Department of Justice Expert Witness Report:
SWAN+ADCIRC Storm Surge and Wave Simulations for Hurricane Katrina within Metropolitan New Orleans and St. Bernard Polder

***St. Bernard Parish v. United States*, No. 05-1119 (Fed. Cl.)**

Prepared by

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1. Introduction

1.1 Purpose of the study

This study (Study) investigates the surge[1] and wave conditions within the Inner Harbor Navigation Canal (IHNC), the Mississippi River Gulf Outlet (MRGO), and the resulting flooding within St. Bernard Polder during Hurricane Katrina (2005), with emphasis upon the flooding experienced on eleven specific plaintiff-owned properties[2] in the Lower Ninth Ward of New Orleans and St. Bernard Parish that are the subject of the upcoming trial in this matter. The Study uses the most recent high resolution computational model of the region and the tightly coupled state-of-the-art SWAN+ADCIRC wave and surge computational codes [Westerink et al., 2008; Zijlema, 2010; Dietrich et al, 2011b; Dietrich et al, 2012a]. The model used in this Study is the most sophisticated modeling effort to date, significantly surpassing that used in the *Katrina Canal Breaches Consolidated Litigation*, No. 05-4182 (E.D. La.) and in fact all previous models.

To perform accurately, the Study computational models geographically incorporate the western North Atlantic Ocean, the Caribbean Sea, the Gulf of Mexico, and the coastal floodplains of Louisiana and Mississippi. The Study Area of specific interest extends along the Inner Harbor Navigation Canal ("IHNC") and the MRGO Reach 1, incorporating these canals from Seabrook to the IHNC Lock to the Paris Rd. Bridge, and the MRGO Reach 2, Figure 1.[3] The Study Area incorporates the St. Bernard Polder. The baseline simulation of surge and wave conditions that occurred during Hurricane Katrina

[1] This study describes the surge or specifically *surface water elevations* that are the combined effect of the winds, atmospheric pressure, waves, riverine flow, and tides that occurred during Hurricane Katrina. The surface water levels reported in this Study are in feet (ft) and are referenced to the vertical datum NAVD88 (2004.65). NAVD88 (2004.65) is positioned about 0.44 ft above Local Mean Sea Level (LMSL) (Bunya et al., 2010). The actual depth of the water at any position must add ground elevations lying *below* zero NAVD88 (2004.65) and must subtract ground elevations lying *above* zero NAVD88 (2004.65).

[2] Table 1 lists the eleven plaintiff-owned properties that are the subject of this Study. For ease of reference, these properties have been assigned abbreviated names and numbers reflecting their relative location throughout the Study Area.

[3] I understand that the parties have adopted the term "MRGO Reach 1" to describe the portion of the MRGO that extends due east from the IHNC and occupies the same channel as the Gulf Intracoastal Waterway ("GIWW") and the term "MRGO Reach 2 to describe the portion of the MRGO channel that runs from the GIWW/MRGO confluence just east of the Paris Rd. Bridge, to the southeast. I adopt the same terminology here.

incorporates the geometry, topography, bathymetry, surface roughness and breach conditions as they existed in 2005. This simulation will be referred to as Model A1 - *Katrina Actual Event Conditions* and is performed using the SL16-DOJ-SB-A1 model, which is based on the well-validated SL16 model with several refinements within the IHNC/MRGO channel and levee system [Dietrich et. al, 2011a; Dietrich et. al, 2012a; Hope et al., 2013].

The Study simulates surge and wave conditions during Hurricane Katrina within the Gulf of Mexico, Southern Louisiana, Mississippi and the Study Area, and validates these simulations using available data. The Study also examines the influence of the MRGO, levees, breaches, and state of the wetlands on surge and wave conditions in the Study Area under different modeled scenarios described below. Specifically, six surge and wave models have been developed for cases in which the physical system description diverges from Model A1 - *Katrina Actual Event Conditions*. These models examine the following influences: breaches in the IHNC floodwalls during Hurricane Katrina; changes in the MRGO's shape from its completed authorized dimensions in 1968 to its actual dimensions in 2005; changes in wetland topography and roughness occurring between the commencement of construction of the MRGO project in 1958 to the time of Hurricane Katrina in 2005; the existence of the MRGO channel itself; and the existence of the federal levees constructed around St. Bernard Polder along the MRGO's banks. These cases are summarized in Table 2.

The opinions expressed in this Study are based upon a reasonable degree of scientific and engineering certainty. If additional information or data becomes available, I reserve the right to revise the conclusions and opinions in this Study. Therefore, I reserve the right to amend my opinions for this purpose. Furthermore, I am also prepared to address any additional issues within my areas of expertise that may be raised at trial.

1.2 Study participants

The Study was performed by Joannes J. Westerink as a portion of an investigation commissioned by the Department of Justice. Components of the hydraulic analyses for the Study were performed by Dr.

John H. Atkinson, Mr. Zach Cobell, Dr. Shan Zou, and Mr. Hugh J. Roberts of ARCADIS in Boulder, CO. Professor Robert A. Dalrymple, the Willard & Lillian Hackerman Professor of Civil Engineering in the Department of Civil Engineering at Johns Hopkins University in Baltimore, MD, also served as a consultant in this Study.

1.3 Summary of Conclusions

1.3.1 Surge and wave conditions in and around the St. Bernard Polder during Hurricane Katrina

Historical storm surge and wave conditions during Hurricane Katrina are well simulated by Model SL16-DOJ-SB-A1, the *Katrina Actual Event Conditions* model presented in this Study. The modeled hydrographs outside of and inside of St. Bernard Polder closely match the historic hydrographs measured during Hurricane Katrina and its immediate aftermath. Likewise, the modeled high water marks (HWM) closely match those measured in the aftermath of the storm.

Model A1, *Katrina Actual Event Conditions*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 10.5 ft at Adams; 10.7 ft at StBP #1; 10.8 ft at StBP #2; 11.0 ft at Tommaseo; 11.3 ft at StBP #3; 11.5 ft at StBP #4; 11.5 ft at Steve's RV; 11.5 ft at StBP #5; 11.6 ft at Bordelon; 11.7 ft at PSSI; and 17.3 ft at Florissant.

1.3.2 Source of the water that flooded St. Bernard Polder

The water that penetrated St. Bernard Polder came predominantly from Lake Borgne and was pushed towards New Orleans by winds from the northeast and east as well as from high water in the Mississippi Sound. The water mass in Lake Borgne followed the path of least resistance and flooded the St. Bernard Polder. The water did not come from Breton Sound, Chandeleur Sound, Caernarvon Marsh, or Biloxi Marsh through MRGO Reach 2.

1.3.3 Impact of the breaching location on the flooding within and around St. Bernard Polder

Flooding in the Lower Ninth Ward and vicinity up to Paris Rd. was dominated by the IHNC breaches. Flooding at locations behind the 40 Arpent levee to the east of Paris Rd. and within the Central Wetlands was dominated by the breaches of the MRGO Reach 2. Thus, when the MRGO Reach 2 breaches are eliminated from the model, flooding levels at locations Adams, StBP #1, and StBP #2 were only moderately reduced by about 1.5 to 2.5 ft while locations to the east of Paris Rd. and within the Central Wetlands saw reductions of 3.9 to 7.7 ft. Florissant was not influenced.

Model A2, *2005 MRGO/2005 Wetlands/IHNC Breaches Only*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 9.0 ft at Adams; 8.5 ft at StBP #1; 8.3 ft at StBP #2; 7.1 ft at Tommaseo; 6.2 ft at StBP #3; 4.6 ft at StBP #4; 4.6 ft at Steve's RV; 4.6 ft at StBP #5; 4.6 ft at Bordelon; 4.0 ft at PSSI; and 17.5 ft at Florissant.

1.3.4 Impact of the maintenance of the MRGO and state of the wetlands on flooding within and around St. Bernard Polder

By defining the MRGO as it was designed and specifying 1956 wetland conditions, Model B1 demonstrates that the actual MRGO maintenance and wetland conditions only minimally impacted flooding in St. Bernard Polder with maximum water surface elevations reducing by about 1 ft at all interior polder locations and not at all at Florissant. Water levels along MRGO Reach 2 were minimally impacted while water levels in the central portion of the IHNC dropped by only 0.7 ft.

Model B1, *MRGO as Designed/1956 Wetlands*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 9.3 ft at Adams; 9.5 ft at StBP #1; 9.7 ft at StBP #2; 10.1 ft at Tommaseo; 10.6 ft at StBP #3; 10.8 ft at StBP #4; 10.8 ft at Steve's RV; 10.8 ft at StBP #5; 10.9 ft at Bordelon; 11.0 ft at PSSI; and 17.2 ft at Florissant.

1.3.5 Impact of the construction of the MRGO on the surge and wave conditions within and around St. Bernard Polder

Model C, the *No MRGO/1956 Wetlands* scenario, models conditions as they existed prior to 1958. This model indicates that while water levels in the central portion of the IHNC were lowered by about 1.4 ft, water levels in the vicinity of the MRGO Reach 1 at the Paris Rd. Bridge increased by about 0.3 ft. Thus, there was a 1.7 ft in flood reduction for properties in the vicinity of the Lower Ninth Ward and little or no flood reduction elsewhere in the polder.

Model C, *No MRGO/1956 Wetlands*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 8.8 ft at Adams; 9.0 ft at StBP #1; 9.1 ft at StBP #2; 10.3 ft at Tommaseo; 11.0 ft at StBP #3; 11.5 ft at StBP #4; 11.5 ft at Steve's RV; 11.5 ft at StBP #5; 11.5 ft at Bordelon; 11.6 ft at PSSI; and 17.2 ft at Florissant.

1.3.6 Impact of the construction of federal levees on surge and wave conditions within and around St. Bernard Polder

Model D, which eliminates the key federal levees, shows that the water from Lake Borgne essentially flows unimpeded into the Central Wetlands and then easily overtops the 40 Arpent levee as well as the levees protecting Poydras, LA and St. Bernard, LA. Flooding at interior polder locations increased by 3 to 5 ft and at Florissant flooding remained the same as in all cases. This model shows that even a deteriorated first line of exterior defense, i.e. the MRGO levees, benefits interior portions of the system.

Model D, *No Federal Levees/2005 MRGO/2005 Wetlands*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 14.1 ft at Adams; 14.3 ft at StBP #1; 14.5 ft at StBP #2; 14.7 ft at Tommaseo; 15.0 ft at StBP #3; 15.6 ft at StBP #4; 15.6 ft at Steve's RV; 15.8 ft at StBP #5; 16.8 ft at Bordelon; 14.8 ft at PSSI; and 17.1 ft at Florissant.

1.3.7 The combined impact of the construction of federal levees, the construction of the MRGO, and the deterioration of the wetlands on surge and wave conditions within and around St. Bernard Polder

Model E eliminates the key federal levees and the MRGO, and considers the wetlands to be in their 1956 condition. This model again shows that the water from Lake Borgne essentially flows unimpeded into the Central Wetlands and then easily overtops the 40 Arpent levee as well as the levees protecting Poydras, LA and St. Bernard, LA. Flooding at interior polder locations increased by 3 to 5 ft and flooding at Florissant flooding remained the same as in all cases. Since the water comes from Lake Borgne and is pushed into the polder unimpeded, the conditions of the wetlands and channels were only of minor consequence.

Model E, *No Federal Levees/No MRGO/1956 Wetlands*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 13.8 ft at Adams; 14.1 ft at StBP #1; 14.3 ft at StBP #2; 14.5 ft at Tommaseo; 14.9 ft at StBP #3; 15.5 ft at StBP #4; 15.6 ft at Steve's RV; 15.7 ft at StBP #5; 16.6 ft at Bordelon; 14.9 ft at PSSI; and 16.9 ft at Florissant.

2. Computational Models for Storm Surge and Waves in Louisiana

2.1 Storm surge and wave codes

Computer modeling of water surface elevation, water currents, and water waves in the coastal ocean and adjacent floodplain has rapidly evolved in the past decade coincident with both recent catastrophic hurricane floods and the exponential growth of the speed and capacity of computers. The water surface elevation (surge in the case of a hurricane) and water flow computer codes solve partial differential equations for conservation of momentum (**F=ma**) and conservation of water volume. These computer codes approximately solve the governing equations at discrete points on a so-called *grid*. The resolution of the grid, *i.e.* the spacing of the grid points, determines how accurately the physical system is represented (information such as topographic elevations, bathymetry, channels, and frictional resistance are specified at the grid points), as well as how accurately the water surface elevation and currents are computed. Unstructured grid water surface elevation/current codes such as ADCIRC, locally vary grid point spacing or grid resolution, with the finest grid resolution provided where solutions change rapidly [Westerink et al., 2008]. The concept of grid resolution is conceptually very similar to *pixilation* of a digital photograph where increases in the density of the pixels result in a much finer representation of the image. Unstructured grids using spatially variable grid resolution is analogous to a technology recently coming into widespread use in video games referred to as *Tessellation*, which essentially increases pixel density locally in regions of specific interest or where the image changes rapidly. This is a much more efficient process than applying equally high resolution everywhere, even in large regions where that is unnecessary.

Surface water elevations and currents during a hurricane are driven by the winds, atmospheric pressure differences, wind waves, tides, and riverine currents, and are strongly influenced by the systems' bathymetry/topography, geometry, and surface and bottom roughness or so called *friction*.

Waves are typically simulated using computer codes that solve a partial differential equation for a variable related to wave energy and describe the generation, propagation, transformation, and dissipation of wind waves. WAM and STWAVE are structured grid wave models that are nested and coupled to each other in order to compute deep-ocean and nearshore waves [Smith et al., 2001; Gunter, 2005; Bunya et. al; 2010]. Recently, the SWAN wave model, a model developed in the Netherlands and used by the U.S. Navy, has been developed into an unstructured grid model permitting high grid resolution to be provided where it is essential and for both the deep ocean and coastal regions to be modeled using one grid [Booij et al., 1999; Ris et al. 1999; Zijlema, 2009; Dietrich et al, 2010b].

Waves are driven by winds and are strongly influenced by the systems' bathymetry/topography, geometry, and surface roughness, as well as water column depths and currents. Water surface elevations, currents, and wave processes do interact. For example, wave conditions strongly depend on total water column depths and currents while wave transformation processes such as wave breaking can drive significant currents and can push storm surge levels up by as much as 2.5 ft during a hurricane [Dietrich et al., 2010]. Therefore surface water elevation/current codes and wave codes must share information with each other. The state-of-the-art in high performance - high resolution coupled wave and surface elevation/current codes is the coupled SWAN+ADCIRC model, jointly developed by Delft University (the developers of the well-tested SWAN model) in the Netherlands and the University of Notre Dame, the University of North Carolina at Chapel Hill, and the University of Texas at Austin (the developers of the ADCIRC model) through a joint contract from the U.S. Office of Naval Research. The SWAN and ADCIRC code components are applied to an identical unstructured grid, allowing for localized increases in resolution without the complexity or cost of nested grids or global interpolation between heterogeneous grids [Dietrich et al., 2011a; Dietrich et al., 2011b; Hope et al., 2013]. In addition, the code is specifically designed to be optimal from a computational perspective for massively parallel high performance supercomputers [Dietrich et al., 2012a].

2.2 The evolution of computational grids and models for Southern Louisiana

As summarized in the previous section, hurricane wave and surge model skill depends on the level of grid resolution, how well the physical system is described, and how accurately winds, air-sea drag, bottom roughness, and wave-current interaction are quantified. A sequence of ADCIRC and SWAN+ ADCIRC models of increasing detail and complexity has evolved over the past decade. These models have continuously improved on both the level of grid resolution, *i.e.* how well they describe the physical system (topography, bathymetry, and surface roughness), and on their descriptive physics (wave-current interaction, air-sea drag, and bottom roughness). In addition, the measurement data sets used to quantify the skill and accuracy of the models have also evolved with more recent storms such as Hurricanes Gustav and Ike, which were subject to detailed measurements in real time and have been modeled repeatedly since, with the results compared to the well-kept historic measurements [Dietrich et al., 2011a; Kennedy et al., 2011; Kerr et. al. 2013a; Hope et al., 2013]. The more storms and the more regions a model can accurately hindcast, the more confident we can be in its ability to correctly describe the storm processes.

The original ADCIRC model for Southern Louisiana was the S08 model and was developed by Westerink et al. [2008] for the U.S. Army Corps of Engineers New Orleans District ("USACE-MVN"). This model was put into use in 2004 and simulated tides, riverine flow and storm surge throughout the Gulf of Mexico. The level of resolution was relatively coarse, with only 314,442 grid nodes and the highest level of grid resolution equal to 320 ft in Southeastern Louisiana. This is the version of the model that was used by the plaintiffs' experts to model Hurricane Katrina for the 2009 trial in the *In re: Katrina Canal Breaches Consolidated Litigation*, No. 05-4182 (E.D. La.) (the "*Robinson*" trial). I also understand that an expert for Plaintiffs in this matter, Dr. Paul Kemp, has offered opinions in this case based on the S08 modeling results presented by the plaintiffs' experts in *Robinson*. This model has much lower grid resolution; a much less accurate representation of the channels, wetlands, bathymetry, and topography; and a much less accurate representation of the surface friction and air-sea drag than the model used in this Study.[4] The S08 model was also not extensively validated with comprehensive data sets and overall has a significantly lower level of skill and accuracy. As implemented by the plaintiffs, the model also applied much less accurate hindcast winds.

Subsequently, a sequence of SL15 models incorporated much more grid detail in both Louisiana and Mississippi (with 2,511,009 grid points and grid resolution down to 65 ft) [Bunya et al., 2011]. The improved grid resolution allowed for a much better description of the geographic system. Barrier islands were dynamically integrated into the system instead of being treated as vertical walls that could not be overtopped, bathymetry was vastly improved based on updated surveys, inland channels and rivers were much better resolved, and topography was based on modern and newly released LIDAR measurements [Bunya et. al., 2010, Dietrich et al., 2010]. The physics was improved by using sophisticated overland surface frictional resistance models based on satellite imagery of land use types. In addition, the effect of waves on storm water levels was accounted for by coupling to a sequence of structured grid wave models [Bunya et al., 2010; Dietrich et al, 2010a]. The coupling to the nested structured grid WAM/STWAVE wave models allowed for the effects of wave transformation forcing on surge and currents to be simulated. The effects of waves forcing can add up to 2.5 ft of surge in Southeastern Louisiana and can also be a significant driver of currents.

The most recent SL16 model adds significantly more detail and grid resolution throughout Southern Louisiana, the adjacent shelf, as well as the Gulf of Mexico itself [Dietrich et al., 2011a; Dietrich et al., 2012a]. The mesh is comprised of 5,036,960 vertices and 9,949,317 triangular elements with resolution as fine as 45 ft. The model captures a very high level of geometric, topographic and bathymetric detail as supported by the high level of resolution in the grid. The model further refines channels and rivers, better resolves the surf zone where wave breaking takes place, and improves the definition of topography in

[4] A comparison of the grid used in this Study and the S08 grid is presented in section 3 of this report which compares Figures 3 and 5 with corresponding Figures 7 and 8.

wetlands by applying USGS land use type maps [Dietrich et al., 2011a]. The SL16 model is specifically designed to work with the tightly coupled SWAN+ADCIRC code and integrally couples the wave – current interaction [Dietrich et al., 2011b]. Note that both waves and currents are computed on the identical unstructured grid at all grid points, a significant advantage compared to earlier nested WAM/STWAVE/ADCIRC models. The SL16 model incorporates a more accurate representation of bottom friction on the continental shelf, recognizing the muddy smooth surface that exists on much of the Louisiana-Texas shelf [Dietrich et al., 2011a; Kennedy et al, 2011; Hope et al., 2013]. The SL16 model also applied a much improved air-sea interaction model based on direct measurements obtained using GPS instrumented dropsondes which were released from NOAA's hurricane hunter planes [Dietrich et al., 2011a]. This air-sea interaction formula used with the SL16 model represents a major advance in hurricane surge forecasting abilities. Hurricanes Katrina, Rita, Gustav and Ike have all been hindcast using the SL16 grid in Louisiana and have achieved a high level of accuracy in hindcasting surges.

ADCIRC and SWAN+ADCIRC codes are used extensively throughout academia, government, and the private sector. A recent National Oceanic and Atmospheric Administration ("NOAA") Integrated Ocean Observing System ("IOOS") study has shown that these models are leaders in accurate hindcasting of hurricane storm surge and wave environments and in fact represent a huge advance over the currently applied SLOSH model (develop in the late 1960's) used in hurricane surge forecasting by the National Weather Service ("NWS") [Kerr et al., 2013b]. This is particularly the case when the ADCIRC models are applied with high resolution grids [Kerr et al., 2013a]. Users and applications of the ADCIRC models include: the Federal Emergency Management Agency ("FEMA") to develop Flood Insurance Rate Maps ("FIRMS") along the U.S. Atlantic and Gulf coasts; the U.S. Army Corps of Engineers ("USACE") to design the levees post Hurricane Katrina in New Orleans; the Nuclear Regulatory Commission which requires ADCIRC studies to evaluate the safety of coastal nuclear power stations; NOAA to forecast tides and extra-tropical storms along the U.S. East coast and in Vertical Datum (VDATUM) projects; the government of South Korea to design and operate tidal power plants; FMGlobal, a large industrial mutual insurance company to evaluate the flooding associated with Hurricane Sandy in New York City as well as to evaluate flood risk in Japan and Korea; the Indian National Centre for Ocean Information Services ("INCOIS") to evaluate storm surge in India; by Delft University, a leading technical university in Europe; by Arcadis for the City of New York to evaluate proposed regional and local coastal flood protection measures for the *2013 New York City Special Initiative for Rebuilding and Resiliency;* and by the State of Louisiana to understand flood risk and mitigation in Southern Louisiana.

3. The SL16-DOJ-SB-A1 SWAN+ADCIRC Model of Southeast Louisiana

In order to hindcast Hurricane Katrina as well as simulate this storm for a number of hypothetical scenarios, the SL16 model was modified in four ways. First, since only Hurricane Katrina will be simulated in this Study, the high resolution grid coverage of inland areas to the west of the Mississippi River was eliminated. This reduces computer simulation time and cost. It does not affect simulation results for areas to the east of the river since the inland flooding impact to the west of the river was minimal. This resulted in the SL16-DOJ-SB-A1 model/grid. This model/grid is designed to represent the physical and geographic system as it existed prior to Hurricane Katrina in 2005. The model domain and bathymetry/topography are shown in Figures 2 and 3. The model grid portions in Southeastern Louisiana and the Study Area (St. Bernard Polder and Lake Borgne connecting to Lake Pontchartrain) are depicted in Figure 4 which shows the unstructured triangle-based grid and the vertices of the triangles that define the actual "computational nodes" of the grid where bathymetry/topography and frictional characteristics are defined and where water levels, currents, and wave characteristics are computed in the model. The element and node density increase where feature definition changes rapidly in space, for example where channels occur. Figure 5 shows the resolution of the grid in feet by color, again indicating that channels, which represent important flow conveyances, are particularly highly resolved. Figure 6 shows the spatial distribution of a frictional parameter known as Manning *n*, a standard way in hydraulic analysis of indicating how much resistance the land surface exerts on the flow (also referred to as *bottom friction*). Muddy flat ocean bottoms offer the least resistance, sandy surfaces more, grasses and wetland scrub and brush and vegetation even more, and forests the most [Dietrich et al., 2011a; Hope et al., 2013].

Second, the SL16-DOJ-SB-A model improves the resolution, bathymetry, and bottom surface frictional definition of the IHNC to better represent this channel in the overall grid. Improved grid resolution results in better system definition and also in better flow and wave computations.

Third, this model accounts for levee degradation along the entire St. Bernard Polder. This includes two major breaches along the IHNC and numerous breaches along the MRGO Reach 2 St. Bernard Polder Levee. The breaches are depicted in Figure 1. The IHNC North breach was initiated at 6am on August 29 and developed to the full breach depth over a 30 min duration; the IHNC South breach was initiated at 6:45am and developed to the full breach depth over a 15 min duration; the MRGO Reach 2 breaches were initiated at 5:45AM and developed to the full breach depths over a 2.5 Hour duration. The IHNC breaching times are based on consensus times [Dalrymple, 2011, Kok et al., 2007, Kok et al., 2008]. The MRGO Reach 2 breaching times are based on Dalrymple [2011] and are essentially consistent with the times adopted by the *Robinson* plaintiffs whose expert Kok et al. [2007, 2008] used 5:00 am to 8:30 am. These breach times also track the physical characteristics of Hurricane Katrina as we have modeled the storm. We note that along the MRGO Reach 2, the surge was at 14.5 ft at 5:45 am while the significant wave heights varied between 6 and 7 ft. The initiation of the degradation of the MRGO Reach 2 levees would have occurred as a result of the combination of these water levels and the wave action and occurred prior to the peak water level of around 17 ft which occurred at around 8:30 am.

Fourth, a wave overtopping module was added that uses wave conditions at the levee in order to compute wave overtopping flows into the polder. The wave overtopping module is based on the *EurOtop* formula [Pullen et al., 2007], ADCIRC water levels, SWAN wave heights and periods, and levee geometry.

The SL16-DOJ-SB-A1 model represents the physical system and breaches as they occurred during Hurricane Katrina. Thus the SL16-DOJ-SB-A1 model is used as the base case in this Study to represent the conditions as they existed and developed prior to and during Hurricane Katrina. The model better describes the details of the water surface within the IHNC and MRGO channels as well as the full dynamic flooding within the St. Bernard Polder itself as compared to previous SL16 and earlier SL15 and

S08 models. The rapid and substantial advances in modeling technology are illustrated by comparing the bathymetry/topography and grid resolution of the S08 grid, Figures 7 and 8, to that of the SL16-DOJ-SB-A1 grid, Figures 3 and 5.

The SL16-DOJ-SB-A1 model simulates the water levels and waves better than any previous model and incorporates advancements that supersede Judge Duval's criticisms of the earlier SL15 model. The model includes no scaling of water surface elevations along the IHNC, MRGO Reach 1, and/or MRGO Reach 2[5] because levee overtopping, breaching, wave overtopping, and interior polder flooding are directly modeled with the SWAN+ADCIRC code. Furthermore, breaching times match previous studies and are consistent with the exterior polder water level and wave physics which degraded the MRGO Reach 2 levees. Finally, interior polder water level time histories and timings closely match measured time histories.

4. SWAN+ADCIRC Hindcast of Hurricane Katrina

4.1 Surge and wave analyses

Hurricane Katrina was a devastating storm that impacted the central Gulf of Mexico. Katrina's winds reached Category 5 strength in the Gulf of Mexico, but weakened to Category 3 strength as the storm approached the continental shelf. Its southerly track placed it within 30 miles of New Orleans and the infrastructure of southeastern Louisiana, and its storm surge of up to 29 ft along the coastline of Mississippi was the largest ever recorded in the United States.

We simulated Hurricane Katrina with the SL16-DOJ-SB-A1 model using the SWAN+ADCIRC code and the optimal H*WIND/OWI analysis data assimilated winds [Cox et al., 1995; Powell et. al; 1996; Powell et al., 1998; Cardone et al., 2007; Bunya et al., 2011]. Katrina was previously modeled with the SL15 grid in conjunction with the combined ADCIRC, WAM, and STWAVE codes as well as with the

[5] In previous modeling for the United States in the *Robinson v. United States* case, a scaling factor or multiplier of 1.04 was used in the SL15 model hydrographs along the IHNC levee, prior to being passed to a separate "interior" HEC-RAS model, to bring the peak elevations there up to measured values at the IHNC lock of 14.2 ft. It is noted that the Plaintiff's ADCIRC S08/FINEL model computed a water surface elevation at the IHNC lock of 17 ft, considerably over-estimating the peak water levels in the IHNC. Thus the earlier SL15 model underestimated surge by 0.5 ft while Plaintiff's model over-estimated by 2.8 ft.

SL16 grid in conjunction with the SWAN+ADCIRC model [Bunya et al, 2010; Dietrich et al, 2010; Dietrich et al, 2012a]. Figure 9 summarizes the development of the wind field as the storm made its first landfall, passed to the east of New Orleans, and passed its second landfall near the Louisiana-Mississippi border. We note sustained easterly winds ranging from 55 to 90 mph early on in the storm, which shifted to southerly 90 to 100 mph winds as the storm passed through Lake Borgne, and then weakened to westerly winds. Figure 10 shows that the easterly winds pushed up to 18 ft of water onto the Mississippi-Alabama shelf and against Plaquemines Parish and the St. Bernard Polder MRGO Reach 2 Levees. The surge is then directed towards the north and reinforced by the very intense southerly winds resulting in the massive 29 ft surge along the Mississippi coast. Figure 11 shows the significant wave height in Southeastern Louisiana and Mississippi during the storm, again indicating that the greater than 48 ft wind waves rapidly change in wave height and wave period as they move into shallower shelf waters and especially when they break over the barrier islands. In fact, most barrier island sheltered waters do not experience waves greater than 8 to 10 ft, while wetlands do not experience waves greater than 5 to 8 ft. In addition, as shown in Figure 12, mean wave periods diminish from 12 to 14 seconds in front of the barrier islands to generally less than 6 seconds behind the barrier islands. This indicates that the long period swell from the ocean is effectively eliminated in the sheltered regions and the wind seas are generated across the extensive sounds and low lying wetlands with 10 to 18 ft of water over them for much of the duration of the storm. Figure 13 illustrates that the extensive shallow water-bodies and low lying wetlands east of the Mississippi River readily allow the development of surge and wind seas in the region driven by easterly winds. This figure also illustrates that the MRGO has little impact on surge and wave processes regionally or locally.

Figure 14 through Figure 17 present more detailed views of the Hurricane Katrina winds and surge and wave response in the Study Area. We note that the easterly winds in the first part of the storm blow across the sounds and wetlands which are extensively inundated. As the storm passes the winds suddenly come from the north, then from the west. Surge builds up to about 17 ft against the MRGO Reach 2 levees. Surge in the Golden Triangle region to the east of Paris Rd. builds up to 15 to 16 ft, with water surface elevations slowly reducing through the MRGO Reach 1, and then diminishing more rapidly in the north section of the IHNC in order to match the water levels in Lake Pontchartrain. Water levels drop faster in the north section of the IHNC which features greater hydraulic resistance and reduced conveyance relative to MRGO Reach 1. Significant wave heights reach about 8 ft in Lake Borgne, but attenuate to 5 to 6 ft in the adjacent wetlands. When these waves cross the MRGO Reach 2 they increase again by about 1 ft such that they are about 7 ft at the base of the MRGO Reach 2 levees. Wave action is largely diminished in the IHNC and MRGO Reach 1 where significant wave heights generally less than 4 ft. At the IHNC lock, these largest waves occurred when the winds were northerly and aligned with the IHNC. In general, wave conditions and wave attenuation in the Study Area depend on the distance the winds blew/waves traveled across the sounds and wetlands, the total water column height (distance from the sea bottom or land surface to the surface water elevation), and the frictional resistance of the bottom. Depth-limited breaking is an important wave attenuation mechanism and is controlled by total water column height.

4.2 Model validation

The SL16-DOJ-SB-A1 *Katrina Actual Event Conditions* computations are validated by comparing to available high water marks (HWM), hydrographs, and wave data [Bunya et al, 2010]. Figure 18 shows the maximum water levels that occurred during the storm and Figure 19 shows the maximum significant wave heights that occurred during the storm. Figure 20 shows a comparison between measured HWM throughout eastern Louisiana and Mississippi as well as in the Study Area, now including interior HWM within St. Bernard Polder. Locations marked in green indicate that the HWM was within 1.65 ft (0.5 m) of the measured HWM. In all our studies, we perform statistical analyses which compare the measured HWMs to the ADCIRC computed values [Bunya et. al, 2010; Dietrich et al., 2010a; Dietrich et al., 2011a; Dietrich et al., 2012a; Hope et al., 2013]. We also perform error analyses on the measurement data itself and estimate the inherent errors in this data to produce error measures for the model itself that consider the error in the measurement data. The average absolute HWM error for this Study using the SL16-DOJ-

SB-A1 grid was 0.3 ft and the 95% HWM confidence interval equal to 1.2 ft (thus it is estimated that 95% of all HWM measurement points fall within 1.2 ft of the high water at measurement locations). This is consistent with other SL16 grid studies which produced: average absolute HWM error measures of 0.4 ft for Katrina, 0.9 ft for Rita, 0.5 ft for Gustav, and 0.6 ft for Ike; and a 95 % HWM confidence interval of 1.1 ft for Katrina, 1.0 ft for Rita, 0.7 ft for Gustav, and 0.9 ft for Ike. An extension of the SL16 grid that included Texas estuaries and the Texas coastal floodplain produced an average absolute error measure of 0.4 ft for and a 95 % confidence interval of 0.6 ft for Ike. The fact that there is consistency in a wide range of very different storms and a wide range of coastal surge and wave processes over a coast that includes Louisiana, Mississippi, and Texas gives us confidence in the skill and accuracy of the model [Dietrich et al., 2011a; Dietrich et al., 2012a; Hope et al., 2013; Kerr et. al, 2013a]. We can expect that surge is predicted within an accuracy of 1 ft. This error measure includes inaccuracies in resolution and the configuration of the physical system; inaccuracies in the physics that we use (specifically the representation of air-sea drag and bottom friction), and inaccuracies in the hurricane wind fields that we use to force the models.

Figure 21 shows the locations of the measured hydrographs (time histories of water surface elevation) both outside of and inside of the St. Bernard Polder in Southeastern Louisiana and the Study Area. While for later storms, such as Hurricanes Gustav and Ike, there is extensive hydrograph data [Dietrich et al., 2011a; Kennedy et al., 2011; Hope et al., 2013] due to improvements in the physical strength of previously existing gages as well as the deployment of many additional gages, during Hurricane Katrina a relatively low number of then existing gages were able to survive the storm and produce recorded time histories of water surface elevation. Some of the available Katrina hydrographs are based on hand measurements, and others are based on reconstructions using photos and/or stopped clocks. Figure 22 compares computed and measured hydrographs through the region while Figure 23 presents computed and measured hydrograph gages within the St. Bernard Polder. We note that the hydrograph at the IHNC lock is now much better represented than in older models such as the SL15 model,[6] in part, due to improvements in grid resolution and improvements in the air-sea drag and bottom friction relationships in the SL16 model, and, in part, due to the most recent improvements in resolution, bathymetry and friction as well as wave overtopping and breaching in the SL16-DOJ-SB-A1 model. Tides, storm surge peaks, and rising and falling water level rates, closely match recorded data indicating that the tide and surge physics are being faithfully simulated. Hydrographs interior to the St. Bernard Polder are also faithfully represented by the model, which matches available timing and peak measurements. Figures 24 through 27 indicate good matches to measured wave properties throughout the Gulf of Mexico. NDBC Stations 42040 and 42007 are of particular interest since they are in the region of immediate interest and demonstrate the wave attenuation that occurs when waves propagate from the deep ocean to the much shallower continental shelf waters. At Station 42040 located to the east of the Mississippi River bird's foot in deep ocean water, significant wave heights were up to 45 ft. At station 42007, located just to the northeast of the Chandeleur Islands, significant wave heights had attenuated to 20 ft. These processes are captured well by the SWAN+ADCIRC model.[7]

4.3 Tracking water sources

In order to ascertain where the water in St. Bernard Polder came from during Hurricane Katrina, we applied particle tracking methodologies developed during the 2010 Horizon Oil Spill in the Gulf of Mexico [Dietrich et al., 2012b]. We tagged masses of water with particles in Lake Pontchartrain and Lake Borgne, Mississippi Sound, Chandeleur Sound, Breton Sound, to the east of the Chandeleur Islands, and within the various navigation channels. The initial placement of the particles on August 28, 2005 at 0000 hrs is shown in Figure 28 with the various colors identifying their initial placement. A total of 60,000,000 particles represent these water masses. Each individual particle represents approximately 475 m^3 of water with the exception of the particles in mustard colored particle zone

[6] The SL15 model was used by the United States' experts in the *Robinson* case.

[7] For more the recent Hurricanes Gustav and Ike, wave gages were deployed in both the nearshore and in the wetlands and have demonstrated that the SWAN+ADCIRC model captures waves characteristics very well there also [Dietrich et al, 2011a; Hope et al., 2013].

number 15 to the east of the Chandeleur Islands where each individual particle represents 2375 m^3 of water. Figure 29 shows the evolution of these water masses during the actual storm event. It is noted that the Lake Borgne waters (red-9) are pushed both into Lake Pontchartrain, the IHNC Channel, MRGO Reach 1, and finally penetrate into the St. Bernard Polder. Waters from Mississippi Sound and vicinity (brown-10; dark green-11; deep blue-12) push into the Mississippi coast and floodplain, into Lake Pontchartrain and push into Lake Borgne. Chandeleur and Breton Sound Waters (medium green-13; light green-14) move into the Caernarvon Marsh and to the west of the Mississippi River Bird's foot delta. Waters in deeper waters to the east of the Chandeleur Islands tend to drive currents around the Bird's Foot delta to the west. It is noted that the flooding in St. Bernard Polder came predominantly from waters in Lake Borgne and not from waters that were driven in from Breton Sound through the MRGO Reach 2 channel. This is based on sound principles of hydraulics in which waters are driven by the wind (easterly and then southerly in this case) and water surface elevation slopes and tend to follow the path of least hydraulic resistance with the largest conveyance (in this case Lake Borgne and the Mississippi Sound).

5. SWAN+ADCIRC Katrina models of various scenarios quantifying the impact of breaches, the MRGO channel, wetland degradation, and the federal levees

In this section, we describe six models that have been developed to understand the impacts of breaches on the St. Bernard Polder, the condition and existence of the MRGO channel, wetland degradation since 1956, and the construction of the federal levees surrounding the St. Bernard Polder. These various models will be compared to the base SL16-DOJ-SB-A1 *Katrina Actual Event Conditions* simulation described in sections 3 and 4. All seven models are summarized in Table 2.

Model A2: *2005 MRGO/2005 Wetlands/IHNC Breaches Only*

This model is identical to the SL16-DOJ-SB-A1 *Katrina Actual Event Conditions* model with the exception that all the breaches along the MRGO Reach 2 were eliminated. This means that only the two breaches on the IHNC channel into the St. Bernard Polder were active.

Model B1: ***MRGO as Designed/1956 Wetlands***

This model is a modified version of the SL16-DOJ-SB-A1 *Katrina Actual Event Conditions* model to reflect conditions representing those that existed when the MRGO was first constructed. As is seen in Figure 30 (comparing to Figure 3), the MRGO is now represented by a narrower channel as it was originally designed. It is approximately as deep as the 2005 MRGO channel but the shallow bank widening that occurred has been eliminated. In addition, the wetlands surrounding the channel are represented by their 1956 state [Barras, 2008]. Figure 31 (as compared to Figure 6) indicates that the bottom surface friction coefficient, *i.e.* the Manning *n* coefficient, has increased in the areas adjacent to the MRGO channels and in the Biloxi Marsh and the Golden Triangle Marsh. In addition, the Central Wetlands within St. Bernard Polder and the La Loutre Ridge reflect increases in densities and resistance of the vegetation that existed there in 1956.

Model B2: ***MRGO as Designed/1956 Wetlands/IHNC Breaches Only***

This model is identical to the SL16-DOJ-SB-B1 *MRGO as Designed/1956 Wetlands* model with the exception that all the breaches along the MRGO Reach 2 were eliminated. This means that only the two breaches on the IHNC channel into the St. Bernard Polder were active.

Model C: ***No MRGO/1956 Wetlands***

This model represents the scenario if the MRGO had not been built and if there had been no wetland degradation since 1956. Model C is a modified version of the SL16-DOJ-SB-A1that replaces the MRGO Reach 1 with the 1958 configuration of the GIWW [Westerink, 2008], eliminates the MRGO Reach 2 out to the southern edge of the Biloxi Marsh, and replaces topography and marsh frictional resistance with 1956 wetland conditions. The model does represent all the St. Bernard Polder breaches as they occurred during Hurricane Katrina. Figure 32 (as compared to Figure 3) shows the channels as they existed in 1956 and has eliminated the dredged mounds along the MRGO that were created during the dredging process. The surface friction resistance, shown in Figure 33 (and compared to Figure 6), reflect the 1956 wetland conditions as established by Barras [2008].

Changes have occurred in the Caernarvon Marsh, the Golden Triangle Marsh, La Loutre Ridge, as well as in the Central Wetlands within the St. Bernard Polder.

Model D: ***No Federal Levees/2005 MRGO/2005 Wetlands***

This model is identical to the SL16-DOJ-SB-A1 *Katrina Actual Event Conditions* with the exception that the sections of the IHNC levee, the MRGO Reach 1 levee, and the MRGO Reach 2 levee have been eliminated. Thus this model eliminates the federal levees built along the MRGO, brings back protection to the 40 Arpent levee,[8] and maintains levees in south around the town of Poydras, LA and St. Bernard LA along Bayou Rd. as is shown in Figure 34. Figure 35 shows that the wetlands are identical to the Model A1.

Model E: ***No Federal Levees/No MRGO/1956 Wetlands***

Model E is a modified version of the SL16-DOJ-SB-A1 that eliminates the federal levees, eliminates all spoil mounds, replaces the MRGO Reach 1 with the 1958 configuration of the GIWW, eliminates the MRGO Reach 2 out to the southern edge of the Biloxi Marsh, and replaces topography and marsh frictional resistance with 1956 wetland conditions. This model represents a scenario in which there had been no federally funded flood protection or navigation works in or around the Polder. The model eliminates the federal levees built along the MRGO, brings back protection to the 40 Arpent levee, and maintains levees in the south around the towns of Poydras, LA and St. Bernard, LA along Bayou Road. The model assumes that the MRGO has not been built and that there had been no wetland degradation since 1956. All dredged spoil mounds have been eliminated. The details of this model are illustrated in Figures 36 and 37.

[8] This levee lies to the west of the Central Wetlands within the St. Bernard Polder and existed prior to the construction of the MRGO Reach 1 and MRGO Reach 2 levees, Figure 1.

6. SWAN+ADCIRC Katrina simulations of various scenarios quantifying the impact of breaches, the MRGO channel, wetland degradation, and the federal levees

The seven different models were run with the SWAN+ADCIRC code and the H*WIND/OWI wind fields and the results were compared to Model A1 or A2, *Katrina Actual Event Conditions* or *2005 MRGO/2005 Wetlands/IHNC Breaches Only*, to understand the differences in the resulting water surface elevations and wave fields (Figures 38, 39, 41, 42, 44, and 45). Cross channel profiles to help understand results are shown in Figures 40 and 43. Positions of *exterior locations* around St. Bernard Polder and of *Plaintiffs' property locations* are shown in Figure 46. Time histories of water surface elevations at both exterior locations and Plaintiffs' property locations are shown in Figures 47 and 48. Maximum surge values at the exterior locations are summarized in Table 3 and at the Plaintiffs' property locations are summarized in Table 4. Finally, surface water elevation fields are shown at various times for Models A1, A2, B1, B2, C, D and E in Figures 49-55 to illustrate how flooding evolved in each of these model configurations.

As summarized in Table 4, Model A1, *Katrina Actual Event Conditions*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 10.5 ft at Adams; 10.7 ft at StBP #1; 10.8 ft at StBP #2; 11.0 ft at Tommaseo; 11.3 ft at StBP #3; 11.5 ft at StBP #4; 11.5 ft at Steve's RV; 11.5 ft at StBP #5; 11.6 ft at Bordelon; 11.7 ft at PSSI; and 17.3 ft at Florissant.

Model A2: *2005 MRGO/2005 Wetlands/IHNC Breaches Only*

This model is identical to the Model SL16-DOJ-SB-A1, *Katrina Actual Event Conditions,* with the exception that all the breaches along the MRGO Reach 2 were eliminated. This means that only the two breaches on the IHNC channel into the St. Bernard Polder were active. Water could still overtop all levees of MRGO Reach 2 by water surface elevations exceeding the crest elevation of the levee and by wave overtopping.

Figure 38a illustrates that when compared to Model A1, there was generally less than 0.5 ft difference in water surface elevations exterior to the St. Bernard Polder. Water levels within the MRGO Reach 2, MRGO Reach 1, and IHNC increased by between 0.2 and 0.6 ft, with the maximum differences occurring along the MRGO Reach 2 levee sections where the breaches were closed. Within the St. Bernard Polder, there was a decrease of several feet in the western portion of the polder while in most of the polder there was a decrease of 5 to 7 ft in the water surface elevation. This suggests that the southwestern section of the polder, *i.e.* the Lower Ninth Ward and vicinity, was dominated by inflow from the IHNC breaches and the Central Wetlands and populated areas to the east of Paris Rd. were dominated by inflow through the breaches of the MRGO Reach 2 levees. It is noted that Paris Rd. lies on a natural high ridge that tends to hydraulically separate the Lower Ninth Ward and vicinity from areas lying to the east. Figure 38b indicates that the already small waves within the polder were further reduced by the fact that water column heights were reduced within the Central Wetlands and populated areas to the east of Paris Rd.

Figure 47 shows hydrographs at exterior locations around the St. Bernard Polder. Again it is noted that Models A1 and A2 result in very similar exterior location hydrographs with Model A2 having 0.2 to 0.6 ft higher peaks along MRGO Reaches 1 and 2. Plaintiffs' property location hydrographs shown in Figure 48 indicate that for Model A1, the first peak at the Adams property was caused by the IHNC breach while the second higher peak was caused by additional water from the breaches and inflow on the MRGO Reach 2 levees. For Model A2, when the MRGO Reach 2 breaches are eliminated, the second higher peak does not occur. The hydrographs at StBP #1 and StBP #2 also show that water from the IHNC breaches again dominated the flooding while the MRGO Reach 2 breaches added to the total water levels for Model A1 and not for Model A2. Overall, flooding at these three locations was reduced only by about 1.5 to 2.5 ft by eliminating the breaching through the MRGO Reach 2 levees, with each property still experiencing maximum water elevations of 8.3 to 9.0 ft. At the other Plaintiff Property locations within St. Bernard Polder and behind the 40 Arpent levee, Figure 48 and Table 4 show that there was a 3.9 to 7.0 ft reduction in flooding for Model A2 as compared to Model A1. Flooding at location PSSI was reduced by 7.7 ft, the largest reduction at any Plaintiff's property. Nevertheless, in the absence of the MRGO Reach 2 breaches, properties Tommaseo, SBP #3, StBP #4, Steve's RV, StBP #5, and Bordelon still experienced high floodwaters, with maximum water levels ranging from 4.6 to 7.1 ft. Flooding at the

Plaintiff property location, PSSI, in the Central Wetlands was still 4.0 ft. Flooding at the Plaintiff property location outside of the polder, Florissant, increased by 0.2 ft and was equal to 17.5 ft.

Figure 49 indicates that when both the IHNC and MRGO Reach 2 breaches are activated, water penetrates the Lower Ninth Ward and the Central Wetlands, and overtops the 40 Arpent levee. The Central Wetlands and areas behind the 40 Arpent levee and to the east of Paris Rd. are filled more than the Lower Ninth Ward and vicinity. Finally, the higher waters equilibrate within the polder; further raising water levels in the Lower Ninth Ward and vicinity.

In Model A2, Figure 50, the Lower Ninth Ward and vicinity are filled early on as in case A1. However the MRGO Reach 2 levee is now only overtopped by surge and waves and not through breaches and the flow into the polder from the MRGO Reach 2 levees is accordingly limited.

Model B1: ***MRGO as Designed/1956 Wetlands***

This model reflects conditions that existed when the MRGO was constructed. Figure 39a shows that the limited reduction in conveyance of the MRGO Reach 1 and Reach 2 as well as the increase in surface friction representing the 1956 wetland system led to a 0.7 ft reduction in water levels in the central and southern portions of the IHNC. Other exterior locations saw much smaller reductions. The minor 0.7 ft reduction in water level within the central and southern portions of the IHNC is explained in Figure 40. The difference in the flow conveyance between the *as designed* MRGO Reach 1 and the 2005 MRGO Reach 1 is small. The small reduction in conveyance, the resulting increase in velocity, and the increase in friction corresponding to Model B1 will result in a small increase in head drop through the MRGO Reach 1, resulting in lower water levels within the central and southern portions of the IHNC as water flows from Paris Rd. to Seabrook and Lake Pontchartrain. Within St. Bernard Polder there was a reduction in water levels of a little more than 1 ft in the Lower Ninth Ward and vicinity and overall reductions in water levels a little less than 1 ft in other areas. These reductions in interior water levels reflect the reduction in the flow through the IHNC breaches since the exterior water levels in the IHNC pushing water into the polder were less. Figure 39b indicates that the differentials in significant wave height between Model A1 and B1 are minor and generally much less than 1 ft. This reduction reflects the lower water levels within the polder.

The hydrographs in Figure 47 indicate that at exterior locations e1, e2, and e3, the shape of the hydrographs for Model B1 are very similar to those of Model A1 with the peaks being lower by 0.2 to 0.3 ft. Within the MRGO Reach 2 channel and especially within the interior portion of the IHNC, the Model B1 hydrographs are lower by up to 0.7 ft up through the peak. On the drawdown phase at these same locations, Model B1 is slightly higher than Model A1. The hydrograph at exterior location e8 (Seabrook at Lake Pontchartrain) is essentially identical for both models. The Plaintiff property location hydrographs are lower by 1.1 to 1.2 ft at Adams, StBP #1 and StBP #2, with the differential reducing to 0.7 to 0.9 ft at the other Plaintiff property locations within the polder as shown in Figure 48 and Table 4. The peak surge at the Plaintiff property location outside of the polder, Florissant, was essentially unaffected.

Figure 51 shows that the evolution of the flooding of the polder for Model B1 is very similar to that of Model A1 shown in Figure 49. The flooding is simply a small amount less since the water levels in the adjacent channels were very modestly reduced. As summarized in Table 4, Model B1, *MRGO as Designed/1956 Wetlands*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 9.3 ft at Adams; 9.5 ft at StBP #1; 9.7 ft at StBP #2; 10.1 ft at Tommaseo; 10.6 ft at StBP #3; 10.8 ft at StBP #4; 10.8 ft at Steve's RV; 10.8 ft at StBP #5; 10.9 ft at Bordelon; 11.0 ft at PSSI; and 17.2 ft at Florissant.

Model B2: *MRGO as Designed/1956 Wetlands/IHNC Breaches Only*

This model is identical to Model B1, the *MRGO as Designed/1956 Wetlands* model, with the exception that all the breaches along the MRGO Reach 2 were eliminated. A comparison to Model A2 is shown in Figure 41a, which shows that the effect of the *MRGO as Designed/1956 Wetlands* specification are essentially identical in channels as in the Model A1/B1 comparison. Furthermore the reductions in peak values from Model A2/B2 in the Lower Ninth Ward and vicinity and in inhabited areas to the east of Paris Rd. are very similar to the Model A1/B1 comparison, essentially lowering water levels in this area by less than 1 ft. In the Central Wetlands the differences between Model A2/B2 are different from the Model A1/B1 comparison, with small increases in water levels occurring in the Central Wetlands. This is related to the changes in interior polder topography in Models B1 and B2 associated with the elimination of some of the MRGO dredged mound spoils, allowing water to more readily flow from the Lower Ninth Ward and vicinity to the Central Wetlands. There are small decreases/increases in the already low wave action associated with the reductions/increases in water levels within the polder, as is shown in Figure 41b.

Figure 47 indicates that the Model B2 exterior location hydrographs are very similar to the Model B1 and Model A2 exterior location hydrographs. These hydrographs see the increase in water level associated with closing the MRGO Reach 2 breaches and the decrease in water level associated with the changed channel and landscape. Plaintiff property location hydrographs at Adams, StB1, and StB2, shown in Figure 48, are lower to reflect the combined effects of the reduction of water levels in the central and southern IHNC as well as not seeing the water from the MRGO Reach 2 breaches. Plaintiff properties Adams, StBP #1, and StBP #2 flooded to 7.5 to 8.0 ft. The Plaintiff property location hydrographs further from the IHNC breaches are not reduced quite as much as for the Model A1/B1 comparisons, with reductions now being less than 1ft. Thus overall peak water levels at Tommaseo, StBP #3, StBP #4, Steve's RV, StBP #5 and Bordelon are reduced further from Model A2, reflecting the reduction in the water from the IHNC breaches due to the lower exterior IHNC water levels associated with Model B. Peak water levels at Plaintiff locations Tommaseo, StBP #3, StBP #4, Steve's RV, StBP #5 and Bordelon range between 4.1 and 6.3 ft. Peak water level at Plaintiff location PSSI was 3.8 ft. The peak water level at the Plaintiff property location outside of the polder, Florissant, is essentially unaffected and equals 17.3 ft.

The progression of flooding through critical times across the polder is shown in Figure 52. This progression is very similar to Model A2 shown in Figure 50, except that more water passes from the Lower Ninth Ward and vicinity into the Central Wetlands.

Model C: ***No MRGO/1956 Wetlands***

This model represents the scenario if the MRGO had not been built and if there had been no wetland degradation since 1956. Figure 42a shows that the reduction in conveyance of the MRGO Reach 1 and the elimination of MRGO Reach 2 as well as the increase in surface friction representing the 1956 wetland system led to about a 1.5 ft reduction in water levels in the central and southern portions of the IHNC. The reduction in flow conveyance from Paris Rd. to Seabrook also led to an increase in water levels in the vicinity of Paris Rd. of about 0.3 ft. The 1.5 ft reduction in water level within the central and southern portions of the IHNC is explained in Figure 43. There is a reduction in the flow conveyance between the GIWW as it existed prior to the construction of the MRGO and the 2005 Reach 1. While not dramatically affecting water levels outside of the canal system, the reduction in conveyance did lead to an increase in resistance between Paris Rd. and Seabrook, leading to an increase in water level of 0.3 ft at Paris Rd. and a faster drop in water level between Paris Rd. and Seabrook and thus leading to the 1.5 ft drop in the central and southern portions of the IHNC. We note that the reduction in interior polder water levels is limited to the Lower Ninth Ward and vicinity in the western portion of the polder, reflecting the lower water levels in the IHNC. Water levels in the remainder of the polder see very little difference from Model A1, *the Katrina Actual Event Condition* Model. This is predominantly the result of an increase in exterior water levels in the vicinity of Paris Rd. Significant wave heights are not dramatically affected except in the MRGO Reach 1 and Reach 2 where they are reduced by about 1 ft.

Figure 47 indicates that at exterior locations e1 and e2, the shape and peak of the hydrographs for Model C is very similar to that of Model A1 with the peaks being 0.1 to 0.2 ft lower. The hydrograph at exterior location e3 at Paris Rd. is 0.3 ft higher while the hydrograph at exterior location e5 in the central portion of the IHNC is 1.4 ft lower and more slender. At the Plaintiff property locations within the polder at Adams, StBP #1, and StBP #2, Figure 48, the hydrographs for Model C are further reduced from Model B1 reflecting the even lower water levels in the central IHNC which is their main driver. Peak water surface elevation levels during Katrina at Plaintiffs' properties reached 8.8 ft at Adams; 9.0 ft at StBP #1; and 9.1 ft at StBP #2. The locations away from the Lower Ninth Ward and vicinity see a 0.0 to

0.7 ft peak water level reduction as compared to Model A1, reflecting the balance in less water from the IHNC breaches but increases in water from a portion of the MRGO Reach 2 breaches driven by the increases in water level from the vicinity of Paris Rd. Peak water surface elevation levels at Plaintiffs' properties reaching 10.3 ft at Tommaseo; 11.0 ft at StBP #3; 11.5 ft at StBP #4; 11.5 ft at Steve's RV; 11.5 ft at StBP #5; 11.5 ft at Bordelon; and 11.6 ft at PSSI. The Plaintiff property location outside of the polder, Florissant, has a peak of 17.2 ft which is essentially identical to Model A1.

Figure 53 shows that the evolution of the flooding for Model C of the polder is very similar to that of Model B1 shown in Figure 51. The flooding is simply a small amount less in the vicinity of the Lower Ninth Ward and vicinity and is greater in other sectors of the polder compared to Model B1.

Model D: ***No Federal Levees/2005 MRGO/2005 Wetlands***

This model is identical to the SL16-DOJ-SB-A1 *Katrina Actual Event Conditions* with the exception that this model eliminates the federal levees built along the MRGO and brings back protection to the 40 Arpent levee and maintains levees in the south around the towns of Poydras, LA and St. Bernard, LA. Figure 44a indicates that compared to Model A1, *Katrina Actual Event Conditions*, there is 0.5 ft less water along the southern portion of MRGO Reach 2, 0.1 to 0.4 ft more water in the MRGO Reach 1 and the IHNC, and between 3 and 5 ft more water in the St. Bernard Polder. There is less water along the southern portion of MRGO Reach 2 since more water moves into the polder. There is more water in MRGO Reach 1 since the water now communicates unimpeded between the polder and the MRGO Reach 1. Finally there is more water within the polder since it can move unimpeded from Lake Borgne and MRGO Reach 1 into the Central Wetlands and over the 40 Arpent levee into the inhabited areas of the polder. There is a coincident increase in significant wave height corresponding to the increased water levels as is shown in Figure 44b.

Exterior location hydrographs e1 and e2, Figure 47, are very similarly shaped but have 0.5 ft lower peaks compared to Model A1. Conversely exterior location hydrographs e3, e4, and e5 show peaks that are about 0.1 to 0.4 ft greater than Model A1. Hydrographs at Plaintiffs' property locations within the polder, Figure 48, increase by 3.1 to 5.2 ft compared to Model A1. The Plaintiff property location outside of the polder, Florissant, is essentially unaffected. As summarized in Table 4, Model D, *No Federal Levees/2005 MRGO/2005 Wetlands*, results in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 14.1 ft at Adams; 14.3 ft at StBP #1; 14.5 ft at StBP #2; 14.7 ft at Tommaseo; 15.0 ft at StBP #3; 15.6 ft at StBP #4; 15.6 ft at Steve's RV; 15.8 ft at StBP #5; 16.8 ft at Bordelon; 14.8 ft at PSSI; and 17.1 ft at Florissant.

Figure 53 shows a sequence of water elevation fields in time illustrating the evolution of flooding. Without the federal levees, the Central Wetlands were easily overwhelmed as water moved in from Lake Borgne. The 40 Arpent levee and the levees protecting Poydras, LA and St. Bernard, LA were subsequently easily overtopped and the interior protected areas were flooded.

Model E: *No Federal Levees/No MRGO/1956 Wetlands*

This model represents a scenario of no federally funded projects in the polder. Figure 45a indicates that this model results in very similar flooding to Model D, the *No Federal Levees/2005 MRGO/2005 Wetlands* model. Compared to Model A1, *Katrina Actual Event Conditions*, there is 0.6 to 0.8 ft less water along the southern portion of MRGO Reach 2, 0.2 ft more water in the eastern portion of MRGO Reach 1, 1.2 ft less water in the central portions of the IHNC, and between 3 and 5 ft more water in the St. Bernard Polder. Again there is less water along the southern portion of MRGO Reach 2 mainly because more water moves into the now unprotected polder. There is more water in the eastern portion of MRGO Reach 1 since the water now communicates unimpeded between the polder and the MRGO Reach 1. There is less water in the central portion of the IHNC since the hydraulic conductivity to that point has still been reduced. Finally, there is much more water within the polder since it can move unimpeded from Lake Borgne into the Central Wetlands and over the 40 Arpent levee into the inhabited areas of the polder. There is again a coincident increase in significant wave height corresponding to the increased water levels as is shown in Figure 44b.

Exterior location hydrographs e1 and e2, Figure 47, show very similar shape, but the peaks are 0.6 to 0.8 ft less compared to Model A1. Exterior location hydrograph e3 has a 0.2 ft higher peak compared to Model A1 while exterior location hydrograph e5 has a peak that is about 1.2 ft less than Model A1. Hydrographs at Plaintiffs' property locations within the polder, Figure 48, are essentially identical to Model D and are still 3.2 to 5.0 ft higher compared to Model A1. The hydrograph peak at the Plaintiff property location outside of the polder, Florissant, is still essentially unaffected as in all previous cases. As summarized in Table 4, Model E, *No Federal Levees/No MRGO/1956 Wetlands*, results in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 13.8 ft at Adams; 14.1 ft at StBP #1; 14.3 ft at StBP #2; 14.5 ft at Tommaseo; 14.9 ft at StBP #3; 15.5 ft at StBP #4; 15.6 ft at Steve's RV; 15.7 ft at StBP #5; 16.6 ft at Bordelon; 14.9 ft at PSSI; and 16.9 ft at Florissant.

Figure 55 shows a sequence of water elevation fields in time illustrating the evolution of flooding. This evolution proceeded almost identically to Model D. Without the federal levees and MRGO and with the pre MRGO wetlands, the interior wetland were easily overwhelmed as water moved in from Lake Borgne.

7. Conclusions and Opinions

7.1 Surge and wave conditions in and around the St. Bernard Polder during Hurricane Katrina

Historical Storm surge and wave conditions during Hurricane Katrina are accurately simulated by Model SL16-DOJ-SB-A1, the *Katrina Actual Event Conditions* Model, presented in this Study. The modeled hydrographs outside and inside of St. Bernard Polder closely match the measured hydrographs. The modeled high water marks (HWM) closely match the measured ones throughout the region.

Model A1, *Katrina Actual Event Conditions*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 10.5 ft at Adams; 10.7 ft at StBP #1; 10.8 ft at StBP #2; 11.0 ft at Tommaseo; 11.3 ft at StBP #3; 11.5 ft at StBP #4; 11.5 ft at Steve's RV; 11.5 ft at StBP #5; 11.6 ft at Bordelon; 11.7 ft at PSSI; and 17.3 ft at Florissant.

7.2 Source of the water that flooded St. Bernard Polder

The water that penetrated St. Bernard Polder came predominantly from Lake Borgne and was pushed towards New Orleans by winds from the northeast and east as well as from high water in the Mississippi Sound. The water mass in Lake Borgne followed the path of least resistance and penetrated the St. Bernard Polder. The water did not come from Breton Sound or Chandeleur Sound nor from the Caernarvon or Biloxi marshes through MRGO Reach 2.

7.3 Impact of the breaching location on the flooding within and around St. Bernard Polder

Flooding in the Lower Ninth Ward and vicinity up to Paris Rd. was dominated by the IHNC breaches. Flooding at locations behind the 40 Arpent levee to the east of Paris Rd. and within the Central Wetlands was dominated by the breaches of the MRGO Reach 2. Thus when the MRGO Reach 2 breaches were eliminated from the model, flooding levels at locations Adams, StBP #1, and StBP #2 were only moderately reduced by about 1.5 to 2.5 ft while locations to the east of Paris Rd. and behind the 40 Arpent levee saw reductions of 3.9 to almost 7.0 ft. Nevertheless, in the absence of the MRGO Reach 2 breaches, properties east of Paris Road and behind the 40 Arpent levee experience flood levels ranging from 4.6 to 7.1 ft. Flooding at location PSSI was reduced by 7.7 ft in Model A2 but still reached 4.0 ft. Flooding at the Florissant location is not influenced by the elimination of the MRGO Reach 2 levee breaches.

Model A2, *2005 MRGO/2005 Wetlands/IHNC Breaches Only*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 9.0 ft at Adams; 8.5 ft at StBP #1; 8.3 ft at StBP #2; 7.1 ft at Tommaseo; 6.2 ft at StBP #3; 4.6 ft at StBP #4; 4.6 ft at Steve's RV; 4.6 ft at StBP #5; 4.6 ft at Bordelon; 4.0 ft at PSSI; and 17.5 ft at Florissant.

7.4 Impact of the maintenance of the MRGO and state of the wetlands on flooding within and around St. Bernard Polder

By defining the MRGO as it was designed and specifying 1956 wetland conditions, Model B1 demonstrates that the actual MRGO maintenance and wetland conditions only minimally impacted flooding in St. Bernard Polder with flooding reducing by about 1 ft at all interior polder locations and not at all at Florissant. Water levels along MRGO Reach 2 were minimally impacted while water levels in the central portion of the IHNC dropped by only 0.7 ft.

Model B1, *MRGO as Designed/1956 Wetlands*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 9.3 ft at Adams; 9.5 ft at StBP #1; 9.7 ft at StBP #2; 10.1 ft at Tommaseo; 10.6 ft at StBP #3; 10.8 ft at StBP #4; 10.8 ft at Steve's RV; 10.8 ft at StBP #5; 10.9 ft at Bordelon; 11.0 ft at PSSI; and 17.2 ft at Florissant.

7.5 Impact of the construction of the MRGO on the surge and wave conditions within and around St. Bernard Polder

Model C, the *No MRGO/1956 Wetlands* scenario, models conditions as they existed prior to 1958. This model indicates that although water levels in the central portion of the IHNC were lowered by about 1.4 ft, water levels in the vicinity of the MRGO Reach 2 at the Paris Rd. Bridge increased by about 0.3 ft. Thus there was about 1.7 ft in flood reduction for properties in the vicinity of the Lower Ninth Ward and little or no flood reduction elsewhere in the polder.

Model C, *No MRGO/1956 Wetlands*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 8.8 ft at Adams; 9.0 ft at StBP #1; 9.1 ft at StBP #2; 10.3 ft at Tommaseo; 11.0 ft at StBP #3; 11.5 ft at StBP #4; 11.5 ft at Steve's RV; 11.5 ft at StBP #5; 11.5 ft at Bordelon; 11.6 ft at PSSI; and 17.2 ft at Florissant.

7.6 Impact of the construction of federal levees on surge and wave conditions within and around St. Bernard Polder

Model D, which eliminates the key federal levees, shows that the water from Lake Borgne essentially flows unimpeded into the Central Wetlands and then easily overtops the 40 Arpent levee as well as the levees protecting Poydras, LA and St. Bernard, LA. Flooding at all interior polder locations increased by 3 to 5 ft while at Florissant flooding remained the same as in all cases. This model shows that the first line of exterior defense, even when compromised, benefits interior portions of the system.

Model D, *No Federal Levees/2005 MRGO/2005 Wetlands*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 14.1 ft at Adams; 14.3 ft at StBP #1; 14.5 ft at StBP #2; 14.7 ft at Tommaseo; 15.0 ft at StBP #3; 15.6 ft at StBP #4; 15.6 ft at Steve's RV; 15.8 ft at StBP #5; 16.8 ft at Bordelon; 14.8 ft at PSSI; and 17.1 ft at Florissant.

7.7 The combined impact of the construction of federal levees, the construction of the MRGO, and the deterioration of the wetlands on surge and wave conditions within and around St. Bernard Polder

Model E, eliminates the key federal levees and the MRGO and considers the wetlands to be in their 1956 conditions. This model again shows that the water from Lake Borgne essentially flows unimpeded into the Central Wetlands and then easily overtops the 40 Arpent levee as well as the levees protecting Poydras, LA and St. Bernard, LA. Flooding at all interior polder locations increased by 3 to 5 ft while at Florissant flooding remained the same as in all cases. Because the water comes from Lake Borgne and is pushed into the polder unimpeded, the conditions of the wetlands and channels are only of minor consequence.

Model E, *No Federal Levees/No MRGO/1956 Wetlands*, resulted in maximum water surface elevation levels during Katrina at Plaintiffs' properties reaching 13.8 ft at Adams; 14.1 ft at StBP #1; 14.3 ft at StBP #2; 14.5 ft at Tommaseo; 14.9 ft at StBP #3; 15.5 ft at StBP #4; 15.6 ft at Steve's RV; 15.7 ft at StBP #5; 16.6 ft at Bordelon; 14.9 ft at PSSI; and 16.9 ft at Florissant.

I declare under penalty of perjury that the foregoing is true and correct.

Joannes J. Westerink
________________________________ Date: August 9, 2013

JOANNES J. WESTERINK

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Table 1: List of the eleven plaintiff-owned properties that are the subject of this Study. For ease of reference, these properties have been assigned numbers (used in Figure 46) and abbreviated names reflecting their relative location throughout the polder.

Property Identifier Number	Property Identification Used in this Report	Detailed Property Description
1	**“Adams”**	2414 Deslonde St., New Orleans, LA
2	**“StBP #1”**	1818 Center Street, Arabi, LA
3	**“StBP #2”**	8600 Victory Dr., Chalmette, LA
4	**“Tommaseo”**	3641-3616 Fenelon St., Chalmette, LA
5	**“StBP #3”**	E. Josephine & Marietta, Chalmette, LA
6	**“StBP #4”**	E. Judge Perez & Judy Dr., Meraux, LA
7	**“Steve’s RV”**	E. 3209 Judge Perez, Meraux, LA
8	**“StBP #5”**	4119 E. Judge Perez, Meraux, LA
9	**“Bordelon”**	3024 Lakewood Dr., Violet, LA
10	**“PSSI”**	6325 Paris Rd. (Portions of Lot 5 (I and J)), St. Bernard Parish, LA
11	**“Florissant”**	2316 Florissant Hwy., St. Bernard Parish, LA

Table 2: Description of the seven models simulated in this Study.

Model	**MRGO Status**	**Marsh Status**	**Levee Breaches**	**Description**
A1 (*Katrina Actual Event Conditions*)	2005 pre-Katrina dimensions	2005 pre-Katrina conditions	Breaching occurring as during Katrina	Base case: Actual Katrina Hindcast
A2 (*2005 MRGO/ 2005 Wetlands/ IHNC Breaches Only*)	2005 pre-Katrina dimensions	2005 pre-Katrina conditions	IHNC Breaches Only	Base case reflecting levee breaches only in the IHNC floodwall
B1 (*MRGO As-Designed/1956 Wetlands*)	MRGO at its authorized dimensions as of completion in 1968	1956 Wetland conditions	Breaching occurring as during Katrina	Katrina impact absent bank erosion channel widening/ wetland degradation
B2 (*MRGO As-Designed/1956 Wetlands/IHNC Breaches Only*)	MRGO at its authorized dimensions as of completion in 1968	1956 Wetland conditions	IHNC Breaches Only	Katrina impact absent bank erosion channel widening/ wetland degradation reflecting INHC breaches only
C (*No MRGO/ 1956 Wetlands*)	No MRGO	1956 Wetland conditions	Breaching occurring as during Katrina	Katrina impact without MRGO, and with 1956 wetland topography
D (*No Federal Levees/2005 MRGO/2005 Wetlands*)	2005 pre-Katrina dimensions	2005 pre-Katrina conditions	No levees along MRGO Reach 1 and 2	Katrina impact with MRGO but without levees along MRGO. MRGO and wetlands with 2005 conditions
E (*No Federal Levees/No MRGO/1956 Wetlands*)	No MRGO	1956 Wetland conditions	No levees along MRGO Reach 1 and 2	Katrina impact with no federal influence

Table 3: Maximum surge values (ft) for the seven models at exterior polder locations[9] defined in Figure 46.

Location	Model						
	A1	**A2**	**B1**	**B2**	**C**	**D**	**E**
e1	17.0	17.3	16.7	17.0	16.8	16.5	16.2
e2	16.8	17.3	16.6	17.1	16.7	16.3	16.2
e3	15.0	15.6	14.8	15.4	15.3	15.1	15.2
e4	14.1	14.6	13.7	14.2	13.4	14.5	14.2
e5	13.4	13.7	12.7	13.0	12.0	13.5	12.2
e6	13.5	13.8	12.8	13.1	12.0	13.7	12.4
e7	12.4	12.6	11.9	12.1	11.5	12.4	11.6
e8	11.6	11.7	11.4	11.4	11.1	11.5	11.0
e9	16.3	16.4	16.0	16.2	16.2	16.3	15.9
e10	13.2	13.3	13.0	13.1	13.2	13.3	13.0

[9] Locations e1, e3, e5, and e6 correspond approximately to locations sf3, sf2, sf1, and sf6 used in Steve Fitzgerald's (SF) expert report. In this study, the locations are positioned to lie within the channels so that we can examine tides and lower water level states while the adjacent SF's locations are positioned adjacent to the base of the levee so that they could provide values to obtain the best approximation to the overtopping of the levee in his calculation procedure. There is typically less than 0.1 ft difference in water level between the e1, e3, e5, and e6 stations and the nearby stations provided to SF. Locations e9 and e10 correspond exactly to SF locations sf4 and sf5 since these locations lie in wetlands.

Table 4: Maximum surge values (ft) for the seven models at Plaintiffs' property locations defined in Figure 46.

Location	Model						
	A1	**A2**	**B1**	**B2**	**C**	**D**	**E**
Adams	10.5	9.0	9.3	8.0	8.8	14.1	13.8
SBP #1	10.7	8.5	9.5	7.5	9.0	14.3	14.1
SBP #2	10.8	8.3	9.7	7.5	9.1	14.5	14.3
Tommaseo	11.0	7.1	10.1	6.3	10.3	14.7	14.5
SBP #3	11.3	6.2	10.6	5.4	11.0	15.0	14.9
SBP #4	11.5	4.6	10.8	4.1	11.5	15.6	15.5
Steve's RV	11.5	4.6	10.8	4.1	11.5	15.6	15.6
SBP #5	11.5	4.6	10.8	4.1	11.5	15.8	15.7
Bordelon	11.6	4.6	10.9	4.1	11.5	16.8	16.6
PSSI	11.7	4.0	11.0	3.8	11.6	14.8	14.9
Florissant	17.3	17.5	17.2	17.3	17.2	17.1	16.9

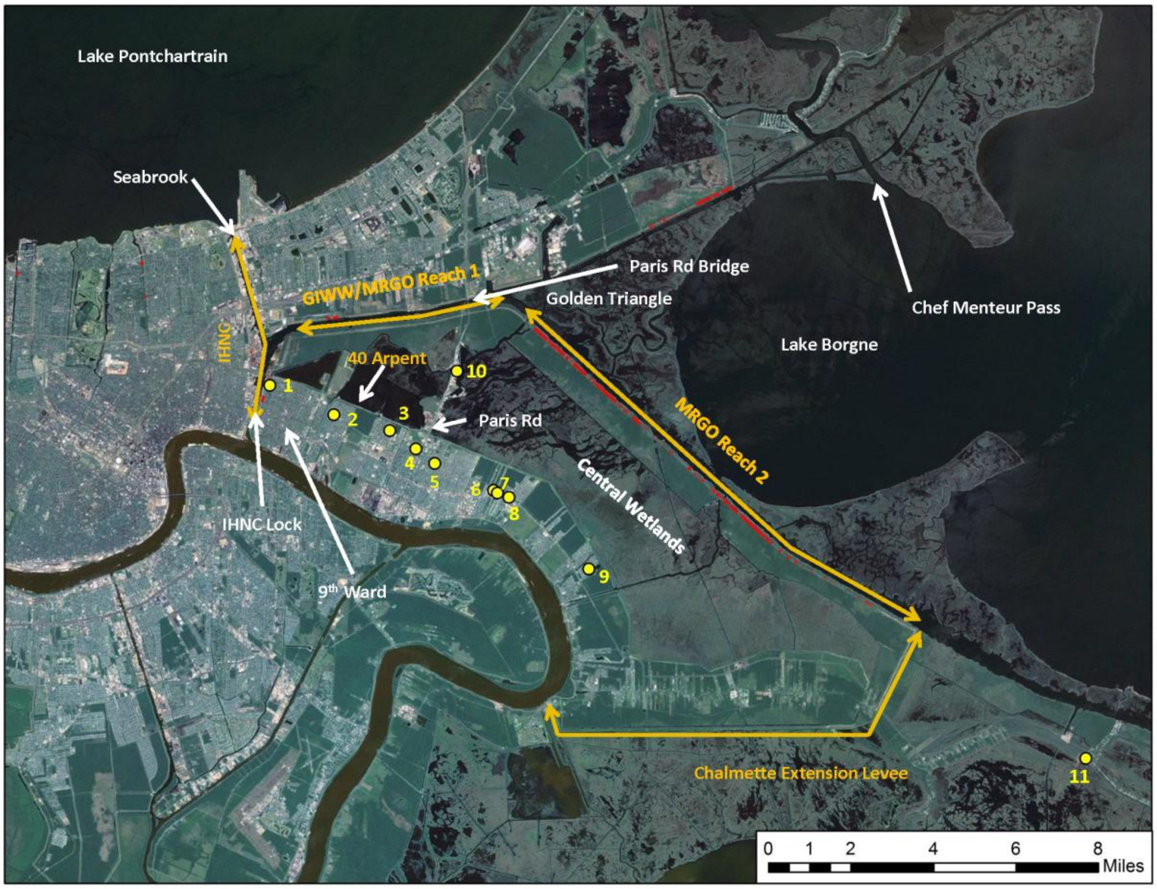

Figure 1: The Study Region includes St. Bernard Polder, the IHNC, the MRGO Reach 1, the MRGO Reach 2, the GIWW between the IHNC and Chef Menteur Pass, the Golden Triangle, the Biloxi Marsh, the Caernarvon Marsh and the eastern portion of Plaquemines Parish. Breaches are indicated in red lines along levees. Plaintiff's properties are indicated by bright yellow locations 1 through 11 and are described in Table 1.

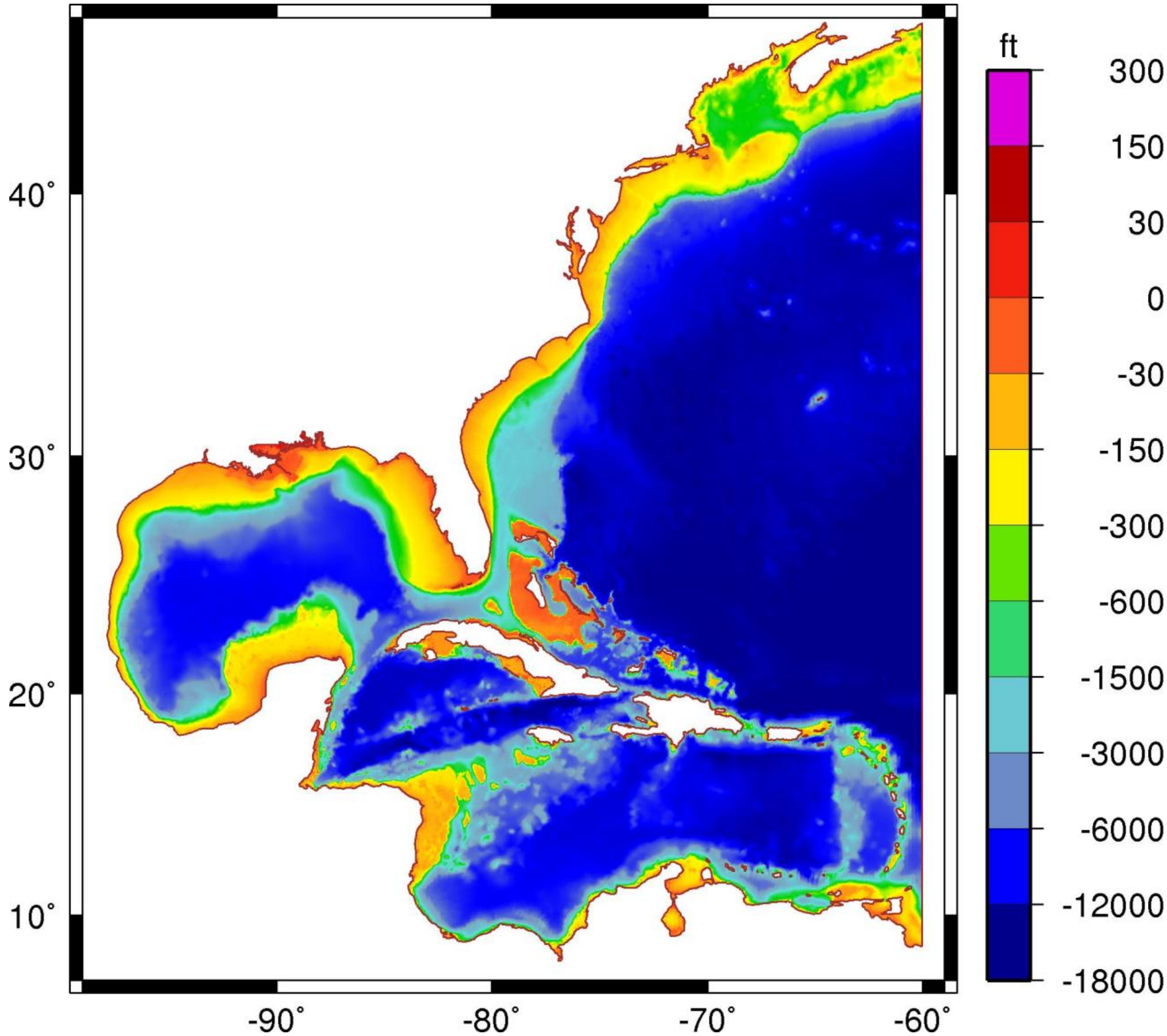

Figure 2: ADCIRC SL16-DOJ-SB-A model domain with bathymetry (ft).

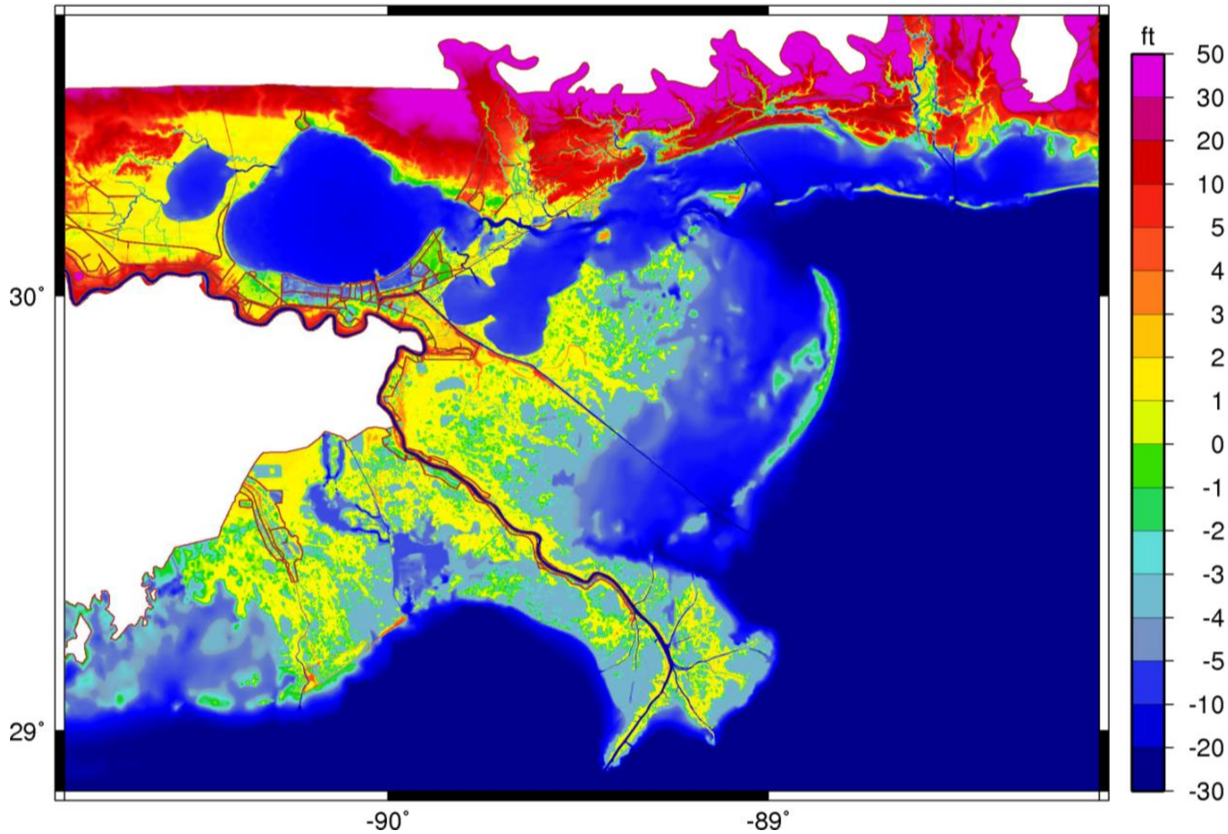

Figure 3a: ADCIRC SL16-DOJ-SB-A bathy and topo (ft), relative to NAVD88 (2004.65), for Southeastern Louisiana.

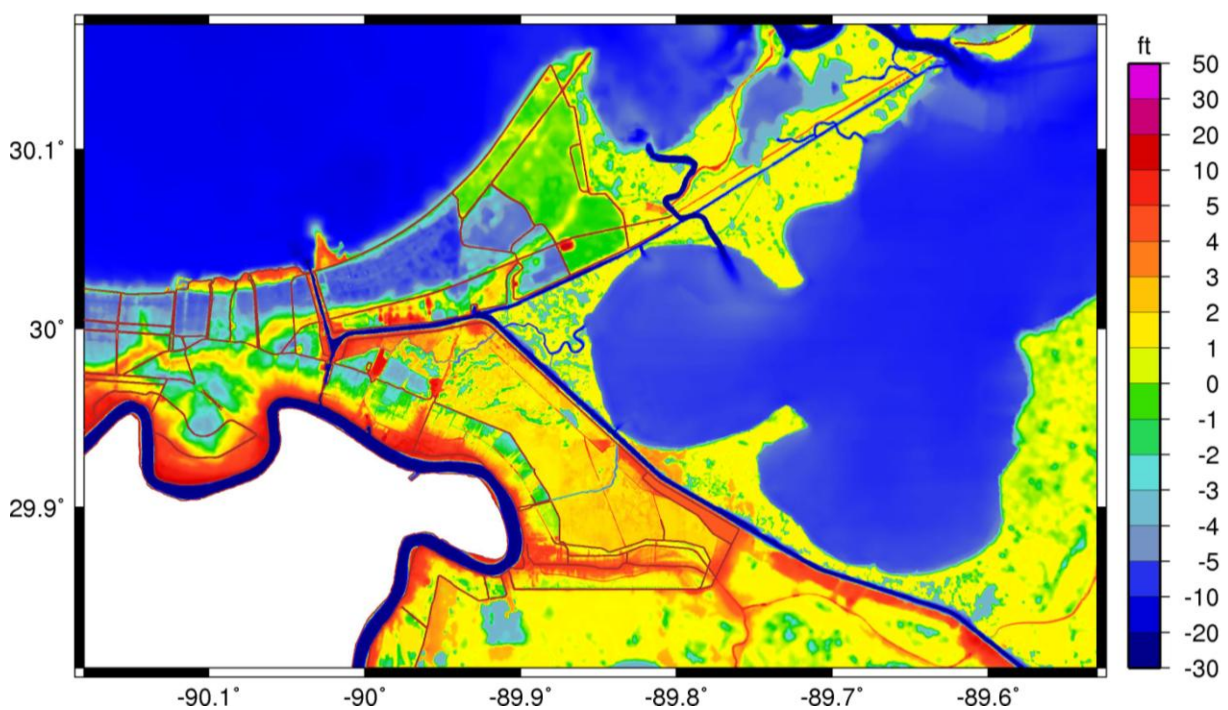

Figure 3b: ADCIRC SL16-DOJ-SB-A bathy and topo (ft), relative to NAVD88 (2004.65), for the Study Area.

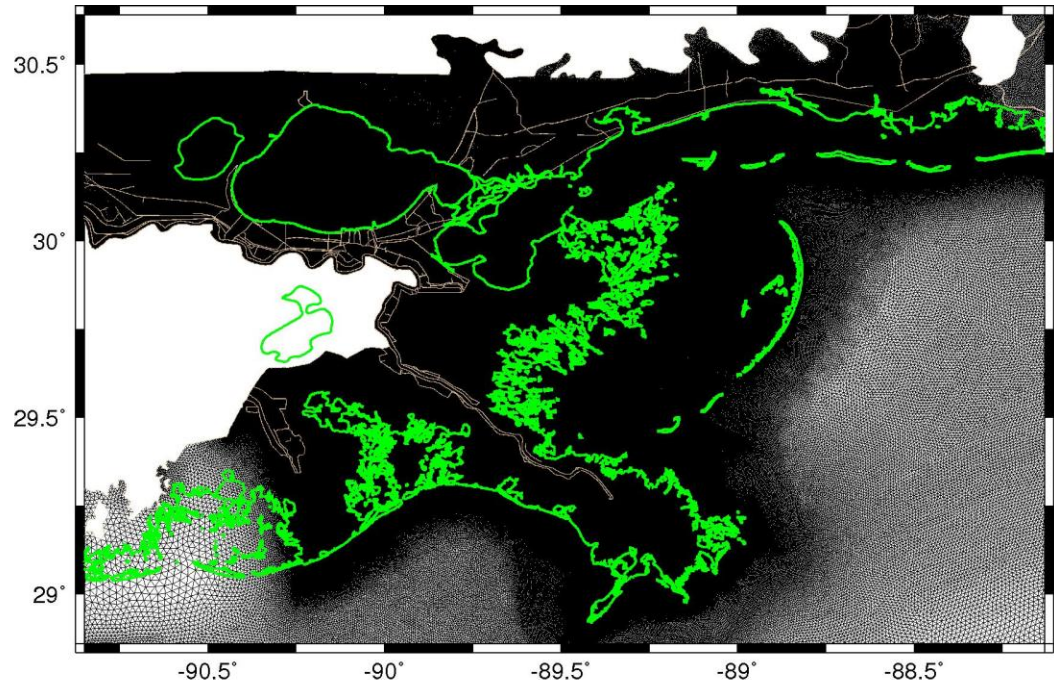

Figure 4a: ADCIRC SL16-DOJ-SB-A finite element triangulation in Southeastern Louisiana. The green line indicates the approximate coastline.

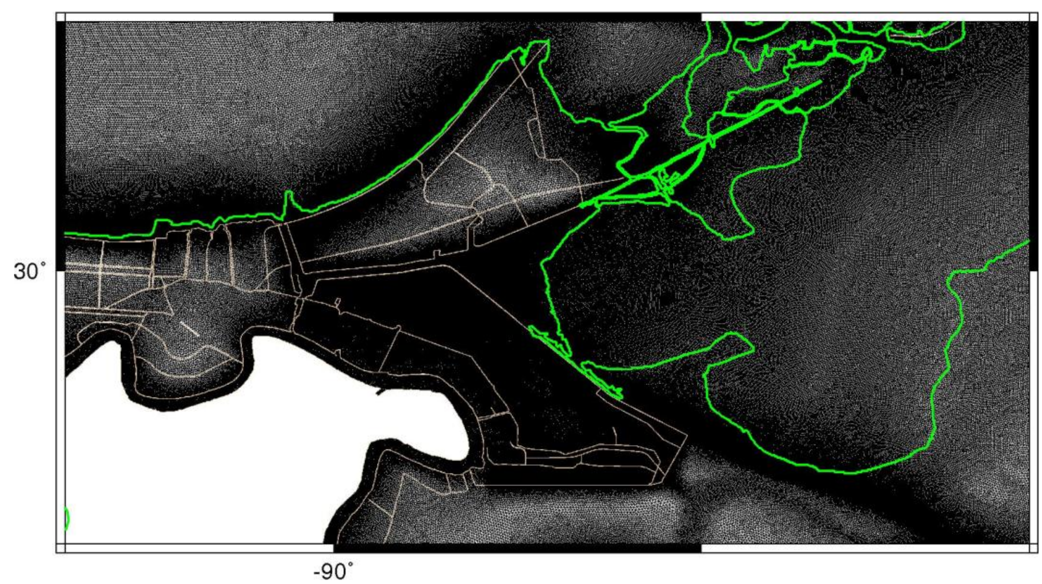

Figure 4b: ADCIRC SL16-DOJ-SB-A finite element triangulation in the Study Area.

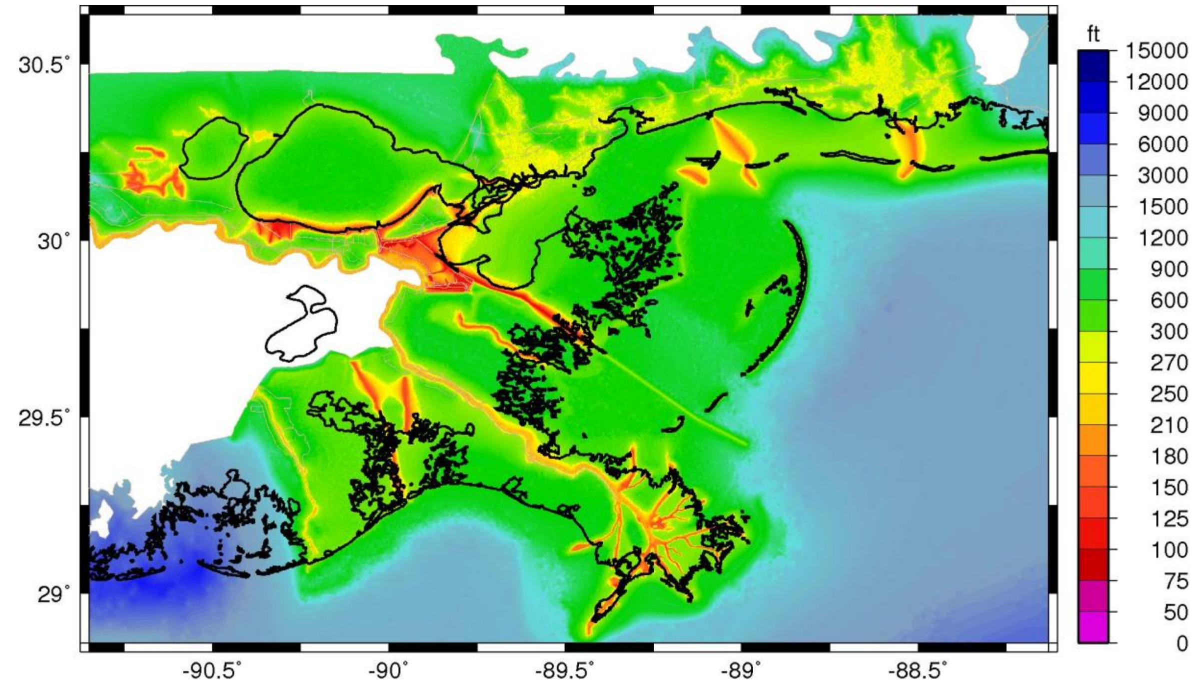

Figure 5a: ADCIRC SL16-DOJ-SB-A grid resolution (ft) in Southeastern Louisiana. The black line indicates the approximate coastline. Grid resolution indicates the horizontal size of the finite elements. The smaller the elements, the more detailed the landscape and the hydrodynamics that can be resolved.

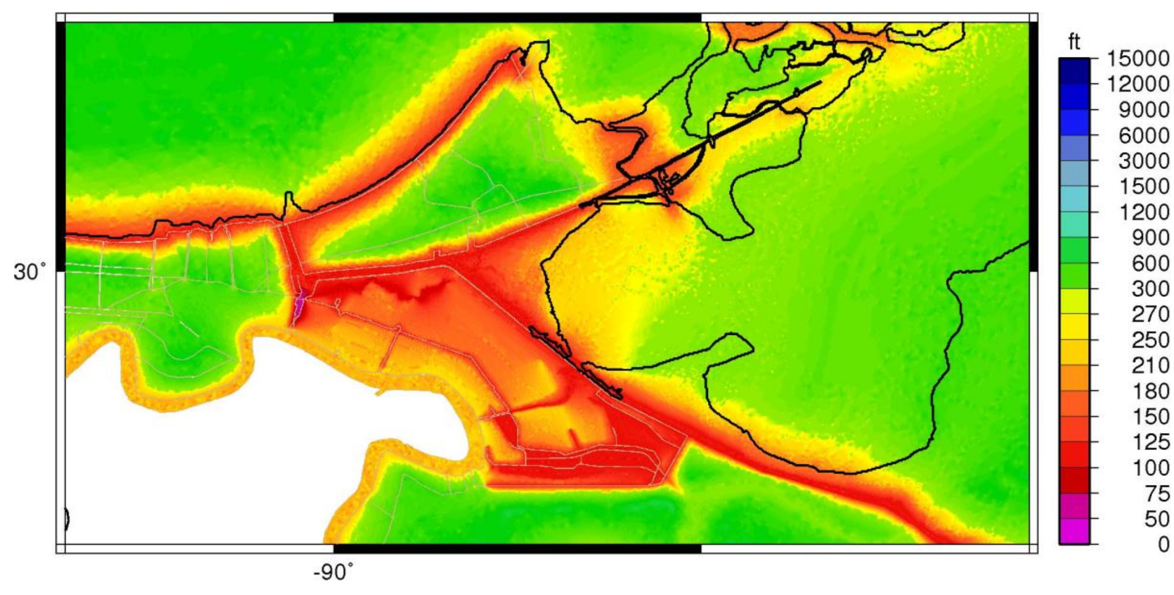

Figure 5b: ADCIRC SL16-DOJ-SB-A grid resolution (ft) in the Study Area.

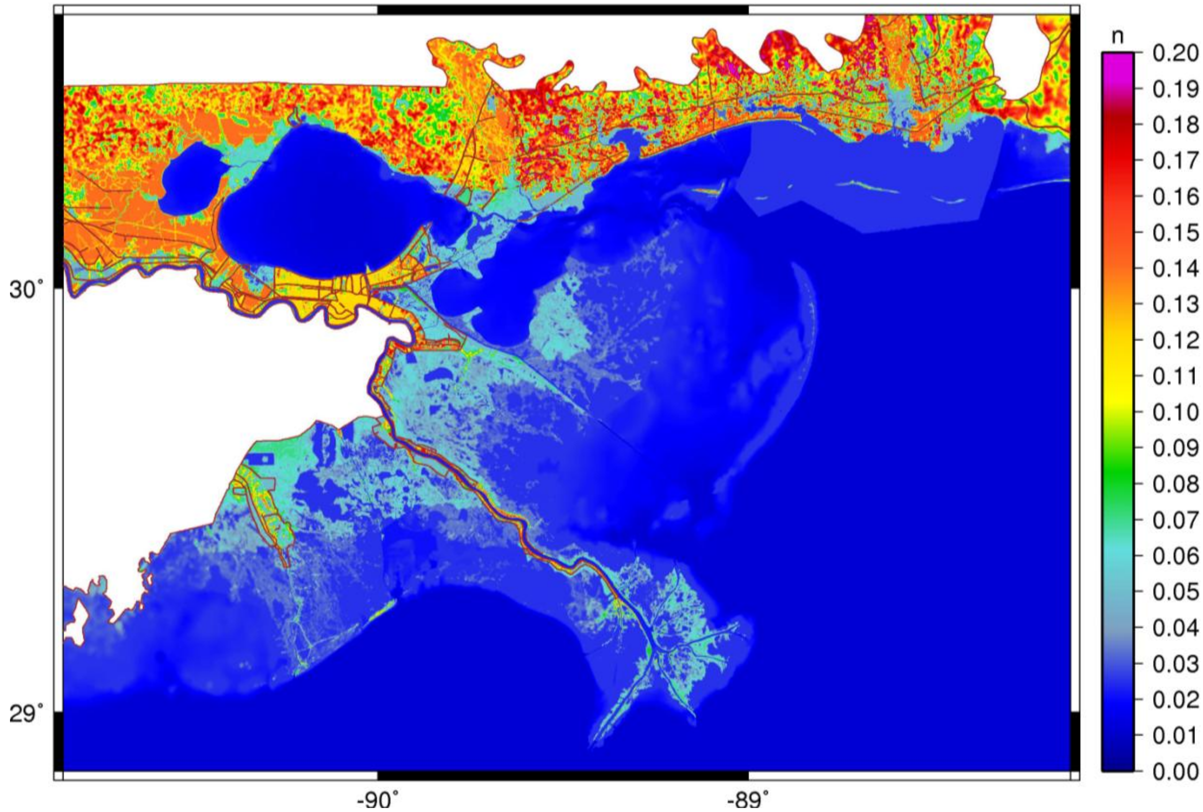

Figure 6a: ADCIRC SL16-DOJ-SB-A Manning *n* bottom friction coefficient in Southeastern Louisiana.

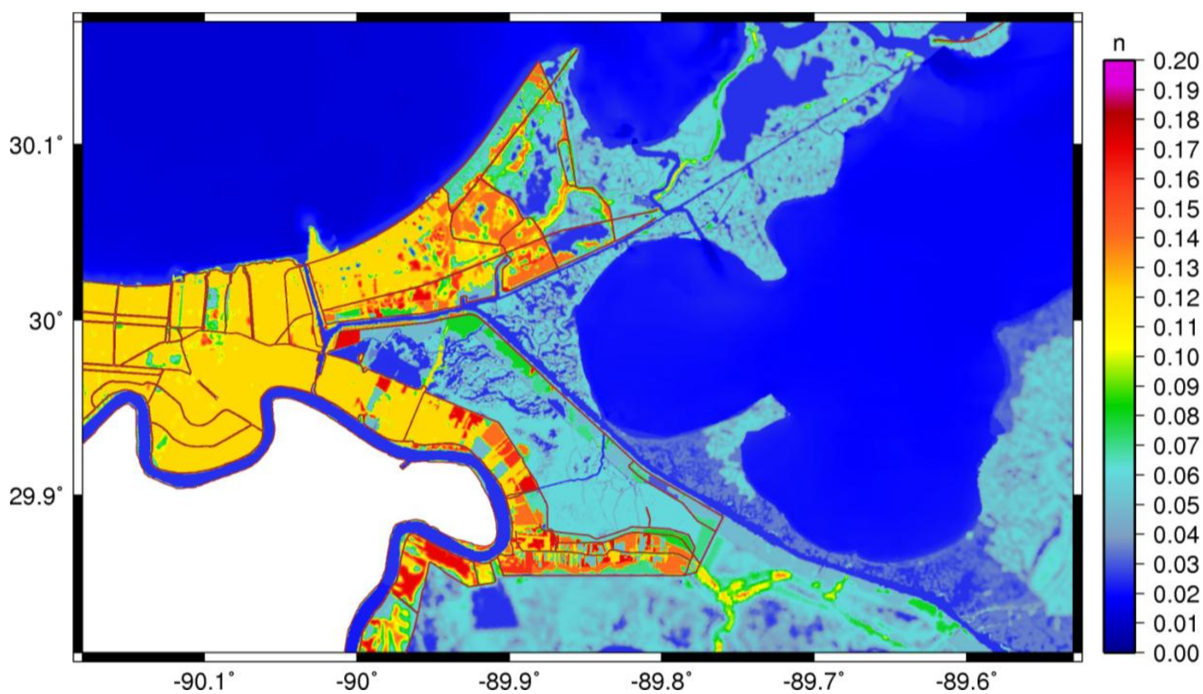

Figure 6b: ADCIRC SL16-DOJ-SB-A Manning *n* bottom friction coefficient in the Study Area.

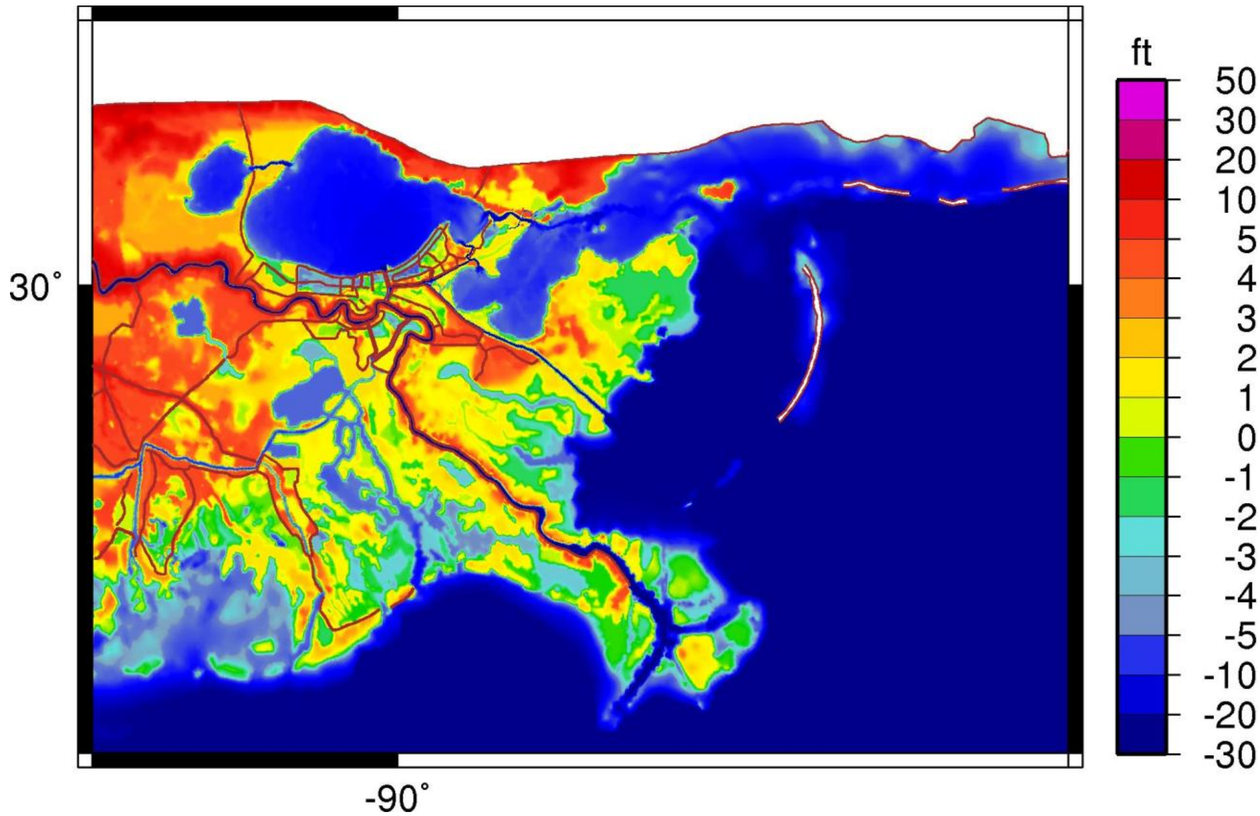

Figure 7a: ADCIRC S08 bathy and topo (ft), relative to NAVD88 (2004.65), for Southeastern Louisiana (compare to Figure 3a).

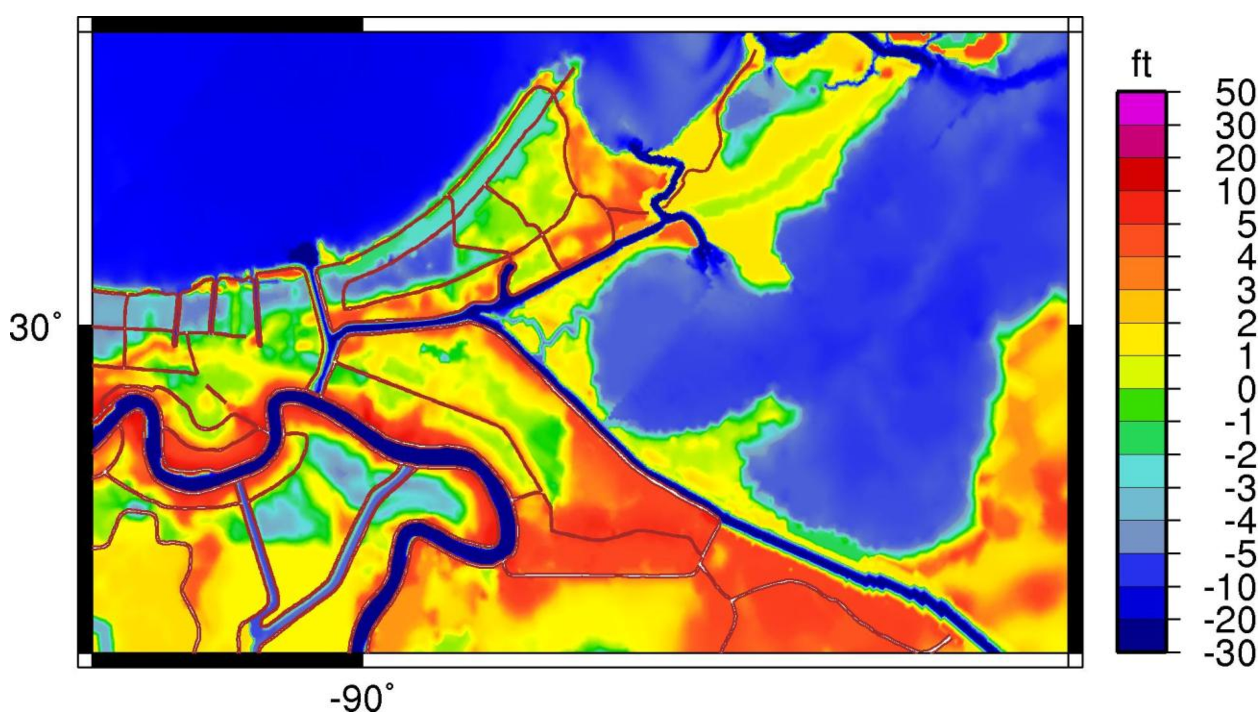

Figure 7b: ADCIRC S08 bathy and topo (ft), relative to NAVD88 (2004.65), for the Study Area (compare to Figure 3b).

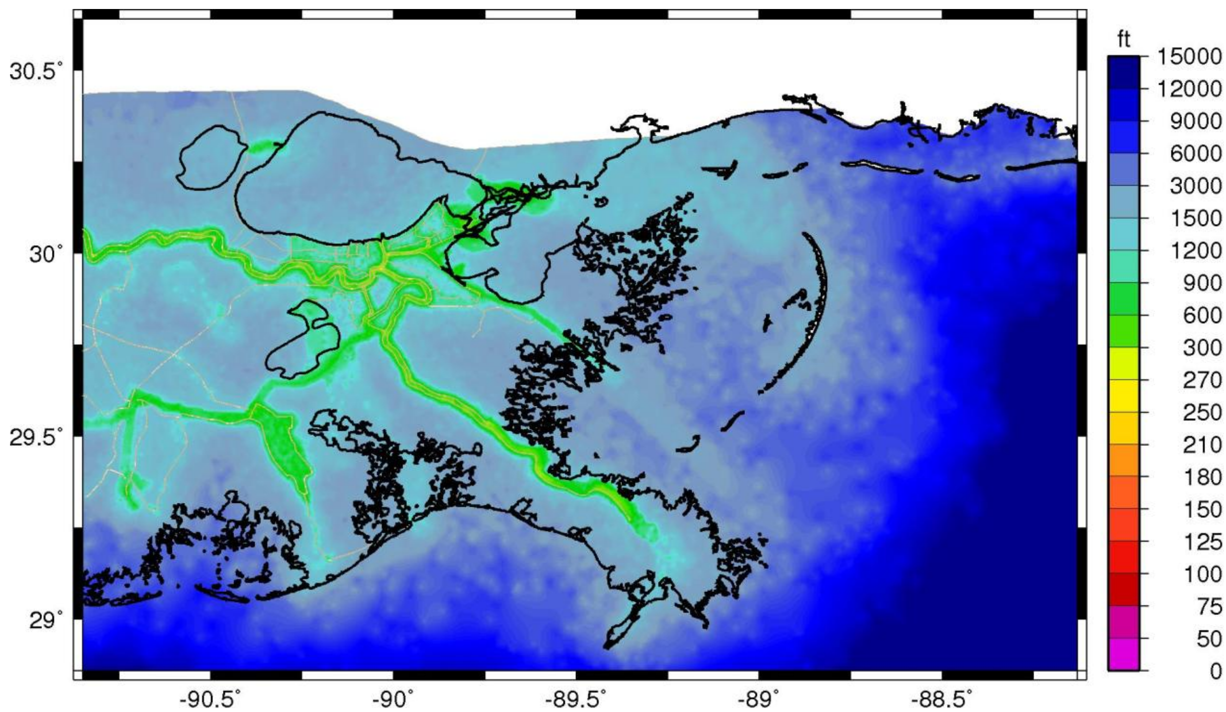

Figure 8a: ADCIRC S08 grid resolution (ft) in Southeastern Louisiana (compare to Figure 5a). The black line indicates the approximate coastline.

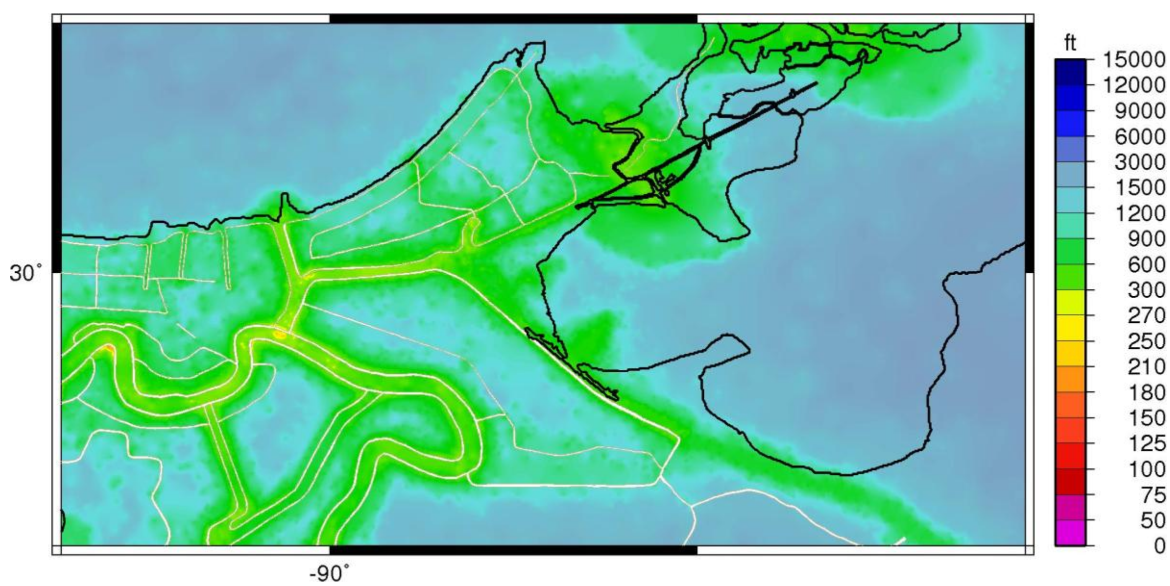

Figure 8b: ADCIRC S08 grid resolution (ft) in the Study Area (compare to Figure 5b). The black line indicates the approximate coastline.

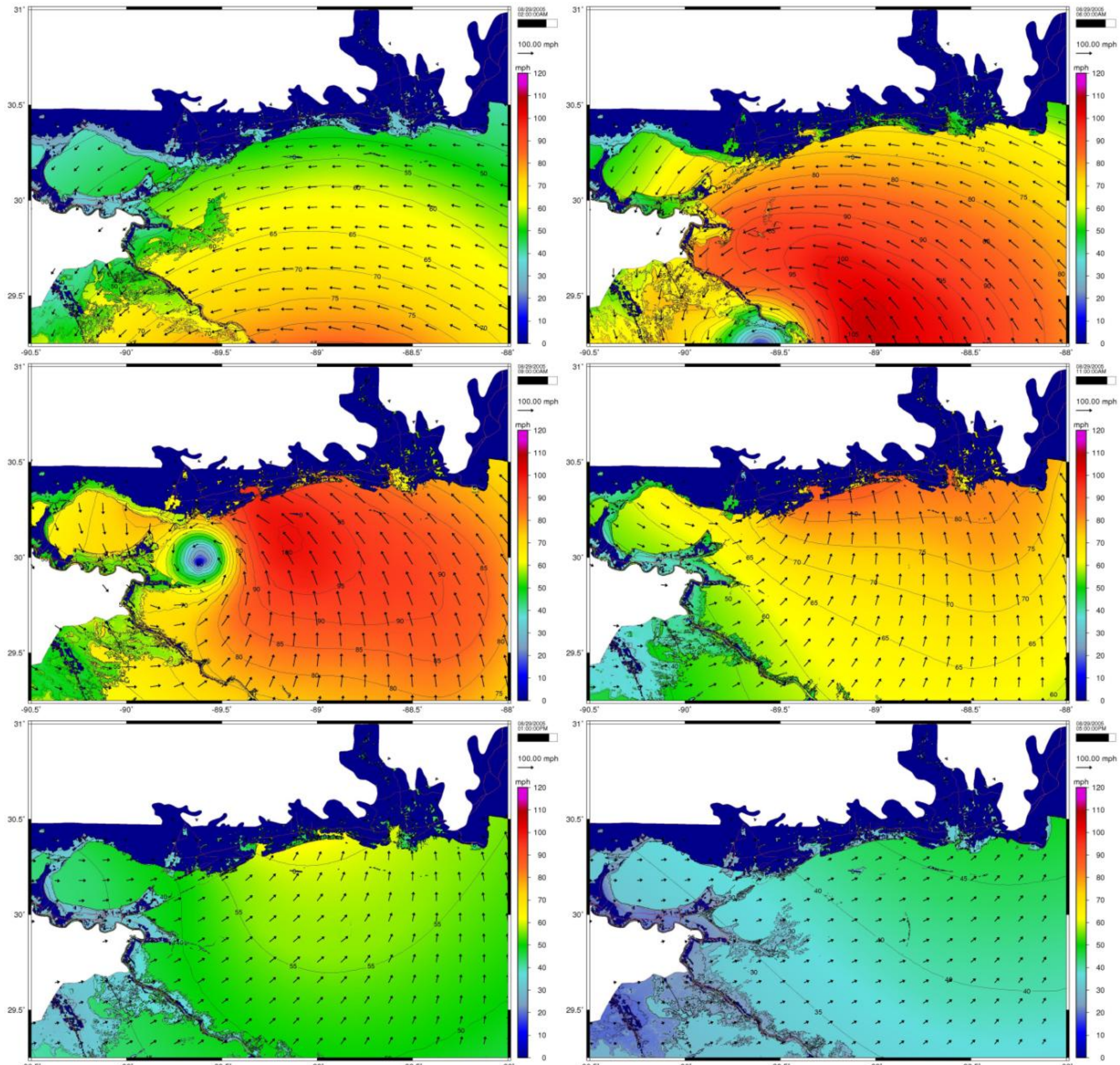

Figure 9: H*WIND/OWI wind contours and vectors (mph), shown with a 10 min averaging period and at 10 m elevation, in Southeastern Louisiana and Mississippi. The six panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, and (f) 1700 CDT.

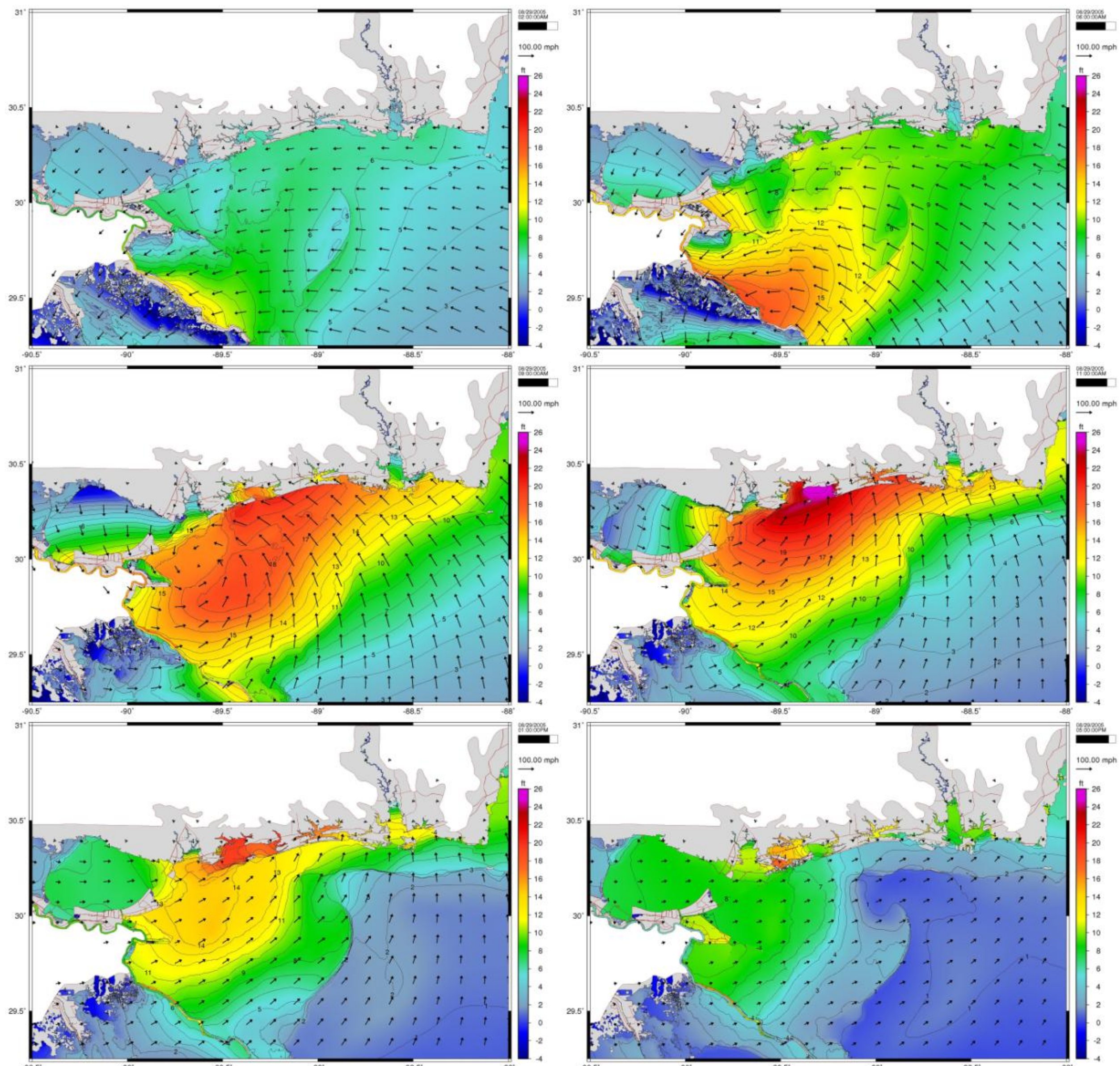

Figure 10: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) surface water elevations (ft) and wind speed vectors (mph), in Southeastern Louisiana and Mississippi. The six panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, and (f) 1700 CDT.

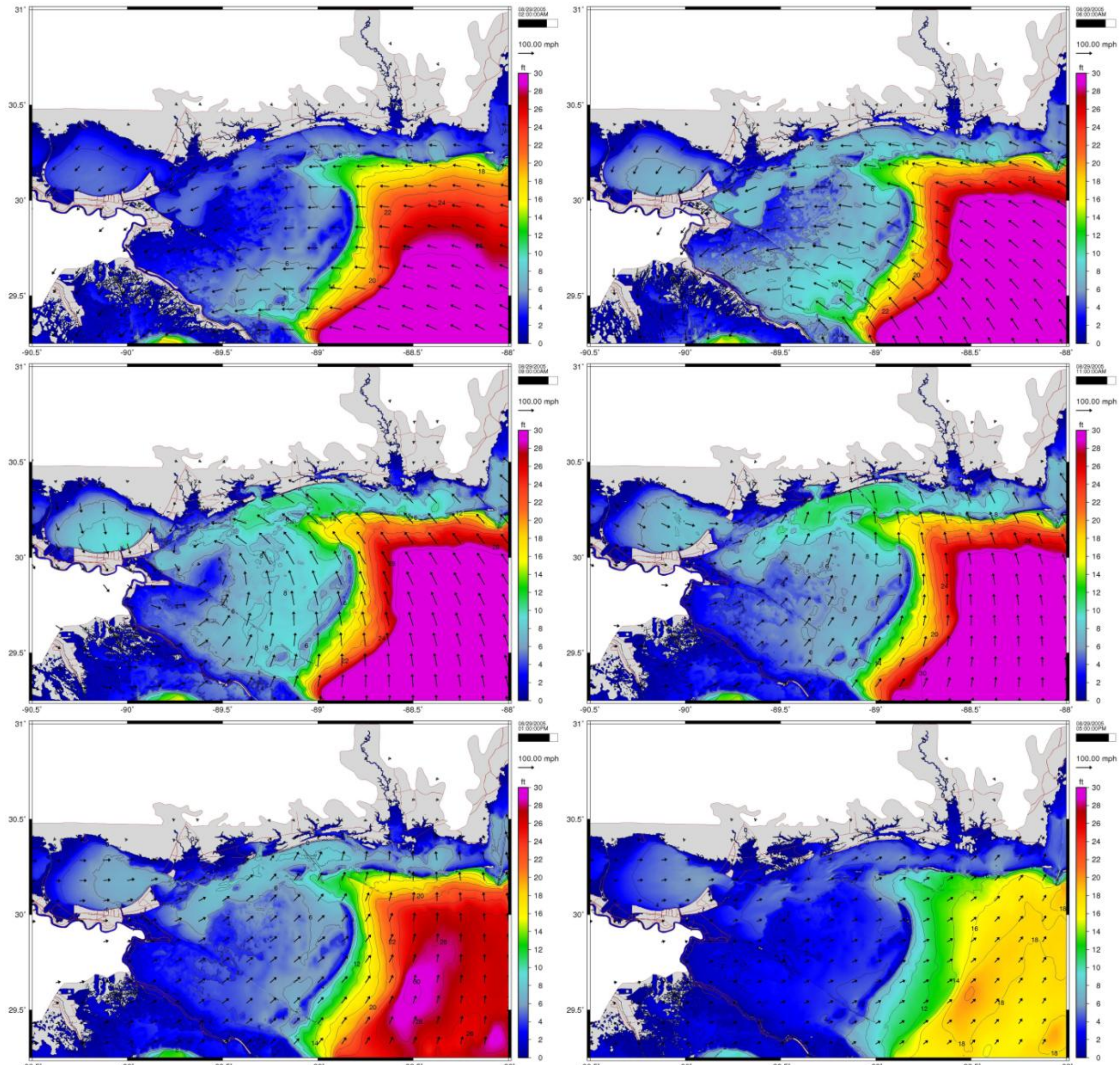

Figure 11: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) significant wave height contours (ft) and wind speed vectors (mph) in Southeastern Louisiana and Mississippi. The six panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, and (f) 1700 CDT.

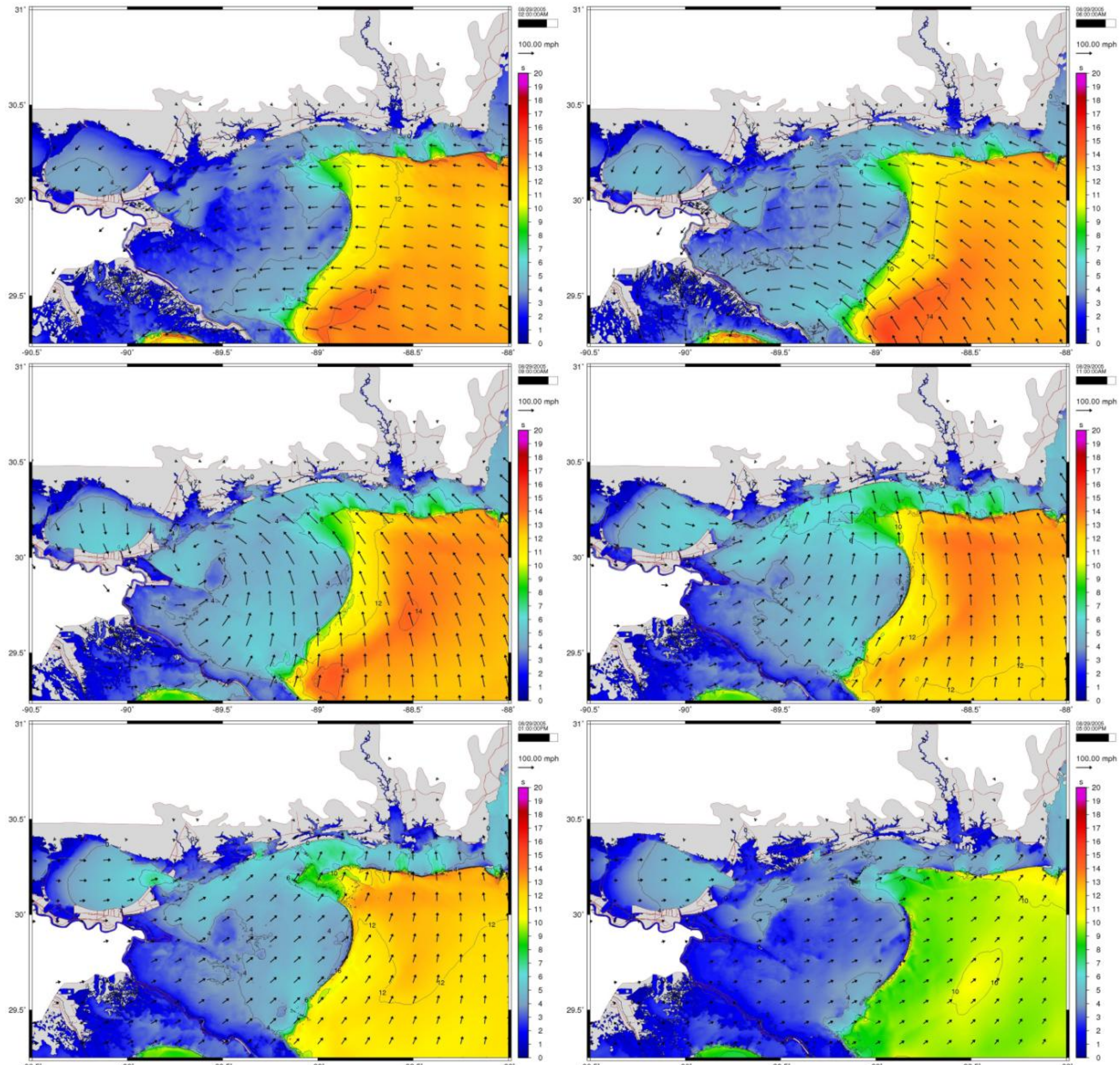

Figure 12: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A) mean wave period contours (s) and wind vectors (mph) in Southeastern Louisiana and Mississippi. The six panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, and (f) 1700 CDT.

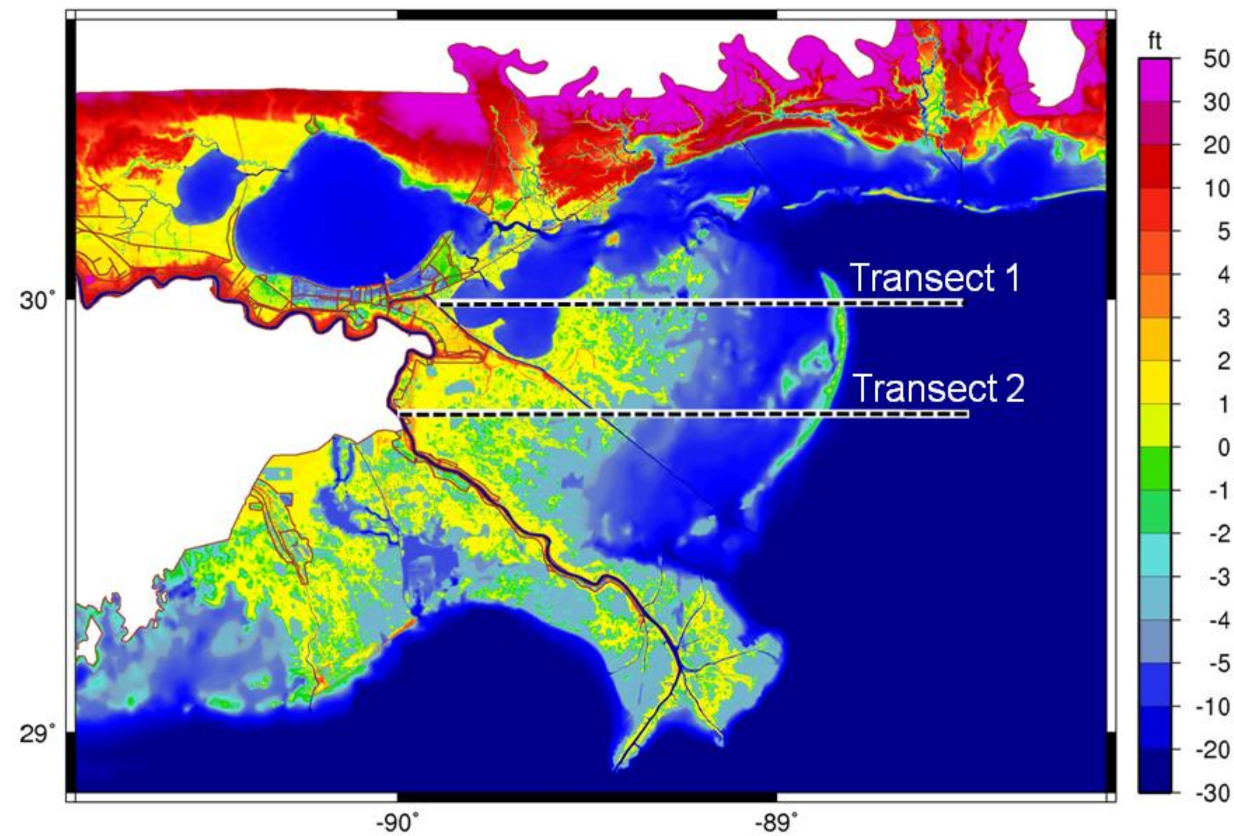

Figure 13a: East-west transect locations for bathymetry/topography to the east of the Mississippi River.

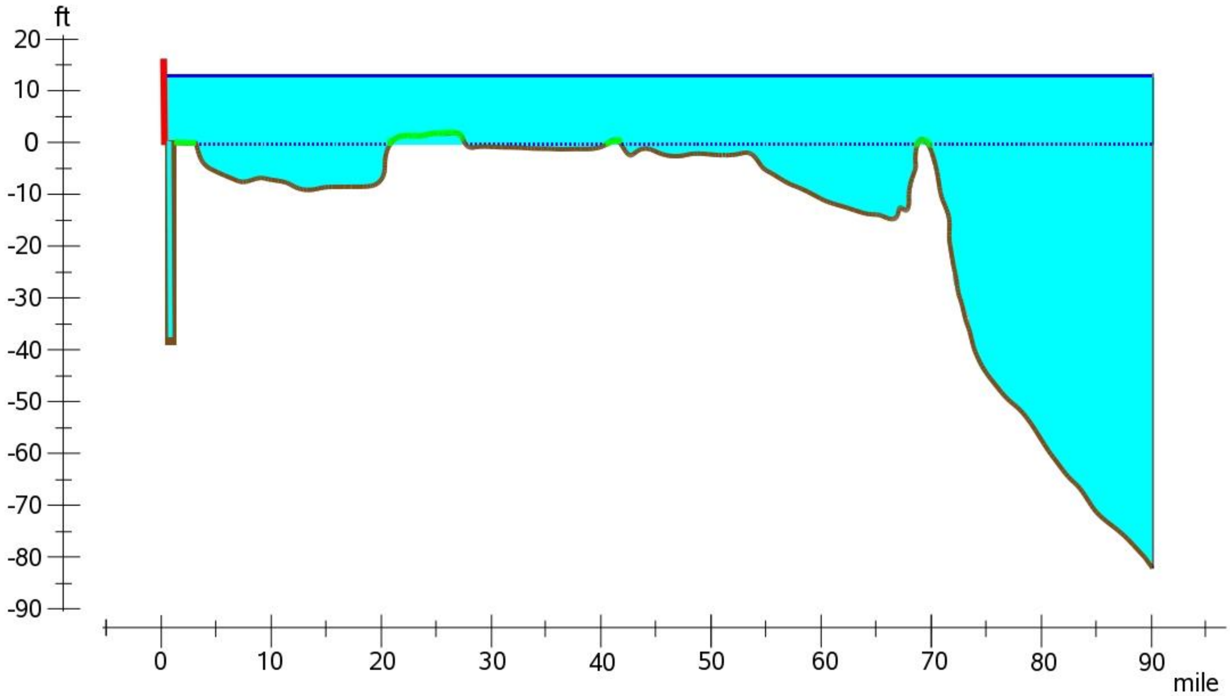

Figure 13b: East-west transect 1 of bathymetry/topography to the east of the Mississippi River. Shallow waters and wetlands with high waters on top allow for surge and wave seas to develop in critical areas. Deep channel represents MRGO Reach 2 which has a deep channel width of approximately 0.16 mi and a shallow surface width of approximately 0.5 mi. Red line represents a St. Bernard Polder MRGO Reach 2 levee. Dashed blue line represents zero NAVD 88 (2004.65). Solid blue line approximates 12 ft of water from storm surge.

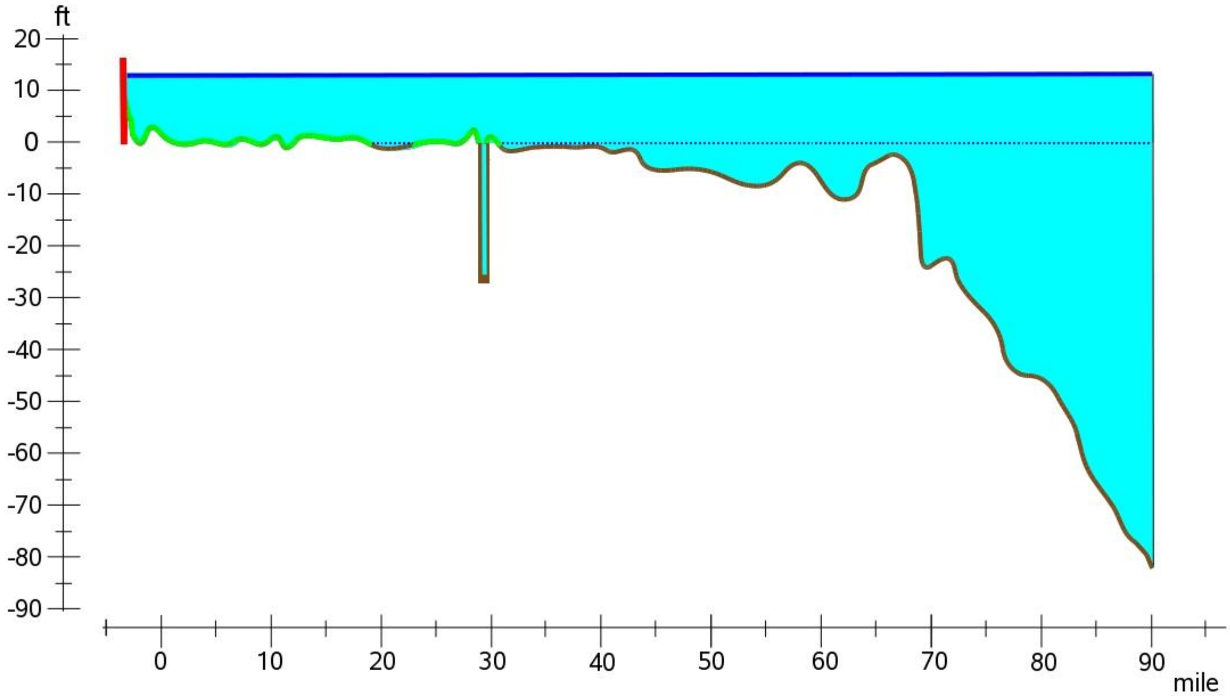

Figure 13c: East-west transect 2 of bathymetry/topography to the east of the Mississippi River. Shallow waters and wetlands with high waters on top allow for surge and wave seas to develop in critical areas. Deep channel represents MRGO Reach 2 which has a deep channel width of approximately 0.16 mi and a shallow surface width of approximately 0.5 mi. Red line represents a Mississippi River east bank federal levee. Dashed blue line represents zero NAVD 88 (2004.65). Solid blue line approximates 12 ft of water from storm surge.

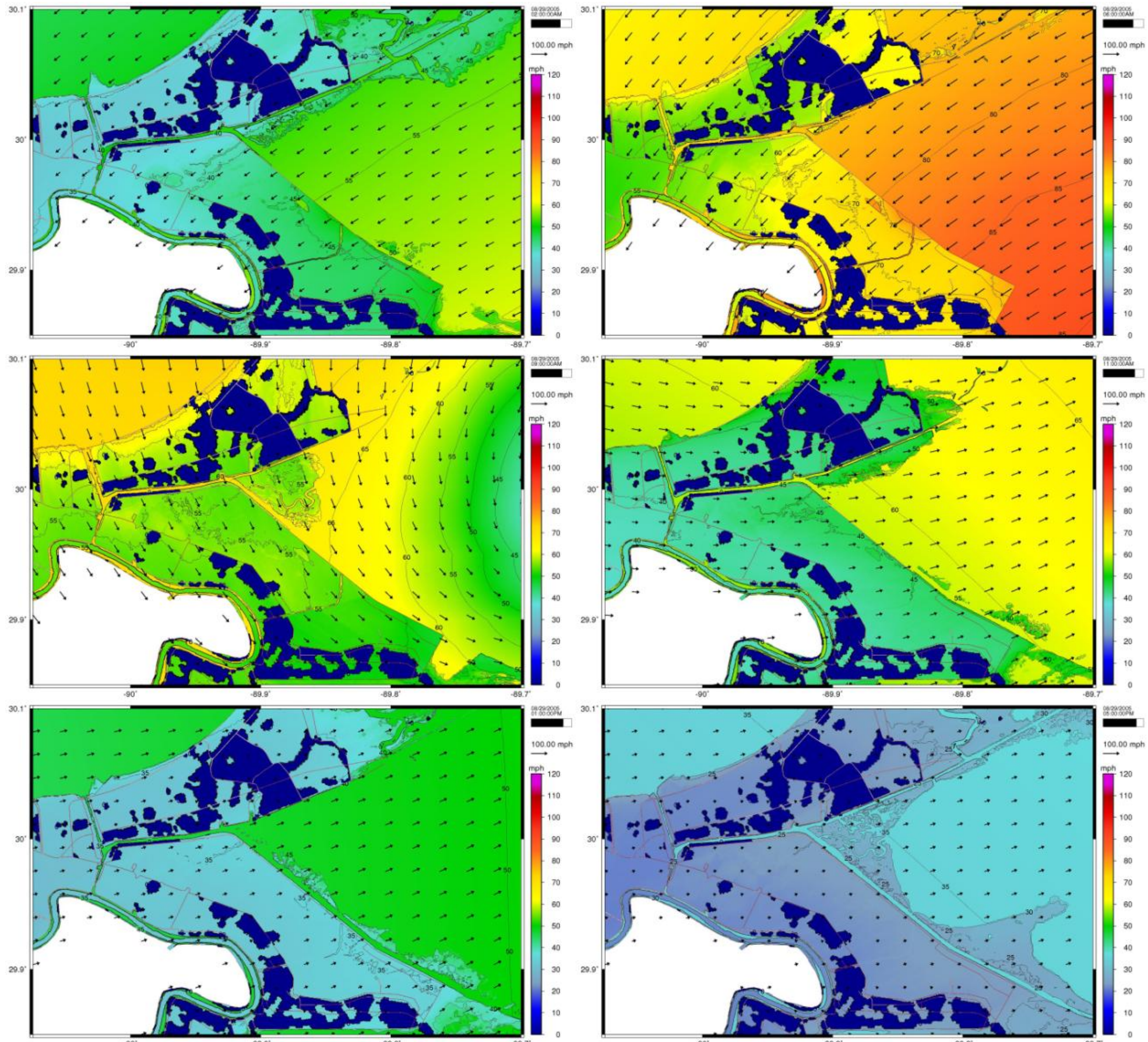

Figure 14: H*WIND/OWI wind contours and vectors (mph), shown with a 10 min averaging period and at 10 m elevation, in Study Area. The six panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, and (f) 1700 CDT.

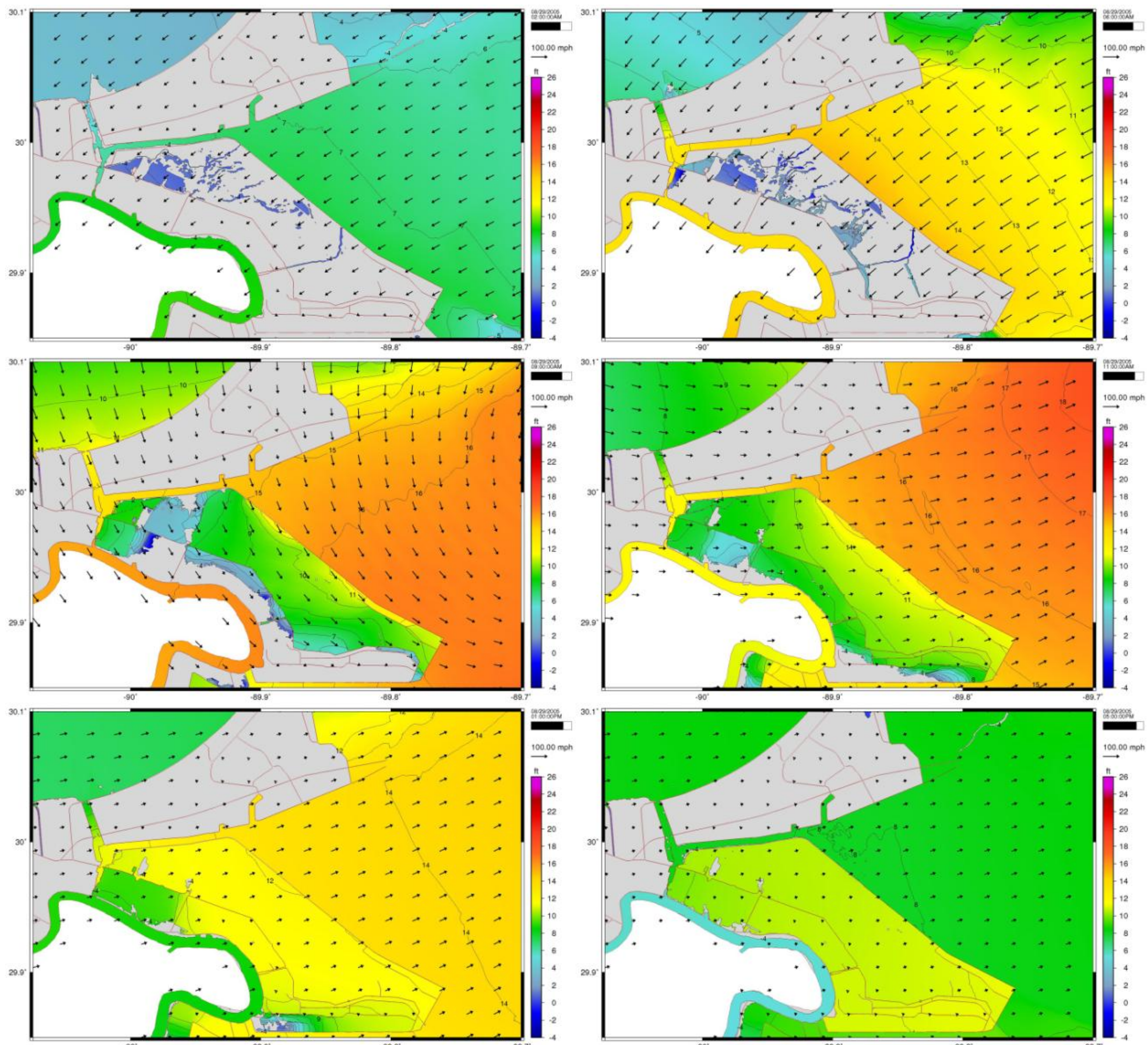

Figure 15: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) surface water elevations (ft) and wind speed vectors (mph), in the Study Area. The six panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, and (f) 1700 CDT.

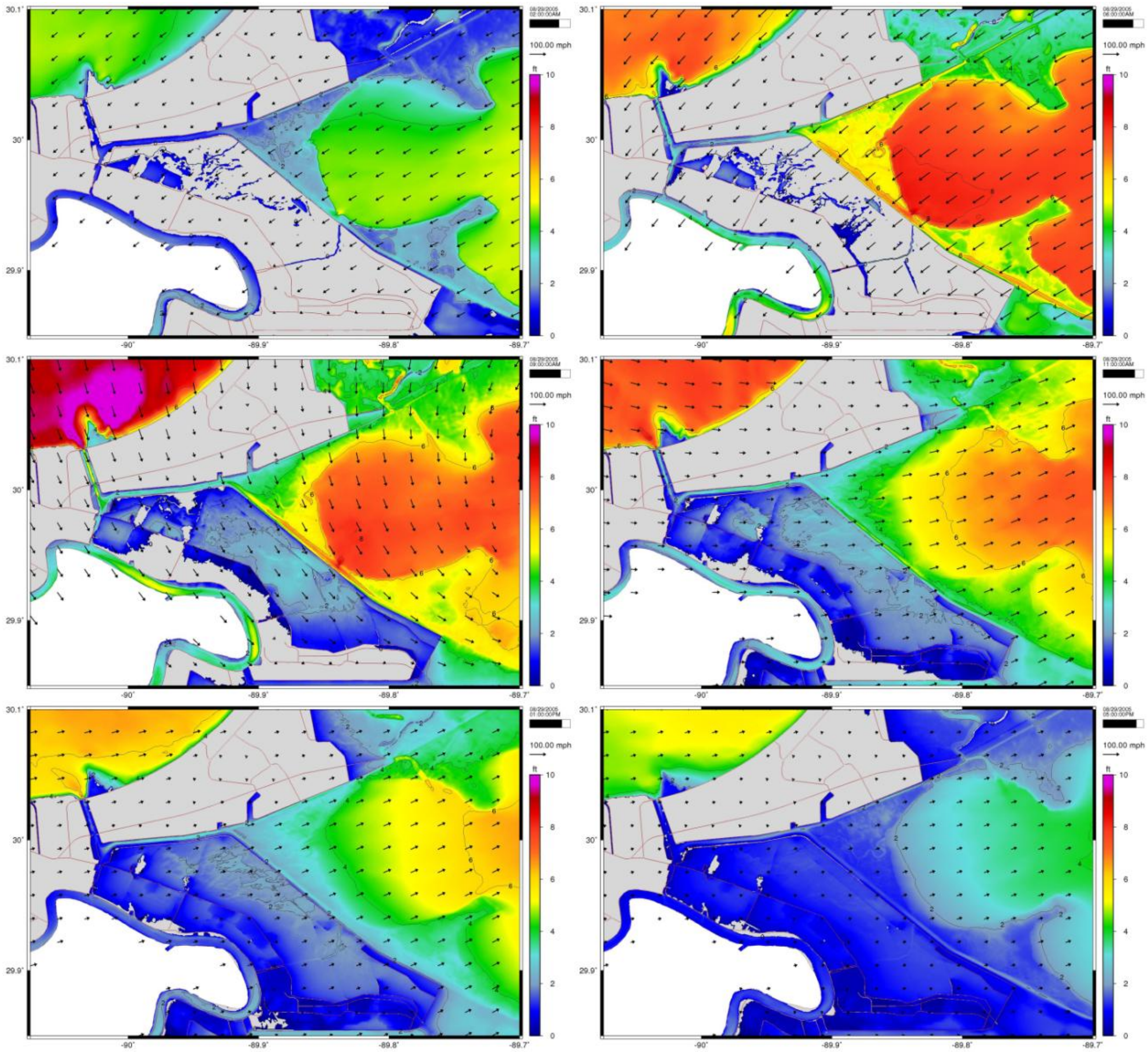

Figure 16: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) significant wave height contours (ft) and wind speed vectors (mph) in the Study Area. The six panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, and (f) 1700 CDT.

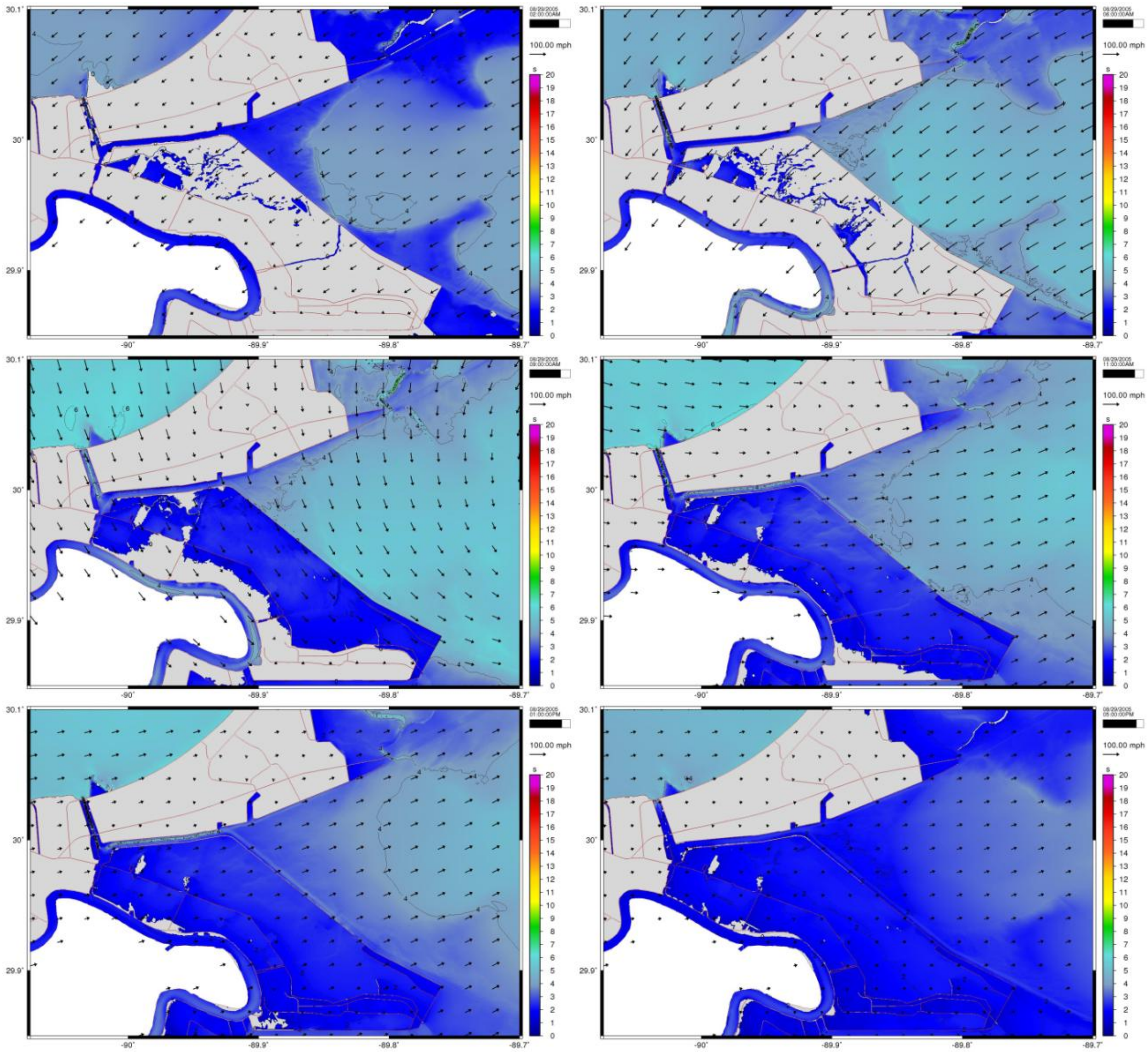

Figure 17: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) mean wave period contours (s) and wind vectors (mph) in the Study Area. The six panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, and (f) 1700 CDT.

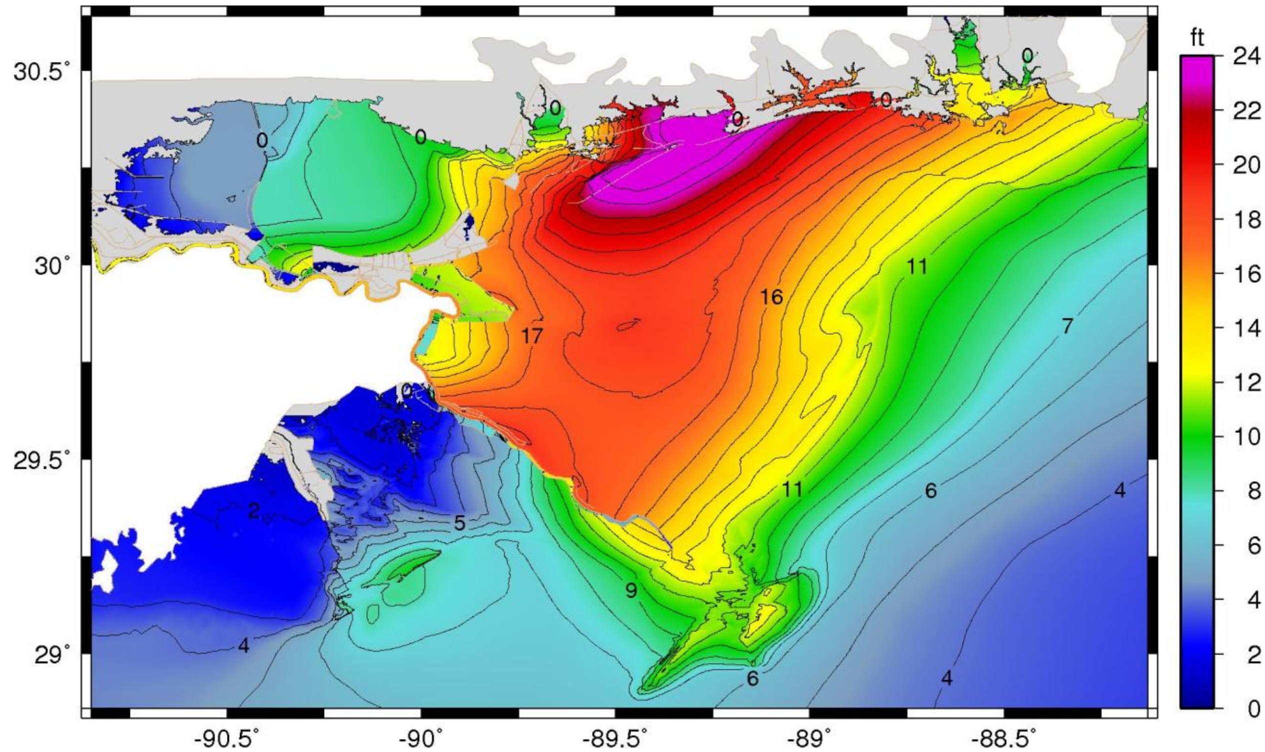

Figure 18a: Maximum Hurricane Katrina event water surface elevation (ft) in Southeastern Louisiana for the Model A1 *Katrina Actual Event Conditions* SL16-DOJ-SB-A1 simulation. Brown lines denote raised features.

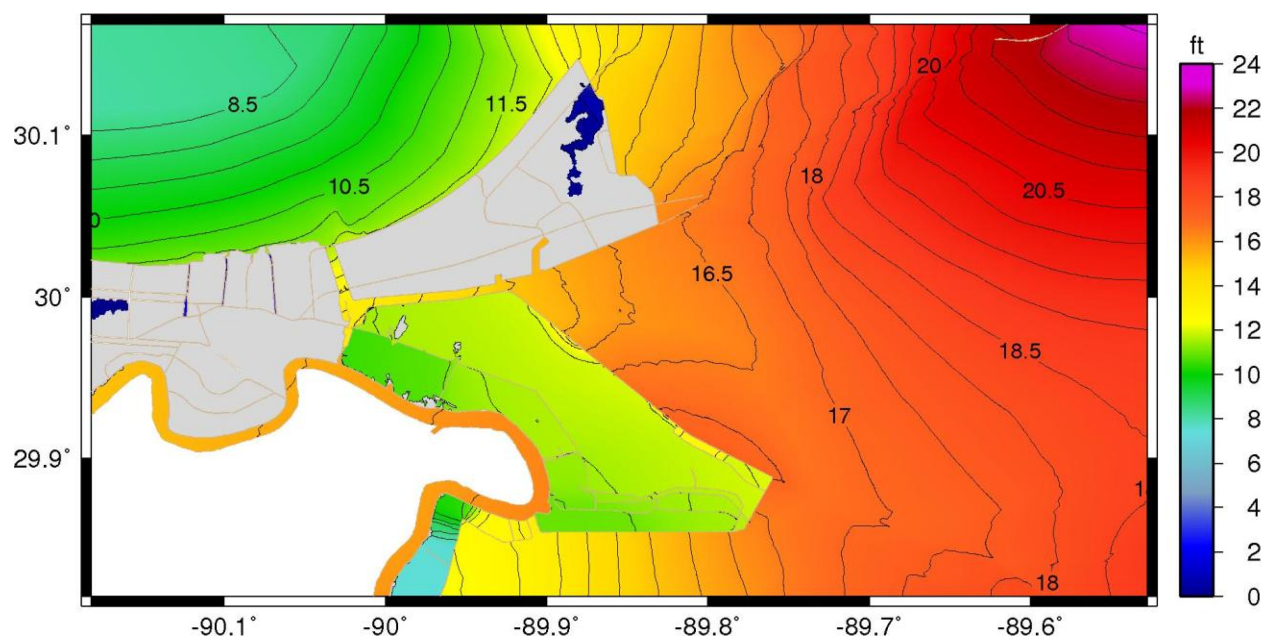

Figure 18b: Maximum Hurricane Katrina event water surface elevation (ft) in the Study Area for the Model A1 *Katrina Actual Event Conditions* SL16-DOJ-SB-A1 simulation. Brown lines denote raised features.

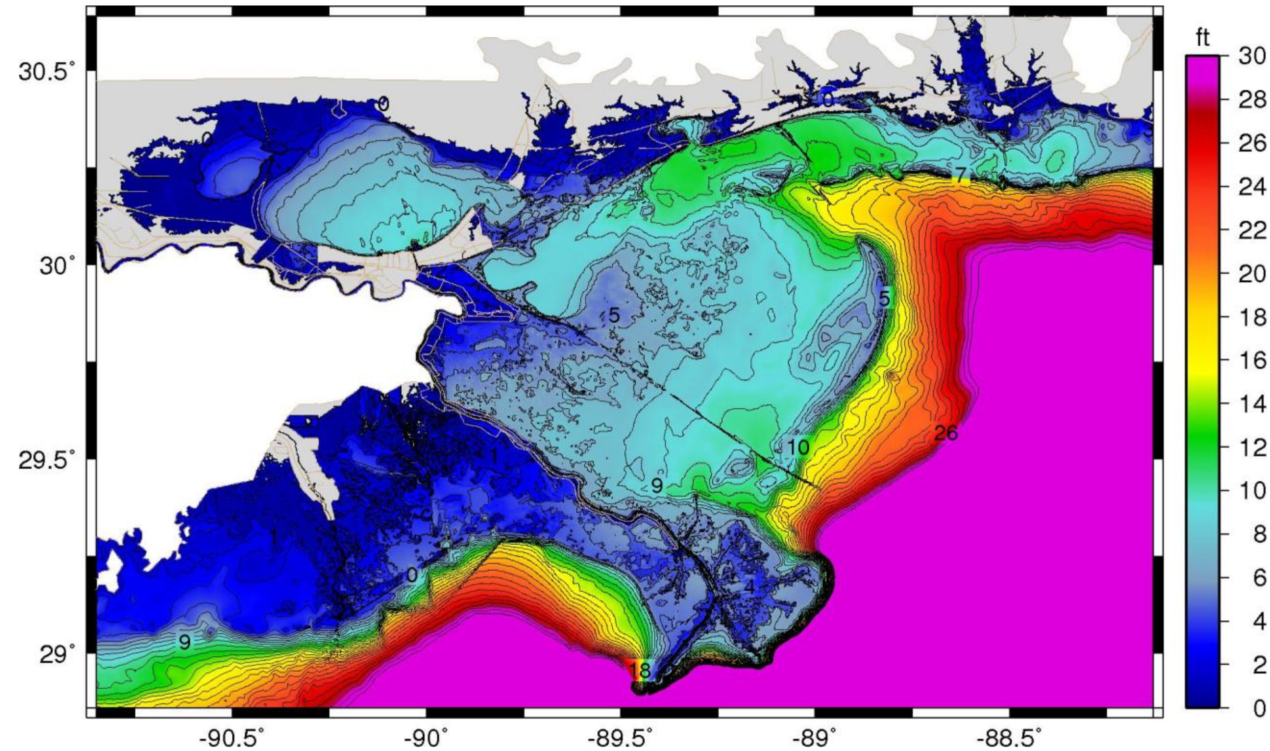

Figure 19a: Maximum Hurricane Katrina event significant wave heights (ft) in Southeastern Louisiana for the Model A1 *Katrina Actual Event Conditions* SL16-DOJ-SB-A1 simulation. Brown lines denote raised features.

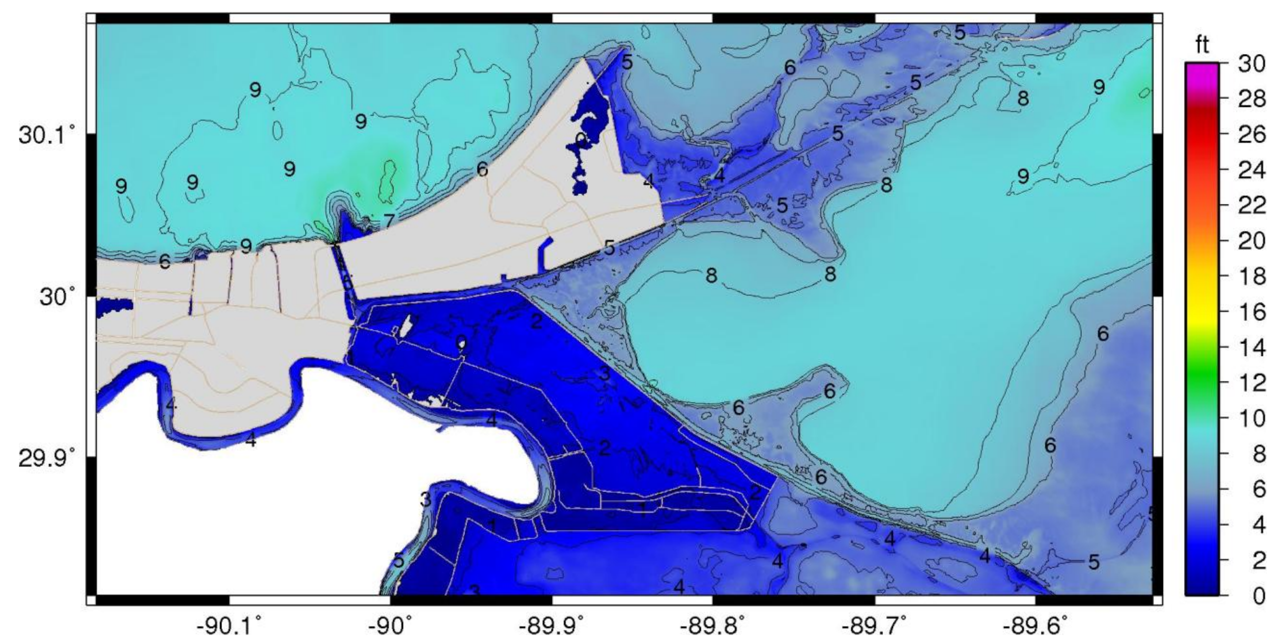

Figure 19b: Maximum Hurricane Katrina event significant wave heights (ft) in the Study Area for the Model A1 *Katrina Actual Event Conditions* SL16-DOJ-SB-A1 simulation. Brown lines denote raised features.

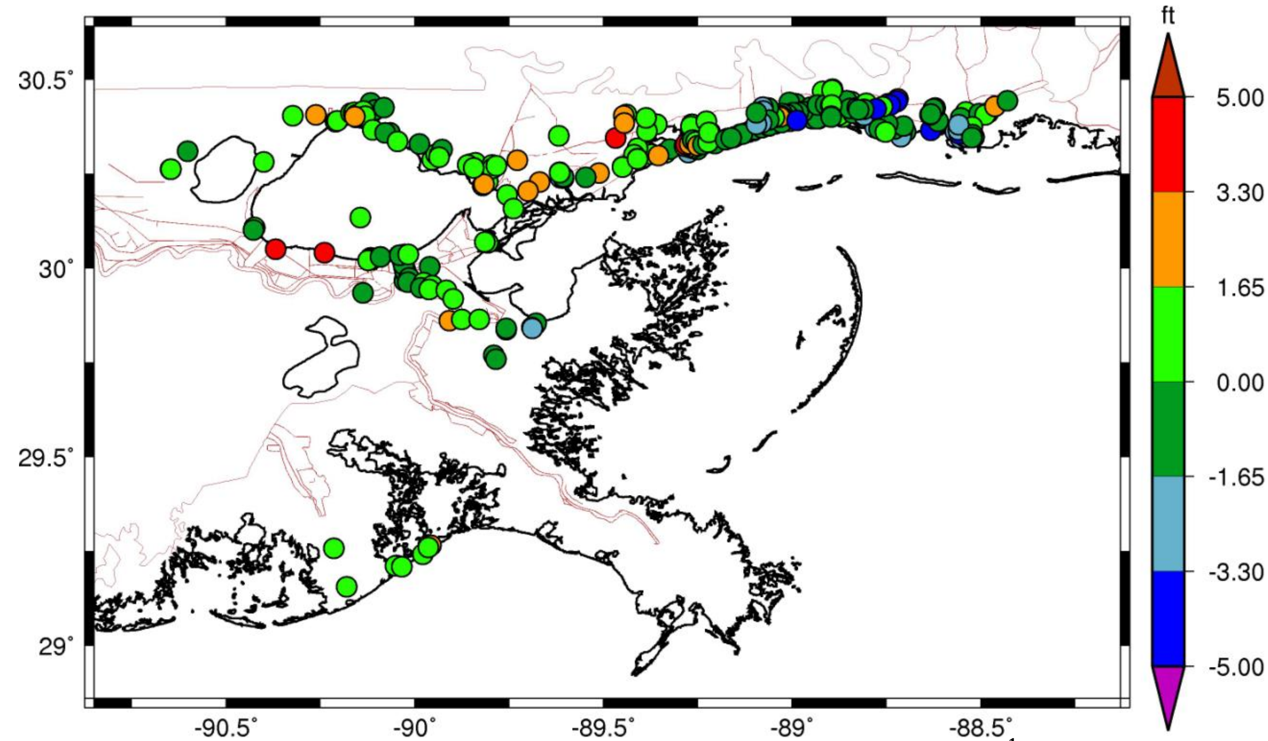

Figure 20a: Locations of HWMs for Hurricane Katrina. Colors indicate the difference[1] between the maximum computed water elevation from the Model A1 *Katrina Actual Event Conditions* SL16-DOJ-SB-A1 hindcast and the measured high water mark (HWM). Green points indicate a match to within 1.65 ft (0.5 m). Red, orange and light green circles indicate over-predictions by the model; green, blue and dark blue circles indicate under-predictions.

[1] These are “raw” difference plots and do not statistically account for the inherent errors in the measurement data as do our statistical error analyses.

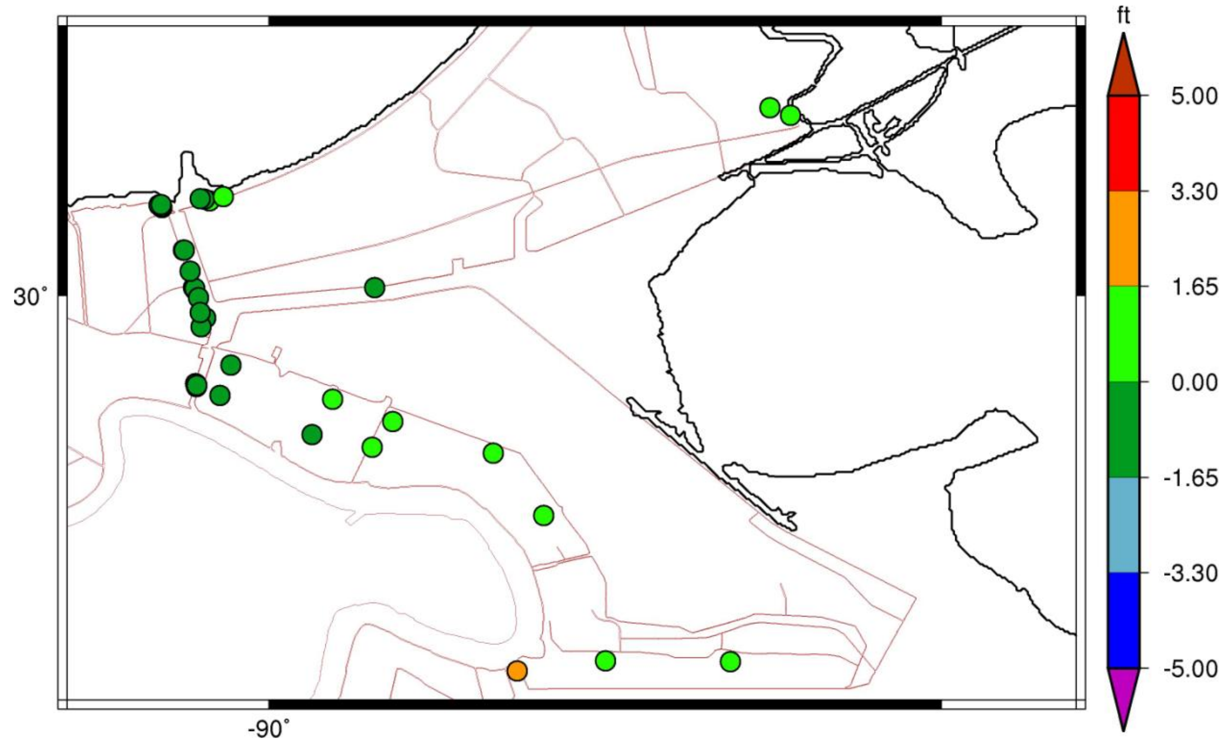

Figure 20b: Locations and differences of HWMs within the Study Area for Model A1 *Katrina Actual Event Conditions* SL16-DOJ-SB-A1 hindcast. Colors and details are as described above for Figure 20a.

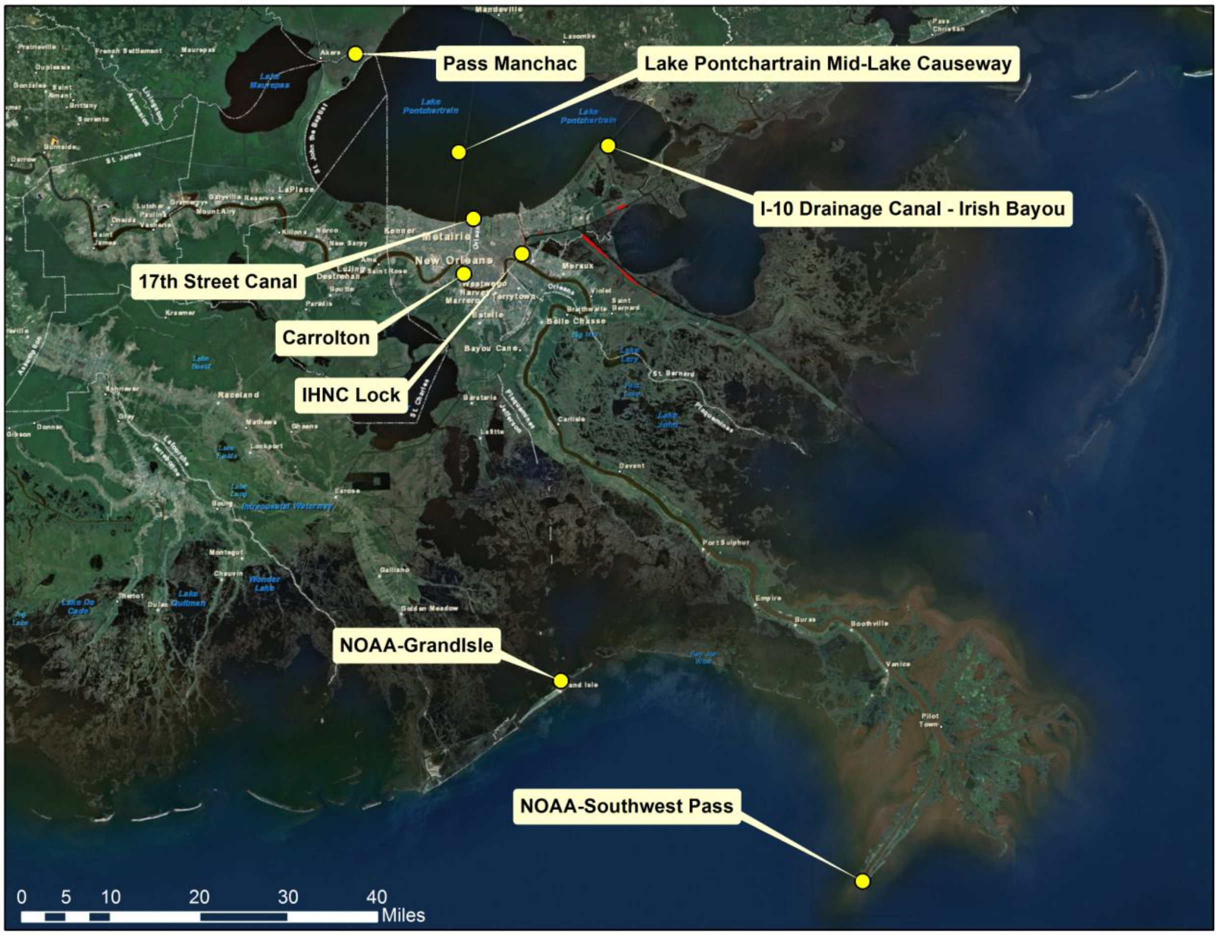

Figure 21a: Map of hydrograph locations with available measured water surface elevation data outside of St. Bernard Polder.

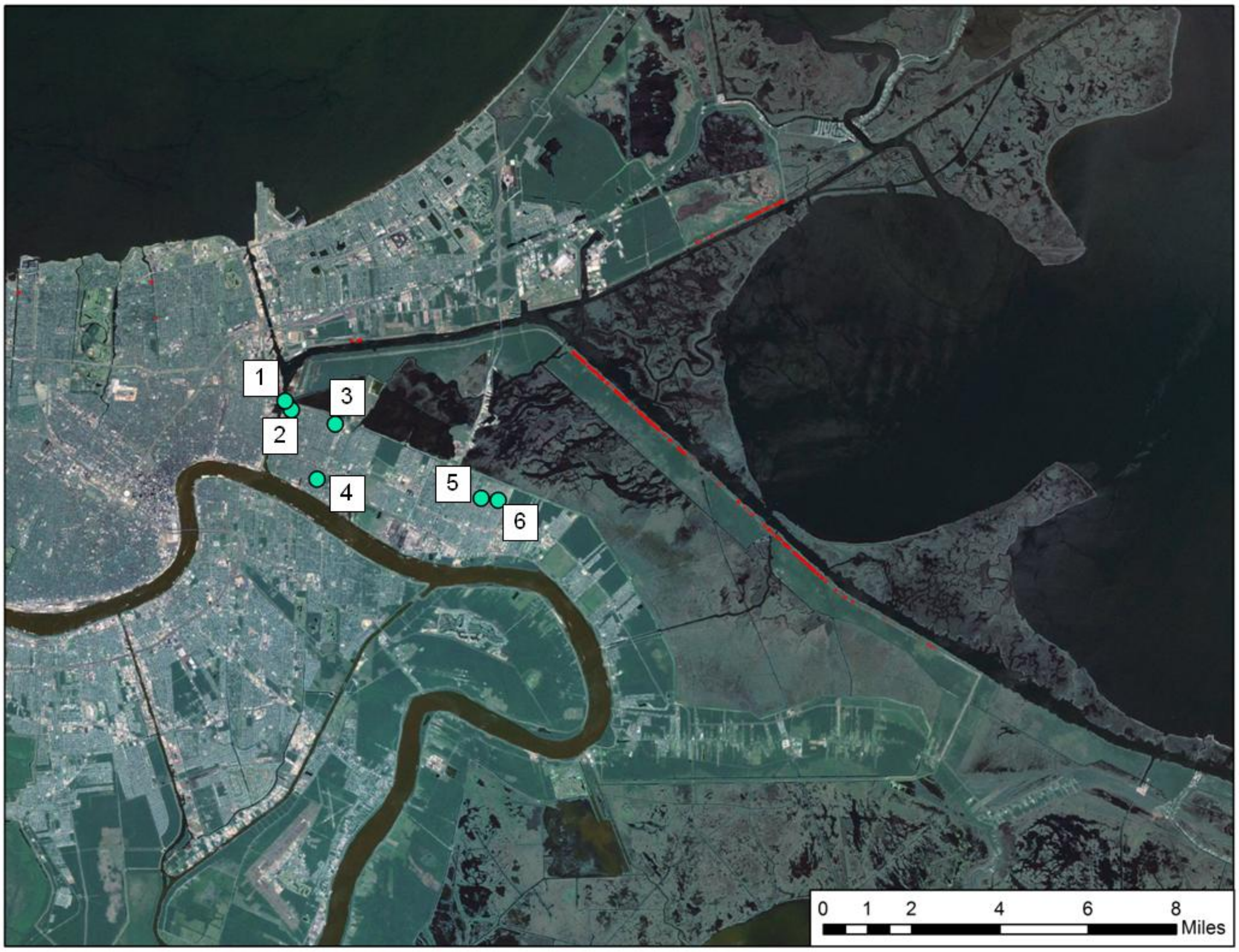

Figure 21b: Map of hydrograph locations with available measured water surface elevation data within St. Bernard Polder.

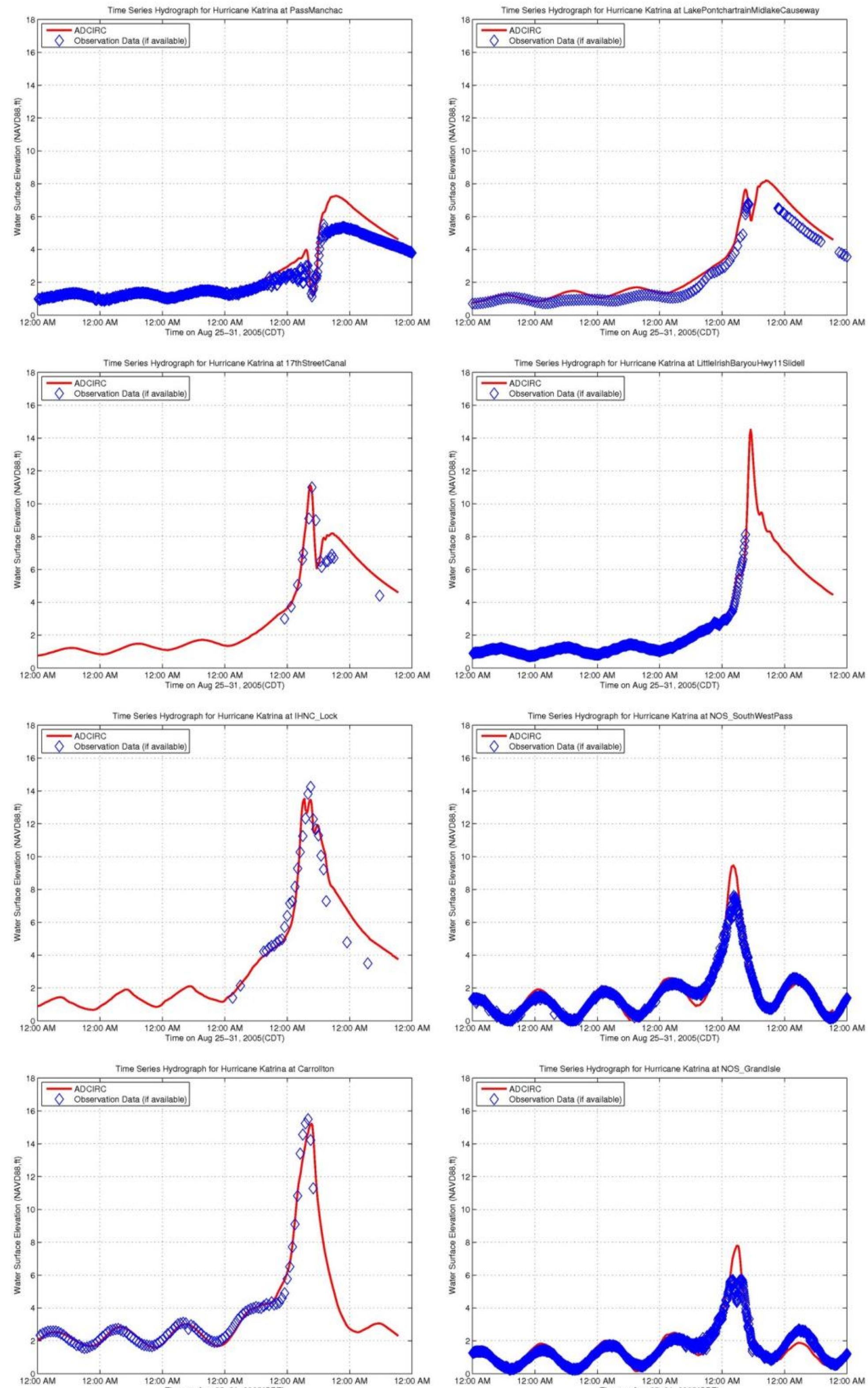

Figure 22: Hydrographs (ft NAVD88 (2004.65) versus date CDT in 2005) for the eight USACE, NOS and NWS stations outside of St. Bernard Polder during Hurricane Katrina. The red lines are the computed water levels from the SL16-DOJ-SB-A1 model, while the blue symbols indicate the measured data.

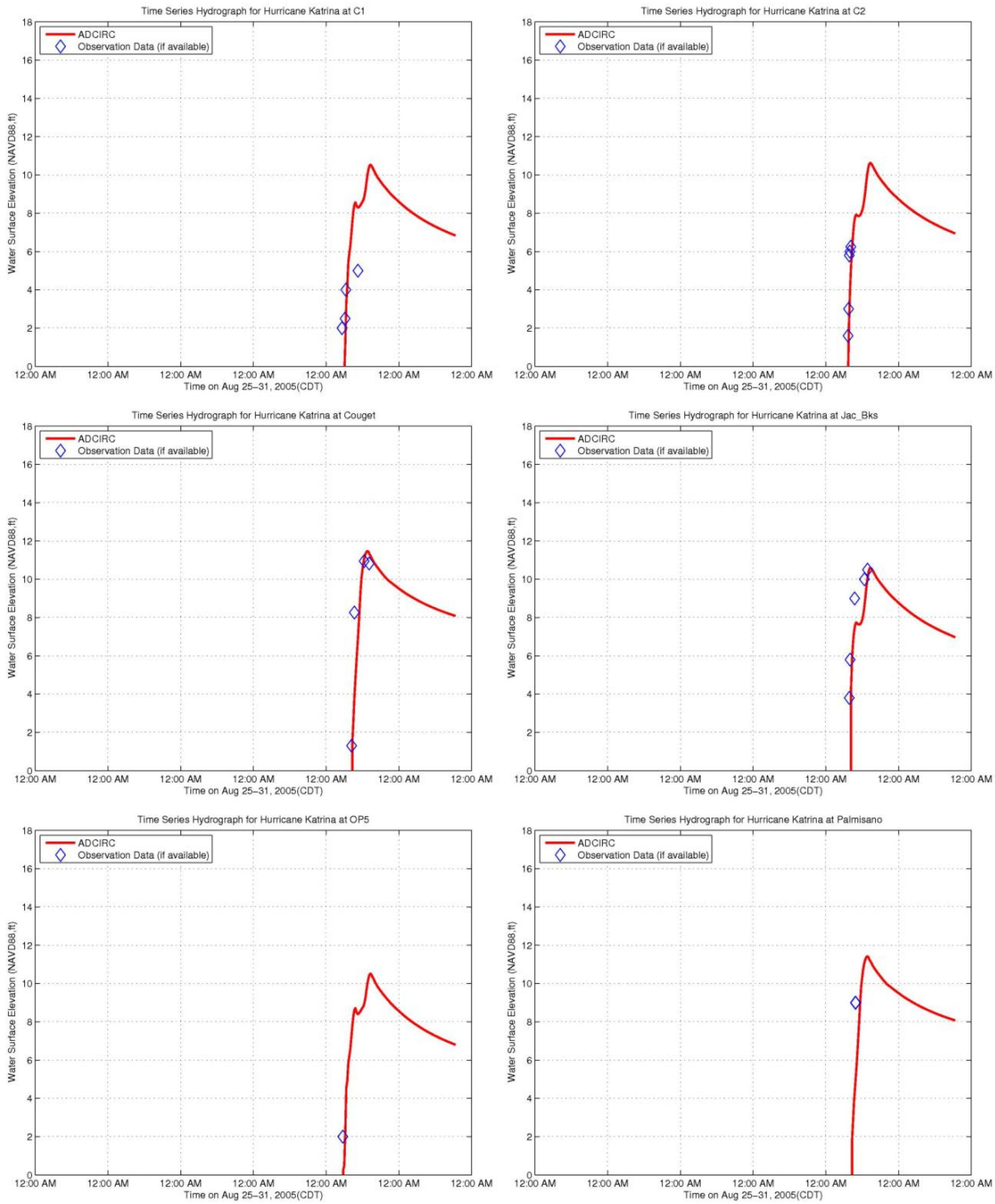

Figure 23: Hydrographs (ft NAVD88 (2004.65) versus date CDT in 2005) within St. Bernard Polder during Hurricane Katrina. The red lines are the computed water levels from the SL16-DOJ-SB-A1 model, while the blue symbols are the measured data.

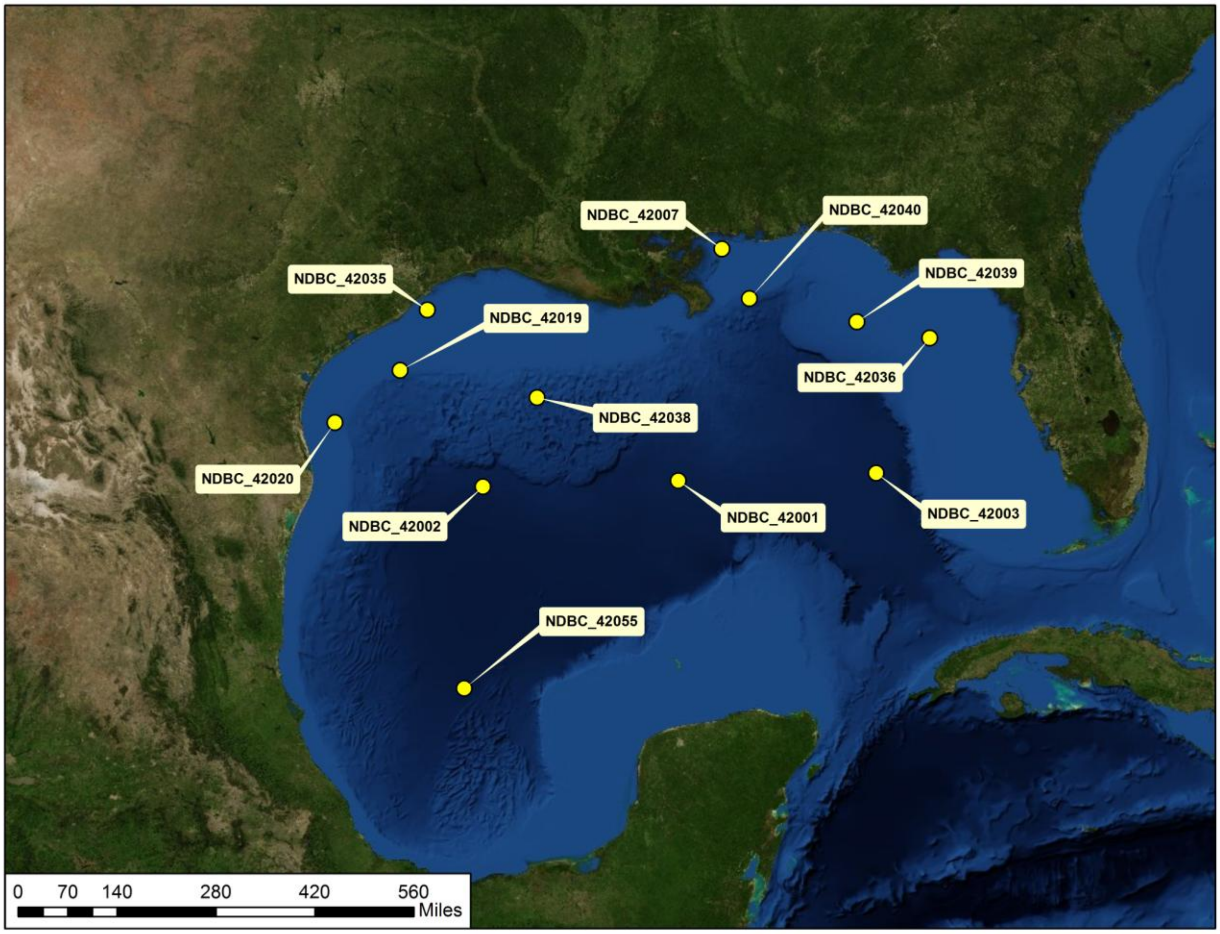

Figure 24: Map of NDBC wave stations.

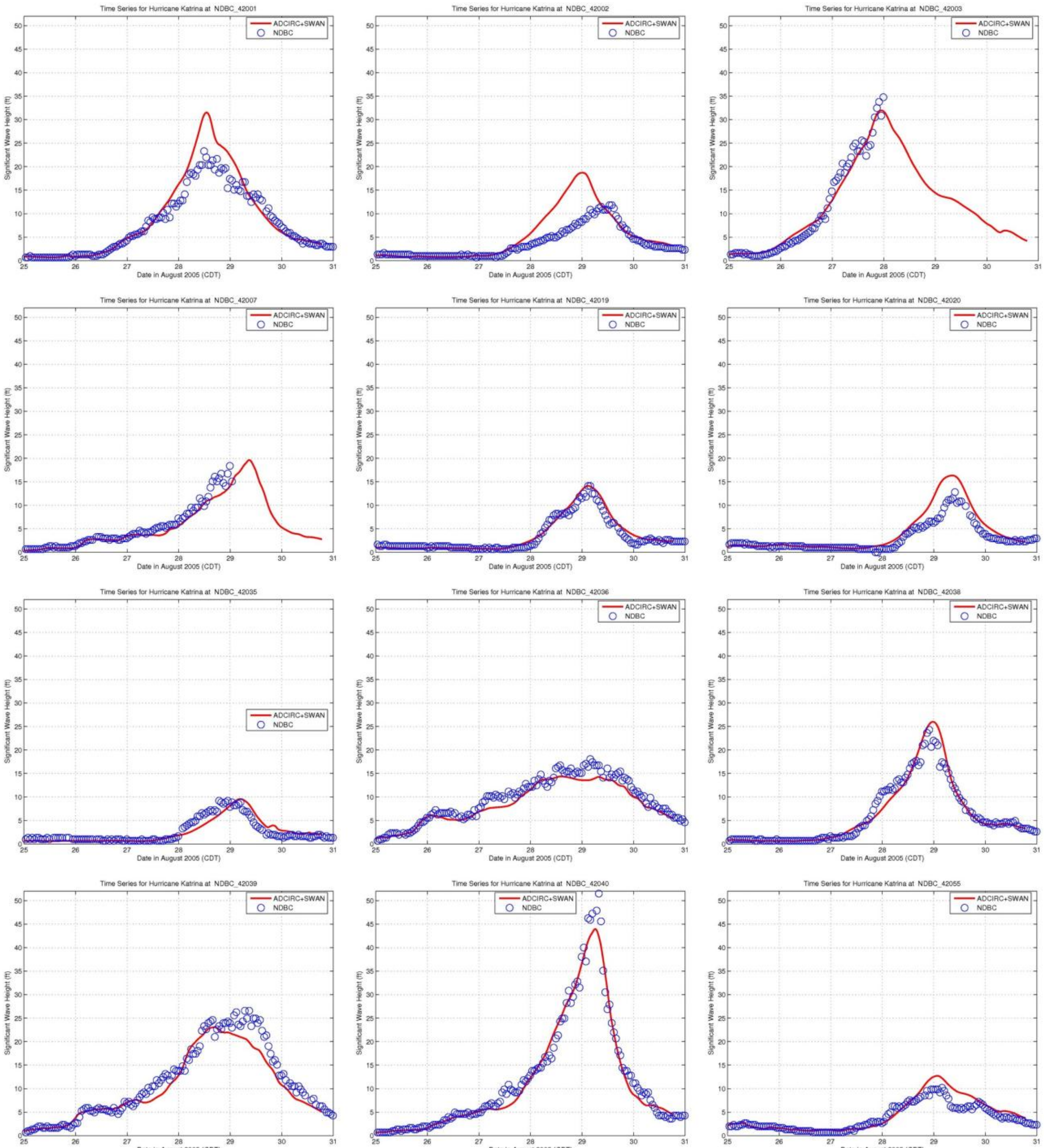

Figure 25: Significant wave heights (ft) during Hurricane Katrina at 12 NDBC buoys. The measured data is shown with blue dots, the modeled SL16-DOJ-SB-A1 results are shown with red lines. See Figure 24 for location of buoys.

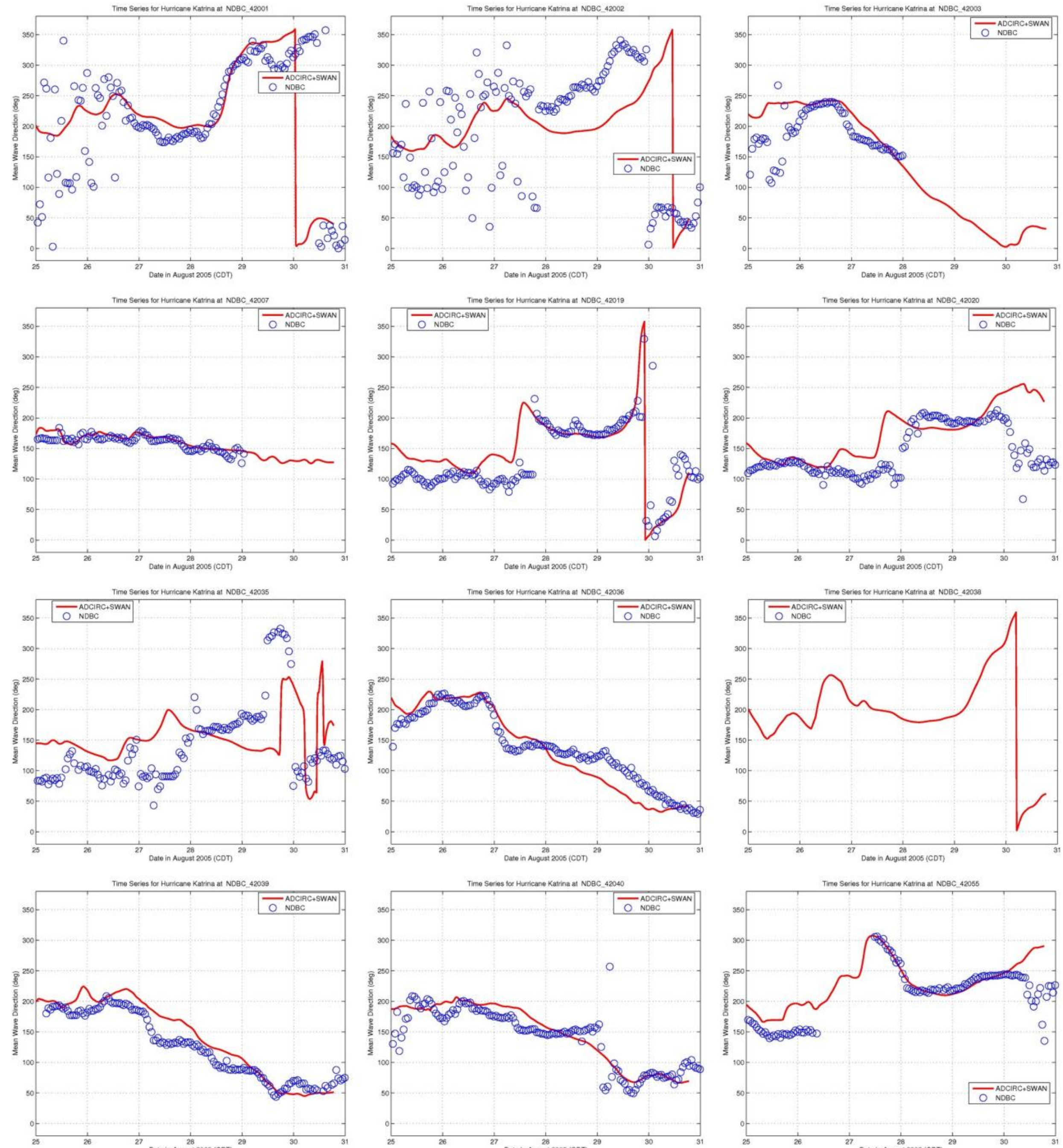

Figure 26: Mean wave directions (°), measured clockwise from geographic north, during Hurricane Katrina at 12 NDBC buoys. The measured data is shown with blue dots; the modeled SL16-DOJ-SB-A1 results are shown with red lines.

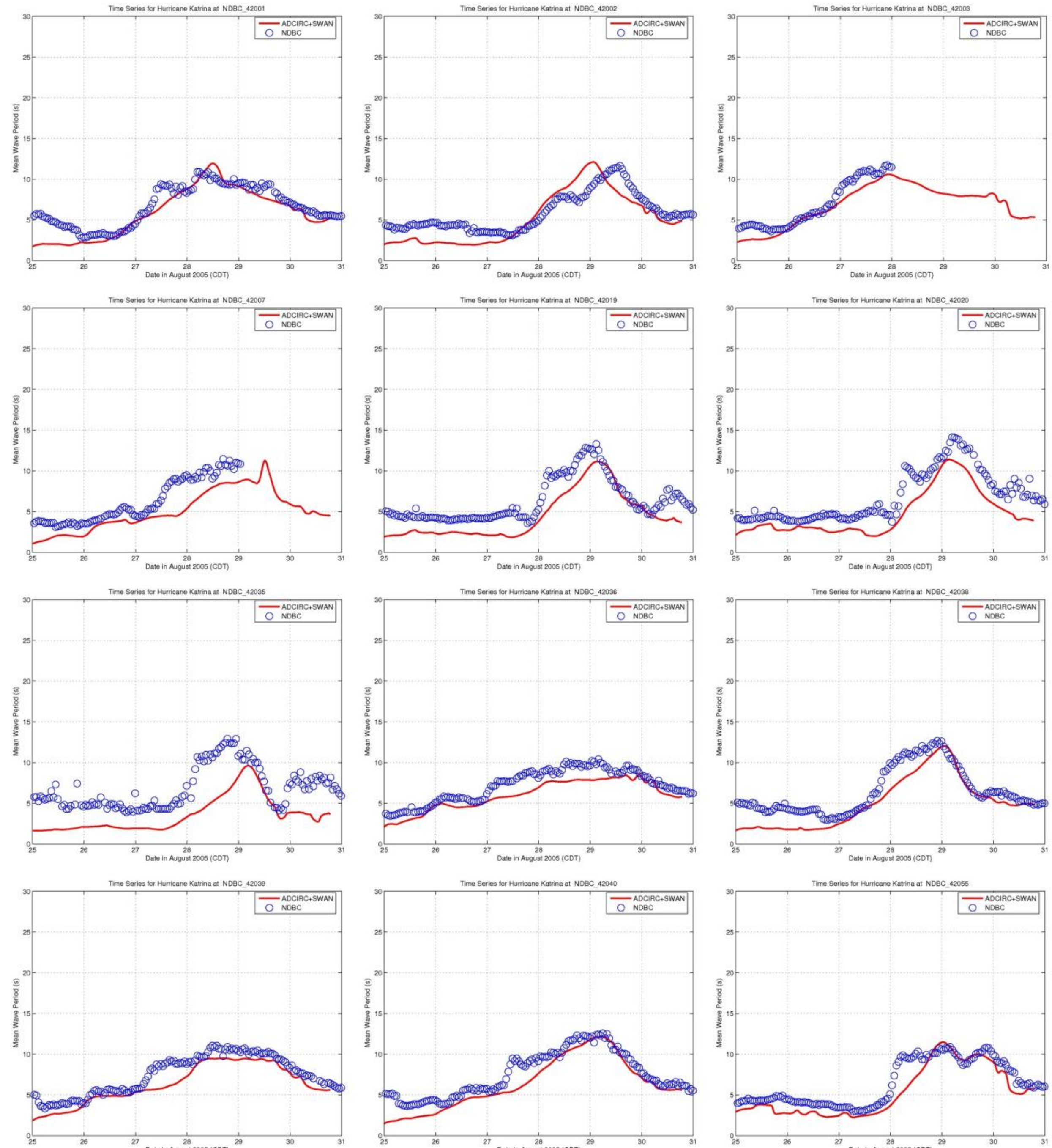

Figure 27: Mean wave periods (s) during Hurricane Katrina at 12 NDBC buoys. The measured data is shown with blue dots; the modeled SL16-DOJ-SB-A1 results are shown with red lines.

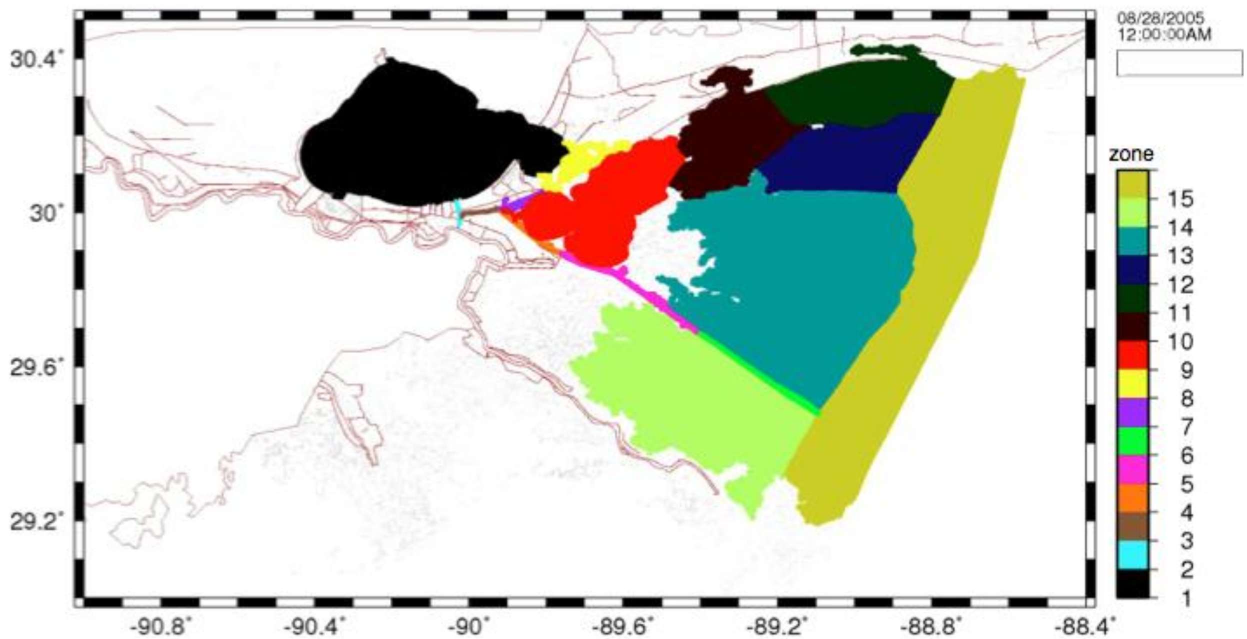

Figure 28: ADCIRC SL16-DOJ-SB-A1 initial particle seeding for Southeastern Louisiana on August 28, 2005 at 0000 CDT.

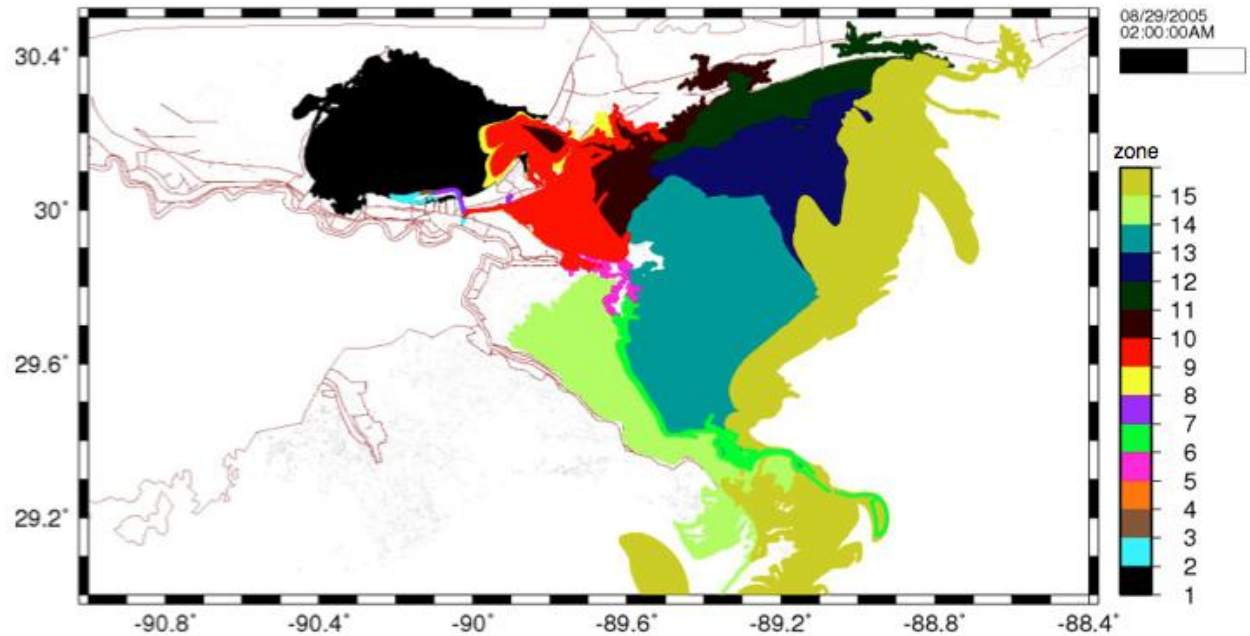

Figure 29a: Model A1 ***Katrina Actual Event Conditions*** **(SL16-DOJ-SB-A1) particle positions on August 29, 2005 at 0200 CDT.**

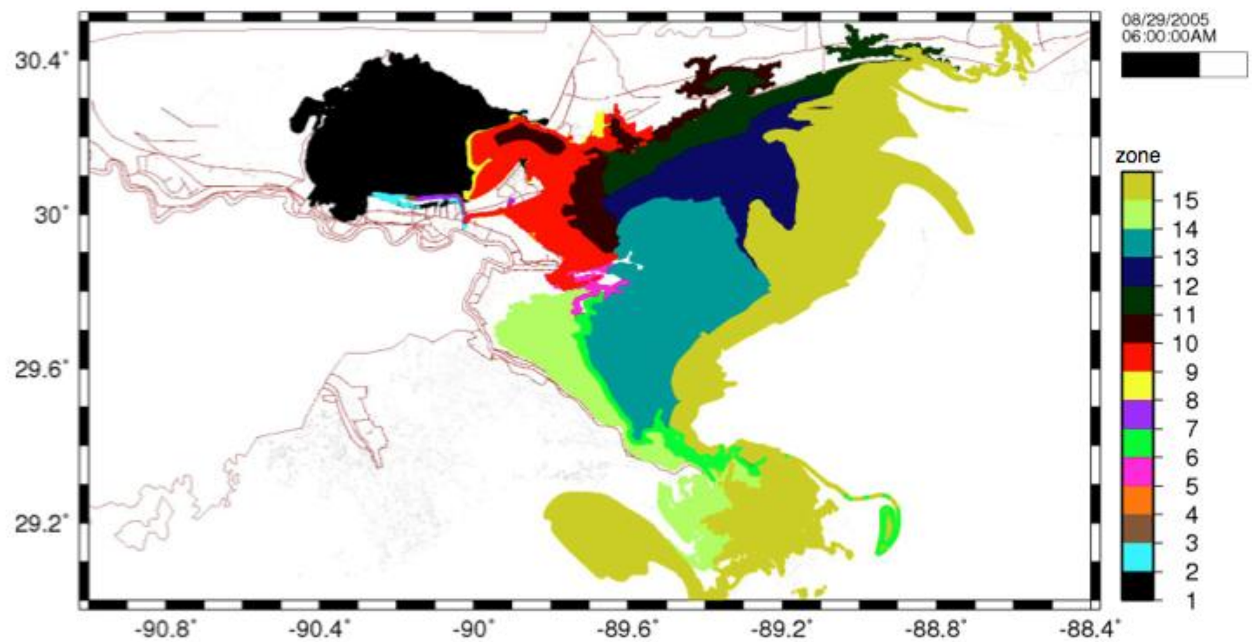

Figure 29b: Model A1 ***Katrina Actual Event Conditions*** **(SL16-DOJ-SB-A1) particle positions on August 29, 2005 at 0600 CDT.**

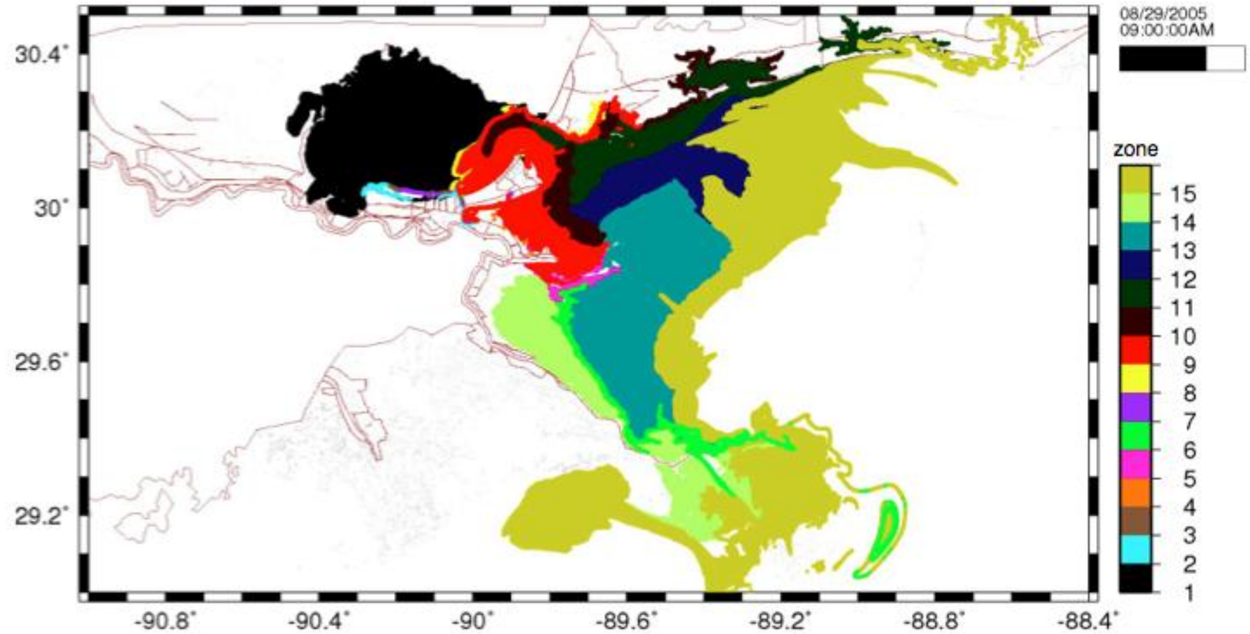

Figure 29c: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) particle positions on August 29, 2005 at 0900 CDT.

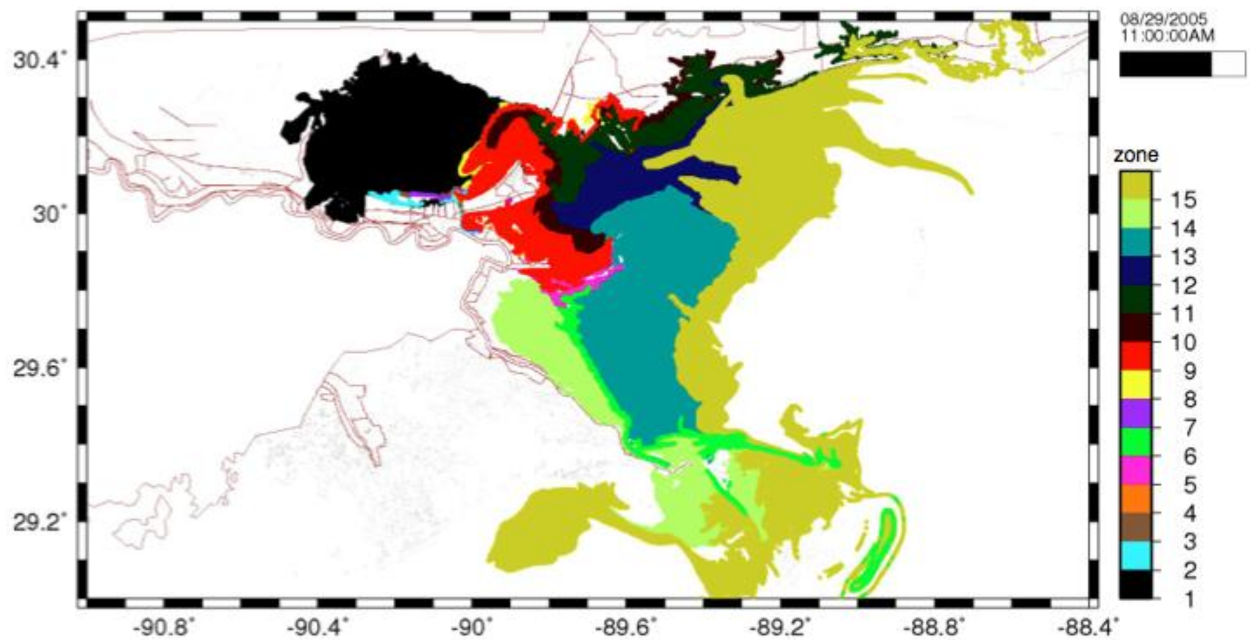

Figure 29d: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) particle positions on August 29, 2005 at 1100 CDT.

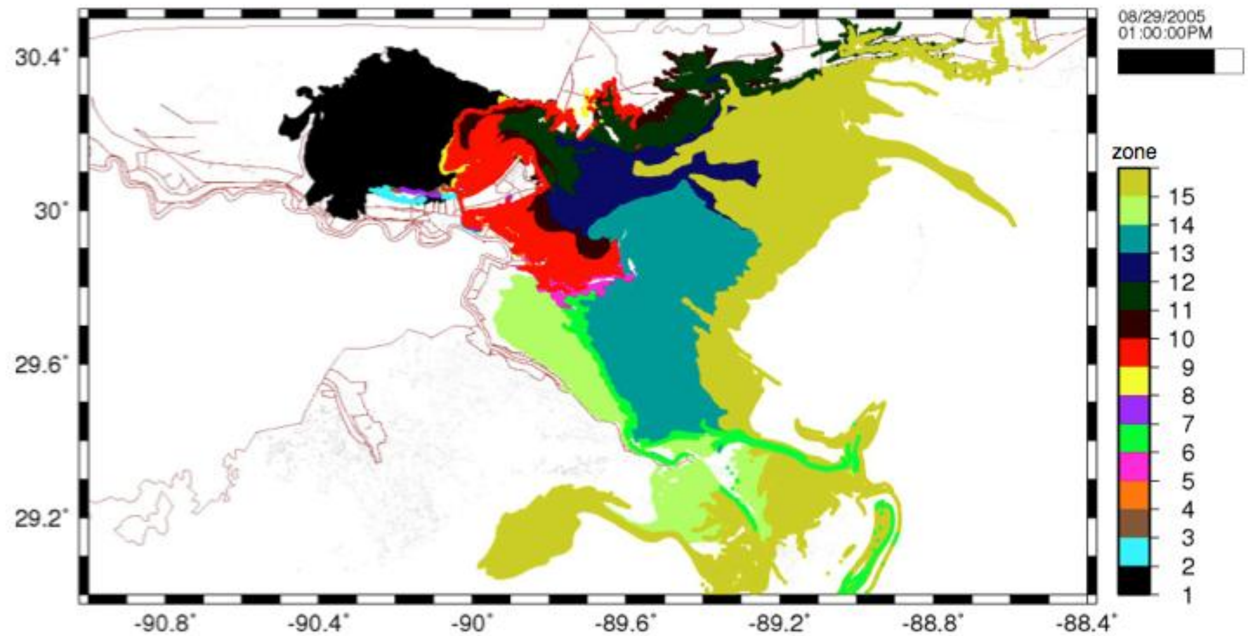

Figure 29e: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) particle positions on August 29, 2005 at 1300 CDT.

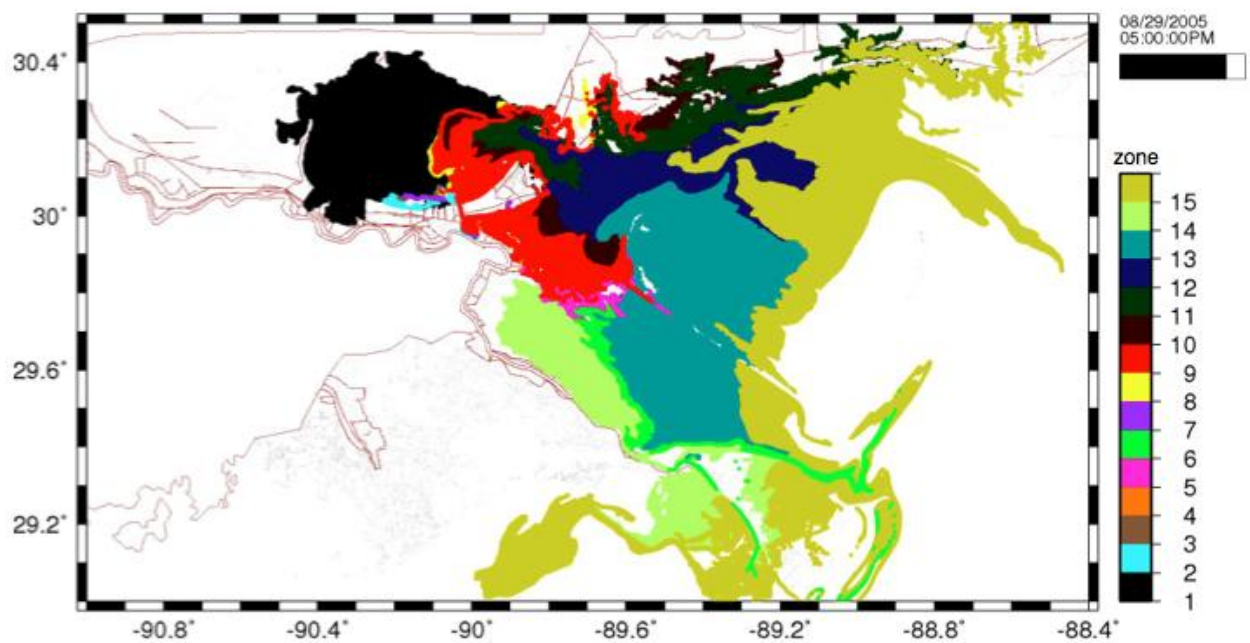

Figure 29f: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) particle positions on August 29, 2005 at 1700 CDT.

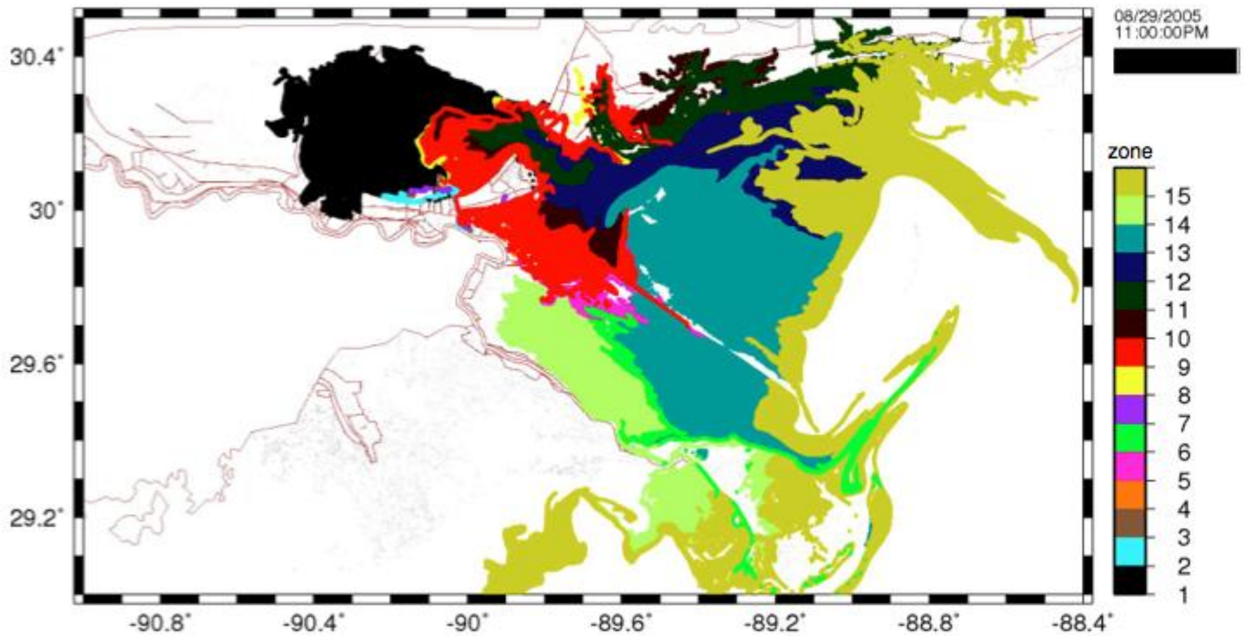

Figure 29g: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) particle positions on August 29, 2005 at 2300 CDT.

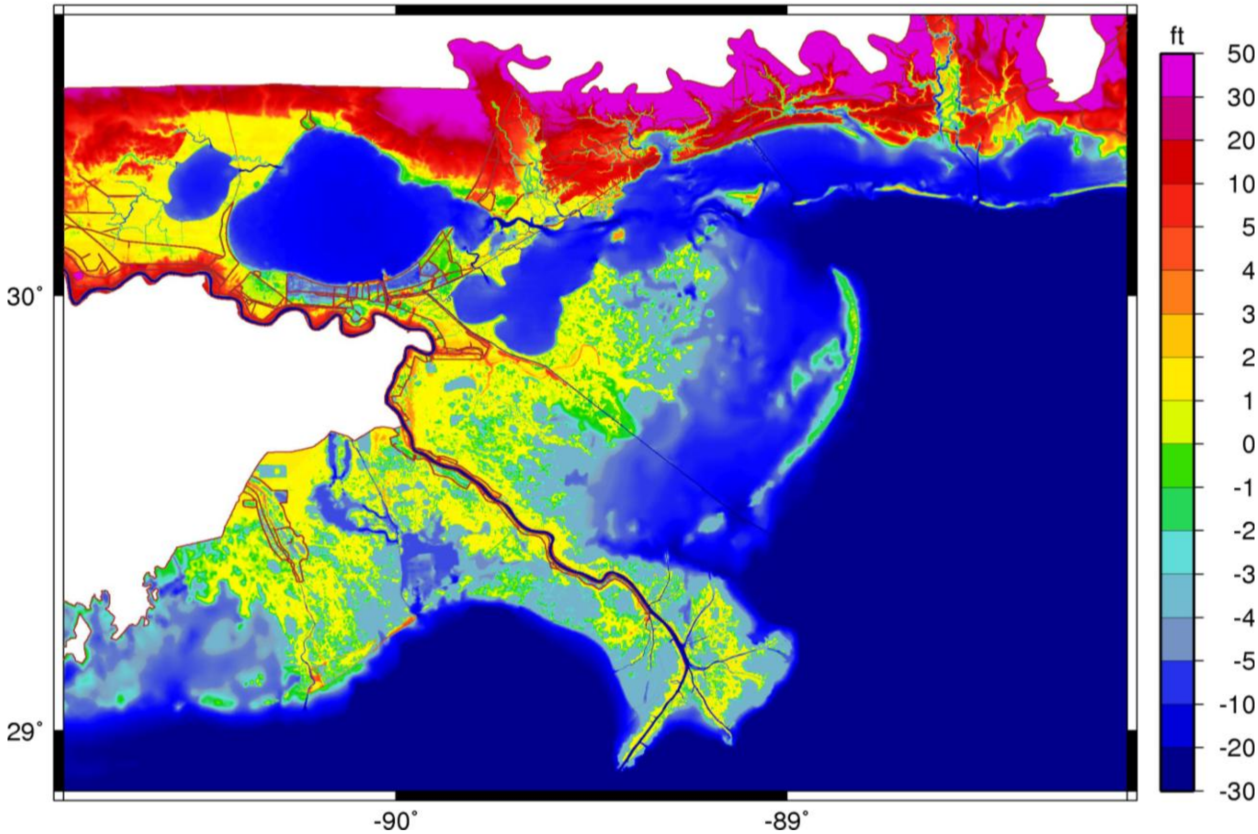

Figure 30a: ADCIRC SL16-DOJ-SB-B bathy and topo (ft), relative to NAVD88 (2004.65), for Southeastern LA.

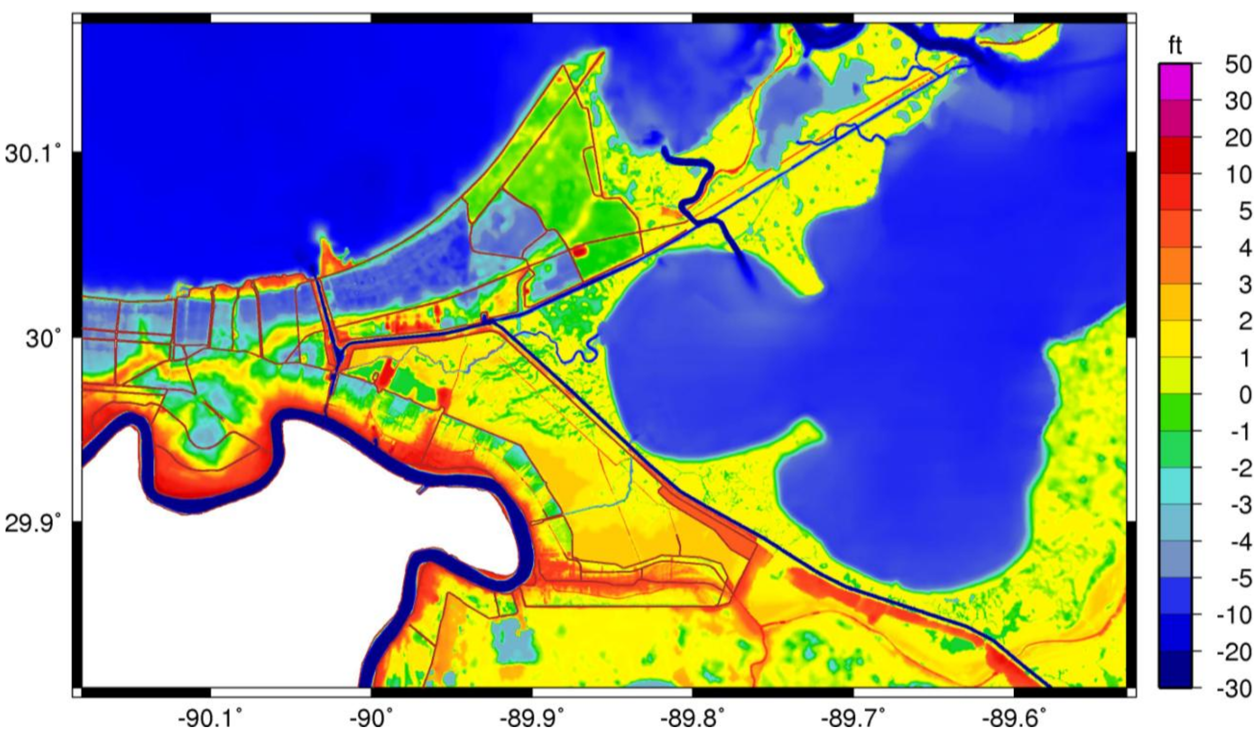

Figure 30b: ADCIRC SL16-DOJ-SB-B bathy and topo (ft), relative to NAVD88 (2004.65), for the Study Area.

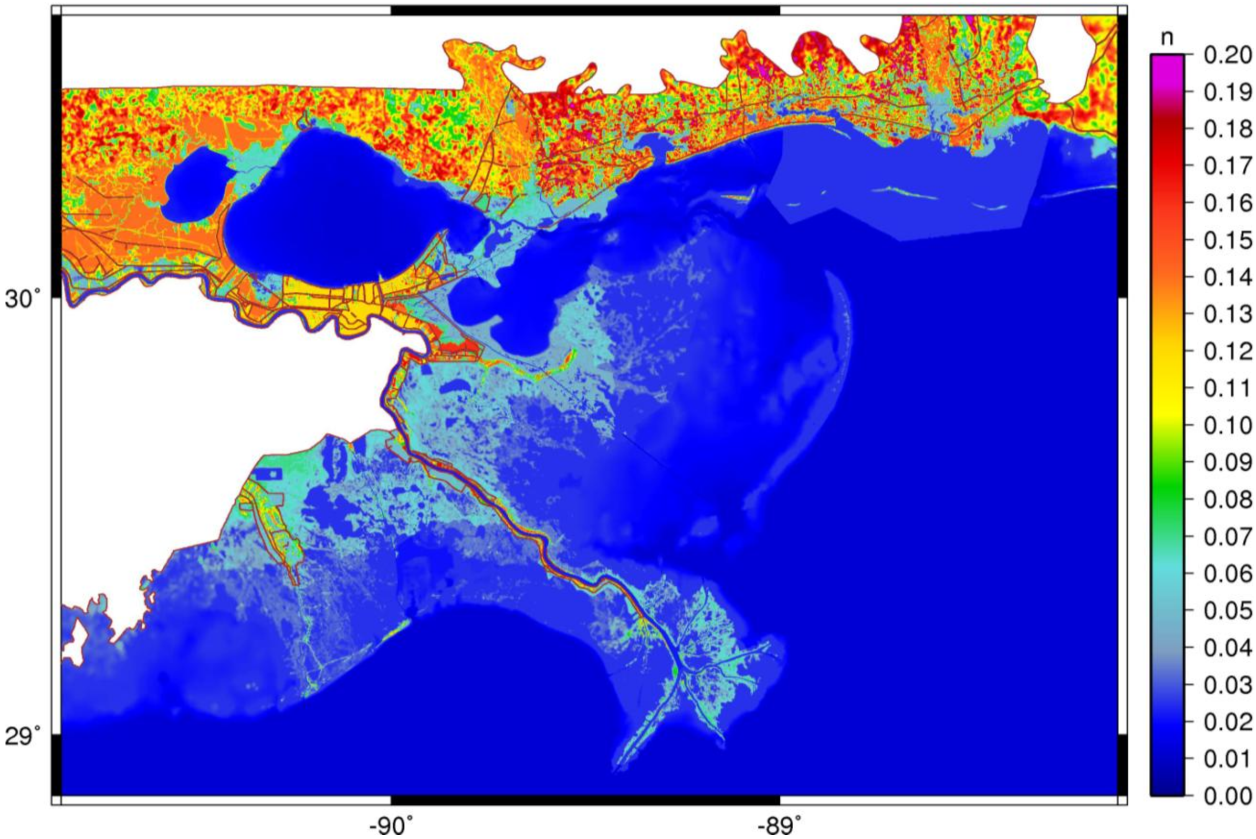

Figure 31a: ADCIRC SL16-DOJ-SB-B Manning *n* in Southeastern Louisiana.

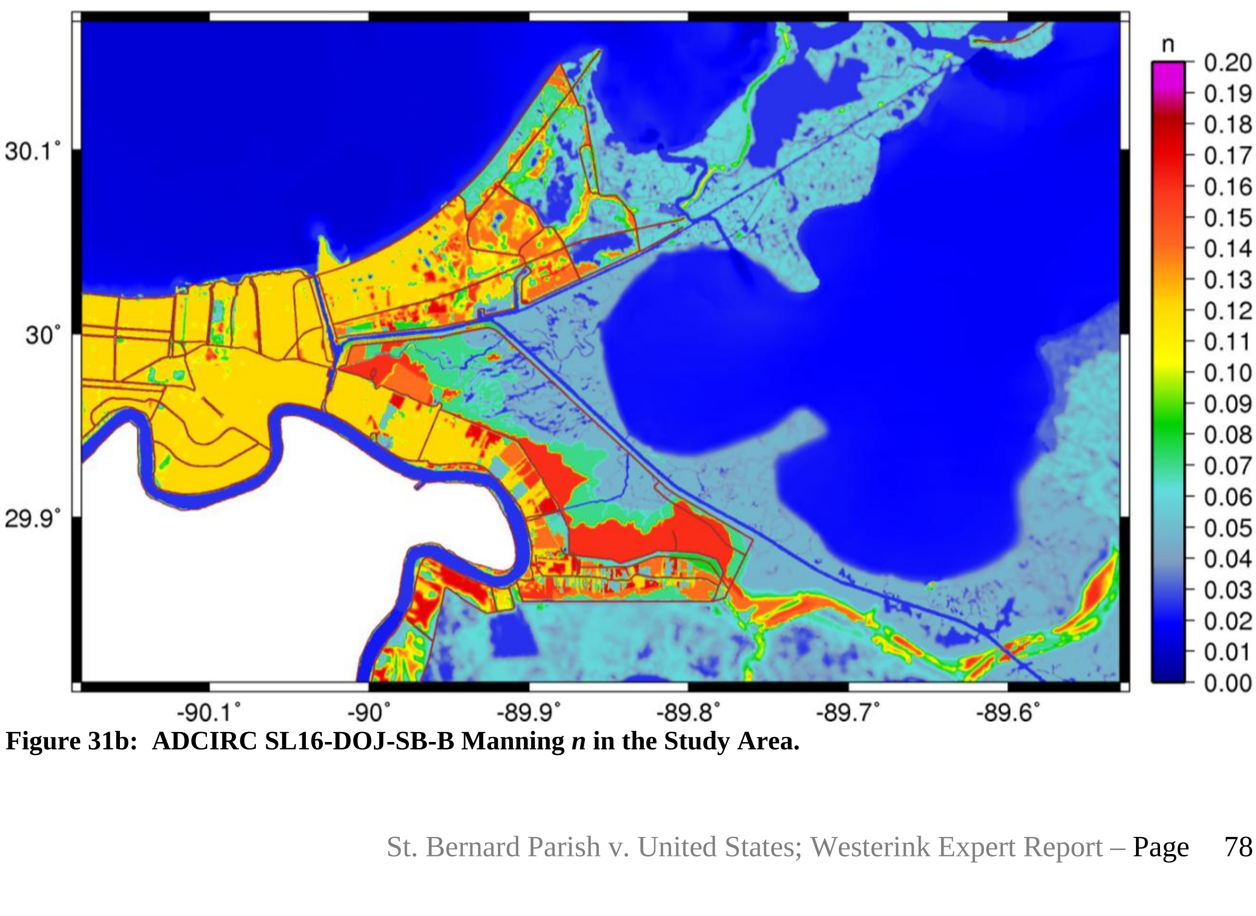

Figure 31b: ADCIRC SL16-DOJ-SB-B Manning *n* in the Study Area.

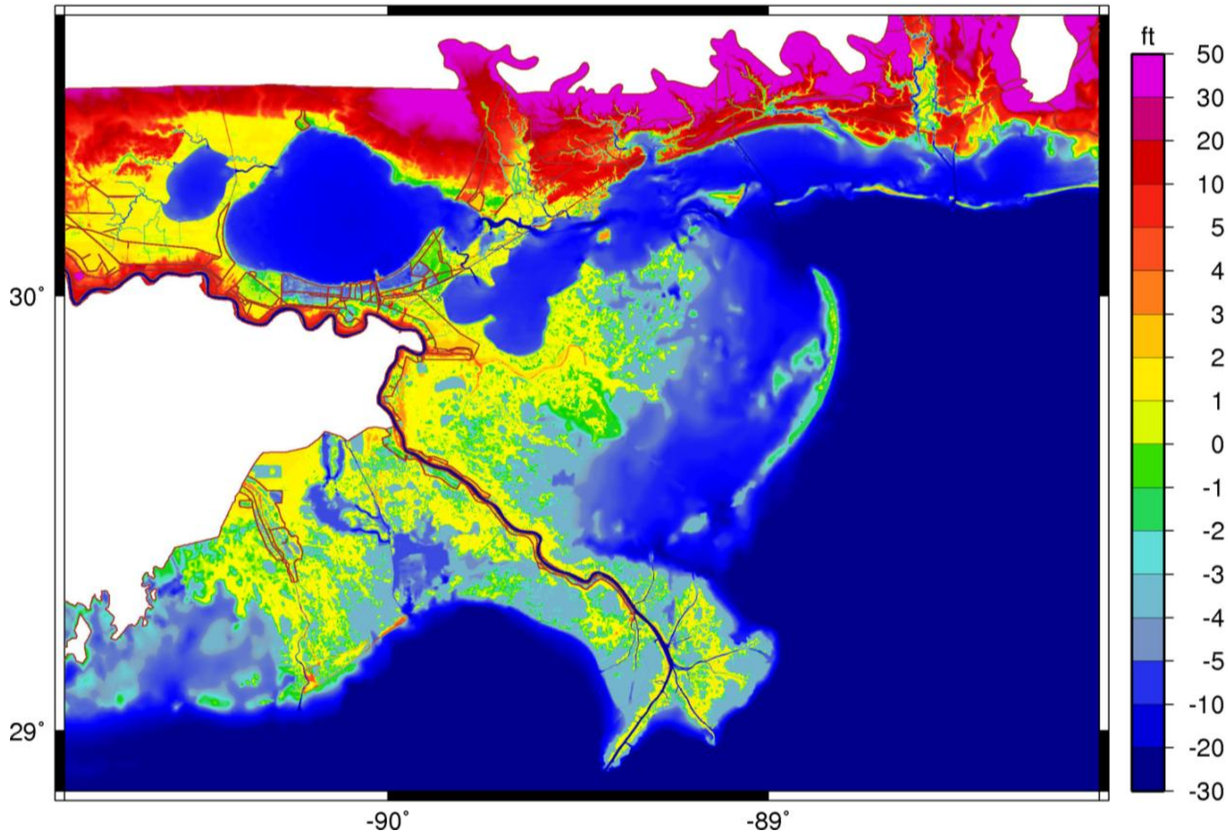

Figure 32a: ADCIRC SL16-DOJ-SB-C bathy and topo (ft), relative to NAVD88 (2004.65), for Southeastern Louisiana.

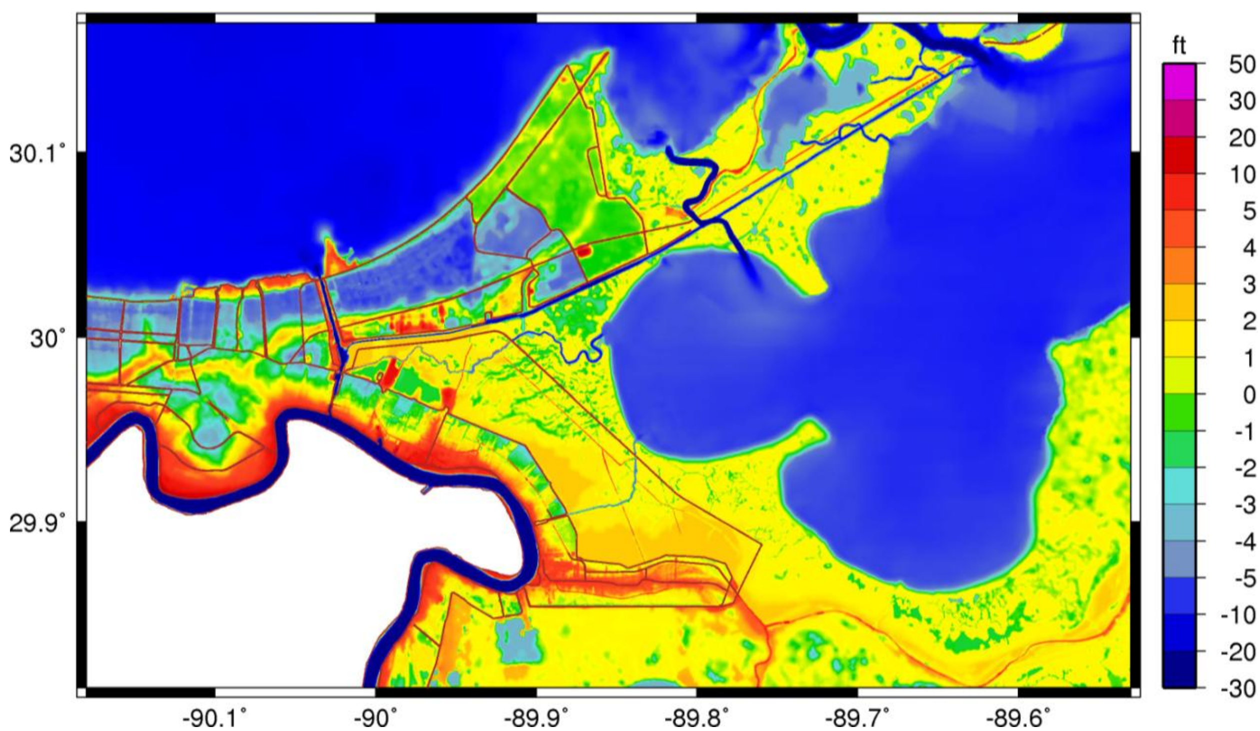

Figure 32b: ADCIRC SL16-DOJ-SB-C bathy and topo (ft), relative to NAVD88 (2004.65), for the Study Area.

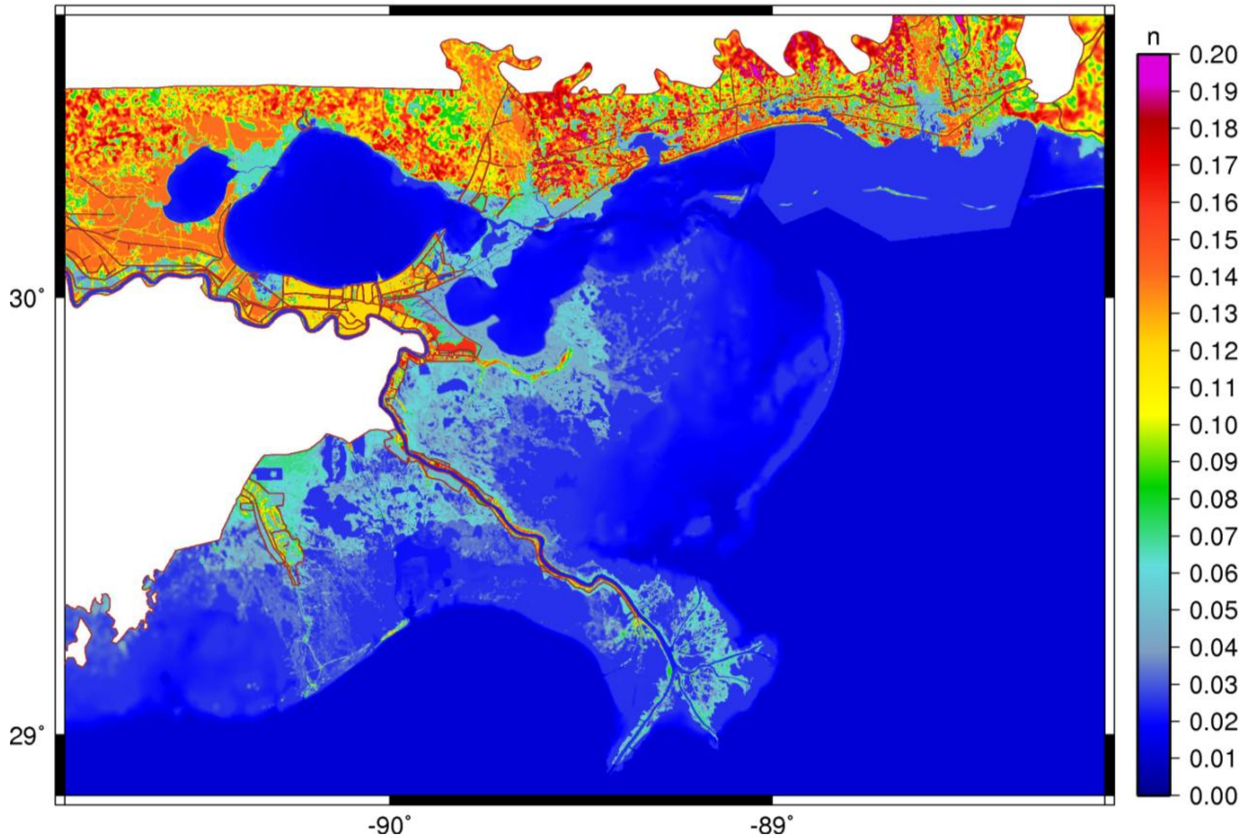

Figure 33a: ADCIRC SL16-DOJ-SB-C Manning *n* in Southeastern Louisiana.

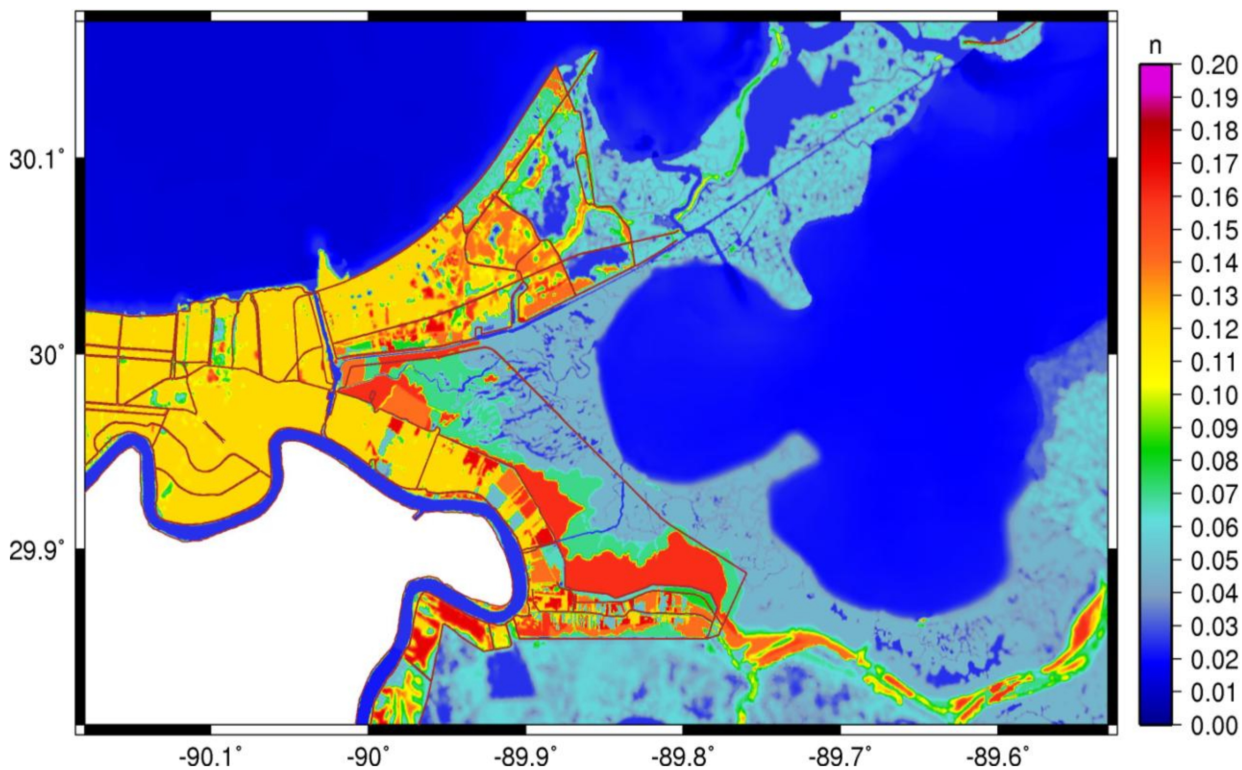

Figure 33b: ADCIRC SL16-DOJ-SB-C Manning *n* in the Study Area.

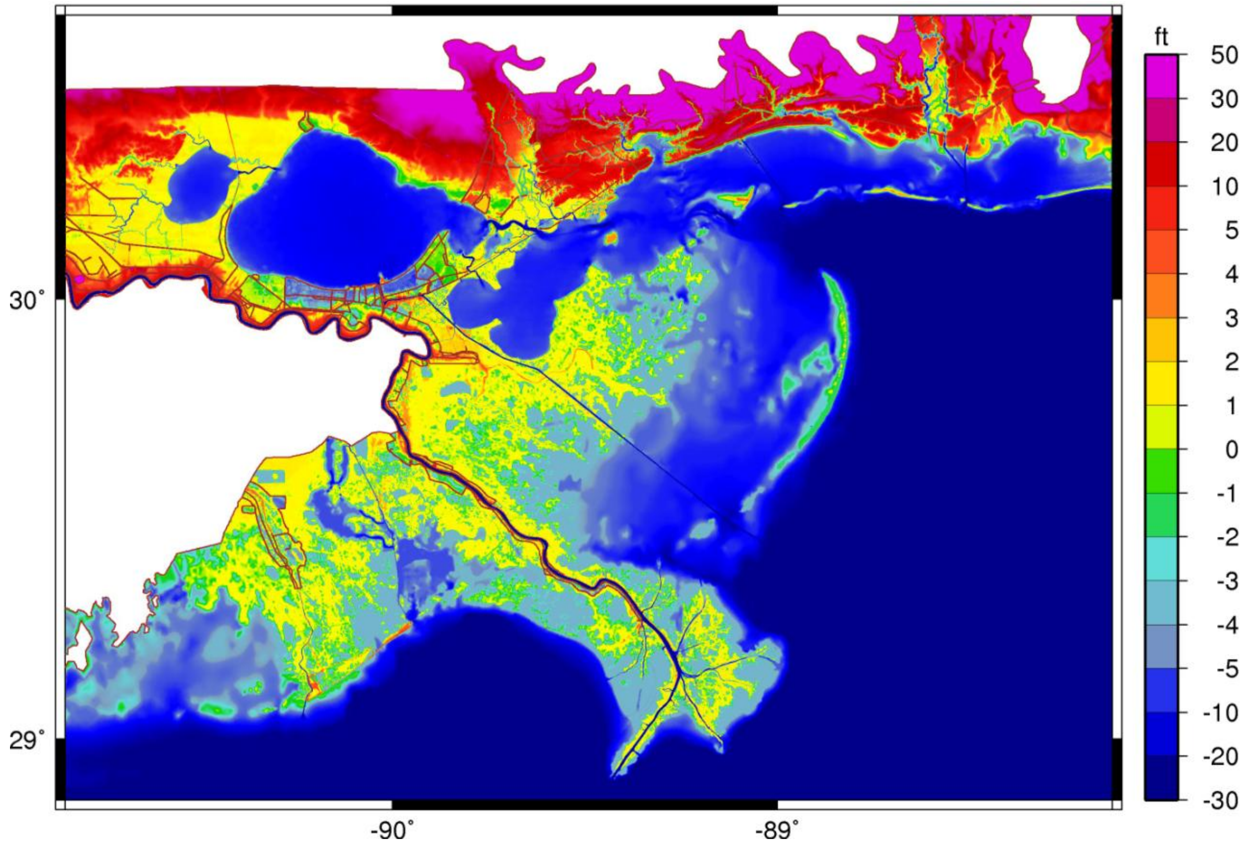

Figure 34a: ADCIRC SL16-DOJ-SB-D bathy and topo (ft), relative to NAVD88 (2004.65), for Southeastern LA.

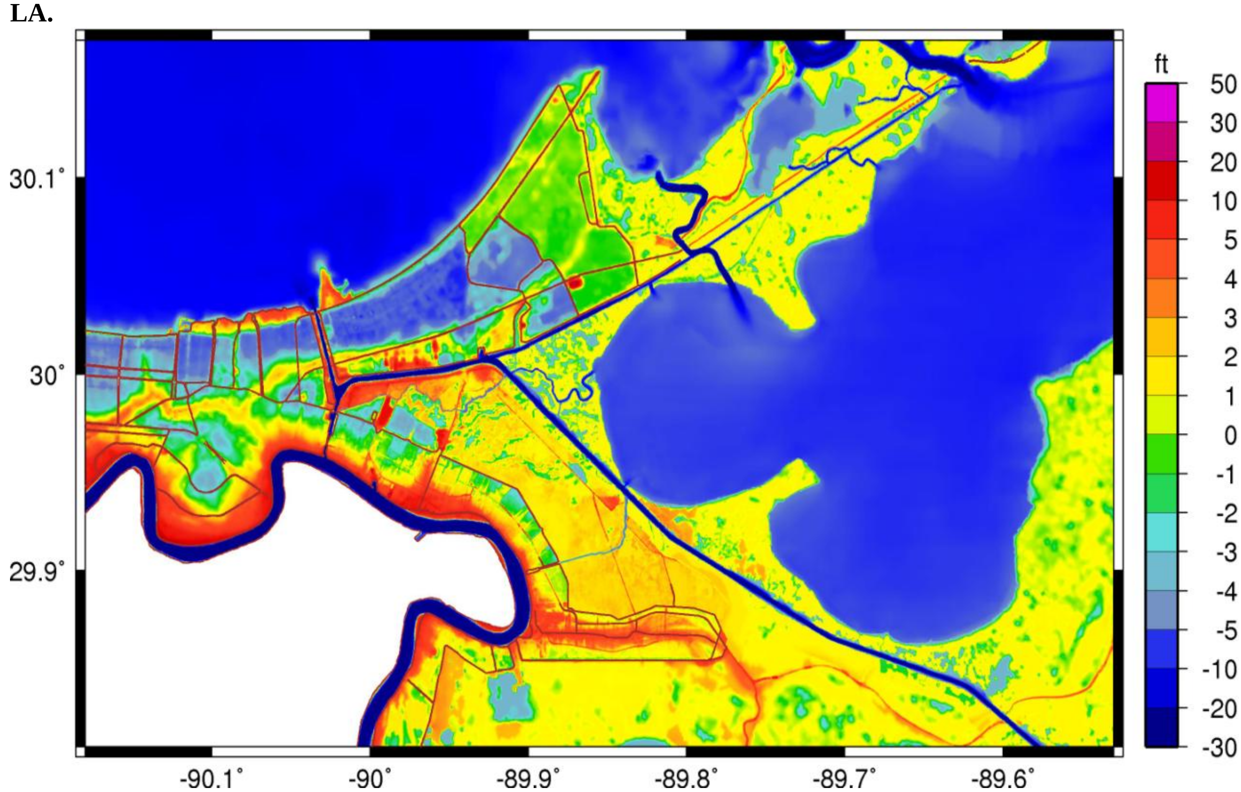

Figure 34b: ADCIRC SL16-DOJ-SB-D bathy and topo (ft), relative to NAVD88 (2004.65), for the Study Area.

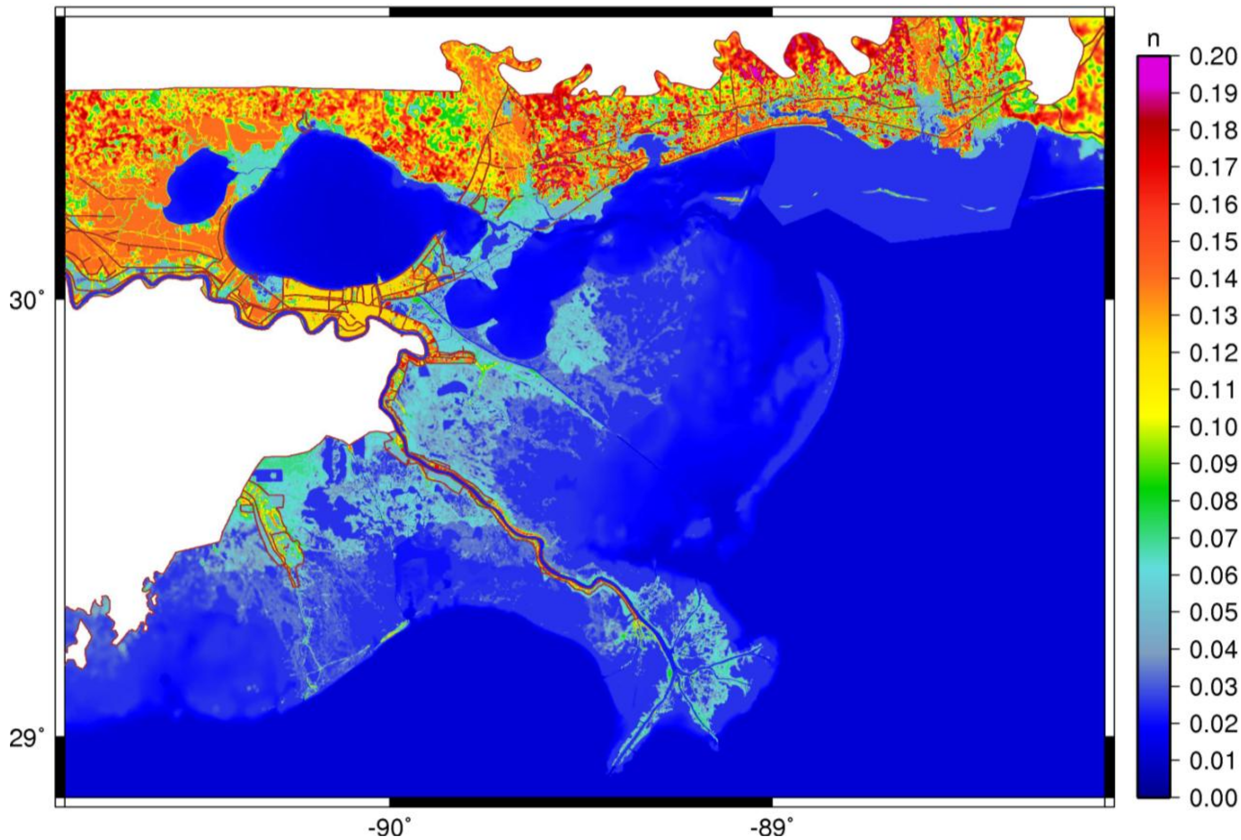

Figure 35a: ADCIRC SL16-DOJ-SB-D Manning *n* in Southeastern Louisiana.

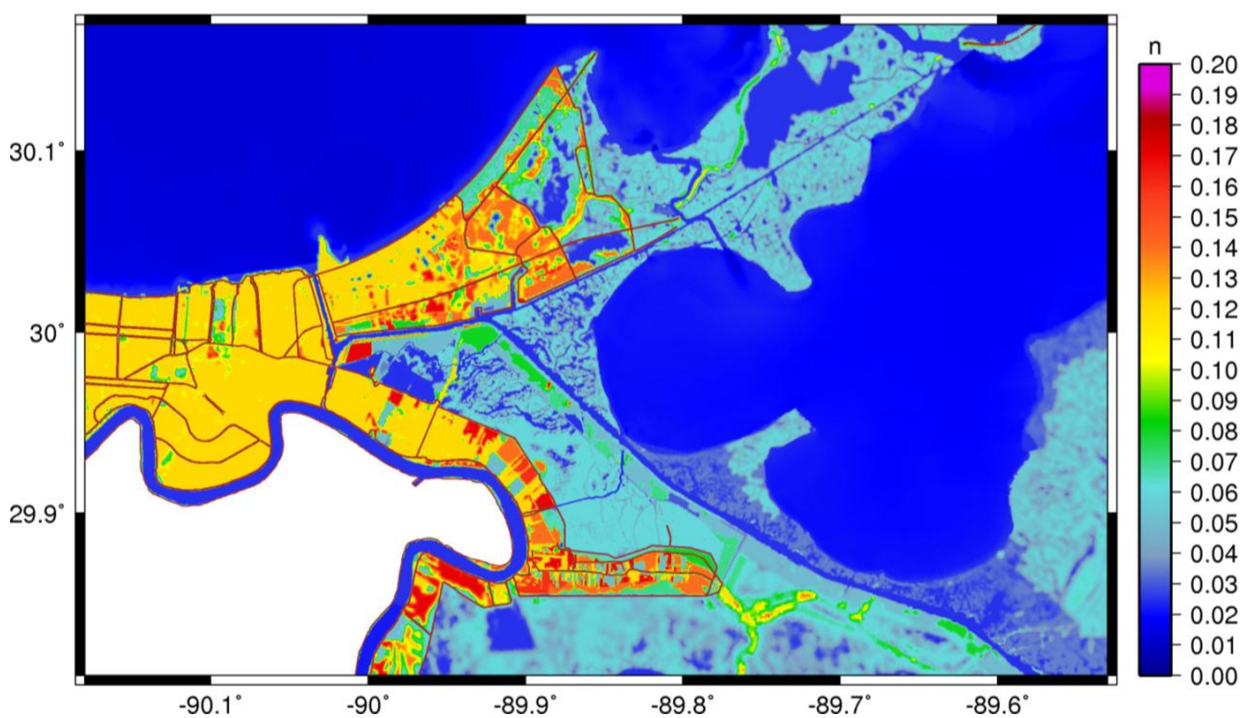

Figure 35b: ADCIRC SL16-DOJ-SB-D Manning *n* in the Study Area.

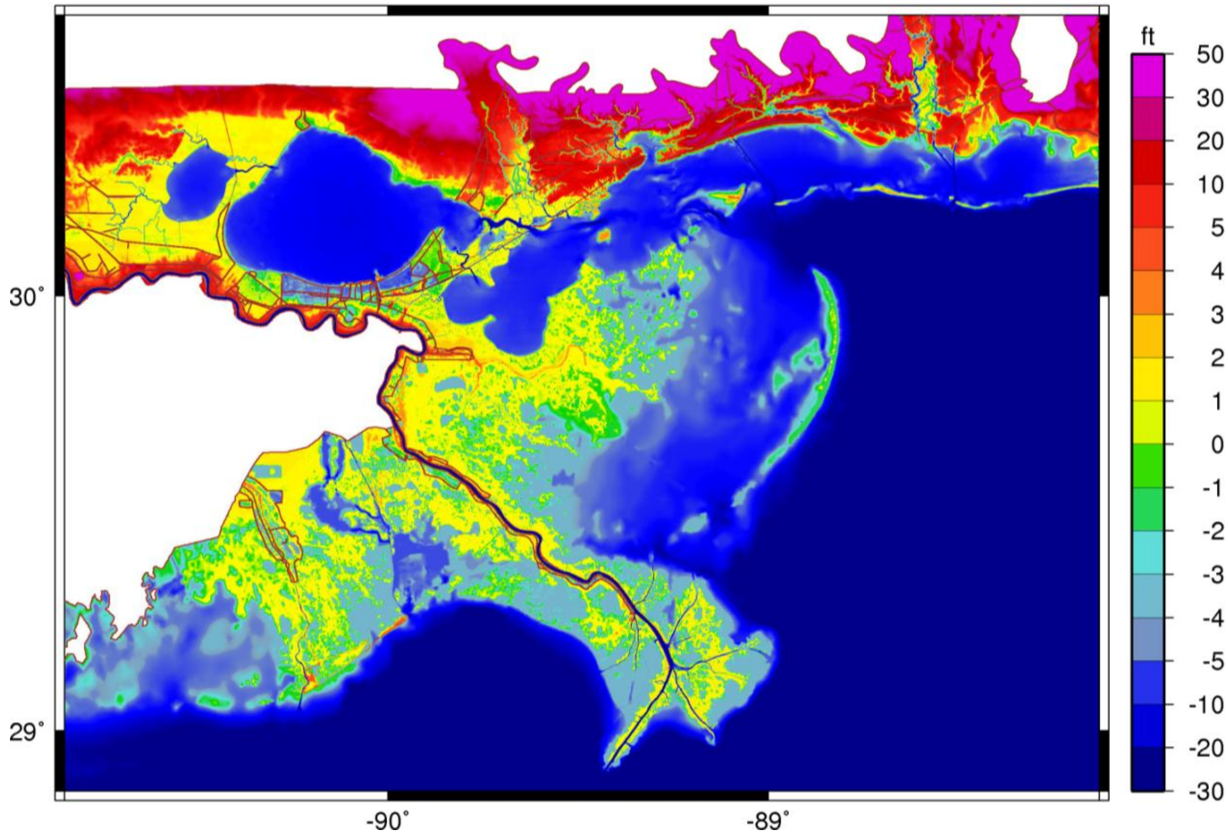

Figure 36a: ADCIRC SL16-DOJ-SB-E bathy and topo (ft), relative to NAVD88 (2004.65), for Southeastern LA.

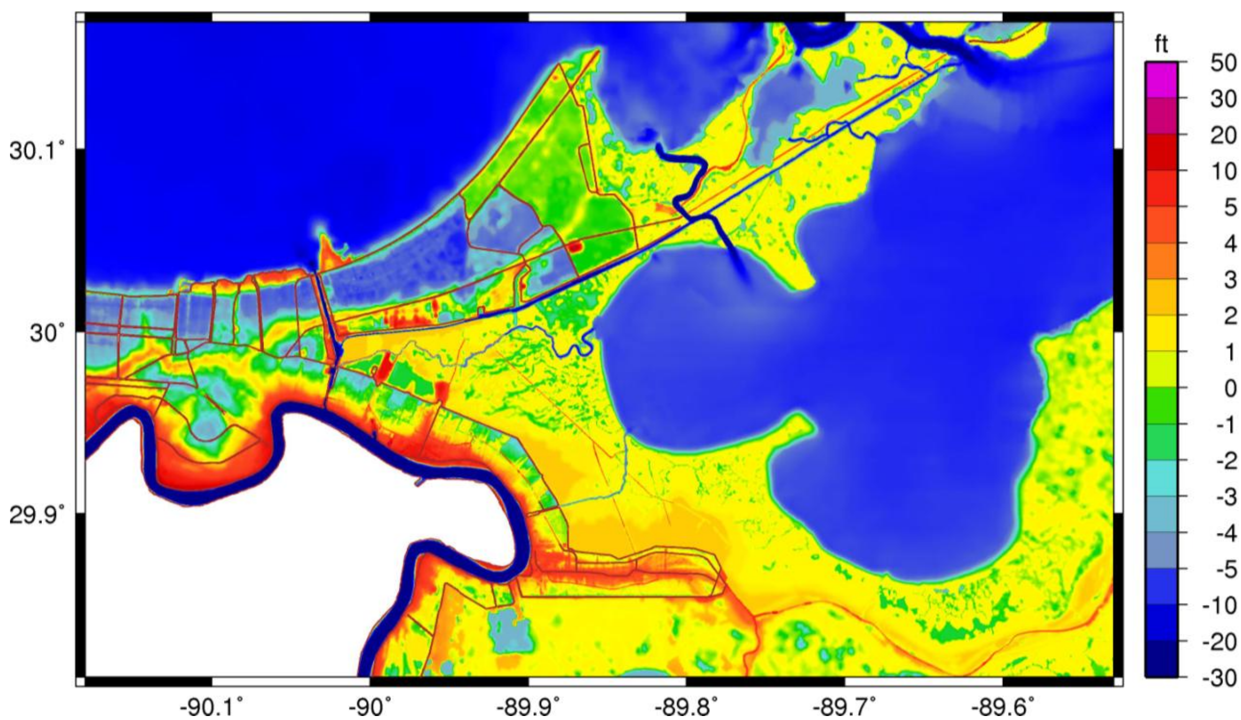

Figure 36b: ADCIRC SL16-DOJ-SB-E bathy and topo (ft), relative to NAVD88 (2004.65), for the Study Area.

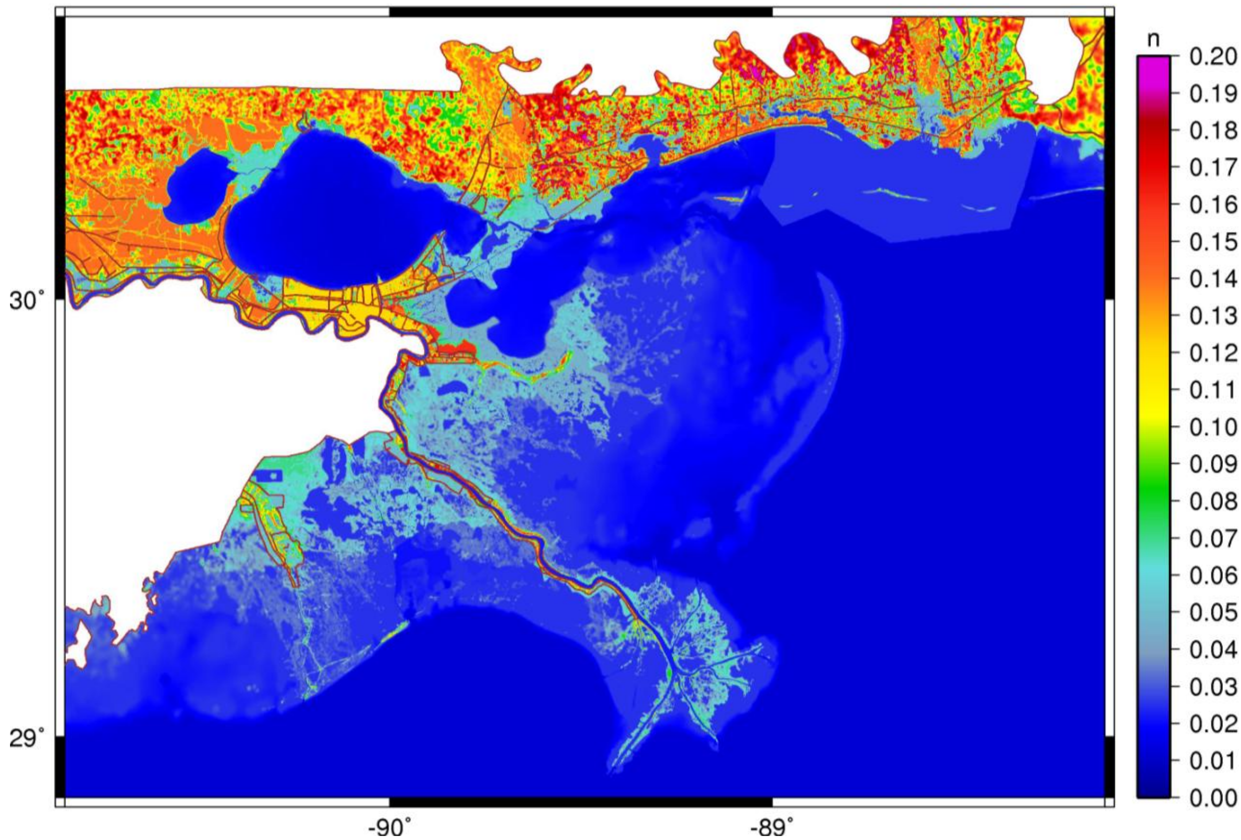

Figure 37a: ADCIRC SL16-DOJ-SB-E Manning *n* in Southeastern Louisiana.

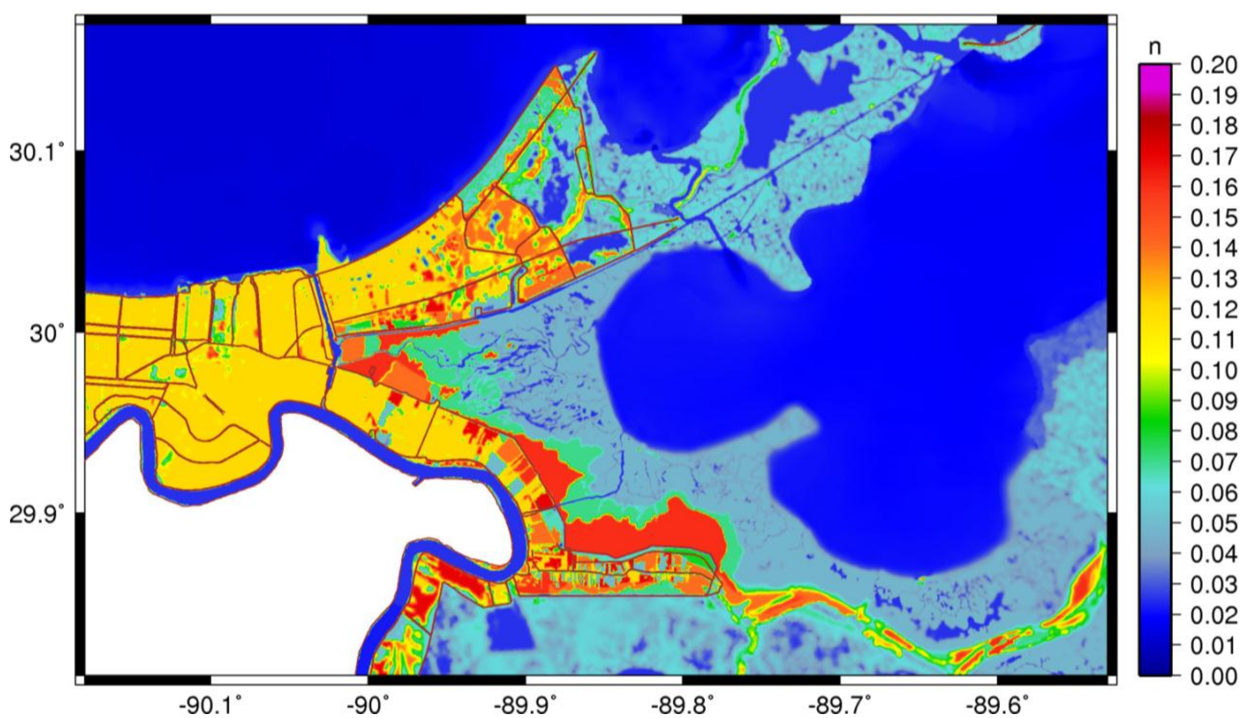

Figure 37b: ADCIRC SL16-DOJ-SB-E Manning *n* in the Study Area.

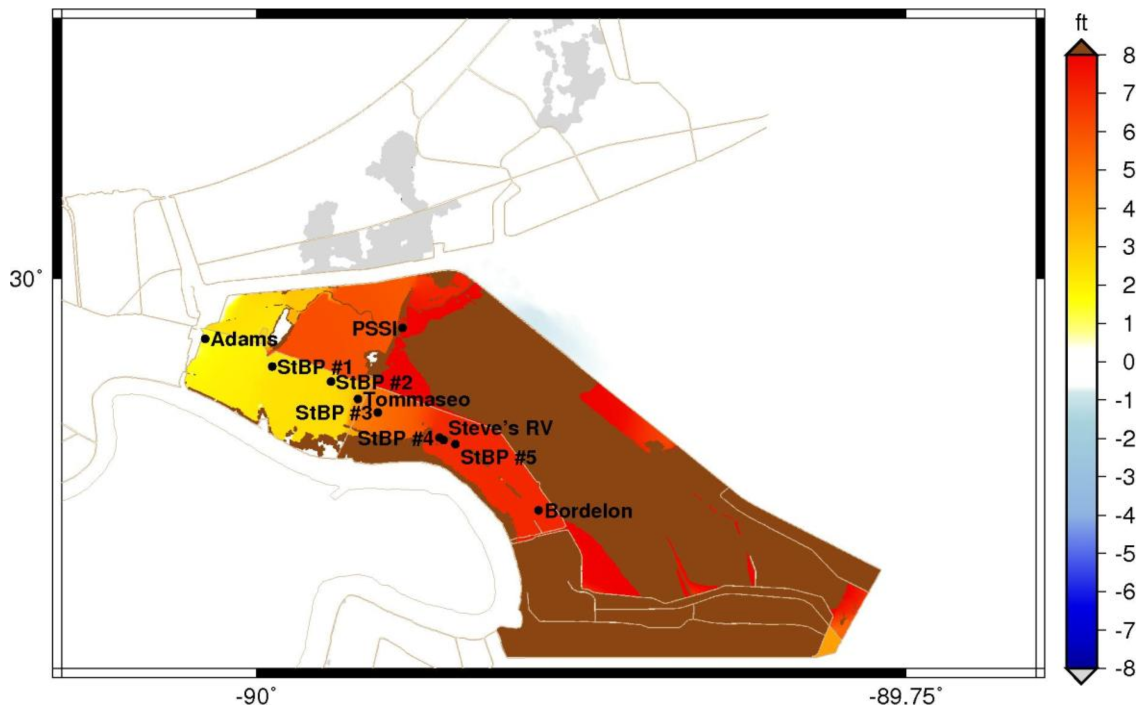

Figure 38a: Difference in maximum Hurricane Katrina event water surface elevations (ft) in the Study Area between Models A1 and A2. Positive values indicate where A1 is higher than A2.

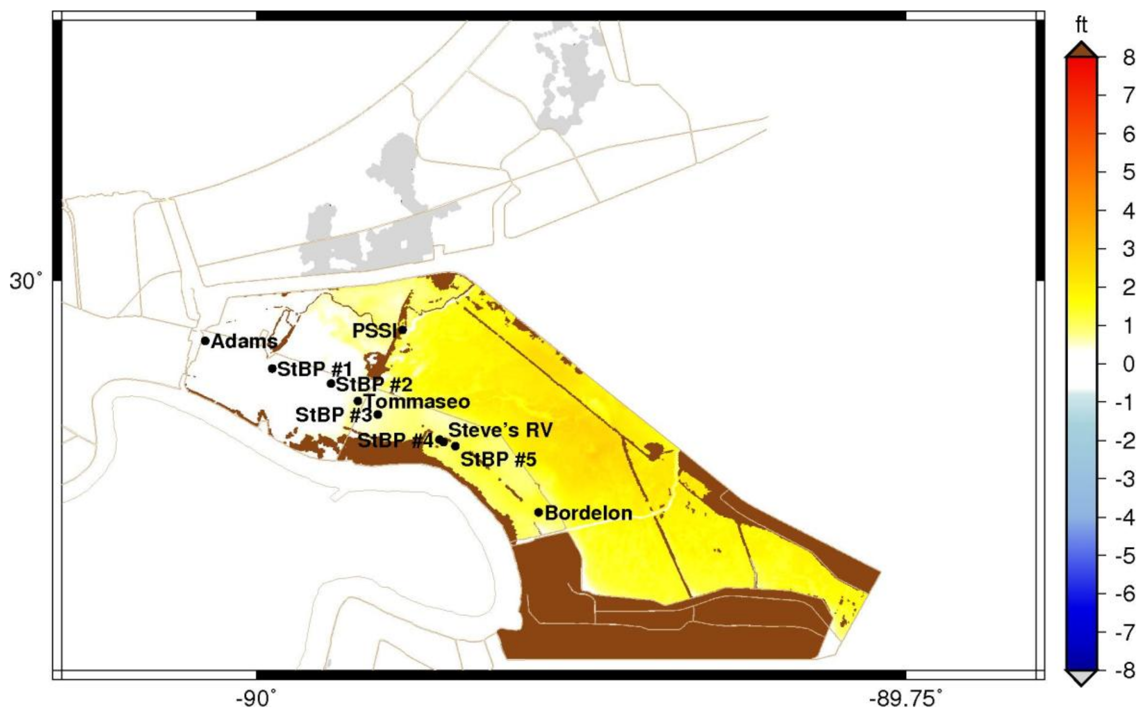

Figure 38b: Difference in maximum Hurricane Katrina event waves (ft) in the Study Area between Models A1 and A2. Positive values indicate where A1 is higher than A2.

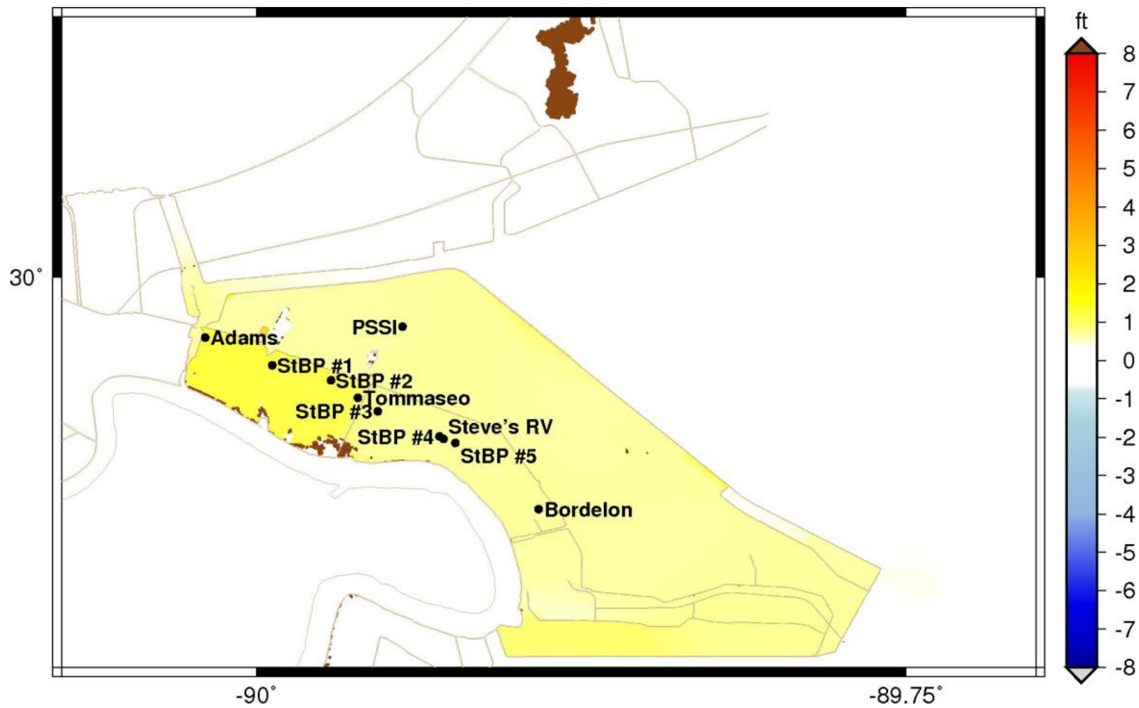

Figure 39a: Difference in maximum Hurricane Katrina event water surface elevations (ft) in the Study Area between Models A1 and B1. Positive values indicate where A1 is higher than B1.

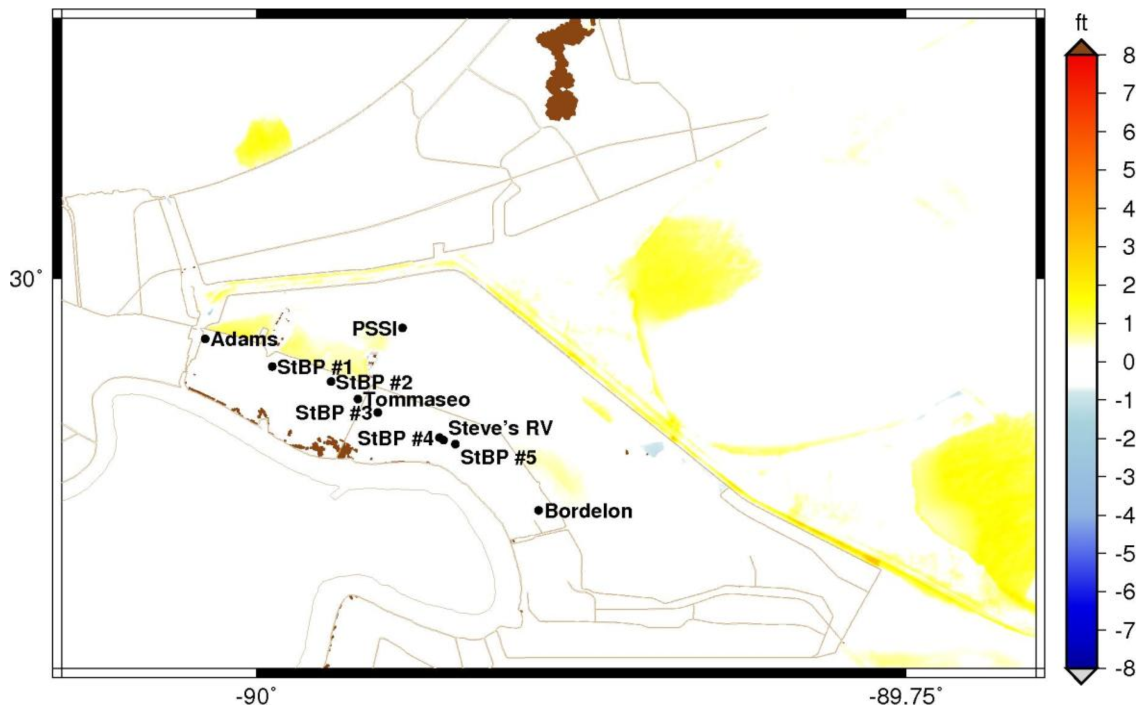

Figure 39b: Difference in maximum Hurricane Katrina event waves (ft) in the Study Area between Models A1 and B1. Positive values indicate where A1 is higher than B1.

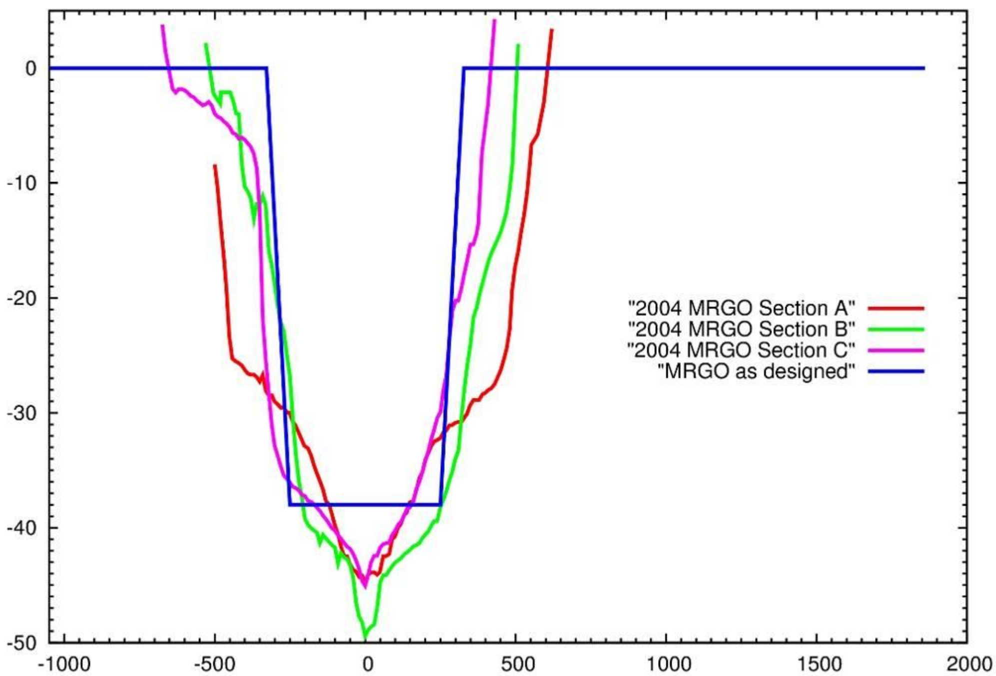

Figure 40: Comparison of the conveyance of three USACE surveyed cross sections of MRGO Reach 1 in 2004 with the MRGO as designed.

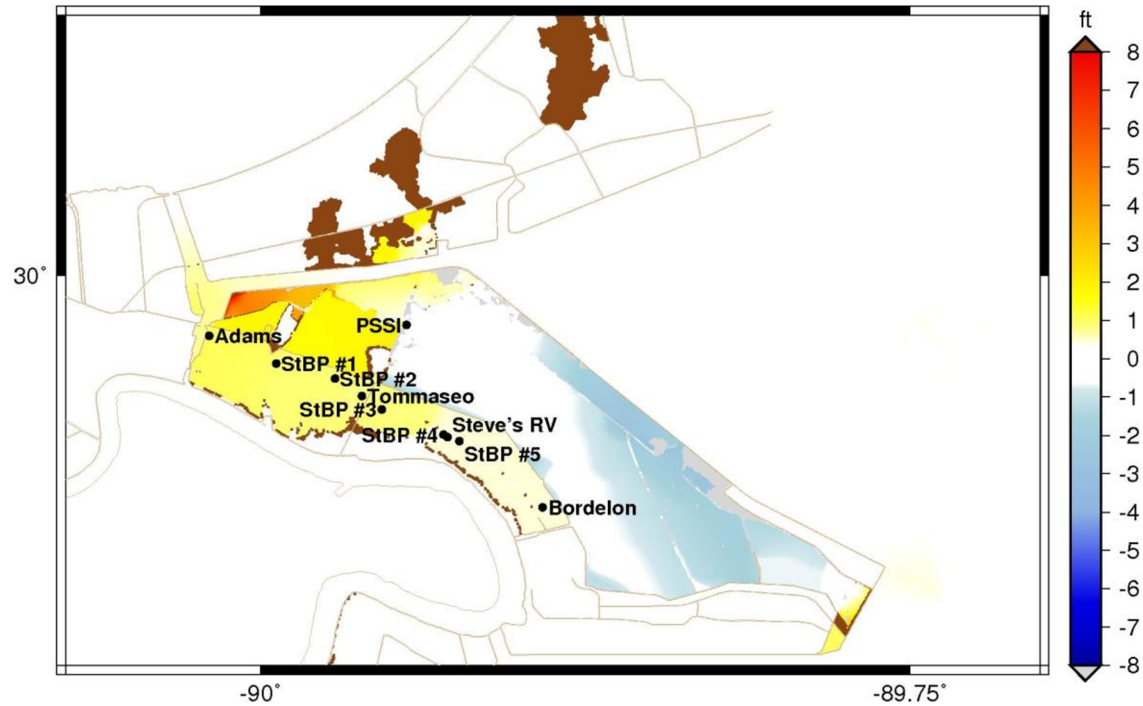

Figure 41a: Difference in maximum Hurricane Katrina event water surface elevations (ft) in the Study Area between Models A2 and B2. Positive values indicate where A2 is higher than B2.

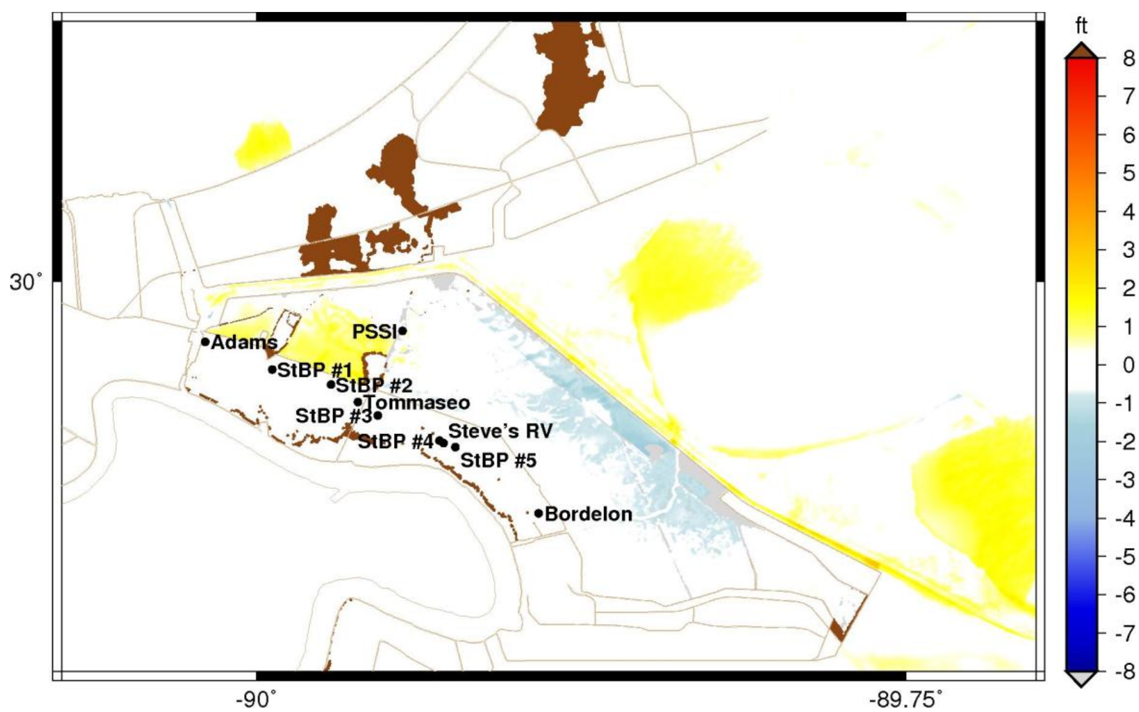

Figure 41b: Difference in maximum Hurricane Katrina event waves (ft) in the Study Area between Models A2 and B2. Positive values indicate where A2 is higher than B2.

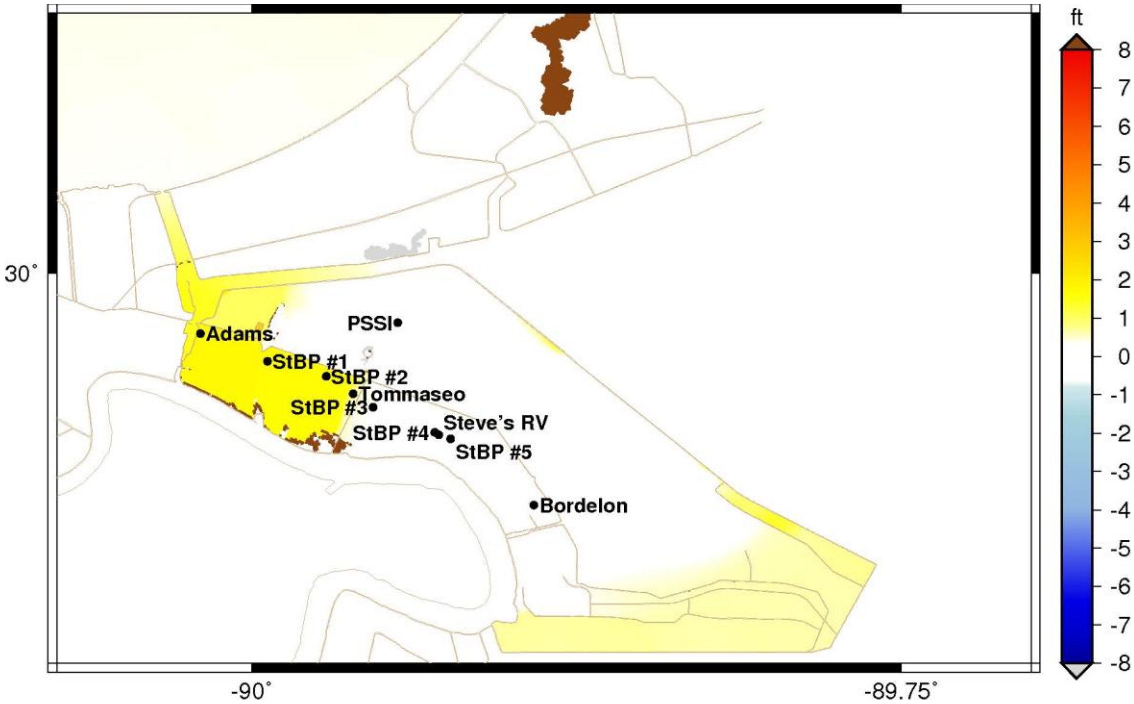

Figure 42a: Difference in maximum Hurricane Katrina event water surface elevations (ft) in the Study Area between Models A1 and C. Positive values indicate where A1 is higher than C.

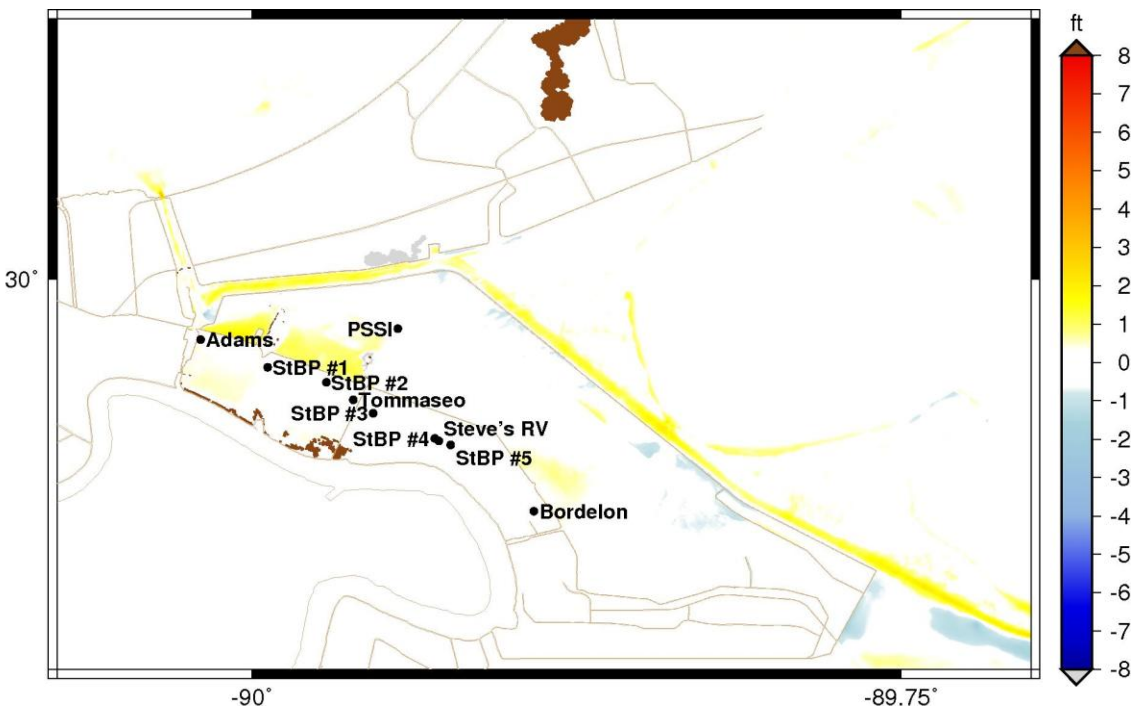

Figure 42b: Difference in maximum Hurricane Katrina event waves (ft) in the Study Area between Models A1 and C. Positive values indicate where A1 is higher than C.

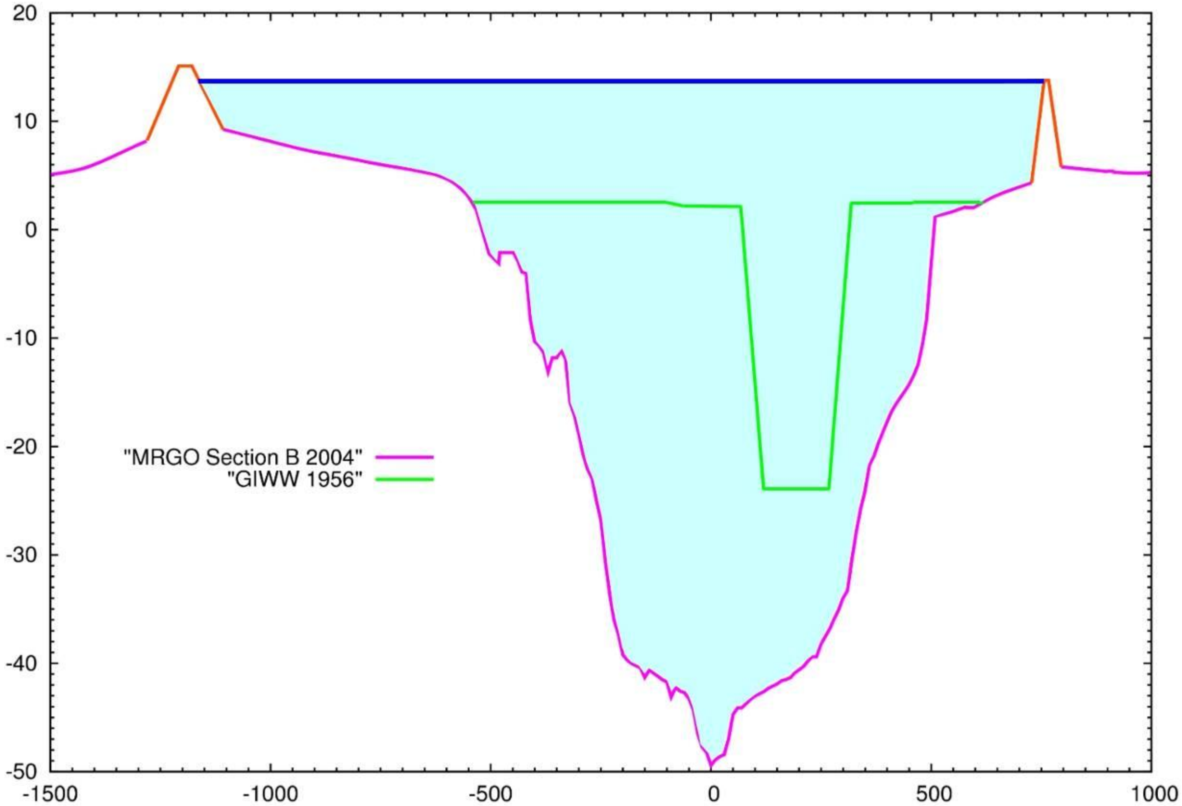

Figure 43: Comparison of a USACE surveyed bathymetric cross section of MRGO Reach 1 (purple line) and the GIWW as it was maintained in 1958 (green line). Red lines are the adjacent levees. Water levels are to 14 ft NAVD88 (2004.65).

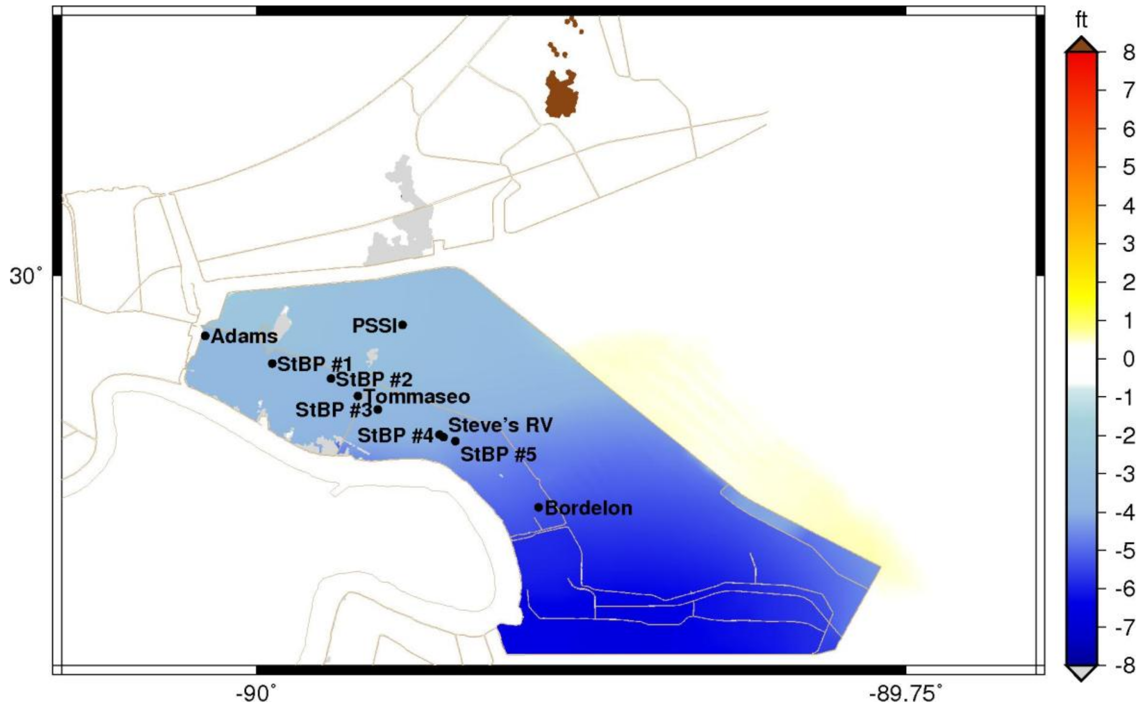

Figure 44a: Difference in maximum Hurricane Katrina event water surface elevations (ft) in the Study Area between Models A1 and D.   Positive values indicate where A1 is higher than D.

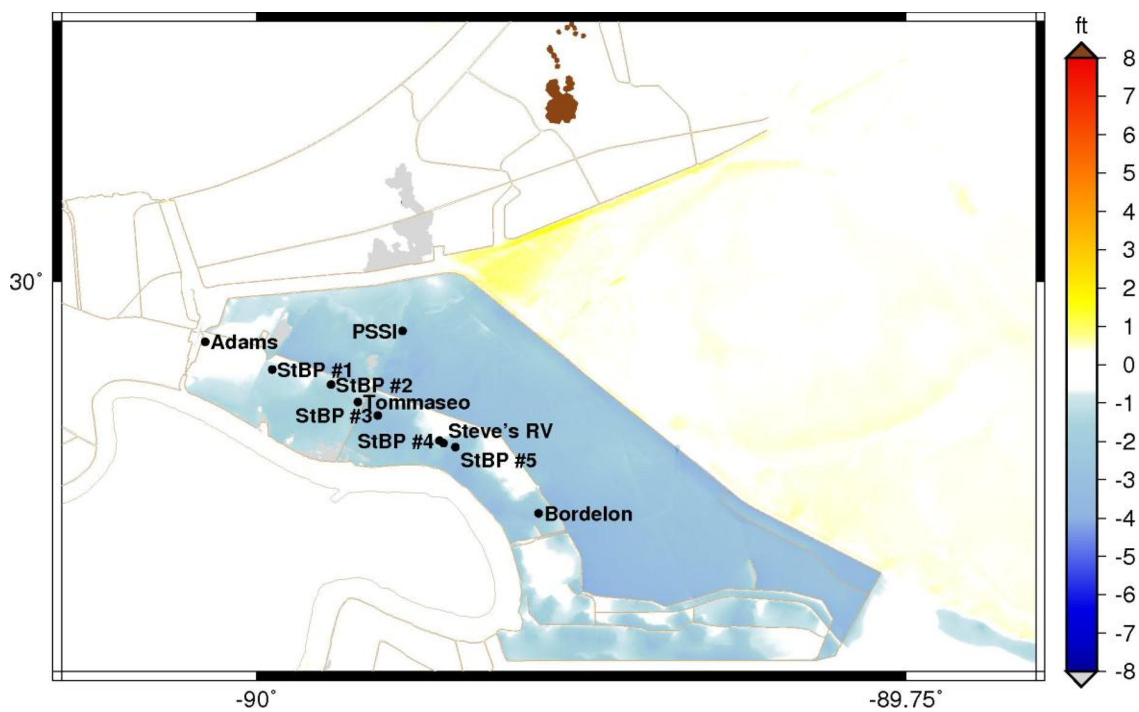

Figure 44b: Difference in maximum Hurricane Katrina event waves (ft) in the Study Area between Models A1 and D. Positive values indicate where A1 is higher than D.

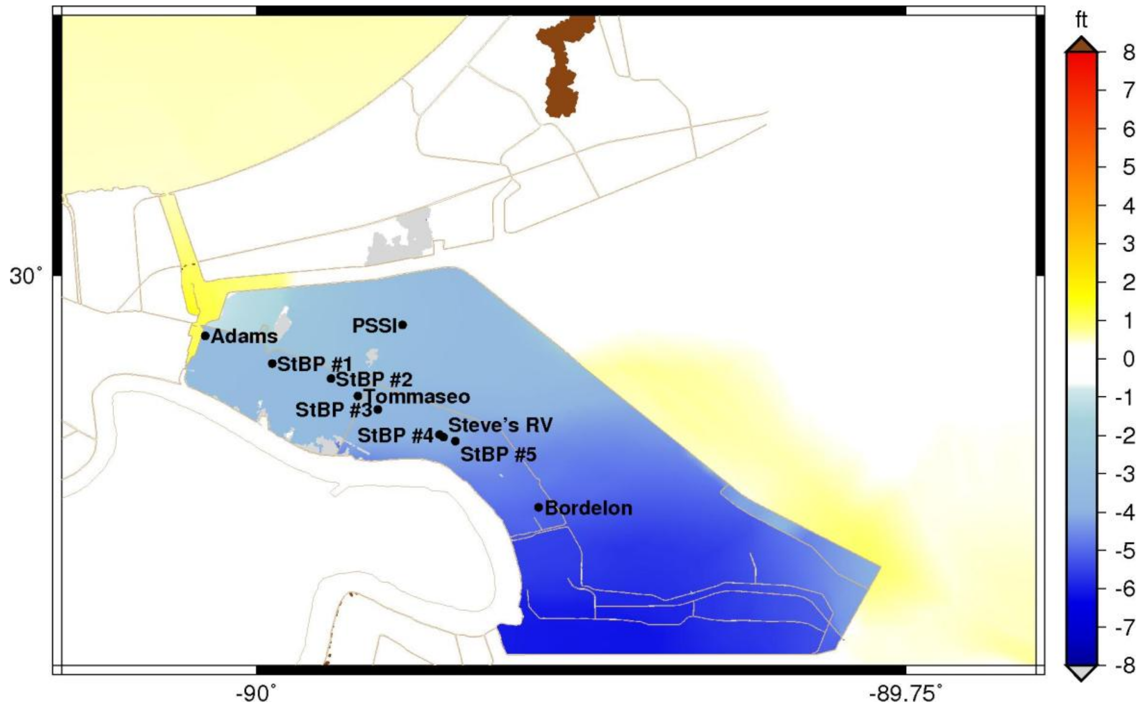

Figure 45a: Difference in maximum Hurricane Katrina event water surface elevations (ft) in the Study Area between Models A1 and E. Positive values indicate where A1 is higher than E.

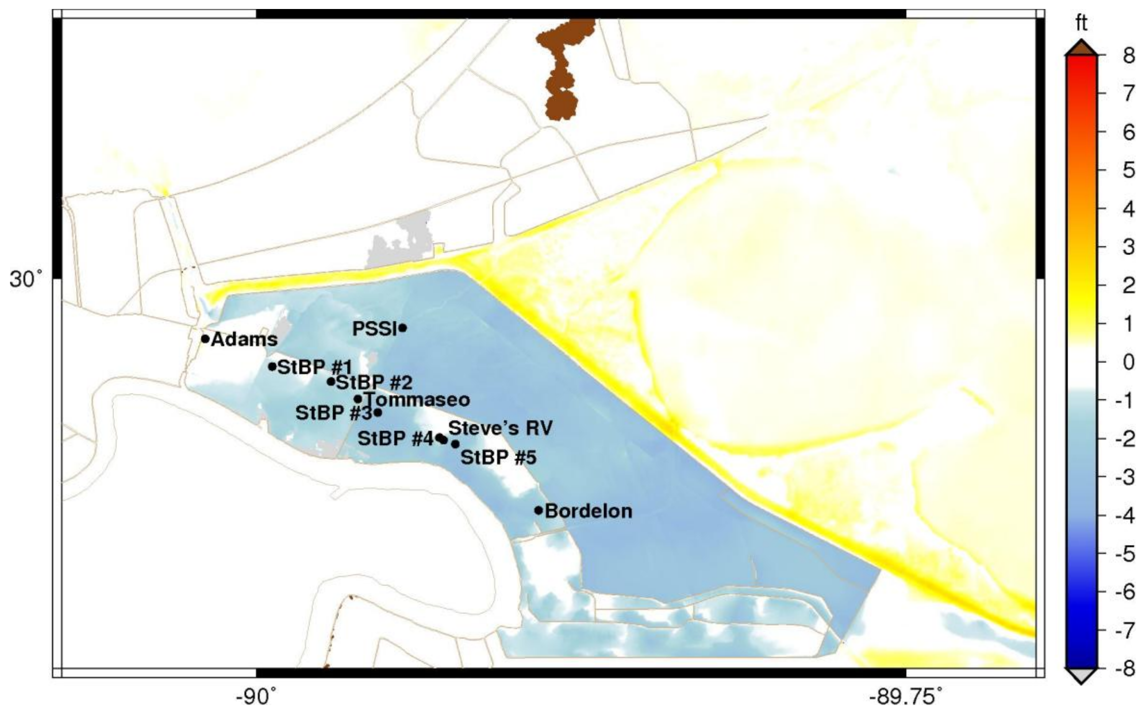

Figure 45b: Difference in maximum Hurricane Katrina event waves (ft) in the Study Area between Models A1 and E. Positive values indicate where A1 is higher than E.

Figure 46: Location of comparison hydrographs: the blue marks indicate locations exterior to the polder and are labeled e1 through e10. The yellow marks indicate the plaintiff property locations and are labeled as follows; 1) Adams, 2) StBP #1, 3) StBP #2, 4) Tommaseo, 5) StBP #3, 6) StBP #4, 7)Steve's RV, 8) StBP #5, 9) Bordelon, 10) PSSI, and 11) Florissant and are described in detail in Table 1.

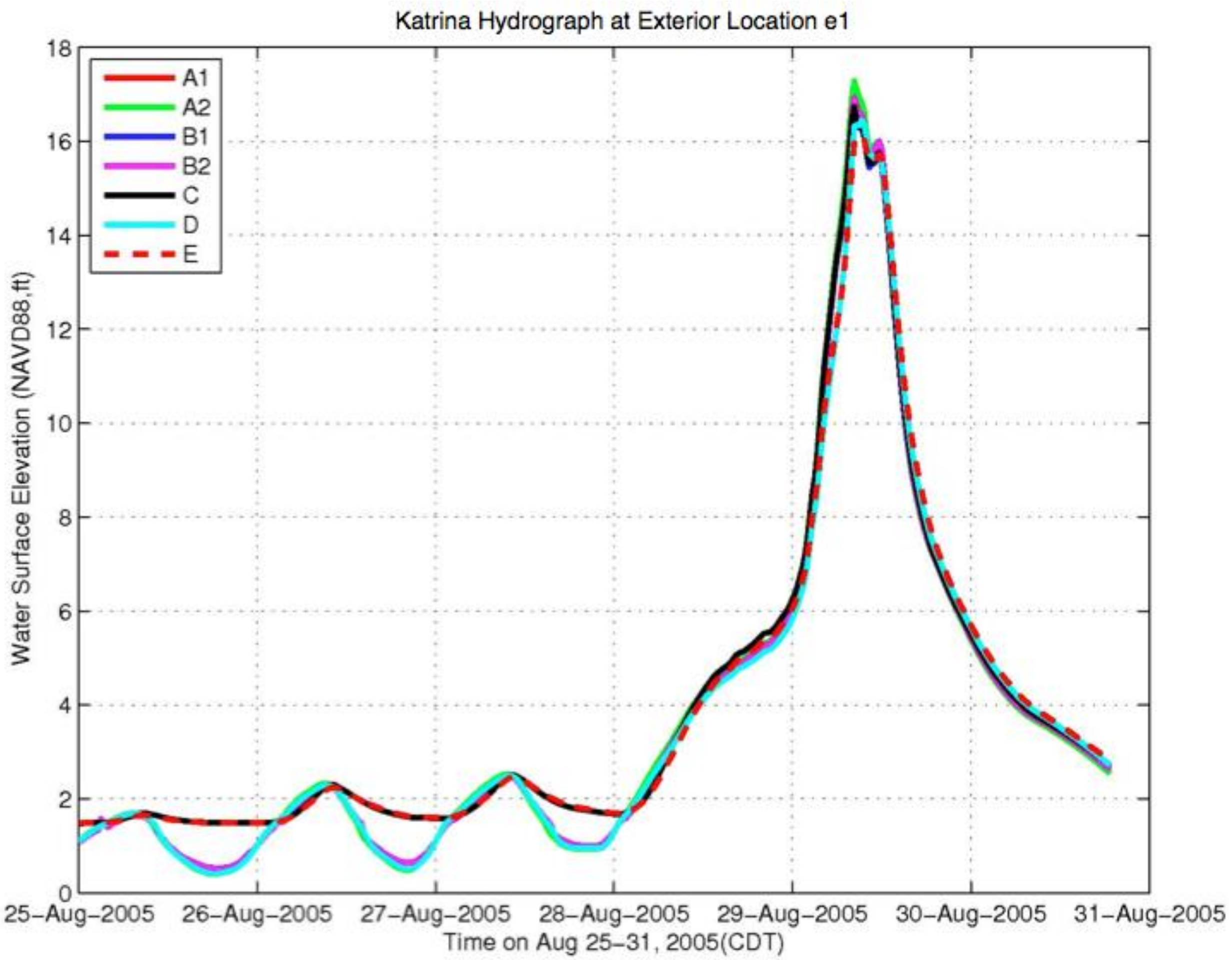

Figure 47a: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at exterior location e1 as shown in Figure 46.

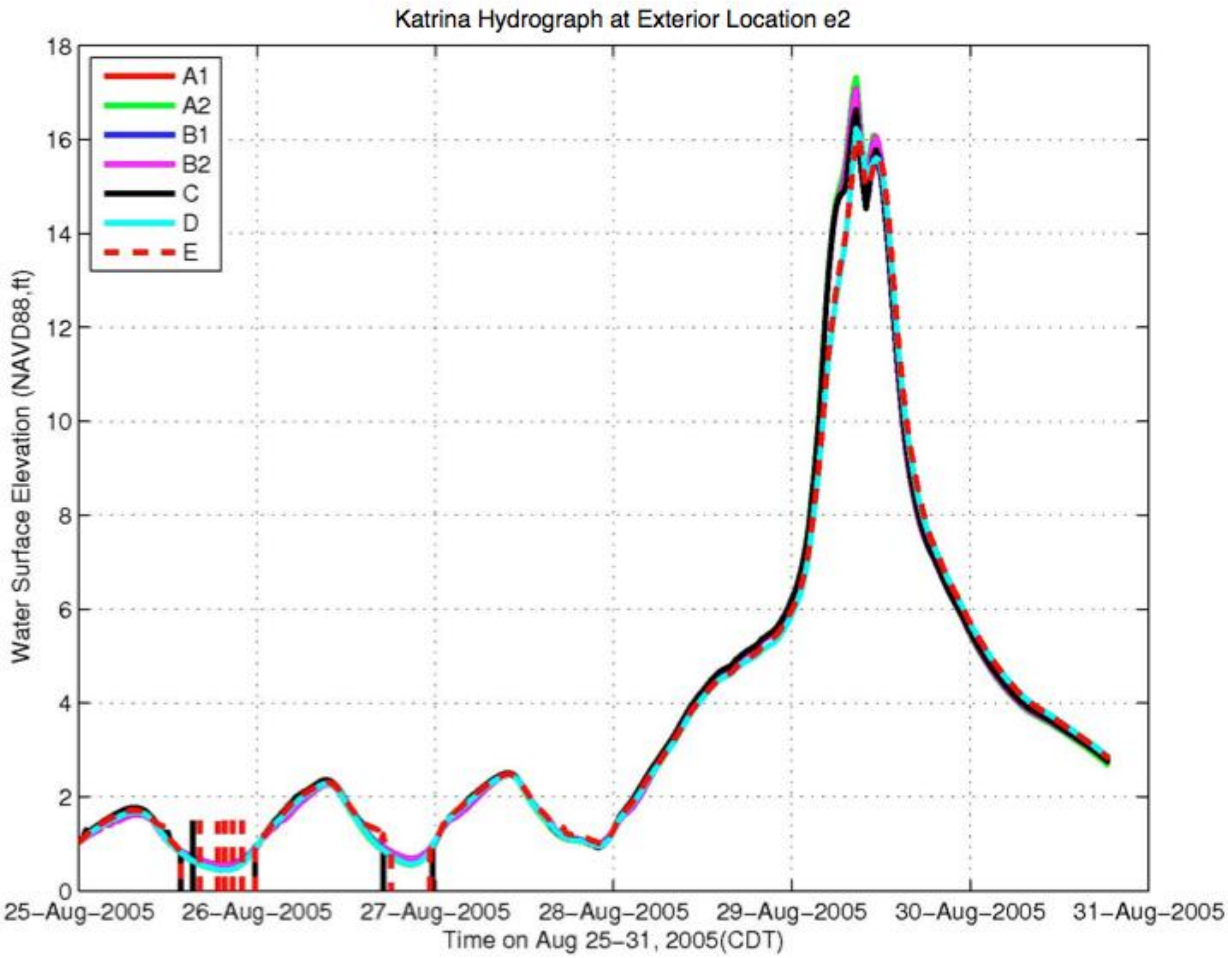

Figure 47b: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at the exterior location e2 as shown in Figure 46.

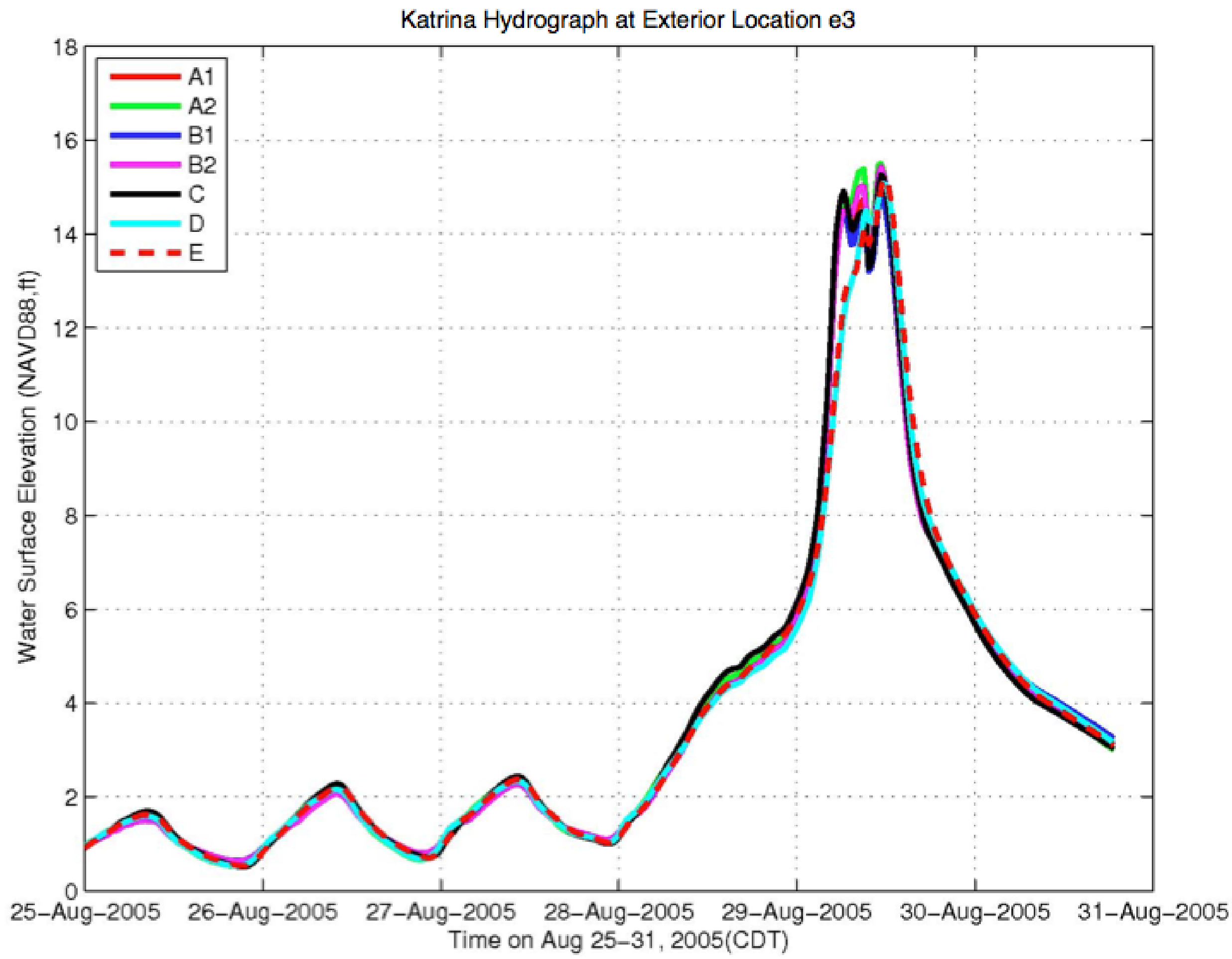

Figure 47c: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at exterior location e3 as shown in Figure 46.

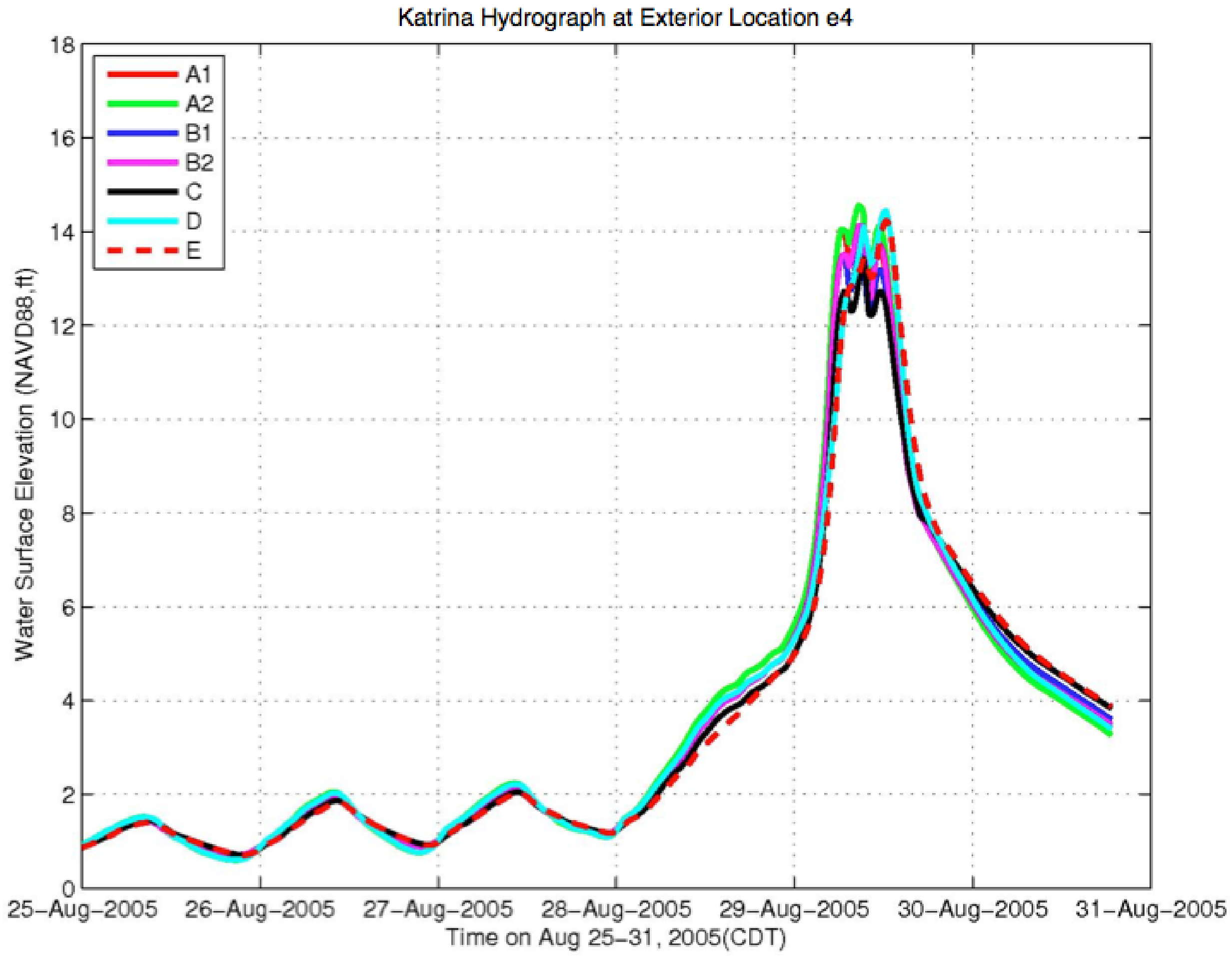

Figure 47d: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at exterior location e4 as shown in Figure 46.

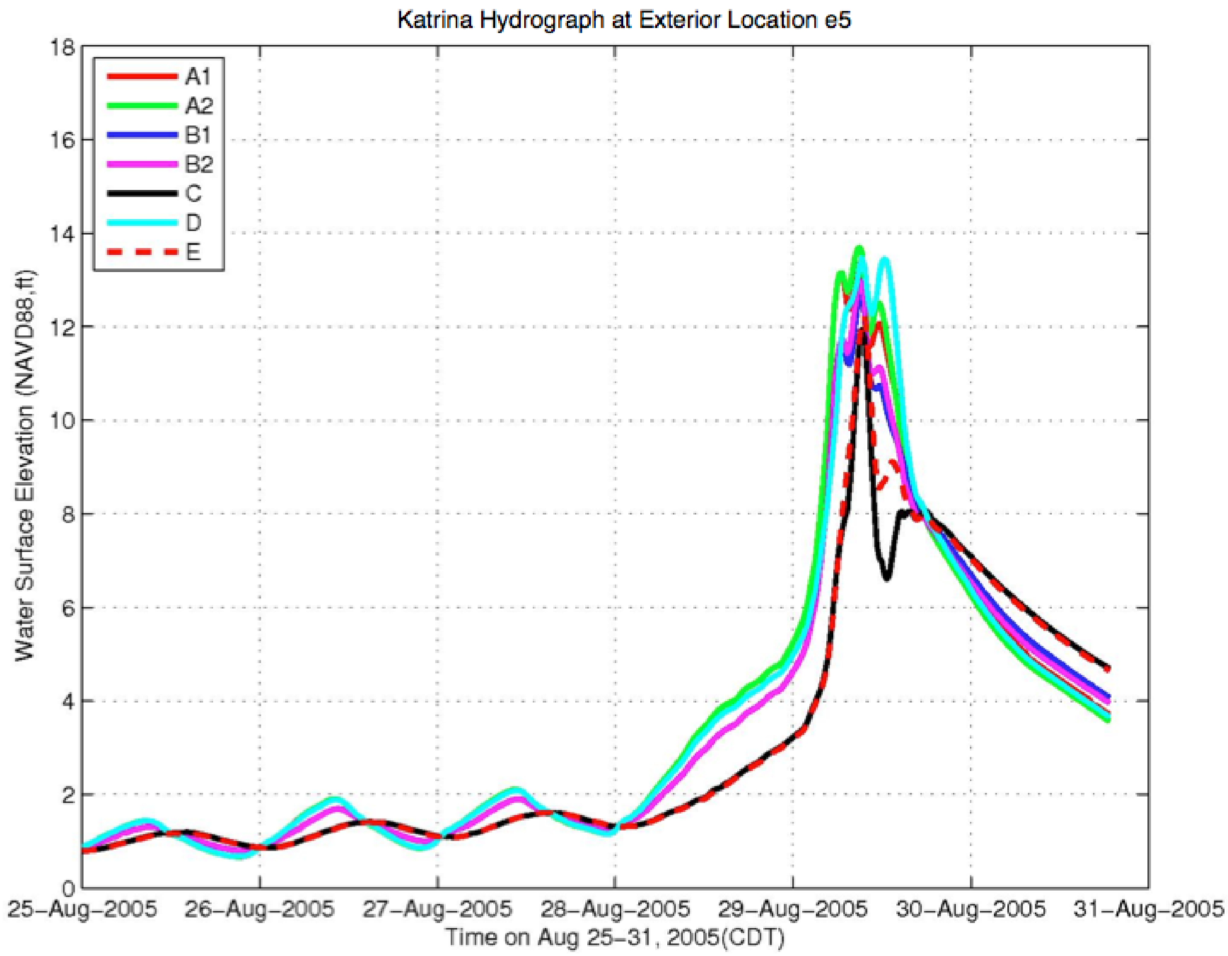

Figure 47e: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at exterior location e5 as shown in Figure 46.

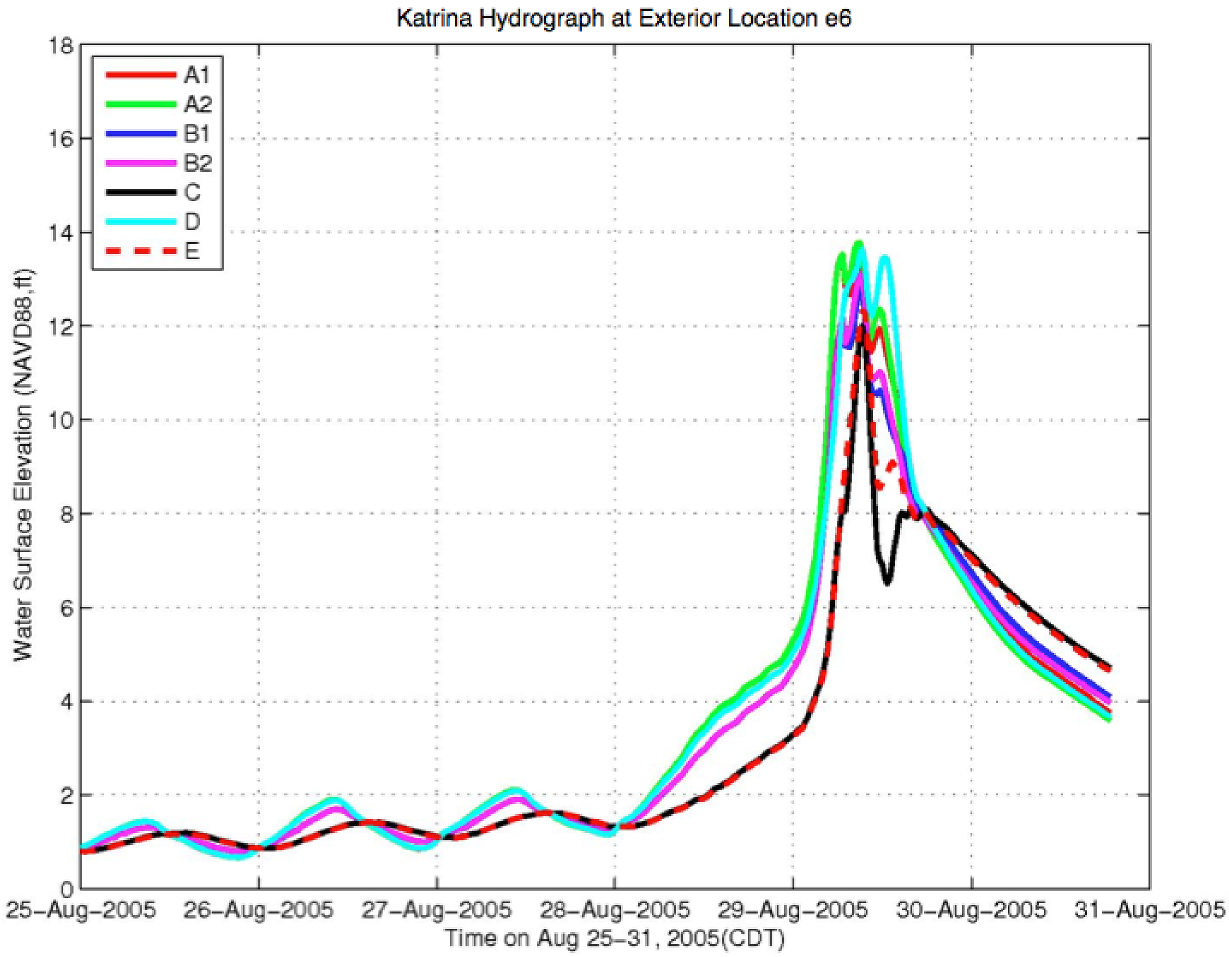

Figure 47f: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at exterior location e6 as shown in Figure 46.

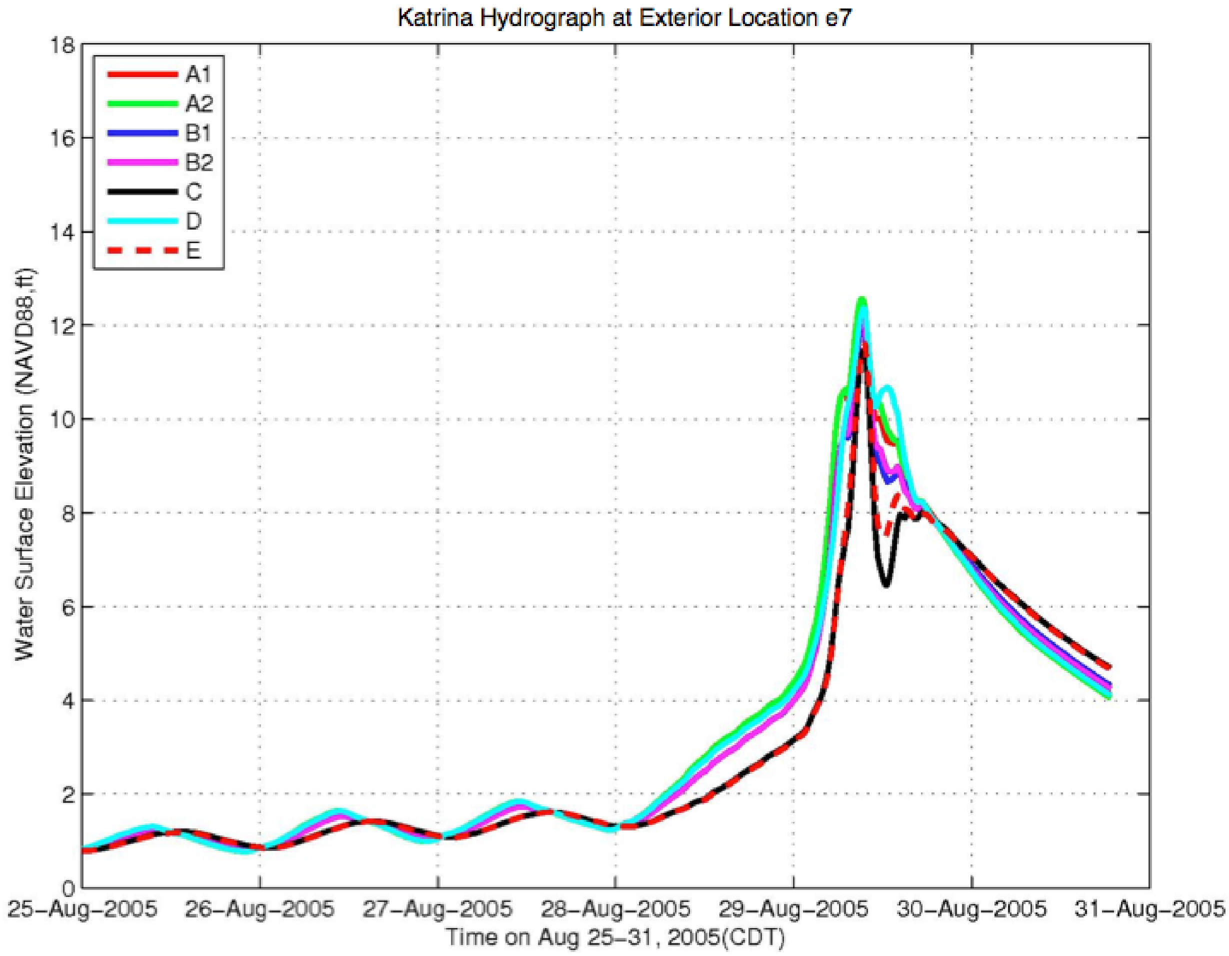

Figure 47g: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at exterior location e7 as shown in Figure 46.

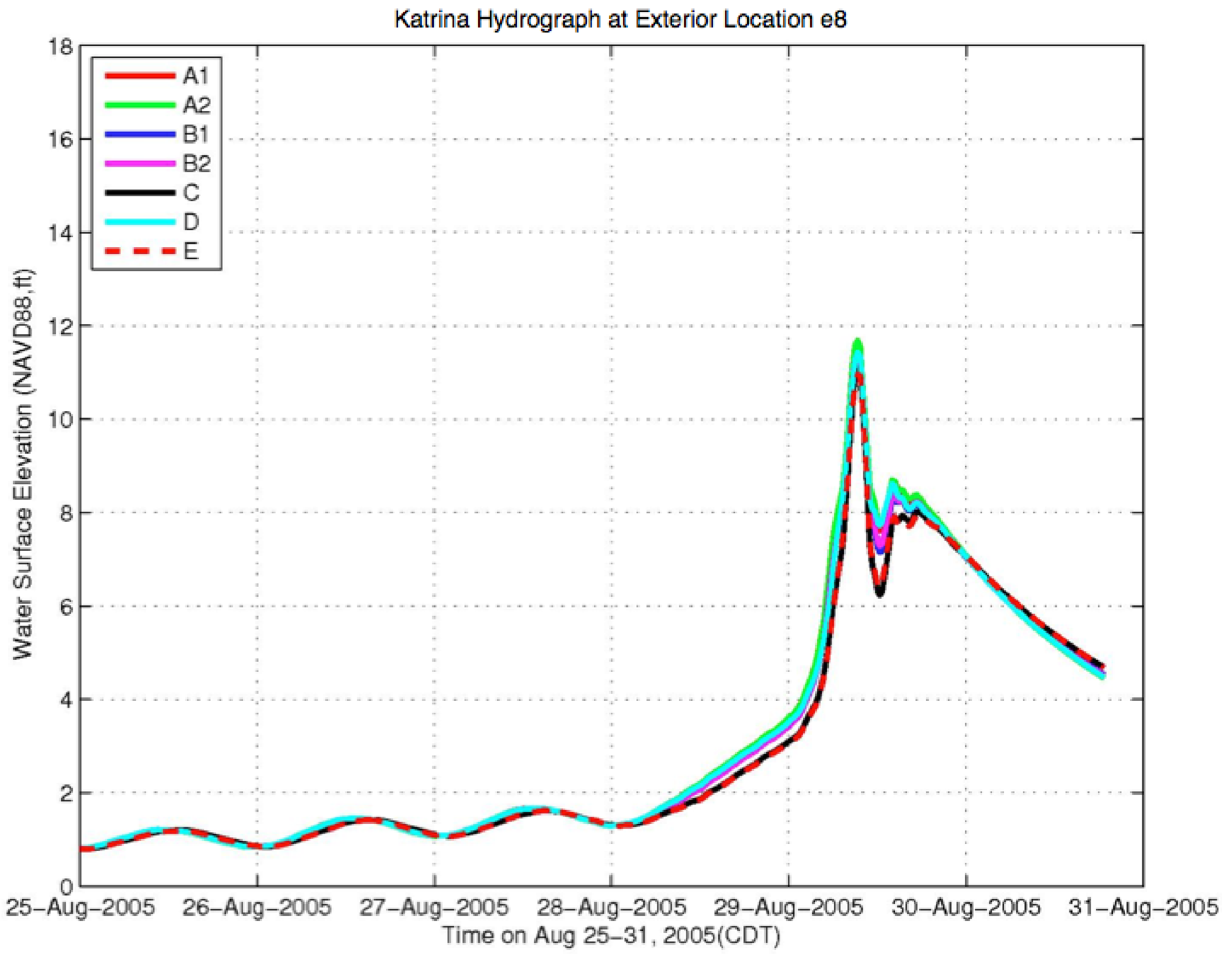

Figure 47h: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at exterior location e8 as shown in Figure 46.

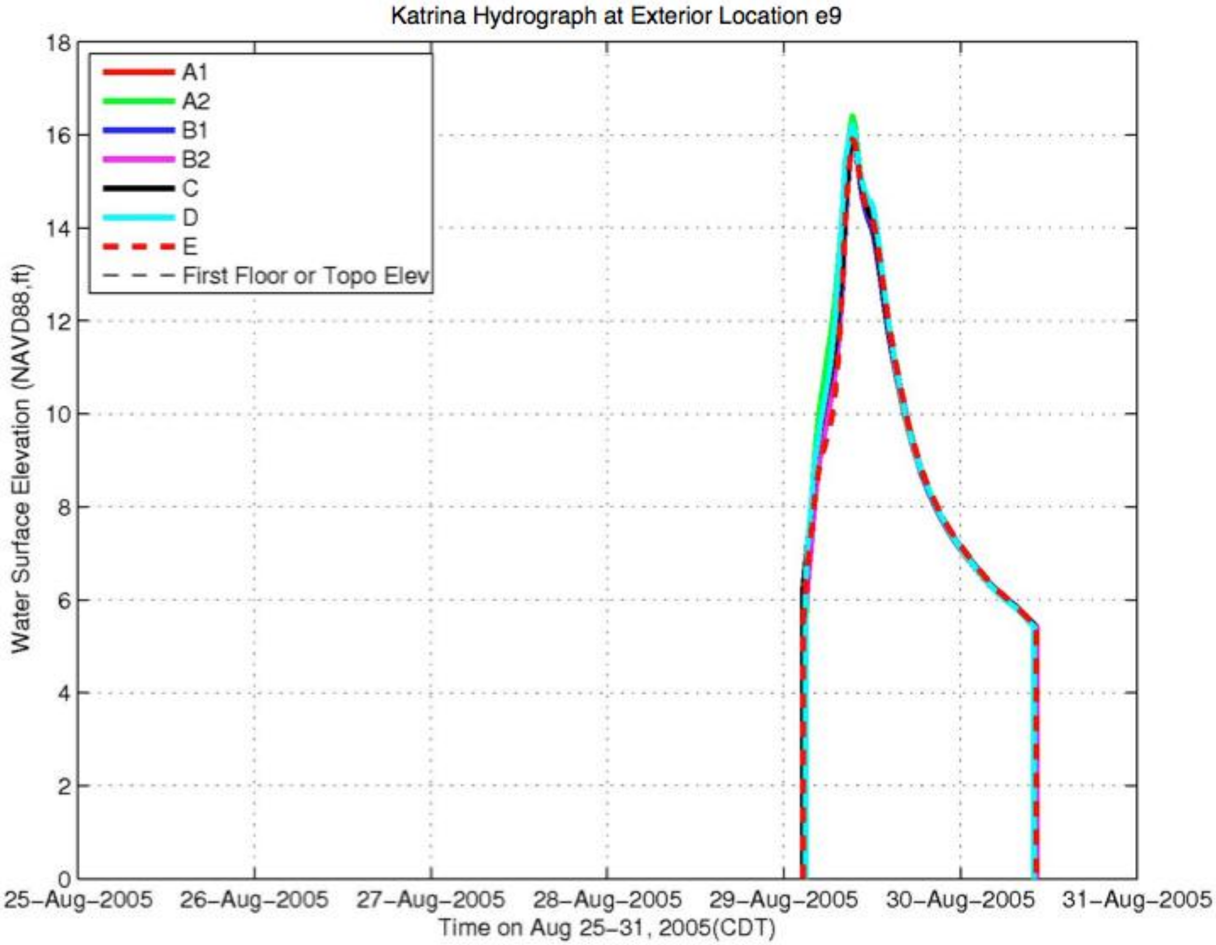

Figure 47i: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at exterior location e9 as shown in Figure 46.

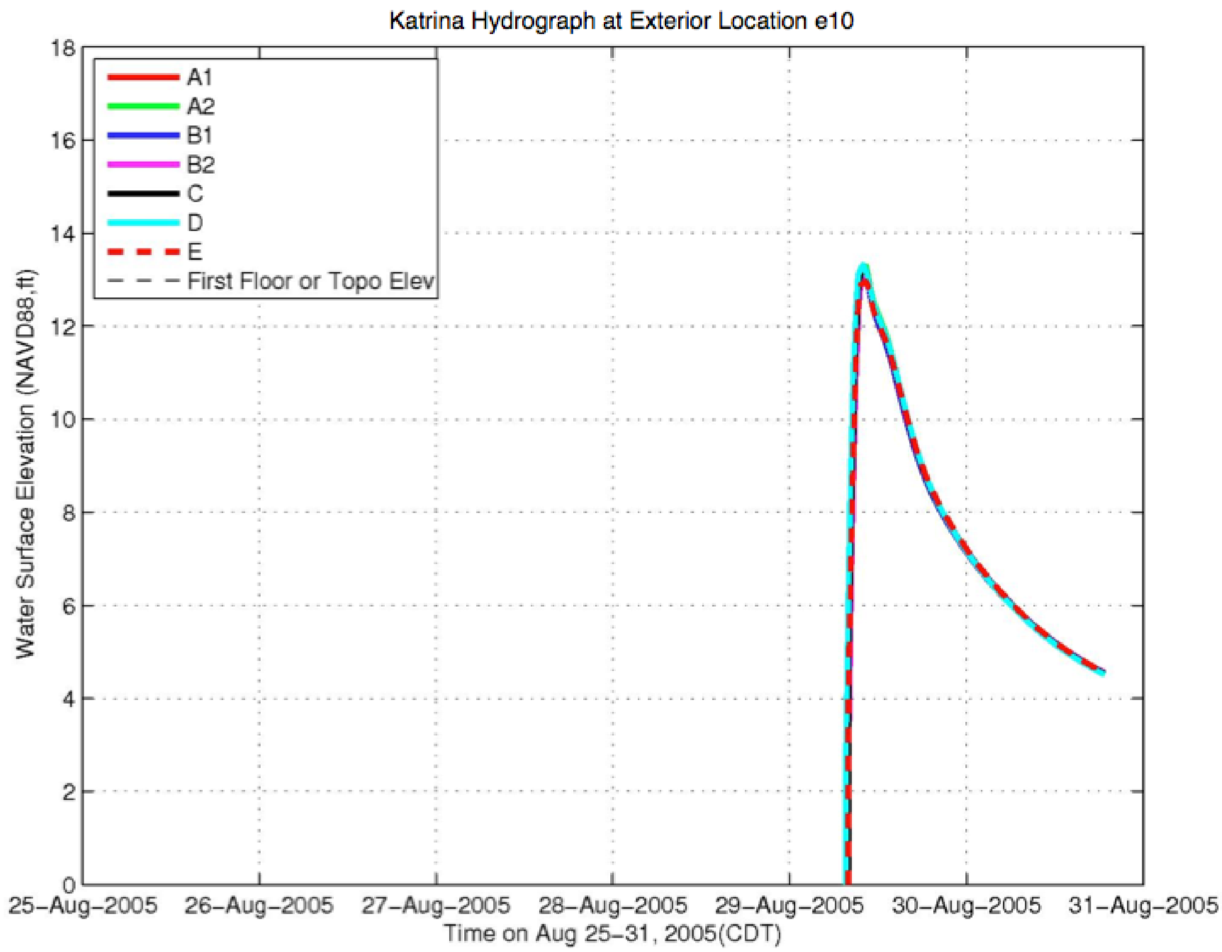

Figure 47j: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at exterior location e10 as shown in Figure 46.

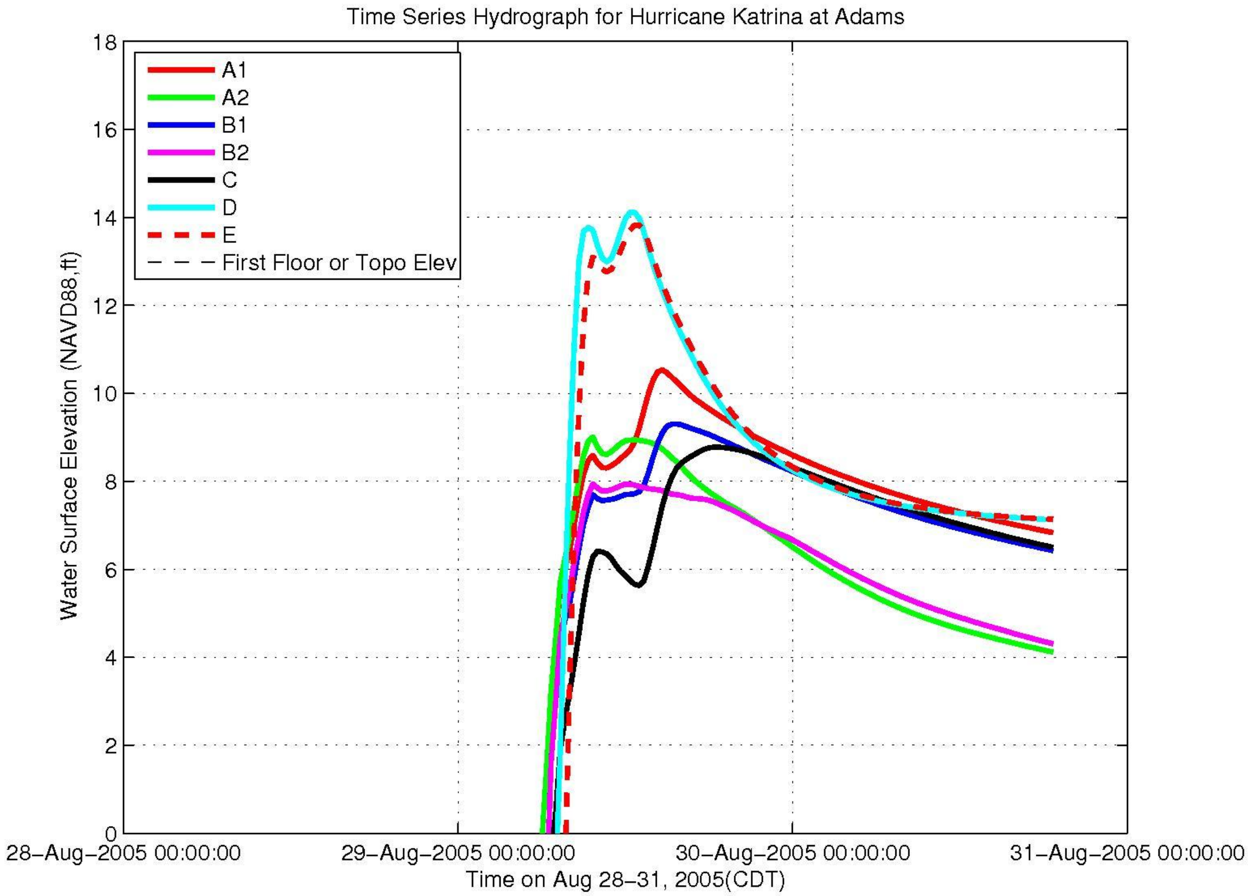

Figure 48a: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at plaintiff location Adams shown in Figure 46. Plot does not indicate a ground elevation because ground elevation is below zero NAVD88 (2004.65).

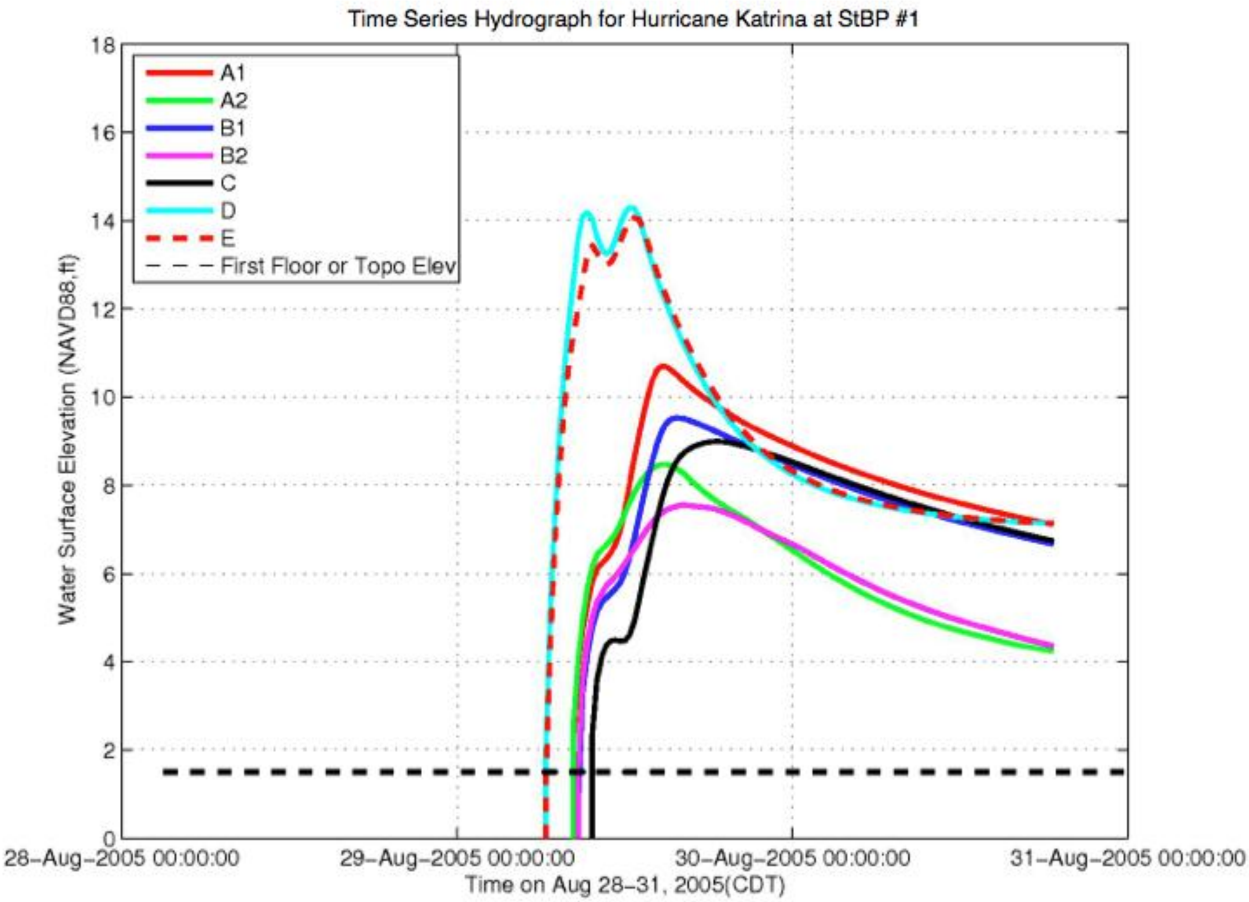

Figure 48b: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at plaintiff location StBP #1 shown in Figure 46. The horizontal dashed black line indicates either the first floor elevation or the ground elevation as appropriate for the property.

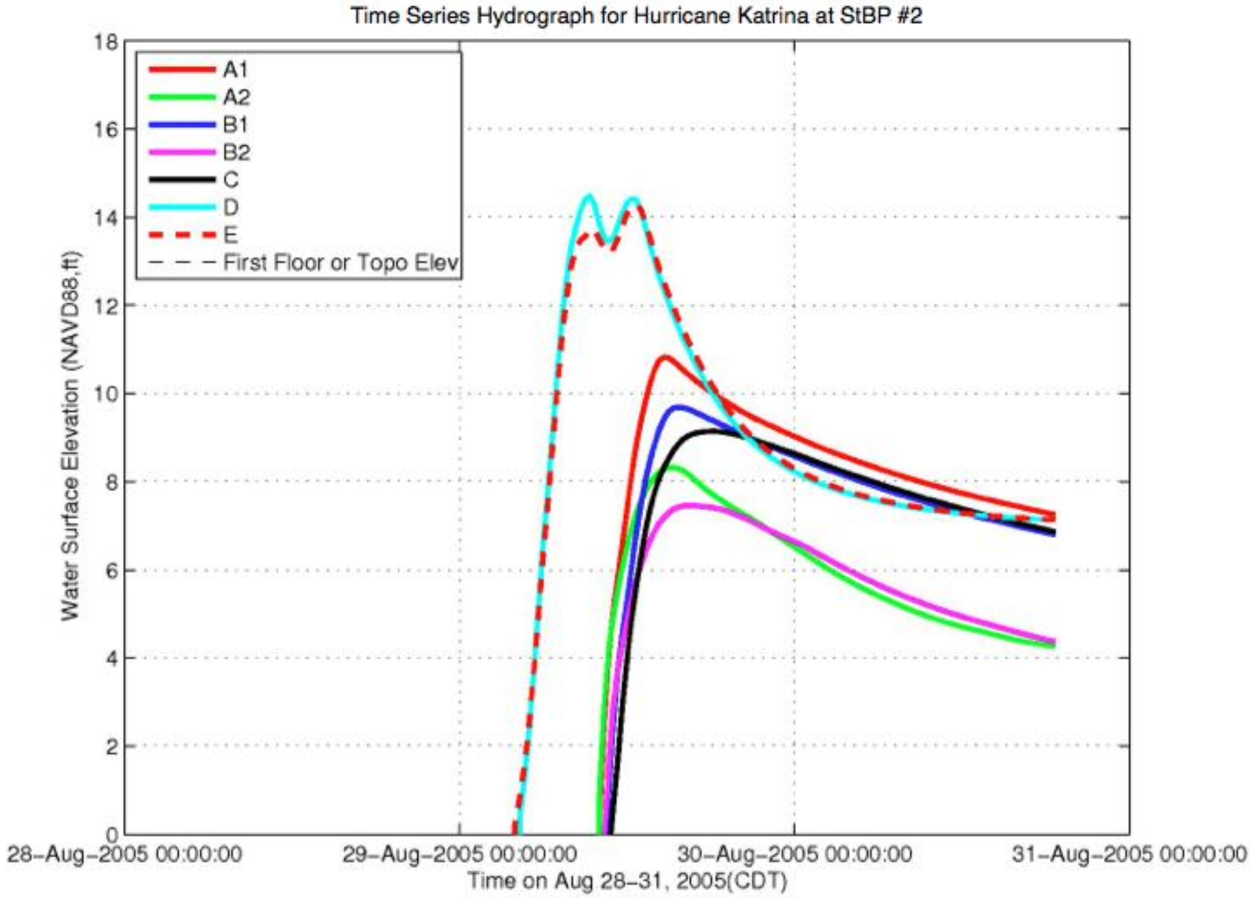

Figure 48c: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at plaintiff location StBP #2 shown in Figure 46. Plot does not indicate a ground elevation because ground elevation is below zero NAVD88 (2004.65).

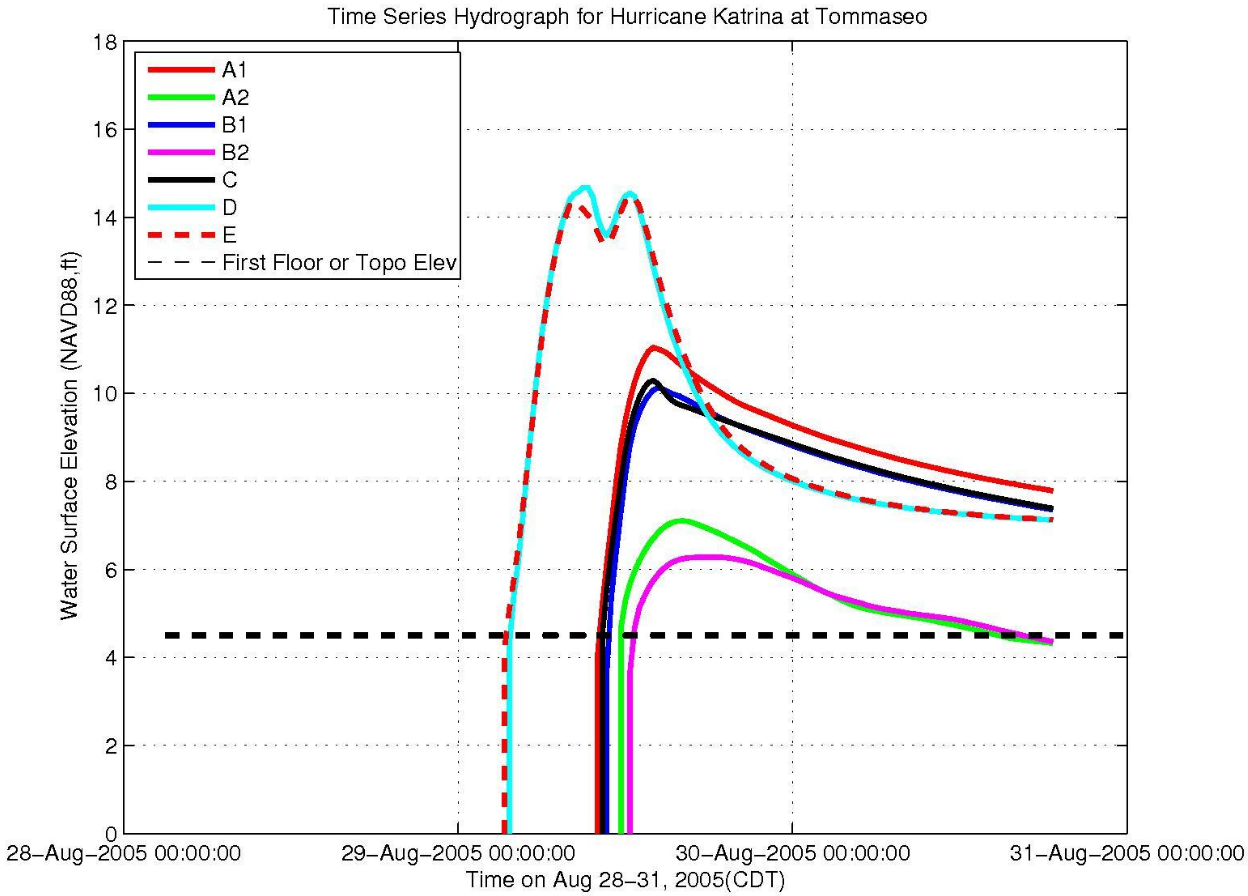

Figure 48d: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at plaintiff location Tommaseo shown in Figure 46. The horizontal dashed black line indicates either the first floor elevation or the ground elevation as appropriate for the property.

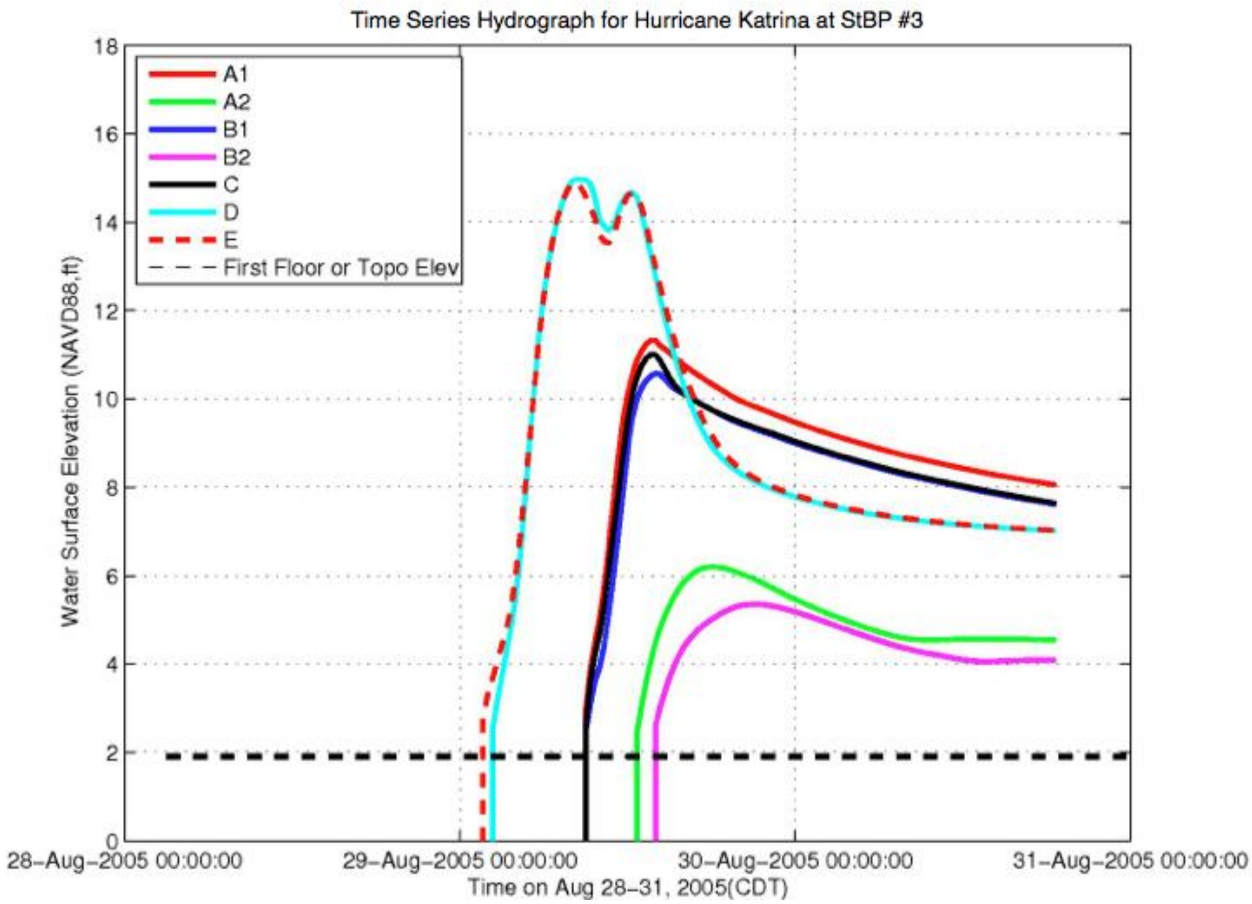

Figure 48e: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at plaintiff location StBP #3 shown in Figure 46. The horizontal dashed black line indicates either the first floor elevation or the ground elevation as appropriate for the property.

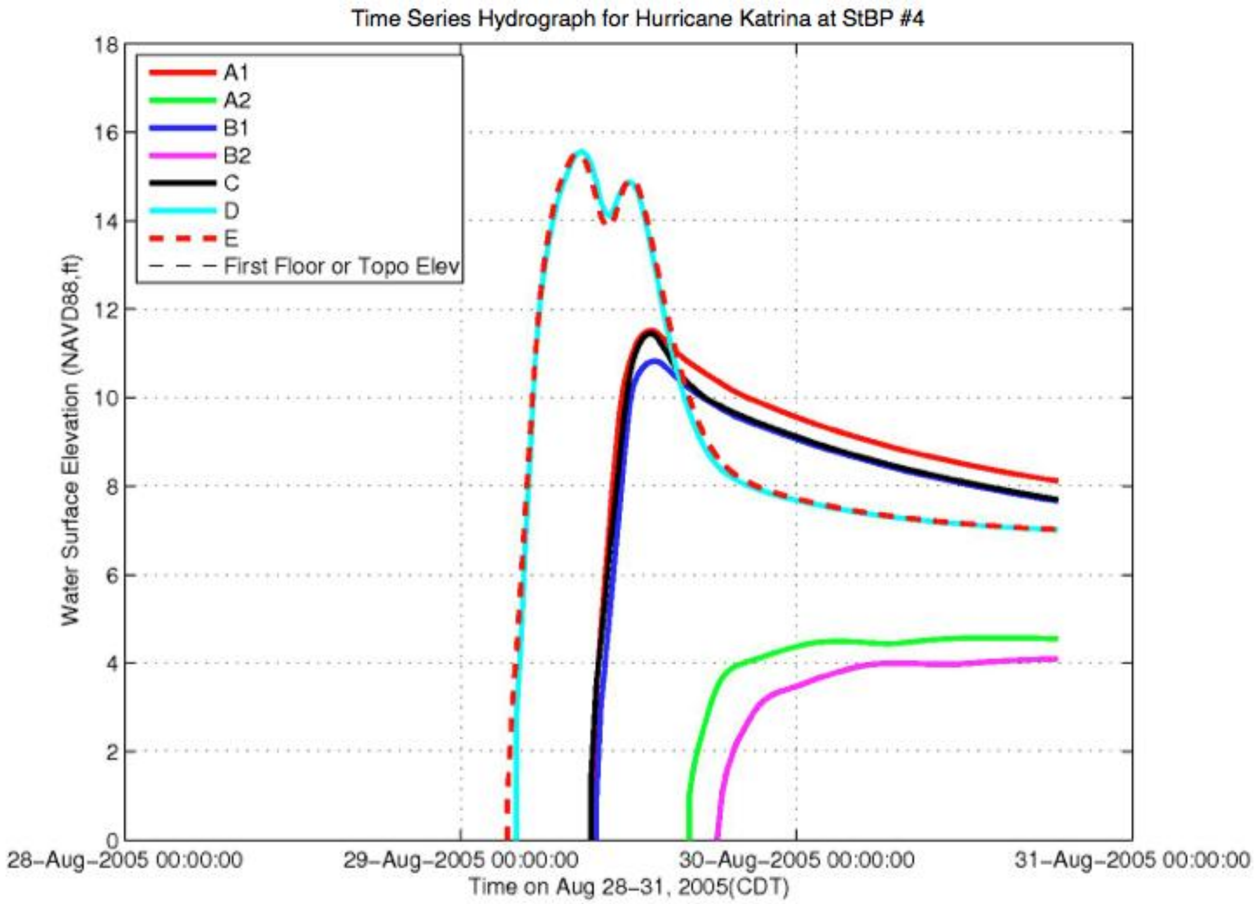

Figure 48f: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at plaintiff location StBP #4 shown in Figure 46. Plot does not indicate a ground elevation because ground elevation is below zero NAVD88 (2004.65).

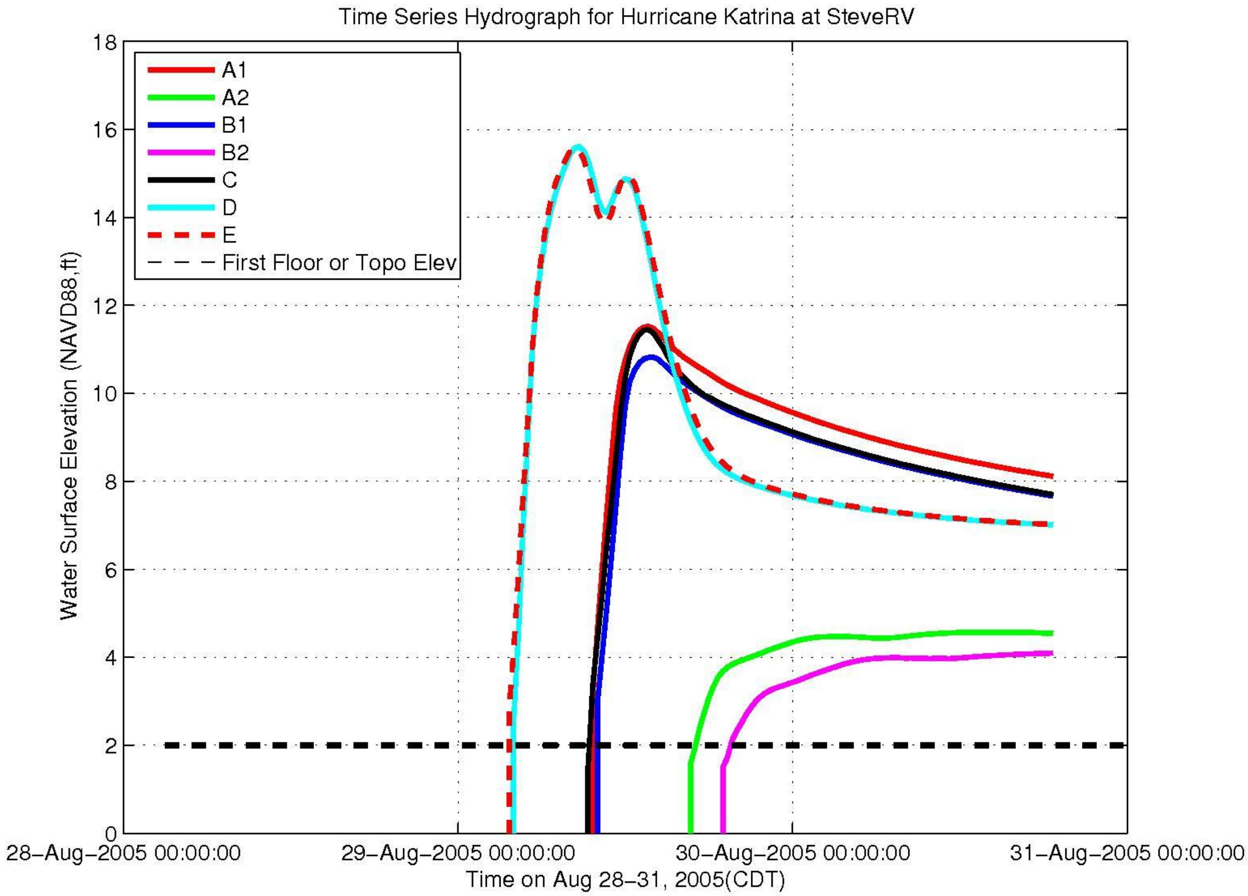

Figure 48g: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at plaintiff location Steve's RV shown in Figure 46. The horizontal dashed black line indicates either the first floor elevation or the ground elevation as appropriate for the property.

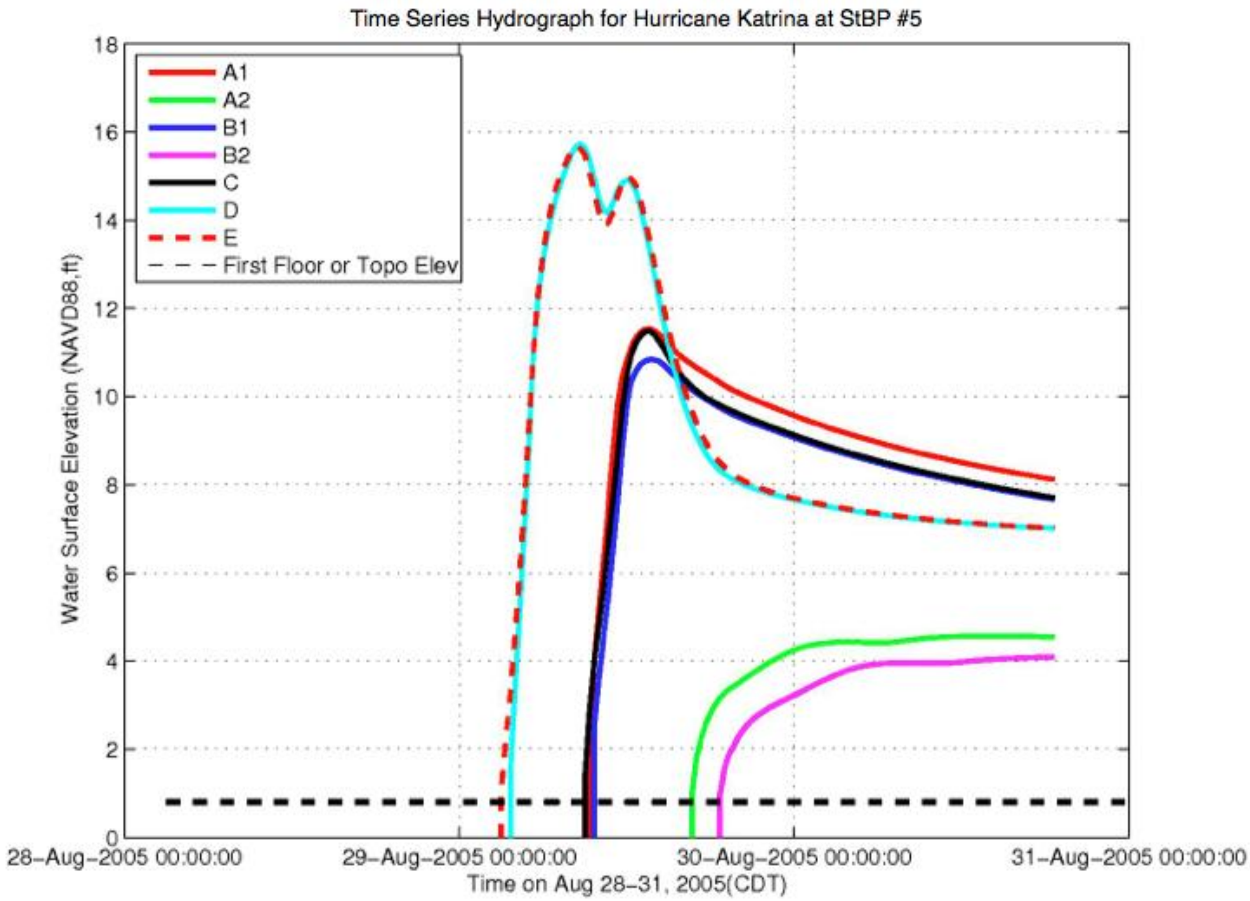

Figure 48h: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at plaintiff location StBP #5 shown in Figure 46. The horizontal dashed black line indicates either the first floor elevation or the ground elevation as appropriate for the property.

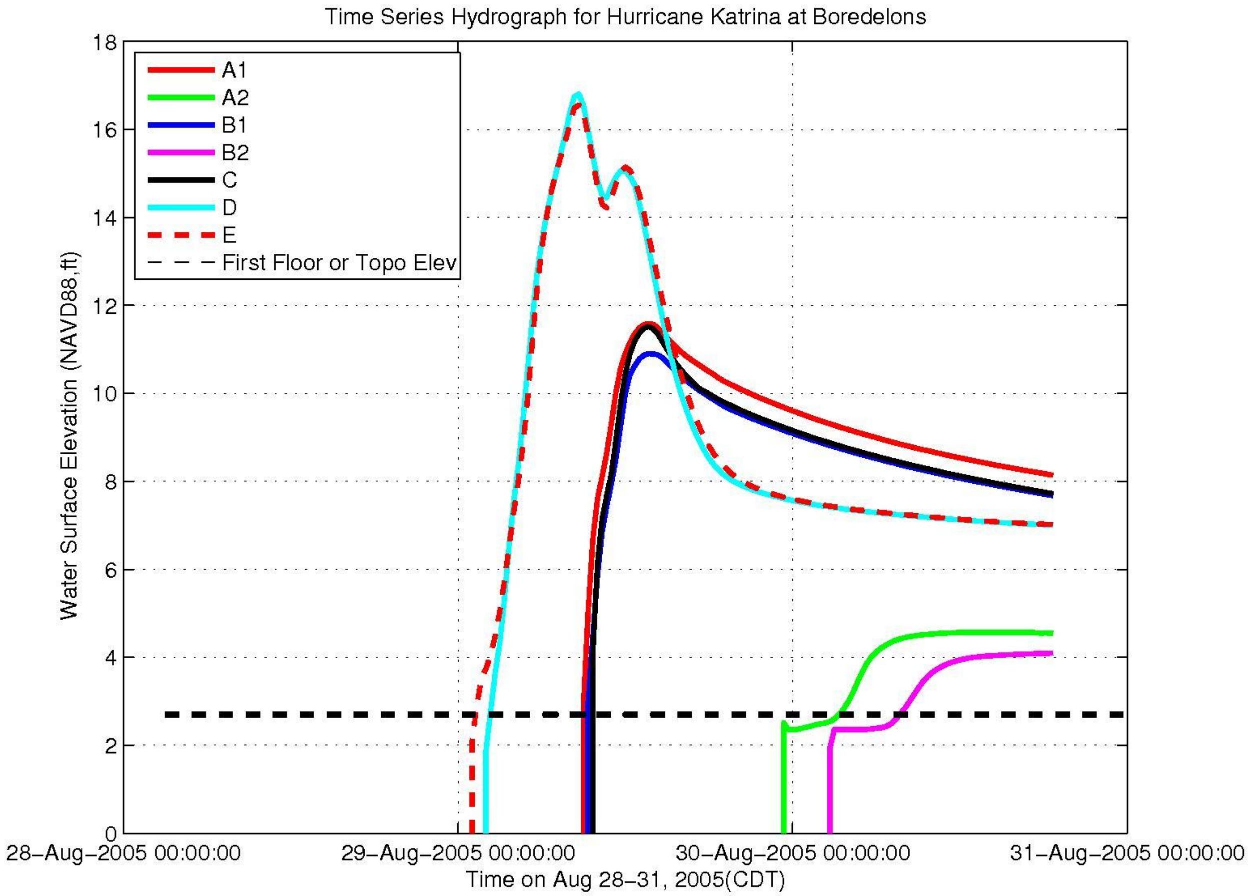

Figure 48i: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at plaintiff location Bordelon shown in Figure 46. The horizontal dashed black line indicates either the first floor elevation or the ground elevation as appropriate for the property.

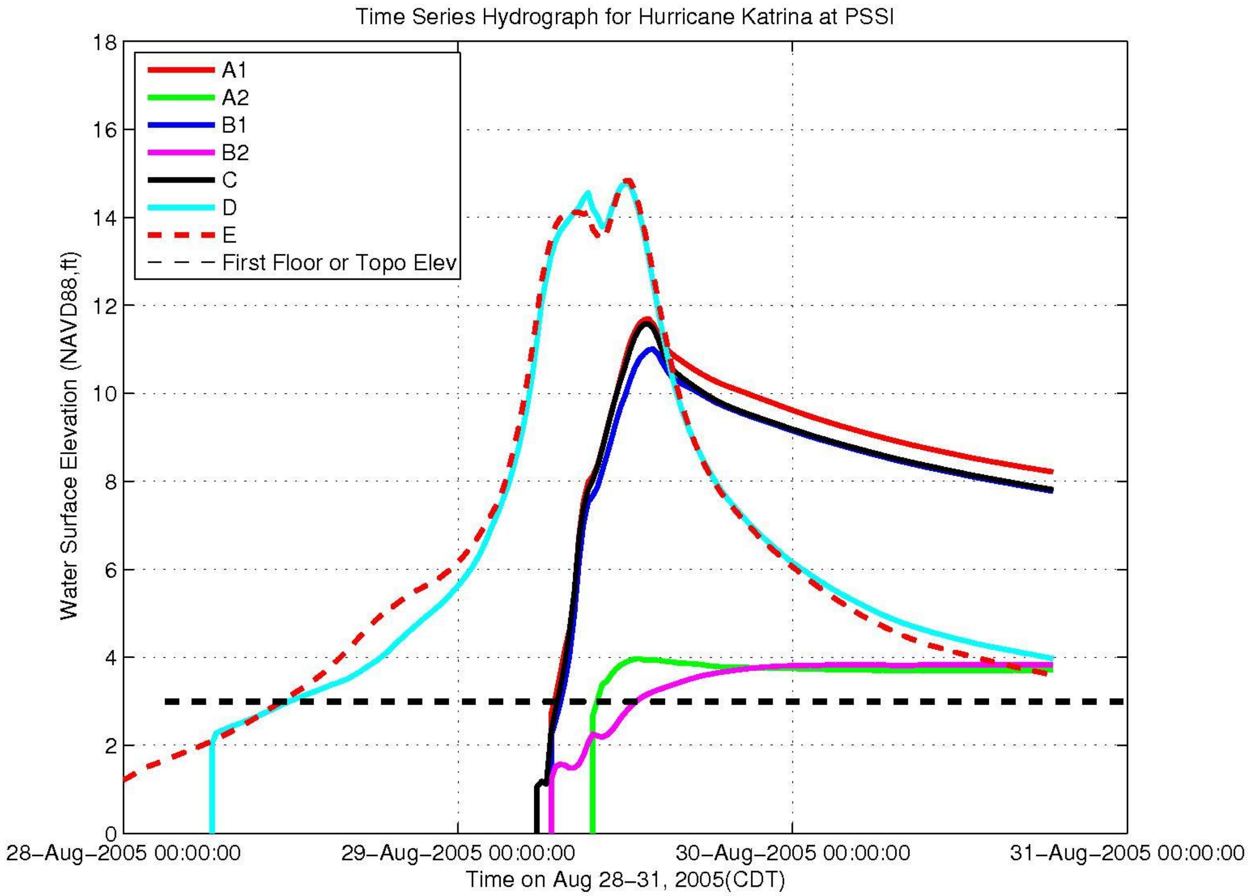

Figure 48j: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at plaintiff location PSSI shown in Figure 46. The horizontal dashed black line indicates either the first floor elevation or the ground elevation as appropriate for the property.

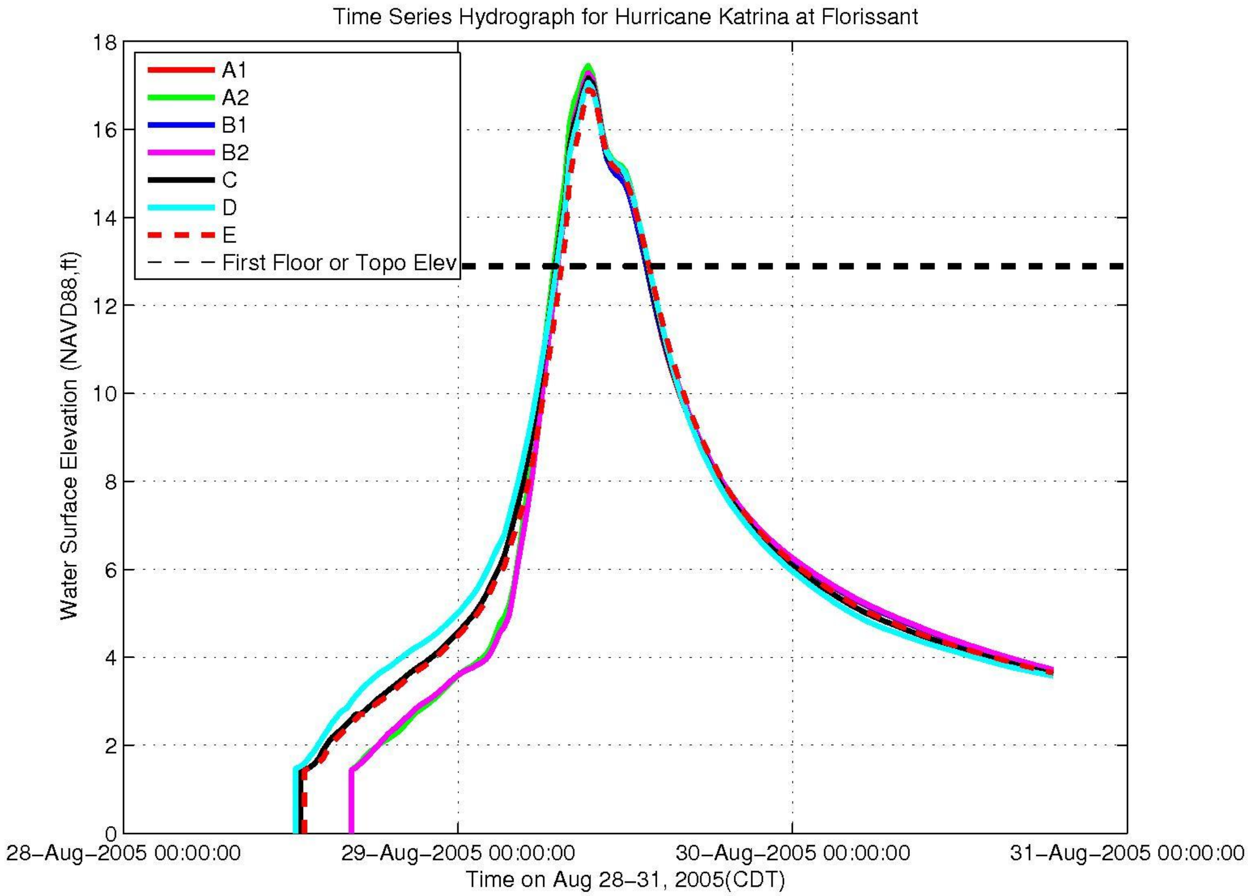

Figure 48k: Comparison of time series of water surface elevation (ft) in late August, 2005 for the Models A1, A2, B1, B2, C, D, and E at exterior plaintiff location Florissant shown in Figure 50. The horizontal dashed black line indicates either the first floor elevation or the ground elevation as appropriate for the property.

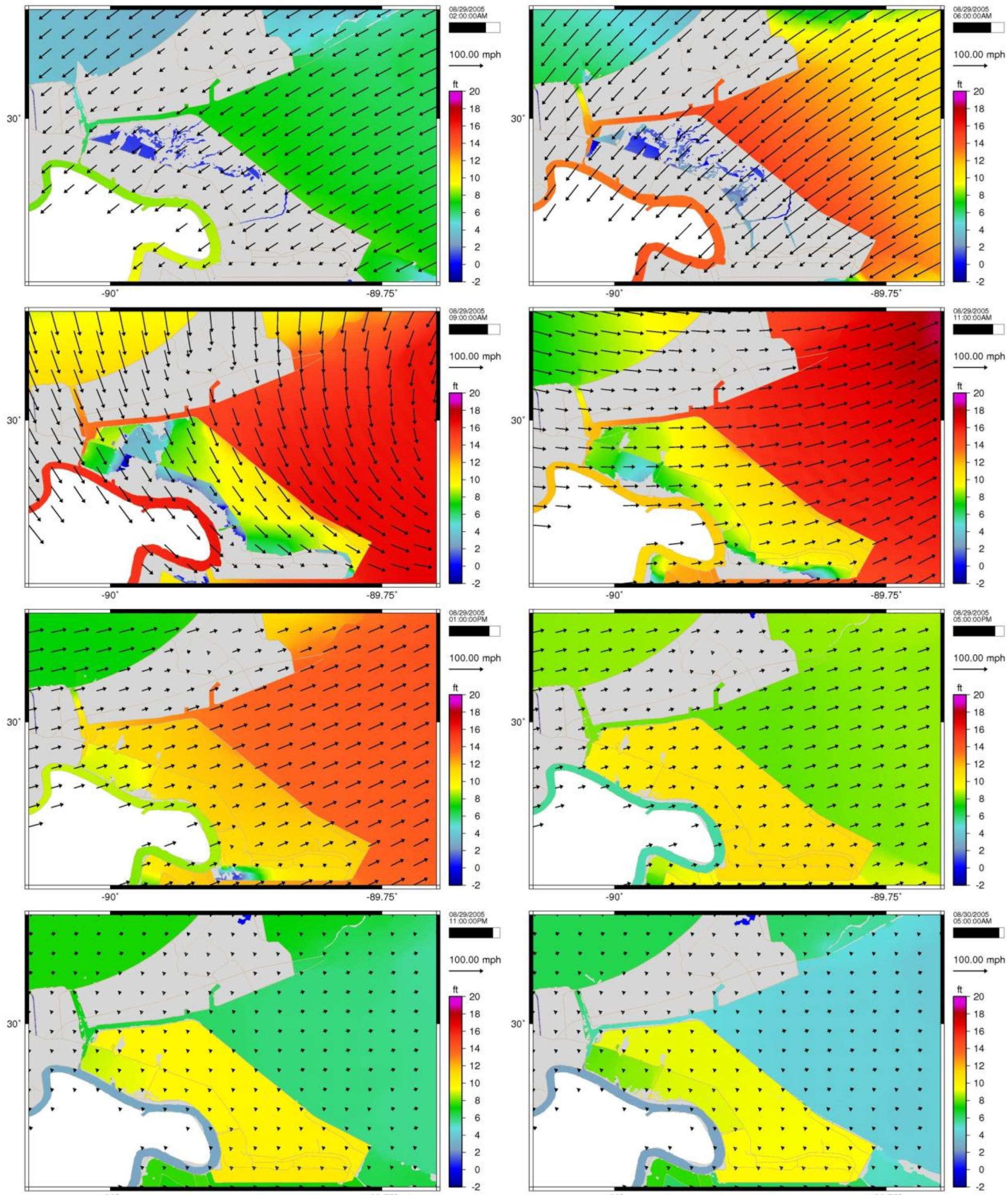

Figure 49: Model A1 *Katrina Actual Event Conditions* (SL16-DOJ-SB-A1) surface water elevations (ft) and wind speed vectors (mph), in the Study Area. The eight panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, (f) 1700 CDT, (g) 2300 CDT; and on August 30, 2005: (h) 0500 CDT.

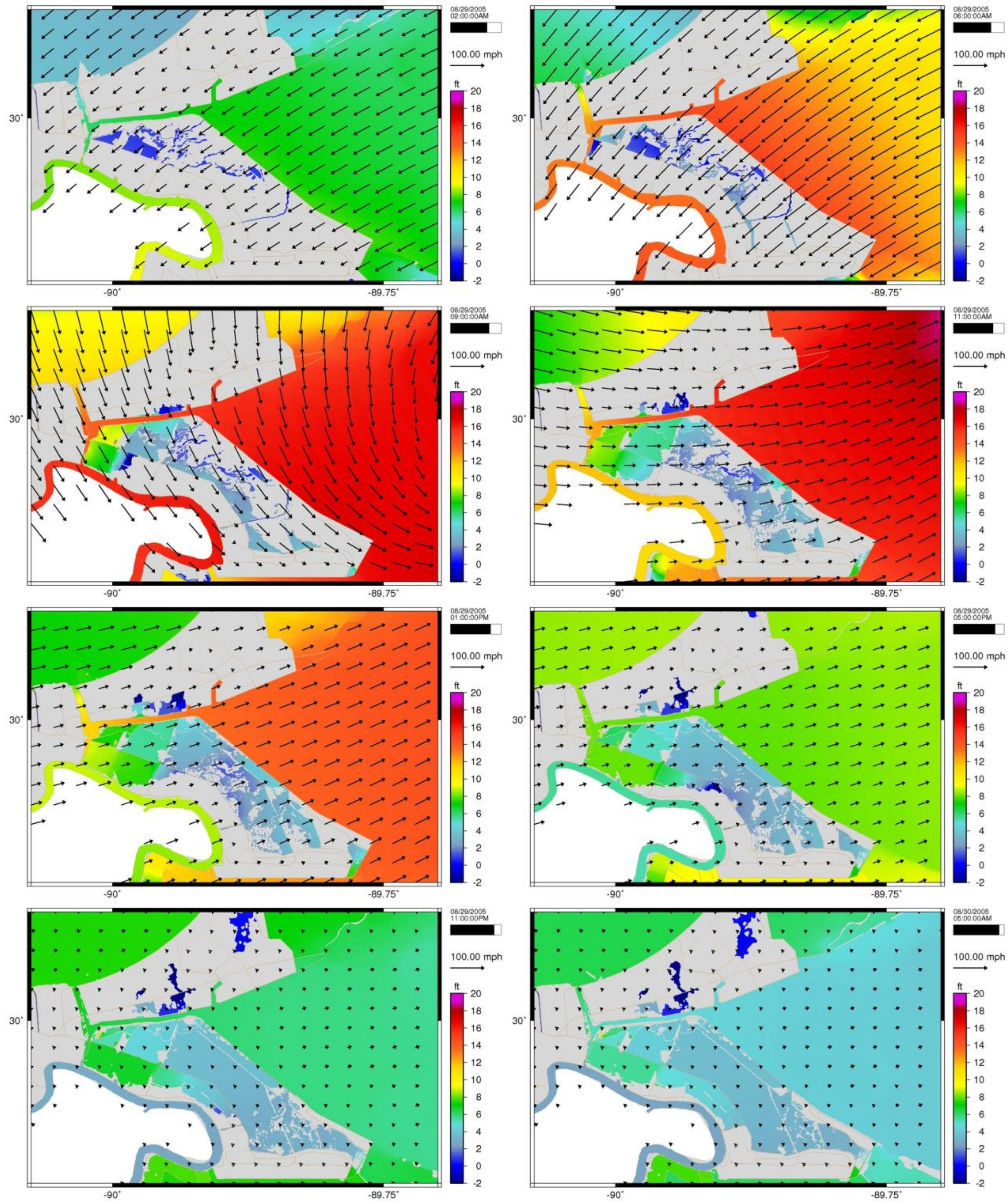

Figure 50: Model A2 *2005 MRGO/2005 Wetlands/IHNC Breaches Only* (SL16-DOJ-SB-A2) surface water elevations (ft) and wind speed vectors (mph), in the Study Area. The eight panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, (f) 1700 CDT, (g) 2300 CDT; and on August 30, 2005: (h) 0500 CDT.

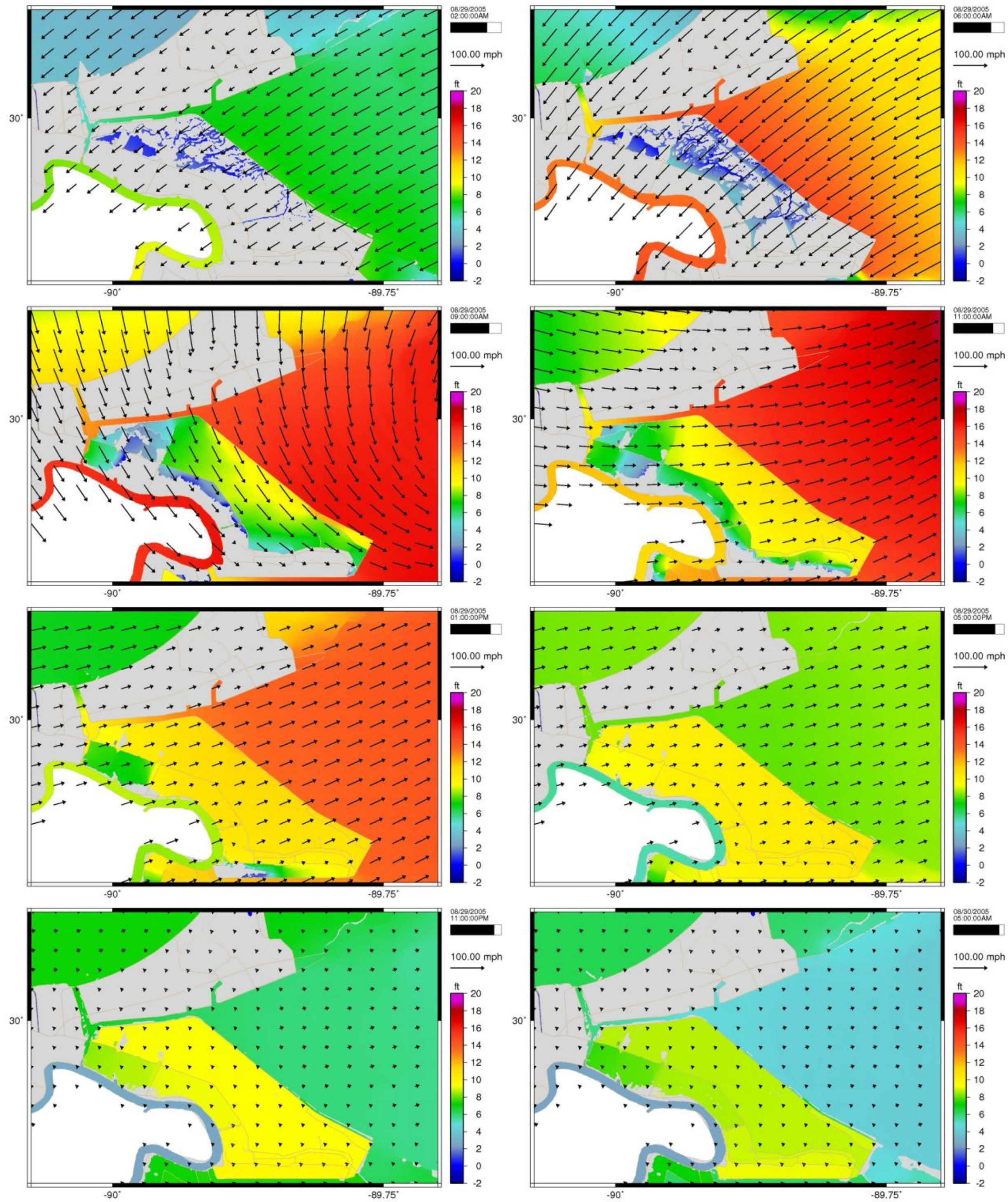

Figure 51: Model B1 *MRGO As Designed/1956 Wetlands* (SL16-DOJ-SB -B1) surface water elevations (ft) and wind speed vectors (mph), in the Study Area. The eight panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, (f) 1700 CDT, (g) 2300 CDT; and on August 30, 2005: (h) 0500 CDT.

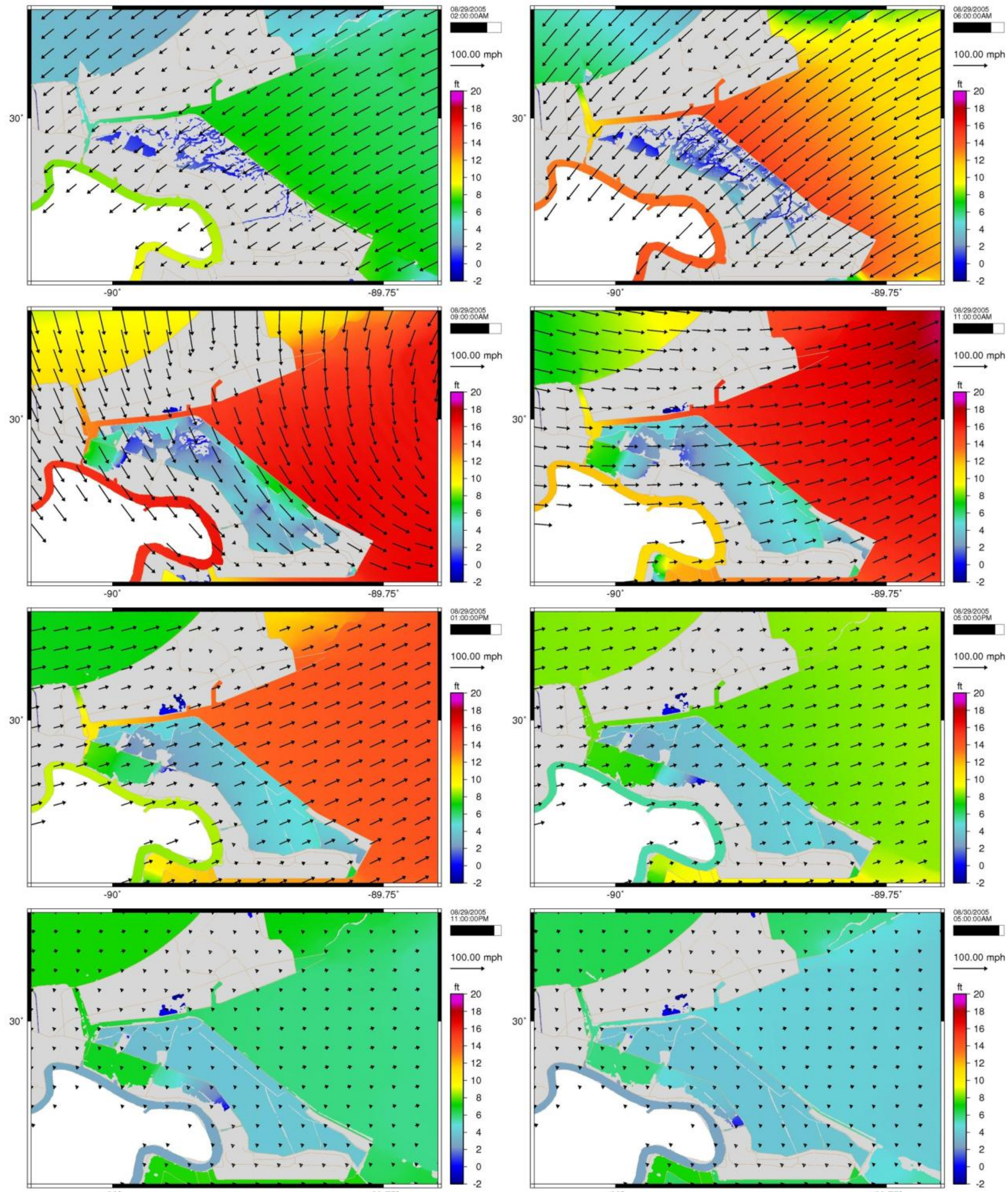

Figure 52: Model B2 *MRGO As Designed/ 1956 Wetlands/IHNC Breaches Only* (SL16-DOJ-SB-B2) surface water elevations (ft) and wind speed vectors (mph), in the Study Area. The eight panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, (f) 1700 CDT, (g) 2300 CDT; and on August 30, 2005: (h) 0500 CDT.

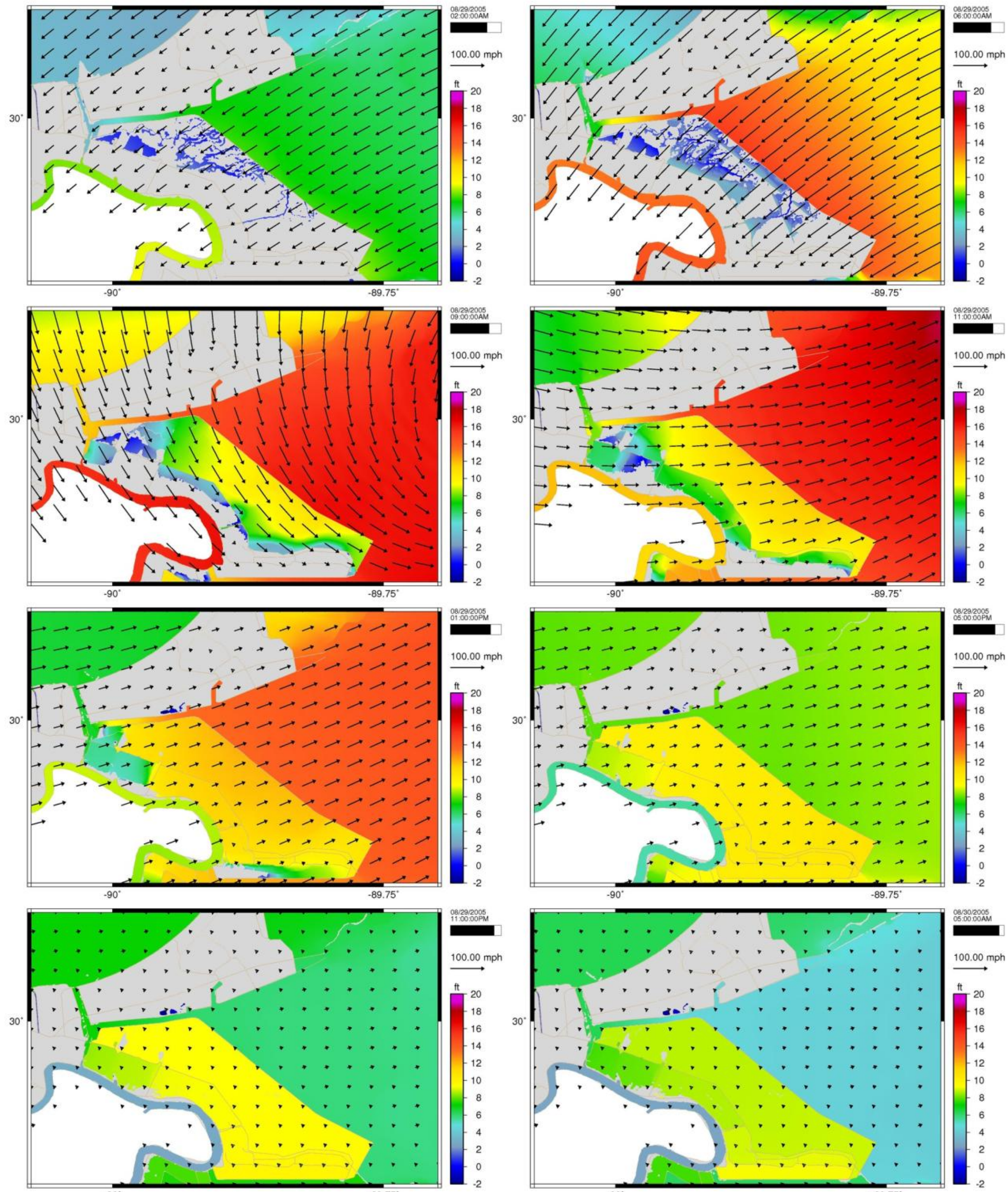

Figure 53: Model C *No MRGO/1956 Wetlands* (SL16-DOJ-SB-C) surface water elevations (ft) and wind speed vectors (mph), in the Study Area. The eight panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, (f) 1700 CDT, (g) 2300 CDT; and on August 30, 2005: (h) 0500 CDT.

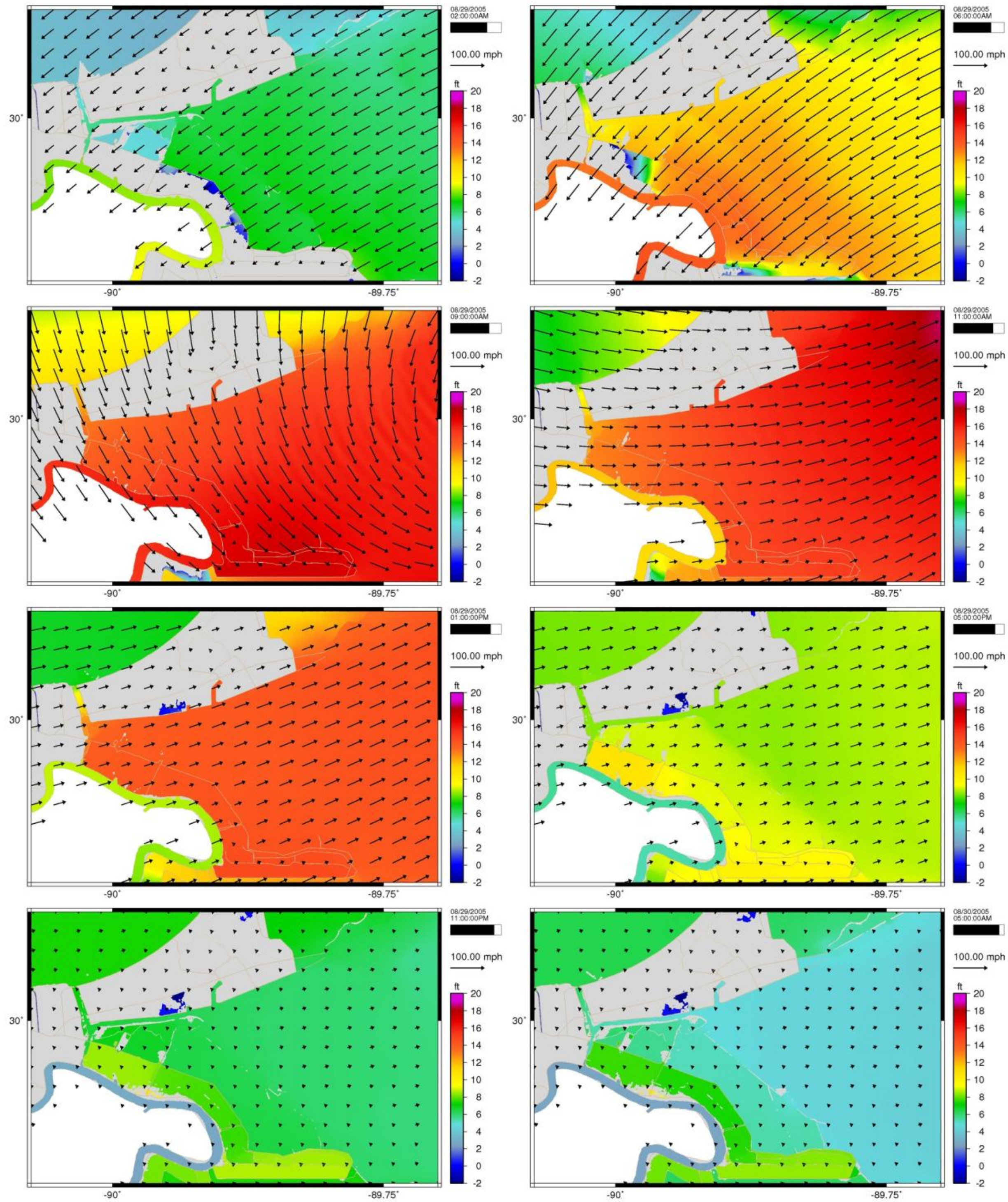

Figure 54: Model D *No Federal Levees/2005 MRGO/2005 Wetlands* (SL16-DOJ-SB-D) surface water elevations (ft) and wind speed vectors (mph), in the Study Area. The eight panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, (f) 1700 CDT, (g) 2300 CDT; and on August 30, 2005: (h) 0500 CDT.

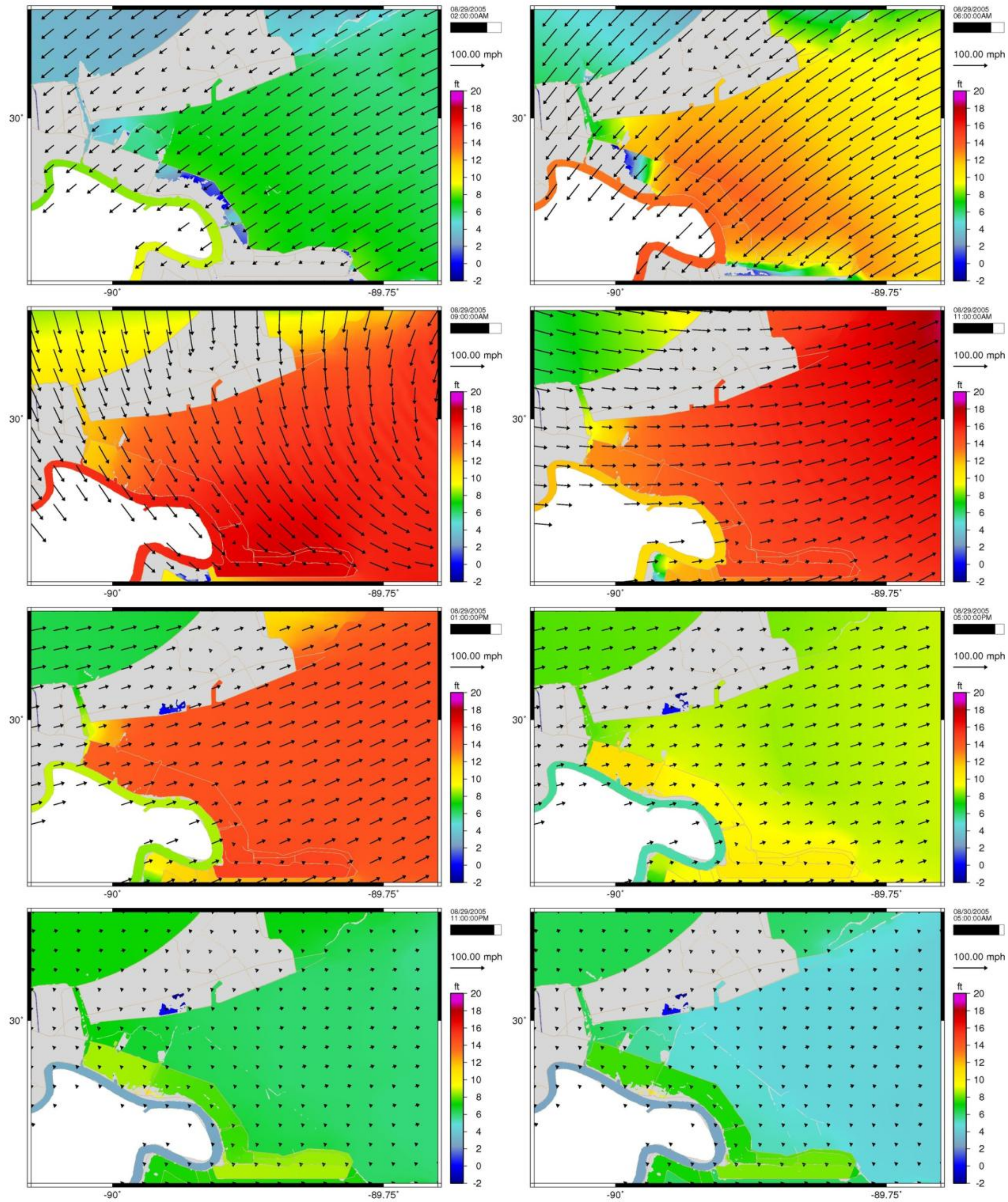

Figure 55: Model E *No Federal Levees/No MRGO/1956 Wetlands* (SL16-DOJ-SB-E) surface water elevations (ft) and wind speed vectors (mph), in the Study Area. The eight panels correspond to the following times on August 29, 2005: (a) 0200 CDT, (b) 0600 CDT, (c) 0900 CDT, (d) 1100 CDT, (e) 1300 CDT, (f) 1700 CDT, (g) 2300 CDT; and on August 30, 2005: (h) 0500 CDT.

APPENDIX A: Curriculum Vita

JOANNES JACOBUS ALOYSIUS WESTERINK

Joseph and Nona Ahearn Professor in Computational Science and Engineering
Henry J. Massman Chairman
Department of Civil and Environmental Engineering and Earth Sciences
Concurrent Professor, Department of Applied and Computational Mathematics and Statistics
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University of Notre Dame
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EDUCATION

1981-1984	Ph.D. Civil Engineering, Massachusetts Institute of Technology
1979-1981	M.S. Civil Engineering, State University of New York at Buffalo
1975-1979	B.S. Civil Engineering, Summa Cum Laude, State University of New York at Buffalo

APPOINTMENTS

2013-present	Joseph and Nona Ahearn Endowed Professor in Computational Science and Engineering, Department of Civil & Environmental Engineering & Earth Sciences
2011-present	Henry J. Massman Chairman, Department of Civil & Environmental Engineering & Earth Sciences (formerly Civil Engineering and Geological Sciences), University of Notre Dame
2011-2013	Notre Dame Chair in Computational Hydraulics, University of Notre Dame
2011-present	Concurrent Professor, Department of Computer Science and Engineering, University of Notre Dame
2010-present	Concurrent Professor, Department of Applied and Computational Mathematics and Statistics, University of Notre Dame
2007-2010	Concurrent Professor, Department of Mathematics, University of Notre Dame
2006-present	Professor, Department of Civil & Environmental Engineering & Earth Sciences (formerly Civil Engineering and Geological Sciences), University of Notre Dame
1995-2006	Associate Professor, Department of Civil Engineering and Geological Sciences, University of Notre Dame
1990-1995	Assistant Professor, Department of Civil Engineering and Geological Sciences, University of Notre Dame
1987-1990	Assistant Professor, Department of Civil Engineering, Texas A&M University
1984-1987	Assistant Professor, Department of Civil Engineering, Princeton University
1981-1984	Research Assistant, Department of Civil Engineering, Massachusetts Institute of Technology
1979-1981	Research Assistant, Department of Civil Engineering, State University of New York at Buffalo

RESEARCH INTERESTS

Computational fluid mechanics
Finite element methods
Modeling of circulation and transport in coastal seas and oceans
Tidal hydrodynamics
Hurricane storm surge prediction

Geophysical turbulence modeling
Numerical modeling of the convection-diffusion and Navier-Stokes equations
Environmental fluid mechanics

AWARDS AND FELLOWSHIPS

R.P. Apmann Memorial Scholarship, State University of New York at Buffalo, 1979
Seagrant Scholar, National Oceanic and Atmospheric Administration, 1979-1981
Kaneb Teaching Award, Department of Civil Engineering and Geological Sciences, Univ. of Notre Dame, 2000
BP Outstanding Teacher of the Year Award, College of Engineering, University of Notre Dame, 2004
Faculty Fellow, John A. Kaneb Center for Teaching and Learning, University of Notre Dame, 2005-2006
U.S. Army Corps of Engineers Interagency Performance Evaluation Task Force Leadership Award, 2007
Department of the Army, Outstanding Civilian Service Medal, 2007
Rev. Edmund P. Joyce, C.S.C. Award for Excellence in Undergraduate Teaching, Univ. of Notre Dame, 2010.

PROFESSIONAL ACTIVITIES

Member American Geophysical Union
Member American Society of Civil Engineers
Member American Meteorological Society
Member of the Society for Industrial and Applied Mathematics
Member of the American Mathematical Society
Editorial board member for *Advances in Water Resources* (1989-1997)
Advisor member of the Computational Hydraulics Committee, ASCE Hydraulics Division (1990-1994)
Affiliate Scientist, Center for Coastal and Land Margin Research, Oregon Graduate Institute (1992-1996)
Control member of the Task Committee on Pre-Standardization of Estuarine Tidal Modeling, ASCE Hydraulics Division (1992-1994)
Control member of the Computational Hydraulics Committee, ASCE Hydraulics Division (1994-1996): Secretary (1994)
Member, International Scientific Advisory Committee, Coastal Engineering 95, Cancun, Mexico (1994-1995)
Member, International Scientific Advisory Committee, Coastal Engineering 97, La Coruna, Spain (1996-1997)
Member, International Scientific Advisory Committee, Coastal Engineering 99, Lemnos, Greece (1998-1999)
Member, Organizing Committee, Fifth SIAM Conference on Mathematical and Computational Issues in the Geosciences, San Antonio, TX, March 24-27, 1999 (1998-1999)
Member, International Organizing Committee, Twelfth International Conference on Finite Element Methods in Flow Problems, Meijo University, Nagoya, Japan, April 2-4, 2003 (2001-2003)
Member, Advisory Committee, Coastal and Environmental Modeling Laboratory, Louisiana State University, Baton Rouge, LA, (2003).
U.S. Congressional Briefing with Clint Dawson entitled, "From Katrina Forward; How Mathematical Modeling Predicts Storm Surges," for the American Mathematical Society, U.S. Congress, Washington D.C., November 3, 2005.
Co-organizer with M. Iskandarani and J. Pietrzak the Fifth International Workshop on Unstructured Mesh Numerical Modeling of Coastal, Shelf and Ocean Flows, Miami FL, November 13-15, 2006.
Numerical Modeling of Hurricane Katrina Surge and Wave Environment Team co-leader for the U.S. Army Corps of Engineers' Interagency Performance Evaluation Task Force (IPET) of New Orleans and Southeastern Louisiana Hurricane Protection Projects (2005-2007).
Commissioner, Southeast Louisiana Flood Protection Authority–West Bank; Appointed by Governor Kathleen Blanco, 2007; Re-appointed by Governor Bobby Jindal, 2009 (2007-2012).
Storm Surge Model Development Team leader for the U.S. Army Corps of Engineers' (USACE) and Federal Emergency Management Agency's (FEMA) Joint Coastal Surge (JCS) study of Louisiana and Texas in support of the USACE Hurricane Protection Office (USACE-HPO) rebuilding of the Southern Louisiana Federal levee systems, the Congressionally mandated Louisiana Coastal Protection and Restoration (LACPR) study, and the FEMA Digital Flood Insurance Rate Maps (DFIRMS) (2006-present).
Member Scientific Organizing Committee, International Workshop on Unstructured Mesh Numerical Ocean

Modeling, Cambridge MA, August 17-20, 2010.

International Expert for the UNESCO Joint World Meteorological Organization – Intergovernmental Oceanographic Commission (WMO-IOC) Technical Commission for Oceanography and Marine Meteorology (JCOMM); Enhancing Forecasting Capabilities for North Indian Ocean Storm Surges (2009-present)

External Peer Reviewer, U.S. Army Corps of Engineer Research Development Center, Coastal Hydraulics Laboratory, May – June 2012.

REFEREED JOURNAL PUBLICATIONS

1. Westerink, J.J., J.J. Connor and K.D. Stolzenbach, "A Primitive Pseudo Wave Equation Formulation for Solving the Harmonic Shallow Water Equations," ***Advances in Water Resources***, **10**, 188-199, 1987.

2. Westerink, J.J., J.J. Connor and K.D. Stolzenbach, "A Frequency-Time Domain Finite Element Model for Tidal Circulation Based on the Least Squares Harmonic Analysis Method," ***International Journal for Numerical Methods in Fluids***, **8**, 813-843, 1988.

3. Westerink, J.J. and D. Shea, "Consistent Higher Degree Petrov-Galerkin Methods for the Solution of the Transient Convection-Diffusion Equation," ***International Journal for Numerical Methods in Engineering***, **28**, 1077-1101, 1989.

4. Westerink, J.J., K.D. Stolzenbach and J.J. Connor, "General Spectral Computations of the Nonlinear Shallow Water Tidal Interactions Within the Bight of Abaco," ***Journal of Physical Oceanography***, **19,** 1350-1373, 1989.

5. Baptista, A.M., J.J. Westerink and P.J. Turner, "Tides in the English Channel and Southern North Sea. A Frequency Domain Analysis Using Model TEA-NL," ***Advances in Water Resources***, **12**, 166-183, 1989.

6. Cantekin, M.E. and J.J. Westerink, "Non-Diffusive N+2 Degree Petrov-Galerkin Methods for Two-Dimensional Transient Transport Computations," ***International Journal for Numerical Methods in Engineering***, **30**, 397-418, 1990.

7. Luettich, R.A. and J.J. Westerink, "A Solution for the Vertical Variation of Stress, Rather than Velocity, in a Three-Dimensional Circulation Model," ***International Journal for Numerical Methods in Fluids***, **12**, 911-928, 1991.

8. Westerink, J.J. and W.G. Gray, "Progress in Surface Water Modeling," ***Reviews of Geophysics***, **29**, April Supplement, 210-217, 1991.

9. Westerink, J.J., R.A. Luettich, A.M. Baptista, N.W. Scheffner and P. Farrar, "Tide and Storm Surge Predictions Using a Finite Element Model," ***Journal of Hydraulic Engineering***, **118**, 1373-1390, 1992.

10. Cantekin, M.E., J.J. Westerink and R.A. Luettich, "Low and Moderate Reynolds Number Transient Flow Simulations Using Space Filtered Navier Stokes Equations," ***Numerical Methods for Partial Differential Equations***, **10**, 491-524, 1994.

11. Kolar, R.L., J.J. Westerink, M.E. Cantekin and C.A. Blain, "Aspects of Nonlinear Simulations Using Shallow Water Models Based on the Wave Continuity Equation," ***Computers and Fluids***, **23**, 3, 523-538, 1994.

12. Kolar, R.L., W.G. Gray, J.J. Westerink and R.A. Luettich, "Shallow Water Modeling in Spherical Coordinates: Equation Formulation, Numerical Implementation and Application," ***Journal of Hydraulic Research***, **32**, 1, 3-24, 1994.

13. Westerink, J.J., R.A. Luettich and J.C. Muccino, "Modeling Tides in the Western North Atlantic Using Unstructured Graded Grids," ***Tellus***, **46A**, 178-199, 1994.

14. Westerink, J.J., R.A. Luettich, J.K. Wu and R.L. Kolar, "The Influence of Normal Flow Boundary Conditions on Spurious Modes in Finite Element Solutions to the Shallow Water Equations," ***International Journal for Numerical Methods in Fluids***, **18**, 1021-1060, 1994.

15. Luettich, R.A., S. Hu and J.J. Westerink, "Development of the Direct Stress Solution Technique for Three Dimensional Hydrodynamic Models Using Finite Elements," ***International Journal for Numerical Methods in Fluids***, **19**, 295-319, 1994.

16. Blain, C.A., J.J. Westerink and R.A. Luettich, "The Influence of Domain Size on the Response Characteristics of a Hurricane Storm Surge Model," ***Journal of Geophysical Research***, **99, C9**, 18467-18479, 1994.

17. Grenier, R.R., R.A. Luettich and J.J. Westerink, "A Comparison of the Nonlinear Frictional Characteristics of Two-Dimensional and Three-Dimensional Models of a Shallow Tidal Embayment," ***Journal of Geophysical Research***, **100, C7**, 13719-13735, 1995.

18. Kolar, R.L., W.G. Gray and J.J. Westerink, "Boundary Conditions in Shallow Water Models - An Alternative Implementation for Finite Element Codes," ***International Journal for Numerical Methods in Fluids***, **22**, 603-618, 1996.

19. Blain, C.A., J.J. Westerink and R.A. Luettich, "Grid Convergence Studies for the Prediction of Hurricane Storm Surge," ***International Journal for Numerical Methods in Fluids***, **26**, 369-401, 1998.

20. Hagen, S.C., J.J. Westerink and R.L. Kolar, "One-Dimensional Finite Element Grids Based on a Localized Truncation Error Analysis," ***International Journal for Numerical Methods in Fluids*, 32**, 241-261, 2000.

21. Hagen, S.C., J.J. Westerink, R.L. Kolar and O. Horstmann, "Two Dimensional Unstructured Mesh Generation for Tidal Models," ***International Journal for Numerical Methods in Fluids***, **35**, 669-686, 2001.

22. Atkinson, J.H., J.J. Westerink and J.M. Hervouet, "Similarities between the Quasi-Bubble and the Generalized Wave Continuity Equation Solutions to the Shallow Water Equations," ***International Journal for Numerical Methods in Fluids***, **45,** 689-714, 2004.

23. Atkinson, J.H., J.J. Westerink and R.A. Luettich, "Two-Dimensional Dispersion Analysis of Finite Element Approximations to the Shallow Water Equations," ***International Journal for Numerical Methods in Fluids***, **45,** 715-749, 2004.

24. Bunya, S., J.J. Westerink and S. Yoshimura, "Discontinuous Boundary Implementations for the Shallow Water Equations," ***International Journal for Numerical Methods in Fluids***, **47**, 1451-1468, 2005.

25. Bunya, S., S. Yoshimura and J.J. Westerink, "Improvements in the Mass Conservation Using Alternative Boundary Implementations for a Quasi Bubble Finite Element Shallow Water Model," ***International Journal for Numerical Methods in Fluids***, **51**, 1277-1296**,** 2006.

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28. Kubatko, E.J., J.J. Westerink and C. Dawson, "*hp* Discontinuous Galerkin Methods for Advection Dominated Problems in Shallow Water Flow," ***Computer Methods in Applied Mechanics and Engineering***, **196**, 437-451, 2006.

29. Ebersole, B.A., D. Resio, and J.J. Westerink, "A Community Approach to Improved Prediction and Characterization of Coastal Storm Hazards," ***Marine Technology Society Journal,*** **40**, 4, 56-68, 2006/2007.

30. Kubatko, E.J and J.J. Westerink, "Exact Discontinuous Solutions of Exner's Bed Evolution Model: Simple Theory for Sediment Bores," ***Journal of Hydraulic Engineering,*** **133**, 305-311, 2007.

31. Kubatko, E.J., J.J. Westerink and C. Dawson, "Semi-discrete Discontinuous Galerkin Methods and Stage Exceeding Order Strong Stability Preserving Runge-Kutta Time Discretizations," ***Journal of Computational Physics,*** **222**, 832-848, 2007.

32. Westerink, J.J., R.A. Luettich , J.C. Feyen, J.H. Atkinson, , C. Dawson, H.J. Roberts, M.D. Powell, J.P. Dunion, E.J. Kubatko, H. Pourtaheri, "A Basin to Channel Scale Unstructured Grid Hurricane Storm Surge Model Applied to Southern Louisiana," ***Monthly Weather Review***, **136**, 3, 833-864, 2008.

33. Resio, D.T. and J.J. Westerink, "Hurricanes and the Physics of Surges," ***Physics Today***, **61**, 9, 33-38, 2008.

34. Kubatko, E.J., C. Dawson, J.J. Westerink, "Time Step Restrictions for Runge-Kutta Discontinuous Galerkin Methods on Triangular Grids," ***Journal Computational Physics,*** **227**, 9697-9710, 2008.

35. Bunya S. and J.J. Westerink, "Hurricane Katrina Storm Surge Hindcast Using a Coupled Storm Surge, Wind Wave, and Tidal Current Model on an Unstructured Grid," (in Japanese), ***Annual Journal of Coastal Engineering, Japan Society of Civil Engineers,*** **55**, 316-320, 2008.

36. Bunya, S., E.J. Kubatko, J.J. Westerink, C. Dawson, "A Wetting and Drying Treatment for the Runge-Kutta Discontinuous Galerkin Solution to the Shallow Water Equations," ***Computer Methods in Applied Mechanics and Engineering,*** **198**, 1548-1562, 2009.

37. Kubatko, E.J., S. Bunya, C. Dawson, J.J. Westerink, "Dynamic *p*-adaptive Runge-Kutta Discontinuous Galerkin Methods for the Shallow Water Equations," ***Computer Methods in Applied Mechanics and Engineering,*** **198**, 1766-1774, 2009.

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39. Bunya, S., J.C. Dietrich, J.J. Westerink, B.A. Ebersole, J.M. Smith, J.H. Atkinson, R. Jensen, D.T. Resio, R.A. Luettich, C. Dawson, V.J. Cardone, A.T. Cox, M.D. Powell, H.J. Westerink, H.J. Roberts, "A High Resolution Coupled Riverine Flow, Tide, Wind, Wind Wave and Storm Surge Model for Southern Louisiana and Mississippi: Part I - Model Development and Validation," ***Monthly Weather Review***, **138**, 345–377, 2010.

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41. Ebersole, B.A., J.J. Westerink, S. Bunya, J.C. Dietrich, M.A. Cialone, "Development of Storm Surge Which Led to Flooding in St. Bernard Polder during Hurricane Katrina," ***Ocean Engineering***, **37**, 91-103, 2010.

42. Wirasaet, D., S. Tanaka, E.J. Kubatko, J.J. Westerink, C. Dawson, "A Performance Comparison of Nodal Discontinuous Galerkin Methods on Triangles and Quadrilaterals," ***International Journal for Numerical Methods in Fluids***, **64**, 1336-1362, 2010.

43. Forbes, C., R.A. Luettich, C.A. Mattocks, J.J. Westerink, "A Retrospective Evaluation of the Storm Surge Produced by Hurricane Gustav (2008): Forecast and Hindcast Results," ***Weather and Forecasting***, **25**, 6, 1577-1602, 2010.

44. Dietrich, J.C., M. Zijlema, J.J. Westerink, L.H. Holthuijsen, C. Dawson, R.A. Luettich, R. Jensen, J.M. Smith, G.S. Stelling, G.W. Stone, "Modeling Hurricane Waves and Storm Surge using Integrally-Coupled, Scalable Computations," ***Coastal Engineering***, **58**, 45-65, 2011.

45. Mirabito, C., C. Dawson, E.J. Kubatko, J.J. Westerink, S. Bunya, "Implementation of a Discontinuous Galerkin Morphological Model on Two-Dimensional Unstructured Meshes," ***Computer Methods in Applied Mechanics and Engineering***, **200**, 189-207, 2011.

46. Tanaka, S., S. Bunya, J.J. Westerink, C. Dawson, R.A. Luettich, "Scalability of an Unstructured Grid Continuous Galerkin Based Hurricane Storm Surge Model," ***Journal of Scientific Computing***, **46**, 329-358**,** 2011.

47. Dawson, C. E.J. Kubatko, J.J. Westerink, C. Trahan, C. Mirabito, C. Michoskia, N. Pandaa, "Discontinuous Galerkin Methods for Modeling Hurricane Storm Surge," ***Advances in Water Resources***, **34**, 1165-1176, 2011.

48. Dietrich, J.C., J.J. Westerink, A.B. Kennedy, J.M. Smith, R. Jensen, M. Zijlema, L.H. Holthuijsen, C. Dawson, R.A. Luettich, Jr., M.D. Powell, V.J. Cardone, A.T. Cox, G.W. Stone, H. Pourtaheri, M.E. Hope, S. Tanaka, L.G. Westerink, H.J. Westerink, Z. Cobell, "Hurricane Gustav (2008) Waves, Storm Surge and Currents: Hindcast and Synoptic Analysis in Southern Louisiana," ***Monthly Weather Review***, **139**, 2488-2522, DOI 10.1175/2011MWR3611.1, 2011.

49. Kennedy, A.B., U. Gravois, B.C. Zachry, J.J. Westerink, M.E. Hope, J.C. Dietrich, M.D. Powell, A.T. Cox, R.A. Luettich Jr., R.G. Dean, "Origin of the Hurricane Ike Forerunner Surge," ***Geophysical Research Letters***, **38**, L08608, 2011.

50. Michoski, C., C. Mirabito, C. Dawson, D. Wirasaet, E.J. Kubatko, J.J. Westerink, "Dynamic p-enrichment schemes for multicomponent reactive flows," ***Advances in Water Resources***, **34**, 1666-1680, doi:10.1016/j.advwatres.2011.09.001, 2011.

51. Michoski, C., C. Mirabito, C. Dawson, D. Wirasaet, E.J. Kubatko, J.J. Westerink, "Adaptive Hierarchic Transformations for Dynamically p-enriched Slope-limiting over Discontinuous Galerkin Systems of Generalized Equations," ***Journal of Computational Physics***, **230**, 22, 8028-8056, 2011.

52. Dietrich, J.C., S. Tanaka, J.J. Westerink, C.N. Dawson, R.A. Luettich, Jr., M. Zijlema, L.H. Holthuijsen, J.M. Smith, L.G. Westerink, H.J. Westerink, "Performance of the Unstructured-Mesh, SWAN+ADCIRC Model in Computing Hurricane Waves and Surge" ***Journal of Scientific Computing***, **52**, 468-497 2012.

53. Dietrich, J.C., Trahan, C.J., Howard, M.T., Fleming, J.G., Weaver, R.J., Tanaka,S., Yu, L., Luettich Jr., R.A., Wells, G., Dawson, C.N., Westerink, J.J., Lu, A., Vega, K., Kubach, A., Dresback, K.M., Kolar, R.L., Kaiser, C., Twilley, R.R.," Surface Trajectories of Oil Transport along the Northern Coastline of the Gulf of Mexico, ***Continental Shelf Research***, DOI 10.1016/j.csr.2012.03.015, **41**, 17-47, 2012.

54. Kennedy, A.B., J.J. Westerink, J.M. Smith, M.E. Hope, M. Hartman, A. Taflanidis, S. Tanaka, H. Westerink, K. Cheung, T. Smith, M. Hamann, M. Minamide, A. Ota, C. Dawson, "Tropical cyclone inundation potential on the Hawaiian Islands of Oahu and Kauai," ***Ocean Modelling***, **52-53**, 54-68, 2012.

55. Kerr, P., J. Westerink, J. Dietrich, R. Martyr, S. Tanaka, D. Resio, J. Smith, H. Westerink, L. Westerink, T. Wamsley, M. van Ledden, W. DeJong, "Surge Generation Mechanisms in the Lower Mississippi and Discharge Dependency," ***Journal of Waterway, Port, Coastal, and Ocean Engineering***, DOI 10.1061/(ASCE)WW.1943-5460.0000185, **139,** 326-335, 2013.

56. Taflanidis, A., A. Kennedy, J. Westerink, J. Smith, K. Cheung, M. Hope, S. Tanaka, "Rapid Assessment of Wave and Surge Risk during Landfalling Hurricanes: a Probabilistic Approach", ***Journal of Waterway, Port, Coastal, and Ocean Engineering***, **139**, 171-182, 2013.

57. Resio, D.T., J.L. Irish, J.J. Westerink, N.J. Powell, "The Effect of Uncertainty on Estimates of Hurricane Surge Hazards," ***Natural Hazards***, **66**, 1443-1459, 2013.

58. Martyr, R., J. Dietrich, J. Westerink, P. Kerr, C. Dawson, J. Smith, H. Pourtaheri, N. Powell, M. Van Ledden, S. Tanaka, H. Roberts, H. Westerink, L. Westerink, "Simulating Hurricane Storm Surge in the Lower Mississippi River under Varying Flow Conditions," ***Journal of Hydraulic Engineering***, **139**, 5, 492-501, 2013.

59. Zhang, Y., A. Kennedy, N. Panda, C. Dawson, J. Westerink, "Boussinesq-Green-Naghdi Rotational Water Wave Theory," ***Coastal Engineering***, **73**, 13-27, 2013.

60. Dawson, C., C. J. Trahan , E.J. Kubatko, J.J. Westerink, " A Parallel Local Timestepping Runge–Kutta Discontinuous Galerkin Method with Applications to Coastal Ocean Modeling," ***Computer Methods in Applied Mechanics and Engineering***, **259**, 154-165, 2013.

61. Dietrich, J., M. Zijlema, P. Allier, L. Holthuijsen, N. Booij, J. Meixner, J. Proft, C. Dawson, C. Bender, A. Naimaster, J. Smith, J. Westerink, "Limiters for spectral propagation velocities in SWAN," ***Ocean Modeling***, http://dx.doi.org/10.1016/j.ocemod.2012.11.005, In Press, 2013.

62. Zachry, B.C.**,** J.L. Schroeder**,** A.B. Kennedy, J.J. Westerink**,** C.W. Letchford**,** and M.E. Hope, "A Case Study of Nearshore Drag Coefficient Behavior During Hurricane Ike (2008***)," Journal of Applied Meteorology and Climatology***, doi: 10.1175/JAMC-D-12-0321.1, In Press, 2013.

63. Zheng, Lianyuan, Robert H. Weisberg, Yong Huang, Rick A. Luettich, Joannes J. Westerink, Patrick Corbitt Kerr, Aaron Donahue, Gary Crane, and Linda Akli, "Implications from the comparisons between two- and three-dimensional model simulations of the Hurricane Ike storm surge, ***Journal of Geophysical Research: Oceans***, DOI: 10.1002/jgrc.20248, In Press, 2013.

64. Chen, Changsheng, Robert Beardsley , Rick Luettich , Joannes Westerink , Harry V. Wang , William Perrie , Qichun Xu , Aaron Donahue , Jianhua Qi , Huichan Lin , Liuzhi Zhao , Patrick Kerr , Yanqiu Meng , Bash Toulany, "IOOS/SURA Extratropical Storm Inundation Testbed: Inter-model (ADCIRC, FVCOM and SELFE) comparisons in Scituate, Massachusetts," ***Journal of Geophysical Research: Oceans***, In Revision, 2013.

65. Hope, Mark, Joannes Westerink , Andrew Kennedy , Patrick Kerr , Joel Dietrich , Clint Dawson , CJ Bender , Jane Smith , Robert Jensen , Marcel Zijlema , Leo Holthuijsen , Rick Luettich , Mark Powell , V. Cardone , Andrew Cox, Hasan Pourtaheri , Hugh Roberts , John Atkinson , Seizo Tanaka , Leendert Westerink, "Hindcast and Validation of Hurricane Ike (2008) Waves, Forerunner, and Storm Surge," ***Journal of Geophysical Research: Oceans***, DOI 10.1002/jgrc.20314, In Press, 2013.

66. Kerr, Patrick, Aaron Donahue , Joannes Westerink , Rick Luettich , Lianyuan Zheng , Robert Weisberg , Yong Huang , Harry Wang , Yi-Cheng Teng , David Forrest , Aron Roland , Amy Haase , Anne Kramer , Arthur Taylor , Jamie R. Rhome , Jesse Feyen , Richard Signell , Jeffrey Hanson , Mark Hope , Richard Estes , Richard Dominguez, Ryan Dunbar , Laura Semeraro , Andrew Kennedy , Jane Smith , Mark Powell , V. Cardone , Andrew Cox, "U.S. IOOS Coastal & Ocean Modeling Testbed: Inter-Model Evaluation of Tides, Waves, and Hurricane Surge in the Gulf of Mexico," ***Journal of Geophysical Research: Oceans***, In Review, 2013.

67. Kerr, Patrick, Rosanne Martyr, Aaron Donahue, Mark Hope, Joannes Westerink, Rick Luettich, Andrew Kennedy, Joel Dietrich, Clint Dawson, "U.S. IOOS Coastal and Ocean Modeling Testbed: Evaluation of Tide, Wave, and Hurricane Surge Response Sensitivities to Mesh Resolution and Friction in the Gulf of Mexico," ***Journal of Geophysical Research: Oceans,*** DOI 10.1002/jgrc.20305, In Press, 2013.

68. Michoski, C., C. Dawson, C. Mirabito, E.J. Kubatko, D. Wirasaet, J.J. Westerink, "Fully Coupled Methods for Multiphase Morphodynamics,"***Advances in Water Resources***, **59**, 95-110, 2013.

69. Wirasaet, D., E.J. Kubatko, C.E. Michoski, S. Tanaka, J.J. Westerink, C. Dawson, "Discontinuous Galerkin Methods with Nodal and Hybrid Modal/Nodal Triangular, Quadrilateral, and Polygonal Elements for Nonlinear Shallow Water Flow" ***Computer Methods in Applied Mechanics and Engineering***, In Revision, 2013.

TRADE JOURNAL PUBLICATIONS

1. Ledden, M. van, W. de Jong, J. Westerink, "New Orleans Wapent Zich met Robuuster Dijkontwerp," (in Dutch). ***Land + Water: Magazine voor Civiele- en Milieutechniek***, 19 Oktober , 16-17, 2007

2. Waart, M. van de, S. Hulscher, M. van de Ledden, J. Westerink, J. Mulder, W. de Jong, "Plaquemines Spillways Zijn een Sterk Alternatief voor Dijkverhoging in New Orleans," (in Dutch). ***$H_2 0$: Tijdschrift voor Watervoorziening and Waterbeheer***, 7, 17-19, 2010.

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1.***I*** Luettich, R.A. and J.J. Westerink, "Continental Shelf Scale Convergence Studies with a Barotropic Tidal Model," in Quantitative Skill Assessment for Coastal Ocean Models, D.R. Lynch and A.M. Davies, Editors, Coastal and Estuarine Studies Series, **47**, American Geophysical Union, Washington, D.C., 1995

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150. A. Donahue, J. Westerink, "A Boussinesq Scaling Approach to Solving Near Shore Phase Resolving Nonlinear Waves," XIX International Conference on Computational Methods in Water Resources, Urbana, IL, June 17-21, 2012.

TECHNICAL REPORTS

1. Harms, V.W., B. Safaie, S.N. Kam, and J.J. Westerink, "Computer Manual for Calculating Wave Height Distributions about Offshore Structures," WREE Report 79-4, Department of Civil Engineering, State University of New York at Buffalo, September 1979.

2. Harms, V.W. and J.J. Westerink, "Wave Transmission and Mooring-Force Characteristics of Pipe-Tire Breakwaters," Lawrence Berkeley Laboratory Report No. 11778, University of California, Berkeley, October 1980.

3. Harms, V.W., J.J. Westerink, R.M. Sorenson and J.E. McTamany, "Wave Transmission and Mooring-Force Characteristics of Pipe-Tire Breakwaters," CERC Technical Paper No. 82-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 1982.

4. Bishop, C.T., V.W. Harms and J.J. Westerink, "Pipe-Tire Breakwater Model Tests Data Report," Hydraulics Division Report L7R4A6, National Water Research Institute, Canada Centre for Inland Waters, Environment Canada, March 1982.

5. Westerink, J.J., J.J. Connor, K.D. Stolzenbach, E.E. Adams and A.M. Baptista, "TEA: A Linear Frequency Domain Finite Element Model for Tidal Embayment Analysis," Technical Report, M.I.T. Energy Laboratory, Cambridge, Mass., February 1984.

6. Westerink, J.J., K.D. Stolzenbach and J.J. Connor, "A Frequency Domain Finite Element Model for Tidal Circulation," Report No. MIT-EL 85-006, M.I.T. Energy Laboratory, Cambridge, Mass., 1985.

7. Westerink, J.J., E. Cantekin and D. Shea, "The Development of Higher Order Finite Element Upwinding Schemes for Convection Dominated Turbulent Flow Problems," Report No. COE-303, Ocean Engineering Program, Texas A&M University, 1988.

8. Westerink, J.J. and R.A. Luettich, "Review of Numerical Modeling Strategies for Predicting the Long Term Hydrodynamic Circulation for Estimating the Fate of Disposed Dredged Materials," Report No. COE-304, Ocean Engineering Program, Texas A&M University, 1989.

9. Westerink, J.J. and R.A. Luettich, "Tide and Storm Surge Predictions in the Gulf of Mexico Using Model ADCIRC-2D," Report to the US Army Engineer Waterways Experiment Station, July 1991.

10. Luettich, R.A., R.H. Birkhahn and J.J. Westerink, "Application of ADCIRC-2DDI to Masonboro Inlet, North Carolina: A Brief Numerical Modeling Study," Contractors Report to the US Army Engineer Waterways Experiment Station, August 1991.

11. Westerink, J.J., "Tidal Prediction in the Gulf of Mexico/Galveston Bay Using Model ADCIRC-2DDI," Contractors Report to the US Army Engineer Waterways Experiment Station, January 1993.

12. Blain, C.A., J.J. Westerink, R.A. Luettich and N.W. Scheffner, "Generation of a Storm Surge Time History Data Base From the Hindcast of Extratropical Storm Events from 1977-1992," Contractors report to the U.S. Army Engineer Waterways Experiment Station, December 1994.

13. Westerink, J.J. and R.A. Luettich, "Tidal Predictions for Galveston Bay, Texas Using Model ADCIRC-2DDI," Report to the Texas Water Development Board, State of Texas, Austin TX, December 1997.

14. Westerink, J.J., R.A. Luettich and A. Militello, "Leaky Internal-Barrier Normal-Flow Boundaries in the ADCIRC Coastal Hydrodynamics Code," Coastal and Hydraulic Engineering Technical Note IV-XX, U.S. Army Engineer Research and Development Center, Vicksburg MS, May 2001.

15. Wamsley, T.V., M.A. Cialone, J.J. Westerink and J.M. Smith, "Influence of Marsh Restoration and Degradation on Storm Surge and Waves," Coastal and Hydraulic Engineering Technical Note I-77, U.S. Army Engineer Research and Development Center, Vicksburg MS, July 2009.

OTHER INVITED LECTURES AND ADDRESSES

1. "A Frequency-Time Domain Finite Element Model for Tidal Circulation," Department of Civil Engineering, University of California at Berkeley, January 1984.

2. "Computations of Nonlinear Shallow Water Tidal Interactions using a General Spectral Finite Element Model," Department of Civil Engineering, The University of Delaware, May 1987.

3. "Numerical Modeling of Coastal Circulation," Naval Oceanographic Research and Development Activity, U.S. Navy, Bay St. Louis, MS, January 1988.

4. "Finite Element Modeling of Shallow Water Tidal Circulation," National Research Council, Ottawa, Canada, March 1989.

5. “Improved Finite Element Methods for Circulation and Transport in Coastal Seas,” Texas Institute for Computational Mechanics, The University of Texas at Austin, March 1989.

6. “Advances in Finite Element Modeling of Coastal Ocean Hydrodynamics,” Department of Civil Engineering, Chuo University, Tokyo, Japan, September 1996.

7. “Convergence and Grid Issues for Finite Element Solutions to the Shallow Water Equations,” Mexican Institute for Water Technology, Jiutepec, Mexico, November 1996.

8. “ADCIRC Overview and Perspective on 20 years of GWCE Based Modeling,” 4th Army-Navy ADCIRC Model Workshop, Naval Research Laboratory, Stennis Space Center, MS, February 20-21, 2001.

9. “ADCIRC Developments and Directions,” 5th ADCIRC Model Workshop, Naval Research Laboratory, Stennis Space Center, MS, February 2-4, 2001.

10. “ADCIRC Overview and Model Features,” “Modeling Strategy and Example Applications,” “Grays Harbor Grid Design and Parameter Selection,” Coastal Inlets Research Program, SMS Steering Module Workshop, U.S. Army Engineering Research and Development Center, Vicksburg, MS, July 29-August 2, 2002.

11. “Hurricane Hindcasts in Southern Louisiana Using a GWCE-based Finite Element Model,” Advisory Board Meeting, Louisiana State University Hurricane Center, Baton Rouge, LA, August 21, 2002.

12. “ADCIRC Progress and Development Report: Implementation of Discontinuous Galerkin Methods for Hydrodynamic and Transport Modeling,” Coastal Inlets Research Program Inlet Modeling System Sediment Transport and Morphology Change Team Meeting # 2, Ponte Vedra Beach, Fl, February 11, 2003.

13. “ADCIRC Tidal Data Bases, Implementation of Discontinuous Galerkin Methods for Hydrodynamic and Transport Modeling, ADCIRC Parallel Processing,” Coastal Inlets Research Program Inlet Modeling System Sediment Transport and Morphology Change Team Meeting # 2, Ponte Vedra Beach, Fl, February 11, 2003.

14. “Overview of the ADCIRC Model,” Florida Coastal Hydraulics Workshop, University of Central Florida, Orlando, FL, June 4-6, 2003.

15. “Louisiana Storm Surge Study,” Florida Coastal Hydraulics Workshop, University of Central Florida, Orlando, FL, June 4-6, 2003.

16. “Future Development of ADCIRC,” Florida Coastal Hydraulics Workshop, University of Central Florida, Orlando, FL, June 4-6, 2003.

17. “Storm Surge Flooding along the Southern Louisiana Coast,” ADCIRC Briefing to U.S. Army Corps of Engineers Management, U.S. Army Engineer Research and Development Center, Vicksburg, MS, June 9, 2003.

18. “Storm Surge Flooding Realities - ADCIRC Modeling,” Center for the Study of Public Health Impacts of Hurricanes, Advisory Committee Meeting, Louisiana State University, Baton Rouge, LA, September 15, 2003.

19. “Impact of Advances in High Performance Computing on Storm Surge Modeling,” Coastal and Environmental Modeling Laboratory, Advisory Committee Meeting, Louisiana State University, Baton Rouge, LA, September 30, 2003.

20. “Hurricane Storm Surge Calculations in Southern Louisiana Using a Finite Element Based Model,” Applied Mathematics Seminar, University of Notre Dame, Notre Dame, IN, October 13, 2003.

21. “Large Scale - Small Scale Applications of the ADCIRC Hydrodynamic Model,” Texas Water Development Board, State of Texas, Austin, TX, April 28, 2004.

22. “Storm Surge Modeling in the Gulf of Mexico Using ADCIRC,” Chester Jelesnianski Seminar in Ocean Engineering, Department of Civil Engineering, Texas A&M University, College Station, TX, April 29, 2004.

23. “An Overview of ADCIRC-IMS, A System of CG and DG Based Solutions for 2D and 3D Hydrodynamics and Transport,” U.S. Army Research and Development Center, Vicksburg, MS, September 8, 2004.

24. “Unstructured Grid Shallow Water Equation Applications and Algorithms,” Delft University of Technology, December 17, 2004.

25. “ADCIRC Storm Surge Computations in Southern Louisiana,” U.S. Army Corps of Engineers New Orleans District, Federal Emergency Management Agency - ADCIRC Meeting, February 16, 2005.

26. “Hindcasting Hurricane Katrina Using an Unstructured Grid Model for Southern Louisiana,” Notre Dame booth at Supercomputing 2005, Seattle WA, November 16, 2005.

27. “The Impact of Hurricane Katrina and Predicting Storm Surges in Southern Louisiana,” Scholars in the classroom series, Kaneb Center for Teaching and Learning, University of Notre Dame, Notre Dame, IN, February 23, 2006.

28. “An Overview of Hurricane Inundation Modeling in the Gulf of Mexico and the Need for Statistical Quantification of High Impact Very Low Frequency Events,” Workshop on Stochastic Modeling, Center for Applied Mathematics, University of Notre Dame, Notre Dame, IN, March 26, 2006.

29. “The Impact of Hurricane Katrina and Predicting Storm Surges in Southern Louisiana,” Interdisciplinary Studies in Tsunami Impacts and Mitigation, Research Experience for Undergraduates, Department of Civil Engineer and Geological Sciences, University of Notre Dame, Notre Dame, IN, June 14, 2006.

30. “Modeling Hurricane Storm Surge along the Gulf Coast in the Wake of Katrina – Towards Petaflop Computations,” Workshop on Scientific Computing, Center for Research Computing, University of Notre Dame, Notre Dame, IN, May 15, 2007.

31. “The Impact of Hurricane Katrina and Predicting Storm Surges in Southern Louisiana,” Interdisciplinary Studies in Tsunami Impacts and Mitigation, Research Experience for Undergraduates, Department of Civil Engineer and Geological Sciences, University of Notre Dame, Notre Dame, IN, July 11, 2007.

32. “Modeling Hurricane Storm Surge along the Gulf Coast in Southern Louisiana – Towards Petaflop Computations,” Department of Civil and Environmental Engineering, University of New Orleans, New Orleans, LA, September 25, 2008.

33. “Modeling Hurricane Storm Surge along the Gulf Coast in Southern Louisiana – Towards Petaflop Computations,” School of Marine and Atmospheric Sciences, State University of New York, Stony Brook, NY, October 10, 2008.

34. “Massively Parallel Coastal Ocean Flow and Wind Wave Simulations,” Department of Computer Science and Engineering Seminar Series, University of Notre Dame, IN, December 11, 2008.

35. “FEMA DFIRM Mapping and Quality Assurance Process,” with Gary Zimmerer, Robert Dean, Billy Edge, Don Resio, Louisiana Coastal Protection and Restoration Authority, DFIRM Committee Meeting, Louisiana Capital Building, Baton Rouge, LA, March 12, 2009.

36. “High Resolution Unstructured Scalable Hurricane Wave and Storm Surge Models in the Gulf of Mexico,” NOAA’s Gulf of Mexico Unstructured Grid Catalog Workshop, Bay St. Louis, MS, March 17-18, 2009.

37. “High Resolution High Performance Scalable Hurricane Wave and Storm Surge Modeling in Southern Louisiana,” 2009 Tulane Engineering Forum, New Orleans, LA, April 3, 2009.

38. “Next Steps in Improving the Physics of Storm Surge Models,” Computational Mechanics Laboratory, Chuo University, Tokyo, Japan, March 30, 2009.

39. “UnSWAN+ADCIRC: High Resolution High Performance Coupled Wave and Current Modeling on Unstructured Grids,” Office of Naval Research Physical Oceanography Program Review, Chicago, IL, June 11, 2009.

40. “Next Steps in Hurricane Storm Surge Modeling,” Delft University, Delft, Netherlands, June 23, 2009.

41. “Modeling Hurricane Waves and Storm Surge using Integrated Tightly Coupled Scalable Computations,” FM Global, Boston, MA, July 14, 2009.

42. “Modeling Hurricane Waves and Storm Surge in Coastal Texas, Louisiana and Mississippi using Integrated Tightly Coupled Scalable High Performance Computations,” Iowa Institute for Hydraulic Research, College of Engineering, University of Iowa, October 2, 2009.

43. “Modeling Storm Surge and Waves,” Hurricane Storm Surge Modeling Workshop, Southeast Louisiana Flood Protection Authority – East, New Orleans, LA, January 26, 2010.

44. “ADCIRC Modeling, Surge Propagation up the Mississippi River,” Hurricane and Storm Damage Risk Reduction System/Mississippi River Levees Design Summit, U.S. Army Corps of Engineers New Orleans District, New Orleans, LA, January 27, 2010.

45. “Computing Hurricane Ike Waves, Forerunner, and Surge: Slow and Fast Processes from the Louisiana-Texas Shelf to San Jacinto Bay,” Institute for Computational Engineering and Sciences, University of Texas at Austin, February 26, 2010.

46. “Computing Hurricane Ike Waves, Forerunner, and Surge: Slow and Fast Processes from the Louisiana-Texas Shelf to San Jacinto Bay,” College of Engineering Retired Faculty Lunch Seminar, University of Notre Dame, March 3, 2010.

47. “Computing Hurricane Ike Waves, Forerunner, and Surge: Slow and Fast Processes from the Louisiana-Texas Shelf to San Jacinto Bay,” Coast Survey Development Laboratory, National Ocean Service, NOAA, March 11, 2010.

48. “Towards Scalable Integrated Hurricane Wave and Current Modeling Systems,” U.S. Army Corps of Engineers and NOAA/Pacific Climate Information System Workshop on Climate Change and Variability, and its Implications to Planning and Design for Coastal Flooding and Erosion in the Pacific, Scripps Institution of Oceanography, July 13-14, 2010.

49. “Computing Hurricanes Gustav and Ike Waves and Surge: Slow and Fast Processes on the Louisiana-Texas Shelf and Coast,” Ocean Engineering Program, Department of Civil Engineering, Texas A&M University, October 14, 2010.

50. “High Performance Scalable Hurricane Wave and Surge Simulations,” Scientific Computing Workshop, Center for Research Computing, University of Notre Dame, February 23, 2011.

51. “High Performance Scalable Computations of Hurricane Driven Wind Waves, Storm Surge, and Flow in Integrated Basin to Shelf to Inland Floodplain Systems,” College of Engineering and Computer Sciences, University of Central Florida, March 4, 2011.

52. “The Evolution of Hurricanes Gustav and Ike,” Louisiana Floodplain Management Association, Lafayette, LA, April 27-29, 2011.

53. “High Performance Scalable Computations of Hurricane Driven Wind Waves, Storm Surge, and Flow in Integrated Ocean Basin to Shelf to Inland Floodplain Systems,” Department of Physics, University of Notre Dame, October 12, 2011.

54. “Storm Surge Modeling,” TXCHART Technical Workshops, Port Arthur, Seabrook, Victoria, Corpus Chisti, Harlingen, Texas, December 6-15, 2011.

54. “High Performance Scalable Computations of Hurricane Driven Wind Waves, Storm Surge, and Flow in Integrated Ocean Basin to Shelf to Inland Floodplain Systems,” Department of Civil and Environmental Engineering, University of Illinois, Urbana, IL, March 9, 2012.

SPONSORED RESEARCH

1. National Science Foundation: Grant EET-8718436, September 1987 - December 1989, “Improved Computations for Convection Dominated Turbulent Flow Problems Using the Fractional Step Method,” Principal Investigator; Award $59,978.

2. Texas A&M Engineering Excellence Award: April 1988 - March 1989, "Development of Filtered Solution Techniques for Turbulent Flow Simulation," Principal Investigator; Award $15,000.

3. U.S. Army Engineer Waterways Experiment Station, Grant DACW39-86-D-0004/0001, July 1988 - December 1989, "Development of a Two-Dimensional Numerical Model for Estimating the Long Term Fate of Dredged Material," Principal Investigator; Award $116,093.

4. National Science Foundation Offshore Technology Research Center: Grant CDR-8721512-Project 6300A13, October 1988 - September 1989, "Forces on Slender Structures," Co-principal Investigator with Jun Zhang, Texas A&M University; Award $96,630.

5. U.S. Army Engineers Waterways Experiment Station, Grant DACW39-86-D-0004/0002, August 1989 - September 1990, "New York Bight Model Feasibility Study," Principal Investigator; Award $54,335.

6. National Science Foundation Offshore Technology Research Center: Grant CDR-8721512-Project 6300A13, October 1989 - September 1990, "Forces on Slender Structures," Co-principal Investigator with Jun Zhang, Texas A&M University; Award $81,217.

7. U.S. Army Engineers Waterways Experiment Station, Grant DACW39-90-M-2965, April 1990 - September 1990, "A Storm Surge Application of the DRP Circulation Model to the Gulf of Mexico," Principal Investigator; Award $21,457.

8. U.S. Army Engineers Waterways Experiment Station, Grant DACW 39-90-K-0021, May 1990 - September 1994, "Two-Dimensional and Three-Dimensional Tidal and Storm Surge Circulation Computations for the Western Atlantic Shelf and the Gulf of Mexico," Principal Investigator with R.A. Luettich, University of North Carolina at Chapel Hill; Award $375,302

9. National Science Foundation Offshore Technology Center: Grant CDR-8721512; October 1990 - November 1992, "Turbulent Flow Modeling with Space-Time Filtered Solutions to the Navier Stokes Equations," Principle Investigator; Award $30,210.

10. U.S. Army Engineers Waterways Experiment Station, Grant DACW 39-92-M-0352, December 1991 - June 1992, "Tidal Predictions in Galveston Bay Using the Gulf of Mexico Model," Principal Investigator; Award $9,443.

11. U.S. Army Engineers Waterways Experiment Station, October 1994 - January 2000, Grant DACW 39-95-K-0011, "Enhancements of the ADCIRC Model for the Analysis of Coastal Inlet Hydrodynamics," Principal Investigator with R.A. Luettich, University of North Carolina at Chapel Hill; Award $343,265.

12. Texas Water Development Board, November 1994 - December 1995, "Computer Simulation of Water Movement and Salinity Transport in Galveston Bay, Texas," Principal Investigator; Award $15,000.

13. U.S. Army Engineers Waterways Experiment Station, May 1995 - December 1996, "Development of Second Generation Long Wave Hydrodynamic Databases for U.S. Coastal and Continental Margin Waters," Principal Investigator with R.A. Luettich, University of North Carolina at Chapel Hill; Award $114,721.

14. U.S. Naval Research Laboratory, April 1997 - September 1999, "Development and Application of a Prognostic 3 Dimensional Baroclinic Capability in the ADCIRC Hydrodynamic Model," Co-Principal Investigator with R.A. Luettich, University of North Carolina at Chapel Hill; Amount $131,972.

15. Army Research Office, April 1998 - March 1999, Grant DAAG55-98-1-0091, "Scalable Meta-Computing in Computational Sciences and Engineering," Co-Principal Investigator with A. Lumsdaine, N. Chrisochoides, E. Maginn, M. Stadtherr and R. Stevenson, University of Notre Dame; Amount $400,000.

16. Texas Water Development Board, State of Texas, September 1998 - August 1999, "Baroclinic Hydrodynamic Simulations for the Texas Gulf Coast and Gulf of Mexico," Principal Investigator; Award $21,000.

17. Texas Water Development Board, State of Texas, September 1999 - January 2001, "ADCIRC Model for Shelves, Coasts and Estuaries to the Texas Gulf Coast," Principal Investigator; Award $21,000.

18. University of Notre Dame Graduate School, Equipment Restoration Fund, January 2000, "Scalable Meta-Computing for High Performance Computational Science and Engineering," Co-Principal Investigator with A.

Lumsdaine, N. Chrisochoides, E. Maginn, M. Stadtherr and R. Stevenson, University of Notre Dame; Amount $200,000.

19. U.S. Army Engineer Research and Development Center, February 2000 - January 2005, Grant DACW 42-00-C-0006, “ADCIRC Hydrodynamic Circulation and Transport Code Development and Applications,” Principal Investigator with R.A. Luettich, University of North Carolina at Chapel Hill; Award $674,450.

20. U.S. Army Corps of Engineers, New Orleans District, September 2000 - August 2001, Grant DACW29-00-C-0085, “Modifications of the ADCIRC-NO Hurricane Model to Enhance Robustness, Accuracy and Ease of Implementation,” Principal Investigator; Award $247,928.

21. National Science Foundation, September 2001 - August 2004, “Adaptive Multinumeric Finite Element Methods for Shallow Water Flow,” Co-Principal Investigator with C. Dawson at University of Texas at Austin; Award to Notre Dame $77,322.

22. Texas Water Development Board, State of Texas, June 2001- May 2002, “ADCIRC Model for Shelves, Coasts and Estuaries to the Texas Gulf Coast,” Principal Investigator; Award $21,000.

23. Millennium Trust, Health Excellence Fund, State of Louisiana/ Subcontract through Louisiana State University Hurricane Center, January 2002 - December 2005, “Hydrodynamic Modeling of Flooding Events in Southern Louisiana,” Principal Investigator; Award to Notre Dame $209,846.

24. Texas Water Development Board, State of Texas, July 2002- June 2003, “ADCIRC Model for Shelves, Coasts and Estuaries to the Texas Gulf Coast,” Principal Investigator; Award $20,000.

25. Sun Microsystems Matching Equipment Grant Program Q4 FY03, July 2003, Principal Investigator; Award $40,896.50.

26. U.S. Army Engineer Research and Development Center, February 2005 - January 2007, Grant W912HZ-05-C-0022, “ADCIRC-CZMS Coastal Zone Modeling System for Circulation, Transport and Morphology: Development and Applications,” Principal Investigator; Award $445,506.

27. Offshore and Coastal Technologies Inc., May 2005 - August 2005, “Chesapeake Bay Sediment Hydrodynamic Modeling,” Principal Investigator; Award $15,000.

28. U.S. Army Corps of Engineers, New Orleans District, September 2005, Addition to Grant W912HZ-05-C-0022, “Category 5 Hurricane Protection for Louisiana Study,” Principal Investigator; Award $77,760.

29. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc. as project managers for FEMA and USACE New Orleans District), October 2005 - October 2006, “Development of a Gulf of Mexico Storm Surge Model from Texas to Florida,” Principal Investigator, Award $141,000.

30. U.S. Army Corps of Engineers, Mobile District, November 2005 – November 2008, contract W91278-05-D-0018/003 (through Woolpert Inc. as part of a project funded through a direct Congressional appropriation), “Morphos 3D Long Wave Hydrodynamic Modeling,” Principal Investigator; Award $175,095.

31. Office of Naval Research, December 2005 – September 2009, “Wave and Circulation Modeling on Unstructured Grids,” Principal Investigator with C. Dawson at the University of Texas at Austin and R.A. Luettich at the University of North Carolina at Chapel Hill; Award $452,910.

    (This project is in cooperation with a separately ONR funded parallel project entitled “A Spectral Shallow Water Wave Model with Nonlinear Energy and Phase Evolution” by L.H. Holthuijsen and G.S. Stelling at Delft University of Technology)

32. National Aeronautics and Space Administration, May 2006 - April 2009, “Topographic and Hydrologic Modeling Constraints on Martian Channel Flow and Erosion,” Co-Principal Investigator with Principal Investigator S. Sakimoto at the University of Notre Dame and Collaborators L. Keszthelyi of the United States Geological Survey and R. Williams of the Planetary Science Institute; Award $99,239.

33. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc. as project managers for FEMA and USACE New Orleans District), November 2006 – November 2007, “USACE/FEMA Storm Surge Modeling Study-Phase I: Eastern Louisiana,” Principal Investigator, Award $531,260.

34. U.S. Army Engineer Research and Development Center, October 2006 - March 2007, "Regional Hydrodynamics Task Co-leadership and Storm Surge Analysis and Modeling," Principal Investigator; $299,644.

35. National Science Foundation, September 2006 – August 2009, "CMG Collaborative Research: Adaptive Numerical Methods for Shallow Water Circulation with Applications to Hurricane Storm Surge Modeling," Co-Principal Investigator with C. Dawson at the University of Texas at Austin and R.A. Luettich at the University of North Carolina at Chapel Hill; Project Award $600,000, Award to Notre Dame $207,723.

36. National Science Foundation, October 2007 – September 2012, "Collaborative Research: NSF PetaApps Storm Surge Modeling on Petascale Computers," Co-Principal Investigator with C. Dawson at the University of Texas at Austin and A. Spagnuolo, Oakland University. Award $1,600,000; Award to Notre Dame $503,809.

37. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc. as project managers for USACE New Orleans District), January 2008 – December 2008, "IHNC Storm Surge Study for USACE HPO," Principal Investigator, Award: $51,770.

38. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc. as project managers for FEMA and USACE New Orleans District), January 2008 - June 2010, "USACE/FEMA Storm Surge Modeling Study of the Texas Coast," Principal Investigator, Award: $323,594.

39. U.S. Army Corps of Engineers, Philadelphia District, April 2008 – June 2009, "USACE - Developing Advanced Hurricane Storm Surge Modeling Capabilities – Research Needs," Principal Investigator, Award: $72,723.

40. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc. as project managers for FEMA and USACE New Orleans District), April 2008 – December 2008, "USACE - St. Charles Parish Surge Sensitivity Analysis," Principal Investigator, Award: $8,000.

41. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc. as project managers for FEMA and USACE New Orleans District), April 2008 – December 2008, "USACE – Mississippi River Surge Propagation," Principal Investigator, Award: $14,700.

42. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc. as project managers for FEMA and USACE New Orleans District), May 2008 – December 2008, "USACE – IHNC Hydroperiod Analysis," Principal Investigator, Award: $5,000.

43. Sun Microsystems Matching Equipment Grant Program, June 2008, Principal Investigator; Award $153,499.

44. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc. as project managers for FEMA and USACE New Orleans District), May 2009 – June 2010, "Mississippi River Model Refinements," Principal Investigator, Award: $44,500.

45. U.S. Army Engineer Research and Development Center, July 2009 – July 2012, "Hurricane Inundation Risk in the North Pacific Ocean," Co-Principal Investigator with A. Kennedy and A. Taflanidis at the University of Notre Dame, Award $598,033.

46. U.S. Army Corps of Engineers, New Orleans District October 2009 – May 2010, (through Arcadis Inc. as project managers for FEMA and USACE New Orleans District), "Comprehensive Services in Support of New Orleans District West Shore Lake Pontchartrain Protection Projects," $47,030.

47. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc. as project managers for FEMA and USACE New Orleans District), November 2009 – December 2010, "USACE/FEMA Storm Surge Modeling," $98,700.

48. FM Global, April 2010 – August 2012, "Combined Wind-Wave, Surge, and Rainfall-Runoff Processes in Evaluating Coastal Inundation During Hurricanes," $257,010.

49. University of Notre Dame Strategic Academic Planning Committee, "ND Environmental Change Initiative (ND-ECI)", September 2009, full grant, Co-Principal Investigator with Principal Investigator David Lodge,

50. University of Notre Dame Strategic Academic Planning Committee, "CYBER-EYE: A Cyber-Collaboratory for National Risk Modeling and Assessment to Mitigate the Impacts of Hurricanes in a Changing Climate", September 2009, seed grant, Co-Principal Investigator with Principal Investigator Tracy Kijweski-Correa.

51. National Science Foundation, Office of Cyberinfrastructure, "Collaborative Research: Extension of the ADCIRC Coastal Circulation Model for Predicting Near Shore and Inner Shore Transport of Oil from the Horizon Oil Spill," June 2010 – May 2011, Award $200,000, Award to Notre Dame $59,863. Additional University of Notre Dame Cost Share $50,273.

52. Department of Homeland Security, "Supplemental Funding Request for the Application of the ADCIRC Coastal Circulation Model for Predicting Near Shore and Inner Shore Transport of Oil from the Horizon Oil Spill," July 1, 2010 – June 30, 2011, $52,000.

53. IOOS NOAA, "Total Water Level and Inundation Component of Super-regional Testbed to Improve Models of Environmental Processes on the US Atlantic and Gulf of Mexico Coasts," June 1, 2010 – December 31, 2011, $174,000.

54. National Science Foundation, "CMG Collaborative Research: Simulation of Wave-Current Interaction Using Novel, Coupled and Non Phase and Phase Resolving Wave and Current Models," October 1, 2010 – August 31, 2013, Principal Investigator with A. Kennedy at the University of Notre Dame, Clint Dawson at the University of Texas at Austin and Ethan Kubatko at the Ohio State University., Award $500,000, Award to Notre Dame $248,815, Additional University of Notre Dame Cost Share $18,967.

55. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc. as project managers for FEMA and USACE New Orleans District), "Comprehensive Services in Support of New Orleans District Atchafalaya River Surge Model," August 27, 2010 – December 13, 2010, $70,000.

56. U.S. Army Corps of Engineers, New Orleans District (through Arcadis Inc.), "Southwest Coastal Louisiana Hurricane Protection Project for ADCIRC and STWAVE Hydraulic Modeling," October 2010 – July 2011, $55,000.

57. Baker AECOM, "Region IV Coastal Develop ADCIRC Model," November 2010 – June 2013, $100,284.

58. U.S. Army Corps of Engineers, New Orleans District and Arcadis US Inc., "Comprehensive Services in Support of New Orleans Modeling Projects," January 2011 – July 2012, $218,448.

59. Arcadis US, Inc., "Southern Louisiana Model Development and Applications," January 2011 – October 2011, $111,000.

60. SURA, "University of Notre Dame Contribution to the US IOOS Coastal Modeling Testbed," August 2011 – April 2013, $40,000.

61. FM Global, "Model Development for Western North Pacific," June 2012 – May 2013, $120,000.

62. DHS, "Wave and Surge Modeling and Operational Forecasting in Puerto Rico," July 2012 – June 2013, $68,821.

63. National Science Foundation, "Collaborative Research: Data-Driven Inverse Sensitivity Analysis for Predictive Coastal Ocean Modeling," September 2012 – August 2015, $189,647.

64. Baker AECOM, "Region VI Coastal: Central Florida Study," July 2012 – December 2013, $65,720.

65. NOAA, "ADCIRC Circulation Modeling Deepwater Horizon Oil Spill NRDA," April 2012 – March 2014, $116,598.

RESEARCH SUPERVISED

Undergraduate Research

D. Shea, Topic: Petrov-Galerkin Solutions to the Convection-Diffusion Equation, senior thesis, August 1986 - July 1987.

S. Liu, Topic: Petrov-Galerkin Solutions to the Convection-Diffusion Equation, senior thesis, August 1986 - May 1987.

H. Zhao, Topic: New York Bight Circulation Studies, January - July 1990.
L. O'Brien, Topic: Finite Element Grid Development for Coastal Circulation Models, NSF Research Experience for Undergraduates, June - July 1991.
S. Hagen, Topic: Truncation Error Analysis for Shallow Water Equations, NSF Research Experience for Undergraduates, June - July 1992.
R. Li, Topic: Finite Element Grid Studies for Coastal Circulation Models, NSF Research Experience for Undergraduates, June - July 1994.
K. Adu-Sarkodie, Topic: Influence of Grid Valence on the Generation of Spurious Modes in Solutions to the Shallow Water Equations, independent study, January - May 2000.
M. Altman, Topic: Hurricane Storm Surge Calculations in Southern Louisiana, January 2001 - May 2002.
P. Drummey, Topic: Tidal Computations in Texas Coastal Inlets, January - December 2001, August 2002 - May 2003.
A. Henisey, Topic: Tidal Computations in Texas Coastal Inlets, January - May 2002.
P.J. Craig, Topic: Resonant Modes of the Gulf of Mexico, September 2004 - May 2005.
J. Breckler, Topic: The Influence of South Western Levees on Storm Surge Propagating Up the Mississippi River Under High River Stage Conditions, September – December 2005.
T. Roy, Topic: Grid Resolution Effects on the Mississippi River, January 2007 – May 2008.
J. Jeray, Topic: Grid Resolution Effects on the Mississippi River, September 2007 – May 2008.
M. Shubert, Topic: Grid Resolution Effects on the Mississippi River, January 2008 – May 2008.
C. Harris, Topic: Grid Resolution Effects on the Mississippi River, January 2008 – May 2008.
Z. Cobell, Topic: Data Analysis of Historical Storm Surge Water Elevations in Southern Louisiana, September 2008 – May 2009.
D. Reimer, Topic: Data Analysis of Historical Storm Surge Water Elevations in Southern Louisiana, September 2008 – May 2009.
S. Keithley, Topic: Performance Analysis of Scalable Finite Element Coastal Storm Surge Models, September 2008 – May 2009.
Z. Cobell, Topic: Applying Lidar and Land Use Data Bases to Quantify Topography and Surface Roughness for Hurricane Models, May 2009 – May 2010.
B. Mitchell, Topic: Verifying Storm Surge Models in Southern Louisiana, June-August 2009, Summer research experience undergraduate student from Xavier University in New Orleans, LA.
N. Tate, Topic: Verifying Storm Surge Models in Southern Louisiana, June-August 2009, Summer research experience undergraduate student from Xavier University in New Orleans, LA.
M. Hartman, January 2010 – May 2010, Topic: Data analysis of hurricane storm surge and runup
D. Iwanski, September 2010 – May 2010, Topic: Assessment of hurricane characteristics and response in the Pacific Ocean
R. Estes, September 2010 – May 2011
R. Dominguez, September 2010 – May 2013
R. Dunbar, September 2011 – May 2012
L. Semeraro, September 2011 – May 2012
M. Eppler – September 2012 – May 2013
K. Krah – September 2012 – May 2013
E. Andruszkiewicz – September 2012 – May 2013
D. Noe – September 2012 – May 2013

Master's Theses Directed

J.C. Muccino, "Grid Resolution Studies of the Western North Atlantic Ocean, Gulf of Mexico and Caribbean Sea," Department of Civil Engineering and Geological Sciences, University of Notre Dame, M.S., completed November 1992.
M.J. Roe, "Achieving a Dynamic Steady State in the Western North Atlantic/Gulf of Mexico/Caribbean Using Graded Finite Element Grids," Department of Civil Engineering and Geological Sciences, University of Notre Dame, M.S., completed August 1998.
A. Mukai, "Tidal Computations within the Western North Atlantic Using a High Resolution Unstructured Finite Element Mesh," Department of Civil Engineering and Geological Sciences, University of Notre Dame, M.S., completed September 2001.

E. Spargo, “Using a Finite Element Model of the Shallow Water Equations to Model Tides in the Eastern North Pacific Ocean,” Department of Civil Engineering and Geological Sciences, University of Notre Dame, M.S., completed September 2003.

H.J. Roberts, “Grid Generation Methods for High Resolution Finite Element Models Used for Hurricane Storm Surge Prediction,” Department of Civil Engineering and Geological Sciences, University of Notre Dame, M.S., completed December 2004.

P. Miller, “Grid Resolution and Parameter Study for Coupled Hydrodynamic Sediment Wave Models over an Idealization of the Shinnecock Inlet, New York,” Department of Civil Engineering and Geological Sciences, University of Notre Dame, M.S., completed April 2005.

M. Agnew, “Surge and Wave Propagation over Wetlands with Respect to Storm Forward Speed,” completed January 2012.

Visiting Graduate Students

A.A. Chavez, Instituto Mexicano de Technologia del Agua, Topic: Simulation of Flushing of Inlets in Cancun, Mexico, February - May 1997.

S. Bunya, University of Tokyo, Topic: Boundary Condition Implementations for Quasi-Bubble Solutions to Shallow Water Equations, July 2003 - June 2004.

Doctoral Dissertations Directed

M.E. Cantekin, “Numerical Simulation with Gaussian Low Pass Filtered Navier Stokes Equations,” Department of Civil Engineering, Texas A&M University, Ph.D., completed July 1991.

C.A. Blain, “The Influence of Domain Size and Grid Structure on the Response Characteristics of a Hurricane Storm Surge Model,” Department of Civil Engineering and Geological Sciences, University of Notre Dame, Ph.D., completed June 1994.

S.C. Hagen, “Truncation Error Analysis and Grid Design for Long Wave Propagation in Continental Margin Waters,” Department of Civil Engineering and Geological Sciences, University of Notre Dame, Ph.D., completed July 1997.

J. H. Atkinson, “Two-dimensional Analysis of Spatial Discretizations of the Shallow Water Equations,” Department of Civil Engineering and Geological Sciences, University of Notre Dame, Ph.D., completed October 2002.

J. C. Feyen, “Predictive Hurricane Storm Surge Modeling through Use of a Large Scale Locally Refined Finite Element Model,” Department of Civil Engineering and Geological Sciences, University of Notre Dame, Ph.D., completed April 2005.

E.J. Kubatko, “Development, Implementation, and Verification of *hp* Discontinuous Galerkin Models for Shallow Water Hydrodynamics and Transport,” Department of Civil Engineering and Geological Sciences, University of Notre Dame, Ph.D., completed December 2005.

J.C. Dietrich, “Development and Application of Coupled Hurricane Wave and Surge Models for Southern Louisiana,“ Ph.D. , completed October 12, 2010.

R. Martyr, Ph.D., “Toward a Unified Parameterization of Bottom Friction for Riverine, Tidal and Storm Surge Analysis,” completed December 2012.

M. Hope, Ph.D. Program, completing spring, 2013.

P. Kerr, Ph.D., “Astronomical Tide, Hurricane Storm Surge, Coastal Inundation, and Wind-Wave Modeling and Response Sensitivities, completed May, 2013.

A. Donahue, Ph.D. Program

S. Brus, Ph.D. Program

J. Gonzalez, Ph.D. Program

Post Doctoral Associates

J.K. Wu, Topic: Finite Element Based Solutions to the Shallow Water Equations, August 1988 - August 1990

M.E. Cantekin, Topic: Analysis of Finite Element Based Solutions to the Shallow Water Equations, August 1991 - July 1992

R.L. Kolar, Topic: Mass Conservation Issues for Finite Element Solutions to the Shallow Water Equations, July - August 1992.

S. Bunya (visiting assistant professor), Topic: Discontinuous Galerkin Implementations for Coupled Shallow

Water Equations, June 2005 – May 2007

E.J. Kubatko, Topic: Discontinuous Galerkin Solutions to the Shallow Water Equations," January – August 2006.

S. Tanaka (assistant research professor), Topic: High Performance Computational Models of the Coastal Ocean, April 2008 – March 2011.

D. Wirasaet, (assistant research professor), Topic: High Performance Computational Models of the Coastal Ocean, August 2008 - present

COURSES TAUGHT

Princeton University

CE 276	Introduction to Water Resources
CE 306	Applied Engineering Hydraulics
CE 508	Numerical Methods in Engineering
CE 581	Advanced Hydraulics

Texas A&M University

ENGR 102	Engineering Analysis II
CVEN 311	Fluid Dynamics
OCEN 678	Hydromechanics
CVEN 688	Computational Fluid Dynamics

University of Notre Dame *with Teacher Course Evaluation (TCE) scores out of 4.0 for fall 1997 – spring 2008; and (CIF) overall effectiveness scores out of 5.0 for fall 2008 – spring 2009 (marked with *)*

CE 242	Introduction to Civil Engineering (3.51, 3.32)
CE 341	Computational Methods (3.60)
CE 344	Hydraulic Engineering (3.73)
CE 441	Numerical Methods in Engineering (3.50, 3.73, 3.73, 3.83, 3.89, 3.83, 3.55)
CE 539	Advanced Hydraulics (3.73, 4.00, 4.00, 4.00)
CE 563	Finite Elements in Engineering (3.60, 3.89, 3.84, 3.63, 3.80)
CE 598	Modeling Surface Water Flow and Transport
CE30125	Computational Methods (3.73, 3.78, 3.88, 4.6*)
CE 33600/43600	Challenges and Innovation in Civil Engineering (4.8*, 4.7*)
CE60130	Finite Elements in Engineering (4.00, 4.00, 4.4*)
CE60450	Advanced Hydraulics (4.00)

CONFERENCE SESSIONS ORGANIZED

Co-organized with W.G. Gray a mini-symposium at the Third SIAM Conference on Mathematical and Computational Issues in the Geosciences, San Antonio, TX, February 8-10, 1995, entitled "Finite Element Methods for Surface Water Flow and Transport"

Co-organized with R. Kolar a mini-symposium at the Fifth SIAM Conference on Mathematical and Computational Issues in the Geosciences, San Antonio, TX, March 24-27, 1999, entitled "Solution Strategies to the Shallow Water Equations"

Co-organized with C. Dawson, S. Yoshimura and K. Kashiyama a mini-symposium at the Eighth U.S. National Congress on Computational Mechanics, Austin, TX, July 24-28, 2005, entitled "Finite Element Methods in Environmental Fluid Mechanics"

Co-organized with K. Kashiyama three technical sessions at the Seventh World Congress on Computational Mechanics, Los Angeles, CA, July 16-22, 2006, entitled "Finite Element Methods in Environmental Fluid Mechanics"

Co-organized with K. Kashiyama a mini-symposium at the Ninth US National Congress on Computational Mechanics, San Francisco, CA, July 22-26, 2007, entitled "Finite Element Methods in Environmental Fluid Mechanics"

Co-organized with T. Wamsley and J. Atkinson two technical sessions at the 10th International Conference on

Estuarine and Coastal Modeling, Newport, RI, November 5-7, 2007, entitled "Hurricane Storm Surge Modeling in Southern Louisiana"

Co-organized with T. Wamsley a technical session at the 10th International Workshop on Wave Hindcasting and Forecasting and Coastal Hazard Symposium, Oahu, Hawaii, November 11-16, 2007, entitled "Estimation of Coastal Hazards"

Co-organized with K. Kashiyama, C. Dawson, and E. Kubatko a mini-symposium at the Tenth US National Congress on Computational Mechanics, Columbus, OH, July 16-19, 2009, entitled, "Finite Element Methods in Environmental Fluid Mechanics"

Co-organized with K. Kashiyama, T. Nomura, and M. Behr a workshop at the International Workshops on Advances in Computational Mechanics, Yokohama, Japan, March 29-31, 2010, entitled, "Advances in Computational Methods for Free and Moving Boundary Problems"

Co-organized with K. Kashiyama a mini-symposium at the 9th World Congress on Computational Mechanics and 4th Asian Pacific Congress on Computational Mechanics, Sydney, Australia, July 19-23, 2010, entitled, "Finite Element Methods and High Performance Computing for Environmental Fluid Mechanics"

TECHNICAL REVIEWER

Journals

Advances in Water Resources
Communications in Applied Numerical Methods
International Journal for Numerical Methods in Fluids
International Journal for Numerical Methods for Heat and Fluid Flow
Journal of Continental Shelf Research
Journal of Engineering Mechanics
Journal of Geophysical Research
Journal of Hydraulic Engineering
Journal of Physical Oceanography
Journal of Waterway, Port, Coastal and Ocean Engineering
Nature
Numerical Methods for Partial Differential Equations
Water Resources Research

COMMITTEES/SERVICE ACTIVITIES

Princeton University

Fall 1985-Spring 1987	ASCE Student Chapter Advisor
Fall 1985-Spring 1987	Departmental Library Liaison

Texas A&M University

Fall 1989-Spring 1990	Member Departmental Computer Committee

University of Notre Dame

Fall 1991-Summer 1992	Member Departmental Computing Committee
Fall 1991-Summer 1994	Member of the College Library Committee
Fall 1992-Summer 1994	Chair of the Departmental Computing Committee
Fall 1992-Spring 1993	Member of the Departmental Undergraduate Curriculum Committee
Fall 1992-Summer 2007	Member of the College Computing Committee
Spring 1993-Fall 1993	Member of the University Subcommittee on Large Scale Technical Computing
Fall 1993	Member of the Departmental Catholic Character Committee
Fall 1993-Summer 1994	Member of the Departmental Honesty Committee
Spring 1994-Summer 1994	Member of the Office of University Computing UNIX Search Committee
Spring 1994-Spring 1995	Member of the University Off-Campus Computer Access Committee
Spring 1994-Summer 1994	Member of the University Subcommittee on Resource Allocation for the

	IBM SP1 Computing Facility
Summer 1994-Summer 1996	Member of the University Committee on Technical Computing
Fall 1994	Member of the College Computing UNIX Search Committee
Summer 1995-Summer 1996	Member of the University Committee on Computing and Information Services
Fall 1995-Summer 1996	Chair of the College Computing Committee
Fall 1995-present	Member of Departmental Committee on Appointments and Promotions
Fall 1997	Moran Search Committee
Fall 2000-Spring 2003	Executive Committee Center for Applied Mathematics
Spring 2000	Member of the University Committee on Technical Computing
Fall 2001-Summer 2002	Member of the Ad Hoc Committee on Computing in the College of Engineering
Fall 2001-present	Civil Engineering Program Class student advisor
Spring 2007	Computing Strategic Plan Task Force
Fall 2007 – Spring 2008	Chair, CE/GEOS Massman Chair Search Committee
Spring 2008 – Spring 2009	CE/GEOS Graduate Studies Committee
Spring 2008 – present	Organizer, Undergraduate Lecture Series, “Challenges and Innovation in Civil and Environmental Engineering”
Fall 2008 – Spring 2009	Chair, CE/GEOS Hydraulics position search committee chair
Spring 2009	Chair, CE/GEOS Ad Hoc Committee for undergraduate studies

APPENDIX B: Litigation Involvement and Compensation

Northrop Grumman Corporation v. Factory Mut. Ins. Co. et al., Case No. CV05-8444 DDP PLAx (C.D. Cal.), for plaintiff Northrop-Grumman. Deposition February 22, 2007.

Robinson v. United States, Case No. 05-4182 (E.D. La.), for defendant United States. Deposition January 27 and 28, 2009; at trial May 12, 13 and 14, 2009.

My consulting rates are $250 per hour for consulting services and $500 per hour for depositions and testimony.