John Walsh:
This is a nicely structured paper that addresses the drivers of the extreme ice loss in the Canadian Archipelago in recent years. The topic is certainly timely, given the fact that five of the six most extreme minima of ice coverage have occurred in the last six years. In addition, the loss of summer sea ice on a pan-Arctic scale has attracted huge attention, with increased shipping opportunities being seen as a potential opportunity. In this regard, the present paper complements the "look forward" to shipping opportunities in the CAA by Smith and Stephenson (2013, Proc. Nat. Acad. Sci.) – a paper that should be cited here.

The study spans a 45-year period, 1968-2012, which provides temporal context beyond the usual post-1978 period of passive microwave satellite coverage. While the longer timeframe is good for perspective, there have been changes in the available information sources, e.g., the recent availability of RADARSAT, IceSAT, IceBridge, in addition to coverage by satellite passive microwave sensors. The heterogeneity of available information has less impact on the study than could have been the case, however, because the four minimum-ice years of greatest focus have all occurred in the most recent 15 years (1998 onward).

Howell et al.
Smith and Stephenson (2013, PNAS) as well as Stephensen et al. (2013; Climatic Change) are now cited in Section 7 of the manuscript and now in the list of references.

John Walsh:
The authors do a commendable job of sorting out the dynamical drivers and the thermodynamic drivers. The computed dynamical transport into (or out of) the key CAA passages is a strength of the paper. However, the paper is somewhat murky (i.e., nonquantitative) about the effect of thermodynamic forcing anomalies. The uncertainty enters through the amount of ice loss that can occur via melt during a summer season. Specifically, how much thickness can be lost by melt in a single melt season? The conventional wisdom seems to have been 1 to 2 meters in the central Arctic, with the greater amounts near in the marginal ice zone. On p. 1328, for example, the authors the authors say that "the imported MYI subsequently melted" in 2012. The MYI thickness in 2012 was 3.7 m, which sounds like a lot of ice to melt. If 3.7 m could melt in 2012, how about the 5.2 m of MYI in 2007? Is there a limit to the thickness that can be lost by melt in one summer? More generally, it would be helpful to address the thermodynamic impacts of the air temperature anomalies reported here. How much additional melt results from a 2_C air temperature anomaly (Fig. 7) over the course of a four-month melt season? (Empirical rules based on thawing-degree days could be used for back-of-the-envelope calculations, although I suppose the picture is complicated by variable amounts of open water and associated heat absorption). In a similar vein, how much additional melt occurs when there is a lengthening of the melt season by a week? A related question is: How does one distinguish loss of MYI by melt from loss of MYI by ice export?

Howell et al.
When comparing 2007 to 2012, more imported Arctic Ocean MYI melted in 2012 (Fig. 5b) because it was thinner and more vulnerable to atmospheric forcing. However, when we stated "the imported MYI subsequently melted" in 2012 we were referring primarily to the MYI that was imported via the M'Clure Strait, not the QEI. Upon re-reading our original text, it does seem

to indicate that we were suggesting all the MYI flowing into the CAA in 2012 melted but our intention was to only to point out that the MYI entering the CAA through the M'Clure Strait did melt out. Indeed some (not all) of the MYI following into the QEI from the Arctic Ocean likely melted given the strong warming signal but it is difficult to ascertain how much. We have revised this section of the text to avoid this confusion. We have also added ICESat and IceBridge ice thickness values just out side of the M'Clure Strait to provide further evidence of thinner ice flowing into the CAA.

We have chosen to avoid including the back of the envelope calculation within the text because there is a lot of uncertainty in the QEI and M'Clure Strait regions regarding percentage losses due to melt versus export – this is the subject of an entirely separate analysis currently being conducted for the entire CAA. It is however worth mentioning that there is no uncertainty in melt loss versus export for the regions south of Parry Channel where ~100% of the MYI loss in years like 2007 and 2012 was due to melt.

The revised paragraph with modified Figure is as follows:
"Pre-melt season ICESat and IceBridge derived ice thickness values in the Canadian Basin, adjacent to the main Arctic Ocean-CAA ice exchange gates are presented in Table 1 and the corresponding anomaly time series is presented in Fig 15. Ice thickness values have clearly decreased near the QEI exchange gates following the 2007 melt season and near the M'Clure Strait gates decreases are apparent following the 2006 melt season. Some recovery in 2009 and 2010 was apparent but values were still thinner by almost 1 m when compared to pre-2005 values. Prior to the melt seasons of 2011 and 2012, which experienced record low conditions, Arctic Ocean ice thickness near the exchange gates were almost 2 m thinner compared to 2004-2006 values (Table 1). Given these considerable reductions in thickness, it is very likely that the Arctic Ocean MYI that has entered the CAA following 2006 at the M'Clure Strait gate and following 2007 at QEI gates has become more vulnerable to positive summer SAT forcing contributing to more direct melt loss when compared to previous years. Arctic Ocean net ice import during September was similar for 2007 and 2012 at the QEI exchange gates (Fig. 10a) but only sustained increases were observed in 2007 (Fig. 5b) suggesting Arctic Ocean MYI is now less resistant to in situ melt in the CAA because it has thinned over the last 4-5 years. Additional evidence of preconditioned Arctic Ocean ice thinning is also apparent in 2012 during which almost no Arctic Ocean ice inflow into the CAA via the M'Clure Strait survived the melt season. Specifically, atmospheric circulation in August 2012 drove the inflow from the Canadian Basin into the CAA via the M'Clure Strait (Fig. 10b), but by the end of the melt season most of this ice melted (Fig. 5b). In recent years large amounts of Arctic Ocean MYI circulating around the Canadian Basin to the Eurasian Arctic have melted out in the vicinity of the Beaufort Sea (Kwok and Cunningham, 2010; Stroeve et al., 2011b) and Maslanik et al. (2011) found that the extent of ice older than 5 years has decreased considerably following 2007."

Table 1. ICESat and IceBridge ice thickness estimates within the Canadian Basin just north of the Arctic Ocean-Queen Elizabeth Islands (QEI) and Arctic Ocean-M'Clure Strait ice exchange gates, 2004-2012.

Year	Ice Thickness (m) QEI	Ice Thickness (m) M'Clure Strait	Sensor	Date
2004	5.6	3.5	ICESat	Feb-Mar
2005	5.6	3.6	ICESat	Feb-Mar
2006	5.1	4.0	ICESat	Feb-Mar
2007	5.2	2.8	ICESat	Apr-May
2008	3.3	2.3	ICESat	Feb-Mar
2009	3.9	2.5	IceBridge	April 2 and 21
2010	4.4	2.7	IceBridge	April 5 and 21
2011	3.7	N/A	IceBridge	March 16
2012	3.3	1.4	IceBridge	March 19 and 22

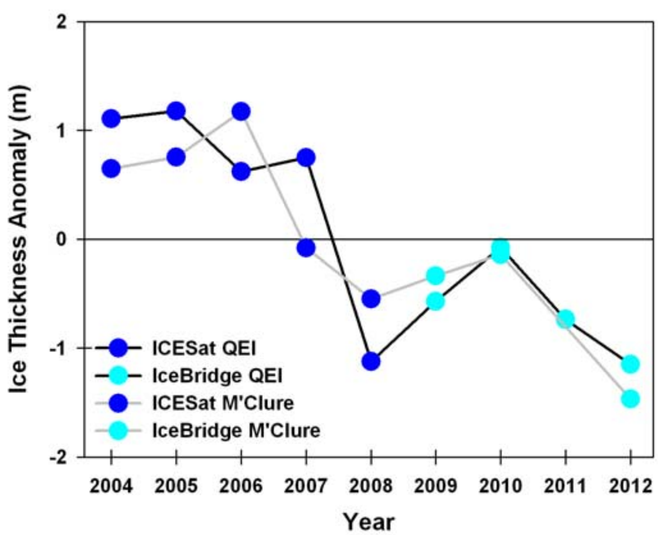

Figure 15. Time series of ICESat and IceBridge winter Arctic sea ice thickness anomalies in the Canadian Basin just north of the Canadian Arctic Archipelago, 2004-2012. Anomalies are calculated with respect to the 2004-2012 period.

John Walsh:
Because of the availability of some information (particularly RADARSAT), there was some subjectivity in the choice of the four "heavy" years. According to p. 1318, 1997 (5th heaviest) and 2004 (6th heaviest) were used instead of 1978 (3rd heaviest) and 1986 (4th heaviest) because the additional information was available for the more recent years. Would the conclusions have been the same if the four "heavy" ice years had been the four heaviest? There is certainly air temperature and sea level pressure (wind) information available for the earlier heavy years.

Howell et al.
Yes, the conclusions are the same. We were careful about the selection of 1997 and 2004 over 1978 and 1986 for this very reason. 1978 and 1986 exhibited almost an identical total ice and MYI evolution as the 1st and 2nd heaviest light years and discussing their evolutions would have been redundant. Specifically, ice replenishment was almost entirely FYI aging to MYI from cooler temperatures and dynamics were restricted because ice congestion – analogous to 1972 and 1979. We have added note to our text to make this clear.

The revised paragraph with modified is as follows:
"The years of 1972, 1979, 1997 and 2004 were selected as the extreme heavy ice years to compare against the four extreme low years of 1998, 2007, 2011 and 2012. 1972 and 1979 rank as to the two years with heaviest September ice conditions since 1968. 1997 (5th heaviest; Fig. 2) and 2004 (6th heaviest; Fig. 2) were selected instead of 1978 (3rd heaviest; Fig.2) and 1986 (4th heaviest; Fig. 2) because the source of the CAA's MYI changed from FYI aging to a combination of FYI aging and Arctic Ocean MYI inflow in 1995 (Howell et al., 2009). Selecting heavy ice years in both periods allows for a more representative investigation of the processes behind heavy ice years. Moreover, 1978 and 1986 exhibited almost an identical ice evolution as the 1st and 2nd heaviest ice years and discussing their evolutions would have been redundant (i.e. the conclusions of the paper do not change)."

John Walsh:
Figure 2 shows some interesting changes over time in the FYI/MYI area ratio. The ratio has become much larger in June and smaller in September. Is this evolution a manifestation of thinner FYI, in addition to the reduction of MYI area in early summer?

Howell et al.
The changes in FYI/MYI ratio are likely the result of a combination of different processes. The first being that thinner FYI is no longer able to survive the longer melt season resulting in larger FYI amounts at the start of the melt season. The second is increases in FYI at the start of the melt season are also likely attributed to a reduced amount of MYI being imported into the CAA the previous season. These processes are beyond the scope of this study but are currently being investigated by looking at long term changes in Arctic Ocean-CAA ice exchange.

John Walsh:
It would be nice to include a plot of fast ice thickness by year (to accompany the trend values in Table 2).

Howell et al.
Done.

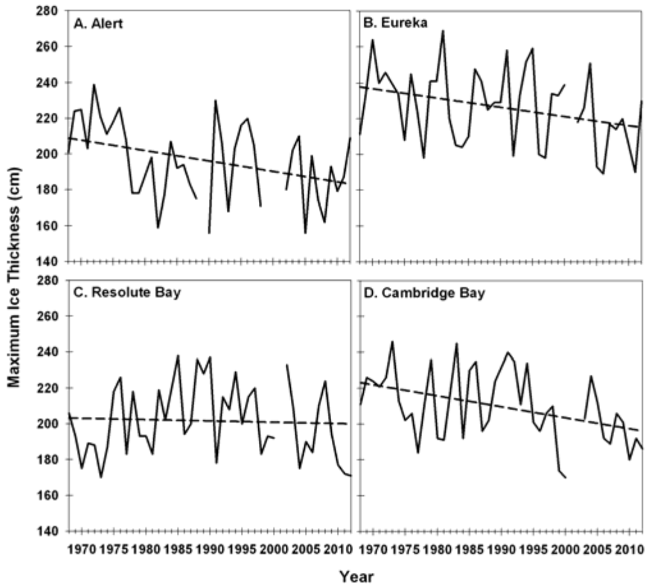

Figure 16. Time series of maximum landfast ice thickness at Alert (a), Eureka (b), Resolute Bay (c) and Cambridge Bay (d), 1968-2012. The dashed line represents the linear trend.

John Walsh:
P. 1329 (lines 19-26): The inferences about inflow and outflow for 1972 and 1979 vis-àvis the SLP patterns (Fig. 13) seem unclear because the discussion does not include explicit mention of wind directions. It would be helpful to clarify which wind directions create inflow for McLure Strait and the QEI region. Can MYI enter the QEI region from the east as well as the northwest?

Howell et al.
Typically north/northwesterly winds create inflow but open water leeway has to be available in the channels. We have added information of wind direction to the text but very little exchange occurred in 1972 and 1979 because of ice congestion (i.e. no open water leeway).

John Walsh:
P. 1316 (also p. 1335): The more precise statement would be "5 of the 6 lightest years in the CAA since 1968 have occurred in the last 6 years".

Howell et al.
Changed both instances.

John Walsh:
p. 1328: Related to my first main point, it seems that pre-existing MYI (not just imported MYI) may also have melted.

Howell et al.
This comment was addressed in response to the first main point.

John Walsh:
P. 1333, lines 13-15: "The only other time period the northern route experienced a longer navigation season was from 1998-2000...". Longer than what? According to Fig. 16, the navigation season lengths of 1998-2000 were not longer than the past several years.

Howell et al.
Rephrased: *“The only other time period the northern route experienced a navigation season longer than 1-2 weeks was from 1998-2000 that was also associated with the extreme sea ice minima (i.e. 1998).”*