Voyage Planning for Fully Electric Harbour Craft

SMI Forum, 7 November 2024

Ravindra Kudupudi

Centre of Excellence for Autonomous and Remotely Operated Vessels (CEAOPS)

Technology Centre for Offshore and Marine, Singapore (TCOMS)

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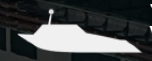
- Acts as focal point to enable multi-disciplinary public R&D expertise to partner industry to solve real-world problems

- Public R&D programmes and industry projects covering wide spectrum of coastal and ocean challenges:


Metocean


Offshore systems


Marine Robotics


Smart Vessels


Coastal Protection & Nearshore Solutions

Challenges for Decarbonization through Electrification

Decarbonizing the maritime sector is crucial for reducing greenhouse gas emissions and combating climate change. Electric harbour craft (e-HC) like tugboats, ferries, and coastal vessels is a promising approach, utilizing new technologies and environmental forces to lower energy usage and carbon footprint

Battery technology still faces challenges related to energy density, weight, and charging time, which can impact the range and endurance of electric harbor craft

The decarbonization of harbour craft through electrification represents a crucial step toward reducing maritime emissions and achieving sustainable operations in port areas

Efficient Operations Leveraging Environmental Forces

The main objective is to develop a tool for estimation of energy consumption of harbour craft on a given voyage considering the metocean conditions along the route.

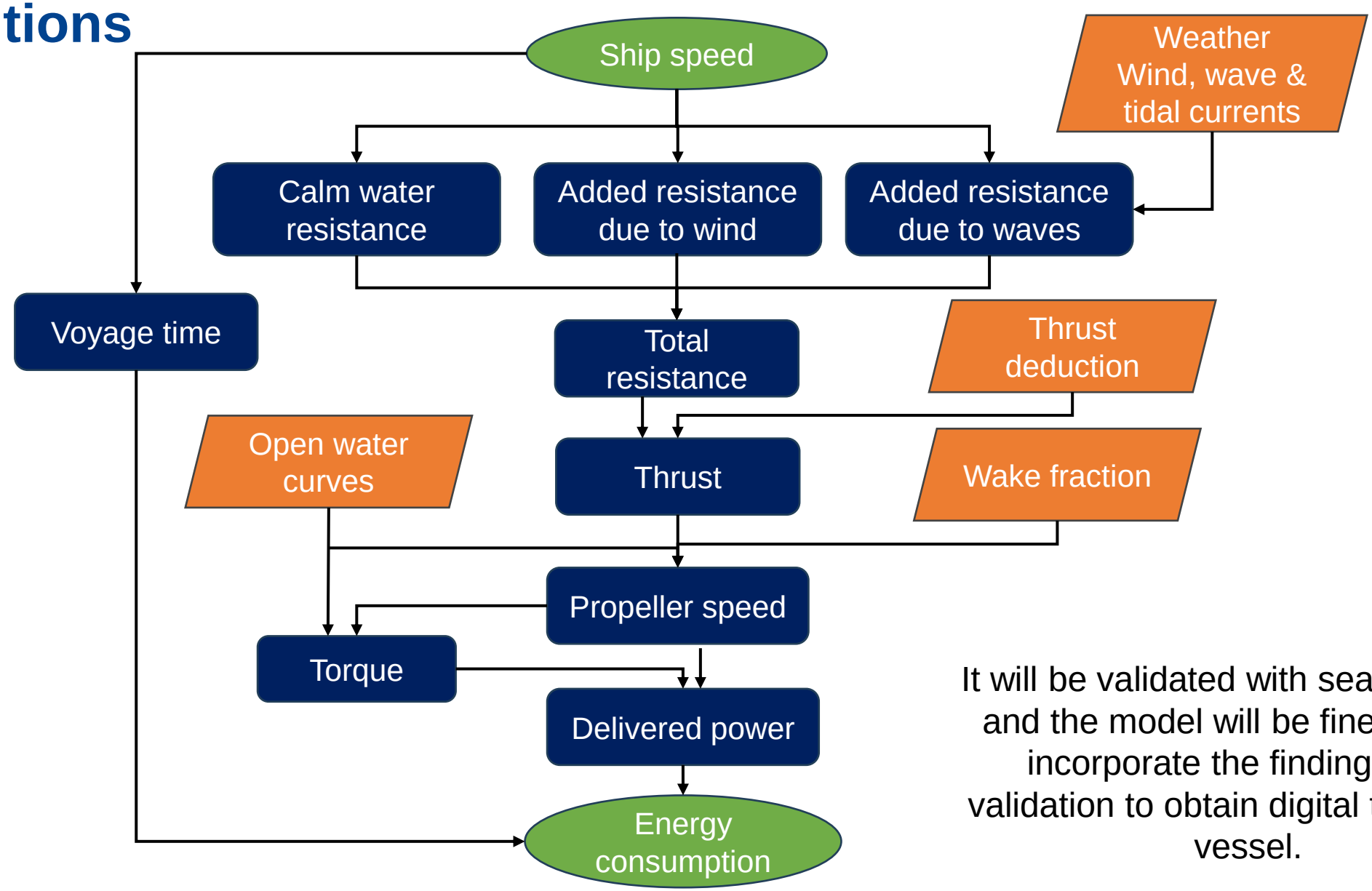
Metocean

- Real-time, high-resolution weather - multiple waypoints along the proposed route.
- The metocean information - significant wave height, peak period, wave direction, wind speed, wind direction, current speed, and current direction.

Vessel Performance

- This includes modelling of resistance components and propulsion characteristics. Resistance include calm water, wind and added resistance.
- Propeller operating point is then calculated for the given ship speed to obtain required power.

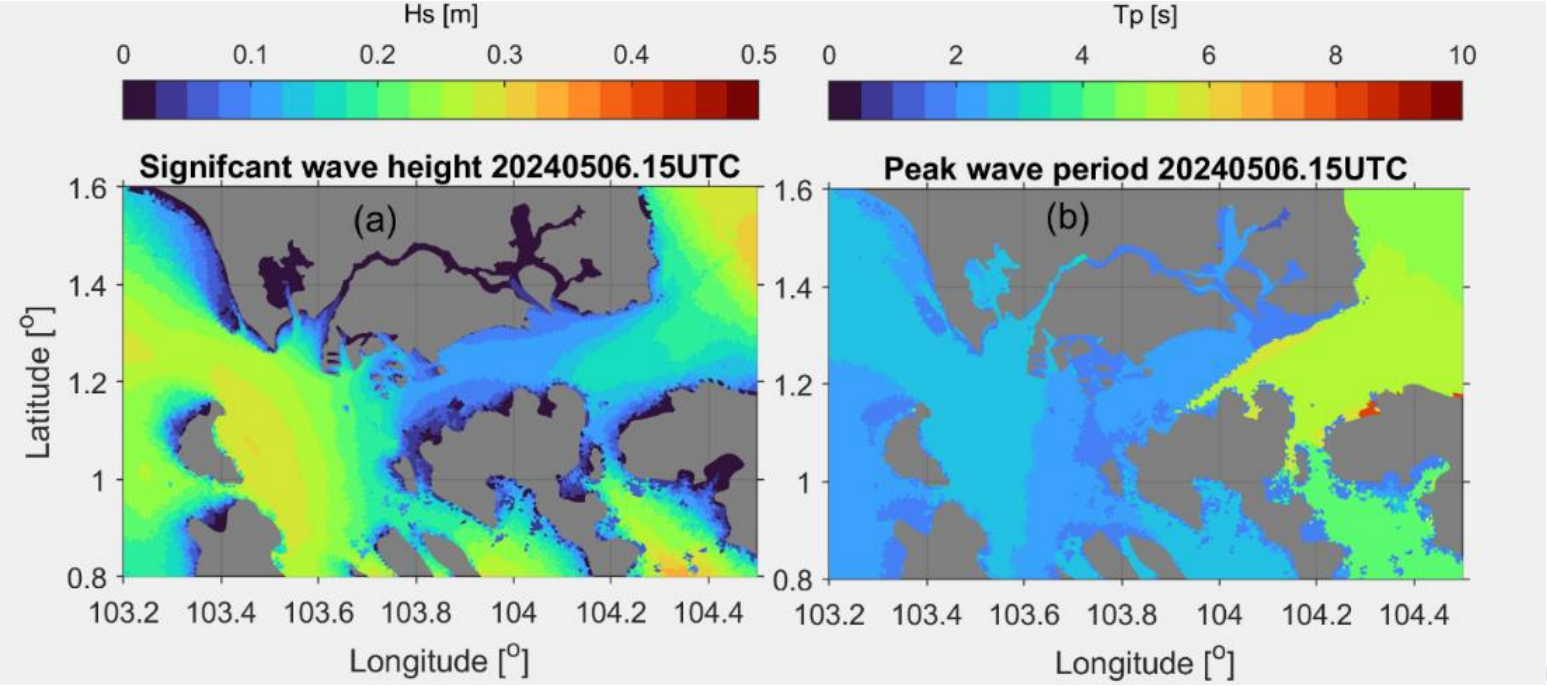
Methodology for Power Prediction in Different Operating Conditions



It will be validated with sea trials data and the model will be fine-tuned to incorporate the findings from validation to obtain digital twin of the vessel.

High-Resolution Metocean Forecasts for Calculation of Energy Consumption

- High-resolution metocean forecasts are needed to resolve variation of wind, waves and currents in the port area
- In TCOMS inhouse wave forecasting system, a high-resolution unstructured mesh was employed with less space resolution around Singapore.
- Forecasted wave fields such as significant wave height and peak wave period are shown in the below plot.

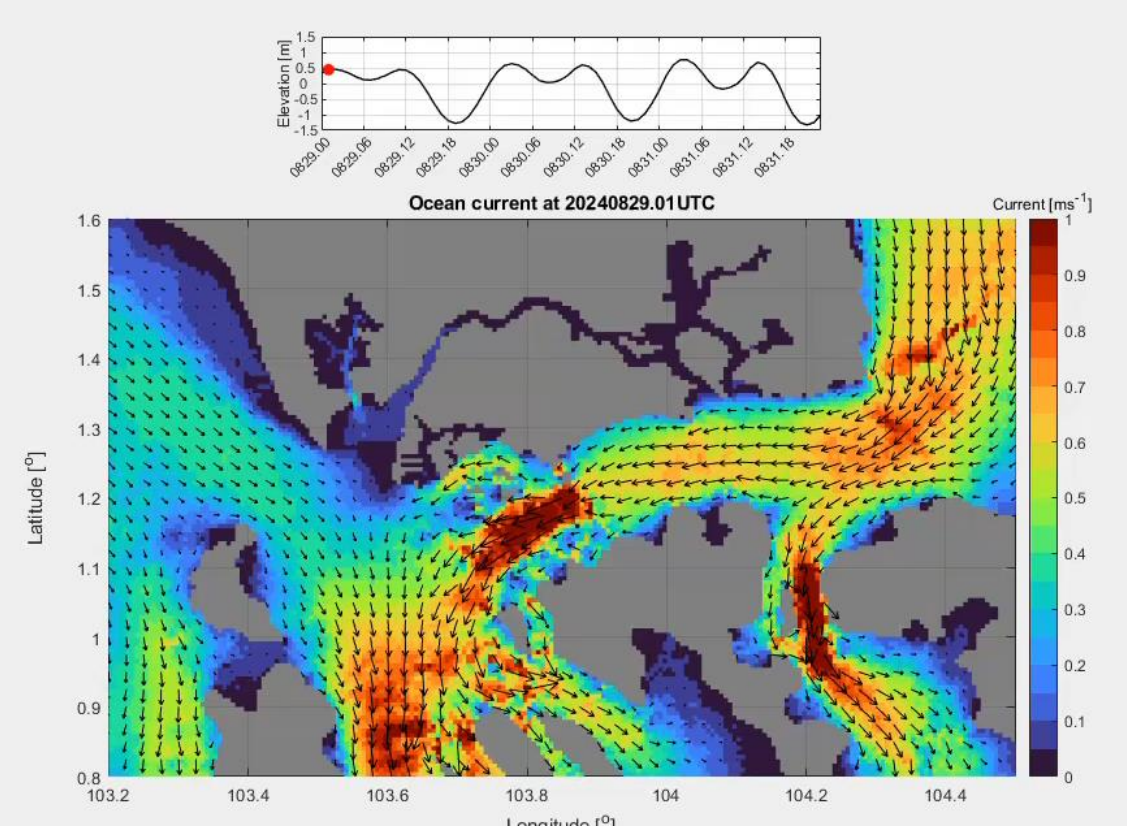


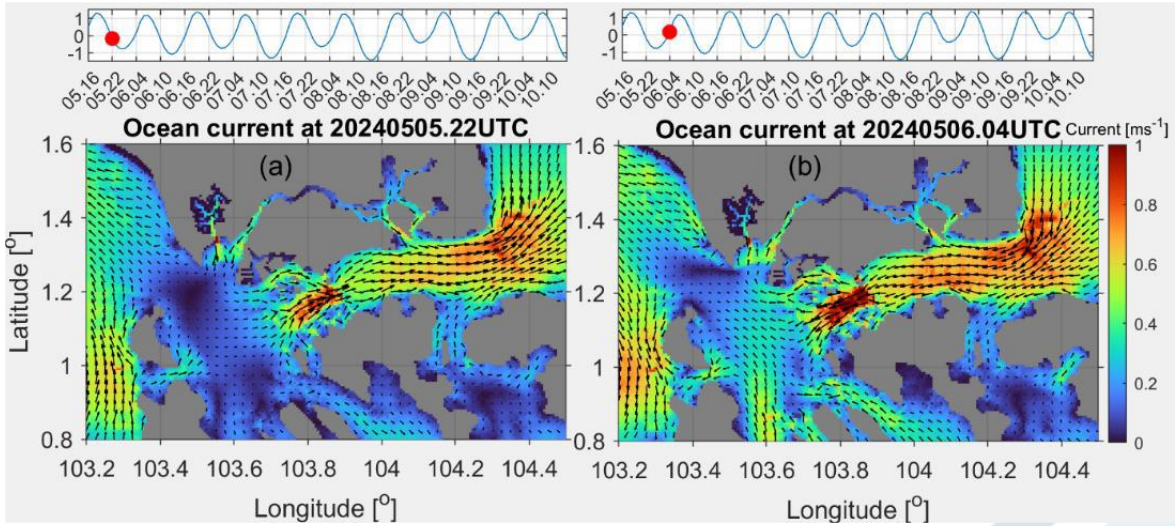
Metocean source: TCOMS

Spatial distribution of wave fields: a) Significant wave height b) Peak wave period

Predictable Tidal Currents Can be Utilized for Navigation

- The high-resolution forecasts of ocean currents are simulated by inhouse forecasting platform based on Delft3D FM.
- Spatial distributions of tidal currents are shown for two different tidal phases and shown in the below plot. Strong currents > 1 m/s can be noted in the Singapore Strait.



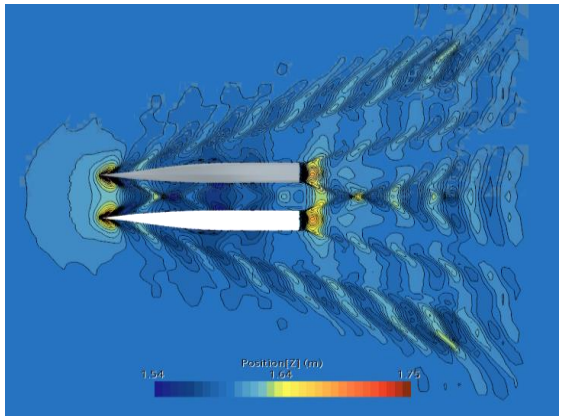


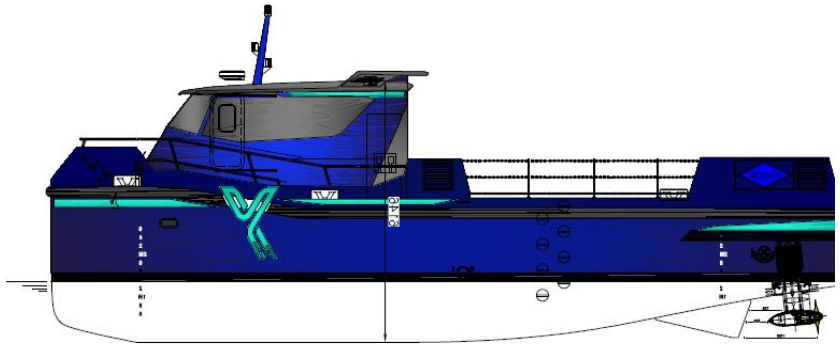
Spatial distribution of tidal currents a) at high to low tidal condition b) low to high tidal condition

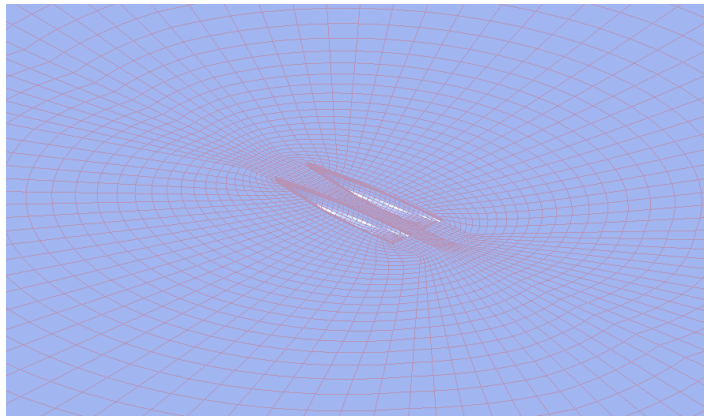
Metocean source: TCOMS

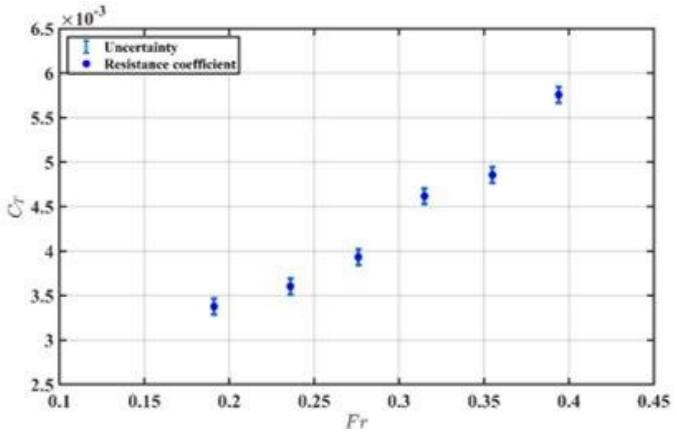
Vessel Performance Model: Resistance Components

- Resistance components including calm water, wind and added resistance have been considered for a speed range of 6 – 12 knots and plotted below for developing the powering digital twin.

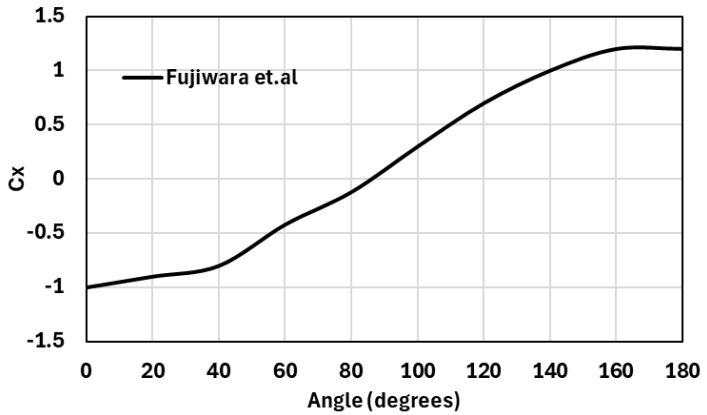




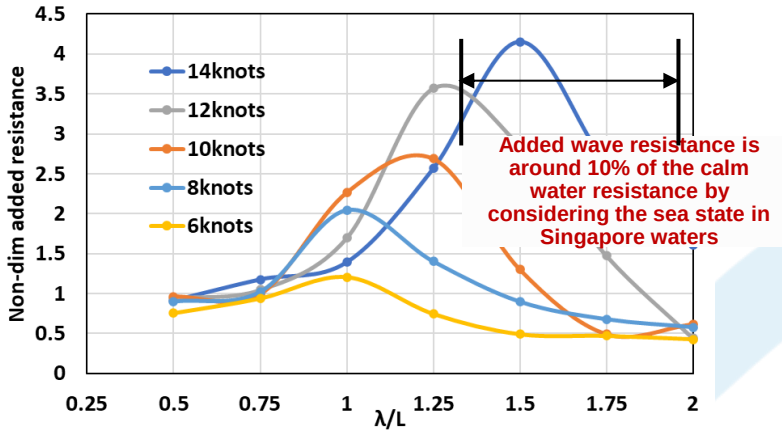




Calm water resistance

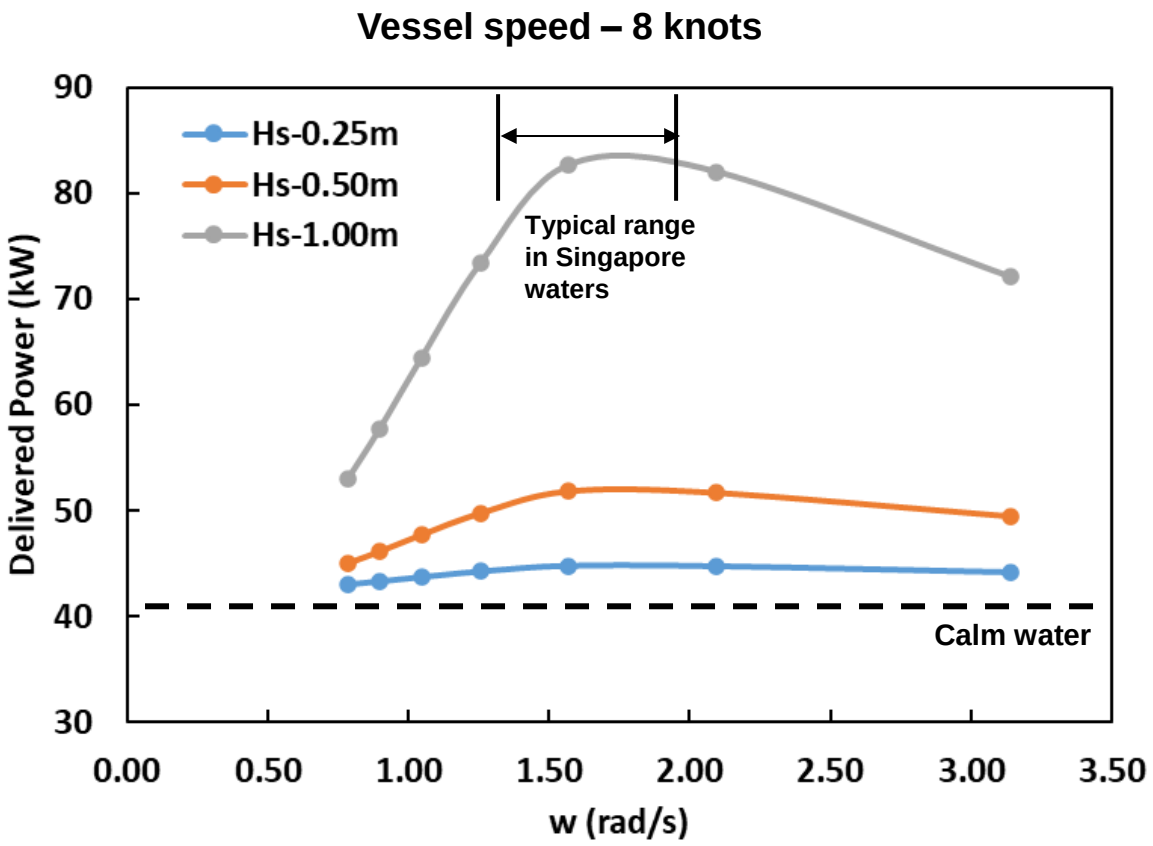


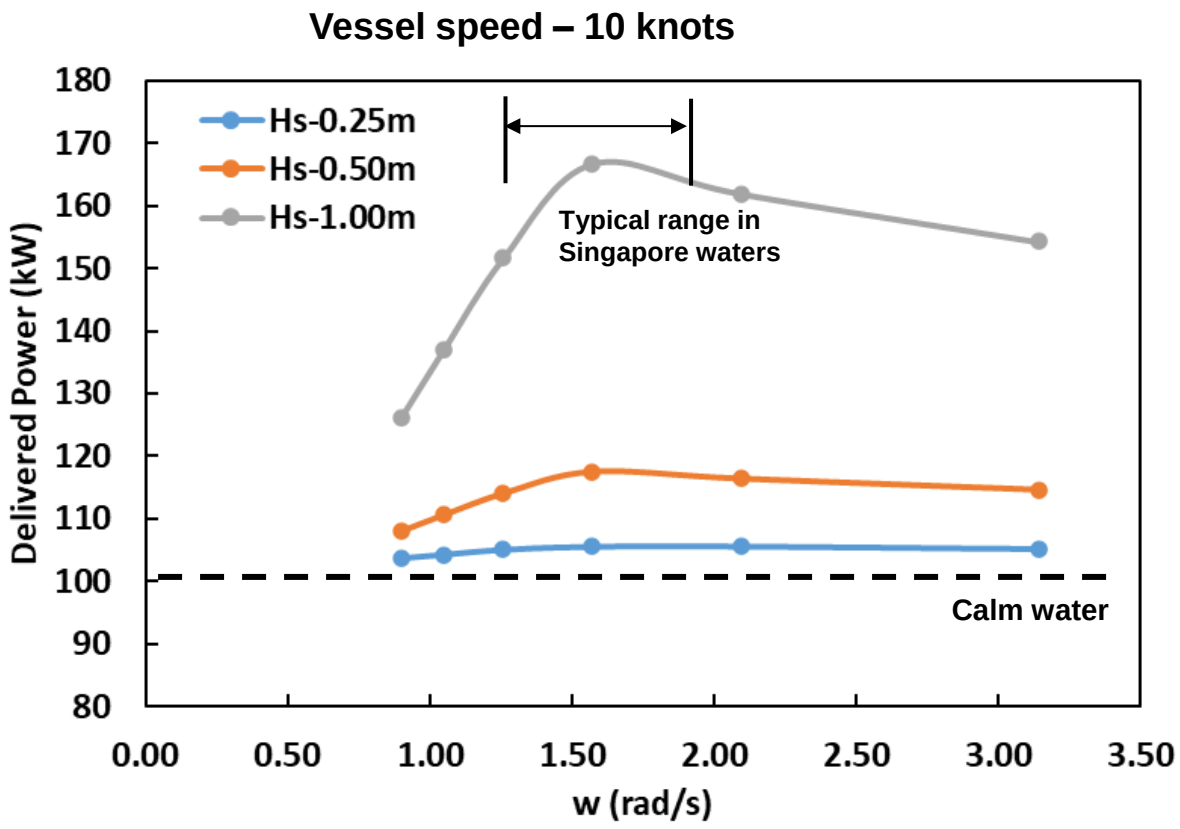
Added wind resistance



Added wave resistance

Power Prediction in Different Operating Conditions





Delivered power is estimated in irregular sea at corresponding significant wave height and peak wave period

Powering Digital Twin

- ❑ Energy/power prediction for a voyage considering environmental conditions
- ❑ Real-time forecast like wind, wave and current effect is incorporated inside the model
- ❑ Interface is linked to the latest wave forecast

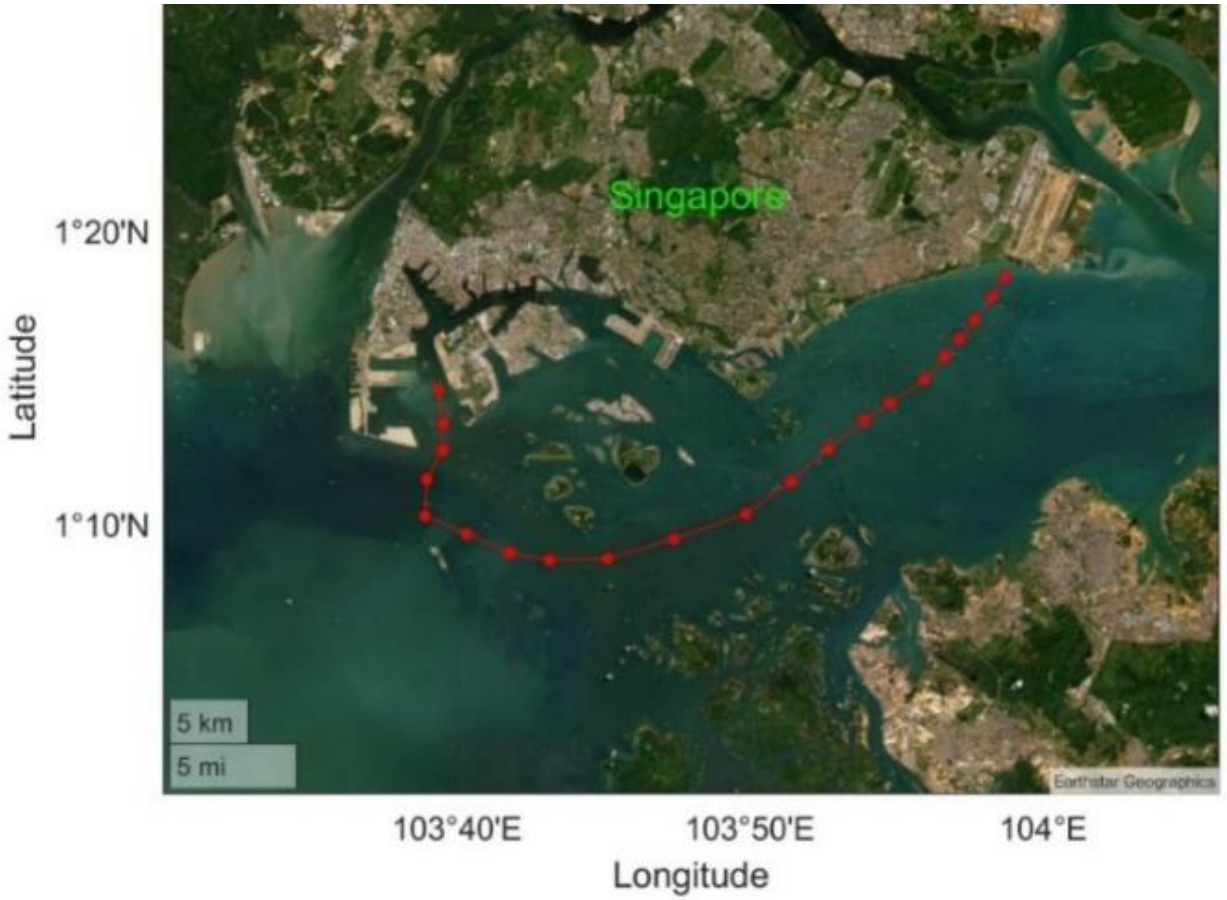
Inputs	Outputs
Vessel speed	Energy/power prediction for a voyage
Draft	
Date and time of voyage	
Voyage (lat & lon)	

Integration with digital twin of shipboard systems

Powering digital twin mimic page

Case Study – Energy Consumption in Different Tidal Conditions

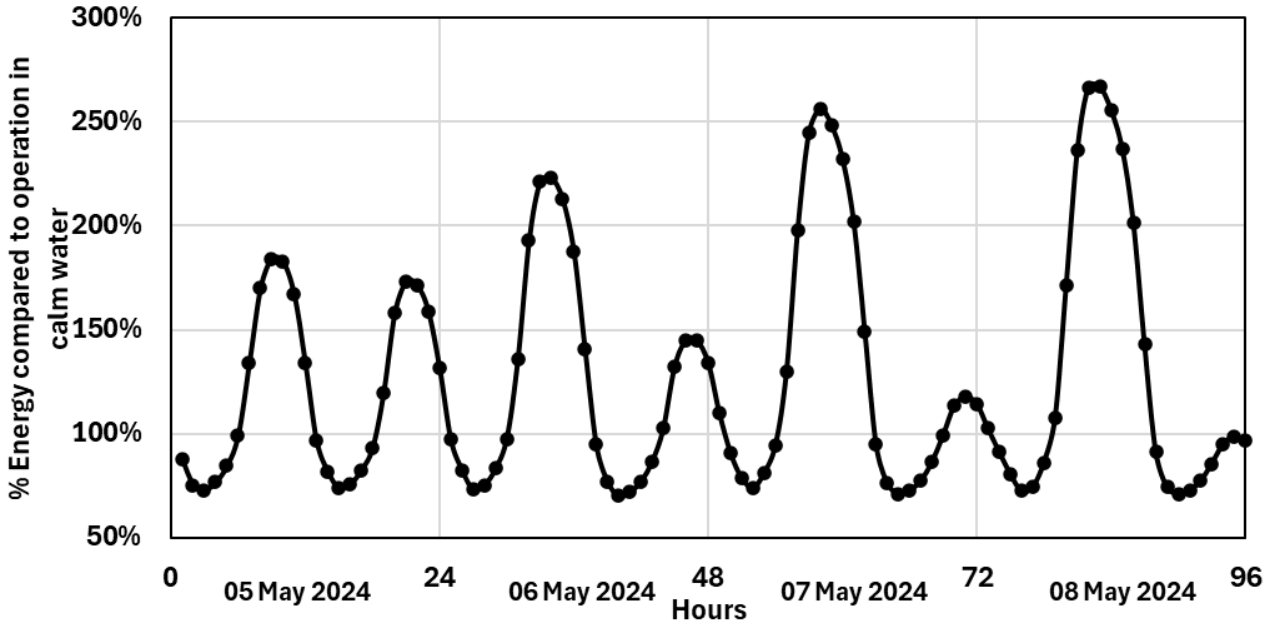
- Route below shown is selected for the case study as the tidal currents are strong in the Singapore straits
- The chosen route is approximately 28 nautical miles with multiple way points.



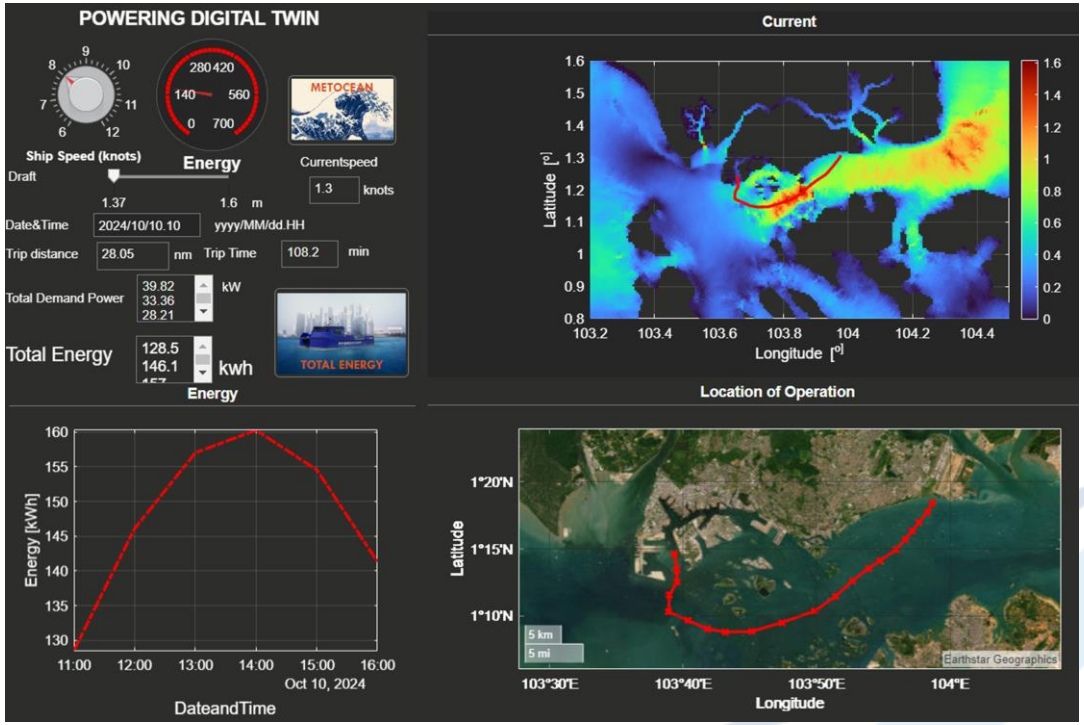
Route used for simulations around Singapore using multiple way points

Effect of Current on Energy Consumption

- Tidal currents can cause additional resistance if the vessel is moving against the current, requiring more power from the engines to maintain speed. On the other hand, energy can be saved by traveling in the direction of current.
- Below plot shows the percentage energy consumption plot for four days in an interval of one hour.
- Baseline energy in calm water (meaning no currents) is shown as 100% and % energy compared to operation in calm water. Values above 100% indicates higher energy requirement and vice versa.



Energy consumption percentage compared to the calm water scenario versus Time for the selected route for four days



Conclusions

- The overall study highlights the importance of hydrodynamic digital twins for the efficient planning of fully electric harbour craft.

- By integrating real-time data on weather conditions such as wind, wave, and current, the digital twin can predict the energy consumption of the craft for a given journey at a specific time. This can be used to ensure that there is sufficient battery change to safely complete the voyage.

- There is significant potential to optimize the voyages by leveraging currents in the areas around Singapore. Since the currents are tide driven, they are predictable which makes it possible to plan future voyages to ensure efficiency.

- By integrating digital twin technology with hydrodynamic models, maritime stakeholders can optimize vessel performance, reduce operating costs, and mitigate environmental impact.

Acknowledgements

- This research is supported by the National Research Foundation of Singapore and Singapore Maritime Institute under its Maritime Transformation Program White Space Funding Support for the Operational Profiling and Digital Twinning of Harbour Craft for Holistic Test-bedding, Life-cycle Optimization and Future Design Enhancements (SMI-2021-MTP-03).

- We would like to express gratitude to the Singapore Maritime Institute (SMI) and the Maritime and Port Authority of Singapore (MPA) for their support and funding of this project continuous commitments to advancing maritime research and innovation have played a pivotal role in the successful execution of this endeavor.

- We would like to acknowledge SeaTech Solutions International (S) Pte Ltd and Yinson Green Technologies as the industry collaborators for their support.

- We would like to acknowledge Professor Tay Zhi Yung and Januwar Hadi from the Singapore Institute of Technology for their work and support in this project.

- We also acknowledge Dr. Xu Haihua and Dr. Pavel Tkalich for setting up the Delft3D FM model and providing the forecast of ocean currents. We would like to thank Dr. Jeng Hei Chow for setting up the data server that hosts all the metocean forecast data.

Thank you