Automatic Identification Systems (AIS) Data Use in Marine Vessel Emission Estimation

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Outline

- Texas State Waters Inventory Context
- AIS Background
- AIS Dataset
- Data Processing Methods
- Results
- Limitations
- Final Discussion of AIS Data Applicability in Inventory Efforts

Inventory Effort: Texas State Waters

- Texas has over 600 miles of tidewater coastline
- Needs for more accurate emission inventories
- Commercial Marine Vessel (CMV) emissions pose unique challenges
- Excludes Houston/Galveston Area
- Automatic Identification Systems (AIS) data for use in activity estimation
- Strengths and limitations of AIS data

AIS - Background

- AIS = Automatic Identification System
- Electronically transmits data to Vessel Traffic Service (VTS) stations and other ships
  - Vessel Identification
  - Position
  - Speed
  - Course
- Uses GPS, ship sensors and VHF radio

AIS Data Transmittal

Every 2 to 10 seconds (underway) and every 3 minutes (at anchor):

- Maritime Mobile Service Identity
- Status (anchor/underway/not under command)
- Rate of turn
- Speed
- Latitude and Longitude
- True Heading
- Time Stamp, Coordinated Universal Time (UTC)

AIS Data Transmittal

Every 6 minutes, underway or at anchor:

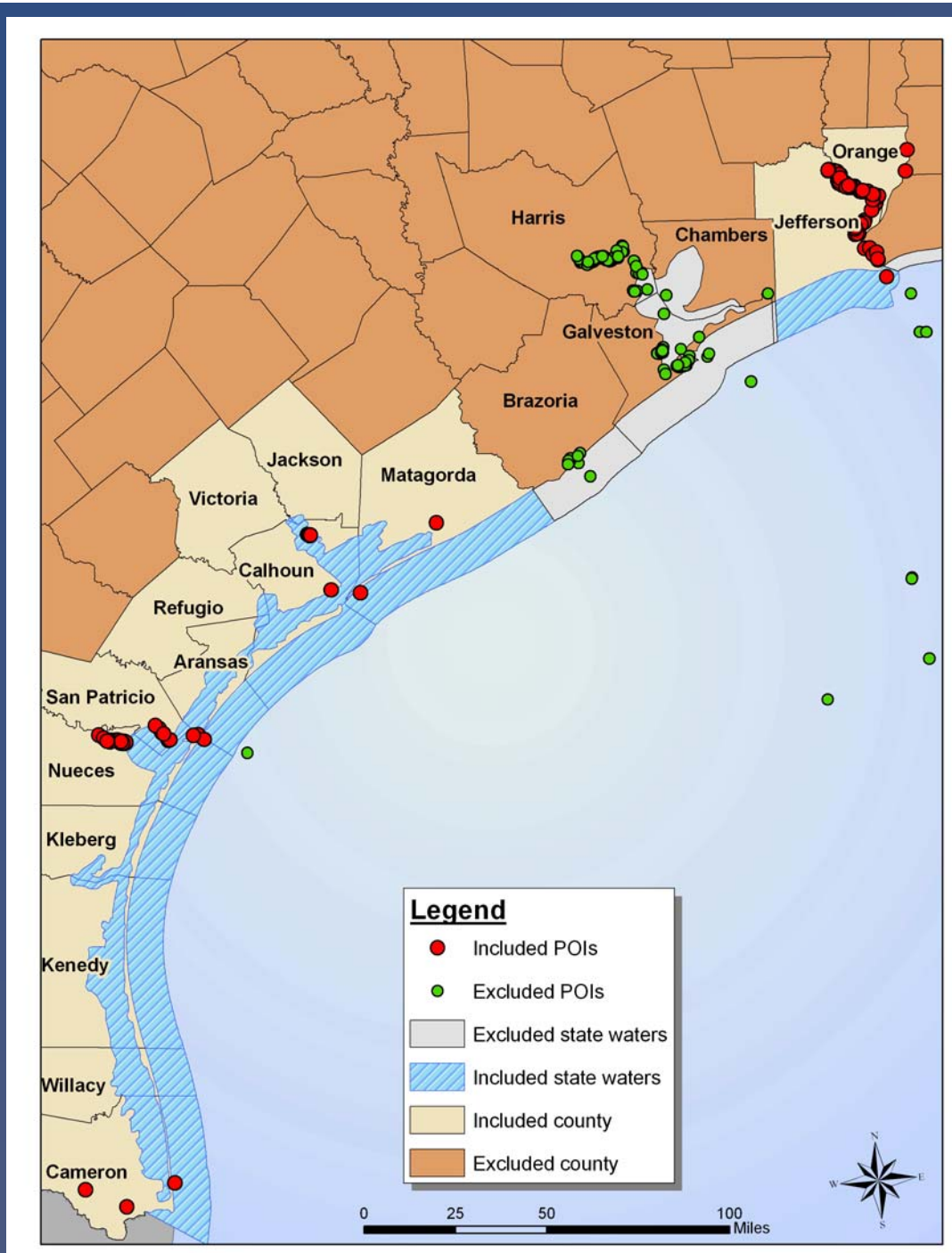
- International Maritime Organization's (IMO) ship identification number
- Vessel Name
- Ship Type/Cargo
- Ship Dimensions
- Destination
- Estimated time of arrival (ETA) at destination – UTC

AIS Data – Coverage

- Required by IMO in 2000 for the following:
  - All international vessels ≥ 300 gross tons
  - All passenger ships
- Required by U.S. Coast Guard in 2005 for all CMV transiting U.S. inland waterways and ports
- Over 40,000 ships worldwide

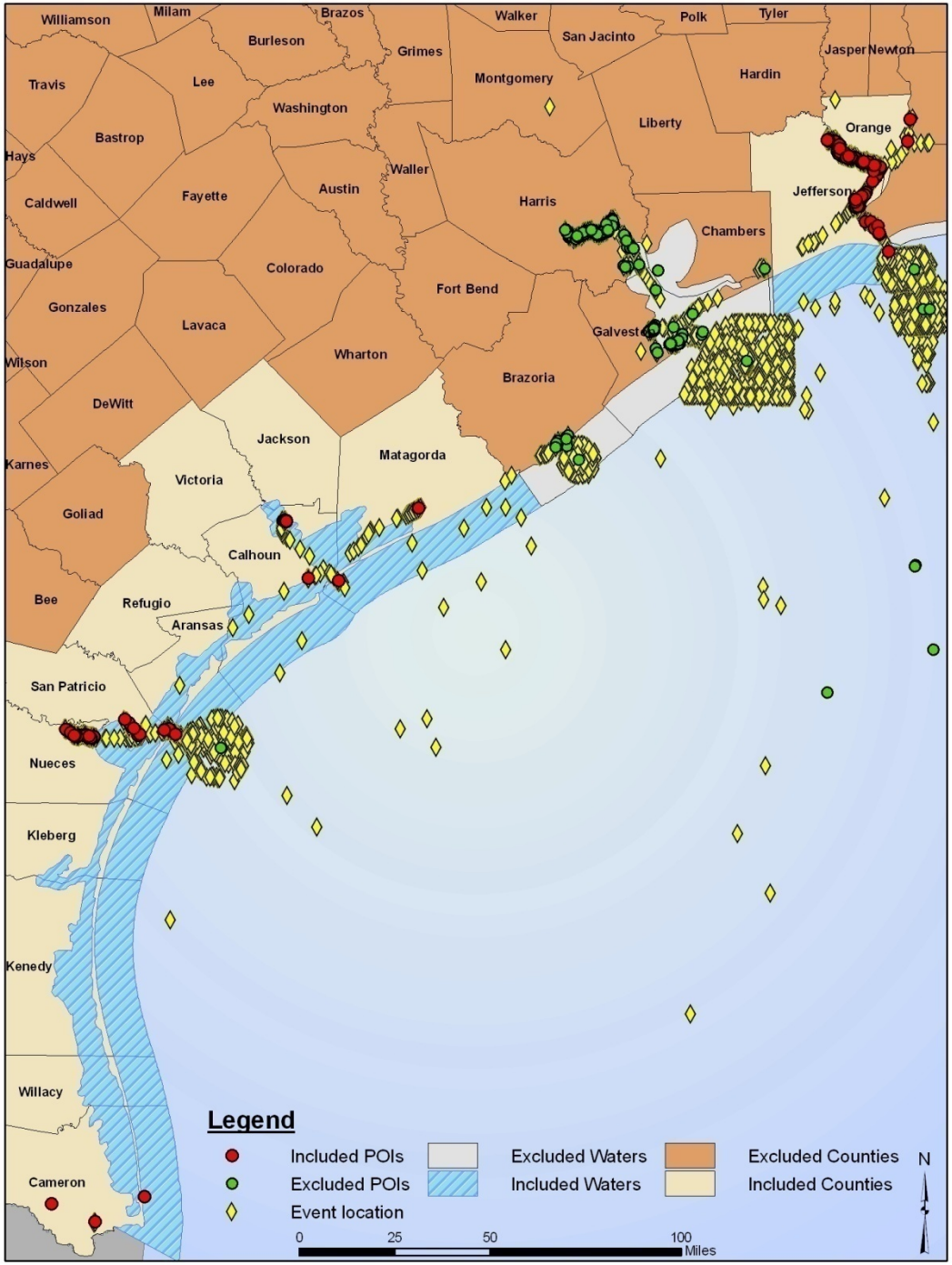
AIS Data Utilization

- AIS data obtained from AIRSIS, Inc.
- Area of Interest (AOI) included all of Texas state waters, including inland waterways and 9 nautical miles from coastline
- Houston-Galveston (HGA) nonattainment area excluded
- Over 132 points of interest (POI) with vessel monitoring stations

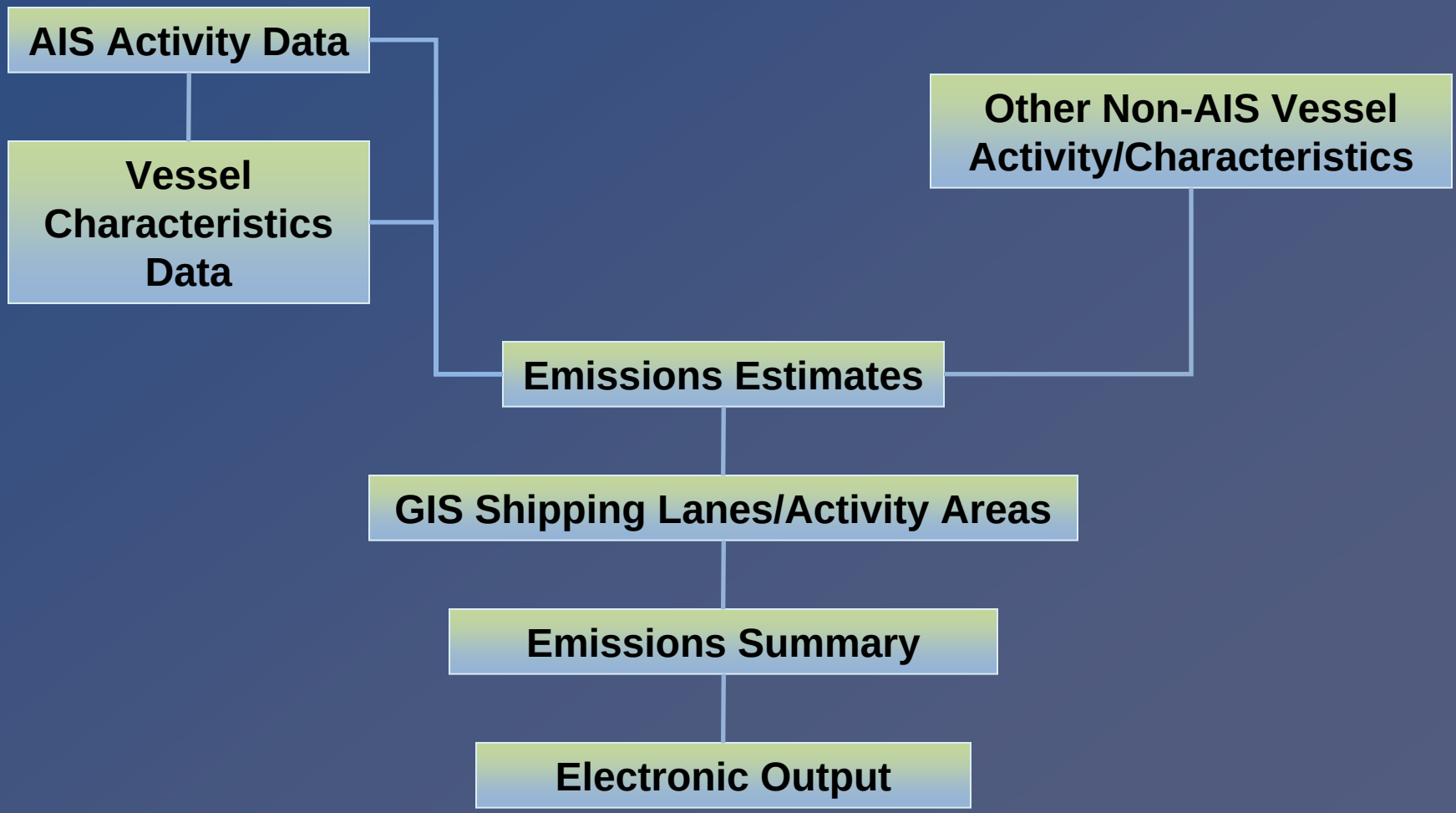

Orange
Harris
Jefferson
Chambers
Galveston
Brazoria
Jackson
Matagorda
Victoria
Calhoun
Refugio
Aransas
San Patricio
Nueces
Kleberg
Kenedy
Willacy
Cameron
Legend
Included POIs
Excluded POIs
Excluded state waters
Included state waters
Included county
Excluded county
0
25
50
100
Miles
N
W
E
S

AIS Data Set

- Base year 2007
- 2,912 matchable vessels
- Trips identified with a unique “Transit ID”
  - 82,355 transits
- Each transit had ≥ 1 “Event IDs” indicating an origin, waypoint, or destination
  - 545,141 events
- Origins/Destinations outside of the AOI were marked as “At Sea”

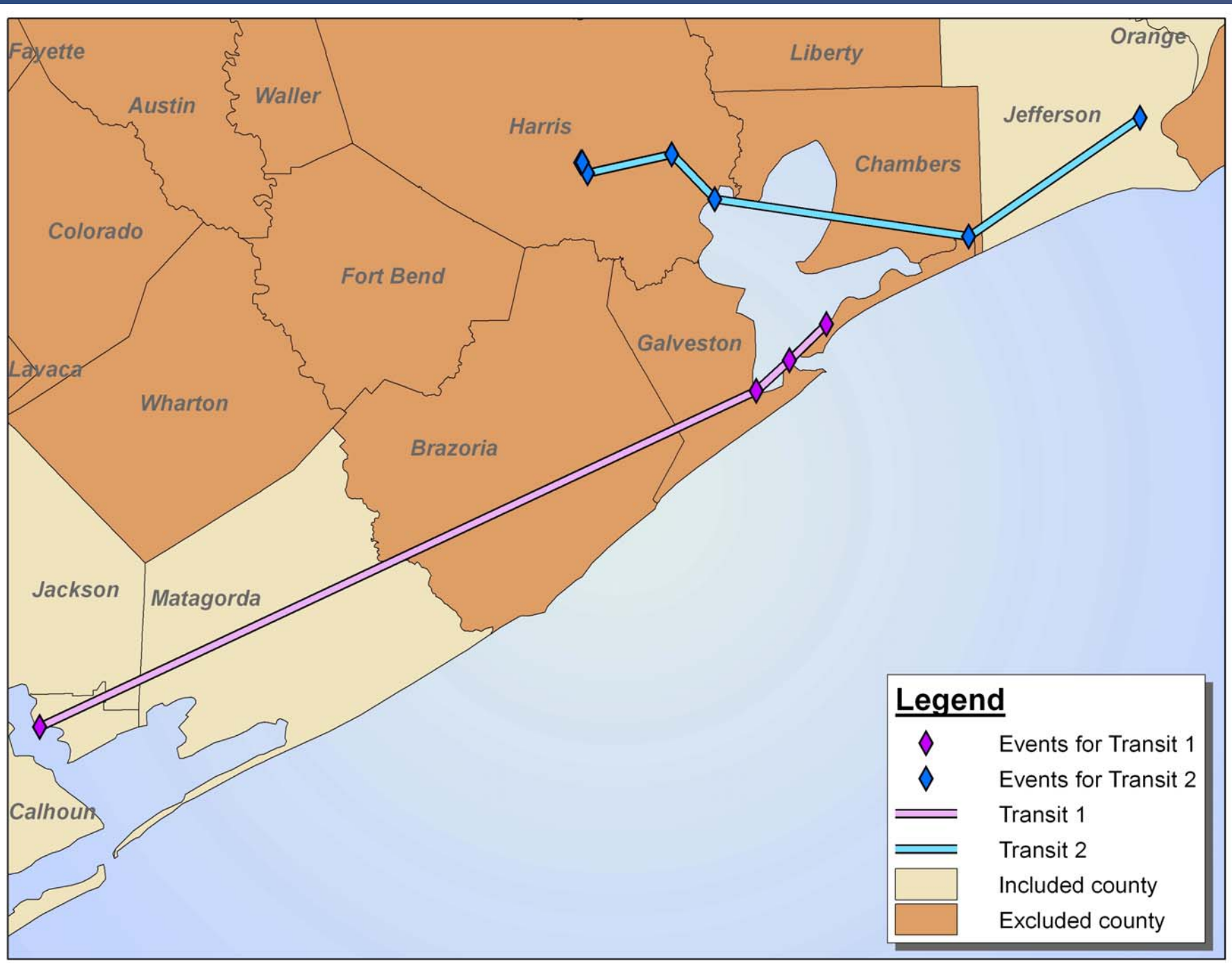

Williamson
Milam
Brazos
Walker
Polk
Tyler
Burleson
Grimes
San Jacinto
Jasper
Newton
Travis
Lee
Montgomery
Hardin
Washington
Liberty
Orange
Bastrop
Hays
Waller
Austin
Harris
Jefferson
Caldwell
Fayette
Chambers
Guadalupe
Colorado
Fort Bend
Gonzales
Lavaca
Galveston
Wharton
Brazoria
Wilson
DeWitt
Jackson
Matagorda
Karnes
Victoria
Goliad
Calhoun
Bee
Refugio
Aransas
San Patricio
Nueces
Kleberg
Kenedy
Willacy
Cameron
Legend
Included POIs
Excluded POIs
Event location
Excluded Waters
Included Waters
Excluded Counties
Included Counties
N
0
25
50
100
Miles

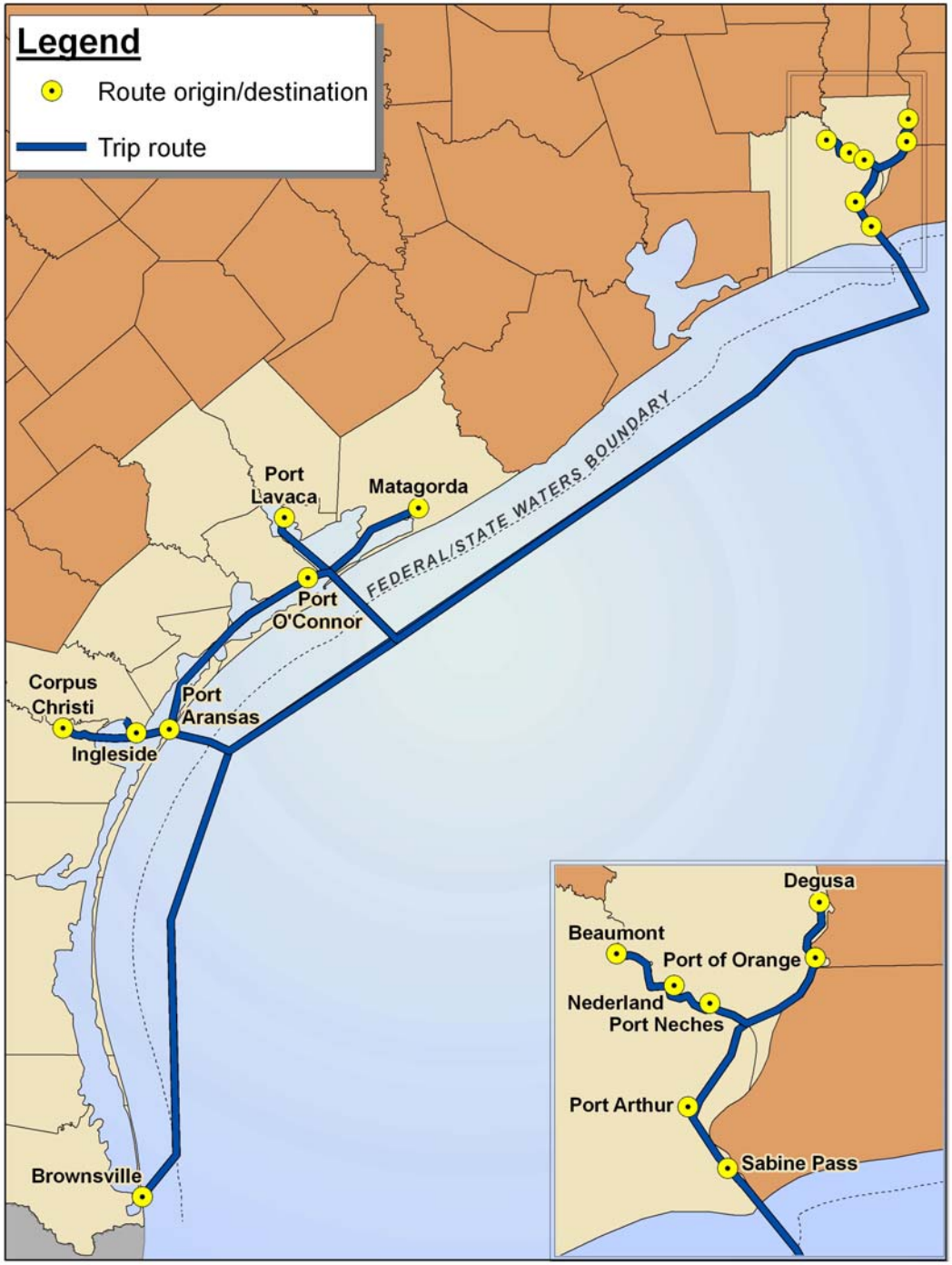
Methods – Overview



Methods - Summary

- Addressed erroneous AIS data using GIS
- Linked AIS data to Vessel Characteristics
- Gap-filled missing characteristics data
- Calculated horsepower-hours of operation
- Assigned emission factors from the Swedish EPA
- Estimated emissions


Fayette
Austin
Waller
Harris
Liberty
Orange
Jefferson
Chambers
Colorado
Fort Bend
Galveston
Lavaca
Wharton
Brazoria
Jackson
Matagorda
Calhoun
Legend
Events for Transit 1
Events for Transit 2
Transit 1
Transit 2
Included county
Excluded county


Legend
Route origin/destination
Trip route
FEDERAL/STATE WATERS BOUNDARY
Port Lavaca
Matagorda
Port O'Connor
Corpus Christi
Port Aransas
Ingleside
Brownsville
Degusa
Beaumont
Port of Orange
Nederland
Port Neches
Port Arthur
Sabine Pass

Methods – Linking AIS

- AIS data linked to vessel characteristic data sets
  - Lloyd's Register of Ships
  - American Bureau of Shipping
  - Bureau Veritas
- Linked by IMO, MMSI, vessel name, and vessel type
- Data gaps filled using averaged data by vessel type

Methods – Linking AIS

Description	Vessel Count	Percent
Total Vessels in AIS	3,398	100%
With IMO	2,657	78%
Matched using IMO	1,913	56%
Matched using MMSI or Name and Type	1,006	30%
Total Matched	**2,919**	**86%**

Methods – Hp-Hrs

- Hp-Hrs = HP * Number of engines * Hours of operation
- Inaccurate AIS time stamps
  - Hp-Hrs = HP * Number of engines * (Distance / Speed)
- 12% had the same origination and destination
  - Assist tugs, pilot boats, patrol boats: all time in state waters
  - Larger vessels ≤ 12 hours: intra-ports shift in state waters
  - Larger vessels > 12 hours: port to state/federal boundary and back

Methods – Calculating Emissions

- 2007 emissions for criteria and various HAPs
- $AE = AH \times CF_1 \times LF \times EF \times CF_2$

  where:

  AE = Annual Emissions

  AH = Annual Activity (hp-hr)

  CF_1 = Conversion factor (0.741 kW/Hp)

  LF = Load factor: 80% cruising/maneuvering
  10% (hoteling)

  EF = Swedish emission factor (g/kw-Hr)

  CF_2 = Conversion factor (1.10231 E-6 ton/g)

Results – All Vessels

Pollutant	Annual (tons)	OSD (tons)
Carbon Monoxide	13,391.10	36.69
Volatile Organic Compounds	3,114.15	8.53
Nitrogen Oxides	162,621.94	445.54
Sulfur Oxides	92,425.76	253.22
Primary PM_{10} (Includes Filterables + Condensables)	7,874.50	21.57
Primary $PM_{2.5}$ (Includes Filterables + Condensables)	7,874.50	21.57

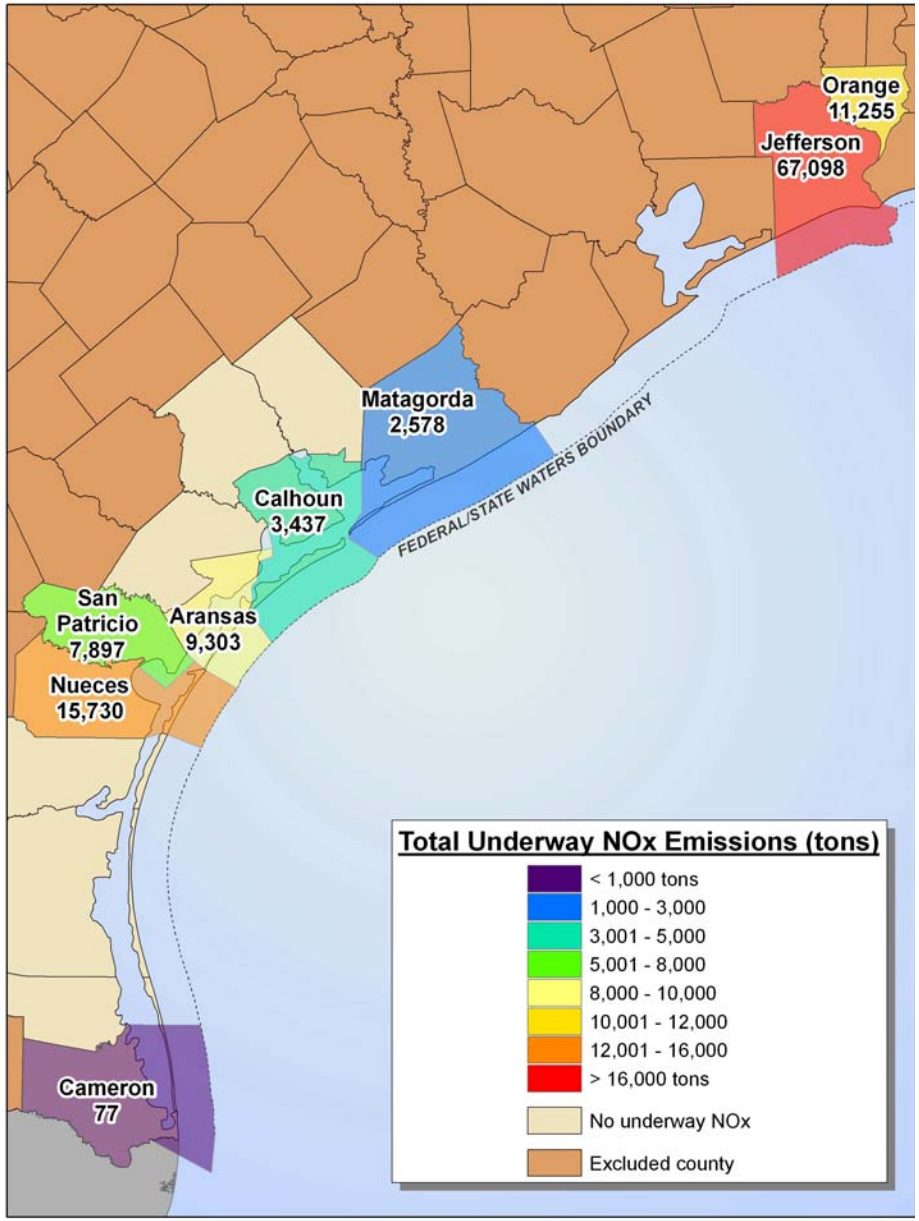
Results – Tugs Comparison

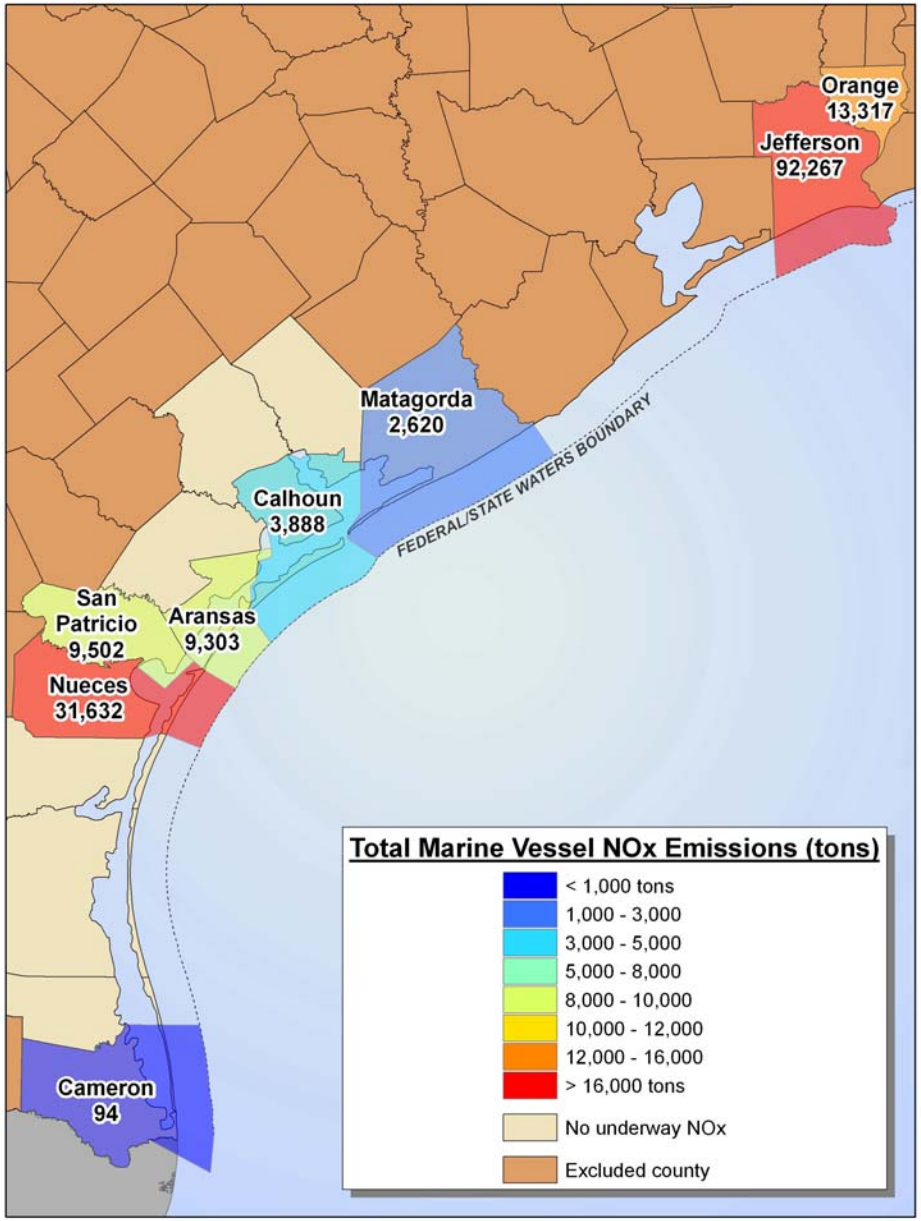
Data and Comparison from Independent Reviewer

Area	U.S. ACE WCUS 2006 Vessel Movements	AIS Vessel Movement 2007*	Result
Sabine-Neches	~ 33,000	~ 33,000	AIS similar to WCUS
Corpus Christi	~ 6,000	12,809	AIS overreports
Brownsville	~ 1,100	(No POIs)	AIS underreports
Victoria	~ 2,400	1,677	AIS underreports **

* Includes Blank/Unknown assumed to be tugs

** Lower AIS movement may be indicative of decline of economic activity (Alcoa and Dow facilities closures)


Orange
11,255
Jefferson
67,098
Matagorda
2,578
FEDERAL/STATE WATERS BOUNDARY
Calhoun
3,437
San
Patricio
7,897
Aransas
9,303
Nueces
15,730
Cameron
77
Total Underway NOx Emissions (tons)
< 1,000 tons
1,000 - 3,000
3,001 - 5,000
5,001 - 8,000
8,000 - 10,000
10,001 - 12,000
12,001 - 16,000
> 16,000 tons
No underway NOx
Excluded county


Orange
13,317
Jefferson
92,267
Matagorda
2,620
FEDERAL/STATE WATERS BOUNDARY
Calhoun
3,888
San
Patricio
9,502
Aransas
9,303
Nueces
31,632
Cameron
94
Total Marine Vessel NOx Emissions (tons)
< 1,000 tons
1,000 - 3,000
3,000 - 5,000
5,000 - 8,000
8,000 - 10,000
10,000 - 12,000
12,000 - 16,000
> 16,000 tons
No underway NOx
Excluded county

Limitations

- Placement of POIs
- Vessels ≥ 300 Gross Tons
- Data Gaps
  - Missing records. Vessels leaving a port, not going past POIs, and appearing in another port
  - Vessels that seem to travel over land.
  - Poor vessel type data (probably includes tugs)

Discussion

- Automatic and electronic nature of AIS improves reporting consistency and minimizes data entry errors.
- Accurate to Tug Comparison with WCUS in biggest port area.
- More POIs will possibly improve AIS data
- Use of other datasets (e.g., U.S. ACE) to refine AIS data

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  - Brian Crawford
  - Kevin Crawford