"Subsidence and its effects on vertical control"

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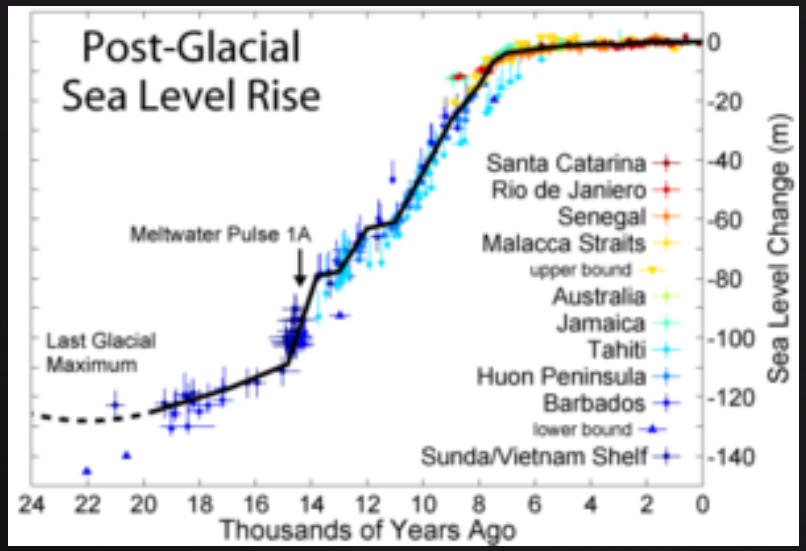
Why do engineers and surveyors need to know about subsidence?

- Subsidence moves BMs away from the datum. Thus, subsidence affects your ability to access the National Spatial Reference System (NSRS). The benchmark you are using to base a design, to prepare a flood certificate, or establish the height of a levee, may no longer be valid.
- Subsidence over time changes the spatial relationship between terrestrial and water datums.
- Subsidence over time can submerge coastal lands, thus affecting land ownership.
- If not fully considered in the design, subsidence over time can compromise the effectiveness of flood protection.

Subsidence FAQ

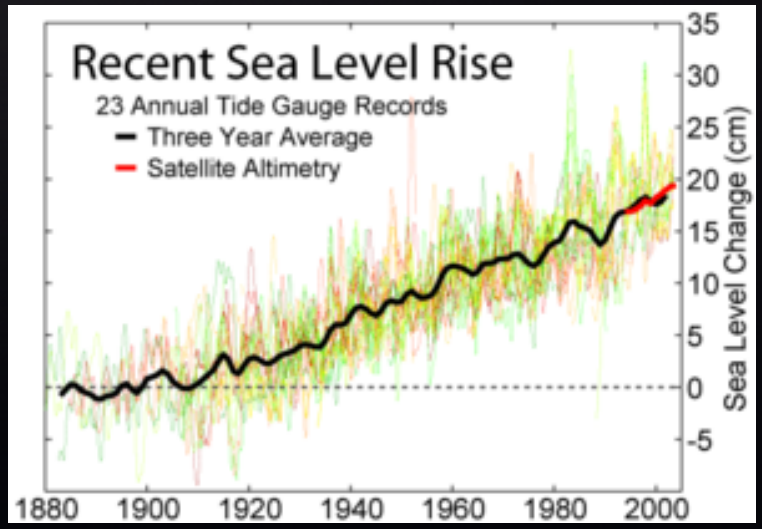
- What is it?
  - *"The downward movement of the Earth's surface with respect to a datum."*
  - *Subsidence has been misunderstood because of inaccurate measurement and false process assumptions.*
  - *It is a condition caused by any one or many natural and anthropogenic processes.*
- Where does it happen?
  - *All of south LA, MS, and TX. Subsidence is 4-D.*
- How fast does it occur?
  - *mm/yr to several dm/yr.*
  - *Subsidence rates are variable in time.*

The Seas Are Rising

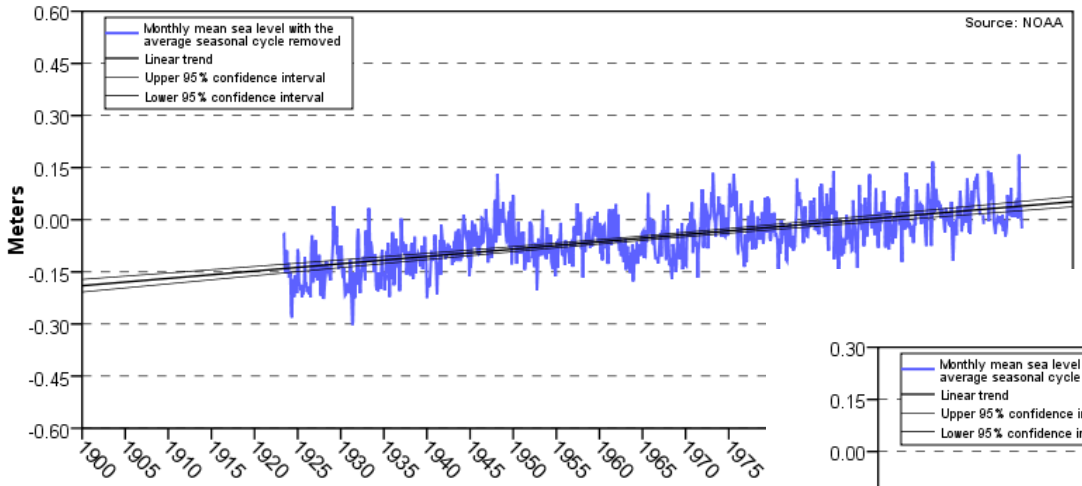


Global sea-level has been slowing since the last glacial maximum.

Global sea-level has been constant over the past 100 years.

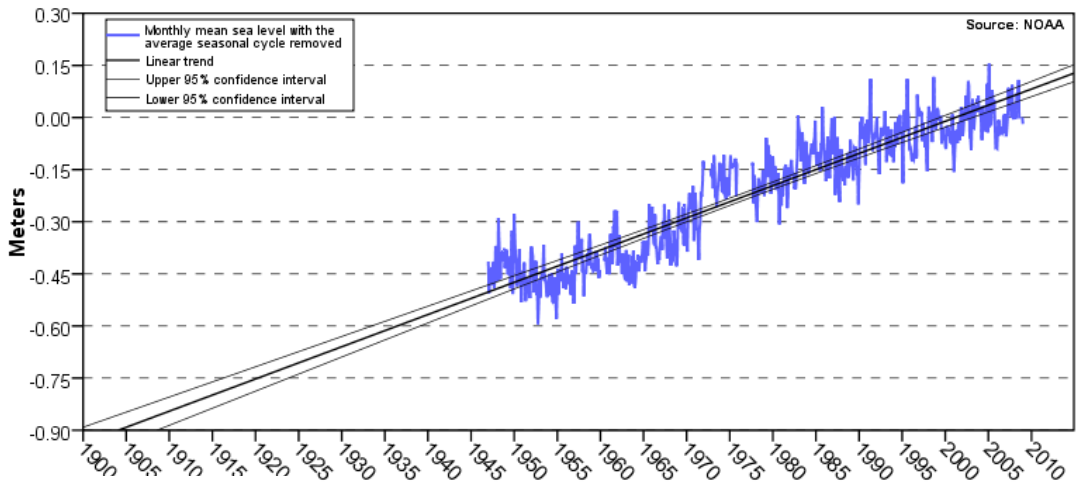


Pensacola, FL 2.10 +/- 0.26 mm/yr

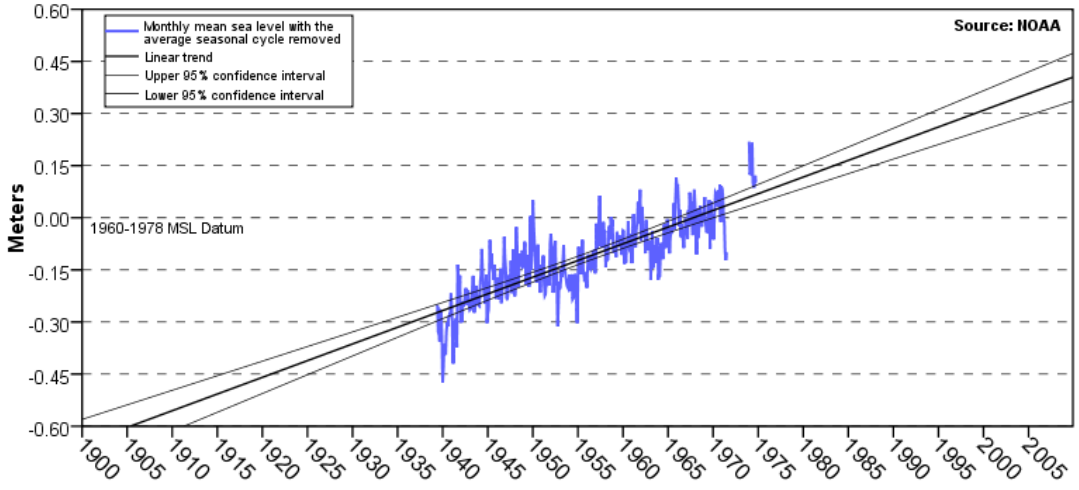


Gulf of Mexico

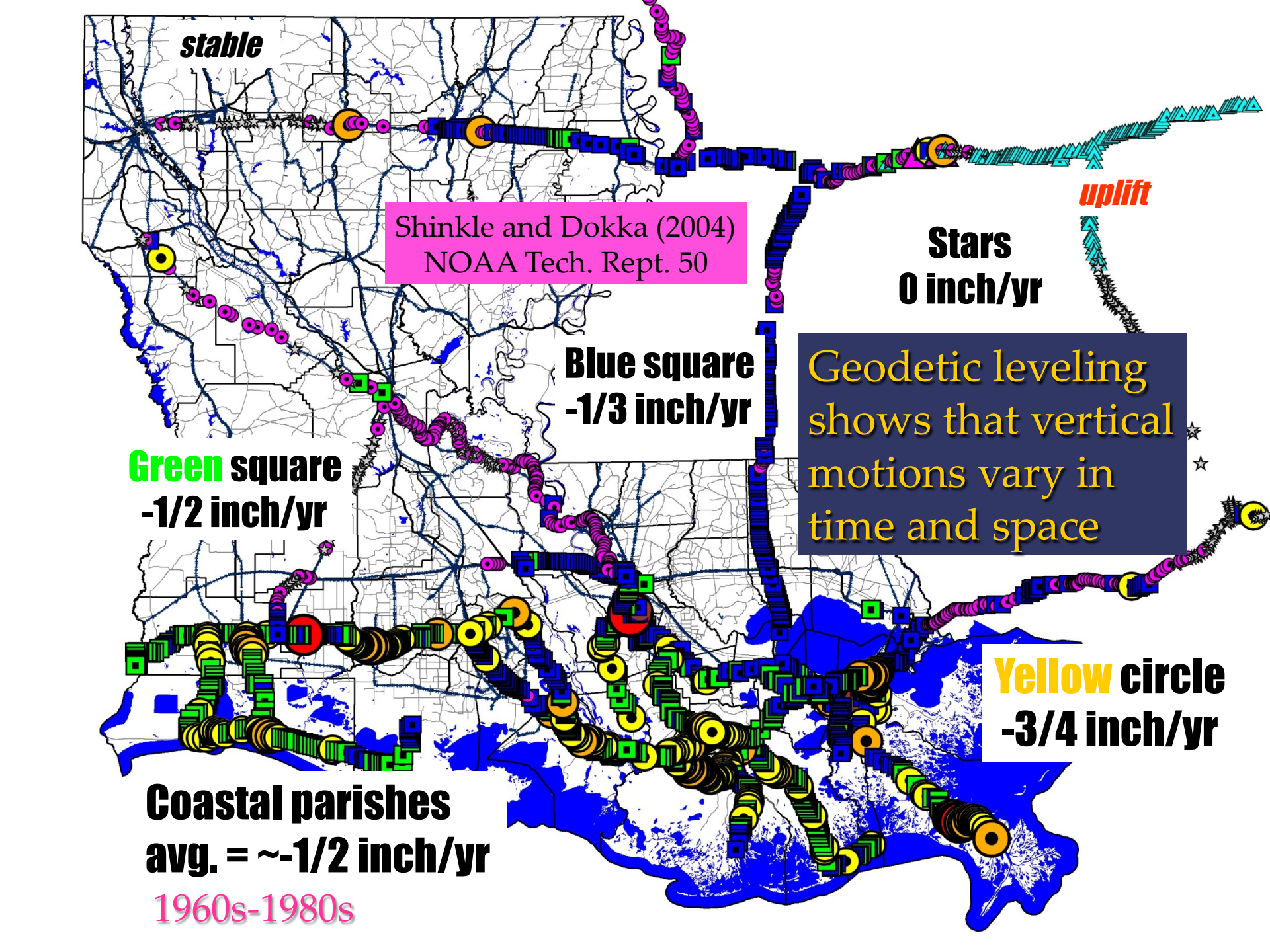
Grand Isle, LA 9.24 +/- 0.59 mm/yr



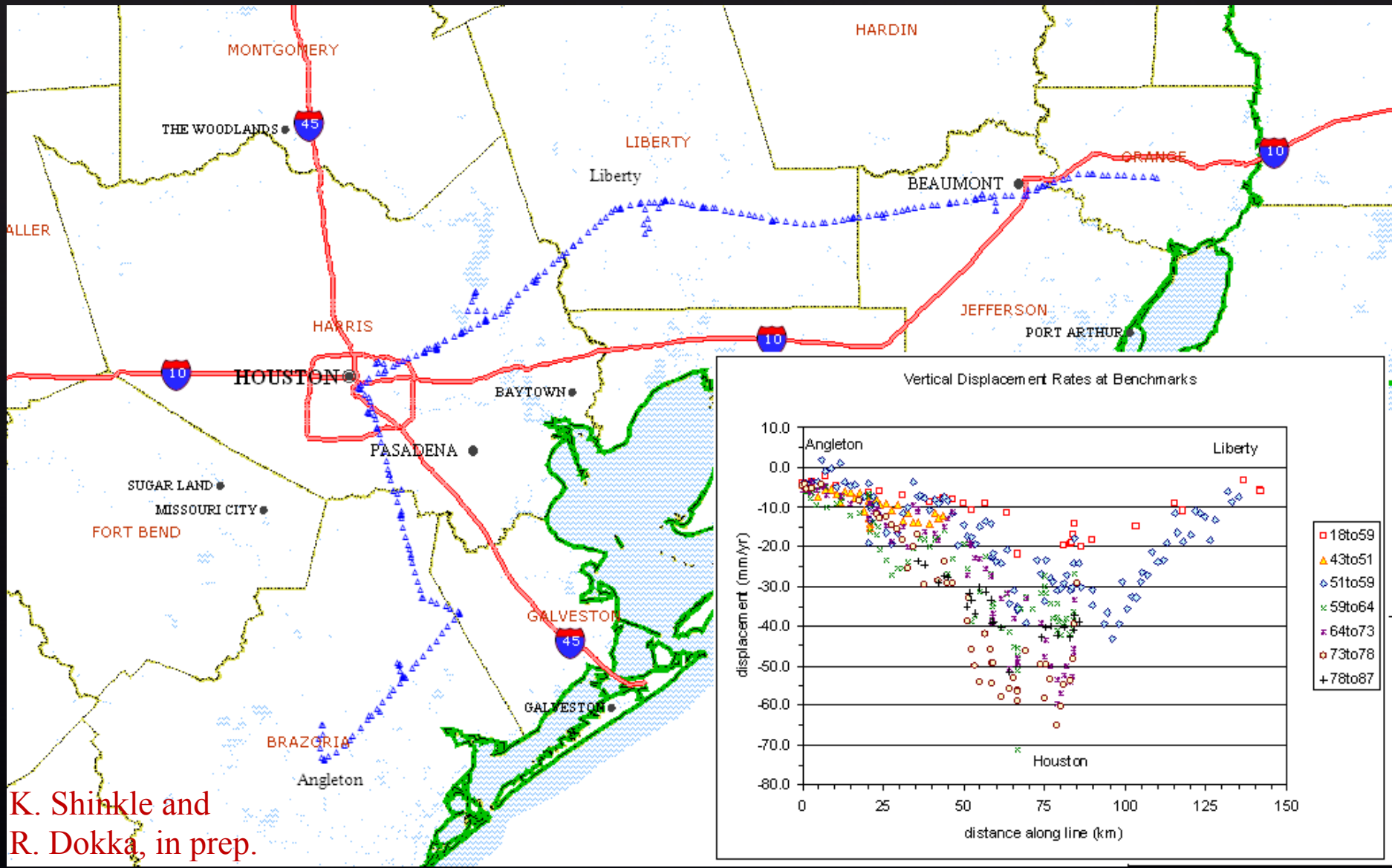
Eugene Island, LA 9.65 +/- 1.24 mm/yr



Tide Gauges


stable
uplift
Shinkle and Dokka (2004)
NOAA Tech. Rept. 50
Stars
0 inch/yr
Blue square
-1/3 inch/yr
Geodetic leveling shows that vertical motions vary in time and space
Green square
-1/2 inch/yr
Yellow circle
-3/4 inch/yr
Coastal parishes
avg. = ~-1/2 inch/yr
1960s-1980s

Subsidence Derived from Geodetic Leveling Southeast Texas



K. Shinkle and
R. Dokka, in prep.

Natural and Anthropogenic Processes that Result in Subsidence

Shallow Processes (processes above aquifers):

→ Natural consolidation and compaction: constant ≤*3 mm/yr*

→ Human-induced consolidation and compaction*: *~30 mm/yr*

- Desiccation by urbanization (behind levees)
- Organic soil oxidation

Deep Processes (processes below and including aquifers):

→ Sediment and water load induced flexure of the lithosphere*: *constant 0 to -8mm/yr*

→ Faulting: *variable up to -20mm/yr*

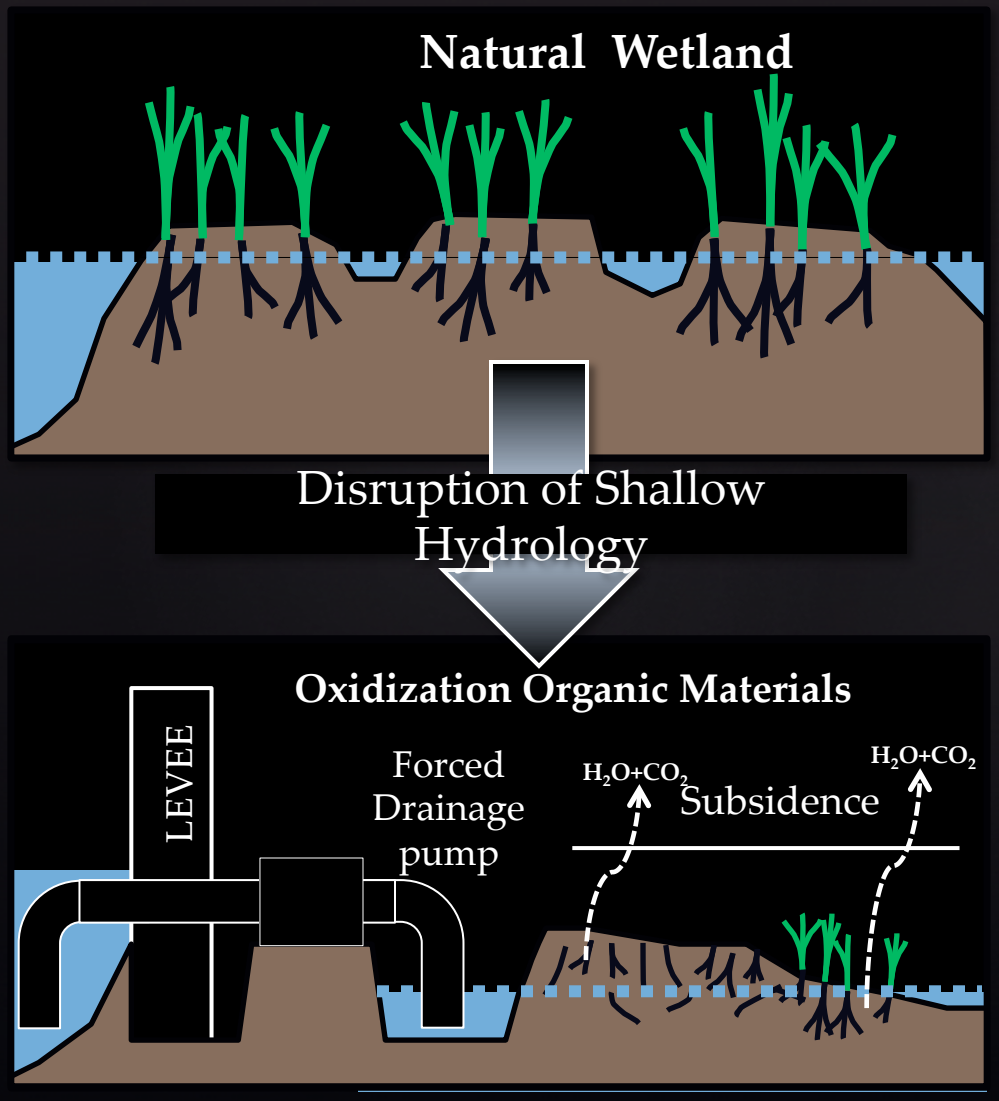
→ Salt evacuation: *variable 0 to -?? mm/yr*

→ Water pumping*: *variable up to -65mm/yr*

→ Oil & gas extraction: *variable 0 to -3 mm/yr*

* *The dominant causes of subsidence in LA*

Shallow Subsidence



Sediment oxidation, compaction and consolidation of organic materials

a,b,c:

0.1 – 10 mm yr^{-1}

- Flood Protection
- Forced Drainage

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

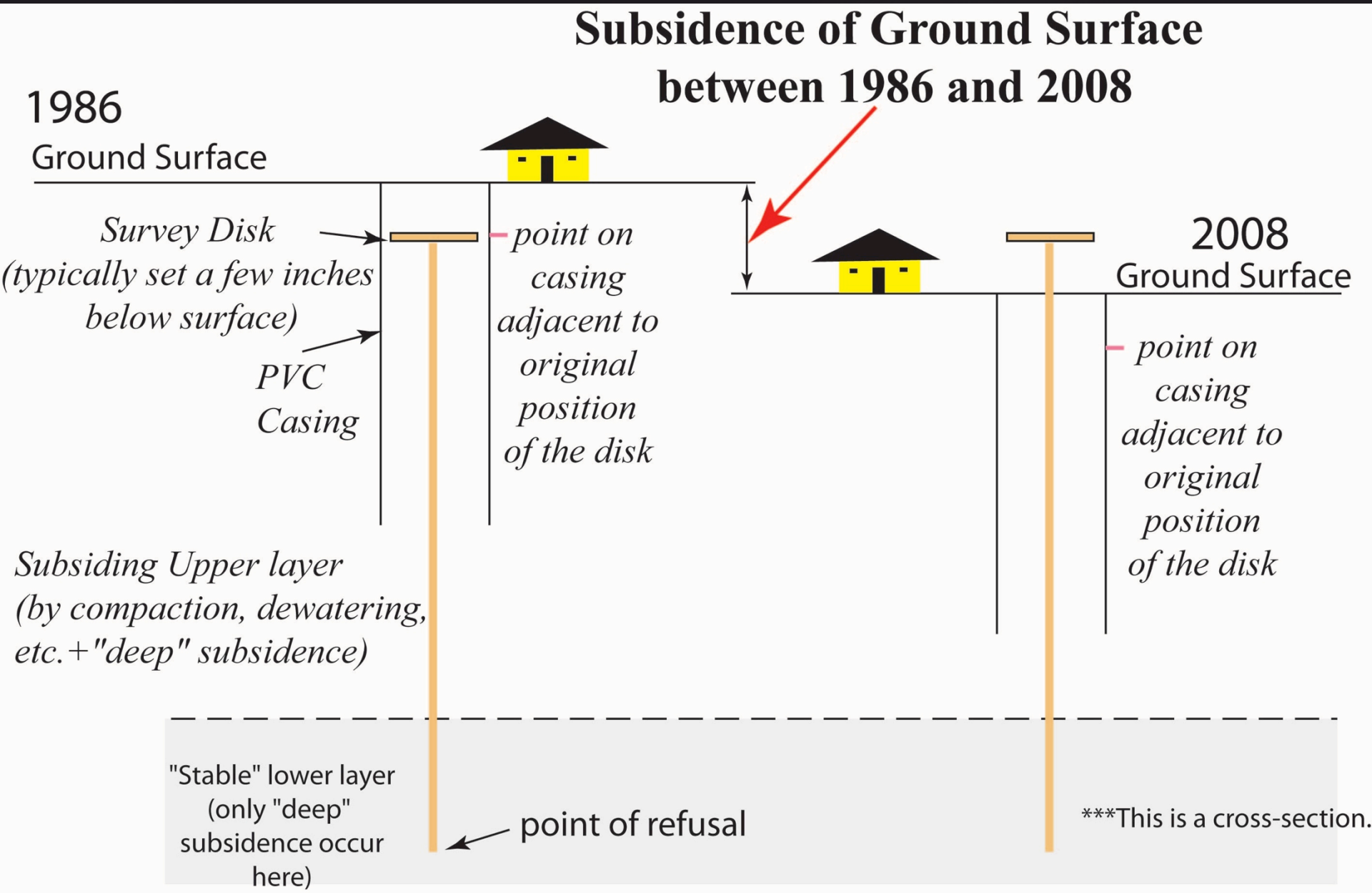
What does shallow subsidence look like?

Forced Drainage Speeds up Compaction

Deep Rods and Shallow Subsidence

- Region above producing aquifers.
- Virtually all BMs and CORS are partially affected.
- Most people think all subsidence is caused by shallow subsidence.

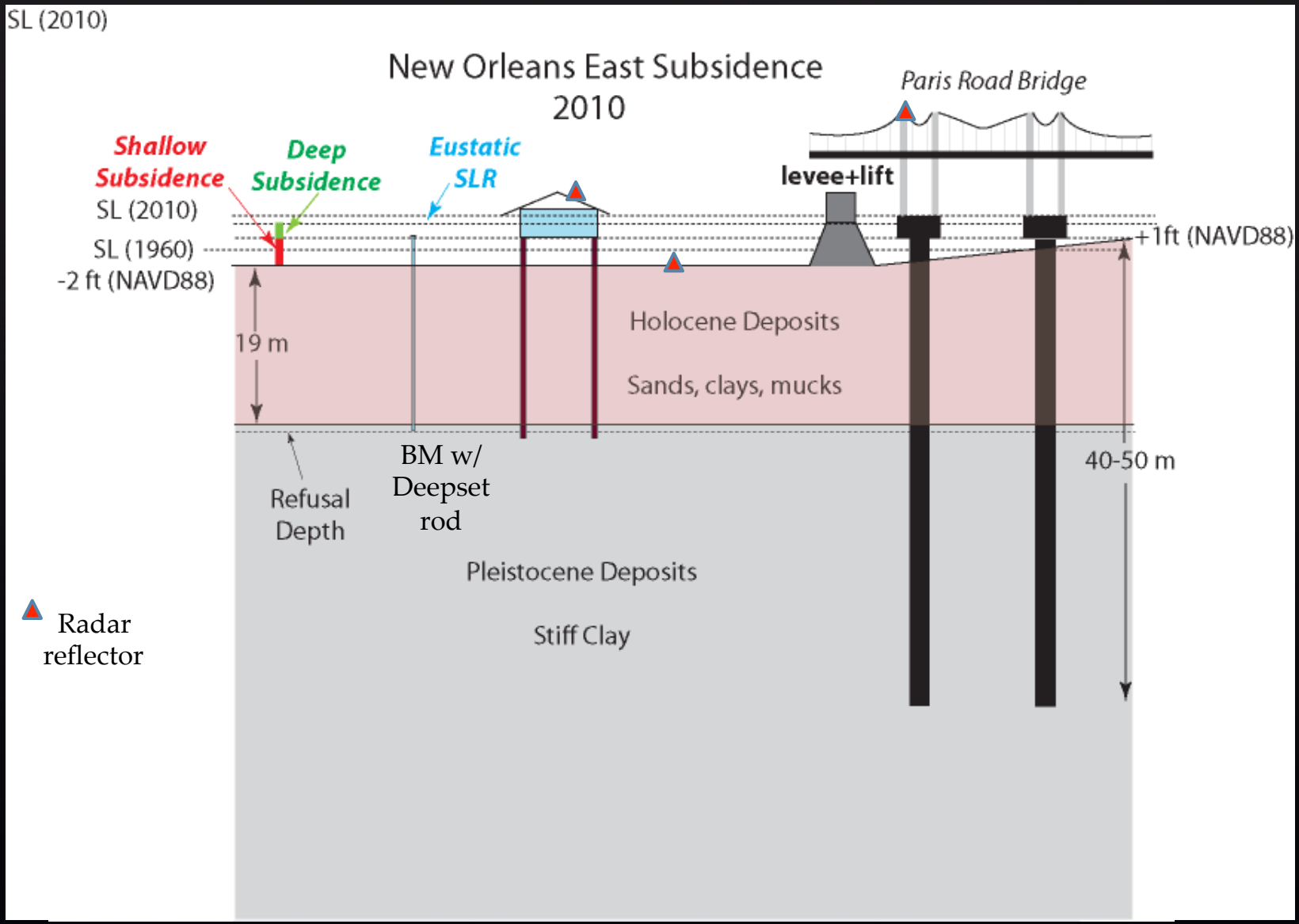
Deep Rods and Shallow Subsidence



Deep Subsidence

- Conventional wisdom has considered subsidence to be constant in time and space.
- Analysis of geodetic data as a function of depth shows that subsidence is variable in time and space (vertical and horizontal).
- Thus, to measure subsidence, you need to understand what the the underlying processes might be so that a proper measurement strategy can be designed.
- It is all about the monumentation!

Monumentation determines how much of the subsidence you measure



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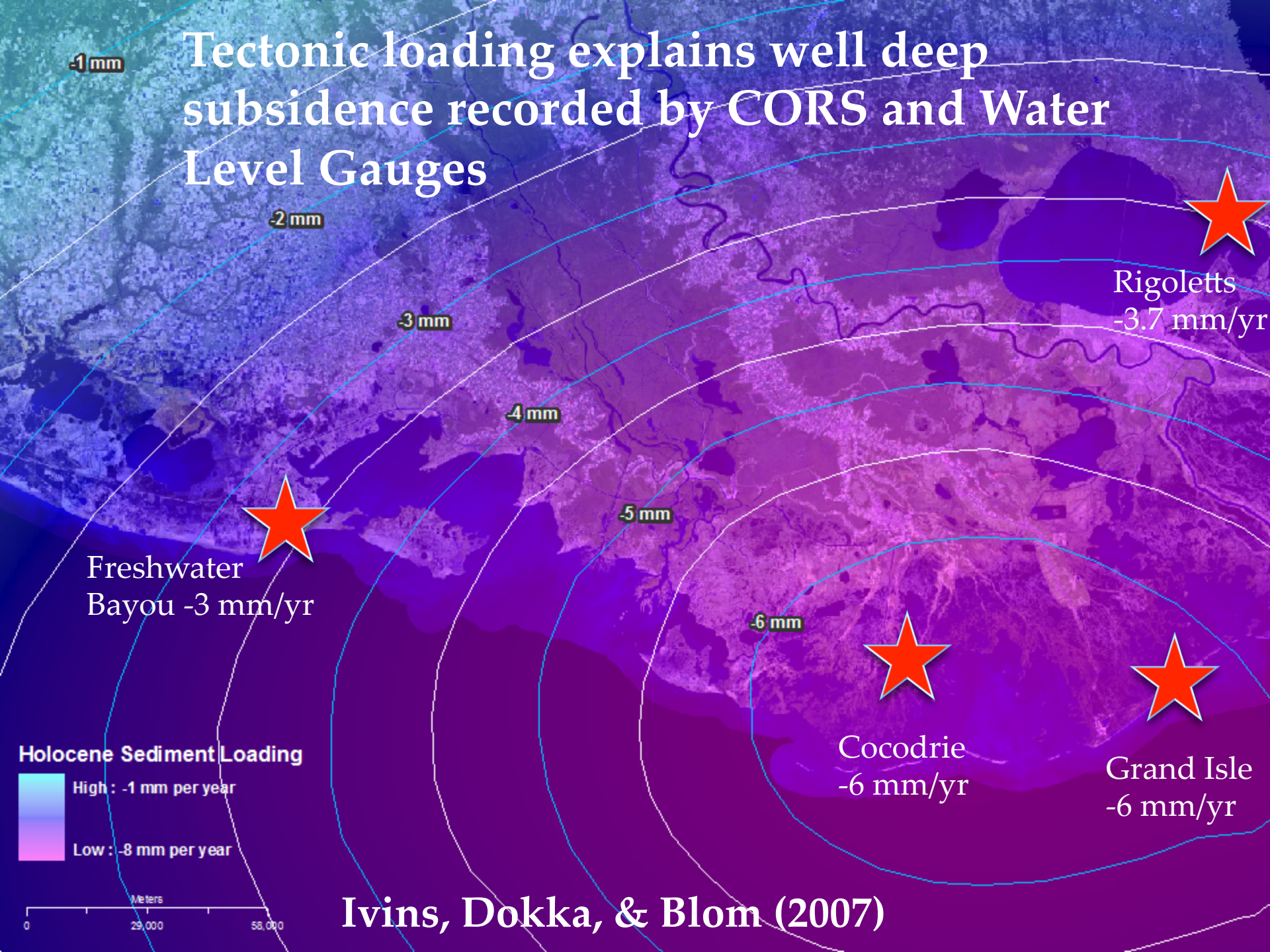
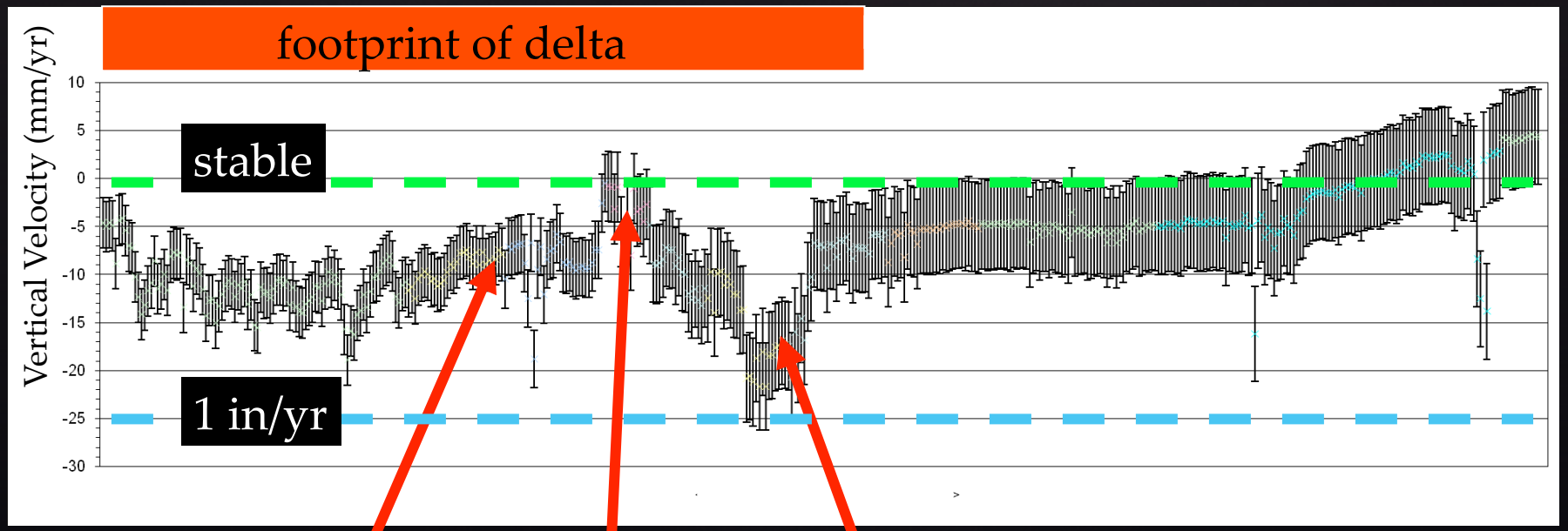

Tectonic loading explains well deep subsidence recorded by CORS and Water Level Gauges
-1 mm
-2 mm
-3 mm
-4 mm
-5 mm
-6 mm
Rigoletts
-3.7 mm/yr
Freshwater
Bayou -3 mm/yr
Cocodrie
-6 mm/yr
Grand Isle
-6 mm/yr
Holocene Sediment Loading
High : -1 mm per year
Low : -8 mm per year
Meters
0
29,000
58,000
Ivins, Dokka, & Blom (2007)

Geodetic Measurements Show that Subsidence Varies in Time and Space

A Regional Subsidence Profile Based on 1970's Leveling

Grand Isle

Pensacola

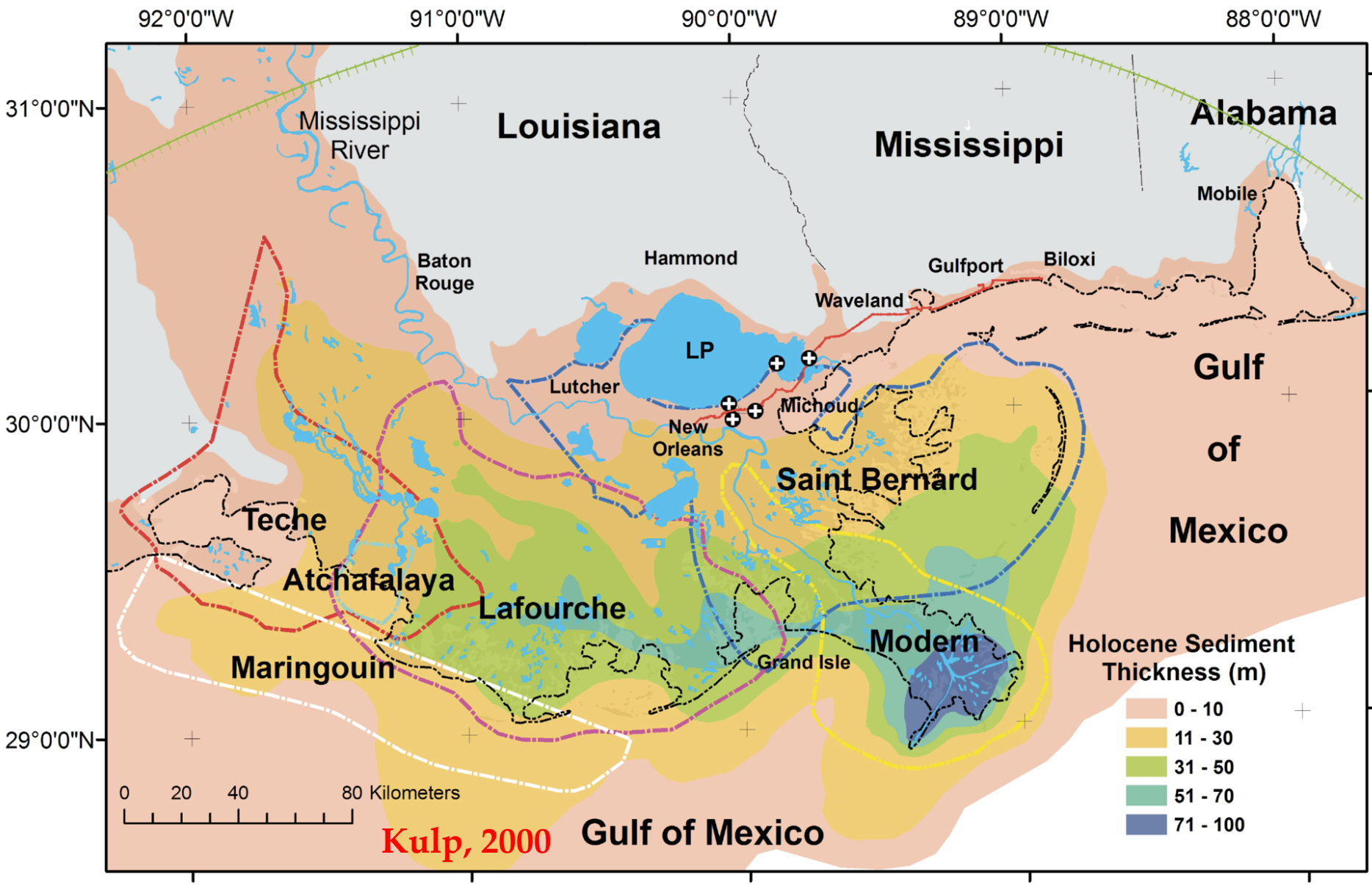


Kenner
moderate subsidence

GRETNA
slight subsidence

New Orleans East
severe subsidence

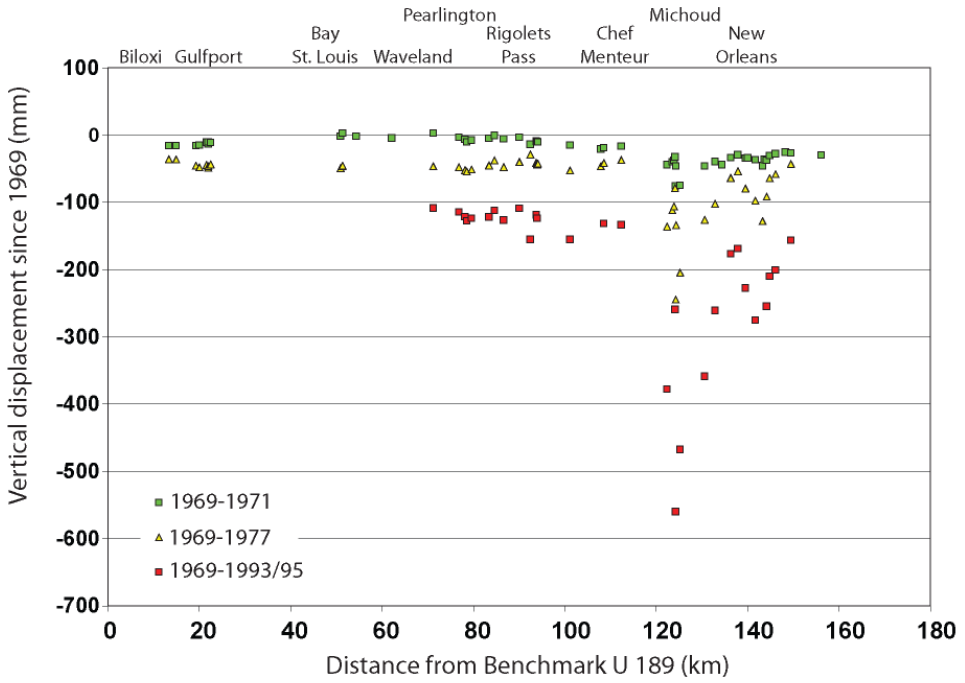
Thickness of the Mississippi River Delta

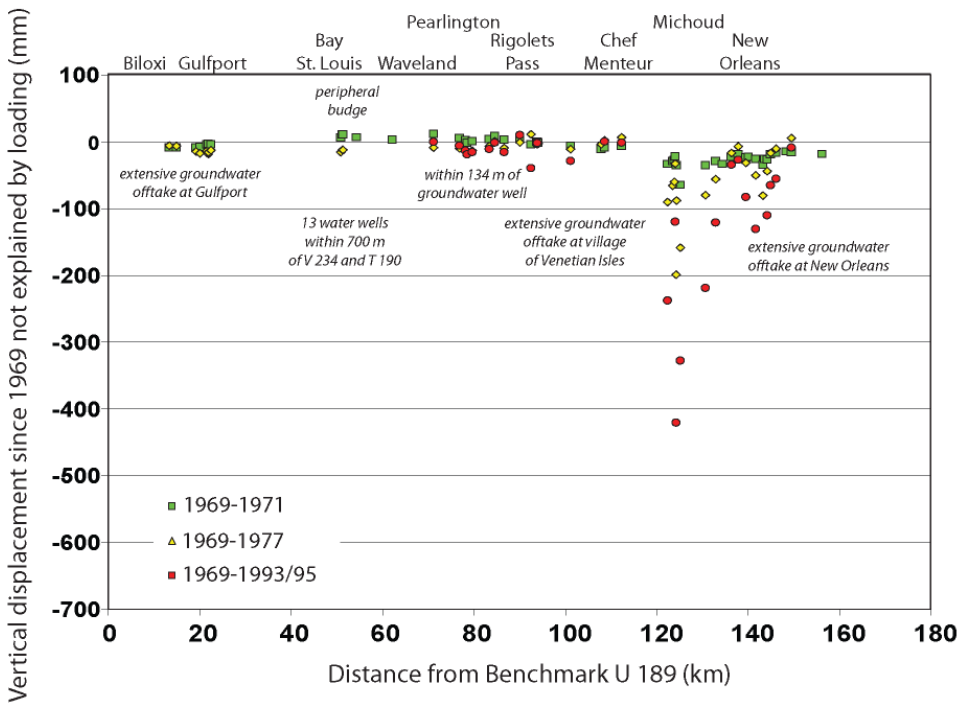


Analysis of National Geodetic Survey 1st Order Level Data

- 1955-1995
- All monuments set below Holocene.
- No Holocene effects!!
- There is a lot of subsidence occurring below the Holocene.
- It's not just compaction.

Let's test the results with water level gauges.

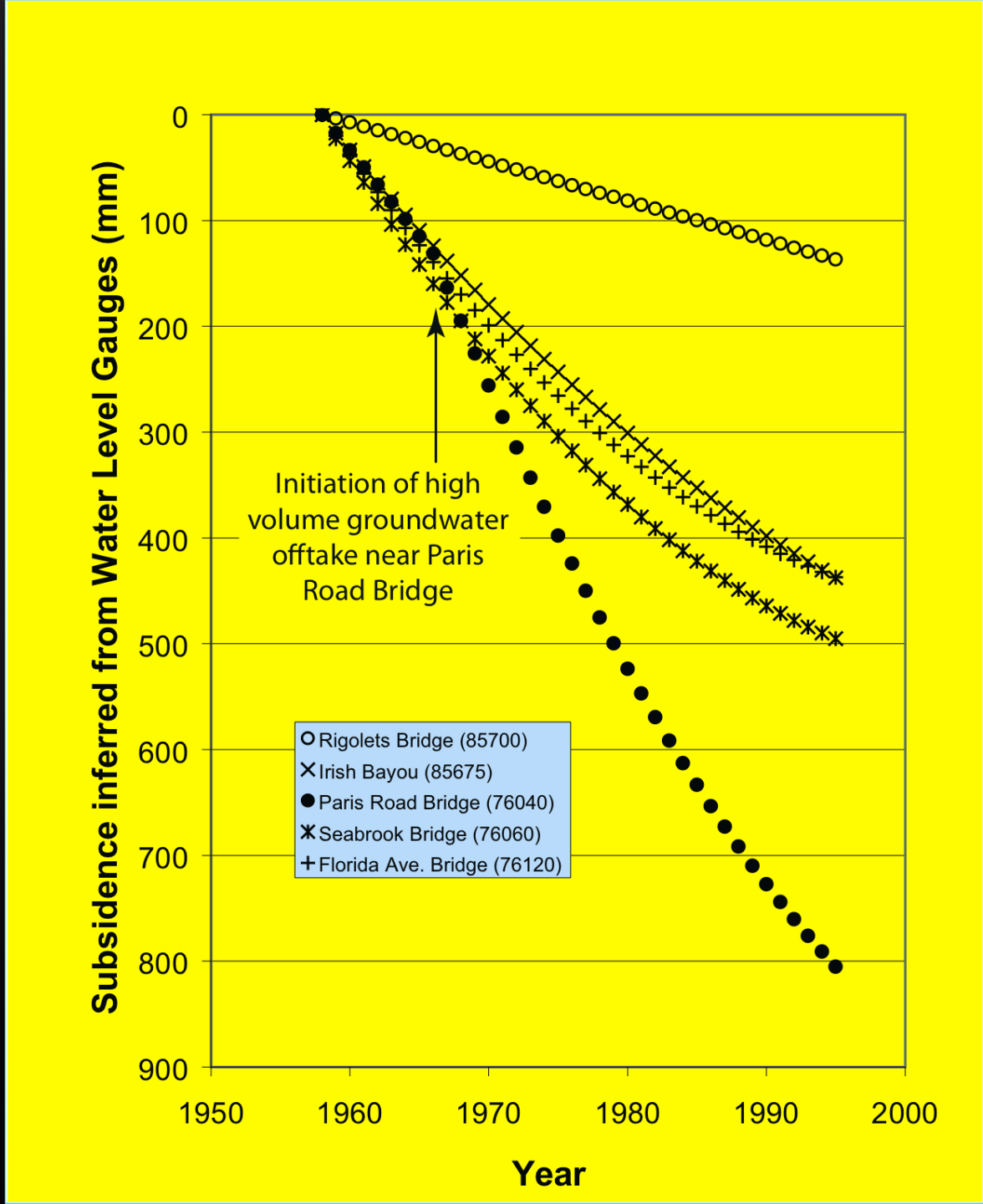




Subsidence from USACE water level gauges in New Orleans: 1960-1995

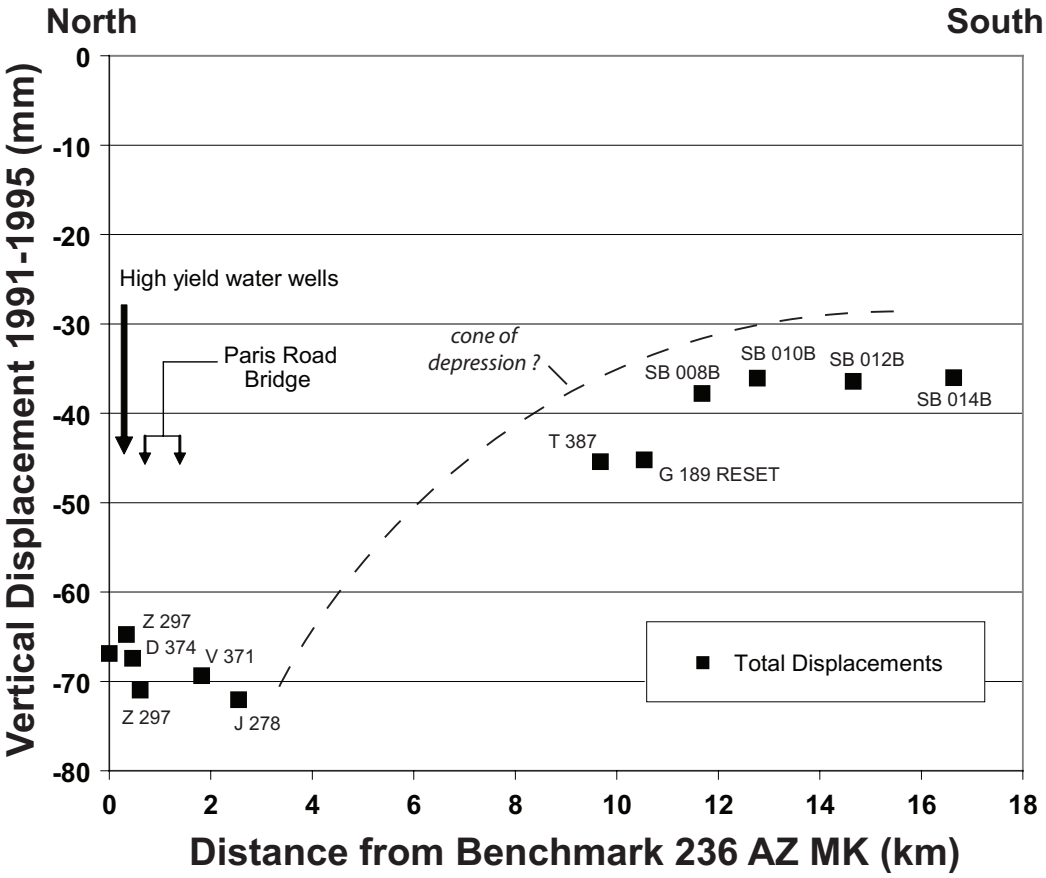
Gauges mounted on piles supporting bridges that penetrate well below Holocene sediments

NO SHALLOW SUBSIDENCE!!



I-610 Bridge: Subsided ~1 m in 35 years

Consistent with groundwater pumping



Why the Louisiana Coast is Being Lost

~~*Sediment Accretion*~~ = [*Global Sea-level Rise* + ~~*Local/Regional effects*~~ + *Subsidence*]

~~*Sediment Accretion = terrigenous (river) + organic (in situ)*~~

Global Sea-level Rise = 2-3 mm/yr

~~*Local/regional effects = negligible*~~

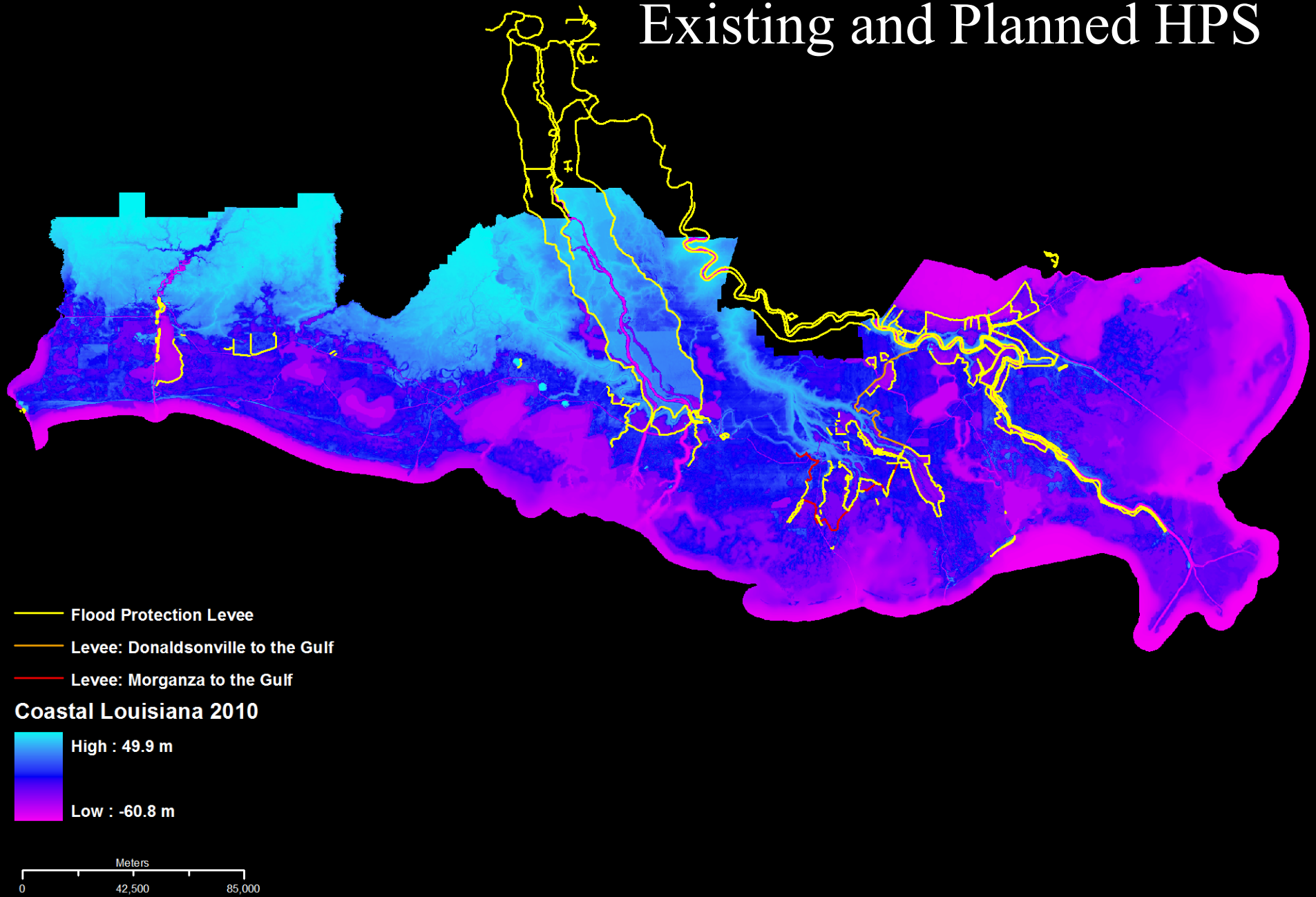
Subsidence = varies in time and space

Let's Predict the Future!

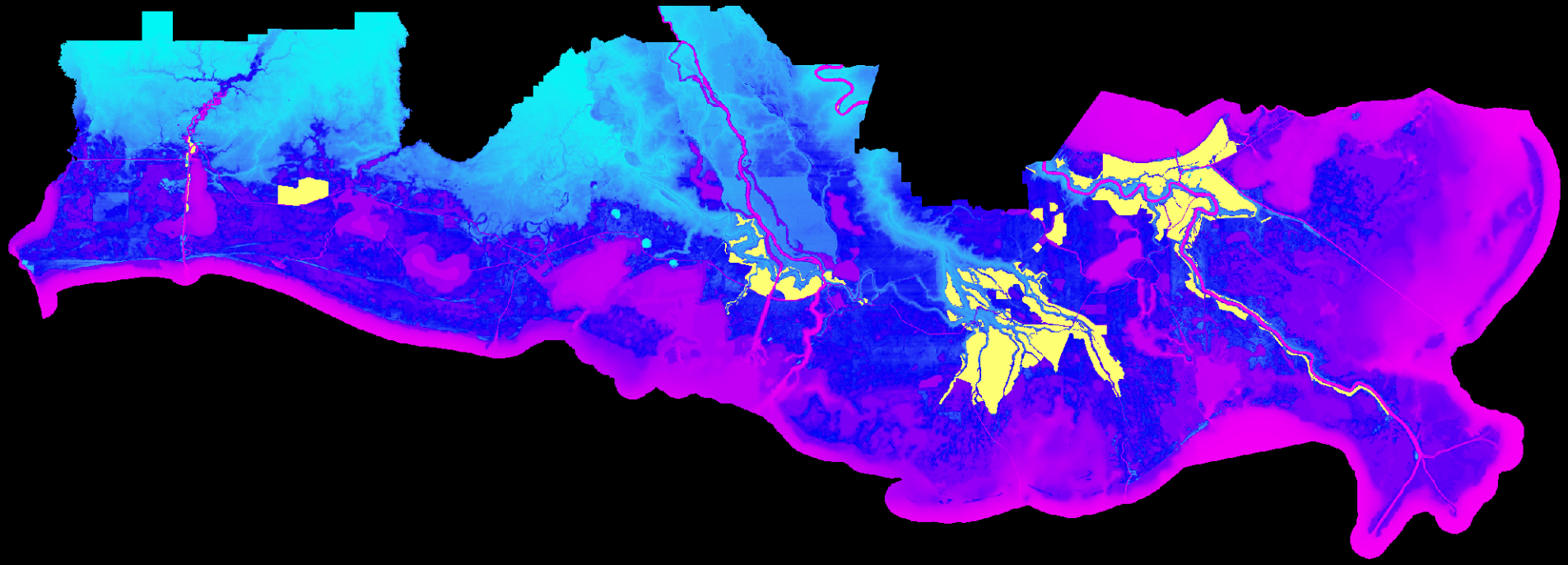
Using the recent past as our guide to the near future.

Subsidence due to tectonic loading, natural compaction, and levee building. Let's assume that we stop groundwater pumping and the faults stop slipping.

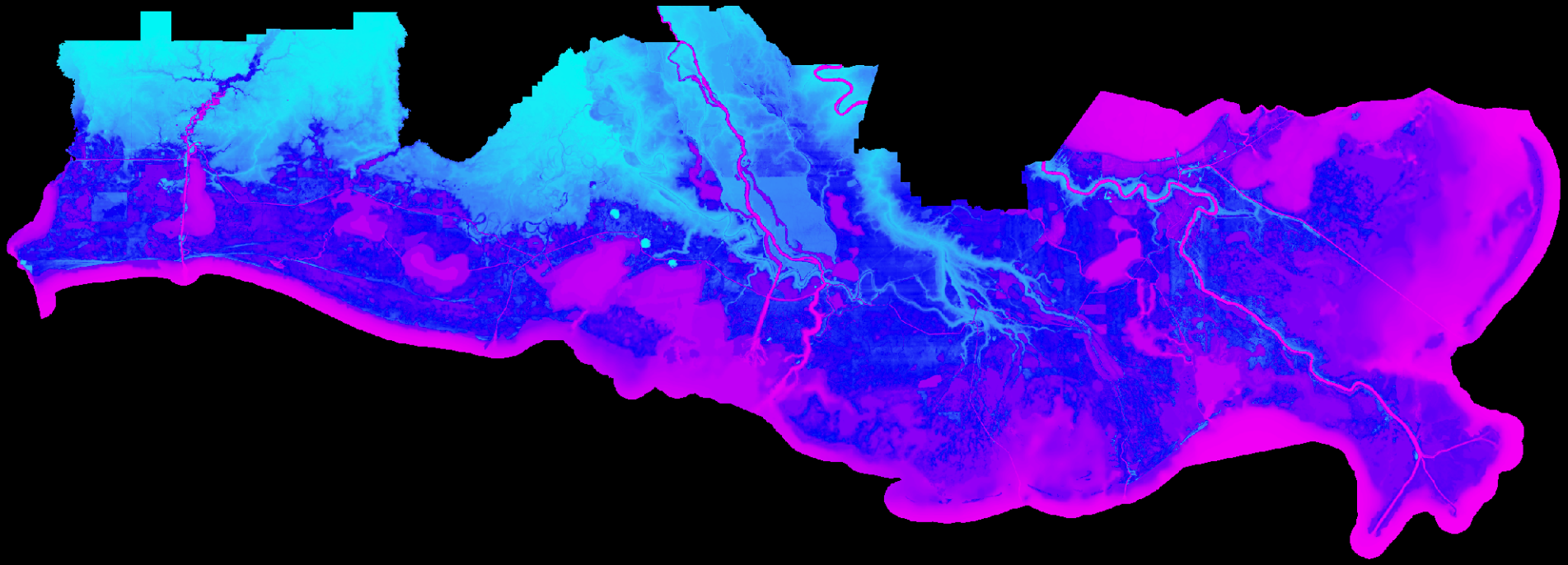
Existing and Planned HPS



Constrained Wetlands, Natural Wetlands, and Natural Levees.



Today



Coastal Louisiana 2010

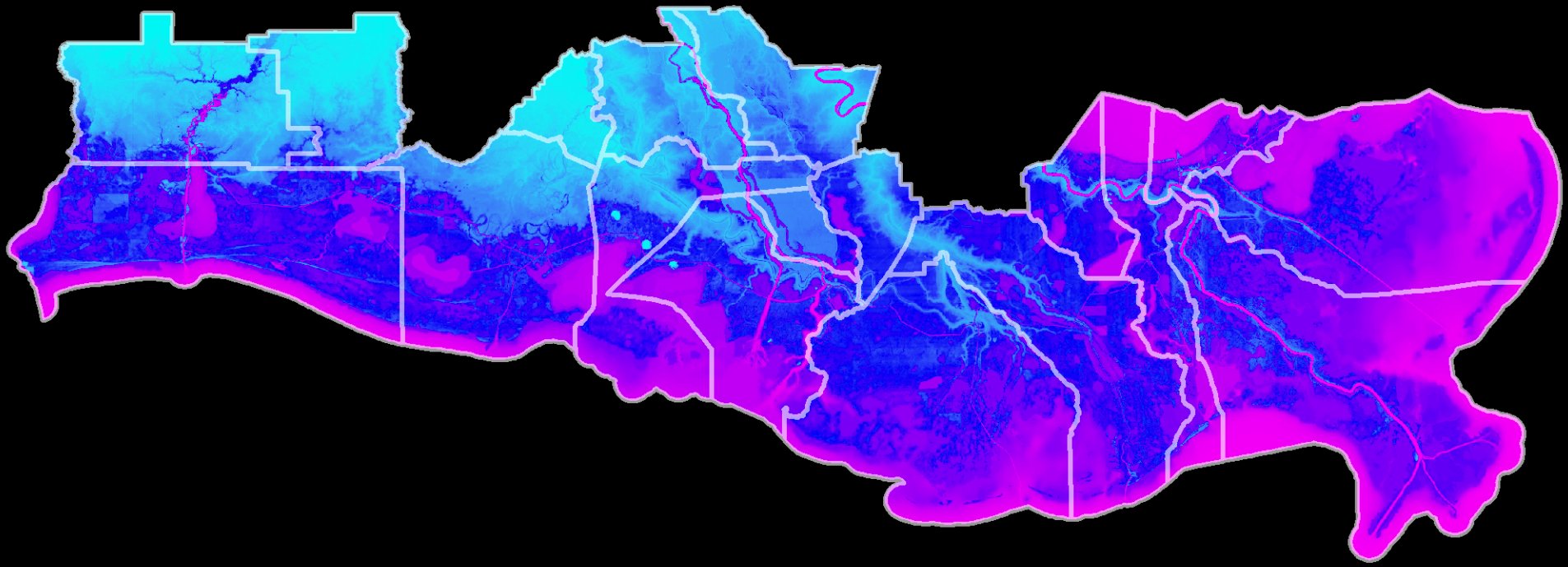
High : 49.9 m

Low : -60.8 m

Meters

0 42,500 85,000

Today



Coastal Zone Parishes

Coastal Louisiana 2010

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Meters

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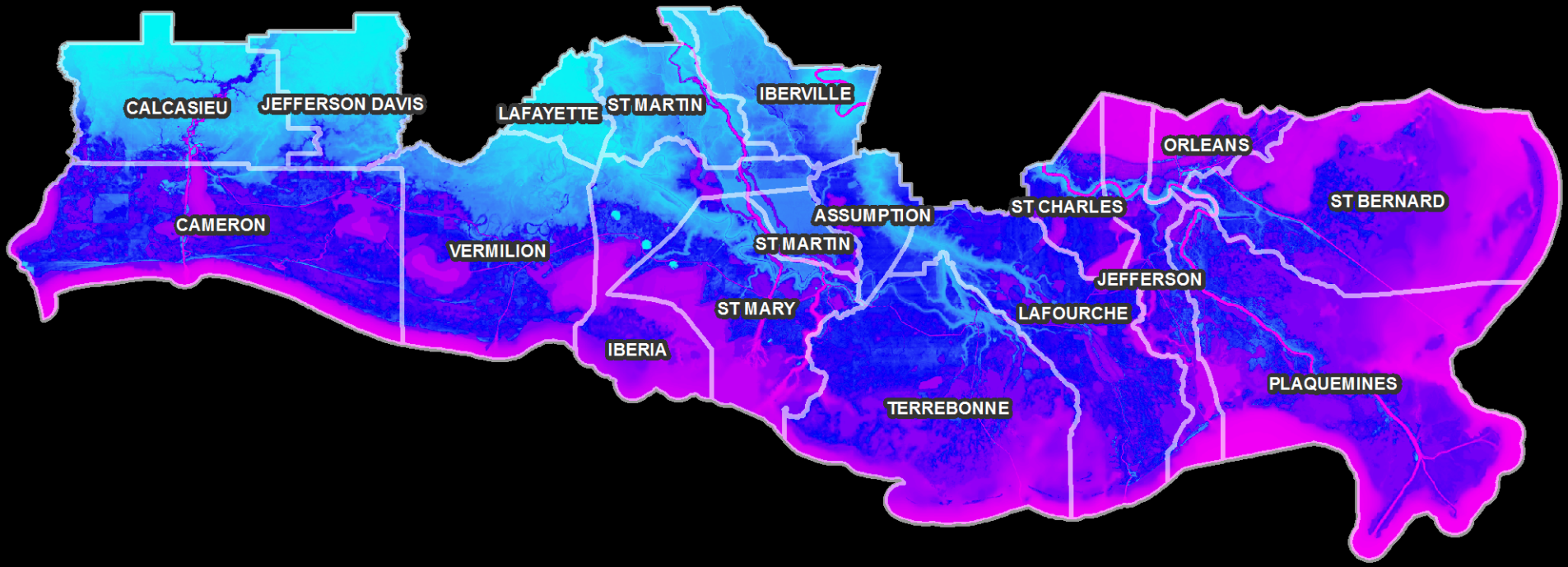

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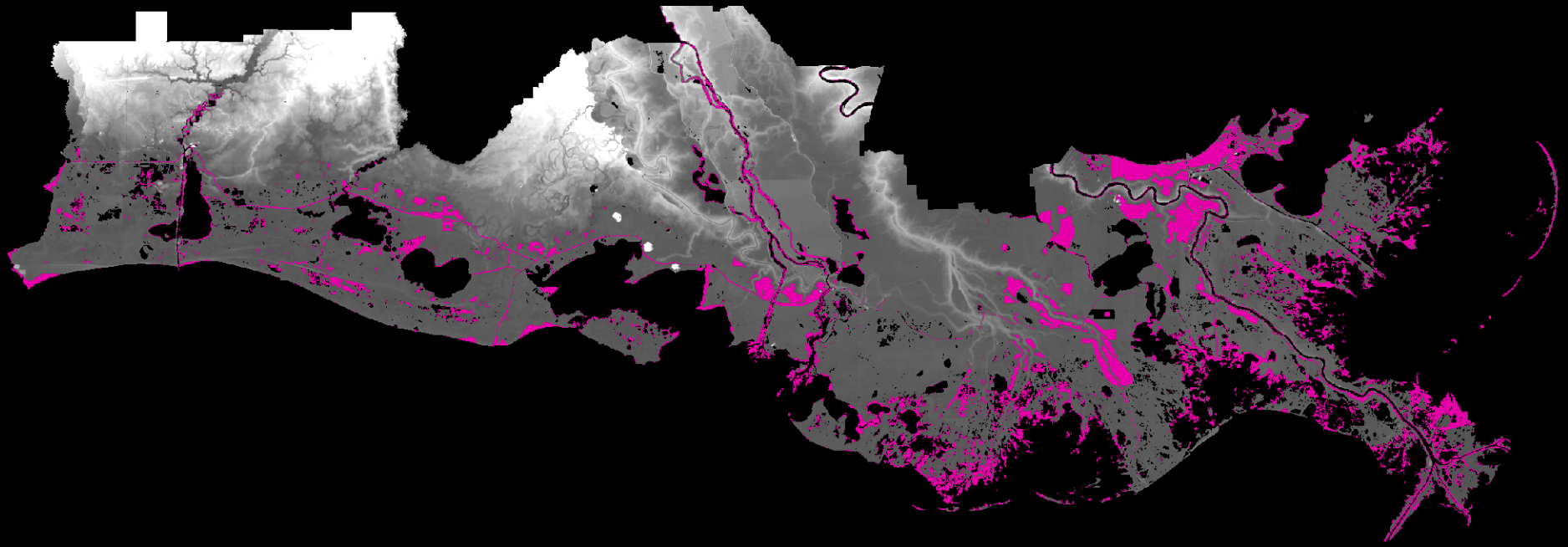


Land Below Sea Level

Coastal Louisiana 2010: Land Elevations

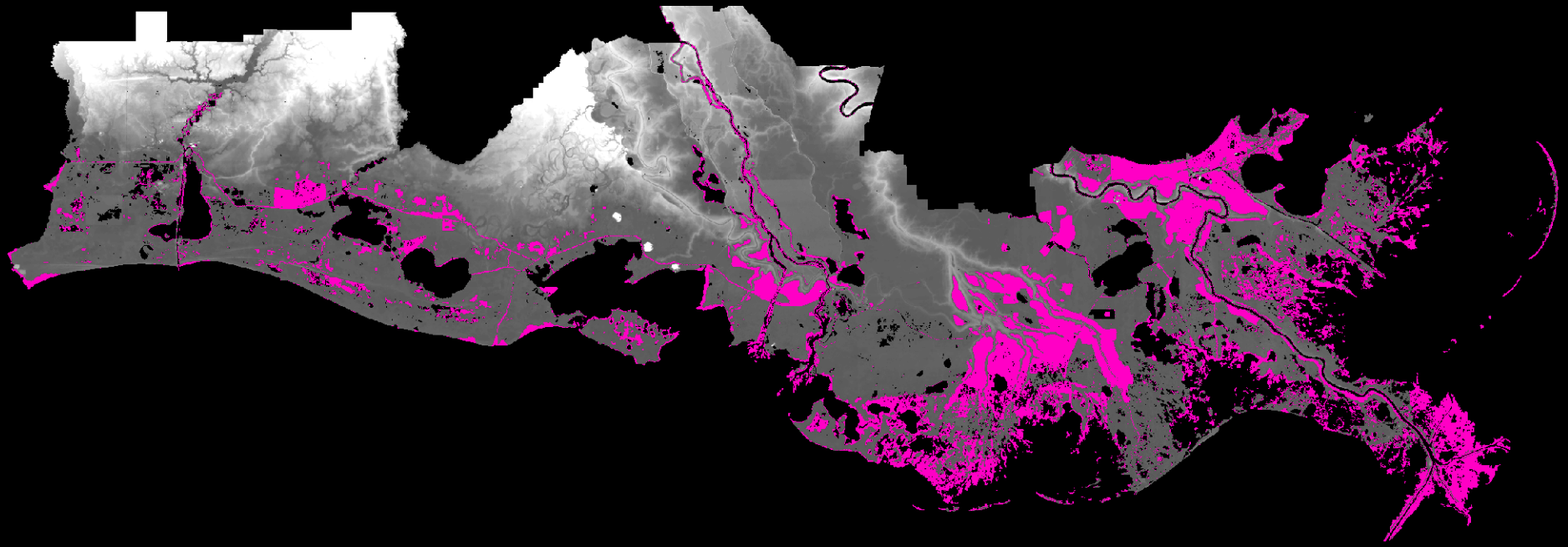
High : 49.9 m

Low : -45.4 m

Meters

0 42,500 85,000

2050



Land Below Sea Level

Coastal Louisiana 2050: Land Elevations

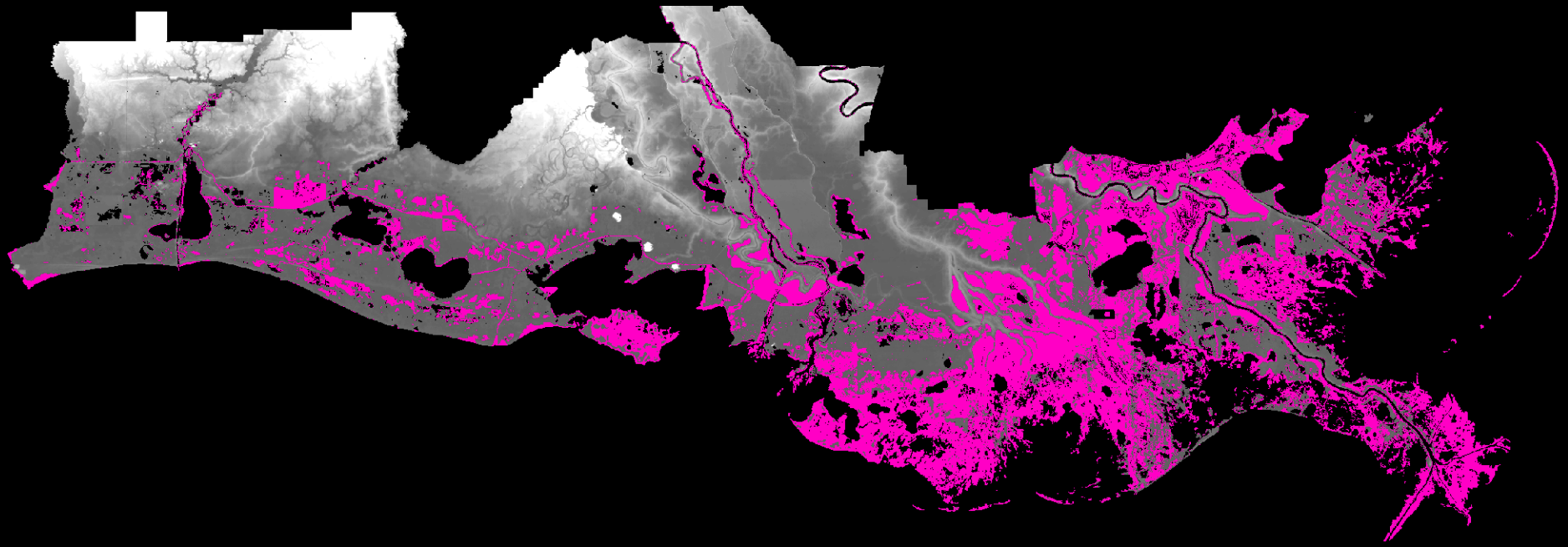
High : 49.9 m

Low : -45.6 m

Meters

0 42,500 85,000

2100



Land Below Sea Level

Coastal Louisiana 2100: Land Elevations

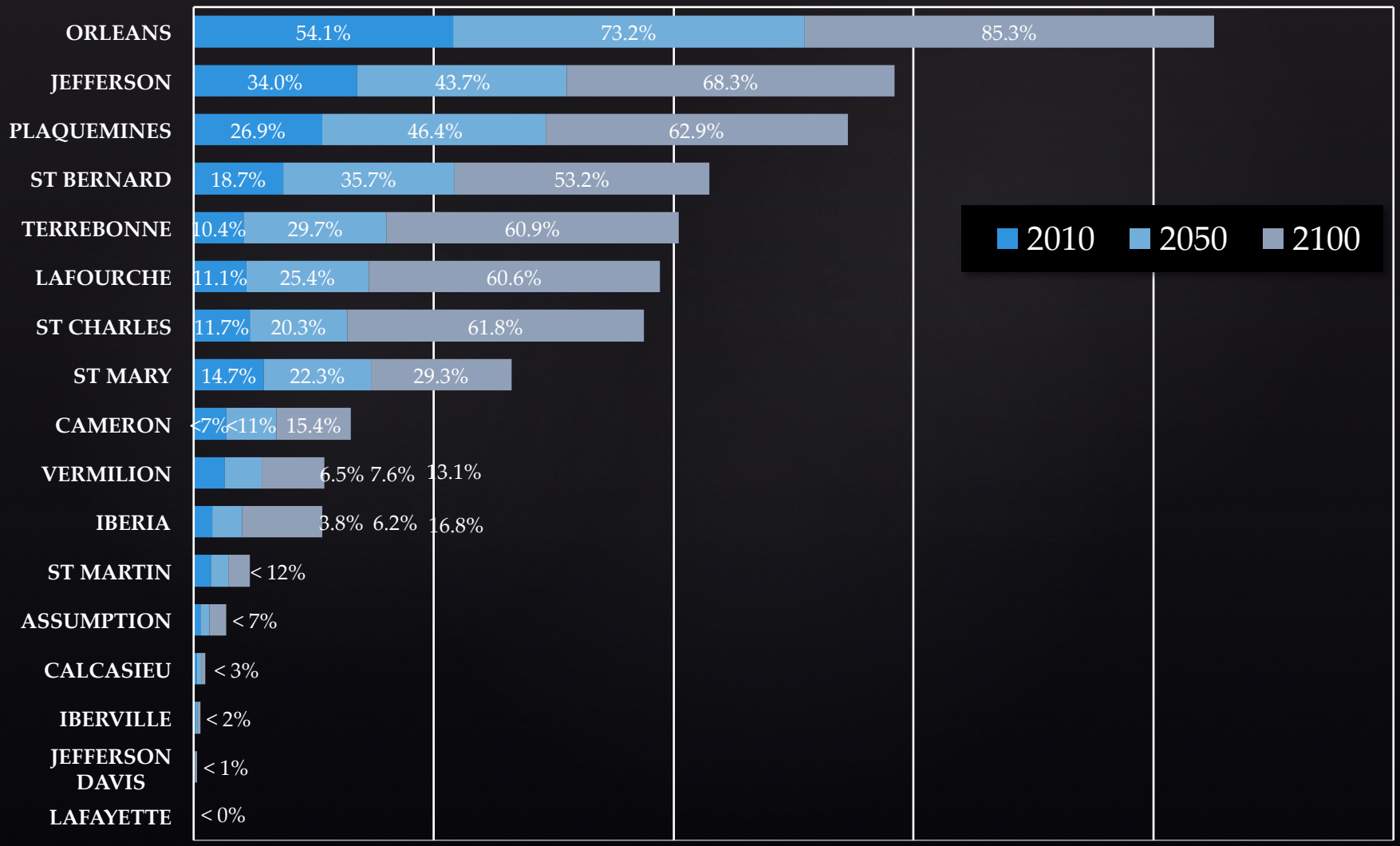
High : 49.9 m

Low : -45.9 m

Meters

0 42,500 85,000

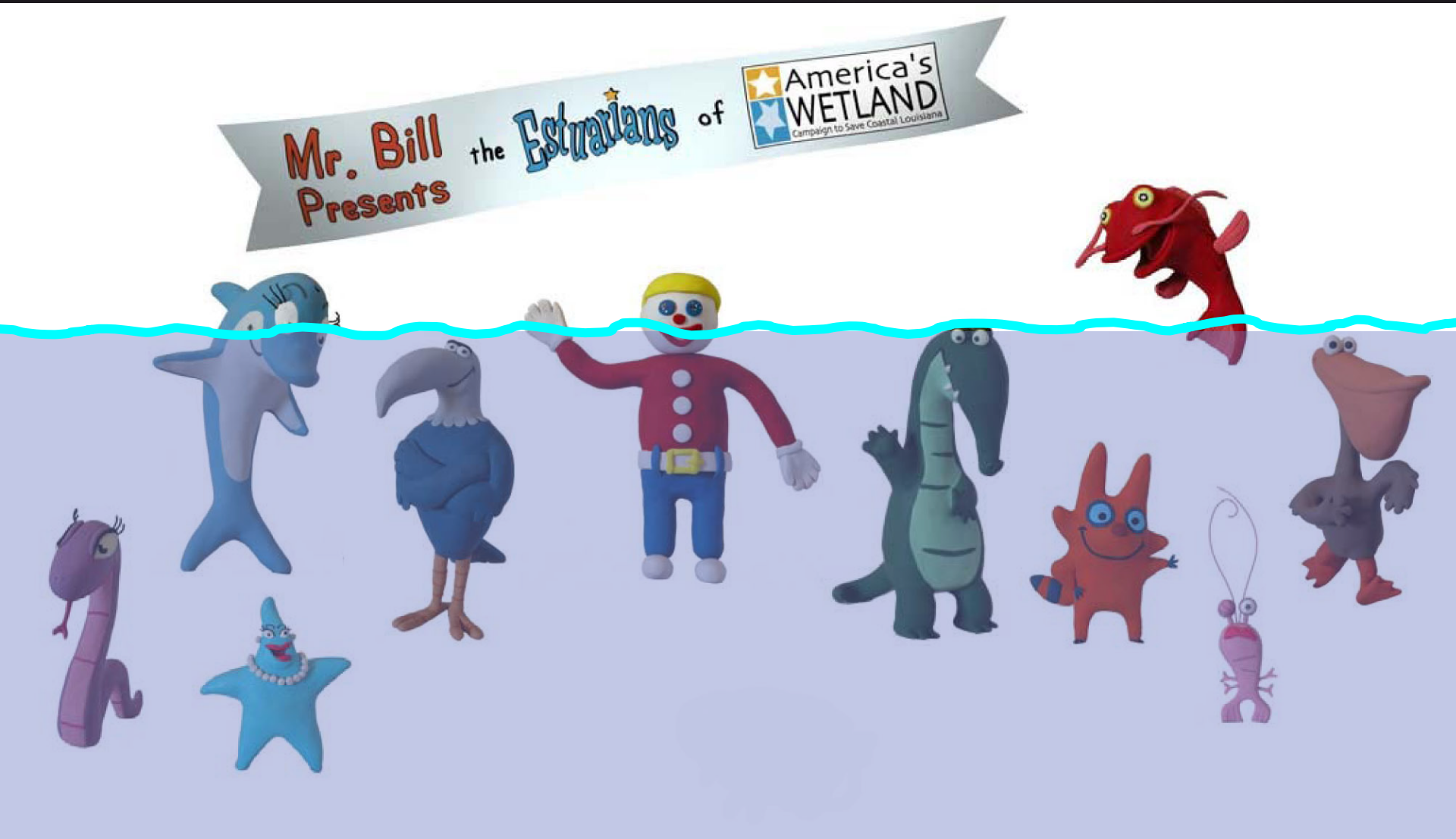
Percent Land Below Sea Level by Parish Through 2100



Conclusions

- Subsidence has and continues to be the dominant challenge to maintaining horizontal and vertical control along the Gulf Coast.
- Anthropogenic causes like groundwater pumping and forced drainage dominate subsidence.
- The loss of elevation is making the coast more vulnerable to storms.

Thank You!


Mr. Bill Presents
the Estuarians
of
America's WETLAND
Campaign to Save Coastal Louisiana