Assessing the Risks of Collision and Grounding in US Coastal Ports using Automatic Information System (AIS) Data

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Nationwide Automatic Information System (NAIS)

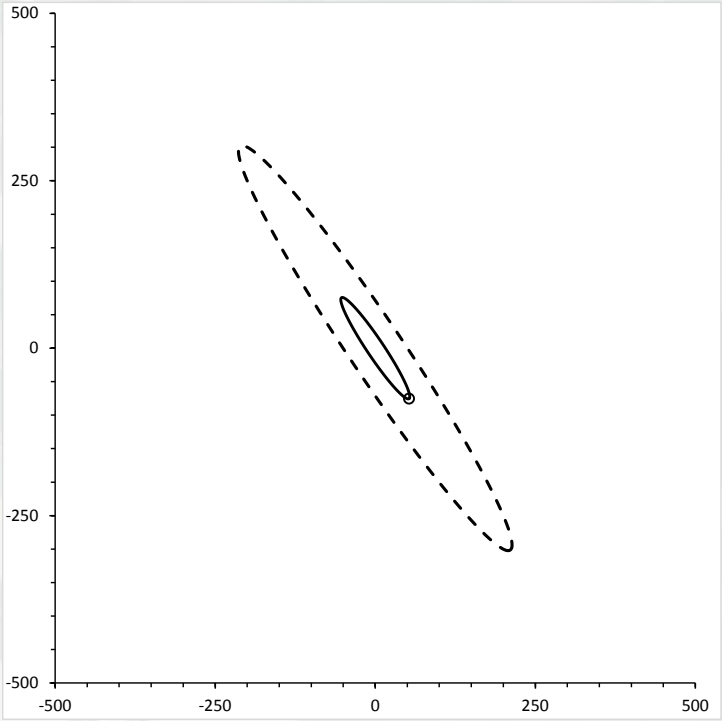
- **Established**: Marine Security Act of 2002.
- **Purpose**: Enhance national security & maritime safety by increasing maritime domain awareness.
- **Plant**: Shore-based VHF receivers intercept AIS signals transmitted by vessels for the purpose of active collision avoidance.
- **Provides**: Real-time information on vessel identity and movements. Data are archived by the US Coast Guard for at least three years.
- **Coverage**: 58 major ports and11 coastal areas out to 50 nm.

Project Objectives

- Investigate use of NAIS to:
  - Assess collision and grounding risk.
  - Inform design and maintenance of navigation channels.
- NAIS can improve the quality of coastal risk assessments.
  - Less uncertainty in characterizing fleet and movements.
  - Archival AIS data can be requested from the US Coast Guard.
  - Data are collected via an existing business process.
  - Data collection is standardized across ports.

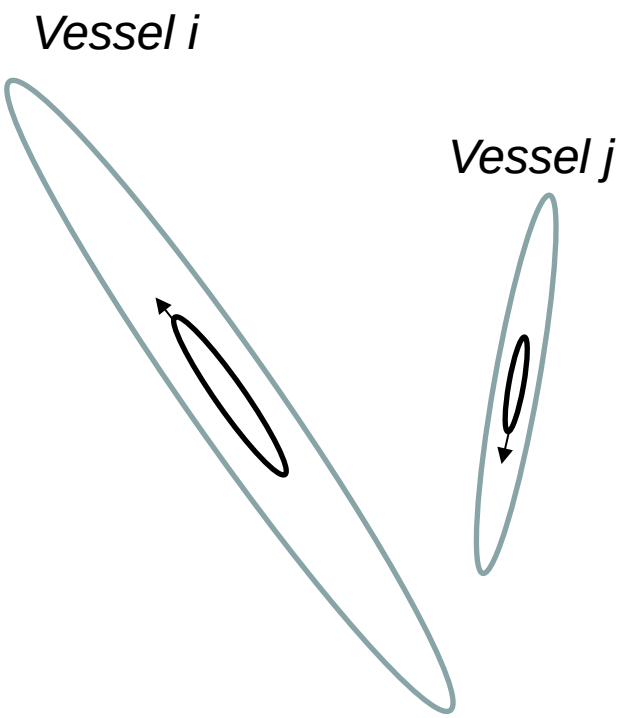
Collision risks can be assessed using the concept of a ship domain.

- **Ship domain**: Area that should remain clear of other vessels.
- Domain is an ellipse aligned with vessel's course:
  - Major axis = 4 * Vessel length
  - Minor axis = 3 * Vessel beam
  - Ellipse center is ship center
- Larger vessels, larger domains.



- Smaller than those used in some other studies to reflect close operation in federal navigation channels.

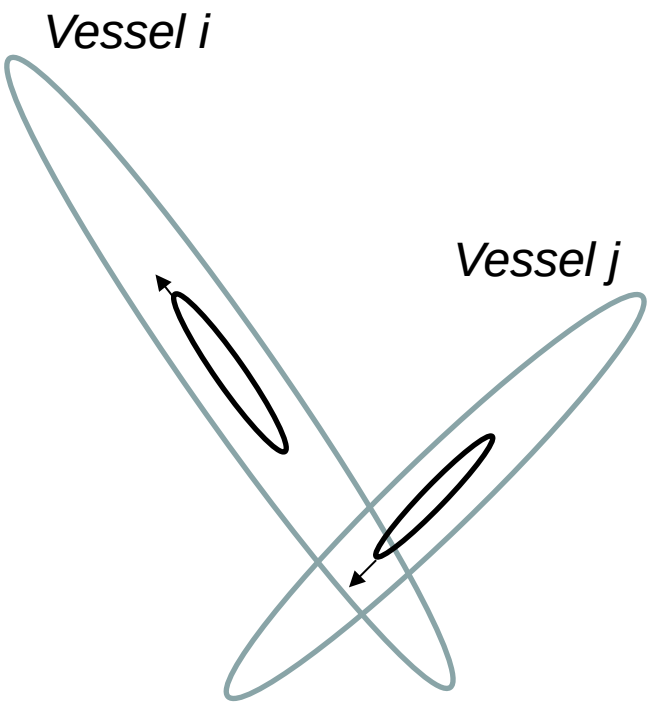
A ship domain violation (SDV) occurs when vessels get too close together.



1 *No violation of ship domains*

- d_{ij} = Distance between vessels i and j.
- e_i = Distance to boundary of ship domain on angle between i and j.
- SDV Criterion: $d_{ij} < e_i$
- Perimeter of vessel j must be inside the domain of vessel i.
- Overlapping ship domains is not a violation.

An SDV occurs when the perimeter of vessel j is inside vessel i's ship domain.



2 *Ship domain violation exists*

- Vessel j is crossing behind. An SDV exists because $d_{ij} < e_i$.
- Encroachment of vessel i's domain is a single SDV.
- Whether or not vessel j's ship domain has also been violated is determined separately.
- A single encounter may result in two SDVs.
- No determination of cause or fault.

Ship domain analysis is limited by vessel type and to federal channels.

- Ship domain analysis excludes harbor work boats.
  - ► Tugs, pilot vessels, port tenders and others using codes 31, 32, & 50 – 59.
  - ► Vessels routinely operate in close proximity to others.
  - ► Disadvantage: excludes towboats.
- Ship domain analysis based on AIS reports from federal channel.

During 2014, there were 1064 incidents of SDVs in Charleston Harbor?

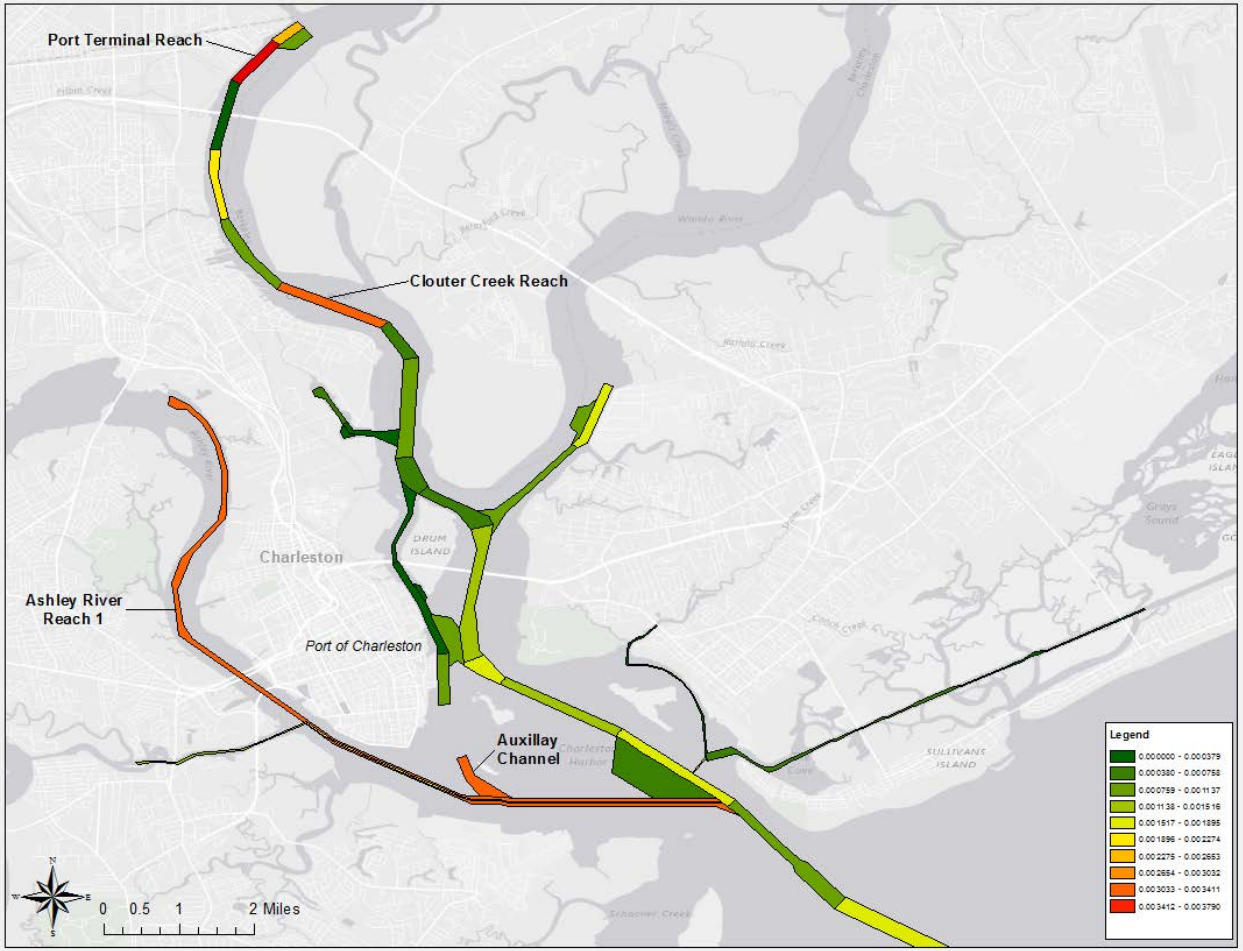
Encroached vessel category	Encroaching vessel category													Total
	Unk (0)	WIG (2)	Fishing (30)	Dredg-ing (33)	Military (35)	Sailing (36)	Plea-sure (37)	High speed (4)	Harbor work boats (5)	Pass-enger (6)	Cargo (7)	Tanker (8)	Other (9)	
Unknown (0)	3	-	-	-	-	-	1	-	-	1	3	-	3	11
WIG (2)	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Dredging (33)	-	-	-	114	-	1	1	-	-	6	12	-	5	139
Military (35)	3	-	-	1	-	1	1	-	-	2	3	-	1	12
Sailing (36)	-	-	-	-	-	5	1	-	-	-	-	-	-	6
Pleasure (37)	1	-	-	-	-	3	22	-	-	1	-	-	-	27
High speed (4)	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Harbor work boats (5)	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Passenger (6)	5	-	-	2	2	5	5	-	-	5	5	-	1	30
Cargo (7)	42	-	3	147	11	48	54	-	-	78	333	28	49	793
Tanker (8)	5	-	-	7	2	3	1	-	-	3	8	6	3	38
Other (9)	3	-	-	1	-	-	-	-	-	1	3	-	-	8
Total	62	0	3	272	15	66	86	0	0	97	367	34	62	1064

SDV frequency is calculated by sampling and classifying AIS position reports.

- AIS reports are sampled at 30-second intervals.
- Each report is classified as an SDV or non-SDV.
- SDV frequency is the ratio of position reports classified as SDVs to the total number of position reports.

AIS reports classified as SDVs	AIS position reports	Frequency
2,119	1,589,587	0.00133

The SDV frequency is the probability of an SDV given a vessel is present.



Charleston reaches with highest SDV frequency:

1. Port Terminal
2. Clouter Creek
3. Ashley River
4. Auxiliary Channel

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Use the SDV frequency to rank projects according to collision risks.

- Frequency is insensitive to the traffic levels.
- SDV frequency is four times higher in the Columbia River than in Boston Harbor.

Navigation Project	SDV Frequency
Boston Harbor	1.19E-03
Charleston Harbor	1.99E-03
Calcasieu Ship Channel	2.13E-03
Jacksonville Harbor	2.58E-03
Columbia River Channel	5.03E-03

Grounding analysis explores the potential effects of shoaling & maneuverability.

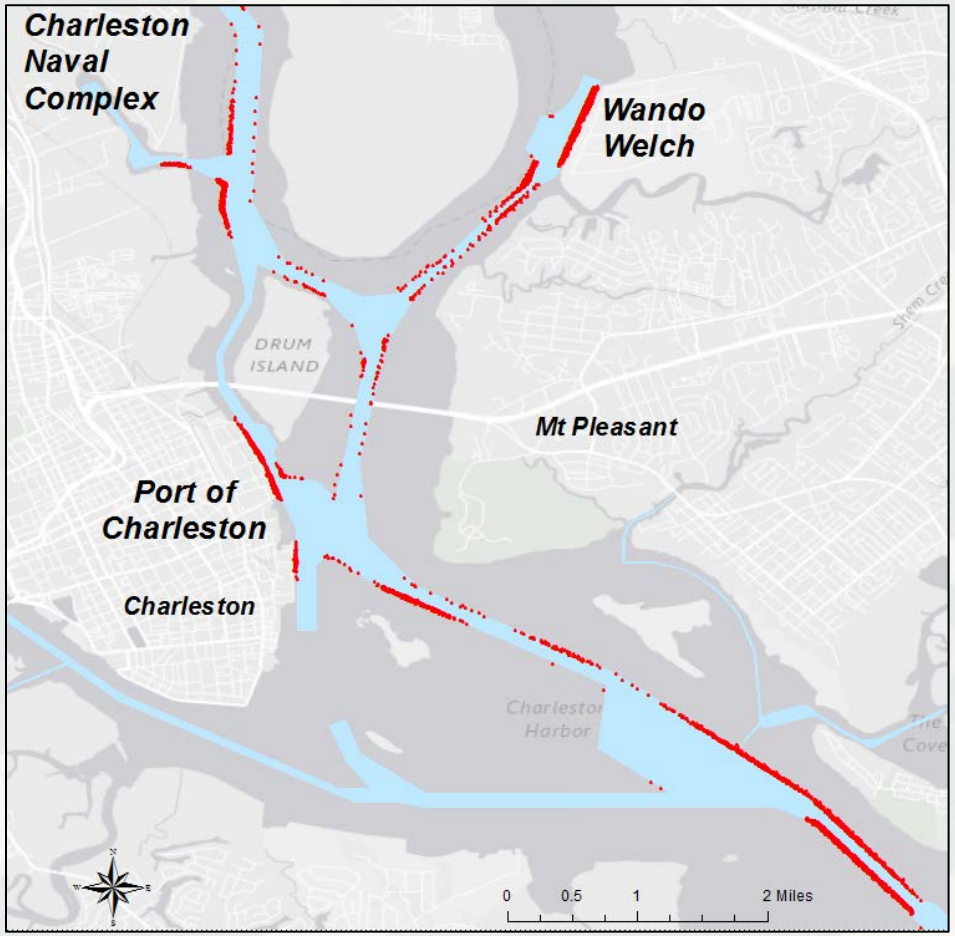
- Depth limited fraction of vessels
  - What fraction of vessels transiting the channel that would be depth-limited under shoaling scenarios?
  - Does not account for squat, tide, and under-keel clearance.
  - Describes the impact of a potential shoaling event.
- Channel side events
  - Where do vessels transit within one beam of the channel boundary.
  - May indicate congestion, avoidance, or issues with maneuverability.

Depth-limited fraction of cargo vessels in Charleston Harbor.

Channel Reach	Maintenance Depth (ft)	Unique Vessels	Reduction in maintenance depth (ft)						
			0	1	2	3	4	5	6
Harbor Entrance Channel	47	594	0.01	0.02	0.03	0.05	0.07	0.10	0.16
Mt. Pleasant Reach	45	594	0.03	0.05	0.07	0.10	0.16	0.21	0.28
Drum Island -- Hog Island	45	409	0.04	0.06	0.09	0.13	0.20	0.26	0.35
Myer's Bend	45	203	0.01	0.01	0.01	0.03	0.10	0.15	0.23
Anchorage Basin	45	98	0.03	0.05	0.05	0.06	0.11	0.15	0.22
Tidewater Reach	40	19	0.00	0.11	0.21	0.26	0.32	0.37	0.47
Lower Town Creek Reach	45	142	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Custom House Reach	45	149	0.00	0.00	0.00	0.01	0.01	0.01	0.03
Town Creek Turning Basin	35	2	0.00	0.00	0.50	0.50	0.50	0.50	1.00
Auxiliary Channel	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wando River Lower	45	266	0.07	0.10	0.14	0.20	0.29	0.36	0.46
Wando River Upper	45	266	0.07	0.10	0.14	0.20	0.29	0.36	0.46
Wando River Turning Basin	45	223	0.08	0.11	0.14	0.22	0.32	0.39	0.48
Daniel Is. – Ordnance Reach	45	203	0.01	0.01	0.01	0.03	0.10	0.15	0.23
Ordnance Reach Turning Basin	45	81	0.02	0.02	0.04	0.06	0.14	0.17	0.23
Ashley River Reach 1	30	72	0.65	0.69	0.74	0.78	0.83	0.86	0.89
Lower Shipyard River	45	20	0.00	0.00	0.00	0.05	0.15	0.20	0.20
Upper Shipyard River	30	6	0.83	0.83	0.83	0.83	0.83	0.83	0.83

Channel side events may indicate which reaches are more difficult to navigate.

- AIS reports from within one beam of the channel side.
- Cargo vessels & tankers drafting > 5 meters.
- Watch out for false positives.
  - Private channels, docks
  - Intentionally leaving federal channel.
- Frequency is hard to calculate.



Validate results by ground truthing.

- Are known problem areas identified as high risk?
- Are proposed improvements consistent with results of the analysis?
- Interview pilots: Can pilots explain why some reaches are difficult to navigate?

Conclusions

- AIS and NAIS were not designed for risk assessment.
  - AIS was designed for active collision avoidance.
  - Data we have *vs.* Data we want.
- Use of NAIS to analyze collision & grounding risk has been demonstrated.
- The analysis is not a conventional risk assessment.
  - Probabilities of collision and grounding are not estimated.
  - Method does not support loss estimation.
- Methods must be robust against error & ambiguity in NAIS database.

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