Modelling of ship interaction with ice floes and its application on the Northern Sea Route

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Background

With the effects of global warming, the Arctic is presenting a new environment where numerous ice floes are floating on the open sea surface. Compared with continuous level ice that used to dominate the region, the ice floe condition has improved Arctic shipping navigability by allowing non-icebreaking ships to operate, as shown in Fig 1, opening many significant shipping routes and access to abundant Arctic natural resources. However, the interaction of such floes with ships is yet to be understood to aid the designing of ships and route planning.

Fig 1: A ship operating in ice floes. Credit: SCF Group

Computational modelling

To address this problem, a high-fidelity simulation model has been built to replicate the ship operation in ice floes, as shown in Fig 2. The technology combines Computational Fluid Dynamics method (CFD) and Discrete Element Method (DEM), which achieves the coupling of the ship-wave-ice interaction process: ship advancement generates waves; waves interact with ice floes; ice floes make contact with each other and with the ship. The simulation can accurately predict the ship resistance caused by water and ice, based on user-defined ship geometry, ship velocity, ice concentration, ice thickness and floe diameter [1].

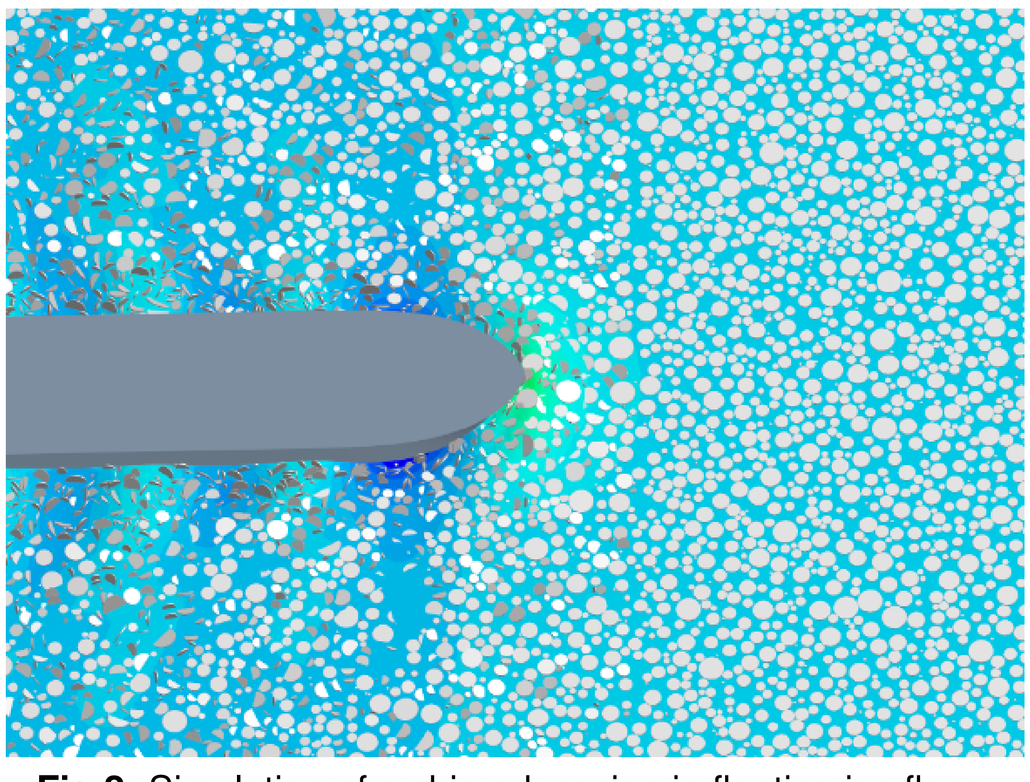

Fig 2: Simulation of a ship advancing in floating ice floes

Real-time applications

Despite that a high-fidelity modelling approach has been developed, the simulation requires a relatively long time to complete, which means it may be impractical to run a simulation each time a resistance estimate is needed. To overcome this limitation, an empirical equation has been derived to enable quick estimation of ice resistance for a given condition, so as to meet real-time purposes [2]. The derived equation was then combined with open-water resistance equations to establish an Arctic Ship Performance Model (ASPM) that can quickly predict a ship's total resistance and fuel consumption for a given ice-infested route [3], and a series of full-scale measurements from voyages on the Northern Sea Route has confirmed the accuracy [2-4].

The ASPM further facilitated a Voyage Planning Tool (VPT) that links with real-time metocean and ice data to calculate a ship's fuel consumption along potential routes, allowing ship operators to select routes with lower energy costs [4, 5]. As shown in Fig 3, the VPT can provide a comprehensive consideration of shorter voyage distance and less ice impact, which signifies its practical value to Arctic shipping. This software is currently being commercialised by GreenSteam.

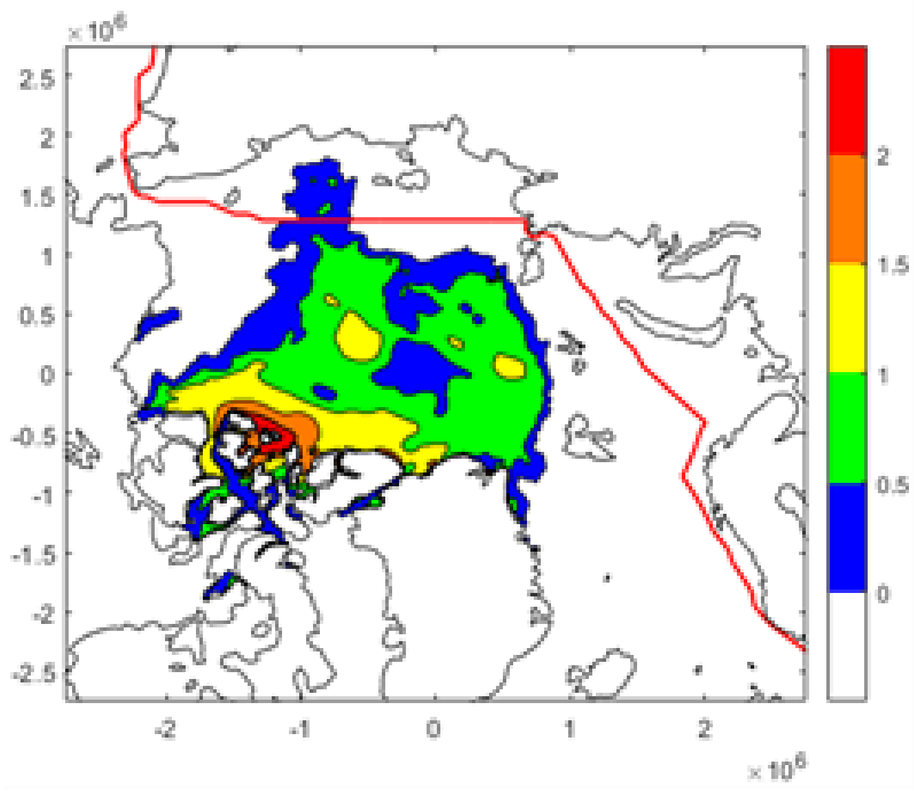

Fig 3: A VPT-optimised route for a ship travelling through the Northern Sea Route, obtained using the metocean and ice data of late summer 2018. Colour bar denotes ice thickness (meter) and the x and y axes denote the distance (meter) with respect to the North Pole origin

Acknowledgements
The reported work is based collaborations contributed by Giles Thomas and Chris Ryan (UCL), Jonas W. Ringsburg, Zhiyuan Li and Minghao Li (Chalmers University of Technology). The project funding was from European Union's Horizon 2020 research and innovation programme under grant agreement No 723526 - SEDNA: Safe maritime operations under extreme conditions; the Arctic case. For more information please check the fully papers listed below.

References

[1] Ship resistance when operating in floating ice floes: A combined CFD&DEM approach. *Marine Structures*. [2] Ship resistance when operating in floating ice floes: Derivation, validation, and application of an empirical equation. *Marine Structures*. [3] An Arctic ship performance model for sea routes in ice-infested waters. *Applied Ocean Research*. [4] A comparison of two ship performance models against full-scale measurements on a cargo ship on the Northern Sea Route. *Ships and Offshore Structures*. [5] A voyage planning tool for ships sailing between Europe and Asia via the Arctic. *Ships and Offshore Structures*