Challenges and Solutions in Large Scale Storm Surge Modeling

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Simulating Storm Surge

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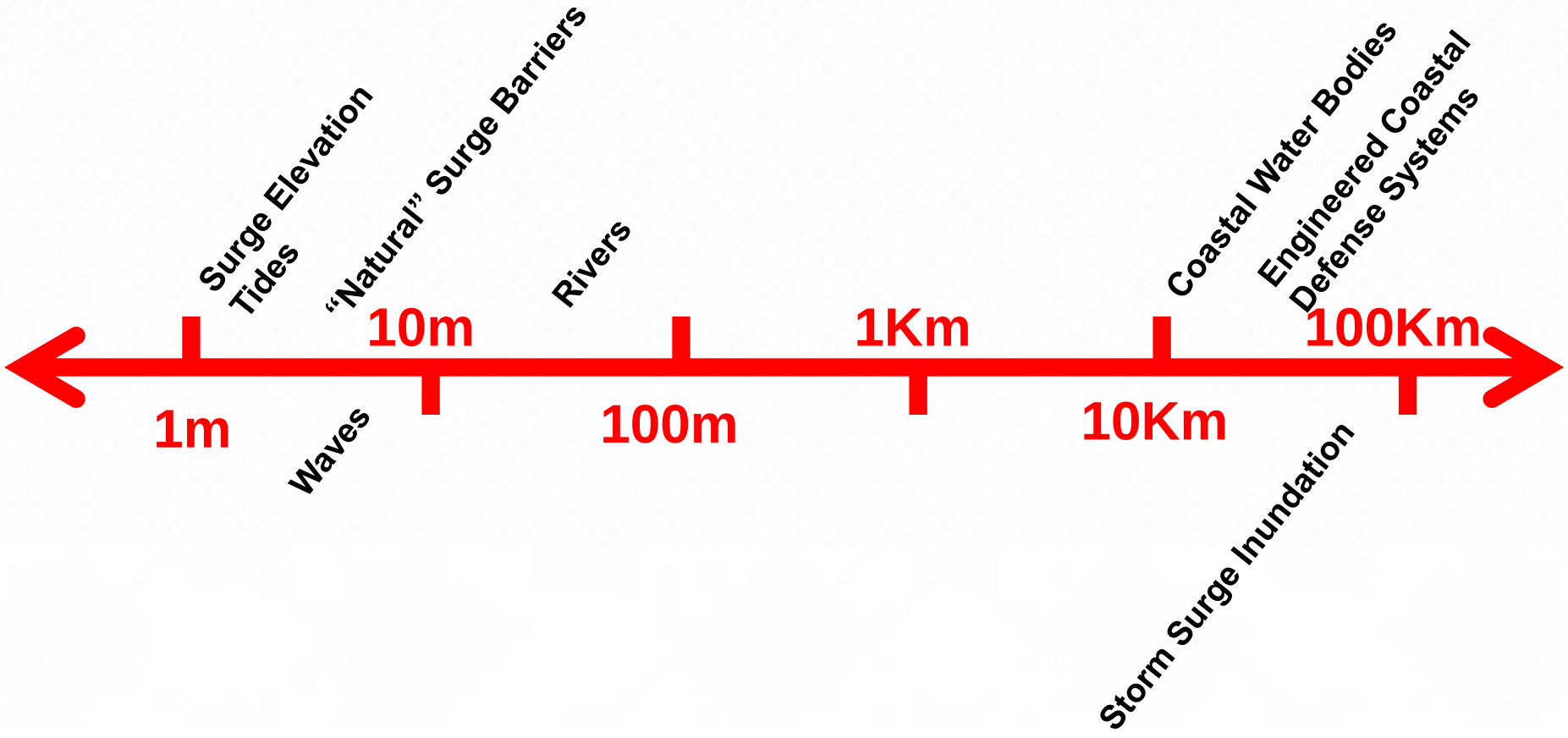
So What is So Challenging About Storm Surge Modeling, Anyway?

- Chaotic Meteorological Conditions
- Dynamic Coastal Environment
- Spatial Resolution
- Scales of Processes

Calculating Surge and Associated Damage on Various Scales

(Eric Larsen/NJ Governor's Office)

What Spatial and Temporal Time Scales Are We Concerned With?



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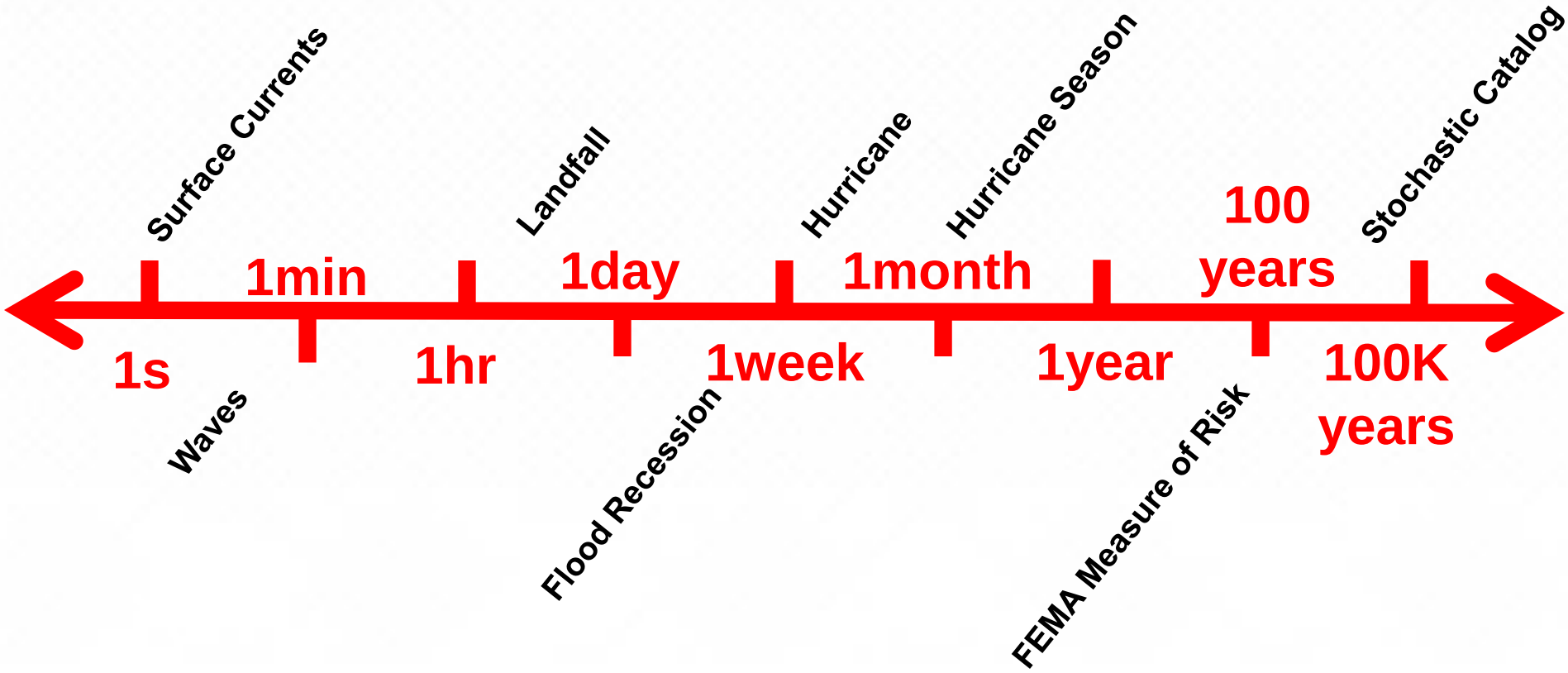
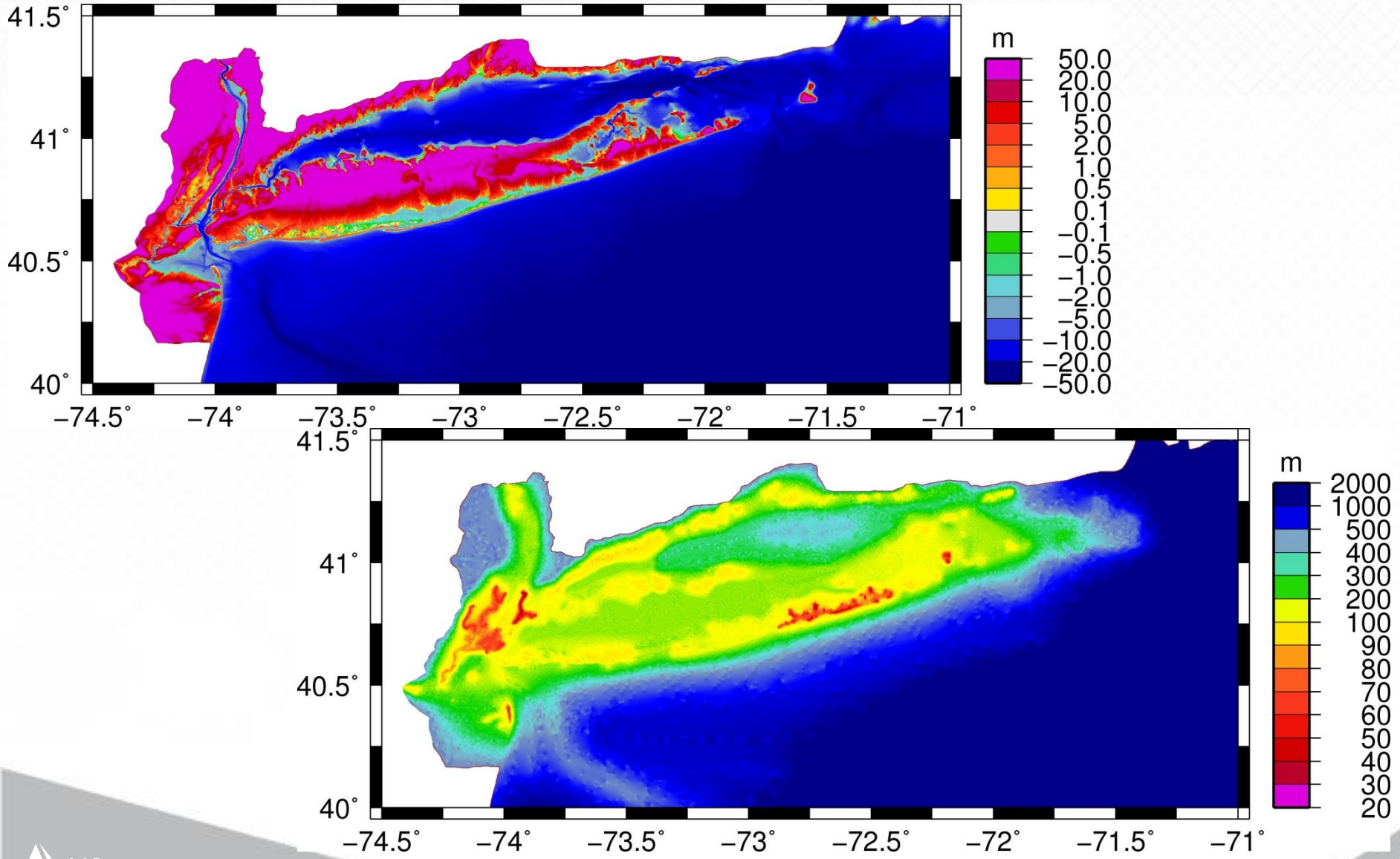


Spatial Resolution Example



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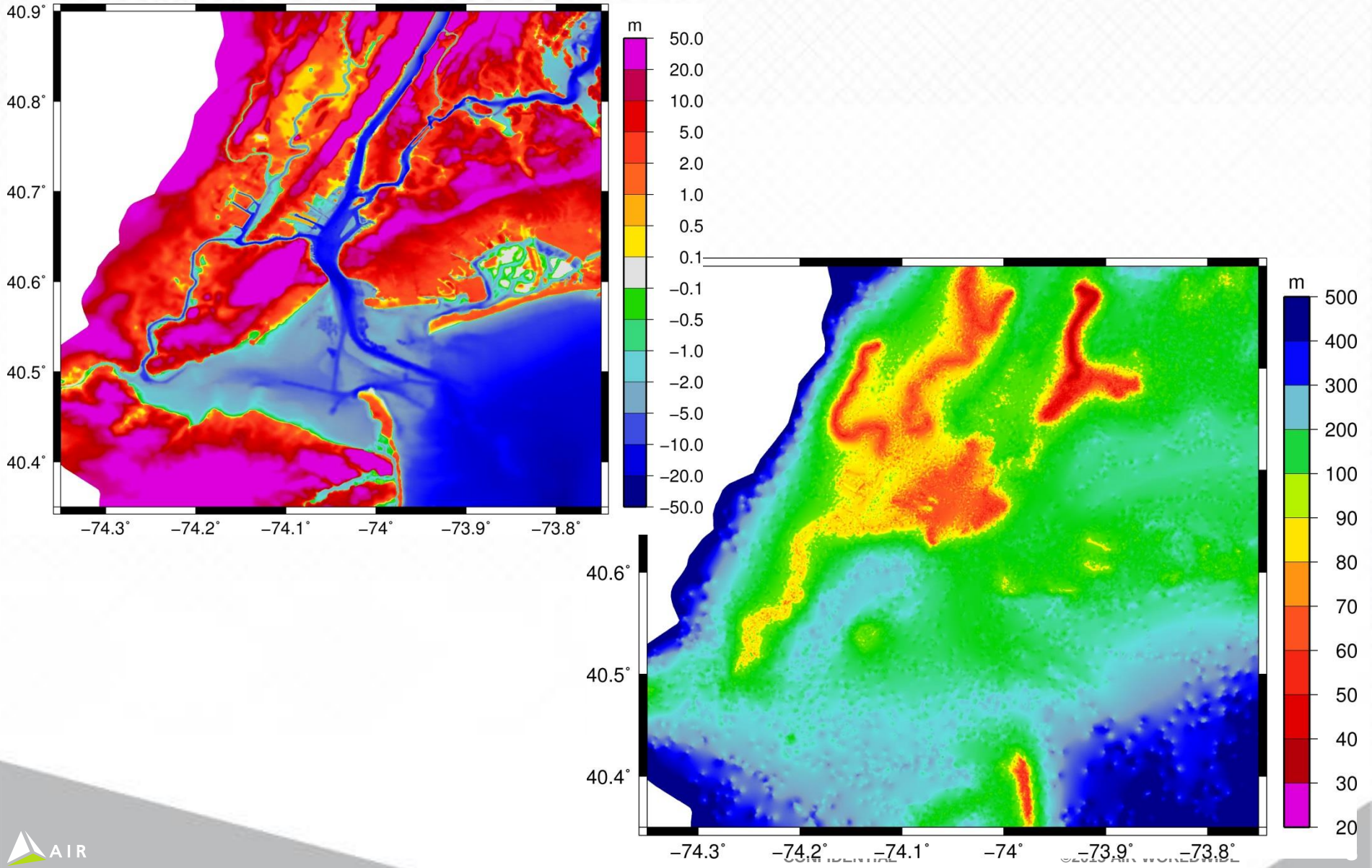
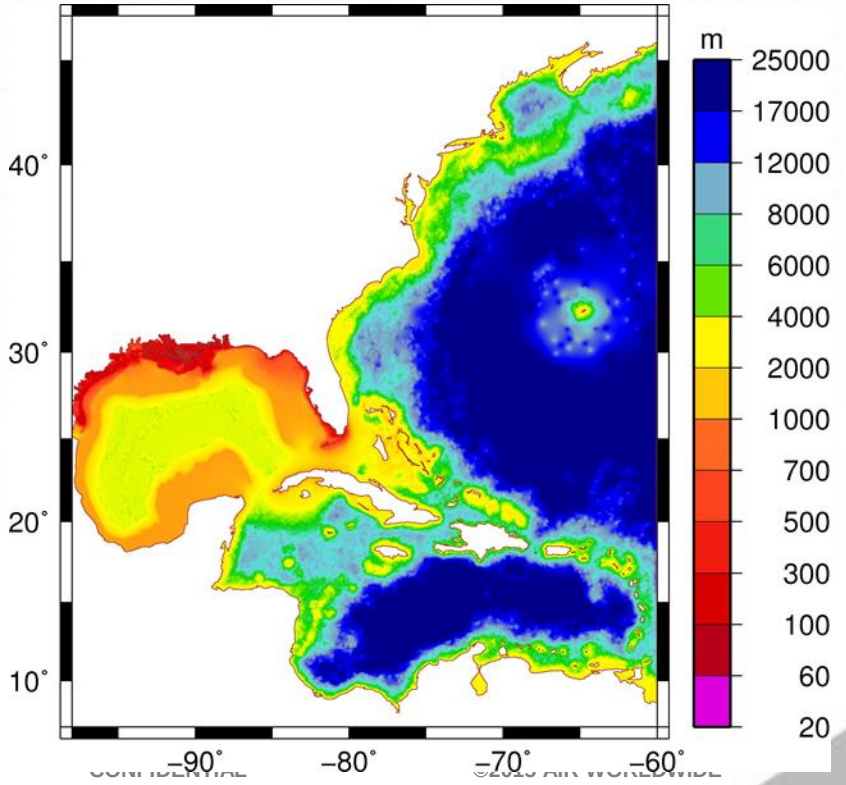


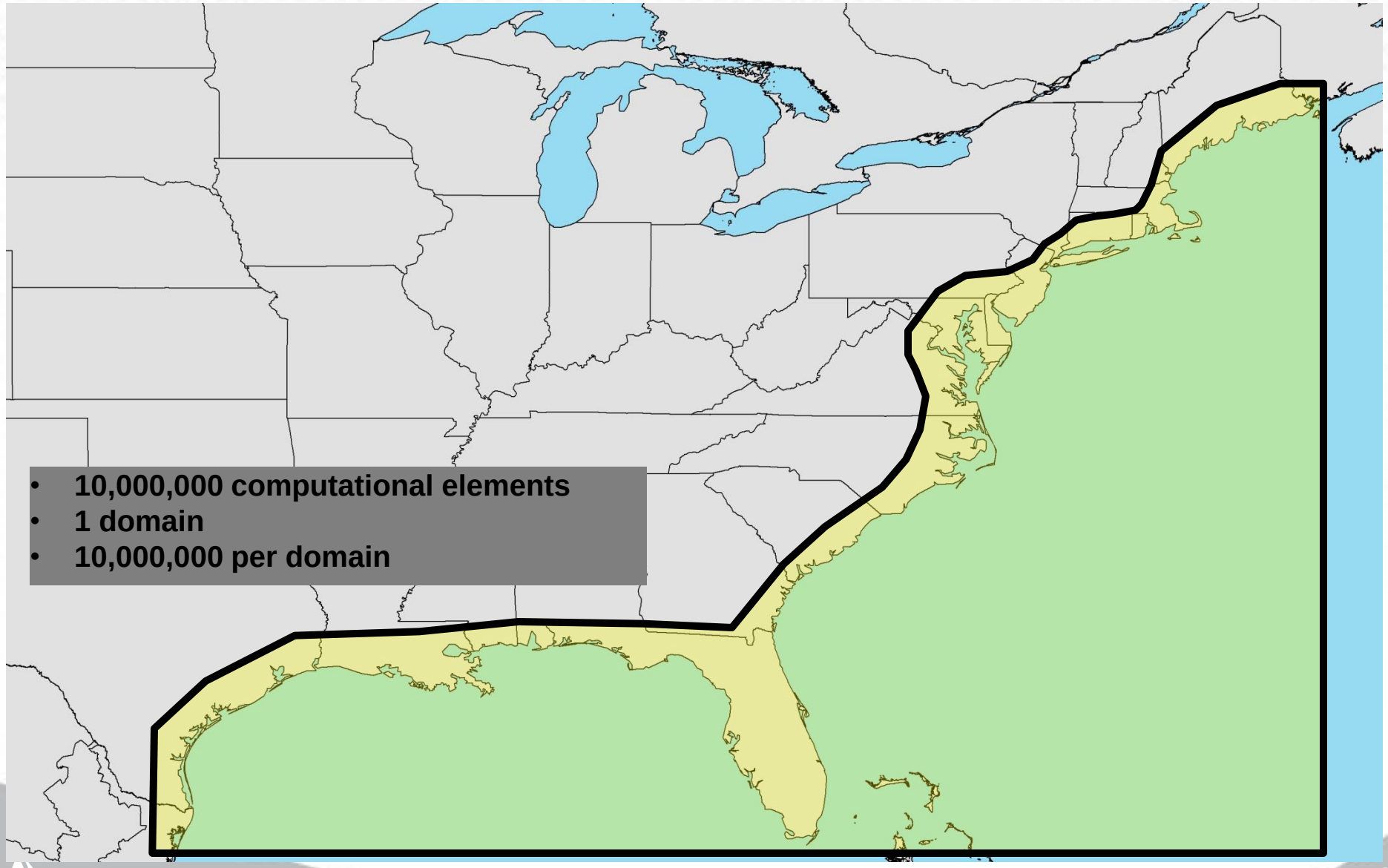
Simulating Surge Locally is (relatively) Easy, but…

- Let's theorize a domain that encompasses the entire US coastline at 100m resolution
  - If we (very coarsely) estimate the length of the US coastline to be 6000km
  - Extend that domain inland 5km and 10km offshore
  - 300 million nodes!

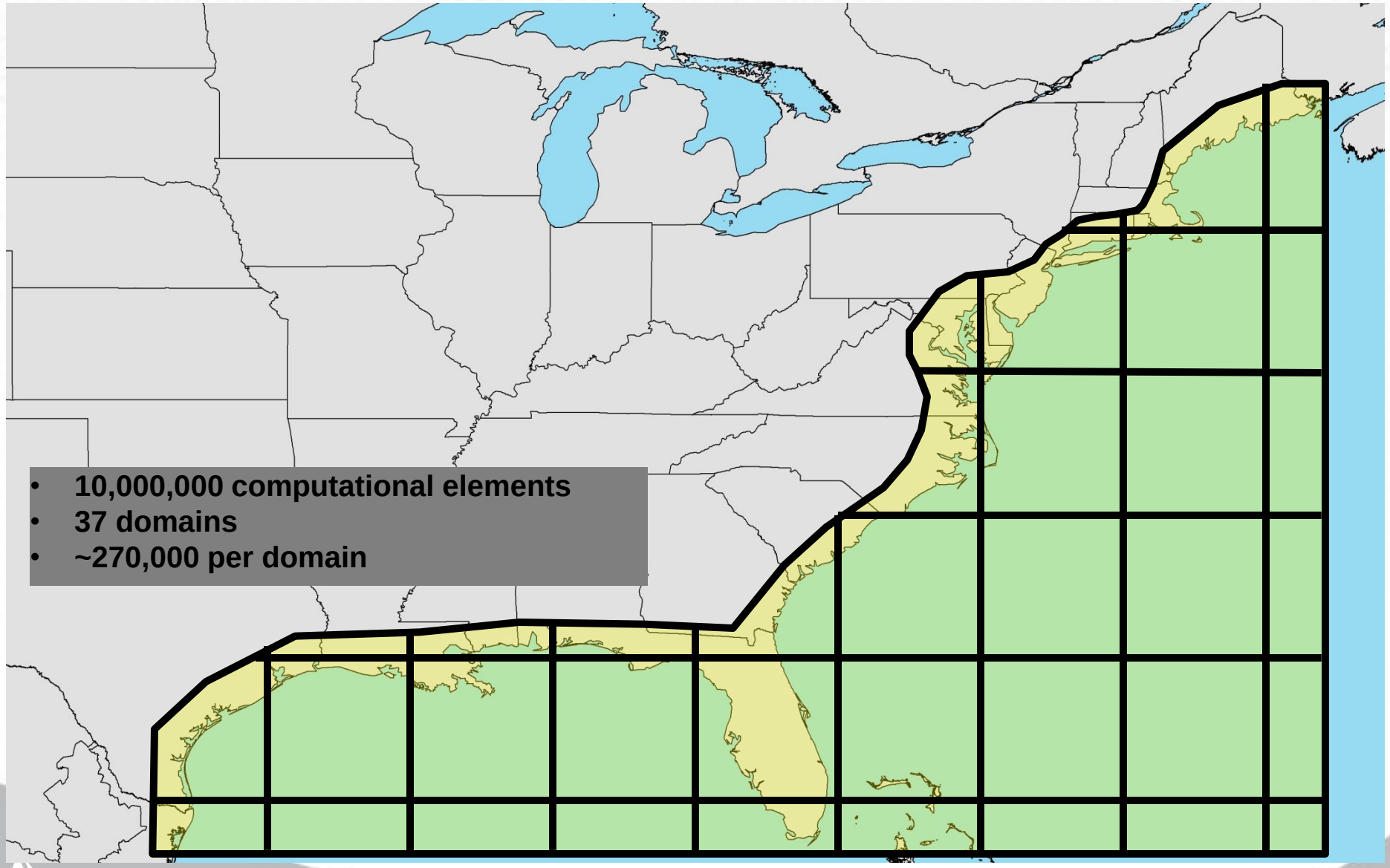


- **For comparison the grid on the right contains 9 million nodes**
- **It required 80 minutes to simulate one day on 2200 cpus**

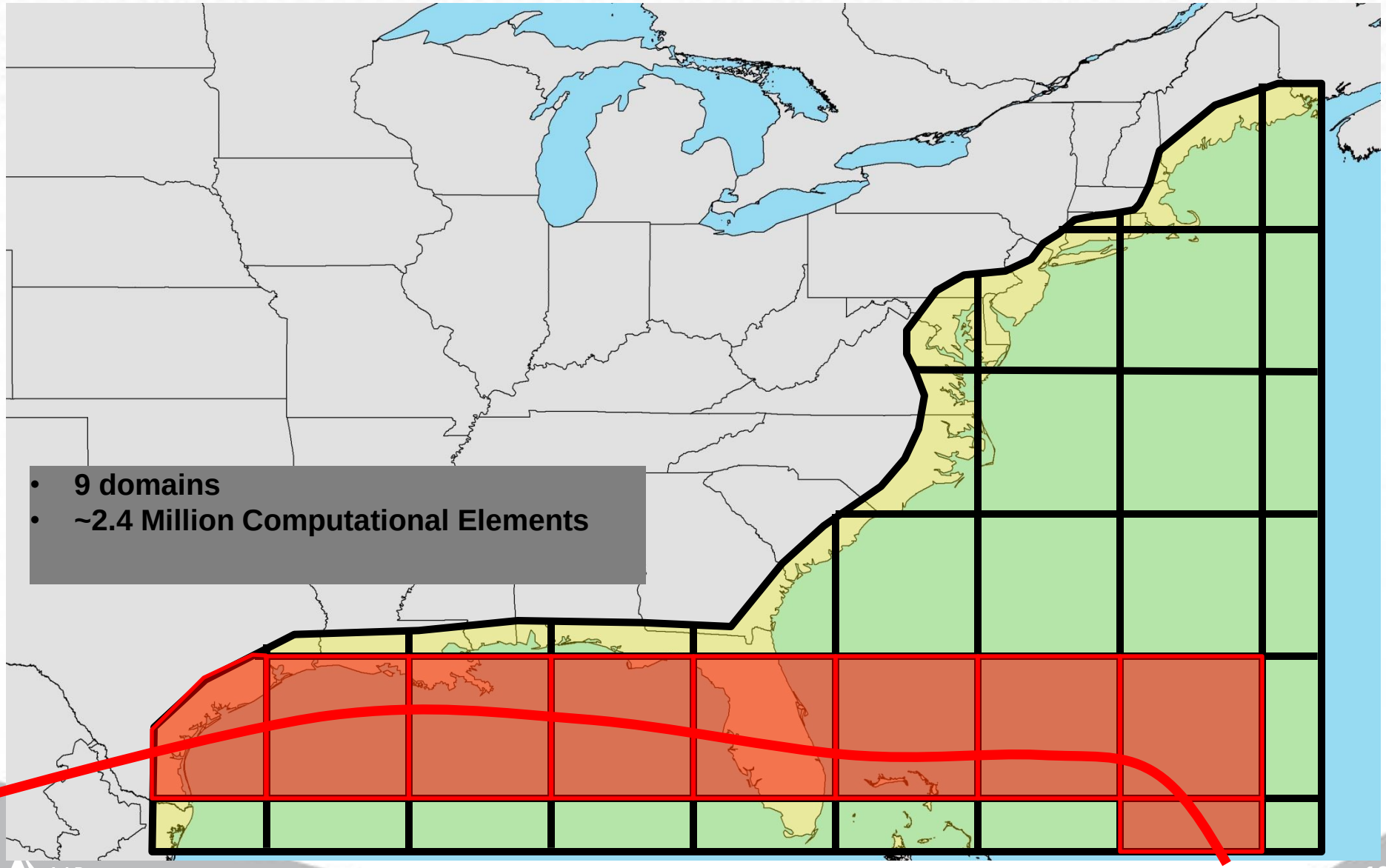
Single Domain Approach



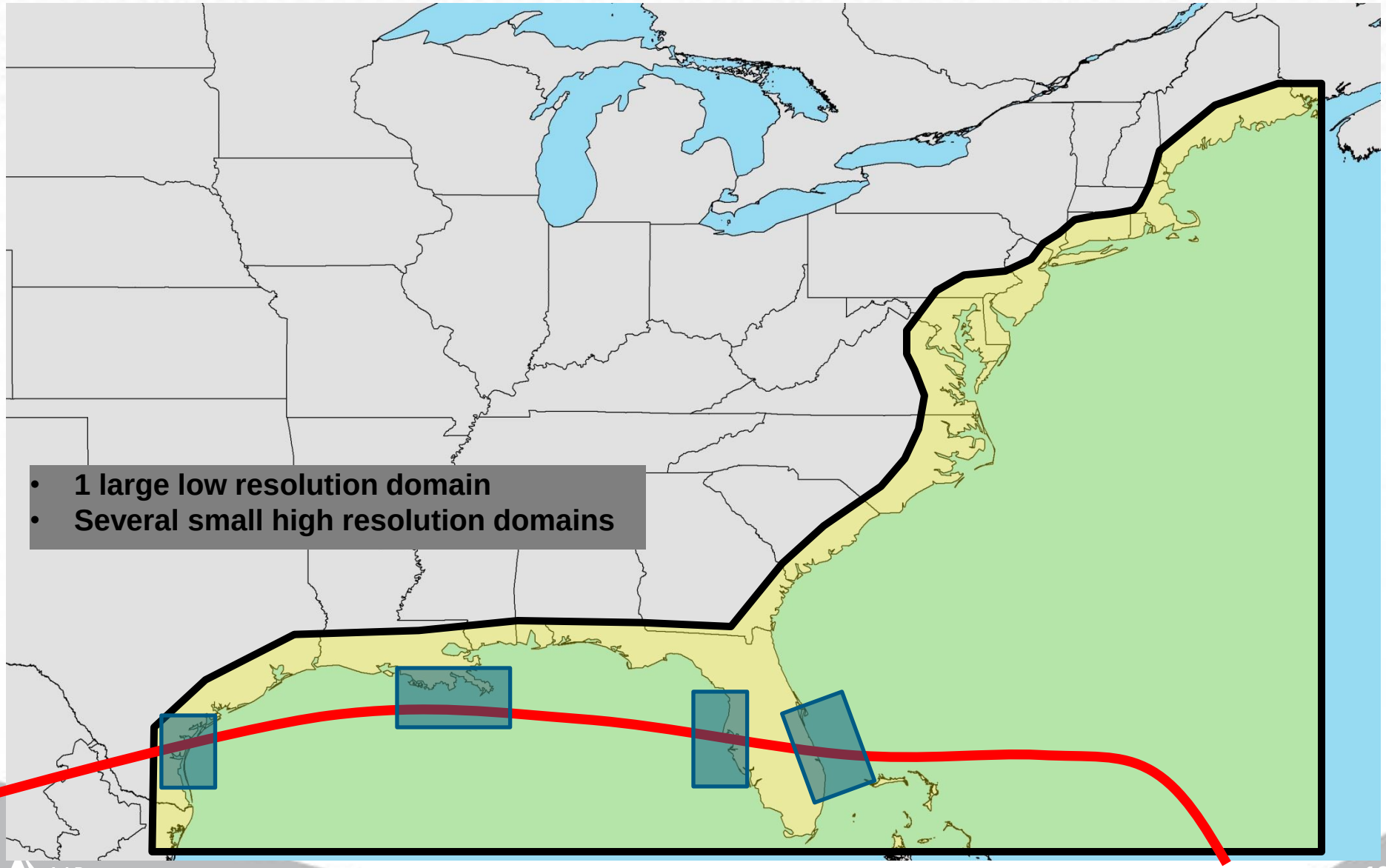
Parallelization



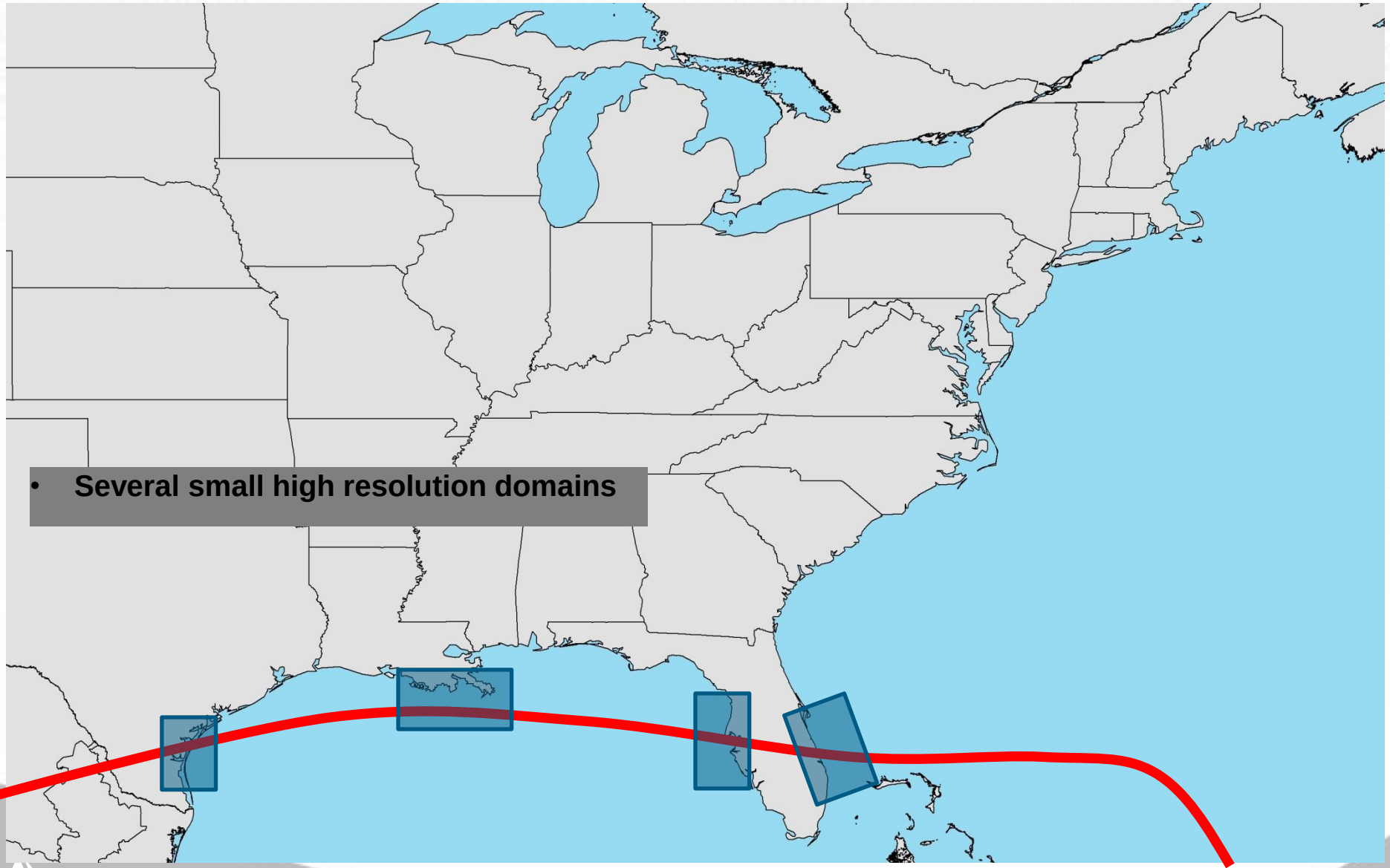
Parallelization & Computational Focus



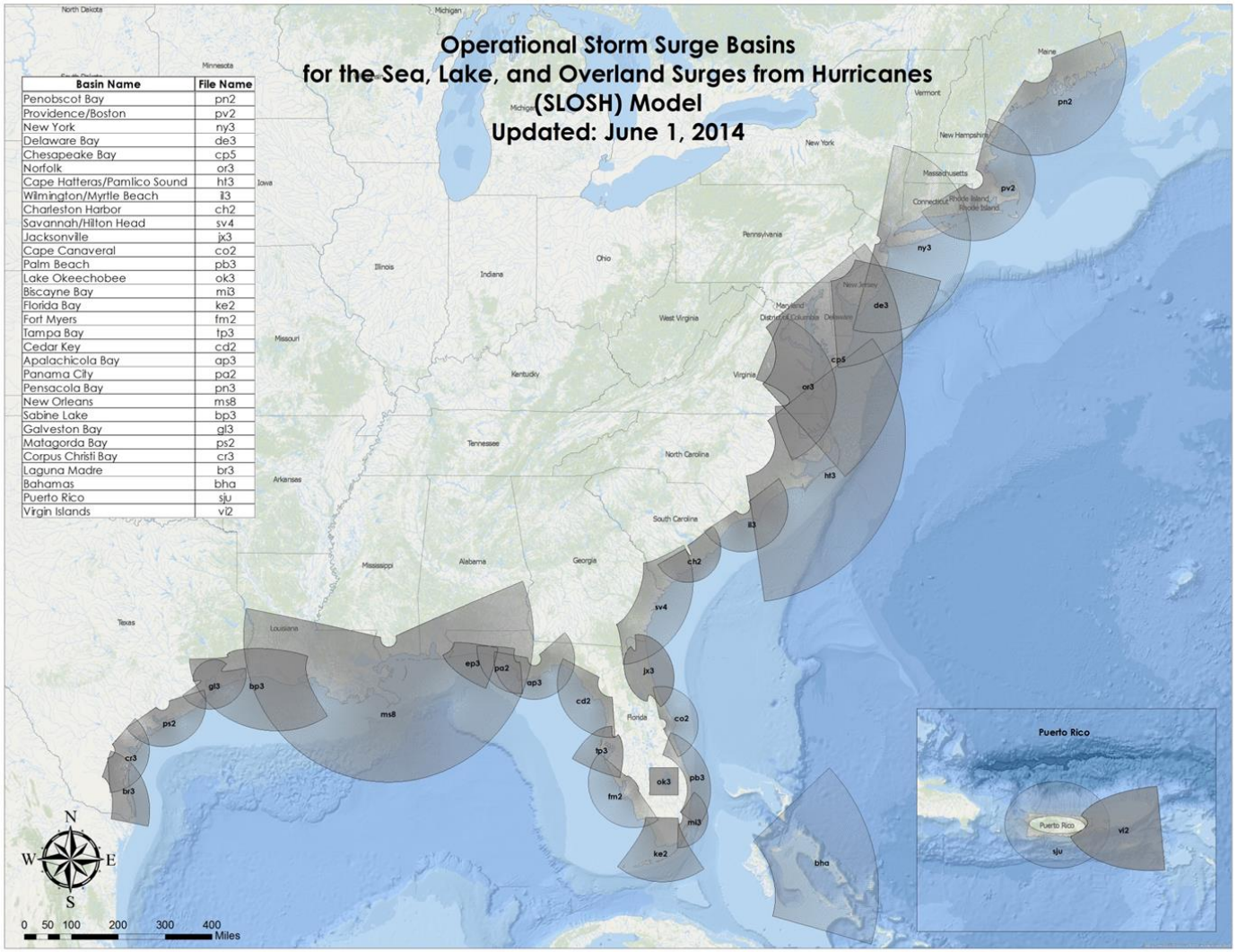
Method 1: Nesting



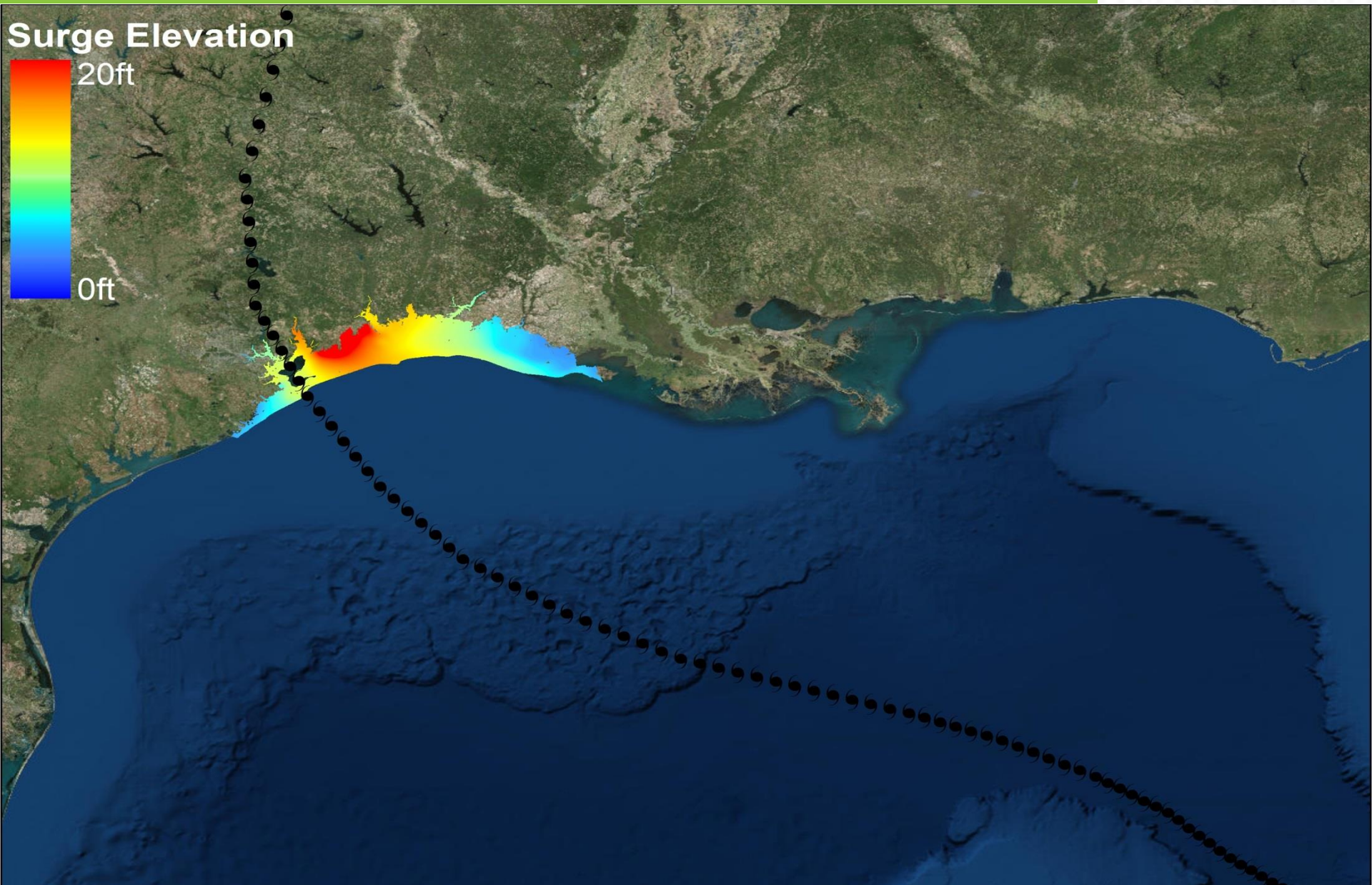
Method 2: Local Simulation



Example of Local Simulation: SLOSH



Example of Local Simulation: AIR Surge Model



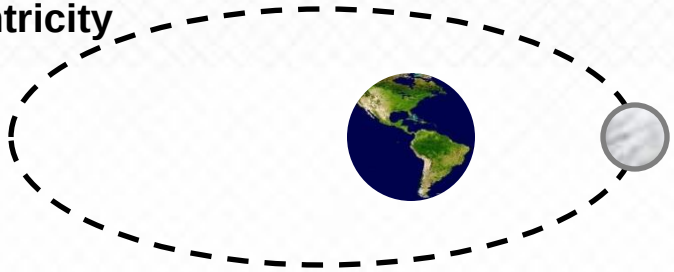
Other Considerations

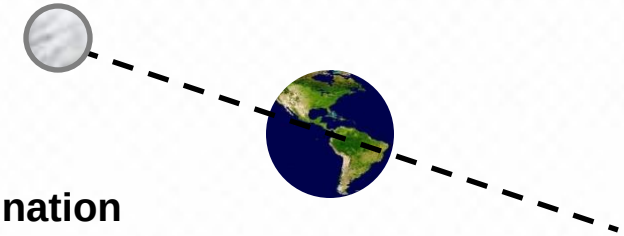
Tides Are a Complex, Non-linear Process

Neap Tide

Spring Tide

Orbital Eccentricity

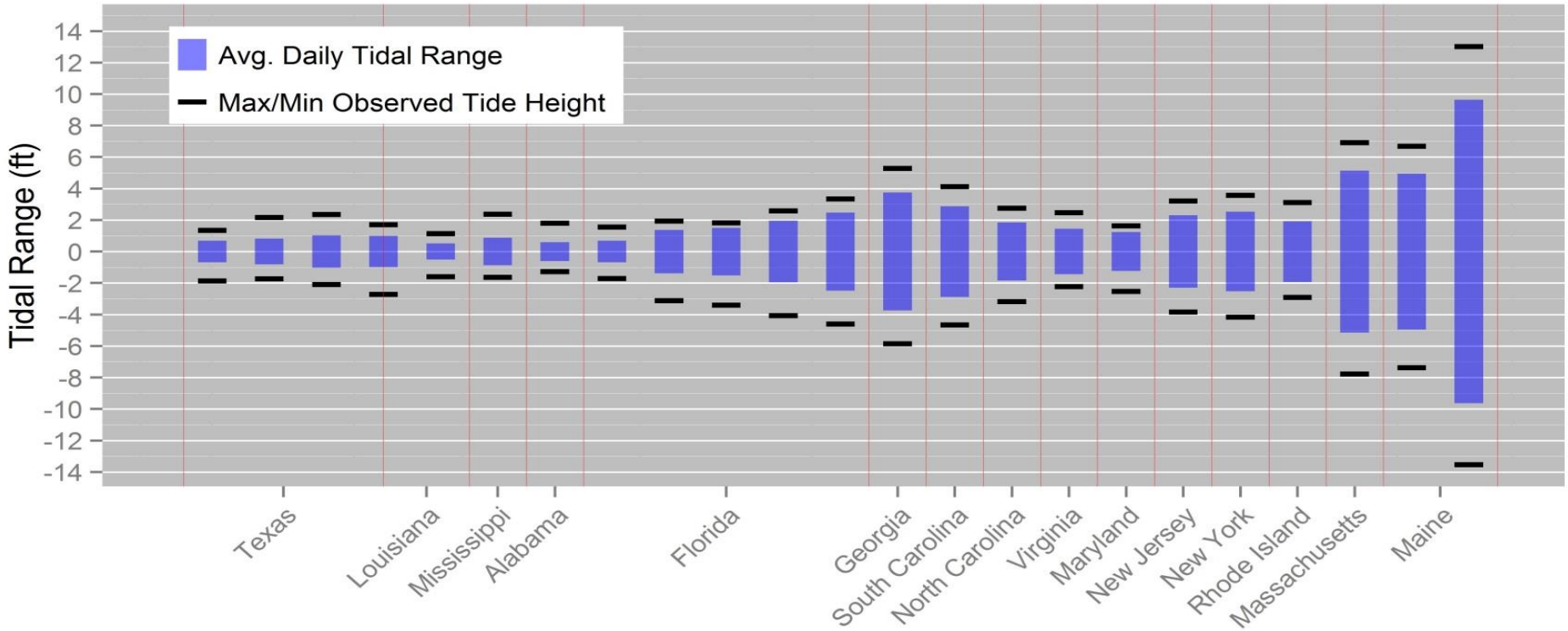




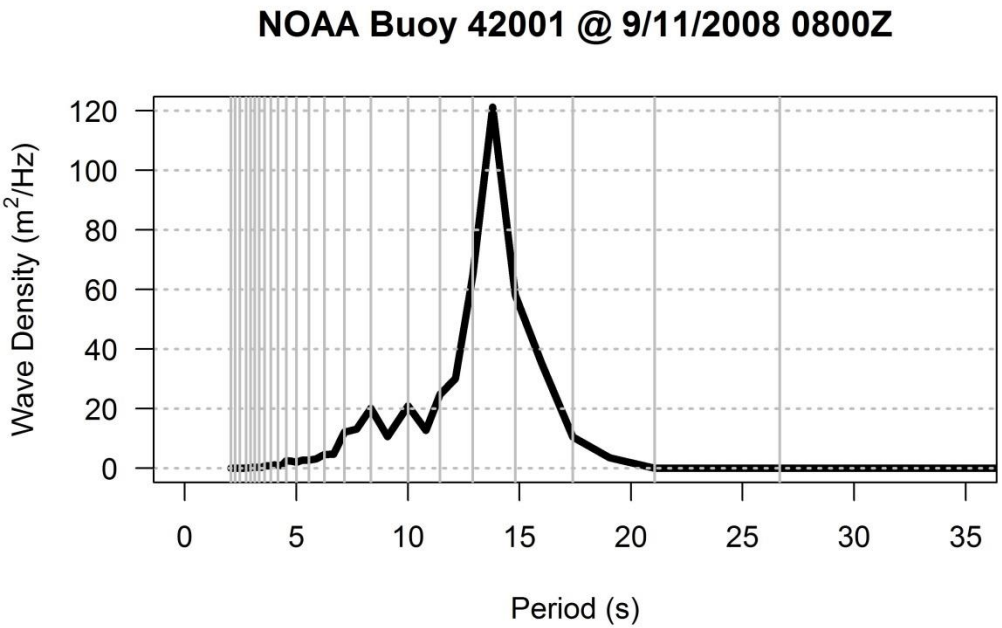
Orbital Declination

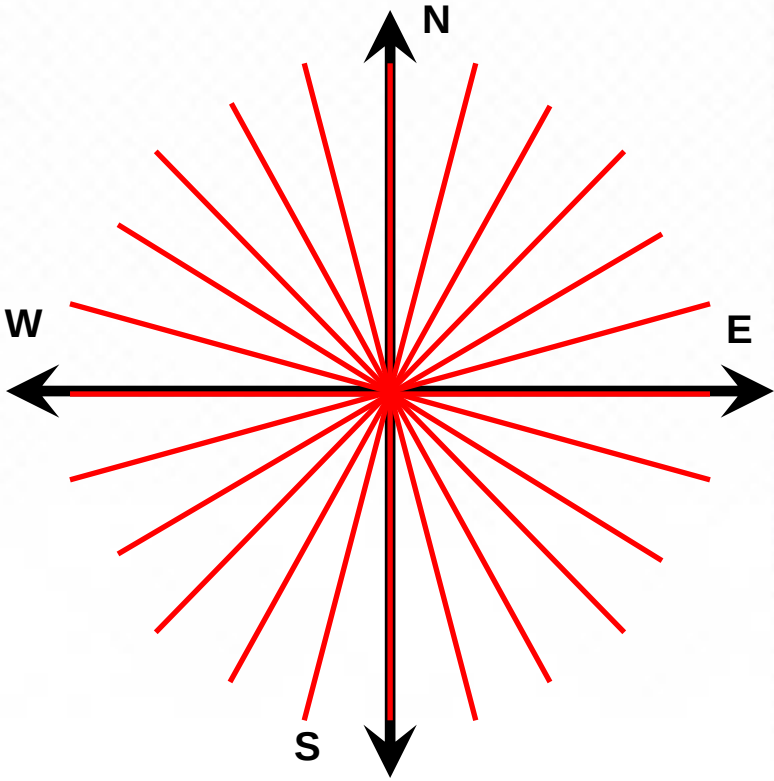
- 19-year cycle
- Local geography modification
- Can cause large departures from mean tides

Tides Vary Spatially and Temporally



Waves Are an Even More Complex Phenomena to Capture than Storm Surge Computationally





- **Storm Surge**
  - **3 Variables to solve for at every time step**
    - **water elevation, currents in x and y directions**
- **Waves**
  - **1 Variable to solve for at every time step**
  - **Must be computed in each direction at each frequency**
  - **Longer time step than storm surge**

Wave Damage Varies Much More than Surge Damage

And there will always be some things we'll never be able to capture…

Photo Credit: David J Phillip

Conclusions

- The tools and data (for the most part) already exist to accurately simulate storm surge
- The eternal struggle of the storm surge modeler is finding the balance between resolving relevant surge processes and computational limitations
- Function will often dictate form
  - Single event or location analysis → high resolution, spatially limited domain
  - Multi-event or continental scale analysis → spatially broad domain, often split into multiple high resolution domains
- Non surge processes (tides, waves) can impact water levels and losses, but may adversely impact computation
- An accurate surge model is only one part of an accurate catastrophe model

Thank You!

Photo Credit: Johnny Hanson