Variability of the Beaufort Ice-Ocean Environment: A Synthesis Report

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Research Project Overview

Rapid environmental, social and economic changes are defining characteristics of the past decade in the Arctic Basin including the Beaufort Sea. The scale and rapidity of change drive the need for more detailed assessment of the potential impacts of environmental and concurrent social change in the Arctic offshore and coastal zones when considering the effects of infrastructure and resource development projects. Long-term sea ice and ocean data, Traditional Knowledge (TK) and predictive ability are all fundamental for managing Arctic ecosystems, protecting the services they provide, enabling safe and efficient marine operations, and understanding the energetic variability and predictability of the underlying physical environment. Traditional Knowledge represents the longest time series available to document ice/ocean processes and associated changes, and in the Inuvialuit Settlement Region, TK is a fundamental aspect to inform on ice and ocean inter-annual variability and the impact on travel and harvesting of marine resources. However, in the harsh and remote offshore Beaufort Sea, the acquisition of year-round information to guide decisions regarding potential resource development and conservation plans remains a challenge. In these deep areas, human observations are very limited, if simply nonexistent. A practical approach is to deploy mooring-based instruments to quantify and characterize processes of importance. Such information when integrated with long term observations from satellite remote sensing is essential to the design, planning and assessment of infrastructure, of practices and of contingency measures necessary for safe and cost effective offshore development, including for oil and gas exploration and maritime shipping.

To this end, the *Variability in the Beaufort Ice-Ocean Environment: A Synthesis Report* project will link up-to date scientific knowledge on the ice-ocean environment of the Beaufort Sea to issues important to environmental assessment and decision making in relation to offshore exploration and development. This project is a multi-year effort produced in three phases, and a collaboration between Amundsen Science, IMG-Golder (Golder), and Fisheries and Oceans Canada (DFO). The Synthesis Report, will seek to identify regional stressors and trends in the Beaufort Sea ocean environment. A primary focus of the report is the identification of seasonal and inter-annual trends and variability in the ice-ocean environment from 2009 to 2019. The reporting process will engage stakeholders in applying the science so that the output is relevant, comprehensible and useful in considerations of offshore development.

Project Purpose and Goals

The Synthesis Report is a multi-year effort produced in three phases. Phase 1 focused on summarizing existing data, developing methods for analysing new data and engaging with indigenous communities. Phase 2 is looking at completing a literature review, conducting the analysis of the data using models developed, and the collection and synthesis of TK. Phase 3 is the creation of the Synthesis report. In 2019-2020, the second year of Phase 2 and the first year of Phase 3, the project will strive to make additional progress toward a Synthesis Report by continuing scientific data analysis and bridging this information with key points stemming from the Inuvialuit TK collection through a coordination with other BRSEA projects. This report will lay the foundation for a future full integration of scientific information and Inuvialuit knowledge in accordance with Inuvialuit requirements. A central element will also be to further verify numerical tools for ice and ocean current prediction that are a necessary aspect of safe and environmental sound marine development projects.

In 2019-2020, work will aim to meet the following objectives:

- Local knowledge coordination: relevant TK will be incorporated to the extent possible through liaison and coordination with Inuvialuit organizations to support the streamlining with ongoing research activities. Inuvialuit feedback on aspects of Phase 2 results will be sought to ensure that collected scientific data are reported and made available in the most appropriate format for Inuvialuit organizations and can be used in support of decision making.
- Completion of Phase 2: this includes: synthesis of ice-ocean data to identify regional stressors and trends in the Beaufort Sea area; contributions to validation of modelling tools.
- Initiation of Phase 3: update and revise interim report based on data collected in 2018-2019; and a model will be used to simulate specific events and conditions and to assess offshore development scenarios including oil spills.

Approach

Analyse New Data and Model Comparison/Ancillary Data

New data refers to observations collected during 10 years (2009-2019) of enhanced observations of the marine physical environment by ArcticNet and DFO. These include industry-sponsored observing during 2009-2011, BREA-sponsored observing during 2011-2014, and Environmental Studies and Research Fund/Imperial Oil Limited sponsored observing during 2014-2019, and Program of Energy Research and Development-sponsoring throughout. The data were acquired by autonomous recording instruments at fixed locations on subsurface moorings. The sites of moorings are clustered within an area on the central Beaufort shelf to the upper slope (700 m isobaths), west to the Mackenzie Trough, and east to southern Banks Island (Fig. 1). Moored instruments routinely measured ice properties, ocean currents, temperature and salinity, and particle fluxes.

Ice profiling sonars (IPS) were incorporated within moorings to provide continuous information on the presence of pack ice, its movement, draft, topographic variation and extreme features.

High resolution data from the moorings are used to characterize ocean currents across the shelf, shelfbreak, and slope and provide evidence and insight into large circulation patterns and small-scale patterns. Temperature and salinity data are used to characterize the variability in physical properties of the water column.

Also included is an overview of the Beaufort Sea climatology for wind, waves, and sea ice as context for the overlapping marine physical datasets. The Meteorological Service of Canada Beaufort (MSCB) hindcast data from 2009 to 2015 is used alongside wave measurements from the observation program to summarize the wind and wave climate and identify and characterize storm events.

Several case studies of ocean circulation are developed, in particular, the characteristics, variability, and features of the shelfbreak jet and off shelf currents.

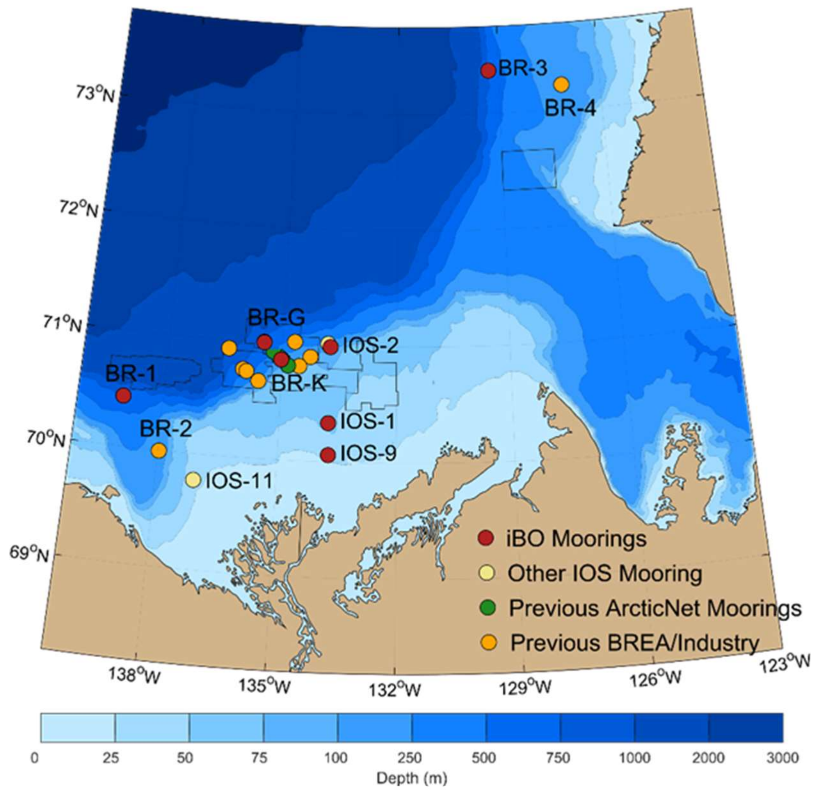

Figure 1: Bathymetric map of the Canadian Beaufort Sea showing the location of iBO moorings (in red) and other moorings used to develop the Report. Offshore oil and gas lease areas are outlined in grey.

Finally, comparison is provided between the mooring observational data and the Regional-Ice Ocean Prediction System (RIOPS) model developed by Environment and Climate Change Canada. RIOPS is a high-resolution operational ocean forecast model with 3-hourly data available for download from January 1, 2017 onward. Predications made by the model are compared to the ocean datasets collected as part of the observing program between 2017 and 2019.

Use of Traditional Knowledge

In this project, local knowledge refers to the collective knowledge of traditions commonly used by Inuvialuit to live sustainably and adapt themselves to their environment through generations. Local knowledge will be incorporated to the extent possible through liaison and coordination with Inuvialuit organizations to support the streamlining with ongoing research activities. Inuvialuit feedback on aspects of Phase 2 results will be sought to ensure that collected data are reported and made available in the most appropriate format for Inuvialuit organizations and can be used in support of decision making.

Relevant information and input in the following areas may include:

- Observations on historic and current ice patterns and associated changes
- Observations on historic and current ocean processes and associated changes
- Effects of ice patterns and ocean processes on traditional harvesting and travel

- Potential effects of changes in sea ice and ocean processes on traditional harvesting and travel
- Harvest of marine resources

Summary of Results/Outcomes

Climatology Overview

Predominant winds, driven by high pressure over the eastern Beaufort and a deep low pressure over northern Alaska, are easterly and southeasterly, forcing the mean sea and swell wave directions and driving them towards the sea ice. Seasonal variation in wave height in the Beaufort Sea is closely coupled to the seasonal variation in ice cover and wind with the highest wave heights typically measured in September and October. Analysis of waves reveals a strong trend to higher sea states for the worst wind storms each summer with mean swells increasing at a faster rate than mean seas, supporting the notion that changes in wave height are driven more by the reduction in ice cover than changes in the wind climate. This trend is expected to persist as open water areas continue to increase with reduced sea ice cover.

Heavy ice of the perennial pack is most likely on the northeast slope nearest the Canadian Archipelago (BR-3) and least likely on the south-central Mackenzie Shelf. The latter is close to the edge of fast ice at its maximum extent in late winter and is most likely to experience periods of no ice movement. For the same reason, it is frequently within the flaw lead when wind blows the pack offshore in winter. The flaw lead may also expand to cover site BR-3, but less often than at DFO-9.

Case studies – ocean circulation

Several case studies of ocean circulation were developed, in particular the characteristics, variability and features of the shelfbreak jet and offshelf currents. The shelfbreak jet, characterized as a subsurface eastward flow from the Mackenzie Trough to Banks Island along the shelf, is assumed to turn at directions corresponding to the spring/neap tidal frequencies. These frequencies are similar to those of winds in the same field. A new feature revealed from the study is that velocity signals of the shelfbreak jet propagate from the west (upstream) to the east (downstream) with a delay of a few days for velocity variations with longer periods at a ~50 km distance between the stations BR-K and IOS-2. The counter current of the shelf break jet, the off-shelf current, appears to change direction according to the shelfbreak jet's fluctuation, with a delay of approximately 4 to 14 days on the slope. The off-shelf current frequently produces eddies, and the analysis in the summer seasons from 2009 to 2017 showed that the number of anti-cyclonic and cyclonic eddies were nearly equal while the direction of eddy propagation is more likely to be westward than eastward. The anti-cyclonic eddies have a higher maximum speed than cyclonic eddies.

Comparison - mooring observational data and RIOPS

The RIOPS model generally appears to reproduce the large-scale circulation patterns seen in the observed data. Current speeds predicted by RIOPS are consistent with respect to vertical structure (higher speeds near the surface reducing in magnitude toward the bottom), observed in the mooring data and RIOPS model velocities are generally of the same order of magnitude but typically lower (up to 50%) than the mean speeds measured by the moorings. This may be related to the RIOPS model treating ice cover rigidly and wind effects not translating through the water column well. Internal waves, mixing, and internal convection are also not expected to be captured well by the model.

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