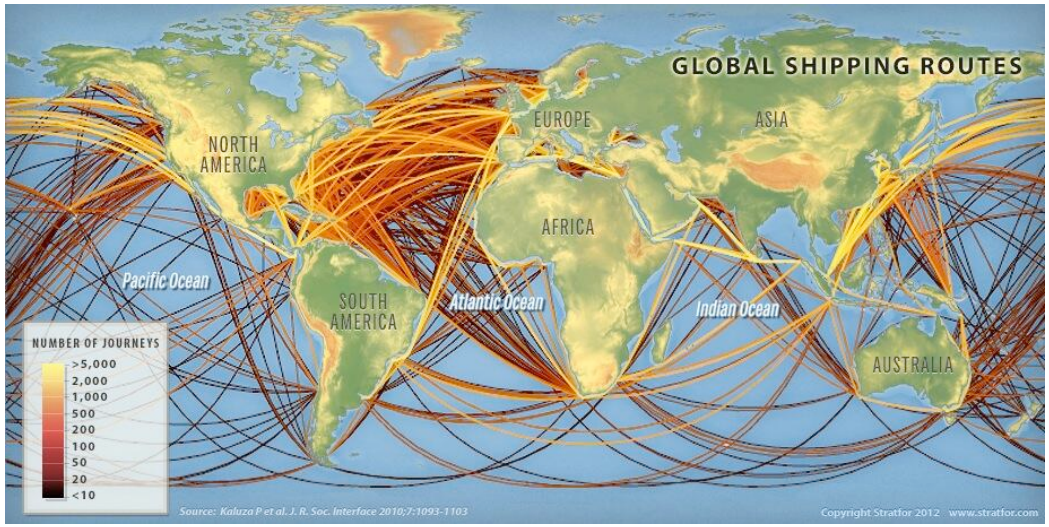
Voyage Optimisation towards Energy Efficient Ship Operations

T. Cui, B. Howett, R. Lu, M. Y. Kim, Y. K. Demirel,
O. Turan, S. Day and A. Incecik
Department of Naval Architecture, Ocean and Marine Engineering
University of Strathclyde
tong.cui@strath.ac.uk

1. Introduction

- Almost 90% goods traded worldwide are transported by sea



- Ship performance prediction
- Grids system design
- Weather routing
- Voyage optimisation
- Post processing

ETA and Fuel consumption

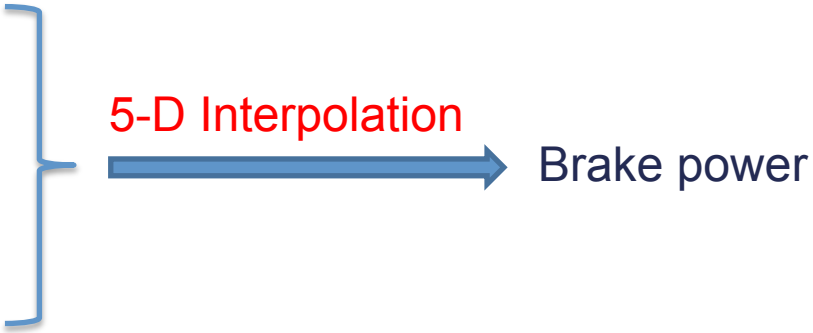
2. Voyage Optimisation Model

2.1. Ship performance prediction

Ship Performance Profile File (netCDF from WSM, WASPP…)

"This file is to package performance related attributes of an individual ship for a whole range of environmental and operational conditions in a single file, allowing data to be pre-calculated for later use in time intensive applications"(Howett, B., 2015).

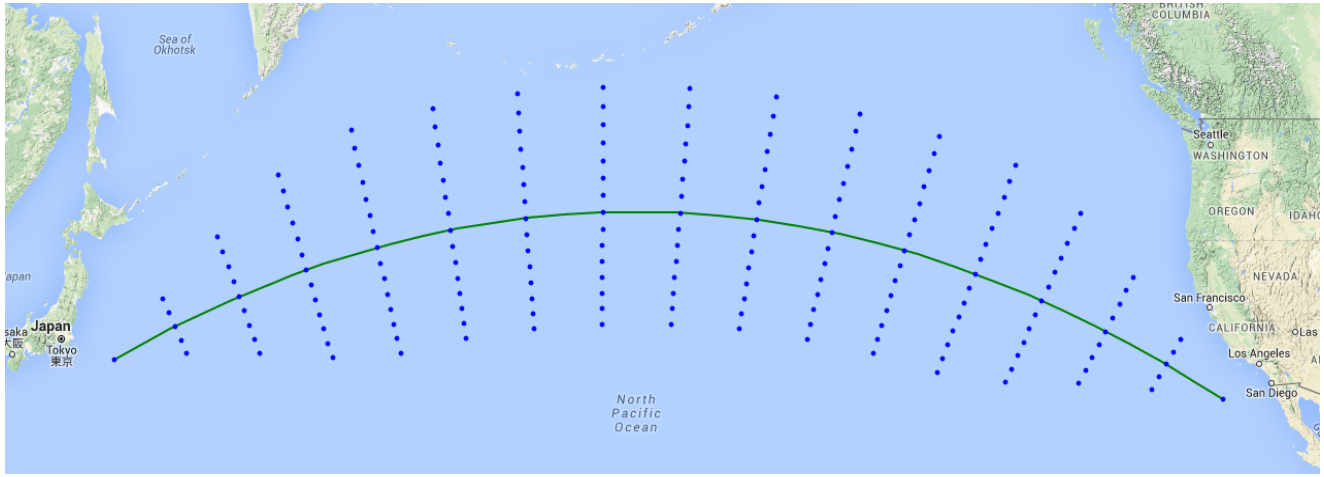
- Speed
- Significant wave height
- Relative wave angle
- True wind speed
- Relative wind angle



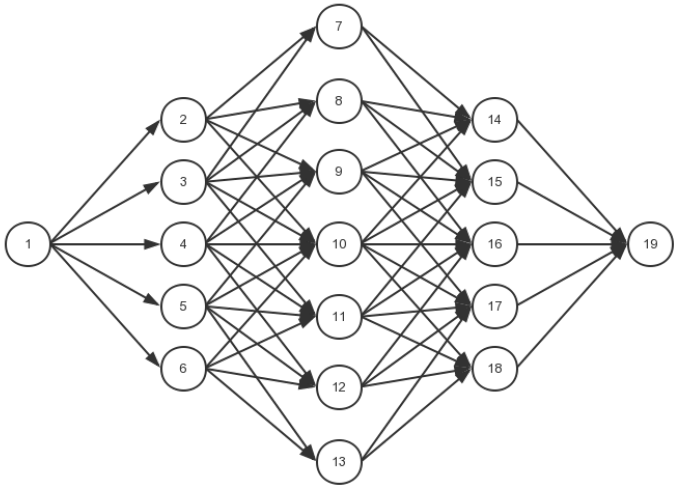
$$FC = P_B \cdot sfoc \cdot t$$

2.2. Grids system design module

2.2.1 Main design principles



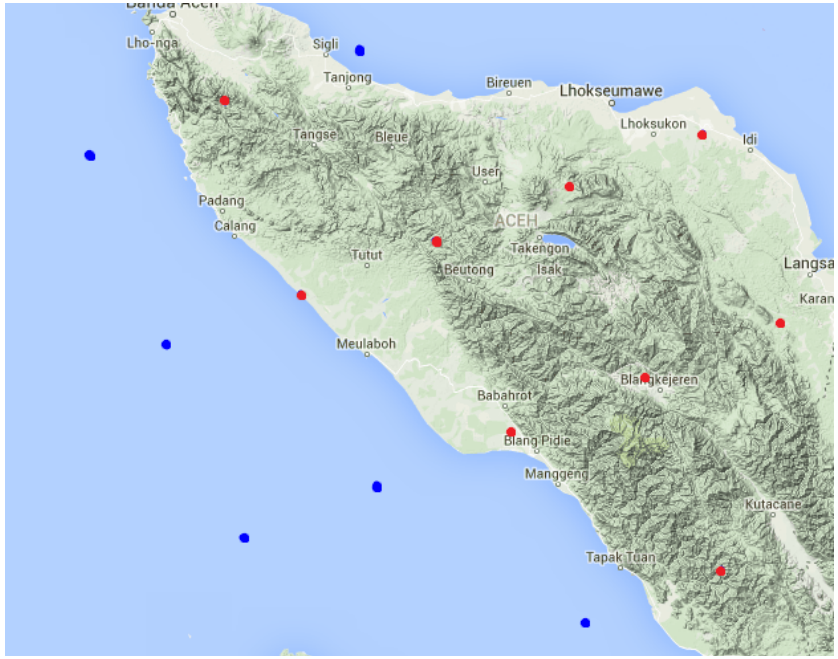
Grids system

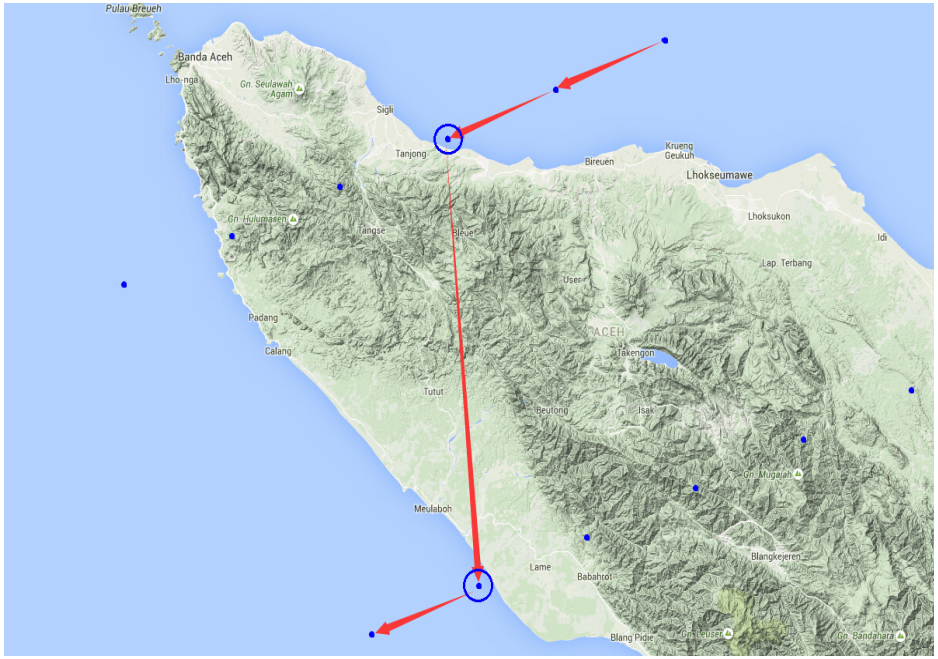


Ship routing network

2.2.2 Land avoidance function

GSHHS (A Global Self-consistent, Hierarchical, High-resolution Shorelines Geography Database) coastline data





2.3. Weather routing module

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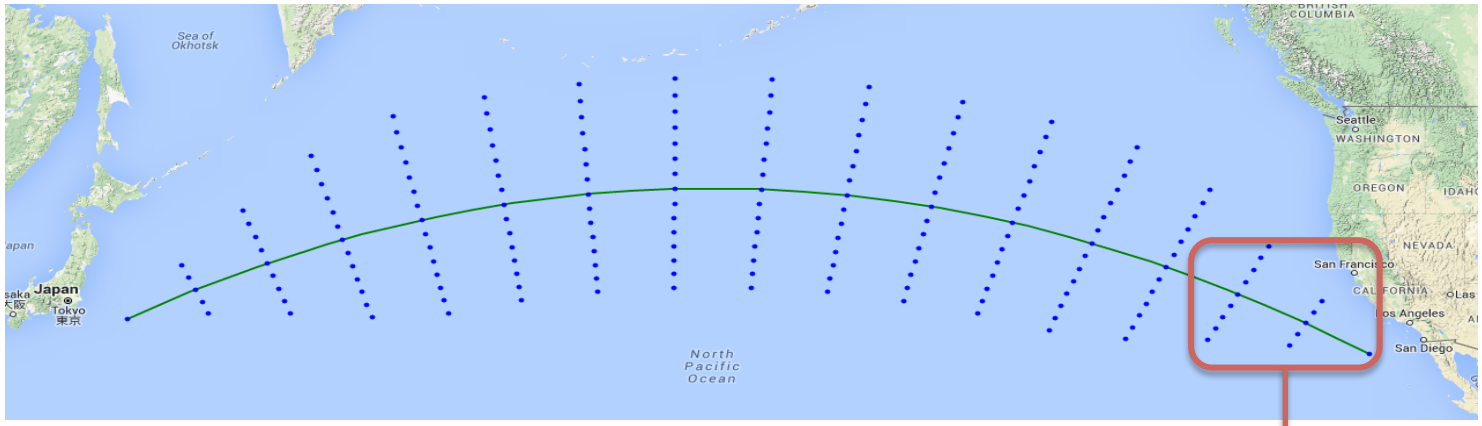
2.3.1 Weather data

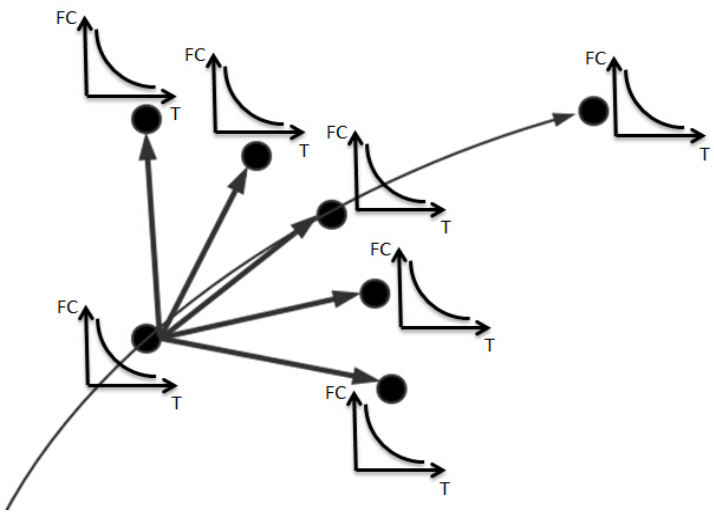
GRIB: waves and winds downloaded from ECMWF (European Centre for Medium-Range Weather)

- 10 meter U wind component
- 10 meter V wind component
- Mean wave direction
- Mean wave period
- significant height of combined wind waves and swell

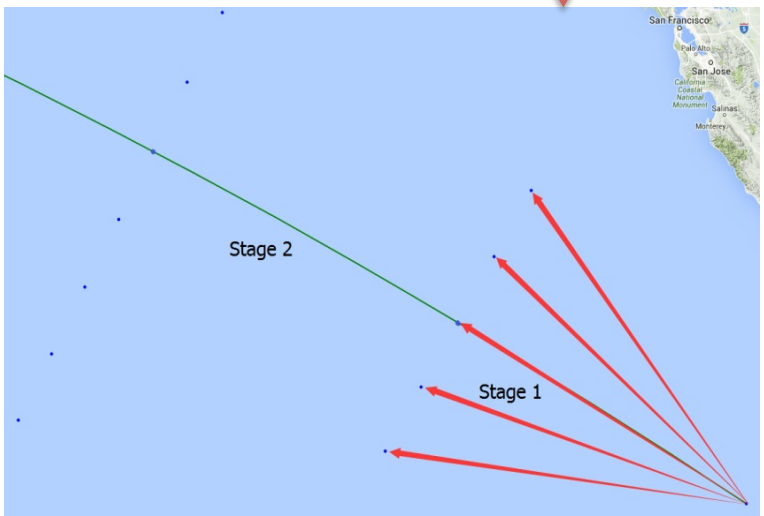
36 years (1979-2014) global historic weather data is downloaded for the shipping simulation.

2.3.2 Weather routing module



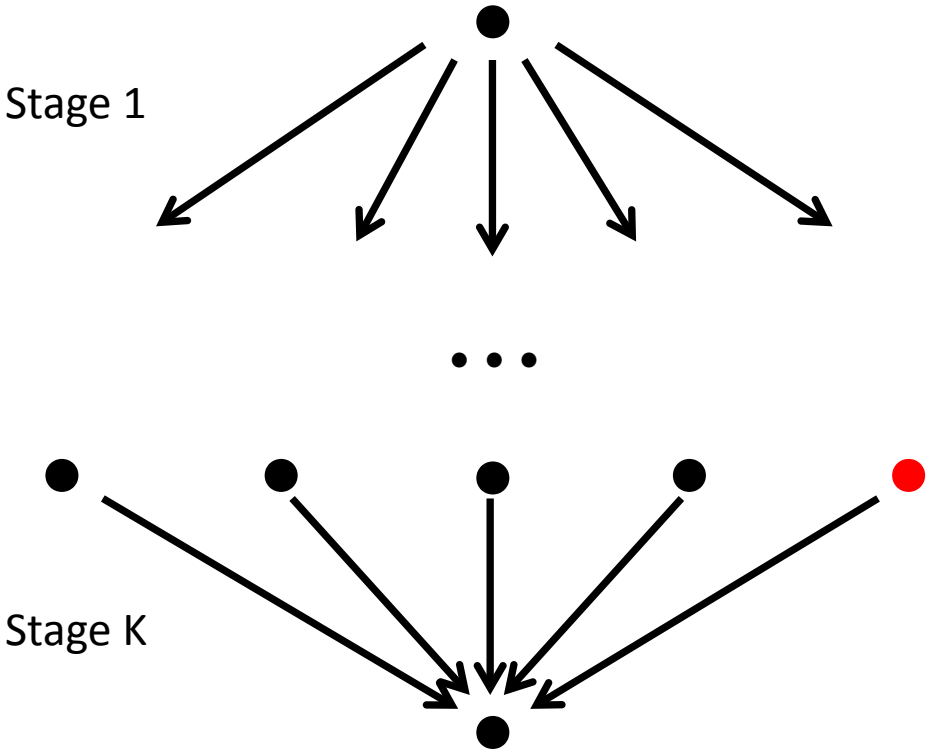


Local Optimisation



Global Optimisation

2.4 Post processing module



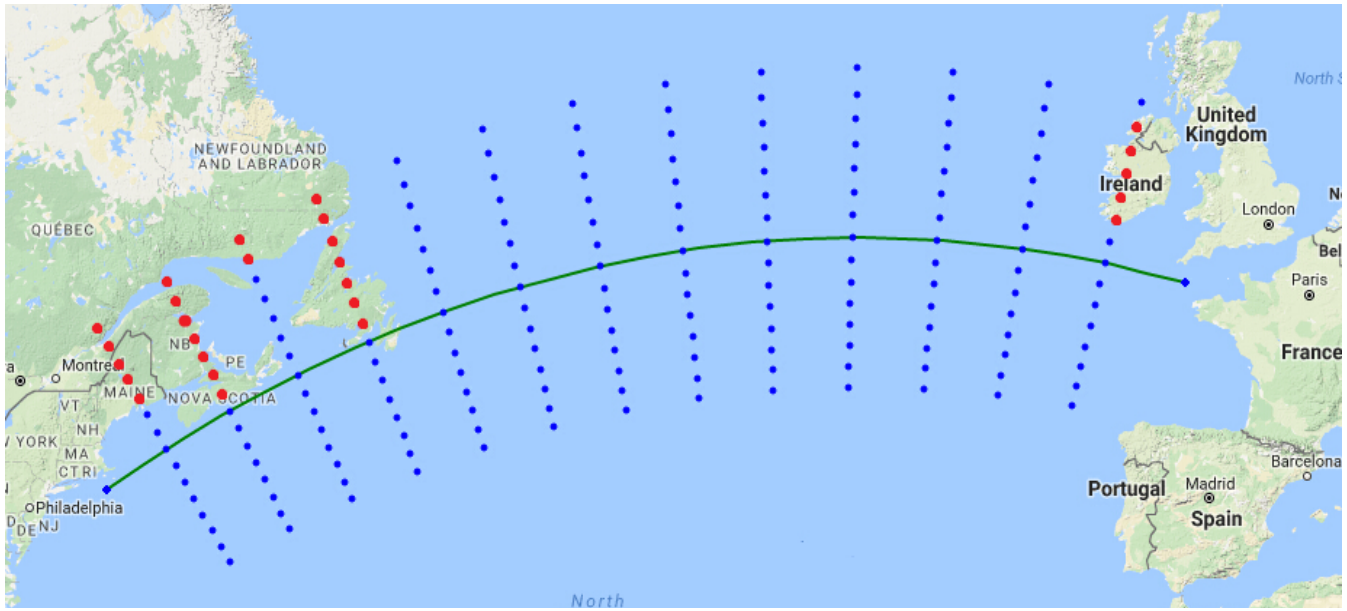
	FC total	ETA total	FC last stage	Duration last stage	Speed last stage	Latitude last stage	Longitude last stage
1	FC_T_1	ETA_T_1	FC_L_1	T_L_1	V_L_1	Lat_L_1	Lon_L_1
2	FC_T_2	ETA_T_2	FC_L_2	T_L_2	V_L_2	Lat_L_2	Lon_L_2
3	FC_T_3	ETA_T_3	FC_L_3	T_L_3	V_L_3	Lat_L_3	Lon_L_3
4	FC_T_4	ETA_T_4	FC_L_4	T_L_4	V_L_4	Lat_L_4	Lon_L_4
5	FC_T_5	ETA_T_5	FC_L_5	T_L_5	V_L_5	Lat_L_5	Lon_L_5
			...				

	FC total	ETA total	FC last stage	Duration last stage	Speed last stage	Latitude last stage	Longitude last stage
1	FC_T_1	ETA_T_1	FC_L_1	T_L_1	V_L_1	Lat_L_1	Lon_L_1
2	FC_T_2	ETA_T_2	FC_L_2	T_L_2	V_L_2	Lat_L_2	Lon_L_2
3	FC_T_3	ETA_T_3	FC_L_3	T_L_3	V_L_3	Lat_L_3	Lon_L_3
4	FC_T_4	ETA_T_4	FC_L_4	T_L_4	V_L_4	Lat_L_4	Lon_L_4
5	FC_T_5	ETA_T_5	FC_L_5	T_L_5	V_L_5	Lat_L_5	Lon_L_5
			...				

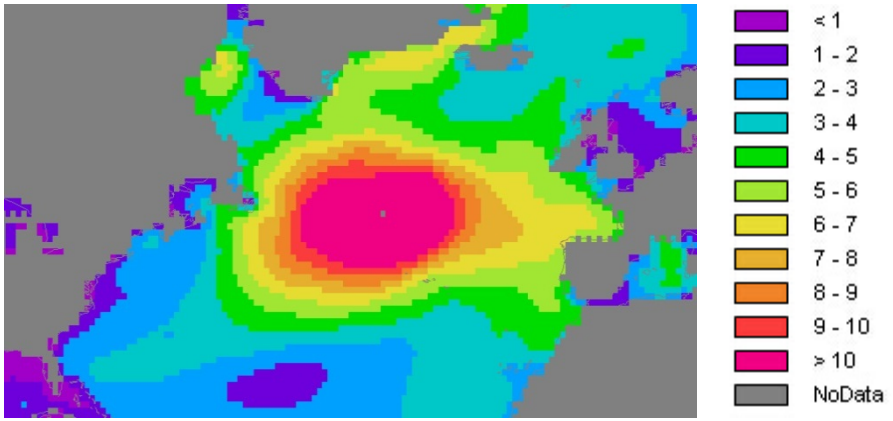
Backward Iteration Algorithm

3. Case Study and Discussion

Ship model: Bulk Carrier.
Departure and destination points: 5°10‘W, 49°18’N and 70°31‘W, 40°48'N.
Departure time: 2014-01-05, 06:00.
Ship speed: 4 knots to 20 knots with interval 0.1 knot.
ETA: 227 hours (average 12 knots).
Interest ETA range: 6 hours (within plus or minus 3 hours).
Grids system has 14 stages, and every stage has maximum 15 waypoints with equal distance of 50 nautical miles.

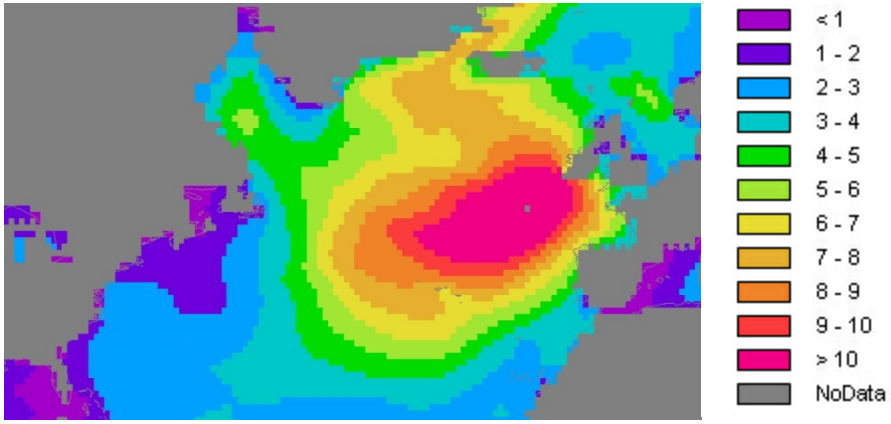


Three days' significant wave height changing from departure time

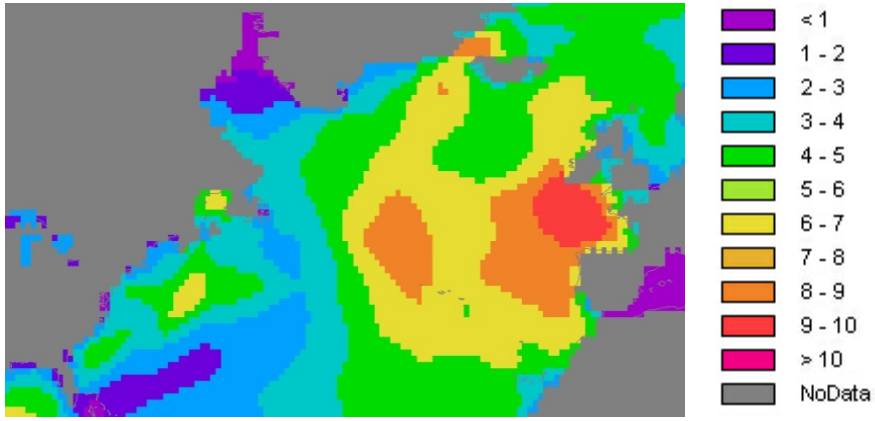


a) 06:00 05/01/2014

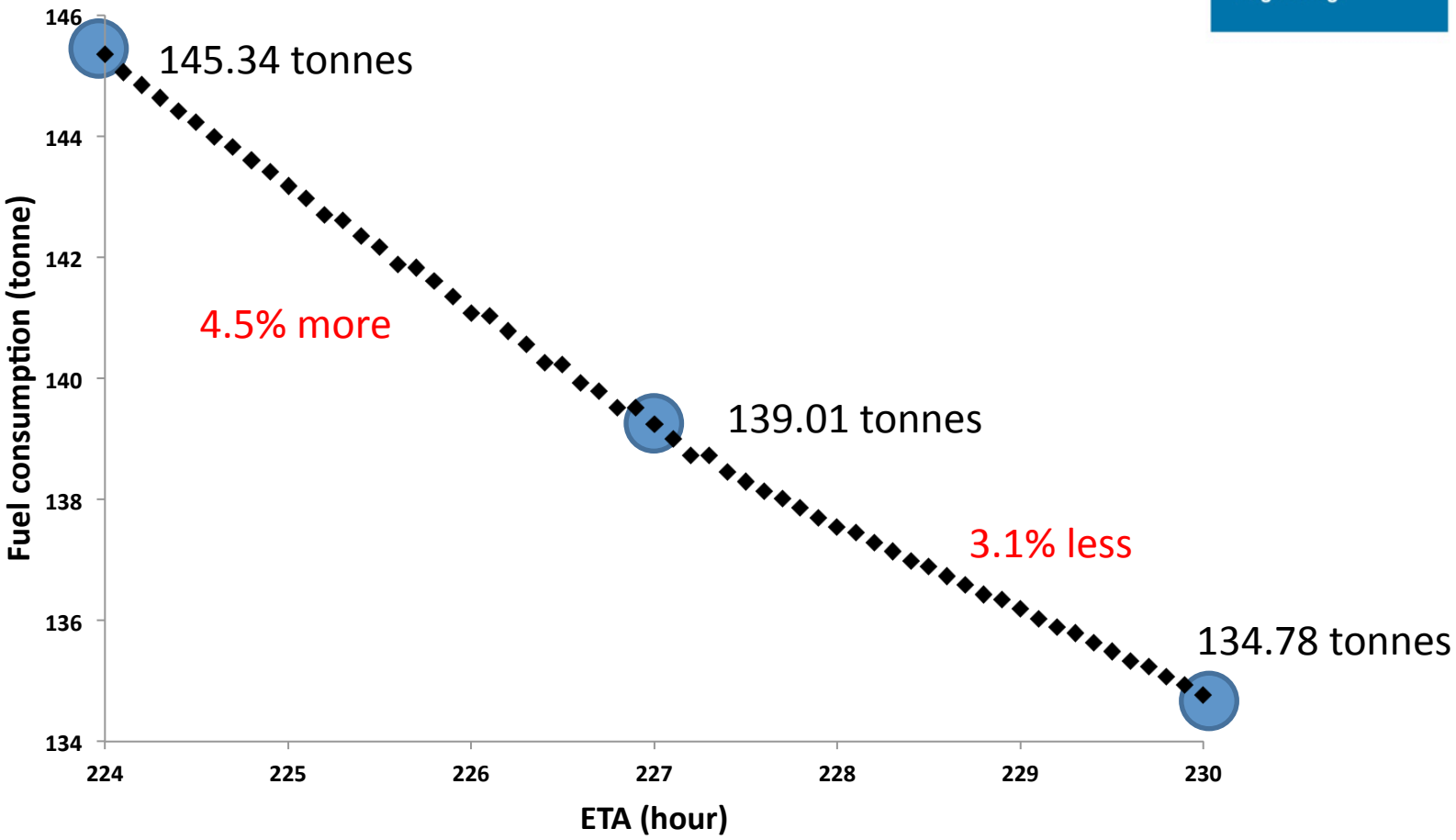
b) 06:00 06/01/2014



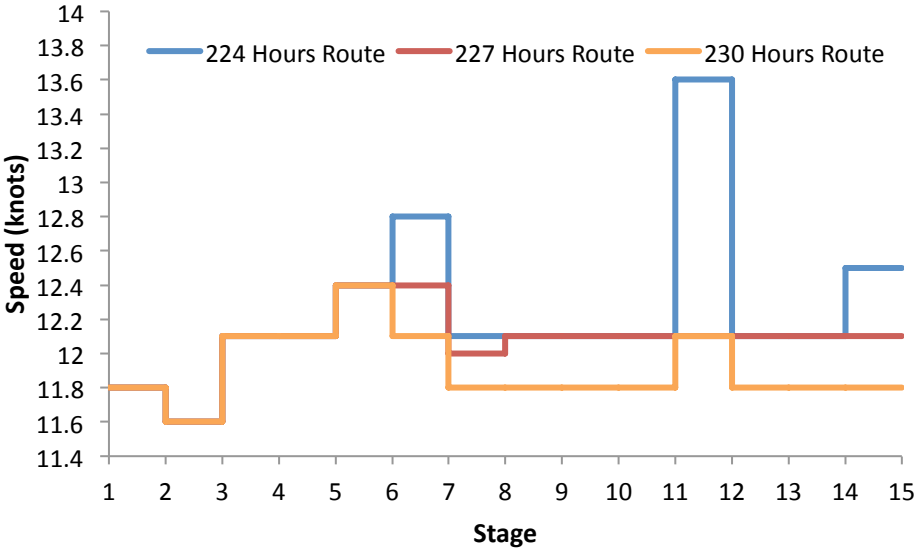
c) 06:00 07/01/2014



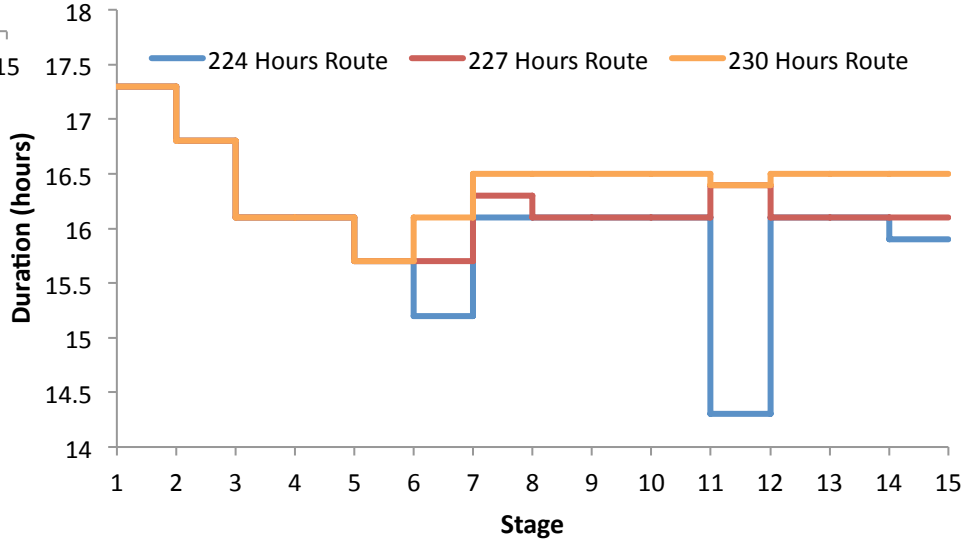
Results



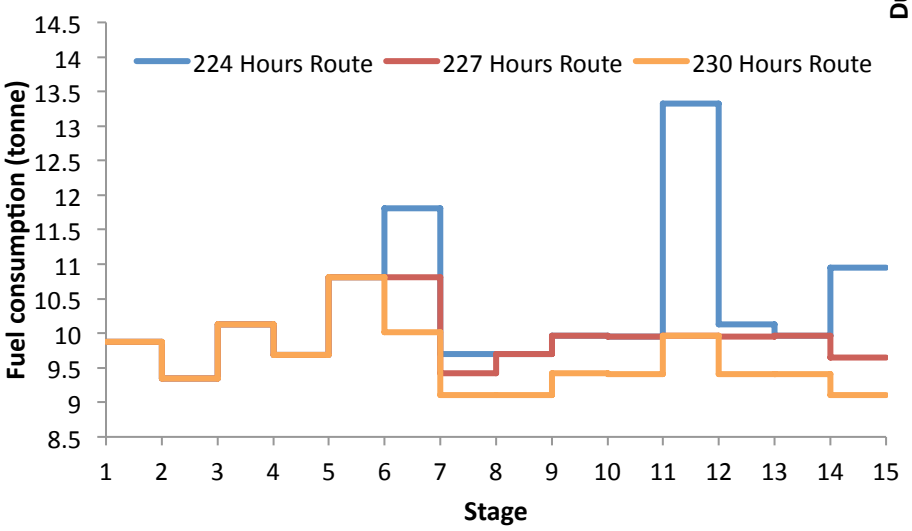
Pareto front of case study



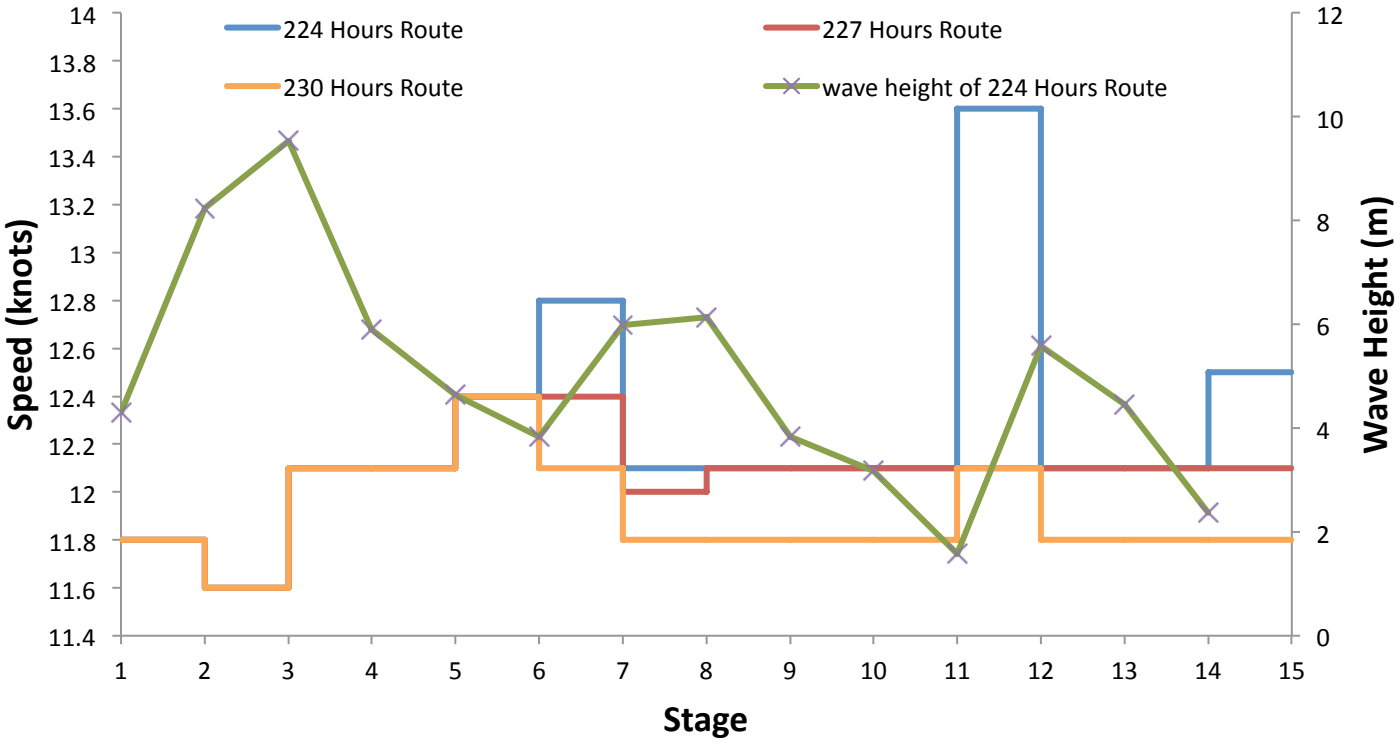
a) Ship speed at each stage



b) Duration at each stage



c) Fuel consumption at each stage



Speed changing with wave height

Optimal routes based on different requirements

4. Conclusion

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This paper presents a voyage optimisation model towards Energy Efficient Ship Operations：

• The core modules and optimisation strategy used in this model are introduced in great detail.

•A case study with Bulk Carrier has been made.

•As can be seen from results, with the strategy of a combination of global and local optimisation, this model can provide related stakeholders optimum routes towards minimum fuel consumption according to the ship navigation schedule.

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