Progress Report: Dynamics and Historical Changes of the Petersen Ice Shelf, Nunavut, Canada

Introduction:
This document is presented to the Royal Canadian Geographical Society in fulfillment of the condition for the Northern Studentship Award which was presented to me in April 2011. The following is a progress report which describes my thesis research which I am completing towards my Masters of Science at the University of Ottawa through the Laboratory for Cryospheric Research, in collaboration with Carleton University.

Project Description:
This study conducts the first comprehensive assessment of the Petersen Ice Shelf which lies on the northern coast of Ellesmere Island between Yelverton Bay and Milne Fjord in Nunavut (Fig.1). The objectives of this study are to measure the extent changes (from 1950s-2010), thickness, and mass inputs of the Petersen Ice Shelf. In addition, the presence of the epishelf lake alongside the ice shelf (a freshwater layer that is dammed by the ice shelf, and remains permanently stratified over the marine water below) will be examined (Jungblut et al. In press).

Fieldwork was successfully undertaken on the Petersen Ice Shelf in May 2011. A ground penetrating radar (GPR) system was used to measure the thickness of the ice shelf and its epishelf lake (Fig.2). The GPR was mounted into a sled and towed by snowmobile at <20 km hr⁻¹ over a distance of 122 km, in a grid-like pattern across the ice shelf (Fig.3). The GPR system used a built-in GPS (global positioning system) that recorded the position of each GPR measurement. To examine the surface mass balance (to quantify ice gains and losses) of the ice shelf, a marker stake network was installed and measured on the ice shelf, and at the front of one of its tributary glaciers. These stakes will be re-measured in May 2012 to determine the rate of surface lowering of both the ice shelf and the tributary glacier, which will quantify the amount of annual ice loss. A GPS was used to determine the
exact position of each stake, and will be used to re-measure the same stakes in May 2012. The change in the position of the stake will show how much the surface has moved which will therefore provide a measure of input (mass gain) contributed from the tributary glacier to the ice shelf. These results will also be used to verify the ice velocities derived for the tributary glacier via speckle tracking, a remote sensing technique which uses repeat pairs of Radarsat-2 satellite imagery to calculate surface motion.

To examine the state of the epishelf lake (which is located along the southern coast of the ice shelf), the temperature and salinity of the lake was measured through a hole which was drilled through the lake ice. These measurements along with salinity/temperature measurements collected in the same area in 2008 and 2009, will be used to examine how the status of freshwater lake has changed. To examine changes in the surface area of Petersen Ice Shelf, air photos (1950s-80s) and satellite imagery (1990s-2011) were used to quantify the change in the extent of the ice shelf.

Preliminary results:
Since the field season, the GPR data has been processed and preliminary results have shown an average ice thickness of 21.8 m for the ice shelf and epishelf lake (Fig.3). The thickest ice across the ice shelf (>100 m) was detected at the front of the tributary glaciers along the northern coastline. These thicker areas confirm the importance of the tributary glaciers to mass input to the ice shelf. The thinner areas of the ice shelf (<30 m) were along the southern coast (beside the epishelf lake). In the eastern portion of the ice shelf in areas of thinner ice (<40 m) the basal reflections detected by the GPR were intermittent which may be indicative of brine inclusion in the basal layers of the ice shelf, a characteristic observed across the Ward Hunt Ice Shelf (located to the northwest of the Petersen Ice Shelf). The ice thickness and presence of brine in these layers will be confirmed in May 2012 by drilling into the ice shelf and extracting ice cores to measure salinity.

![Figure 3: Radarsat-2 ultrafine image from April 2011 showing thickness measurements derived from GPR measurements across the Petersen Ice Shelf.](image)

Area measurements show that in 1959, the Petersen Ice Shelf had a surface area of ~51.5 km². By 2011, the area had reduced to ~30.2 km², a loss of >41% over a 52-year period. Analysis of air photos and Landsat images from 1959 to 2000 showed the majority of area loss (~2 km²) occurred along the
southern edge of the ice shelf, alongside the epishelf lake. The greatest losses have occurred over the last decade (2002-2009) when the ice shelf lost ~18 km² from its outer portion (west side).

Results thus far have shown that GPR data is a successful method for determining ice thickness across the ice shelf, particularly in thicker areas. The data collected clearly shows thicker ice at the front of tributary glaciers and indicates that these features have been an important source of ice shelf input in the past. Through the analysis of satellite images and air photos, it is apparent that Petersen Ice Shelf has undergone large-scale areal changes over the past 50 years and that these changes have accelerated over the past decade. Having formed 4000 years ago under colder conditions (England et al. 2008), it seems as though the Petersen Ice Shelf, like its neighbouring Milne and Serson Ice Shelves, is unlikely to remain under present climate conditions (Copland et al. 2007).

Pending results and future research:
Over winter 2012, data processing and analysis will be focused on remote sensing to derive surface motion and past changes in the status of the epishelf lake. In May 2012 a second field season on the Petersen Ice Shelf will be conducted. The GPR survey conducted in May 2011 will be repeated to measure thickness changes over a year. GPR measurements will also be expanded to include the northwest portion of the ice shelf which was impassable due to difficult terrain in 2011. Ice coring will be conducted in the eastern portion of the ice shelf in areas where GPR basal reflections were intermittent to measure the depth and salinity of the ice. Finally, marker stakes that were installed in 2011 will be re-measured to determine surface mass balance of the ice shelf. Surface motion for both the ice shelf and tributary glaciers will also be determined via repeat GPS measurements and compared against surface motion estimates derived from the speckle tracking technique.

Presentations and publications:
The recent findings including the thickness measurements and areas changes for Petersen Ice Shelf were shared as a poster presentation to an international audience at the American Geophysical Union conference in December 2011. Several researchers from organizations such as the British Antarctic Survey (BAS), the Office of Naval Research (ONR) and NASA were particularly interested in the results of this work and provided valuable feedback for expanding the project. The findings of this project, including the epishelf lake study and ice velocities will be presented at the IPY/ArcticNet conference in Montreal in April 2012.

The final thesis for this study will be written and defended in front of a committee at the University of Ottawa by the end of summer 2012. After this time, the results will be formatted into an article and submitted for publication to the Journal of Glaciology.

References:
