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Introduction to Storm Surge Modeling

Rick Luettich
University of North Carolina

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Rick Luettich

Director, Institute of Marine Sciences
Director, DHS Coastal Hazards Center of Excellence

Hampton Roads Sea Level Rise/Flooding Adaptation Forum
Storm Surge Modeling Tools for Planning and Response
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THE UNIVERSITY
of NORTH CAROLINA
at CHAPEL HILL

Storm Surge Model Starting Point

Basic Governing Equations

Mass Conservation

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Newton's 2nd Law of Motion: $\mathbf{F} = M \times \mathbf{a}$

Storm Surge Model Starting Point

Basic Governing Equations

Mass Conservation

Newton's 2nd Law of Motion: **F** = M x **a**

+ Assumptions & Averaging

Shallow Water Equations (partial differential eqs.)

- water surface elevations (flooding)
- currents
- timescales > 10 minutes

What to Include?

Meteorology

- ✓ atmospheric pressure
- ✓ wind stress (friction at air-water surface)
- ○ precipitation/runoff

What to Include?

Ocean Processes

- ✓ tides
- ✓ rotation of earth
- ✓ surface wave effects (may be problem dependent)
- ○ large ocean processes (currents, thermal, SLR)
- ☒ water density
- ☒ explicit vertical representation (3D)

What to Include?

Land

- ✓ topography – land surface elevations, features
- ✓ friction at land surface
- ✓ inundation and dewatering of dry areas

How to Include?

Meteorology (wind / pressure in space & time)

- Observational wind fields - H*Wind
  - Historical events
- Constructed from storm characteristics (e.g., max wind speed, storm size, center location)
  - Risk studies, design studies, forecasting
- Dynamical (gridded) meteorological models
  - Reanalysis – historical events
  - Forecasts – forecasting
- MUST CONVERT WIND SPEED TO WIND STRESS

How to Include?

Meteorology (precip / runoff in space & time)

- Observational data – river discharge
  - Historical events
- Statistical models
  - Risk studies, design studies
- Dynamical models
  - Reanalysis – historical events
  - Forecasts – forecasting

How to Include?

Ocean Processes

- tides
  - specify values at edges of model domain
- rotation of earth – included shallow water eqs
- surface wave effects
  - couple a dynamical wave model – SWAN, WaveWatch3, WWM
- large ocean processes
  - specify starting water levels

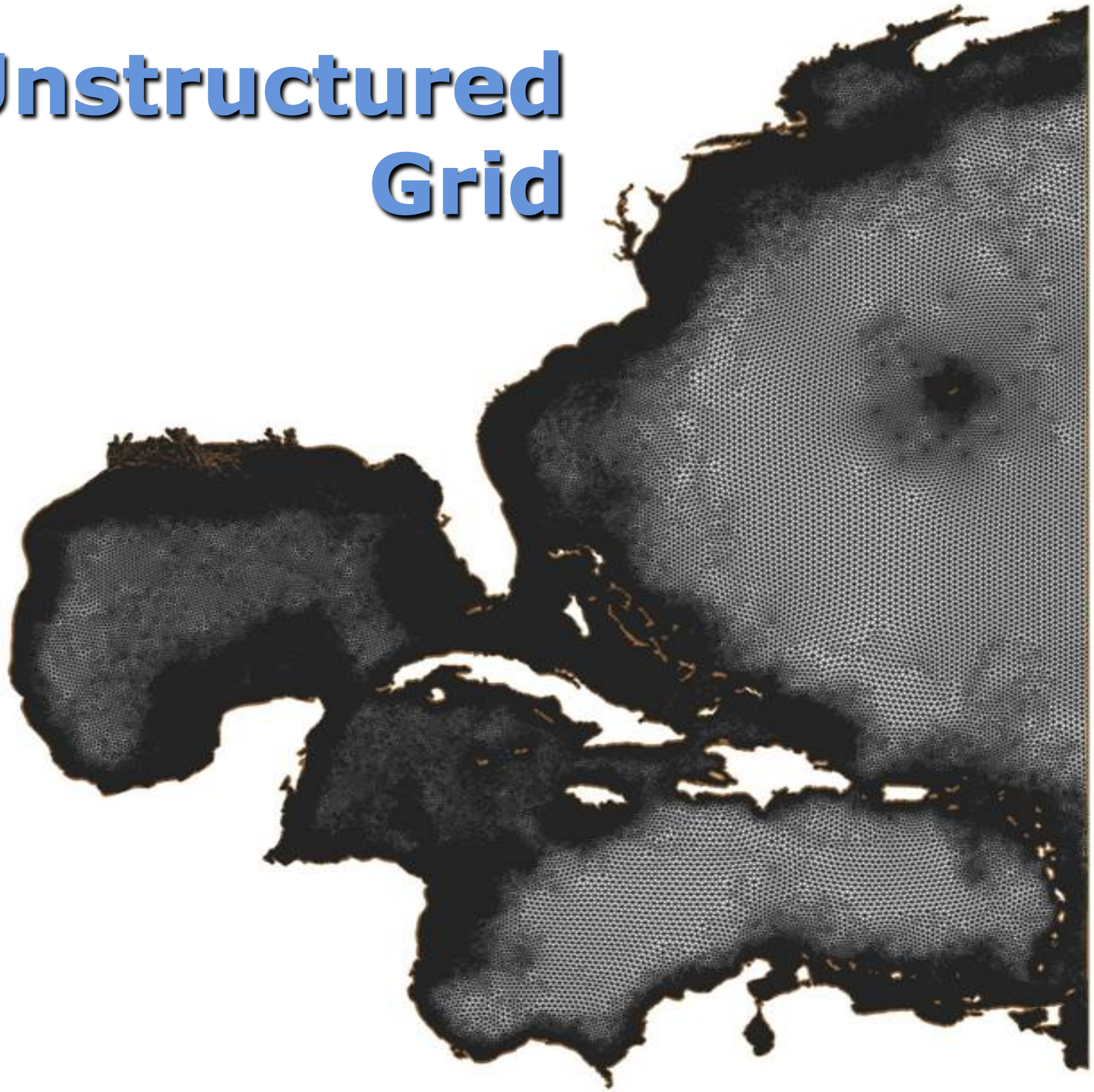
How to Include?

Land – Basis of the "GRID"

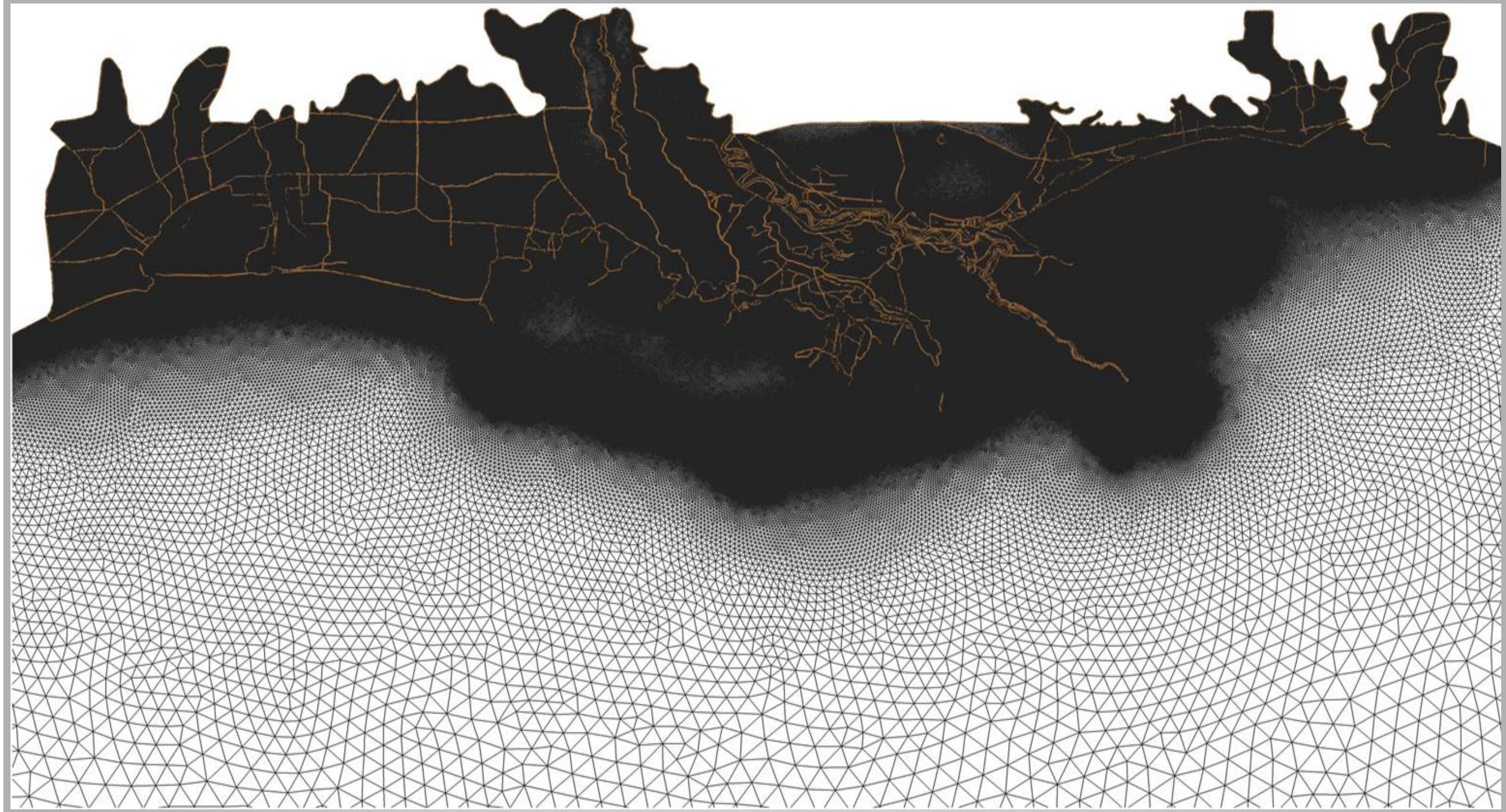
- topography – land surface elevations, features
  - location specific
  - lidar or other sources of data
  - Needed for both dry land and ocean
- friction at land surface
  - Dependent on surface cover and characteristics – (don't include buildings explicitly)
- inundation and dewatering of dry areas
  - specialized treatment in shallow water eqs.
  - must be supported by the GRID

The three R's of Storm Surge Modeling
"Resolution, Resolution, Resolution"

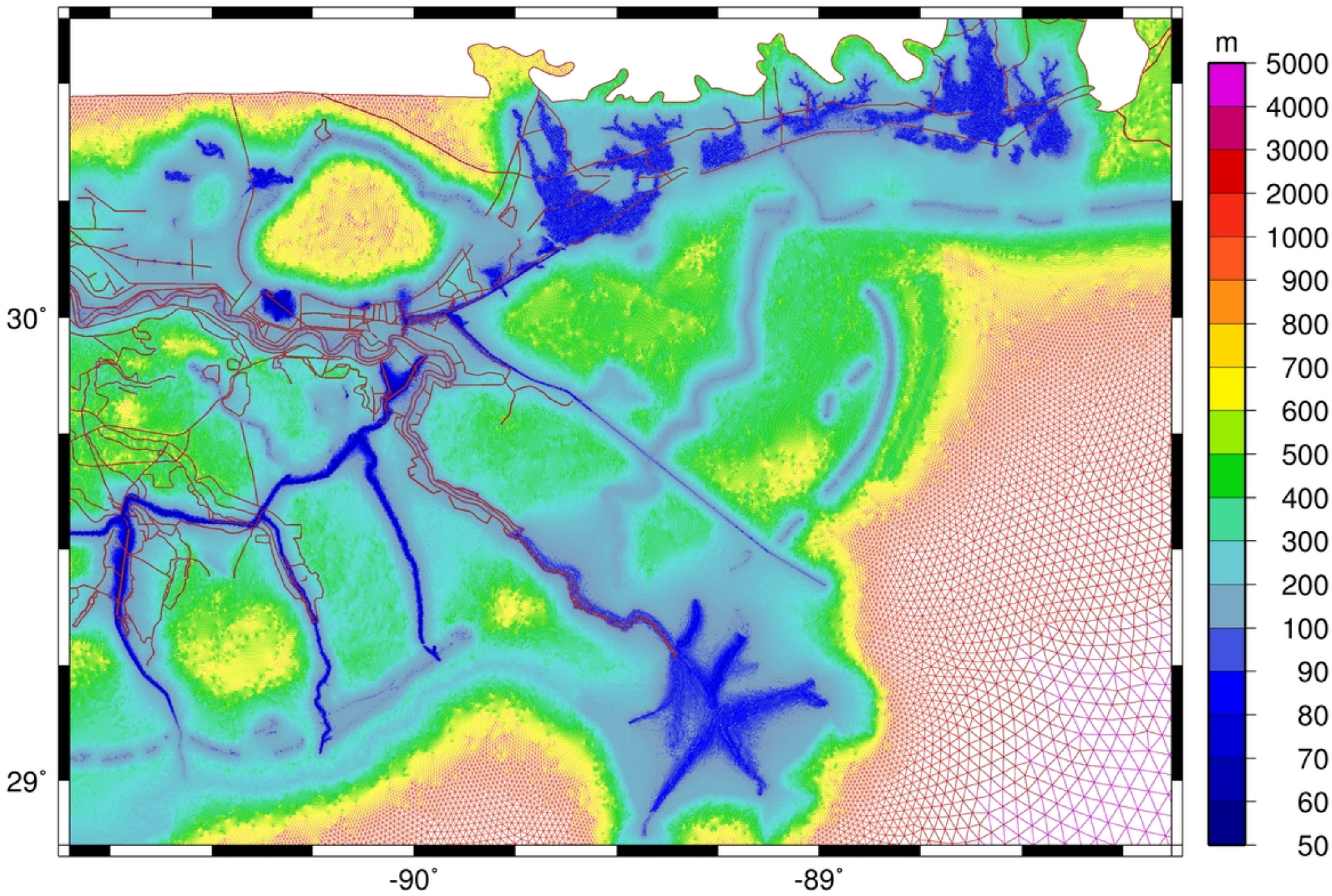
Unstructured Grid



Northern Gulf of Mexico



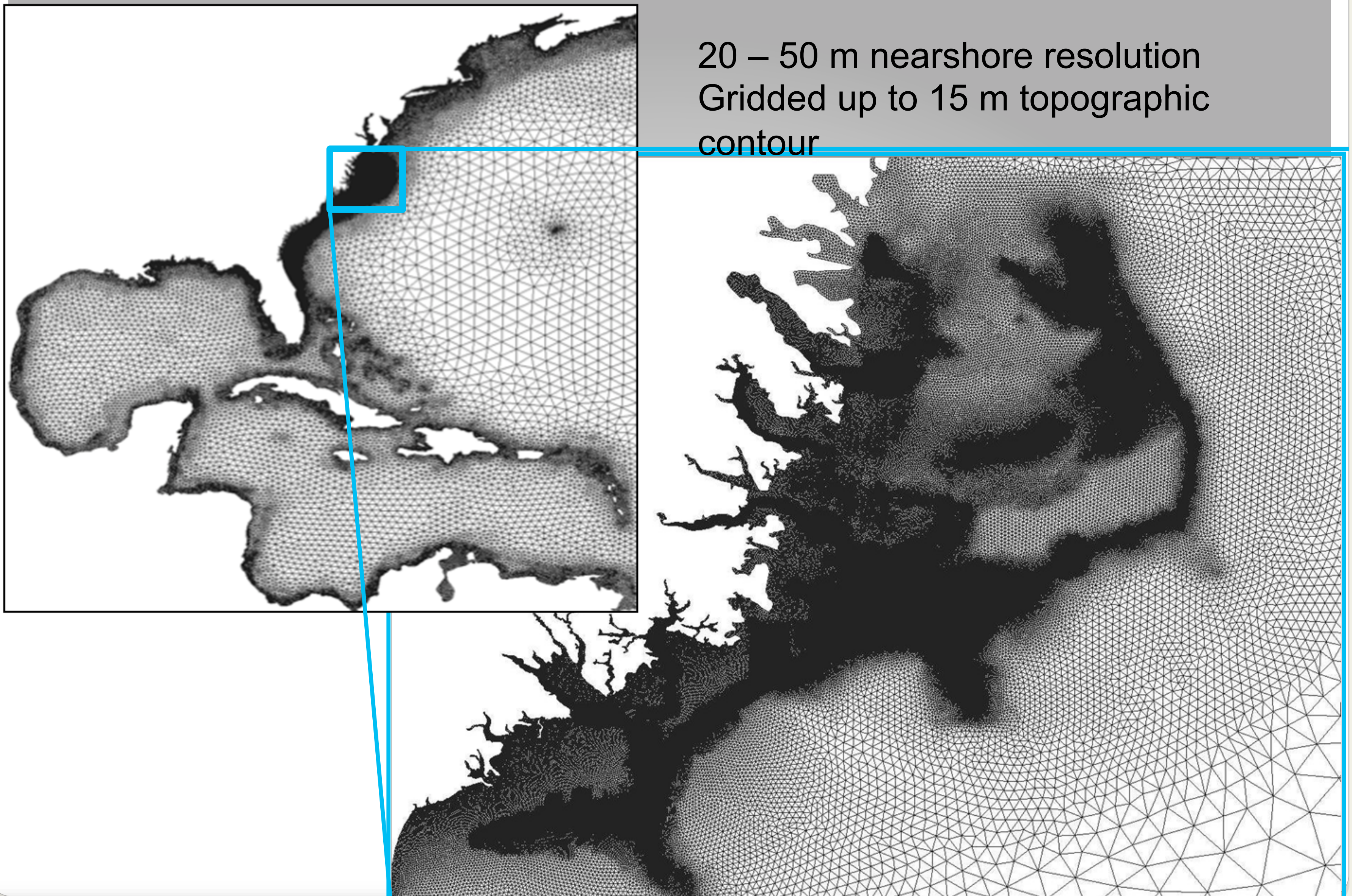
Grid Size



30˚
29˚
-90˚
-89˚
m
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50

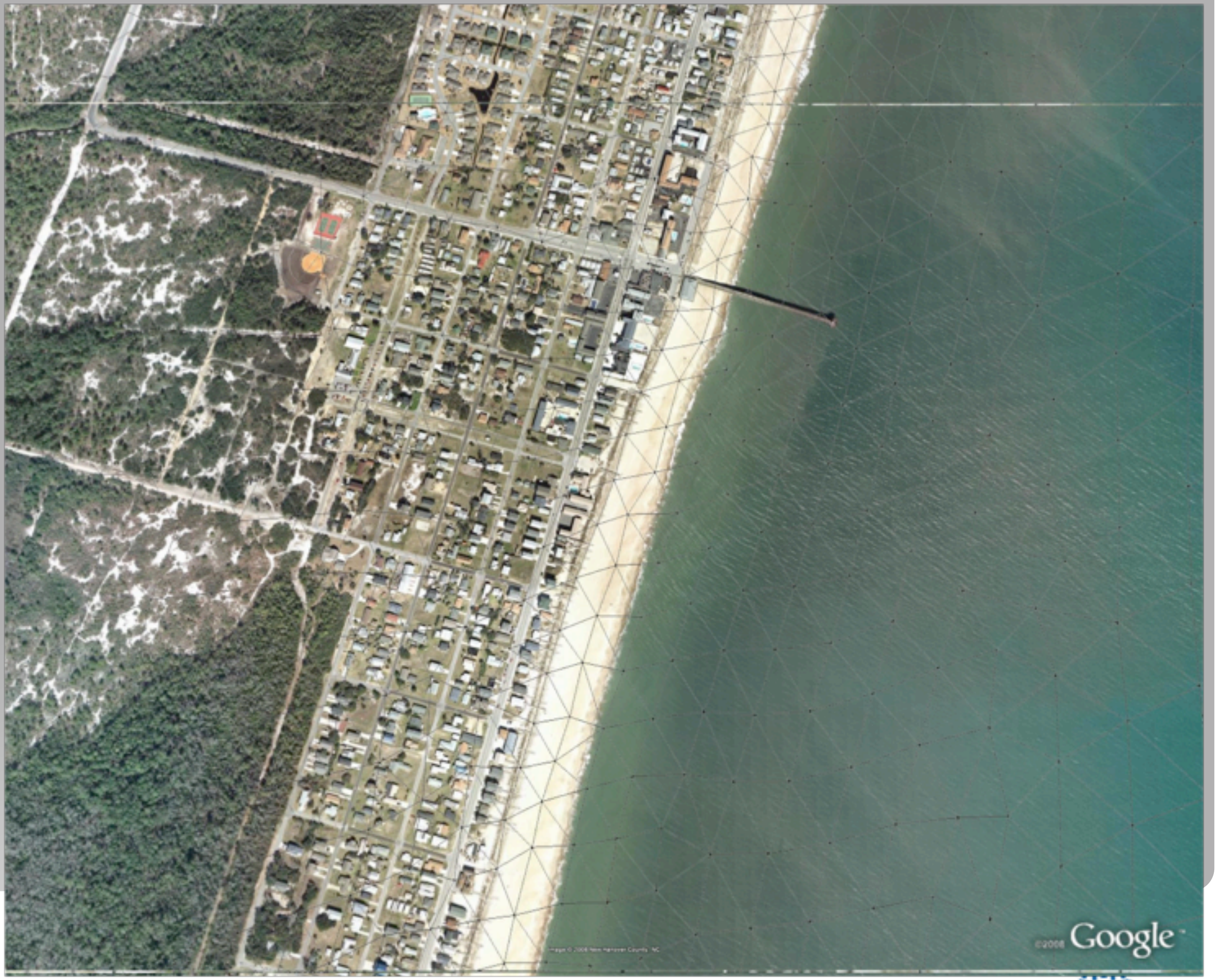
North Carolina

20 – 50 m nearshore resolution
Gridded up to 15 m topographic contour

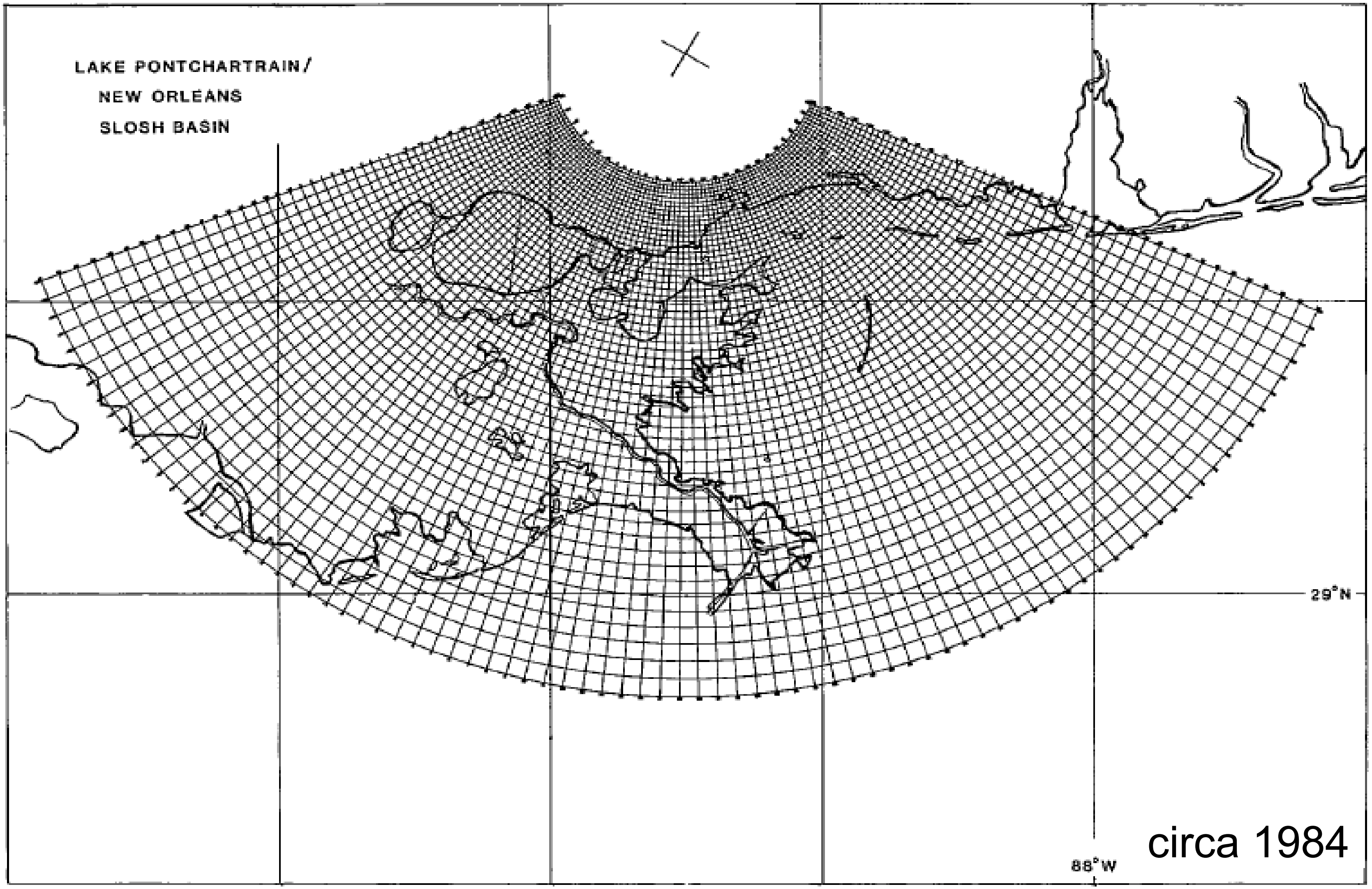


Coastal North Carolina Detail

- Grid (triangles) in Wrightsville Beach Area
- Try to align grid "lines" with coastline
- 20-30 meter beach resolution

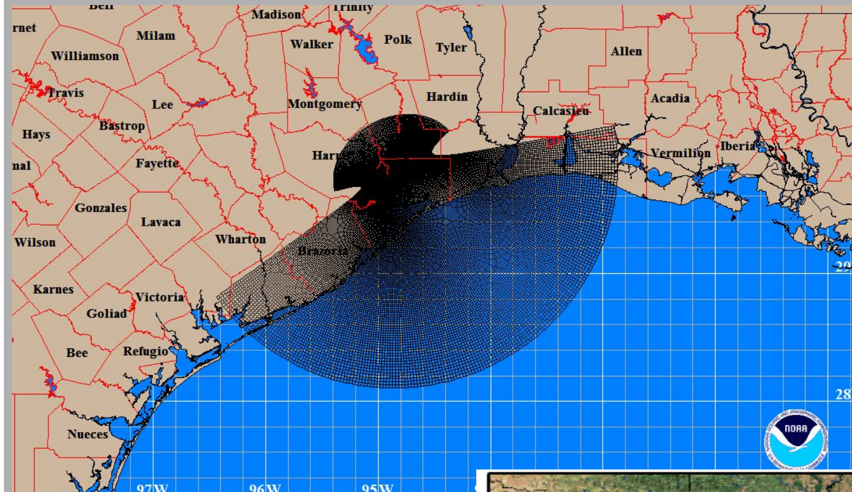


Structured Grid

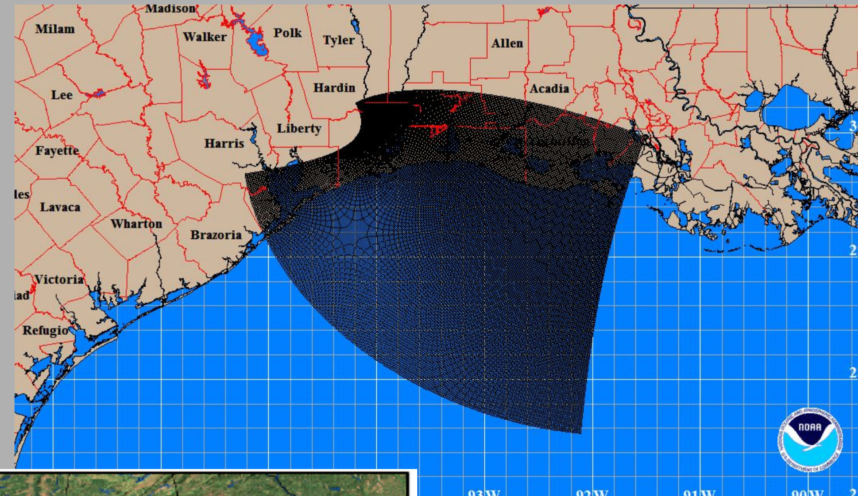


circa 1984

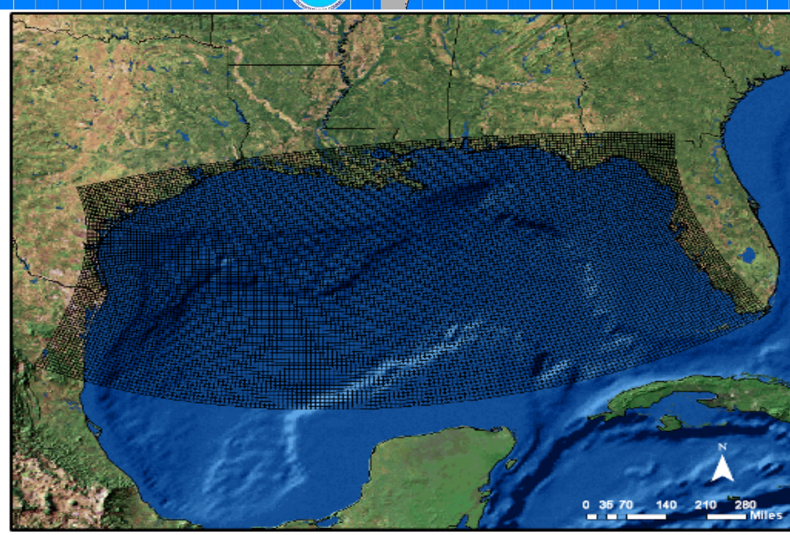
Gulf of Mexico SLOSH Grids



Galveston 3
Slosh Basin



Sabin Pass
Slosh Basin



GoMx Extratropical
Storm Surge Grid

How to get an Answer?

Approximate shallow water equations + various inputs and solve on computer, visualize results

- Different approximation methods
  - depend on type of GRID
  - optimized for type of computer - scaling
- Answer at every element in GRID
  - big GRIDS take more computer resources and more time
- Visualization of storm surge, flooding is important
  - GIS, Google Earth, etc – high resolution
  - high resolution visualization doesn’t necessarily mean high resolution model