Navigating the New Arctic through Investigating Ice-Structure Interactions

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MOTIVATIONS

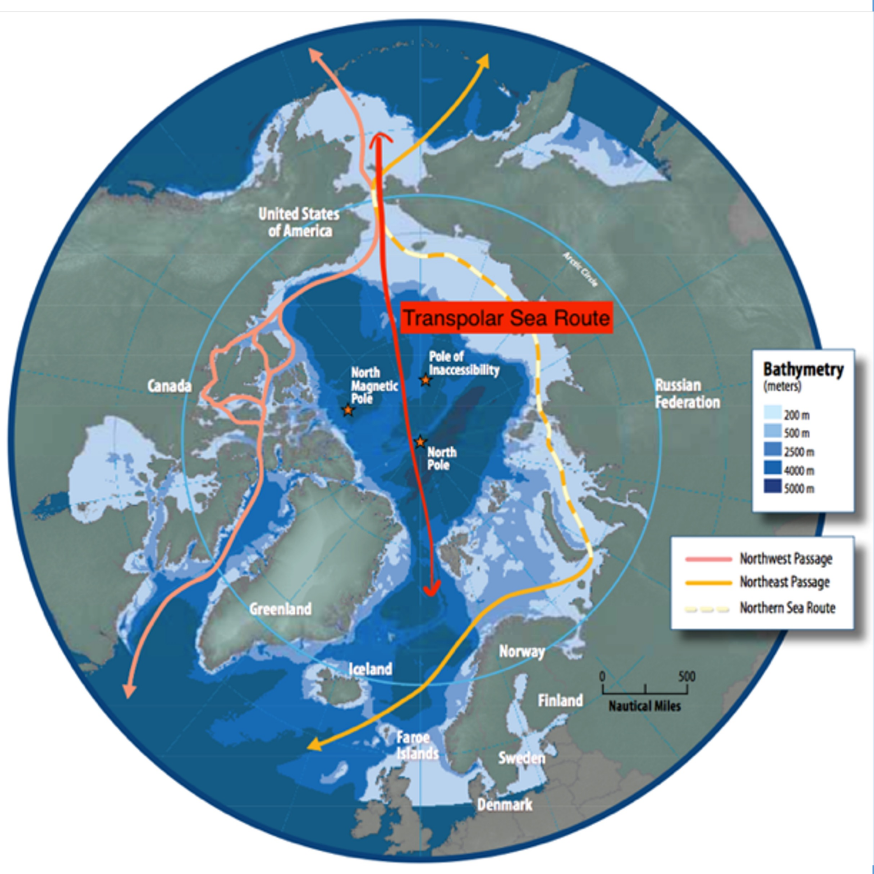

Fig. 1 Shipping Lanes: The Transpolar Sea Route (red color), compared to the Northwest Passage (orange color) and Northeast Passage (gold color).

- Diminishing multiyear sea ice is driving:
  - the increase in sea ice movement in the Marginal Ice Zone (MIZ)
  - the need for risk prediction, mitigation and impact on communities
  - the increase in maritime activities in ice-infested areas hence increased risk of sea ice-structure collision
  - the increase in Arctic shipping. Opens potential new shipping routes (i.e., Transpolar Sea Route is expected to become the primary Arctic maritime route within the next two decades)
- Initial focus areas: Bering and Chukchi Seas

UNDERSTANDING THE ENVIRONMENT : COPERNICUS + AIS

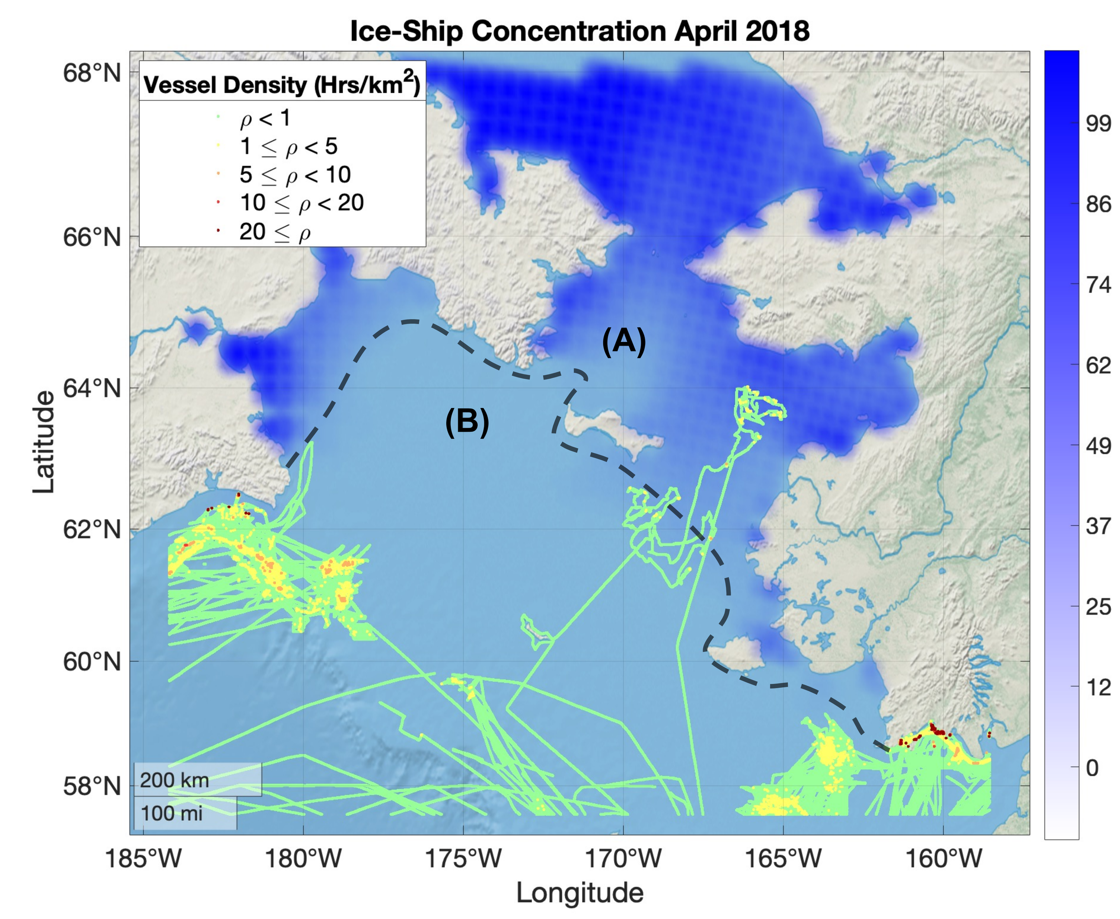

Fig. 2 AIS ship location overlaid on top of Copernicus sea ice concentration. (A) represents the region with more than 50% ice concentration and (B) represents the region with less than 50% ice concentration.

AIS: Shipborne Automatic Identification System
- Ship course, speed, and heading
- Ship identification data, length, breadth, draft
- Voyage information (i.e., cargo, navigation status)

The Copernicus Reanalysis Products
- EU's Earth Observation Program
- Estimates climate parameters globally
- Datasets include (not limited to)
  - Ice thickness
  - Ice concentration
  - Ice type
  - Air temperature
  - Wind speeds

AIS + Satellite Ice Information = Potential Ice-Ship Interactions

FLUID-ICE-STRUCTURE INTERACTION FRAMEWORK

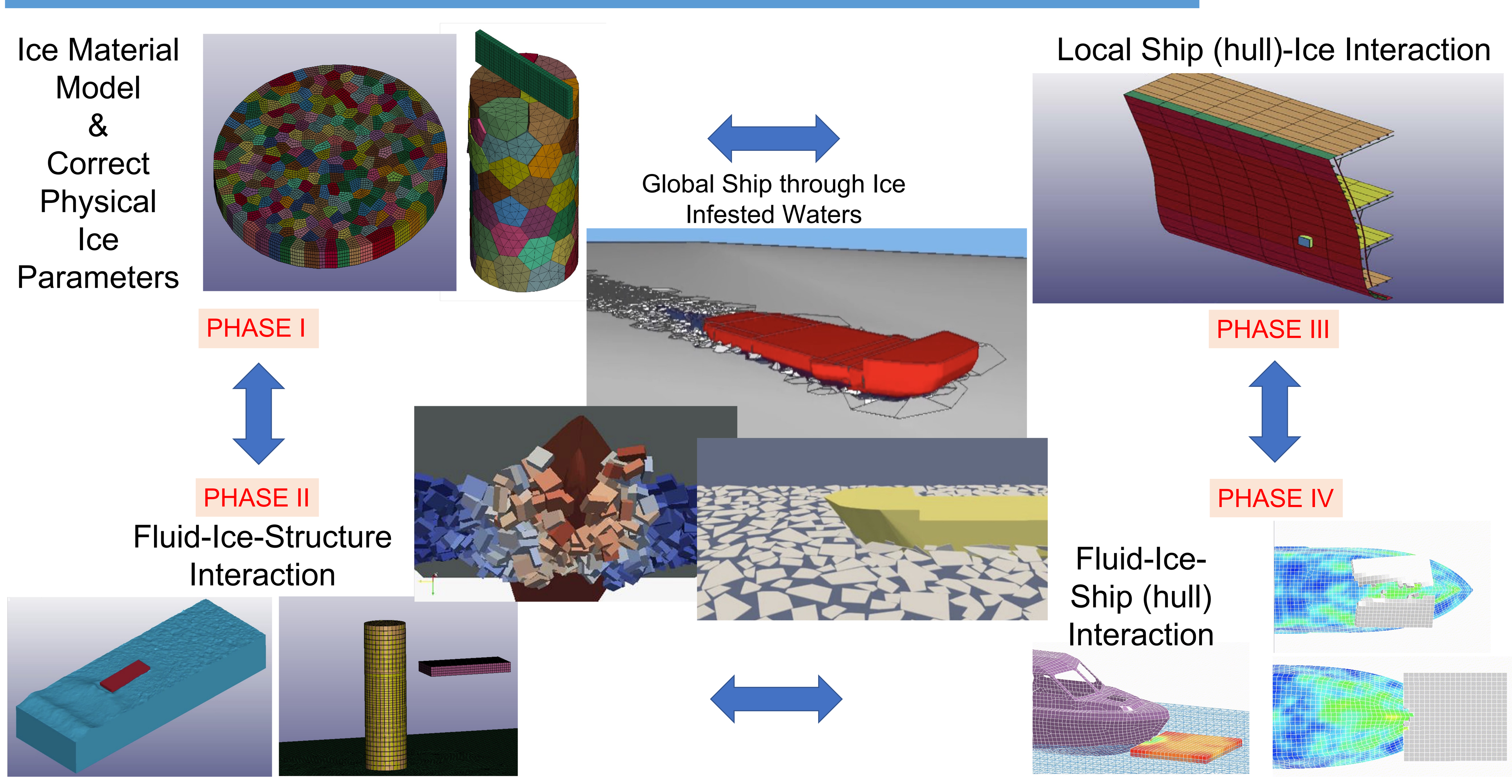

Fig. 3 Fluid-structure interaction modeling framework (starting from Phase I to Phase IV). Center image: Full-scale potential ice-ship interactions.

GOAL: Develop a numerical model to determine the global forces acting on a ship navigating through ice infested waters. To do this, we must understand both the environment as well as the structure.

PHASE I: Investigation of ice material model (validation from experiments and full-scale measurements).

PHASE II: Integrate the ice model into the simulation environment.
- Ice-structure interactions
- Wave-ice interactions
- Wave-ice-structure interactions

PHASE III: Conduct case studies.
- Local ship hull and ice interaction
  - Ship hull forms are based on ship density information in the Alaska region (e.g., fishing vessels, service vessels, supply vessels, passenger vessels etc.)

PHASE IV: Global ice-structure interaction analysis and risk assessment.

STAKEHOLDER ANALYSIS → RISK ASSESSMENT

In Arctic operations and transports, the physical environment can cause additional risks compared to what's normal in non-Arctic waters. Vessel Masters and operators need to know how such events may affect an operation/installation/ transportation. Key stakeholders identified within Fishing, Shipping and Logistics, Construction and Port Operations are participating in a survey for a stakeholder risk analysis.

PREPARE RISK MANAGEMENT PLAN (RMP)
- UNDERSTAND impacts
- UNDERSTAND stakeholder interest, expectations, and needs

→ **IDENTIFY RISKS AND ENTERPRISE ENVIRONMENTAL FACTORS**
- CREATE stakeholder questionnaire
- CONDUCT survey

→ **PERFORM RISK ANALYSES**
- PERFORM risk assessment
- PERFORM qualitative and quantitative risk analysis
- PERFORM sensitivity analysis

→ **MITIGATE AND CONTROL RISKS**
- IMPLEMENT risk responses
- TRACK identified risk
- MONITOR residual risks

Fig. 4 Project risk management and stakeholder risk analysis.

DATA GAPS

- Limited AIS data
- Limited sea ice data (i.e., ice thickness, ice type)
- Limited field observations and data for validations

CONCLUSIONS AND FUTURE WORK

- As the sea ice extent decreases, the number of maritime activities in the ice infested regions increases (e.g., fishing and shipping activities)
- In recent years, potential ship-ice interactions have stretched to lower latitudes in the Alaska region
- No risk assessment and ice going guidance is available for small ships and boats
- Through modeling complex ice-ship and structure interactions, and assessing Metocean conditions we aim to develop recommendations for safe operating conditions for various vessels in the given environmental conditions
- Later, this will be generalized to general ice-structure interaction problems

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