Let it Rain on your mesh
Integrating Hydrologic and Hydraulic Modeling to Simulate Hurricane Flooding in Coastal Areas

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Flooding caused by Hurricanes and Tropical Storms

- Storm surge / Sea level rise
- River flooding
- Local rainfall / runoff
Sturm Surge
Sea Level Rise

The Battery, NY  
2.77 +/- 0.09 mm/yr

Source: NOAA
Hydrologic model
→ Runoff, losses, and Q(t) hydrograph

Hydraulic model
→ Flood routing [depths and velocities]

Integrated Hydrologic and Hydraulic model
→ Runoff, losses, and Flood routing [depths and velocities]
Integrated Hydrologic-Hydraulic Modeling Challenges

- Urban environment (buildings, streets, etc.)
  - Resolve complex terrain and geometry
  - Wetting-drying

- Structures (levees, walls, roads)
  - Geometrical adaptation to arbitrary polylines

- Multiple inflow/outflow boundaries
  - Water may enter and leave mesh during simulation
  - Discharge and stage BCs

- Combined forcing
  - Extreme rainfall + storm surge

- Extremely long model runtimes
  - Large meshes required
  - Rapid changes in depths and velocities
Flexible Mesh

\[ \eta, u, v, z_b \]
HYDROLOGIC COMPONENT

- Rainfall/Evaporation
  - Spatially distributed, varied in time
  - Rainfall input: Radar, gauges, etc.
  - ASCII Grid or polygon input

- Infiltration loses
  - Spatially distributed parameters/methods
  - Horton
  - Green-Ampt
  - SCS-CN
Addressing Computational Challenge with RiverFlow2D GPU

- CPU → Central Processing Unit (OpenMP)
- GPU → Video Cards
- GPUs → 5000+ processors (cores)
- Requires specialized programming (NVIDIA CUDA)

<table>
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<th>GPU CARD</th>
<th>Number of Cores</th>
<th>Memory GB</th>
<th>Cost US$</th>
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Evolution of RiverFlow2D GPU Performance

~ 9 days vs 20 minutes
RiverFlow2D GPU in the Cloud

- Google or Amazon Cloud Services
- Create Virtual Machines with top of the line GPU hardware
- Cost effective: < US$ 2/hour
- Drawback...Data transfer to and from the Cloud...
Hurricane Sandy flooding Simulations

- 5-7 in. rainfall
Figure 54: Water levels above Mean Lower Low Water (MLLW) at The Battery, NY. Lines denoting Highest Astronomical Tide (HAT) and Historical Maximum Water Level are displayed. Maximum recorded water level value exceeded the historical maximum value. Sandy made final landfall near Atlantic City, NJ on 10/30/2012 00:00 GMT as a Category 1 hurricane.
- ddd
Observed Flooding vs RiverFlow2D Flooding Area
Final Comments

- Integrated hydrologic-hydraulic modeling is more realistic

- Taking advantage of GPU technology makes possible using high resolution and large meshes

- Use of Cloud services (e.g. Google, Amazon) minimizes modeling costs
Thank you! Questions?