The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2018-136-AC2, 2018

The Cryosphere Discussions

Interactive comment on "Satellite-observed sea ice area flux through Baffin Bay: 1988–2015" *by* Haibo Bi et al.

Haibo Bi et al.

bhb@qdio.ac.cn

Received and published: 30 November 2018

In reference to the review criteria provided by The Cryosphere (https://www.thecryosphere.net/peer_review/review_criteria.html), I submit the following general commentary on this work. The scientific quality of this work is Fair. The purpose of the work is articulated, however the objectives laid out in the second-to-last paragraph of the introduction section do not strike this reviewer as testable hypotheses. They are rather statements resulting in the paper becoming something of a data report. The analyses presented are somewhat perfunctory, and potentially these points indicate a lack of understanding of the physical atmospheric and/or oceanic processes acting on the surface (ocean or sea ice) within Baffin Bay.

Response: Thanks for the overall insightful comments. In the revised manuscript, we make it clear that our primary attempt is to quantify the sea ice inflow and outflow components through the key fluxgates of Baffin Bay and to investigate the related causes for their variability and trends. According the suggestions of reviewers, the fluxgates have been reslected to account for different sources of ice (Figures 1 and 4). In addition to the interannual variability, the trend of sea ice area flux for different gates are discussed and possible causes are analyzed. Compared with the first submission, we try to present our study in a form of investigation rather than a data report. We present more knowledge with regard to the atmospheric and/or oceanic process. For instance, the general circulation pattern of ocean currents in the bay is shown in Figure 1. The description of NWP (Figure 6) and associated ice bridges in Nares Strait are given (Figure s1). Additionally, the fast-ice extent is presented in Figure 2 to discriminate the grid cells with a zero flux and interpret the slow ice motion in the areas nearby the coast. For the first time, the inflow and outflow components through Baffin Bay over the past nearly four decades (1978/79-2016/2017) are quantified (Sec.4, Figures 10 and 11). Further investigation suggests that, the warmer atmosphere are found to be a main driver to the increased sea ice motion as well as the area flux to a thinner ice floe in the bay (Figures 15 and 16). Therefore, in the new submission we made efforts to improve the understanding of the variability and trends of Baffin Bay sea ice area flux associated with inflow and outflow components (See the discussion section, Sec.5) for more details).

The first mention of the hemispherically significant North Water Polynya does not occur until Line 6 on page 23 of this work. In this vein, it's not really explained that the sea ice in Baffin Bay may be as a result of import from the Lincoln Sea as a result of motion through Nares Strait, Kane Basin, and then Smith Sound before it might either enter Baffin Bay, or encounter an ice-bridge blocking inflow to Baffin Bay from the north. The annual and seasonal presence/absence of this very important ice-bridge feature and the amount of MYI imported from the North is not explicitly investigated in this work.

Response: As North Water Polynya (NWP) is an important scenario in the northern Baffin Bay (Figures 1 and 6). In this study, we outline its importance and location not only in the introduction section, but also in the description of sea ice condition in Section 3.1 (Figure 6, panel for April). Moreover, the contribution to the sea ice inflow into Baffin Bay is quantified. The presence and absence of ice-bridge in Nares Strait are illustrated in Figure S1 and its importance to sea ice flux stoppage is discussed in the relevant texts. Anyway, the significance of NWP and ice bridge are reiterated in the new submission. The importance and effects of sea ice bridge to block ice inflow are outlined in the revised manuscript (Section 2.1.3). Figure S1 gives a typical case of ice bridge formed in Nares Strait. However, due to the coarseness of NSIDC ice motion data (25km), compared to smith sound ($\sim$30 km), it is unlikely to accurately estimate sea ice flux in such a narrow gate. For narrow fluxgate like Smith Sound, land contamination would be a server problem to satellite observations. Instead, with reference to a published result of between 1996/97 and 2008/2009 about ice flux via Nares Strait that was derived high-resolution satellite observations (such as SAR in Kwok (2007), with a spatial resolution of several hundred meters), we get an estimate of ice grown in NWP. That is, by subtracting the inflow from Nares Strait and inflow from Jones Sound from the ice inflow across the North Gate, the part of sea ice grown in NWP is then obtained as, on average, 78%$\sim$85% of the inflow through the North Gate

First-year stages of development of sea ice in Baffin Bay may then also have been grown in place within the North Water and exported southward, depending on the formation of the ice-bridge, and the amount of ice in the Bay, which has been imported from the Canadian Arctic Archipelago (CAA), mostly through Lancaster Sound.

Response: In the revised manuscript, the sea ice area inflow to the Baffin Bay and ice produced from NWP are both quantified. Please see Section 5.1 for the investigation of the possible ice sources for sea ice entering into the Baffin Bay.

Since the authors chose a position for their northernmost 'Gate A' south of Lancaster Sound, the flux of sea ice from the CAA in the west, or from Smith Sound in the north,

cannot be differentially discerned. Other important considerations that occur to this reviewer include sea ice melt during transport southward within Baffin Bay, especially considering that new and young stages of development (<30cm thick) may be grown and exported from the North Water Polynya.

Response: Following the suggestions and in order to discern the diverse Baffin Bay sea ice inflow ice sources, we redefined the North Gates to a further north location (Figure 4). Examination of sea ice inflow through the North Gate reveals that NPW is the main contributor of inflow (Section 5.3) and a smaller fraction of inflow come from Nares Strait (Section 5.1) and/or Jones Sound. In addition, sea ice inflow through the Lanscater Sound is also obtained (Section 5.2). Meanwhile, taking into account the outflow of sea ice via the South Gate, we find a net gain of sea ice between the regime of $\sim$65°N and $\sim$75°N within the bay during cold periods (winter and spring) and a net loss during warm melting period (autumn and summer). The addition of sea ice is mainly through the freezing mechanism whereas the ice loss is caused by enhanced melt during transport southward within the Bay. Please refer to section 4.2 for more information.

Finally, it might be that the authors have not accounted for the presence of fast ice around Baffin Bay in fall, winter and spring, especially on the Greenlandic (east) ends of their passages A, B, and C. All of these points above make the comparison of these presented data in Baffin Bay to the data presented from Fram Strait a bit of a stretch to this reviewer. I appreciate that Kwok 2007 makes a comparison of the annual volume export he calculated for Baffin Bay and Davis Strait to the annual export of sea ice through Fram Strait, but it's my opinion that Kwok made that comparison in his 2007 work to simply highlight the amounts of sea ice exported southward in the two regions, and not to compare the processes or sea ice stages of development that typically are exported in the two areas which are not physically similar.

Response: In the new submission, land-fast ice distribution is discerned from Canadian Ice Service (CIS) atlas (as shown in Figure 4). According to the suggestions, we

remove the comparison with sea ice area flux through Fram Strait. The fluxgates are reselected. The North Gate and Lanscater Sound are chosen to stand for ice inflow while the South Gate is selected to represent the ice outflow via Baffin Bay. The middle gate is not useful to convey new knowledge and not kept. The North Gate is different from the first submission for its relocated place toward further north. This gate is designed to provide valuable information about ice inflow from different ice sources, including Jones Sound, Nares Strait, as well as NPW.

The significance of this work is Poor. I think especially a re-worked version of this paper could improve our understanding of sea ice flux form this important region, but as it stands this work falls short of improved scientific understanding of the region and its relevant physical oceanographic, atmospheric, and/or sea ice processes. The analyses are comparative rather than investigative, and their presentation is in the style of a data report.

Response: Compared with the first submission, we try to present our study in a form of investigation rather than a data report. We present more knowledge with regard to the atmospheric and/or oceanic process. For instance, the general circulation pattern of ocean currents in the bay is shown in Figure 1. The description of NOW (Figure 6) and associated ice bridges in Nares Strait are given (Figure s1). The fast-ice extent is presented in Figure 2 to discriminate the grid cells with a zero flux and interpret the slow ice motion in the areas nearby the coast. For the first time, the inflow and outflow components through Baffin Bay are quantified for the past nearly four decades (1978/79-2016/2017) (Sec.4, Figures 10 and 11). Further investigation suggests that, the warmer atmosphere are found to be a main driver to the increased sea ice motion as well as the area flux to a thinner ice floe in the bay (Figures 15 and 16). Anyway, in the new submission we made every effort to advance the understanding of the variability and trends of Baffin Bay sea ice area flux associated with inflow and outflow components (See the discussion section, Sec.5) for more details).

The presentation quality of this work is Fair. The figures are too numerous, and each

conveys too little information. The authors convey too much data in Tables, while the text does not explain either the figures or tables more than superficially. This work is way too long, and clarity of direction is missing from the objectives onward through the results and discussion sections. The reason for the decadal period break at 2000/2001 is not obvious to this reviewer. It seems a break of convenience rather than scientific reasoning. Little in the way of conclusions is presented in that section of the text, though ": : :A comparison shows that our SIF estimates are reasonable consistent with previous results" (page 25 Line 8) is encouraging, it's not a conclusion. There are two more conclusions stated in Lines 9-11 of Page 25, but their validity is brought into question for this reviewer by the changing definition in the work (Oct or Nov to May depending on the section I read). The conclusions based on the three defined Gate locations make this reader interested in why their locations were chosen (especially given my previous note on the position of the northernmost Gate)? The last two paragraphs of the conclusions section are statements, which cannot be concluded as a result of the new work presented here.

Response: Based on the suggestions, we remove the numerous figures and Tables that convey little usefule information. The main objective of this study is clarified in the Introduction section, including the quantification of sea ice inflow and outflow of Baffin Bay, the examination of the variability and trends of ice area flux, as well as the investigation of causes for the observed trends in ice motion and area flux. We remove the discussion of area flux associated with climate change with a break of decadal period at 2000/2001 since this simplified partition has no clear geophysical implications rather than for the convenience of calculation. Rather, the month-to-month variability of sea ice area flux across the fluxgate for different decadal periods are given in Figure 10 (Sec. 4.1). Throughout the revised manuscript, the definition of seasonal and annual fields, as in reference to sea ice area flux, are clarified in the associated texts, with Winter spans from December to February, spring (March-May), summer (June-August), autumn (September-November), and the annual cycle (September-next August). We remove the middle gate since the little useful information is conveyed by

the comparison with other gates. Besides, comparing with the first submission, the location of the fluxgates to study the sea ice area flux are relocated, especially for the northward shift for the North Gate (Figure 4). The redefinition of the North Gate is favorable to the quantification of ice production in NWP (see 5.1.3 for more details), the well-known recurring polynyas in the northern Baffin Bay.

Specific Comments: P1. L12: This sentence should make some reference to sea ice melt? L14: Why three passages, this really isn't useful information in the abstract given there is no geographical reference to their actual positions. L20: Causation is not shown in the work. Could the decline in SIM be a result of the fact that the SIM data are calculated in part from the SIC data? L24: Unclear what you mean here.

Response: P1. L12: we have rewritten the sentence to refer the exported sea ice from Baffin Bay as one of important solid fresh waters input to the seas downstream. L14: The passages are redefined in the new submission and renamed with a reference to its location: North Gate, South Gate, and Lanscater Sound, etc. L20: The causation of the increased SIM is presented in the revision. L24: The ambiguous sentence has been removed.

L28FF: The data exist to determine if the sea ice is in free drift in Baffin Bay and Fram Strait, but quantification is not attempted. Not sure why the authors insist on acronyms, especially for Fram Strait?

Response: This sentence is removed since the comparison with Fram Strait conveys limited knowledge. The acronyms 'FS' for Fram Strait is not saved in the revision.

P2. L7: What is the potential impact? L9: Does outflow imply melt?

Response: Since outflow does not necessarily represent melting, we remove the sentences.

P3: L1: "passages" is a poor word choice, my opinion only. L2: Is there an effect to the trends/forcing? L5: What is the point of the comparison to Fram Strait? L7: "preferred:

: :" Whose preference? Why? L28: I wonder what causes the discrepancy in the SMMR and SSM/I records with respect to sea ice motion data?

Response: L1: we use fluxgate or gate instead of passage. L2: There is not an effect to the trend from the atmosphere (Section 5.1 or Figure 14) and the causes for the trend are examined with respect to ice thickness changes (Section 5.3). L5: The comparison is removed. L7: The analysis with large-scale atmospheric index is not held in the revision according to suggestions of the reviewer. In the revision, connections with regional atmosphere variability, with reference to cross-gate SLP difference, is taken as an important predictor for the variability in Baffin Bay sea ice area flux. L28: The sea ice concentration is available every other day for the period of SMMR which would bring a discrepancy. A temporal interpolation method is used to fill the gap and daily SIC is obtained for the period Nov 1978 to July 1987. Thereby we can extend the whole study time series to 1978/1979-2016/2017.

P4. L5-9: this whole section is worded like the authors actually did this processing? Response: The relevant reference has been added in the revision.

L10: Maybe use the whole words? Especially in a Section Heading? Figure 1: The position of Gate A is too far south to allow for quantification of ice flux from Lancaster Sound. I'm not really sure of the point of Gates B and C unless there's some quantification of melt? There's no scale for the magnitude of the vectors displayed on the figure. Response: L10: the whole words is used in all Section Heading. The position of the North Gate is moved to further north and the ice flux from Lanscater Sound is quantified. Gates B is removed as no information of melt can be derived. The scale of the magnitude of ice motion vectors are added on the relevant figures. The fluxgates are rearranged in the revision (Figure 4). The North Gate and Lanscater Sound are chosen to assess ice inflow while the South Gate is selected to study the ice outflow via Baffin Bay. The middle gate is not useful to convey new knowledge and not kept in the revision. The North Gate is different from the first submission for its northwardly relocated place. This gate is designed to provide valuable information about ice in-

flow from different ice sources, including Jones Sound, Nares Strait, as well as NPW (Section 5.1.3).

P5. L8-10: What is the mechanism for ice motion through Baffin Bay with the NAO atmospheric patterns? Especially considering the height of the Greenland Ice Sheet that separates the Icelandic low from Baffin Bay? Does it even make sense that the NAO should drive ice drift in Baffin Bay? Some justification of this use of the NAO should be made?

Response:L8-10: Based on the suggestions, we remove the analysis with regard to the connections between NAO and sea ice drift in Baffin Bay.

L17-24 and Table 1: Why order the Gates A, C, B, in the explanation of their positions? Why are all their lengths different in the text and the table? Seems like those lengths should be consistent?

Response: The gates have been redefined and relocated for A (the North Gate), and the middle gate (B) is removed in the revision. Gate C is renamed as the South Gate. The reasoning to rearrange the fluxgate is mentioned above. In addition, we examine the texts and table to ensure a consistent use of the length for the Gates.

P6. L2-3: Is this assumption valid? L11: Maybe call the Gates “North”, “Mid”, and “South” if you’re going to continue using three so their positions are immediately apparent to the reader?

Response: L2-3:The assumption is widely adopted in previous studies and especially one may refer to Kwok’s studies associated with sea ice area flux. L11: The Gates are renamed following the suggestions to specify the geographic information.

L14, L16: Here’s where I first noticed that the months used for “winter” change constantly through the work. Nov-May vs. Dec-May? There’s got to be a consistent set of winter months used I think? This really reduced my trust in the analysis presented. L18: Where is the Cuny Gate in relation to Gates B, or C?

Response: L14, L16: In the revision, four seasons are considered, including the winter (Dec-Feb), Spring (Mar-May), summer (Jun-Aug), and autumn (Sep-Nov). Also, the cold period is referred to include the winter and spring months while the warm period spans the summer and autumn months, if no particular annotation is given. These definitions hold constantly in the new submission unless particular annotation is shown. L18: Cuny’s estimate is related to the South Gate in the revision (Figure 4). In Figure 5, the comparisons are confined to a time span from Nov to May in the following year.

P7. Figure 2: The lines, colours are too hard to discern. Now winter is Nov-May. L12: Now winter is Oct-May? There are a bunch of typos in this paragraph. L13: It’d be nice to see the sea ice concentration data? L14: Where is the wind forcing data?

Response: The figure is modified to make a discernable color. To neatly convey information about sea ice drift pattern in Baffin Bay, this part has been reworked in the new submission (see section 3.2)

P8. Figure 3: The previous figure was in cm/s, now we’ve changed to km/day, and we have a legend for the magnitude of the quivers. Maybe add the Gates to the figure? It would be nice to see the actual sea ice concentration? What portion of the sea ice motion in Baffin Bay is driven by ocean currents? L3: Doesn’t the data exist to determine this? Even the magnitude of the gradient? L6: Could the pattern not be visible due to your use of monthly averages? Seems like the higher the ice concentration the more likely that ice motion events might be temporally discrete due to the magnitude of the forcing required?

Response: Figure 3: The unit has been changed to km/day throughout the manuscript. The sea ice concentration changes of an annual cycle are shown in Figure 6. The portion of sea ice motion driven by ocean currents can be observed through the comparison with Figure 1 and Figure 6. Relevant explanations have been given in associated texts in the revision. Besides, the sea level pressure (SLP) fields are overlaid on Figure 6. The presence of SLP is helpful to distinguish the effects of wind forcing on facilitating

the sea ice motion ice motion in Baffin Bay.

P9. L5: Why 4c before 4b? Figure 4: I don't understand why the comparison to Fram Strait. Probably should specify the Gates in the figure caption? L16-17: Why not quantify this? Also now winter is Dec-May?

Response: Following the suggestions, the comparison with Fram Strait is removed and the figure captions as depicted in Figure 10 is specified. The season discrimination is redefined (see response above).

P10. L7: There seems no scientific reason to break at 2000? L9: Now December is in the autumn? L15: What use the sci.notation? Why not just write -21km2/day? L31: Not really a decadal change, it's a change between two decades.

Response: Based on the relevant suggestions, we removed this part of results.

P11.L12: Now winter is Nov-May P12. L10-11: This is not a result of this work and is left unsubstantiated.

Response: in the revision, the delayed ice freezing period due to warmer climate is refer to the published literature of Stroeve et al. (2014) (see P22. L21 in the revised manuscript)

L8: I don't know where this statement comes from. It' unsubstantiated by the work presented.

Response: the summer or autumn trend in ice flux is negligible and no further analysis is given in the revision.

P14. Table 1: There's a better way to graphically display the pertinent/important parts of this Table. You're asking the reader to do too much work to understand your analysis.

Response: The table is removed for a clear interpretation but rather a comprehensive figure is provided (Figure 14)

P15-16. Figures 8, 9, 10: These figures are to small, to hard to read. Why use the three different significance levels? Figure 10: the y-axis keeps changing, makes it hard to compare within the columns.

Response: Since these figures show little useful information, we remove them and integrate them into a comprehensive one (Figure 14). More details are given in the following associated texts.

P17. L3: The increasing sea ice motion trend is not caused by a positive sea ice flux trend; you've put the cart before the horse here. L12: now winter is from Oct-May

Response: Reformulated as suggested.

P18. L3: What's the point of this section? L4: What does this sentence actually mean? Maybe this is some reference to melt within an area between two Gates?

Response: This part is reworked and relevant explanation is reformulated in the revision, please see section 4.2 for more details.

P20. L15FF: What about the source of the exported sea ice? Smith Sound? Grown in the Northwater? From the CAA through Lancaster Sound? Surface winds in Baffin Bay are tricky to model because of the elevation of the Greenland ice sheet and the CAA islands? How well do these model winds actually represent reality? L16: What do all these acronyms mean? L20: Surface winds towards the southeast are northwesterly winds.

Response: The inflow components to Baffin Bay from diverse sources, Nares Strait, Lanscater Sound, or grown in the North Water Polynya are discussed in Section 5.1. Wind data is not used in the revision.

P22. This whole page seems like conjecture, it should all actually be borne out by some analysis. Kind of seems like the authors are listing possibilities rather than elucidating processes.

Response: In order to understand the associated air and physical processes, we investigate the connections of sea ice flux variability with cross-gate SLP difference (Sec. 5.2), and examine the linkage between ice motion and ice thickness through a preliminary simulation (Sec. 5.3).

P23. L16-17: isn't the NAO calculated from the pressure difference between these two atmospheric phenomena? Hurrell 1995?

Response: NAO is not considered in the revision based on the above comments of the reviewer.

P24. L16-18: The internal stress of the sea ice pack should be able to be approximated at least. This sentence seems like conjecture as is.

Response: The linkage to a faster movement of ice pack is mostly attributable to ice thickness decline and the analysis with internal stress is beyond our scope of this study.

P25. Figure 17. Any actual information in these panels is undiscernable due to their size. Response: This Figure is removed in the revision.

There's no mention of the North Water Polynya in the conclusions section. L15-20: I think the statements in this paragraph remain unsubstantiated by this work. What about fast ice extent? The last two sentences are not conclusions of this work. I don't really understand why you've listed surface winds and sea level pressure because they're two sides of the same coin, same goes for SAT and SST?

Response: The NWP is reiterated in the revision. For instance, one may refer to Figure 1 and 6 and associated texts. In particular, Section 5.1.3 also specify the contribution of sea ice grown in NWP. We kept well-demonstrated SLP and SAT fields, and remove the SST and winds. As suggested, SLP and winds (or SAT and SST), reflect the same climatic scenario.

P26: These are not new results. As indicated in part by your reference to Kwok's papers. The last sentence of this paragraph is not a conclusion that is supported by

the work presented.

Response: The conclusions are reworked and the associated unproven texts are eliminated.

Please also note the supplement to this comment:
https://www.the-cryosphere-discuss.net/tc-2018-136/tc-2018-136-AC2-supplement.pdf

---

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2018-136, 2018.