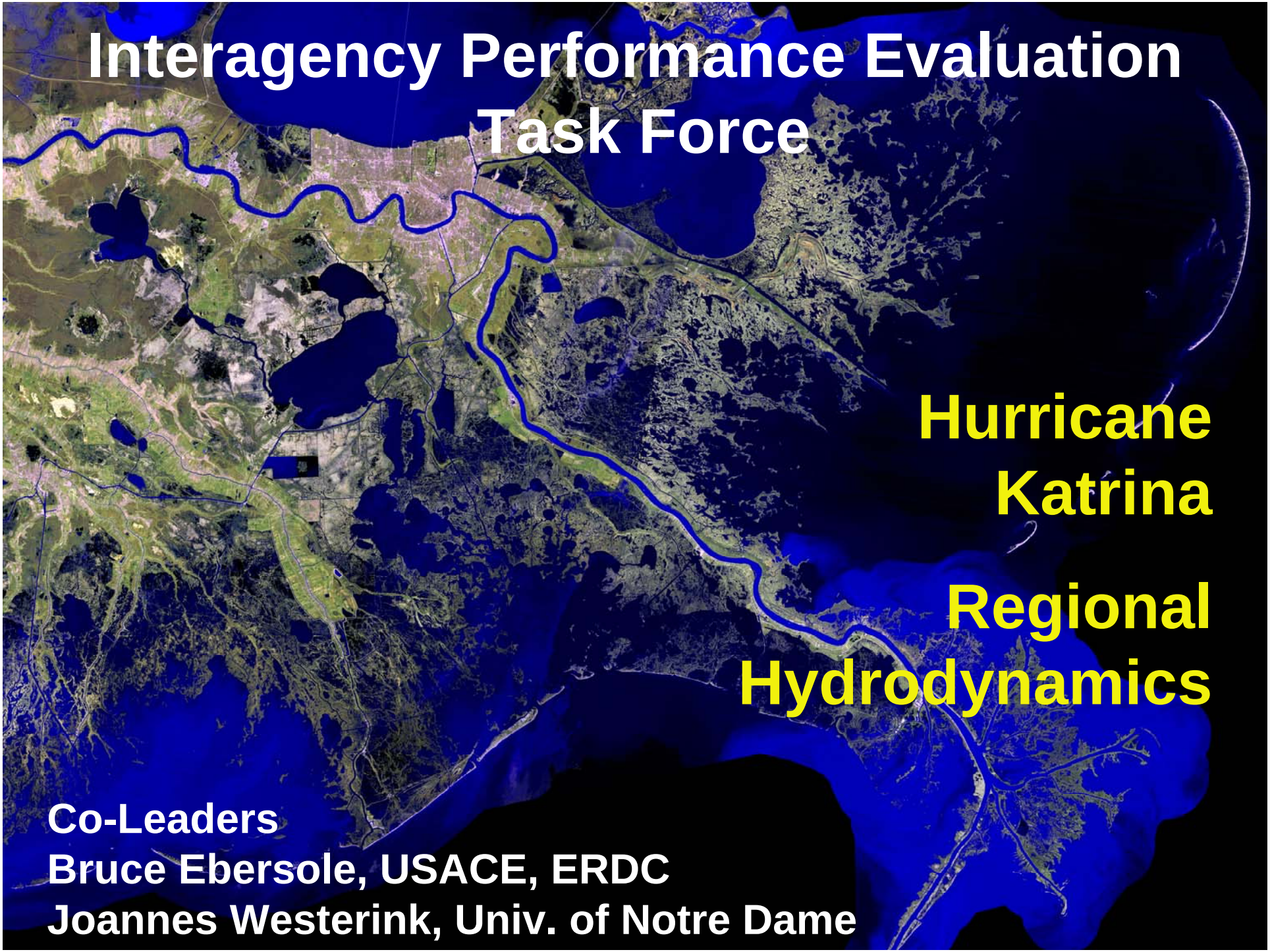

Interagency Performance Evaluation Task Force
Hurricane Katrina
Regional Hydrodynamics
Co-Leaders
Bruce Ebersole, USACE, ERDC
Joannes Westerink, Univ. of Notre Dame

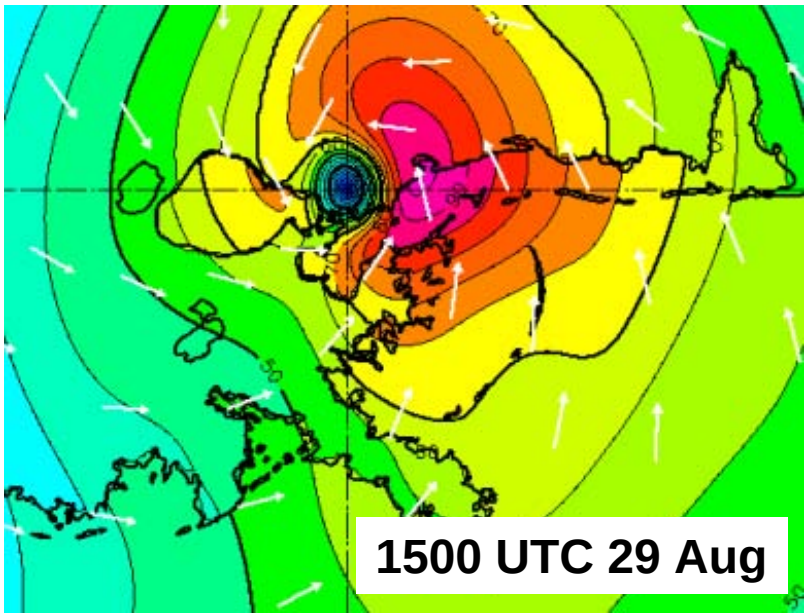
# Questions to Answer

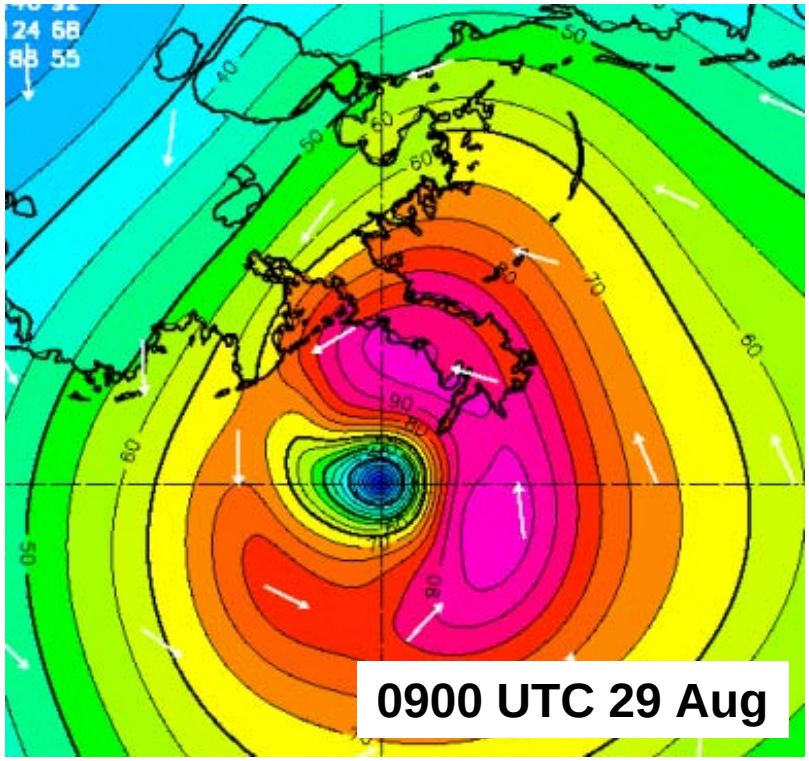
- What were the storm surges and waves during Hurricane Katrina?
- How do these compare to values used as the basis for design?

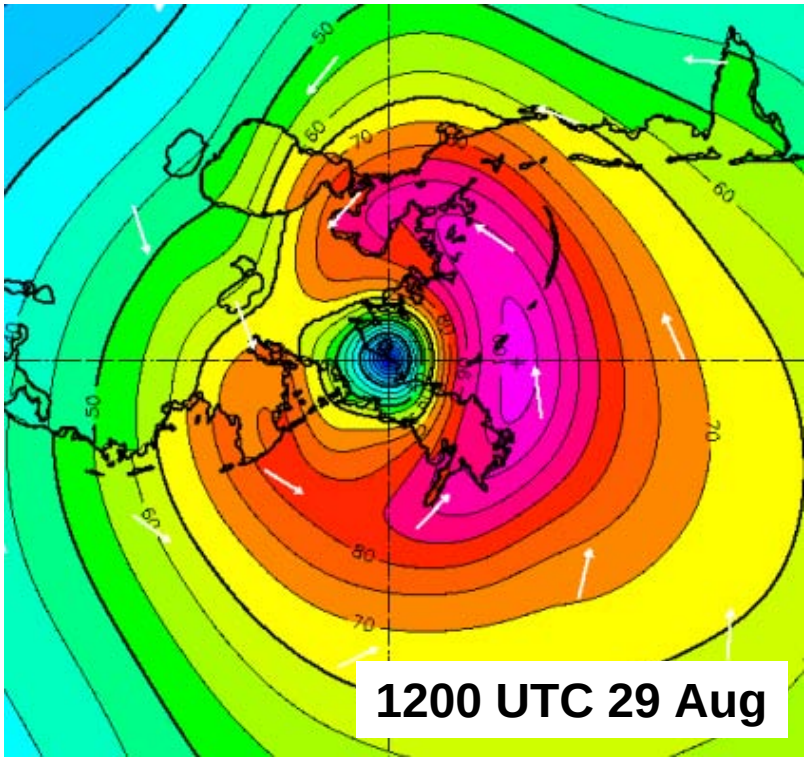
Utilize Measurements and Modeling

# H*Wind Snapshots Near Landfall

## Quality of Wind Input is Critical

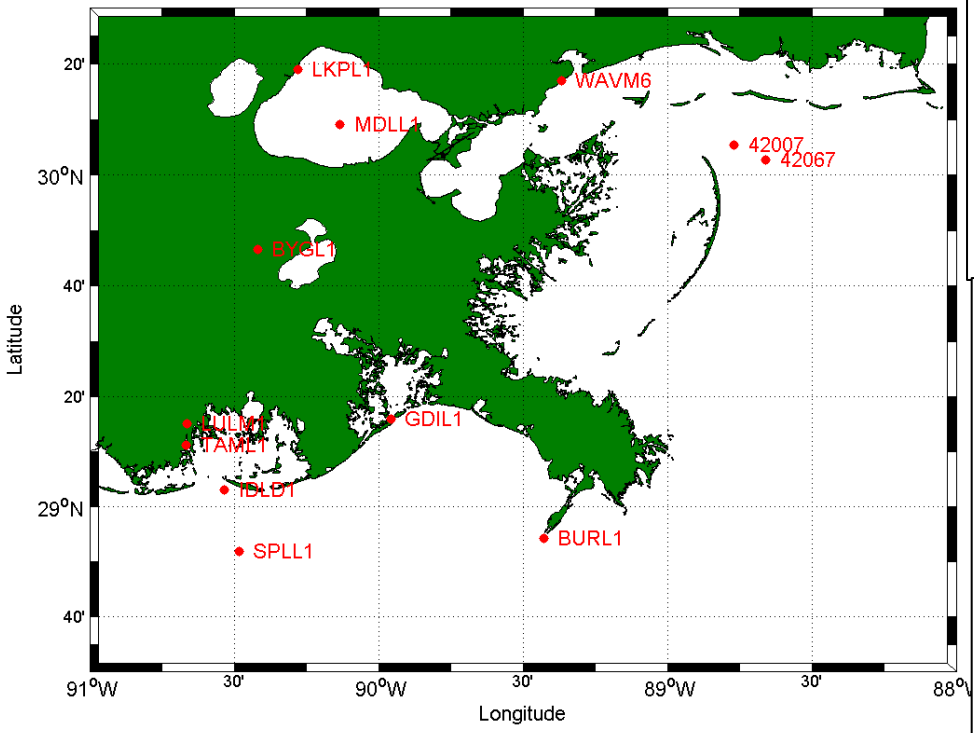


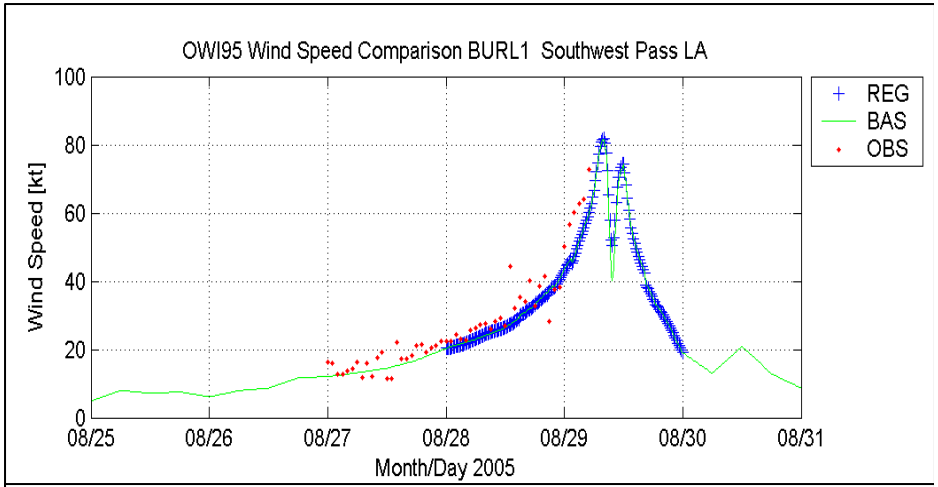



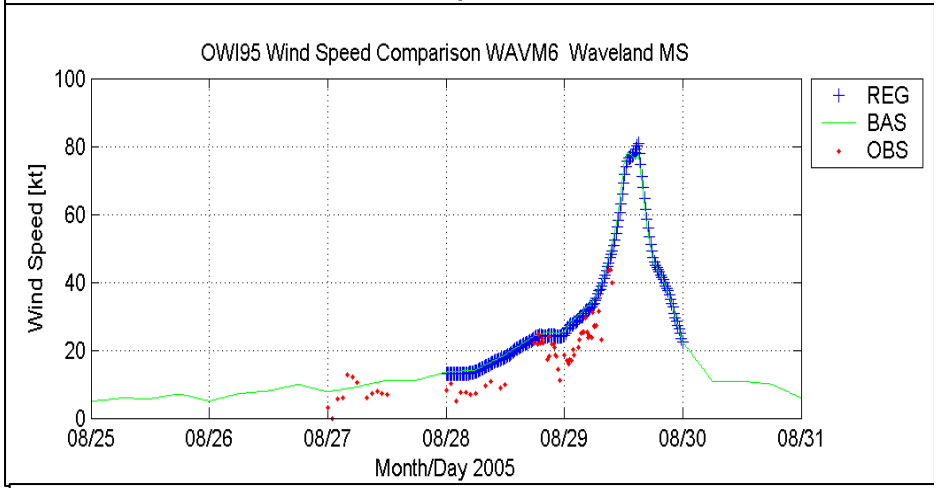



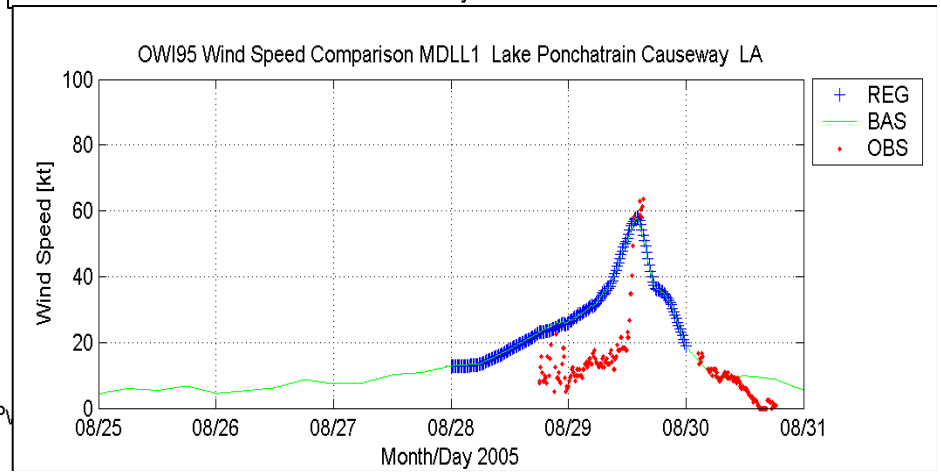
# Surface Wind Measurements

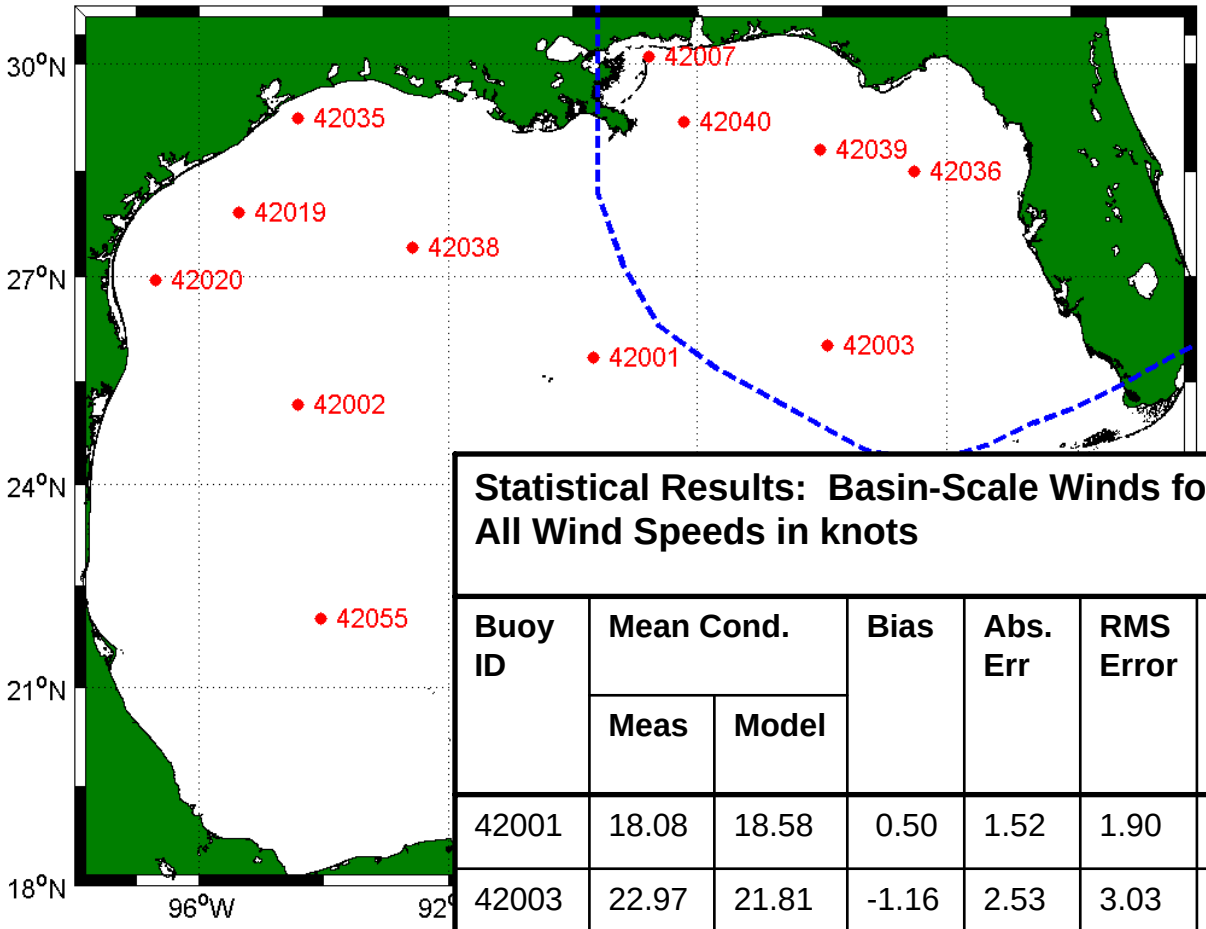
- Nearly all surface anemometers in the region failed and did not capture the peak conditions
- Mid-Lake Pontchartrain gage provided most complete record, but data quality is suspect



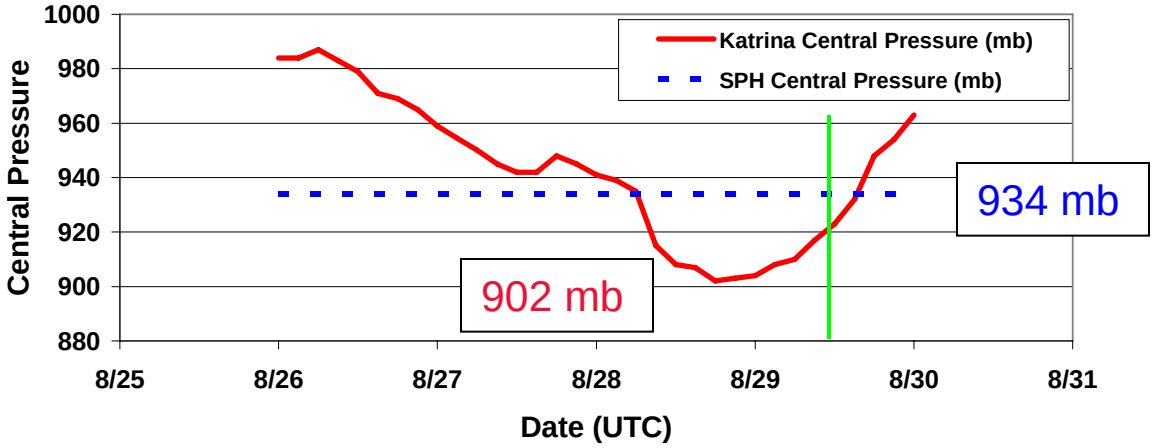


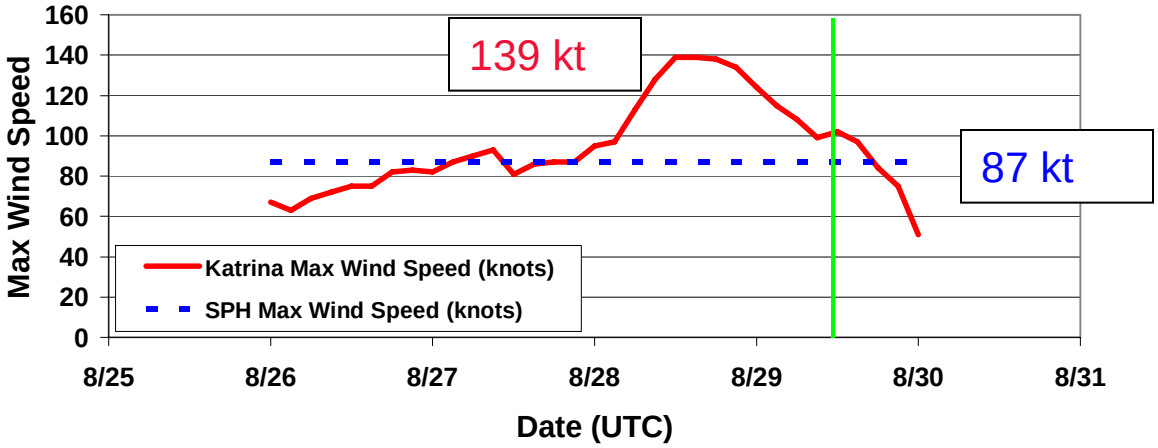

# H*Wind/IOKA Product vs Wind Measurements

**Statistical Results: Basin-Scale Winds for Hurricane Katrina**
**All Wind Speeds in knots**

| Buoy ID | Mean Cond. | | Bias | Abs. Err | RMS Error | Scat Indx | Linear Regression Estimators | | | | No. Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Meas | Model | | | | | Corr | Sys b | Slope | Intercp. | |
| 42001 | 18.08 | 18.58 | 0.50 | 1.52 | 1.90 | 10 | 0.99 | 1.03 | 1.03 | 0.04 | 82 |
| 42003 | 22.97 | 21.81 | -1.16 | 2.53 | 3.03 | 13 | 0.99 | 0.92 | 0.82 | 3.05 | 42 |
| 42007 | 15.92 | 15.49 | -0.43 | 2.60 | 3.42 | 21 | 0.92 | 0.98 | 0.93 | 0.62 | 57 |
| 42036 | 21.36 | 21.01 | -0.35 | 1.32 | 1.73 | 8 | 0.95 | 0.98 | 0.89 | 1.92 | 83 |
| 42038 | 12.97 | 13.41 | 0.44 | 1.94 | 2.35 | 18 | 0.95 | 1.01 | 0.90 | 1.71 | 82 |
| 42039 | 21.71 | 22.32 | 0.61 | 1.94 | 2.58 | 12 | 0.95 | 1.01 | 0.87 | 3.38 | 84 |
| 42040 | 20.74 | 21.62 | 0.87 | 2.06 | 2.72 | 13 | 0.98 | 1.01 | 0.93 | 2.27 | 84 |
| 42055 | 9.43 | 10.48 | 1.05 | 2.92 | 3.48 | 37 | 0.64 | 1.05 | 0.44 | 6.36 | 84 |

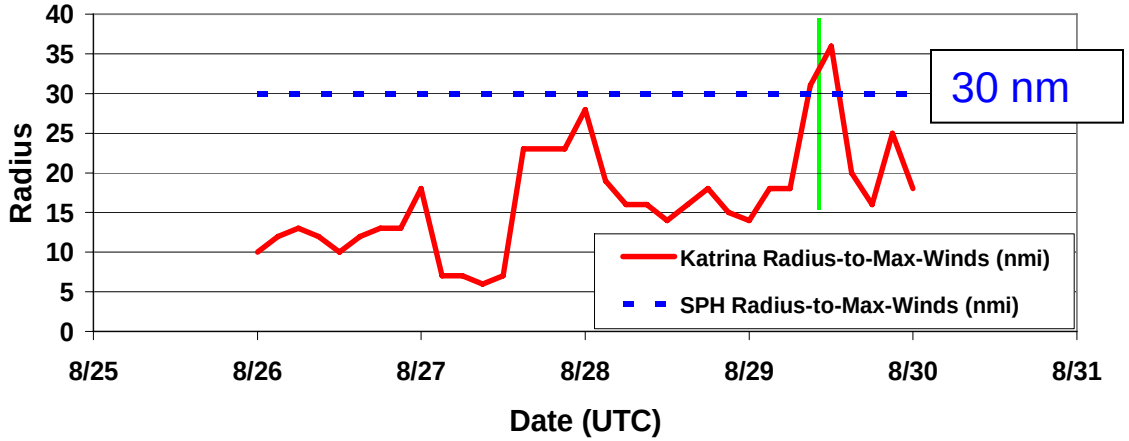
# Katrina vs SPH Winds



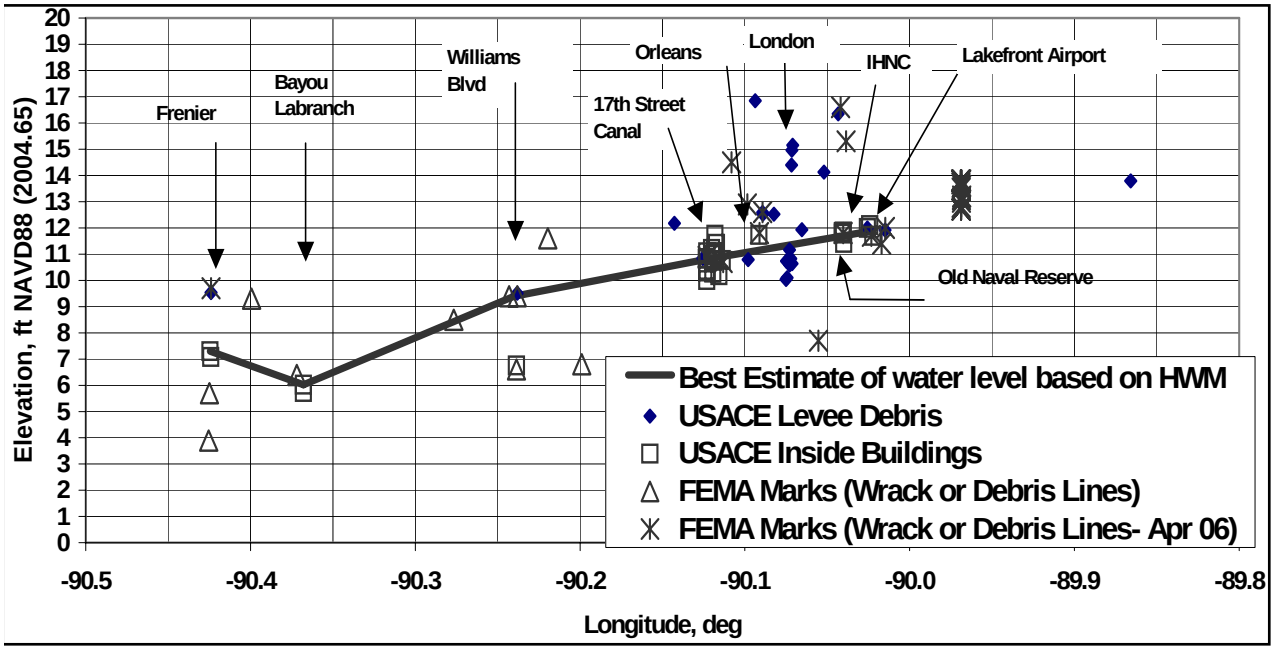

139 knot (Katrina) vs. 87 knot (SPH) at peak intensity

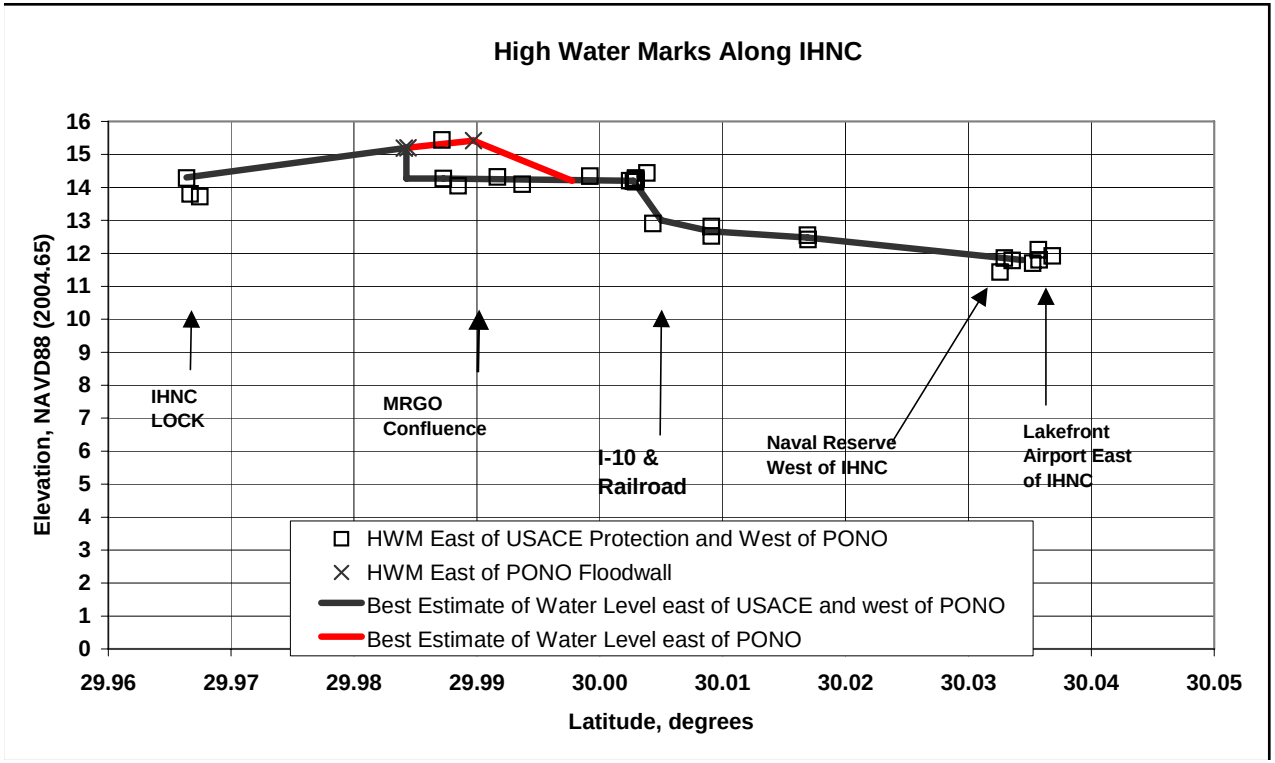
In deeper water, 2.5 times wave producing potential of the SPH




100 knot (Katrina) vs. 87 knot (SPH) at landfall

In shallow water, 1.3 to 1.5 times surge producing potential of the SPH

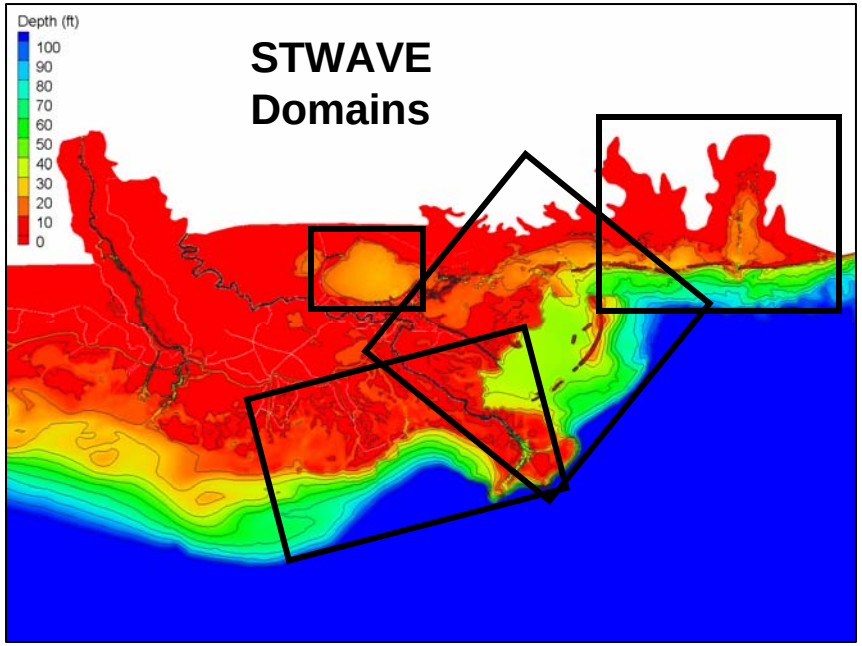


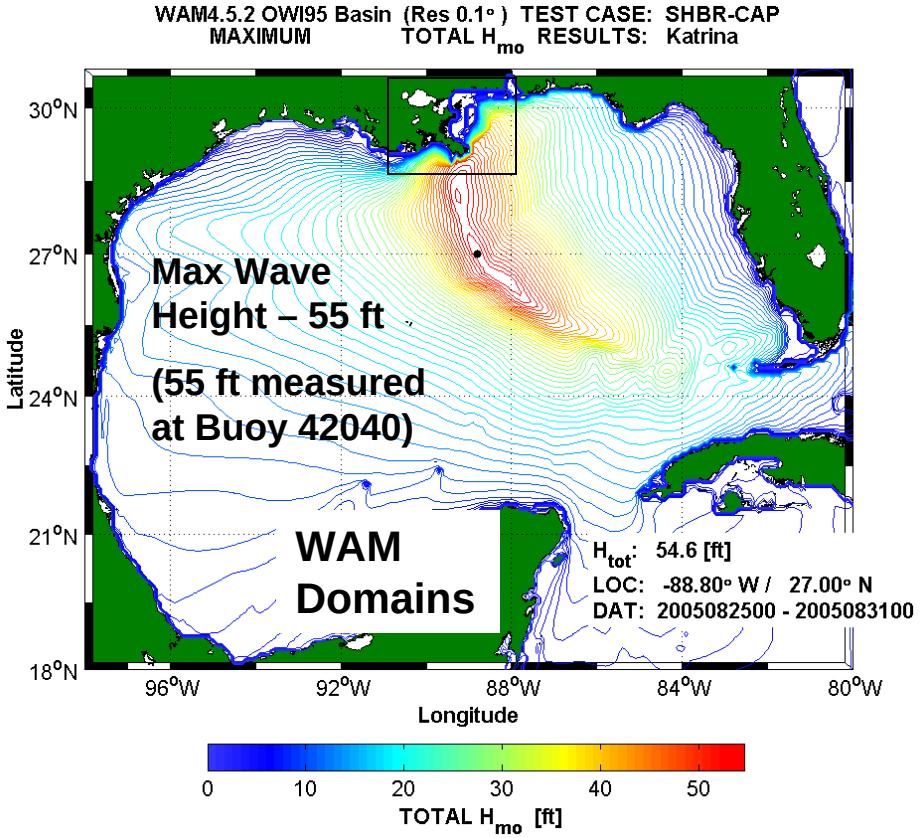

# High Water Mark and Hydrograph Analysis

- 13 measured hydrographs considered in the region (**only** 1 captured peak in N.O. vicinity)
- 2 constructed hydrographs from digital photos (17th Street Canal and Lakefront Airport were crucial
- 15% of non-protected HWMs rated excellent
- Debris/wrack line marks contain considerable uncertainty; low reliability as indicator of storm water level

# Nested Wave Modeling Approach (3 Levels)

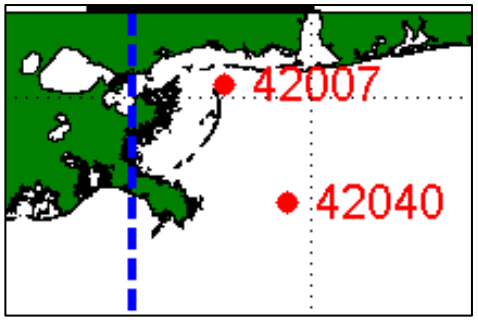



- Basin – Regional – Nearshore
- Wave-storm surge interaction handled at the nearshore level



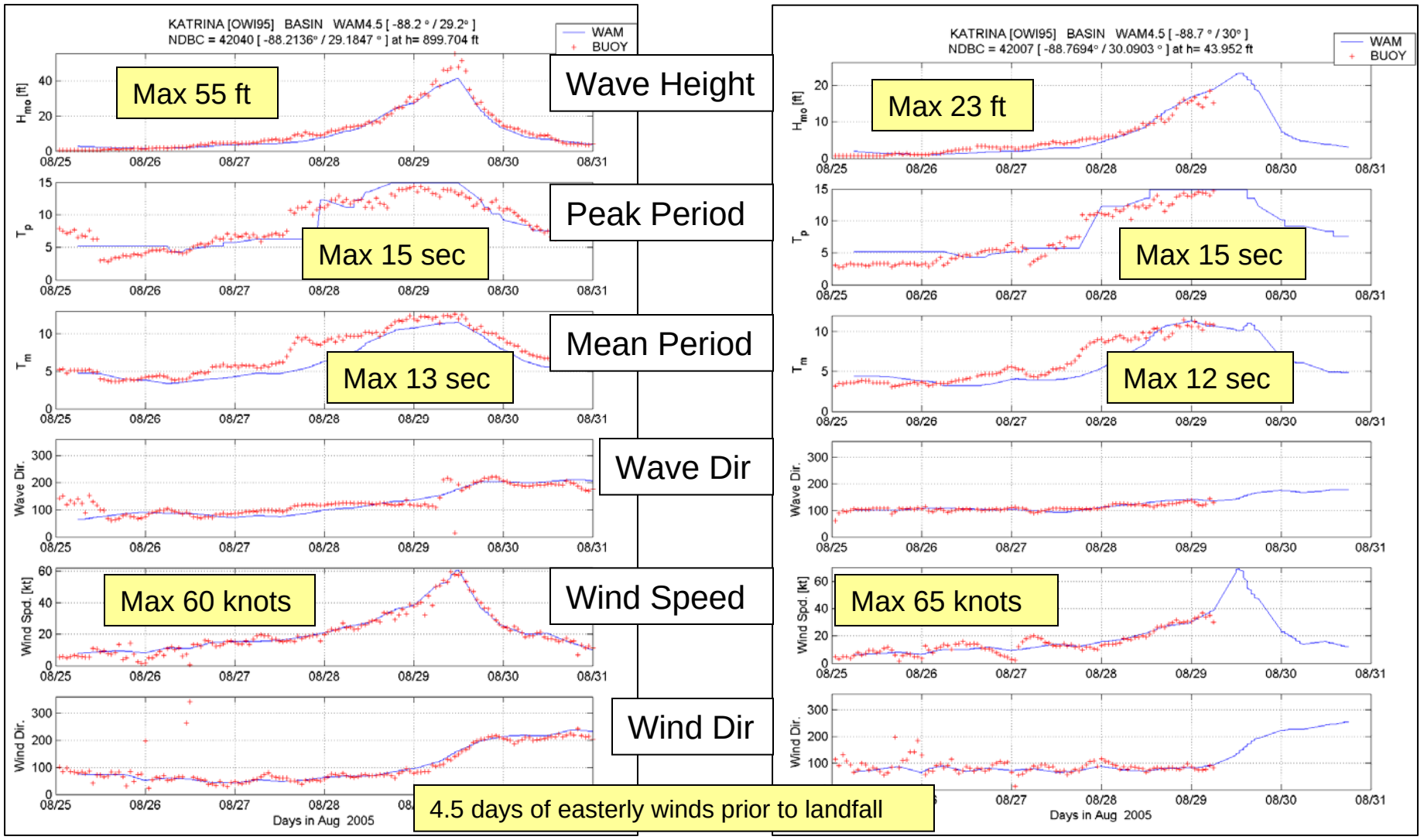

- Maximize model-to-measurement comparisons
- STWAVE compared to SWAN
- Examine steady-state assumption in STWAVE
- WAM compared to WAVEWATCH III

# WAM Model Computations and Measurements – SE Louisiana



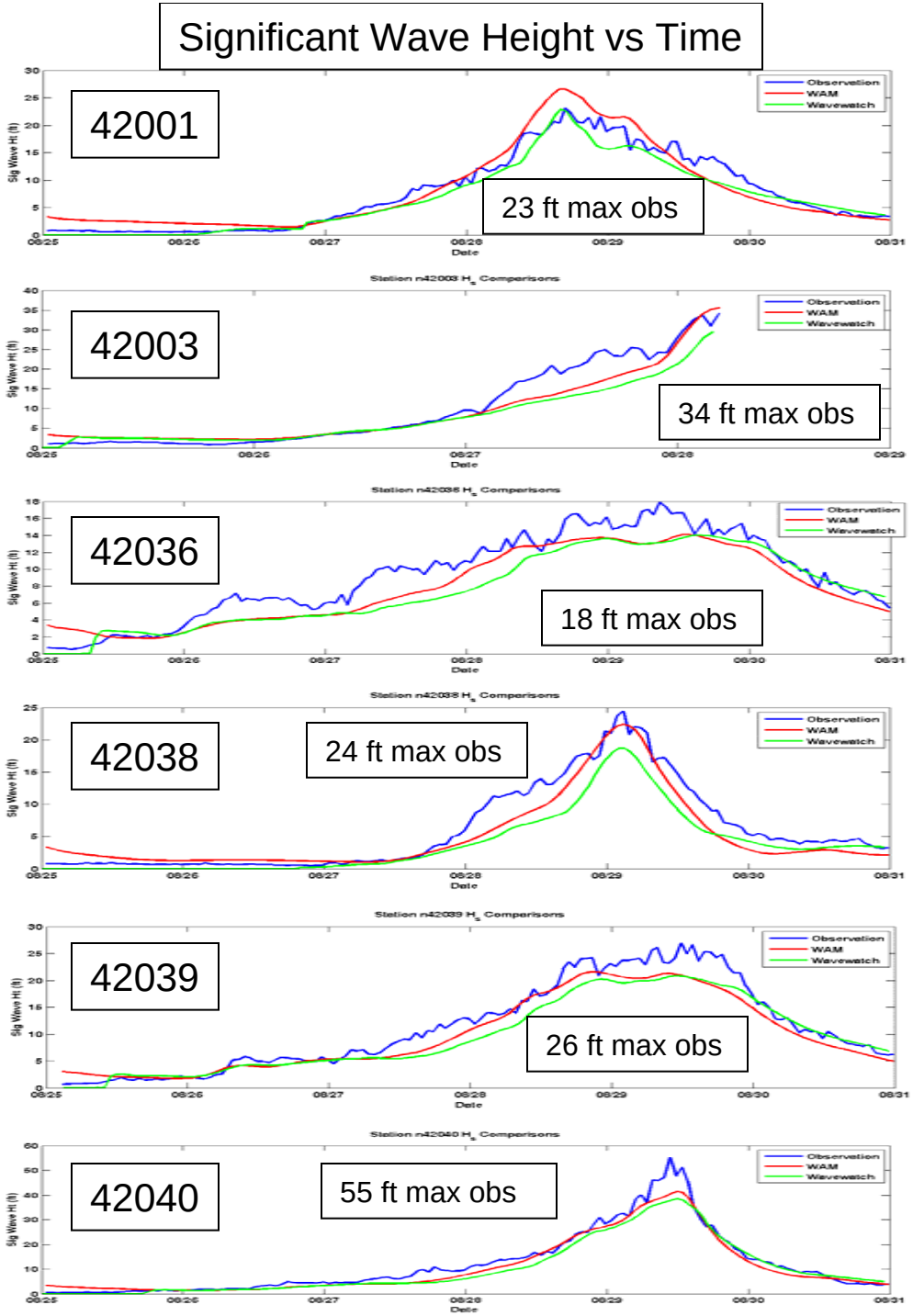

Buoy 42040

Buoy 42007

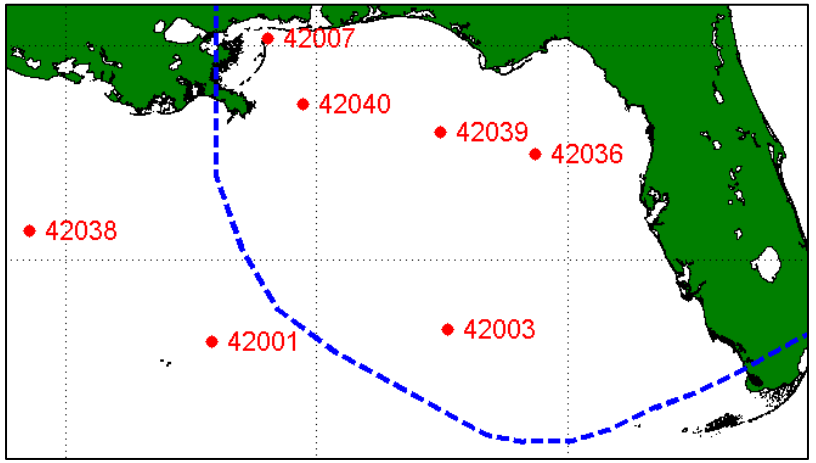



4.5 days of easterly winds prior to landfall

# WAM and Wavewatch III Comparisons

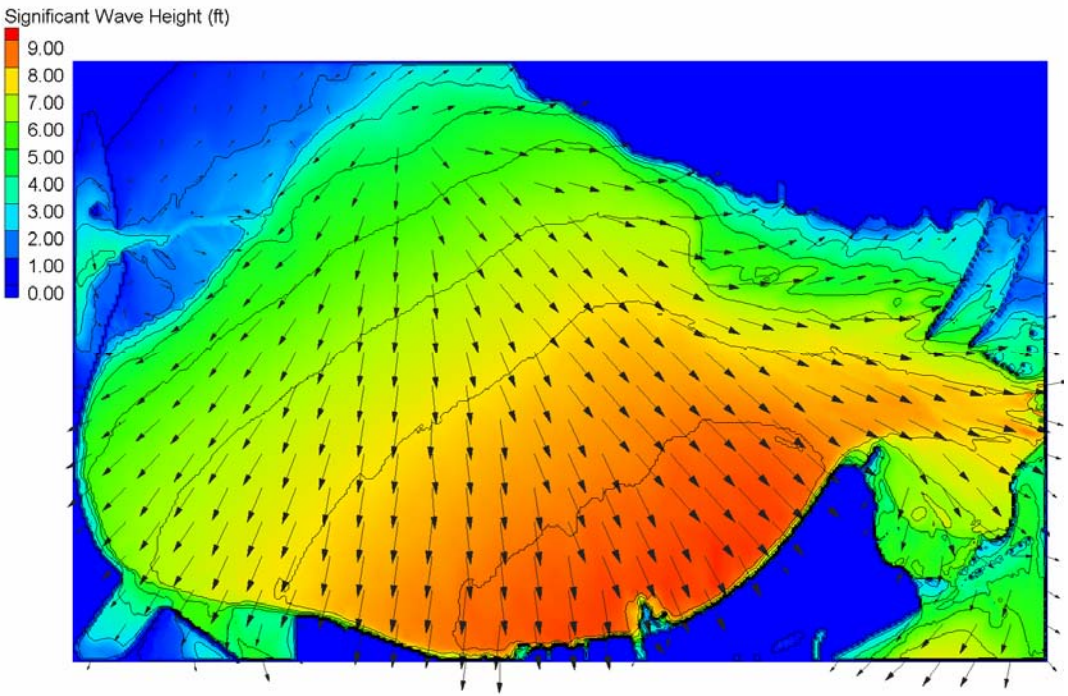


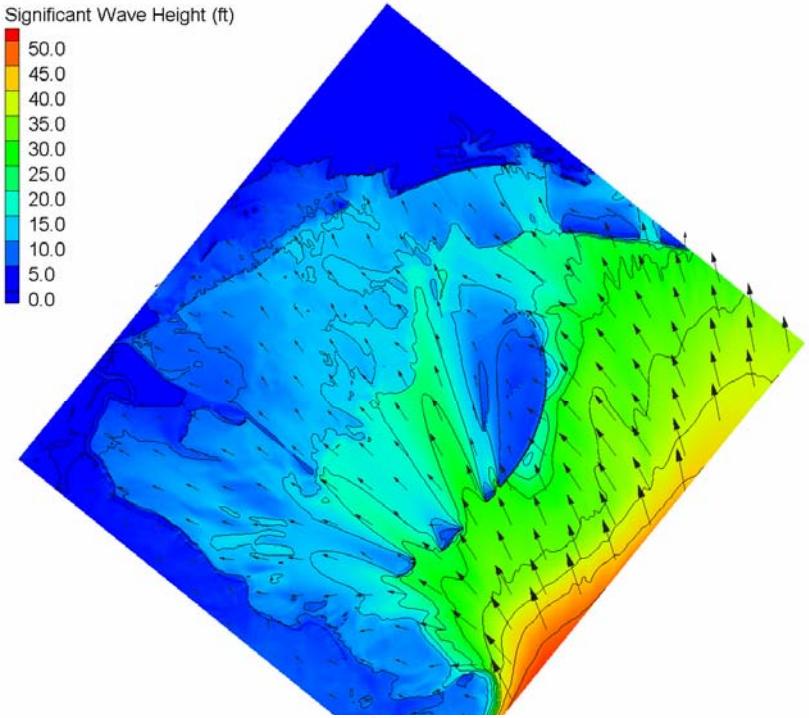

| Wave Height Performance Summary | | | | |
|---|---|---|---|---|
| | Temporal Correlations | | Quantile-Quantile | |
| Component | WAM | WW3 | WAM | WW3 |
| Windsea | 0.86 | 0.85 | 0.87 | 0.88 |
| Young Swell | 0.75 | 0.74 | 0.76 | 0.78 |
| Mature Swell | 0.85 | 0.72 | 0.87 | 0.73 |
| Combined | 0.83 | 0.80 | 0.84 | 0.82 |

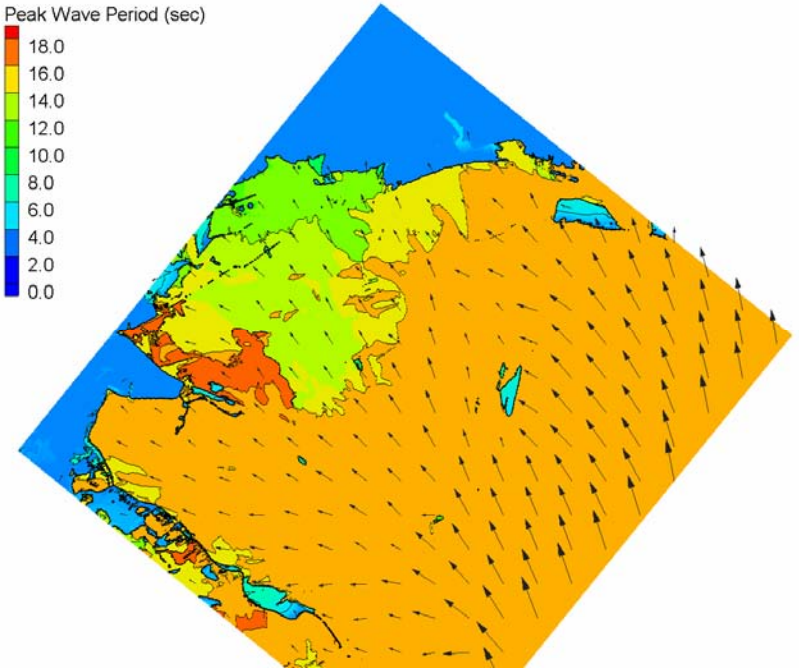


# Maximum Nearshore Wave Conditions

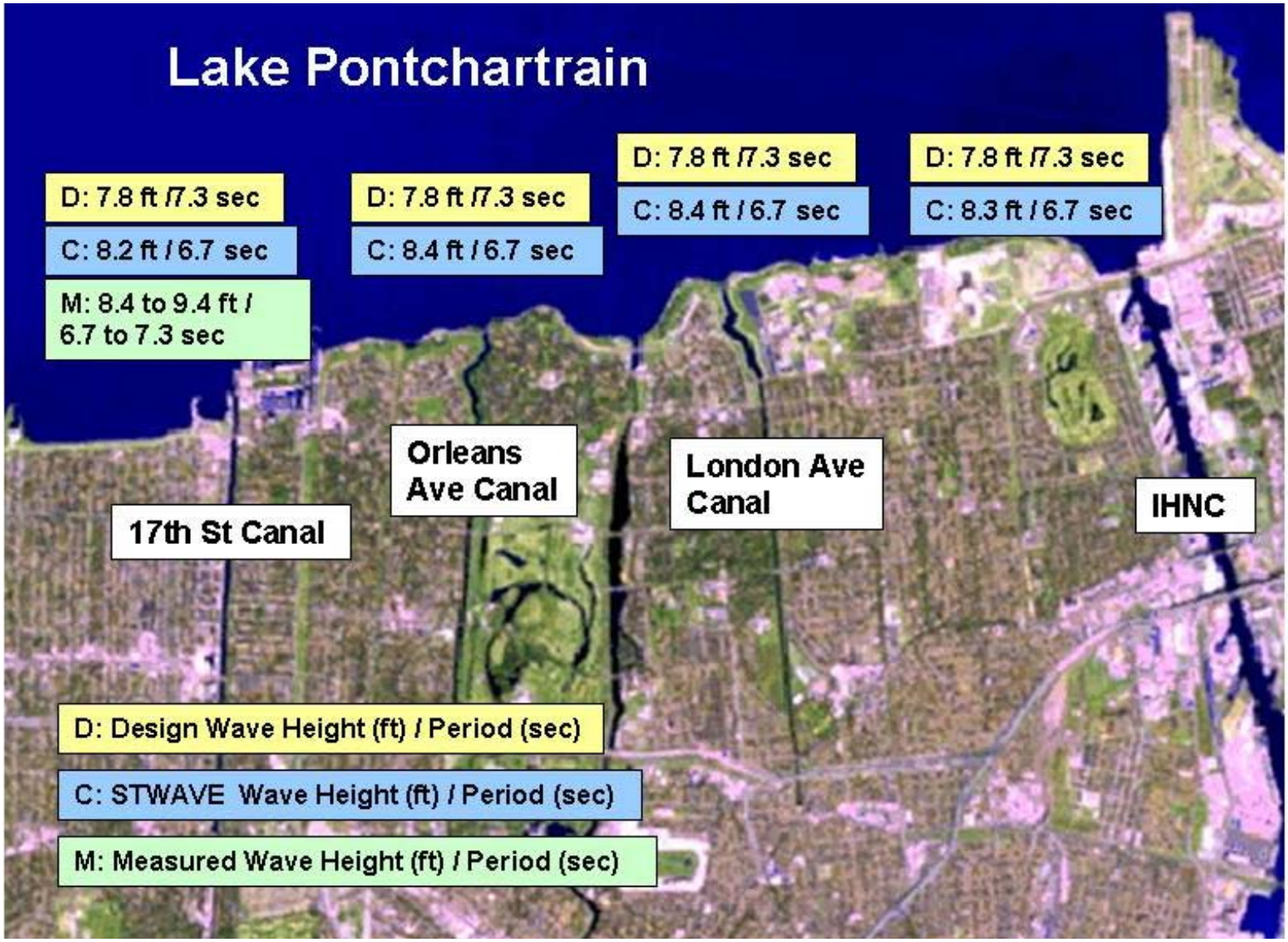
- Lake Pontchartrain – max significant wave heights of 9 ft, peak periods of 7 sec
- St. Bernard – wave heights of 6 ft; periods exceeding 15-16 sec
- Plaquemines (east-facing)– wave heights of 7-10 ft, periods 15-16 sec
- Levees exposed to long period wave energy



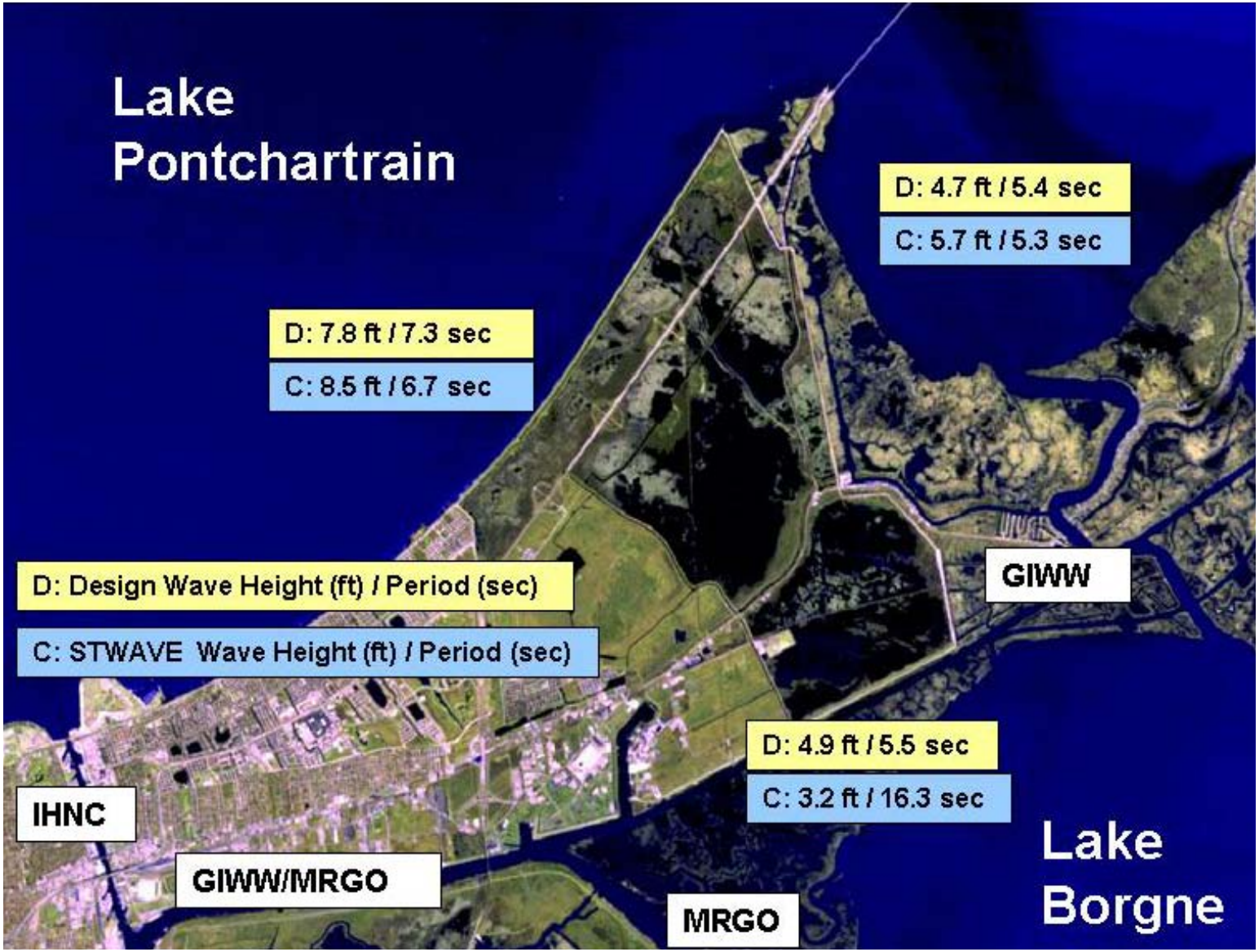



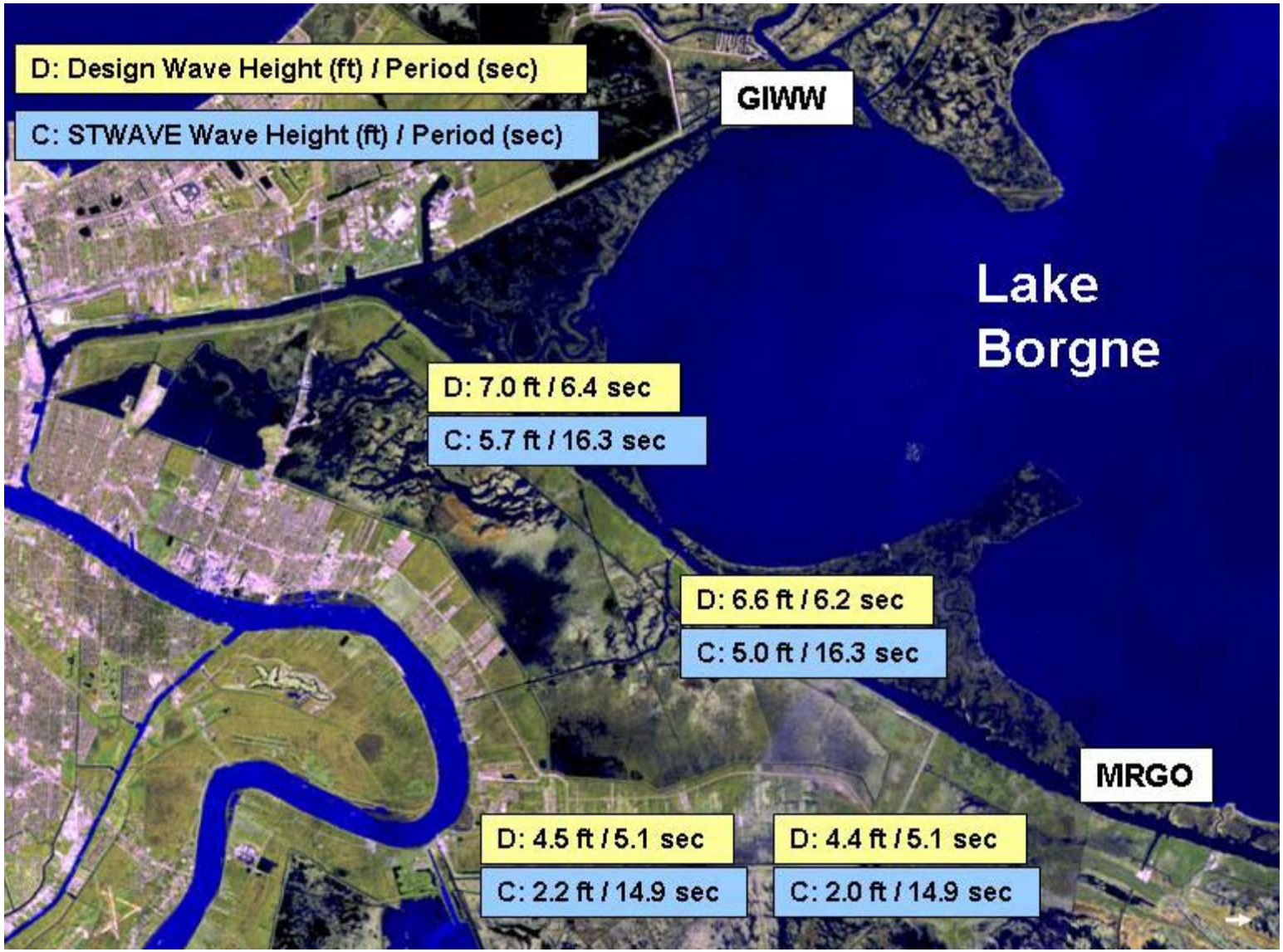
# Peak Wave Conditions
# (Comparison: Katrina and Design Values)



# Peak Wave Conditions
# (Comparison: Katrina and Design Values)



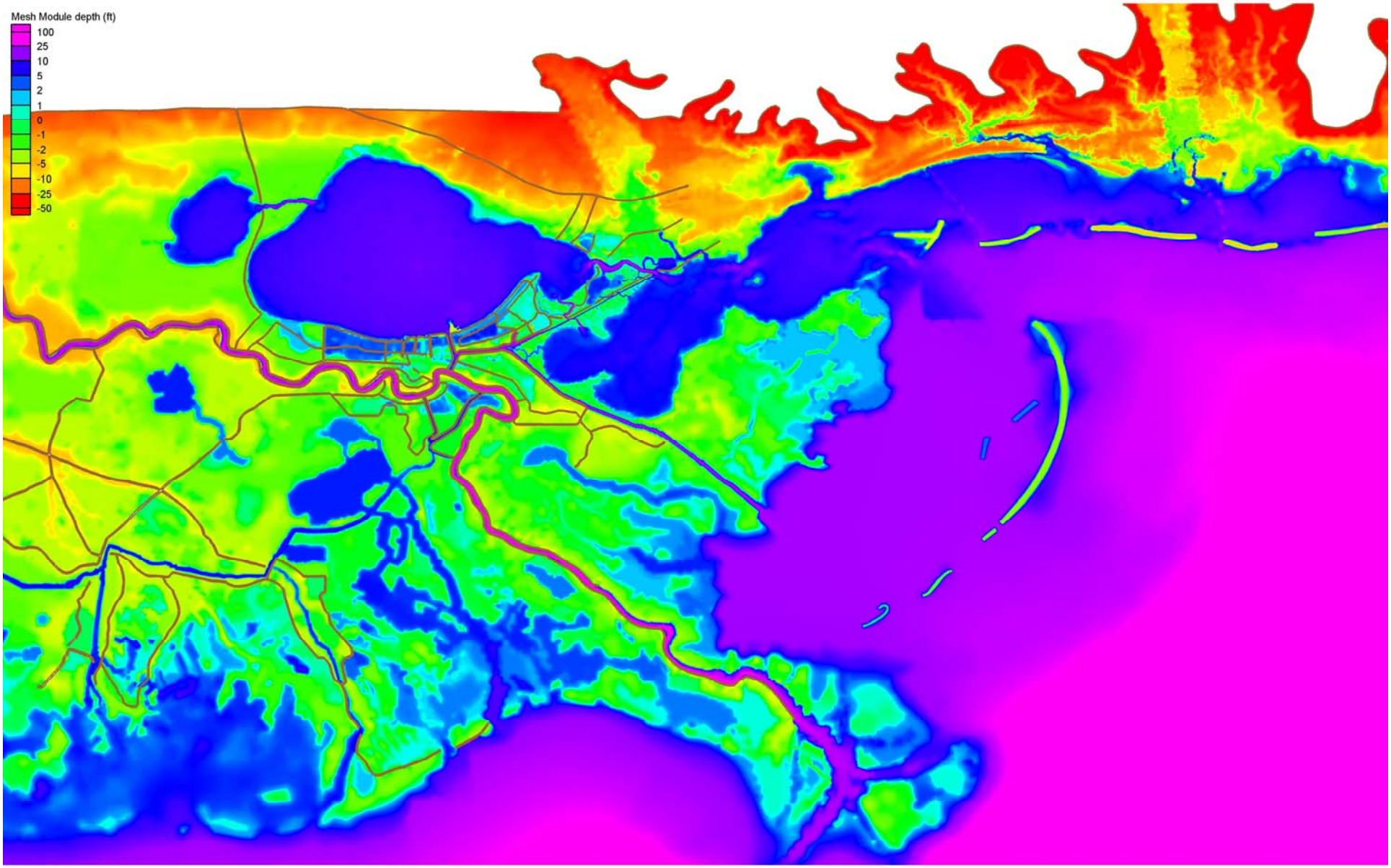
# Peak Wave Conditions
# (Comparison: Katrina and Design Values)

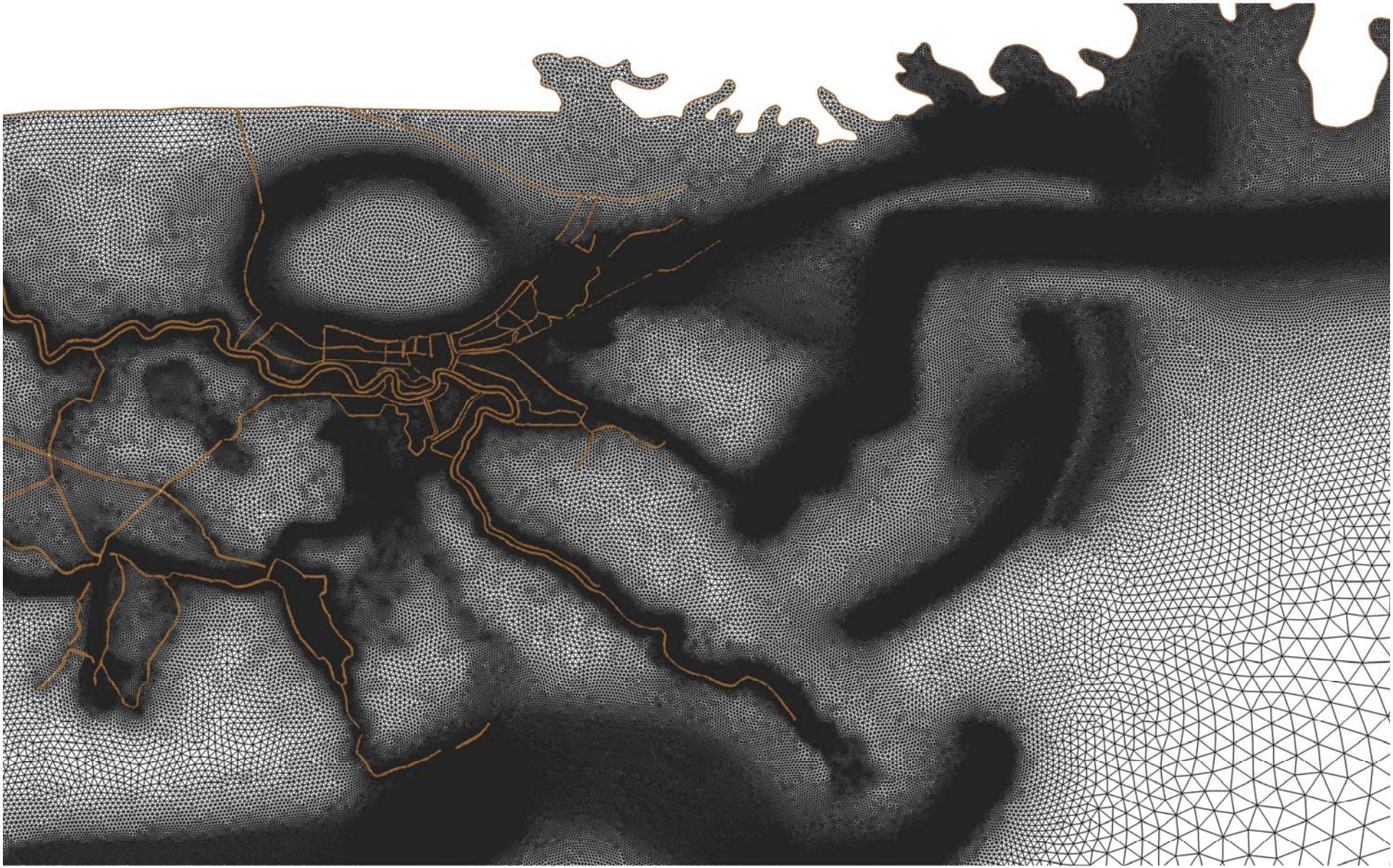


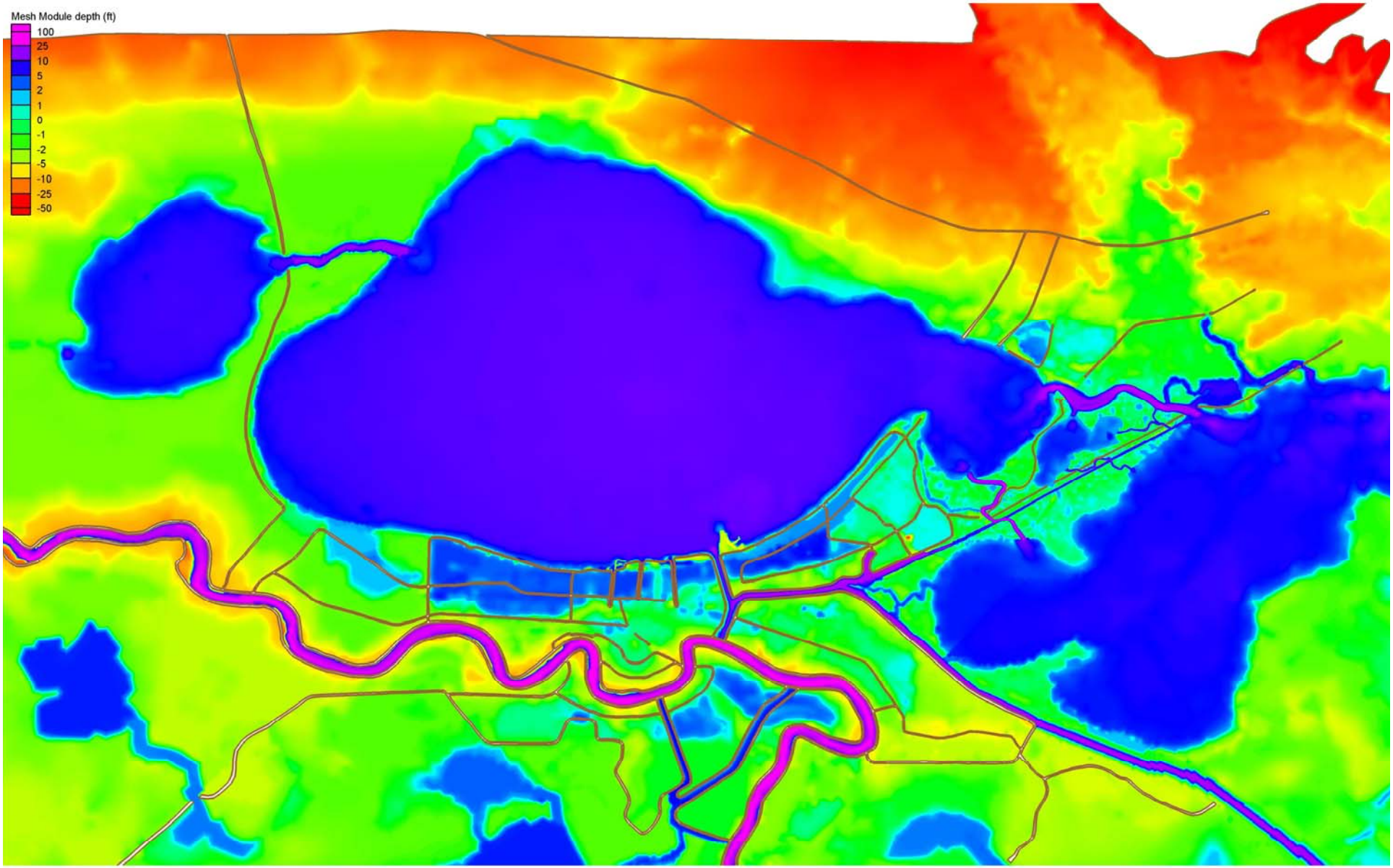
# Peak Wave Conditions
# (Comparison: Katrina and Design Values)

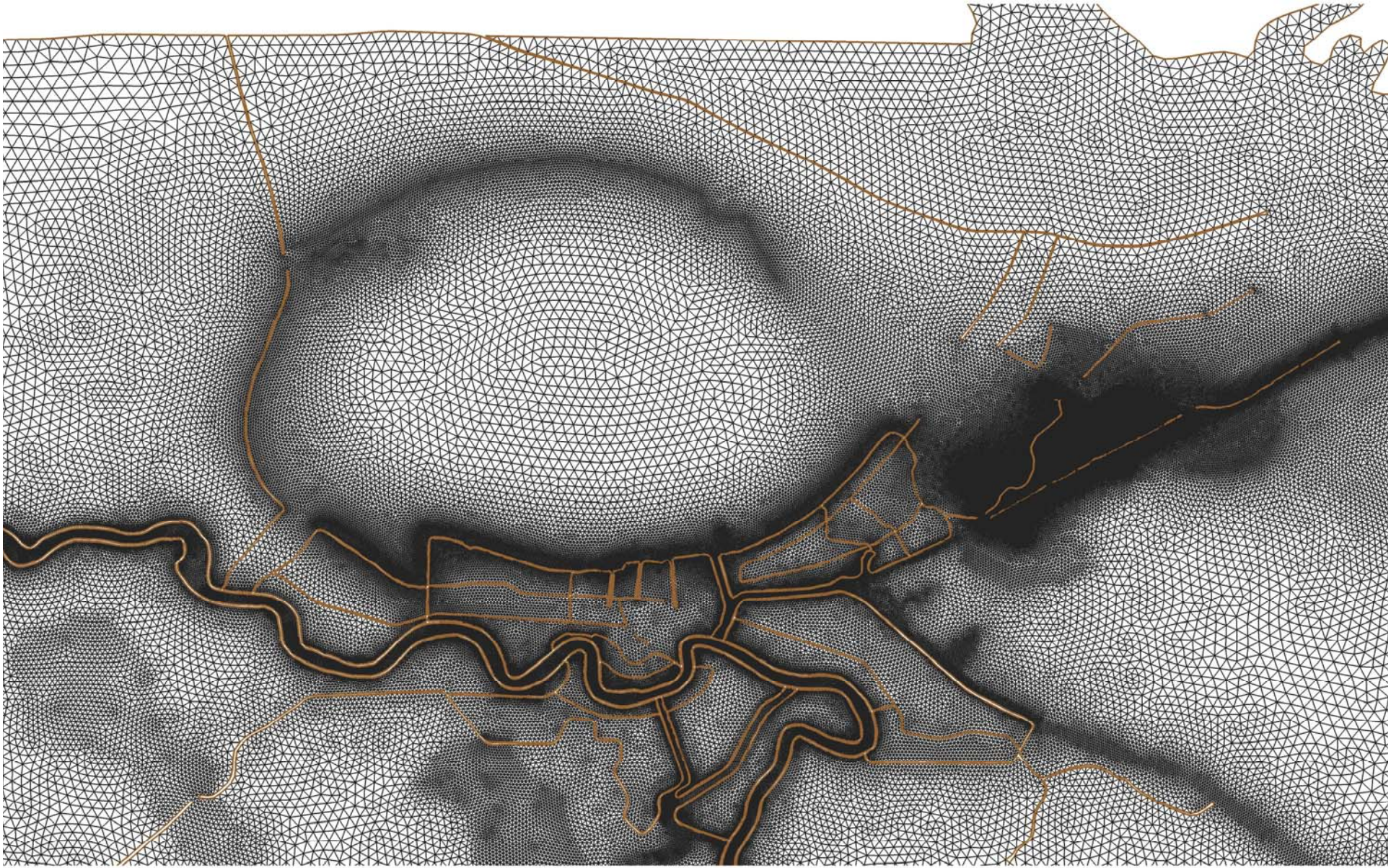
# TF01x2 Surge Hindcasts

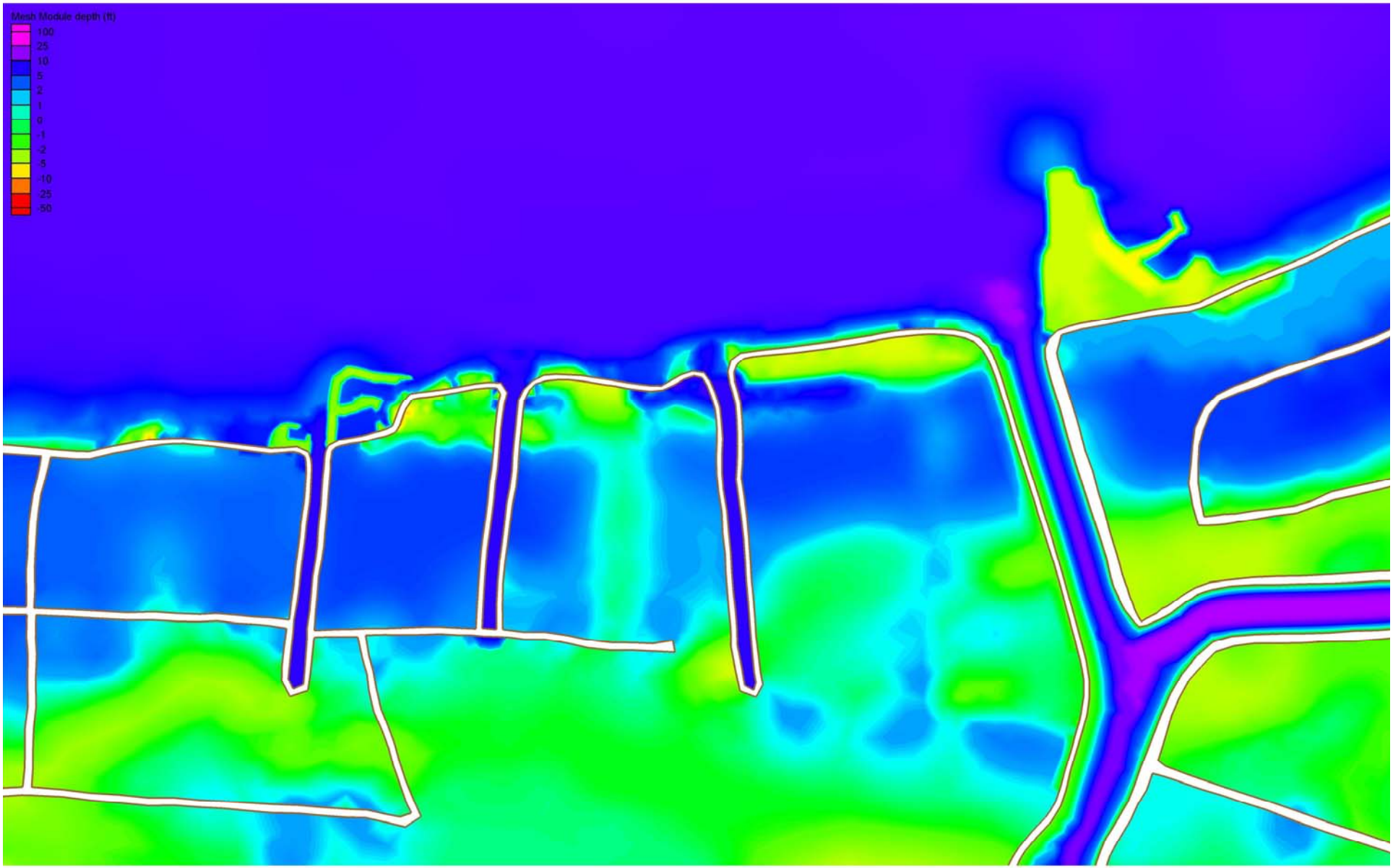
- Describe and resolve the physical system
  - TF01x2 grid encompasses many new details
- Provide accurate forcing functions
  - Tides
  - Force in Mississippi River at Baton Rouge and Atchafalaya River at Simmesport
  - H*wind/IOKA winds and OWI pressures
  - Carefully consider air-sea interaction
  - STWAVE wave radiation stress forcing along all critical coasts
  - Steric expansion
  - Carefully define reference levels – NAVD 88 2004.65

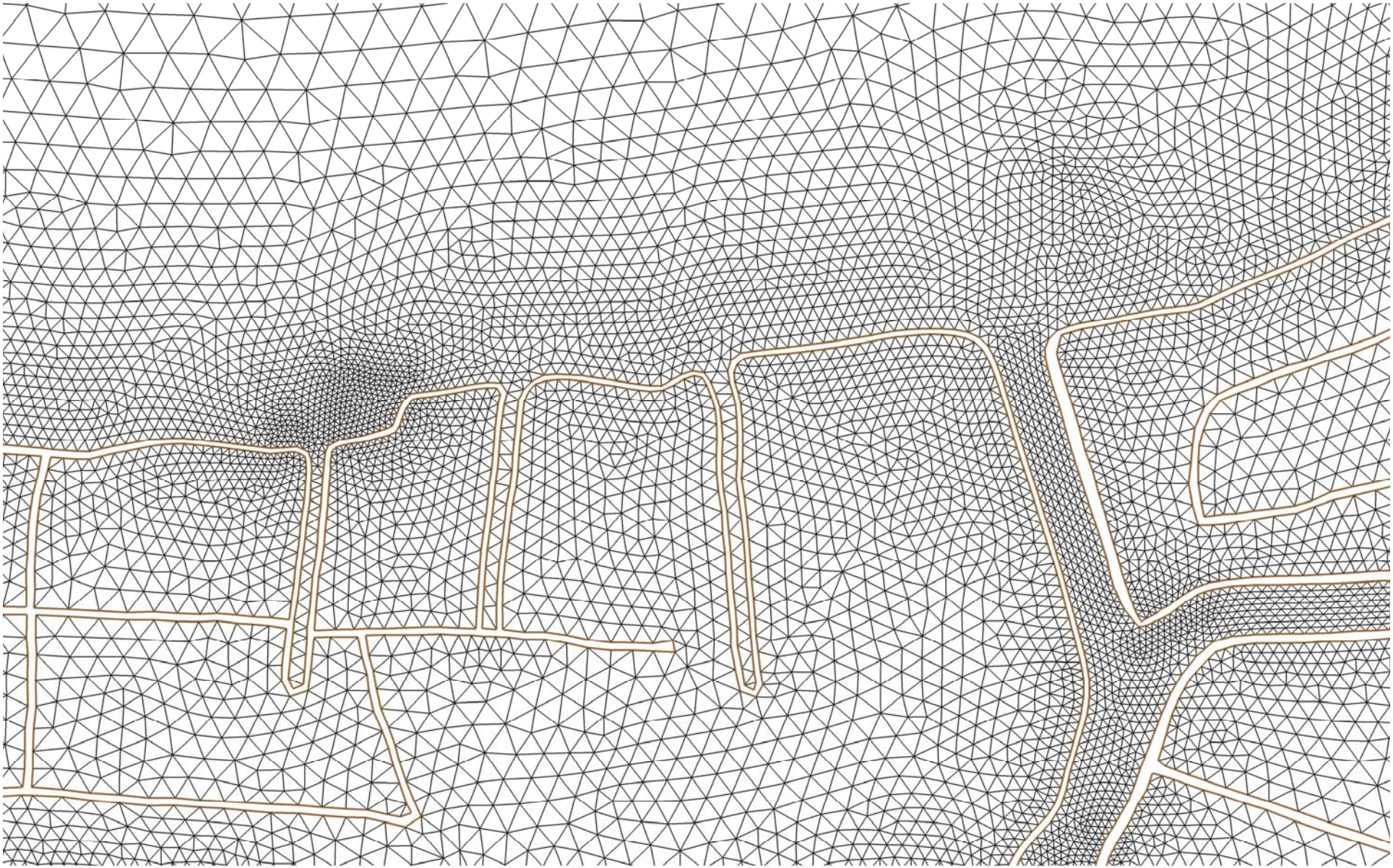

Mesh Module depth (ft)
100
25
10
5
2
1
0
-1
-2
-5
-10
-25
-50



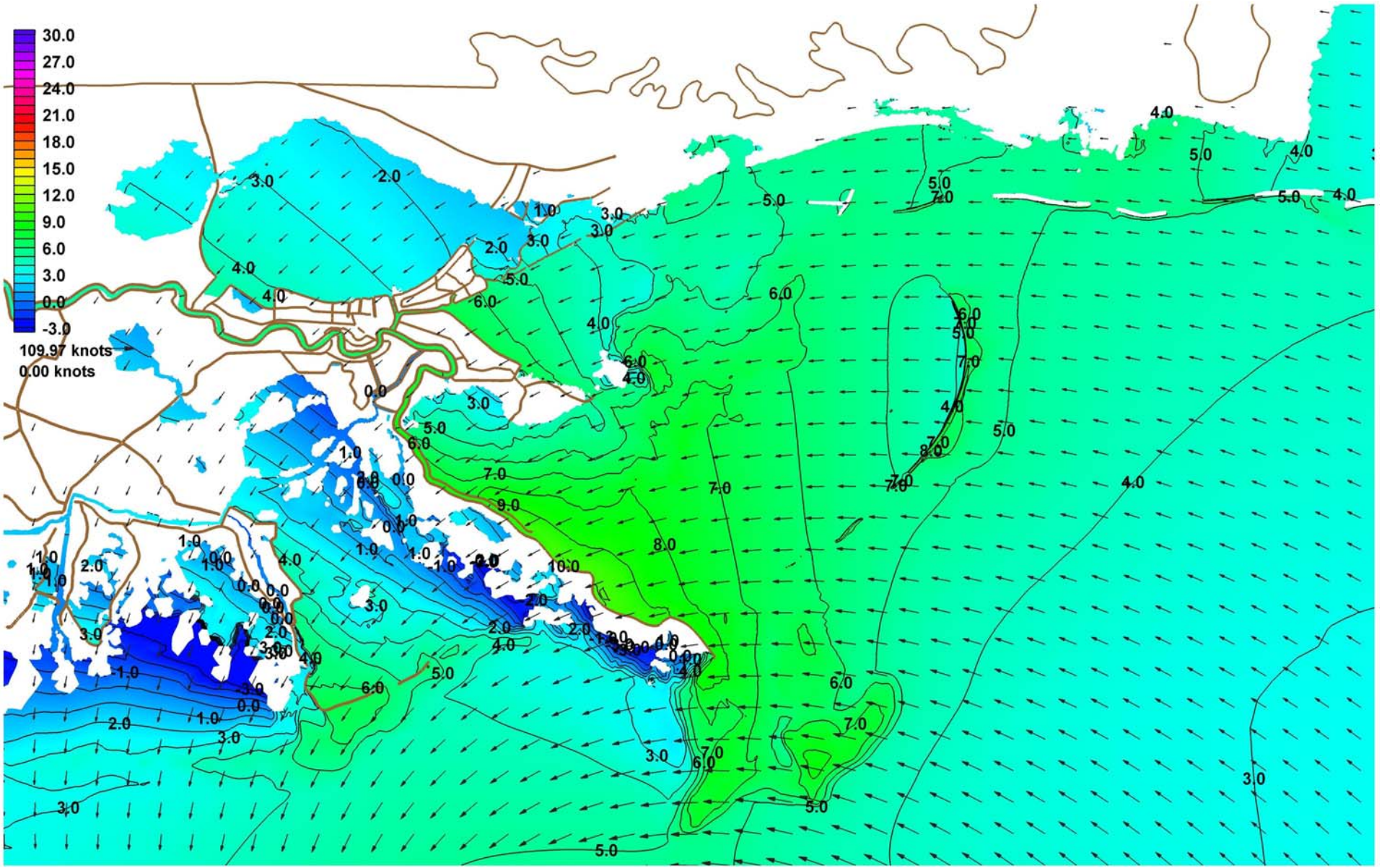

Mesh Module depth (ft)
100
25
10
5
2
1
0
-1
-2
-5
-10
-25
-50




Mesh Module depth (ft)
100
25
10
5
2
1
0
-1
-2
-5
-10
-25
-50



8/29/07Z



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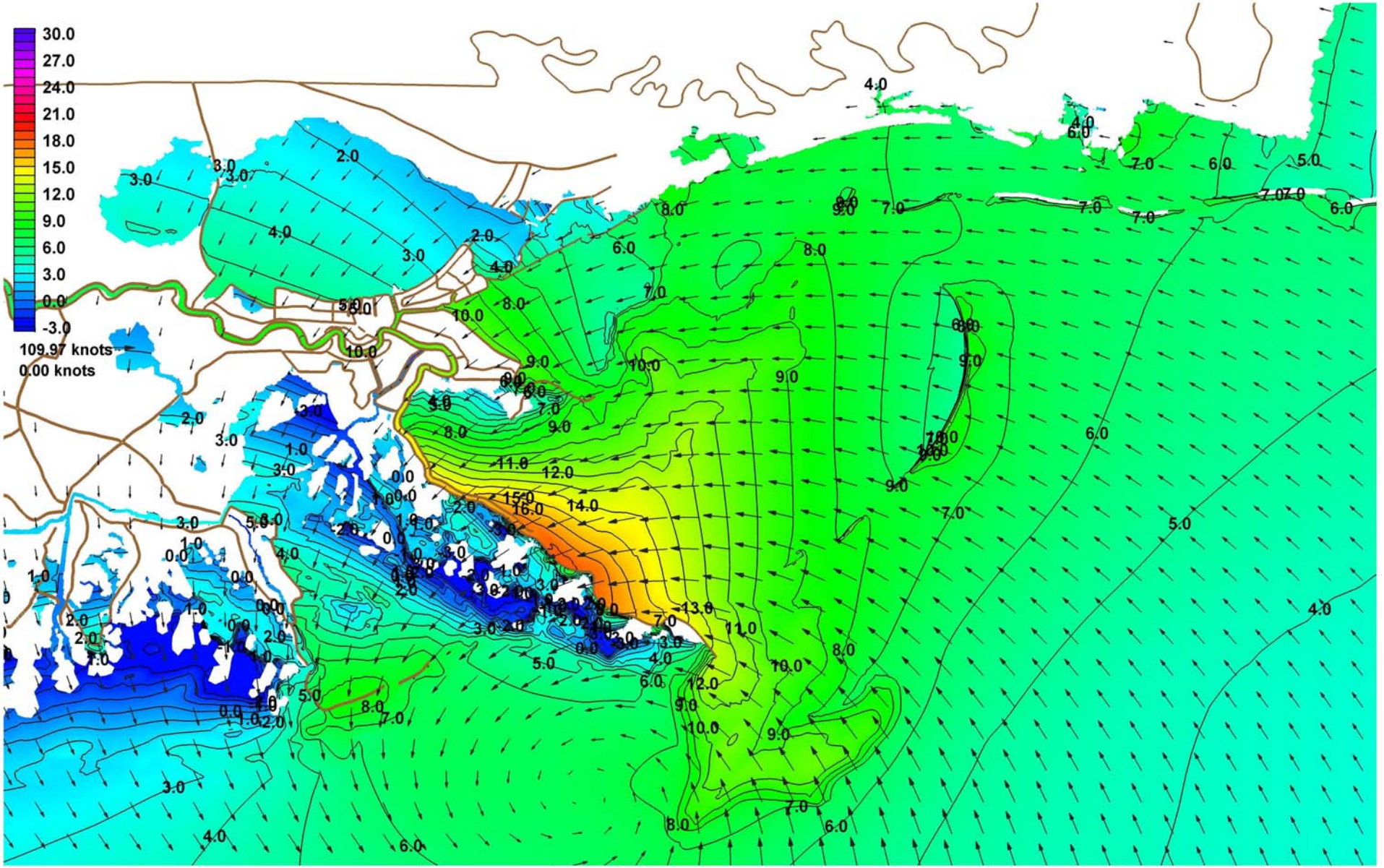

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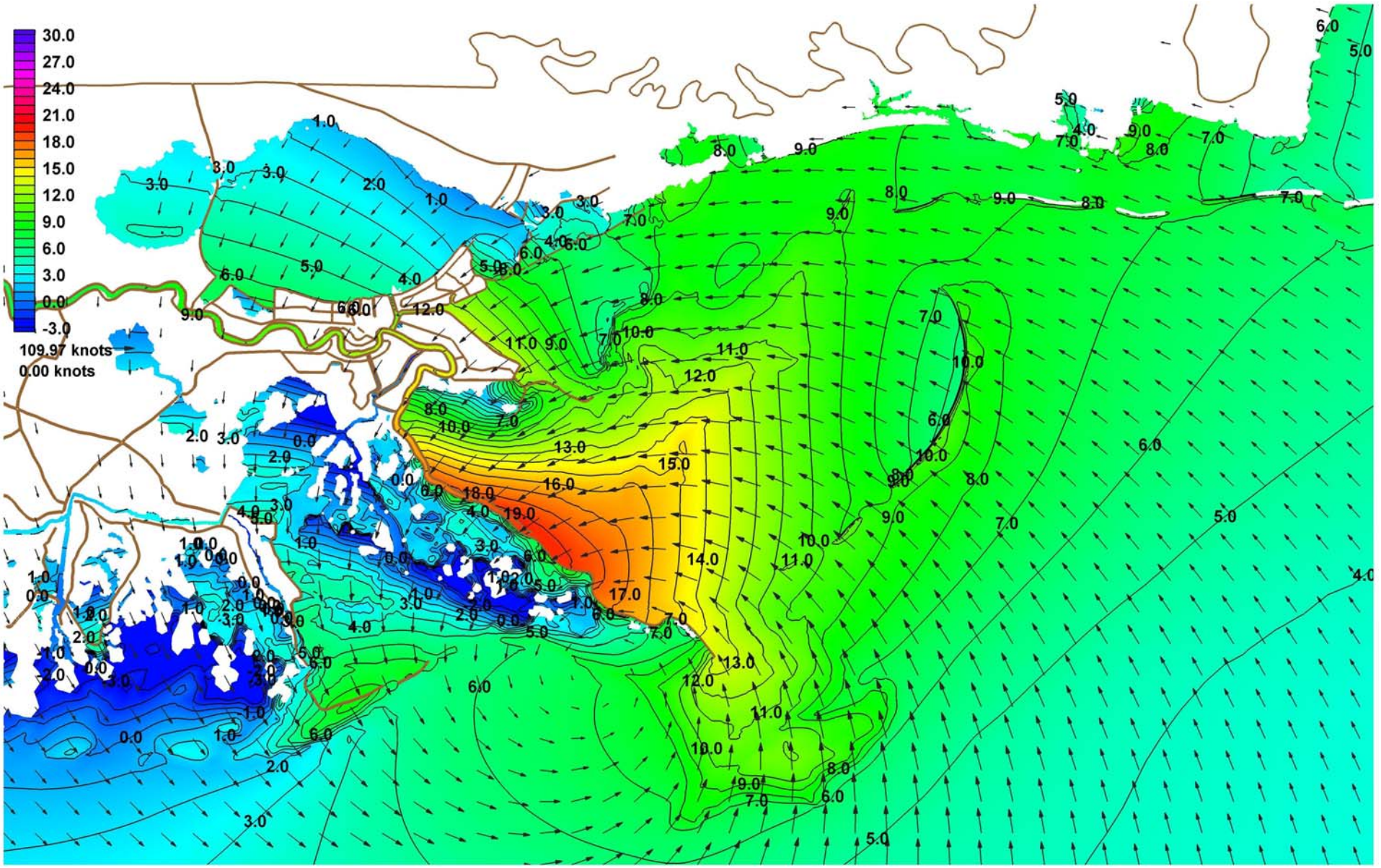

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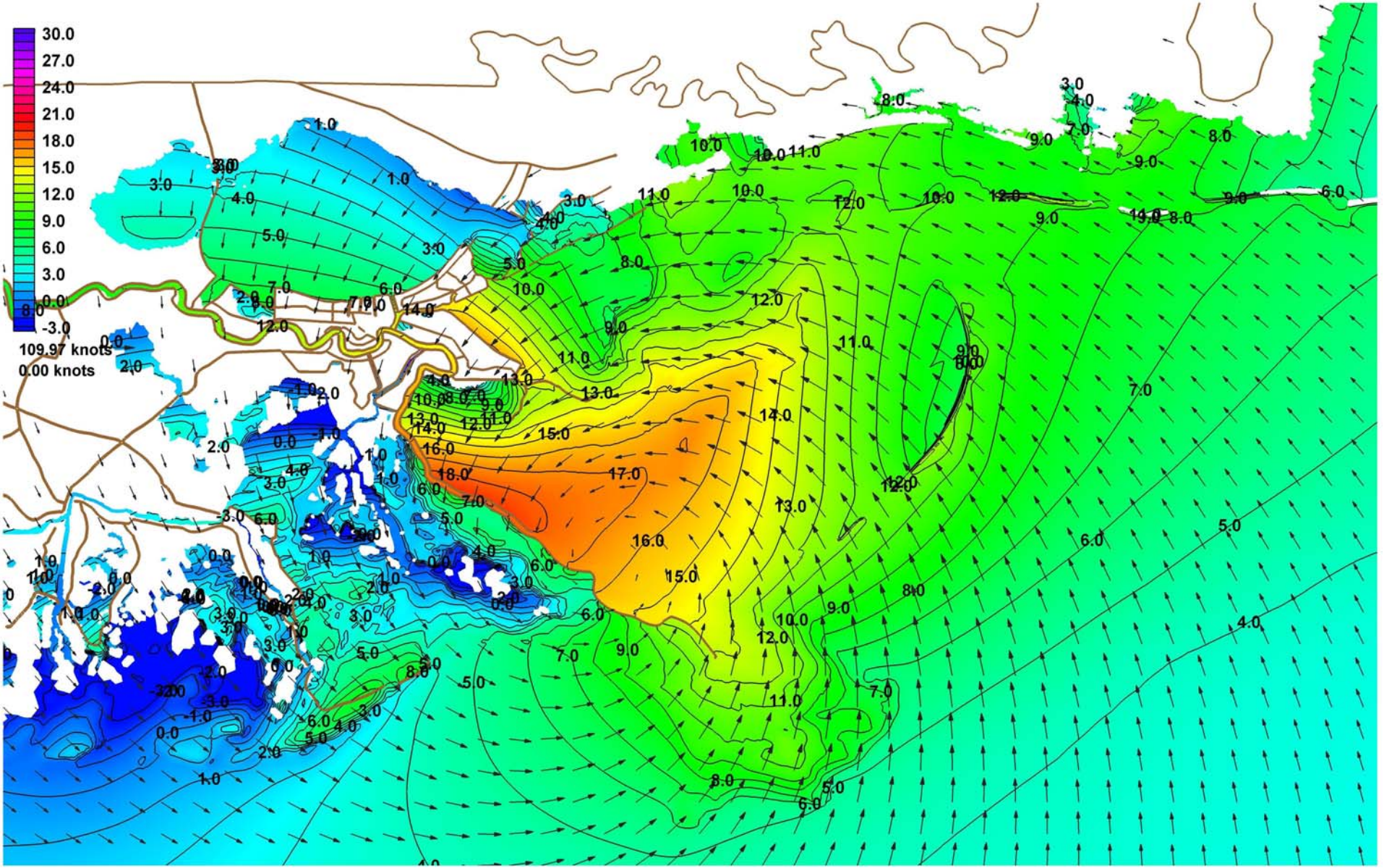

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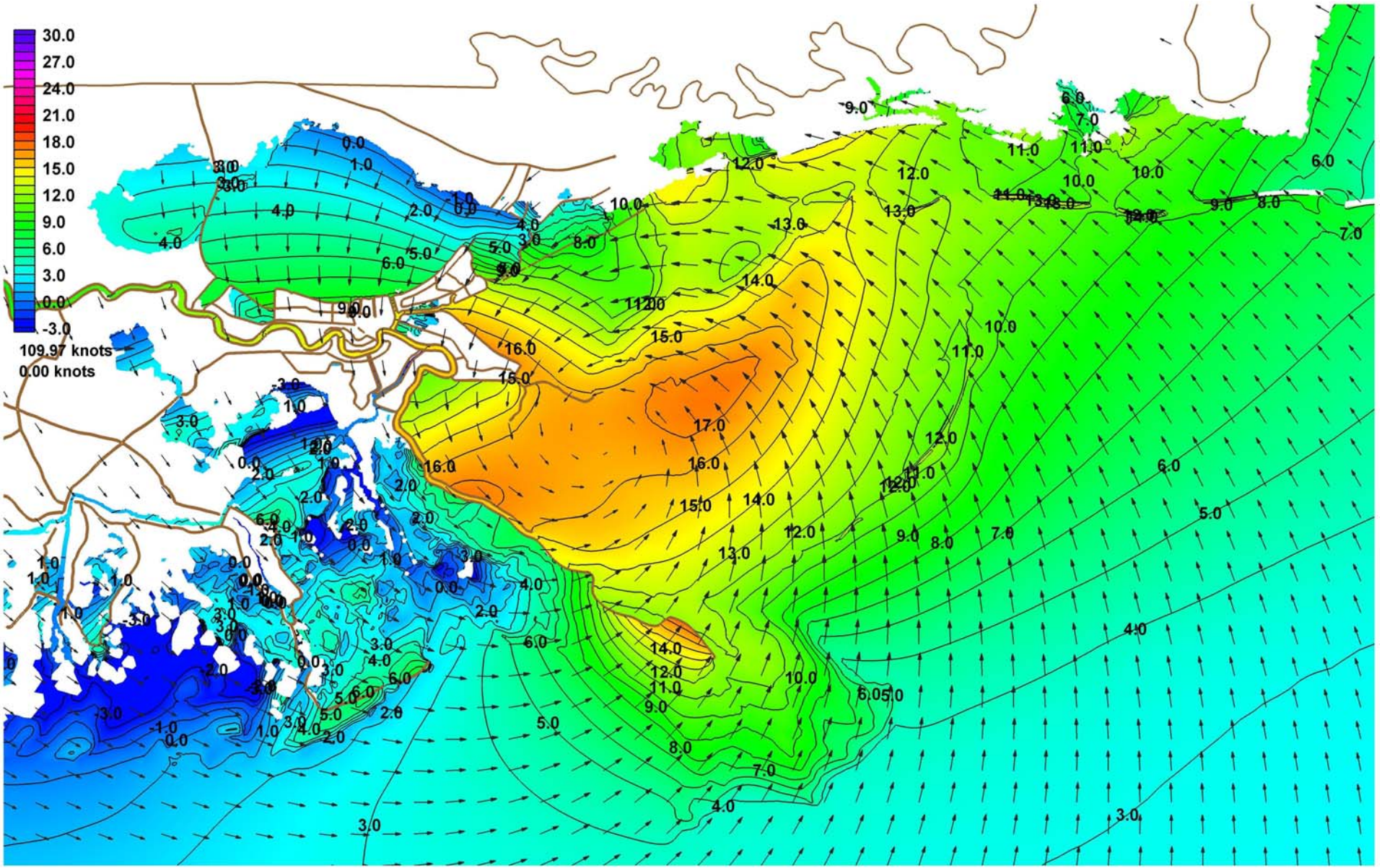

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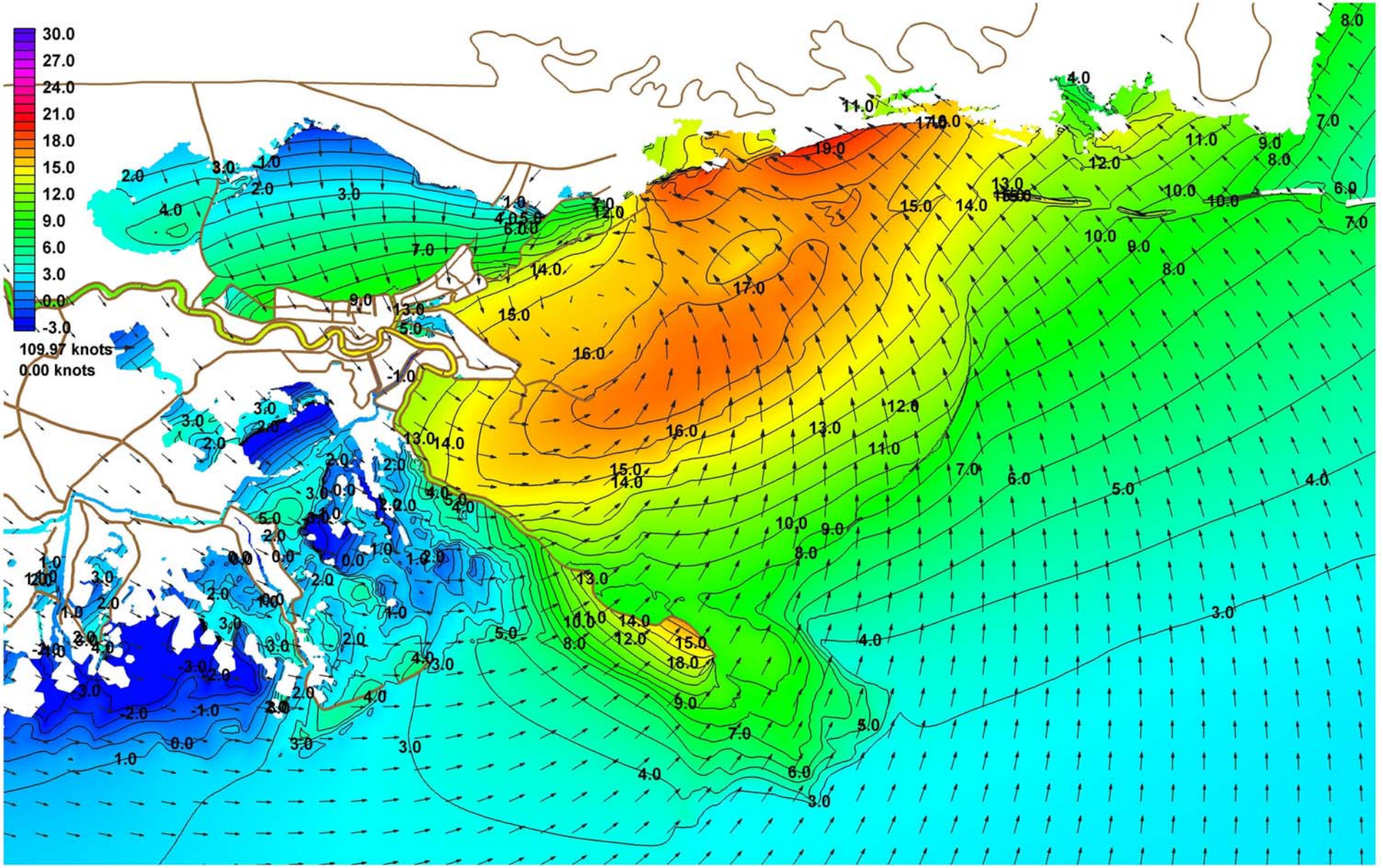

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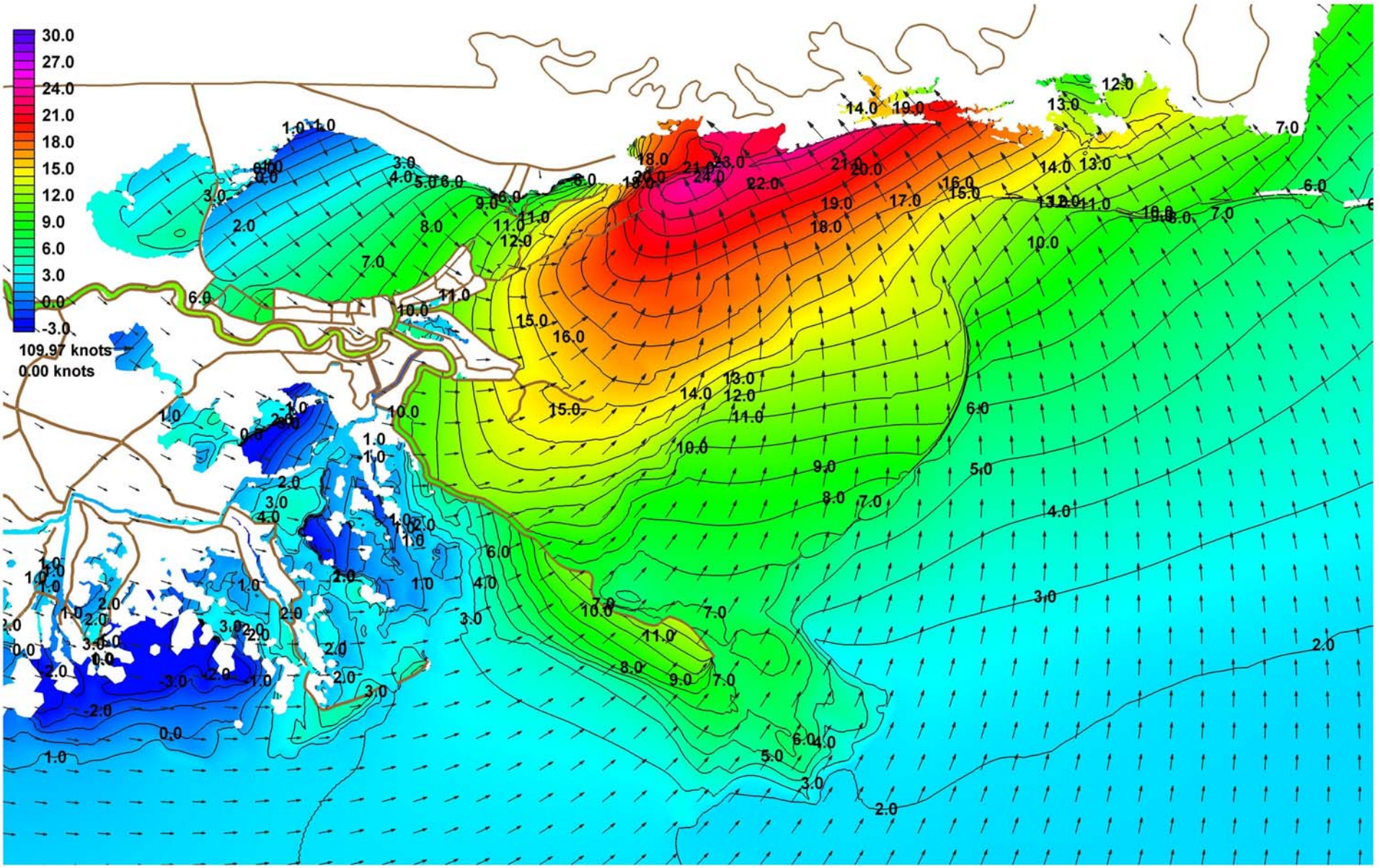

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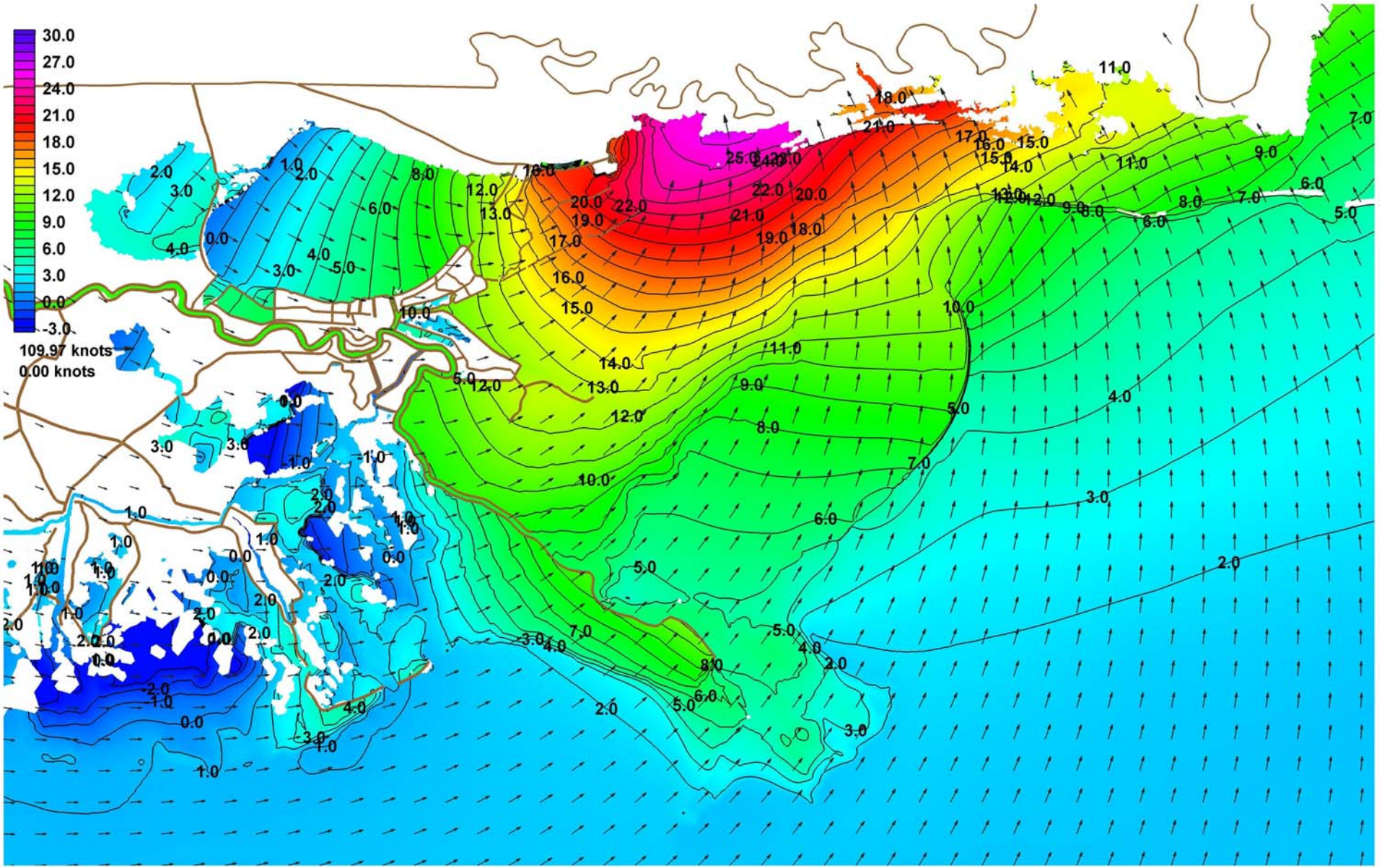
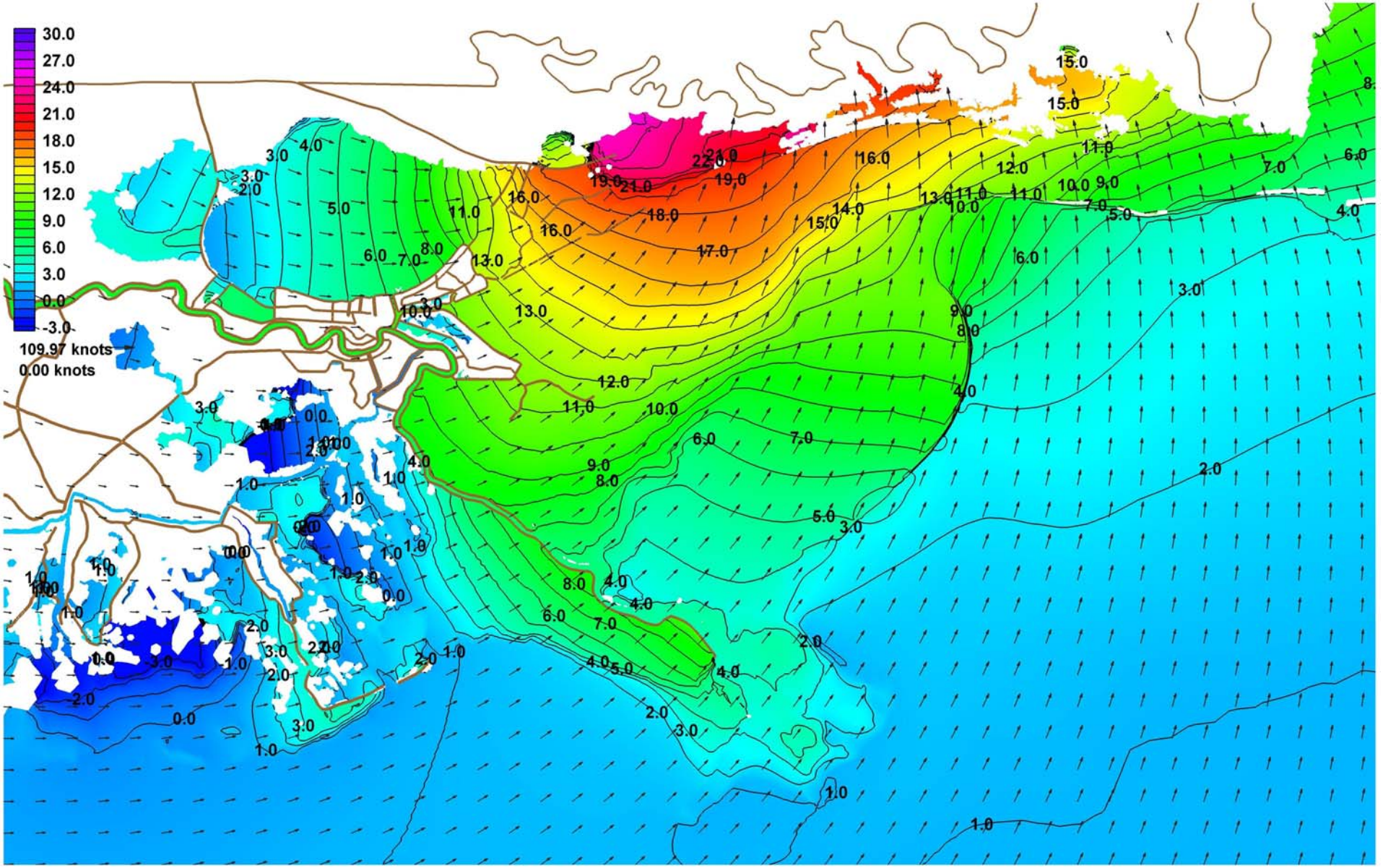


8/29/17Z



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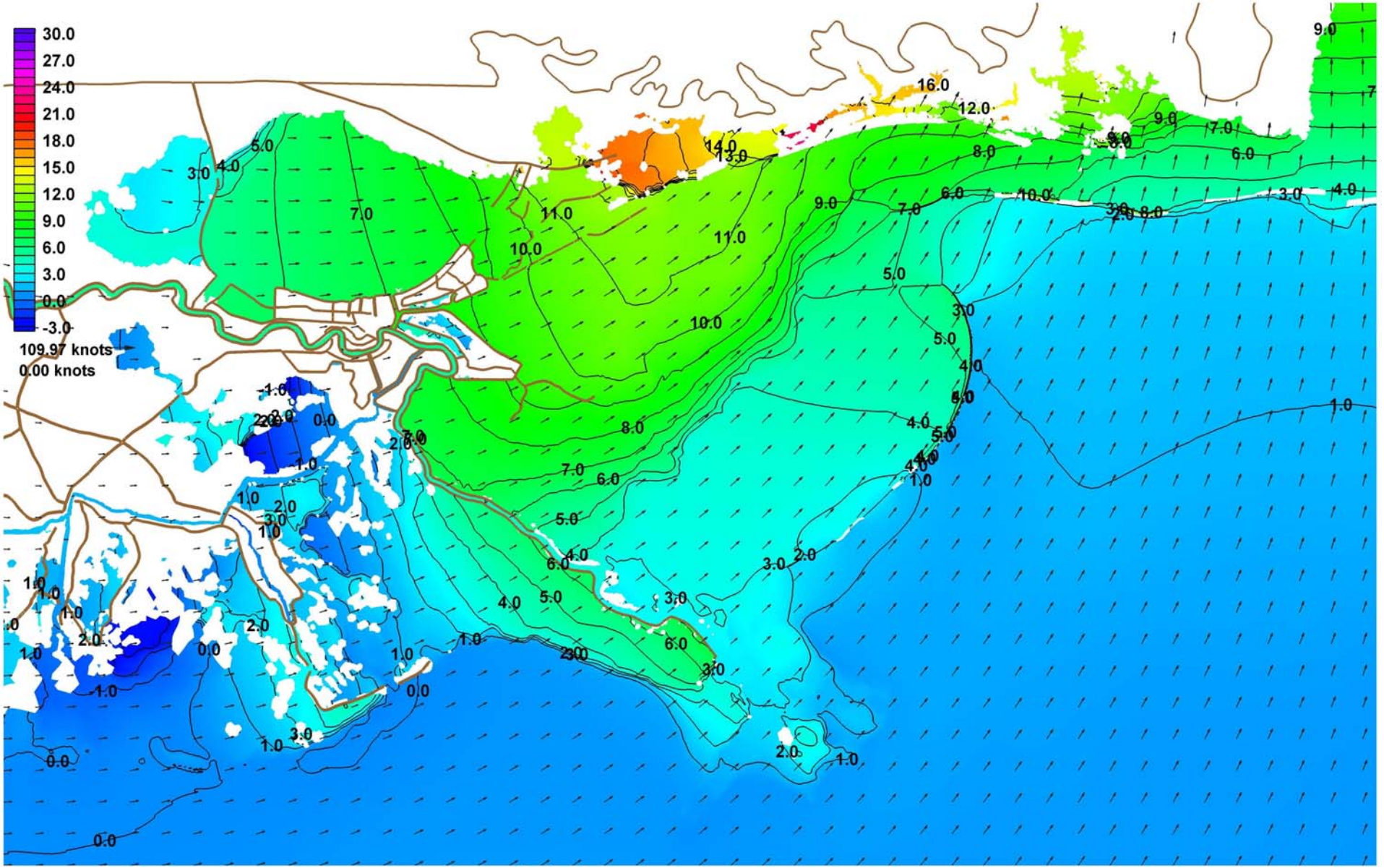

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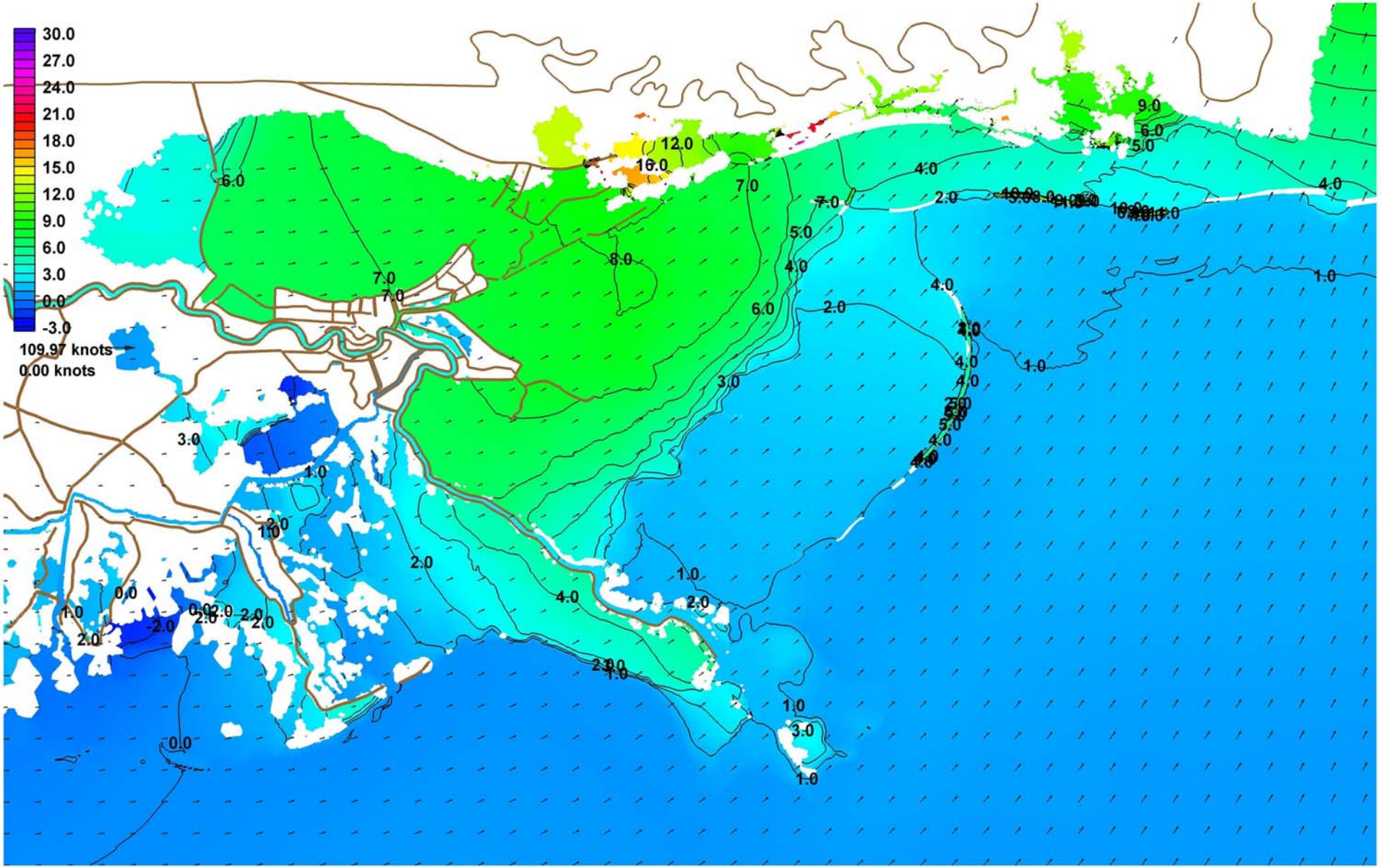

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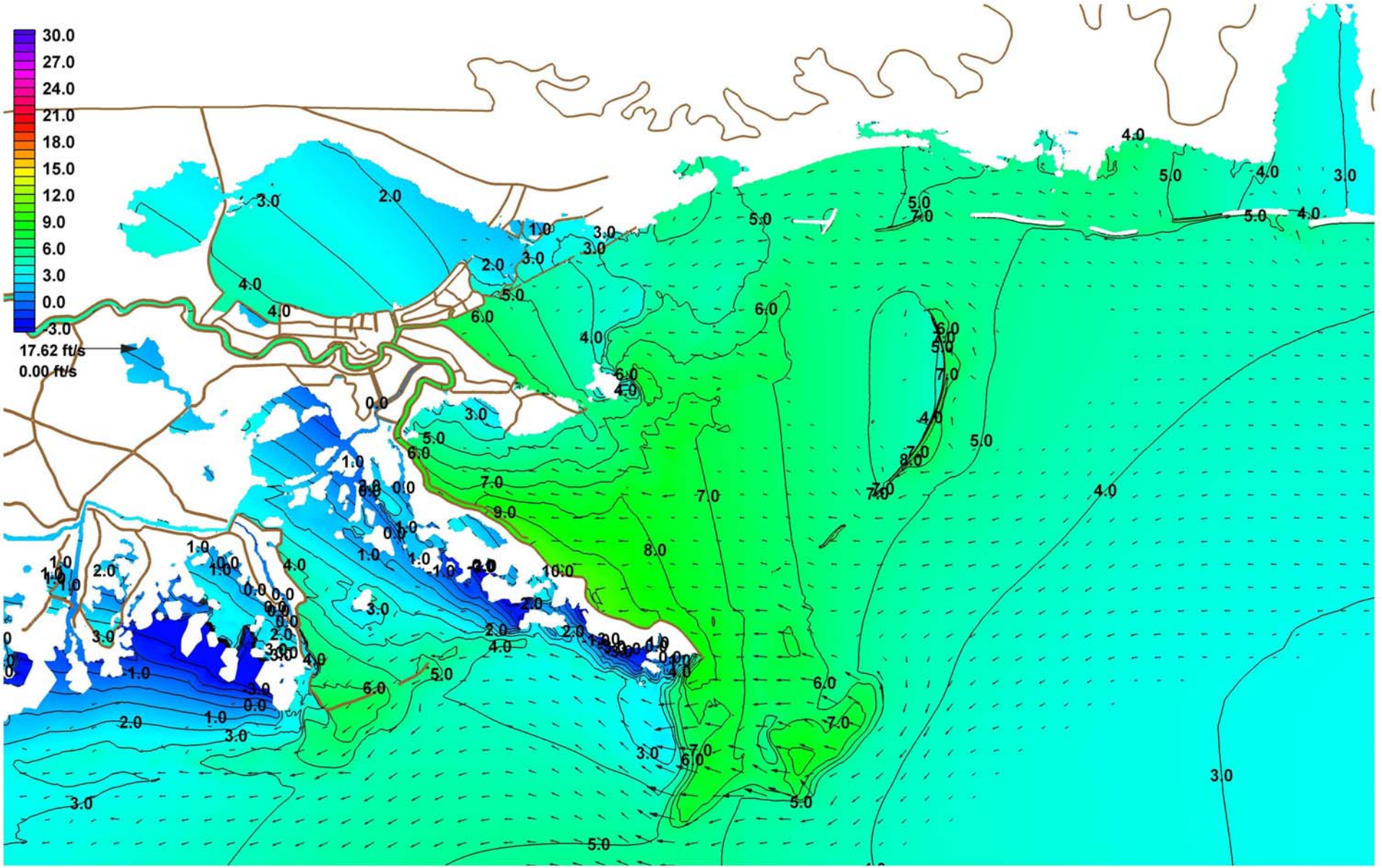

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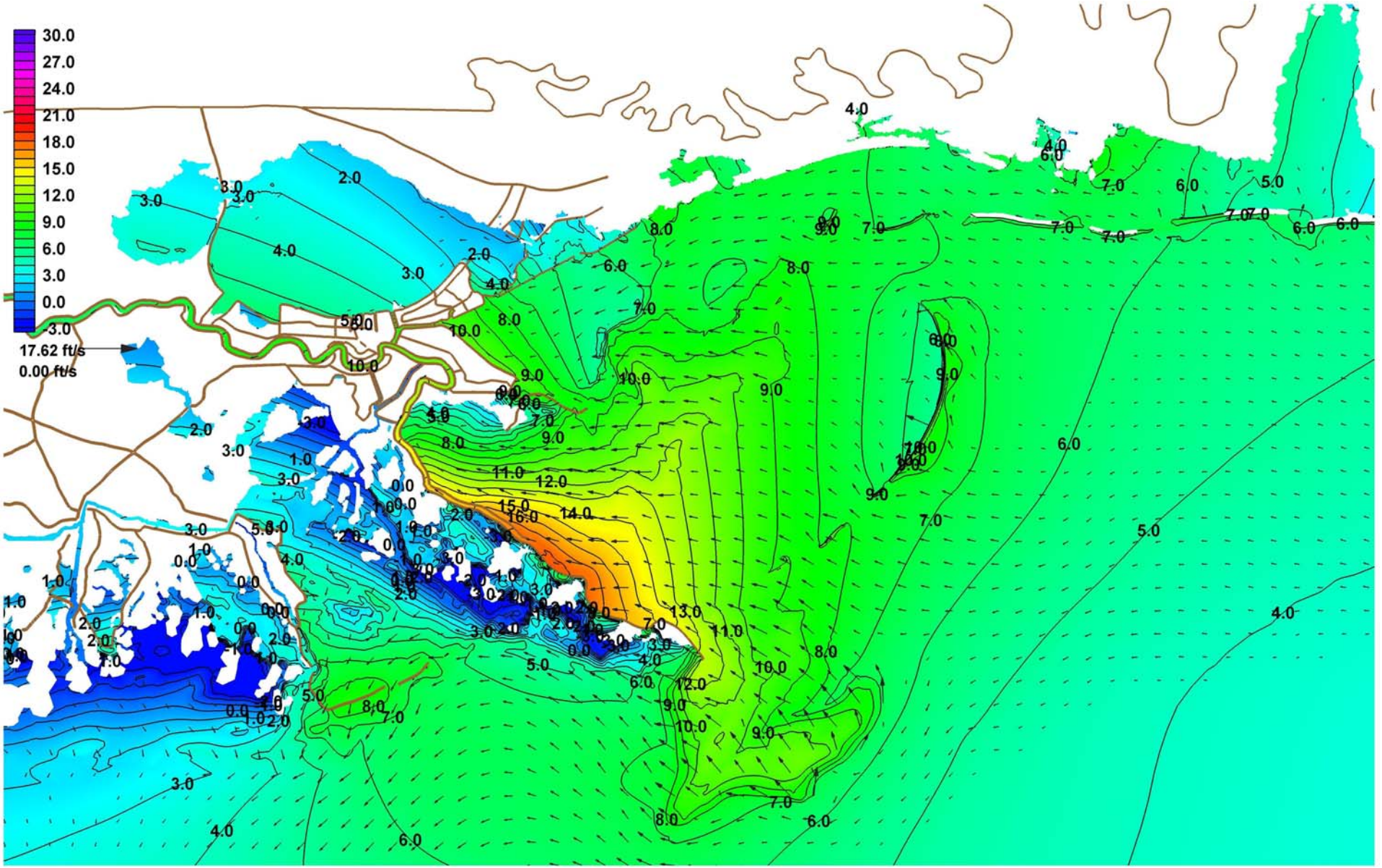

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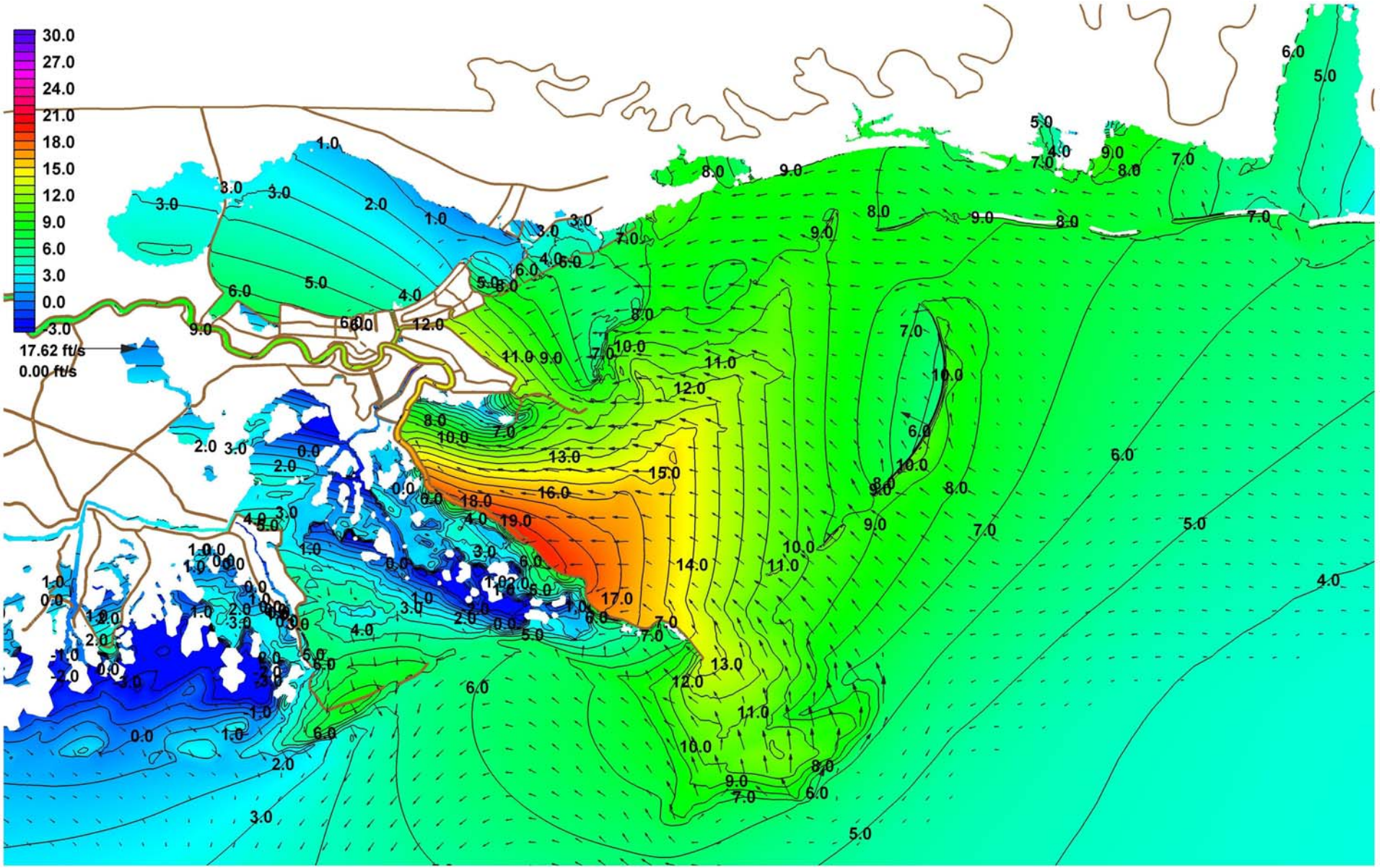
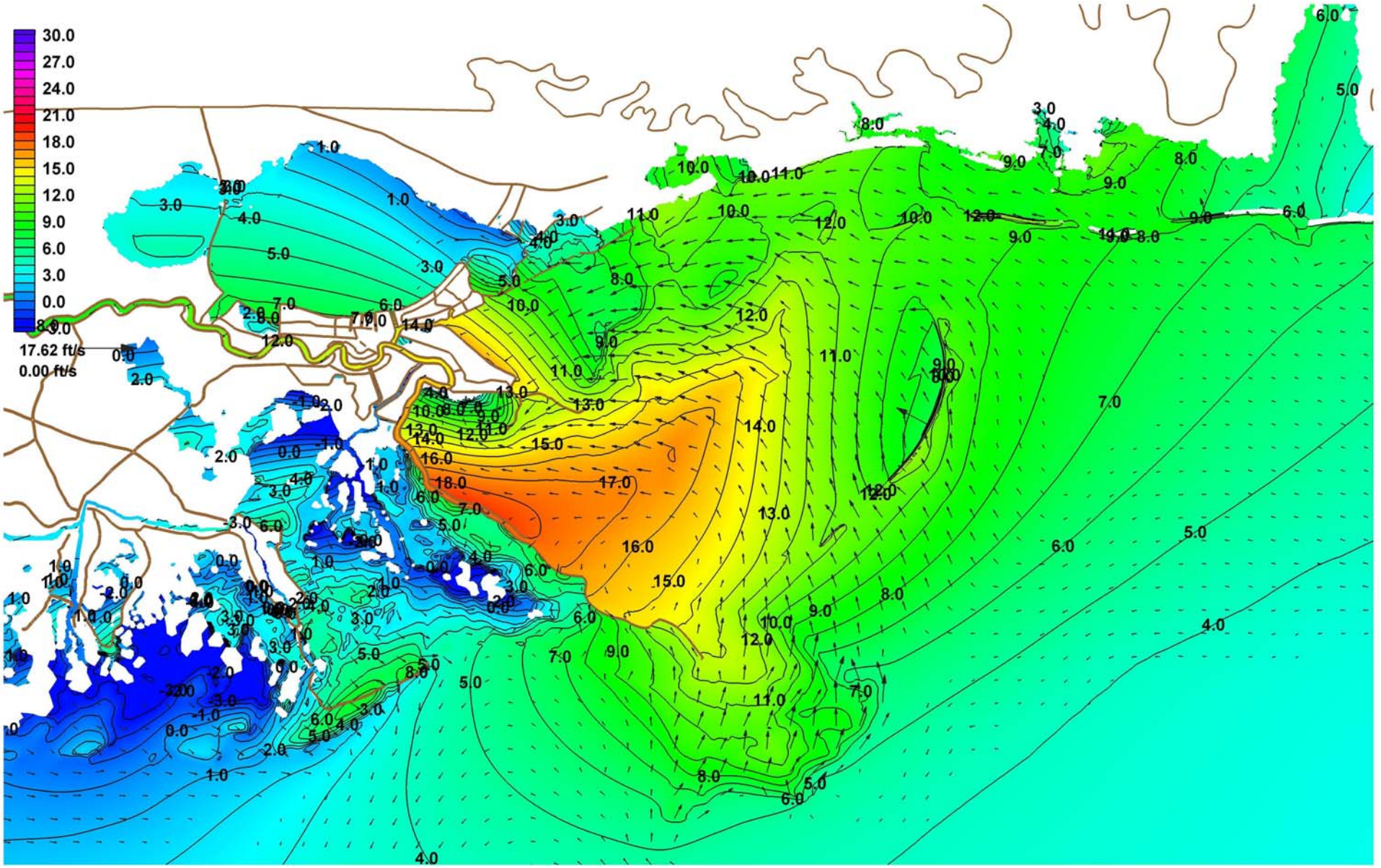
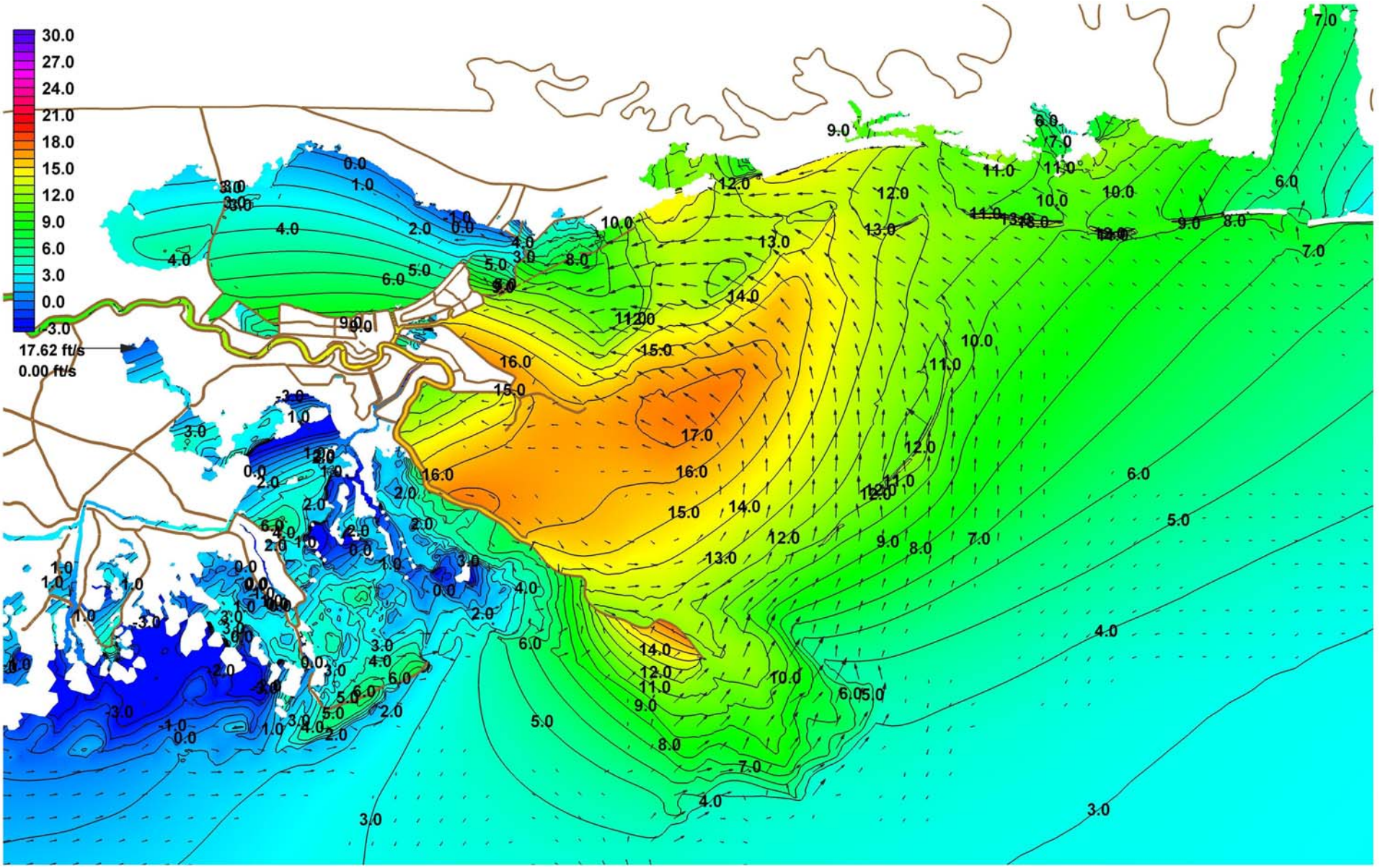


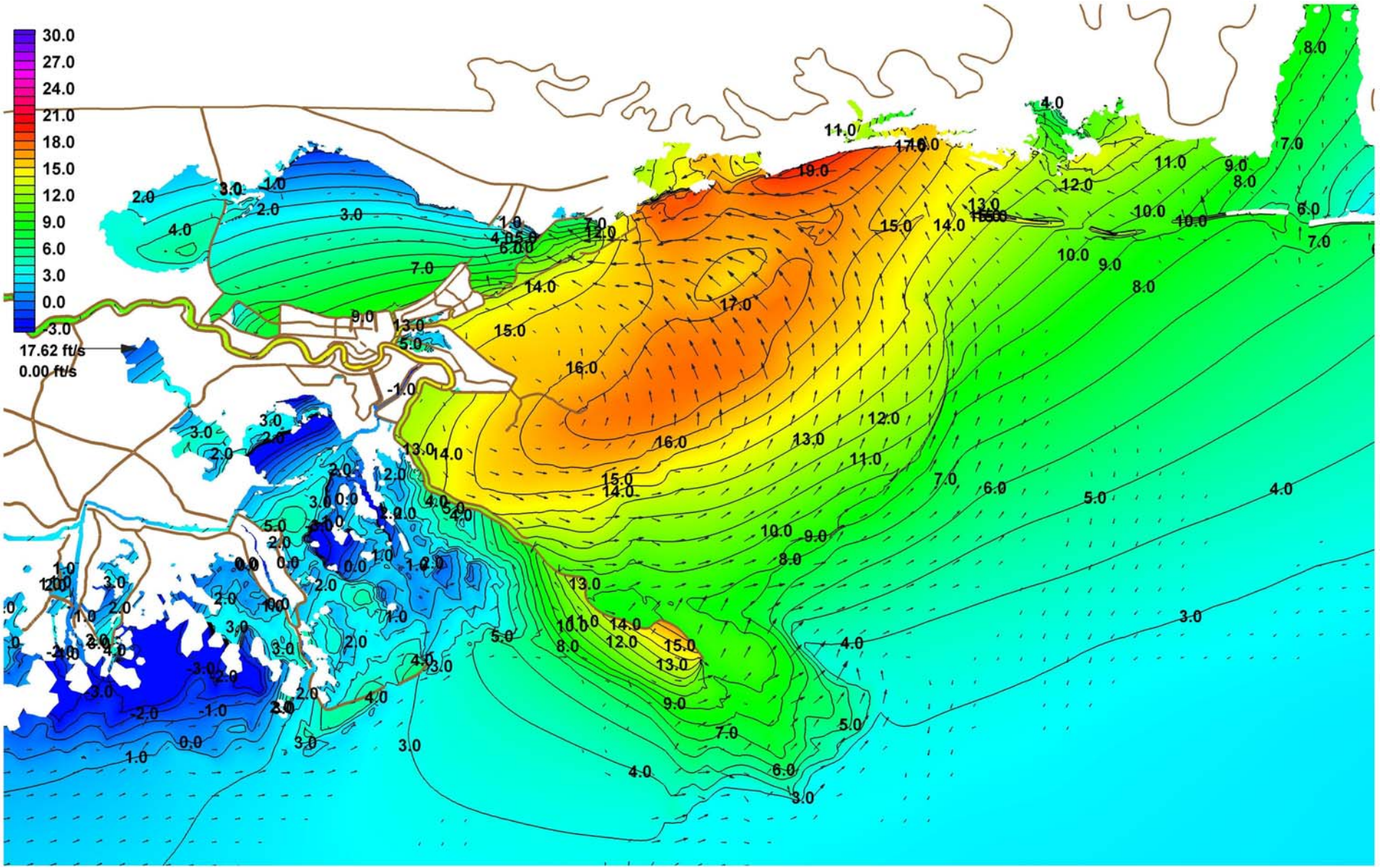
8/29/12Z



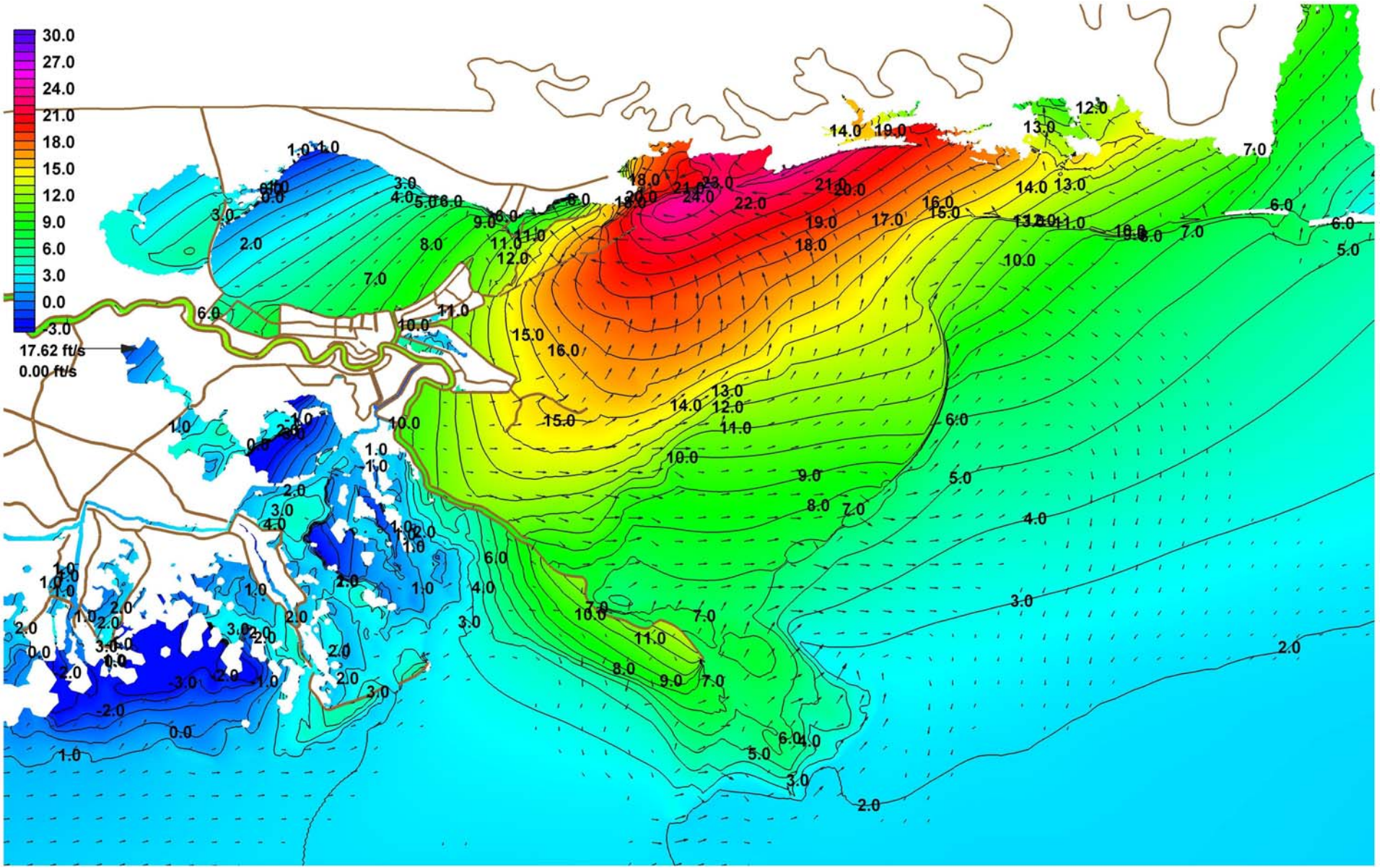
8/29/13Z



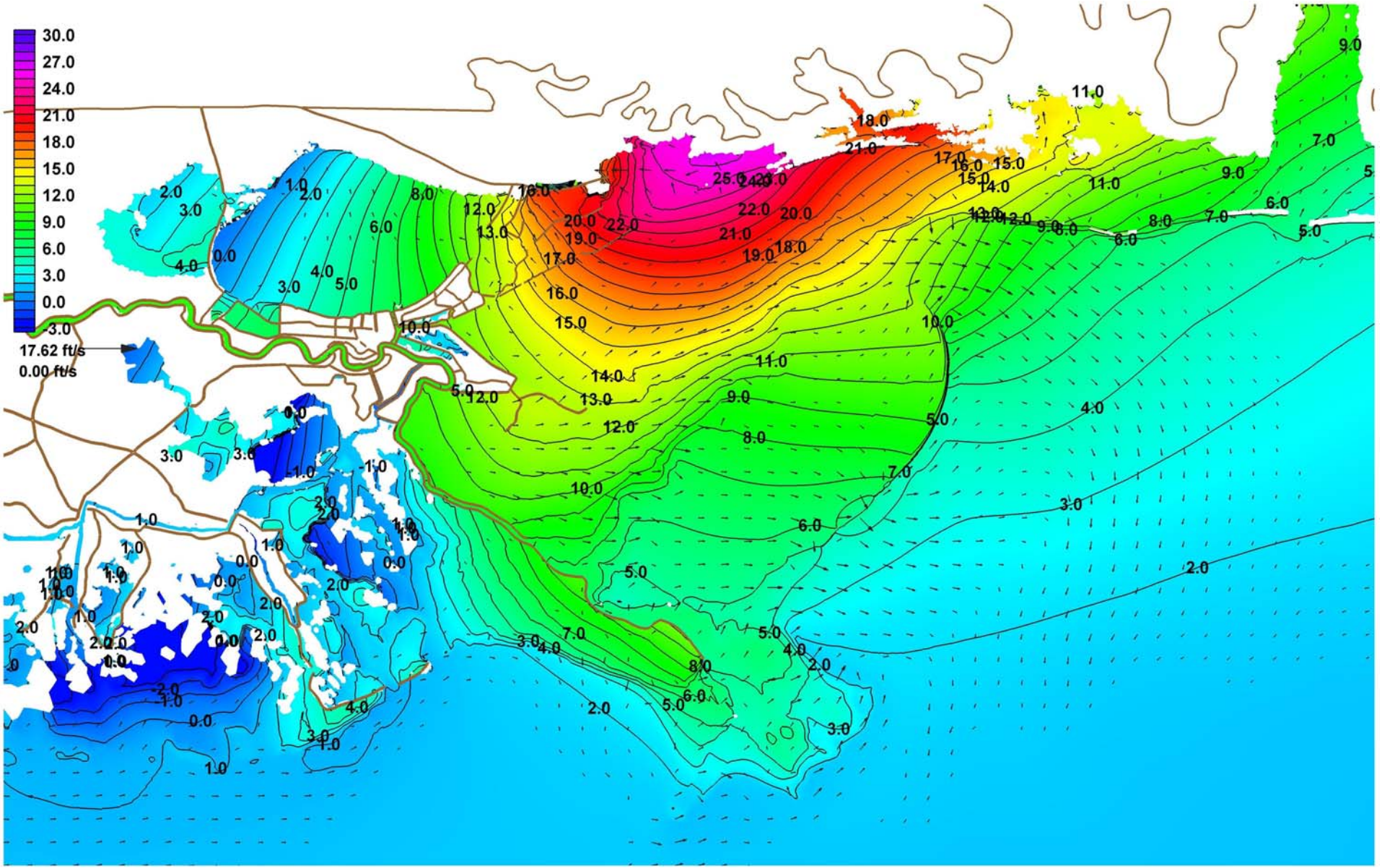
8/29/14Z



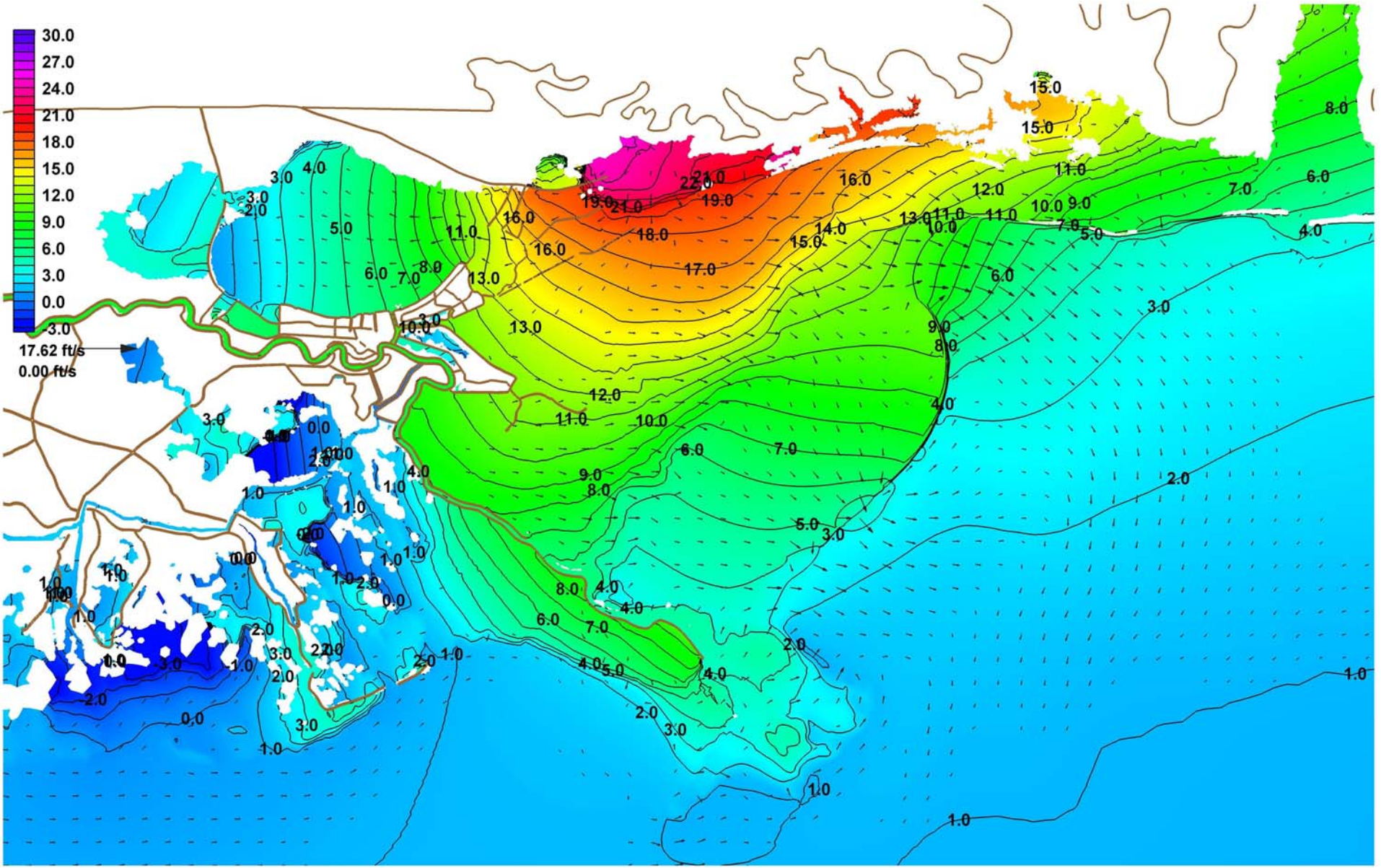
8/29/15Z



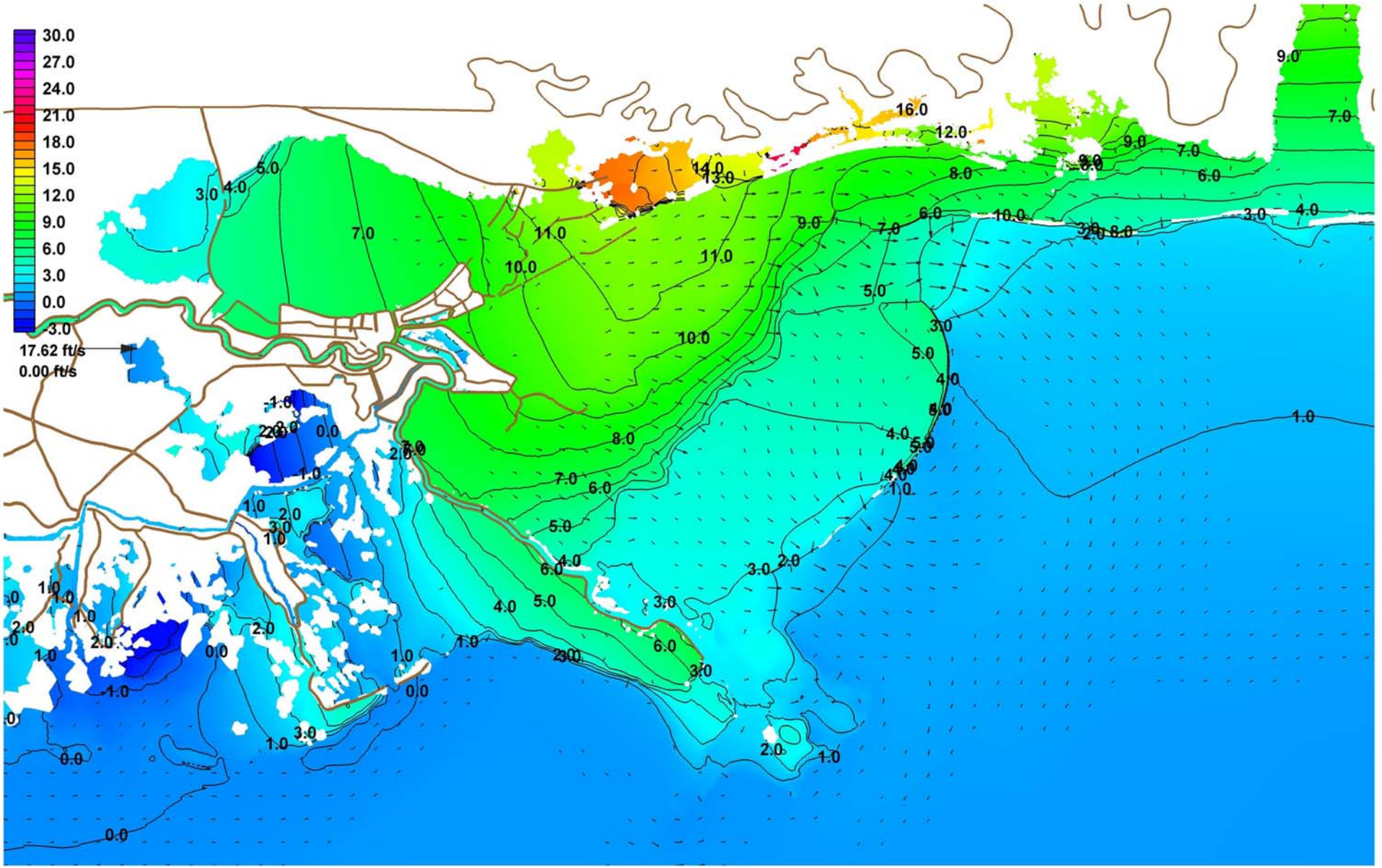
8/29/16Z



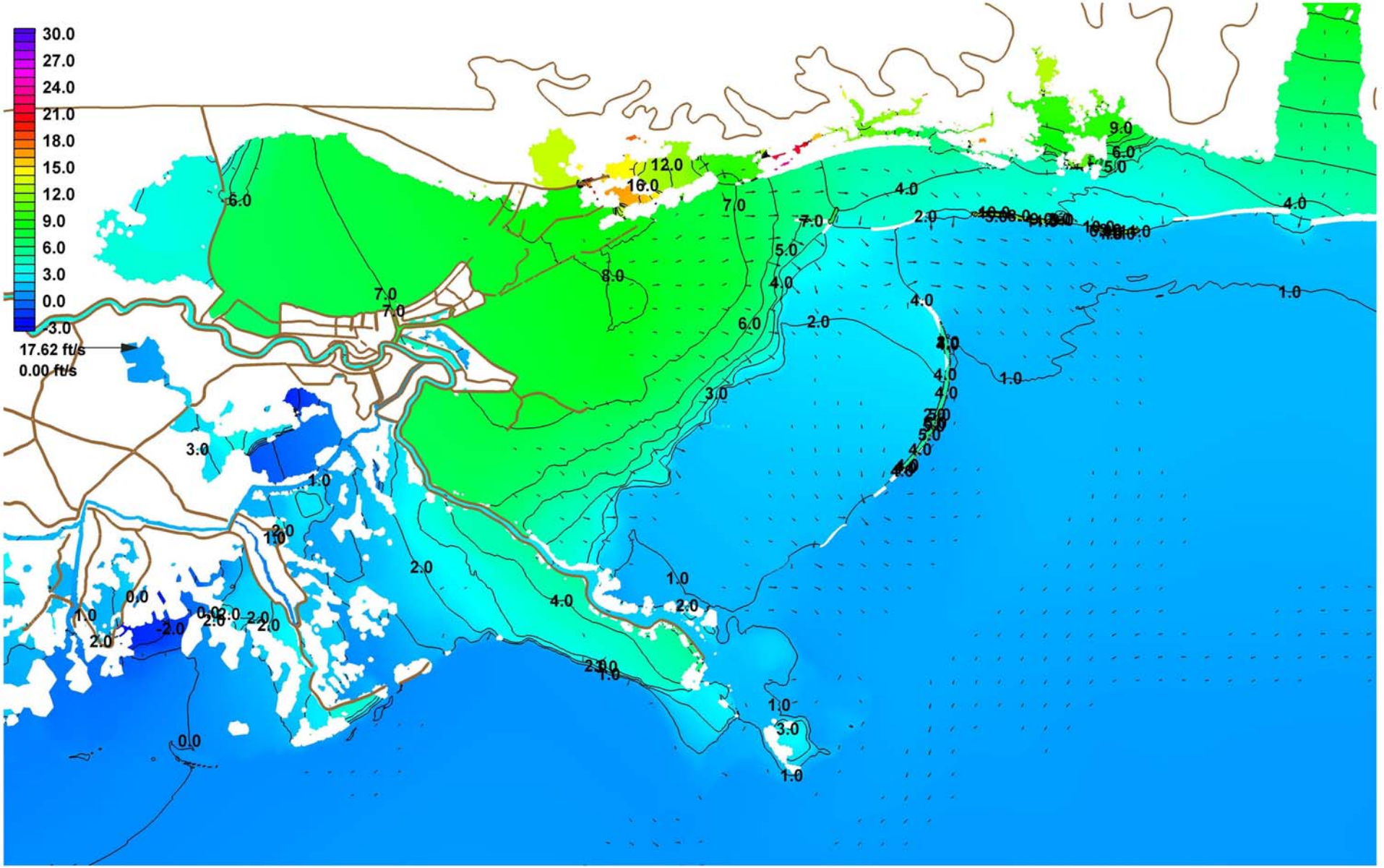
8/29/17Z



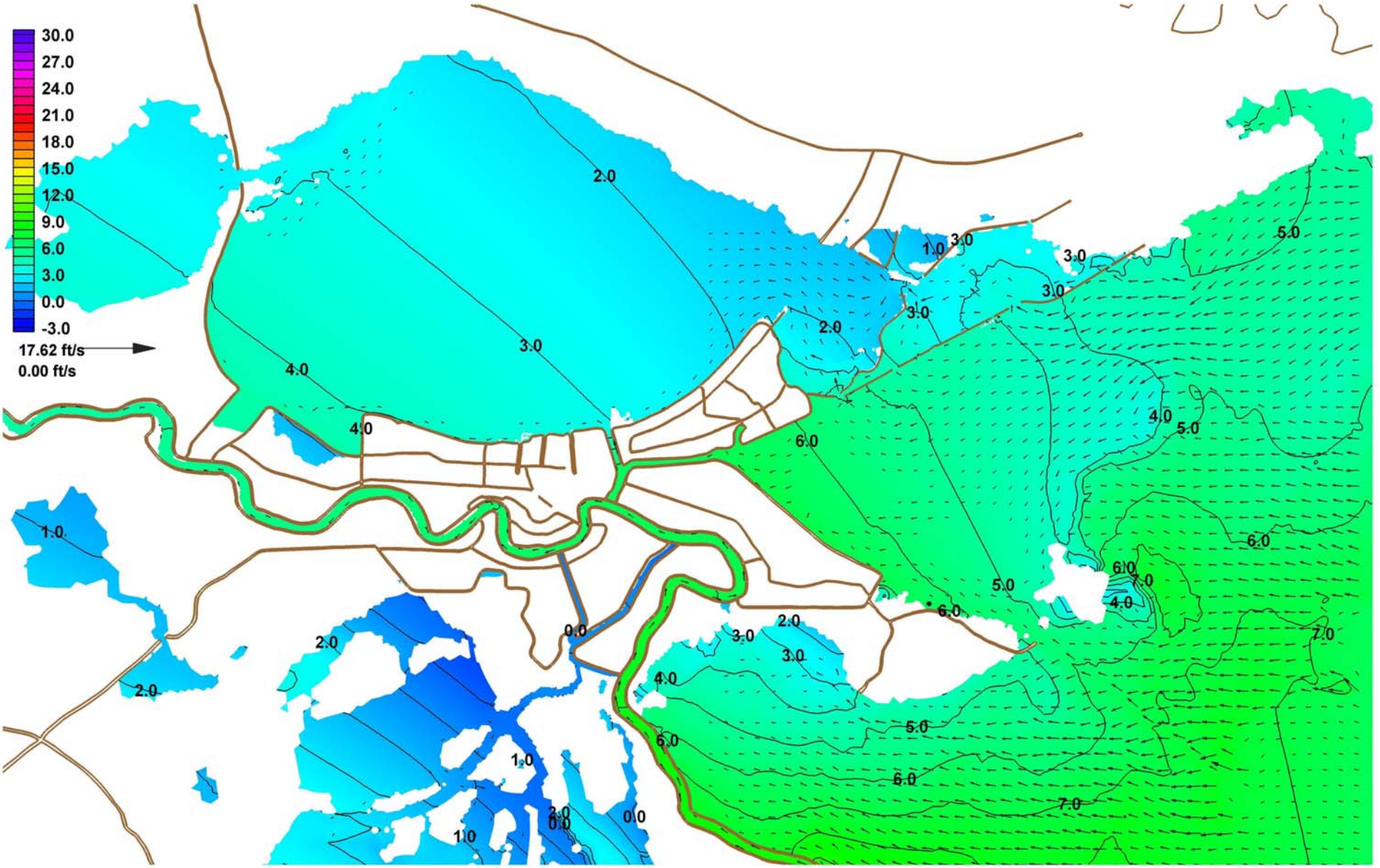
8/29/20Z



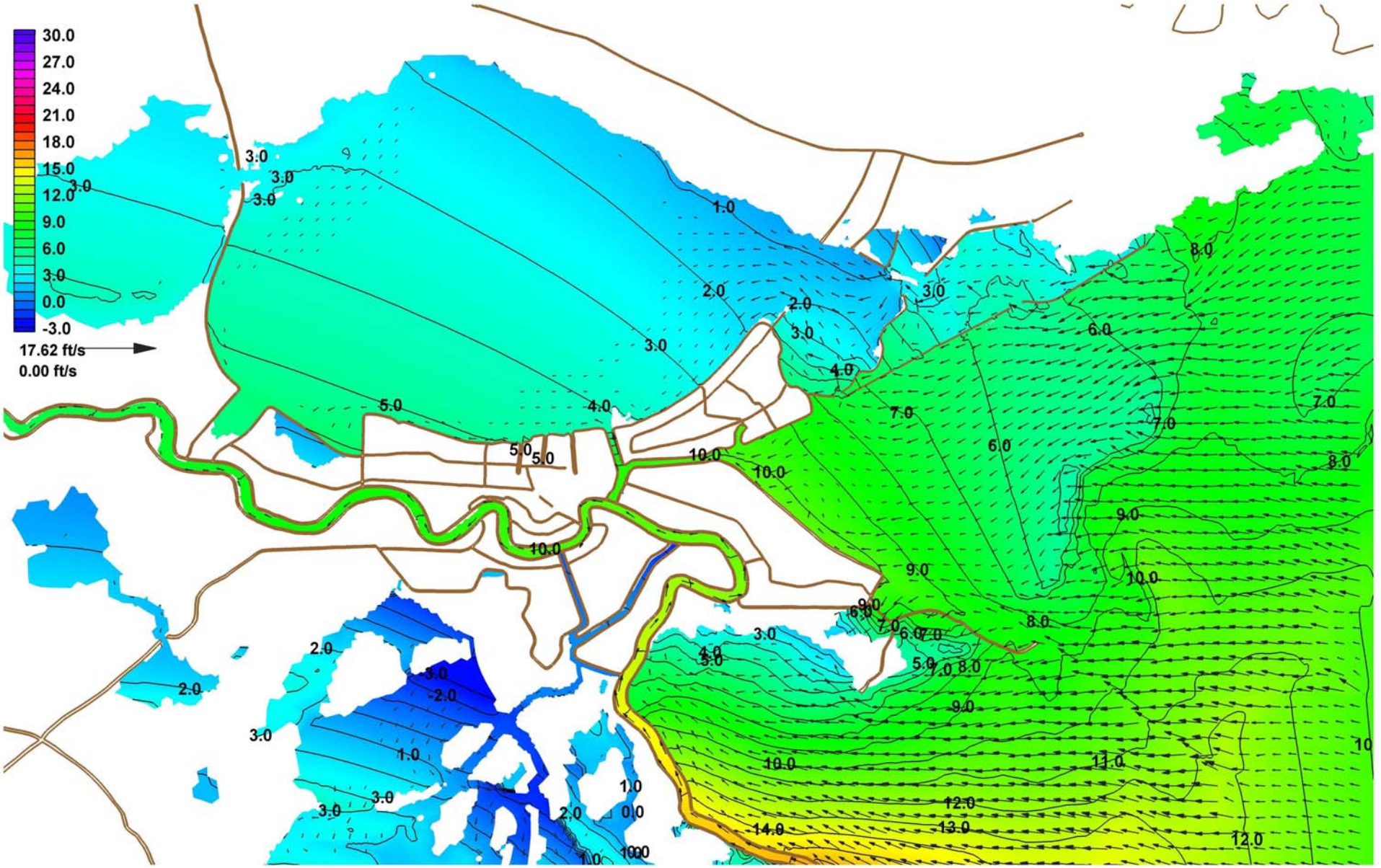
8/29/23Z



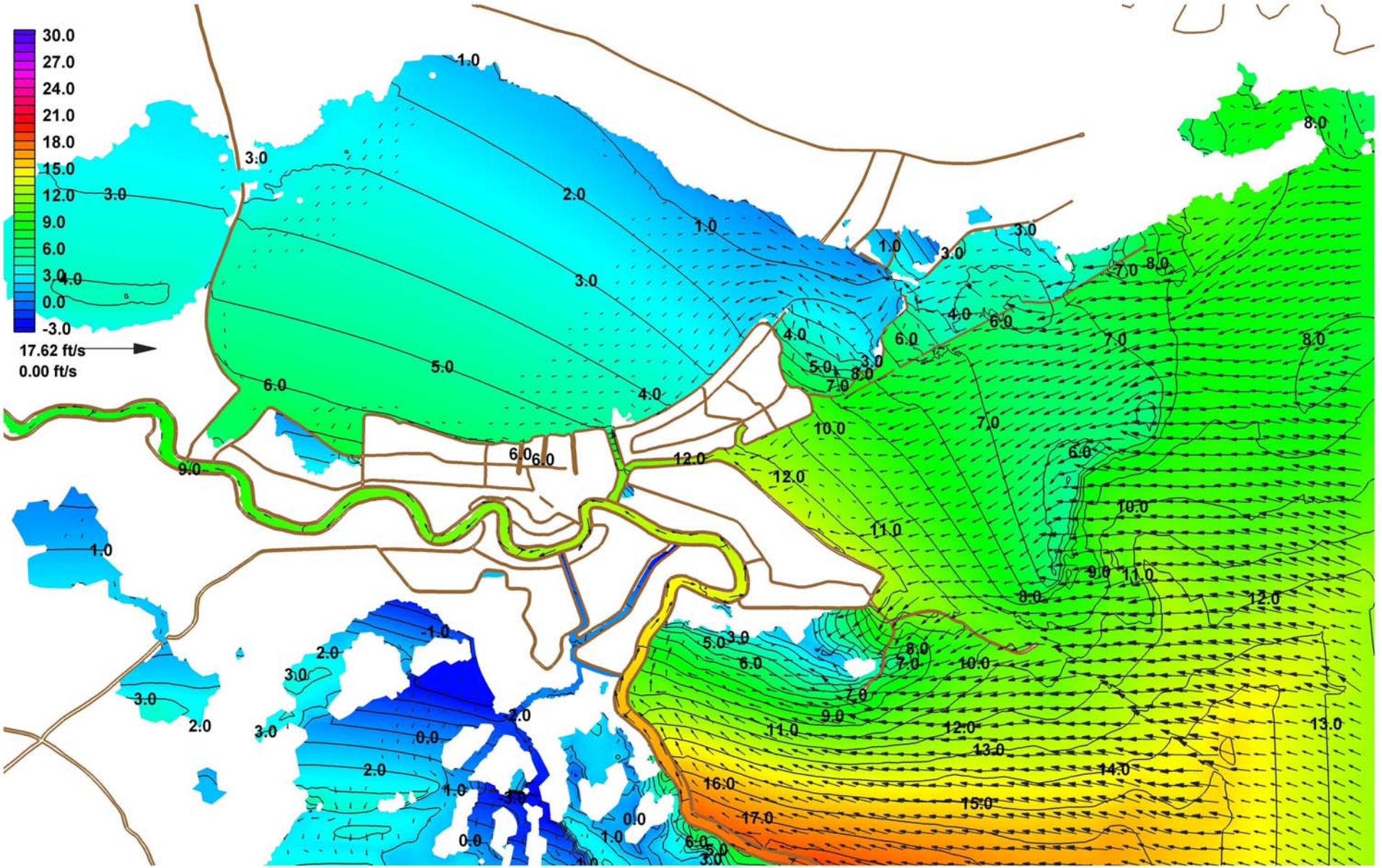
8/29/07Z



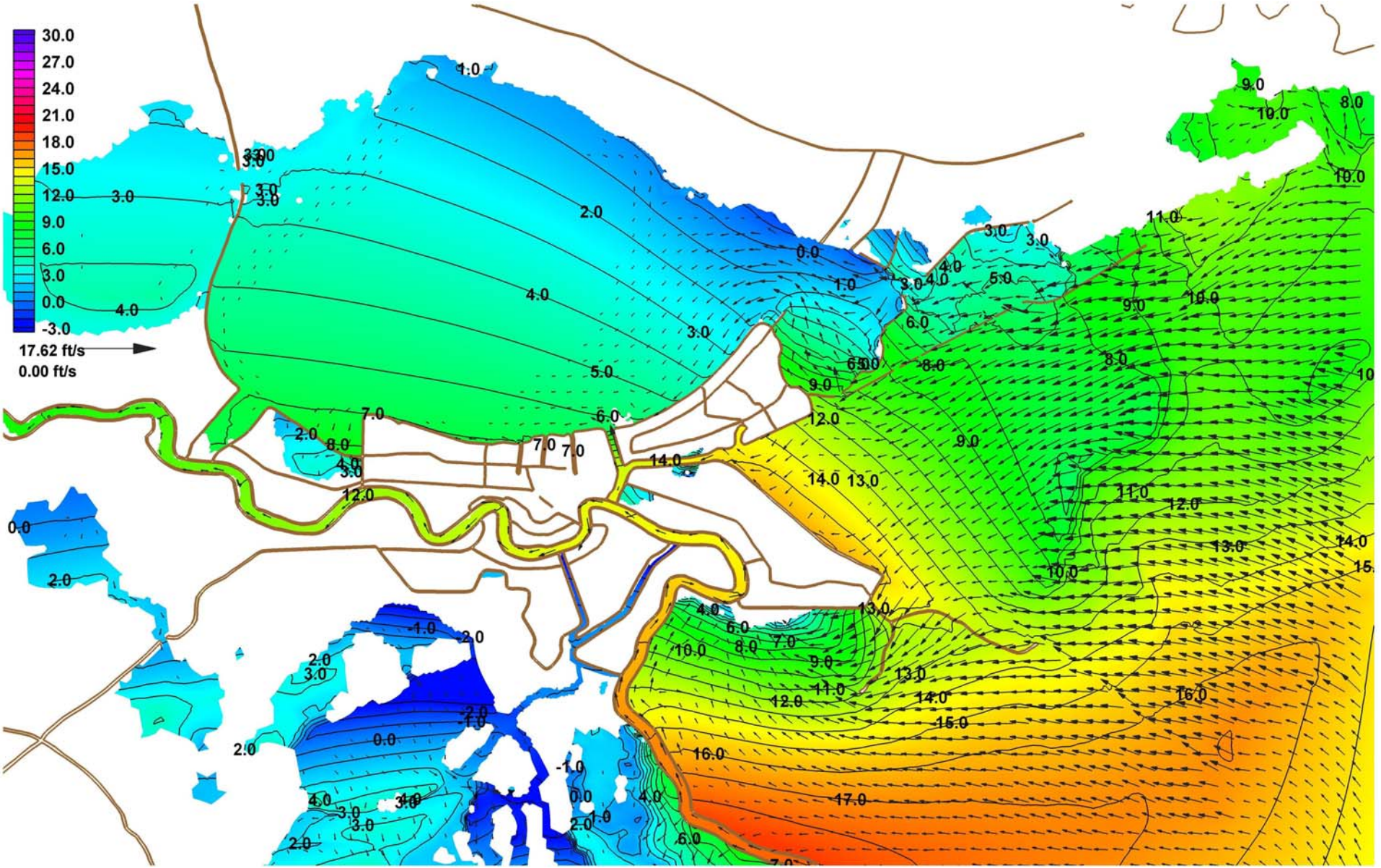
8/29/10Z



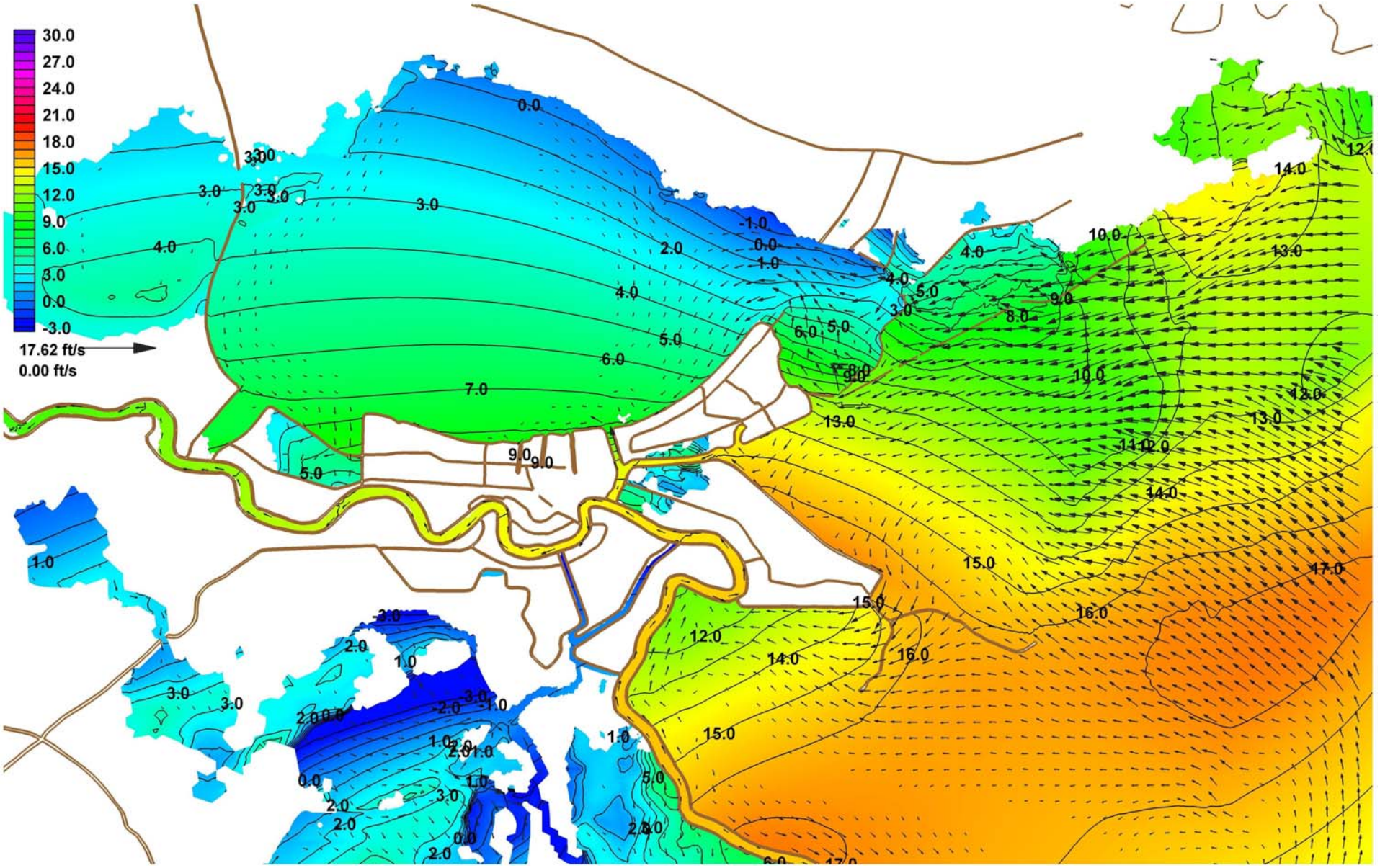
8/29/11Z



8/29/12Z



8/29/13Z



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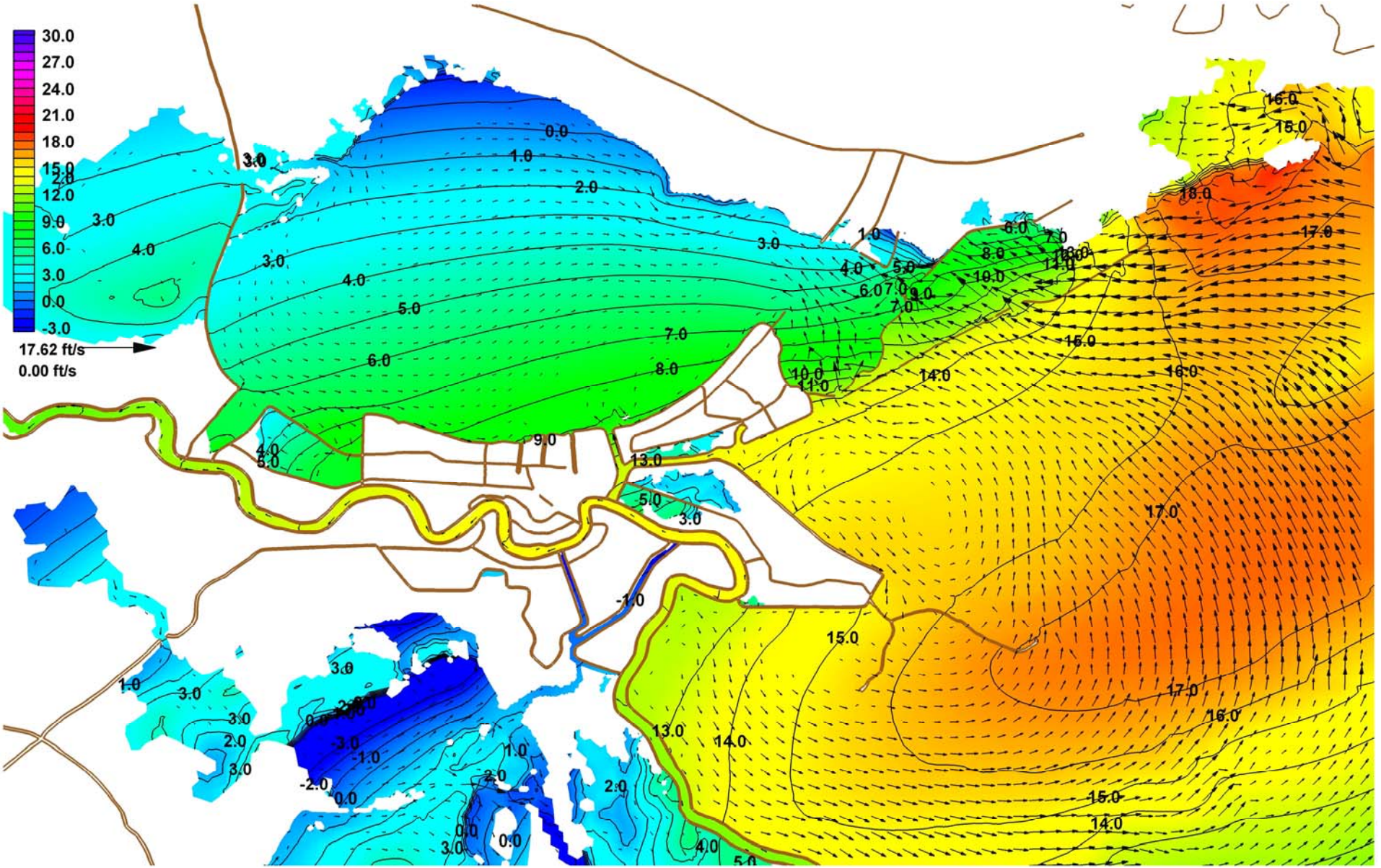
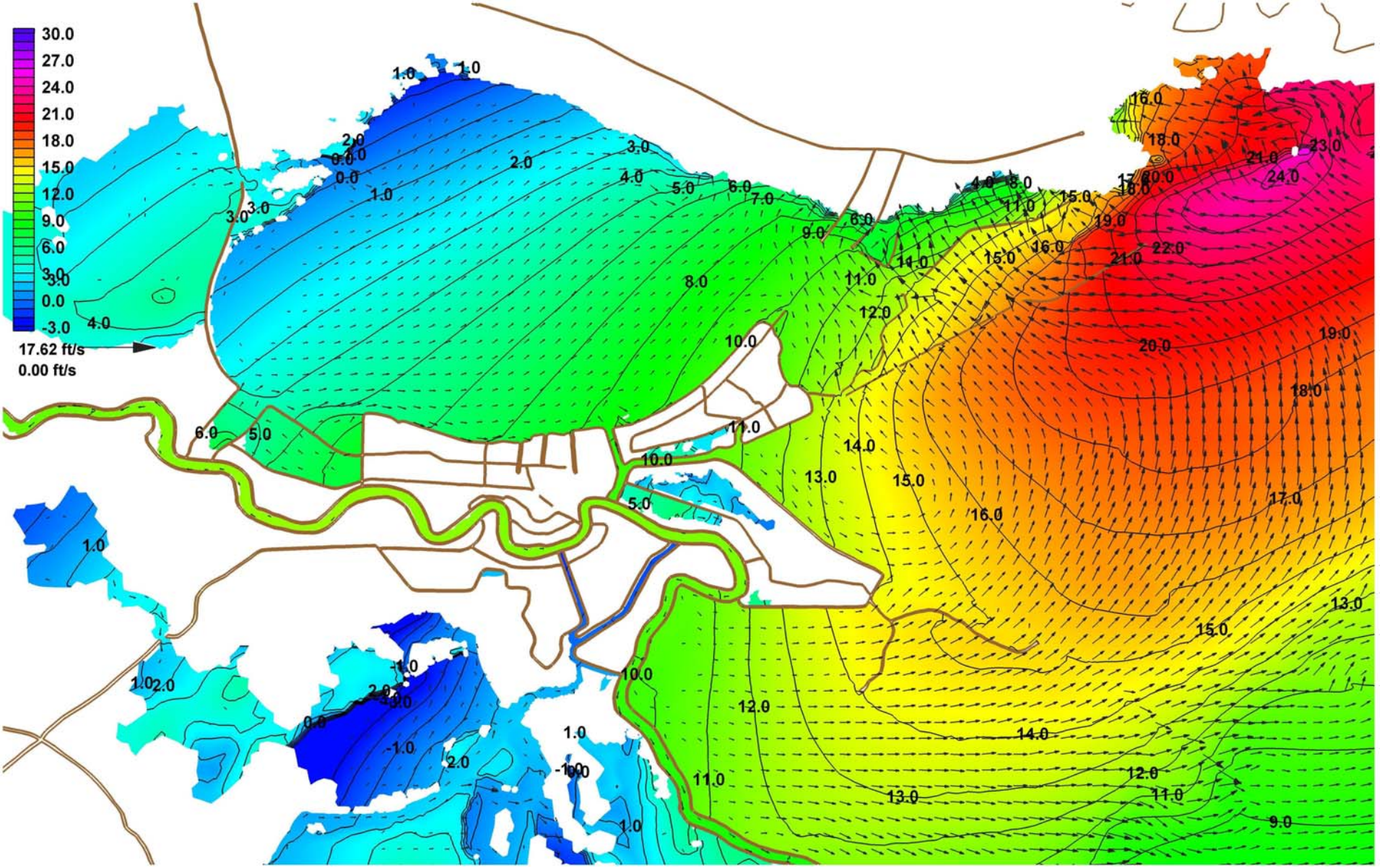
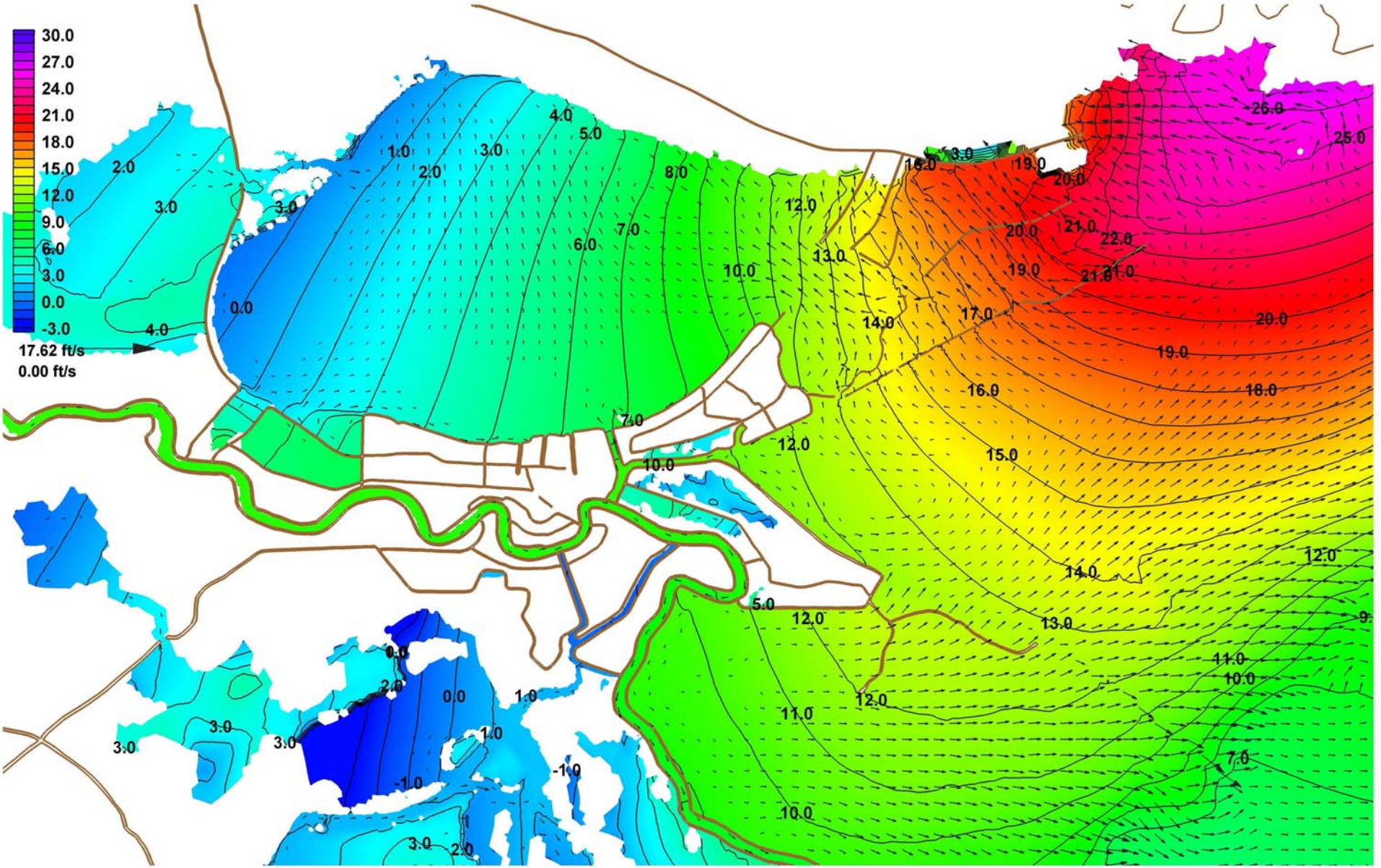


8/29/15Z



8/29/16Z



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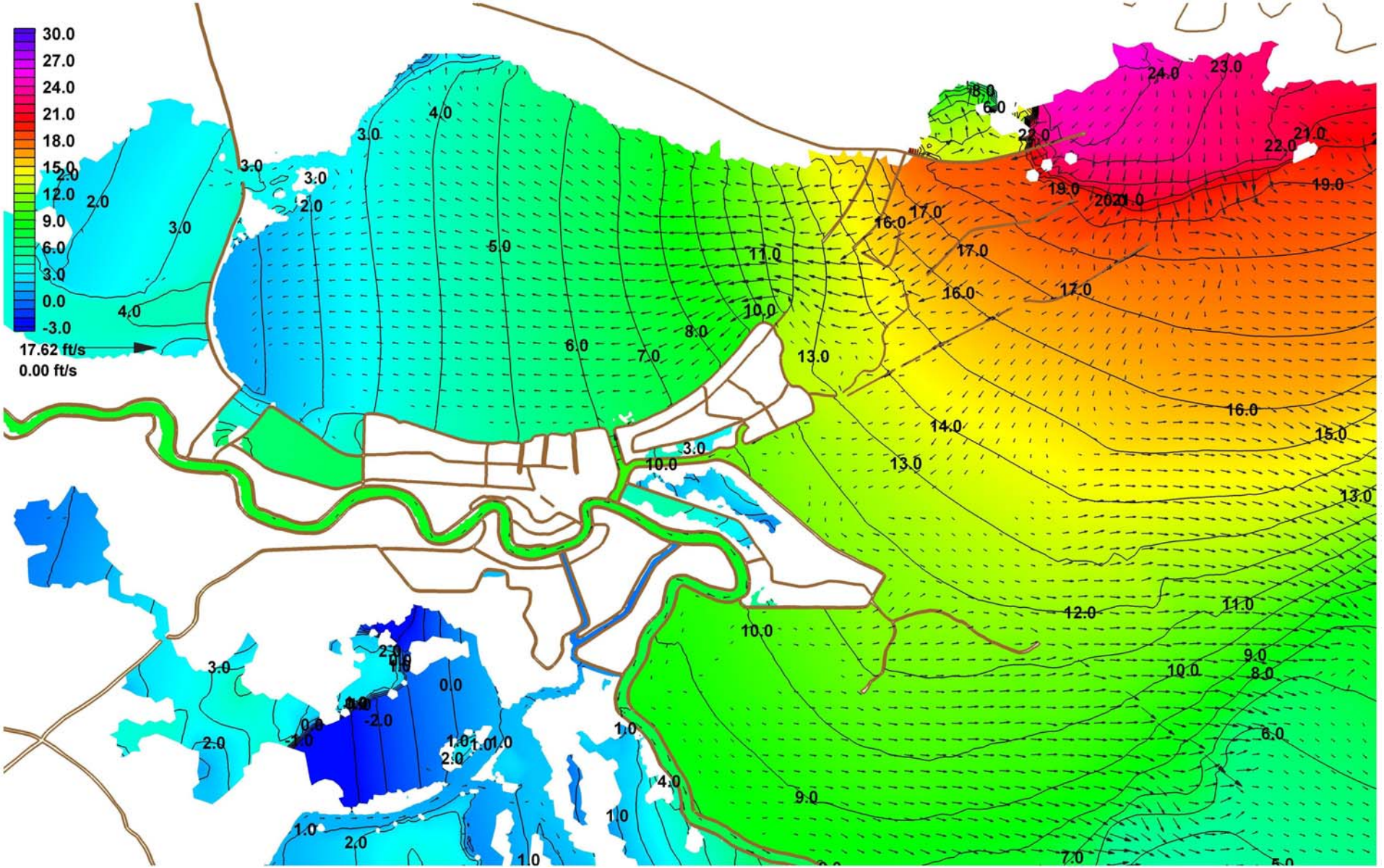
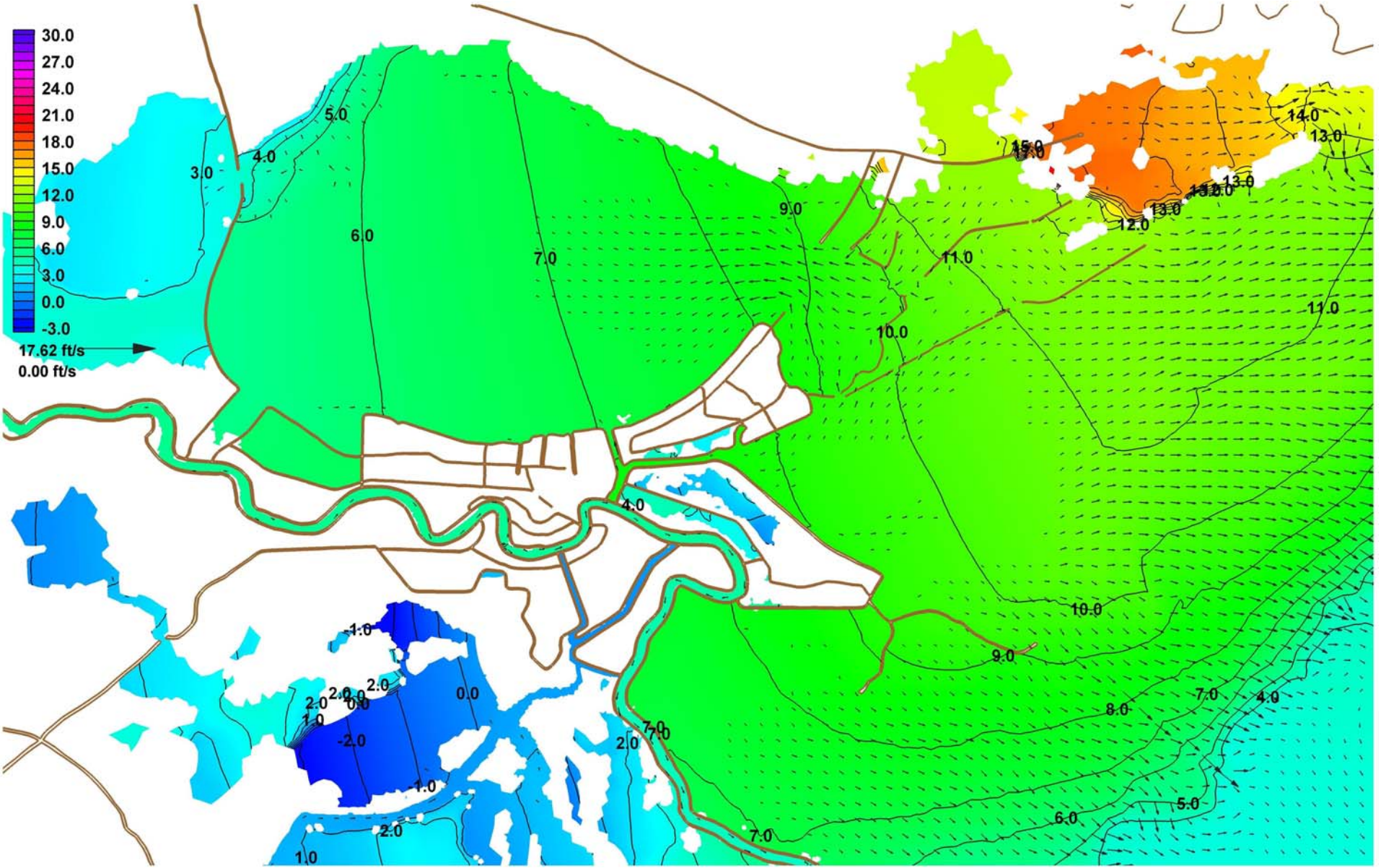
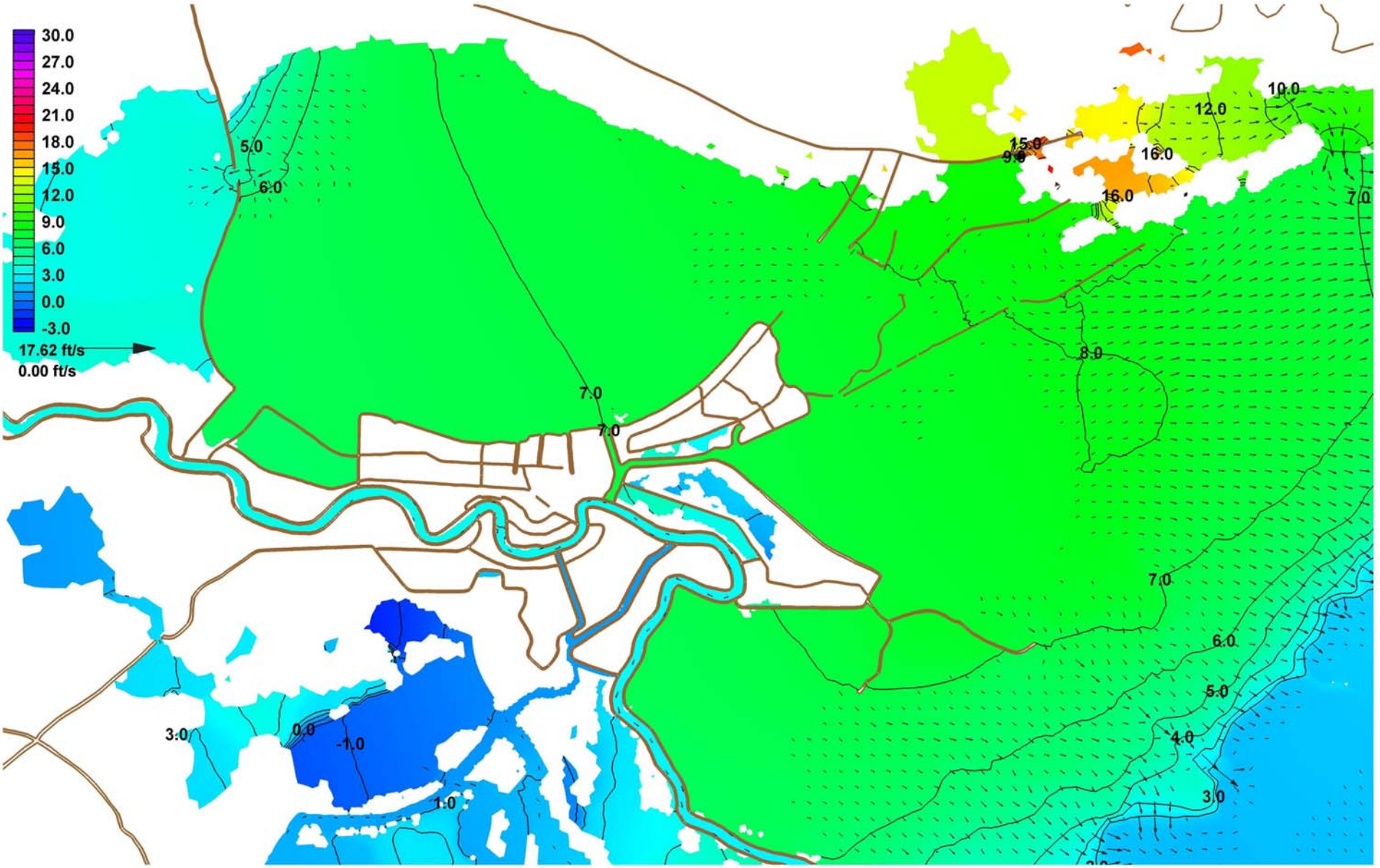


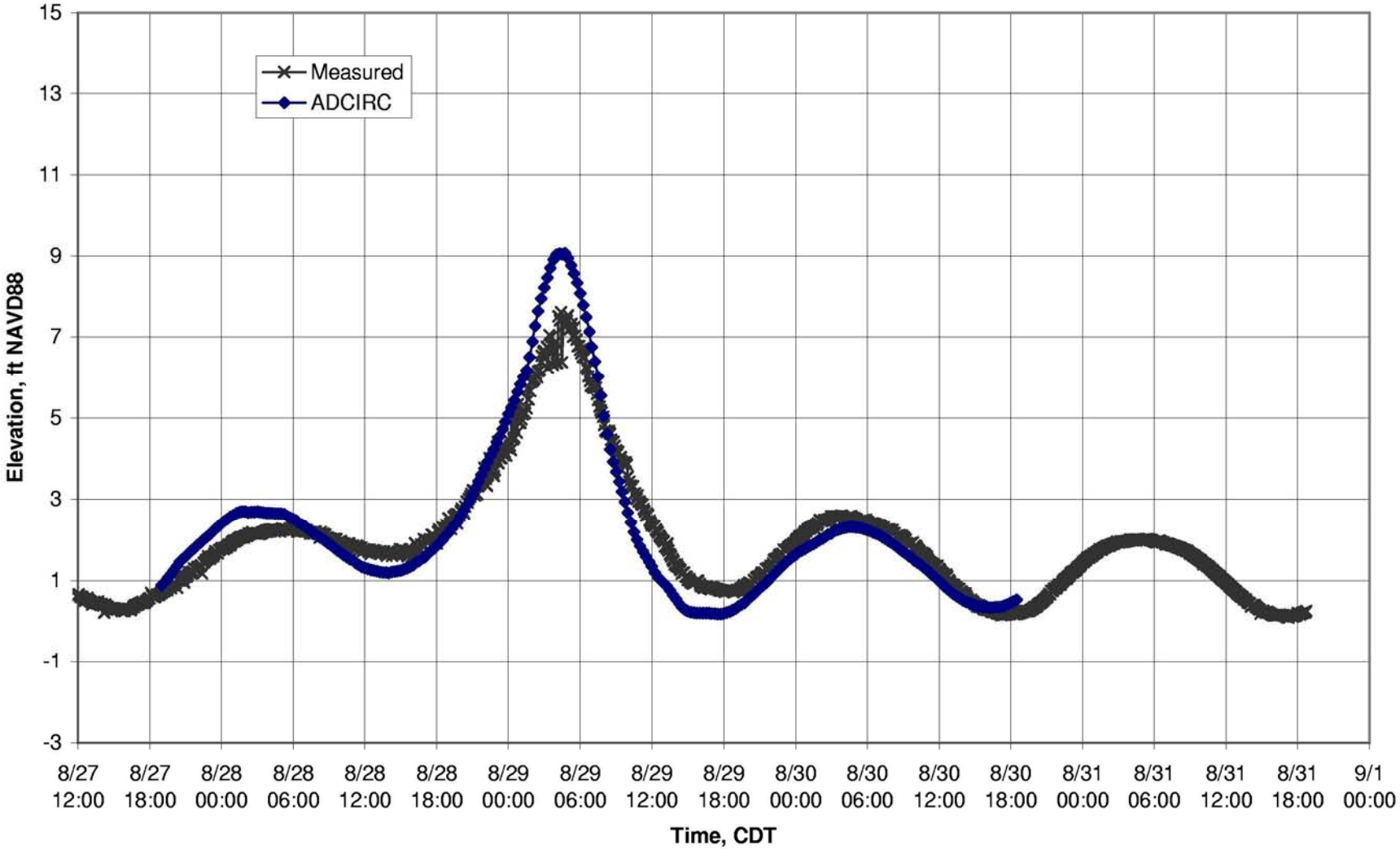
8/29/20Z

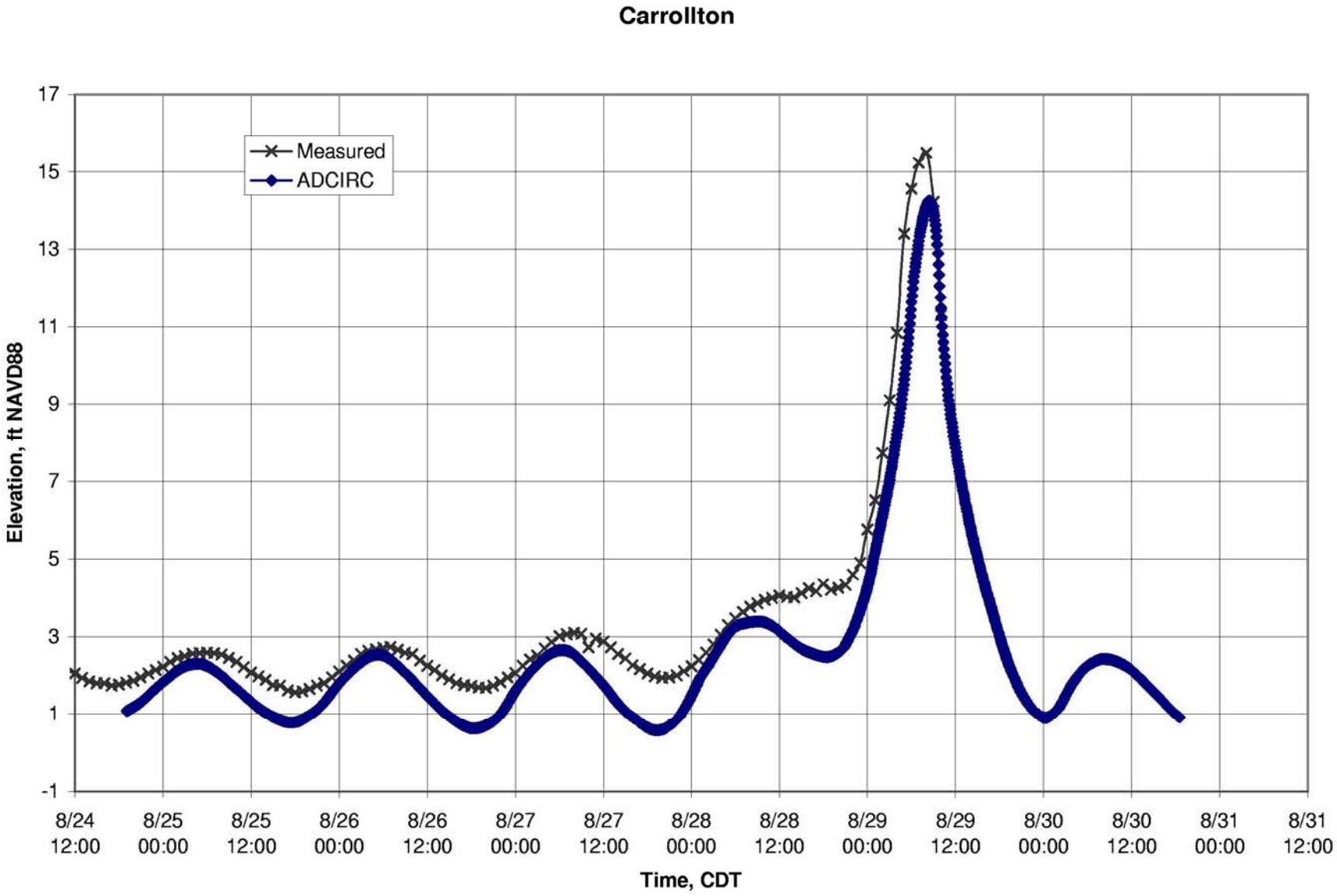


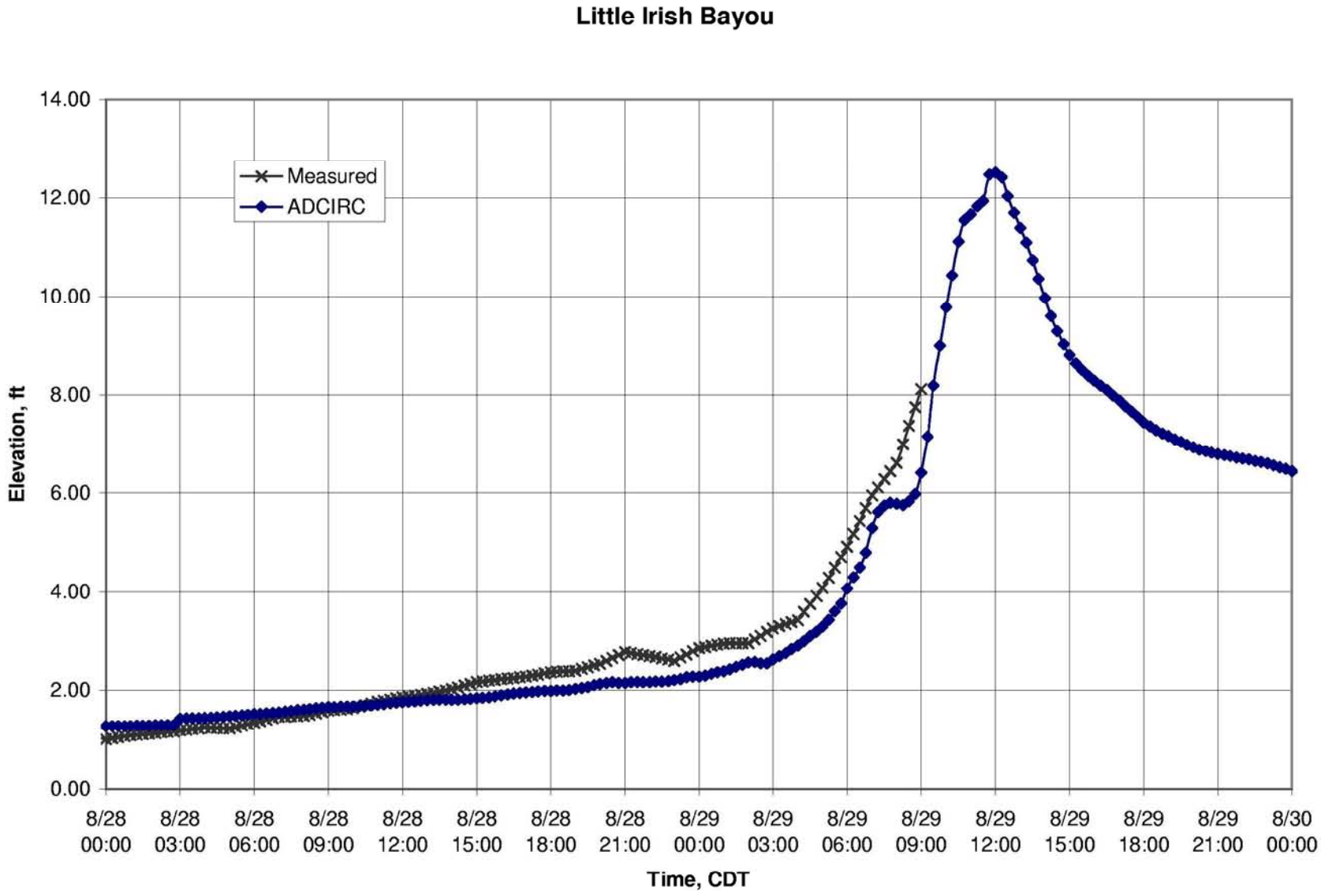
8/29/23Z


30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
-3.0
17.62 ft/s
0.00 ft/s
5.0
6.0
7.0
7.0
8.0
9.0
10.0
12.0
15.0
16.0
16.0
7.0
6.0
5.0
4.0
3.0
3.0
0.0
-1.0
1.0

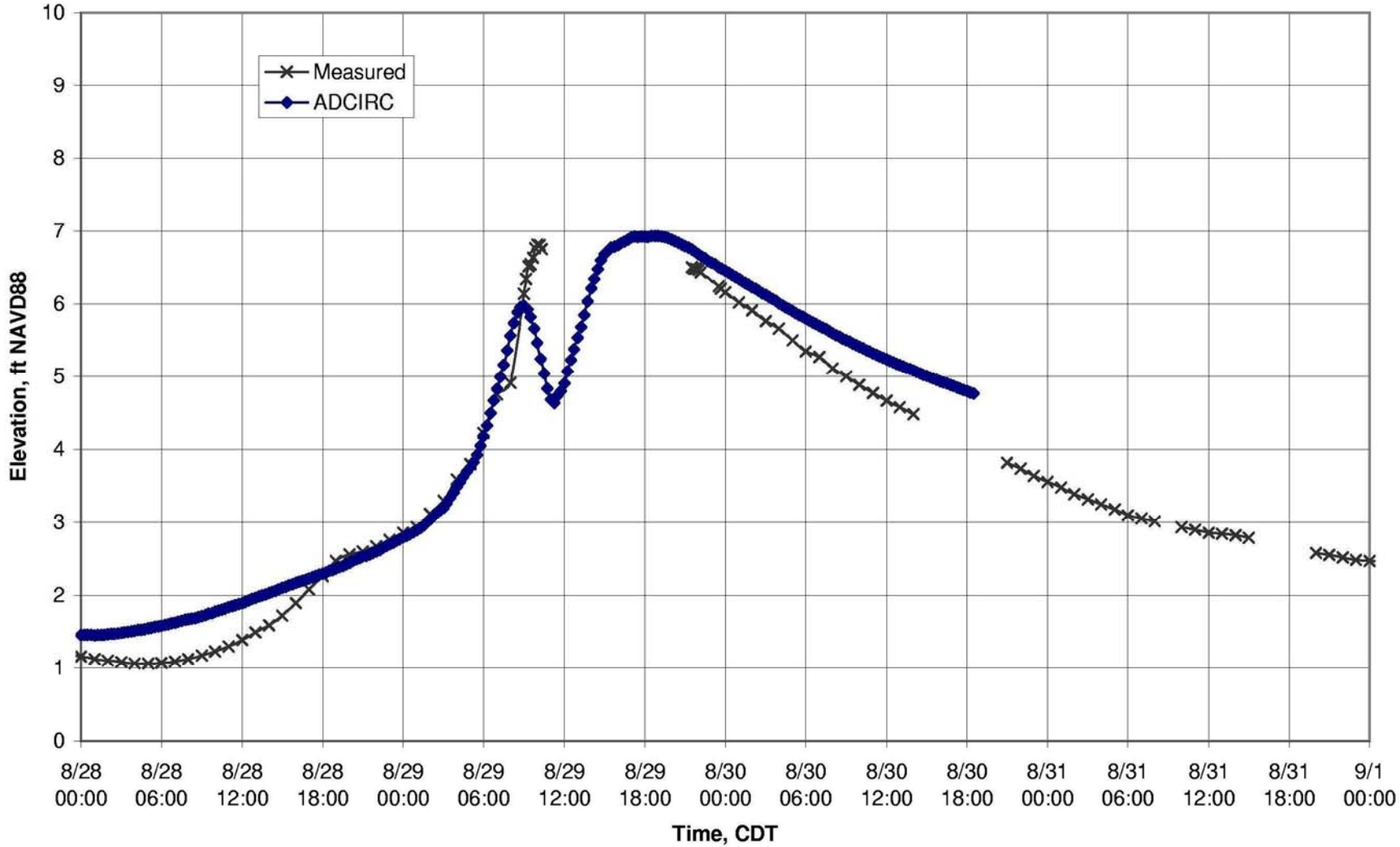
## South Pass

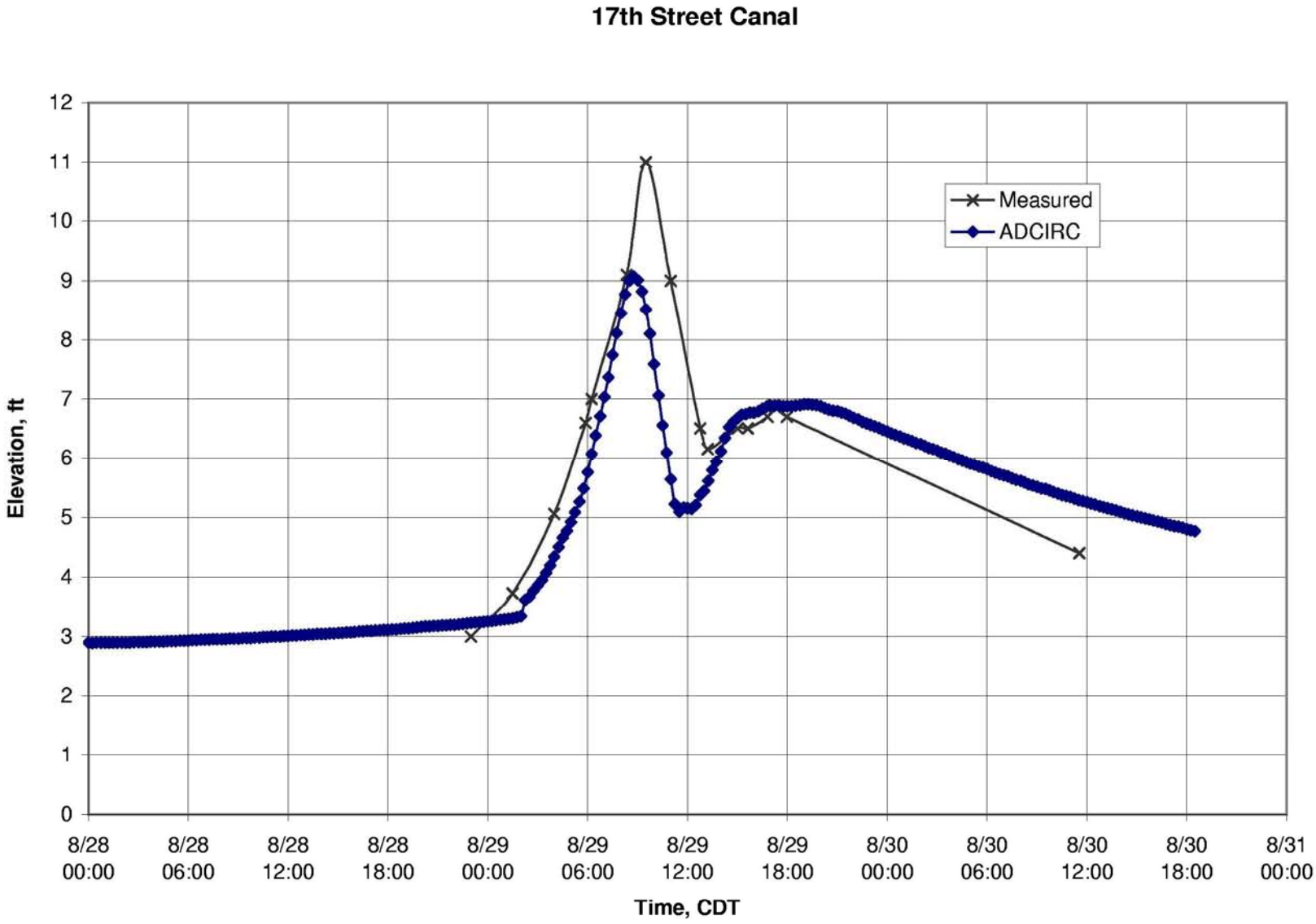

Measured
ADCIRC
Elevation, ft NAVD88
15
13
11
9
7
5
3
1
-1
-3
8/27 12:00
8/27 18:00
8/28 00:00
8/28 06:00
8/28 12:00
8/28 18:00
8/29 00:00
8/29 06:00
8/29 12:00
8/29 18:00
8/30 00:00
8/30 06:00
8/30 12:00
8/30 18:00
8/31 00:00
8/31 06:00
8/31 12:00
8/31 18:00
9/1 00:00
Time, CDT

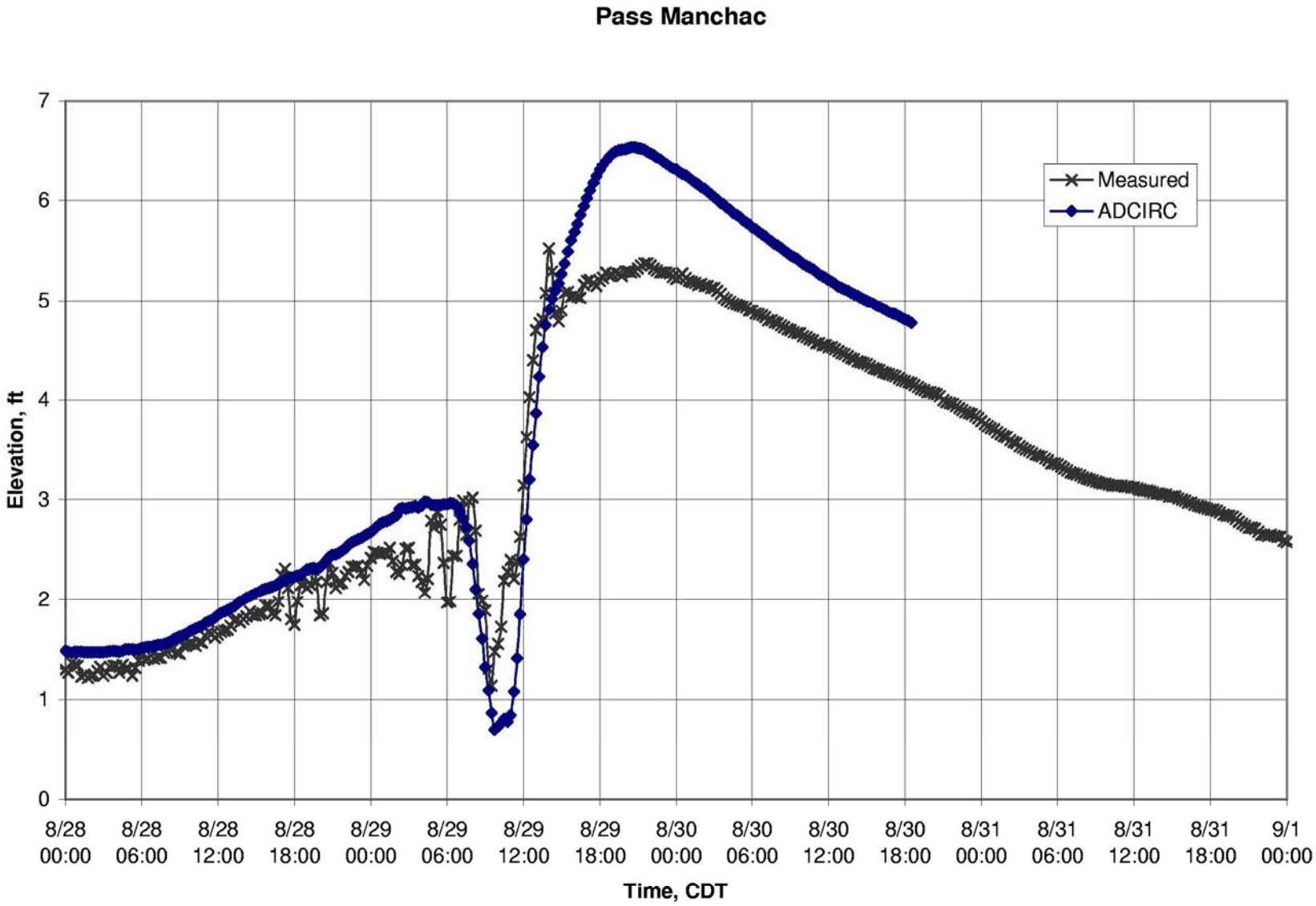

Carrollton
Measured
ADCIRC
Elevation, ft NAVD88
17
15
13
11
9
7
5
3
1
-1
8/24 12:00
8/25 00:00
8/25 12:00
8/26 00:00
8/26 12:00
8/27 00:00
8/27 12:00
8/28 00:00
8/28 12:00
8/29 00:00
8/29 12:00
8/30 00:00
8/30 12:00
8/31 00:00
8/31 12:00
Time, CDT

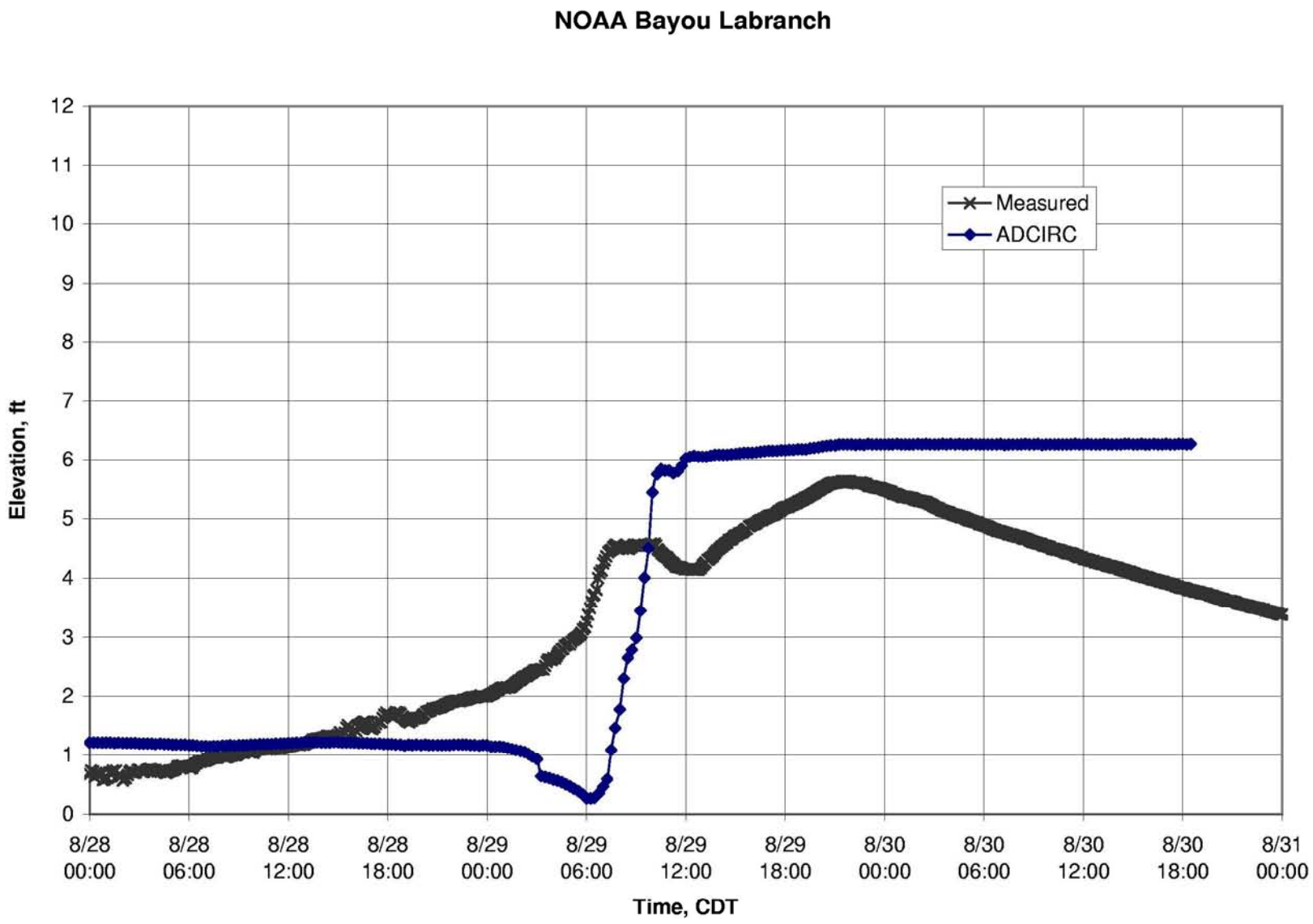

Little Irish Bayou
Measured
ADCIRC
Elevation, ft
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
8/28 00:00
8/28 03:00
8/28 06:00
8/28 09:00
8/28 12:00
8/28 15:00
8/28 18:00
8/28 21:00
8/29 00:00
8/29 03:00
8/29 06:00
8/29 09:00
8/29 12:00
8/29 15:00
8/29 18:00
8/29 21:00
8/30 00:00
Time, CDT

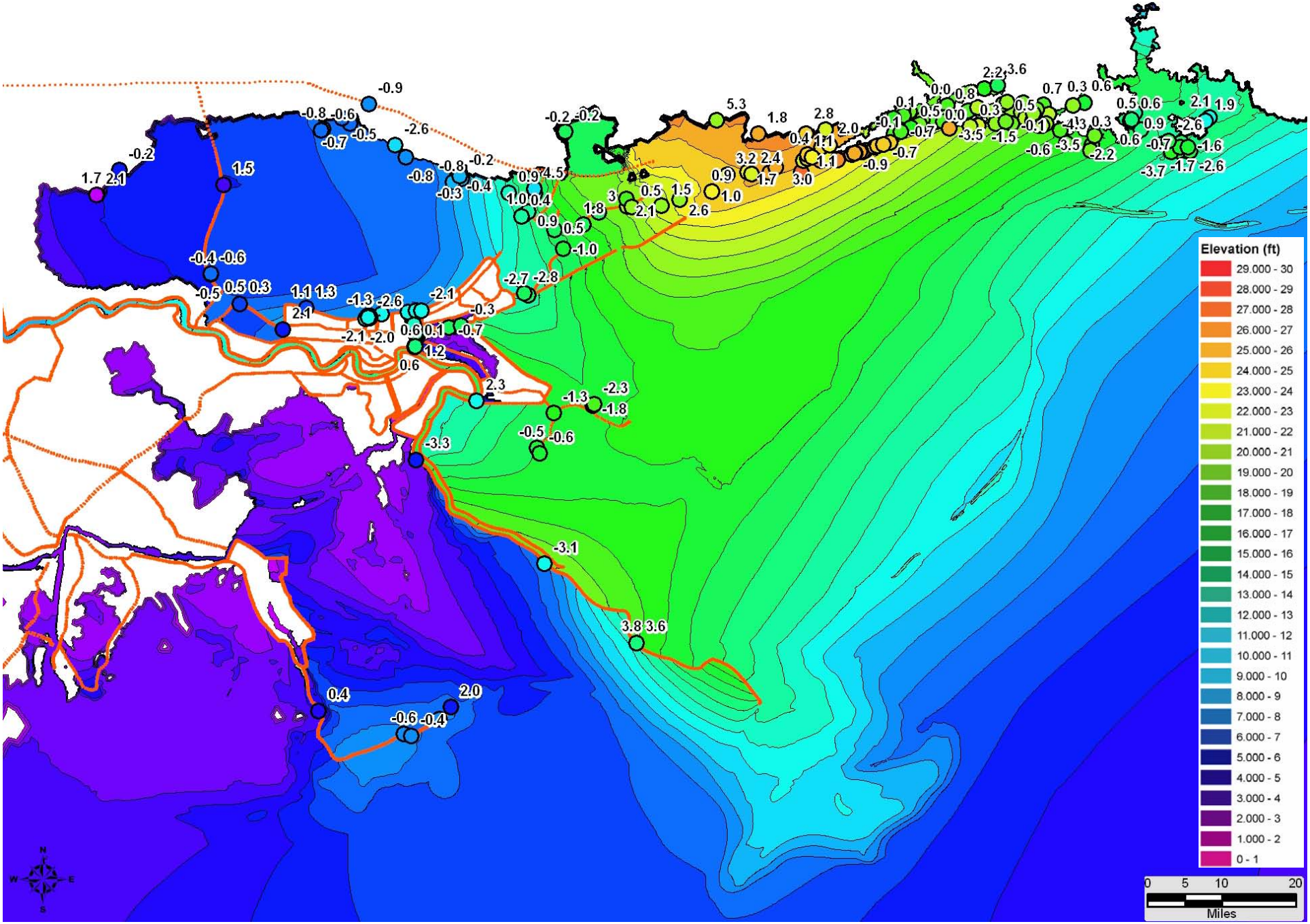
## (NWS) Lake Pontchartrain at Midlake on Causeway

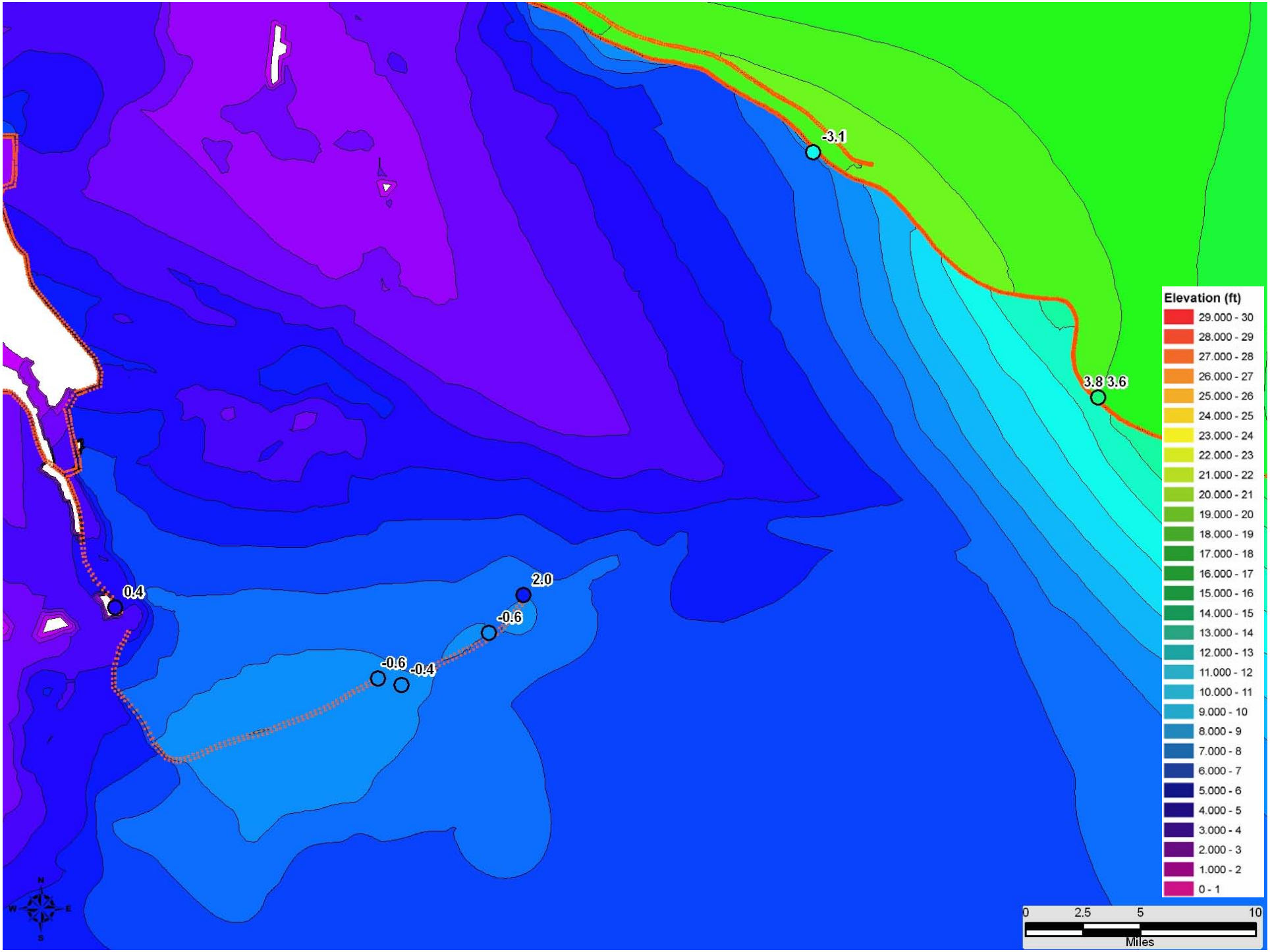


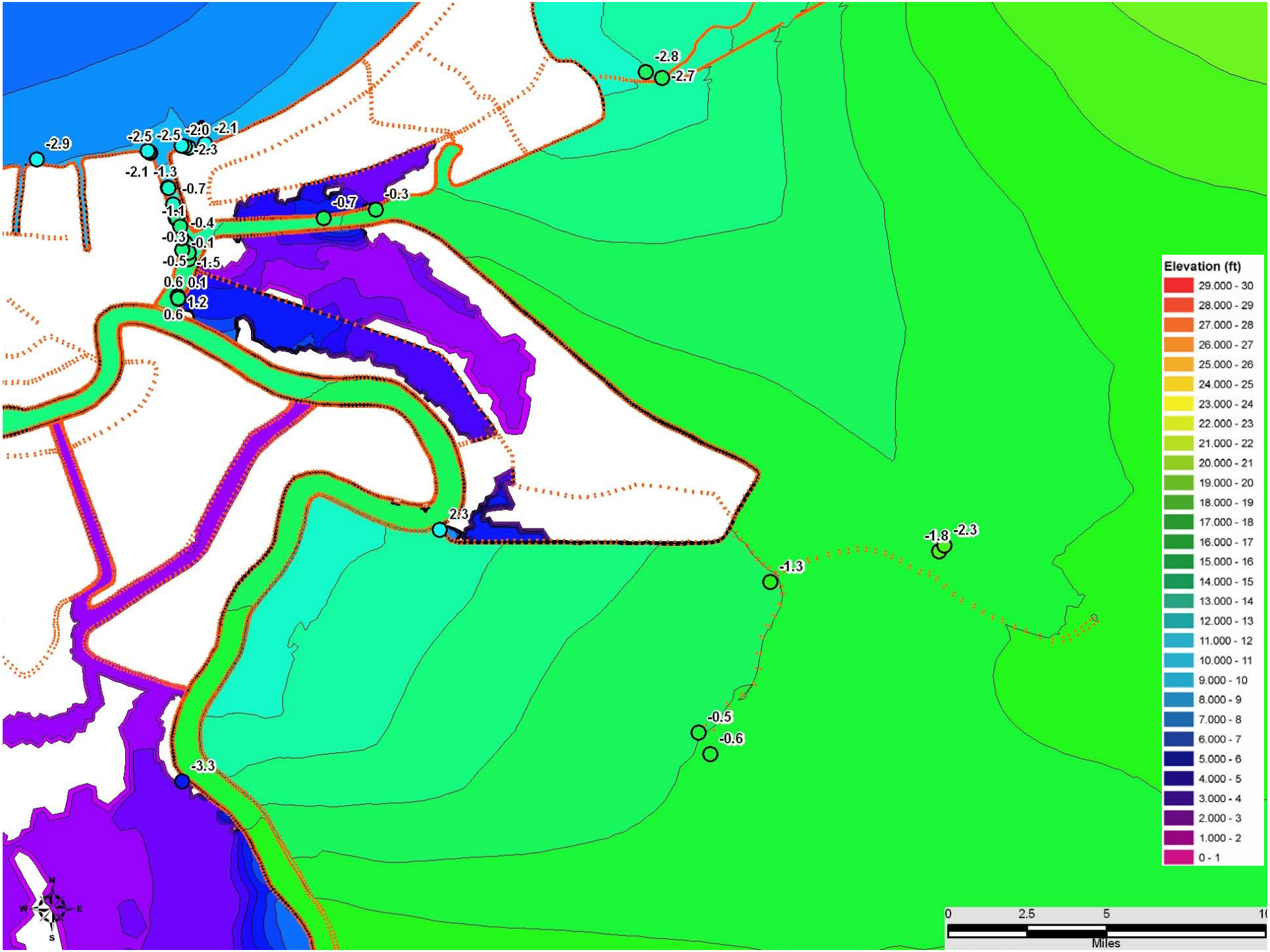

17th Street Canal
Measured
ADCIRC
Elevation, ft
0
1
2
3
4
5
6
7
8
9
10
11
12
8/28 00:00
8/28 06:00
8/28 12:00
8/28 18:00
8/29 00:00
8/29 06:00
8/29 12:00
8/29 18:00
8/30 00:00
8/30 06:00
8/30 12:00
8/30 18:00
8/31 00:00
Time, CDT


Pass Manchac
Measured
ADCIRC
Elevation, ft
0
1
2
3
4
5
6
7
8/28 00:00
8/28 06:00
8/28 12:00
8/28 18:00
8/29 00:00
8/29 06:00
8/29 12:00
8/29 18:00
8/30 00:00
8/30 06:00
8/30 12:00
8/30 18:00
8/31 00:00
8/31 06:00
8/31 12:00
8/31 18:00
9/1 00:00
Time, CDT

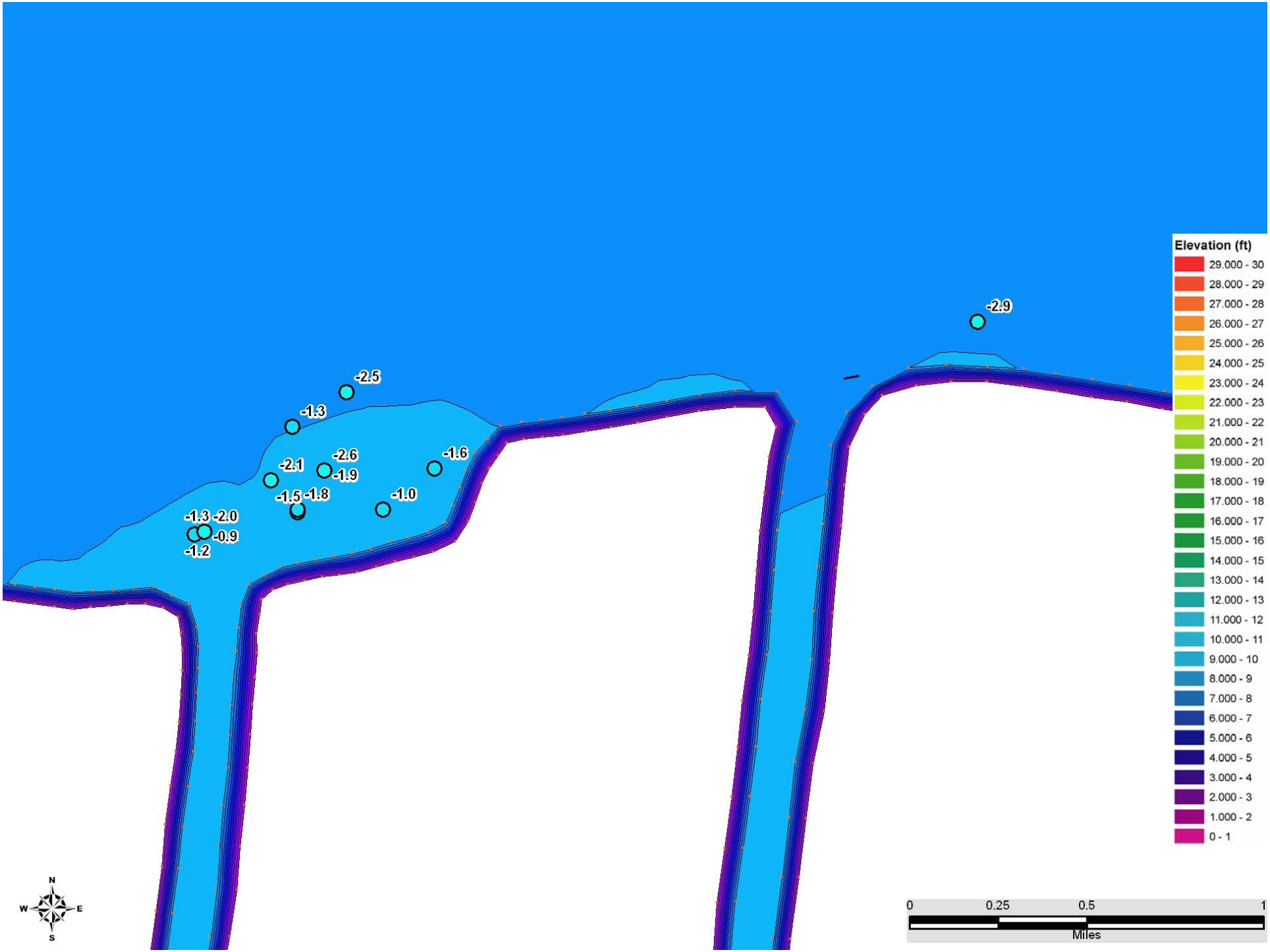

NOAA Bayou Labranch
Measured
ADCIRC
Elevation, ft
0
1
2
3
4
5
6
7
8
9
10
11
12
8/28 00:00
8/28 06:00
8/28 12:00
8/28 18:00
8/29 00:00
8/29 06:00
8/29 12:00
8/29 18:00
8/30 00:00
8/30 06:00
8/30 12:00
8/30 18:00
8/31 00:00
Time, CDT

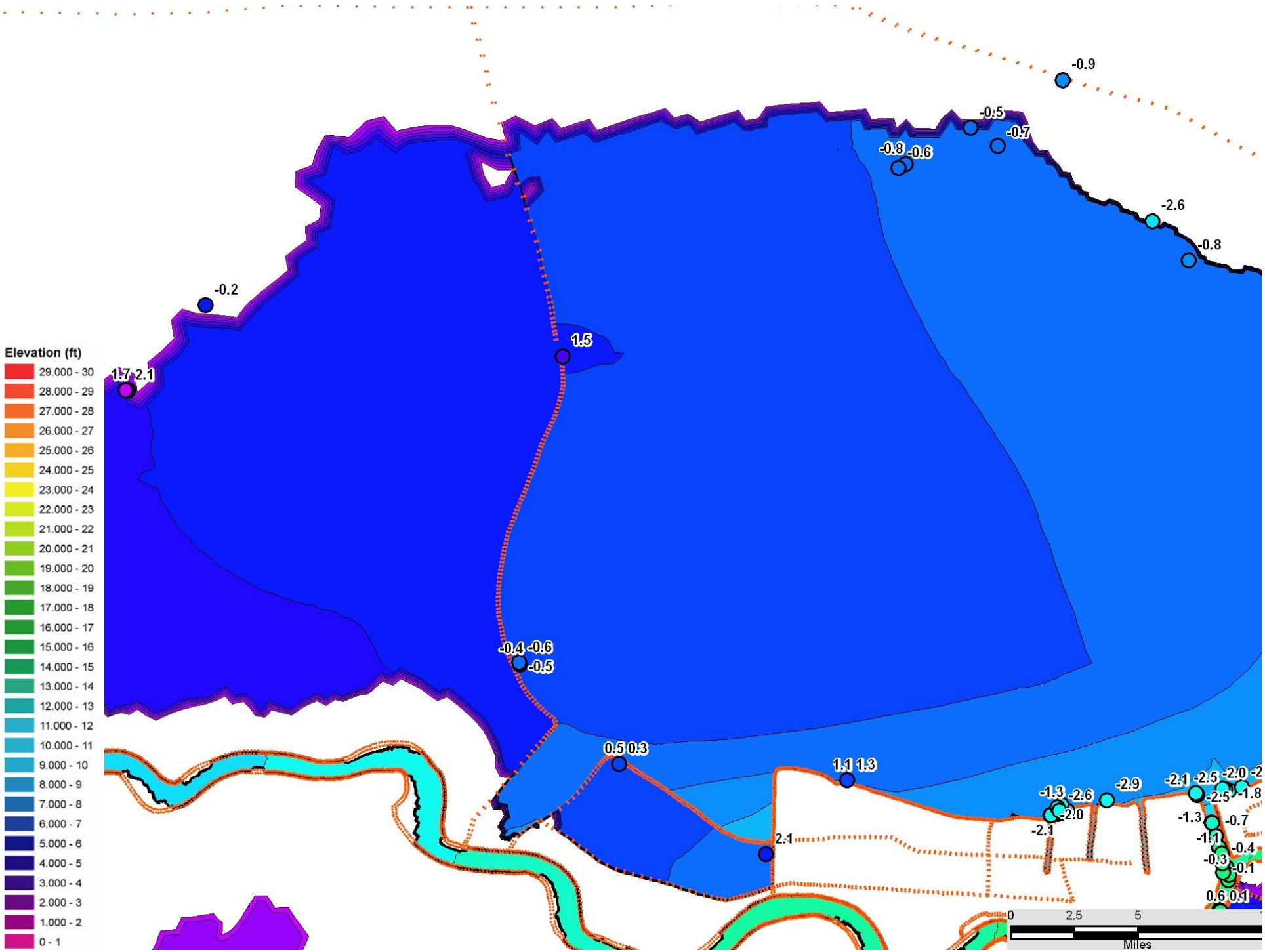

Elevation (ft)
29.000 - 30
28.000 - 29
27.000 - 28
26.000 - 27
25.000 - 26
24.000 - 25
23.000 - 24
22.000 - 23
21.000 - 22
20.000 - 21
19.000 - 20
18.000 - 19
17.000 - 18
16.000 - 17
15.000 - 16
14.000 - 15
13.000 - 14
12.000 - 13
11.000 - 12
10.000 - 11
9.000 - 10
8.000 - 9
7.000 - 8
6.000 - 7
5.000 - 6
4.000 - 5
3.000 - 4
2.000 - 3
1.000 - 2
0 - 1
0 5 10 20
Miles
N
W
E
S


-3.1
3.8 3.6
2.0
-0.6
-0.6
-0.4
0.4
Elevation (ft)
29.000 - 30
28.000 - 29
27.000 - 28
26.000 - 27
25.000 - 26
24.000 - 25
23.000 - 24
22.000 - 23
21.000 - 22
20.000 - 21
19.000 - 20
18.000 - 19
17.000 - 18
16.000 - 17
15.000 - 16
14.000 - 15
13.000 - 14
12.000 - 13
11.000 - 12
10.000 - 11
9.000 - 10
8.000 - 9
7.000 - 8
6.000 - 7
5.000 - 6
4.000 - 5
3.000 - 4
2.000 - 3
1.000 - 2
0 - 1
0
2.5
5
10
Miles
N
W
E
S


-2.8
-2.7
-2.9
-2.5
-2.5
-2.0
-2.1
-2.3
-2.1
-1.3
-0.7
-1.1
-0.4
-0.3
-0.1
-0.5
-1.5
0.6
0.1
1.2
0.6
-0.7
-0.3
2.3
-1.8
-2.3
-1.3
-0.5
-0.6
-3.3
Elevation (ft)
29.000 - 30
28.000 - 29
27.000 - 28
26.000 - 27
25.000 - 26
24.000 - 25
23.000 - 24
22.000 - 23
21.000 - 22
20.000 - 21
19.000 - 20
18.000 - 19
17.000 - 18
16.000 - 17
15.000 - 16
14.000 - 15
13.000 - 14
12.000 - 13
11.000 - 12
10.000 - 11
9.000 - 10
8.000 - 9
7.000 - 8
6.000 - 7
5.000 - 6
4.000 - 5
3.000 - 4
2.000 - 3
1.000 - 2
0 - 1
N
W
E
S
0
2.5
5
Miles

Elevation (ft)
29.000 - 30
28.000 - 29
27.000 - 28
26.000 - 27
25.000 - 26
24.000 - 25
23.000 - 24
22.000 - 23
21.000 - 22
20.000 - 21
19.000 - 20
18.000 - 19
17.000 - 18
16.000 - 17
15.000 - 16
14.000 - 15
13.000 - 14
12.000 - 13
11.000 - 12
10.000 - 11
9.000 - 10
8.000 - 9
7.000 - 8
6.000 - 7
5.000 - 6
4.000 - 5
3.000 - 4
2.000 - 3
1.000 - 2
0 - 1
-2.9
-2.1
-2.5
-2.5
-2.0
-2.3
-2.1
-1.8
-1.4
-1.3
-0.4
-0.7
-1.5
-1.4
-1.5
-1.1
-0.4
-0.5
-0.1
-1.5
-0.3
-1.2
-1.2
0.6
0.1
0.6
1.2
-0.7
-0.3
0 0.25 0.5
Miles


-2.9
-2.5
-1.3
-2.1
-2.6
-1.9
-1.6
-1.5
-1.8
-1.0
-1.3
-2.0
-0.9
-1.2
Elevation (ft)
29.000 - 30
28.000 - 29
27.000 - 28
26.000 - 27
25.000 - 26
24.000 - 25
23.000 - 24
22.000 - 23
21.000 - 22
20.000 - 21
19.000 - 20
18.000 - 19
17.000 - 18
16.000 - 17
15.000 - 16
14.000 - 15
13.000 - 14
12.000 - 13
11.000 - 12
10.000 - 11
9.000 - 10
8.000 - 9
7.000 - 8
6.000 - 7
5.000 - 6
4.000 - 5
3.000 - 4
2.000 - 3
1.000 - 2
0 - 1
N
W
E
S
0
0.25
0.5
1
Miles


Elevation (ft)
29.000 - 30
28.000 - 29
27.000 - 28
26.000 - 27
25.000 - 26
24.000 - 25
23.000 - 24
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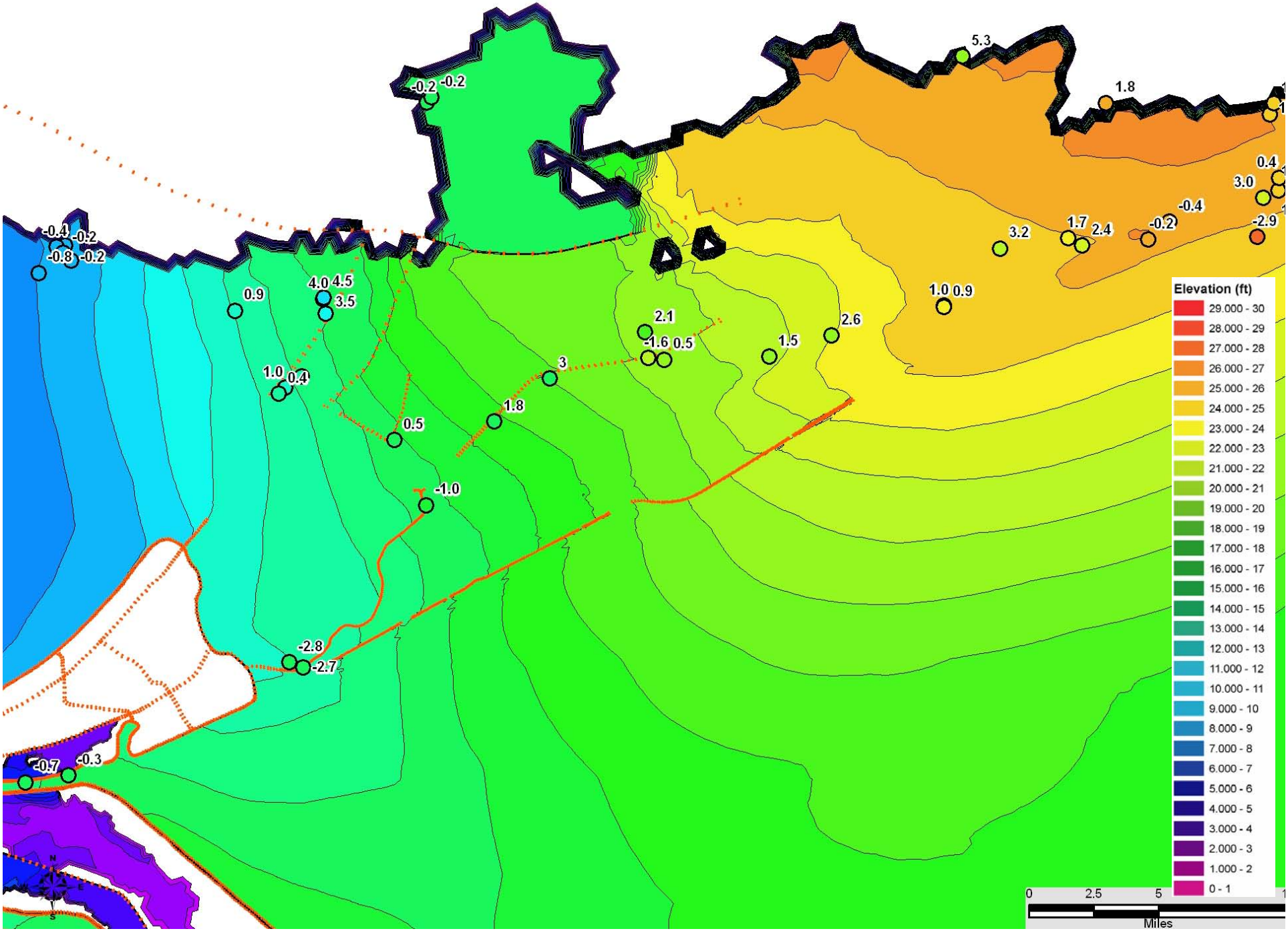
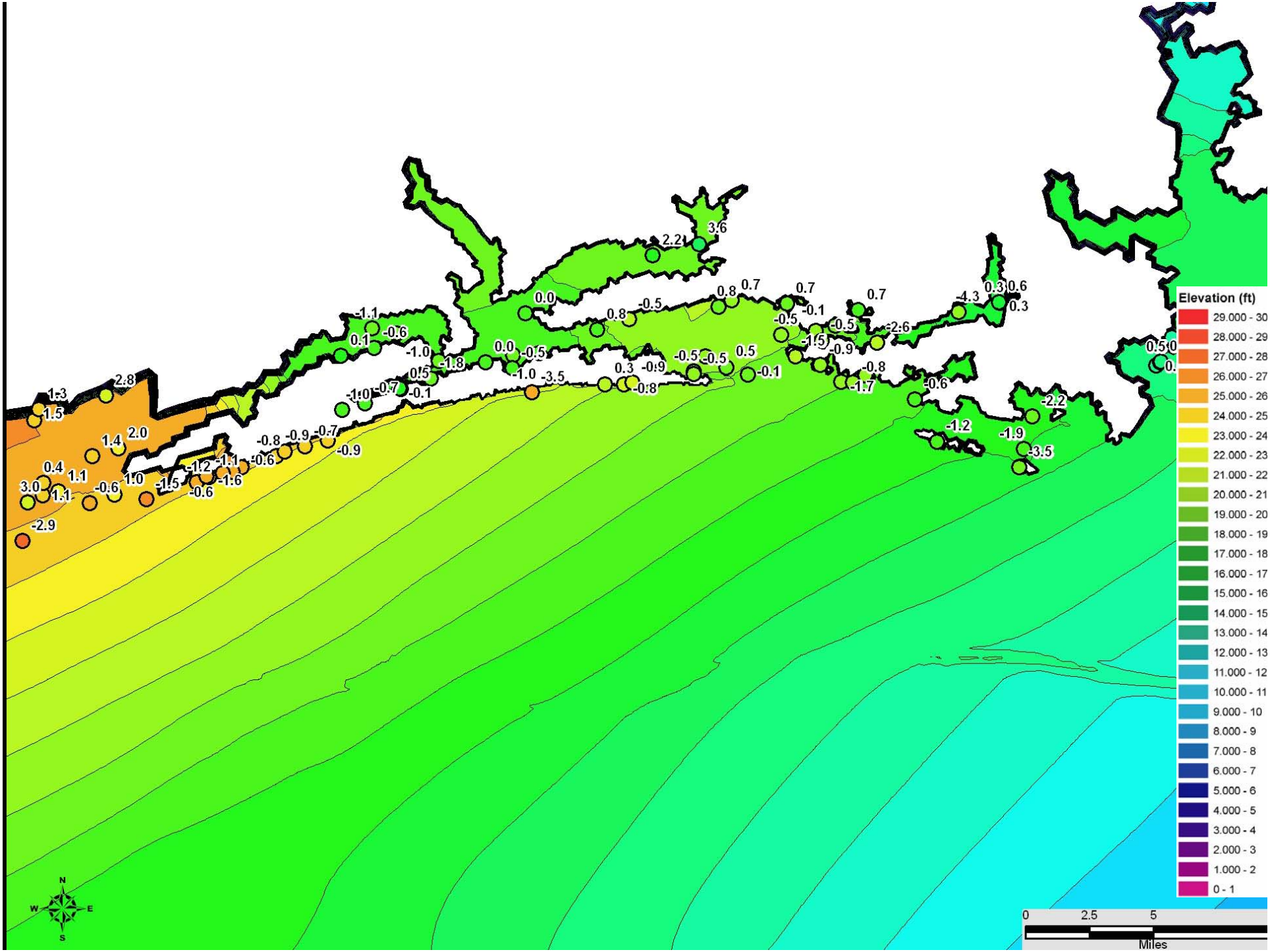
21.000 - 22
20.000 - 21
19.000 - 20
18.000 - 19
17.000 - 18
16.000 - 17
15.000 - 16
14.000 - 15
13.000 - 14
12.000 - 13
11.000 - 12
10.000 - 11
9.000 - 10
8.000 - 9
7.000 - 8
6.000 - 7
5.000 - 6
4.000 - 5
3.000 - 4
2.000 - 3
1.000 - 2
0 - 1
-0.9
-0.5
-0.7
-0.8
-0.6
-2.6
-0.8
-0.2
1.5
1.7
2.1
-0.4
-0.6
-0.5
0.5
0.3
1.1
1.3
-1.3
-2.6
-2.9
-2.1
-2.5
-2.0
-2.5
-1.8
-2.0
-2.1
2.1
-1.3
-0.7
-1.1
-0.4
-0.3
-0.1
0.6
0.1
0
2.5
5
Miles


5.3
1.8
-0.2
-0.2
0.4
3.0
-0.4
-0.2
-2.9
1.7
2.4
3.2
-0.4
-0.2
-0.8
-0.2
0.9
4.0
4.5
3.5
1.0
0.9
2.1
-1.6
0.5
2.6
1.5
1.0
0.4
3
1.8
0.5
-1.0
-2.8
-2.7
-0.7
-0.3
Elevation (ft)
29.000 - 30
28.000 - 29
27.000 - 28
26.000 - 27
25.000 - 26
24.000 - 25
23.000 - 24
22.000 - 23
21.000 - 22
20.000 - 21
19.000 - 20
18.000 - 19
17.000 - 18
16.000 - 17
15.000 - 16
14.000 - 15
13.000 - 14
12.000 - 13
11.000 - 12
10.000 - 11
9.000 - 10
8.000 - 9
7.000 - 8
6.000 - 7
5.000 - 6
4.000 - 5
3.000 - 4
2.000 - 3
1.000 - 2
0 - 1
0
2.5
5
Miles


Elevation (ft)
29.000 - 30
28.000 - 29
27.000 - 28
26.000 - 27
25.000 - 26
24.000 - 25
23.000 - 24
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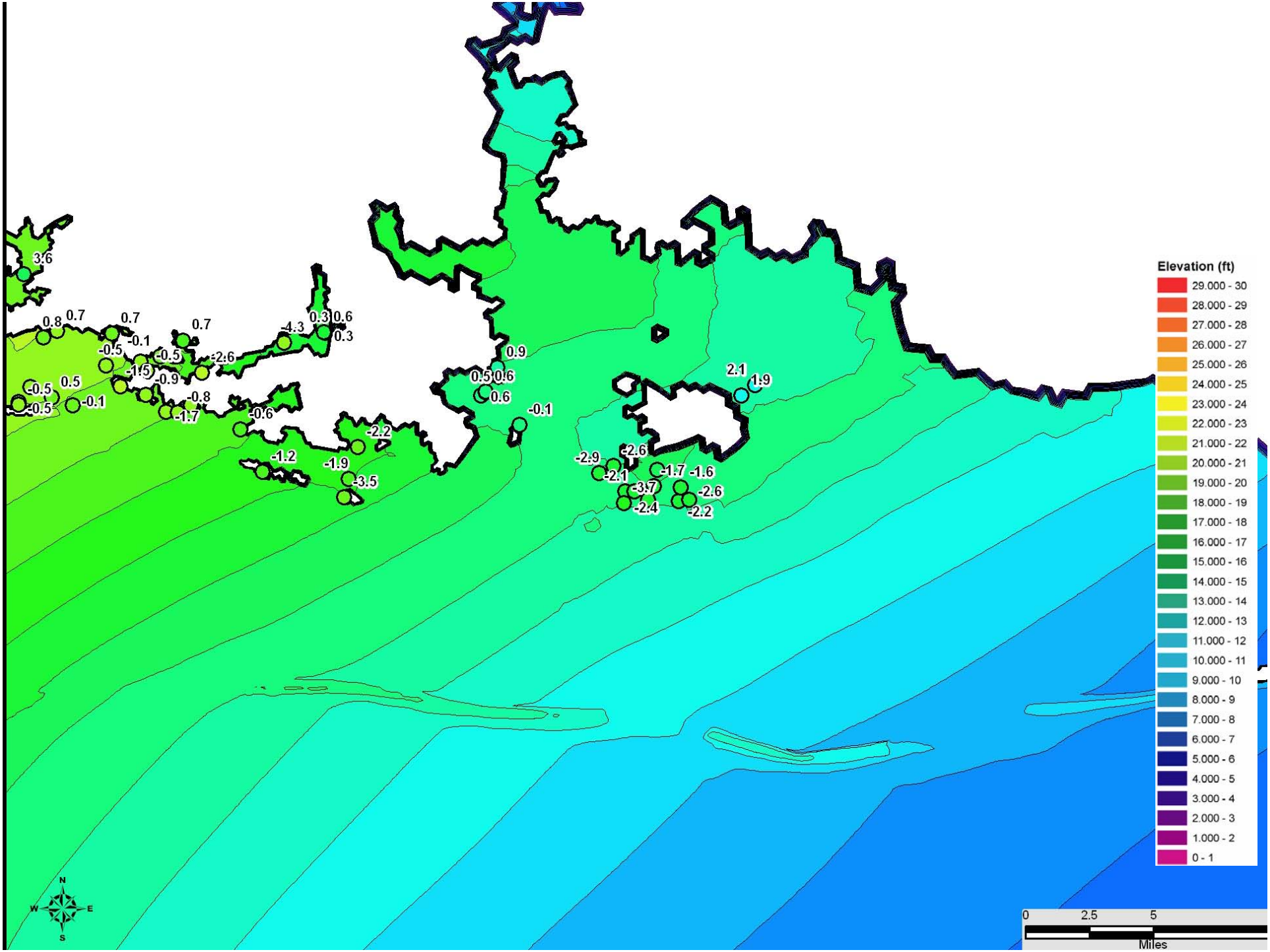
21.000 - 22
20.000 - 21
19.000 - 20
18.000 - 19
17.000 - 18
16.000 - 17
15.000 - 16
14.000 - 15
13.000 - 14
12.000 - 13
11.000 - 12
10.000 - 11
9.000 - 10
8.000 - 9
7.000 - 8
6.000 - 7
5.000 - 6
4.000 - 5
3.000 - 4
2.000 - 3
1.000 - 2
0 - 1
N
W
E
S
0
2.5
5
Miles


Elevation (ft)
29.000 - 30
28.000 - 29
27.000 - 28
26.000 - 27
25.000 - 26
24.000 - 25
23.000 - 24
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21.000 - 22
20.000 - 21
19.000 - 20
18.000 - 19
17.000 - 18
16.000 - 17
15.000 - 16
14.000 - 15
13.000 - 14
12.000 - 13
11.000 - 12
10.000 - 11
9.000 - 10
8.000 - 9
7.000 - 8
6.000 - 7
5.000 - 6
4.000 - 5
3.000 - 4
2.000 - 3
1.000 - 2
0 - 1
3.6
0.8
0.7
0.7
-0.1
0.7
-0.5
-0.5
-1.5
-0.9
-2.6
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-1.9
-3.5
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0.6
0.6
-0.1
2.1
1.9
-2.9
-2.6
-2.1
-1.7
-1.6
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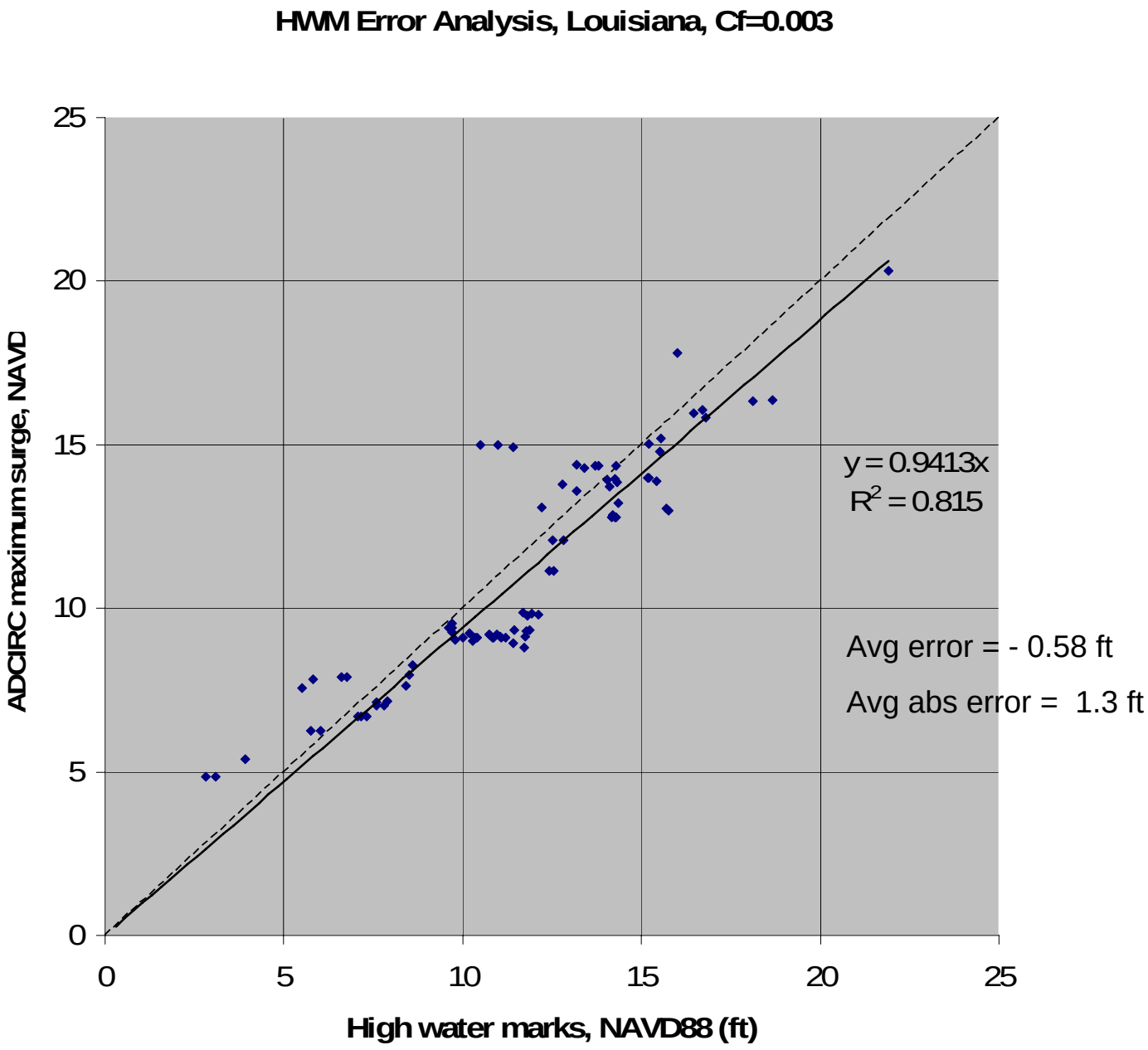
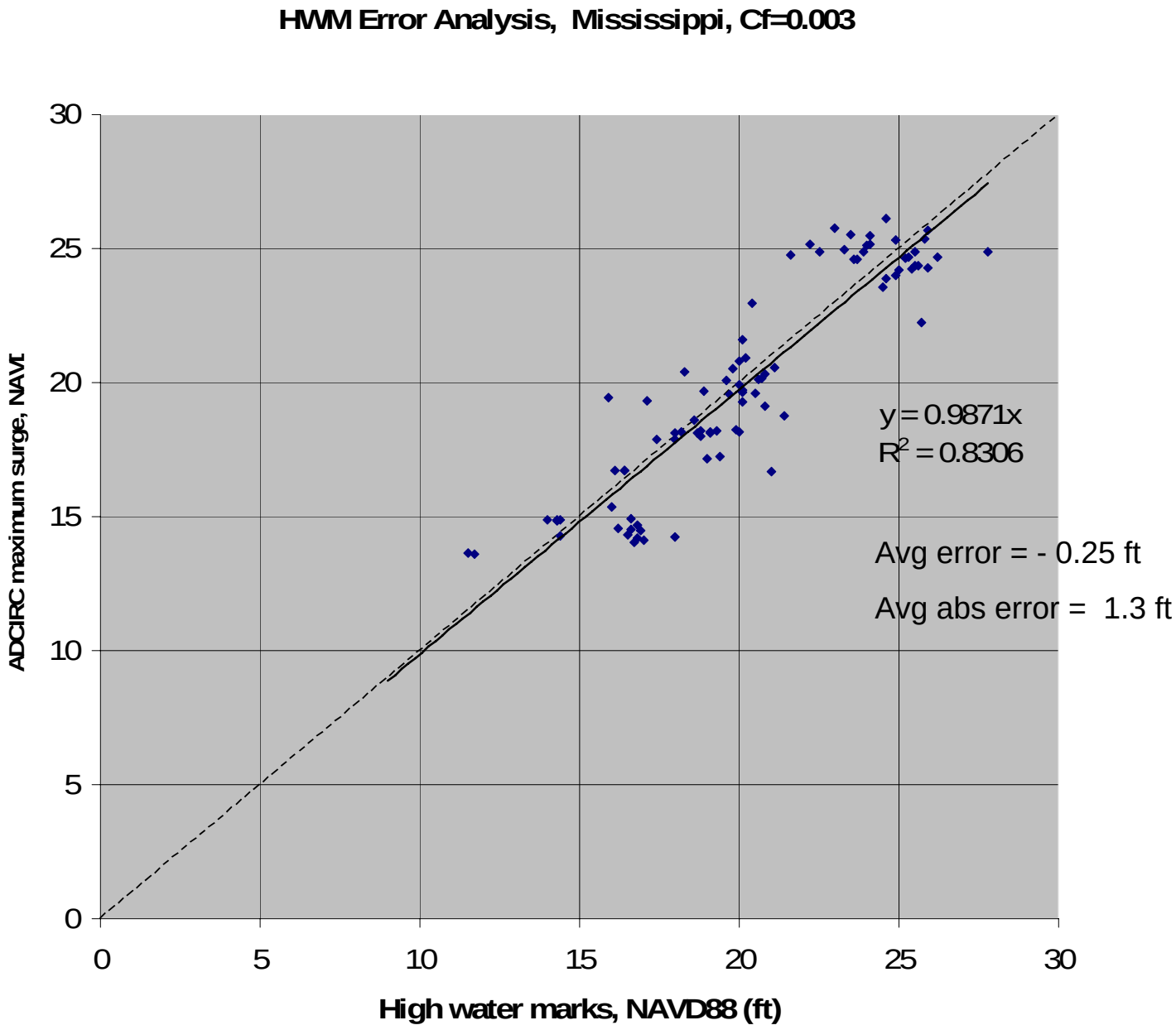
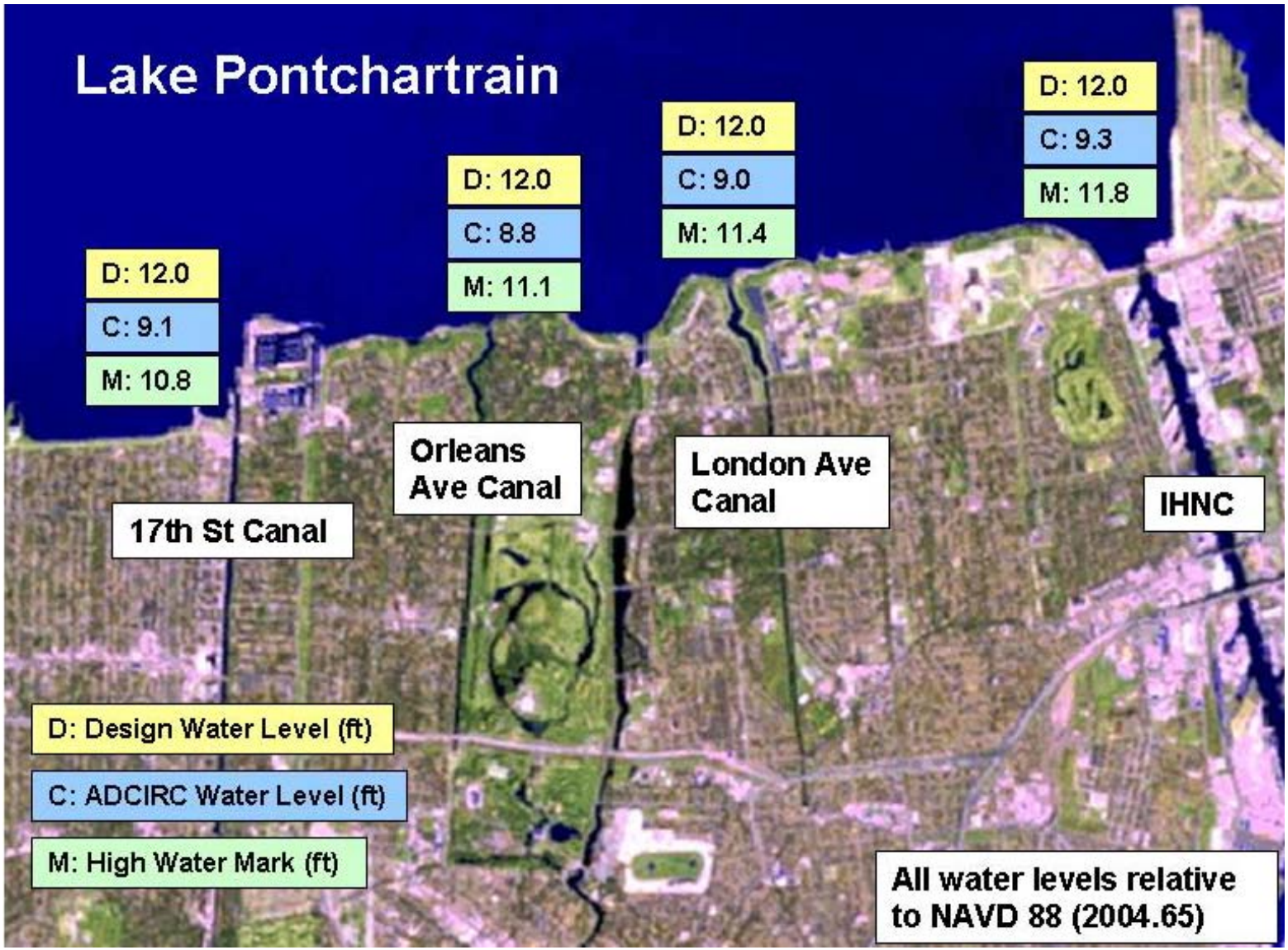
-2.6
-2.4
-2.2
N
W
E
S
0
2.5
5
Miles

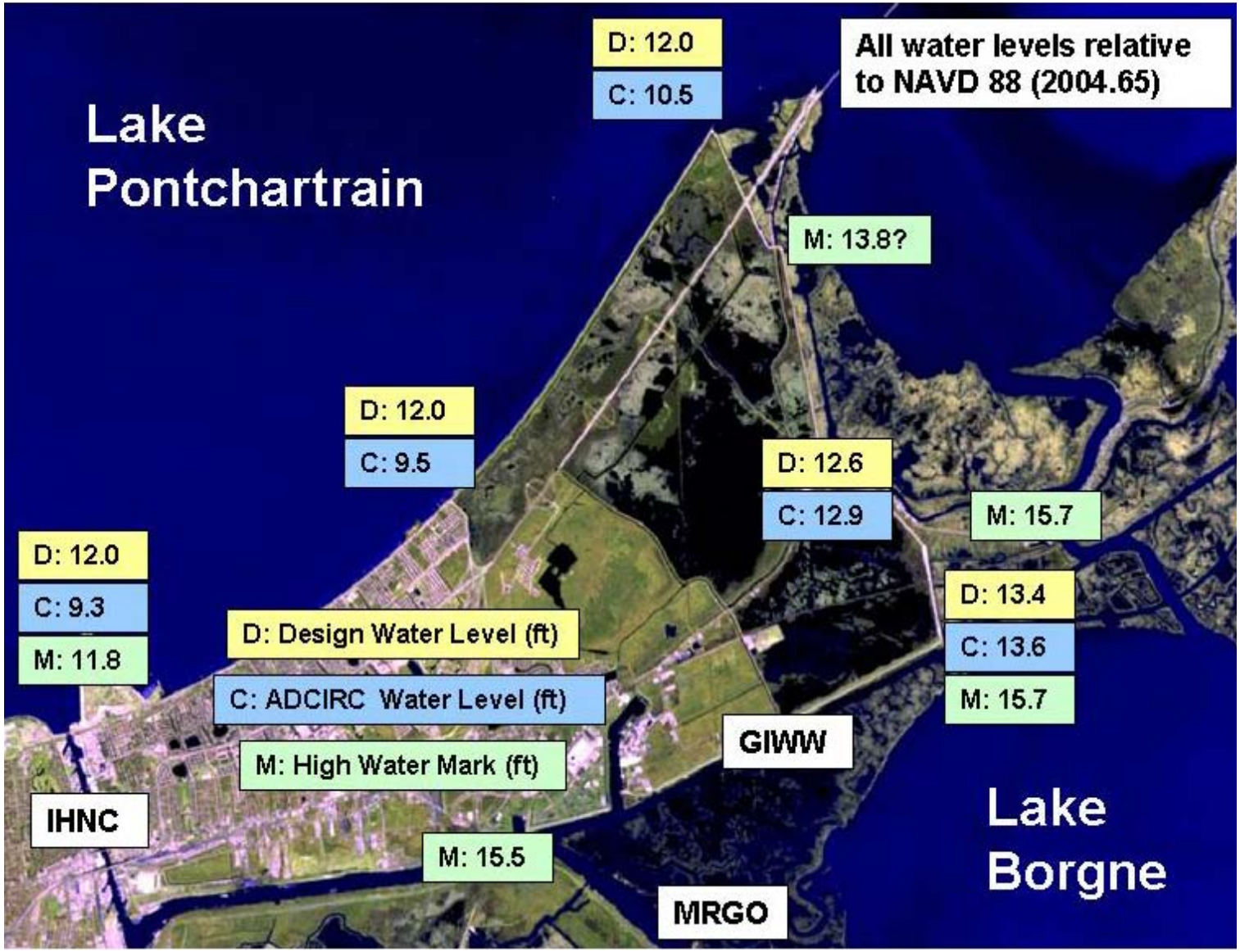

HWM Error Analysis, Louisiana, Cf=0.003
ADCIRC maximum surge, NAVD
High water marks, NAVD88 (ft)
0
5
10
15
20
25
y = 0.9413x
R2 = 0.815
Avg error = - 0.58 ft
Avg abs error = 1.3 ft


HWM Error Analysis, Mississippi, Cf=0.003
ADCIRC maximum surge, NAVD
High water marks, NAVD88 (ft)
0
5
10
15
20
25
30
y = 0.9871x
R2 = 0.8306
Avg error = - 0.25 ft
Avg abs error = 1.3 ft

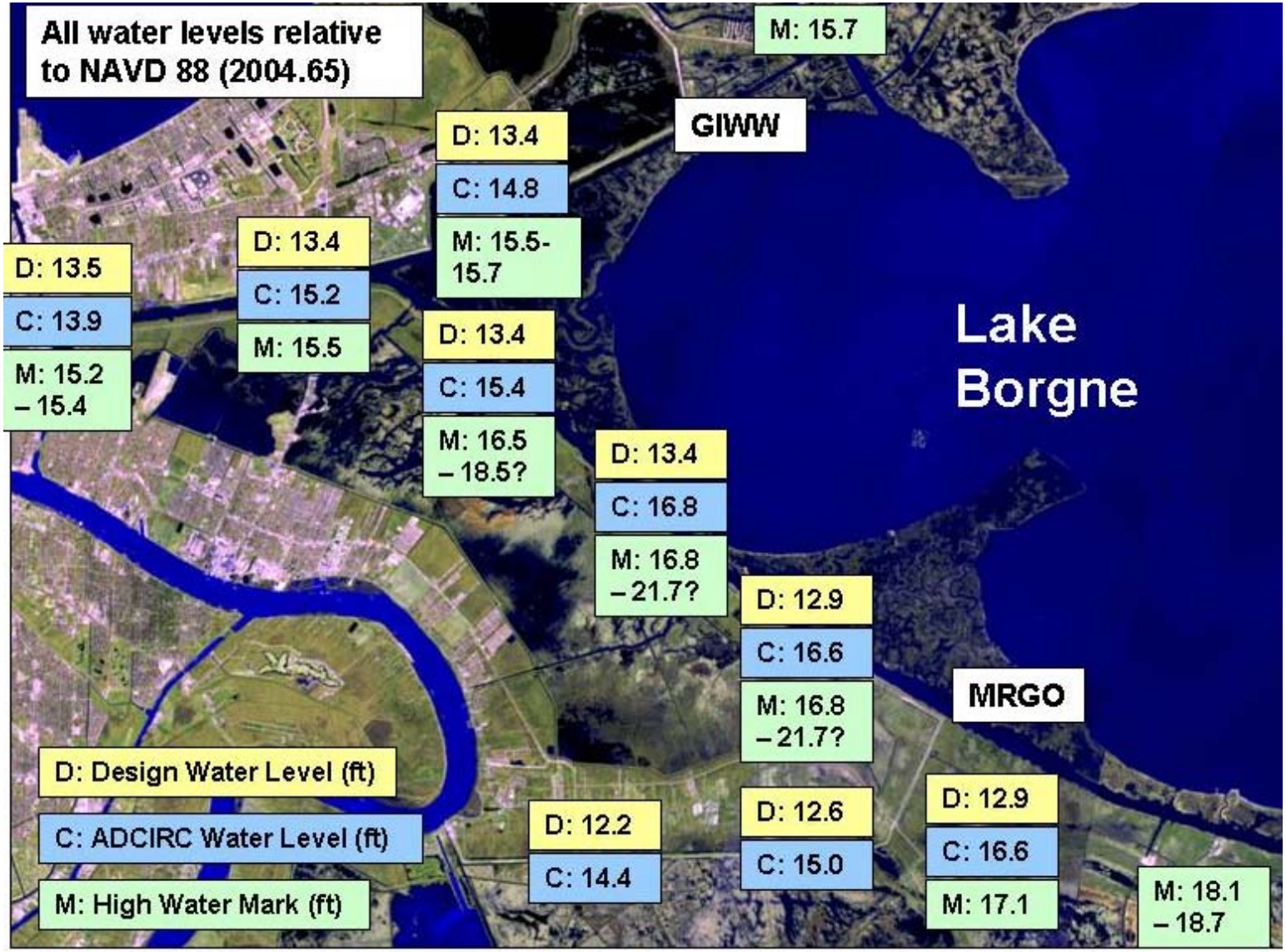
# Peak Water Level Conditions (Comparison: Katrina and Design Values)



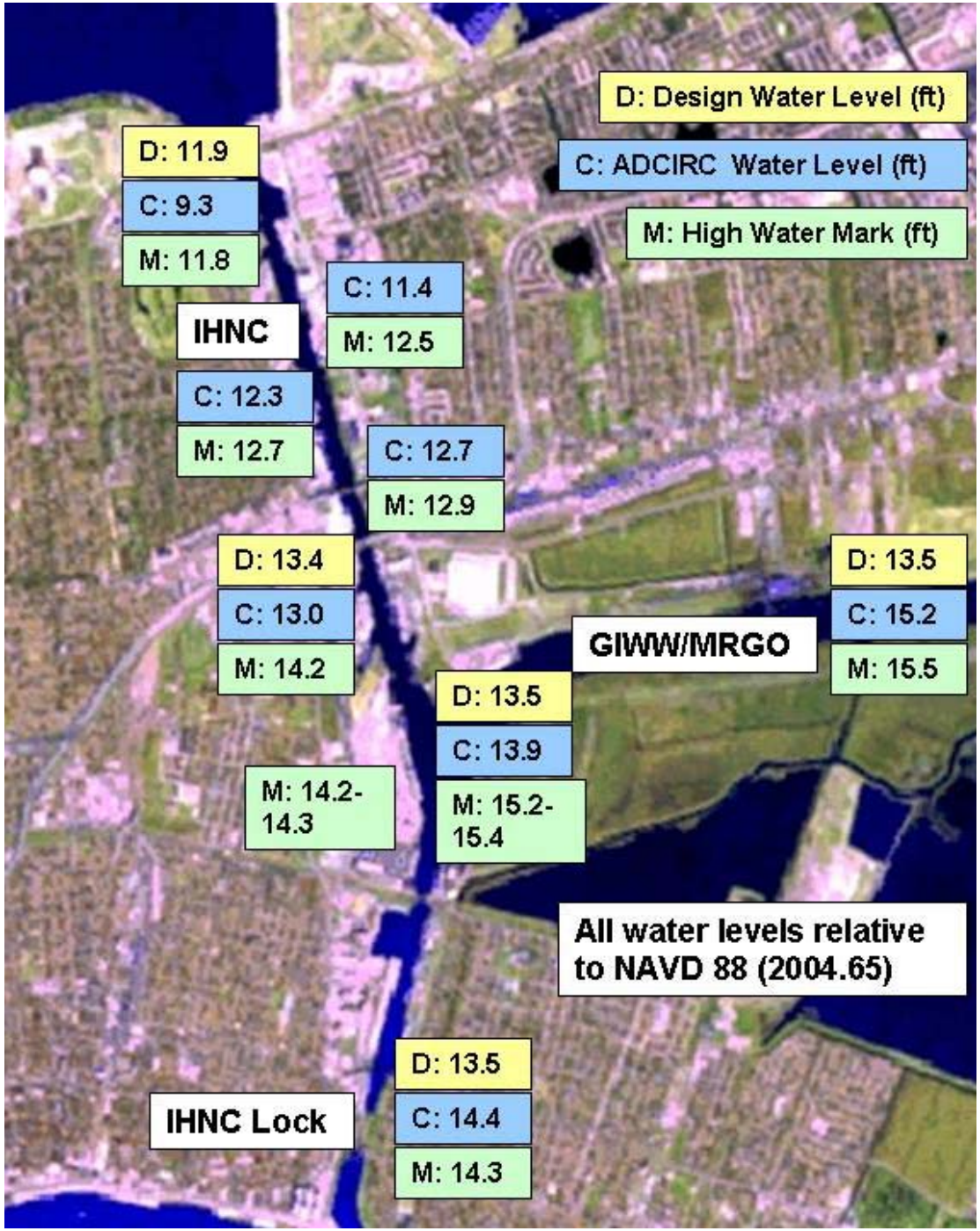
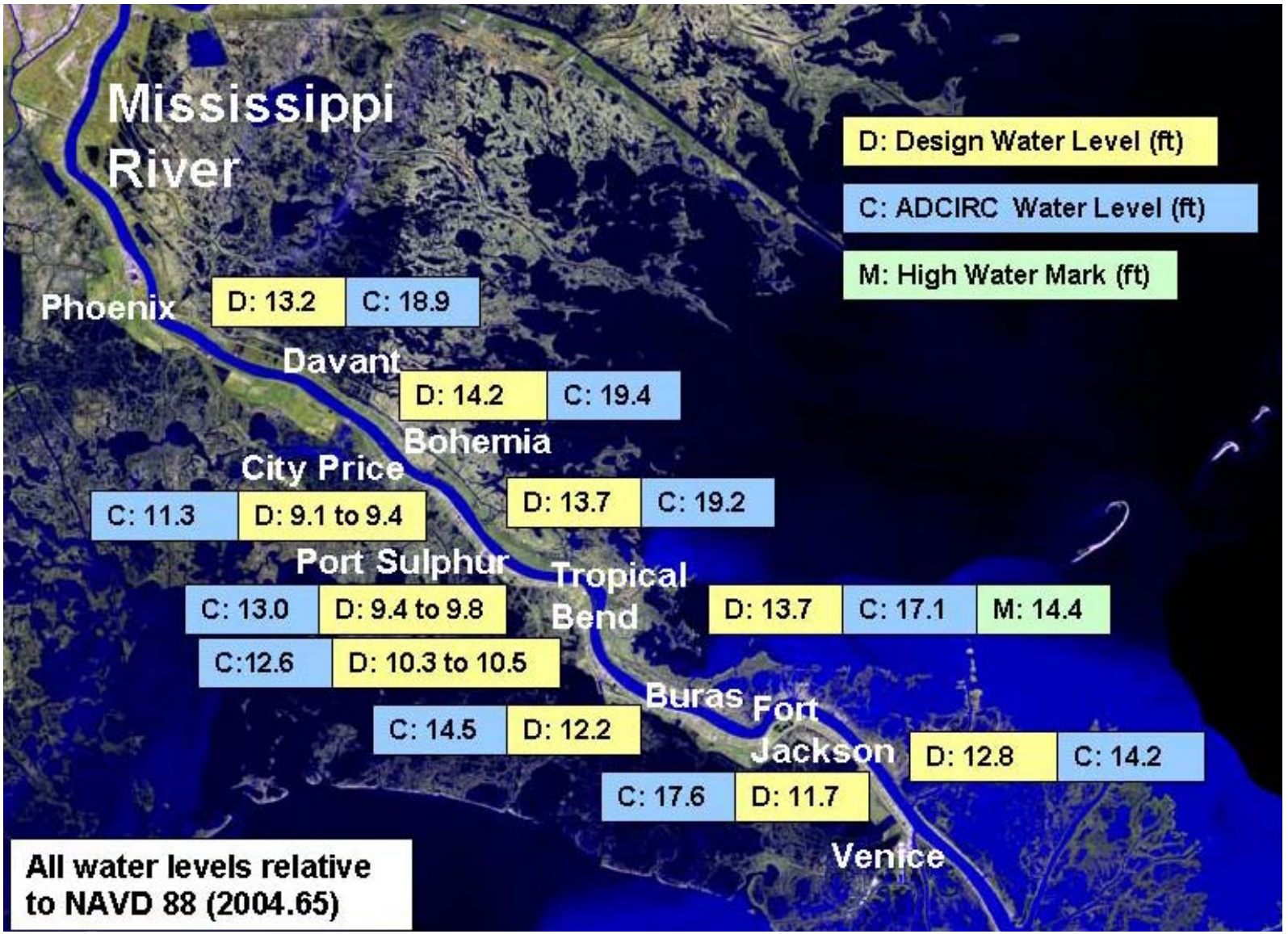
# Peak Water Level Conditions (Comparison: Katrina and Design Values)



# Peak Water Level Conditions (Comparison: Katrina and Design Values)



# Peak Water Level Conditions (Comparison: Katrina and Design Values)



# Peak Water Level Conditions (Comparison: Katrina and Design Values)