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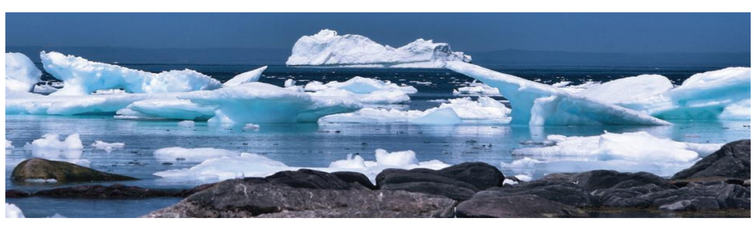
Overview of NRC Sea Ice and Iceberg Forecasting and Engineering Tools

ICEBERG AND SEA ICE HAZARDS

Icebergs pose a serious threat to navigation and oil and gas operations off Canada's East Coast. For shipping companies, offshore petroleum operators, and the associated regulatory bodies, the presence of icebergs necessitates many safety precautions and considerations. Reconnaissance flights are carried out by Environment Canada and the International Ice Patrol to locate icebergs over the North Atlantic, but this is only part of the required response. Forecasting the drift paths of icebergs is essential for safe travel, shipping and oil drilling operations. The NRC **Iceberg Drift Forecasting Model** is used to predict the tracks of icebergs in the vicinity of offshore oil operations on the Grand Banks. NRC has also created three **Iceberg Engineering Databases** to provide key data on historical iceberg sightings, iceberg management events, and iceberg shapes. These databases are a repository of information that can be used for planning of offshore operations.

Sea ice is also an important consideration for offshore operations in many Canadian regions. Environmental forces can drive the ice cover to compact and ridge, causing ice convergence or pressure. If a ship becomes beset or stuck in pressured ice many concerns arise, including the health and safety of the crew, the increasing cost of operations and the risk of adverse environmental effects. The NRC **Vessel Besetting Database** contains a wealth of information on ships beset or damaged by pressured ice. Forecasting the drift of pack ice and ice pressure build-up, predicting the risk of a vessel besetting, and quantifying ice pressure conditions are all essential for safe and efficient operations in northern waters. The forecasting of ice drift and pressure has to be carried out on a scale relevant to shipping and offshore drilling operations. For this purpose, NRC has created the **Pressured Ice Model**.



NRC ICEBERG DRIFT FORECASTING MODEL

By the late 1990s, the Canadian Ice Service (CIS) identified the need for a new forecasting model that could meet the demands of modern operations. The NRC undertook a research effort aimed at developing a reliable iceberg drift model in collaboration with CIS, academia and private consultants.

NRC's Iceberg Drift Model incorporates comprehensive physics of iceberg motion, deterioration and calving, as well as a robust numerical method. The model development has included extensive collaboration with industry to ensure proper validation of model predictions against observations.

Requirements of the end users were of paramount significance at each stage of the development. Today, the model is used by meteorological agencies that issue iceberg forecasts including CIS, the International Ice Patrol (IIP), and the Norwegian Meteorological Agency. NRC has customized the model to suit the needs of offshore operators. For example, the model is licensed to Provincial Aerospace Ltd. (PAL), global leaders in airborne maritime surveillance. PAL has been successfully integrating the model into their business for several years to support the iceberg towing operations that protect the oil drilling platforms on the Grand Banks.

Collaborating with clients and partners, NRC continues to develop and enhance the Iceberg Drift Model to meet the needs of the offshore and shipping industries.

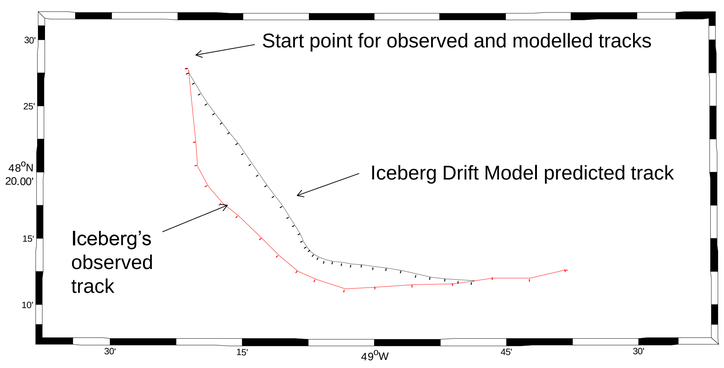


Figure 1. Example of Iceberg Drift Model predicted track vs. iceberg track observed in field.

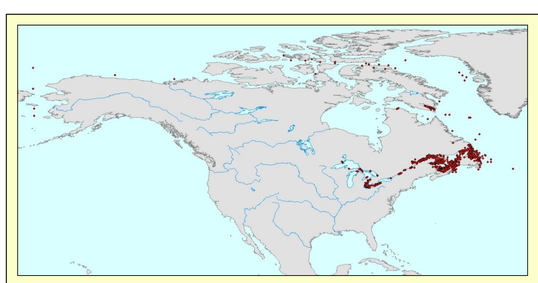


Figure 2. Map of reported incidents of ship besetting and damage due to ice pressure.

NRC-PERD ICEBERG ENGINEERING DATABASES

In the early days of oil and gas development on the Grand Banks, each petroleum company collected and managed its own iceberg data sets and the data were scattered and isolated. NRC, with the support of the Program of Energy Research and Development (PERD), began a program to work with both industry and the offshore regulators to develop industry standard databases on key iceberg information. NRC has maintained and updated these databases for nearly 20 years, and is continually seeking new data.

Iceberg Sightings Database

The NRC-PERD Iceberg Sightings Database is the result of a major effort to collect visual and radar-detected iceberg sightings from ships, aircraft, offshore structures and satellite from the past 400 years. Current data is added at the end of each ice season. Information from the IIP makes up a large part of the database; aircraft sighting data are available since 1941, and regular iceberg sightings began in 1960. Data from the Grand Banks oil operators have been collected since 1973. In more recent years, satellite data have become available. A considerable effort was made to preserve historic iceberg sighting data from sporadic ship-ice collision and other reports dating back to the 1600s, along with more frequent sightings reported since the 1800s. The database includes the source, date and time of sightings, geographic coordinates, and iceberg shape and size categories (with dimensions if available). A total of over 400,000 iceberg sightings are included, of which about 100,000 are confirmed re-sights (same iceberg tracked more than once). The Iceberg Sightings Database has become the industry standard for historic iceberg sightings off shore eastern Canada.

Iceberg Management Database

Iceberg management operations have been documented since the 1970s and are now a routine part of oil development operations offshore Newfoundland and Labrador. The NRC-PERD Iceberg Management Database is an extensive compilation of records of iceberg management operations, bringing together information from numerous oil and gas exploration and development companies. It contains over 1,800 records of iceberg management operations compiled by PAL, mainly from the Grand Banks and offshore Labrador, with one year of data from West Greenland. The database includes parameters such as iceberg size and shape, management method(s) used, and iceberg trajectory information and photos.

Figure 3. The Atlantic Kestrel towing an iceberg on the Northwest Grand Banks. Photo taken by a PAL reconnaissance aircraft on June 1, 2014.
Photo contributed by Shane McKay, NRC.

Iceberg Shapes Database

The NRC-PERD Iceberg Shapes Database has been compiled from detailed 2D and 3D information on 878 iceberg geometries. Data were sourced from 1976 to 2004 from the Hibernia and Terra Nova development studies and from various research projects on iceberg characterization. Eighty percent of the data are from Grand Banks region, with the remainder from the Labrador Sea. The iceberg height, waterline length and width, and draft are summarized, and 2D or 3D shape coordinates are given where available.

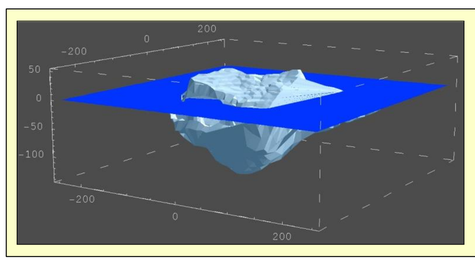


Figure 4. 3D visualization of one iceberg in NRC-PERD Iceberg Shapes Database.

NRC VESSEL BESETTING DATABASE

A database documenting cases of ship besetting in Canadian waters has been created by NRC from the compilation and analysis of over 1,700 reports of ship entrapment or damage in pressured or ridged ice conditions. This work was funded in part by PERD and Transport Canada. The database includes information on the time and location of the event, vessel characteristics, and details of the ice conditions and environmental conditions that led to the ship besetting. A snapshot of the locations of reported incidents as of 2014 is shown in Figure 2. Most reported cases occurred over the Gulf of St. Lawrence, likely due to the high frequency of shipping over this area. The Vessel Besetting Database is updated regularly as new reports become available.

NRC PRESSURED ICE AND PACK ICE DRIFT FORECASTING MODEL

Pressured ice conditions arise when environmental forces cause the convergence of ice, creating dangerous build-ups. NRC's research on this topic is aimed at developing specific characterizations of pressured ice, and quantifying the ability of ships to navigate in such conditions. The result of this research, the Pressured Ice Model, is now being used successfully by organizations that have major operations in the Canadian Arctic and North Atlantic waters.

Figure 5. The UMIAK, an icebreaking bulk carrier, was beset in pressured ice off the Labrador Coast for 10 days in June 2007. Photo contributed by Tim Keane, Fednav.

The Pressured Ice Model is used by ship owners and operators, offshore platform operators, and ship captains to enhance the safety and efficiency of navigation in severe ice. It has been implemented at the Canadian Coast Guard regional office in St. John's, NL, licensed for use by a large petroleum operator and licensed for training at the Fisheries and Marine Institute of Memorial University, NL. In addition, forecasts generated by the model have been provided to CIS for the regions of the Gulf of St. Lawrence, Strait of Belle Isle and the Newfoundland Coast.

The complexity of dealing with problems of navigation in sea ice arises, to a large extent, because of scale effects. The deformation of ice covers and associated stresses vary according to the scale under consideration. Larger-scale forecasts based on ice dynamics models and analyses of remote sensing imagery can resolve ice deformation processes over lengths of a few kilometers. Ships, however, experience different modes of ice deformation (e.g. ridging and lead opening) and different stress levels. This discrepancy limits the value of many ice forecasting products to evaluate the threat of pressured ice conditions to navigation.

The Pressured Ice Model deals with ice dynamics on a scale relevant to a vessel. The numerical solution is based on a hybrid Lagrangian-Eulerian formulation and an implicit finite-difference solver. It considers appropriate physics of ice properties and high-resolution deformation processes including ridging and lead opening. It predicts jamming and arch formation in narrow channels, such as those of the Canadian Arctic archipelago. Maps created by the model demonstrate the evolution of ice thickness, concentration, pressure build-up and ridging. This allows for the prediction of ice movement and dynamics, and most importantly, regions of pressured ice conditions. The tool is unique in that it allows the input of local conditions, making the display of information more reliable and decreasing the risk of vessel besetting. The model is continuously enhanced to incorporate feedback from end users.

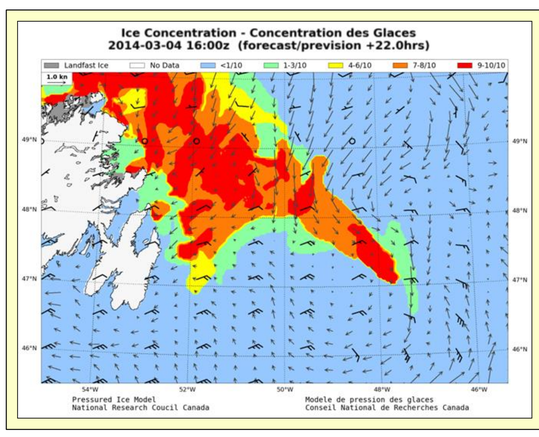


Figure 6. Example of Pressured Ice Model forecast.
Ice concentration is shown over the Grand Banks region. Black arrows indicate water current, and barbs indicate wind.

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