

“Subsidence and its effects on vertical control”

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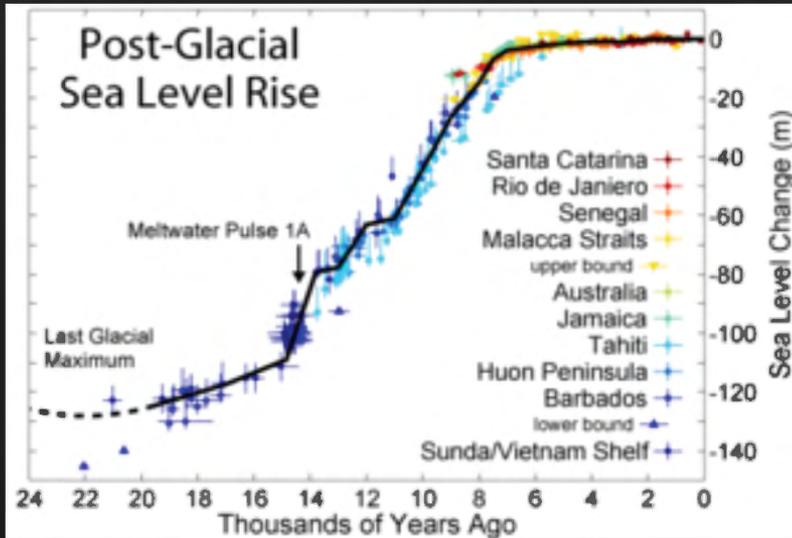
Why do engineers and surveyors need to know about subsidence?

- 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

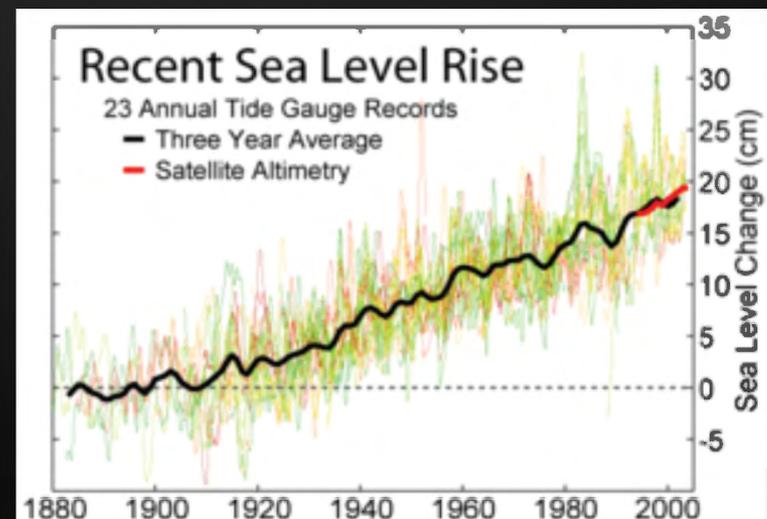
- What is it?
 - *“The downward movement of the Earth’s surface with respect to a datum.”*
 - *Subsidence has been misunderstood because of inaccurate measurement and false process assumptions.*
 - *It is a condition caused by any one or many natural and anthropogenic processes.*
- Where does it happen?
 - *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

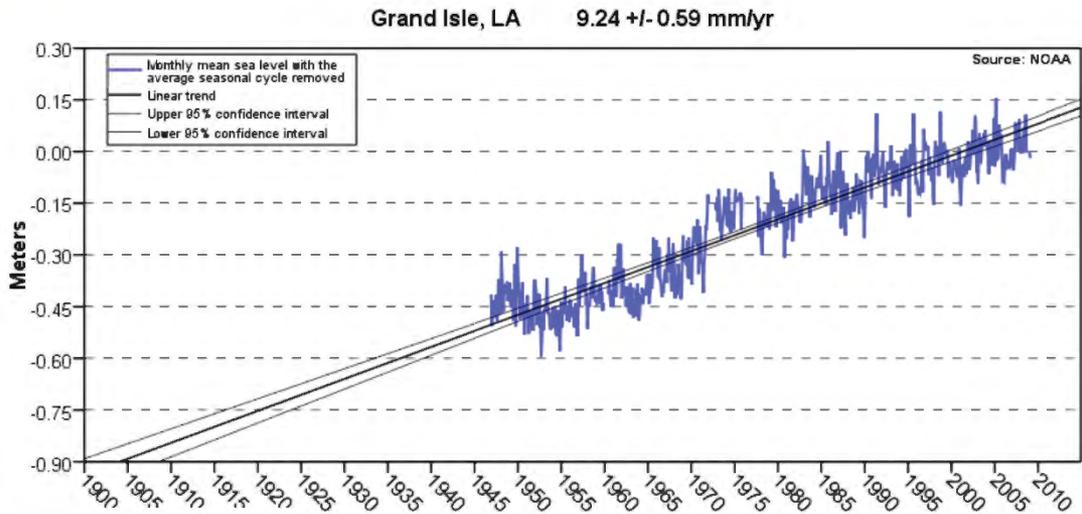
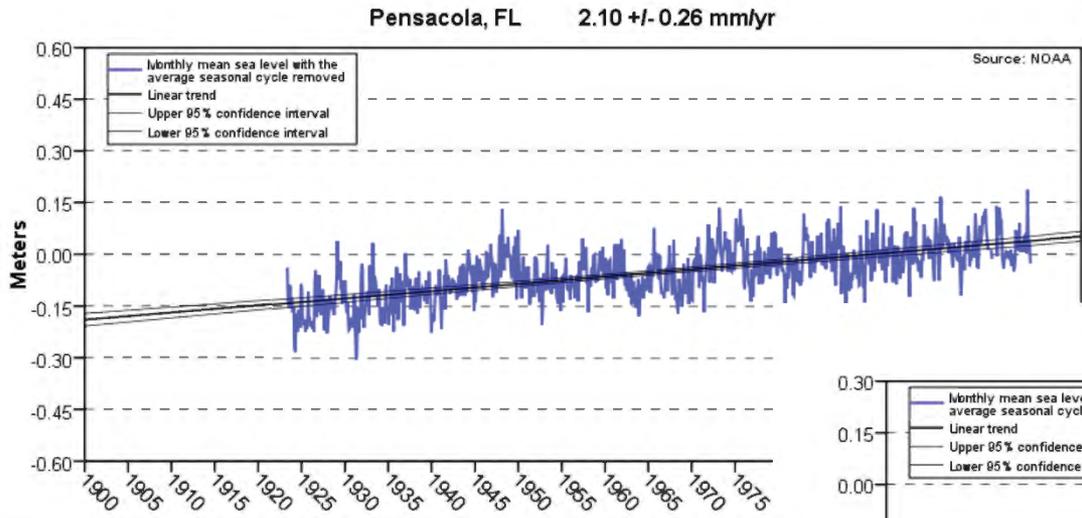


Global sea-level has been slowing since the last glacial maximum.

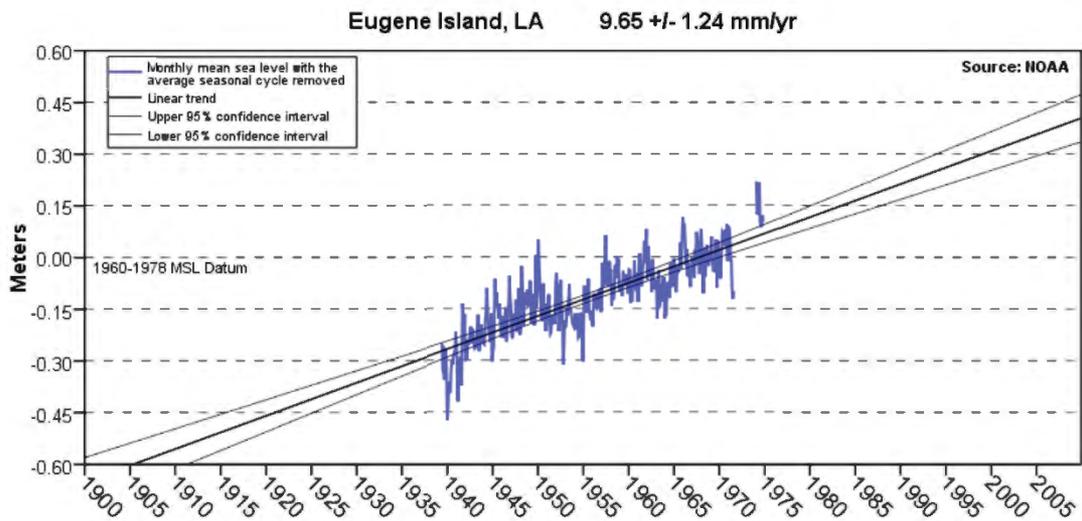
Global sea-level has been constant over the past 100 years.



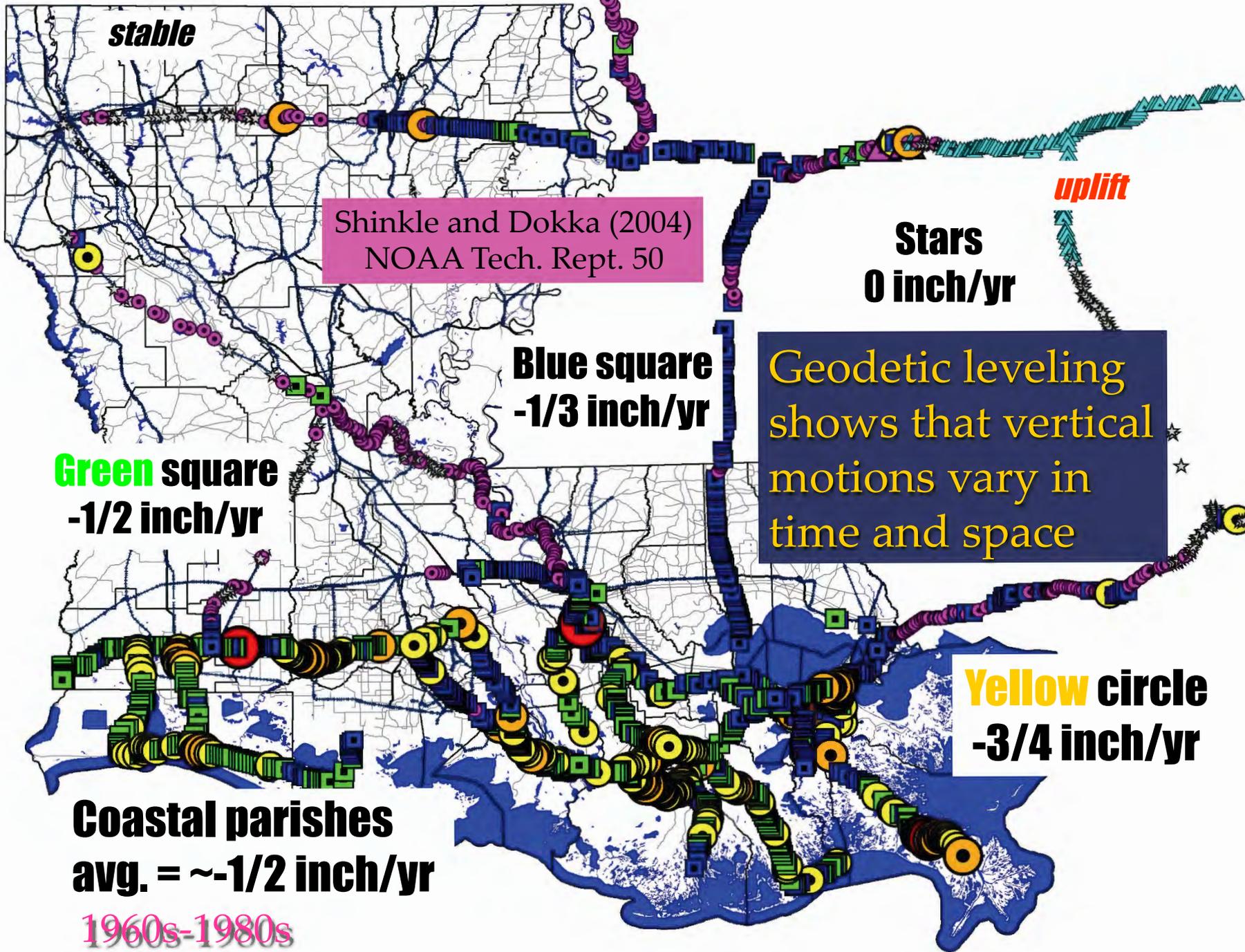
Gulf of



Mexico



Tide Gauges



stable

Shinkle and Dokka (2004)
NOAA Tech. Rept. 50

Blue square
-1/3 inch/yr

Green square
-1/2 inch/yr

Stars
0 inch/yr

Geodetic leveling
shows that vertical
motions vary in
time and space

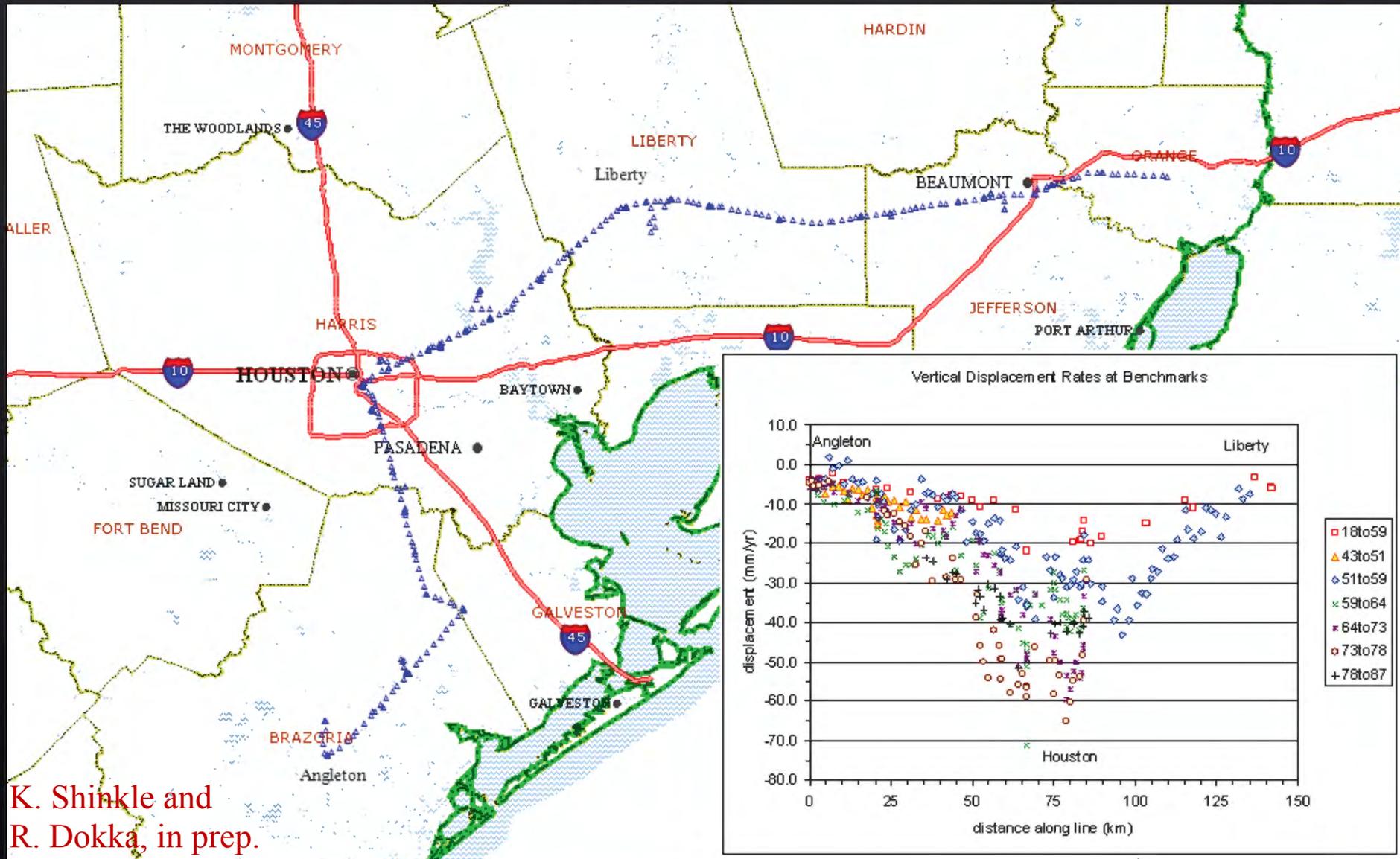
uplift

Yellow circle
-3/4 inch/yr

Coastal parishes
avg. = ~-1/2 inch/yr

1960s-1980s

Subsidence Derived from Geodetic Leveling Southeast Texas



Natural and Anthropogenic Processes that Result in Subsidence

Shallow Processes (processes above aquifers):

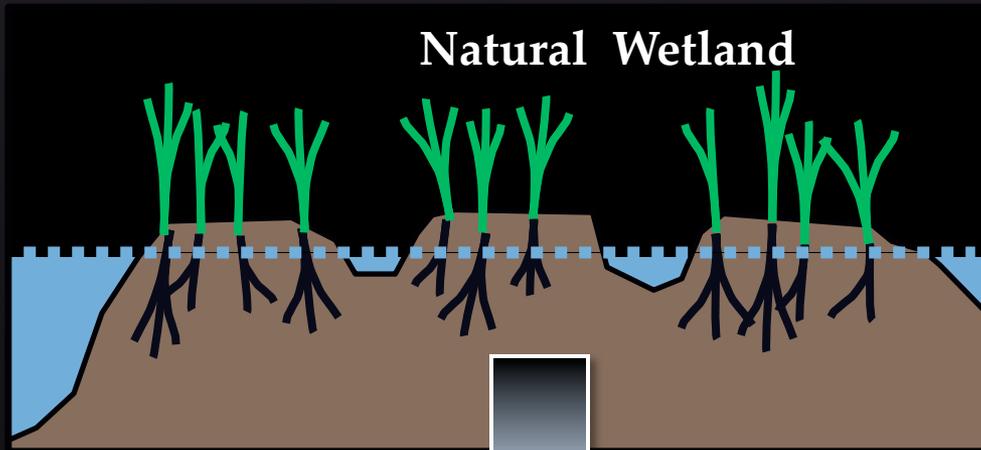
- Natural consolidation and compaction: constant ≤ 3 mm/yr
- Human-induced consolidation and compaction*: ~ 30 mm/yr
 - Desiccation by urbanization (behind levees)
 - Organic soil oxidation

Deep Processes (processes below and including aquifers):

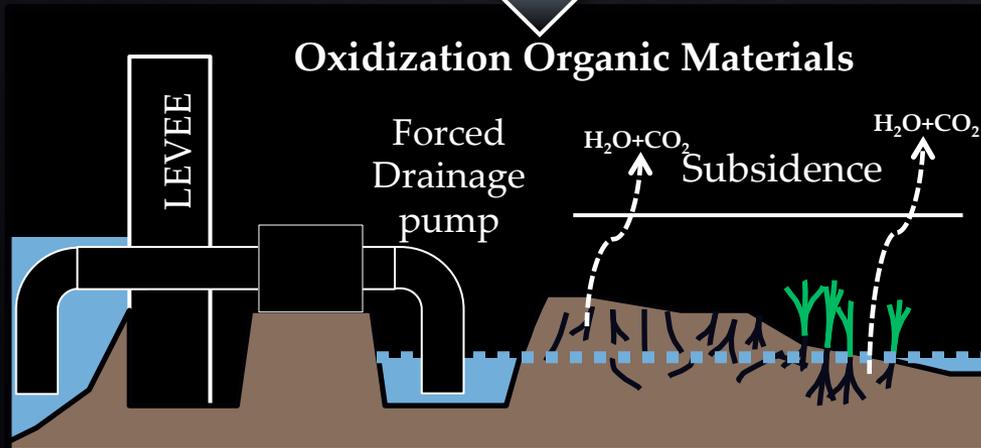
- Sediment and water load induced flexure of the lithosphere*:
constant 0 to -8mm/yr
- Faulting: *variable up to -20mm/yr*
- Salt evacuation: *variable 0 to -?? mm/yr*
- Water pumping*: *variable up to -65mm/yr*
- Oil & gas extraction: *variable 0 to -3 mm/yr*

* *The dominant causes of subsidence in LA*

Shallow Subsidence



Disruption of Shallow Hydrology



Sediment oxidation,
compaction and
consolidation of
organic materials

a,b,c:

0.1 – 10 mm yr⁻¹

- Flood Protection
- Forced Drainage

^a Deverall & Rojstaczer, 1996

^b Stephens & Speir, 1969

^c Snowden et al., 1968

**What does shallow subsidence
look like?**

Forced Drainage Speeds up Compaction



House built on piles (45ft) in 1964.
The driveway, yard, and street have
subsided over 2 ft (0.5 in/yr)

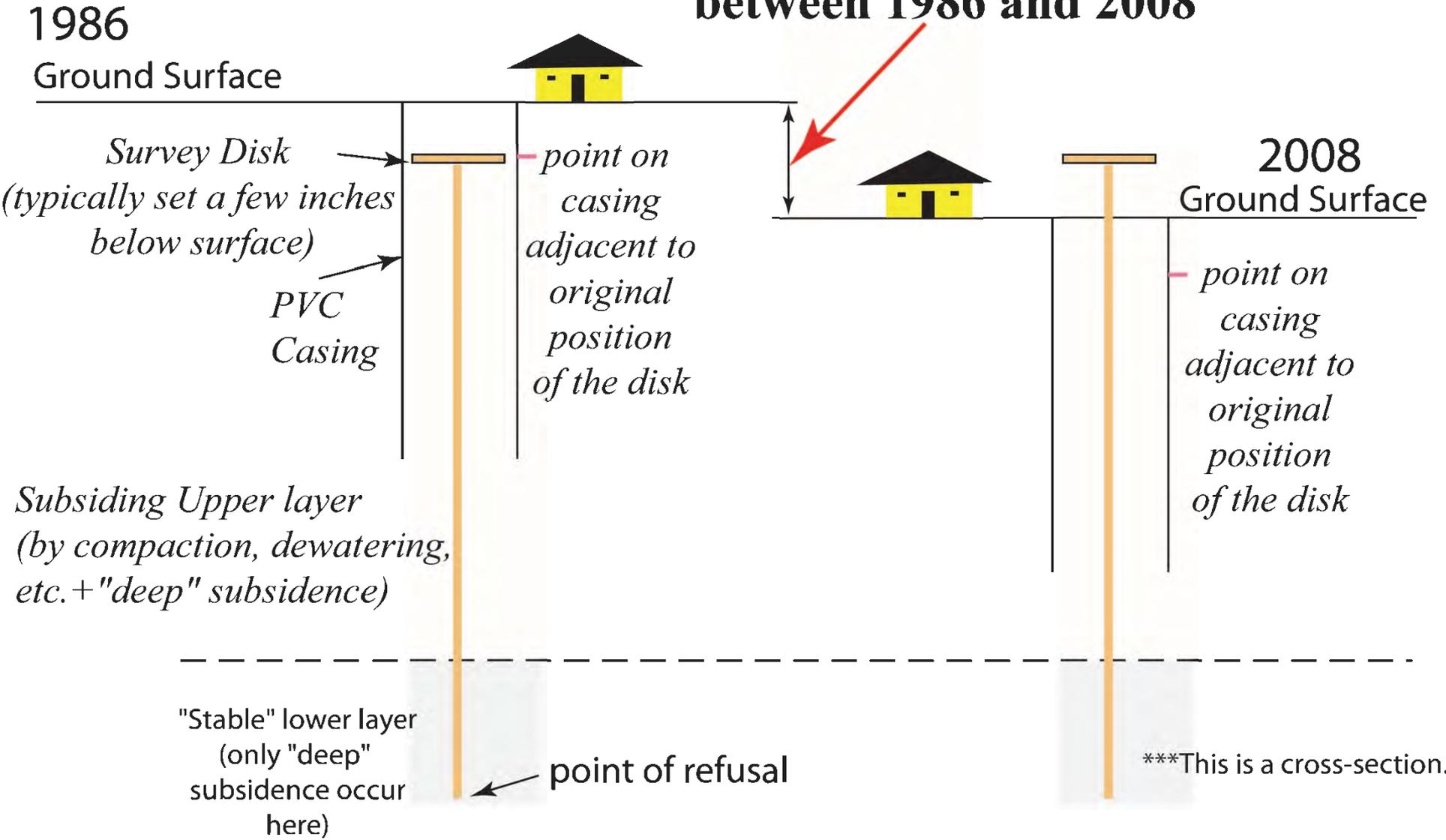
Deep Rods and Shallow Subsidence

- 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

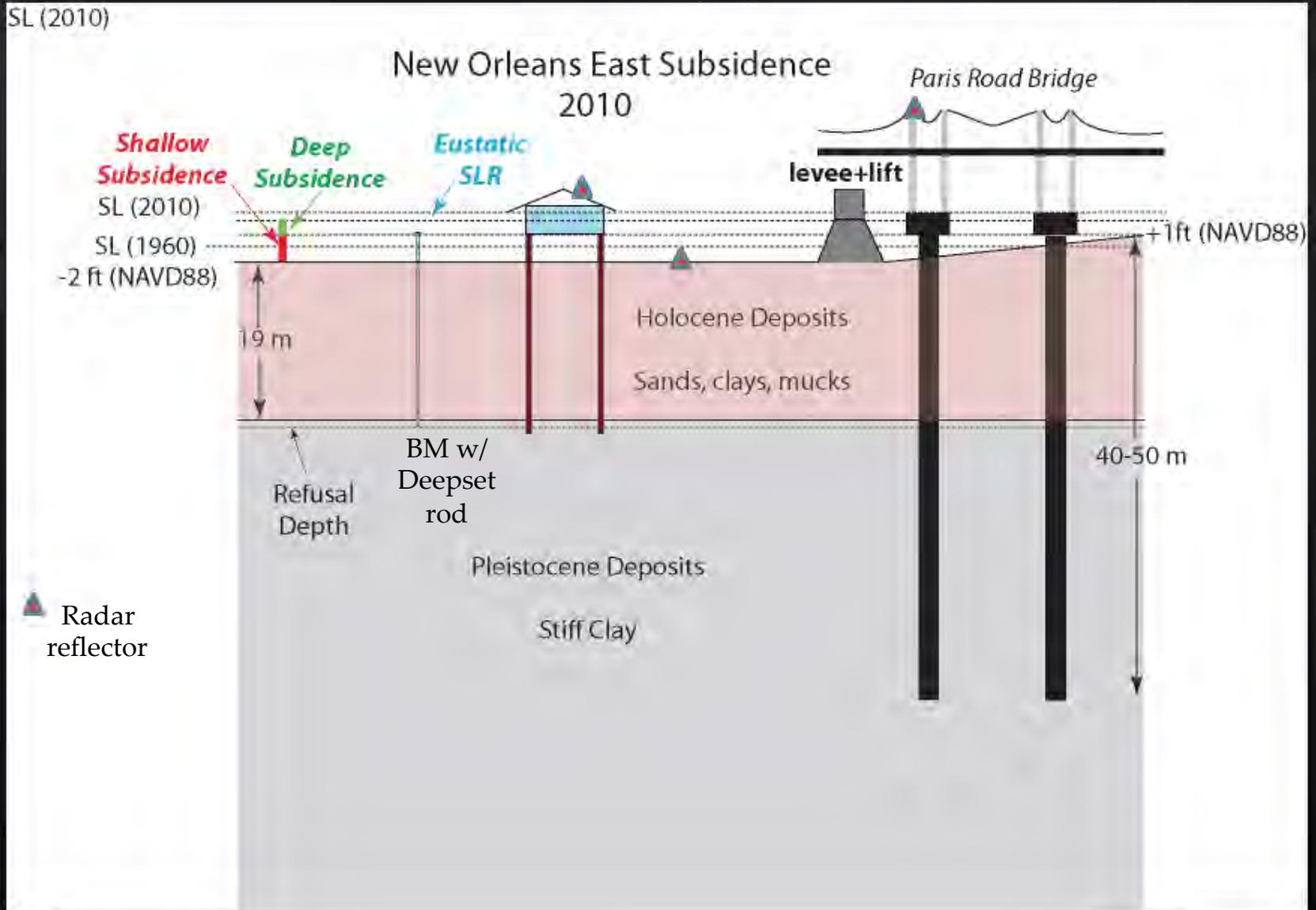
Subsidence of Ground Surface between 1986 and 2008



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



Natural and Anthropogenic Processes that Result in Subsidence

Shallow Processes (processes above aquifers):

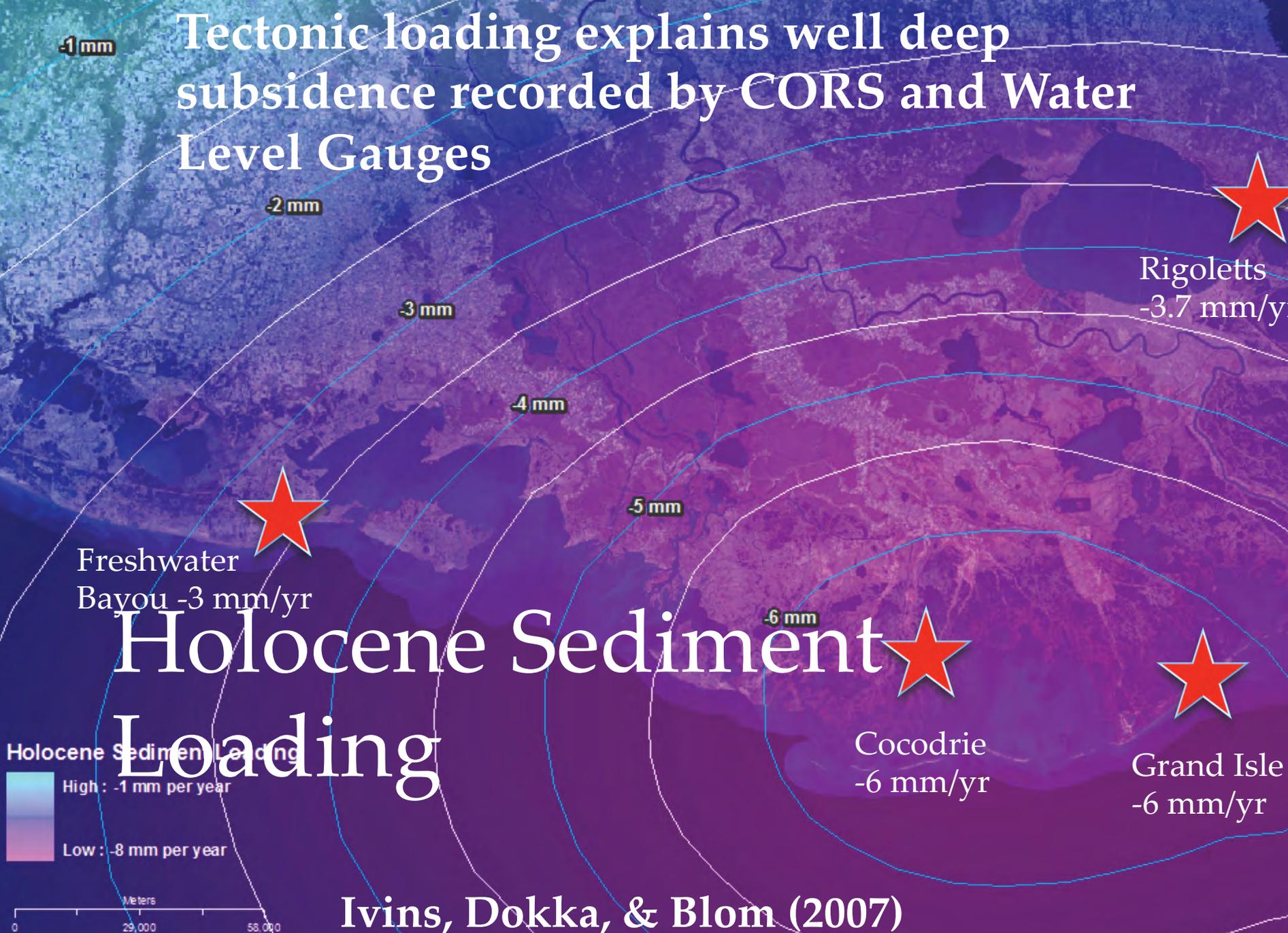
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Tectonic loading explains well deep subsidence recorded by CORS and Water Level Gauges



Holocene Sediment Loading

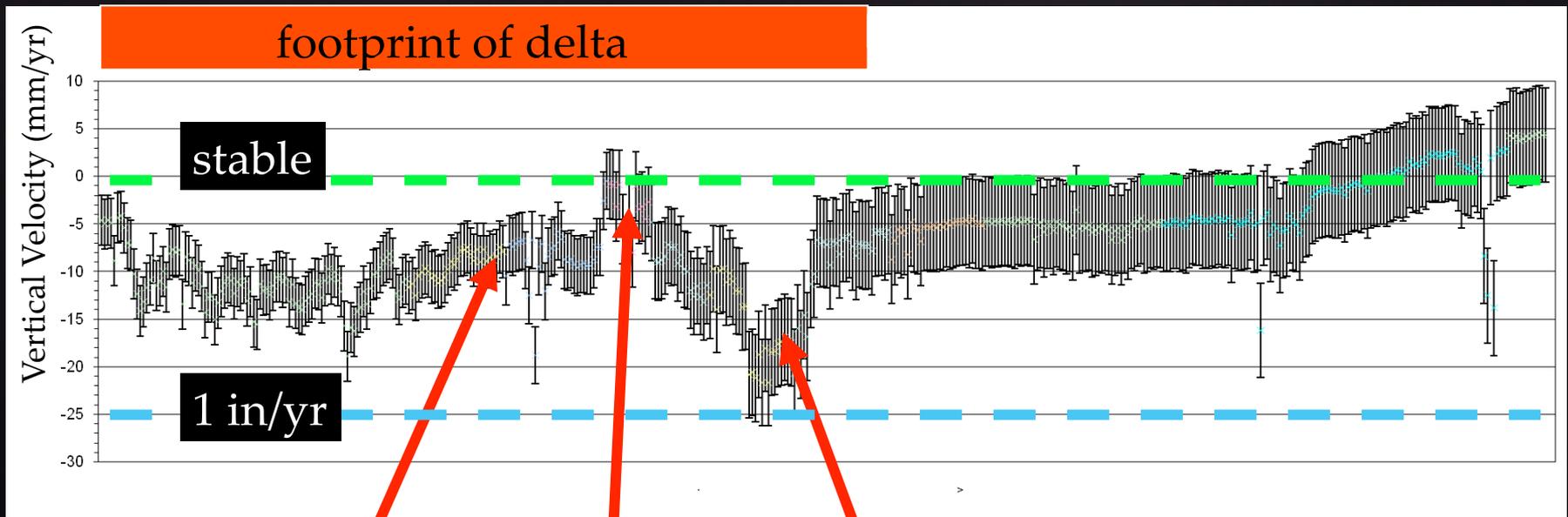
Ivins, Dokka, & Blom (2007)

Geodetic Measurements Show that Subsidence Varies in Time and Space

A Regional Subsidence Profile Based on 1970's Leveling

Grand Isle

Pensacola

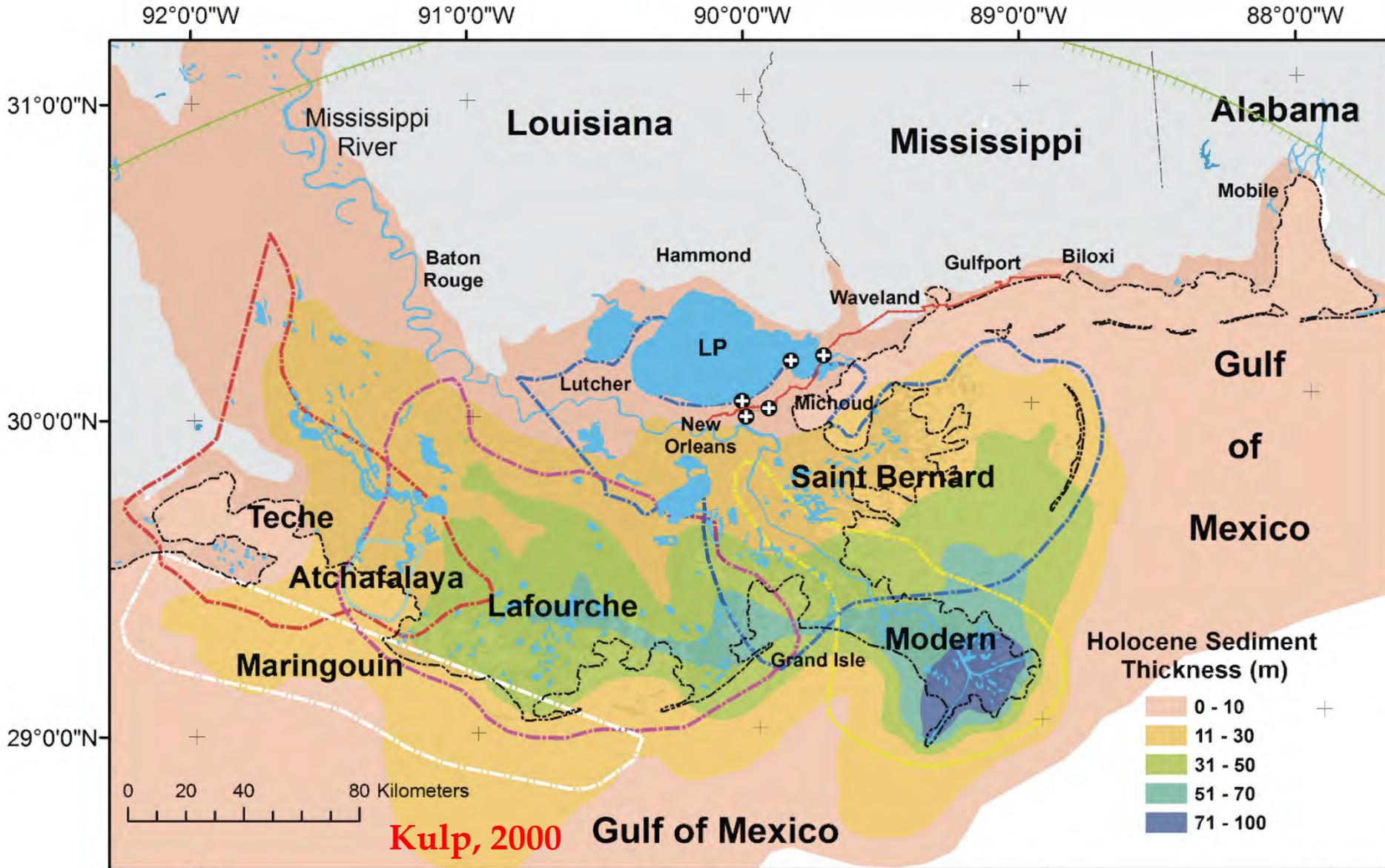


Kenner
moderate subsidence

GRETNA
slight subsidence

New Orleans East
severe subsidence

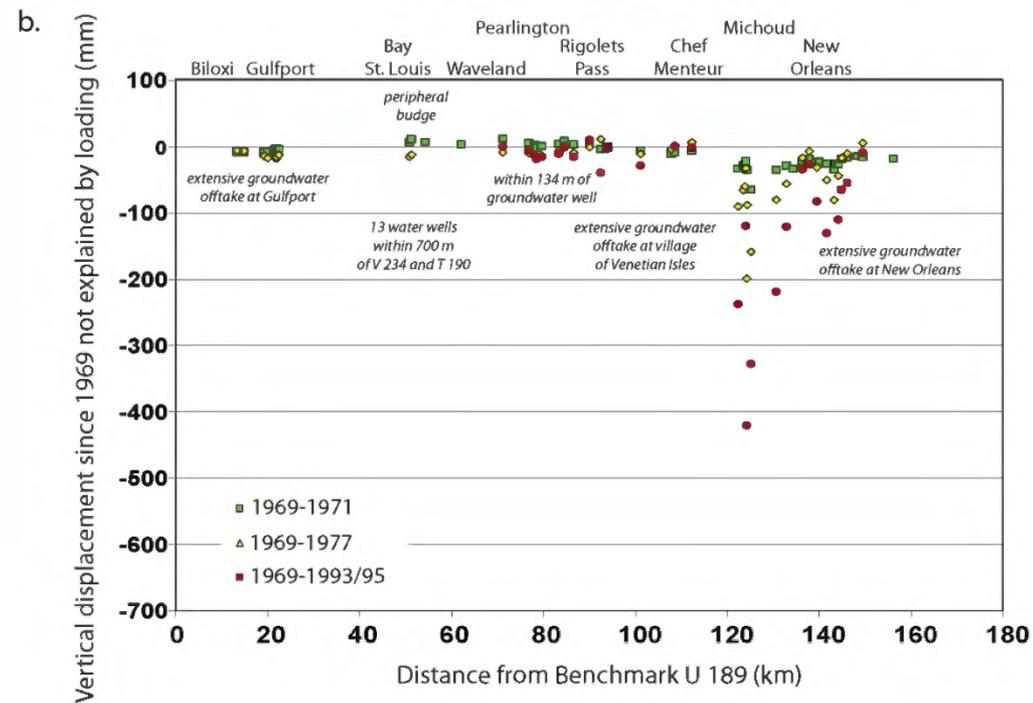
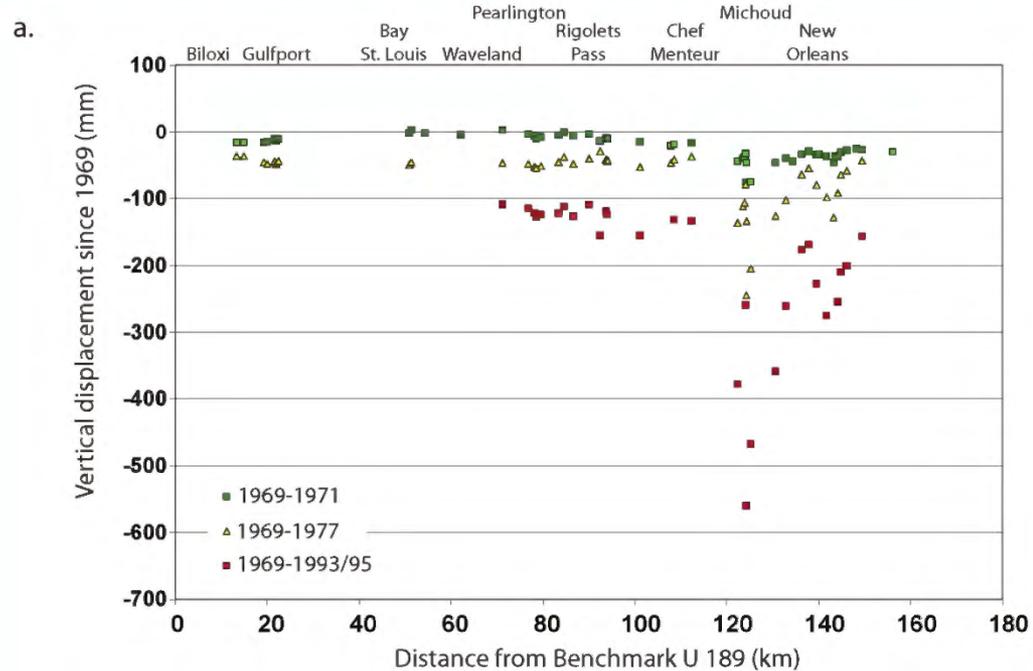
Thickness of the Mississippi River Delta



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.

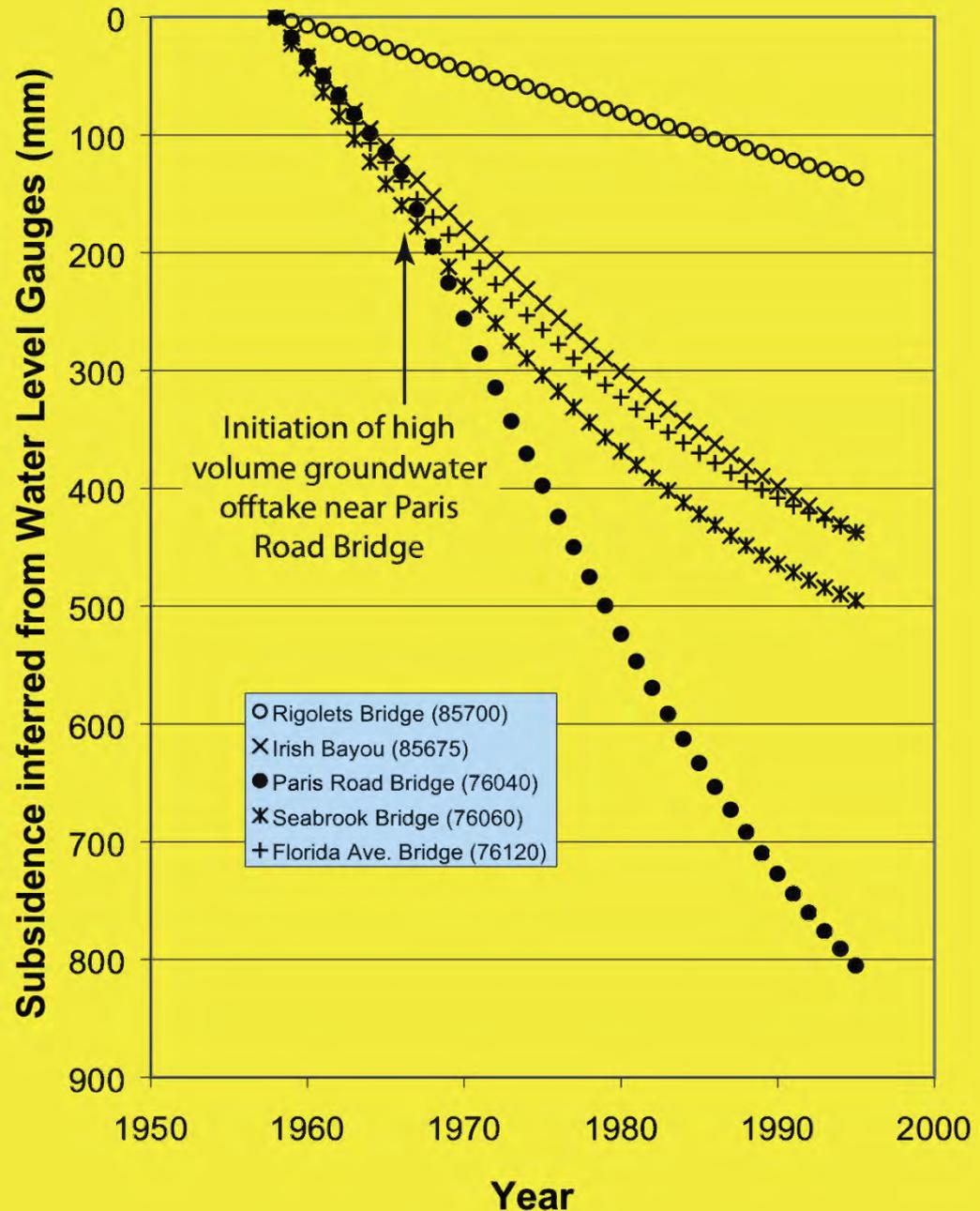
Let's test the results with water level gauges.



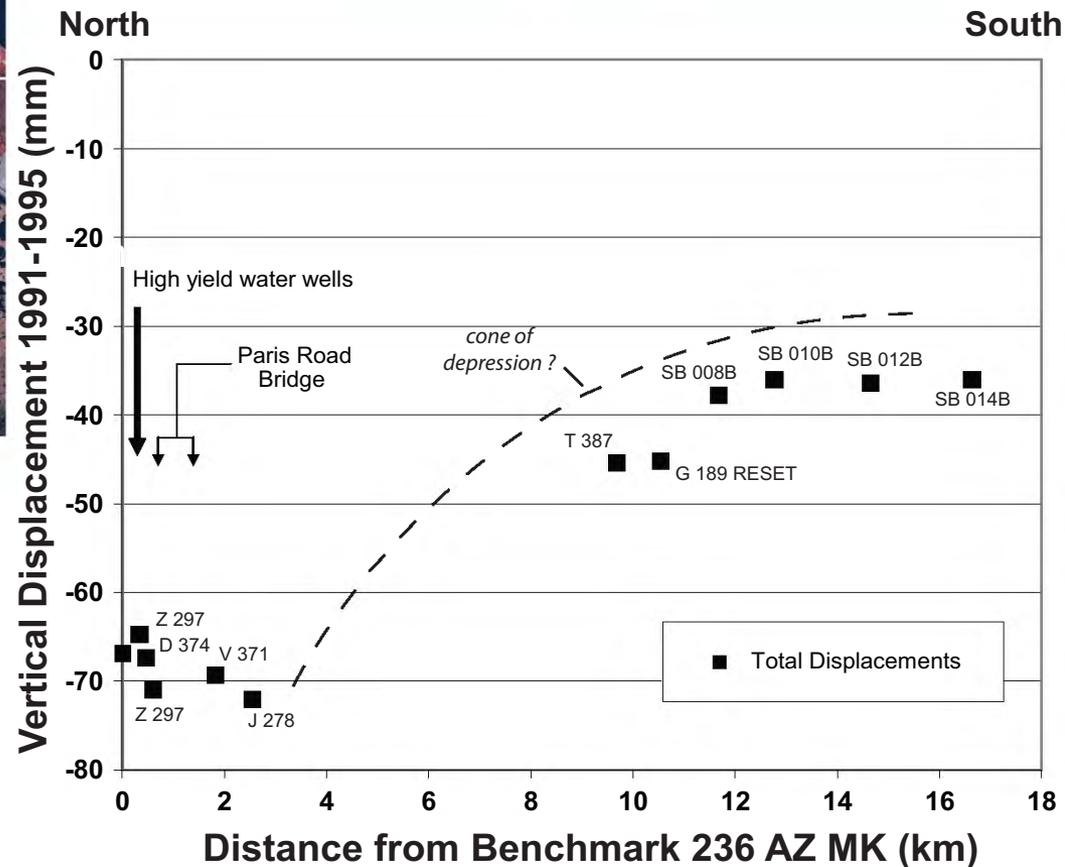
Subsidence from USACE water level gauges in New Orleans: 1960-1995

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

$$\cancel{\text{Sediment Accretion}} = \left[\text{Global Sea-level Rise} + \cancel{\text{Local/Regional effects}} + \text{Subsidence} \right]$$

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

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

Local/regional effects = negligible

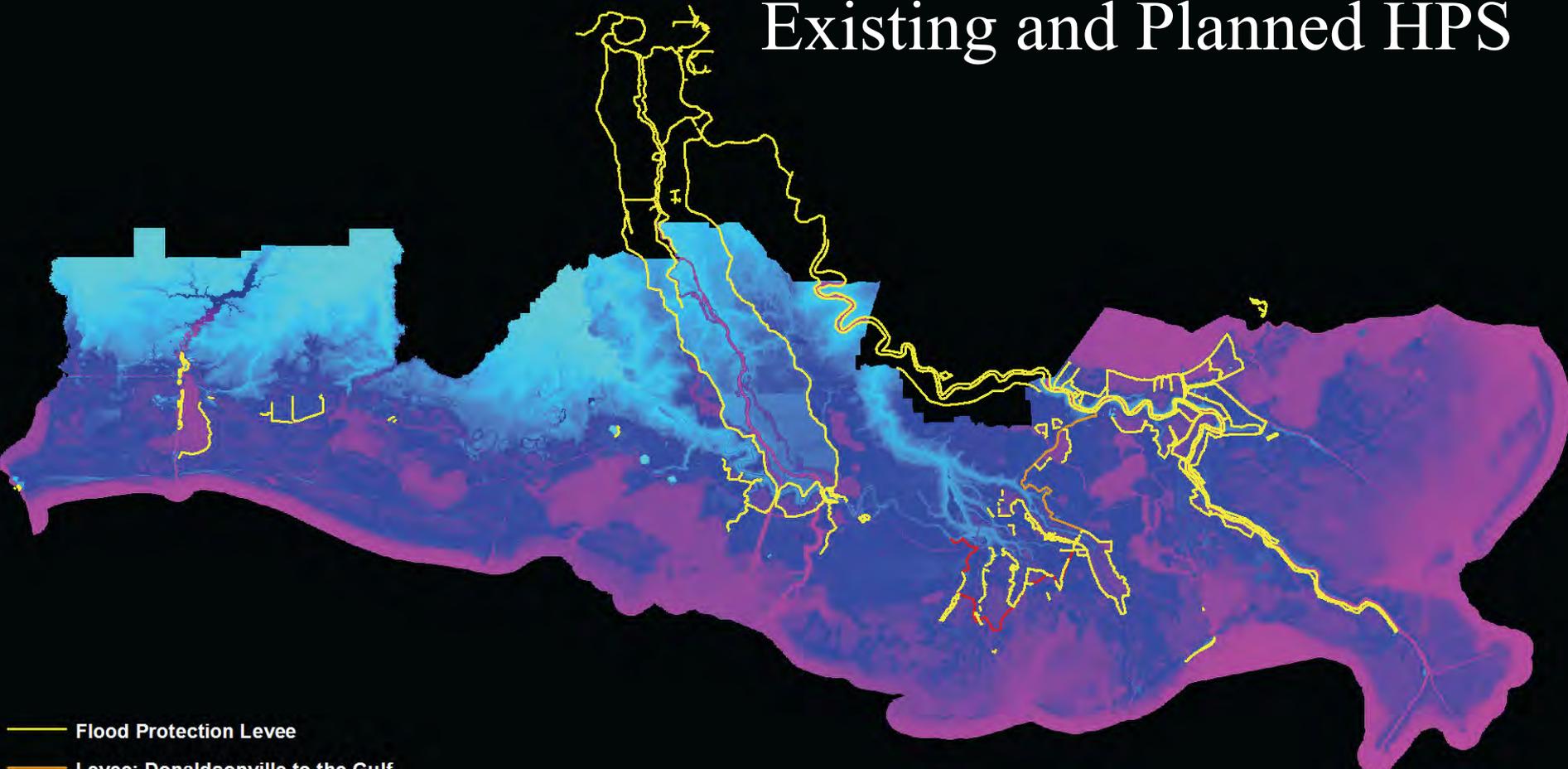
Subsidence = varies in time and space

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



- Flood Protection Levee
- Levee: Donaldsonville to the Gulf
- Levee: Morganza to the Gulf

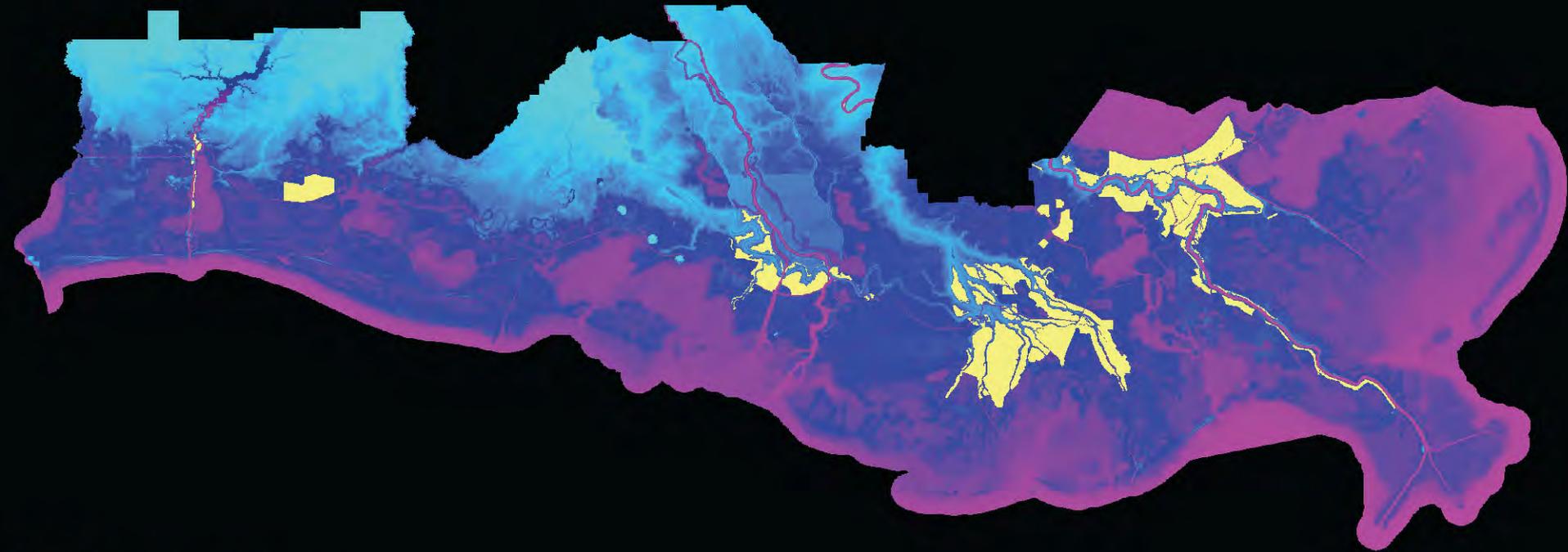
Coastal Louisiana 2010



Flood Protection Levees

- Approximately 1,500 km of levee structures currently cross the Louisiana Coastal Zone.
- An additional 200 km of levee is proposed for the Morganza and Donaldsonville to the Gulf projects.

Constrained Wetlands, Natural Wetlands, and Natural Levees.

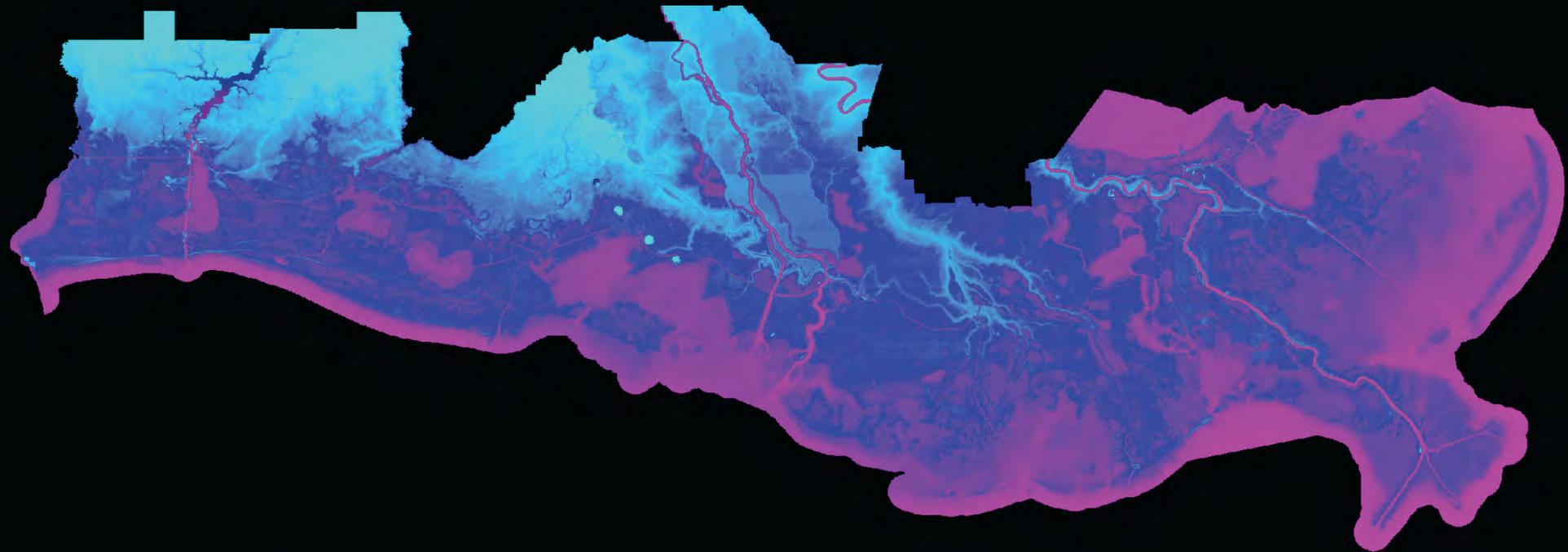


 Constrained Wetlands
Coastal Louisiana 2010
 High : 49.9 m
 Low : -60.8 m

Constrained Wetlands
2,159 km² of manipulated land

Meters
0 42,500 85,000

Today



Coastal Louisiana 2010

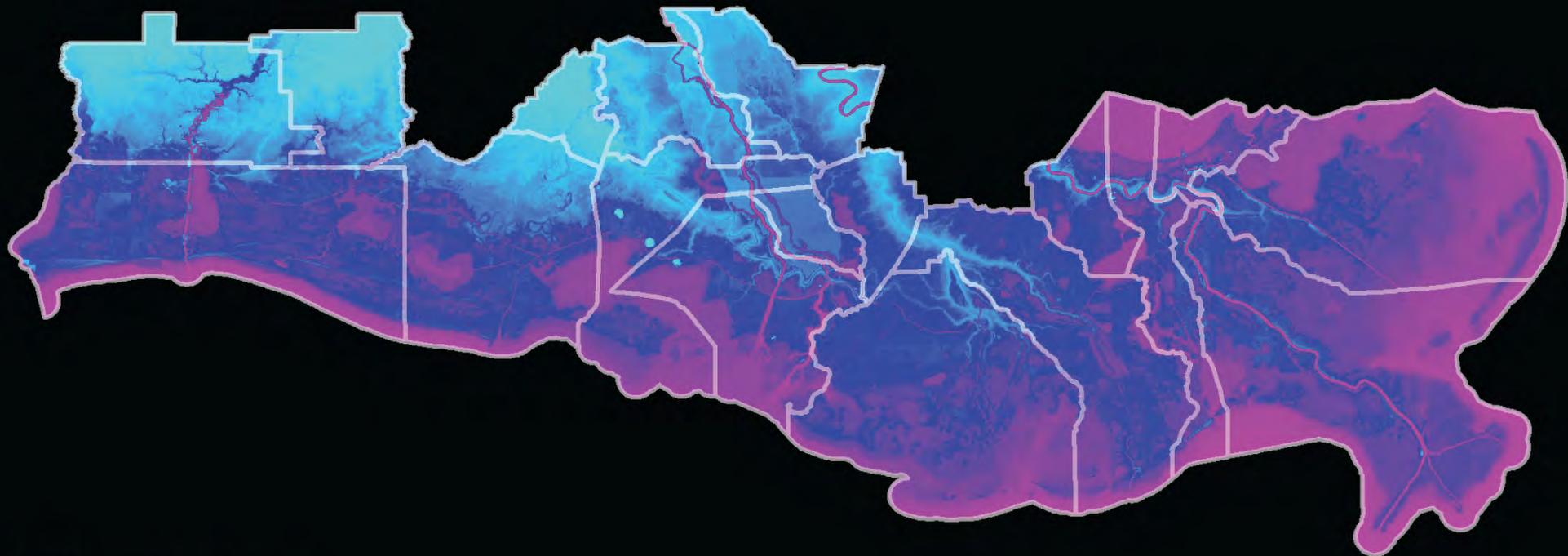
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Today



 Coastal Zone Parishes

Coastal Louisiana 2010

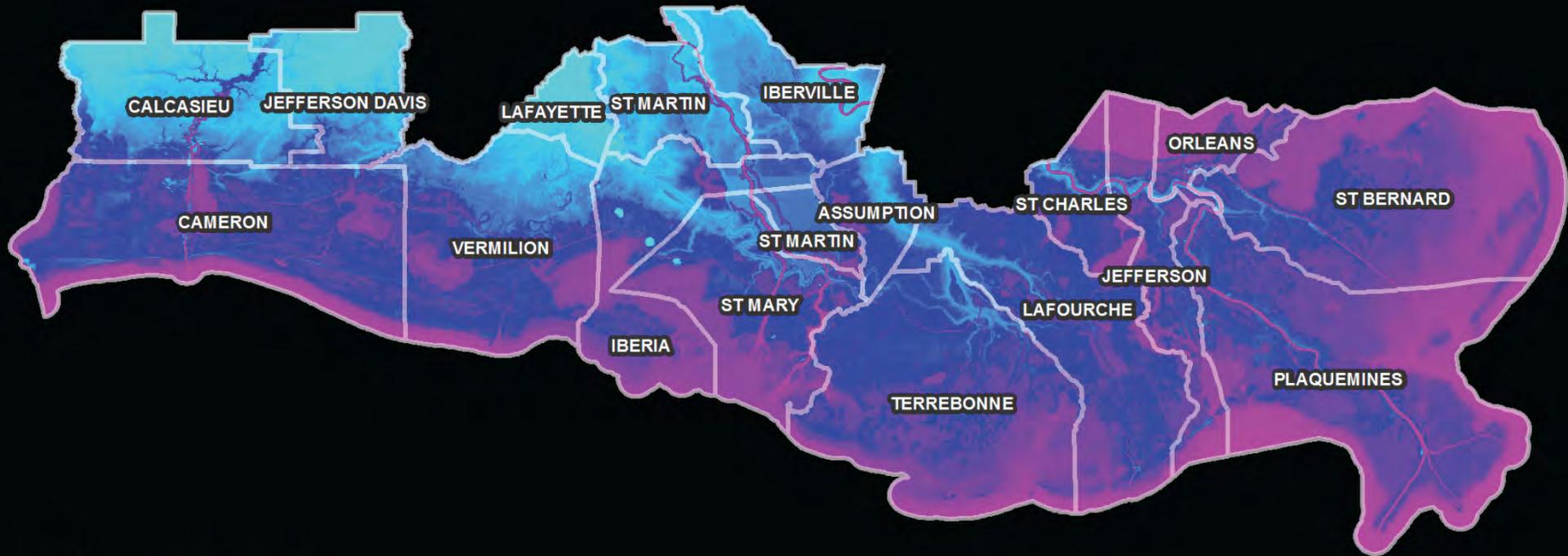
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Meters

0 42,500 85,000

Today



Coastal Zone Parishes
Coastal Louisiana 2010
High : 49.9 m
Low : -60.8 m



2010



 Land Below Sea Level

Coastal Louisiana 2010: Land Elevations

 High : 49.9 m

Low : -45.4 m



2010 DEM Elevations

- 8.9% Land Area at or below Sea Level
- Approximately 397 miles² (2.3 million km²)

2050



 Land Below Sea Level

Coastal Louisiana 2050: Land Elevations

 High : 49.9 m

Low : -45.6 m



2050 DEM Elevations

- 15.5% Land Area at or below Sea Level
- Approximately 1,558 miles² (4 million km²)

2100



 Land Below Sea Level

Coastal Louisiana 2100: Land Elevations

 High : 49.9 m

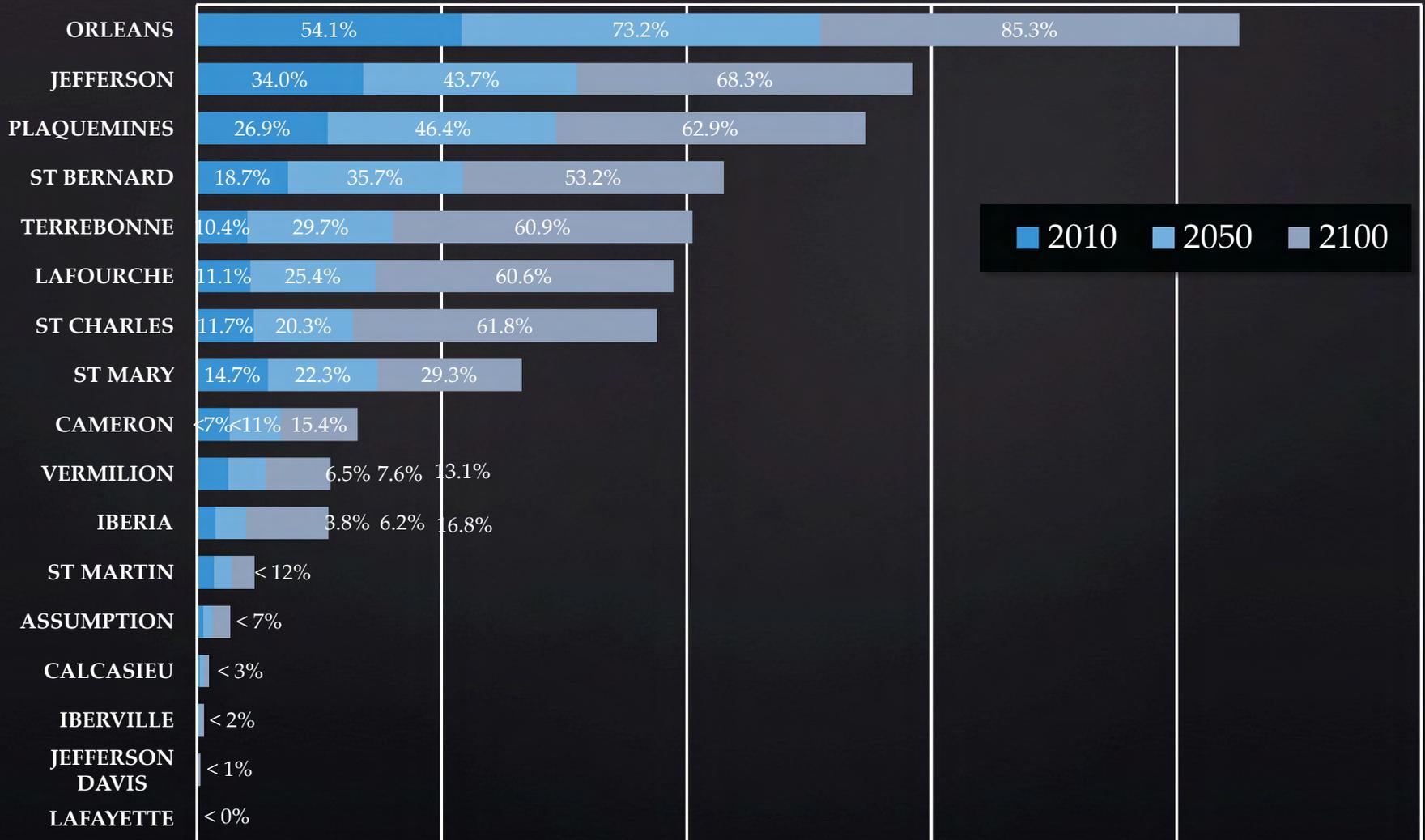
Low : -45.9 m

2100 DEM Elevations

- 27.1% Land Area at or below Sea Level
- Approximately 2,724 miles² (7 million km²)



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

