UNIVERSITY OF LJUBLJANA
Faculty of Maritime Studies and Transportation

Optical and SAR remote sensing for marine applications (oil spill and ship detection)

Marko Perkovič

13th ESA Training Course on Earth Observation 2023

18 | 09 | 23 - 22 | 09 | 23
Osijek, Croatia

European Space Agency - Space Solutions

Josip Juraj Strossmayer University of Osijek
Faculty of Electrical Engineering, Computer Science and Information Technology Osijek

Old space

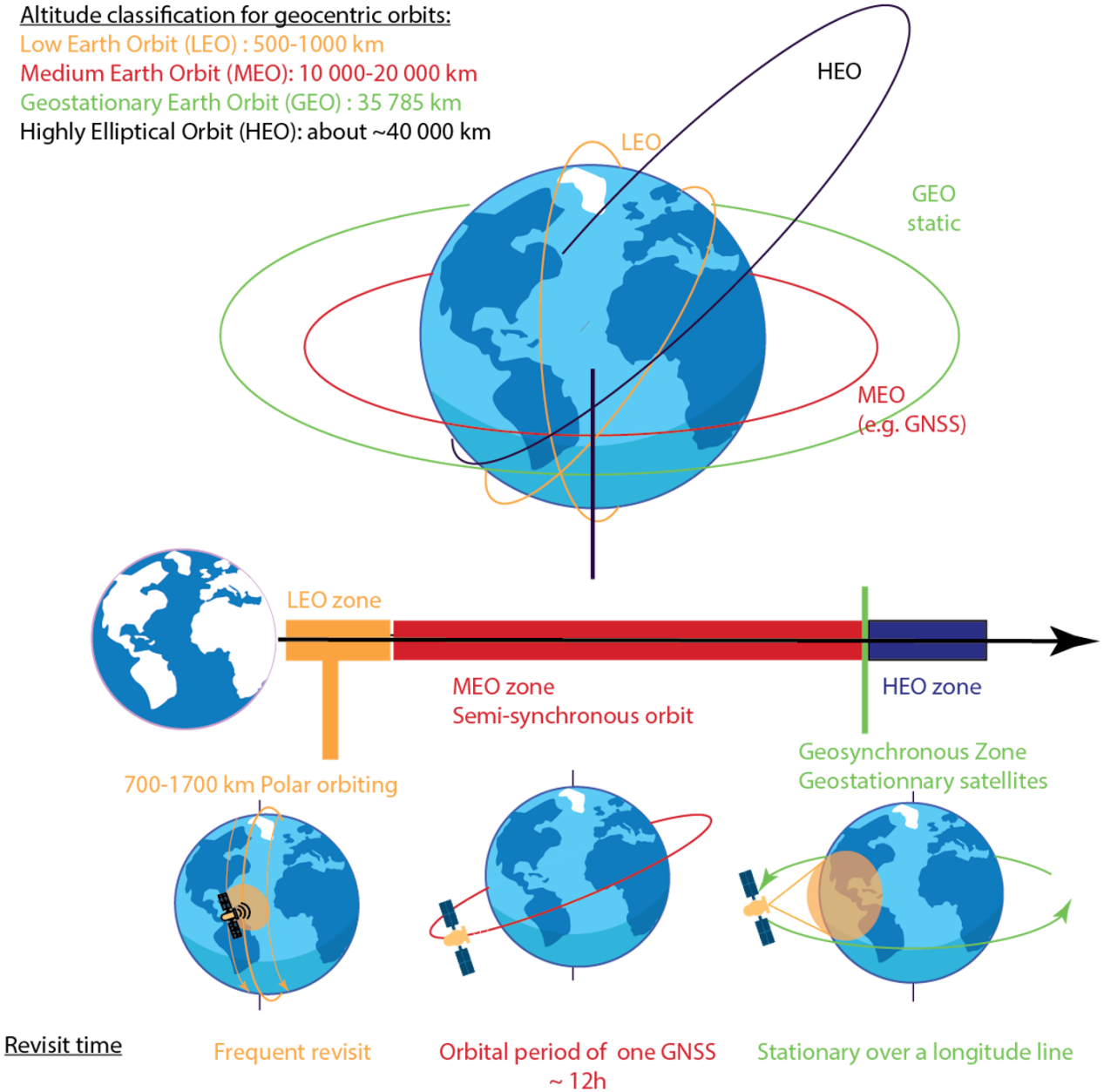
- Few, big, expensive satellites
- Government initiatives
- Few countries
- Hardware
- Traditional engineering
- Space is empty
- Satellites are nice to have
- Satellites are unassailable

New space

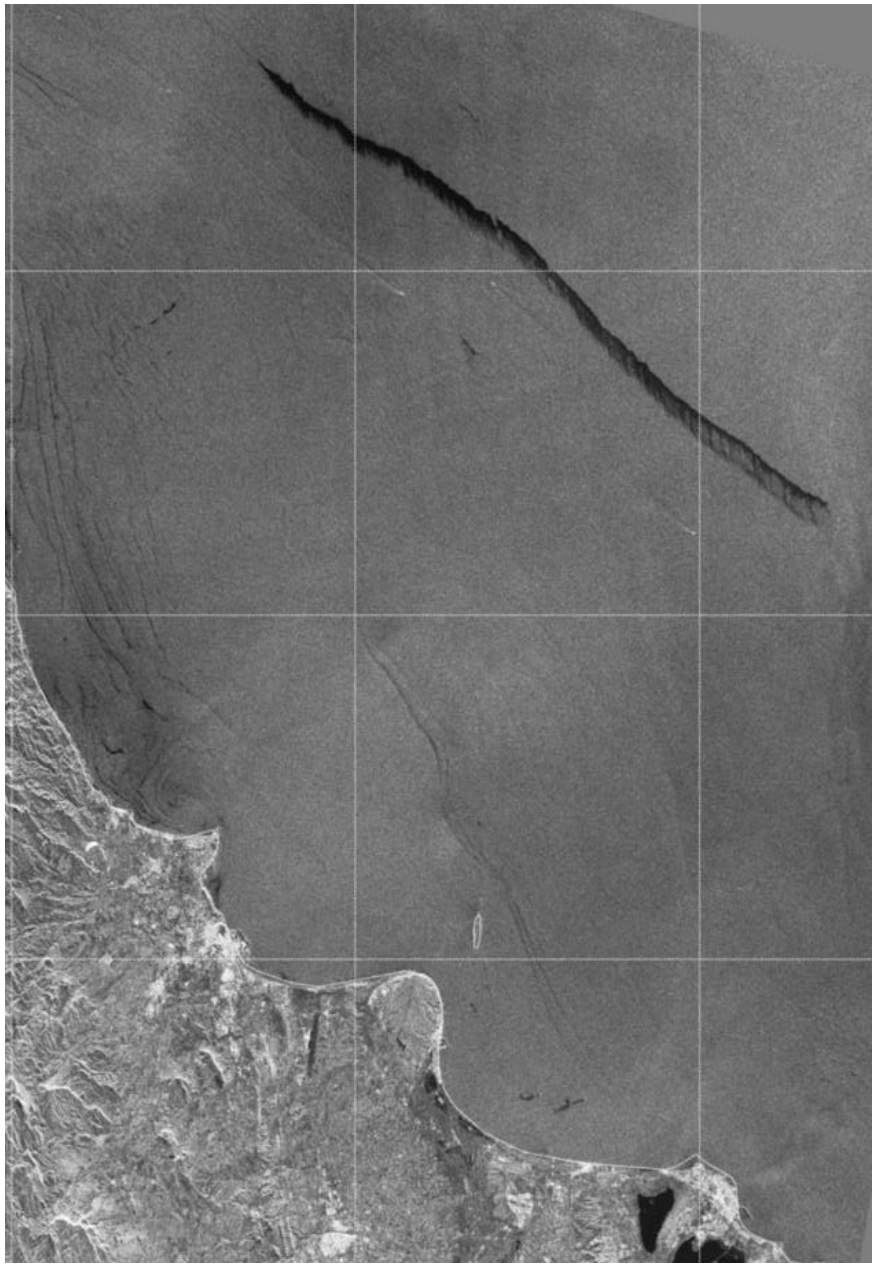
- Many, small, cheap satellites
  - Low cost of technology
- Commercial initiatives
  - Venture capital, low interest rates
- Many countries
- Software
- New manufacturing (digital, 3D print)
- Orbits and RF spectrum congested
- Crucial for economy, military
- Anti-satellite weapons

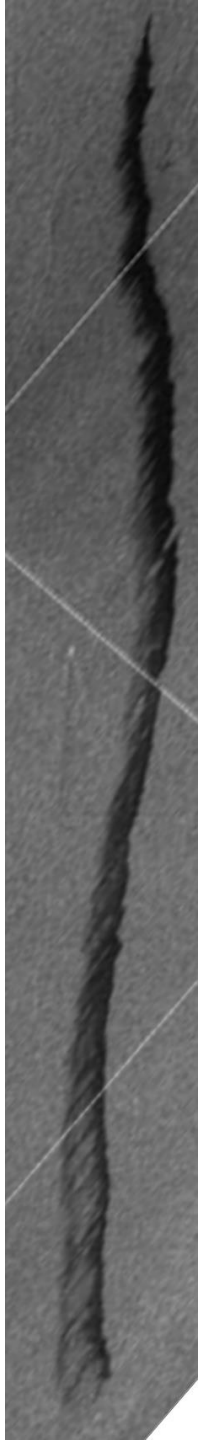
Functions of space

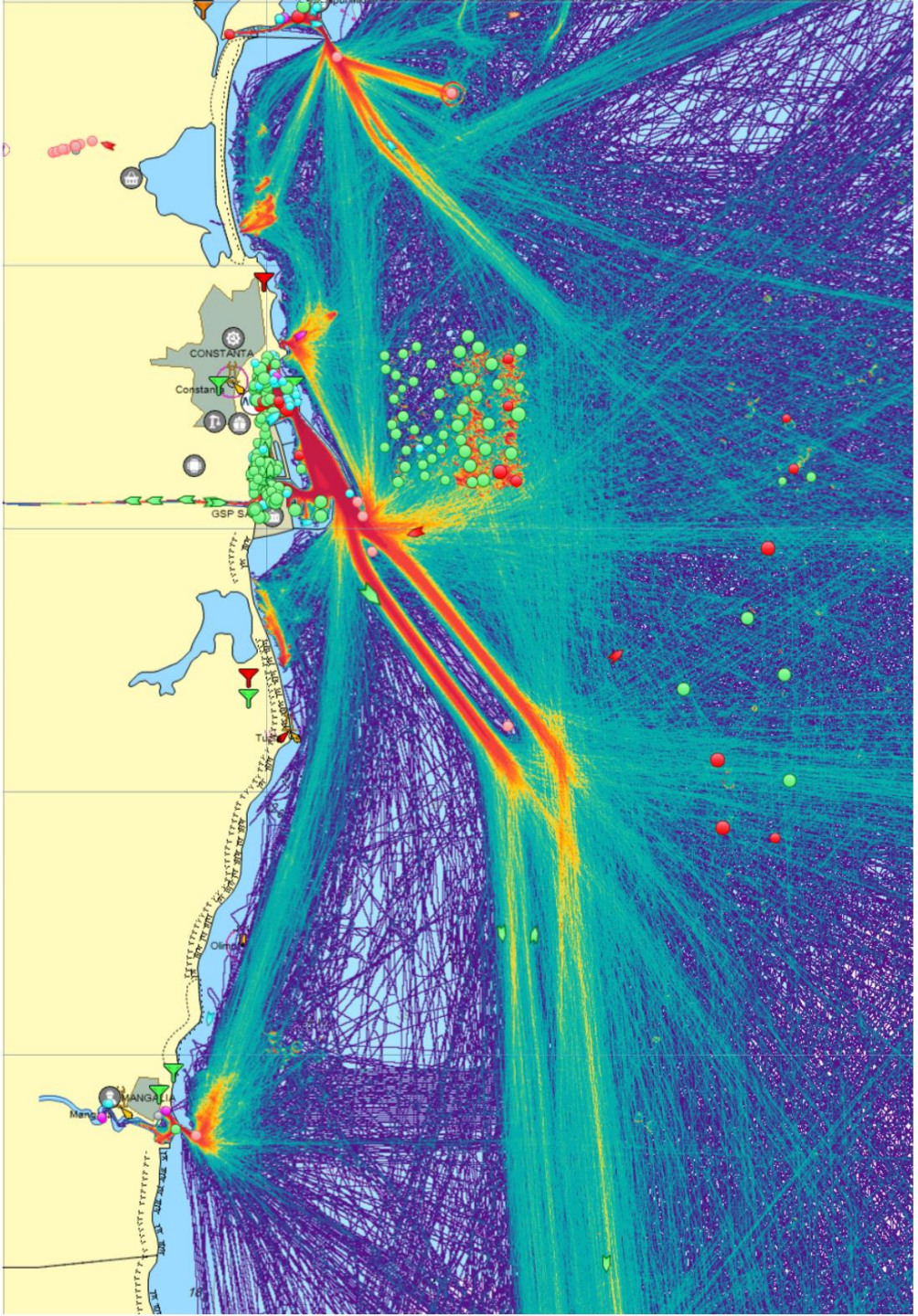
- Science & exploration
- Exploitation
  - Moon, Mars, Asteroid mining
- Observation
  - Earth monitoring, intelligence
- Positioning, Navigation & Timing
  - GPS, others
- Communication
  - Oceans, air, remote areas, 5G

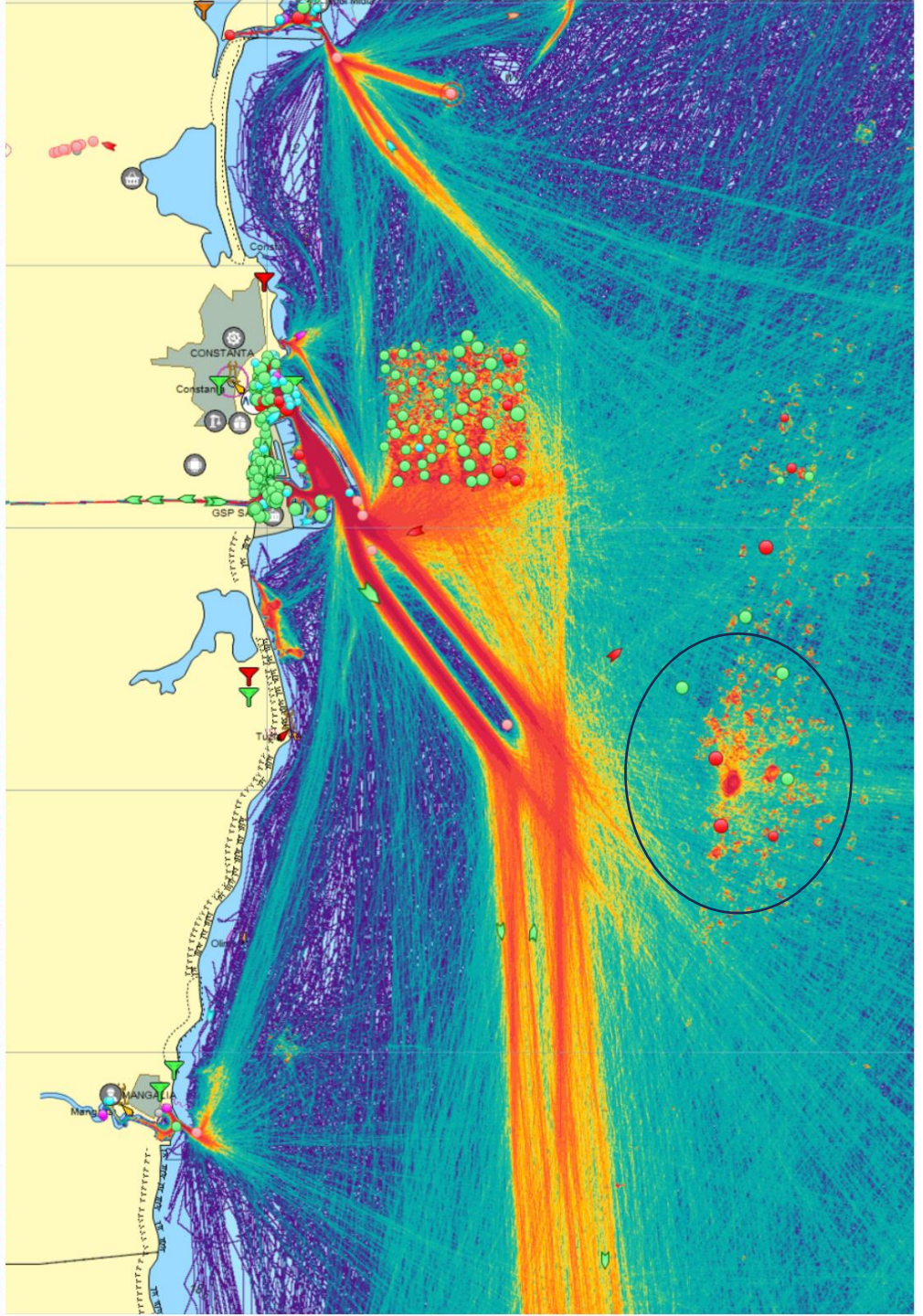


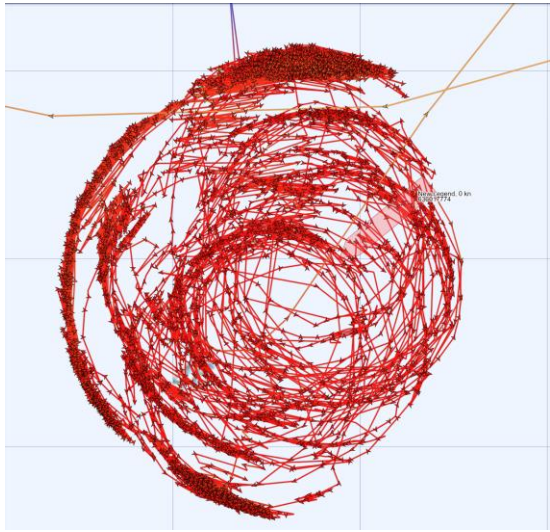
Maritime Situational Awareness

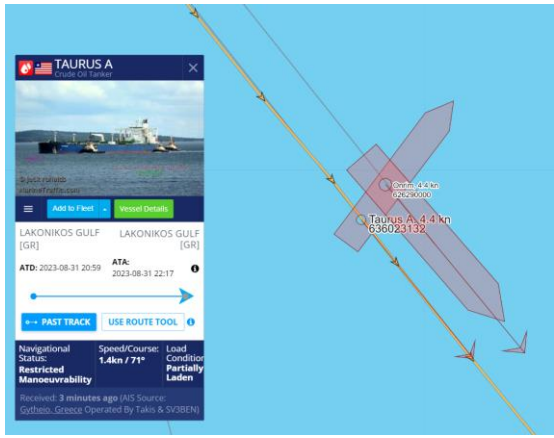


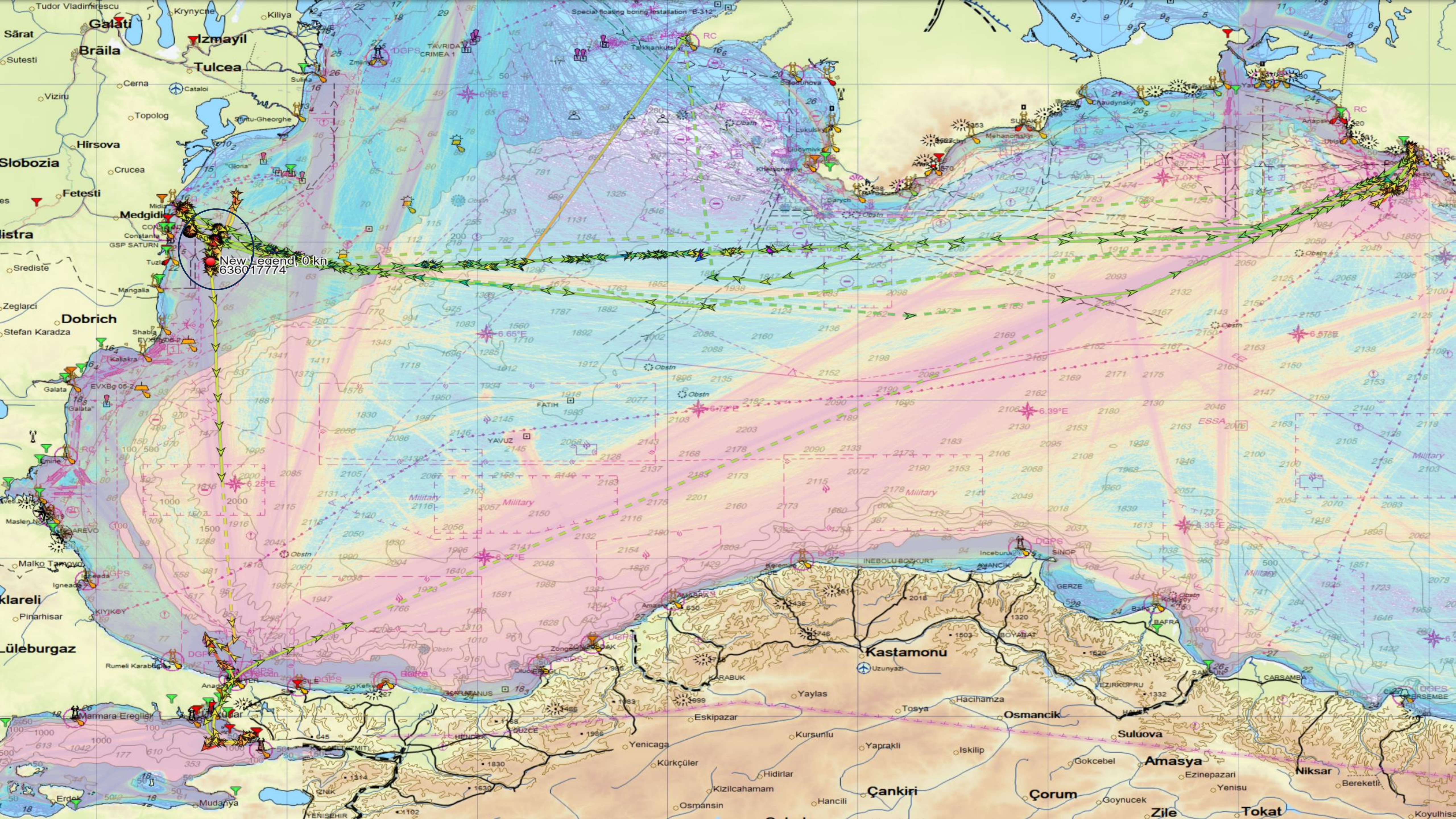



CONSTANTA
Constanța
GSP S.A.
MANGALIA

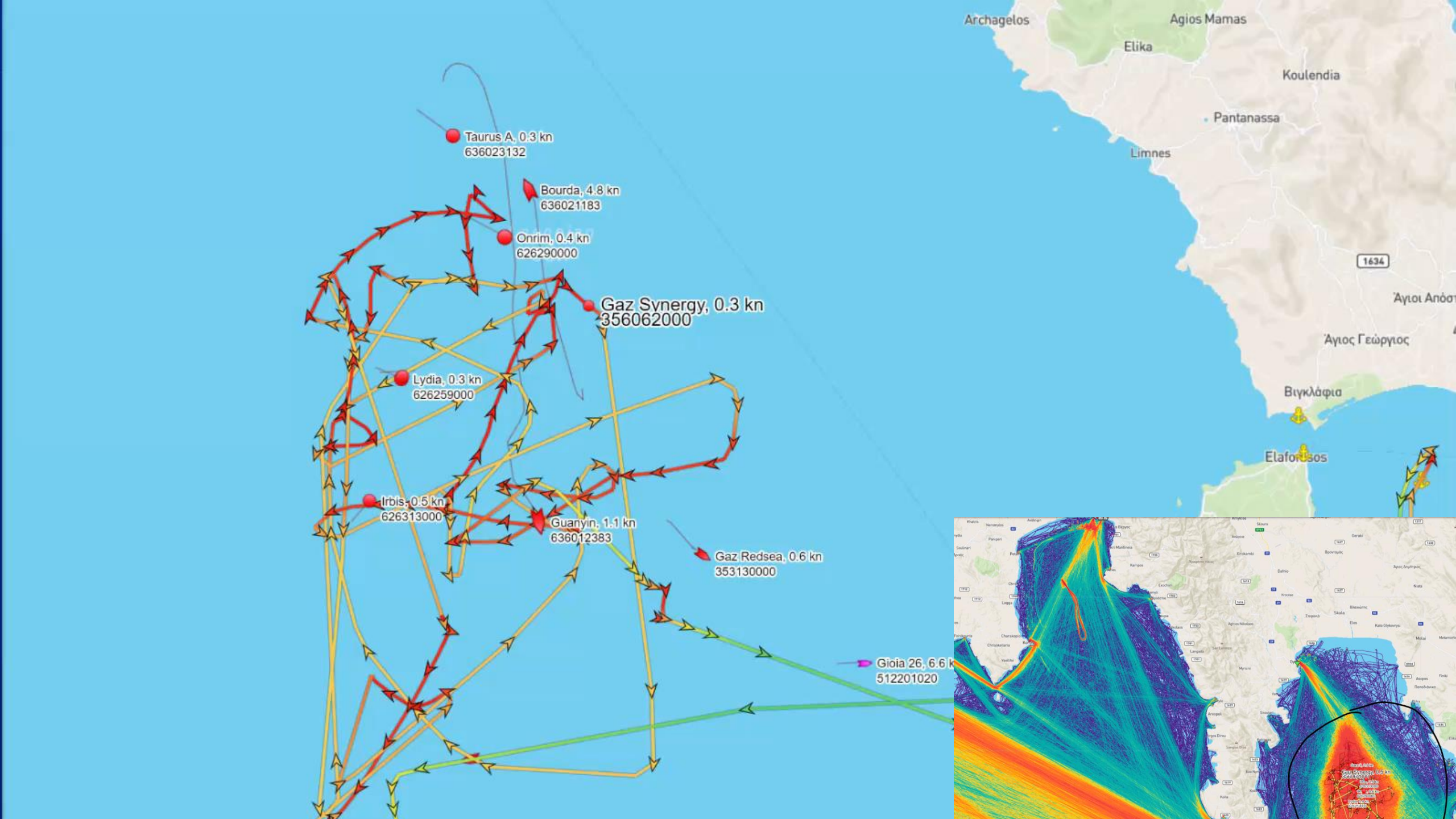

CONSTANTA
Constanța
GSP S.A.
MANGALIA



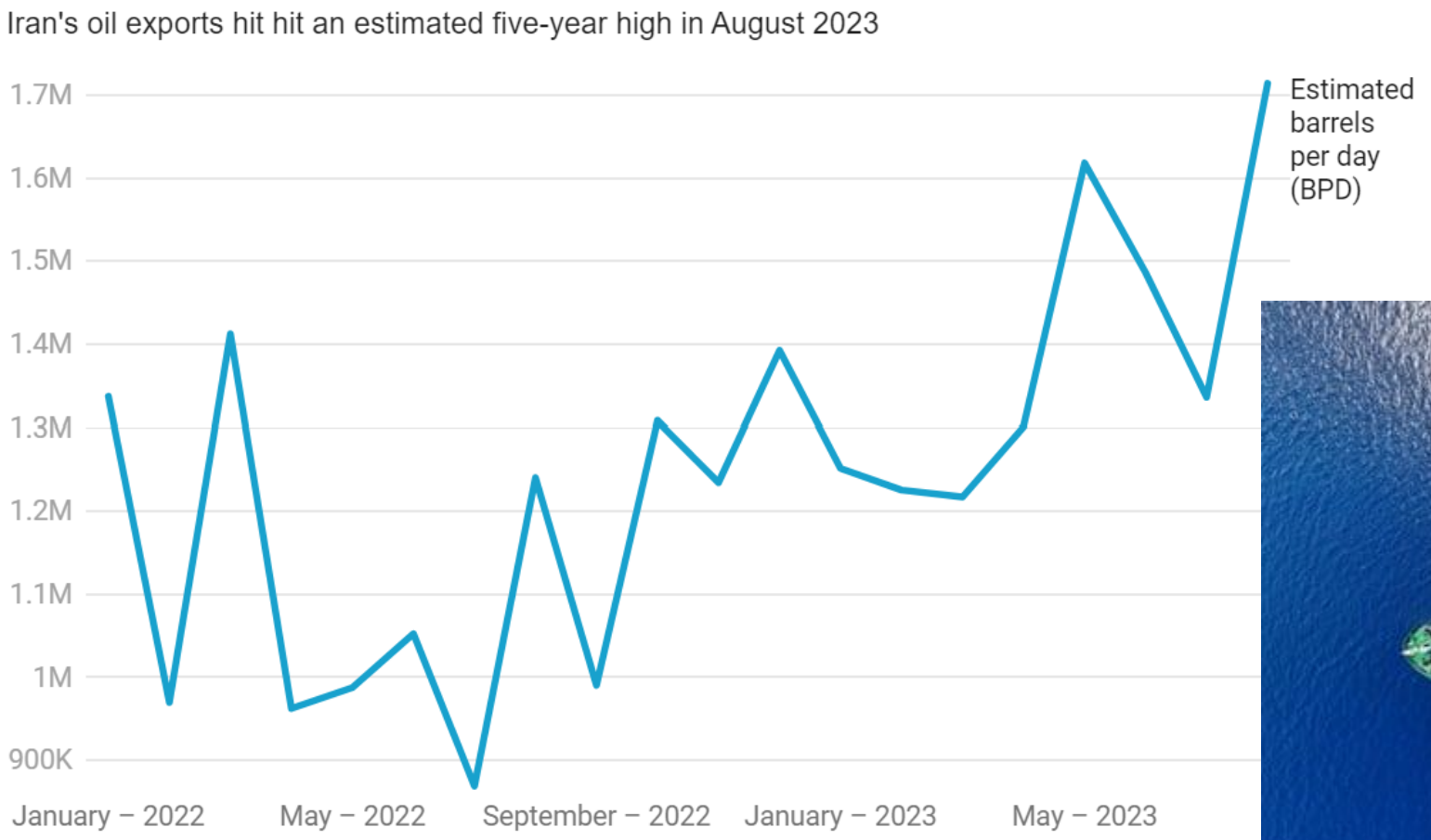

TAURUS A
Crude Oil Tanker
Add to Fleet
Vessel Details
LAKONIKOS GULF [GR]
LAKONIKOS GULF [GR]
ATD: 2023-08-31 20:59
ATA: 2023-08-31 22:17
PAST TRACK
USE ROUTE TOOL
Navigational Status: Restricted Manoeuvrability
Speed/Course: 1.4kn / 71°
Load Condition: Partially Laden
Received: 3 minutes ago (AIS Source: Gytheio, Greece Operated By Takis & SV3BEN)
Taurus A, 4.4 kn
636023132



New Legend, 0 kn
636017774
Tudor Vladimirescu
Galati
Krynychne
Kiliya
Izmayil
Sărat
Brăila
Tulcea
Sutesti
Cerna
Viziru
Topolog
Hîrsova
Slobozia
Crucea
Fetesti
Medgidia
Constanta
GSP SATURN
Središte
Mangalia
Zeglarci
Dobrich
Stefan Karadza
Galata
Emine
Maslen Nos
Malko Tarnovo
Kirklareli
Pinarhisar
Lüleburgaz
Rumeli Karaburun
Marmara Ereglisi
Mudanya
Erdek
Special floating boring installation "B-312"
TAVRIDA CRIMEA 1
DGPS
RC
Sudak
Anapa
Sarych
ESSA
Obstn
FATIH
YAVUZ
Military
INEBOLU BOZKURT
AYANCIK
Inceburun
SINOP
GERZE
BAFRA
Amasra
Zonguldak
Kastamonu
Uzunyazi
KARABUK
Yaylas
Tosya
Hacihamza
Osmancik
Eskipazar
Kursunlu
Yenicaga
Yaprakli
Iskilip
Suluova
Amasya
Ezinepazari
Niksar
Kürkçüler
Hidirlar
Kizilcahamam
Çankiri
Çorum
Gokcebel
Goynucek
Yenisu
Bereketli
Zile
Tokat
Koyulhisar
Osmansin
Hancili
DUZCE
HENDEK
IZNIK
YENISEHIR
CARSAMBA
TERSEMBE
Samsun


Archagelos
Agios Mamas
Elika
Koulendia
Pantanassa
Limnes
1634
Άγιοι Απόστ
Άγιος Γεώργιος
Βιγκλάφια
Elafonisos
Taurus A, 0.3 kn
636023132
Bourda, 4.8 kn
636021183
Onrim, 0.4 kn
626290000
Gaz Synergy, 0.3 kn
356062000
Lydia, 0.3 kn
626259000
Irbis, 0.5 kn
626313000
Guanyin, 1.1 kn
636012383
Gaz Redsea, 0.6 kn
353130000
Gioia 26, 6.6 k
512201020

The number of vessels transporting sanctioned oil is booming and the consequences can be felt across the world – from Iran, to China, to Ukraine



Despite the tough sanctions, UANI calculates that thanks to the shadow fleet, [Iranian monthly oil exports hit a five-year-high in August of this year](#).

[How a burnt out, abandoned ship reveals the secrets of a shadow tanker network | Oil | The Guardian](#)

Tracking Dark Vessels

- How a burnt out, abandoned ship reveals the secrets of a shadow tanker network: [How a burnt out, abandoned ship reveals the secrets of a shadow tanker network | Oil | The Guardian]
- **FINDING DARK SHIPS VIA SATELLITE,** [Finding Dark Ships Via Satellite | Hackaday]
- **Satellite dark vessel detection for maritime domain awareness;** [Satellite dark vessel detection for maritime domain awareness | Starboard Maritime Intelligence]
- [Satellites are hunting "dark vessels" that evade sanctions at sea (qz.com)]

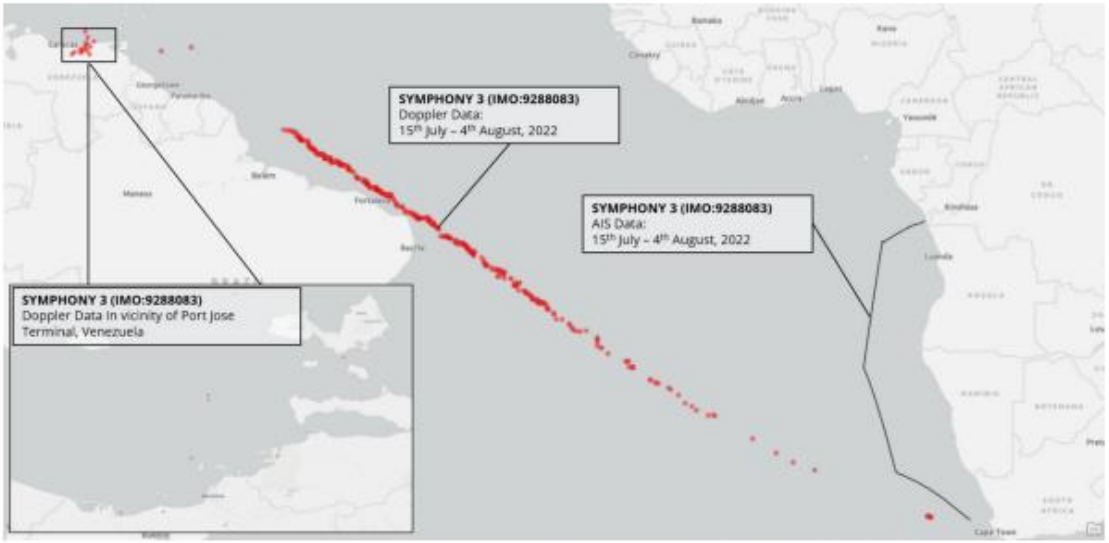


Figure 3: AIS Positions (Black Line) and Doppler Data (Red Dots) of the Symphony 3 from July 15th to August 4th, 2022

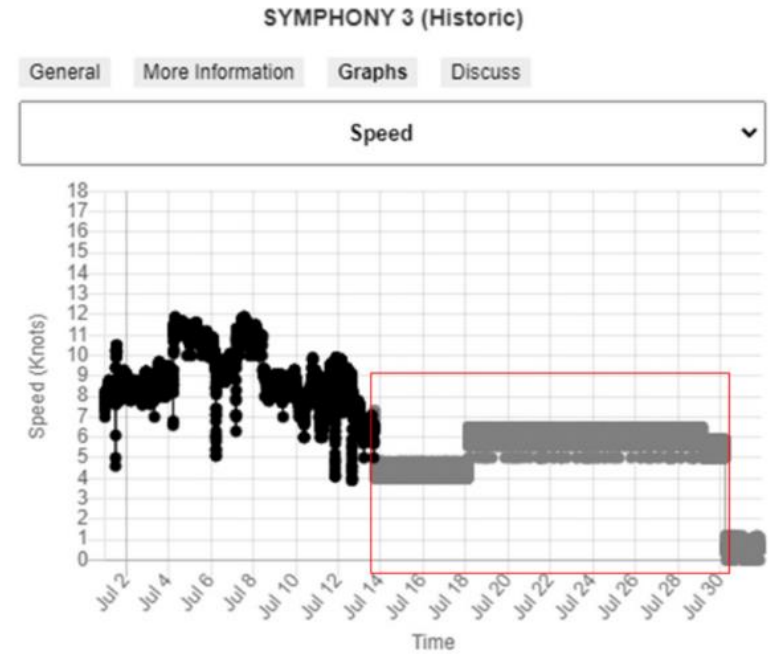
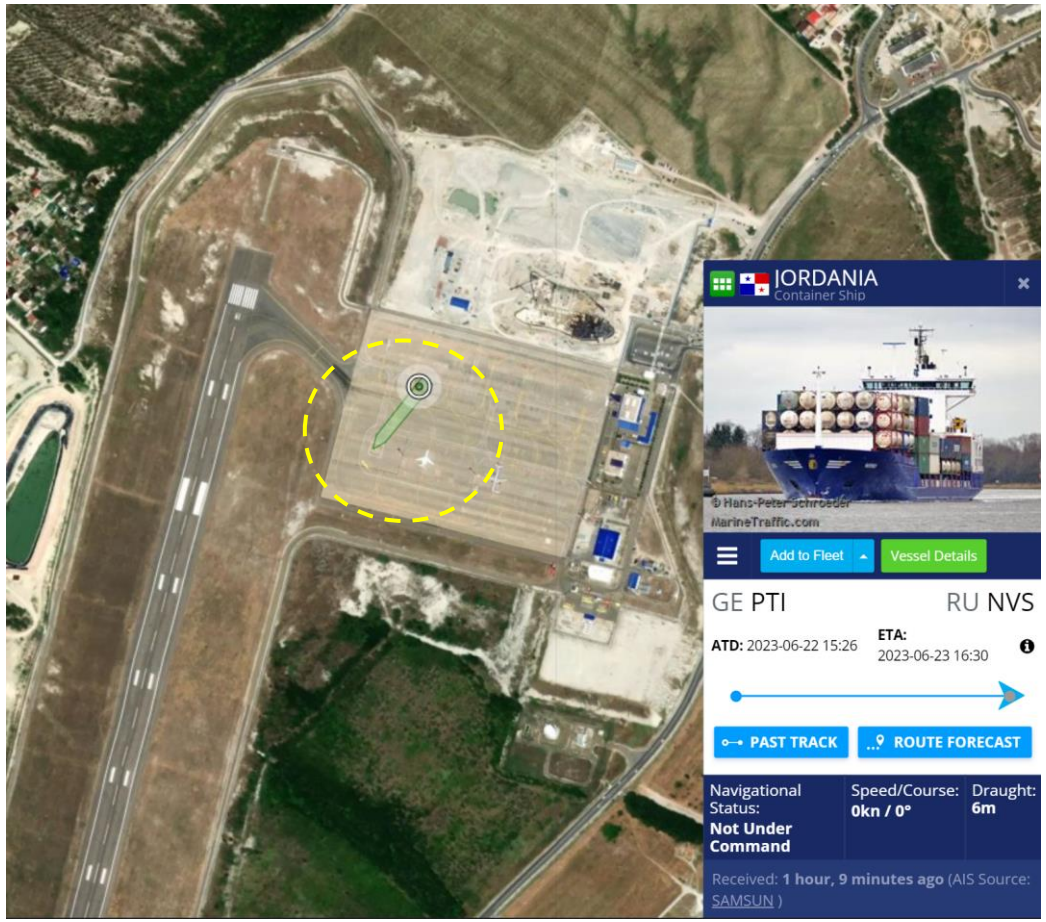
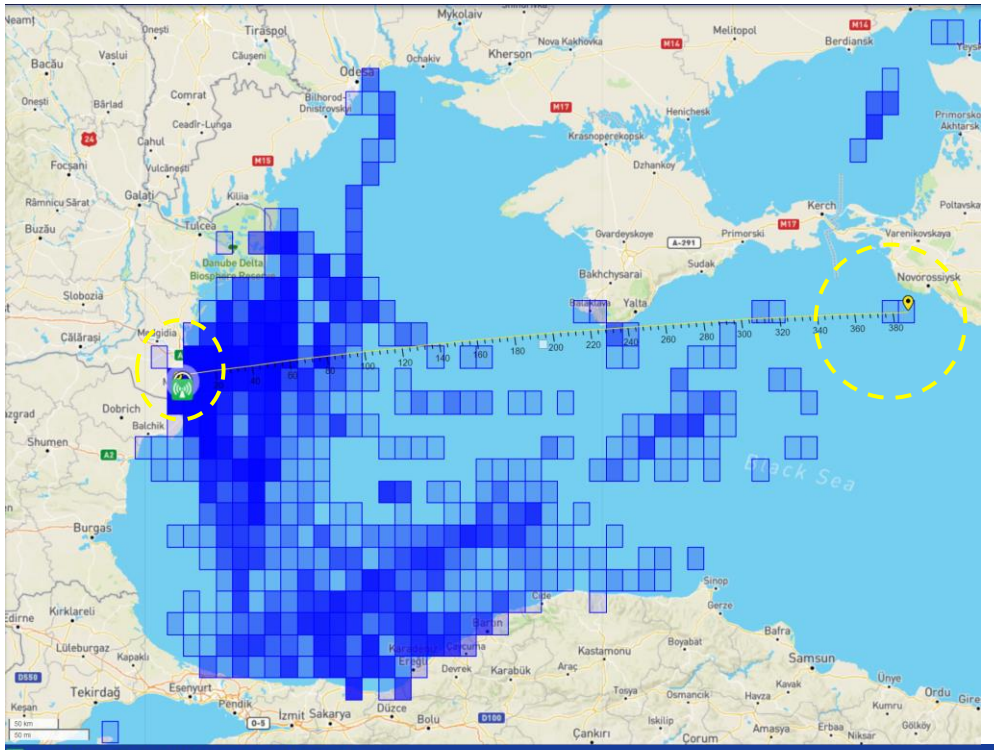
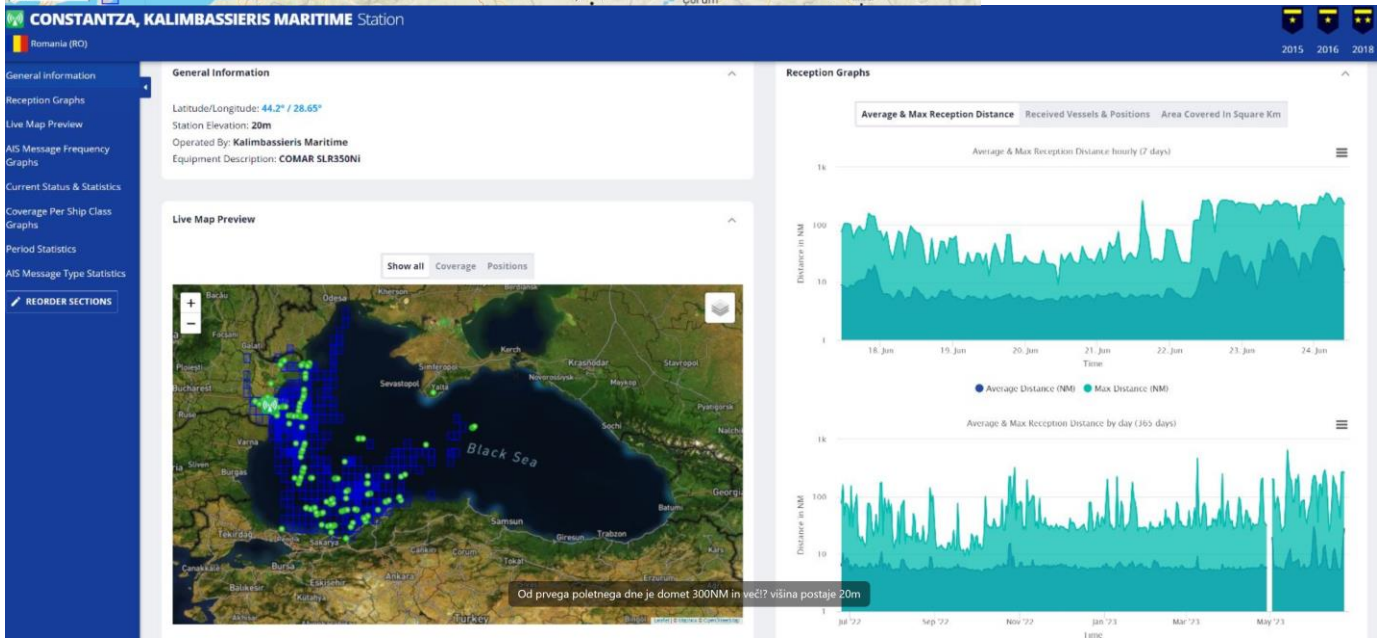


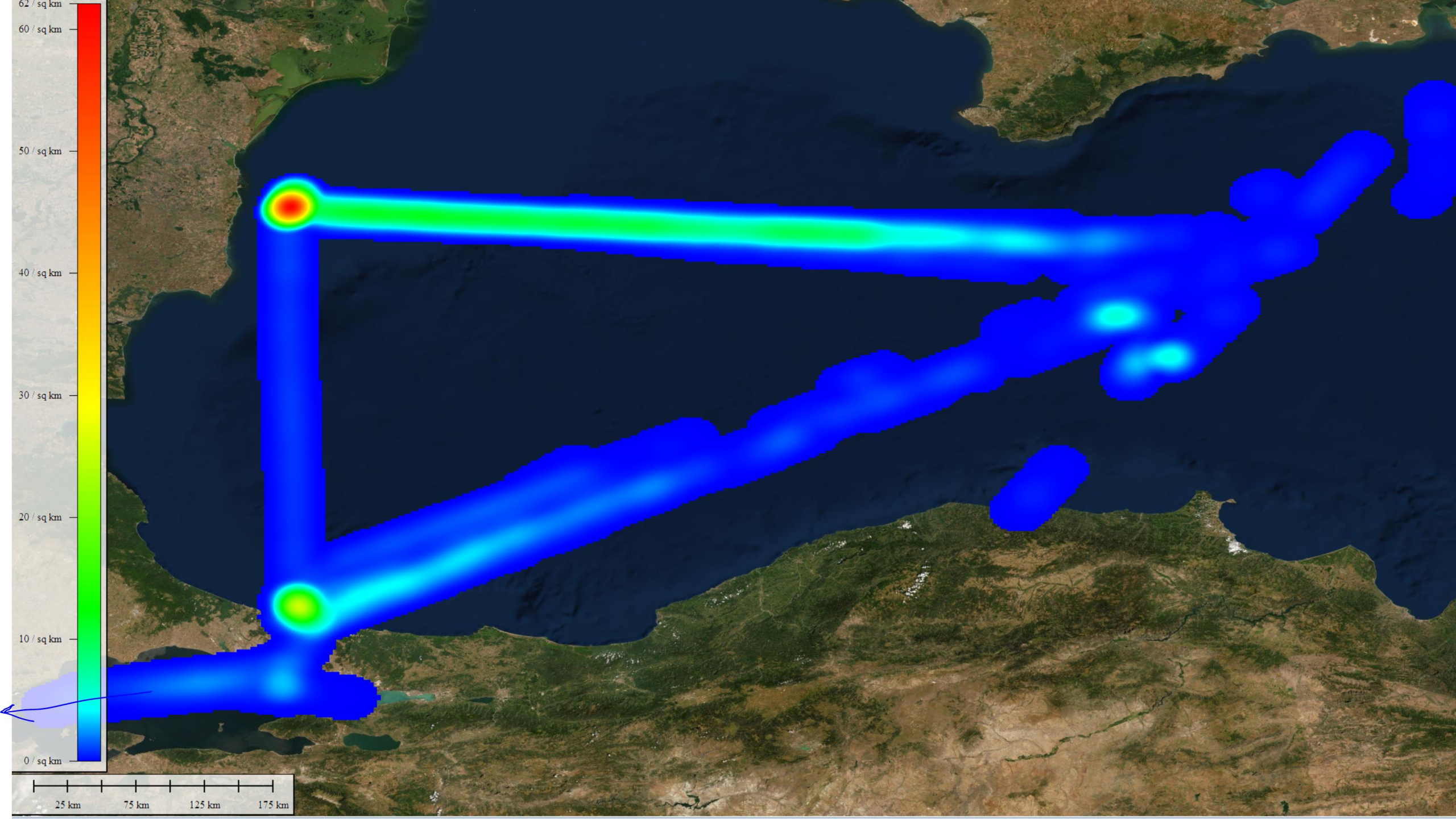
Figure 2: Speed Record of the Symphony 3 for July 20222

Tracking Dark “Grey” ships



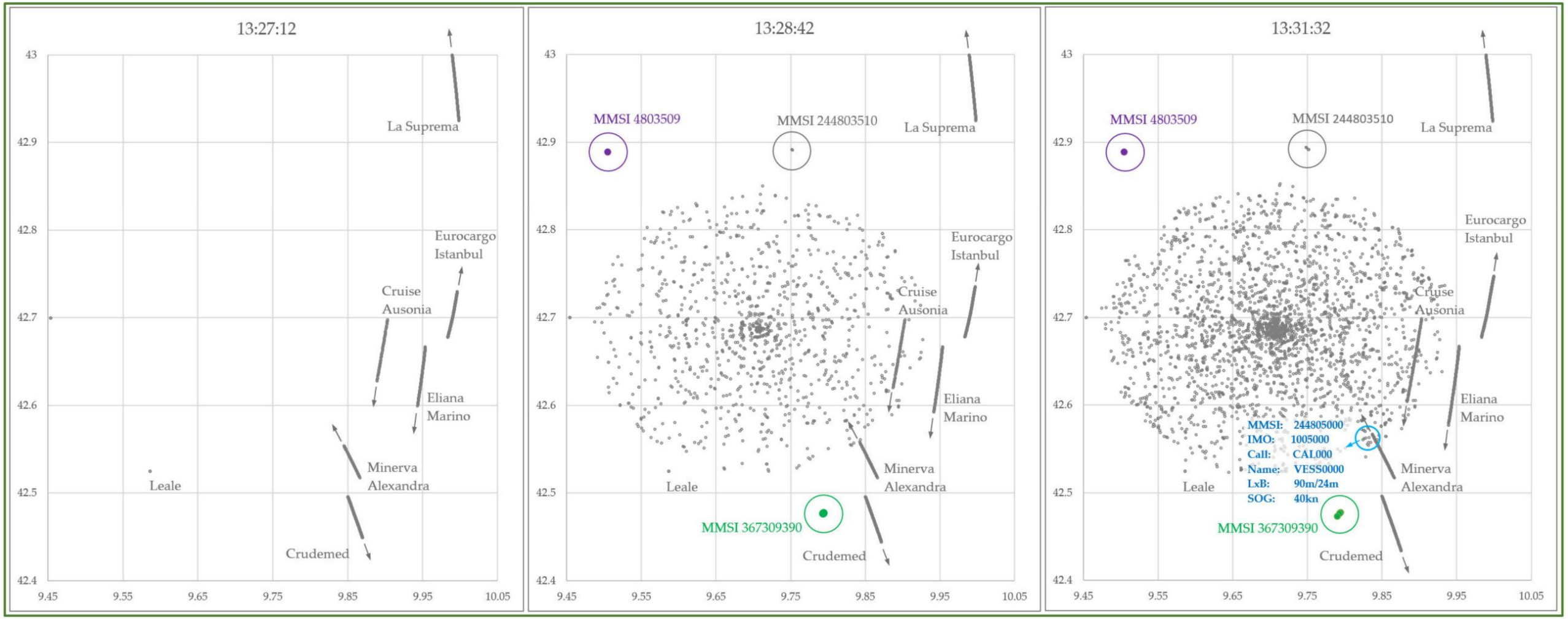




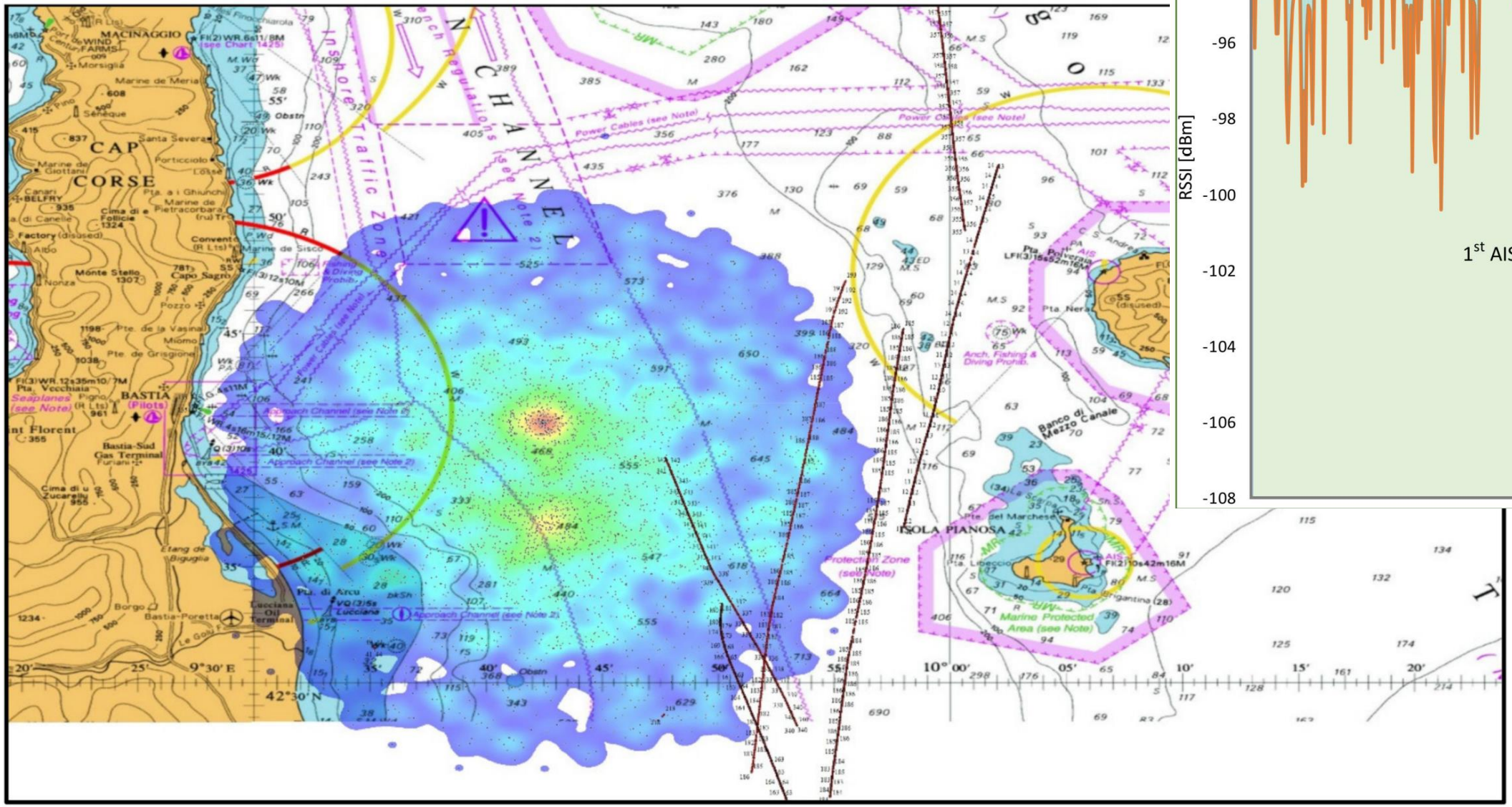

62 / sq km
60 / sq km
50 / sq km
40 / sq km
30 / sq km
20 / sq km
10 / sq km
0 / sq km
25 km
75 km
125 km
175 km

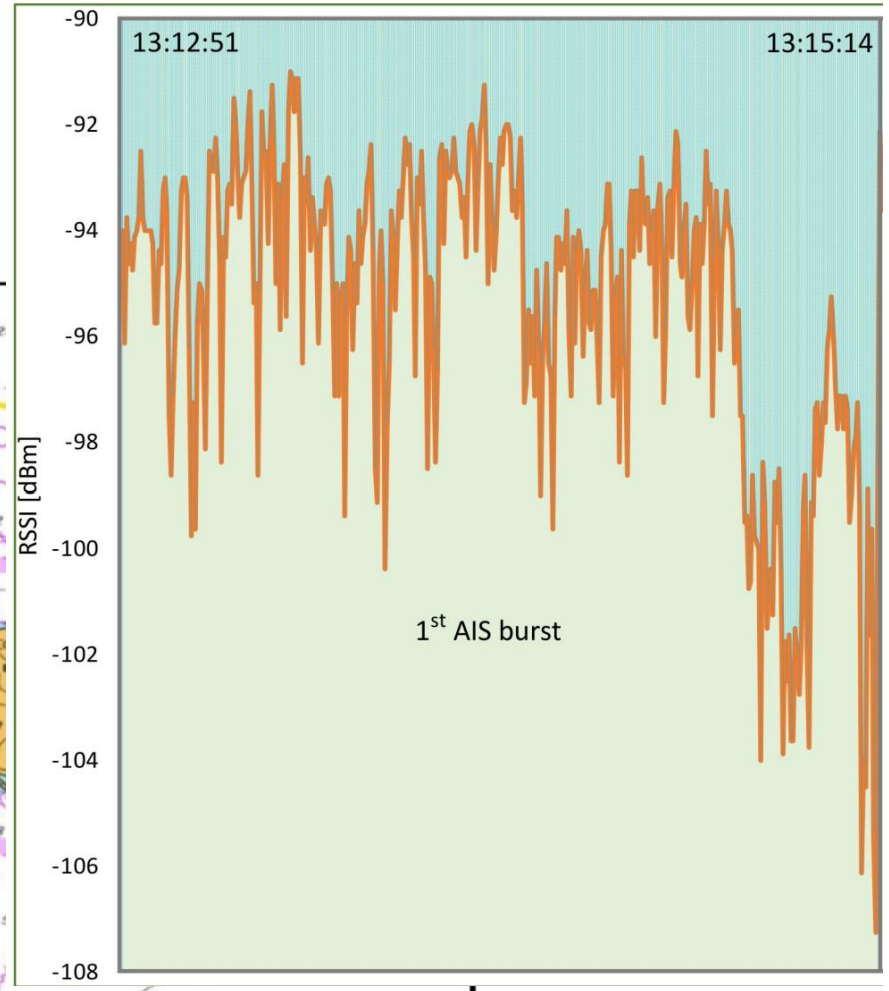
Spoofing – Elba Case

AIS Data Vulnerability Indicated by a Spoofing Case-Study

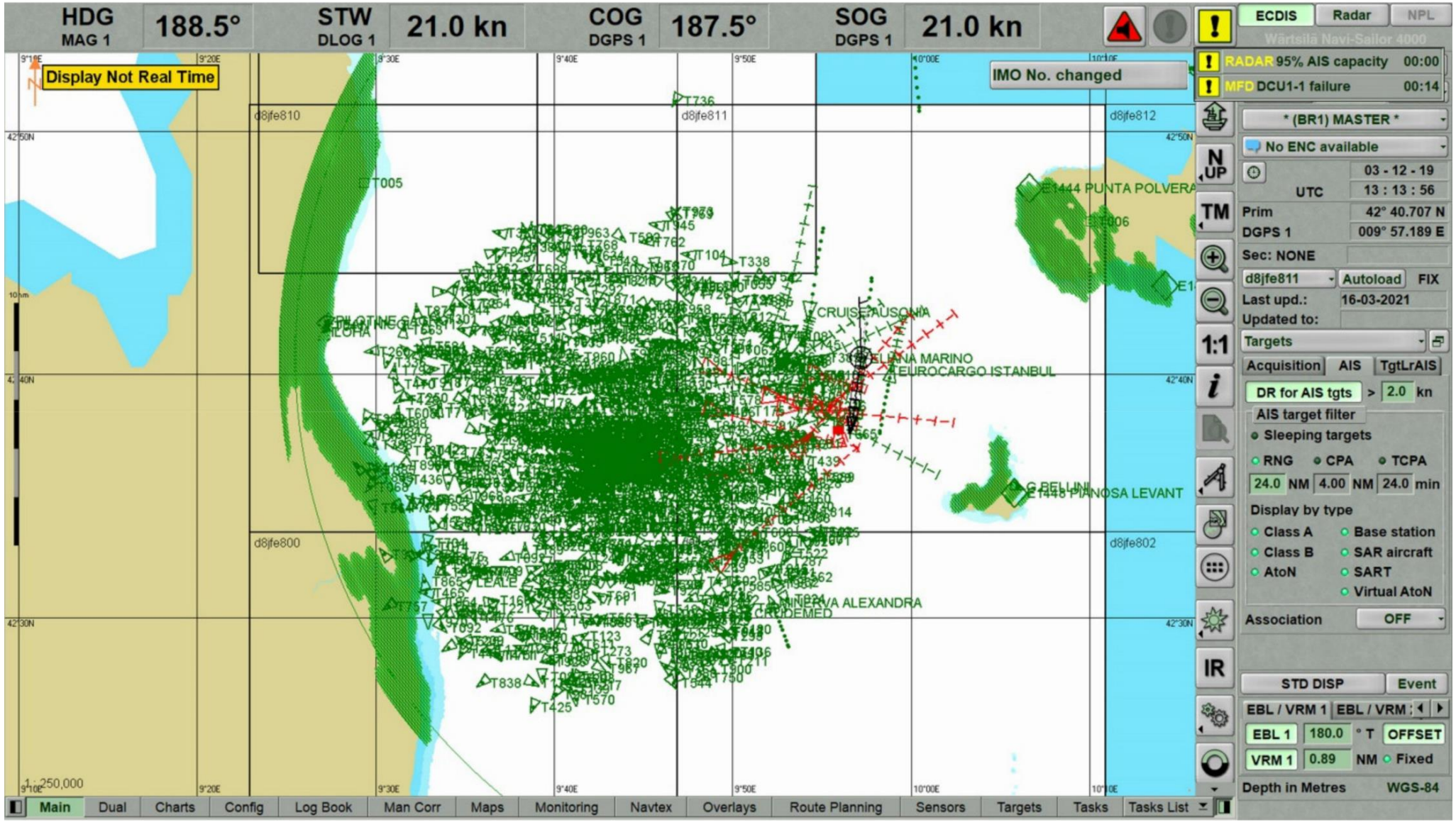


Spoofing – Elba Case

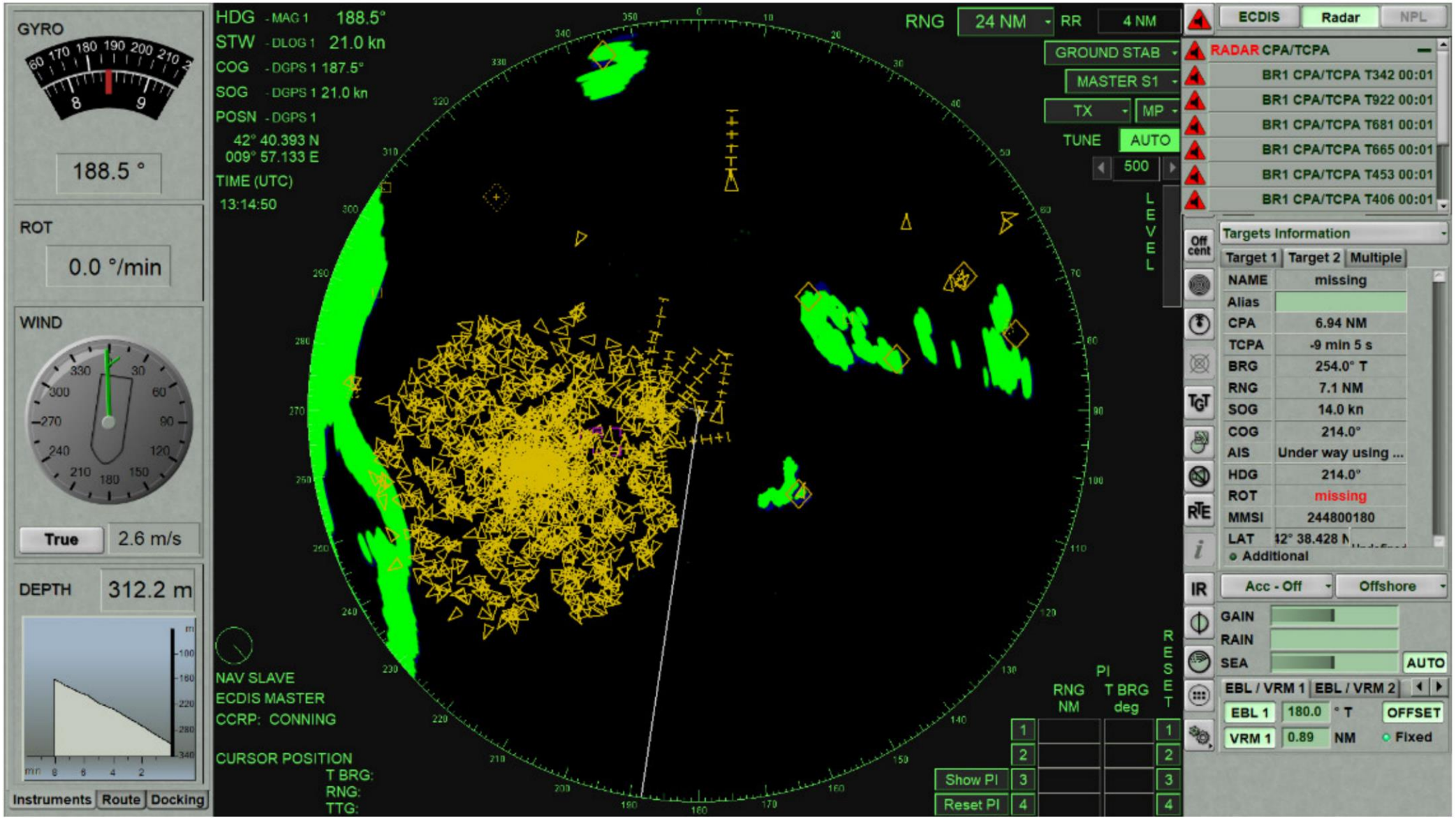




Spoofing – Elba Case



Spoofing – Elba Case



EMODnet

- European Marine Observation and Data Network
- Network with secretariat, funded by European Commission
- Maritime data portal

"Your gateway to marine data in Europe"
http://www.emodnet.eu/

EMODnet provides access to European marine data across seven discipline-based themes:

• **Bathymetry** • **Geology** • **Seabed habitats** • **Chemistry** • **Biology** • **Physics** • **Human activities**

Ship density maps Europe

Layers | Catalogue

- Maritime Spatial Planning
- Military Areas
- Oil and Gas
- Other Forms of Area Management
- Pipelines
- Route Density
  - [x] All vessels (Annual totals 2019-2022)
  - [ ] All vessels (Monthly totals 2019-2023)
  - [ ] All vessels (Seasonal totals 2019-2023)
  - [ ] Cargo vessels (Annual totals 2019-2022)
  - [ ] Cargo vessels (Monthly totals (2019-2023)
  - [ ] Cargo vessels (Seasonal totals 2019-2023)
  - [ ] Fishing vessels (Annual totals 2019-2022)
  - [ ] Fishing vessels (Monthly totals (2019-2023)
  - [ ] Fishing vessels (Seasonal totals 2019-2023)
  - [ ] Other vessels (Annual totals 2019-2022)
  - [ ] Other vessels (Monthly totals 2019-2023)
  - [ ] Other vessels (Seasonal totals 2019-2023)
  - [ ] Passenger vessels (Annual totals 2019-2022)
  - [ ] Passenger vessels (Monthly totals 2019-2023)
  - [ ] Passenger vessels (Seasonal totals 2019-2023)
  - [ ] Tanker (Annual totals 2019-2022)
  - [ ] Tanker (Monthly totals 2019-2023)
  - [ ] Tanker (Seasonal totals 2019-2023)
- Vessel Density
  - [ ] All Types (Annual averages 2017 - 2022)
  - [ ] All Types (Monthly totals 2017-2022)

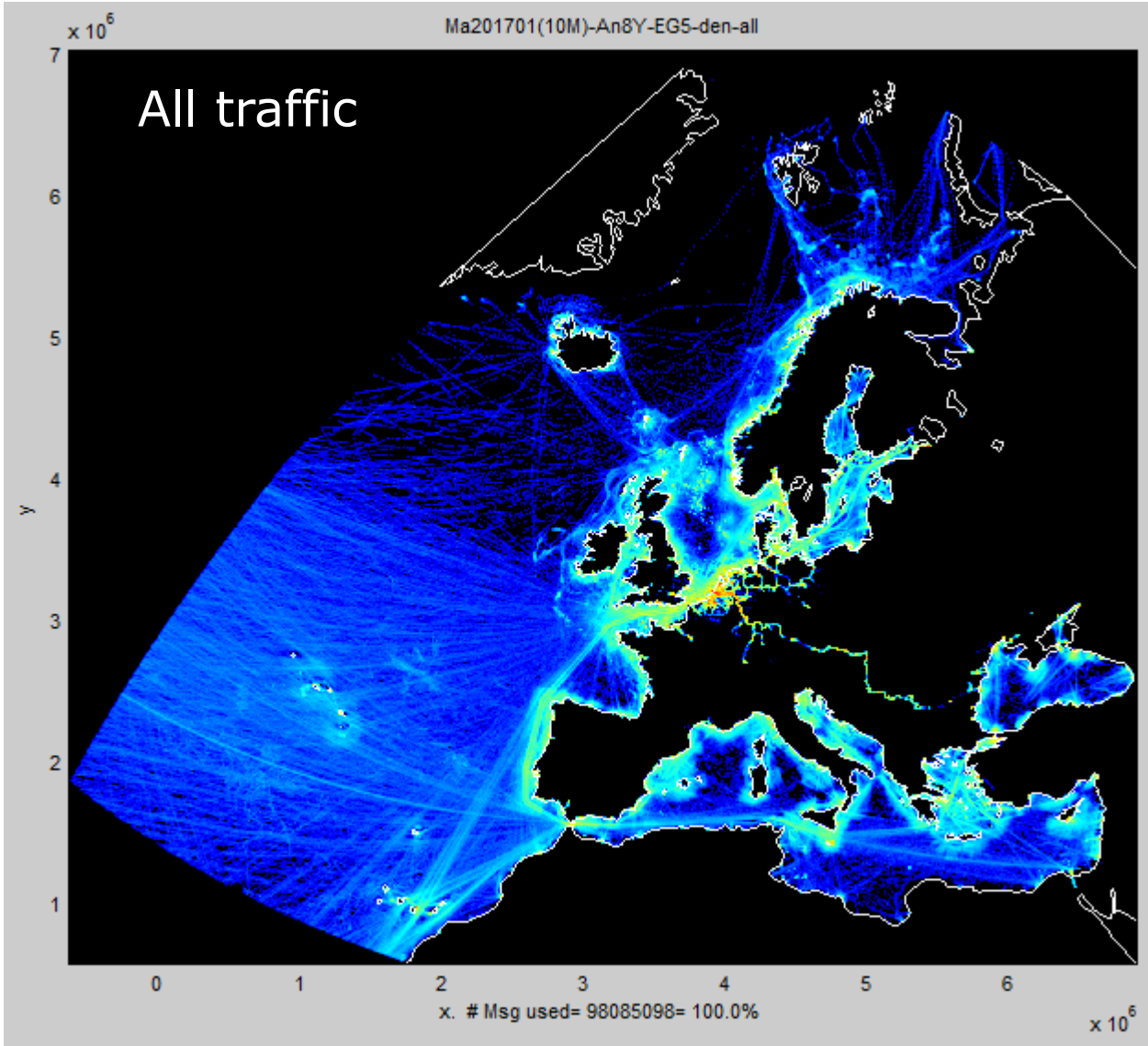
+ Add external layers

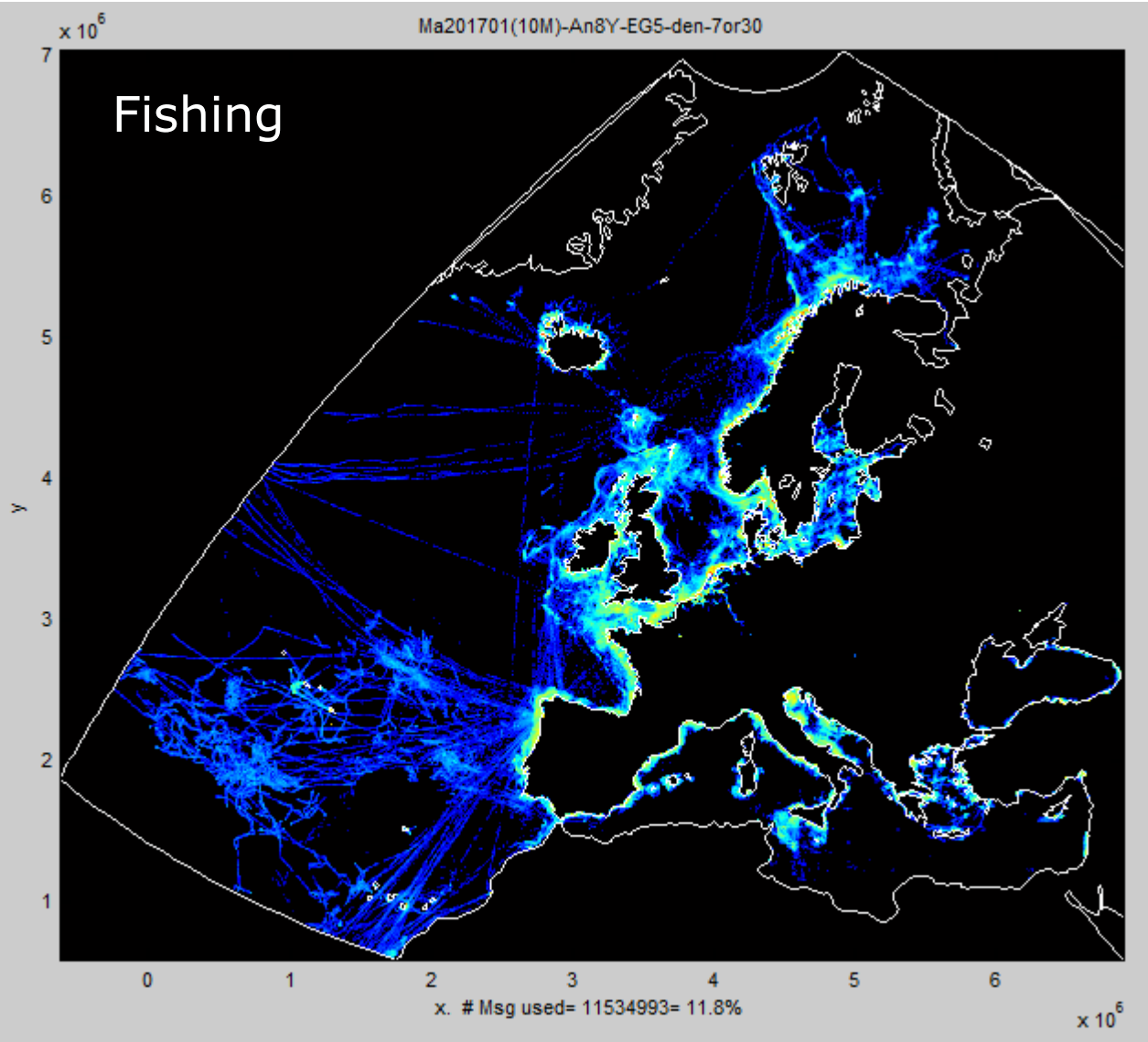
Marine regions: Search for a region ...

Change basemap: Esri.Ocean

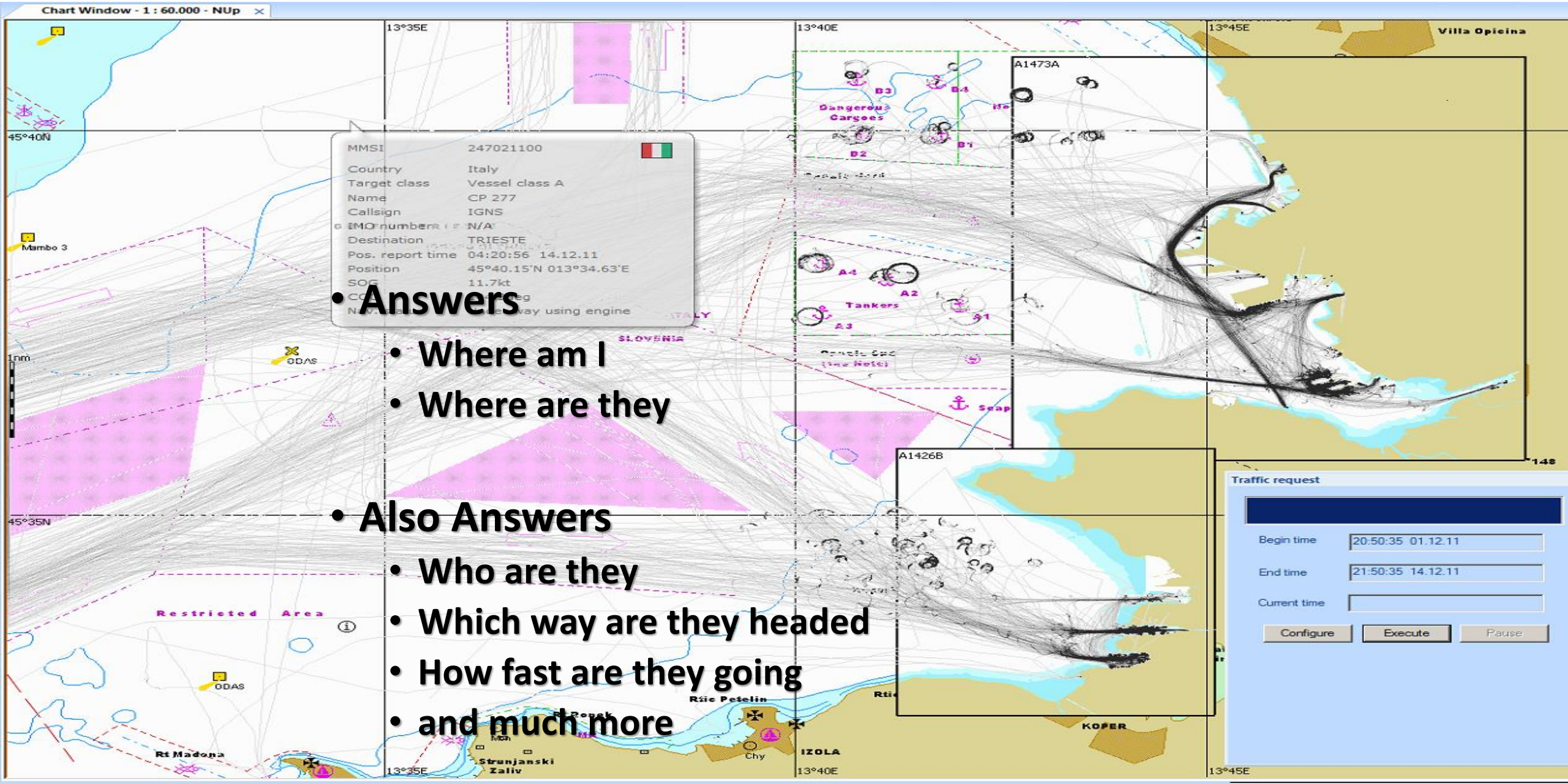
Coastal AIS
Satellite AIS
Produced by industry
Support by JRC

Ship density Jan 2017





Automatic Identification System



- **Answers**
  - **Where am I**
  - **Where are they**
- **Also Answers**
  - **Who are they**
  - **Which way are they headed**
  - **How fast are they going**
  - **and much more**

AIS information's update rates

The data is autonomously sent at different update rates:

1. dynamic information dependent on speed and course alteration,

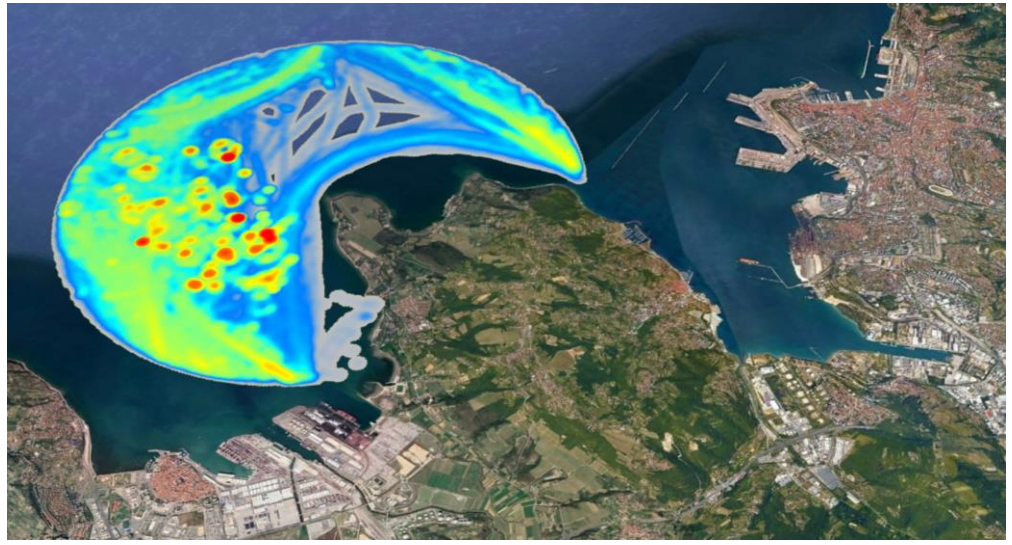
2. static and voyage-related data every 6 minutes or on request (AIS responds automatically without user action).

AIS Class A Transponder-Ships Dynamic Conditions	Dual-Channel	Single-Channel
Ship at anchor or moored	3 min	6 min
SOG 0–14 knots	10 s	20 s
SOG 0–14 knots and changing	3.3 s	6.6 s
SOG 14–23 knots	6 s	12 s
SOG 14–23 knots and changing course	2 s	4 s
SOG > 23 knots	2 s	4 s
Ship static information	6 min	12 min
AIS Class B Transponder-Ships Dynamic Conditions	**Dual-Channel**	**Single-Channel**
SOG < 2 knots	3 min	6 min
SOG > 2 knots	30 s	1 min
SOG		
Ship static information	6 min	12 min

$$D = 2.5\left(\sqrt{h_1} + \sqrt{h_2}\right)$$

$$D = 2.5\left(\sqrt{1028\ \text{m}} + \sqrt{30\ \text{m}}\right) = 93.85\ \text{NM}$$

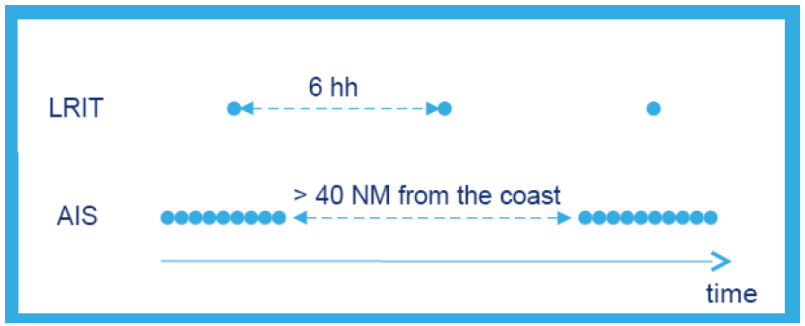
$$2250\ \text{min}^{-1} = \frac{9600\ \text{bit/s}}{256\ \text{bit}} \cdot 60\ \text{s}$$



AIS ship reports (collection)

"BIG DATA"

- ~150,000 ships carry transponders
- each may send 10,000 messages / day

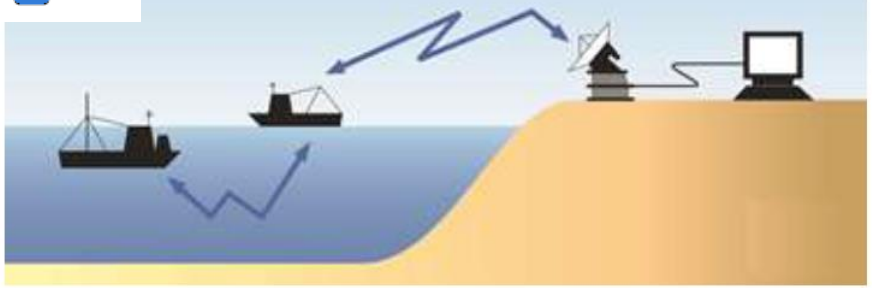


Automatic Identification System (AIS)

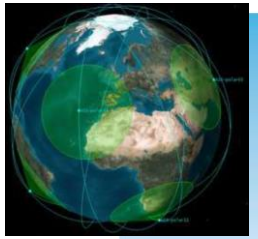
FREQUENCY High
(few sec to min)

IRREGULAR
(spatial/temporal gaps)

ACCESS
Free



Long Range Identification and Tracking (LRIT)

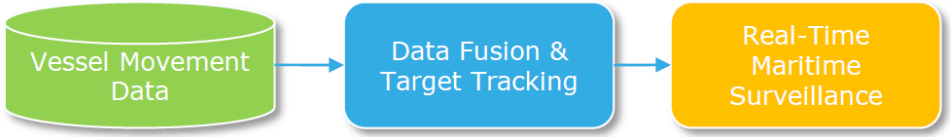


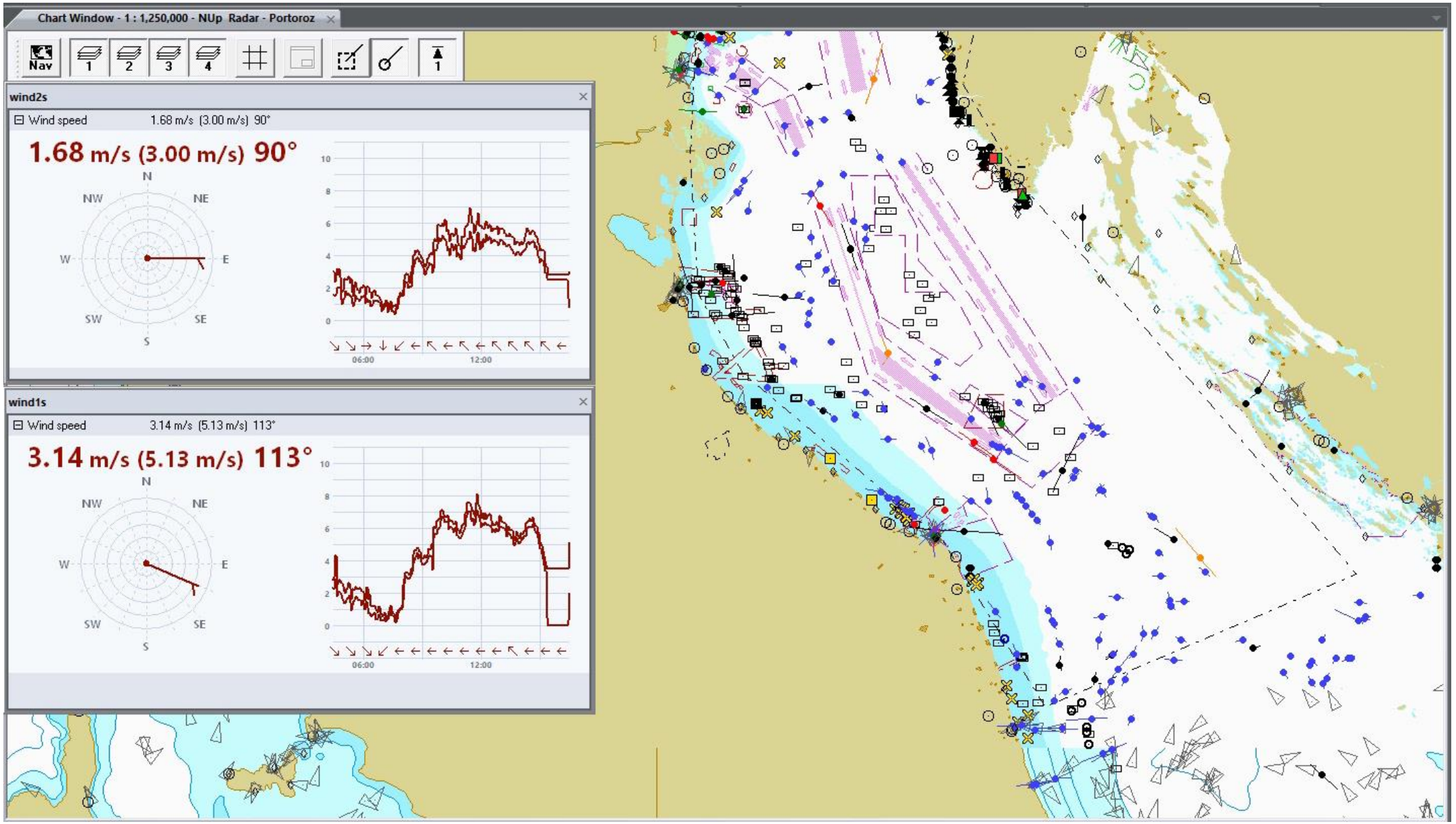
FREQUENCY Fix
(to 6 hours)

REGULAR
(space and time)

ACCESS
Restricted

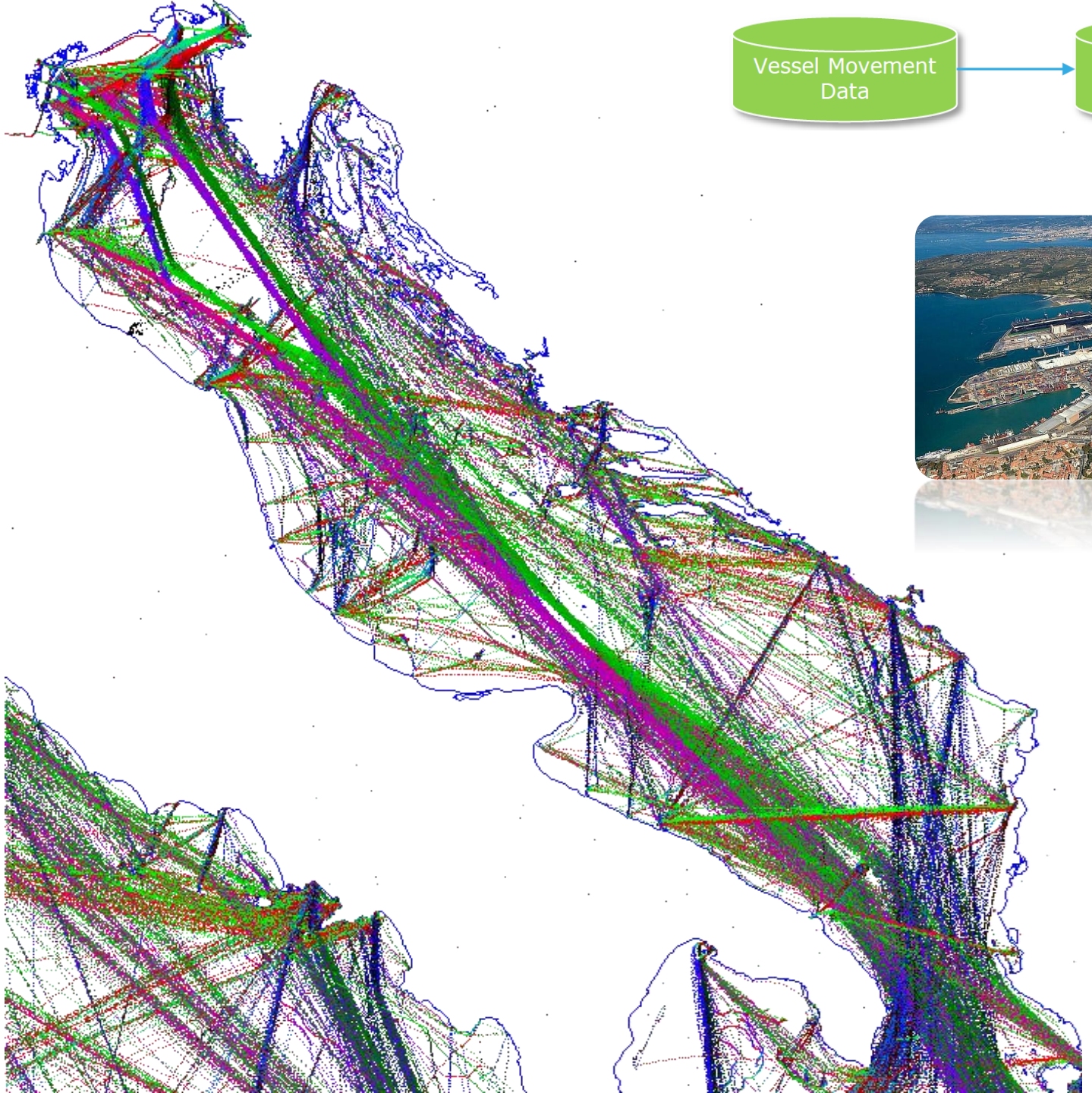
Data Fusion & Real Time Surveillance

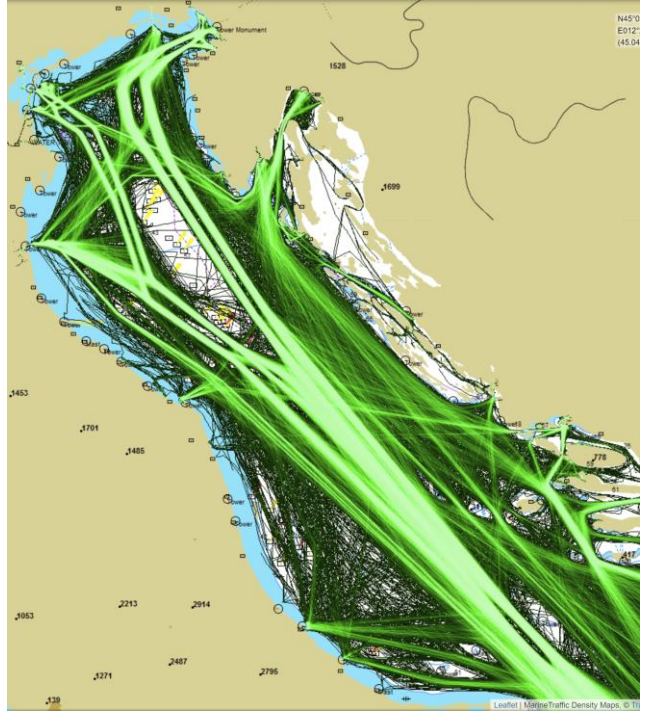
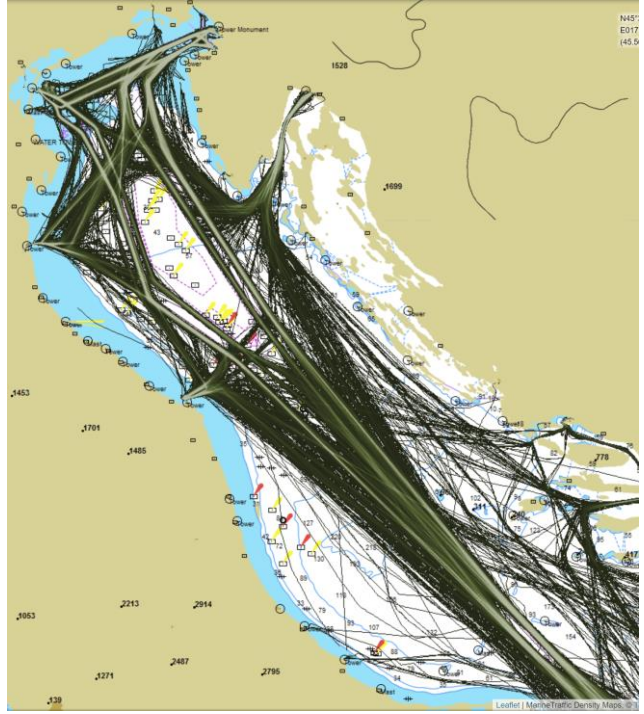
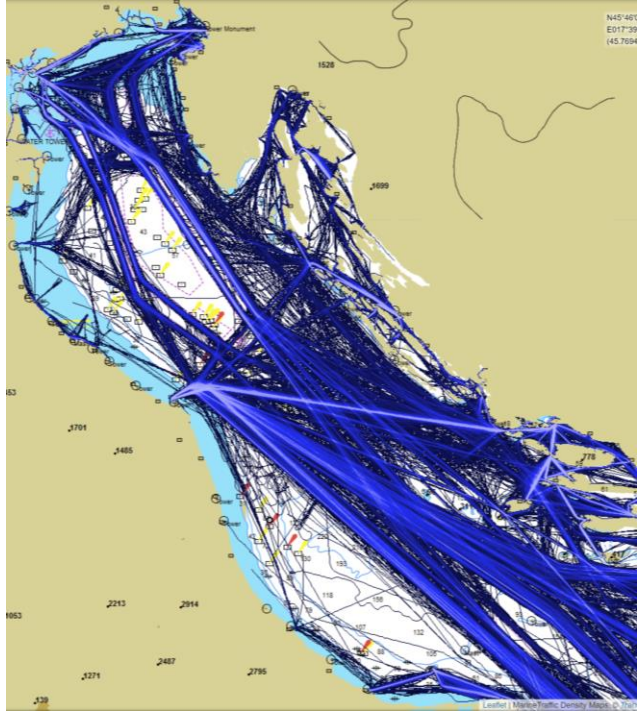
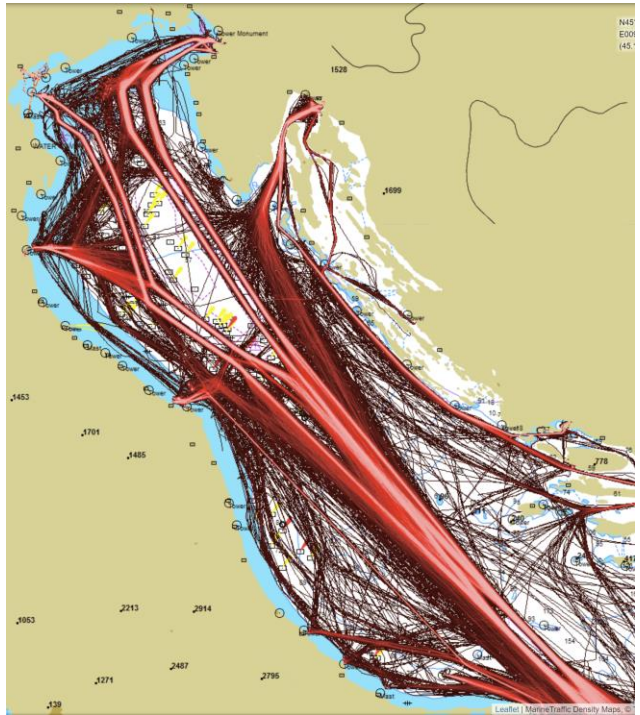
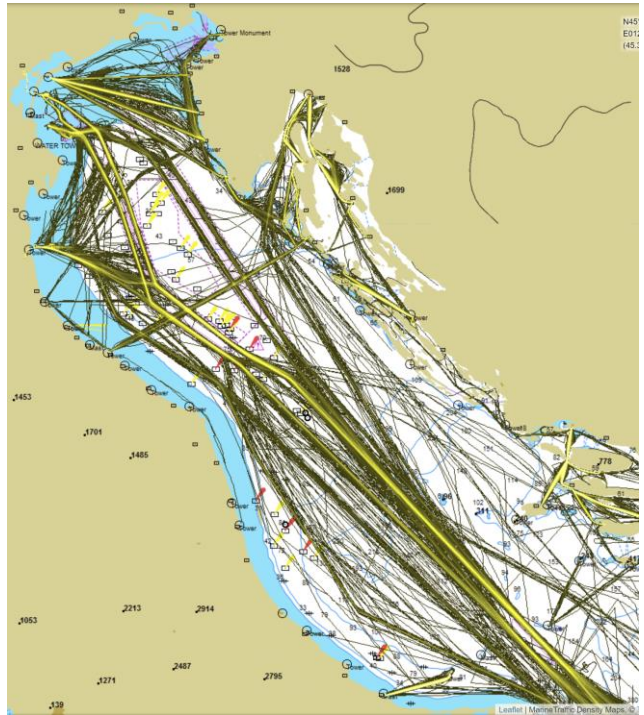
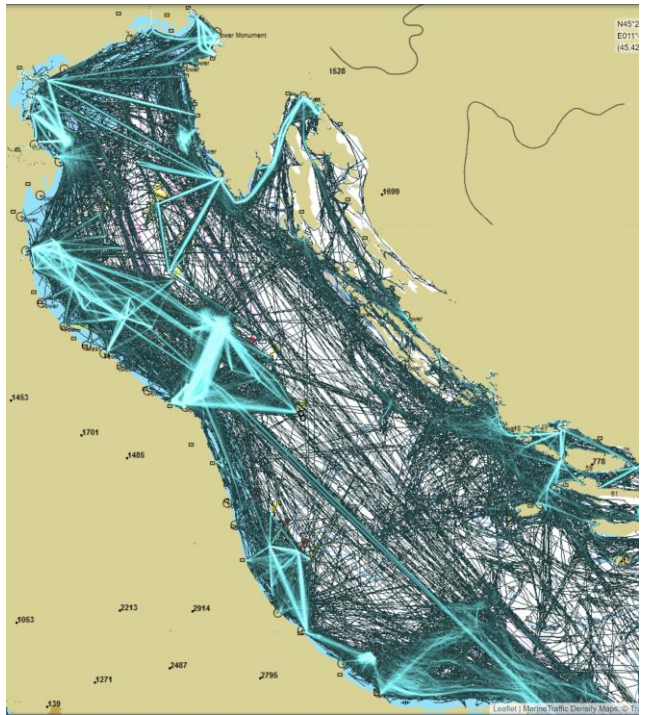


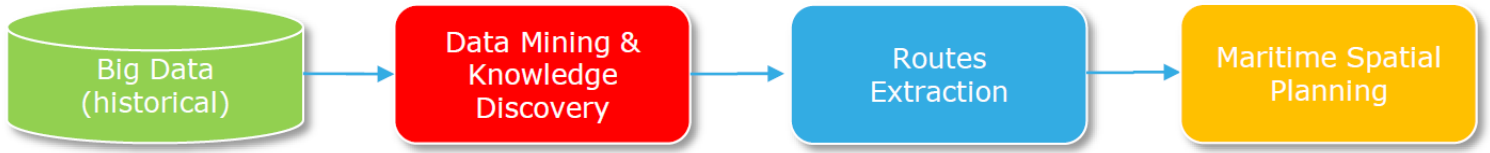


Tracking and Traffic Routes

Adriatic Sea;
Traffic AIS density

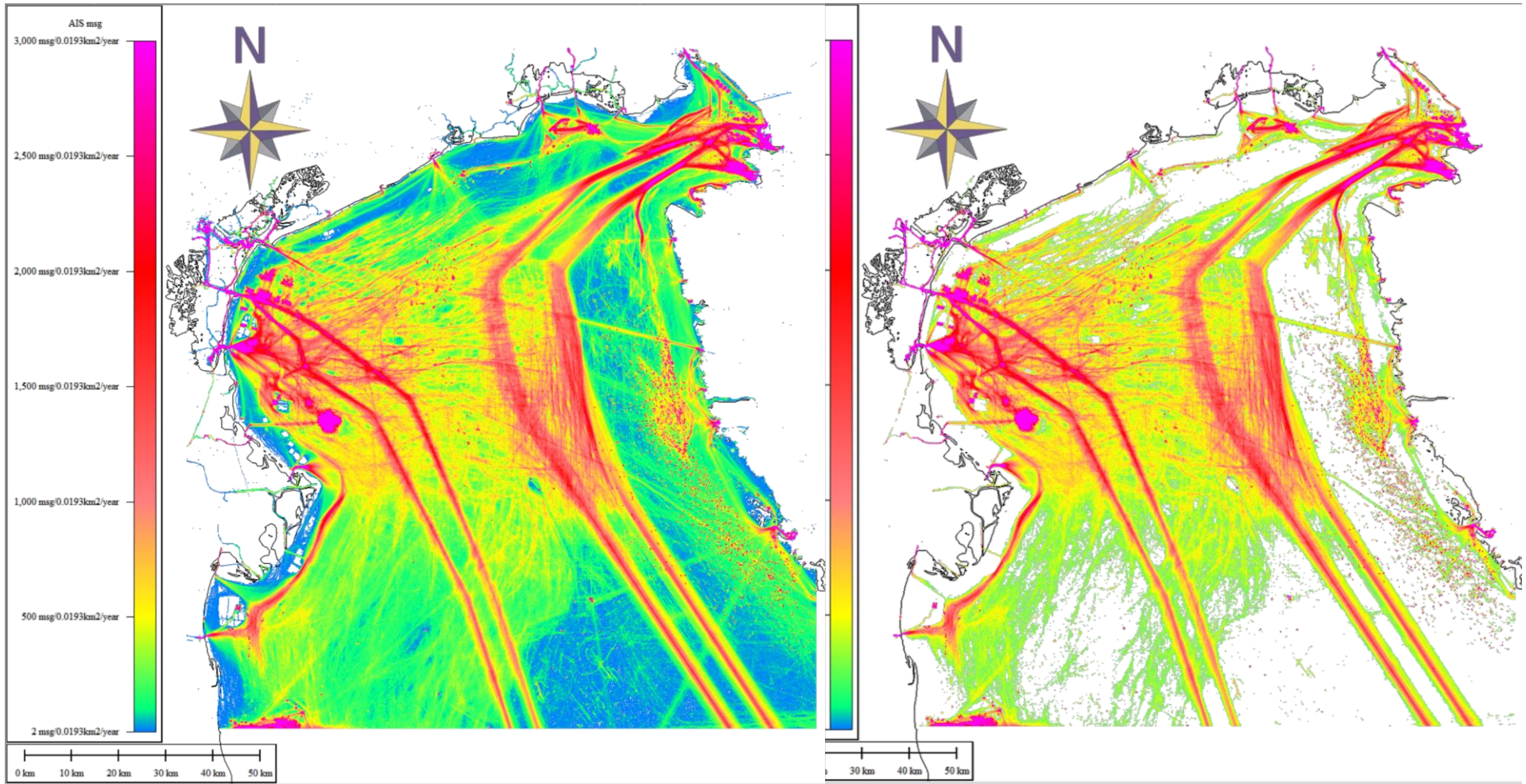


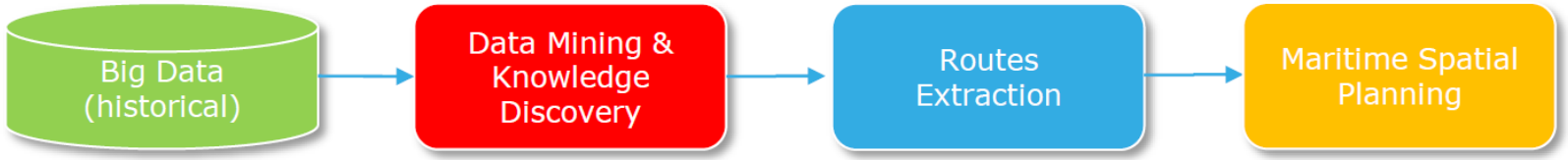







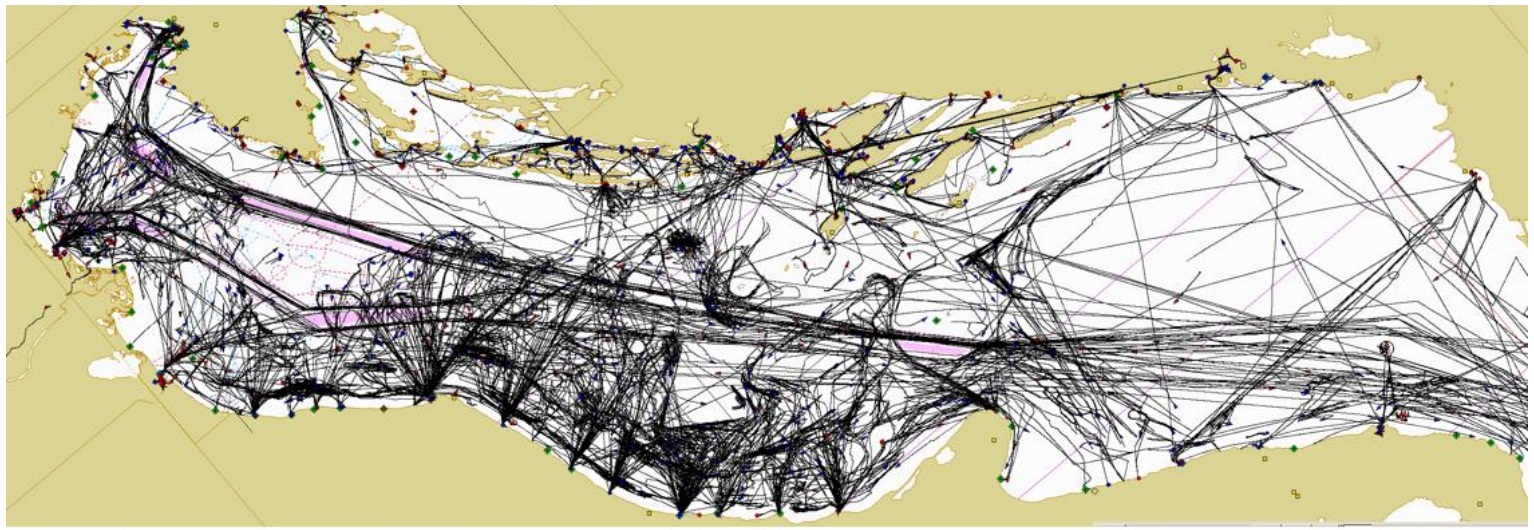


AIS 2017

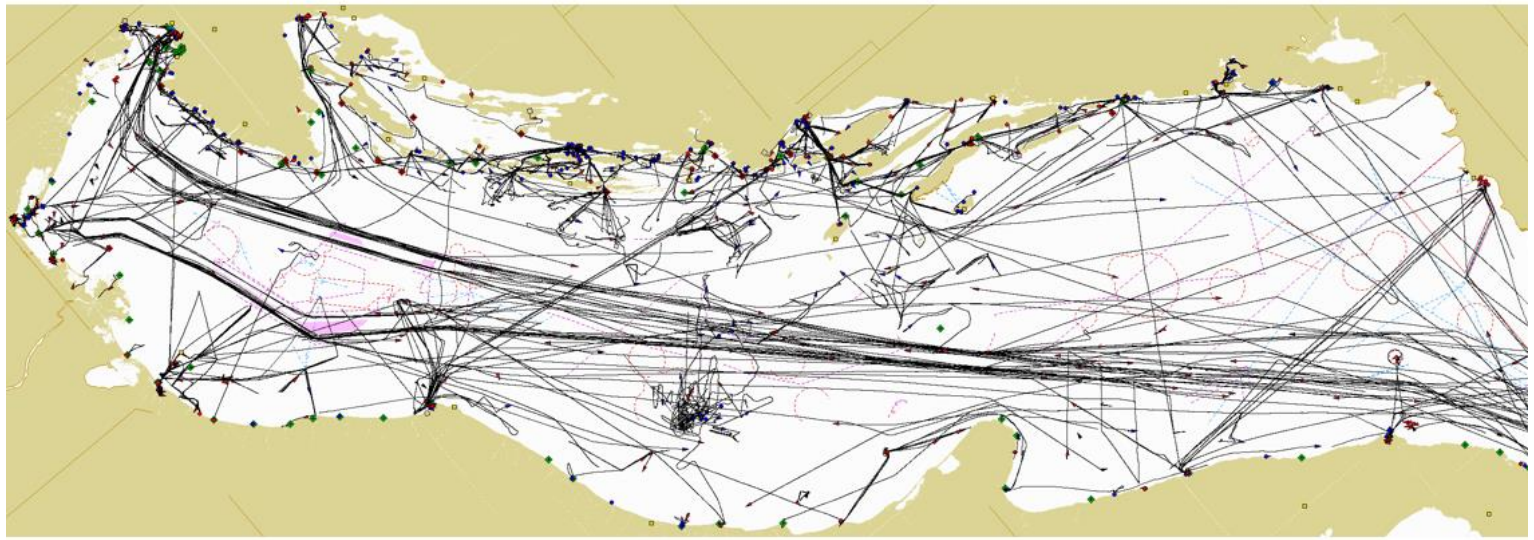
(“all” reports vs. dense area reports)



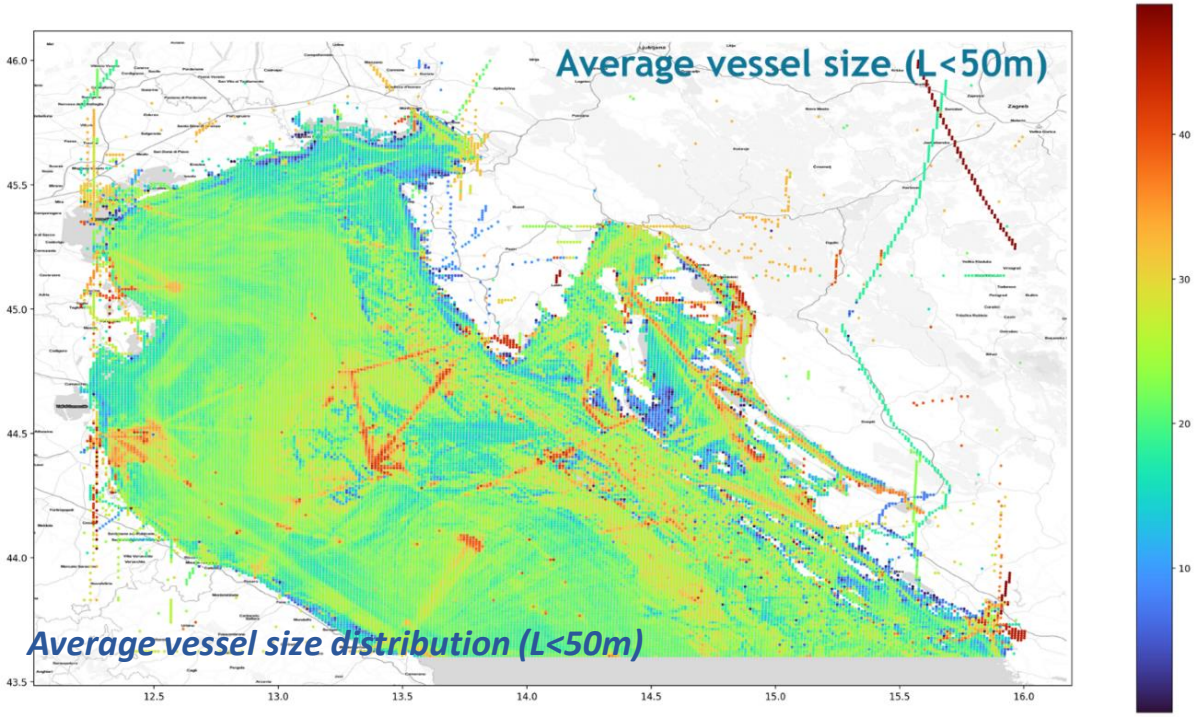




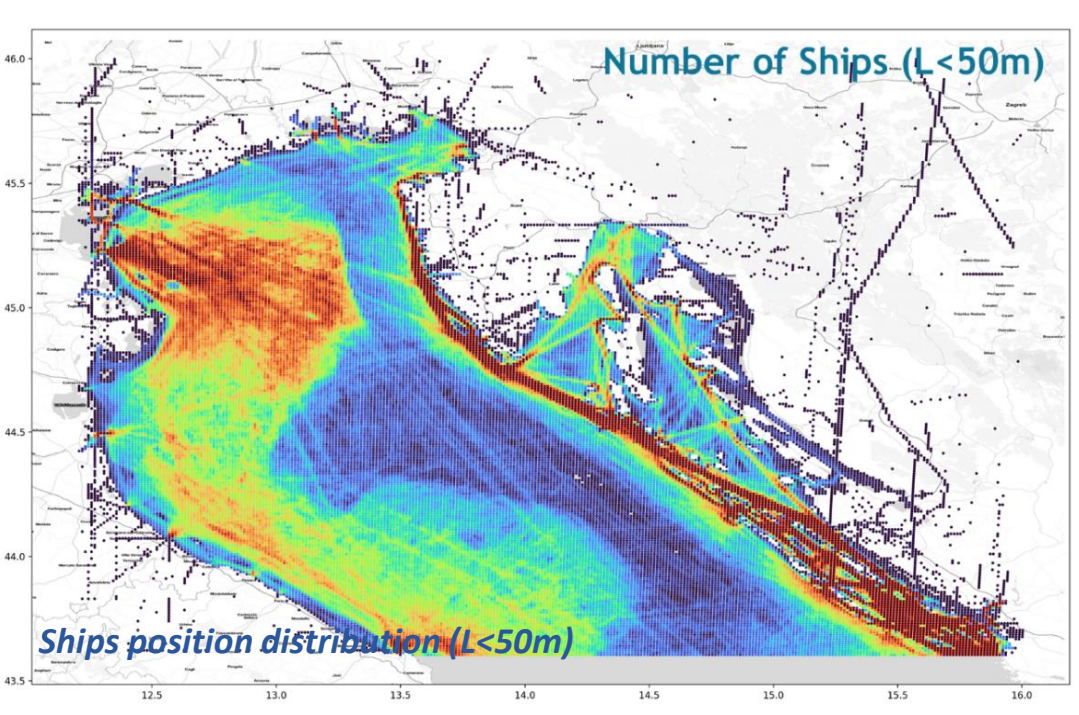
Daily shipping activities in the Adriatic on weekdays (up to 1400 vessels)



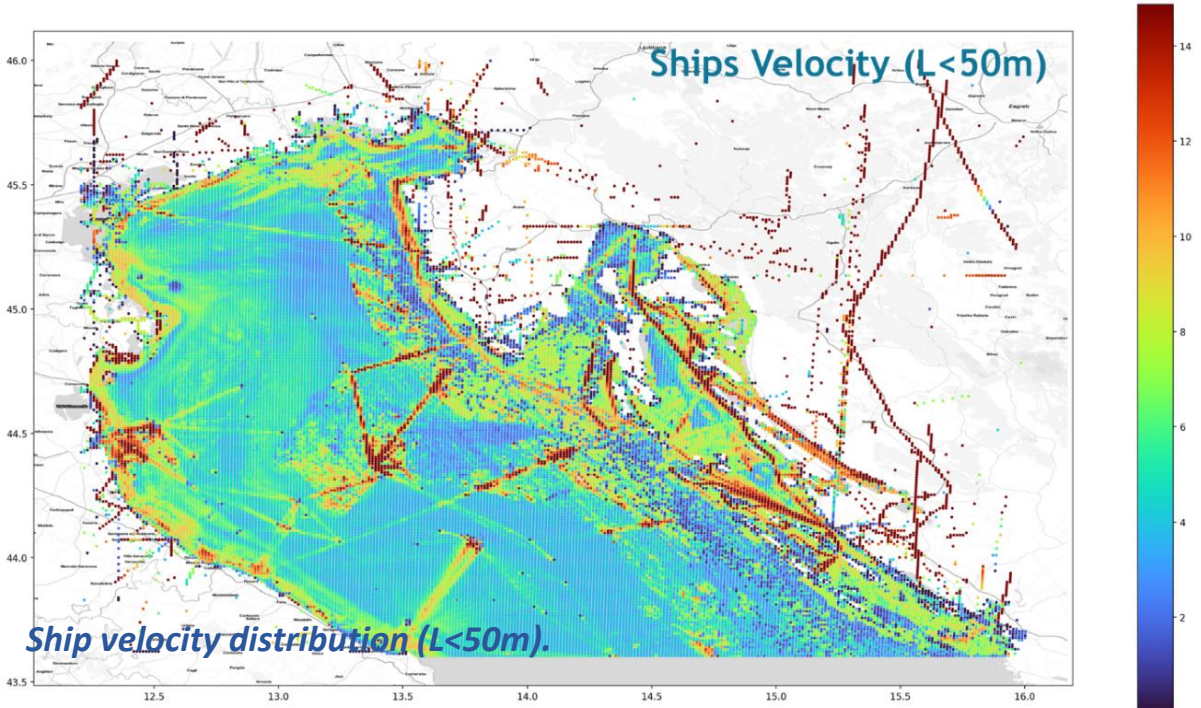
Daily shipping activities in the Adriatic on (up to 950 vessels).



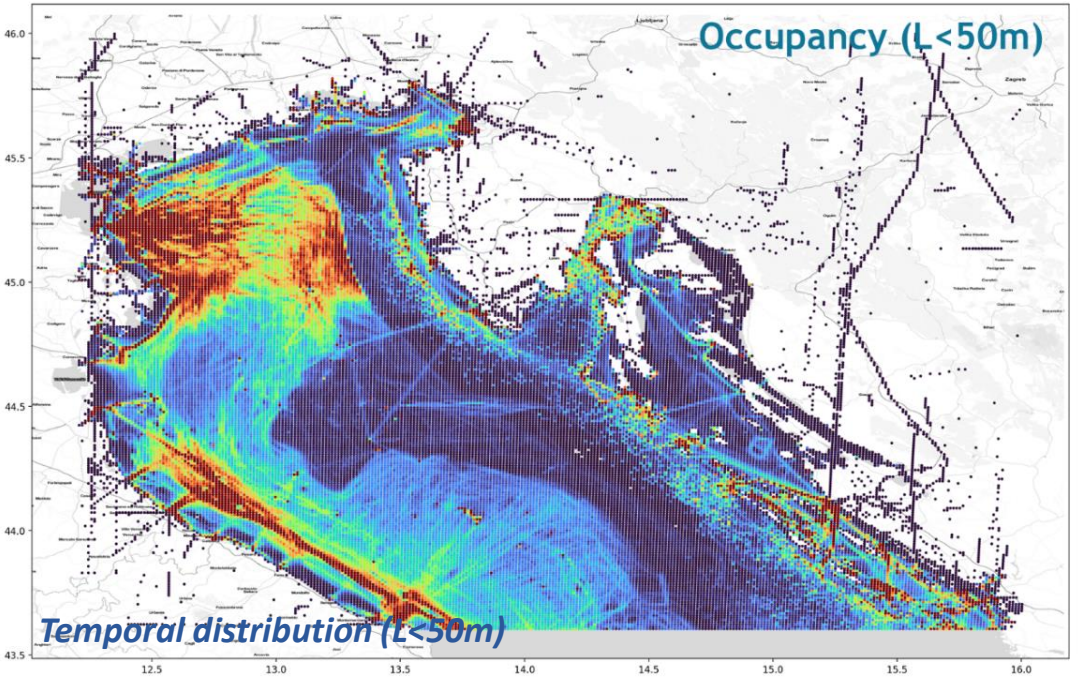
Average vessel size distribution (L<50m)



Ships position distribution (L<50m)

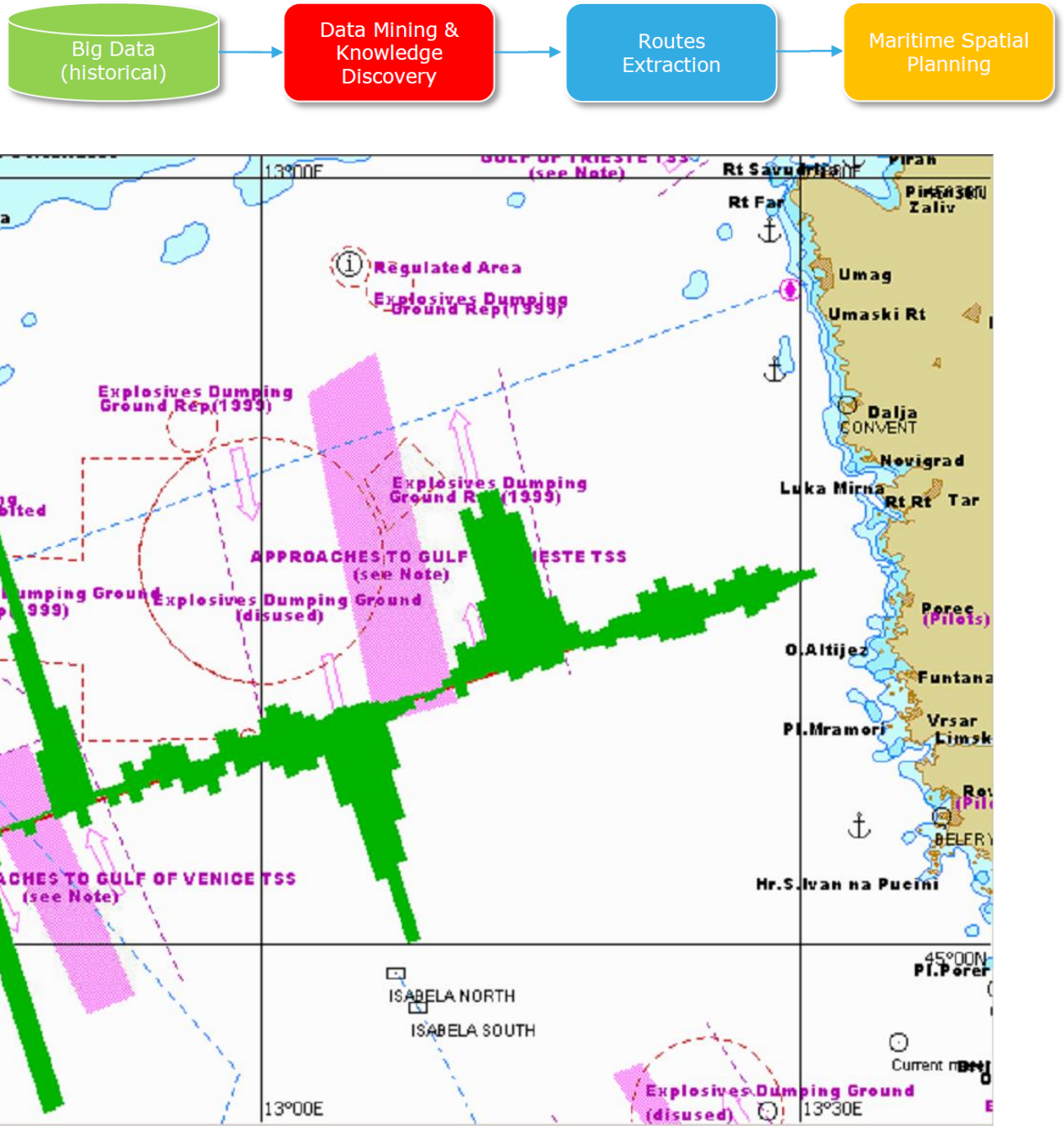


Ship velocity distribution (L<50m).

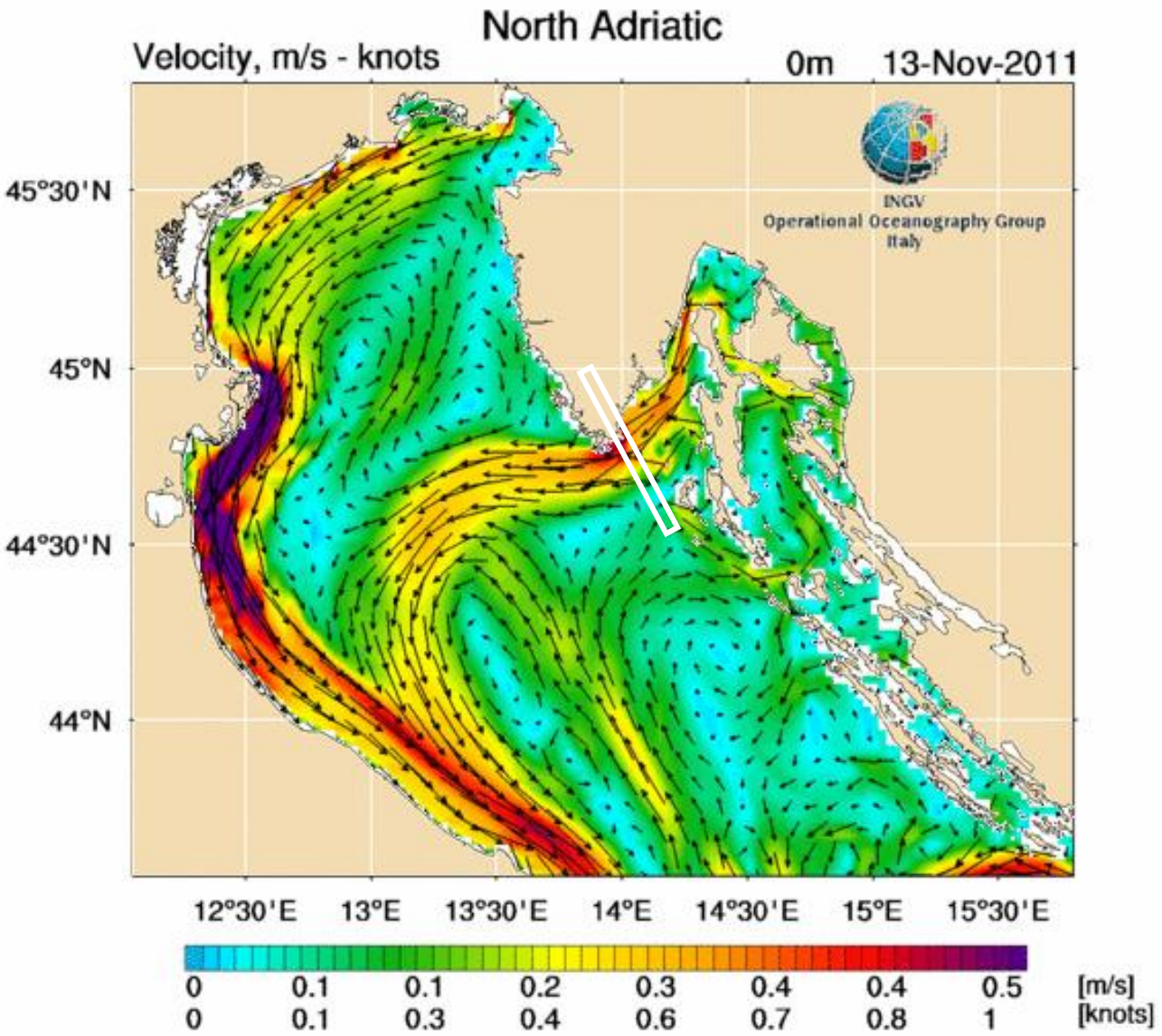


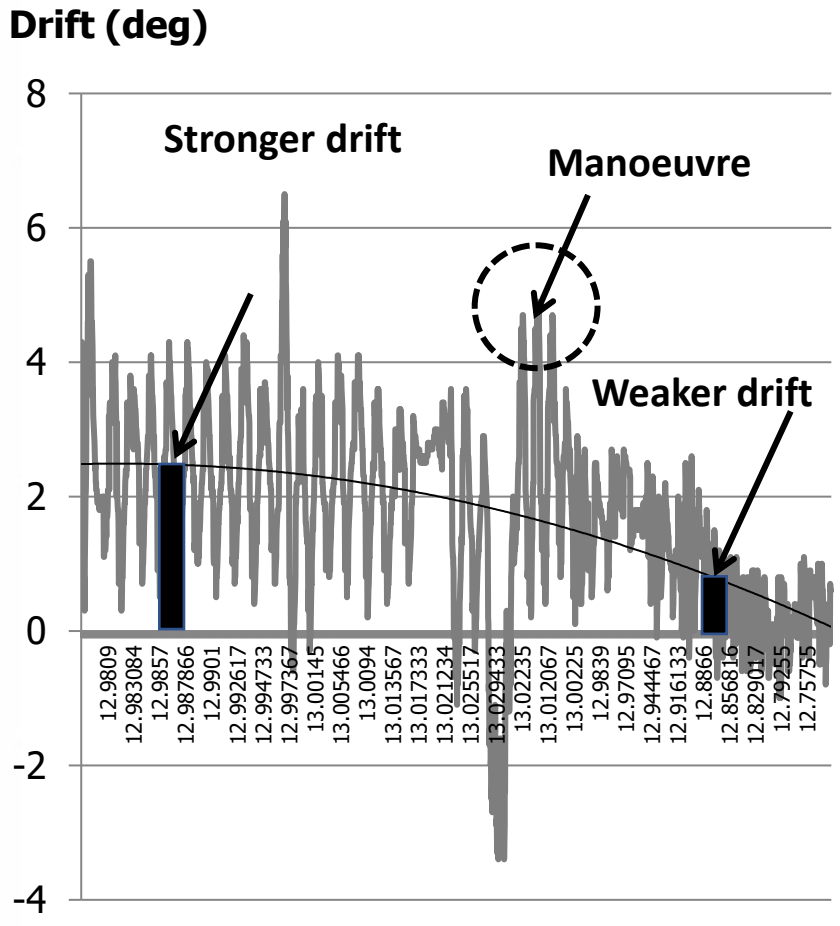
Temporal distribution (L<50m)

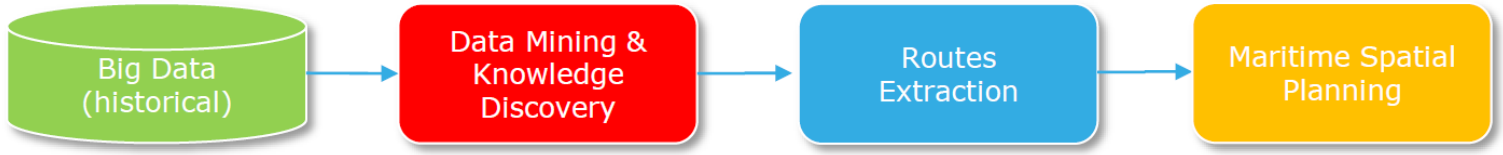
Tracking and Traffic Routes

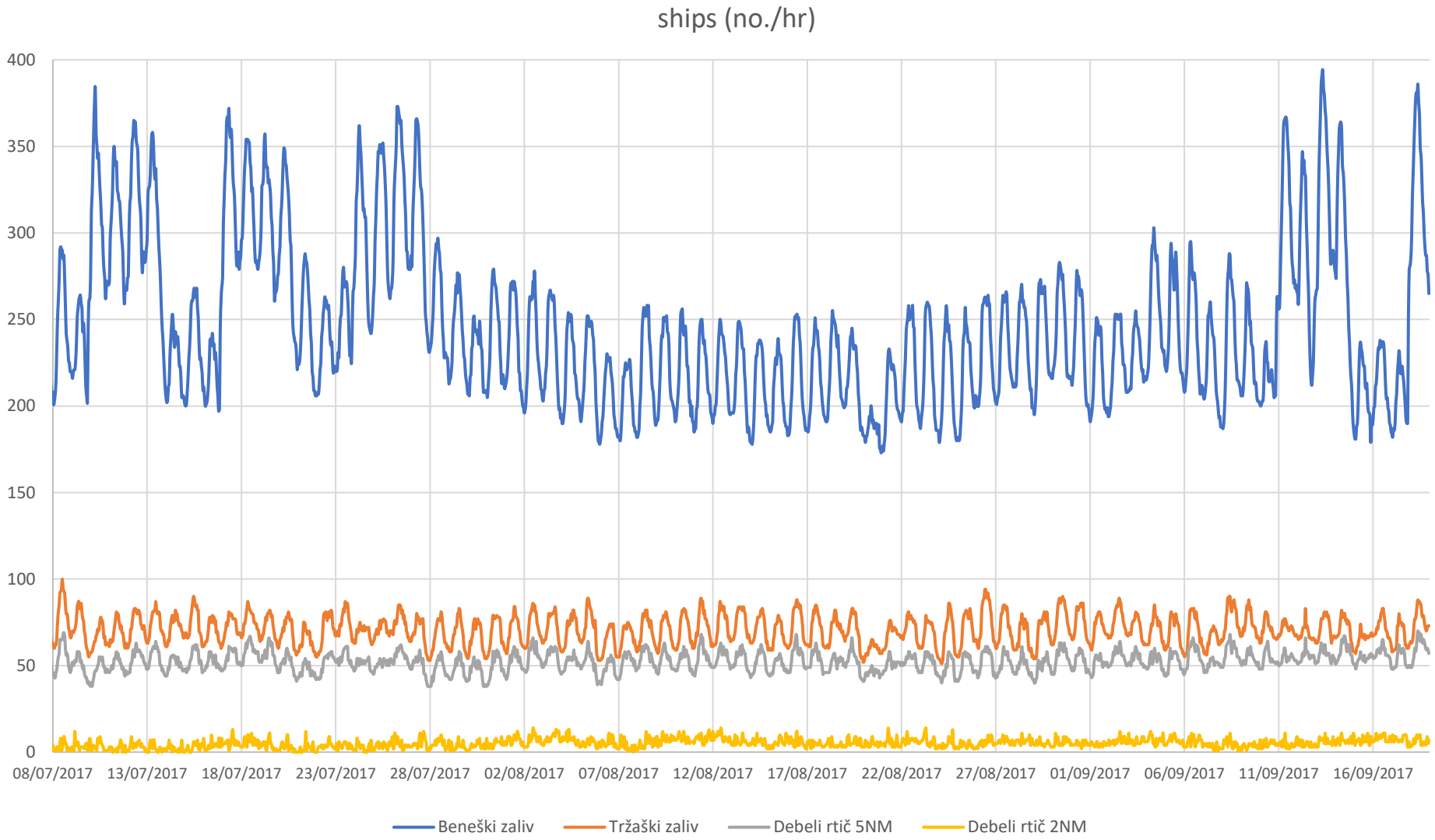


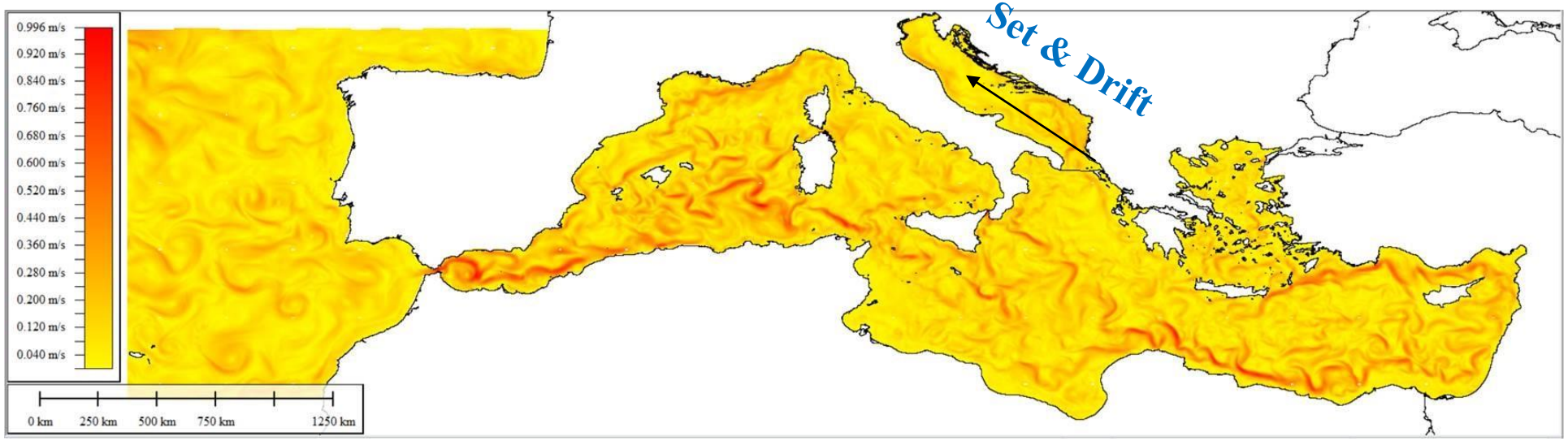
Sailing in current

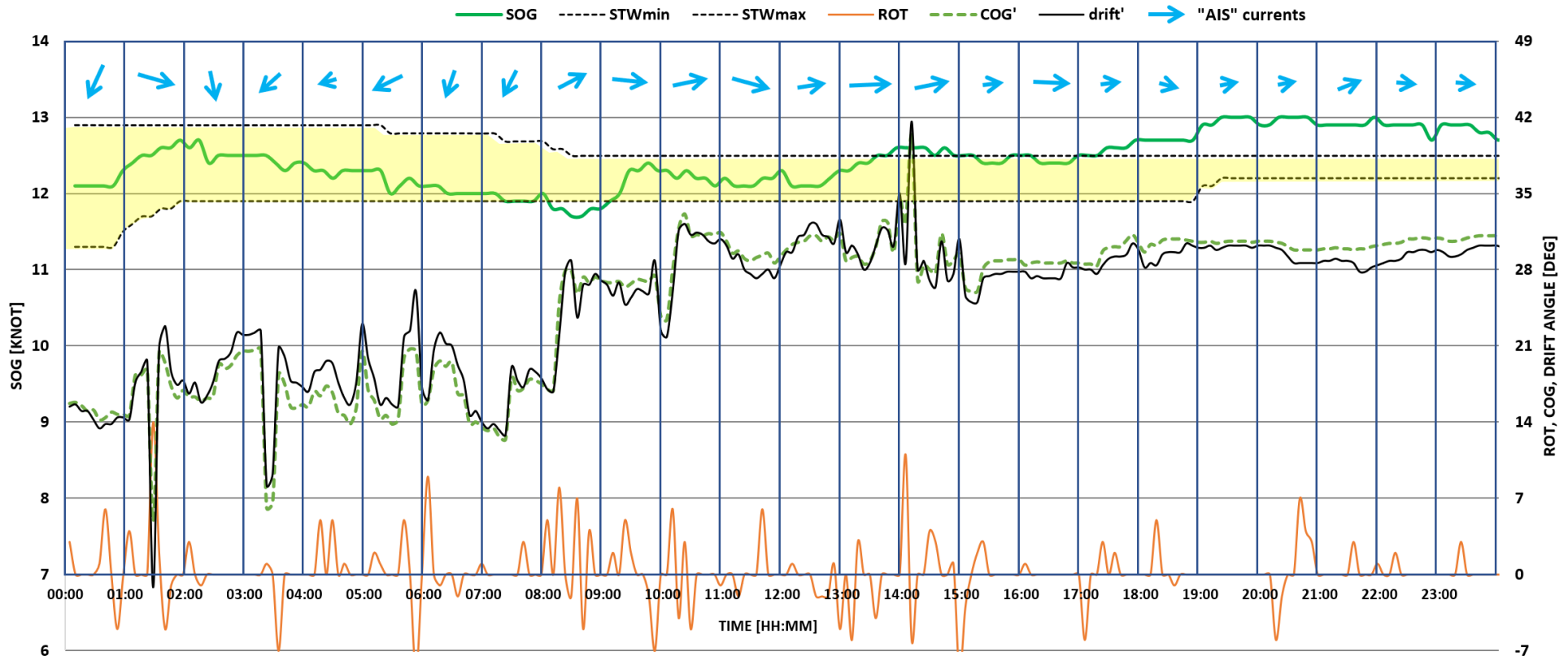




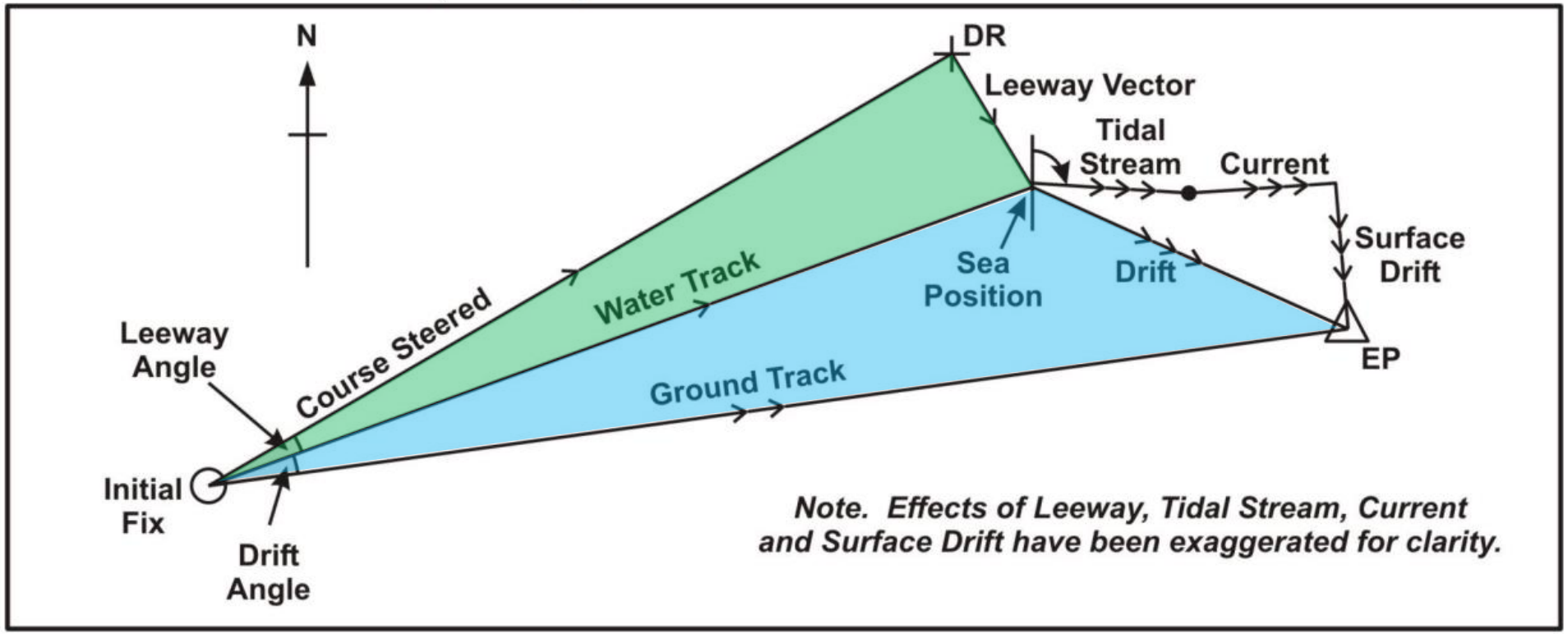

Big Data (historical)
Data Mining & Knowledge Discovery
Routes Extraction
Maritime Spatial Planning


ships (no./hr)
400
350
300
250
200
150
100
50
0
08/07/2017
13/07/2017
18/07/2017
23/07/2017
28/07/2017
02/08/2017
07/08/2017
12/08/2017
17/08/2017
22/08/2017
27/08/2017
01/09/2017
06/09/2017
11/09/2017
16/09/2017
Beneški zaliv
Tržaški zaliv
Debeli rtič 5NM
Debeli rtič 2NM


0.996 m/s
0.920 m/s
0.840 m/s
0.760 m/s
0.680 m/s
0.600 m/s
0.520 m/s
0.440 m/s
0.360 m/s
0.280 m/s
0.200 m/s
0.120 m/s
0.040 m/s
0 km
250 km
500 km
750 km
1250 km
Set & Drift

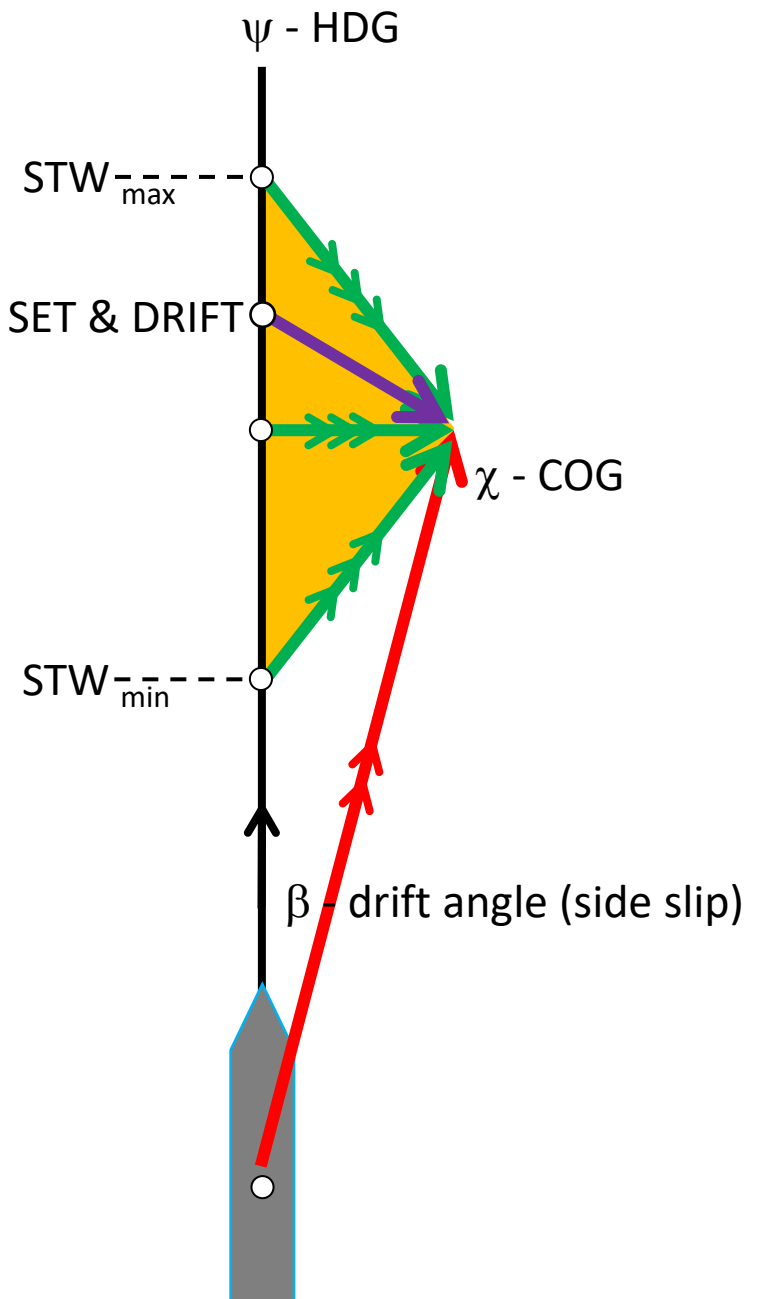

SOG
STWmin
STWmax
ROT
COG'
drift'
"AIS" currents
SOG [KNOT]
ROT, COG, DRIFT ANGLE [DEG]
TIME [HH:MM]
14
13
12
11
10
9
8
7
6
49
42
35
28
21
14
7
0
-7
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00

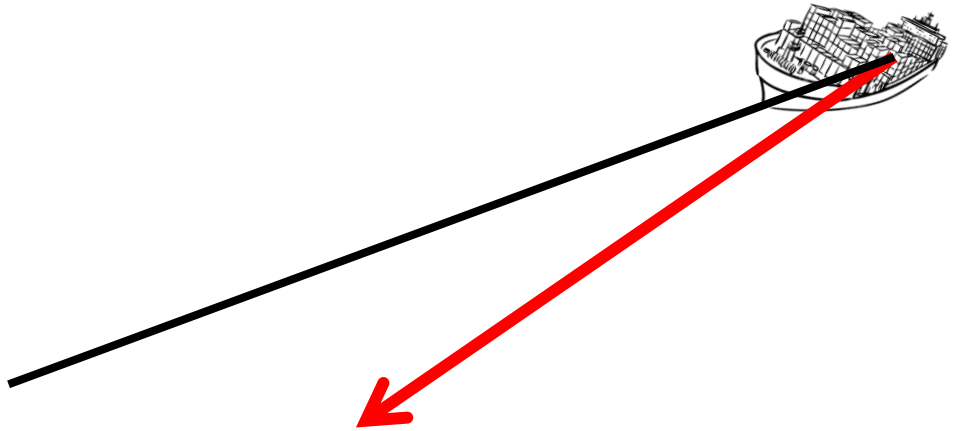
Leeway and Set & Drift

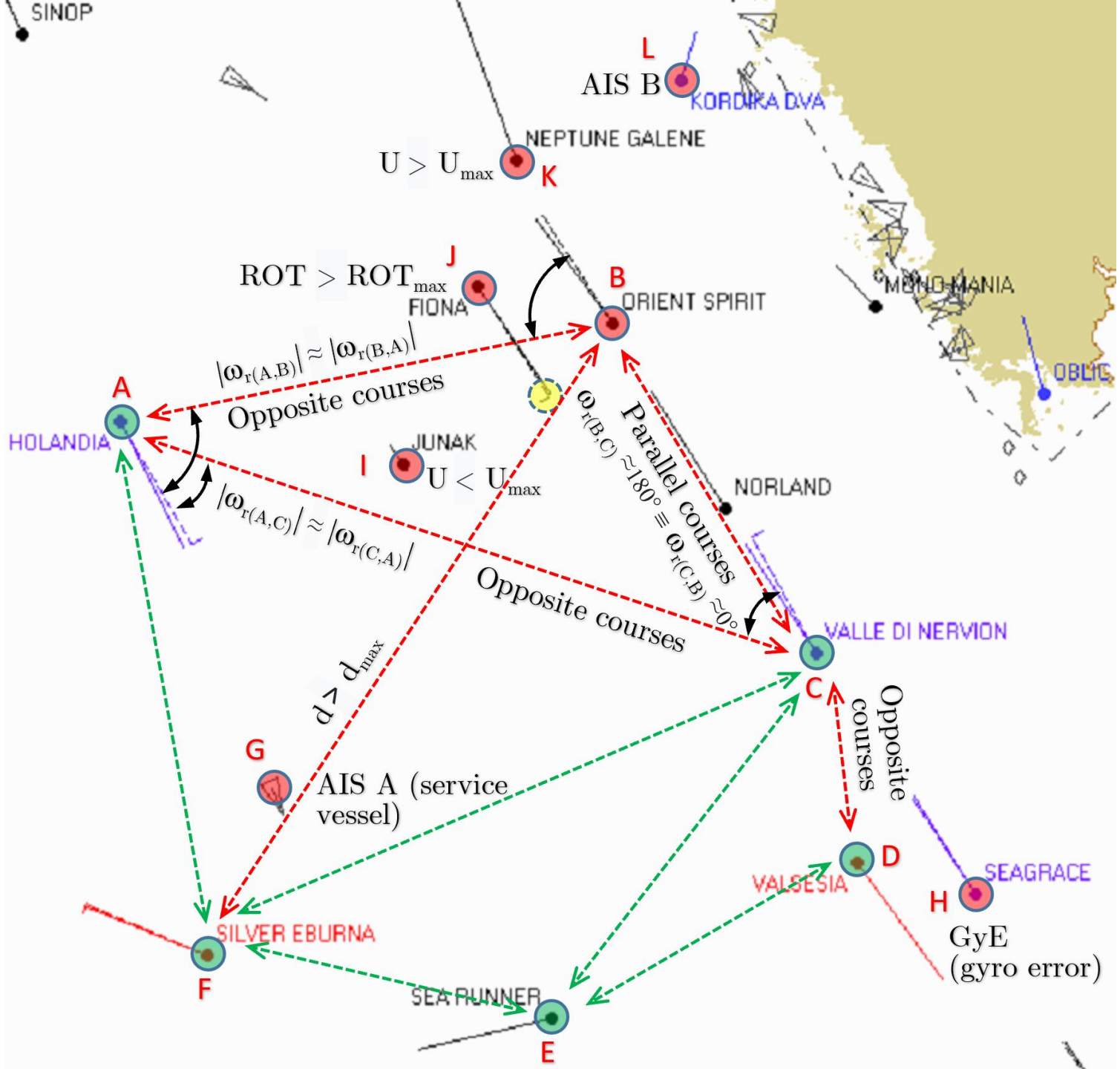


American Practical Navigator (Bowditch)

Sailing in current







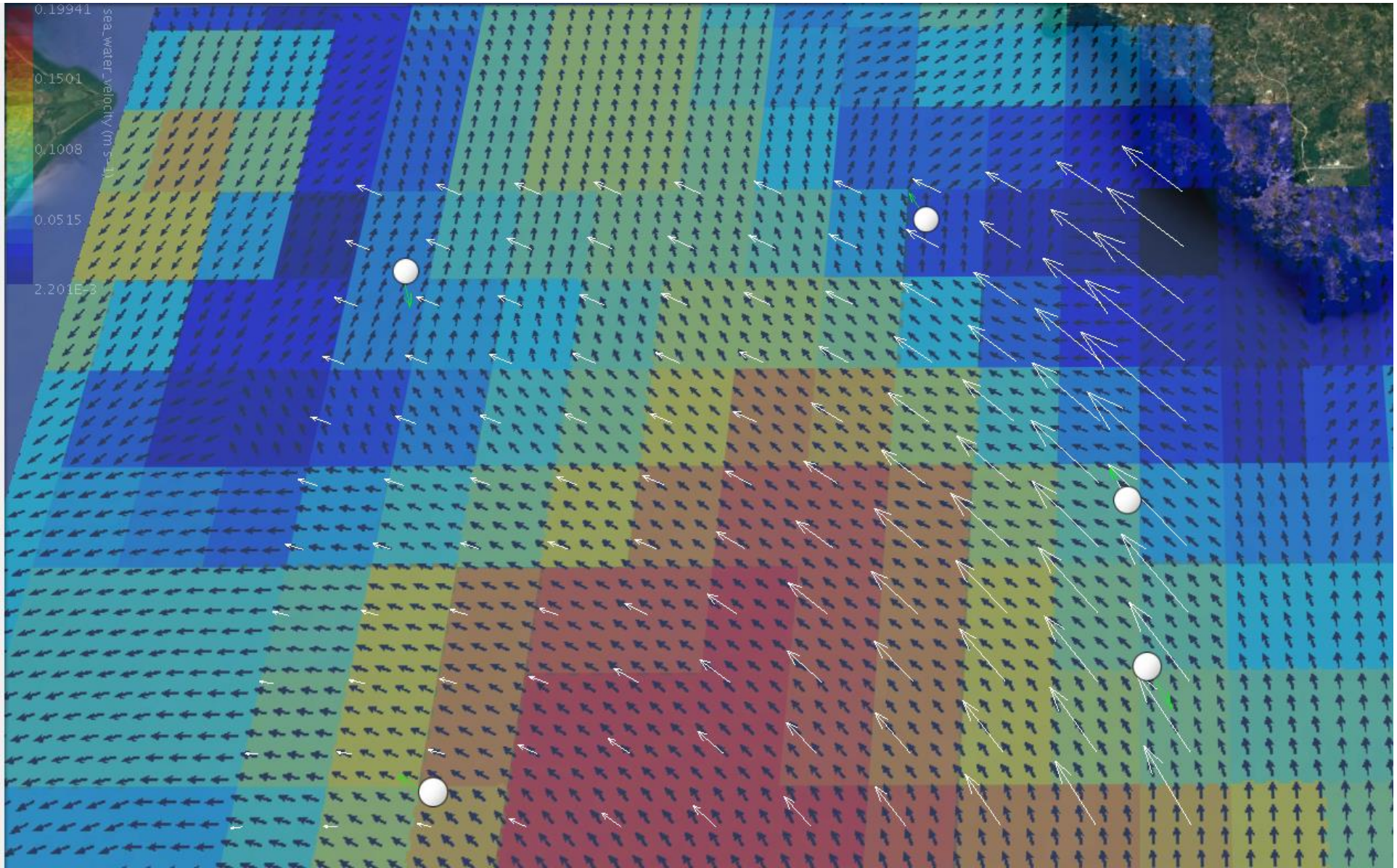
Set & Drift

Multiple vessel

High resolution model

Multiple vessel drifting approach towards metocean validation

Surface currents model analysis data vs “AIS currents”



Oil Pollution; Categories (vectors) of oil pollution

U.S. National Academy of Sciences

average total worldwide annual release of petroleum (oils) from all known sources to the sea has been estimated at 1.3 million tonnes

1. natural seeps: 46%
2. discharges from consumption of oils (operational discharges from ships and discharges from land-based sources): 37%
3. accidental spills from ships; 12%
4. **Operational spills; 8%**
5. extraction of oil: 3%

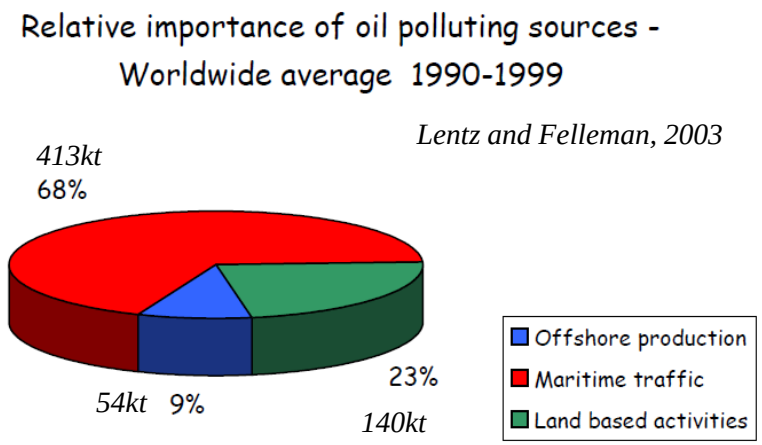
Australian Petroleum Production and Exploration Association

1. Land-based sources (urban runoff and discharges from industry): 37%
2. Natural seeps: 7%
3. The oil industry - tanker accidents and offshore oil extraction: 14%
4. **Operational discharges** from ships not within the oil industry: **33%**
5. Airborne hydrocarbons: 9%

Group of Experts on the Scientific Aspects of Marine Environmental Protection-GESAMP

estimated a total input of oils at 2.3 million tonnes per year and ranked the sources:

1. Land-based sources (urban runoff, coastal refineries): 50%
2. Oil transporting and shipping (**operational discharges**, tanker accidents): **24%**
3. Offshore production discharges: 2%
4. Atmospheric fallout: 13%
5. Natural seeps: 11%



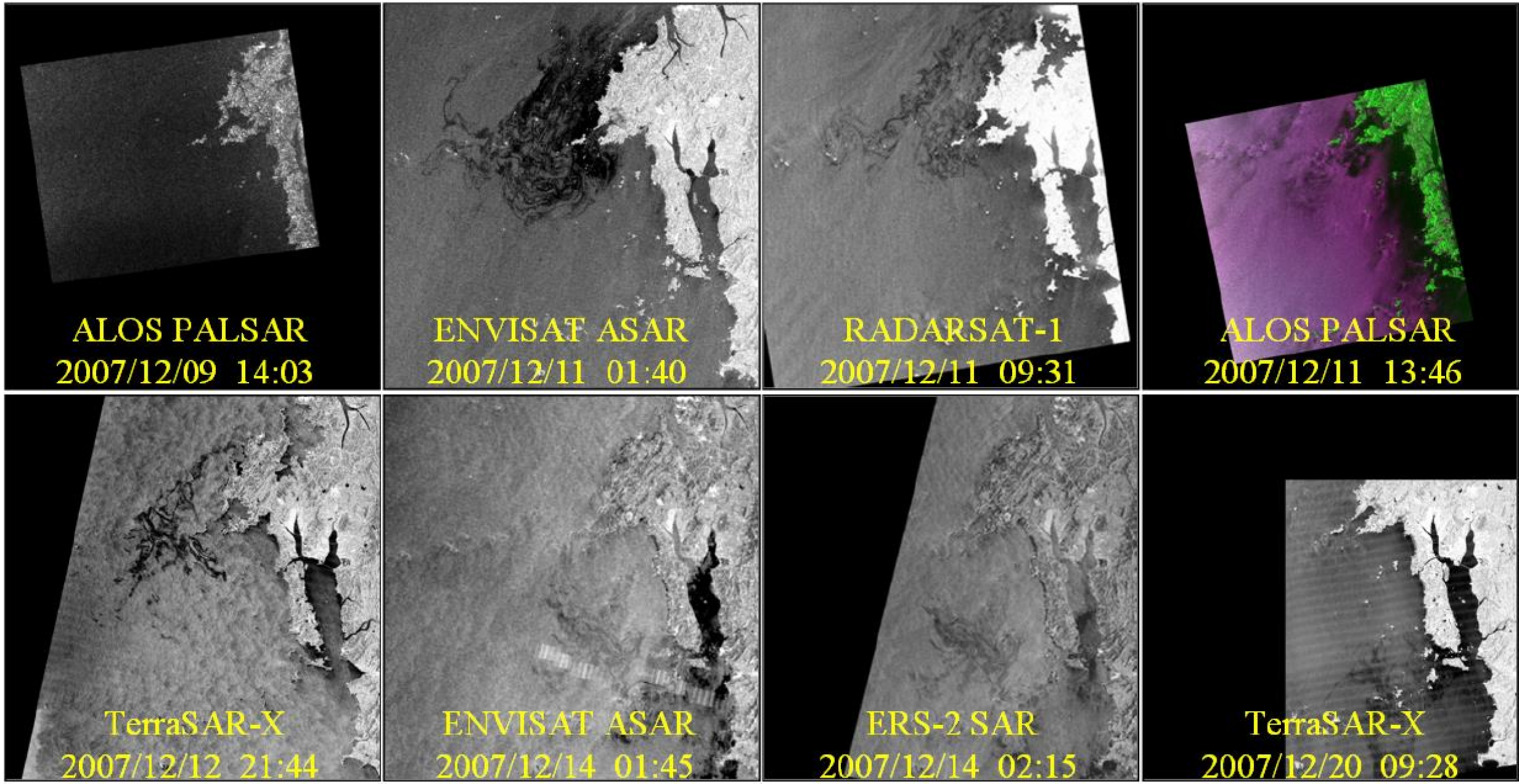
http://oils.gpa.unep.org

Adriatic Sea !??!

MT Hebei Spirit, 2007, South Korea – TAEAN port

Thousands of tons of oil spilled into the Yellow Sea off the western coast of South Korea Friday after an oil tanker collided with a barge carrying a crane, the Maritime Ministry of Korea reported. About 10,000 tons of oil gushed out of the Hebei Spirit after the crane punctured holes in the side of the tanker around 7:15 a.m. local time (5:15 p.m. Thursday). The flow had stopped by Friday evening as efforts continued to contain the spill. "Because of the current wind and wave movements the maritime ministry is not expecting to see much environmental damage on the west coast of Korea," the ministry said. The spill is the largest in South Korean history, a police spokesman said, according to South Korea's Yonhap news agency. The previous record was set in 1995 when the Sea Prince struck a reef, releasing more than 5,000 tons of oil into waters off the southern coast.

Disaster Management "South Korea Case"

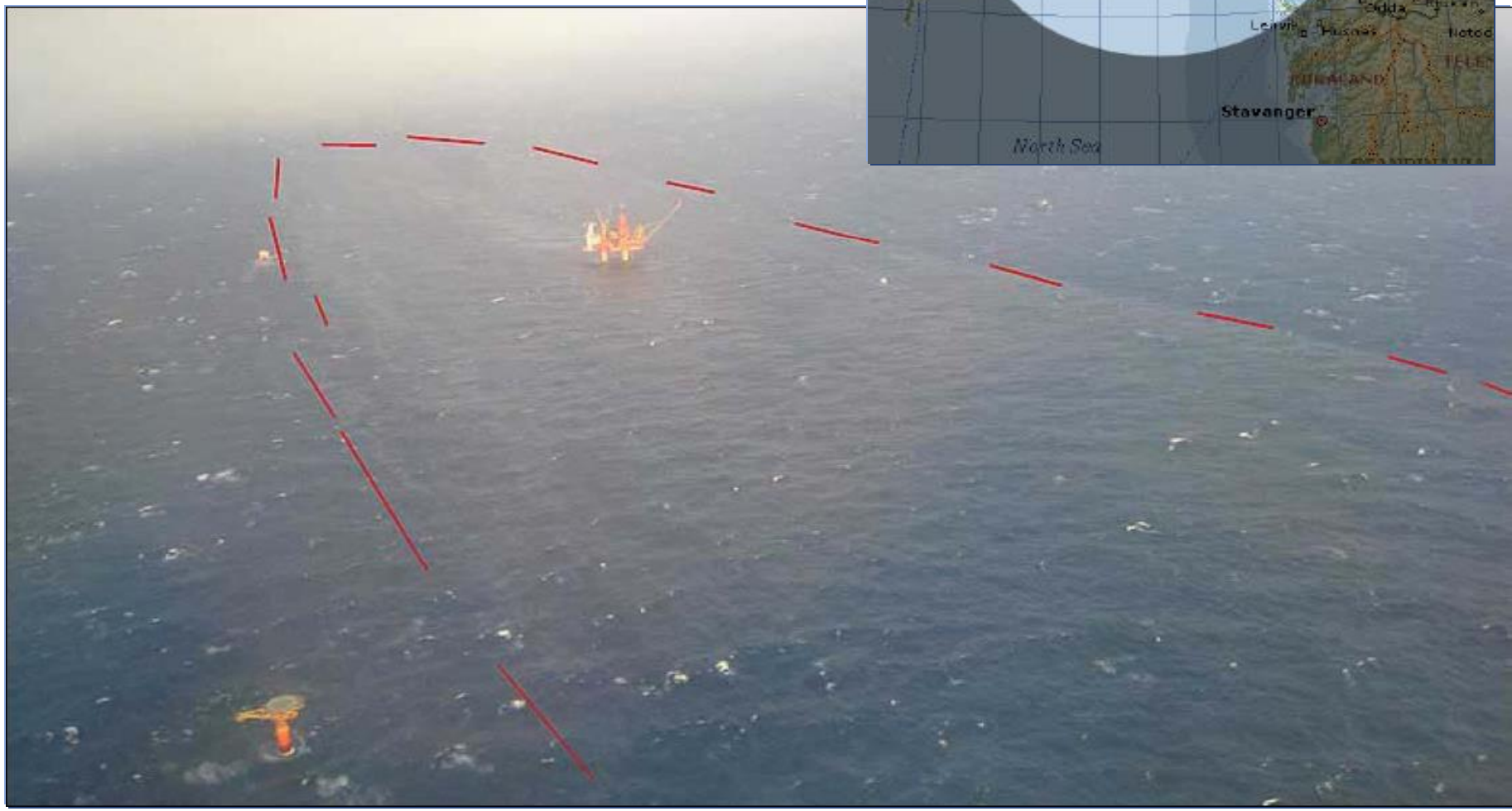


12 December - Norway: An oil spill has been

observed on Wednesday in the Norwegian sector of North Sea near the Statfjord oilfield operated by StatoilHydro. "This could be the second largest spill in Norwegian oil history," the Petroleum Safety Authority's (PSA) spokeswoman Inger Anda said. She said the spill was estimated at 3,840 cubic meters of oil, which corresponds to 24,154 barrels of oil. The biggest oil spill ever off Norway occurred in the Bravo blowout in 1977 when around 12,000 cubic meters of oil were spilled, Anda said. StatoilHydro information director Ola Morten Aanestad confirmed that the company had had a spill at its Statfjord Alpha platform, about 200 kilometers west of Bergen, near the border of the British continental shelf. StatoilHydro said the spill was about 4,000 cubic meters, and occurred in connection with the tank ship "Navion Britannica" loading aboard oil from a loading buoy. StatoilHydro spokesman Vegar Stokset said the cause of the spill was not immediately known but the loading had immediately been stopped. "It is a significant amount and we are taking it seriously," said Stokset, adding that production from the field was not affected because tanker loading is a separate operation. The Norwegian Rescue Coordination Center South had been notified and planes and helicopters from the Norwegian Pollution Control Authority (SFT) were deployed to get an overview of the extent of the spill. Weather in the area is poor, with **45 knot** (51.8 pmh) **winds and choppy seas.** Meteorologist Hilde Holdhus at the Storm Weather Center said the conditions were good for seabirds, as they would prevent the oil being blown inland. The winds will make it more difficult for aircraft to get an overview of the situation.

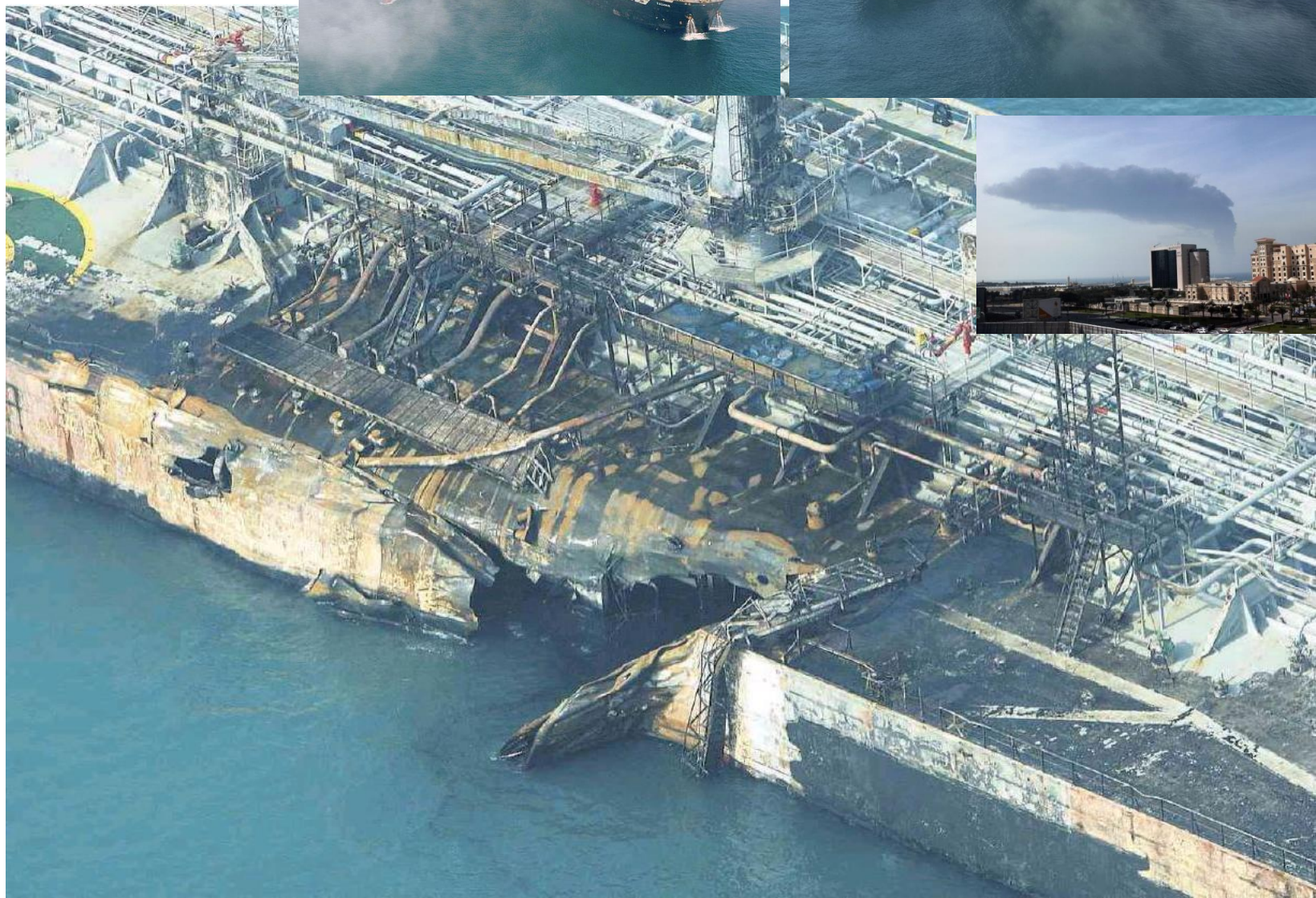
Statfjord Alpha

Second largest spill in Norwegian oil history

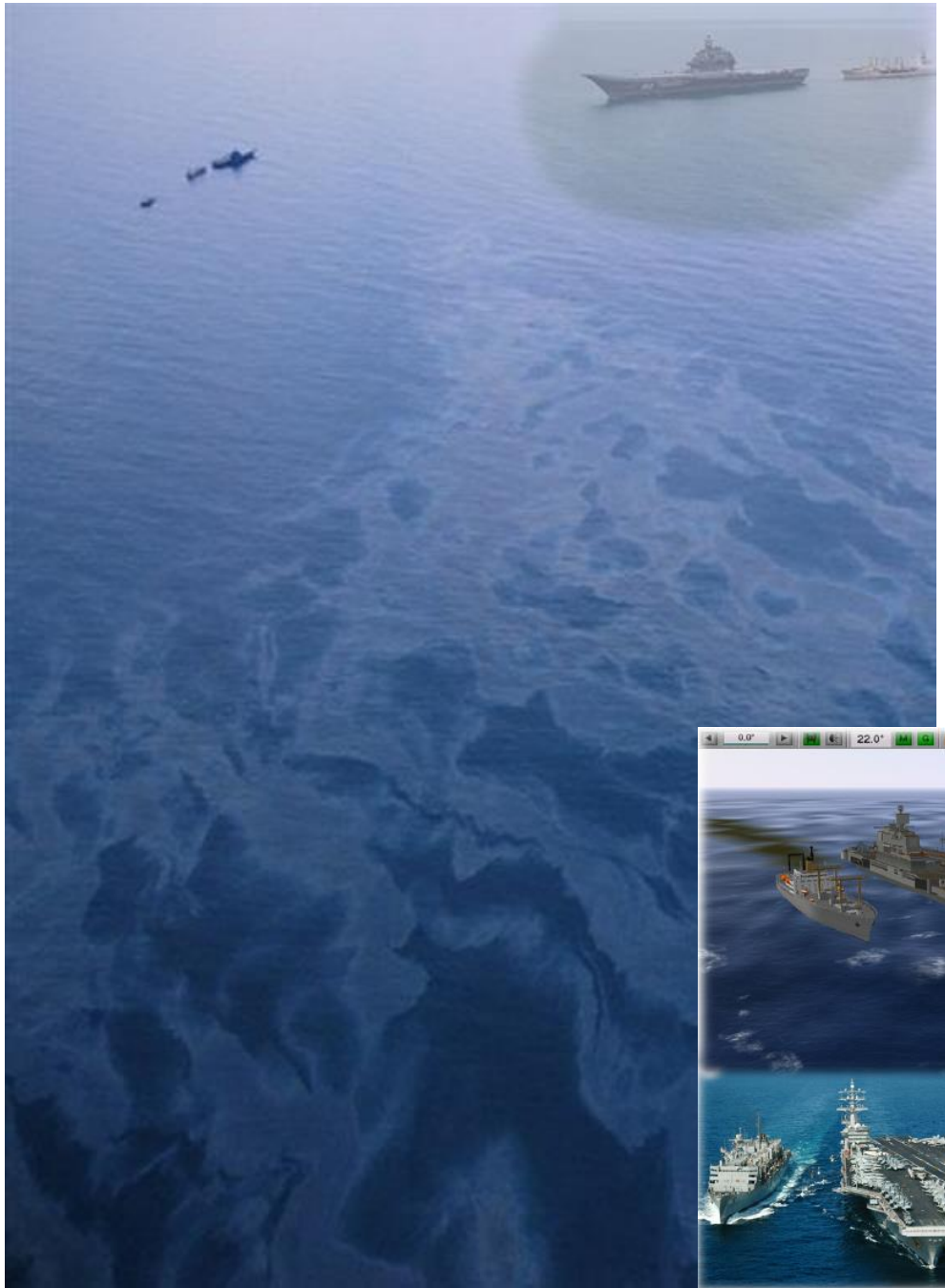


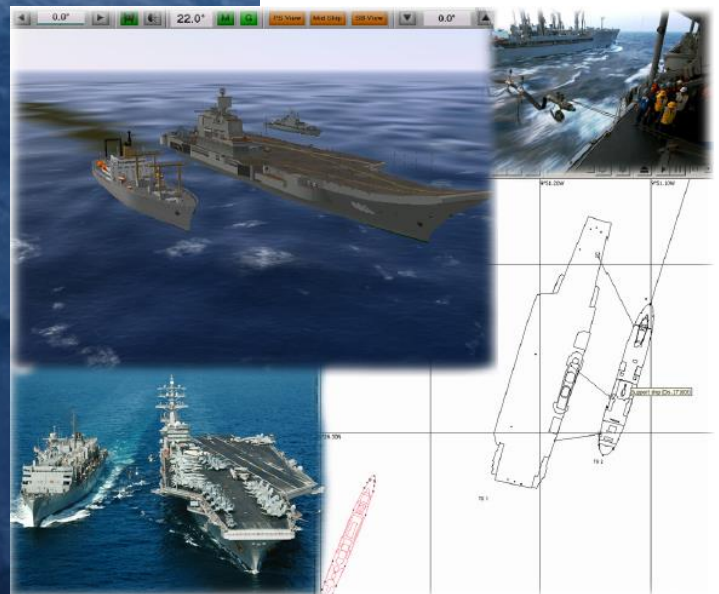
Queensland

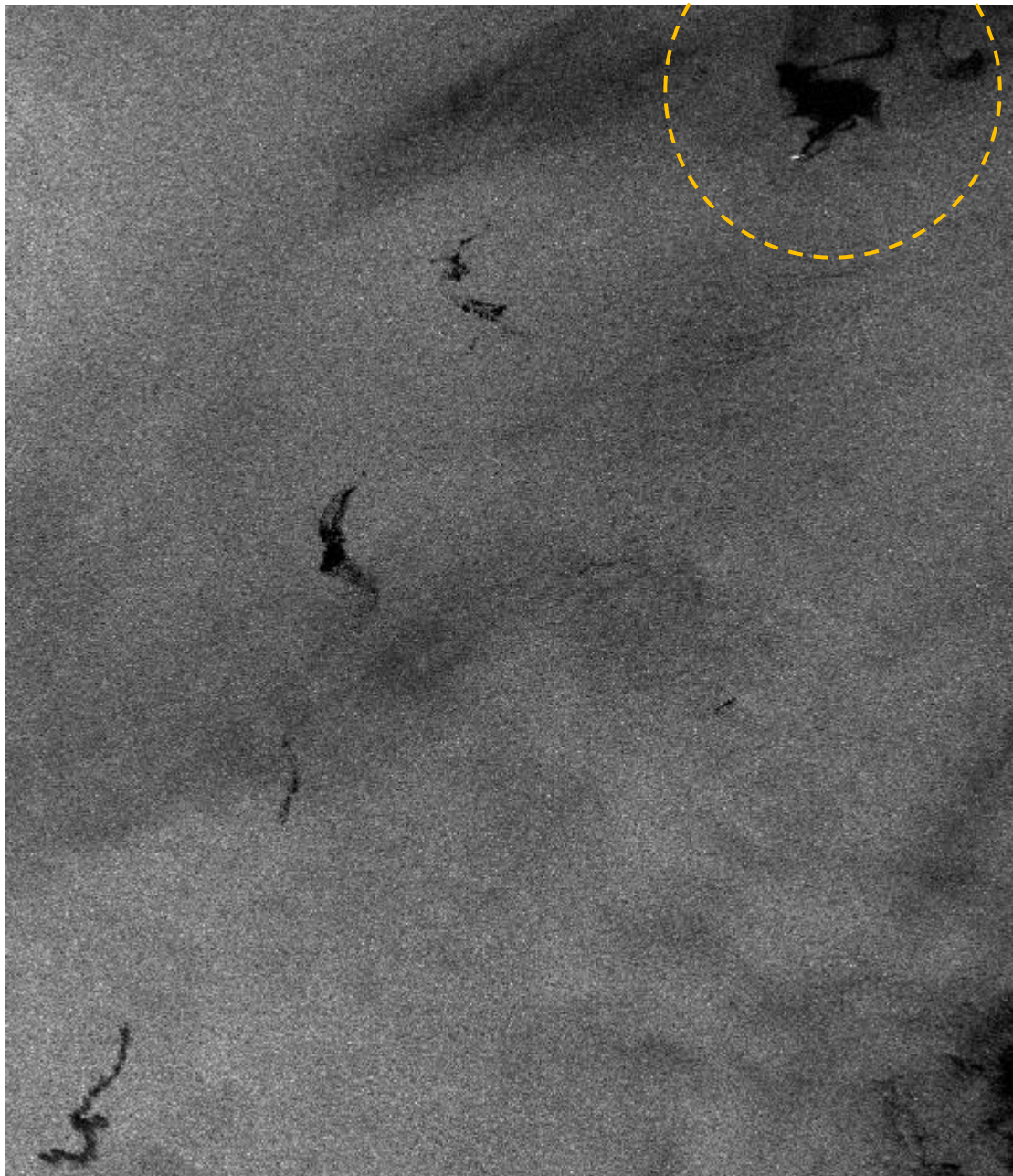
vs Jebel Ali Port



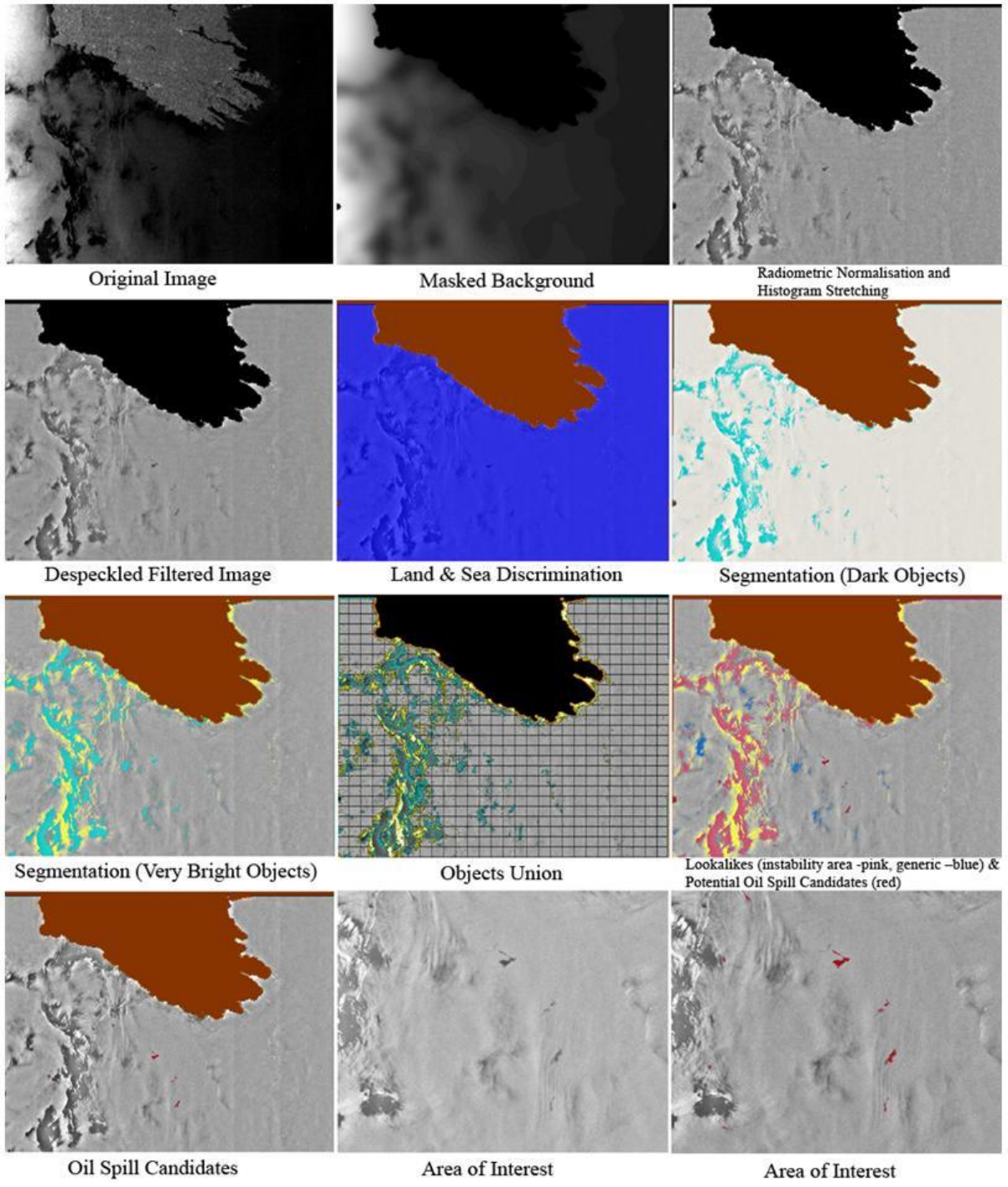
Russian Navy; Underway fuel replenishment (Bunker) accident off the southern Irish coast.

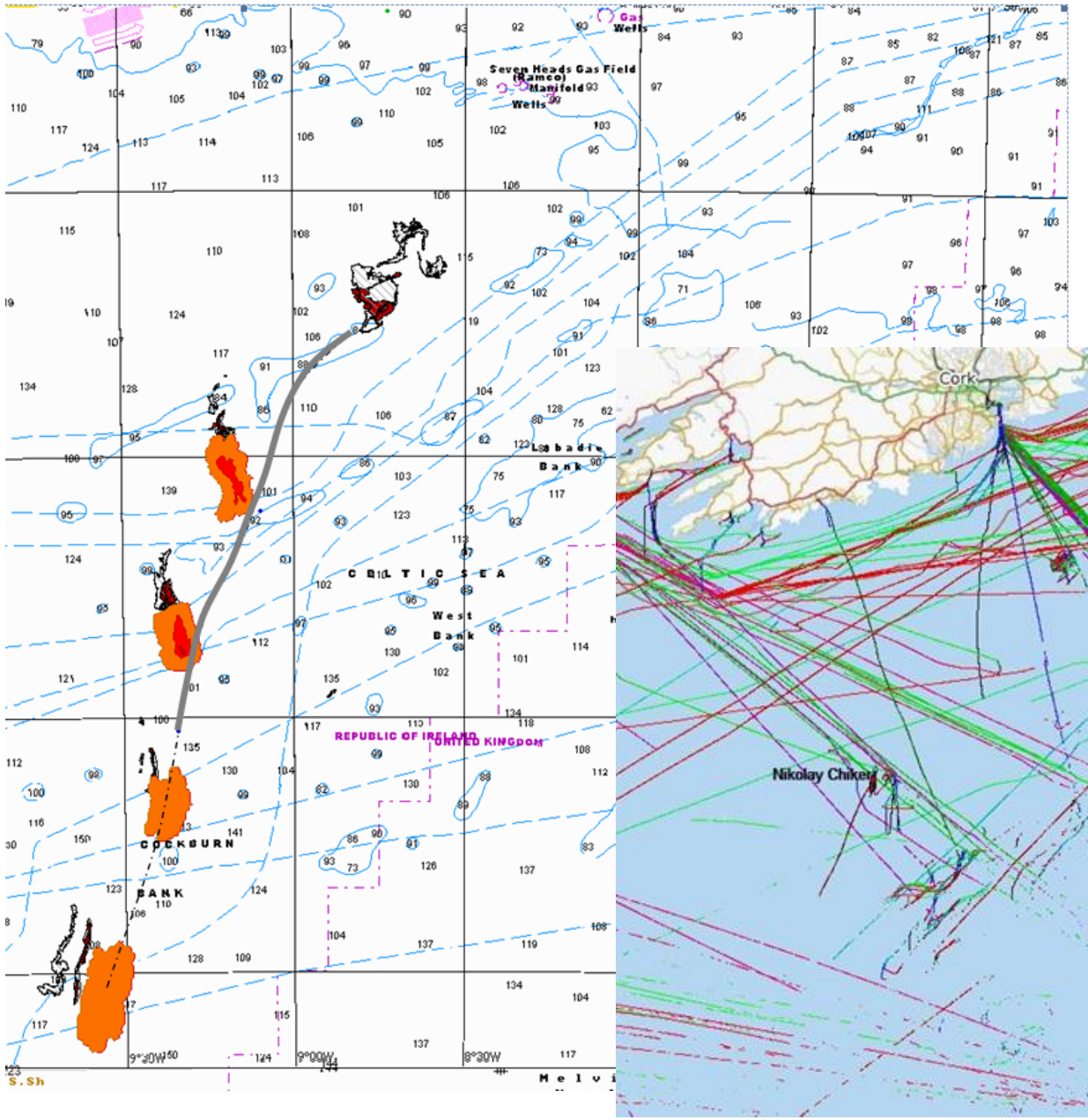






(i) image *pre-processing*, (ii) image *segmentation*, (iii) *feature extraction*, and (iv) *classification*.

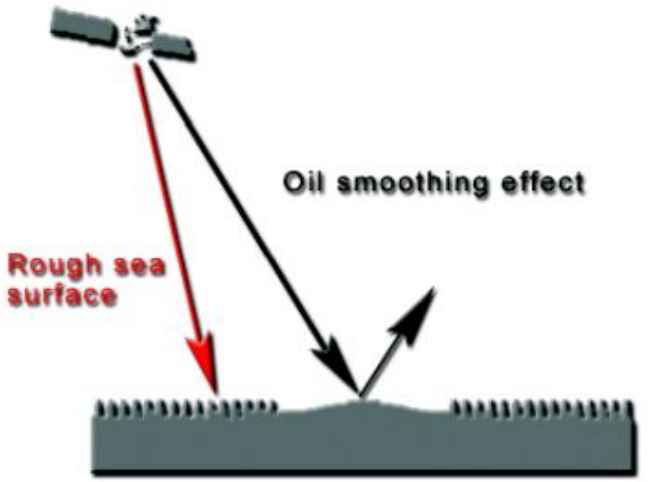


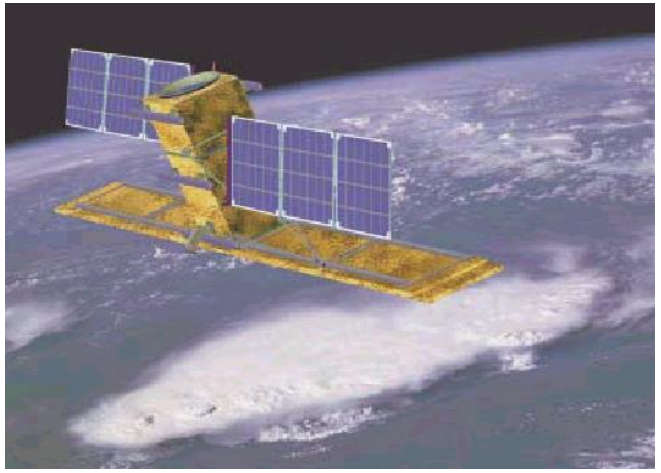


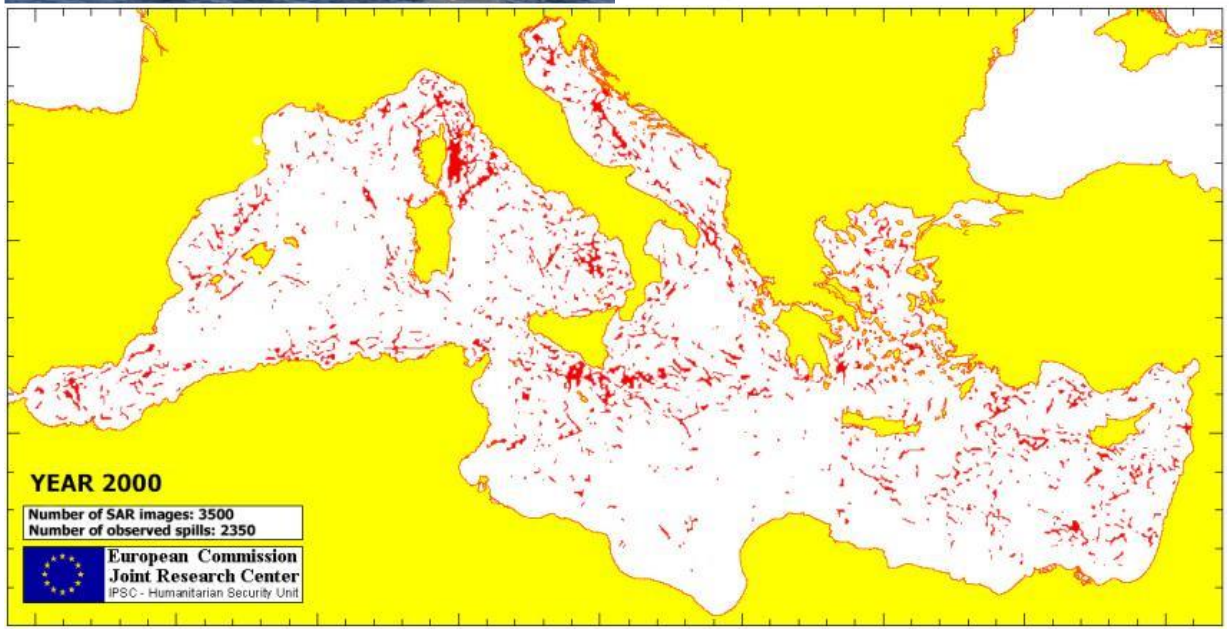
Operational pollution

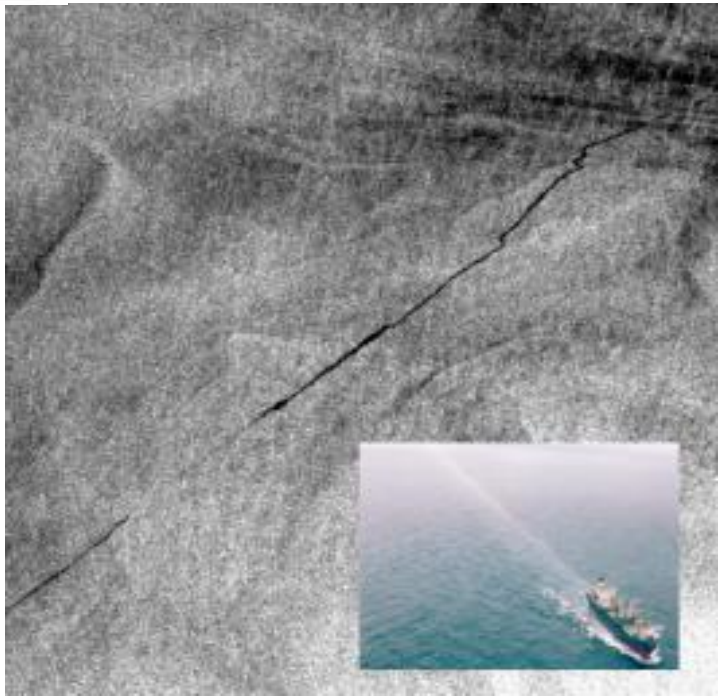
reduction/elimination; can navigational/informational and surveillance technology contribute?

Monitoring (EMSA – CleanSeaNet Service)

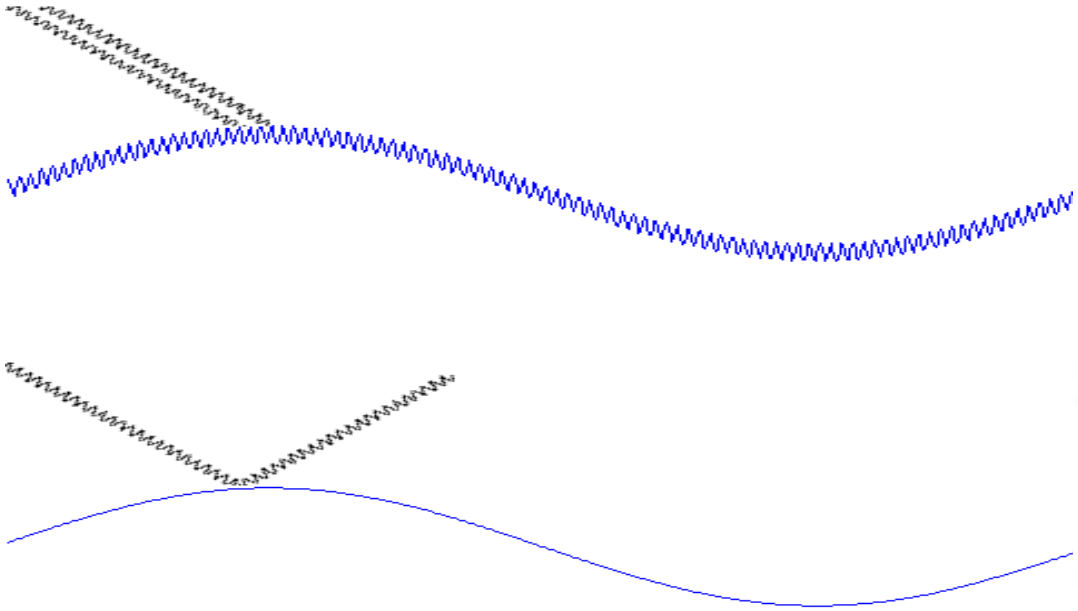


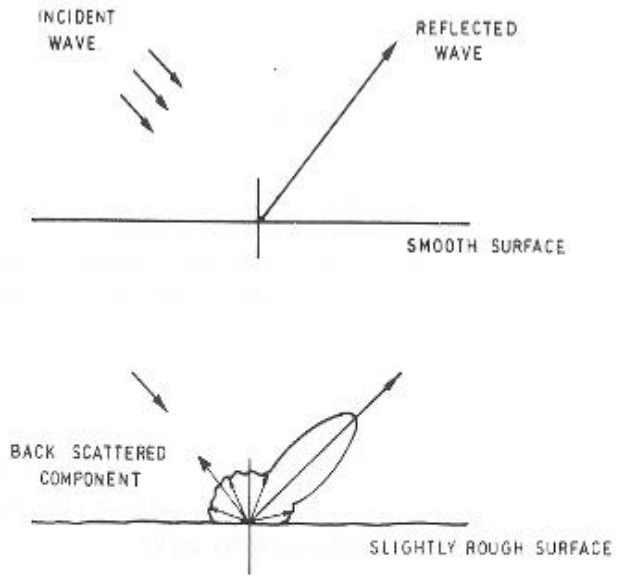






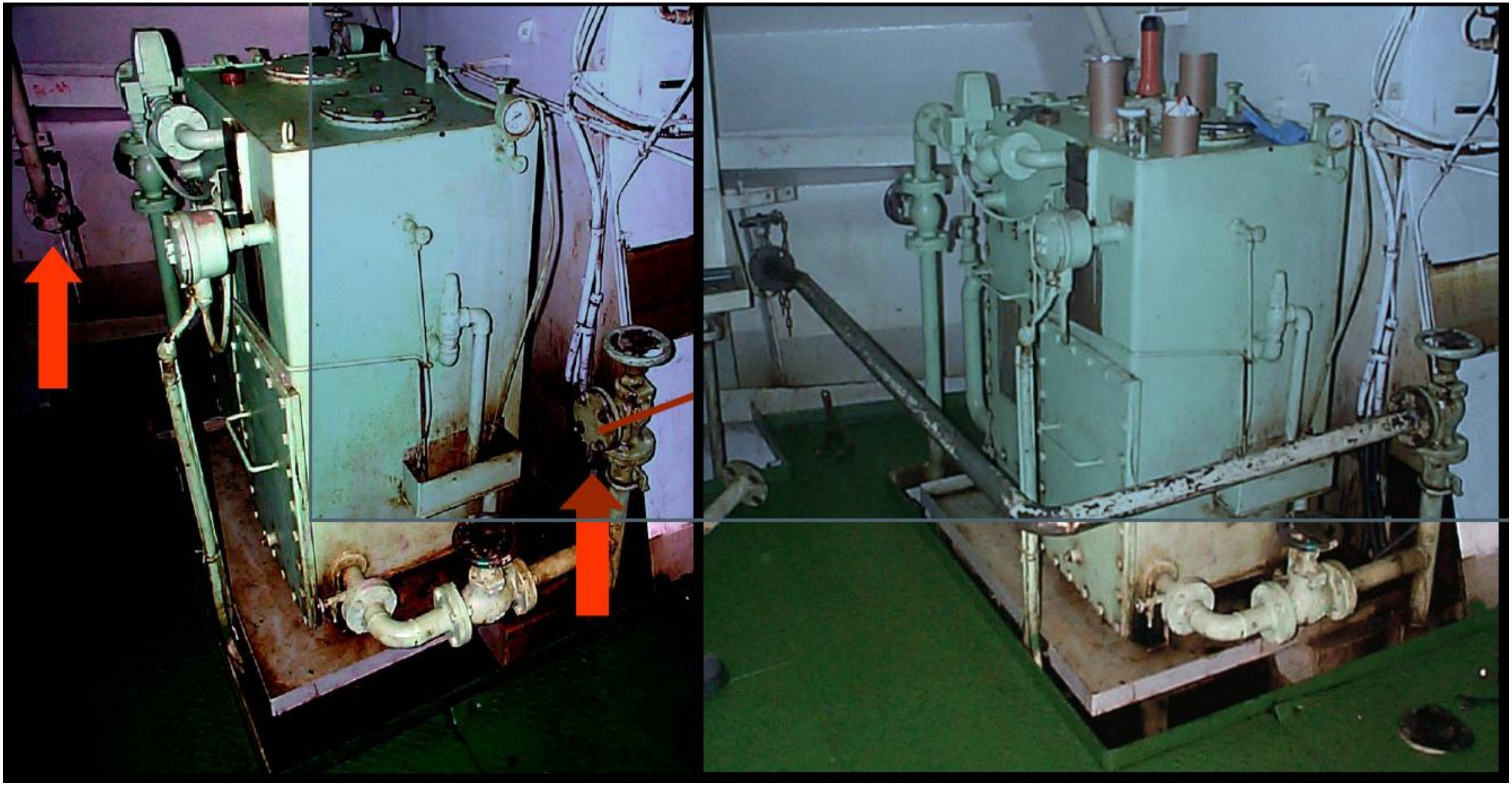
Sea surface backscatter



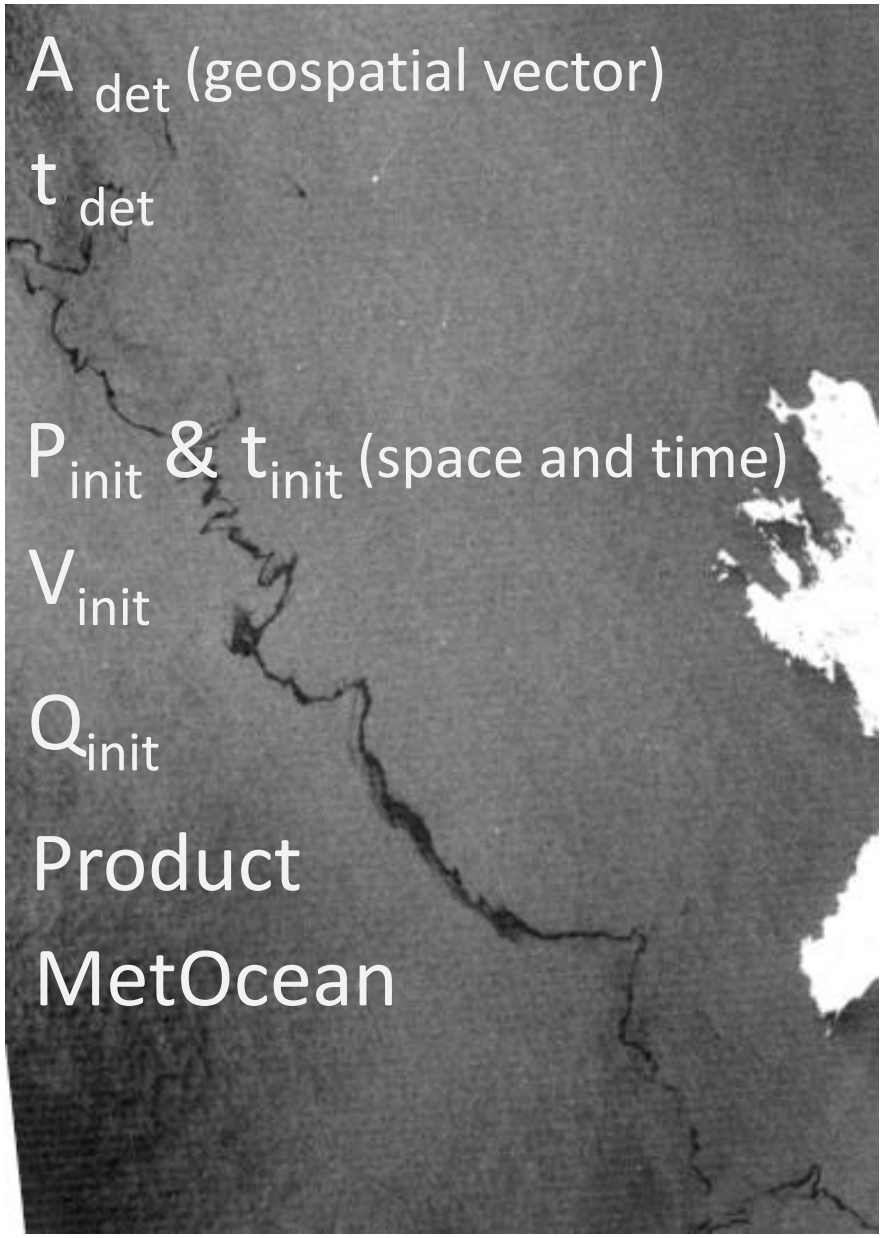


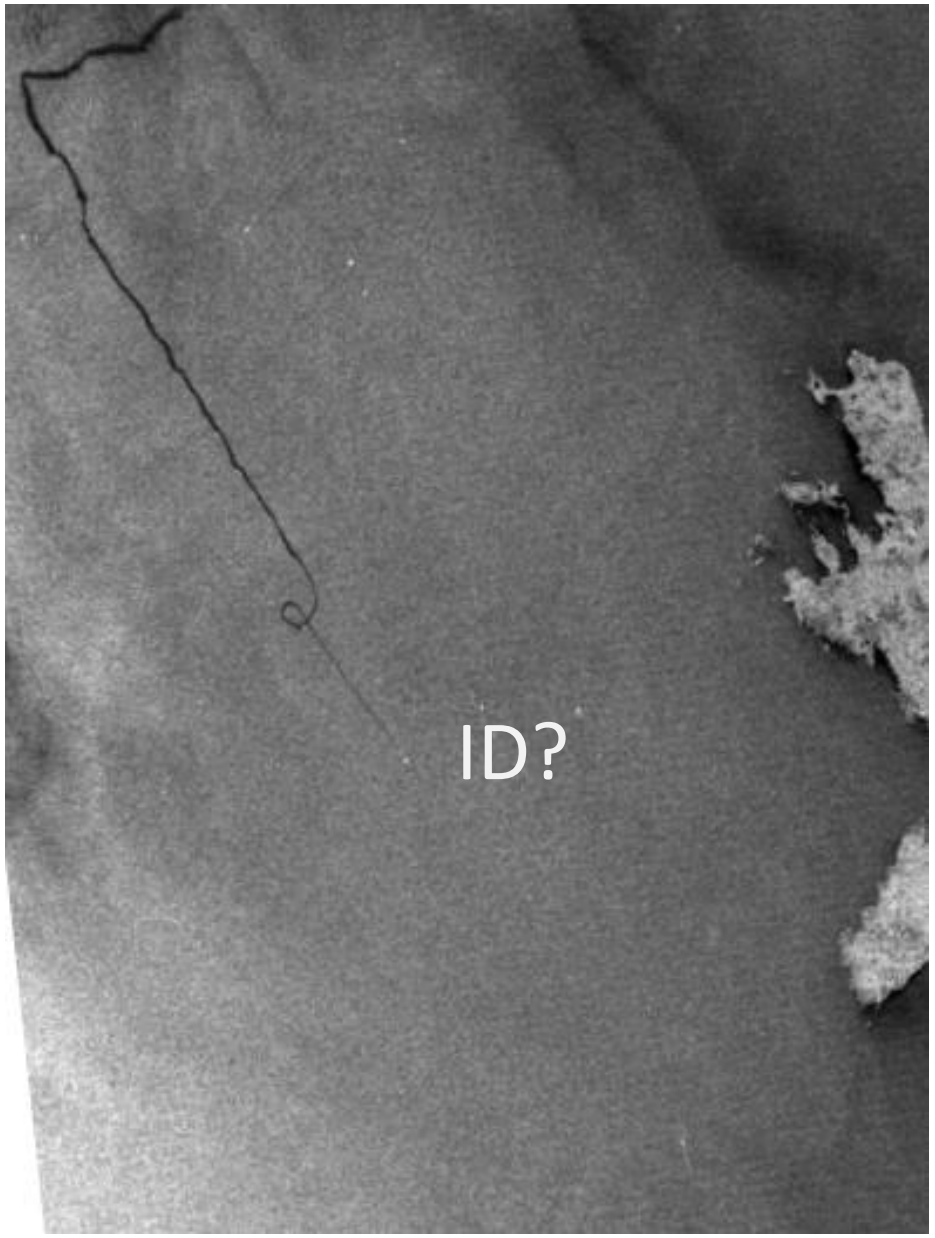
- Backscatter when surface roughness has wavelength of the same order as radar wavelength (5 cm)
- Backscatter proportional to roughness amplitude
- “Bragg backscattering”

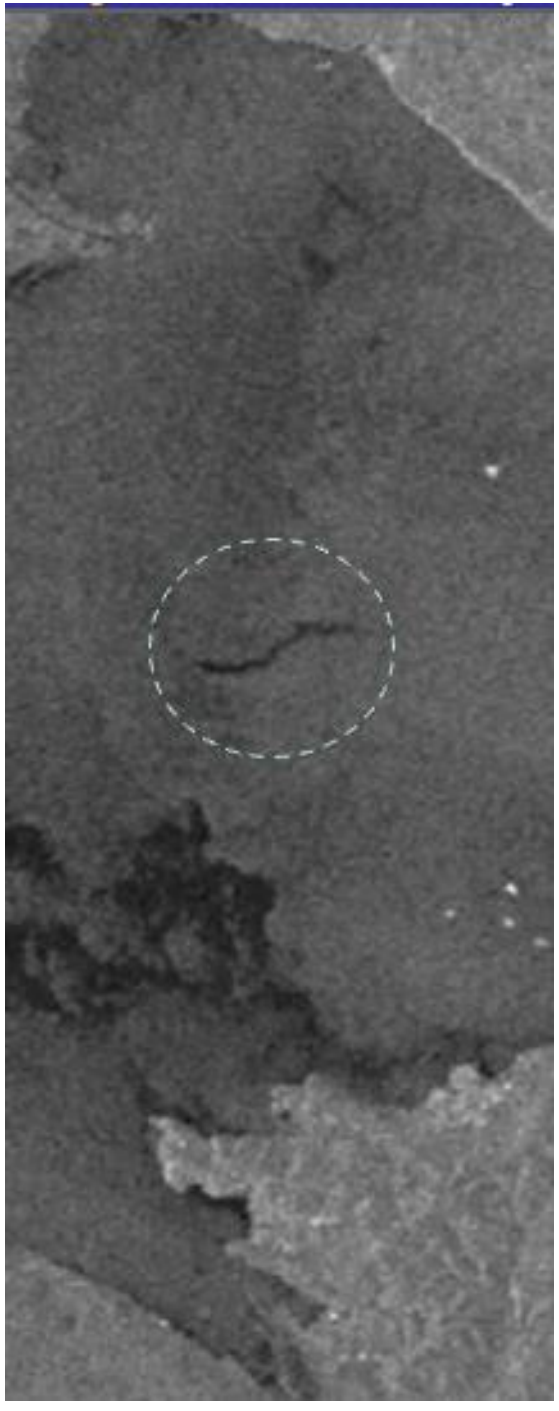
Most Common Violation

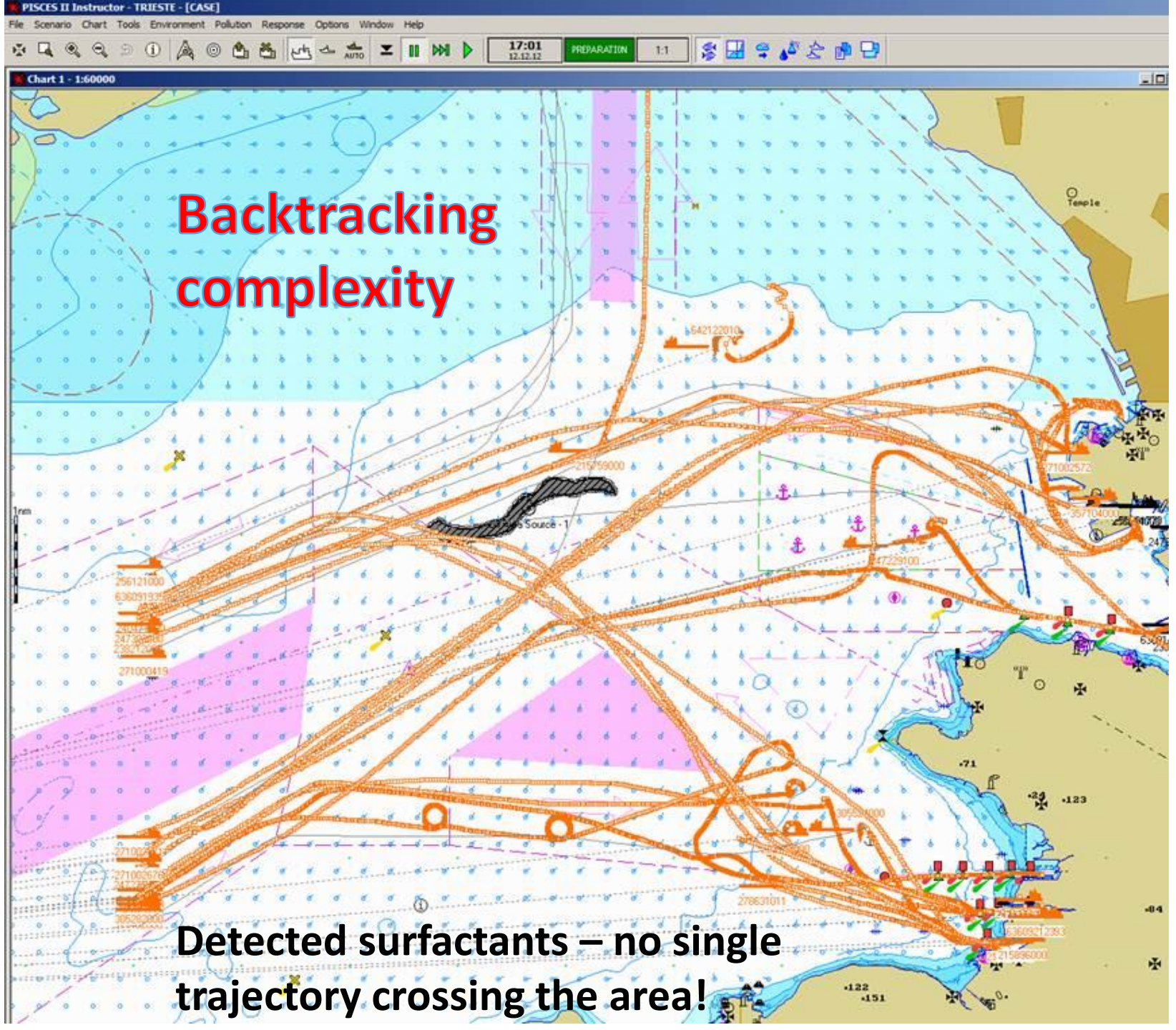


Operational pollution and polluter identification challenges'

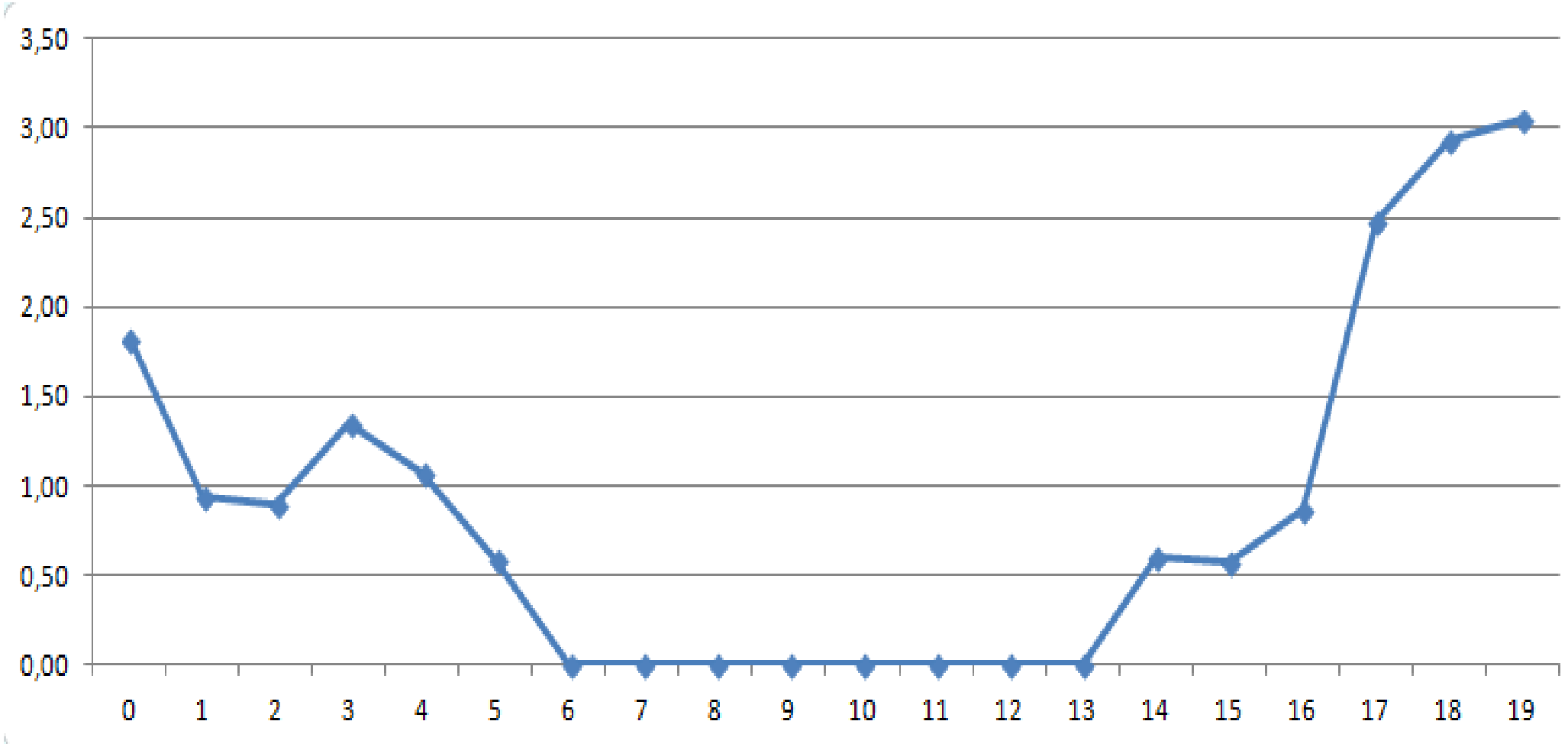




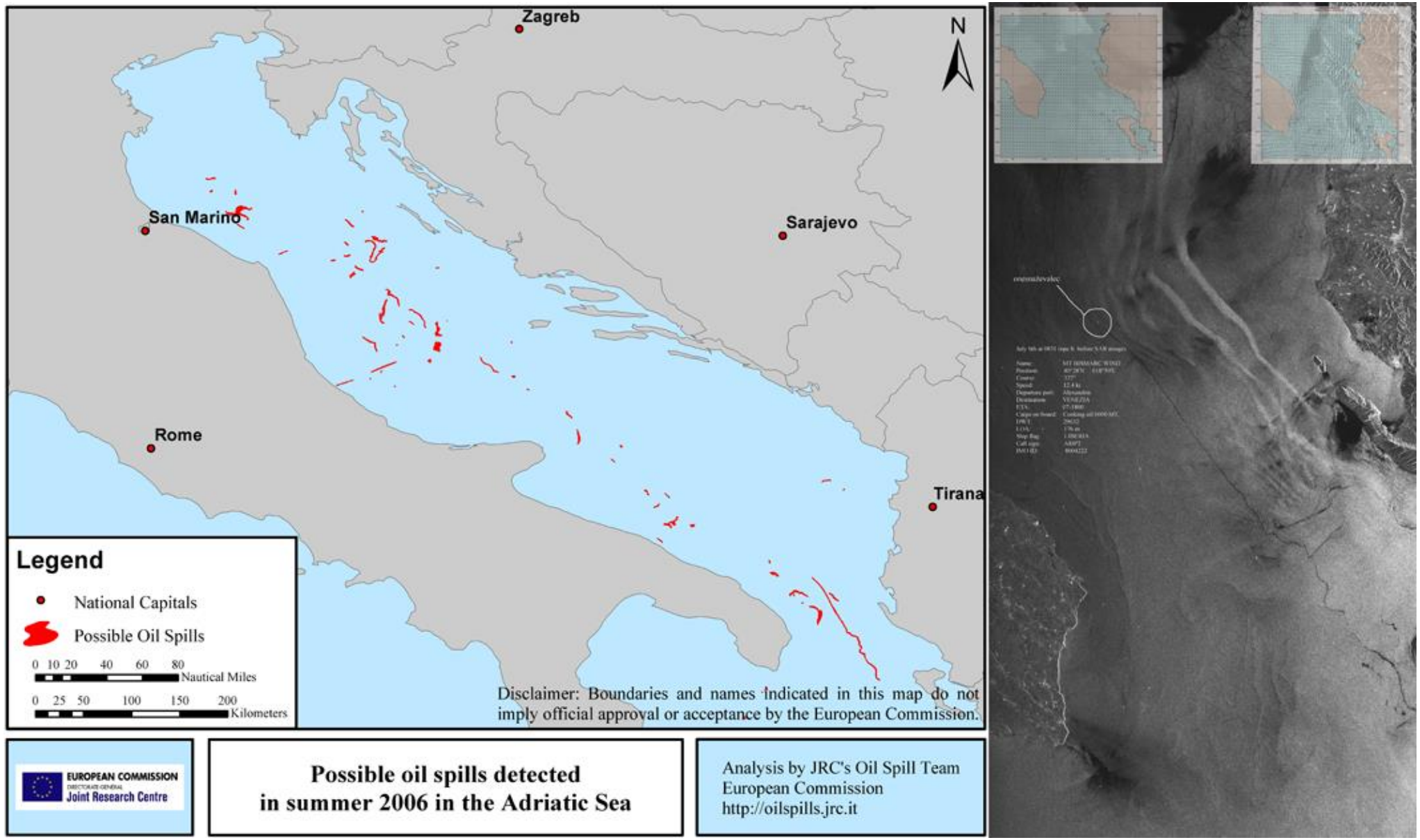



PISCES II Instructor - TRIESTE - [CASE]
File Scenario Chart Tools Environment Pollution Response Options Window Help
17:01
12.12.12
PREPARATION
1:1
Chart 1 - 1:60000
Backtracking complexity
Detected surfactants – no single trajectory crossing the area!

Redhanded/100 fh vs TAKE-OFF time (UTC)

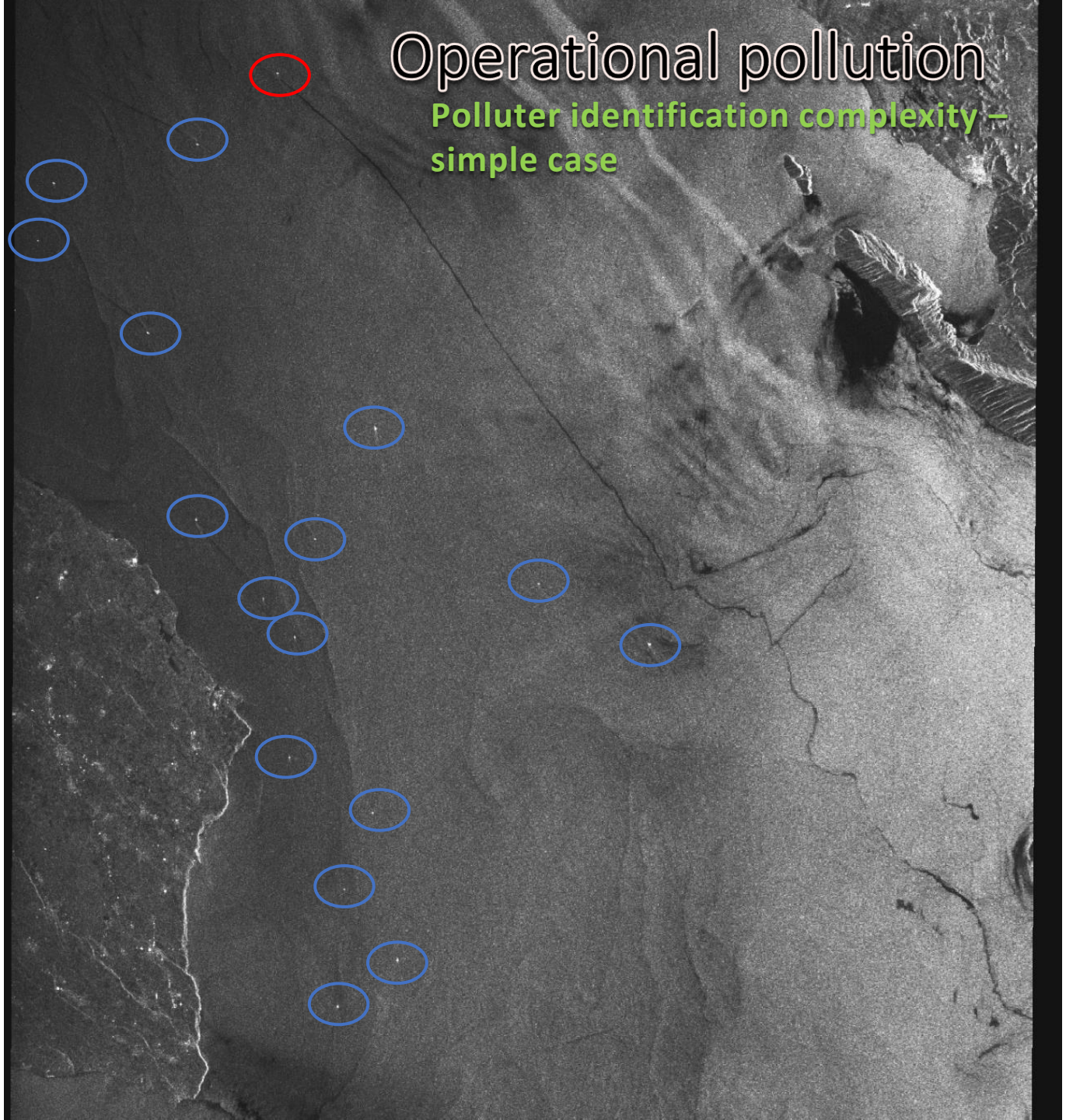


Simple identification “red handed case”; without AIS

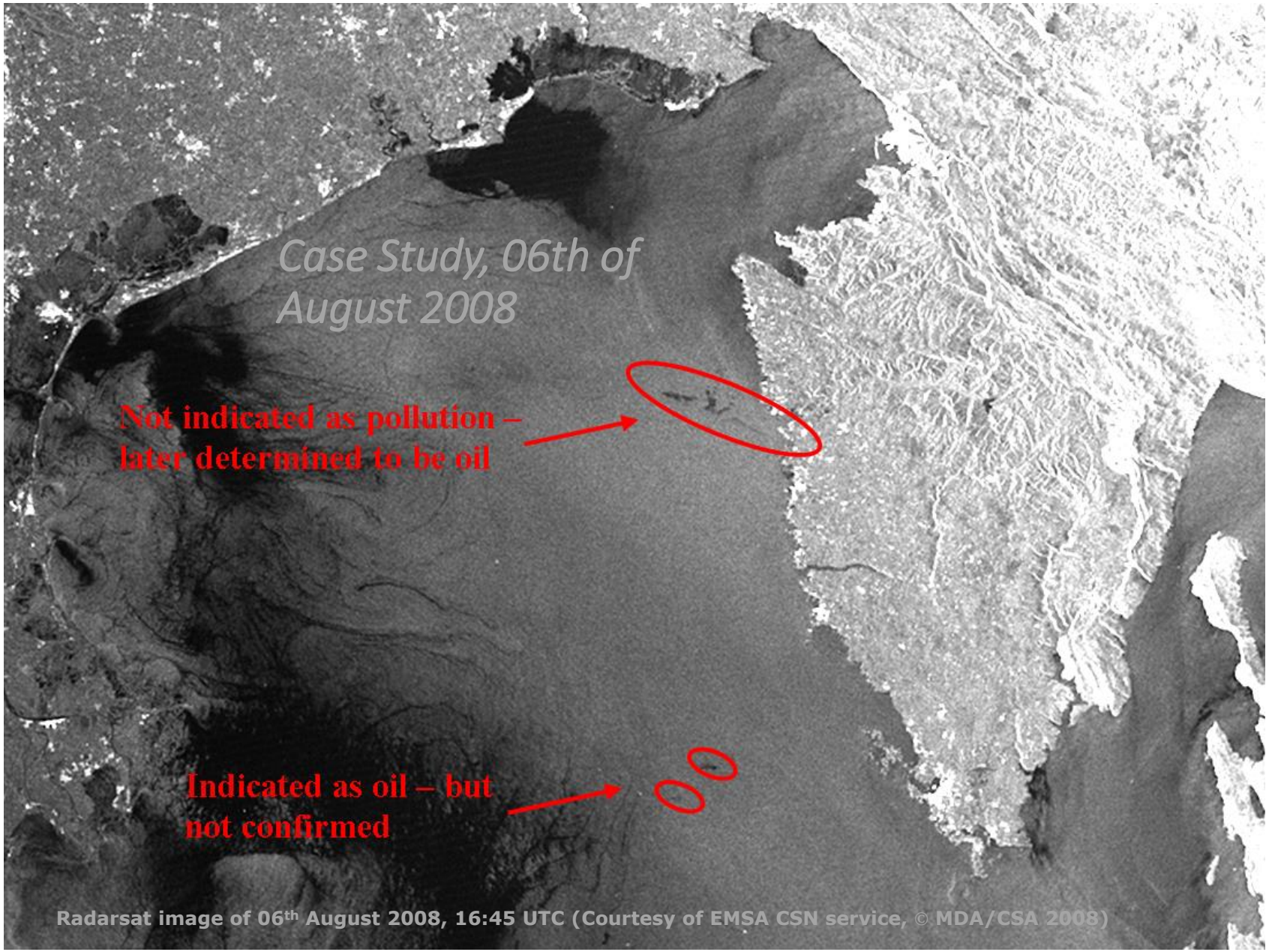


July 6th 2006

0928 GMT



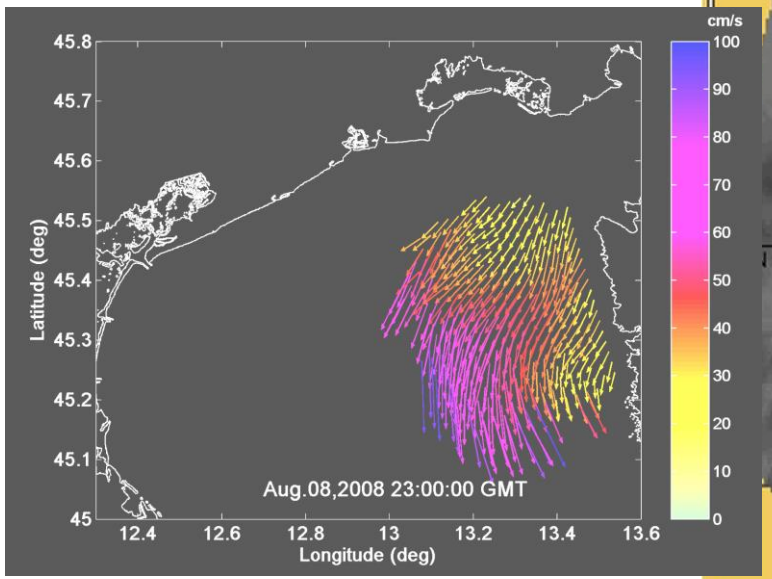
Identification of „potential" polluter - integration of ADRIREP information system with SAR image

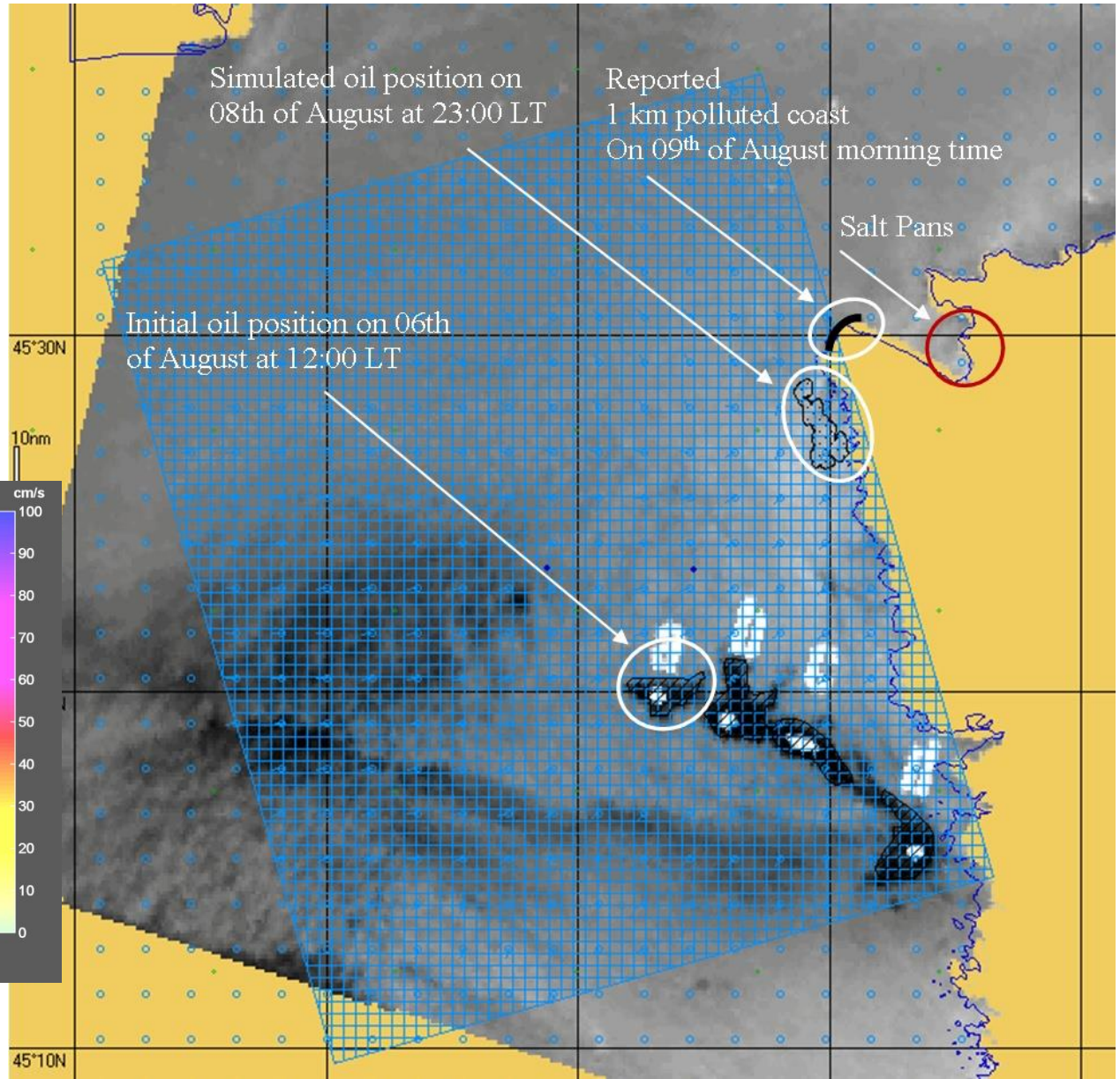

Case Study, 06th of August 2008
Not indicated as pollution – later determined to be oil
Indicated as oil – but not confirmed
Radarsat image of 06th August 2008, 16:45 UTC (Courtesy of EMSA CSN service, © MDA/CSA 2008)

Highly weathered oil slick
Respond and backtracking issue "**dt 60 h**"

Identification feasible with:

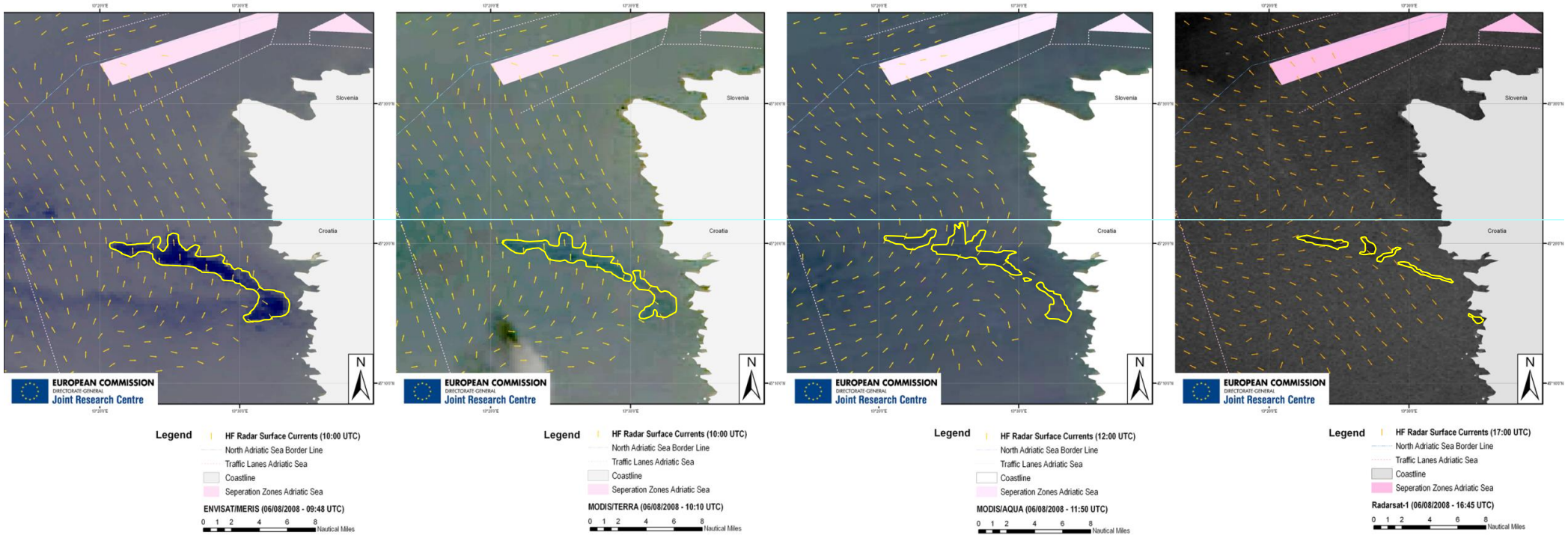
HF currents,
Accurate AIS,
Low wind area,
Persistent oil,
Uniform salinity...





HF currents validation

"finger print vs. sensor, time, respond and HF currents"



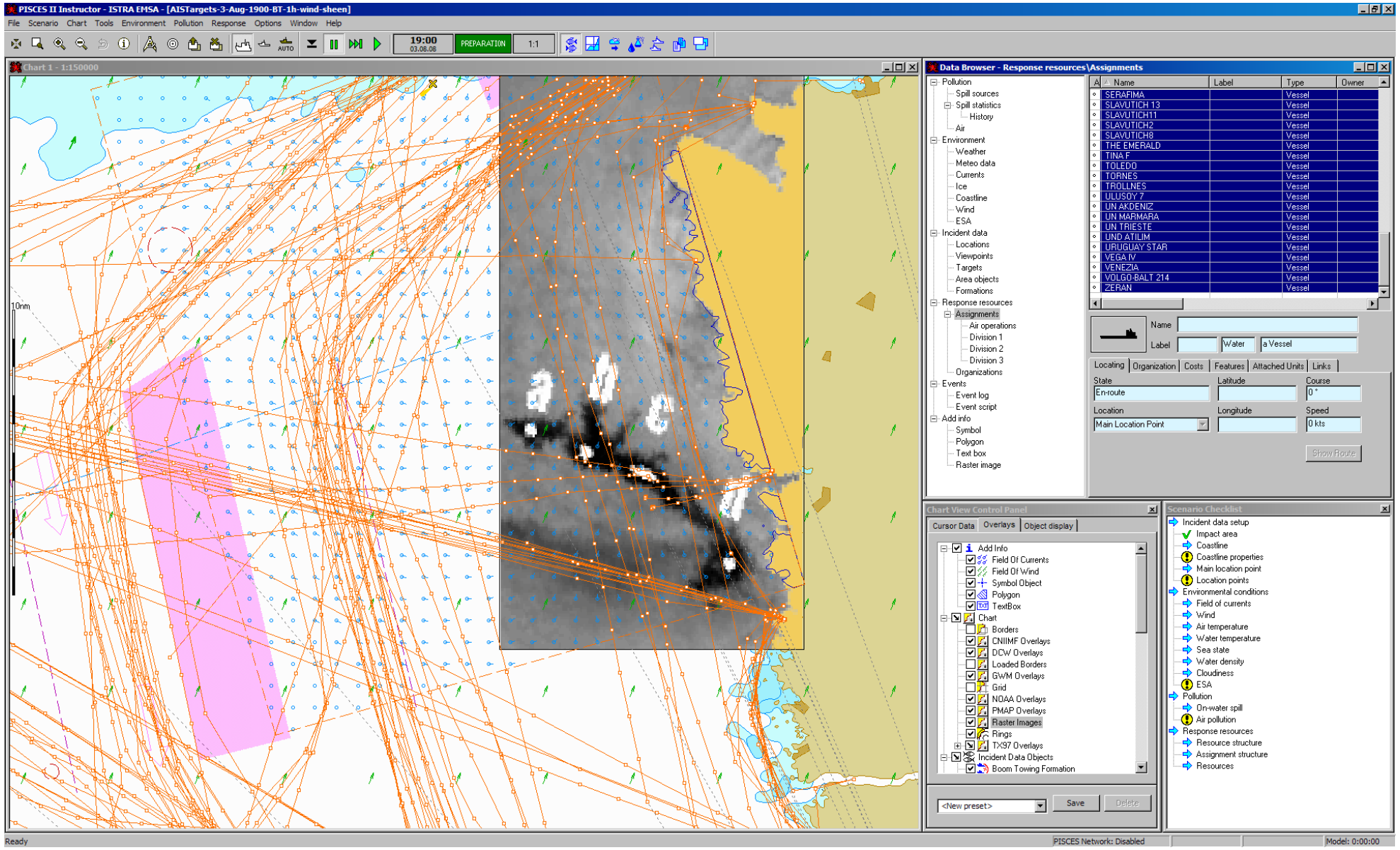
(ESA) ENVISAT/MERIS 09:48 (NASA) MODIS/TERRA 10:10 (NASA) MODIS/AQUA 11:50 (MDA/CSA) RADARSAT-1 16:45

EMSA – CSN

18:45

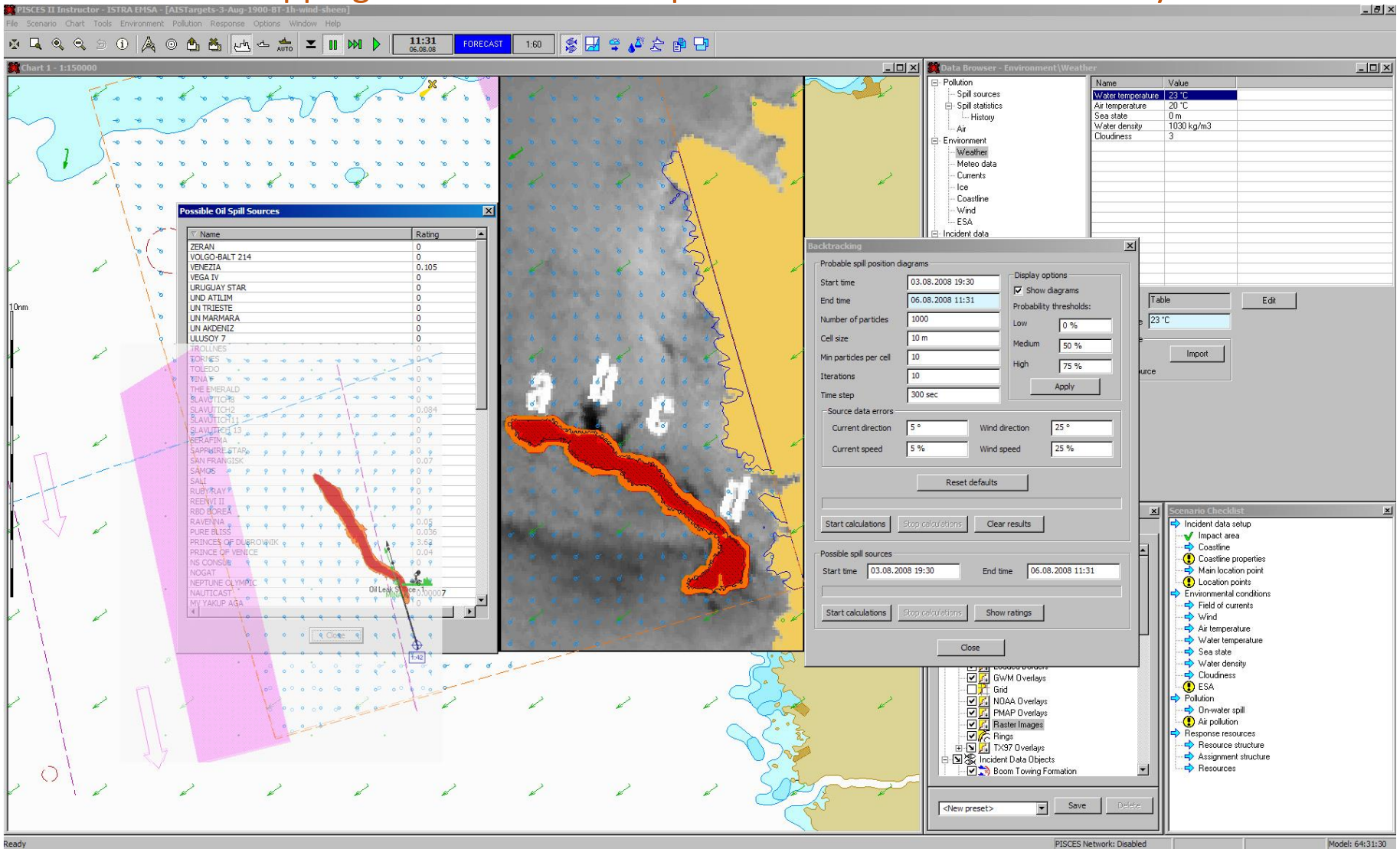
INTEGRATION

Sat image, AIS shipping, HF currents and Wind Stress on top Navigational chart

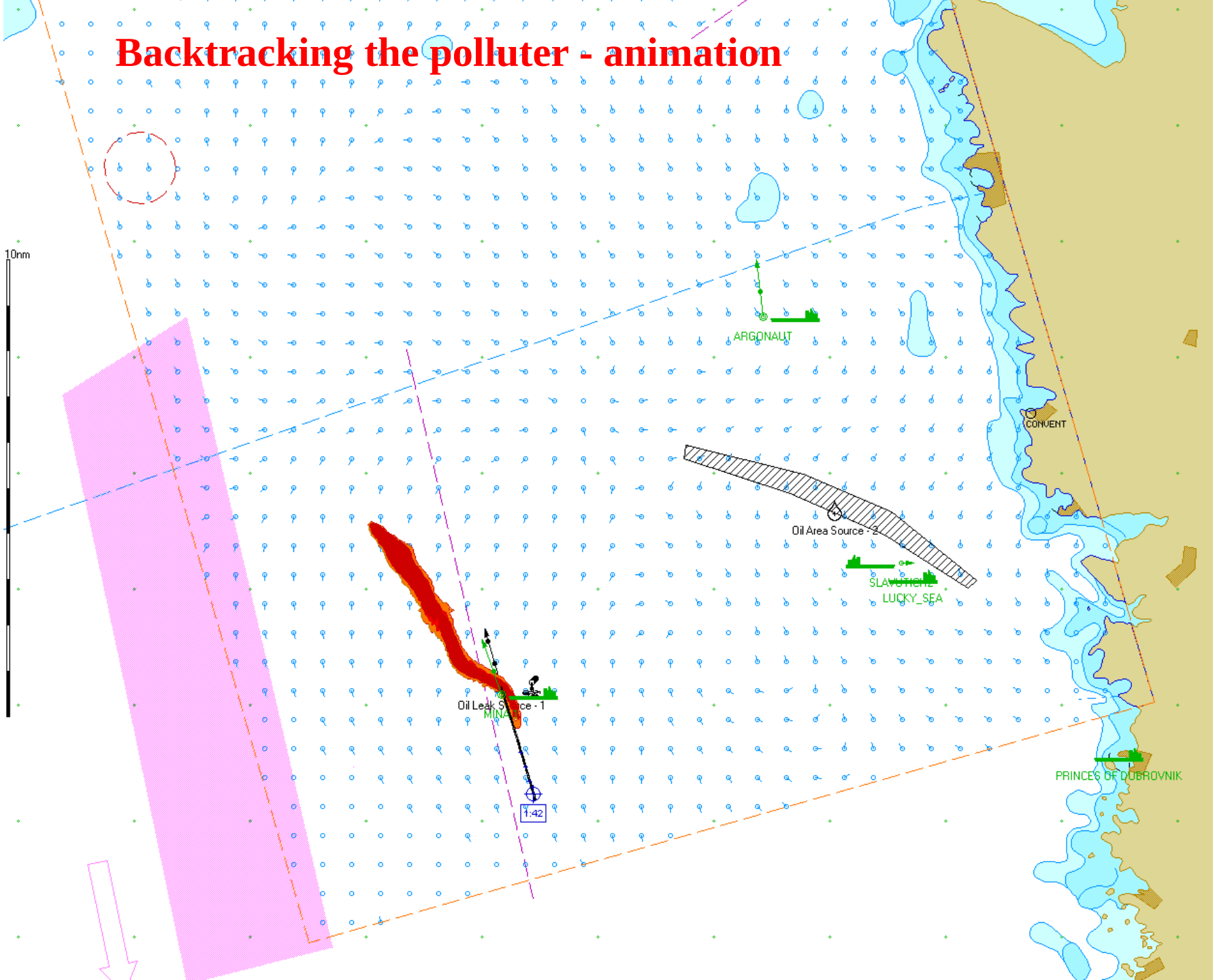


Backward and Foreward Simulation

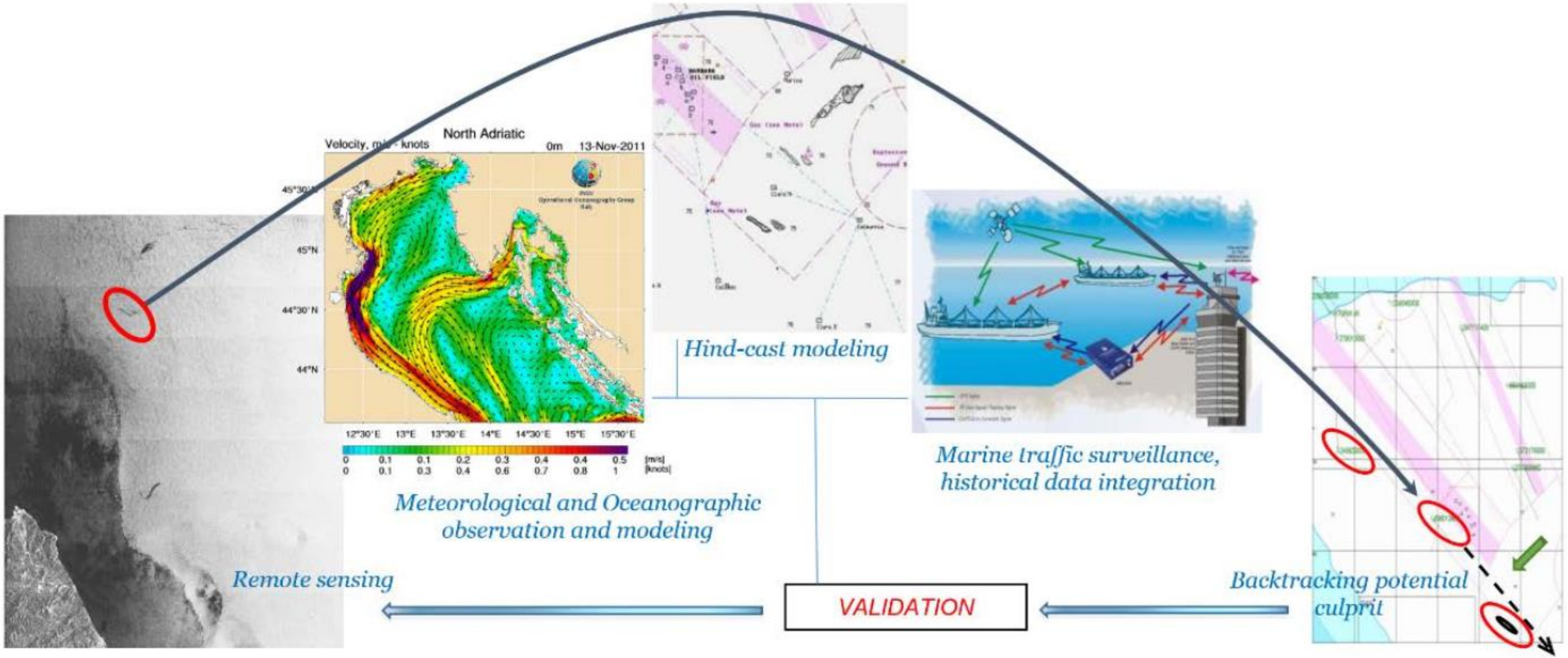
Backward (Hindcast) modeling and Foreward Simulation based on HF Radars and VTS shipping database increase polluter identification feasibility!



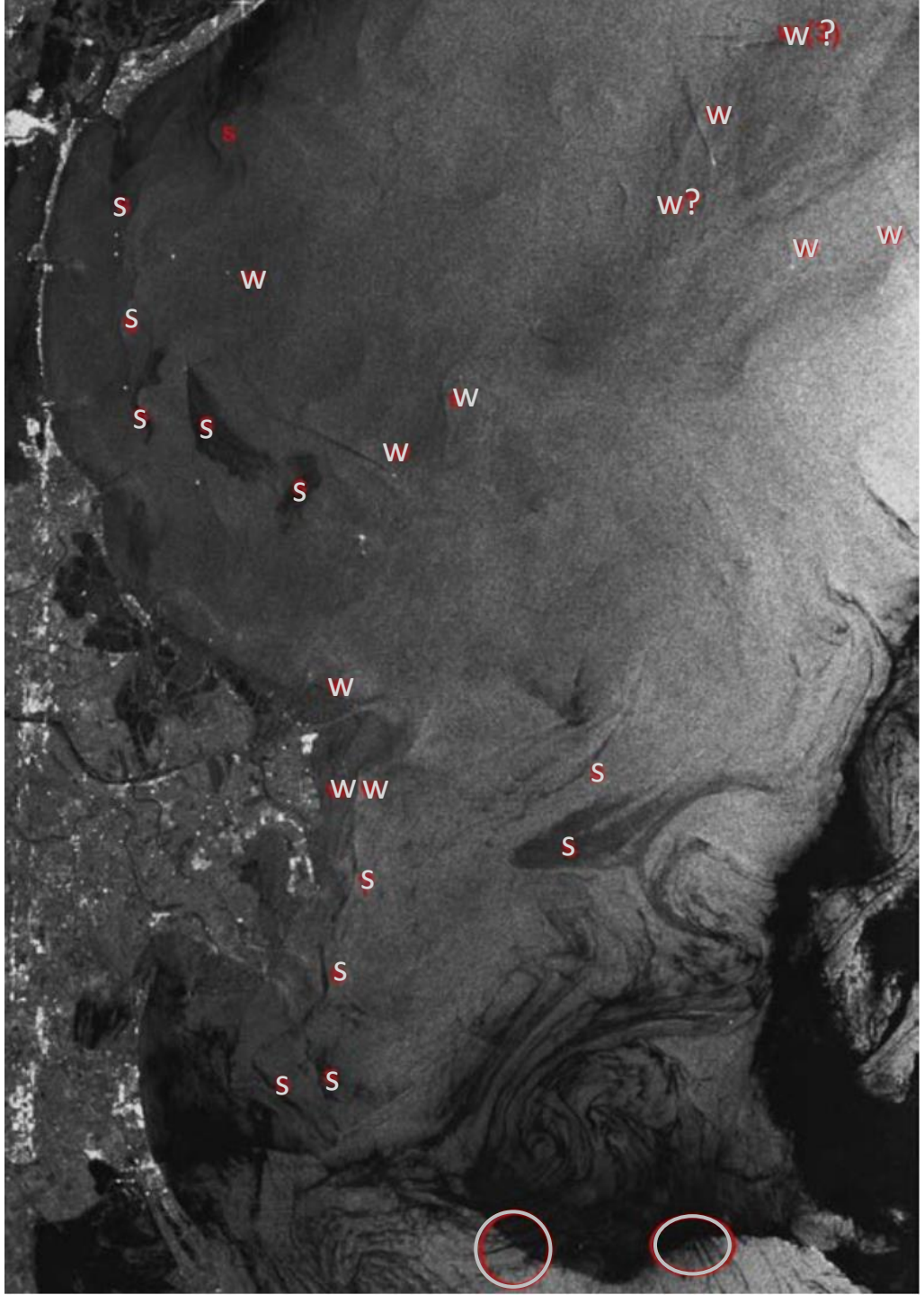
Backtracking the polluter - animation



Backtracking concept



wind, waves and currents are needed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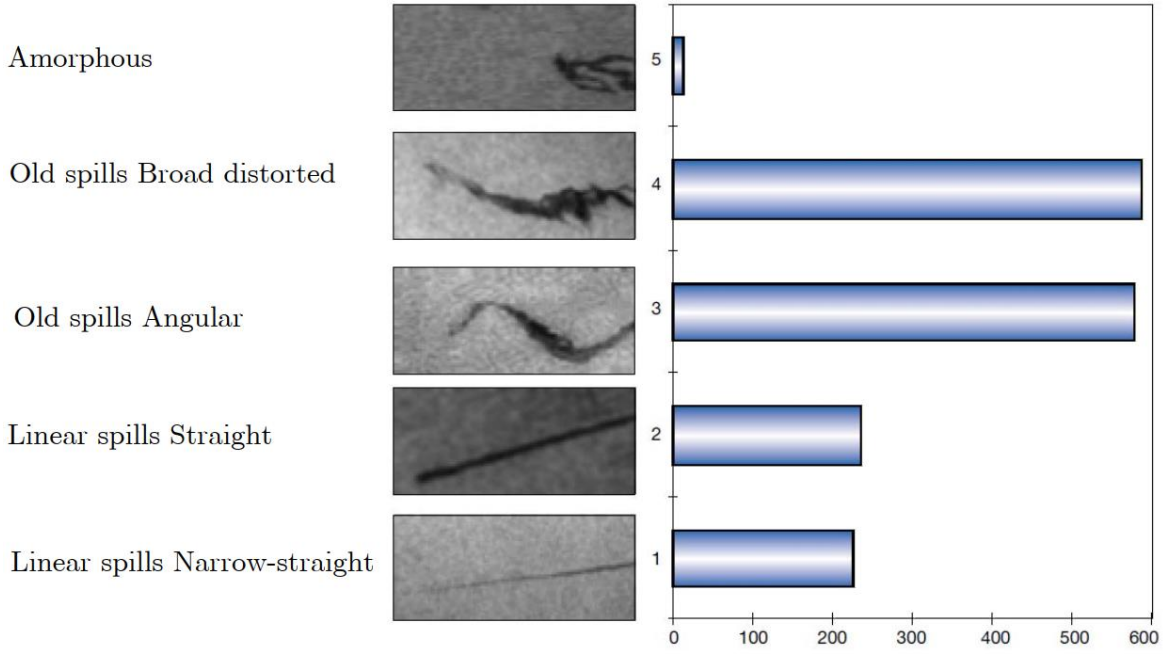
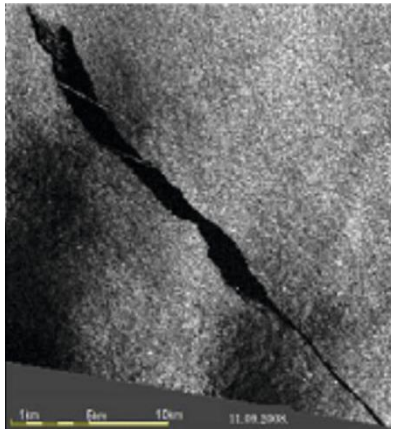
Biogenic slicks

Remote sensing and monitoring



Spill signatures

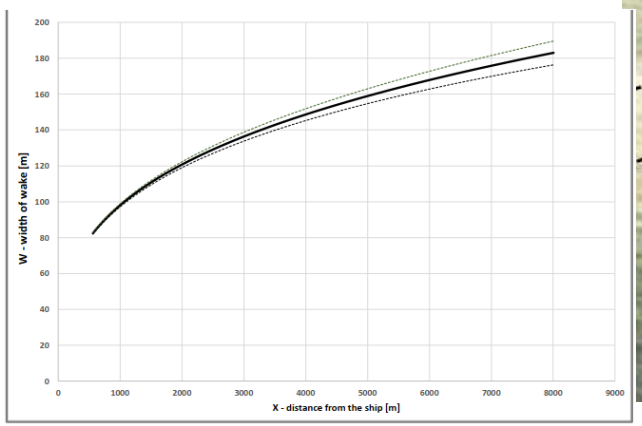


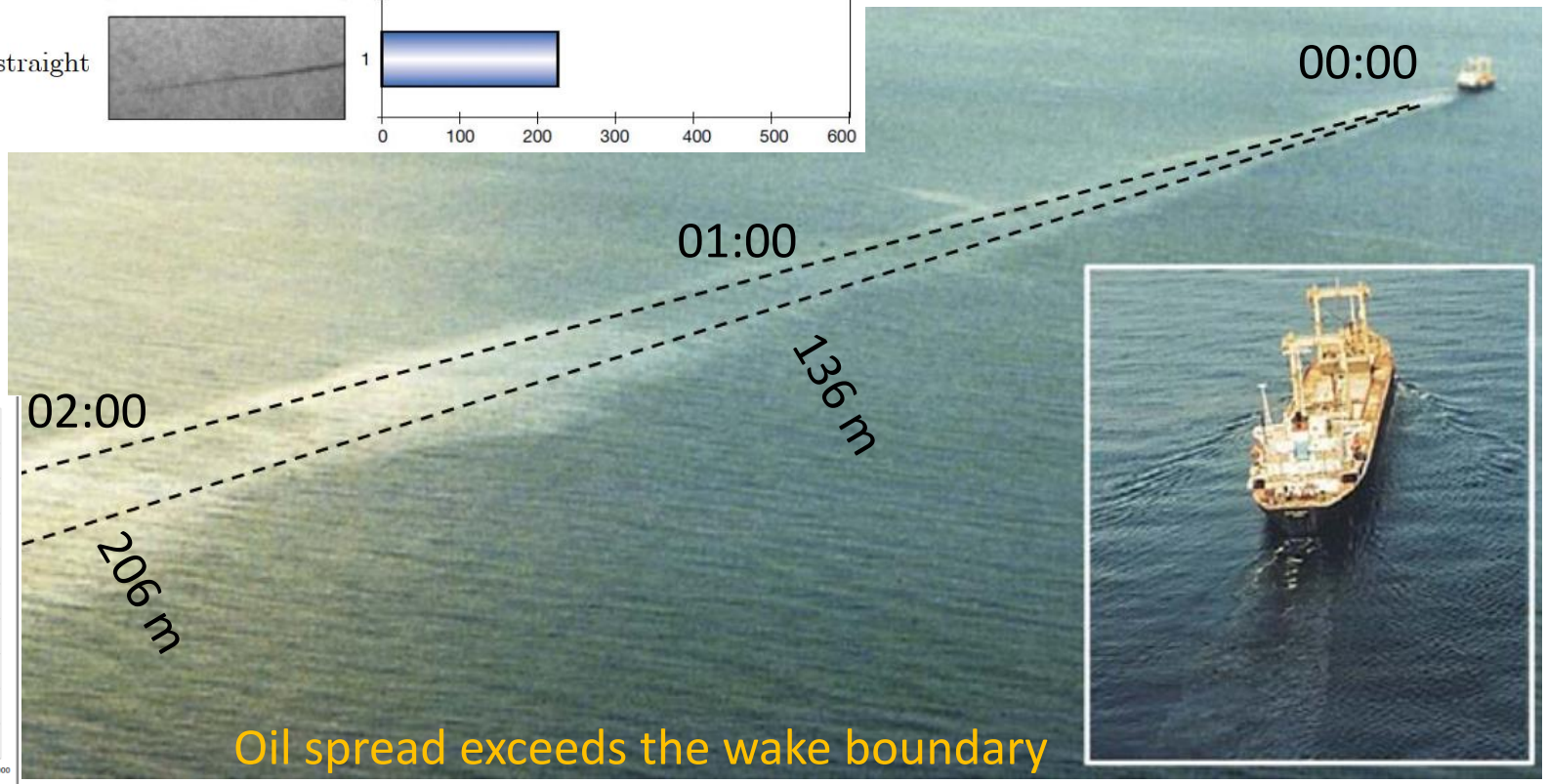
Small operational releases →

typical spreading rates equal to time raised to the 0.6 power ($t^{0.6}$)

$$W = 17.986\ X \left(\frac{\rho\ U^3\ X^2}{P} \right)^{-0.44}$$

Ship wake width

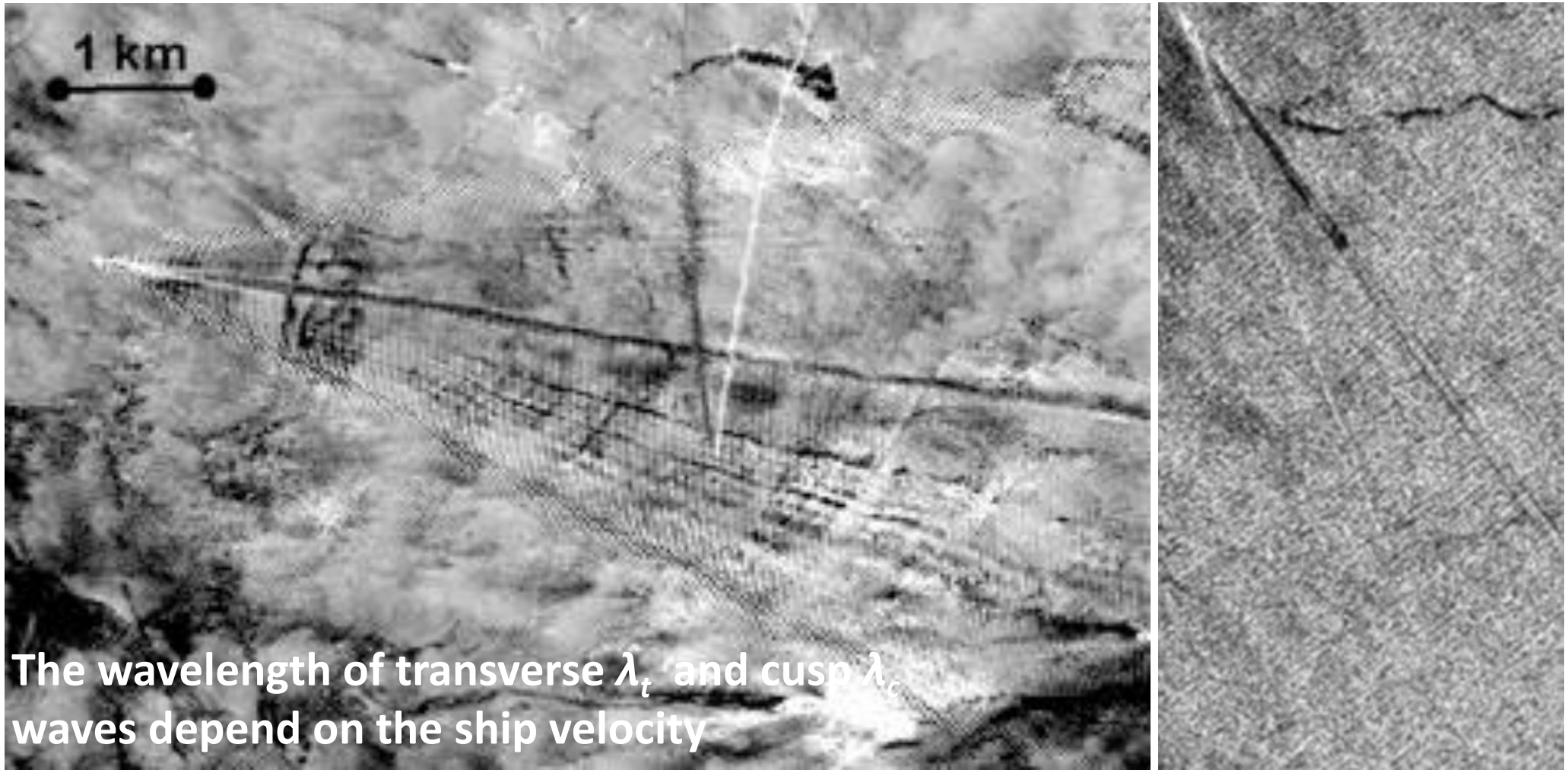




Remote sensing and monitoring

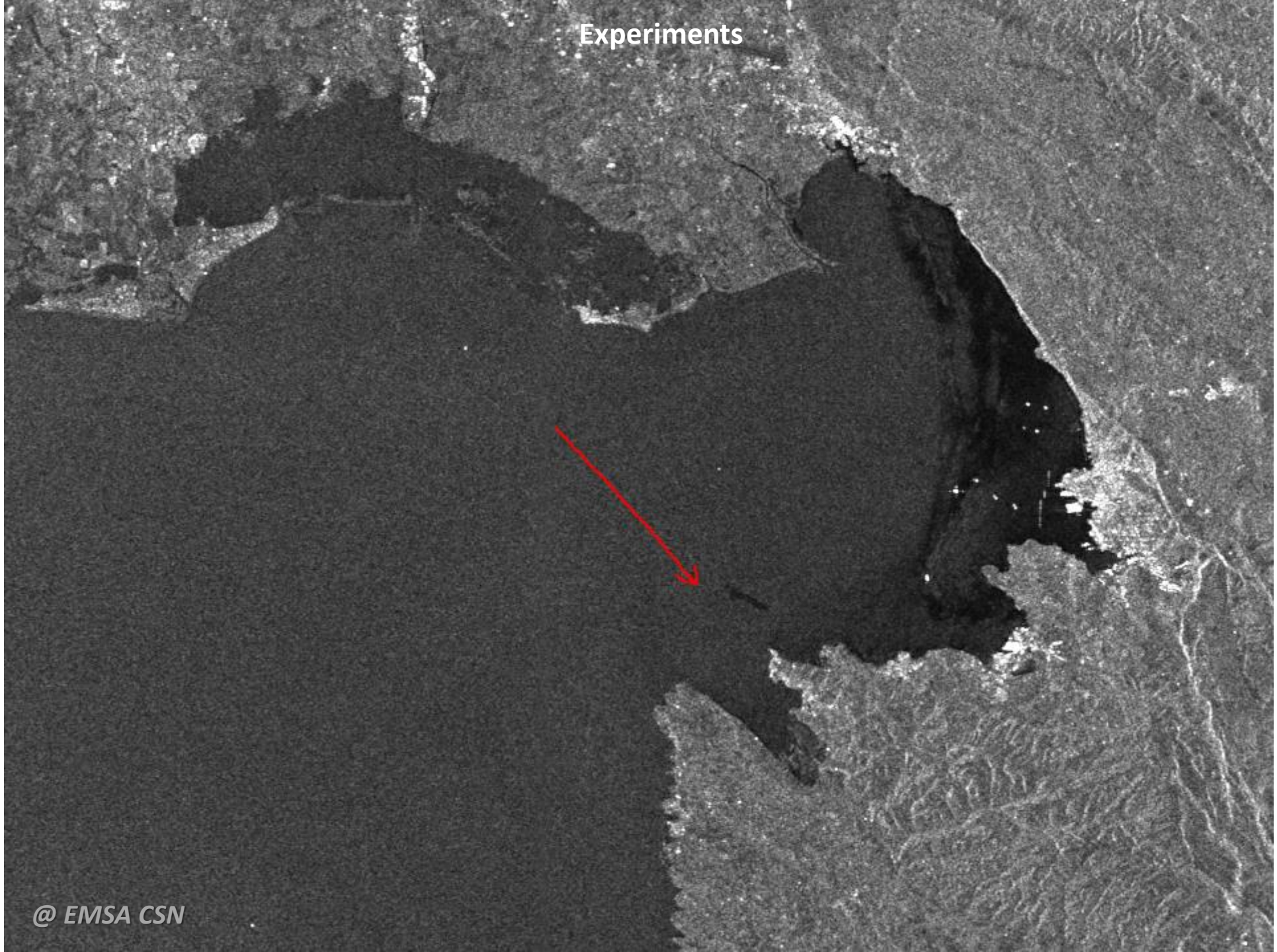
“Identification” of noncooperative vessels

Ship speed from SAR observation – wake signatures

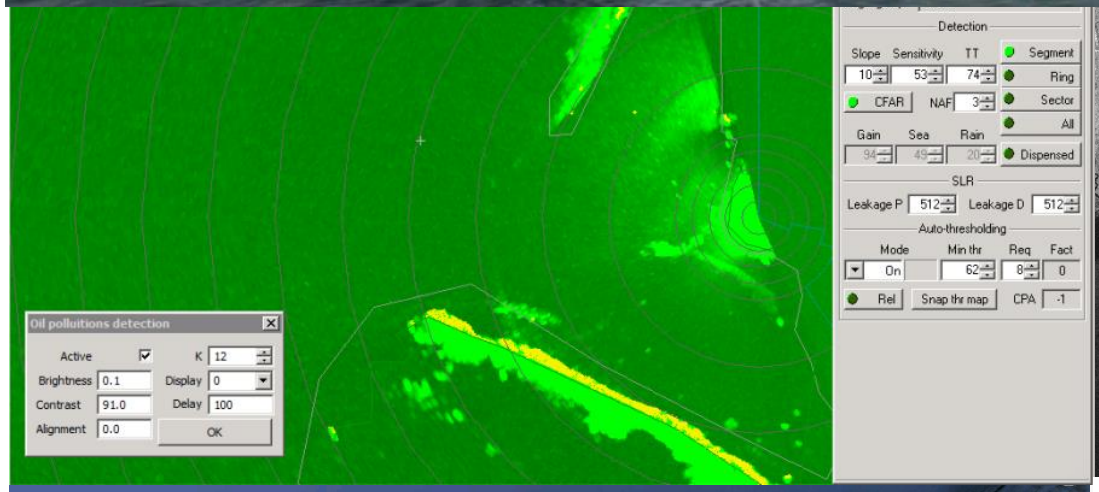


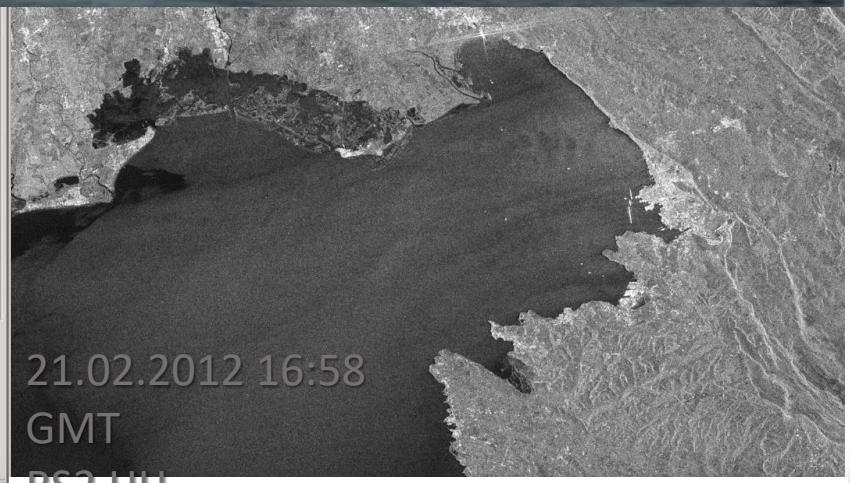
$$\lambda_t = \frac{2\pi U^2}{g} \quad and \quad \lambda_c = \frac{4\pi U^2}{\sqrt{3}g}$$

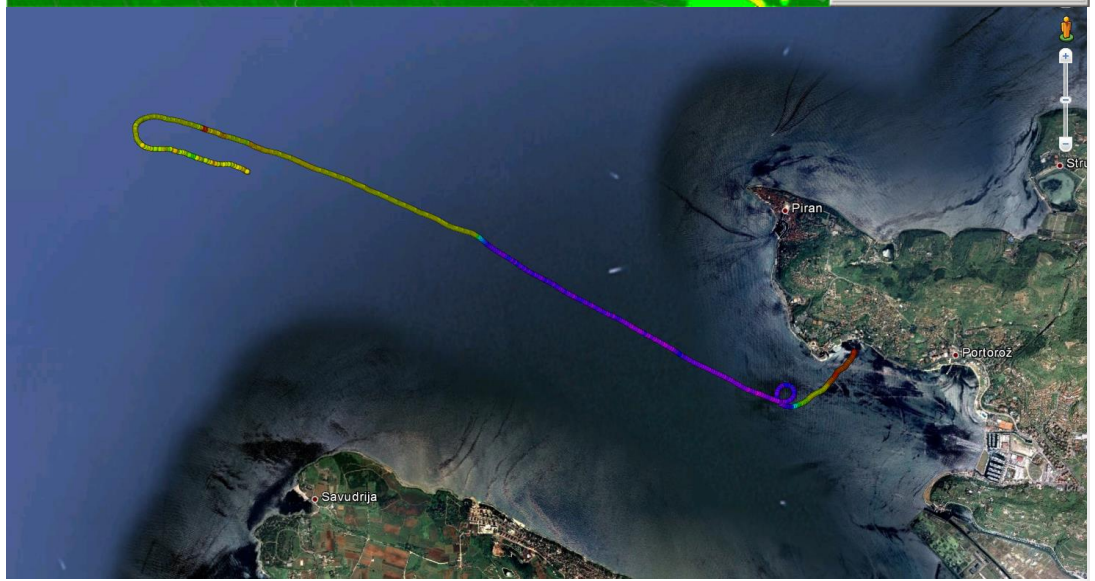

07:15:22 (LT)
Experiments
ScanSAR Narrow 14.05.2012; 05:17:23 (UTC)
wind=9m/s
@ EMSA CSN

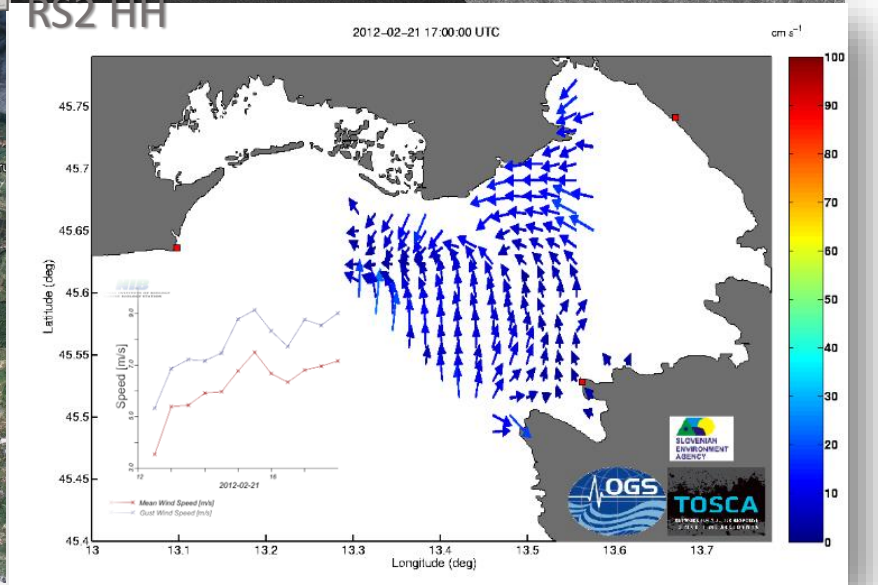

Experiments
@ EMSA CSN

Experiments



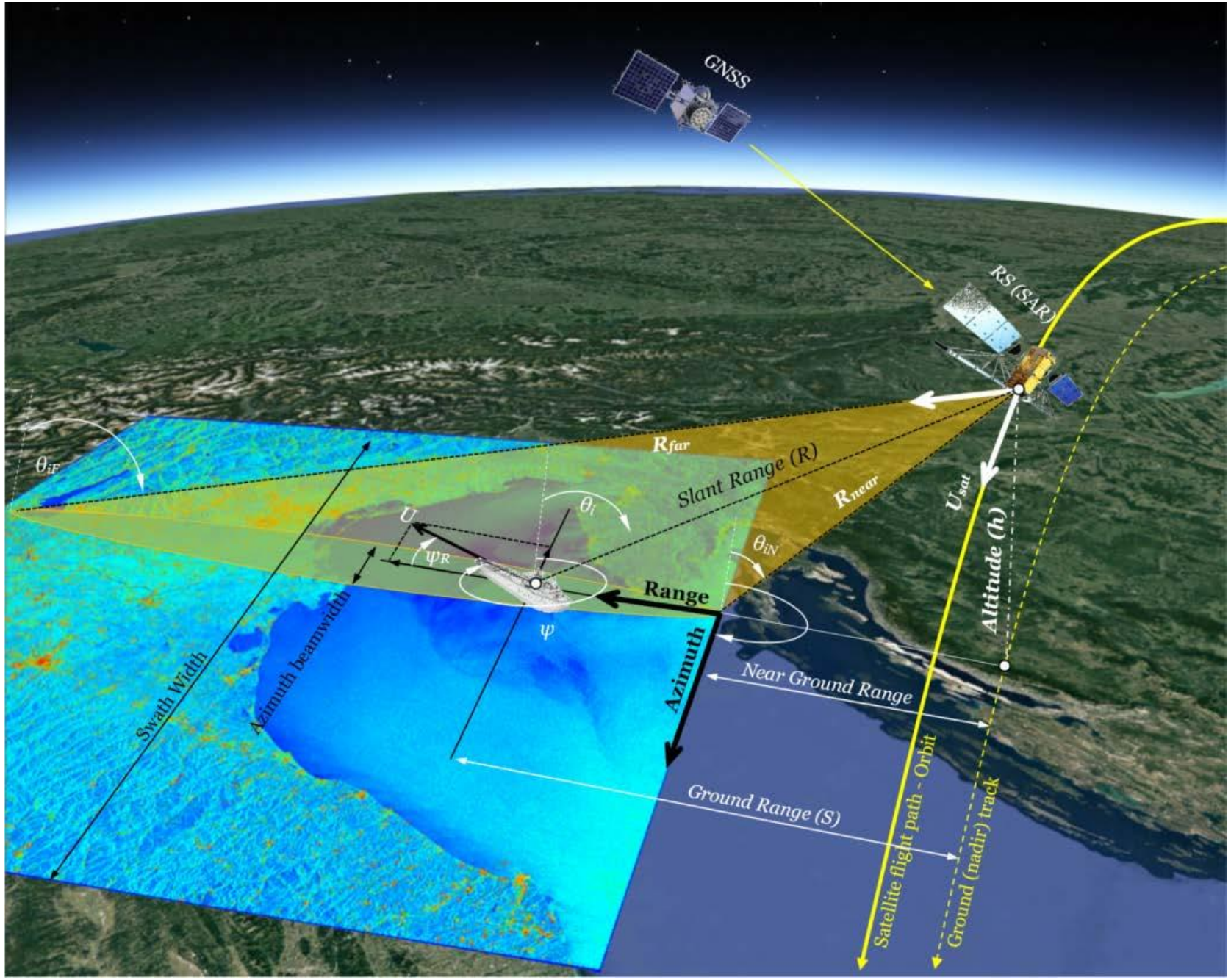






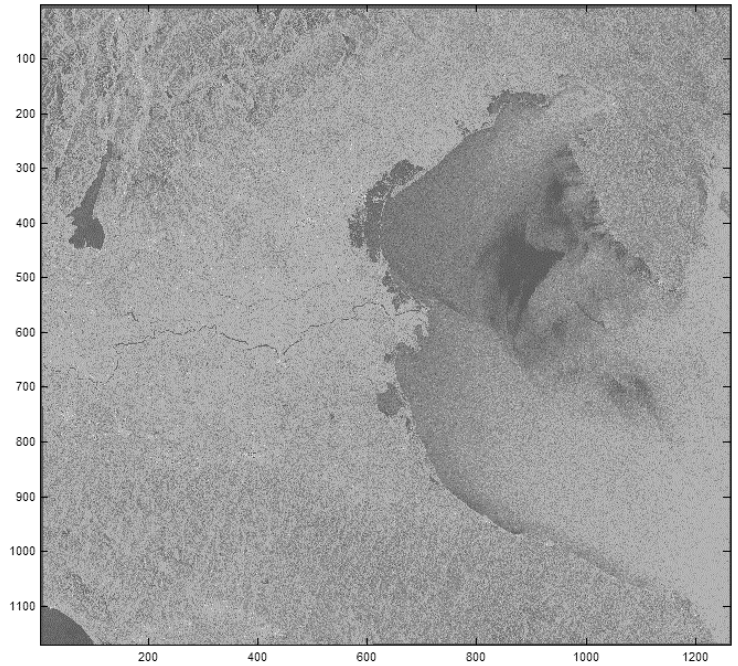
Remote sensing and monitoring

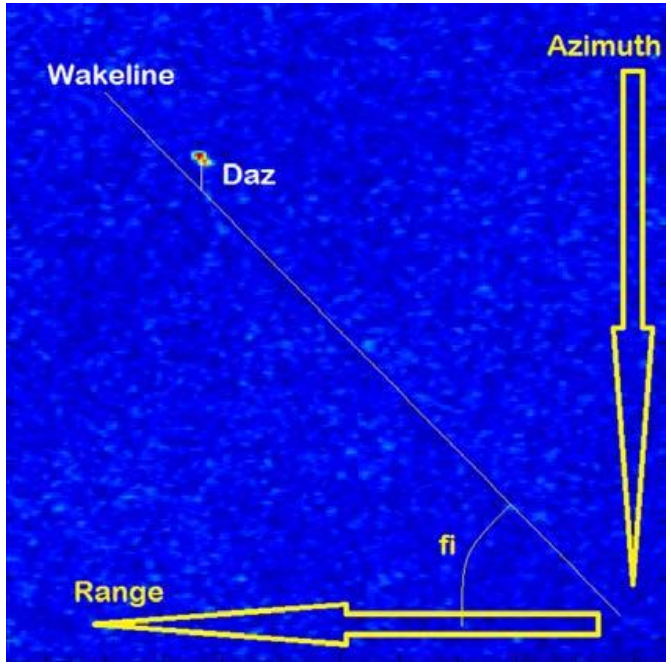
“Identification” of noncooperative vessels



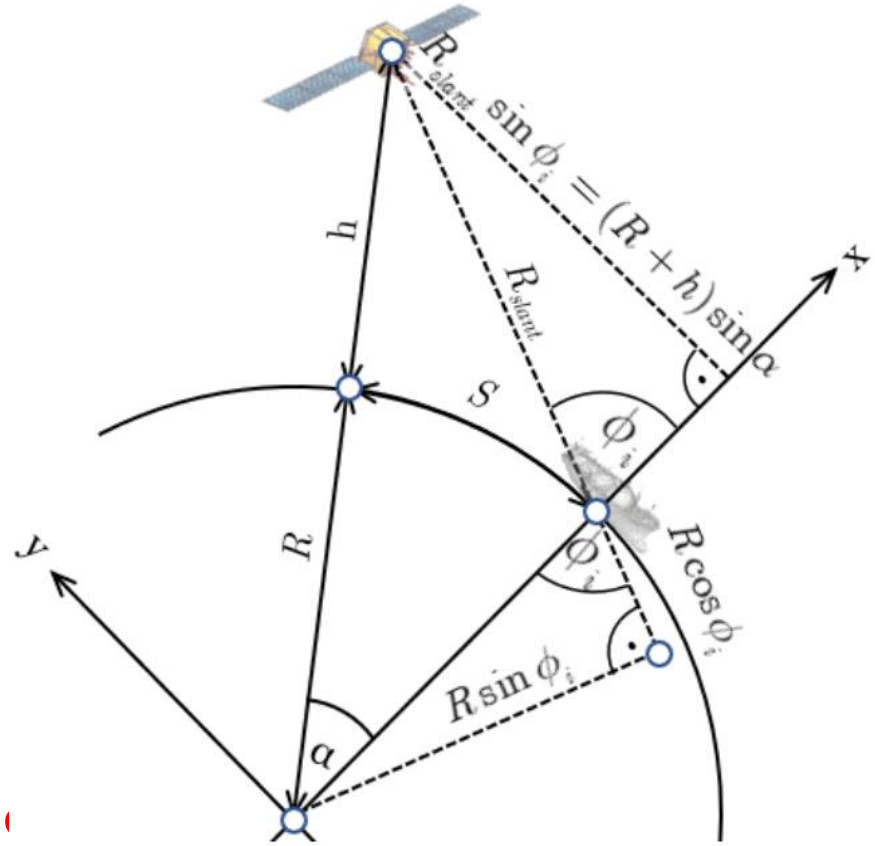
Remote sensing and monitoring

Ship speed from SAR observation – Doppler shift

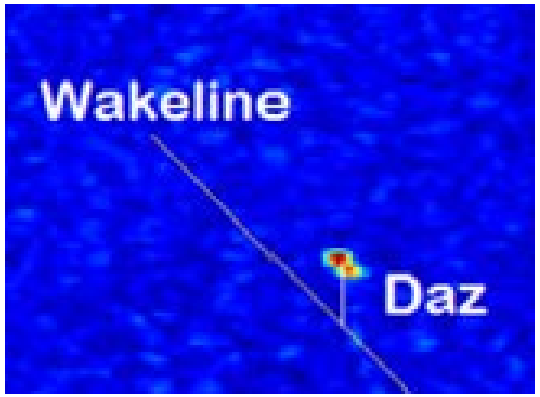




"Identification" of noncooperative vessels



The radius of Earth R, height h to satellite and near range slant angl



$$x^2 + y^2 = \left(R+h\right)^2$$

$$y = \left(x - R\right)\tan\phi_i \qquad x = R\sin^2\phi_i + \cos\phi_i\sqrt{\left(R+h\right)^2 - R^2\sin^2\phi_i} \qquad \cos\alpha = \frac{x}{R+h}$$

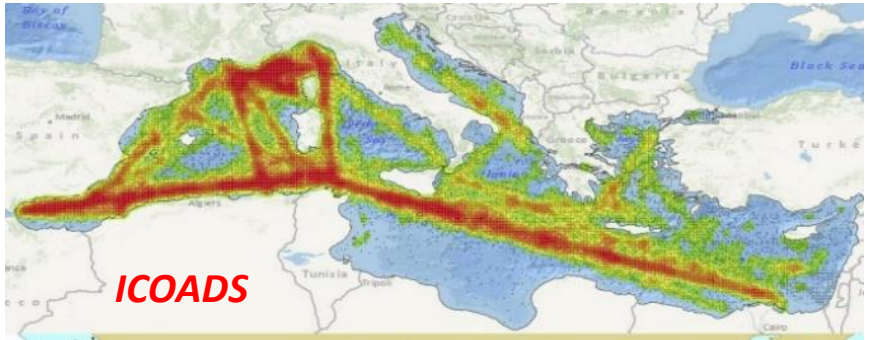
$$R_{slant}\sin\varphi = (R+h)\sin\alpha \qquad R_{slant} = \sqrt{R^2 + \left(R+h\right)^2 - 2R\left(R+h\right)\cos\alpha} \qquad S = R\cdot\alpha$$

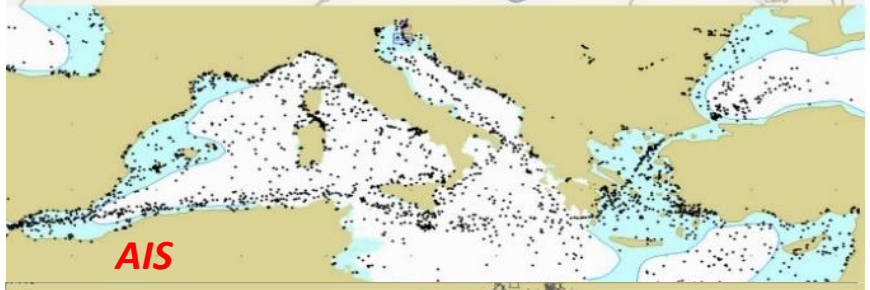
$$\alpha = \sin^{-1}\left(\frac{R_{slant}}{R+h}\sin\phi_i\right) \qquad U = \frac{D_{az}}{R_{slant}\cdot U_{sat}^{-1}\cdot\sin\phi_I\cdot\cos\psi_R}$$

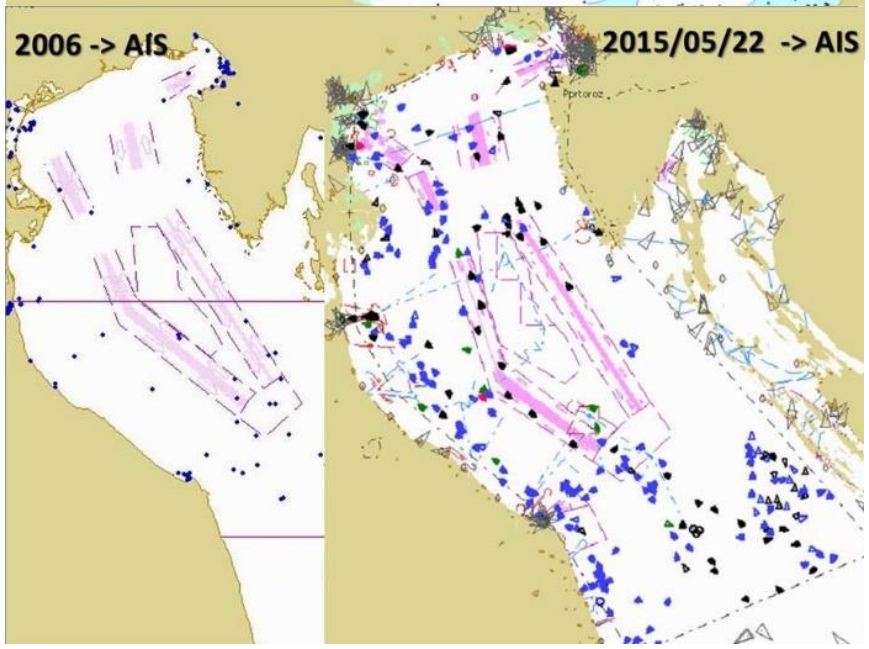
Remote sensing and monitoring

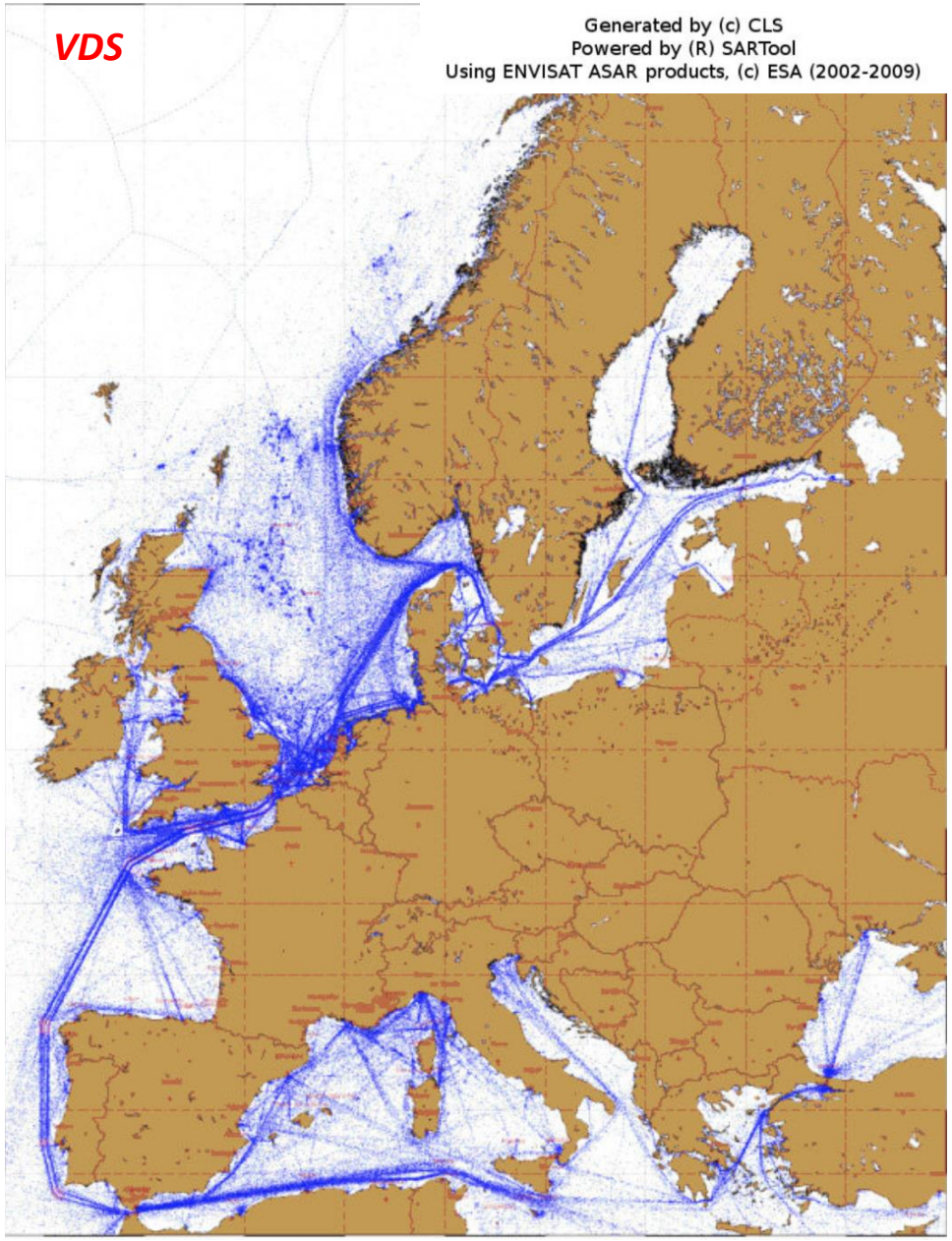
Vessel positions shown using ICOADS, VDS and AIS

"Identification" of noncooperative vessels









Remote sensing and monitoring

Vessel positions using AIS “triangulation” i.e., trilateration

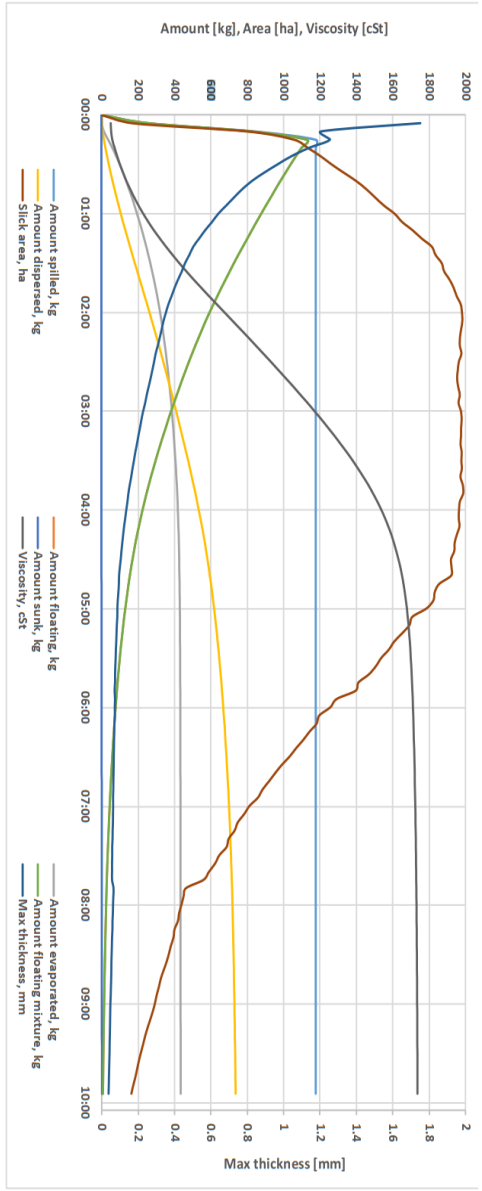
“Identification” of noncooperative vessels

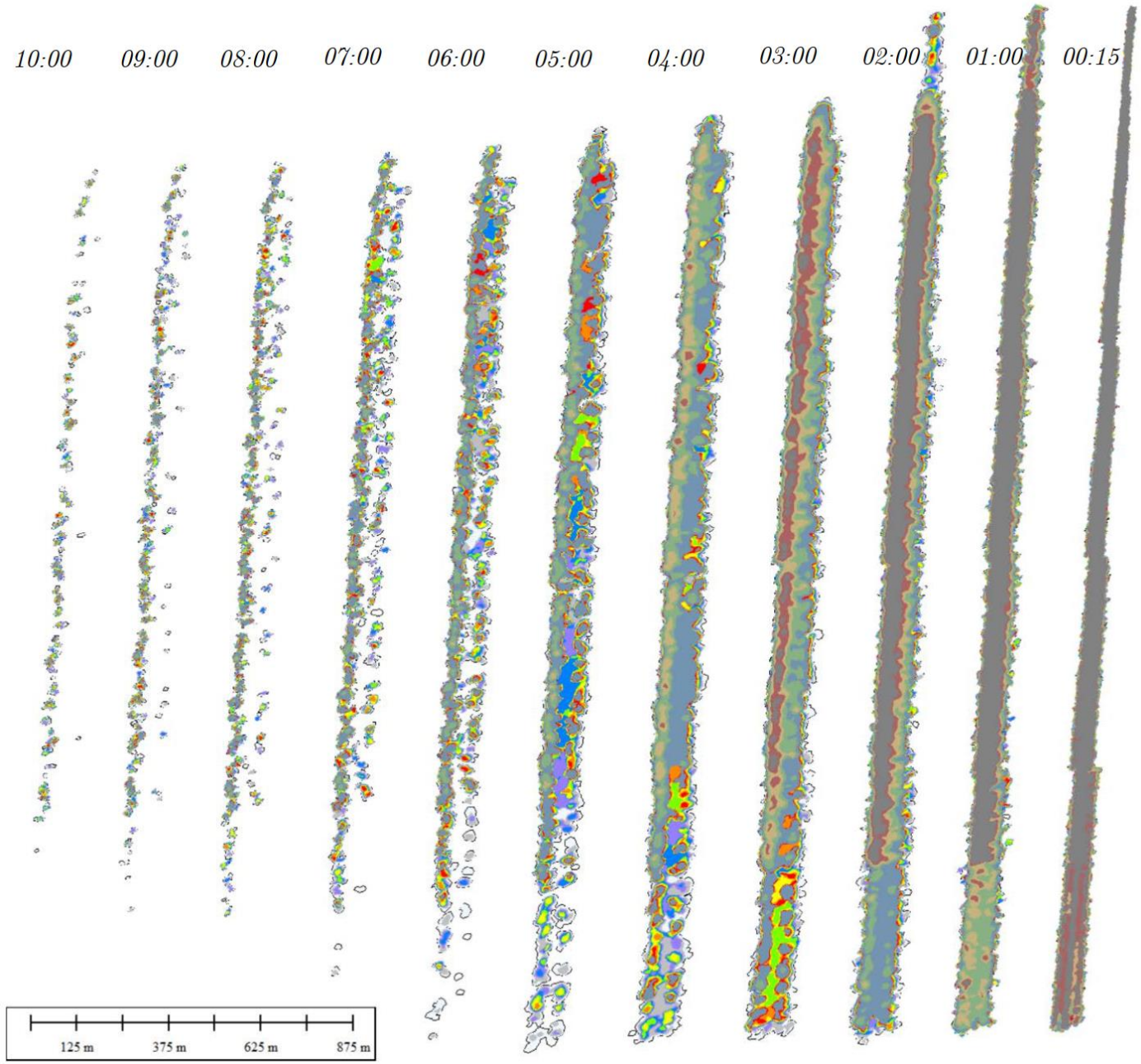
c:1436866761,S:002780202*09\$ACVSI,IZOLA,7,093912.856843,482,-93,29*10
c:1436863768,S:002780202*68\$ACVSI,IZOLA,1,084919.657218,737,-108,14*20

- UNIX Epoch
- BS
- Unique Identifier
- VDM/VDO
- TOA, time of message arrival
- First slot no. of VDL
- Signal to noise ratio (dB)

The dynamic of disposal at sea

Advection and weathering of operational released slick (overriding regulations)





The dynamic of disposal at sea

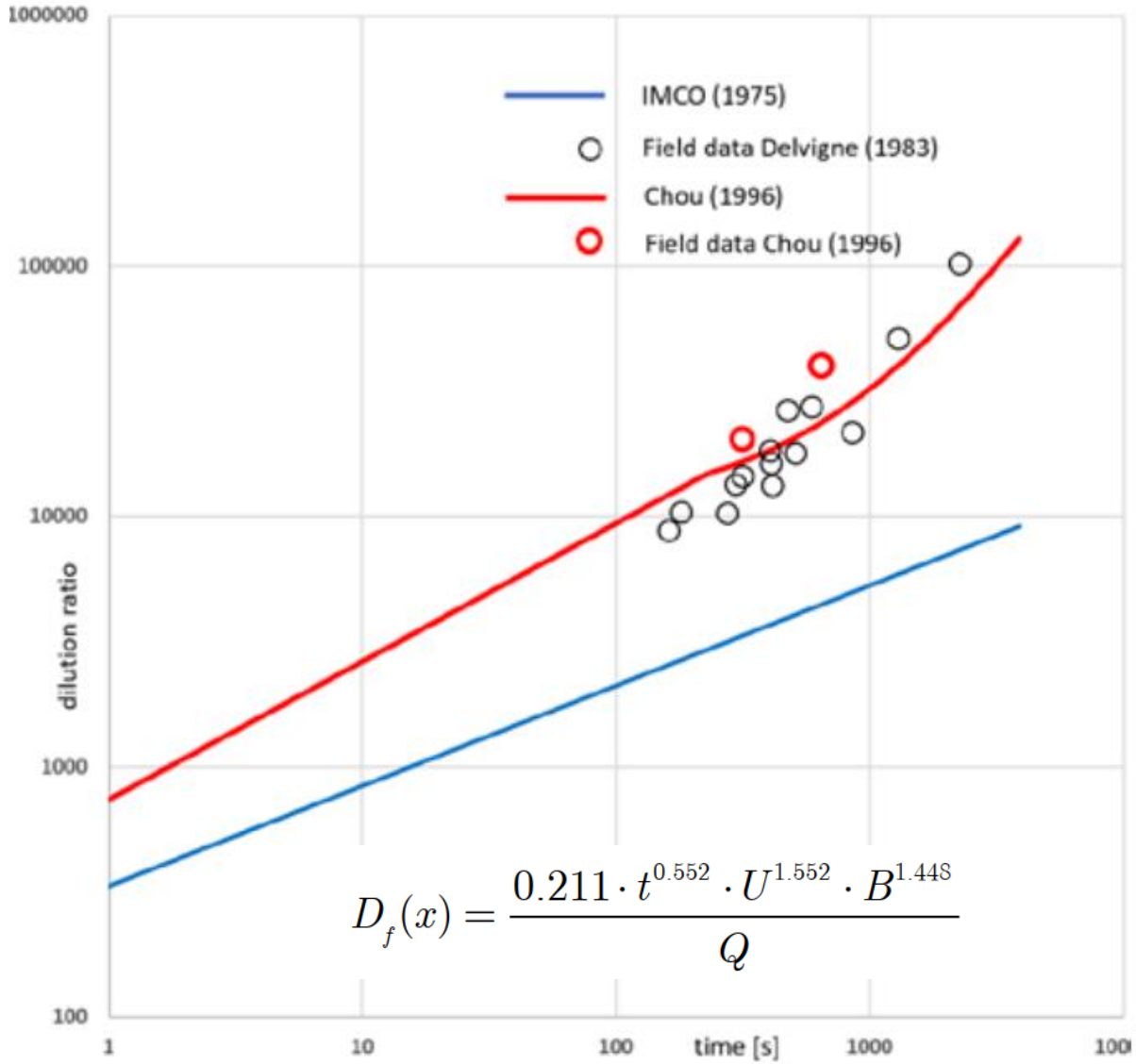
Dilution and concentration at a point in the wake

IMCO - dilution effected in three different stages:

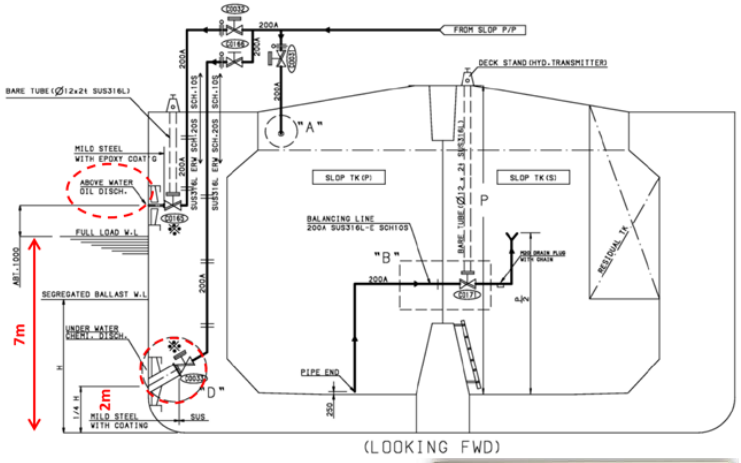
(i) turbulent mixing in the ship's boundary measurable in seconds,

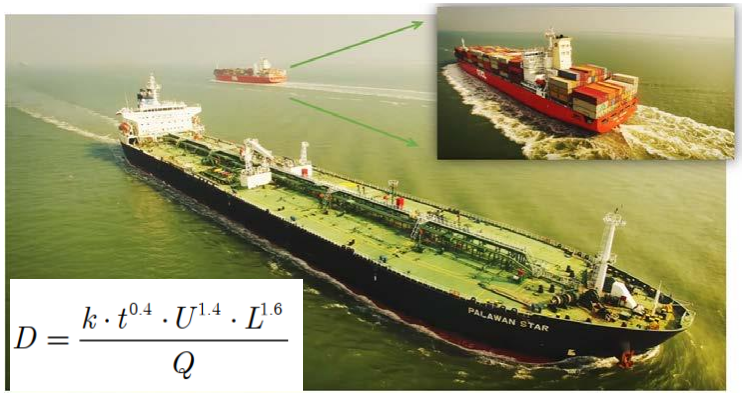
(ii) in the second stage - after about 20 minutes - due to the turbulent mixing, the concentration is declining rapidly, and

(iii) dilution due to subsequent diffusion
into the surrounding sea will occur.



some detected pollutions are not necessarily illegal



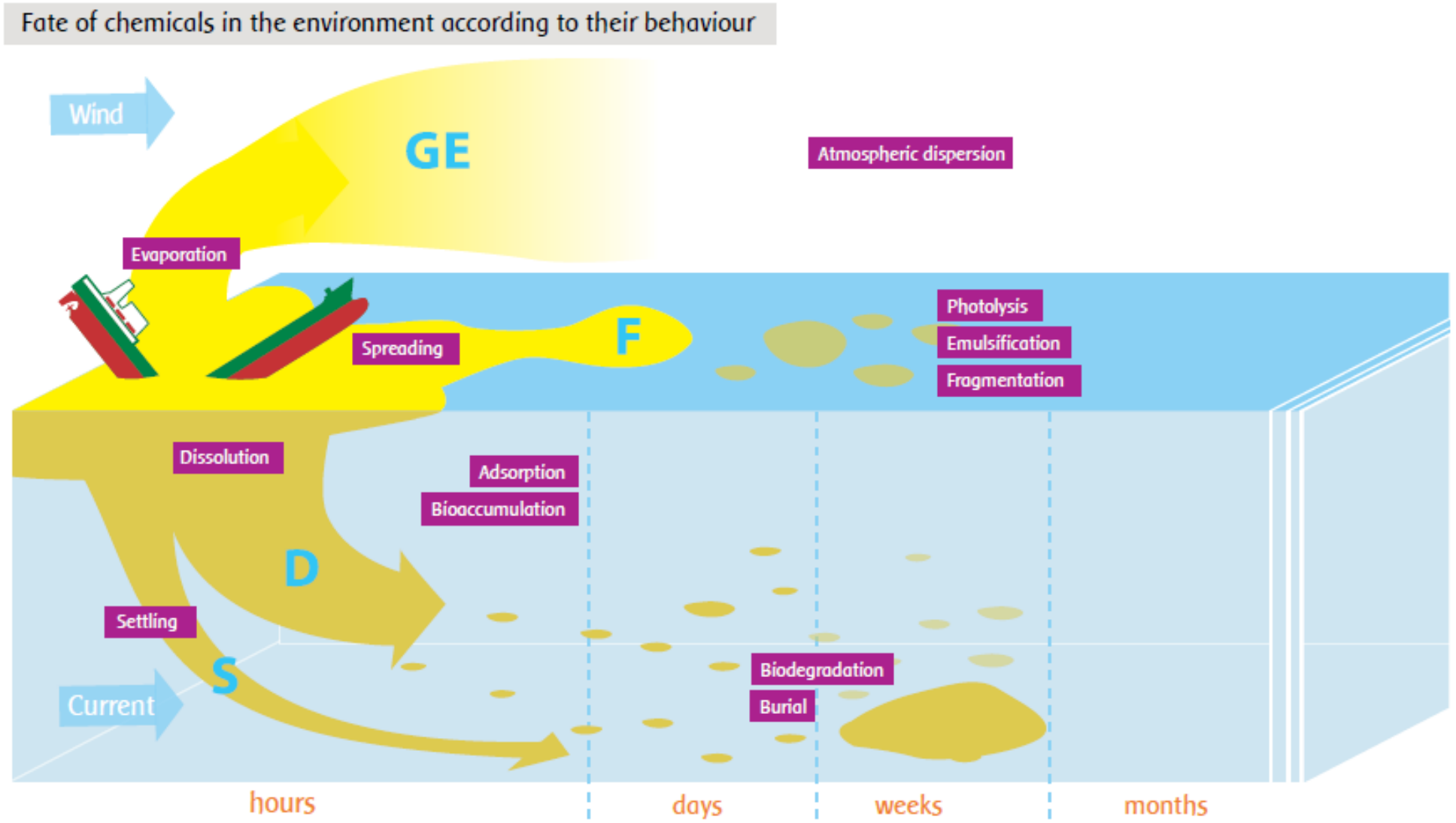


$$D = \frac{k \cdot t^{0.4} \cdot U^{1.4} \cdot L^{1.6}}{Q}$$

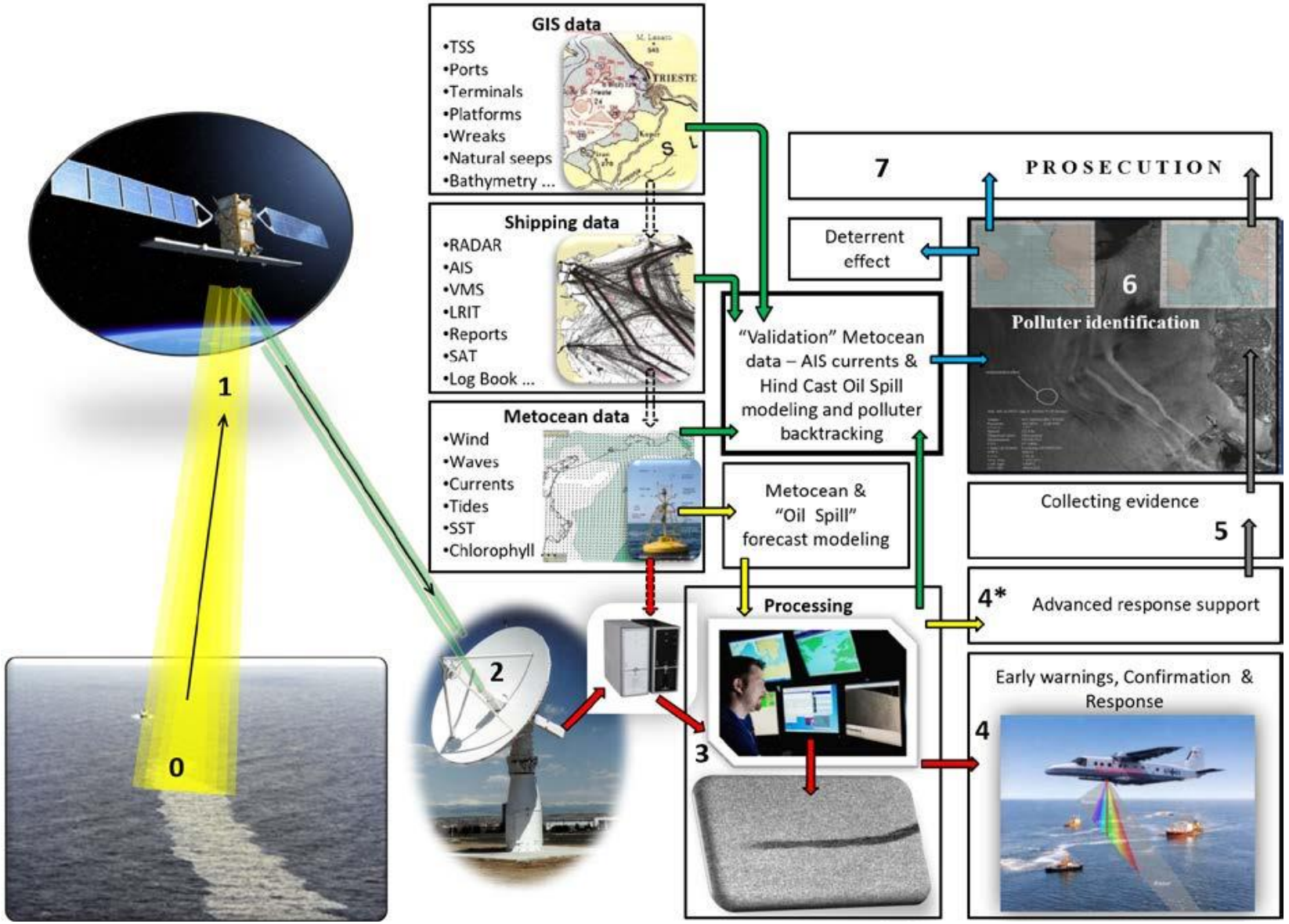
Requirement	*MARPOL Annex II* (1/7/1986)				*MARPOL Annex II* (1/1/2007)			
Pollution Category [2]	*A*	*B*	*C*	*D*	X	Y	Z	
	Major Hazard	*Hazard*	*Minor Hazard*	*Recognizable Hazard*	Major Hazard	Hazard	Minor Hazard	
Maximum Residue After Stripping	MARPOL Annex II				**Ship Details**			
					IBC/BCH			Other
X [1] < 1/7/86 (BCH Ships)	*Not Applicable*	*300 +50* liters#*	*900 +50* liters#*	*No minimum*	300 +50* liters#	300 +50* liters#	900 +50* liters#	If "Z" and in IBC Ch.18, empty to maximum extent
1/7/86 ≤ X [1] < 1/1/2007 (IBC Ships)		*100 +50* liters#*	*300 +50* liters#*	*No minimum*	100 +50* liters#	100 +50* liters#	300 +50* liters#	If "OS" and in IBC Ch.18, not applicable
X [1] ≥ 1/1/2007 (IBC Ships)	*Not Applicable*				75 liters#	75 liters#	75 liters#	75 liters#
** performance test tolerance # performance test required*								
Discharge								
Concentration	Any residue to reception facility, except 0.1% by weight or below.	≤ 1 ppm *in the wake astern of the ship*	≤ 10 ppm *in the wake astern of the ship*	≤ 1 part NLS to 10 parts water	Any residue to reception facility, except 0.1% by weight or below.	Any residue to sea	Any residue to sea	
En route	≥ 7 Knots				≥ 7 Knots			
Piping Outlet Location	Underwater		Not Applicable		Underwater (not mandatory for ships with X [1] <1/1/2007 carrying Cat. Z)			
Nearest land	≥ 12 nautical miles and water depth ≥ 25m				≥ 12 nautical miles and water depth ≥ 25 m			

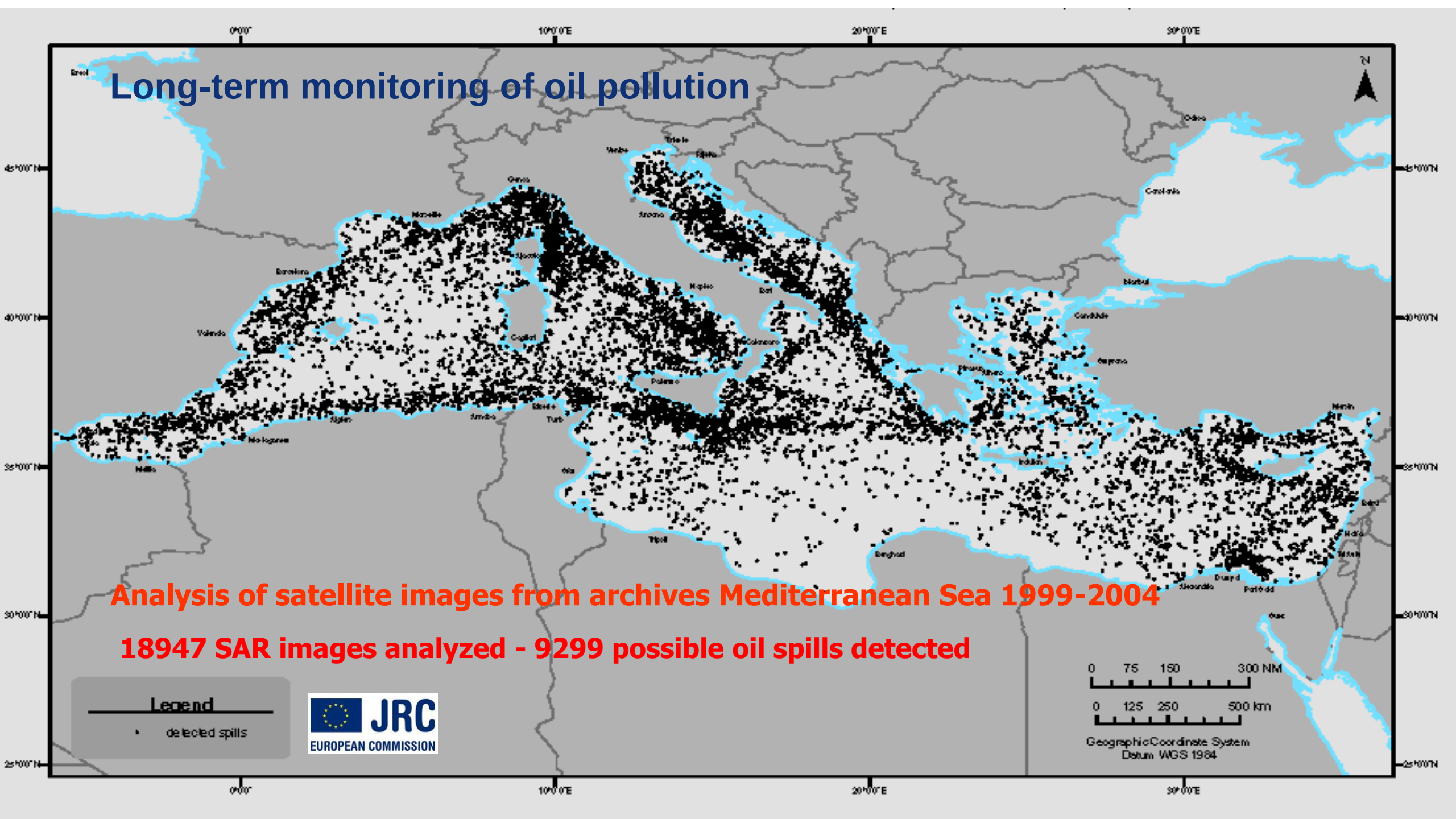
X[1] - *Keel laying date or commencement date of conversion to a chemical carrier*
Pollution Category [2] - *Annex III and OS categories not listed, there are no carriage requirements*

HNS Weathering

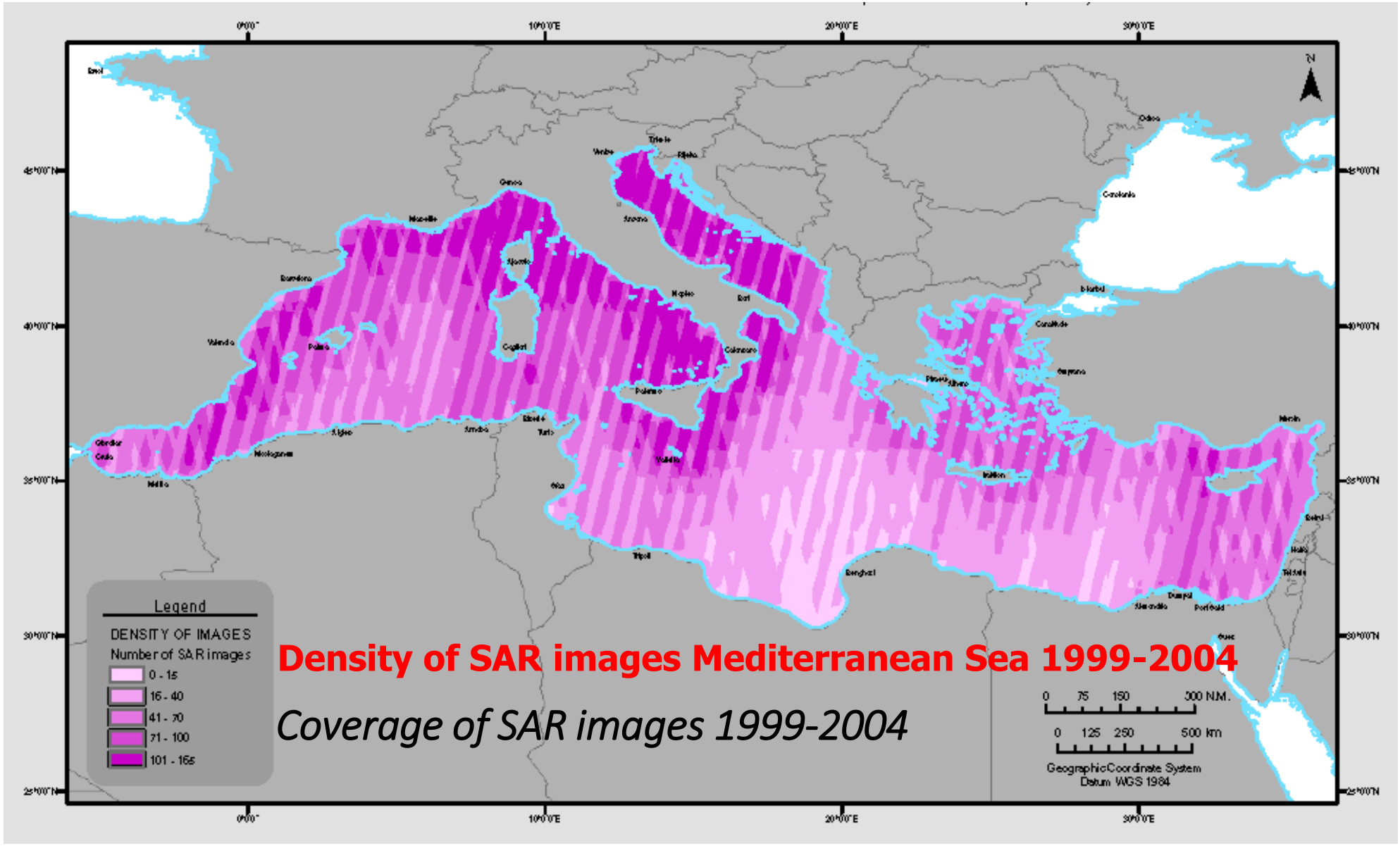


Advanced backtracking model, based on GIS contextual data, the shipping data, and the metocean data




Long-term monitoring of oil pollution
Analysis of satellite images from archives Mediterranean Sea 1999-2004
18947 SAR images analyzed - 9299 possible oil spills detected
Legend
detected spills
JRC
EUROPEAN COMMISSION
0 75 150 300 NM
0 125 250 500 km
Geographic Coordinate System
Datum WGS 1984

Long-term monitoring of oil pollution

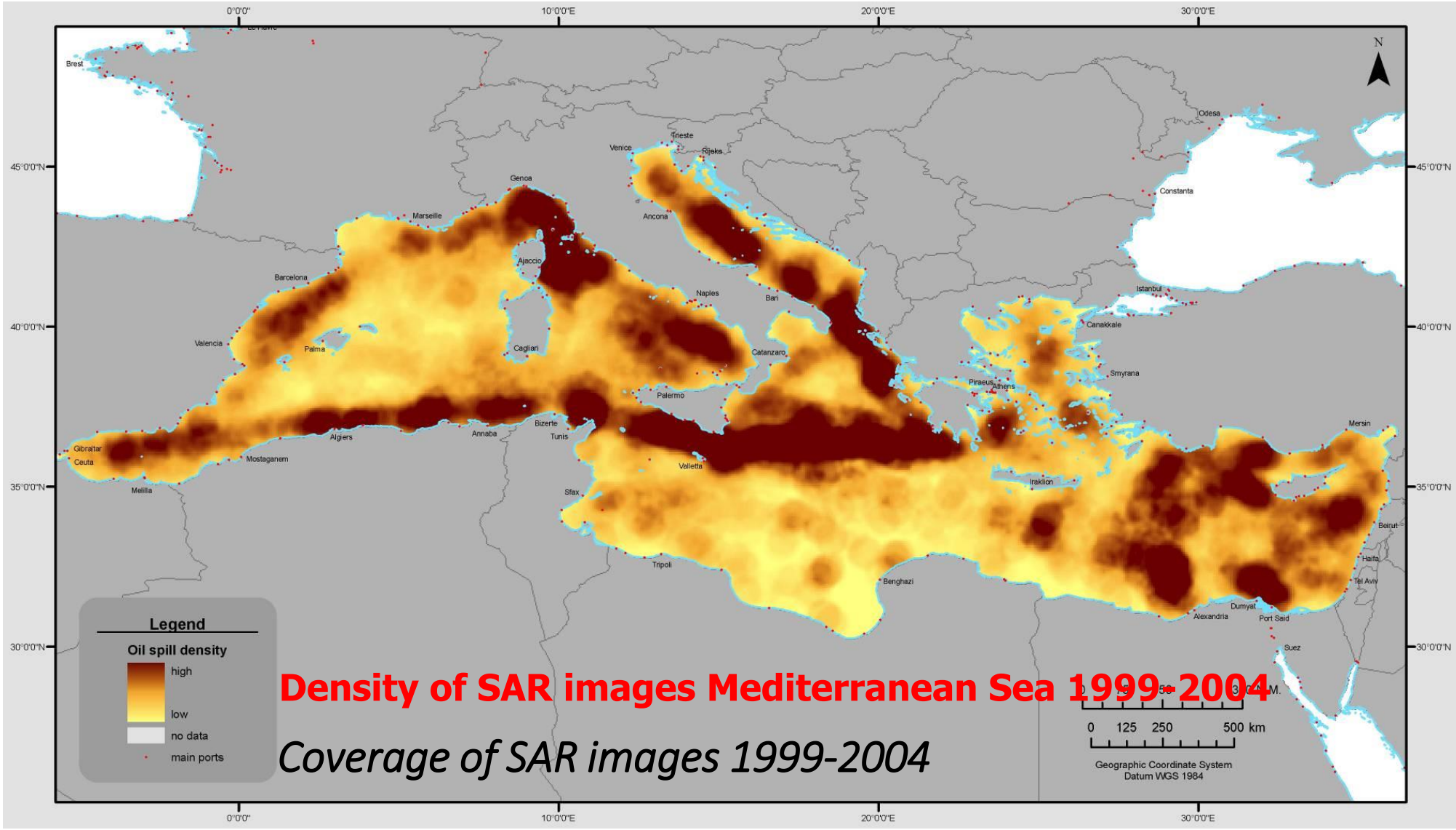


Density of SAR images Mediterranean Sea 1999-2004

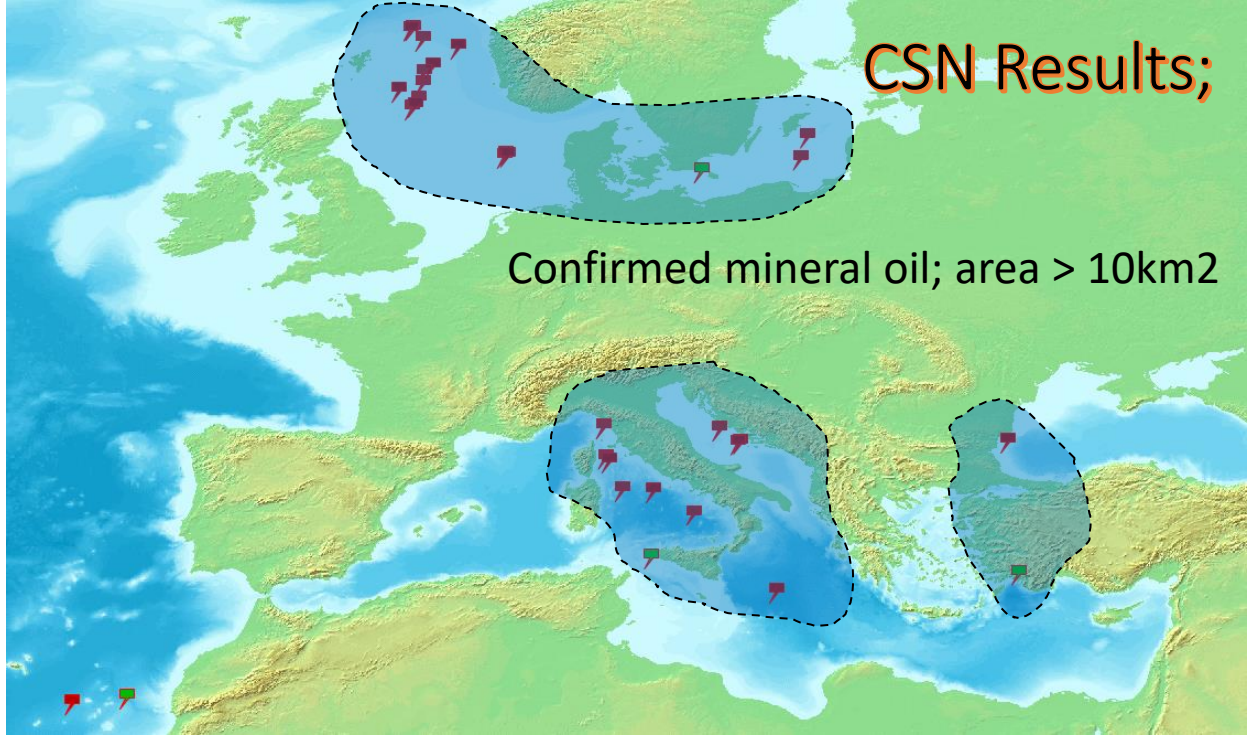
Coverage of SAR images 1999-2004

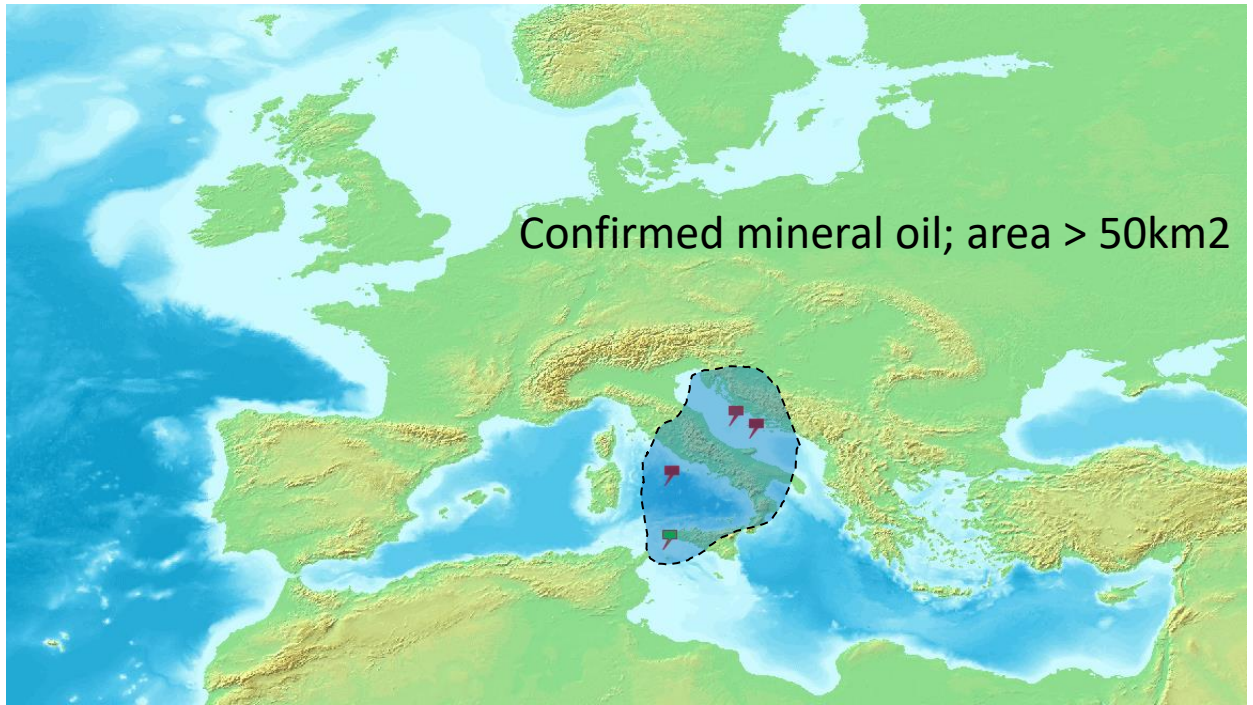
JRC
EUROPEAN COMMISSION

Long-term monitoring of oil pollution



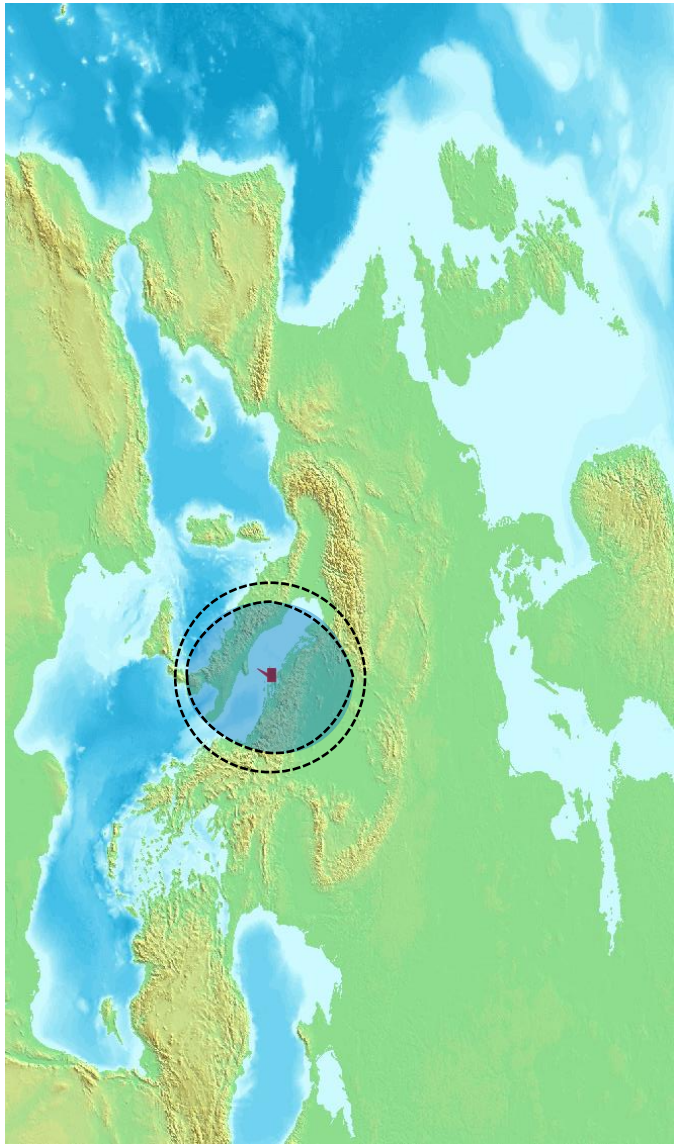
JRC
EUROPEAN COMMISSION





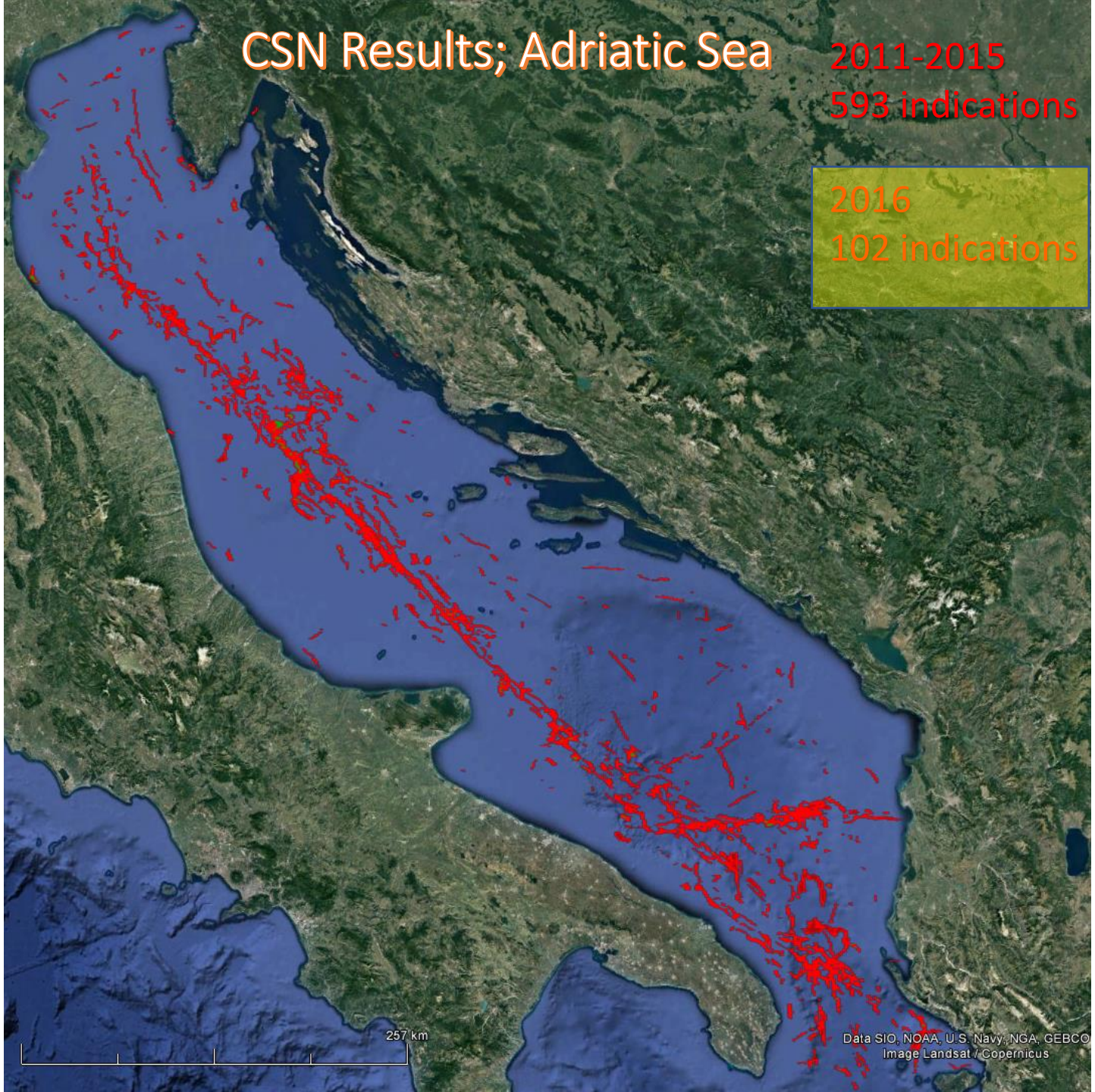
large slicks

Confirmed mineral oil; area > 100km2



2016
102 indications

34; < 1 km2
56; 1 – 10 km2
9; > 10 km2
3; > 50 km2

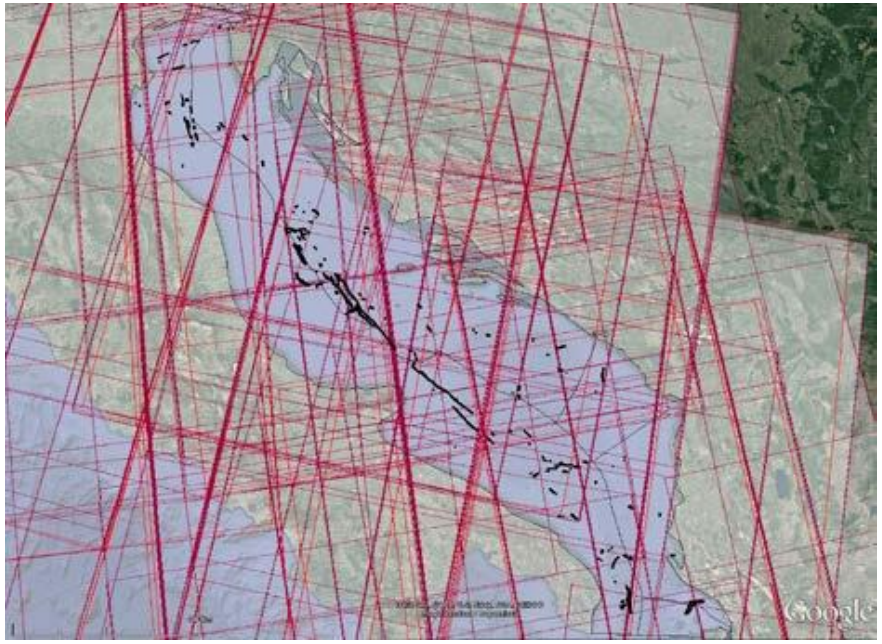


Analyses

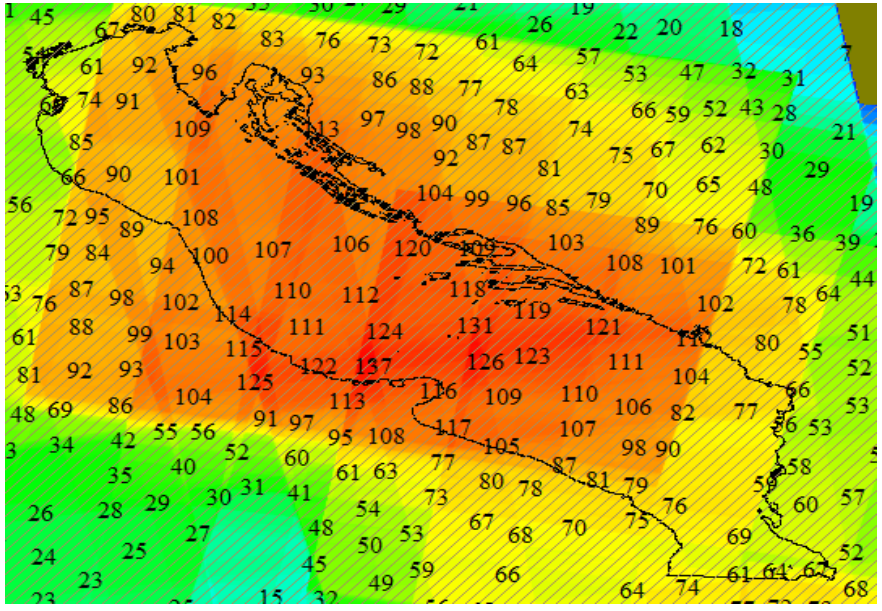
211 slicks identified

35 within territorial waters

328 images acquired



Coverage calculated

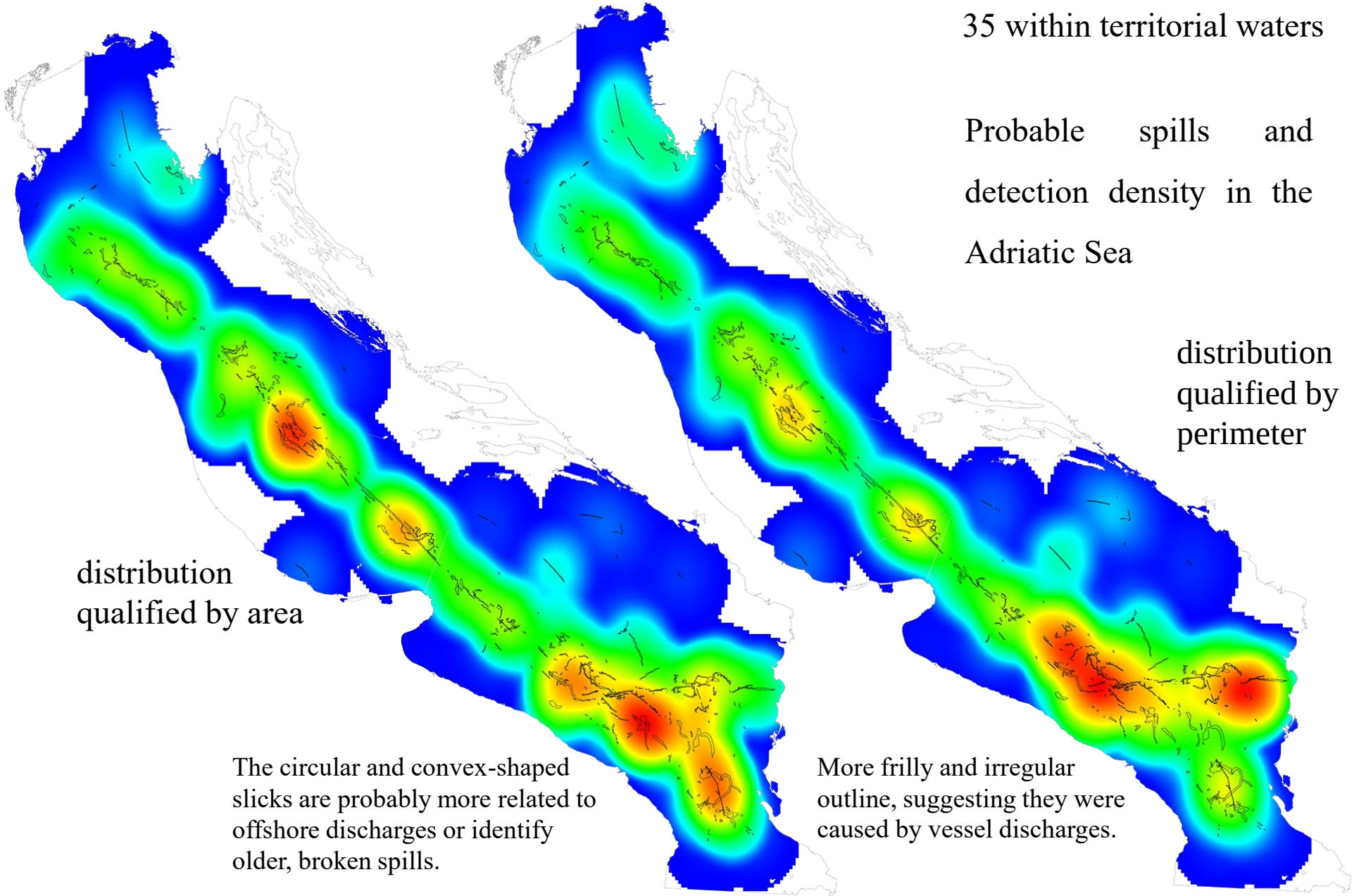


2014-2015 analyses

211 slicks identified

35 within territorial waters

Probable spills and detection density in the Adriatic Sea



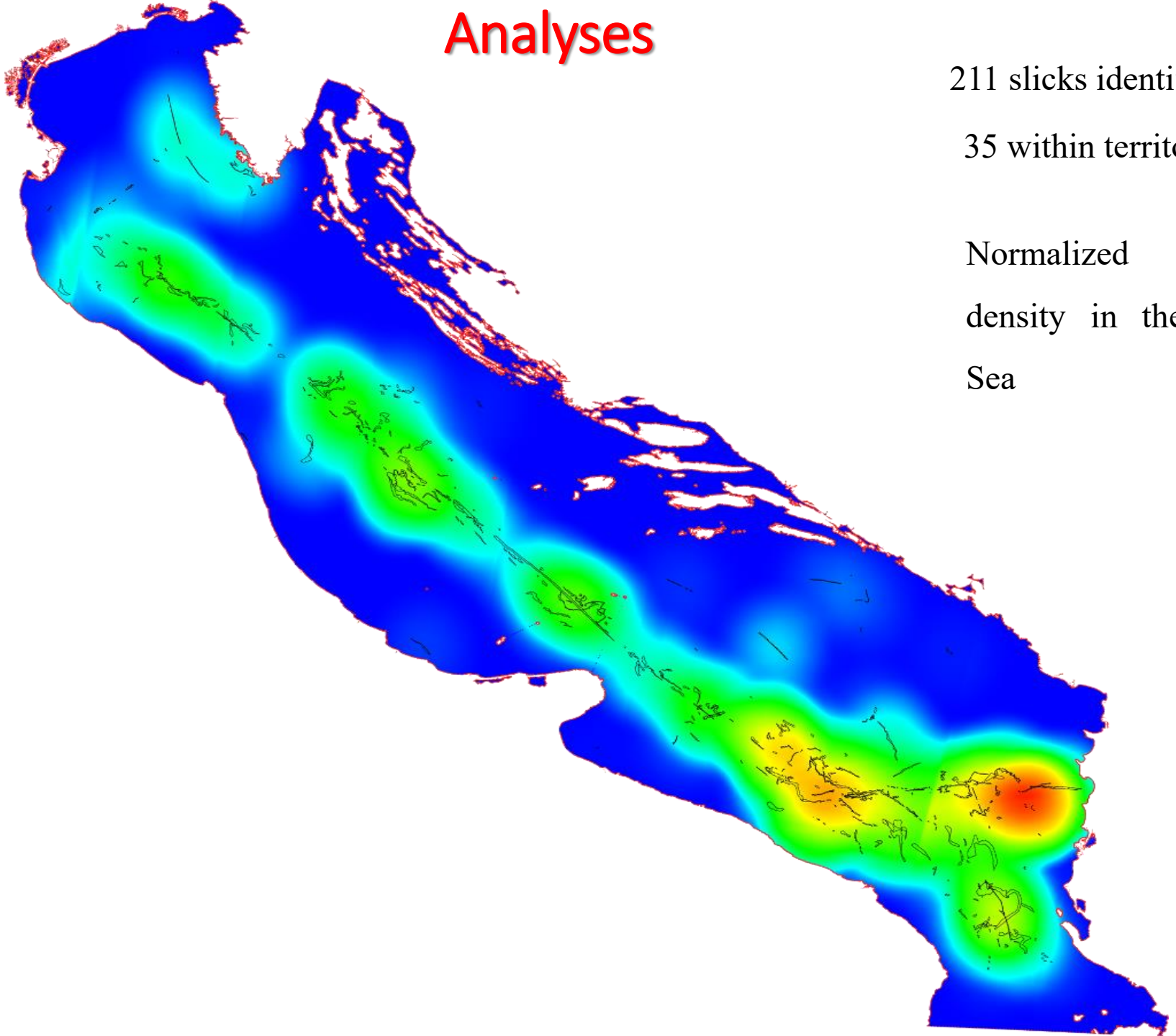
distribution qualified by area

distribution qualified by perimeter

The circular and convex-shaped slicks are probably more related to offshore discharges or identify older, broken spills.

More frilly and irregular outline, suggesting they were caused by vessel discharges.

Analyses



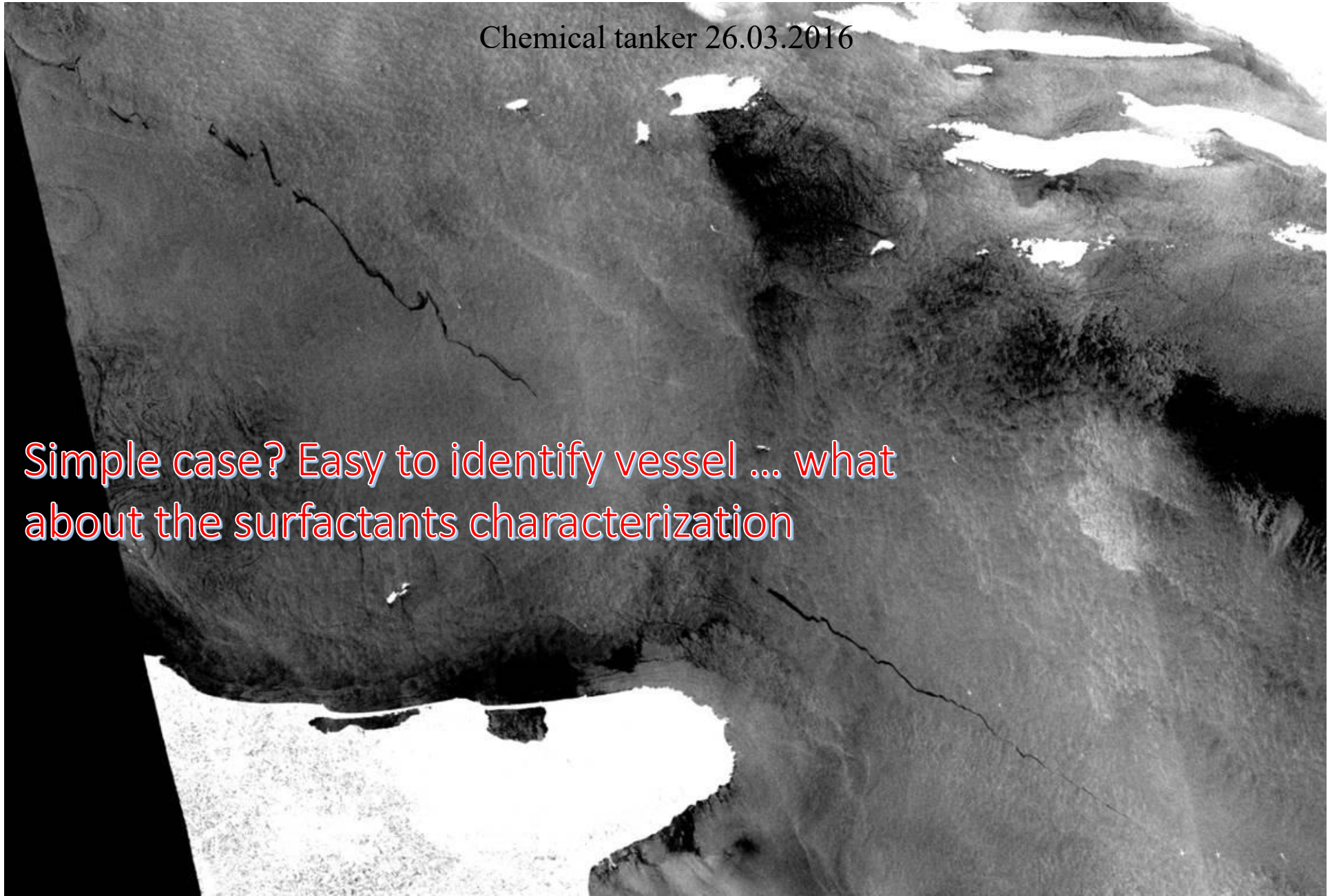
211 slicks identified

35 within territorial waters

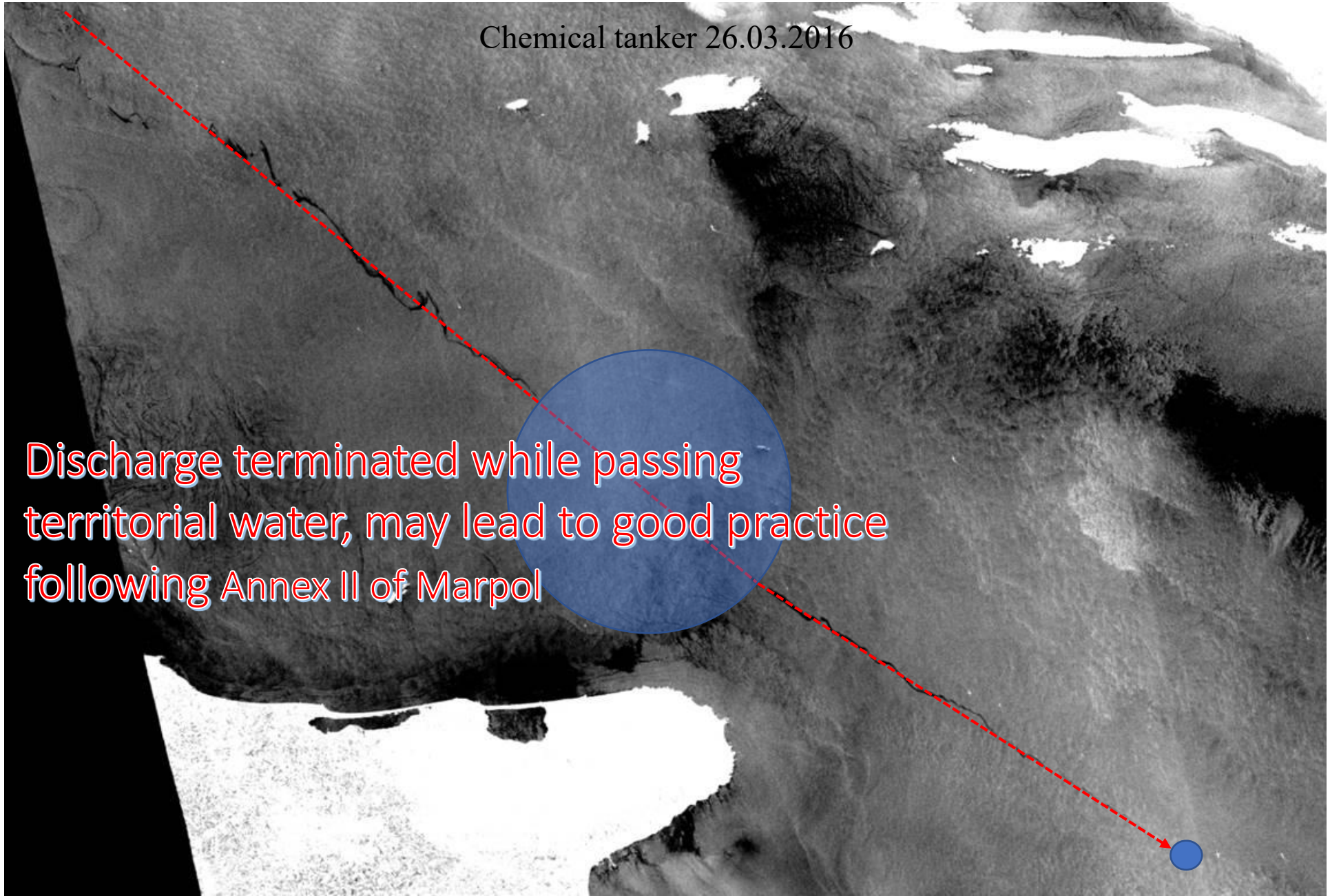
Normalized detection density in the Adriatic Sea

Case Study I; Annex II

Chemical tanker 26.03.2016

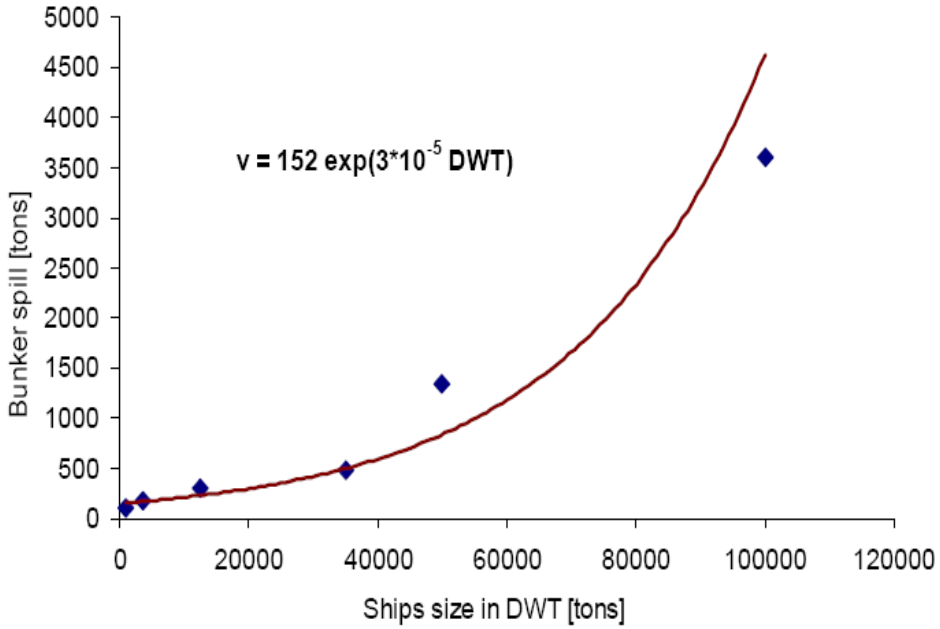


Case Study I; Annex II

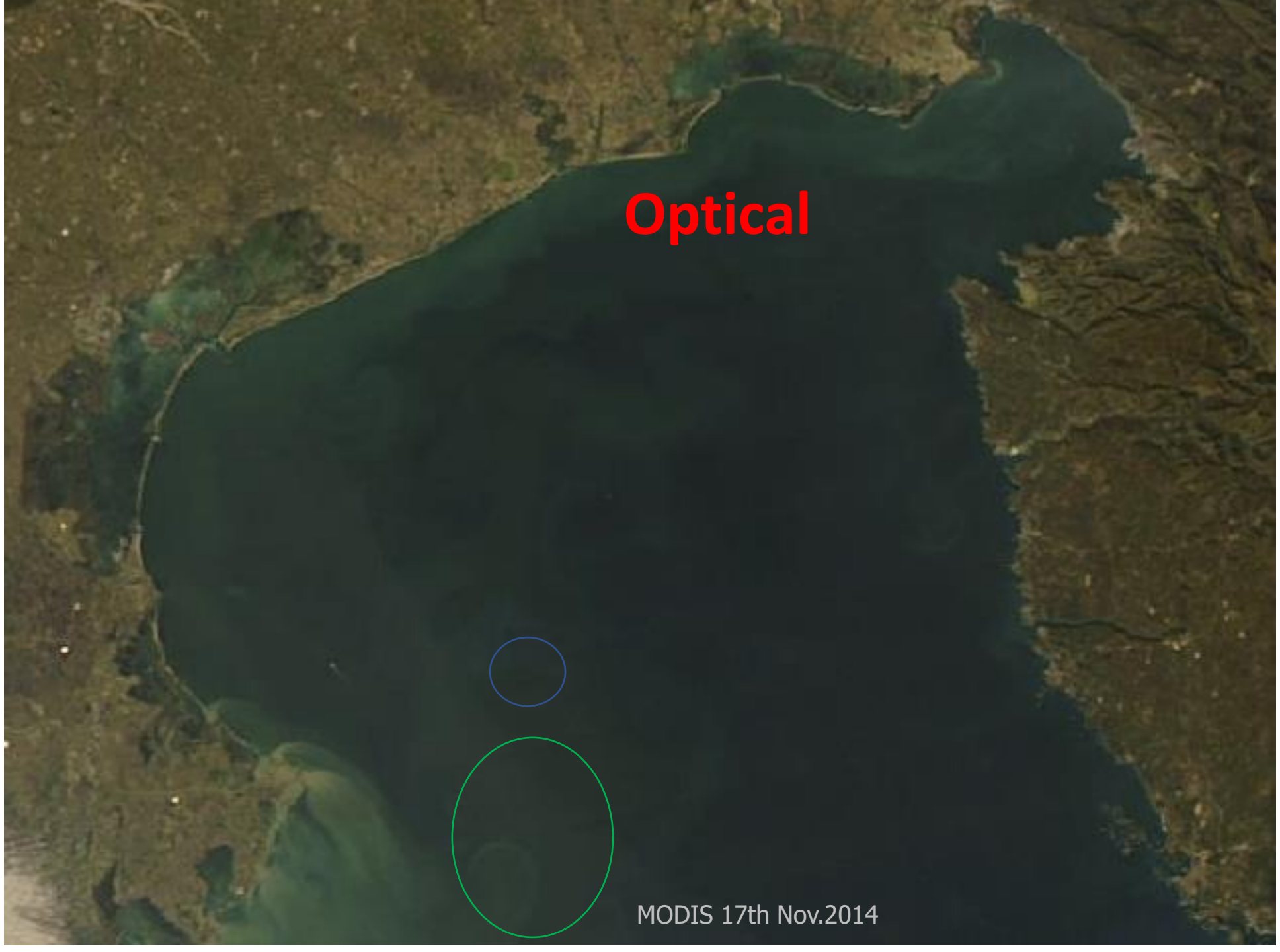


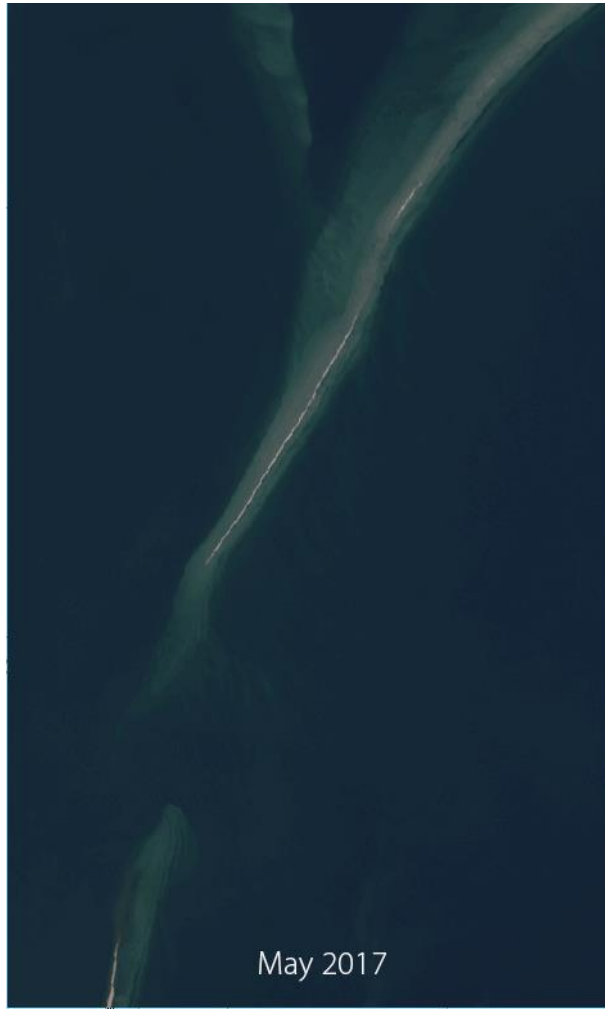
CONSEQUENCE'S

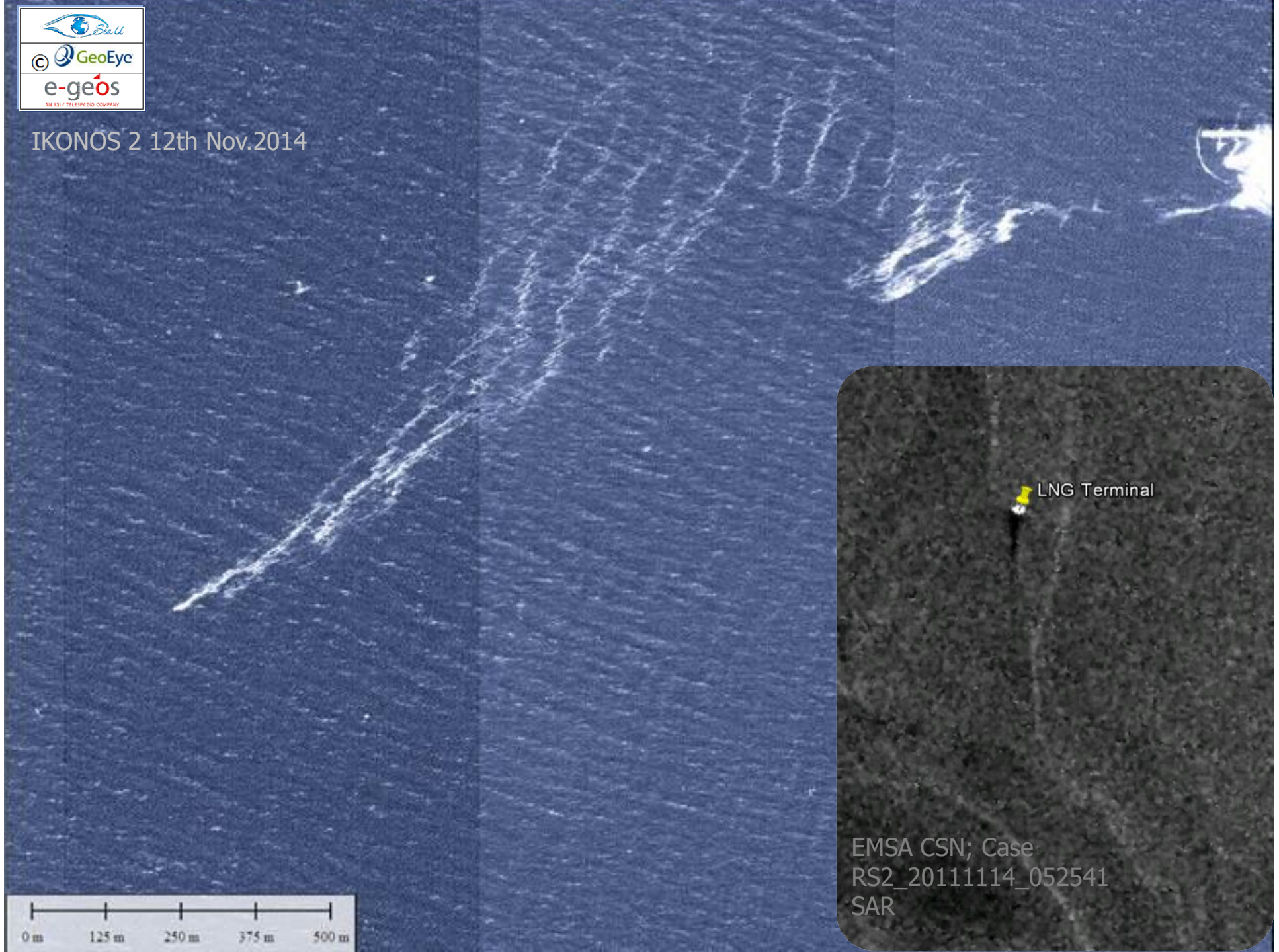
AVERAGE CLEANING COSTS AND EXPECTED OIL RELEASE




Operational or accidental pollution?
Polluter identification complexity


Optical
MODIS 17th Nov.2014


May 2017


© GeoEye
e-geos
IKONOS 2 12th Nov.2014
0 m
125 m
250 m
375 m
500 m
LNG Terminal
EMSA CSN; Case
RS2_20111114_052541
SAR

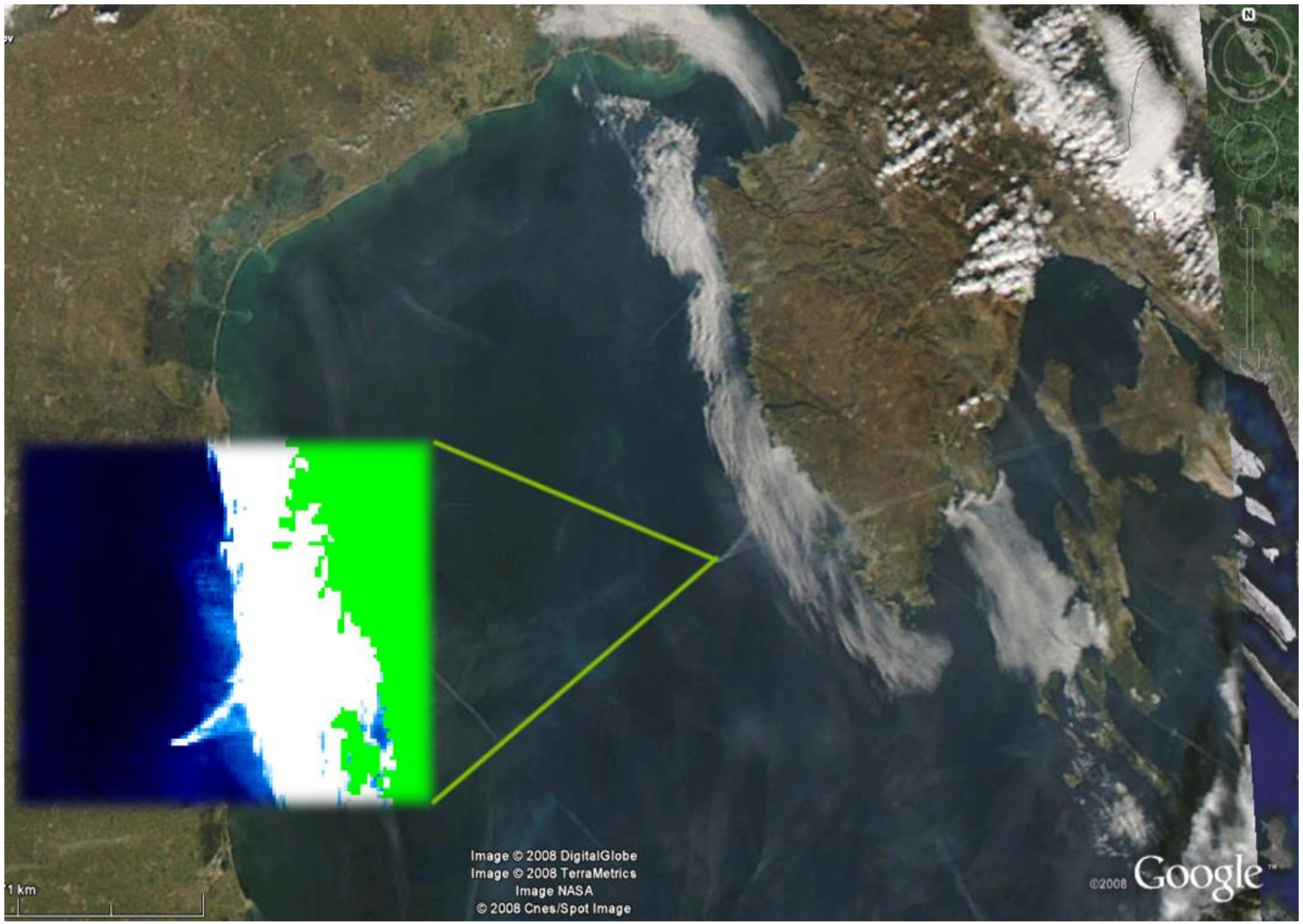
Crisis Management “Und Adriyatik Case”

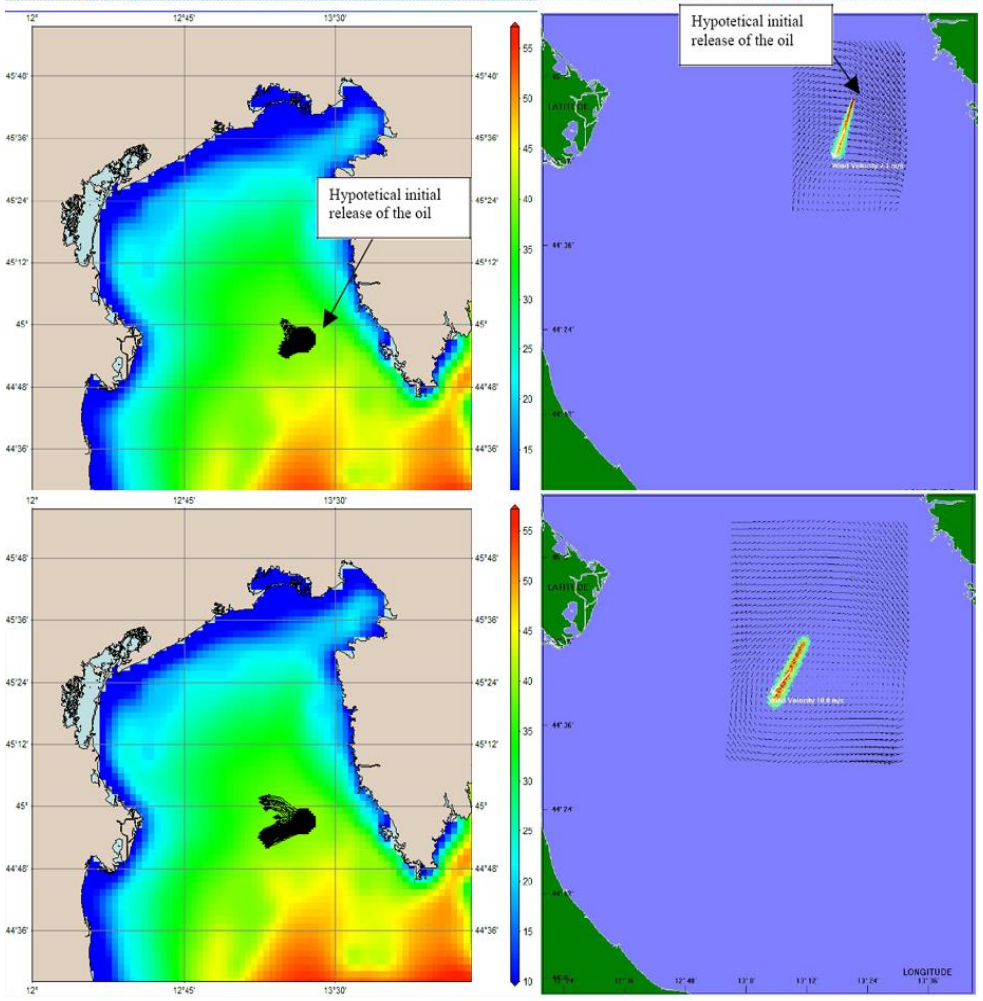
Simulation based decision making

Contingency planning

Croatia - Istria - Premantura / Medulin [Options]

GFS 06.02.2008 06 UTC	We 06. 07h	We 06. 10h	We 06. 13h	We 06. 16h	We 06. 19h	We 06. 22h	Th 07. 04h	Th 07. 07h	Th 07. 10h	Th 07. 13h	Th 07. 16h	Th 07. 19h	Th 07. 22h	Fr 08. 04h	Fr 08. 07h	Fr 08. 10h	Fr 08. 13h	Fr 08. 16h	Fr 08. 19h	Fr 08. 22h	Sa 09. 04h	Sa 09. 07h	Sa 09. 10h	Sa 09. 13h	Sa 09. 16h	Sa 09. 19h	Sa 09. 22h
Wind speed (knots)	10	5	4	2	3	6	11	12	12	11	9	11	14	14	16	18	20	21	22	20	15	14	14	11	11	15	16
Wind direction	→	→	↗	↘	↓	↓	↓	↓	↓	↓	↓	↓	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙	↙
Temperature (°C)	10	11	11	11	10	10	10	10	11	11	11	10	9	7	7	7	8	8	7	8	7	7	8	9	10	9	8
Cloud cover (%)	-	46	56	50	56	79	68	67	43	43	49	35	8	7	9	12	16	12	13	11	9	12	12	11	5	5	4
Rain (mm/3h)	-																										
Windguru rating								★	★	★			★	★	★	★	★	★	★	★	★	★	★	★		★	★



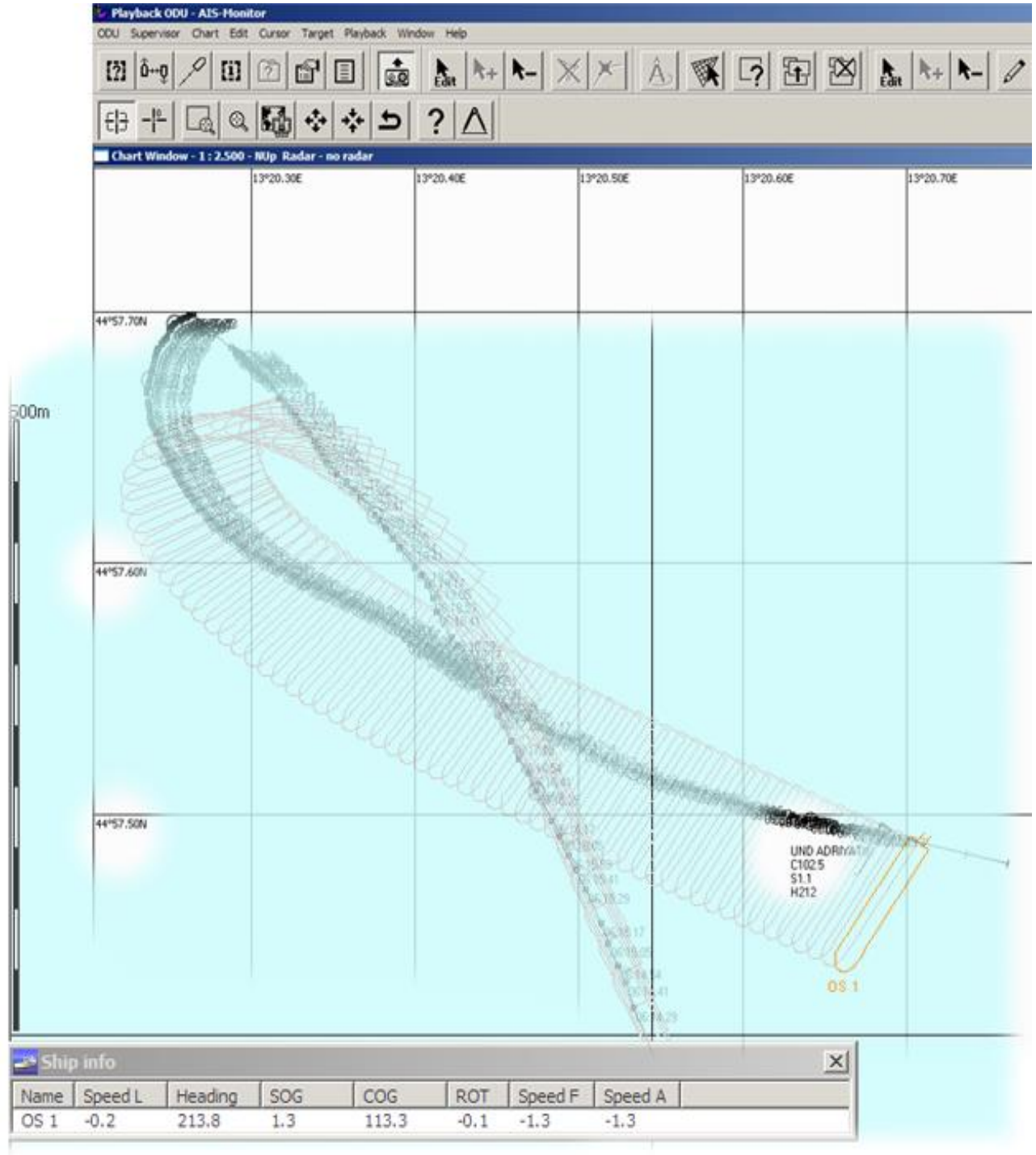


Simulation based decision making
Determining wind and currents
Contingency planning

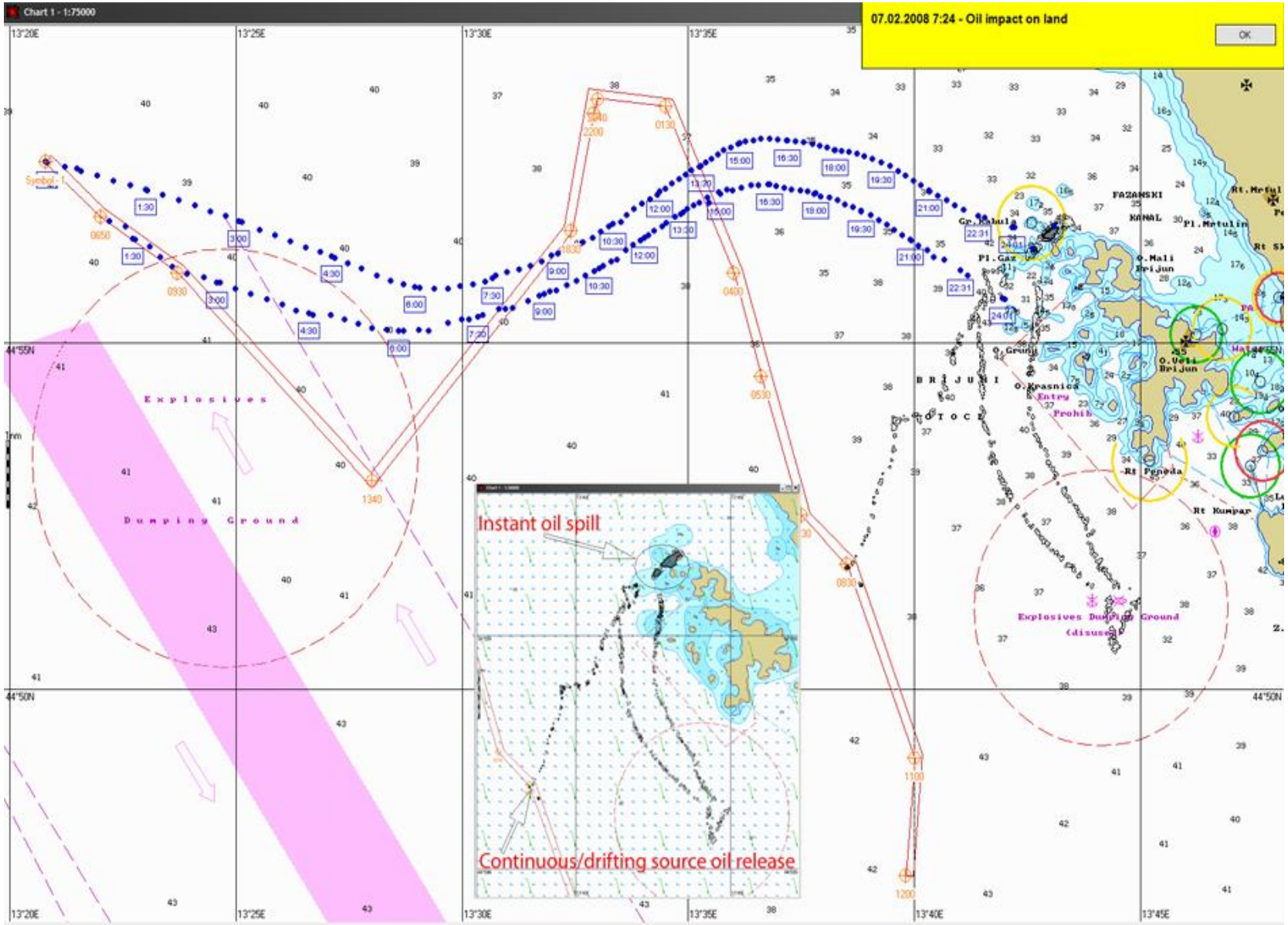
Comparison of the ship's drift based on the real AIS trajectory with the simulated one.

Analyzing the life raft drift!

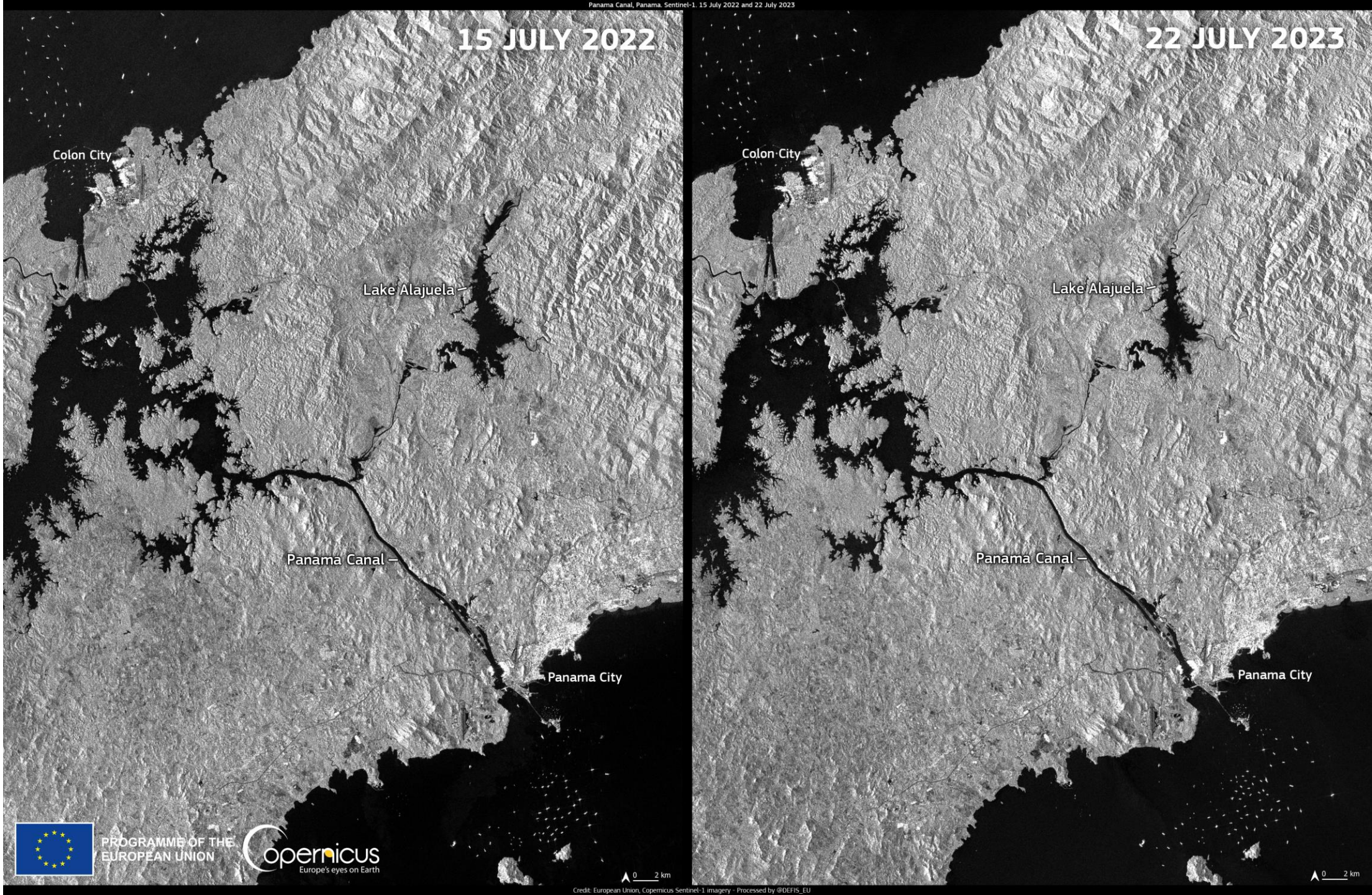
A ship handling simulator was used as a tool for modelling the ship's drift



Oil spill simulation – with the winds and the field of surface currents (Δt=24h)



Water level


Panama Canal, Panama. Sentinel-1. 15 July 2022 and 22 July 2023
15 JULY 2022
22 JULY 2023
Colon City
Lake Alajuela
Panama Canal
Panama City
PROGRAMME OF THE EUROPEAN UNION
Copernicus
Europe's eyes on Earth
0 2 km
Credit: European Union, Copernicus Sentinel-1 imagery - Processed by @DEFIS_EU

PROGRAMME OF THE EUROPEAN UNION

Copernicus
Europe's eyes on Earth

Copernicus Marine Service

24 July 2023

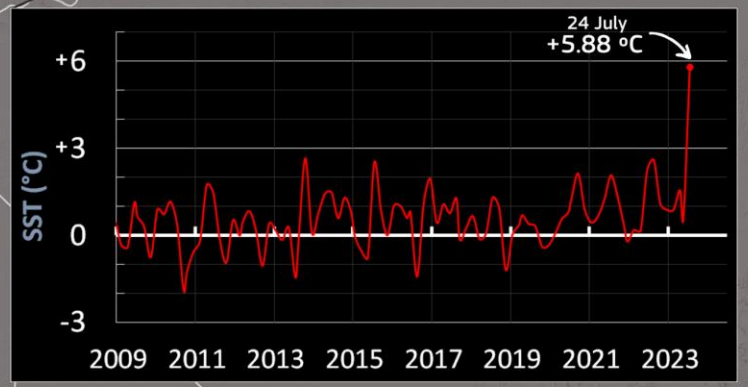
Sea Surface Temperature Anomaly (°C)

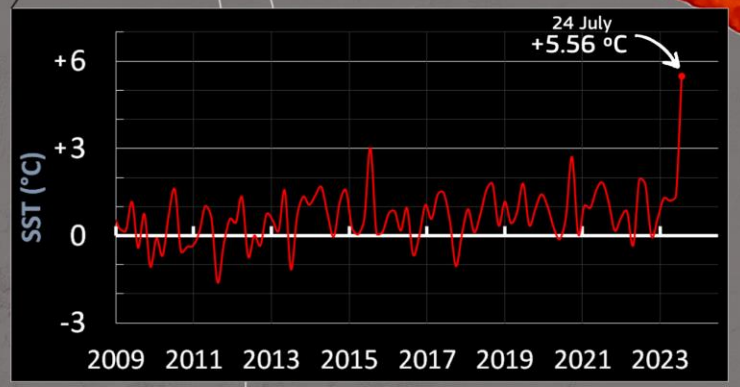
<0°C ≥5°C

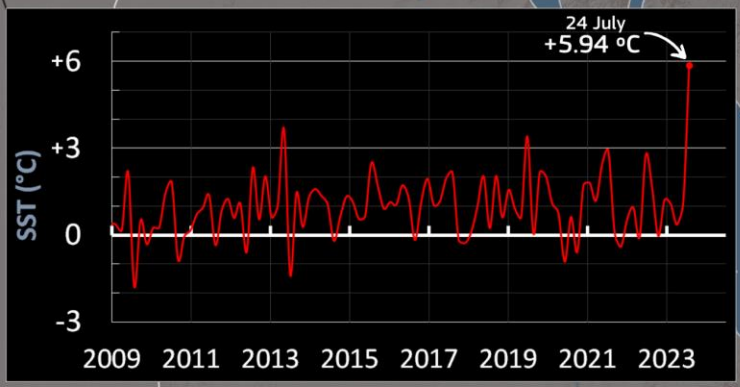
N

150 km

Geneva
Milan
Ljubljana
Zagreb
Belgrade
Bucharest
San Marino
Monaco
Sarajevo
Andorra
Pristina
Sofia
Podgorica
Skopje
Istanbul
Rome
Tirana
Ankara
Madrid
Lisbon
Athens
Nicosia
Algiers
Tunis
Beirut
Damascus
Valletta
Rabat
Casablanca
Tel Aviv-Yafo
Amman
Jerusalem
Tripoli
Cairo

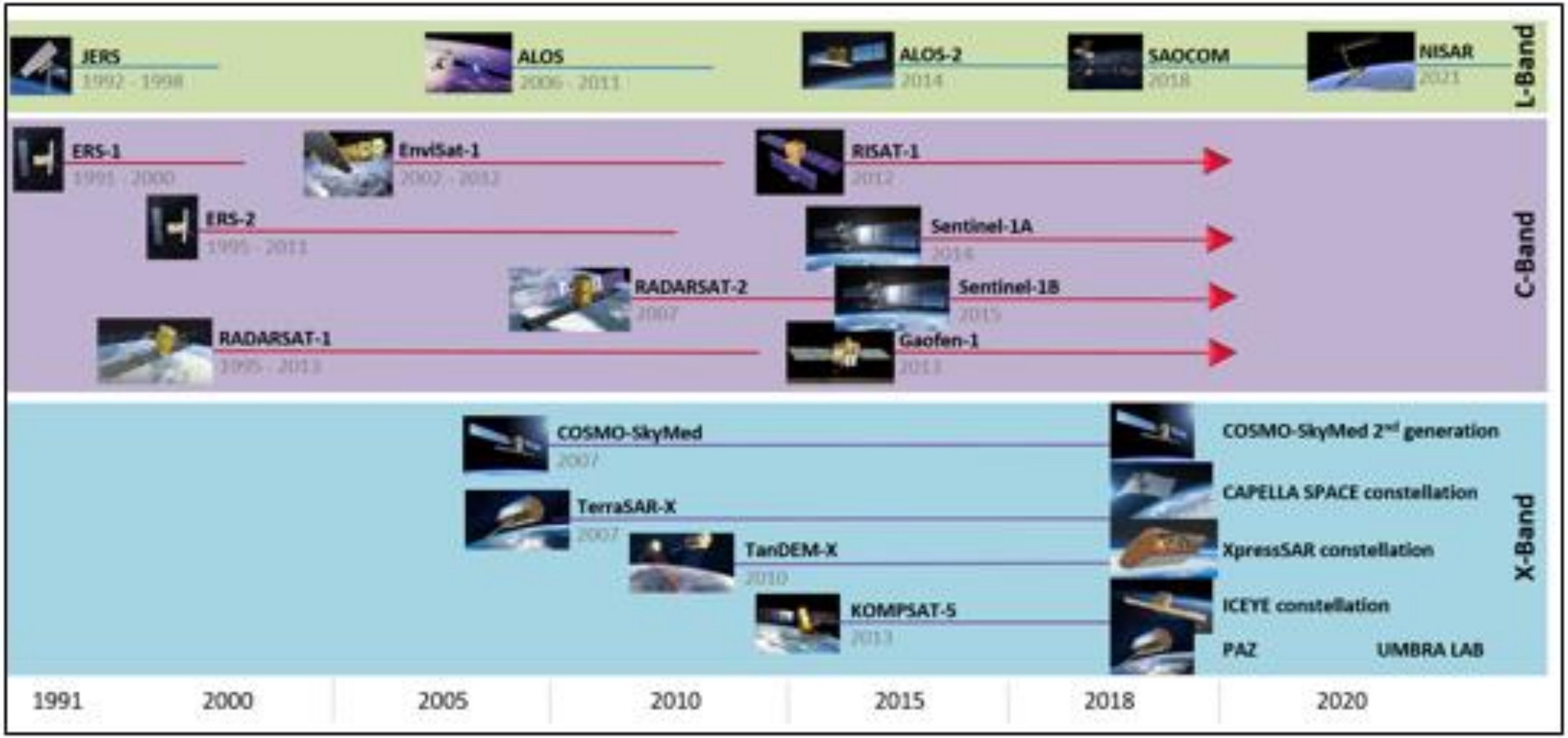




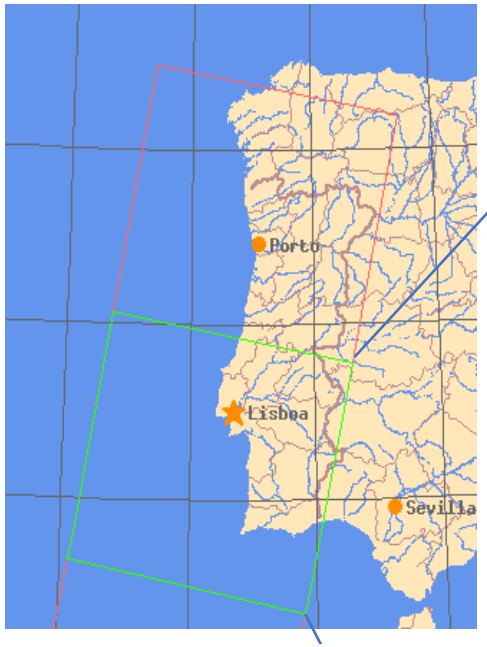



Conclusion
inert gas; scrubber effluent
(soot)

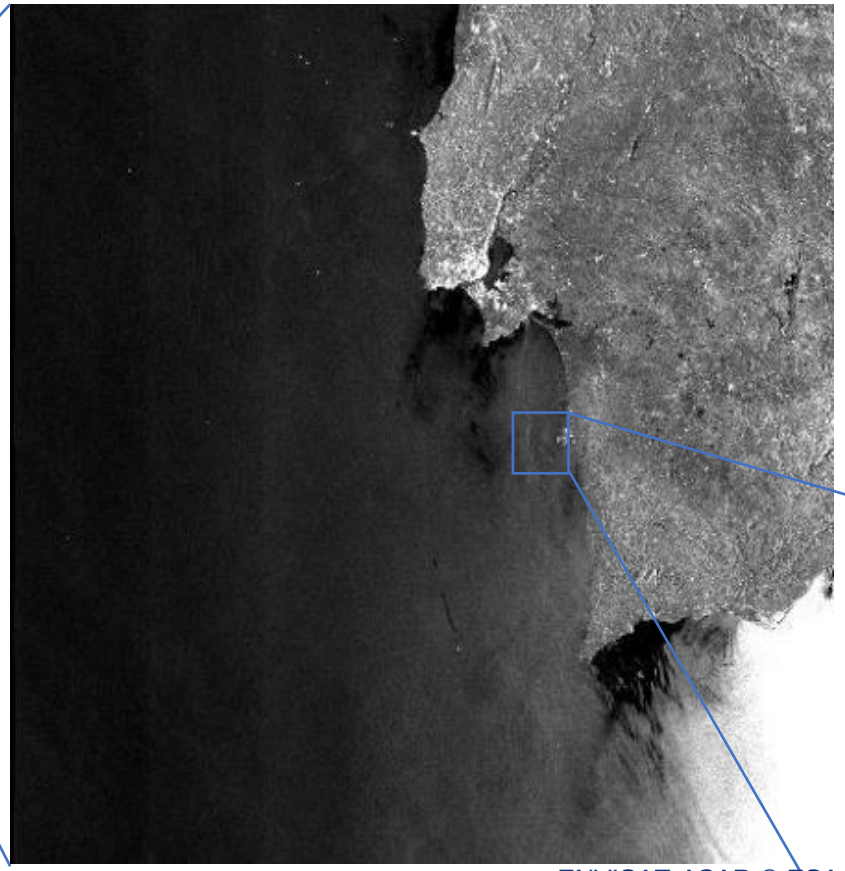
Thank You


JERS
1992 - 1998
ALOS
2006 - 2011
ALOS-2
2014
SAOCOM
2018
NISAR
2021
L-Band
ERS-1
1991 - 2000
EnviSat-1
2002 - 2012
RISAT-1
2012
ERS-2
1995 - 2011
Sentinel-1A
2014
RADARSAT-2
2007
Sentinel-1B
2015
RADARSAT-1
1995 - 2013
Gaofen-1
2013
C-Band
COSMO-SkyMed
2007
COSMO-SkyMed 2nd generation
CAPELLA SPACE constellation
TerraSAR-X
2007
XpressSAR constellation
TanDEM-X
2010
ICEYE constellation
KOMPSAT-5
2013
PAZ
UMBRA LAB
X-Band
1991
2000
2005
2010
2015
2018
2020

Satellite radar image – Wide

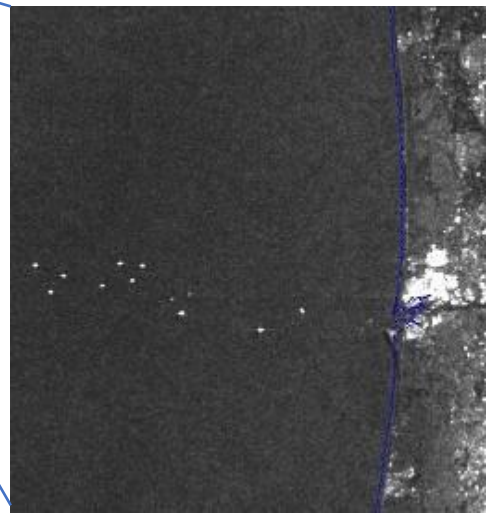


300-400 km swath



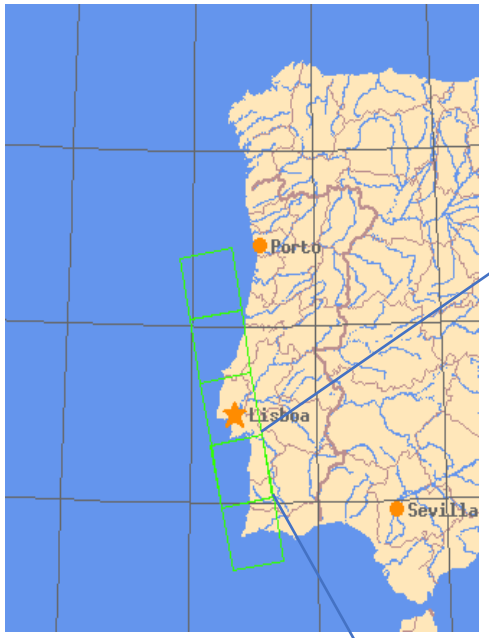
ENVISAT-ASAR © ESA

50-150 m resolution

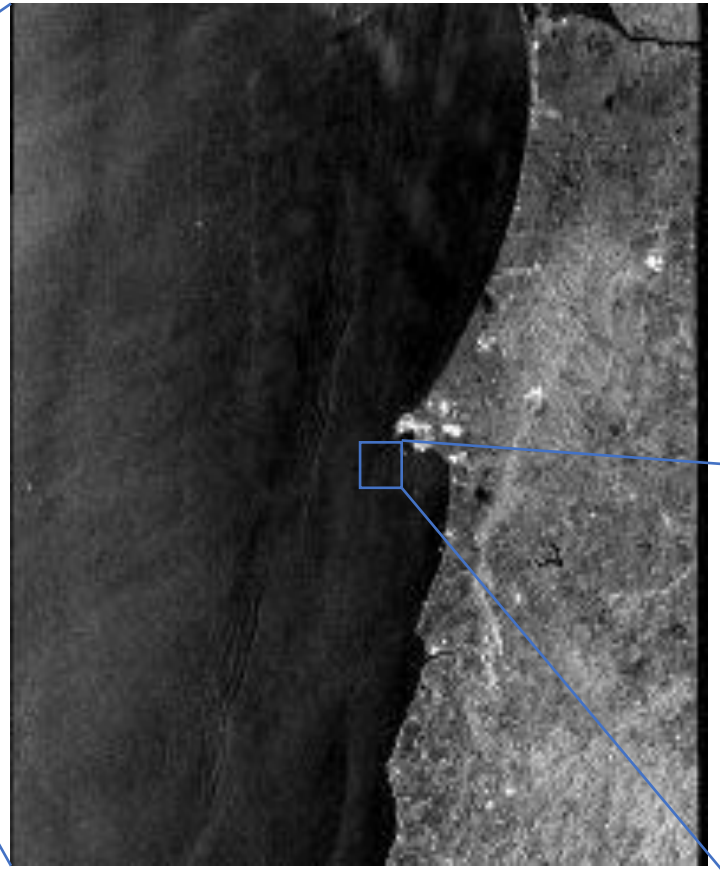


only to show relative size, not actual zoom→

Satellite radar image – Standard

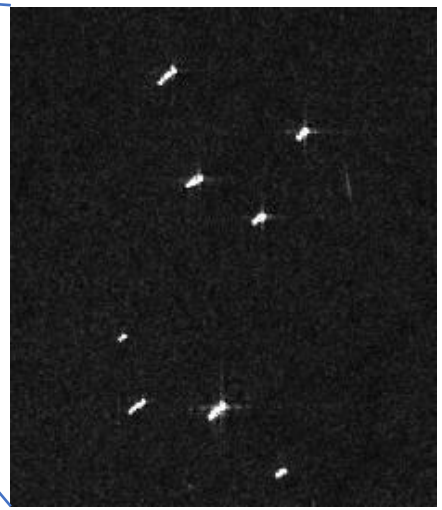


100 km swath



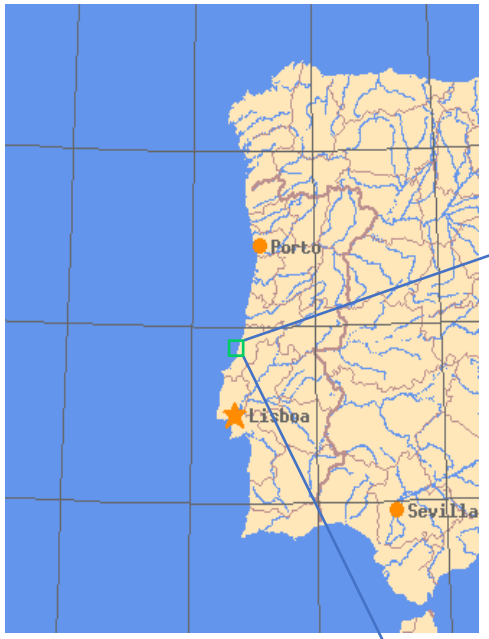
ENVISAT-ASAR © ESA

25 m resolution

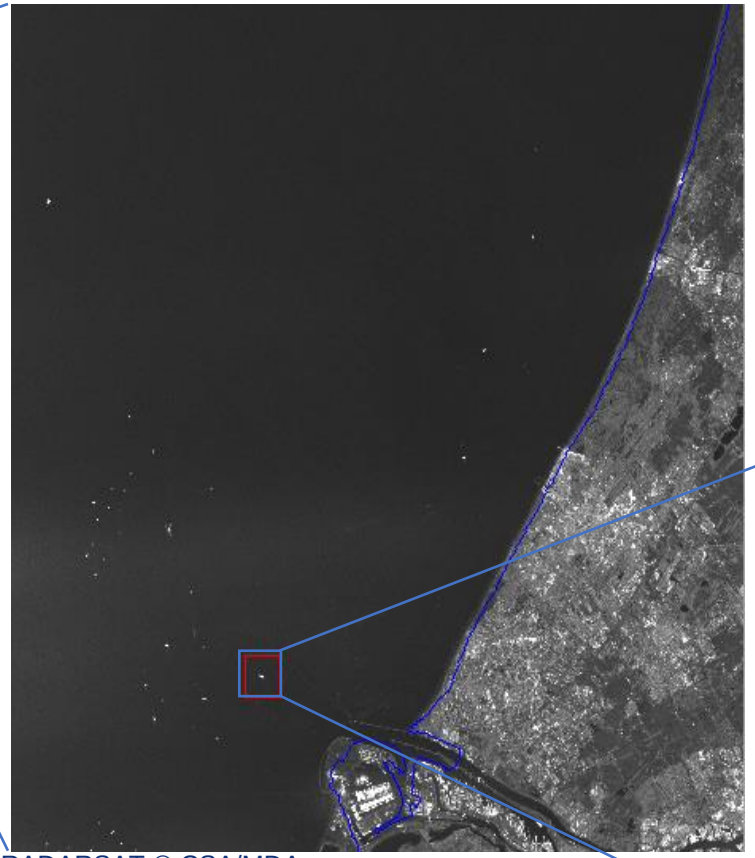


RADARSAT © CSA/MDA

Satellite radar image – High resolution

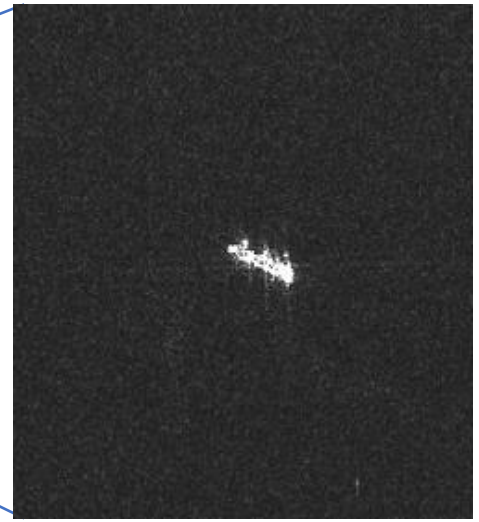


50 km swath



RADARSAT © CSA/MDA

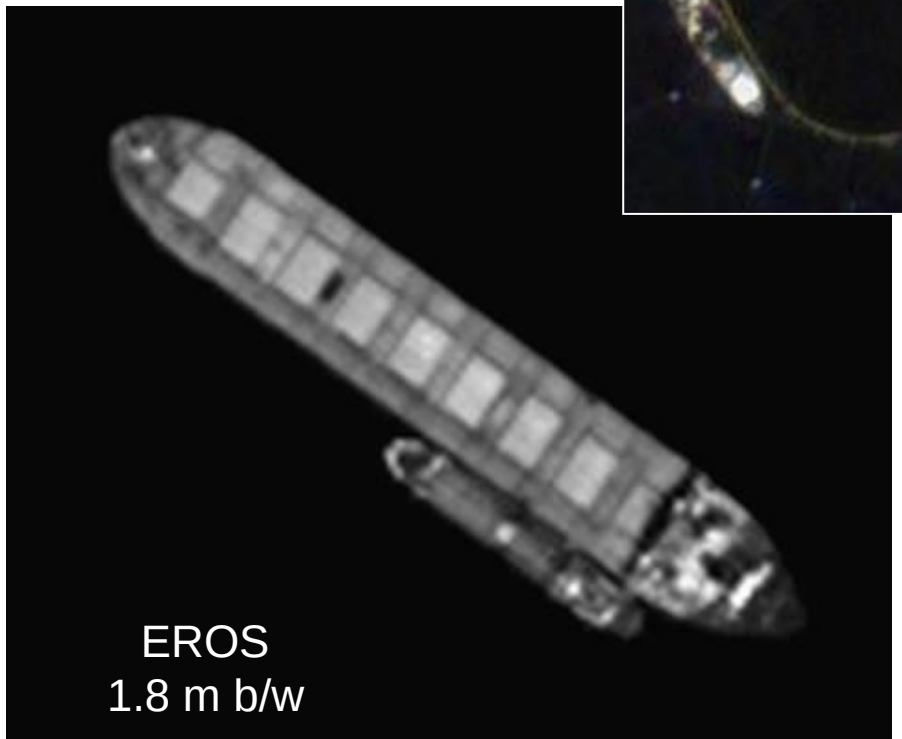
10 m resolution

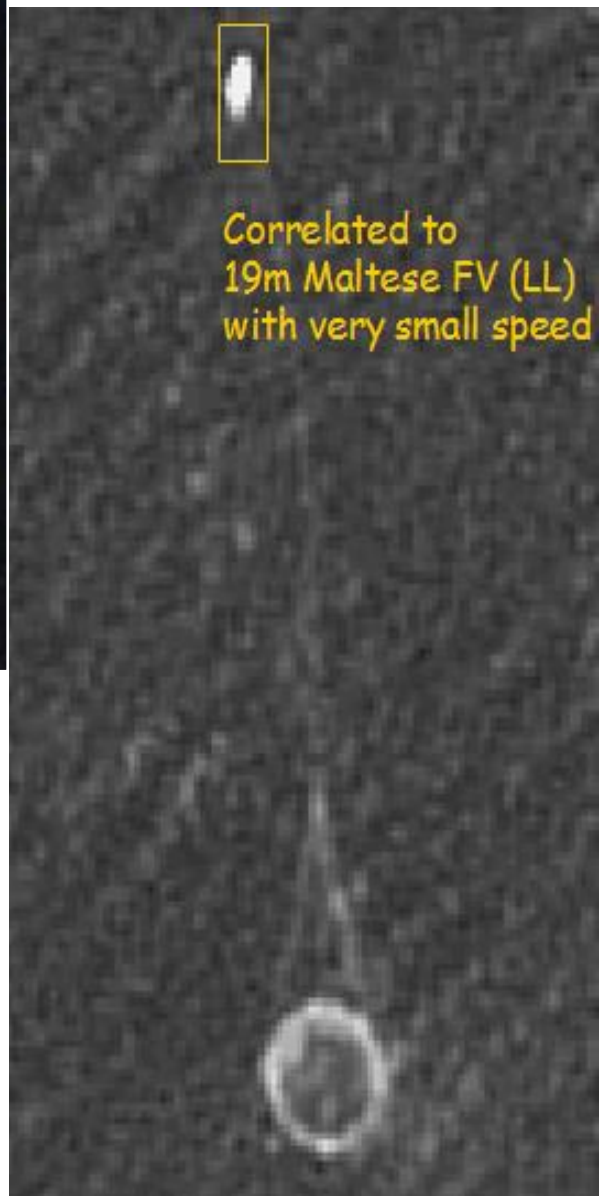


RADARSAT © CSA/MDA

Optical satellite images

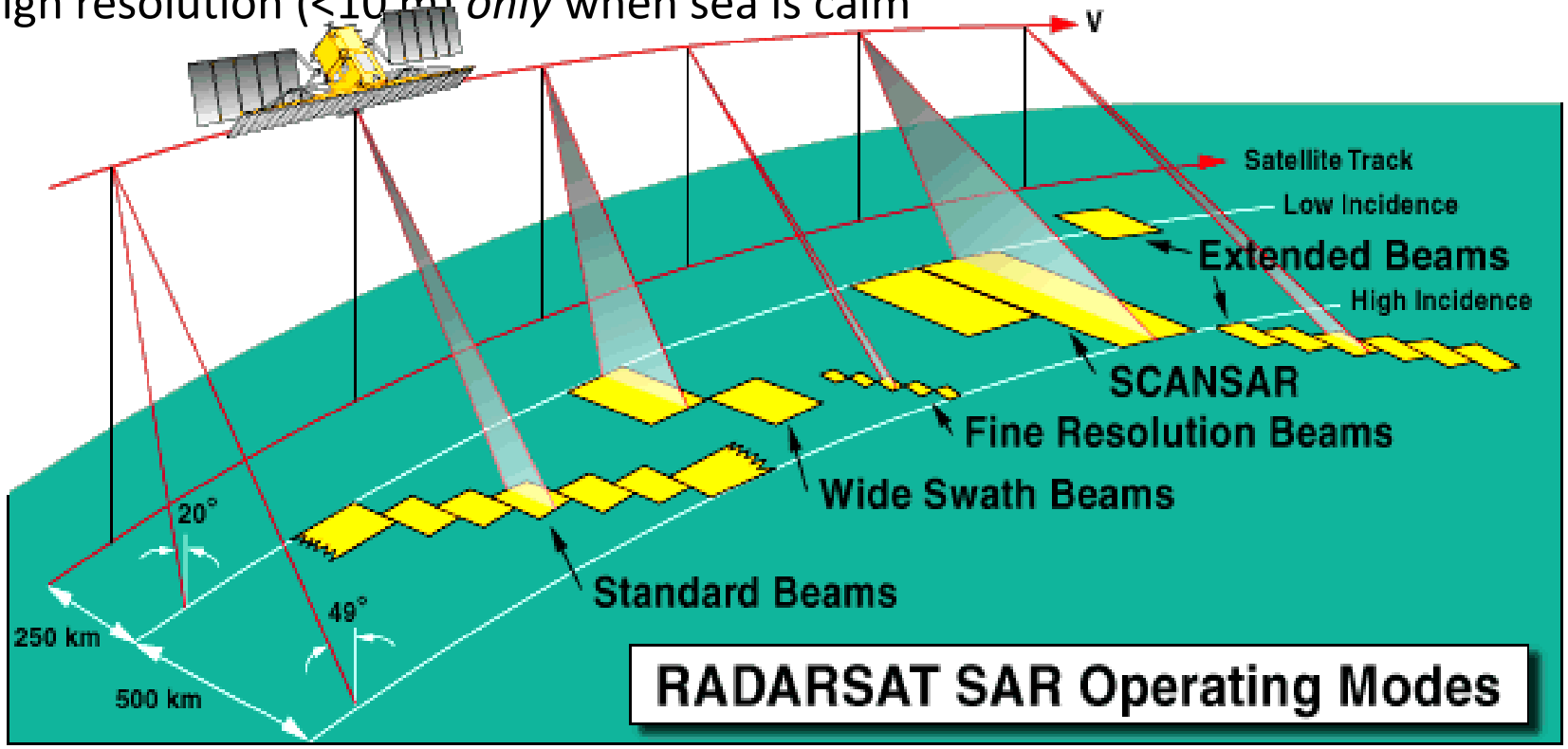
Sub-meter resolution, ~15 km swath





Synthetic Aperture Radar (SAR)

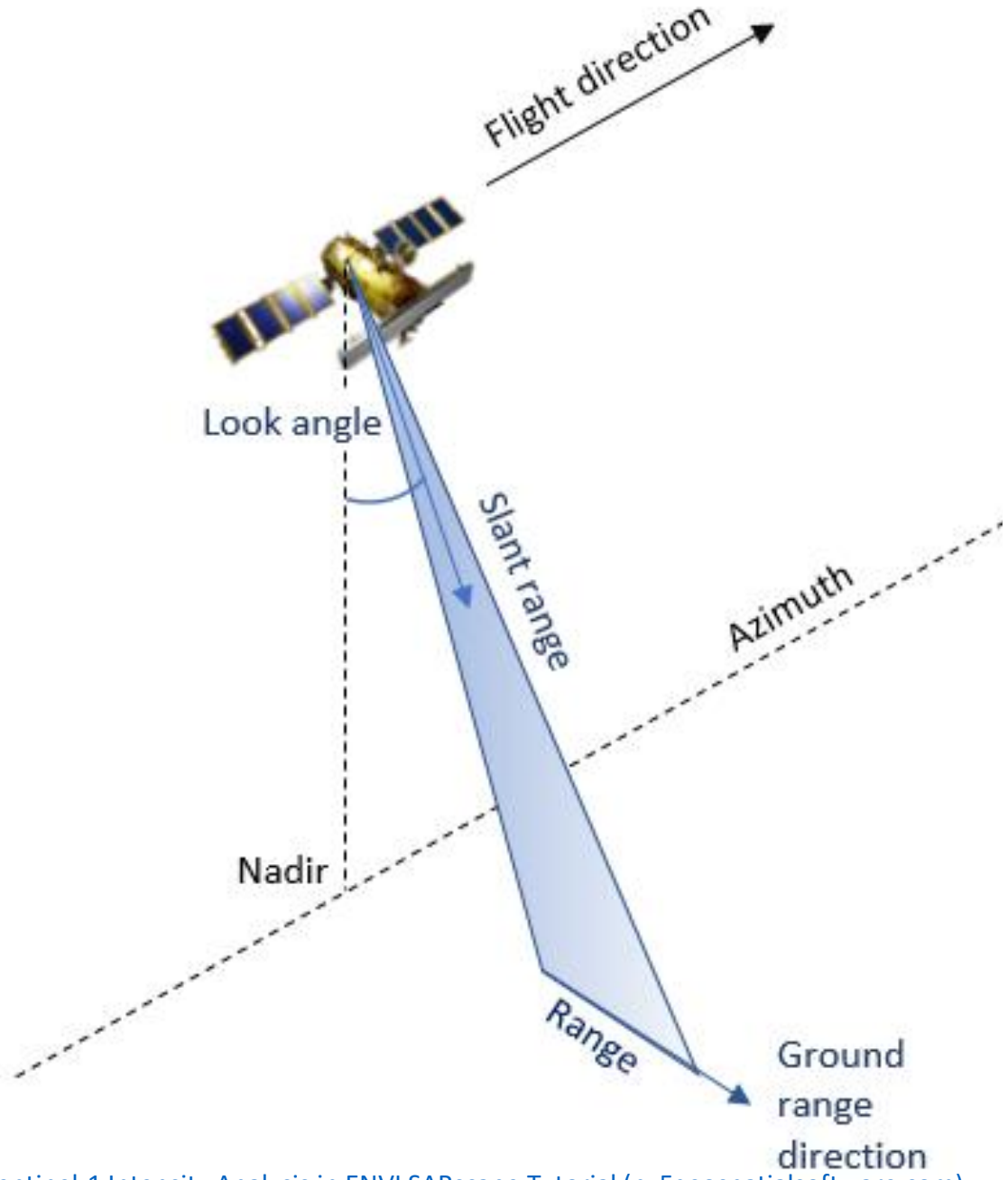
- Radar, suitable for use on satellite
- Wide area, low resolution
- Narrow area, high resolution
- High resolution (<10 m) *only* when sea is calm

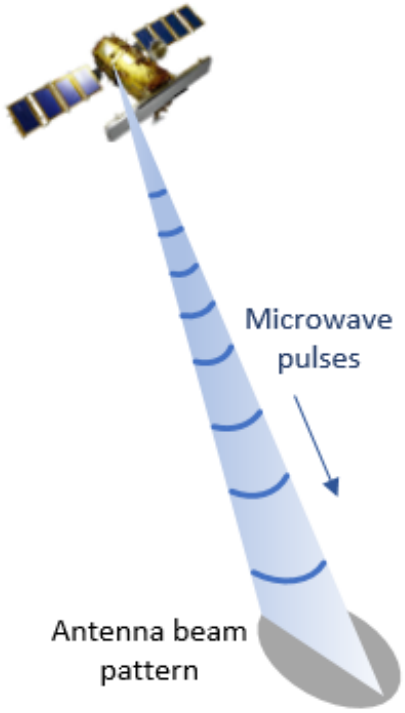


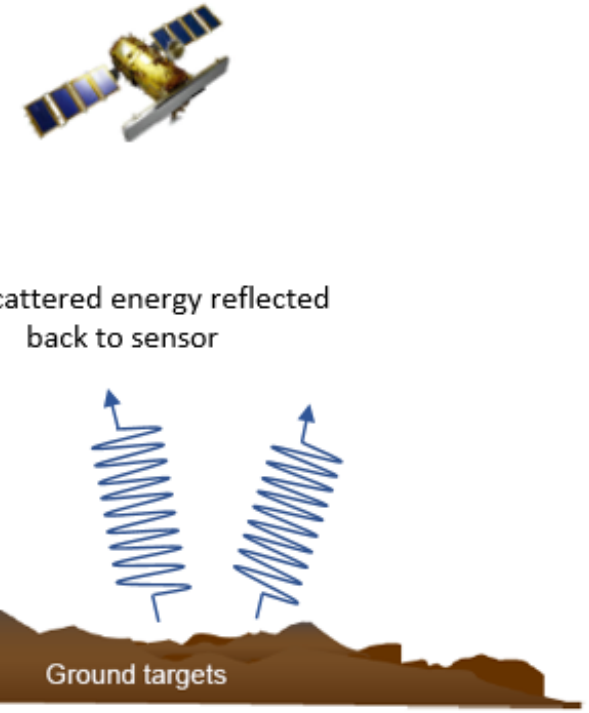
Sentinel Online – Technical Guide

- Sentinel-1 SAR - Technical Guide - Sentinel Online - Sentinel Online (esa.int)
- Ground Range Detected - Sentinel-1 SAR Technical Guide - Sentinel Online - **Sentinel Online (esa.int)**
- **ASAR-Product-Handbook.pdf (esa.int)** **OIL**

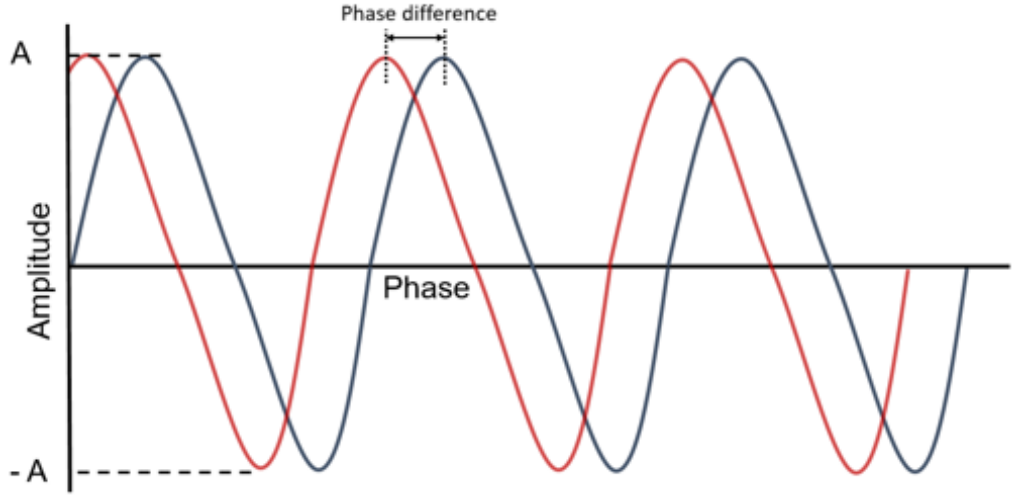
Ocean







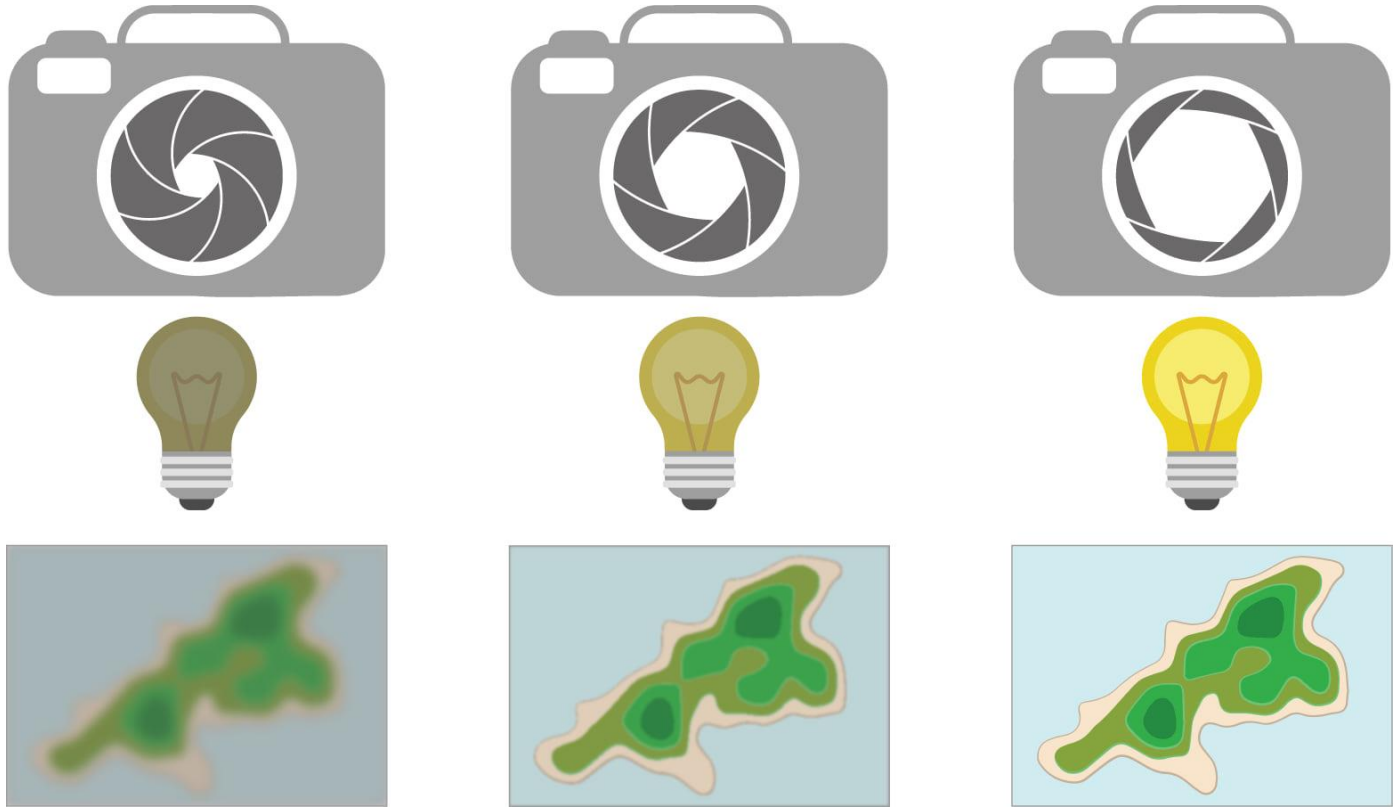
Backscatter consists of two variables: *amplitude* and *phase*



[Sentinel-1 Intensity Analysis in ENVI SARscape Tutorial (nv5geospatialsoftware.com)]

ESRI

- Introduction to Synthetic Aperture Radar (esri.com)
- GUIDE: FUNDAMENTALS OF SYNTHETIC APERTURE RADAR (SAR) (arcgis.com)



NASA-ARSET

- ARSET - Introduction to Synthetic Aperture Radar | NASA Applied Sciences
- **Session 1: Basics of Synthetic Aperture Radar (SAR)**
- **Session 2: SAR Processing and Data Analysis**
- **Session 3: Introduction to Polarimetric SAR**
- **Session 4: Introduction to SAR Interferometry**