Assessing Ship Movements Using Volunteered Geographic Information

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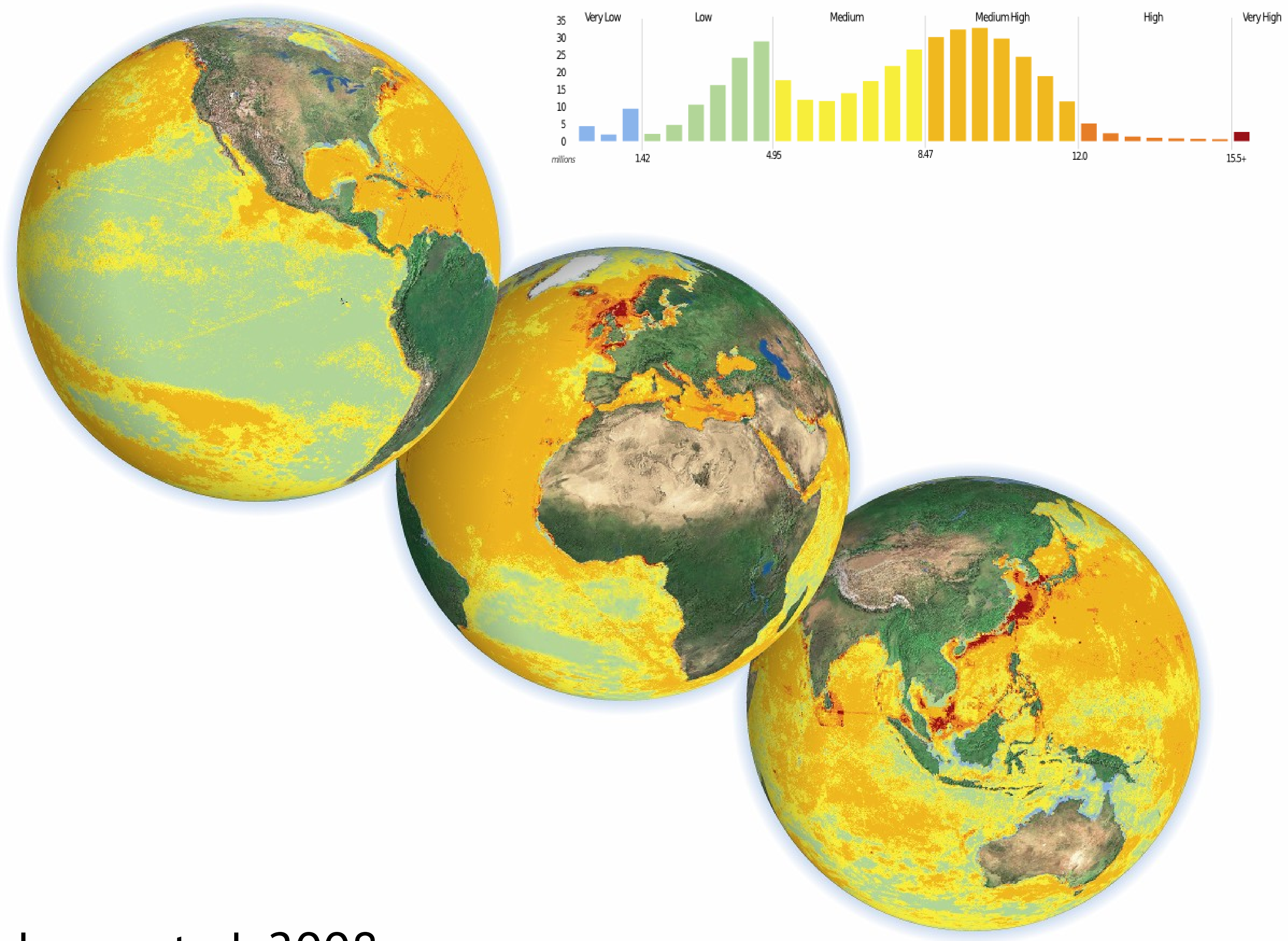
age Credit: Mike Baird,
ckr.com/photos/mikebaird

Goals

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



Halpern et al, 2008

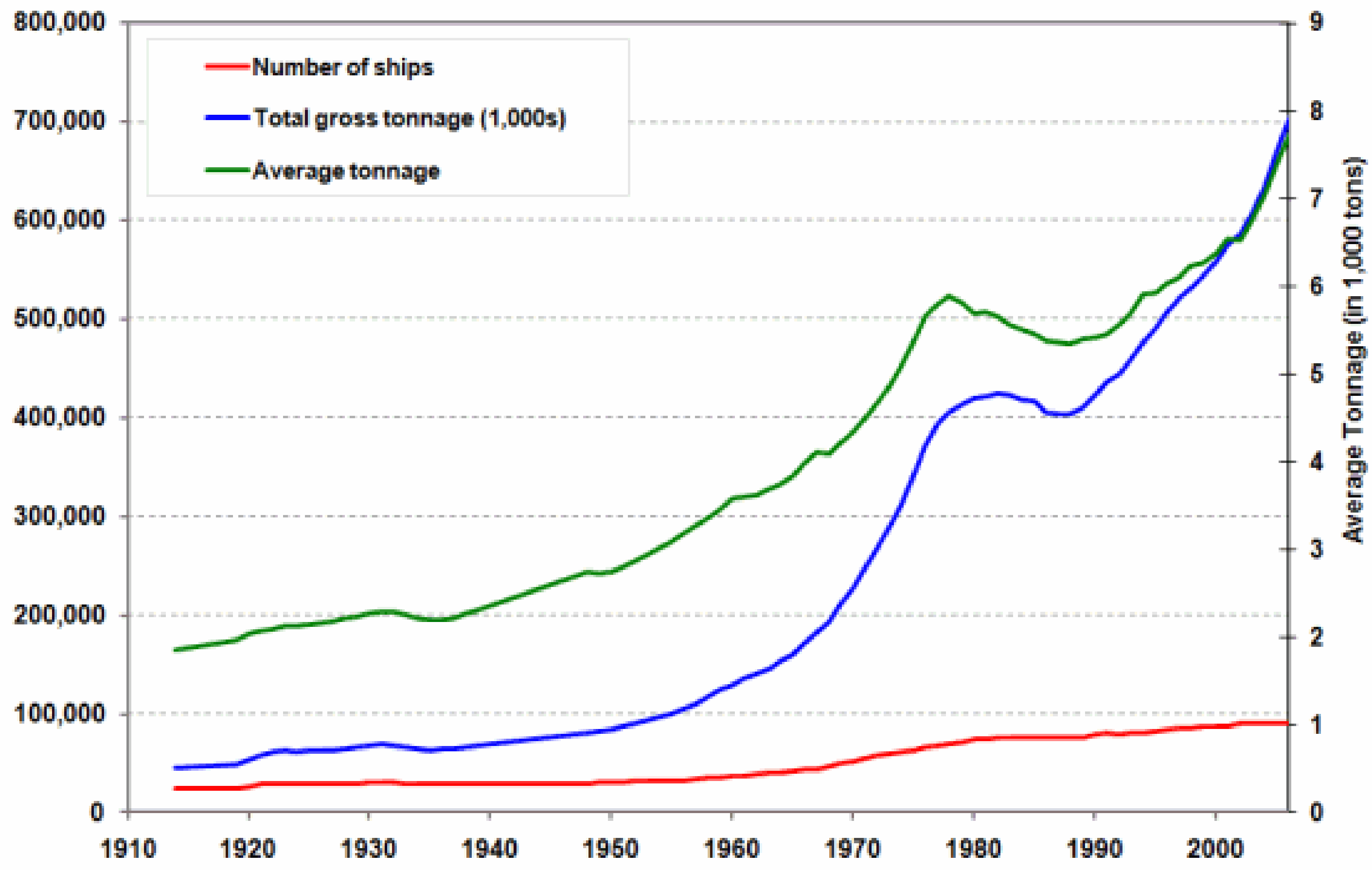
The largest cumulative impacts:

Climate Change

Fishing

Shipping

Maritime Trade



90% of global trade volume

$1.8T of goods in '08

Baltic Dry Index a leading economic indicator

Data is valuable ($)

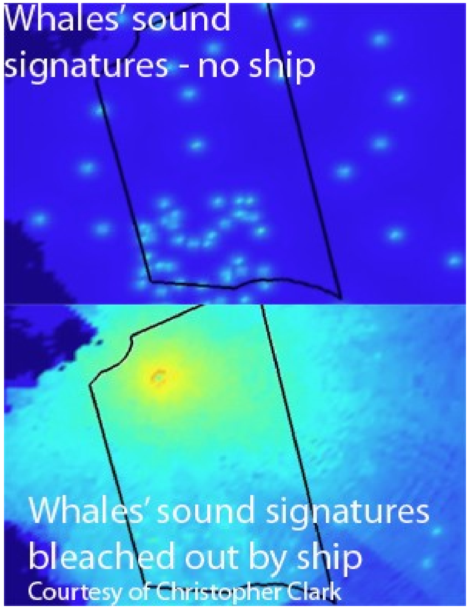
Lloyds of London, 2007

Ecological Effects

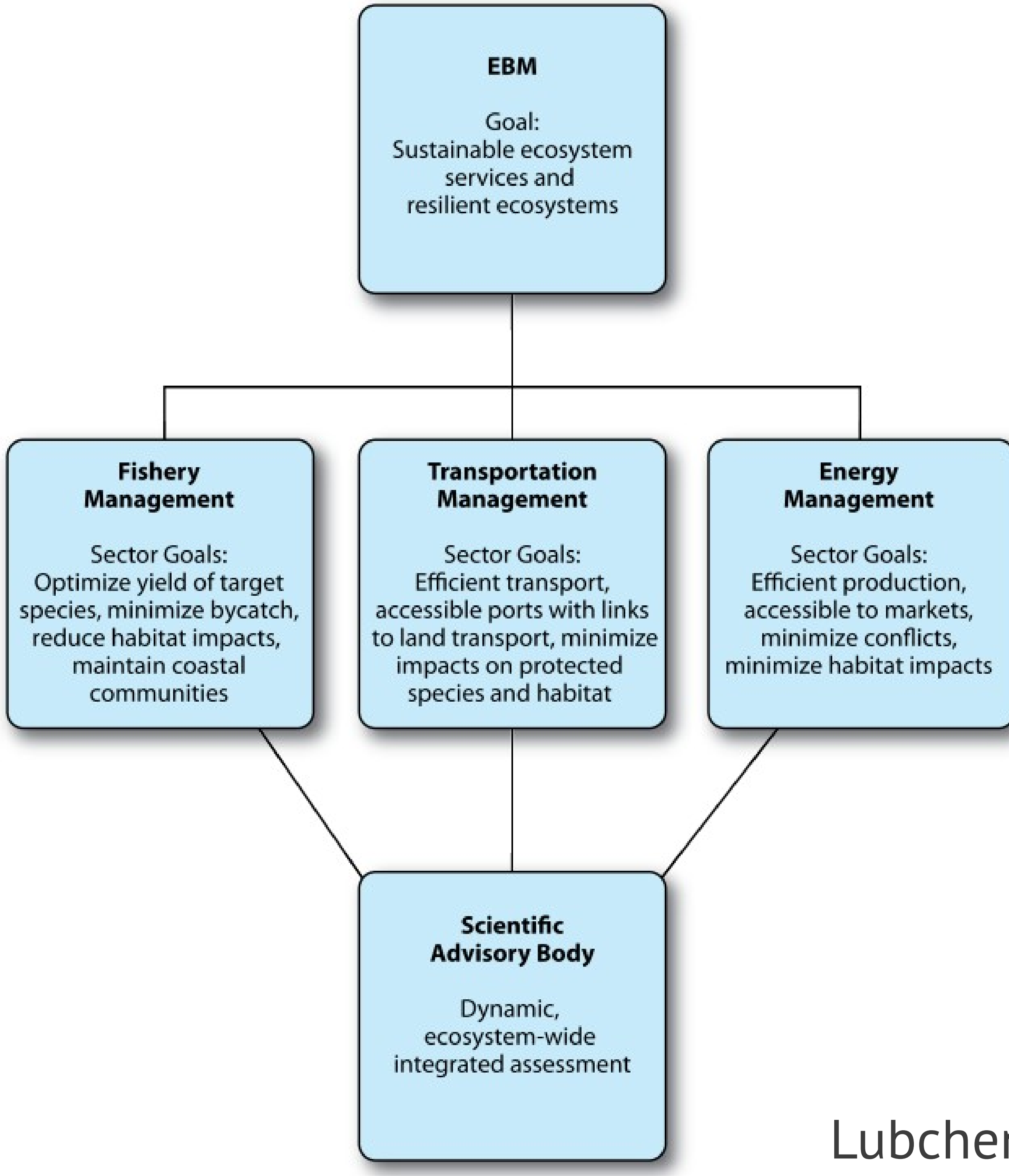
- Invasive Species ballast water
- Emissions 5% global GHG, 25% NOx; 60,000 deaths yr^{-1}
- Direct Pollution sewage, marine debris, gray water

Ship Strikes

Noise Pollution

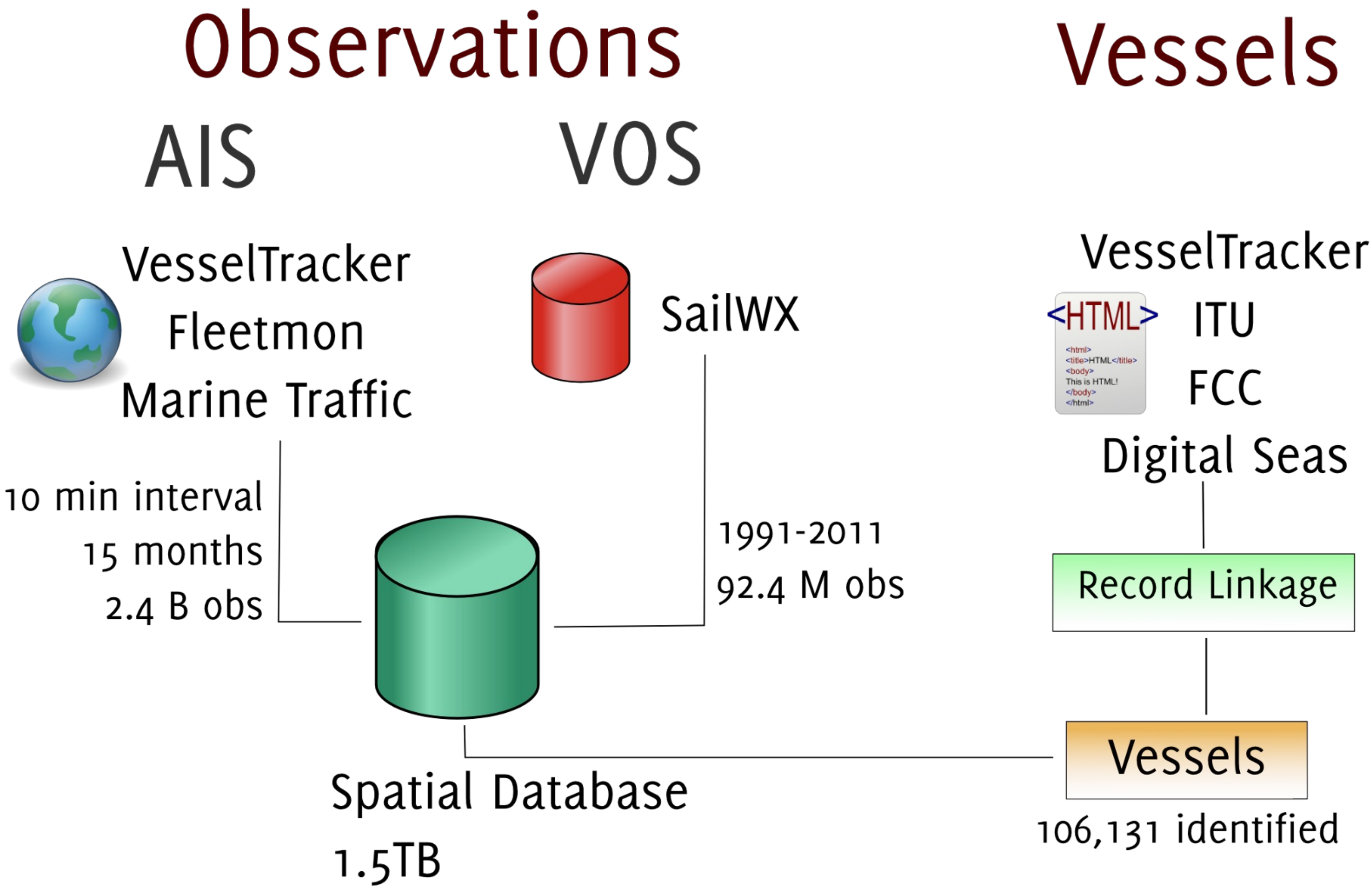


Ship Groundings

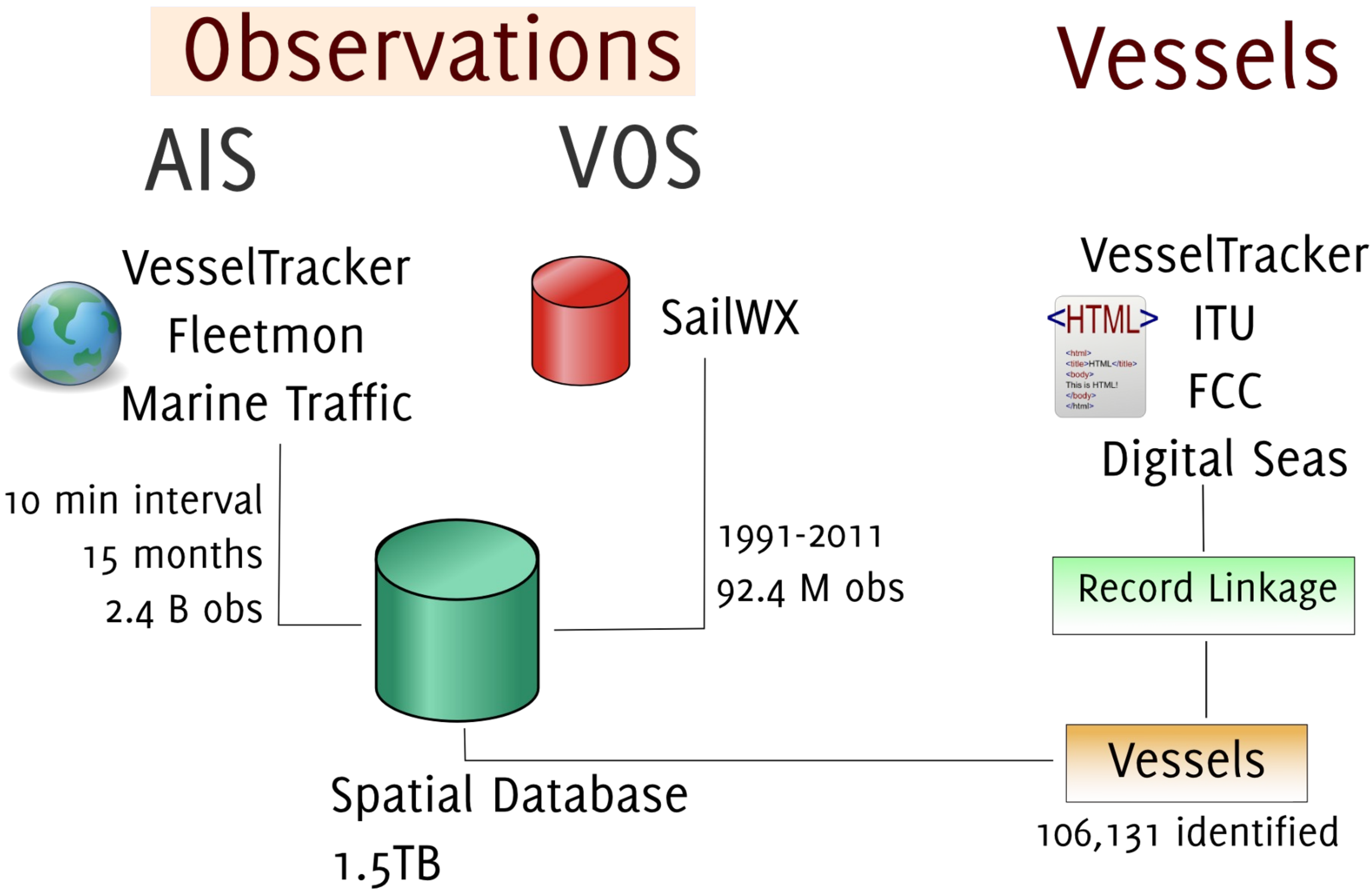


Lubchenco et al, 2010

Data Fusion Workflow

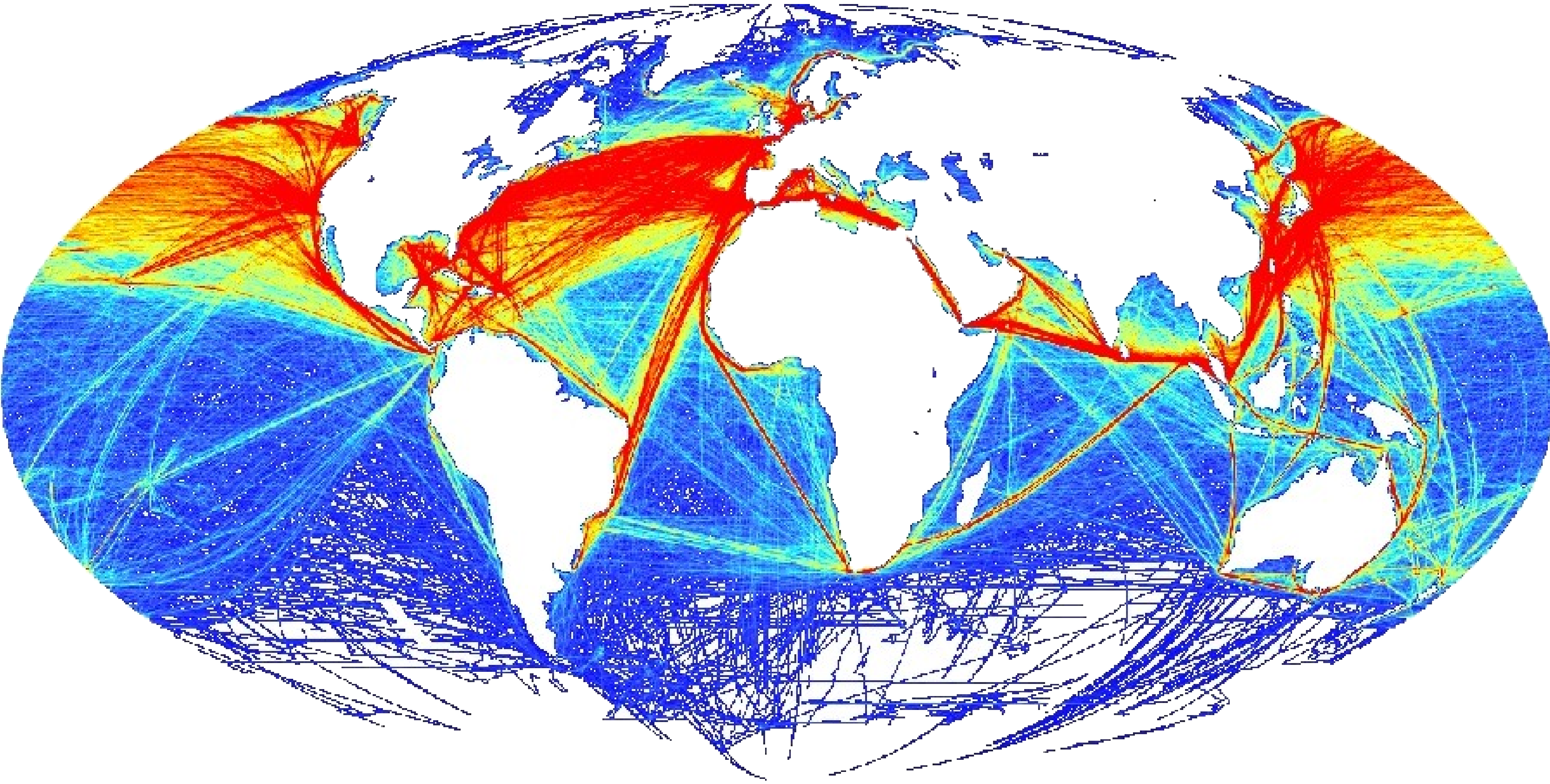


Data Fusion Workflow

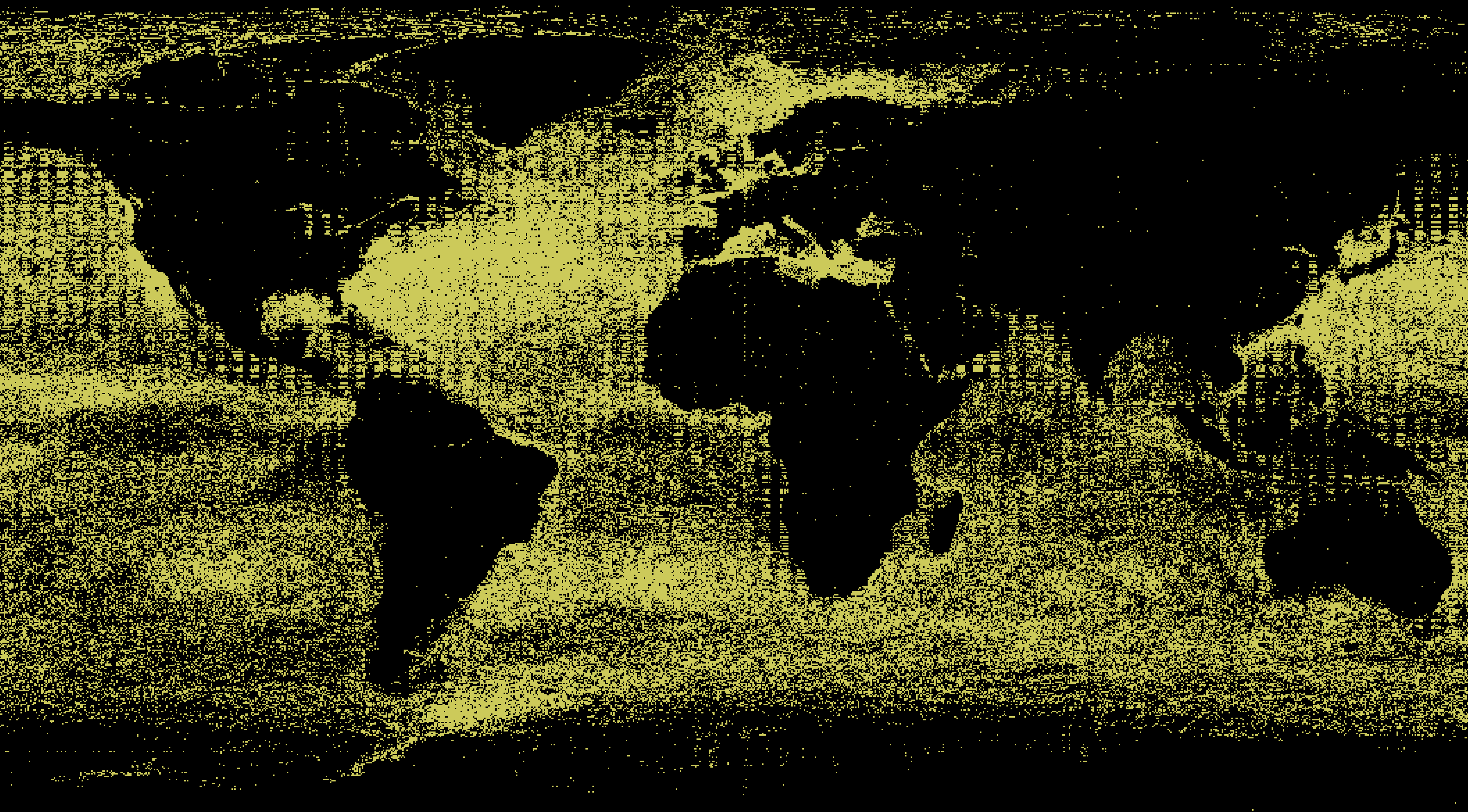


Voluntary Observing Ship (VOS) Fleet

- 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:

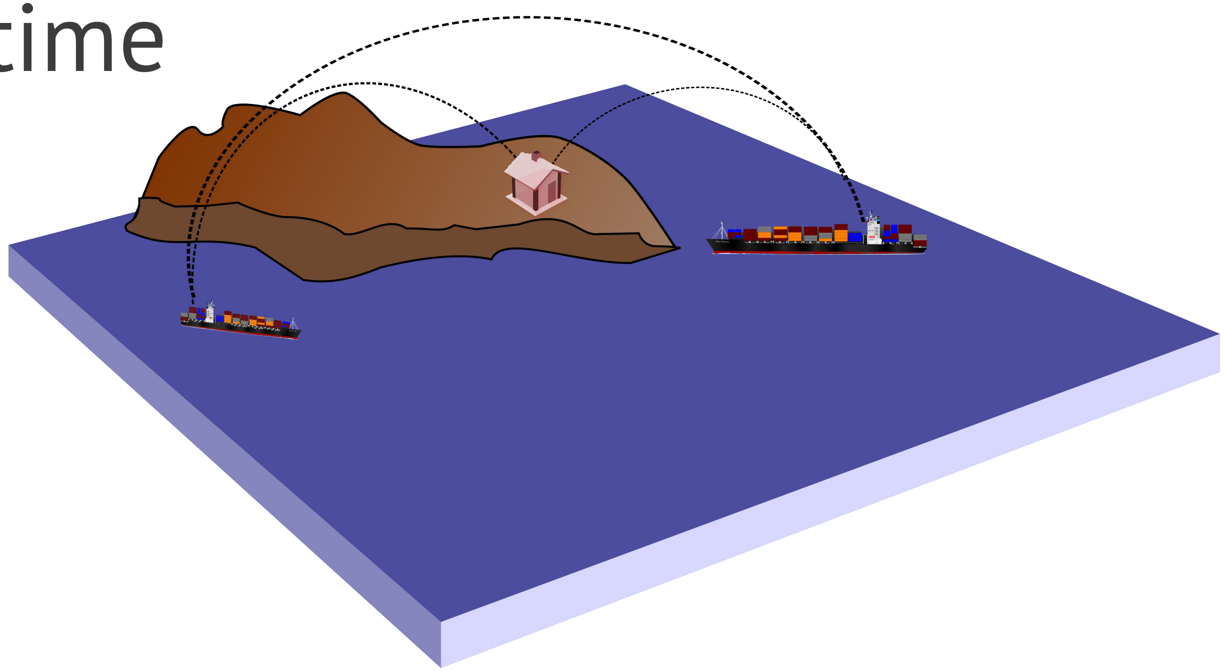
ship id

(x,y)

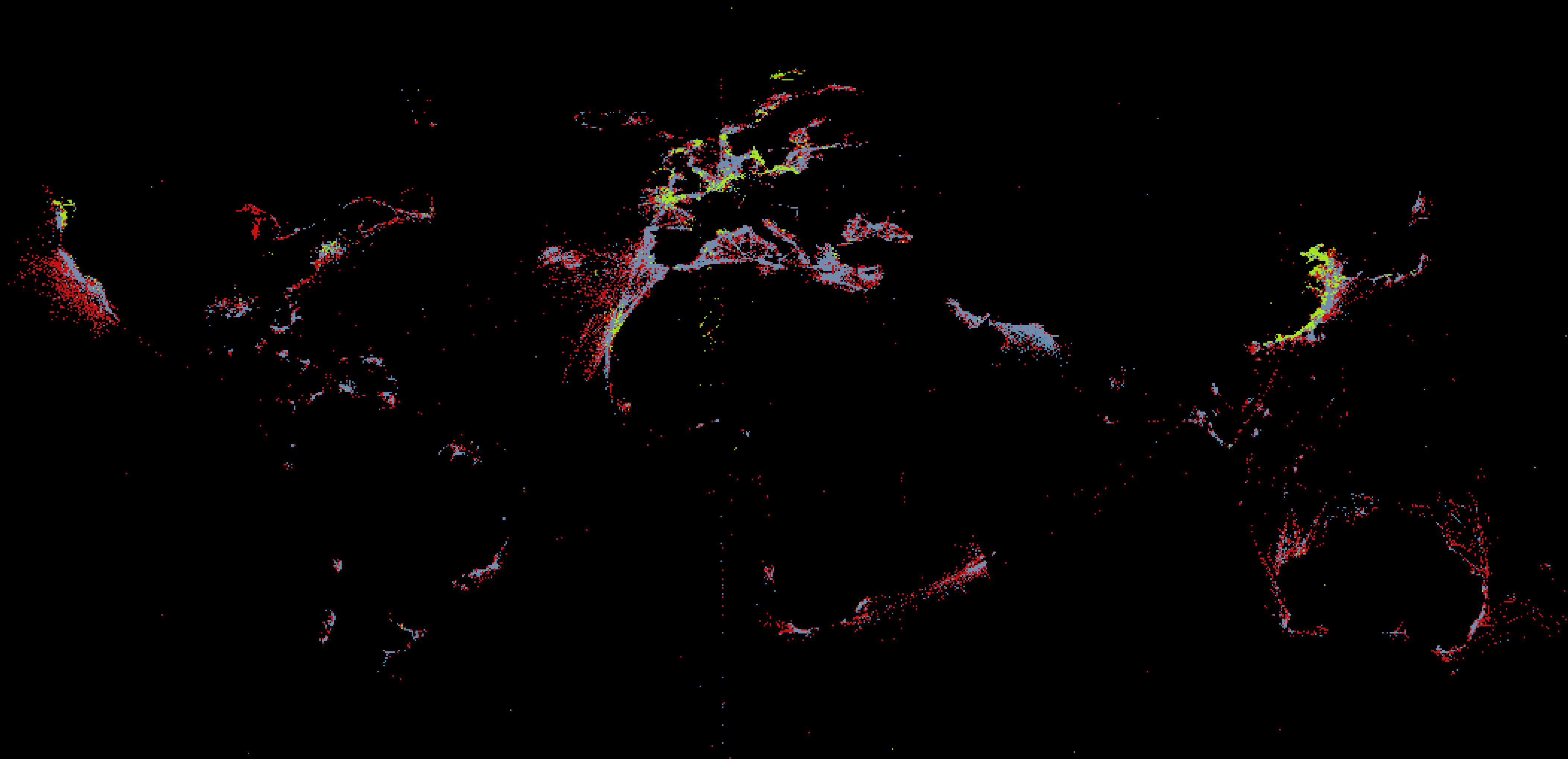
heading

type

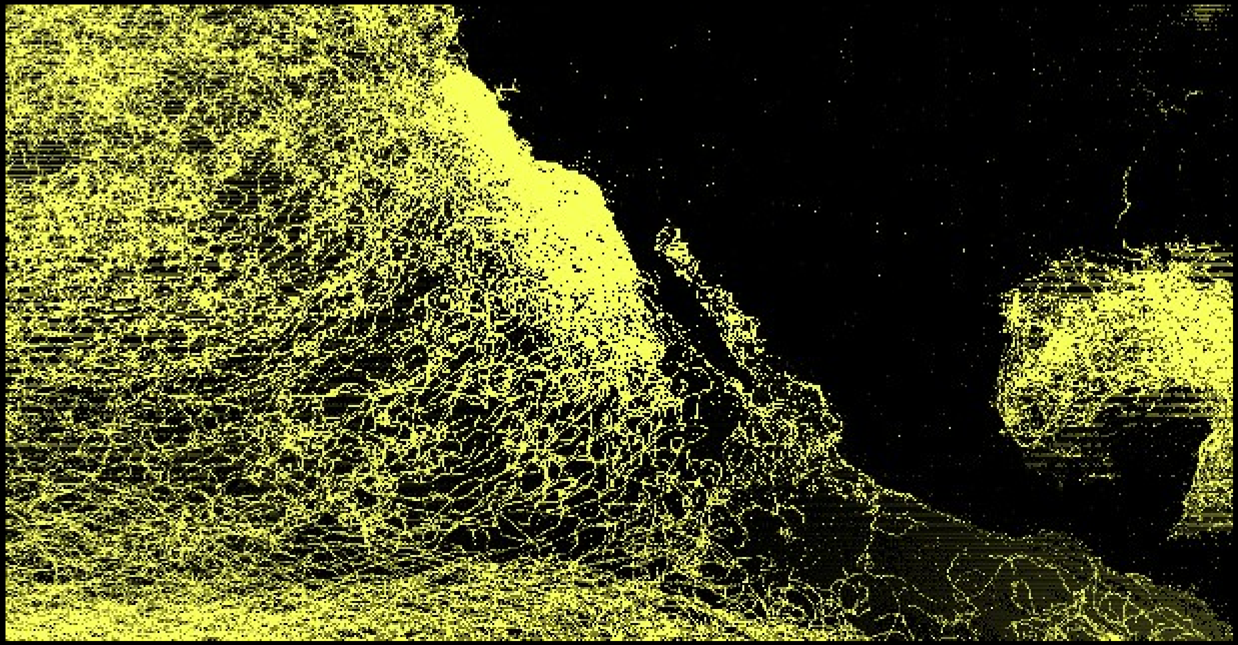
speed



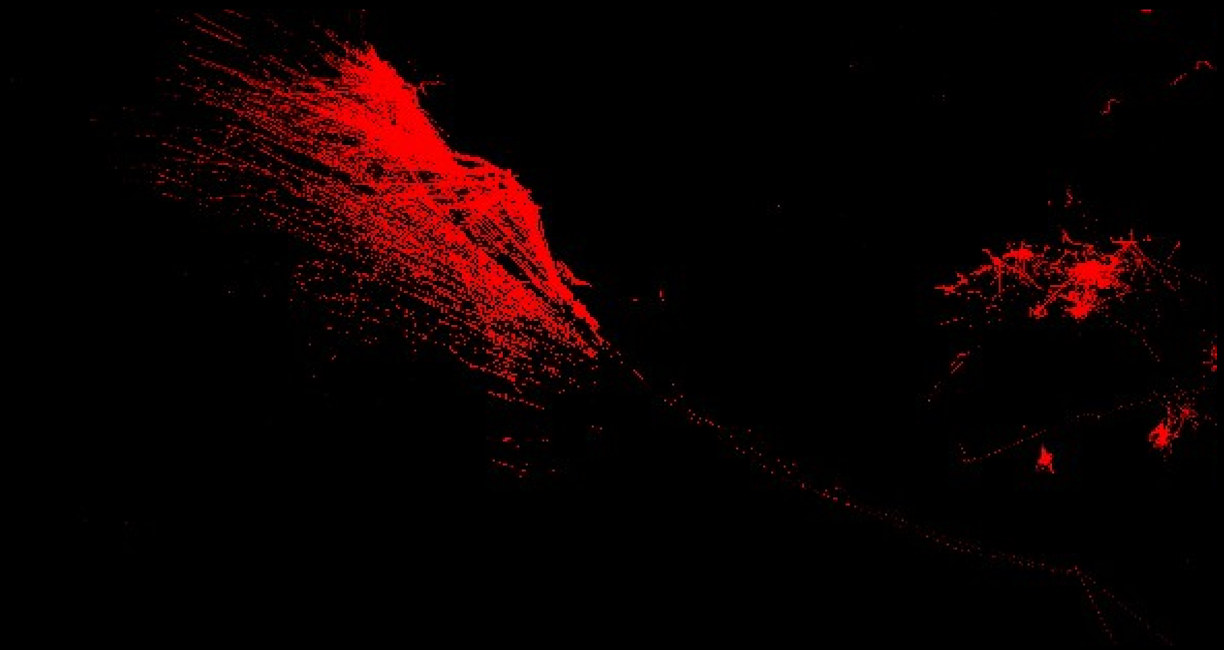
AIS: Nov, 2011



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



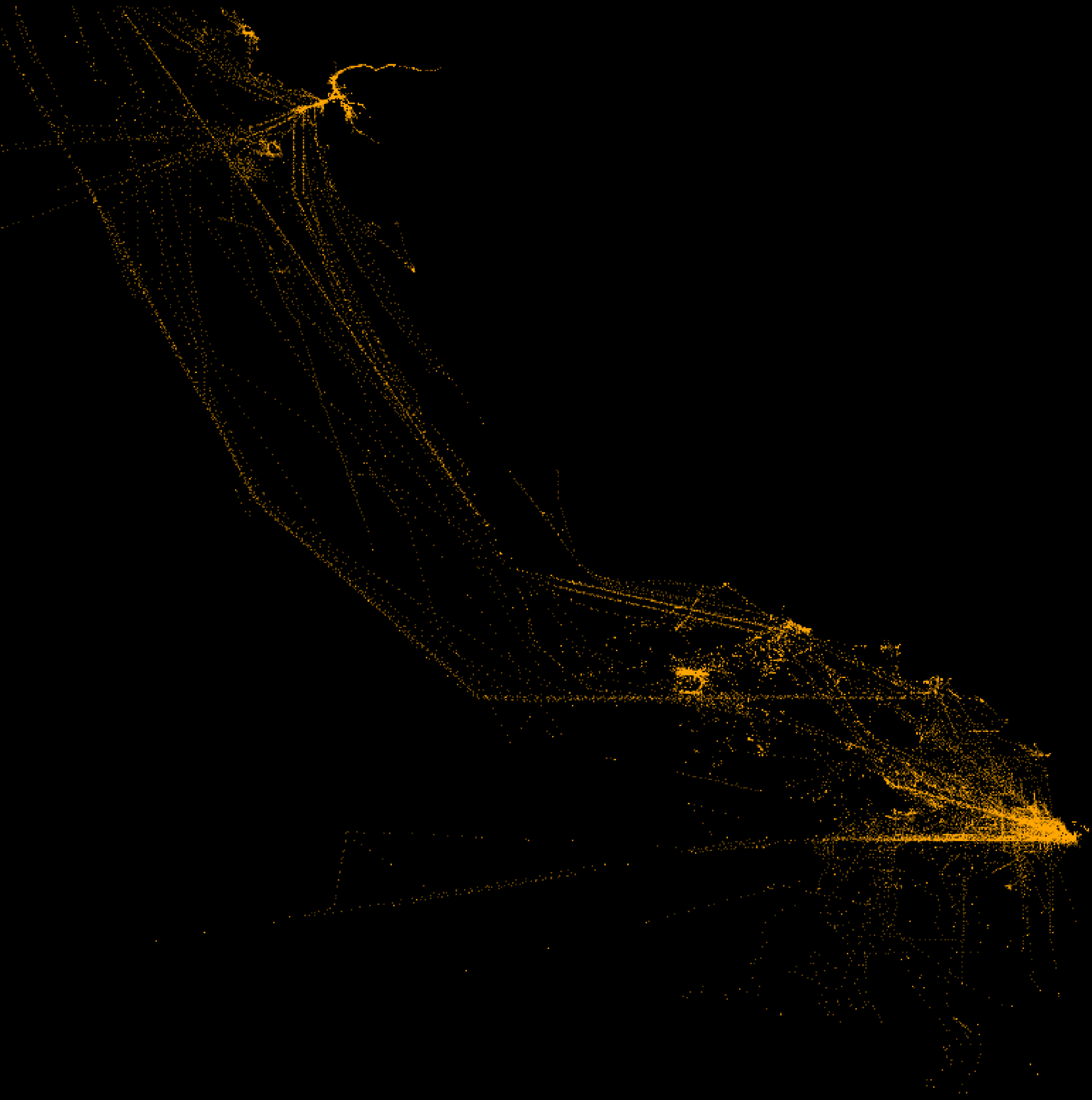
VOS: 2003-2011



AIS: Cargo Ships
Nov, 2011

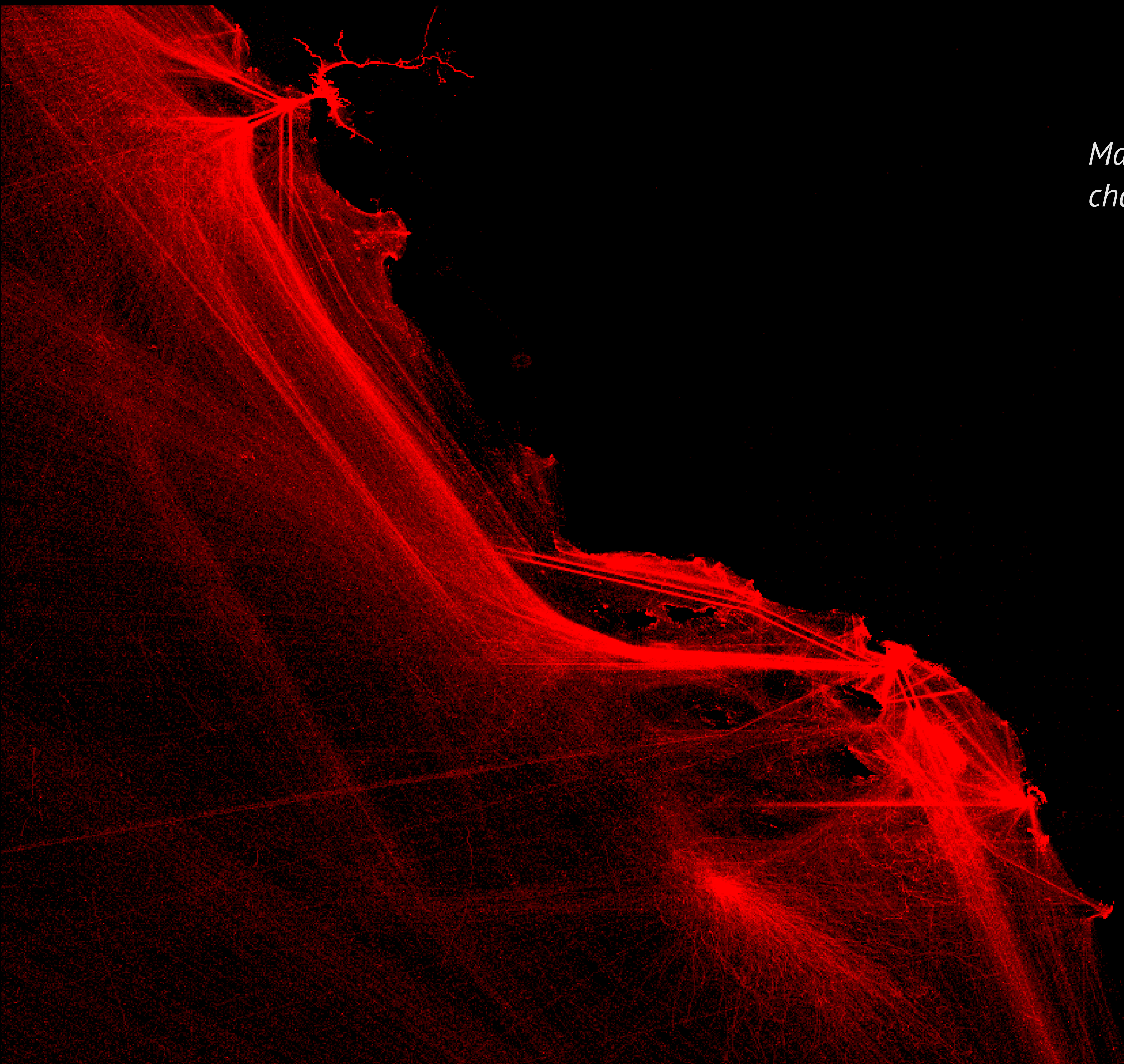

AIS Density Maps
Nov 2010-Dec 2011

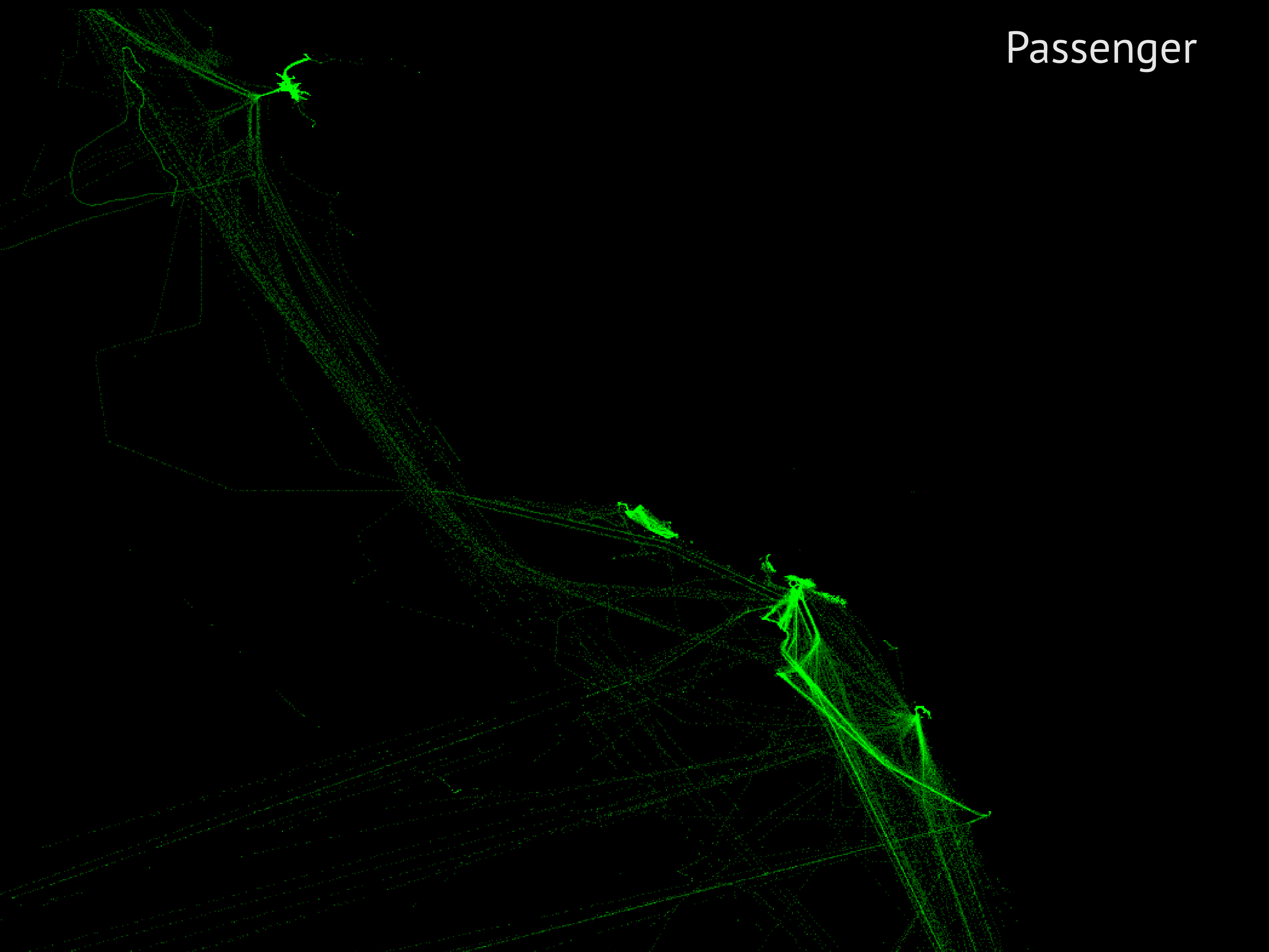
Authority



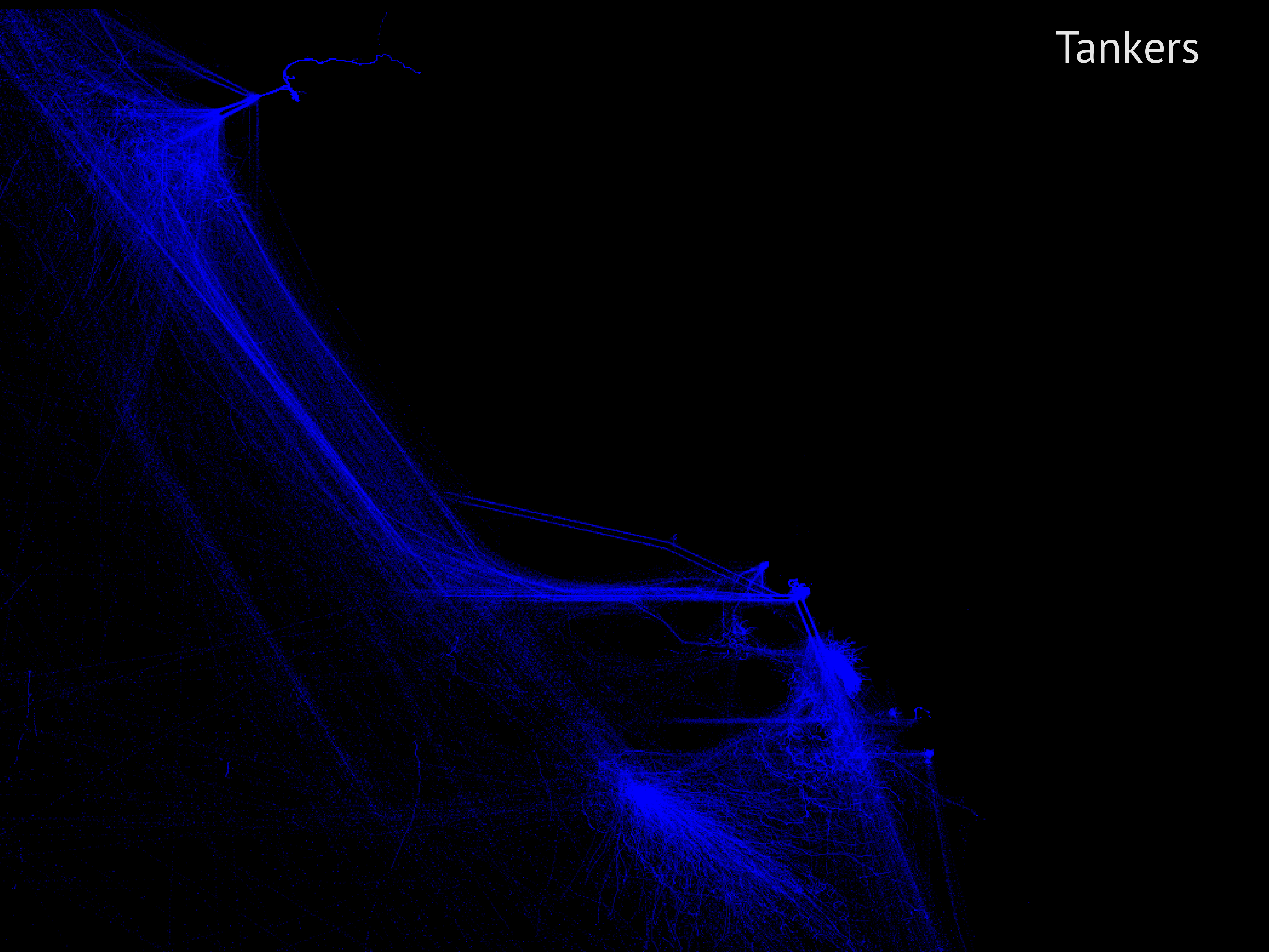
Cargo

Maersk may use channel, most don't



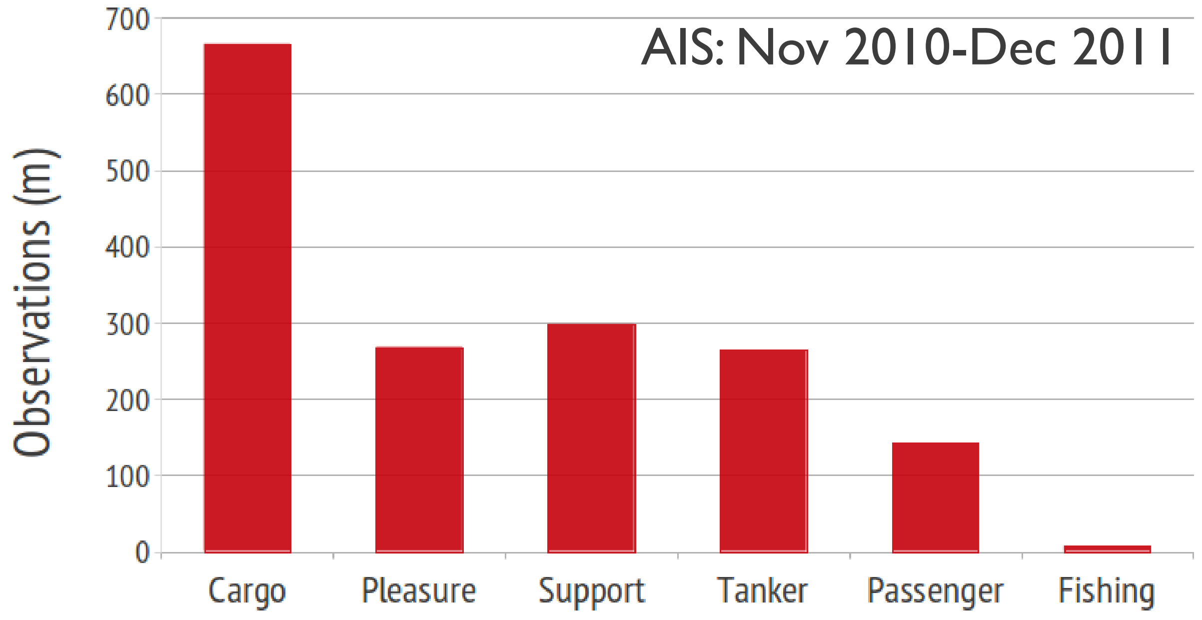

Passenger

Fishing

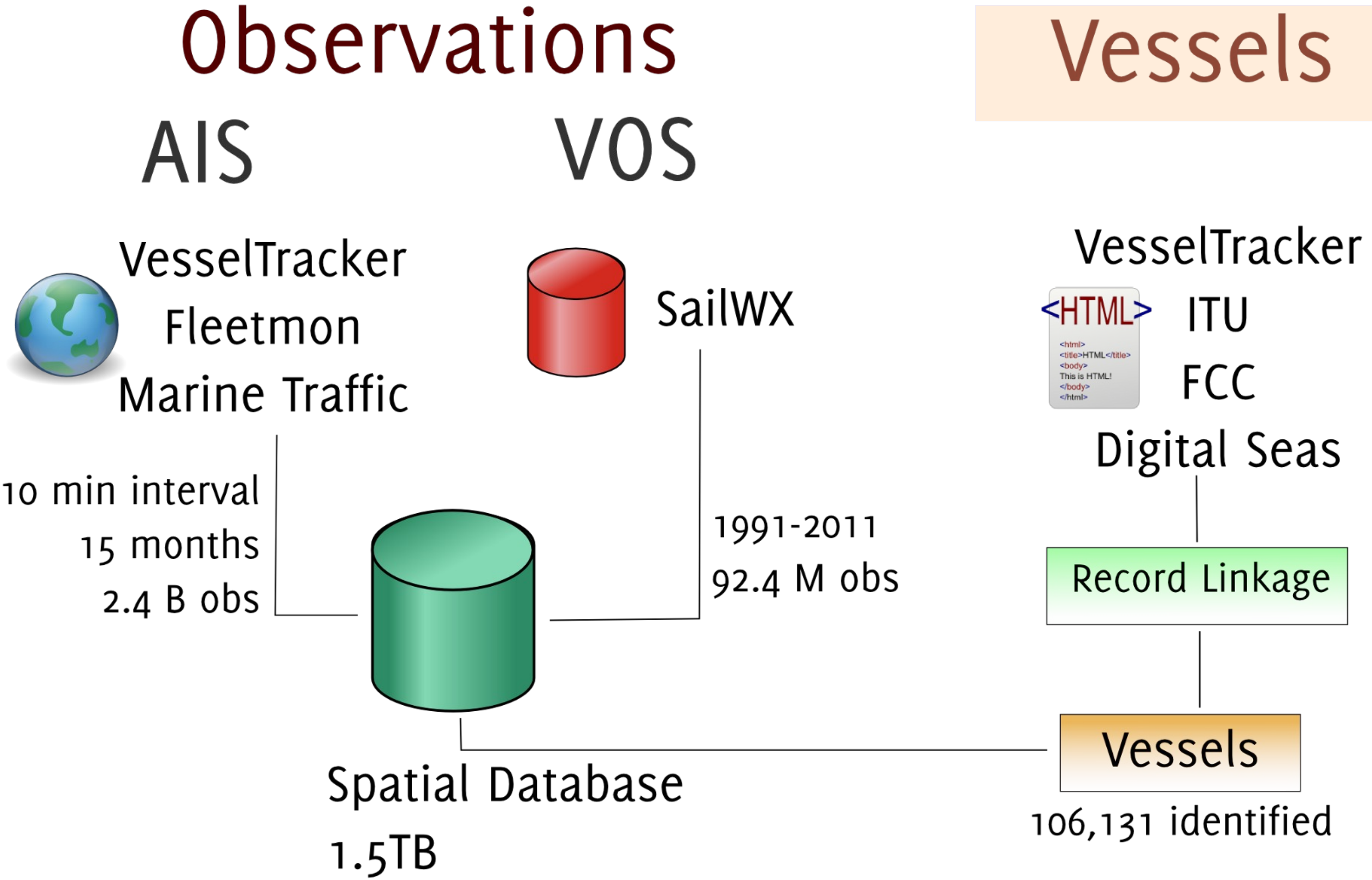

Tankers

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



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

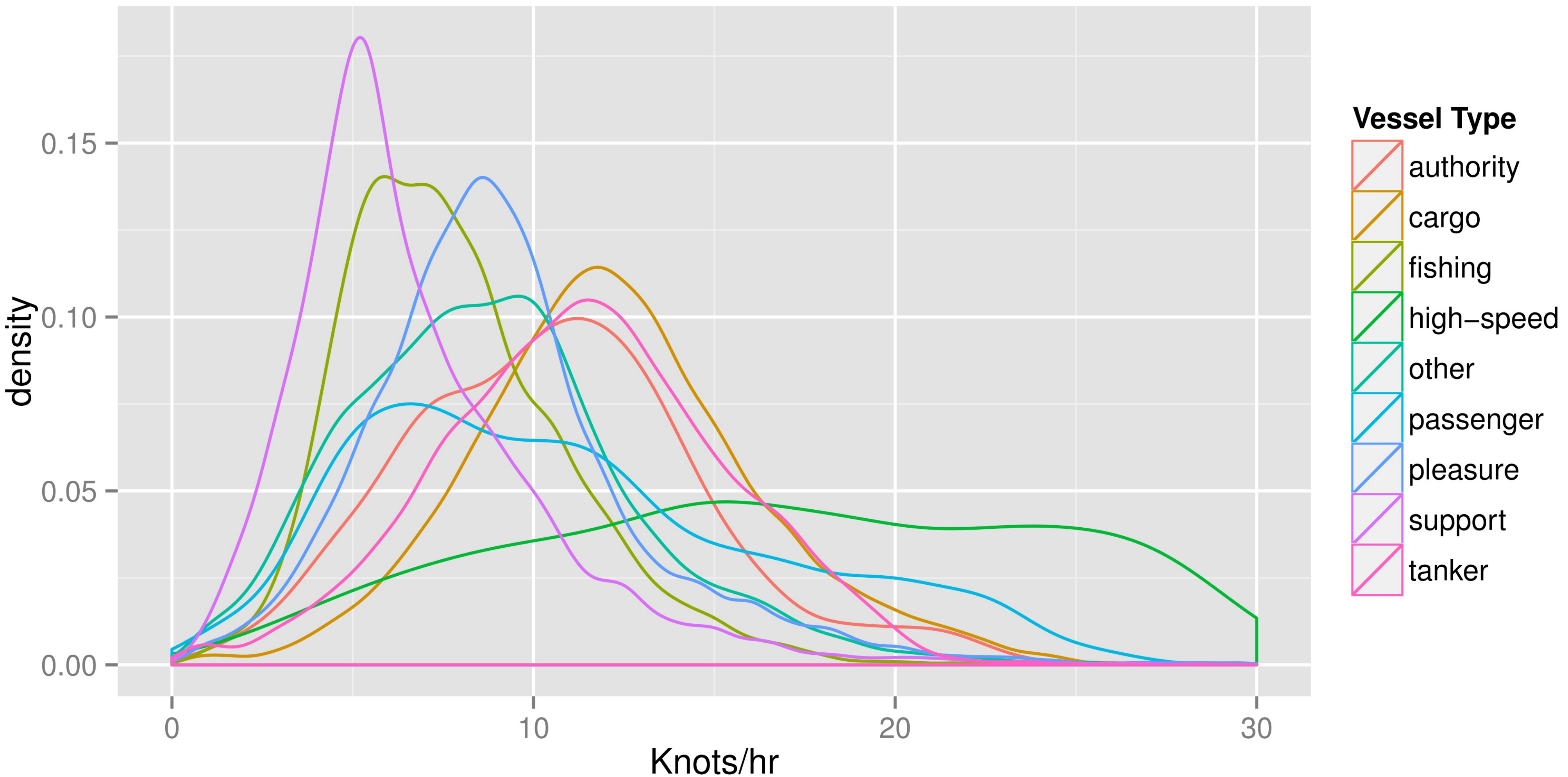
Record Linkage: Use fuzzy reasoning to cross-link records from differing sources

Probabilistic pairwise combinations between source pairs:

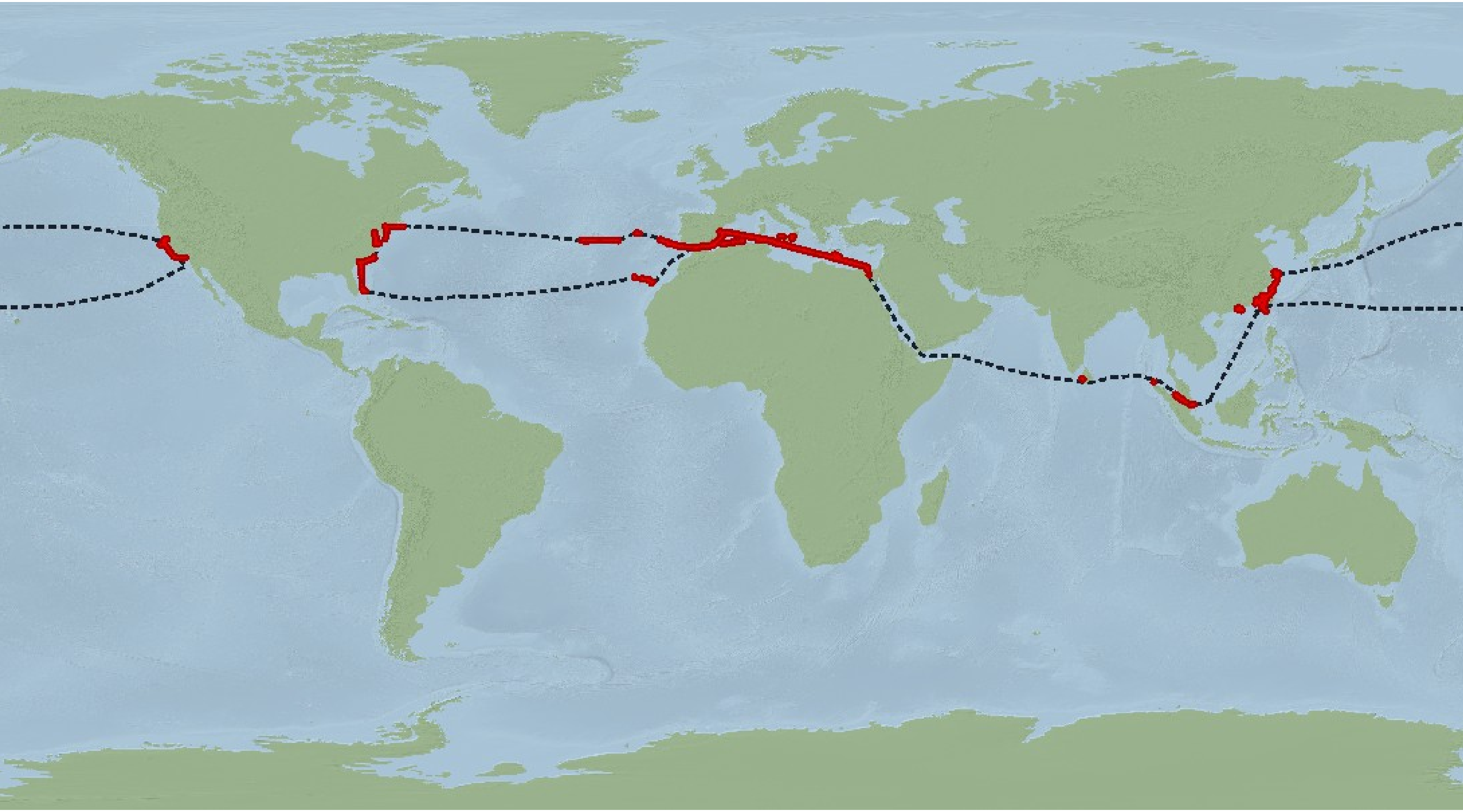
Comparison	Name	IMO	MMSI	Callsign	Type	Length	Confidence
A	MONIUSZKO	8513730	248623000	9HLM6	Cargo Ship	159	100
A	Moniuszko	8513730	248623000	9HLM6	Cargo Ship	159	100
B	ATLAS		372913000	3EVP4		190	93
B	Atlas	9222340	372913000	3EVP4	Cargo Ship	155	93

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

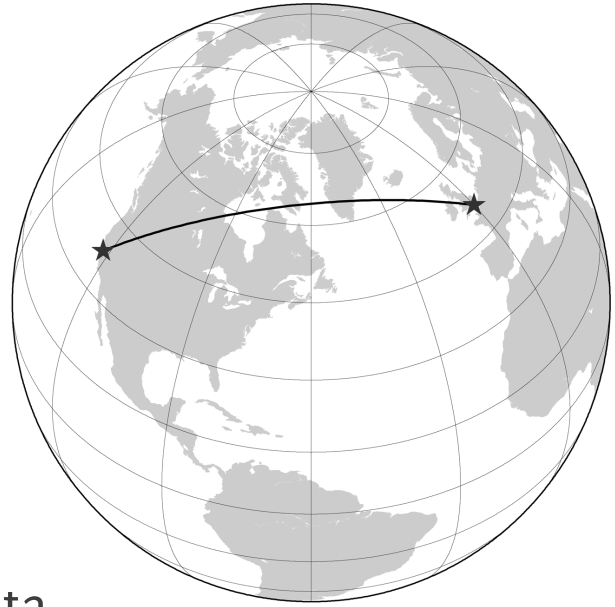
Vessel Speeds by Type



Vessel Movement Models



Building individual ship tracks



Track creation:
- geographic filtering
- great circle distances

Rasterization:

Ship: PURKI
Country: Malta
IMO: 9004217
MMSI: 248495000
Callsign: 9HA2386
Length: 147m
Width: 26m
Type: cargo ship
Obs: 24225

Merge by vessel type

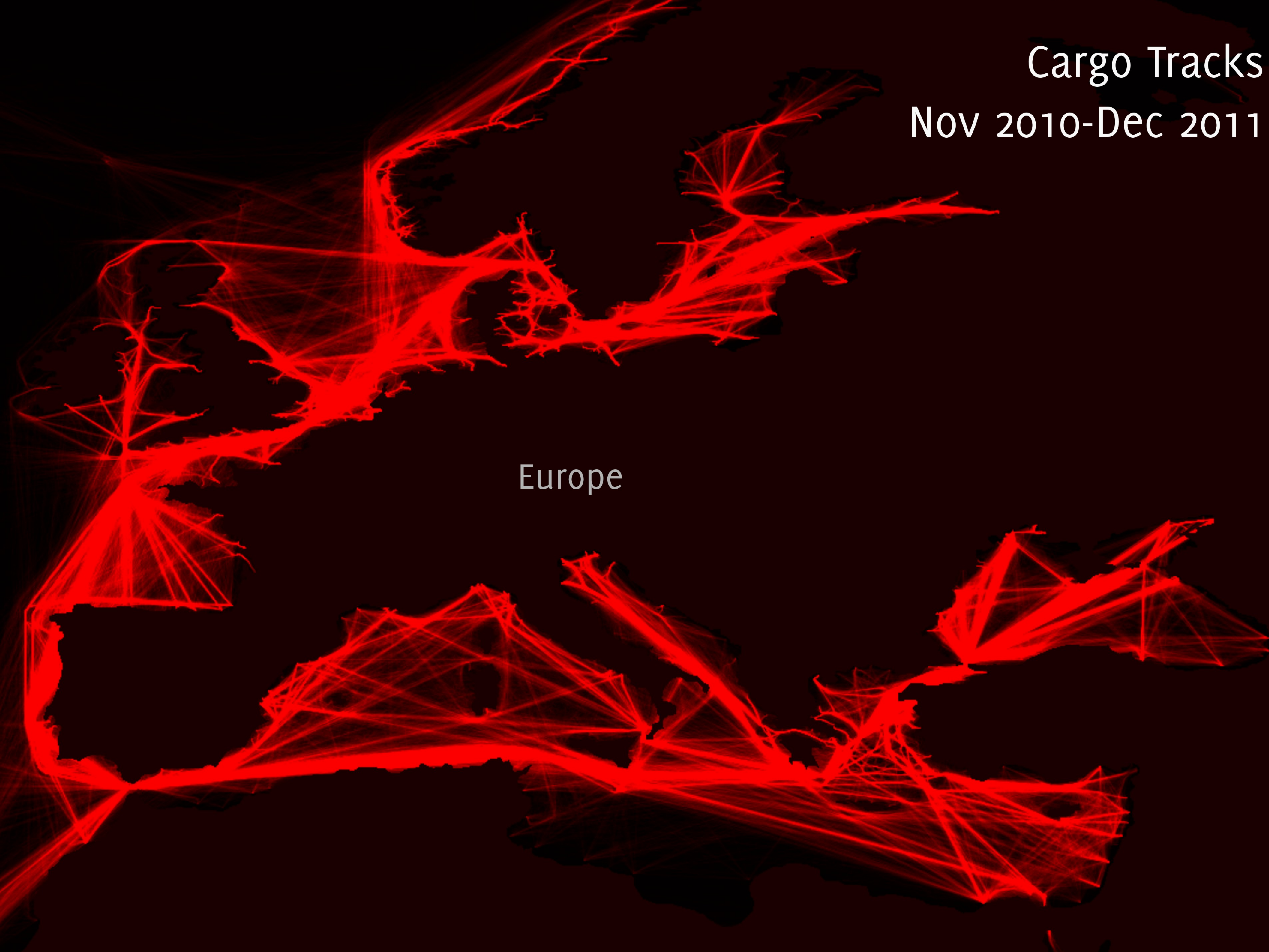
Initial views

Density function:

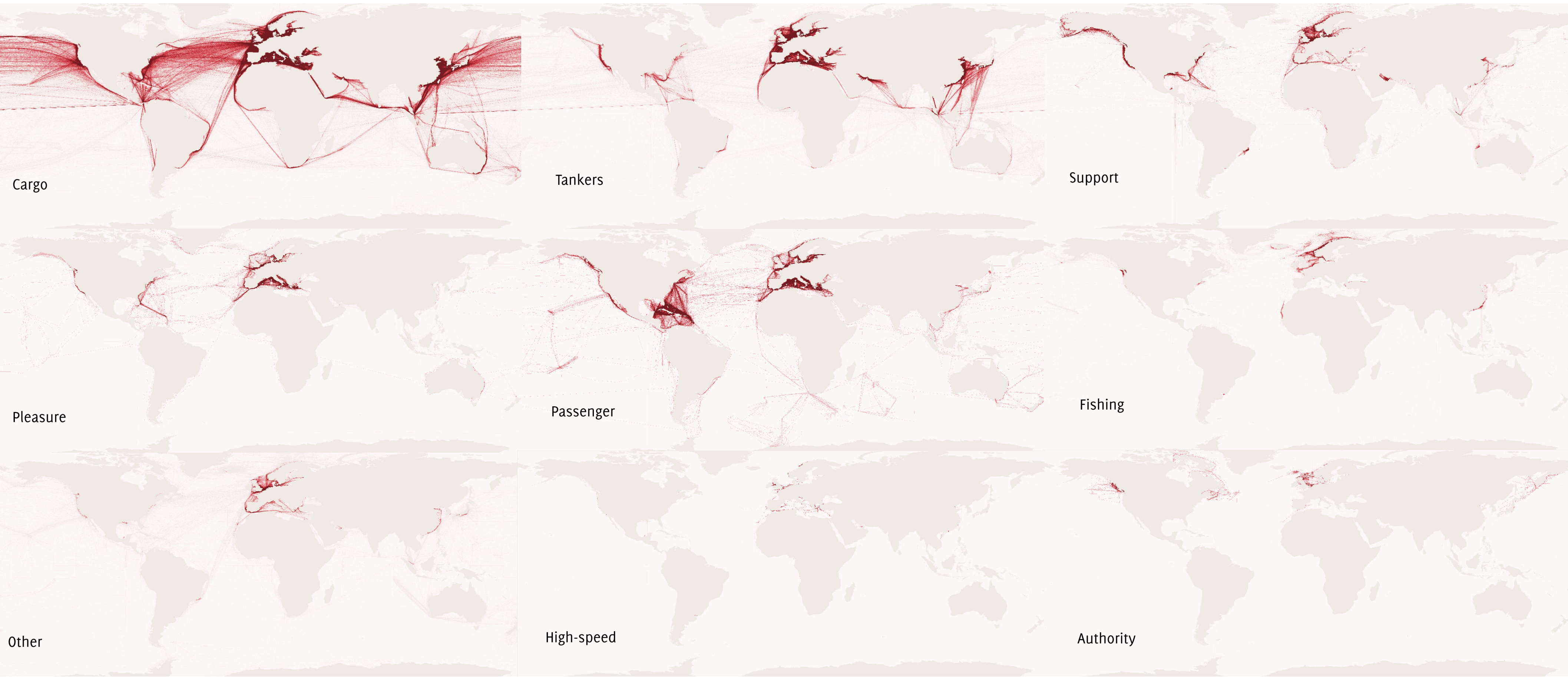
$$s = \frac{R_{AIS}}{max(R_{AIS})} + \frac{R_{VOS}}{max(R_{VOS})}$$

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

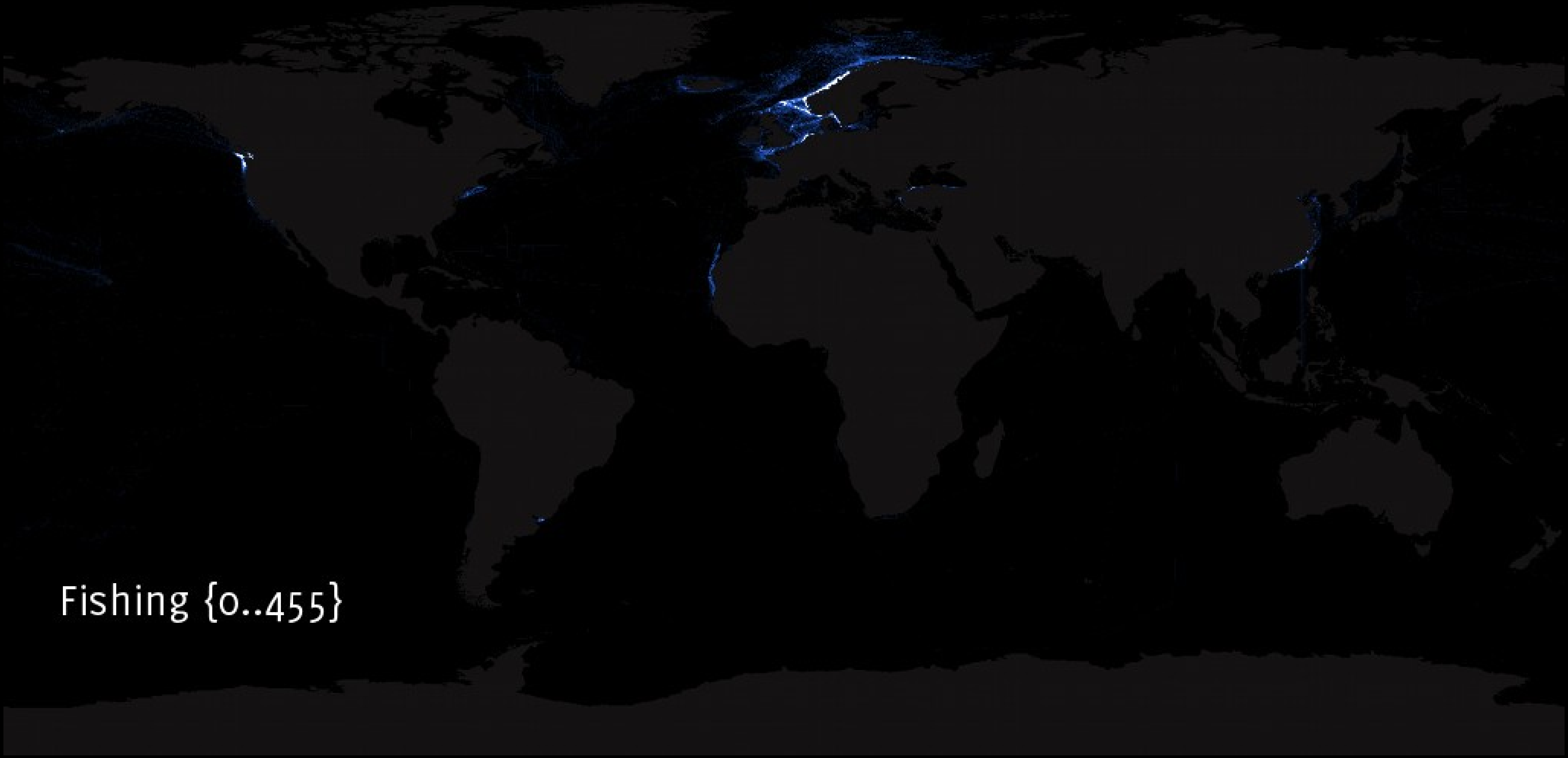
Vessel Densities by Type

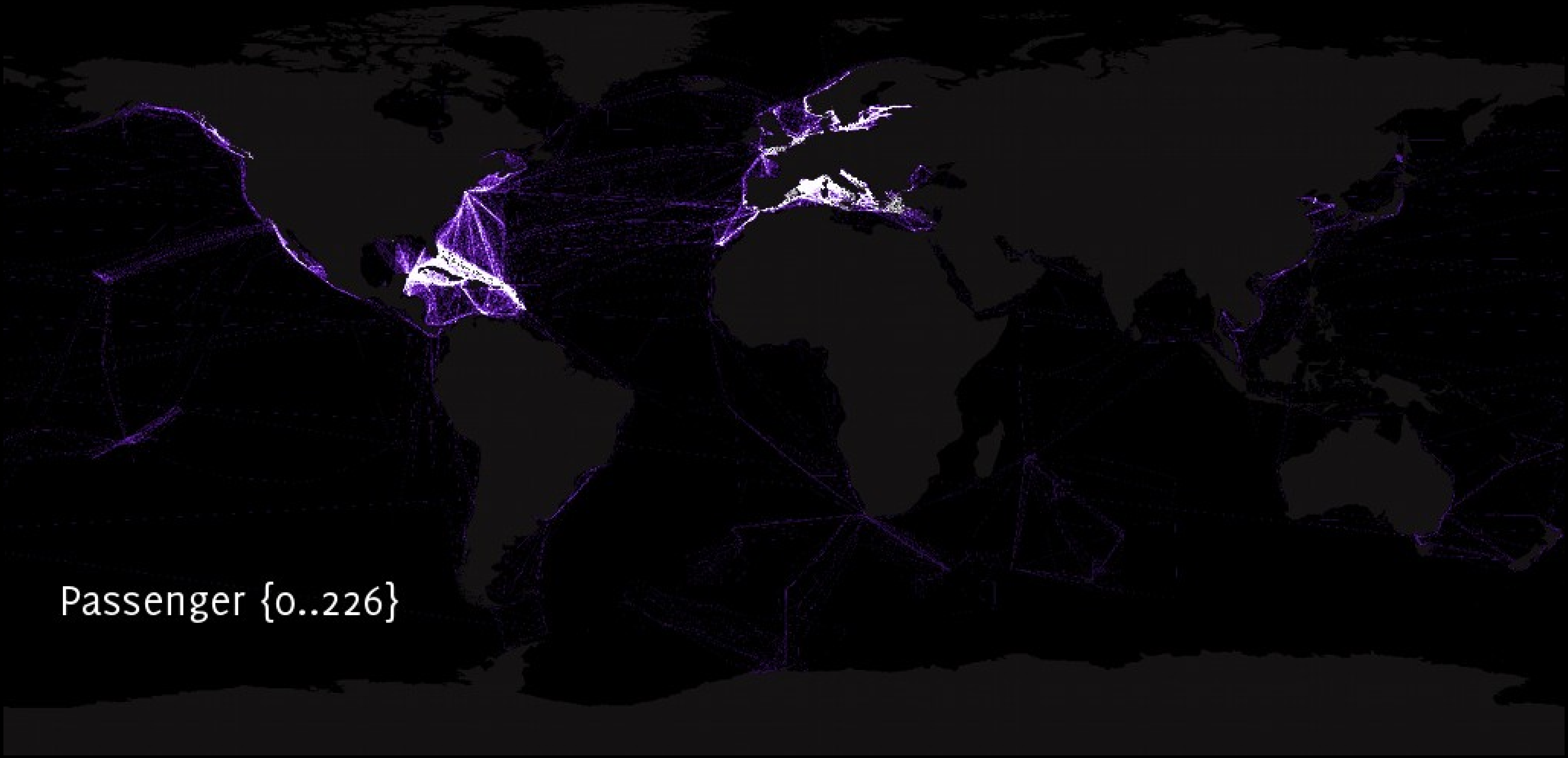


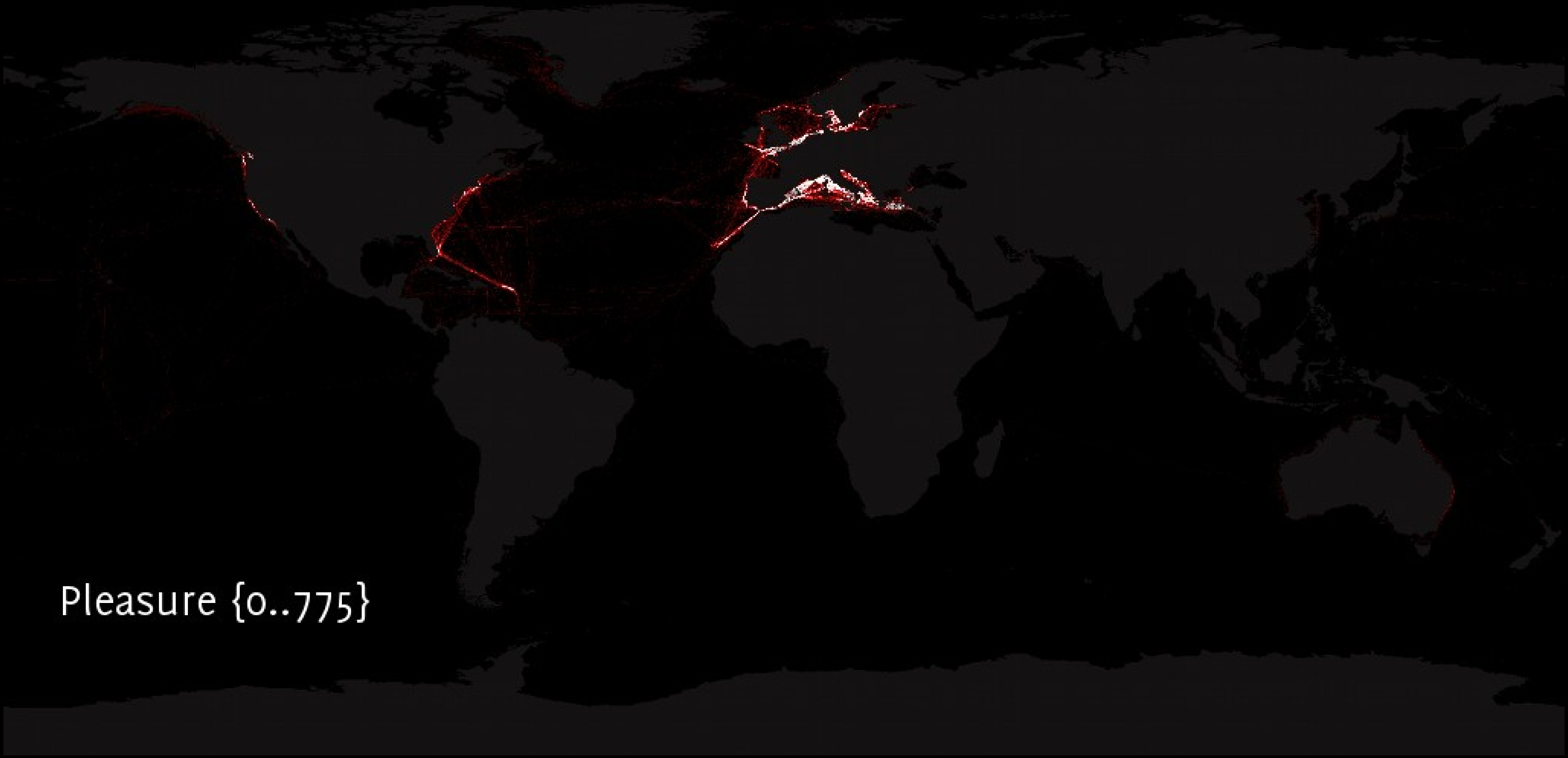

High Speed {0..48}

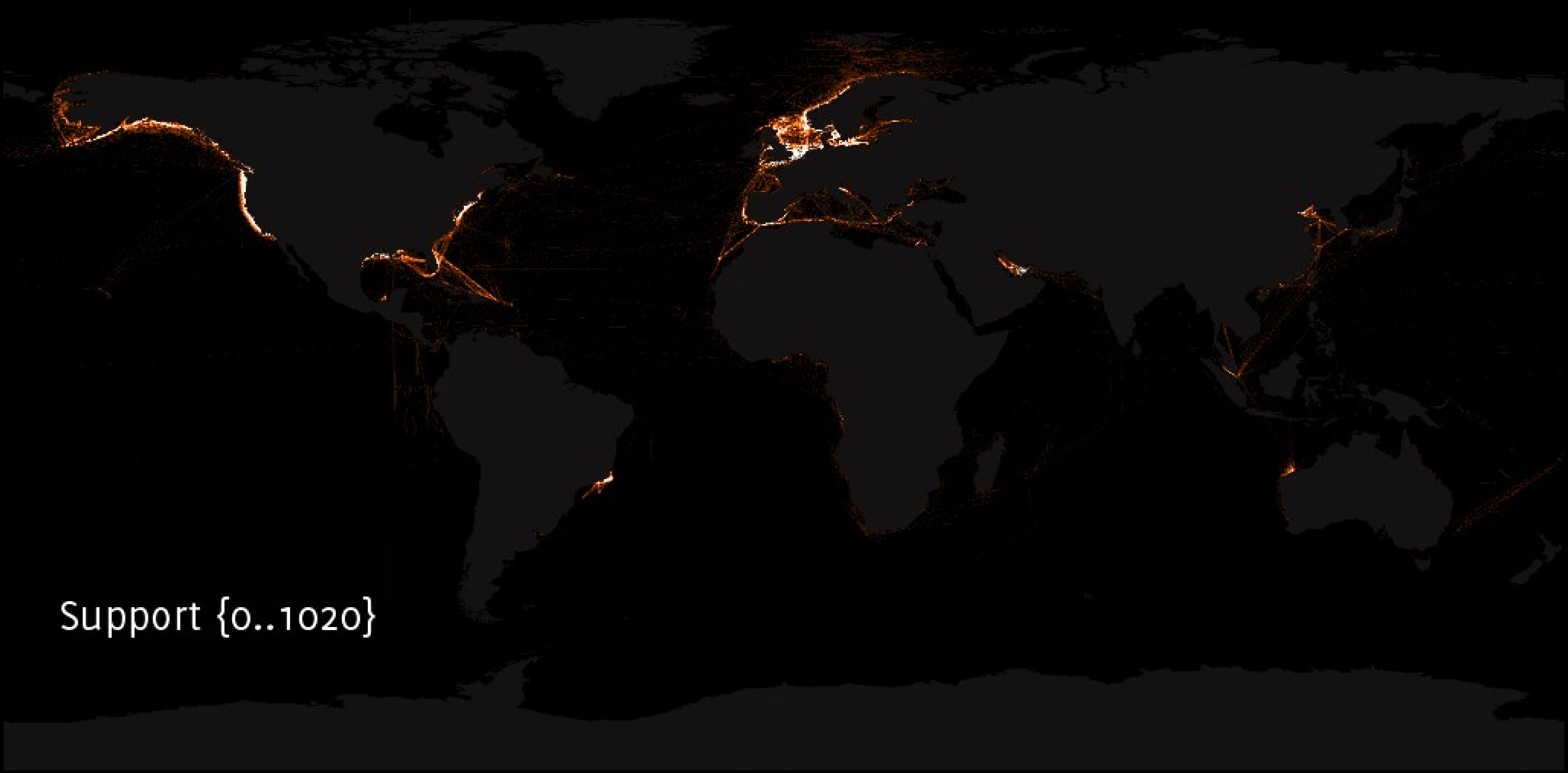

Authority {0..60}

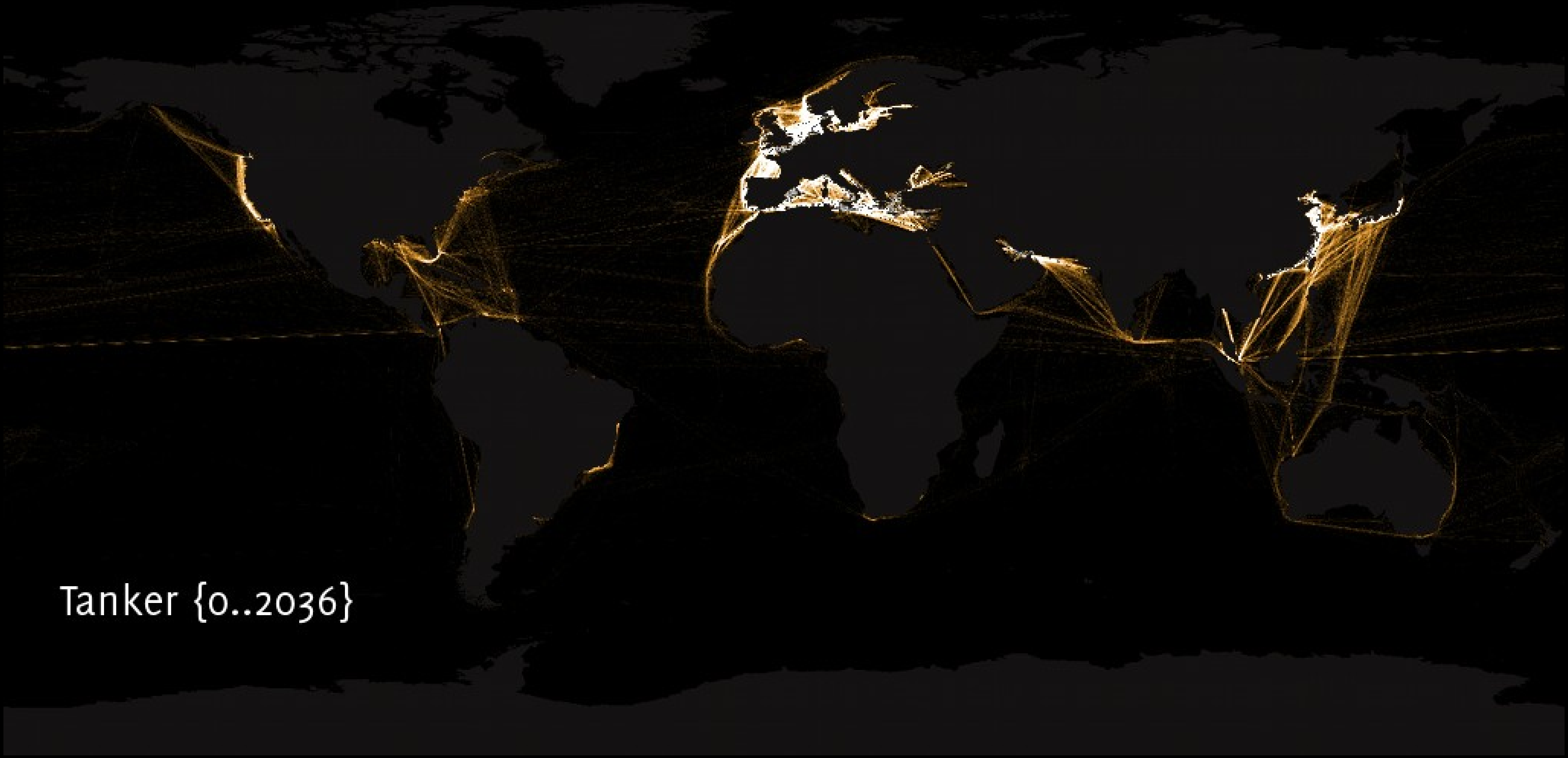

Other {0..1699}


Fishing {0..455}

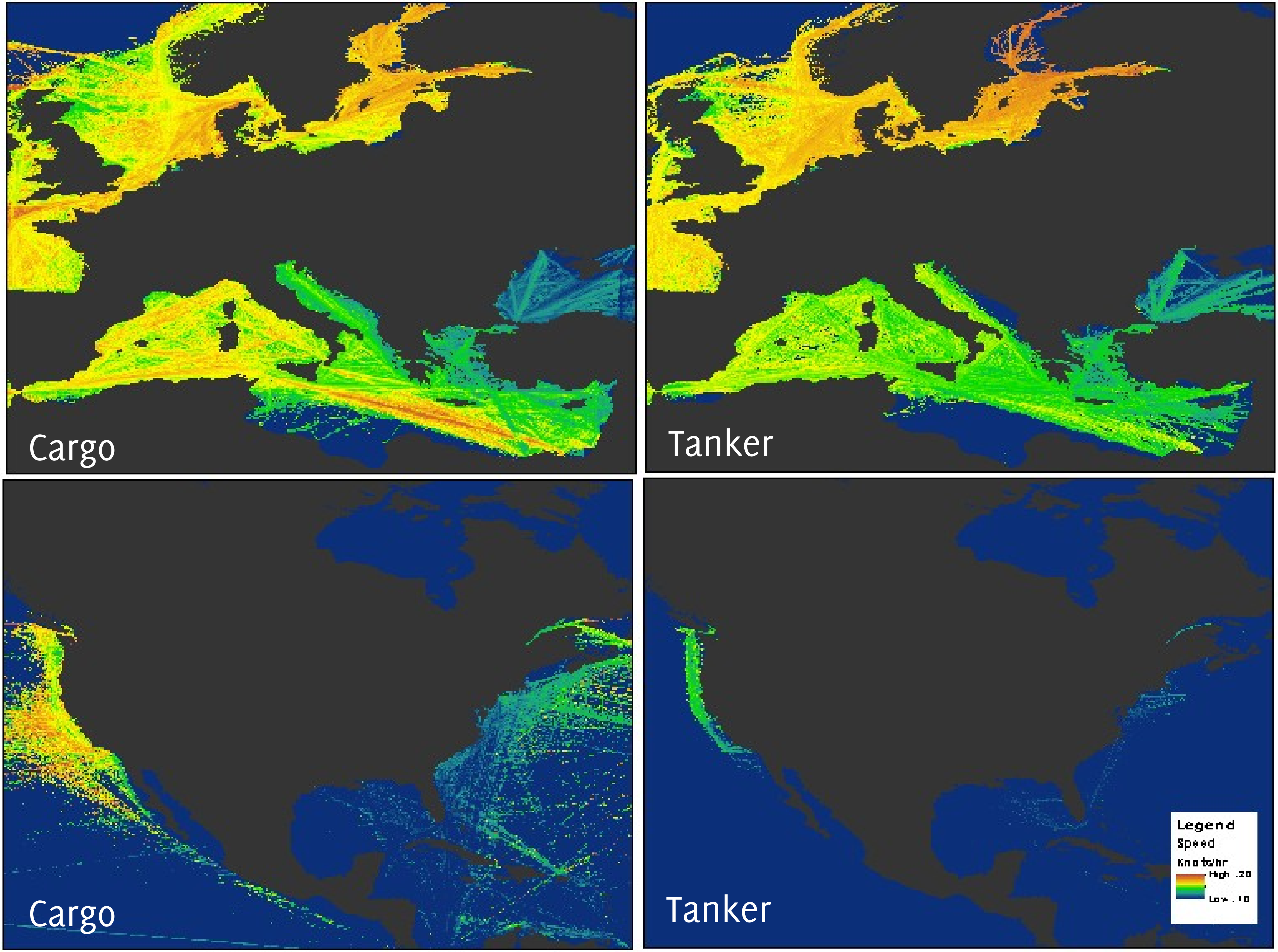

Passenger {0..226}


Pleasure {0..775}

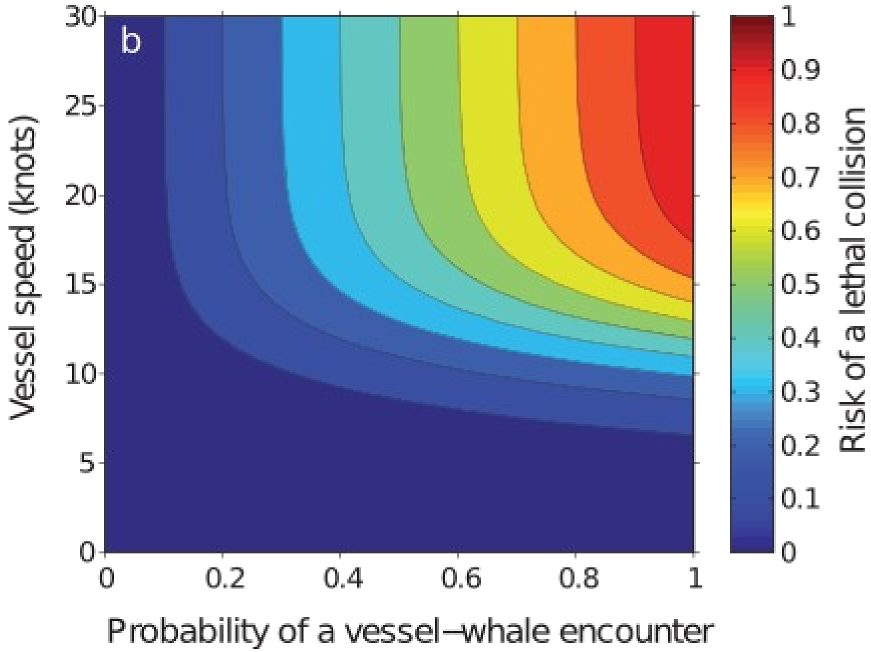

Support {0..1020}


Tanker {0..2036}

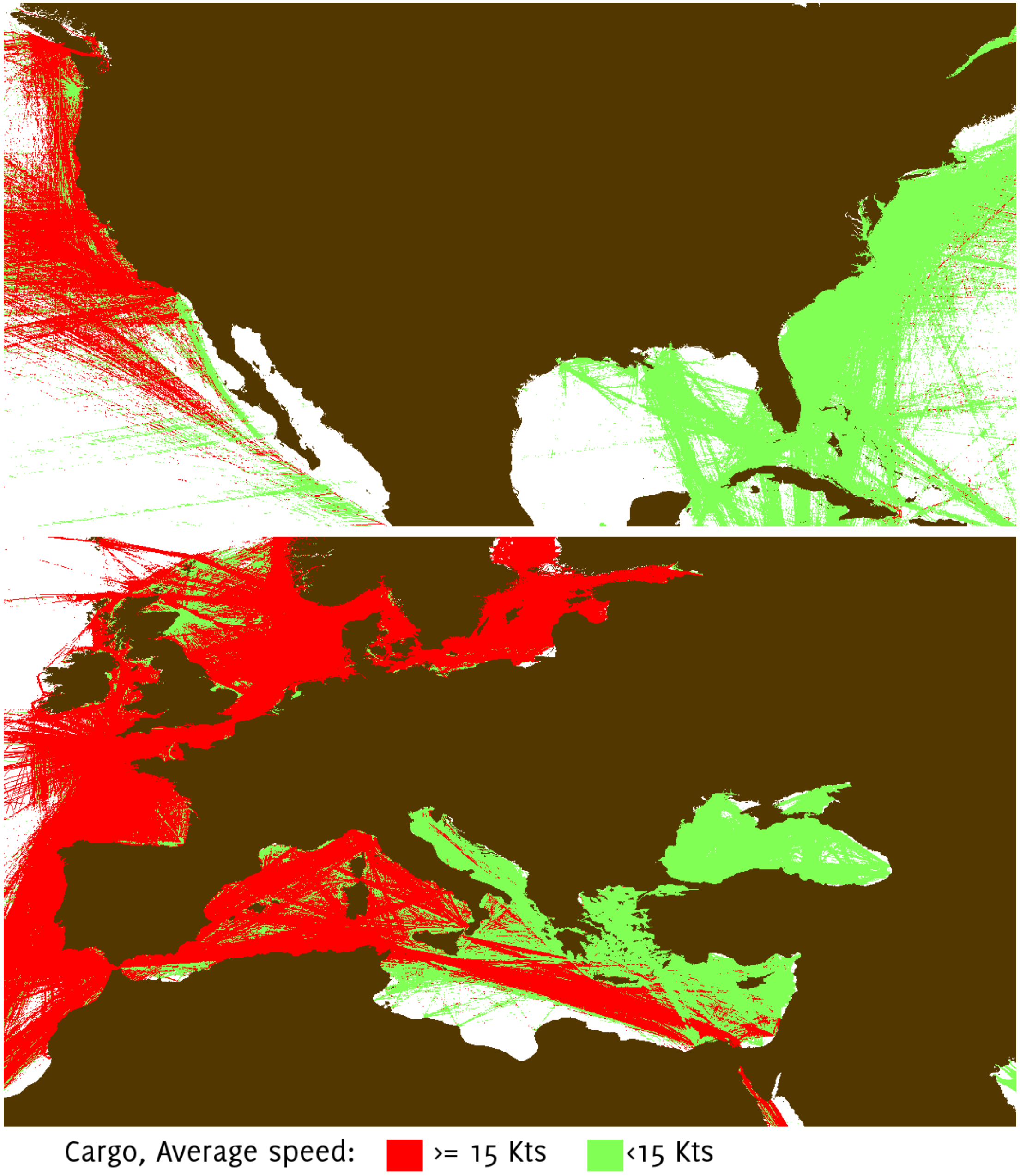

Cargo {0..4134}


Cargo
Tanker
Cargo
Tanker
Legend
Speed
Knots/hr
High : 20
Low : 10

Ship Strikes

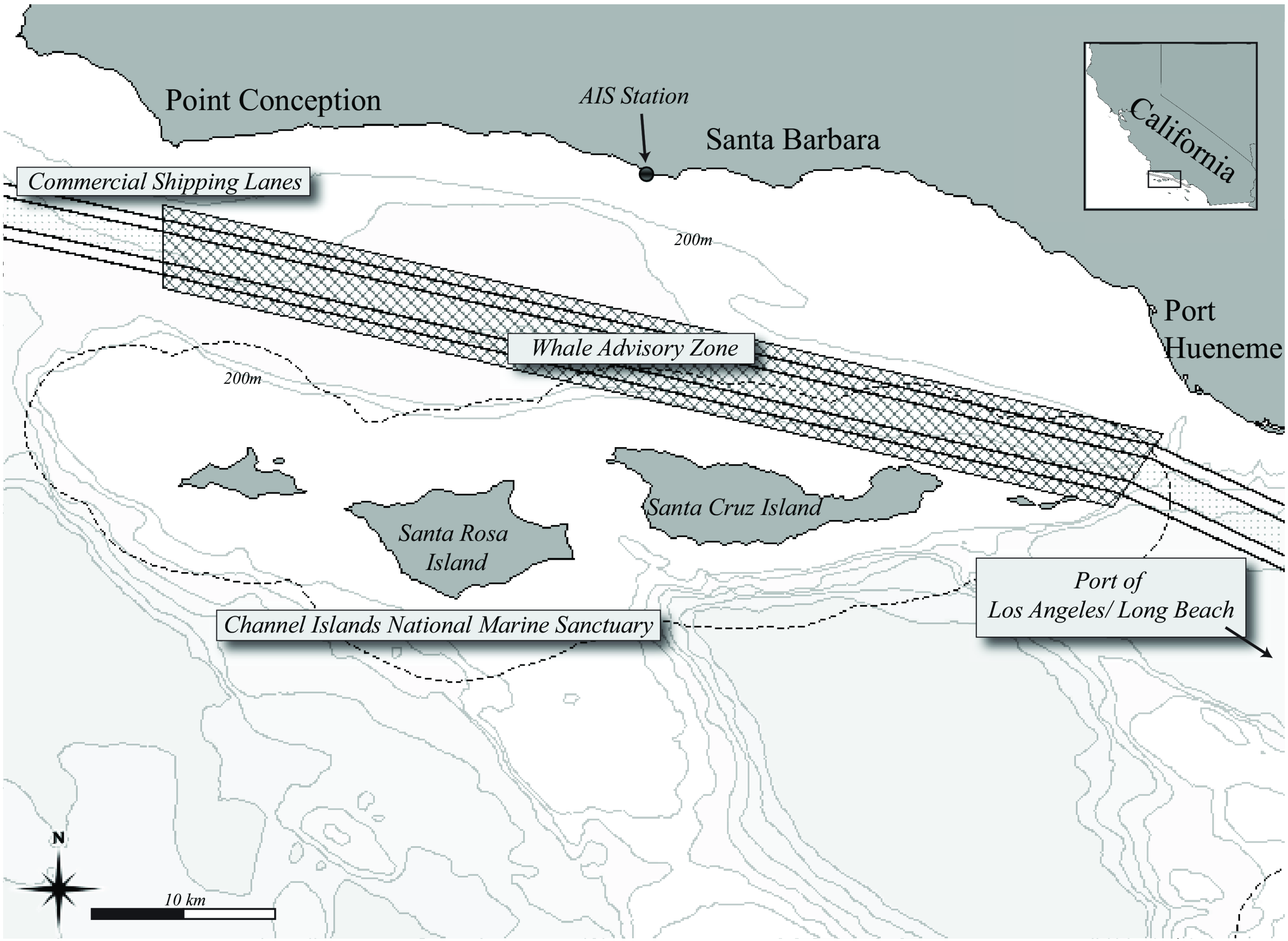


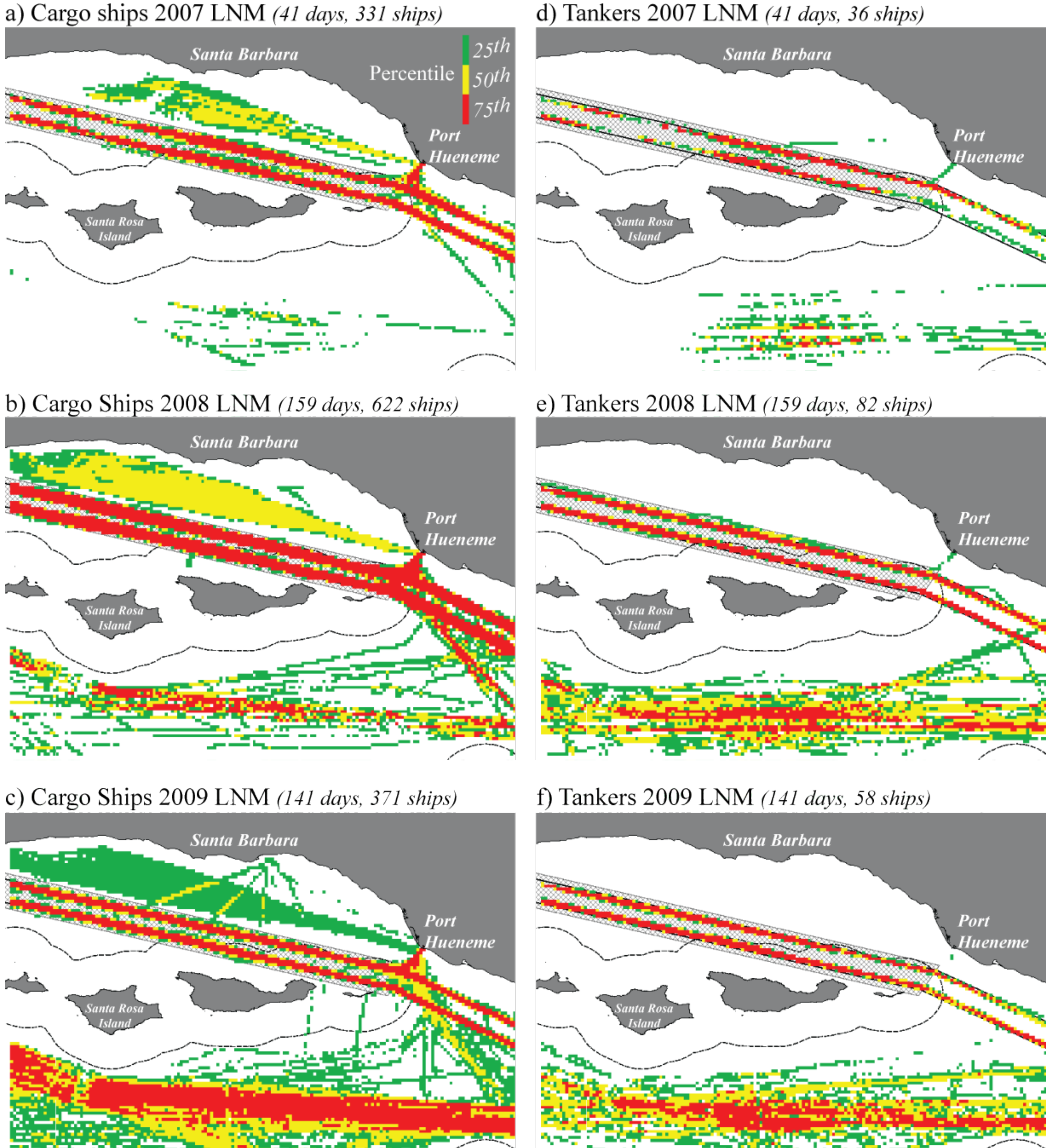
Vanderlaan et al. 2008

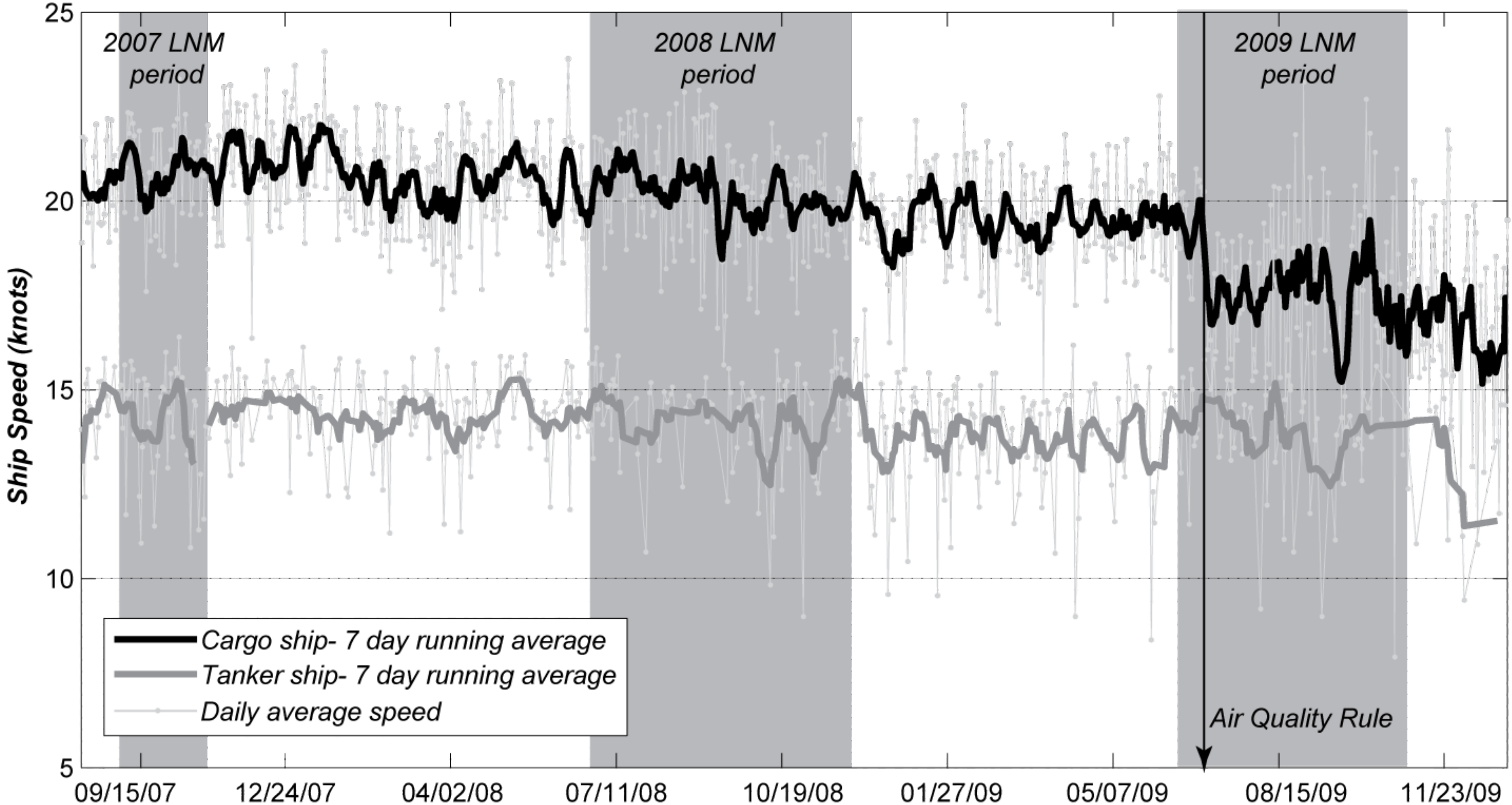


Response of Commercial Ships to a Voluntary Speed Reduction Measure: Are Voluntary Strategies Adequate for Mitigating Ship-Strike Risk?

MEGAN F. MCKENNA,[1,2] STEPHEN L. KATZ,[3]
CHRISTOPHER CONDIT,[4] AND SHAUN WALBRIDGE[5]

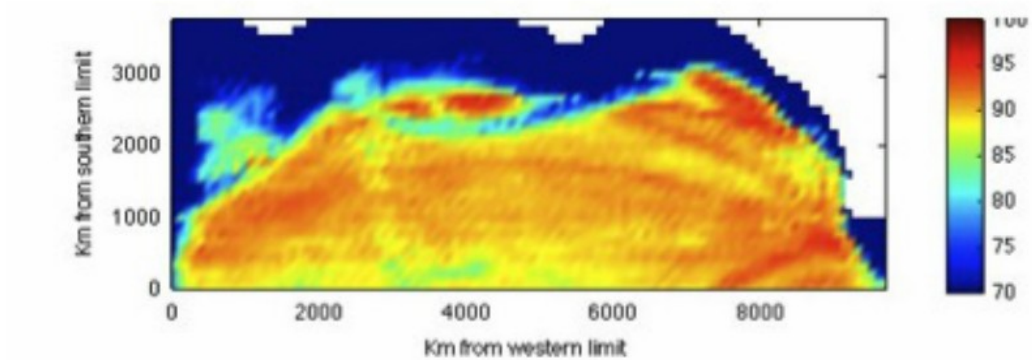



a) Cargo ships 2007 LNM (41 days, 331 ships)
d) Tankers 2007 LNM (41 days, 36 ships)
b) Cargo Ships 2008 LNM (159 days, 622 ships)
e) Tankers 2008 LNM (159 days, 82 ships)
c) Cargo Ships 2009 LNM (141 days, 371 ships)
f) Tankers 2009 LNM (141 days, 58 ships)
Percentile
25th
50th
75th
Santa Barbara
Port Hueneme
Santa Rosa Island

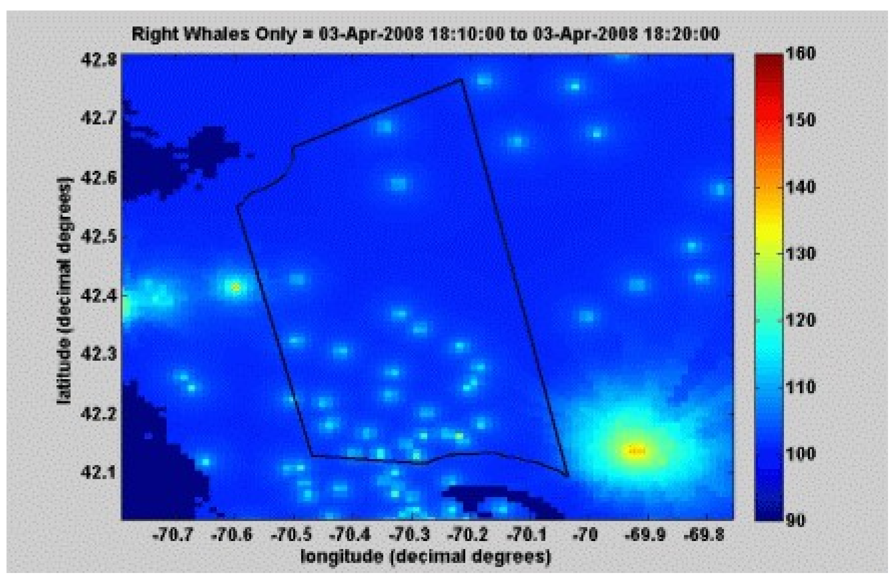


McKenna et al, 2012

Noise Pollution: NOAA WG

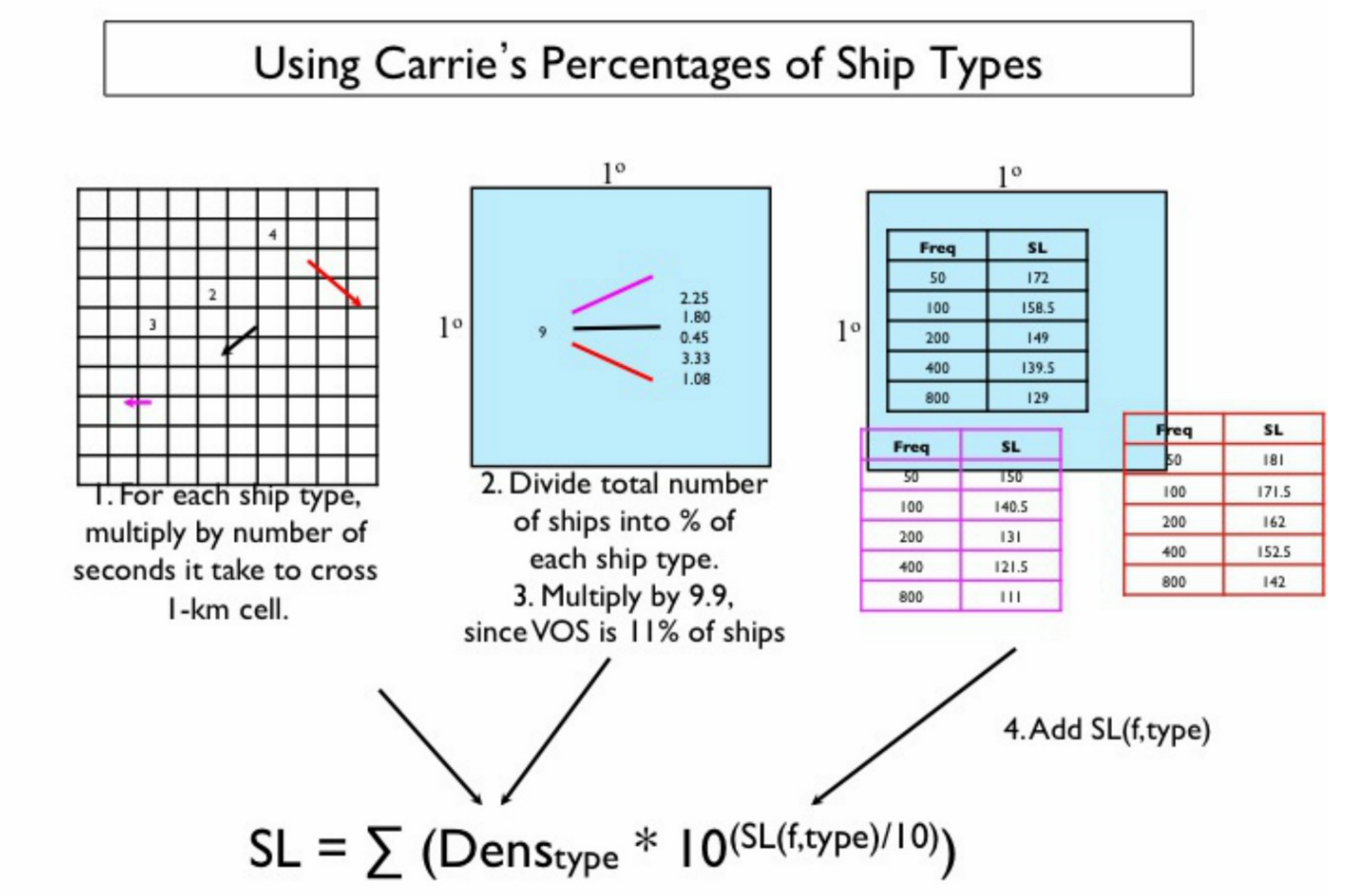


Noise Level (dB) at 50 Hz in the North Pacific with realistic environment and actual shipping



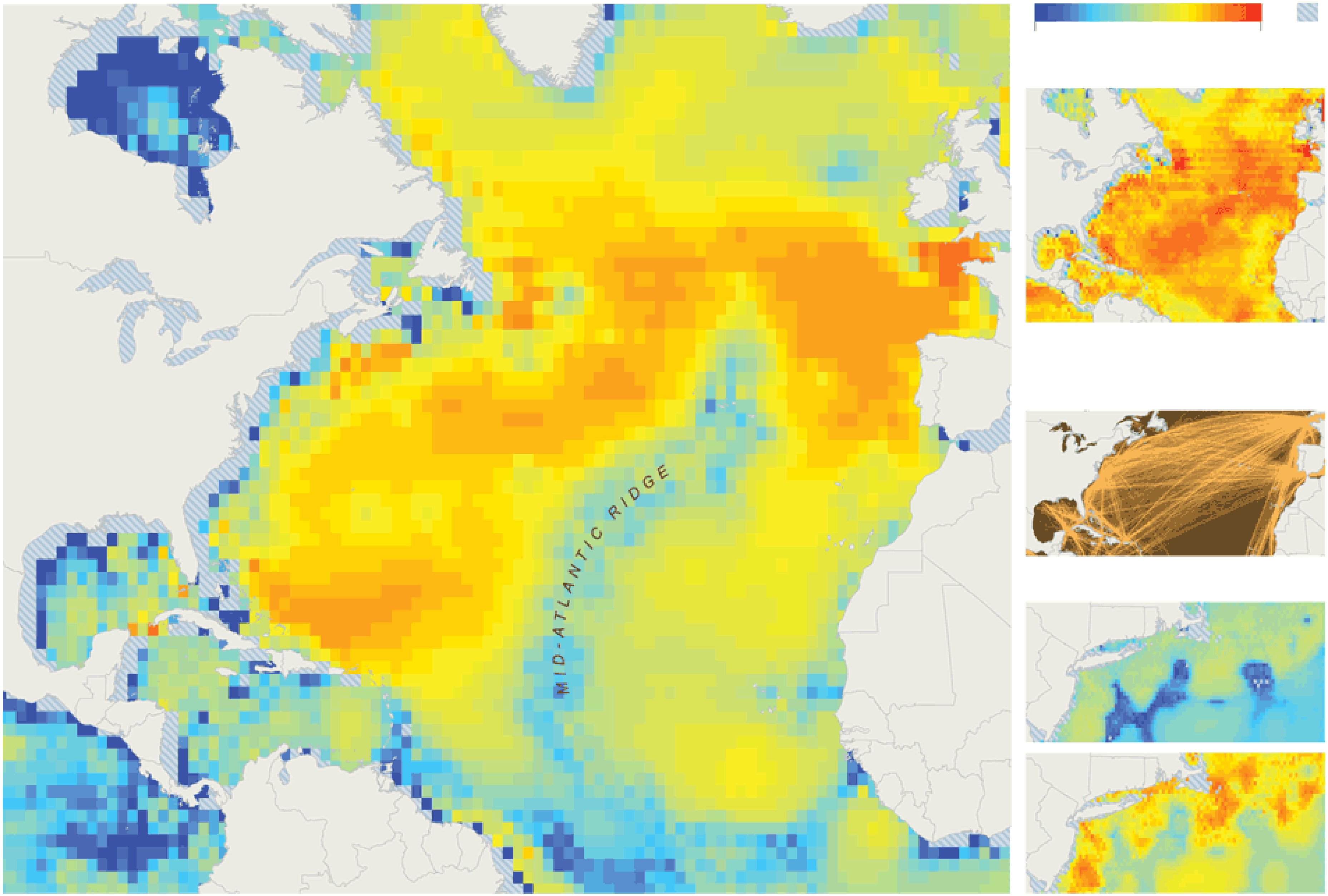
NOAA, Cornell Ornithology

Noise Pollution: NOAA WG



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

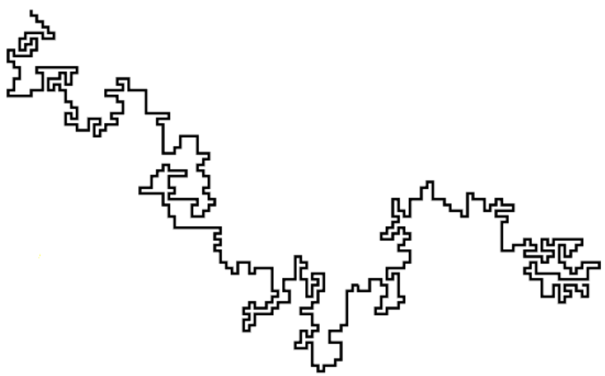
World Database on Protected Areas (WDPA):
- 7481 Marine
- Top 50 shown for traffic volume

Ligurian Sea Sanctuary, 341d ago

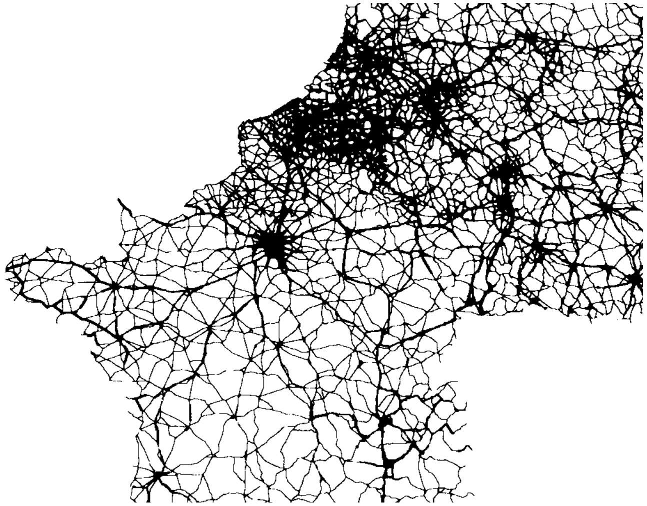
Image Credit: DigitalGlobe

Future Work: Simplification

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



2D Random Walk

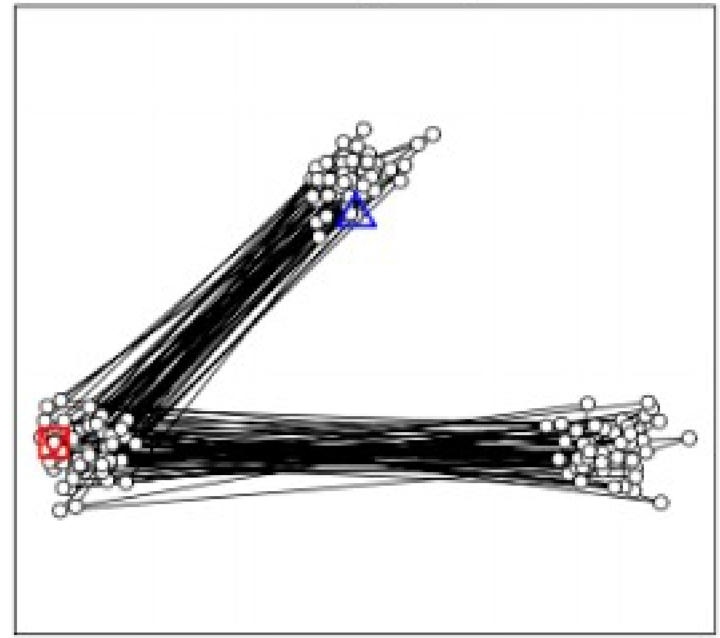


Constrained Network

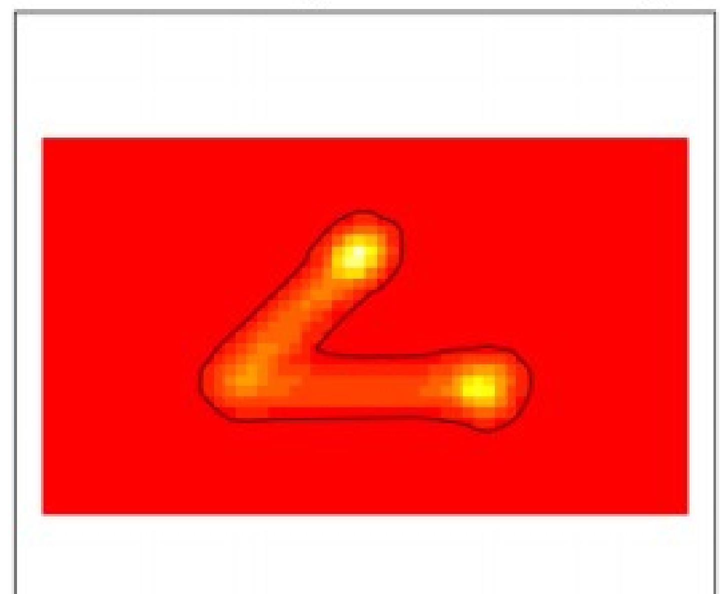
Shipping: attributes of both

Movement models

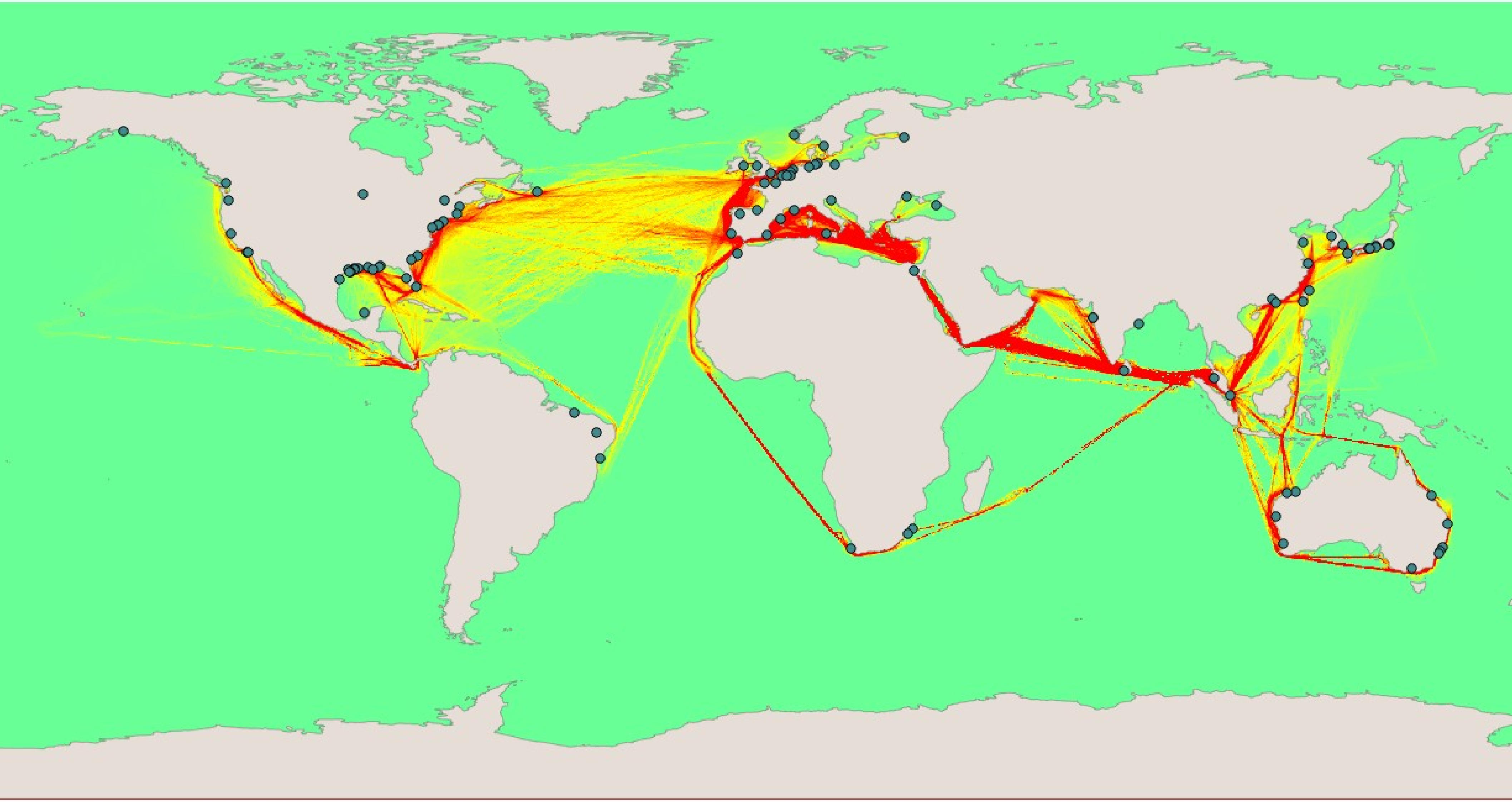
- Common in landscape ecology & geography
- Predict distributions and trajectories from limited observations
- Capture travel time and effort instead of assuming great circle distances

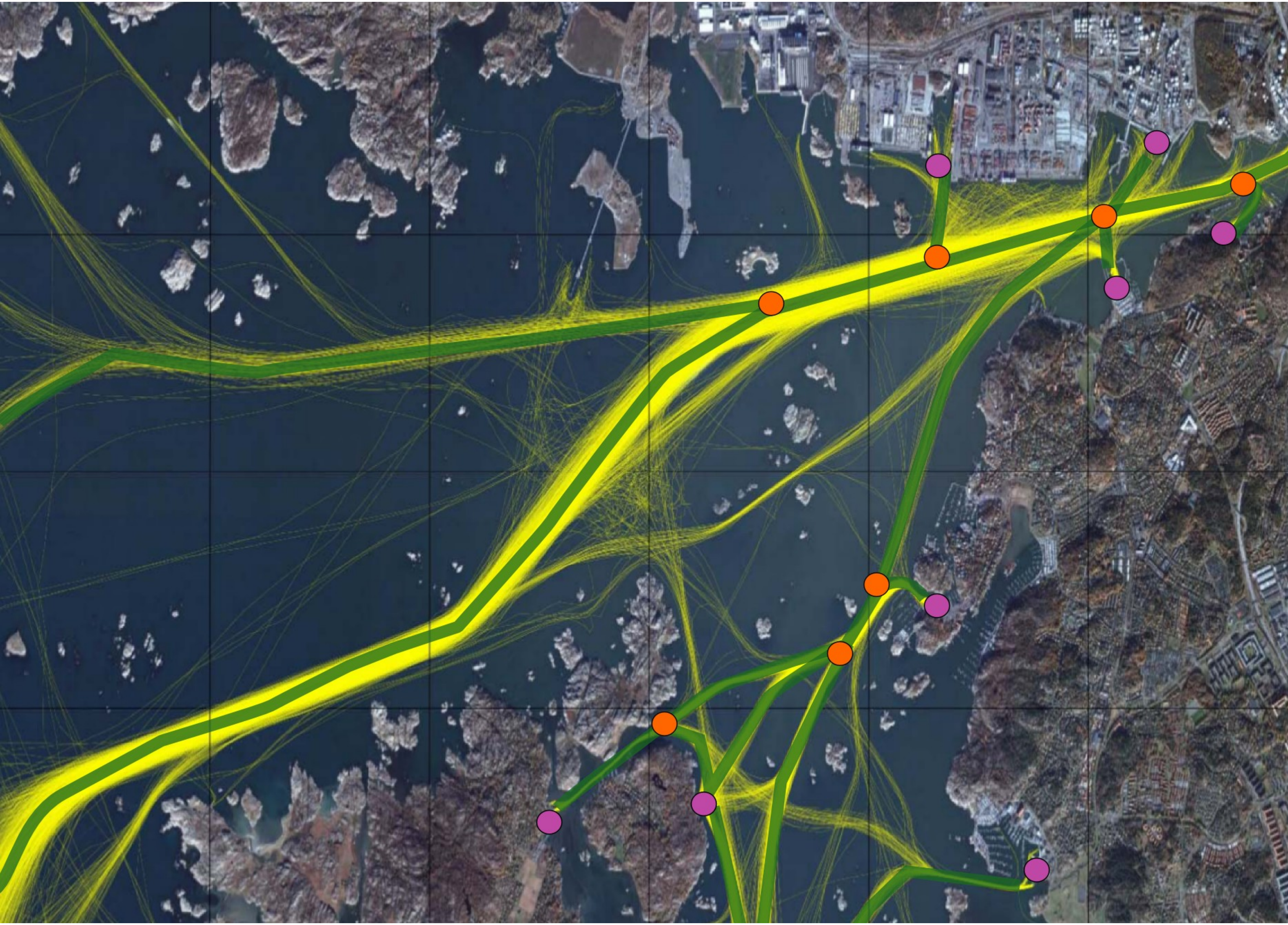


Brownian bridge kernel home range

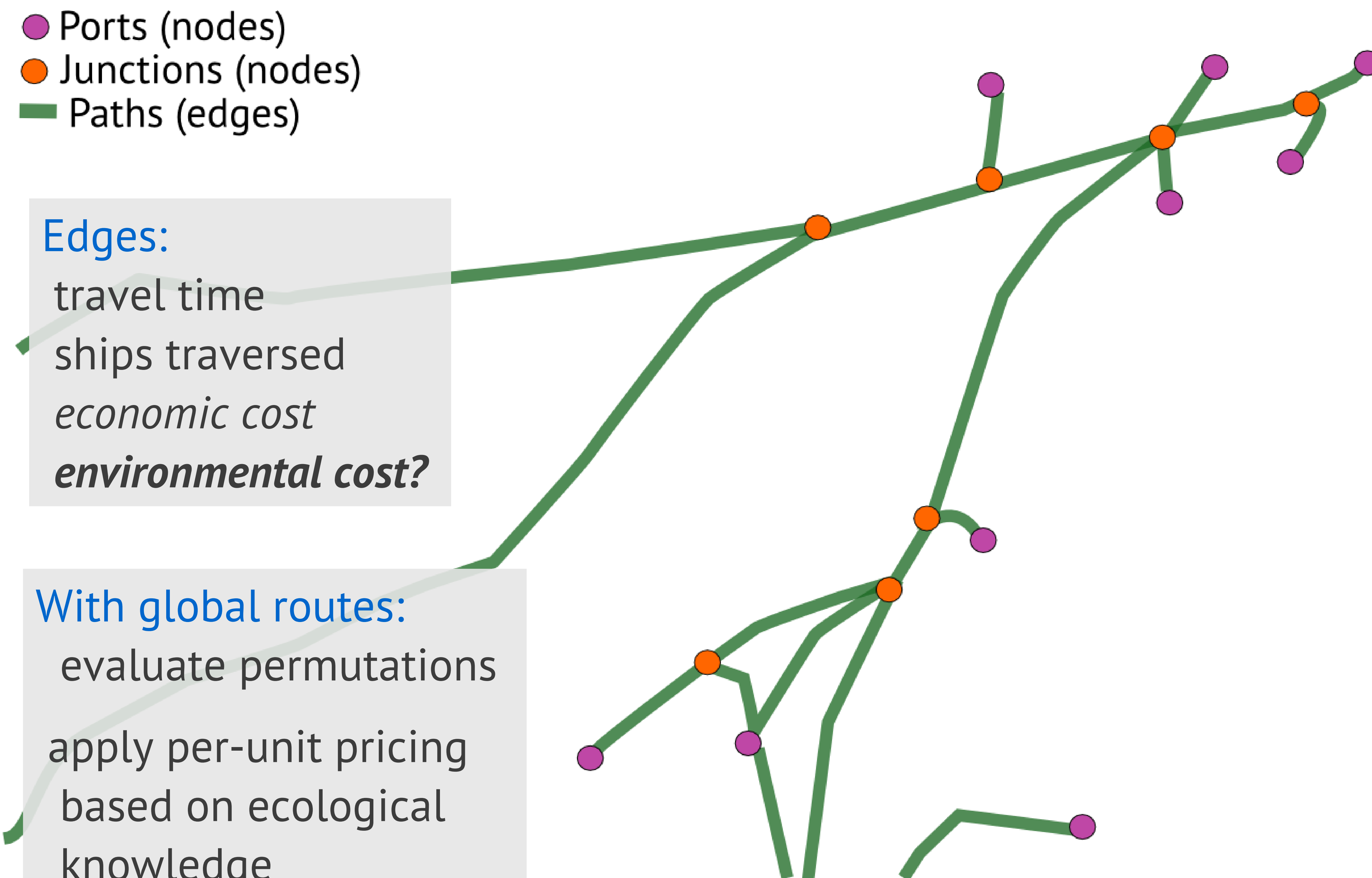


Circuit-based movement model





Shipping as a geographic network



Edges:

travel time

ships traversed

economic cost

environmental cost?

With global routes:

evaluate permutations

apply per-unit pricing based on ecological knowledge

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

Credit: Roger Freedman, UCSB