Responses to referee #2

Dear Dr. Céline Heuzé:

Thanks for your helpful comments to improve this manuscript.

Below, we repeat each comment and insert our replies in the text. All responses are in blue font for clarity of reading.

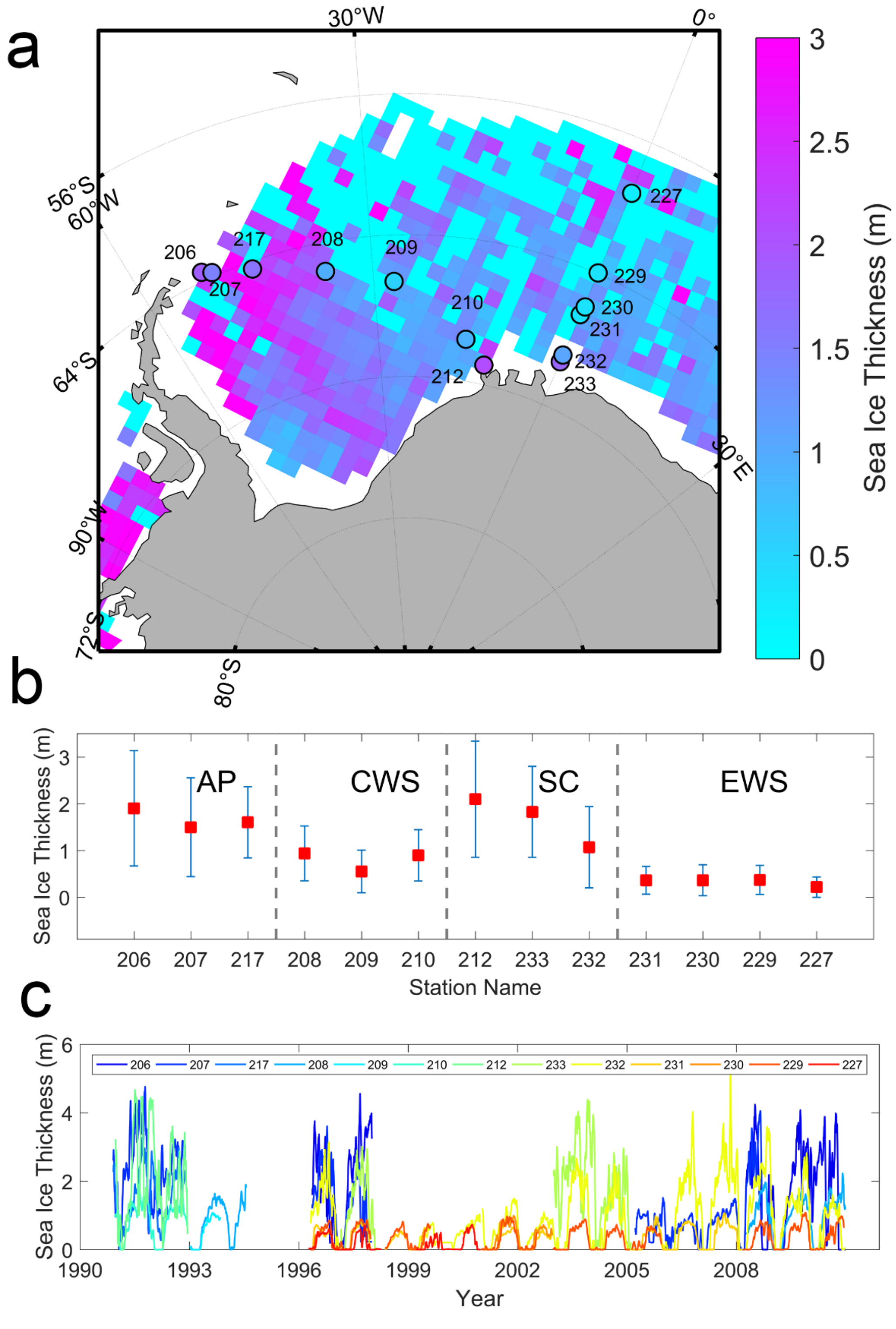
Qinghua Yang

On behalf of all the authors

Main Comments:

Point 1: The regions On Fig 1, you present the four regions into which you split the Weddell Sea, and that you analyse in Fig 3. You base that split on data from ULS, but you present only their mean, not the uncertainty attached to it. I am particularly surprised that 210 and 212 would be in different regions. So at least on Fig 1b, add the errors bars. Then modify the region split if needed.

Response: We divided 13 ULS stations according to their ice conditions. Following your suggestion, we added the uncertainty of daily SIT records (here we use the standard deviation representing the uncertainty) in the new figure 1b. The mean SIT of station 210 is similar to other stations of the CWS group, lower than that of the SC group. In addition, the uncertainties of station 208, 209 and 210 are all around 0.5 m, while the uncertainties of stations of SC group are all higher than 0.85 m. Therefore, we think our division criterion is reasonable. In order to provide more information on ULS records following another reviewer, we added the time series of daily SIT of all 13 stations after a 15-day moving average in the new Figure 1c.



New Figure 1: a) The ICESat-1 sea-ice thickness in autumn of 2005 in the Weddell Sea and the locations of the moored upward looking sonars with their mean thicknesses shaded. b) The mean ULS sea-ice thickness from west to the east in the Weddell Sea. The error bars represent the standard deviation of daily ice thickness for individual stations. Grey dotted lines divide the 13 stations into four parts: the Antarctic Peninsula (AP), the central Weddell Sea (CWS), the southern coast (SC), and the eastern Weddell Sea (EWS). C) The time series of daily sea ice thickness of all 13 stations after a 15-day moving average.

Point 2: The more recent time period and long term perspective most of the analysis is performed on the time period common to all four reanalyses (late 2000s), which I understand. Unfortunately, it is a bit old and short. Southern Ocean sea ice has behaved very differently since. So please, include a short extra subsection dedicated to comparing GIOMAS and GECCO to SICCI (CryoSat2 at least) and APP. Ideally, also add something about trends in these reanalyses

Response: Thanks for the suggestion. We added the comparison of GECCO2, GIOMAS, Cryosat-2 and APP-x from 2011 to 2016 in the Figure supp1. The SIT of GECCO2 and GIOMAS have an obvious lower SIT than SICCI (Cryosat-2), but their spatial pattern are similar to SICCI (Cryosat-2) in the period from 2005 to 2008. The thickest ice of GECCO2 and GIOMAS concentrate on the southwestern Weddell Sea in all seasons, without spatial shift as Cryosat-2 or Envisat shows. APP-x has lower SIT than Cryosat-2 in summer and autumn. Then, its SIT increases rapidly in winter and spring and has the thickest mean ice thickness in the spring of all four data sets. Its abnormal thick ice (> 3 m) in the central and eastern Weddell is contrary to the ULS observations in the literature. Besides, the spatial pattern of APP-x SIT presents obvious zonal symmetry. That is to say, the evolution of APP-x SIT is mainly controlled by thermodynamic processes and cannot well reflect the dynamic processes.

Though, we showed the yearly-mean sea ice thickness in the Weddell Sea of GECCO2, GIOMAS and APP-x from 2000 to 2019 (Figure supp2). The Cryosat-2 sea ice thickness has also been added to this plot. Even though the magnitudes of SIT are quite different among the four data sets, all of them show relatively high mean SIT in 2014. GECCO2 and GIOMAS present an upward trend from 2000 to 2019 (exceed 95% significance level), while APP-x presents a downward trend at the same time but cannot pass significance text. Currently, we still cannot conclude whether the upward signal of GECCO2 and GIOMAS SIT is realistic. Further, more reliable and longer data sets are needed to investigate the trend of Antarctic SIT is necessary.

We have not put this part in the main document, since both the CryoSat-2 and the APP-x ice thickness are with large uncertainties. In particular, the uncertainties of the radar altimeter can result from the inaccuracy snow-ice interface and snow-ice formation (Willatt et al., 2010), and also the surface type mixing and surface roughness (Schwegmann et al., 2016; Paul et al., 2018; Tilling et al., 2019).”. APP-x almost cannot grasp the dynamical thickening of sea ice, that is to say, it cannot keep the memory of sea ice cover in the Weddell Sea, which exist abundant multi-year ice.

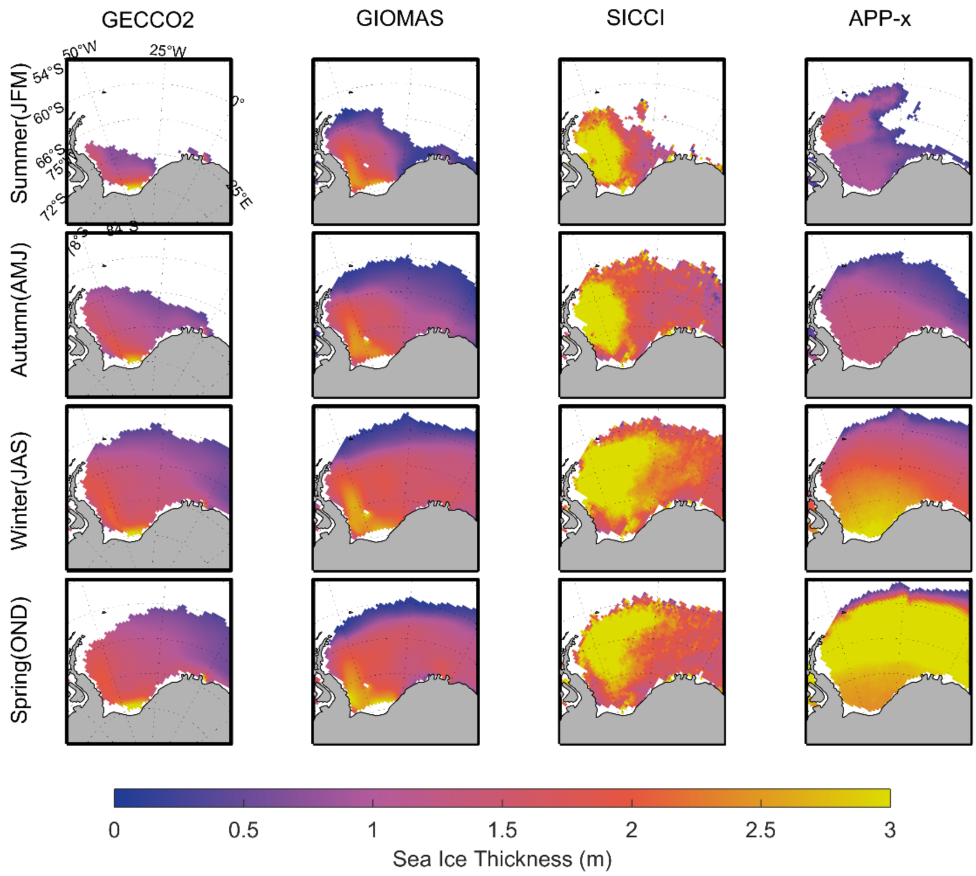


Figure supp1: Seasonal mean sea-ice thickness (summer to spring) from GECCO2, GIOMAS, SICCI and APP-x for the 6-yr period 2011-2016.

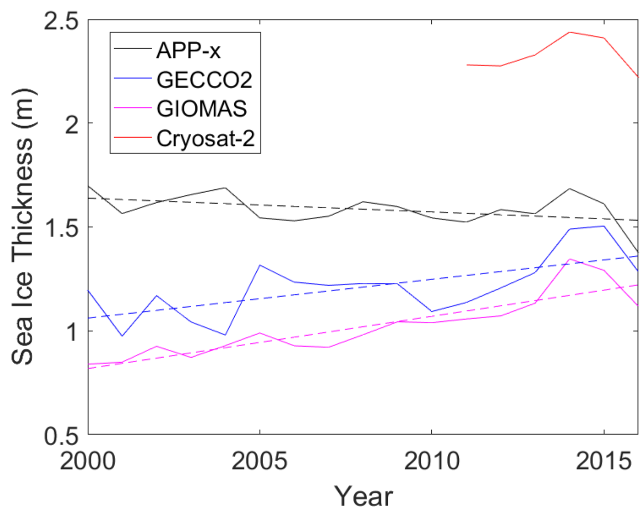


Figure supp2: Trends of yearly-mean sea ice thickness from 2000 to 2016. The dotted lines represent the linear regression fittings.

Minor Comments:

1 Line 109: say that all the information to come is summarised in Table 1. Try to write this entire section in a more structured manner, giving the same information about all four products (at least time period and resolution).

Response: We added the following sentences at the end of Line 111 "Its horizontal spatial resolution is 1°×1/6°.". At the end of Line 134, we added "The horizontal spatial resolution of GIOMAS is 4/5°×4/5°.".

2 Line 140: you mention ASPeCT now, but only introduce the product line 170

Response: We changed the "ASPeCt" here as "ship-based observations".

3 Fig 1a: add the lines separating the four regions plotted there too Fig 1b: see comment above, add the error bars, and potentially modify your region division accordingly

Response: We added error bar in the new Figure 1b and explained the reason for using such division criterion in the response of Point 1.

4 Fig 4b-d: why are you showing different thickness bands for different products? They are not even the thicknesses you comment on in the text. Please show only one range, so that the reader can compare the reanalyses.

Response: First, we are sorry because the old caption for Figure 4 was wrong and this caused the misleading. It is not "Locations of model sea-ice thickness are shown in b …", but should be "Locations of modal sea-ice thickness are shown in b …". We have corrected this. Second, the different modal ice thickness corresponds to the leading ice types of different reanalyses. Their similar spatial locations mean the modal ice thickness is a representative parameter in comparison with ASPeCt SIT.

5 Table 3: have you checked whether the reanalyses are correlated with each other? It is suspicious that they all seem to have similar biases when compared against ICESat-1.

Response: We are very sorry as there is indeed something wrong with the old Table 3, please see the following new Table 3 (the old values are in parentheses). Based on the new results, NEMO-EnKF has obvious higher CC than the other three reanalyses and the CC of GIOMAS close to 0.

New Table 3: The mean ice thickness bias, root-mean-square error estimate and correlation between ICESat-1 and four sea-ice thickness reanalyses.

Reanalysis	Mean error (m)	RMSE (m)	Correlation
GECCO2	-0.67(-1.02)	0.55(0.71)	0.19(0.18)
SOSE	-0.99(-1.20)	0.51(0.63)	0.26(0.20)
NEMO-EnKF	-0.63(-0.99)	0.44(0.68)	0.54(0.31)
GIOMAS	-0.52(-0.90)	0.68(0.79)	0.03(0.17)

6 Fig 7: present it like Fig 6, as difference against reference rather than actual values. This way, we can compare with Fig 6 (alternatively, present Fig 6 like Fig 7).

Response: Corrected. Please see the new Figure 7.

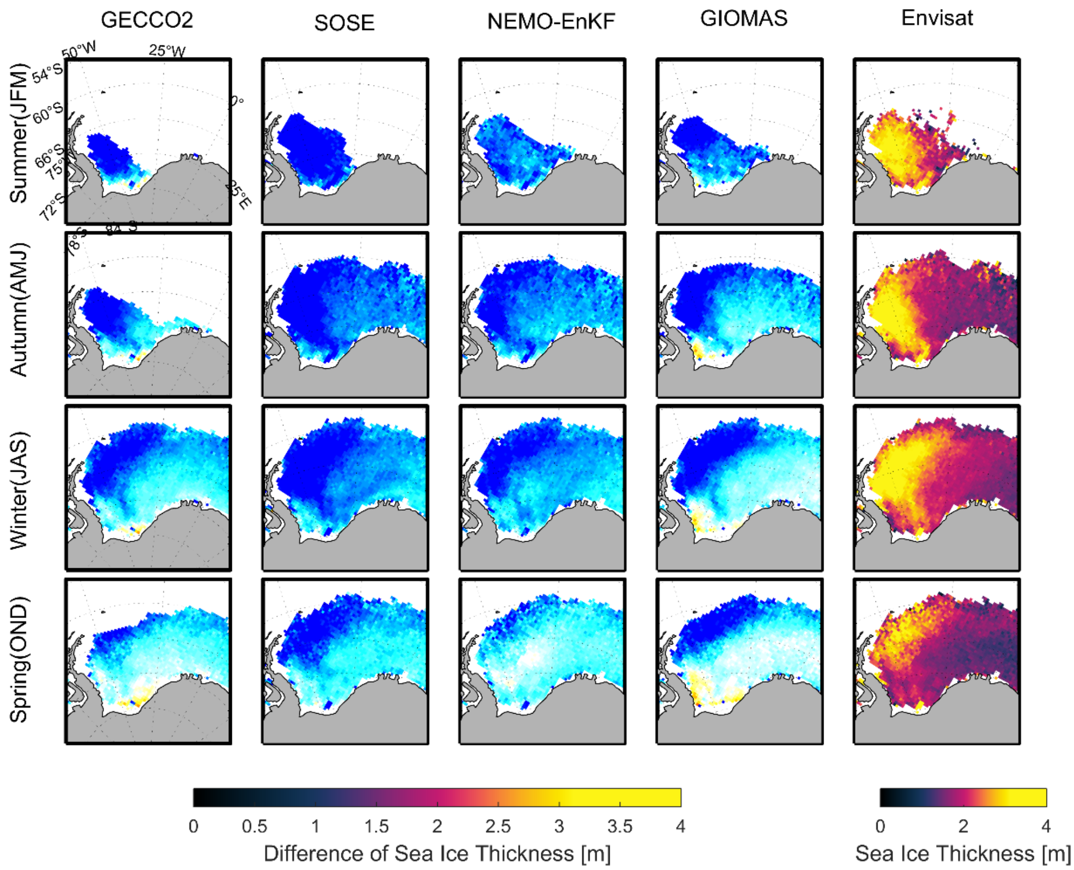


Figure 7: Same as Figure 6 but with respect to Envisat (last column) for the 4-yr period 2005-2008.

7 Fig 8 (and text corresponding): since the sea ice concentration is about right, and that all reanalyses present similar biases in thickness when compared to satellite retrievals, can it be that the thickness retrievals are the ones that are not perfect yet? Sea ice concentration retrieval is after all more mature.

Response: Yes, the performance of sea ice concentration is better than the sea ice thickness, both for remote sensing retrieval and numerical modeling. Comparing with the sea ice concentration, both the satellite and the model ice thickness estimates have large errors, because the modeled ice concentration can be constrained by the satellite observations, but this is not the case for the modeled ice thickness.

8 Line 331: you meant to refer to Fig 8 here.

Response: Yes. We corrected this.

9 Line 345/Fig 9: I know you write that you will not investigate the reasons for biases in the reanalyses, but I find the north sea ice of GIOMAS in winter/spring surprising. Is the reanalysis known for having too fast an Antarctic Circumpolar Current? Or is the ice too thin/mobile?

Response: Good suggestion. On the one hand, the relative low ice concentration in the marginal ice zone and high ice motion speed of GIOMAS (Figure 8) than the other four data sets can accelerate the sea ice loss (local melting or northward advection). On the other hand, the thin ice thickness will make ice more mobile driven by the same wind speed. Currently, we still cannot give the explicit casualty between thin ice and fast ice motion of GIOMAS.

10 Line 342-346: you forgot to refer to Fig 9 here. The caption of Fig 9 refers to itself

instead of Fig 8 by the way

Response: Corrected.

11 Table 5: the units need to be fixed. Indicate the net flux in the reference product as well (at least in the caption).

Response: Corrected.

12 Line 373: not "sea ice ocean models", reanalyses. Sea ice ocean models have their own series of problems, but that's beyond the scope of this review.

Response: This sentence will be replaced by "We conclude that sea ice thickness reanalyses in the Weddell Sea have a varying degree of realism."