EVALUATION OF THE SIGNIFICANT WAVE HEIGHT FROM HY2B/ALT USING CRYOSAT2/SIRAL AND ICESAT2/ATLAS DATA SETS IN THE ARCTIC

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ABSTRACT

The significant wave height (SWH) is an important factor in the study of polar ocean and the forecast of polar marine environment. This study evaluated the SWH observed by the microwave altimeter (ALT) on board the HaiYang-2B (HY2B) satellite, using Cryosat2/SIRAL (SAR/Interferometric Radar Altimeter) and Icesat2/ATLAS (Advanced Topography Laser Altimeter System) data Comparison results show that the bias and the standard deviation (STD) of the SWH difference between HY2B/ALT and Cryosat2/SIRAL are -0.05±0.26m, and the difference between HY2B/ALT and Icesat2/ATLAS are 0.02±0.41m. The SWH from HY2B/ALT shows good consistency with that from Cryosat2/SIRAL and Icesat2/ATLAS. It can effectively reflect the real wave conditions in the Arctic

Index Terms— Significant wave height, HY2B, Cryosat2, Icesat2, The Arctic

1. INTRODUCTION

As an important part of the global climate system, the Arctic has received more and more attention due the amplified worming effect. Significant wave height (SWH) is one of the main parameters describing the characteristics of ocean waves and is important for ocean research and ocean environment forecasting in the Arctic. It also plays an important role in verifying ocean waves and other ocean process models [1]. The satellite altimeter is an active microwave sensor, which can measure the distance from the altimeter to the instantaneous surface, and then to calculate the sea level, sea surface wind and wave information. The HaiYang-2B (HY2B) satellite was launched on October 25, 2018. It is the second marine dynamic environmental satellite in China. This satellite integrated active and passive microwave remote sensors, with high accurate orbit measurement, orbit determination capabilities and all-weather, all-weather, global detection capabilities. The radar altimeter (ALT) on board the HY2B can measure the sea surface height, SWH and gravity field parameters. [2].

At present, some evaluation studies have carried out about the SWH data from ALT onboard the HaiYang series satellites. For example, Xu et al. evaluated the SWH data from HY2A/ALT by comparing it with the altimeters on the synchronized Jason1 and Jason2 satellites and draw a conclusion that the SWH observed by HY2A/ALT has an bias of 0.3-0.4m [3]; Ye et al. compare SWH data from HY2A/ALT with the NDBC buoy data from October 1, 2011 to September 30, 2014, and concluded that the root mean square error (RMSE) of the SWH is 0.3m, and the bias is -0.13±0.335m [4]. Jiang et al. also evaluated the HY2A/ALT SWH data by comparing it with the Jason2, Cryosat2, SARAL(Satellite with ARgos and ALtiKa) and NDBC (National Data Buoy Center) data during October 1, 2011 to March 15, 2016, the bias between HY2A and NDBC is 0.117m, and the RMSE is 0.215m [5]. Jia et al. compared the SWH from HY2B/ALT with Jason3 and concluded that the SWH accuracy of HY2B/ALT is better than 0.3m in the area between 66°N and 66°S [6]. So far, most of the evaluation work for SWH data from ALT onboard the HY series satellites is focused on the area between 66°N and 66°S [4-6]. In this study, in order to evaluate the observation performance of SWH data from HY2B/ALT in the Arctic, two SWH data sets are used from Cryosat2/SIRAL (SAR/Interferometric Radar Altimeter, SAR/Interferometric Radar Altimeter) and Icesat2/ATLAS (Advanced Topography Laser Altimeter System). The main configurations of the three sensors are shown in Table 1:

Table 1 The configurations of the altimeters.

Sensor	Lunch time	Working band/wavelength	Repeat period (days)
HY2HY2B/ALT	20181025	C band, Ku band	14
Cryosat2/SIRAL	20100408	Ku band	369(30)
Icesat2/ATLAS	20180915	532nm	91

2. DATA

This study used three SWH data sets from difference, they are:

The HY2B radar altimeter GDR data, which is provided by NSOAS (National Satellite Ocean Application Service, https://osdds.nsoas.org.cn). Due to the existence of sea ice in winter, it is impossible to obtain accurate SWH and SSH observation data in most areas of the Arctic from October to March of the following year. In this study, the temporal coverage of the data we used is 2019 and 2020, from April to October every year according to the overlapping time of the three data sets, and the spatial coverage is north of 66°N. The HY2B/ALT has two working bands, Ku-band and C-band. The main purpose of C-band is for atmospheric delay correction. This study used the Ku-band observation data, because the accuracy of it is higher than that of the C-band [2].

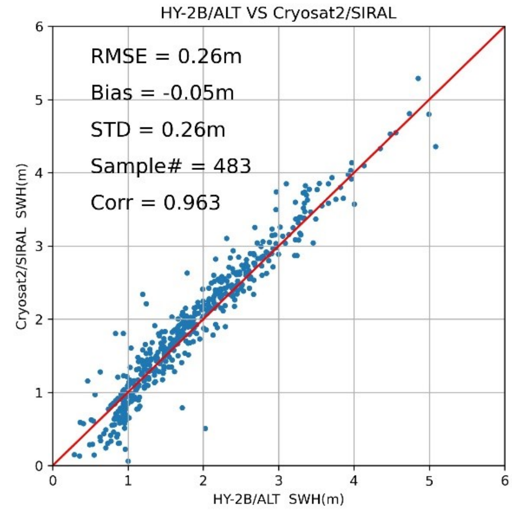
Cryosat2/SIRAL SWH data set. SIRAL has three working modes: LRM, SAR and SARin, which correspond to the observation of the ocean, the inside of ice sheet and the edge of ice sheet, separately. This study used the Level 2 SWH data from LRM mode, which is equivalent to the traditional radar altimeter. The noise level of the observed SWH is 1.6cm, 1.8cm and 2.7cm when the SWH is 2m, 4m, and 8m, respectively. SIRAL LRM model data is provided by European Space Agency (ESA) and distributed by Cryosat-2 Science Server (https://science-pds.cryosat.esa.int/)[7].

Icesat2/ATLAS SWH data set. The data is provided by National Snow and Ice Data Center (NSIDC, https://nsidc.org/data/ATL12/versions/3). This study used ATL12 L3A data set, which including 3 groups of strong and weak beam observations of SWH and mean surface sea height observations [8].

In addition, the FY3C/MWRI L2 sea ice concentration product [9] is used to remove the matchup grid including sea ice, which is to eliminate the error caused by the imprecision of surface type.

3. RESULTS AND DISCUSSIONS

When comparing the SWH data sets, we set the time window of matching process to 30 minutes, and the spatial window to 50km. After preprocessing of three data sets, we obtained 483 pairs of match up data for HY2B/ALT and Cryosat2/SIRAL, while 322 pairs for HY2B/ALT and Icesat2/ATLAS. The matching results and the distribution of the matching points are shown in Figure 1 and Figure 2:



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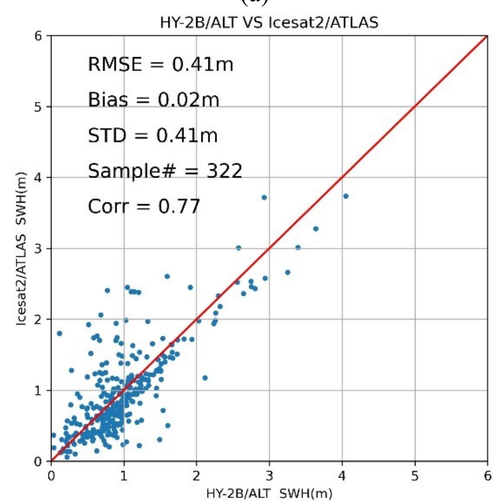
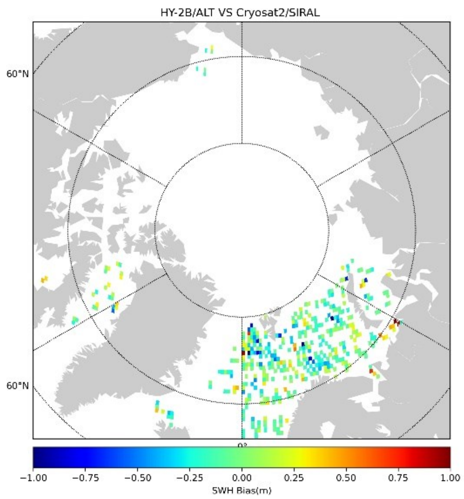


(b)

Fig 1 Scatterplots of matchup SWH in 50km spatial window. (a: Cryosat2/SIRAL vs HY2B/ALT; b: Icesat2/ATLAS vs HY2B/ALT)

It can be seen that when the SWH is lower than 1m, the values of HY2B/ALT are higher than that of Cryosat2/SIRAL, but as the SWH increases, the relative difference between the two data sets gradually decrease, and they match well in the entire data range; On the whole, the SWH of HY2B/ALT is slightly lower than that of Cryosat2/SIRAL. While the comparison between HY2B/ALT and Icesat2/ATLAS shows that the SWH match up data are mainly concentrated within 2m, and the SWH of HY2B/ALT is higher than that of Icesat2/ATLAS.



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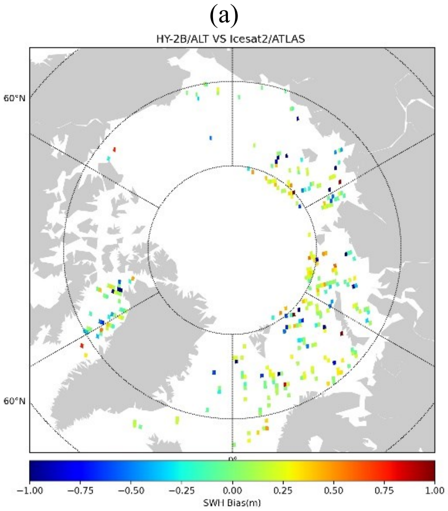


(b)

Fig 2 The distribution of match up SWH data. The color represents the SWH differences and white regions indicate no matchup data. (a) HY2B/ALT minus Cryosat2/SIRAL. (b) HY2B/ALT minus Icesat2/ATLAS.

The distribution of match up data is relatively scattered, and the SWH difference between them is greater than that between HY2B/ALT and Cryosat2/SIRAL. The statistics of the comparing results are shown in Table 2:

Table 2 The statistics of the SWH comparison results in 50km spatial window.

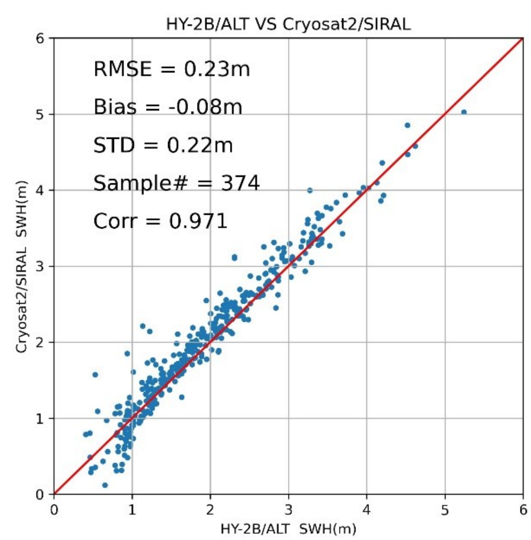
Data set	Number of match up data	Bias (m)	STD (m)	RMSE (m)	Correlation coefficient (Corr)
HY2B/ALT - Cryosat2/SIRAL	483	-0.05	0.26	0.26	0.963
HY2B/ALT - Icesat2/ATLAS	322	0.02	0.41	0.41	0.77

Analyzing the sources of the differences, there may be from the following aspects: the First is the differences in the atmospheric correction methods and the SWH retrieval algorithms; secondly, it may be caused by the difference of the special resolution, because the ground footprint of different satellite sensor and the uncertainty of the geoid are also error source in altimeter measurements [10]; The third is the different positions of match up data. In this paper, the matching space window is set to 50km as commonly used, but due to the complicated composition of sea waves, spatial differences may lead to different SWH. While the reason for the SWH difference between HY2B/ALT and Cryosat2/SIRAL is lower and shows a relatively good consistency than that between HY2B/ALT and Icesat2/ATLAS, may have two resources. One is that the HY2B/ALT and Cryosat2/SIRAL are both microwave sensors, the echo signals are affected by the atmosphere similarly, and the ground footprints are close; the other is the position differences of SWH matching points as shown in Figure 2. The matching data of HY2B/ALT and Cryosat2/SIRAL are mainly in the southern part of Svalbard, Barents Sea, Kara Sea, Laptev Sea and the Baffin Sea. They are relatively concentrated. While the matching data of HY2B/ALT and Icesat2/ATLAS are distributed throughout the Arctic. The diverse conditions in different regions may lead to the SWH observation differences.

To verify the influence of spatial window on the comparison, we also calculate the matching results with the spatial window of 25km, as shown in Table 3 and Figure 3:

Table 3 The statistics of the SWH comparison results in 25km spatial window.

Data set	Number of match up data	Bias (m)	STD (m)	RMSE (m)	Coefficient of determination (R^2)
HY2B/ALT - Cryosat2/SIRAL	374	-0.08	0.22	0.23	0.971
HY2B/ALT - Icesat2/ATLAS	216	0.06	0.3	0.3	0.884



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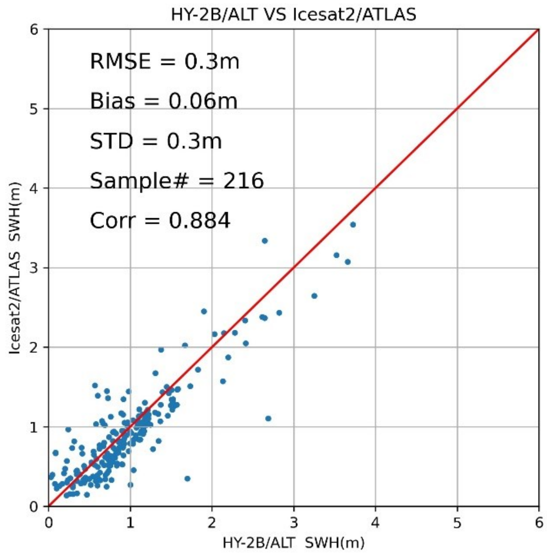

(b)

Fig 3 Scatterplots of matchup SWH in 25km spatial window. (a: Cryosat2/SIRAL vs HY2B/ALT; b: Icesat2/ATLAS vs HY2B/ALT)

It can be seen that under the 25KM spatial window, the numbers of the SWH match up data are decreased to 374 and 216, respectively. The bias between HY2B/ALT and Icesat2/ATLAS is slightly increased, but the RMSE and STD are declined， accompanied with the coefficient of determination increasing. While the SWH difference between HY2B/ALT and Cryosat2/SIRAL is influenced slightly. It can be seen that the different matching space windows have little influence on the matching results of the same microwave altimeters, but have great influence on that of microwave and laser altimeters.

4. COCLUSION

In this study, we used the SWH data sets from Cryosat2/SIRAL and Icesat2/ATLAS to evaluate the SWH data from HY2B/ALT in the Arctic. The comparison results showed that the SWH data from HY2B/ALT have better consistency with that from Cryosat2/SIRAL and Icesat2/ATLAS. When the matching spatial window is 50km, the bias between HY2B/ALT and Cryosat2/SIRAL are -0.05m, while between HY2B/ALT and Icesat2/ATLAS is 0.05m; the STDs are 0.26m and 0.41m, and the RMSEs are 0.26m and 0.41m, respectively. When the spatial window is 25km, the deviation increases slightly due to the number decrease of match up, the RMSE between HY2B/ALT and Cryosat2/SIRAL decreases slightly, while that between HY2B/ALT and Icesat2/ATLAS decreases significantly compared with 50km window. It can be concluded that the SWH data from HY2B/ALT can reflect the sea wave condition well and can be used to simulate the marine environment in the Arctic.

It should be pointed out that since the HY2B satellite has just been in orbit for less than three years, we got few match up data samples which may lead to the limitation of the conclusion. As time accumulates, the evaluation results will be more accurate.

5. ACKNOWLEDGMENT

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