

Interactive comment on “Characterizing sudden changes in Arctic sea ice drift and deformation on synoptic timescales” by Jennifer V. Lukovich et al.

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Please find below a list of responses to reviewers' comments regarding the submitted manuscript, “Characterizing sudden changes in Arctic sea ice drift and deformation on synoptic timescales”, by J.V. Lukovich, C.A. Geiger, and D.G. Barber. General comments are presented, followed by responses to reviewers' specific comments and suggestions. Please note that changes implemented may also be found in the attached supplementary material in response to reviewers' suggestions.

General comments:

The authors would like to thank both reviewers for their constructive comments and suggestions. In consideration of reviewer recommendations, and the initial motivation for the triplet analysis, the authors have in the revised manuscript presented a frame-

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work based on Lagrangian dispersion, and single-, two-, and three-particle dispersion statistics in particular to provide a quantitative analysis and more focused narrative of sudden changes in ice drift paths as well as associated changes in sea ice deformation, based on distance from the coastline.

Please find below specific comments to suggestions and recommendations.

Specific comments:

A. Provenzale (Referee) antonello.provenzale@cnr.it Received and published: 1 December 2016

Dr. Provenzale:

Thank you for your comments and suggestions. In light of your comments and those of the first reviewer, the paper has been revised to provide a more quantitative and focused interpretation of Arctic sea ice dynamics based on Lagrangian dispersion statistics. As is noted in the first comment to the first reviewer, emphasis in the revised manuscript is on the development of a Lagrangian framework based on single-, two-, and three-particle dispersion statistics to quantify sudden changes in ice drift and associated deformation in response to atmospheric forcing for varying distances from the coastline.

Please find below more specific responses to your queries.

The paper "Characterizing sudden changes in Arctic sea ice drift and deformation on synoptic timescales" discusses the use of Lagrangian triplet dynamics, combined with characterizations such as the Okubo-Weiss parameter, to identify "sudden changes" in sea ice drift in the Arctic.

The material is interesting and it builds upon previous works by the same lead author. However, I find the paper rather difficult to read, and not very clear in its message. First, most of the figure are simple displays of time series, without too much statistical analysis and/or quantitative interpretation. The paper would benefit from a more

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quantitative approach, with results of the statistical analyses, to assess the validity and significance of the conclusions.

The authors agree that the original version of the manuscript was qualitative in nature. In response to both reviewers' comments, the authors have revised the manuscript to provide a framework for examining sea ice dynamics based on Lagrangian dispersion statistics, and one-, two-, and three-particle dispersion in particular. Results from single-particle dispersion (Figure 3) highlight a transition in dynamical regimes evident in a change in slopes following 8 October, 2009 during which a SLP high induced strong Ekman convergence, offshore ice drift, and subsequent deterioration in the ice cover near the ice edge. Two-particle dispersion (Figure 9) also illustrates differences in zonal and meridional separation due to along- and cross-shear transport associated with interruptions to anticyclonic circulation of the Beaufort Gyre. Scatter plots (Figure 15) indicating the frequency of events falling within wind and DKP bins for varying distances from the coastline also illustrate differences in sea ice response to atmospheric forcing and associated deformation processes for varying distances from the coastline.

I also urge the authors to streamline the paper, making it more palatable and understandable.

The paper has been rewritten to provide a more focused interpretation of sudden changes in ice drift paths based on the Lagrangian dispersion approach. Single-particle dispersion is shown to capture sudden changes in sea ice drift, and a transition in dynamical regimes following the incursion of a SLP high into the region that induces Ekman convergence in the ice drift field. Two- and three-particle dispersion are shown to capture deformation associated with ice drift events due to northerly winds, and deterioration in the ice cover following the 8 October SLP high responsible for loss of spatial coherence in the ice cover and synchronicity in ice-atmosphere interactions.

In particular, I would like to add a paragraph at the beginning of the Introduction explaining some more fact about Arctic sea ice and sea ice drift.

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Thank you for this suggestion. In consideration of your comments, and to provide additional context for this study, the authors have included an introductory paragraph on Arctic sea ice dynamics and its role in understanding changes in the sea ice cover, as follows:

"Central to our understanding of changes in the Arctic sea ice cover in response to a changing climate and continued anthropogenic forcing is an understanding of sea ice drift and deformation, namely sea ice dynamics. Accelerated ice drift speed over the past several decades reflects a weaker and more mobile ice cover associated with the loss of multiyear ice and changes in atmospheric circulation (Hakkinen et al. 2008; Barber et al., 2009; Rampal et al. 2009b; Spreen et al., 2011; Kwok et al., 2013). Sea ice deformation, or spatial gradients in the ice drift field, associated with opening and closing in the ice cover due to sea ice divergence and convergence, influences moisture and heat exchange between the ocean and atmosphere, ice ridging, sea ice thickness and redistribution (Hutchings et al., 2011, Bouillon et al., 2015) with implications ice hazard detection, and pollutant and contaminant transport. In the Beaufort Sea region, sea ice dynamics is governed by large-scale anticyclonic circulation of the Beaufort Gyre, with reversal to cyclonic circulation throughout the annual cycle (LeDrew et al., 1991; Preller and Posey, 1989; Proshutinsky et al., 2015)."

Finally, it is not clear what "sudden changes" in sea ice are, and to what meteorological/climatic events are related. This point should be further explored and clarified.

The authors agree with both reviewers' comments that the definition for sudden changes was not clear in the initial version of the manuscript. In the revised version, as is noted in the response to the first reviewer, sudden changes are defined at the beginning of the manuscript as changes in the ice drift path (page 2, line 20), and quantified as minima in the ice drift variance and inflection points in single-particle dispersion. In addition, reference is no longer made to the "shear-shock event". Single-particle dispersion analyses demonstrate a transition in the sea ice dynamical regime on 8 October, 2009, associated with a SLP high and strong Ekman convergence and

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offshore ice drift. Distinction is also made between sudden (ice drift) events associated with wind reversals (e1, e3, e4, e6, e8), and those associated with persistent northerly winds (e2, e5, and e7) through evaluation of two- and three-particle dispersion statistics.

Thank you once again for helpful comments and suggestions.

Please also note the supplement to this comment:

<http://www.the-cryosphere-discuss.net/tc-2016-219/tc-2016-219-AC2-supplement.pdf>

Interactive comment on The Cryosphere Discuss., doi:10.5194/tc-2016-219, 2016.

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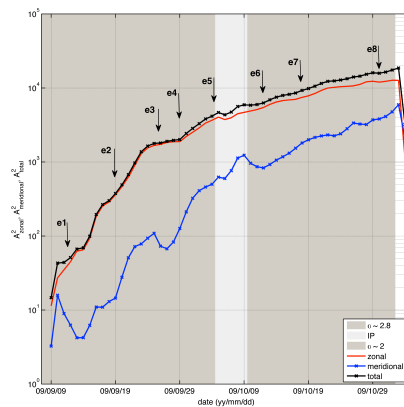


Fig. 1. Figure 3 (revised version): Absolute (single-particle) dispersion statistics for triplets A to D, depicting zonal (red), meridional (blue), and total (black) dispersion.

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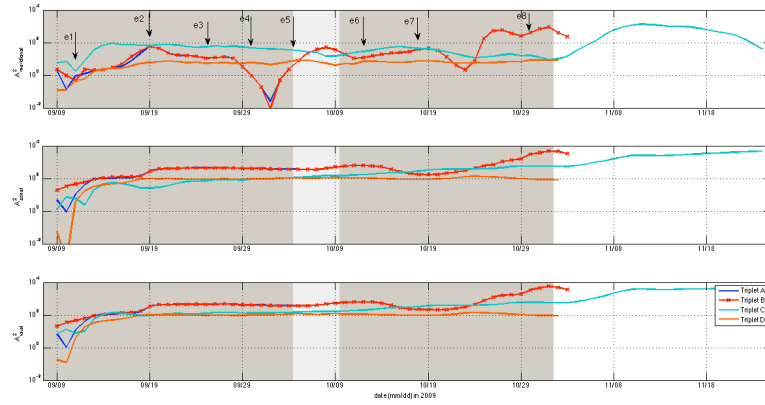


Fig. 2. Figure 4 (revised version): Absolute (single-particle) dispersion statistics depicting meridional (top), zonal (middle), and total (lower) dispersion to characterize local changes in ice drift.

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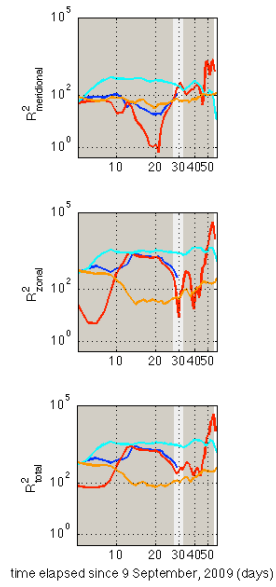


Fig. 3. Figure 9 (revised version): Relative (two-particle) dispersion showing meridional (top), zonal (middle), and total (lower panel) relative dispersion as a function of elapsed time.

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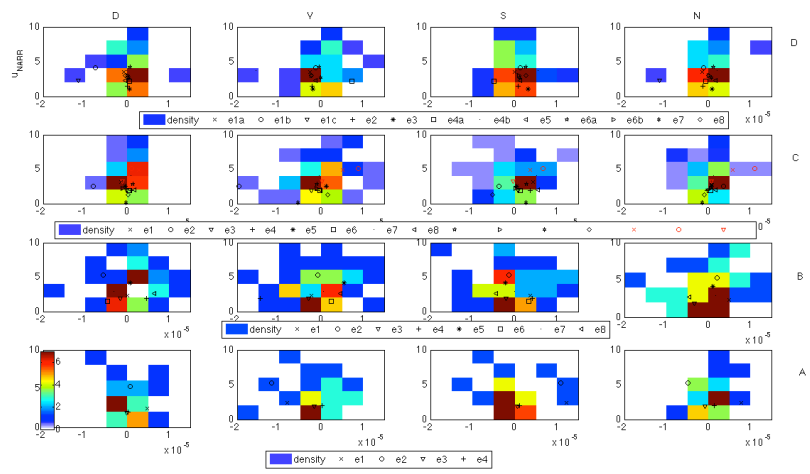


Fig. 4. Figure 15 (revised version): Scatter plots of NARR winds versus DKPs for triplets A to D showing density of values in wind and DKP bins. Symbols depict sudden change events.