Storm Surge Applications using Lidar

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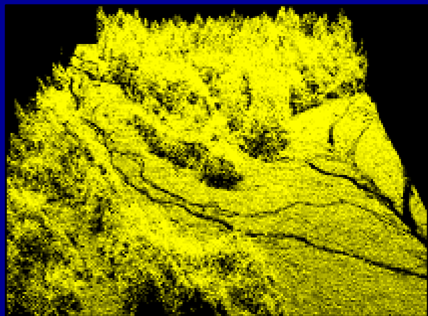
Workshop on Airborne Lidar Technology and Applications
June 20, 2007

Today’s Topics

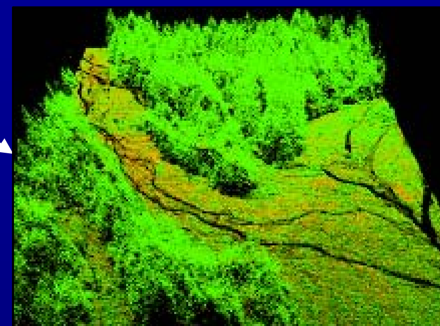
- Hurricane Katrina
  - New Orleans flooding
  - Regional storm surge surface
- Hurricane Rita
  - Temporal characteristics of storm surge
- Seamless topographic/bathymetric data development
- Delineation of lands vulnerable to sea level rise

USGS

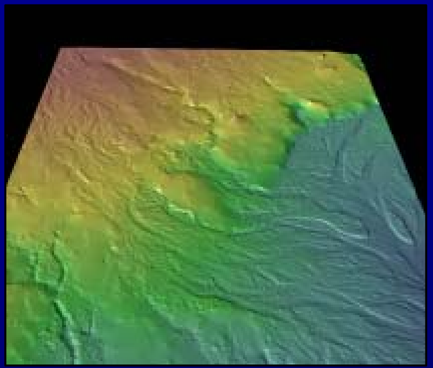
LIDAR Flow



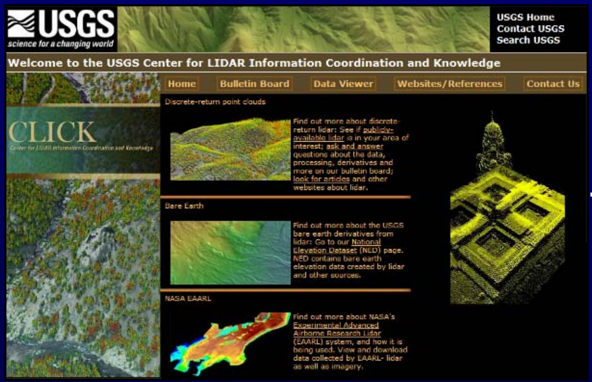
Raw Points



Processing



Bare Earth

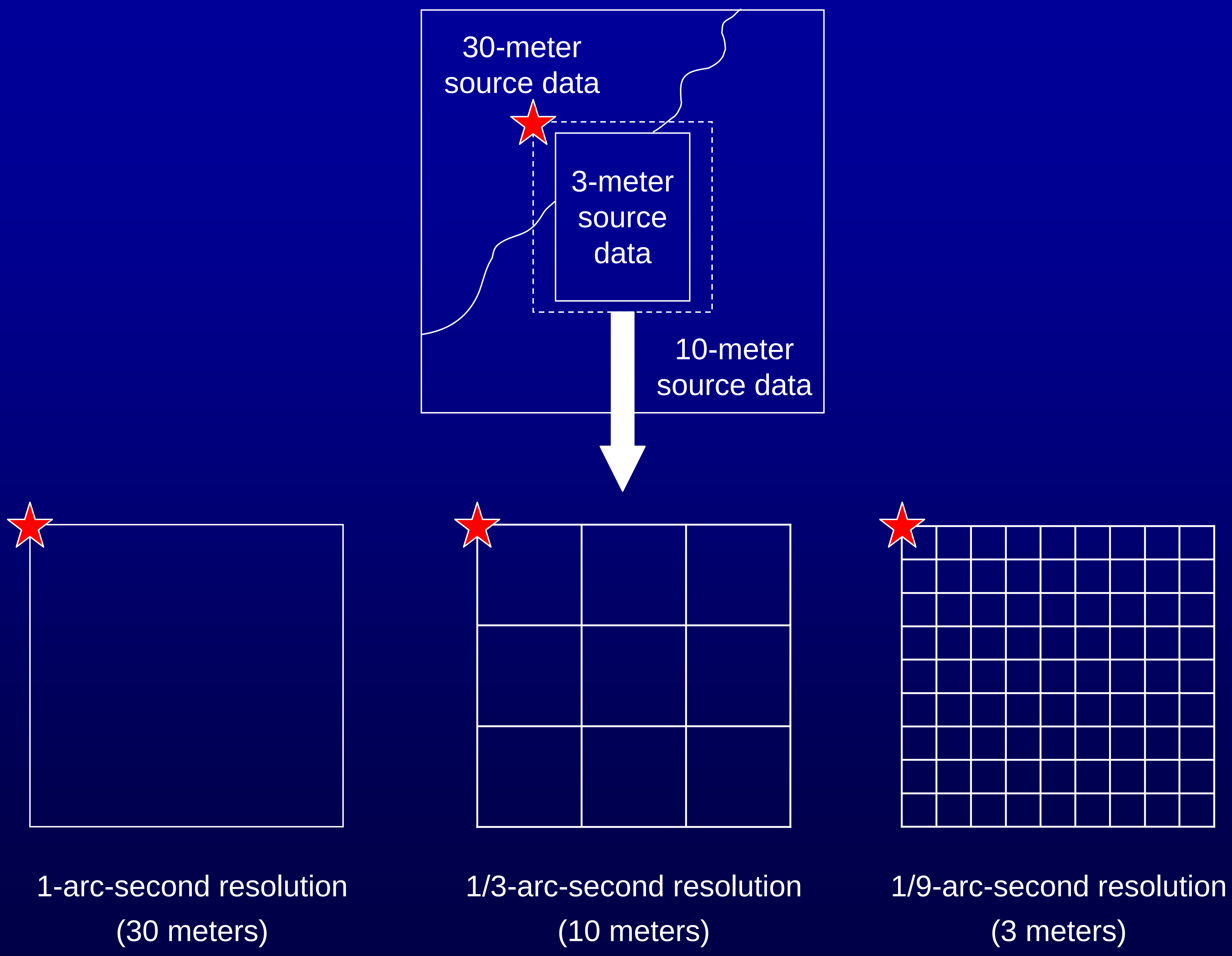


Research and Derivatives

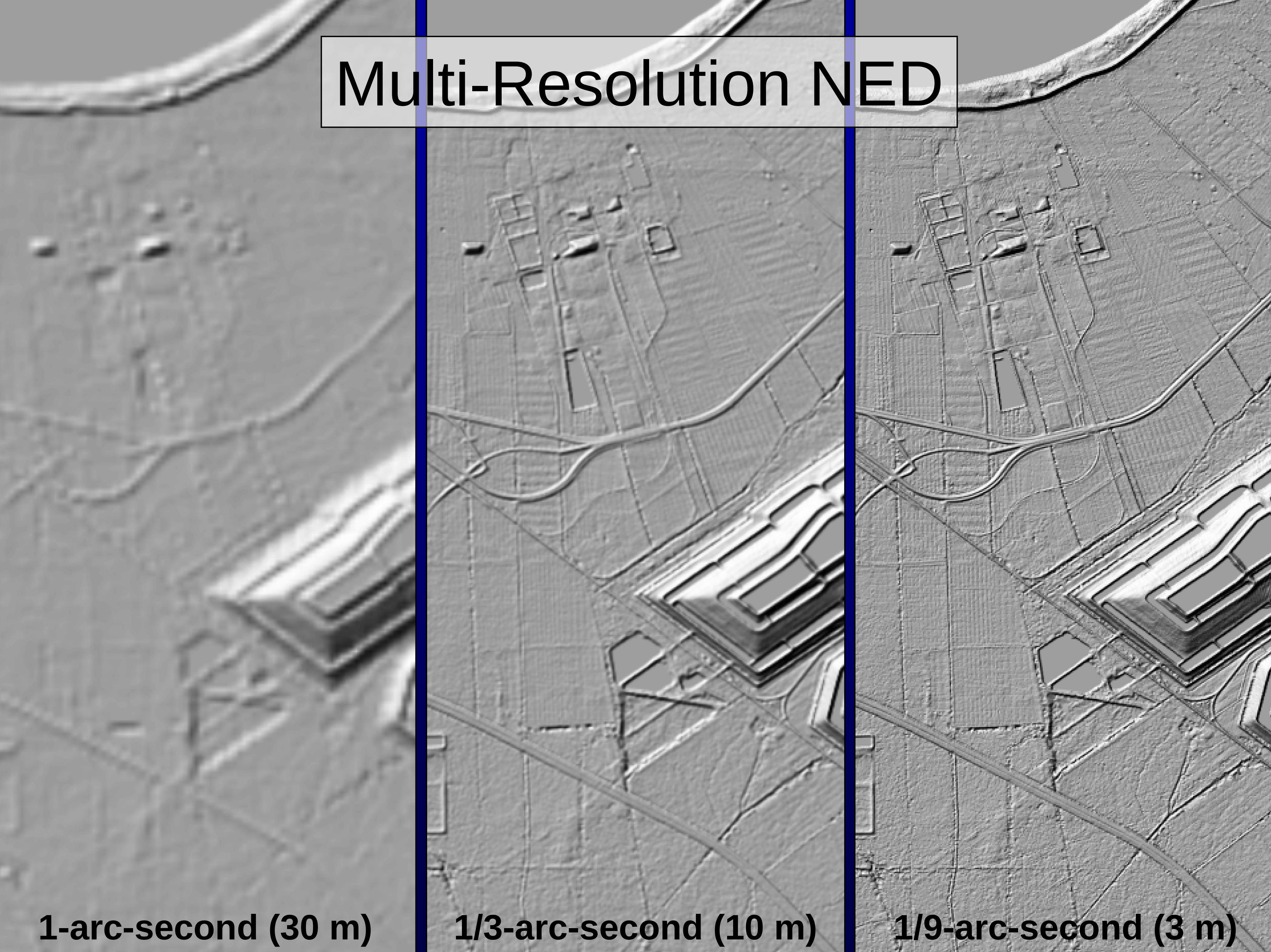
USGS

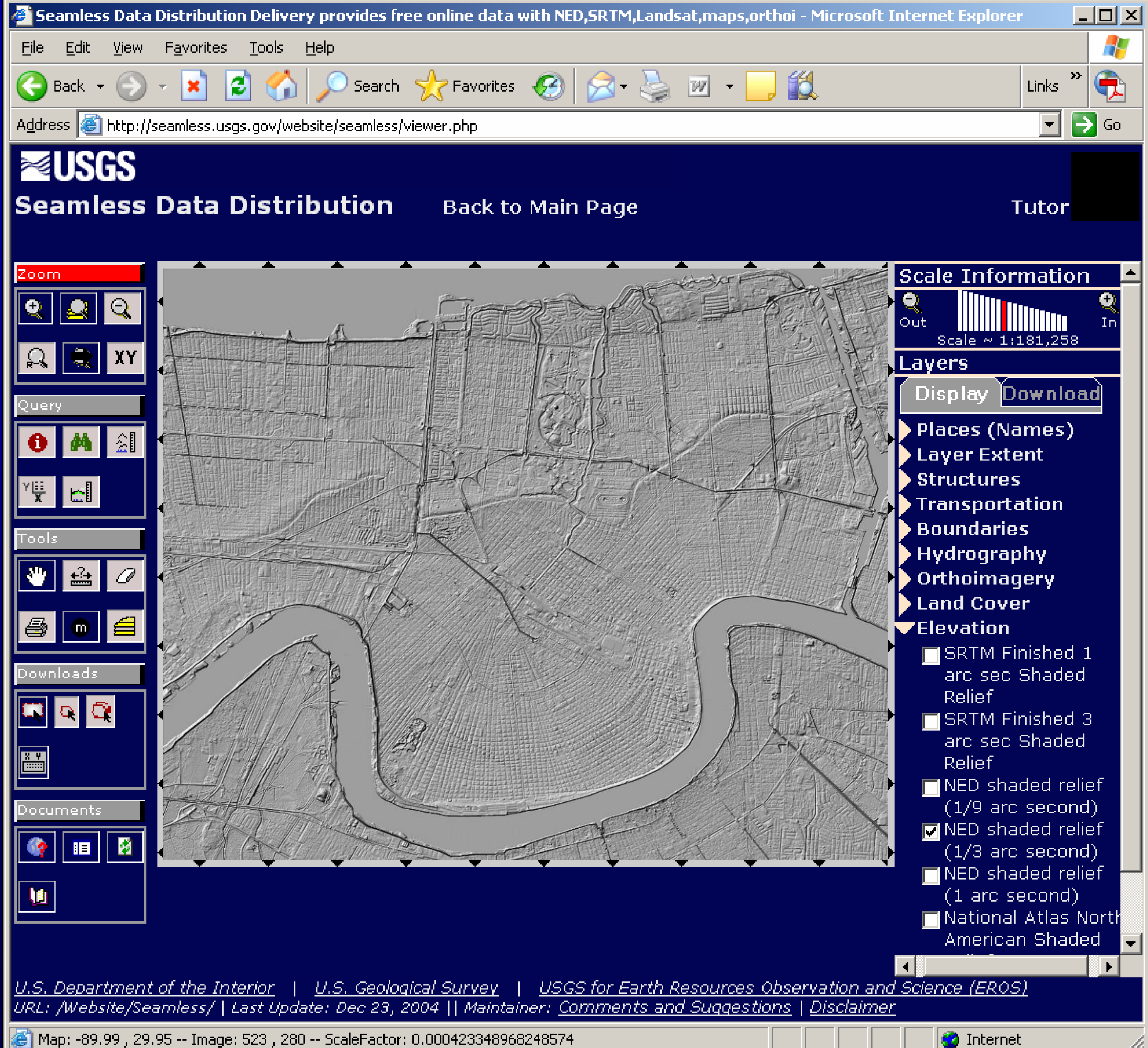
The National Elevation Dataset (NED)

- Seamless national coverage of "best available" raster elevation data
  - Geographic "projection"
  - 1-arc-second (30-meter), 1/3-arc-second (10-meter), and 1/9-arc-second (3-meter) grid spacing
    - Alaska: 2-arc-second grid spacing
  - Datum: NAD 83 horizontal; NAVD 88 vertical
  - Elevation units: decimal meters
  - Updated bi-monthly to incorporate all new USGS DEM production and other newly available source data
- NED is the elevation layer of *The National Map*


30-meter source data
3-meter source data
10-meter source data
1-arc-second resolution (30 meters)
1/3-arc-second resolution (10 meters)
1/9-arc-second resolution (3 meters)

Multi-Resolution NED

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SRTM Finished 1 arc sec Shaded Relief
SRTM Finished 3 arc sec Shaded Relief
NED shaded relief (1/9 arc second)
NED shaded relief (1/3 arc second)
NED shaded relief (1 arc second)
National Atlas North American Shaded
U.S. Department of the Interior | U.S. Geological Survey | USGS for Earth Resources Observation and Science (EROS)
URL: /Website/Seamless/ | Last Update: Dec 23, 2004 || Maintainer: Comments and Suggestions | Disclaimer
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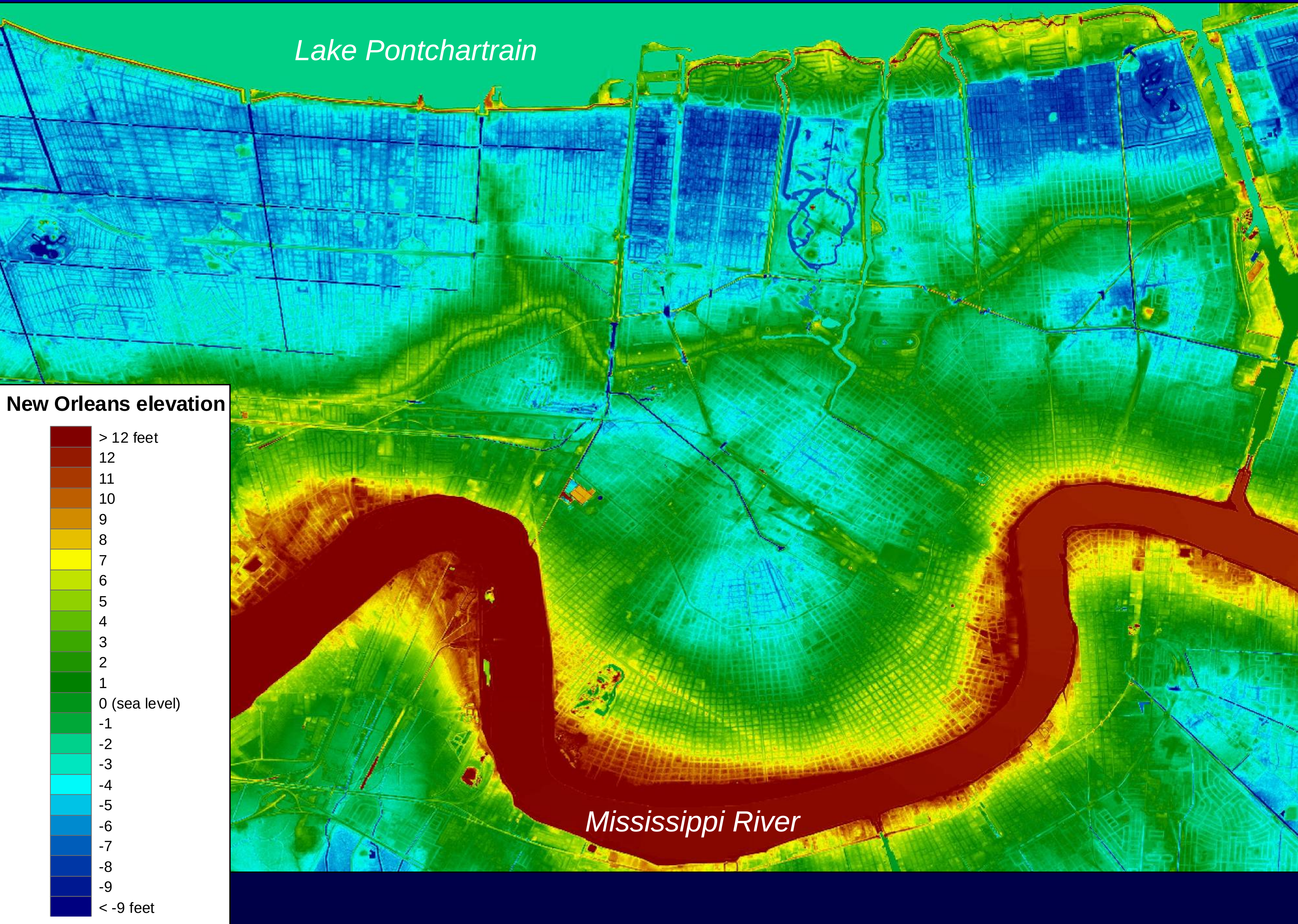
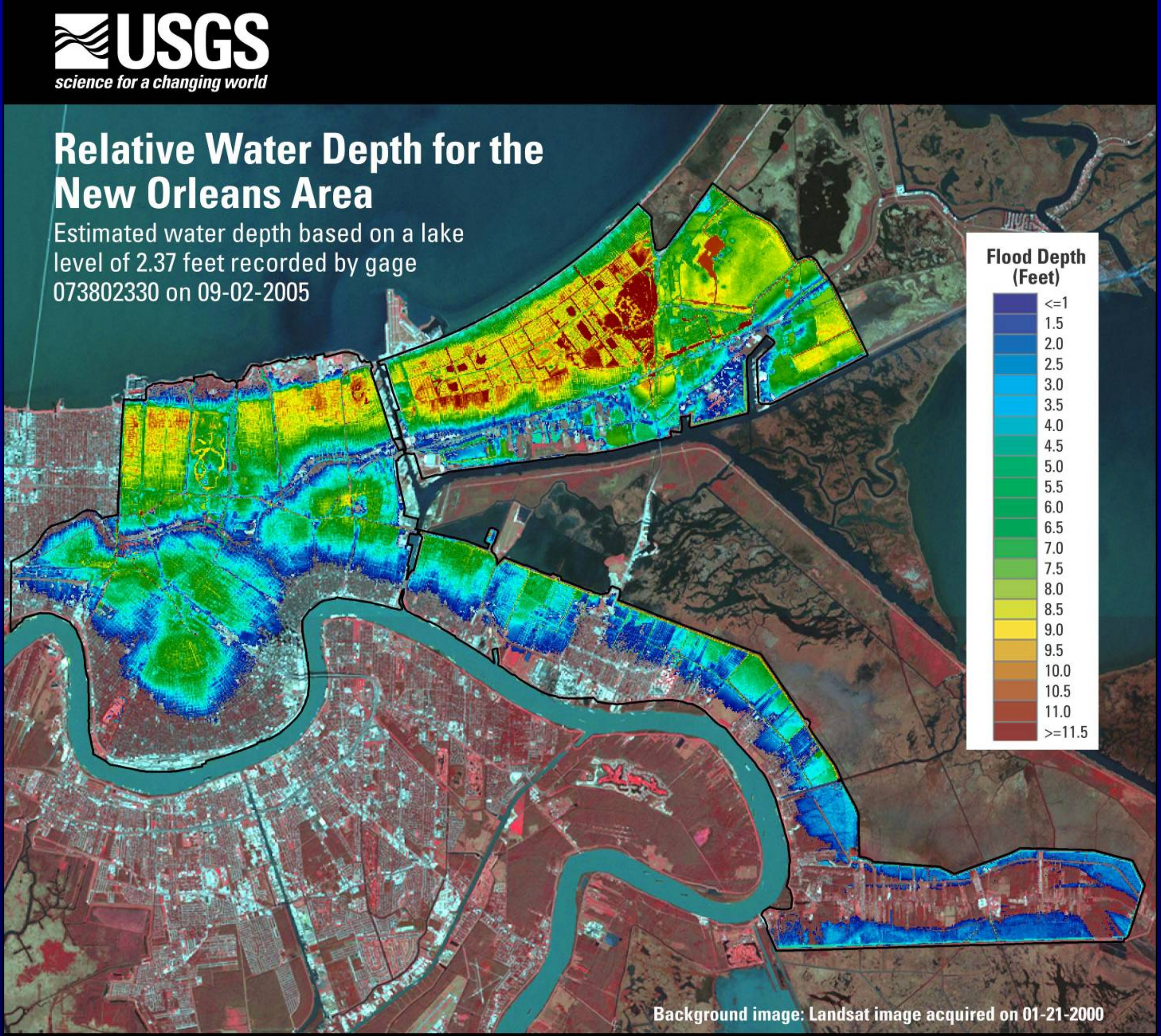
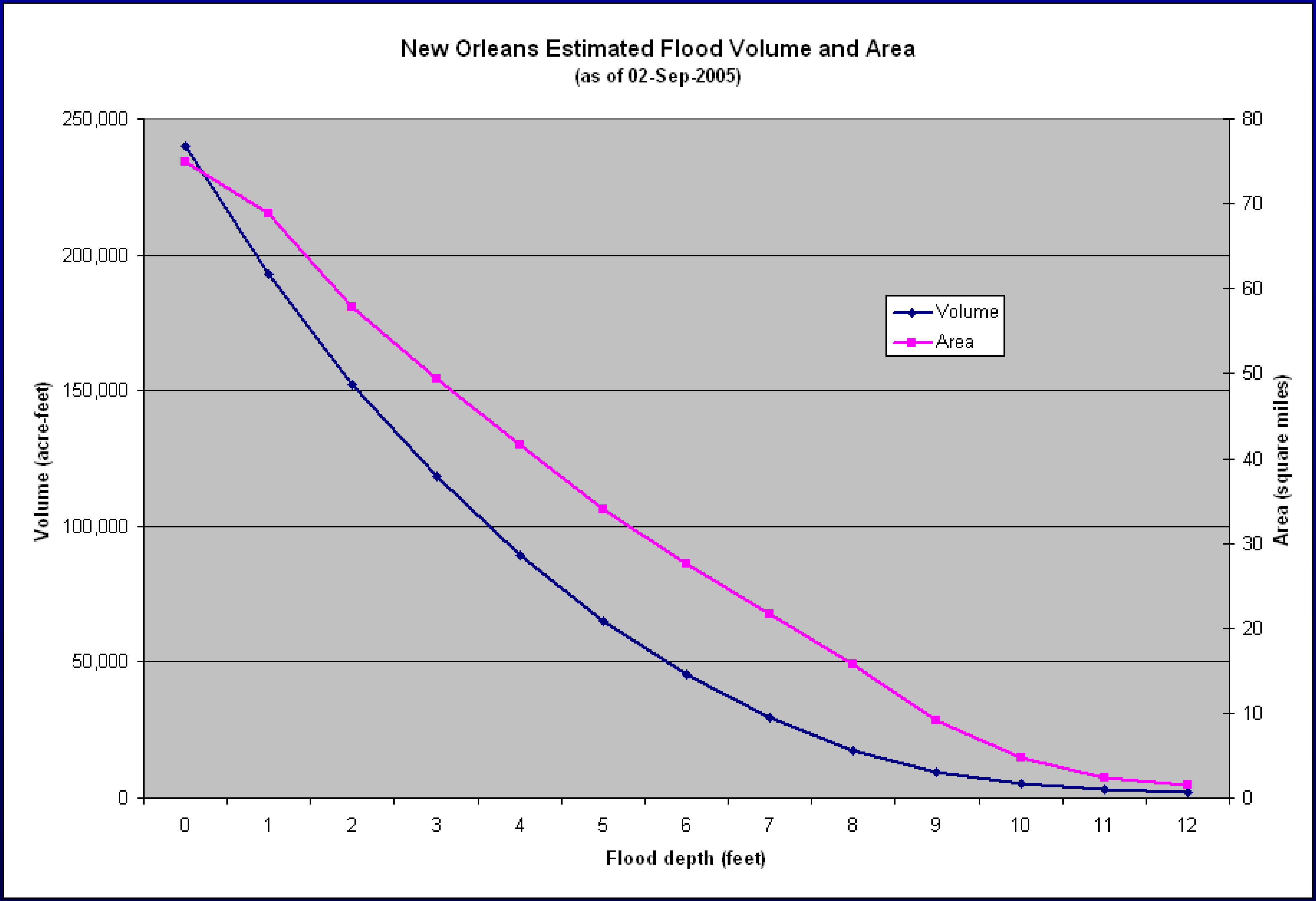
Internet


Lake Pontchartrain
Mississippi River
New Orleans elevation
> 12 feet
12
11
10
9
8
7
6
5
4
3
2
1
0 (sea level)
-1
-2
-3
-4
-5
-6
-7
-8
-9
< -9 feet



Flood depth estimated from 10-m elevation data derived from 5-m lidar data collected in 2002.

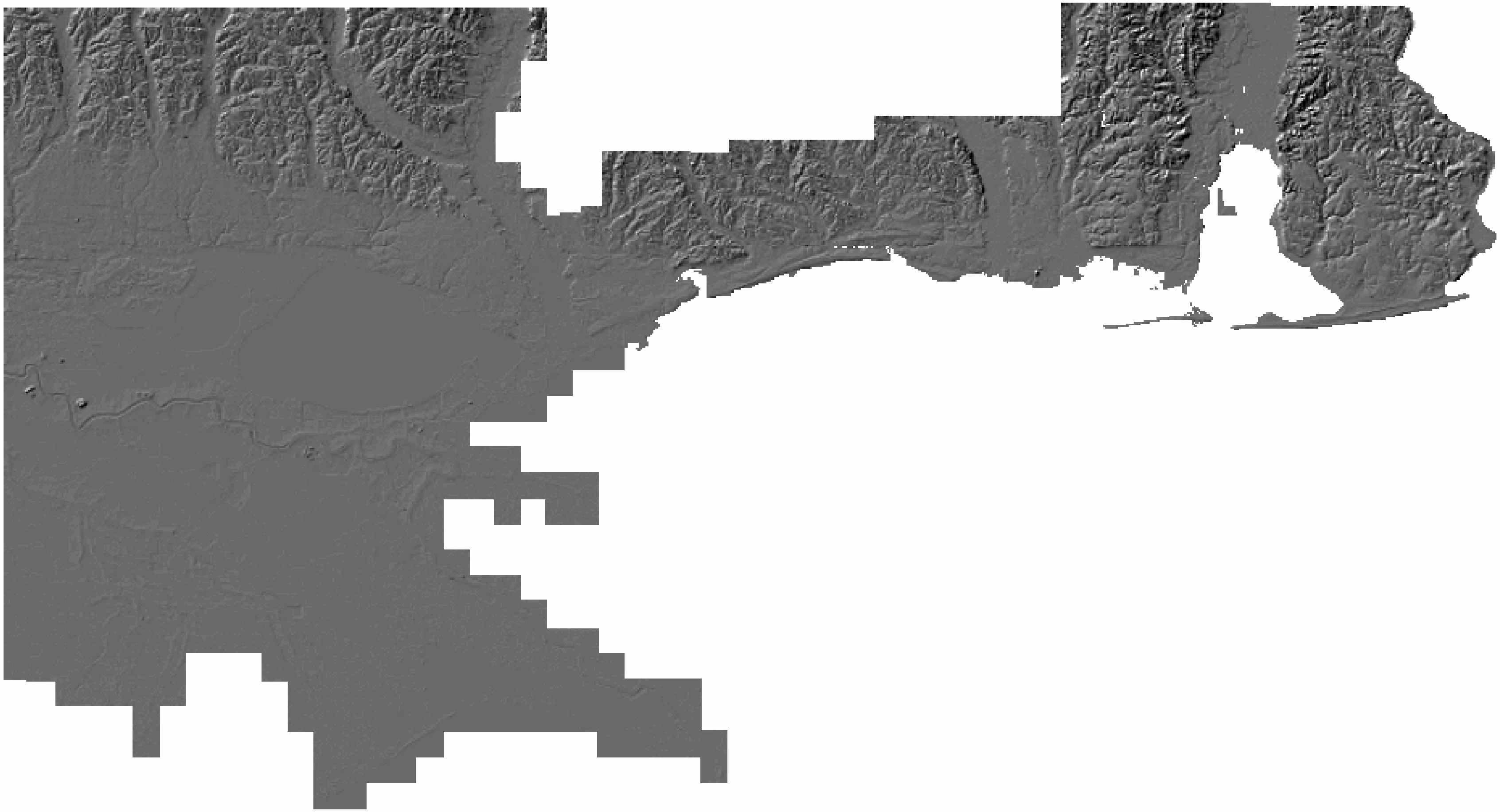
U.S. Department of the Interior
U.S. Geological Survey


New Orleans Estimated Flood Volume and Area
(as of 02-Sep-2005)
Volume (acre-feet)
250,000
200,000
150,000
100,000
50,000
0
Area (square miles)
80
70
60
50
40
30
20
10
0
Volume
Area
0
1
2
3
4
5
6
7
8
9
10
11
12
Flood depth (feet)

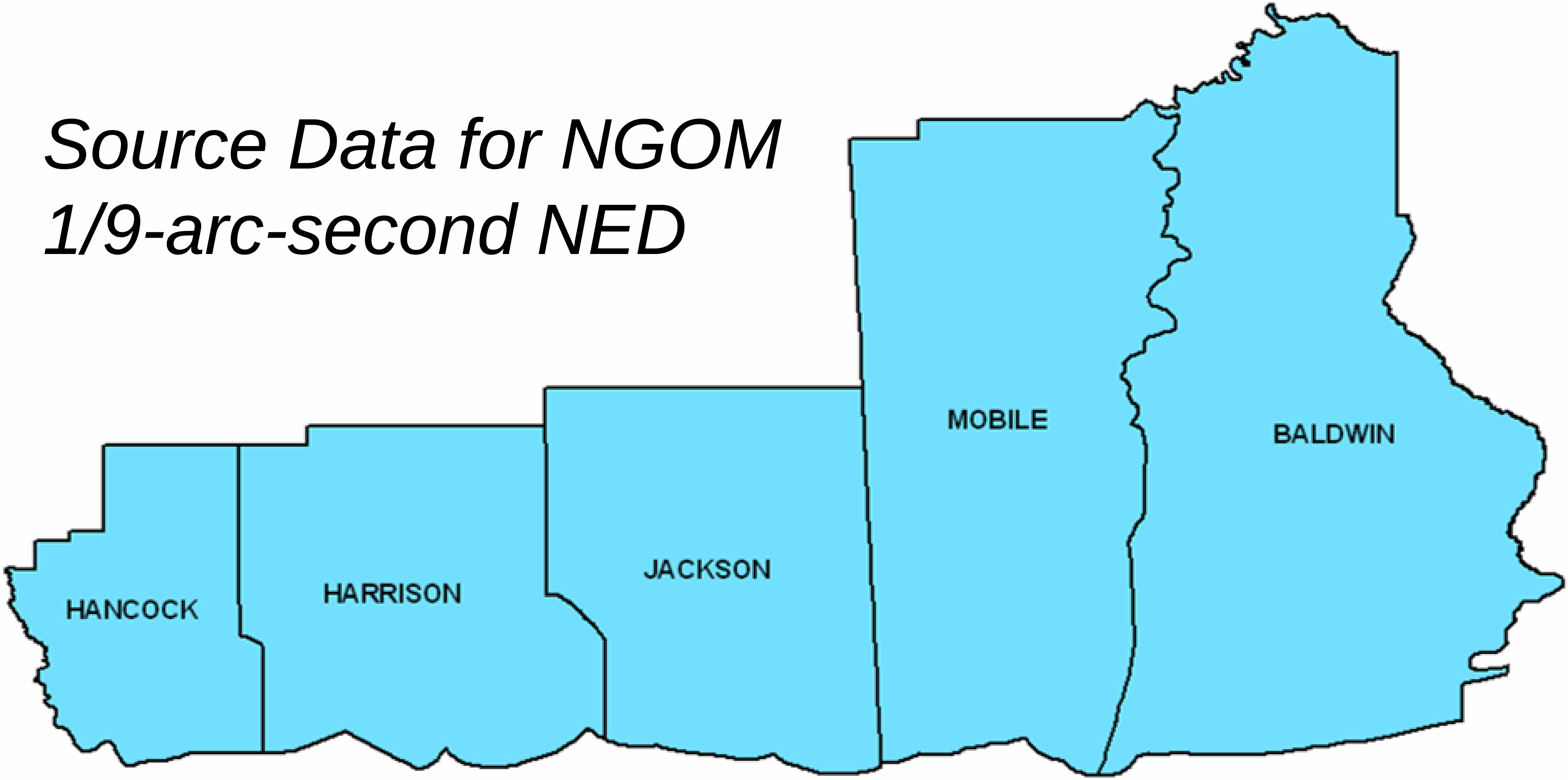
1/9-arc-second (3-meter) NED

USGS

1/9-arc-second (3-meter) NED

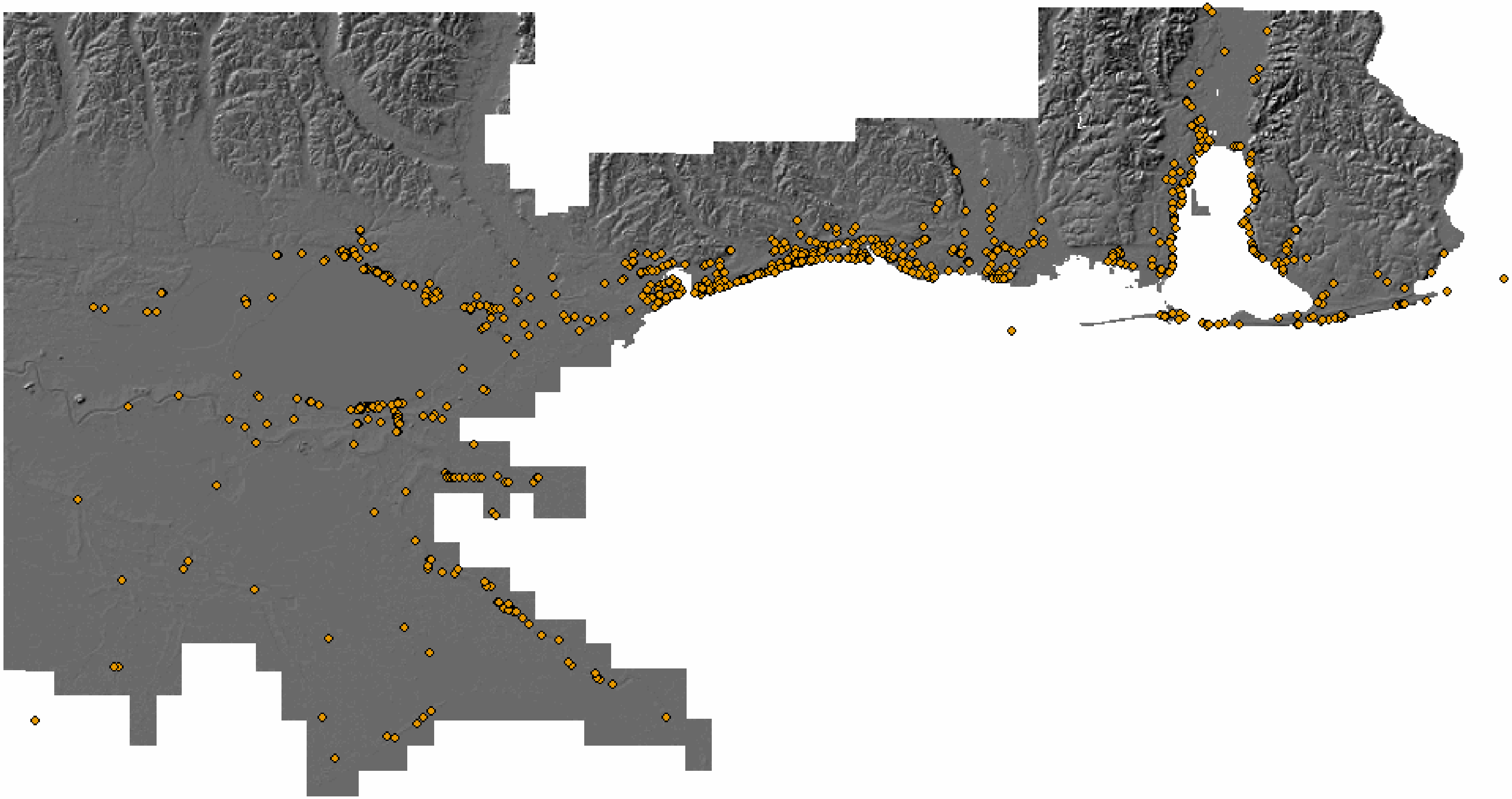


Source Data for NGOM 1/9-arc-second NED



Area	Format	Projection	Elevation Units	Metadata?
Louisiana	5-m DEM (raster)	UTM	Feet	Yes
Hancock Co., MS	LAS binary (points)	MS State Plane (m)	Feet	Yes
Harrison Co., MS	ASCII XYZ (points)	MS State Plane (ft)	Meters	No
Jackson Co., MS	LAS binary (points)	MS State Plane (m)	Feet	Yes
Mobile Co., AL	LAS binary (points)	AL State Plane (ft)	Feet	Partial
Baldwin Co. AL	Shapefile (MPBL)	AL State Plane (ft)	Meters	Partial

Katrina: surveyed high water marks



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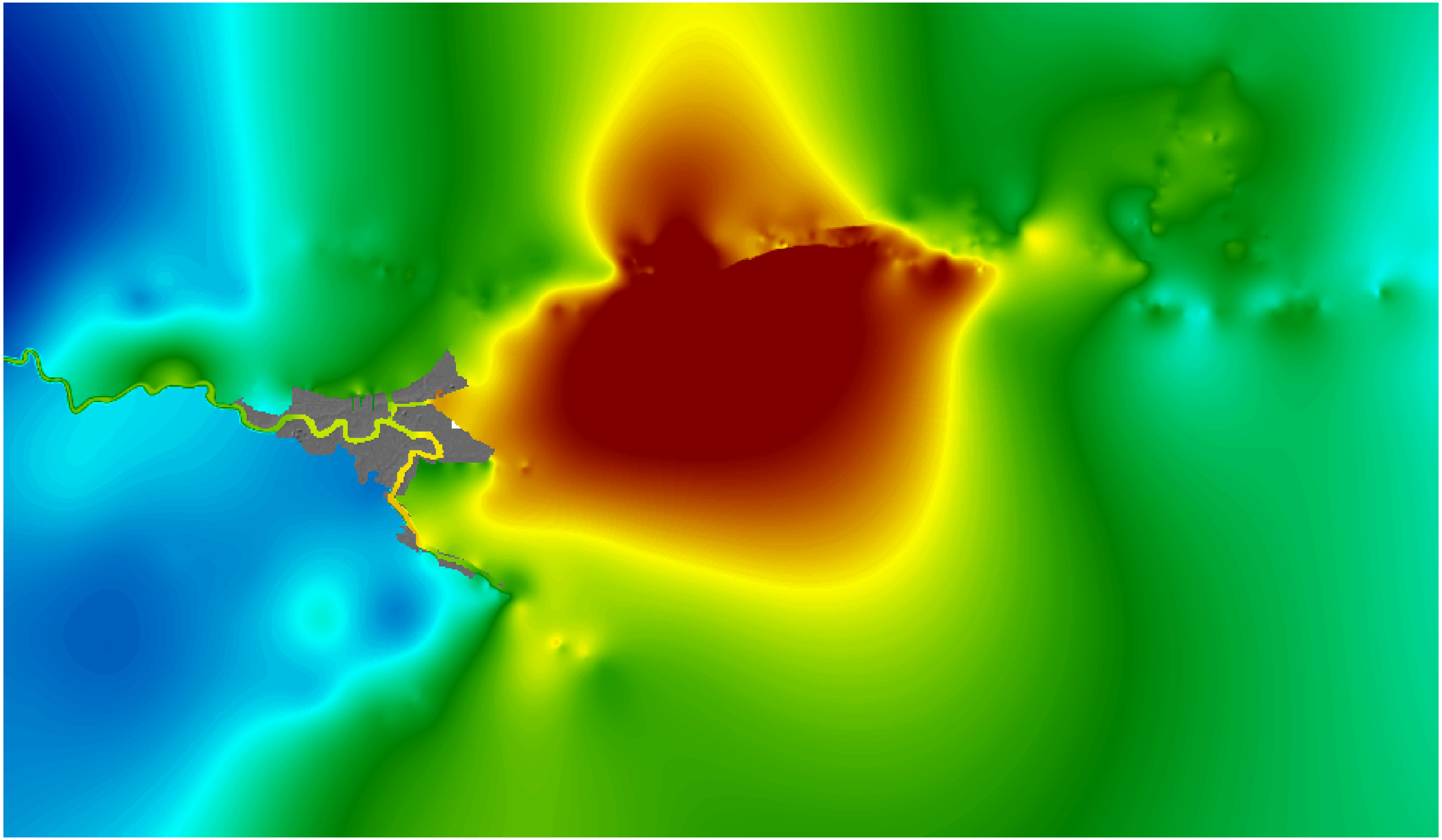
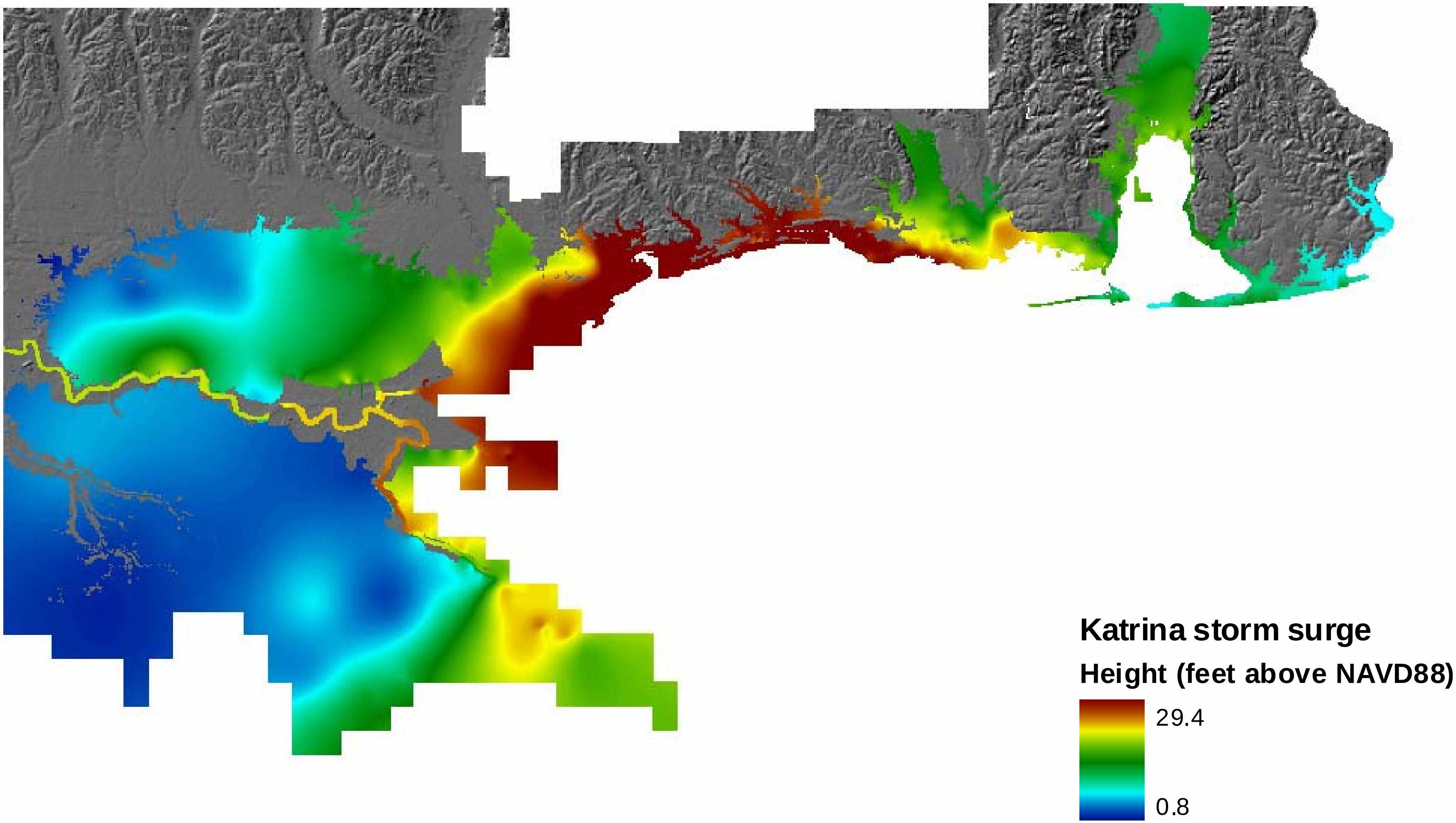
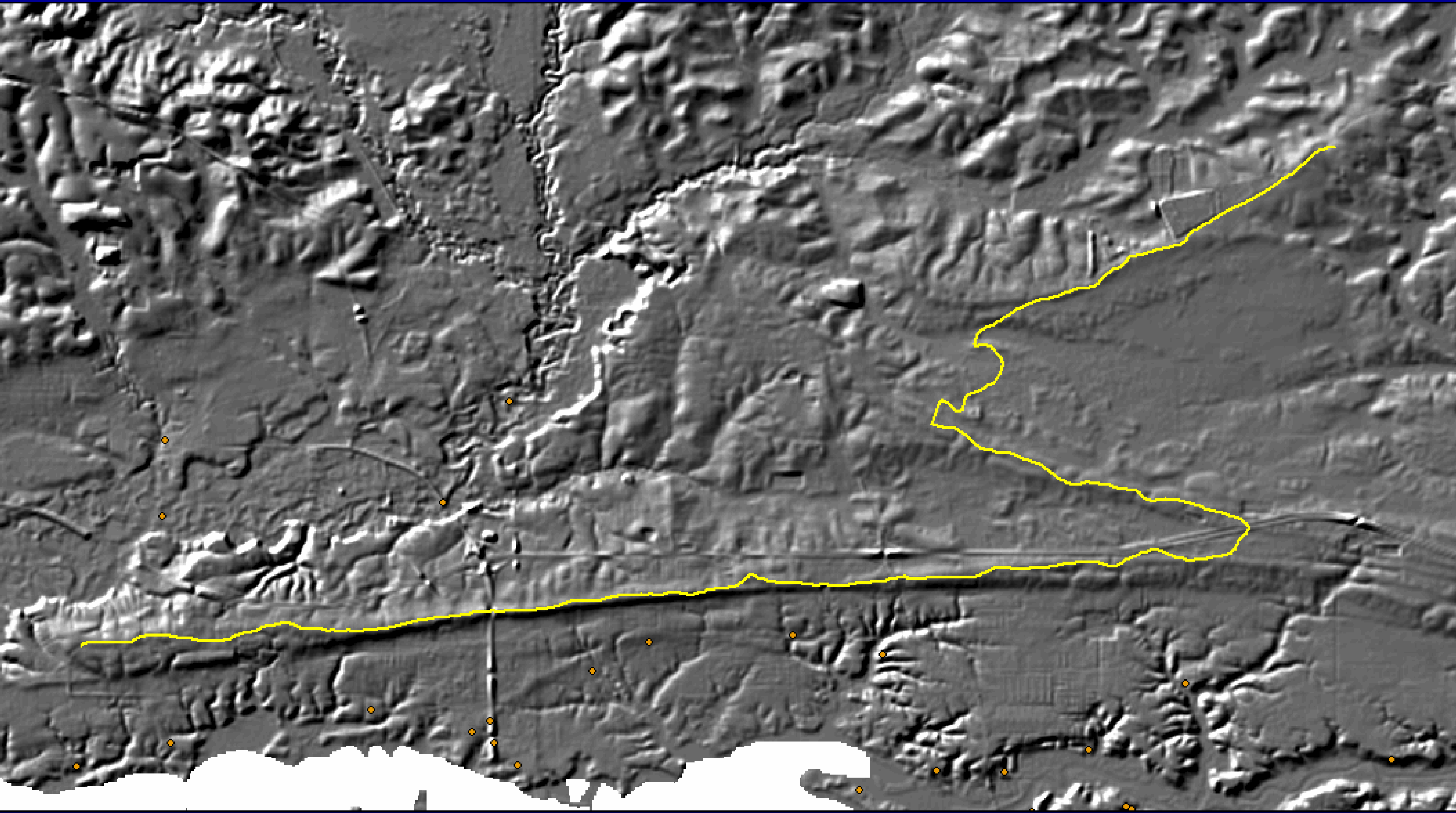
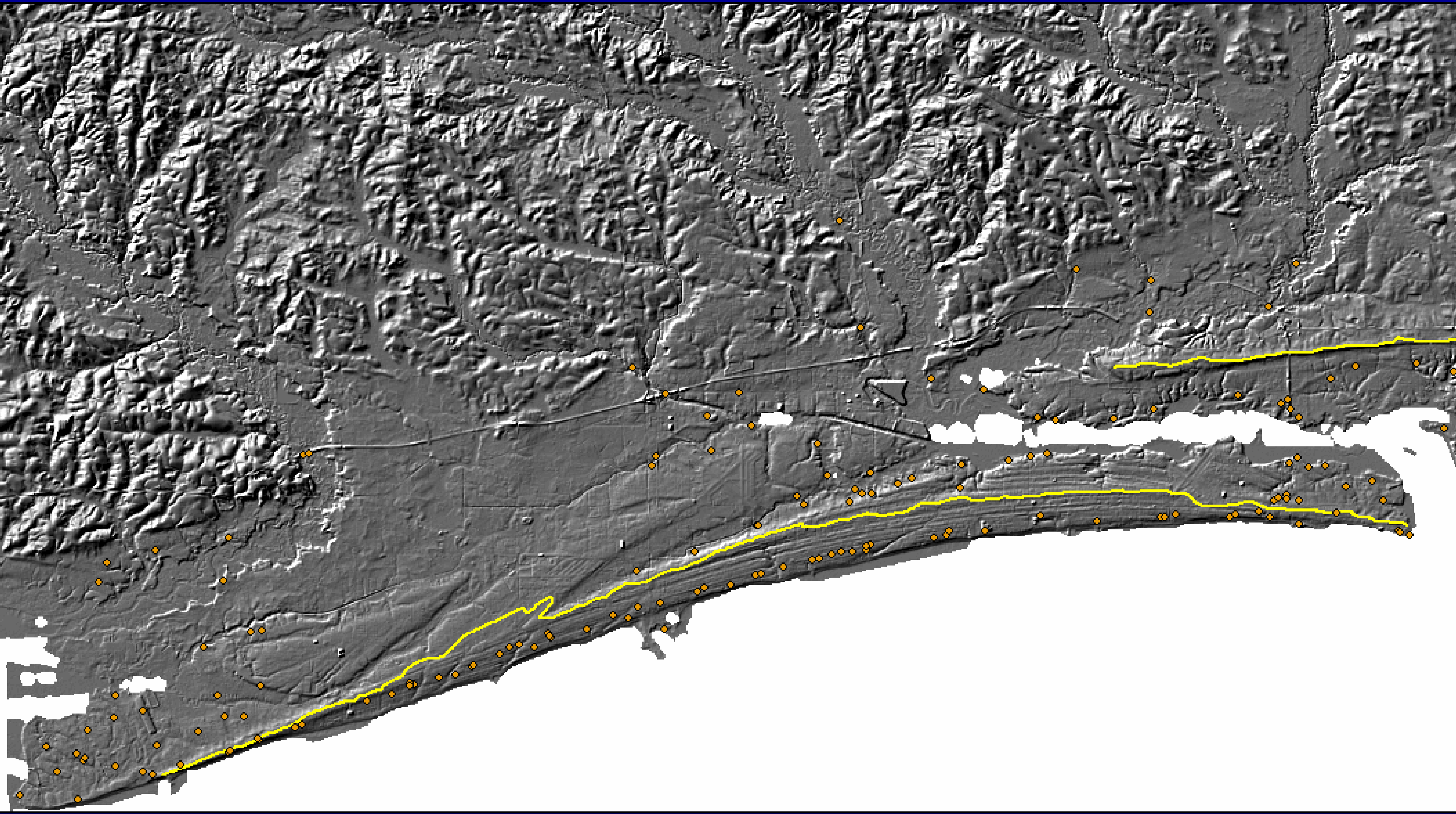



Katrina storm surge
Height (feet above NAVD88)
29.4
0.8





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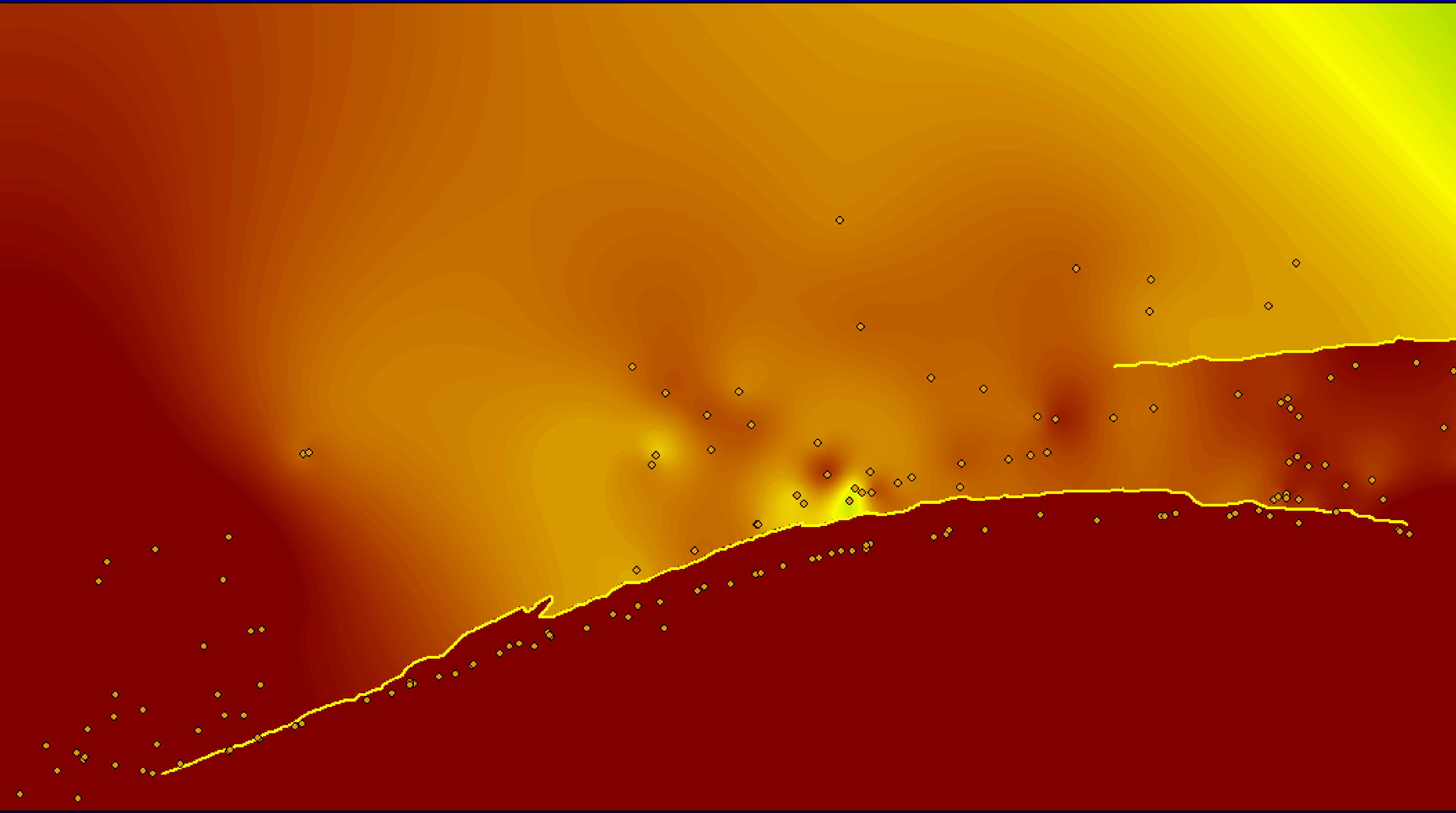

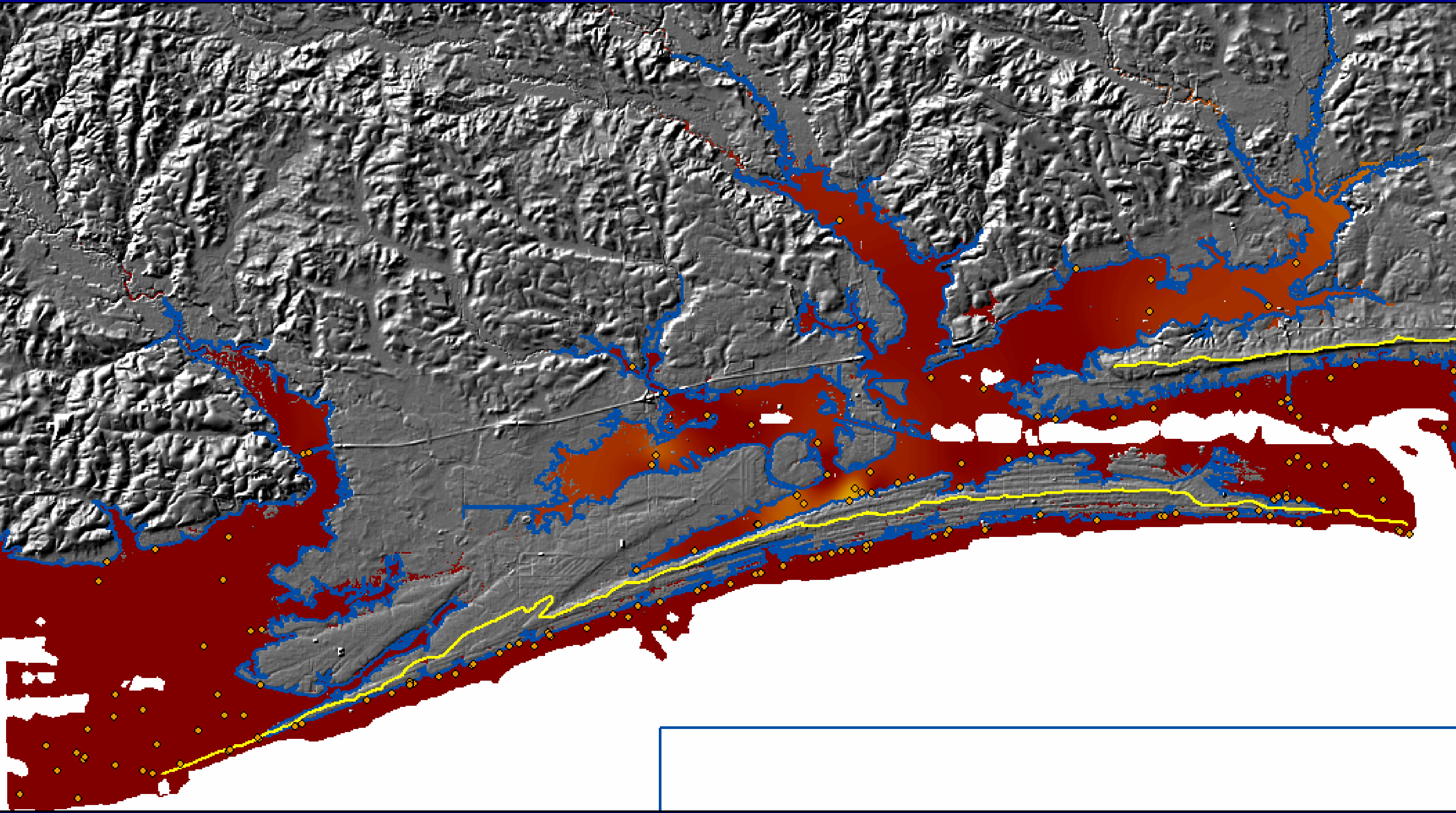

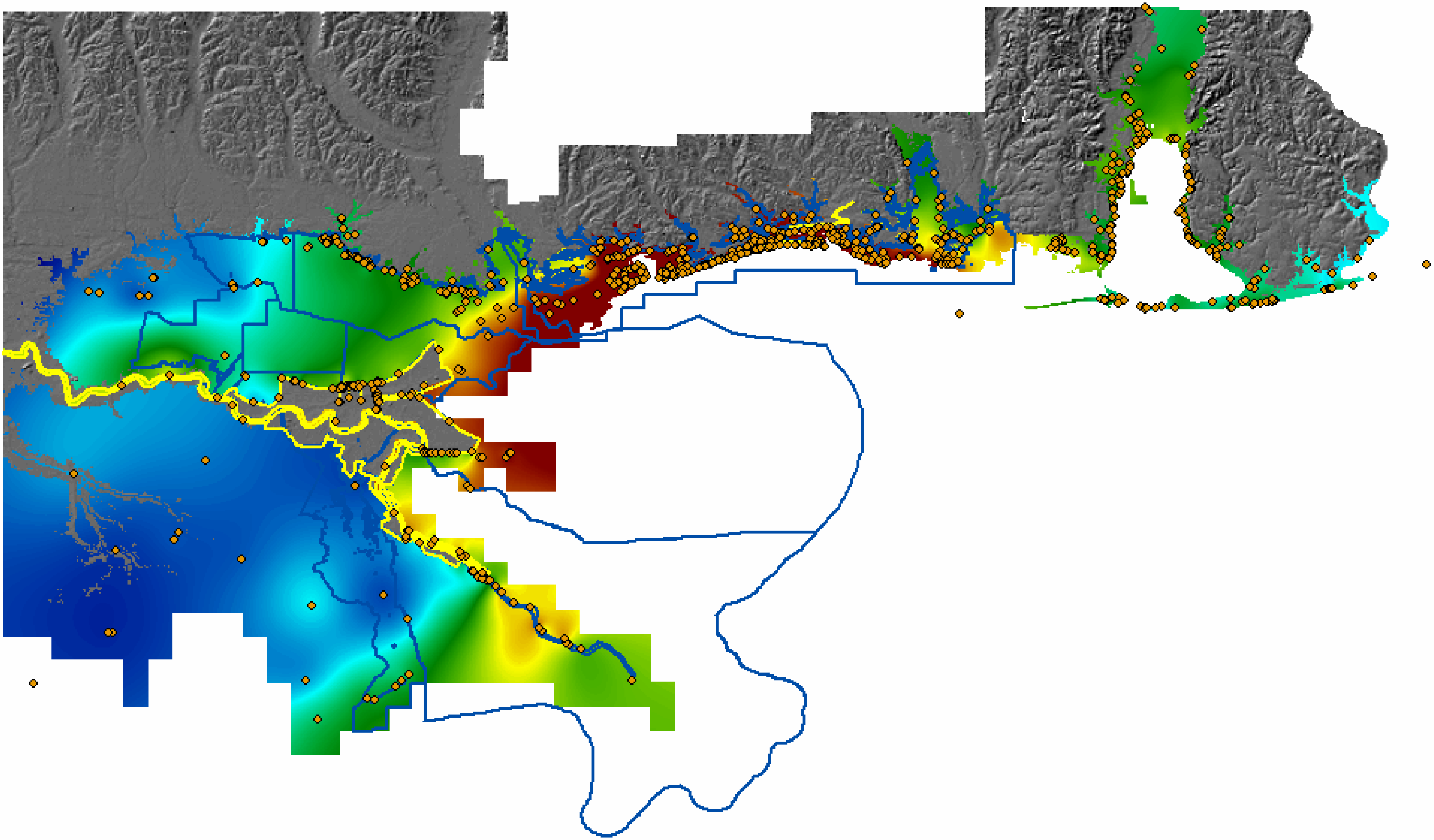

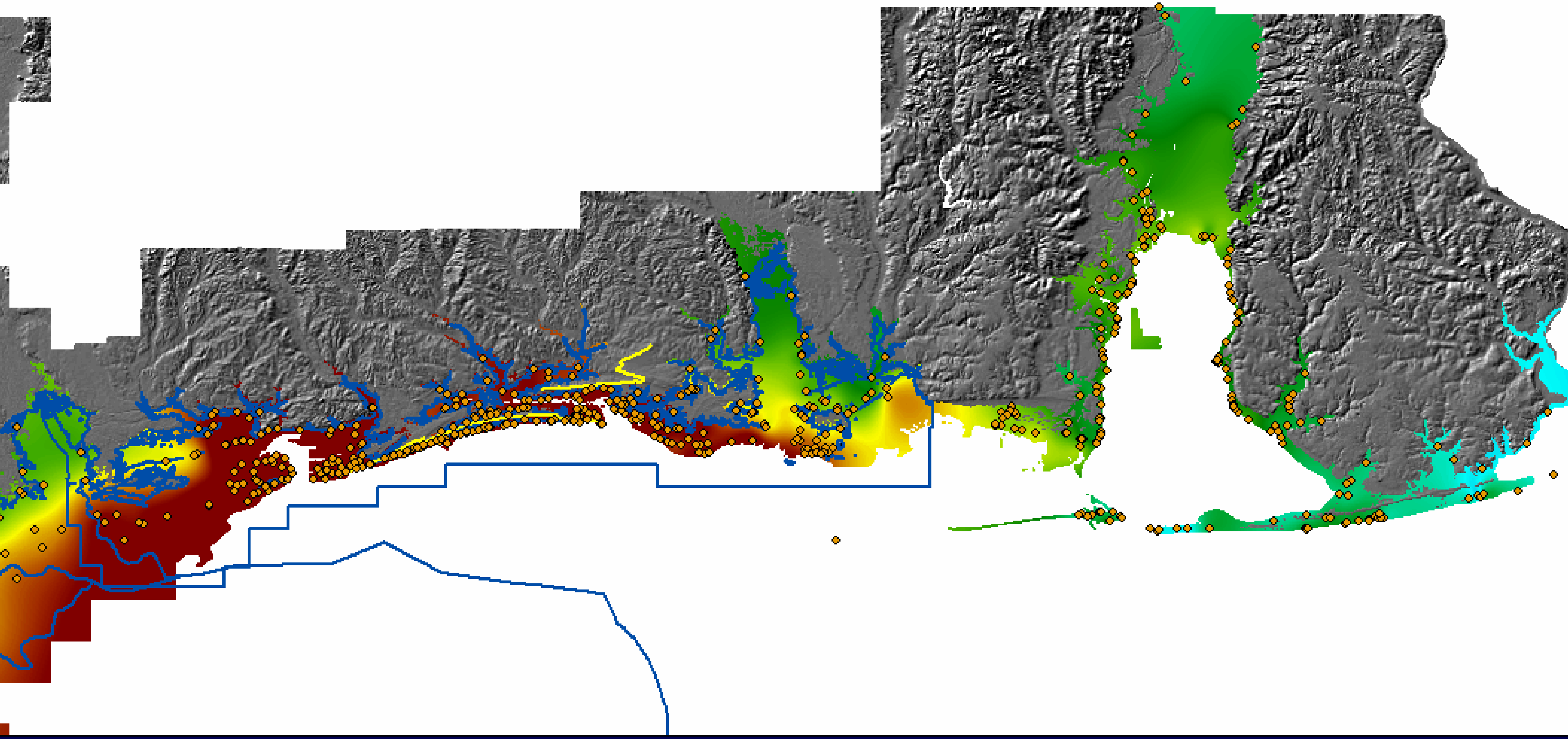

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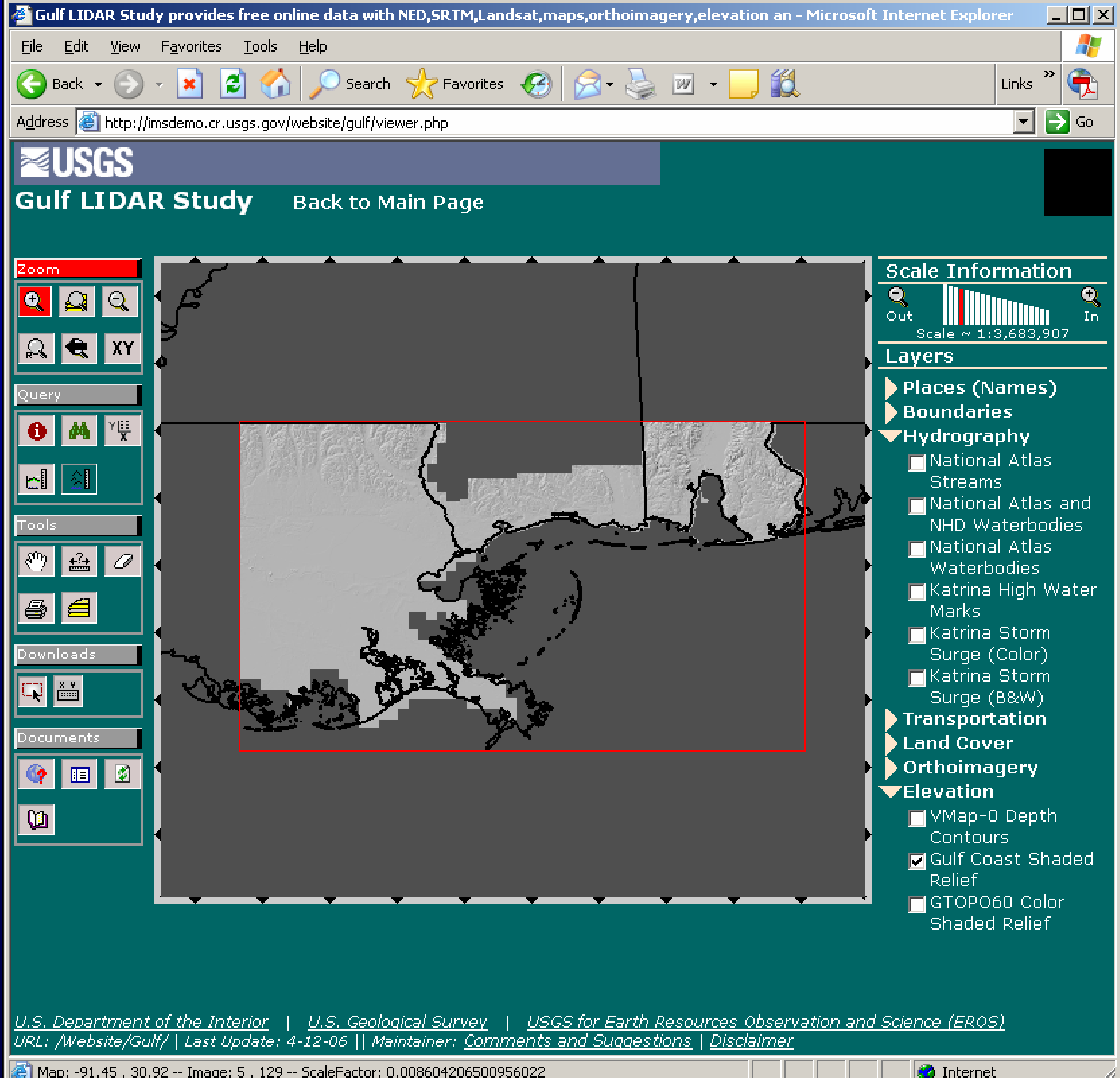
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Transportation
Land Cover
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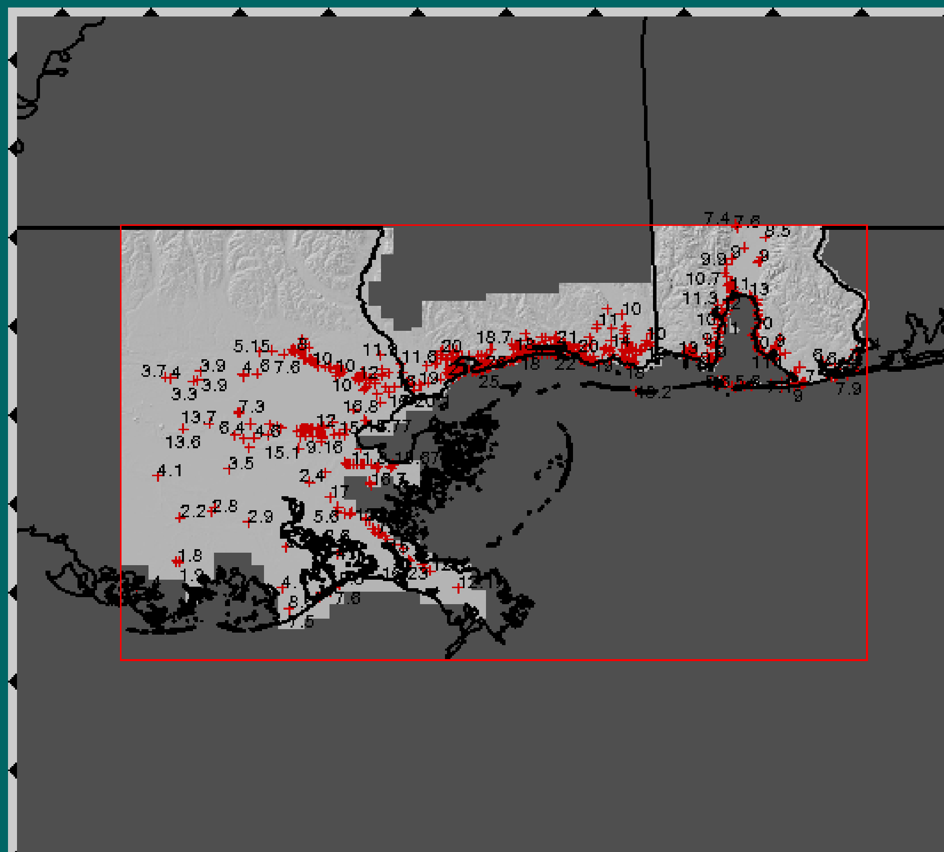

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  - Katrina Storm Surge (Color)
  - Katrina Storm Surge (B&W)
- Transportation
- Land Cover
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- Elevation
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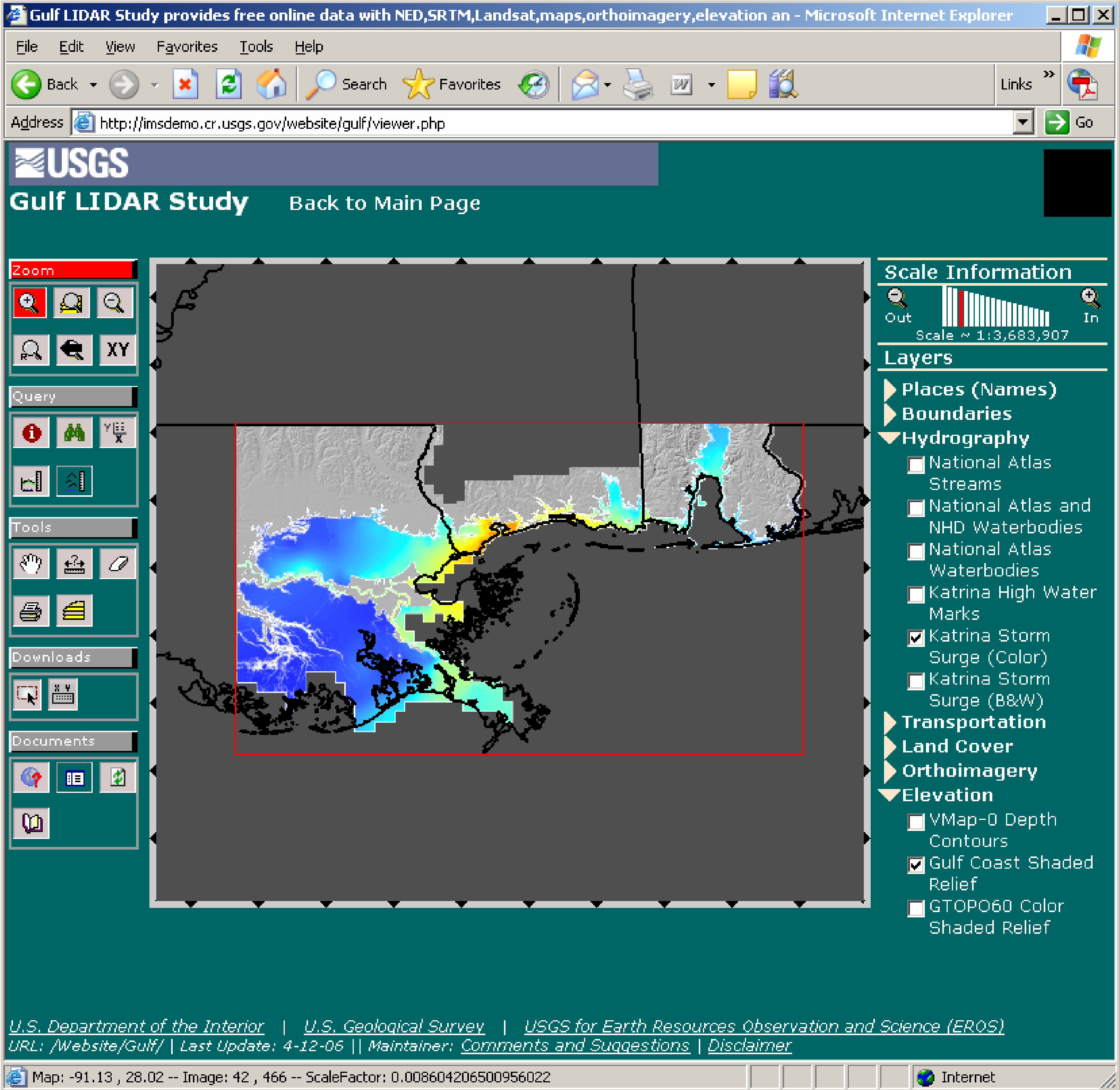
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Layers
Places (Names)
Boundaries
Hydrography
National Atlas Streams
National Atlas and NHD Waterbodies
National Atlas Waterbodies
Katrina High Water Marks
Katrina Storm Surge (Color)
Katrina Storm Surge (B&W)
Transportation
Land Cover
Orthoimagery
Elevation
VMap-0 Depth Contours
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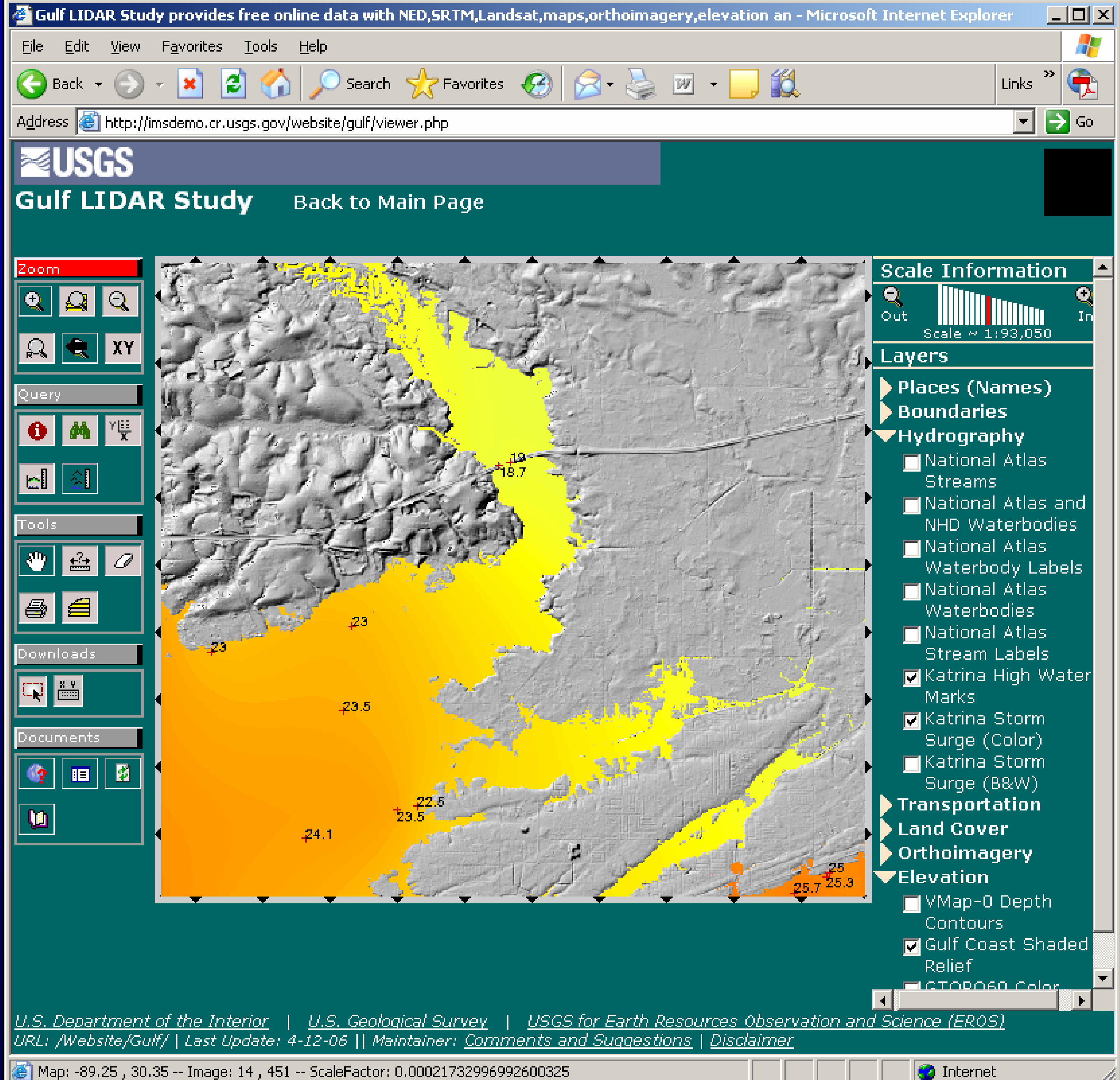
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Query
Tools
Downloads
Documents
19
18.7
23
23
23.5
22.5
23.5
24.1
25
25.7
25.3
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Layers
Places (Names)
Boundaries
Hydrography
National Atlas Streams
National Atlas and NHD Waterbodies
National Atlas Waterbody Labels
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National Atlas Stream Labels
Katrina High Water Marks
Katrina Storm Surge (Color)
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Transportation
Land Cover
Orthoimagery
Elevation
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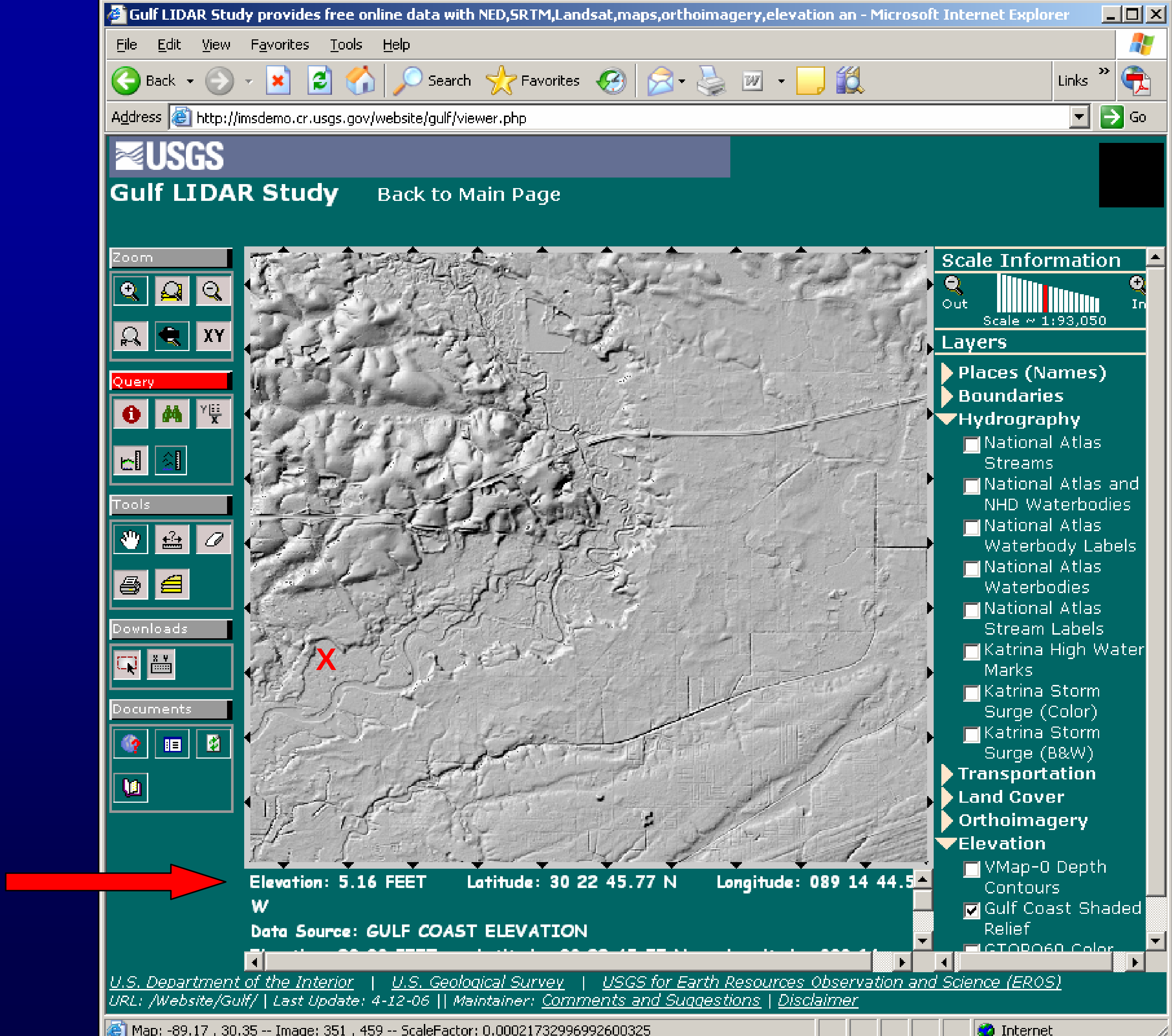
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Out
In
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Layers
Places (Names)
Boundaries
Hydrography
National Atlas Streams
National Atlas and NHD Waterbodies
National Atlas Waterbody Labels
National Atlas Waterbodies
National Atlas Stream Labels
Katrina High Water Marks
Katrina Storm Surge (Color)
Katrina Storm Surge (B&W)
Transportation
Land Cover
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Elevation: 5.16 FEET Latitude: 30 22 45.77 N Longitude: 089 14 44.5 W
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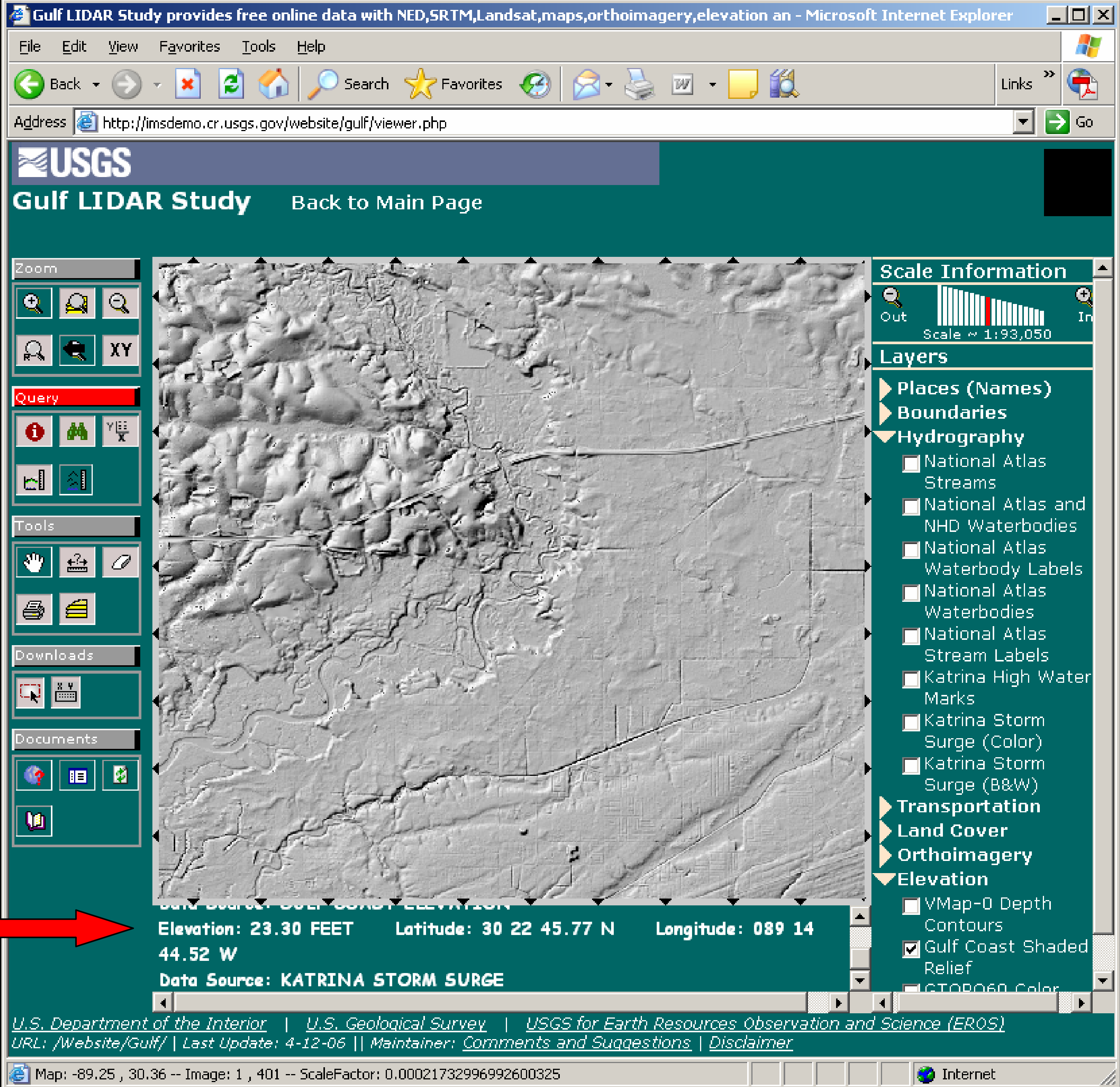
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Boundaries
Hydrography
National Atlas Streams
National Atlas and NHD Waterbodies
National Atlas Waterbody Labels
National Atlas Waterbodies
National Atlas Stream Labels
Katrina High Water Marks
Katrina Storm Surge (Color)
Katrina Storm Surge (B&W)
Transportation
Land Cover
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Elevation
VMap-0 Depth Contours
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Elevation: 23.30 FEET Latitude: 30 22 45.77 N Longitude: 089 14 44.52 W
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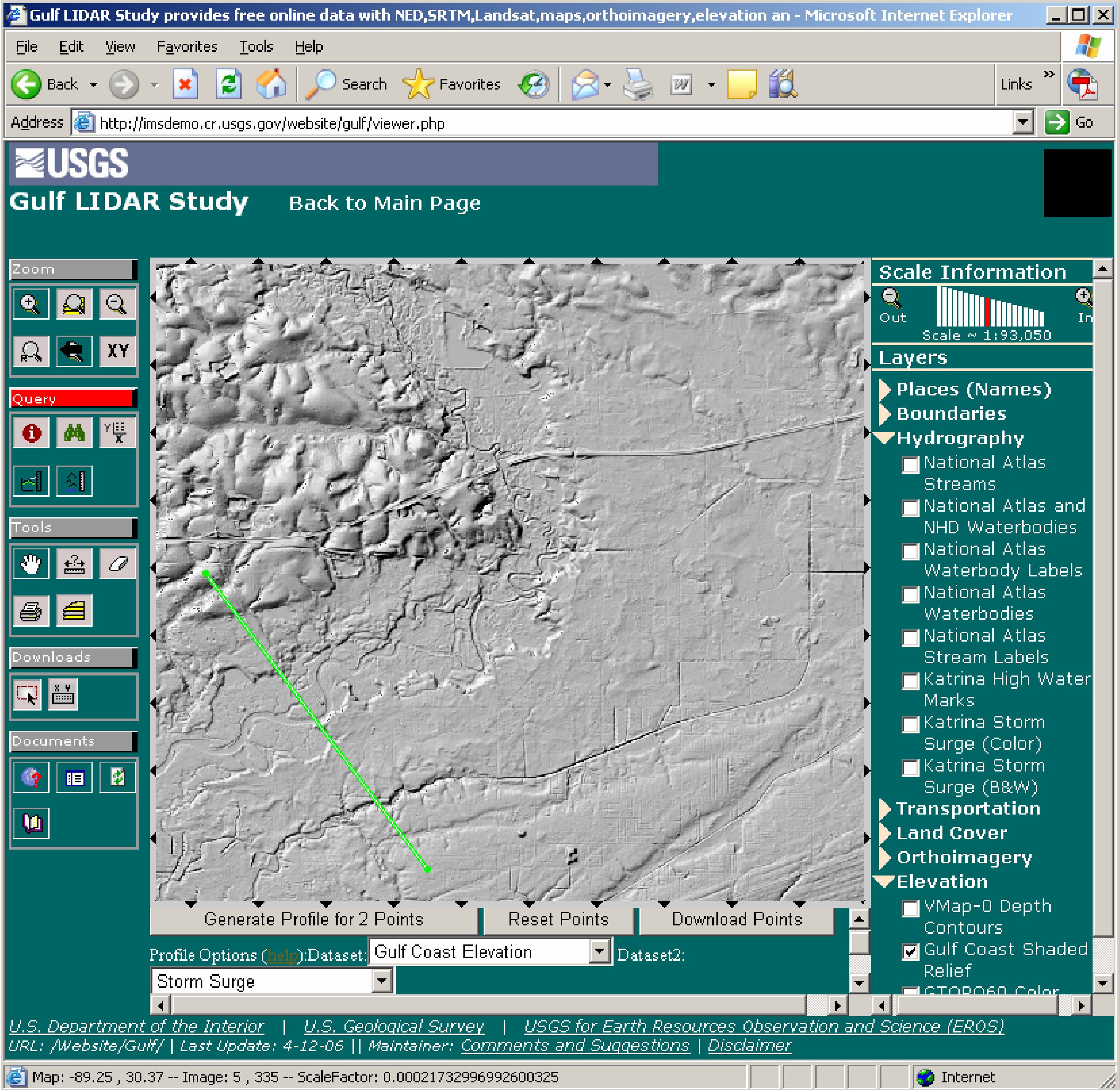
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Places (Names)
Boundaries
Hydrography
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Katrina High Water Marks
Katrina Storm Surge (Color)
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Transportation
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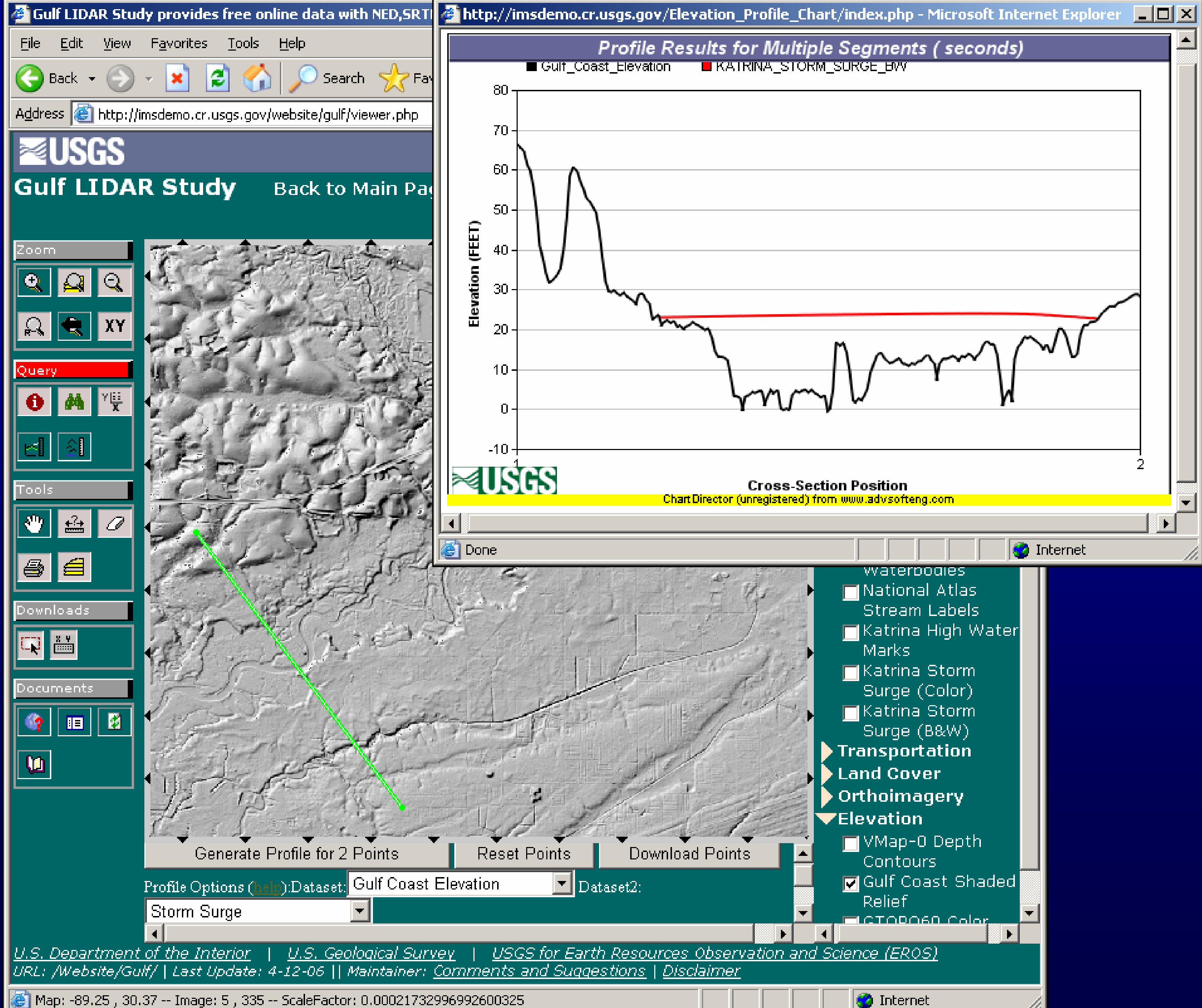
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KATRINA_STORM_SURGE_BW
Elevation (FEET)
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10
0
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Cross-Section Position
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National Atlas Stream Labels
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Land Cover
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Elevation
VMap-0 Depth Contours
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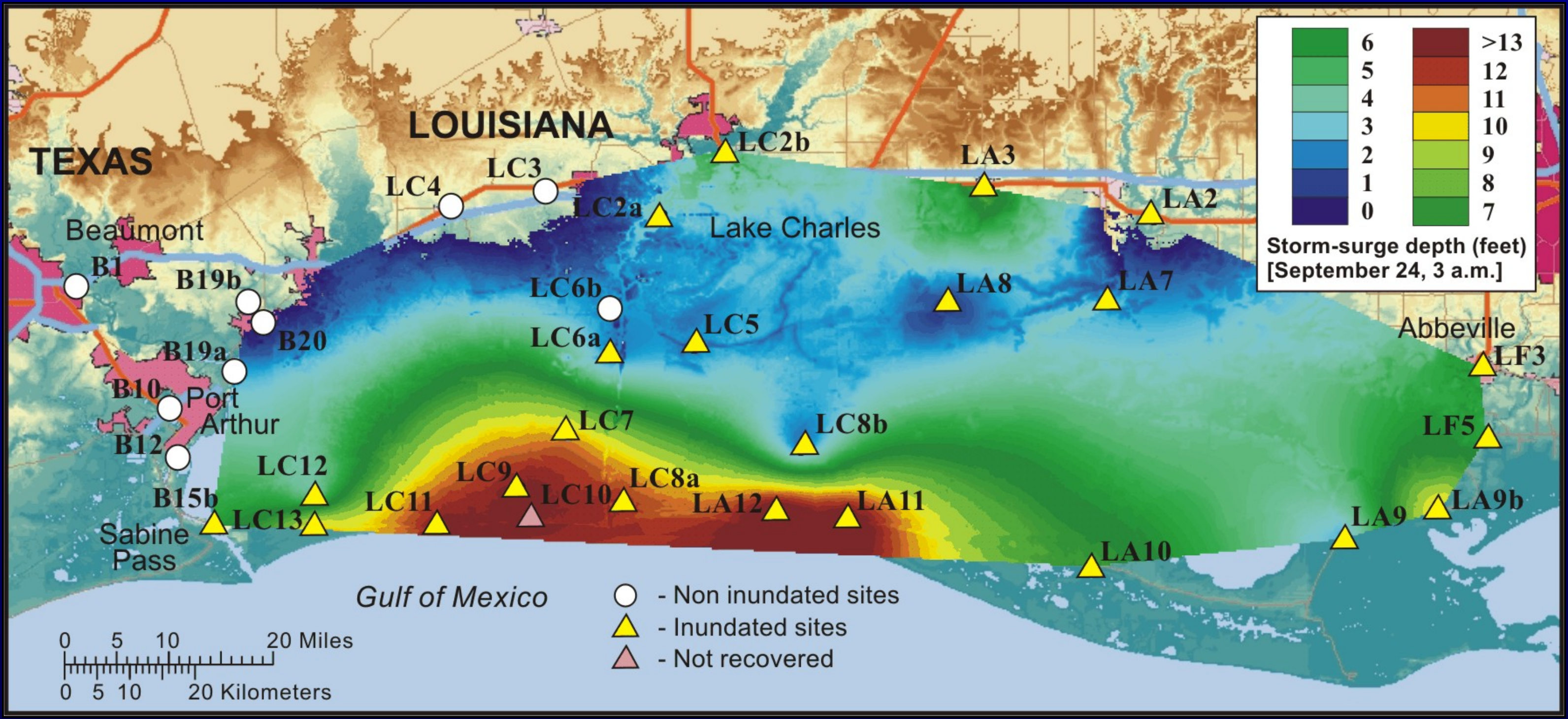
Objective – Provide water data to document the shape, size, and transit of surge domes and the effect of the coastal landscape and infrastructure on the timing, extent, and duration of surge-induced flooding.



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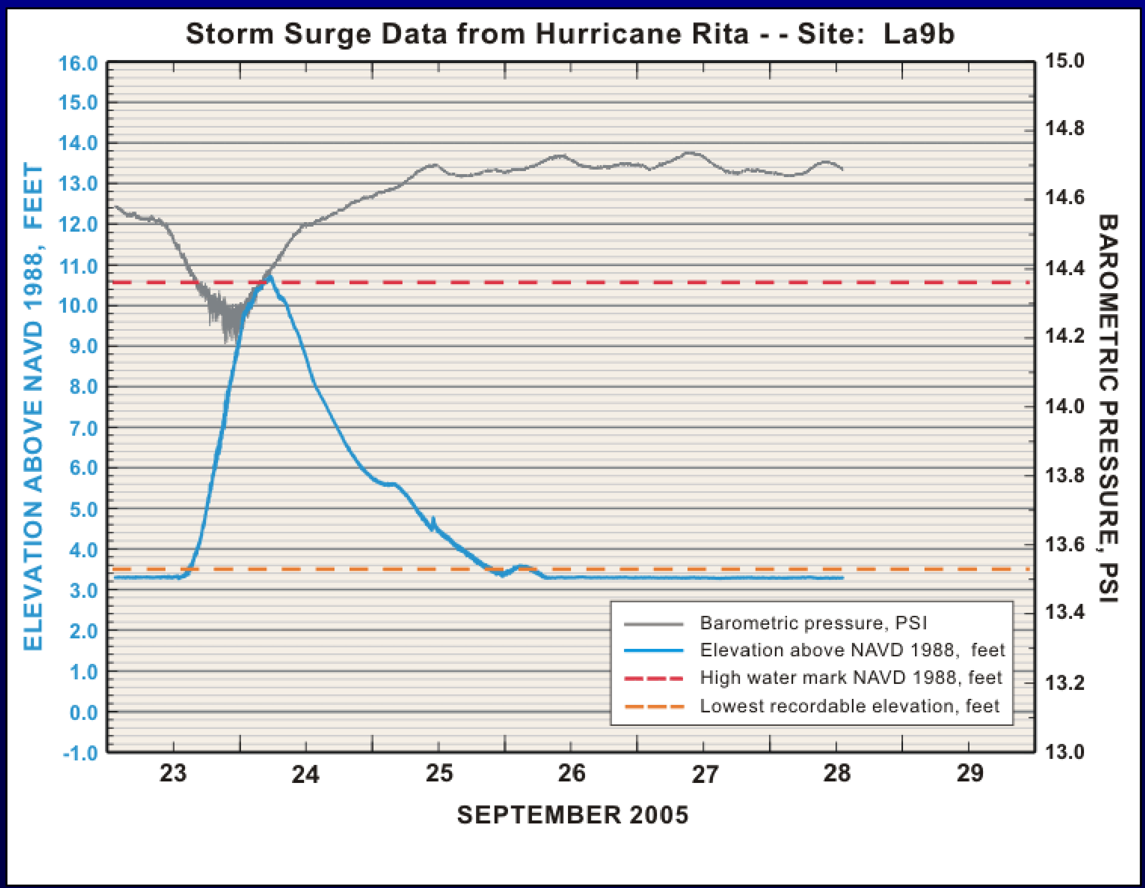
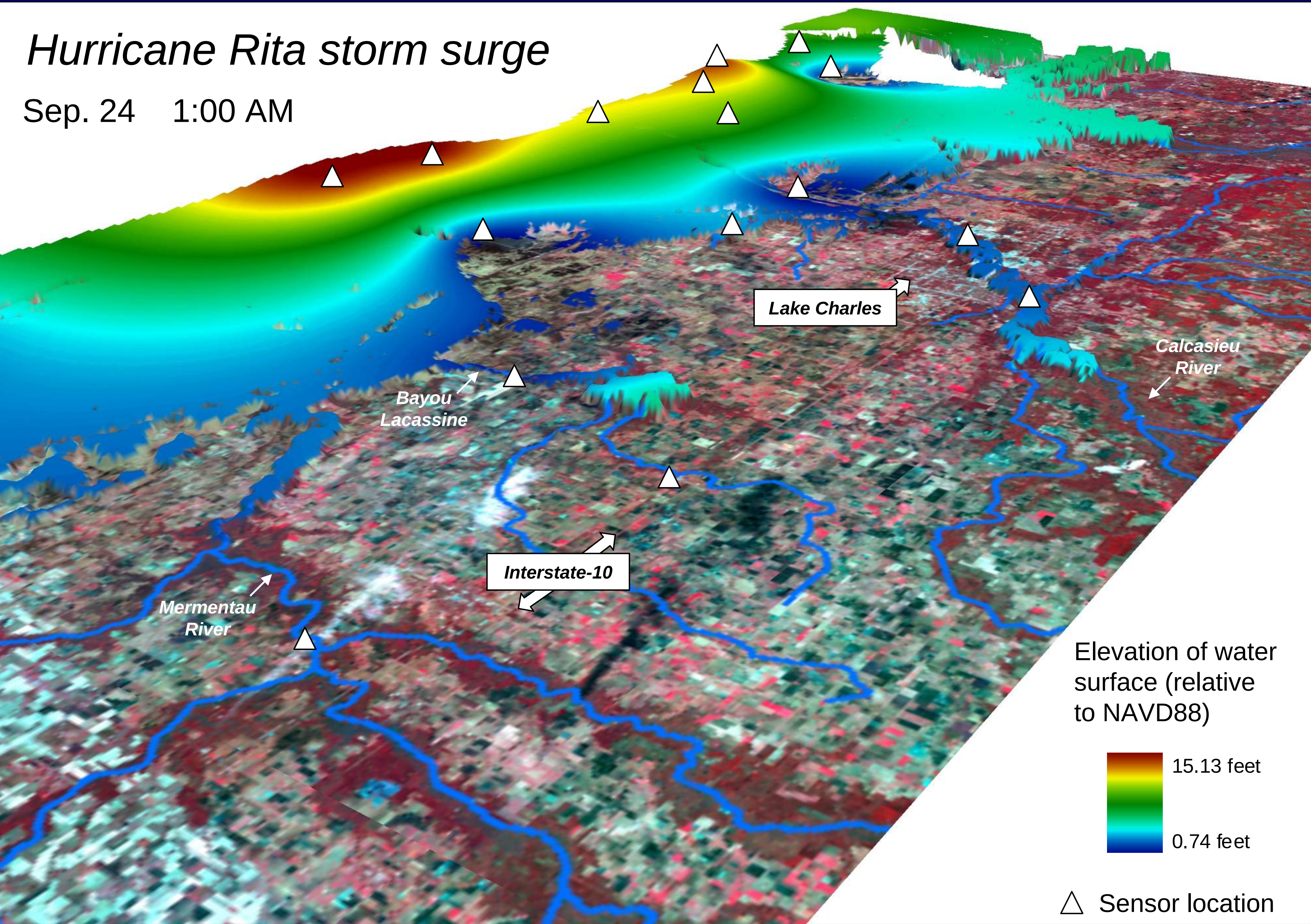

Storm Surge Data from Hurricane Rita - - Site: La9b
ELEVATION ABOVE NAVD 1988, FEET
BAROMETRIC PRESSURE, PSI
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
15.0
14.8
14.6
14.4
14.2
14.0
13.8
13.6
13.4
13.2
13.0
23
24
25
26
27
28
29
SEPTEMBER 2005
Barometric pressure, PSI
Elevation above NAVD 1988, feet
High water mark NAVD 1988, feet
Lowest recordable elevation, feet

Hurricane Rita Storm Surge Time Series

Hurricane Rita storm surge

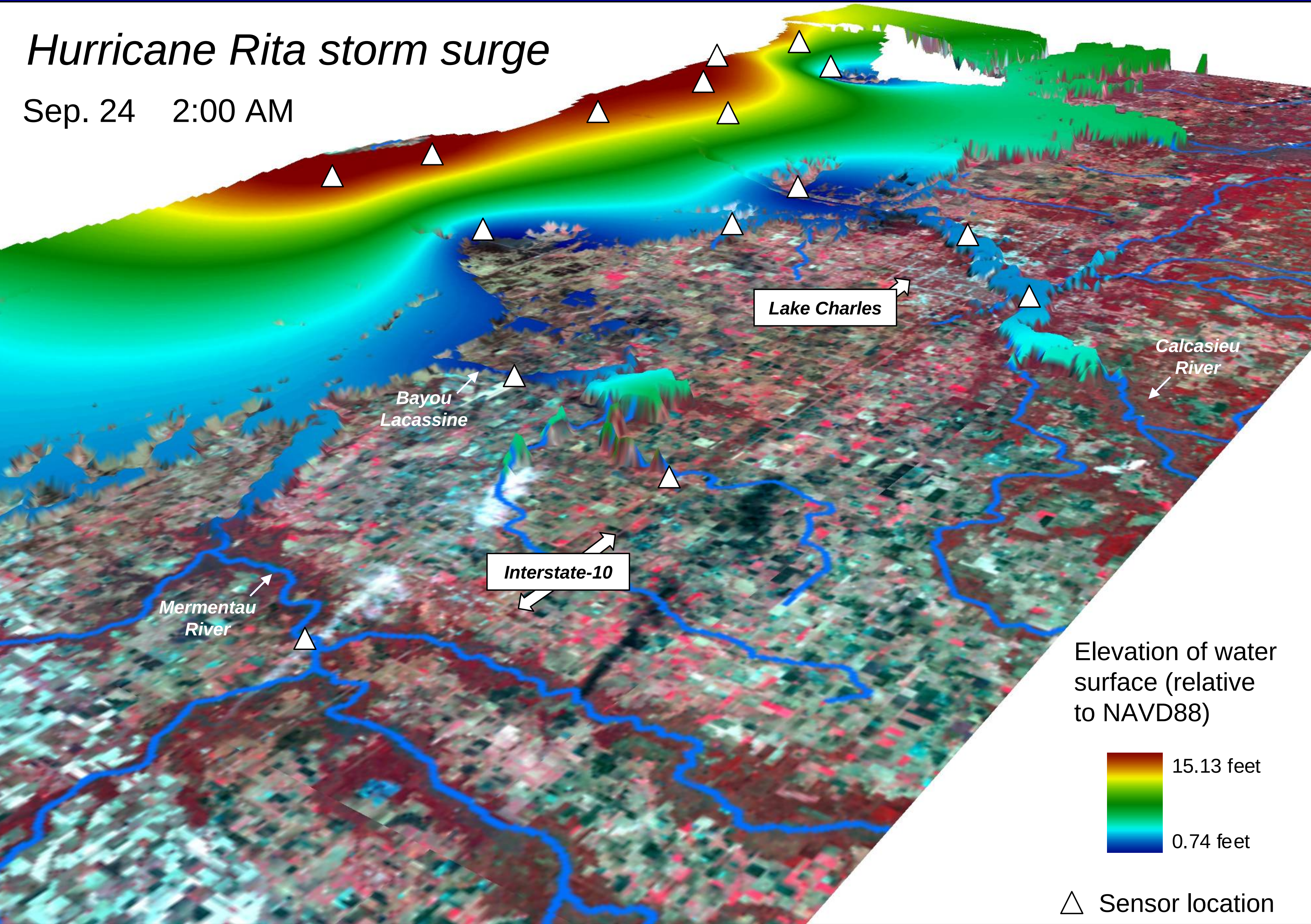
Sep. 24 1:00 AM



(View looking from the northeast toward the southwest)

Hurricane Rita storm surge

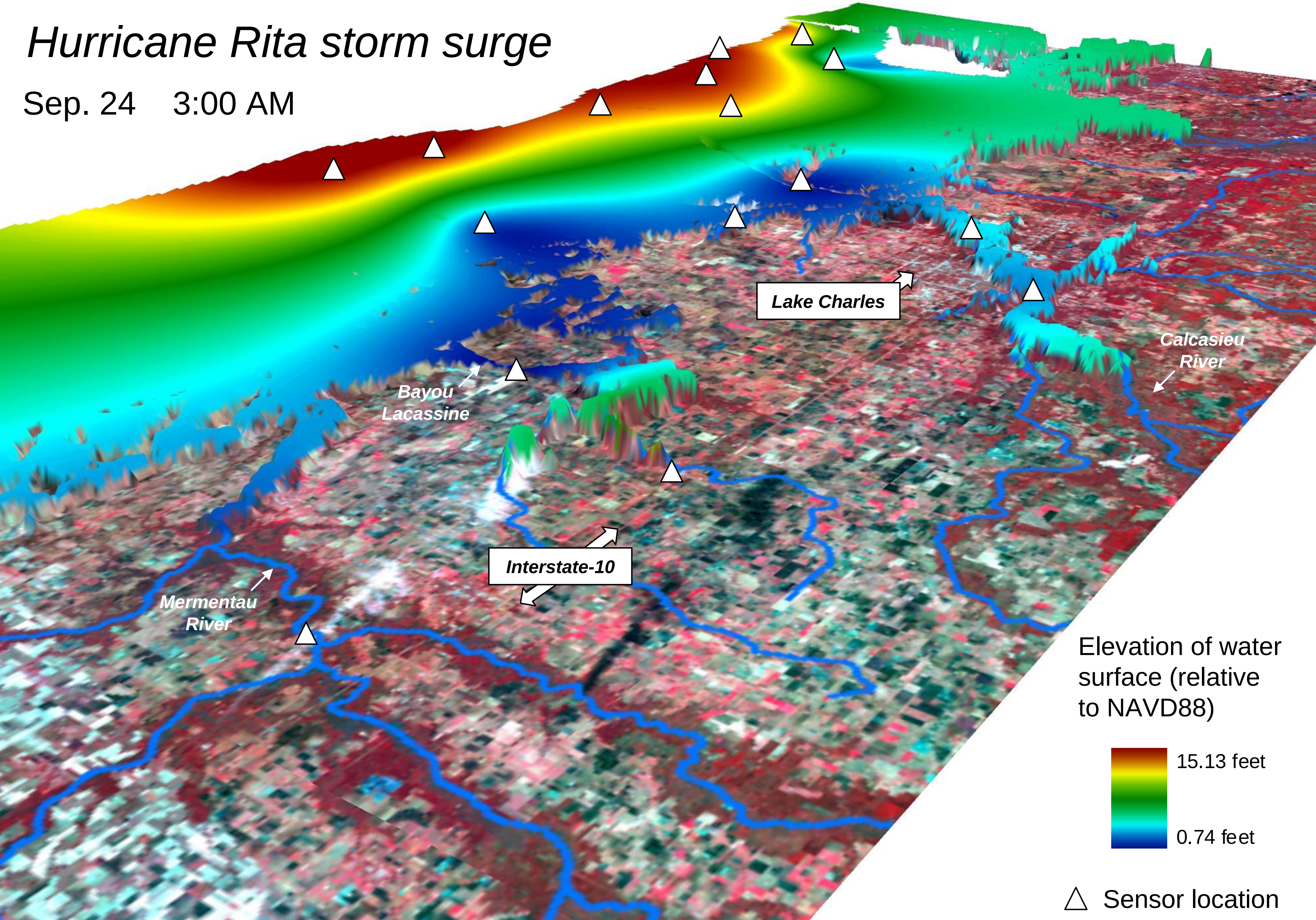
Sep. 24 2:00 AM



(View looking from the northeast toward the southwest)

Hurricane Rita storm surge

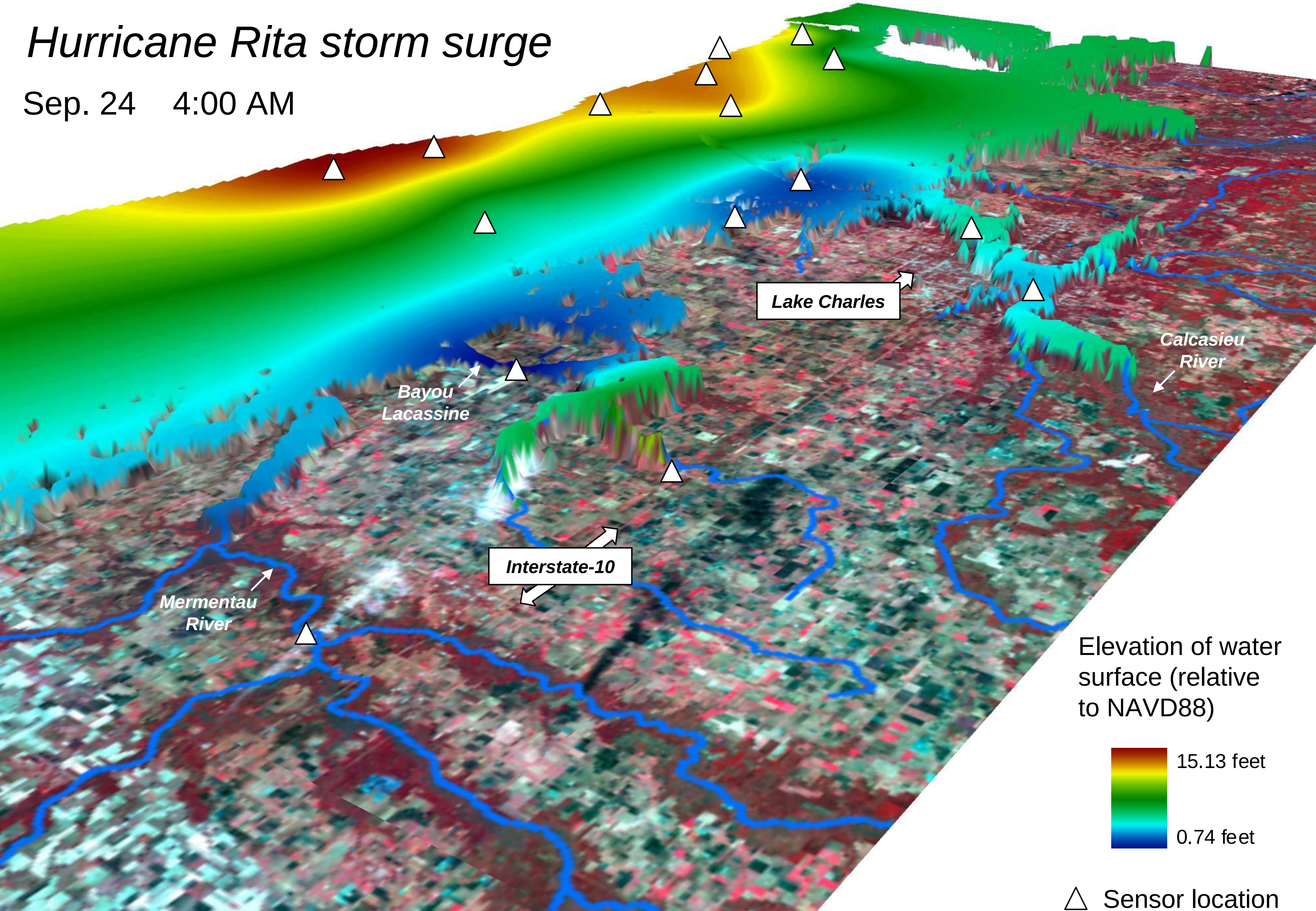
Sep. 24 3:00 AM



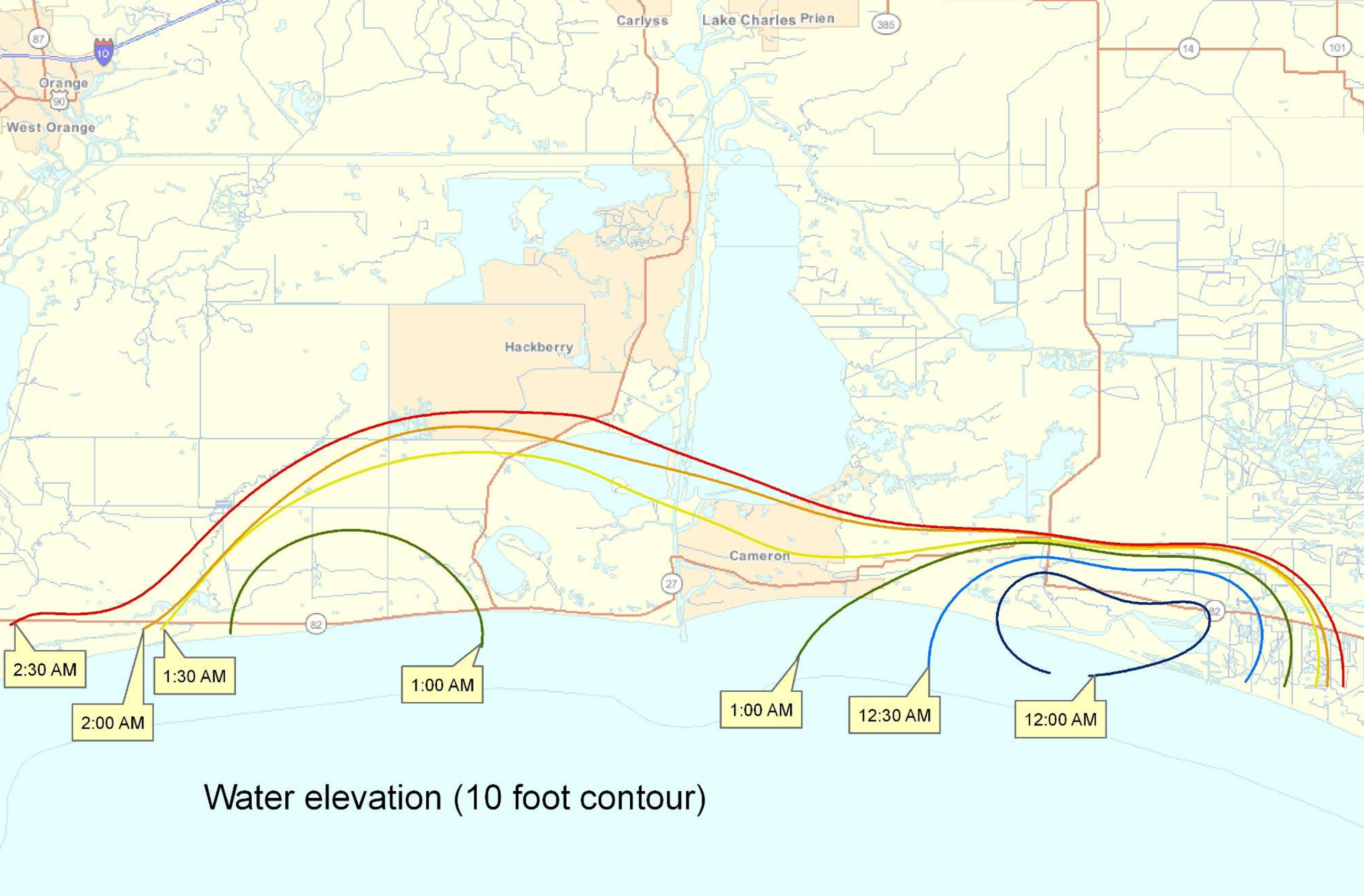
(View looking from the northeast toward the southwest)

Hurricane Rita storm surge

Sep. 24 4:00 AM



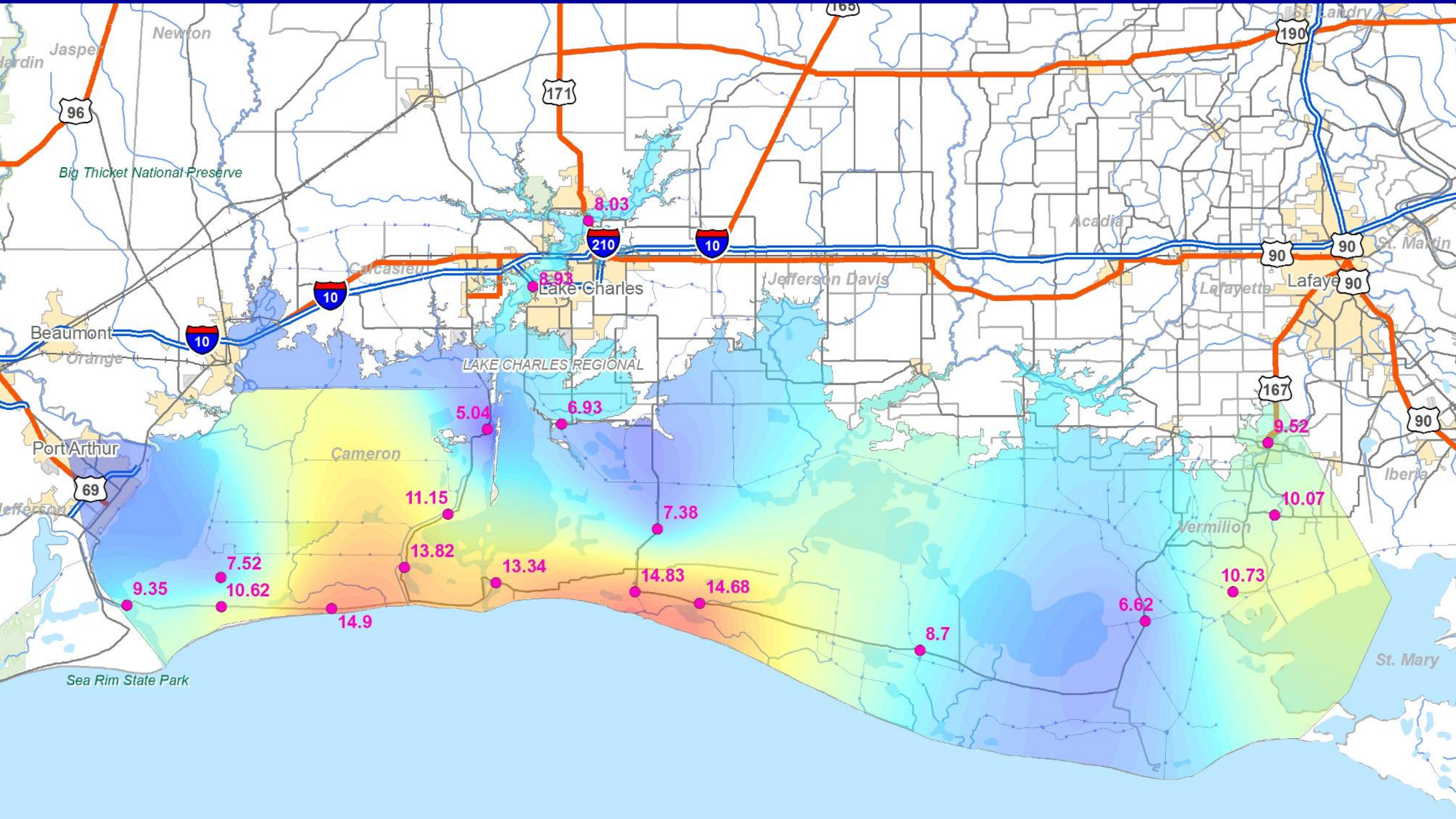
(View looking from the northeast toward the southwest)



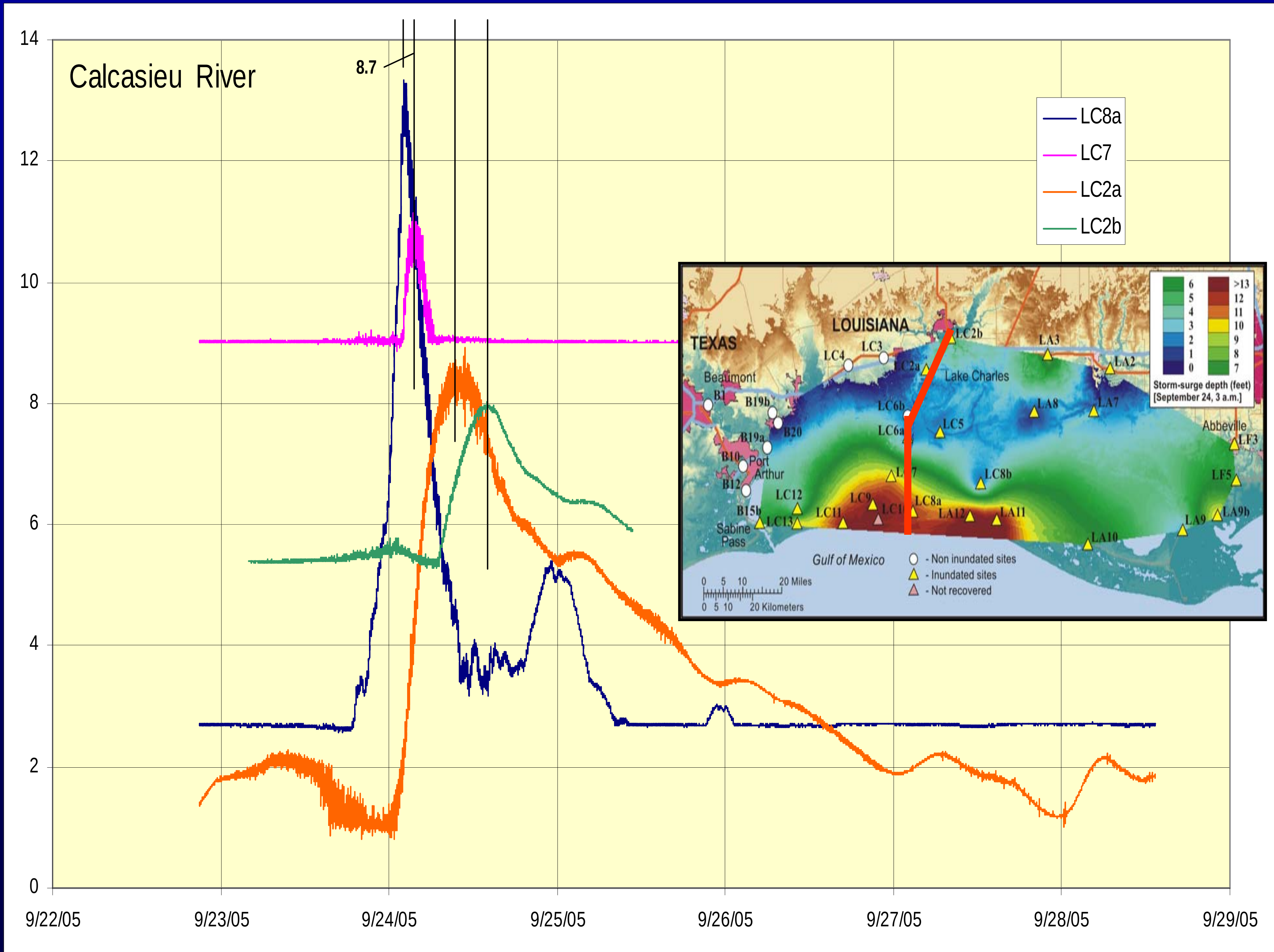
Water elevation (10 foot contour)

USGS

Hurricane Rita: Maximum Storm Surge



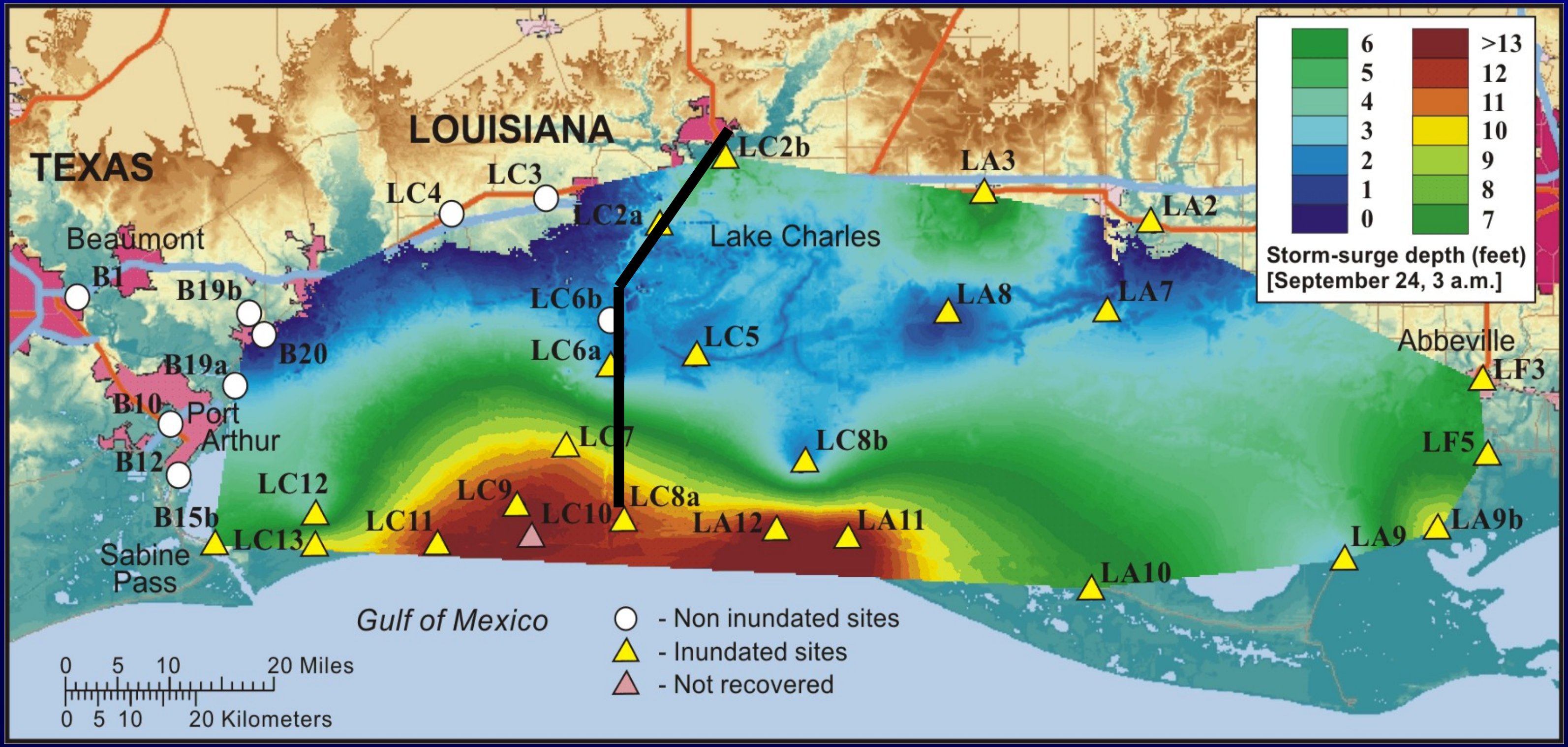
USGS



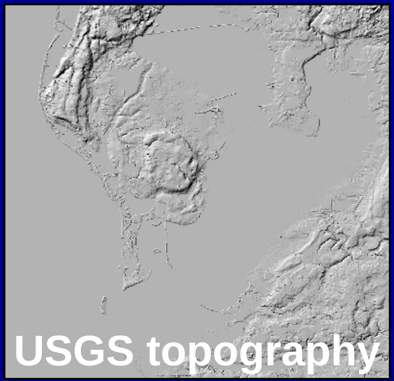
Calcasieu River
8.7
LC8a
LC7
LC2a
LC2b
14
12
10
8
6
4
2
0
9/22/05
9/23/05
9/24/05
9/25/05
9/26/05
9/27/05
9/28/05
9/29/05
TEXAS
LOUISIANA
Beaumont
Port Arthur
Sabine Pass
Lake Charles
Abbeville
Gulf of Mexico
Storm-surge depth (feet) [September 24, 3 a.m.]
- Non inundated sites
- Inundated sites
- Not recovered
20 Miles
20 Kilometers

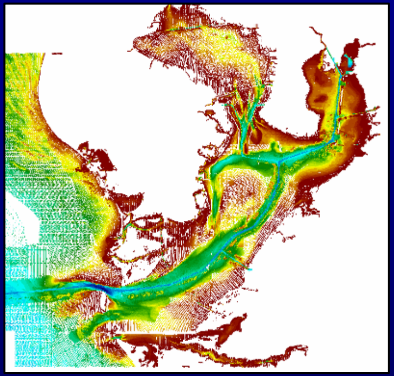
Table -- Calculation of velocity at the peak water level.

Site	Time of Peak	Integer time of peak (s)	Total time (s)	Accumulative time (s)	Distance from coast (ft)	Velocity from previous site (ft/s)
LC8a	9/24/2005 2:25:27	8727	0	0	12,588.6	--
LC7	9/24/2005 3:32:27	12747	4,020	4,020	47,601.7	8.7
LC2a	9/24/2005 9:49:57	35397	22,650	26,670	164,227.4	5.1
LC2b	9/24/2005 14:08:57	50937	15,540	42,210	207,218.8	2.8



National VDatum - Vertical Datum Transformation Tool



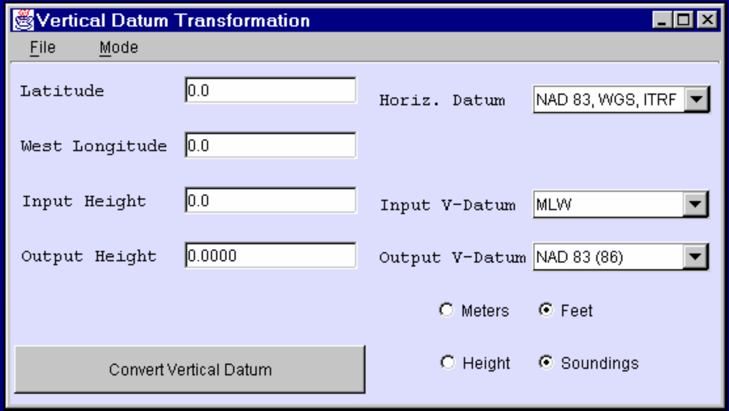


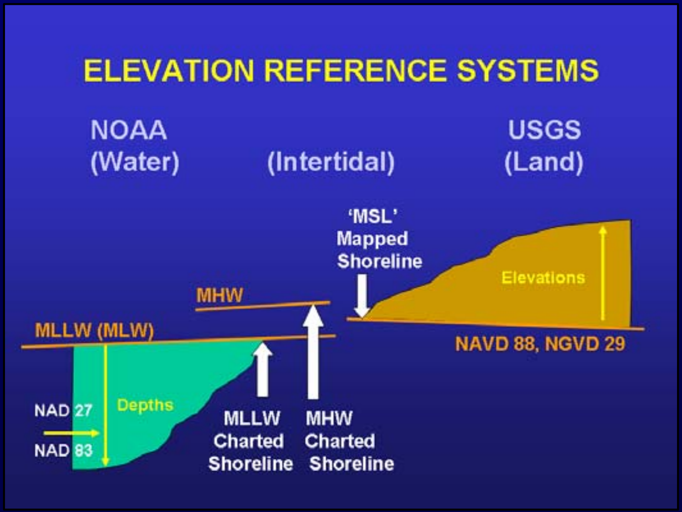
NOAA bathymetry

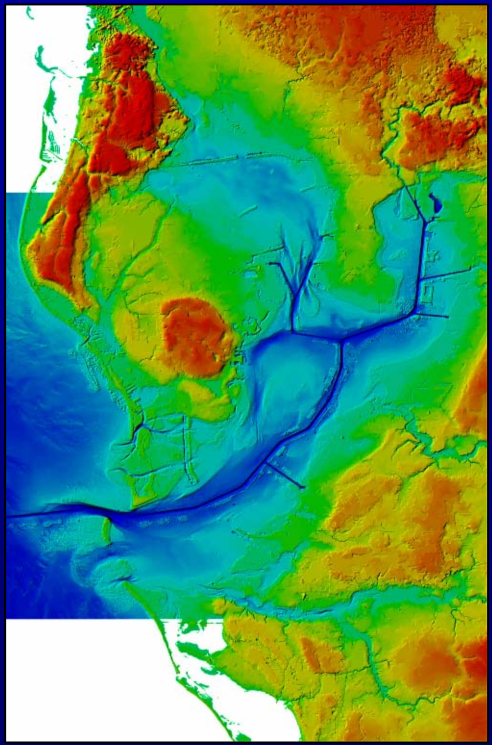
Geoid model

Tide model

Ellipsoid model

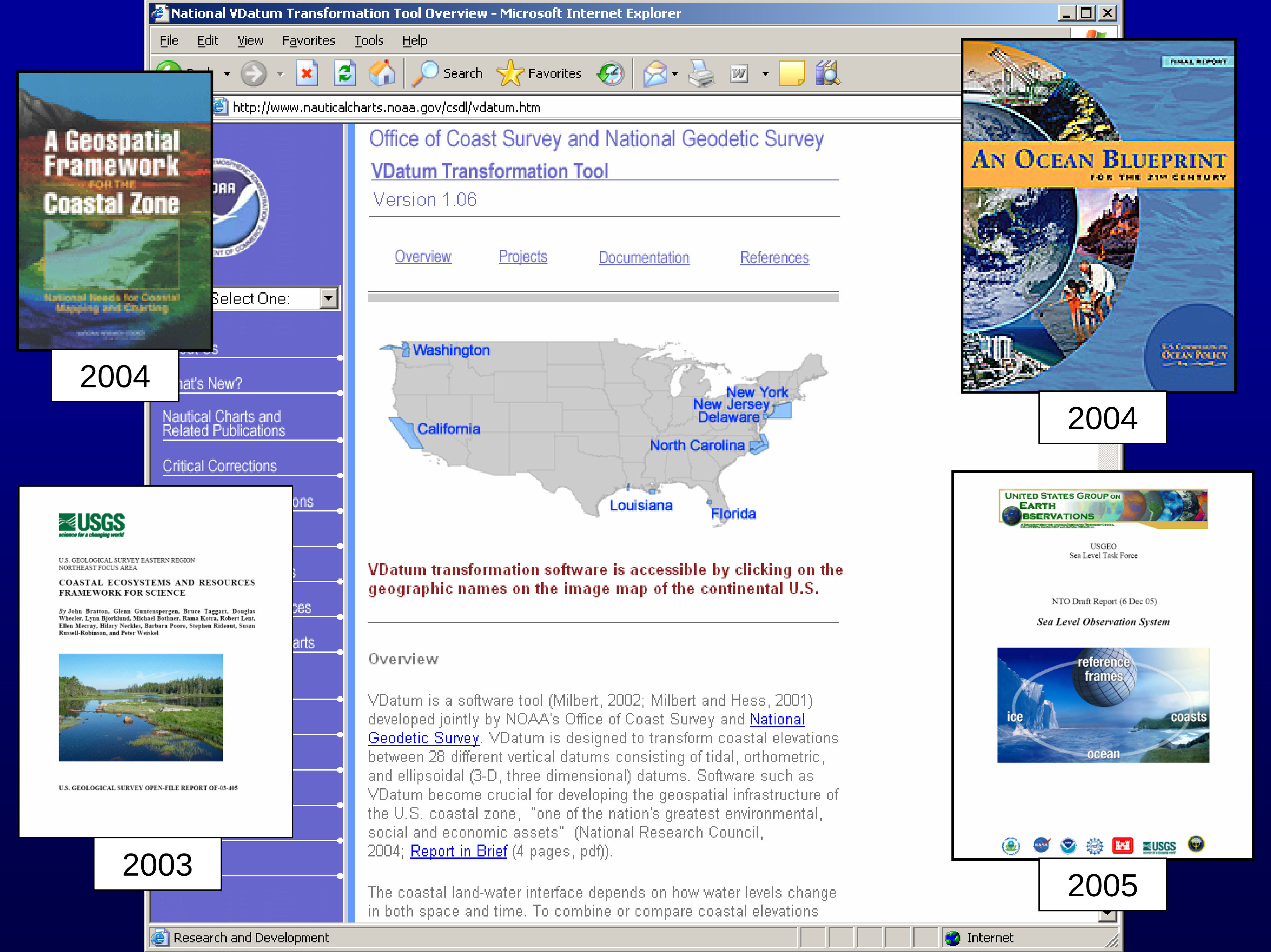


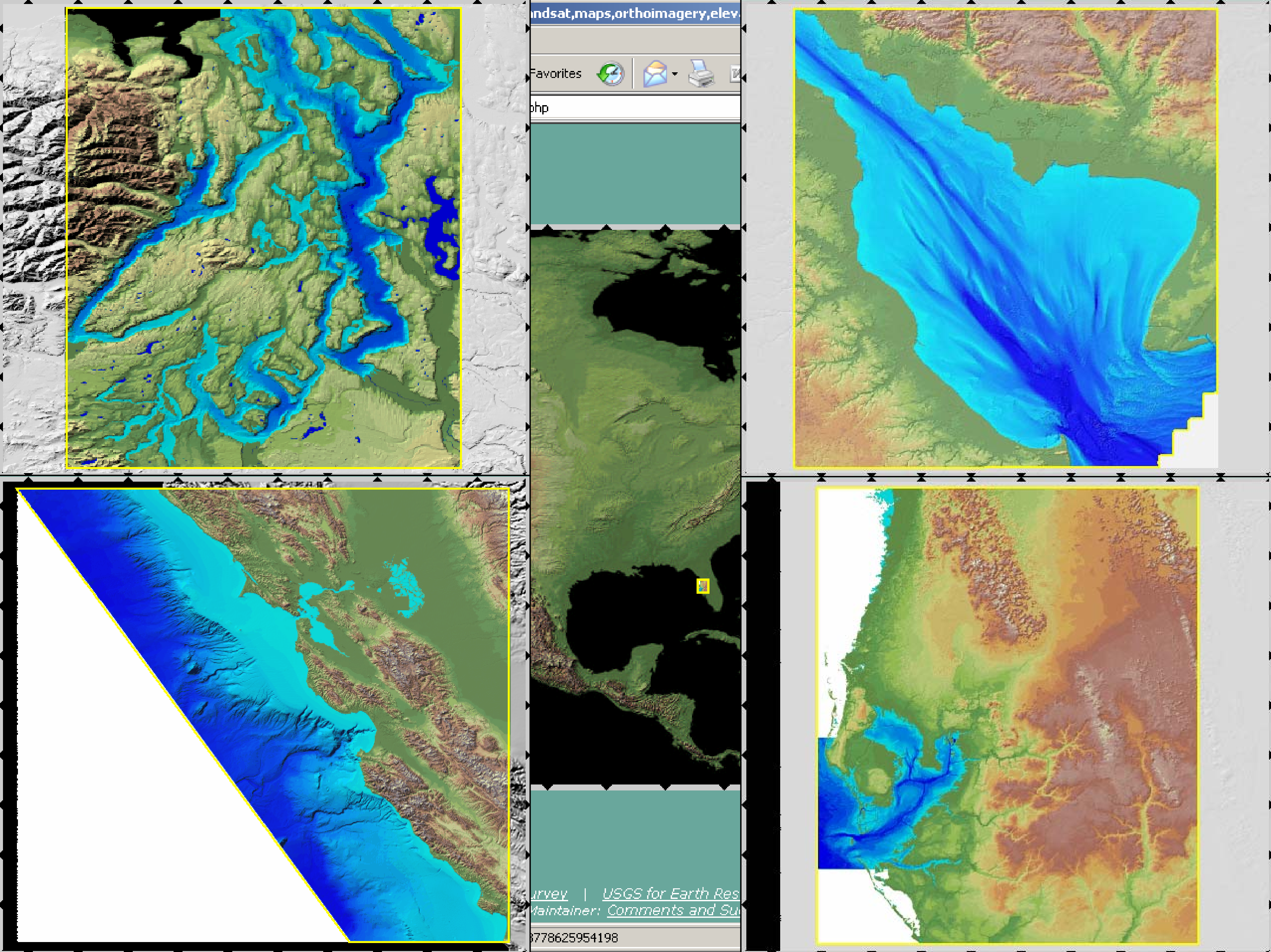




Integrated topo/bathy elevation model

USGS


National VDatum Transformation Tool Overview - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Search Favorites
http://www.nauticalcharts.noaa.gov/csdl/vdatum.htm
Select One:
Nautical Charts and Related Publications
Critical Corrections
Office of Coast Survey and National Geodetic Survey
VDatum Transformation Tool
Version 1.06
Overview Projects Documentation References
Washington
California
New York
New Jersey
Delaware
North Carolina
Louisiana
Florida
VDatum transformation software is accessible by clicking on the geographic names on the image map of the continental U.S.
Overview
VDatum is a software tool (Milbert, 2002; Milbert and Hess, 2001) developed jointly by NOAA's Office of Coast Survey and National Geodetic Survey. VDatum is designed to transform coastal elevations between 28 different vertical datums consisting of tidal, orthometric, and ellipsoidal (3-D, three dimensional) datums. Software such as VDatum become crucial for developing the geospatial infrastructure of the U.S. coastal zone, "one of the nation's greatest environmental, social and economic assets" (National Research Council, 2004; Report in Brief (4 pages, pdf)).
The coastal land-water interface depends on how water levels change in both space and time. To combine or compare coastal elevations
Research and Development
Internet
A Geospatial Framework
FOR THE
Coastal Zone
National Needs for Coastal Mapping and Charting
2004
FINAL REPORT
AN OCEAN BLUEPRINT
FOR THE 21ST CENTURY
U.S. Commission on Ocean Policy
2004
USGS
science for a changing world
U.S. GEOLOGICAL SURVEY EASTERN REGION
NORTHEAST FOCUS AREA
COASTAL ECOSYSTEMS AND RESOURCES FRAMEWORK FOR SCIENCE
By John Bratton, Glenn Guntenspergen, Bruce Taggart, Douglas Wheeler, Lynn Bjorklund, Michael Bothner, Rama Kotra, Robert Lent, Ellen Mecray, Hilary Neckles, Barbara Poore, Stephen Rideout, Susan Russell-Robinson, and Peter Weiskel
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT OF-03-405
2003
UNITED STATES GROUP ON EARTH OBSERVATIONS
USGEO
Sea Level Task Force
NTO Draft Report (6 Dec 05)
Sea Level Observation System
reference frames
ice
coasts
ocean
USGS
2005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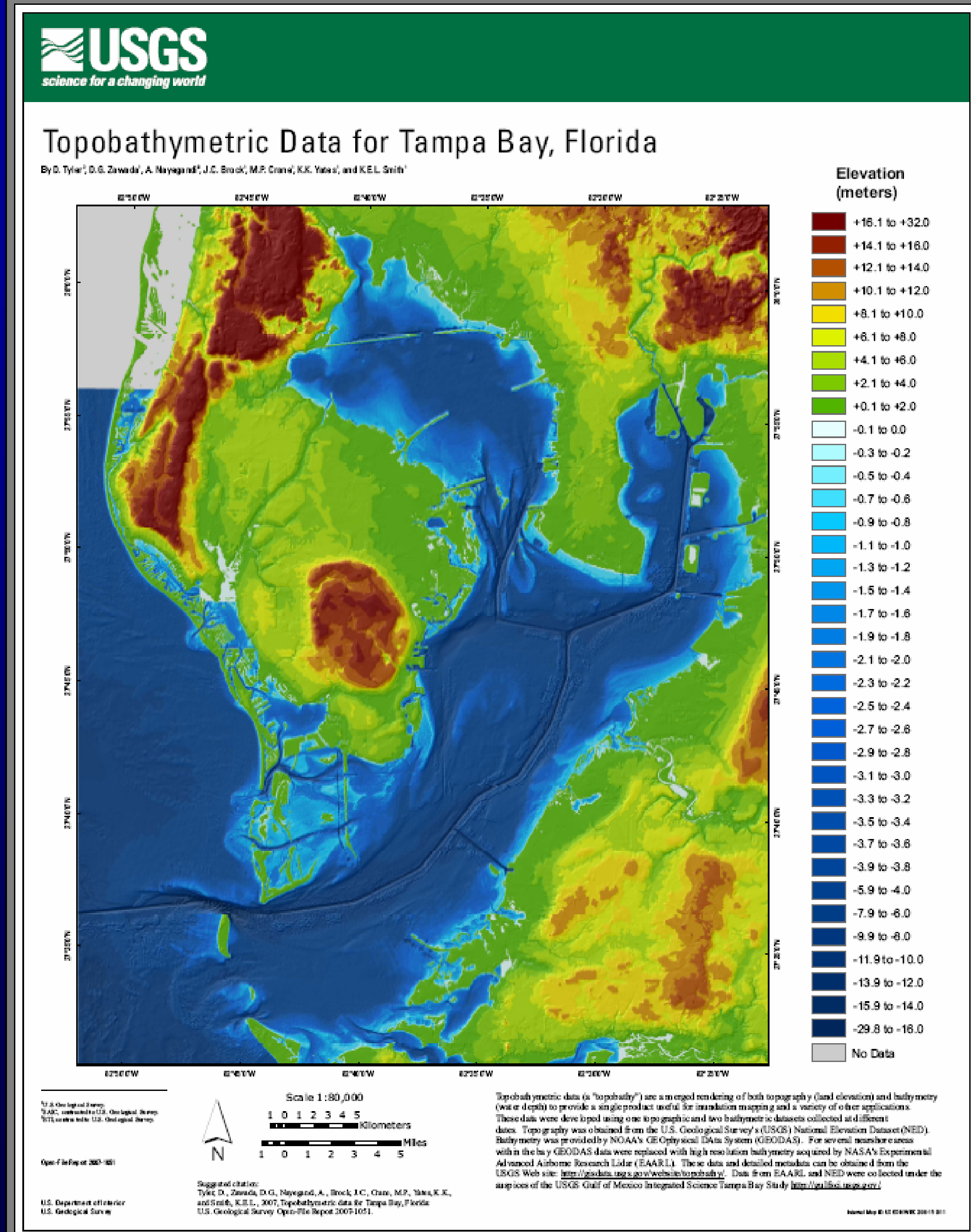
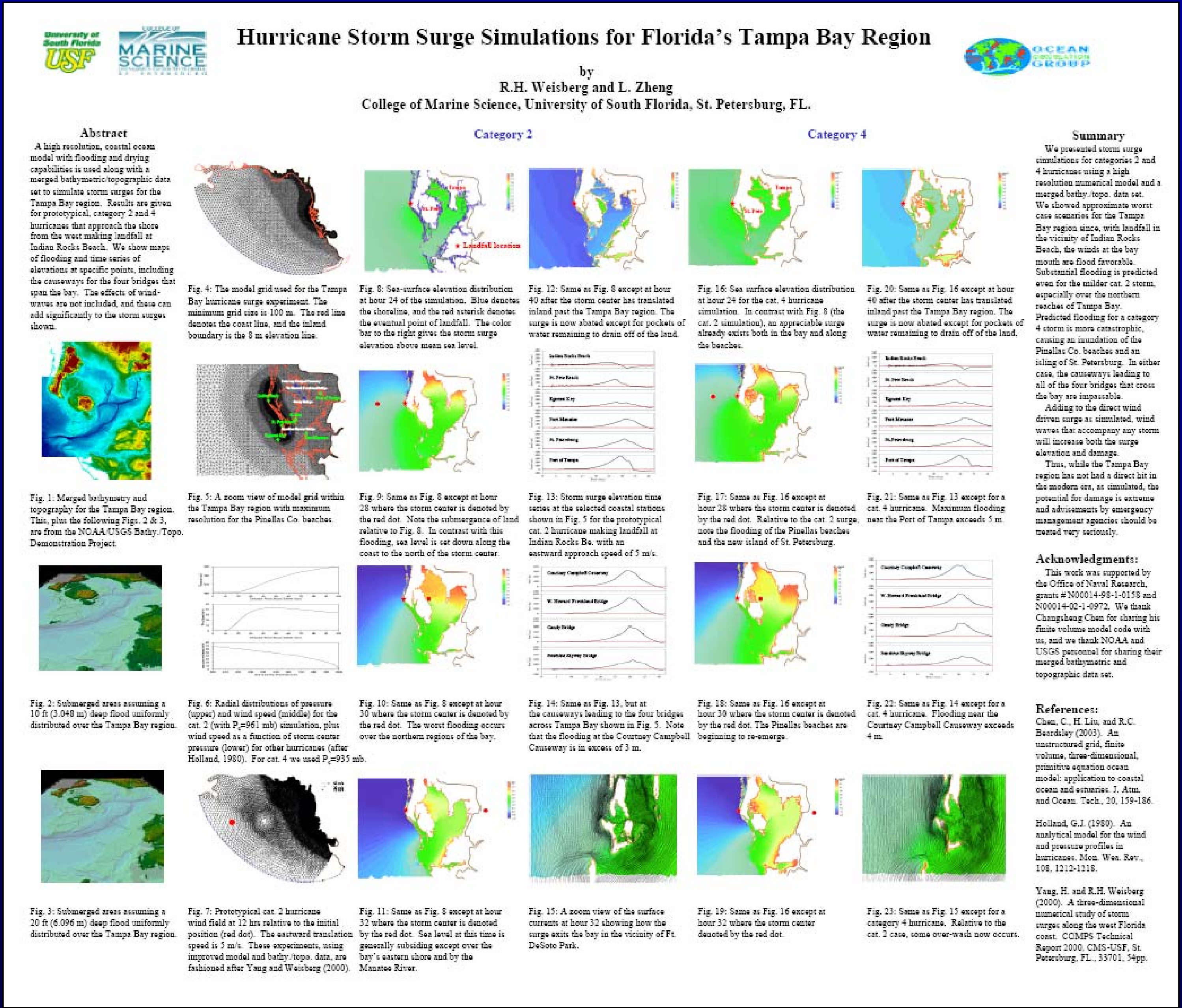

USGS
science for a changing world
Topobathymetric Data for Tampa Bay, Florida
By D. Tyler, D.G. Zawada, A. Nayegandi, J.C. Brock, M.P. Crane, K.K. Yates, and K.E.L. Smith
Elevation (meters)
+16.1 to +32.0
+14.1 to +16.0
+12.1 to +14.0
+10.1 to +12.0
+8.1 to +10.0
+6.1 to +8.0
+4.1 to +6.0
+2.1 to +4.0
+0.1 to +2.0
-0.1 to 0.0
-0.3 to -0.2
-0.5 to -0.4
-0.7 to -0.6
-0.9 to -0.8
-1.1 to -1.0
-1.3 to -1.2
-1.5 to -1.4
-1.7 to -1.6
-1.9 to -1.8
-2.1 to -2.0
-2.3 to -2.2
-2.5 to -2.4
-2.7 to -2.6
-2.9 to -2.8
-3.1 to -3.0
-3.3 to -3.2
-3.5 to -3.4
-3.7 to -3.6
-3.9 to -3.8
-5.9 to -4.0
-7.9 to -6.0
-9.9 to -8.0
-11.9 to -10.0
-13.9 to -12.0
-15.9 to -14.0
-29.8 to -16.0
No Data
Scale 1:80,000
Kilometers
Miles
N
Open-File Report 2007-1051
U.S. Department of Interior
U.S. Geological Survey
Suggested citation:
Tyler, D., Zawada, D.G., Nayegandi, A., Brock, J.C., Crane, M.P., Yates, K.K., and Smith, K.E.L., 2007, Topobathymetric data for Tampa Bay, Florida
U.S. Geological Survey Open-File Report 2007-1051.
Topobathymetric data (a "topobathy") are a merged rendering of both topography (land elevation) and bathymetry (water depth) to provide a single product useful for inundation mapping and a variety of other applications. These data were developed using one topographic and two bathymetric datasets collected at different dates. Topography was obtained from the U.S. Geological Survey's (USGS) National Elevation Dataset (NED). Bathymetry was provided by NOAA's GEOphysical DAta System (GEODAS). For several nearshore areas within the bay GEODAS data were replaced with high resolution bathymetry acquired by NASA's Experimental Advanced Airborne Research Lidar (EAARL). These data and detailed metadata can be obtained from the USGS Web site: http://gisdata.usgs.gov/website/topobathy/. Data from EAARL and NED were collected under the auspices of the USGS Gulf of Mexico Integrated Science Tampa Bay Study http://gulfsci.usgs.gov/

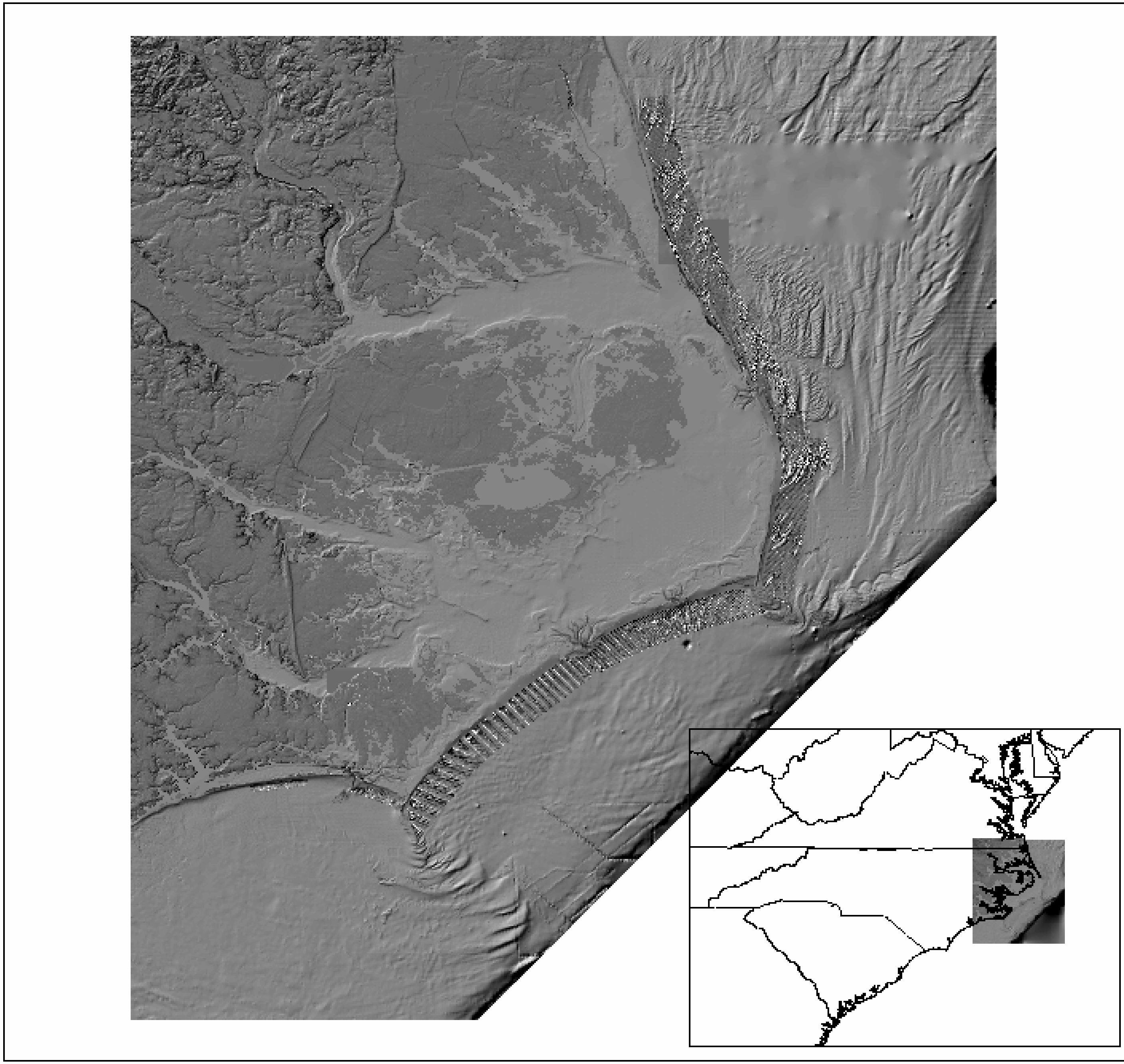
Application: Coastal storm surge modeling

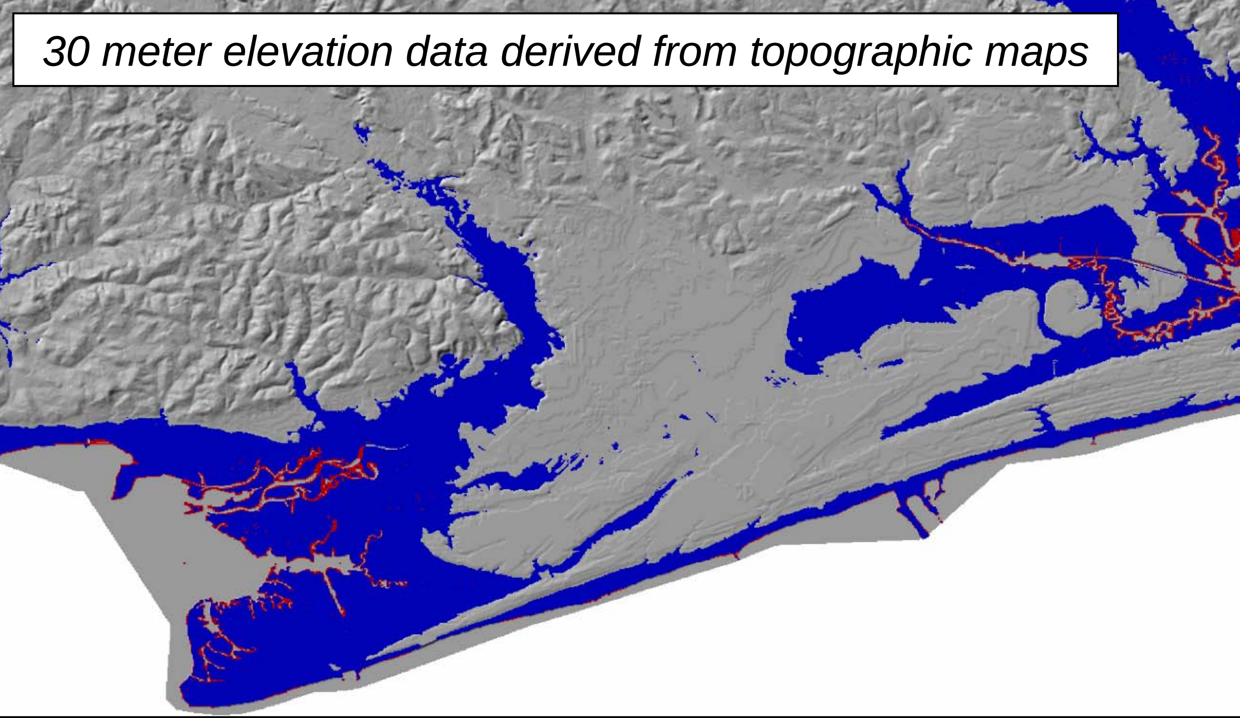


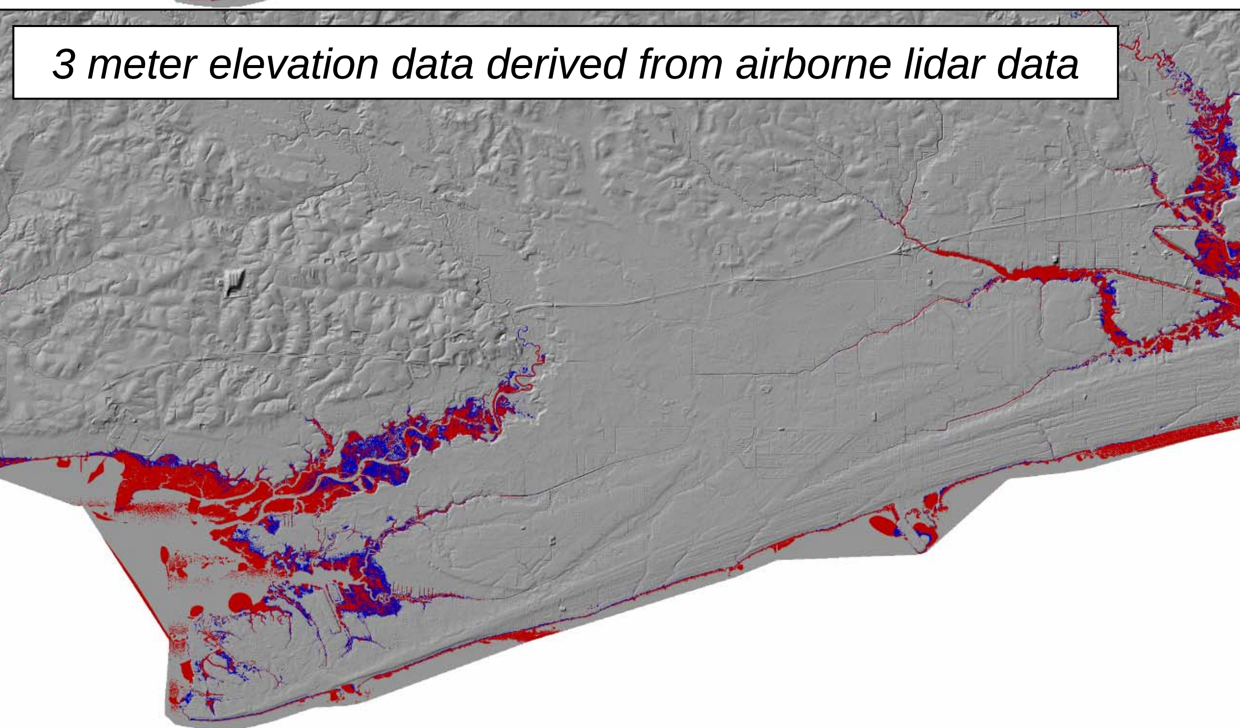
Director's Venture Capital Fund Project

- "Improved Identification and Delineation of Lands Vulnerable to Sea-Level Rise: Communicating the Risk"
- Collaborators:
  - – Woods Hole Science Center (J. Williams, R. Thieler)
  - – Patuxent Wildlife Research Center (D. Cahoon)

North Carolina NED 1/3", NOAA Bathy, LIDAR







Harrison County, MS

Land subject to 1 meter sea level rise

Red = elevation < 1 m

Blue = 95% confidence interval on elevation < 1 m (given vertical accuracy of elevation data)

Eos, Vol. 88, No. 9, 27 February 2007

EOS

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 88 NUMBER 9
27 FEBRUARY 2007
PAGES 105–116

Risk of Rising Sea Level to Population and Land Area

PAGES 105, 107

Low-elevation land areas and their populations are at risk globally from rising sea level. Global sea level has risen by about 2 millimeters per year over the past century. About half of this rise may be attributed to thermal expansion of the ocean and the melting of temperate-latitude glaciers [*Dyurgerov and Meier*, 1997]. The remainder of the rise is believed to come from a net loss of mass from the Antarctic and Greenland ice sheets, although the exact contribution is unknown.

Throughout the next century, the rate of sea level rise is expected to increase due to greenhouse warming, with the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concluding that the rise of global average sea level by 2100 will be in the range from 18–38 to 26–59 centimeters depending on the emissions scenario [*IPCC*, 2007]. However, this assessment does not take into account the rapid changes in ice sheet mass flux that have been observed since 2003 [e.g., *Rignot and Kanagaratam*, 2006], and therefore actual sea level changes may be larger than predicted by the IPCC.

If the rate of sea level rise increases substantially, it will cause serious and direct environmental impacts to many low-lying coastal areas around the world. Such impacts include increased beach erosion, loss of vital agricultural and cultural resources, and, as we will show here, potential inundation of thousands of square kilometers of coastal land and the resulting displacement of millions of coastal residents. These outcomes will be complex and in some cases may be mitigated, but it is important to understand their general scope.

Using recently produced global elevation and population data sets, we took an 'inundation' approach to determine land area lost and current population affected by hypothetical sea level increases between 1 and 6 meters.

By R. J. Rowley, J. C. Kostelnick, D. Braaten, X. Li, and J. Meisel

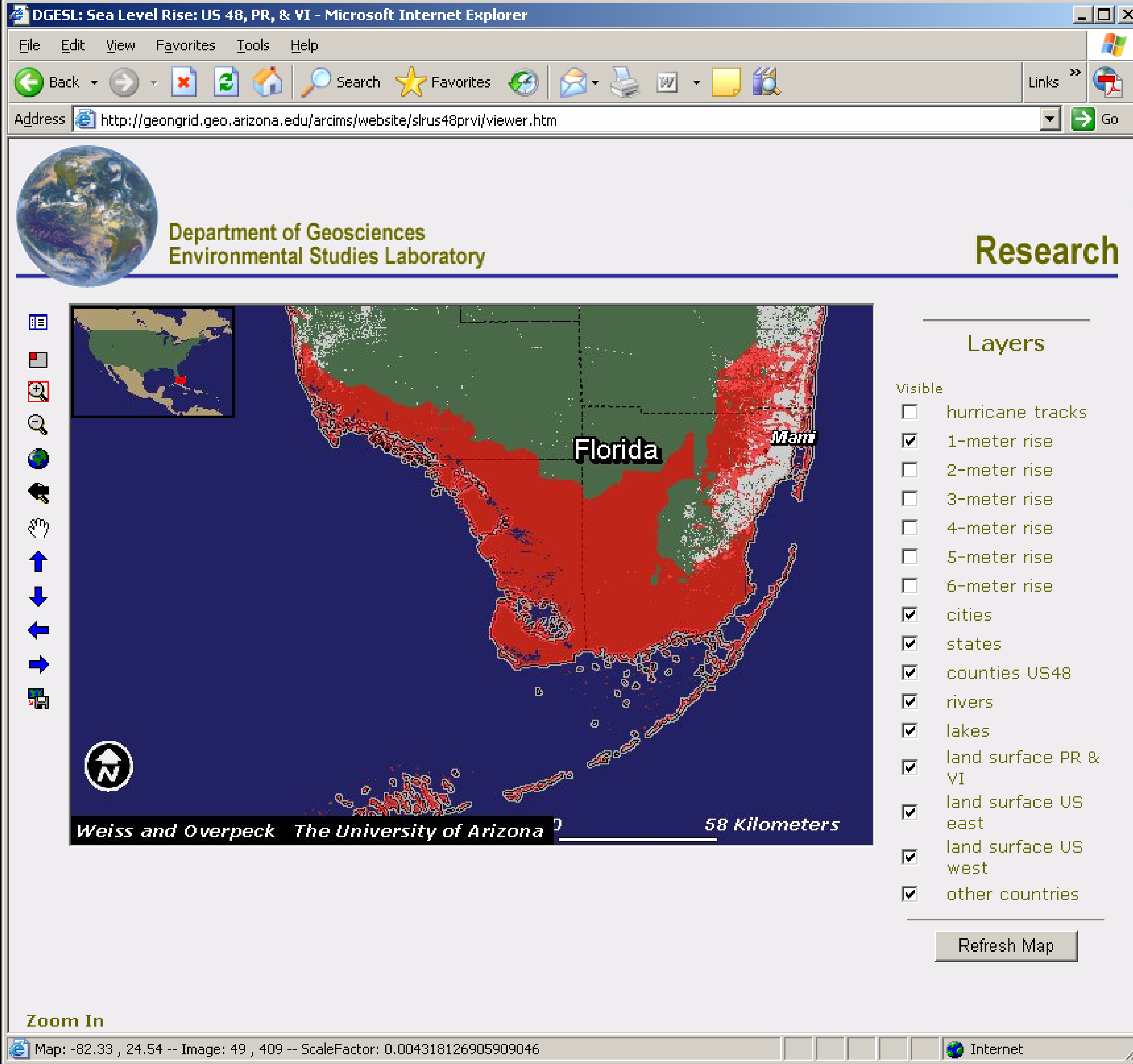
Elevation and Population Data Sets

Inundation zones were calculated from the Global Land One-Kilometer Base Elevation (GLOBE) digital elevation model (DEM) [*Hastings and Dunbar*, 1998], a raster (i.e., gridded) elevation data set covering the entire world. Cells in GLOBE have a spatial resolution of 30 arc seconds of latitude and longitude (approximately 1 kilometer at the equator), with each land cell in the grid assigned an elevation value (meters) in whole-number increments. GLOBE was developed through a collaboration of international experts and was compiled from the best global and regional raster (e.g., DEMs) and vector (e.g., contours) elevation data sets available at the time of compilation.

In addition to GLOBE, inundation zones were also computed from the ETOPO2 raster elevation data set developed by the NOAA National Geophysical Data Center (NGDC) [*NOAA NGDC*, 2001]. The coarser resolution of ETOPO2 (2 minutes of latitude and longitude; approximately 3.7 kilometers at the equator) is ideal for visualizing the inundation process on a map animation of the entire world (see available products, discussed below).

Populations in the inundation zones were estimated from LandScan, a global population data set developed by the Oak Ridge National Laboratory Global Population Project for estimating populations at risk [*Dobson et al.*, 2000]. LandScan was compiled from the best available population census data for each country that were then disaggregated into cells based on land cover type, proximity to roads, slope, and nighttime lights (see *Dobson et al.* [2000] for discussion of the data sets and methods used to develop LandScan as well as data set validation and verification results). LandScan has been used for a variety of humanitarian applications, such as estimating populations affected by natural disasters and wartime conflicts. A particular advantage of using LandScan in this study is that the spatial res-

Fig. 1. Inundation of 6 meters (in red) for portions of the southeastern United States, Central America, and the Caribbean. Land cover and shaded relief map from Natural Earth, Tom Patterson, U.S. National Park Service.



DGESL: Sea Level Rise: US 48, PR, & VI - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back
Search
Favorites
Links
Address
http://geongrid.geo.arizona.edu/arcims/website/slrus48prvi/viewer.htm
Go
Department of Geosciences
Environmental Studies Laboratory
Research
Florida
Miami
Weiss and Overpeck The University of Arizona
58 Kilometers
Layers
Visible
hurricane tracks
1-meter rise
2-meter rise
3-meter rise
4-meter rise
5-meter rise
6-meter rise
cities
states
counties US48
rivers
lakes
land surface PR & VI
land surface US east
land surface US west
other countries
Refresh Map
Zoom In
Map: -82.33 , 24.54 -- Image: 49 , 409 -- ScaleFactor: 0.004318126905909046
Internet

Concluding Thoughts

- Elevation data derived from recent, high resolution, high quality lidar surveys facilitates storm surge applications
  - Allows applications in low relief coastal areas that aren't possible with older, lower resolution, cartographically-derived elevation data
- Pre-assembled, pre-staged lidar-derived bare earth elevation data aids storm response and recovery operations