Measuring Freshwater Transports Through the Canadian Archipelago: Addressing the Climate Change Question

Jim Hamilton and Simon Prinsenberg

The Arctic Ocean is unique among the world's oceans because of its vast ice cover. Almost half of this ocean is capped year-round with a layer of ice that averages 3 m in thickness, and the ice-covered area is nearly doubled over the long winter season. There is evidence that the perennial portion of this ice cap is shrinking, and open-water conditions are persisting longer in the seasonally-covered areas of the Arctic Ocean. Such changes have an impact on the local ecosystem and the people depending on it. Furthermore, ice cover insulates the atmosphere from the ocean, and reflects solar radiation into space with minimal heating affect, so there is concern that a loss of ice cover could accelerate regional warming and result in further melting, not only of sea ice, but also of some of the vast glaciers of Greenland and the Canadian Archipelago. The resulting release of fresh water from both of these sources may have significant, farther-reaching effects. Global circulation patterns connect the world's oceans, redistributing heat and salt, thereby having a significant impact on climate. In the upper Atlantic Ocean, warm, salty water moving northward from the equator becomes heavier when cooled by Arctic air, and sinks to generate a deep southward return flow. If there is increased export of this lighter fresh water from the Arctic Ocean into the surface waters of the North Atlantic, it may inhibit this convection process, thereby altering this large scale ocean circulation pattern.

To understand the response of the Arctic Ocean to global warming, it is necessary to have knowledge of its many components and their interconnections. With the potential impact of increased melting on global ocean circulation, the freshwater cycle in the Arctic is a primary concern. The principal sources of new fresh water into the Arctic Ocean are river runoff, inflow of slightly fresher Pacific water through Bering Strait, and precipitation. These are balanced by exports of fresh water (in ice and liquid form) through Fram Strait along the east coast of Greenland, and export through the three main passages of the Canadian Archipelago into the Northwest Atlantic Ocean. None of these parameters is easy to quantify accurately, but our knowledge is improving with the application of new tools and techniques for making the required measurements. Until recently, transports through the Canadian Archipelago have not been well quantified, but a research program that started in 1998 has provided the opportunity to develop the required specialized instrumentation, and to obtain a six-year time series of current, salinity, and temperature data through Barrow Strait (Figure 1). These data have been used to calculate freshwater transports through this strait, and with the extended time series, have allowed us to quantify the seasonal and inter-annual variability of this parameter.

Unique aspects of the polar ocean environment have required development of specialized instrumentation and techniques to collect the data needed for this study. One challenge was measuring ocean current direction where our proximity to the north magnetic pole renders compasses in commercially available current meters useless because of the small horizontal component of the earth's magnetic field there. The technique developed to overcome this difficulty uses a precision heading reference system to measure the orientation of an upward-looking acoustic Doppler current profiler (ADCP) mounted in a streamlined underwater buoyancy (SUB) package. One of these assemblies is shown in Figure 2. SUBs are a patented technology previously developed by BIO staff. The SUB ensures alignment with the flow, thereby reducing the time that the power-hungry precision heading reference needs to be on for each five-minute current profiler sample. The modest battery requirement allows for the complete instrument assembly to be a manageable, self-contained unit. These units serve as the top buoyancy in several of the sub-surface moorings in our array across Barrow Strait (Figure 3), providing detailed current speed and direction measurements, and ice drift, over a 75 m depth interval. These moorings, and others, also support "CTD" instruments for measuring salinity, temperature, and depth, while yet another mooring in the array measures ice thickness. Since 2003, an ADCP with an extended range of 250 m has been used at one site. A deployment of this instrument is shown in Figure 4.

Ice covers the mooring location for ten months of the year. Ridges that form when ice is driven together by currents and winds can reach down to 20 or 30 m and sweep through the mooring area, presenting a real hazard to any equipment in this near surface layer. For this reason, none of our conventional moorings extend into this high risk ice zone. Yet, it is in this near-surface layer that we can expect to see the freshest water, since it is lighter than the saltier water below. Since a principal goal of the study is to determine freshwater transport through the Strait, instrumentation was also developed at BIO to make these upper ocean salinity measurements. Icycler, shown in Figure 5, consists of a winch in the main float of a mooring, which reels out a CTD float once a day using a sonar to detect both the depth of the ice and a safe reel-out distance. When not profiling, the CTD float is reeled in below any danger of ice impact. A yearlong record from Icycler is also shown in Figure 5. Through August to mid-October, water in the upper water column is 1-5 ppt (parts per thousand) fresher than at the 30 m level. The lack of data above 10 m from mid-March to mid-May suggests that an ice ridge formed and remained over the mooring until break-up commenced. Some of the data gaps earlier in the record are caused by ice avoidance, but others are a result of mooring knock-down in high currents.

The six-year series of comprehensive data we have now collected and analyzed, has allowed us to determine transports through Barrow Strait to a greater certainty than has been possible for any of the pathways that connect the Arctic Ocean to the Atlantic Ocean. We have found that the average freshwater flux through Barrow Strait is 1500 km^3/year, which is about 20% of the total freshwater export out of the Arctic Ocean, and substantially greater than previously thought. Seasonal variability is high as might be expected, with summer seeing the greatest freshwater transports, but more interesting is the substantial differences from year to year. We find that the annual freshwater transport can vary by as much as a factor of two from one year to the next. It seems then, that detecting a trend caused by increased ice cap melting will require a longer time series than we have collected to date. But correlations of the inter-annual variability we see in Barrow Strait with other components of the Arctic Ocean climate system are now being investigated. Slowly varying atmospheric patterns have a strong influence on the weather in the region, and likely generate oceanic response as well. Finding the links between the different components of this intricately coupled system will put us in a better position to predict how this sensitive part of the world will respond to climate change, and how changes there will affect the global ocean and climate systems.

Figure 1. Map shows the Canadian Archipelago and surrounding waters with pathways connecting the Arctic Ocean to the Atlantic, including the Barrow Strait study site. Perennial sea ice is shown in dark green while glaciers are shown in light green.

Figure 2. Mooring deployment preparations showing one of the instrumented buoyancy assemblies: the acoustic Doppler current profiler protrudes through the top of the package, while the compass is the silver cylinder mounted in the tail.

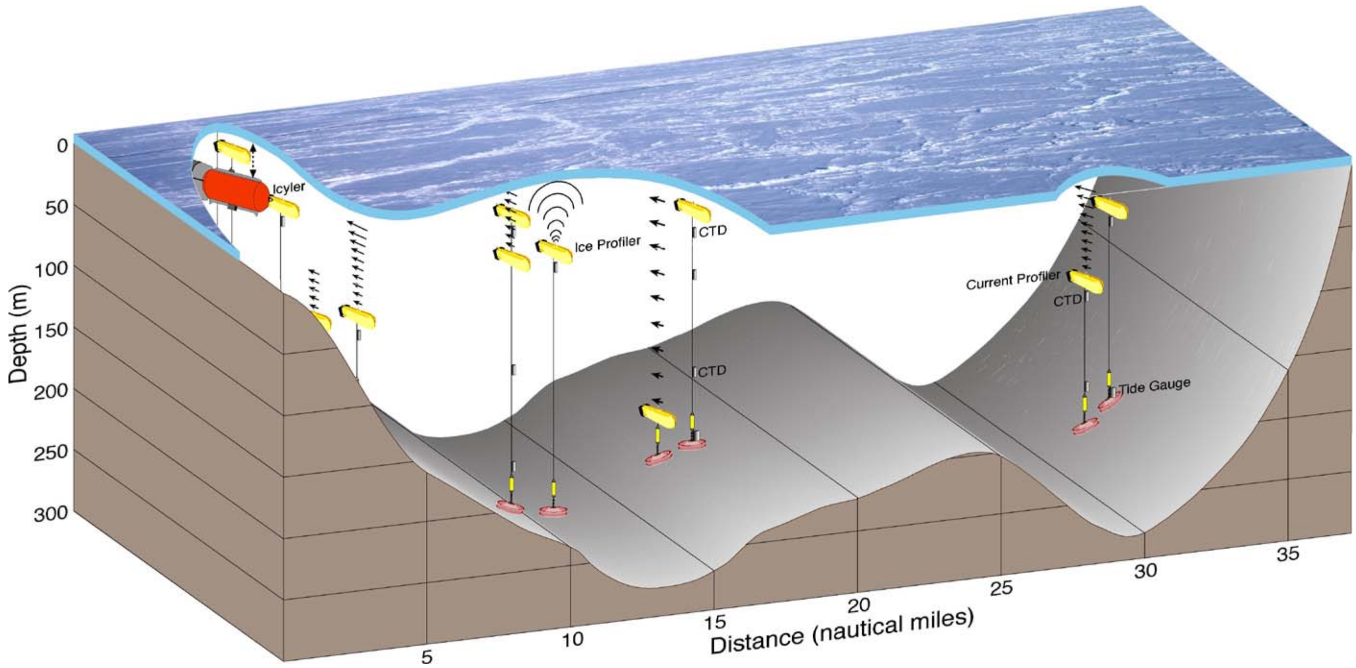

Figure 3. The instrumented mooring array across Barrow Strait

Figure 4. Deployment of an instrumented mooring

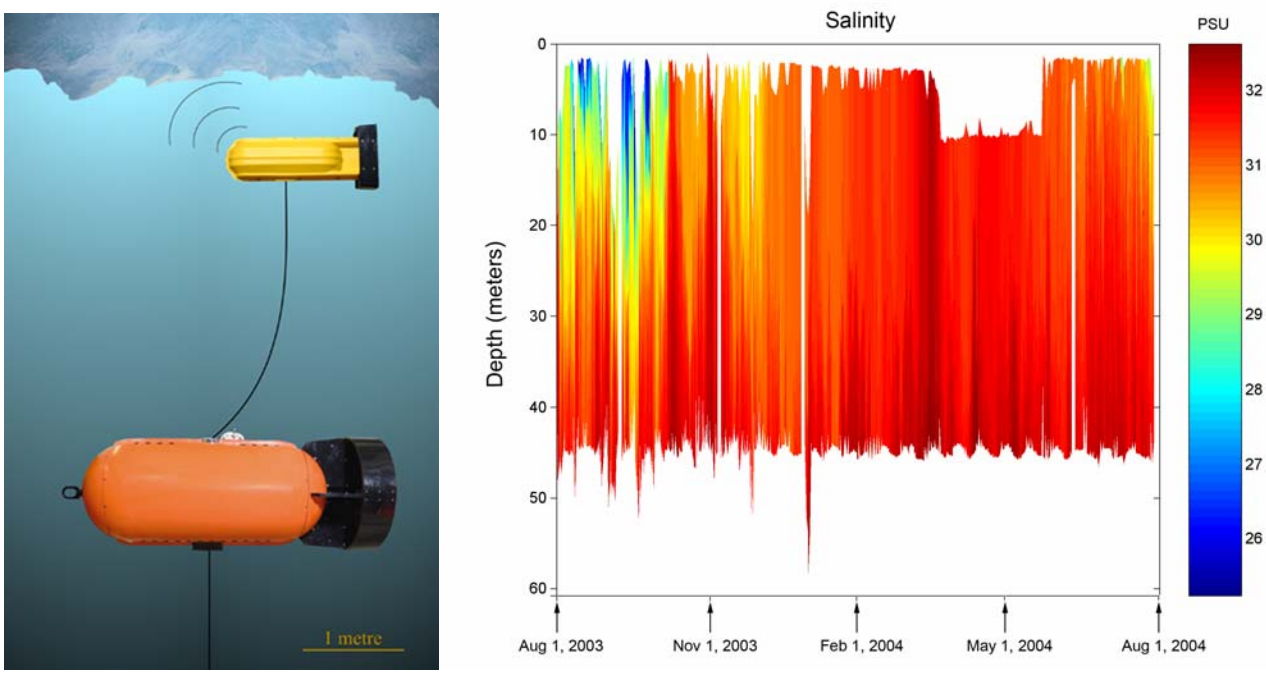

Figure 5. The "Icycler" Profiler, and a yearlong salinity record collected by the prototype in 2003-2004

Figure 6. A mooring recovery

Figure 7. Part of the Barrow Strait team, from back to front: Bosun Gilles Gaudet and Seaman Eric Frenette, CCGS Des Groseilliers*; Murray Scotney and Brian Beanlands, BIO*