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The Cryosphere Discussions

Interactive comment on "Recent wind driven high sea ice export in the Fram Strait contributes to Arctic sea ice decline" *by* L. H. Smedsrud et al.

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This paper analyses sea ice area export through Fram strait from (i) sea ice velocity vectors obtained from Envisat SAR images, combined with concentration data to obtain area export from 2004 to 2010, and (ii) a linear correlation between ice drift velocity and geostrophic wind velocity, observed between 2004 and 2010, then used to extrapolate an ice speed time series back to 1957. The main conclusion is a positive trend on ice area export through Fram strait over the period 1957-2010, and consequently an important role of ice export on Arctic sea ice decline over the last decades. Overall, I found this paper interesting, well written and the analyses and conclusions (expect some specific points listed below) rather sound. In particular, the comparison with ASMR data on figure 2 is convincing. For this reason, I recommend the publication in

TC, once the points listed below are taken into account.

The two main points are:

1) The correlation between geostrophic wind and ice drift (Fig. 2), which is the backbone of the analysis, is clear, and indeed in agreement with well-known previous works (Thorndike and Colony, 1982). However, figure 2 shows also a significant variability which is not explain by the linear trend. In the manuscript, the authors simply ignore this variability, as well as its possible interpretation. As already discussed e.g. in Thorndike and Colony, this variability is not negligible, and can have various origins: - ocean currents. The present authors implicitly assume that the oceanic forcing is strictly constant over time. This could appear reasonable, at least in first order, but this should be mentioned and discussed. - errors on the ice velocity and on geostrophic wind velocity: how much these errors can explain the observed remaining variability ? - intrinsic stochastic variability of ice velocity. The ice velocity field can be decomposed into a "general circulation" (the component of interest here), and a stochastic component (Rampal et al., JGR, 114, C10014, 2009). To entirely remove the impact of this stochastic component, seasonally-averaged (instead of monthly-) values should be used. - the response of sea ice to wind forcing depends on the ice state (concentration, compaction, thickness) and on the amount of internal stresses. A weak, less concentrated and compacted ice cover will respond better to wind forcing. This ice state has hanged in recent decades, and we can expect this evolution to have significantly impacted the ice export, independently of stronger geostrophic winds. Once again, the authors do not consider this problem, as they assume a constant regression coefficient in equation (1) back to 1957. A possible way to explore this would be, over each annual cycle, from 2004 to 2010, to calculate the regression coefficient between Vice and Vg, and see if it increased over time. I agree that 6 years is a quite limited dataset and so it would be probably difficult to conclude on this basis. However, this point should be at least discussed.

2) From figure 7, the authors calculate a positive trend of 4.9 +/- 3.0 %. However, es-

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pecially in the second part of the time series, there is apparently some autocorrelation in the signal. This will reduce the number of degrees of freedom, and therefore widen the errors bars on the trends (e.g. Wilks, Statistical Methods in the Atmospheric Sciences, Academic Press, 2006; Wunsch, Discrete Inverse and State Estimation Problems, Cambridge University Press, 2006). I'm not sure that the authors are taken into account the effect of this autocorrelation in the estimation of the error bar, and this should be done to check the robustness of the trend.

Other more specific points:

a) When discussing ice speed increasing within the Arctic basin (page 1313, line 25; page 1319 line 22), the reference (Rampal et al. JGR, C05013, 2009) should be also mentioned. In this paper, a trend of +9% per decade was reported for the average ice speed over the Arctic basin. It would be interesting to compare this value with that derived from the present analysis through Fram strait. For this, it would be useful to show an ice velocity time series, as deduced from the present analysis, from 1957 to 2010.

b) On the "Data and methods" section, it would be useful to further detail the methodology, and particularly how the uncertainties (on displacement vectors, area exports, etc..) are determined.

c) Equation (3): I guess that units are in km^2/month

d) Figure 1: the ice velocity data shown are out-of-phase with the annual cycle of sea ice speed within the basin, where ice drifts slower during winter when it is more compact and concentrated (Rampal et al. JGR, C05013, 2009). This difference could be mentioned, as it shows the special role of forcing (wind vs ocean) in the Fram strait region.

e) Figure 5: the linear fit between the two dataset shows a slight deviation from the diagonal. What could be the source of this bias ?

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f) In the discussion/conclusion, it could be mentioned that: - the trend shown on figure 7 is probably a lower bound, as it is likely reinforced by a mechanical effect (looser, less concentrated ice drifts faster) which is not taken into account in the present analysis (see comment 1 above) - the trend of figure 7 is on absolute values. In relative values (normalized by the total sea ice area within the arctic), it will be larger, thus stressing further the role of ice export on recent decline.

Interactive comment on The Cryosphere Discuss., 5, 1311, 2011.