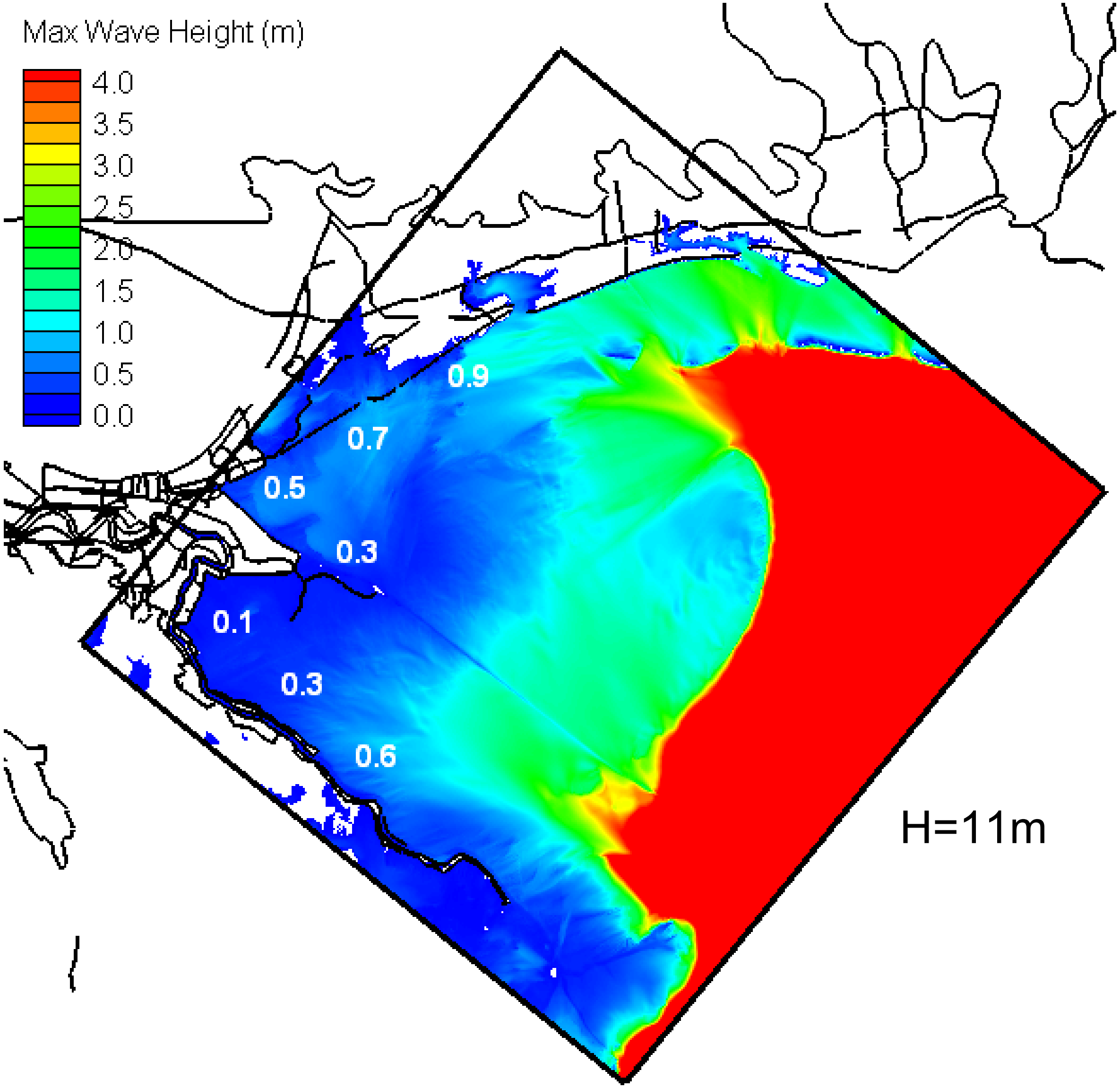
HUR2 (Hurricane Katrina-like)

- **Central Pressure: 900 mb**
- **Rmax: 22 nm**
- **Forward Speed: 11 knots**

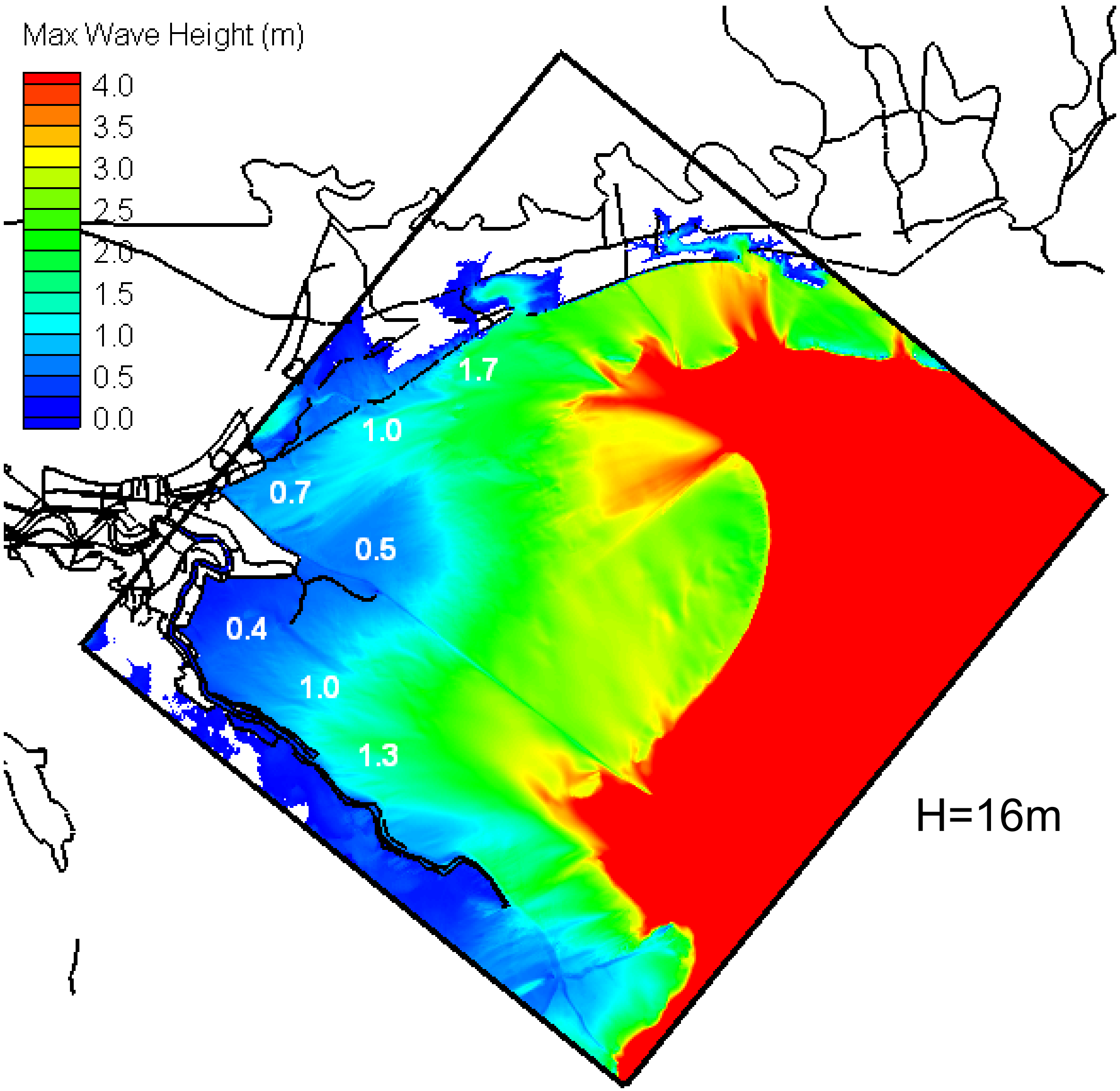
Peak Surge



Max Wave Height HUR1

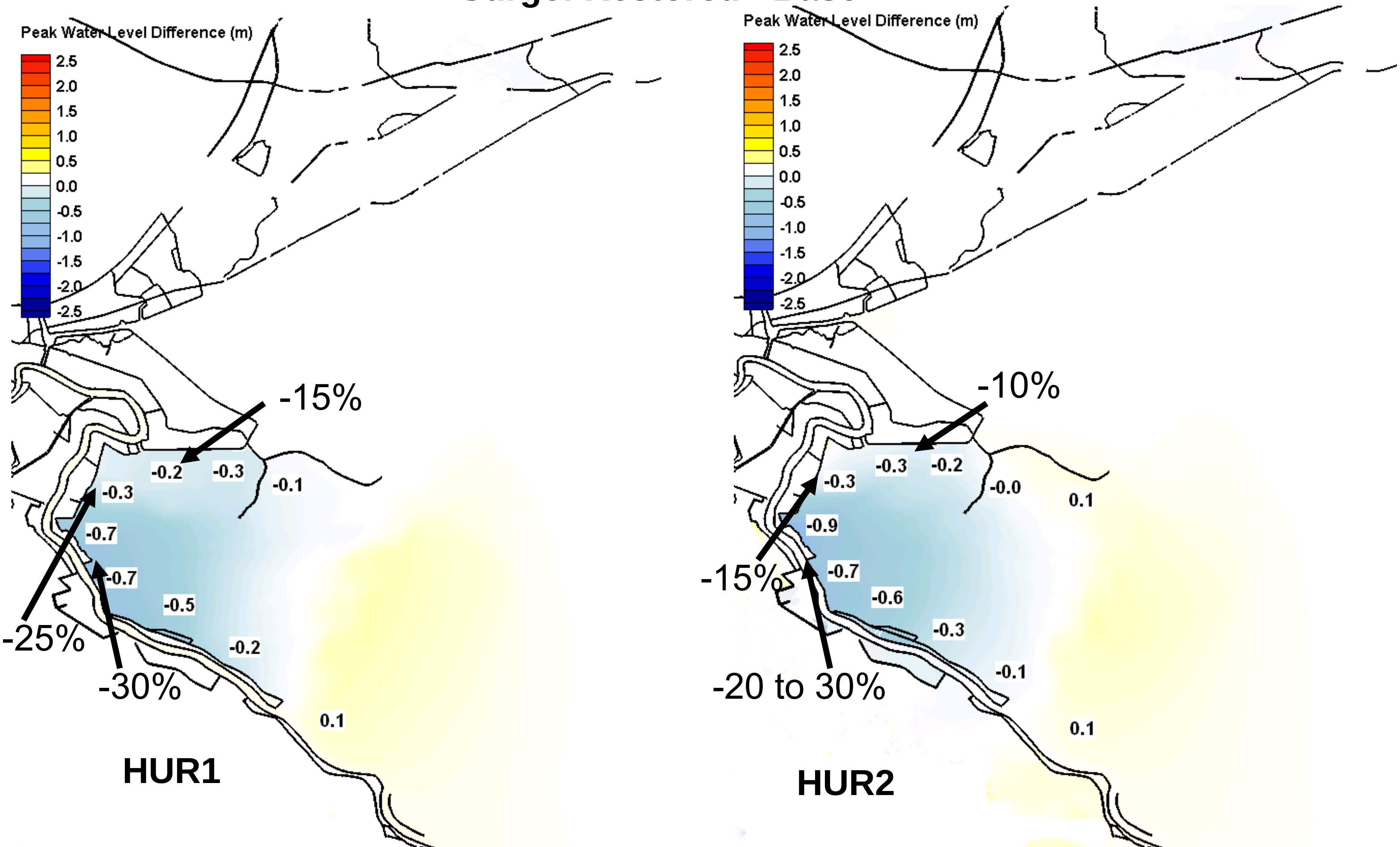


Max Wave Height HUR2



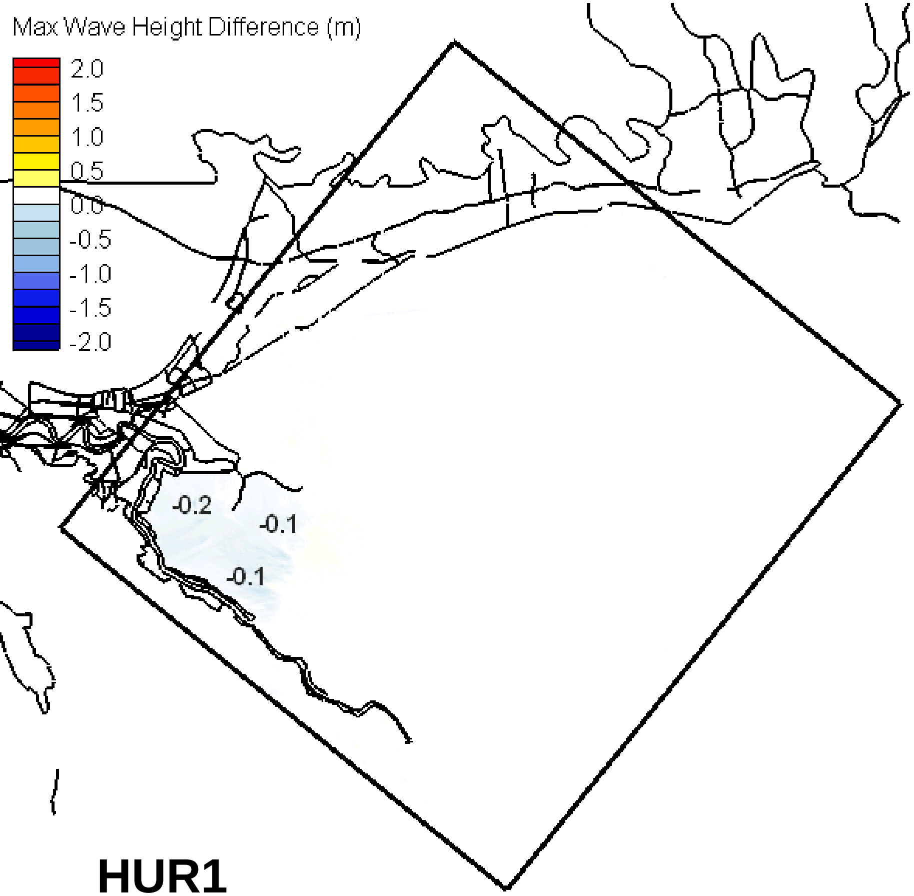
Caernarvon Restoration

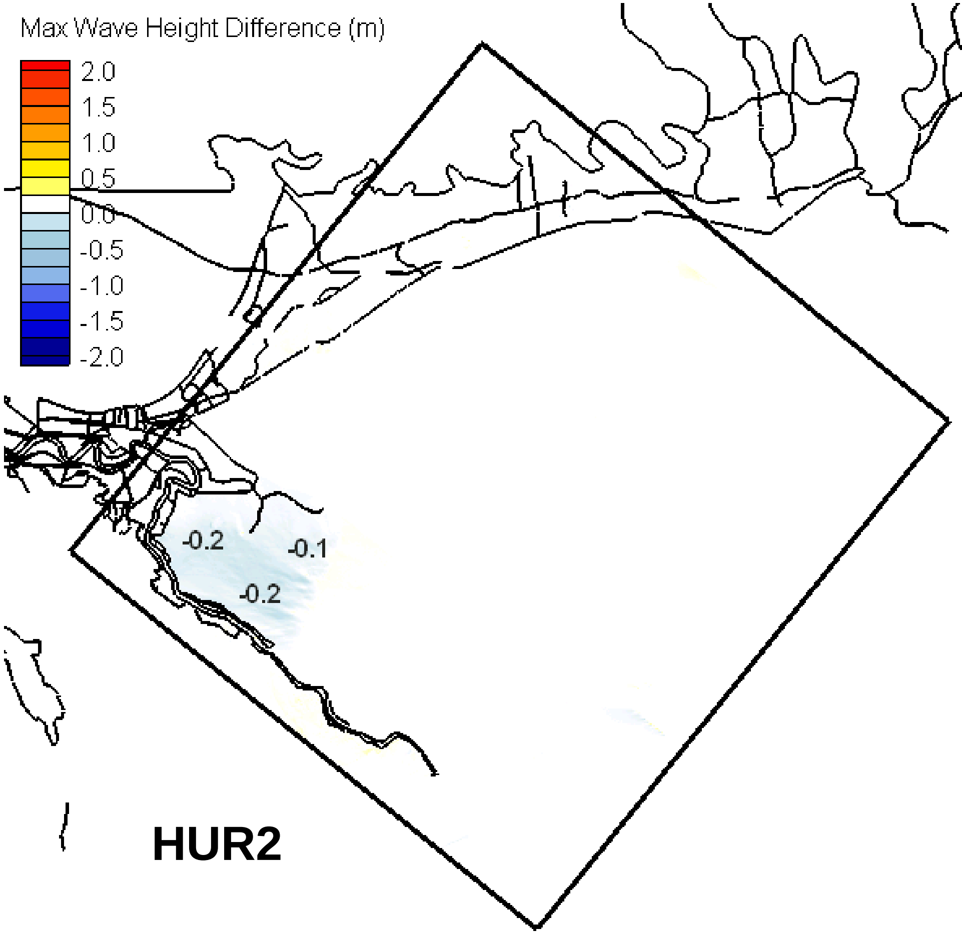
Surge: Restored - Base



Caernarvon Restoration

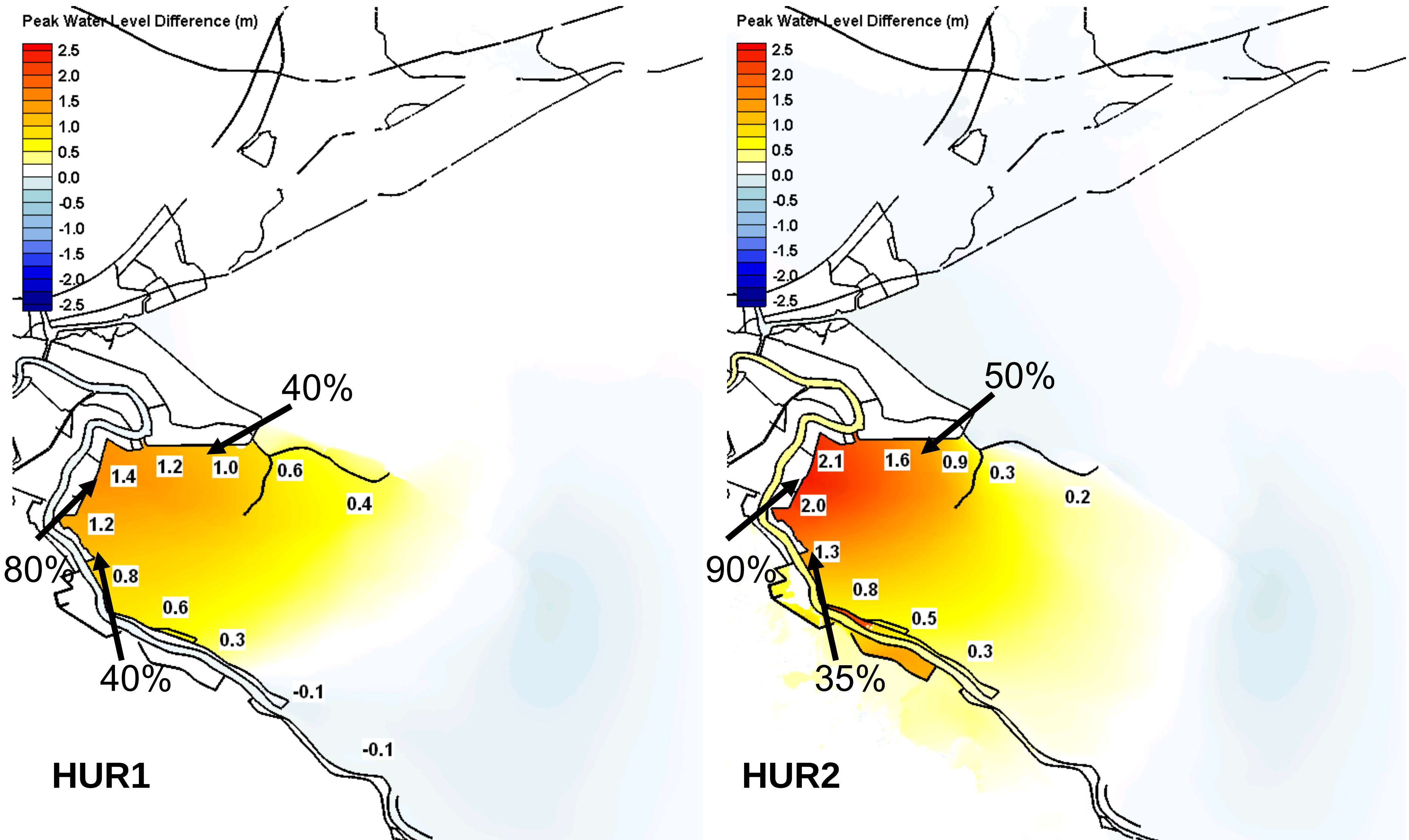
Waves: Restored - Base





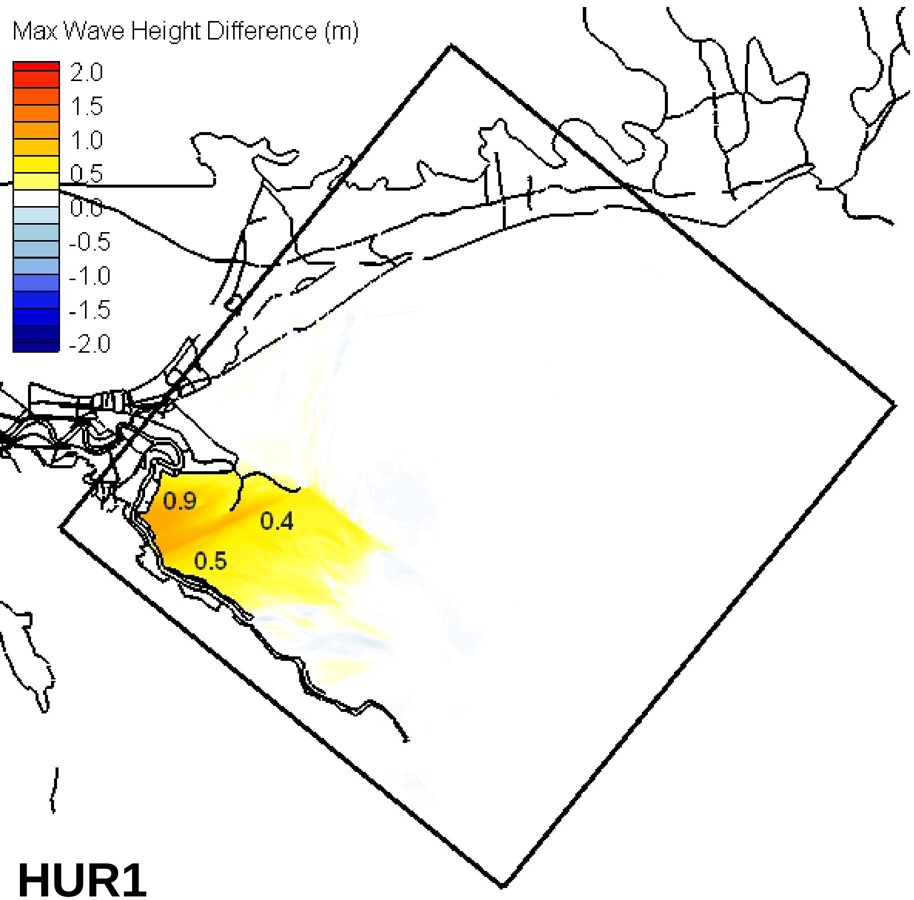
Caernarvon Degradation

Surge: Degraded - Base

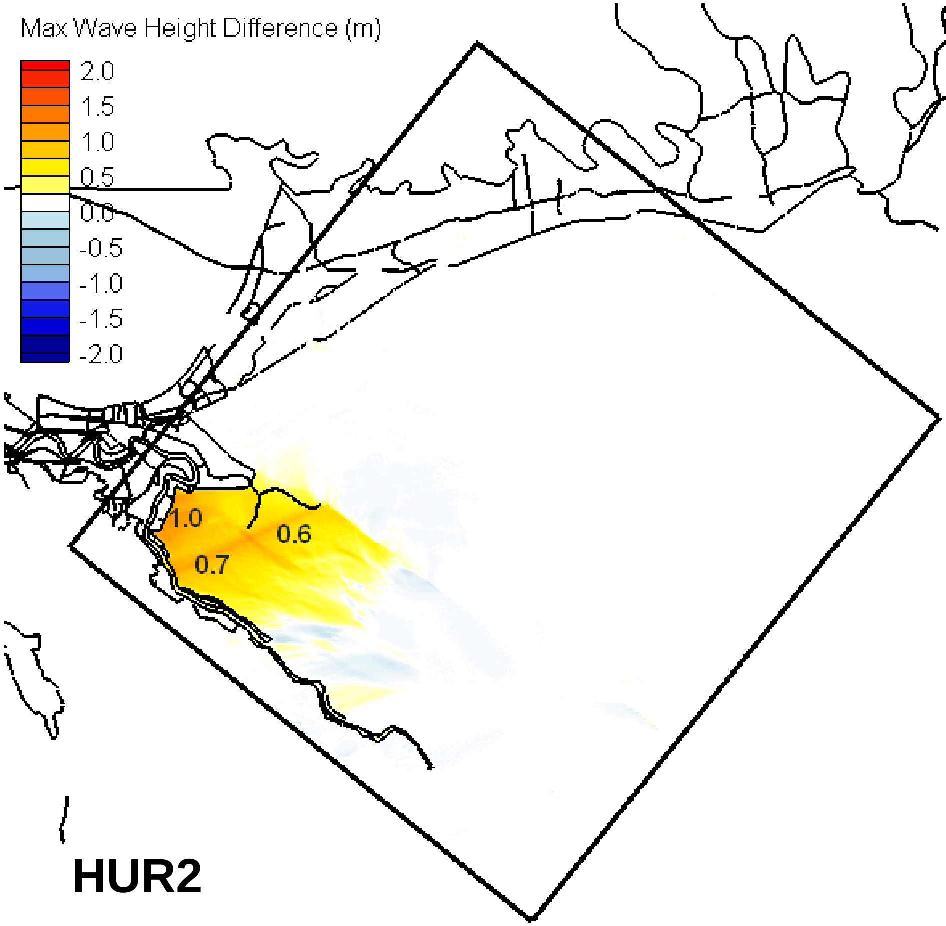


Caernarvon Degradation

Waves: Degraded - Base



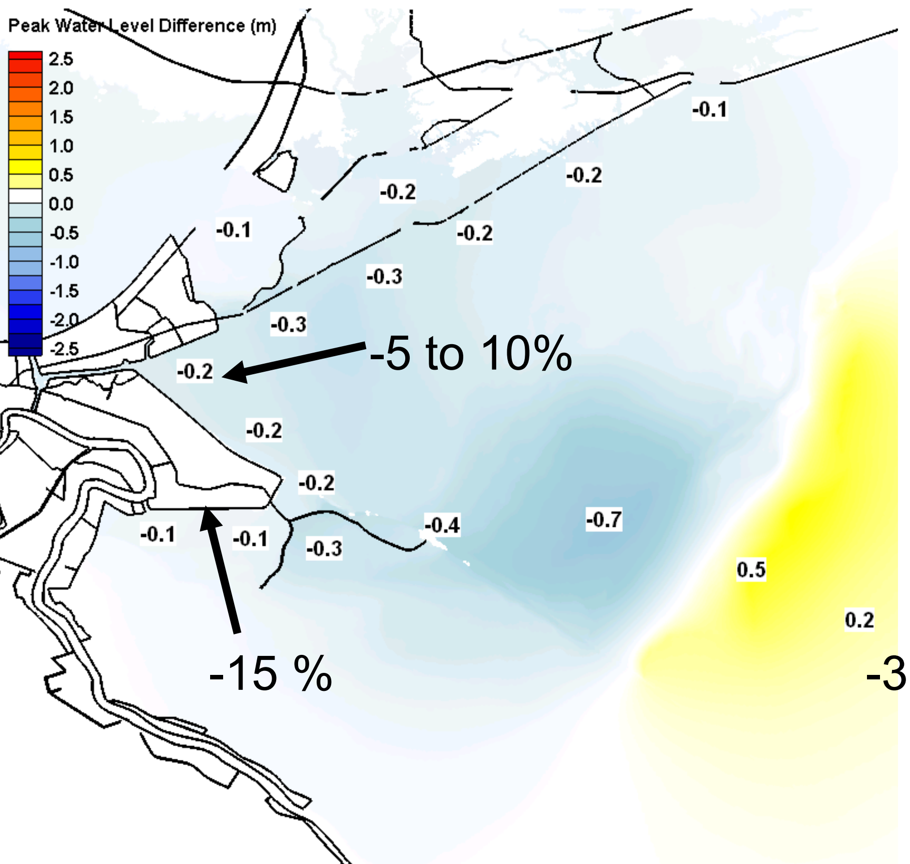
HUR1



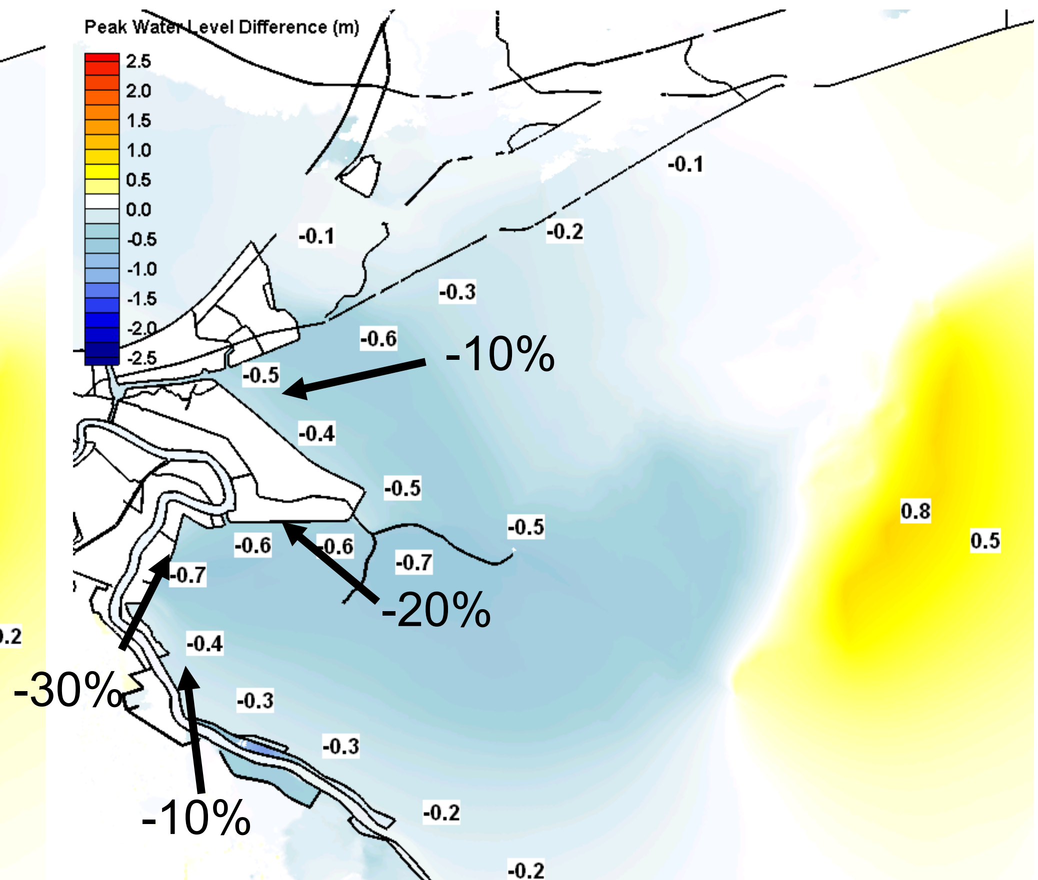
HUR2

Biloxi Restoration

Surge: Restored - Base



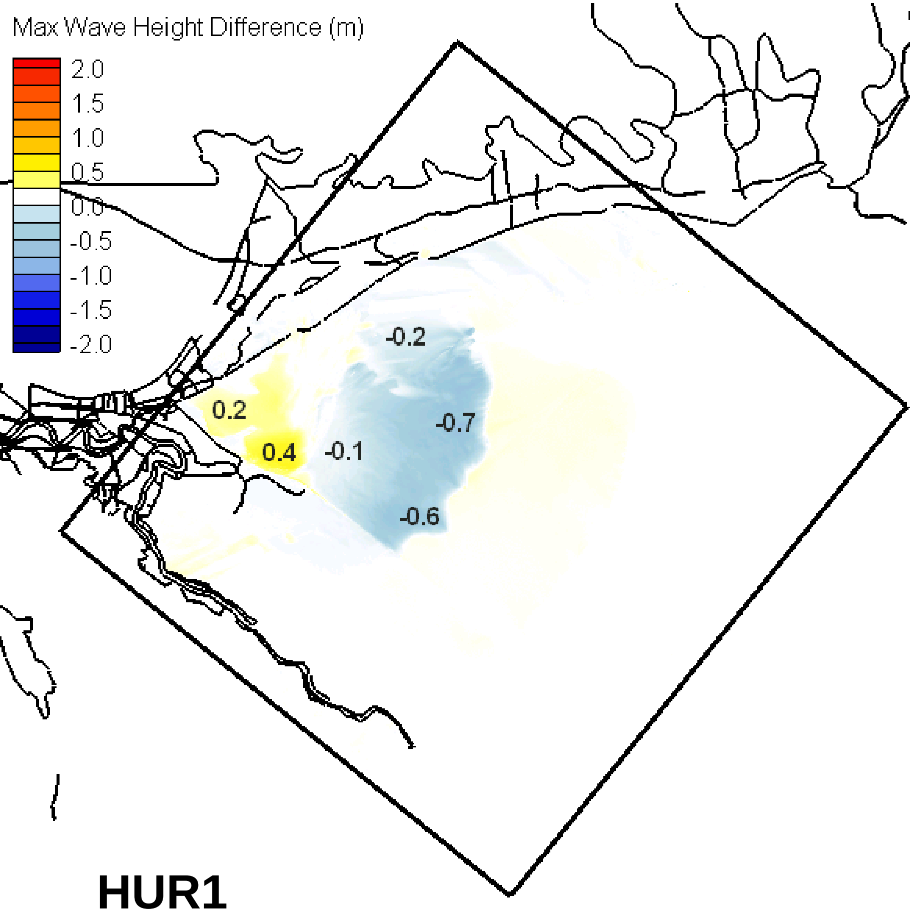
HUR1



HUR2

Biloxi Restoration

Waves: Restored - Base



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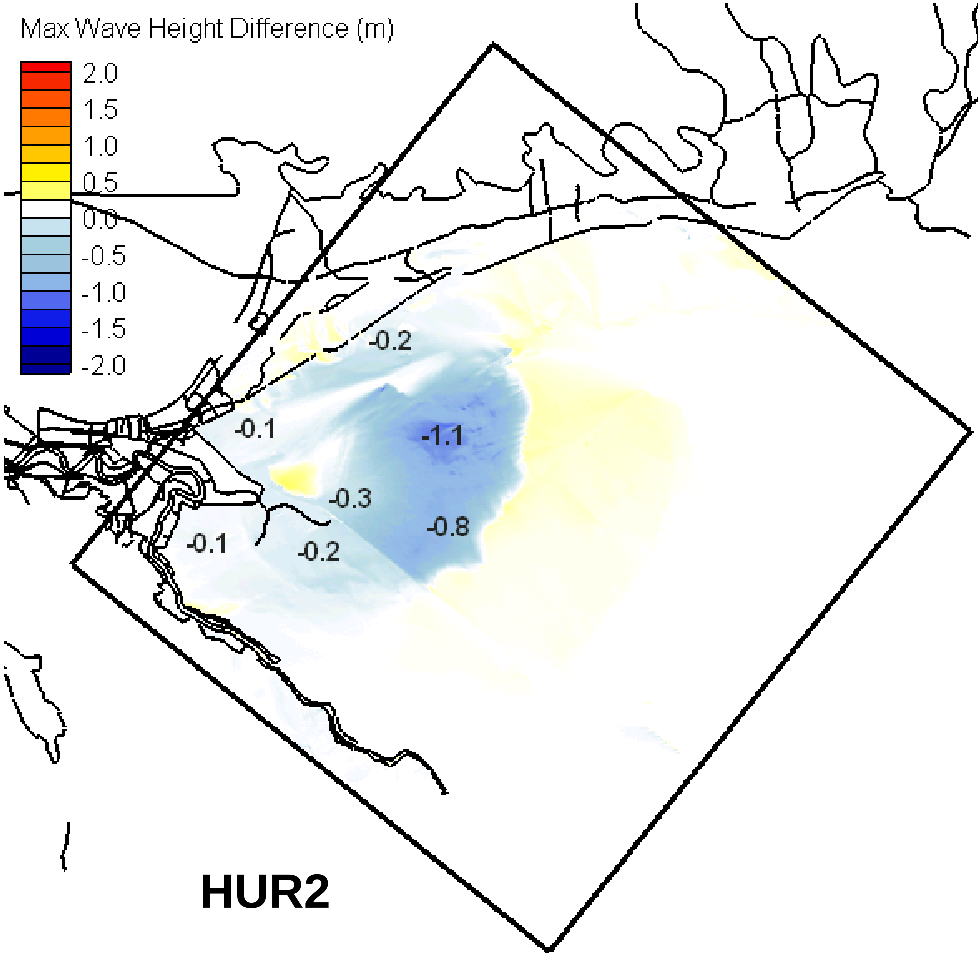
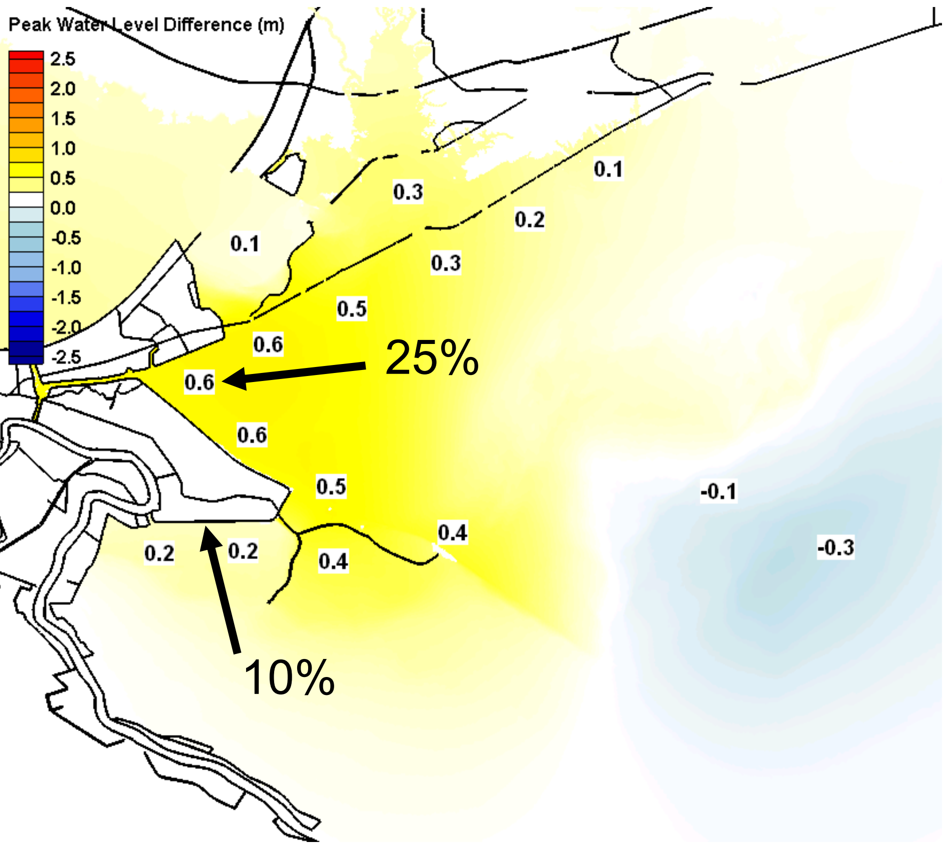


HUR2

Biloxi Degradation

Surge: Degraded - Base



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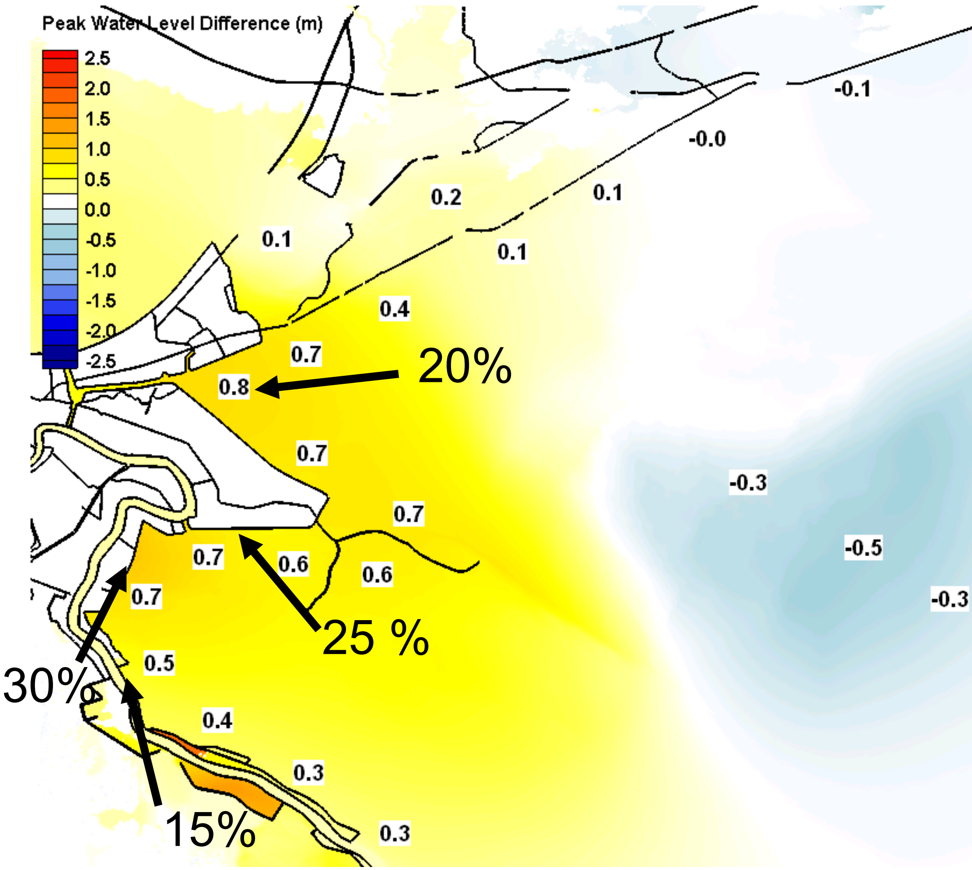
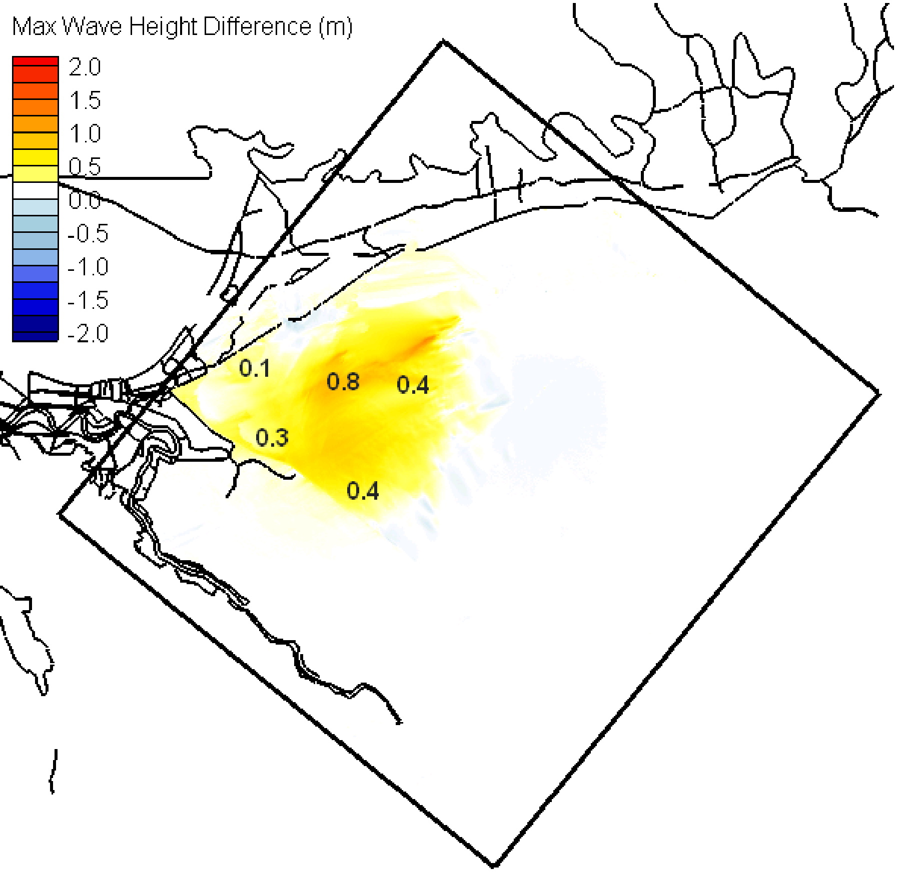


HUR2

Biloxi Degradation

Waves: Degraded - Base



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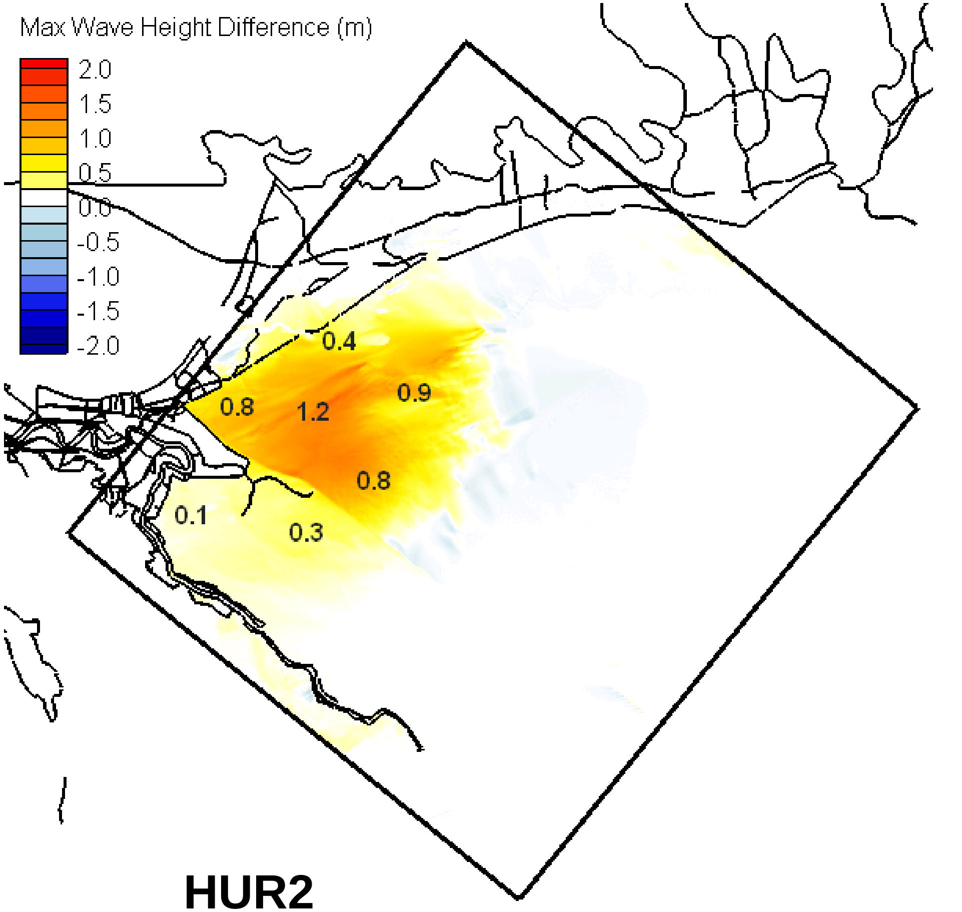
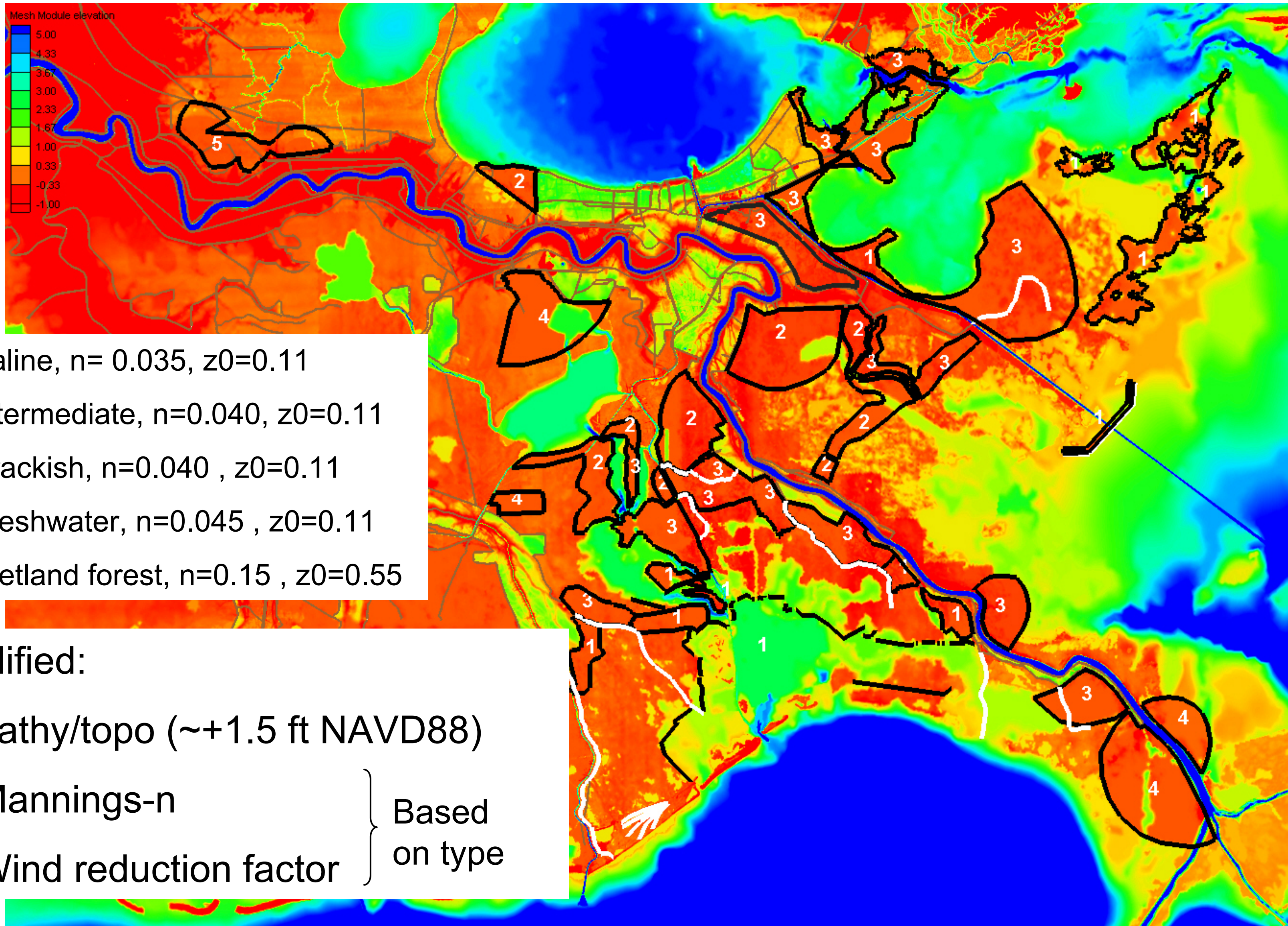


HUR2

Restored Landscape



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5-Wetland forest, n=0.15 , z0=0.55

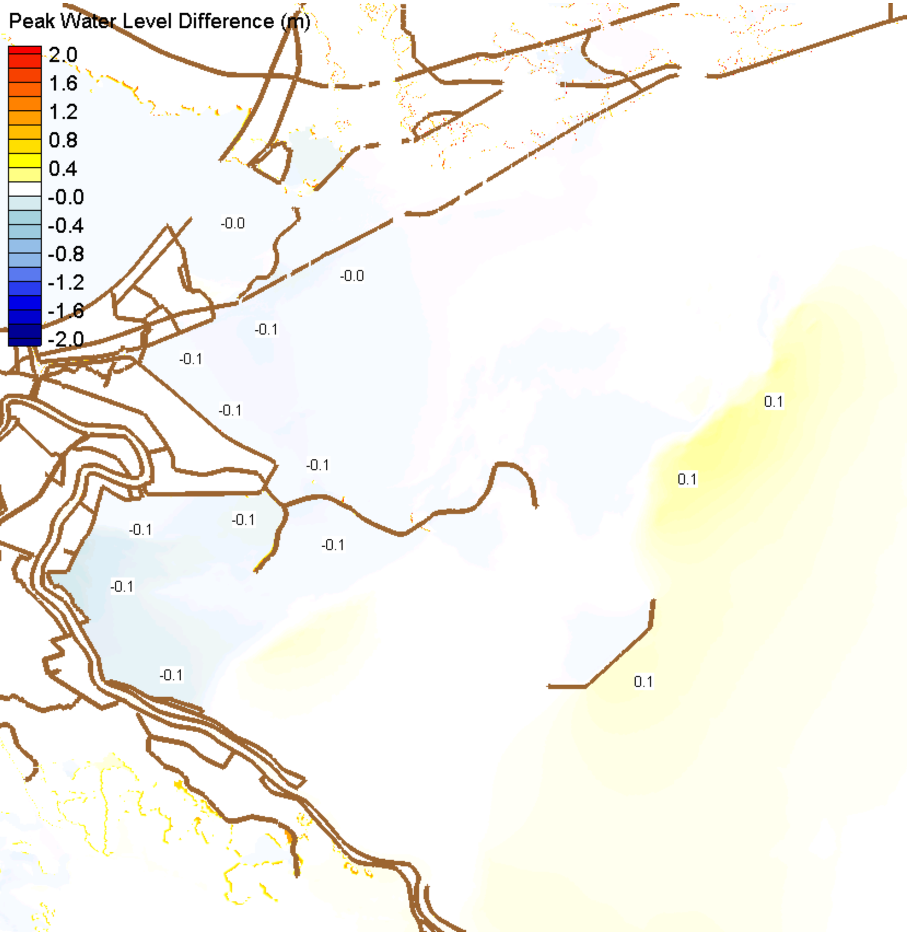
Modified:

- bathy/topo (~+1.5 ft NAVD88)
- Mannings-n
- Wind reduction factor

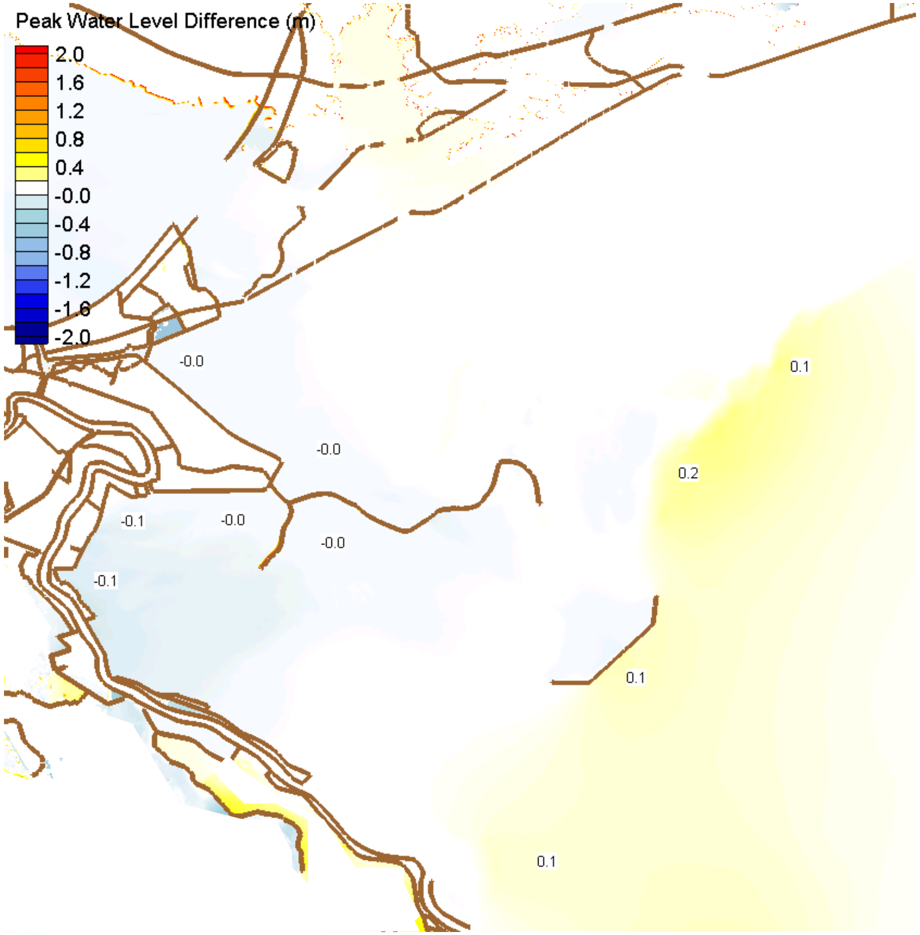
} Based on type (Mannings-n and Wind reduction factor)

Restored Landscape

Surge: Restored - Base



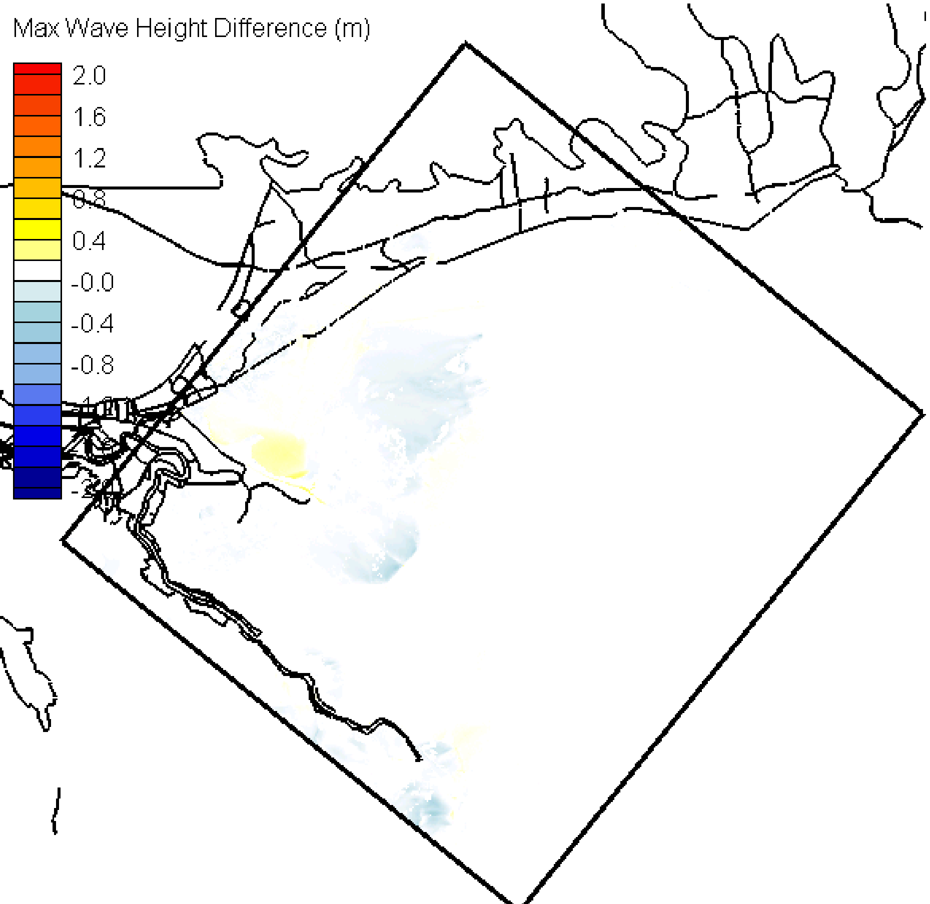
HUR1



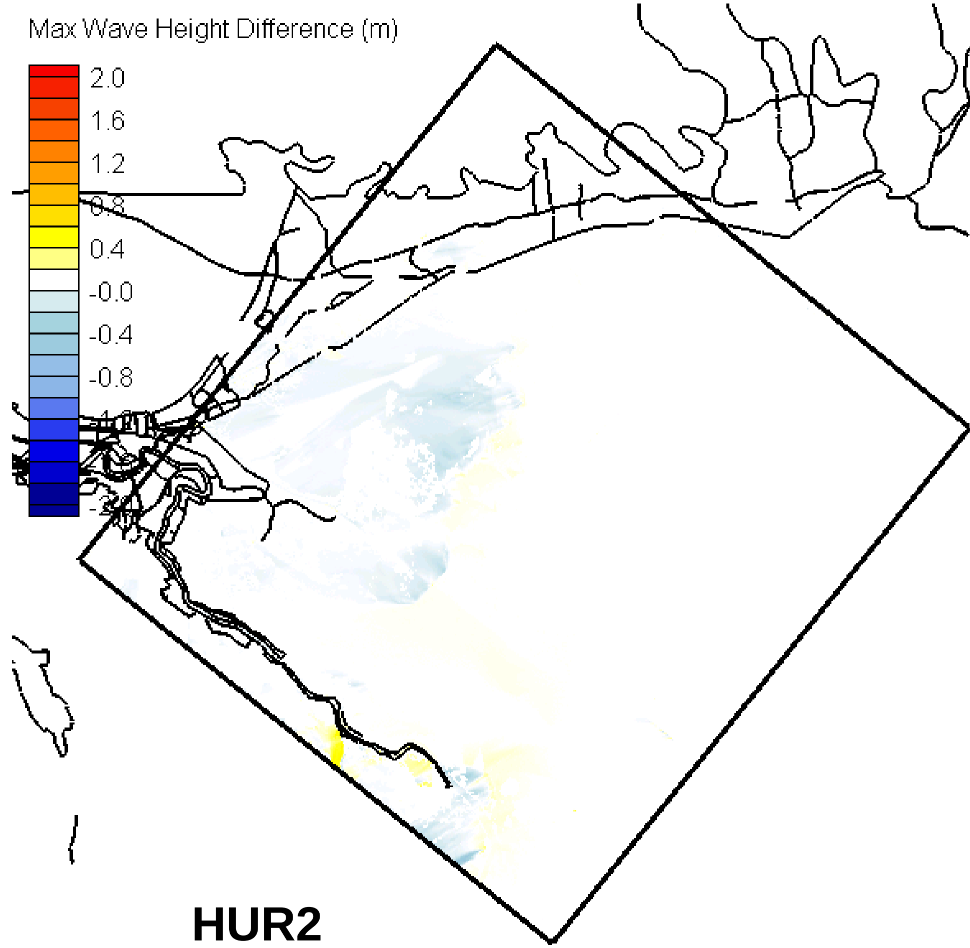
HUR2

Restored Landscape

Waves: Restored - Base

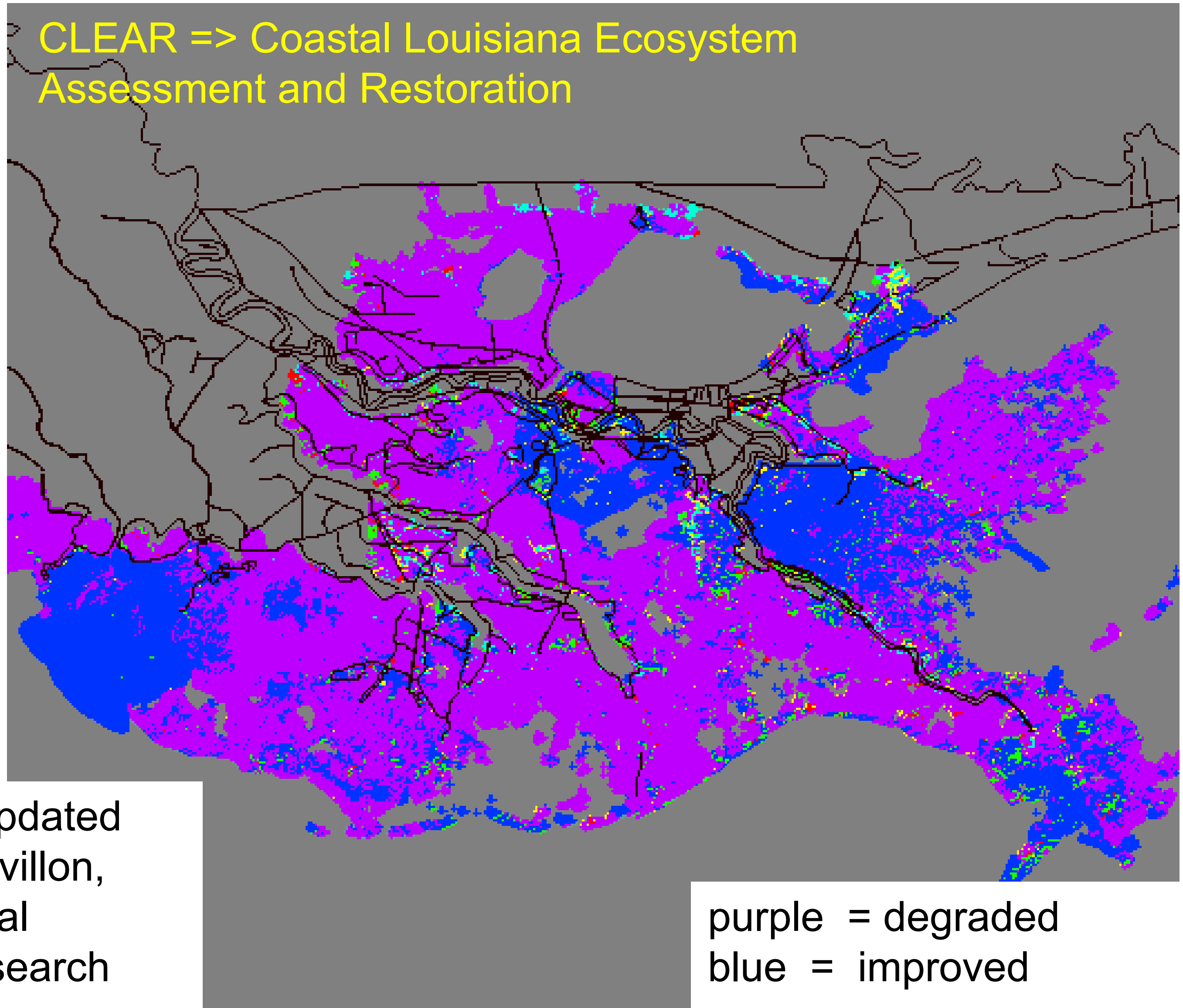


HUR1



HUR2

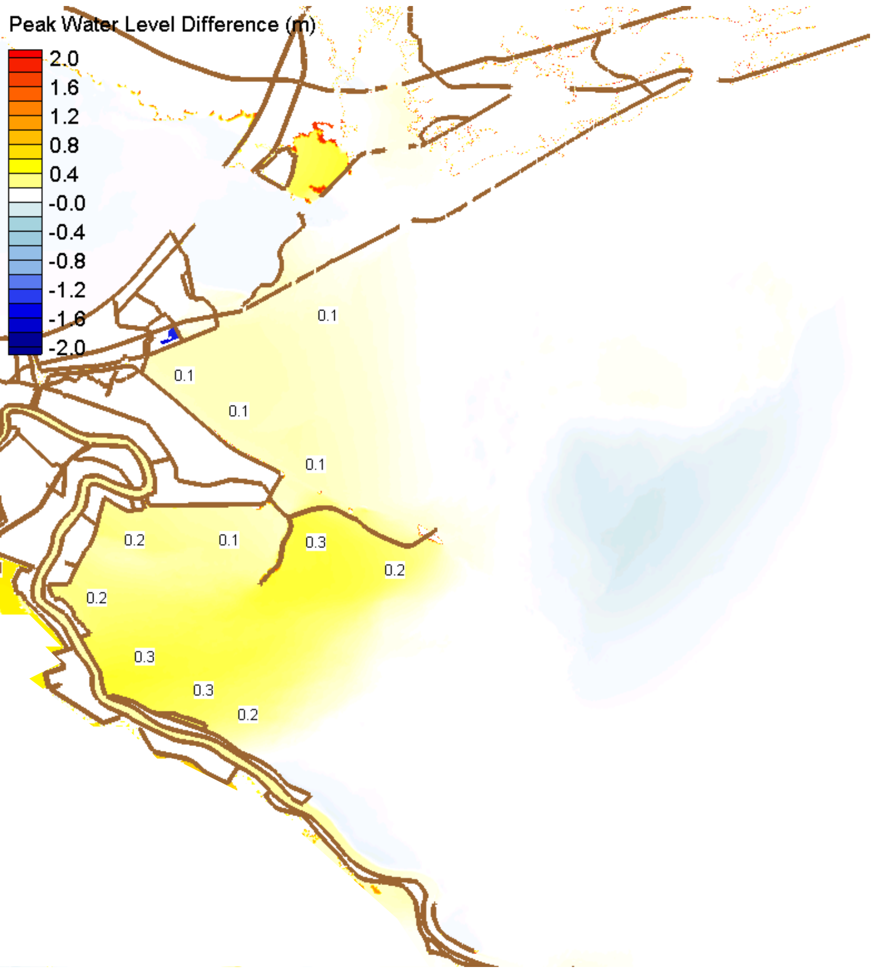
Future NIA Landscape Changes



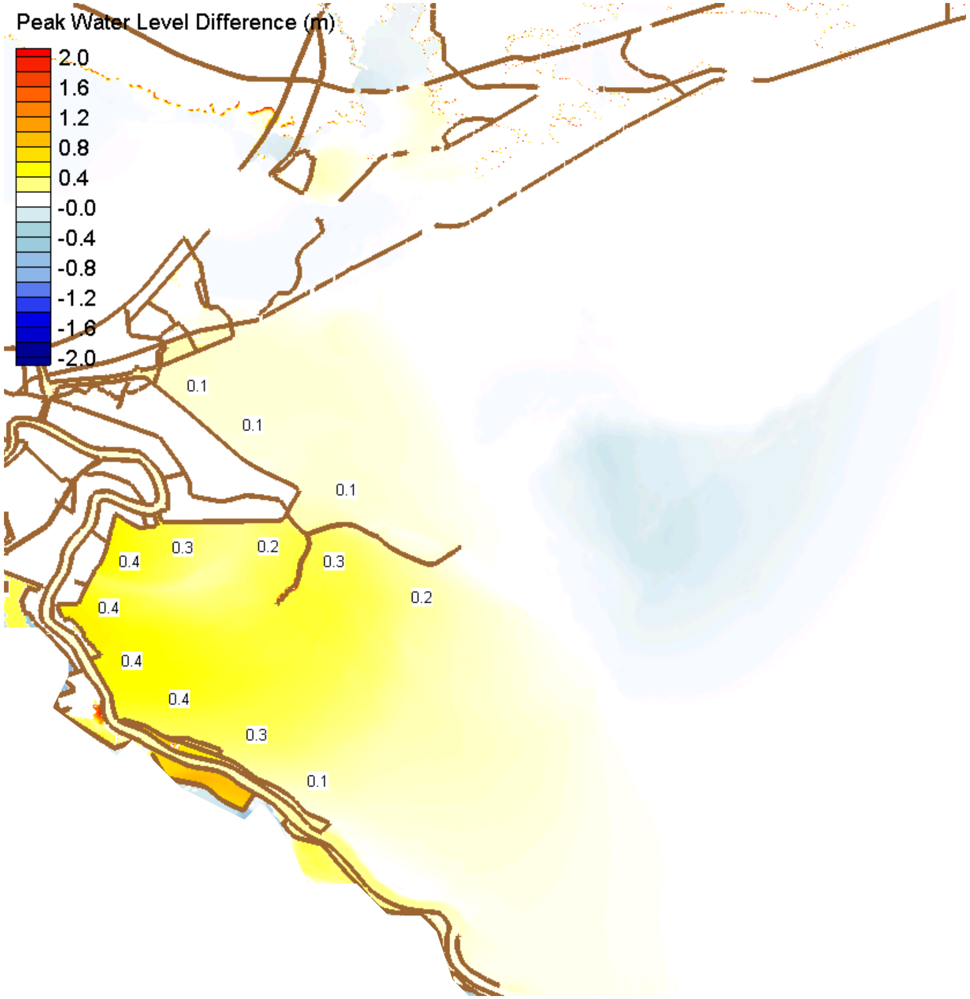
Topo/Bathy updated by Brady Couvillon, USGS National Wetlands Research Center

purple = degraded
blue = improved

Future NIA

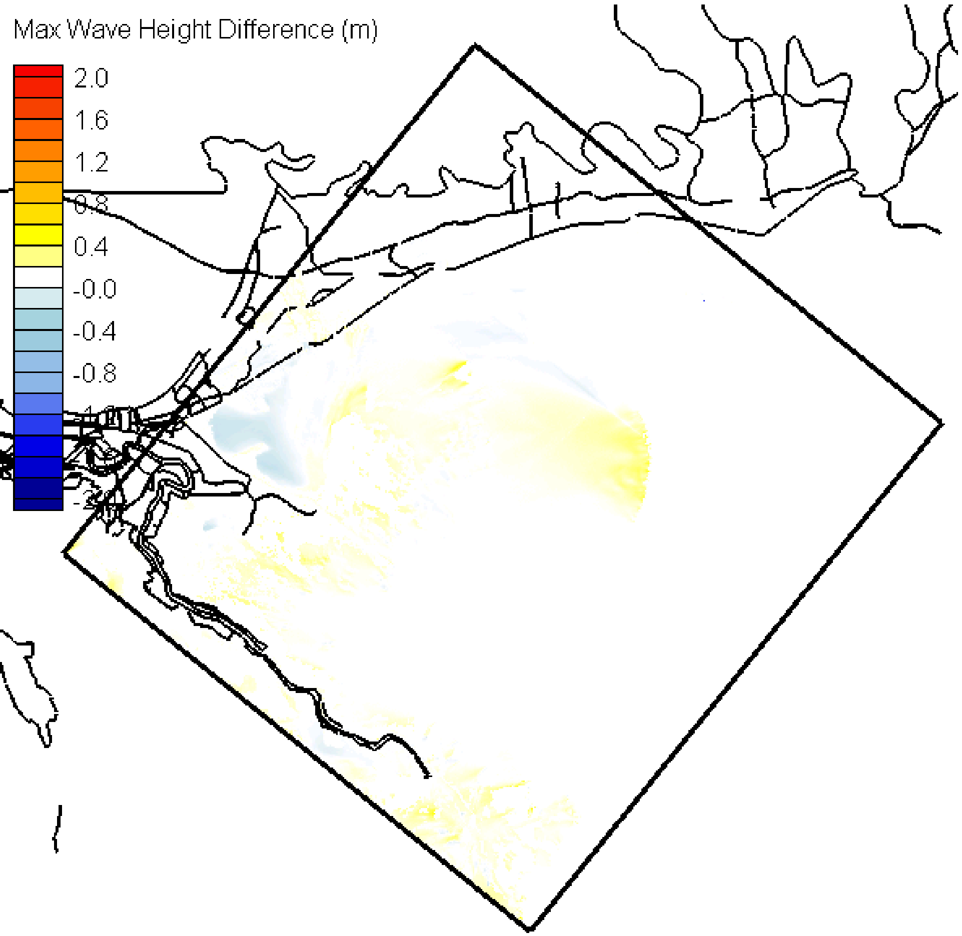


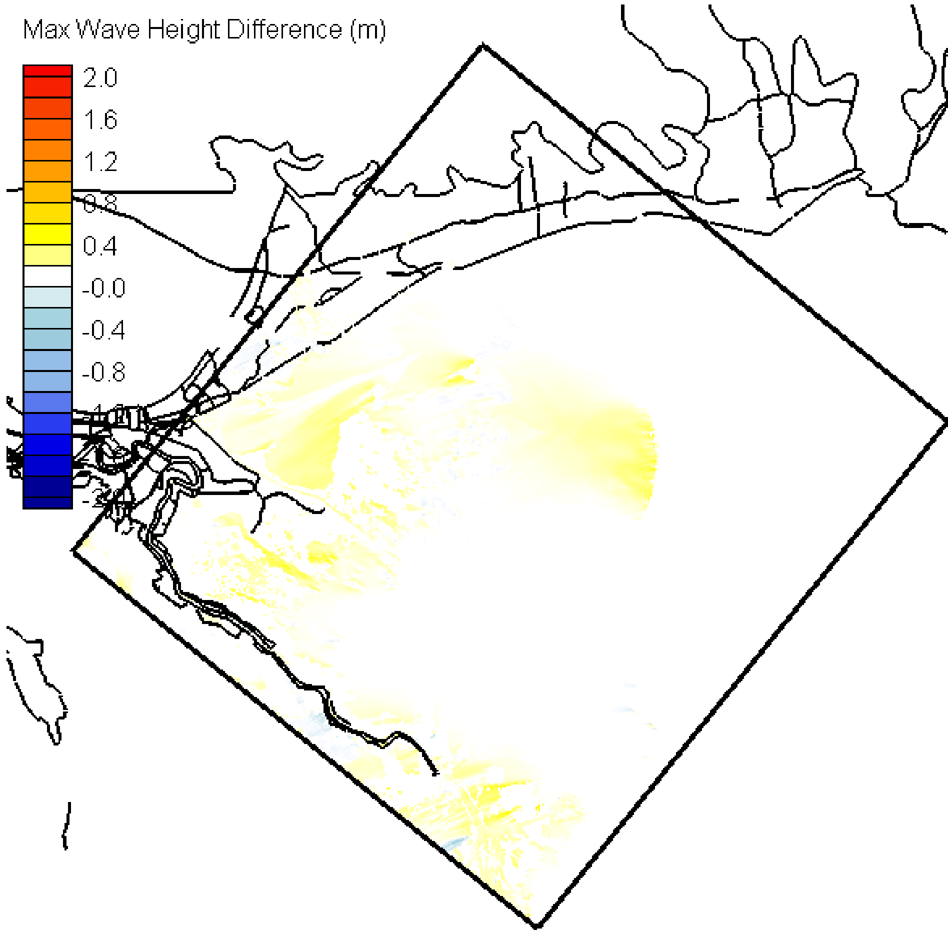
HUR1



HUR2

Future NIA


Max Wave Height Difference (m)
2.0
1.6
1.2
0.8
0.4
-0.0
-0.4
-0.8


Max Wave Height Difference (m)
2.0
1.6
1.2
0.8
0.4
-0.0
-0.4
-0.8

Plan/Progress

- Workshop – held March, 2006
- Literature Review
- Initiate data collection efforts
- Coast-wide numerical assessment
  - Degraded (or No Increased Action)
  - Restored
- "Numerical experiments"
  - Sensitivity to isolated landscape features
  - Sensitivity with Idealized grid setup