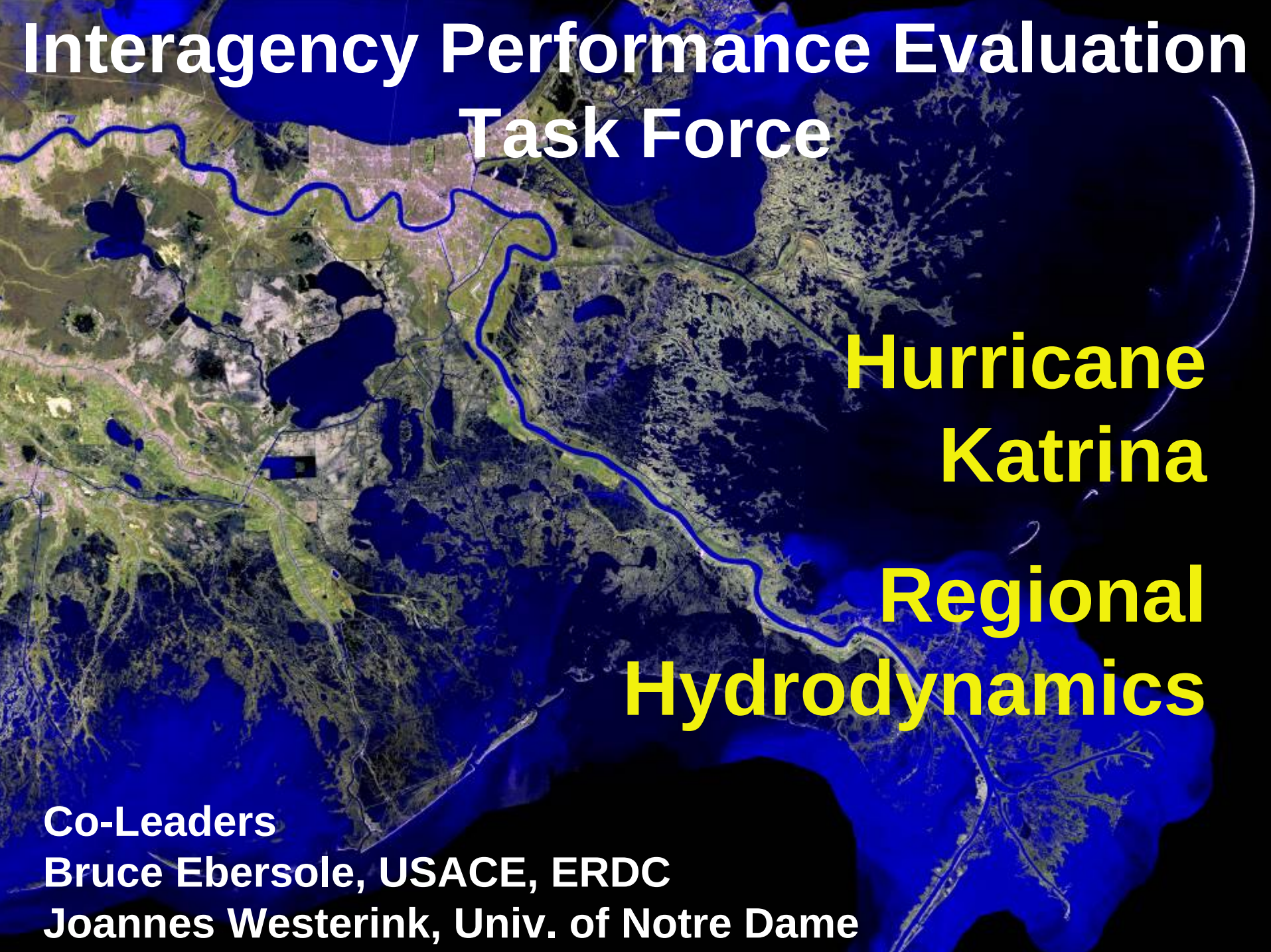
Interagency Performance Evaluation Task Force



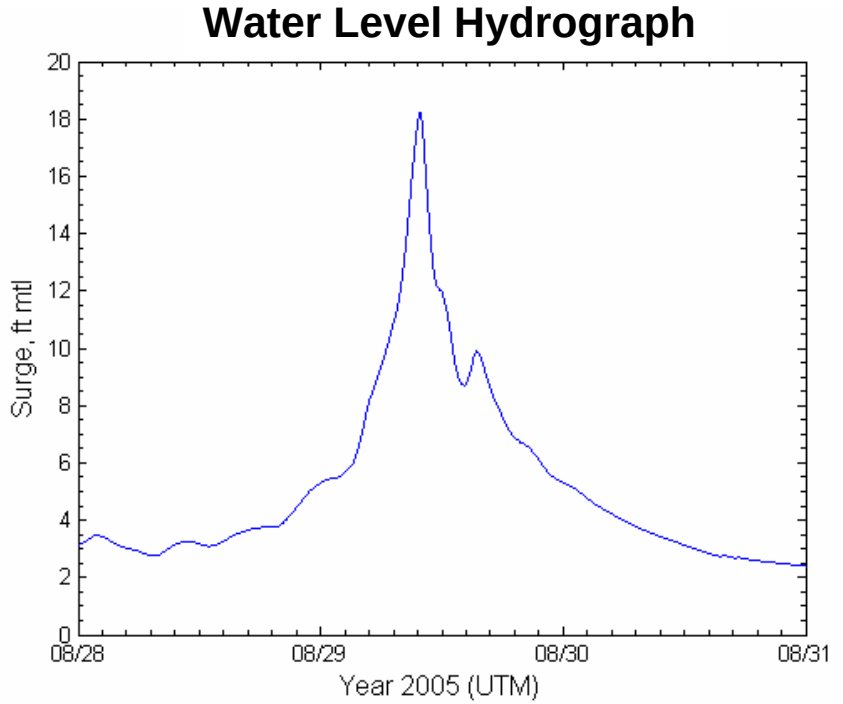
Hurricane Katrina

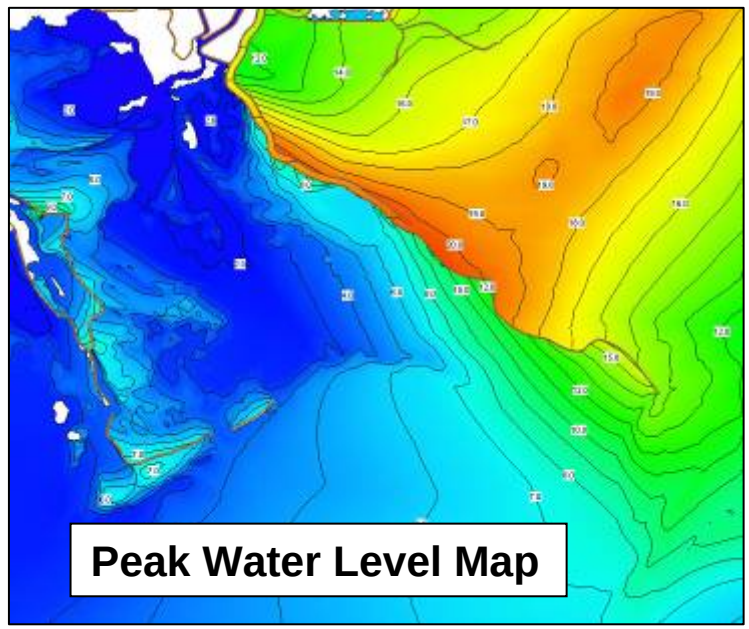
Regional Hydrodynamics

Co-Leaders
Bruce Ebersole, USACE, ERDC
Joannes Westerink, Univ. of Notre Dame

Objective

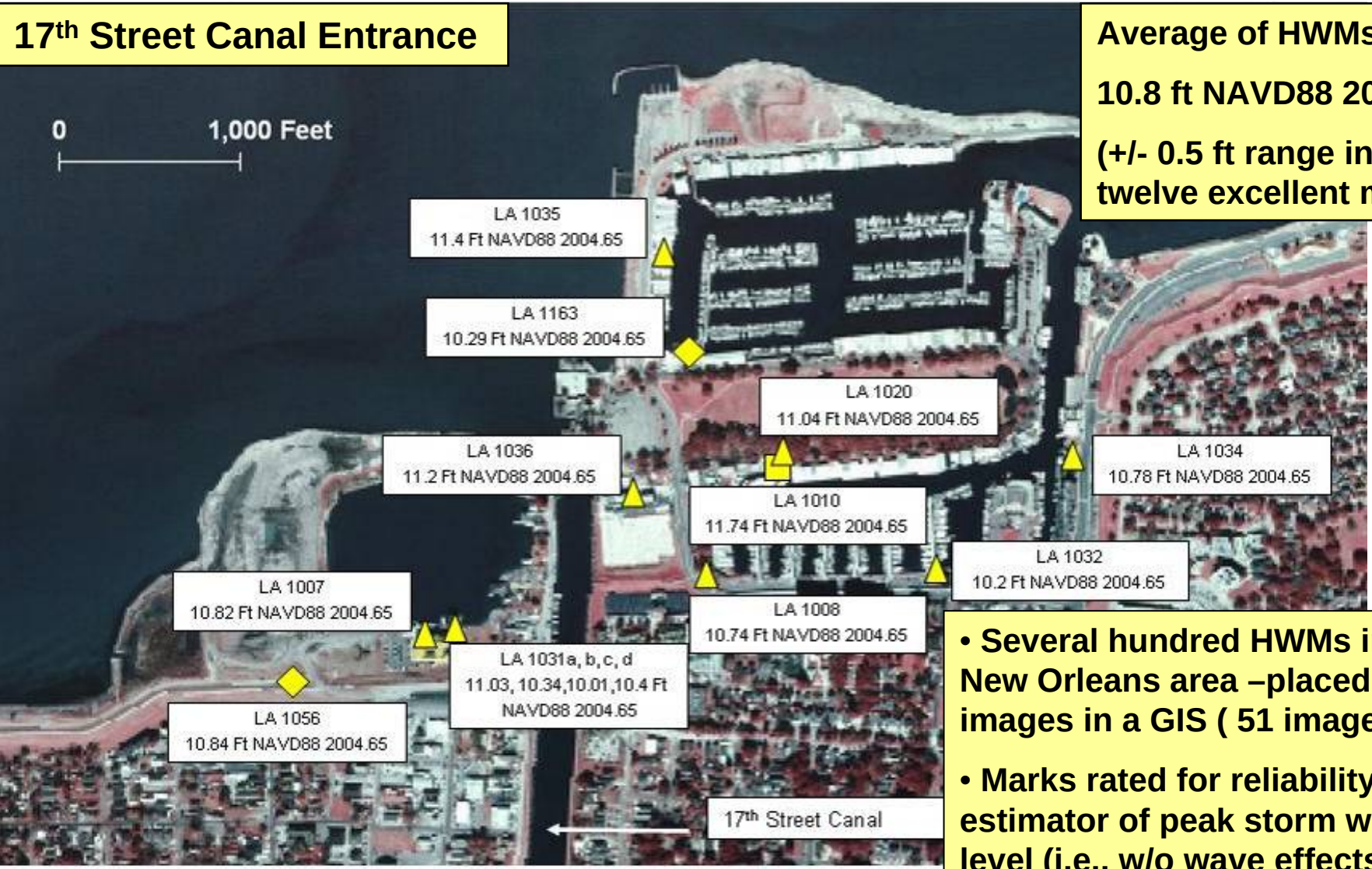
- **Characterize storm wave and water level conditions along entire periphery of the hurricane protection system**
  - Wave height, period, direction, energy spectrum as a function of time
  - Water level as a function of time (to common datum, NAVD88 2004.65)
  - Peak wave and water level values
- **Define conditions using combination of measurements and model results**
- **Measurements at only a few places**





High Water Mark (HWM) Analysis

17th Street Canal Entrance



Average of HWMs

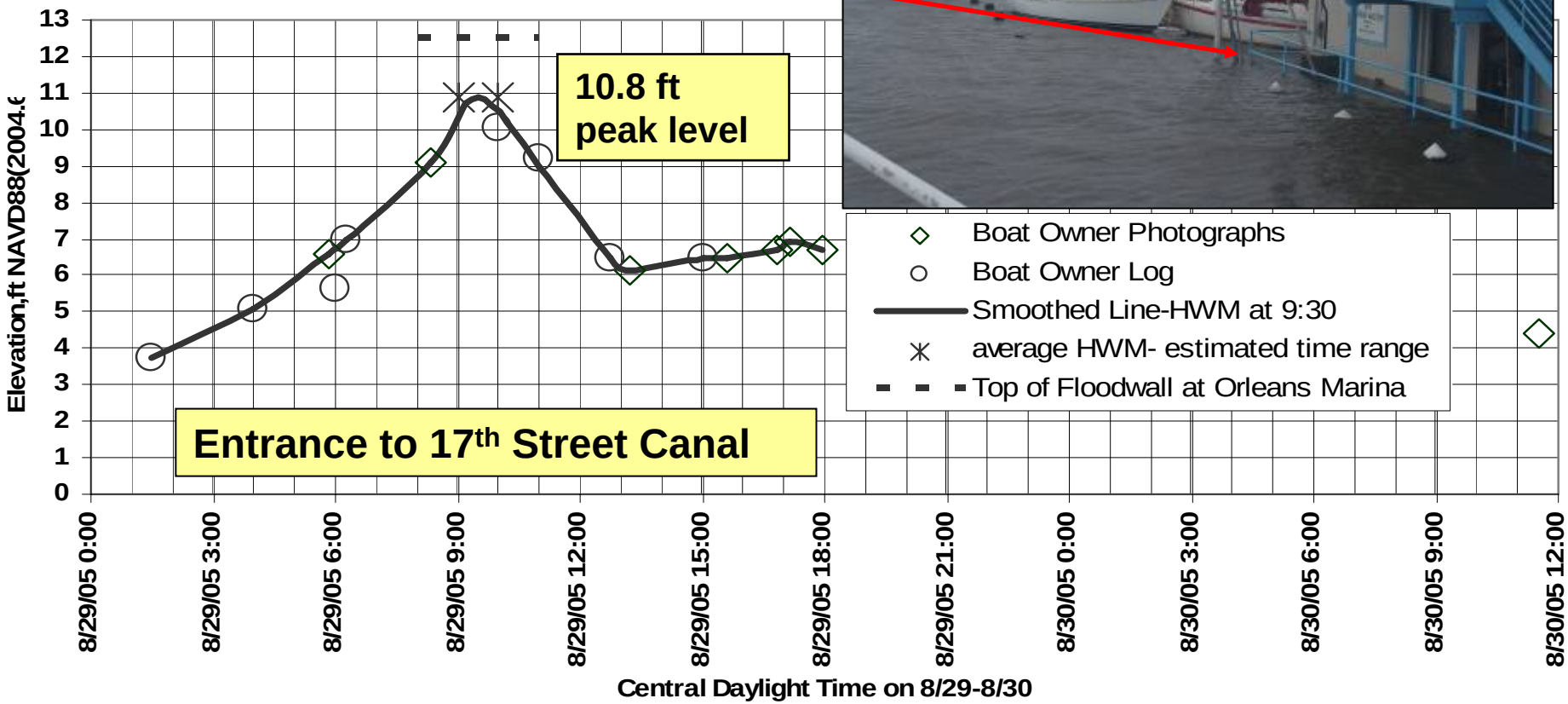
10.8 ft NAVD88 2004.65

(+/- 0.5 ft range in twelve excellent marks)

- **Several hundred HWMs in the New Orleans area –placed on images in a GIS (51 images)**
- **Marks rated for reliability as estimator of peak storm water level (i.e., w/o wave effects)**
- **15% of HWMs in non-protected areas rated excellent**

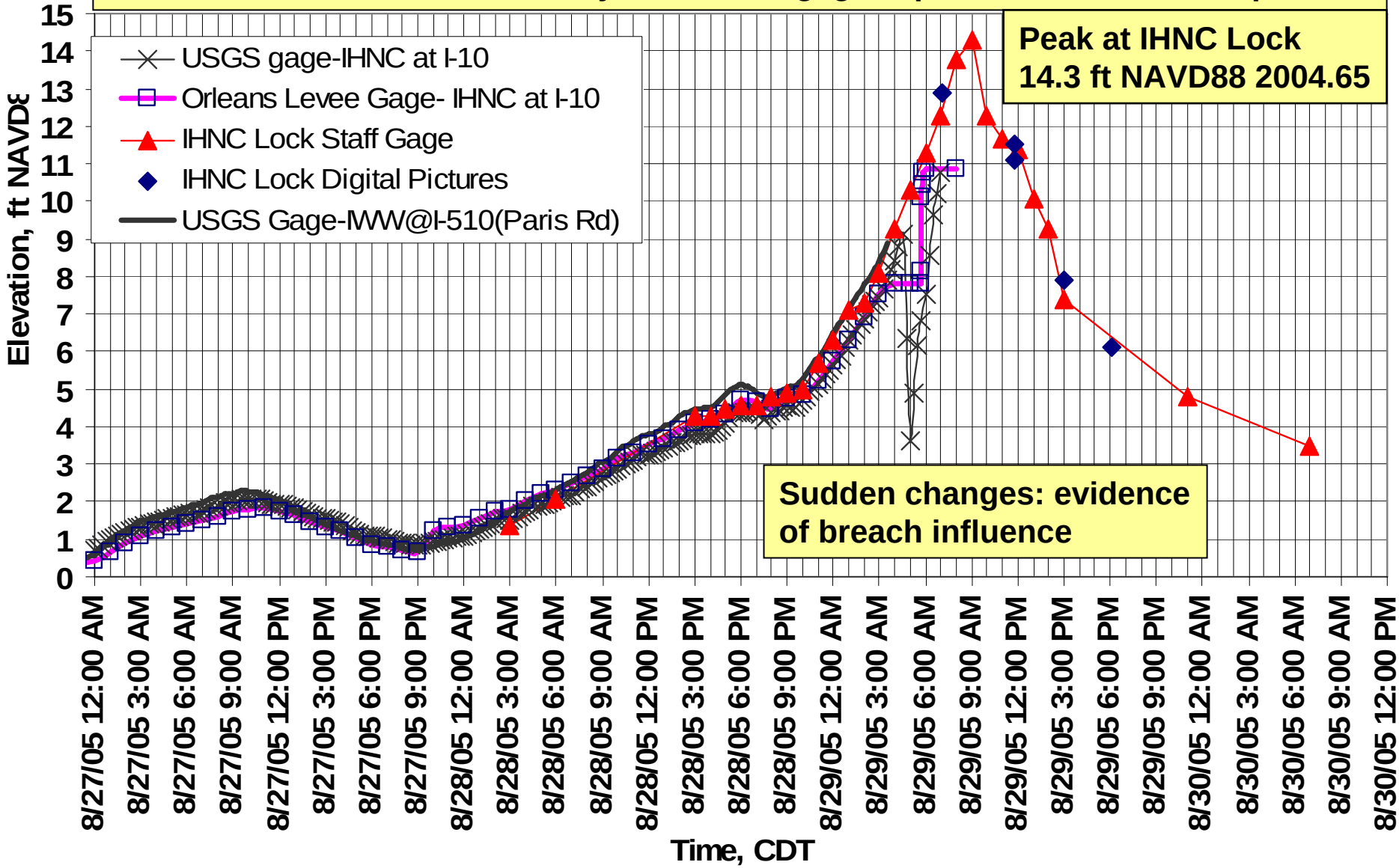
Reconstructed Hydrograph Analysis

- **Two reconstructed hydrographs from digital photos (17th St Canal and Lakefront Airport)**
- **Distances scaled from photos; marks surveyed**
- **Multiple marks reduce uncertainty due to wave effects (ex. multiple rail supports)**



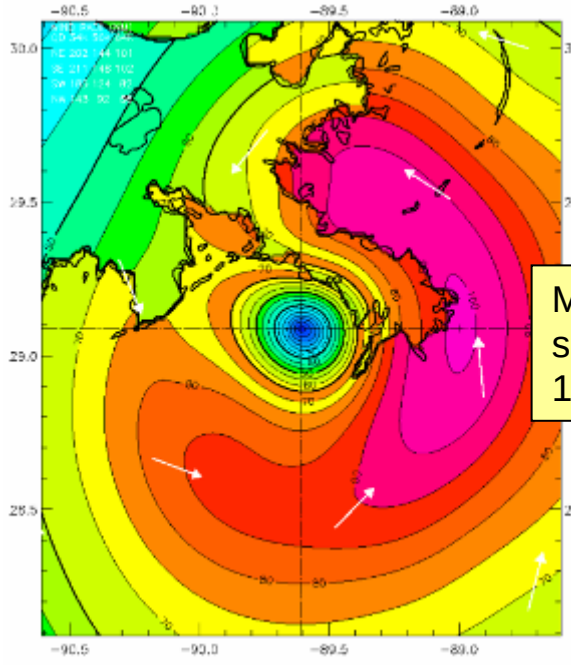
Measured Hydrographs

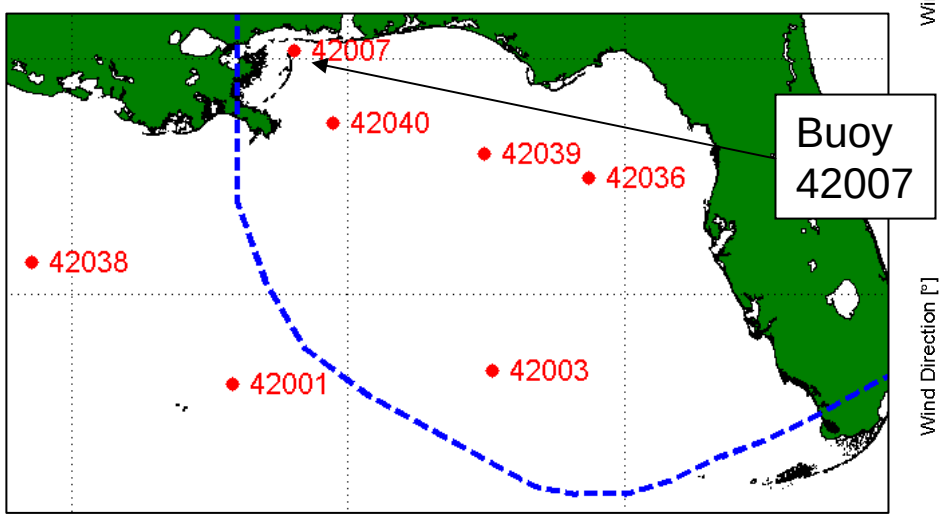
- 13 measured hydrographs considered in the region
- In metro New Orleans area, only IHNC Lock gage captured the water level peak

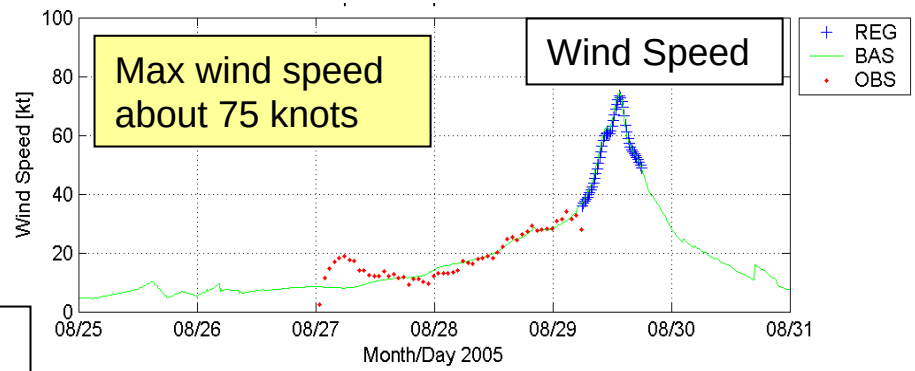


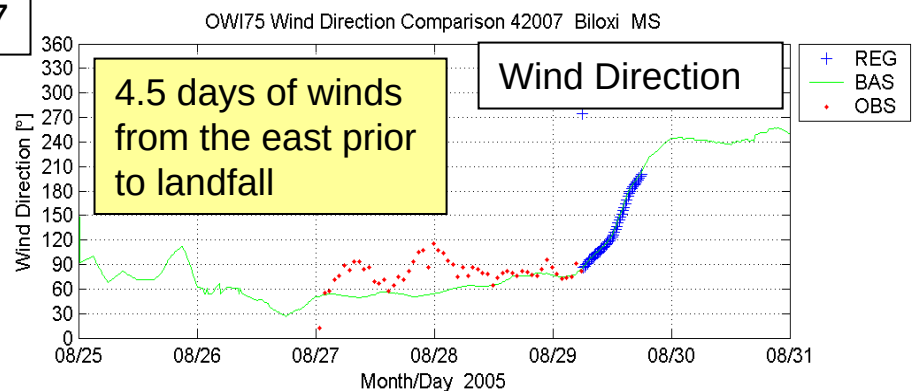
Wind and Atmospheric Pressure Fields

- **Primary input to Wave and Storm Surge Modeling**
- **Wind fields are blend of model results and measurements (Basin and higher-resolution Regional Winds produced)**
  - NOAA Hurricane Research Div H*Wind snaps blended to NCEP model winds and data using Oceanweather, Inc. IOKA wind analysis process
- **Most anemometers close to the storm failed near the peak**

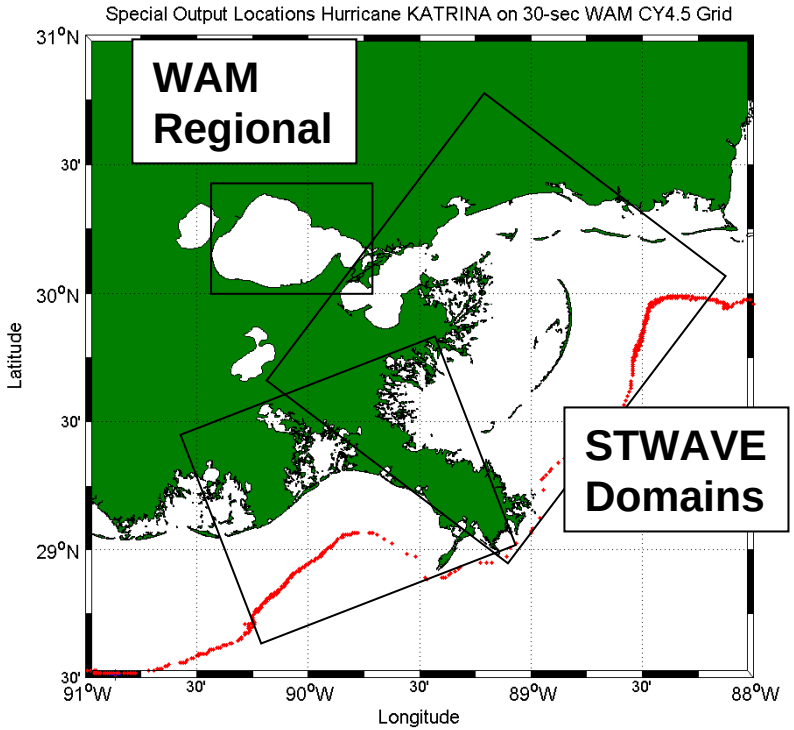




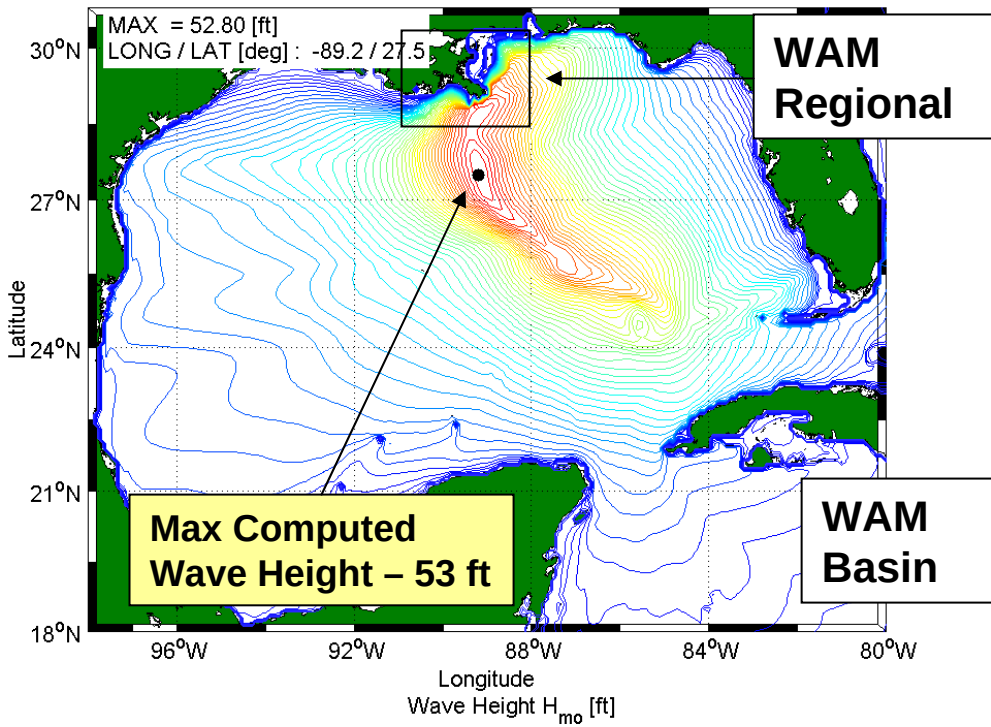




Nested Wave Modeling Approach (3 Nests)



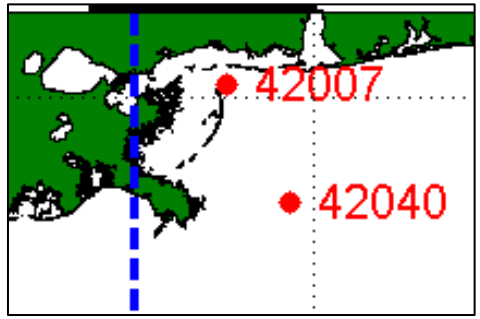
- Basin – Regional – Nearshore Domains
- Wave-storm surge interaction handled at the nearshore level



Max Wave Height Map, in feet

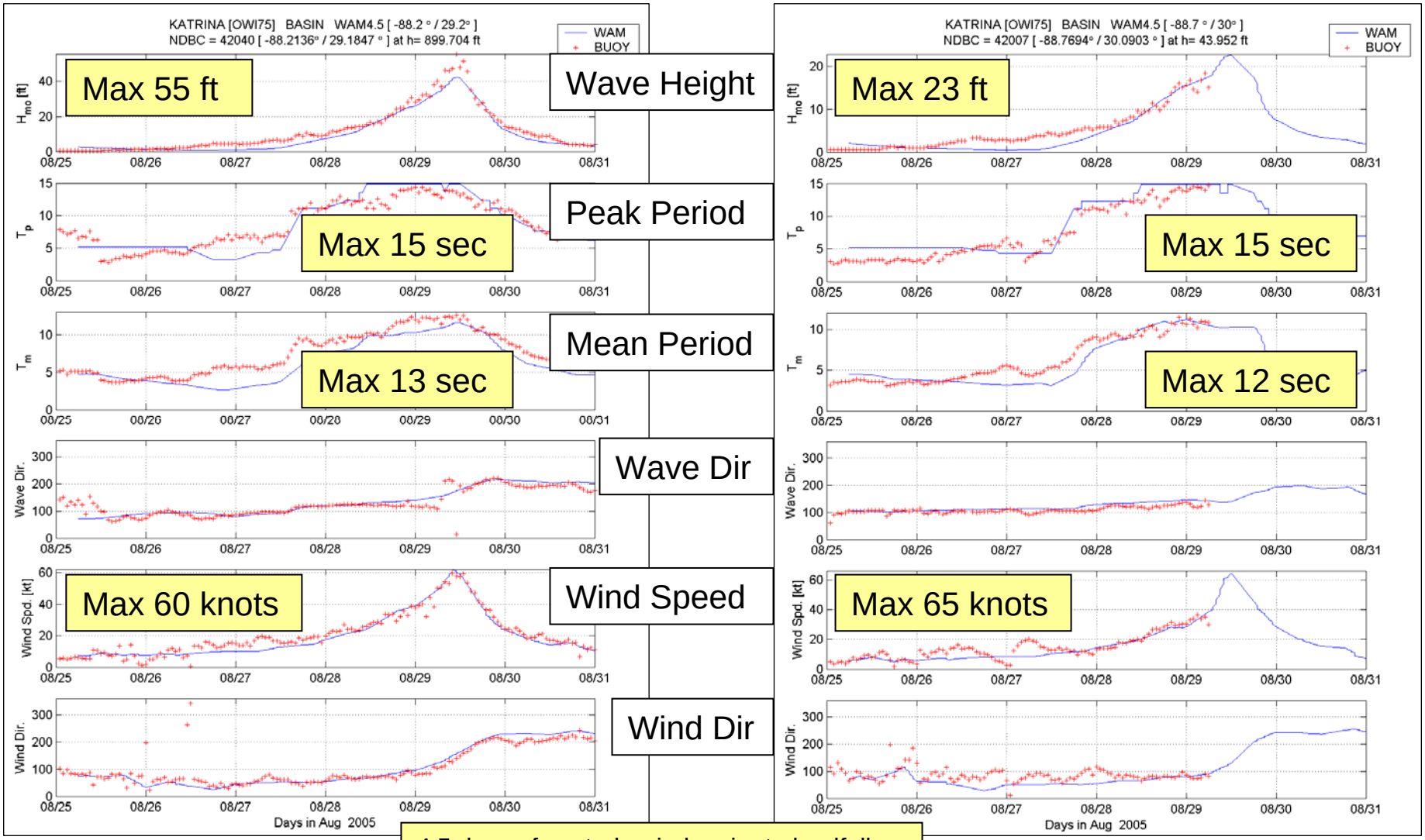
- Standard Corps of Engineers wave models used (WAM and STWAVE)
- Maximize model-to-measurement comparisons
- STWAVE compared to SWAN
- WAM compared to WAVEWATCH III

WAM Model Computations and Measurements



Buoy 42040

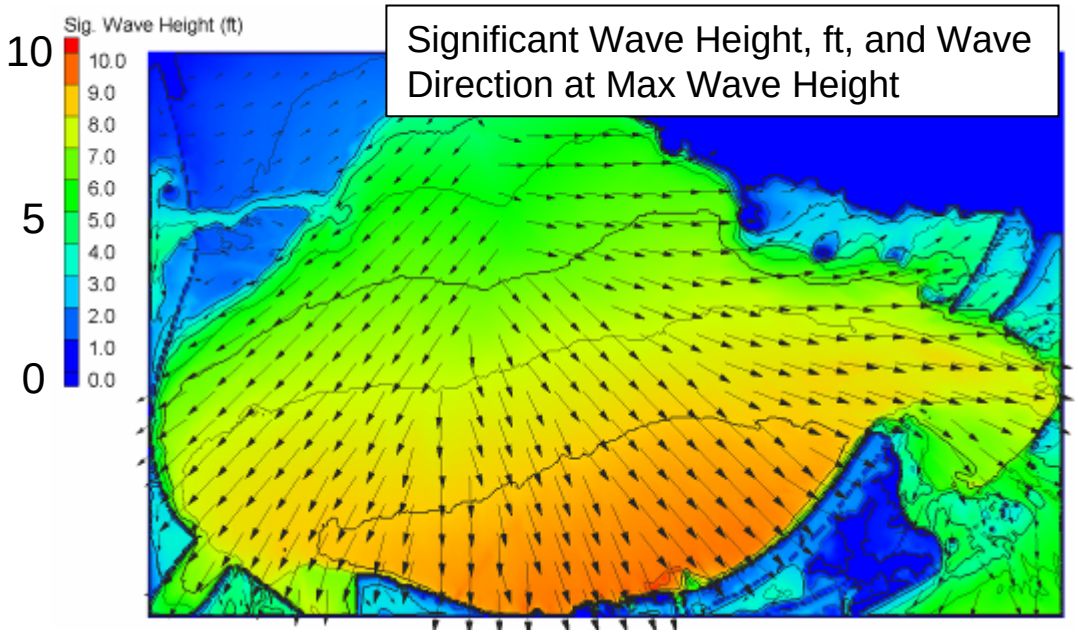
Buoy 42007

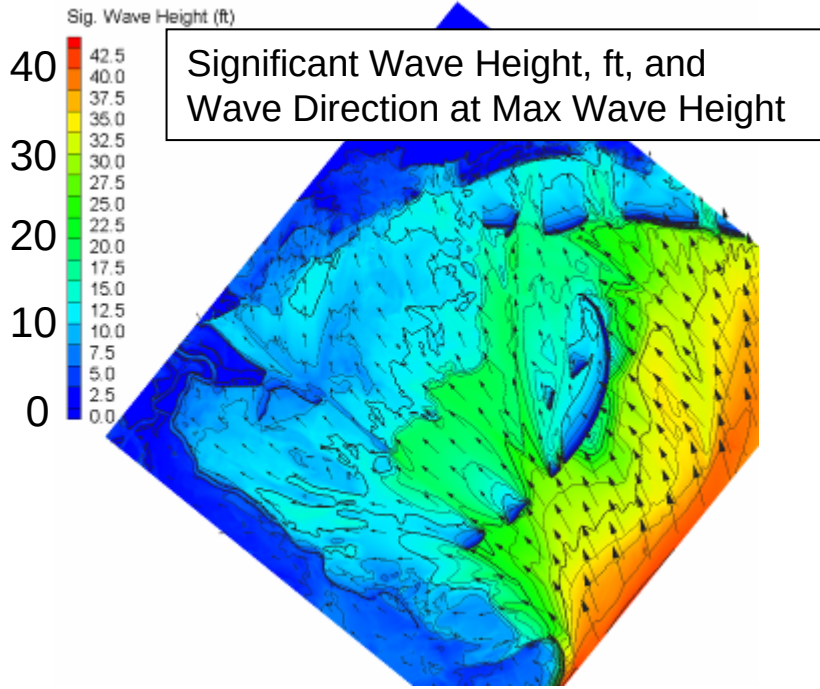


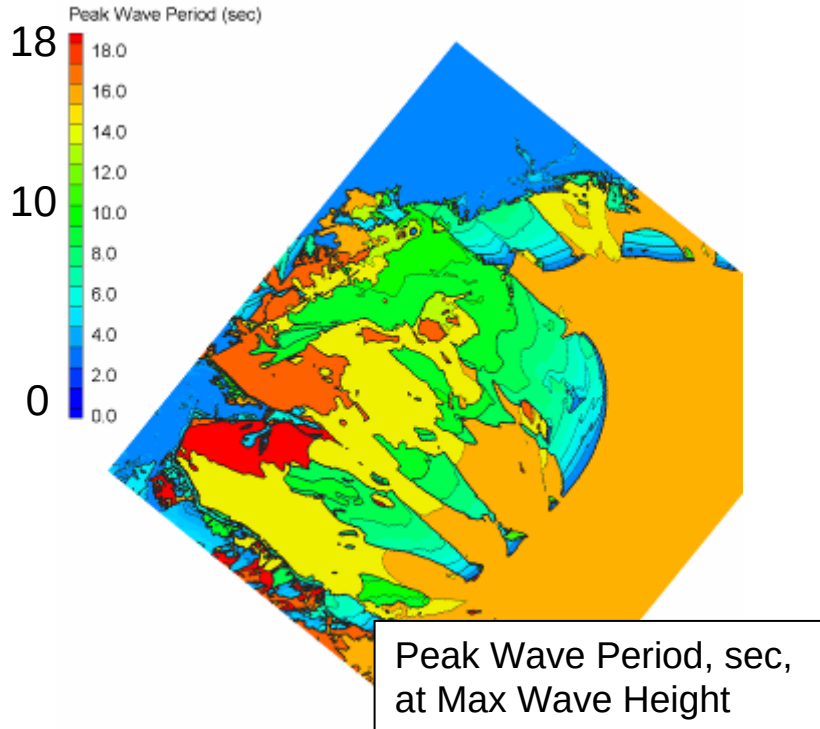
4.5 days of easterly winds prior to landfall

Maximum Nearshore Wave Conditions

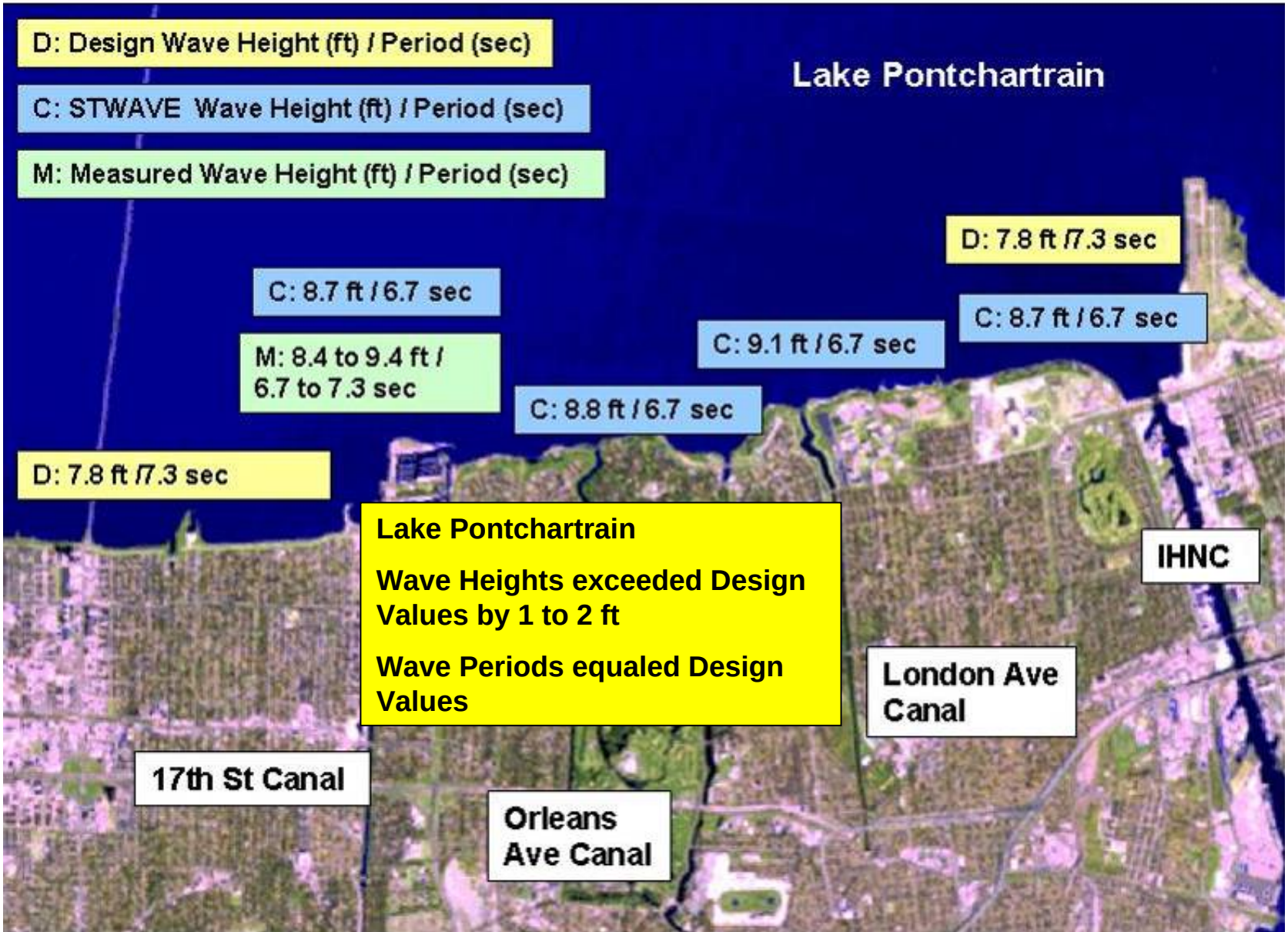
- **Lake Pontchartrain – max significant wave heights of 9 ft, peak periods of 7 sec**
- **St. Bernard – max wave heights of 5 ft; periods exceeding 15 sec**
- **Plaquemines (east-facing)– max wave heights of 7-10 ft, periods 13-15 sec**
- **East-facing levees exposed to considerable long period wave energy**



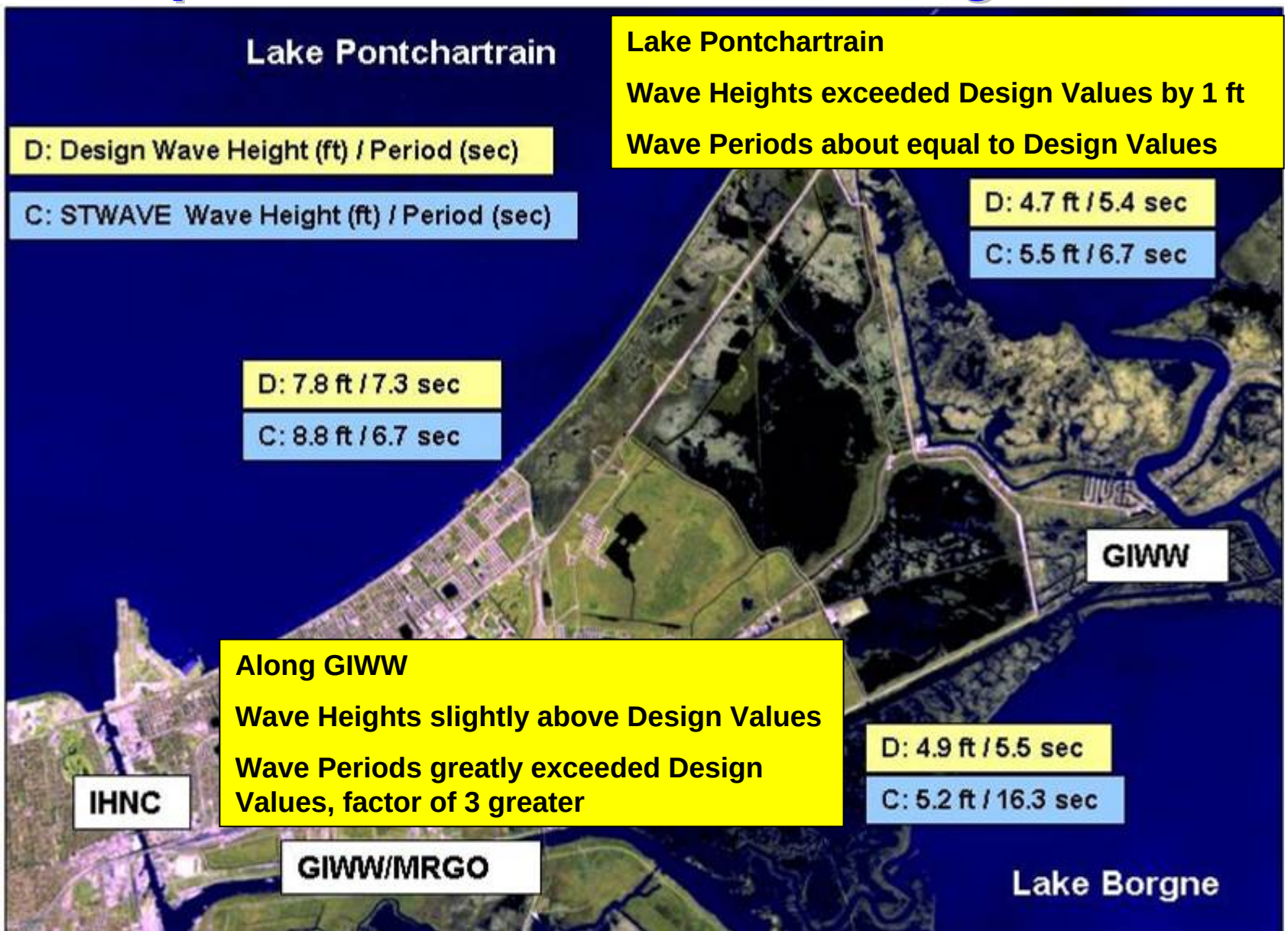




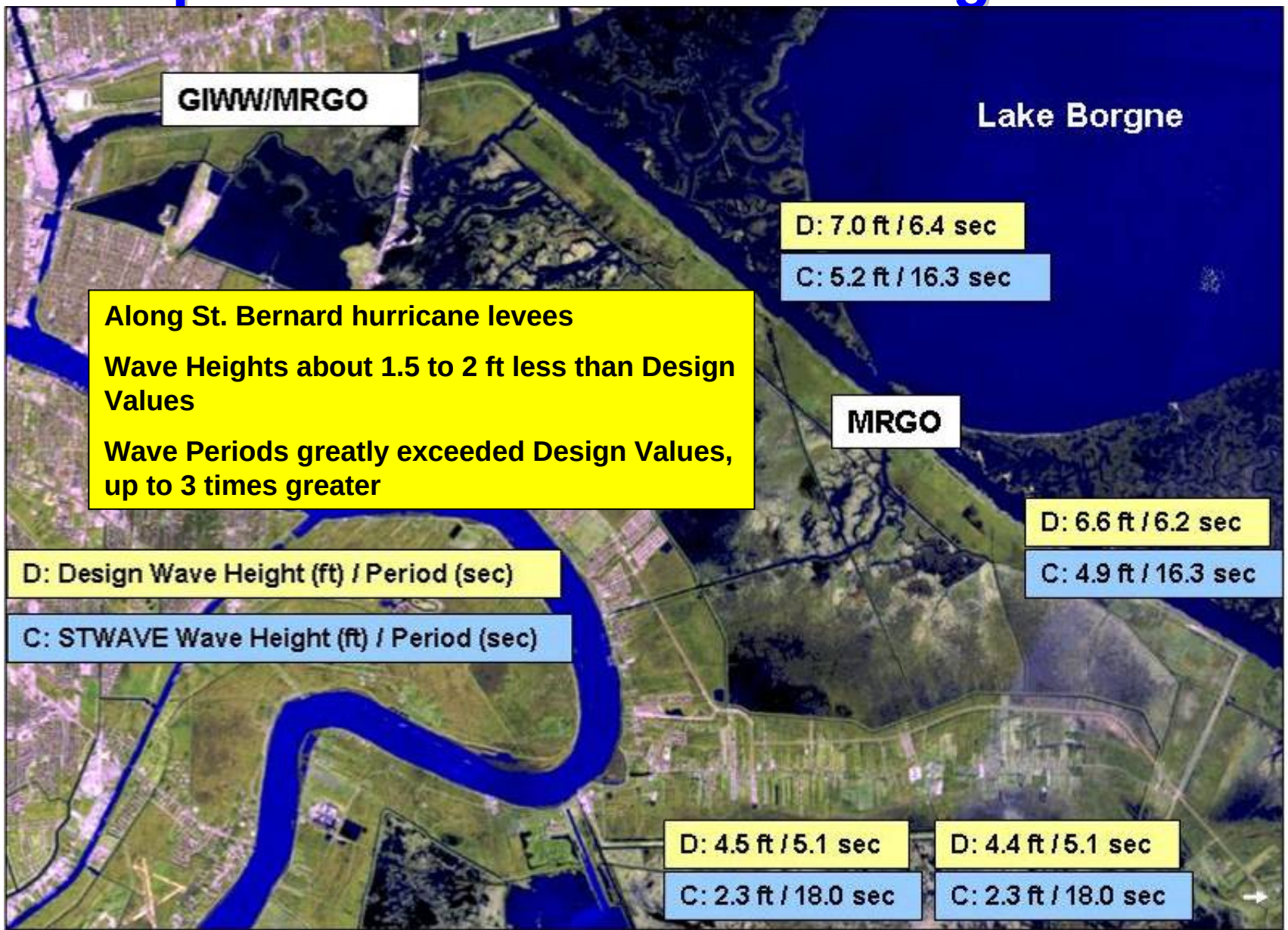
Peak Wave Conditions
Comparison: Katrina and Design Values



Peak Wave Conditions
Comparison: Katrina and Design Values



Peak Wave Conditions
Comparison: Katrina and Design Values



Peak Wave Conditions
Comparison: Katrina and Design Values

The Way Ahead - Waves

- Mississippi coast STWAVE domain
- ADCIRC-STWAVE coupling – depths and radiation stresses
- Update all wave modeling with 95% winds
- Consider spatially variable winds in all STWAVE domains
- Sensitivity tests (wind uncertainty, barrier island degradation, changed bottom roughness)
- Update model-to-measurement comparisons and Katrina vs Design value comparisons

Katrina Surge Hindcasts

- Domain/Grid Improvements
  - TF01 Add North Shore, Alabama and Mississippi
  - TF01x2 Add resolution for waves and critical regions
  - S14 Add resolution, features, apply Lidar
  - S14x2 S14 with additional resolution in North Shore of LP, for MS and AL and for wave radiation fields
- Define directional wind reduction coefficients across LA, MS and AL
- Define Manning n coefficients

Katrina Surge Hindcasts

- Incorporation of tides
- Detailed synthesis of wind and pressure fields
  - PBL Analysis
  - H*Wind / 90% OWI preliminary synthesis
  - H*Wind re-analysis / 95% OWI synthesis
  - Refines historical winds and assesses sensitivity to wind field variability
- Incorporation of wave radiation stress fields
  - WAM
  - STWAVE (up to 4 grids)

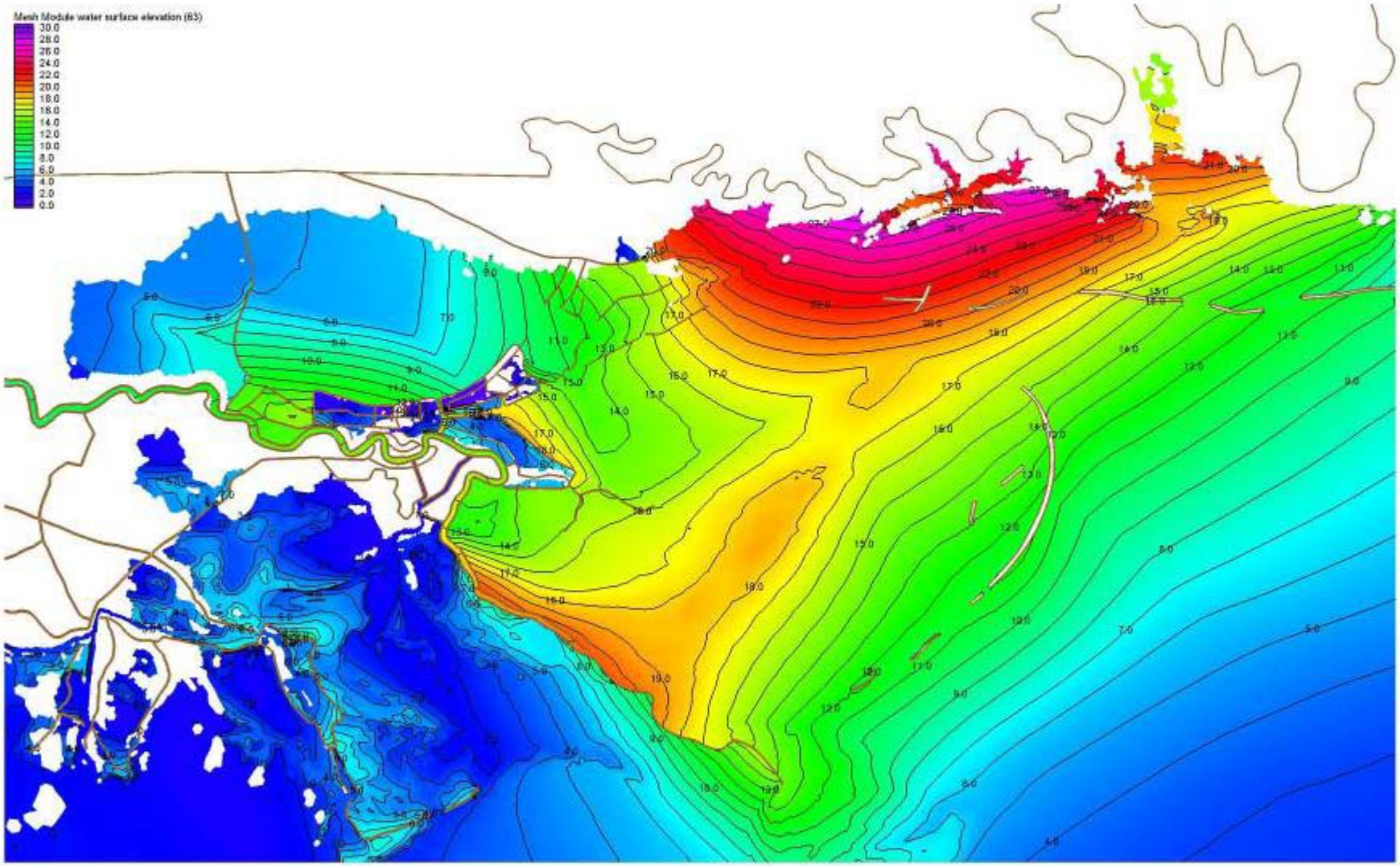
Katrina Surge Hindcasts

- QA/QC of the physical system in the model (bathymetry, topography, levee elevations, hydraulic features)
- Adjustment of MLLW, NGVD29 and NAVD88 to Geoid for simulations
- Incorporation of high density Lidar topo data
- Incorporation of updated levee heights
- Output converted to NAVD 88 2004 to match HWM's and hydrographs

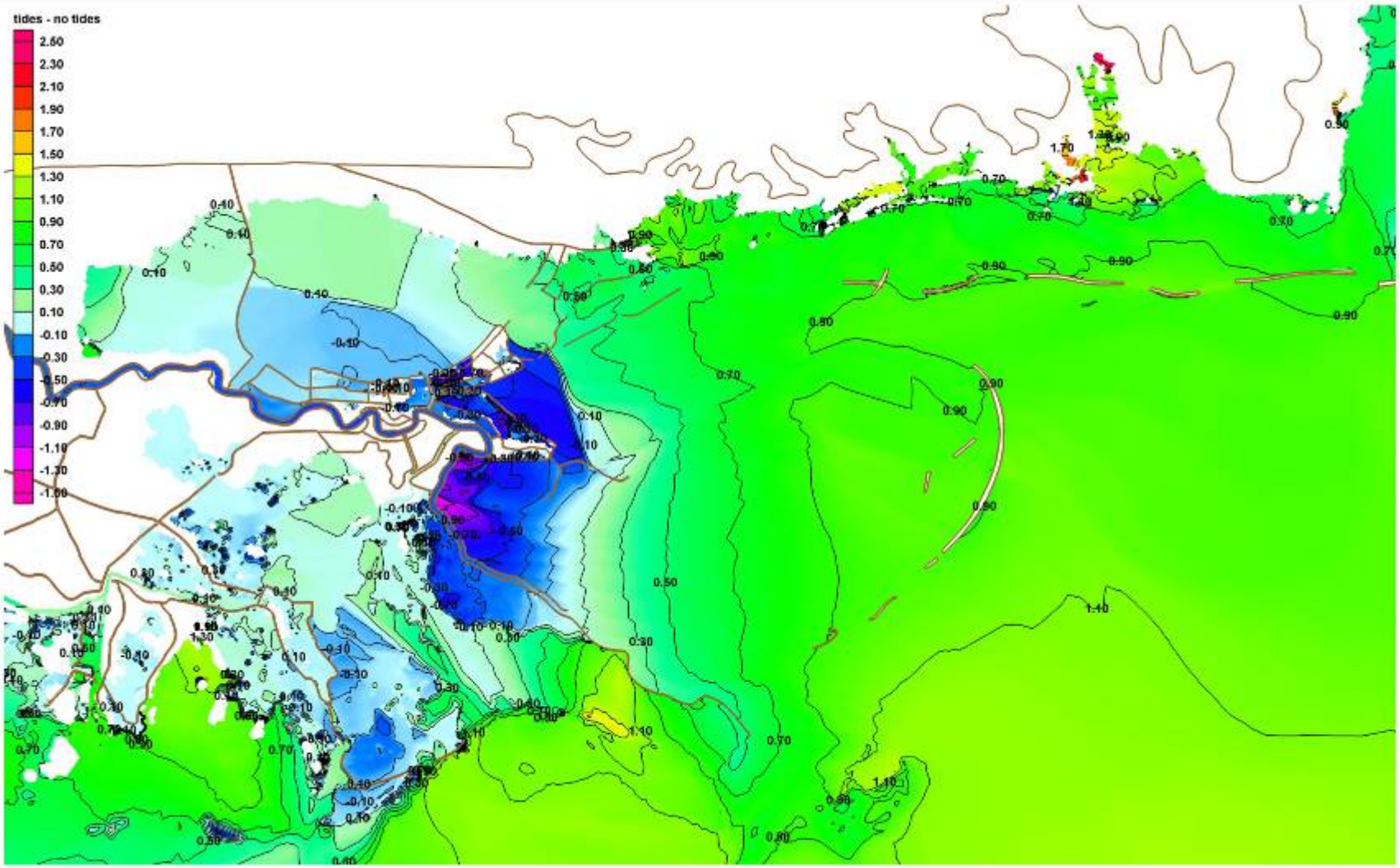
Katrina Surge Hindcasts

- Base Case
  - TF01 grid
  - PBL Wind field using final track info
  - River flows
  - No tides
- Run information
  - 377,815 computational points, solved every 1 second for 6 days.
  - On a Cray XT3 using 256 processors computation takes 74.9 wall clock minutes

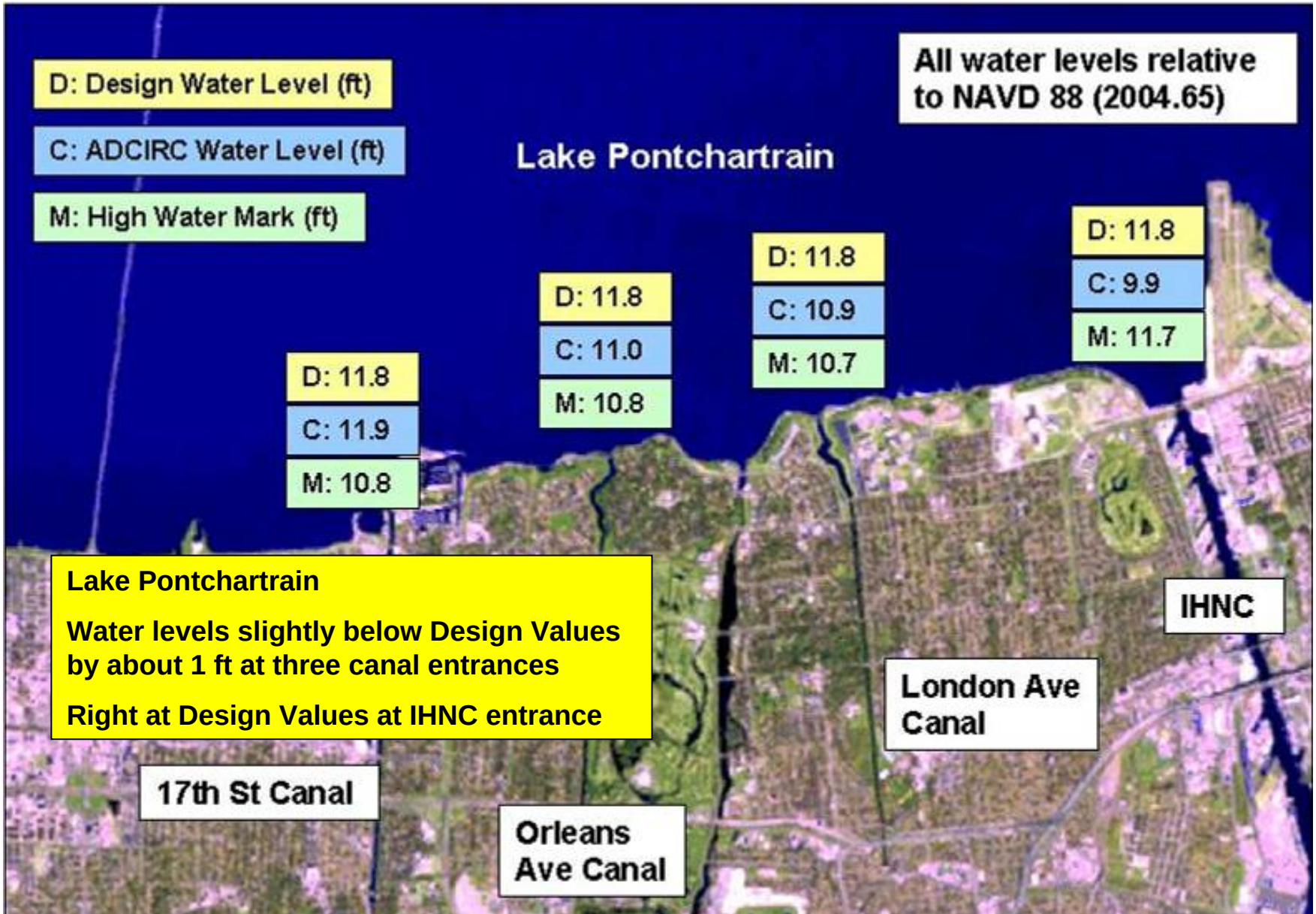
Base case: TF01 grid - PBL winds, no tides, no waves



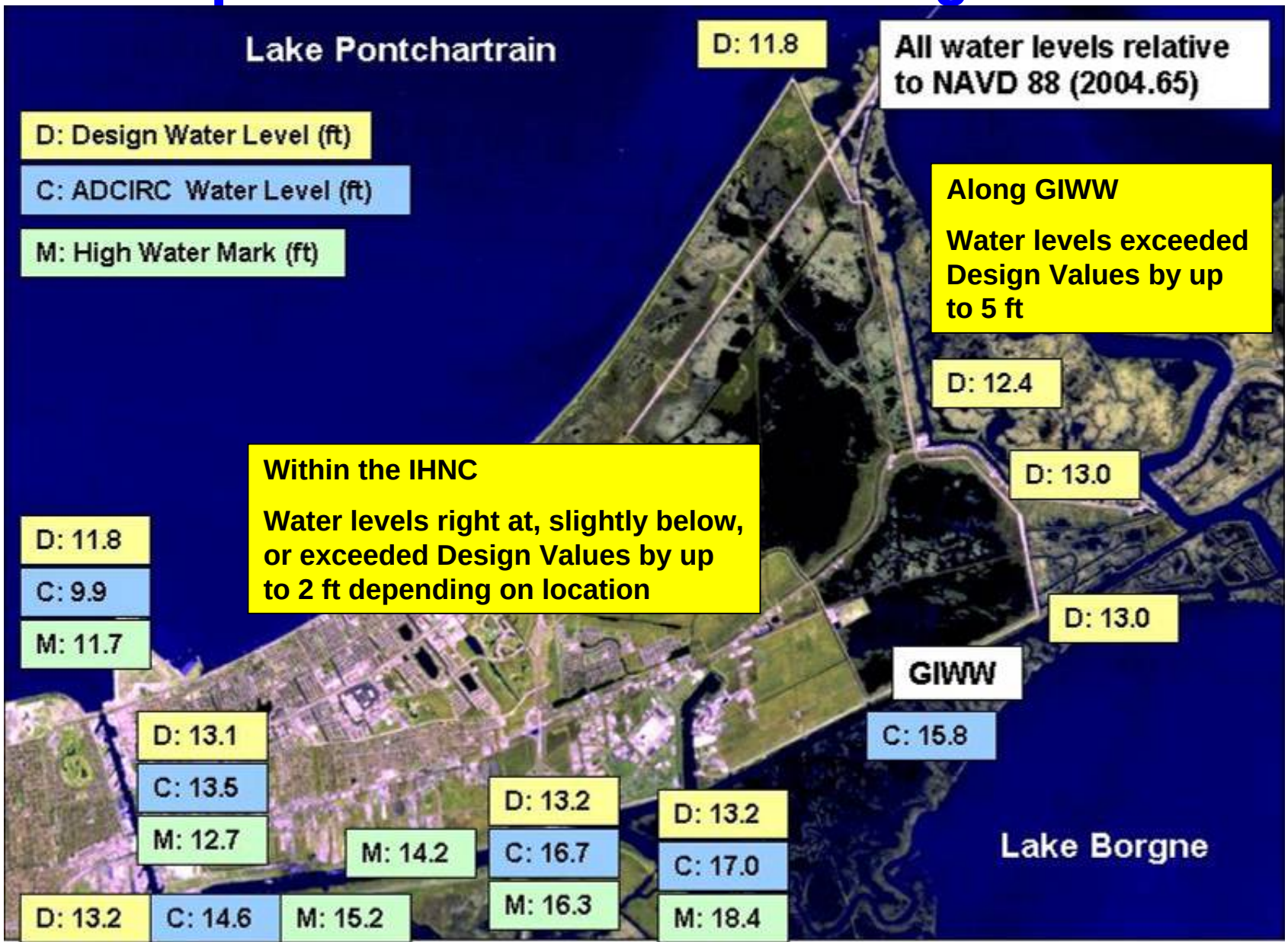
Effect of tides: TF01, no tides – with tides



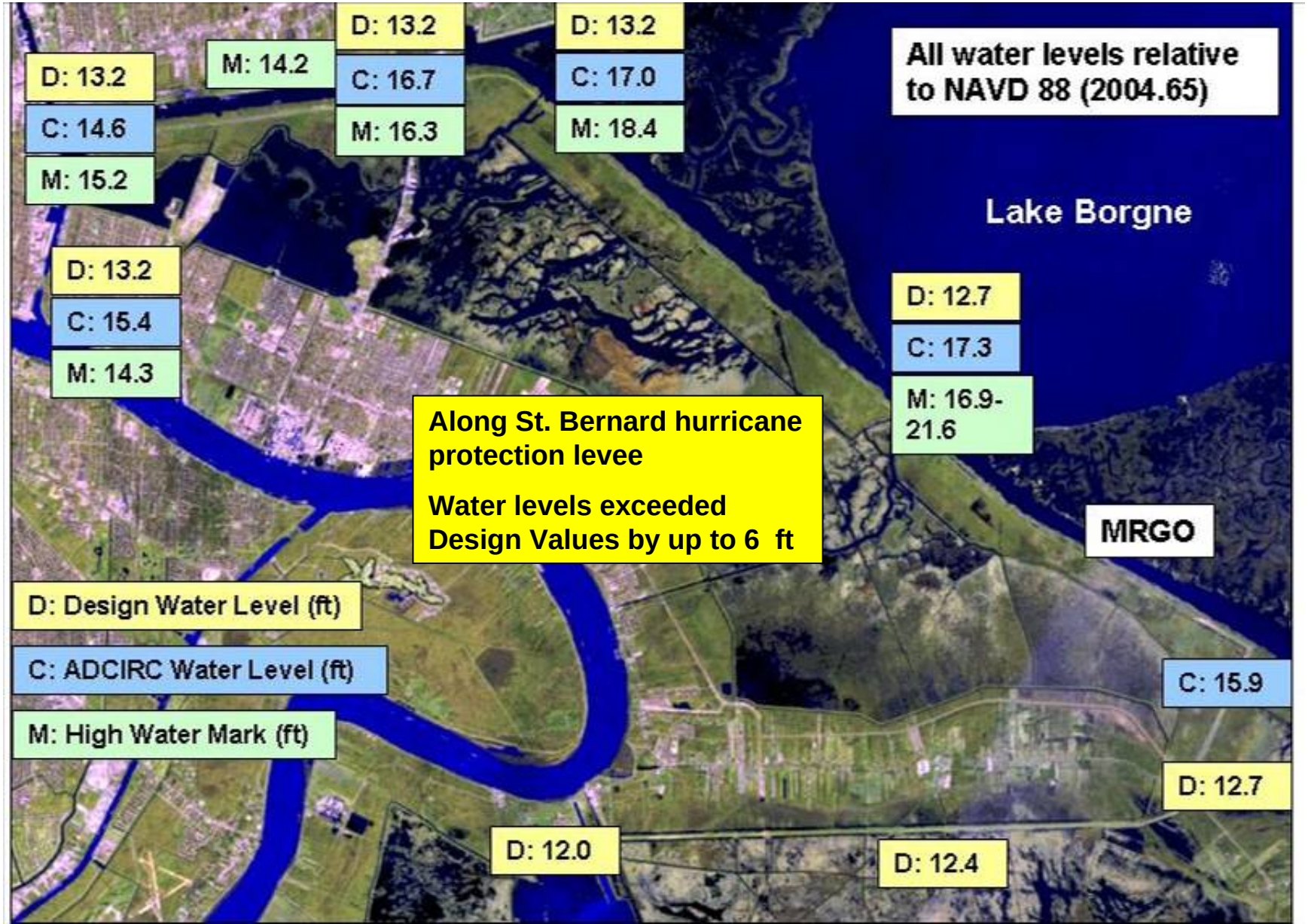
Peak Water Level Conditions
Comparison: Katrina and Design Values



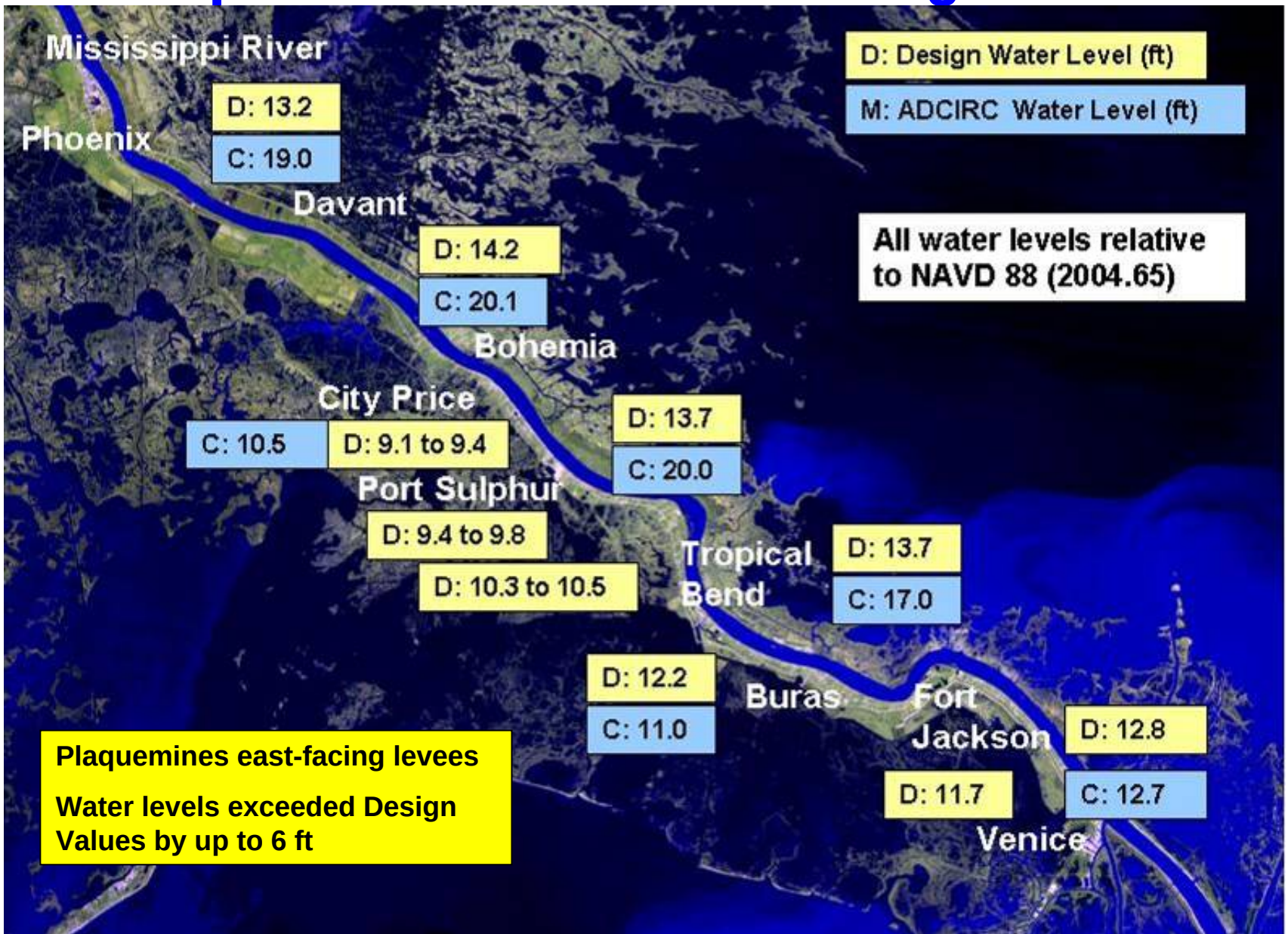
Peak Water Level Conditions
Comparison: Katrina and Design Values



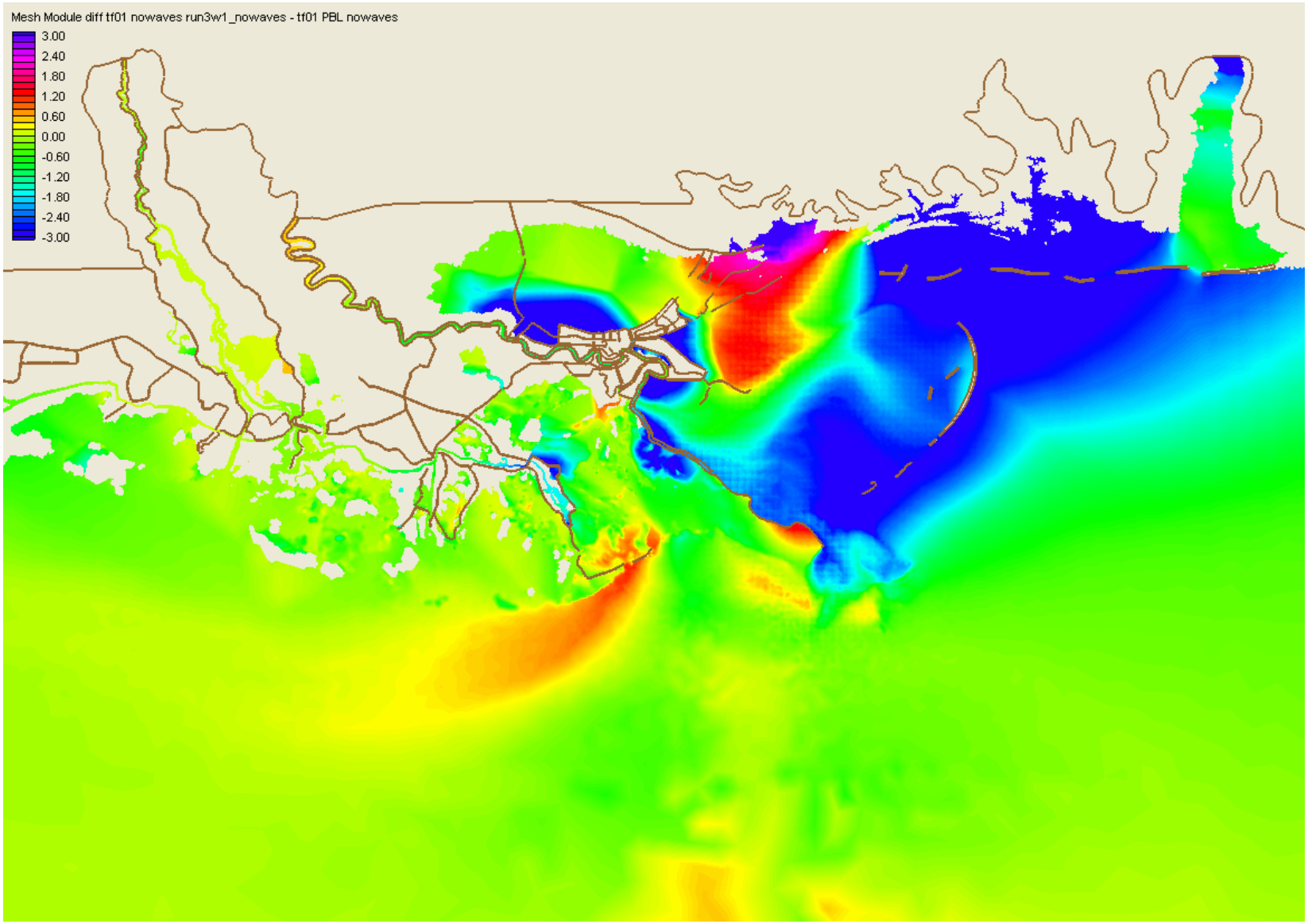
Peak Water Level Conditions
Comparison: Katrina and Design Values



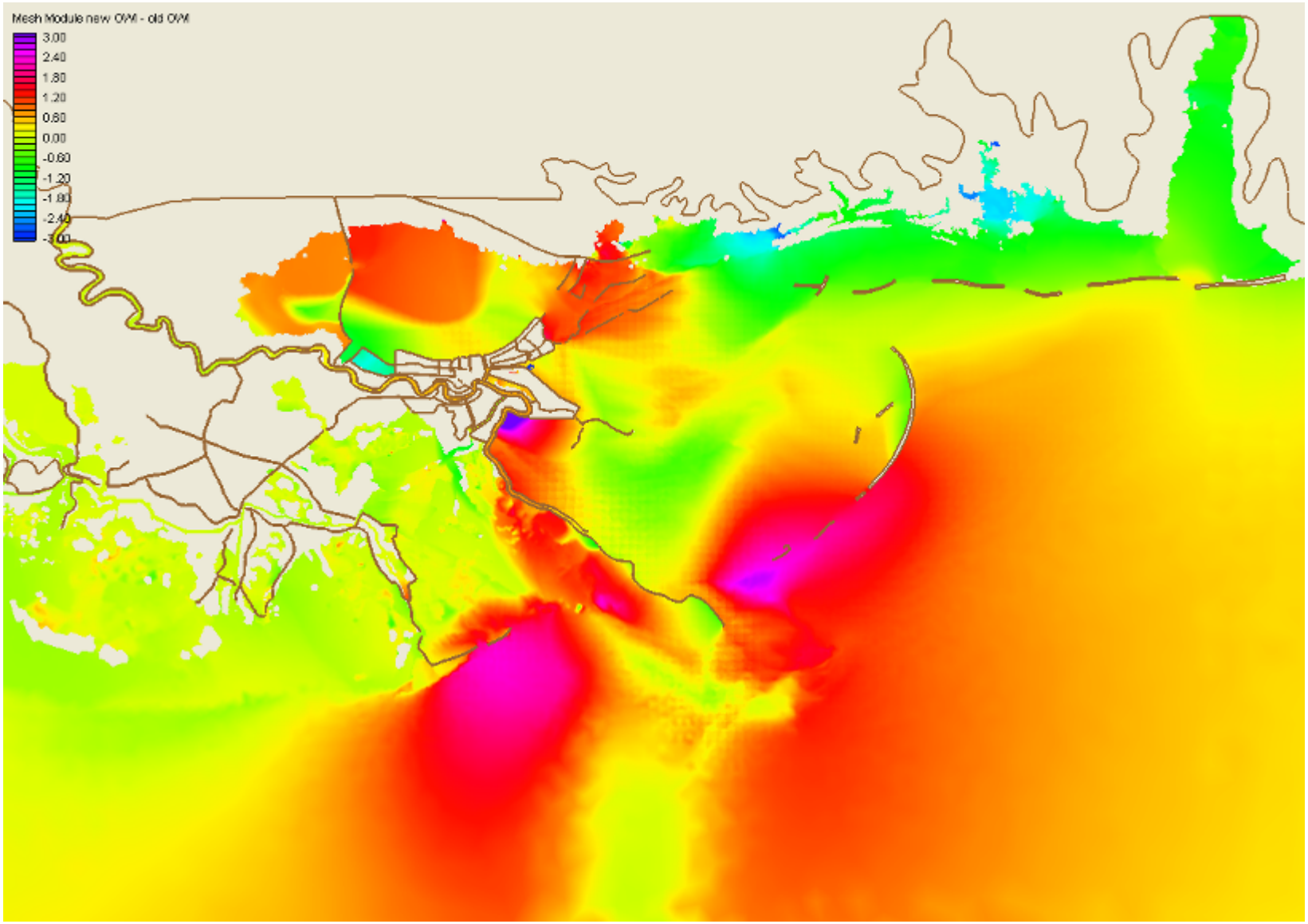
Peak Water Level Conditions
Comparison: Katrina and Design Values



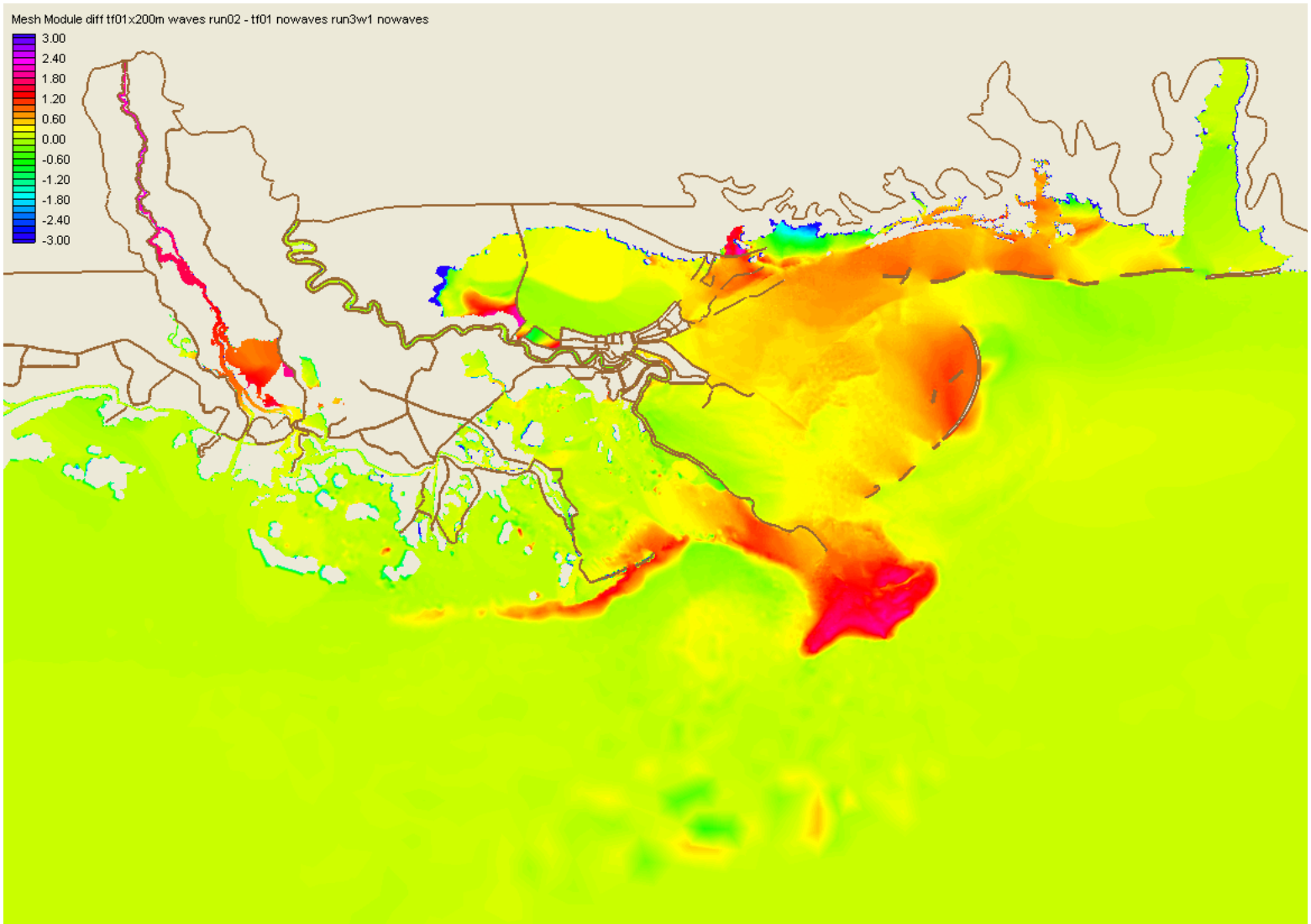
Effect of wind models: TF01, 90% OWI – PBL winds



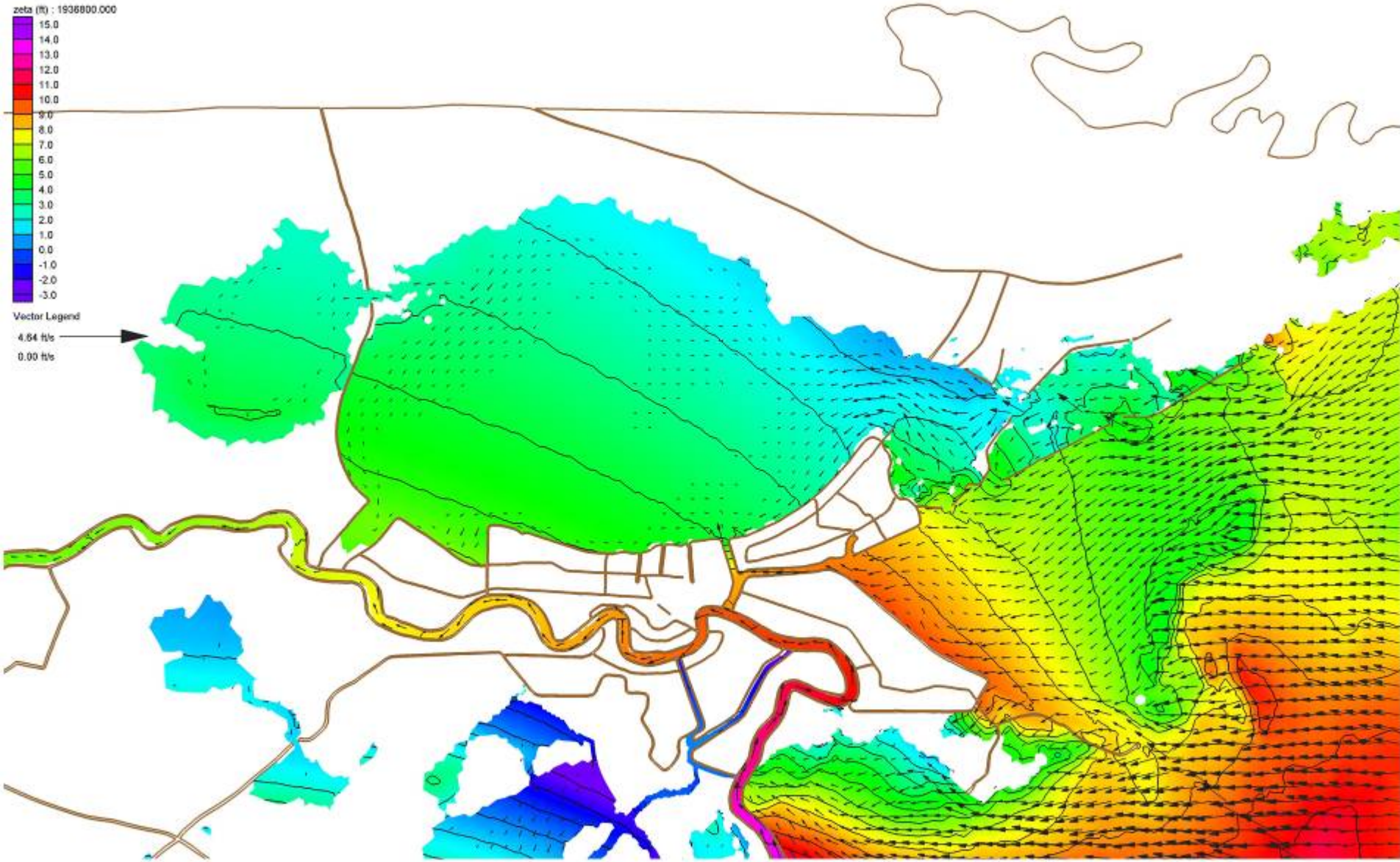
Effect of wind models: TF01, 95% OWI – 90% OWI



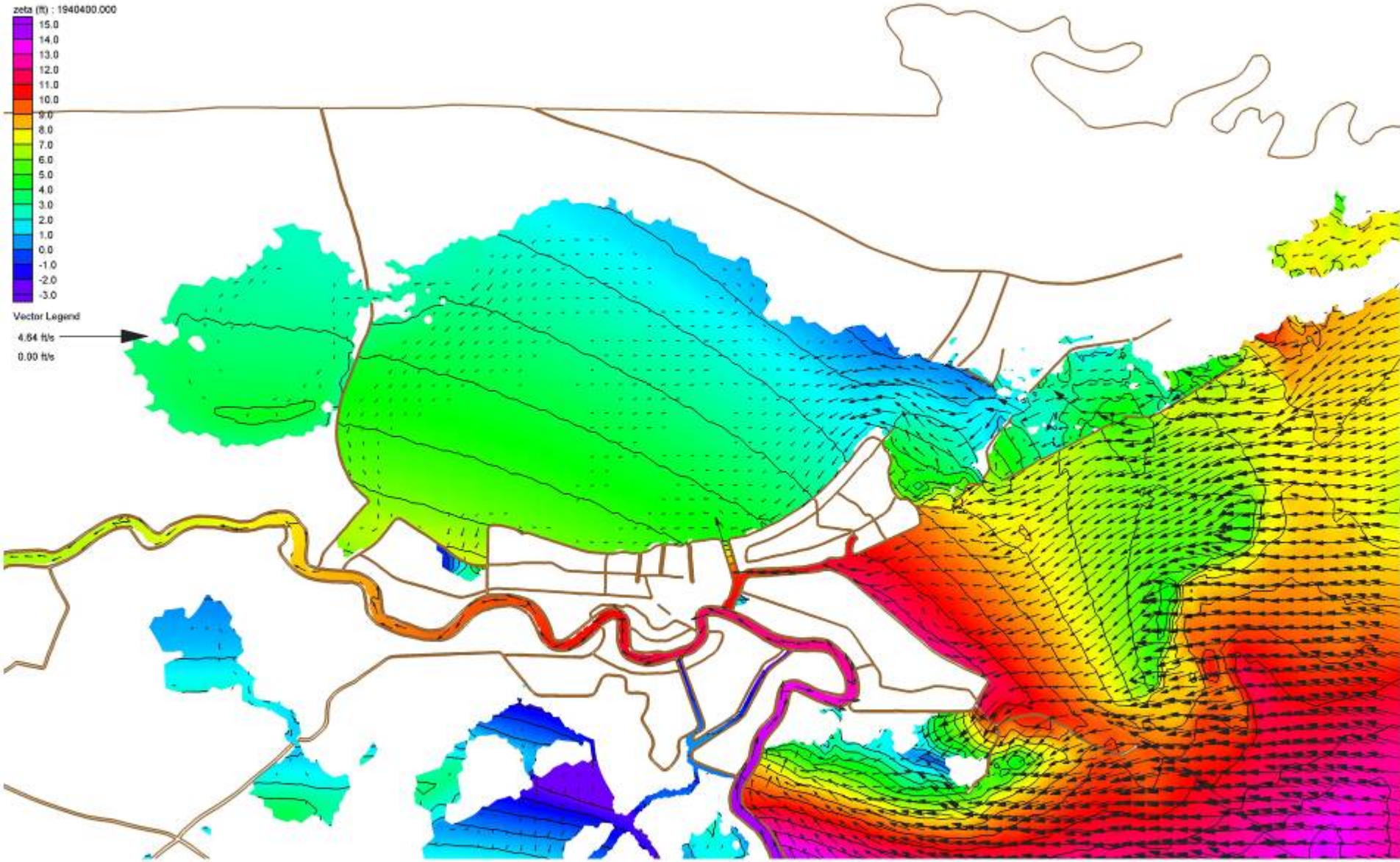
Effect of waves: TF01x1 STWAVE – TF01 no waves, 90% OWI winds



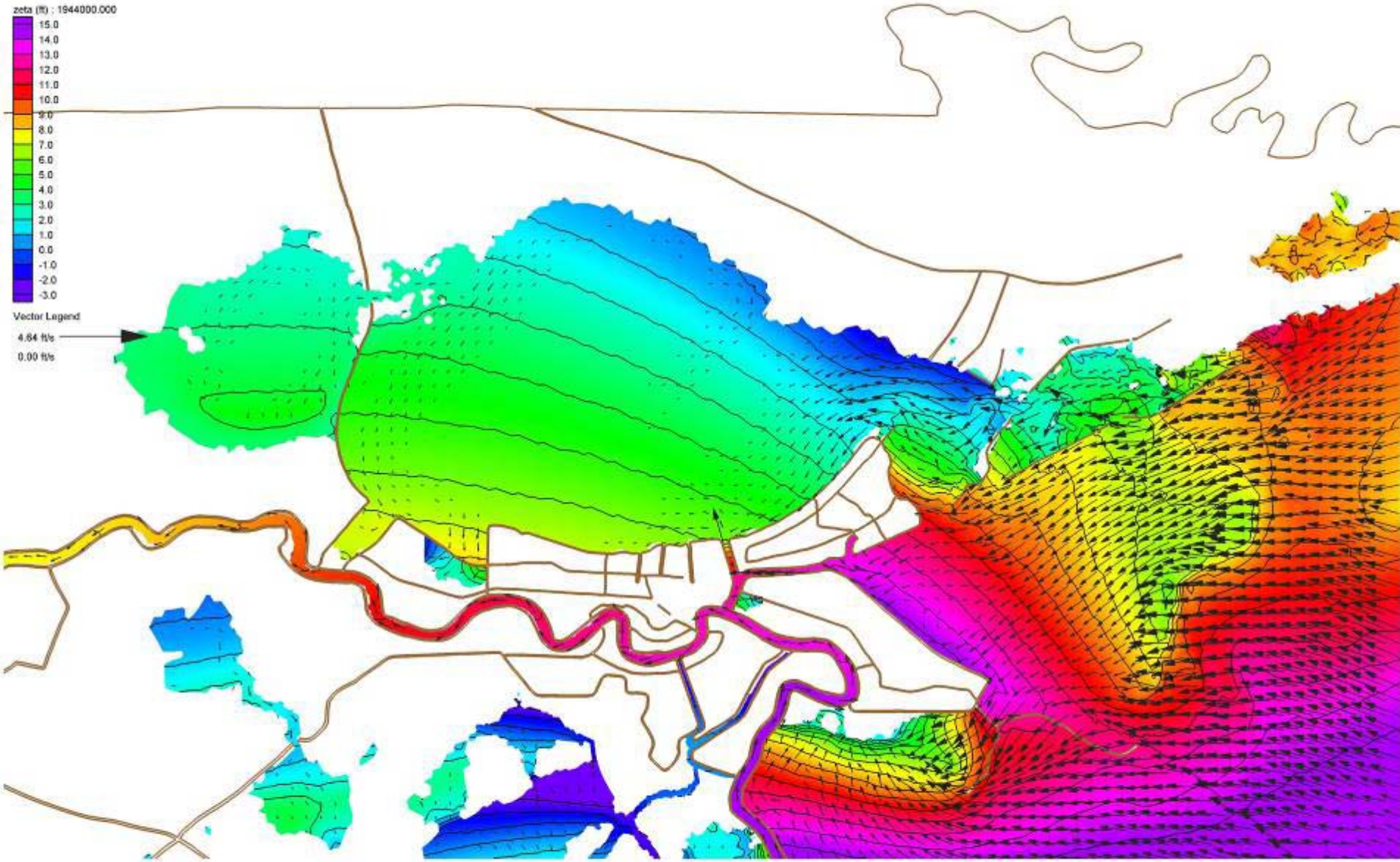
8/29/10Z TF01x1, OWI 95% winds, STWAVE, tides



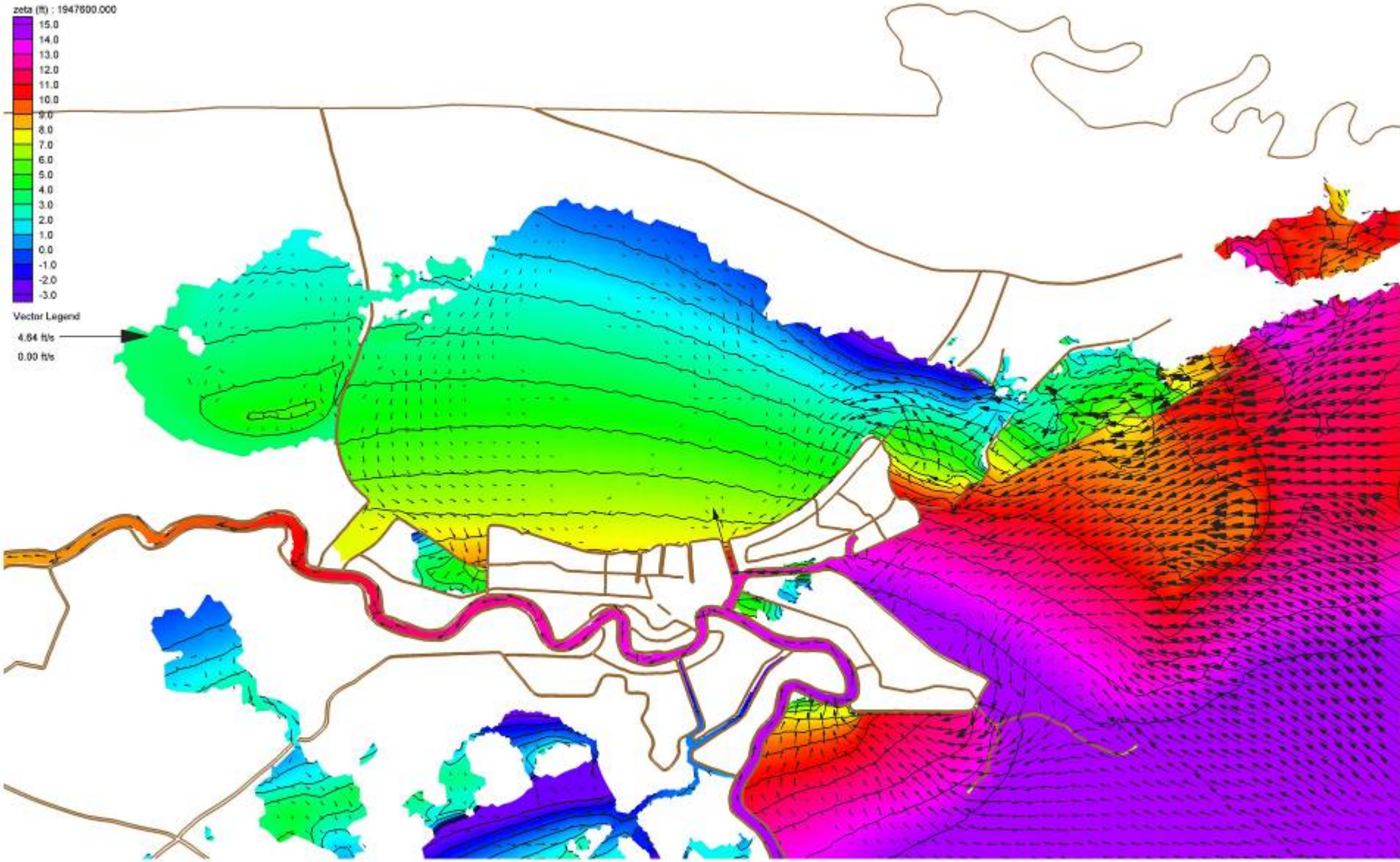
8/29/11Z


zeta (ft) : 1940400.000
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Vector Legend
4.64 ft/s
0.00 ft/s

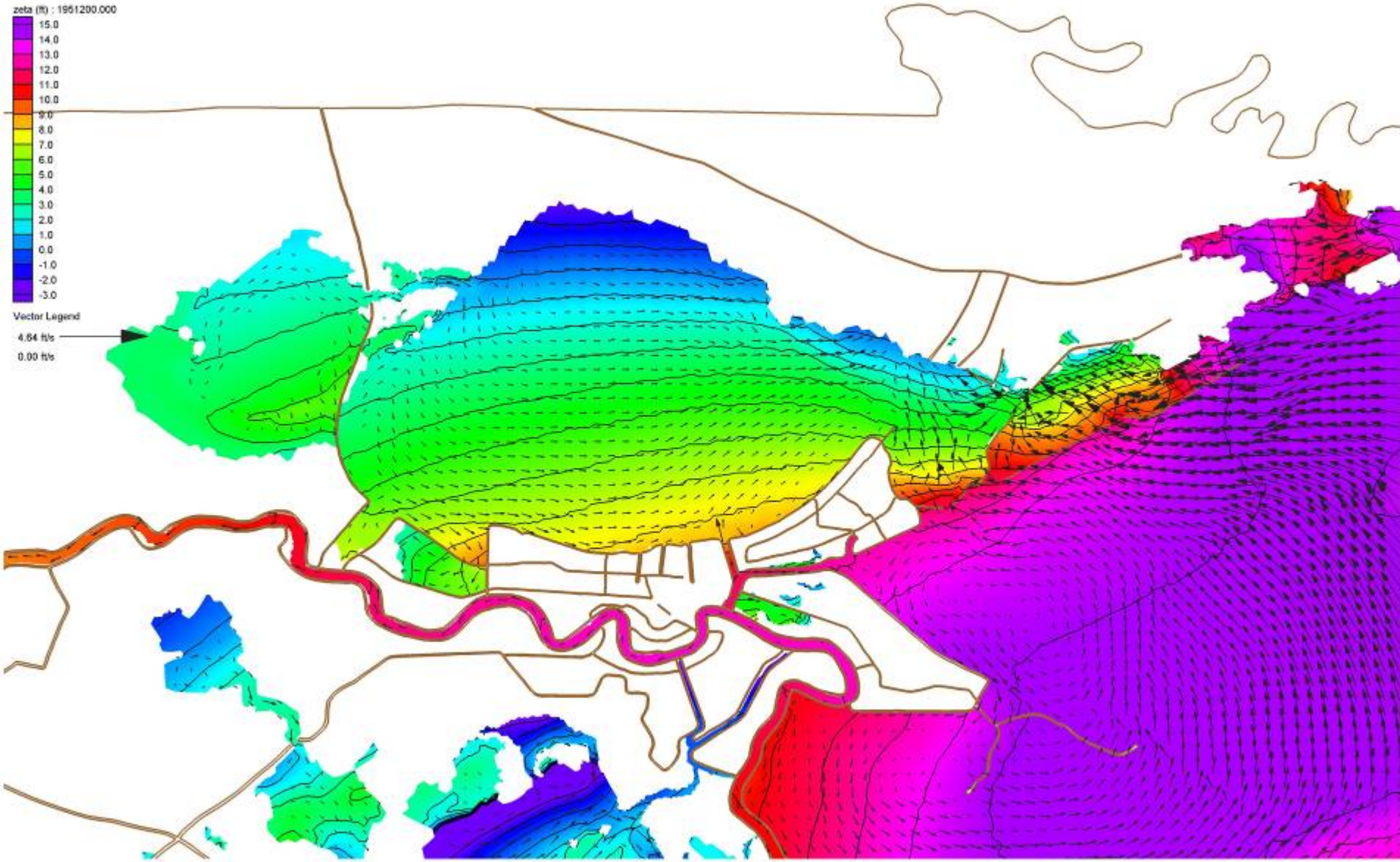
8/29/12Z


zeta (ft) : 1944000.000
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Vector Legend
4.64 ft/s
0.00 ft/s

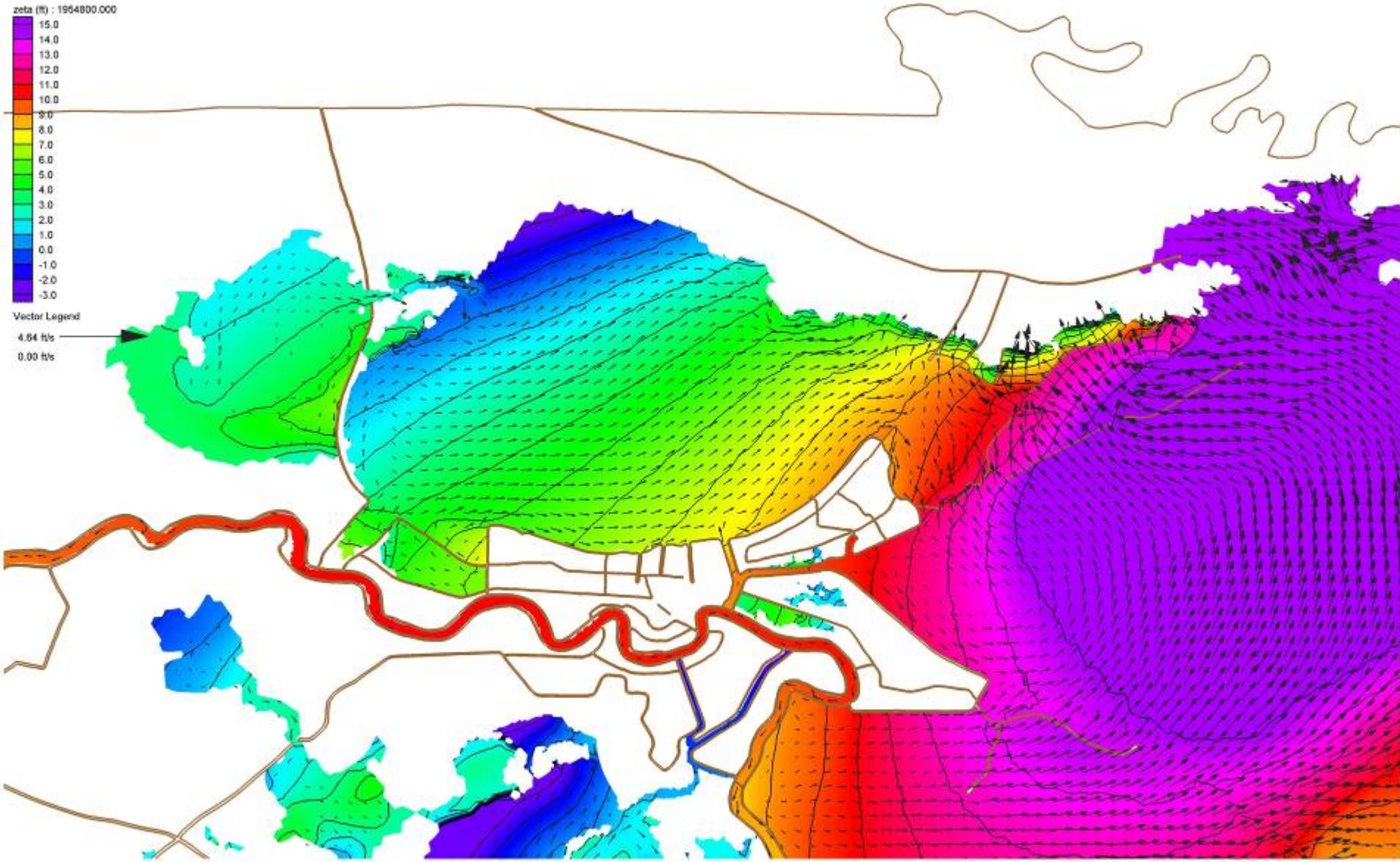
8/29/13Z


zeta (ft) : 1947600.000
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Vector Legend
4.64 ft/s
0.00 ft/s

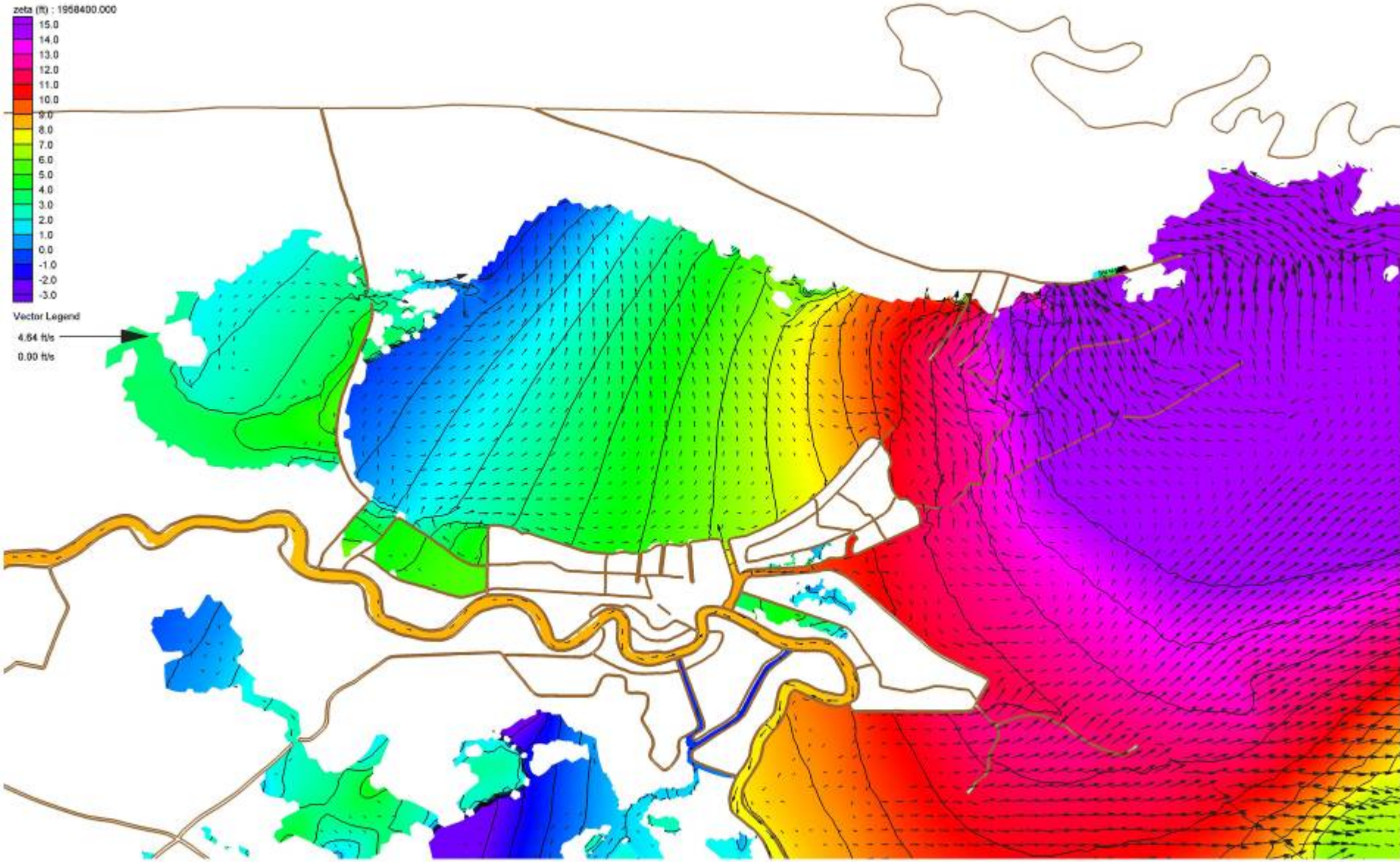
8/29/14Z


zeta (ft) : 1951200.000
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Vector Legend
4.64 ft/s
0.00 ft/s

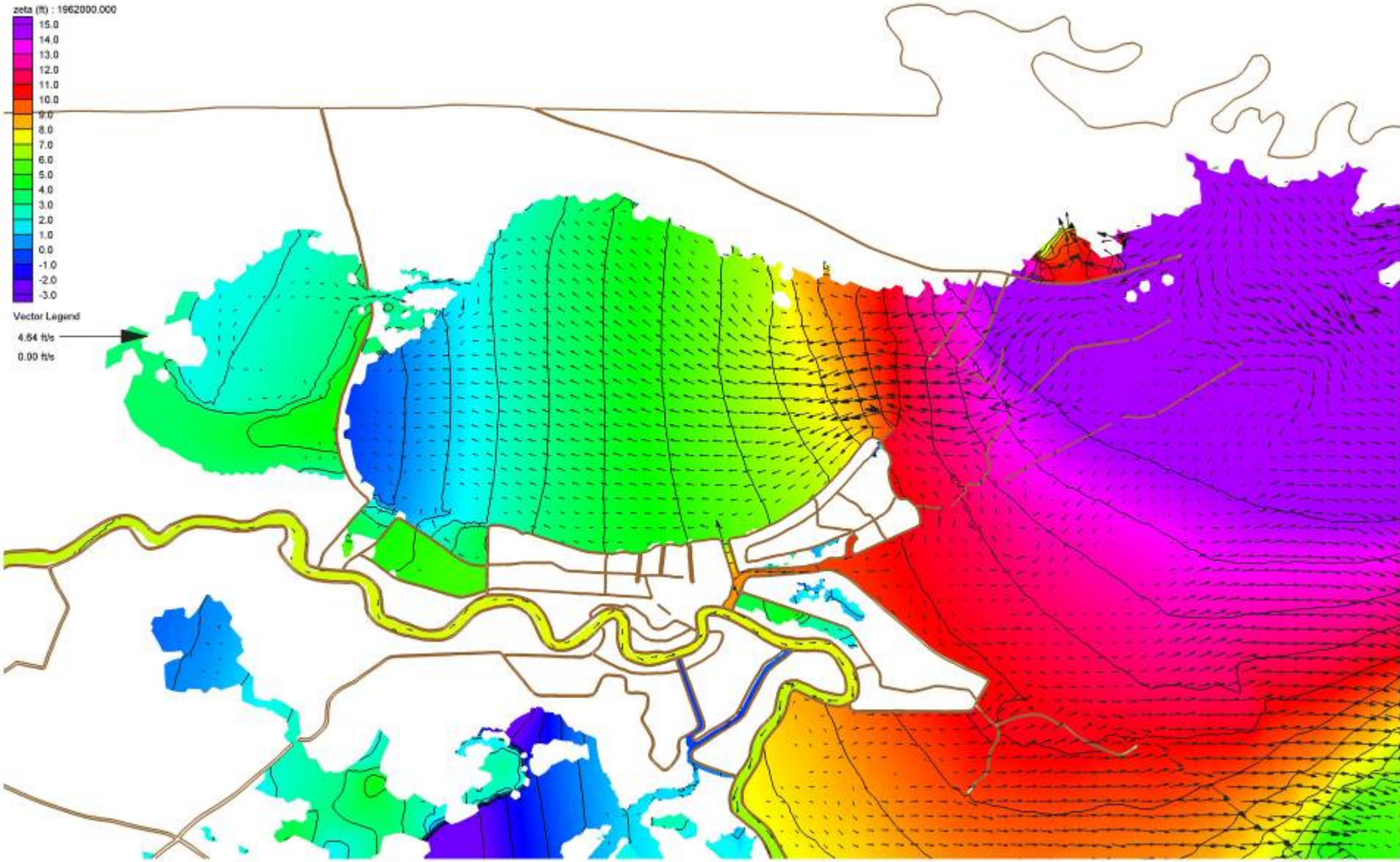
8/29/15Z


zeta (ft) : 1954800.000
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Vector Legend
4.64 ft/s
0.00 ft/s

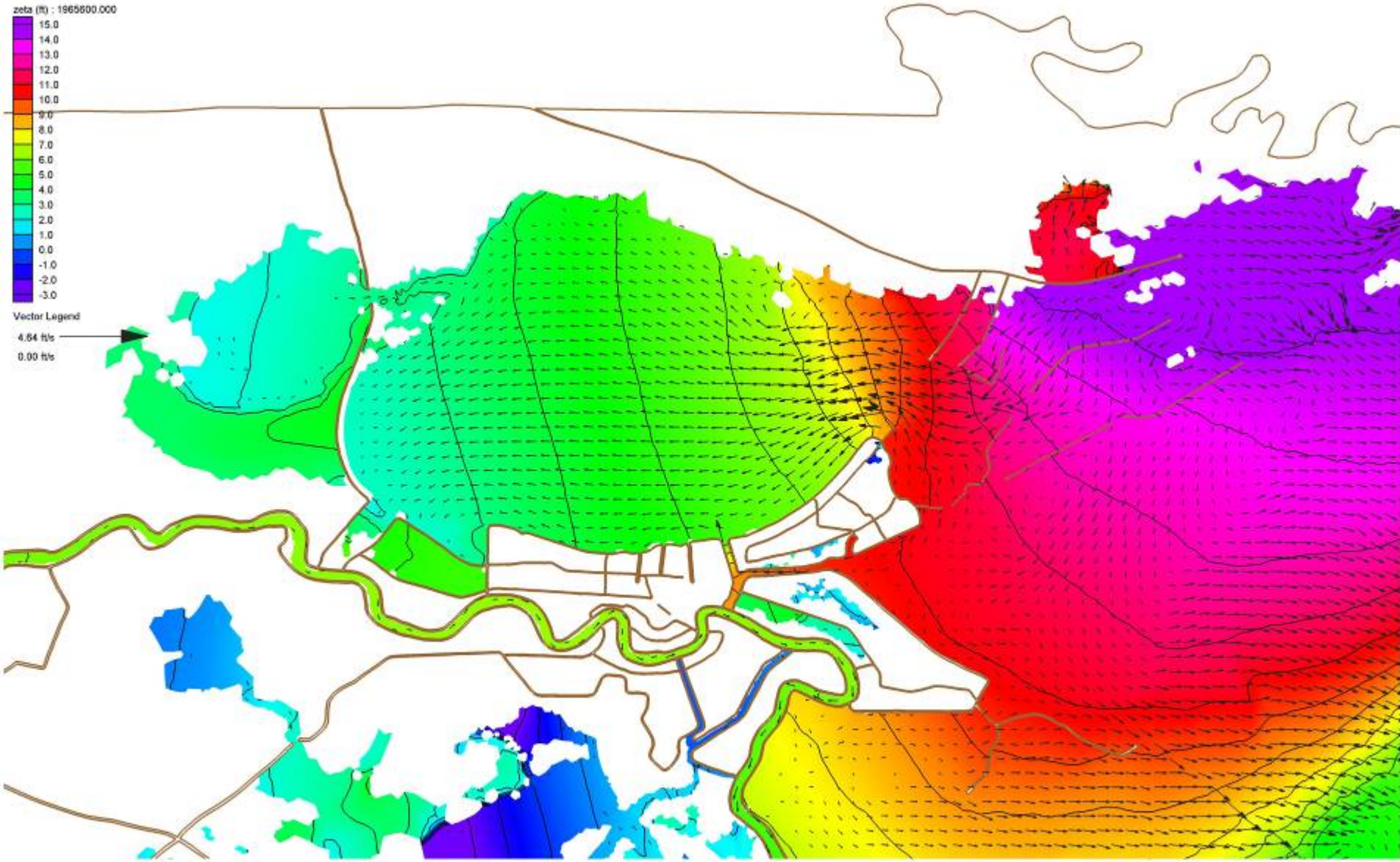
8/29/16Z


zeta (ft) : 1958400.000
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Vector Legend
4.64 ft/s
0.00 ft/s

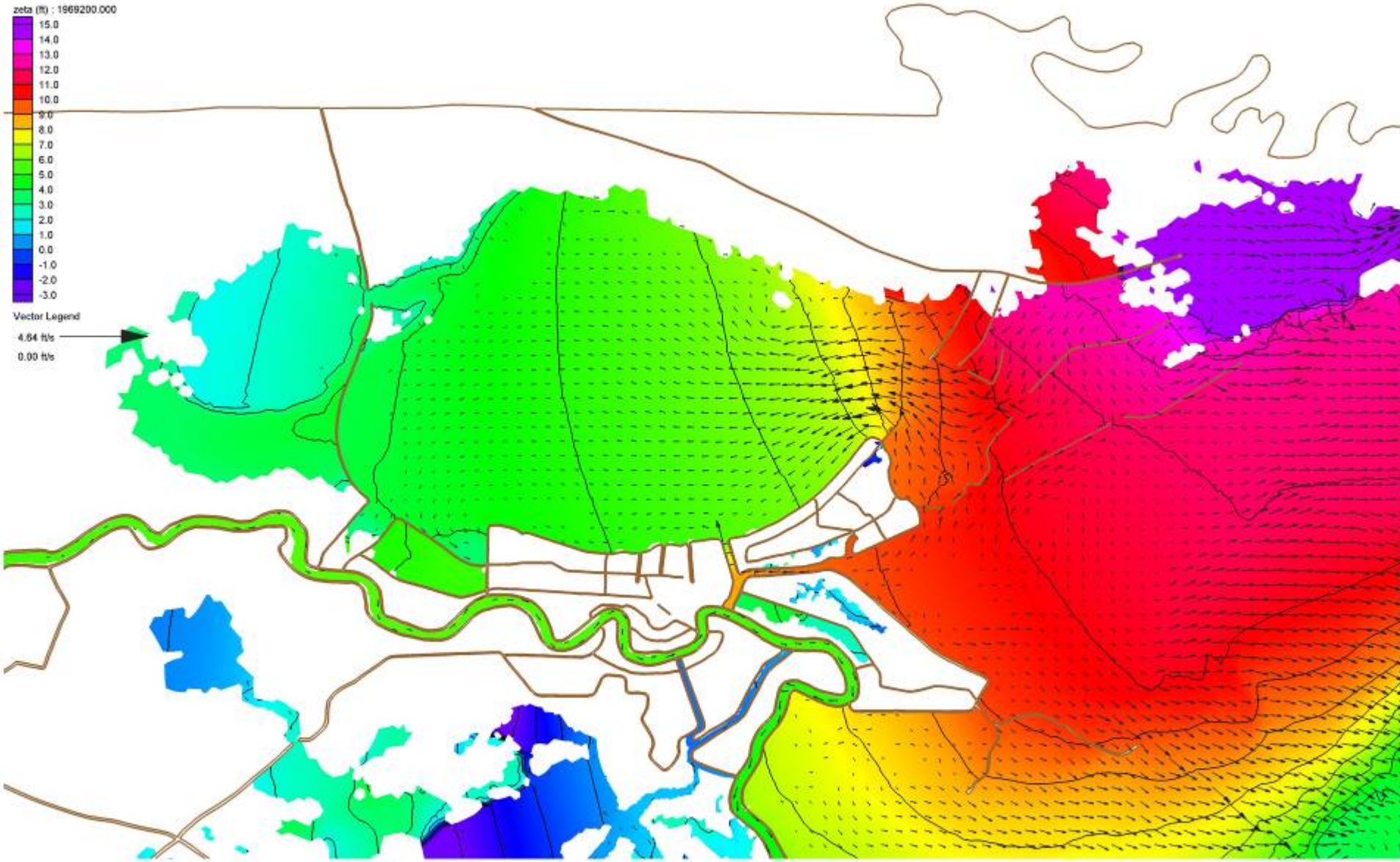
8/29/17Z


zeta (ft) : 1962000.000
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Vector Legend
4.64 ft/s
0.00 ft/s

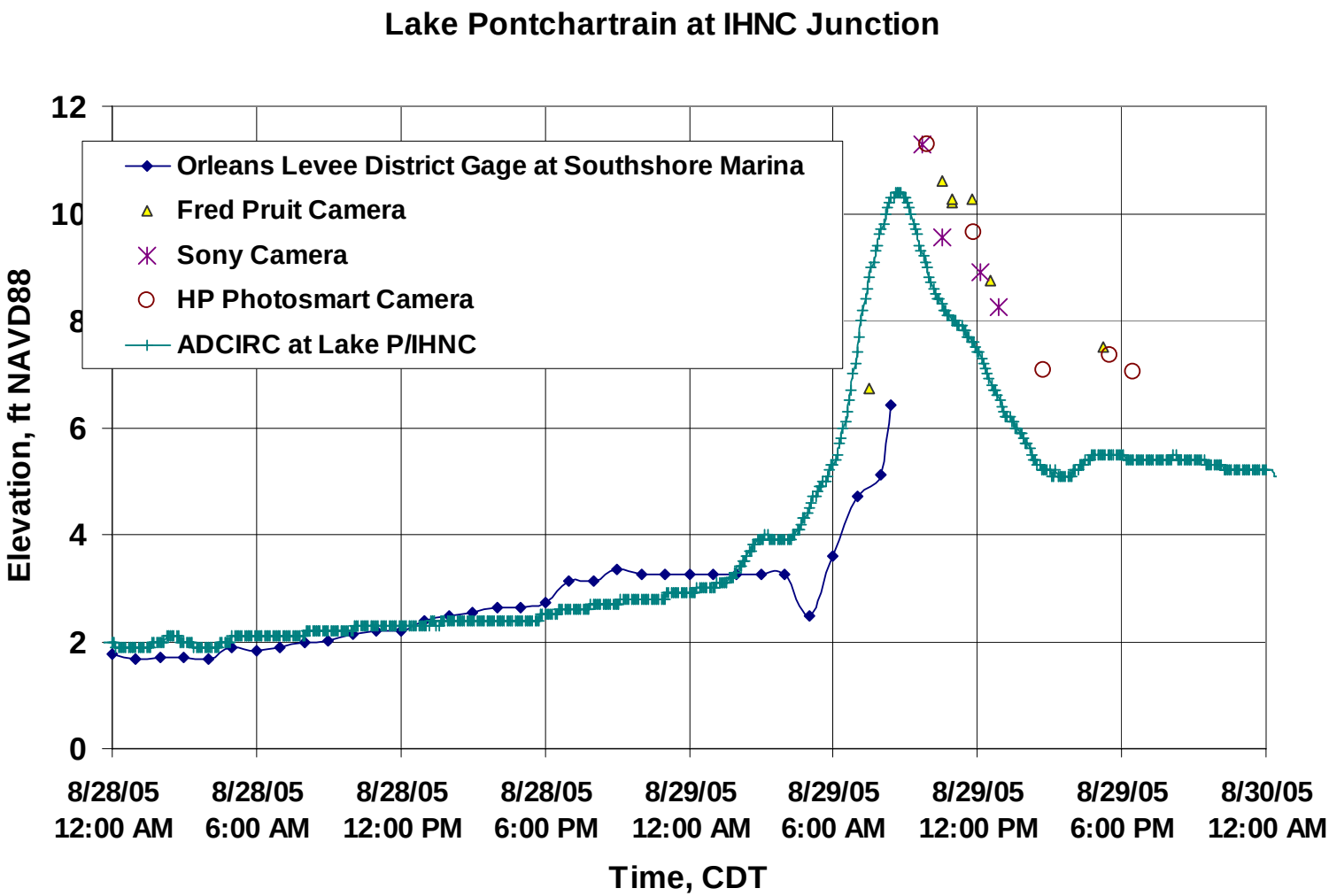
8/29/18Z


zeta (ft) : 1965600.000
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Vector Legend
4.64 ft/s
0.00 ft/s

8/29/19Z


zeta (ft) : 1969200.000
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Vector Legend
4.64 ft/s
0.00 ft/s

Comparison to Hydrographs



The Way Ahead

- Mesh resolution is key
  - Refine entrances, canals, waterways, and lakes
  - Add more levees and roads
- Improve bathymetry and topography (Lidar)
- Couple to wave models (ST-WAVE 4 grids)
  - Wave radiation stress
  - Modify bottom stress