

XI HOTINE-MARUSSI SYMPOSIUM



GENOVA, 7–11 SEPTEMBER 2026

S2 - GEODETIC QUALITY/INTEGRITY MODELLING

FROM VESSEL TRACKS TO OCEAN DYNAMICS: ASSESSING AIS AND GNSS DATA FOR LOCAL MARINE VARIABILITY

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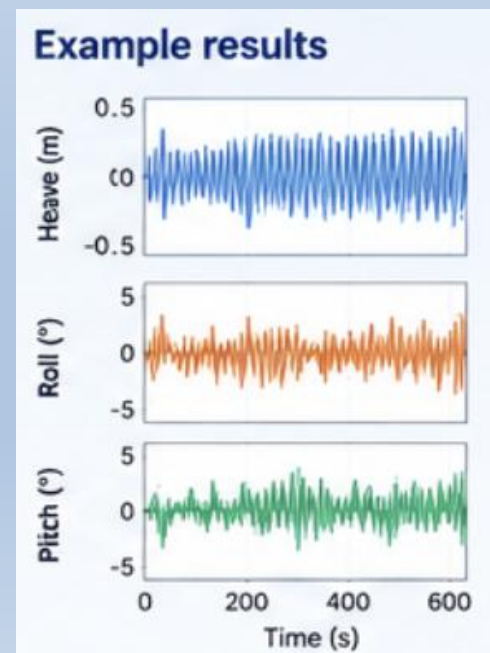
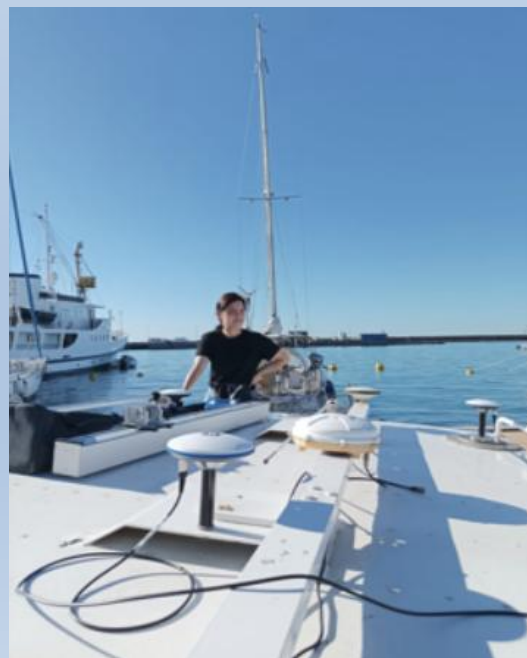
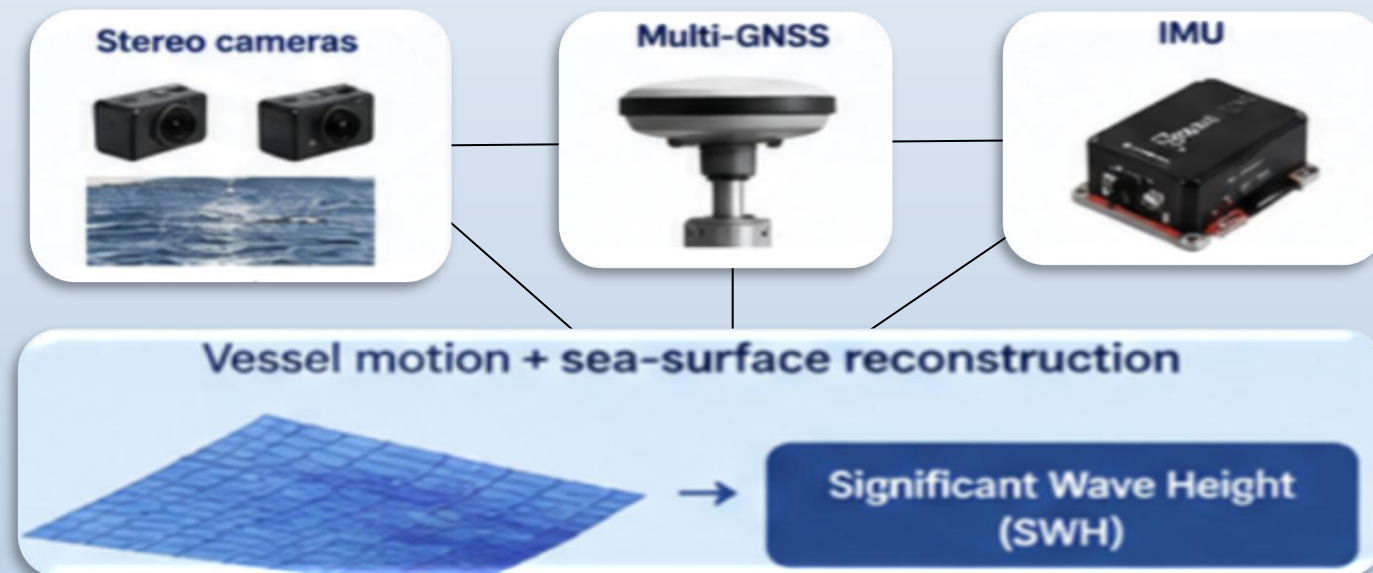
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WHERE DID THIS RESEARCH IDEA COME FROM?

PhD Research

**Moving vessel based Stereophotogrammetry
and GNSS fusion for Significant Wave Height
Estimation**



External Research Period



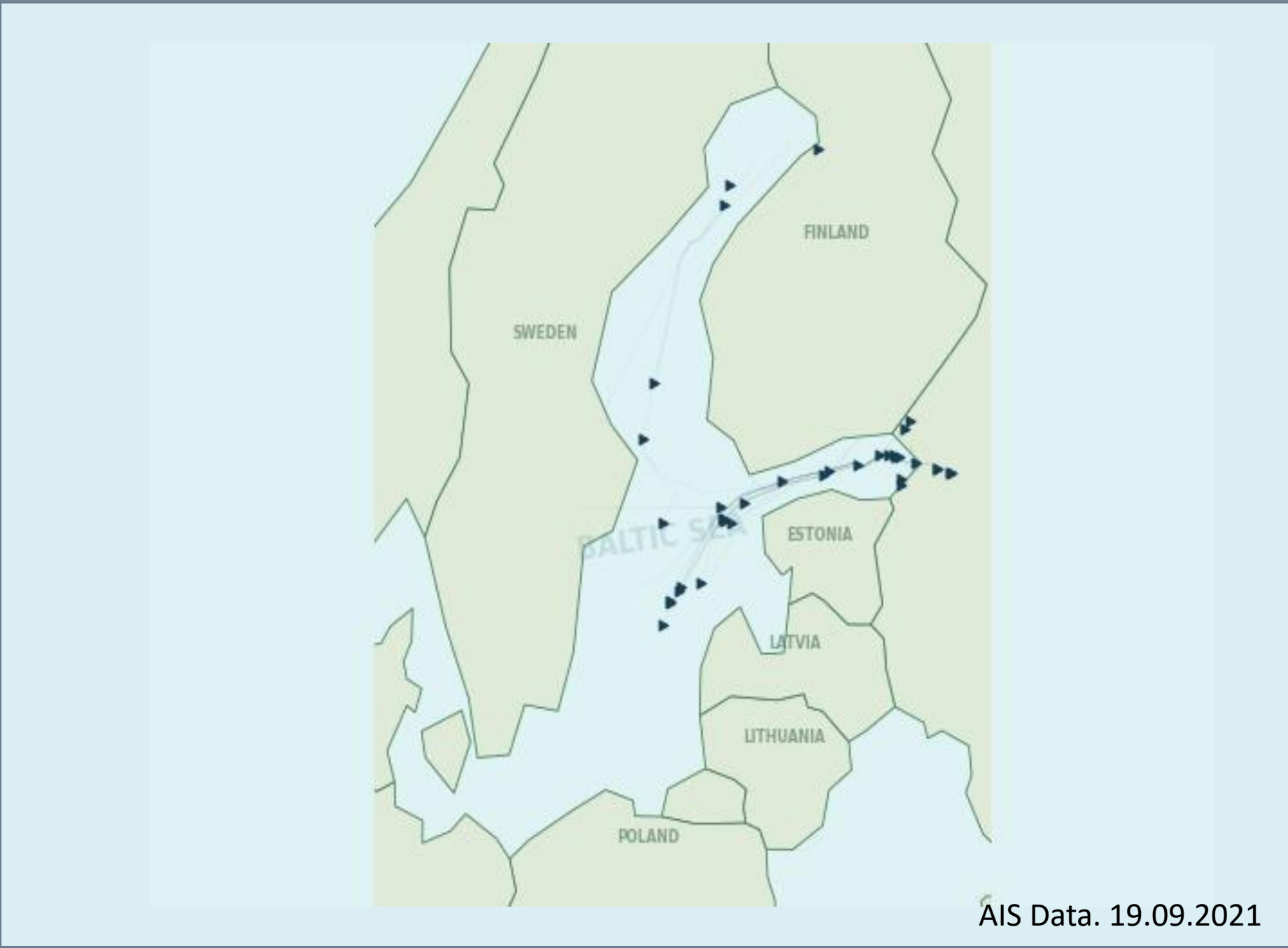
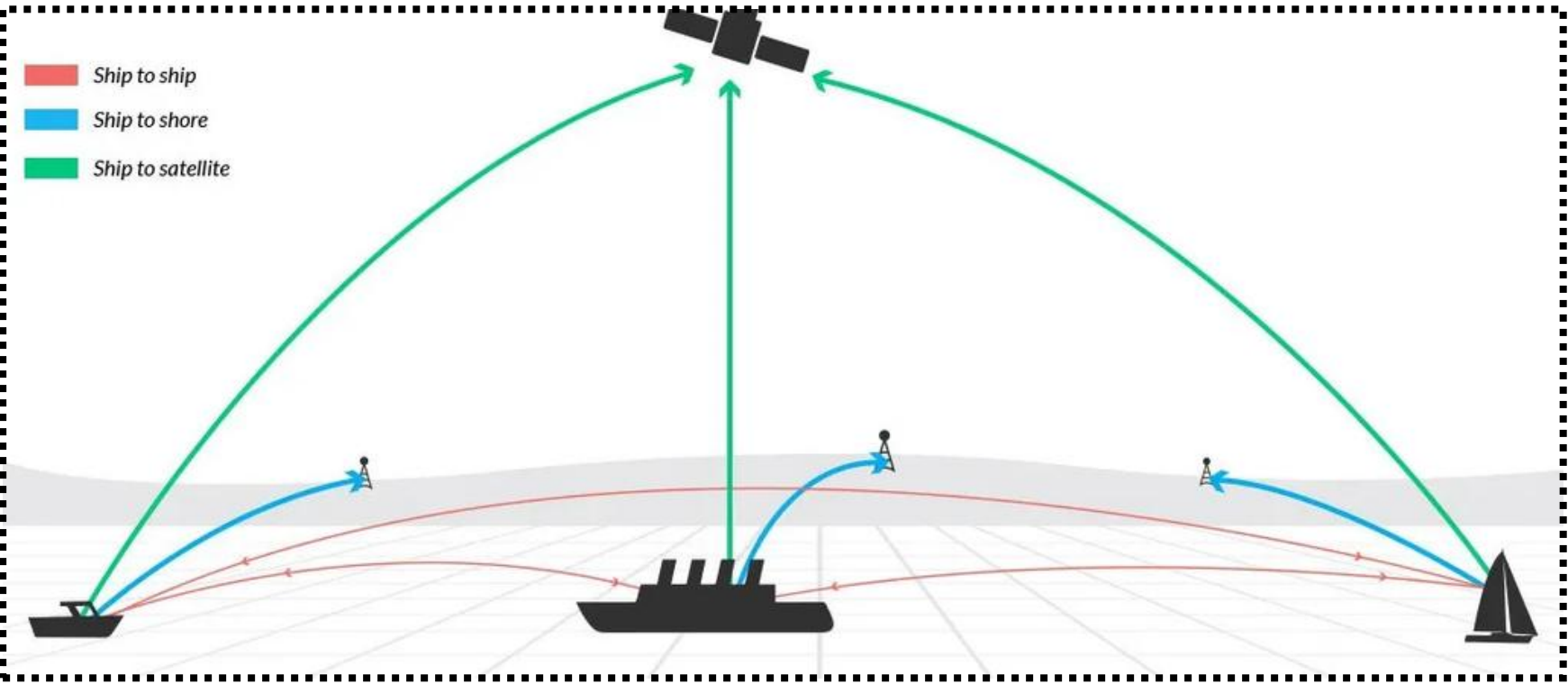
Key inspiration :

Vessels already navigating across the world ocean and continuously generates navigation data. Could they also provide information about the surrounding environment/ environmental changes factors?

AUTOMATIC IDENTIFICATION SYSTEM (AIS)

The main objectives of AIS are to:

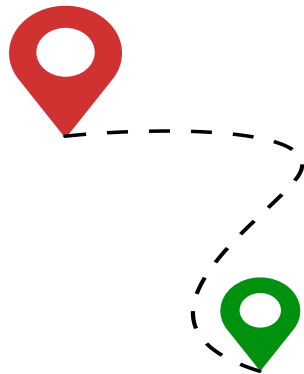
- **Improve maritime safety by preventing collisions;**
- Support vessel traffic monitoring and situational awareness;
- Enable search and rescue and emergency response;



Total AIS position records	3,320,874
Unique vessels (MMSI)	1,094
Vessels with SOG $\geq$ 1 kn	687
Moving vessels in displayed map area*	675

AUTOMATIC IDENTIFICATION SYSTEM (AIS) DATA INCLUDES REAL-TIME INFORMATION BROADCAST BY SHIPS.

Type	Information	Typical update
Dynamic data	Position (latitude, longitude), SOG (Speed Over Ground), COG (Course Over Ground), Heading, Rate of Turn (ROT), navigation status, UTC/time information	Every few seconds to minutes, depending on vessel speed/status and AIS class
Static data	MMSI, IMO number, vessel name, call sign, ship type, length and width	Infrequently / when information changes
Voyage-related data	Destination, ETA (Estimated Time of Arrival), draught	Typically entered/updated for the voyage



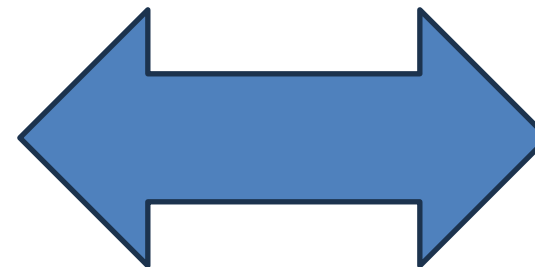
Unlike GNSS observations, AIS lacks **vertical position** information, making direct estimation of heave and wave height impossible. Consequently, environmental effects must be inferred indirectly from changes in vessel speed, course, drift, and navigation behaviour.

METHODOLOGICAL CONCEPT

AIS – AS A VESSEL – RESPONSE INDICATOR – NOT A DIRECT MEASUREMENT

SHIP BEHAVIOR

- SPEED
- TRACK/COURSE
- MANOEUVRES



ENVIRONMENTAL CONDITIONS

- WIND
- SIGNIFICANT WAVE HEIGHT (SWH)



GOAL: DETERMINE WHETHER CHANGES IN VESSEL BEHAVIOUR CORRESPONDS TO ENVIRONMENTAL FORCING.

AIS ANOMALY CLASSIFICATION

1

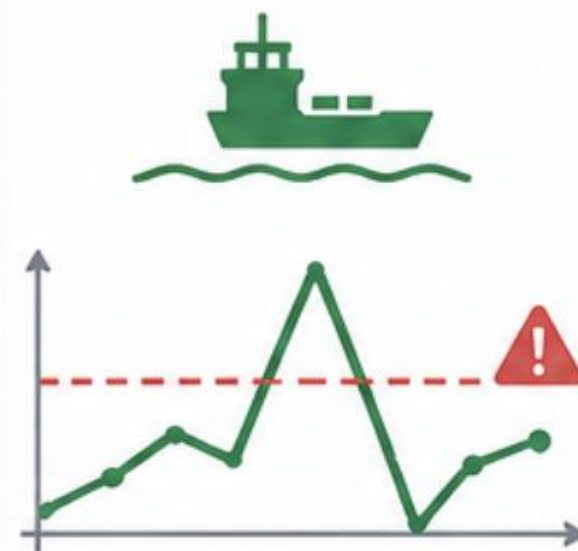
SPEED ANOMALY



Unusually high/low speed or sudden speed change compared to vessel behavior.

2

ACCELERATION ANOMALY



Abnormal acceleration or deceleration beyond expected limits.

3

COURSE / HEADING ANOMALY



Large COG–heading drift or unstable directional behavior.

4

ANCHOR-MOVING ANOMALY



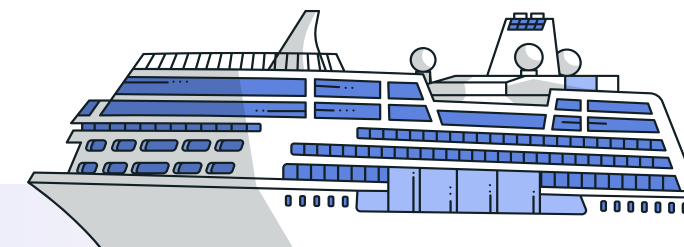
Vessel is reported anchored but shows significant movement.

5

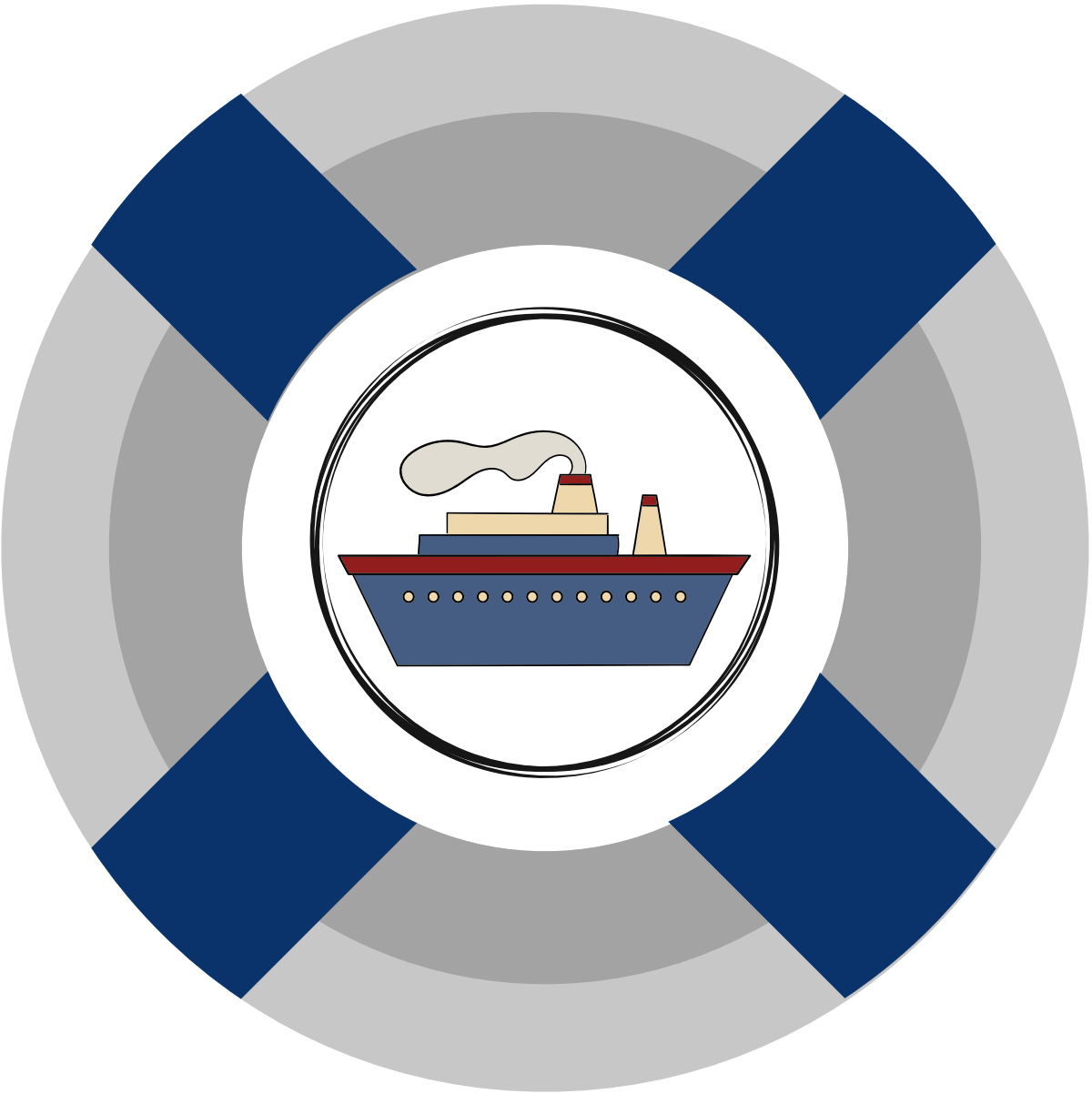
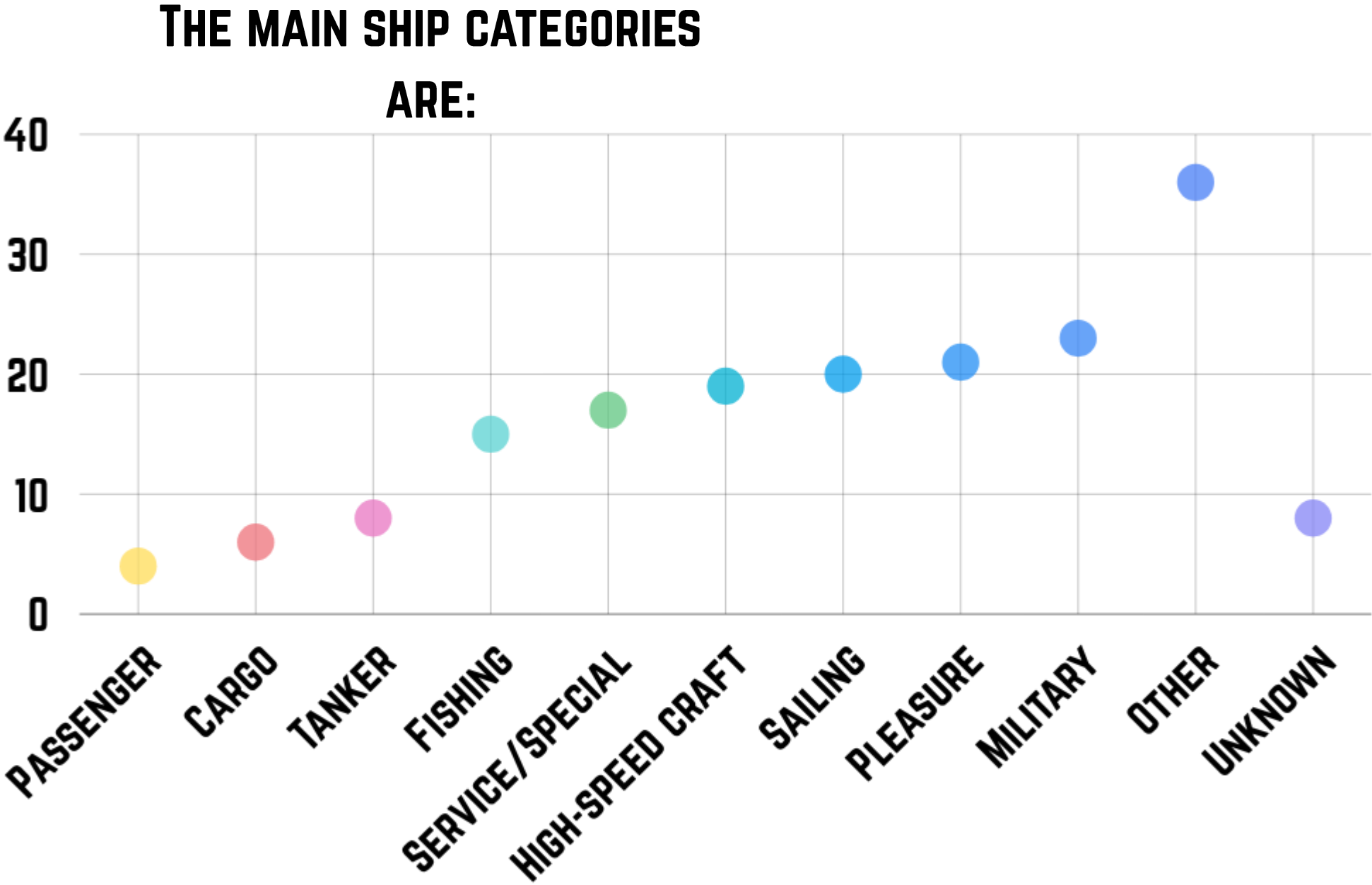
AIS ARTIFACT / POSITION JUMP



Unrealistic position jump or possible AIS/spoofing error.



SHIP CATEGORIZATION



REGIONAL AND HOTSPOT ANALYSIS



MAIN REGIONS INCLUDE:



GULF OF FINLAND



HELSINKI-TALLINN CORRIDOR



ÅLAND SEA / NORTHERN BALTIC PROPER



ARCHIPELAGO SEA / TURKU-ÅLAND



OPEN BALTIC SOUTH OF FINLAND



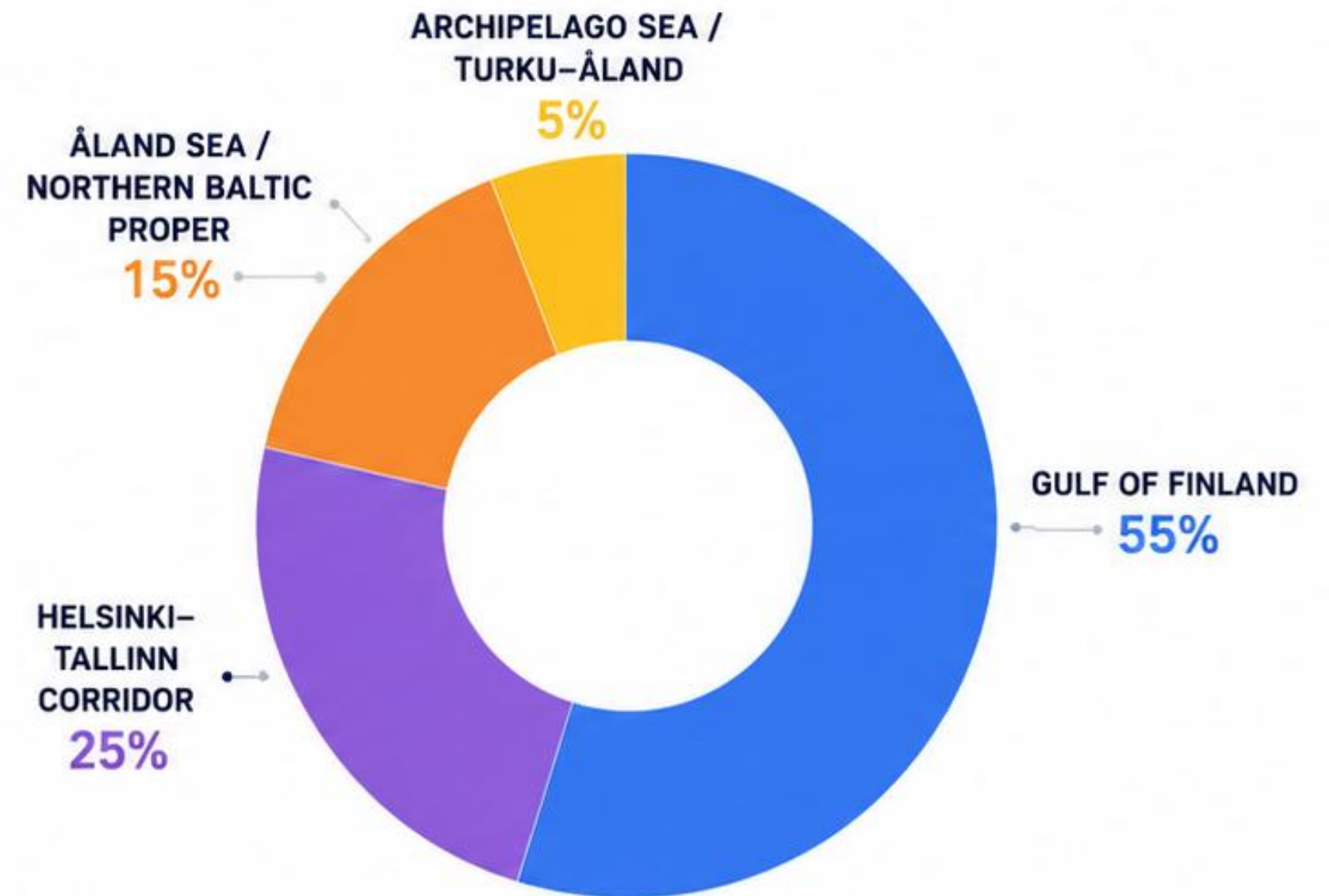
KVARKEN / VAASA



BOTHNIAN SEA



BAY OF BOTHNIA



EXAMPLE: STATISTICS OF ONE MONTHS DATA ANALYSIS(DEXEMBER 2021).



COPERNICUS CLIMATE ERA5 WIND DATA PROCESSING

- Data description
- Horizontal coverage: Global
- Horizontal resolution : $0.25^\circ \times 0.25^\circ$ (~31 km)
- Temporal resolution: Daily
- The input data: hourly
- Update frequency: Daily (with a delay of 6 days)

COPERNICUS MARINE SWH DATA

Product ID: BALTICSEA_ANALYSISFORECAST_WAV_003_010

Source: Numerical models

Spatial extent

Baltic Sea Lat 53.01° to 65.91° Lon 9.01° to 30.21°

Spatial resolution: 2 × 2 km

Temporal resolution: Hourly

Processing level: Level 4

Variables: significant wave height....

Update frequency: Daily – Twice per day at 10:00 UTC and 22:00 UTC

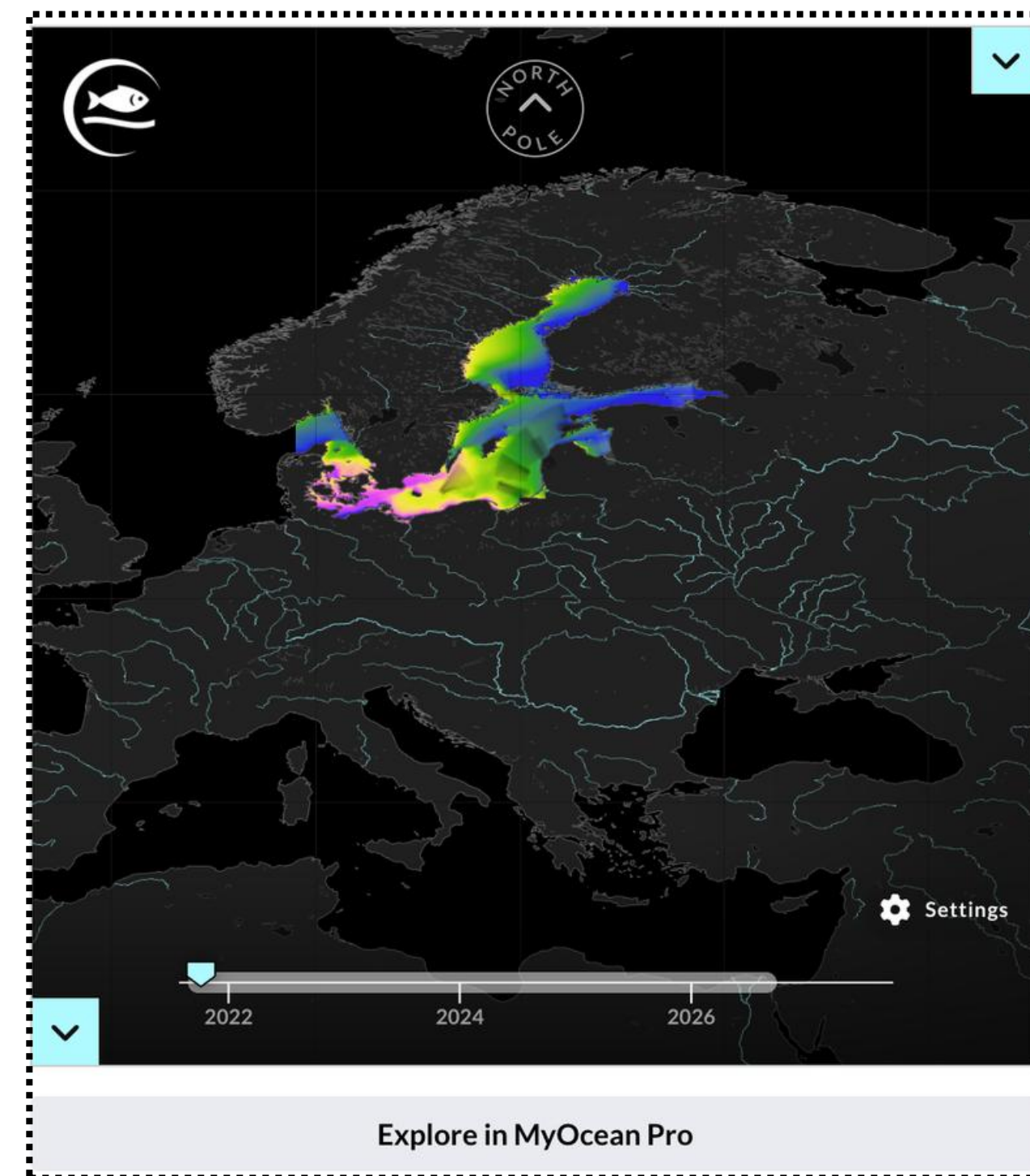
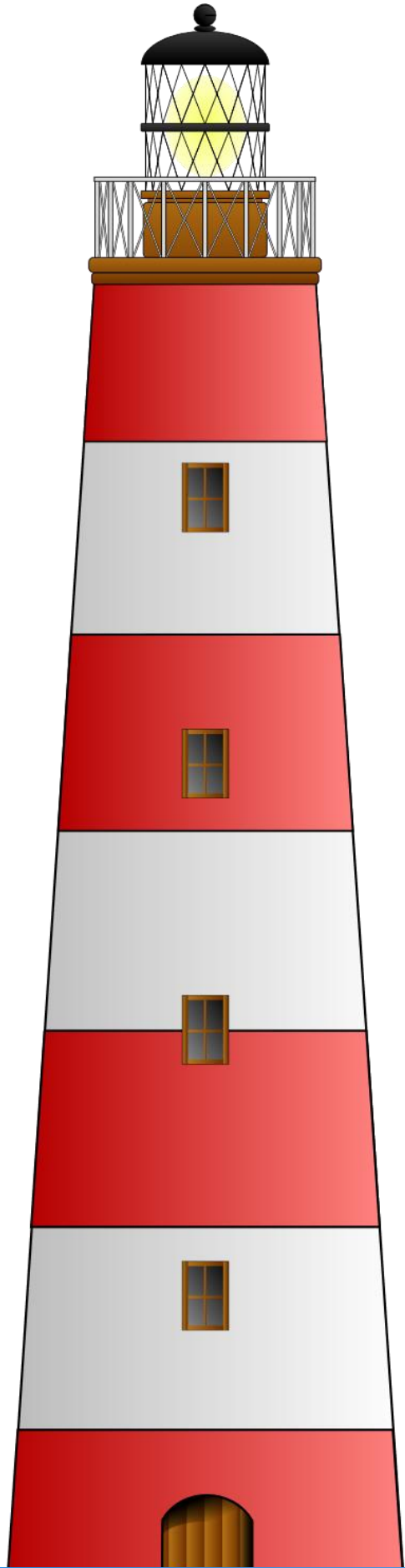


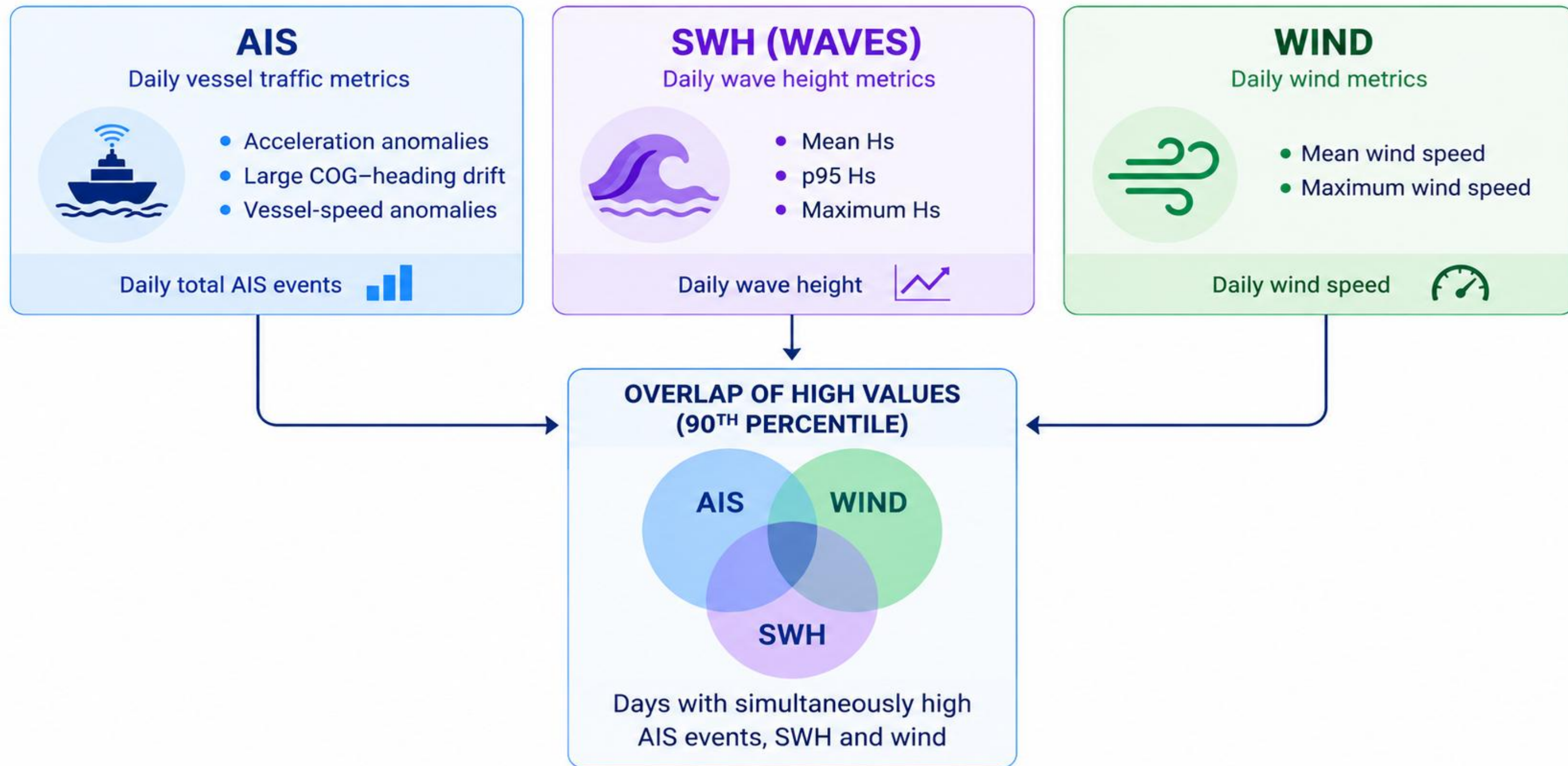
IMAGE SOURCE:

[HTTPS://DATA.MARINE.COPERNICUS.EU/PRODUCT/BALTICSEA_ANALYSISFORECAST_WAV](https://data.marine.copernicus.eu/product/BALTICSEA_ANALYSISFORECAST_WAV)

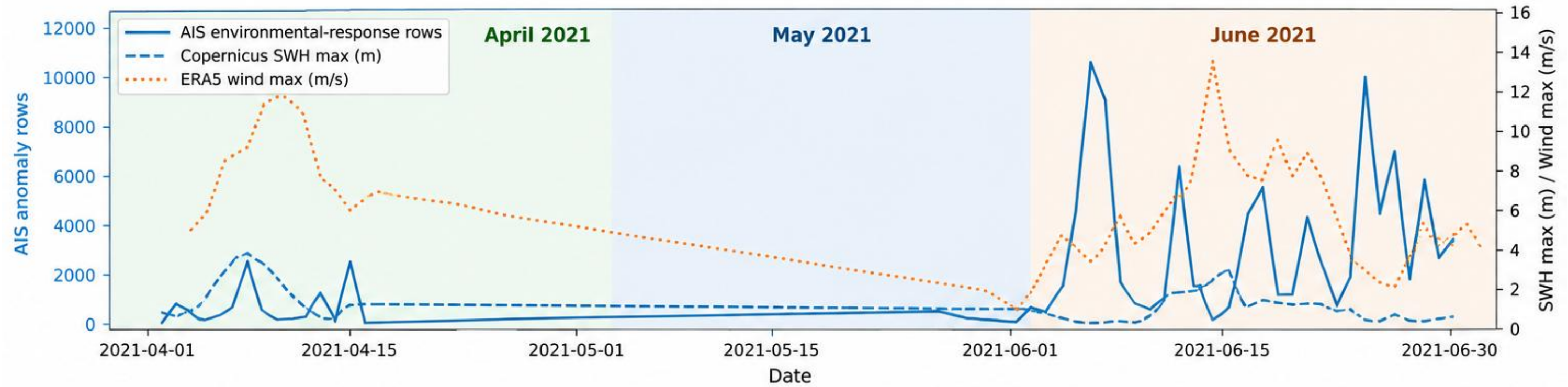


FINAL INTERPRETATION LOGIC

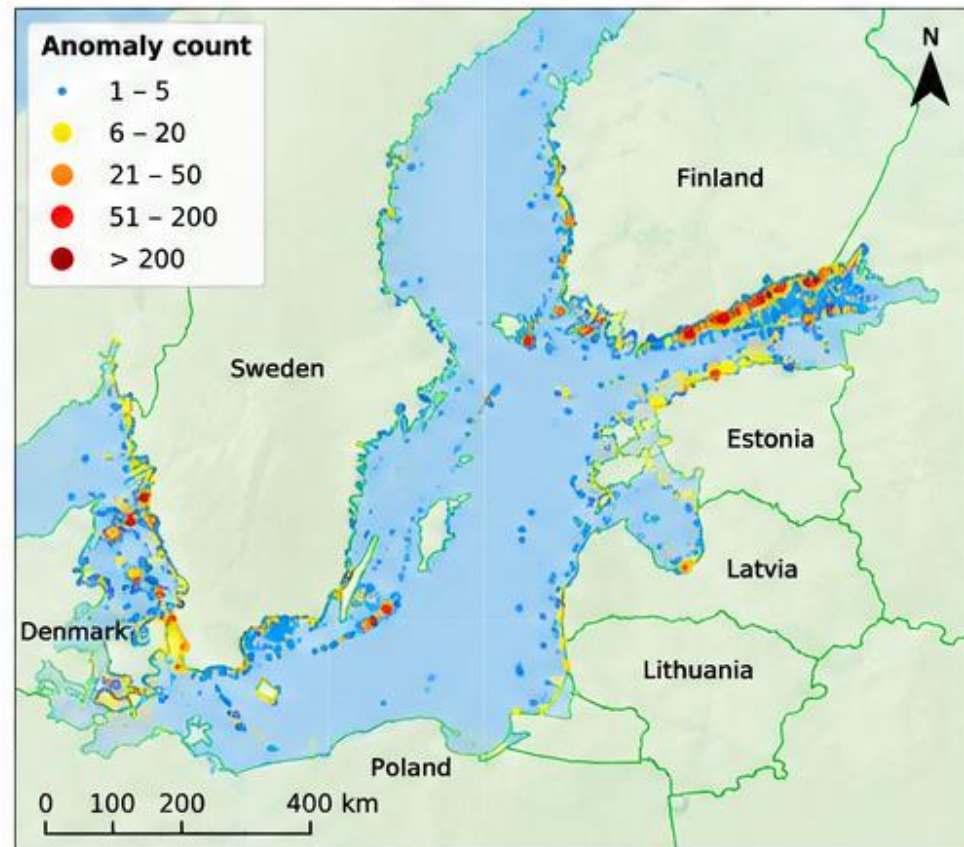
ANALYSIS & COMPARISONS



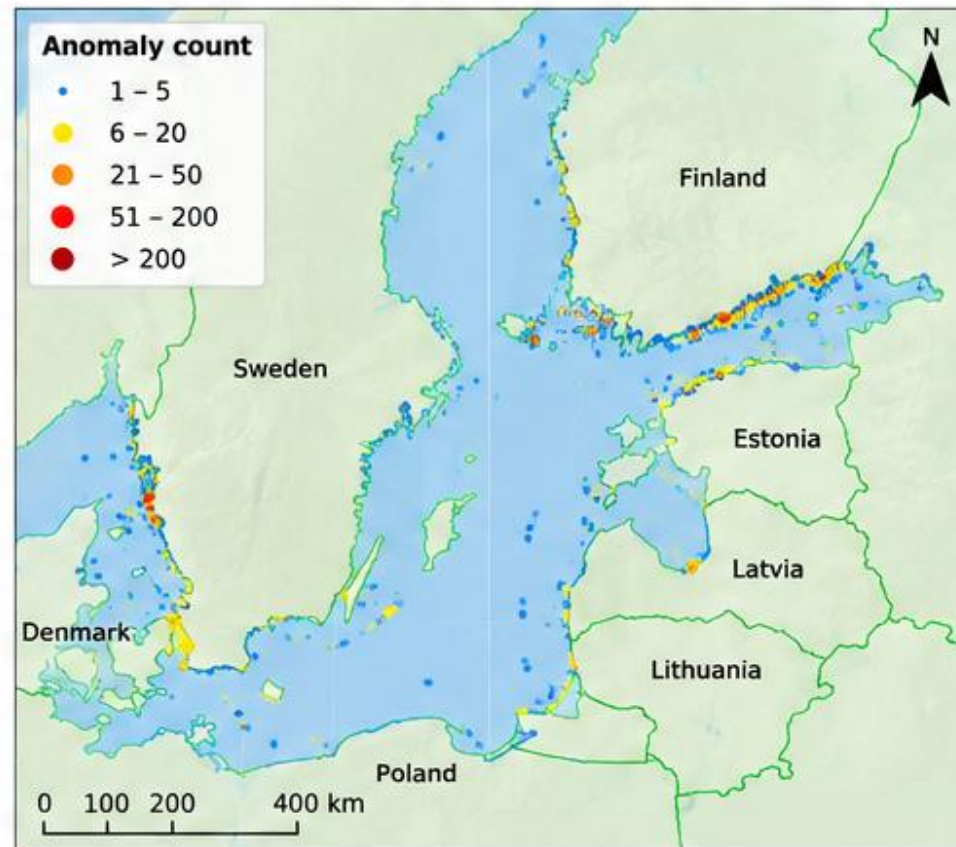
April–June 2021: AIS response with Copernicus SWH and ERA5 wind



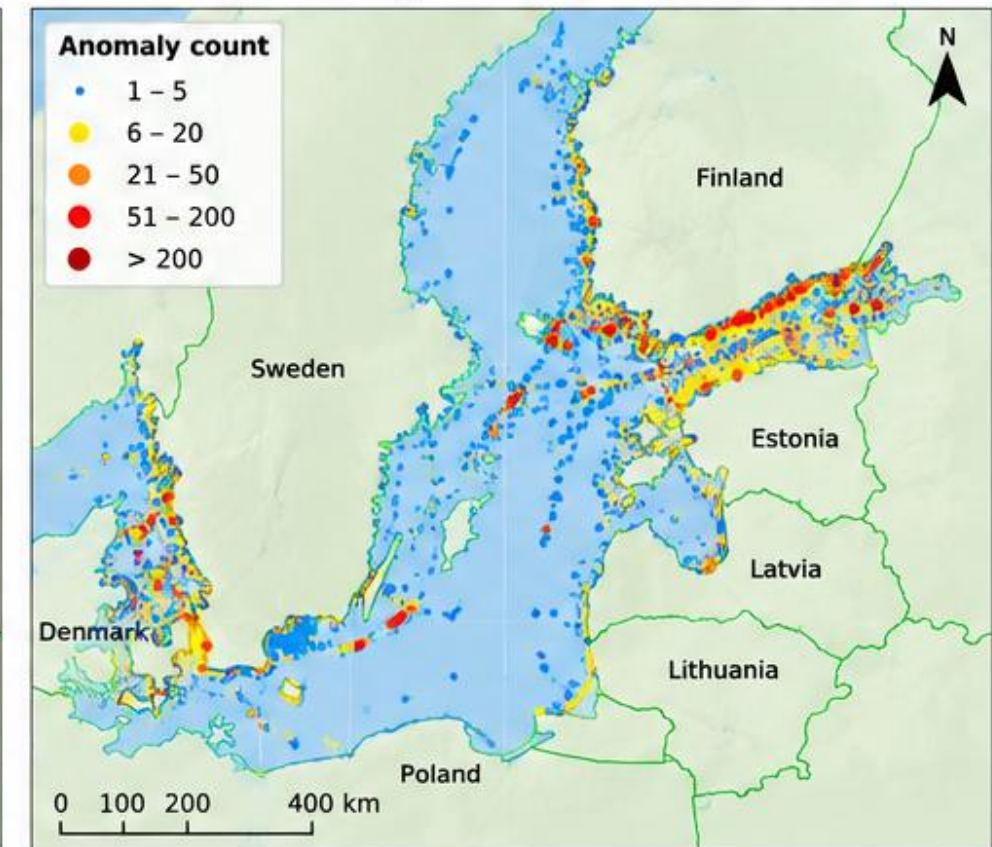
AIS anomaly locations – April 2021



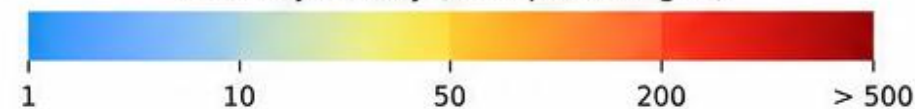
AIS anomaly locations – May 2021



AIS anomaly locations – June 2021



Anomaly density (rows per 0.1° grid)



Date	AIS environmental- response rows	SWH max	Wind max	RMetS wind class	Interpretation
23 Apr	1,012	4.34 m 	12.69 m/s	Bft 6 – Strong Breeze	MATCH
24 Apr	2,580	3.96 m 	13.13 m/s	Bft 6 – Strong Breeze	BEST APRIL MATCH
14 Jun	763	3.24 m 	14.90 m/s	Bft 7 – Near Gale	METOCEAN / weak AIS
5 Jun	11,051 	0.67 m	5.10 m/s	Bft 3 – Gentle Breeze	AIS ONLY
26 Jun	7,288 	1.17 m	2.58 m/s	Bft 2 – Light Breeze	AIS ONLY

CONCLUSIONS



IMAGE MAP: HELCOM.FI

LEGEND : BALTIC AREA

- AIS HIGH ANOMALY
- AIS MODERATE ANOMALY

FUTURE WORK/PERSPECTIVES

- Inclusion of local wave-buoy observations
- Use of wave direction and wind direction
- Improved ship-category analysis
- Spatial susceptibility mapping
- Toward predictive or operational use
- Possible ML implementations
- FULL DATA (X,Y,Z) REQUESTS



DATASET SOURCES

1.AIS DATASET FINNISH WATERS:

<https://doi.org/10.5281/zenodo.8112336>

2.BALTICS LOCAL DATA: <https://helcom.fi/baltic-sea-trends/data/>

3.COPERNICUS MARINE GLOBAL DATA:

<https://marine.copernicus.eu/>

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Duka, A.; Zhang, H.; Vidan, P.; Li, G. “Exploring Recent Maritime Research on AIS-Based Ship Behavior Analysis and Modeling.” *Journal of Marine Science and Engineering*, **2026**, 14, 712. DOI: 10.3390/jmse14080712.

Aouedi, O.; et al. “AIS-Based Hybrid Vessel Trajectory Prediction for Enhanced Maritime Navigation.” *IEEE Transactions on Machine Learning in Communications and Networking*, **2026**, 4, pp. 198–210. DOI: 10.1109/TMLCN.2025.3644333.

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*Thank
you!*