The Cryosphere Discuss., 6, C2131–C2149, 2012
www.the-cryosphere-discuss.net/6/C2131/2012/

The Cryosphere Discussions

Interactive comment on "Variability and trends in Laptev Sea ice outflow between 1992–2011" *by* T. Krumpen et al.

T. Krumpen et al.

tkrumpen@awi.de

Received and published: 6 November 2012

Dear Reviewer 2, we very much appreciate the careful and detailed work you did on our manuscript! We agree that the description of the dataset, as well as the error discussion became quite short. However, as you stated, a validation of the IFREMER ice drift dataset is beyond the scope of the manuscript in particular because the accuracy of the drift product was previously investigated by Rozman (2011) and Girard-Ardhuin (2012). Nevertheless, we agree that some parts of the methodology section require revision and a different structure. In particular the section that deals with the comparison of the IFREMER data with SAR and ADCP ice drift information is incomplete.

Please find our answers and revised sections (in latex format, marked with "...") to the questionnaire below. Again, many thanks for helping in improving this manuscript.

Best regards Thomas Krumpen

****

****

****

Comment: 2893, L15: “Smedsrud et al. (2011)” instead of “Smedsrud and Skogseth (2011)”. This reference is wrong several times in the text. Please check. It might also be worth mentioning that, to my knowledge, this is the only study, which found a strong ice export increase in Fram Strait.

Answer: Reference corrected. Indeed it is the only study mentioning a strong increase. We changed the abstract to: “Climate models agree that the sea ice extent and thickness will further decline through the 21st century in response to atmospheric greenhouse gas loading \citep{Zhang2006}. As a consequence, ice drift and deformation increase and net ice growth rates decrease \citep{Spreen2011, Rampal2009}. To determine associated changes in the Arctic sea ice volume requires consideration of changes in ice volume fluxes that appear at the major gates of the Arctic, such as Fram Strait. Trends in Fram Strait sea ice export were previously found first time by \cite{Smedsrud2011}. The authors used geostrophic winds derived from reanalysis data to calculate the ice area export between Spitsbergen and Greenland and found it to be about 25 \% larger than during the 1960’s. Whether Arctic ice volume loss accelerates further, or if the reduction in sea ice thickness is capable of compensating for the observed increased ice export out of the Arctic is currently under discussion.”

Comment: 2894, L3: what is the time span for the 1.57 m mean? 1930 until when?

Answer: Data was collected during an aircraft program carried out between 1972 and 1982 (March – April). Earlier data was not included in the analysis. Sorry for that. “The ice cover can be divided into three regimes: the fast ice, the pack ice, and flaw polynyas \citep{Eicken2005}. The freely floating ice pack offshore of the fast ice edge consists mainly of ice formed during fall. According to systematic observations carried out by the Soviet Union between 1972 to 1982 (March – April), it reaches a mean thickness of 1.57 m $\pm$ 0.25 m \citep{Romanov1996}. The pack ice drift is dominated by persistent offshore winds leading to a continuous export of ice out of the Laptev Sea into the basin and/or the East Siberian Sea \citep{Timokhov1994, Rigor1997}."

Comment: 2894, L10: hav -> have. The connection and importance to the sentence before is not clear to me. Maybe it can be shortened and combined with the sentence before.

Answer: Second sentence was shortened and combined with the previous one: "\cite{Rigor1997} found by means of a combination of modeling results and observations that as much as 20 \% of the ice transported through Fram Strait is produced in the Laptev Sea, giving it a key role in the future fate of the Arctic sea ice. The seasonal and interannual variability of sea ice exchange with the surrounding seas was first examined by \cite{Zakharov1966a, Zakharov1967}. Their estimates are based on average monthly gradients of atmospheric pressure across the northern and northeastern Laptev Sea boundaries and revealed a mean winter sea ice area transport of approximately 3.3 $\times$ 10^{5} km^{2}. \cite{Alexandrov2000} investigated ice area fluxes by means of a numerical model and found flow rates of 4.83 $\times$ 10^{5} km^{2} per winter. In addition a number of studies examine sea ice circulation patterns and their linkage to atmospheric and oceanic forcing on shorter time scales \citep[e.g.,][]{Rigor1997, Eicken1997, Haas2001}."

Comment: 2894, L16: word like "using" missing

Answer: Changed

Comment: 2895, L15: Which "boundaries"

Answer: We changed it to "Laptev Sea boundaries". However, note that following your comment on 2896, L15ff the structure of the entire section was changed.

Comment: 2895, L17: maybe add an "e.g." before the two references as there are

TCD

6, C2131–C2149, 2012

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

many more studies using the mentioned technique especially older ones from e.g. Emery et al.

Answer: That's true. Thanks for hint. "e.g." was inserted and a paper of Emery et al. (1991) added. In addition, we deleted the word "correlation", since there are more techniques...

Comment: 2896, L7: European

Answer: Changed. Note that description was simplified. See our answer to comment 2896, L11.

Comment: 2896, L11: "over 3-days overlapping time periods" This part of the sentence is not clear to me. Maybe spend a few more words on that. Also the next sentence is hard to follow.

Answer: We refer to the temporal resolution. Sentence has been slightly changed. In addition the following sentence was shortened, a reference was taken out and the description of the involved satellites being used for the drift vector retrieval was improved. "The accuracy of ice drift data in the Laptev Sea was investigated by \cite{Rozman2011} through a comparison with in situ measurements. The best performance was found in the ice drift product provided by the European Space Agency (ESA) via the Center for Satellite Exploitation and Research (CERSAT) at the Institut Français de Recherche pour d'Exploitation de la Mer (IFREMER), France. Hence, in the following the IFREMER data set is used to calculate winter fluxes at the NB and EB. The motion fields are available on an operational level from September 1 until the end of May, covering the period from 1992 to present. They are based on a combination of drift vectors estimated from scatterometer data (the National Aeronautics and Space Administration SeaWinds/QuikSCAT for 1992-2009 period, and the European Advanced Scatterometer (ASCAT)/MetOp for 2009 - present) and radiometer data (the 85 GHz channel data of Special Sensor Microwave Imager SSM/I on-board the Defense Meteorological Satellite Program, available since 1992). The data are available on a polar stereographic grid with a grid size of 62.5 km, using time lags of 3 days. Details about processing and validation of these data can be found in \cite{Girard-Ardhuin2012}."

Comment: 2896, L15ff: It is surprising to find this validation in the "Data and methodology" section. I would rename it (e.g. "Dataset description and validation") and also add a new subsection 2.2. To me a clearer and easier to follow structure would for example be: 2.1 Sea ice drift dataset 2.2 Sea ice drift validation 2.3 Sea ice concentration 2.4 Sea ice area flux estimates at the Laptev Sea boundaries

Answer: We agree. Changing the titles of the section/subsections makes the structure more easy to read. The wording is now following your suggestions.

Comment: 2896, L18-20: The description of the ASAR drift dataset is very brief and no further reference is given. Which months are used? How many scenes per month? How was the comparison done (down-scaling of high resolution to low resolution dataset etc.).

Answer: The description of the ASAR dataset was extended and an additional reference is provided. With respect to how the comparison was done: Due the lack of ENVISAT data coverage, we derived monthly mean ice drift information at boundaries only. Rozman et al. (2011) did the comparison at higher temporal resolution, simply because the data coverage is much higher in the central Laptev Sea as compared to the EB and NB. The monthly mean SAR drift information was compared to monthly mean IFREMER motion, calculated from the 3-day product. We also compared SAR drift estimates with the monthly mean product provided by IFREMER directly with no substantial differences. The ENVISAT monthly drift information used for comparison were obtained for 2004 (April), 2007 (Dec, Jan), 2008 (Jan, Feb, Mar, Apr, May, Dec), 2009 (Feb, Dec) and 2011 (Feb, Mar). Note that the time range given in the manuscript is slightly off. This was changed. The number of scenes used, and some statistical parameters are given in Fig. 2. However, we agree that this should be part of the text

TCD
6, C2131–C2149, 2012

Interactive Comment

(see revised abstract). The comparison is done by interpolation of the IFREMER ice drift data to the location of the SAR ice drift vector. “As an additional quality control we compare the IFREMER motion estimates with monthly ice drift information obtained from Environmental Satellite (ENVISAT) Synthetic Aperture Radar (SAR) images (Fig. \ref{Fig2}). Ice drift information from ENVISAT SAR scenes can be easily extracted by identifying identical ice flows on consecutive images. In this study, monthly ice drift information from ENVISAT Wide Swath (WS) scenes were obtained in areas near the NB and EB from images covering the beginning and end of April 2004, December and January 2007, January to May and December 2008, February and December 2009, and February to March 2011. The ENVISAT C-band WS data is VV polarized and covers an area of approximately 400 × 400 km$ˆ2$ with a spatial resolution of 150 × 150 m$ˆ2$ \cite{Krumpen2011a, Krumpen2011b}. Overall 12 monthly ice drift estimates are available. The comparison with the IFREMER dataset was done by interpolating IFREMER estimates to the locations of SAR ice drift retrieval. The agreement between IFREMER data and manually extracted ENVISAT ice drift information is high for both, the zonal (U) and meridional (V) ice drift components (correlation coefficient (R) = 0.87 and 0.95, Fig. \ref{Fig2}). The estimated standard deviation (SE) for the IFREMER ice drift velocity is 0.56 cm$/$sec for V and 0.6 cm$/$sec for the U drift components. For comparison, the uncertainty in ice drift velocity reported by \cite{Rozman2011} is around 1 cm$/$sec for the Laptev Sea.”

Comment: 2896, L21ff: What is the beam width of the ADCP? In any case it will be very small compared to the satellite ice drift resolution. How is the comparison done? I guess interpolation of the satellite data to the ADCP location. In the end you are comparing the mean of about 10 independent (10 x 3 days per month) satellite sea ice drift estimates with a special scale of > 50km with probably hundreds (what is the sampling frequency of the ADCP?) almost point-wise ADCP ice drift estimates. Even for perfectly accurate satellite and ADCP drift measurements one can expect quite some deviation between the two datasets under these conditions (one would need the spatial and time variance of the ice drift at this location to calculate numbers). Therefor

I am not sure that the difference of the correlation coefficient between the ADCP and ASAR comparison is significant. Your conclusion that the polynyas are responsible for the difference sounds reasonable. However, I don't think you can show that using these two very different validation datasets. An in depth validation with error estimate of the ice drift dataset is probably beyond the scope of the paper. However, you should briefly discuss some of the issues involved doing such a validation. In any case you should give a few more numbers for the comparison not only the correlation coefficient. What is the SE mentioned in the graph? What is the mean difference, i.e., bias between the datasets?

Answer: We agree. The spatial and temporal resolutions of the sensors are different and hence problems may arise when comparing ADCP with IFREMER drift estimates. The difference of the correlation coefficient is indeed not significant and therefor the conclusion we have drawn may be a bit risky. Nevertheless, as you supposed an in depth validation and discussion of the ice drift dataset is beyond the scope of the paper. We revised the entire abstract and provide more details on the ADCP data itself (frequency, beam width, processing) and a few more statistical parameters. In addition we briefly discuss the factors that impact accuracy of the comparison. "As stated earlier, the accuracy of passive microwave drift products may be reduced in near-shore areas. However, in section 3 we identify the origin of sea ice leaving the Laptev Sea in late winter by means of a backtracking approach. Therefore the quality of the IFREMER data in shore areas is checked through a comparison of IFREMER ice drift data with ice drift estimates taken from long-term moorings equipped with Acoustic Doppler Current profilers (ADCP). The moorings were deployed between 2007 and 2009 near the fast ice edge in the south eastern Laptev Sea (for exact position see Fig. \ref{Fig1}). The sampling frequency of the device is 30 minutes with a beam width (footprint) of 5 m. An in-depth description of the mooring design and ADCP processing is given in \cite{Hoelemann2011}. Prior comparison, the monthly mean ice drift was calculated from the ADCP data, and IFREMER drift data was interpolated to the mooring position. The correlation between IFREMER and ADCP data is slightly lower (Fig. \ref{Fig2},

R = 0.84 and 0.9 for U and V) with a higher standard deviation (0.72 cm$/$s for V and 0.83 cm$/$s for U). The limited number of samples included in this comparison and the differences in spatial and temporal sensor resolutions may impact the reliability of the comparison. In addition, the presence of fast ice, the complex coastline and the occurrence of polynyas are restricting factors. Nevertheless, the high agreement shows that IFREMER data is capable of producing ice drift in near-coastal Laptev Sea areas correctly."

Comment: 2897, L3: "EASE" not defined

Answer: EASE was taken out since it is not really of interest for the reader. For same reason, the last sentence of abstract was removed. "The ice concentration data used in this paper are also made available by IFREMER \citep{Ezraty2007}. The product is based on 85 GHz SSM/I brightness temperatures, using the ARTIST Sea Ice (ASI) algorithm developed at the University of Bremen \citep{Spreen2008b}."

Comment: 2897, L5-6: I don't understand the second half of the sentence.

Answer: Sentence was deleted, since it is not of interest for this paper.

Comment: 2897, L13-14: Was the seasonal cycle removed before calculating trends and significance? Otherwise these statistics are not valid.

Answer: Yes it was. This is now also mentioned in the manuscript. "After removing the seasonal cycle, trends were calculated in a least square sense, and significance at the 95 \% confidence level (p) was measured using the Student's t-test following \cite{Kwok2009a}. Please see \cite{Kwok2004} and \cite{Kwok2009a} for a more detailed method description and error analysis."

Comment: 2897, L21: "NSIDC drift" not mentioned in data section and no reference given. Please add and shortly mention the differences to the IFREMER drift dataset. 2898, L7: What is the 14% supposed to mean? Please also give a number for the variability also in km2 for better comparison.

TCD
6, C2131–C2149, 2012

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

Answer: Please see answer to comment 8298, L8-9

Comment: 2898, L8-9: I guess these are now fluxes calculated with the IFREMER data only. Mention that. Please explain in a little bit more detail what you have learned from the NSIDC to IFREMER comparison. Why did you choose the IFREMER data for the rest of the study? What does the comparison mean for the error estimates of your results? 2898, L17: double 2007/08

Answer: The entire description of Fig. 3 has been revised. Since the NSIDC drift data does not contribute to the results directly, we decided not to mention it in the data section itself. However, we agree that a reference is missing. We now refer to Fowler et al. 2003. In addition, we provide more details on the difference between datasets. We decided to use the IFREMER data instead of the NSIDC vectors because NSIDC is only available until 2010. Furthermore, a comparison of NSIDC data with the ADCP and SAR based drift estimates showed that it underestimates observations (which is also visible in Fig. 3). This is now mentioned in the abstract. However, to include the validation of the NSIDC dataset is beyond the scope of the paper. We also made clear that in the following, IFREMER data is used to compute fluxes. The mentioned 14 % refers to the differences in average IFREMER and NSIDC export at gates which are relatively small compared to the large mean and SE of the annual ice area flux at NB and EB. However, we decided to take it out, since it does not seem to be useful information. The errors in flux estimates that arise from the uncertainties are discussed in Sect. 4. “We present ice flux estimates at the northern and eastern Laptev Sea boundaries computed from IFREMER ice drift information. In order to assess the relative consistency and to quantify the importance of Laptev Sea ice export for the total Arctic sea ice budget, the results are compared with flux estimates from NSIDC drift data \citep{Fowler2003} and export rates through Fram Strait \citep{Smedsrud2011}. In the following, we analyze the interannual and seasonal variability of meridional and zonal area fluxes through NB and EB, and relate the observed fluctuations to changes in sea level pressure (SLP) gradients across the boundaries. Finally, the origin of the sea ice contributing to the annual export is examined through a backtracking approach of sea ice leaving the Laptev Sea in early spring. \subsection{Laptev sea ice area flux} Figure \ref{Fig3} compares the cumulative winter (October to May) total ice area flux from 1992 - 2011 through the NB and EB calculated from IFREMER data with estimates based on NSIDC drift data. The ice drift data, provided by the NSIDC \citep{Fowler2003} are computed from Advanced Very High Resolution Radiometer (AVHRR), SSM/I and IABP buoy data. Information is given at a higher spatial resolution (25 km grid) but is only available until 2010. The IFREMER flux estimates are higher than those from NSIDC (3.39 $\times$ 10^{5} km^2 $\pm$ 1.17 $\times$ 10^{5} km^2 vs. 2.91 $\times$ 10^{5} km^2 $\pm$ 1.13 $\times$ 10^{5} km^2). A comparison of the NSIDC dataset with the SAR and ADCP derived drift information reveals that NSIDC drift vectors generally underestimate observed drift velocities (not shown here). This is in agreement with findings made by \cite{Schwegmann2011} in the Antarctic. According to the authors, 71 \% of the NSIDC drift velocities are significantly lower than those observed by buoys. Nevertheless, the high agreement between NSIDC and IFREMER data (R = 0.82) gives confidence about the relative consistency of the IFREMER data. “

Comment: 2899, L14: Fig. 8 is mentioned before Fig. 7 in the text. Please swap.

Answer: Changed. Fig. 7a is now referenced before Fig. 7b and 8.

Comment: 2899, L20ff: Between which points or regions is the SLP gradient calculated?

Answer: Text changed: “The monthly mean SLP gradients across the boundaries provide a measure of the strength of the geostrophic wind component. The SLP gradients are the difference between the eastern and western end of the NB and northern and southern end of the EB. Gradients were calculated using monthly mean SLP data from the National Centers for Environmental Prediction (NCEP)/Department of Energy (DOE, \cite{Kalnay1996}).”

Comment: 2900, L8: when

Answer: Changed.

Comment: 2900, L11: “likely”? You should be able to explain that exactly as the blue line is the product of the red and black line. Is the normalized or % trend in drift speed larger than the area flux trend?

Answer: We agree. “Likely” is misleading. The blue line is the product of the red and black line, and hence, the increase in drift velocity balances the decreasing ice concentration. And yes, the trend in drift speed is larger than the one for area flux. The word “likely” is taken out.

Comment: 2900, L16: What is the approximate mean ocean circulation across the two transects? Would one expect the ocean to play a big role at these locations in any case?

Answer: The most important oceanographic feature in that area is the Arctic Boundary current that enters at the western side of the NB and exists through the EB. This is however happening at several hundred meter water depth (http://www.agu.org/pubs/crossref/2011/2010JC006637.shtml, paper about Arctic Boundary currents) What is happening at the surface is not known. Nevertheless, tides are expected to play a minor role only, since the NB and EB are too far out. Thus, wind (or ice) can be expected to be the main driver for surface currents. At least to our knowledge there is no reason why ice drift should not be primarily controlled by wind. We added a sentence to the discussion of the flux estimates where we mention that surface current is believed to be ice driven/wind driven.

Comment: 2900, L17: It is not clear to me what I am supposed to learn from the comparison to the SLP gradients. Please explain in more detail. Naturally SLP gradients and ice drift are correlated. However, as you mention the SLP gradient is not a good predictor for the ice drift in all cases. The internal ice state and ocean forcing can play a significant role. Is that your point?

Answer: Yes, that's our point. SLP is the main factor that controls ice drift and trends in SLP coincide with trends in ice drift... but not in all cases. We tried to make this more clear by reformulating/rearranging some sentences. However, aim of this section is to describe the results. The description of additional factors such as ice state and ocean forcing that may alter ice flux are discussed later in the discussion section (see last sentence of the abstract). "Figure \ref{Fig7} suggests that the overall positive trend in January and March total ice area flux (Fig. \ref{Fig6} and description in text) is the consequence of a significant increase in ice flux across the EB in January and NB in March, respectively. Interestingly during September and October, when the average ice concentration has undergone a dramatic decrease throughout the last decade, the ice export across the NB is increasing, rather than decreasing. The fact that negative trends in the ice concentration are not seen in the ice area flux rates is explained by the balance between an increase in ice drift velocities during September and October and the decrease in ice coverage. Changes in the ice drift velocity in all months are in turn reflected in changes in the SLP gradient. The agreement between variations in the SLP gradients and ice velocities is \$R\$ = 0.92 for the NB and slightly lower (\$R\$ = 0.81) for the EB. The strong coupling between across-boundary SLP gradient and ice drift velocity apparent in each month indicates that monthly variations in ice area flux are primarily controlled by changes in the magnitude of the geostrophic winds. In particular along the NB, positive or negative trends in ice drift rates between November and May are the consequence of positive or negative trends in SLP gradients. However, along the EB, trends in SLP gradients and ice drift rates coincide less or are even of opposite sign (for example November and December). Variations in SLP gradients still explain year-to-year changes in monthly zonal ice transport rates, but do not account for observed trends in drift rates. Here, changes in the internal ice state and\$/\$or ocean forcing may be responsible for the observed trends in drift and ice area transport rates. This is discussed in more detail in section 4."

TCD

6, C2131–C2149, 2012

Comment: 2901, L27ff: I had problems to understand the meaning of this sentence. Suggestion: "Because the origin of most of the ice leaving the Laptev Sea is situated in the Central Laptev Sea in November and not in near-coastal, polynya areas : : :"

Answer: Yes, sounds better. We now use your formulation

Comment: 2901, L5: : : : end of winter. " However, mostly melts during summer again and the ice produced in Laptev polynyas does not contribute significantly to the ice in the Transpolar Drift or elsewhere in the Arctic Basin. If I understand correctly. I think this is an interesting finding and could be pointed out even stronger. Or is it likely that a lot of the ice from polynyas is transported out of the Laptev Sea after April?

Answer: With the data we can show that most of the ice exported until end of April was formed during freeze-up. Polynya ice does not to contribute to the Transpolar Drift in winter. Nevertheless, the polynya ice becomes a substantial part of the Laptev Sea ice at the end of the winter. If it is melted, or if its incorporated into the Transpolar Drift is difficult to say. Unfortunately we are missing summer ice drift data. We tried to use the NSIDC dataset that covers all seasons, however, the summer data is not really realistic and underestimates ice drift even stronger than the NSIDC winter data. Hence, at the current state we can not say how much ice produced in polynyas melt in the Laptev Sea and how much is incorporated into the Fram Strait. We modified the abstract and tried to point this out stronger. "Hence, most of the ice that is incorporated into the Transpolar Drift originates from the central and western part of the Laptev Sea, while the exchange with the East Siberian Sea is primarily dominated by ice coming from the central and south-eastern Laptev Sea. Figure \ref{Fig8} c) presents the frequency distribution map of the origin of sea ice (positions of ice in November) calculated from pathways between 1992 and 2011. Because the origin of most of the ice leaving the Laptev Sea by the end of April is situated in the central Laptev Sea in November and not in near-coastal zones, the contribution of polynyas to the winter ice area flux is rather small and limited to events that take place in the vicinity of the Laptev Sea boundaries (for example NS and NET polynyas; see Fig. \ref{Fig1}). Hence, ice export during

TCD
6, C2131–C2149, 2012

winter months is dominated by ice formed during freeze-up. Nevertheless, ice that is formed in polynyas occupies large portions of the Laptev Sea area at the end of the winter. If the polynya ice is then incorporated into the Transpolar Drift during summer months, or if it becomes subject of melting can not be answered. Too little information is available on the drift of Laptev Sea ice in summer."

Comment: 2902, L16: How do these numbers compare to the difference to the NSIDC based area estimates, which can be used as another uncertainty estimate or give a hint to possible biases.

Answer: The NSIDC data underestimate ice drift significantly. This was found out through a comparison with SAR and ADCP data (see also revised section "Laptev sea ice area flux"). We used the NSIDC data only to check relative consistency. Therefore it is not included in the uncertainty analysis.

Comment: 2902, L22: "4.83" What was your mean area flux again?

Answer: 3.48 +- 1.2. The numbers were added for comparison.

Comment: 2902, L24: do you mean quantitative?

Answer: Yes, corrected.

Comment: 2902, L10: "accuracy : : : is high" give some numbers.

Answer: See revised section that deals with the comparison of IFREMER data to SAR and ADCP ice drift information.

Comment: 2903, L2: What SSMI ice drift dataset does Alexandrov et al use? If it would be the NSIDC one the positive difference would be consistent with your earlier findings. Anyhow, I would mention here again that your IFREMER area flux estimates are higher than the NSIDC mainly SSMI based one. Low resolution SSMI/QS ice drift datasets tend to have a negative bias, i.e., are to slow. Thus I assume your higher IFREMER estimate is more realistic. Again, it would be interesting to know if you find any bias in your comparison to the SAR ice drift data.

Answer: With respect to the bias in the NSIDC dataset, see answers to your comments concerning the comparison IFREMER vs. SAR and ADCP as well as comments on the NSIDC dataset. Alexandrov used a method developed by Martin and Augstein, (2000, title: “Large-scale drift of Arctic Sea ice retrieved from passive microwave satellite data” published in JGR). The method is based on a correlation technique using only 85 GHz SSM/I data. So it is not the NSIDC dataset. Unfortunately, it is difficult to get the differences in both, since information given is incomplete and a proper validation missing. Anyway, I believe it to be closer to the IFREMER technique than to the one from NSIDC. Note that there is a misunderstanding: Alexandrov found by means of a comparison of his model results with satellite drift data from Martin and Kaufmann, that his model computations overestimate observations by 24 /%, not underestimate. The overestimation is approximately equal to the offset of his model computations to our satellite estimates. Below you find the slightly reformulated abstract. We hope that it is now more easy to follow. “Sea ice circulation in the Laptev Sea and ice exchange with the Arctic Ocean have been studied in more detail by \cite{Alexandrov2000}. The authors investigated ice exchange through the NB and EB based on a large-scale thermodynamic-dynamic sea ice model from 1979 to 1995. Following \cite{Alexandrov2000}, the average winter (October to May) ice flux varies between 2.51 $\times$ $10ˆ{5}$ km$ˆ2$ and 7.32 $\times$ $10ˆ{5}$ km$ˆ2$ with a mean value of 4.83 $\times$ $10ˆ{5}$ km$ˆ2$. Due to the different study period, a quantitative comparison of our flux estimates with model estimates of \cite{Alexandrov2000} is not possible. However, their computations exceed our calculations by approximately 40 \% (3.48 $\times$ $10ˆ{5}$ km$ˆ2$). A direct comparison of data from the three year overlap between the two time series (1992/93 - 1994/95) indicates an offset of 29 \%. This number is consistent with the uncertainty in model computations of \cite{Alexandrov2000}. Through a comparison of model results with satellite derived fluxes (SSM/I) for the winter of 1987/88 and 1994/95 the authors could show that their model calculations overestimate observations by as much as 24 \%.”

Comment: 2905, L13-15: So your observations for 92-10 are in contrast with observations for the 70s and 90s? Clarify this please. I think for the Fram Strait area flux correlation with AO also dropped during recent years (sorry, don't have a reference at hand right now).

Answer: Thanks, this was clarified. I also thought that there must be something published about de-coupling of AO and e.g. Fram Strait flux. However, I could not find anything. In case you remember the reference, please let me know. Would be good to mention here.

Comment: 2906, L19: ": : : enhance the northward ice transport" Shouldn't this depend if the cyclone enters the Laptev Sea on the eastern or western side (compare also Fig.7). And you are only talking about summer situations here (warm air) I guess, which are not part of your study, or?

Answer: Yes. South western cyclones increase advection to the north, while south eastern cyclones in principal favor ice import along the NB but increase export at EB. The wording was changed to... "cyclones entering the Laptev Sea from the south west,..." And yes, I am only talking about the summer situation here, which is not part of the study. This first paragraph aims in giving an overview of processes different to preconditioning processes in late winter and spring.... as there are synoptic-scale processes (e.g. cyclones) superimposed on the large-scale atmospheric circulation during summer....

Comment: 2907, L20-22: You were right. You can update this now.

Answer: Okay...

Comment: 2908, PSSM: Wouldn't it be more consistent to also describe the PSSSM data in the "Data Section"?

Answer: Bringing this section up in the "Data Section" requires quite some explanation of why this is needed later.... If ok for you, we leave it like it is.

TCD

6, C2131–C2149, 2012

Interactive Comment

Comment: 2908, L17-18: ": : : by means of : : :" I don't understand this part of the sentence. Are the AMSR-E and SSM/I data inter-calibrated?

Answer:... it is not really an intercalibration. The sentence was reformulated to "The PSSM was driven with the daily Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E)/Aqua L2A Global Swath Spatially Resampled Brightness Temperatures data set \citep{Ashcroft2008}, available since 2002. Prior to 2002 the polynya area is deducted from the open water area in specific regions using a polynomial regression model that describes the relation between polynya area (from PSSM with AMSR-E) and SSM/I sea ice concentrations. The model is derived from the data overlapping period (2002 - 2008). A detailed description of the methodology is given in \cite{Willmes2011}."

Comment: 2908, L26: Before you call a R =-0.62 weak (p 2905).

Answer: Yes, that's inconsistent. We removed the term "rather weak" on p 2905: "However, the correlation is negative (R = -0.62), which stands in contrast to findings of \cite{Wu2006} and \cite{Watanabe2006}."

Comment: 2910, L14: I would add "For comparison this is : : :" Otherwise one might imply you are talking about a connection to the FS export (I assume you are giving these numbers only to illustrate the magnitude of the flux).

Answer: Correct, we may give a wrong impression here. "From comparison" was added. See also comments made by reviewer one with respect to Fram Strait export rates.

Comment: 2910, L25: "less pronounced" As a fraction of the mean flux (0.61) the EB trend is even more pronounced. I would reformulate this sentence.

Answer: It is, yes. We reformulated the sentence: "The total ice area flux out of the Laptev Sea is undergoing a statistically significant positive trend of 0.85 $\times$ 10^{5} km^2$/$decade between 1992 and 2010. The trend in zonal ice area flux across EB is 0.55 $\times$ 10^{5} km^2$/$decade. The positive trend in the meridional transport across NB is 0.3 $\times$ 10^{5} km^2$/$decade but not statistically significant."

Comment: 2917: "positions"? I only can find one black star.

Answer: Sorry, Three deployment at one position. This was changed.

Comment: 2918: Meaning of lines not described.

Answer: Meaning was added to figure description.

Comment: 2920: Does the FS flux drop dramatically in 09/10? If not remove the black line or mention the time series end in the caption.

Answer: No, it doesn't. See also comments from reviewer 1. Vertical black line at the end of time series was removed.

Comment: 2923: The location of the Laptev Sea is hard to identify. Maybe add the NB and EB flux transects for clarity.

Answer: NB and EB gates added.

Comment: 2927: blue line

Answer: Changed.

Comment: 2928: what does the gray, shaded area mean?

Answer: Here went something wrong. An old version of the figure was included. The gray shaded area initially marked the -1 to 1 range. However, it is probably not needed and was therefore removed.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/6/C2131/2012/tcd-6-C2131-2012-supplement.pdf

TCD

6, C2131–C2149, 2012

Interactive comment on The Cryosphere Discuss., 6, 2891, 2012.

TCD

6, C2131–C2149, 2012

Interactive Comment