INTERNATIONAL MARITIME ORGANIZATION

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| MARINE ENVIRONMENT PROTECTION COMMITTEE<br>84th session<br>Agenda item 6 | MEPC 84/6/5<br>22 January 2026<br>Original: ENGLISH<br>Pre-session public release: ☒ |

# ENERGY EFFICIENCY OF SHIPS

## The impact of adverse weather on fuel consumption and CII rating

**Submitted by Cook Islands, India, Malaysia, Panama, United Arab Emirates, ICS, IPTA and WSC**

**SUMMARY**

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| *Executive summary:* | According to the work plan for phase 2 of the review of the short-term GHG reduction measure, further proposals for CII corrections will be considered at MEPC 86 and MEPC 87. In preparation, this document details the impact of adverse weather on a ship's CII rating and further highlights the need for an adverse weather voyage adjustment. Using authoritative references, this document explains the significant variations in sea states that are experienced within the regions of the world, and how these can significantly affect fuel consumption and CII ratings. To demonstrate the impact, a case study for a Faroe Islands-based ro-ro cargo ship details how the ship is experiencing a 45% seasonal variation in CII due to the weather. This document invites the Committee to recognize the significant impact of adverse weather on CII, and to allocate sufficient time within the review to address this system anomaly. |
| *Strategic direction, if applicable:* | 3 |
| *Output:* | 3.2 |
| *Action to be taken:* | Paragraph 40 |
| *Related documents:* | MEPC 76/7/25; MEPC 83/WP.7, MEPC 83/17/Add.1; ISWG-GHG 12/2/4; MEPC.1/Circ.796; resolutions MEPC.354(78), MEPC.355(78) and MEPC.364(79) |

## Introduction

1 Although the 2021 Revised MARPOL Annex VI adopted at MEPC 76 required a review of the carbon intensity indicator (CII) to be completed by 1 January 2026, it was agreed at MEPC 83 (MEPC 83/17/Add.1, annex 5) that the necessary scope of system improvements would require a second review phase, extending to 2028. The agreed work plan confirms that further proposals for CII correction will be considered at MEPC 86 and MEPC 87.

Hence, in preparation, this document details the impact of adverse weather on a ship's CII rating and further justifies the need for an adverse weather voyage adjustment.[1,2,3]

**Background**

2 Within the Correspondence Group (CG) on Carbon Intensity Reduction that defined the *2022 Interim Guidelines on correction factors and voyage adjustments for CII calculations (CII Guidelines, G5)* (resolution MEPC.355(78)), proposals for including adverse weather as a reason for applying the $FC_{voyage}$ adjustment were previously considered:

.1 at that time, the threshold sea state for application of the $FC_{voyage}$ adjustment was proposed as:

"Periods of 8 hours or more sailing in sea states at or more severe than

- Mean significant wave height – 4.0 m
- Mean wind speed – 28 knots"

i.e. a sea state consistent with a sustained wind speed of Beaufort force 7;

.2 the CII Guidelines, G5 define a voyage adjustment as the deduction relevant fuel consumption, as well as the associated distance travelled from the calculation of attained CII for a defined period subject to certain threshold conditions being met; and

.3 on this matter, the round 4 CG responses were summarized as follows by the CG coordinators (MEPC 78/7/11, annex 5):

"<u>Voyage adjustment for Adverse Weather</u>

28 CG members provided an evaluation of this proposal. Based on the answers provided, the overview for this proposal is as follows:

| **Capacity to Assess Effects** | | **Policy Justification** | | | **Accuracy** | **Applicability** | |
|---|---|---|---|---|---|---|---|
| Merit further consideration ? | Considered now or later? | Issue solved? | Negative Impact? | Perverse Incentives addressed ? | Do the proposals.. | Is verification feasible? | Evidence sufficient? |
| **67.86%** | **73.68%** | **54.55%** | **57.14%** | **54.17%** | **66.67%** | **61.90%** | **60.00%** |

The CG had significant concerns about the proposal for voyage adjustments due to adverse weather and this will not be incorporated into G5.

Result: Rejected".

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1 Det Norske Veritas. (April 2014). DNV-RP-C205 - *Environmental Conditions and Environmental Loads*.

2 Semedo, A. (20 March 2018). *Seasonal Variability of Wind Sea and Swell Waves Climate along the Canary Current: The Local Wind Effect*. Journal of Marine Science & Engineering.

3 Vossers, P. I. (1962). *Resistance, Propulsion and Steering of Ships, Behaviour of Ships in Waves*. De Technische Uitgeverij H.Stam N.V.

3 ISWG-GHG 12 subsequently recommended that an adverse weather voyage adjustment should not be included in the CII Guidelines, G5; and MEPC 78 adopted the CII Guidelines, G5 (resolution MEPC.355(78)) without further change.

4 Hence, despite a majority of the correspondence group agreeing that voyage adjustment for adverse weather should be given further consideration, it is not currently included within the CII Guidelines, G5.

5 During the discussion on the CII system anomalies at ISWG-APEE 1, it was agreed to keep consideration of the adverse weather voyage adjustment in abeyance until further concrete proposals were submitted to a future session of the Committee (MEPC 83/WP.7, paragraph 71).

6 Previous submissions on this topic are summarized within table 1.

**Table 1: Previous submissions to MEPC on voyage adjustment for adverse weather**

| Document | Co-Sponsors | Summary |
|---|---|---|
| MEPC 76/7/25 | Indonesia, Russian Federation, Saudi Arabia, UAE, ICS, INTERTANKO, IPTA, WSC | Proposed exclusion of voyages of Beaufort 7 and above from the CII calculation. |
| ISWG-GHG 12/2/4 | Malaysia, Panama, United Arab Emirates, ICS, INTERTANKO, INTERCARGO and WSC | Explained the importance of the adverse weather voyage adjustment due to the significant variation in weather and sea conditions across the globe.<br><br>Proposed X-band radar systems, or equivalent technologies as practical means of recording a verifiable time history of the sea conditions experienced by a ship. |

7 During the CG, those members who objected to the adverse weather voyage adjustment cited the following reasons:

.1 difficulties in verifying the claimed adjustments, and the recording of adverse weather in a robust and transparent manner;

.2 adverse weather is already included within the reference lines for the various ship types; and

.3 a preference to wait until 2026 to consider the need for an adverse weather voyage adjustment.

8 Document ISWG-GHG 12/2/4 (Malaysia et al.) responded to these concerns, but due to a shortage of time at the ISWG-GHG 12 meeting, it was not considered in detail.

**Variation in global metocean conditions**

9 When considering the potential impact of adverse weather on a ship's fuel consumption and CII rating, it is important to understand the significant variation in metocean conditions experienced by different regions of the world. In this respect, the 100-year significant wave height is a metric that is often quoted by Naval Architects and Mariners. The data within table 2 below is taken from DNVGL-OS-E301[4] and provides a comparison:

[4] Det Norske Veritas. (July 2018). *DNVGL-OS-E301 Position Mooring*.

**Table 2: Comparison of 100-year significant wave heights for various regions**

| Region | 100-year significant wave height (metres) |
|---|---|
| Offshore Norway | 16.5 |
| Gulf of Mexico (hurricane) | 15.8 |
| South China Sea (Typhoon) | 13.6 |
| Offshore Egypt | 12.1 |
| Offshore Brazil | 8.0 |
| Timor Sea (Typhoon) | 5.5 |
| Gabon | 4.0 |
| Nigeria | 3.8 |

10 Figure 1 below, from the 2012 paper by Young et al.,[5] also plots the 100-year significant wave heights for the world's oceans. As may be seen, a ship operating close to the equator can expect to experience benign conditions with 100-year significant wave heights of 4 metres or less, whereas ships operating in the high latitudes of the Atlantic and Pacific oceans will experience far worse conditions with 100-year wave heights in excess of 16 metres.

11 As a rule of thumb, the maximum wave height (i.e. the maximum distance between a wave peak and trough) is roughly double the 100-year significant wave height, and therefore in the high latitudes, maximum wave heights in excess of about 32 metres are possible.

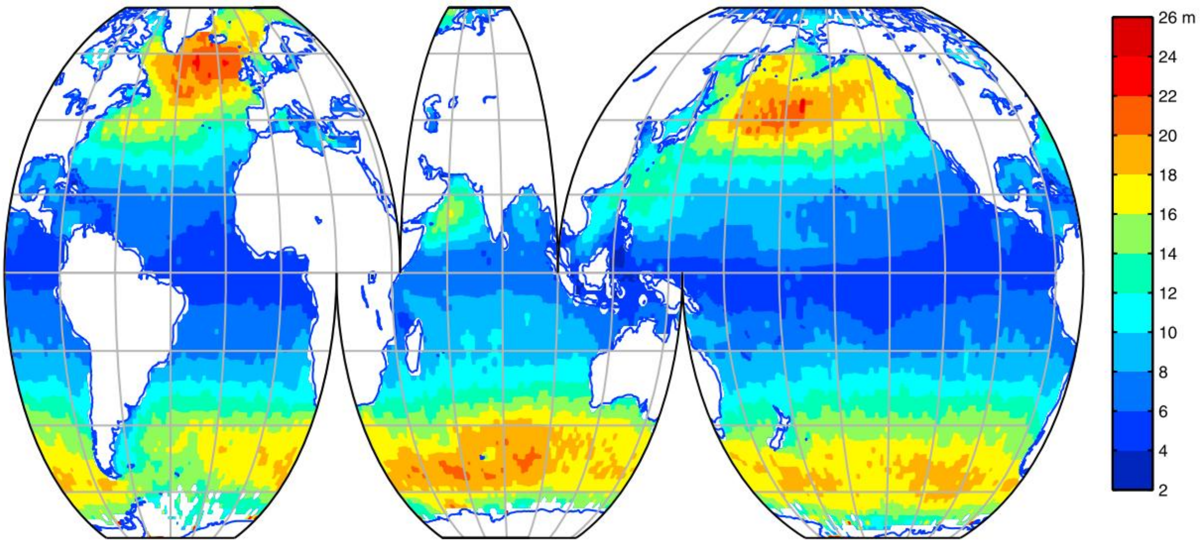


**Figure 1: 100-year significant wave height between June 2004 and June 2008 (Young et al., 2012)**

12 Whereas a ship operating in the tramp trade might expect to experience a variety of regions and sea states, a ship operating within a liner trade will be constrained to operate in a particular locality. Therefore, if operating at the high latitudes, such a ship may spend its entire lifespan in adverse metocean conditions, whereas a ship providing an equatorial liner service would routinely experience more benign conditions.

[5] I. R. Young, J. Vinoth et al. (2012). *Investigation of trends in extreme value wave height*. Journal of Geophysical Research.

13 To some extent, ships do weather route to avoid the very worst weather. However, it is often impossible for a ship to divert entirely from the vicinity of a storm.

**The impact of adverse weather on required engine power and fuel consumption**

14 The effect of adverse weather on a ship's fuel consumption is well understood by naval architects and seafarers. It is comprehensively documented and its impact is incontrovertible.

15 For example, Rawson and Tupper (2005)[6] have presented the data within figure 2 below, which summarizes the impact of power requirement versus speed for a 150-metre-long ship in predominantly head seas. As may be seen, when comparing with still water and to maintain a speed of 15 knots, Beaufort 7 would require about a 25% increase in power and Beaufort 9 a 75% increase.

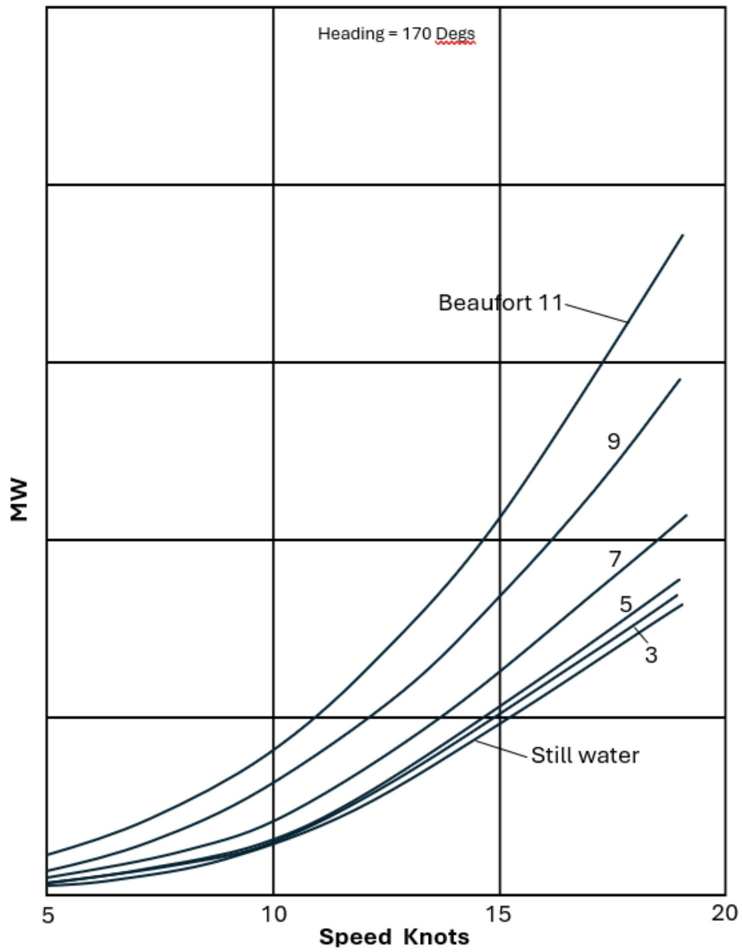


**Figure 2: Power versus speed for varying sea state**

16 For the same ship with three assumed pitch radii of gyration ($K_{yy}/L$), figure 3 below considers the impact at constant power. When comparing between calm water and a Beaufort 8 sea state, the speed reduces from 18 knots to about 15 knots, a reduction of approximately 17%. Hence, the time to complete the voyage increases by the same amount, therefore also giving an increased fuel consumption of about 17%.

[6] K. J. Rawson & E. C. Tupper. (2005). *Basic Ship Theory*.

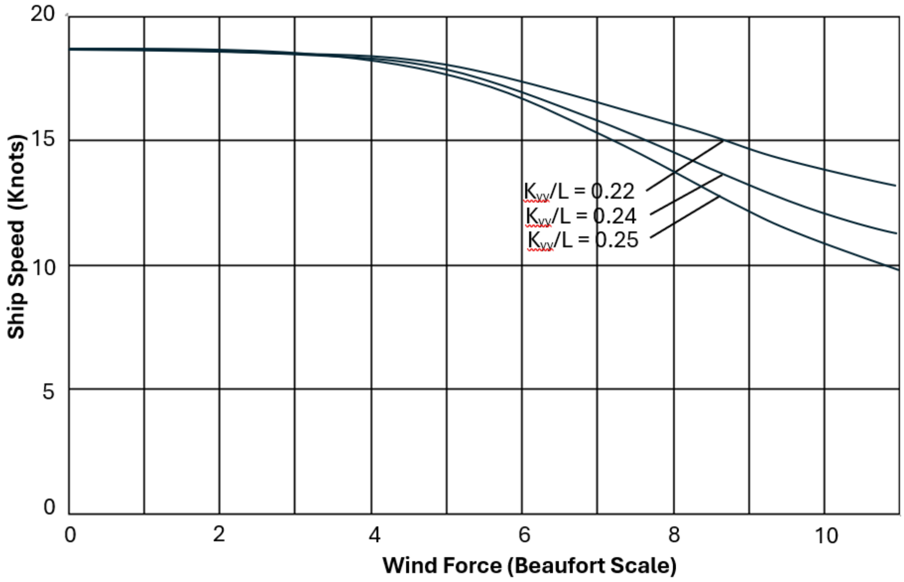


**Figure 3: Sea state versus speed at constant power**

17 Figure 4 below is also taken from Molland et al. (2017)[7] and confirms there is little equivalent compensating effect in following seas, i.e. the impact on the fuel consumption does not average out with variations in course, the effect is almost entirely to increase consumption, regardless of the ship's heading relative to the waves.

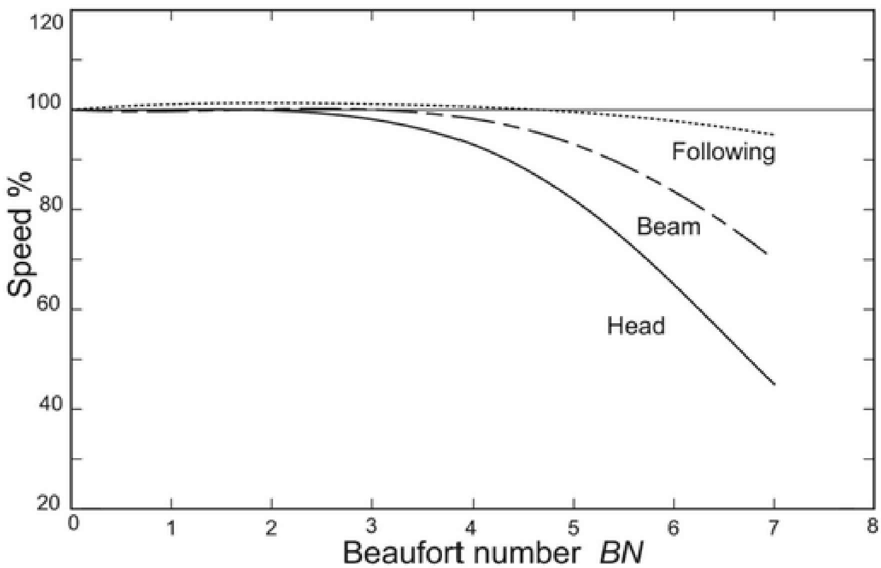


**Figure 4: Speed loss in following, beam and head seas (Molland et al., 2017)**

**Comparison with the Energy Efficiency Design Index (EEDI)**

18 The *2022 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships* (resolution MEPC.364(79)), include the $f_w$ factor for speed reduction at sea.

7 Anthony F. Molland, S. R. Turnock et al. (2017). *Ship Resistance and Propulsion - Practical Estimation of Ship Propulsive Power*. Cambridge University Press.

19 Further guidance is provided in the *Interim guidelines for the calculation of the coefficient $f_w$ for decrease in ship speed in a representative sea condition for trial use* (MEPC.1/Circ.796). For constant power, $f_w$ defines how much a ship will slow down as a result of the representative sea condition, which is defined within the circular as a wind speed of Beaufort 6, together with a significant wave height of 3 metres.

20 MEPC.1/Circ.796 includes an example calculation for a 217-metre-long ship. For a speed of 14.3 knots in calm conditions, an $f_w$ of 0.846 is derived. For the Beaufort 6 sea state, there is a resulting reduction in ship speed to 12.1 knots. Figure 5 below illustrates further. This 15% reduction in speed equates to a 15% increase in voyage time, and at constant power, a 15% increase in fuel consumption.

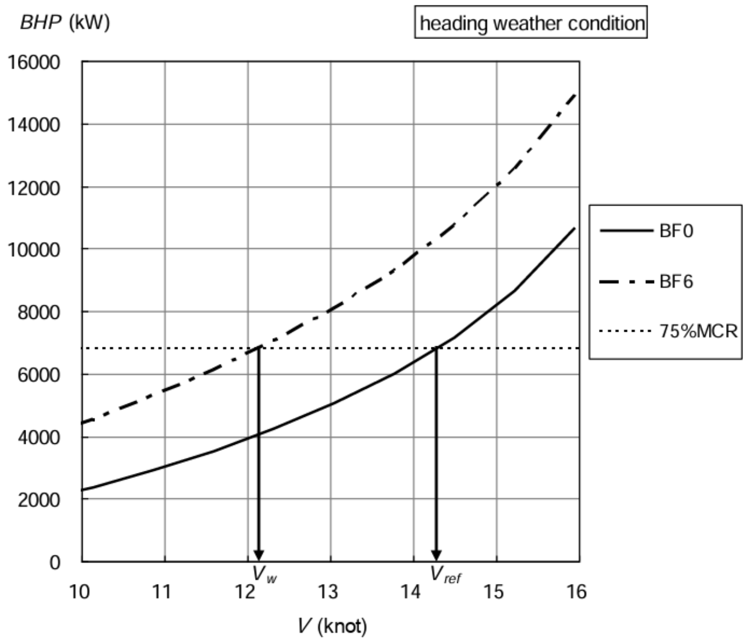


**Figure 5: Example $f_w$ calculation from MEPC.1/Circ.796 for a 217-metre-long ship**

**Impact on CII rating**

21 The basis metrics for CII are AER and cgDIST as follows:

$$AER \text{ and } cgDIST = \frac{\text{Fuel consumed x carbon factor}}{\text{Transport work}}$$

22 Within the above examples, for sea states corresponding to Beaufort 6 and 9, the fuel consumption increases by about 15% to 75% relative to calm conditions. Because CII is directly proportional to AER, the attained CII will increase by approximately the same amount, i.e. 15% to 75%. Or looking at it another way, the CII rating can be expected to increase by about 60% when moving from Beaufort 6 to Beaufort 9.

23 Considering, for example, a tanker with a required CII of 5.51, the required rating boundaries as per the CII Rating Guidelines, G4 (resolution MEPC.354(78)), are:

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|---|---|
| A/B = 4.52 = -18% relative to the required CII<br>B/C =5.12 = -7% relative to the required CII<br>C/D = 5.95 = +8% relative to the required CII<br>D/E = 7.05 = +28% relative to the required CII | 46% of required CII |

24 Therefore, the approximate 60% increase in CII rating when changing from a Beaufort 6 to a Beaufort 9 sea state is more than equivalent to the 46% difference between an A and an E rating for the tanker.

**Definition of existing CII reference lines**

25 As per the CII Reference Lines Guidelines, G2 (resolution MEPC.353(78)), each ship type (e.g. tanker, bulk carrier, etc.) has its own reference line. The boundaries for the A, B, C, D and E ratings are offset by specified amounts from each reference line.

26 Each reference line is defined by fitting a curve through the data from a large number of ships. Hence, each reference line reflects the average weather conditions of all the ships that contributed data to that line. Therefore, any ship experiencing worse than average weather conditions will have its CII rating adversely impacted.

**Wind-assisted propulsion**

27 For certain routes, and for ships equipped with wind-assisted propulsion (WAP), adverse weather may be viewed as a beneficial resource. However, WAP is not appropriate in all circumstances, and therefore cannot on its own be considered as alleviating the need for an adverse weather voyage adjustment within CII. For example:

.1 regular routes may have wind from an inappropriate direction, insufficient strength, or insufficient regularity to warrant a WAP installation;

.2 ships may not have sufficient deck space to fit proven WAP systems (e.g. container ships);

.3 cargo handling equipment may limit or prohibit the use of WAP; and

.4 for older ships, the WAP payback period may exceed the remaining life of the ship.

**Smyril Line's MV Mykines – a case study**

28 Headquartered in the Faroe Islands, Smyril Line operates a fleet of 4 passenger and freight ro-ro ships, employs 610 staff across 4 countries and operates under a DNV-certified ISO 14001:2015 environmental management system.

29 Smyril Line's **MV Mykines** operates year-round services between Rotterdam (Kingdom of the Netherlands), Tórshavn (Faroe Islands), and Þorlákshöfn (Iceland). Built in 1998, the ship is 138.5 metres in overall length and has a deadweight of 12,800 tonnes.


**Figure 6: Smyril Line's freight ro-ro ship, MV Mykines**


**Figure 7: The routes operated by MV Mykines**

30 As may be seen from table 3, the sea area between Iceland and the Faroe Islands experiences extreme winter weather with a 100-year significant wave height for January of 15.1 metres. The conditions are also seasonal, with the 100-year significant wave height reducing to 6.7 metres in August. The corresponding location for the table 3 wave height data is shown in figure 8.

**Table 3: 100-year significant wave height for location 63°N, 13°W**

| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **100-year significant wave height (metres)** | 15.1 | 12.9 | 12.8 | 9.8 | 7.8 | 7.2 | 7.2 | 6.7 | 9.7 | 11.5 | 11.7 | 14.8 |

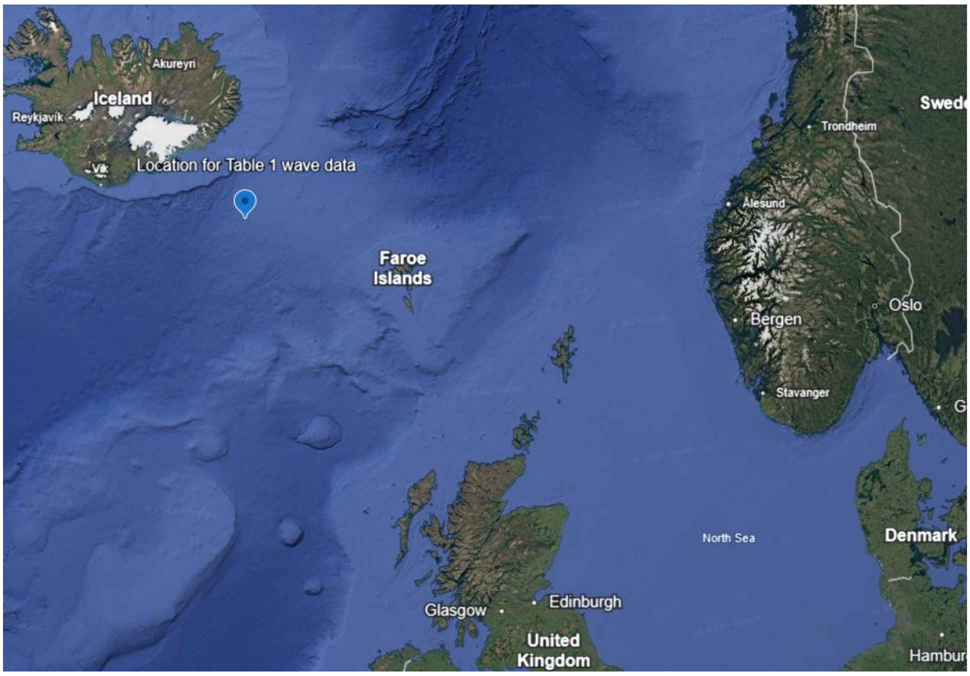


**Figure 8: Location for table 3 wave data**

31 To monitor CII ratings, Smyril Line utilizes a proprietary software package, and from the analysed data, it is apparent that the ratings are following a similar seasonal variation to the weather. For example, figure 9 below is the 2024 data for **MV Mykines** and confirms a peak CII in February of 16 $gCO_2$/(DWT.nm) and a minimum in August of 11 $gCO_2$/(DWT.nm), i.e. a seasonal variation of about 45%.

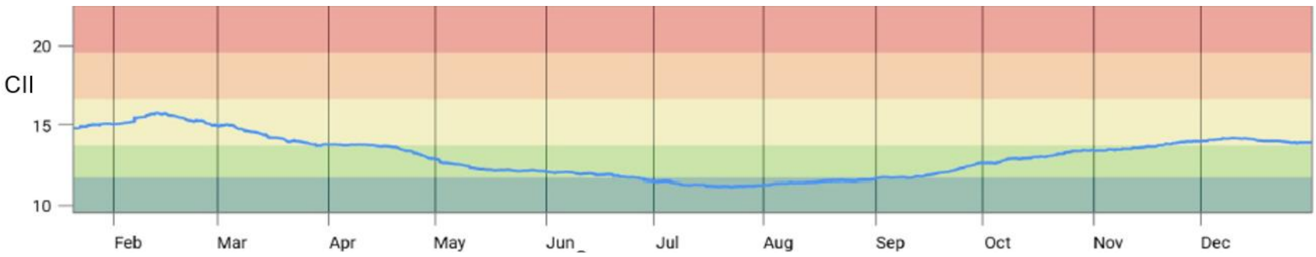


**Figure 9: MV Mykines – 2024 CII rating by month $gCO_2$/(DWT.nm)**

32 **MV Mykines** operates a year-round schedule with the same number of sailings in winter as in summer. Other than the weather, Smyril Line is not aware of any other seasonal factors that could be impacting the CII rating.

33 As can be seen from figure 1, there are significant areas in tropical regions where 6.7 metres or lower is not the seasonal lowest, but the annual average. Therefore, if operating a similar service within tropical regions, it is likely that **MV Mykines** would be awarded an annual CII of no more than 11 $gCO_2$/(DWT.nm), as opposed to the 12.9 $gCO_2$/(DWT.nm) it received in 2024, i.e. moving the ship to an A rating as opposed to the B rating received for North Atlantic operation.

34 Clearly such a factor is outside of the control of the shipowner and represents a significant system inaccuracy if left unaddressed.

**The southern hemisphere**

35 Figure 1 of this document clearly demonstrates that adverse weather is not just a northern hemisphere phenomenon, with the high southern latitudes experiencing similarly harsh conditions. For ships serving remote islands, the consequences are not limited to the higher-than-average fuel consumption and CII ratings, but can be further compounded by the more direct impacts on the communities of weather-related delayed shipping arrivals leading to shortages of essential goods and economic impacts, e.g. to tourism.

**Discussion**

36 It is extensively documented and well proven that sea state has a significant impact on fuel consumption, and thereby influences the CII ratings.

37 Conducting a global analysis of the impact of adverse weather on fuel consumption and CII ratings is an unrealistic expectation as sea state is not currently recorded within the IMO DCS and equivalent data does not exist within any other global database. Nevertheless, carrying out such an exercise would be unnecessary as, through many previous sea trials, model tests, analyses and mariner experience, the impact is already well understood, quantified and documented.

38 Being constituted of data from large numbers of ships, each CII reference line represents an average sea state. Therefore, any ship constrained to operate in a region with a more severe state than the reference line average will score a worse CII rating than a sister ship operating in a region with a sea state less severe than the reference line average. This variation in the ratings is not a measure of the relative efficiency, but a consequence of where the ships operate. It represents a significant anomaly or system gap, which must be addressed if CII is to become an accurate and fair rating system.

39 To address several of the CII system anomalies and gaps, MEPC 82 and ISWG-APEE 1 considered two proposals for a refocusing of the CII rating system on the fuel consumption during the sea passage. The sponsors consider this approach as beneficial and worthy of further development within phase 2 of the CII review. It could for example address anomalies relating to port waiting time and short voyages. However, a refocusing of the rating system on the sea passage would not address the adverse weather anomaly. Indeed, the sea passage is where the most onerous sea states are experienced.

**Action requested of the Committee**

40 The Committee is invited to take note of the justifications within this document and to:

.1 recognize the significant impact of adverse weather on fuel consumption and CII, an impact that is currently unaddressed within the rating system;

.2 allocate sufficient time within phase 2 of the CII review to give detailed consideration of this system anomaly, and the proposals within previous documents MEPC 76/7/25 and ISWG-GHG 12/2/4, together with other relevant submissions that may yet be made to the review; and

.3 take action as appropriate.

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