Greener approach to ship design and optimal route planning

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AMOS, NTNU, Trondheim, 4th March 2015

Supported by:

AMOS - Centre for Autonomous Marine Operations and Systems - Norwegian Centre of Excellence

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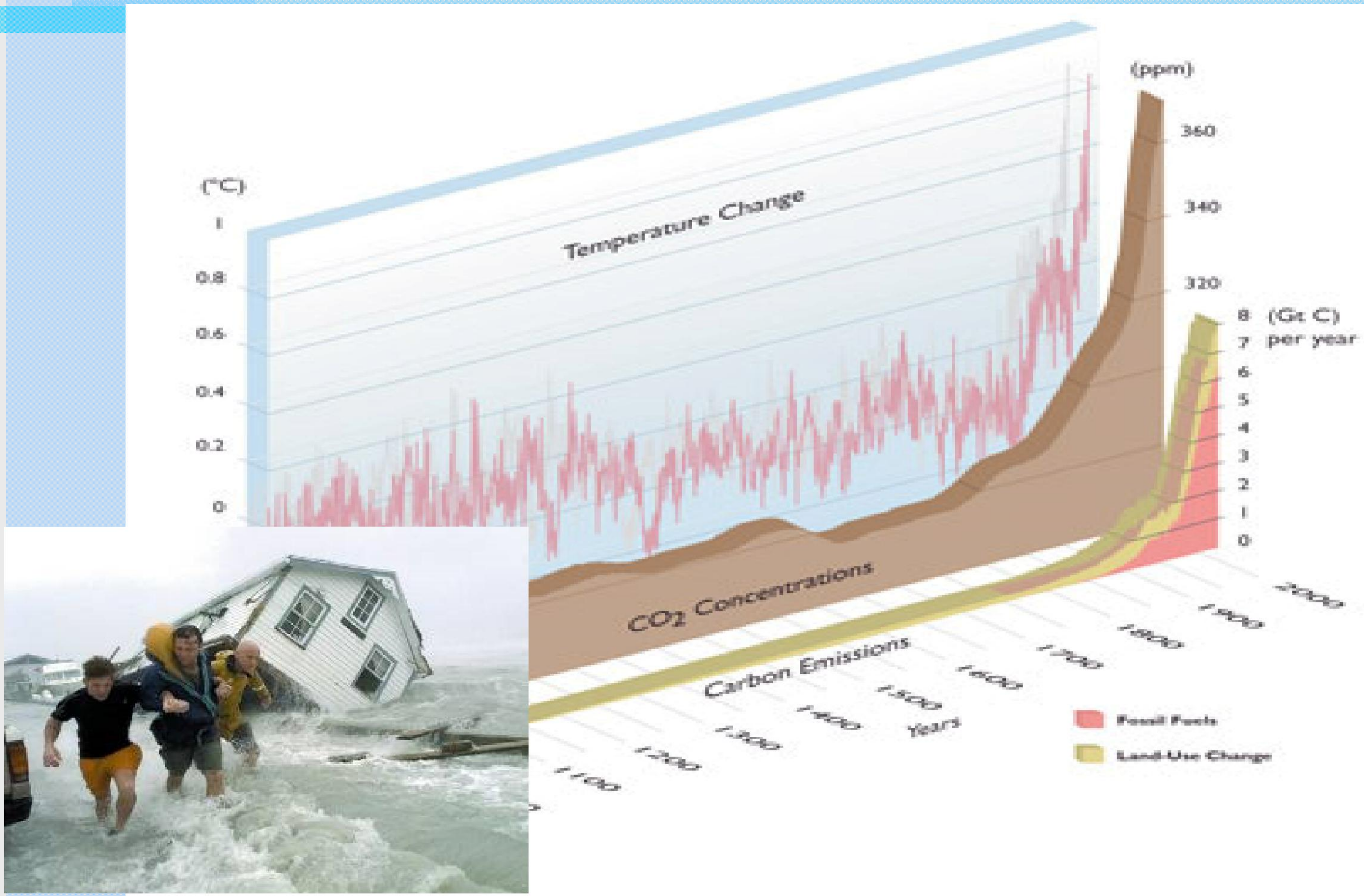
Summary

Basic characteristics of an efficient transportation are safety, cost effectiveness and friendliness with the environment. According to various environmental impact assessments, ocean-going vessels, as the most important part of maritime transportation industry, will have increasing influence on the global ecosystem in the near future. In the modern approach to ship design the problems related to energy efficiency and environmental protection must not be left aside. A methodology for estimating the attainable speed in moderate and severe sea is proposed. Reliable ship speed loss estimation under real environmental conditions allows a more accurate prediction of the power increase and fuel consumption as well as gas emissions from ships.

The objective is to improve ship design and performance taking into accounts the environmental issue, creating a so-called eco-efficient or “green” ship design. The problem is multidisciplinary and requires the joint work of experts in the naval architecture, mechanical engineering, marine engineering and other engineering field.

Contents:

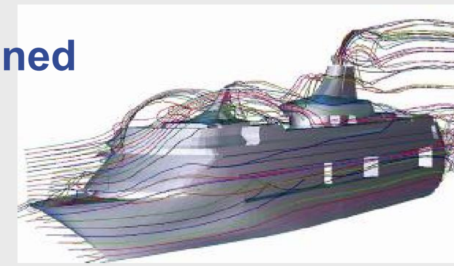
1. Introduction

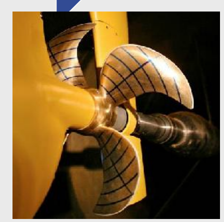


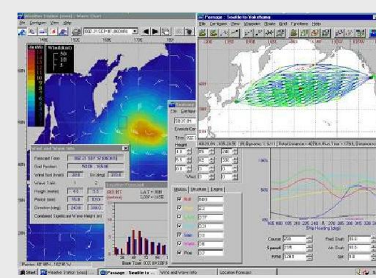
1. Introduction

Assessment of potential reductions of CO_2 emissions from shipping by using known technology and practices (Marine Environment Protection Committee (MEPC) 59 Report, April, 2009)

	Saving of CO_2, tonne-mile	Combined	
Design (new ships)			
Concept, speed and capability (practical constrains)	2% to 50%		
Hull and superstructure	2% to 20%		
Power and propulsion systems	5% to 15%	10% to 50%	
Low-carbon fuels	5% to 15%		**Combined** **25% to 75%**
Renewable energy	1% to 10%		
Operation (all ships)			
Fleet management & logistics	5% to 50%		
Voyage optimization	1% to 10%	10% to 50%	
Energy management	1% to 10%		

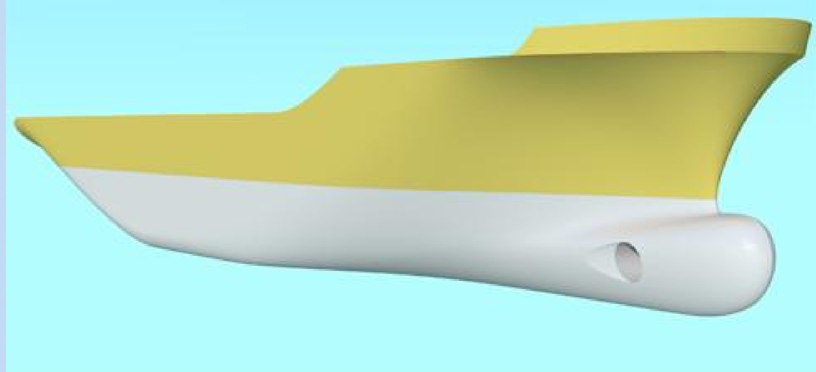


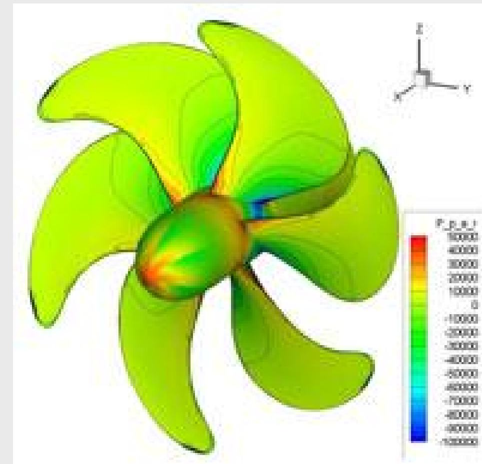




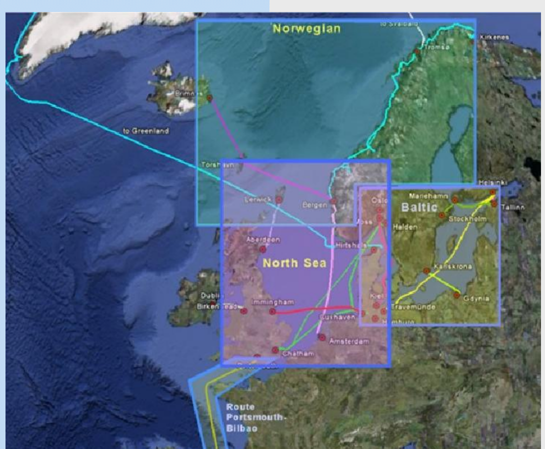
1. Introduction

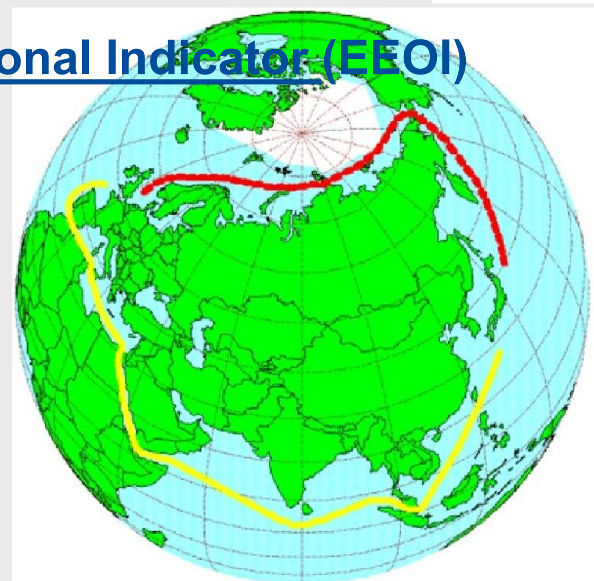
Energy Efficiency Design Index (EEDI)





Energy Efficiency Operational Indicator (EEOI)





1. Introduction

Energy Efficiency Design Index (EEDI)

Measure: $\frac{\text{Cost (i.e. emission)}}{\text{Transport work capacity}}$ Unit: $\frac{\text{g } CO_2}{\text{deadweight tonnage} \cdot \text{nautical mile}}$

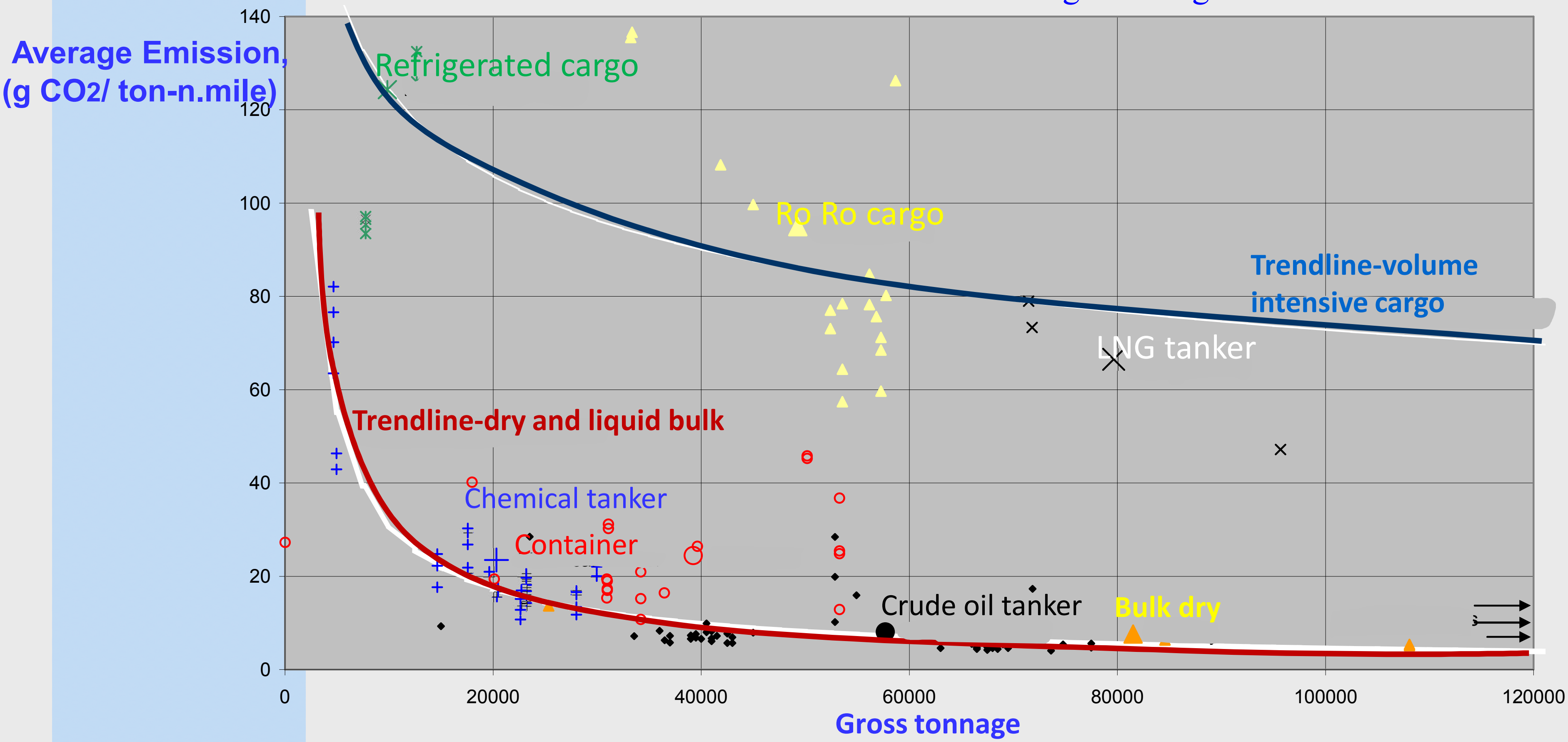


Fig. 1. Average CO2 index and average gross tonnage for ship groups and individual observations

J. Prpić-Oršić, O. M. Faltinsen: Greener approach to ship design and optimal route planning

1. Introduction

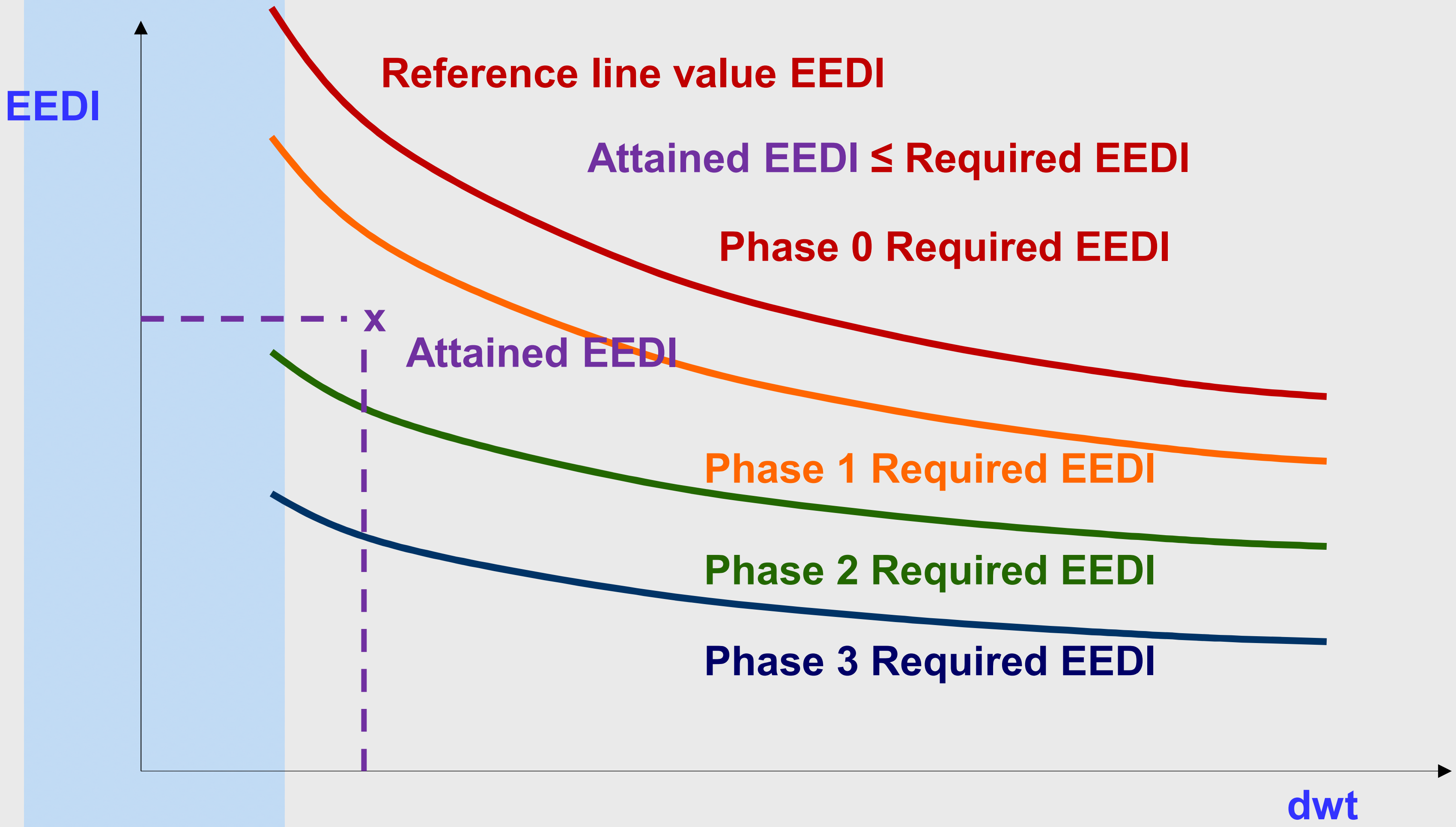


Fig. 2. Required EEDI

2. Speed loss calculation

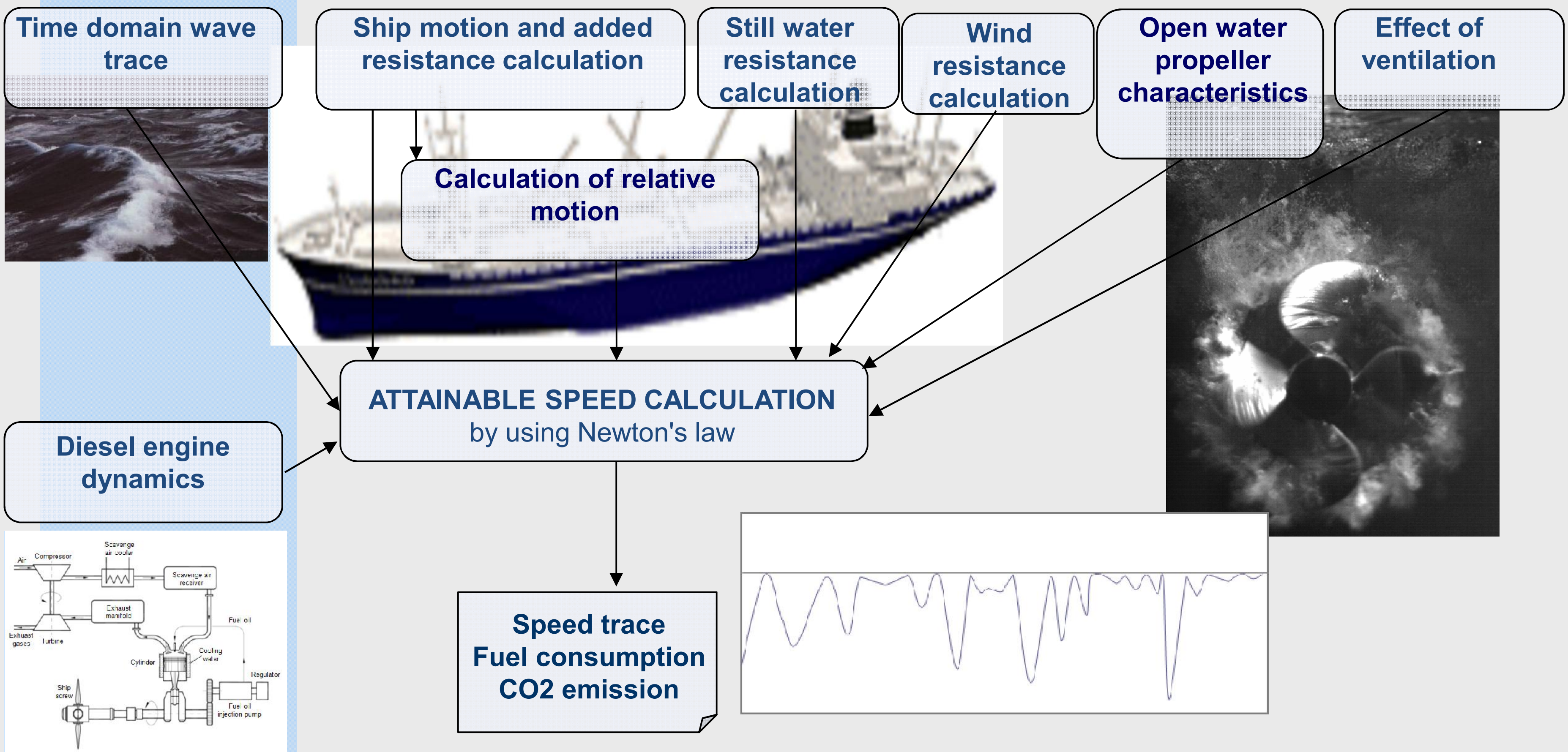


Fig. 3. Scheme of the computations of ship speed in a given sea state

3. Numerical results

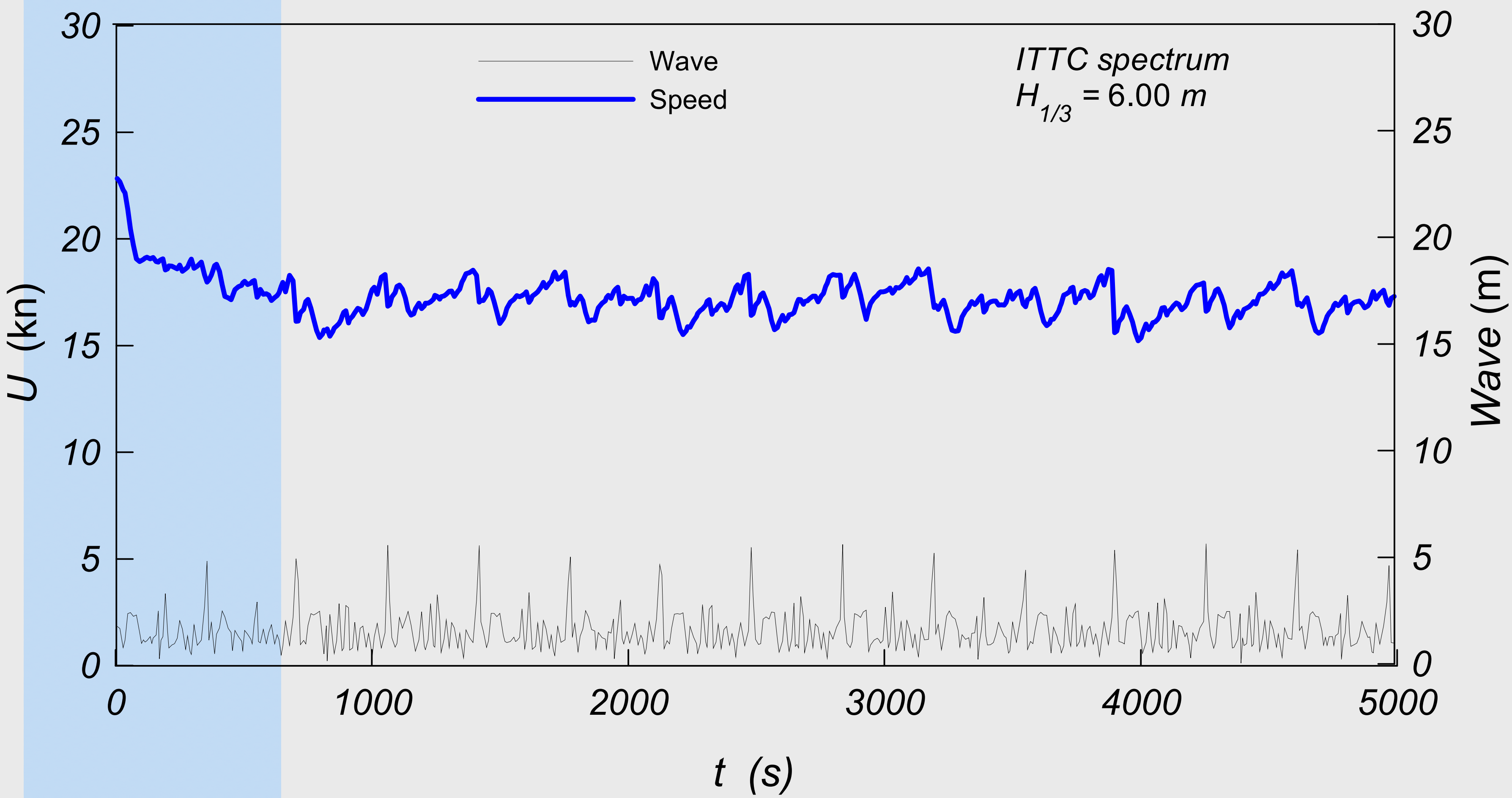


Fig. 5. Time trace of ship speed in head waves ($H_{1/3}$=6 m)

3. Numerical results

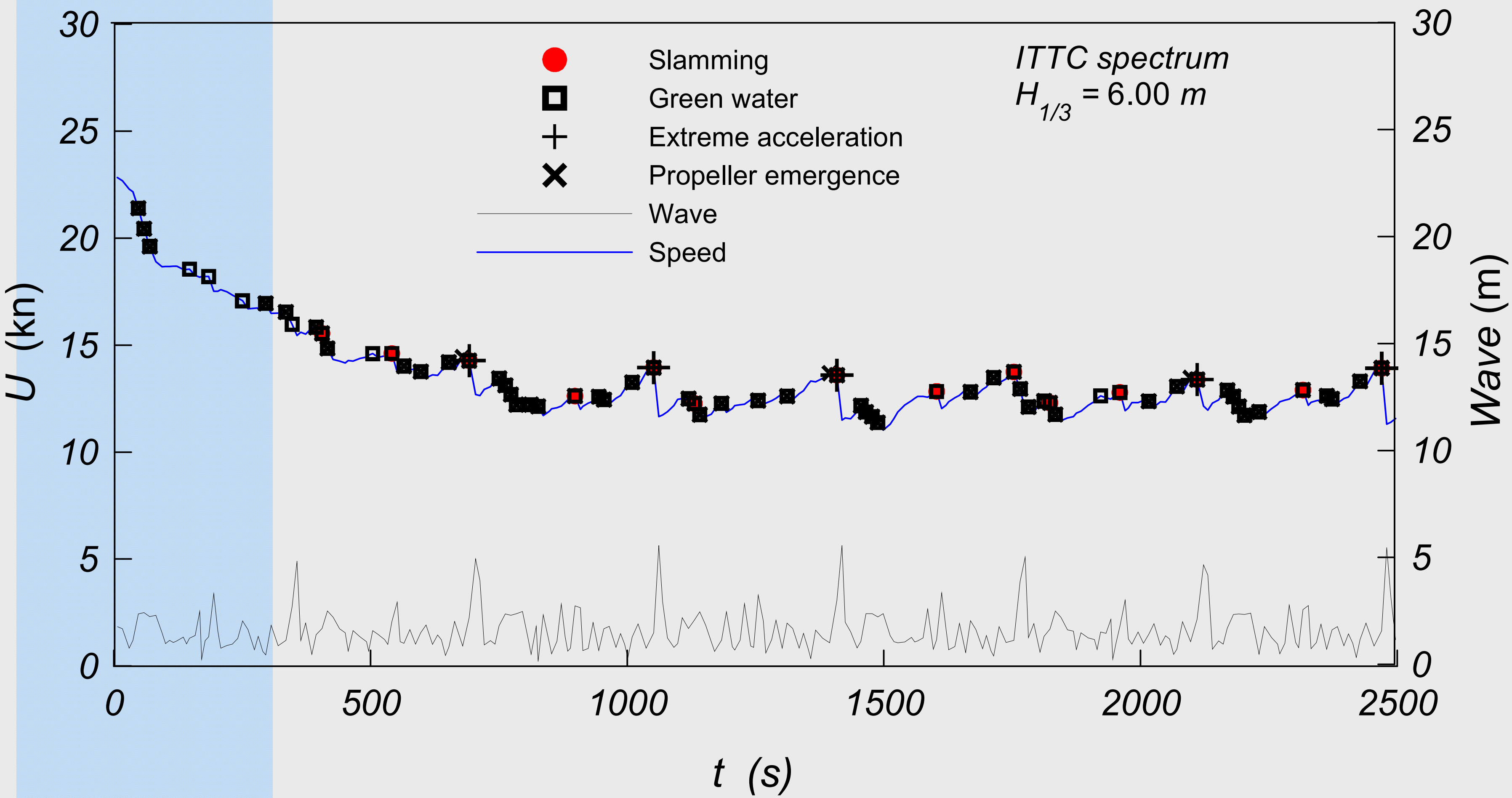


Fig. 6. Voluntary speed reduction in head waves ($H_{1/3}$ = 6 m)

3. Numerical results

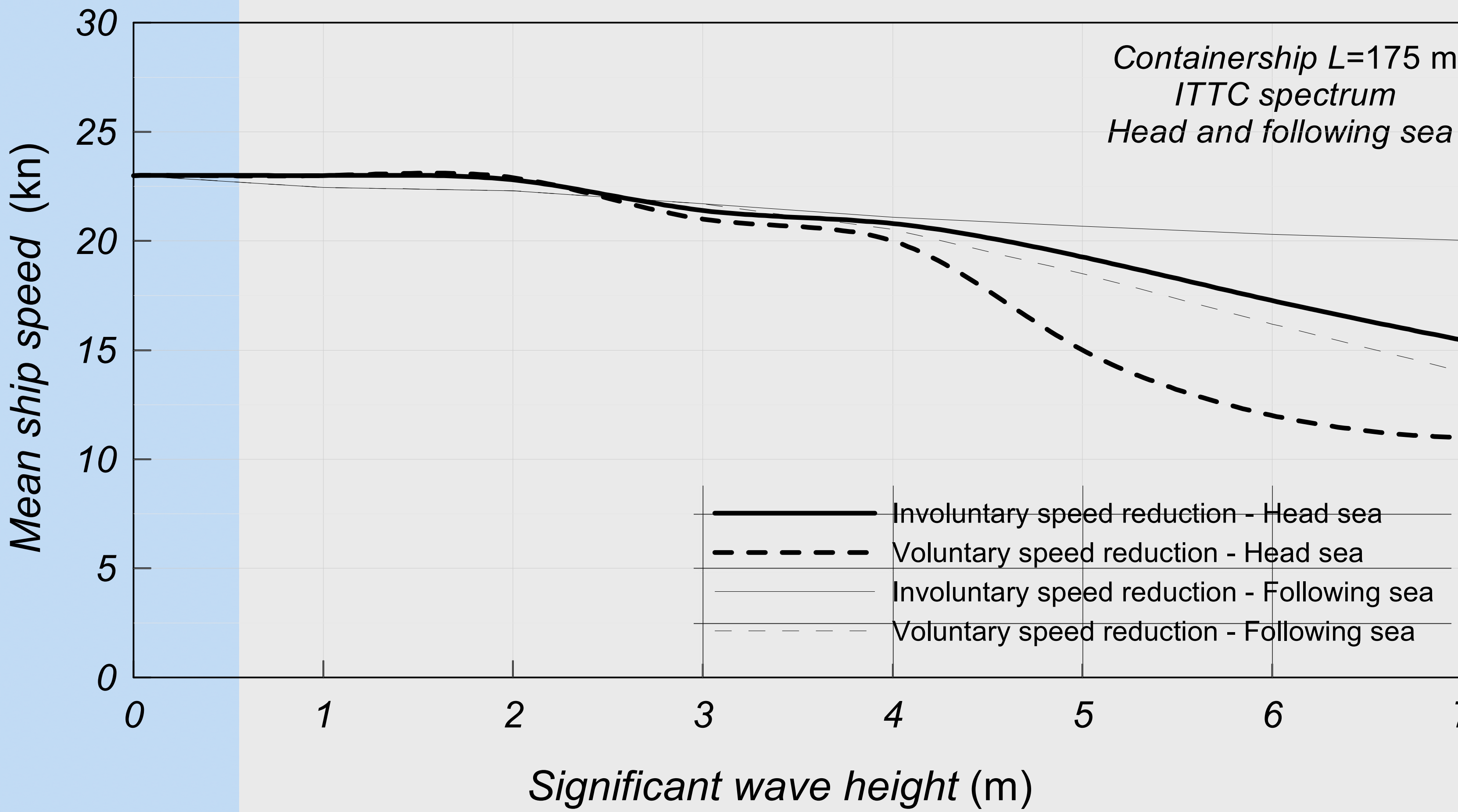


Fig. 7. Average ship speed for involuntary and voluntary speed reduction in head and following waves

3. Numerical results

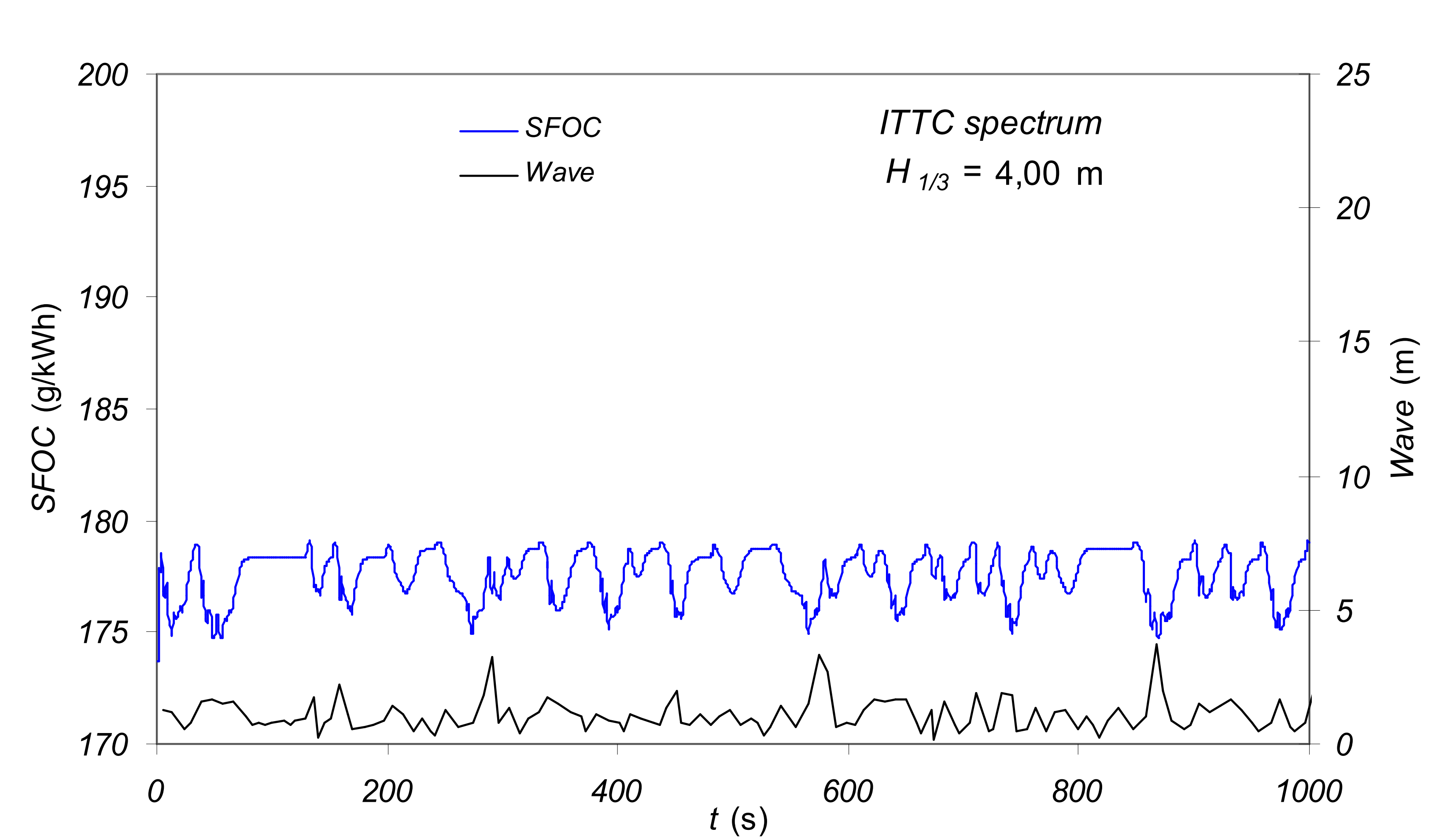


Fig. 8. Specific fuel consumption in head waves ($H_{1/3}$ = 4 m)

3. Numerical results

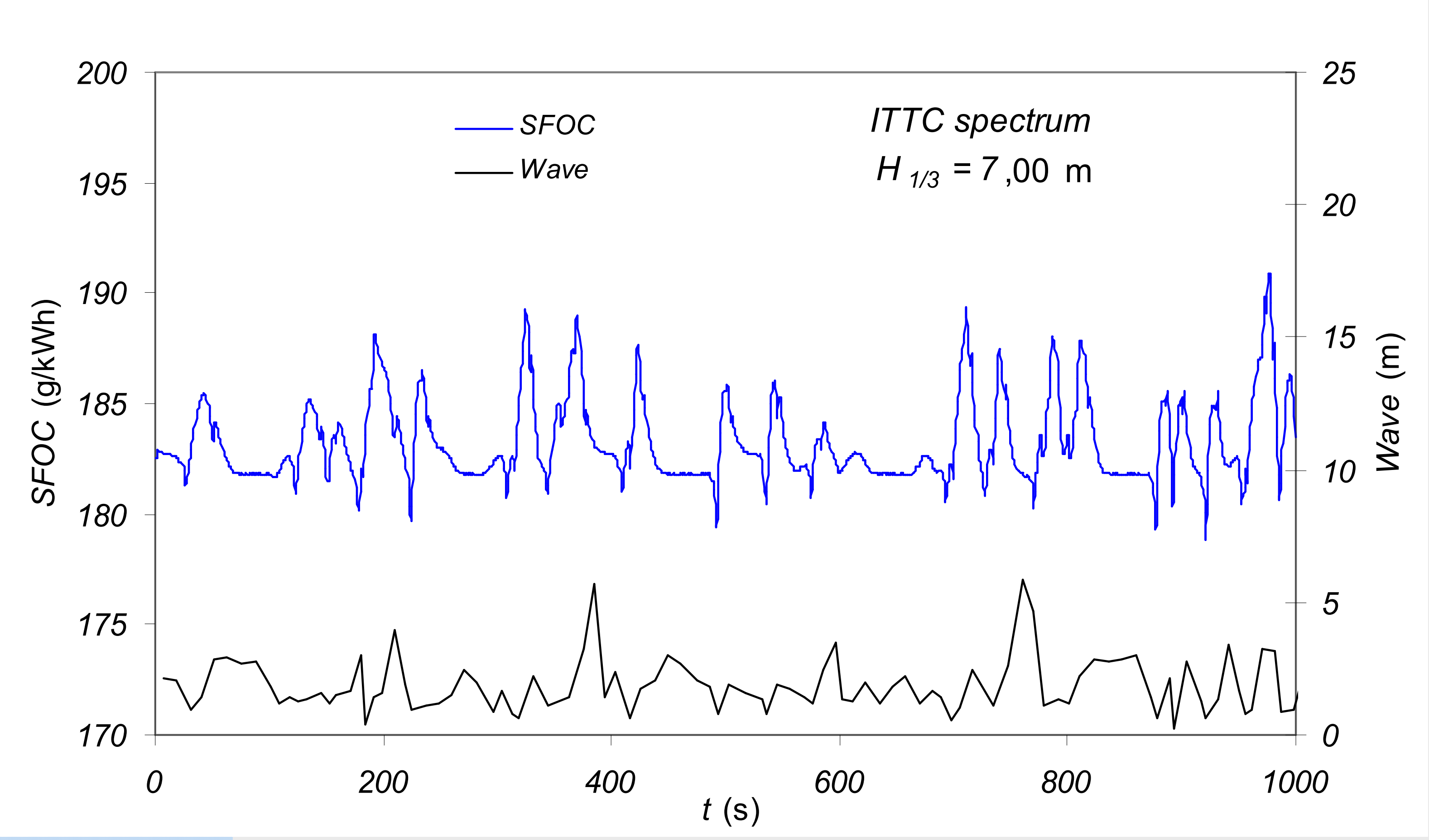


Fig. 9. Specific fuel consumption in head waves ($H_{1/3}$ = 7 m)

3. Numerical results

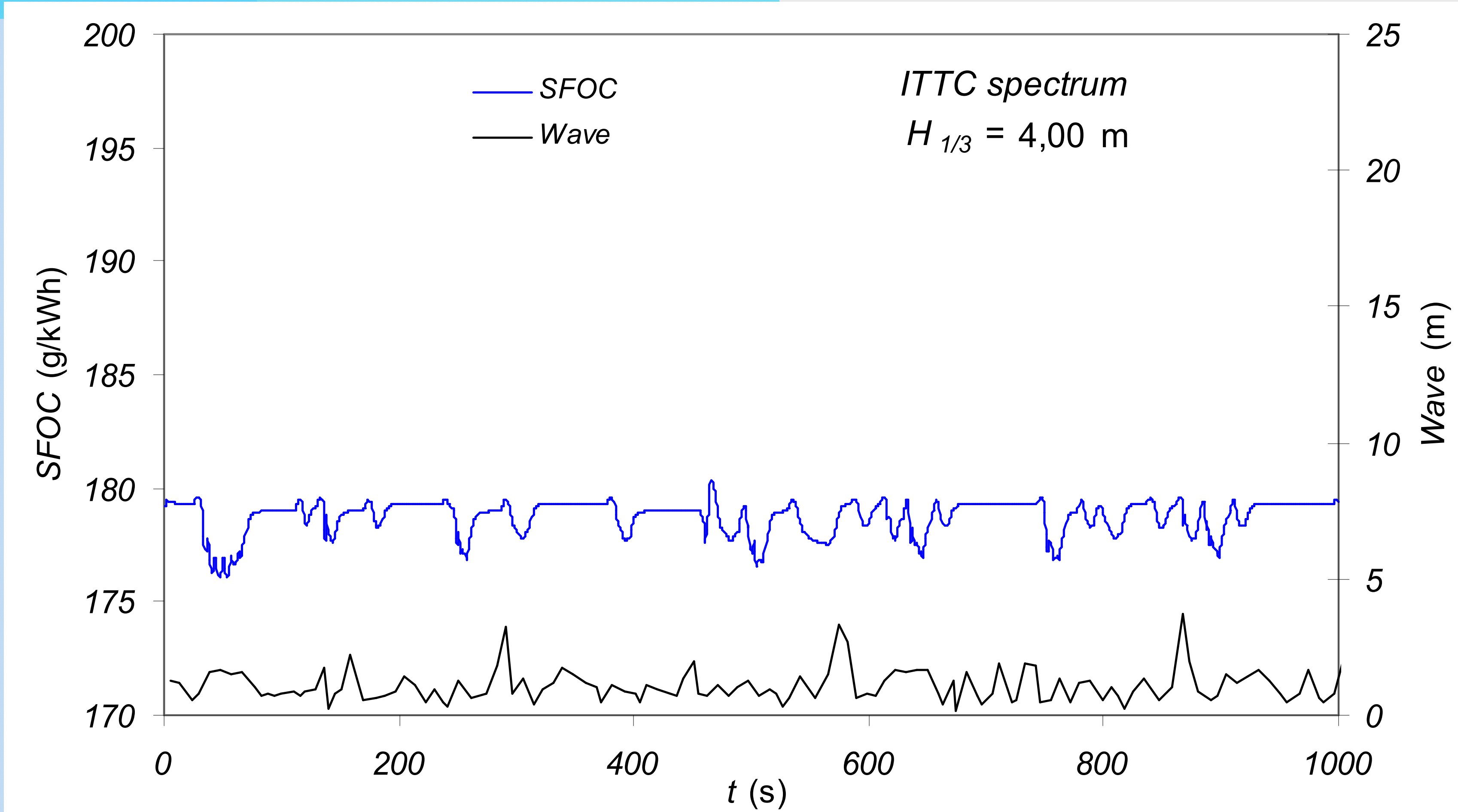


Fig. 10. Specific fuel consumption in head waves – voluntary speed reduction ($H_{1/3}$ = 4 m)

3. Numerical results

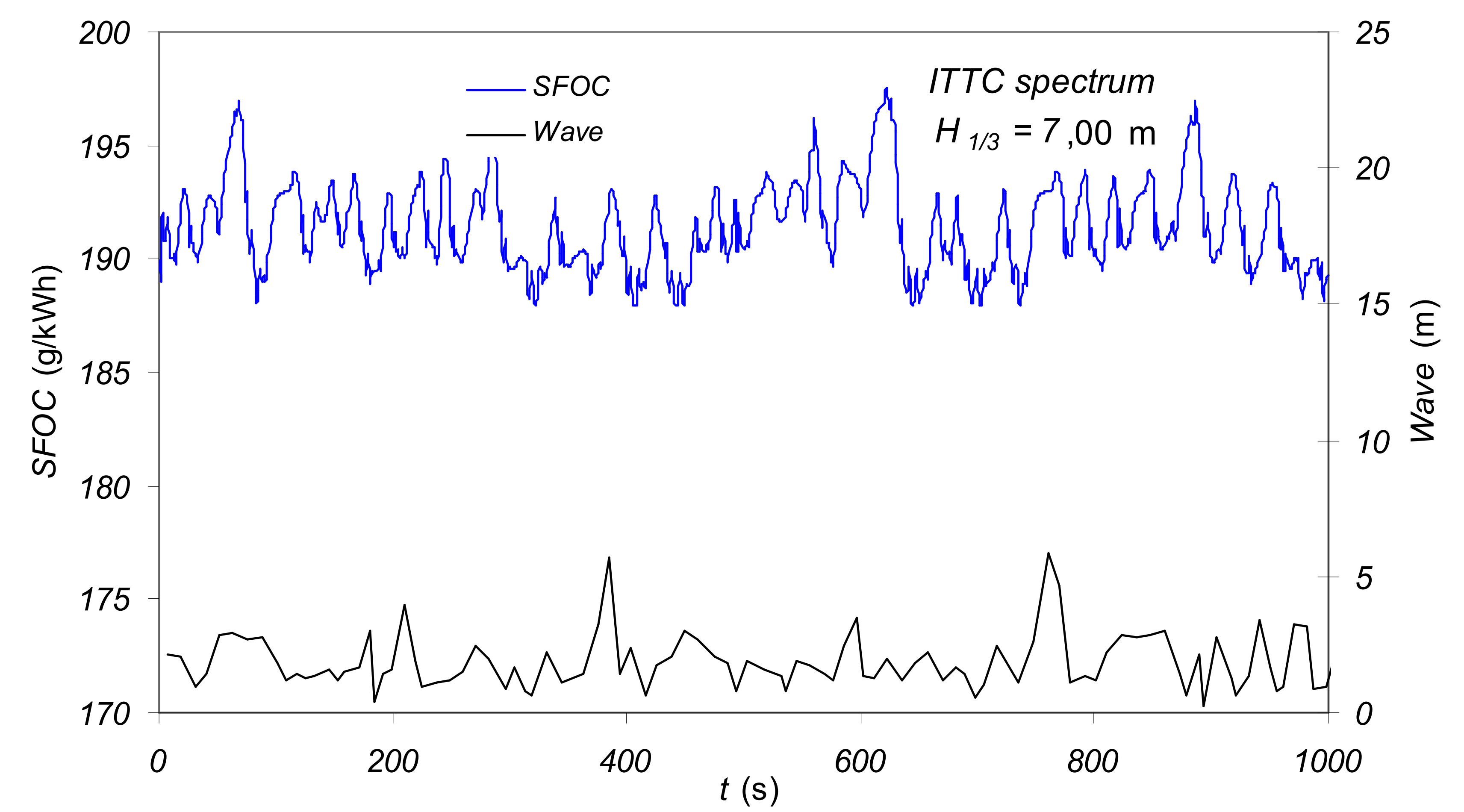


Fig. 11. Specific fuel consumption in head waves – voluntary speed reduction ($H_{1/3}$ = 7 m)

3. Numerical results

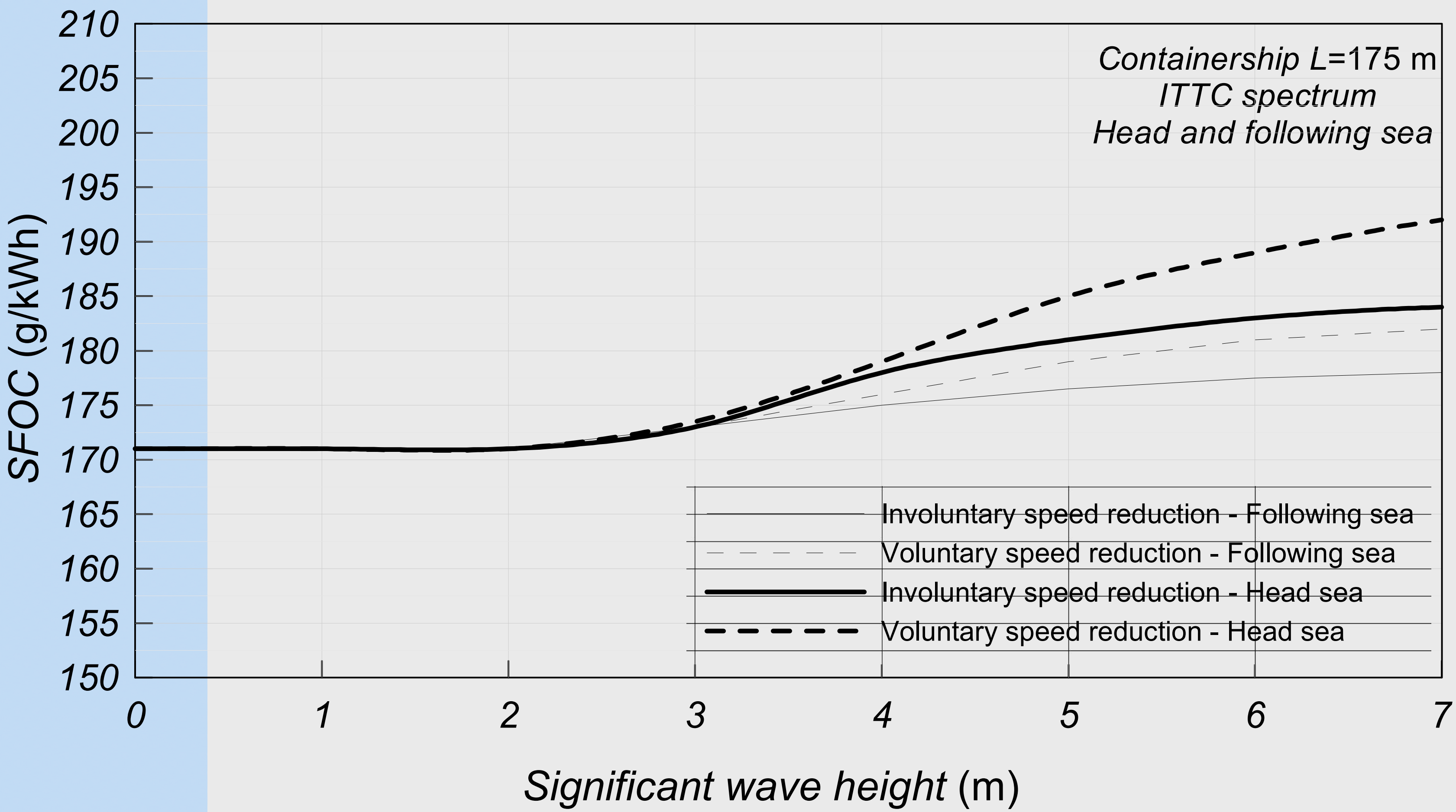


Fig. 12. Average specific fuel consumption for involuntary and voluntary speed reduction

3. Numerical results

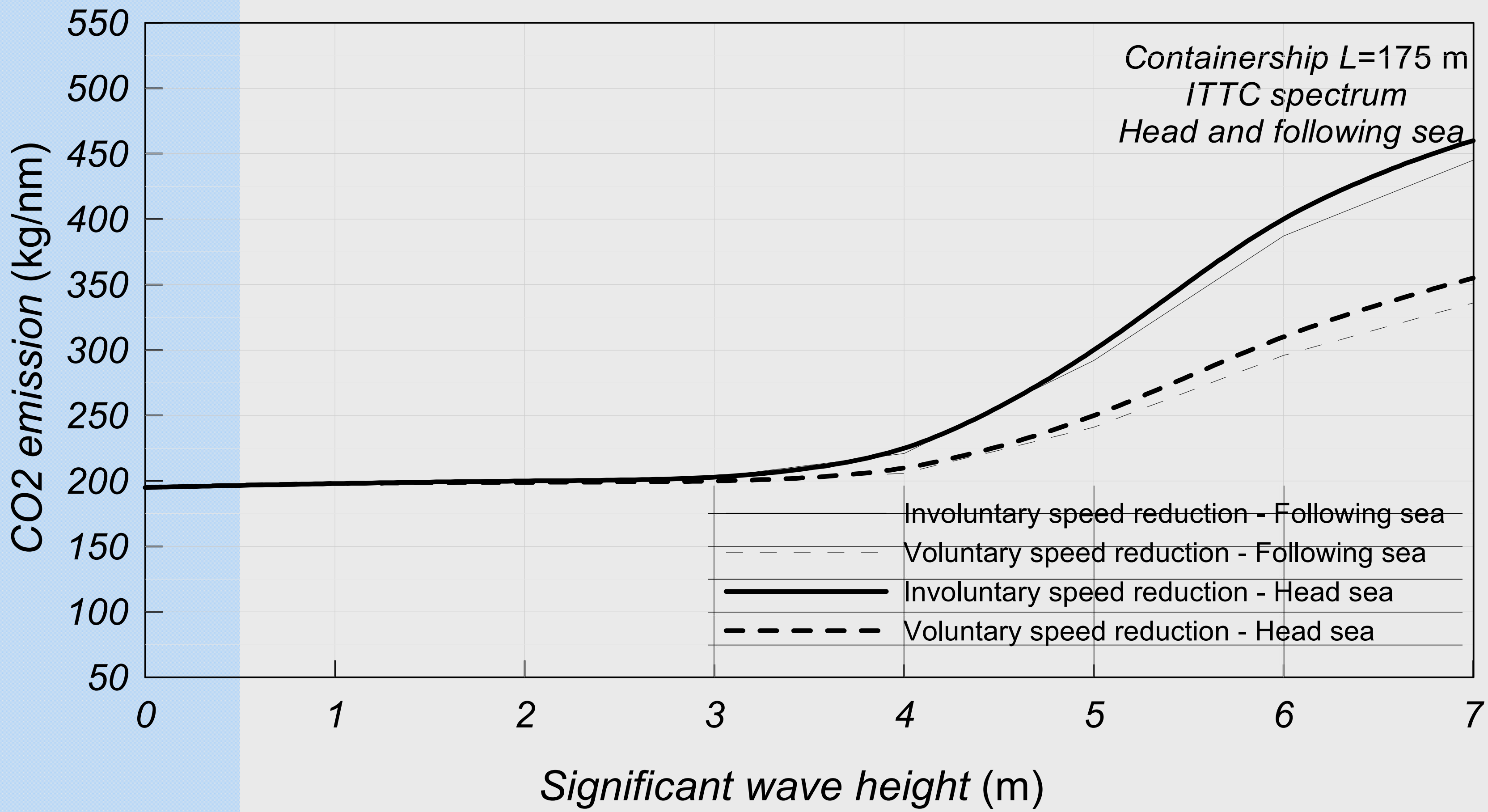


Fig. 13. Average CO_2 emission for involuntary and voluntary speed reduction in head waves

3. Numerical results

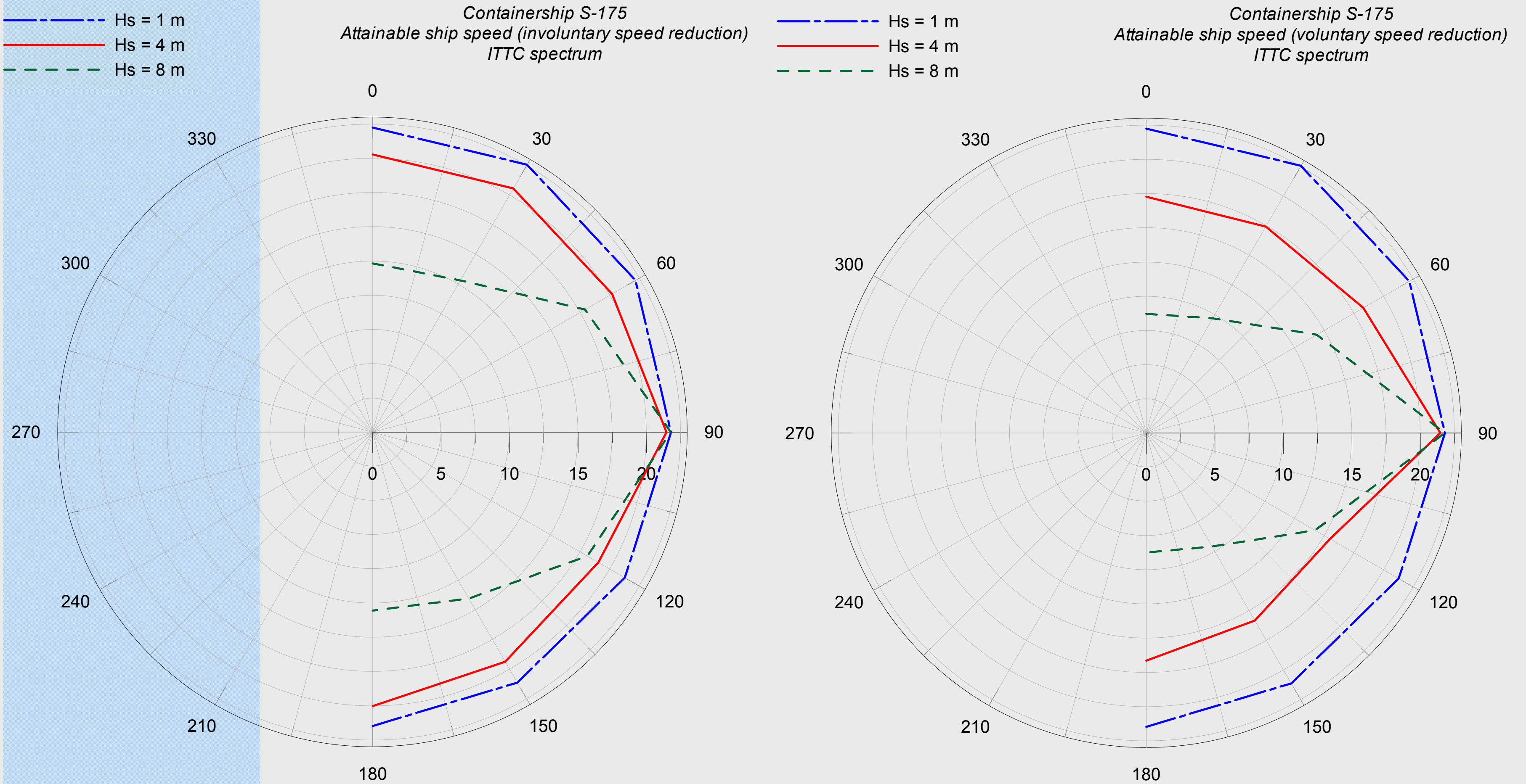
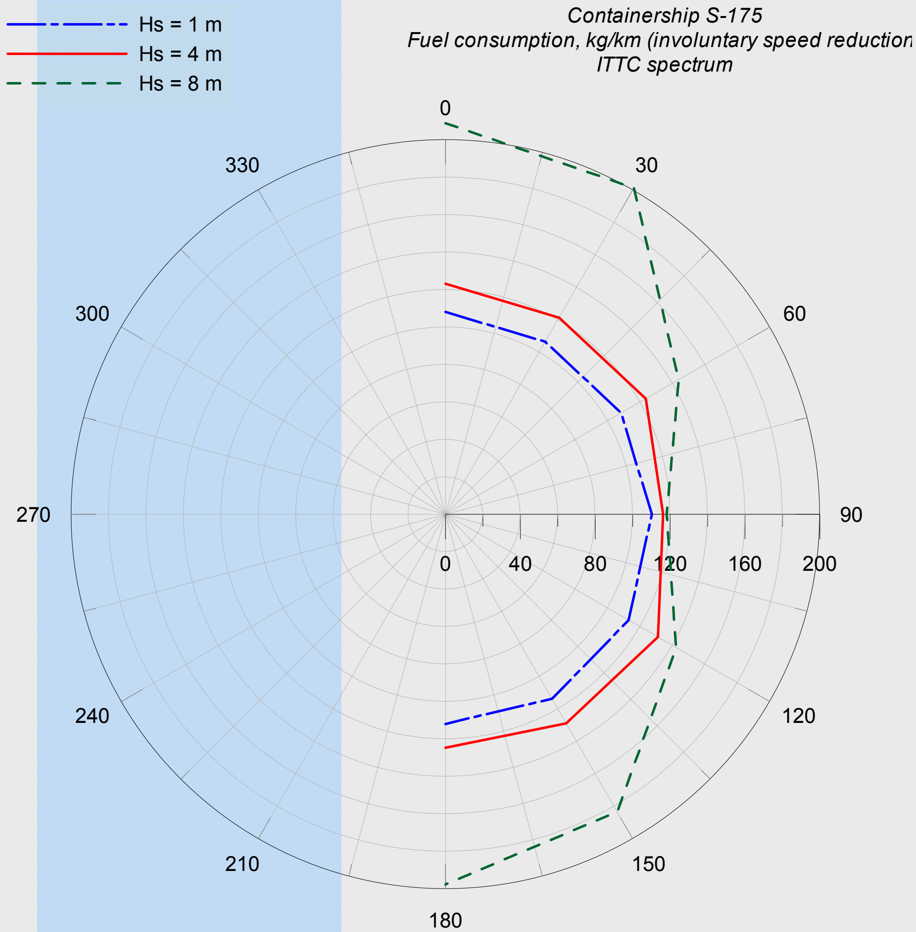


Fig. 14. Attainable ship speed for involuntary and voluntary speed reduction

3. Numerical results



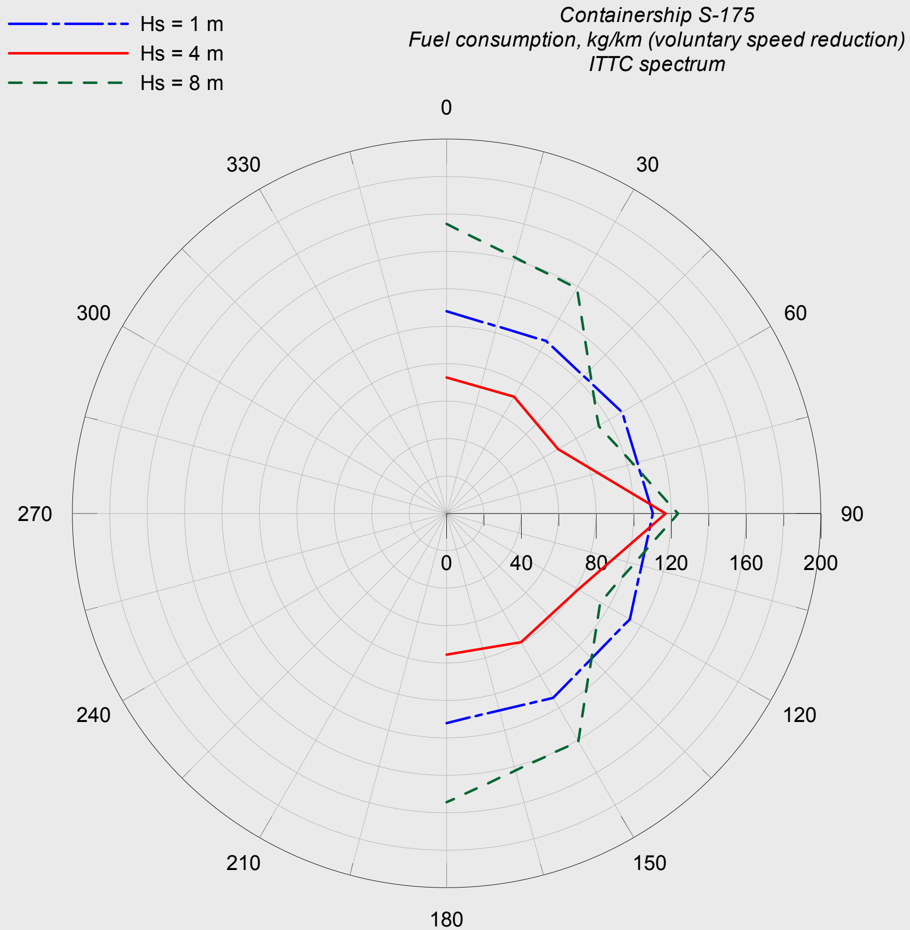
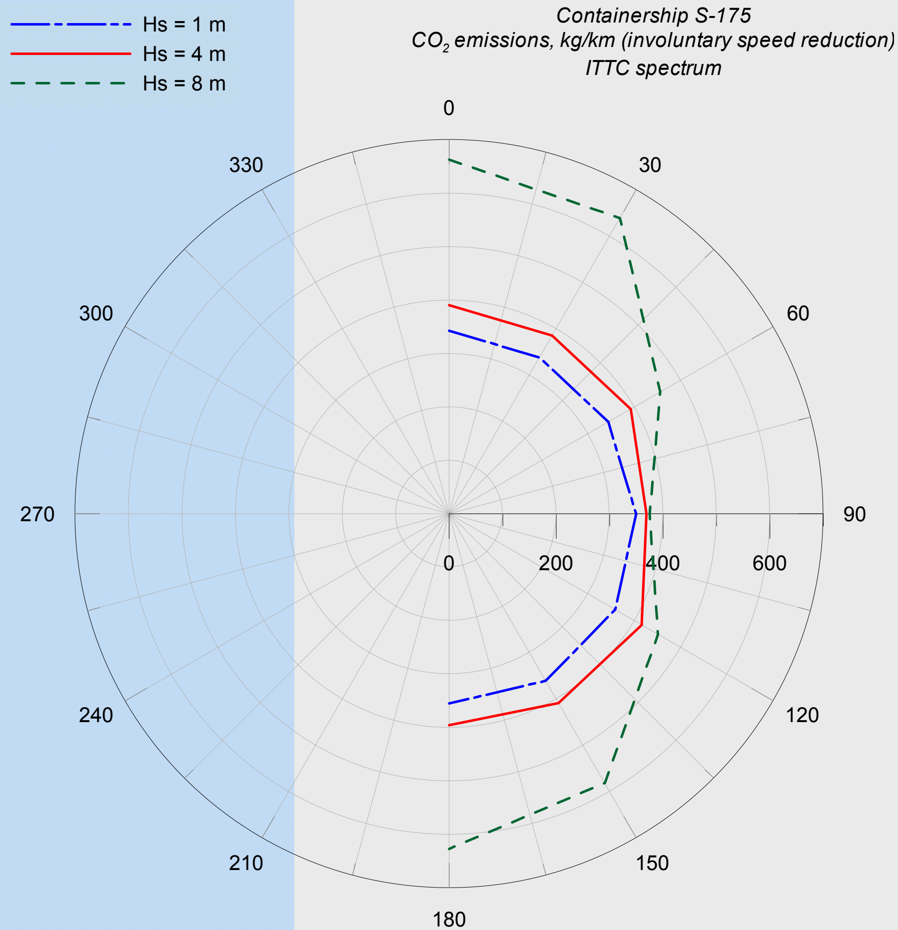


Fig. 15. Fuel consumption for involuntary and voluntary speed reduction

3. Numerical results



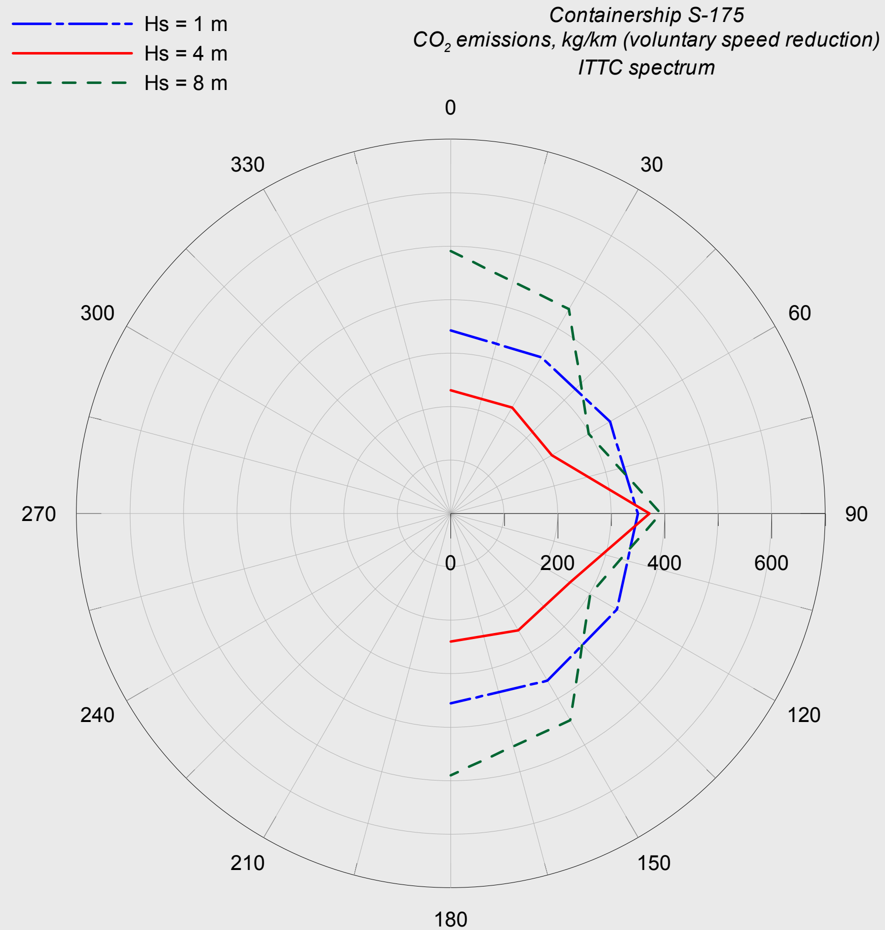


Fig. 16. CO2 emissions for involuntary and voluntary speed reduction

3. Numerical results

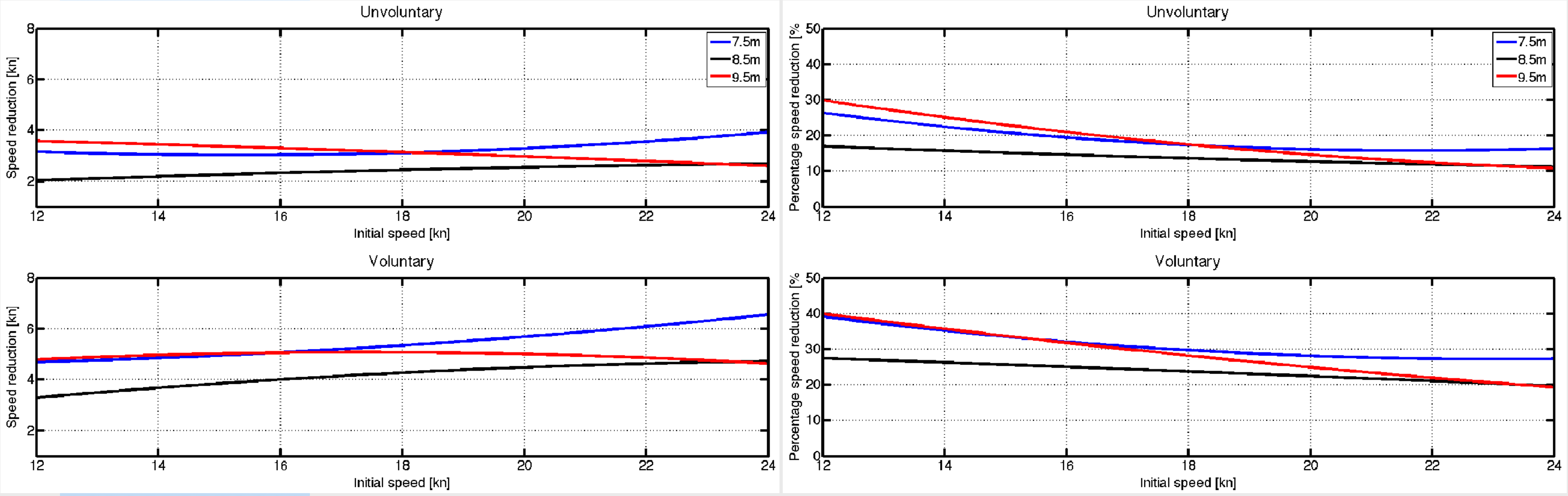


Fig. 17. Speed reduction vs. initial speed for different loading conditions

3. Numerical results

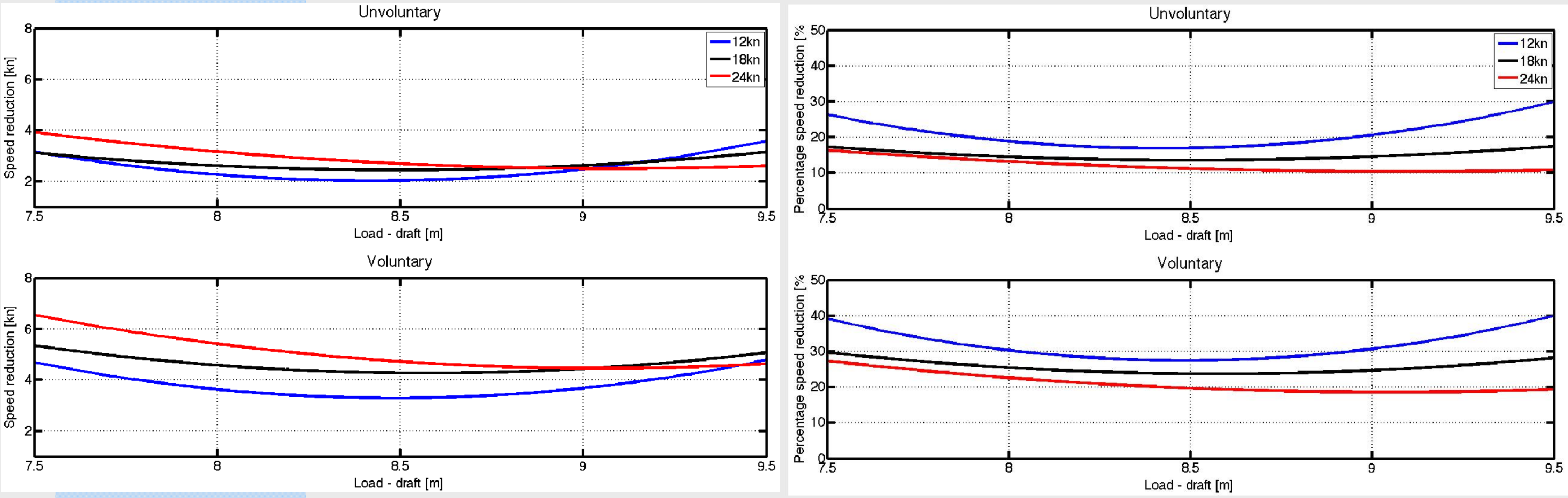


Fig. 18. Speed reduction vs. draft (loading condition) for different speeds

3. Numerical results

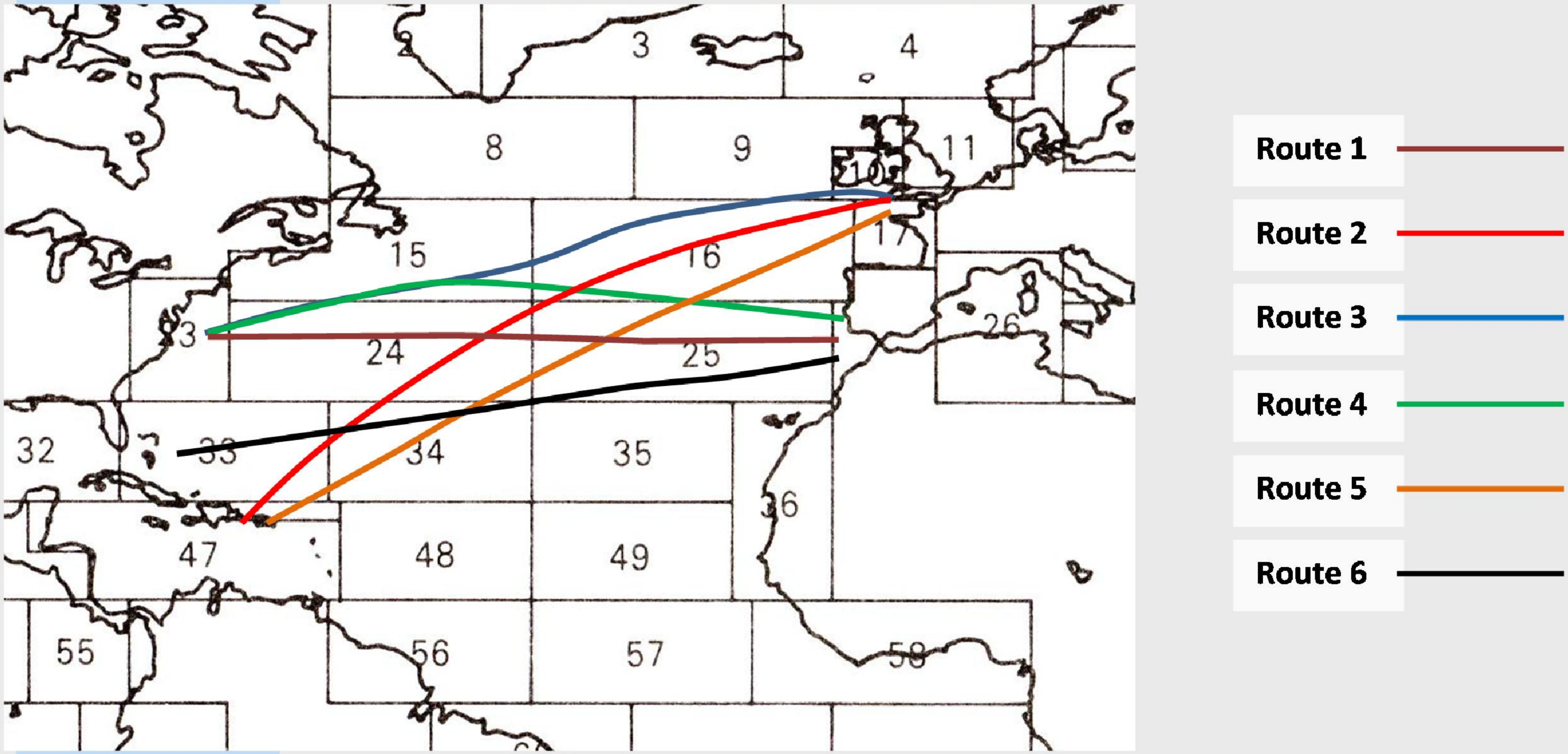
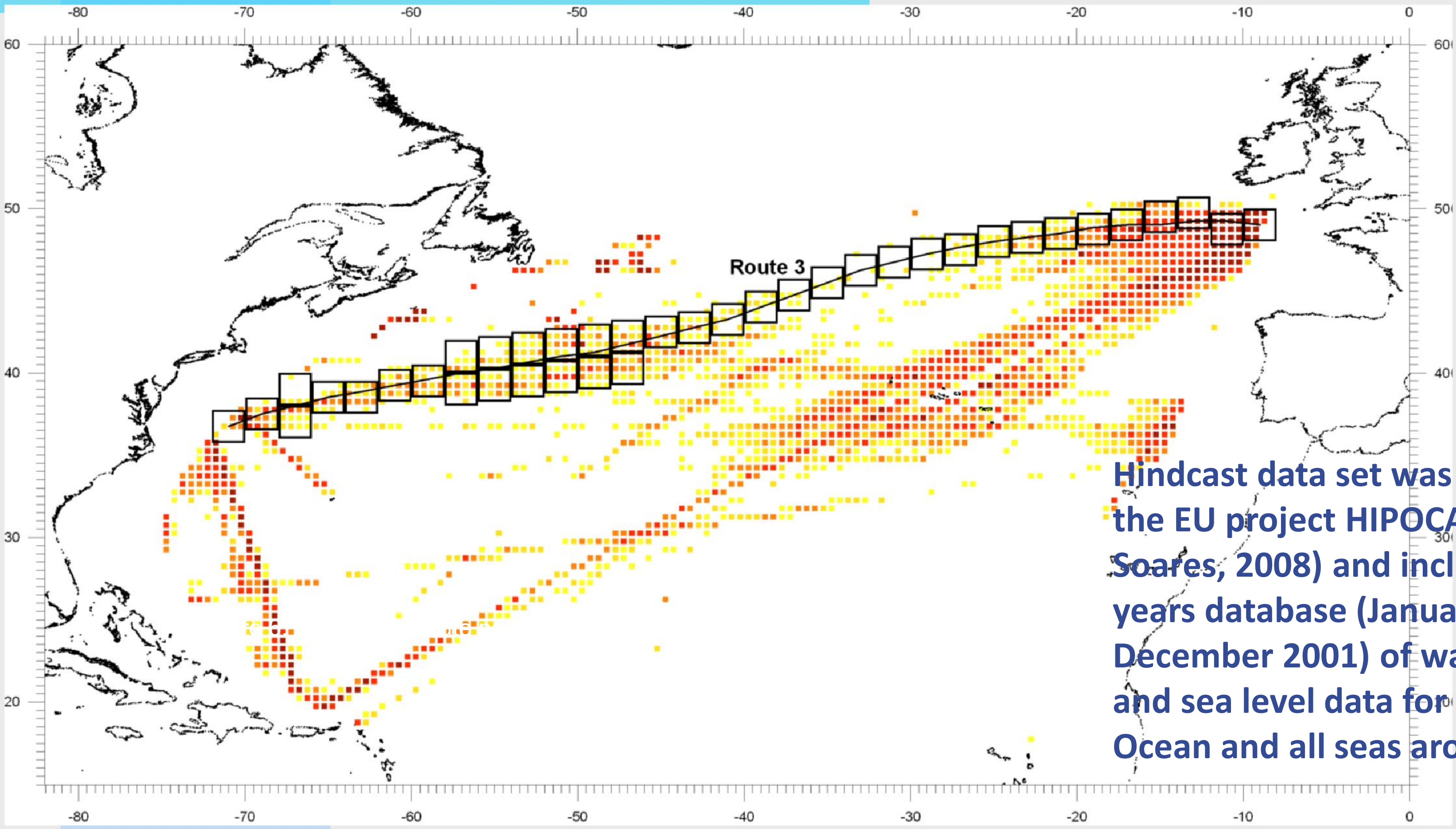


Fig. 19. Main North Atlantic trans-oceanic routes

3. Numerical results



Hindcast data set was produced in the EU project HIPOCAS (Guedes Soares, 2008) and includes a 44 years database (January 1958 to December 2001) of wave, wind and sea level data for the Atlantic Ocean and all seas around Europe.

Fig. 20. Example of route panels

Table 2. Absolute fuel consumption during voyage (calm weather condition).

	Route 1	Route 2	Route 3	Route 4	Route 5	Route 6
Length [nmi]	3210	3253	2811	3048	2740	2762
Time [h]	147.3	149.2	129.0	139.8	125.7	126.7
FOC [t]	654.73	663.54	573.34	621.69	558.91	563.32
CO_2 [kg]	2077.5	2105.4	1819.2	1972.6	1773.4	1787.4

Table 3. Fuel consumption and CO2 emissions (real weather conditions –involuntary speed reduction).

		Route 1	Route 2	Route 3	Route 4	Route 5	Route 6
Speed	[kn]	20.9	20.7	20.2	21.2	20.6	20.8
Time	[h]	153.6	157.2	138.9	143.8	133.2	132.7
	% increase	4.3%	5.3%	7.7%	2.9%	6.0%	4.7%
FOC	[kg/km]	114.7	115.3	115.6	112.7	114.5	113.6
	% increase	4.2%	4.6%	5.0%	2.3%	4.0%	3.1%
CO_2	[kg/km]	364.0	365.7	366.9	357.6	363.4	360.4

3. Numerical results

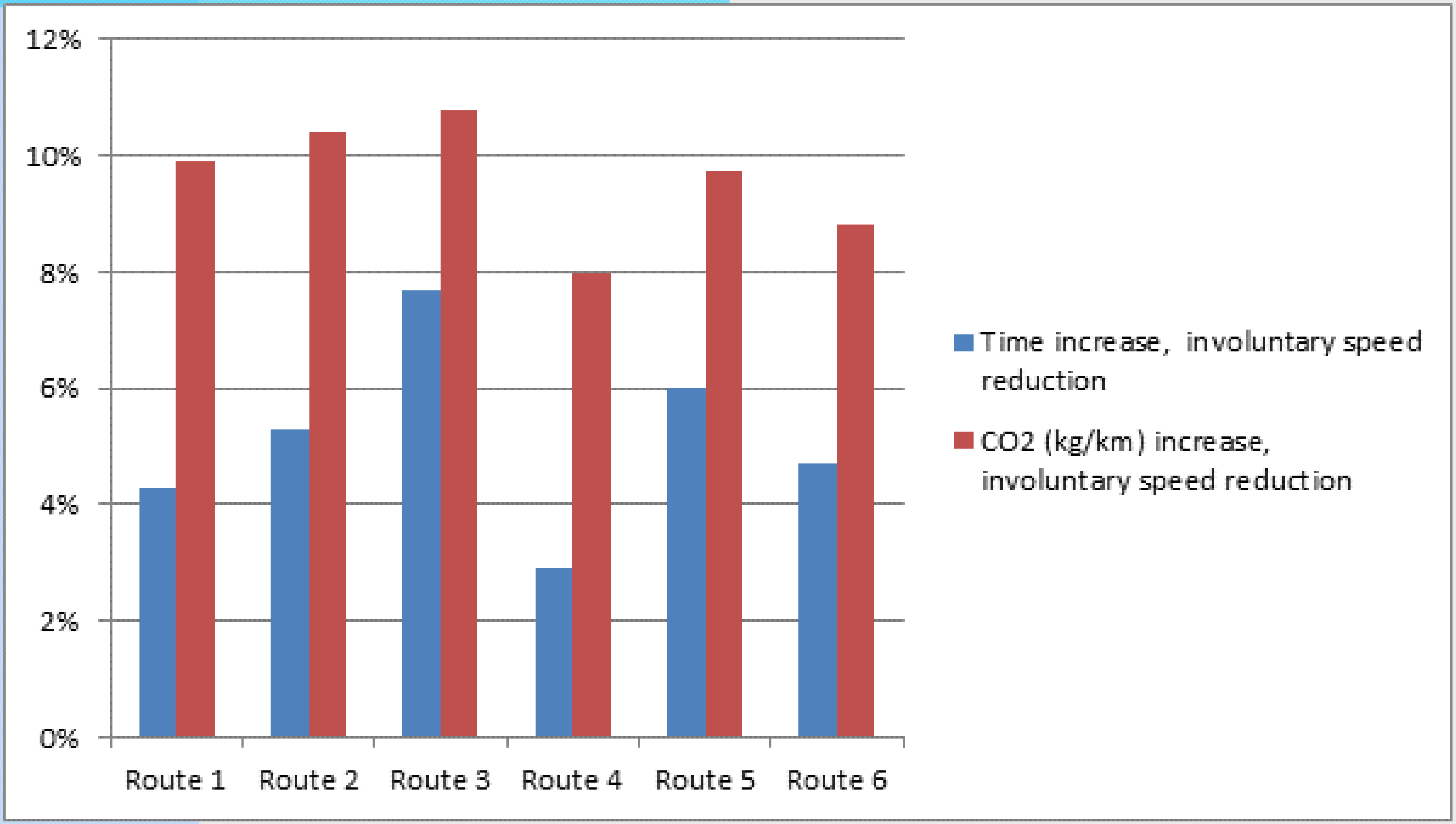


Fig. 21. Time increase and CO_2 emission increase (involuntary speed reduction)

Table 2. Absolute fuel consumption during voyage (calm weather condition).

		Route 1	Route 2	Route 3	Route 4	Route 5	Route 6
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CO_2	[kg]	2077.5	2105.4	1819.2	1972.6	1773.4	1787.4

Table 4. Fuel consumption and CO2 emissions (real weather conditions – voluntary speed reduction).

		Route 1	Route 2	Route 3	Route 4	Route 5	Route 6
Speed	[kn]	20.3	19.9	19.3	20.8	19.8	20.2
Time	[h]	158.4	163.1	145.8	146.7	138.4	136.8
	% increase	7.6%	9.3%	13.1%	4.9%	10.1%	8.0%
FOC	[kg/km]	103.2	102.2	99.5	104.6	100.8	102.2
	% increase	-6.3%	-7.2%	-9.7%	-5.0%	-8.4%	-7.2%
CO_2	[kg/km]	327.5	324.4	315.6	332.0	320.0	324.1

3. Numerical results

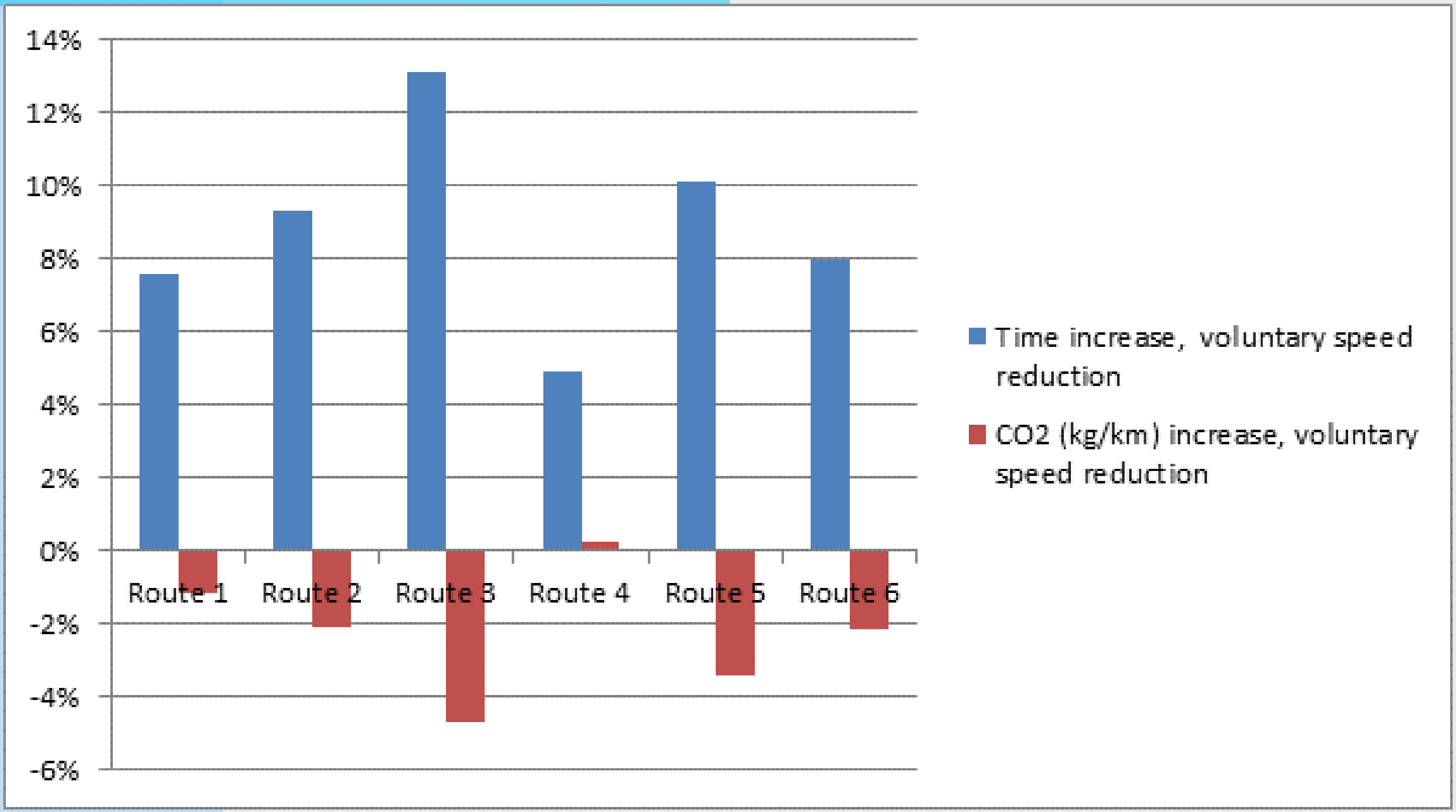

Fig. 22. Time increase and CO_2 emission increase (voluntary speed reduction)

4. Conclusions

The proposed method allows reliable prediction of voyage duration and fuel consumption as well as CO_2 emissions from main engine. It allows considering various strategies and scenarios of voyage and selection of the optimal one taking into account ship safety and operability as well as economic and environmental aspects.

Knowing the mean values of speed loos, fuel consumption and CO_2 emission for the whole range of different ship loading cases and service speeds the ship owner would be able to estimate the economic benefit of various voyage regimes taking into account ship safety and, of course, the ship mission.

Further research

- Computationaly faster engine model
- Relative importance of chosen voluntary speed reduction criteria
- Optimum hull design (minimized resistance)
- Uncertainties and reliability of the methodology
- Optimal vessel route planning ...

Thank you for your attention