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EVALUATION OF MERGED SEA-ICE THICKNESS FROM CRYOSAT-2 AND SENTINEL-3A ALTIMETERS IN ARCTIC

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ABSTRACT

Sea ice thickness is one of the important environmental parameters describing the material balance of sea ice and controlling regional heat exchange, which has an extremely important impact on global climate change, resource development and shipping in polar regions. Over the last three decades, with the development of satellite altimeters, a variety of sea ice thickness data products have been publicly released. These products usually provide complete coverage of polar regions for one month, which is limiting for polar sea ice monitoring and sea ice forecasting applications. The recently launched CryoSat-2 (CS2) and Sentinel-3A (S3) are able to invert sea ice thickness more accurately. The different orbital configurations make the fusion of sea ice thickness data possible. In this study, the first half-monthly Arctic regional sea ice thickness fusion product (CS2_S3) based on the spatial complementarity of CS2 and S3 is proposed. The comparison with airborne OIB measurements and elevation sonar data both show high agreement.

1.INTRODUCTION

CryoSat-2 (CS2) is the first altimeter specifically designed to measure sea ice drywall with high accuracy, and is capable of complete Arctic coverage once a month. Currently, several monthly average sea ice thickness products have been released internationally based on SAR Interferometric Radar Altimeter (SIRAL) data. These products have some limitations in sea ice forecasting due to the low temporal resolution of the observations. In addition, remote sensing tools such as passive microwave radiometers are also capable of acquiring sea ice thickness. The recently released CS2 and Soil Moisture and Ocean Salinity Satellite (SMOS) weekly fusion product (CS2SMOS) . While enhancing the ability to detect one year of ice, it also underestimates multi-year ice thickness. 2016 Sentinel-3A (S3) was launched by ESA in and is the next SAR Radar Altimeter (SRAL) operating in Ku-band after CS2. The very different orbital configurations of CS2 and S3 mean that the two satellites' data are somewhat complementary in terms of spatial coverage. The combination of the CS2 and S3 satellites would greatly increase the frequency of sea ice thickness monitoring in the Arctic region.

2.DATA AND METHODS

In this study, sea ice thickness was calculated from CS2 L1b and S3 L2 WAT Enhanced waveform data from October 2018 to April 2019. In this process, sea surface classification and waveform distance retracking are the key steps. For sea surface classification, three echo waveform features, Radar Backscatter Coefficient (Sigma0), Leading Edge Width (LEW), and Pulse Peakiness (PP), were used for type identification. Based on the identification of sea ice and inter-ice channel waveforms, the Threshold First Maximum Retracker Algorithm (TFMRA) algorithm was used for both CS2 and S3 for waveform distance retracing. For CS2, 50% of the first maximum power was used as the retracker threshold for both inter-ice channel and sea-ice type waveforms。 while S3 used a comparison with OIB data to select the optimal retracker threshold. The final re-tracking threshold was determined to be 50% for both inter-ice channels and sea ice types.

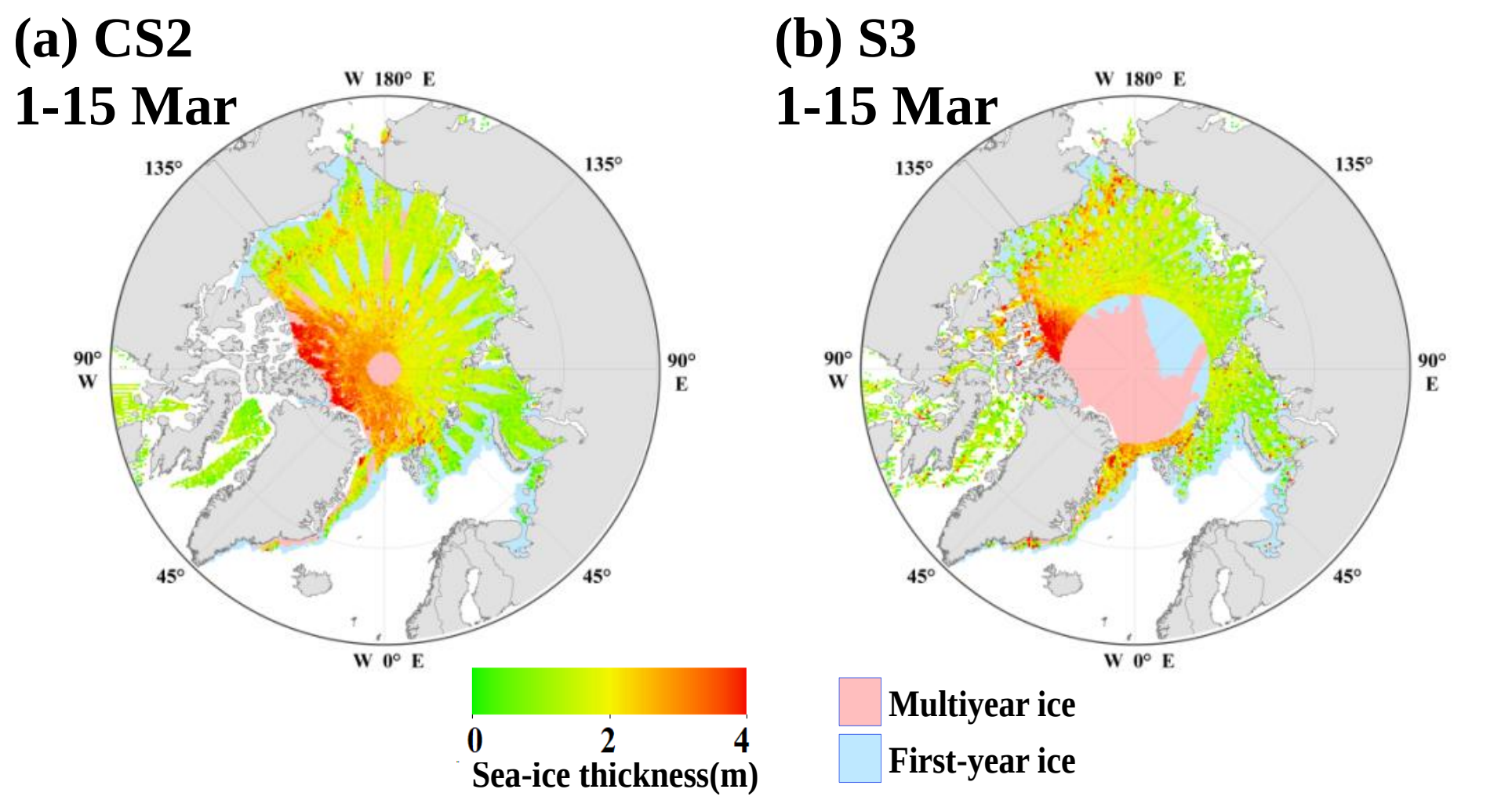

Fig. 1 Examples of satellite sea ice thickness semimonthly grid data entered in November 2018 and March 2019. schematic diagrams of CryoSat-2 and Sentinel-3A satellite altimeter sea ice thickness 25 km grid data.

The IDW method is used to fuse altimeter data from different sources. Considering the reliability of the generated data products, we will calculate a weighted average of the sea ice thickness and uncertainty estimates contained in each grid cell in the final generated 25 × 25 km grid product, and the fused product is shown in Fig. 2.

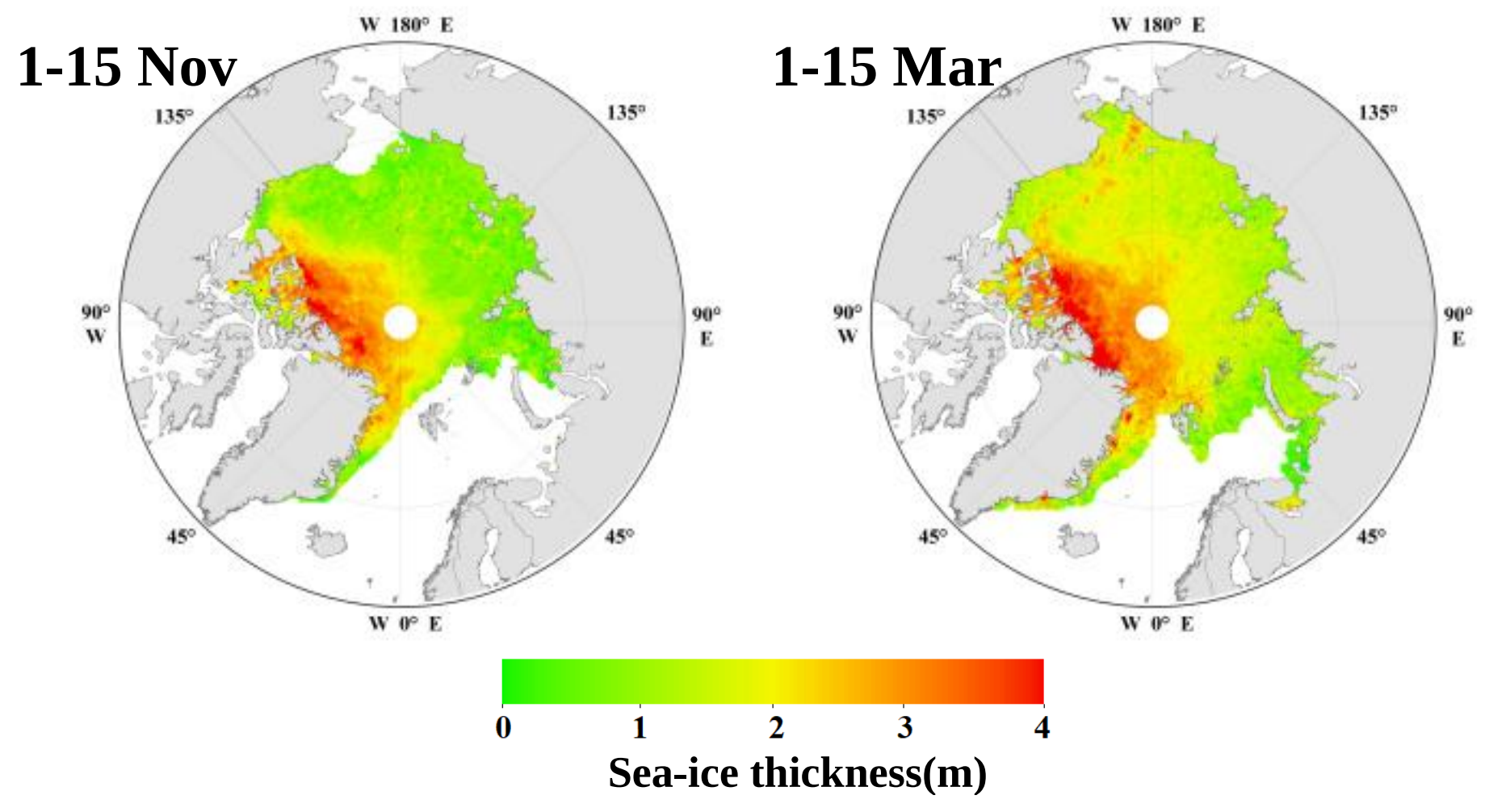

Figure 2 CS2_S3 Arctic 25km grid half-moon sea ice thickness products

3. CS2_S3ANALYSIS AND EVALUATION

3.1 Comparison with input data

As can be seen in Figure 3, the large differences between products (±1m) are mainly concentrated in the area of the sea ice edge.The absolute value of the difference in the inner Arctic region is usually less than 1 m. CS2_S3 has a good agreement with CS2 in the average thickness of each month, with deviations between 0.01 m and 0.22 m. In terms of StdDev, the trend of variation is the same for all three products, reaching the minimum value in January-March(Table 1).

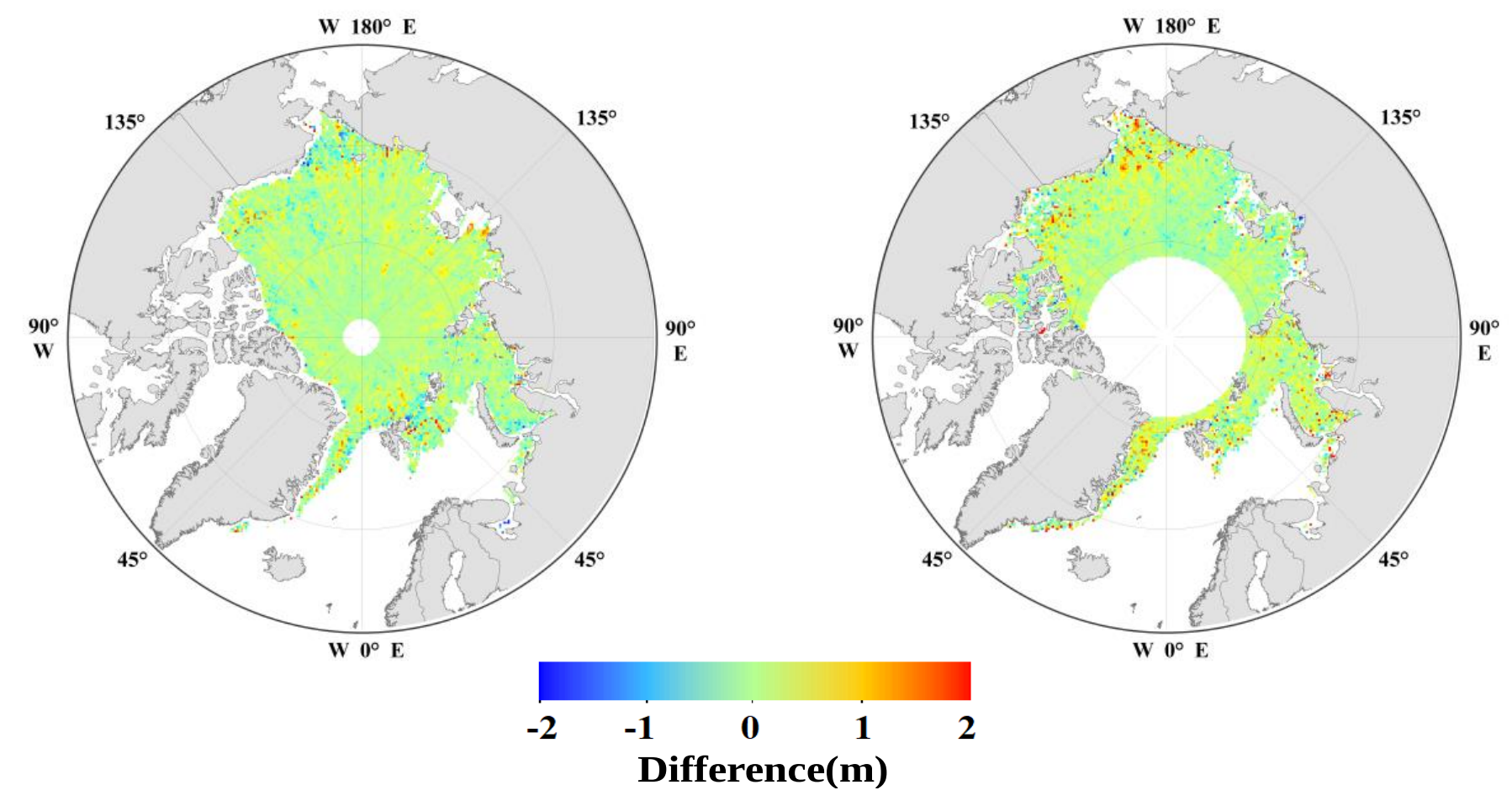

Figure 3 Difference between the CS2_S3 semimonthly product and the Sentinel-3A and CryoSat-2 monthly average sea ice thickness in March 2019

Table 1 Arctic-wide mean sea ice thickness (Mean) and standard deviation (StdDev) of the 2018-2019 winter fusion products (CS2_S3), individual satellite products CryoSat-2 (CS2), and Sentinel-3A (S3) inversions

Mean（m）	Oct	Nov	Dec	Jan	Feb	Mar	Apr
CS2_S3	1.22	1.50	1.54	1.58	1.67	1.85	1.97
CS2	1.40	1.38	1.40	1.46	1.68	1.87	1.96
S3	1.56	1.41	1.34	1.39	1.55	1.76	1.86
StdDev（m）							
CS2_S3	0.82	0.91	0.81	0.78	0.78	0.79	0.84
CS2	0.75	0.92	0.83	0.76	0.74	0.77	0.83
S3	1.04	1.05	0.94	0.88	0.87	0.85	0.94

3.2 Compared with OIB

A total of six OIB flight measurements were made in the first half of April 2018 (Fig. 4). The average sea ice thickness in the measurement area is highly variable (between 0.2-4m) and is typical of a mixed area of first-year and multi-year ice.

The comparison of the whole dataset shows that CS2_S3 has the smallest MAE (0.44m) and RMSE (0.60m) with the OIB measurements and is in good agreement with the OIB measurements (*r*=0.62). Compared to the single-star products (CS2 and S3), CS2_S3 showed an overall improved ice thickness performance.

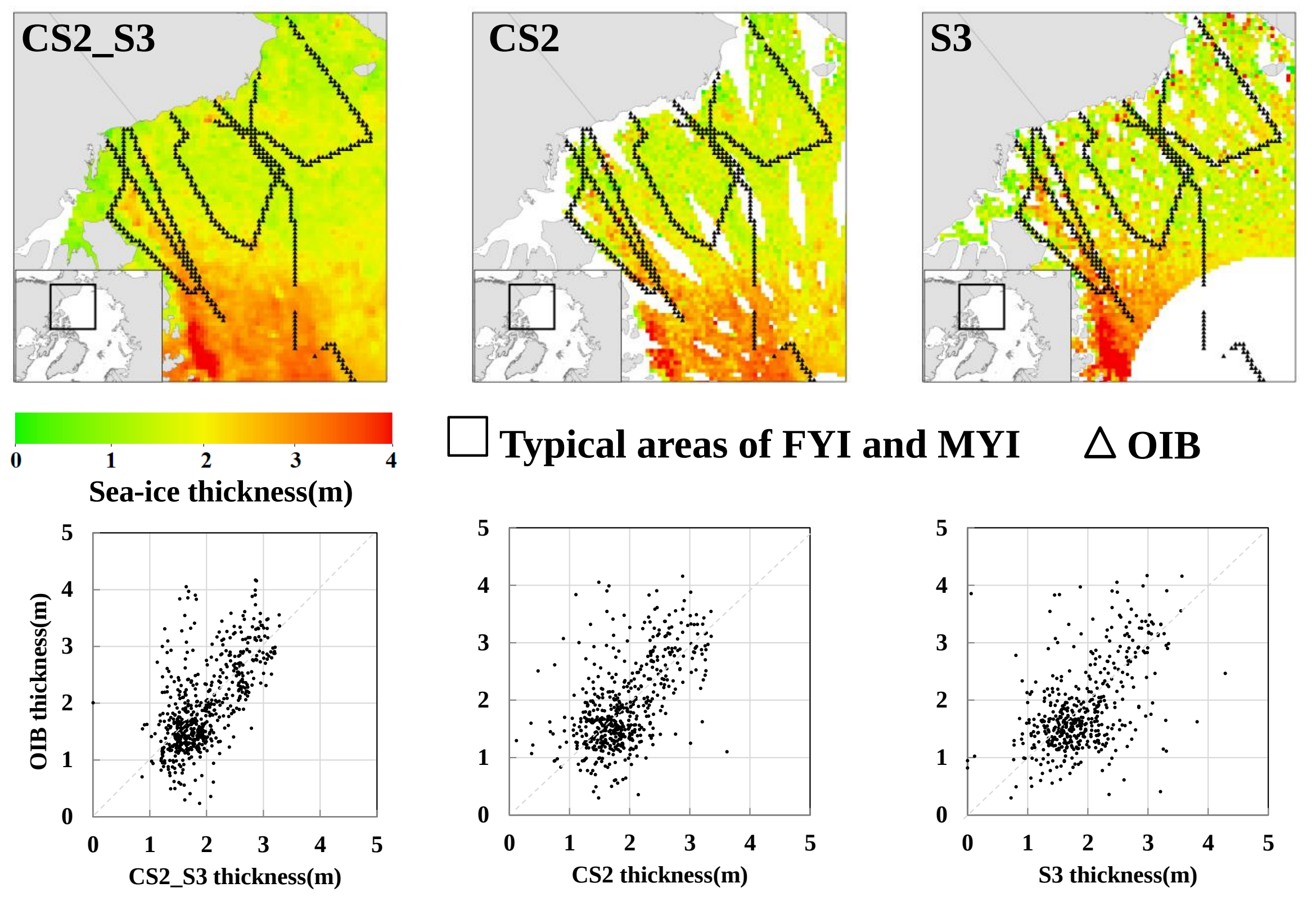

Fig. 4 Comparison of satellite inversion sea ice thickness with OIB measurements for mixed one-year ice and multi-year ice in the Beaufort Sea in the first half of April 2018.

3.3Comparison with ULS observations

As shown in Figure 5, the sea ice draft depths at the mooring sites were mainly concentrated in 1.4-1.6m, and the CS2_S3 and S3 sea ice thicknesses were concentrated in 1.6-1.8m, with a scale factor of 0.9 between them, which was in good agreement. Possibly influenced by the 25km spatial averaging, no thin ice (<0.8m) or thicker ice floes (>3m) were observed for any of the three satellite products.

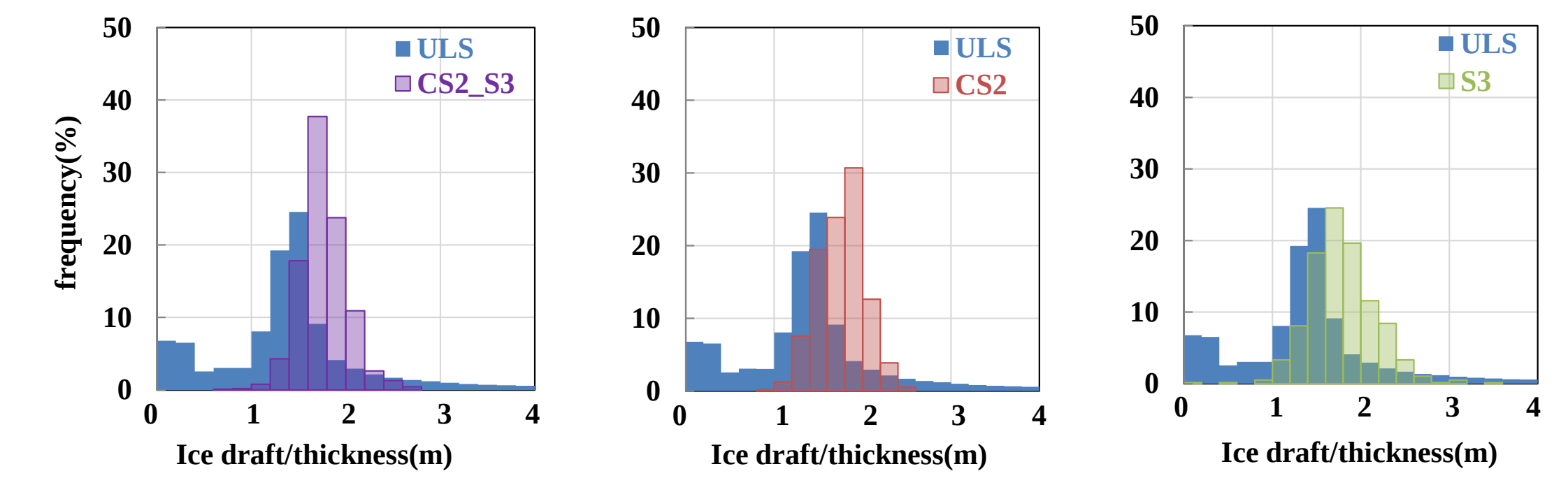

Figure 5 Histogram statistics of sea ice thickness distribution of satellite data products within 100 km radius of the ULS mooring location versus sea ice draft depth distribution observed at the mooring site for the first half of April 2018

4. CONCLUSION

This study demonstrates the possibility of CS2 and S3 fusion as well as its reliability. The comparison with OIB shows that the root-mean-square error of CS2_S3 is reduced by about 0.24 m and the mean absolute error is reduced by 0.15 m compared with that of the single satellites (CS2 and S3).The comparison with the sea ice draft depth observed by ULS shows that all three satellites can observe the distribution of sea ice thickness in the Beaufort Sea more accurately. Among them, the results of CS2_S3 and S3 observations are the most reliable.

5. REFERENCE

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