Louisiana's Height Modernization Efforts

Joshua D. Kent, PhD
Louisiana Spatial Reference Center

2014 National Height Modernization Partner's Meeting

April 29, 2014 | Mobile, Alabama

Presentation Overview

- Center Overview and Program Background
- Challenges facing Louisiana's Vertical Control
- Current Height Modernization Efforts
- Addressing Challenges in the Short & Long Term
- Conclude

Center Overview & Background

Center for GeoInformatics (C4G) and the LA Spatial Reference Center (LSRC)

- 2001 - C4G established in in College of Engineering at LSU
- 2002 - LSRC established to promote the utilization of the National Spatial Reference System (NSRS)
- 2004 – Louisiana CORS Network
  - 18 continuous GPS Reference Stations

Center Overview & Background

Center for GeoInformatics (C4G) and the LA Spatial Reference Center (LSRC)

- 2006 – LSU CORS network becomes a Legal Source for elevations in LA (R.S. 50:173.1)
- 2007 – Established Real-Time Network (RTN)
- 2009 – GNSS Integration within the RTN

Who Are the LSRC?

George Z. Voyiadjis, Boyd Professor
Interim Director: Civil & Environmental Engineering

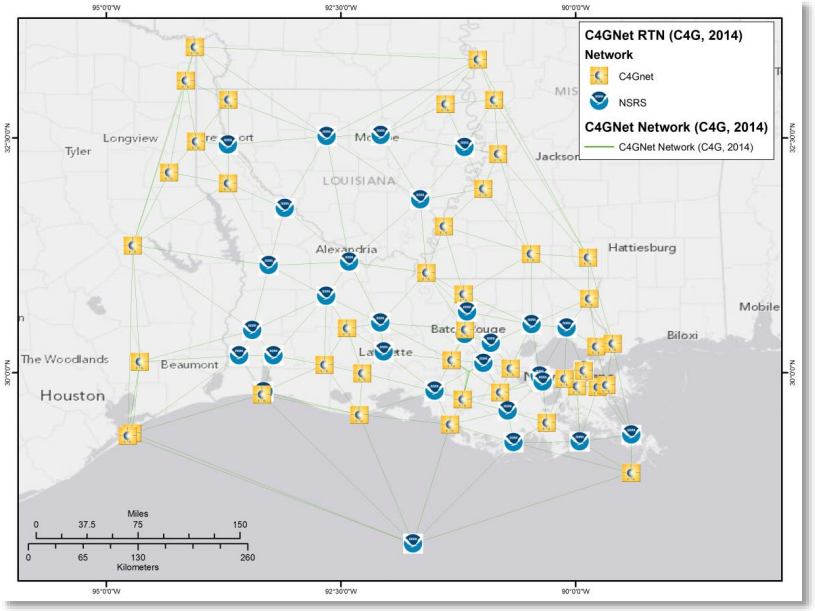
Clifford Mugnier
Instructor & Chief of Geodesy

Randy Osborne
Network Administrator

Larry Dunaway
Field Operations Manager

J. Anthony Cavell
Surveyor

Joshua D. Kent
GIS Manager



Why Height Modernization in Louisiana?

Relative Sea Level Rise in Louisiana:

> 10mm year^{-1} since 1932

- ~1 football field hour $^{-1}$

South of Chauvin, Louisiana
Terrebonne Parish
Photo provided by Terrebonne Levee & Conservation District

Why Height Modernization in Louisiana?

Engineering and design, community development, and hazard mitigation planning depend on accurate land elevations and bathymetry.

Why Height Modernization in Louisiana?

The lack of consistent, reliable Vertical Control has lead to compromised DEMs, unrealistic surge models, inaccurate flood maps that fail to reveal risk, and historically misguided coastal planning policy.

Photo by Tim Osborne (NOAA)

Tropical Storm Lee Inundates LA Hwy-1

Why Height Modernization in Louisiana?

Significant Consequences to Natural Resource Planning and Cultural Sustainability…

Water swamps tombs at this 105 year old cemetery in Leeville, LA

(© James Wray/ EPA/BEVIL KNAPP, 2010)

Why Height Modernization in Louisiana?

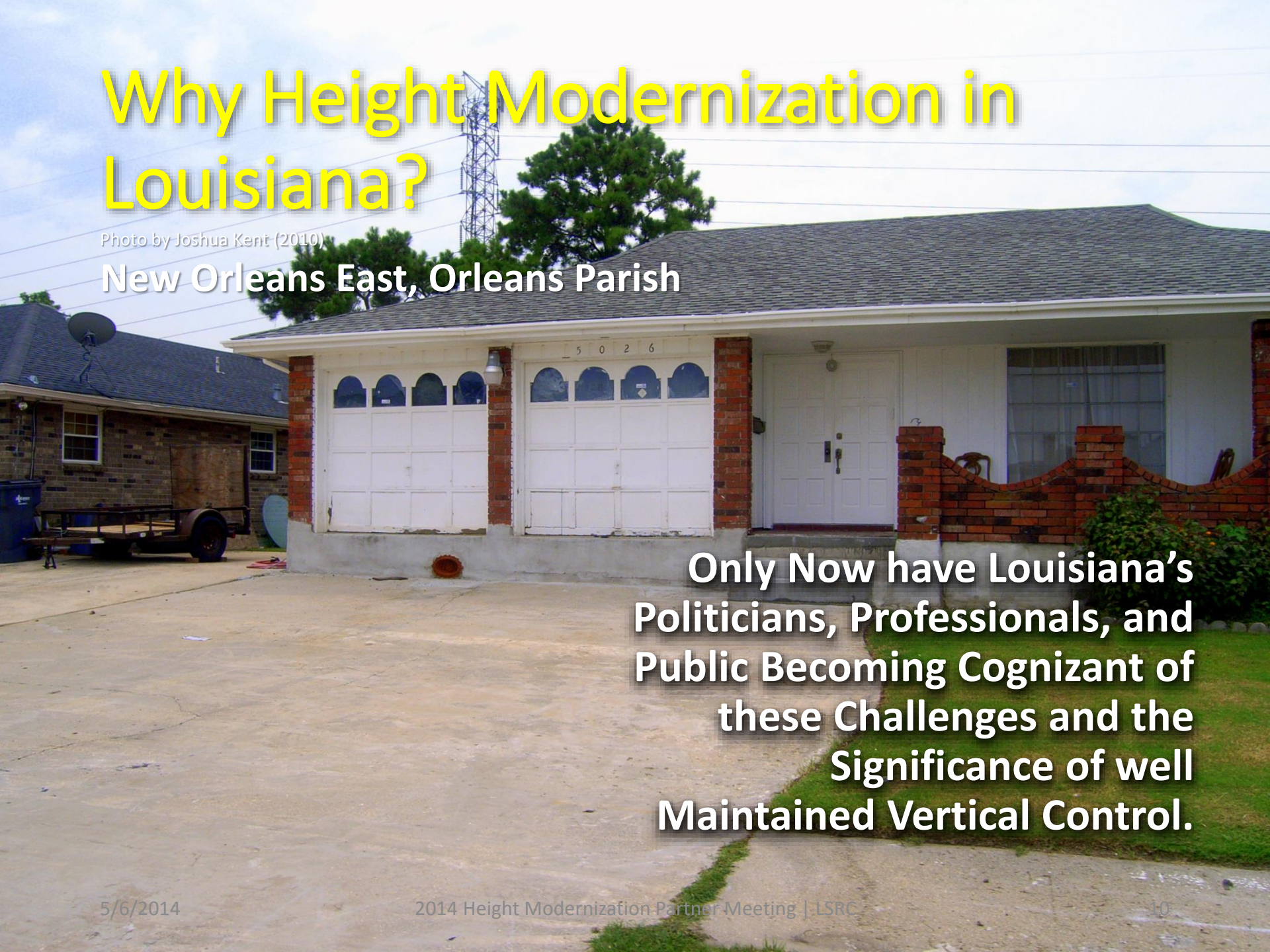
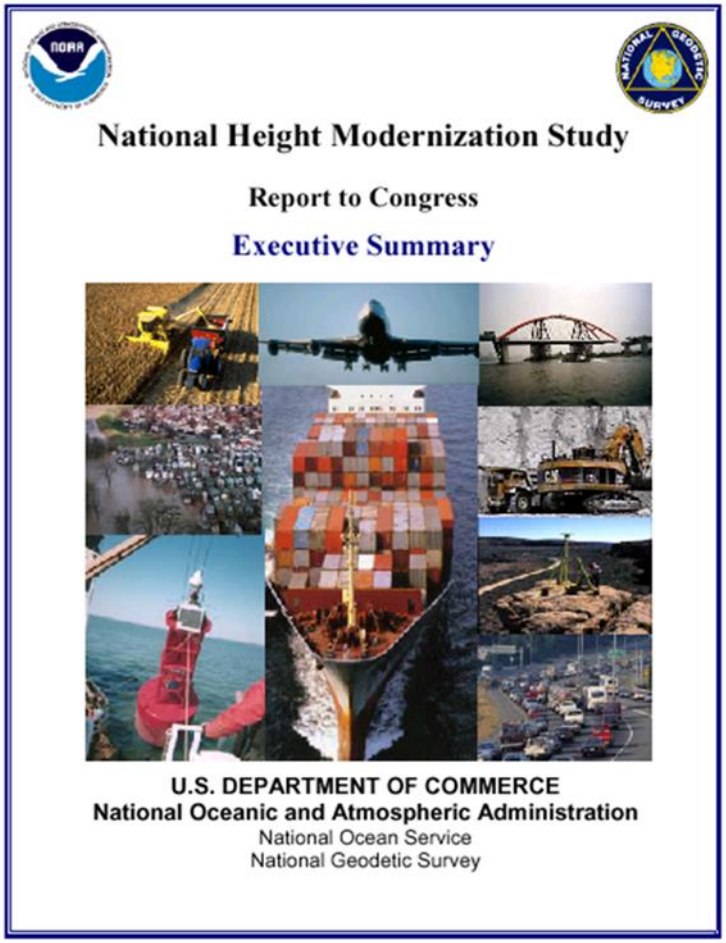


Photo by Joshua Kent (2010)

New Orleans East, Orleans Parish

Only Now have Louisiana's Politicians, Professionals, and Public Becoming Cognizant of these Challenges and the Significance of well Maintained Vertical Control.

Maintaining Vertical Control in LA



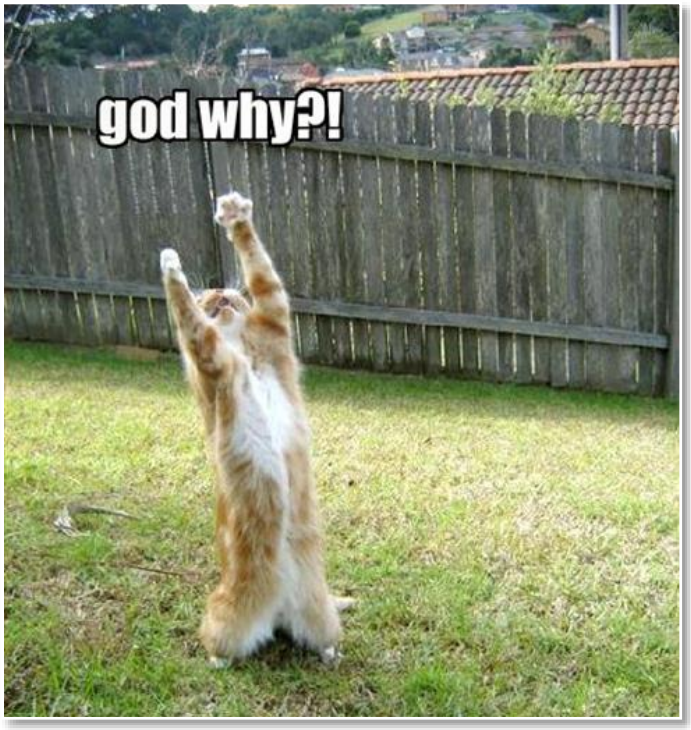
2001 Report to Congress: geodetic vertical control in LA was:

"obsolete, inaccurate, and unable to ensure public safety "

- Accurate elevations were not available until 2005.
- Elevations used between 2001 and 2005 were highly suspect.

Subsidence!

- Conventional wisdom considered subsidence to be **constant in time and space**…
- Analysis of data as a function of depth shows that **subsidence varies in time and space**.
- To measure subsidence, we need to **better understand the processes**.



The Significance of Subsidence

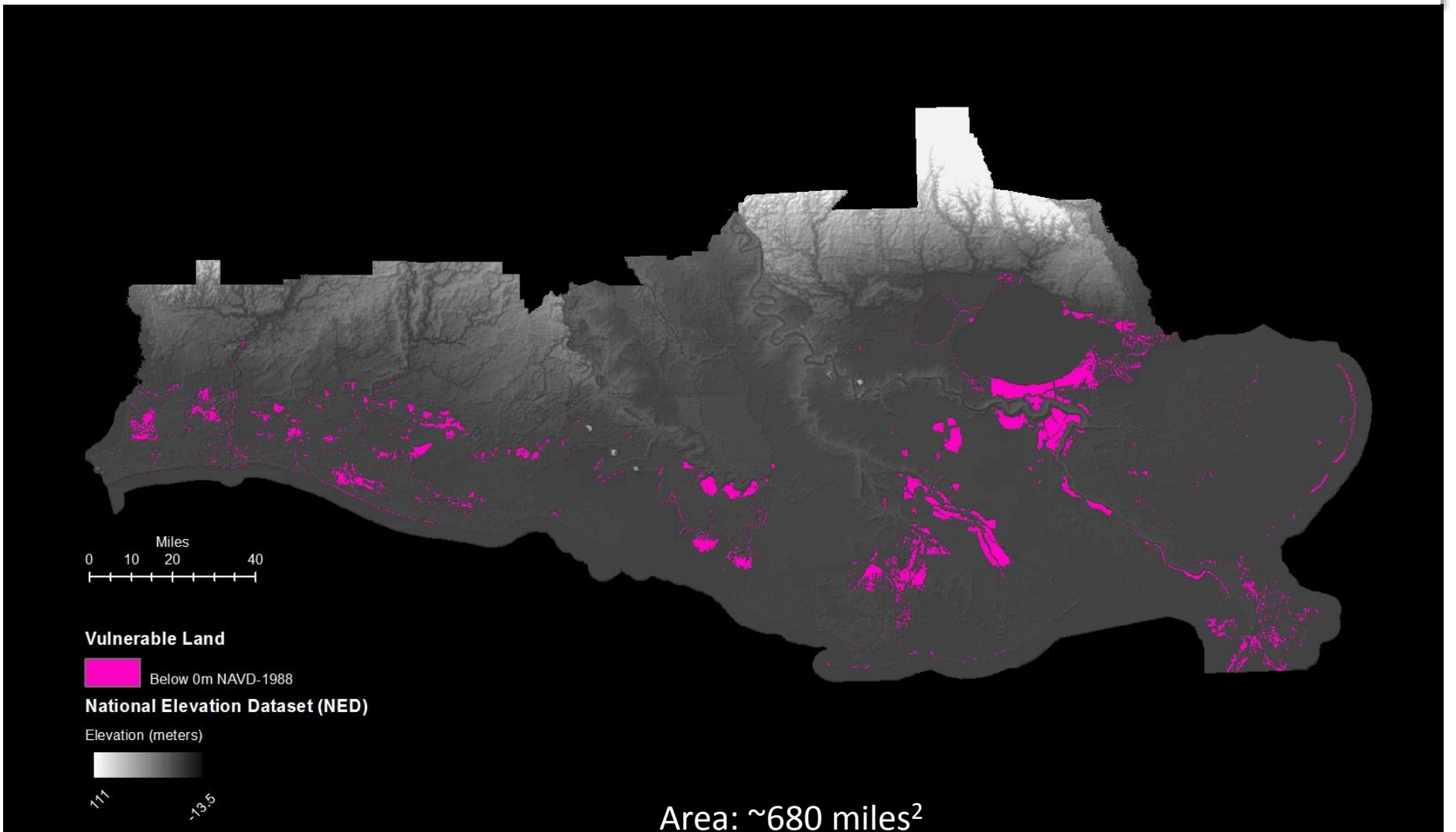
Using a Deterministic Model to Illustrate the Impact of Subsidence Across Southern Louisiana:

- Look at impact of subsidence on our landscape and communities.
- Project these rates into the future…
  - 2015
  - 2025
  - 2050
  - 2100

Jurassic Park, 1993

Land at or Below ‘Sea Level’

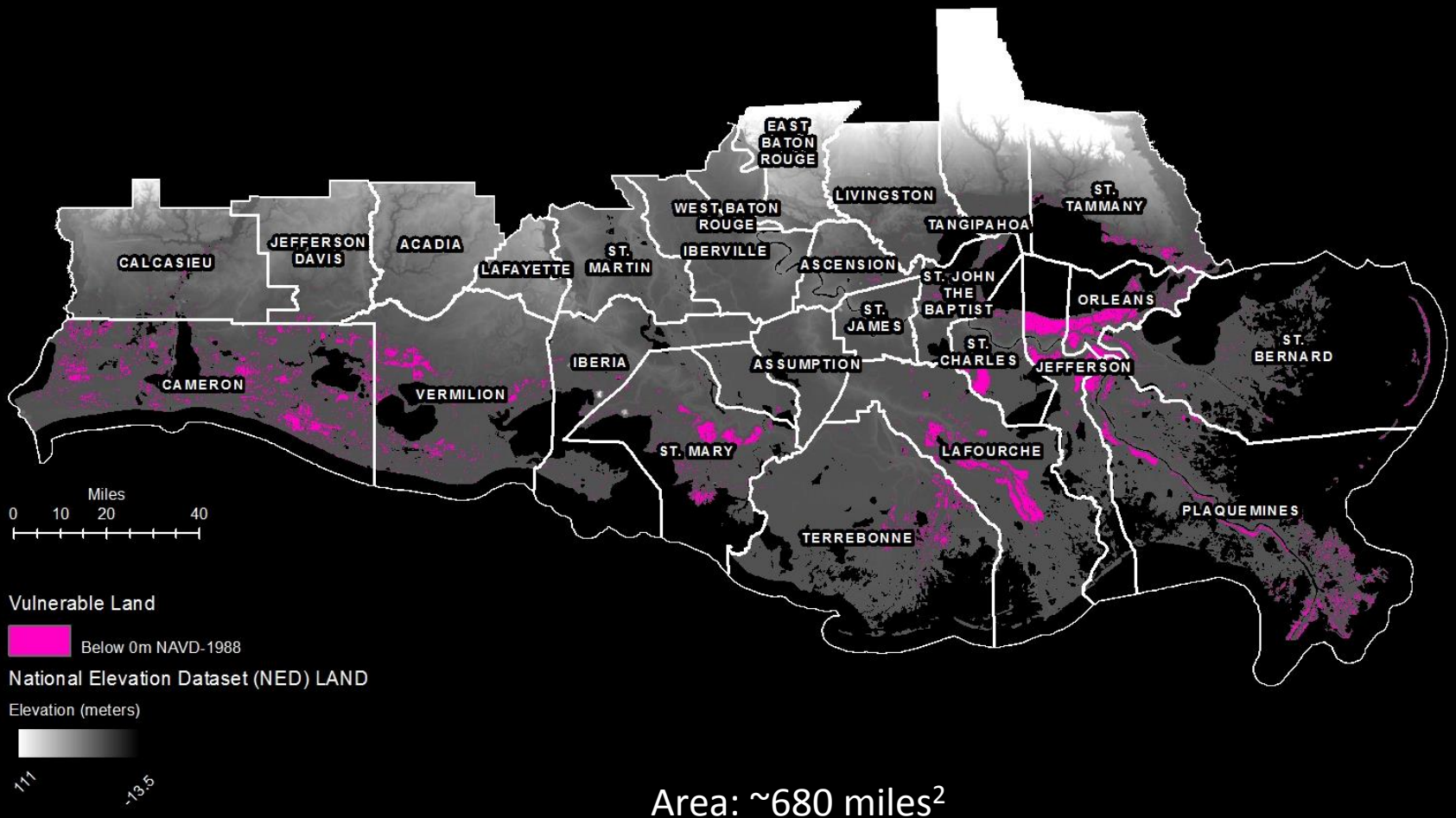
~10m USGS Composite DEM: 2002 - 2008



Area: ~680 miles^2

Land at or Below ‘Sea Level’

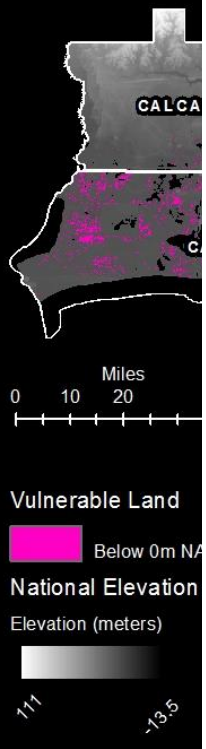
~10m USGS Composite DEM: 2002 - 2008

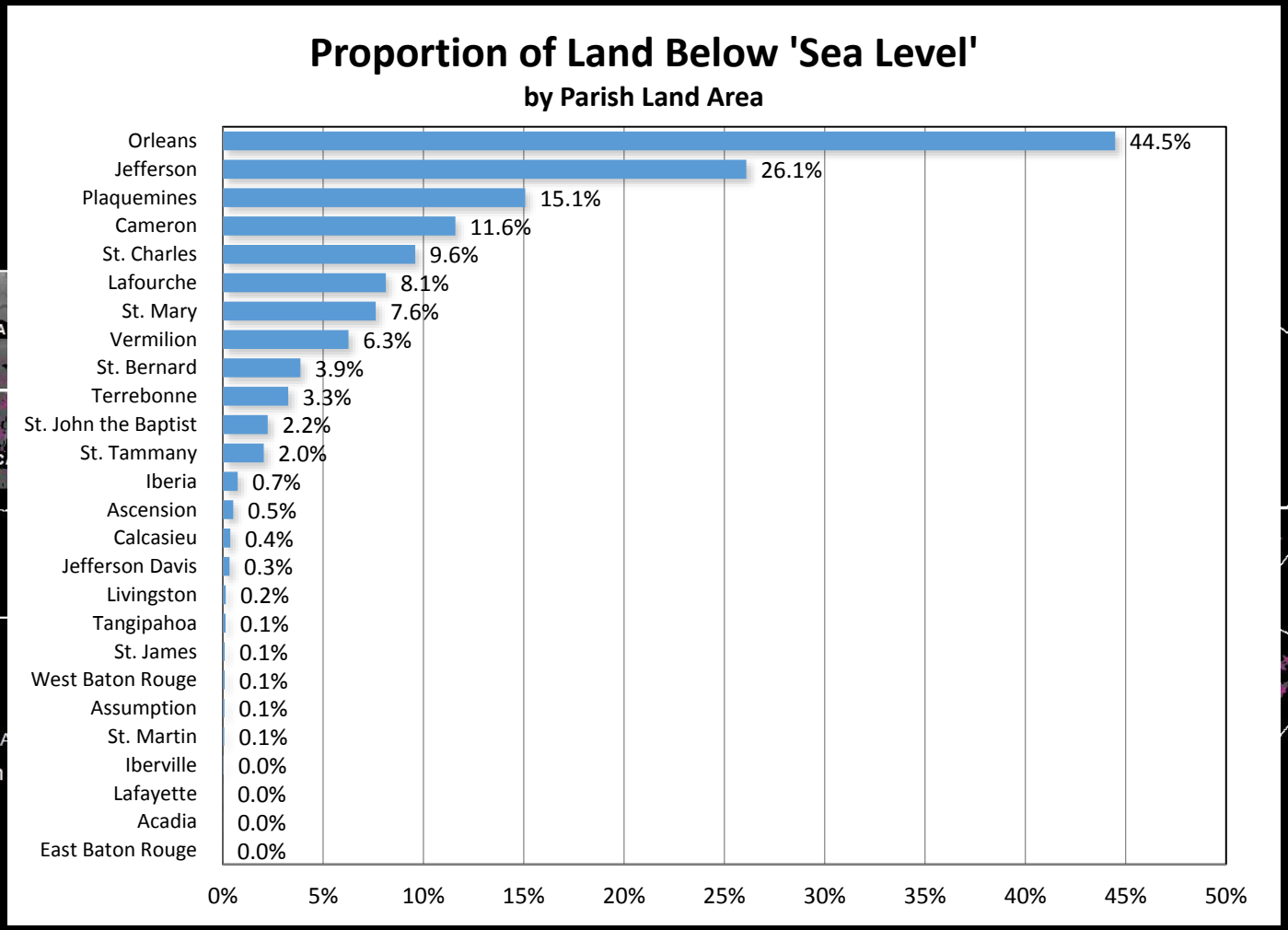


Area: ~680 miles^2

Land at or Below 0m NAVD88

~10m USGS Composite DEM: 2002 - 2008

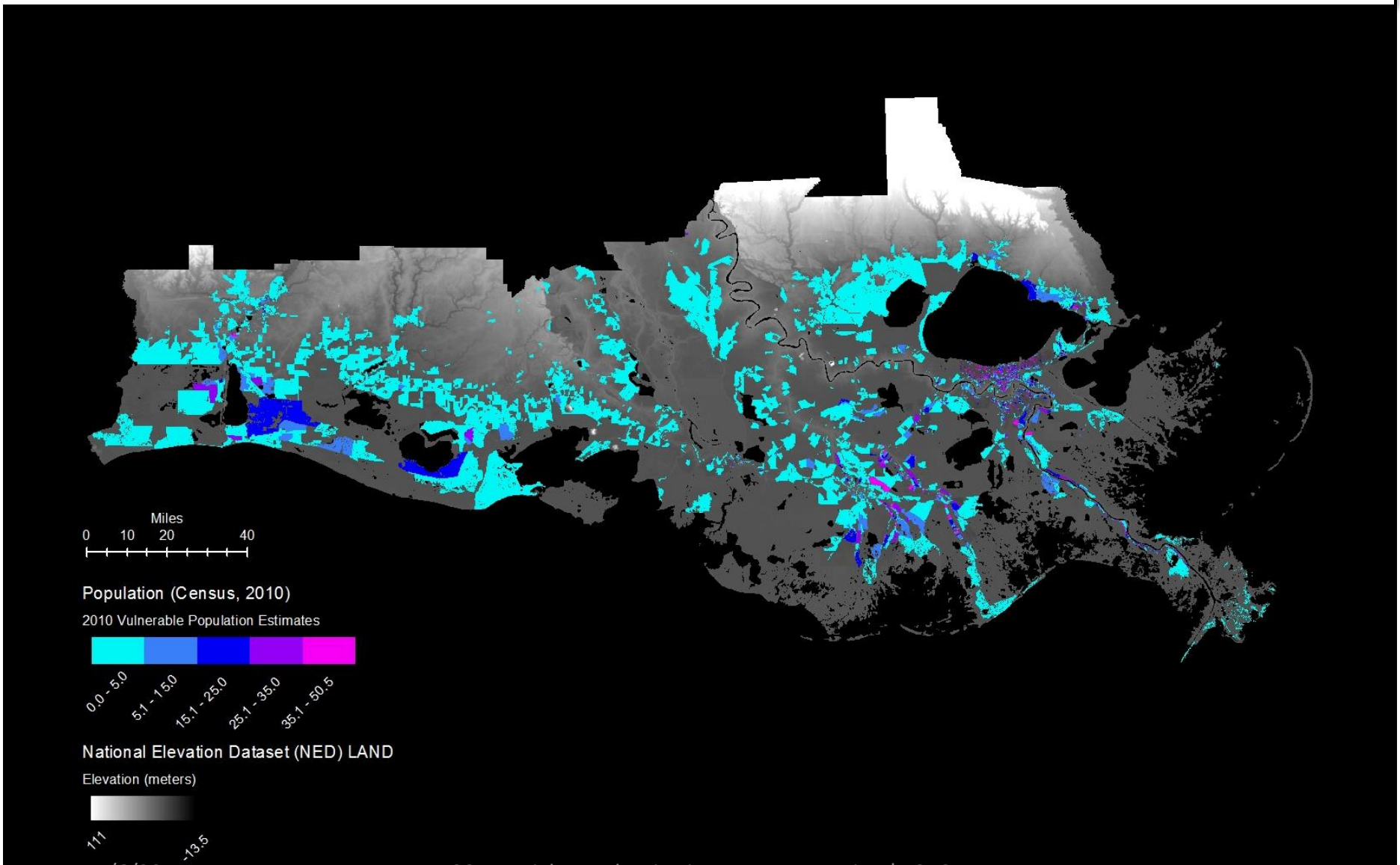




(4.5%)

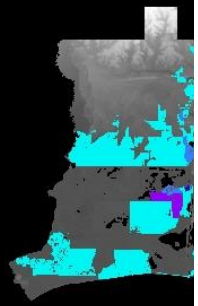
Populations at or Below 0m NAVD88

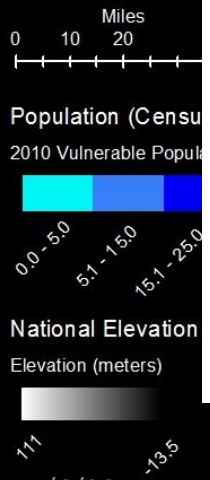
2010 Census Demographics: Households ≤ Sea Level

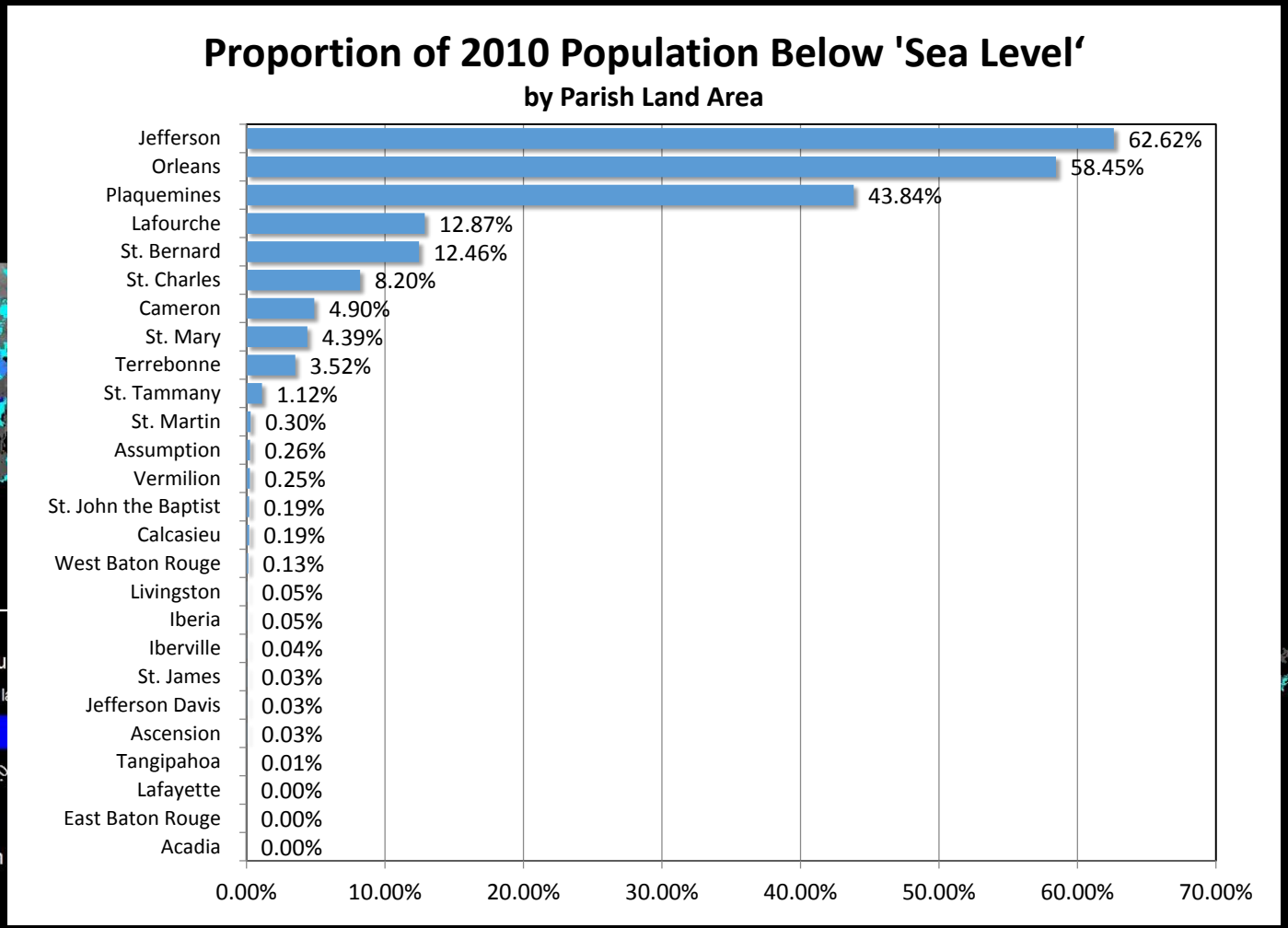


Populations at or Below 0m NAVD88

2010 Census Demographics: Households ≤ Sea Level





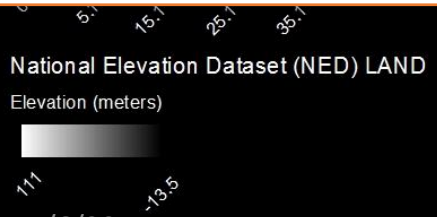


Populations at or Below 0m NAVD88

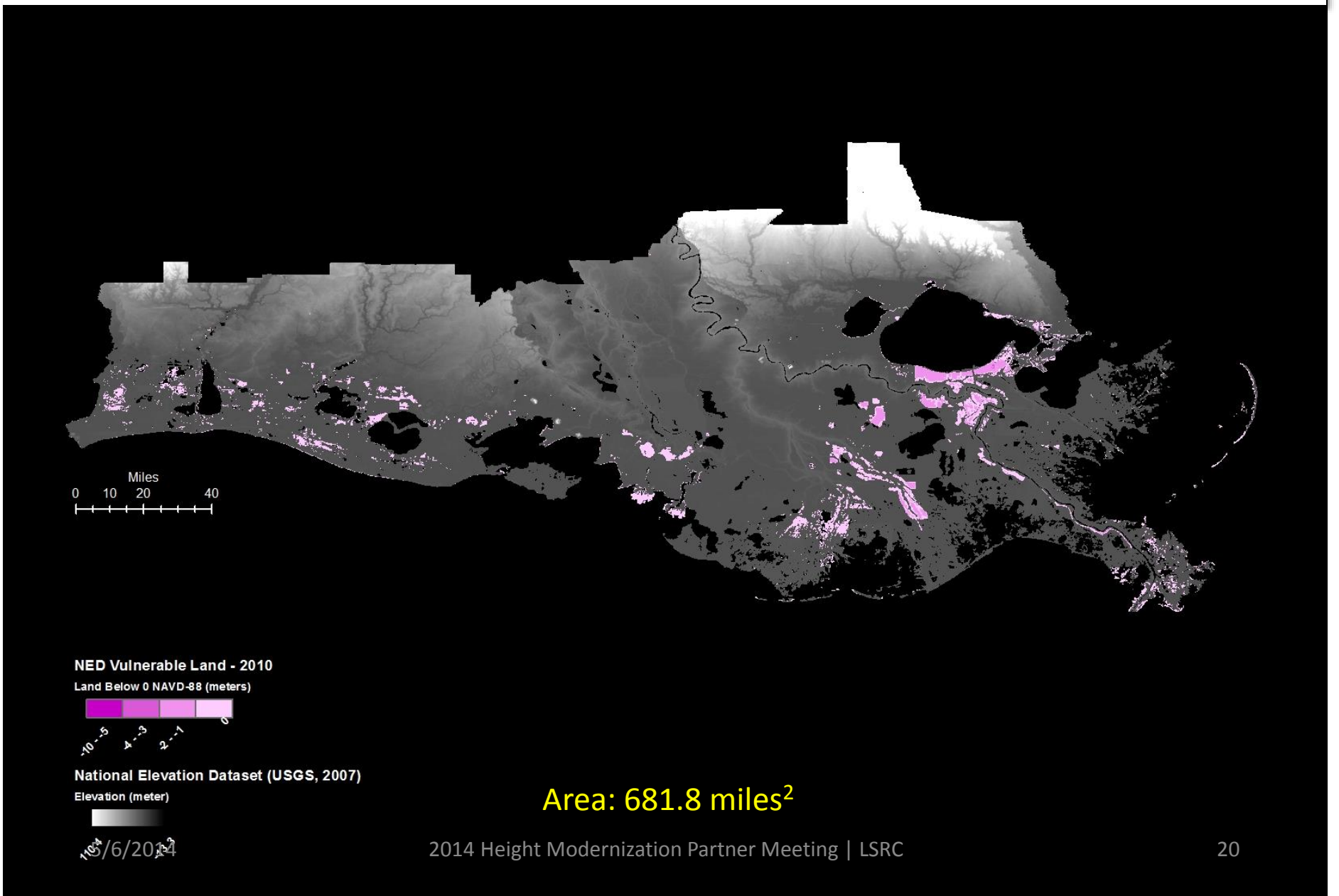
2010 Census Demographics: Households ≤ Sea Level

Subsidence Increases Our Vulnerability to Disaster and Challenges How We Choose to Occupy the Landscape

Communities inhabiting the landscape are at constant risk of flooding in inundation.

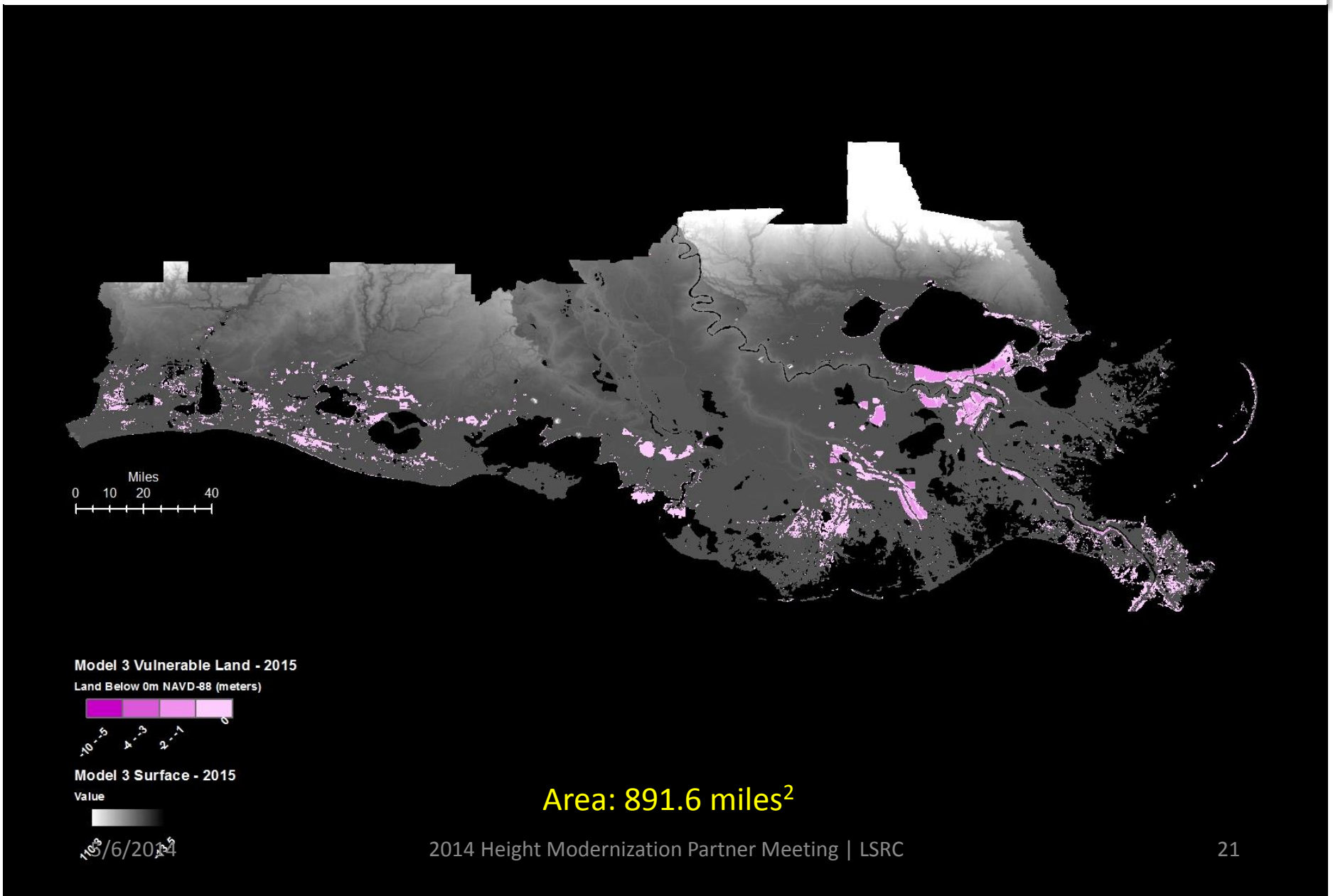


Existing Condition: 2010



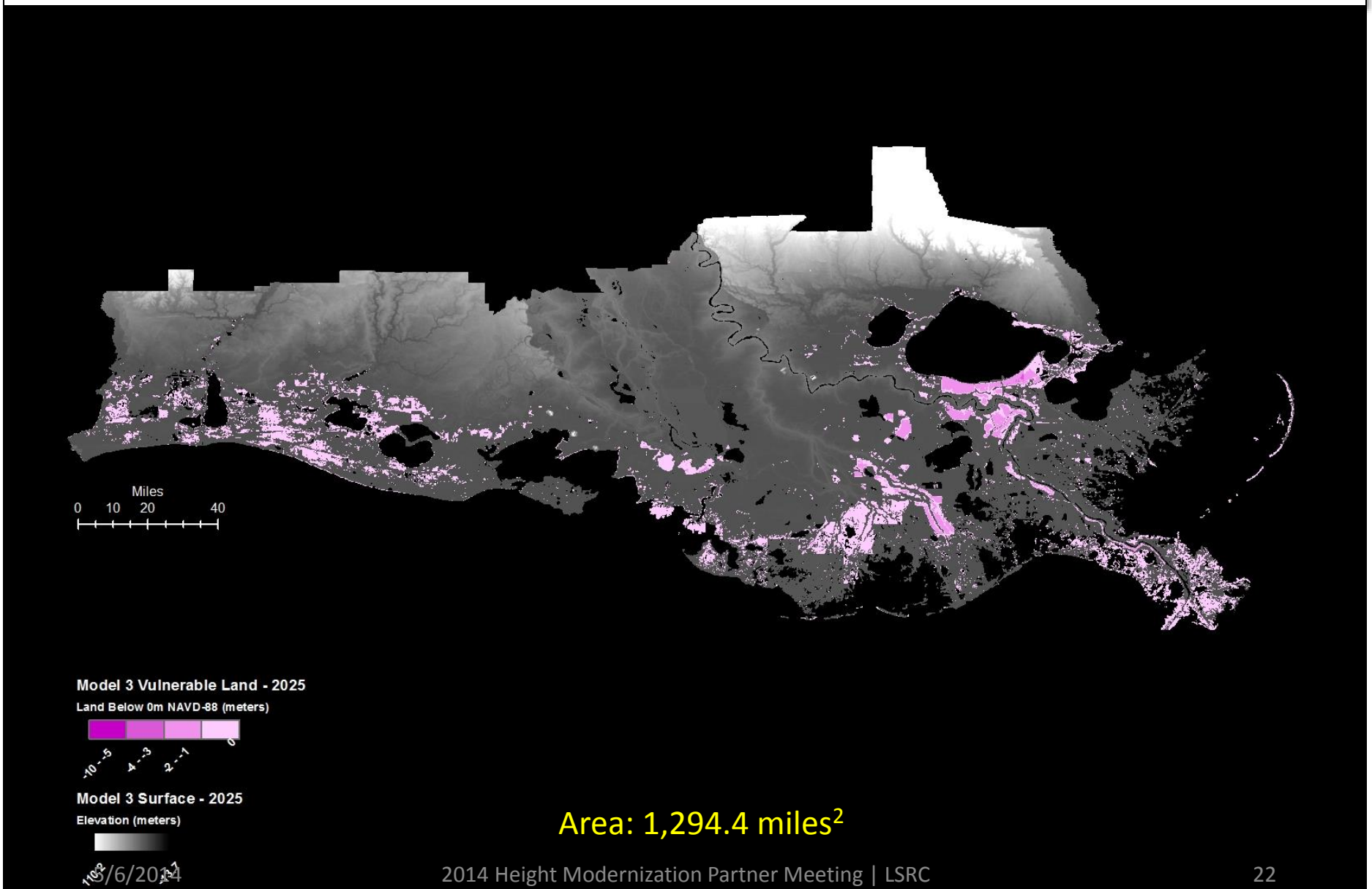
Area: 681.8 miles^2

Model Results: 2015



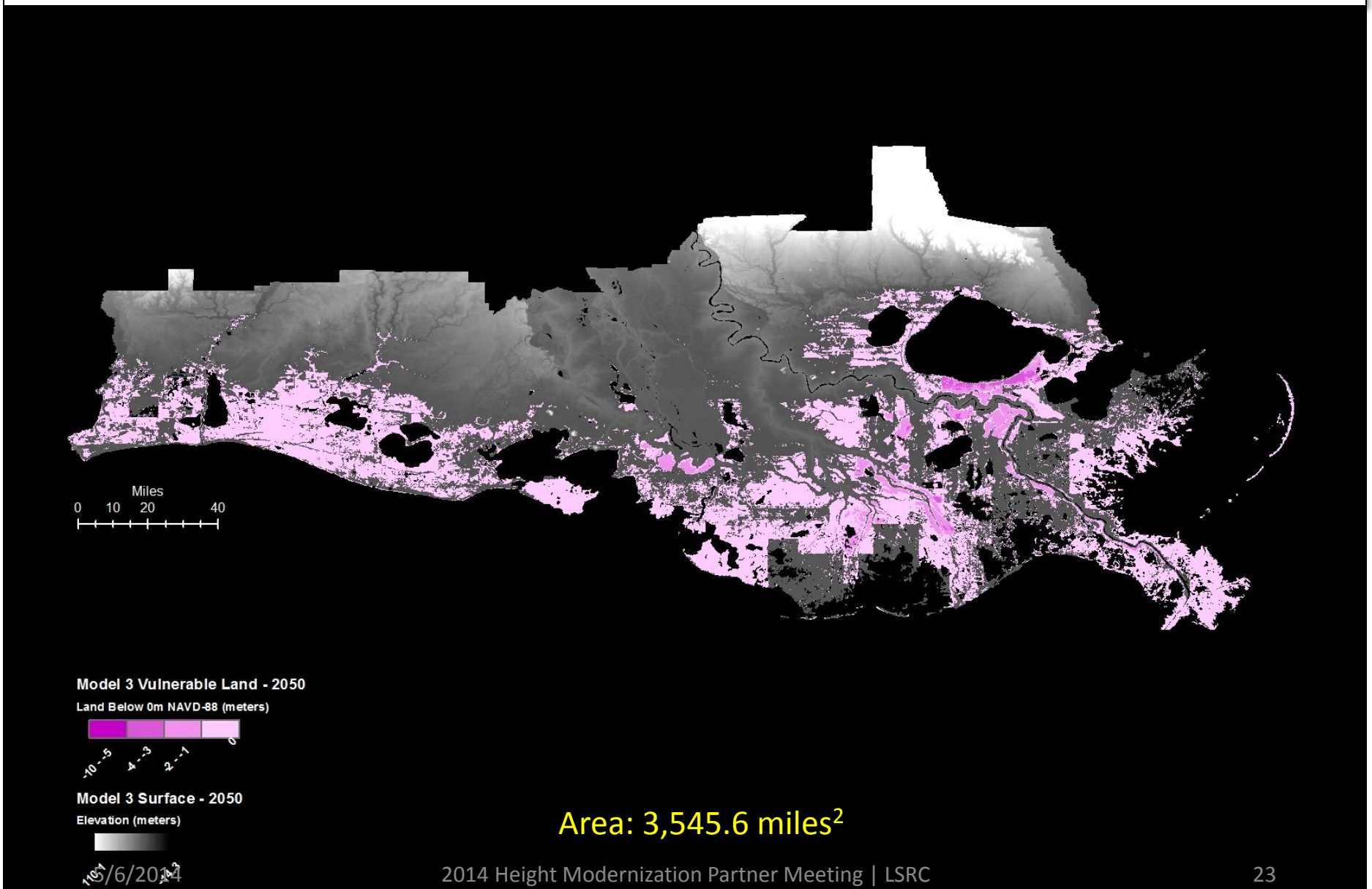
Area: 891.6 miles^2

Model Results: 2025



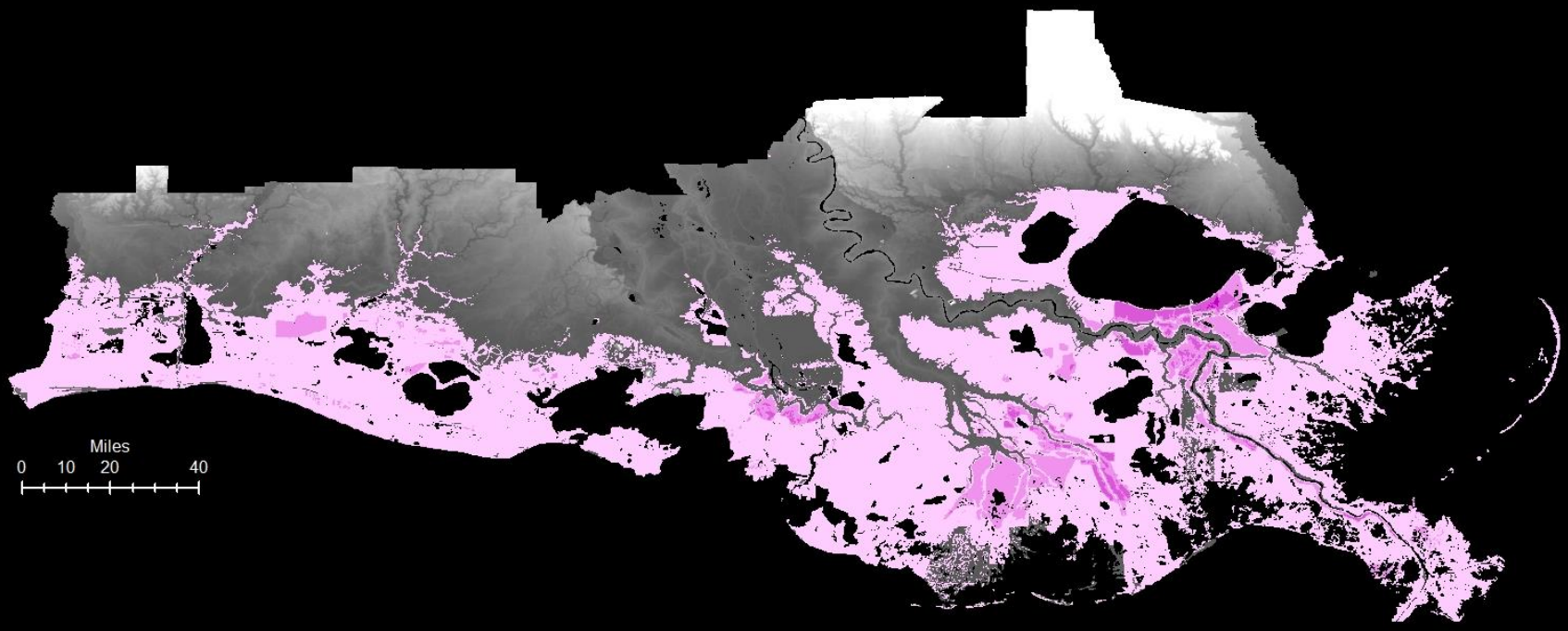
Area: 1,294.4 miles^2

Model Results: 2050



Area: 3,545.6 miles^2

Model Results: 2100



Model 3 Vulnerable Land - 2100

Land Below 0m NAVD-88 (meters)

-20 - -5 -4 - -3 -2 - -1 0

Model 3 Surface - 2100

Elevation (meters)

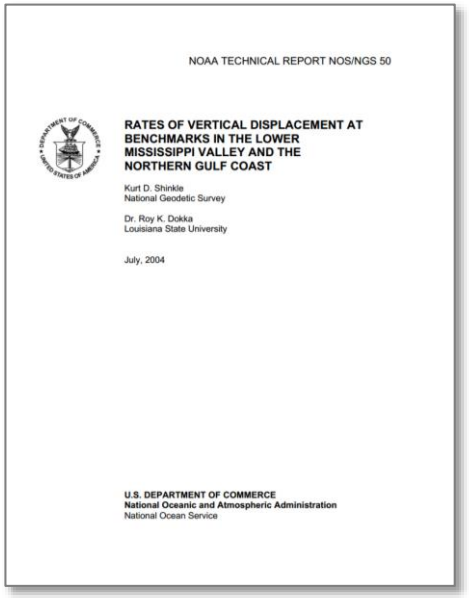
108.8 -2.5

Area: 6,535.8 miles^2

NOAA Technical Report 50

Rates of Vertical Displacement at Benchmarks in the Lower Mississippi Valley and the Northern Gulf Coast

- Analysis of 1st Order Geodetic Leveling Survey between 1920 and 1995
- Tied to National Ocean Service Tide Gauge Data
- Foundation for VTDP Values on Benchmarks
- Subsidence Rates in Louisiana are Spatially and Temporally Variable.


NOAA TECHNICAL REPORT NOS/NGS 50

RATES OF VERTICAL DISPLACEMENT AT BENCHMARKS IN THE LOWER MISSISSIPPI VALLEY AND THE NORTHERN GULF COAST

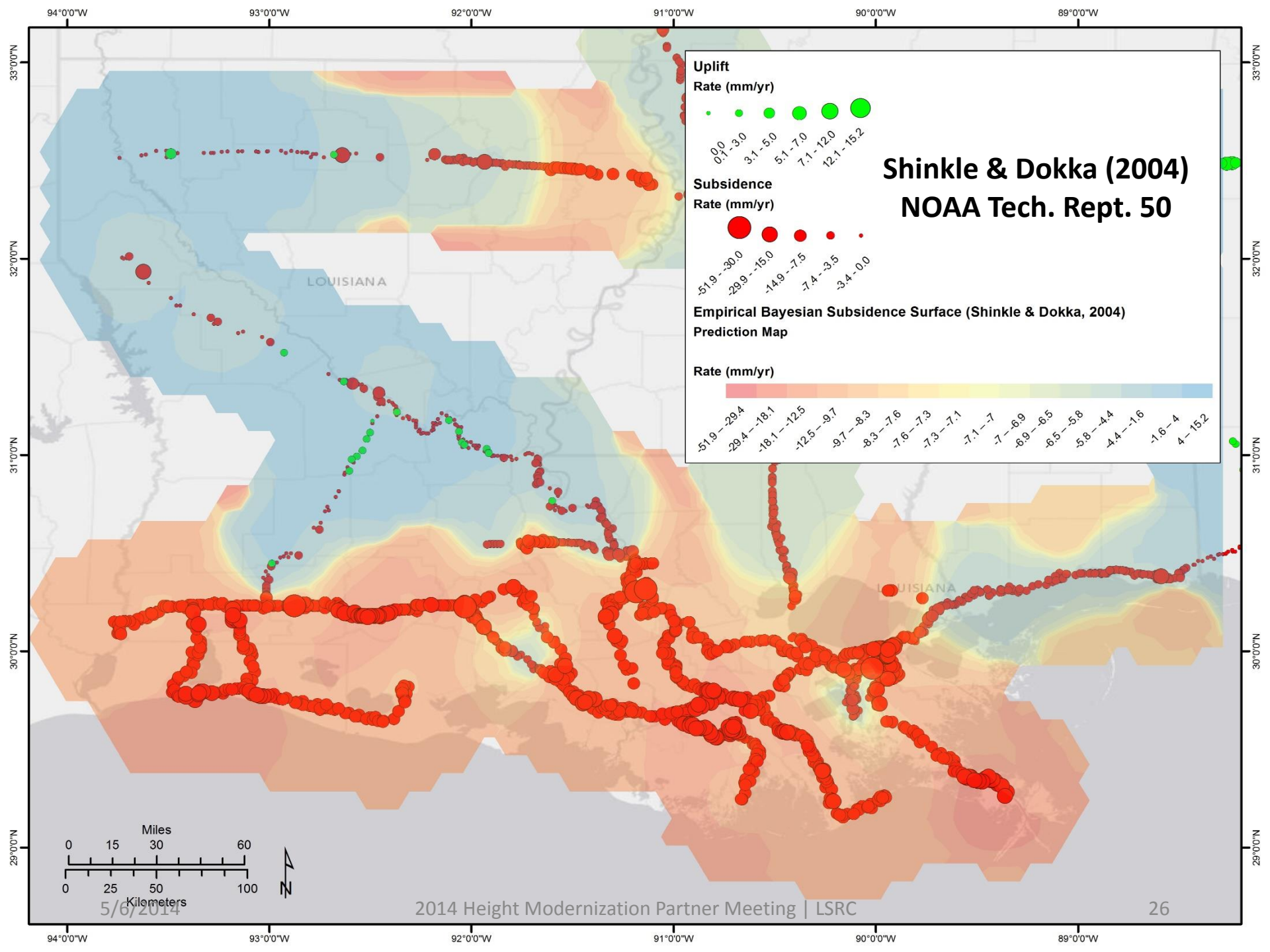
Kurt D. Shinkle
National Geodetic Survey

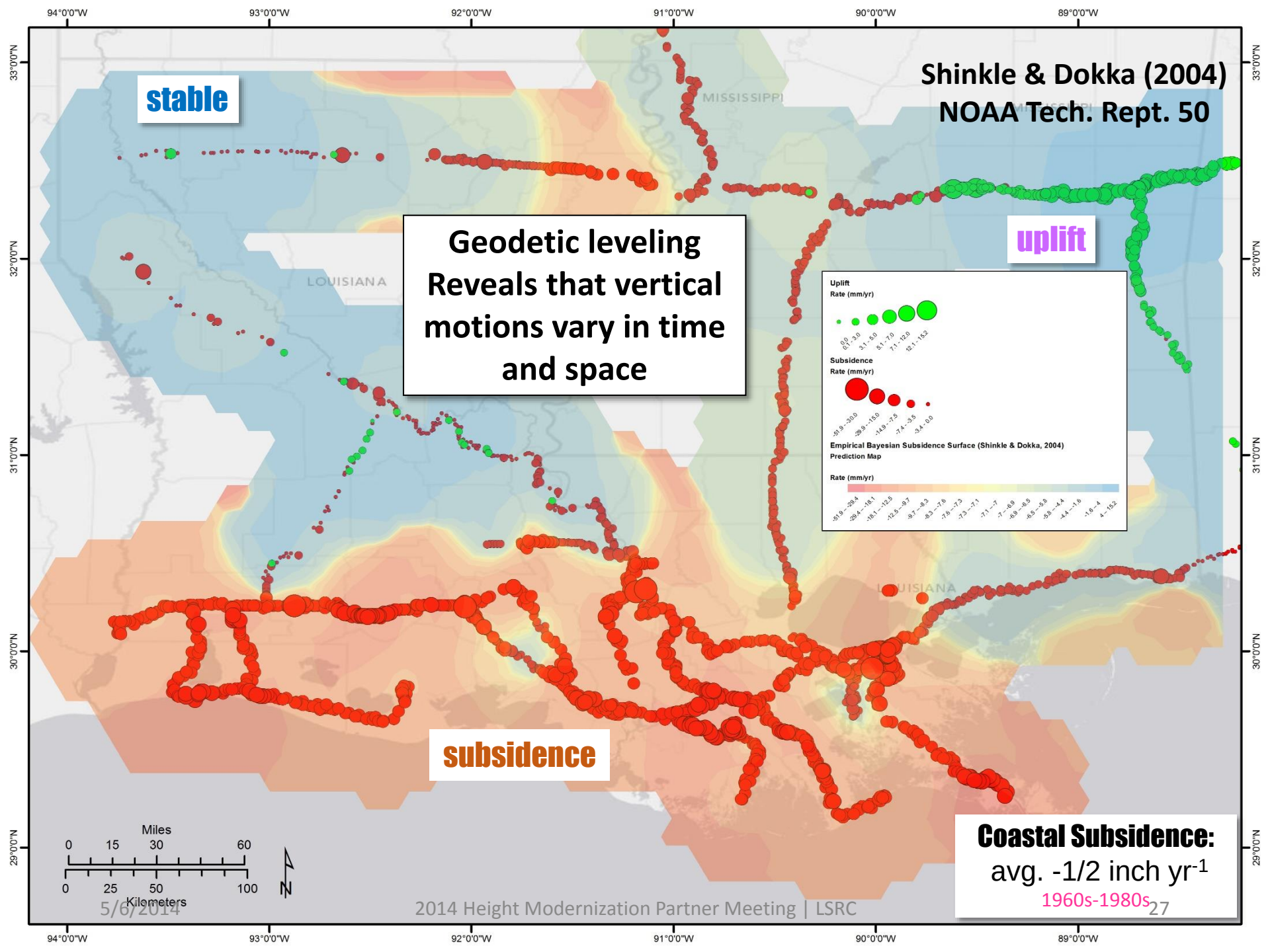
Dr. Roy K. Dokka
Louisiana State University

July, 2004

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Shinkle & Dokka, 2004)


Uplift
Rate (mm/yr)
0.0
0.1 - 3.0
3.1 - 5.0
5.1 - 7.0
7.1 - 12.0
12.1 - 15.2
Subsidence
Rate (mm/yr)
-51.9 - -30.0
-29.9 - -15.0
-14.9 - -7.5
-7.4 - -3.5
-3.4 - 0.0
Shinkle & Dokka (2004)
NOAA Tech. Rept. 50
Empirical Bayesian Subsidence Surface (Shinkle & Dokka, 2004)
Prediction Map
Rate (mm/yr)
-51.9 – -29.4
-29.4 – -18.1
-18.1 – -12.5
-12.5 – -9.7
-9.7 – -8.3
-8.3 – -7.6
-7.6 – -7.3
-7.3 – -7.1
-7.1 – -7
-7 – -6.9
-6.9 – -6.5
-6.5 – -5.8
-5.8 – -4.4
-4.4 – -1.6
-1.6 – 4
4 – 15.2
LOUISIANA
LOUISIANA
94°0'0"W
93°0'0"W
92°0'0"W
91°0'0"W
90°0'0"W
89°0'0"W
33°0'0"N
32°0'0"N
31°0'0"N
30°0'0"N
29°0'0"N
Miles
0 15 30 60
0 25 50 100
Kilometers
N


stable
Shinkle & Dokka (2004)
NOAA Tech. Rept. 50
Geodetic leveling
Reveals that vertical
motions vary in time
and space
uplift
Uplift
Rate (mm/yr)
Subsidence
Rate (mm/yr)
Empirical Bayesian Subsidence Surface (Shinkle & Dokka, 2004)
Prediction Map
Rate (mm/yr)
subsidence
Miles
0 15 30 60
0 25 50 100
Kilometers
N
Coastal Subsidence:
avg. -1/2 inch yr-1
1960s-1980s

TIDES & CURRENTS

Sea Level Trends

Alabama
Alaska
California
Connecticut
Delaware
Florida
Georgia
Hawaii
Louisiana
Maine
Maryland
Massachusetts
New Jersey
New York
North Carolina
Oregon
Pennsylvania
Rhode Island
South Carolina
Texas
Virginia
Washington
Washington DC
Island Stations

Sea Level Trend Table in mm/yr

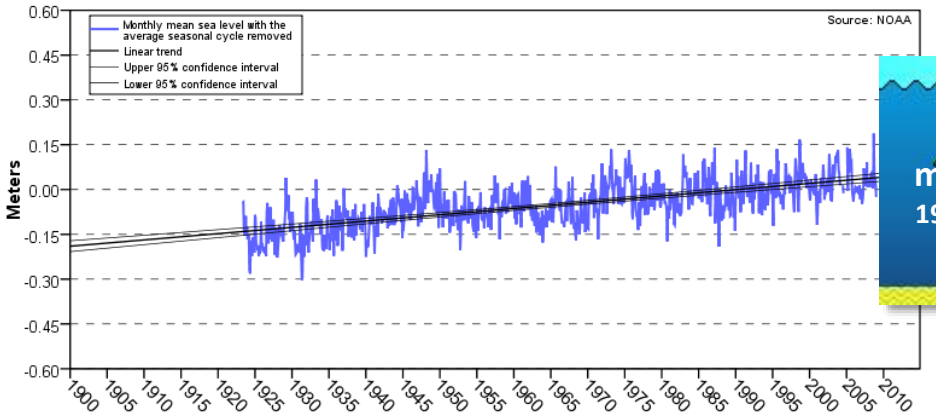
Sea Level Trend Table in feet/century

Global Stations

Global Sea Level Trend Table in mm/yr

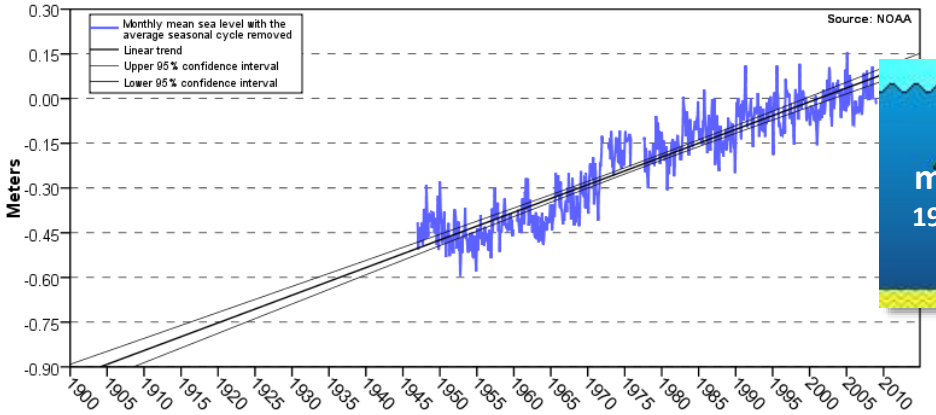
Global Sea Level Trend Table in feet/century

Pensacola, FL 2.10 +/- 0.26 mm/yr



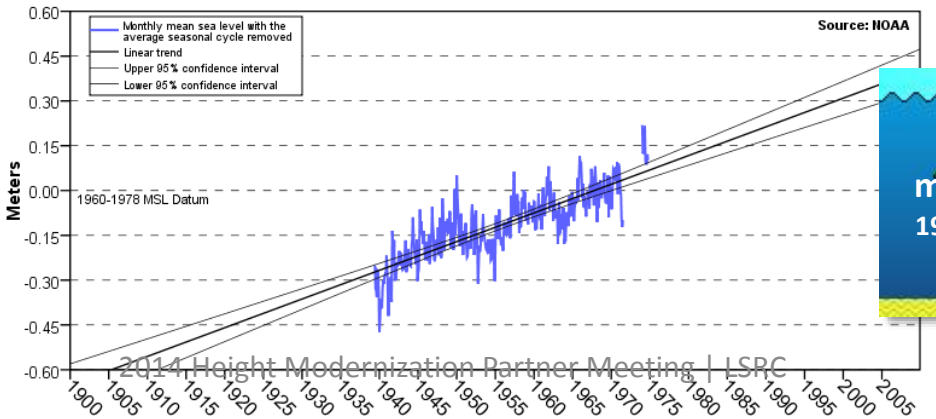
2.10 mm/year 1923 - 2006

Grand Isle, LA 9.24 +/- 0.59 mm/yr

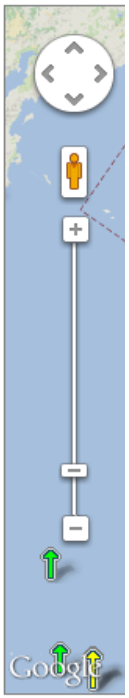


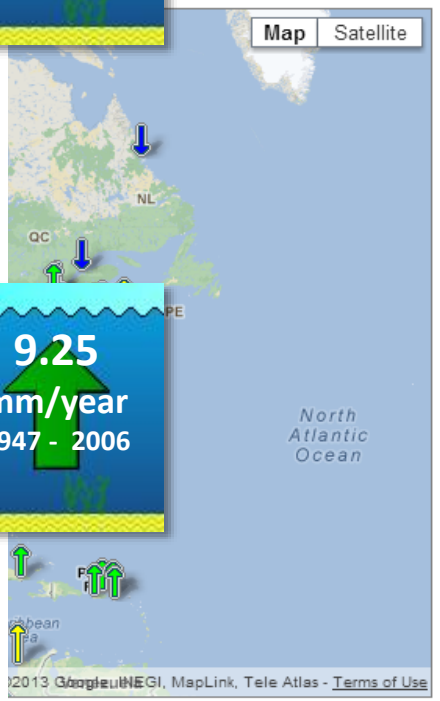
9.25 mm/year 1947 - 2006

Eugene Island, LA 9.65 +/- 1.24 mm/yr



9.65 mm/year 1939 - 1974





The map a *gnitude of change. Click on an arrow to*

The Center with tide stations of the National Wa MSL), either a sea level rise or sea level fall, have b of observations at each location. These measuremer order to compute an accurate linear sea level trend.

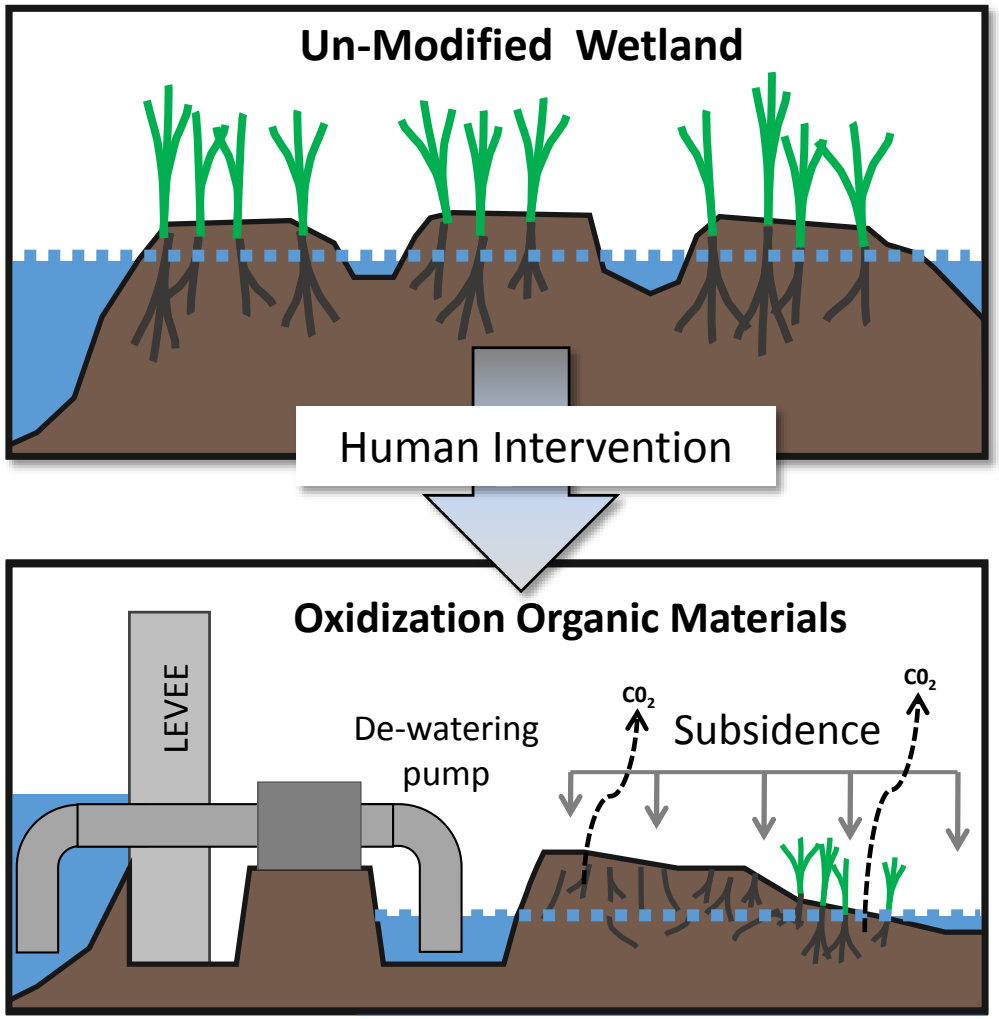
http://tidesandcurrents.noaa.gov/sltrends/index.shtml

Understanding Subsidence

"The downward movement of the Earth's surface with respect to a datum."

- Subsidence is a **4D** problem!
- Associated with any one or many **natural** and **anthropogenic** processes.
- Examine these processes according to depth.

Subsidence above Aquifers…



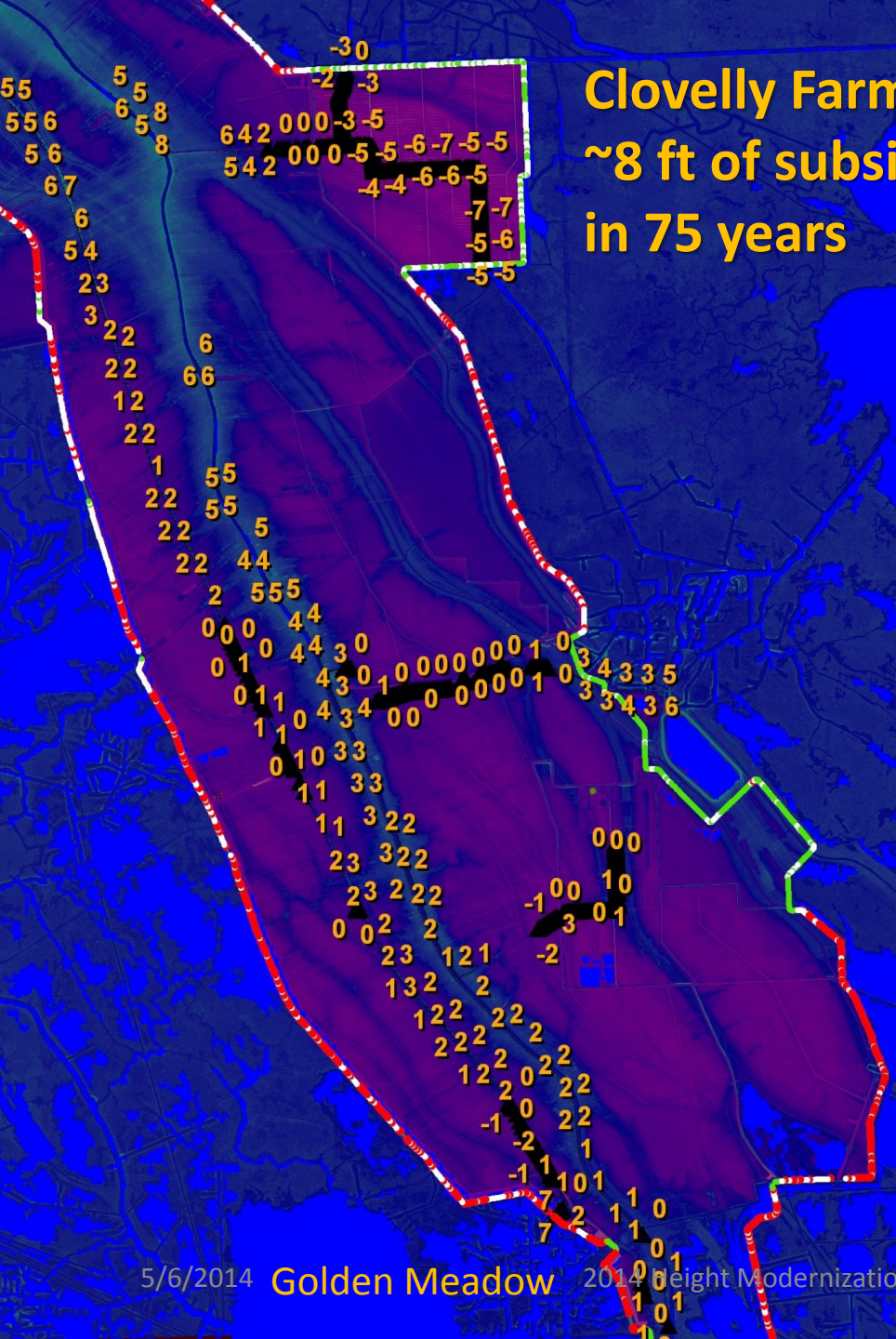
(modified from Reed & Yuill, 2009)

Compaction, Consolidation, Ground Water Withdrawal & more…

5mm – 30 mm per year

- Flood Protection
- Water Drainage & Management

[a] Deveral & Rojstaczer, 1996
[b] Stephens & Speir, 1969
[c] Snowden et al. , 1968



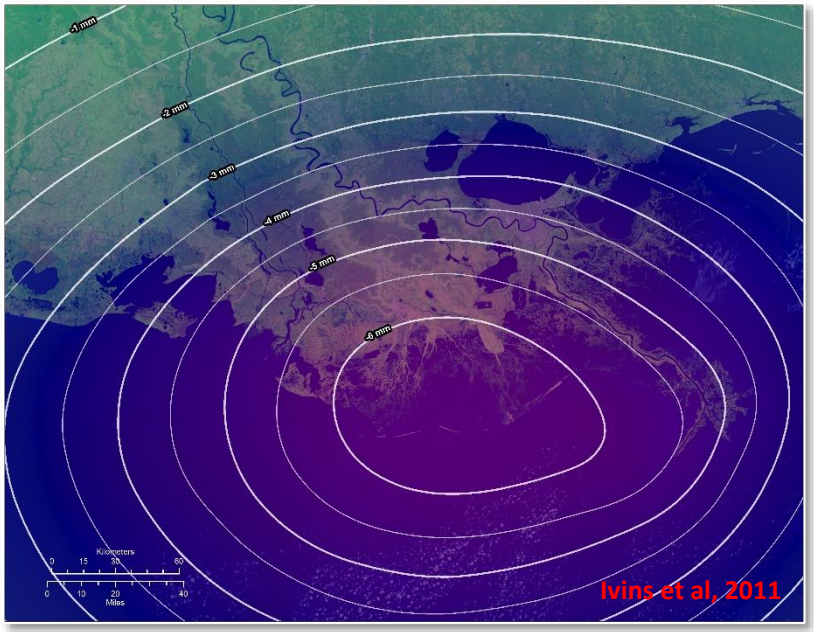
Clovelly Farms
~8 ft of subsidence
in 75 years

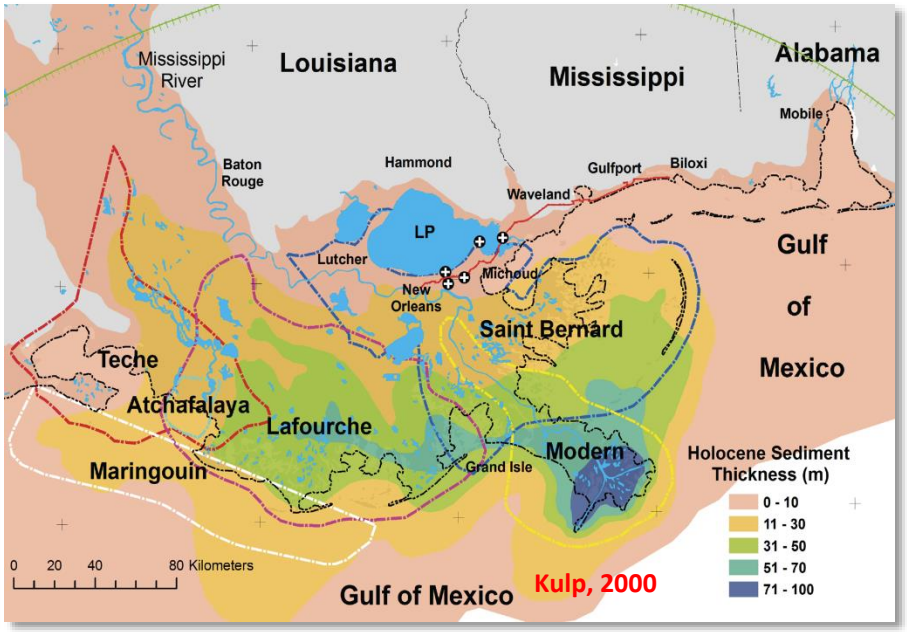
Building levees speeds up compaction, but may be the only way to provide protection to communities.

South Lafourche Parish, Louisiana

Subsidence below Aquifers…

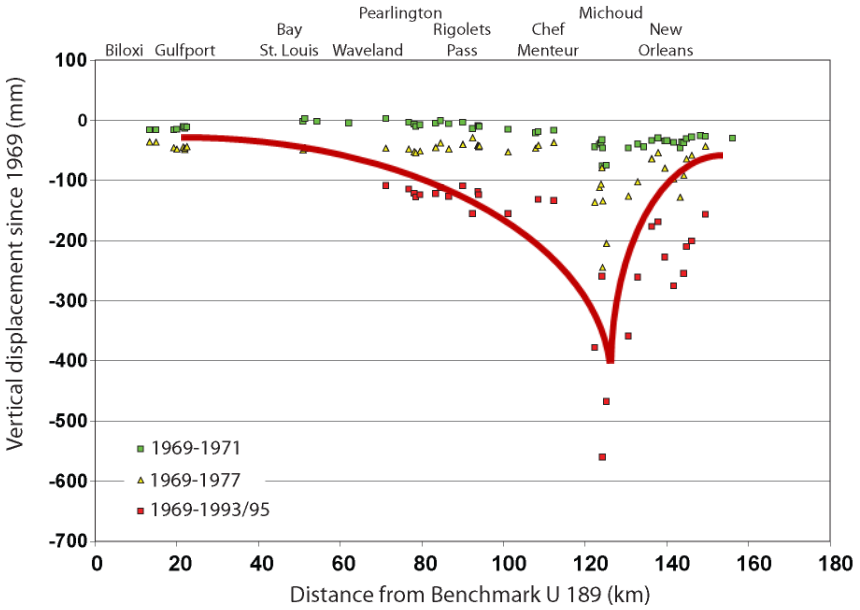
Viscoelastic Deformation of the Lithosphere Created by 10,000 years of Sediment Loading, Ocean Loading, and Glacial Isotactic Adjustment…

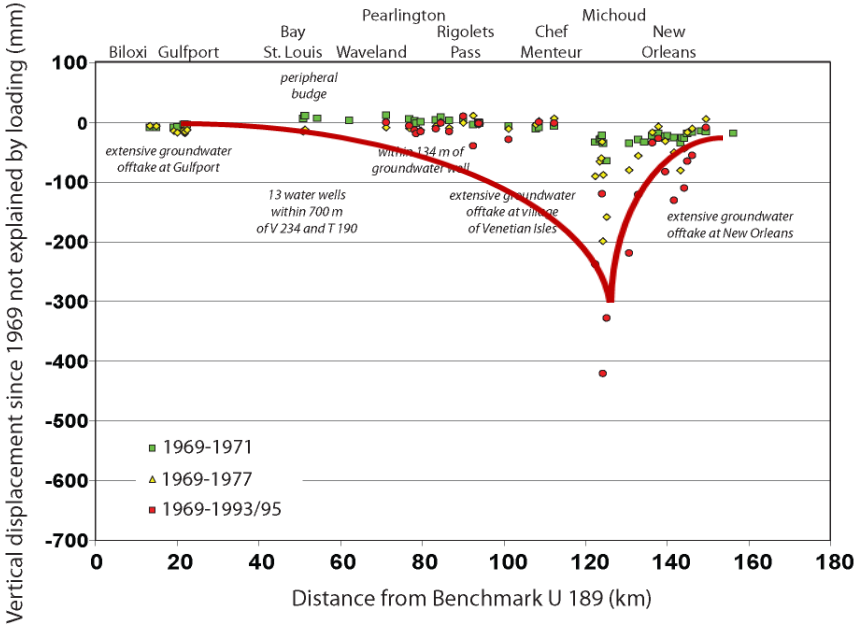




Analysis of 1st Order Geodetic Leveling Data

- 1955-1995
- Pensacola – New Orleans
- All monuments driven below Holocene.
- There is a lot of deep subsidence occurring below the Holocene.
- It's not just compaction.



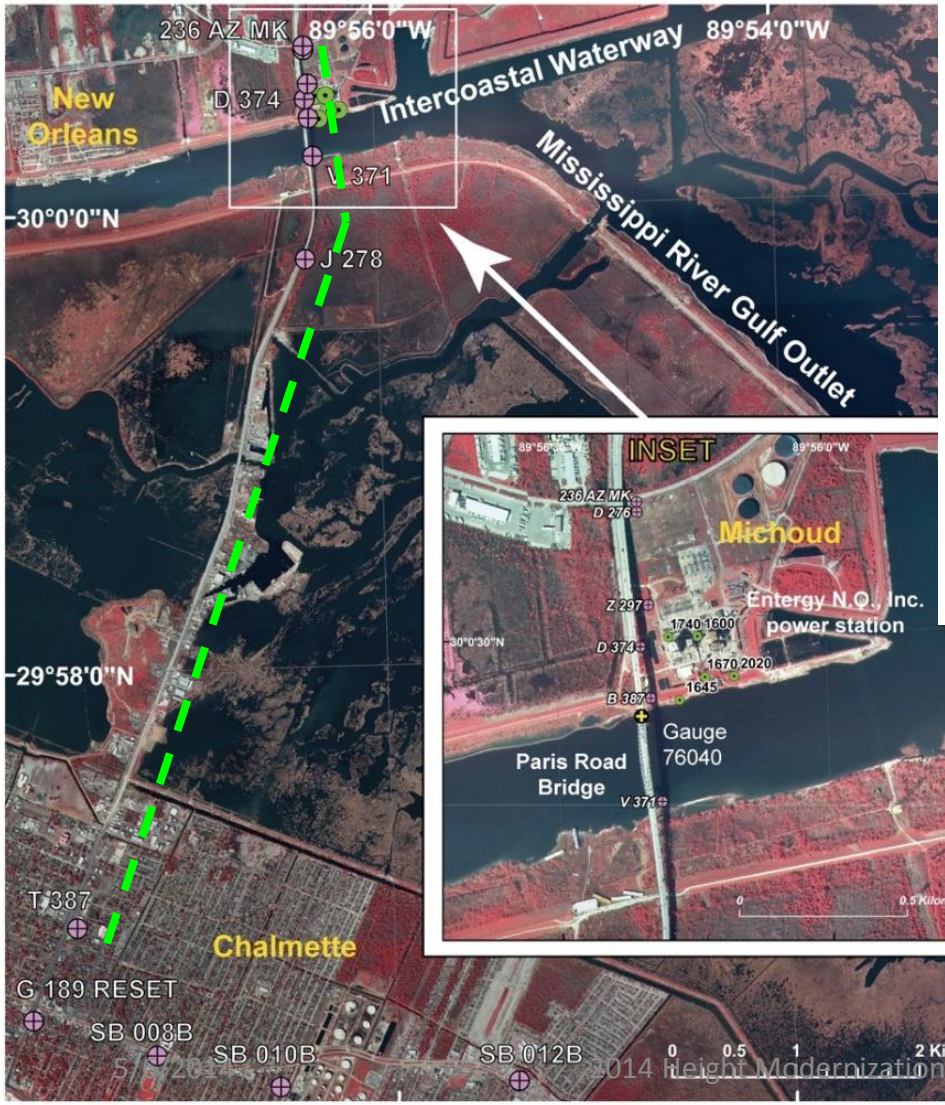


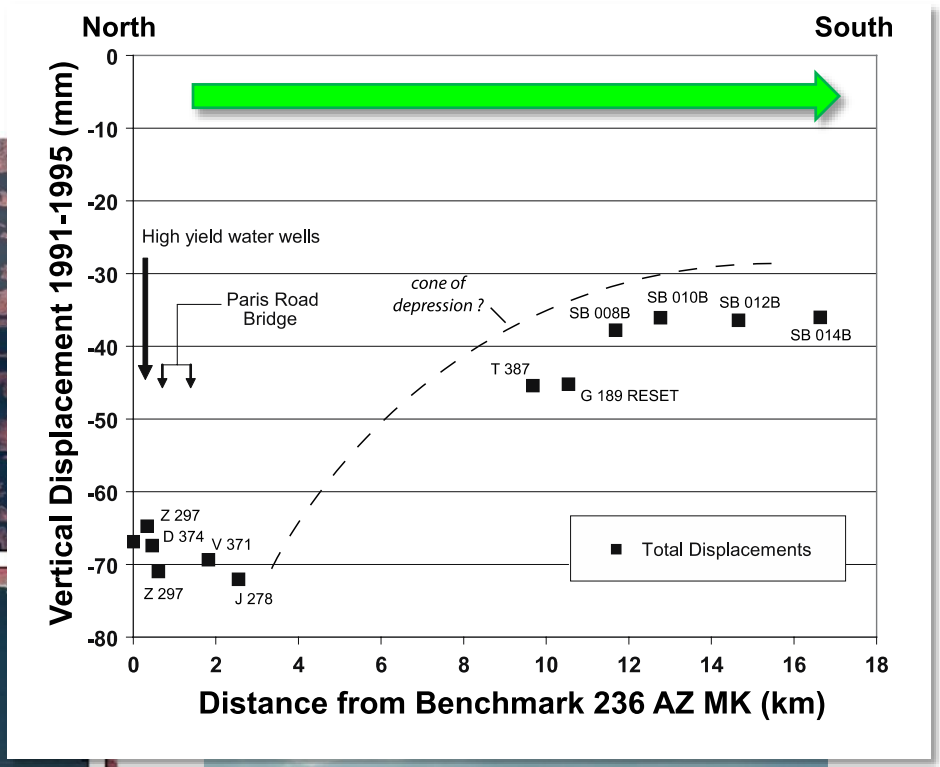
Subsidence below Aquifers…

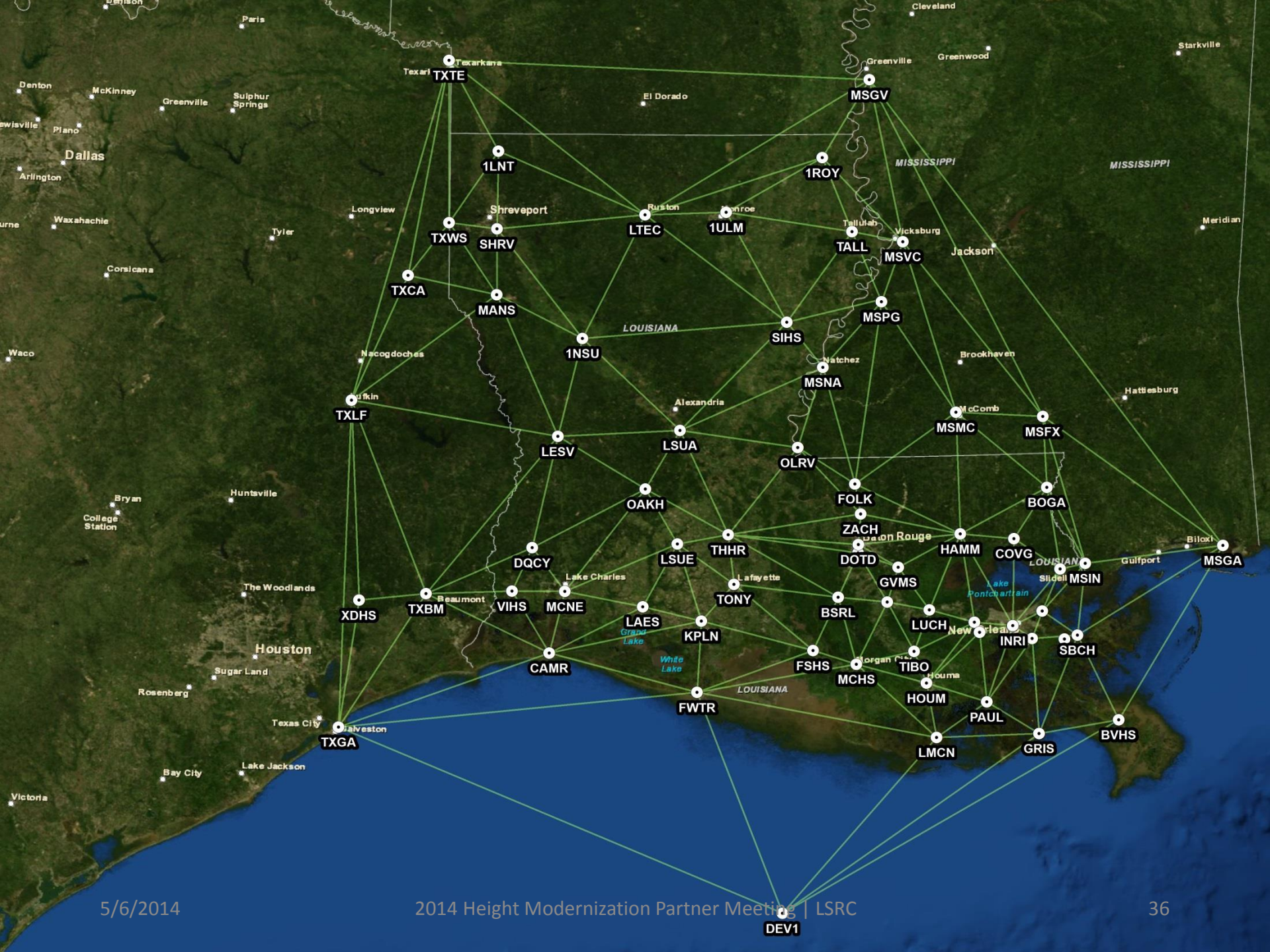
LSRC Research Finds Anomalous Rates of Subsidence in New Orleans East, Near the NASA Michoud Assembly Facility

- Subsidence at deep marks on waste wells…
- Relative sea level rise measured at tide gauges…
- Analysis of aquifer discharge...

Paris Rd. Bridge (LA-47): Subsided ~1m in 50 years

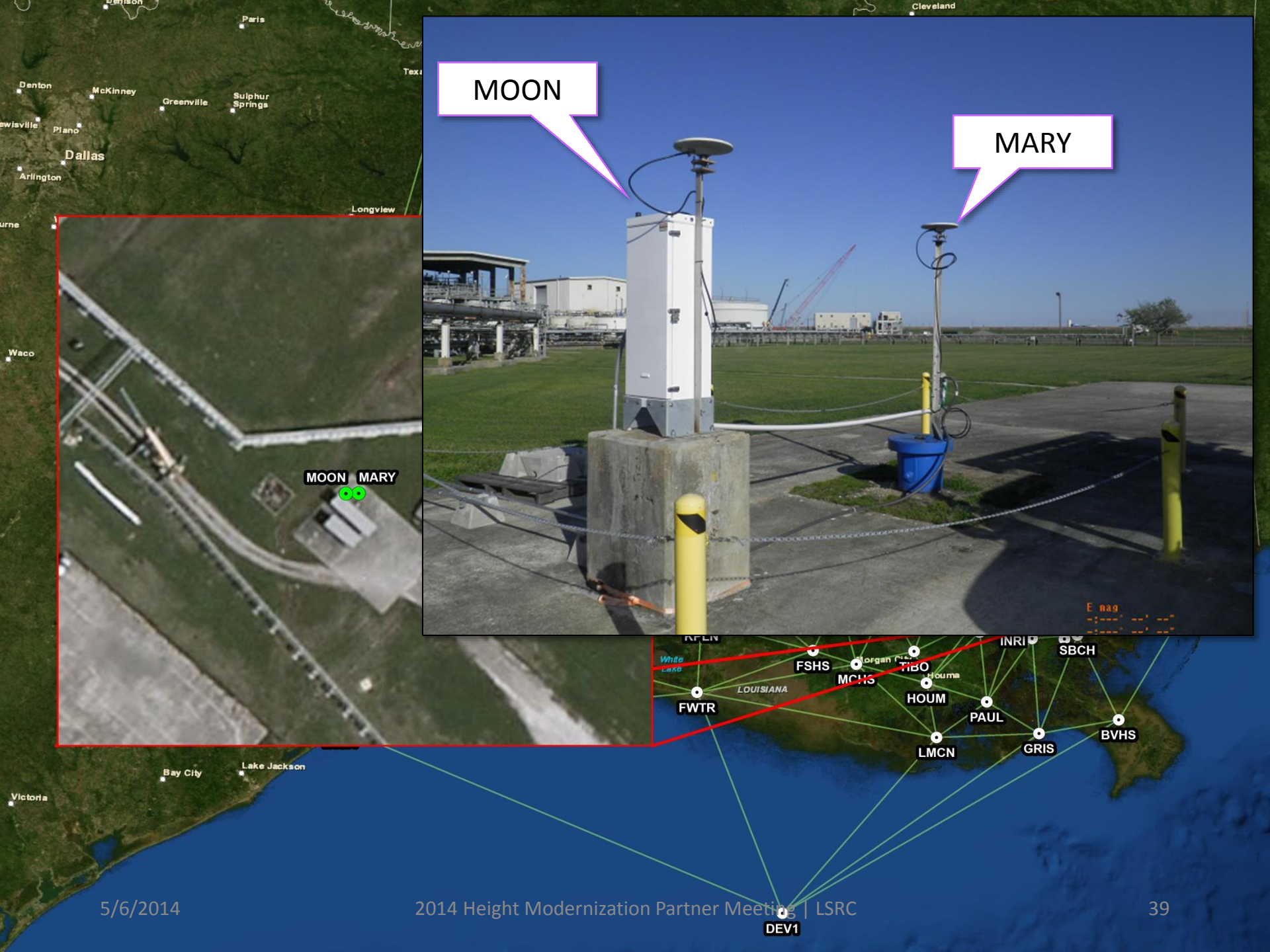





TXTE
MSGV
1LNT
1ROY
TXWS
SHRV
LTEC
1ULM
TALL
MSVC
TXCA
MANS
MSPG
1NSU
SIHS
MSNA
TXLF
LESV
LSUA
OLRV
MSMC
MSFX
OAKH
FOLK
BOGA
ZACH
THHR
DQCY
LSUE
DOTD
HAMM
COVG
MSGA
MSIN
GVMS
TONY
BSRL
LUCH
INRI
SBCH
XDHS
TXBM
VIHS
MCNE
LAES
KPLN
FSHS
MCHS
TIBO
HOUM
CAMR
FWTR
PAUL
TXGA
LMCN
GRIS
BVHS
DEV1
Texarkana
Greenville
El Dorado
Shreveport
Ruston
Monroe
Tallulah
Vicksburg
Jackson
Longview
Tyler
Waxahachie
Dallas
Plano
McKinney
Denton
Sulphur Springs
Corsicana
Waco
Nacogdoches
Natchez
Brookhaven
Alexandria
Hattiesburg
McComb
Bryan
College Station
Huntsville
Lake Charles
Lafayette
Baton Rouge
Slidell
Biloxi
Gulfport
The Woodlands
Beaumont
Houston
Sugar Land
Rosenberg
Texas City
Galveston
Bay City
Lake Jackson
Victoria
Meridian
Starkville
Greenwood
Cleveland
Paris
MISSISSIPPI
LOUISIANA
Lake Pontchartrain
Grand Lake
White Lake
Houma


MOON
MARY
TXTE
MSGV
1LNT
1ROY
1ULM
TALL
MSVC
MSPG
SIHS
MSNA
LSUA
OLRV
MSMC
MSFX
FOLK
BOGA
ZACH
THHR
LSUE
DOTD
HAMM
COVG
MSIN
MSGA
GVMS
TONY
BSRL
LUCH
KPLN
INRI
SBCH
FSHS
TIBO
MCHS
HOUM
FWTR
PAUL
BVHS
LMCN
GRIS
DEV1
Texarkana
Greenville
Starkville
Greenwood
El Dorado
Denton
McKinney
Sulphur Springs
Plano
Dallas
Arlington
Longview
Shreveport
Ruston
Monroe
Tallulah
Vicksburg
Jackson
Meridian
Waco
Natchez
Brookhaven
Hattiesburg
Alexandria
McComb
Baton Rouge
Biloxi
Gulfport
Slidell
Lafayette
Houma
Bay City
Lake Jackson
Victoria
MISSISSIPPI
LOUISIANA


Hon. Moon Landrieu
Sen. Mary Landrieu
MOON
MARY
TXTE
1LN
FOLK
BOGA
ZACH
THHR
LSUE
DOTD
HAMM
COVG
MSIN
MSGA
GVMS
TONY
BSRL
LUCH
KPLN
INRI
SBCH
FSHS
TIBO
HOUM
FWTR
PAUL
BVHS
LMCN
GRIS
DEV1
Dallas
Plano
Denton
McKinney
Greenville
Sulphur Springs
Arlington
Longview
Waco
Paris
Texarkana
Cleveland
Greenwood
Starkville
Meridian
Biloxi
Gulfport
Slidell
Lafayette
Baton Rouge
New Orleans
Houma
Bay City
Lake Jackson
Victoria
LOUISIANA


MOON
MARY
MOON MARY
Paris
Denton
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Greenville
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Cleveland
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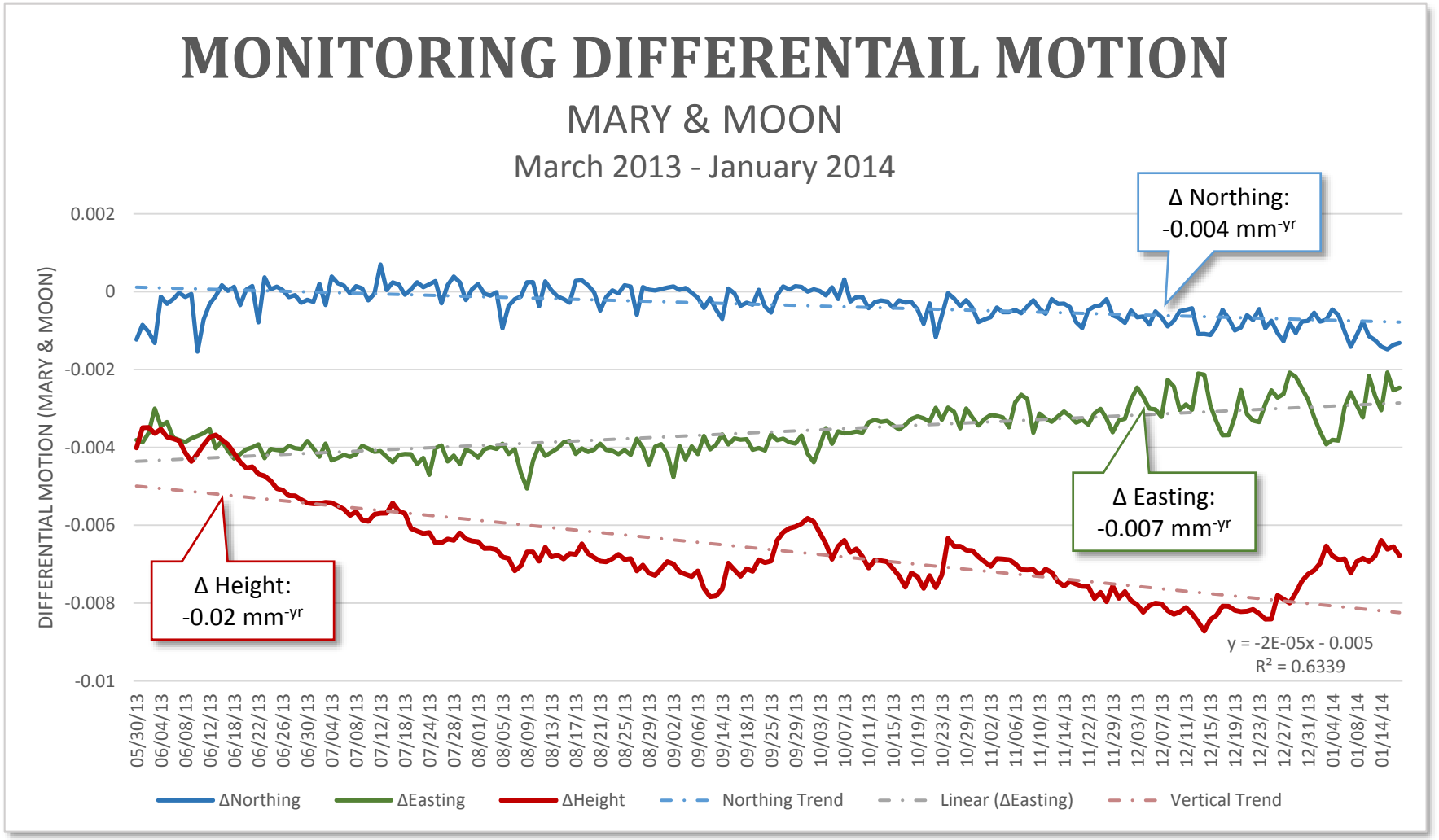
SBCH
LOUISIANA
DEV1

Differential Motion

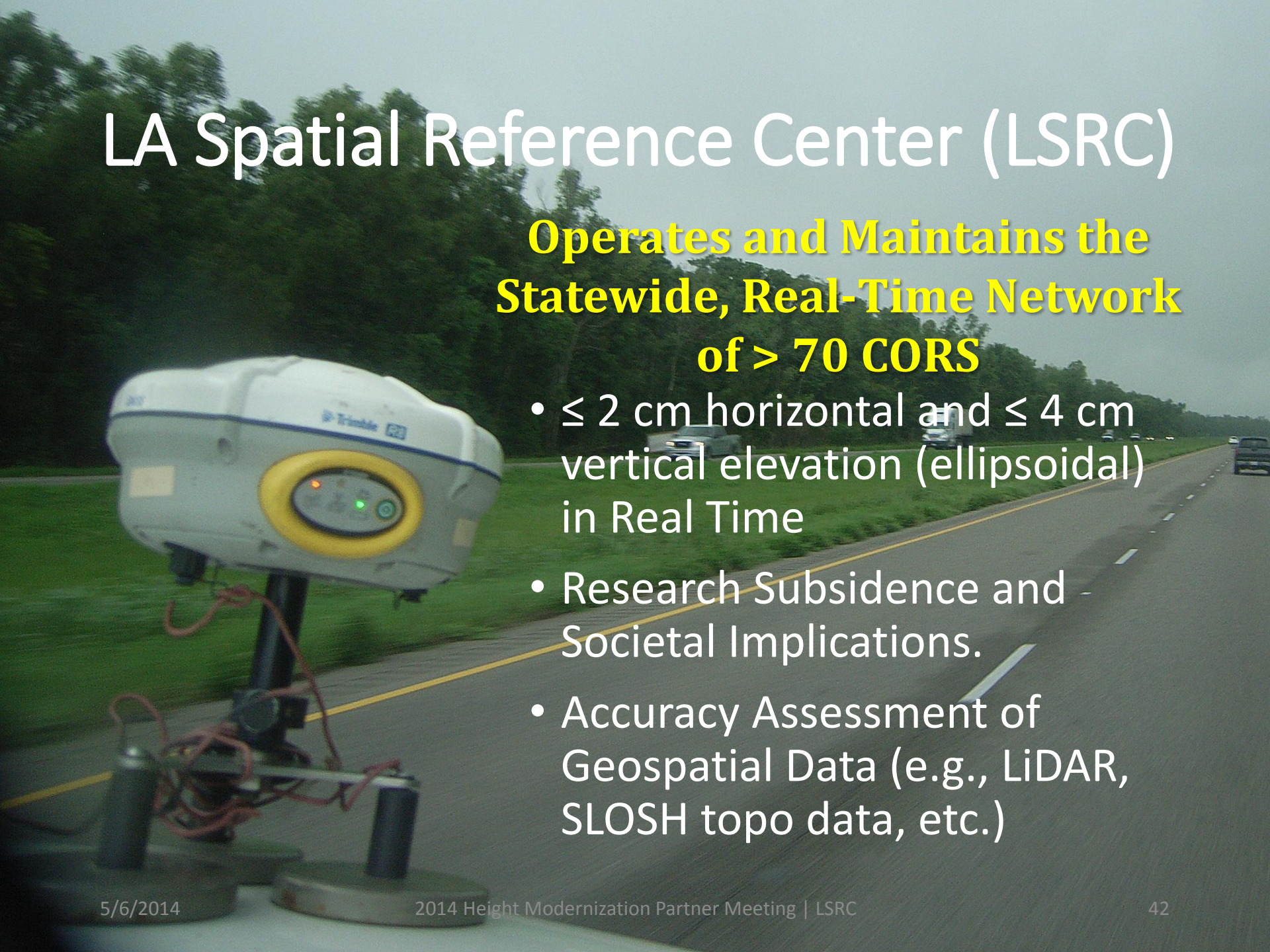


What is the Overall Geodetic Vertical Control Strategy in LA?

Coordinated Approach to Provide Consistent, Reliable Access to NSRS.

- **Expand & Maintain CORS Network** in Louisiana.
- **Collaboration** with Stakeholders
  - OPUS Projects Training - Dave Newcomer/Denis Riordan
- Support NGS Efforts for **Updating the NSRS** into the Future…
  - Transition to GNSS CORS
  - Improved Geodetic Modeling
  - Enhance Geoid Models

LA Spatial Reference Center (LSRC)

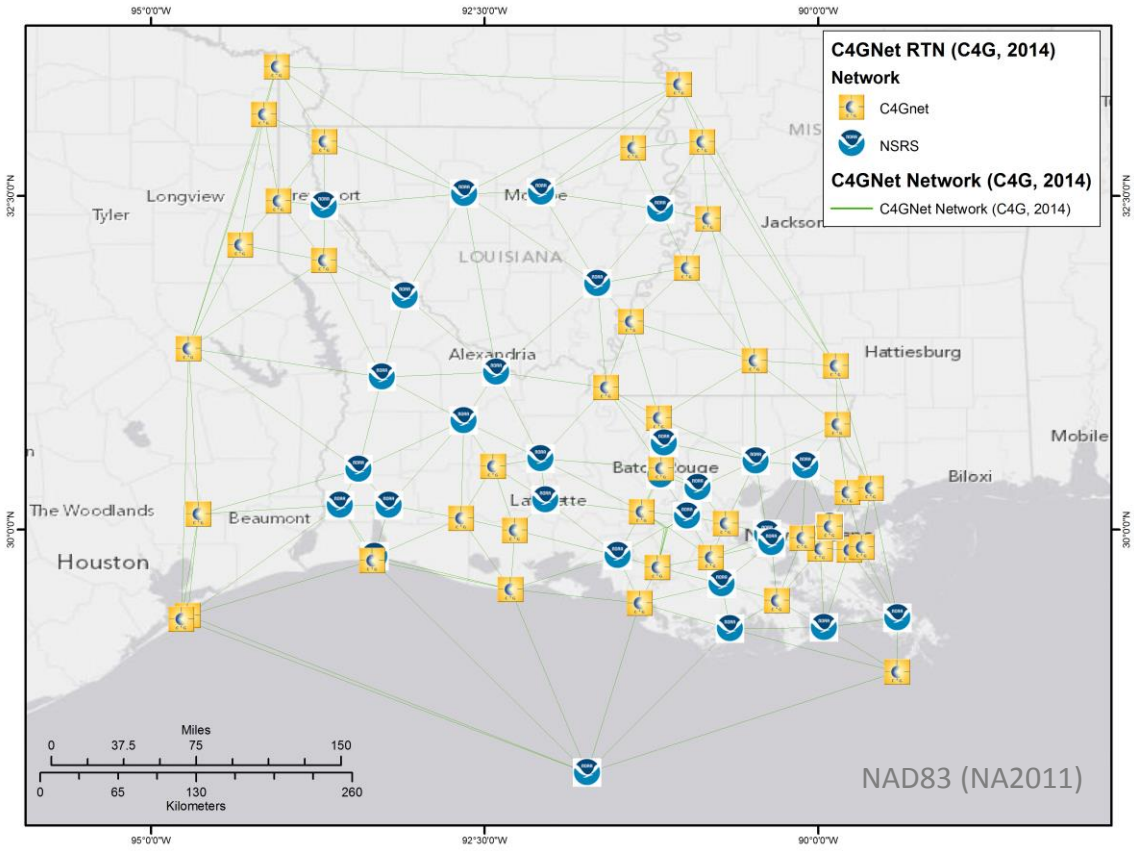


Operates and Maintains the Statewide, Real-Time Network of > 70 CORS

- ≤ 2 cm horizontal and ≤ 4 cm vertical elevation (ellipsoidal) in Real Time
- Research Subsidence and Societal Implications.
- Accuracy Assessment of Geospatial Data (e.g., LiDAR, SLOSH topo data, etc.)

C4Gnet: Real-Time Network

- LSU operated since 2004
- State Law in 2006: RS 50:173.1
- The most reliable component of the NSRS in Louisiana.
- Maintained with self generated funds & research grants.

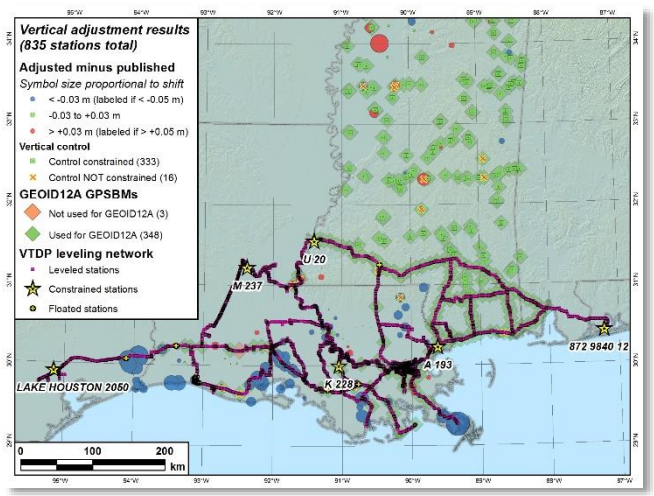


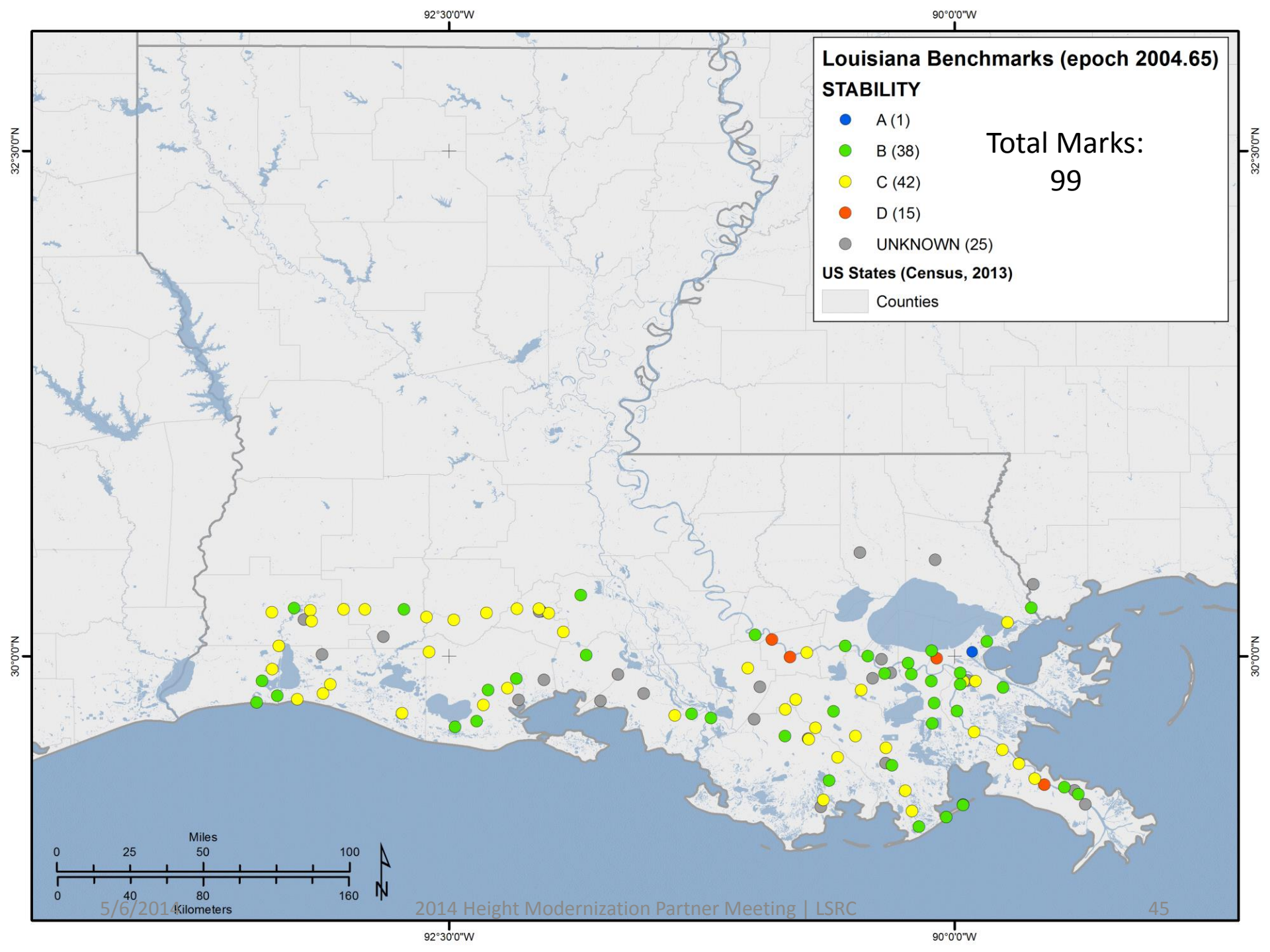
75 CORS: 30 – NSRS, 45 – C4GNet

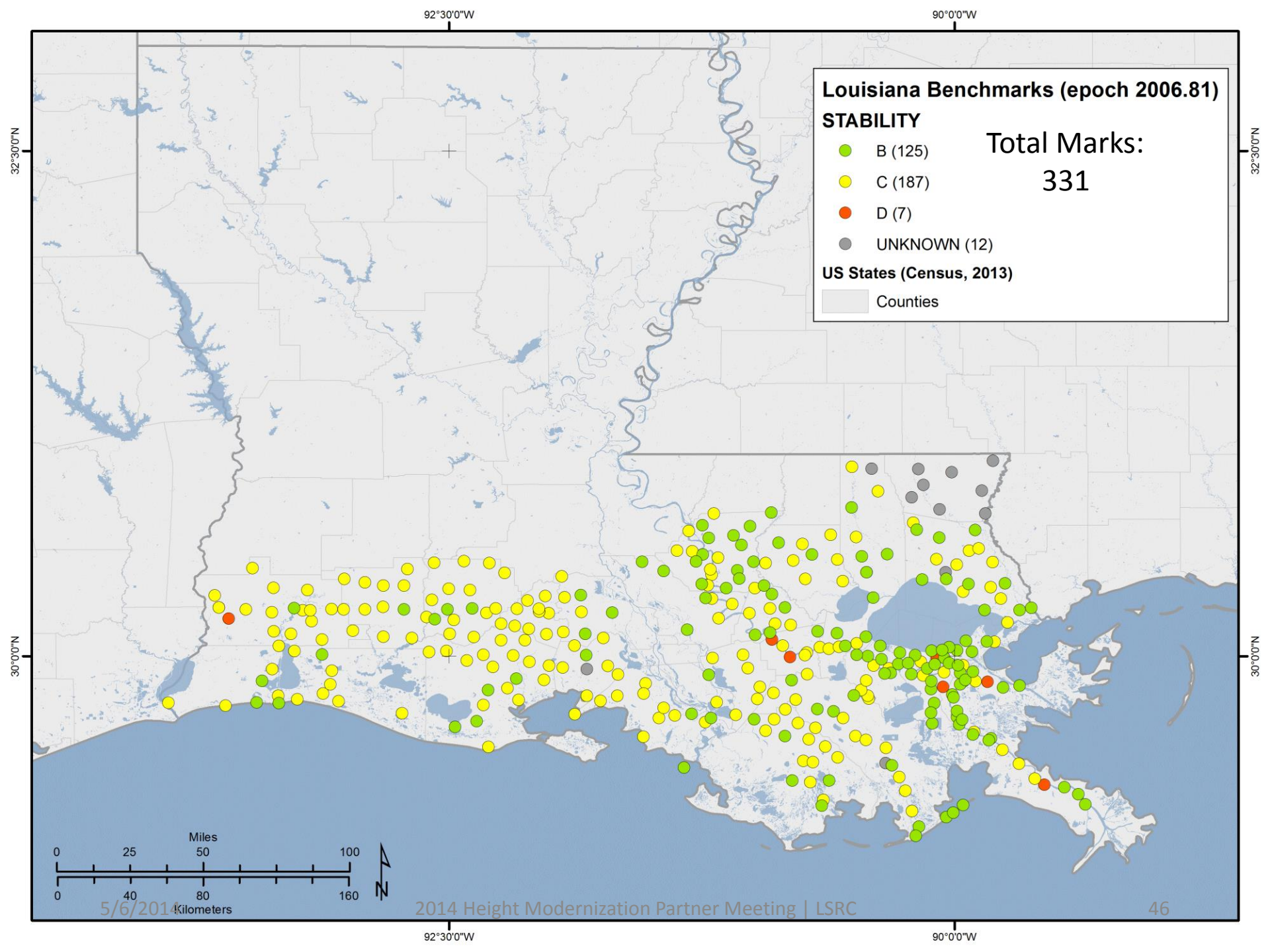
Height Modernization Activities in Louisiana

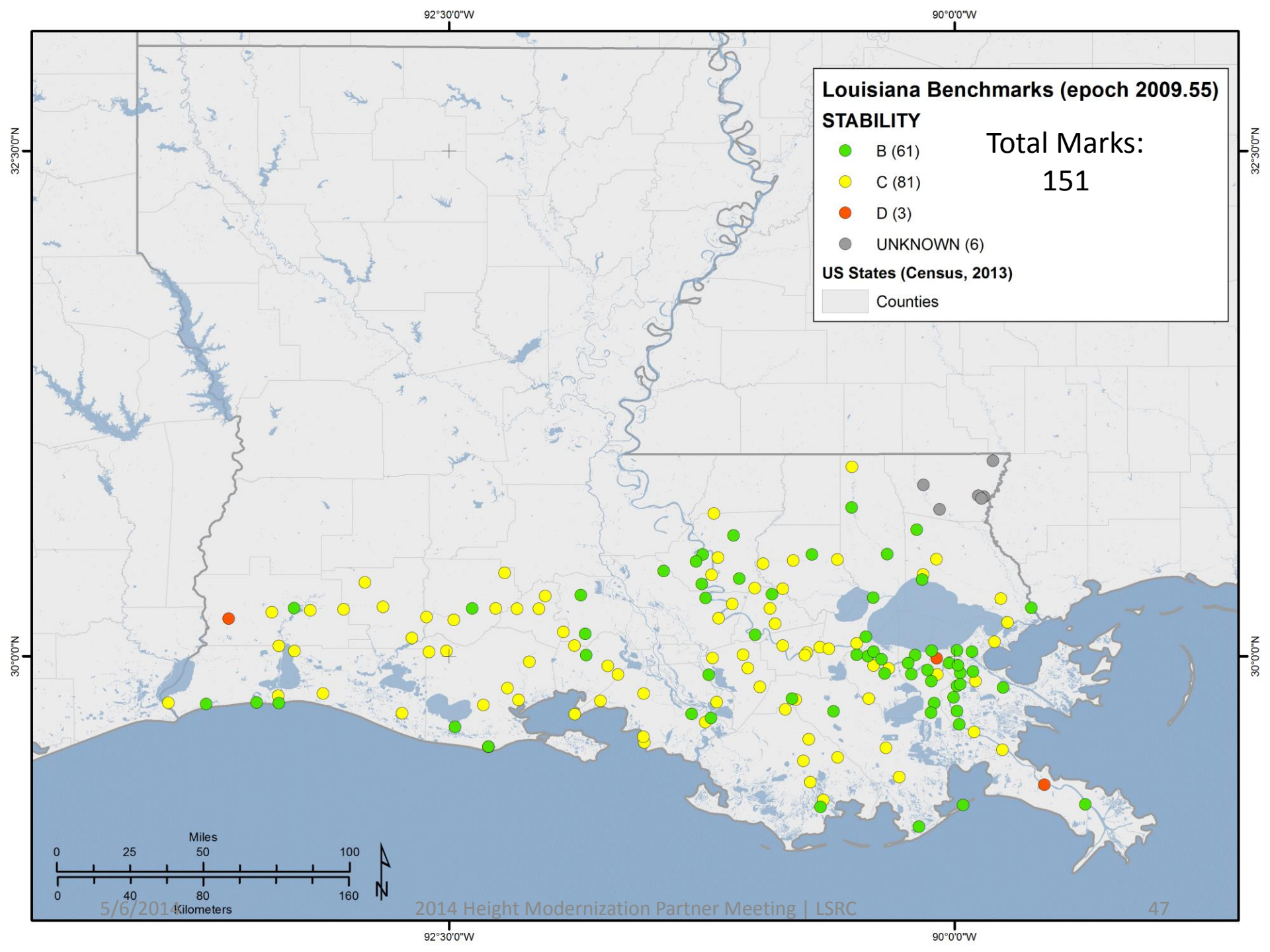
- 2004 – NOAA Technical Report 50
  - 1st Order Geodetic Leveling Survey
  - Establish rates of subsidence across Louisiana
  - Foundation for VTDP values on benchmarks
- 2004.65 – NGS Height Modernization Project
  - GPS Benchmark Survey, update VTDP values.
  - 99 marks
- 2006.81 – NGS Height Modernization Project
  - GNSS Benchmark Survey using CORS RTN, gravity observations, and established several new NOAA tide stations.
  - 331 marks
- 2009.55 – NGS Height Modernization Project
  - GNSS Benchmark Survey using Leveling observations from MS
  - LA Field Observations in 2010.73 – 2010.81
  - 151 marks

Height Modernization 2009.55




92°30'0"W
90°0'0"W
32°30'0"N
30°0'0"N
Louisiana Benchmarks (epoch 2004.65)
STABILITY
A (1)
B (38)
C (42)
D (15)
UNKNOWN (25)
US States (Census, 2013)
Counties
Total Marks:
99
Miles
0
25
50
100
0
40
80
160
Kilometers
N

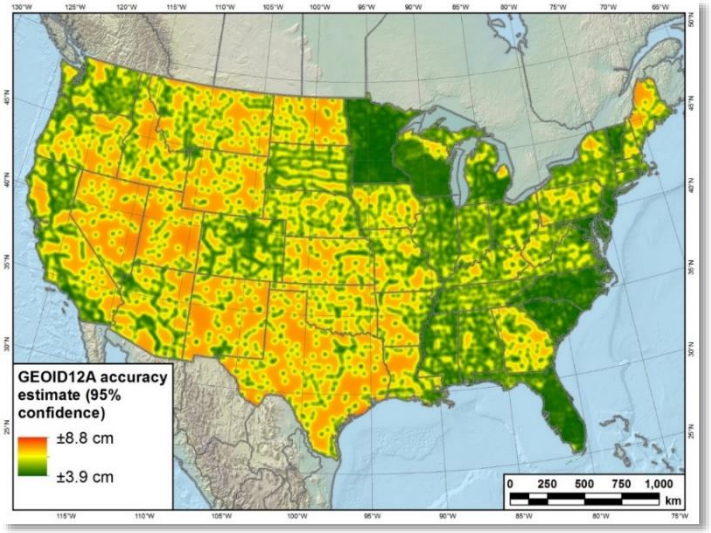

92°30'0"W
90°0'0"W
32°30'0"N
30°0'0"N
Louisiana Benchmarks (epoch 2006.81)
STABILITY
B (125)
C (187)
D (7)
UNKNOWN (12)
US States (Census, 2013)
Counties
Total Marks:
331
Miles
0
25
50
100
0
40
80
160
Kilometers
N


92°30'0"W
90°0'0"W
32°30'0"N
30°0'0"N
Louisiana Benchmarks (epoch 2009.55)
STABILITY
B (61)
C (81)
D (3)
UNKNOWN (6)
US States (Census, 2013)
Counties
Total Marks:
151
Miles
0
25
50
100
0
40
80
160
Kilometers
N

Goals & Objectives

- **Short Term (Now – 2015)**
  - Establish GNSS infrastructure to monitor subsidence
  - New ~2015 GNSS Height Mod survey
- **Medium term (2016 – 2022)**
  - Terrestrial gravity surveys
  - Incorporate GRAV-D aerial gravity into geoid model
- **Long term (> 2022)**
  - New vertical datum based on gravimetric geoid

Geoid 2012A Confidence Interval (NGS, 2012)



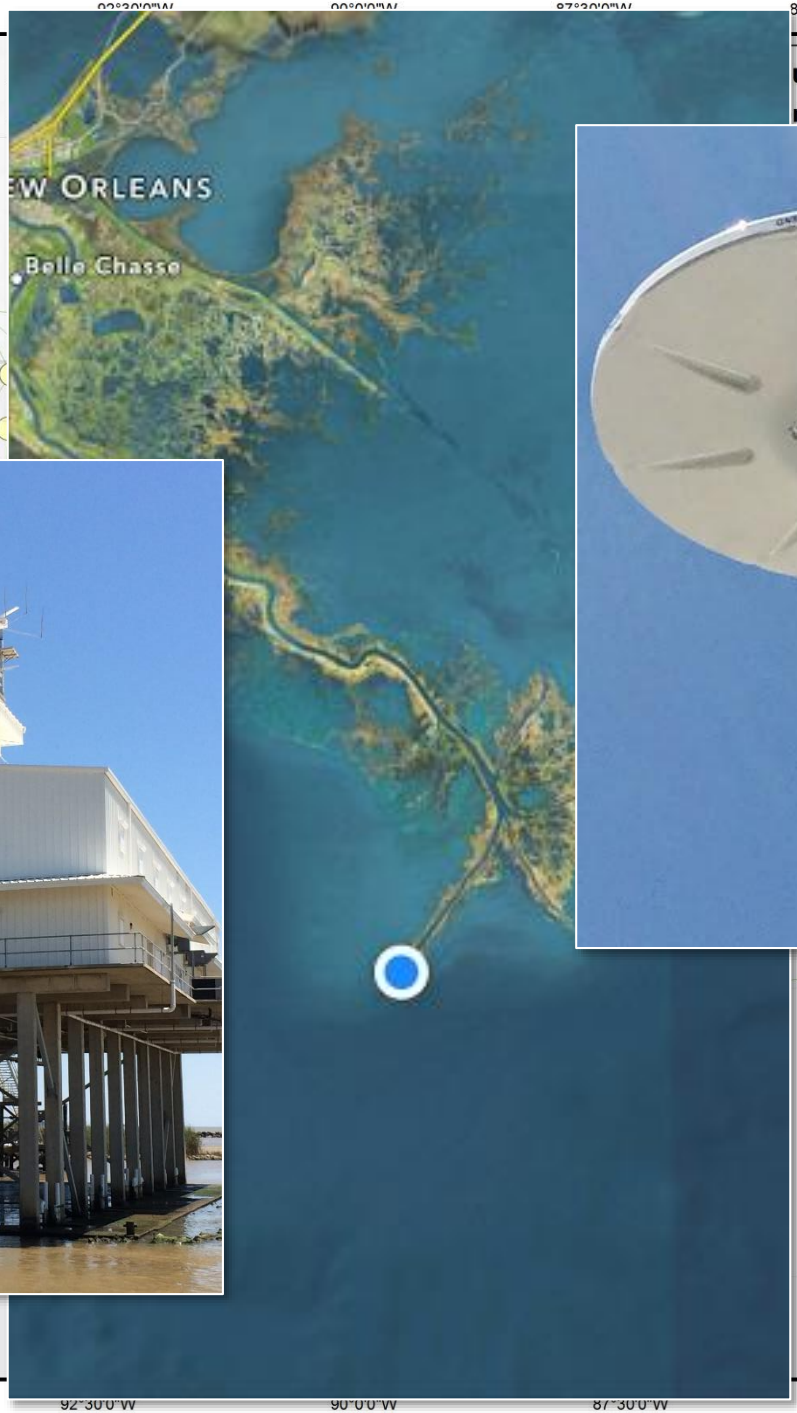
Source: Michael Dennis and Dan Roman

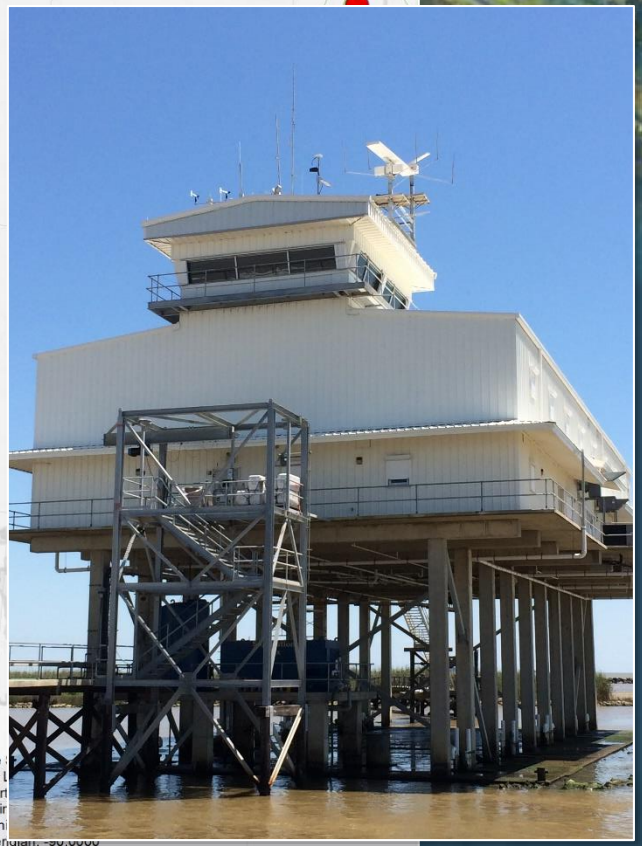
Current Program

Consortium of Gulf Coast Spatial Reference Centers: Texas, Louisiana, Mississippi, Alabama, and Florida

- ***Objective 1*: Enhance the geodetic infrastructure.**
  - Install and maintained CORS stations across the U.S. Gulf Coast. Nominate CORS to the National CORS Network.
  - Tie Terrestrial and Tidal Datums to a common framework. – Establish CORS positioning with geodetic leveling at Tide stations along the Gulf Coast.
  - Update LA CORS sites with reference heights above ground.
  - 2nd Order Gravitmetric Surveys at each CORS site to precisely measure elevation.
- ***Objective 2*: Support education, capacity building, and technology transfer.**
  - Conduct Local and Regional Workshops for NHMP community, decision makers, and all other geodetic stakeholders.
  - Promote HNMP activities at forums, conference, and workshops.
  - Media production and distribution of forums via Web videos, podcasts
- ***Objective 3*: Coordinate partnerships with local geodetic stakeholders.**
  - Develop and strengthen partnerships between the various geodetic stakeholder communities and the
  - Develop, Distribute, and compile geodetic resources poll.
- ***Objective 4*: Maintain CORS data archives and distribution services.**
  - Maintain, distribute and archive data collected by project CORS sites via infrastructure software.
  - Provide data via NGS National CORS Network.
  - Distribute data to NWS Earth Science Research Laboratory (ESRL)

2014 Gulf Coast Consortium



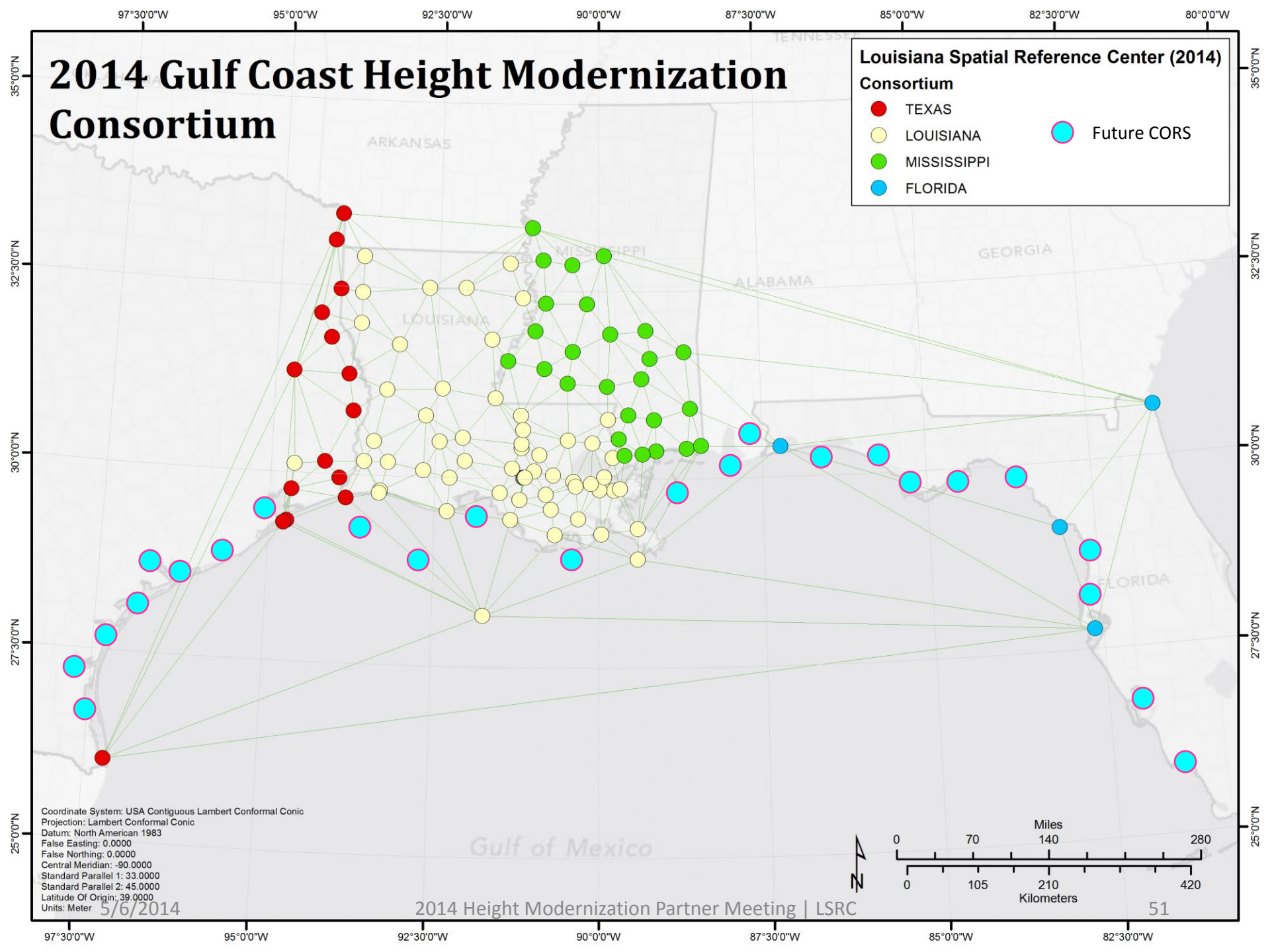


uisiana Spatial Reference Center (2014)
nsortium

97°30'0"W
95°0'0"W
92°30'0"W
90°0'0"W
87°30'0"W
85°0'0"W
82°30'0"W
80°0'0"W
35°0'0"N
32°30'0"N
30°0'0"N
27°30'0"N
25°0'0"N

Coordinate
Projection:
Datum: Nort
False Eastir
False Northi
Central Meridian:
Standard Parallel 1: 33.0000
Standard Parallel 2: 45.0000
Latitude Of Origin: 39.0000
Units: Meter

Miles
0 70 140 280
0 105 210 420
Kilometers


2014 Gulf Coast Height Modernization Consortium
Louisiana Spatial Reference Center (2014) Consortium
TEXAS
LOUISIANA
MISSISSIPPI
FLORIDA
Future CORS
97°30'0"W
95°0'0"W
92°30'0"W
90°0'0"W
87°30'0"W
85°0'0"W
82°30'0"W
80°0'0"W
35°0'0"N
32°30'0"N
30°0'0"N
27°30'0"N
25°0'0"N
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
TENNESSEE
Gulf of Mexico
Coordinate System: USA Contiguous Lambert Conformal Conic
Projection: Lambert Conformal Conic
Datum: North American 1983
False Easting: 0.0000
False Northing: 0.0000
Central Meridian: -90.0000
Standard Parallel 1: 33.0000
Standard Parallel 2: 45.0000
Latitude Of Origin: 39.0000
Units: Meter
Miles
0 70 140 280
Kilometers
0 105 210 420
N

Terrestrial & Gravimetric Surveys

Maintain & Update CORS Attributes for Better Vertical Control

- Tie CORS to Tide Stations
- Establish eccentric marks near CORS
- Measure ARP from marks
- Measure relative gravity from marks…

Conclusions

- **Subsidence** has and continues to be the dominant challenge to maintaining **geodetic vertical control** in Louisiana.
- The loss of elevation is making the coast more **vulnerable to hazards**.
- Height modernization is a **shared responsibility**, one that necessitates coordinated efforts to achieve better results.
- LA has joined a NHMP consortium in support of **regional geospatial modeling**

Image Source: M. Wolcott

Questions?

LSU Center for GeoInformatics
http://c4g.lsu.edu

Louisiana Spatial Reference Center