Decarbonizing Maritime Transport

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Coriolis Seminars
for the Environment

Développement
Durable à l'X

WORLD SHIPPING INDUSTRY

~ 60 000 SHIPS (>5000GT)

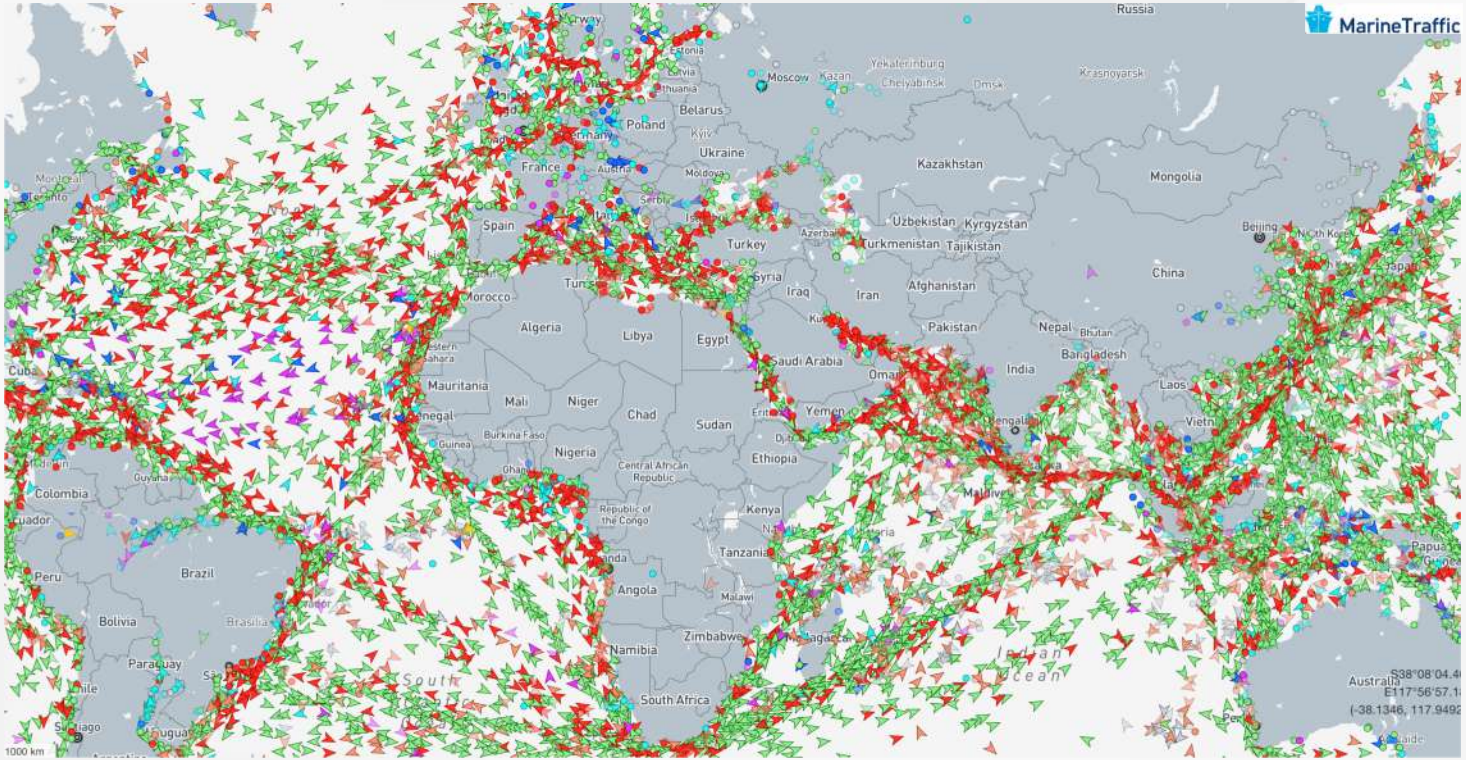
~ 300 Mt / year

~ 170 B€ / year

~ 1 Gt / year [(1)]

[(1)] IEA

TODAY SNAPSHOT …

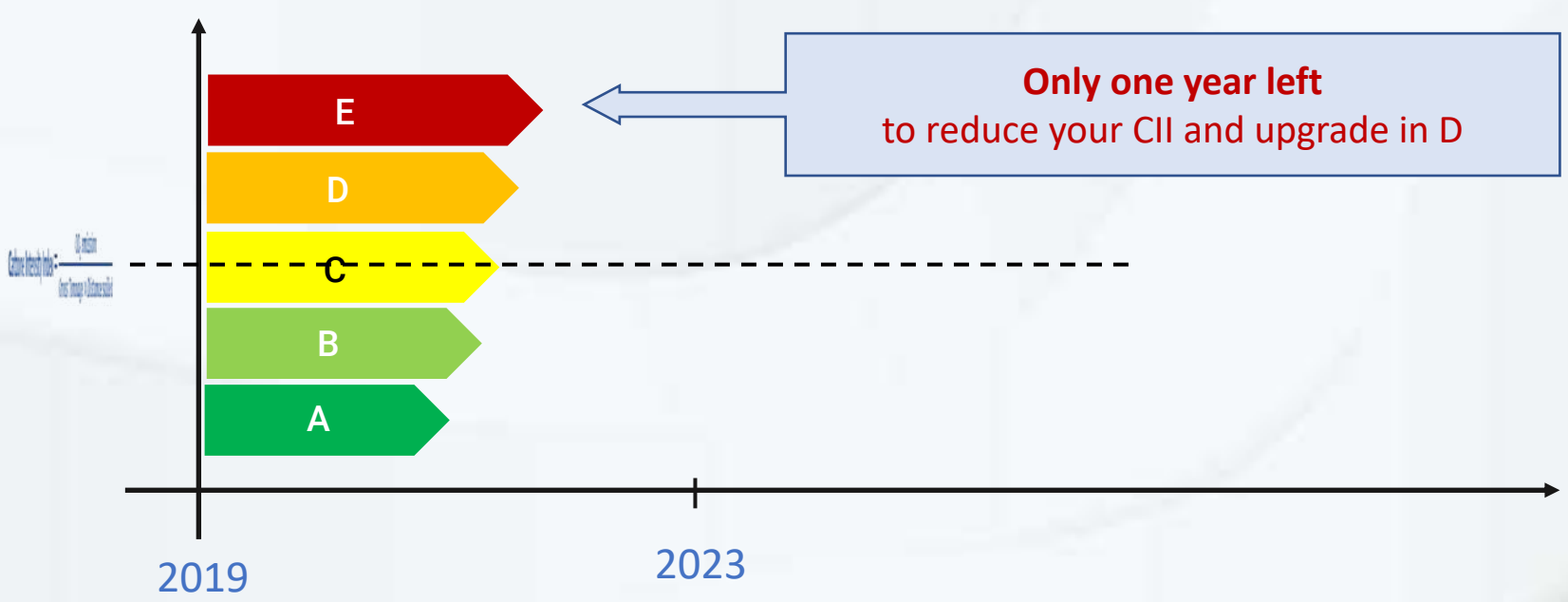


REGULATIONS FOR DECARBONIZATION

NEW INTERNATIONAL REGULATION

Carbone Intensity Index = $\frac{CO_2\ emission}{Gross\ Tonnage \times Distance\ sailed}$

From 1st of January 2023
every ship
needs to calculate it's annual ***CII***



Only one year left
to reduce your CII and upgrade in D

NEW INTERNATIONAL REGULATION

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every ship
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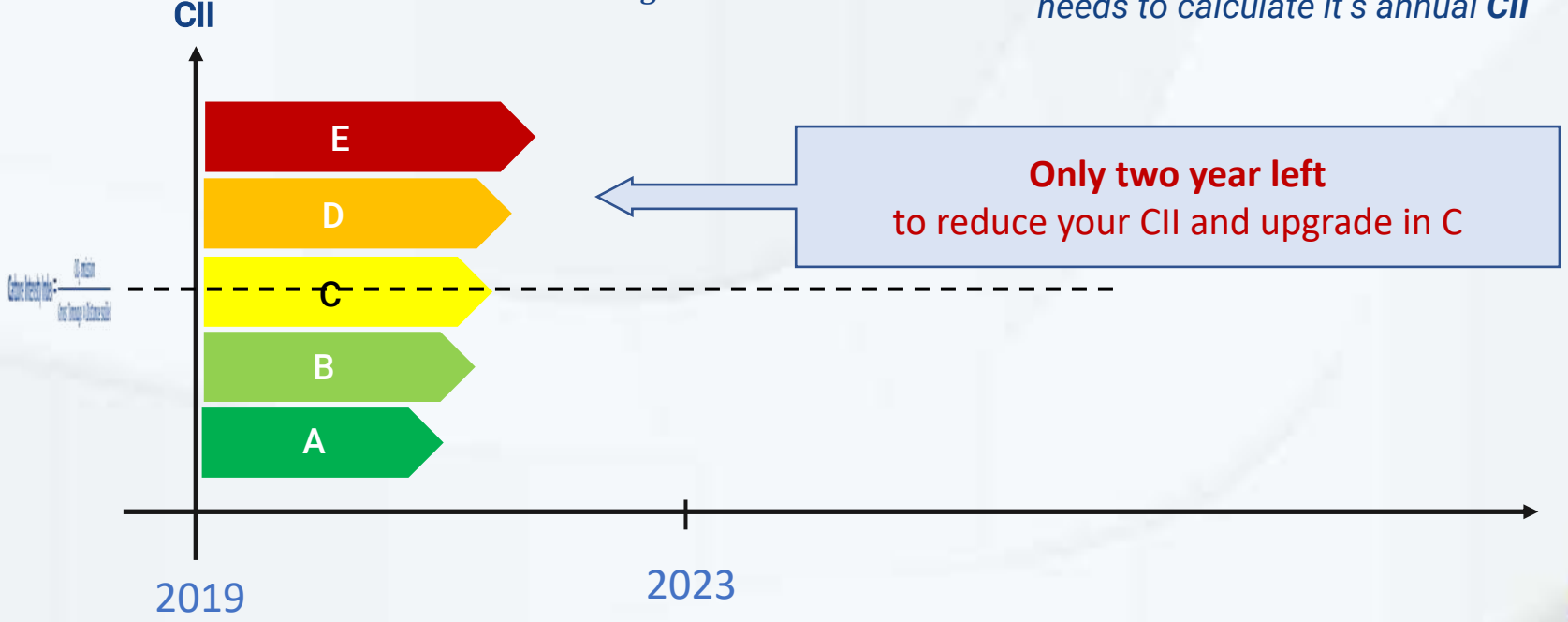
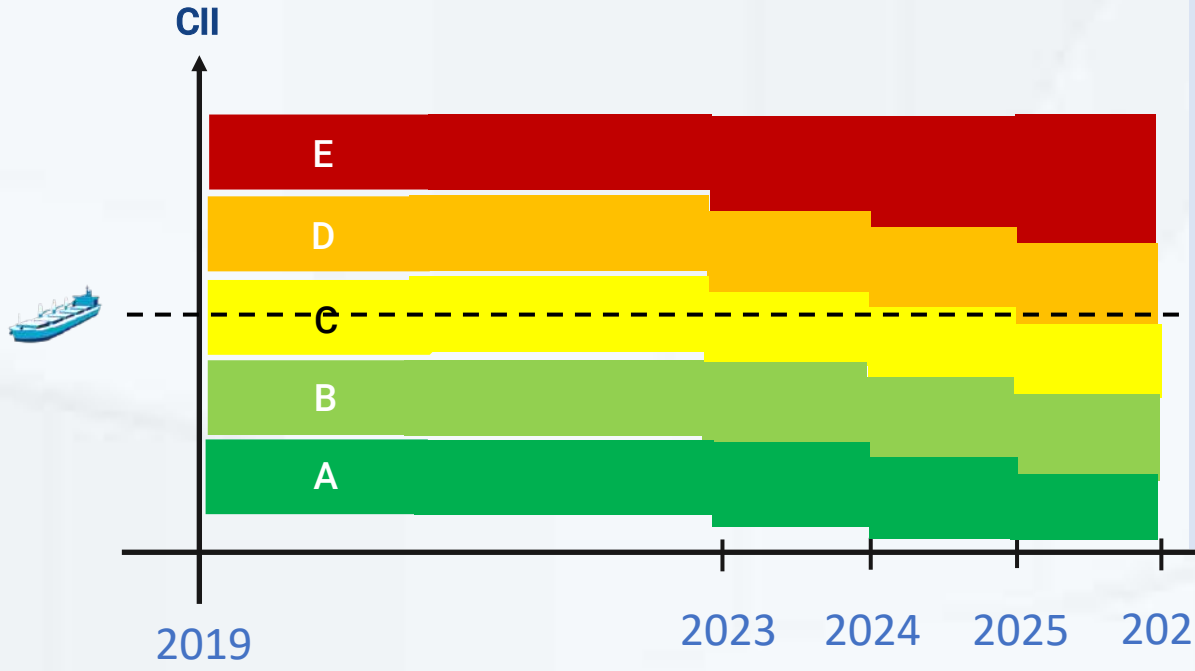


CII DRIVES MARITIME DECARBONISATION

Class margins drop by 2% every year and a ship that doesn't improve it's **CII** will eventually be demoted !



Charterers, banks and S&P market mount pressure on CII !

SHIPOWNERS

CHARTERERS → FREIGHT

BANK → RATES

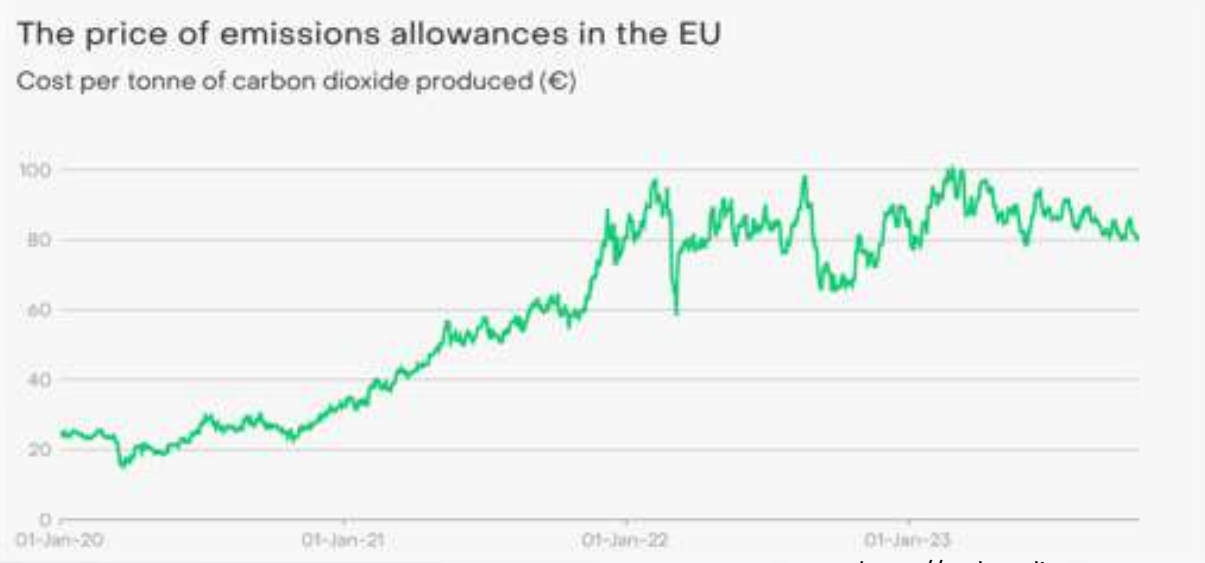
S&P Market → Ship VALUE

EU Emission **T**rading **S**ystem (**ETS**)

HAVE YOU HEARD ABOUT IT ?

EU Emission Trading System (ETS)
WILL DRIVES MARITIME DECARBONISATION AFTER 2024 ?

Cap and Trade of **E**mission **U**nit of **A**llowance (1 **EUA** = 1 CO_2 Tonne)



https://ember-climate.org

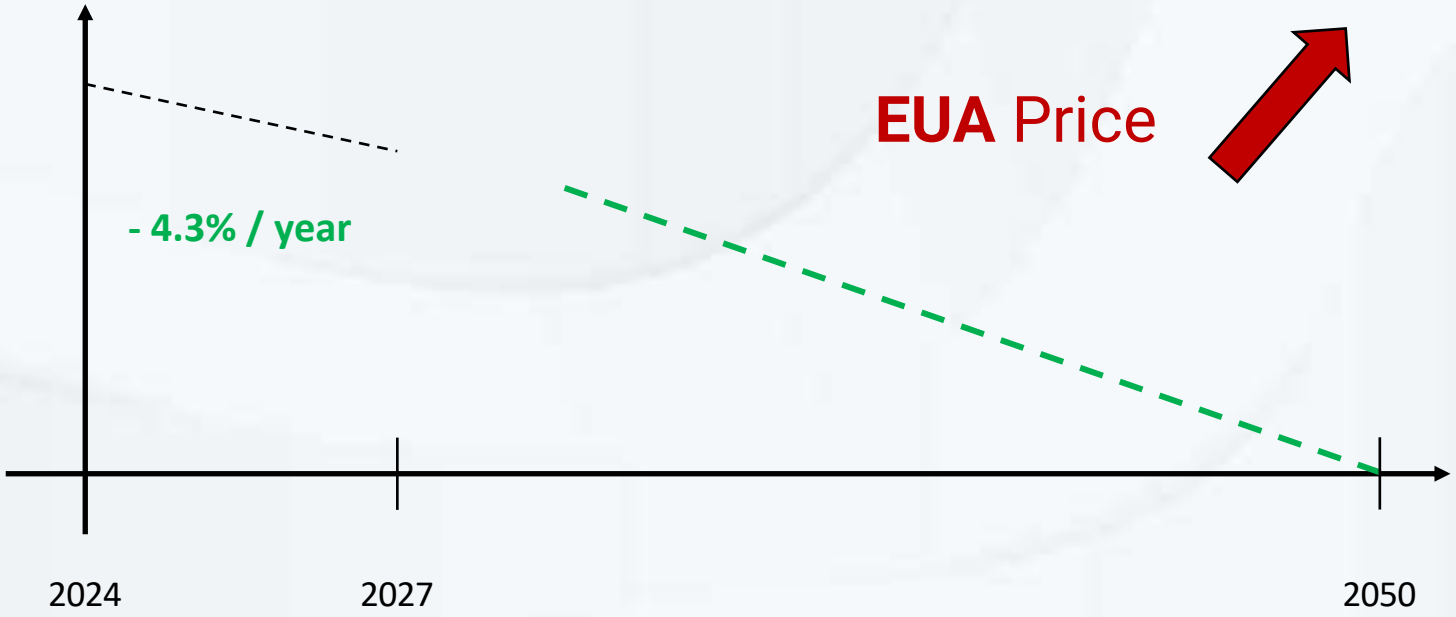
~ 80-90 €

1 T of HFO=3.1 T of CO_2

Free allowances will not be granted to shipping !

EU Emission Trading System (ETS)
WILL DRIVES MARITIME DECARBONISATION AFTER 2024 ?

Total number of **E**mission **U**nit of **A**llowance (1 **EUA** = 1 CO_2 Tonne)



EU Emission Trading System (ETS)
WHICH VOYAGES ARE CONCERNED ?

All cargo ships (>5000 GT) entering EU port will have to pay for its CO_2 emissions

EU Emission Trading System (ETS)
WHICH SHIPS ARE CONCERNED ?

Year	Ships regulated	% of covered emissions regulated	GHGs
2024	Cargo and passenger above 5,000 GT	40%	CO_2
2025		70%	
2026		100%	CO_2 - CH_4 - N_20
2027	Cargo and passenger above 5,000 GT *Depending on legislative review: offshore ships above 5,000 GT and cargo and passenger ships above 400 GT*		

EU Emission Trading System (ETS)
IMPACT ON « TOTAL FUEL PRICE » ?

1 Ton HFO ➡ 3.1 Ton CO_2 ➡ 3.1 EAU

495 $	(100% ETS)	248 €	+ 50%
	(50% ETS)	124 €	+ 25%

TOMORROW ?

WHICH SOLUTIONS FOR DECARBONISATION ?

TODAY

OPTIMISATION
FOR A GREEN VOYAGE

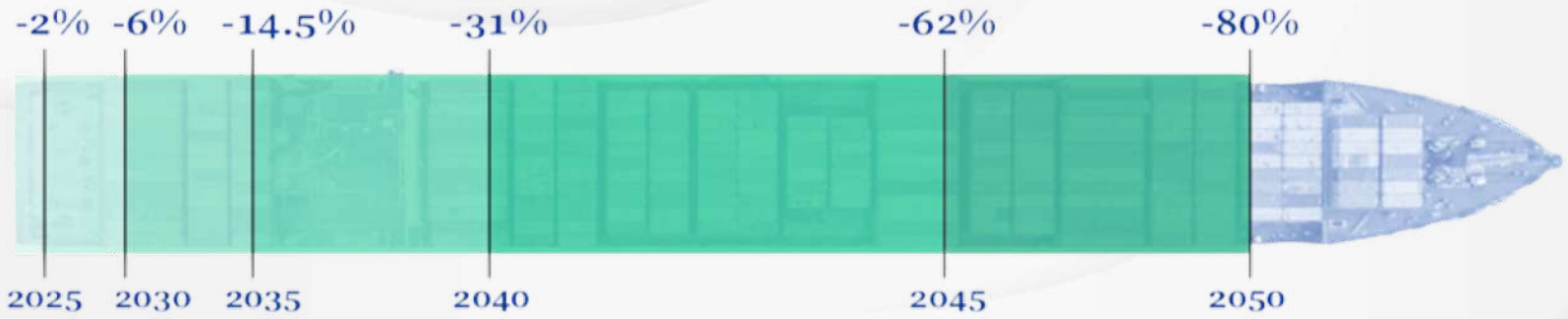
MID- TERM

New/Bio Fuels

LONG-TERM

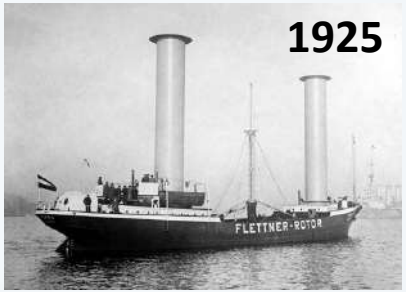
New Ships/Propulsion

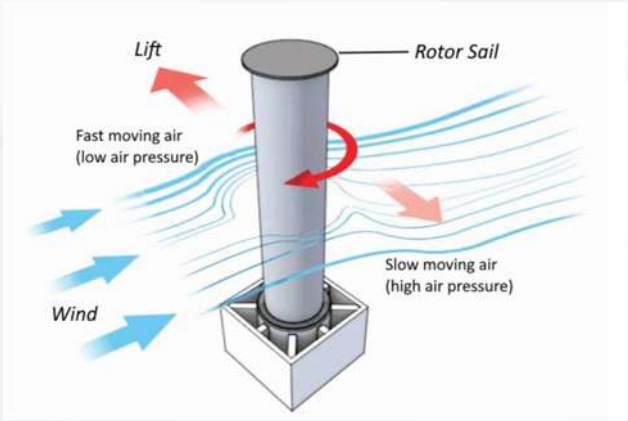
Annual average carbon intensity reduction compared to the average in 2020



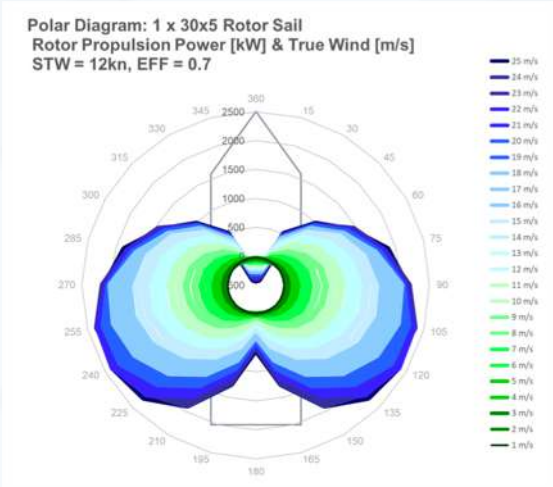
WIND ASSITSED SHIP PROPULSION

WIND PROPULSION FOR SHIPS: Flettner rotors





Lift force perpendicular to the wind



WIND PROPULSION FOR SHIPS: Flettner rotors

© Wind Ship

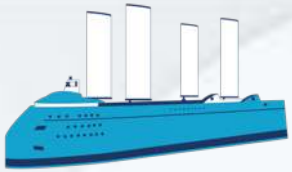
up to **5-25 %**

fuel reduction

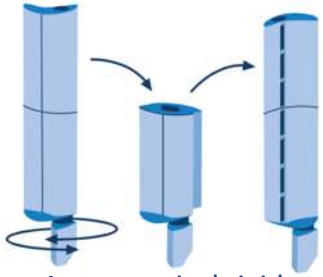
depending on winds

2025 : 200 rotors ?

WIND PROPULSION FOR SHIPS: Sails



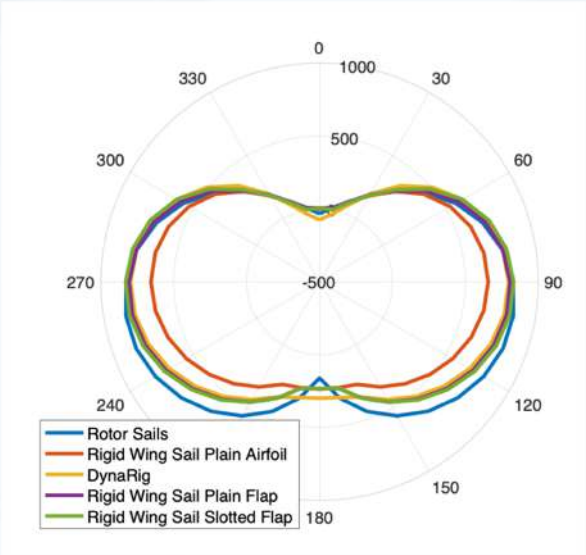
Symmetrical inflatable



Asymmetrical rigid

Multi-elements
reefable/furlable

Optimal performance
for **sideway winds**



WIND PROPULSION FOR SHIPS: Sails

up to **5-25 %**

fuel reduction

depending on wings, winds and boat speed

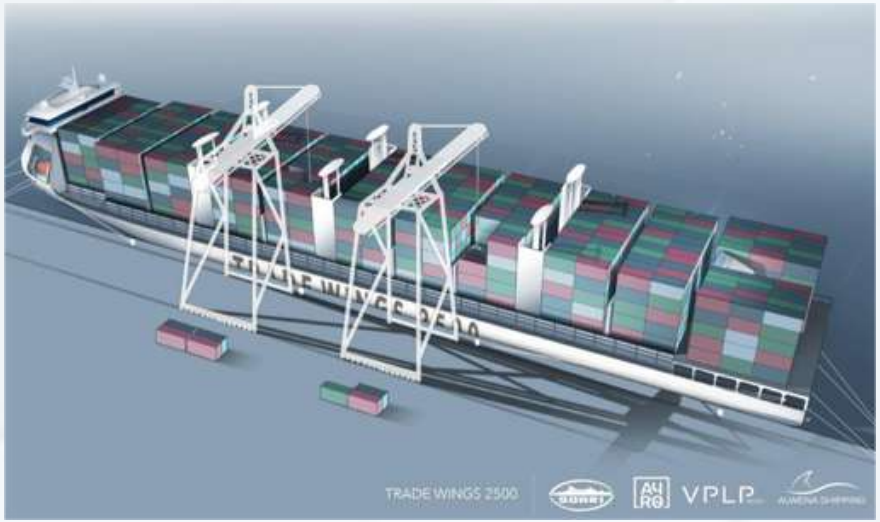
WIND PROPULSION FOR SHIPS: OTHER DRAWBACKS

Retractable systems
for **complex harbors**

Retractable systems
for **loading/unloading**

WIND PROPULSION FOR SHIPS: OTHER DRAWBACKS

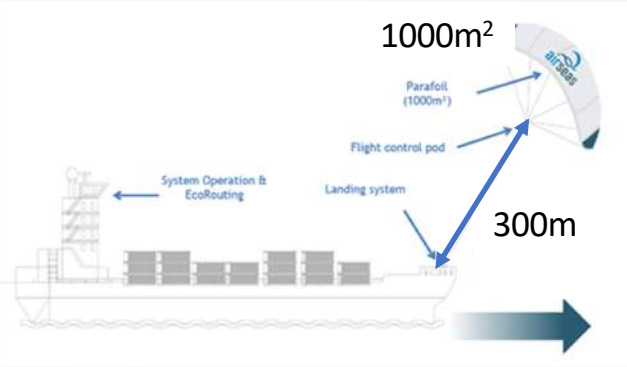
Retractable systems
for **complex harbors**



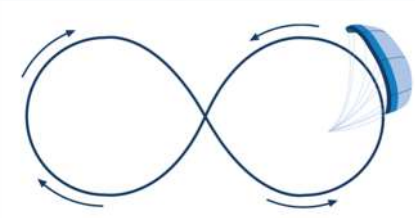
Retractable systems
for **loading/unloading**

WIND PROPULSION FOR SHIPS: Kite

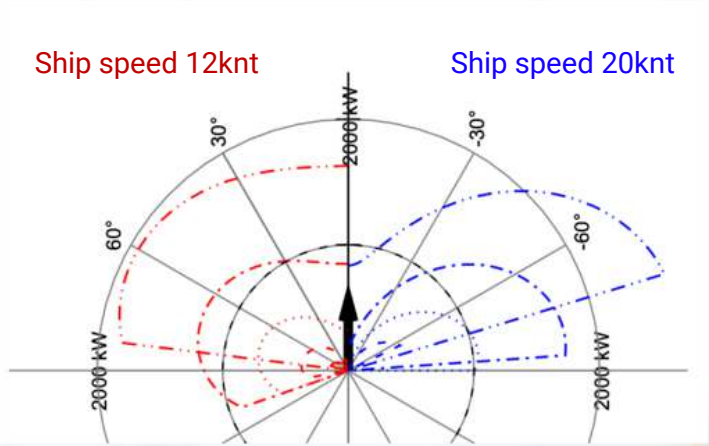
Higher altitude winds



Dynamic flight



Optimal performance
for **upwinds**



WIND PROPULSION FOR SHIPS: parafoil kite

up to **20 %**

fuel reduction

under trial

WIND PROPULSION FOR SHIPS: CargoKite + foils !

Kite up to 300m

Foils with control & stabilization system

Traction mode
speed up to 30knots

Power generation mode
electricity generation

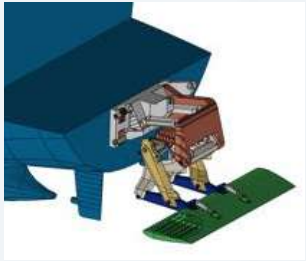
Micro Cargo
16-48 EVP

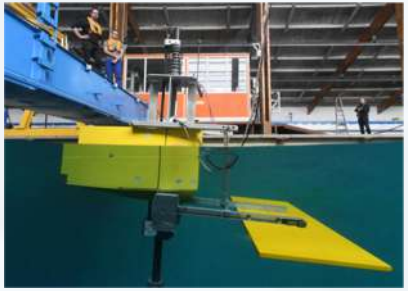
Micro Ro-Ro

First prototype
under trial !

info@cargokite.com

WAVE PROPULSION FOR SHIPS : WHALE TAIL !





Articulated hydrofoil
on the stern of the ship

Hydrofoils
with control & stabilization system

Propulsion mode
harnesses the power of the swell
Benefit from ship's pitch

up to **20-30 %**

fuel savings

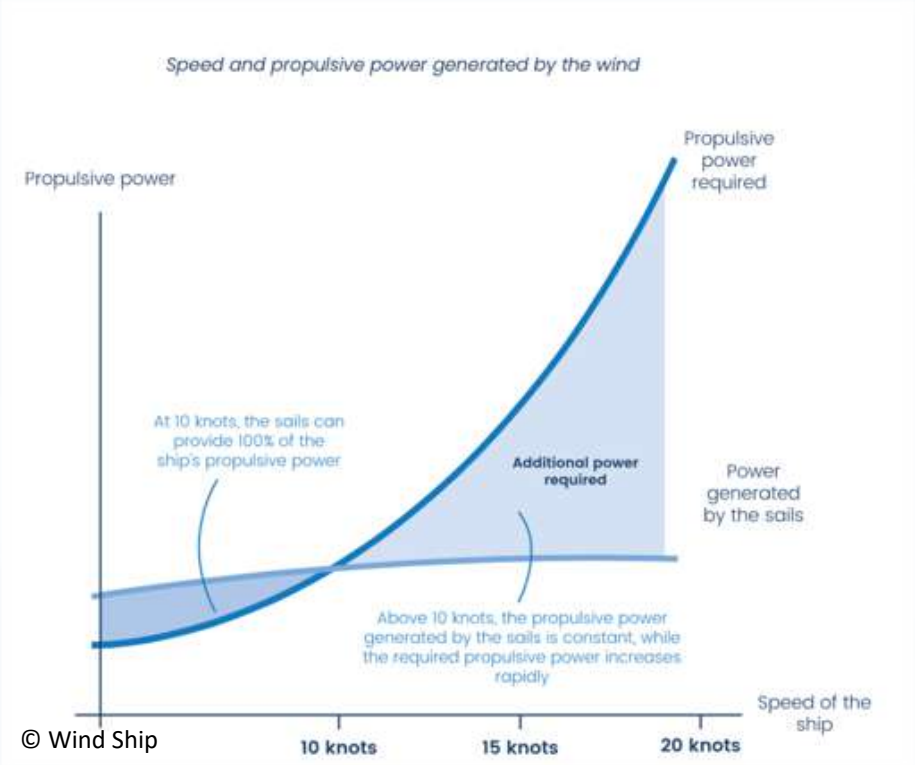
according to

BLUEFINS

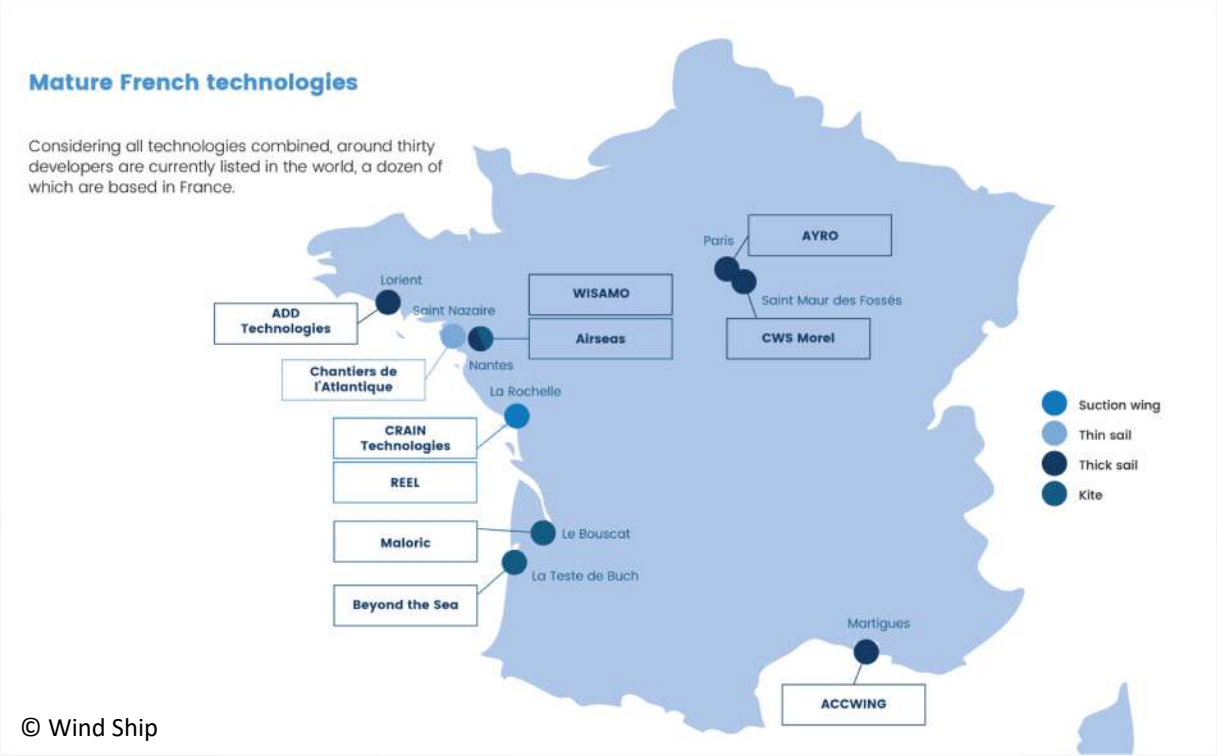
https://bluefins-systems.com

Prototype test
IFREMER test tank

WIND PROPULSION FOR SHIPS: HYBRID or 100% ?



WIND PROPULSION FOR SHIPS: Several French companies



© Wind Ship

WIND ASSISTED SHIP PROPULSION

Twenty-height large cargo vessels using WASP in September 2023 …

still a long way to go !

DECARBONIZED FUEL

BIOFUELS & LOW CARBON FUELS: TODAY

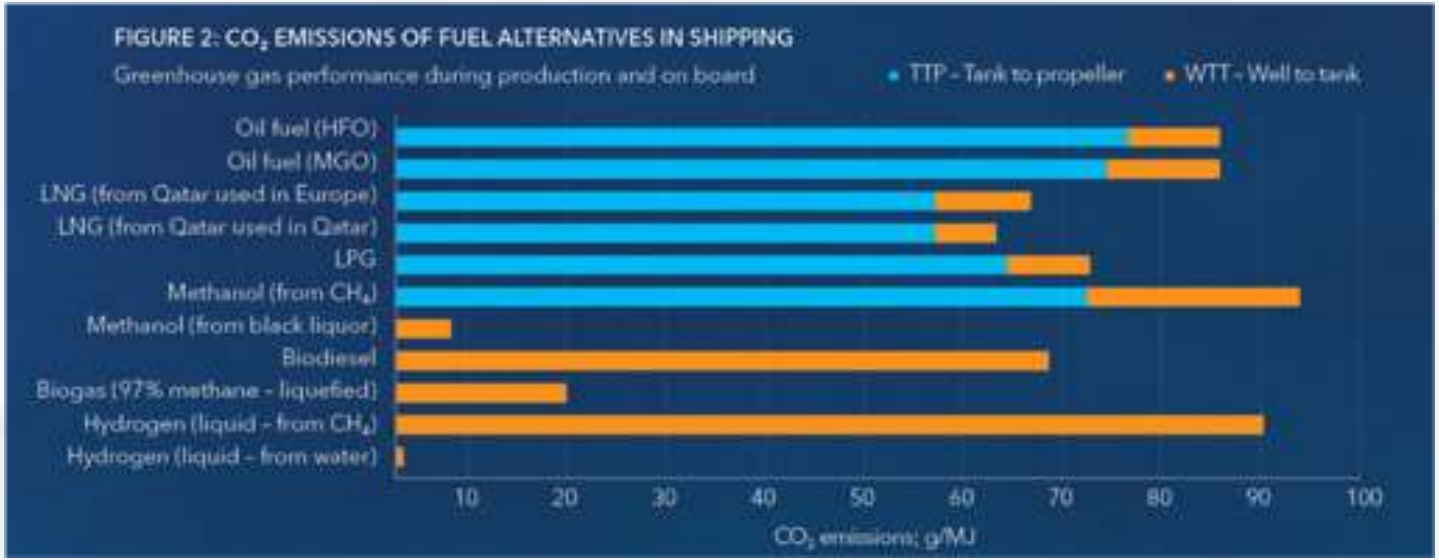
July 2023

Only a few ships are ammonia ready

https://www.dnv.com

LNG : CH_4 Methanol : CH_4O Ammonia : NH_3

BIOFUELS & LOW CARBON FUELS: HOW MUCH LESS ?



https://www.dnv.com

WTT CO_2 & SO_2 EMISSIONS

FUEL	relative % of CO_2	SOx
Heavy Fuel Oil (HFO)	100%	3.5%
Very Low Sulfur Fuel Oil (VLSFO)	100%	0.5%
Marine Gas Oil (MGO)	100%	0.2%
Bio-MGO	79%	0.15%
Liquefied Natural Gaz (LNG)	76 %	0%
BioGaz	20%	0%
Bio Methanol	10%	0%
e-Hydrogen	1-2%	0%

Warning on LNG leakage

GLOBAL WARMING POTENTIAL (GWP): METHANE vs CO2

$CH_4 = 28 \times CO_2$

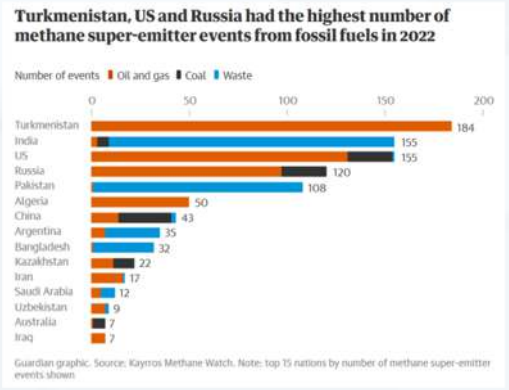
100 year time horizons: GWP100[(1)]

$CH_4 = 80 \times CO_2$

20 year time horizons: GWP20[(1)]

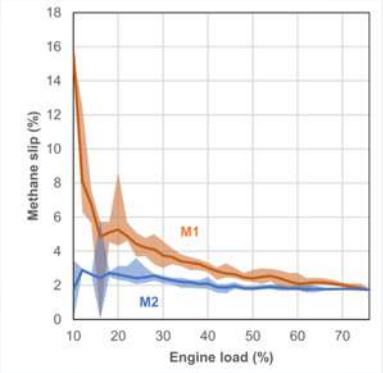
[(1)] IPCC AR6 report 2021

Production /Extraction / Transport



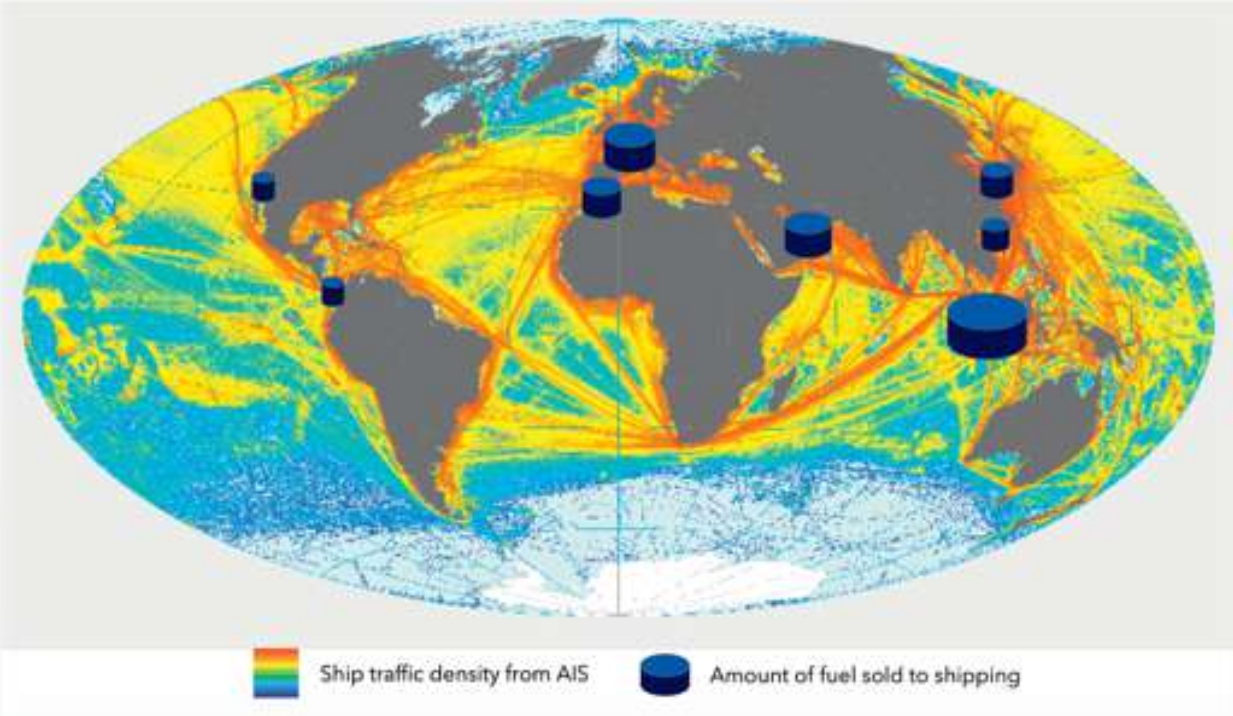
1-2% leakage ruins the benefit on CO_2 reduction

Incomplete combustion LNG Carrier

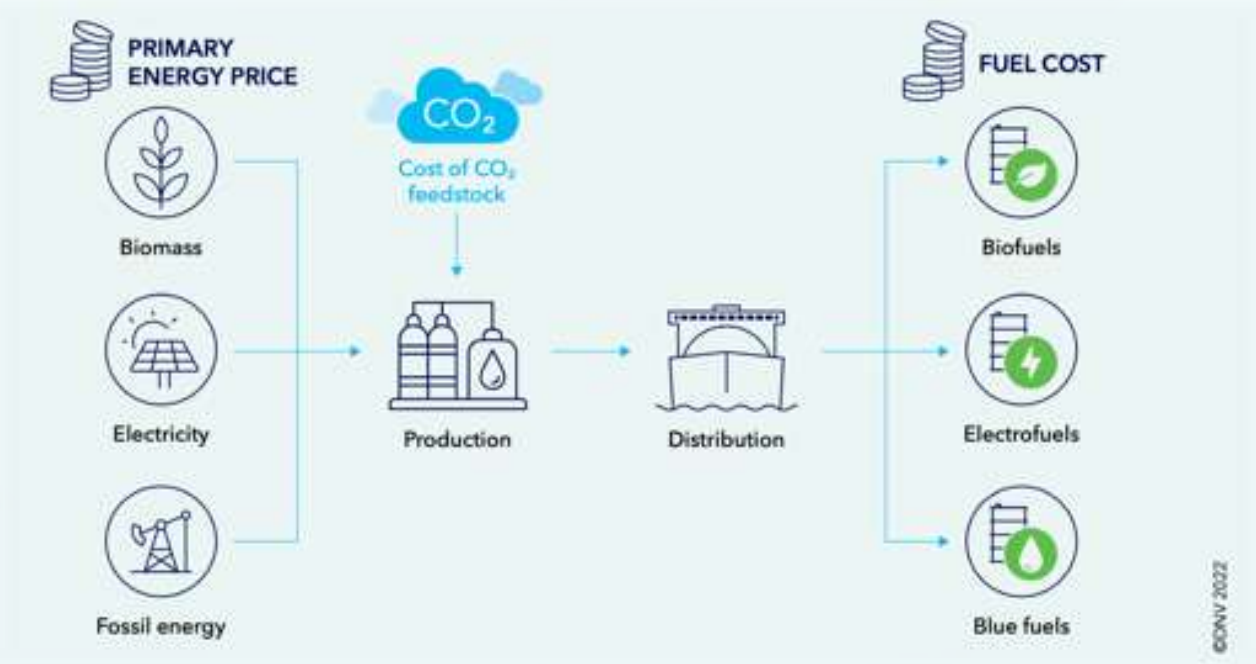


Belcombe *et al.* (2022)

BUNKERING HUBS



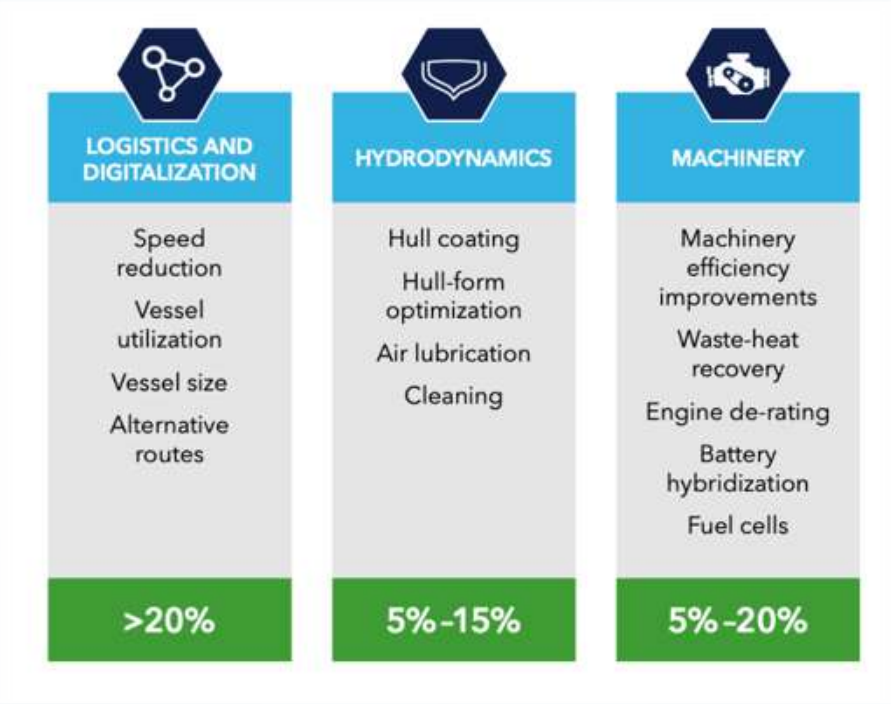
Well To Wheel pricing



FUTURE PRICES OF LOW CARBON MARINE FUELS

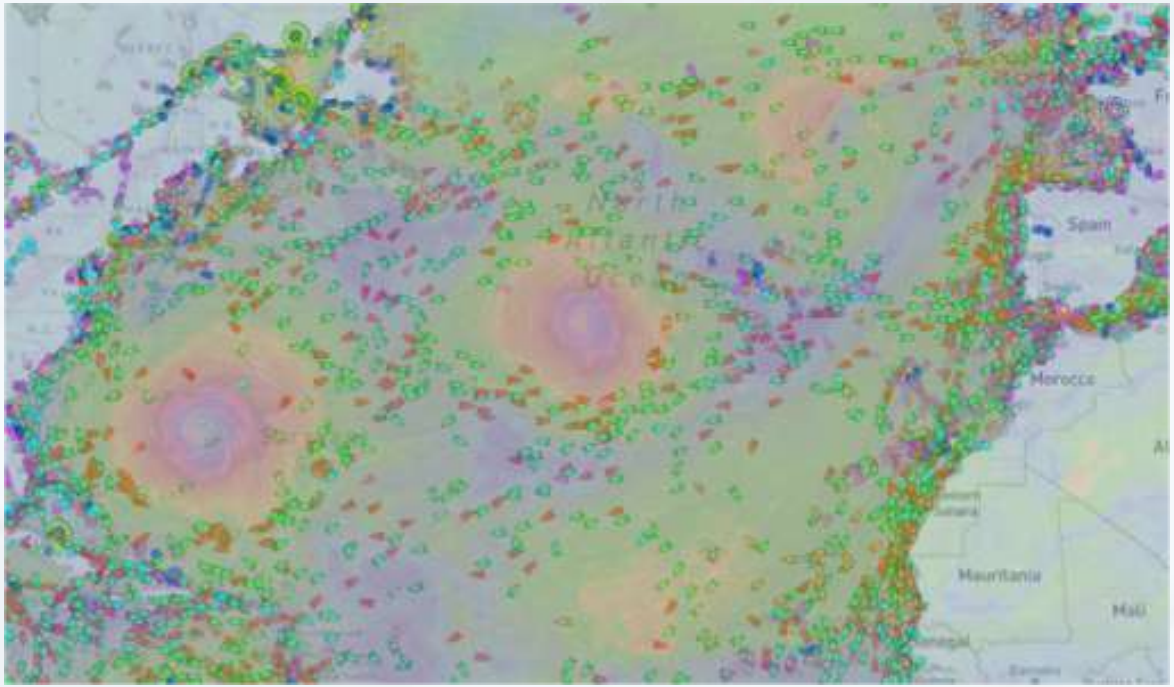
OPTIMIZATIONS

VARIOUS OPTIMIZATIONS: AVAILABLE RIGHT AWAY !



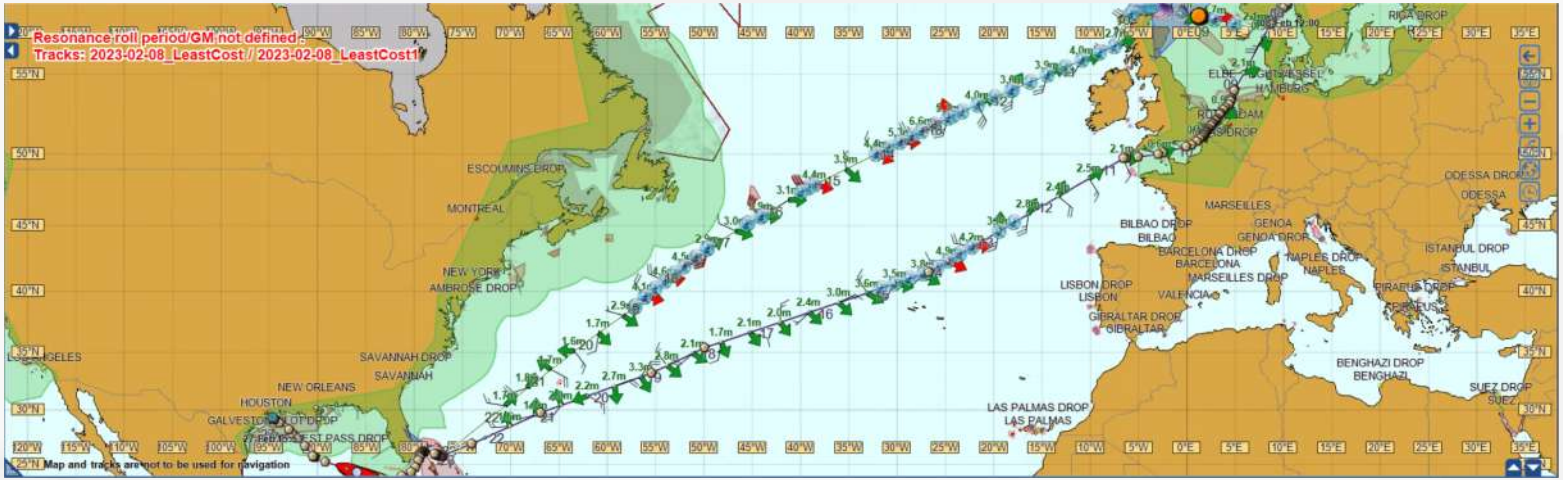
ROUTE & VOYAGE OPTIMISATION

STANDARD WEATHER ROUTING



AVOID STORMS & BAD SEA STATES !

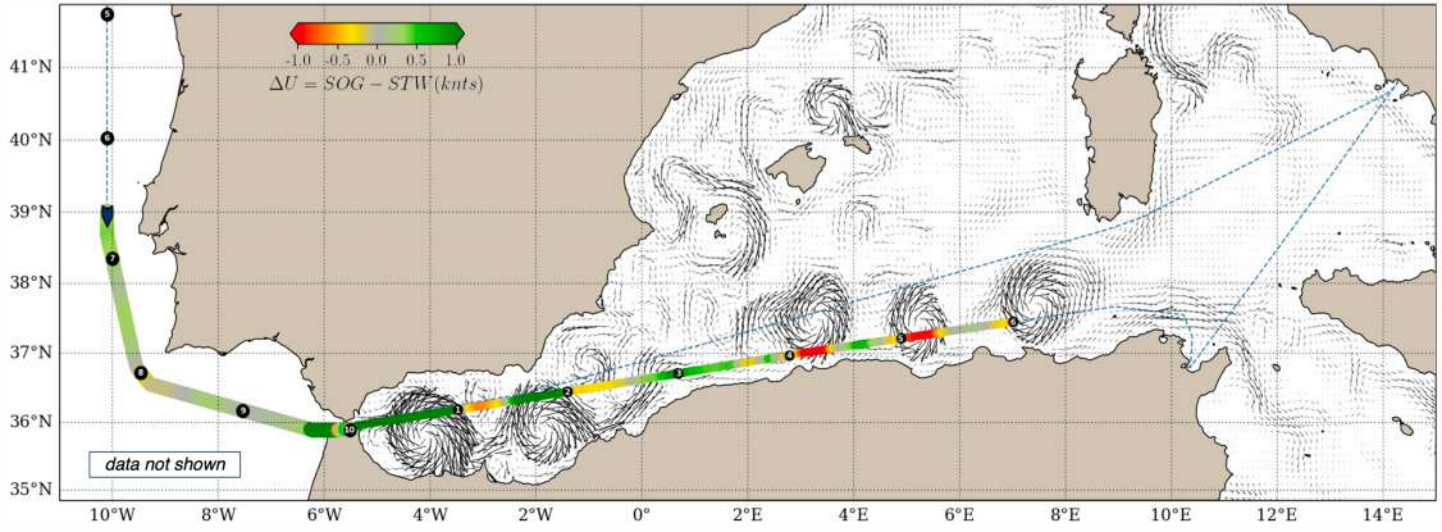
STANDARD WEATHER ROUTING



EXAMPLE OF ROUTE OPTIMIZATION
TO AVOID STORMS & BAD SEA STATES

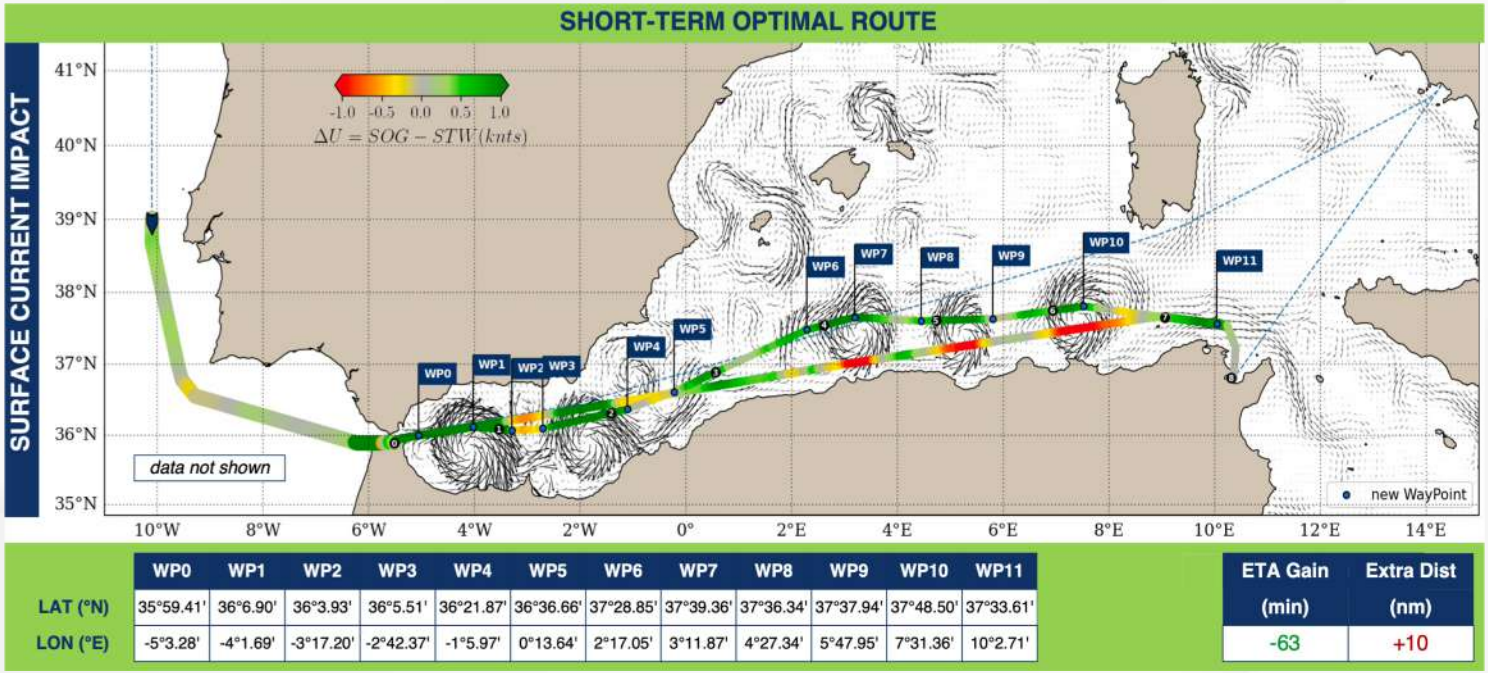
Fuel savings up to 5 -15%

SHORT TERM OPTIMAL ROUTING



DIRECT ROUTE

SHORT TERM OPTIMAL ROUTING



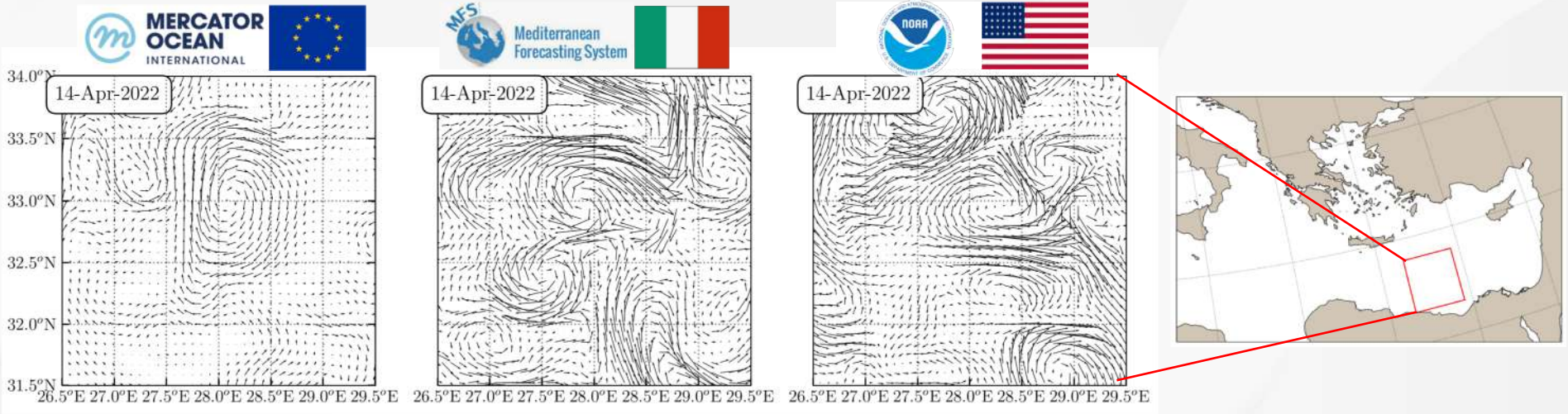
	WP0	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	WP10	WP11
LAT (°N)	35°59.41'	36°6.90'	36°3.93'	36°5.51'	36°21.87'	36°36.66'	37°28.85'	37°39.36'	37°36.34'	37°37.94'	37°48.50'	37°33.61'
LON (°E)	-5°3.28'	-4°1.69'	-3°17.20'	-2°42.37'	-1°5.97'	0°13.64'	2°17.05'	3°11.87'	4°27.34'	5°47.95'	7°31.36'	10°2.71'

ETA Gain (min)	Extra Dist (nm)
-63	+10

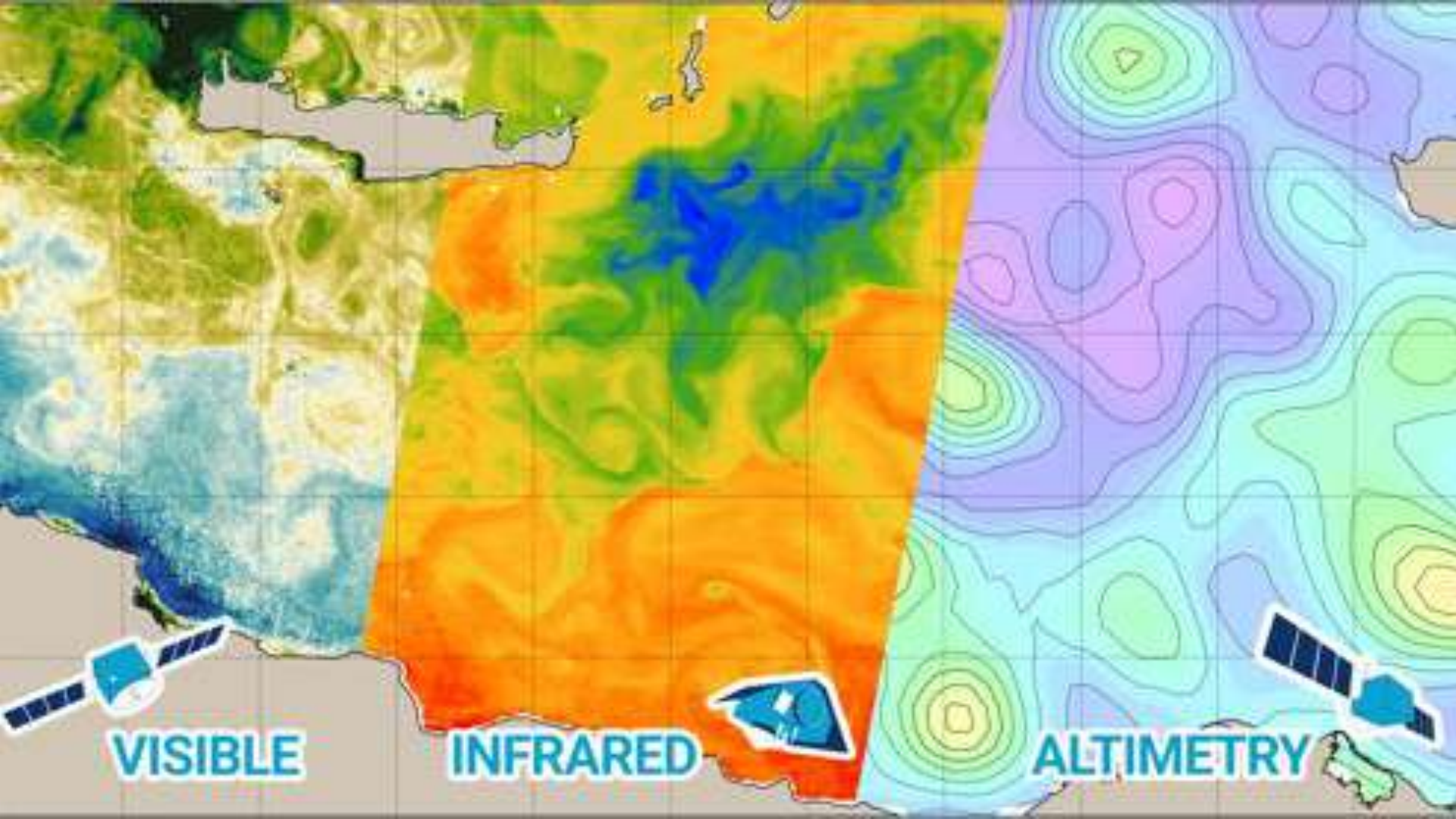
OPTIMIZED ROUTE

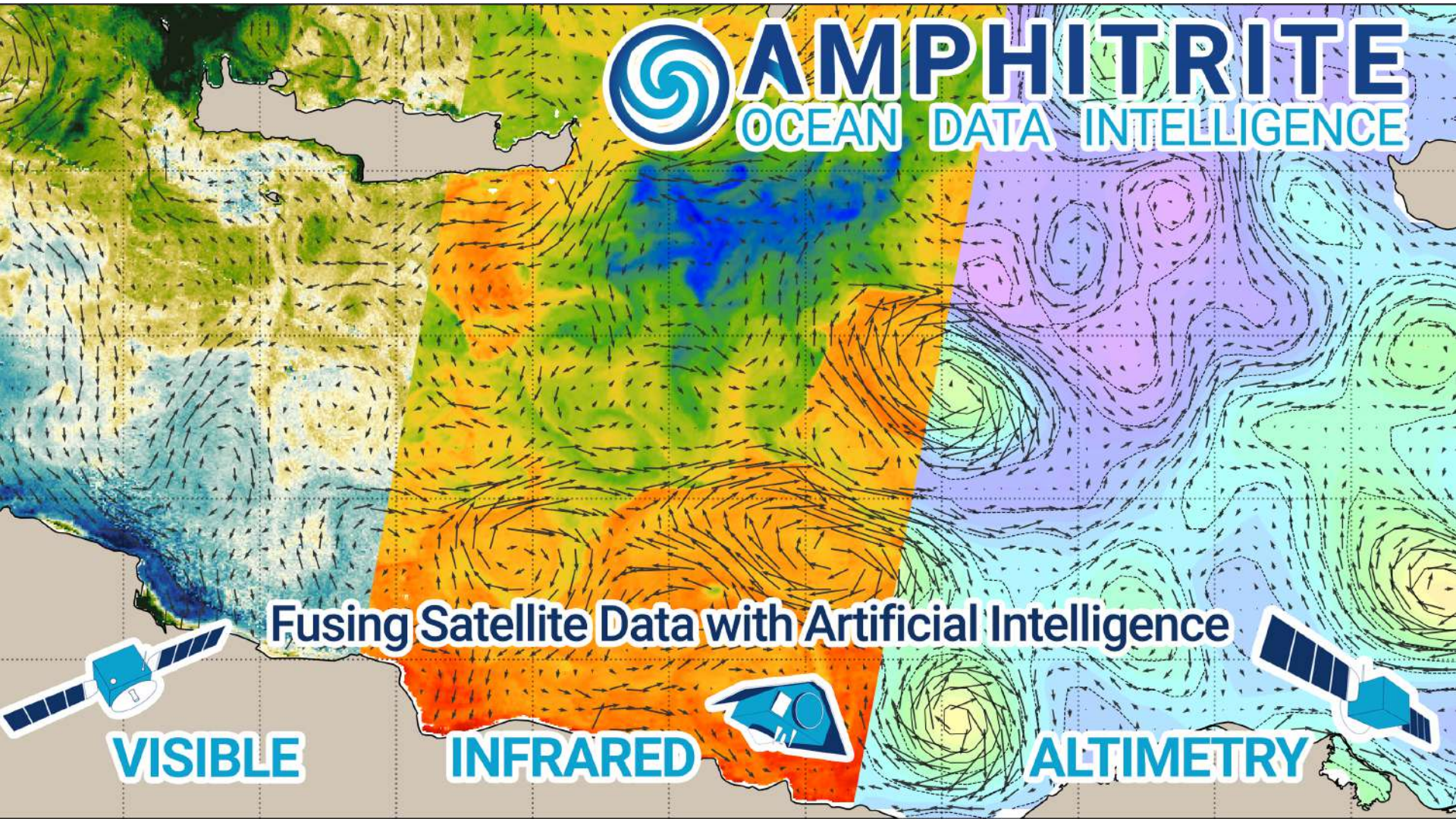
Reliable and **accurate** ocean data
are **needed** to
optimize fuel consumption and **emissions**
of commercial ships.

HOW RELIABLE OCEAN NUMERICAL MODELS ARE ?



Operational oceanic models often disagree on surface currents !

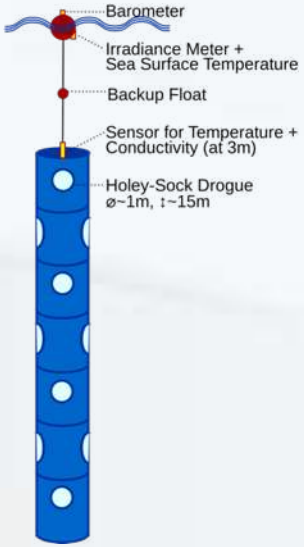

VISIBLE
INFRARED
ALTIMETRY

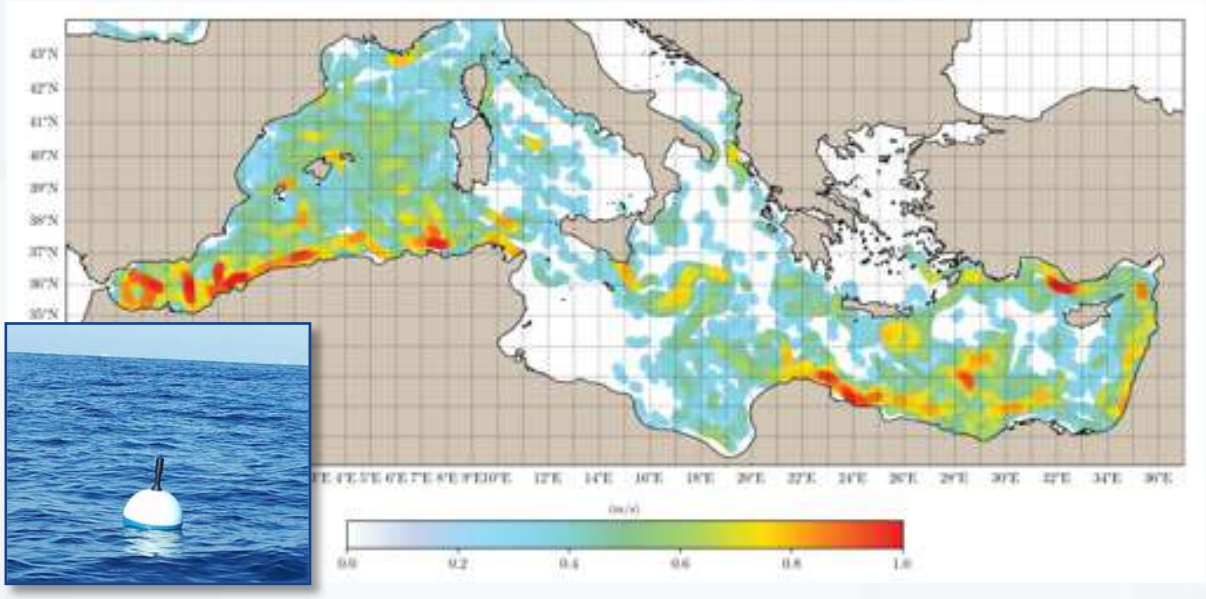

AMPHITRITE
OCEAN DATA INTELLIGENCE
Fusing Satellite Data with Artificial Intelligence
VISIBLE
INFRARED
ALTIMETRY

DATA VALIDATION USING OCEAN DRIFTERS

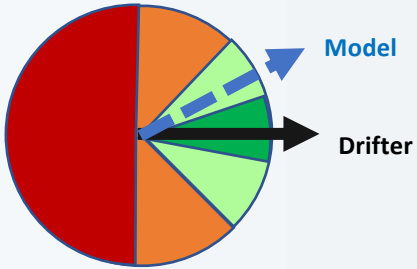
46 000 Surface Drifter Measurements

along the Suez-Malta-Gibraltar road in 2020-22 (strong currents 0.5 > kt)





CURRENT ANGLE ERROR EVALUATION



$\theta < 15°$

EXCELLENT DIRECTION

$45° > \theta > 15°$

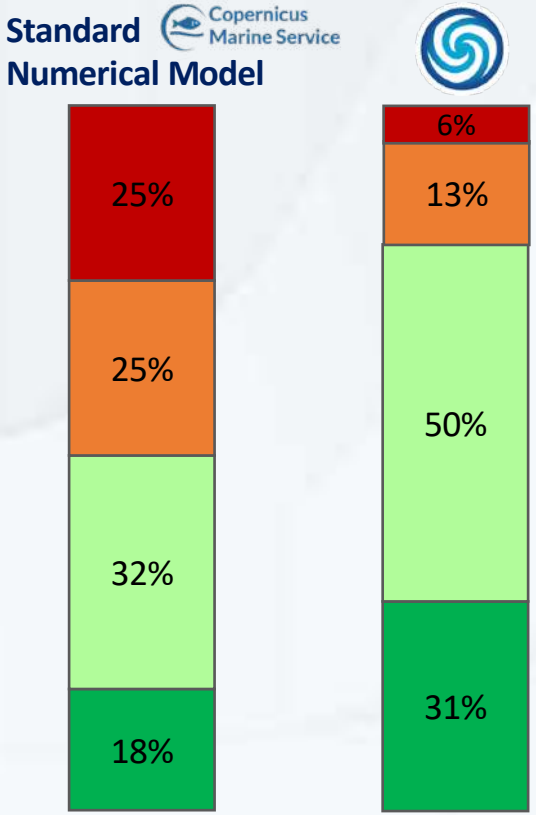
CORRECT DIRECTION

$90° > \theta > 45°$

INACCURATE DIRECTION

$\theta > 90°$

WRONG DIRECTION



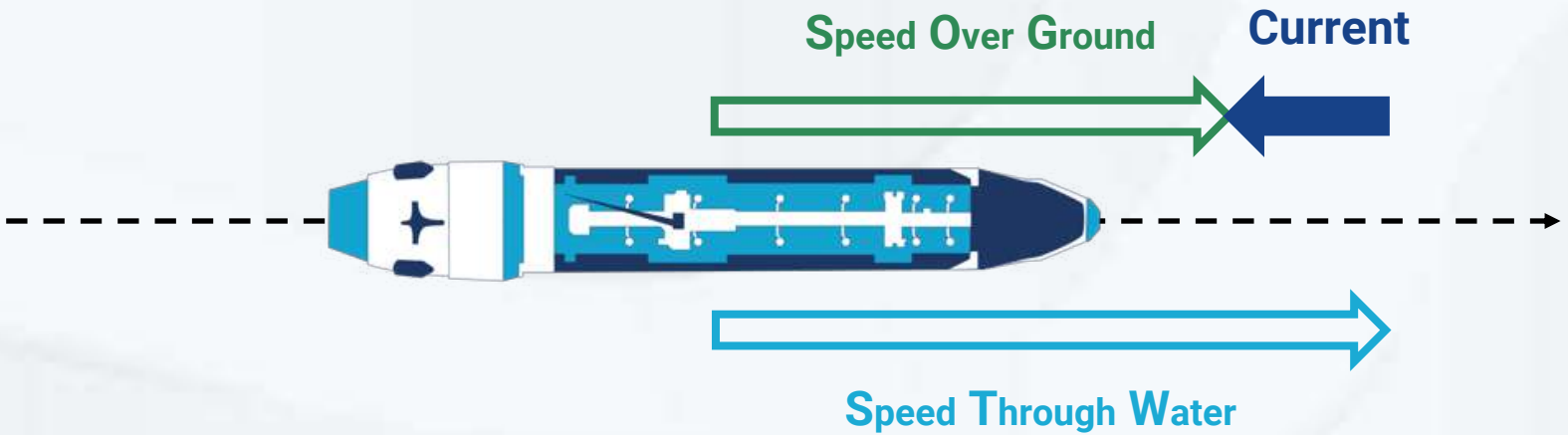
80%

Correct & Excellent

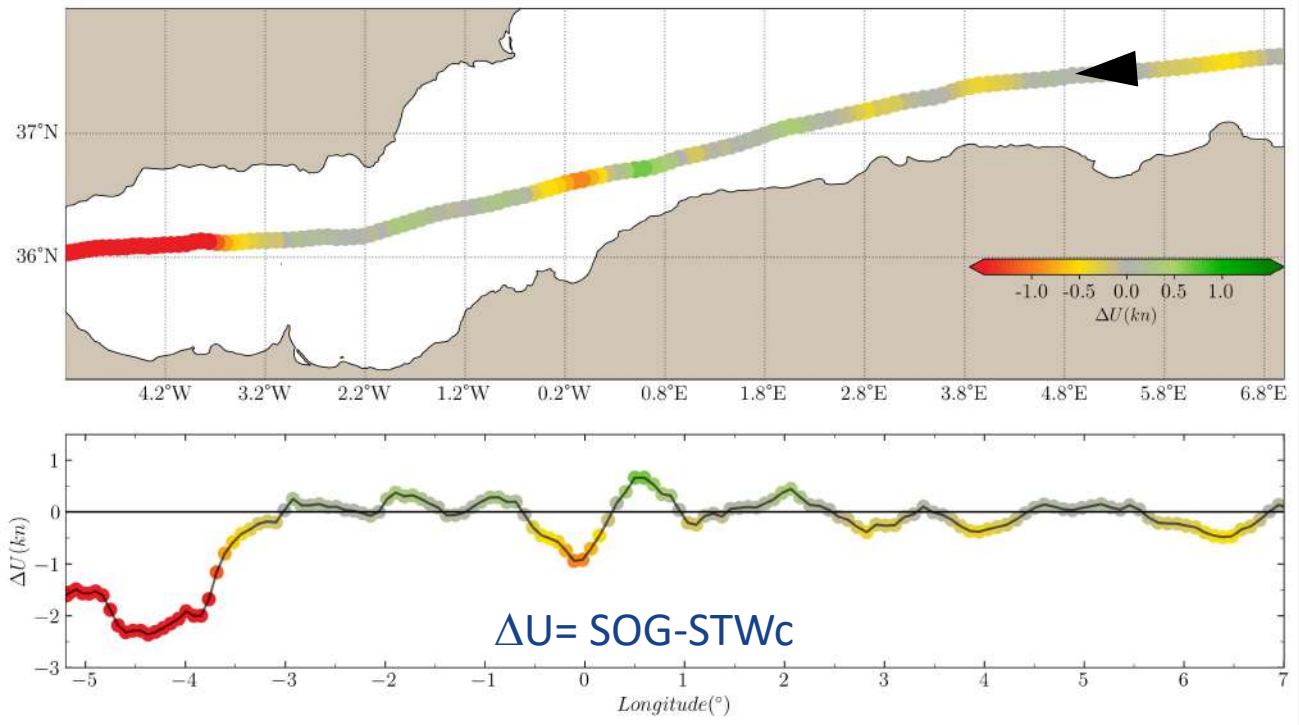
4 Times Less

Wrong Data

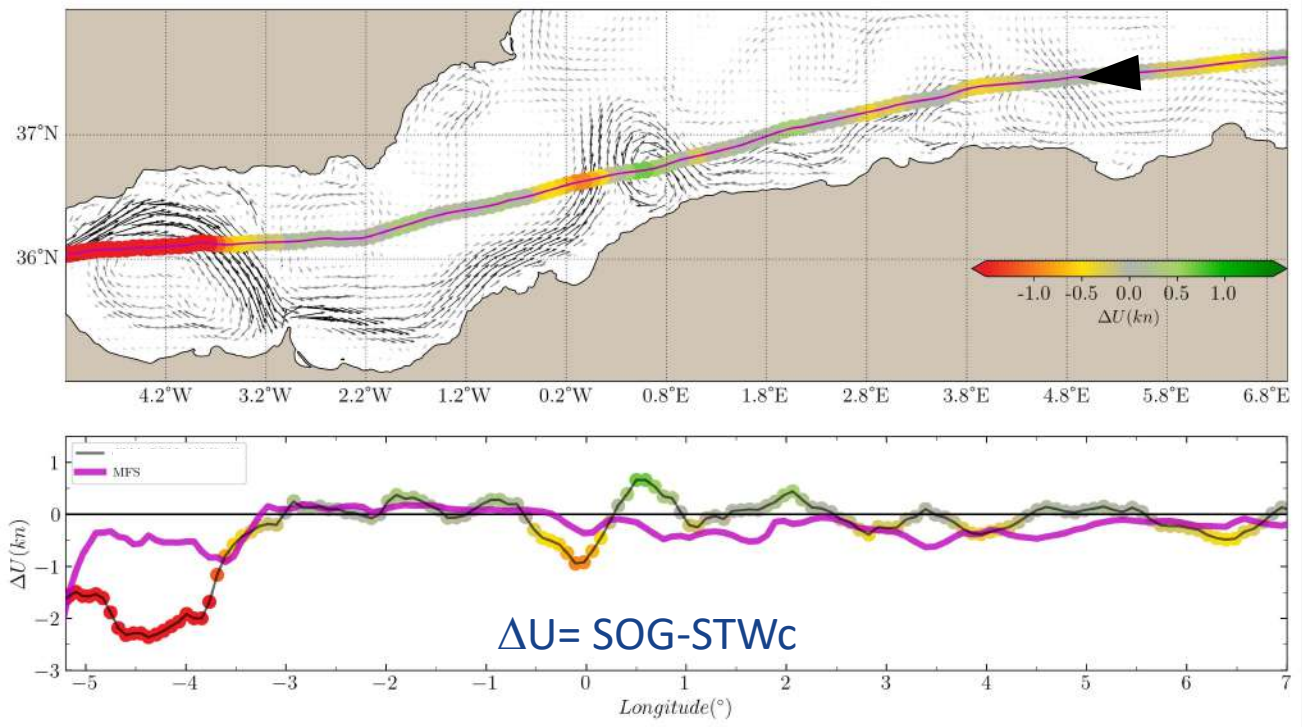
CURRENTS IMPACT ON VESSEL: SOG - STW



CURRENTS IMPACT ON VESSEL: SOG - STW

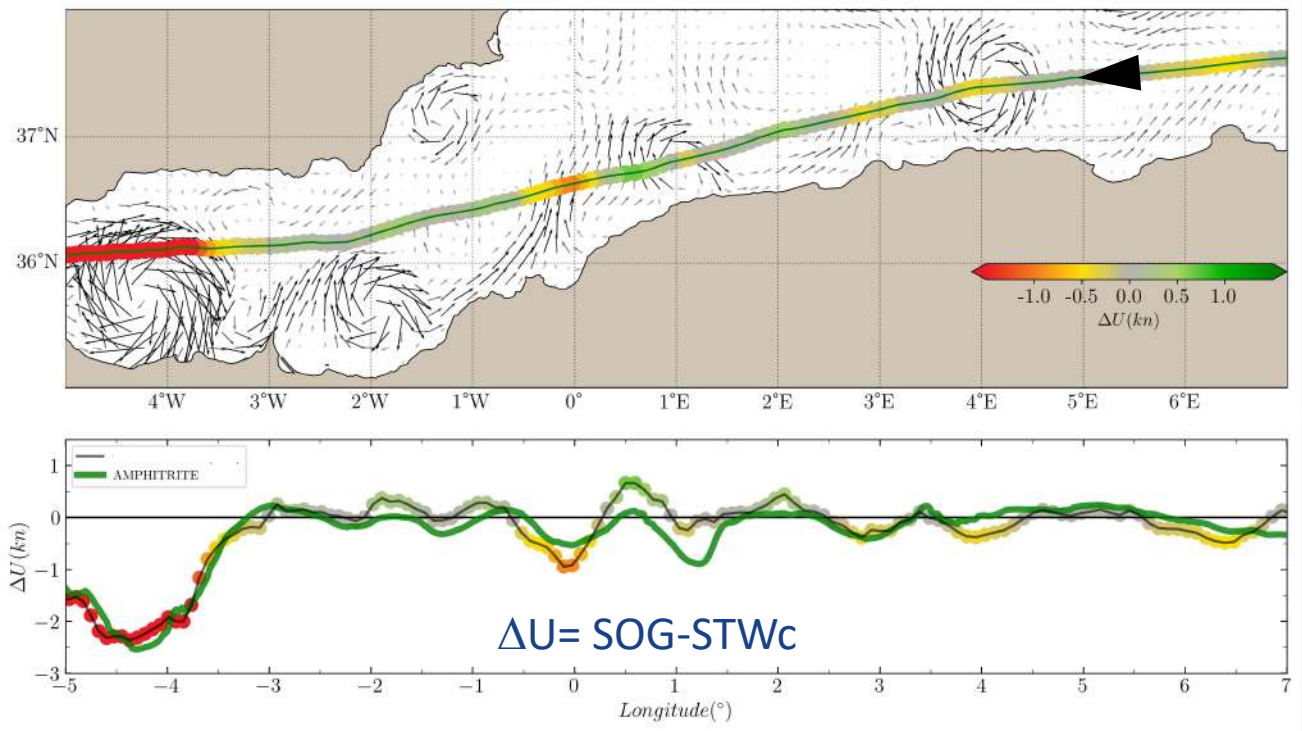


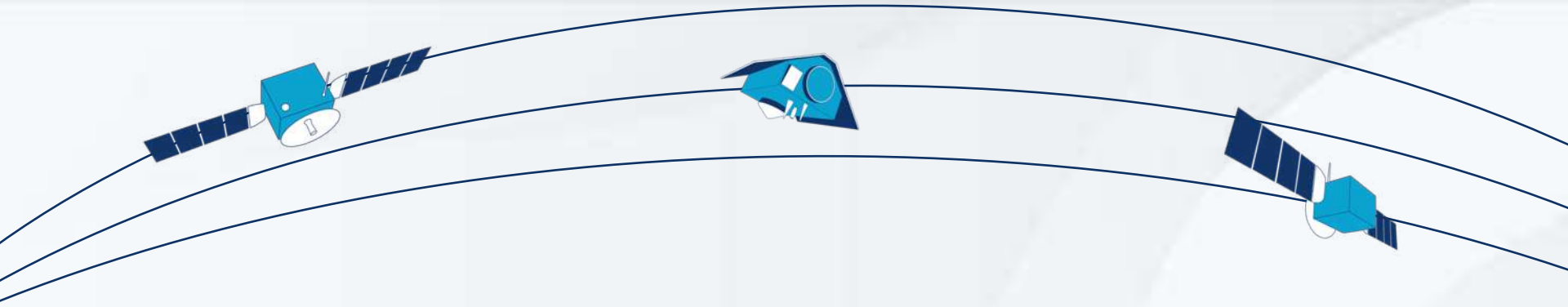
OCEAN MODEL FORECAST: MFS REGIONAL



AMPHITRITE FORECAST

AMPHITRITE
HIRES SURFACE CURRENTS





ACCURACY OF AI SATELLITE DATA FUSION GOES FAR BEYOND STANDARD OCEAN FORECASTS

AMPHITRITE
HIRES SURFACE CURRENTS

GREEN SHIPPING: OUR AMBITION/MISSION

5 - 5 - 30

5% of fuel (& CO_2) reduction per voyage

5% of the total fleet (>5000 GT) use short-term optimal routing

in **2030**

~ 150 Net Zero Ships

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