Voyage Optimization with the VISIR-2 Model on the Shanghai–Los Angeles Green Corridor of shipping

M.L. Salinas*, G. Mannarini
CMCC Foundation - Euro-Mediterranean Center on Climate Change, Italy

EGU General Assembly #EGU25 27 April - 2 May 2025

check the abstract and supplementary material:

Sharing is encouraged

1. Introduction & method

- International shipping was responsible for emitting approximately 740 million tonnes of CO_2 in 2018 [1].
- **Voyage optimization**, or ship weather routing, is an operational strategy leveraging meteo-oceanographic data to **minimize energy consumption.**
- **VISIR-2** [2] is an open-source Python-based model that **computes least-CO_2 routes** by optimizing spatial diversions. Using a validated graph-search algorithm, the model **integrates ocean currents and avoids adverse sea conditions** [3]
- VISIR-2 was applied to an ocean-going vessel operating on the Shanghai–Los Angeles/Long Beach outbound and return route, one of the first designated green corridors in shipping [4]
- Simulations were conducted for departures any 5 days across the year 2024, with and without ocean currents. We then assessed CO_2 savings on optimal routes, analysing their **sensitivity to seasonal and directional factors.**

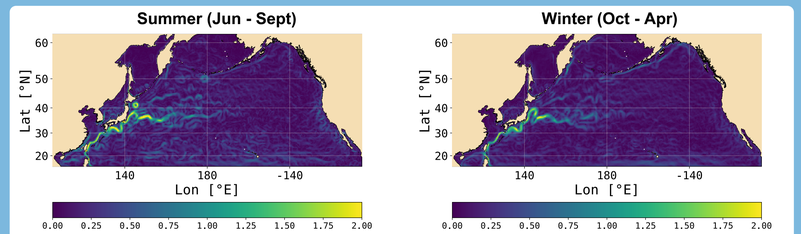


Figure 1. *Mean ocean currents magnitude over the northern Pacific*

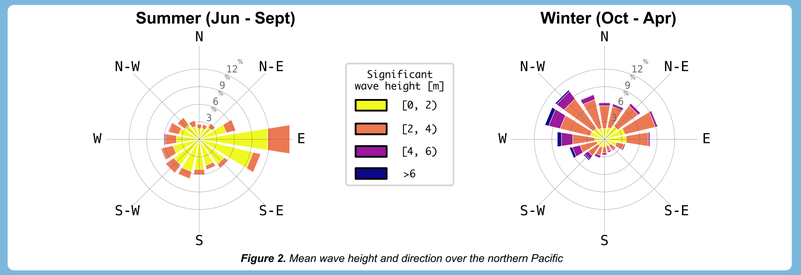


Figure 2. *Mean wave height and direction over the northern Pacific*

- As shown in Fig.1, **the Kuroshio Current** is consistently present with a magnitude of about 2 kn, and **can support eastbound navigation**.
- From Fig. 2 it is clear that **north-westerly waves are more frequent during winter and are generally the highest**, exceeding 6 m significant height. In contrast, summer conditions feature predominantly waves from east with average heights below 4 m.

2. Climatology of routes

A total of 1,776 routes were simulated in 2024 for a 355 m container ship sailing between the ports of Shanghai (CNSGH) and Los Angeles (USLAX) and vice versa, using wave and ocean current data from the Copernicus Marine Service. The ship's performance curve is displayed in Fig.3, for two distinct speed levels (70% and 90% engine load).

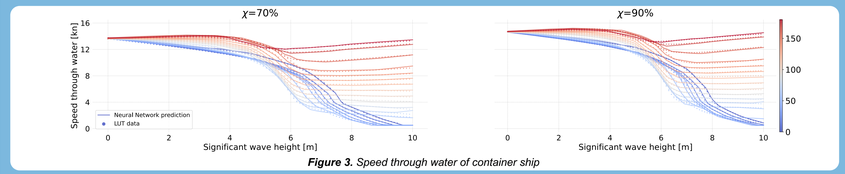


Figure 3. *Speed through water of container ship*

The aim of this work is to assess the impact of environmental conditions, speed level, and route orientation on relative CO_2 savings.

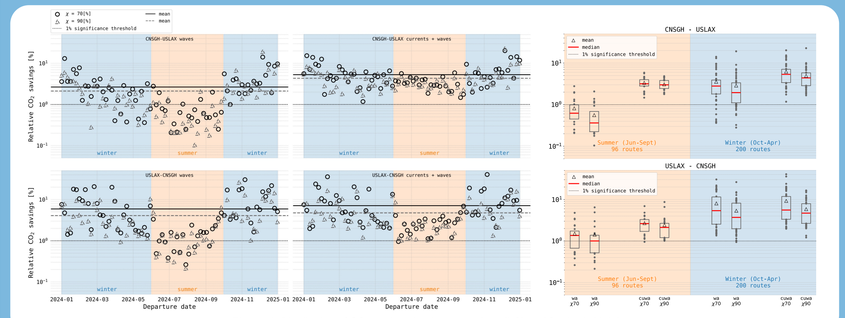


Figure 4. *Distribution of CO_2 savings by departure days (left) and forcing/χ (right)*

- **Higher savings are observed in winter** (on average 3x summer values), and accounting for ocean **currents doubles the savings** (Fig. 4).
- **Lowering the engine load results in greater savings**, with the reduced power setting saving approximately 20% more CO_2 than the higher setting (Fig. 4).

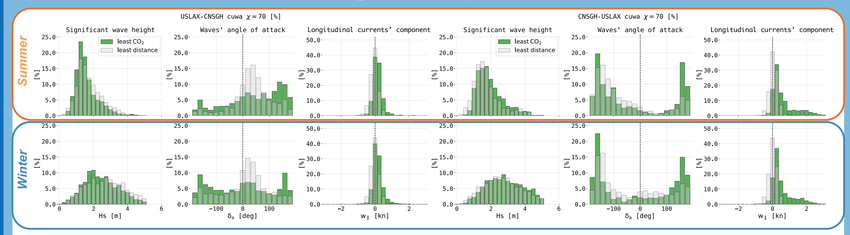


Figure 5. *Histograms of metrics along the routes*

- When **departing from the USA, higher savings** can be achieved by avoiding rough (Fig. 5 Hs column) and head seas (Fig.5 δ_a column). However, when **departing from China,** it appears to be **even more beneficial to exploit the persistent eastbound current** (Fig. 5 $w_{\parallel}$ column) as waves typically come from the vessel's stern and lead to reduced speed loss (cf. Fig. 2, 3, 5).

Fig. 6 shows that seasonal effects alone do not drive consistent route diversions. However, **adding current information shifts eastbound crossings to exploit the Kuroshio** Current while eastbound **voyages from USA divert northward** regardless.

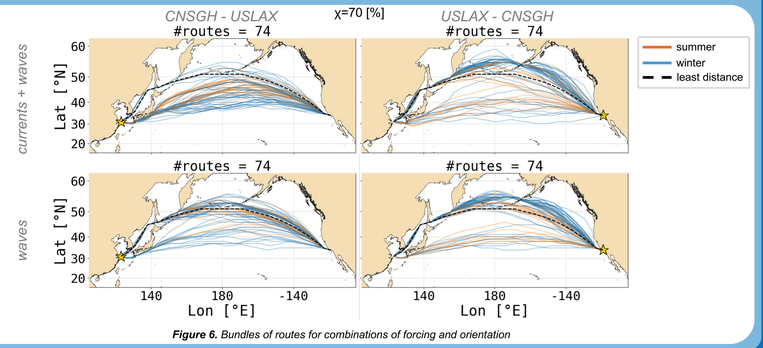


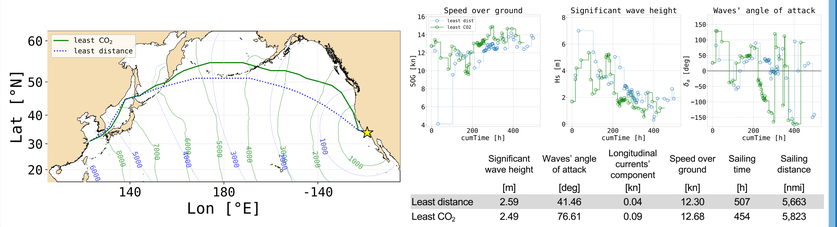
Figure 6. *Bundles of routes for combinations of forcing and orientation*

3. USA – China case study

We showcase a specific optimal route from USLAX to CNSGH by accounting for both ocean currents and waves. For this specific voyage, the **least-CO_2 route:**

- diverts northward to **exploit favourable currents and milder sea states**.
- **cuts emissions by 981 metric tonnes CO_2** (on a total of 9,284 metric tonnes CO_2)

Los Angeles – Shanghai χ=70 [%]
currents + waves
2024-01-31 03:00 UTC
981 [tons] of CO_2 saved (~10%)



	Significant wave height [m]	Waves' angle of attack [deg]	Longitudinal currents' component [kn]	Speed over ground [kn]	Sailing time [h]	Sailing distance [nmi]
Least distance	2.59	41.46	0.04	12.30	507	5,663
Least CO_2	2.49	76.61	0.09	12.68	454	5,823

Figure 7. *Isoline plot (left) and metrics (right) for the specific route*

4. Conclusions

- This study demonstrates the potential of voyage optimization as an operational strategy for reducing CO_2 emissions.
- Key factors influencing savings include seasonal environmental conditions and the ability to harness favourable currents while avoiding head seas.
- The open-source VISIR-2 model is also part of the European digital ocean twin within the EDITO-Model Lab project [5], illustrating how digital tools can support IMO and EU decarbonization goals for shipping.

References
[1] https://www.imo.org/en/ourwork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx
[2] https://doi.org/10.5281/zenodo.8305526
[3] Mannarini, G., Salinas, M. L., Carelli, L., Petacco, N., and Orović, J.: VISIR-2: ship weather routing in Python, Geosci. Model Dev., 17, 4355–4382, https://doi.org/10.5194/gmd-17-4355-2024, 2024
[4] https://www.c40.org/news/la-shanghai-implementation-plan-outline-green-shipping-corridor/
[5] https://www.edito-modellab.eu/

*Contact: mario.salinas@cmcc.it