Technological innovations for detecting hidden vessels and activity

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Starboard
Maritime
Intelligence

Outline

Introduction:
Vessel traffic over space and time: Largely empty and very busy at the same time

Principles of vessel track analysis: Connecting the dots

Identifying vessels of interest: Finding the needle in the haystack

Revealing hidden activity: Indian Ocean example

Revealing hidden relationships: Network analysis of vessel encounters

Revealing hidden vessels: Satellite dark vessel detection

Further discussion

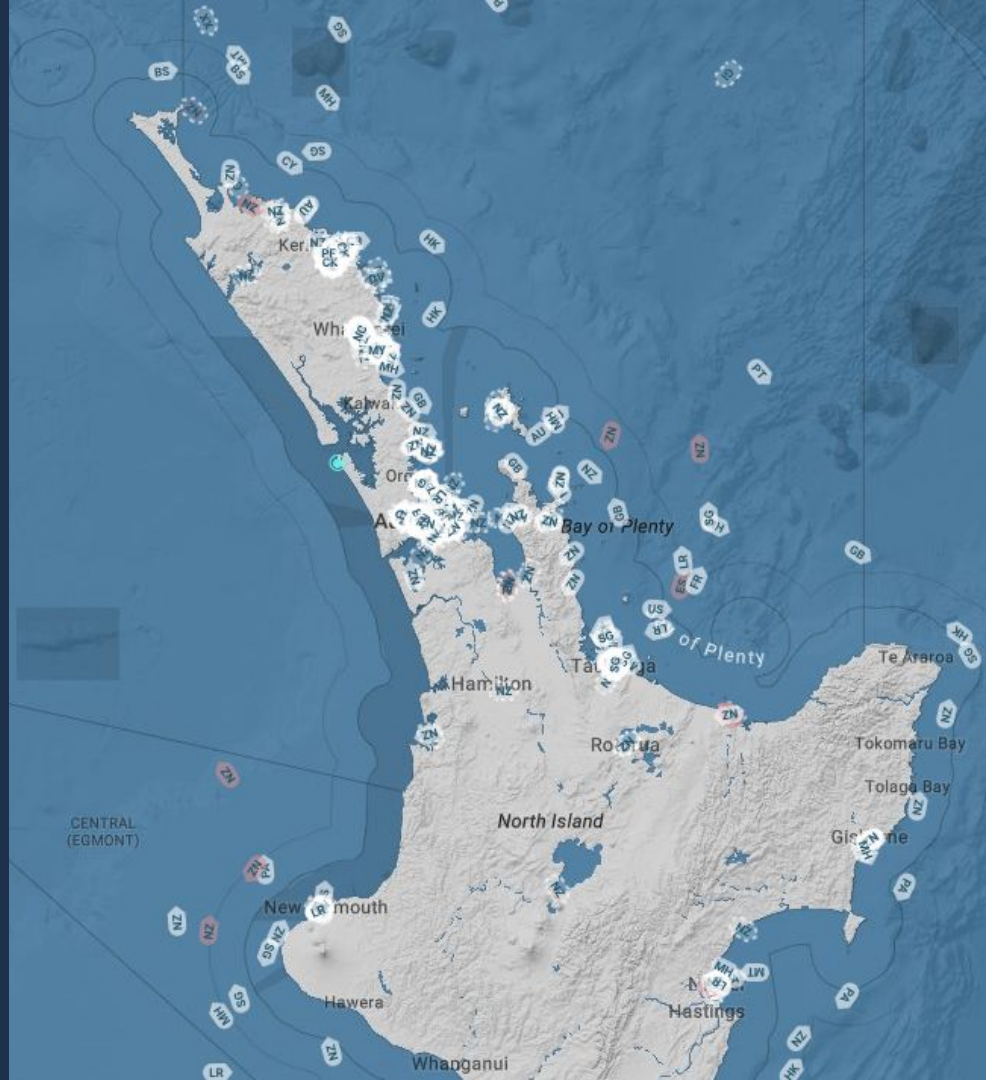
Scales of oceanic vessel traffic

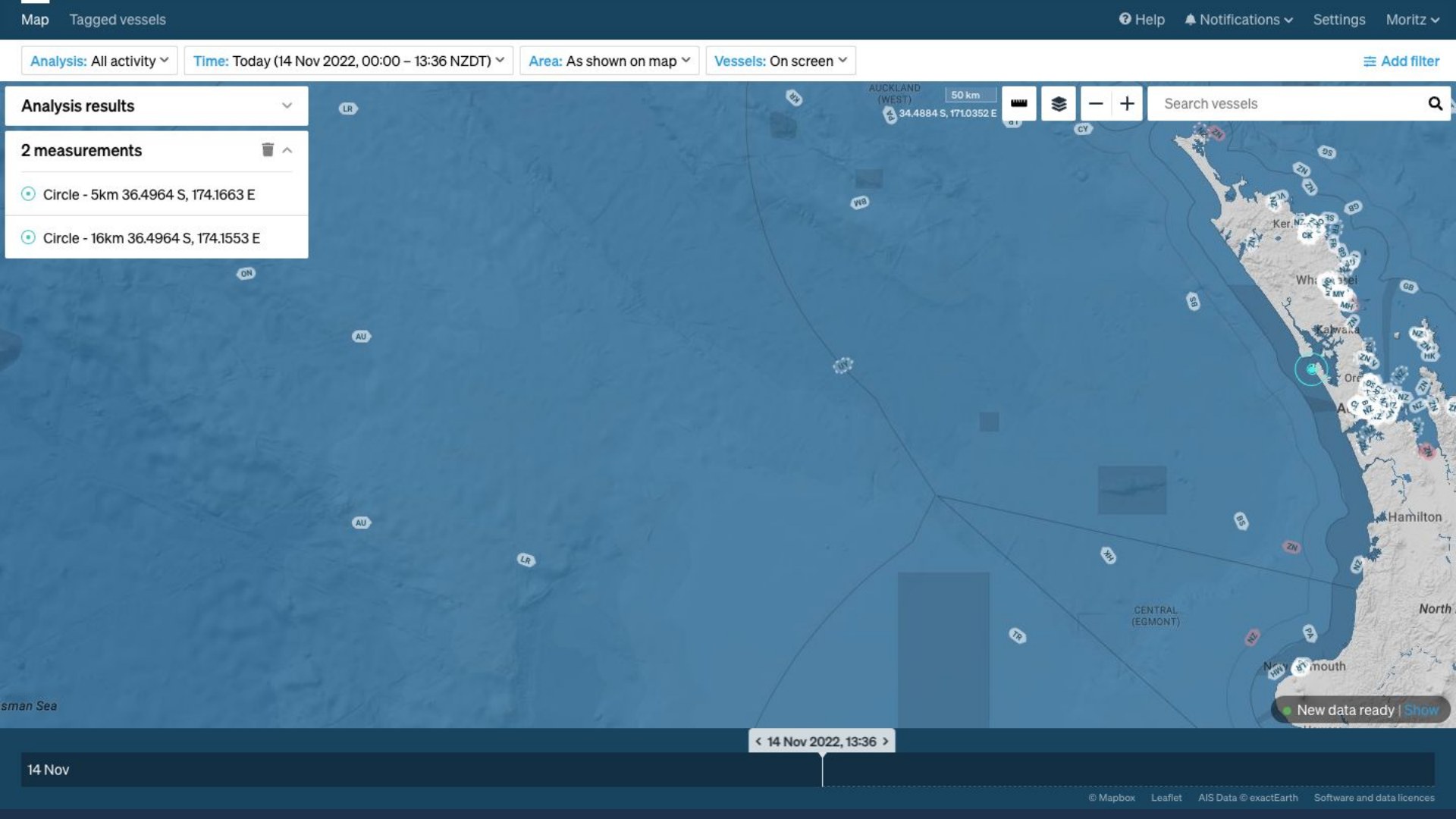
VESSEL TRAFFIC OVER SPACE AND TIME

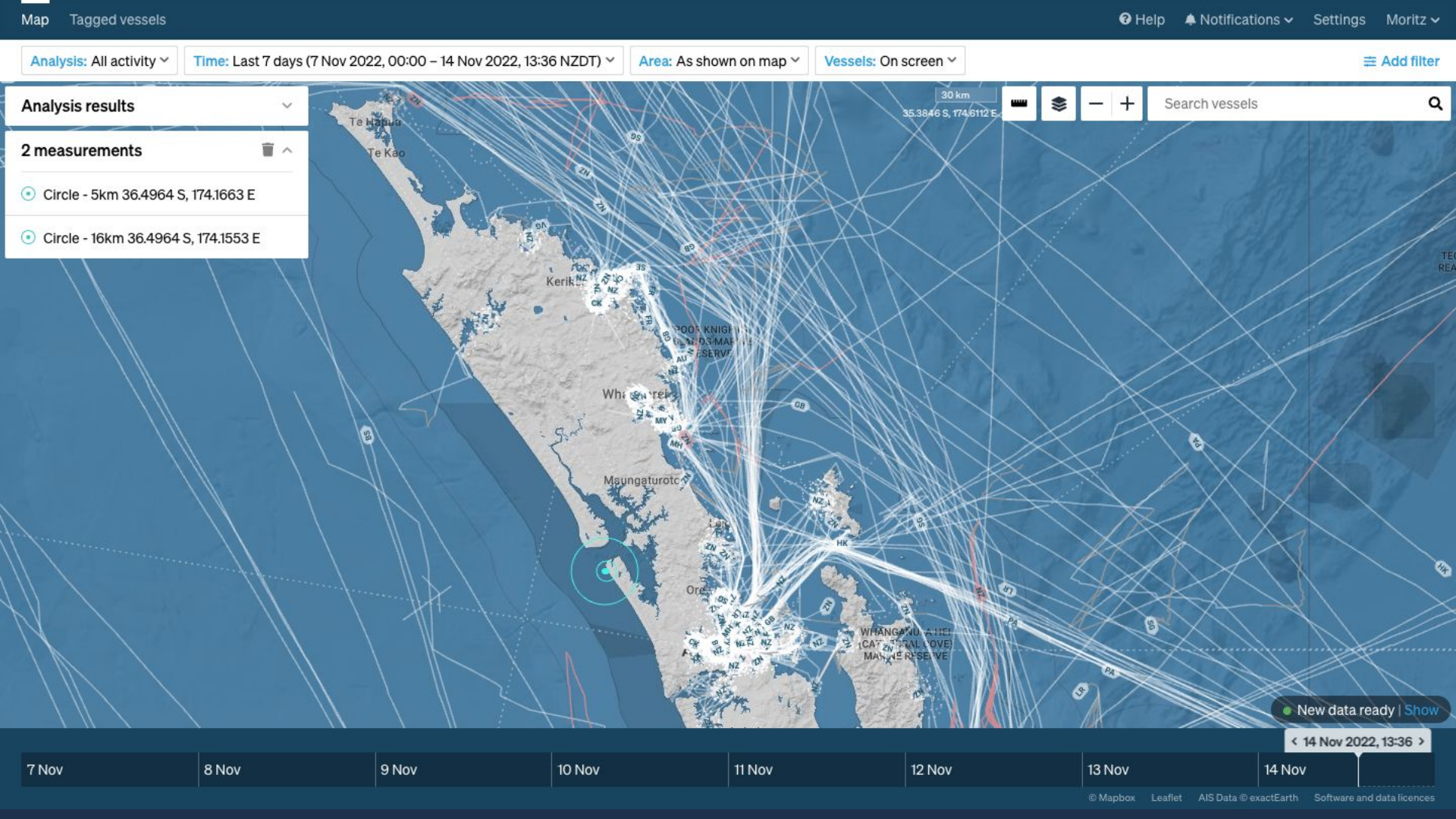
The ocean is a big place; line-of-sight 5-20 km.

At the same time, the ocean is a really busy place; vessel traffic over one week with tracks.

Overwhelming activity makes it really hard to find a ship of interest.




Map
Tagged vessels
Help
Notifications
Settings
Moritz
Analysis: All activity
Time: Today (14 Nov 2022, 00:00 – 13:36 NZDT)
Area: As shown on map
Vessels: On screen
Add filter
Analysis results
2 measurements
Circle - 5km 36.4964 S, 174.1663 E
Circle - 16km 36.4964 S, 174.1553 E
AUCKLAND (WEST)
50 km
34.4884 S, 171.0352 E
Search vessels
Hamilton
CENTRAL (EGMONT)
New data ready | Show
14 Nov 2022, 13:36
14 Nov
© Mapbox
Leaflet
AIS Data © exactEarth
Software and data licences


Map
Tagged vessels
Help
Notifications
Settings
Moritz
Analysis: All activity
Time: Last 7 days (7 Nov 2022, 00:00 – 14 Nov 2022, 13:36 NZDT)
Area: As shown on map
Vessels: On screen
Add filter
Analysis results
2 measurements
Circle - 5km 36.4964 S, 174.1663 E
Circle - 16km 36.4964 S, 174.1553 E
30 km
35.3846 S, 174.6112 E
Search vessels
Te Hapua
Te Kao
Kerikeri
Whangarei
Maungaturoto
Orewa
WHANGAMUMU (CATHEDRAL COVE) MARINE RESERVE
New data ready | Show
14 Nov 2022, 13:36
7 Nov
8 Nov
9 Nov
10 Nov
11 Nov
12 Nov
13 Nov
14 Nov
© Mapbox
Leaflet
AIS Data © exactEarth
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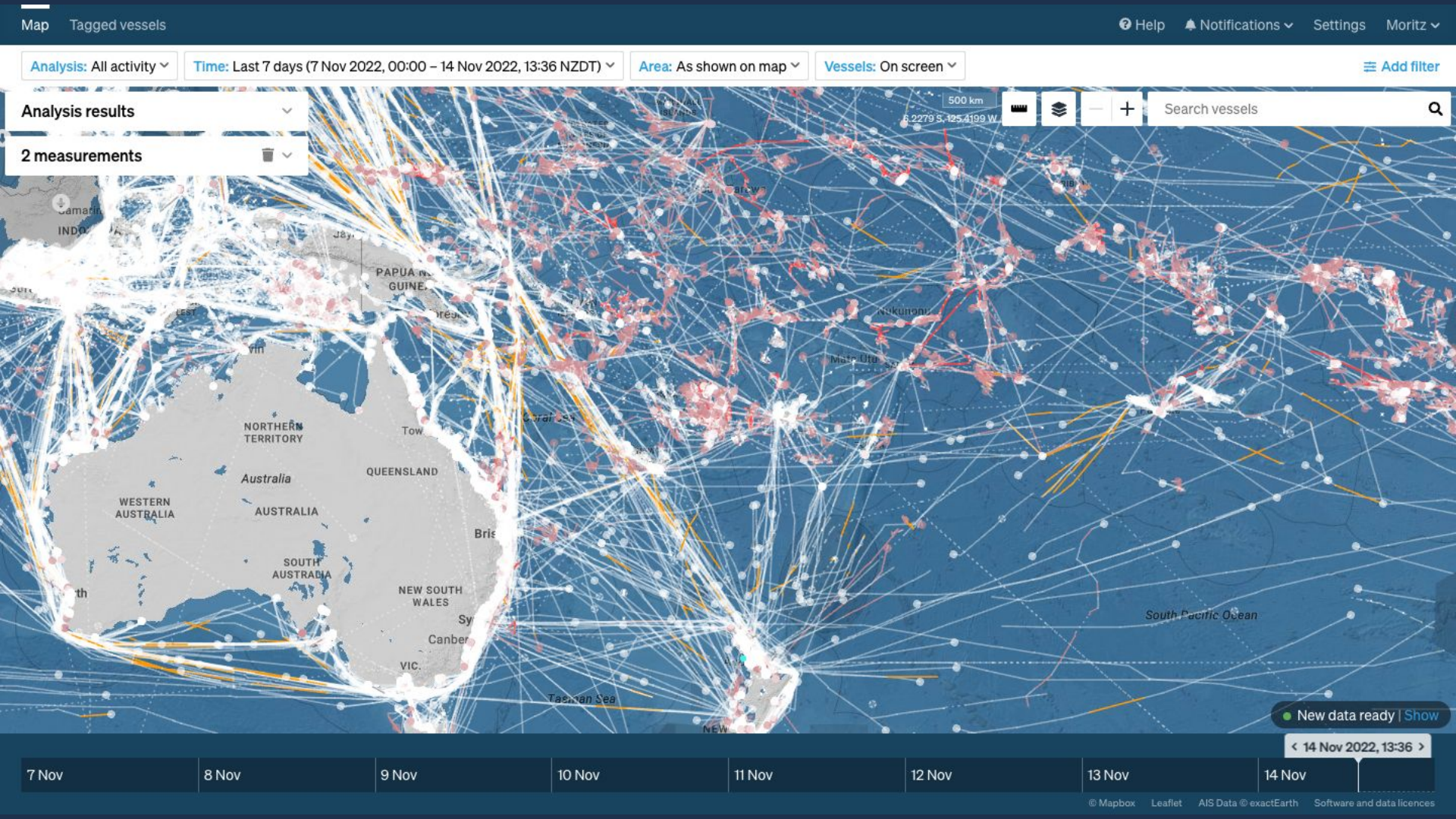
Map
Tagged vessels
Help
Notifications
Settings
Moritz
Analysis: All activity
Time: Last 7 days (7 Nov 2022, 00:00 – 14 Nov 2022, 13:36 NZDT)
Area: As shown on map
Vessels: On screen
Add filter
Analysis results
2 measurements
500 km
6.2279 S, 125.4199 W
Search vessels
NORTHERN TERRITORY
QUEENSLAND
Australia
WESTERN AUSTRALIA
AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VIC.
Tasman Sea
South Pacific Ocean
New data ready | Show
14 Nov 2022, 13:36
7 Nov
8 Nov
9 Nov
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11 Nov
12 Nov
13 Nov
14 Nov
© Mapbox
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AIS Data © exactEarth
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Scales of oceanic vessel traffic

VESSEL TRAFFIC OVER SPACE AND TIME

The ocean is a big place; line-of-sight 5-20 km.

At the same time, the ocean is a really busy place; vessel traffic over one week with tracks.

Overwhelming activity makes it really hard to find a ship of interest.

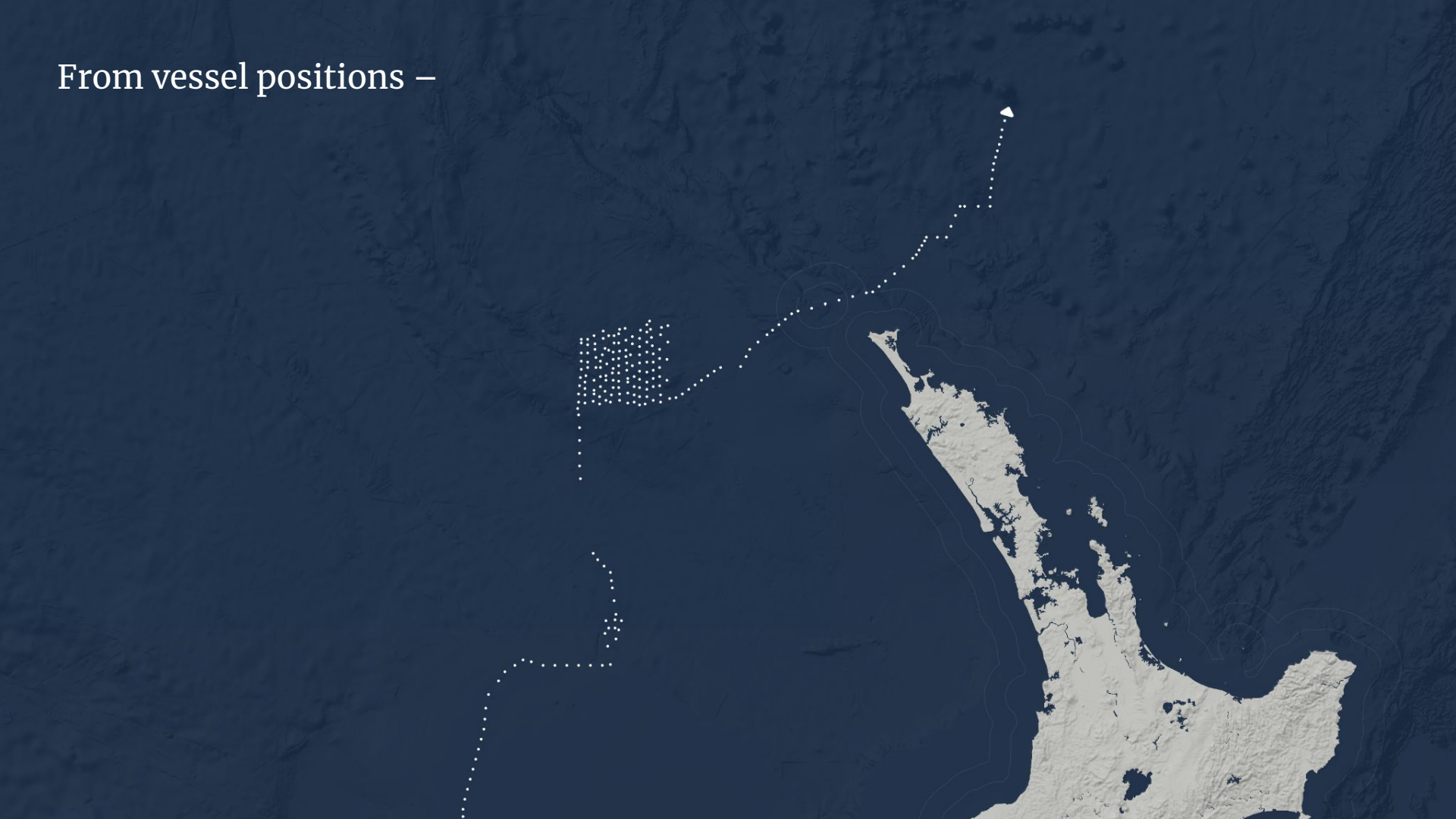
VESSEL TRACK ANALYSIS

Vessel trackers (e.g., AIS, VMS) just provide geolocations.

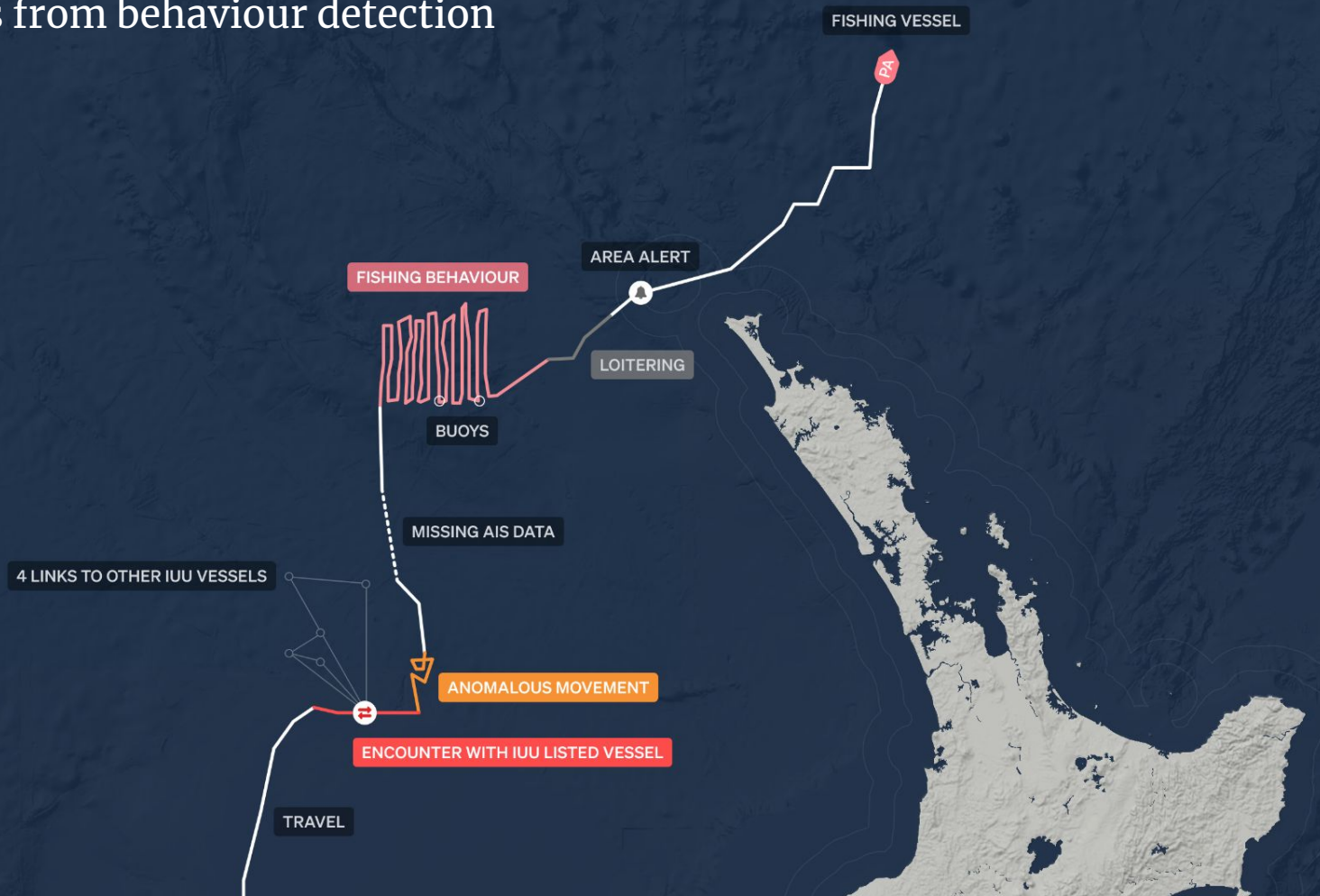
Vessel tracks contain behavioural information.

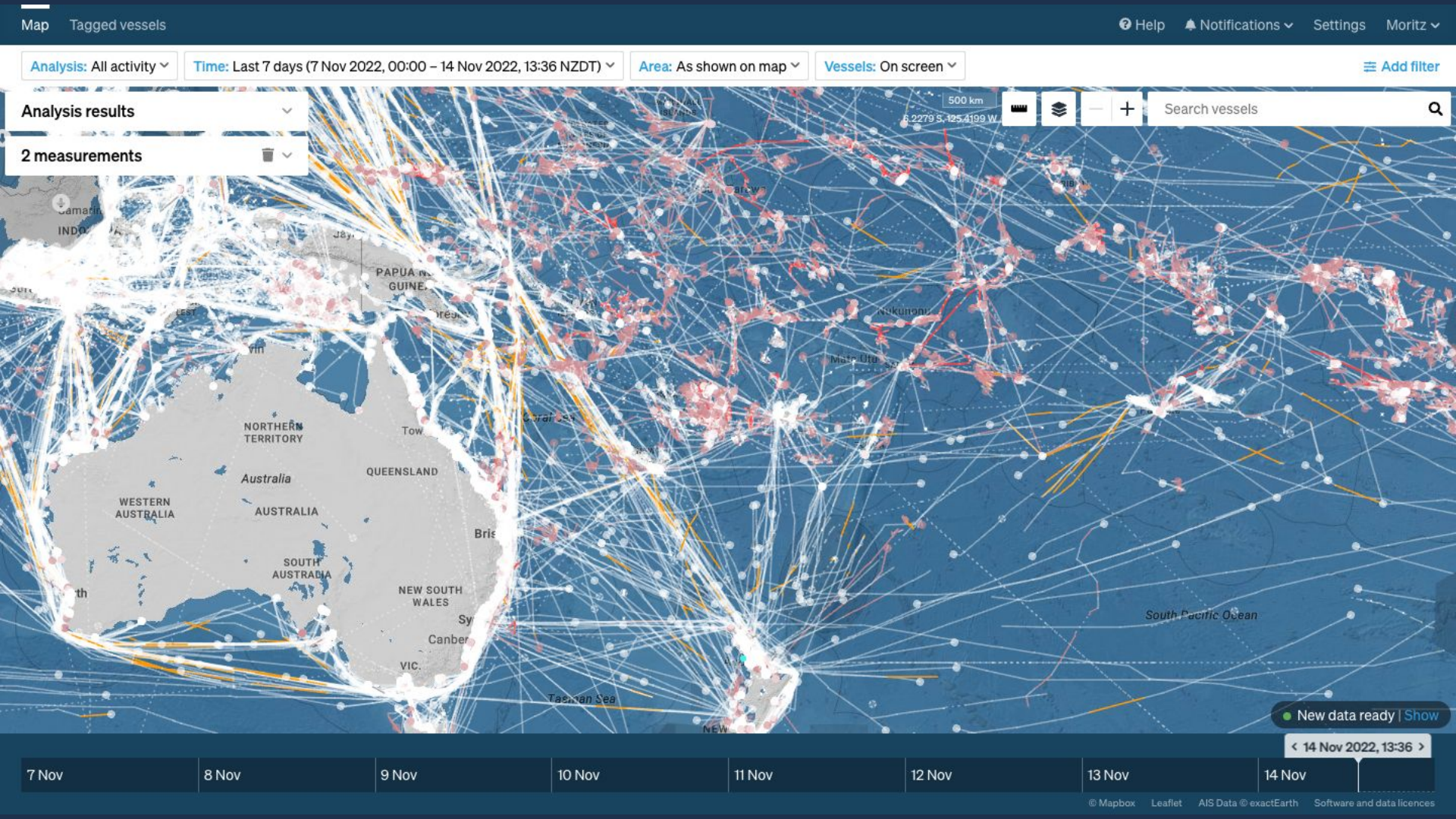
Reduce complexity to show just the vessels of interest.

From vessel positions –



– to insights from behaviour detection algorithms.




Map
Tagged vessels
Help
Notifications
Settings
Moritz
Analysis: All activity
Time: Last 7 days (7 Nov 2022, 00:00 – 14 Nov 2022, 13:36 NZDT)
Area: As shown on map
Vessels: On screen
Add filter
Analysis results
2 measurements
500 km
6.2279 S, 125.4199 W
Search vessels
NORTHERN TERRITORY
QUEENSLAND
Australia
WESTERN AUSTRALIA
AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VIC.
Tasman Sea
South Pacific Ocean
New data ready | Show
14 Nov 2022, 13:36
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10 Nov
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14 Nov
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AIS Data © exactEarth
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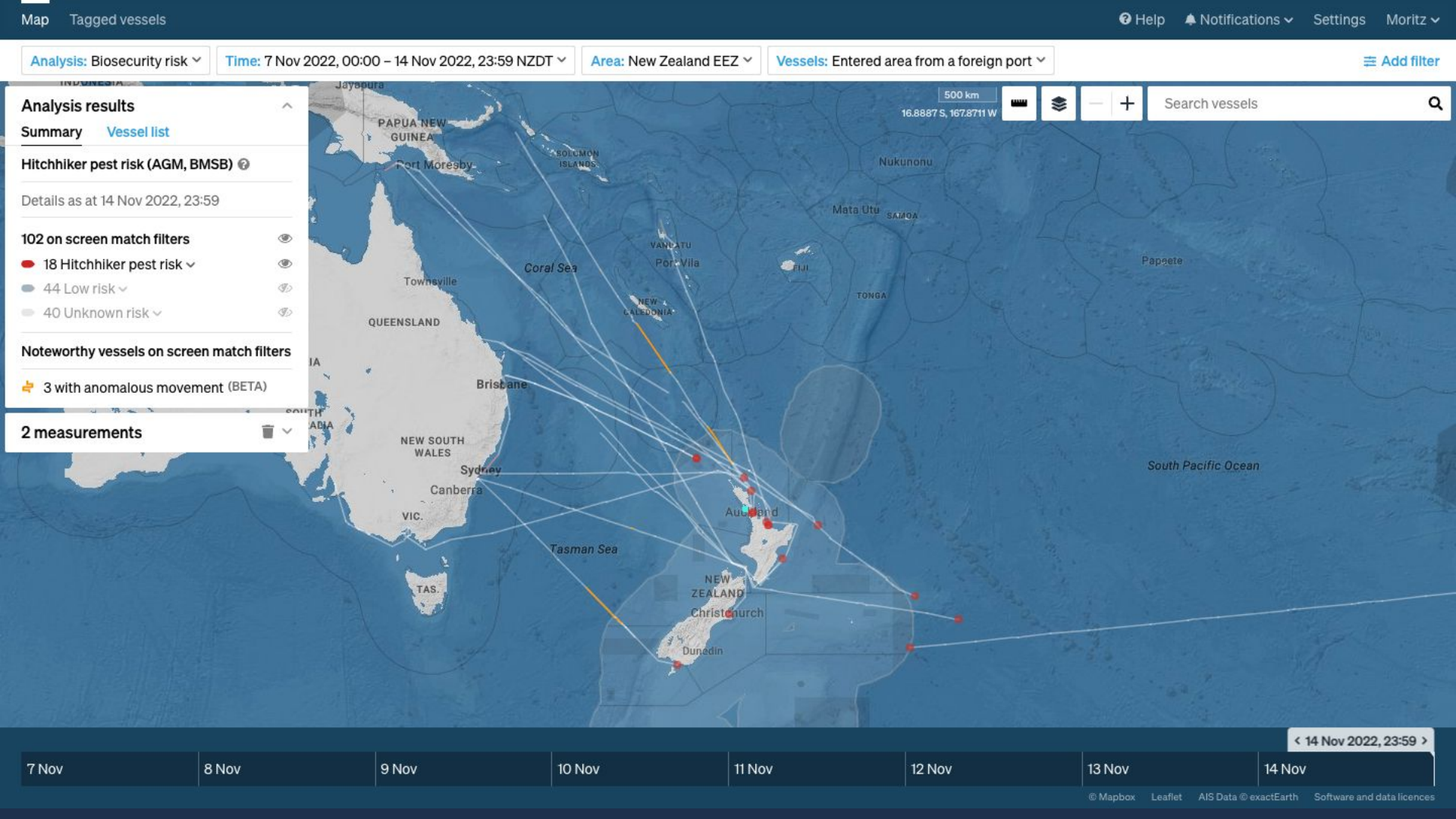
Map
Tagged vessels
Help
Notifications
Settings
Moritz
Analysis: Biosecurity risk
Time: 7 Nov 2022, 00:00 – 14 Nov 2022, 23:59 NZDT
Area: New Zealand EEZ
Vessels: Entered area from a foreign port
Add filter
Analysis results
Summary
Vessel list
Hitchhiker pest risk (AGM, BMSB)
Details as at 14 Nov 2022, 23:59
102 on screen match filters
18 Hitchhiker pest risk
44 Low risk
40 Unknown risk
Noteworthy vessels on screen match filters
3 with anomalous movement (BETA)
2 measurements
500 km
16.8887 S, 167.8711 W
Search vessels
PAPUA NEW GUINEA
Port Moresby
SOLOMON ISLANDS
Nukunonu
Mata Utu
SAMOA
VANUATU
Port Vila
FIJI
TONGA
Papeete
Coral Sea
Townsville
NEW CALEDONIA
QUEENSLAND
Brisbane
NEW SOUTH WALES
Sydney
Canberra
VIC.
Tasman Sea
TAS.
South Pacific Ocean
Auckland
NEW ZEALAND
Christchurch
Dunedin
< 14 Nov 2022, 23:59 >
7 Nov
8 Nov
9 Nov
10 Nov
11 Nov
12 Nov
13 Nov
14 Nov
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AIS Data © exactEarth
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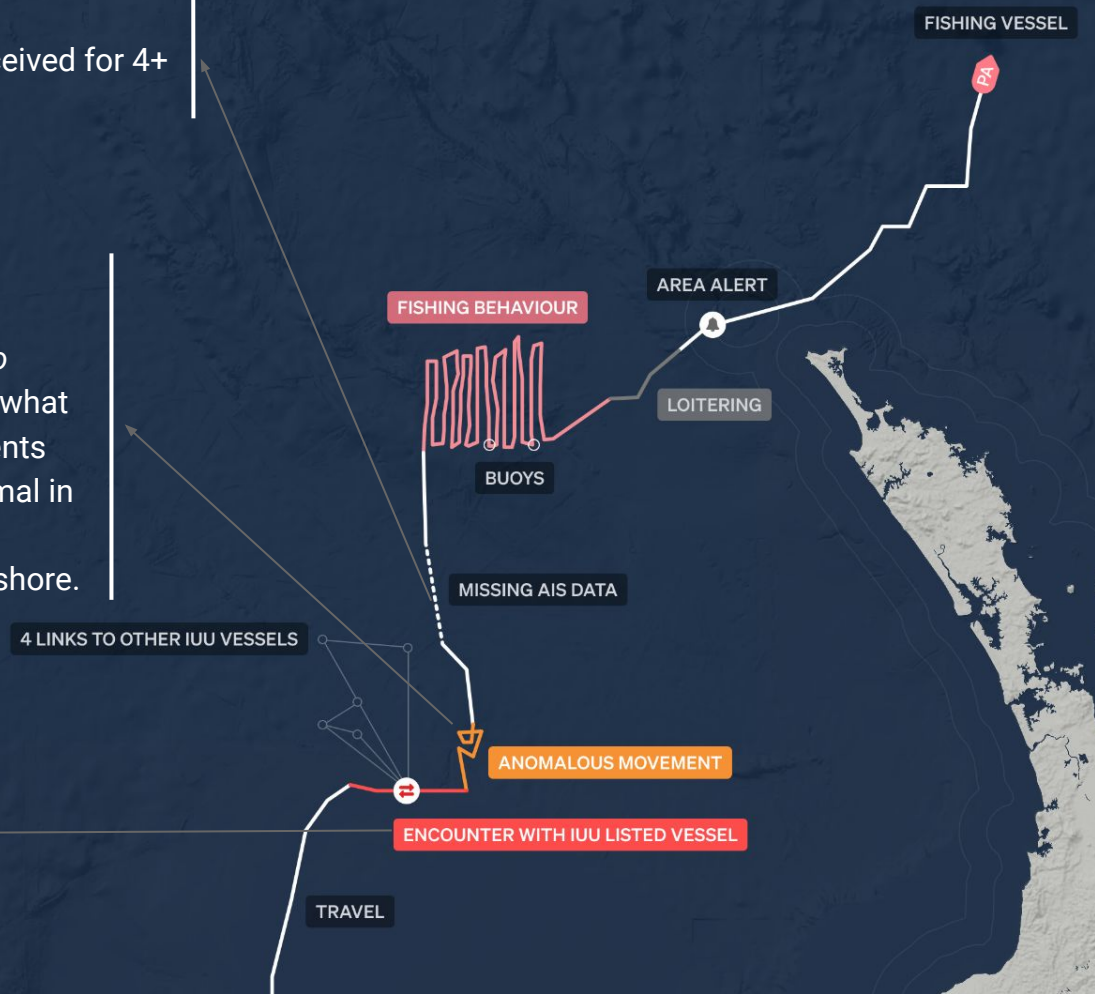
Missing AIS:
No AIS data received for 4+ hours

Anomalous movement (beta):
Anomaly detector that uses probabilistic representation for AIS tracks and *a contrario* anomaly detection (GeoTrackNet). It learns what is normal based on historical track movements and then flags any movement that is abnormal in relation to this.
Applied to non-fishing vessels > 3 km from shore.

Encounters:
< 50 metres from each other for 10+ minutes; or
< 200 metres from each other for 30+ minutes.



Track analytics reveal hidden activity

Suspicious behaviour in the Indian Ocean

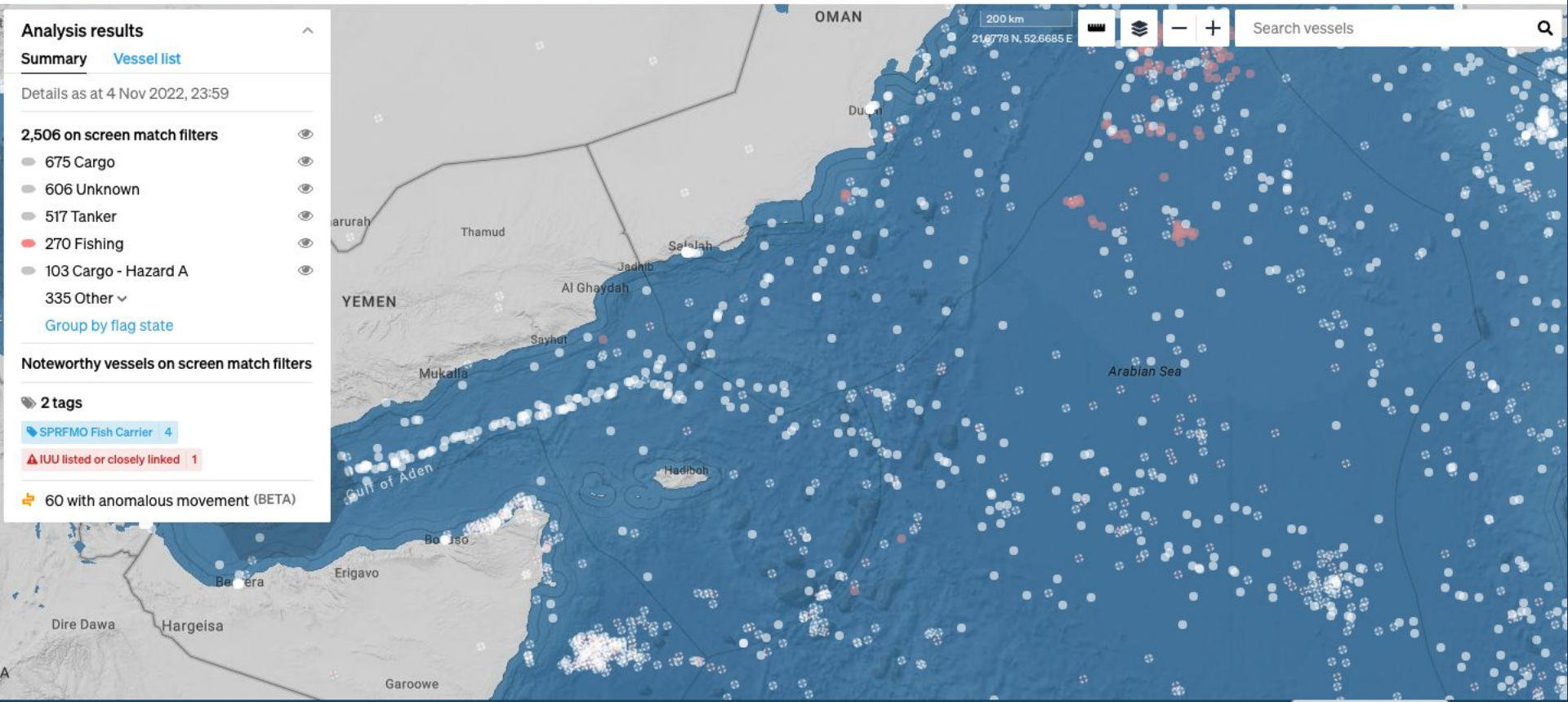
Plenty of ships in the western Indian Ocean almost random.

Turning on tracks shows shipping lanes and fishing activity.

Filtering for anomalous movements and AIS gaps reveals an ‘intersection’ where ships slow down and change course.

The ‘*Grey Palm*’ loiters in the intersection. Its vessel report shows that is has not been to a port in years.

Analysis: All activity | Time: 1 Nov 2022, 00:00 – 4 Nov 2022, 23:59 NZDT | Area: As shown on map | Vessels: On screen | Add filter



Analysis results

Summary | Vessel list

Details as at 4 Nov 2022, 23:59

2,506 on screen match filters

- 675 Cargo
- 606 Unknown
- 517 Tanker
- 270 Fishing
- 103 Cargo - Hazard A
- 335 Other

Group by flag state

Noteworthy vessels on screen match filters

2 tags

- SPRFMO Fish Carrier 4
- IUU listed or closely linked 1

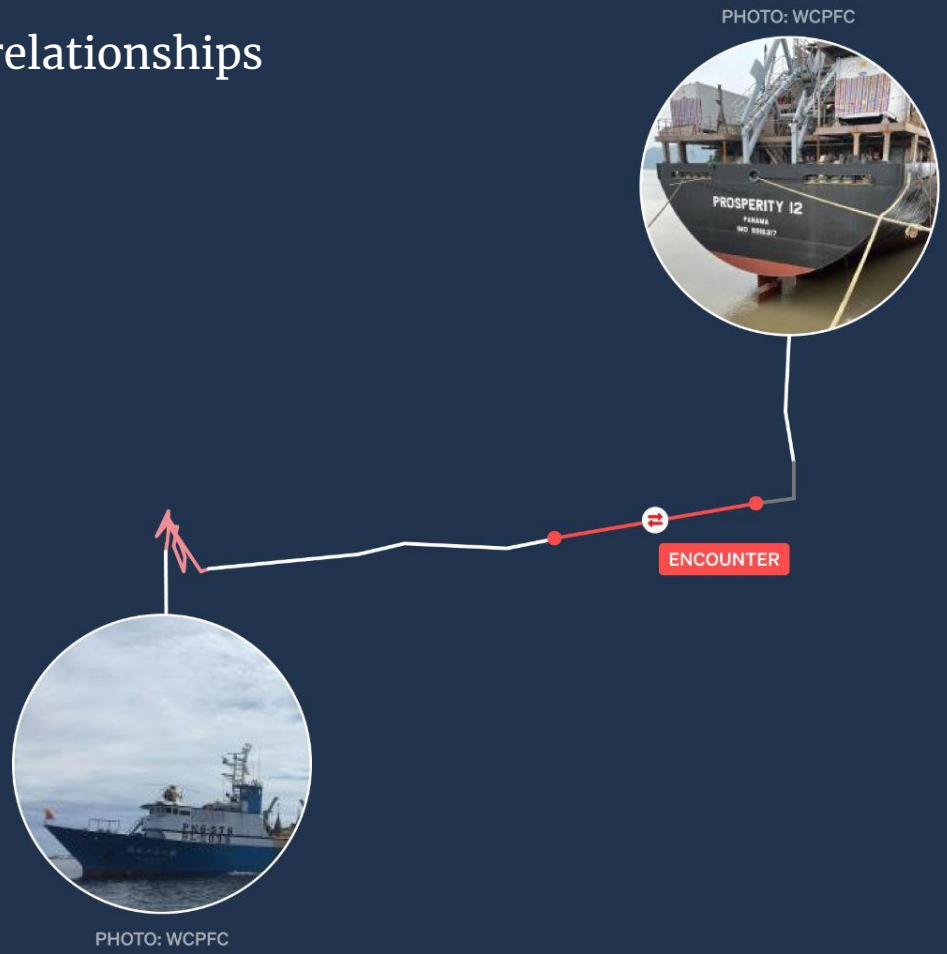
60 with anomalous movement (BETA)

4 Nov 2022, 12:59

1 Nov | 2 Nov | 3 Nov | 4 Nov

Network analysis reveals hidden relationships

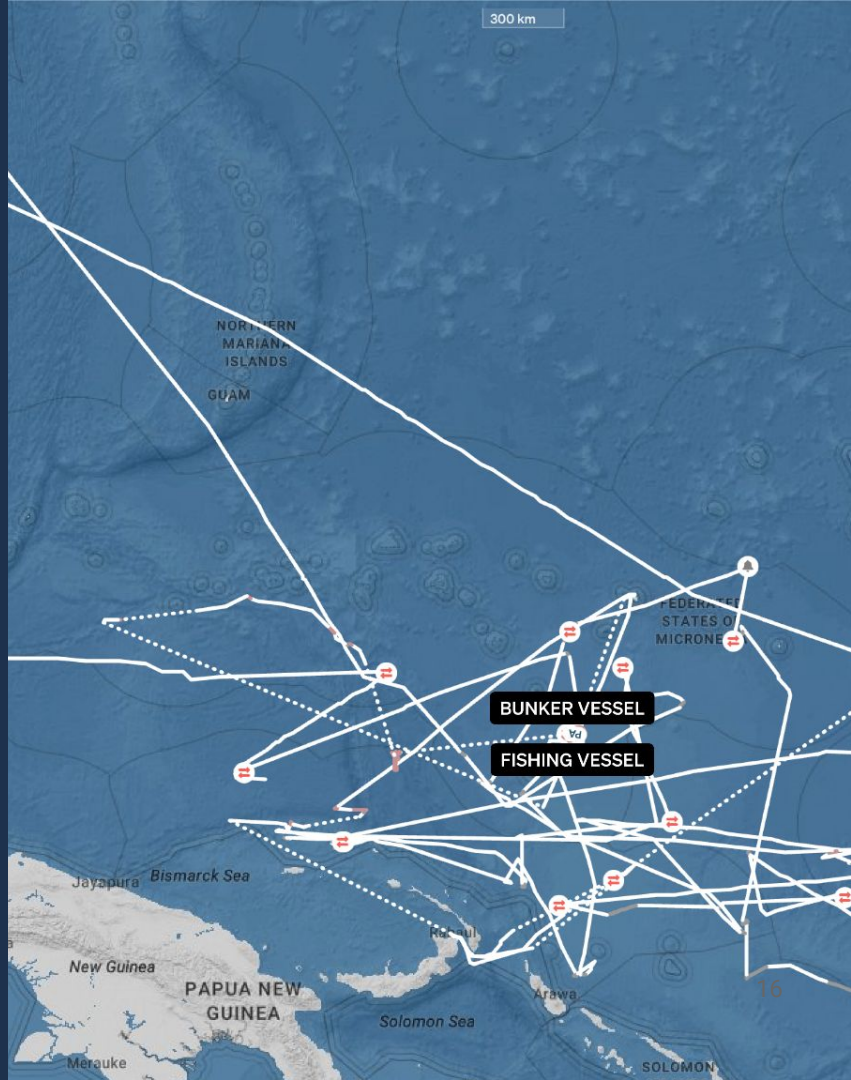
At-sea encounters can be a tell-tale of suspicious activity.



Network analysis reveals hidden relationships

At-sea encounters can be a tell-tale of suspicious activity.

But they are hard to disentangle, especially if second-degree encounters are considered relevant.

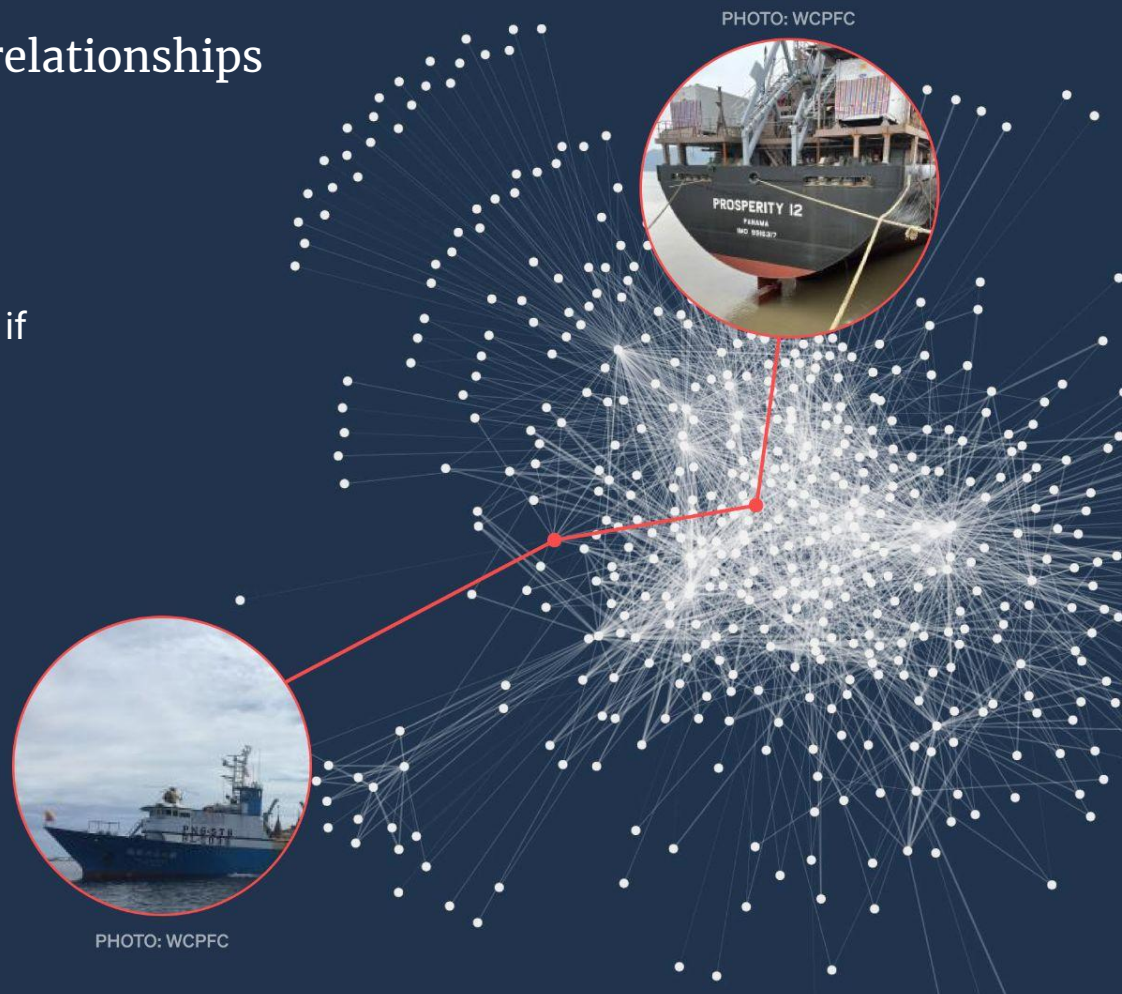


Network analysis reveals hidden relationships

At-sea encounters can be a tell-tale of suspicious activity.

But they are hard to disentangle, especially if second-degree encounters are considered relevant.

Encounter networks allow modelling the structure of relationships between vessels.



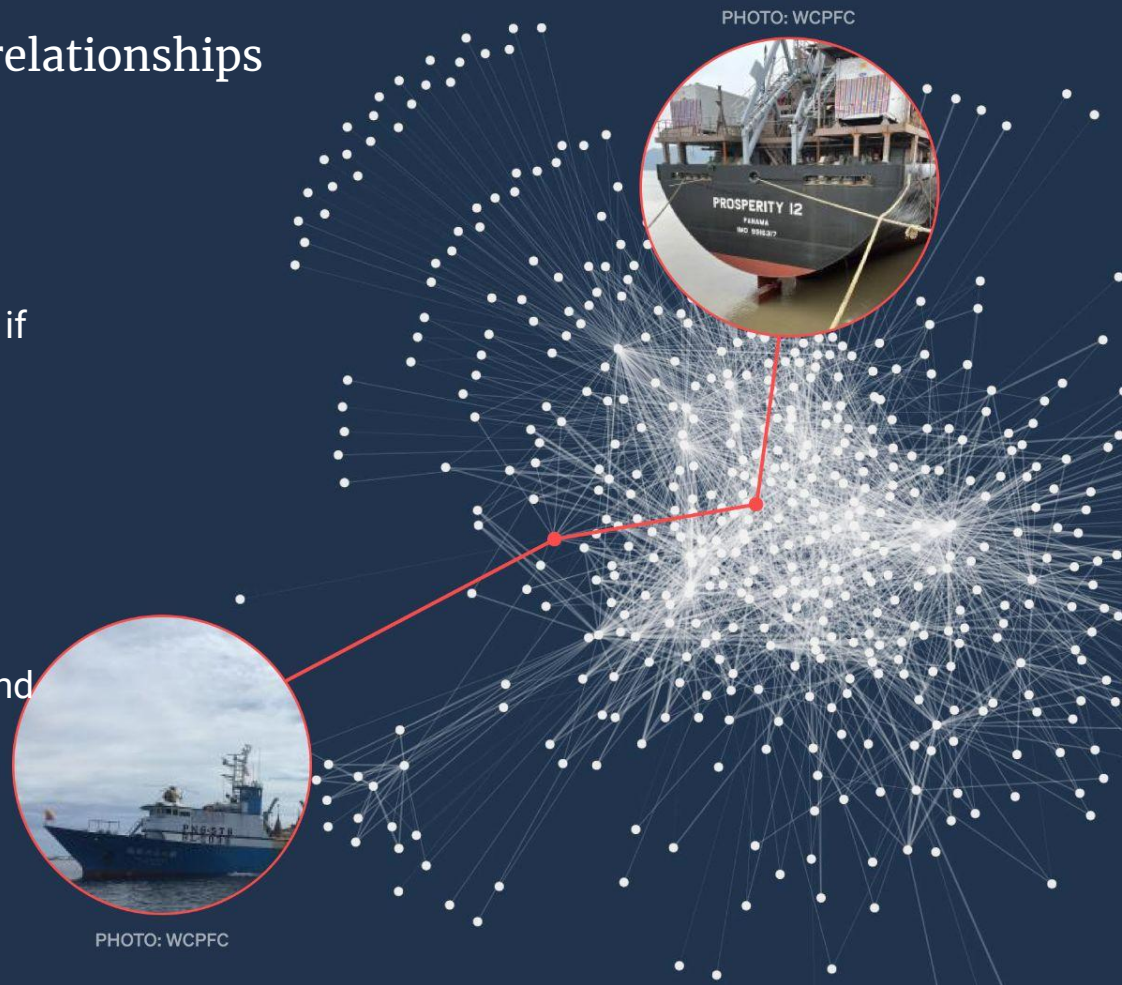
Network analysis reveals hidden relationships

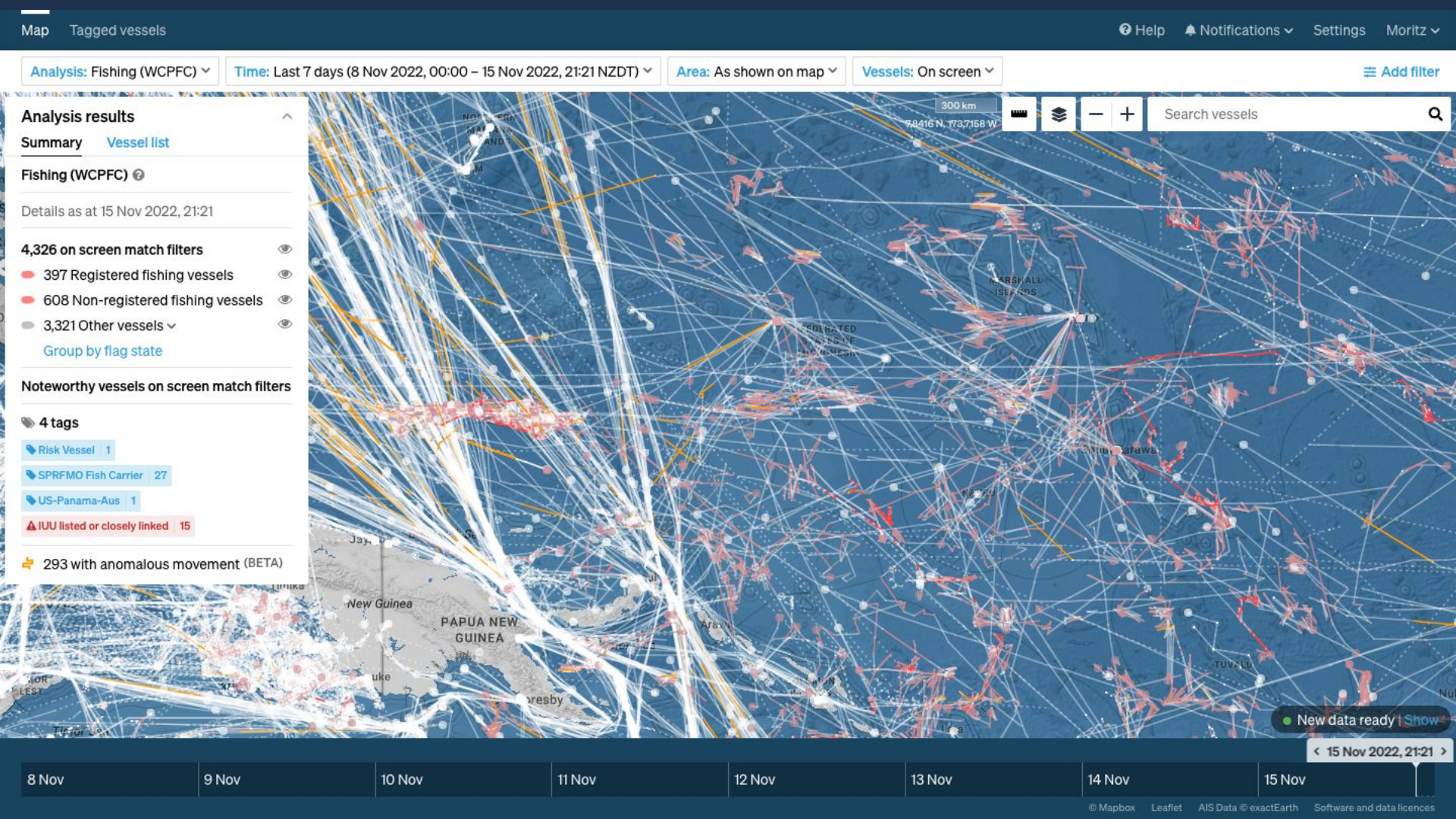
At-sea encounters can be a tell-tale of suspicious activity.

But they are hard to disentangle, especially if second-degree encounters are considered relevant.

Encounter networks allow modelling the structure of relationships between vessels.

For example, the link between any vessel and a set of vessels of special concern (IUU listed) is quantified using a weighting function of first and second order encounters. Western Pacific.




Map
Tagged vessels
Help
Notifications
Settings
Moritz
Analysis: Fishing (WCPFC)
Time: Last 7 days (8 Nov 2022, 00:00 – 15 Nov 2022, 21:21 NZDT)
Area: As shown on map
Vessels: On screen
Add filter
Analysis results
Summary
Vessel list
Fishing (WCPFC)
Details as at 15 Nov 2022, 21:21
4,326 on screen match filters
397 Registered fishing vessels
608 Non-registered fishing vessels
3,321 Other vessels
Group by flag state
Noteworthy vessels on screen match filters
4 tags
Risk Vessel 1
SPRFMO Fish Carrier 27
US-Panama-Aus 1
IUU listed or closely linked 15
293 with anomalous movement (BETA)
300 km
7.8416 N, 173.7158 W
Search vessels
MARSHALL ISLANDS
FEDERATED STATES OF MICRONESIA
New Guinea
PAPUA NEW GUINEA
TUVALU
New data ready | Show
15 Nov 2022, 21:21
8 Nov
9 Nov
10 Nov
11 Nov
12 Nov
13 Nov
14 Nov
15 Nov
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AIS Data © exactEarth
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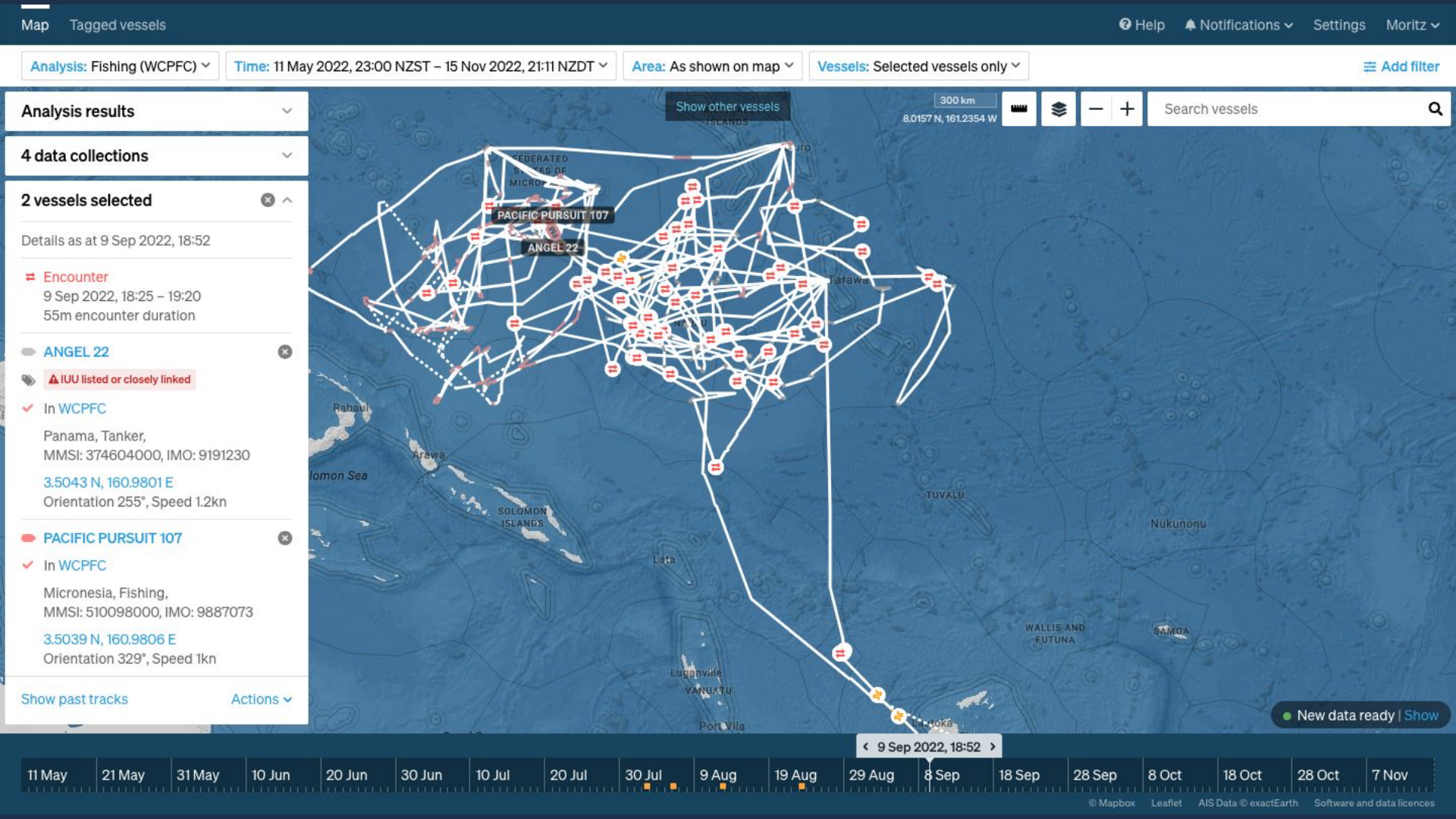
Map
Tagged vessels
Help
Notifications
Settings
Moritz
Analysis: Fishing (WCPFC)
Time: 11 May 2022, 23:00 NZST – 15 Nov 2022, 21:11 NZDT
Area: As shown on map
Vessels: Selected vessels only
Add filter
Analysis results
4 data collections
2 vessels selected
Details as at 9 Sep 2022, 18:52
Encounter
9 Sep 2022, 18:25 – 19:20
55m encounter duration
ANGEL 22
IUU listed or closely linked
In WCPFC
Panama, Tanker,
MMSI: 374604000, IMO: 9191230
3.5043 N, 160.9801 E
Orientation 255°, Speed 1.2kn
PACIFIC PURSUIT 107
In WCPFC
Micronesia, Fishing,
MMSI: 510098000, IMO: 9887073
3.5039 N, 160.9806 E
Orientation 329°, Speed 1kn
Show past tracks
Actions
Show other vessels
300 km
8.0157 N, 161.2354 W
Search vessels
PACIFIC PURSUIT 107
ANGEL 22
Tarawa
Rabaul
Arawa
Solomon Sea
SOLOMON ISLANDS
TUVALU
Nukunonu
Lata
WALLIS AND FUTUNA
SAMOA
Luganville
VANUATU
Port Vila
New data ready | Show
9 Sep 2022, 18:52
11 May
21 May
31 May
10 Jun
20 Jun
30 Jun
10 Jul
20 Jul
30 Jul
9 Aug
19 Aug
29 Aug
8 Sep
18 Sep
28 Sep
8 Oct
18 Oct
28 Oct
7 Nov
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Satellite dark vessel detection

Dark vessel: Not transmitting geolocation

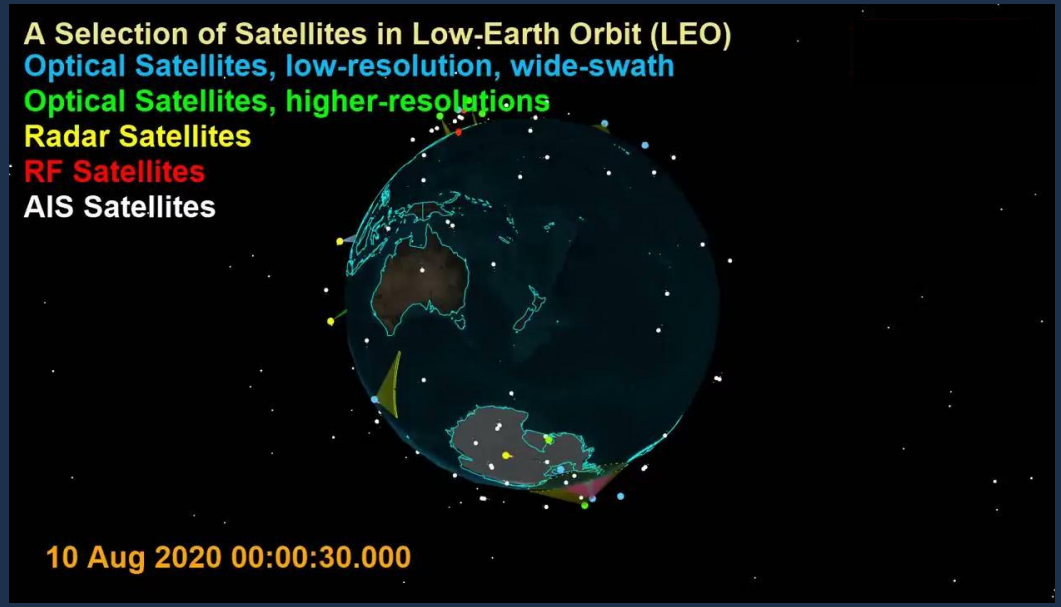
Most efficient coverage in terms of area and frequency of all surveillance approaches.

Sensors for ship detection:

- Optical (satellite imagers);
- Synthetic aperture radar (SAR);
- Radio frequency detectors.

Satellites in orbit:

- Pass overhead periodically, but are not always watching;
- Most data acquisition has to be tasked ($);
- Large, but limited field of view;
- Tradeoff: area coverage vs. pixel resolution;
- Latency: hours from acquisition to delivery.



Analysis results

6 data collections

1 detection selected

Detection matches AIS

7 May 2020, 22:33 - Optical

Detection details

Location 38.0635 S, 157.4741 E

Detection method Manual

Confidence it's a vessel

low medium high

View vessel details

Image © Airbus. SPOT, pixel size 1.5m.

30 m
38.0602 S, 157.4798 E

Search vessels

Zoom in
or Ctrl Drag

FU CHUN NO.128

7 May

7 May 2020, 22:33

Satellite dark vessel detection

Optical sensors

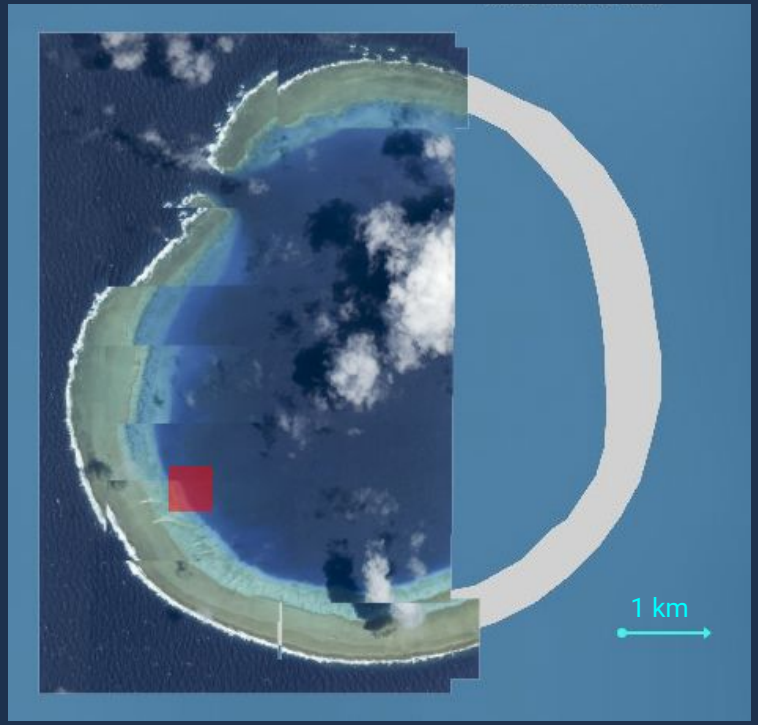
Satellite-based optical sensors provide free and commercial imagery over regions up to 10,000 km^2 at spatial resolutions between 0.5 and 10 m.

Advantages

- Intuitive visual images with added value for other applications;
- Free sources of data over coastal oceans (10 m resolution);
- Regular collection of commercial images over many areas.

Disadvantages

- Usable coverage limited by weather/ocean conditions;
- Open ocean imagery needs tasking and ships may be hard to spot.



PlanetScope image over Minerva Reef. 3 m resolution. 19 Nov. 2020, 10:55 NZDT.

Satellite dark vessel detection

Synthetic aperture radar (SAR)

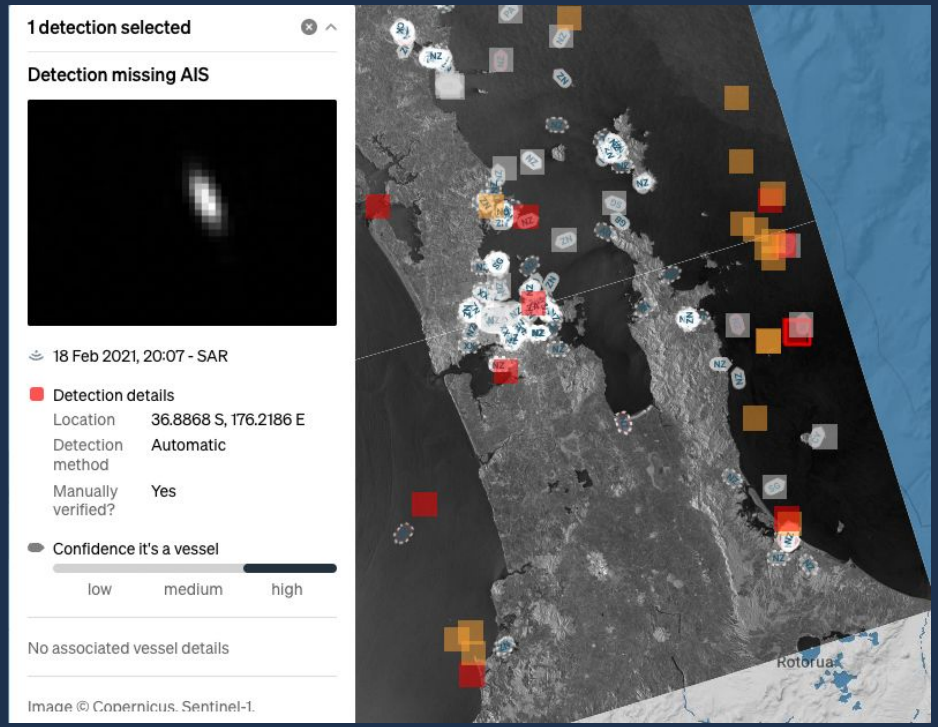
Satellite-based synthetic aperture radar (SAR) systems provide imagery over areas of 25 to 225,000 km^2 at spatial resolutions between 0.5 and 25 m.

Advantages

- Radar signals work through clouds and during the night;
- Free data from Copernicus Sentinel-1 in coastal regions;
- Commercial systems available with dedicated, large-scale ship detection modes.

Disadvantages

- Vessel detection not identification;
- Radar images not intuitive.



Sentinel-1 SAR image. 18 Feb. 2021 20:07 NZDT.

Satellite dark vessel detection

Radio frequency detection

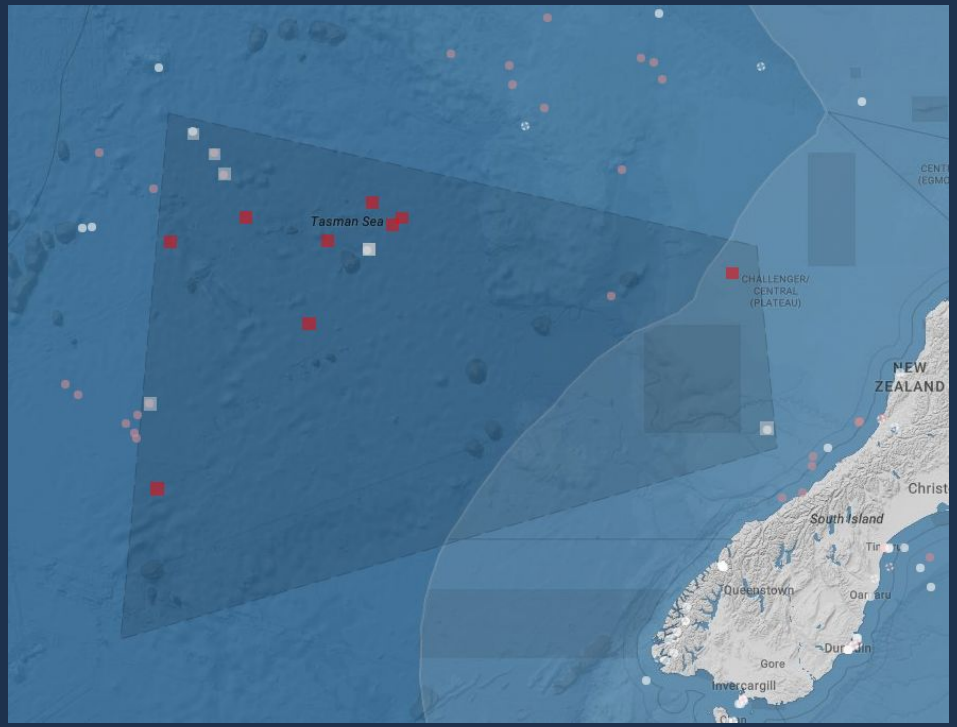
Radio Frequency (RF) systems provide vessel signal location data (marine radar, VHF) for dark vessel detection.

Advantages

- Large area coverage;
- Frequent sensor coverage (several a day).

Disadvantages

- Only detects vessels that are transmitting RF signals;
- Raw data not available (limited ability to interrogate false detections).



Unseenlabs RF detection. 5 May 2022 23:00 NZST

Satellite dark vessel detection

Conclusions

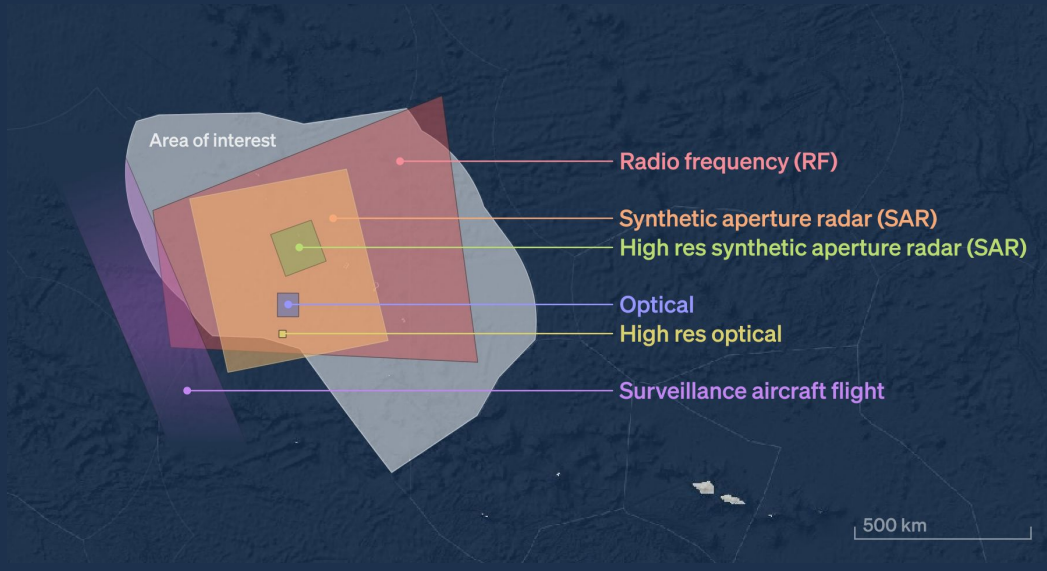
Satellites offer the most efficient coverage in terms of area and frequency of all surveillance approaches.

Dark vessel detection requires AIS/VMS matching

All sensors can yield false detections (-ve, +ve), but ground truthing is very difficult (due to latency and space scales).

Satellite technology and ground systems are evolving; improvements are needed in tasking efficiency, data downlink speed, false detections.

We believe a seamless integration into MDA is 3-5 years away.



Satellite detection footprints relative to the Tuvalu EEZ (750,000 km^2)

Tēnā koutou

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