The authors are very grateful for the editor's time and effort in providing comments. Their work has greatly improved our manuscript. Our responses to each comment are included in black below.

General Comments

I would like the authors to nuance their statement in the introduction that the best assimilation framework is not assimilating SIC and only assimilating snow. This seems in contrast to a vast amount of recent literature (i.e. on the importance of assimilating SIT), and is also showing a lack of understanding of the current lack of good snow on sea ice observations (they remain highly uncertain).
The authors have added text to the manuscript to address this comment.

Line 9: "Findings indicate that assimilating both sea ice thickness and snow depth observations while omitting sea ice concentration observations produced the best sea ice and snow forecasts, in our idealized experimental setup."

Lines 46-71: "The application of data assimilation to sea ice problems is not a novel idea since this research topic has been investigated for more than two decades. Common observation descriptive quantities for sea ice are concentration (e.g., the fraction of a grid cell covered with sea ice) and thickness (e.g., the sea ice surface extending down into the ocean). Previous studies have highlighted the importance of initial conditions when trying to predict Arctic sea ice from local to seasonal time scales, especially regarding accurate initialization of sea ice thickness (Msadek et al., 2014; Day et al., 2014; Dirkson et al., 2017). Although different data assimilation techniques have been used to update sea ice state variables (Meier and Maslanik, 2003; Van Woert et al., 2004; Lindsay and Zhang, 2006; Stark et al., 2008), numerous studies have tested updating sea ice state variables using the EnKF data assimilation method (Lisæter et al., 2003; Barth et al., 2015). These EnKF studies were tested both in a synthetic observation framework referred to as observing system simulation experiments (OSSEs; Barth et al. 2015; Kimmritz et al. 2018; Zhang et al. 2018) and using real observations from remote sensing platforms (Sakov et al., 2012; Massonnet et al., 2015). These studies found improvements in both sea ice analyses and their corresponding forecasts related to the spatial sea ice concentration field but little improvement in sea ice thickness. In addition, studies have improved the initialization of sea ice cover when updating sea ice thickness via a multivariate framework when assimilating only sea ice concentration observations (Massonnet et al., 2015; Sakov et al., 2012). More recent studies have tested the assimilation of sea ice thickness observations and found further improvements to both sea ice thickness and sea ice concentration states (Mathiot et al., 2012; Chen et al., 2017; Fritzner et al., 2018; Mu et al., 2018; Fiedler et al., 2022). While results from assimilating sea ice thickness observations are positive, they contain large observation uncertainties because satellite remote sensing retrieval algorithms contain large uncertainties due to input parameters and instrument errors (Kwok and

Cunningham, 2008; Zygmuntowska et al., 2014; Tilling et al., 2016; Xie et al., 2016; Ricker et al., 2017). Further research is needed to determine how to properly handle these uncertainties when assimilating sea ice observations. Lastly, there have been recent attempts to obtain observed snow depth from satellites; however, the uncertainties associated with these observations remain high (Maaß et al., 2013; Rostosky et al., 2018). Because snow is closely connected to albedo and sea ice melting, further understanding of the impacts of assimilating snow depth observations is needed. For example, Fritzner et al. 2019 found assimilating snow depth observations had positive effects on short-term forecasts of snow depth and sea ice concentration."

Line 185: "Since real world snow depth observations still have their limitations (Rostosky et al., 2018; Fritzner et al., 2019), the synthetic snow depth observations generated for this OSSE will test the impacts if high-quality snow observations are available year-round in the future."

Lines 451-469: "The first three experiments explore the impact of different assimilated synthetic observation subsets on the generation of the most accurate forecasts for both sea ice and snow states. According to the daily biases and aggregated statistics, EAKF-ThickSnow is more accurate, when compared to the truth, for sea ice area, sea ice volume, and snow volume. This highlights the negative impacts that SIC observations have on forecasts when they are assimilated in EAKF-ConcThick and EAKF-ConcThickSnow. This result contradicts previous studies that found positive impacts from assimilating SIC observations (Sakov et al., 2012; Massonnet et al., 2015; Posey et al., 2015). However, this result could be linked to differences in the observation error specification chosen for SIC observations in the different studies. In our study, early springtime SIC truth values are still close to one, maximizing their observation error (15% of the truth value), which leads to synthetic SIC observations being drawn further below the truth due to the bound at one. In addition, the prior spread increases because of the onset of springtime melt and prior inflation. Combining the low-bias observations with the increase in the prior spread leads to an enhancement of the non-Gaussian effects during early springtime. A similar but opposite effect (high-biased SIC observations) would be observed during winter; however, prior ensemble spread in the modeled SIC fields is smaller, resulting in a lower weighting of SIC observations. While potentially different from other studies, our chosen SIC observation error specification intensified the non-Gaussian effects of assimilating SIC observations while also showing the potential impact accurate SIT observations can have during data assimilation multivariate updating. Interestingly, SIC observations do provide positive updates in the marginal ice zone, as shown by SPS and total IIEE being lower in EAKF-ConcThick and EAKF-ConcThickSnow. Because of positive updates in the marginal ice zone, it would be optimal to assimilate SIC observations within the data assimilation system."

I am not totally satisfied as well that the authors have addressed the reviewers' comments regarding incorrect uncertainty attribution (0.1 for SIT is the current goal set for the future mission CRISTAL and is highly ambitious and by no means the current standard). I feel that the authors would do best to nuance their findings by adding 'in a idealised/synthetic/model data assimilation testing framework' or something along those lines.
The authors have modified the manuscript to ensure that the readers understand that this is an observing system simulation experiment (OSSE) that is being used as an "experimental" data assimilation framework to test different configurations.

Line 6: "This study presents different observing system simulation experiments (OSSEs), which through experimental observation networks and synthetic observations will provide a data assimilating testing framework."

Line 162: "The SIT observation error of 0.1 m is a goal for future satellite platforms and is not the observation error for current observing platforms."

Line 73: "Using OSSEs provides an experimental framework to test the impacts of synthetically generated observations in different data assimilation configurations."

Figure 2 is referring to real data location. Can you provide the data sources in the text. For panel (D) are you sure there are SST values along the CryoSat-2 tracks (?!). Again make it cristal clear (pun intended) to explain in the abstract, conclusion, text that your analysis is synthetic and doesn't use realistic data.
I have included the data source in the text.

Line 167: "The locations for all synthetic observation types that are assimilated were based on CryoSat-2 locations (locations measured every 10 seconds; more details on locations see CryoSat-2 Product Handbook at https://earth.esa.int/eogateway/documents/20142/37627/ CryoSat-Baseline-D-Product-Handbook.pdf), which provides the observational network for testing (Fig. 2)."

Caption for Figure 2 had been modified. Panel D is showing the locations of the synthetic sea ice surface temperatures (SISTs).

Figure 2 Caption: "A snapshot example of the spatial locations of the OSSE synthetically generated (A) sea ice area, (B) sea ice thickness, (C) snow depth and (D) sea ice surface temperature observations that are assimilated. The observation locations are from Cryosat-2 latitude and longitude ground tracks. Colorfill is the ensemble mean of the sea ice area and the dots are the observation locations along with their associated value."

I have included "synthetic" throughout the manuscript to be more clear that the observations that are assimilated in this study are not "real".

Line 6: "This study presents different observing system simulation experiments (OSSEs), which through experimental observation networks and synthetic observations will provide a data assimilating testing framework."
Line 52: "These EnKF studies were tested both in a synthetic observation framework referred to as observing system simulation experiments (OSSEs;"
Line 70: "Using OSSEs provides an experimental framework to test the impacts of synthetically generated observations in different data assimilation configurations."
Line 151: "Since satellites can not retrieve multi-category model quantities, aggregate synthetic observations are generated from the truth member to produce sea ice concentration (SIC), sea ice thickness (SIT),"
Line 152: "In this OSSE framework, synthetic observations are generated from the truth member using the forward operators and are assimilated."
Line 155: "This method was chosen to create the synthetic sea ice surface temperature observations

that were assimilated."
Line 157: "Because of this, we will use a single (SIT,D_{snow}) and double (SIC) truncated normal distribution when generating the synthetic sea ice and snow observations that are assimilated in our OSSEs."
Line 165: "Due to the SIC observation error method, only synthetic SIC observations greater than 0.01 (approximately the precision found in passive microwave sea ice concentration observation files, Meier et al. 2021) are assimilated."
Line 167: "The locations for all synthetic observation types that are assimilated were based on CryoSat-2 locations (locations measured every 10 seconds; more details on locations see CryoSat-2 Product Handbook at `https://earth.esa.int/eogateway/documents/20142/37627/CryoSat-Baseline-D-P` `pdf`), which provides the observational network for testing (Fig. 2)."
Line 177: "In EAKF-ConcThick, we allow the category-based sea ice area and volume to be updated independently by synthetic SIC and SIT observations while updating snow volume via post-processing."
Line 185: "In EAKF-ConcThickSnow, snow volume is no longer updated by post processing and assimilation of synthetic D_{snow} is included in the assimilated observation subset."
Line 88: "To test the non-Gaussian effects of the synthetic SIC observations, EAKF-ThickSnow only assimilates synthetic SIT and D_{snow} while allowing the category-based sea ice area, sea ice volume, and snow volume state variables to be updated from the observation increments."
Line 196-198: "Finally, EAKF-SIST tests the impacts of assimilating additional synthetic SIST observations to further improve the updates of sea ice and snow states. While synthetic SIST observations are assimilated, sea ice surface temperatures in the different thickness categories are not updated from the data assimilation step."
Line 253: "The first three experiments investigate which assimilated synthetic observation subset produces the most accurate forecasts for both sea ice and snow."
Line 307: "Evaluating analysis increments will help determine how the assimilation of synthetic SIC observations impact the different data assimilation experiments."
Line 323: "Even with a slightly higher IIEE, the removal of the synthetic SIC observations from the assimilate observation subset did provide better results."
Line 326: "The removal of SIC as an assimilated synthetic observation improved forecasts of total sea ice, however, forecasts of the sea ice edge were less accurate according to the total IIEE and SPS."
Line 330: "Three additional experiments were completed to investigate the impacts on sea ice when using a non-Gaussian RHF, modified forward operators for synthetic thickness observations, and the assimilation of synthetic SISTs."
Line 369: "With a constant truth value that does not change, synthetic observations are created that will be assimilated over the cycling period."
Line 374: "The experiments were cycled 5,000 times, assimilating the synthetic observations generated from the truth using a truncated normal distribution."
Line 445: "CICE-DART is used to conduct OSSEs to test different data assimilation configurations and the assimilation of different sea ice and snow observation subsets synthetically generated from a truth member."
Line 448: "The first three experiments explore the impact of different assimilated synthetic observation subsets on the generation of the most accurate forecasts for both sea ice and snow states."
Line 454: "In our study, early springtime SIC truth values are still close to one, maximizing their observation error (15% of the truth value), which leads to synthetic SIC observations being drawn

further below the truth due to the bound at one."

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