Response to Referee 1's comments

Below we summarise the comments of Referee 1, along with our responses and actions:

#	Comment (verbatim)	Response	Action
R1.1	"In general, my concern is that this manuscript lacks of an in-depth analysis. The focus of this paper is set on the comparison and difference between the NRT and the final released product. But more elaboration of these differences is needed."	We agree that the paper would benefit from a more in-depth analysis of the differences between our NRT and archive data products. Please see our response to **R1.2** and **R1.4** for specific examples.	We have expanded our comparison of our NRT and archive data products. Please see action for **R1.2** and **R1.4** for specific examples.
R1.2	"The volume comparison in Figure 2 reveals higher values for the final release product. You state that this is mostly because of the use of different ice concentrations, but also due to the absence of orbits in the NRT level1b data. Nevertheless, Figure 1, 3, 4 and Table 1 only show statistics with respect to the NRT product. Can you include the same statistics for the final release product (as in Figure 3 and Table 1 for the NRT product) and also the different ice concentrations, you used? I think this is needed in order to proof your statement above and to turn out the differences."	We agree that readers may desire more information on differences between NRT and archive sea ice thickness products. After further inspection, we find that it is the absence of certain geophysical corrections (wet tropospheric, dry tropospheric and inverse barometer), rather than orbits, that drive the remaining differences in sea ice thickness and volume. This can be shown by plotting the spatial variability of these differences for two different months: one with corrections absent and one with corrections present.	We have included a new figure (Figure 3), which consists of 2 maps, detailing the spatial differences between NRT and archive sea ice thickness for data absent and present geophysical corrections. The explanatory text for this figure (Data and Methods final paragraph, final few sentences) reads: *"The remaining difference is likely due to the combined absence of the wet tropospheric, dry tropospheric and inverse barometer corrections in 93.8% of the Baseline-B fast delivery CryoSat-2 data. This is reduced to 0.3% for Baseline-C data. The mean sea ice thickness for both the NRT and archive datasets is ~1.8 m, and there is no bias between them, with or without geophysical corrections applied. When the corrections are missing the NRT and archive thickness values at any given location differ, on average, by 1.1 cm with a standard deviation of 23.0 cm (Figure 3a). This is reduced to 0.1 cm with a standard deviation of 7.4 cm when the corrections are present (Figure 3b). There is no spatial*

			pattern to these differences. Despite the improvement in performance of Baseline-C NRT data compared with Baseline-B we conclude that the satellite orbits and on-ground processing applied to fast delivery CryoSat-2 data are sufficient to determine accurate measurements of Arctic sea ice thickness and volume for both baselines. The thickness differences between the archive and NRT data products are not significant for either baseline given the estimated uncertainty on thickness and the typical thickness of sea ice floes." We have also added archive data to figures 3 and 4b (figures 4 and 5b in updated version), with discussion in the relevant places. Please see action to **R1.12** and **R1.13** for more details. We have also included a description of the spatial and temporal differences between NRT and archive sea ice thickness data in our Discussion and Conclusions section, second paragraph. This reads: *"The NRT and archive thickness differences, although small, vary temporally. The differences are reduced when all geophysical corrections are present in the fast delivery CryoSat-2 data, which is the case in 99.7% of the data since March 26th 2015, when the ESA on-ground processing chain switched from Baseline-B to Baseline-C. There is no spatial variability in the differences between our NRT and archive data products."*
R1.3	"Although many readers are interested only in the final thickness product, comparing only the thickness histograms of both products, is not enough from my point of view. I suggest to show freeboard (and thickness) maps of difference	Agreed. Please see response to **R1.2**	Please see action to **R1.2**

	between the NRT and the archive product in autumn and spring. This would give further information about the spatial distribution of differences between both products."		
R1.4	"The CS-2 data processing starts with the NRT level1b data and the processing of each orbit segment. Therefore I would suggest also to consider differences on the orbit-scale, like the comparison of freeboard along track between both products or even just the comparison between the ellipsoidal elevations (after retracking). And what about the detected leads? Is it the same for both products?"	We agree that there is likely to be interest in the accuracy of our NRT data on an orbit-scale, and so we have included further illustrations and analysis of this in our revised paper. We feel that an along-track comparison of sea ice freeboard is sufficient, as the differences in sea surface heights at the leads will form part of the small differences seen in freeboard. If the referee is asking whether there is a difference in the number of leads detected in the NRT product compared to the archive then we can include this in our revision, but it is not clear from the question.	We have added an additional panel to Figure 2. Figure 2a now shows the point-by-point freeboard differences for our archive and NRT data products for an individual Arctic pass. This has been described in the final Data and Methods paragraph: *"Firstly we assessed our orbit-scale processing by calculating point-by-point differences of NRT and archive sea ice freeboard using one track of CryoSat-2 data from April 2015, for which all geophysical corrections were present in the NRT and archive data. These showed excellent agreement, with an average difference of 0.1 cm (Fig. 2a)."*
R1.5	**P2 L38:** "The oil and gas sector requires sea ice information for feasibility studies. Why is the reduction of plans for exploration and drilling a consequence? I think it needs one more sentence to explain this."	We agree that this sentence would benefit from further justification, and so we have done this in our revised paper.	We have added an extra sentence that reads: *"Without these studies companies cannot be sure that their infrastructure is suitably robust for the Arctic environment, such as when the Shell oil rig Kulluk ran aground in January 2013."*
R1.6	**P2 L28-30**: "So you use NRT SAR and SIN, right? Is there a difference between handling both modes in the NRT product. Or to be more specific, are the differences between NRT SAR and archive SAR the same as between NRT SIN and archive SIN? Would it make sense to separate	We agree that it is not clear in the paper which data modes we use, how we use them, and whether this differs for NRT and archive thickness processing. We have done this in our revised paper.	We have added an explanation of the way in which we process SAR and SARIn data for NRT situations. The first Data and Methods paragraph, first five sentences, now read: *"We use fast delivery radar altimeter measurements from the ESA CryoSat-2 satellite [Wingham et al., 2006] synthetic aperture radar (SAR) and SAR interferometric (SARIn) mode data products to produce NRT estimates of Northern*

	between the modes in this study?"		*Hemisphere (latitudes above 40° N) sea ice thickness and volume. The data are Level 1b, and consist of an echo for each point along the ground track of the satellite. For Arctic sea ice processing we assume that the ice surface is relatively flat and that slope variations are minimal [Rapley et al., 1983], so are concerned principally with power returns from nadir. Therefore SARIn mode waveforms are cropped to include only the central 128 range bins. This allows for identical processing of SAR and SARIn mode data as both now have 128 bins in their waveform data."* We have also clarified that our processing of SAR and SARIn data is the same for NRT and archive cases. There is now a sentence in the final paragraph of Data and Methods that reads: *"Aside from this, the CryoSat-2 SAR and SARIn mode data are processed identically to the NRT case."*
R1.7	**P4 L5:** "Can you be more specific: Which geophysical corrections are missing in the fast delivery data? What does 'often' mean in this statement?"	We agree that it would be helpful to be specific about which geophysical corrections are missing, and so we have done this in our revised paper.	The sentence in question has been expanded to read: *"In the fast delivery data the wet tropospheric, dry tropospheric and inverse barometer corrections are missing in 93.8% of cases for Baseline-B data, but only 0.3% of cases for Baseline-C data. In these cases, all three of the corrections are missing. "* We have also moved the sentence further up in the paragraph as we feel it makes more sense to include it immediately after the baseline processing is introduced.
R1.8	**P4 L15-19:** "How do you justify using the Warren climatology in regions where W99 is not based on measurements, for example in the Baffin Bay. W99 is a 2d fit and therefore it is not constraint in such areas and can produce substantial biases	We realise now that our treatment of the Warren climatology and our justification of its use are not clearly explained. We share the referee's concerns regarding the Warren climatology, especially in regions where it is not constrained by *in situ* measurements. Hence we use the mean climatology values of snow depth and density from a	A sentence has been added to summarise our treatment of the Warren climatology. It reads: *"To obtain snow depth and density we average the values from a climatology (Warren et al. 1999) that fall within the ICESat domain, where the climatology is constrained by in situ*

	which are not considered in the uncertainty estimates. In some areas like Barents Sea in November, it can even cause negative snow depths.“	fixed central Arctic domain (where snow parameters are constrained) in all freeboard to thickness conversions, no matter where they are located. There are known differences between the climatology and the current snow depth on younger Arctic sea ice (Kurtz *et al*. 2011; Webster *et al*. 2014) so we halve the snow depth on FYI to account for reduced snow accumulation. Although this approach cannot capture all of the known variability, it removes the possibility of errors being introduced through extrapolation. This detail is now included in our revised paper.	*measurements."* The ICESat domain itself is defined earlier in the paper. Should the reader require further information, the second paragraph in the Data and Methods section, first sentence, now reads: *"The processing steps for fast delivery CryoSat-2 data are identical to those used for the final delivery data, and are described in Tilling et al. (2015)."*
R1.9	**P4 L27-29:** "Why do you use the same weighting for all points? If you project on a 5 km grid, but using a 25 km radius for averaging, this means that the grid cell covers only 1% of the area which goes into the average (5x5 km = 25 km^2, pi x (25km)^2 = 1963 km^2)? Is that right? But then the grid cell is hardly representative for the thickness at this location. What is the circular operator doing? Would it make sense to apply a distance weighting?"	We agree that employing a distance weighting when computing our gridded thickness product may potentially be of benefit (it also may not). However, the aim of this study is not to alter our current processing method. Rather, our aim is to apply our existing method to fast delivery CryoSat-2 data and compare the results to calculations based on archive data, and to do this requires that our processing to remain the same. The effect of gridding methods on gridded sea ice thickness could form the basis of another study.	There is now a sentence in the final Discussion and Conclusions paragraph that reads: *"We will also investigate the impact of different gridding methods, including the application of a distance weighting, on our gridded NRT sea ice thickness product."*
R1.10	**P4 L33-34: "**How is the gap filled at the pole?"	We realise that our approach for filling the polar gap in volume calculation was not explained. Note that this procedure only applies to the volume calculation in the comparison with archive results, it is not required for the thickness products.	Our sea ice volume method description now includes a sentence that reads: *"Empty thickness grid cells within the sea ice extent mask, including those north of 88°N, are filled by nearest neighbour interpolation with a maximum search radius of 300 km."*
R1.11	**P6 L1:** "... absence 'o'f ..."	Agreed	Changed to "of"

R1.12	**Figure 3:** "Can you add the data for the final release product? I think it would be helpful to understand the differences in coverage between both products."	We agree that this would be helpful, as would a description of the differences. Both are added to the revised paper.	The final data are now included in the figure (now Figure 4). The second Results paragraph, first sentence, now reads: *"To determine the utility of the 5 km grid measurements of NRT sea ice thickness for operational use, we performed a detailed assessment of the spatial and temporal distribution of the data and compared these to the equivalent for archive data."* The paragraph then discusses these comparisons.
R1.13	**Figure 4b:** "Can you add the data coverage of the final release product (see previous comment)?"	We agree that this would also be helpful, as would a description of the differences. Again, both are added to the revised paper.	The final data are now included in the figure (now Figure 5b). The third Results paragraph, second sentence, now reads: *"We calculated the percentage of ice cover mapped by our NRT product for six key oceanographic basins (Fig. 5a), for the final 28 days of each month of the 2014-2015 sea ice growth season and compared this to the percentage of ice cover mapped by our archive data (Fig. 5b)."* The paragraph then discusses these comparisons. The third results paragraph summarises the new contents of figures 4 and 5b, saying: *"Although there is spatial variation in the coverage of our NRT sea ice thickness data, both with latitude (Fig. 4) and oceanographic basin (Fig. 5b), there is no significant spatial variability in the difference between the NRT and archive data coverage (Fig. 4 and Fig. 5c)."*

References

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