

Assessing Ship Movements Using Volunteered Geographic Information

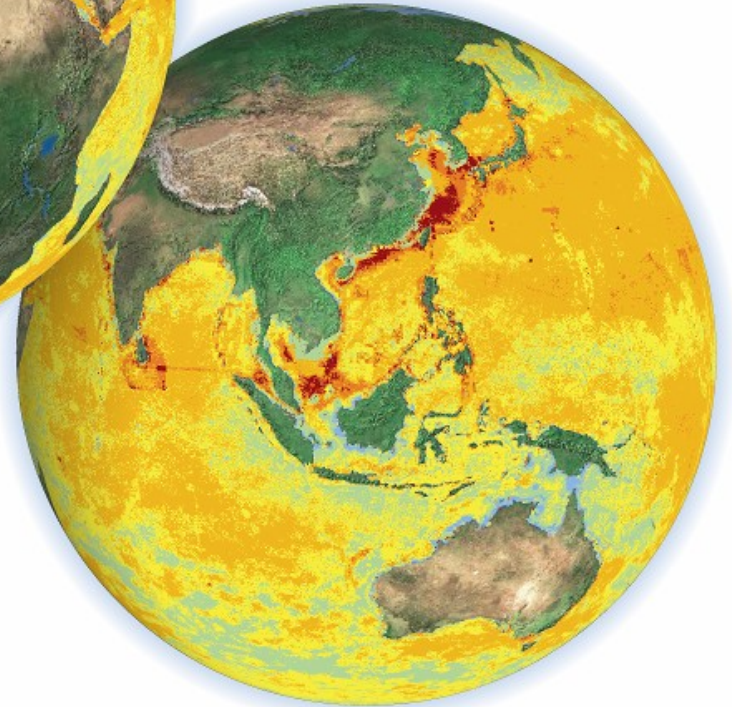
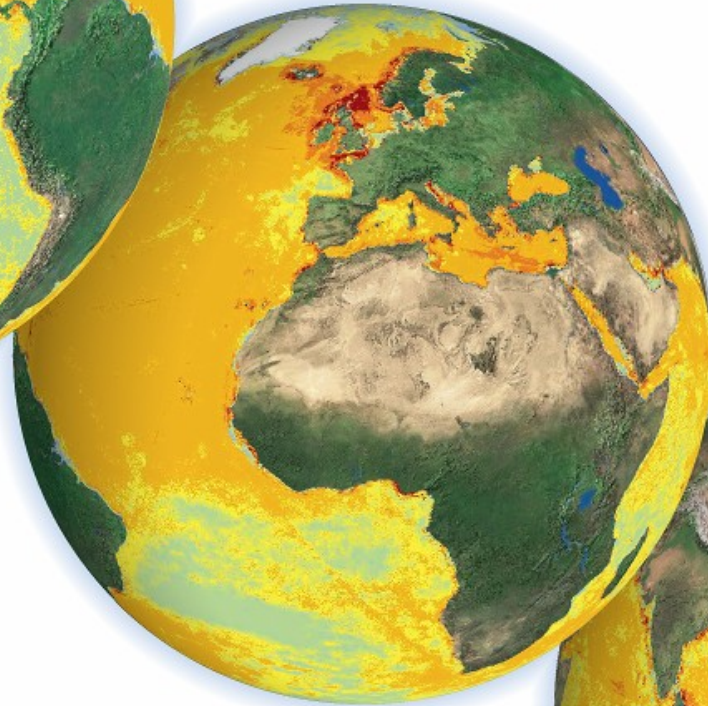
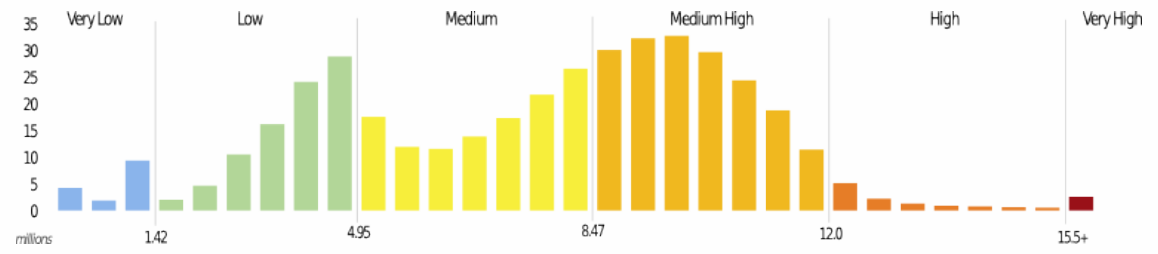
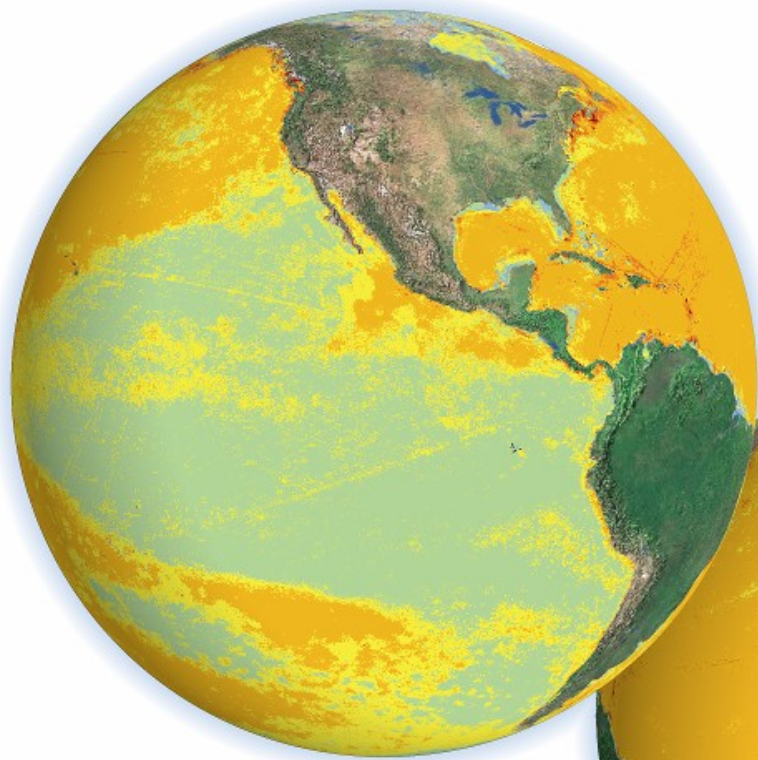


Image Credit: Mike Baird,
[flickr.com/photos/mikebaird](https://www.flickr.com/photos/mikebaird)

Shaun Walbridge
walbridge@lifesci.ucsb.edu

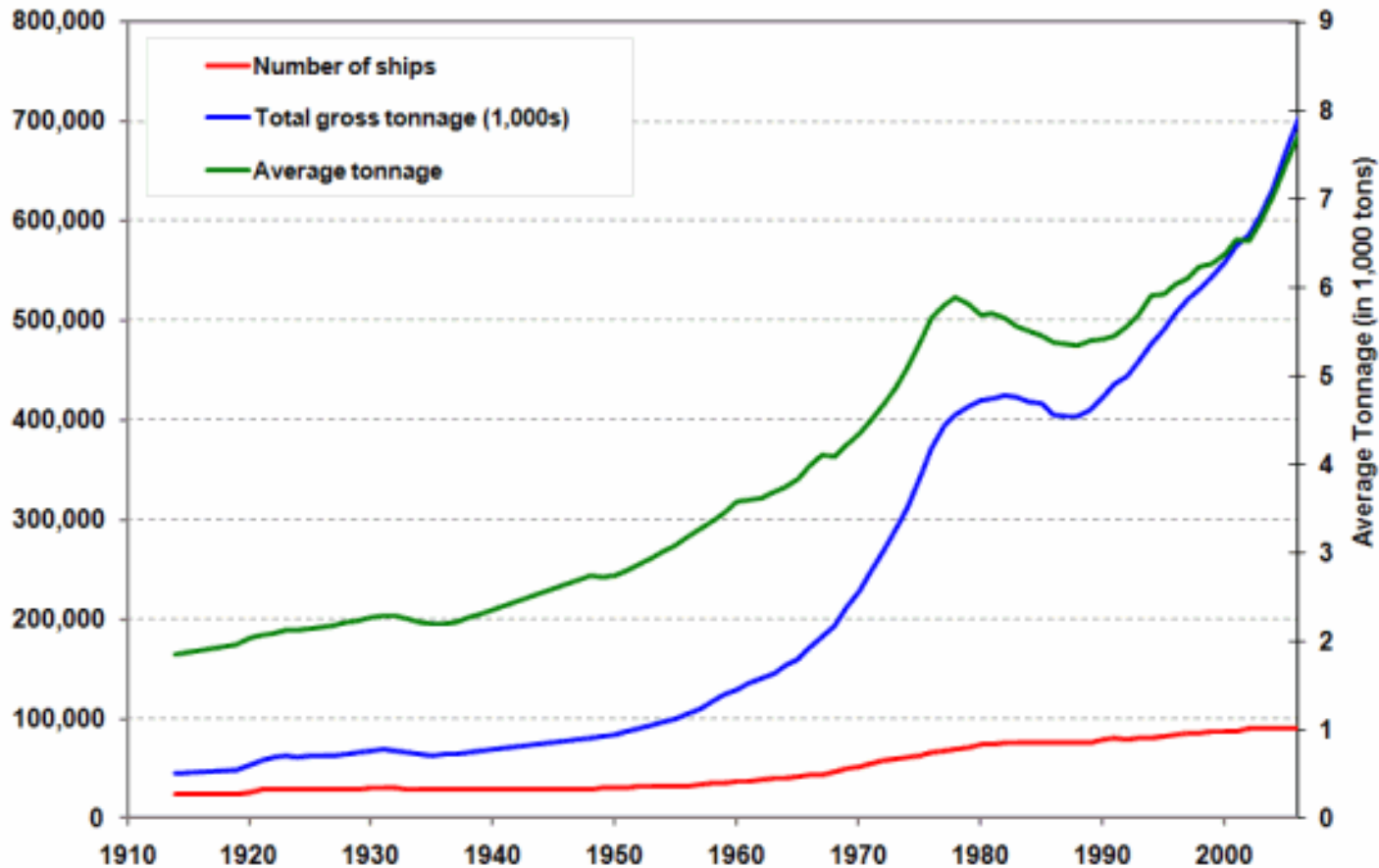
Goals

- Background on ship data
- Fusing volunteered data
- Cover relevant Ecological models:
 strikes, noise, groundings
- The future: networks



Halpern et al, 2008

Maritime Trade



90% of global trade volume

\$1.8T of goods in '08

Baltic Dry Index a leading economic indicator

Data is valuable (\$)

Lloyds of London, 2007

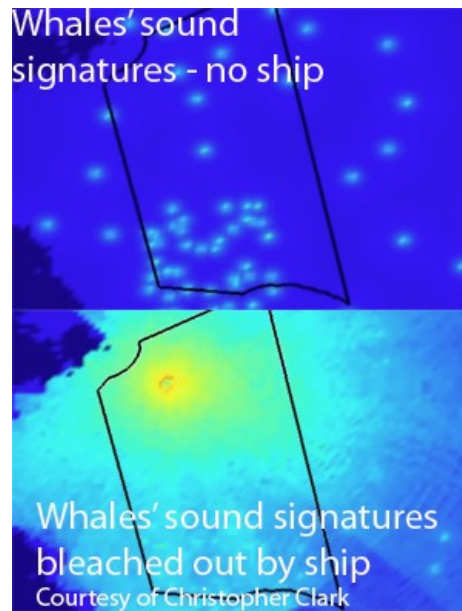
Ecological Effects

- Invasive Species ballast water
- Emissions 5% global GHG, 25% NO_x; 60,000 deaths yr⁻¹
- Direct Pollution sewage, marine debris, gray water

Ship Strikes

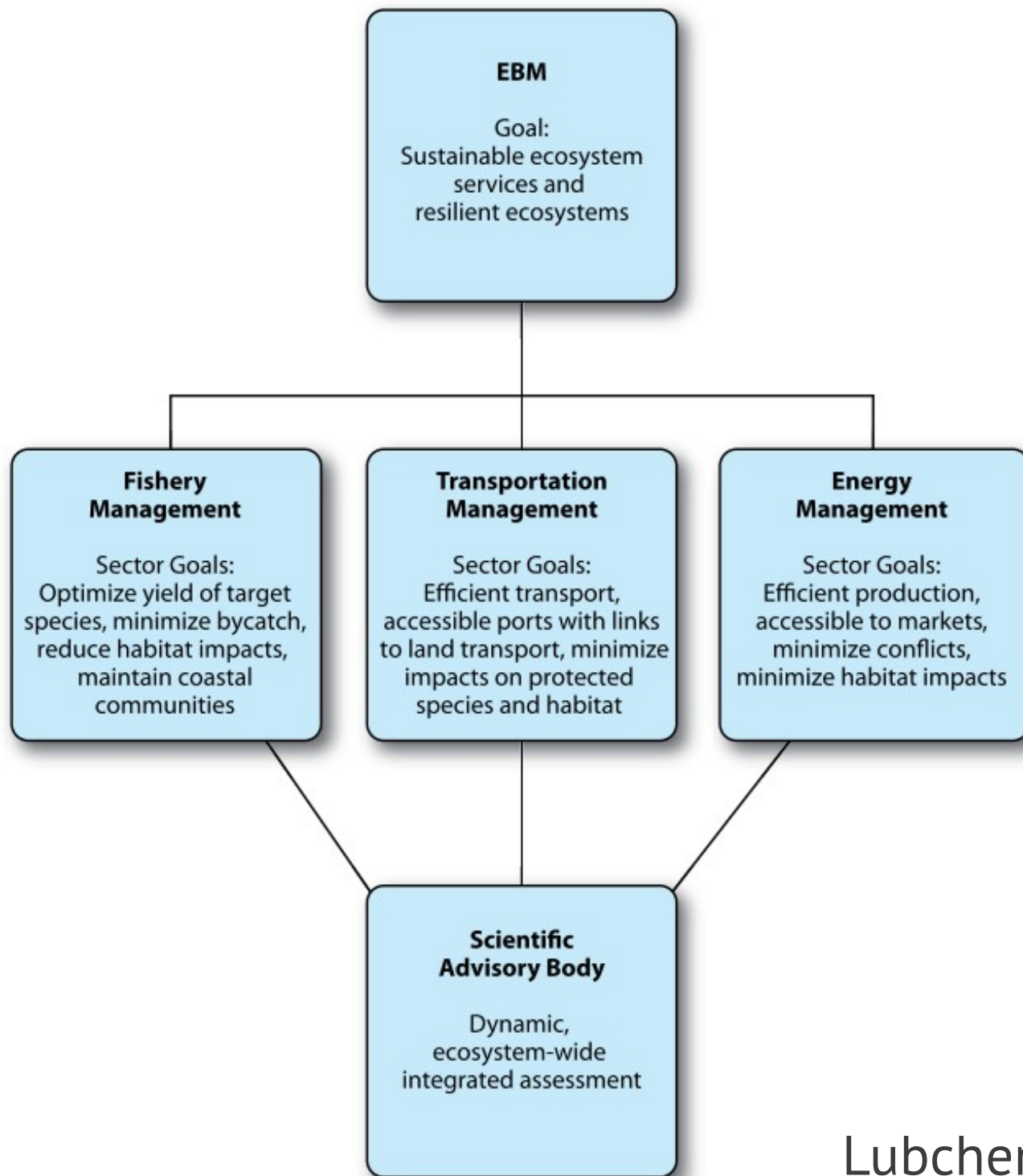


Noise Pollution



Ship Groundings





Data Fusion Workflow

Observations

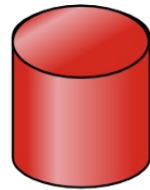
Vessels

AIS

VOS

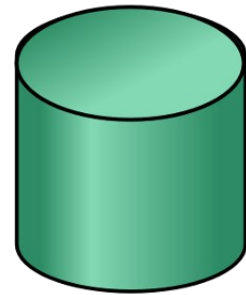


VesselTracker
Fleetmon
Marine Traffic



SailWX

10 min interval
15 months
2.4 B obs



1991-2011
92.4 M obs

Spatial Database
1.5TB

VesselTracker



ITU
FCC

Digital Seas

Record Linkage

Vessels

106,131 identified

Data Fusion Workflow

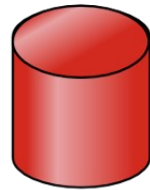
Observations

AIS

VOS

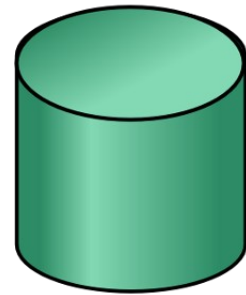


VesselTracker
Fleetmon
Marine Traffic



SailWX

10 min interval
15 months
2.4 B obs



1991-2011
92.4 M obs

Spatial Database
1.5TB

Vessels

VesselTracker



ITU
FCC

Digital Seas

Record Linkage

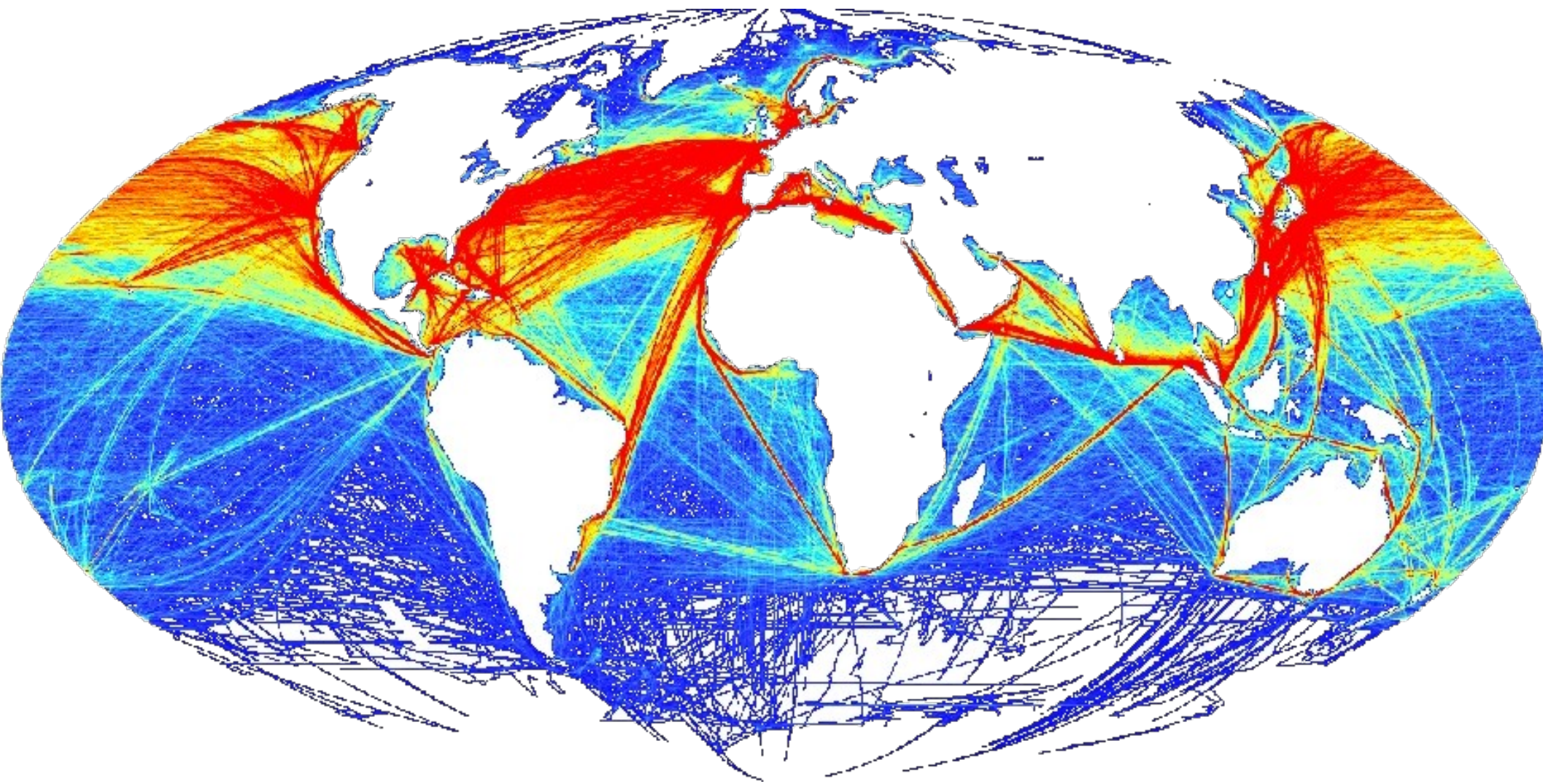
Vessels

106,131 identified

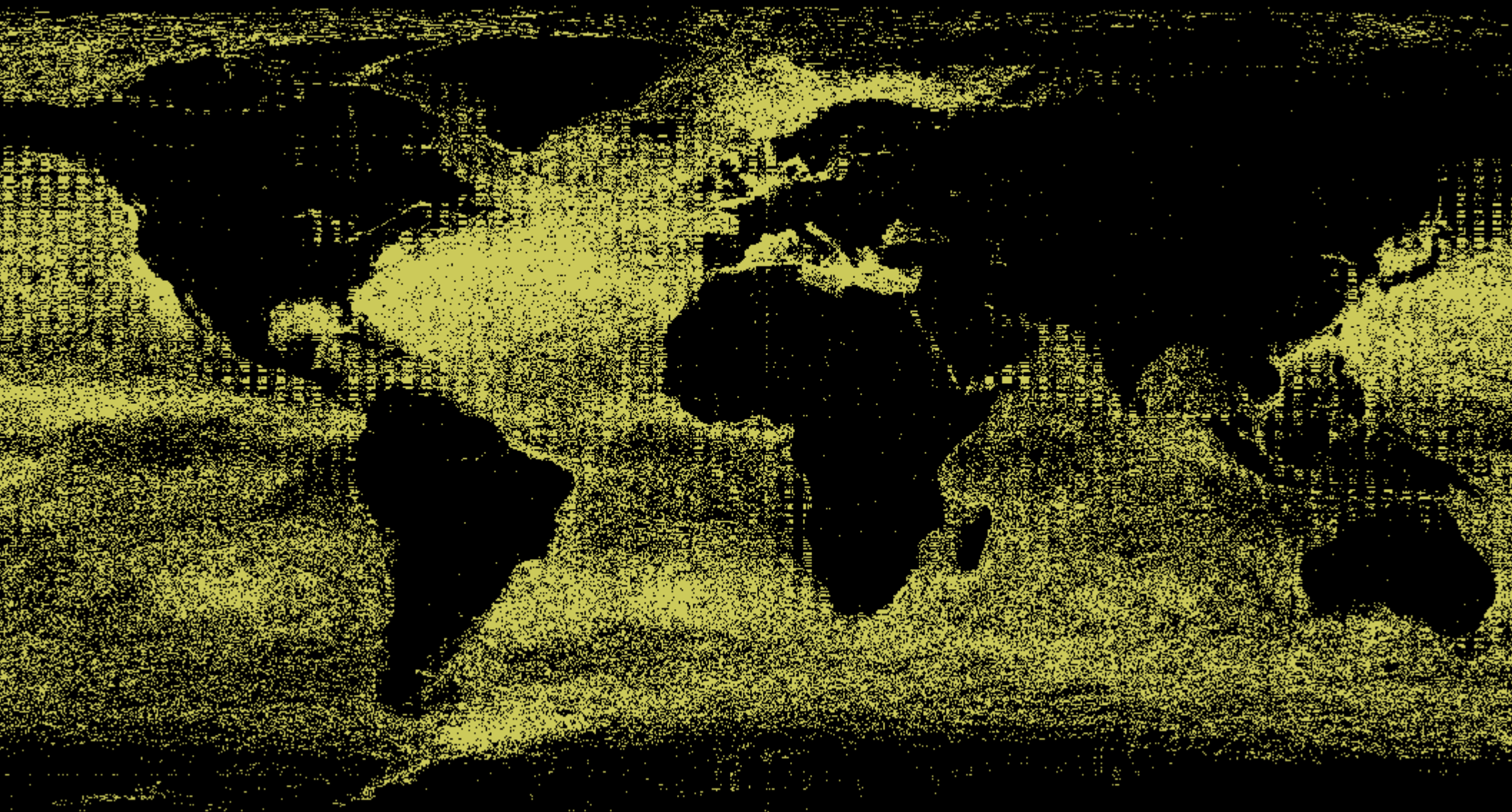
Voluntary Observing Ship (VOS) Fleet

- Intent is ocean climate
- Volunteered, 5–15% of ships
- No ship type in 56% of records
- Here, records from 1991-2011 used





Pretty map, pretty poor for analysis



VOS: 2003-2011, 68.8m

Automatic Identification System (AIS)

- GPS based, high spatial accuracy (~10m) and high temporal frequency
- Mandated on large vessels and passenger ships
- Intent is safety
- Radio based, real-time

Attributes:

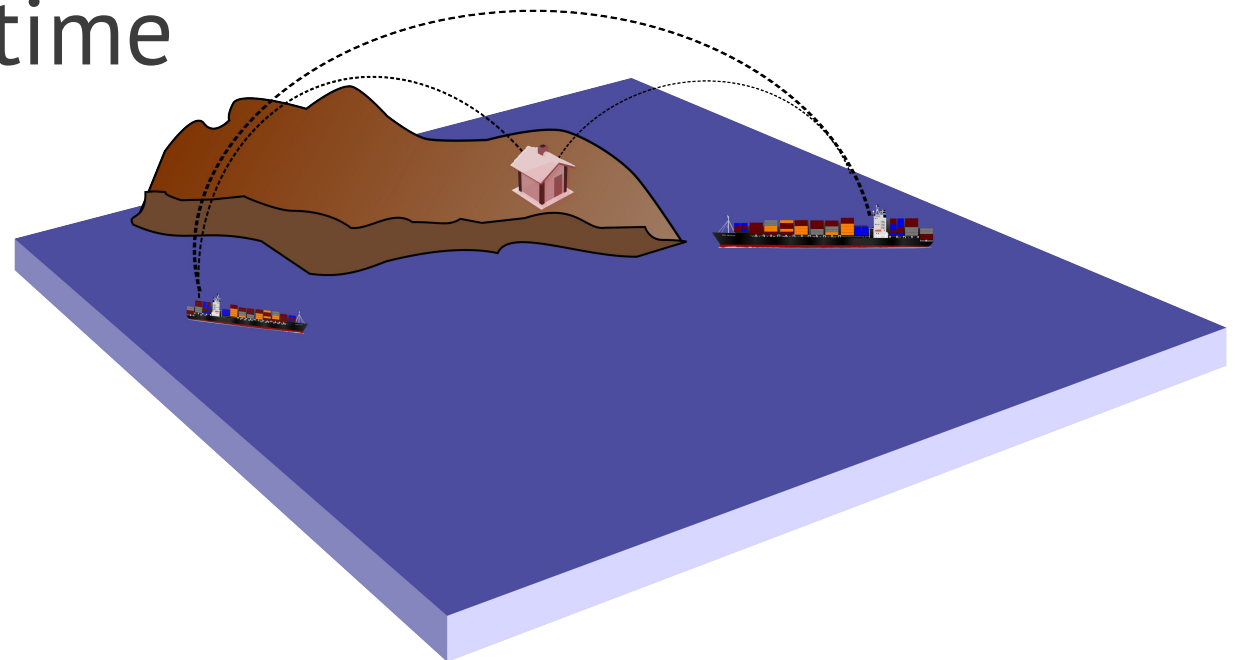
ship id

(x,y)

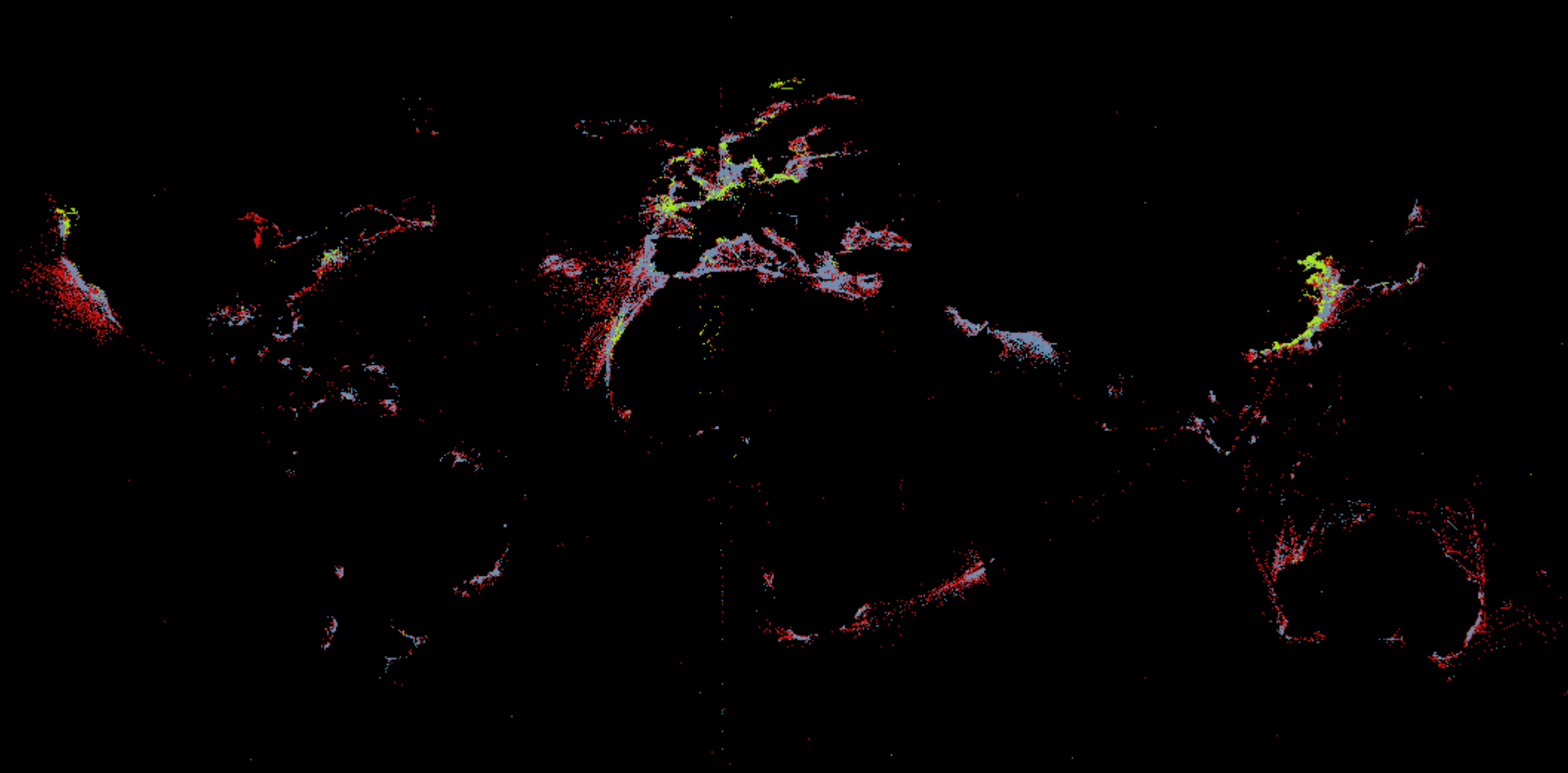
heading

type

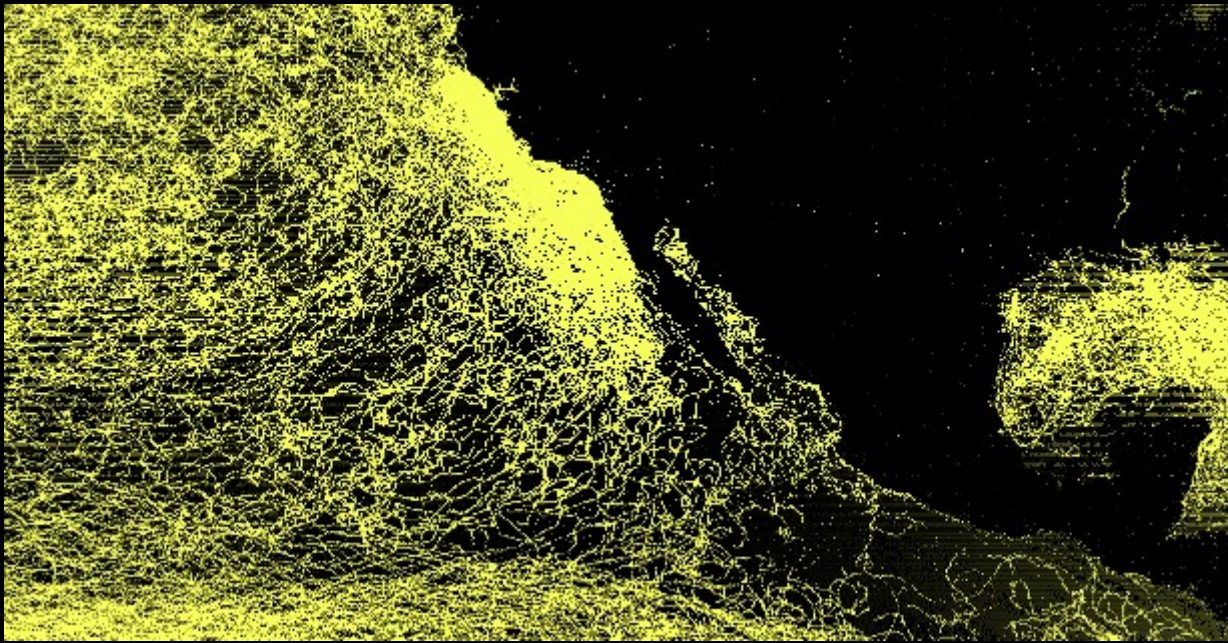
speed



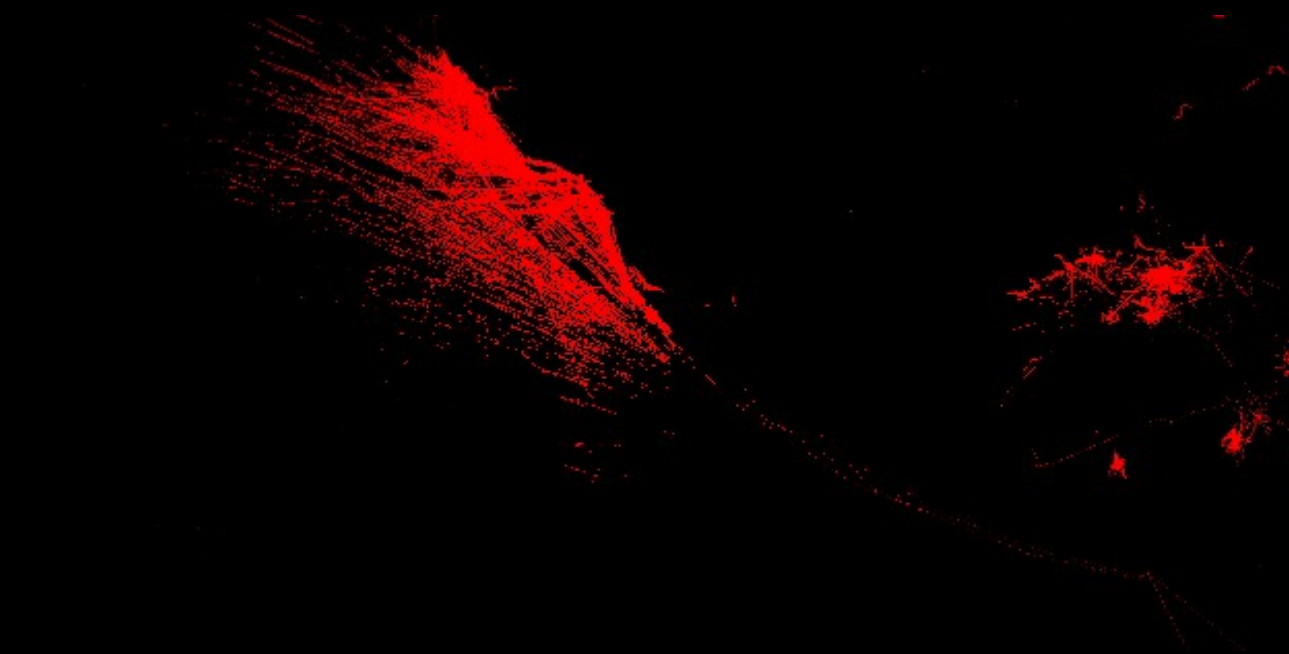
AIS: Nov, 2011



Green:	Fishing	6.8m
Blue:	Tankers	31m
Red:	Cargo	48m



VOS: 2003-2011



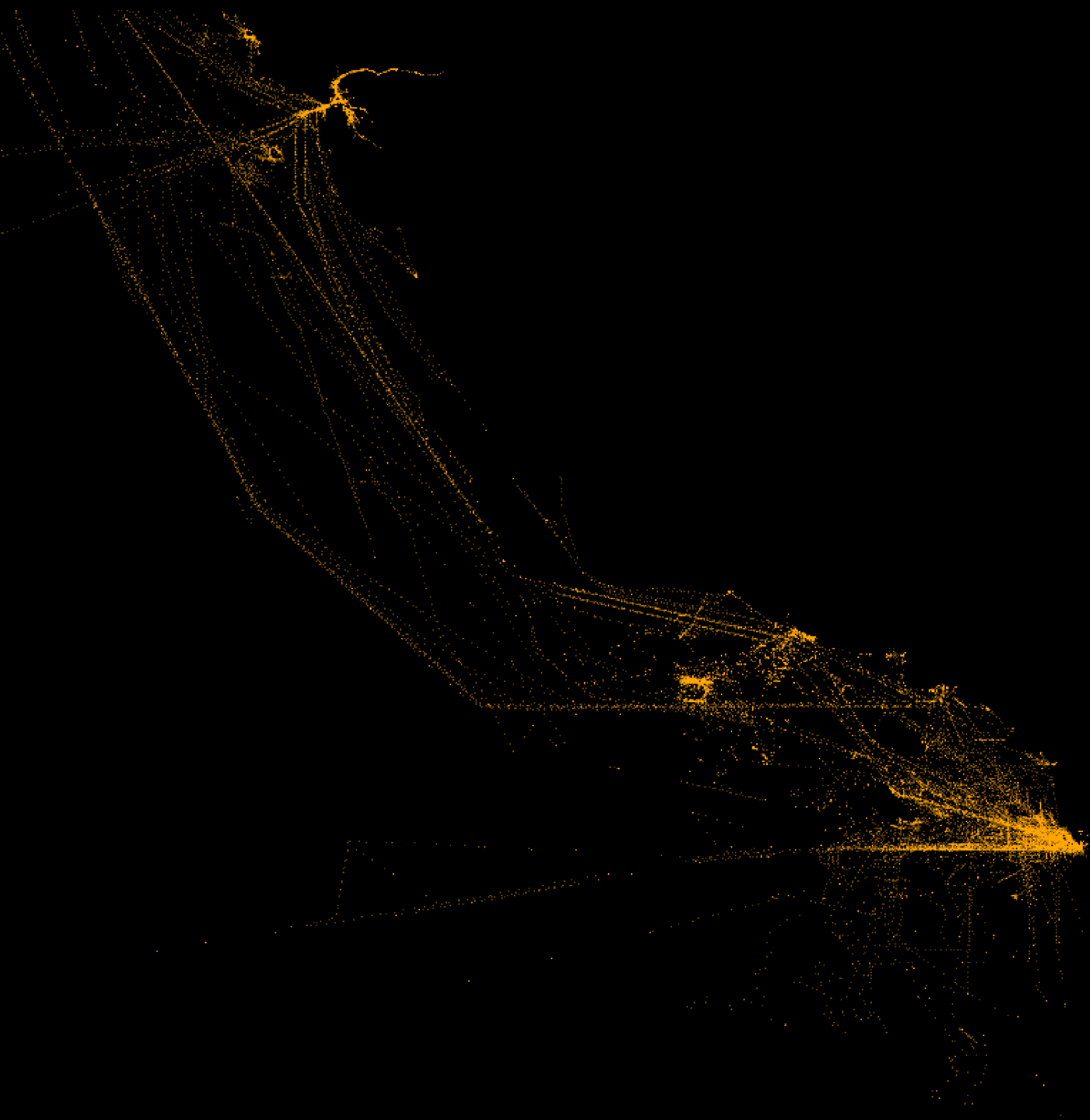
AIS: Cargo Ships
Nov, 2011

AIS Density Maps

Nov 2010-Dec 2011

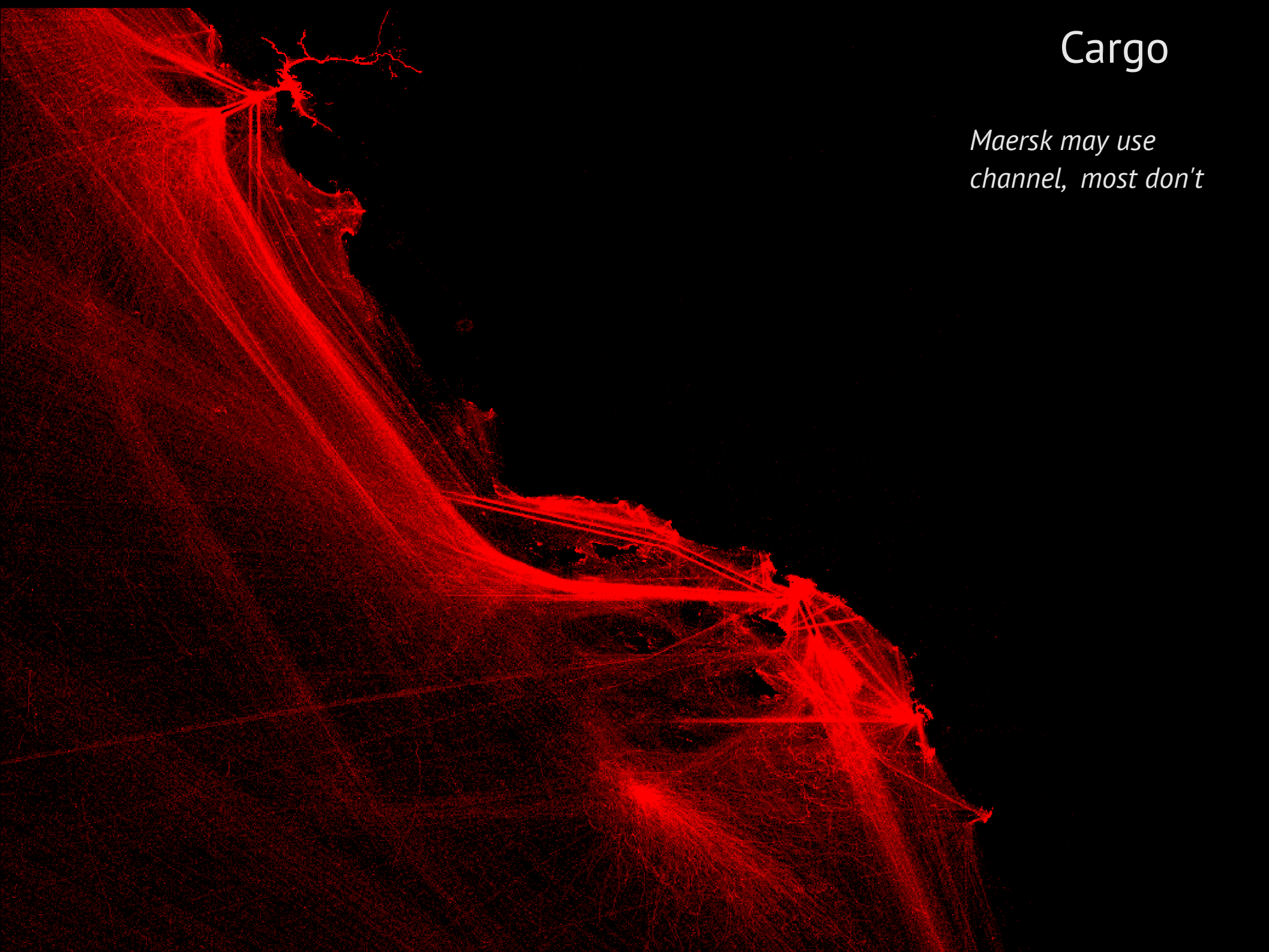


Authority

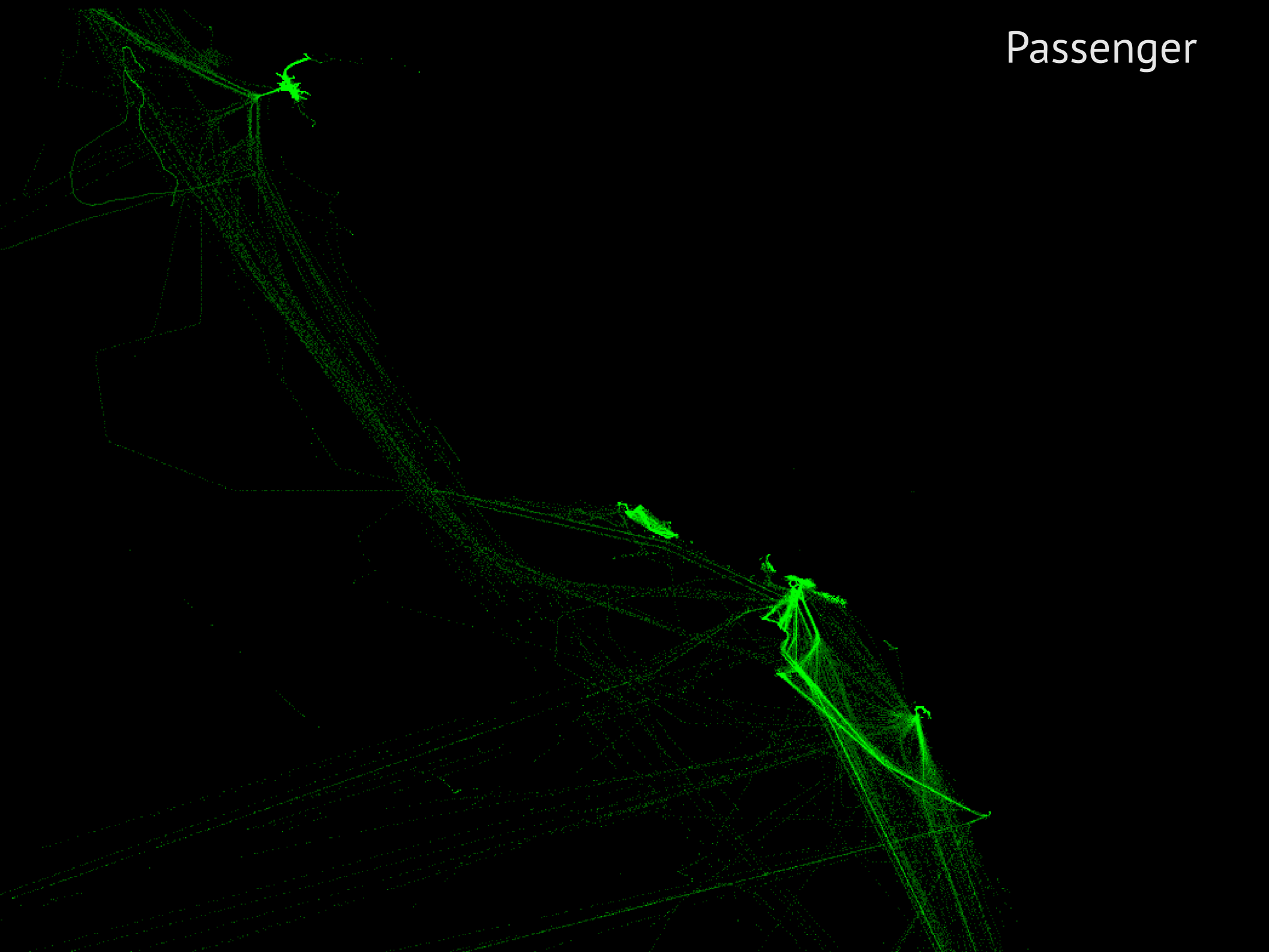


Cargo

*Maersk may use
channel, most don't*



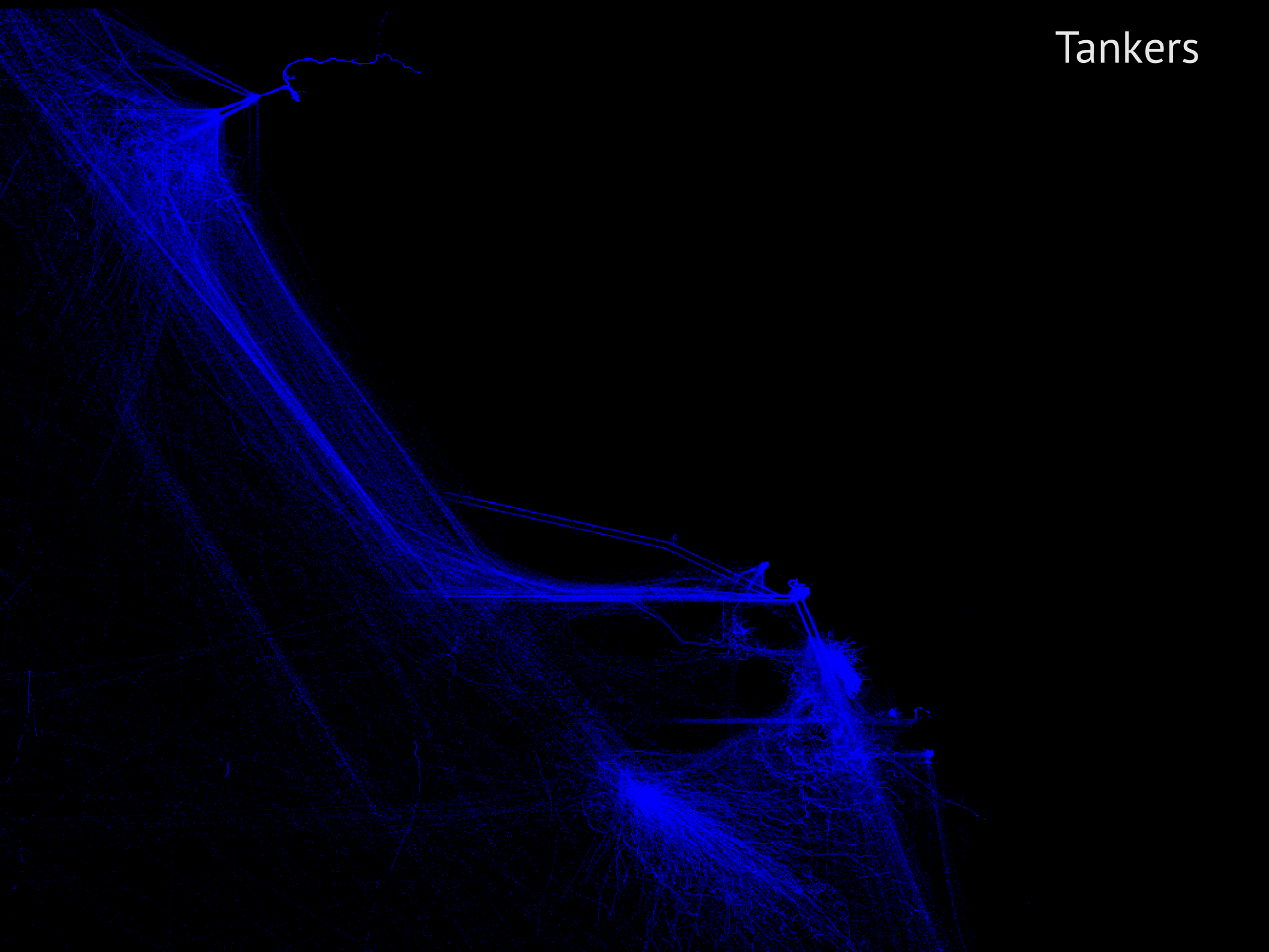
Passenger



Fishing

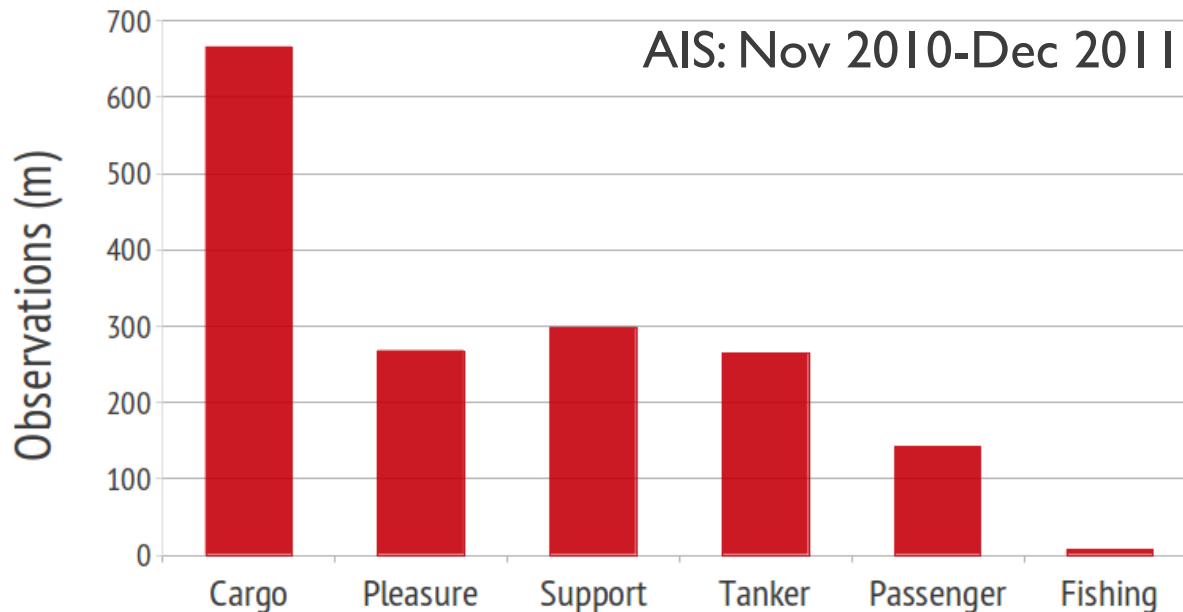


Tankers



Fused Data

- Observations (426 GB):
 - AIS: 2.37 Billion, 15 months, 2010-2011
 - VOS: 92.4 Million, 1991-2011
- Related data: 200,000 vessels, 5,000 ports
- Linkage of records across datasets



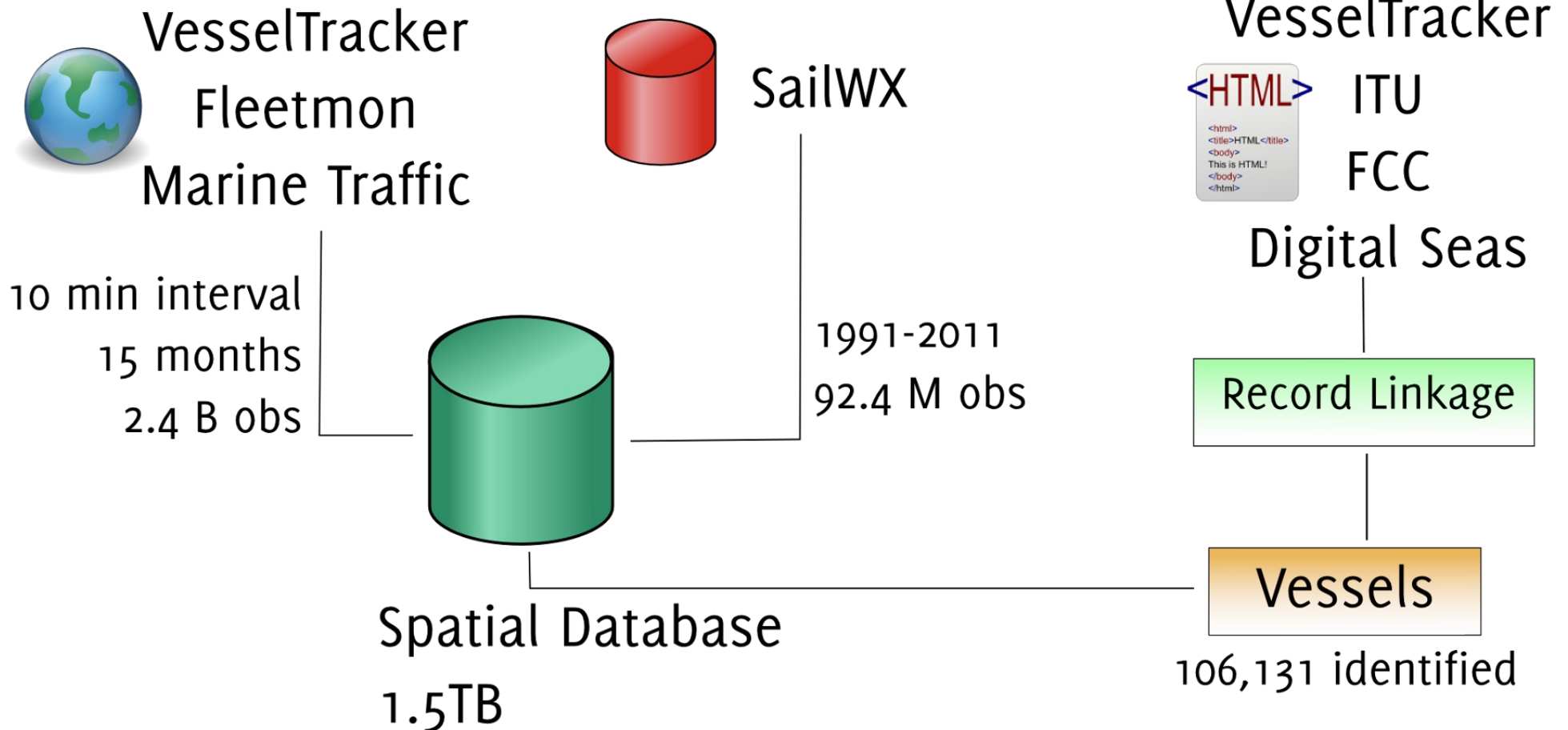
Data Fusion Workflow

Observations

AIS

VOS

Vessels



Ship Records

Want to know: which vessel is this? What kind?

Attributes useful for ecological questions:

Noise: engine type, length, type

Ballast: type, length

Strikes: Maximum speed, type, draft

Source	Code	Records	Cross-linked	Attributes
Digital Seas	DS	212166	68002	name, IMO, MMSI, callsign, type, width, length
FCC ¹ ULS ²	FCC	319964	24531	name, MMSI, callsign, class, gross gonnage, length
ITU ³ MARS ⁴	ITU	372183	75928	name, IMO, MMSI, callsign, class, owner, gross tonnage
VesselTracker	VT	126534	83372	name, IMO, MMSI, callsign, class, length

Ship Records

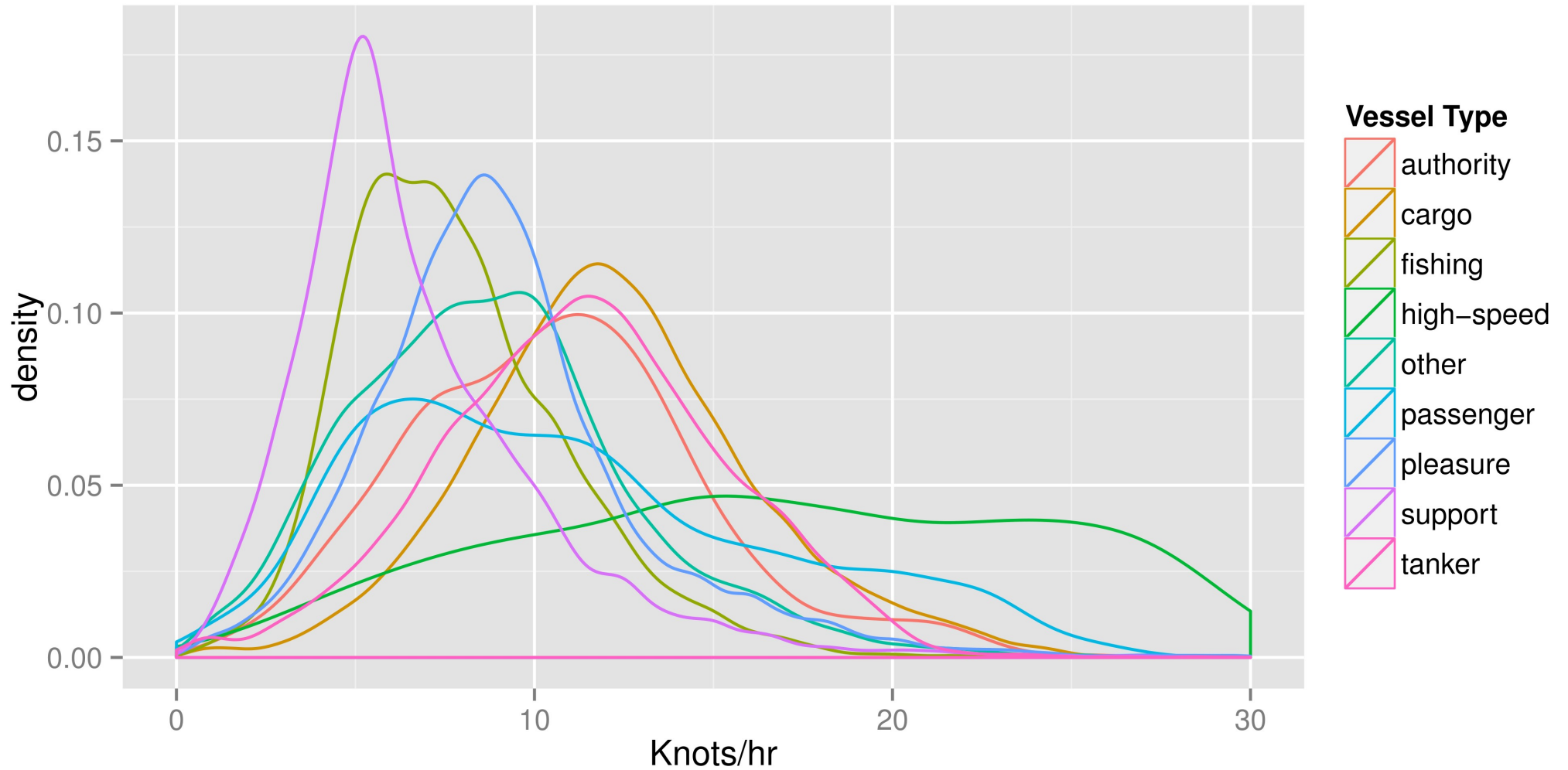
Record Linkage: Use fuzzy reasoning to cross-link records from differing sources

Probabilistic pairwise combinations between source pairs:

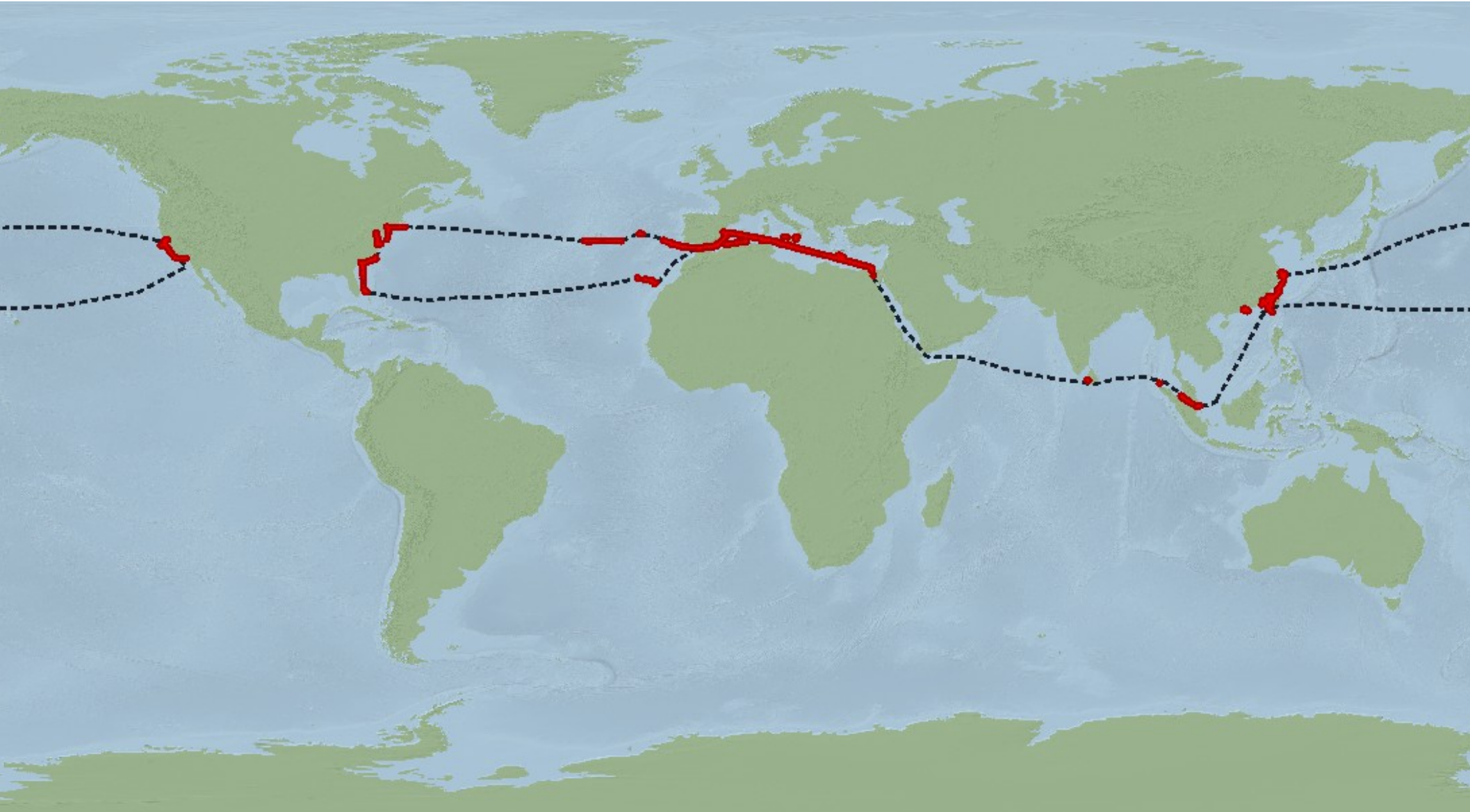
Comparison	Name	IMO	MMSI	Callsign	Type	Length	Confidence
A	MONIUSZKO	8513730	248623000	9HLM6	Cargo Ship	159	100
A	Moniuszko	8513730	248623000	9HLM6	Cargo Ship	159	100
B	ATLAS		372913000	3EVP4		190	93
B	Atlas	9222340	372913000	3EVP4	Cargo Ship	155	93

205,030 linked pairs. Merged pairs into validated individual vessels, AND link our observations to these records

Vessel Speeds by Type



Vessel Movement Models



Building individual ship tracks

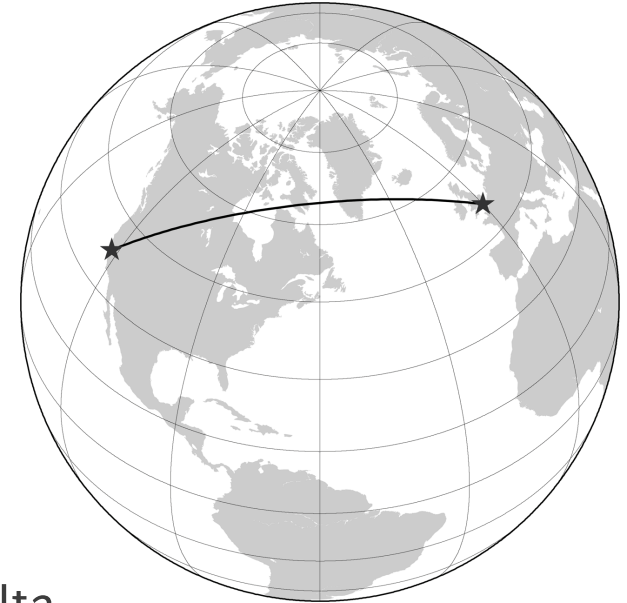
Track creation:

- geographic filtering
- great circle distances

Rasterization:



Merge by vessel type



Ship: PURKI

Country: Malta

IMO: 9004217

MMSI: 248495000

Callsign: 9HA2386

Length: 147m

Width: 26m

Type: cargo ship

Obs: 24225

Initial views

Density function:

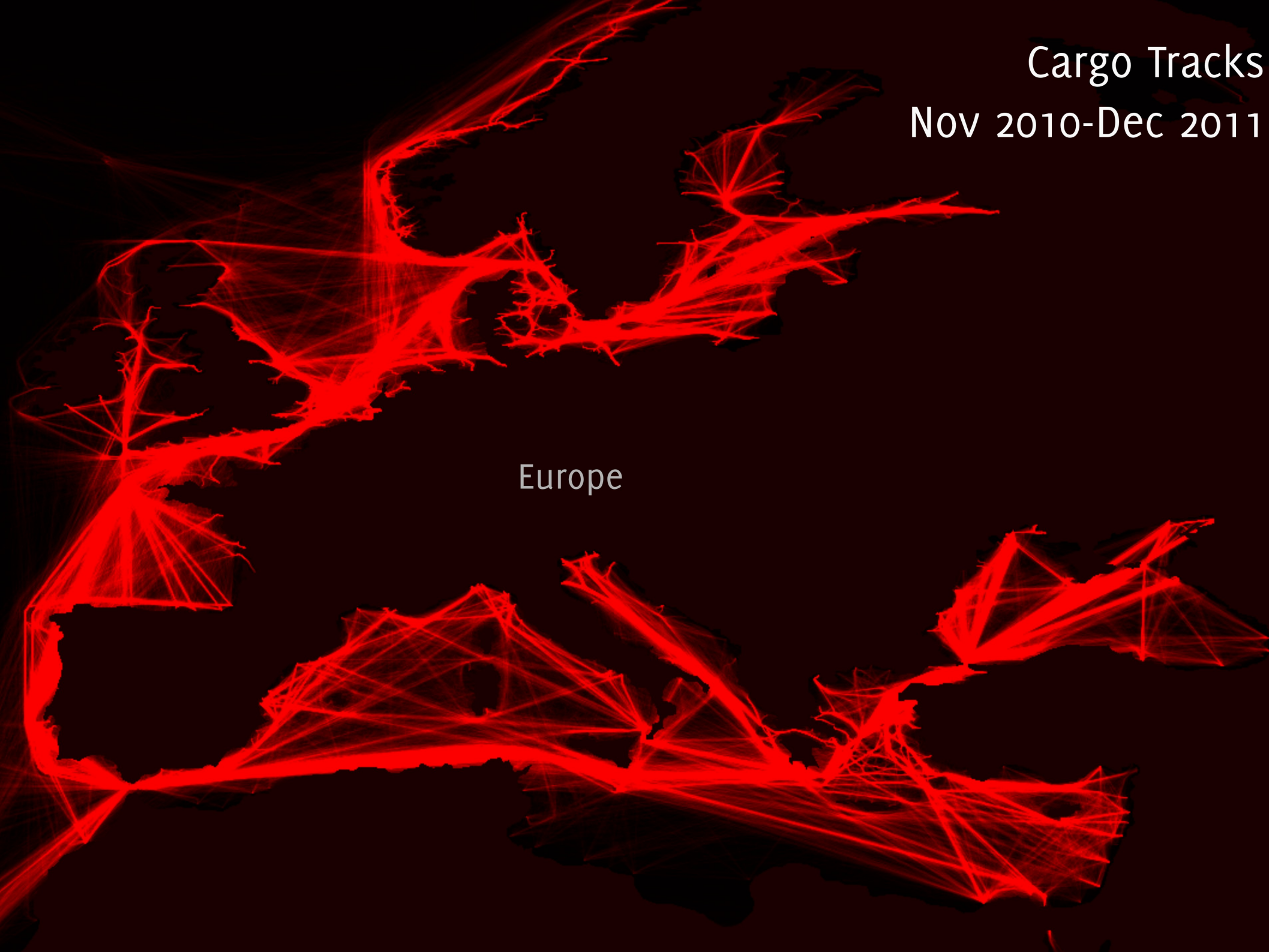
$$s = \frac{R_{AIS}}{\max(R_{AIS})} + \frac{R_{VOS}}{\max(R_{VOS})}$$

Speed:

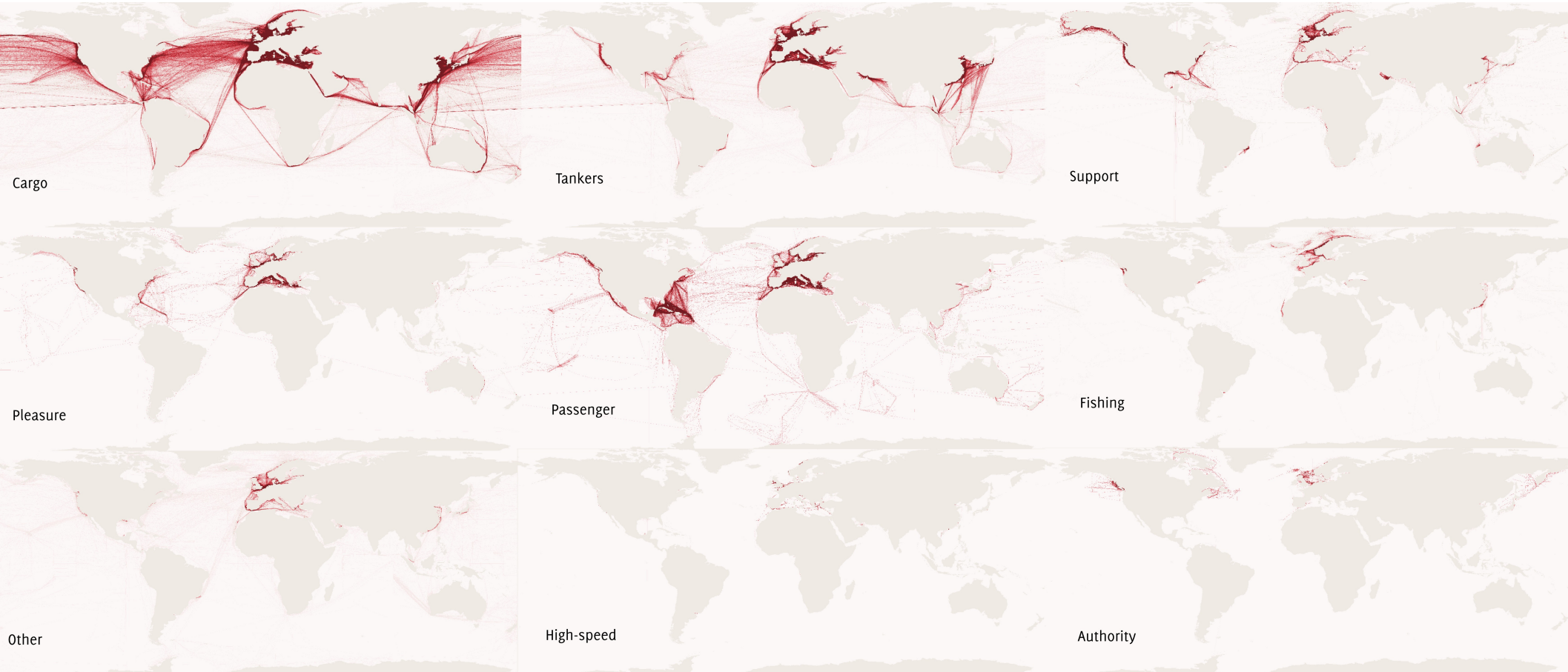
$$\bar{s} = \begin{cases} \frac{\sum_{i=0}^n s}{x} & s \geq 10 \\ 0 & s < 10 \end{cases}$$


Cargo Tracks
Nov 2010-Dec 2011

Europe



Vessel Densities by Type




A world map with a dark blue background. A network of high-speed rail lines is shown in a light blue color, primarily concentrated in Europe, Asia, and North America. The lines connect major cities and form a dense network in Europe and Asia. The text "High Speed {0..48}" is located in the bottom left corner of the map area.

High Speed {0..48}



Authority {0..60}

A world map with a dark background. Several regions are highlighted in a light blue color. These include parts of North America (USA and Canada), a large area in Europe and Western Asia, and parts of Africa and South America. The highlighted areas form a network across the globe.

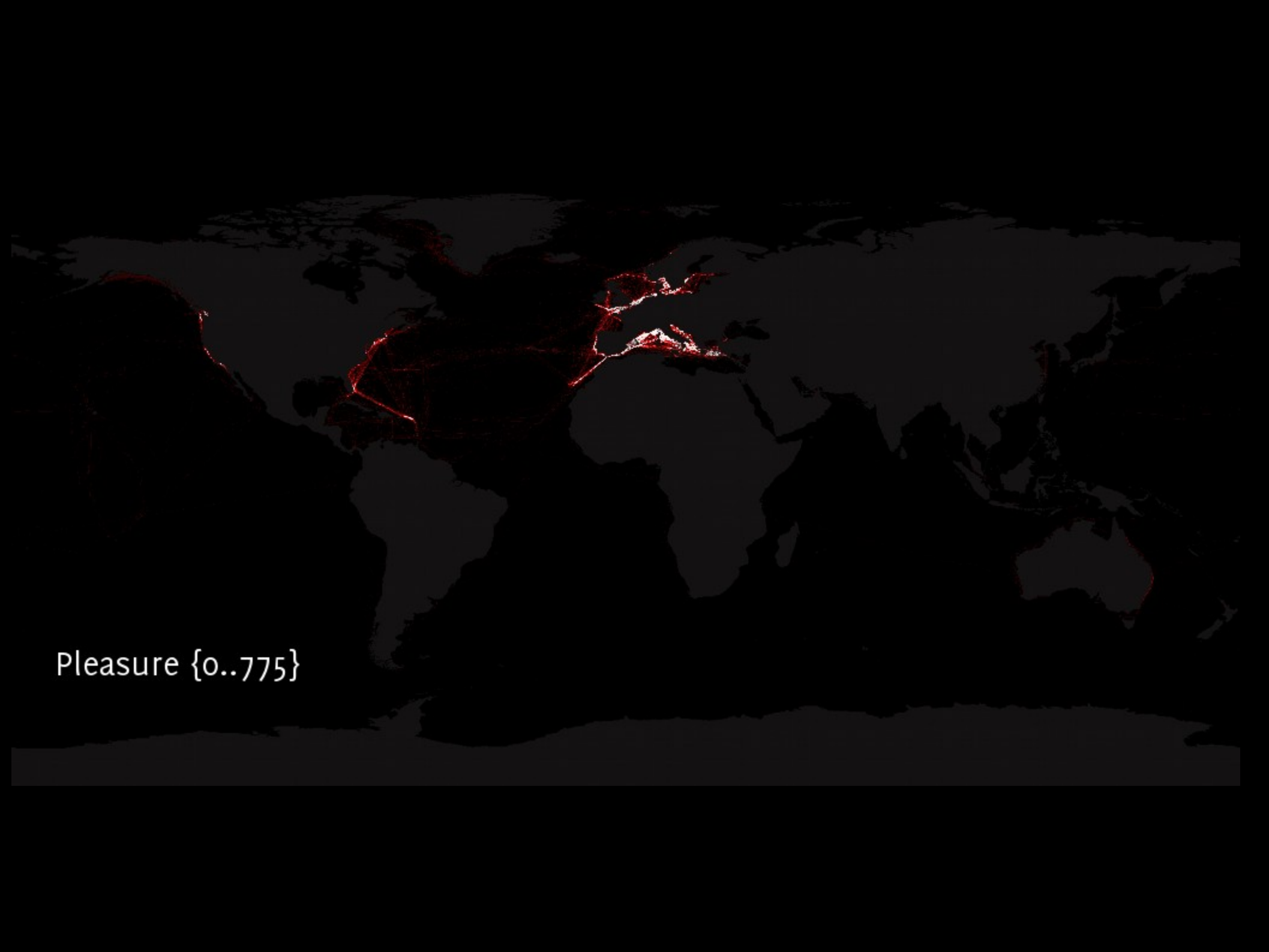
Other {0..1699}



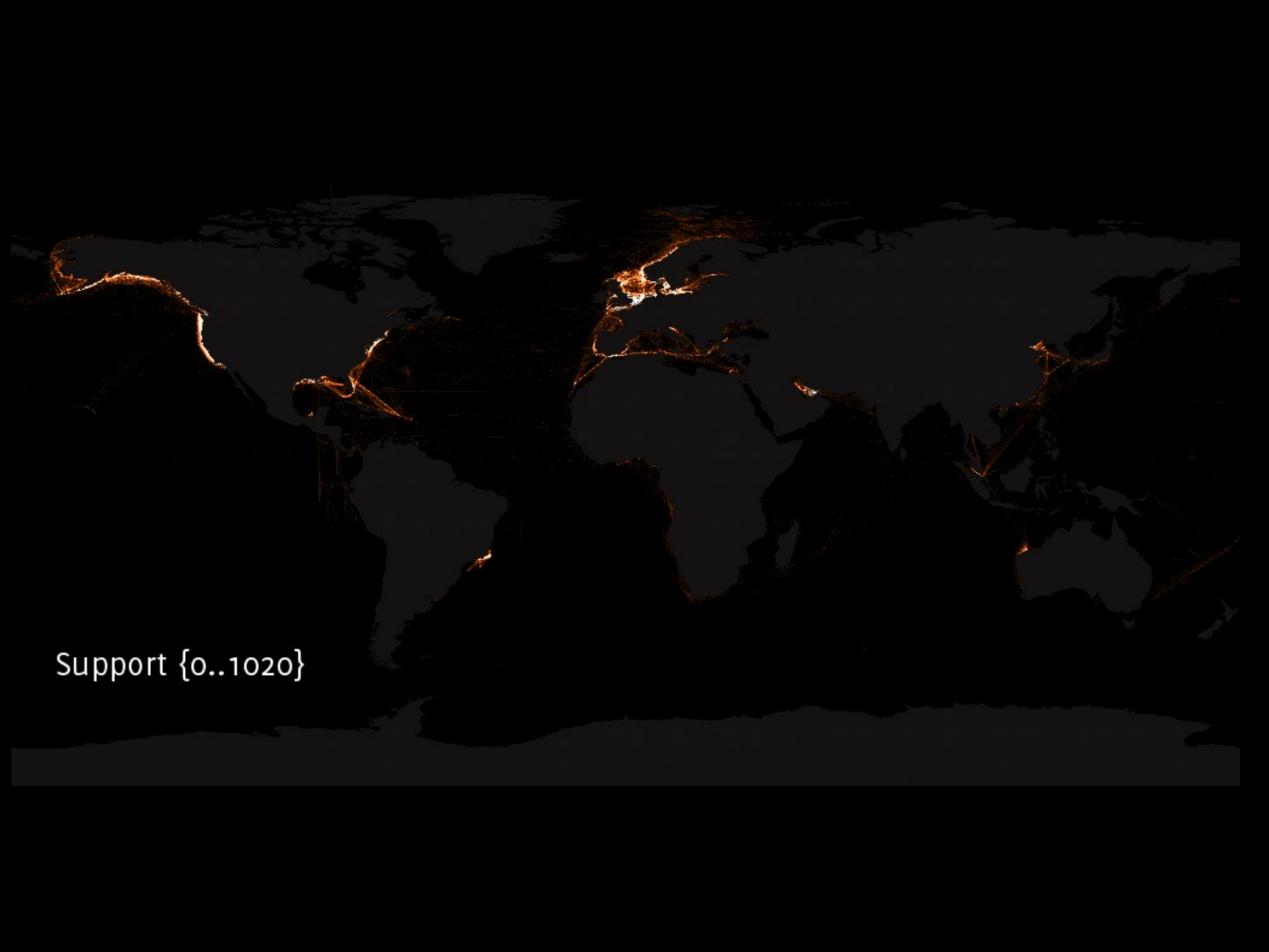
Fishing {0..455}



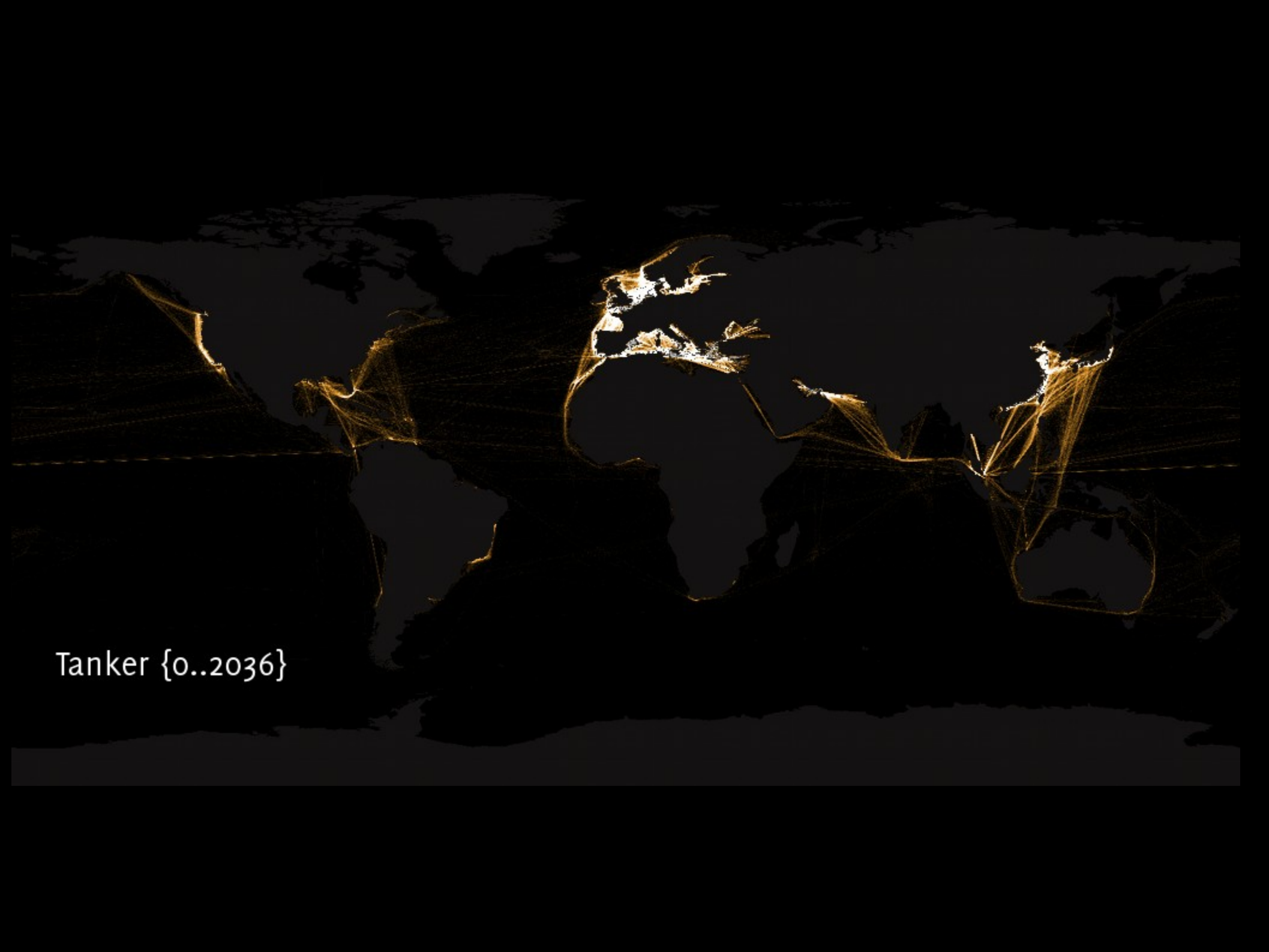
Passenger {0..226}



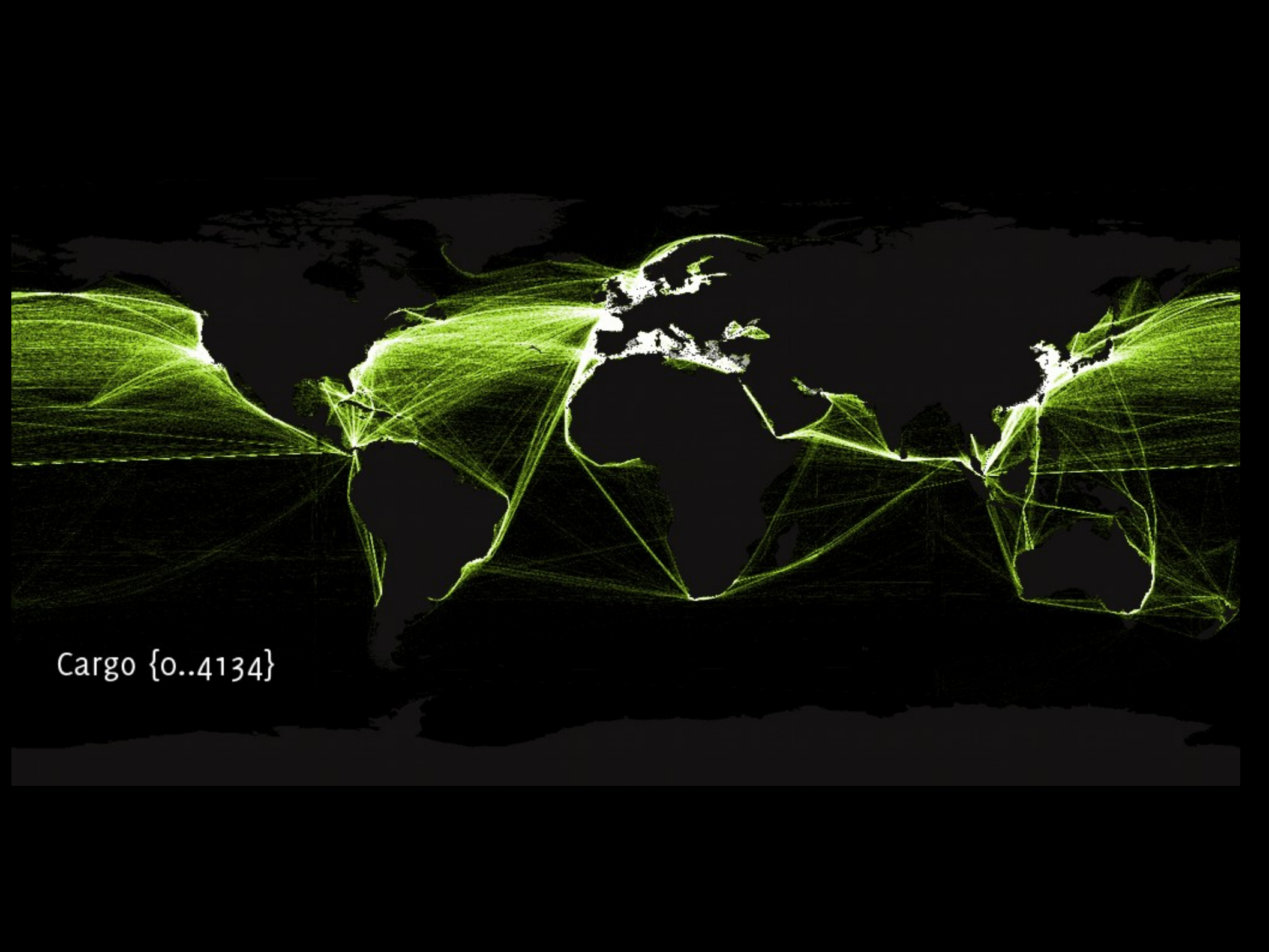
Pleasure {0..775}



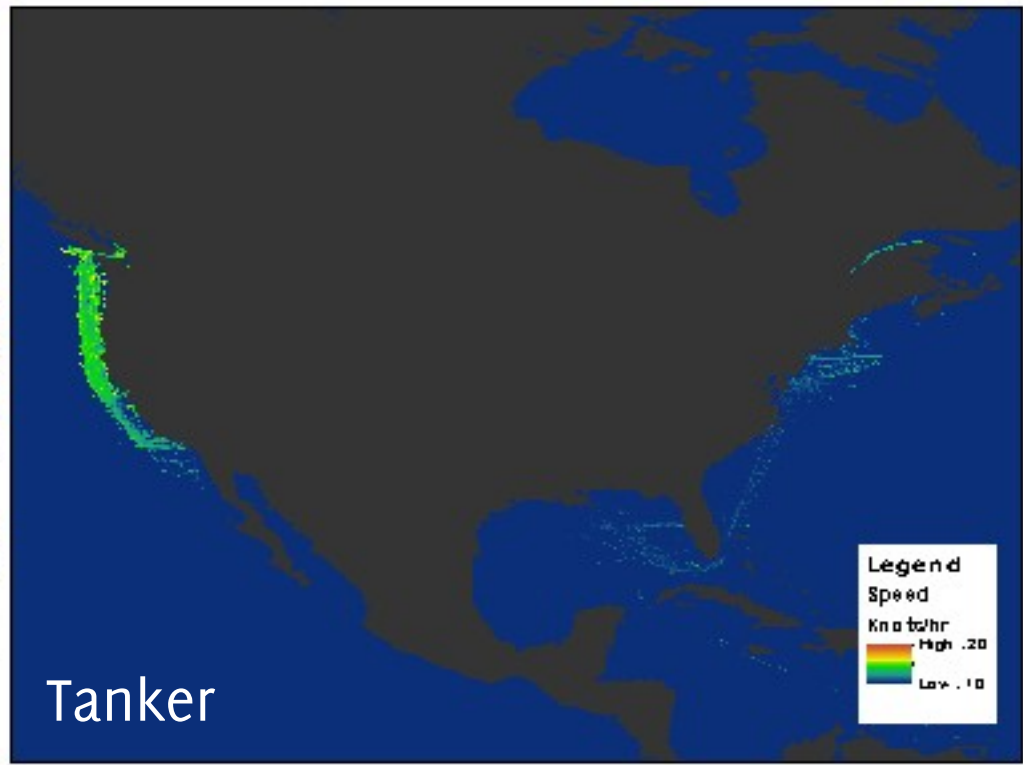
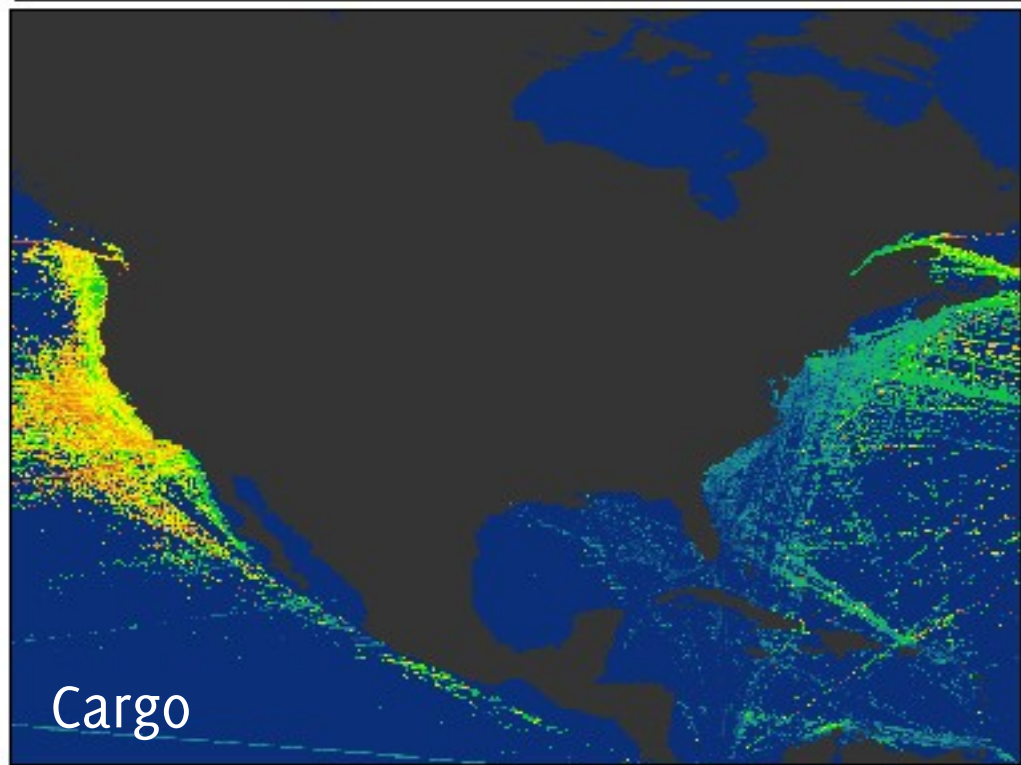
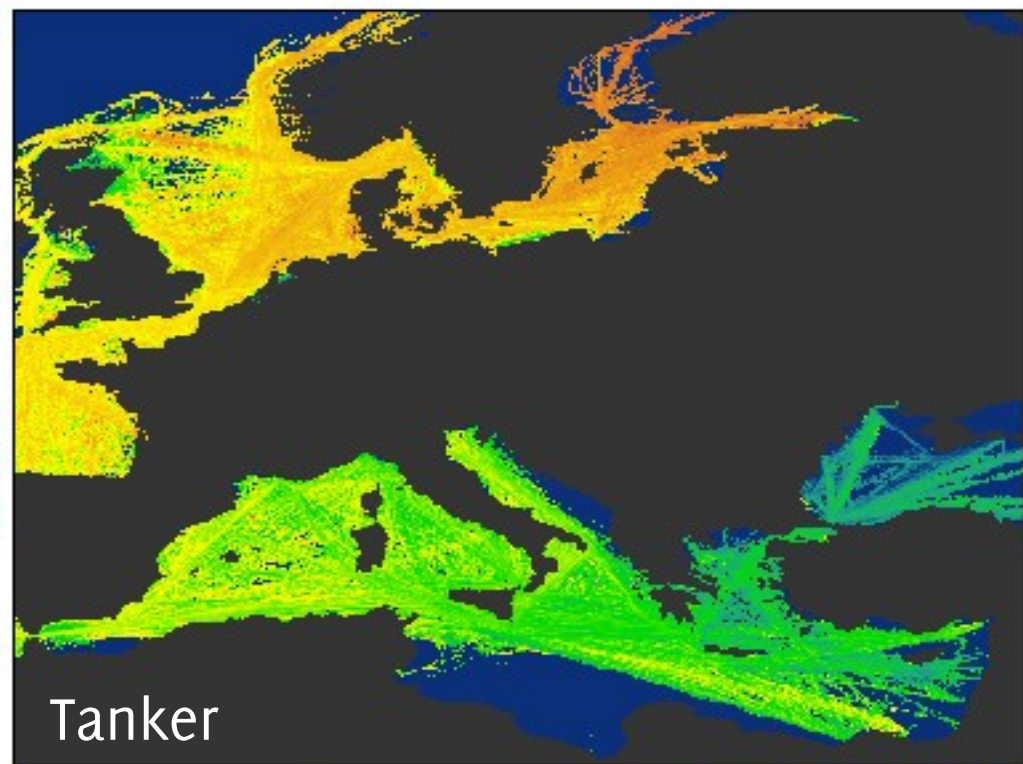
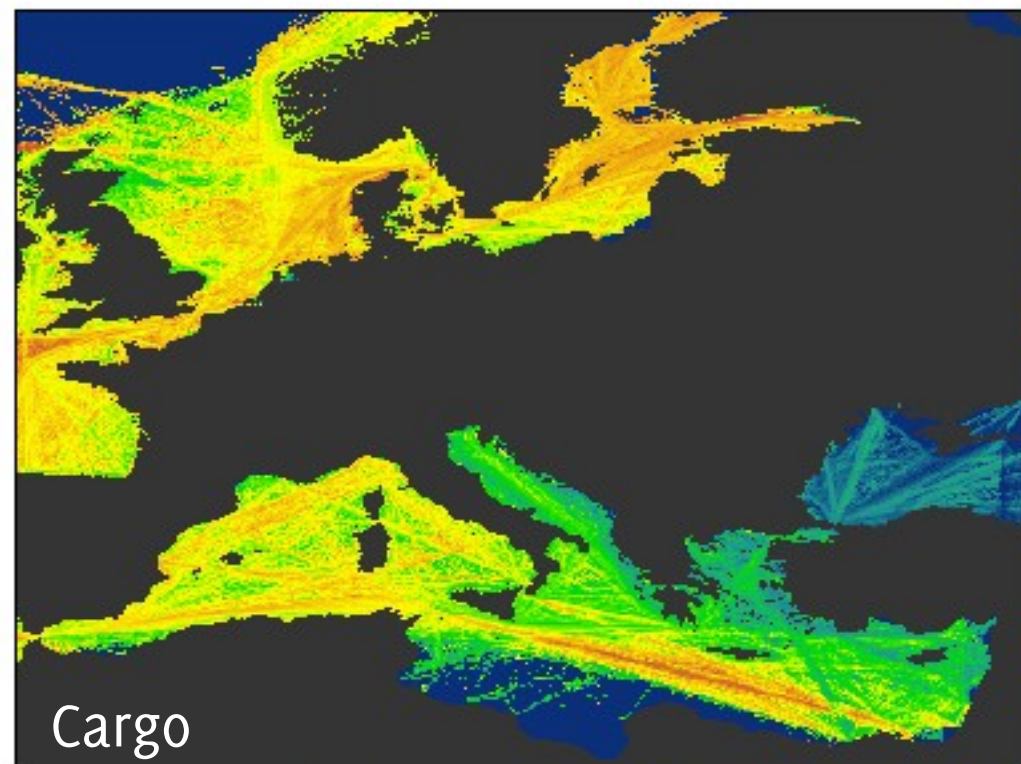
Support {0..1020}

A world map with a dark background, showing the outlines of continents. Overlaid on the map are numerous thin, glowing yellow lines representing shipping routes. These routes are most prominent in the North Atlantic, the Mediterranean, and the Indian Ocean, with many lines connecting major ports and shipping lanes. The lines vary in thickness, suggesting different volumes of traffic.

Tanker {0..2036}

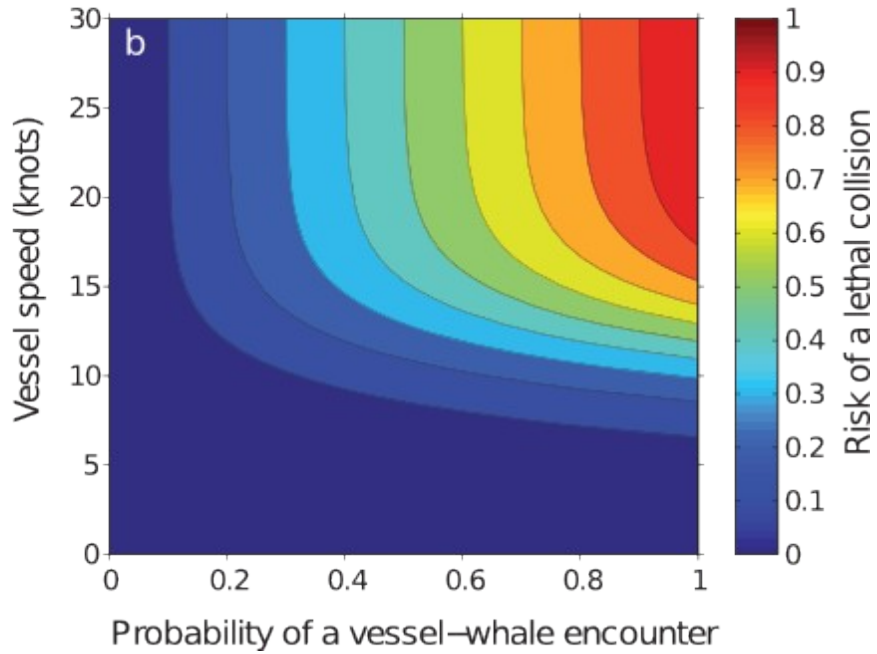


Cargo {0..4134}

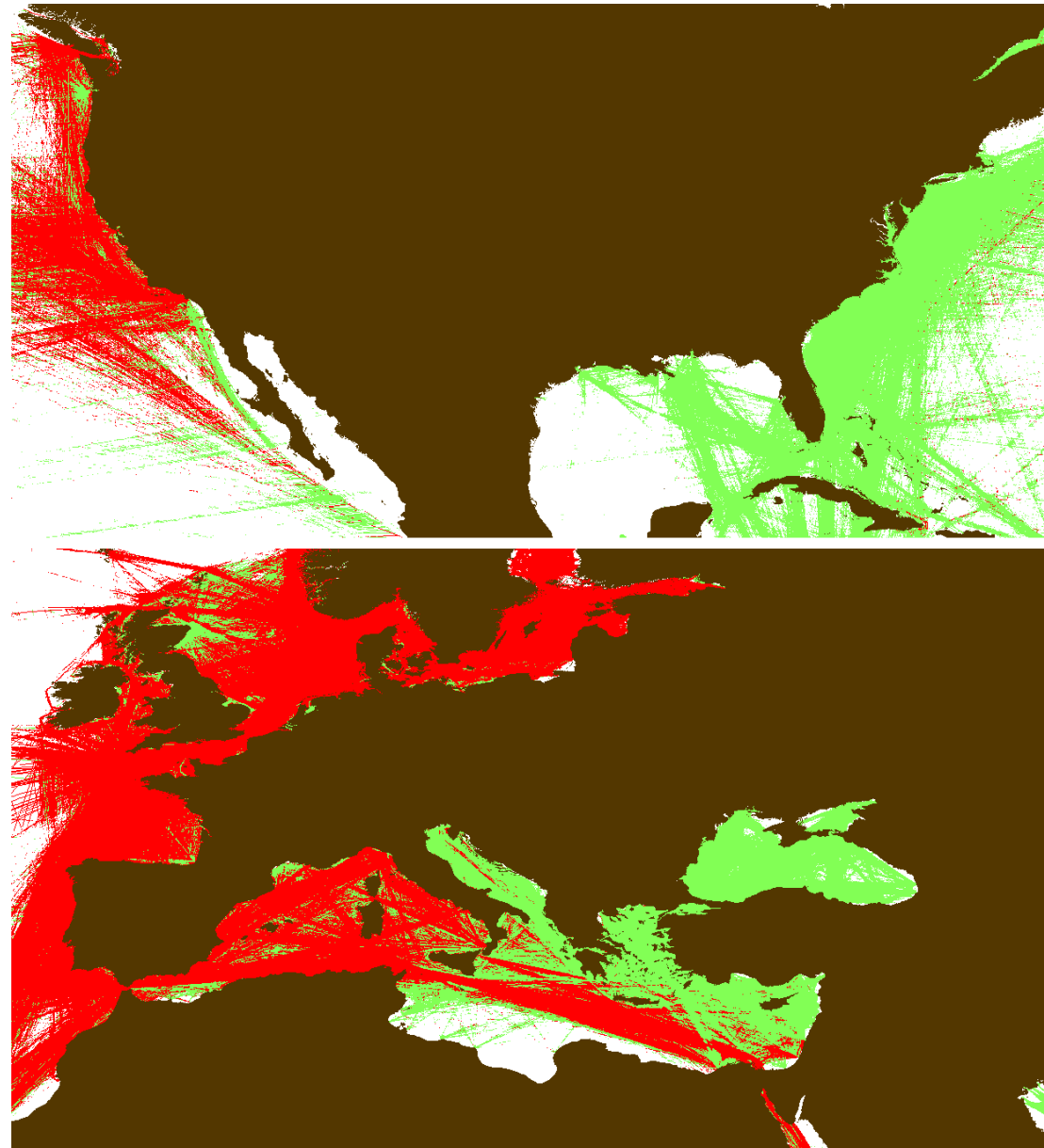




Ship Strikes



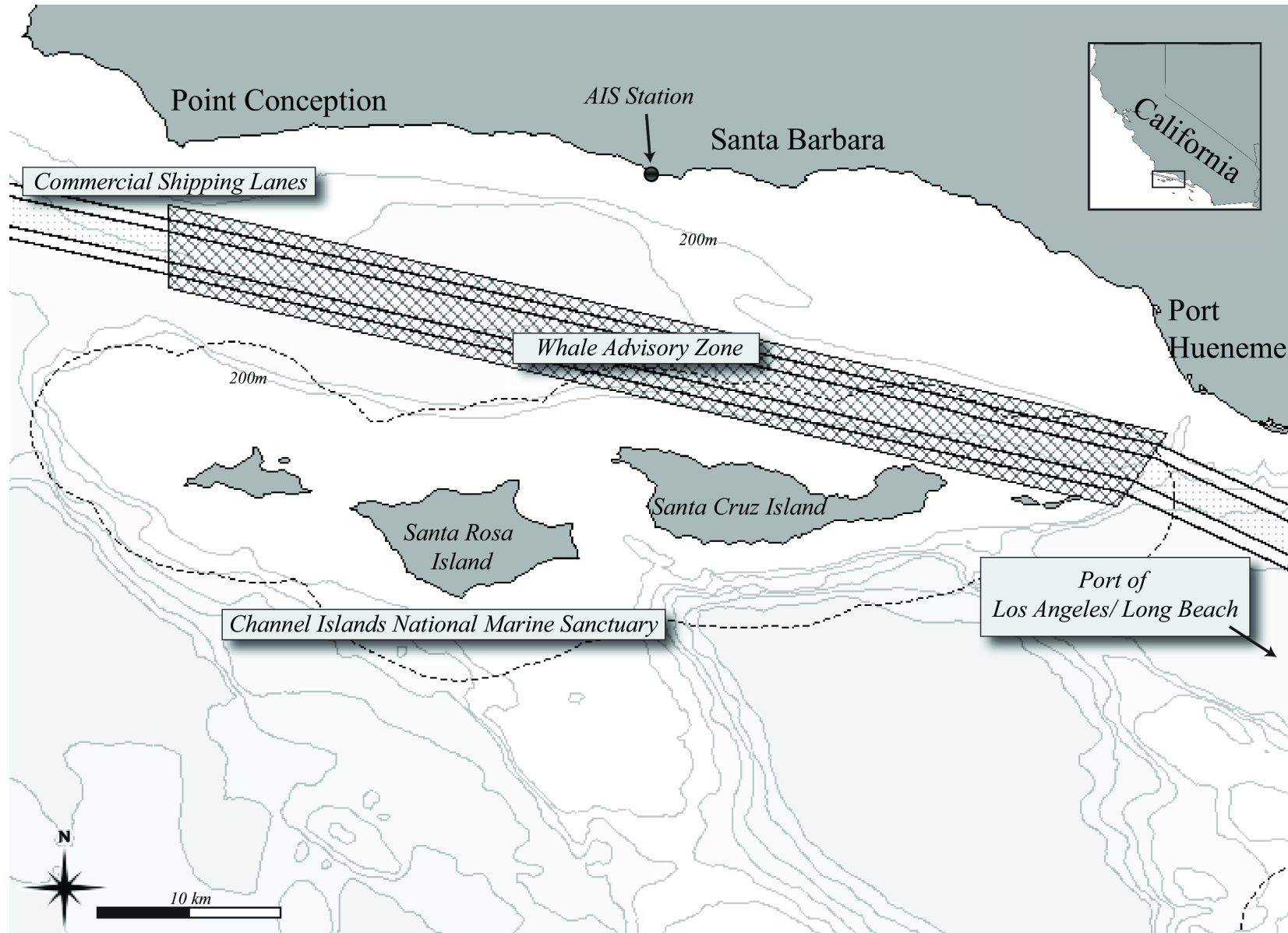
Vanderlaan et al. 2008



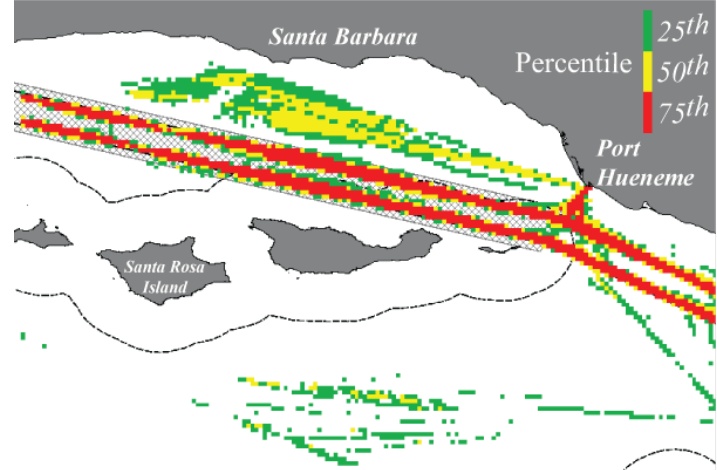
Cargo, Average speed: ■ ≥ 15 Kts ■ < 15 Kts

Response of Commercial Ships to a Voluntary Speed Reduction Measure: Are Voluntary Strategies Adequate for Mitigating Ship-Strike Risk?

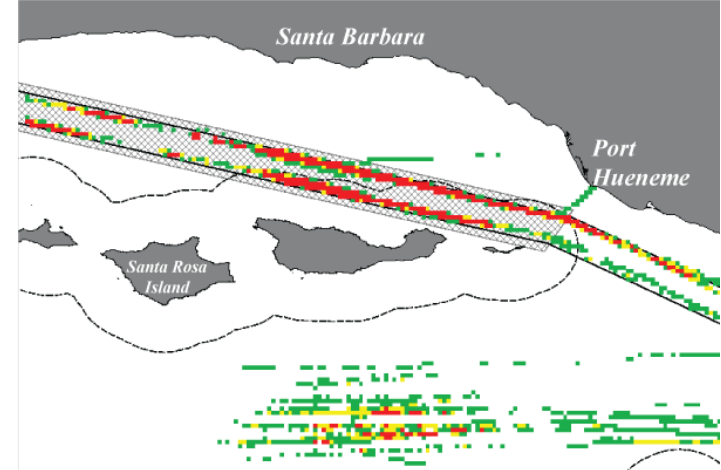
MEGAN F. MCKENNA,^{1,2} STEPHEN L. KATZ,³
CHRISTOPHER CONDIT,⁴ AND SHAUN WALBRIDGE⁵



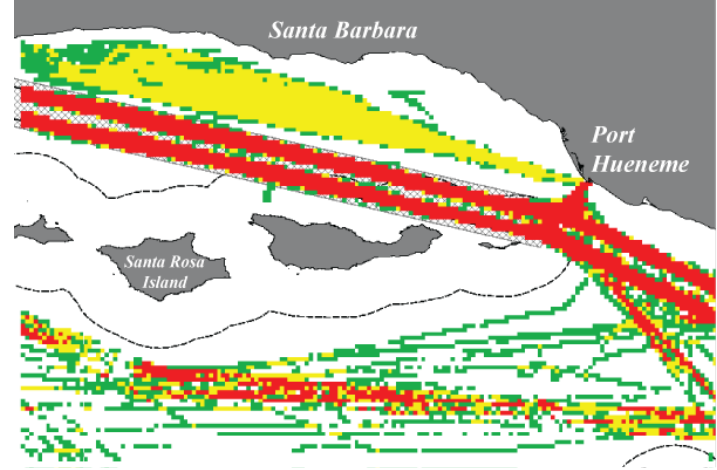
a) Cargo ships 2007 LNM (41 days, 331 ships)



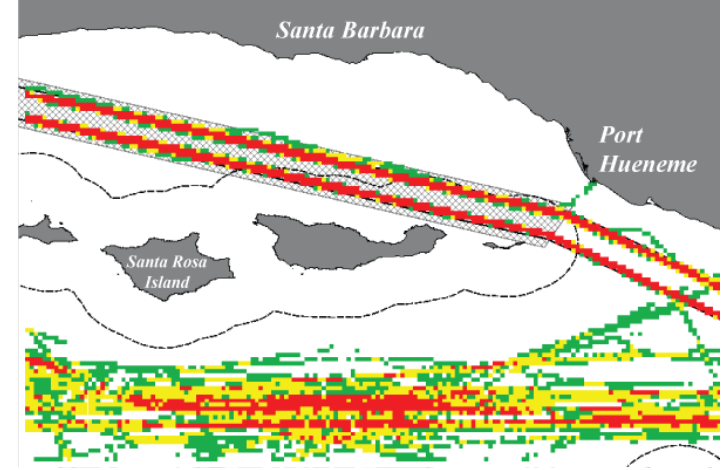
d) Tankers 2007 LNM (41 days, 36 ships)



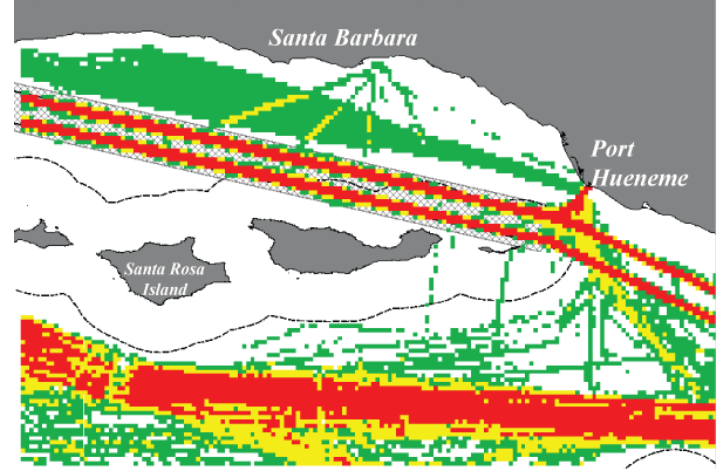
b) Cargo Ships 2008 LNM (159 days, 622 ships)



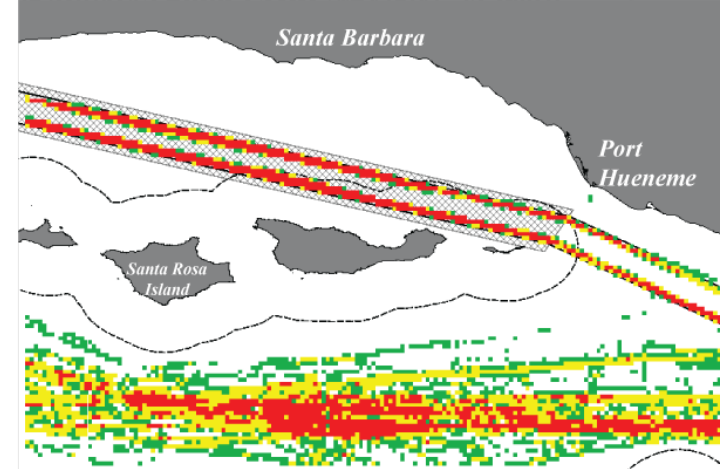
e) Tankers 2008 LNM (159 days, 82 ships)

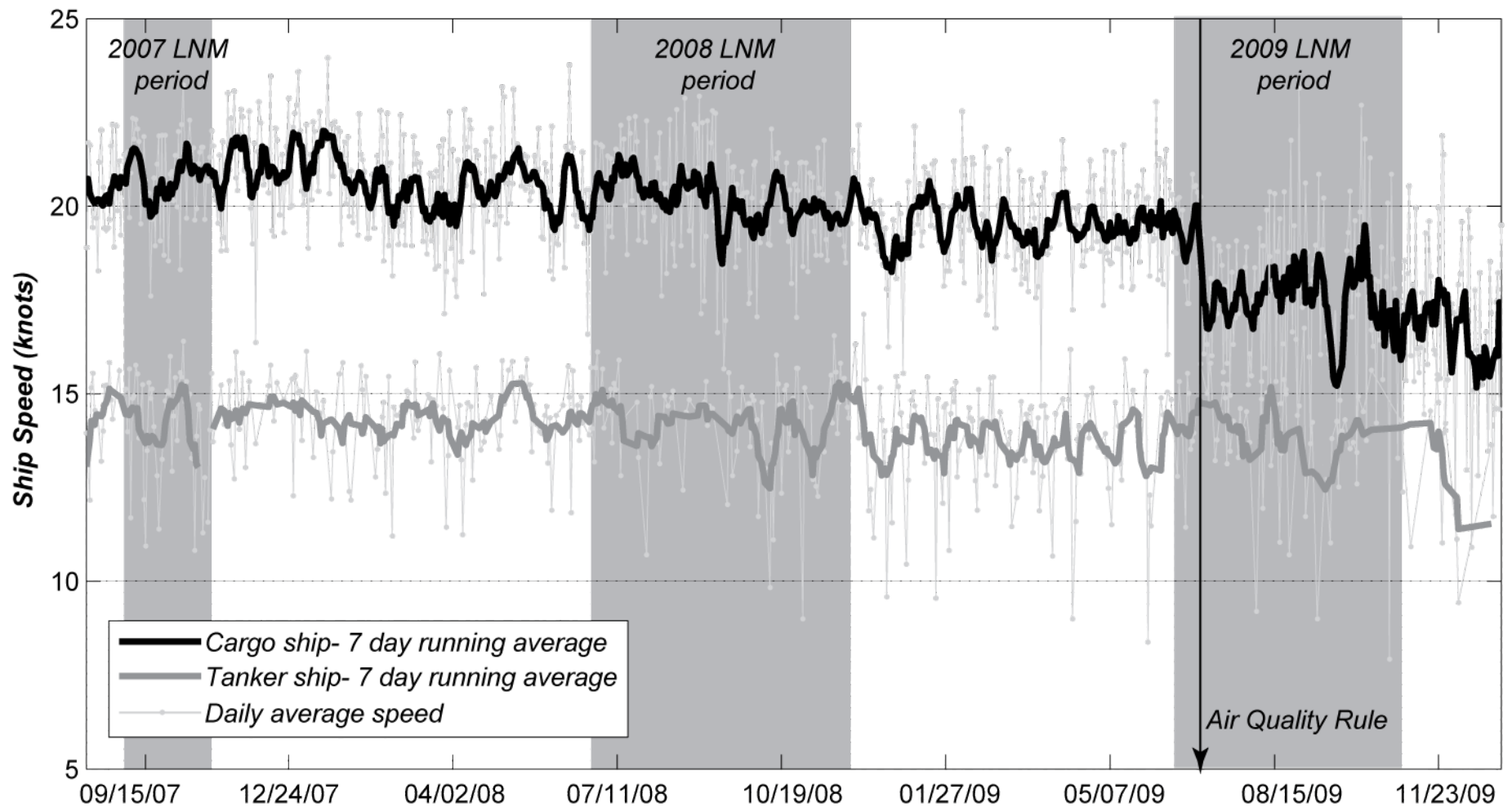


c) Cargo Ships 2009 LNM (141 days, 371 ships)

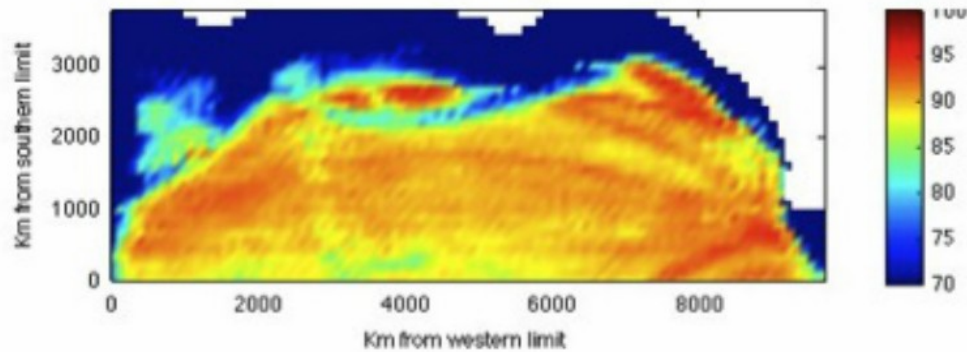


f) Tankers 2009 LNM (141 days, 58 ships)

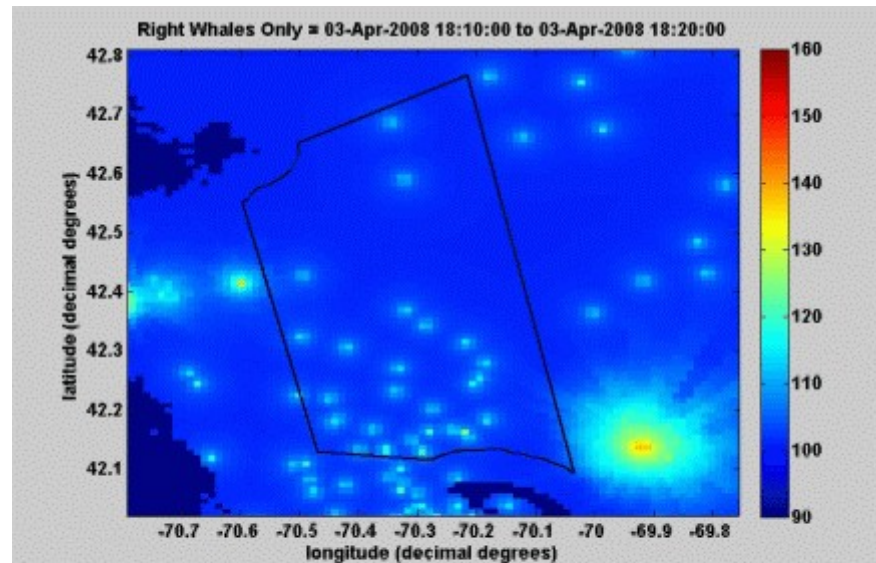




Noise Pollution: NOAA WG



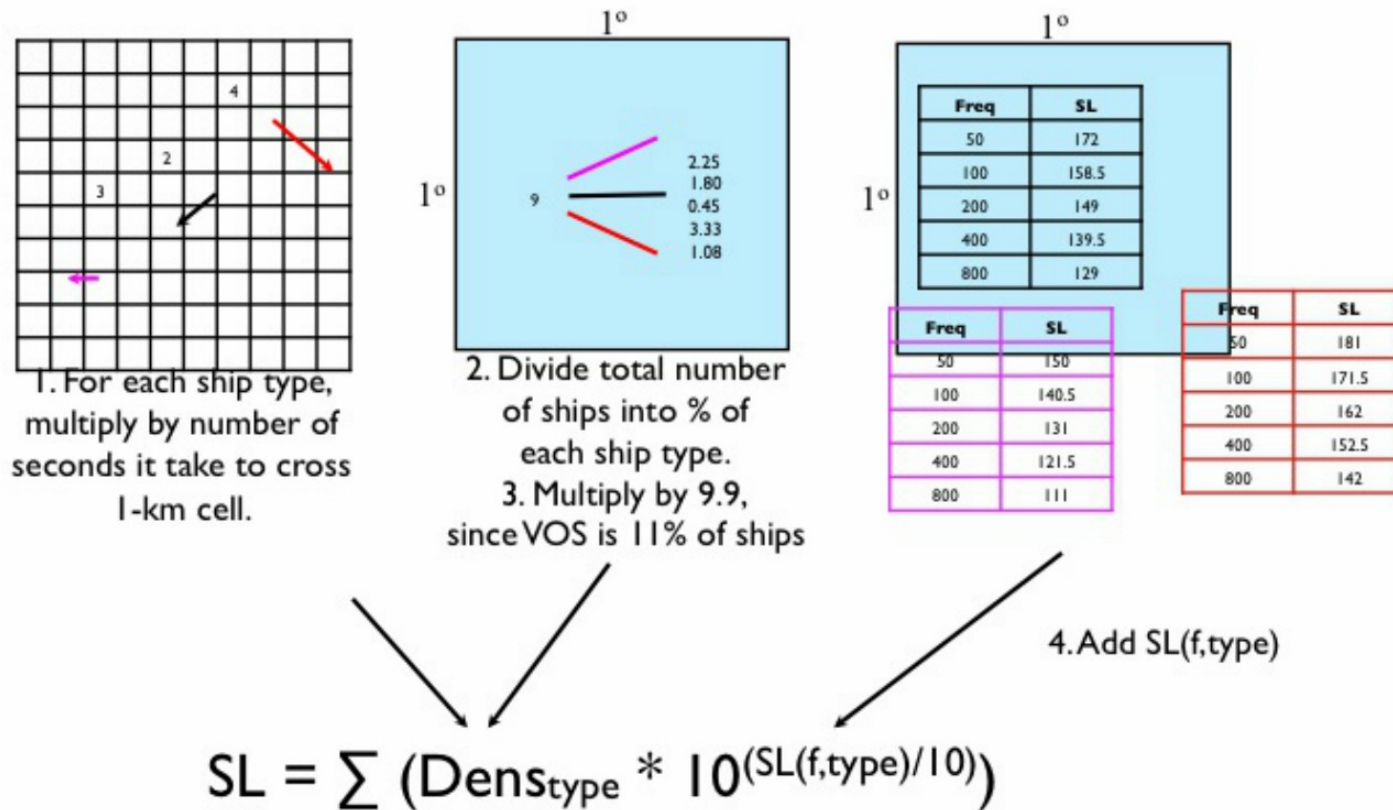
Noise Level (dB) at 50 Hz in the North Pacific with realistic environment and actual shipping



NOAA, Cornell Ornithology

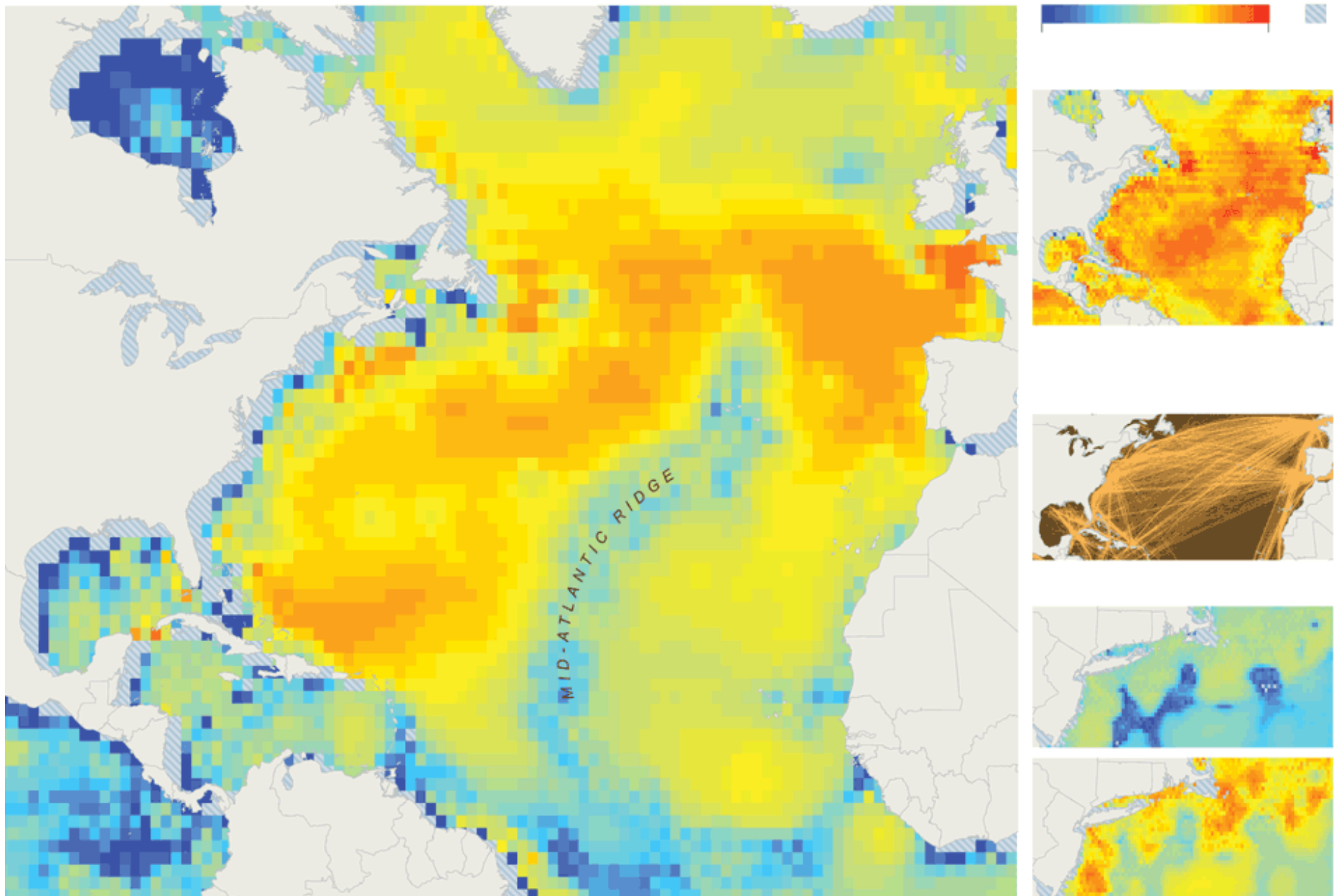
Noise Pollution: NOAA WG

Using Carrie's Percentages of Ship Types



Current model using VOS; next iteration can use the movement model discussed today

Noise Pollution: NOAA WG



New York Times, 2012-12-11
<http://nyti.ms/UxKuqK>

High Traffic Protected Areas



World Database on Protected Areas (WDPA):

- 7481 Marine
- Top 50 shown for traffic volume



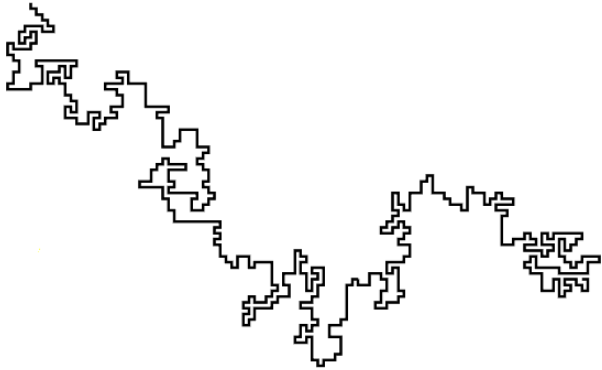
Ligurian Sea Sanctuary, 341d ago



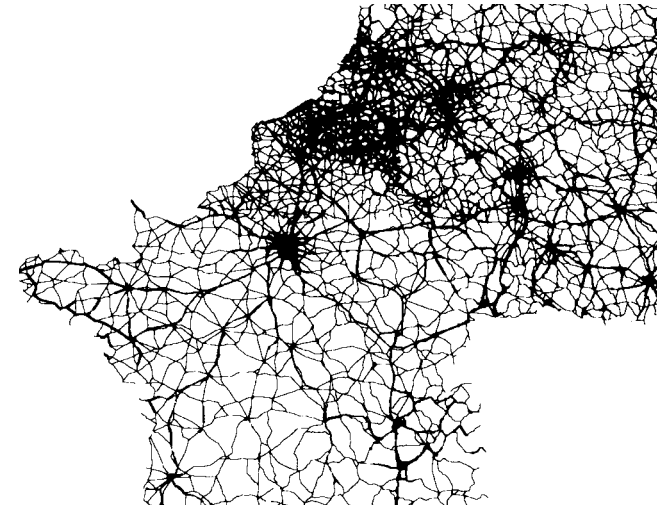
Image Credit: DigitalGlobe

Future Work: Simplification

- Many observations, can we simplify?
- Extremes of movement models:



2D Random Walk

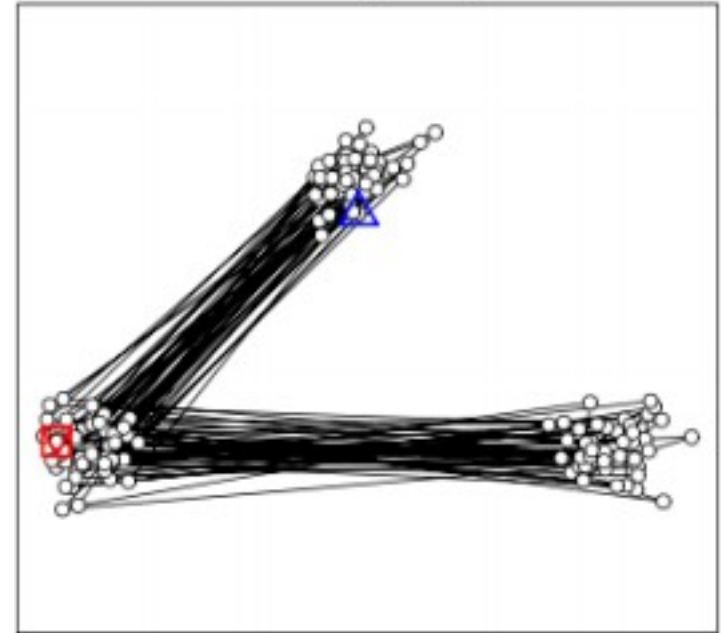


Constrained Network

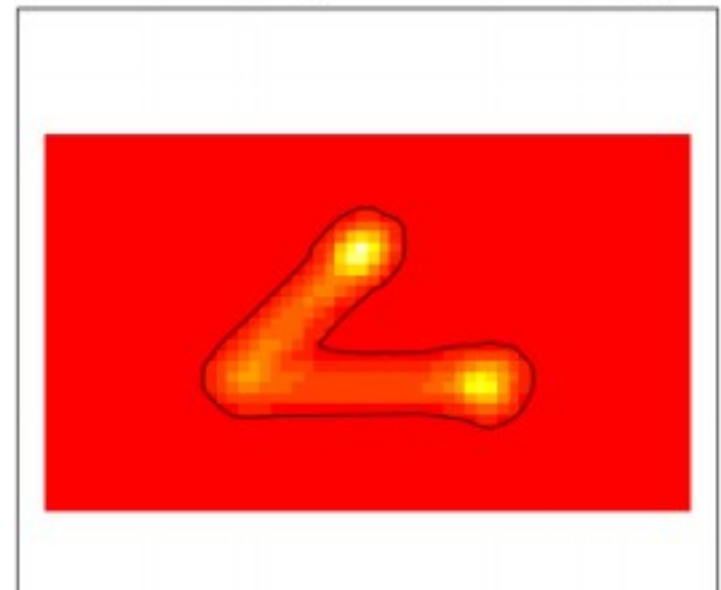
Shipping: attributes of both

Movement models

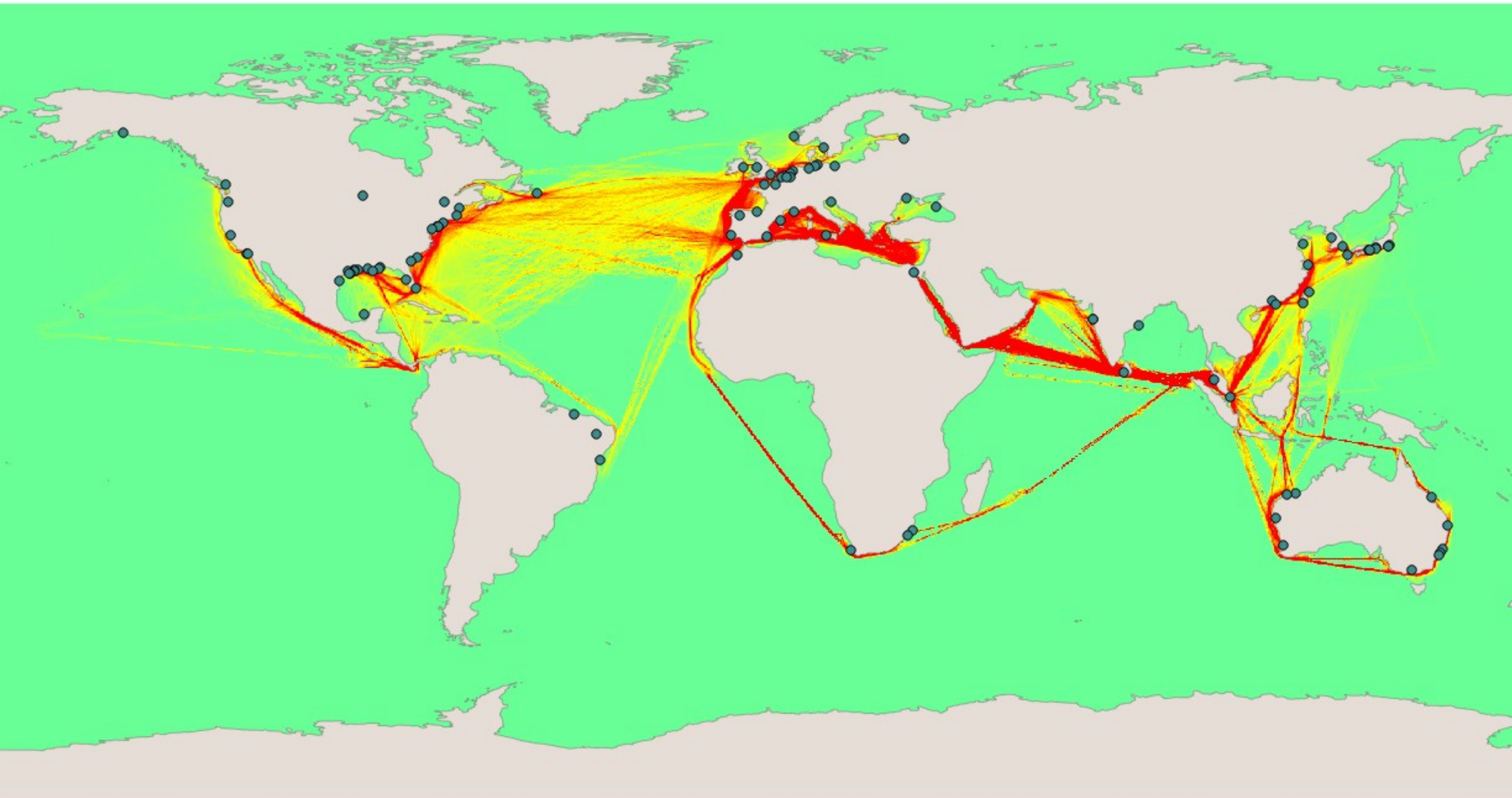
- Common in landscape ecology & geography
- Predict distributions and trajectories from limited observations
- Capture travel time and effort instead of assuming great circle distances



Brownian bridge kernel home range



Circuit-based movement model





Shipping as a geographic network

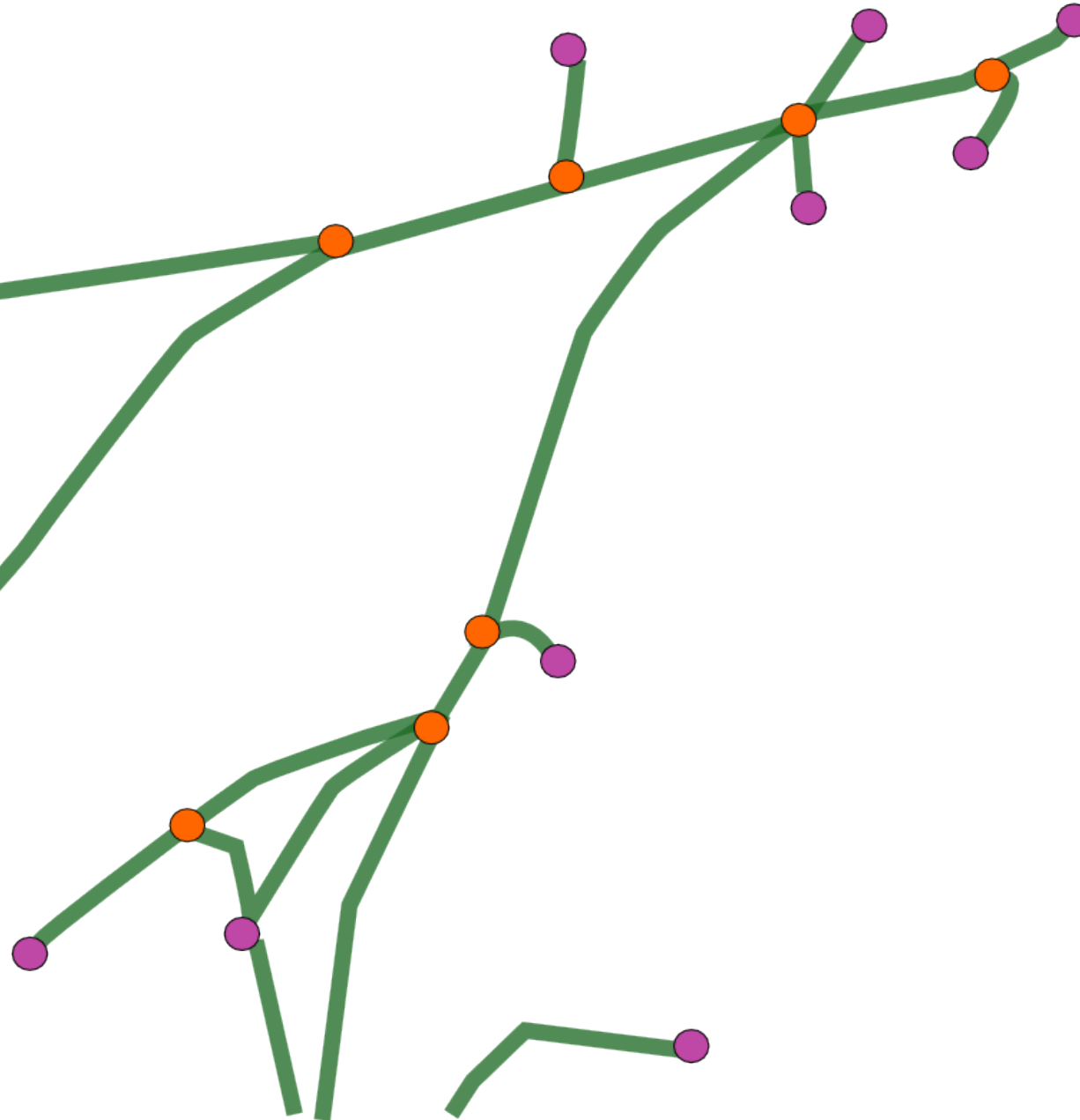
- Ports (nodes)
- Junctions (nodes)
- Paths (edges)

Edges:

travel time
ships traversed
economic cost
environmental cost?

With global routes:

evaluate permutations
apply per-unit pricing
based on ecological
knowledge



An aerial photograph of a coastal town and harbor. In the foreground, a large white cruise ship with multiple decks is sailing on the blue water. The harbor is filled with many smaller boats and a pier. The town is built on a hillside, and in the background, there are large, rugged mountains under a blue sky with some clouds.

Thanks

NCEAS

The Gaines Lab

Jennifer Balch, Ben Best,
Ben Halpern, Carrie Kappel,
Steve Katz, Megan McKenna,
Jessica Phillips, Jai Ranganathan,
Oliver Soong, Dawn Wright