Response to RC 2:
(The reviewer comments appear in black, the responses are in blue and the proposed changes to manuscript are in ***bold italics***.)

General comment

This manuscript presents the inter-comparison of various SIT products from microwave remote sensing data. The performance of the SIT products was evaluated and the causes of differences in the products were analyzed. SIT has been used as an important information in research for global climate change and future prediction. Therefore, a comparative study on the performance of the operationally used SIT products is of high importance.

The manuscript is well written, and appropriate tables and figures are used to explain the results. It seems very meaningful to analyze the comparison results in time and space. However, in order for this manuscript to be published in the Cryosphere, more descriptions should be added about the data and methodology used in the study (requires a section on methodology). More discussion of the results is required.

Reply:

Thank you for the thorough review. Your comments and suggestions are highly appreciated. For better comparison and evaluation of the sea ice type products, we will revise the manuscript from the following two aspects:

1) The "Data" section will be re-structured. This section will include four sub-sections: "2.1 Microwave remote sensing", "2.2 Sea ice type products" and "2.3 Other data". In section 2.1, specifications of the sensors and the satellite data will be introduced in a chronological order, with subsections of passive/active microwave remote sensing data. In section 2.2, theory of SIT classification will be introduced at the beginning, followed with the overall description of the respective SIT products in terms of grid size, projection, availability period, a summary of the satellite data used and the algorithm with necessary details. In section 2.3, sea ice age product (with evaluations from previous studies) and the SAR images will be described accordingly.
2) A new section of "Methods" will be added, which includes "3.1 Estimation of MYI extent" and "3.2 Interpretation of SAR imagery". We will modify the computation of MYI extent in the revision for consistent griding, projection among all the SIT products. In section 3.1, Information such as co-locating/re-griding the data and calculation of the MYI extent will be introduced. In section 3.2, the theory and characteristics of sea ice classification in SAR images will be introduced with references from previous studies and examples from our study. In addition, we will interpret the entire SAR images, consult with ice experts regarding the results, convert the sea ice classification results from ice types polygons to grided ice classification results, and eventually give quantitative evaluation results.

Besides, case studies will be presented in the chronological order with more discussions referring to the physical background and the algorithms of SIT products. Figures will be modified for better presentation. A thorough edit of the language style and grammar will be conducted. And all the references and citations will be double-checked and corrected accordingly.

Specific comments

Abstract: Specify the names of the SIT products (algorithms) analyzed in this study.

Reply: Thanks for the advice. We will modify the sentence as follows.
"This study analyzed nine daily SITY products from five SITY retrieval approaches covering the winters from 1999 to 2018, namely OSISAF-, C3S-, KNMI-, IFREMER- and Zhang-SITY."
(Note that sea ice type is abbreviated as SITY in the revision)

Line 27: Please state clearly why sea ice is a sensitive indicator of climate change.
Reply: Thanks. The sentence will be modified as follows in the revision.
"***Sea ice is an important component of the earth system. Due to its high albedo, sea ice reflects more solar radiation than the ocean. Because of the ice-albedo positive feedback, sea ice loss and decreased surface albedo (increased absorption of solar radiation) enhance each other, making sea ice a sensitive indicator of climate change."***

Line 29: It would be nice if it quantitatively indicated how much the thickness and volume of sea ice decreased.
Reply: Thanks. How much the thickness and volume of sea ice decreased will be added, using quantities from the references.

Line 35-37: Please specify how sea ice patterns affect Arctic and mid-high latitude regions and how they affect Arctic ecosystems.
Reply: Thanks. We will modify the sentence accordingly in the revision.

Line 68: The authors did three scientific questions, but the second question (how we choose SIT product for different applications) is lacking in discussion.
Reply: Thanks. How we choose SIT product for different applications will be added to the discussion in the revision.

Line 83: How are the microwave scattering and radiometric characteristics of MYI and FYI different?
Reply: Thank you for your advice. We will revise the manuscript as suggested.

In the "Introduction" section, we will include sentences about the physical background for microwave SITY classification as mentioned above. The sentences included additionally start with:
"On one hand, brightness temperatures (Tbs) of MYI tend to be lower than that of FYI because of high loss of radiation caused by scattering when going through the bubbly layer in the sub-surface of hummock area (Sinha and Shokr, 2015). Such difference depends on the wavelength of the radiation with respect to the typical dimensions of the bubbles (they should be comparable for the loss to be effective). On the other hand, due to the high volume scattering and low scattering loss, MYI have relatively higher backscatter than FYI at the same frequency (Carsey, 1992)."

References:
Sinha, N. K., & Shokr, M. (2015). Sea ice: physics and remote sensing. John Wiley & Sons.
Carsey, F. D. (Ed.). (1992). Microwave remote sensing of sea ice. American Geophysical Union.

In the "Data" section, before introducing the individual sea ice types, we will include a paragraph that describes the physical background. The paragraph starts with:

"Microwave radiometer and scatterometer are used to discriminate MYI and FYI due to their distinctive signatures. Microwave radiometer Microwave radiometers measure the upwelling radiation emitted by the Earth in terms of brightness temperature (Tb), which is linearly proportional to the physical temperature and microwave emissivity of the observed object…"

Line 77: Each product has a different grid size. It should be explained how it was dealt with in the comparative evaluation.
Reply: Thanks for the advice. We will modify the computations in the revision to account for the factor of different grid size. SITY products in polar-stereographic projection will be firstly regridded to the EASE grid before the computation of MYI extent. Details of such will be presented in the new Section"3 Methods" (3.1 Estimation of MYI extent).

Line 78-143: Please describe in more detail how FYI and MYI are distinguished due to which characteristics in each SIT algorithm. For example, if a SIT product is produced based on PR and GR, an explanation is required for the differences between the values of PR and GR of ice types and why the differences occur.
Reply: Thank you for the advice. In the revision, the section of "Data" will be modified as follows. The new section 2.1 will be entitled with "Microwave remote sensing data", where the specification of the sensors and the satellite data used in all the SIT products be will introduced. Definition (and equation) of PR and GR will be introduced in this section. The new section 2.2 will be "sea ice type products", where the grid resolution and details of the algorithm used in each SIT product will be introduced.

Line 150: NSIDC-SIA was used as reference data. How accurate is NSIDC-SIA?
Reply: Thanks. In the revision, references regarding the evaluation of NSIDC-SIA will be added and summarized.

Line 153: How and what information was retrieved from the SAR images for the SIT products evaluation should be described.
Reply: To answer the questions here, the sentence will be modified as below.
"Radarsat-1 (referred to as RS-1) and Sentinel-1 SAR images were both visually interpreted in terms of sea ice type classification and used for validation."
In the revision, we will add a new section regarding the theory of SAR interpretation. The theory and characteristics of sea ice classification in SAR images will be introduced in the section "3.2 visual interpretation of SAR imagery". In addition, we will interpret the entire SAR images, convert the sea ice classification results from ice types polygons to grided ice classification results, and eventually give the quantitative evaluation results.

Line 173: Is it the result of this study that different SIT distribution patterns were found in the regions selected by the authors?
Reply: It is a misleading sentence here. We will delete the sentence in the revision.

Line 185-186: Is 'divergent movements' the only cause of increase in the MYI extent?
Reply: "Advection from neighbouring regions" could also lead to increase in the MYI extent. The sentence will be modified as follows in the revision.
"However, it can temporarily or regionally increase due to ice divergence or advection from neighbouring regions (Kwok, Cunningham, et al. 1999)."

Line 263: The authors compared SIT daily products with the SAR images. It is necessary to discuss the comparison between the image captured at a specific time and the daily product.
Reply: Thank you for the advice. In the revision, the impact of such will be discussed in the comparison.

Line 263: The authors identified the distribution of MYI by visually analyzing the SAR image. It would be better if MYI could be determined by quantitatively analyzing backscattering or textures from the SAR images.
Reply: Thank you for the advice. In the revision, we will add a new section regarding the theory of SAR interpretation. The theory and characteristics of sea ice classification in SAR images will be introduced in the section "3.2 visual interpretation of SAR imagery". In addition, we will interpret the entire SAR images, convert the sea ice classification results from ice types polygons to grided ice classification results, and eventually give the quantitative evaluation results.

Line 368-371: How are the input parameters affected by atmospheric factors and surface features? More discussion is needed.
Reply: Thank you for the advice. We further investigate the magnitude of cloud liquid water values (atmospheric factors) and its impact. It turns out that variation of the cloud liquid water path has little impact on GR. We will therefore remove this sentence in the revised manuscript. Regarding the impact of surface features, more discussion will be added. The sentences in the next few lines will be modified as below:
"In the beginning and ending stage of winter, the variability of GR_{37v19v} can be significant when air temperature exhibits warm-cold cycles which triggers wet-dry cycles or melt-refreeze cycles of snow (Ye et al., 2016a 2016b; Voss et al., 2003), or when wet/thick precipitation suddenly appears (Voss et al., 2003; Rostosky et al., 2018). This can partly explain"

Line 393: Explain clearly about the training dataset.
Reply: Thanks. To better explain the training dataset, we will rephrase the sentence as below:
"Some use fixed threshold classification algorithm, while others employ dynamic thresholds, which may vary with time, region and the satellite sensors"

Technical comments
Line 157: SAR Wide B → SAR Wide Beam
Reply: Done

Line 199: What does (2000) mean?
Reply: It is a typo here. The reference and citation will be corrected.

Line 402: Is [55] a reference number?
Reply: Yes. The citation will be corrected.

Figure 4: Delete 'Jan' on the horizontal axis.
Reply: Done