Responses to referee #1

Dear Reviewer:

We would like to thank you for the constructive comments to improve this manuscript. We overall agree with the points raised by the referee, and the points have been considered in revising the manuscript. In the following, our detailed responses are shown in italic.

Qinghua Yang

On behalf of all the co-authors

General Comments:

1) Use consistent use of shortwave and longwave (not short-wave, long-wave) throughout the paper. For example see lines: 202, 205, 215. Figure 6 caption uses correct form.

   Response: Thanks for the suggestion. We have now rephrased the texts in the revised.

2) Lines 86-88: Gate positions at 82°N between 12°W and 20°E and 20°E between 80.5 and 82°N are defined. Which position(s) are included in Table 1?

   Response: Table 1 includes the sum of sea ice export volume through the gate positions at 82°N between 12°W and 20°E and 20°E between 80.5 and 82°N. We have now added a new figure to the Supplement of the revised version of our manuscript (as shown in the Figure S1 below). The thick green line in Figure S1 represents zonal and meridional sea ice gates to derive sea ice volume flux through the Fram Strait.
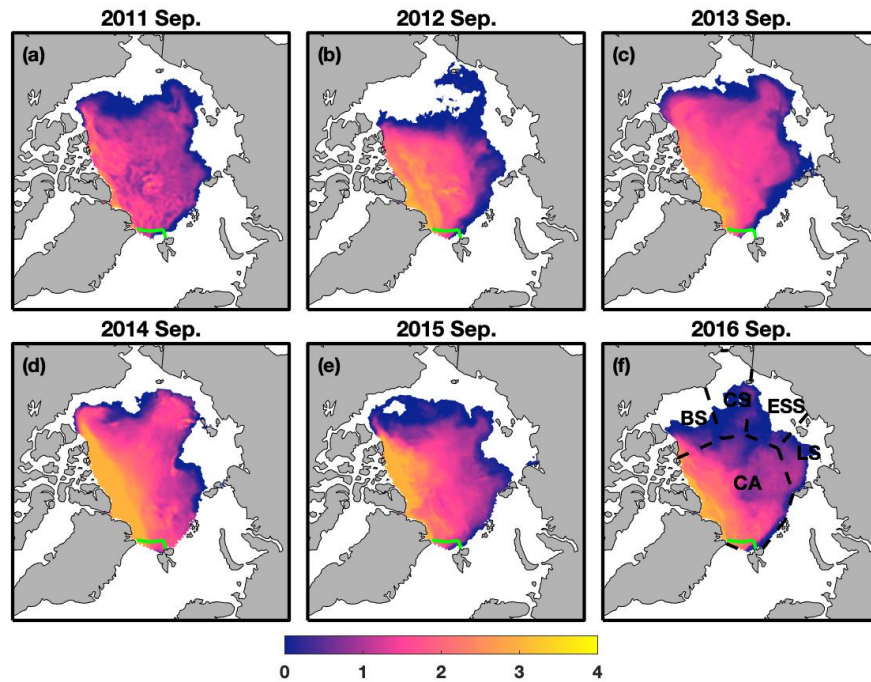
Figure S1. Arctic sea ice thickness in September calculated from CMST (2011–2016). The thick green line represents zonal and meridional sea ice gates to derive sea ice volume flux through the Fram Strait. (f) The mean sea ice thickness is computed within the Arctic basin bounded by the gateways into the Pacific (Bering Strait), the CAA, and the Greenland (Fram Strait) and Barents Seas subdivided into maritime boundaries provided by NSIDC via MAISIE.

3) Although not a major contributor to Arctic ice export, please comment on the role of the absence of ice arches (or bridges) in 2008-2009 and 2009-2010 (Ryan and Munchow, 2017) on the potential impact of ice export through the Fram Strait in those years.

Ryan, P. A. and A. Munchow (2017), Sea ice draft observations in Nares Strait from 2003 to 2012, J. Geophys. Res. Oceans, 122, 3057–3080, doi:10.1002/2016JC011966.

Response: The periods 2008-2009 and 2009-2010 actually are not spanned in our study. Nonetheless, we agree that the ice arches (or bridges) contribute to the ice export which is normally not well simulated in coarse sea ice models. We further addressed this potential effect in our manuscript:

"The sea ice arches over the channels and the fast-ice along the coast of the Arctic marginal seas may further add variability to the sea ice export through the Fram Strait (e.g., sea ice export study in Nares Strait by Ryan and Münchow, 2017)*. This potential impact is not considered in current study and will be investigated in our further research."*

Ryan, P. A. and Münchow, A.: Sea ice draft observations in Nares Strait from 2003 to 2012, J. Geophys. Res. Ocean., 122(4), 3057–3080, doi:10.1002/2016JC011966, 2017.

Technical Corrections:

1) Line 74: Should be CryoSat-2

   Response: *Done.*

2) Line 82: What is the source of the sea ice concentration used?

   Response: *The sea ice concentration data uses the concentration that comes with the CS2 product.*

3) Line 130: Do you mean CAA instead of CA? Line 145: Same comment as above

   Response: *Thanks for the suggestion. We have now rephrased the texts in the revised: "In the regions where multi-year ice exists along the BS and CAA, a strong sea ice thinning is found, only very weakly offset by convergence and advection (Figure 3f,g)." and "The enhanced transpolar advection transported sea ice from the BS and CAA to the Fram Strait (Fig.5a)"*

4) Line 170: Include years October **2011**-April **2012**

   Response: *We have now reworded this sentence to: The total sea ice and multiyear sea ice fluxes through Fram Strait from October **2010**-April **2011** are 1611±229 km3 and 1315 km3, respectively (Table 1).*

5) Line 233: I assume you mean "net surface shortwave"?

Response: We have now changed "net surface short" to "net surface shortwave" in the revised: In addition, the ice-albedo feedback also can modulate the net surface shortwave radiation.

6) Line 380: Include years of 2010, 2011 in caption.

Response: We have changed the caption, as suggested by the reviewer: "Figure 4: Monthly mean arctic sea (a) Arctic Oscillation index (b) ice export anomaly at Fram Strait (unit: km3 month-1; the positive anomaly represents more ice export), (c) surface air temperature anomaly (unit: K) and (d) surface net heat flux anomaly (unit: W m-2) from October 2010 to September 2011."

7) Line 385: Why not show 4-month averages for all 3 plots shown: Oct-Jan, Feb-May, June-Sep? Any particular reason why Fig. 5g, 5h. 5i encompass a larger area than the two panels above?

Response: The month division in Figure 5 is mainly based on the phase of AO index from October 2010 to September 2011. As shown in Figure 4a, AO has a continuous negative AO phase between Oct-Jan. In Feb-May, AO changes to a positive phase, while in June-Sep, AO returns to a negative phase.

The arrow in the top two panels represents the dynamic term of sea ice thickness budget and sea ice drift anomalies, so we need to plot the area with sea ice. Bottom panels show Winds and sea level pressure anomalies, so a larger area needs to be mapped to analyze the wind anomaly due to the pressure gradient.

8) Table 1: Include 6-year mean in bottom of table

Table 1: First- and multiyear ice (FYI/MYI) volume export through the Fram Strait in km3 month-1. The bold numbers indicate the anomalies are statistically significant.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	FYI	-	-	-	-	-	-	-	-	-	-13	-6	-20
2010	MYI	-	-	-	-	-	-	-	-	-	**-219**	-185	-218
	TOT	-	-	-	-	-	-	-	-	-	**-233±21**	-193±23	-241±42
	FYI	-36	-4	-132	-71	-71	-36	-25	-15	-1	-7	-14	-15
2011	MYI	**-201**	-29	**-306**	-157	**-205**	**-147**	**-90**	-46	-26	-142	-161	-274
	TOT	**-238±15**	-34±64	**-442±15**	-230±49	-279±39	-185±26	-115±17	-64±34	-27±28	-151±25	-175±18	-290±43
	FYI	-4	-32	-69	-147	-166	-103	-144	-91	-29	-36	-27	-28
2012	MYI	-136	-267	-197	-223	-164	-113	-37	-41	-66	-123	-123	-105
	TOT	-137±25	-300±38	-267±19	-372±21	-334±21	-218±19	-187±25	-131±42	-95±21	-160±13	-149±16	-134±23
	FYI	-23	-44	-109	-146	-118	-52	-38	-39	-8	-28	-85	-72
2013	MYI	-59	-64	-101	-69	-72	-90	-69	-60	-18	-198	-281	-117
	TOT	-78±12	-108±33	-217±22	-219±18	-194±20	-140±26	-107±36	-98±32	-25±18	-228±16	-367±25	-191±35
	FYI	-28	-65	-128	-229	-132	-105	-64	-85	-26	-6	-10	-55
2014	MYI	-34	-47	-148	-190	-100	-53	-48	-99	-172	-163	-151	-217
	TOT	-61±21	-114±14	-282±14	-425±13	-232±13	-161±20	-112±28	-184±8	-198±11	-170±5	-162±17	-275±26
	FYI	-44	-140	-145	-103	-68	-80	-58	0	-15	-2	-32	-99
2015	MYI	-76	-211	-188	-199	-99	-154	-53	-11	-92	-74	-157	-136
	TOT	-128±32	-355±23	-339±33	-308±12	-171±19	-239±14	-113±8	-11±27	-107±31	-78±18	-191±23	-244±24
	FYI	-69	-117	-80	-161	-126	-89	-56	-71	-5	-	-	-
2016	MYI	-74	-149	-201	-122	-56	-95	-46	-126	-70	-	-	-
	TOT	-145±24	-267±11	-287±23	-289±8	-196±9	-194±6	-113±26	-198±55	-75±13	-	-	-
	FYI	-34	-67	-110	-143	-113	-77	-64	-50	-14	-15	-29	-48
mean	MYI	-97	-128	-190	-160	-116	-109	-57	-64	-74	-153	-176	-178
	TOT	-131±21	-196±30	-306±19	-307±20	-234±20	-190±18	-125±23	-114±36	-88±21	-170±15	-206±18	-229±34