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Interactive comment on "Abrupt transitions in Arctic open water area" *by* M. A. Goldstein et al.

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A full response to major and minor comments by the reviewer is attached in a PDF. What follows is a response to the major comments by Reviewer 1.

We thank the reviewer for the useful comments and recommendations, which have helped clarify the manuscript.

We had missed the supplemental material in Eisenman et al. (2014) that examined the inconsistencies between different versions of the Bootstrap and NASA Team algorithms for the Arctic. This is an important omission, and we have included references to the paper and the supplemental material in the revised manuscript. Of the fields considered in the supplement, ice extent findings are analogous to the open water area measure we are using. We note that we use the 95% and 99% confidence intervals, which are well within the 68% error bars suggested by, for example Comiso and Nishio

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Discussion paper

(2008) and 90% confidence interval used by the IPCC AR5.

Comiso, J. C. and Nishio, F. 2008. Trends in the sea ice cover using enhanced and compatible AMSR-E, SSM/I, and SMMR data. Journal of Geophysical Research, 113, C02S07, doi:10.1029/2007JC004257. Eisenman, I., W.N. Meier and J.R. Norris. 2014a. A spurious jump in the satellite record: has Antarctic sea ice expansion been overestimated? The Cryosphere, 8, 1289-1296, doi:10.5194/tc-8-1289-2014. Eisenman, I., W.N. Meier and J.R. Norris. 2014b. Supplement of: A spurious jump in the satellite record: has Antarctic sea ice expansion been overestimated? The Cryosphere, 8, 1289-1296, doi:10.5194/tc-8-1289-2014-supplement.

We apologize for the brevity of the description of the exploratory phase of the analysis. We elaborate on the process here and have added this to the text. There are several different ways to test for structural changes in a time series. We used several and checked using an additional one on the basis of this review. As noted in the text, in an exploratory mode, we split the record into sub-periods and tested the differences in the means. In addition, we examined the data by looking for the years that displayed the largest change in one moving three year average to the next. The two largest changes that were already not included in a previously identified six year period (two three-year moving average periods) using this measure were 1988-1989 and 2006-2007. The next stand-alone change had a much smaller change and the magnitude of the change was relatively similar to the next few candidates. While there is no particular justification for choosing the top 2, 3 or N values, the first two stood out as noticeably different in magnitude than the ones following and suggested reasonably long periods. We also ran a statistical test of the quality of various models of the time series. For example, we tested two structural shifts using a model that compared the statistical significance of a model that defined three different means and no trend to a model that defined a single trend. The former model was significant and the trend was not.

In order to increase confidence in the signal, we have now applied the method of Rodionov et al. (2004) to the NASA Team (NSDIC) record, which yielded the same two

breakpoints. While it also suggested a third breakpoint around 2001 (which is also suggested in the graph in Figure 3), using that breakpoint would create a rather small structural break. In addition, a breakpoint at around 2001 was not as strongly supported by the three year rolling average test. We therefore limited our analysis to two breakpoints. We have also added this new analysis to the paper.

Rodionov, S.N. 2004. A sequential algorithm for testing climate regime shifts. Geophysical Research Letters, 31, L09204, doi:10.1029/2004GL019448.

As noted in the manuscript, however, the short record of the satellite derived time series is a limitation. In addition, as raised by Eisenman et al. (2014) and the reviewer, there is potential for processing artifacts. As noted on page 7, line 31, we do not rule out the possibility that these shifts may be associated with artifacts in the satellite record. As the reviewer observes, it is difficult to obtain a truly independent record of the Arctic sea ice record, which is why we often use the term "quasi-independent". That said, the Barrow-Prudhoe Bay navigable days time series is a good candidate for independence, and yielded the same behavior. Nevertheless, we agree that it is not possible to completely rule out the conclusion that these shifts are not driven by physical processes. We feel that we have taken this as far as we can in the data realm and are conducting ongoing analysis using a model.

Finally, if as we suggest the structural shifts are physical in nature, there is no reason to expect that they should be periodic. If these shifts represent, for example, tipping points in ice thickness, then there is no inherent oscillation in the system that is likely to generate this behavior (although of course that is an hypothesis that could be tested in a climate model.)

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/tc-2016-108/tc-2016-108-AC1-supplement.pdf

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