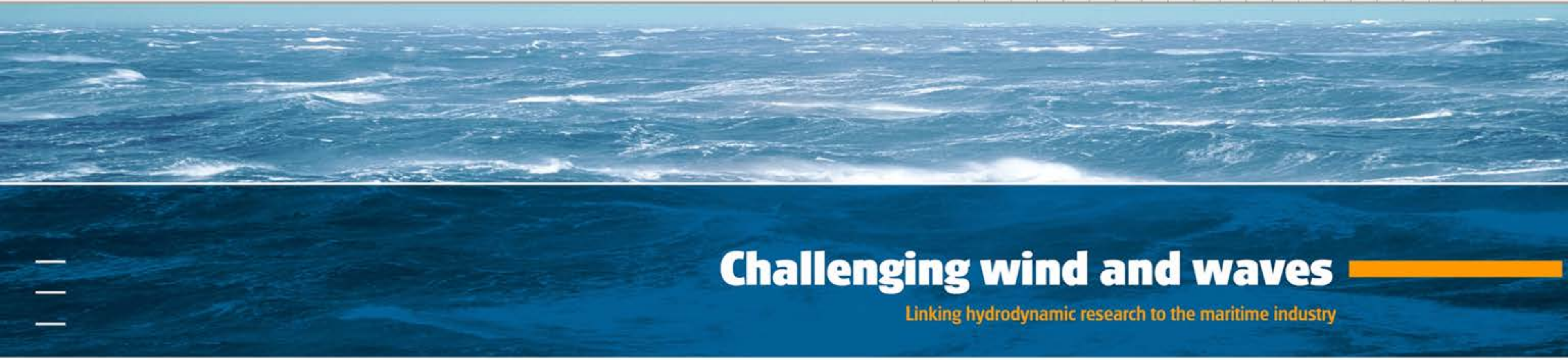
MARIN

The Greek Section of The Society of Naval Architects and Marine Engineers



MAKING SMART USE OF THE ENVIRONMENT IN SHIPPING

Guilhem Gaillarde
Head of Ships department – MARIN

Rogier Eggers, Rob Grin, Rien de Meij, Peter Boelens

CONTENT

- MARIN status and strategy
- Why can wind propulsion revive?
- Overview of latest trends and concepts
- Wind availability and voyage simulation
- Two examples of recent studies: Wind Hybrid Coaster and SAIL
- Upcoming challenges and perspectives

MARIN STATUS AND STRATEGY

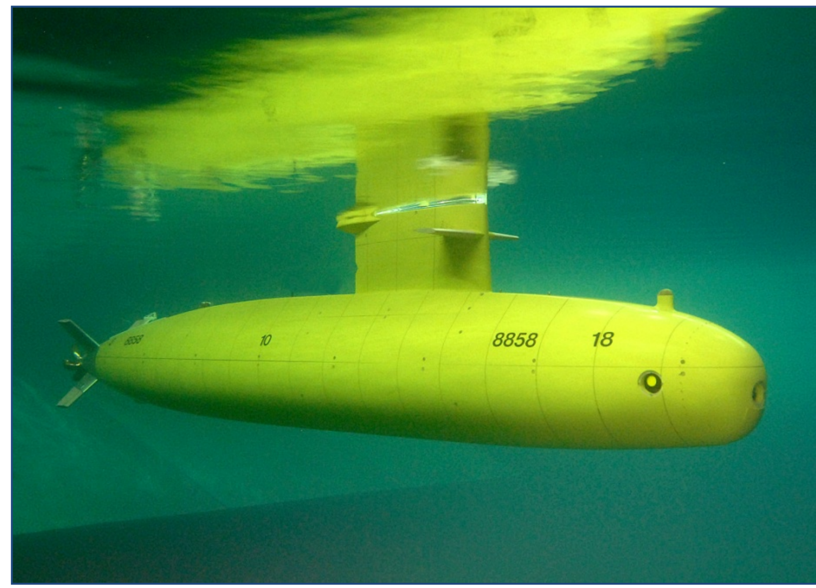
MARIN STATUS AND STRATEGY

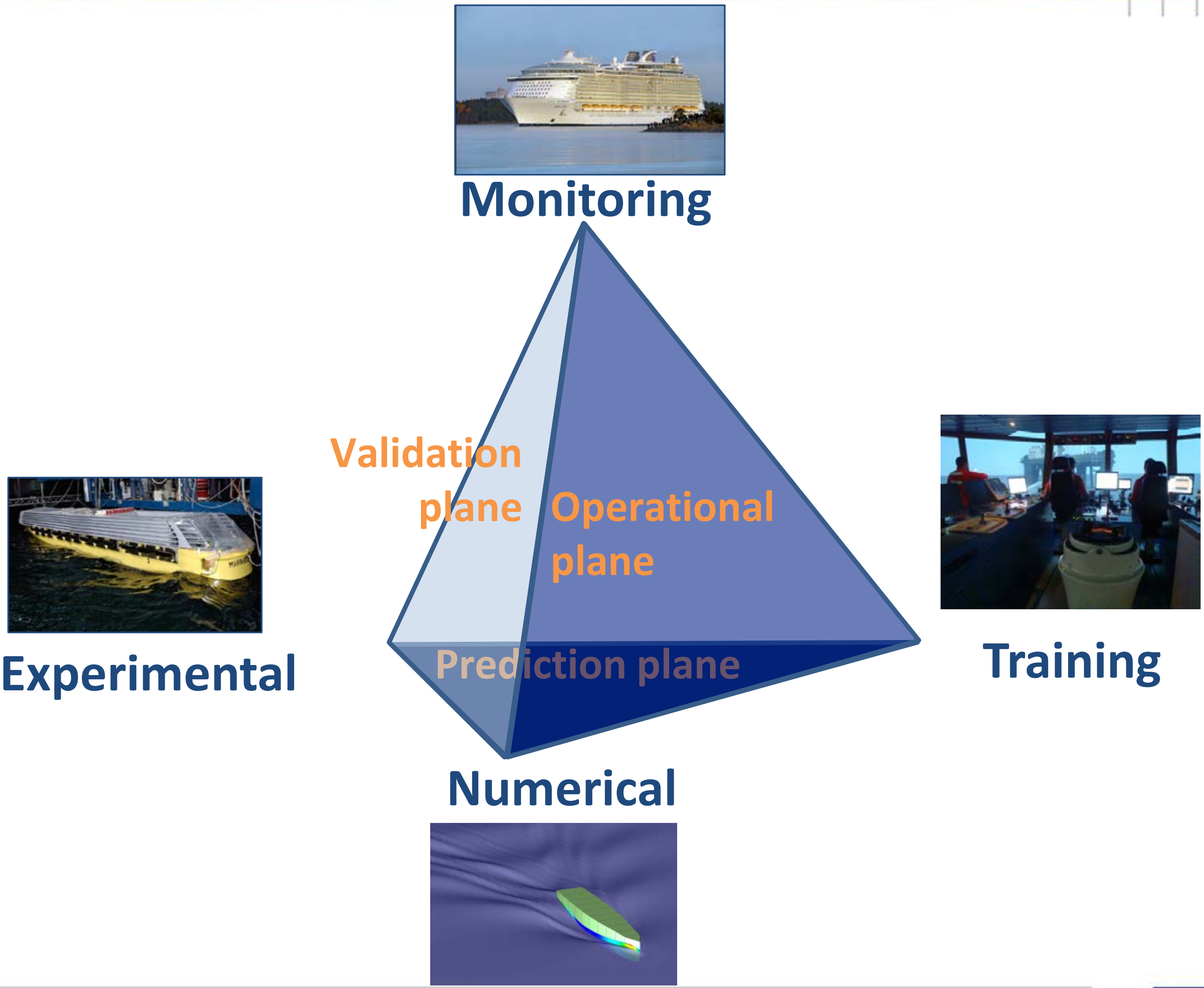
Independent and innovative service provider for the maritime sector in hydrodynamic and nautical research

MARIN STATUS AND STRATEGY

Dual mission

- To provide industry with innovative design solutions
- To carry out advanced research for the benefit of the maritime sector as a whole




Monitoring
Validation plane
Operational plane
Experimental
Prediction plane
Training
Numerical

SIMULATIONS - FROM CONCEPT TO OPERATION

Simulation is the imitation of real-world operations. This broad definition fully applies to MARIN's contribution to the maritime world as MARIN models many processes and systems. But why is this necessary?
Because we need to:
- optimise performance
- engineer for safety
- design for operations
- train and educate

- Database & experience
- Potential and semi-empirical methods
- Viscous methods
- Simulations including weather & human factors

Simulation based design & operations

1 Start design process

It starts with an idea or a concept of a ship, offshore structure, or an intended maritime operation.

2 Think tank with brain waves

It is useful to share ideas with experienced experts and extremely beneficial to get early, independent feedback. MARIN offers multidisciplinary teams to challenge and improve your ideas. Right from the start, this provides an integrated approach, which is focusing on your future operations.

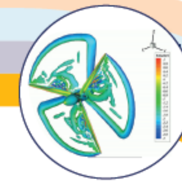
3 Performance exploration

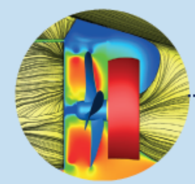
The use of databases links your concept with available statistics to identify the performance that can initially be achieved. Robust, fast and sufficiently accurate methods provide a quick assessment of the various performance aspects of a given design.

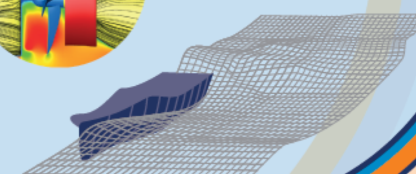
Early simulation on critical aspects and even simulator sessions could, and more often will, assist in exploring the design space in relation to its envisaged operations.

4 Prediction and optimisation of hydrodynamic characteristics

As design constraints continue to tighten during this stage, the exploratory design loops continue. The identified optimal (multi-criteria) performance solutions provide data for further and ultimately, final engineering. A set of flexible, accurate and coherent tools is needed in this phase.







8 On-board monitoring & operational advice and training

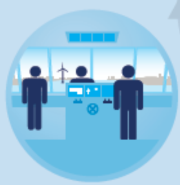
Relevant on-board data are monitored to improve the quality of operations and to generate feedback on in-service performance. Analysis of this data could lead to advice about how to improve operations (safer, higher efficiency or more effective). Training is a prerequisite for safe and efficient operations.
Various training tools, suitable for different levels are available, or dedicated tools can be developed.

7 Full-scale verification

Critical commissioning aspects, structures and operations often require full-scale verification either as part of the contract or a Class (IMO) requirement.

6 Verification of training & operations

The design or the operation is verified in a fully simulated environment, and further attention is given to human aspects. Simulator sessions of operations provide operational procedures and their limits, communication protocols, the outline of necessary decision support tools and the required training programmes. 'Serious gaming' can be used for very complex and/or emergency response operations.



5 Operational performance analysis

Future designs require a multiple criteria optimisation to account for the specific environments they will be operating in and for their required mission capability. This analysis provides an assessment of the efficiency, safety and/or workability of a design.
Fast-time (scenario) simulation tools provide the answers on each aspect and where needed, how they connect to one another.

Simulation categories

Simulation domains
Resistance & Propulsion
Waves & Workability
Manoeuvring & Nautical
Operations @ sea

Completeness of hydrodynamic models
- Statistical & emperical methods
- 2D and 3D potential flow methods
- Navier Stokes CFD viscous methods

Completeness in dynamics
- Frequency domain
- Time domain
- Linear
- non-linear

Completeness in scope of the assessment
- Isolated models
- Combined models
- Combined models including human factors
- Multiple combined models including human factors

Team Cruise & Ferry

Team Yacht

Team Navy

SHIPS @ MARIN

Team Specialised Vessels

Team Merchant Ships & Workboat

Team Inland Waterway Transport (IWT)

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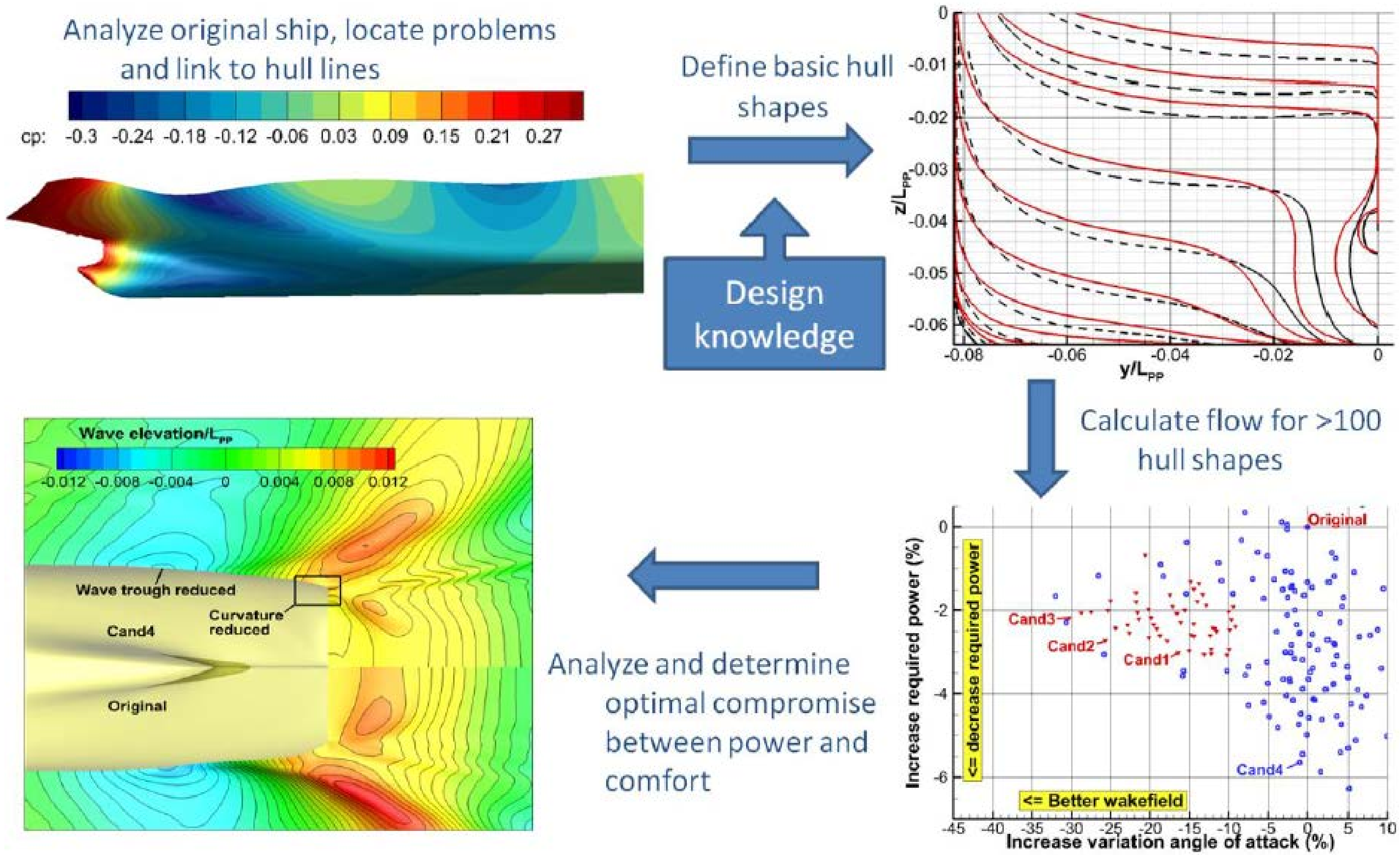
WHY CAN WIND PROPULSION REVIVE

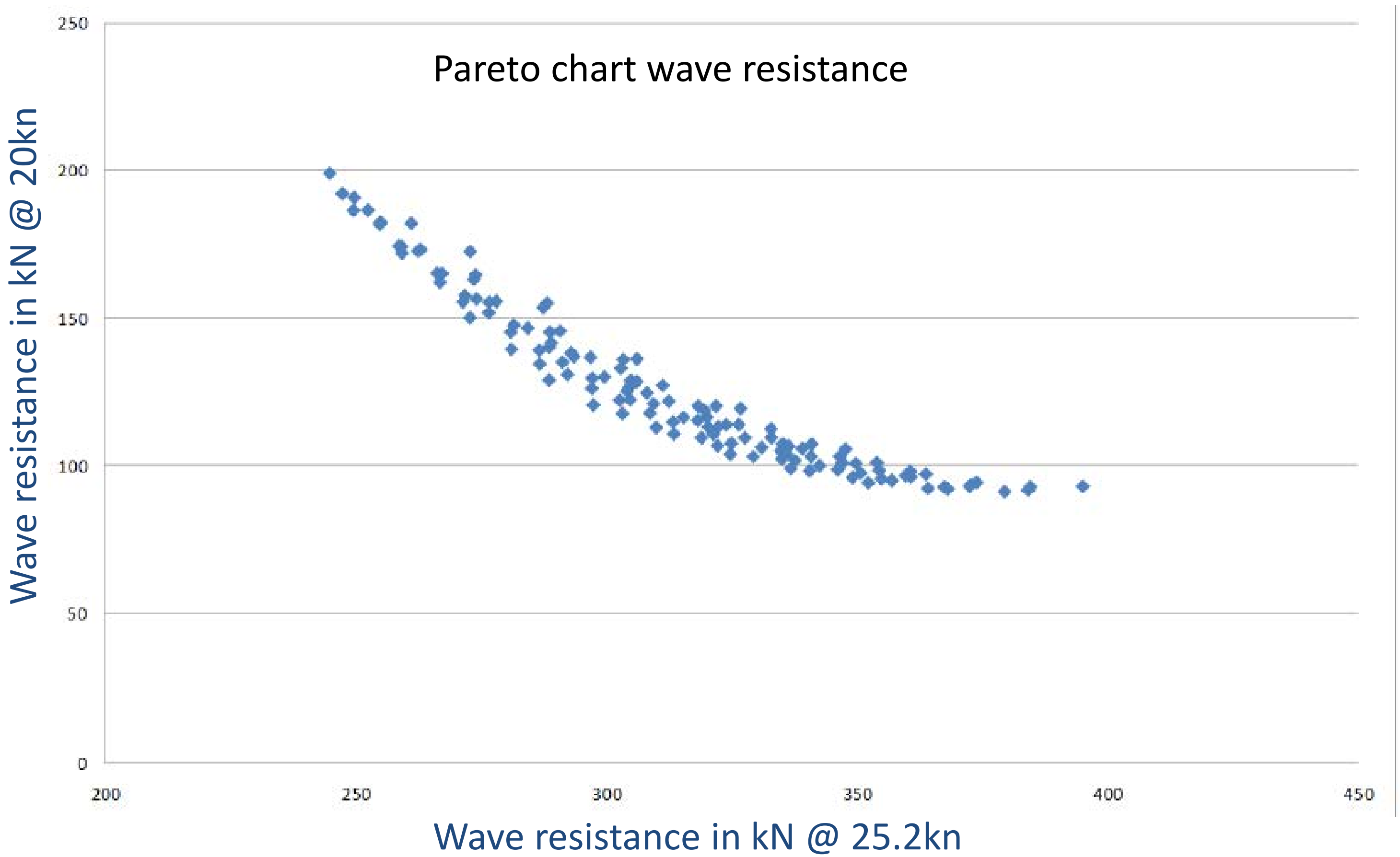
- Ships hydrodynamic optimisation, propulsion systems and ESD

How far can we still go?



WHY CAN WIND PROPULSION REVIVE?

- Ships hydrodynamic optimization, propulsion systems and ESD



Pareto front from RAPIDExplorer at multiple draughts

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WHY CAN WIND PROPULSION REVIVE?

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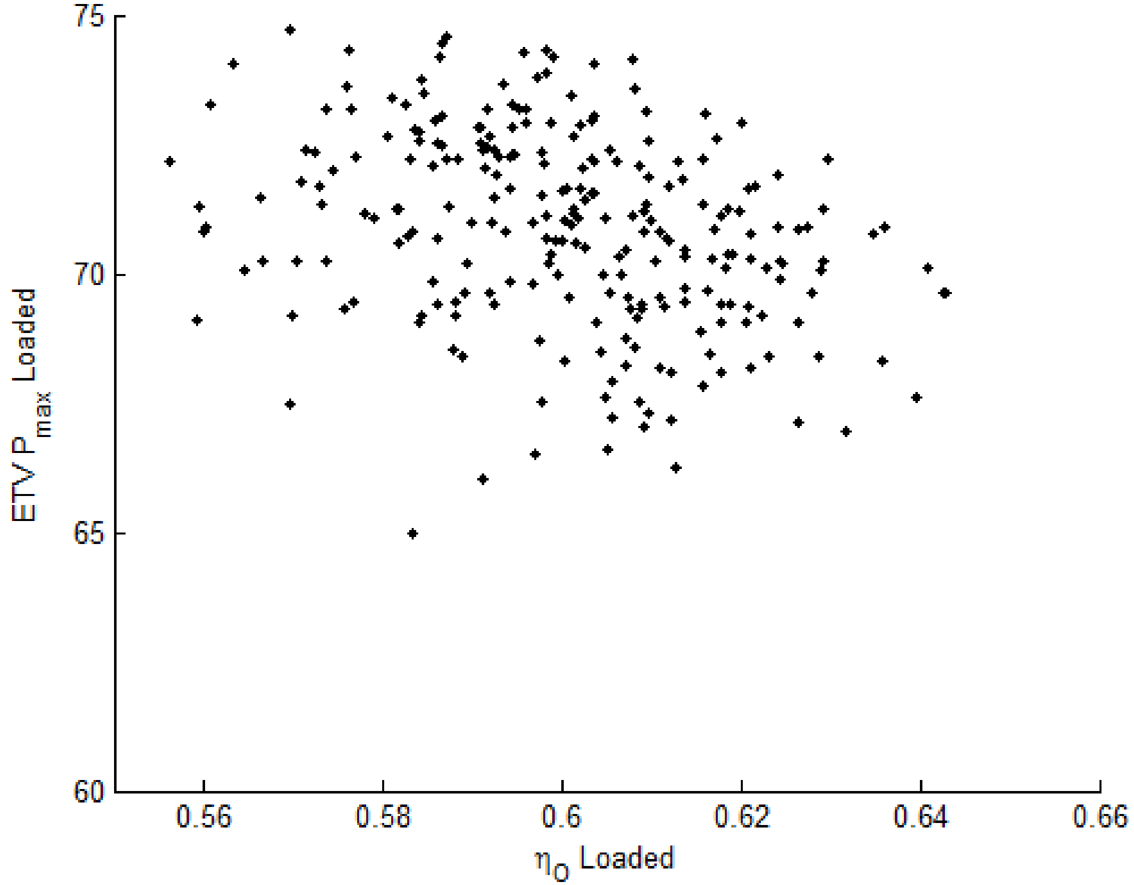
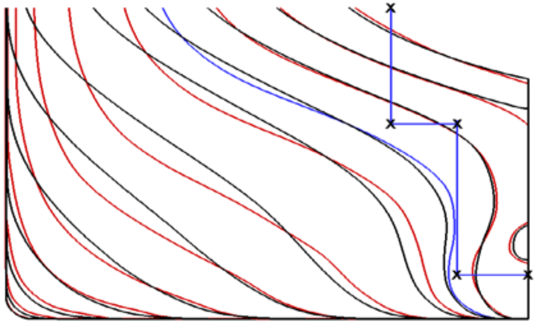
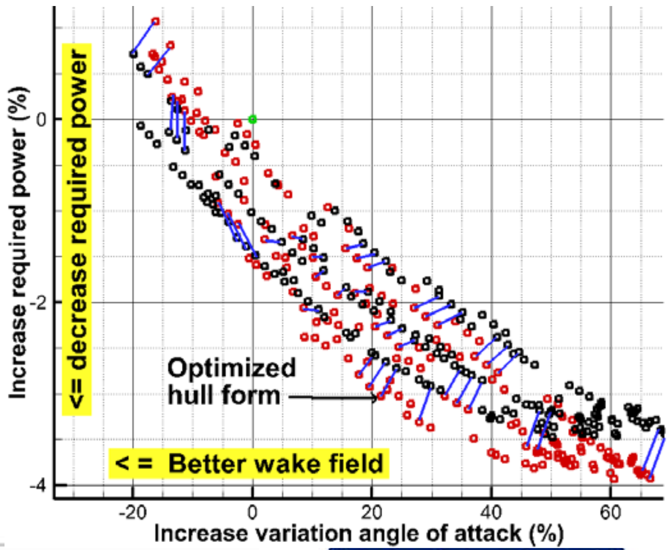


Constraints
Initial hull form
Optimized hull form





WHY CAN WIND PROPULSION REVIVE?

- Ships hydrodynamic optimisation, propulsion systems and ESD

Expected long term future potential gain in power (for actual optimised designs) through:

- New type of hull form
- Designing for service conditions
- Reducing added resistance
- Propulsive / propeller efficiency
- Energy saving devices ESD
- Lowering resistance (air lubrification or paint/coating)

} Within 2-8%

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WHY CAN WIND PROPULSION REVIVE?

- Ships hydrodynamic optimisation, propulsion systems and ESD

When it becomes marginal to improve propulsive efficiency and reduce resistance, where can we find additional power and make the difference?

Something out of the box …

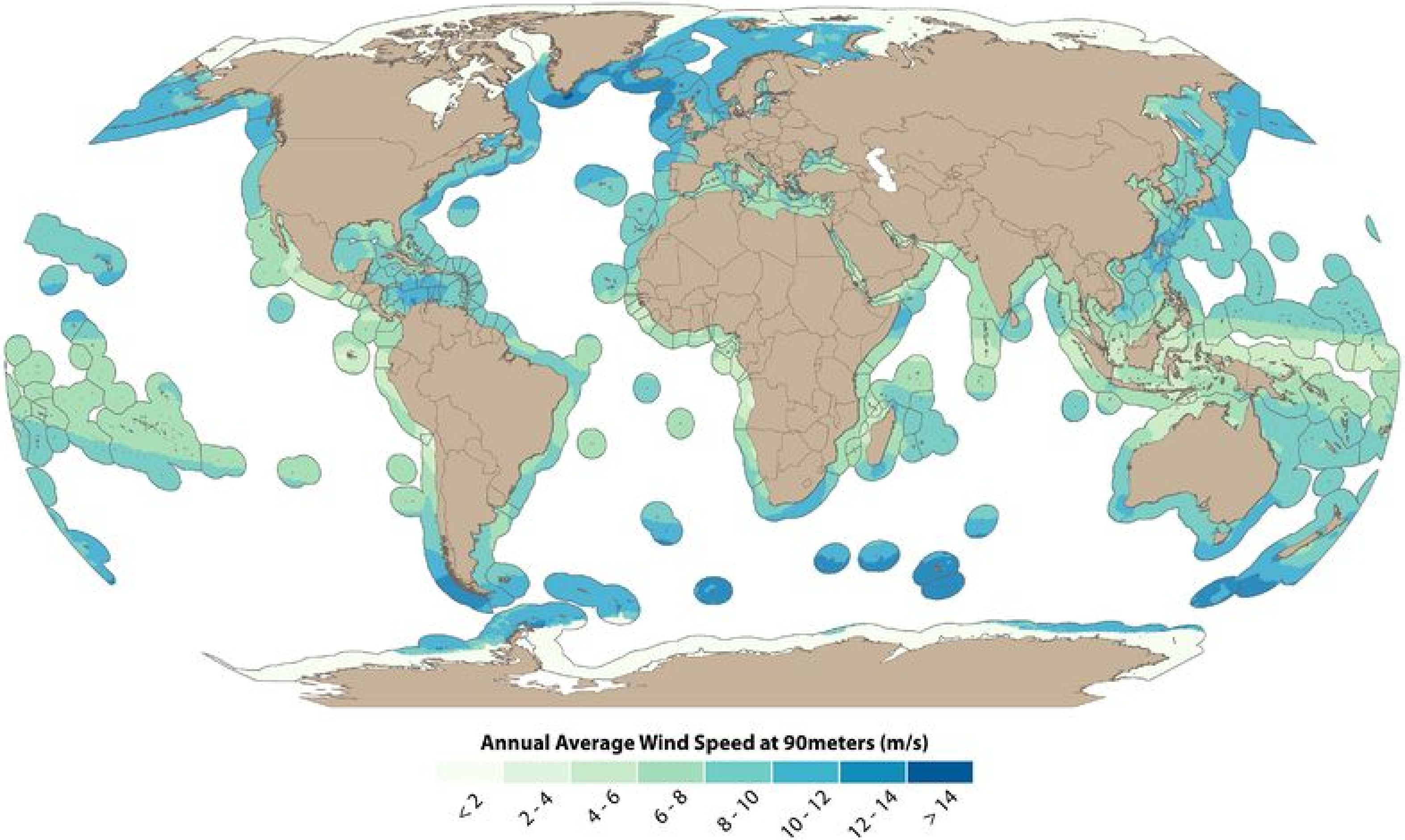
WHY CAN WIND PROPULSION REVIVE?

- Ships hydrodynamic optimisation, propulsion systems and ESD

When it becomes marginal to improve propulsive efficiency and reduce resistance, where can we find additional power and make the difference?

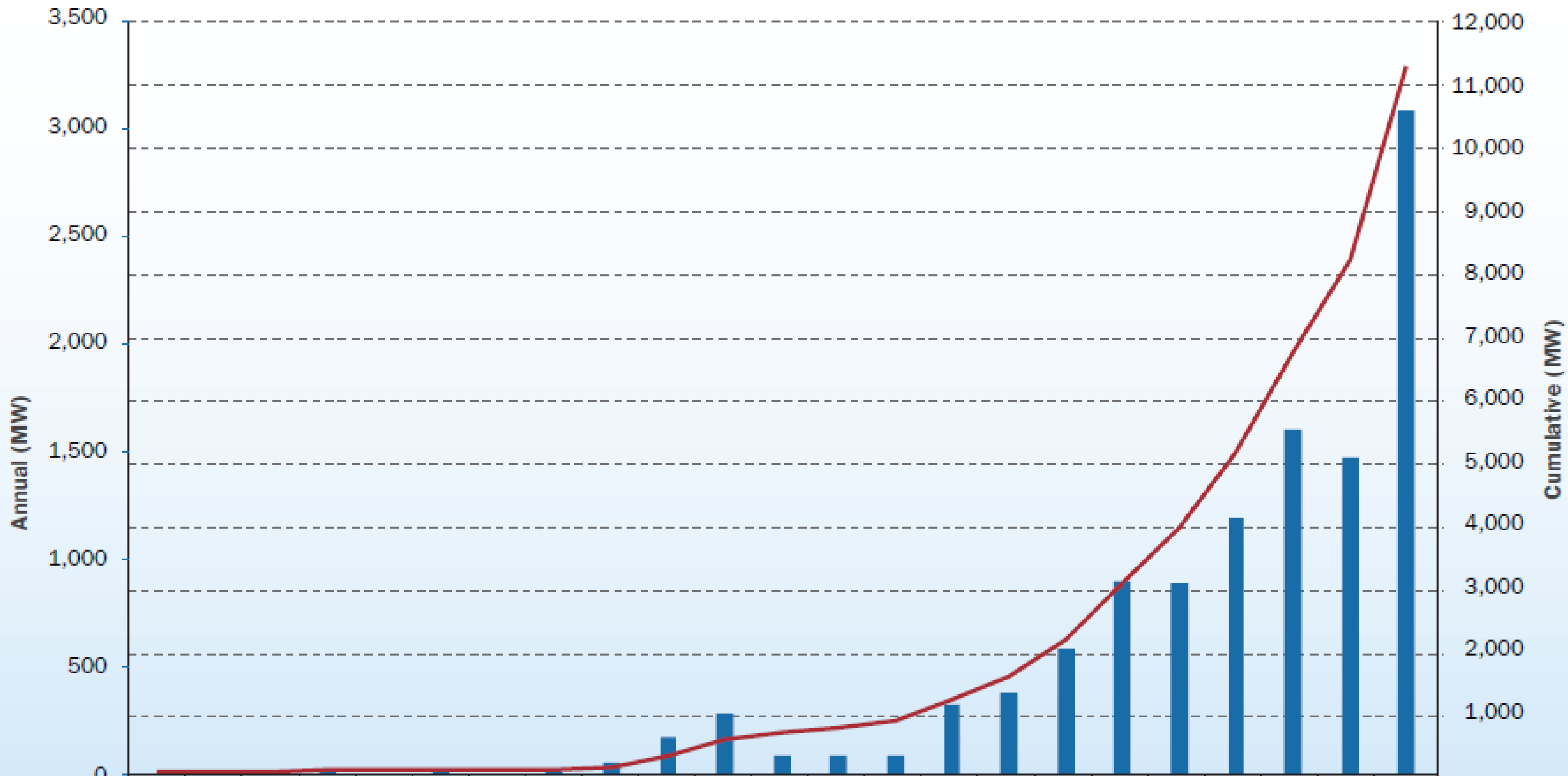
IN THE AIR !

WHY CAN WIND PROPULSION REVIVE?



WHY CAN WIND PROPULSION REVIVE?

Cumulative and annual offshore wind installation EU (MW)

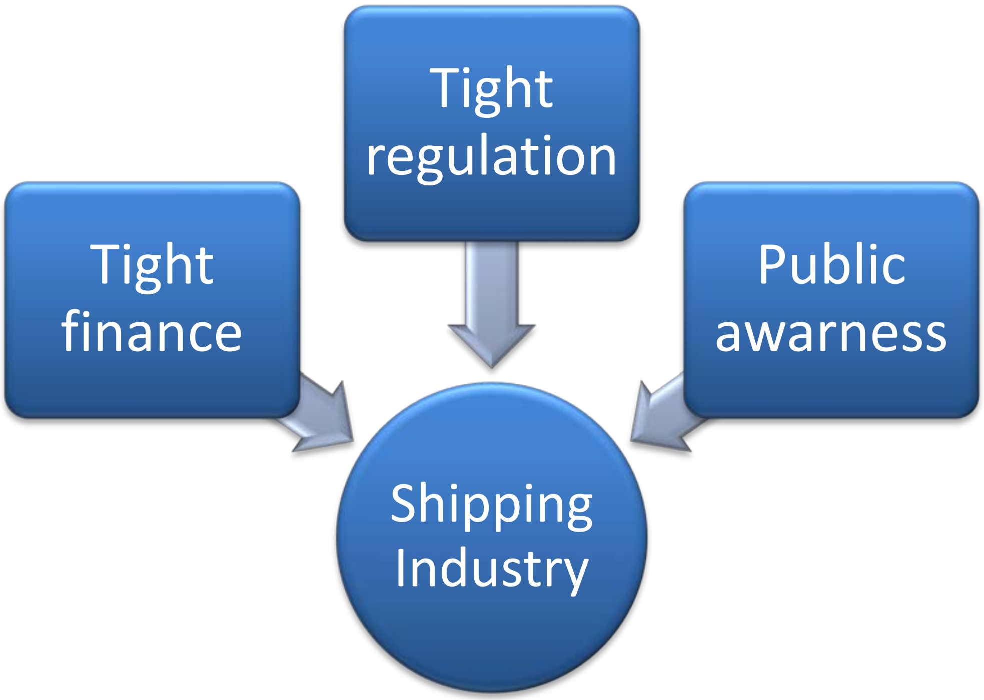


	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Annual	-	2.00	5.00	16.8	-	2.80	-	4.00	50.5	170.	276.	89.7	90.0	92.5	318.4	373.5	576.9	882.7	873.5	1165	1567	1446	3018
Cumulative	4.95	6.95	11.9	28.7	28.7	31.5	31.5	35.5	86.0	256.1	532.3	622.0	712.0	804.5	1122	1496	2073	2955	3829	4994	6561	8008	11027

WHY CAN WIND PROPULSION REVIVE?

- IMO regulation, EEDI
- COP21
- Local CO2 and other reduction program

- Available and free energy that can be captured
- Always interesting to save fuel (whatever price level)



- Environmental concerns
- Clean tech trend and marketing

OVERVIEW OF LATESTS TRENDS AND CONCEPTS

OVERVIEW OF LATESTS TRENDS AND CONCEPTS

IWSA
International Windship Association

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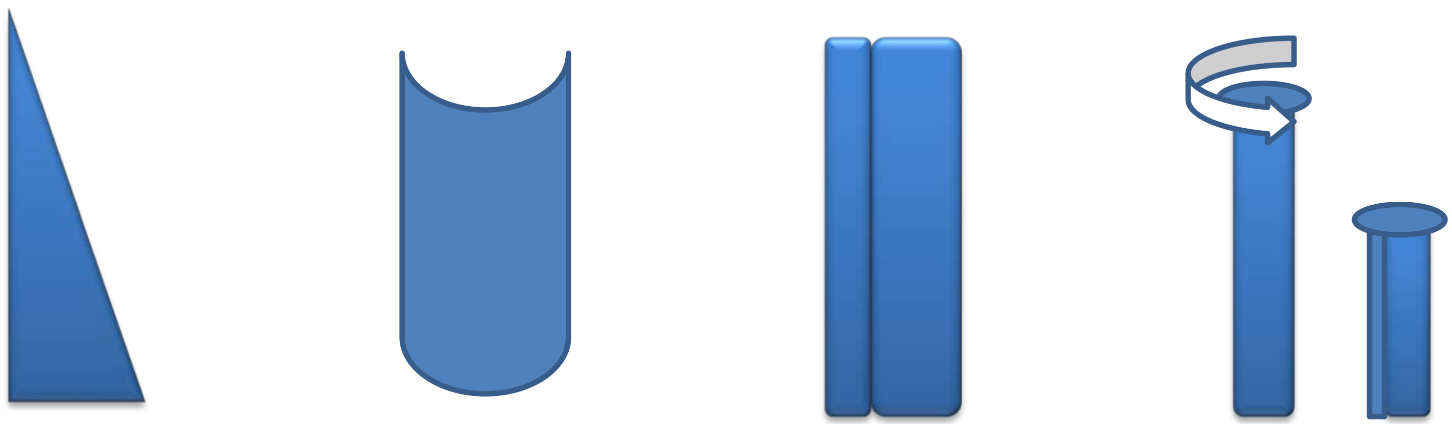
OVERVIEW OF LATESTS TRENDS AND CONCEPTS

- Wind propulsion devices (WPD) for shipping
- Markets (leisure, passengers, transport, support, …)



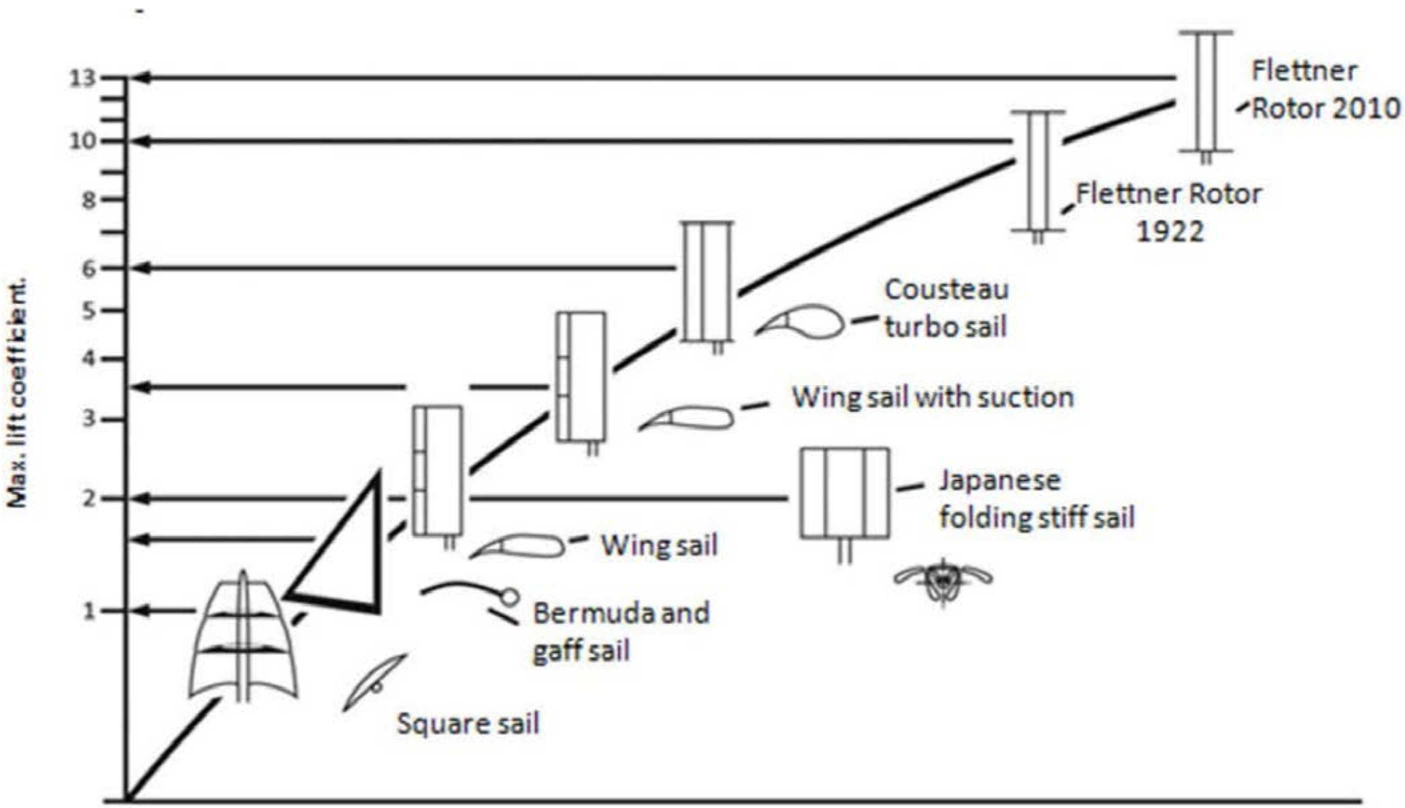
Soft

Semi-rigid
(Dynarig)

Rigid

Cylinder
(Flettner or air suction)

- Wind propulsion devices (WPD) for shipping
- Markets (leisure, passengers, transport, support, …)



OVERVIEW OF LATESTS TRENDS AND CONCEPTS

- Wind propulsion devices (WPD) for shipping
- Markets (leisure, passengers, transport, support, …)

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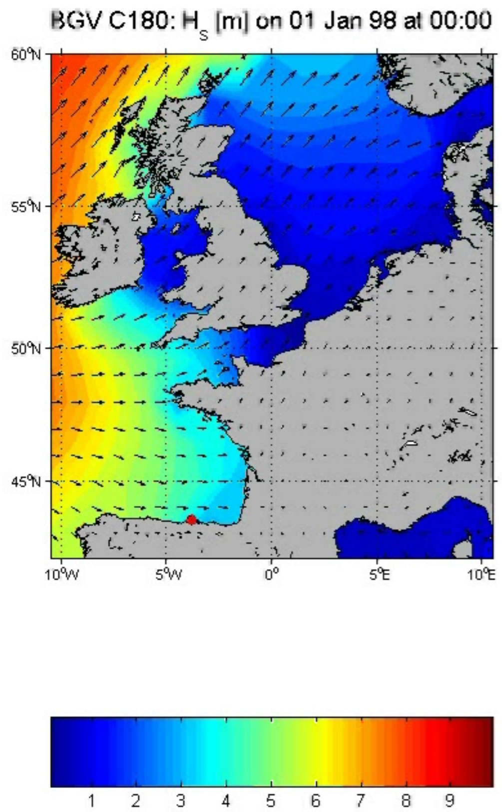
WIND AVAILABILITY AND VOYAGE SIMULATIONS

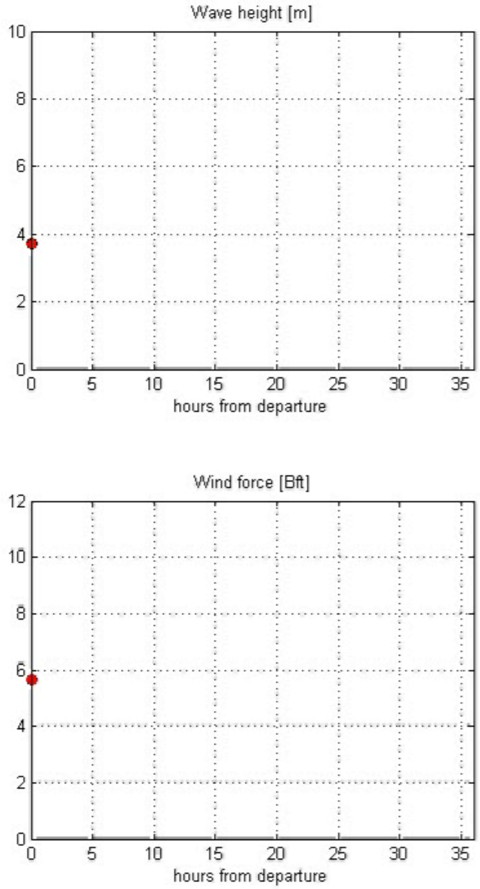
WIND AVAILABILITY AND VOYAGE SIMULATION

- Driving factors for the availability are:
  - Route, which determines the distribution of true wind speed and direction
  - Vessel speed

WIND AVAILABILITY AND VOYAGE SIMULATION

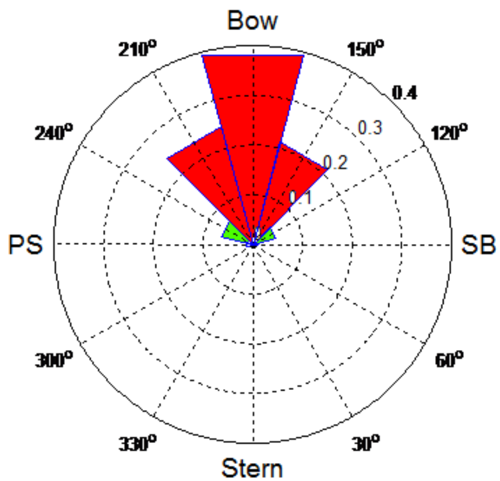
Several tools are available to obtain the wind climate. Within Marin we use so-called voyage simulations





VIDEO

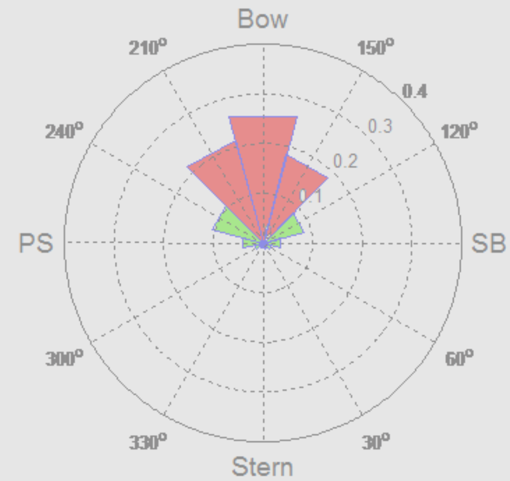
WIND AVAILABILITY AND VOYAGE SIMULATION



Southampton to NY

Vs = 20 kn

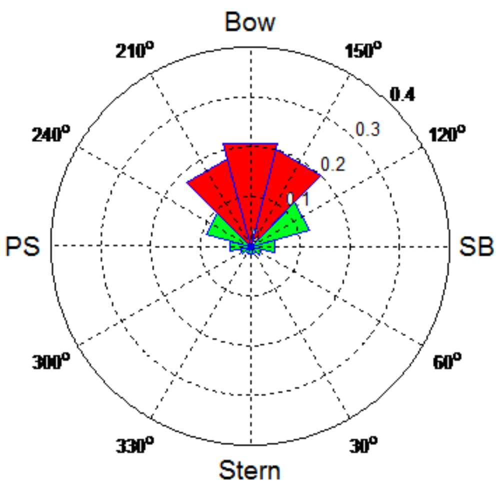
Availability 15%



Southampton to NY

Vs = 10 kn

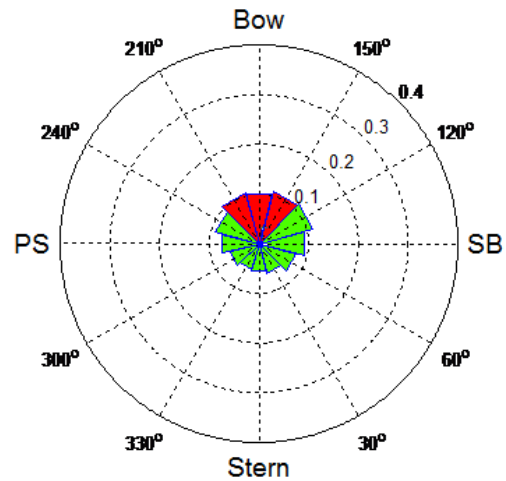
Availability 34%



NY to Southampton

Vs = 20 kn

Availability 40%



NY to Southampton

Vs = 10 kn

Availability 68%

WIND AVAILABILITY AND VOYAGE SIMULATION

- Scatter diagram of apparent wind direction and speed for Southampton to New York sailing at 10 kn

	35%	13%	4%	2%	2%	3%	11%	31%	
70	0%							0%	0%
	0%	0%					0%	0%	0%
50	2%	0%	0%				0%	2%	4%
	7%	2%	0%	0%	0%	0%	1%	6%	16%
30	14%	4%	1%	0%	0%	0%	3%	12%	35%
	10%	5%	2%	1%	1%	2%	5%	9%	32%
10	2%	2%	1%	1%	1%	1%	2%	2%	12%

Apparent wind speed [kn]

Head | PS | Stern | SB | Head

Apparent wind direction [deg]

RECENT STUDIES

RECENT STUDY: WIND HYBRID COASTER

- Sub project of MARITIM
- Main objective was to develop a Flettner rotor for coasters
- MARIN delivered design advice, model tests, performance predictions and **voyage simulations**
- Vessel not in build; scope for improvement
- Development continuing under the banner of "ECO FLETTNER"

Unterstützt durch / Mede mogelijk gemaakt door:

provincie groningen
provincie Drenthe
provinsje fryslân provincie fryslân
provincie Gelderland
Provincie Noord-Brabant
Ministerie van Economische Zaken, Landbouw en Innovatie
Niedersächsisches Ministerium für Wirtschaft, Arbeit und Verkehr
Ministerium für Wirtschaft, Energie, Bauen, Wohnen und Verkehr des Landes Nordrhein-Westfalen
INTERREG Deutschland Nederland
INTERREG - Grenzregionen gestalten Europa
Europäischer Fonds für Regionale Entwicklung der Europäischen Union
INTERREG - Grensregio's bouwen aan Europa
Europees Fonds voor Regionale Ontwikkeling van de Europese Unie
EDR

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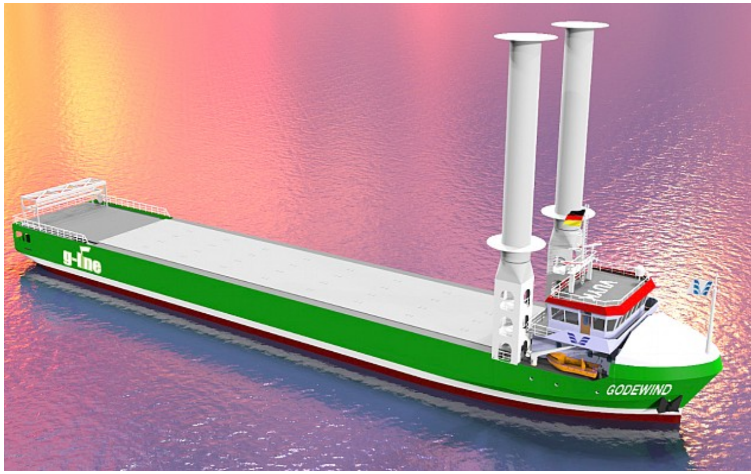
ECO FLETTNER™



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RECENT STUDY: SAIL (ECOLINER)

- Broad scope; large group of participants
- In principle independent from any specific design
- Ecoliner, developed by Dykstra Naval Architects (DNA), used as main reference
- MARIN provided voyage simulations for the Ecoliner
- Design development ongoing at DNA

European Union
The European Regional Development Fund
provinsje fryslân
provincie fryslân
www.nsrsail.eu

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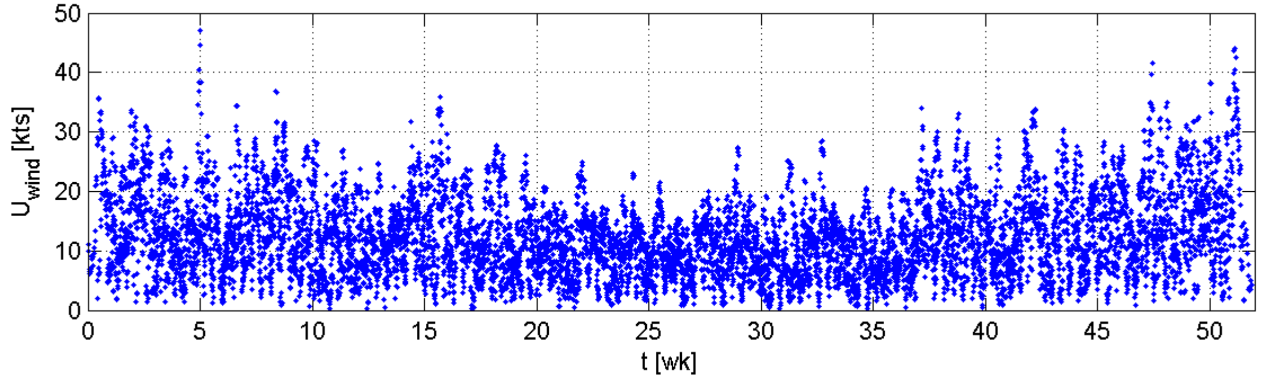
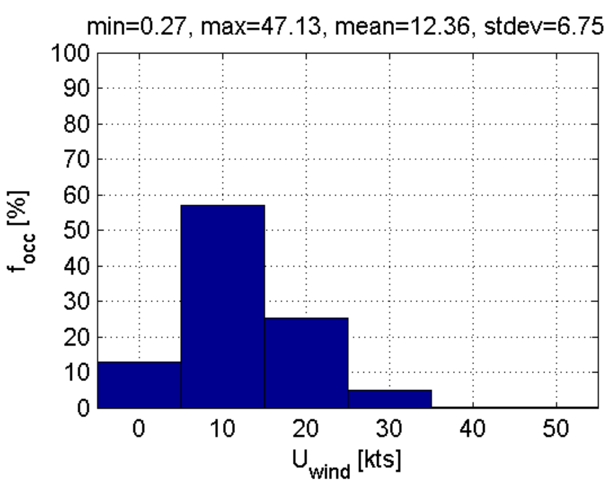
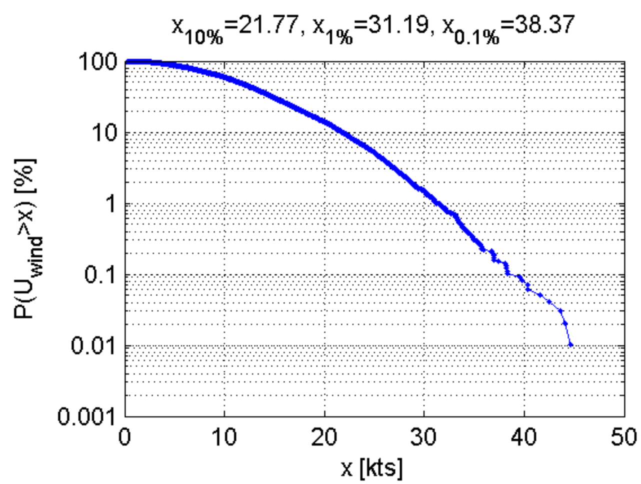
RECENT STUDY: VOYAGE SIMULATIONS

- Voyage simulations using GULLIVER (Scensim) are used at MARIN to evaluate the actual environment a ship is sailing in
- Intended for the design phase
- To study e.g.:
  - Complete operational profile
  - Involuntary speed loss due to wave and wind added resistance
  - Voluntary speed loss due to accelerations, slamming, green water ("Caption Decision Mimic" criteria)
  - Actual speed, power, emissions
  - The certainty of arrival time versus engine power (Sea Margin)
  - **The fuel consumption of wind assisted ships !**

RECENT STUDY: VOYAGE SIMULATIONS







U_{wind} [kts]

RECENT STUDY: VOYAGE SIMULATIONS

- Hydrodynamic forces (towing tank or CFD)
  - Parasitic resistance
  - Lift and lift induced resistance
- Aerodynamic forces (wind tunnel or CFD)
- Propulsion installation performance
  - Specific fuel consumption map
    (versus engine power and speed)
  - Losses along the propulsion line
- Seakeeping
  - Motions and accelerations, relative wave height
  - Added resistance

RECENT STUDY: SHIP CHARACTERISTICS (HYDRODYNAMIC)

Wind Hybrid Coaster

- Conventional hull, adjusted for speed range
- Partial load condition
- L_{WL}, B_{WL}, T = 85.0, 14.0, 4.7 m
- Displ. = 4590 t
- Speed = 8 kn
- GM = 0.7 m
- Single rudder

SAIL - Ecoliner

- Dedicated hull shape for motor-sailing
- L_{WL}, B_{WL}, T = 138.0, 18.0, 7.2 m
- Displ. = 11916 t
- Speed = 11 kn
- GM = 0.6 m
- Single rudder

Wind Hybrid Coaster

- Twin Flettner rotors side by side integrated with deck house
- L / D = 18 / 3 m
- Max. rot. rate = 280 RPM
- Max. C_L = 10.1

SAIL - Ecoliner

- Three Dynarigs, spread along the length of the vessel
- 3 masts
- Mast height = 61 m
- Sail area = 3859 m^2
- Max. C_L = 1.5

Additionally, each design is simulated without wind propulsor as “conventional”

RECENT STUDY: SHIP CHARACTERISTICS (PROPULSION)

Wind Hybrid Coaster

- Single diesel direct installation
- Installed power = 1520 kW
- Controllable pitch propeller

SAIL - Ecoliner

- Four generator sets (constant RPM) – an assumption
- Electric propulsion motor
- Installed power = 4x750 kW
- Controllable pitch propeller

RECENT STUDY: GULLIVER INPUT DATA

Wind Hybrid Coaster

- Model tests at MARIN
- TUHH Flettner wind tunnel tests
- Wageningen CD propeller series
- SHIPMO seakeeping calculations
- D3TAW added resistance
- Simplified specific fuel consumption map based on engine catalogue

SAIL - Ecoliner

- Input Dykstra for hydrodynamic performance (bare hull model tests at TU Delft), excl. yaw balance
- Wolfson Unit wind tunnel tests
- Wageningen CD propeller series
- SHIPMO seakeeping calculations
- D3TAW added resistance
- Simplified specific fuel consumption map based on engine catalogue

MARIN

RECENT STUDY: GULLIVER INPU

- Large matrix with variations:
  - Leeway
  - Speed
  - Rudder angle
  - Thrust
- A detailed description of forces was derived to use in the voyage simulations

Wind Hybrid Coaster

- Model tests at MARIN
- TUHH Flettner wind tunnel tests
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RECENT STUDY: ENVIRONMENT & SCENARIO

- Hindcast data for 1999 for WHC and 1995-1999 for the Ecoliner
  - Waves
  - Wind
  - Tidal or ocean current as appropriate for the route

- A ship leaving every 3 days -> favorable statistical uncertainty

- Ships are required to arrive in time (or early) according to a fixed speed on the shortest possible distance:
  - Wind Hybrid Coaster: 8 kn
  - Ecoliner: 11 kn

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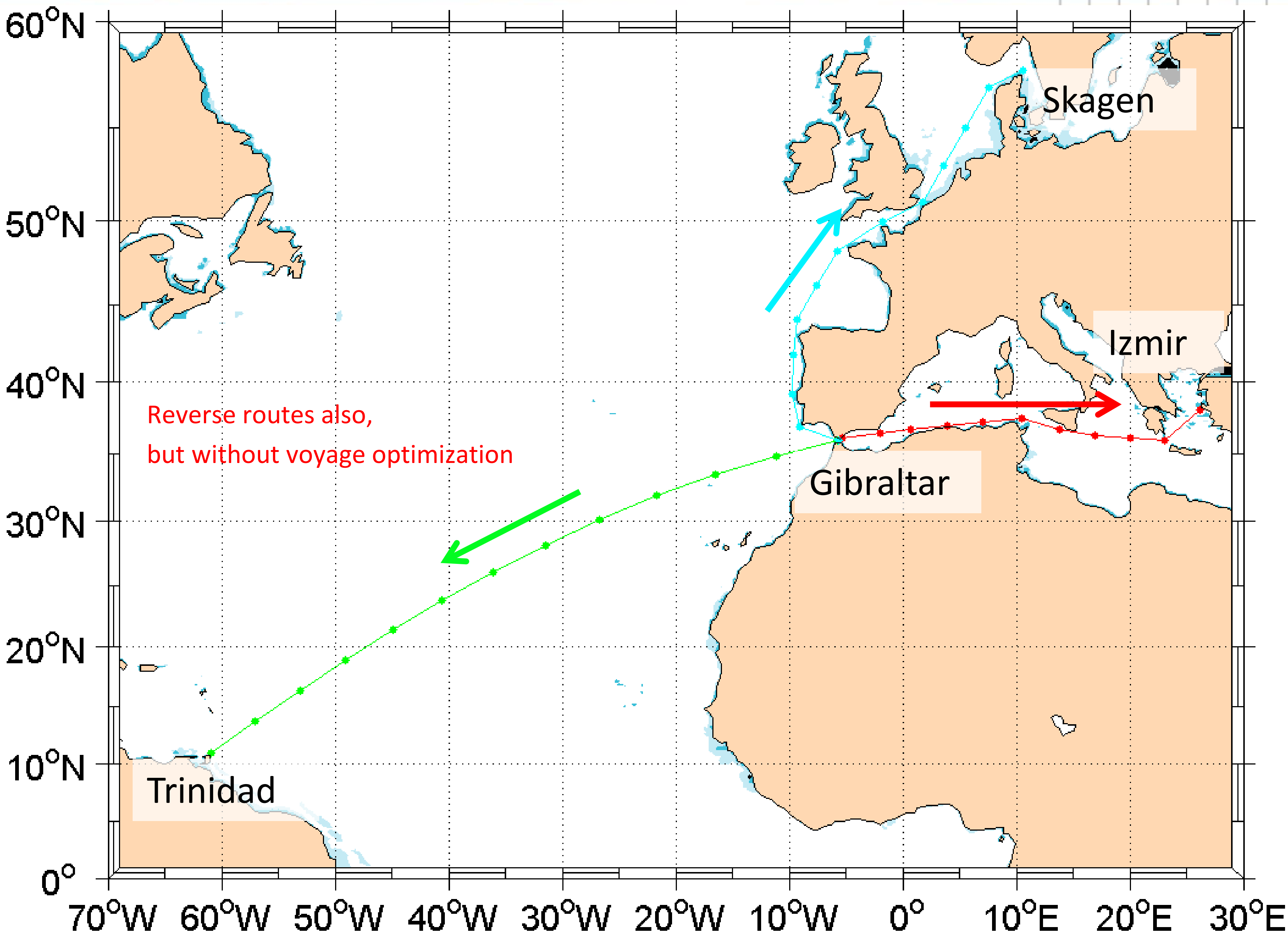
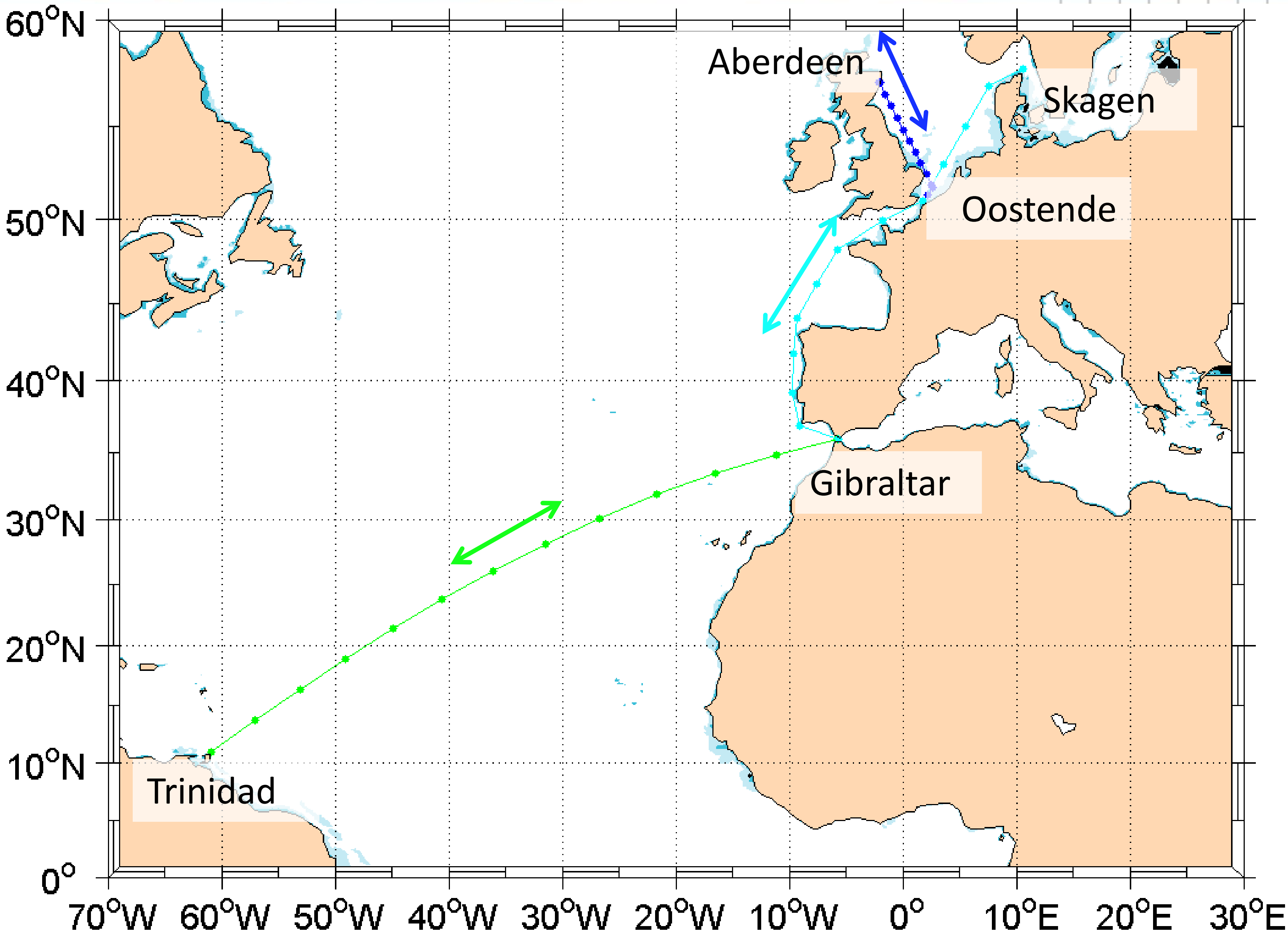
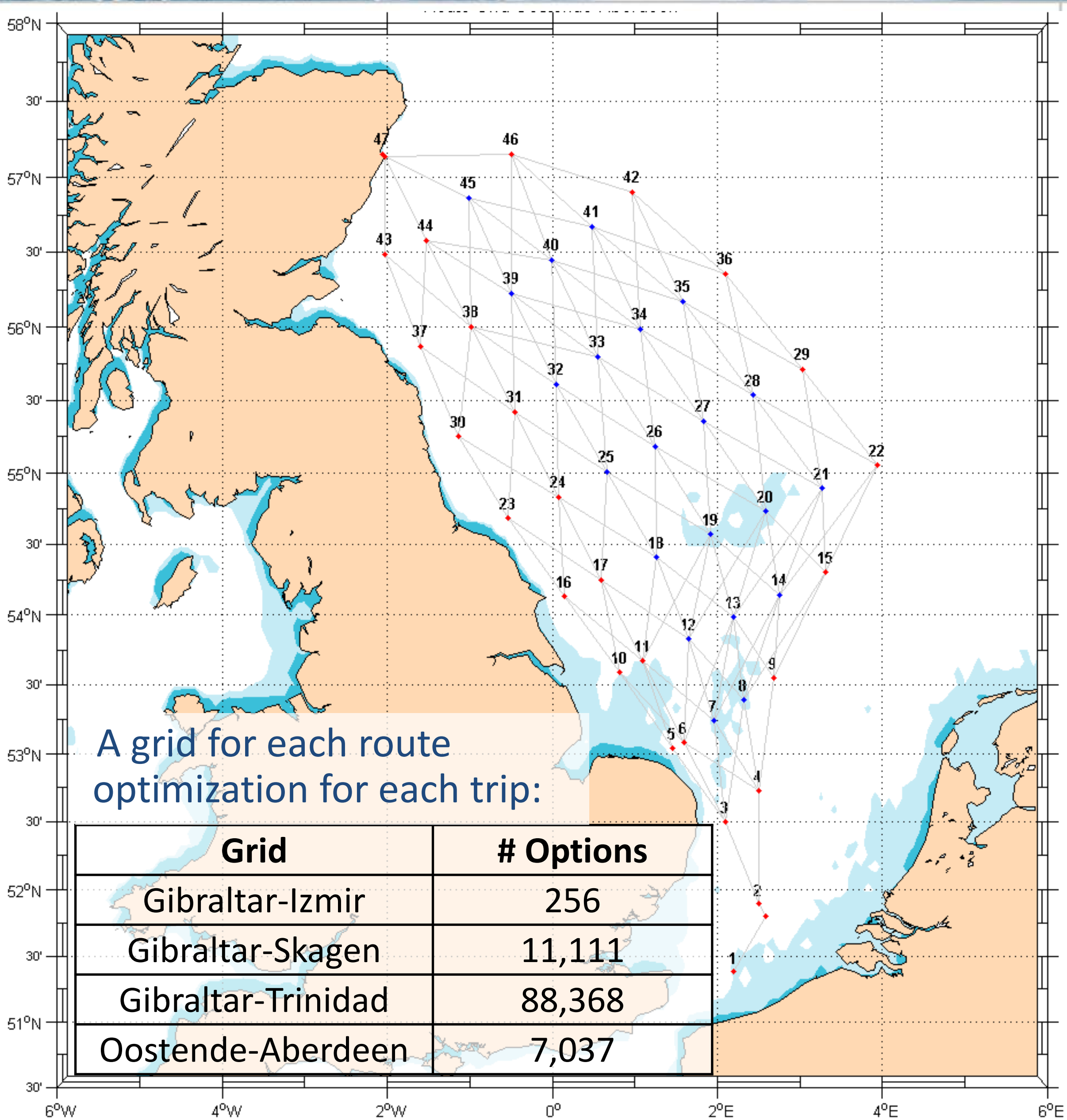
RECENT STUDY: ROUTES WIND HYBRID COASTER



RECENT STUDY: ROUTES ECOLINER



RECENT STUDY: ROUTE OPTIMISATION



A grid for each route optimization for each trip:

Grid	# Options
Gibraltar-Izmir	256
Gibraltar-Skagen	11,111
Gibraltar-Trinidad	88,368
Oostende-Aberdeen	7,037

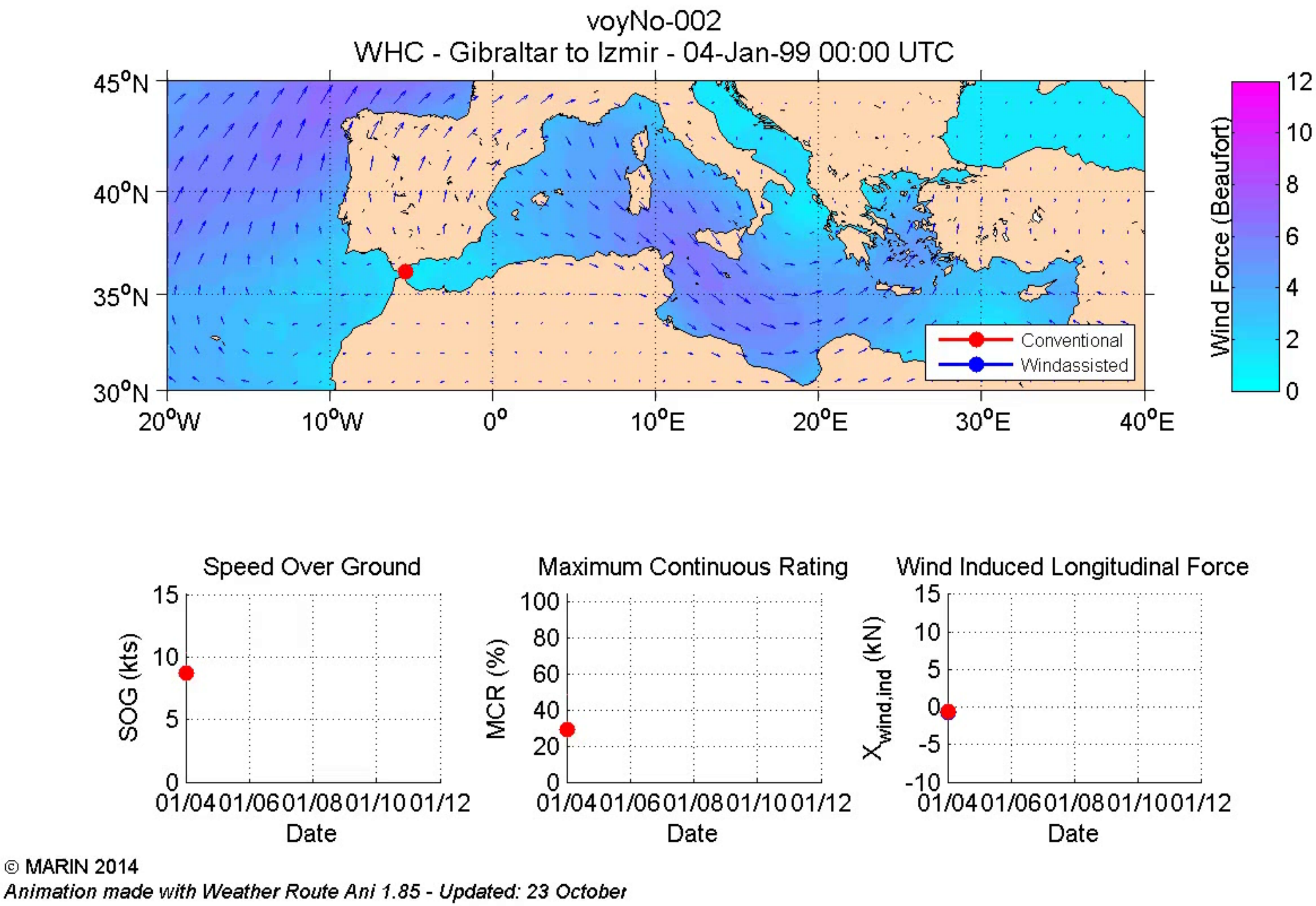
RECENT STUDY: ROUTE AND SPEED OPTIMIZATION

- Option to increase or decrease speed on each individual leg of the grid
- Combined with route optimization, this delivers quite a lot of options per route.....

Grid	#Combinations
Gibraltar-Izmir	8.7M
Gibraltar-Skagen	3,362M
Gibraltar-Trinidad	26,741M
Oostende-Aberdeen	239M

- Finally, for each departure, the single most efficient route and speed profile is selected and used for final analysis

RECENT STUDY: AN ANIMATION…

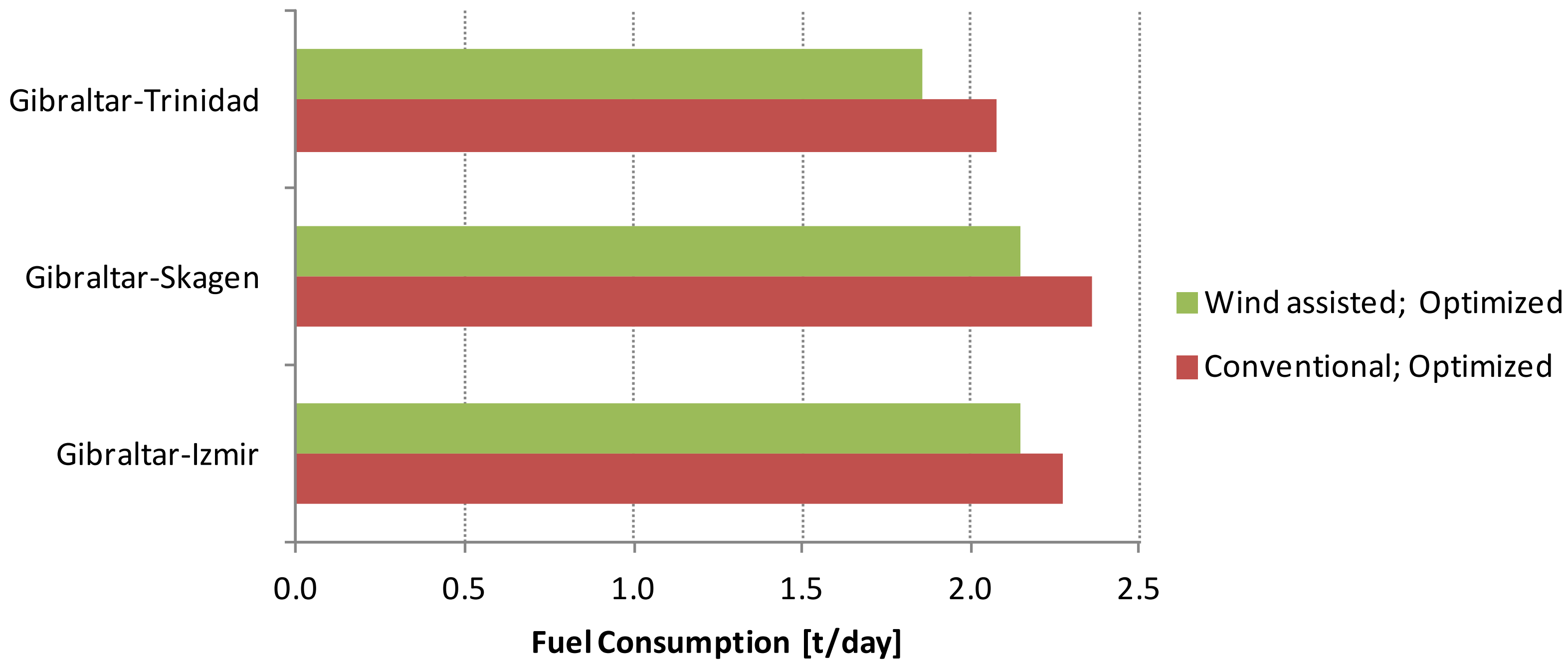


video

WIND HYBRID COASTER - FUEL CONSUMPTION

Overall average fuel savings

- 10% on routes Gibraltar-Skagen and –Trinidad
- Small savings towards Izmir (very little wind)



Note: Only the power required for propulsion

WIND HYBRID COASTER - FUEL CONSUMPTION

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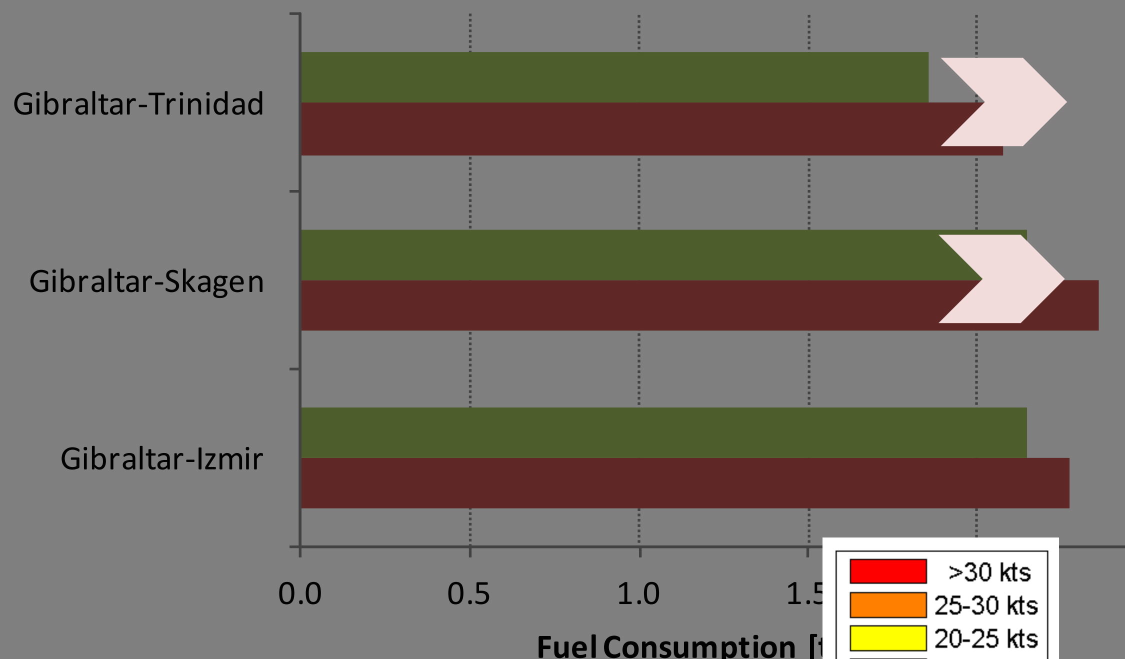
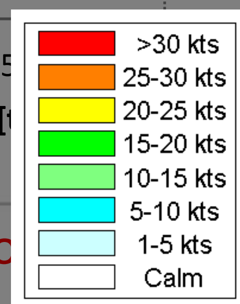
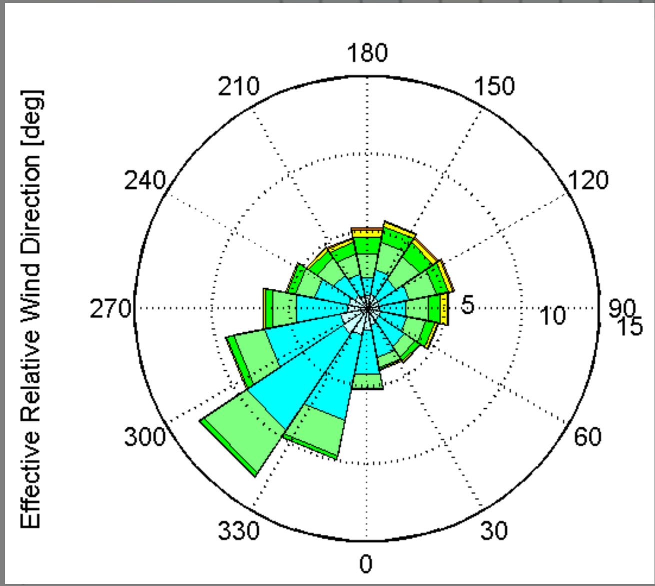
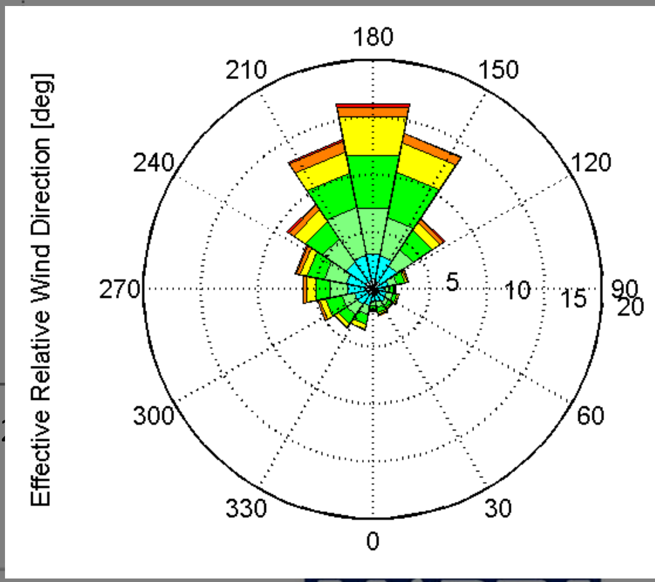


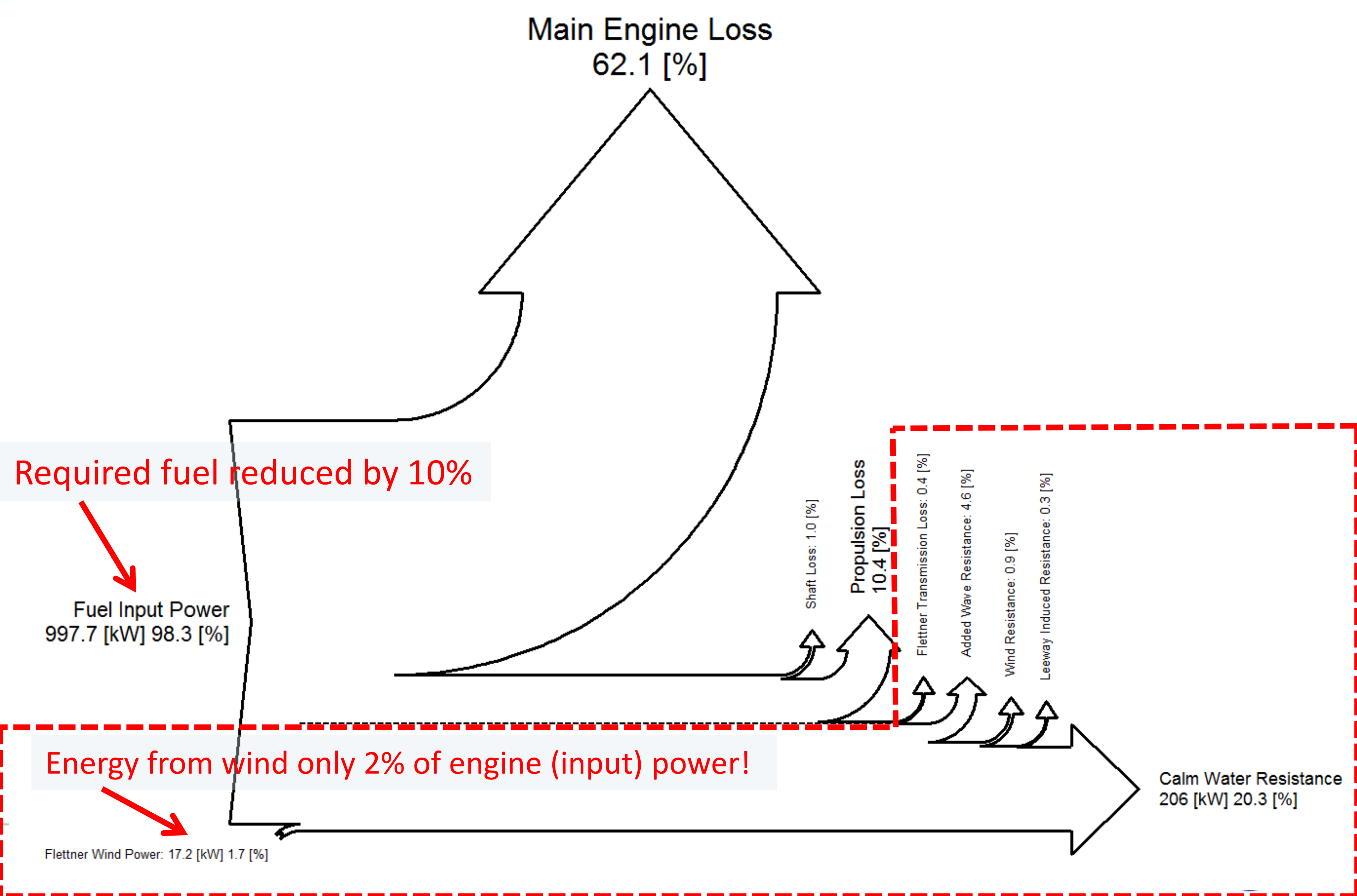




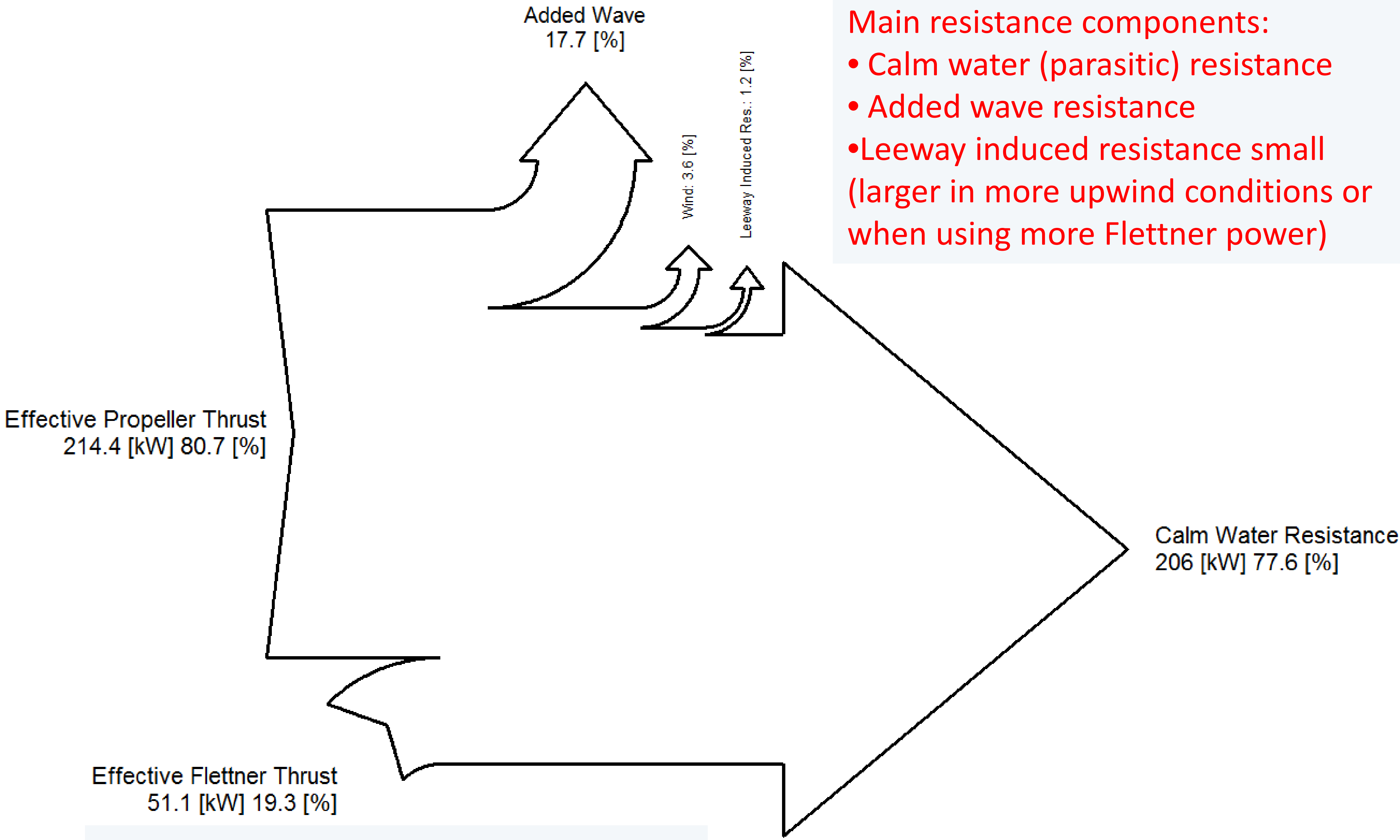


Note: Only the power required fo … on

WIND HYBRID COASTER - POWER BALANCE – WIND ASSISTED (1)



WIND HYBRID COASTER - POWER BALANCE – WIND ASSISTED (2)

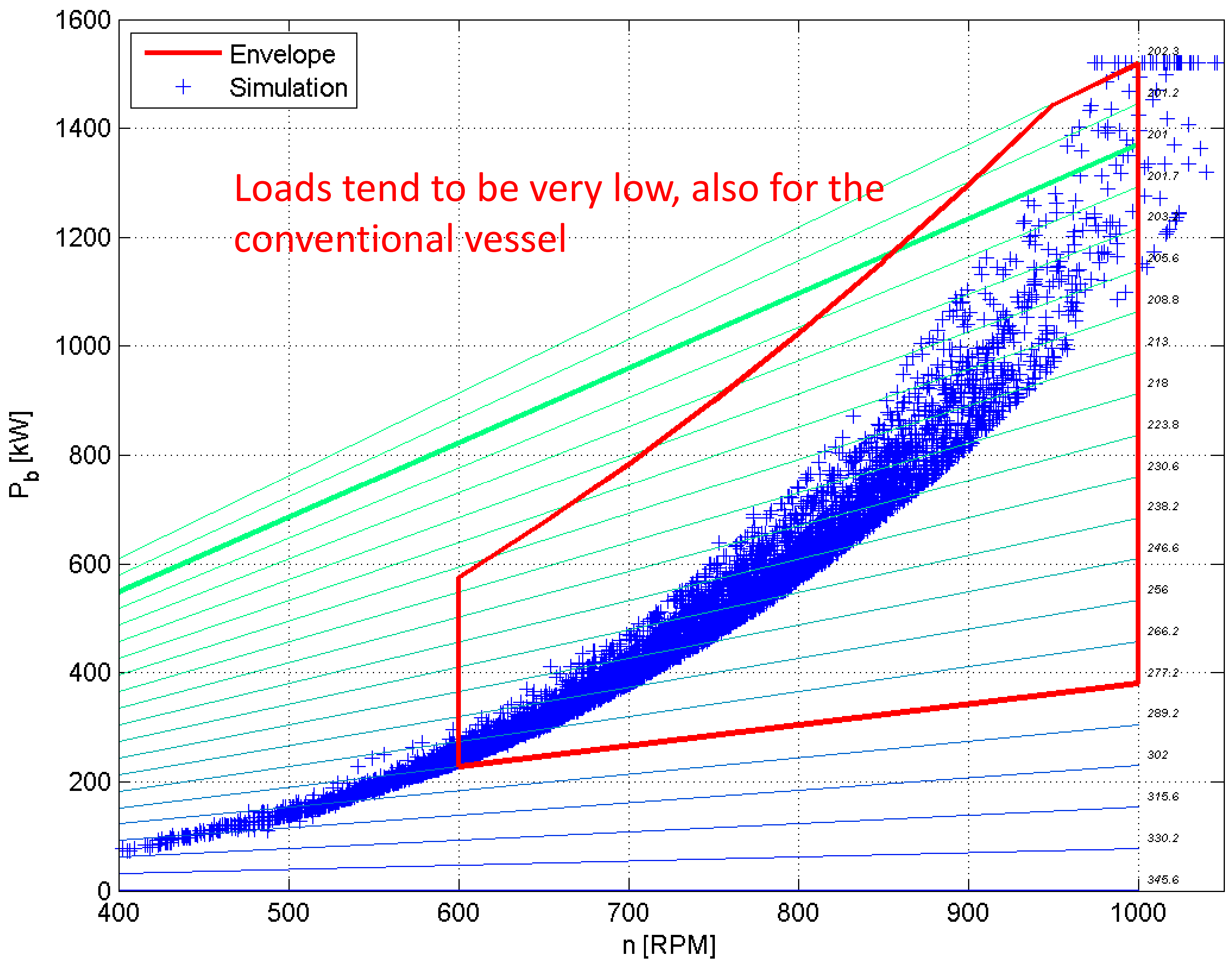


Main resistance components:

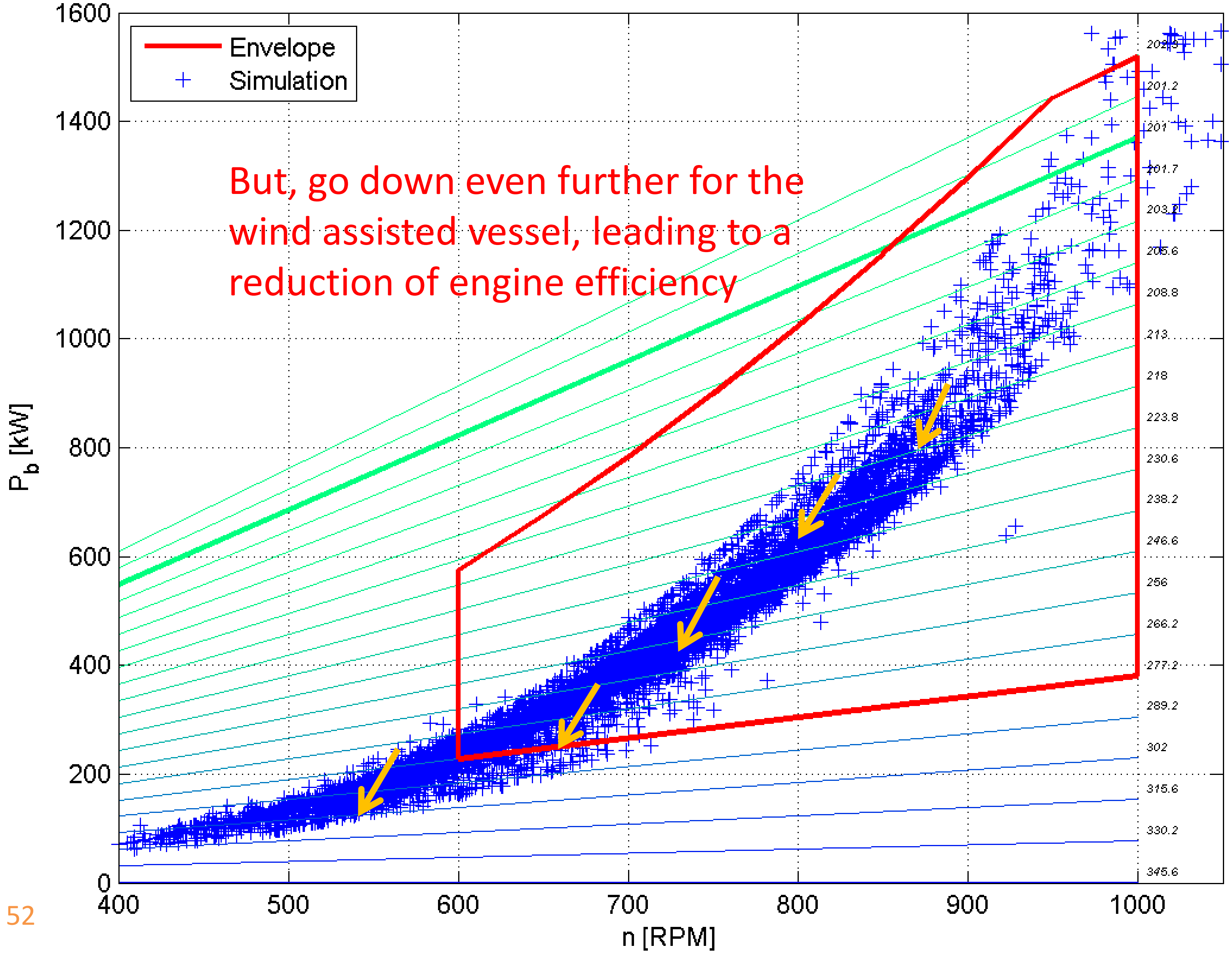
- Calm water (parasitic) resistance
- Added wave resistance
- Leeway induced resistance small (larger in more upwind conditions or when using more Flettner power)

Total thrust by rotors ~19% of total

WIND HYBRID COASTER - ENGINE – CONVENTIONAL

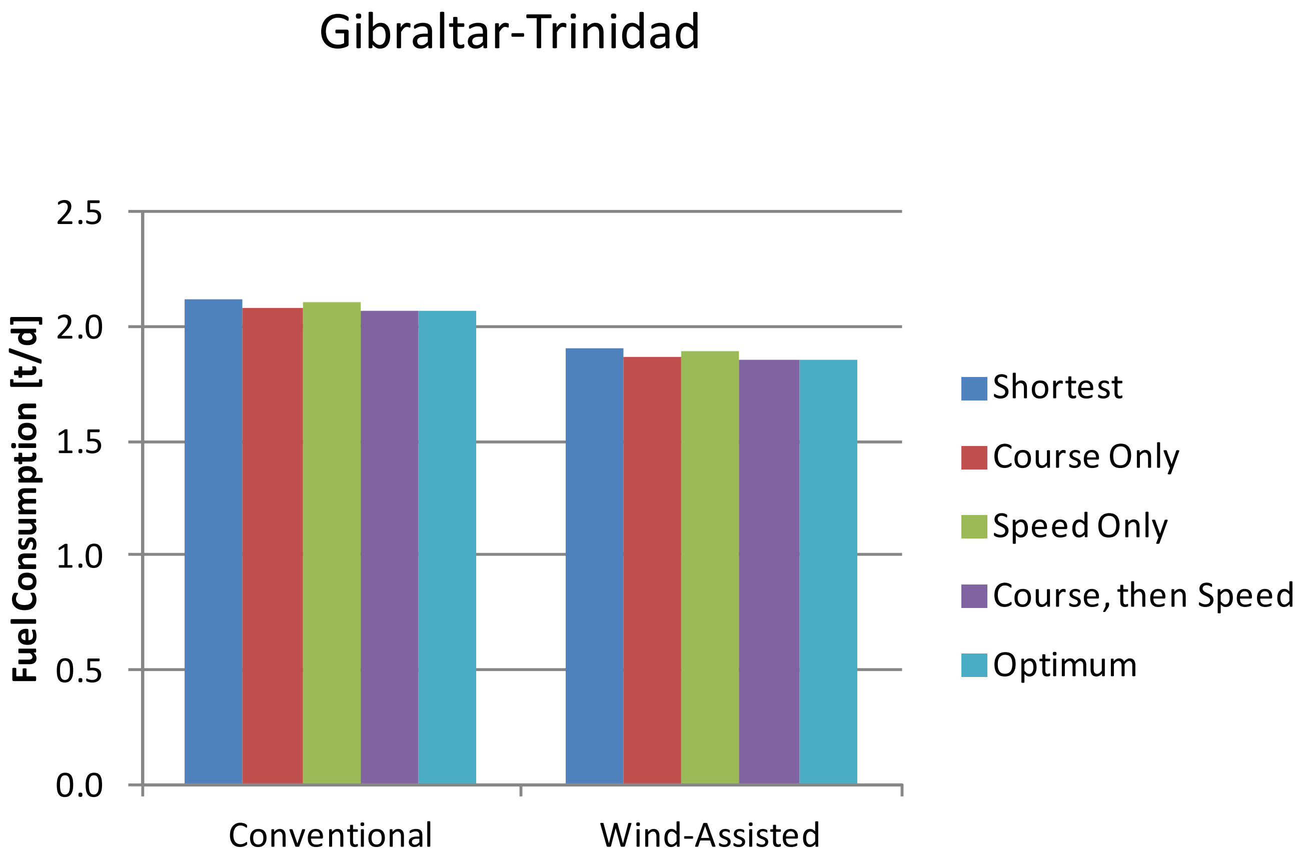


WIND HYBRID COASTER - ENGINE – WIND ASSISTED



WIND HYBRID COASTER - VOYAGE OPTIMIZATION

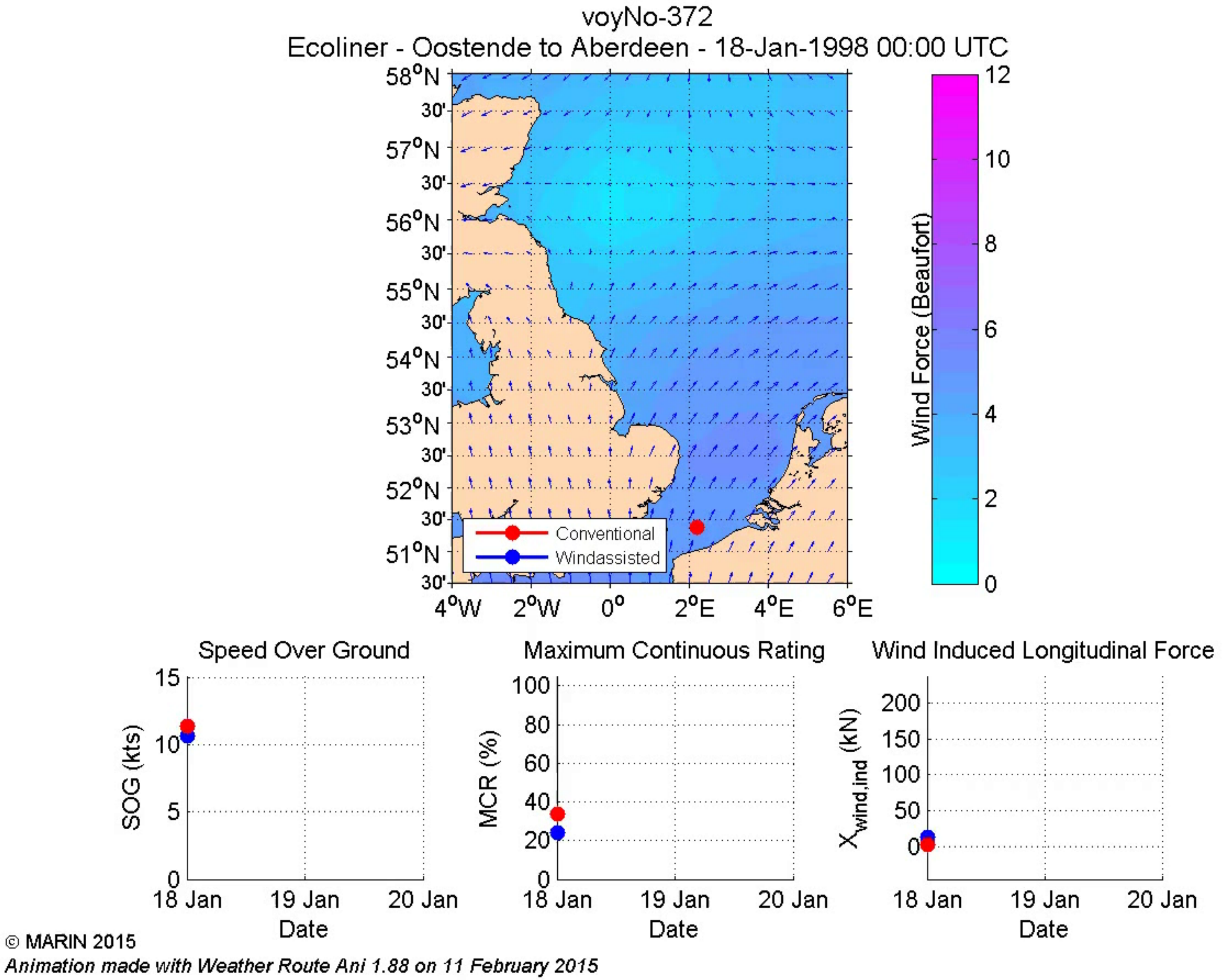
- Benefits are small on average on chosen routes
- Similar small benefits are achieved for the “conventional” vessel



WIND HYBRID COASTER - MAIN OBSERVATIONS

- Conventional hull shape not a big problem for this magnitude of wind propulsion
  - Special appendages not required
  - Except at low ship speed and high wind speed
- Propeller efficiency stays constant or slightly improves
- Contribution in thrust about 20% (favorable routes)
- Small losses due to:
  - Interaction effects of Flettner rotors
  - Required power for Flettner rotation
  - Low engine loads (engine manufacturer data preferred!)
  - Lift induced resistance
- Resulting in an effective saving of about 10% (favorable routes)

RECENT STUDY: AN ANIMATION…

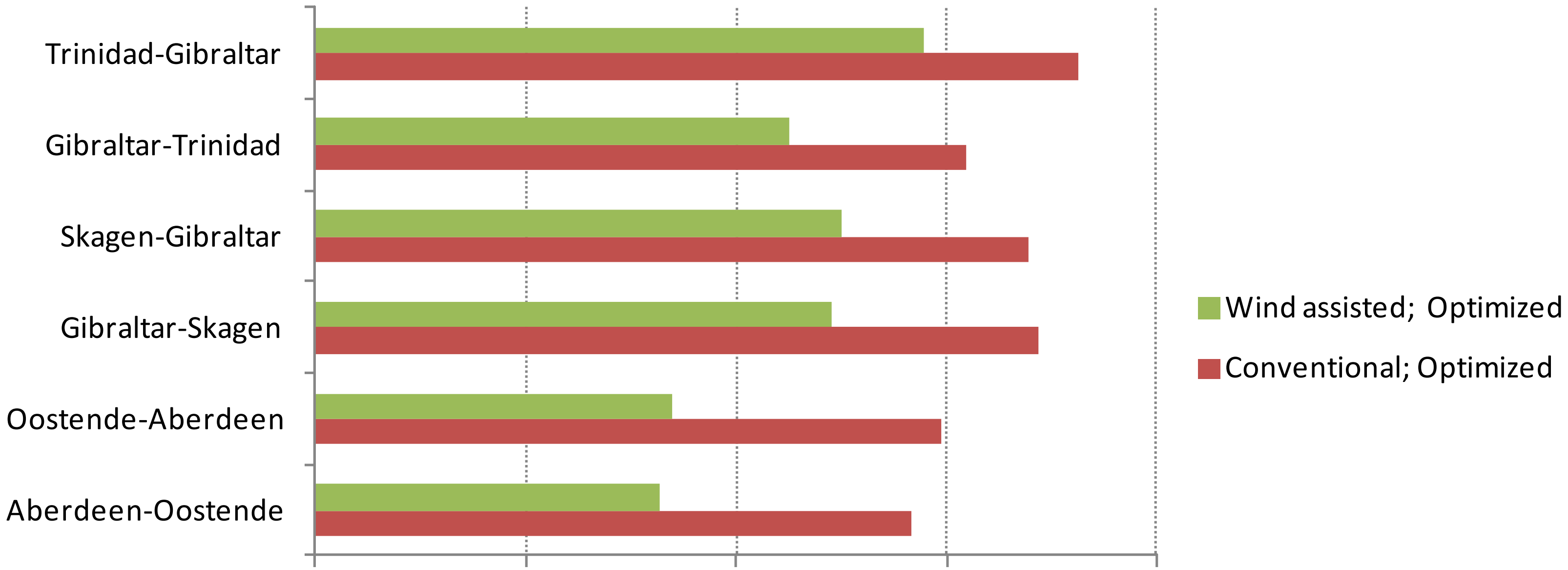


video

ECOLINER - FUEL CONSUMPTION

Overall average fuel savings:

- 10%: Trinidad-Gibraltar (unfavorable route)
- 25%: Most routes
- 40%: Oostende-Aberdeen and vice-versa



Note: Only the power required for propulsion

ECOLINER - FUEL CONSUMPTION

Overall average fuel savings:

- 10%: Trinidad-Gibraltar (unfavorable route)
- 25%: Most routes
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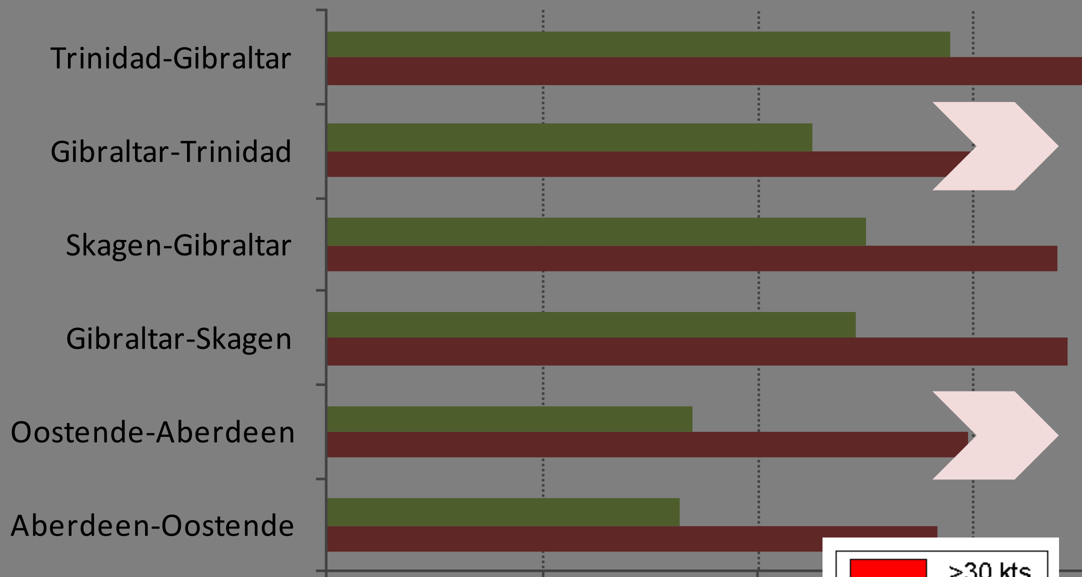
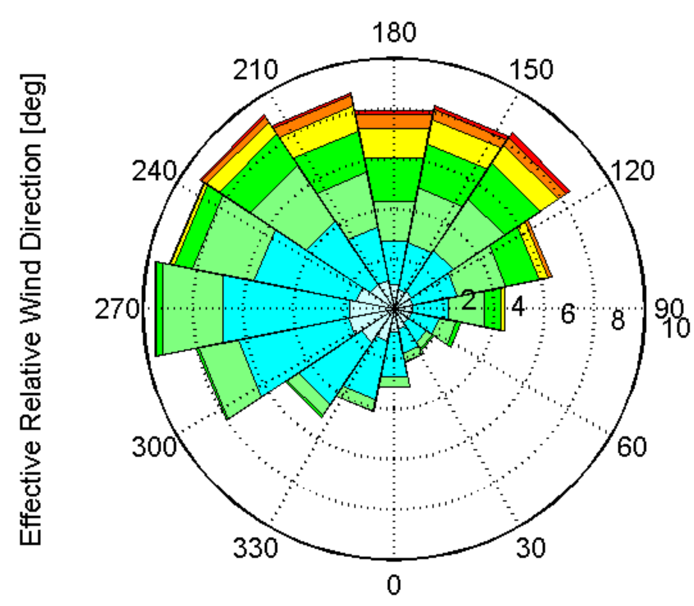
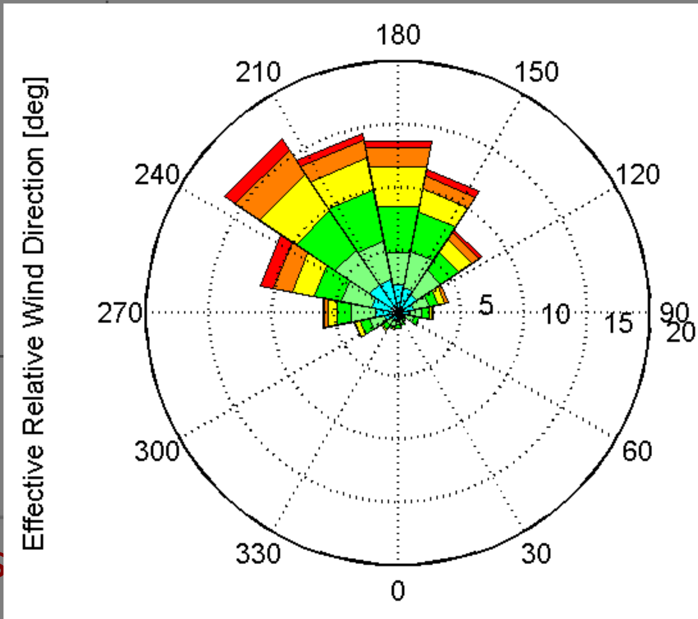
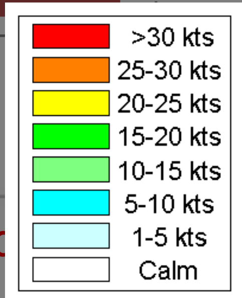


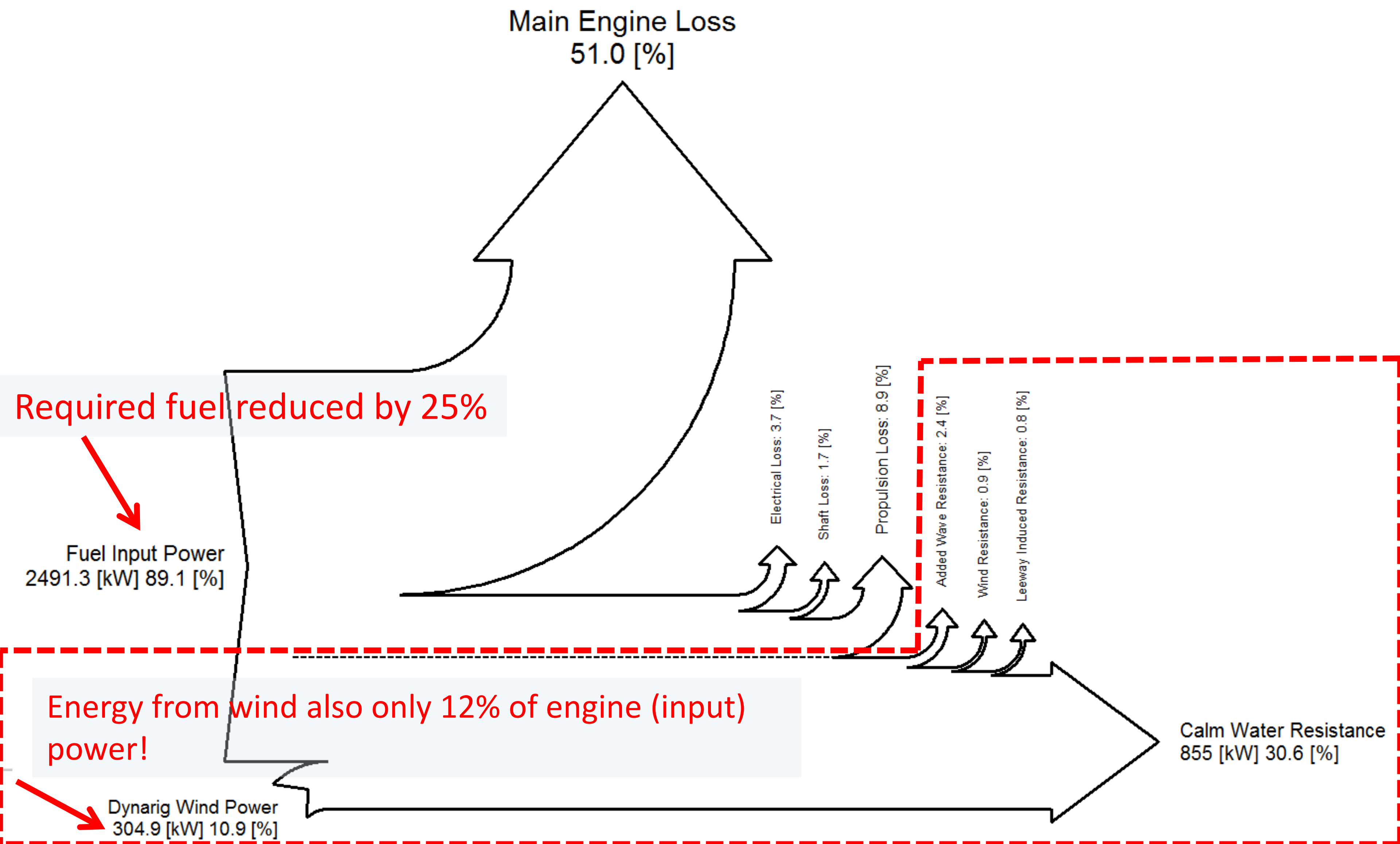






Note: Only the power required

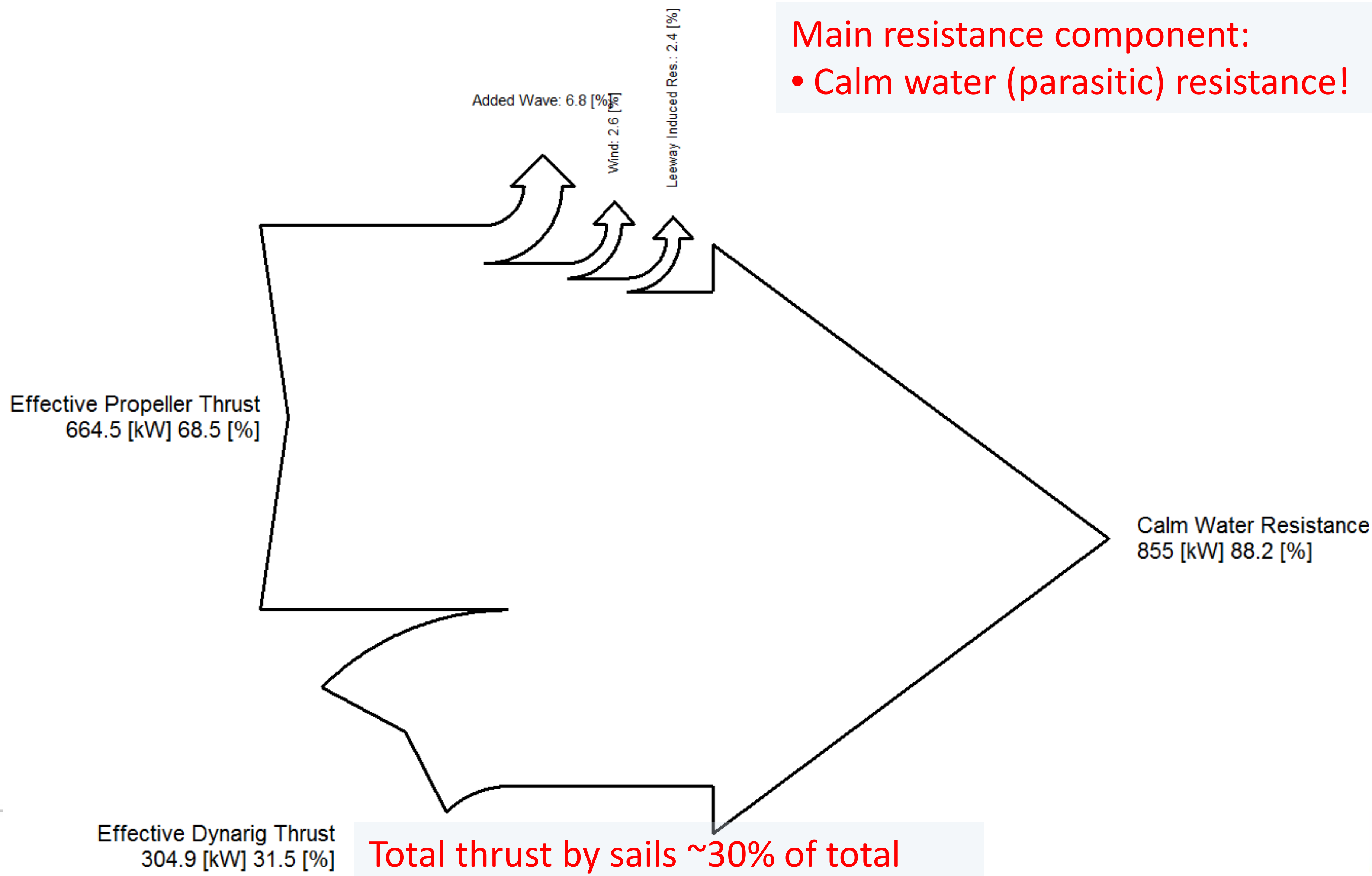
ECOLINER- POWER BALANCE – WIND ASSISTED (1)



ECOLINER- POWER BALANCE – WIND ASSISTED (2)

Main resistance component:

- Calm water (parasitic) resistance!

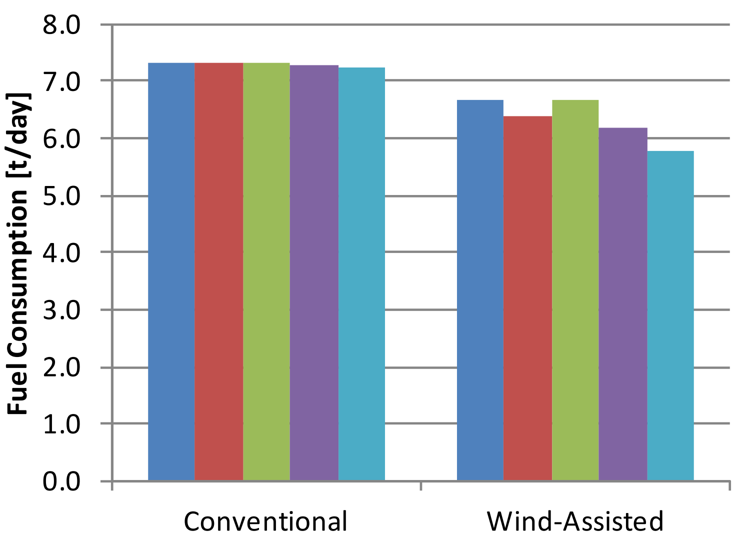


Total thrust by sails ~30% of total

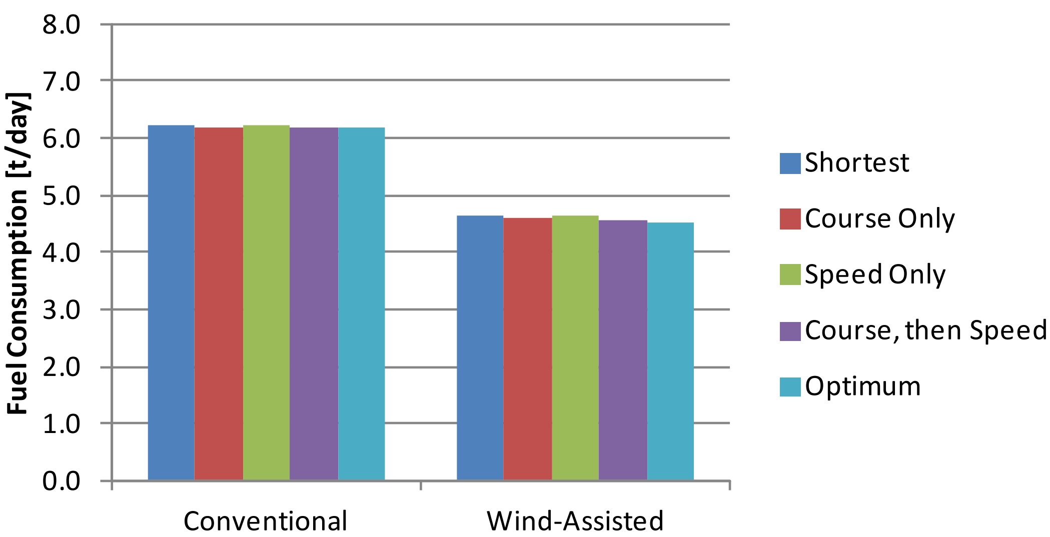
ECOLINER - VOYAGE OPTIMIZATION

- Almost no benefit from speed and route optimization for "conventional" vessel as added resistance is proportionally low
- Benefit for wind assisted vessel very much dependent on route
  - Favorable routes with little variability benefit hardly
  - Unfavorable routes benefit the most

Trinidad-Gibraltar



Gibraltar-Trinidad



MARIN

UPCOMING CHALLENGES AND PERSPECTIVES

UPCOMING CHALLENGES AND PERSPECTIVES

- Operational profile and service conditions need to be put forward on specifications. Ship speed, routes and loading conditions combinations will provide information on:
  - Potential ressources (wind availability)
  - Simulations of options with operational constraints included (type of system)
  - Expected return on investment (costs + CO_2&emission saving)

- Integration of the systems needs to be engineered at large scale
  - Fully integrated devices in the superstructure
  - Appendages similar to ESD (easy to refit or remove)

- Costs (investment and maintenance) will hopefully decrease with volume of solutions available on the market and produced

- The market needs several investors who will dare to invest a large scale and dare to take the risk

MARIN

UPCOMING CHALLENGES AND PERSPECTIVES

- A new area is going to grow between hydrodynamics and aerodynamics: natural propulsion systems and their integration within the propulsion train (control, safety, …).

- Making a smarter use of the available resources and environment is technically possible. Step towards a generalized use is in front of us for wind. Other energy recovery systems from ship motions (at anchor or transit) is still unexplored.

- Main players not yet known and all niche markets not yet explored. Who will take the lead and create new chances of business? Anybody in this room?

THANK YOU!   EFKHARISTO!

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NATURAL PROPULSION SEMINAR – BLUEWEEK