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ICEBERG MANAGEMENT STRATEGY FOR BAFFIN BAY 2012 SCIENTIFIC CORING CAMPAIGN

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ABSTRACT

During the summer 2012, Shell Kanumas A/S led a consortium of companies to conduct a scientific coring program in Melville Bay. The area of operations is in northern Baffin Bay, off the northwest coast of Greenland, and is characterized by a very high density of icebergs, with 316 tracked targets within 5 nautical miles of the coring vessel during the two-month campaign. To achieve the coring objectives, a comprehensive iceberg management strategy had to be developed, requiring a good understanding of the sea ice and iceberg conditions in the area. This paper presents an overview of the iceberg management plan by describing the detection, monitoring, forecasting systems and the decision protocols. The campaign also allowed testing of new iceberg drift forecasting and growler detection techniques.

INTRODUCTION

In August-October 2012, Shell Kanumas A/S (Shell), acted as an operator on behalf of the Baffin Bay operators & Licensee consortium (ConocoPhillips, Maersk Oil, Cairn Energy, Nunaoil, GDF SUEZ, Dong Energy and Statoil), to conduct a scientific coring program offshore northwest Greenland as shown in Figure 1. Overseas Drilling Limited provided the scientific coring vessel JOIDES Resolution to undertake the coring operations. The primary objective of the campaign was to obtain samples of the sediments and rocks beneath the seabed to improve the understanding of the lithology and age of the sedimentary sequences. In addition, there is an obligation to acquire coring samples as part of the Exploration Licenses in Baffin Bay.

The main challenge of the campaign was managing the high concentrations of icebergs and growlers in the region. To achieve the coring objectives, a comprehensive iceberg management strategy was developed, requiring a good understanding of the iceberg conditions. The following sections describe the iceberg conditions, the different components of the iceberg management plan and some typical operational conditions.

ICEBERG CONDITIONS

Figure 1 gives an idea of the typical iceberg conditions prevailing in the region. The detection product was derived from low resolution RADARSAT-2 Synthetic Aperture Radar (SAR) imagery, which can reliably detect icebergs with waterline lengths greater than 100 m, although smaller icebergs may be detected. The dots show the coring sites in Melville Bay with high iceberg concentrations. Only one site was located further south offshore in a license block where iceberg density was lower.

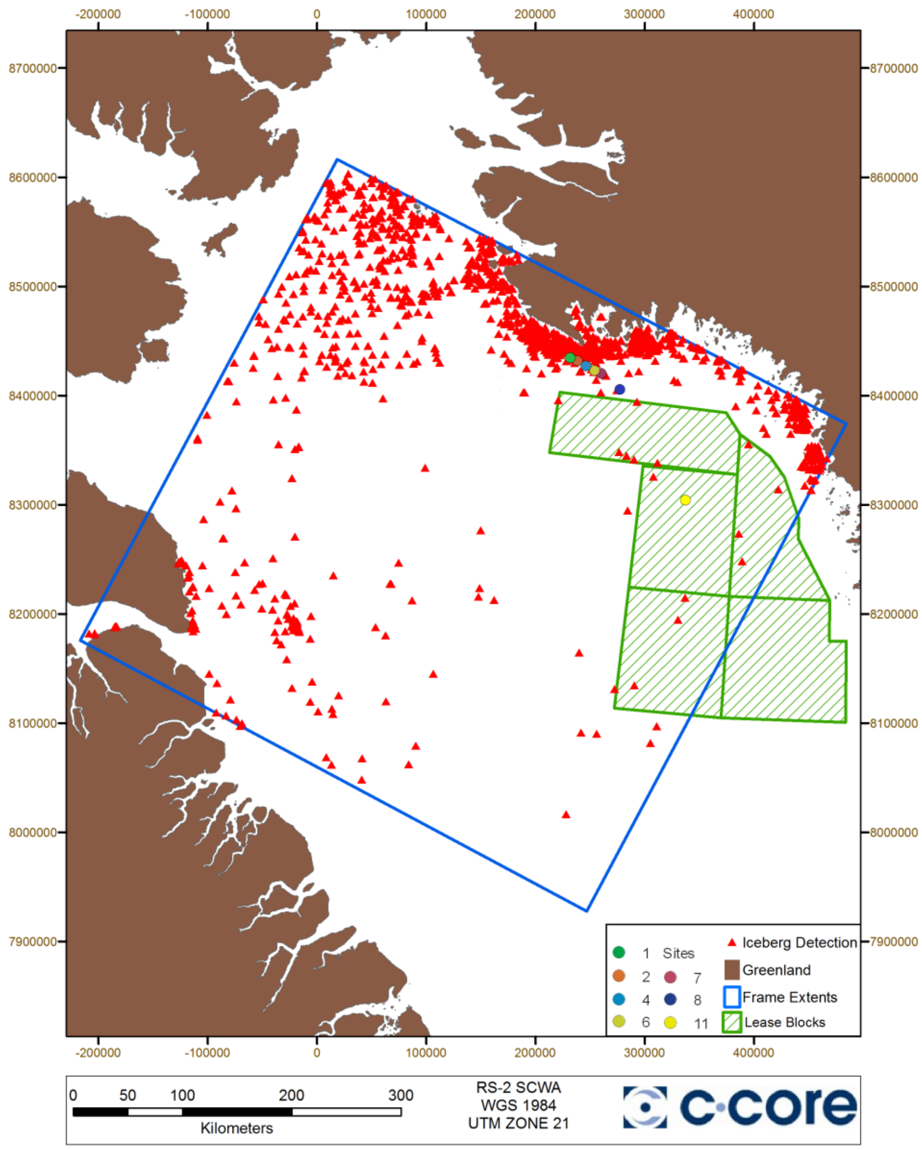


Figure 1. Location of icebergs (red triangles) detected from satellite imagery on 19th September 2012. This also shows the main coring sites (coloured dots) and the license blocks (hatched green).

During the campaign, icebergs that were a potential threat to the operation were tracked. The locations and sizes of 446 icebergs were thus recorded. Amongst these, 316 and 61 icebergs were, respectively, within 5 and 1 nautical miles (nm) of a coring site. In addition, 188 growlers were recorded and documented. 62 of these growlers were also tracked reliably with 29 of them encroaching within 1 nm of the coring vessel.

The iceberg drift direction was mainly to the west as most of the drift tracks were recorded at the northern sites. The average iceberg drift speed at these northern sites was also faster than further south with mean 1-hour values of 0.8 knots in Melville Bay versus 0.4 knots in the license block. The maximum observed 1-hour values for icebergs including bergy bits were 1.5 knots. The growlers had higher mean 1-hour drift speeds of 1 knot with recurring events at 1.5-2 knots.

ICEBERG MANAGEMENT PLAN

The Iceberg Management Plan (IMP) specifies how to achieve the requirements of our iceberg management philosophy by using available services and resources. The IMP has two main objectives: (1) to ensure the safety of people, the environment, installations and operations and (2) to maximize operational efficiency by minimizing downtime due to icebergs.

The development of the iceberg management philosophy and the IMP were based on the coring vessel specifications, an iceberg downtime analysis and the iceberg management systems. These elements are described in the following subsections.

CORING VESSEL SPECIFICATIONS

The SIEM Offshore drilling JOIDES Resolution (JR) is an ICE Class 1B vessel. The JR is designed to perform riserless drilling and utilize a hollow drill string through which seawater drilling fluid, is pumped to lubricate and cool the drill bit and clear cuttings from the borehole. The actual coring operations are performed by rotary drilling with the use of wireline coring systems. The JR will maintain position over the coring site via DP thrusters.

A major feature of the JR was its short time to both pull off the pipe and move off location. This led to very low Total Times (T-Time) i.e. time to retrieve the pipe just below the seafloor. For example, in good borehole conditions, a T-Time of approximately 1 hour was required to retrieve the pipe from a coring depth of 200 meters to a level just below the seafloor. The T-Time does not include the time to be considered for the Exclusion Zone. This is the time required for retrieving the pipe above the seafloor and moving the vessel off location, and was defined as 30 minutes.

In addition, Free Fall Funnels were also available to be deployed on the seafloor to enable fast re-entry in case of pull-off situations due to iceberg encroachment or drill bit changes.

ICEBERG DOWNTIME ANALYSIS

Iceberg conditions were evaluated for the different coring locations prior to the start of the operations. Iceberg densities were derived by analysing historical satellite imagery as well as the high resolution satellite imagery and the field data collected during the 2011 site survey. A downtime methodology was then used to estimate iceberg encounter rates of a stationary vessel (McKenna R. et al., 2003). The encounter rate was based on the evaluated iceberg densities, iceberg drift speed and waterline length in addition to operational parameters including detection, forecasting and physical management capabilities, and the size of the required coring T-time zones. The high density of icebergs at some of the northern coring sites led to the projection of significant potential downtime. This led to the consideration of shallower coring and more numerous sites to increase the probability of success. The modelled results matched well the observed operational downtime from icebergs, except for the coring locations where high resolution satellite imagery was not acquired in 2011. At these locations, the non-detection factors could not be derived so accurately leading to higher differences between the modelled and observed operational downtime from icebergs.

ICEBERG MANAGEMENT SYSTEMS

The iceberg management system was designed to provide reliable weather, ice and iceberg information to the field operations and planning managers during the operational season. These are part of the iceberg management philosophy to reduce the weather-related risks and to optimize operations' performances. These elements are described below and include skilled ice advisors, weather forecasts and sea ice charting, marine radars, satellite imagery and iceberg drift forecast.

Ice Advisors

Four ice advisors supported the operations providing 24/7 coverage. Their tasks included:

- Monitoring hourly sea ice and icebergs using the marine radar systems
- Monitoring weather forecast
- Evaluating hourly Closest Point of Approach (CPA), T-Time and Iceberg Alert Levels
- Reporting iceberg properties: location, type, estimated size, drift direction and speed
- Evaluating iceberg size by taking digital photography
- Analysing and validating satellite imagery products
- Providing and analysing iceberg drift forecasts
- Liaising with vessel's captain, OIM and Shell representative

Weather forecasts and sea ice charting

Daily sea ice charting was only provided at the beginning of the season in June and July. By the time the coring vessel departed from St Johns on the 4th August 2012, Melville Bay was free of sea ice. On the other hand, weather forecasts were provided four times per day via email for the transits and the various coring locations. The main parameters of interest were the wind direction and fog. Indeed, these two parameters strongly affect the density and detection of growlers which are a main concern in this region. The weather forecast system was tested in the same region during the summer 2011 through the deployment of a Wavescan metocean buoy.

Marine Radars

Several marine radars were implemented and used to track icebergs including:

- A Kelvin Hughes (KH) X-band radar
- A KH S-band SharpEye system with advanced ice processing system
- A Sperry X-band radar

In addition, to improve the growler detection capability, a FLIR system (Geostabilized Infrared camera, M612L) was also used. The KH navigation system allowed integration of the display of the Infrared camera as well as the wind information measured by the vessel. A KH data logger was also installed to export and store the data from its navigation system.

Satellite imagery

Satellite imagery at various spatial resolutions was acquired daily to derive sea ice charts and iceberg density maps and included:

- Low resolution (100 meters) SAR imagery from RADARSAT-2 and COSMO-SkyMed
- High resolution SAR imagery from COSMO-SkyMed (5 m) and TerraSAR-X (18 m)
- Low resolution optical imagery from MODIS (250 m) and AVHRR (1.1 km)

The products derived from this satellite imagery were provided in Near-Real-Time by C-CORE (Bobby at al., 2012) in less than 3 hours to the vessel by email (Figures 1 and 2). These products were used strategically to identify operational windows outside the 20 nm detection range of the marine radars. Validation of these products was conducted by the ice advisors against icebergs detected by the marine radar within 12 nautical miles of the vessel location.

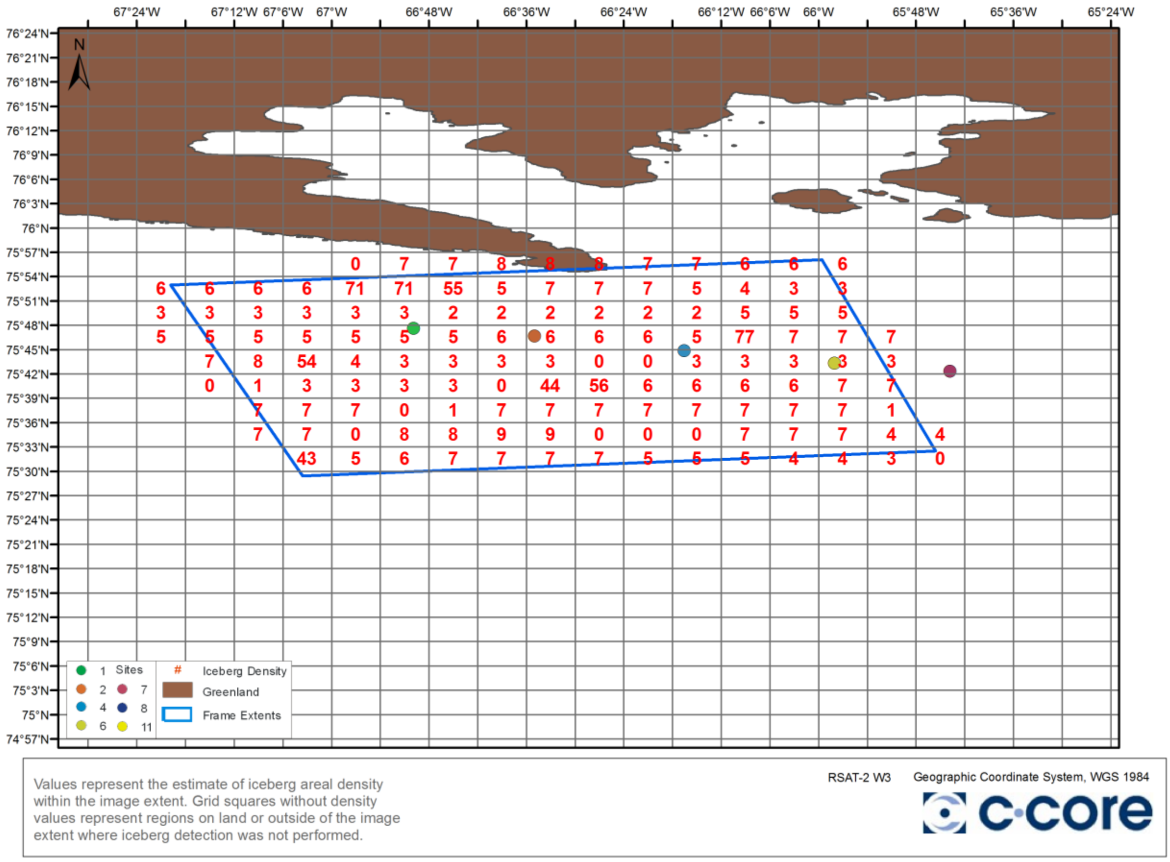


Figure 2. Iceberg density map (5 km x 5km) derived from high resolution satellite imagery

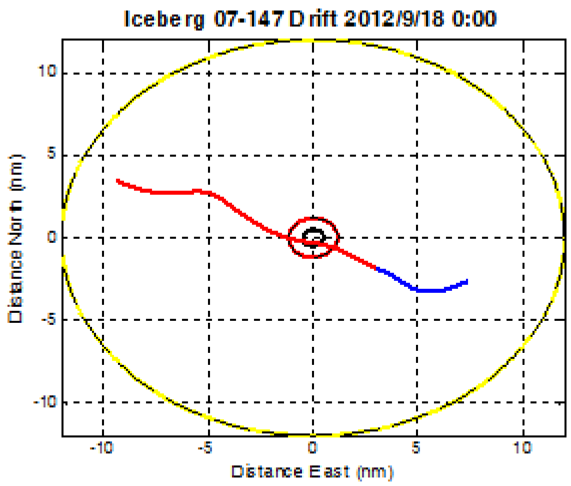
Iceberg drift forecast

Iceberg drift modelling was used by the ice observers to provide forecasts of the trajectory of the threatening icebergs. The model was developed by Canatec and is based on the iceberg drift model presented in Kubat et al. (2005). It accounted for the following forces: air and water drag, Coriolis, wave drift and water pressure gradient. The model was tailored to the iceberg management plan in terms of its ability to automatically generate the T-Time and Exclusion Zone alerts' ranges and CPA for specific icebergs. The following input data were required for the iceberg forecast model:

- Iceberg shape, length and height
- Iceberg drift speed and direction
- Ocean current including predicted tidal current
- Measured wind speed and direction, and wave height and direction

Icebergs were monitored in a 12 nautical mile zone around the vessel and a forecast was initiated for those remaining a threat at 6 nautical miles. The collected drift data for each iceberg ensured the model was first tuned in hindcast mode before issuing a forecast for the same iceberg to the bridge. The forecast was then used to evaluate whether the icebergs would enter the T-time and Exclusion zones. Forecasts were generally issued for a 12-24 hours time period. An example of a forecast bulletin generated by the drift forecast model is shown in Figure 3. This gives a 24-hour iceberg drift forecast (red line) based on the observed drift (blue line). The red circle is the T-Time zone, here four hours, and the black circle is the Exclusion Zone. Iceberg 07-147 was forecast to drift to the WNW and enter the red zone and skirt the black exclusion zone, but then drift away from the site. The iceberg in fact drifted slightly further away from the coring site than forecast, and site abandonment was not required.

ICEBERG FORECAST: KH target 639



Forecast time for berg 07-147 is 2012/9/18 0:00.
Forecast final alert level is yellow.
Forecast CPA is 0.3 nautical miles and 191 degrees.
Forecast CPA time is 2012/9/18 6:19.
T-Time is 1 hours and associated forecast red alert distance is 1.2 nautical miles at 121 degrees, 3 hours and 58 minutes from forecast time.
Forecast red alert time is 2012/9/18 3:58.
Forecast black alert distance is 0.5 nautical miles at 140 degrees, 5 hours and 31 minutes from forecast time.
Forecast black alert time is 2012/9/18 5:31.
Iceberg speed is 0.7 knots at 304 degrees, averaged over previous 2 hours.

Figure 3. Iceberg drift forecast bulletin on 18th September 2012.

Figure 4 shows the measured drift of iceberg 07-147 from September 17th at 16:00 to September 18th at 08:00 (blue line), the hindcast drift from September 17th at 16:00 to September 18th at 00:00 (black line), and the first eight hours of the forecast thereafter until 08:00. The iceberg's forecast CPA was at 0.3 nm from the vessel against the actual value of 1 nm. In addition, its actual CPA occurred about 1.3 hour earlier than the forecast.

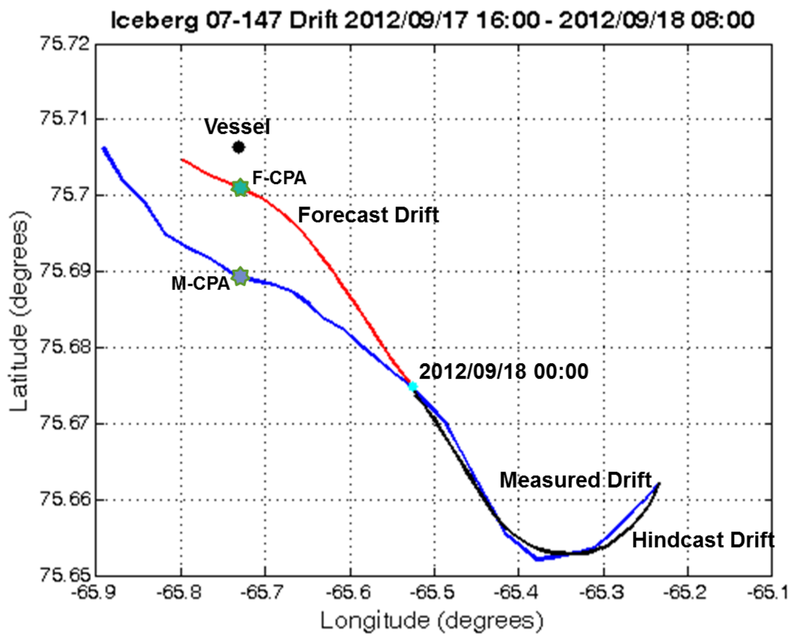


Figure 4. Measured, hindcast, and forecast drift of iceberg 07-147.

Hence, a method was devised to estimate total current driving an iceberg by assuming icebergs drifted at speeds 5% slower than their depth-mean current down their keel, and 30° to the right of the current direction due to Coriolis forcing. The justification for this estimate was based on the experience of the ice advisors with the iceberg drift observations and current measurements on rigs on the Grand Banks. The predicted tidal currents were then subtracted from the estimated total current to obtain a time-mean non-tidal current over the period of iceberg drift observation. This non-tidal current was subsequently applied to the iceberg drift forecast along with the forecast tidal currents.

In parallel, to provide short-term CPA information to the bridge, a spreadsheet calculator was developed. This used the observed iceberg data only to evaluate the CPA range and bearing relative to the site, the T-Time zone diameter and the times to CPA and T-Time zone. This information was posted on a whiteboard on the bridge as well as communicated verbally.

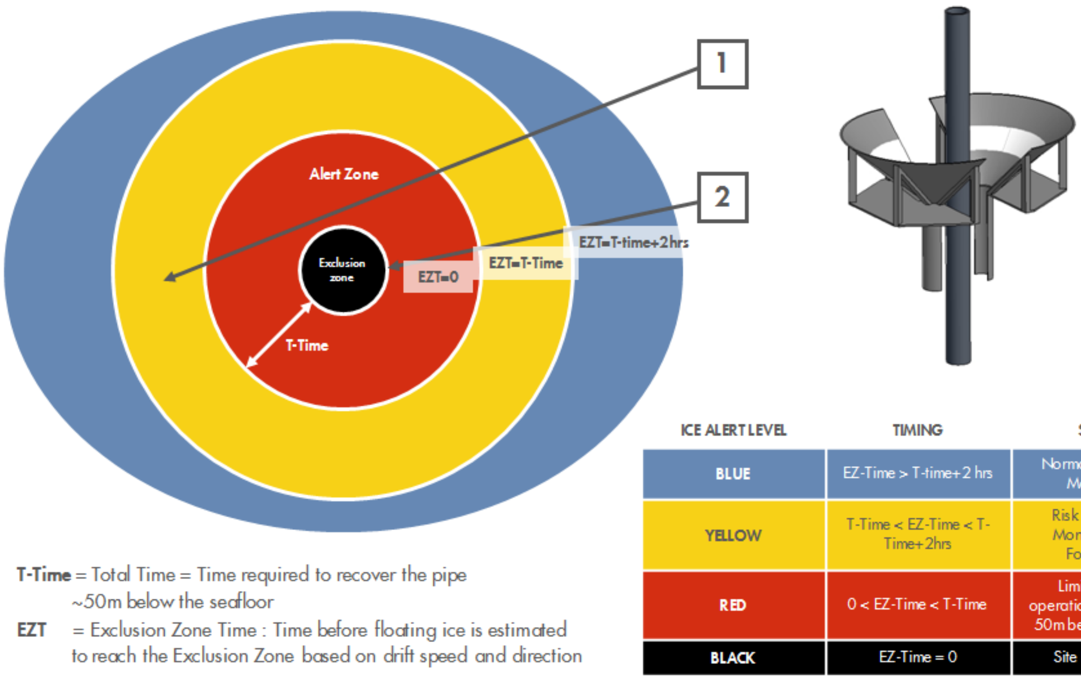
ICEBERG MANAGEMENT STRATEGY

Prior to start of the coring campaign a ice management strategy was developed for the area, which include not using towing vessels for the operations. The following where the main considerations which drove the strategy:

- Short JR T-Times and Exclusion Zone time
- Re-entry systems (Free Fall Funnels) were available
- Numerous shallow cores instead of a few deep ones were considered
- Pre-season testing and validation of the iceberg detection and forecasting tools

The combination of these elements provided the flexibility required to operate in this environment without towing vessels. Therefore, a lot of focus was applied on the iceberg management plan to minimize downtime due to inadequate detection or forecasting. Indeed, these were essential to identify coring locations with an operating window as well as to support the decision on whether or not to interrupt operations.

Figure 5 shows the associated iceberg alert levels and decision protocols. Four Alert Levels are defined. The Alert Level depends on the T-Time and the forecast times for the iceberg to reach the Exclusion Zone (EZ-Time) and the vessel. Iceberg 1 encroaches on the Exclusion Zone but is forecast to move away from the Exclusion Zone. The vessel is in standby mode until the iceberg moves clearly away from the Exclusion Zone. Iceberg 2 encroaches on the Exclusion Zone and is forecast to pursue its trajectory toward the vessel leading to disconnection and moving off location.



ICE ALERT LEVEL	TIMING	STATUS
BLUE	EZ-Time > T-time+2 hrs	Normal operations Monitoring
YELLOW	T-Time < EZ-Time < T-Time+2hrs	Risk assessment Monitoring and Forecasting
RED	0 < EZ-Time < T-Time	Limited coring operations Pipe pulled 50m below sea floor
BLACK	EZ-Time = 0	Site Evacuation

Figure 5. Iceberg Alert Zones, Decision Protocols and a Free Fall Funnel

TYPICAL OPERATIONAL CONDITIONS

An example of a disconnection situation occurred on the 19-20th September 2012 at the coring site U0070. At 20:00 on the 19th September, two icebergs at 5.8 (07-157) and 8.8 (07-158) nautical miles (nm) approached the site at a speed of 0.8 and 1 knot, respectively. The T-Time zone was 2.75 hours or 2.9 nm. At 22:00, the icebergs were at 4.3 nm and 6.9 nm. However, it was decided to move off site due to:

- Reduced visibility and rain
- Difficult detection of growlers in sea state above 1 meter
- Forecasts for the icebergs to encroach the T-time zone
- No escape route in case one of the icebergs would enter the Exclusion Zone

At 00:00, the pipe was fully recovered and the JR vessel moved on standby 1 nm south of the coring location. By this time, the icebergs were at 2.8 and 5 nm from the site. They reached their CPAs of 0.68 and 1.24 nm from the coring location at 04:00 and 06:30, respectively (Figures 6 and 7). The vessel then moved back and was on site U0070 at 09:00 on the 20th September.

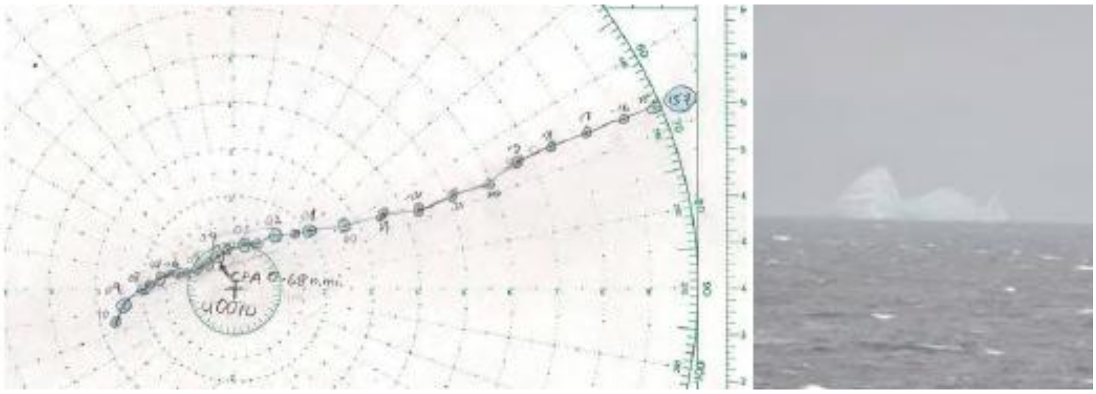


Figure 6. Drift track and photo of Iceberg 07-157

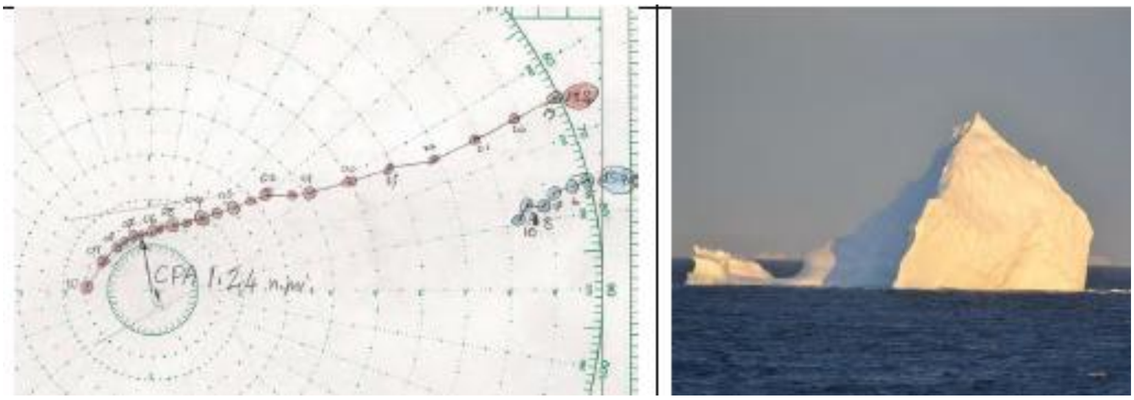


Figure 7. Drift track and photo of Iceberg 07-158

CONCLUSIONS

The iceberg management strategy presented in this paper was an essential element of the success of the 2012 coring operations. Conducting coring operations in such high density iceberg environment allowed the identification of important gaps and learning for preparing future drilling operations in the region:

- It is essential for the bridge crew, representatives and ice advisors to be well prepared. This includes the understanding of the iceberg conditions, the appropriate use of detection and forecasting tools and the alignment on the T-Time calculation and associated decision protocols;
- The marine radar is an essential component of the iceberg management system. However, these systems still suffer from strong limitations in detecting growlers especially in high sea states. Additional testing of the existing systems has to be undertaken to identify the optimal systems for growler detection across a range of sea states.
- Concerning iceberg drift forecasting, the main challenge concerns the modeling of tidally-forced or inertial oscillations. The periods of inertial oscillations at 75°N and tidal currents are both about 12 hours, so it was difficult to differentiate which forcing was at work at any time. Proper modeling of these phenomena requires adequate iceberg draft information and ocean current data. Both are difficult parameters to obtain. Adequate instrumentation needs to be installed on support vessels to acquire such data.

- Forecasts of ocean current and fog are also a major challenge. Fog has a strong impact on vessel operations as it limits the growler detection in strong sea states. Further real-time met-ocean measurements are required to validate and optimize the weather forecasts in the region.

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