AIS Analysis of Vessel Traffic at Coastal Structures

Coastal Navigation Portfolio Management

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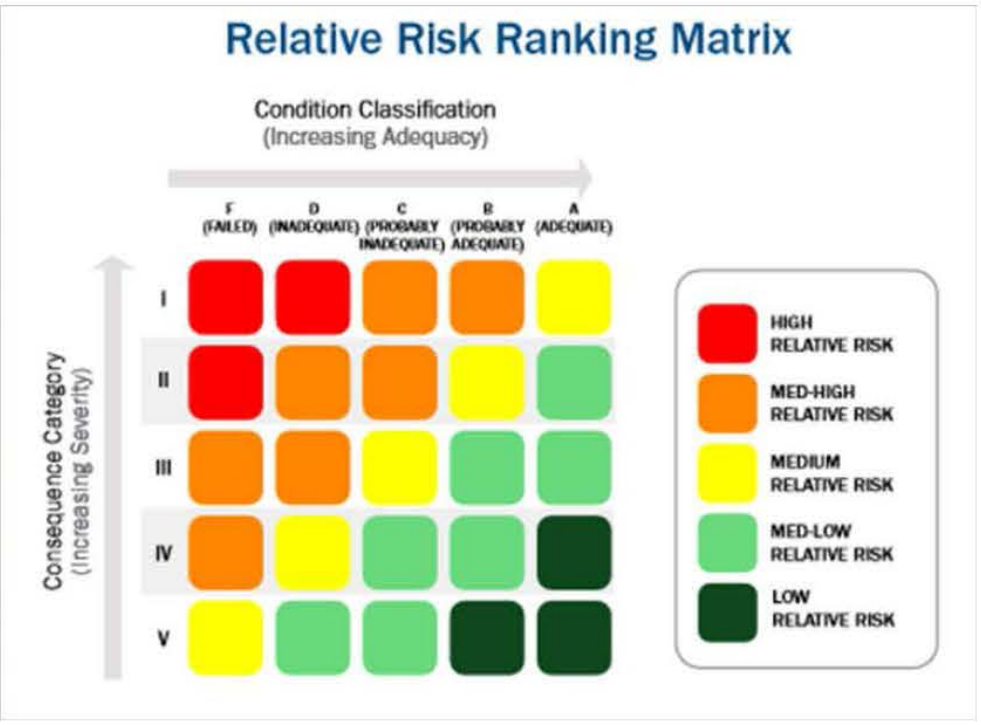
Coastal Navigation Portfolio Management

Advance objective, quantitative, and systems-based approaches to management of the Corps' large coastal navigation portfolio of projects.

- **Statements of Need:**
  - **2017-N-52 Further Development of CPT and AIS software products**
  - **2016-N-14 Long-term modeling of coastal structure functionality**
  - **2015-N-15 - Integration of national and local monitoring datasets to support navigation and operations projects**
  - **2015-N-34 - Incorporating methods to evaluate length of navigation channel required for safe and efficient travel of two way traffic in ship simulations**
  - **2015-N-38 - AIS investigation of Dredge Behavior**
  - **2015-N-40 - Reducing the need for dredging**

Research Goals

- Augment subjective, qualitative navigation structure performance metric (OCA), and proxy project maintenance prioritization metrics (tonnage, value).
- Cast structure performance in terms of vessel activity for navigation structures.
- Formulate management metrics at “portfolio scale”.



Why this matters…

USACE has awarded contracts valued at ~$47M per year since 2007 on Jetty maintenance, repair, and construction.

The average maintained HMTF project (~521) costs $~1.9M annually.

There are ~541 HMTF projects that are not maintained.

10-year coastal structure expenditure ≈ 24 HMTF projects.

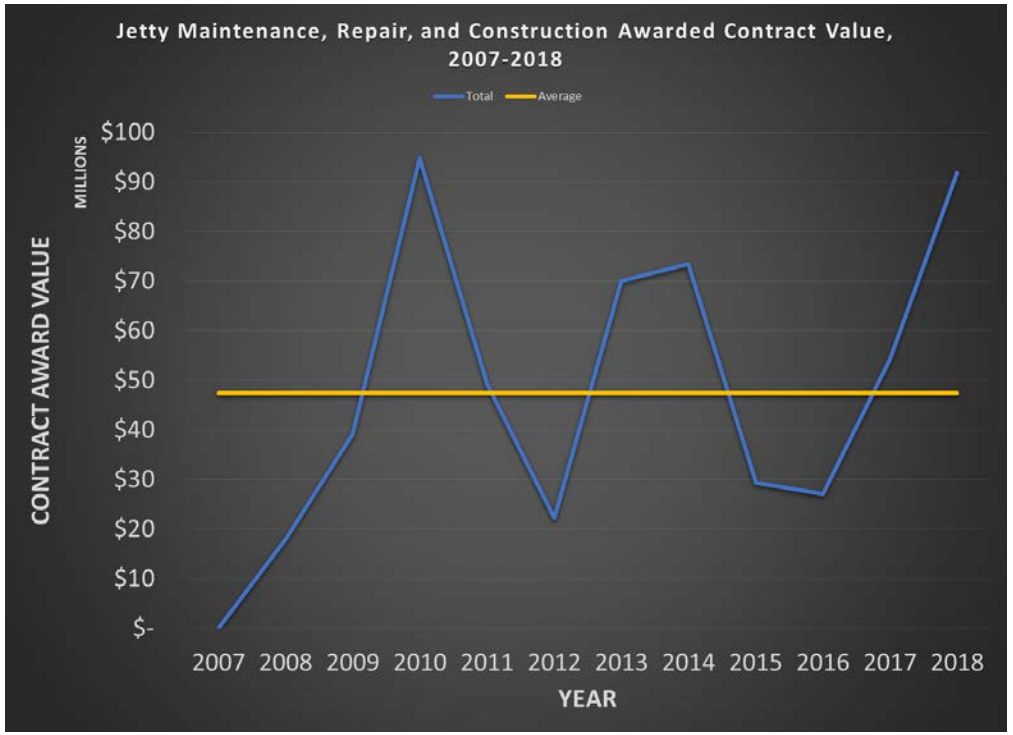
MCR Repair costs ($257M):

- **North Jetty: $79,797,000**
- **South Jetty: $146,884,000**
- **Jetty A: $30,520,000**

Project BCR: 1.1

http://cdm16021.contentdm.oclc.org/utils/getfile/collection/p16021coll7/id/3/filename/4.pdf

MCR Repair Costs ≈ 25% annual USACE dredging budget.



Structure Functional Assessment

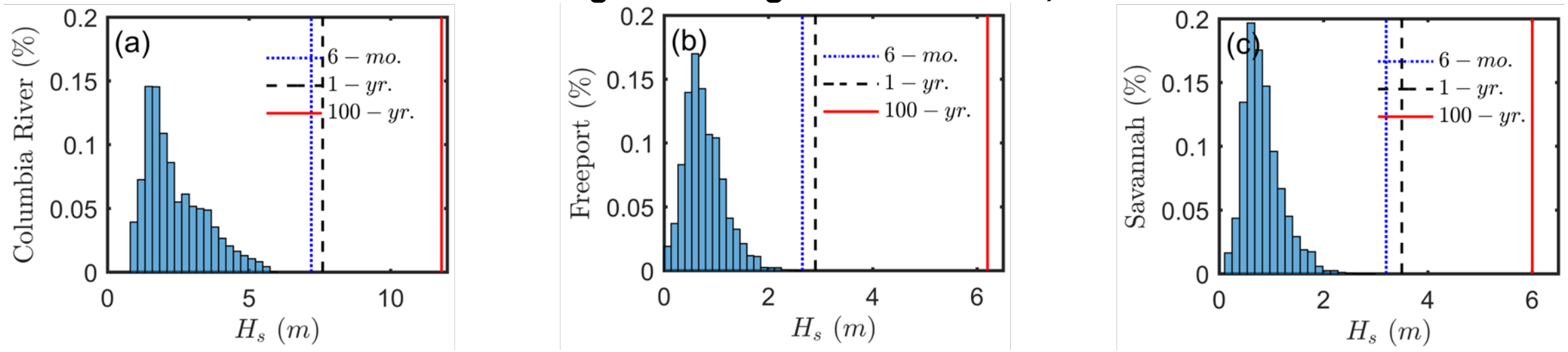
- Structure function is tied to vessel navigability, O&M dredging increases.
- Currently no direct way to measure vessel navigability.
- O&M dredging increases relates to bathymetric elevation, not the ability of vessels to transit.
- Other research has shown that vessels:
  - Frequently call at drafts below design vessel draft
  - Frequently call at water levels above design water level.
- Currently no practice for quantifying the vessel operating functions described in FCR

Level of Functionality	TABLE F-10 Coastal Navigation Structures Functional Condition Rating (FCR) Table
Full -- A	No notable impact, project performing as designed.
Sufficient – B	(1) Infrequent or periodic limitations on navigability, or (2) minor/periodic increases in dredge quantity
Reduced -- C	(1) Less than 10% of the time, design vessels cannot navigate or operate within authorized limits; (2) O&M dredging requirements in the Entrance and Bar Channel have increased less than 10%, as compared to the long-term average annual rate.
Severely Degraded -- D	(1) 10-20% of the time, design vessels cannot navigate or operate within authorized limits; (2) O&M dredging requirements in the Entrance and Bar Channel have increased 10-20%, as compared to the long-term average annual rate.
Completely Degraded -- F	(1)-20-40% of the time, design vessels cannot navigate or operate within authorized limits; (2) O&M dredging requirements in the Entrance and Bar Channel have 20-40%, as compared to the long-term average annual rate.

Previous Effort

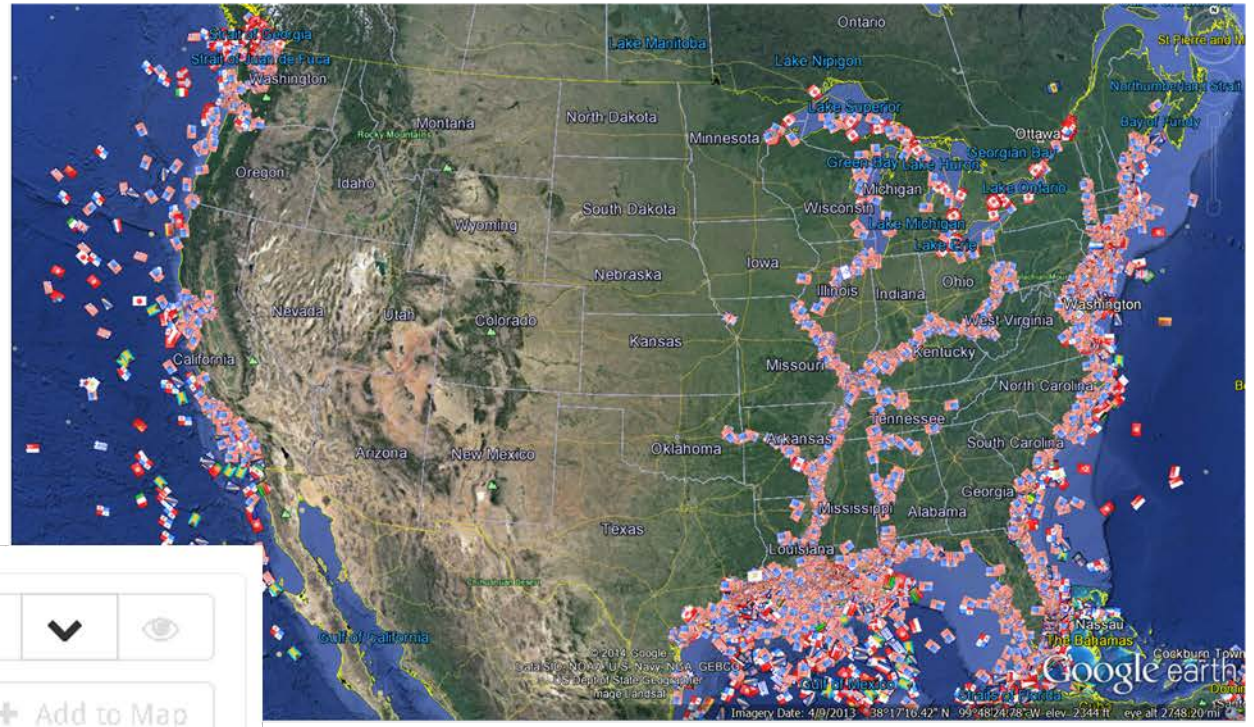
- **Quantifying sheltering effects on vessels using AIS data, 2012-2014:**
  - **Mouth of Columbia River, OR; Savannah, GA; Freeport, TX**
  - **~10,000 historical vessel transit observations**
  - **Findings indicate:**
    - **Vessels within/behind the structure had significantly less heading-course deviation than outside in high and low wave environments, i.e. improved attitude when sheltered by jetties.**
    - **Vessel maximum wave height operating condition was below the 6-month return period wave height, i.e. structures provide no direct benefit to vessels during more energetic conditions.**

Wave heights during vessel transits, 2012-2014



Marine Cadastre

- **Nationwide AIS 1-minute sampling**
- **Available 2009-2017**
- **Marinecadastre.gov**



2009 - 2017 National AIS at 1 Minute Intervals

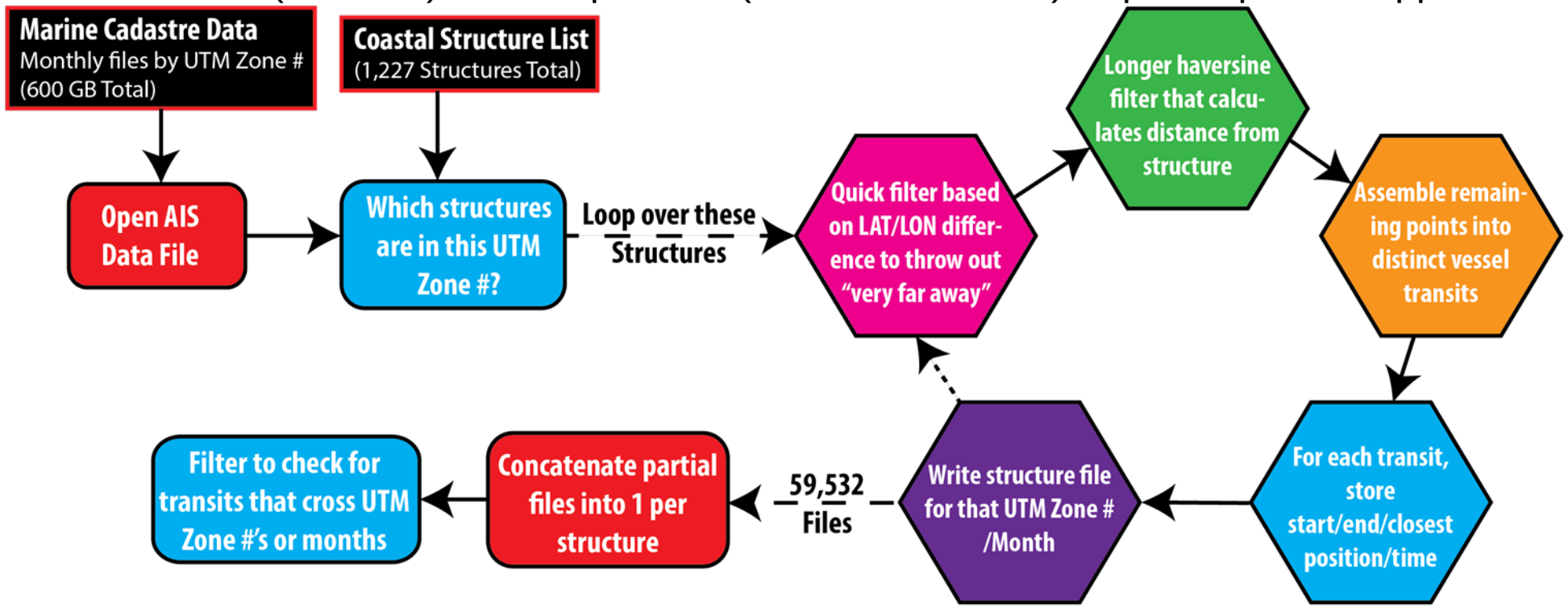
MarineCadastre.gov

Add to Map

Automatic Identification System (AIS) data are information collected by the U.S. Coast Guard to monitor real-time vessel information to improve navigation safety. Data such as ship name, purpose, course, and speed are acquired 24 hours per day primarily in coastal U.S. waters. However, the data sets featured on this website are the 2009 to 2017 archived AIS data sets intended to be used by the ocean planning community to better understand vessel traffic patterns. These data are provided for analysis in desktop GIS software. For more information, visit the Nationwide Automatic Identification System website.

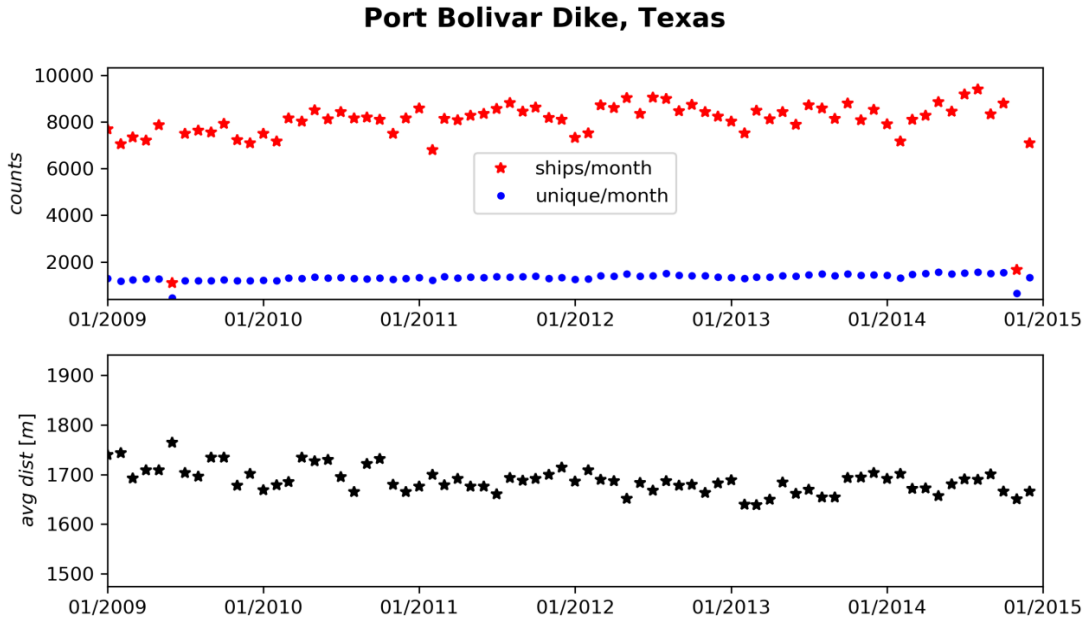
Distributed AIS-derived Inlet Structure Metrics

- Metrics are easy:
  - Vessel count
  - Vessel closest point of approach
- Historical vessel data (~600GB) and the portfolio (~1,200 structures) require a parallel approach



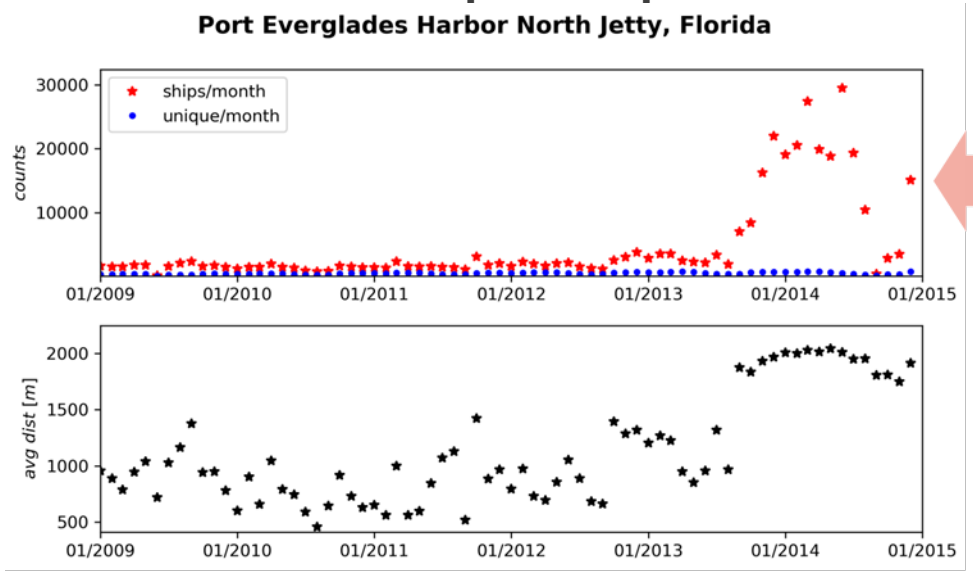
Preliminary Results

- Max Counts: 571,985 - Port Bolivar Dike, Texas
- Max Unique Counts: 14,878 – Port Bolivar Dike, Texas
- Min Counts: 1 – Stone Lagoon, California; Goshen Creek North Jetty, New Jersey; Goshen Creek South Jetty, New Jersey; Oconto Harbor North Pier, Wisconsin; Oconto Harbor South Pier, Wisconsin; Fripp Inlet, South Carolina; North Inlet, South Carolina; North Santee River, South Carolina; South Santee River, South Carolina; Trenchards Inlet, South Carolina; McQueen Inlet, Georgia
- Median Counts: 2,951.5
- Median Unique Counts: 223
- Average Counts: 20,145.9
- Average Unique Counts: 777.6



How do we find interesting structures?

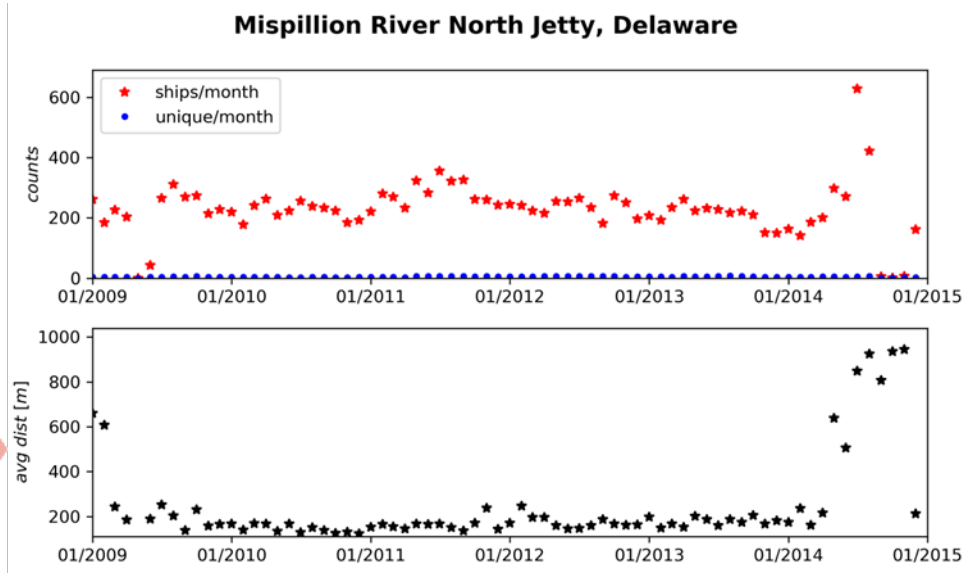
- **Information Entropy**
  - Entropy = $\sum [P(k) * ln(P(k))]$
  - Indicator of how “clustered” monthly transits are throughout the year.
  - Uniformly distributed – maximum entropy, i.e. “boring”
  - Fully clustered – minimum entropy, e.g. “interesting” (?)
- **Average trip per user = Total/Unique**
  - Indicates frequent trips relative to the user base



Entropy = 1.328

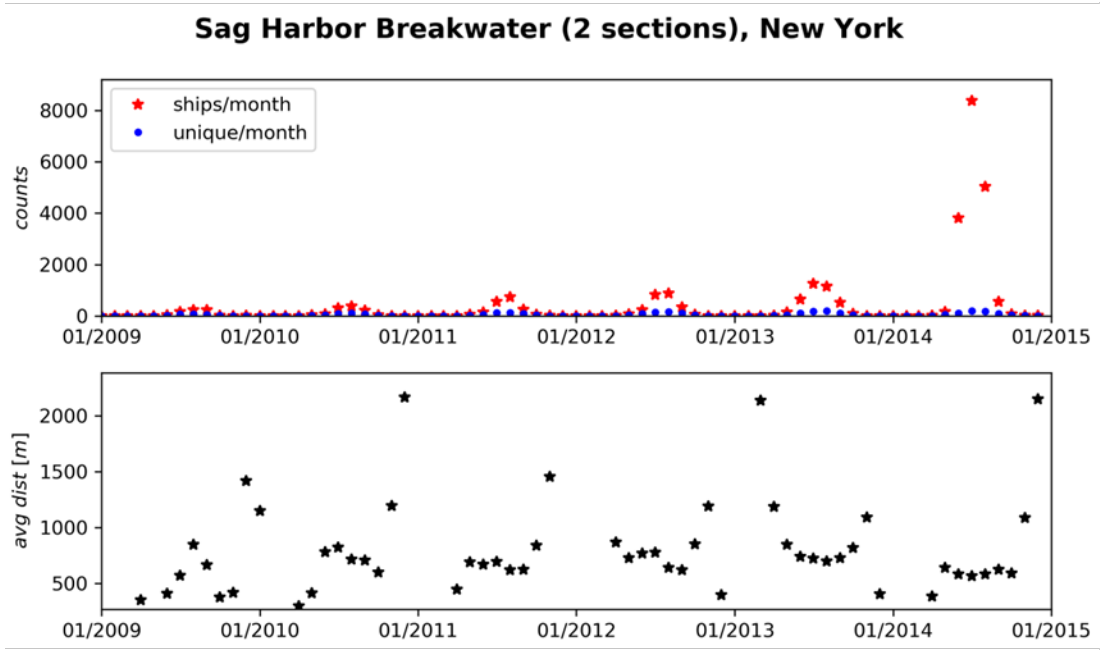
Total/Unique = 47.5

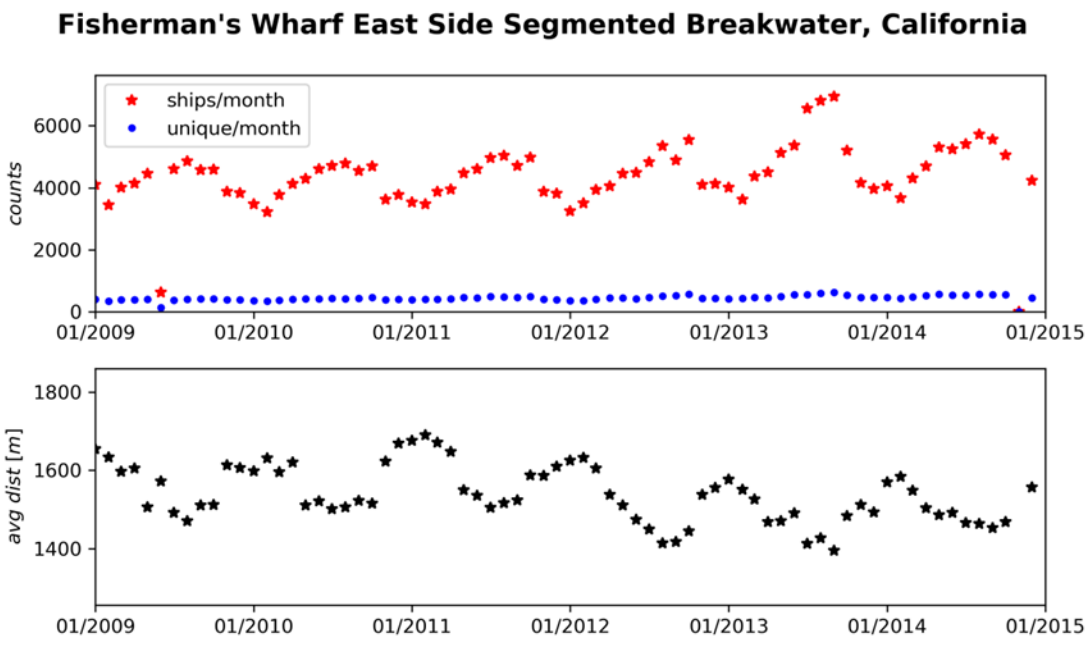
Total/Unique = 16366/28 = 584.5



Seasonality

- It’s possible that peak structure loading occurs outside of peak user activity.

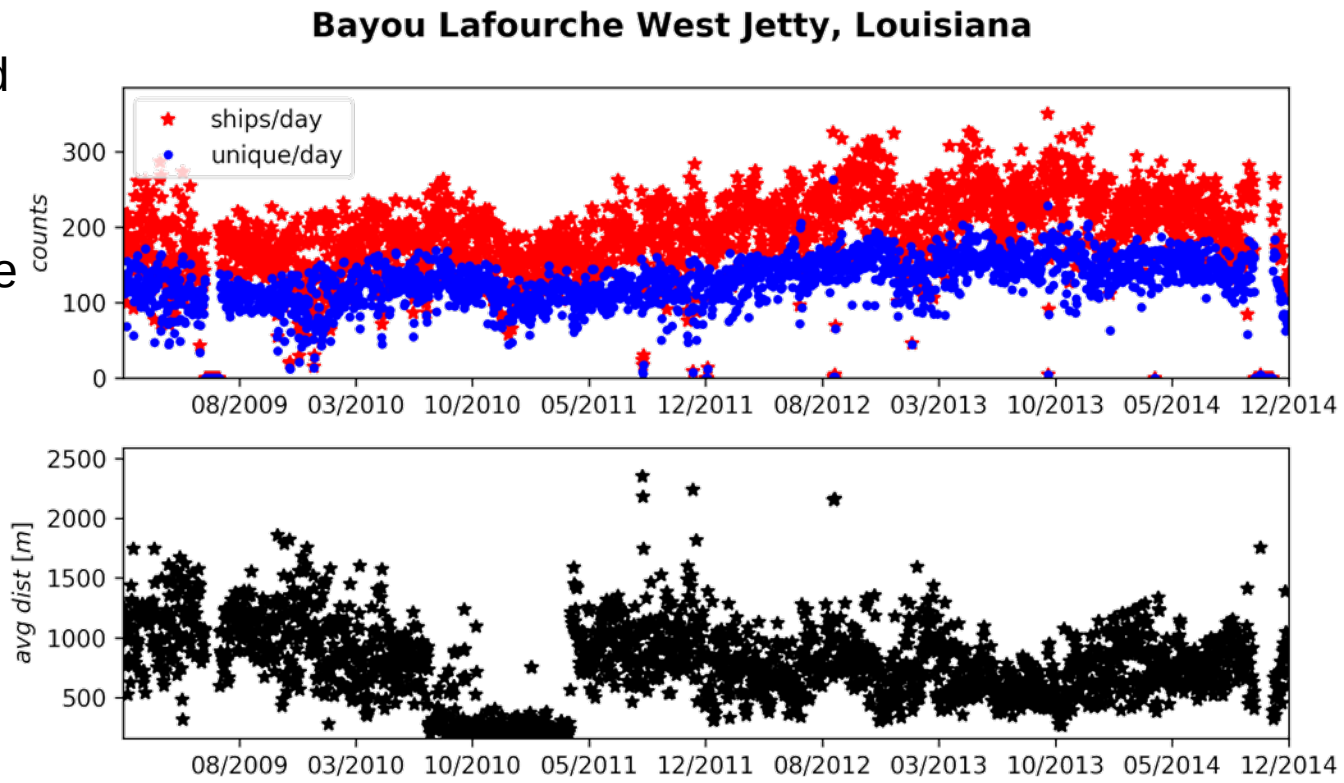




Informing Operations

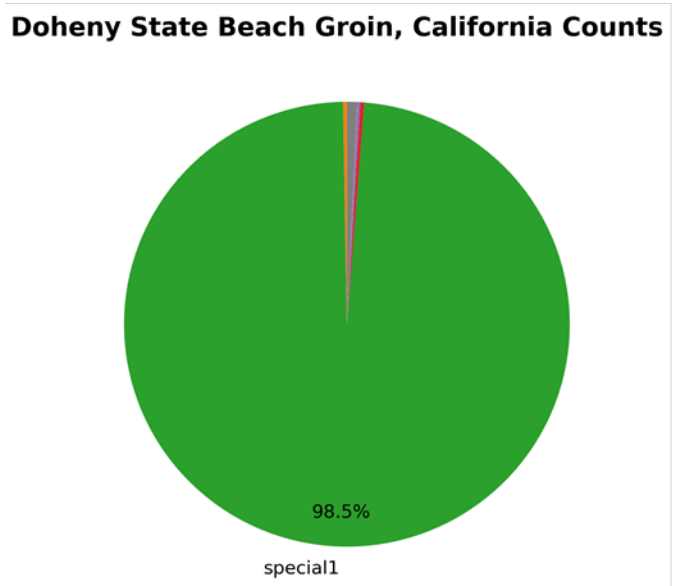
- Bayou Lafourche shows an interesting period where vessel closest point of approach reduced to ~25% of the average for ~8 months. Why?

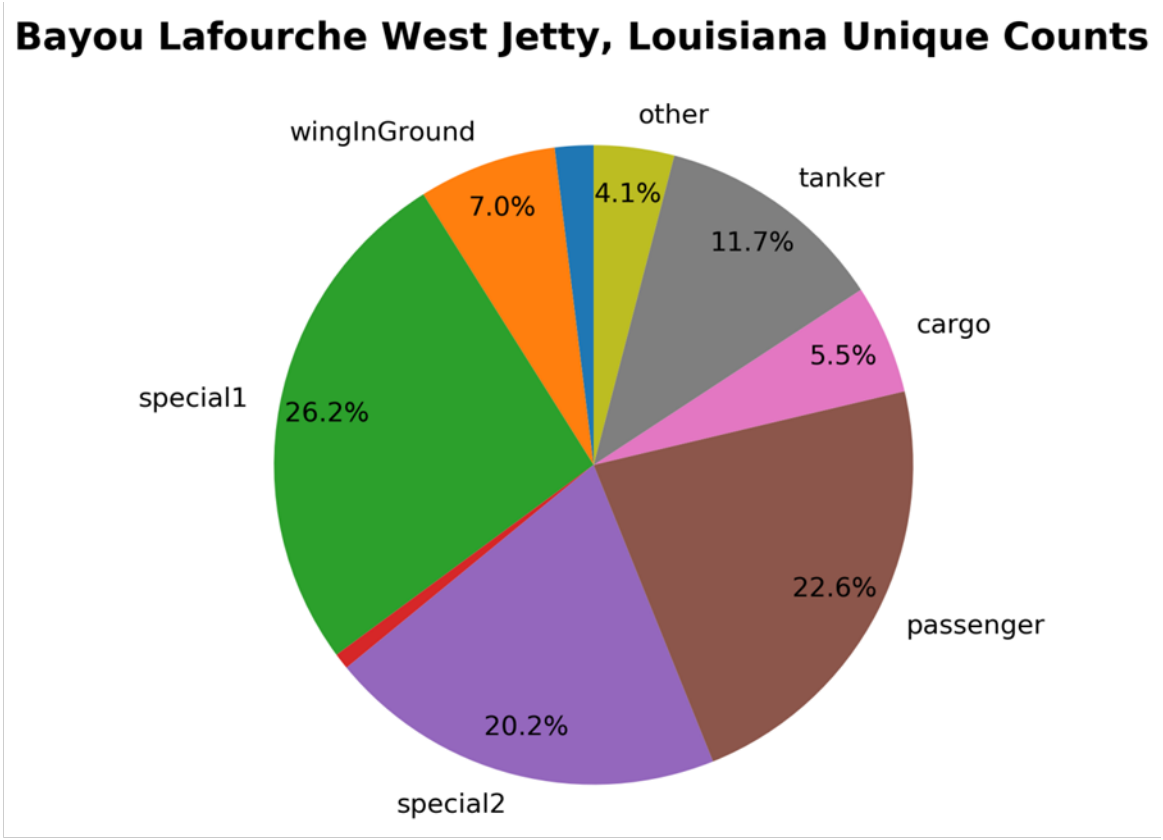
- This information is available at scale and can be tied back to any spatio-temporal dataset of interest, creating opportunities to answer specific District questions.



Vessel Type Distributions

- Provides insight into vessel use types.
- Can be used to cluster structures into groups
- Clustering can subsequently be used to inform some overarching goal, e.g. prioritize energy ports highly





Mouth of the Columbia River, Jetty “A”

Rank (tonnage)	USACE Deep Draft and Shallow Draft Navigation Projects	5-Year Avg. 2001-2005	5-Year Avg. 2001-2005	5-Year Avg. 2001-2006	
	Project - Civil Works Identification System Number	Expenditures	Tonnage	$/Ton	% of Total Expenditures
22	COLUMBIA RIVER AT MOUTH, OR AND WA-003600	$ 9,792,281	37,564,544	0.26068	1.524%

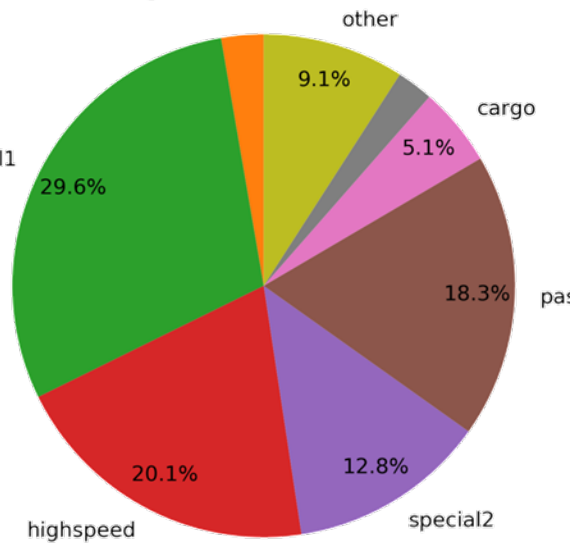
Rank: 99th out of 1080

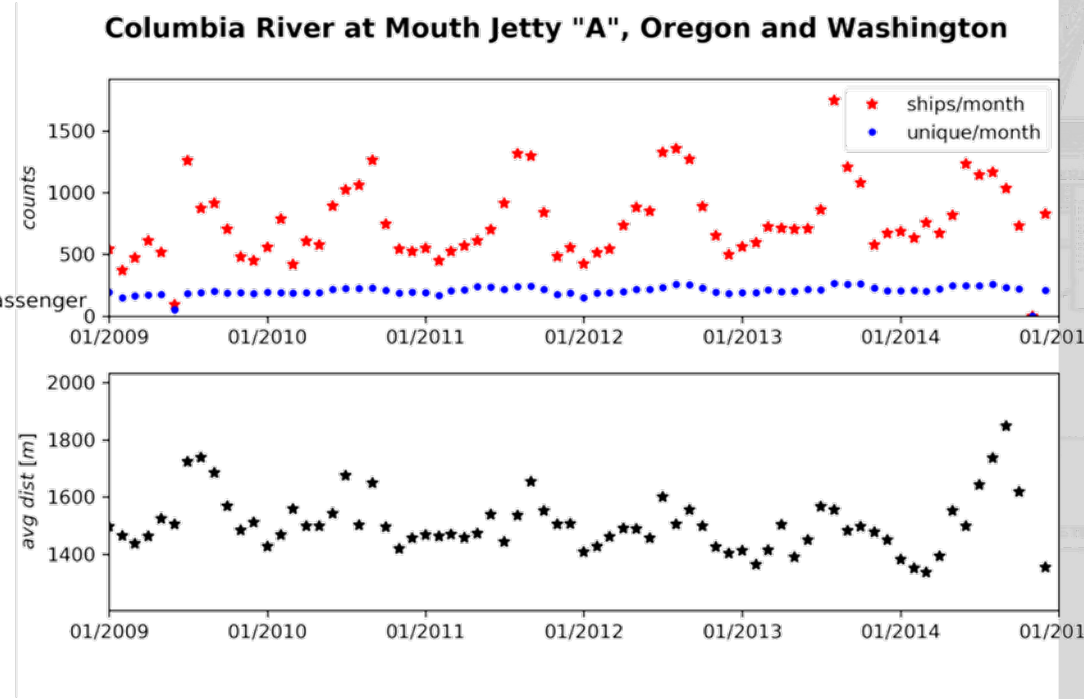
Counts: 54,849

Unique Counts: 4,760

Median Counts in 1 Month – 703.5

Median Unique in 1 Month – 204.5





Benefits

- **Working at scale strategically positions CNPM to explore other AIS-derived portfolio-wide metrics**
  - **4-D around-ship clearance – FY 19 goal**
  - **Vessel-based infrastructure classification**
  - **Large scale quantification of navigation risk**
- **A variety of alternative datasets can be swapped in for structure dataset**
  - **Ports**
  - **Habitat**
  - **Population centers**
- **Nationwide answers – navigation projects don't exist in a vacuum.**

Conclusions

- AIS-derived vessel count, CPA quantitatively relate portfolio assets (structures) to use (vessels)
- AIS-derived metrics facilitate rational allocation of scarce operating funds
- Parallel computing approach facilitates “portfolio scale” analysis
- Development of parallel computing capability in this space strategically positions CIRP within the vessel computational analysis space.