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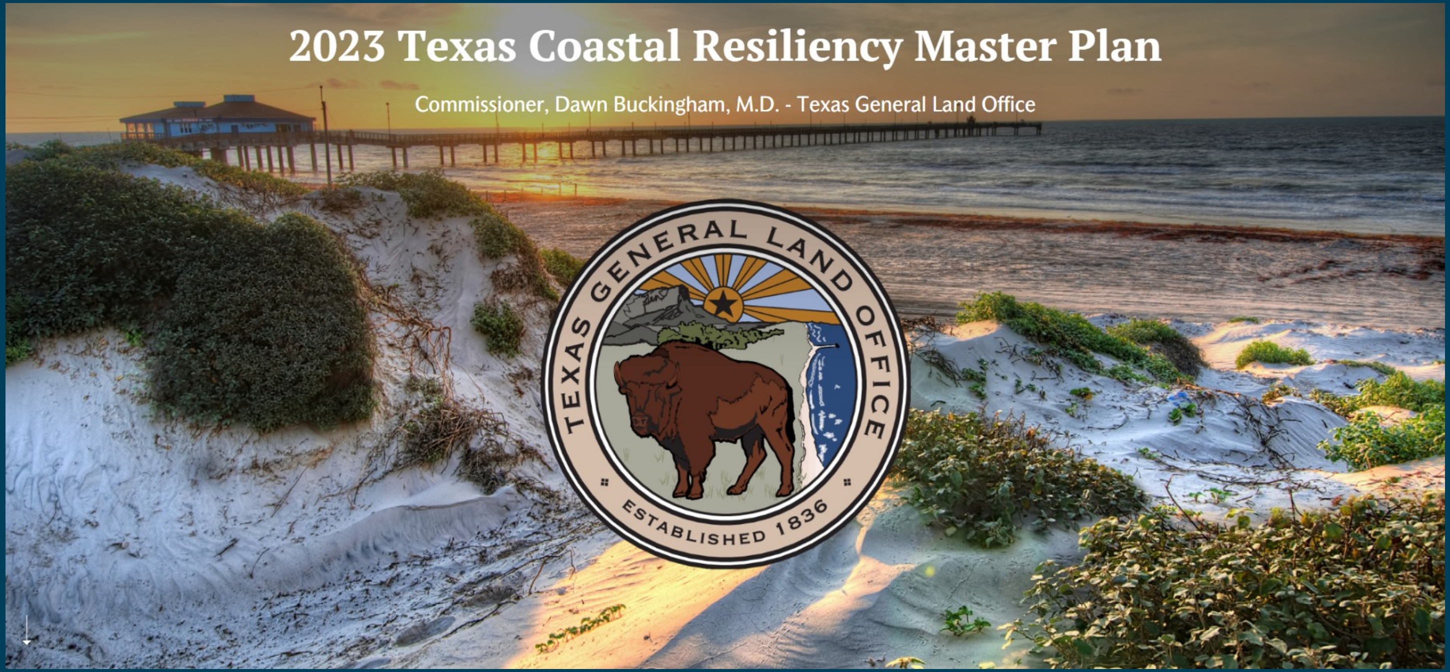
Building the knowledge base for the 2019 Texas Coastal Resiliency Master Plan: Sediment Budget Analysis of the Texas Coast

Michiel Knaapen

Principal Scientist Coastal sand transport

Texas Coastal Resiliency Master Plan

https://www.glo.texas.gov/coastal/protecting-coast/coastal-planning



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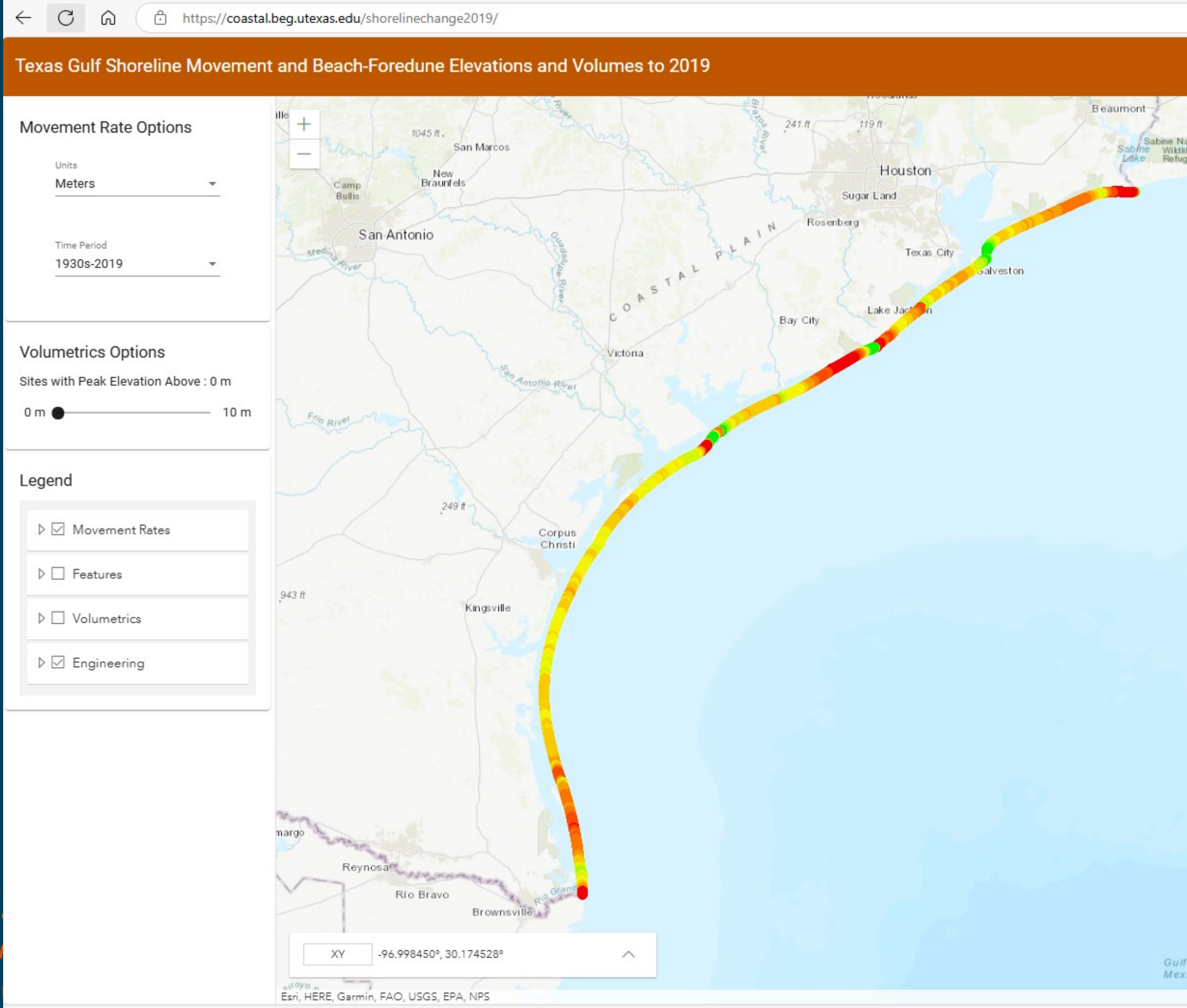
Texas Coastal Resiliency Master Plan



Texas Coastal Resiliency Master Plan

- On average, the Texas coast erodes 4.1 feet per year.
- Some areas lose more than 30 feet per year.
- The Federal Emergency Management Agency (FEMA) says that for every dollar we spend on erosion mitigation, we save four dollars in the future.
- **WHEN THE TEXAS COAST ERODES:**
  - Coastal properties lose value and buildings are lost
  - Tourism declines and local economies suffer
  - Farming and fishing industries risk revenue loss
  - Ports, roads, and key infrastructure are at risk
  - Key storm surge buffers become weakened

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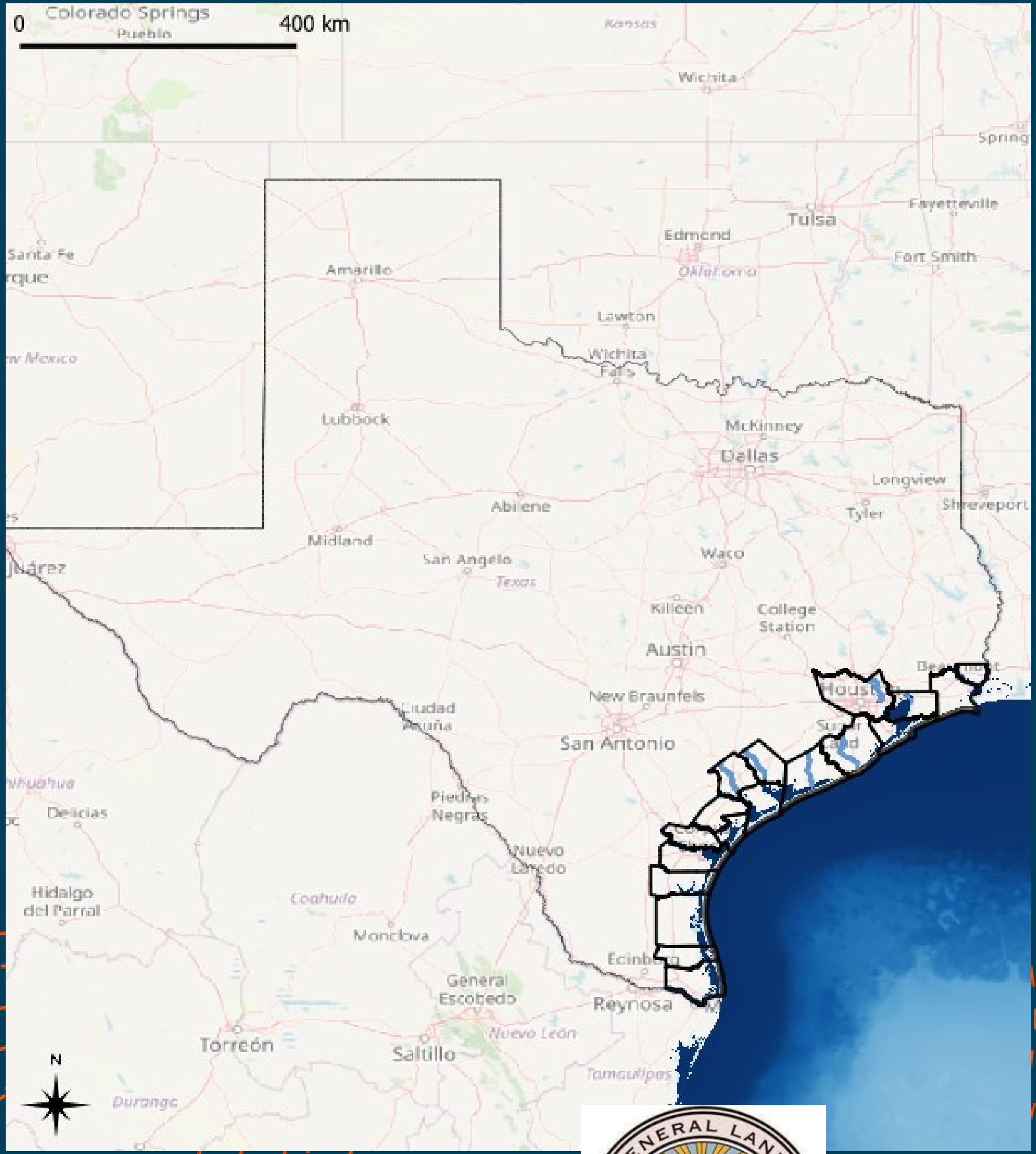
Soft solutions for coastal management

- Increasing number of nourishments
- Nourishment disappearing
- Need more sources for sediment



Coastal processes 101

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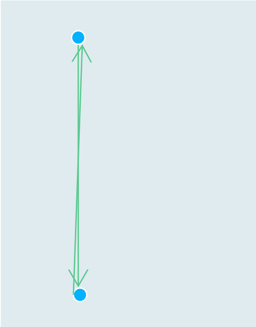
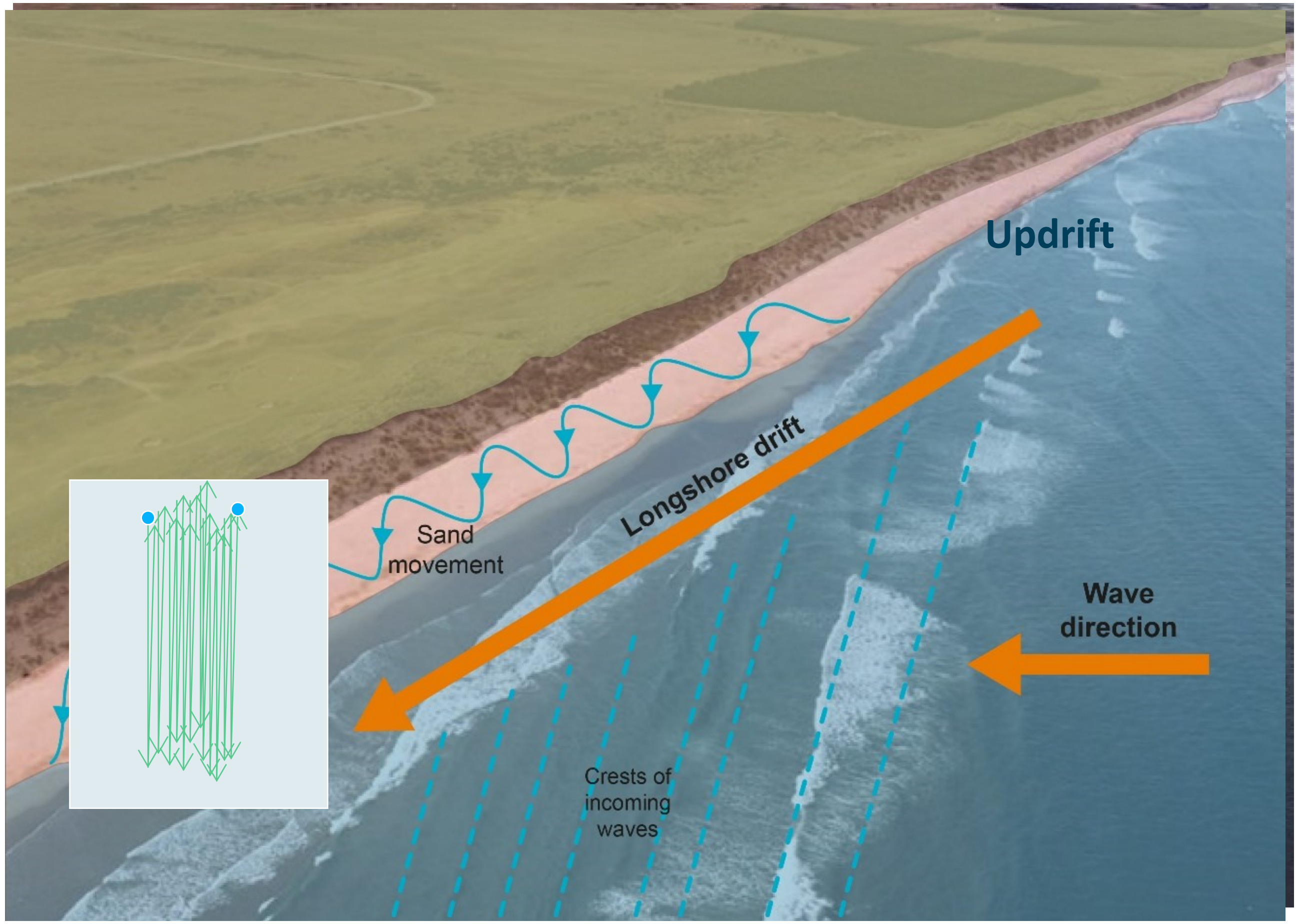
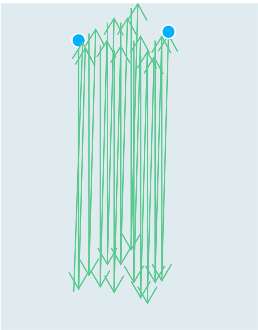
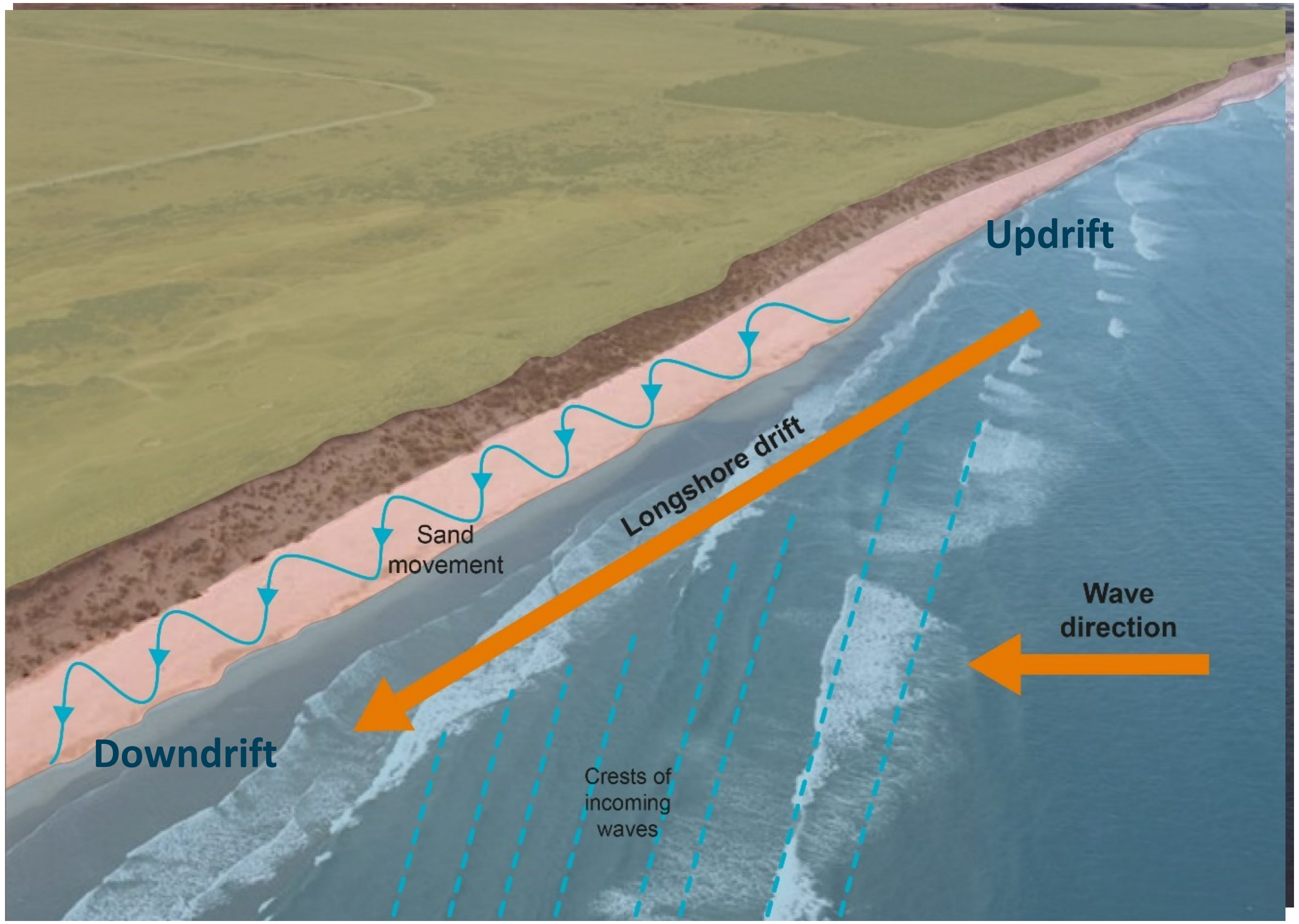
Longshore drift



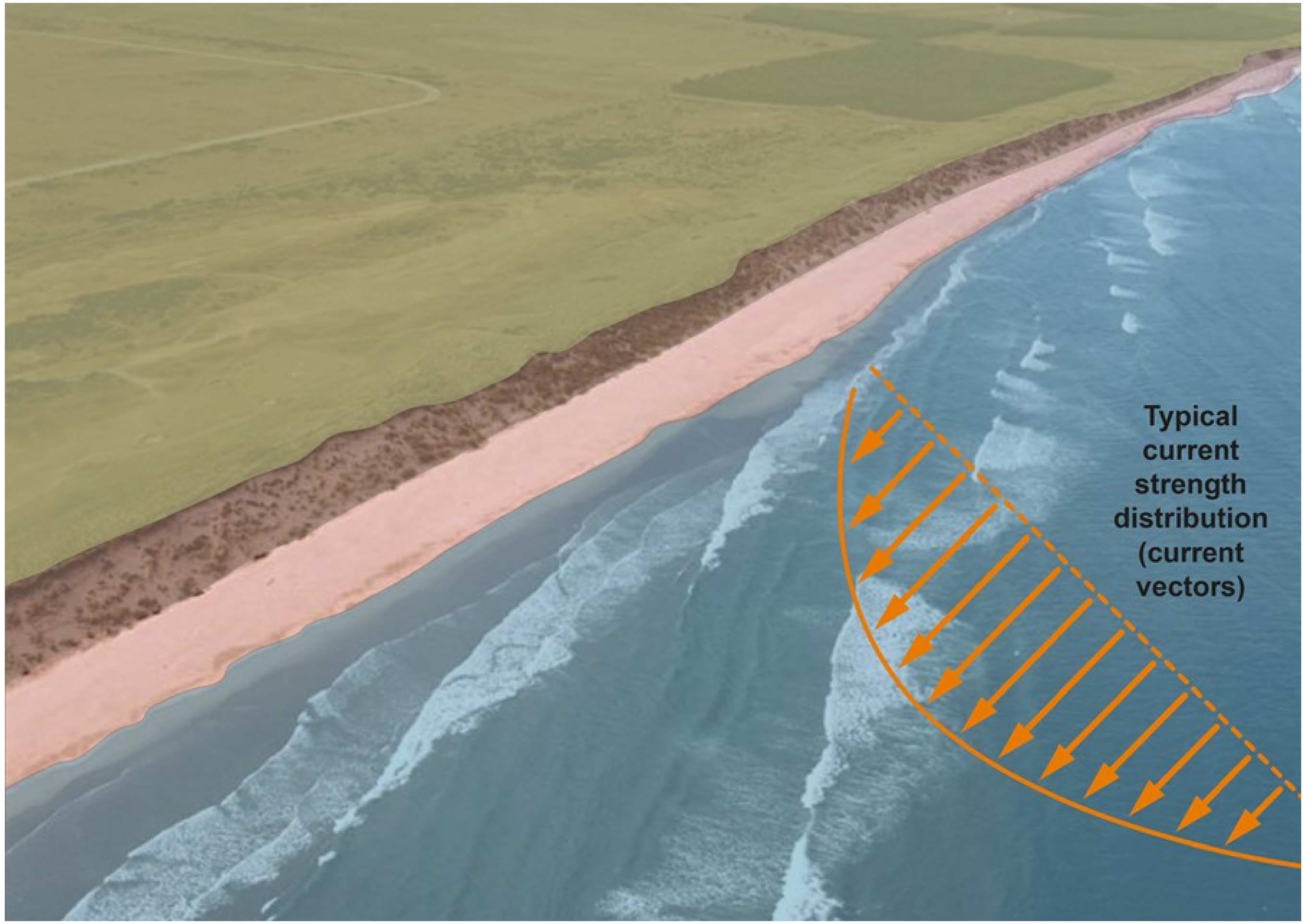


Longshore drift





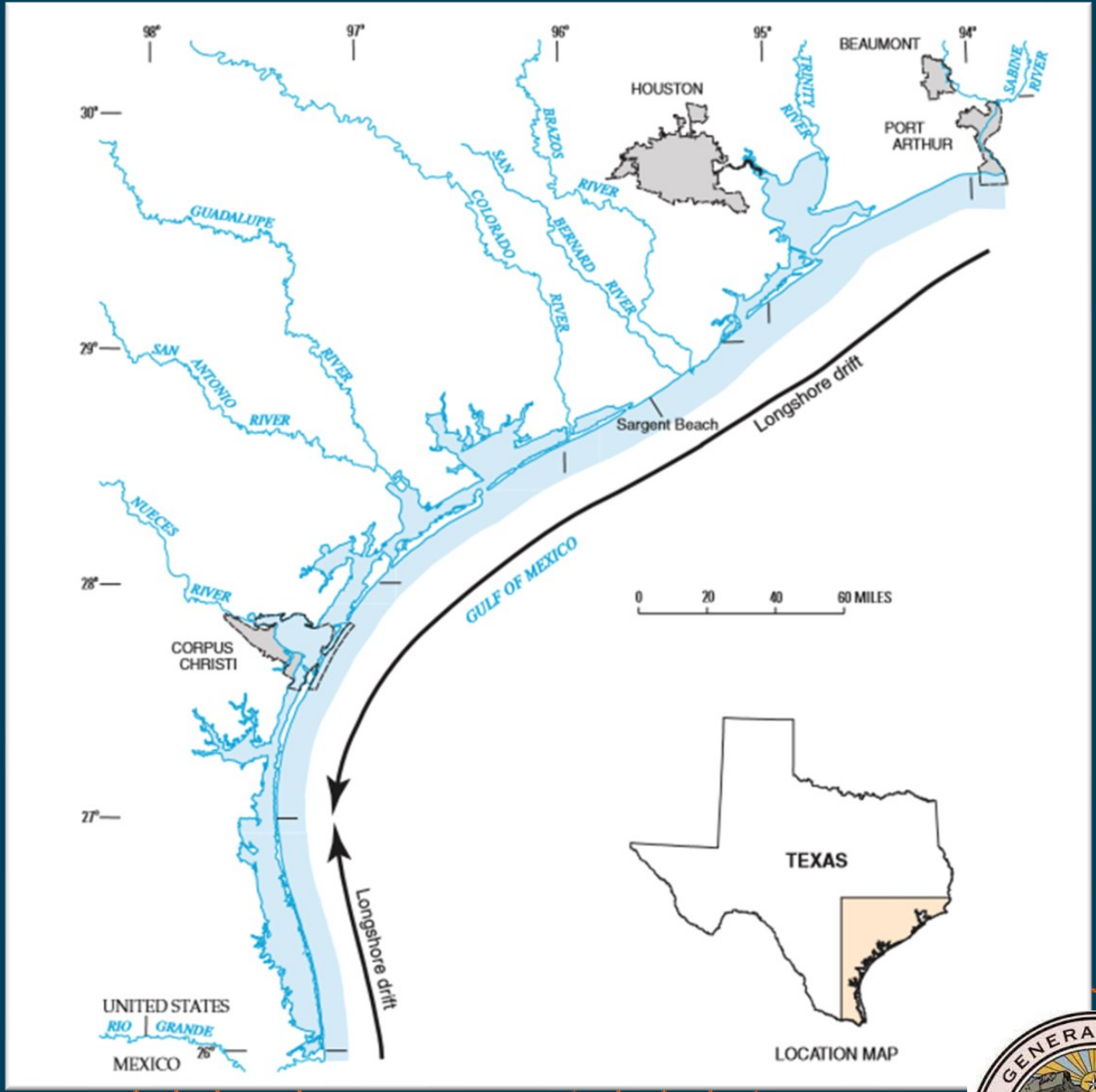
Cross shore distribution of longshore drift



Existing knowledge

Based on littoral drift due to waves from sector E-S, ignoring currents

Literature based on McGowen et al (1977)

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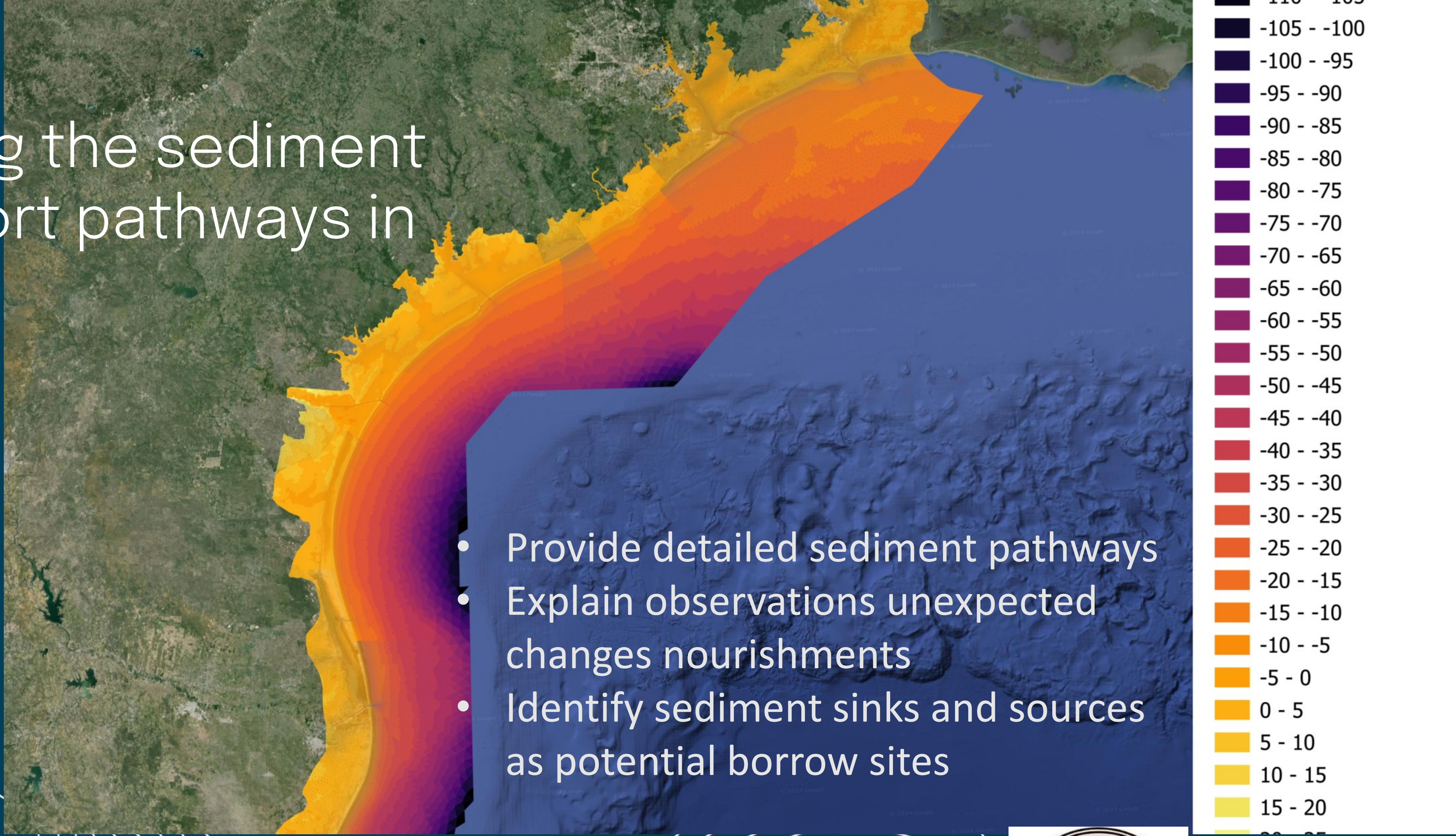
Mapping the sediment transport pathways in detail

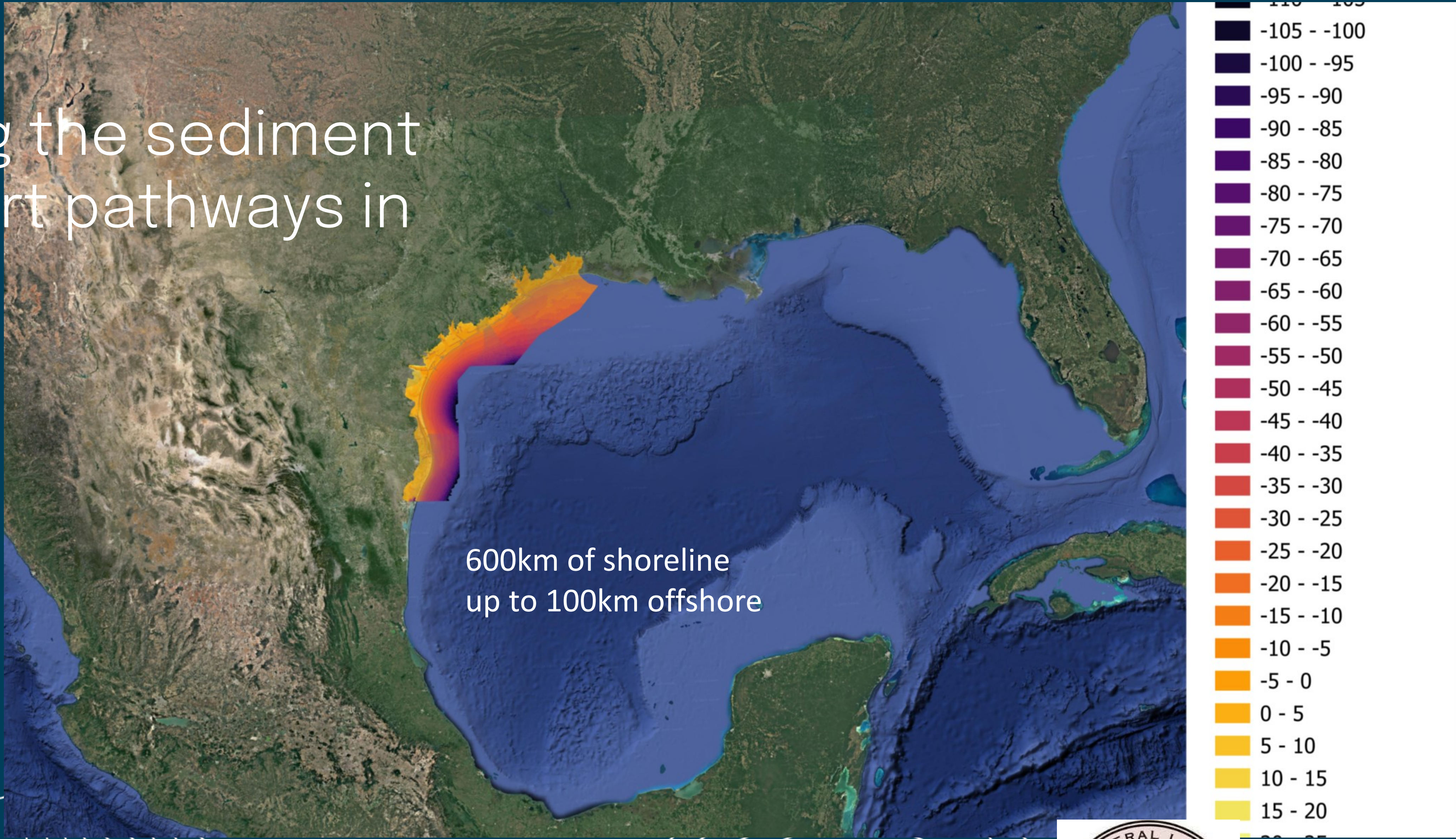
- Sand deposits in the area limited
- Most too far offshore
- Others are sandbanks

Mapping the sediment transport pathways in detail



- Provide detailed sediment pathways
- Explain observations unexpected changes nourishments
- Identify sediment sinks and sources as potential borrow sites

Mapping the sediment transport pathways in detail



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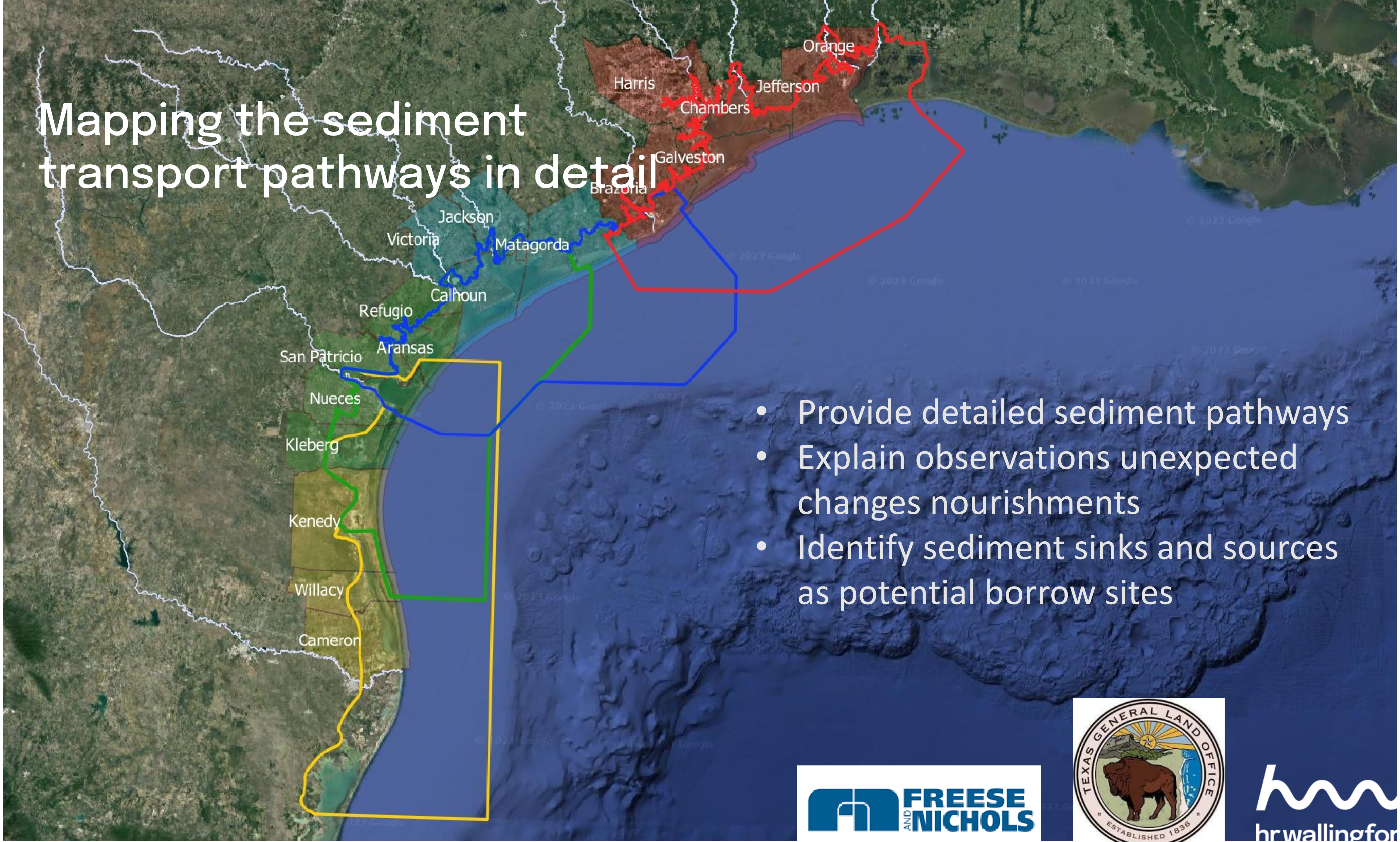
The model: TELEMAC-TOMAWAC-SISYPHE

http://www.opentelemac.org/

Mapping the sediment transport pathways in detail



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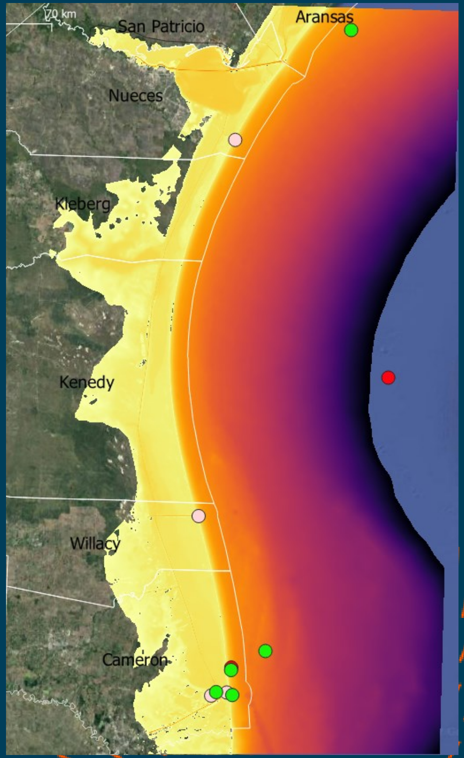
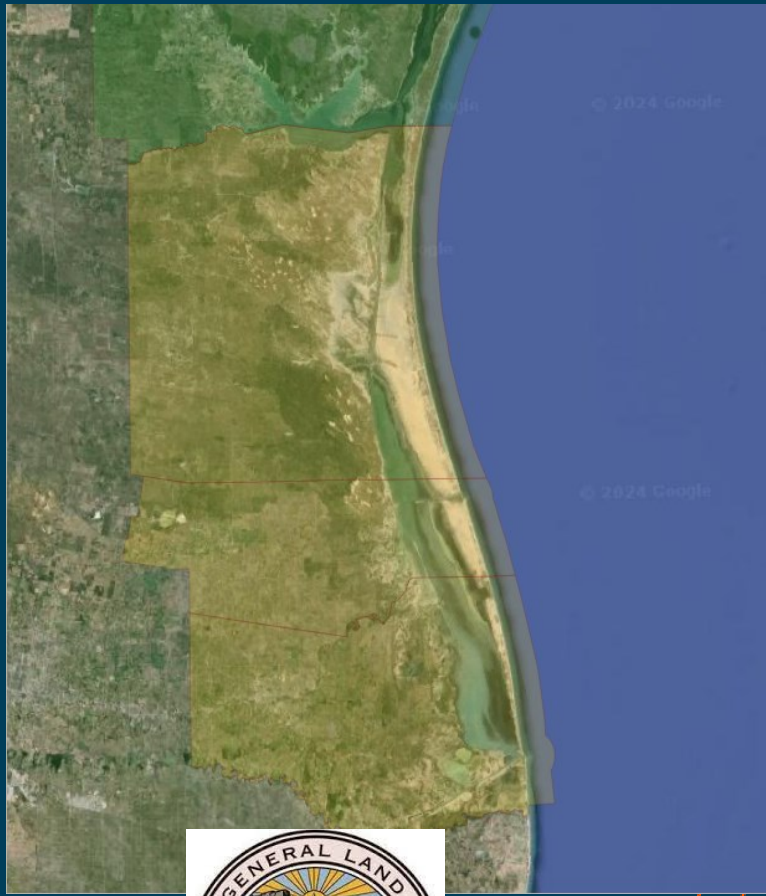
Model set-up sand transport modelling

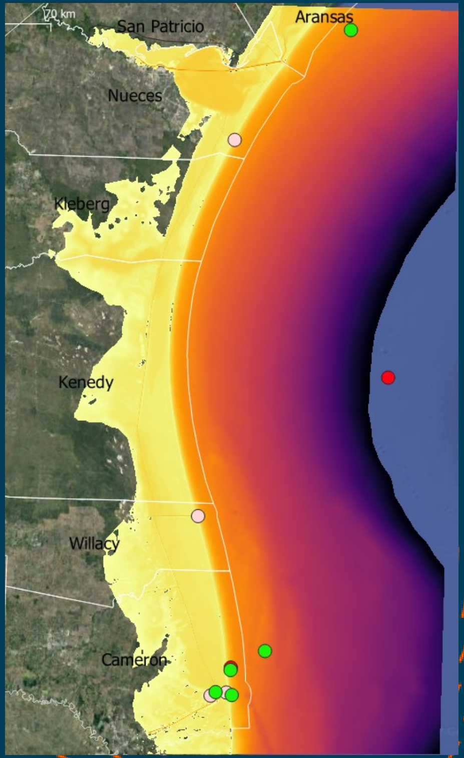


Mesh

- 500,000 nodes;
- 10m at breaker line;
- 5km on offshore boundary;
- barrier islands in bathymetry



Model set-up sand transport modelling



Mesh

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- 10m at breaker line; 5km on offshore boundary
- barrier islands in bathymetry

Forcing conditions from global models

- Currents: HYCOM
- Waves: Spectral from ERA5 Hindcast
- Atmospheric: ECMWF Forecasting

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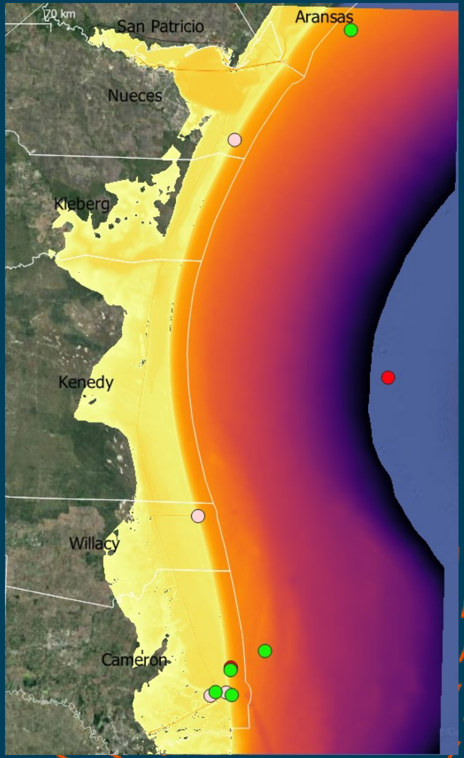

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Forcing conditions from global models

- Currents: HYCOM
- Waves: Spectral from ERA5 Hindcast
- Atmospheric: ECMWF Forecasting

Simulated every month of 2018

- Most representative for last decade
- 2nd Representative for last 30 years

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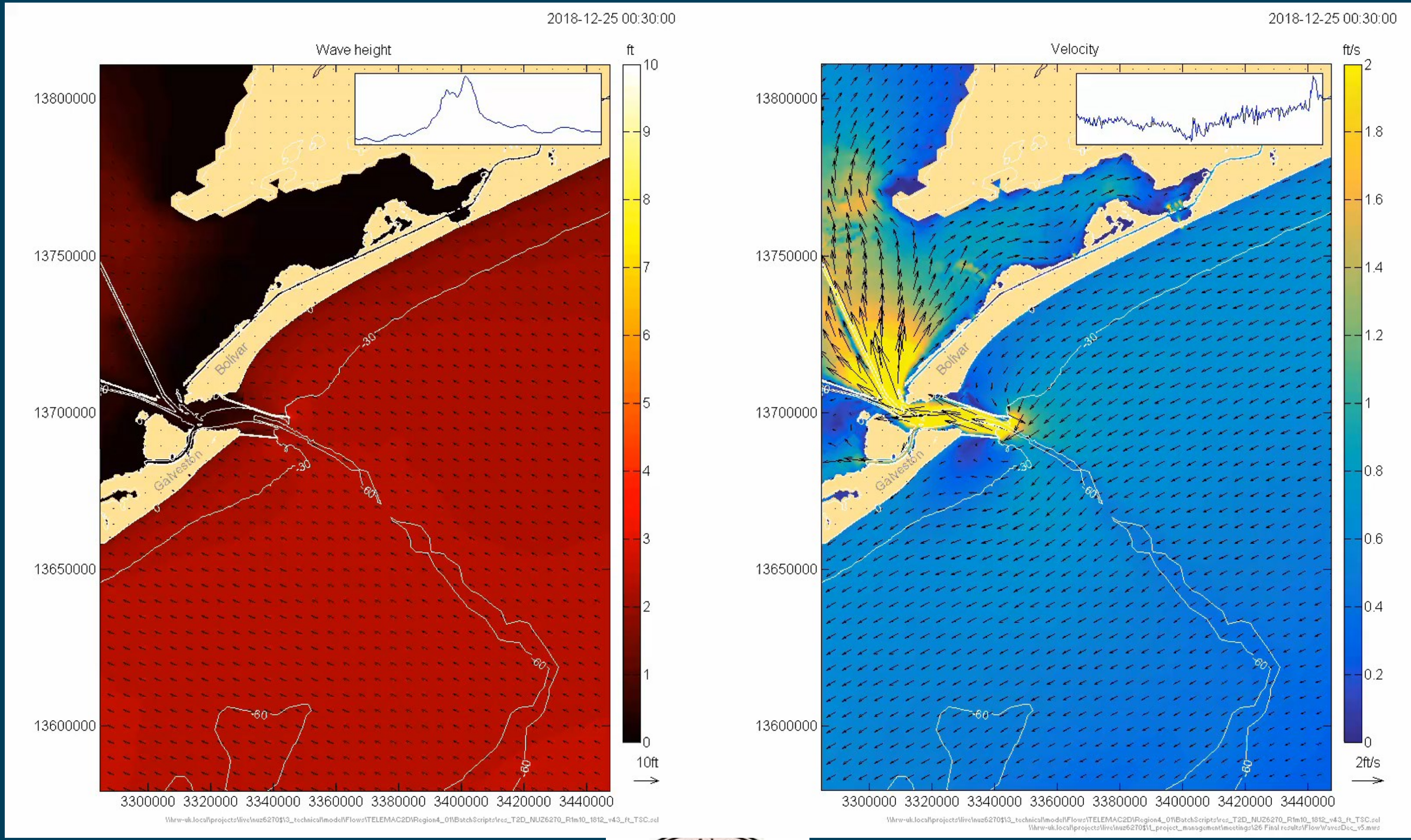
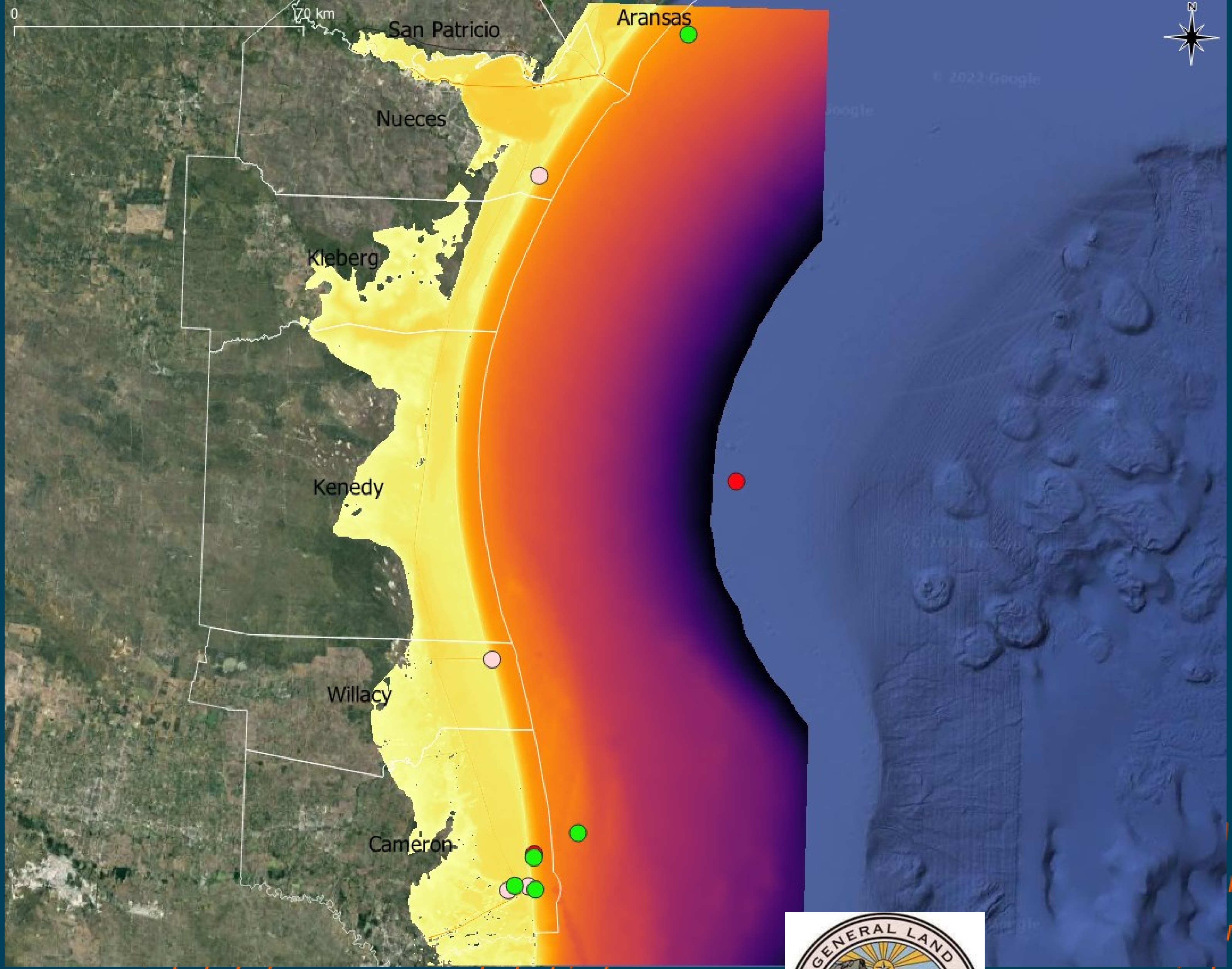
Regional wave / flow model



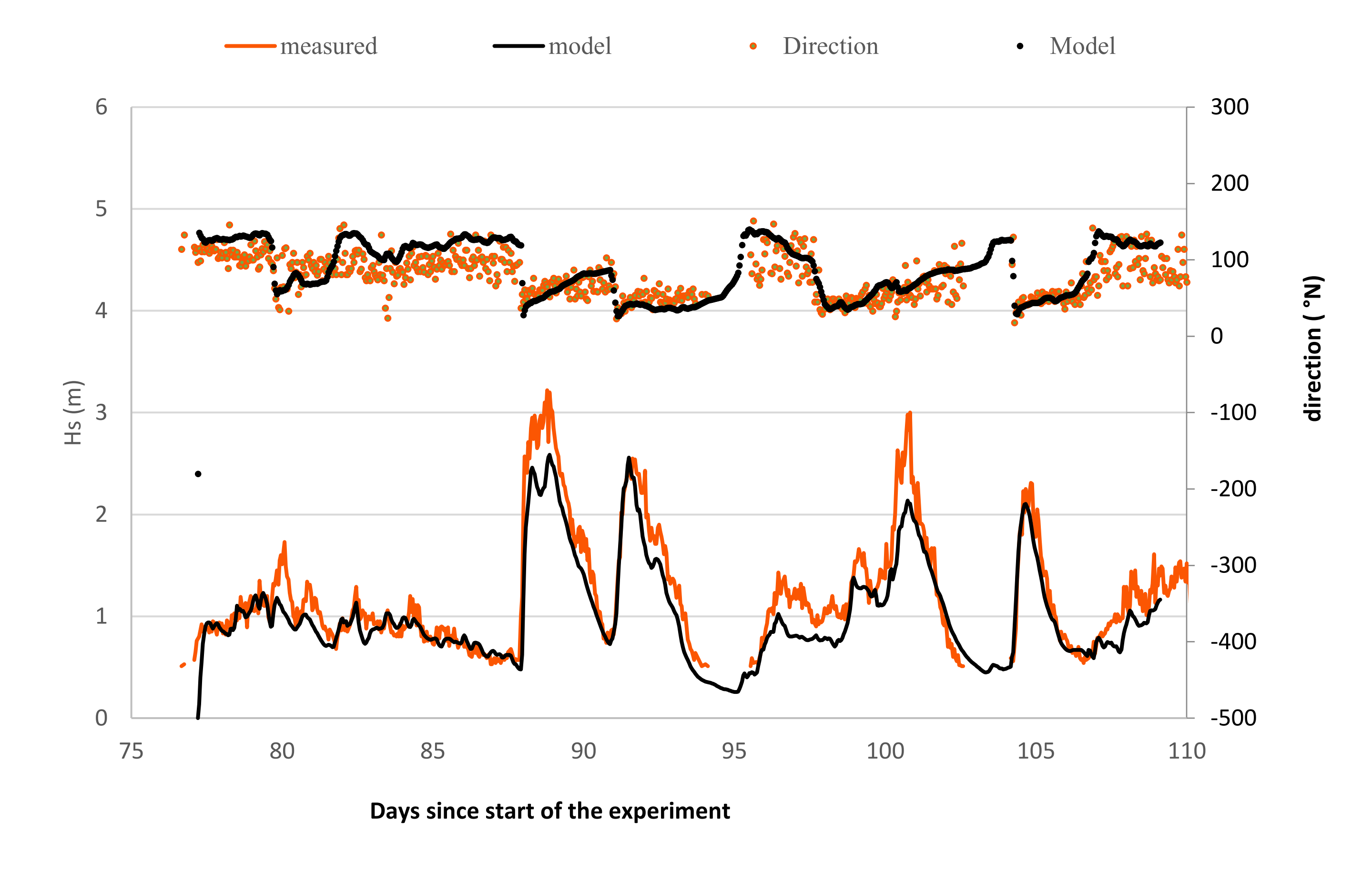
Validation

Calibration/Validation data

Waves: 2 points (red)
Currents: 5 points (green)
Levels: 4 points (pink)



Validation results nearshore waves



Validation results nearshore currents

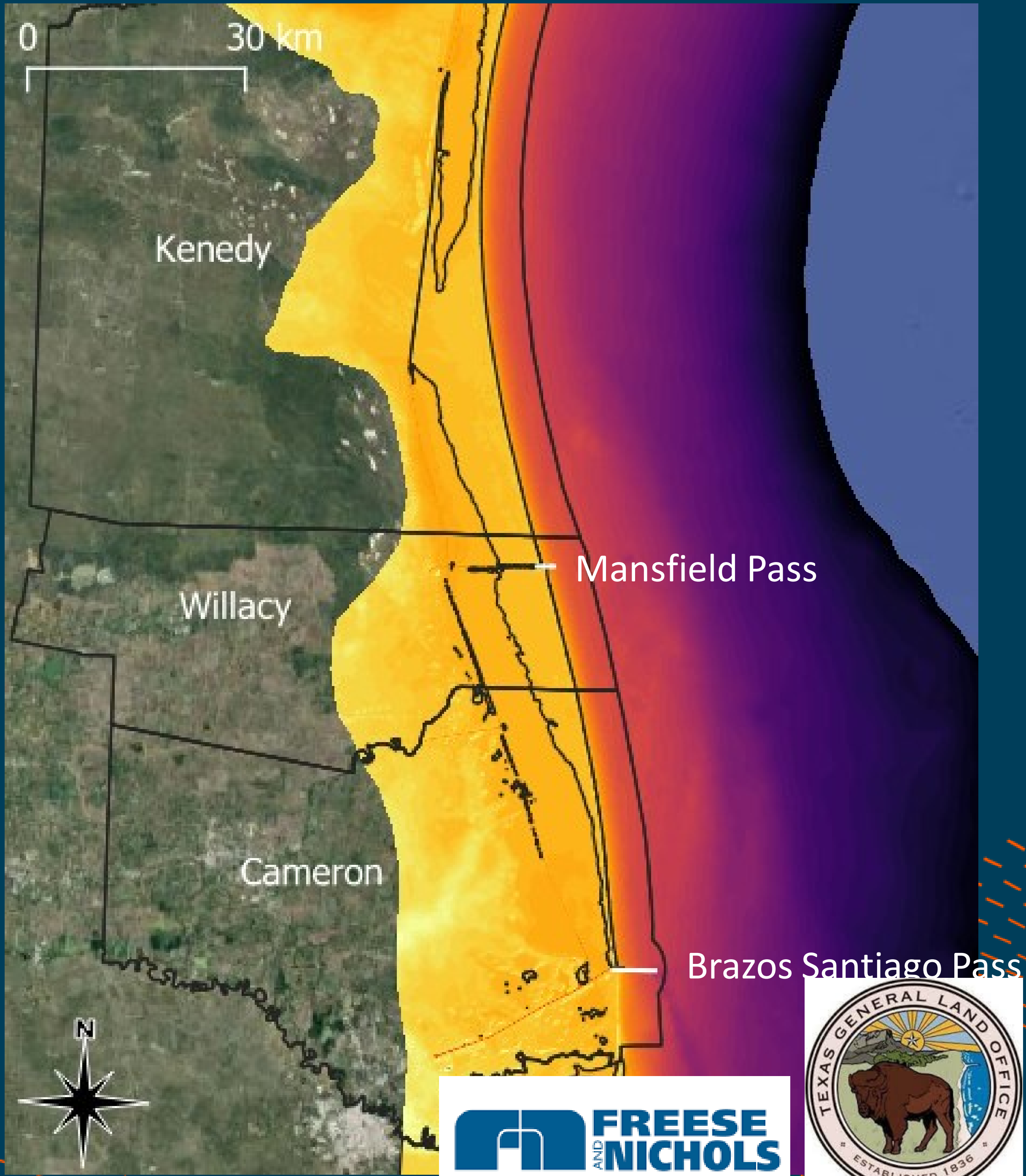
Error statistics validation

Variable	Location		RMSE	Skill
Water level (m)	Aransas Pass	Inlet	0.29	0.93
	Bob Hall Pier	Coast	0.29	0.93
	South Padre Island	Inlet	0.27	0.89
	Port Isabel	Laguna	0.28	0.94
Velocity (m/s)	Tabs Buoy D	Ocean	0.14	0.55
	Tabs Buoy J	Ocean	0.06	0.66
	South Padre Island September*	Coast	0.06	0.60
	South Padre Island November*	Coast	0.11	0.89
Wave height (m)	NDBC 42045	Ocean	0.28	0.85
	South Padre Island November*	Coast	0.14	0.95

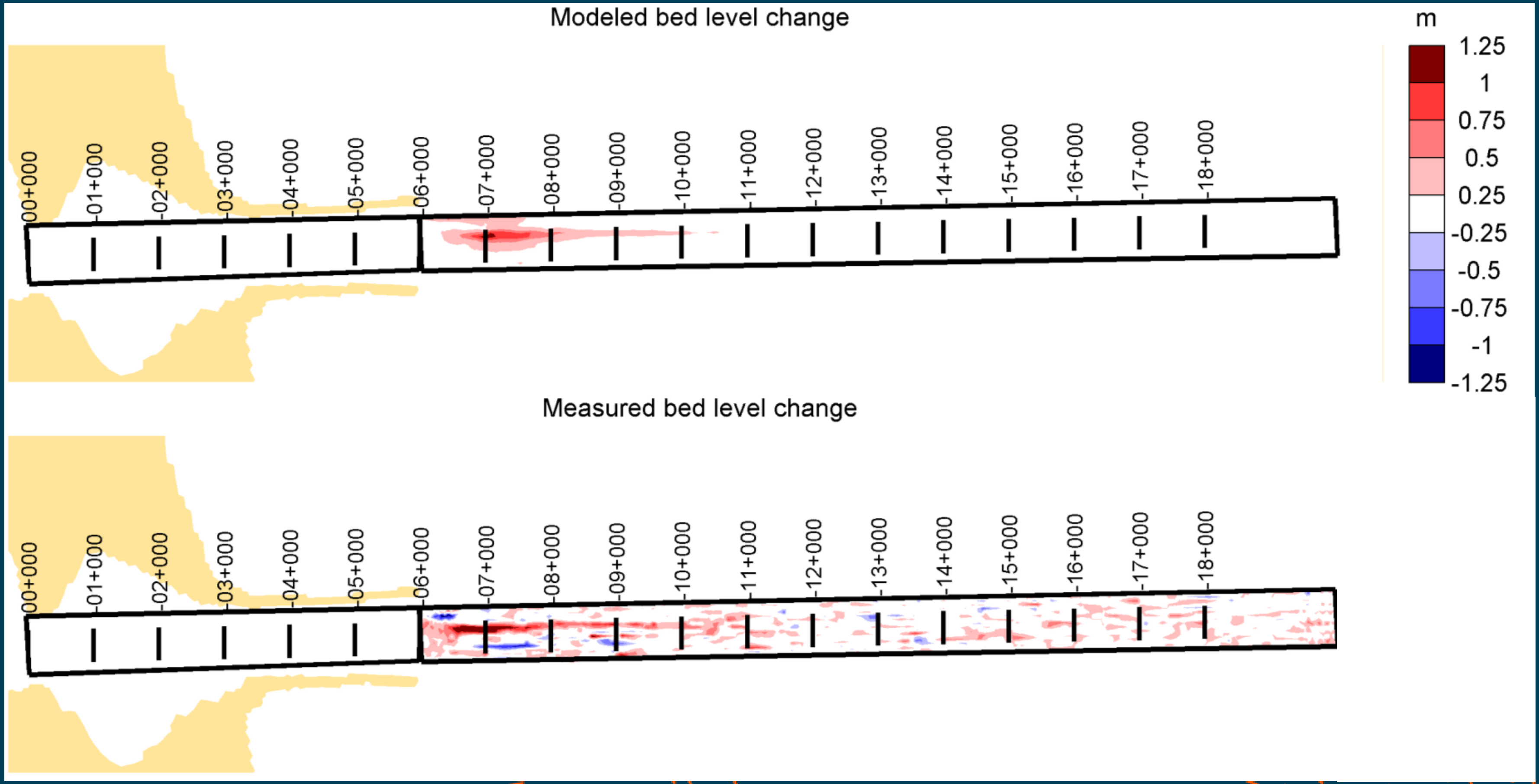
*Engel et al (2019)

Sediment verification

Channel sedimentation



Channel sedimentation outside Brazos Santiago Pass



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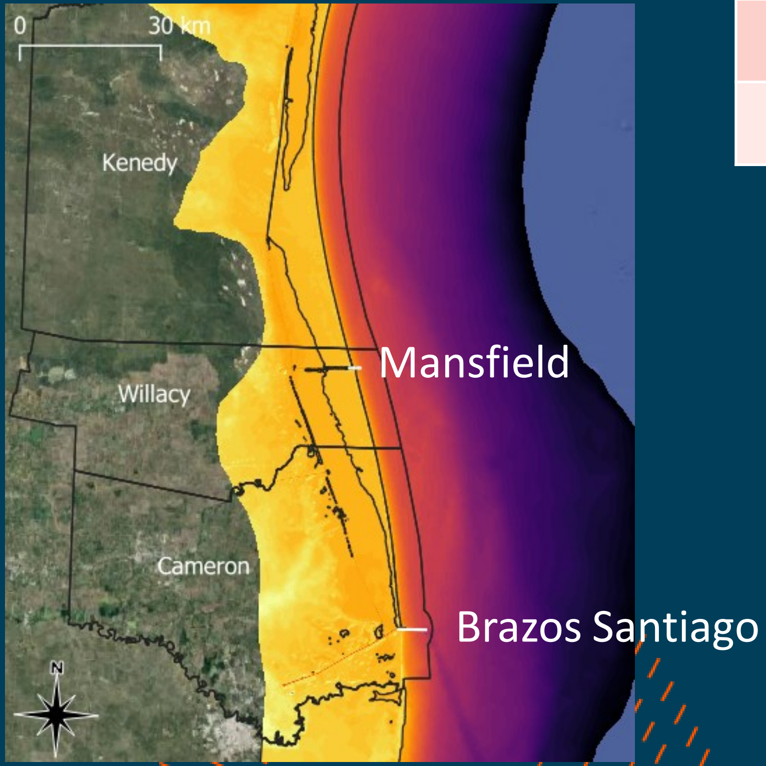
Quantification evolution 3 months

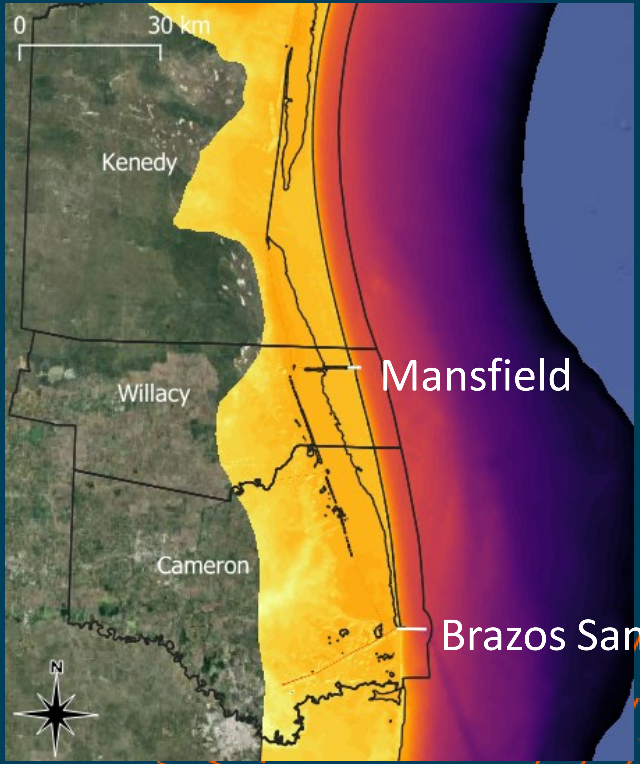
Channel	Measured infill	Model infill	Error
	m^3/y	m^3/y	%
Brazos Santiago jetties	62,000*	58,000	-6
Brazos Santiago outer	78,000	73,000	-6
Mansfield jetties	-45,000	-22,000	-51

*includes correction of reference level

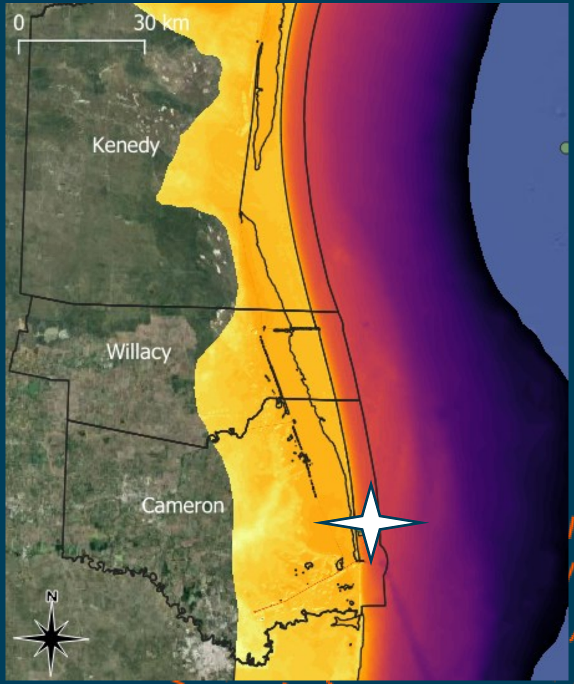


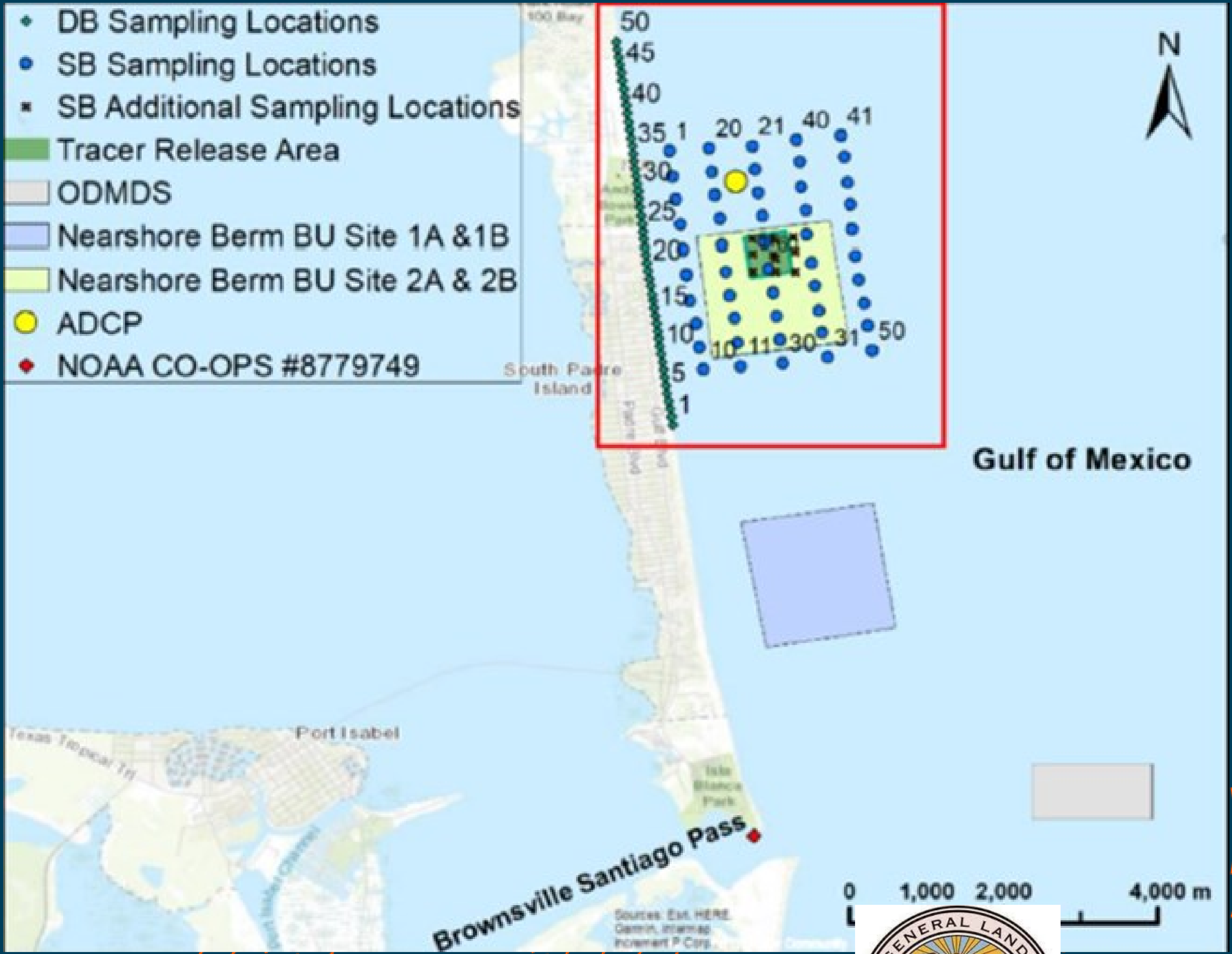
Quantification long-term infill /dredging volumes

Channel	Measured infill	Model infill	Error
	m^3/y	m^3/y	%
Brazos Santiago jetties	115,000	147,000	28
Brazos Santiago outer	154,000	124,000	19
Mansfield jetties	27,000	41,000	52
Mansfield outer	2,000	0	-100



Tracer study
Figlus et al (2021)





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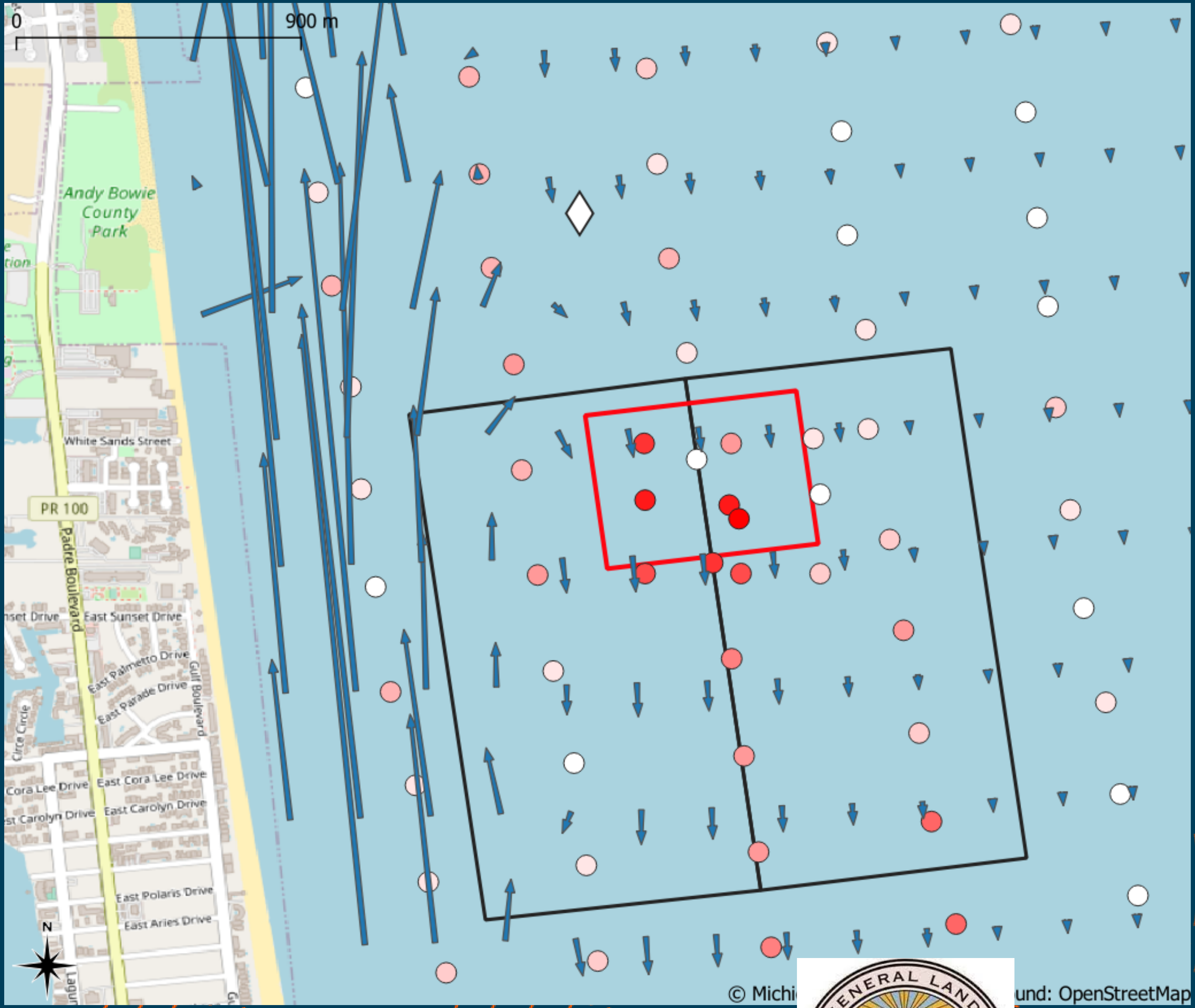
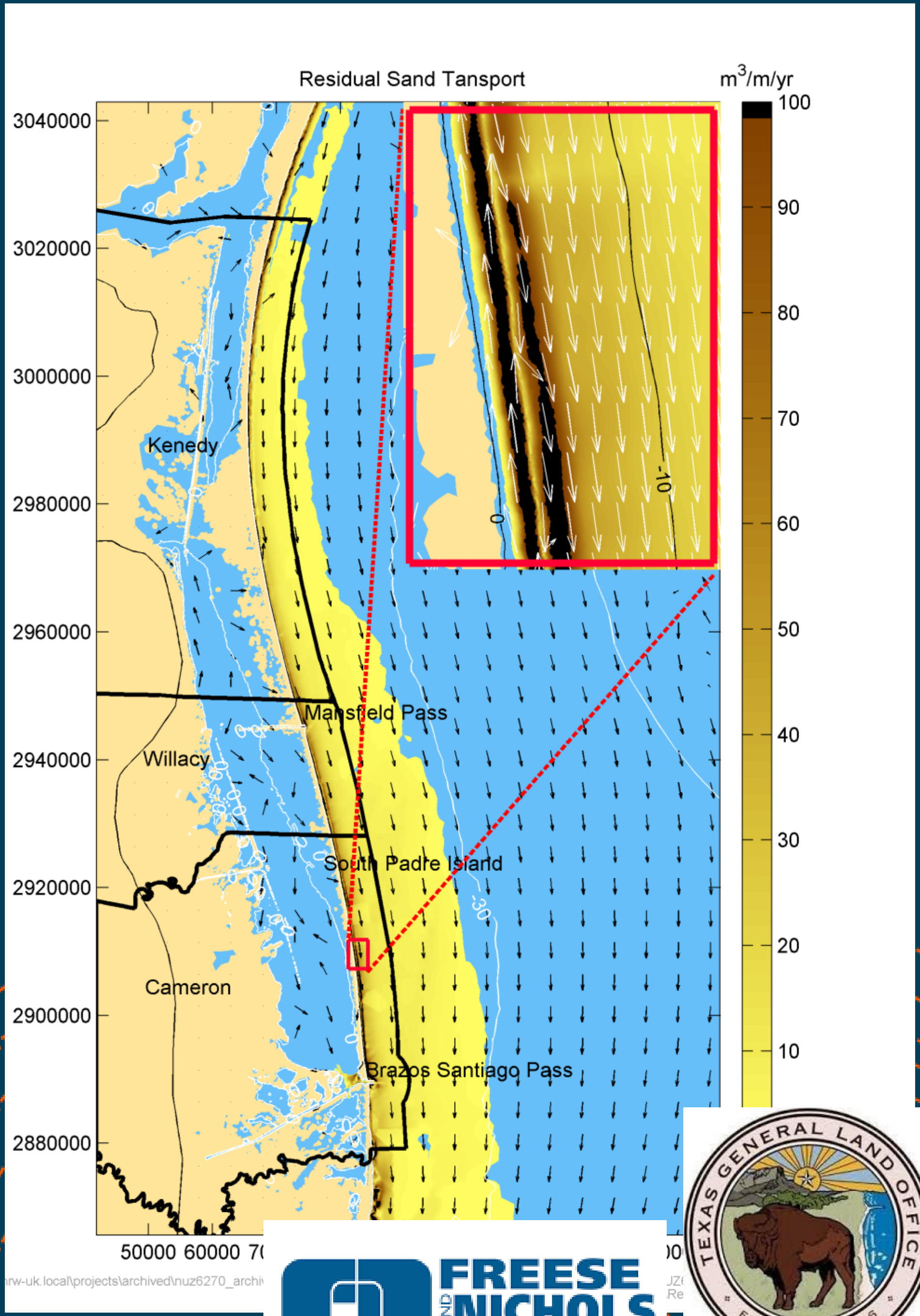
Sediment tracers
Figlus et al (2021)



Resulting sediment pathways

Yearly residual sand transport



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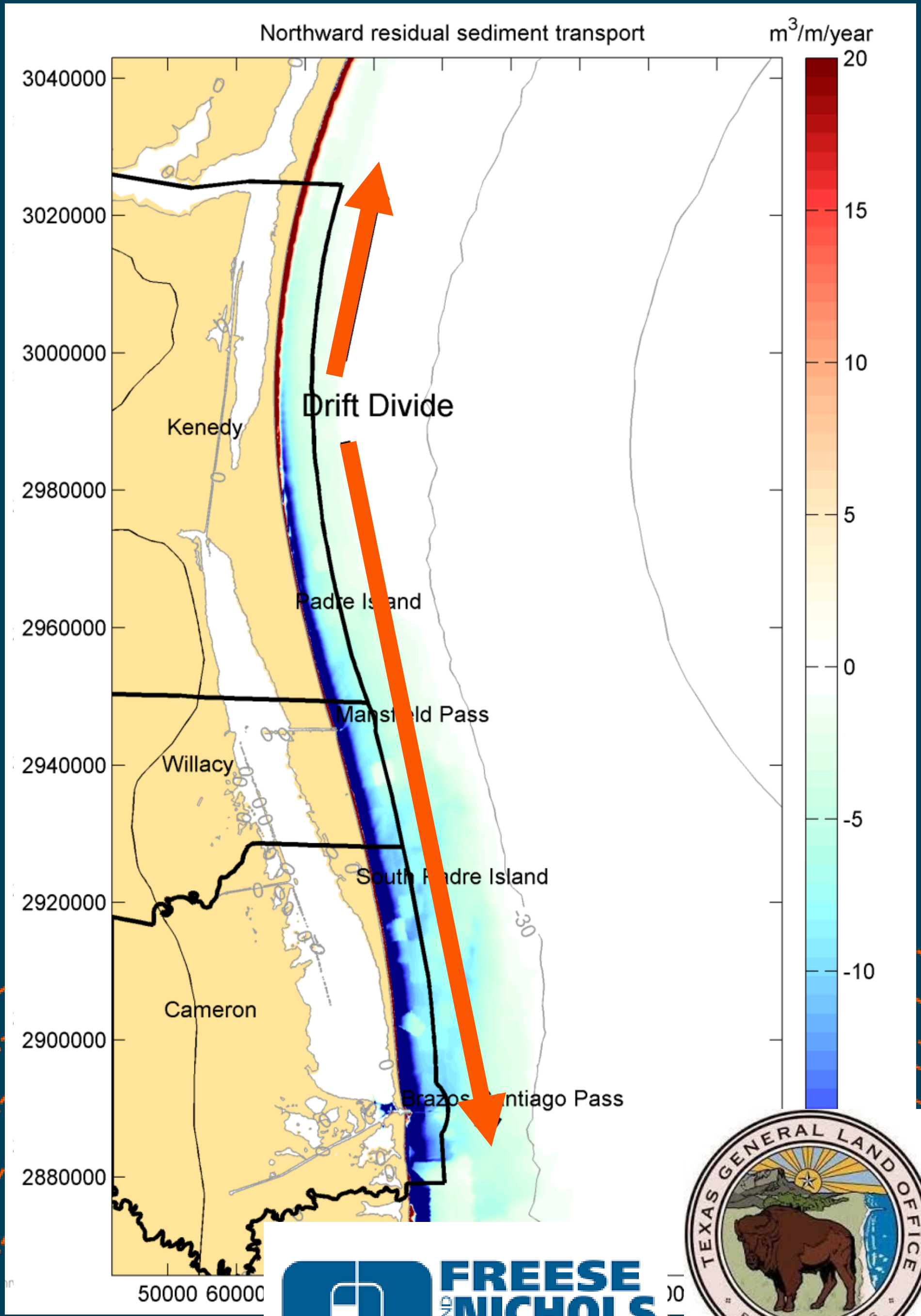
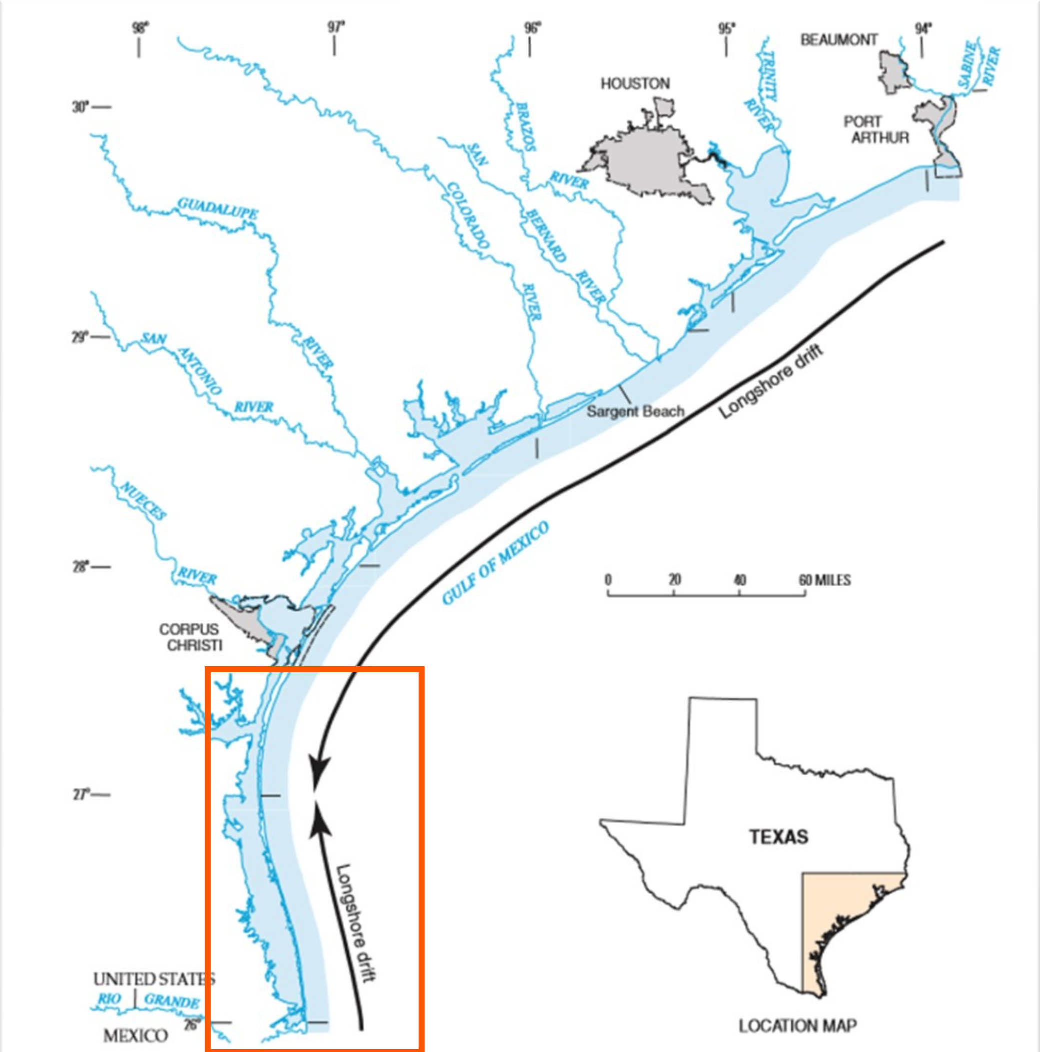
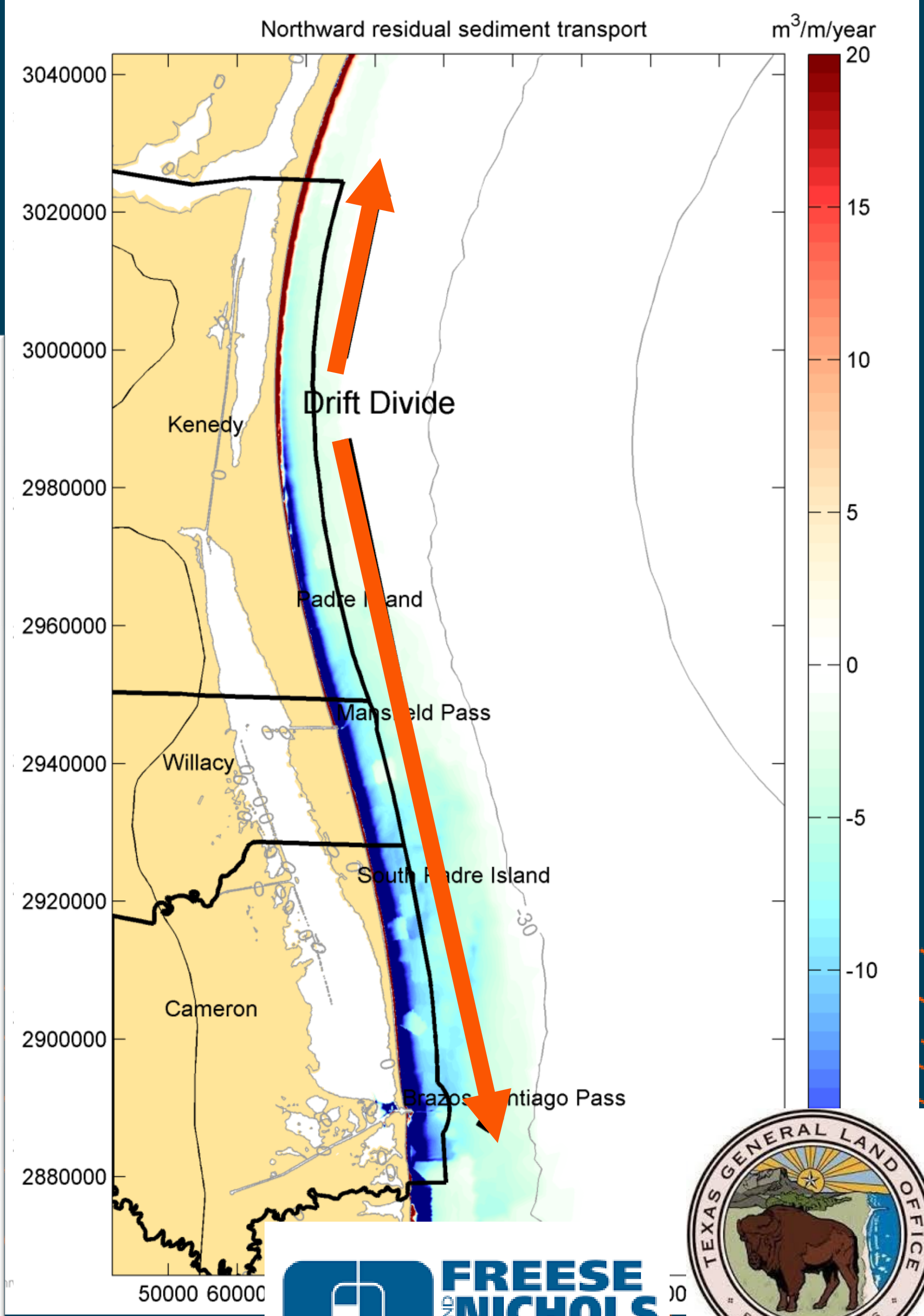
Yearly residual sand transport

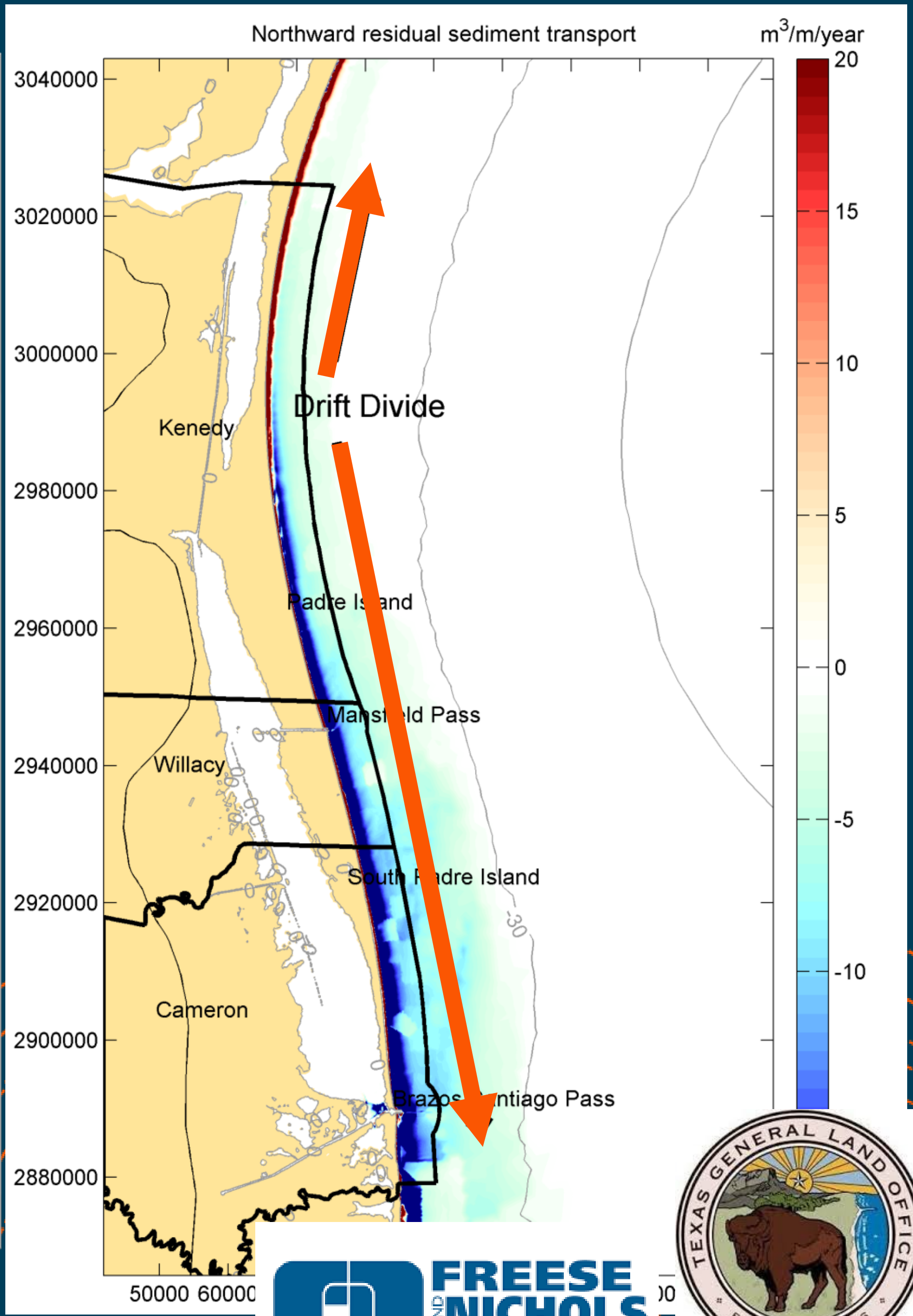




98°
97°
96°
95°
94°
30°
29°
28°
27°
26°
BEAUMONT
HOUSTON
PORT ARTHUR
SABINE RIVER
TRINITY RIVER
BRAZOS RIVER
SAN BERNARD RIVER
COLORADO RIVER
GUADALUPE RIVER
SAN ANTONIO RIVER
NUECES RIVER
Sargent Beach
Longshore drift
GULF OF MEXICO
0 20 40 60 MILES
CORPUS CHRISTI
Longshore drift
TEXAS
LOCATION MAP
UNITED STATES
MEXICO
RIO GRANDE



Northward residual sediment transport
m3/m/year
20
15
10
5
0
-5
-10
3040000
3020000
3000000
2980000
2960000
2940000
2920000
2900000
2880000
Drift Divide
Kenedy
Willacy
Cameron
Mansfield Pass
South Padre Island
Brazos Santiago Pass
50000
60000



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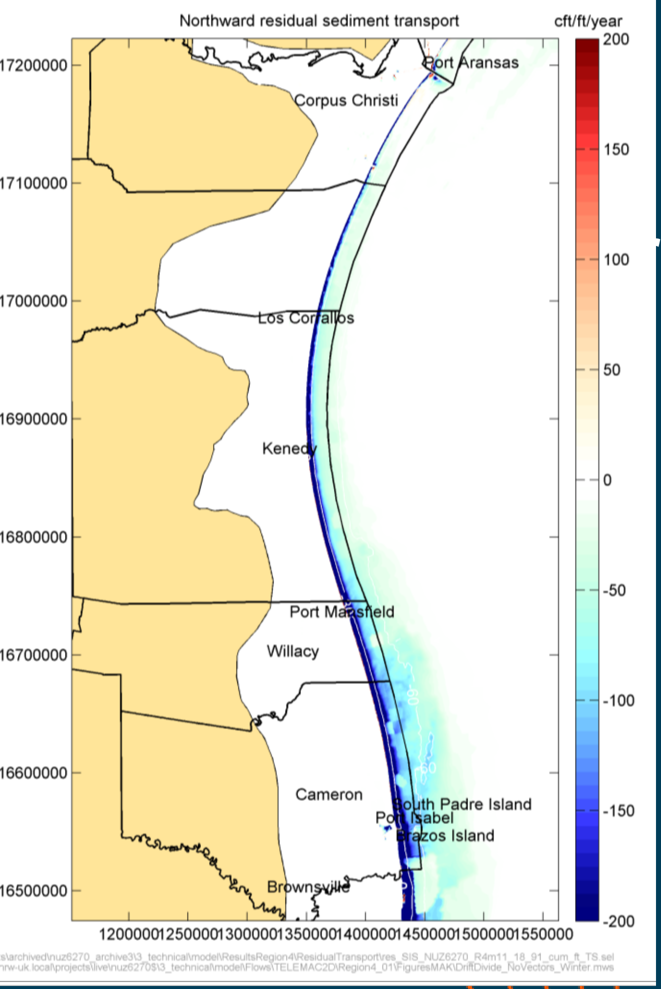
Northward residual sediment transport
cft/ft/year
200
150
100
50
0
-50
-100
-150
-200
Port Aransas
Corpus Christi
Los Corrallos
Kenedy
Port Mansfield
Willacy
Cameron
South Padre Island
Port Isabel
Brazos Island
Brownsville
17200000
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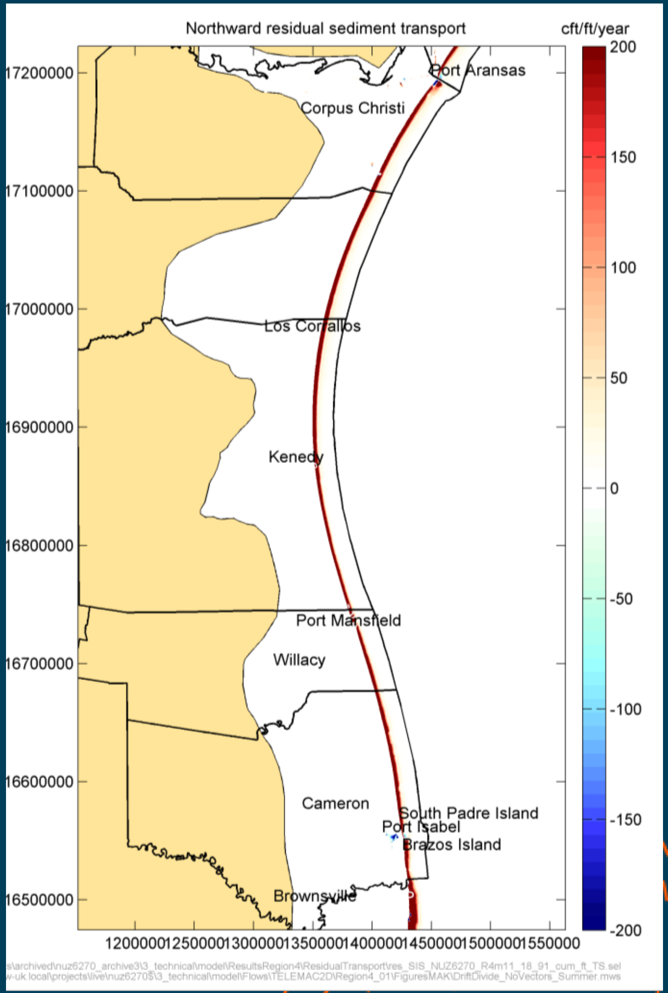
17000000
16900000
16800000
16700000
16600000
16500000
1200000 1250000 1300000 1350000 1400000 1450000 1500000 1550000

iation


Northward residual sediment transport
cft/ft/year
200
150
100
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0
-50
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-150
-200
Port Aransas
Corpus Christi
Los Corrallos
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Willacy
Cameron
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Port Isabel
Brazos Island
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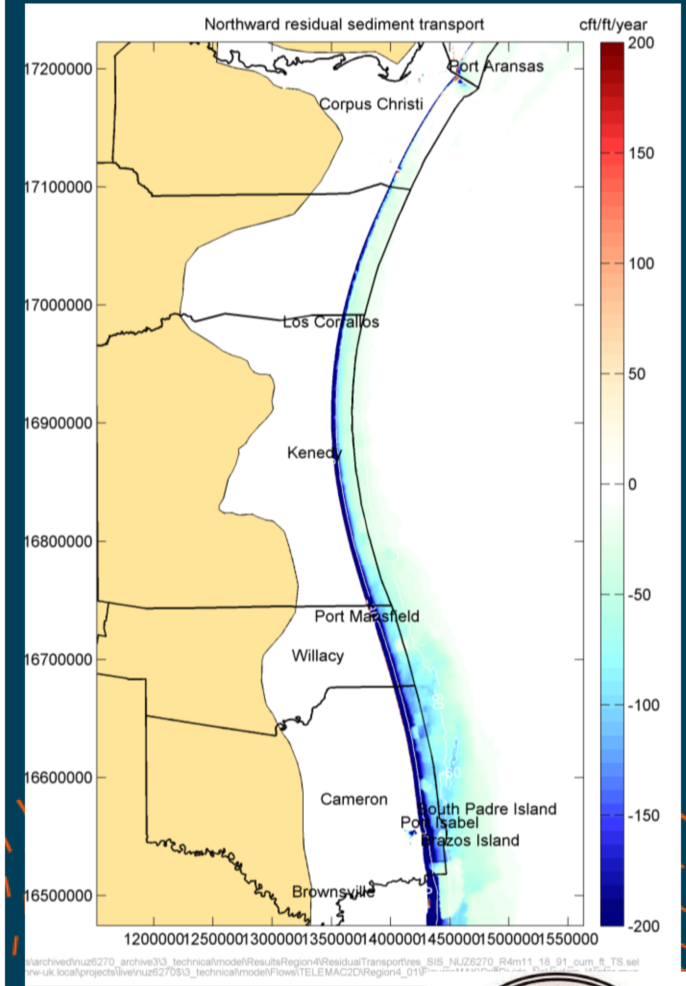
Northward residual sediment transport
cft/ft/year
200
150
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0
-50
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-200
Port Aransas
Corpus Christi
Los Corrallos
Kenedy
Port Mansfield
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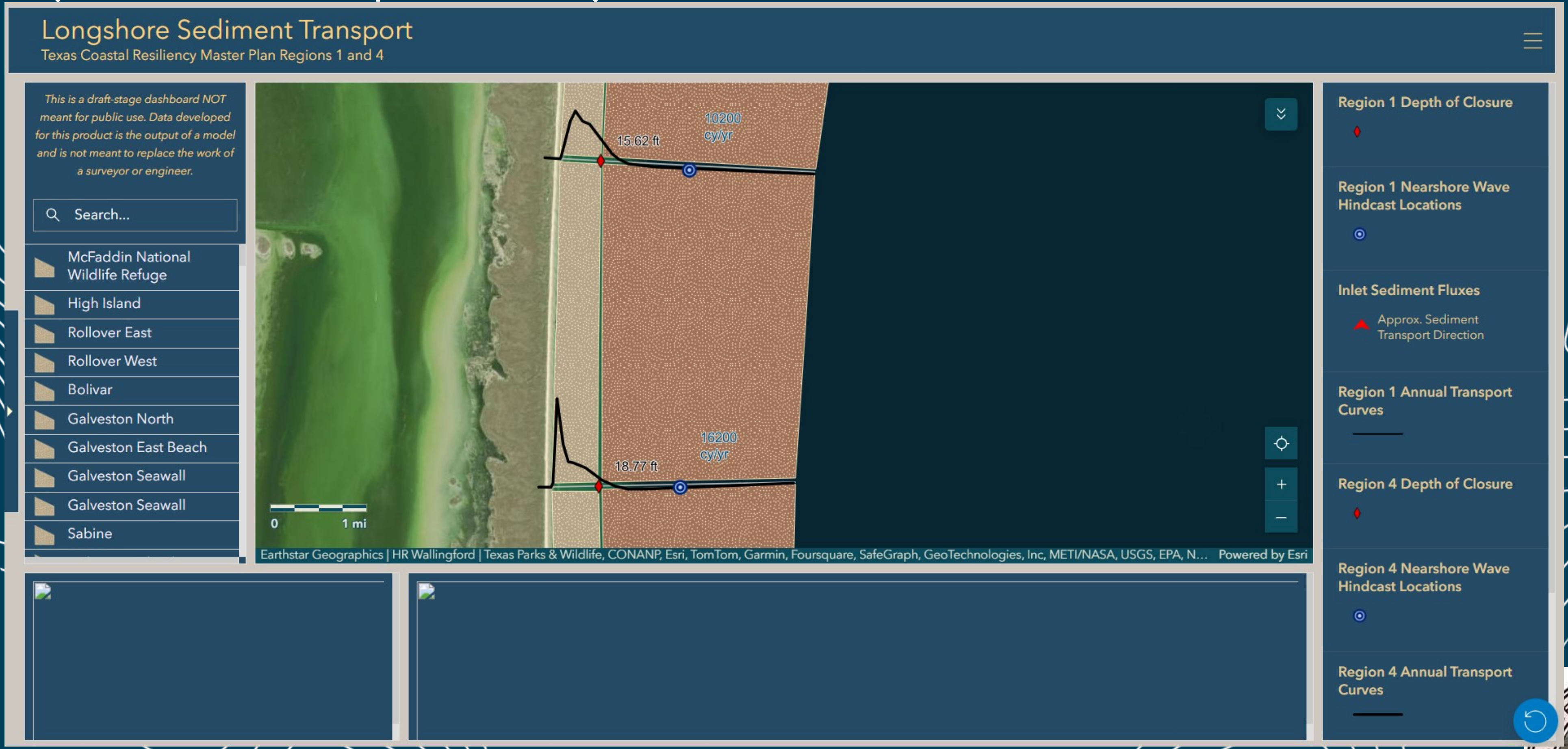
Cameron
South Padre Island
Port Isabel
Brazos Island
Brownsville
17200000
17100000
17000000
16900000
16800000
16700000
16600000
16500000
1200000 1250000 1300000 1350000 1400000 1450000 1500000 1550000

Area modelling changes the conventional knowledge on littoral drift in Texas

Conclusion:

- Even thought the current velocities in the Gulf of Mexico are low, they cannot be neglected in nearshore sediment transport calculations

Open access GIS (in development)



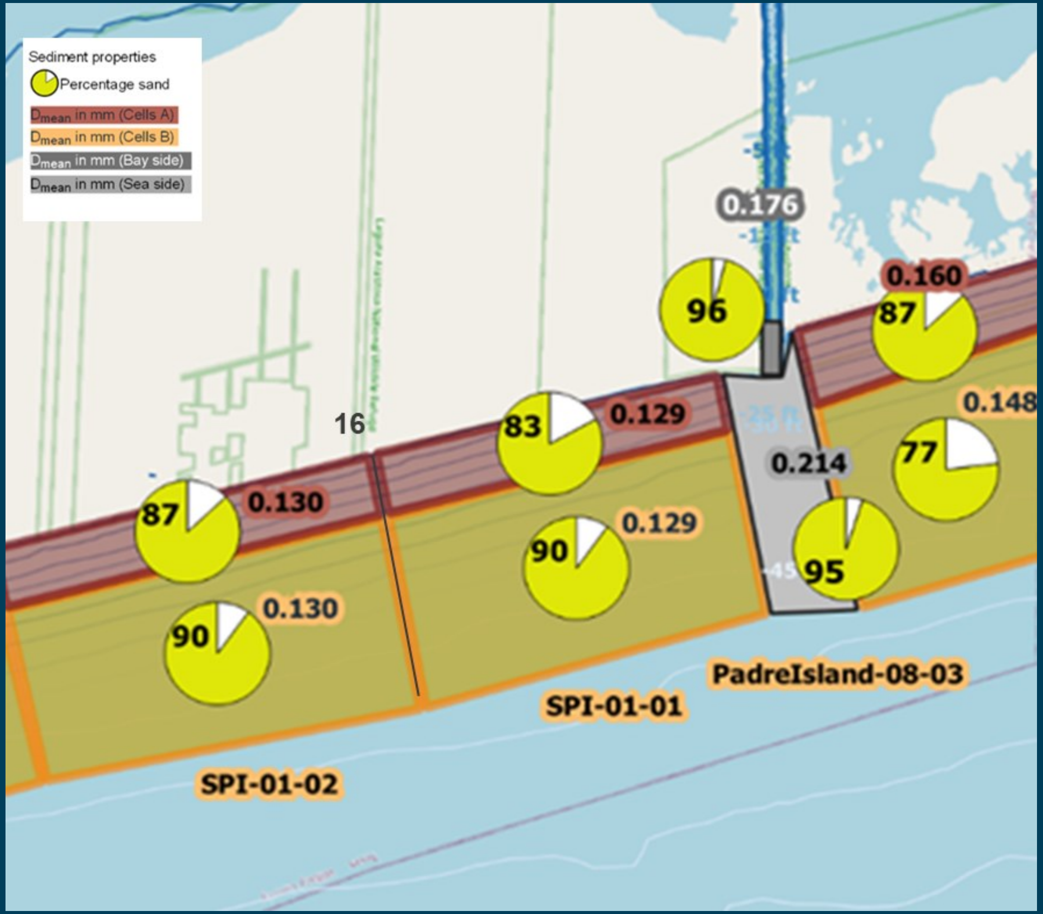
Static layers

For each cell:

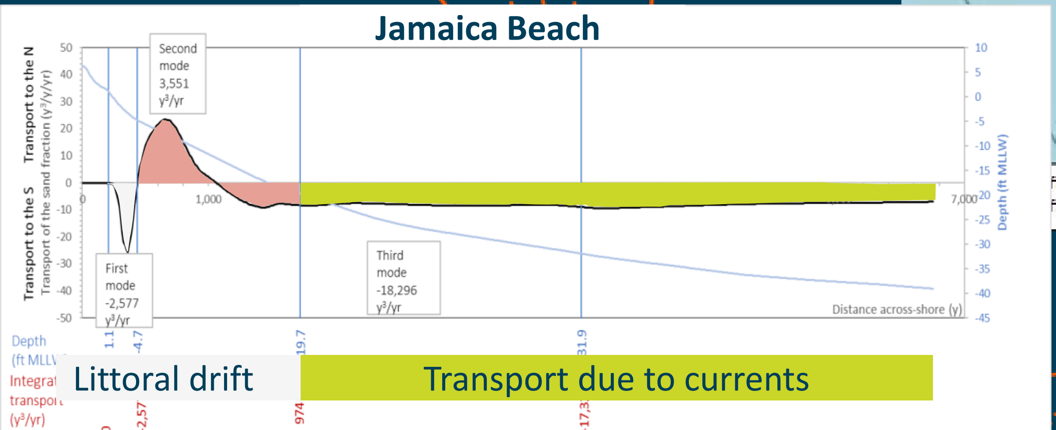
- Sediment characteristics
  a. dmean
  b. % of sand

  and

  c. % of the 5 fractions used in the modeling



Monthly residual sand transport



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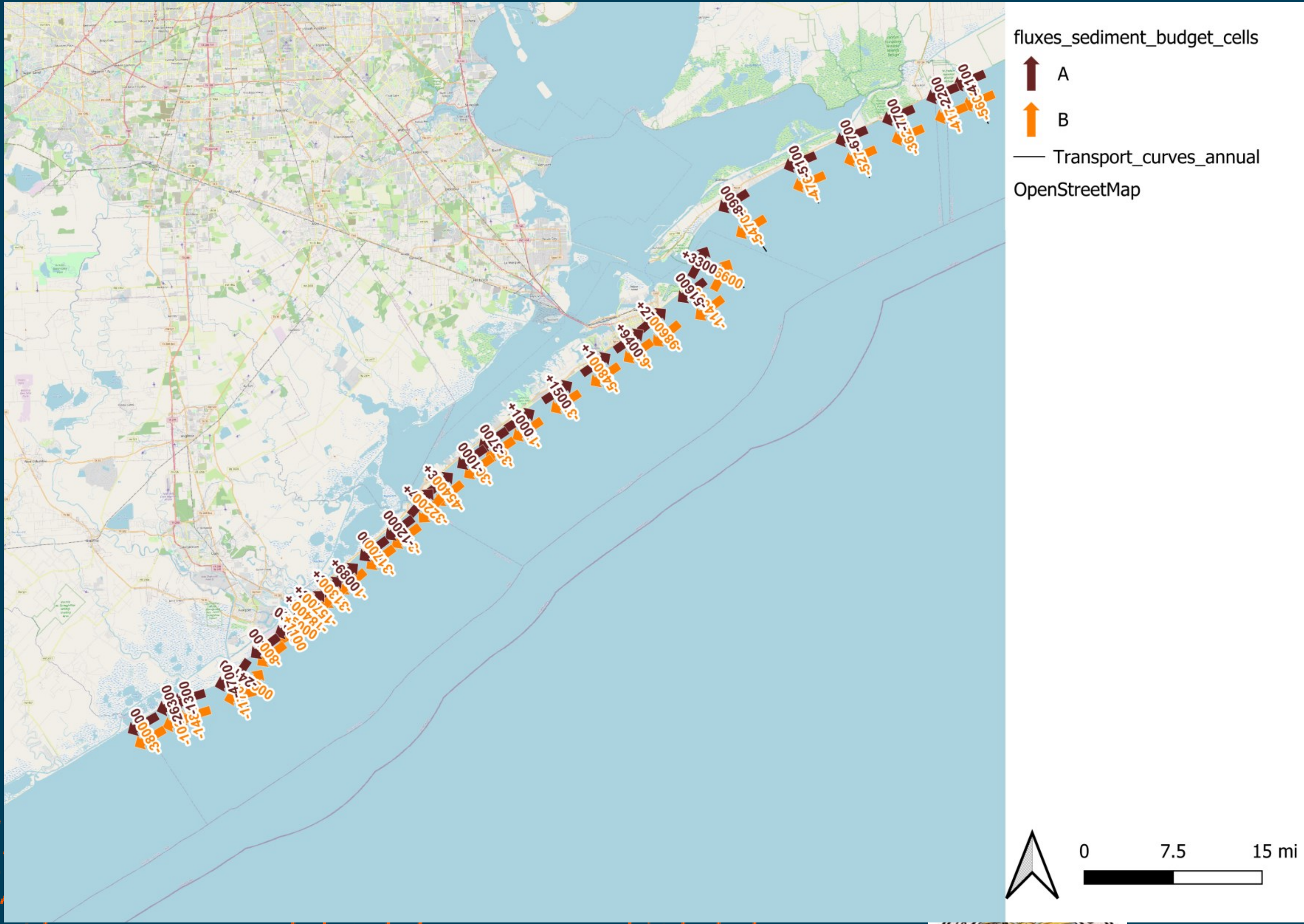
Annual littoral drift
Gross
Nett



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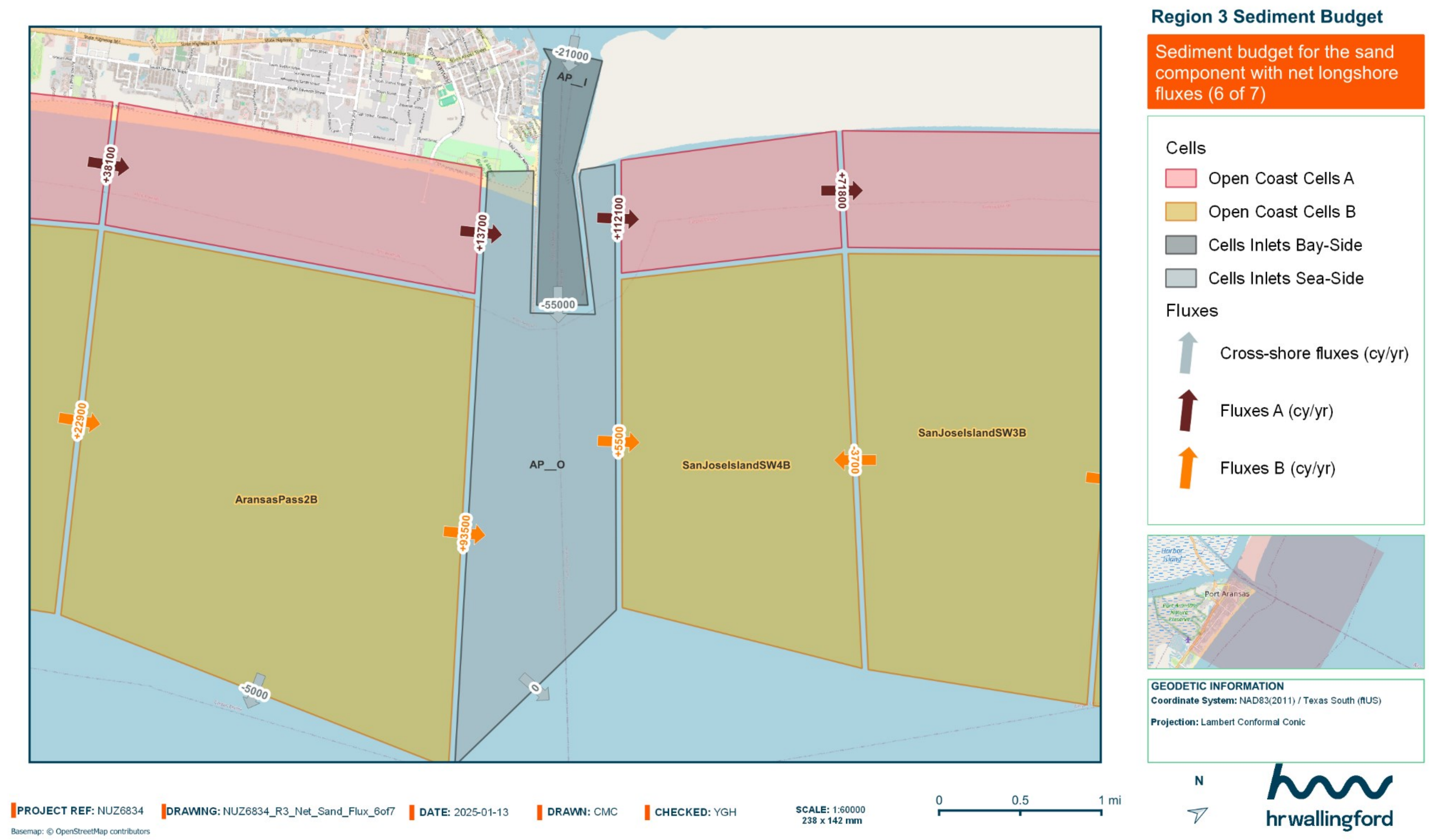
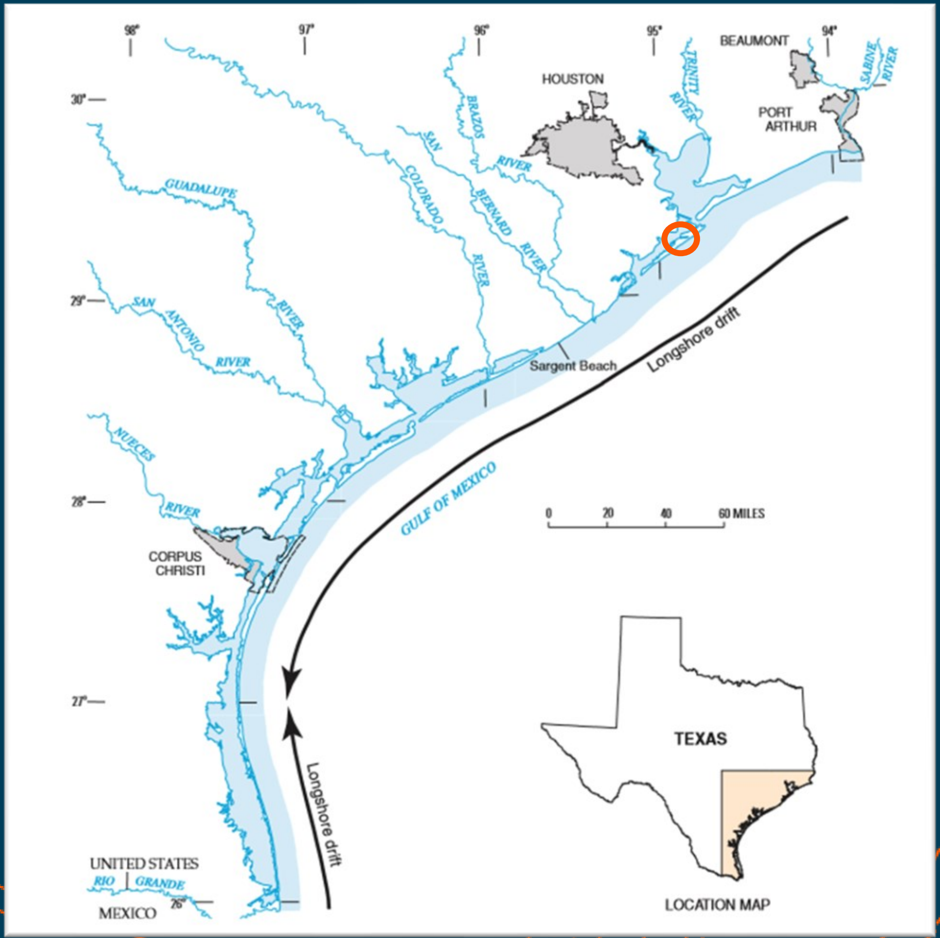
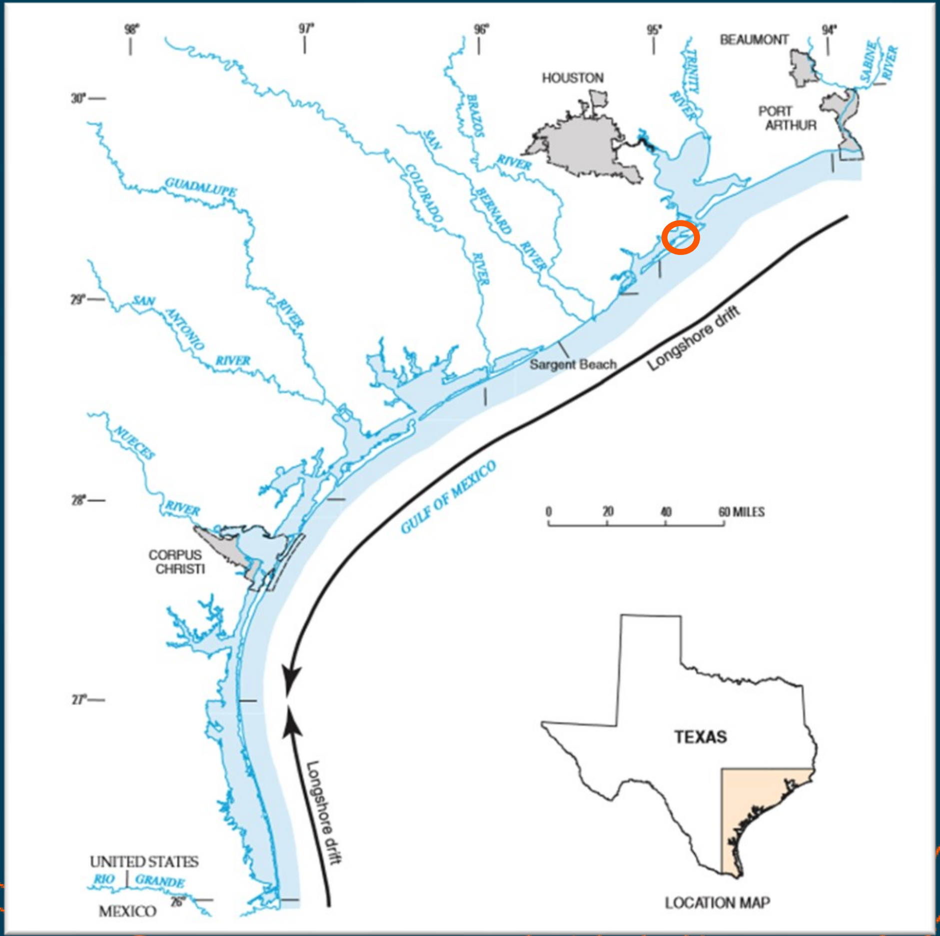


Beach nourishment Galveston



Beach nourishment Galveston



- Sediment was expected to slowly move east
- After first storm nourished material had disappeared

Beach nourishment Galveston

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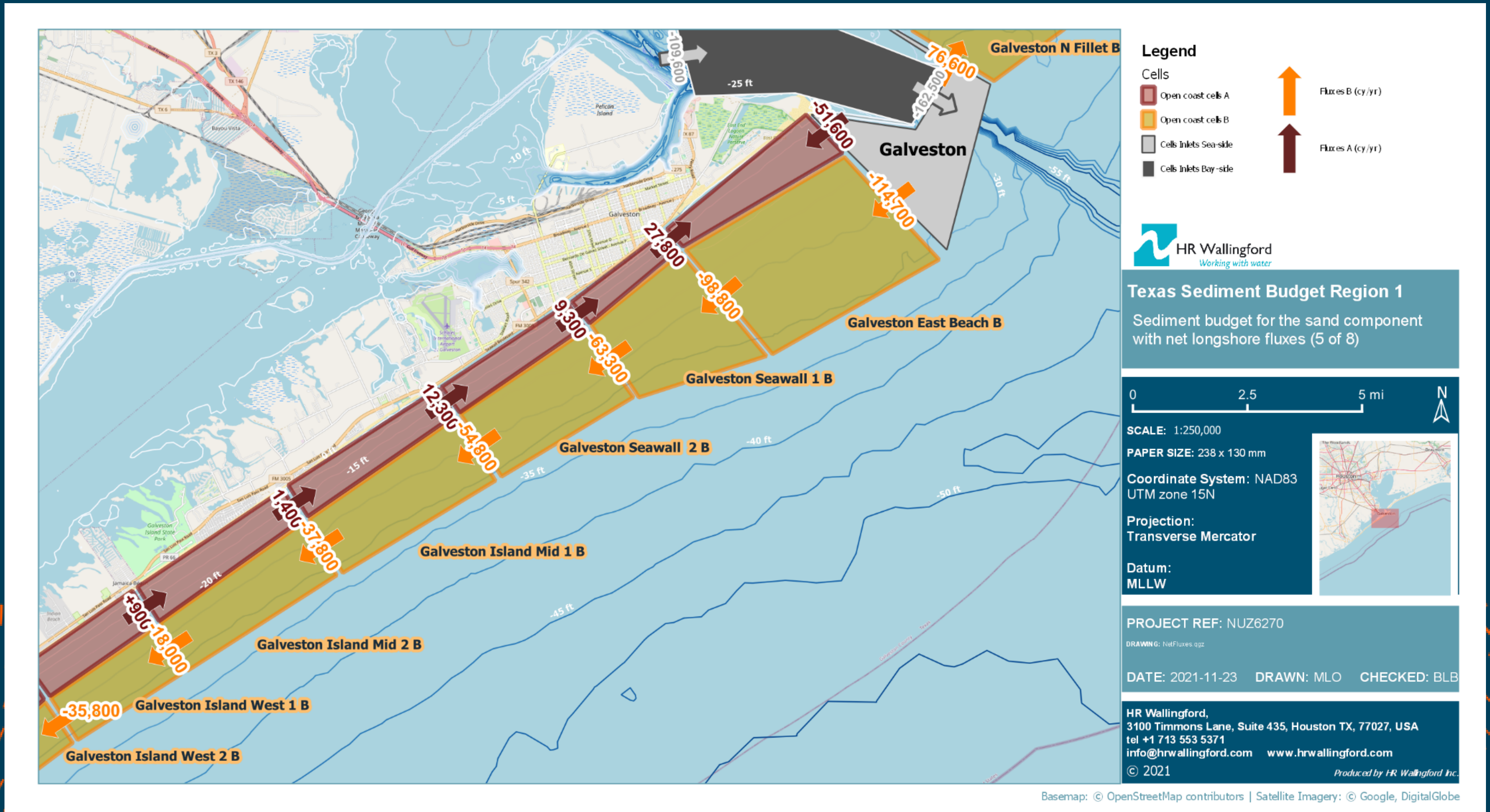
Beach nourishment Galveston



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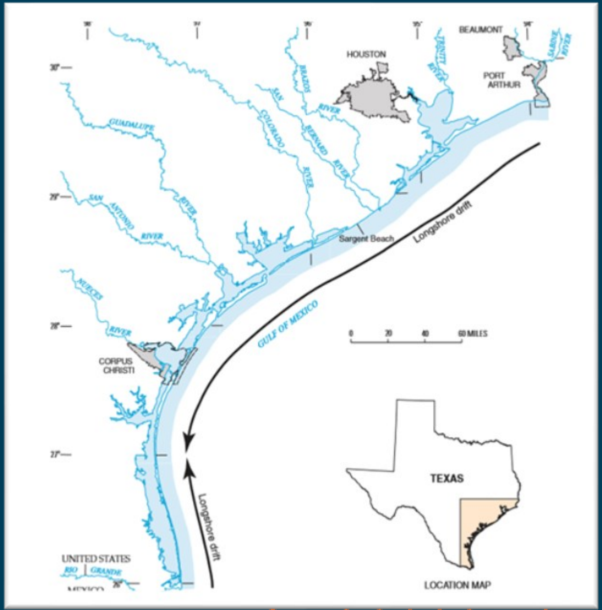
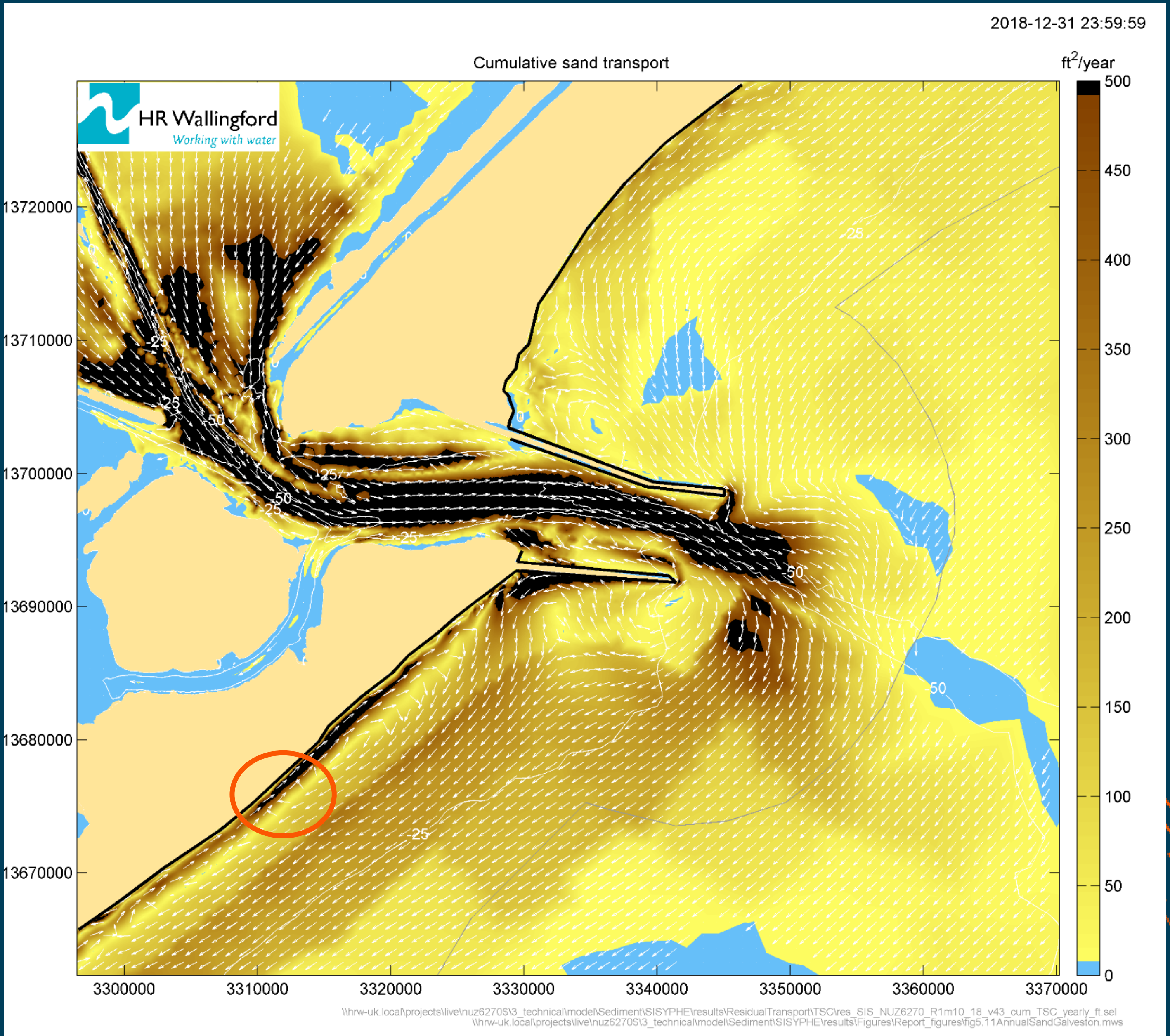
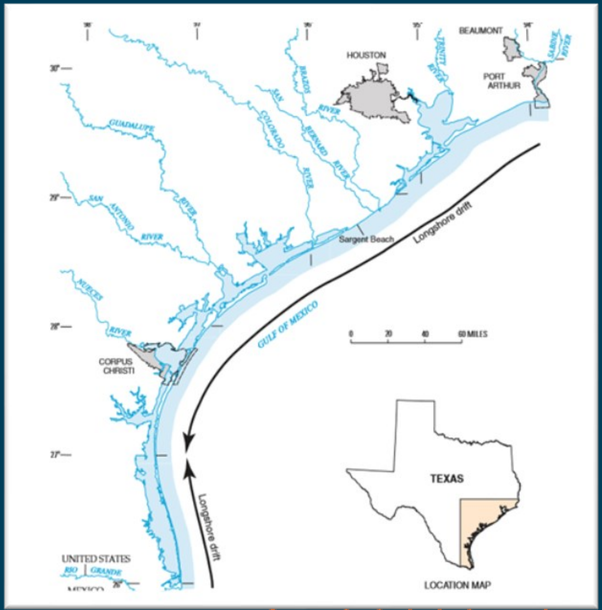
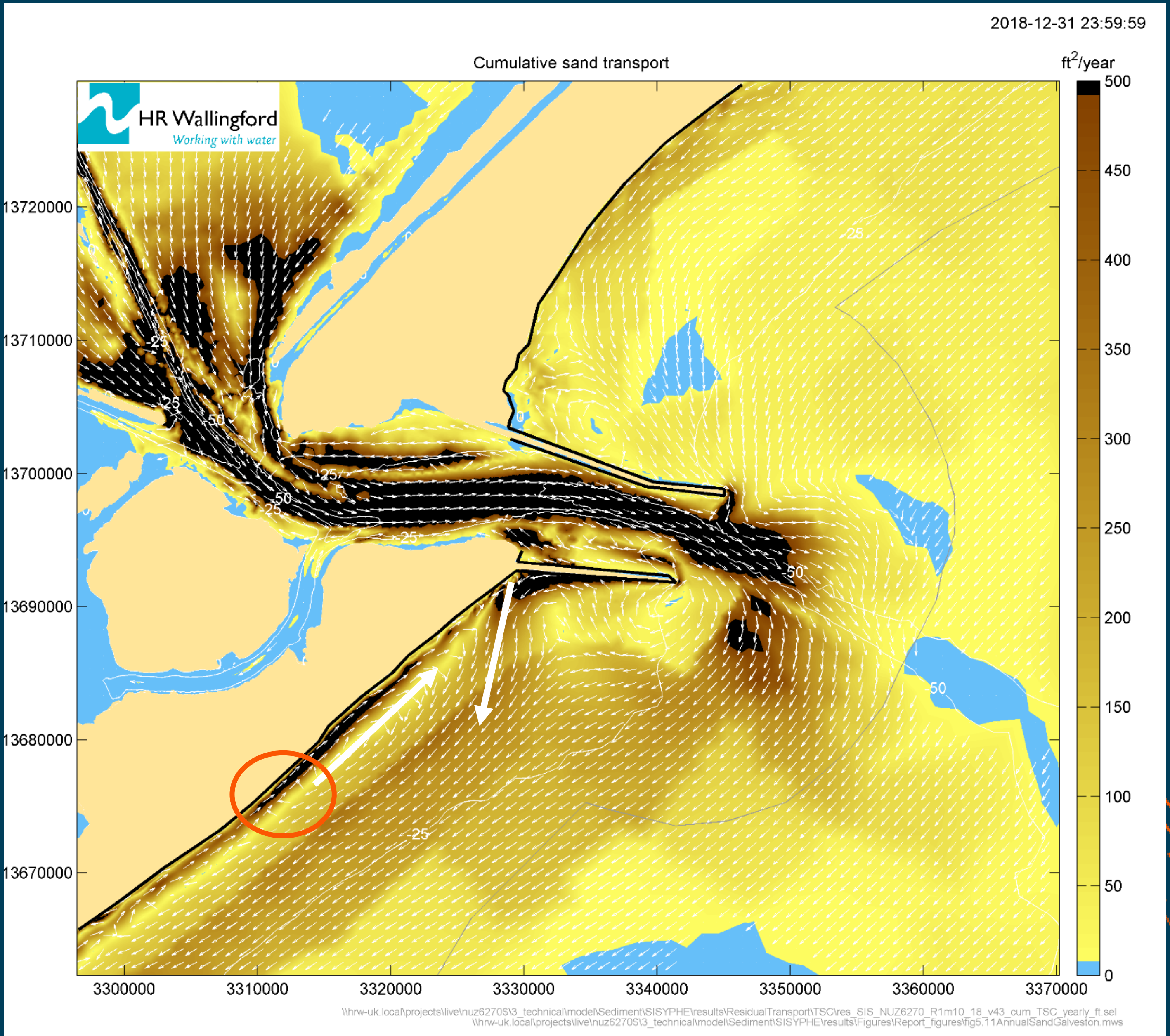
Beach nourishment





Beach nourishment





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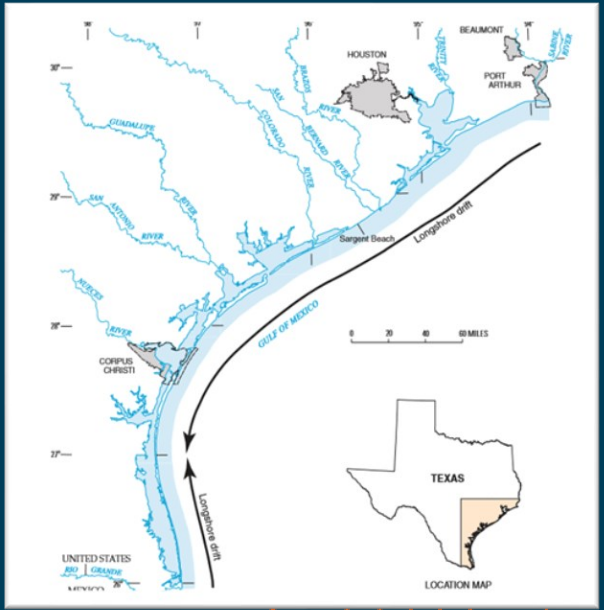
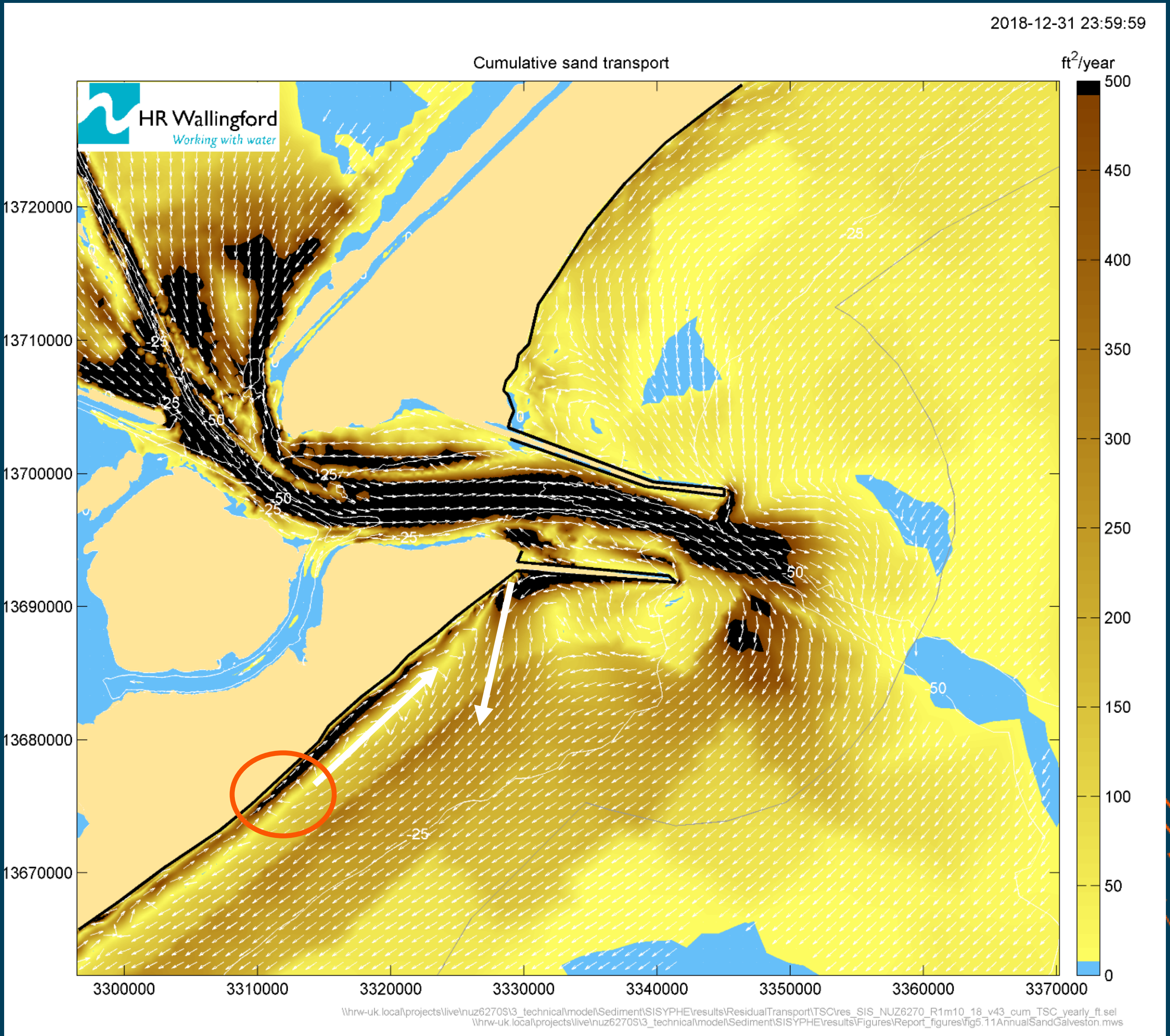
Monthly residual sand transport





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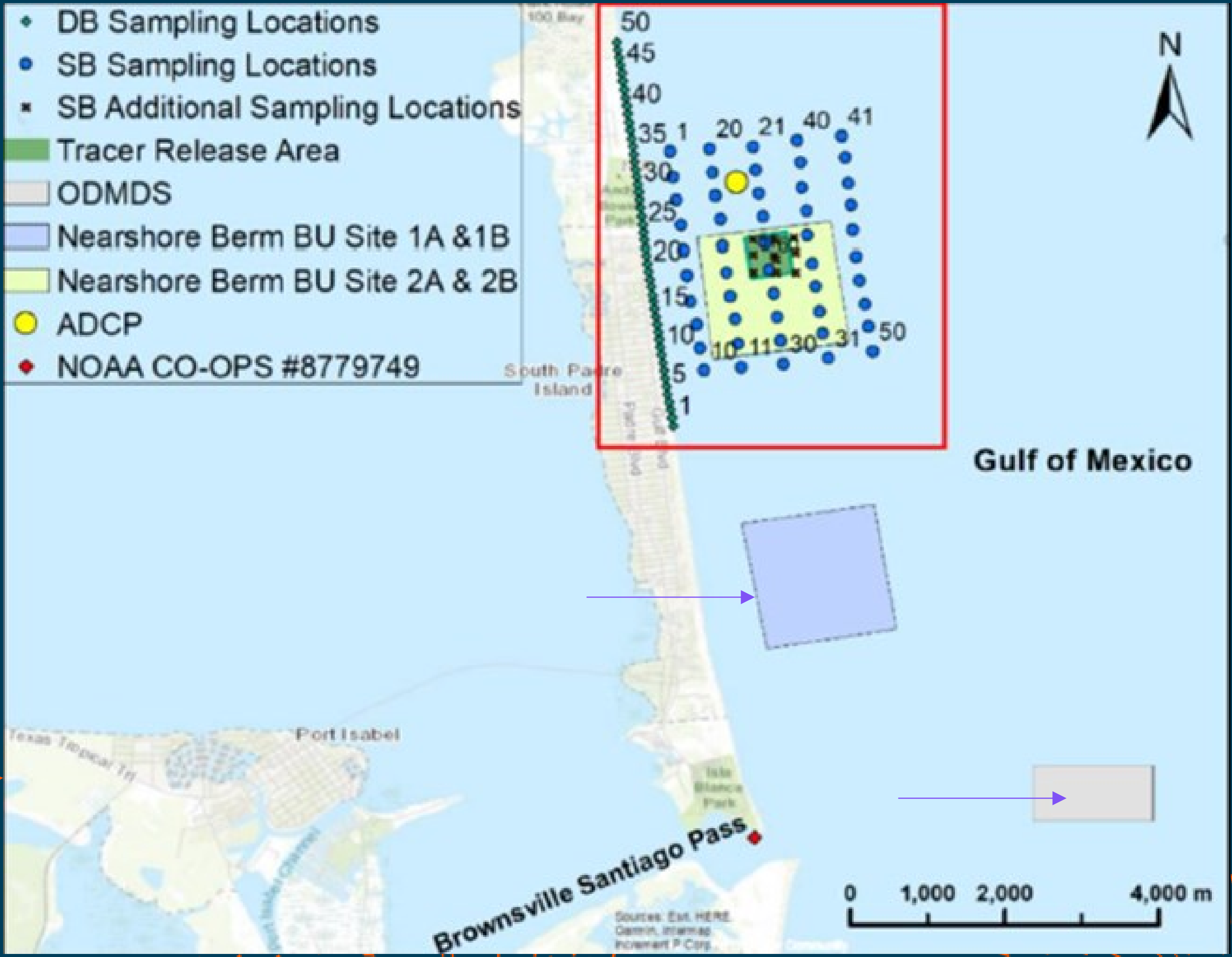
Area modelling changes the conventional knowledge on littoral drift in Texas

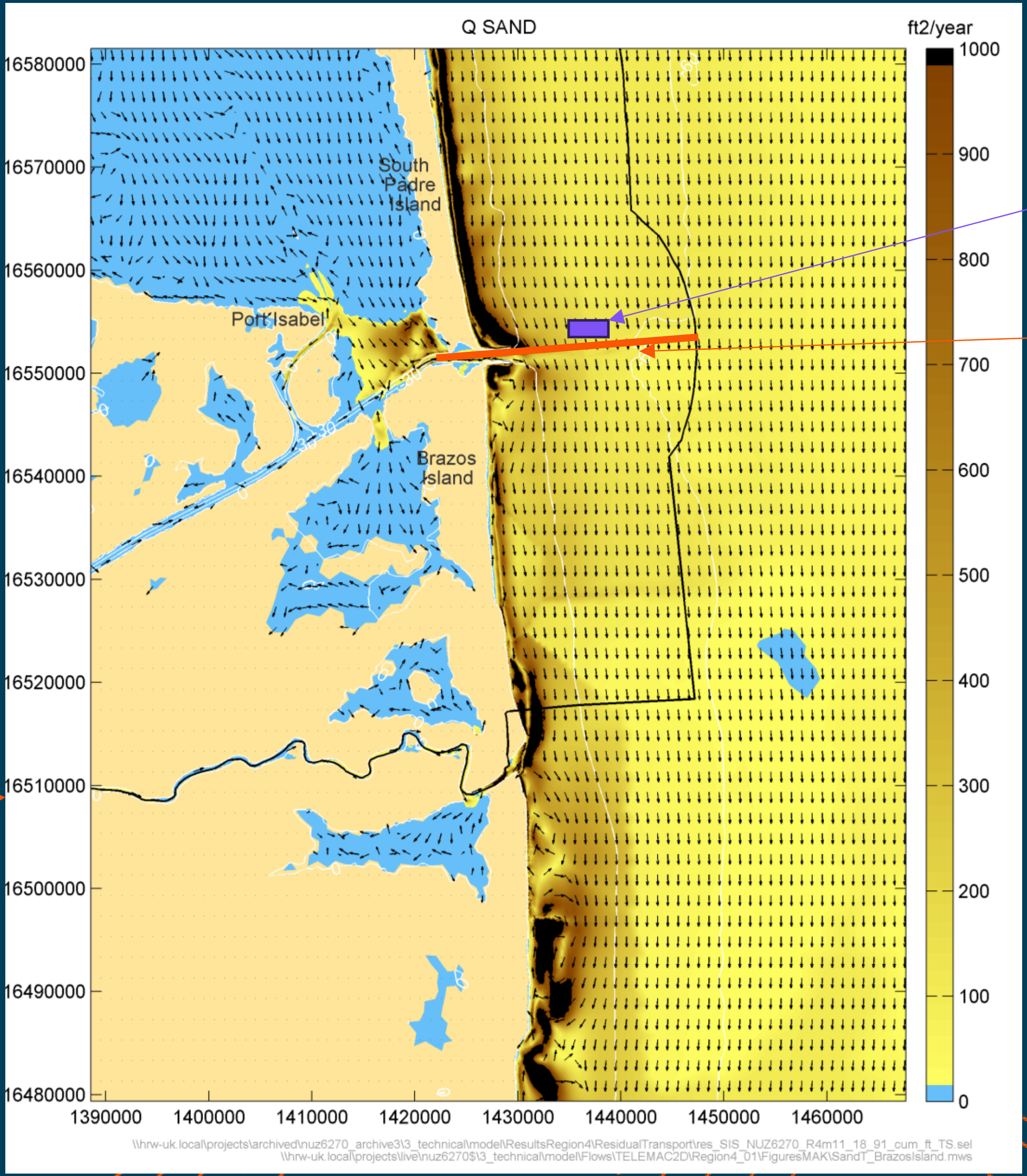
Implications:

- Placement of nourishment:
  - Sediment was expected to slowly move east
  - In first storm nourished material had disappeared
- Location of Nourishment:
  - Distance offshore might affect direction of movement
- Breakwaters/groynes:
  - The length of the groyne might influence not only the magnitude but also the direction of sediment bypassing

Dredge material placement sites



Monthly residual sand transport



Placement site

Channel

Area modelling changes the conventional knowledge on littoral drift in Texas

Implications:

- Placement of dredged material:
  - Placement sites north of the entrance channel
  - Sediment could rapidly return to channel
- Location of Nourishment:
  - Distance offshore might affect direction of movement
- Breakwaters/groynes:
  - The length of the groyne might influence not only the magnitude but also the direction of sediment bypassing

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Thank you

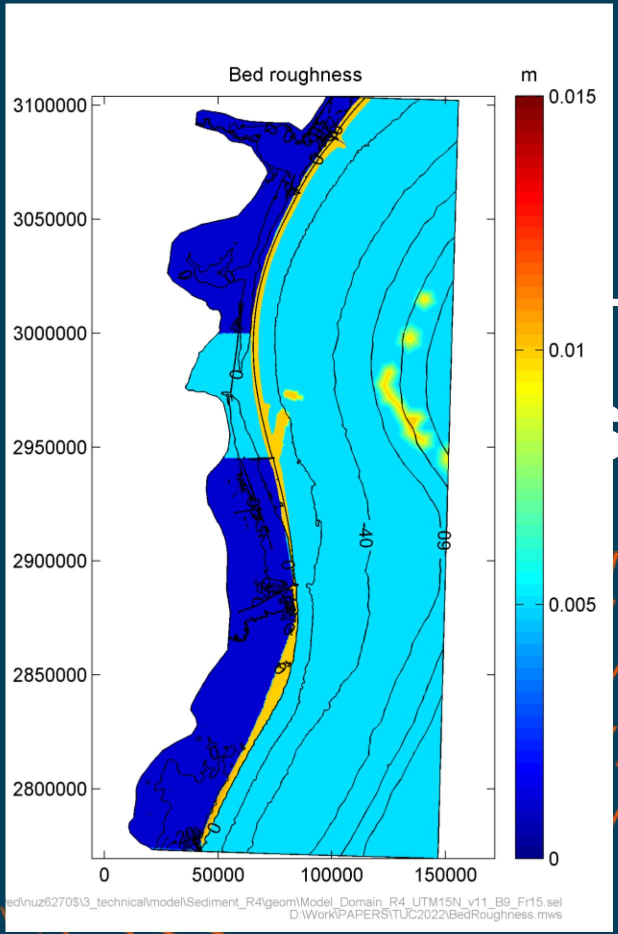
Model set-up sand transport modelling

(Following Knaapen TUC 2019)

- Model setting:
- Waves: TOMAWAC

- Model settings as close to default as possible, exceptions:
- Wind generation of waves: Yan (Texas) /Janssen(elsewhere)
- Wind efficiency correction for storm waves

- Model setting:
- Waves: TOMAWAC
- Currents: TELEMAC 2D



-up
sport

- Model settings as close to default as possible, exceptions:
- Numerical stability settings
- Smagorinski turbulence model
- Friction: Nikuradse, spatially varying

hrwallingford

-up
sport

- Model setting:
  - Waves: TOMAWAC
  - Currents: TELEMAC 2D
  - Sediment: SISYPHE

- Model settings as close to default as possible, exceptions:
  - Bedload sediment transport: Soulsby-van Rijn
  - Suspended sediment transport: Soulsby-van Rijn
  - Settling lag
  - Grain size: Spatially varying: 5