Tracking Changes in Iceberg Calving Events and Characteristics from Trinity and Wykeham Glaciers, SE Ellesmere Island, Canada

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ABSTRACT

The Canadian Ice Service (CIS) produces charts to identify iceberg presence in Canadian waters for navigational purposes, but there is uncertainty surrounding the origin of these features. Previous work has been conducted on the location of the main tidewater glaciers in Canada and the volumes of ice that they discharge to the ocean, but little research has been done on the processes controlling iceberg production and drift patterns in Canadian Arctic waters. Recent and rapid changes have been observed in the ice discharge patterns of glaciers in this region. For example, Trinity and Wykeham glaciers contributed ~62% of total iceberg discharge from the Canadian Arctic Archipelago in 2016, compared to ~22% in 2000. Given these changes, an important question is whether there is a relationship between changing sea ice conditions (e.g., thickness, extent, freeze up dates, break up dates) and iceberg production from these glaciers. Using SAR and optical imagery to identify iceberg calving events between 1997 and 2015, iceberg calving events are classified in two ways: through the identification of iceberg plumes, and through the measurement of glacier terminus changes. Often when a calving event occurs a plume of glacial ice debris is also produced at the terminus and is clearly visible in SAR imagery. In some cases, such as when a large event composed of a single iceberg rather than many small pieces of ice, a plume is not always produced making it difficult to detect in SAR imagery. Glacier area loss detected in optical imagery data is compared to the plume event data from SAR imagery between 1997 and 2015 to determine whether a relationship exists between glacier area loss and plume size. To understand where these icebergs drift to, how they deteriorate and the time scale of these processes, a series of satellite tracking beacons were deployed in summer 2016. These were helicopter-deployed from aboard the CCGS Amundsen, and provide near real-time (hourly) information concerning the movement of 13 icebergs and ice islands within Baffin Bay. Initial results show that, to date, the most active iceberg has drifted over 3200km south through Baffin Bay. Some of the icebergs have also exhibited a spiraling pattern as they drift west across Baffin Bay and are influenced by ocean currents and tides. Results from this work provide information about patterns of iceberg movement, including common areas where icebergs become grounded in relation to bathymetry.

Keywords: Icebergs, Remote Sensing, Glacier Dynamics, Iceberg Drift, Canadian Arctic

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GLACIERS, ICEBERGS AND ICE ISLANDS

Background and Objectives

Tidewater glaciers drain glaciers, ice caps and ice sheets and terminate into the ocean where they discharge through the calving of icebergs and ice islands (large tabular icebergs). The Canadian Ice Service (CIS) produces charts to identify the presence of icebergs but has little knowledge about the sources and sinks of icebergs in Canadian waters. It is important to understand where these icebergs and ice islands originate, where they drift, how they deteriorate and the time scale of these processes. Trinity and Wykeham Glaciers on SE Ellesmere Island have increased iceberg production from 22% of total discharge from the CAA (Canadian Arctic Archipelago) in 2000 to 62% in 2016. They are the only two glaciers in the Queen Elizabeth Islands (QEI) to have shown consistent acceleration between 1999 and 2015 making it an area of significance for the study of ice discharge into Canadian Waters (Van Wychen et al., 2016). Operations during this leg will address the following gaps in knowledge surrounding the production and movement of icebergs and ice islands in Canadian waters:

- Which tidewater glaciers are the sources of icebergs and ice islands in Canadian waters and where do they drift?
- Are there changes in the size, shape or timing of iceberg production in the recent past and is this linked to glacier dynamics?
- Do sea ice conditions impact the production of icebergs at the termini of tidewater glaciers?

Iceberg Plume Detection

Trinity and Wykeham Glaciers were chosen to be the focus of this study due to recent and rapid changes in their velocities and ice discharge identified by Van Wychen et al. (2016). Through plume analysis, they were found to be the most active iceberg plume producing glaciers in the study with 139 and 134 plumes detected, respectively. Trinity Glacier was found to be the most active glacier in this study with regards to iceberg plume production (Figure 1). Most of the plume events detected occurred during the open water season or immediately before/after with fewer events occurring when sea ice was present. Very few plume events were detected between January and June for all years, with the only winter events being seen in recent years (2013-2015). Most of the plumes produced by Trinity Glacier were size 1 or size 2 in magnitude. Trinity Glacier produced the most size 3 plume events of all glaciers in the study with 11. Similar to Trinity Glacier, most of the iceberg plume events produced by Wykeham Glacier (Figure 2) were detected during the open water season however more events were detected when sea ice was present (approximately December to May). All of these events were smaller in size (size 1 or 2) compared to the events that occurred during the open water season. Two size 3 events and one size 4 event were produced by Wykeham Glacier however these were only detected in recent years, between 2011 and 2014. Sea ice did not break out of Trinity Fiord in 1997 and no iceberg plume events were detected from either Trinity or Wykeham Glaciers during that year. In summary, when sea ice is present, fewer iceberg calving events occur. Once the sea ice begins to break out of the fiord there is an increase in the size and frequency of iceberg calving events.

Iceberg Beacon Deployment

Between July 31, 2016 and August 14, 2016 a total of 13 beacons were deployed on icebergs and ice islands in Baffin Bay. Through a contract with Environment and Climate Change Canada (ECCC) six CALIB beacons were deployed onto icebergs and ice islands within Baffin Bay and Nares Strait (Table 1). Two beacons were deployed onto targets chosen by CIS and the remaining four targets were chosen based on size, location and whether they were likely to drift (Figure 3).

Five of six beacons have since successfully transmitted data remotely. One of the beacons deployed (ID#: 300234011758690) is suspected to have had issues with the battery and has not transmitted any data since being deployed.

Seven additional beacons were deployed containing iridium GPS receivers (RockStar), batteries and solar panels (Figure 4). Three of these beacons were deployed onto icebergs/ice islands within Baffin Bay and four were deployed within Trinity Fiord to track movement of icebergs produced by Trinity Glacier within and out of the fiord (Table 2; Figure 6). Positions of these seven beacons will be viewed on www.core.rock7.com to monitor movement and identify drift patterns of icebergs around Baffin Bay. An additional 14 beacons were deployed onto icebergs and ice islands in 2017. Nine of these beacons were of a similar design to those in Figure 5 however they were updated with a larger battery and the addition of a solar regulator. The remaining five beacons were deployed on behalf of CIS.

Table 1. CIS beacon deployment summary.

Asset Name	*Deployment Date*	*Deployment Time (UTC)*	*Latitude (start position)*	*Longitude (start position)*	*Deployment Location*	*Notes*
ICALIB (4701652-8690)	02-Aug-16	11:30 AM	72.06178	-73.31847	Baffin Bay	Buchan Gulf Iceberg. **Faulty Device - Not working**
ICALIB (4701653-3030)	02-Aug-16	12:20 PM	71.88914	-72.25875	Baffin Bay	Unk_S1 Ice Island
ICALIB (4701654-5450)	09-Aug-16	11:35 UTC	76.30836	-74.81636	Baffin Bay	S Nares Strait Ice Island
ICALIB (4701655-1040)	09-Aug-16	12:45 UTC	76.84956	-75.88631	Baffin Bay	East of Manson Icefield Ice Island
ICALIB (4701657-3450)	14-Aug-16	11:31 AM	79.74294	-64.96186	Baffin Bay	Humboldt Glacier Ice Island
ICALIB (4701656-8060)	14-Aug-16	11:49 AM	79.83578	-67.35725	Baffin Bay	Kane Basin Ice Island

Table 2. RockStar beacon deployment summary.

Unit #	**Deployment Date**	**Deployment Time (UTC)**	**Latitude (start position)**	**Longitude (start position)**	**Deployment Location**
3655	31-Jul-16	18:37	70º45'46.76"	67º51'26.50"	SE of Sam Ford Fiord
3534	06-Aug-16	18:34	76º11'02.29"	69º55'31.80"	SW of Thule
3651	06-Aug-16	18:58	76º35'15.51"	71º35'00.91"	W of Thule
20781	10-Aug-16	17:54	77º57'01.57"	78º31'25.99"	Trinity Terminus
3635	10-Aug-16	17:59	77º56'07.96"	78º08'41.42"	Trinity Island
20785	10-Aug-16	10:22	77º56'30.47"	77º55'50.91"	Trinity Mid Fiord
20784	10-Aug-16	10:28	77º54'17.19"	77º29'8.83"	Trinity Outer Fiord

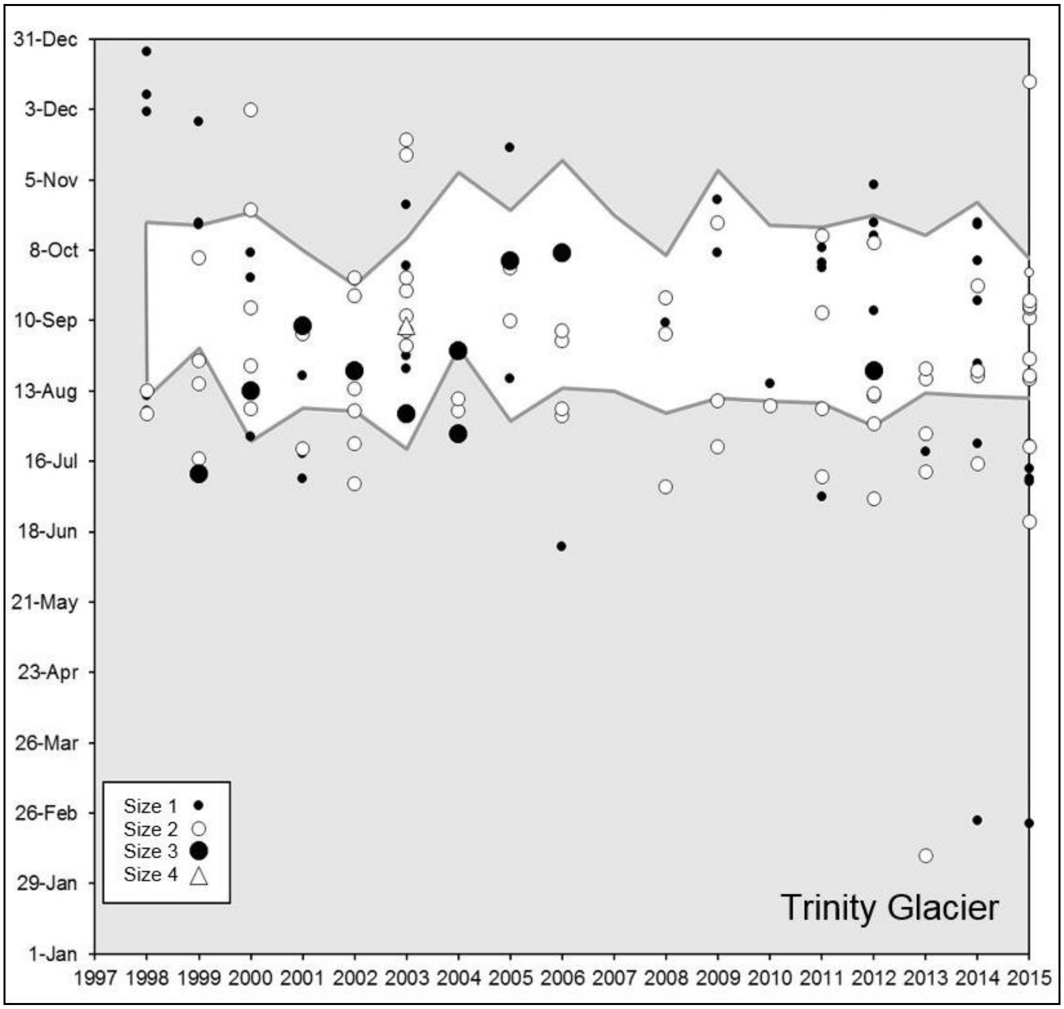

Figure 1. Temporal variability of iceberg plumes produced by Trinity Glacier between 1997 and 2015. Grey area represents the presence of landfast sea ice and white area represents absence of landfast sea ice.

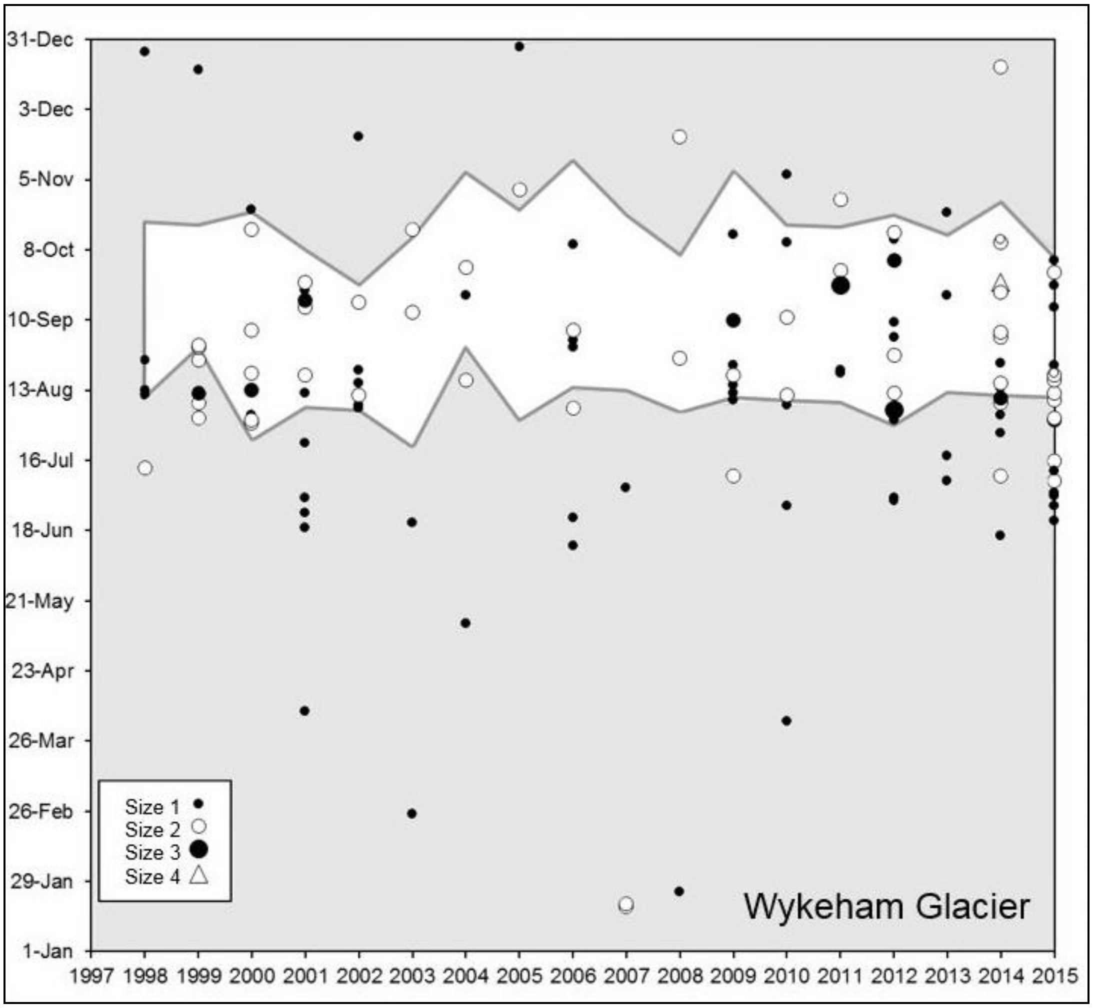

Figure 2. Temporal variability of iceberg plumes produced by Wykeham Glacier between 1997 and 2015. Grey area represents the presence of landfast sea ice and white area represents absence of landfast sea ice.

Figure 3. Example of placement of CIS beacon. Deployed on iceberg near Buchan Gulf (72.06178, -73.31847), August 2, 2016. Photo courtesy of Luke Copland.

Figure 4. Example of placement of beacon on ice island. Deployed SE of Sam Fiord, July 31, 2016. Photo courtesy of Abby Dalton.

Figure 5. Iceberg tracking beacons built by Abby Dalton and Luke Copland. Three of these beacons were deployed onto icebergs in Baffin Bay and four were deployed onto icebergs within Trinity Fiord to monitor their movement. GPS trackers transmit their position using the Iridium satellite network and can be programmed remotely to modify transmission frequency according to activity (e.g. less frequent transmission during winter when they are frozen in sea ice and have minimal movement). Photo: Luke Copland.

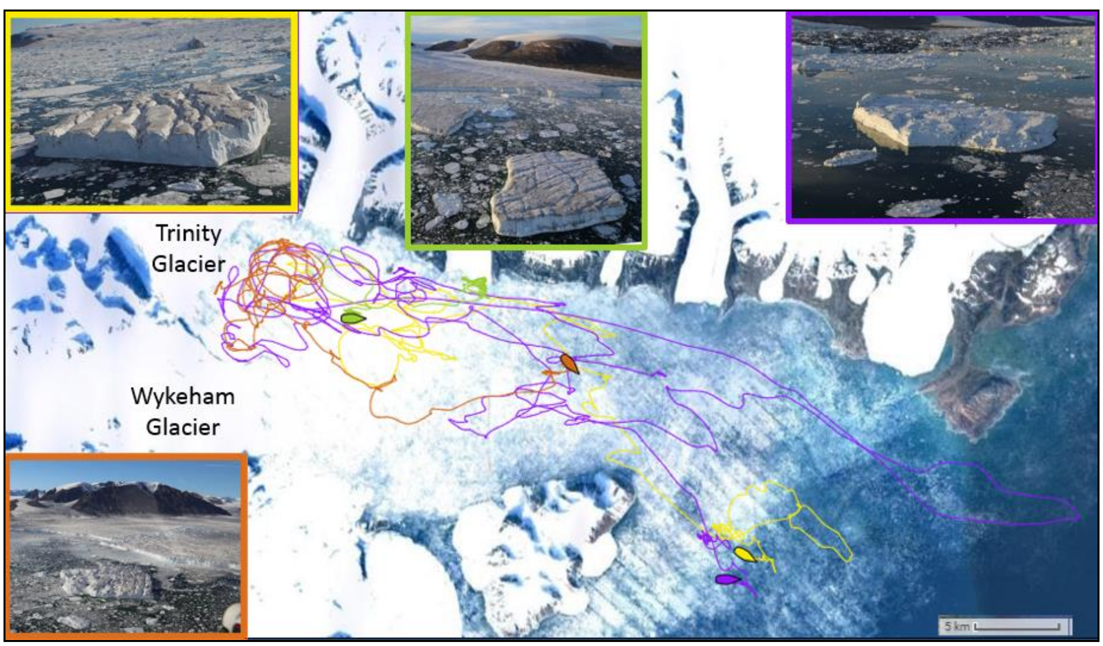

Figure 6. Drift tracks of icebergs tagged with beacons between August and December 2016. One of the icebergs (purple track) travelled approximately 25km in one day on September 13, 2016.

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Van Wychen W, Davis J, Burgess DO, Copland L, Gray L, Sharp M, Mortimer C. 2016. Characterizing interannual variability of glacier dynamics and dynamic discharge (1999-2015) for the ice masses of Ellesmere and Axel Heiberg Islands, Nunavut, Canada. *Journal of Geophysical Research – Earth Surface*, **121**. doi: 10.1002/2015JF003708.