We thank the reviewer for their thoughtful comments and address each one below (shown in red).

Interactive comment on "Warm Winter, Thin Ice?" by Julienne Stroeve et al. Anonymous Referee #1 Received and published: 3 February 2018 Warm Winter, Thin Ice by Stroeve and others

Summary: Stroeve and others investigate the impact of 2016/2017 anomalously warm winter on sea ice thickness using the CICE model and CS2 thickness observations. A secondary objective of the study is to compare three difference approaches of ice thickness retrievals from CS2 to CICE. The authors demonstrate that recent warm fall temperatures (i.e. since 2012) impact winter sea ice thickness by reducing wintertime growth which was particularly strong in 2016/2017. Overall, I think this manuscript can find a place in the literature when the author's address my major concern that thinning in 2016/2017 especially, north of Greenland and the Canadian Archipelago was not entirely driven by thermodynamics (i.e. positive snow depth anomalies) but rather reduced ice convergence.

We thank the reviewer for their comment. We agree with the reviewer that the anomaly in 2016/2017 was not entirely driven by thermodynamics and thus it is a fair point that we should have discussed in more detail. In response we have now stated more explicitly the role that dynamics also played in reducing the ice thickness north of CAA. We actually already showed this in our model results (strong negative dynamical thickness reduction for 2017 in Figure 4 from CICE and also the free-CICE simulation as well as by the ice motions in Figure 8. Thus, we have now made this point clearer in our discussion of the results. We appreciate the reviewer pointing out our need to expand on this discussion.

Major comment: The authors have not made a convincing argument that snow depth is the primary mechanism for reduced ice thickness north of Greenland and the Canadian Archipelago in April 2017. While I agree snow depth is the major source of uncertainty in CS2 retrievals, ice dynamics during the winter of 2017 in this region was likely more influential and should be discussed.

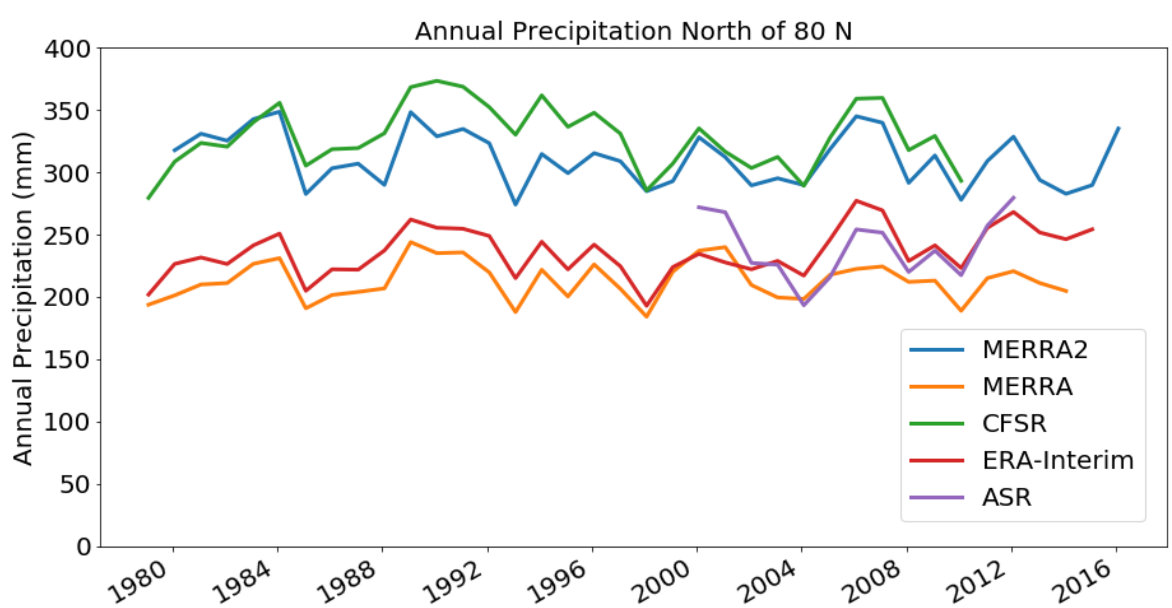
See our comments above.

The authors suggest the positive ice thickness anomaly in November 2016 north of Greenland and the Canadian Archipelago did not persist because of snow loading and in turn reduced thermodynamic growth but ice dynamics (i.e. lack of ice convergence) is more likely the culprit here. Indeed, the fall of 2016 was the warmest on record and these temperature anomalies persisted into 2017, thinning ice in some regions (Barents Sea) but this thinning also manifested enhanced surface heating changing atmospheric circulation over the Arctic and especially over the Beaufort Sea. Consequently, the Beaufort High collapsed in the winter of 2017 and this reduced ice convergence against the northern Canadian Archipelago and Greenland which is clearly apparent from the sea ice motion vectors in Figure 8 of the author's paper. The latter process seems to be more likely the cause of why the November ice thickness anomaly in this region was not preserved as atmospheric circulation prevented dynamic ice growth (convergence) which typically dominates during the winter in this region. I think the authors should acknowledge that ice thinning in the Arctic is not entirely thermodynamically driven and ice dynamics also play a role which is underscored by Kwok, 2015, GRL.

We agree with the reviewer (as noted in our comments above) and we have discussed this more extensively in the revised version.

A second related point is that multi-year ice is the dominant ice type north of Greenland and the Canadian Archipelago which has consistently been preserved despite the shift from multi-year ice to first-year ice elsewhere in the Arctic. This suggests that the snow depth here should be somewhat similar to the Warren Climatology. This was actually reported to be the case based on recent measurements from Haas et al., 2017, GRL and hence CS2 estimates in this thick MYI region should be reliable.

While I was a co-author on the Haas et al. paper, I disagree with the assertion that we should expect each year the snow depth to be on the same order as climatology. Snow depth varies considerably from year to year. In fact, we find in the reanalysis data used in the CICE simulations that there are years with anomalously high and low snow accumulation which is illustrated in Figure 10. Regions with the largest standard deviation are actually north of the CAA. In addition, the figure below shows the interannual variability of Arctic precipitation from 5 different reanalysis, which clearly shows large interannual variability. Thus, we cannot conclude that snow depth anomalies do not play a role in year-to-year sea ice thickness variability in the currently processed CS2 data products.



The latter point also lends further support to reduced ice convergence being more influential on thinning than thermodynamics.

Specific Comments

1. Line 286-288 Ok, but there appears to be a mix of positive and negative anomalies. The most prominent feature worth mentioning is the CS2 strongest thinning anomalies are along the northern coast of the Canadian Archipelago.
   Made changes as suggested by the reviewer. Below is the new paragraph:
   *Focusing more on April 2017, the 3 CS2 products suggest widespread thinner ice in April 2017 north of Ellesmere Island (up to -80 cm thinner) relative to the 2011-2017 mean [**Figure 4(top)**]. Thinner ice is also found within the Chukchi and East Siberian seas (on average -10 to -35 cm thinner) despite a mix of positive and negative anomalies. CICE simulations on the other hand show more widespread thinning throughout the western Arctic, including the Beaufort Sea and positive thickness anomalies north of Ellesmere Island **[Figure 4(middle and bottom)]**. In the Beaufort Sea, there is general disagreement among the 3 CS2 products and the CICE simulations: regional mean anomaly of -5 cm (CPOM), 0 cm (AWI), +20 cm (NASA), -25 cm (CICE-ini) and -30 cm (CICE-free). North of Ellesmere Island, CICE-ini indicates positive thickness anomalies (up to +50 cm), whereas all 3 CS2 products show negative thickness anomalies (up to -80 cm). In this region, the CICE-free simulation also shows mostly negative thickness anomalies (-20 to -80 cm), with a small positive area (up to +25 cm).*

2. Line 297-299 I'm not convinced that the snow loading in CS2 has caused this difference in April 2017 north of the Canadian Archipelago and Greenland. If I recall, the Beaufort High collapsed in the winter of 2017 and this reduced convergence against the northern Canadian Archipelago and Greenland which appears to the case in Figure 8. The latter seems more likely the cause of why the thickness anomaly in this region was not preserved as atmospheric circulation prevent dynamic ice growth. This seems to be captured across all CS2 products but not CICE-ini. This needs revision. See major comment.
   We agree. See our responses to your major comment above, and see the revisions made between lines 316 to 343 pasted below.
   *On the other hand, thickness is also strongly influenced by dynamics, such as convergence against the CAA and Greenland which leads to thicker ice in this region [Kwok et al., 2015]. During winter 2017 however, the Beaufort High largely collapsed, reducing convergence against the northern CAA and Greenland [**Figure 8**]. One advantage of using CICE, is that we can more readily diagnose thermodynamic vs. dynamical contributions to the observed thickness anomalies. For the region directly north of Ellesmere Island, both the CICE-ini and CICE-free simulations support reduced sea ice convergence, leading to thinner ice from dynamical contributions. At the same time, this region also exhibited reduced thermodynamic ice growth in both CICE simulations. One would expect thermodynamic ice growth to be reduced in regions of enhanced snow depth and thicker November ice. Positive snow depth anomalies extended from this region through the northern Beaufort Sea, in agreement with extended regions reductions in thermodynamic ice growth in both CICE-free and CICE-ini. At the same time, regions of positive 2016 November thickness anomalies are also associated with regions of reduced CICE thermodynamic ice growth.*

3. Line 413-415 The snow is important but ice thickness is strongly influence by dynamics (i.e. convergence against the Canadian Archipelago and Greenland) and this needs to be mentioned in the discussion as well. See Kwok, 2015, GRL. Furthermore, MYI is the dominant ice type north of Greenland and the Canadian Archipelago which has consistently been preserved despite the shift from MYI to FYI elsewhere. This suggests the snow depth here should be similar to the W99 which was found reported by Haas et al., 2017, GRL hence CS2 estimates here should be reliable and lends further support to reduced ice convergence was more influential on thinning. See major comment.
   See our responses to your major comment above.

4. Table 1 What is the source of the data in this table? The passive microwave algorithm from Markus et al., 2009, JGR?
   Yes, from Markus et al. 2009 and from Stroeve et al., 2014. References were mentioned in the body text, but now also added to the Table caption.
5. References: Haas, C., Beckers, J., King, J., Silis, A., Stroeve, J., Wilkinson, J., Notenboom, B., Schweiger, A., & Hendricks, S. (2017). Ice and snow thickness variability and change in the high Arctic Ocean observed by in situ measurements. Geophysical Research Letters, 44, 10,462–10,469. https://doi.org/10.1002/2017GL075434 Kwok, R. (2015), Sea ice convergence along the Arctic coasts of Greenland and the Canadian Arctic Archipelago: Variability and extremes (1992–2014), Geophys. Res. Lett., 42, 7598–7605, doi:10.1002/2015GL065462.
   Thank you, these have been added.