Reviewer #1

Dear Reviewer,

Thank you for your helpful comments and suggestions to improve the manuscript. Further changes are made in the revised manuscript, including adding discussions about the observation error estimation used in GIOMAS, necessary figure, and a table together with the explanations and discussion. Below, we repeat each comment and reply to them one by one. All responses are in a blue font for clarity of reading.

Hao Luo

On behalf of all the authors

1. Regarding the inclusion of additional model diagnostics or simulations, I am disappointed that the authors could not include additional analysis - this is a missed opportunity to give the paper much more depth and value. However, I accept the author's decision that this is outside of the scope of their paper and can be subject of future research. The inclusion of additional discussion and caveats in the revised manuscript is appreciated.

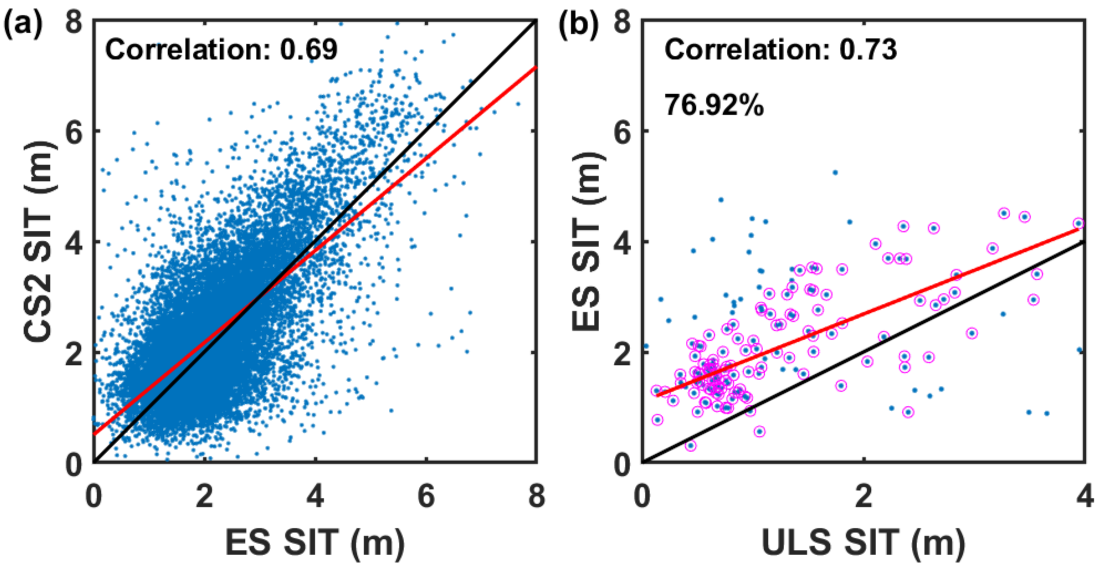
Response:

Thanks for your suggestion. **In the revised manuscript, we added more discussions about the observation error estimation used in the GIOMAS as follows**: "Thirdly, due to the characteristics of SIC observations derived from the passive microwave instrument, observation errors of SIC should vary with time and location (Lindsay and Zhang, 2006). However, a fixed value of observation errors is adopted in GIOMAS because of limited information on observation errors of SIC. Thus, a better estimation of SIC observation errors might further improve the performance of GIOMAS." (*Please see lines 387-391 in our revised manuscript*)

2. The new analysis on observational uncertainty in the authors' response is a nice piece of work, however it is not adequately reflected in the revised manuscript. I would insist that Fig 1 and Tab 1 in the response together with the accompanying explanations and discussions are added to the manuscript, to put the model-observation discrepancies in the context of observational uncertainties.

Response:

Thanks for your suggestion. In the revised manuscript, **RFig. 1 and RTab. 1 and related captions were added** (*Please see Figure 2 and Table 1 in our revised manuscript*). **The explanation and discussion of RFig. 1 was added into the introduction of observations in the data part as follows**: "Since both satellite observations and in situ observations are involved in the evaluation, it is necessary to investigate the relationship between them. To achieve this, direct comparisons among satellite observations and ULS observations are conducted in the Weddell Sea where ULS SIT observations are available. The monthly SIT of ES and CS2 during their coincident segments (i.e., November 2010 to November 2011) in the Weddell Sea is displayed in Fig. 2a. The SIT of ES and CS2 is mainly distributed around the one-to-one line and there is a significant correlation of 0.69 between them, indicating ES-derived SIT is comparable to CS2-derived SIT. Then the monthly ES SIT is compared with monthly ULS SIT during the coincident segments at sites 206, 207, 208, 229, 231 and 233 (Fig. 2b). CS2 dataset is not involved since there are only four data pairs between CS2 and ULS observations. The distribution of data pairs indicates ES tends to overestimate SIT compared with ULS observations, because the scattering surface of the radar altimeter can be inside the snow (Willatt et al., 2010; Wang et al., 2020). However, 77% of ULS SIT is within the uncertainty of ES (Fig. 2b). Besides, the correlation between the ULS SIT that is within the uncertainty of ES and the corresponding ES SIT is 0.73. All those indicate ES-derived SIT is comparable to ULS observations when the uncertainty is considered." (*Please see lines 144-157 in our revised manuscript*)



RFig. 1 (a) The monthly ES and CS2-derived SIT in the Weddell Sea during the coincident segment from November 2010 to November 2011 and (b) the monthly ES-derived SIT and ULS observations during the coincident segments at sites 206, 207, 208, 229, 231 and 233. The red lines are linear regression lines and the black lines are one-to-one lines. The dots surrounded by red circles indicate the ULS SIT is within the uncertainty of ES and the percentage in (b) denotes the proportion of such dots. The correlation and regression line in (b) are only for dots surrounded by red circles.

Meanwhile, **the explanations and discussion of RTab. 1 was added into the results part as follows**: "To prove this, a direct inter-comparison between the monthly SIT of GIOMAS, ES and ULS at site 206 is conducted and the biases of GIOMAS and ES relative to ULS at site 206 and the uncertainties of each dataset are displayed in Table 1. The bias of GIOMAS is larger than the uncertainty of ULS while the bias of ES is smaller than the uncertainty of ULS (Table 1). This suggests there is a significant discrepancy between GIOMAS and ULS/ES SIT while ES SIT is comparable to ULS SIT at site 206." (*Please see lines 229-234 in our revised manuscript*)

RTab. 1 The biases of GIOMAS and ES SIT relative to that of ULS and the uncertainties of SIT at ULS 206 (Unit: m).

Dataset	Bias	Uncertainty
ULS	0	1.17
ES	0.89	1.37
GIOMAS	-1.99	0.34

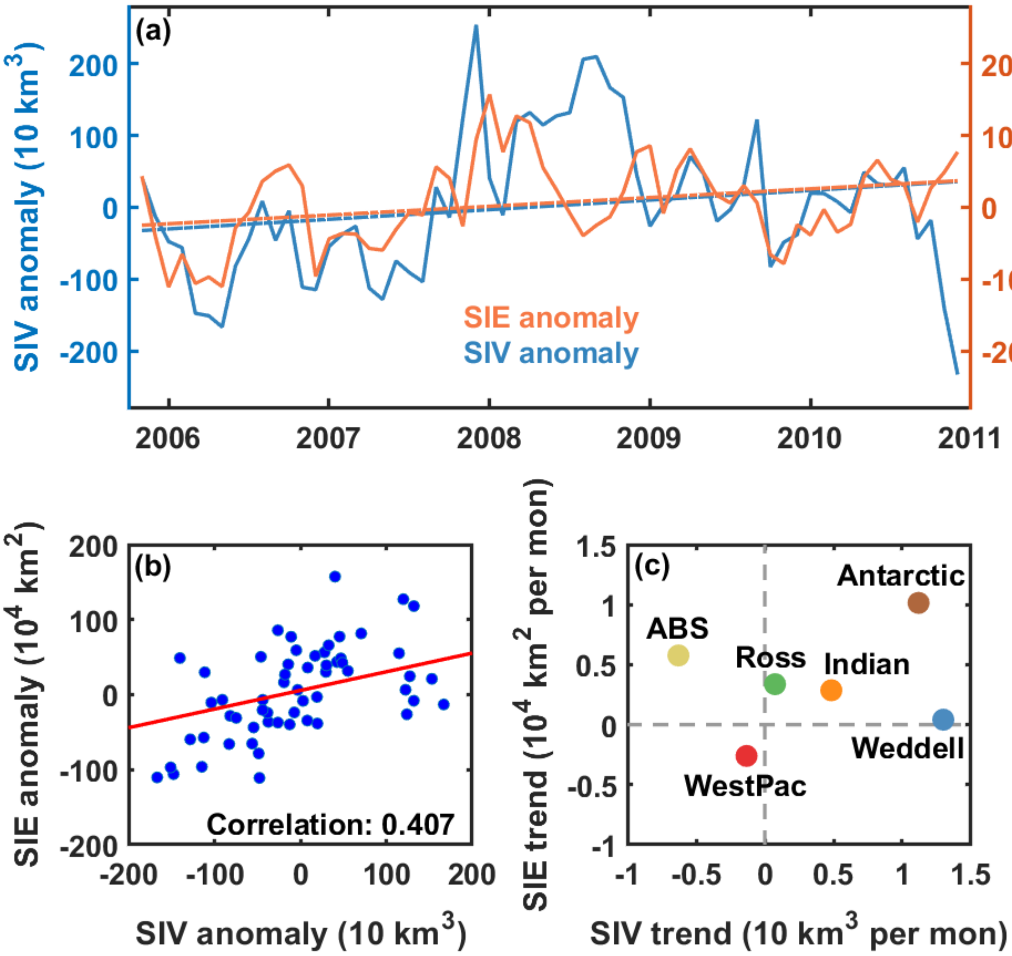
3. This is a misunderstanding - I was asking for total Antarctic SIE/SIV, not regional. I would expect the correlation between SIE and SIV to be higher for total Antarctic than for the Amundsen and Bellingshausen Seas as shown in Figure 4 of the response. Can you please provide the figures for the entire Antarctic, and modify the text in the manuscript accordingly?

Response:

We are sorry for the misunderstanding. As you suggested, the sea-ice extent/sea-ice volume (SIE/SIV) anomalies and the corresponding trend for the whole Antarctic are shown in RFigs. 2a-b. It is suggested that the total Antarctic SIV and SIE anomalies have similar linear trends while the correlation between them is 0.407 and has passed a 99% F test. **Those indicate a relatively good consistency between Antarctic SIE and SIV as you mentioned.**

Due to the distinct regional differences in the variation of Antarctic sea ice (e.g., Parkinson, 2019), the trends of SIV/SIE anomalies in the whole Antarctic and different sectors are shown in RFig. 2c. For the whole Antarctic, the trends are the same as those in RFig. 2a. However, for the Amundsen Sea and the Bellingshausen Sea, the trends of SIV and SIE are opposite. Meanwhile, for the Weddell Sea and the Ross Sea, differences can also be found in the trends of SIV and SIE. This implies that it is necessary to investigate the Antarctic SIV variation.

In the revised manuscript, **the statements were added to clarify the significant correlation between Antarctic SIE and SIV** (*Please see lines 256-257 in our revised manuscript*).



RFig. 2 (a) The monthly SIV and SIE anomalies and (b) their scatter plot in the Antarctic. (c) The scatter plot of the trends of SIV and SIE anomalies in the whole Antarctic and different sectors. The time of the data is from November 2005 to December 2010. The red line in (b) is a linear regression line and the gray dotted lines in (c) are zero lines.

Reference:

Lindsay, R. W., and J. Zhang, 2006: Assimilation of Ice Concentration in an Ice–Ocean Model. *Journal of Atmospheric and Oceanic Technology*, **23**, 742-749.

Parkinson, C. L., 2019: A 40-y record reveals gradual Antarctic sea ice increases followed by decreases at rates far exceeding the rates seen in the Arctic. *Proceedings of the National Academy of Sciences of the United States of America*, **116**, 14414.

Wang, J., C. Min, R. Ricker, Q. Yang, Q. Shi, B. Han, and S. Hendricks, 2020: A comparison between Envisat and ICESat sea ice thickness in the Antarctic. *The Cryosphere Discussions*, **2020**, 1-26.

Willatt, R. C., K. A. Giles, S. W. Laxon, L. Stone-Drake, and A. P. Worby, 2010: Field Investigations of Ku-Band Radar Penetration Into Snow Cover on Antarctic Sea Ice. *IEEE Transactions on Geoscience and Remote Sensing*, **48**, 365-372.