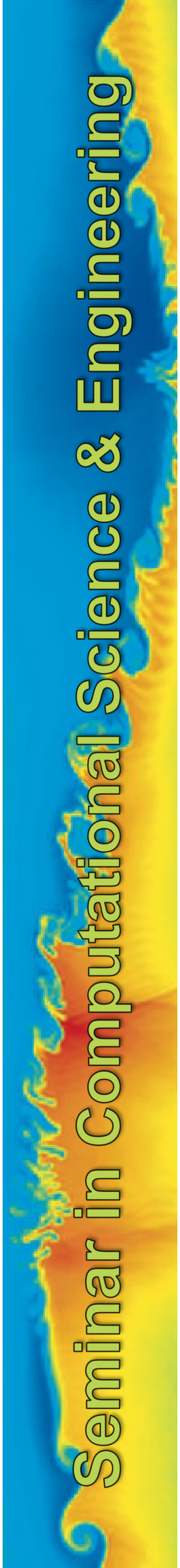

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Hurricane Storm Surge Models Using Integrated Ocean Basin to Shelf to Inland Floodplain Unstructured Grids

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Hurricane wind wave, storm surge, and current environments in the coastal ocean and adjacent coastal floodplain are characterized by their high energy and by their spatial variability. These processes impact offshore energy assets, navigation, ports and harbors, deltas, wetlands, and coastal communities. The potential for an enormous catastrophic impact in terms of loss of life and economic losses is substantial.

Computational models for wind waves and storm driven currents and surge must provide a high level of grid resolution, fully couple the energetic processes, and perform quickly for risk assessment, flood mitigation system design, and forecasting purposes. In order to accomplish this, high performance scalable codes are essential. To this end, we have developed an MPI based domain decomposed unstructured grid framework that minimizes global communications, efficiently handles localized sub-domain to sub-domain communication, applies a local inter-model paradigm with all model to model communications being kept on identical cores for sub-domains, and carefully manages output by assigning specialized cores for this purpose. Continuous Galerkin (CG) and Discontinuous Galerkin (DG) implementations are examined. Performance of explicit and implicit implementations of the wave-current coupled system on up to 32,000 cores for various platforms is evaluated.

The system has been extensively validated with an ever increasing amount of wave, water level and current data that has being collected for recent storms including Hurricanes Katrina (2005), Rita (2005), Gustav (2008), Ike (2008), and Sandy (2012). The modeling system helps understand the physics of hurricane storm surges including processes such as geostrophically driven forerunner, shelf waves that propagate far away from the storm, wind wave – surge interaction, surge capture and propagation by protruding deltaic river systems, the influence of storm size and forward speed, and frictionally controlled inland penetration.

These models are being applied by the US Army Corps of Engineers (USACE) in the development of the recently completed hurricane risk reduction system in Southern Louisiana as well as for the development of FEMA Digital Flood Insurance Rate Maps (DFIRMS) for Texas, Louisiana, Mississippi, and other Gulf and Atlantic coast states. NOAA applies the models in extra-tropical and tropical storm surge forecasting.

Current algorithmic development is focused on DG solvers, ideally suited for the associated strongly advective flows. Due to the larger numbers of degrees of freedom for a specific grid, DG solutions have traditionally been more costly than CG solutions. It is demonstrated that high order implementations of DG leads to several orders of magnitude improvement in cost per accuracy performance as compared to lower order methods. In addition, loop level optimization further improves the efficiency of DG solutions by a factor of 4 to 5. It is noted that curved boundaries must be treated using super-parametric elements for p=1 and p=2 and iso-parametric elements for p=3 in order to achieve anticipated convergence rates.

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