SOFAR

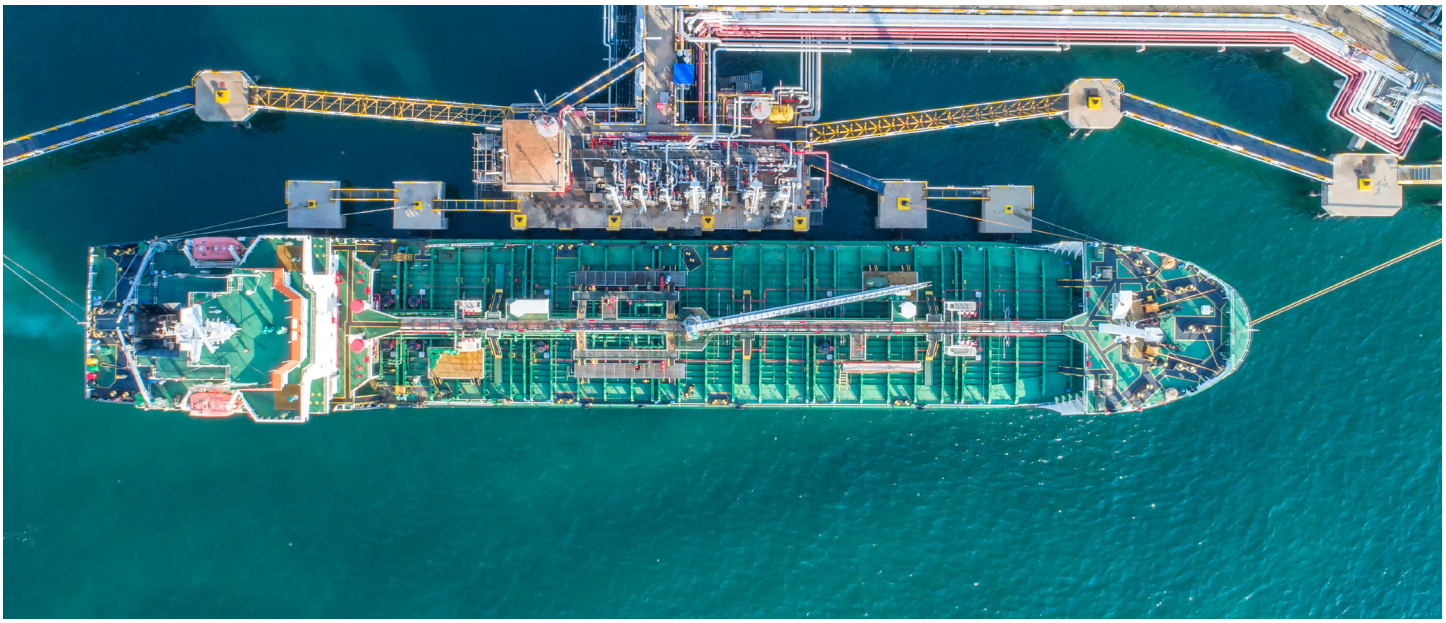
WHITE PAPER

The key components of an effective voyage optimization platform

The time to implement a leading edge voyage optimization platform is now. Before you invest in a solution, make sure to understand the key differentiators that make a platform exceptional.

The maritime shipping industry is in the midst of a sea change. New emissions regulations and ongoing macroeconomic uncertainty are shifting carriers' strategic priorities and complicating the path to profitability. These challenges are prompting executives and decision makers in charge of fleet performance, operations, safety, and decarbonization to ask themselves a simple question: is my fleet operating as efficiently as possible?

Shoreside teams are turning to voyage optimization platforms to help answer this question. A voyage optimization platform ensures that a vessel follows the most efficient path to port given weather conditions, market factors, business constraints, safety considerations, and the ship's performance characteristics. The most efficient route is unique to each vessel and voyage — some optimal paths minimize fuel consumption, while others prioritize a fast arrival time, reduced emissions, and so on.



Voyage optimization platforms address a major pain point for shipping companies. Although shoreside teams have access to an abundance of data, it requires extensive calculation to turn that data into actionable insights. Voyage optimization platforms solve this problem by inputting vessel, voyage, weather, and market information and outputting optimized route guidance.

Shipping companies stand to benefit from optimized route guidance now more than ever. In 2018, the International Maritime Organization (IMO) set a goal to lower industry-wide carbon intensity by as much as 70% by 2050, a commitment that puts pressure on individual carriers to decarbonize quickly.[1] So far, not good: the industry's emissions in 2021 were on par with its emissions in 2015.[2] One of the primary barriers to progress is that cost-effective decarbonization strategies that are impactful in the short-term are hard to come by. For example, new propulsion solutions, like wind-assisted sailing and alternative fuels — both of which are frequently cited as key strategies for cutting emissions — are nascent and expensive. In 2021, biofuels accounted for less than 0.5% of the fuel used by carriers, and per metric ton costs continue to exceed those of fossil fuels.[3][4]

Voyage optimization platforms can help shipping companies lower fuel consumption, reduce emissions, and save money in the immediate term. At Sofar Ocean, our Wayfinder platform's continuous route guidance reduces vessels' fuel consumption by an average of 3-5% per voyage. These incremental savings accumulate over time and can be used to fund sustained investment in the development of low-carbon fleets.

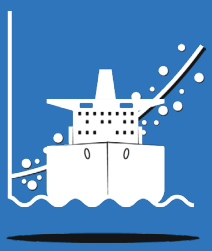
Not all voyage optimization platforms, however, are equally effective, and choosing the wrong solution can leave potential efficiency gains on the table. In this white paper, we will help decision makers choose a solution — or validate the effectiveness of their current solution — by detailing the three key components of a world-class voyage optimization platform:

- **Highly accurate weather forecasts** that augment government models
- **Vessel Performance Models (VPM)** that accurately predict speed and fuel consumption in all weather conditions
- **Proactive route guidance** that continuously optimizes for changing market factors and weather conditions

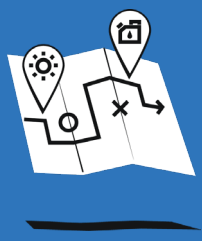
[1] Cutting GHG emissions from shipping - 10 years of mandatory rules
[2,3] International Shipping – Analysis - IEA
[4] Indicative shipping fuel cost ranges – Charts – Data & Statistics - IEA

The 3 key components of a world-class voyage optimization platform

Highly accurate weather forecasts that outperform government models



Vessel Performance Models (VPM) that accurately predict speed and fuel consumption in all weather conditions



Proactive route guidance that continuously optimizes for changing market factors and weather conditions

A brief history of voyage optimization

Before we unpack the key elements of a leading edge voyage optimization platform, it is important to understand how ship routing has evolved up to this point.

Initially, shipping companies had access to simple weather routing solutions. These interfaces supply Captains with weather forecasts, which they can use to chart safe routes in extreme conditions. Shoreside teams and crew can also use the weather forecasts as evidence in claims cases; if, for example, a vessel fails to meet a speed requirement during a voyage, a carrier can prove it was due to stormy seas and invoke a "good weather" clause in a charter party agreement. Weather routing solutions are reactive; they are not optimizing for other variables, like fuel consumption. In the absence of a storm, the platforms are of little use to Captains and shoreside teams.

The rapid modernization of the shipping industry redefined the role of weather routing providers. Today, vessels increasingly have reliable internet access, weather forecasts are far more accurate, and economic information, such as bunker prices and hire rates, is becoming more widely available. Shoreside teams that once struggled to access useful data are now inundated by it, creating an opportunity to be more data-driven when finding the best route to sail.

In response, weather routing providers have adapted, expanding their platforms' capabilities to meet the needs of newly-empowered shoreside teams. Now, a voyage can be optimized for arrival time, fuel consumption, emissions output, and other key variables. These basic voyage optimization solutions are a step above their predecessors, but remain deficient. Many continue to provide only reactive guidance — once a passage is planned, mid-voyage adjustments to a vessel's course or speed are only made upon request by a Captain or Operator — while others do not aptly account for commercial factors.

Leading edge voyage optimization providers have zeroed in on these inefficiencies. What if a platform could optimize for all key variables continuously, and prioritize safety and profitability simultaneously? Updated speed and waypoint recommendations could be sent repeatedly over the course of a voyage, taking into account changing commercial factors and weather conditions along a route.

Continuous, proactive, and holistic route guidance is at the core of today's world-class voyage optimization platforms.

This continuous, proactive, and holistic route guidance is at the core of today's world-class voyage optimization platforms. Two critical inputs power this guidance: highly accurate weather forecasts and Vessel Performance Models (VPM) that accurately predict speed and fuel consumption in all weather conditions. Let's unpack the value of each.

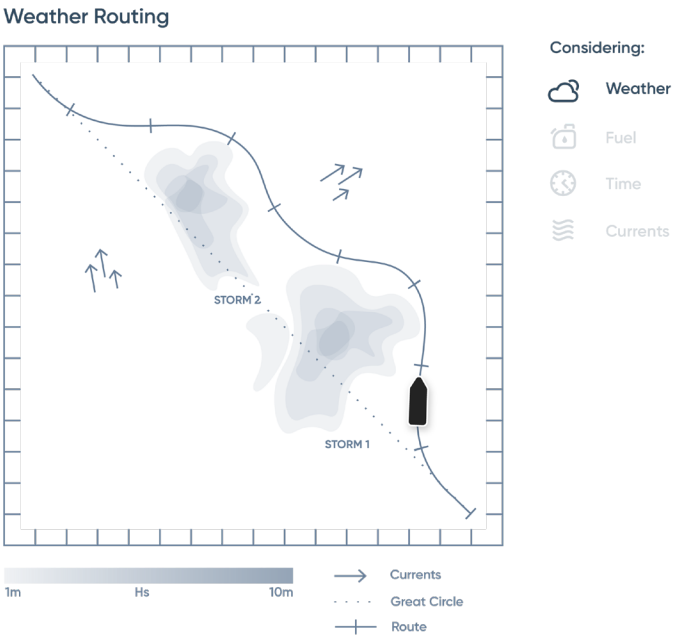


Figure 1. Early weather routing platforms were reactive and only issued route guidance in response to inclement weather. In **Figure 1**, we simulate a vessel following a weather routing platform's recommendations. The vessel heads northwest, making two mid-voyage diversions to avoid inclement weather along its route. The recommended route is not optimized for additional variables like fuel and time cost, as evidenced by its failure to capitalize on favorable currents west of the inclement weather.

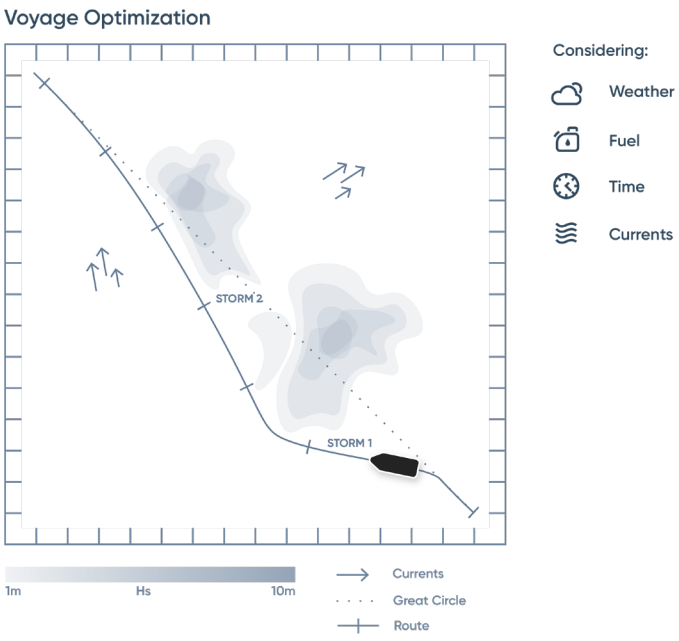


Figure 2. Voyage optimization platforms send vessels proactive and continuous route guidance over the course of a voyage. In **Figure 2**, we simulate a vessel following a voyage optimization platform's recommendations. Unlike the vessel in **Figure 1**, this ship follows a more western course that accounts for the weather forecasted along the entire route, as well as other key variables like fuel and time cost. This enables the vessel to minimize its exposure to the inclement weather and capitalize on favorable currents.

Highly accurate weather forecasts create new value for Captains and Operators

The weather forecasts used by shipping companies all share a common starting point: the government. Organizations like the National Oceanic and Atmospheric Administration (NOAA) and the European Centre For Medium-Range Weather Forecasts (ECMWF) produce powerful models that generate the forecasts used industry-wide.

Weather routing tools and voyage optimization platforms use these forecasts to guide Captains and shoreside teams. Typically, third-party providers layer new insights on top of the forecasts; for example, if a storm is forecasted along a vessel's intended route, a platform might recommend new waypoints that avoid the inclement weather.

Sofar's marine weather forecasts outperform government models by 40-50%.

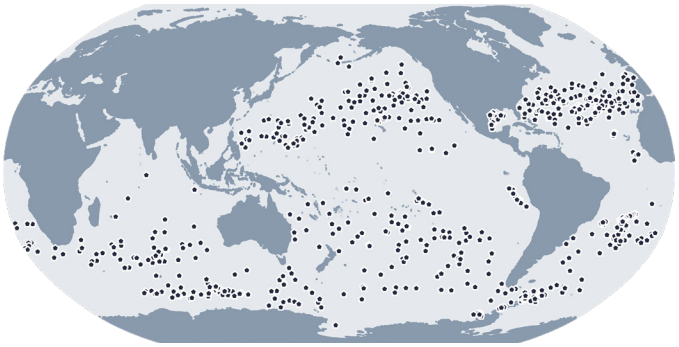


Figure 3. Locations of Spotter buoys in Sofar's global buoy network, as of January 1, 2023.

The weather forecasts themselves, however, tend not to change as they pass from government to third party provider to vessel. This is a missed opportunity; central to our voyage optimization strategy at Sofar Ocean is the use of sophisticated ocean data collection techniques to augment government models and produce superior weather forecasts. Our marine weather forecasts outperform government models by 40-50%.[5] This performance improvement is driven by our global network of marine weather

Figure 4. A Sofar Spotter buoy floating in the Pacific Ocean. Sofar's vast, global network of free-drifting Spotters collects and transmits data in real-time.

sensors — known as Spotter buoys — which collect real-time ocean data at a planetary scale. Each day, we assimilate 200,000 ground truth ocean observations from these sensors — which comprise the largest privately owned network of its kind — into our operational weather forecasts, along with additional satellite and in-situ observations. The addition of this real-time data increases the accuracy of our forecasts.

[5] Operational Assimilation of Spectral Wave Data From the Sofar Spotter Network

With global forecasts that are 40-50% more accurate come countless benefits. For Captains and Navigation Officers, more reliable weather data translates to more trustworthy route guidance, and represents an opportunity to improve the safety of the crew and cargo. Ensuring that a voyage is incident-free is a particularly pressing concern for Captains, who are navigating seas made increasingly volatile by the effects of climate change. In 2020 and 2021, for example, more containers were lost at sea than in eleven of the twelve previous years, with "an unusually high number of weather-related incidents" cited as a key cause.[6][7]

Accurate forecasts also empower shoreside teams to optimize the commercial outcomes of a voyage by improving their ability to predict the effect of individual routing decisions. Even minor changes in ocean weather can have a major impact on a vessel's performance, particularly the amount of fuel required to complete a trip. For example, Wayfinder voyage data shows that a Capesize bulk carrier sailing in Beaufort 6 — classified by NOAA as a "strong breeze" — increases its fuel cost by $5 per nautical mile relative to sailing in Beaufort 5 conditions — a "fresh breeze." Multiply that increase across an entire route — which can frequently cover more than 5,000 nautical miles — and it is easy to see how significantly weather can impact voyage costs. Robust marine weather forecasts help Operators project outcomes like these and empower them to make the most cost-effective decisions in response.

Highly accurate weather forecasts predict the conditions along a vessel's route, but do not tell us how a particular vessel will behave in those conditions. Enter: Vessel Performance Models (VPM).

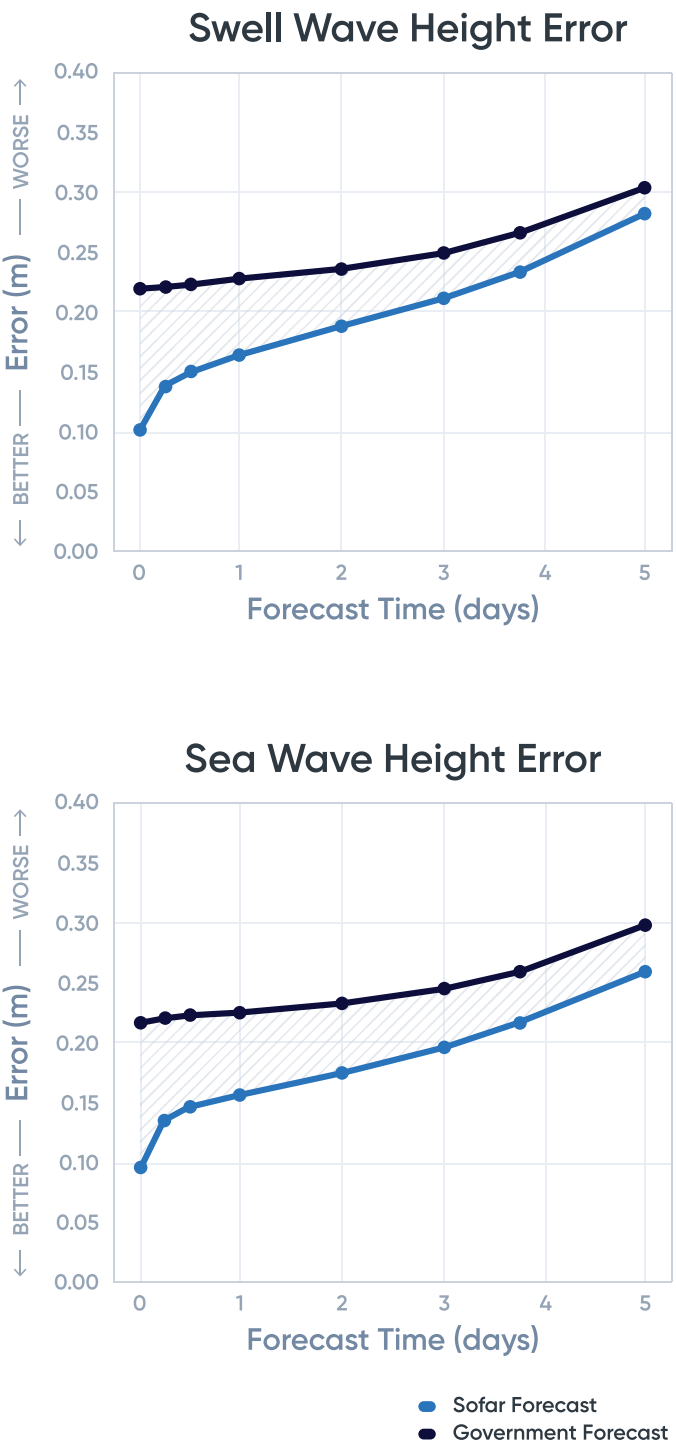


Figure 5. Most voyage optimization providers take government weather forecasts at face value. Sofar enhances these forecasts by assimilating the real-time ocean observations captured by our global Spotter buoy network each day. In **Figure 5**, we show how Sofar's augmented forecasts reduce swell and sea wave height error relative to government weather forecasts. Sea wave height and swell wave height comprise significant wave height, which is the average measurement of the largest 1/3 of waves and the most widely used wave height metric. Sofar's wave height forecasts are more accurate at all lead times and most accurate zero to two days into the future.

[6] Containers Lost at Sea, p.3
[7] World Shipping Council Containers Lost at Sea Report 2022

How to ensure that your Vessel Performance Model (VPM) is accurate in all weather conditions

A VPM is a module that calculates the relationship between a vessel's propeller RPM, engine power, speed, and fuel consumption, and predicts how that relationship will change in different sea states. A VPM's predictions inform the route guidance that a voyage optimization platform sends to a Captain.

Consider a bulk carrier that needs to travel at 12 knots in order to reach port within a required arrival window. Along one route, its VPM calculates that 35 MT/day of fuel and an RPM of 55 are required to travel at 12 knots. Along another route, its VPM calculates that, due to foul weather, 42 MT/day of fuel and an RPM of 60 are required to travel at 12 knots. These scenarios have markedly different economic outcomes: consuming seven additional MT of fuel can add upwards of $5,000 to a voyage's daily cost. A reliable VPM will forecast this gap in performance and cost, and use it to inform the route guidance issued by a voyage optimization platform.

Shoreside teams must ensure that a VPM's predictions are highly accurate in all weather conditions. To do so, decision makers should ask two key questions:

- How was the VPM built?
- How accurate is the weather data used by the VPM?

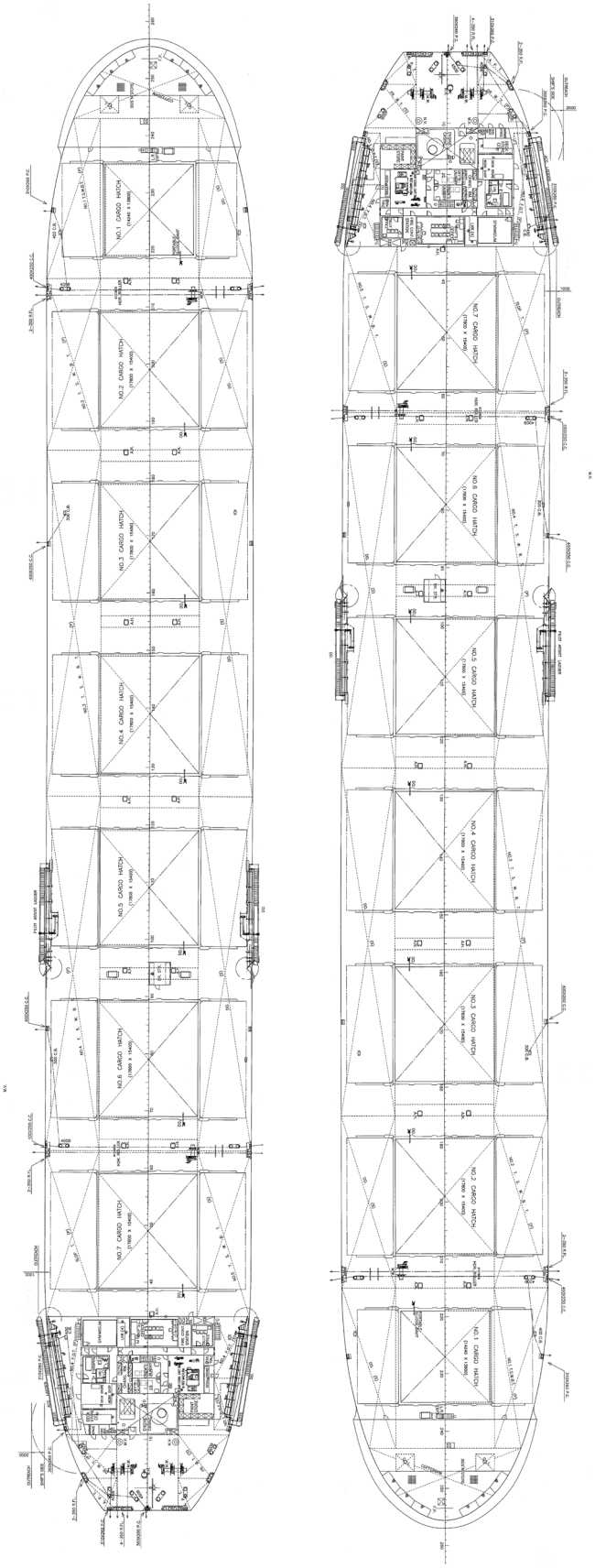


Figure 6. A ship's physical particulars are a critical component of an accurate Vessel Performance Model (VPM). A VPM that is purely physics-based, however, does not make use of the troves of voyage data collected by modern shipping companies.

First, let's break down the different ways that VPMs are built. Some VPMs are physics-based and use propeller characteristics, hull geometry, engine limits, and other vessel particulars to gauge how a ship will perform. These models provide reasonable estimates of speed and fuel consumption, but fail to leverage readily available voyage data to improve a VPM's predictions.

Other VPMs take advantage of this voyage data, using at-sea performance statistics to power predictions. These modules, however, can be over reliant on voyage data, which can be low quality; for example, noon reports can be imprecise, and high frequency data may only be sporadically available.

At Sofar, we combine these methodologies, using a hybrid physics-based and data-driven approach to calibrate Wayfinder's AdaptiveVPM™.

We utilize advances in machine learning to ingest as much high-quality data as possible, while remaining faithful to fundamental naval architecture principles. The resulting module is less susceptible to the potential shortcomings introduced by a purely physics or data-driven VPM.

The quality of the weather data used by a VPM is another key differentiator between modules. To calibrate a VPM, noon reports or high frequency data are collocated with a hindcast — the best prediction of past weather at a given place and time — to create a historical record of a vessel's performance in different sea states. The accuracy of a hindcast has a domino effect, impacting the accuracy of:

- The VPM calibration
- The VPM's speed and fuel predictions
- The route guidance sent to a vessel

Wayfinder's AdaptiveVPM™

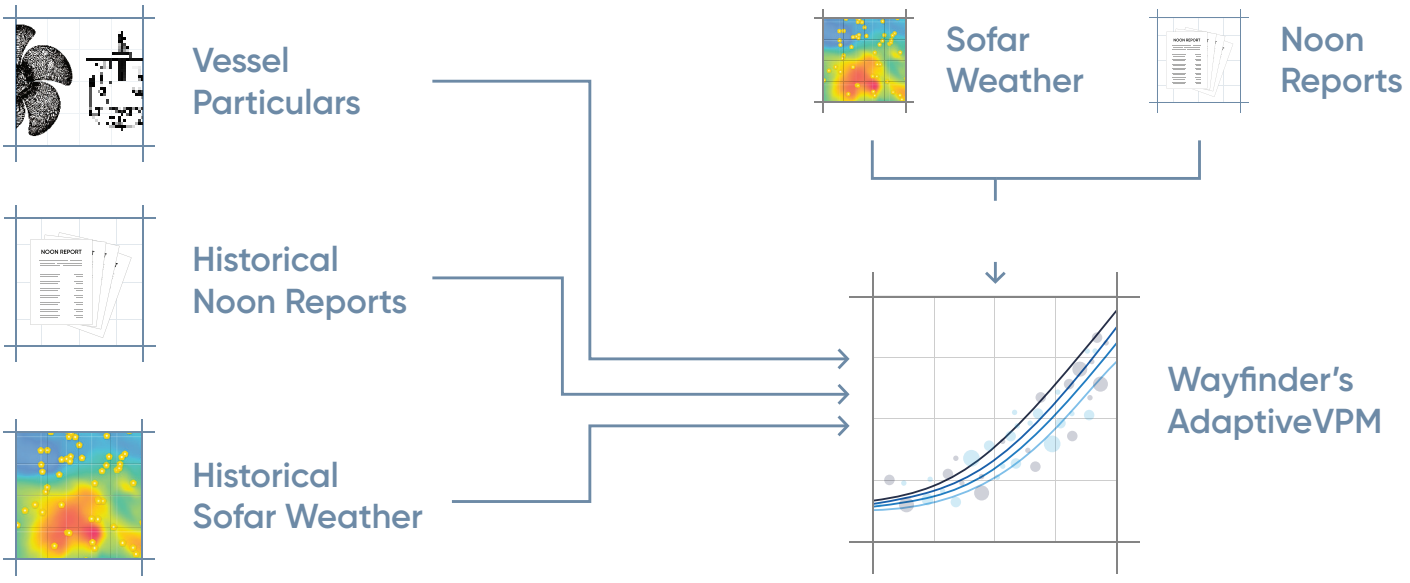


Figure 7. A schematic of AdaptiveVPM™, the Sofar Wayfinder platform's vessel performance model. Inputs to the AdaptiveVPM™ include vessel particulars, Sofar hindcast data, and historical noon reports (plus high-frequency data, when available). AdaptiveVPM™ outputs speed and fuel consumption prediction curves for a vessel in all sea states. Sofar's forecasts and data from the vessel are used to assess the performance of AdaptiveVPM™ over time and, when necessary, to initiate periodic recalibrations of the model to improve its accuracy.

As we discussed in the previous section, voyage optimization based solely on government weather forecasts sacrifices potential savings. The same logic applies to hindcasts. VPMs that use less accurate hindcasts are calibrated less effectively, make less accurate speed and fuel predictions, and negatively impact the route guidance sent to a vessel.

Wayfinder's AdaptiveVPM™ is calibrated using highly accurate hindcasts that assimilate real-time Spotter buoy observations. It predicts vessel speed within an average of 0.5 knots and fuel consumption within an average of 2% of metric tons consumed; according to one customer, its predictions are "scary accurate." Our AdaptiveVPM™'s output is continuously monitored and periodically recalibrated using the latest weather and vessel data to account for the degradation of a ship's physical structure or performance over time.

A voyage optimization platform's two critical inputs — highly accurate VPMs and weather forecasts — combine to produce its key output: route guidance. Let's identify the optimal type of route guidance and detail the best way to deliver that route guidance.

The best route guidance is proactive and delivered continuously

Imagine a vessel that is preparing to sail:

- In an ocean with no waves, winds, or currents
- In an economic market with no variability

In this scenario, the vessel's route can be completely optimized before the voyage begins. To minimize fuel consumption, for example, the optimal power setting could be calculated, set, and used without adjustment for the entirety of the voyage. Set it and forget it.

Of course, this scenario is impossible. Weather in the open ocean is volatile and market factors, such as spot rates and bunker prices, change constantly. This creates an ever-shifting environment that continuously alters the economics of a voyage in progress. In these real world conditions, a ship that uses constant power, constant speed, or preset waypoints will not operate as efficiently as possible because guidance is based on obsolete weather and market information from a fixed moment in the past.

Nevertheless, voyage optimization providers often recommend these "set it and forget it" strategies, ignoring significant opportunity costs. For example, a vessel that maintains constant power in inclement weather may keep its fuel costs constant, but could extend the duration of its journey and miss its arrival window. This delay, which can be exacerbated by port congestion and extended wait times, can lead to time charter disputes and missed fixtures, creating new costs that far exceed any expected savings.

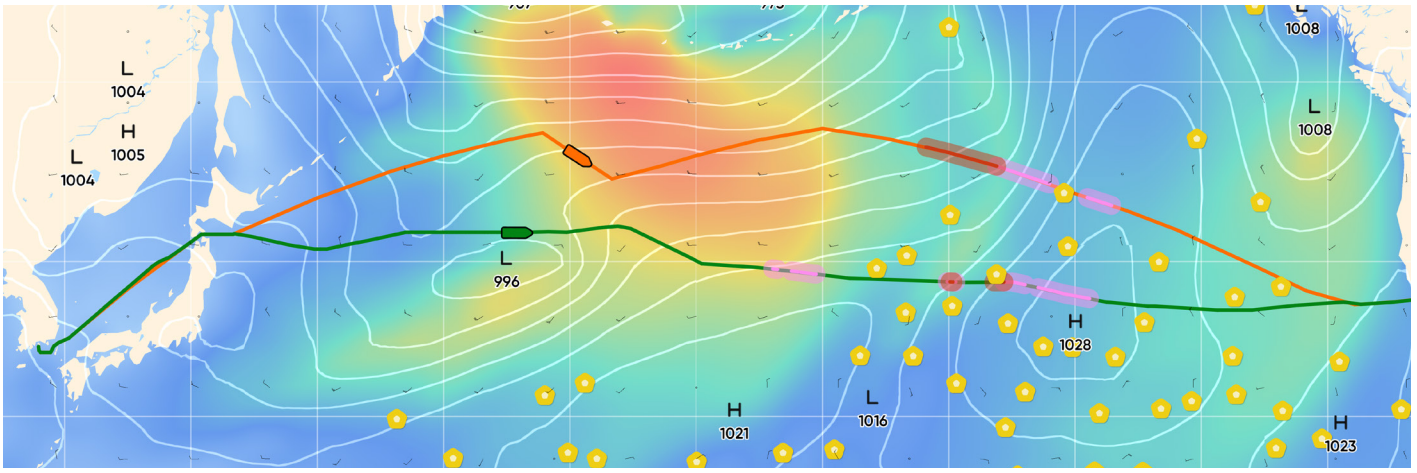
Route guidance that is optimized continuously — rather than once at the beginning of a voyage — takes opportunity cost into account by constantly searching for the most efficient path to port. Sofar's Wayfinder voyage optimization platform considers hundreds of millions of route options before proactively sending daily waypoint and RPM guidance based on a vessel's specific business and safety constraints. Each day, the Captain and engineers can set the RPM with confidence, knowing that the predicted speed and fuel consumption is constantly monitored by the AdaptiveVPM™.

Just as Waze considers the latest traffic and gas price information during a car trip, Wayfinder factors in the latest weather forecasts — informed by Spotter buoy observations — along a vessel's route, as well as changing market factors, before issuing its daily route guidance. If, for example, a vessel needs to avoid waves greater than five meters and minimize emissions to hit a target Carbon Intensity Indicator (CII) score, Wayfinder can identify the route that burns the least fuel while staying out of inclement weather. At all times, a highly trained team of Sofar routing analysts supplements this guidance, providing direct support to Captains and shoreside teams.

To demonstrate how proactive and continuous guidance is superior to one-off, reactive guidance, we built an in-depth routing demo using real voyage data that compares each approach. A preview of the routing demo is shown below; to view the full demo and detailed analysis, check out our Voyage Optimization Demo.

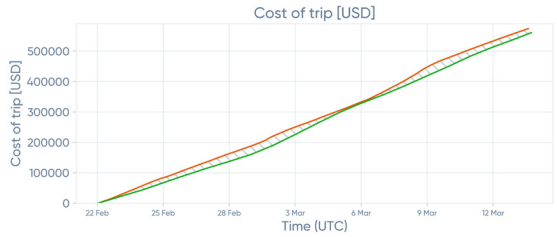
Preview: Voyage Optimization Demo

VIEW FULL DEMO + ANALYSIS →

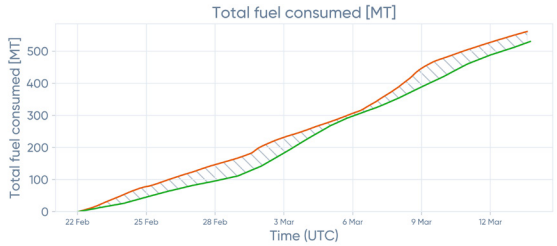


In this demo, we analyze two routes taken by a bulk carrier traveling from Asia to the west coast of the United States. The first is an actual optimized route that was produced by Sofar's Wayfinder platform (**green line**). This route is continuously optimized throughout the voyage, with RPM and waypoint guidance assessed daily by Wayfinder. The second is a simulated, non-optimized route (**orange line**) that uses constant speed and fixed waypoints set prior to the start of the voyage. While vessels would often change speeds when encountering weather, this example assumes the voyage maintains speed to hit a required time of arrival.

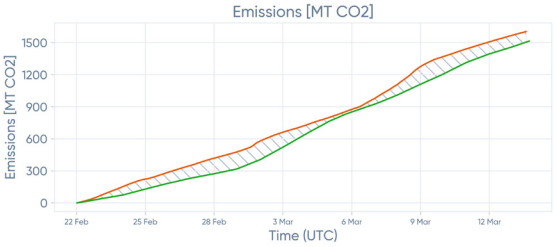
Overall, the vessel following the Wayfinder optimized route spends less time in high wave conditions, burns less fuel, produces fewer emissions, and has a lower cost of trip than the vessel following the non-optimized route. These performance gaps are attributable to the voyage guidance underpinning each route. By adhering to the continuous RPM and waypoint recommendations sent by Wayfinder, the vessel following the optimized route sails as efficiently as possible given changing ocean weather and economic factors. By sailing at a constant speed with inflexible waypoints, the vessel following the non-optimized route is more susceptible to inclement weather and subpar voyage outcomes. Whether maintaining constant speed, power, or route, sailing without continuous optimization will always produce inferior results.



↓$13,464 • $574,207 • $560,744



↓31.08 MT • 561.21 MT • 530.13 MT



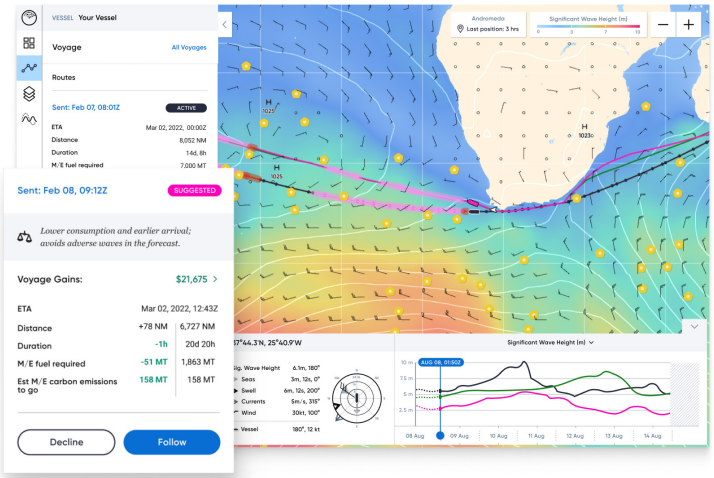
↓88.82 MT • 1603.73 MT • 1514.91 MT

The time to invest in a world-class voyage optimization platform is now

Voyage optimization platforms provide shipping companies with an immediate opportunity to increase operational efficiency fleetwide. By ensuring that a vessel takes the most efficient route based on its specific business and safety constraints, voyage optimization platforms help reduce fuel consumption, lower emissions output, and save money in the short term. Given the increased economic pressure brought on by decarbonization regulations and external market factors, the smartest shipping Operators are taking advantage of this opportunity now.

Voyage optimization platforms that use highly accurate weather forecasts and Vessel Performance Models (VPM) to deliver proactive, continuous, and holistic route guidance represent the gold standard. Major global shipping companies, including leading dry bulk carriers Star Bulk and Eagle Bulk, trust Sofar's Wayfinder solution to deliver reliable daily route guidance to their vessels around the world. To find out how Wayfinder can help your fleet, please schedule a demo with the Sofar team using this form.

Wayfinder by SOFAR



Connecting the world's oceans to power a more sustainable future

Sofar has designed, built, and deployed the largest privately owned network of ocean sensors, which it uses to produce the world's best marine weather forecasts. Sofar's Wayfinder platform couples these forecasts with robust vessel performance models to provide continuously optimized voyage guidance to fleets. This guidance helps maritime shipping companies reduce emissions, prioritize safety, increase operational efficiency, and maximize profitability.

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