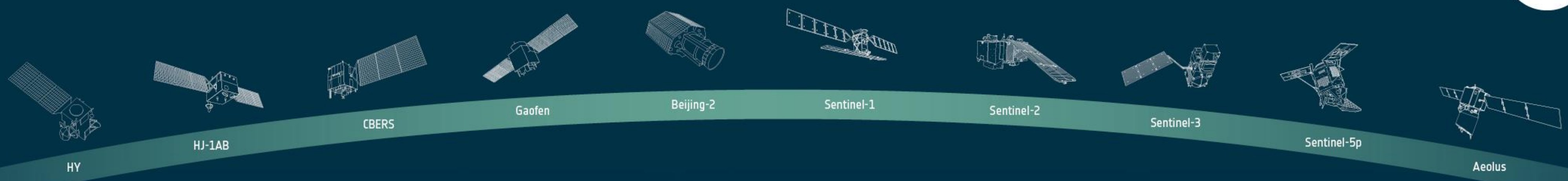

2022 DRAGON 5 SYMPOSIUM

MID-TERM RESULTS REPORTING

17-21 OCTOBER 2022

[PROJECT ID. 58900]

[MARINE DYNAMIC ENVIRONMENT MONITORING IN THE CHINA SEAS AND WESTERN PACIFIC OCEAN BY SATELLITE ALTIMETERS]

< DAY 2, 18 OCT 2022>

ID. 58900

PROJECT TITLE: MARINE DYNAMIC ENVIRONMENT MONITORING IN THE CHINA SEAS AND WESTERN PACIFIC OCEAN SEAS BY SATELLITE ALTIMETERS

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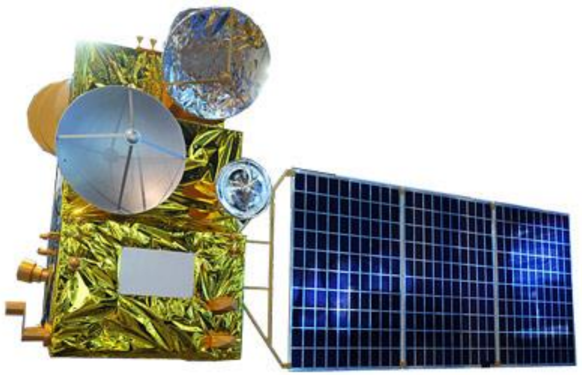
PRESENTED BY: JUNGANG YANG, FIRST INSTITUTE OF OCEANOGRAPHY, MNR, CHINA

1. The project's objectives

- To combine European and Chinese altimeters to improve the abilities of data applications and the ocean dynamic monitoring abilities in the China seas.
- To develop the reprocessing method of Sentinel-3, HY-2 series in the China seas, to merge these satellite altimeters to grid SSH and SWH data with high spatial resolution.
- to applicate these data in the study of ocean wave, ocean current and mesoscale eddies in the China seas and western Pacific Ocean.

Sentinel-3A
Launched on 16 Feb. 2016

Sentinel-3B
Launched on 25 Apr. 2018



HY-2B
Launched on 25 Oct. 2018

HY-2C: 21 Sep. 2020
HY-2D: 19 May 2021

EO Data Delivery

Altimeter data of Sentinel-3A/3B and Sentinel-6, Sentinel-1A/B SAR data from Europe and altimeter data of HY-2 series satellites from China are used in this study.

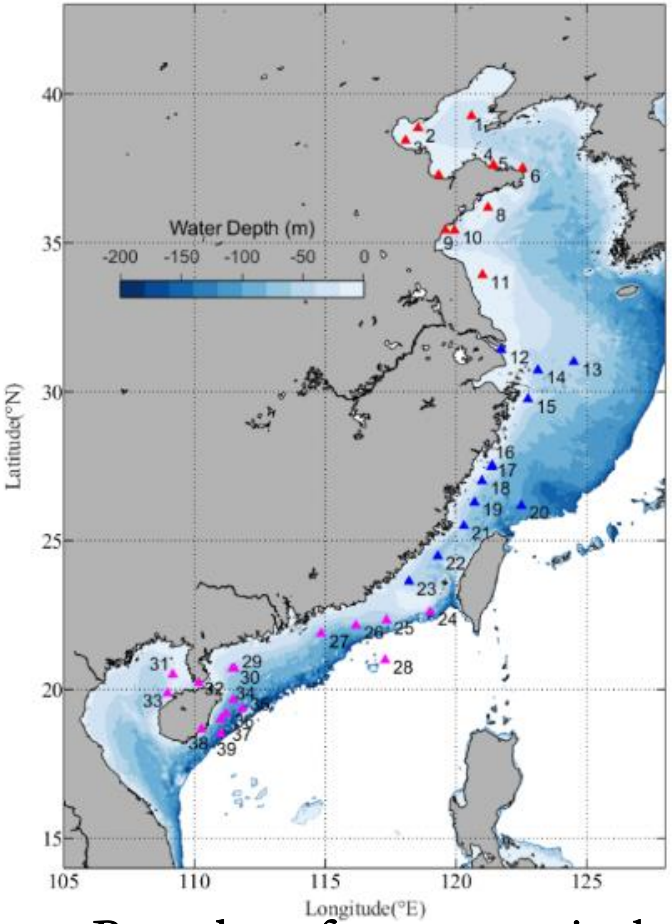
Copernicus Sentinels data	No. Scenes
1. SENTINEL-3A/B SRAL Altimetry	all achieved data until to 2021 in study area
2. SENTINEL-1A/B Wave (WV)	all achieved data until to 2021 in study area
3. SENTINEL-6 POSEIDON-4 L2	all L1 & L2 achieved data until to 2021 in study area
Total:	
Issues:	

Chinese EO data	No. Scenes
1. HY-2A ALT	all achieved data until to 2021 in study area
2. HY-2B ALT	all achieved data until to 2021 in study area
3. HY-2C ALT	all achieved data until to 2021 in study area
Total:	
Issues:	

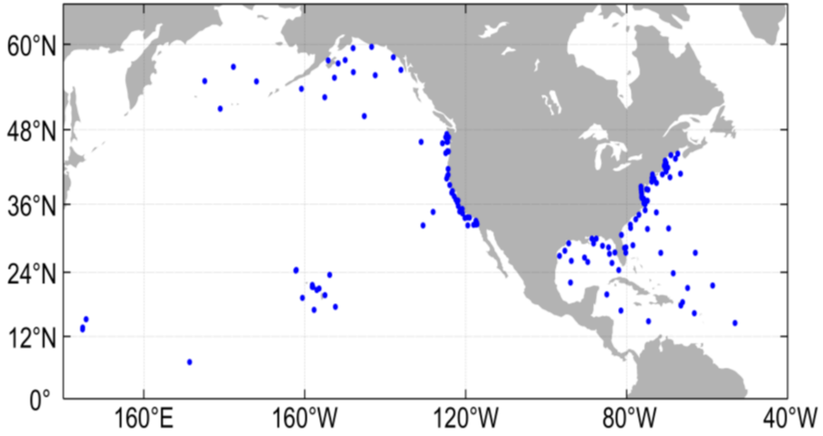
In addition, Jason-2/3, SARAL altimeter data and CFOSAT SWIM data were used in this study.

Detail the in-situ data measurements and requirements

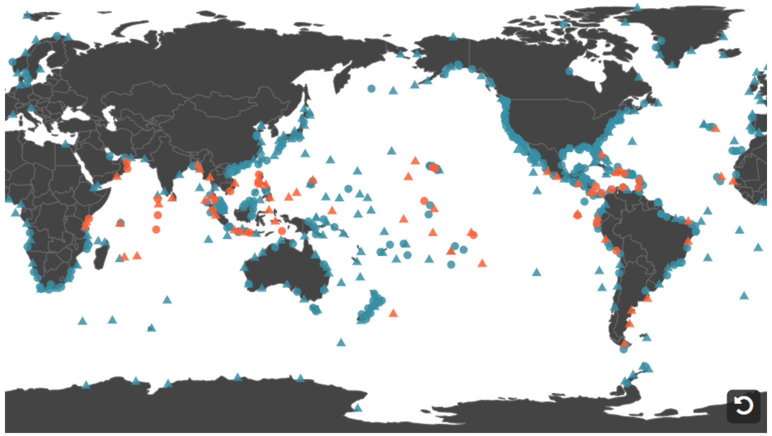
In-situ data: Ocean wave data from buoys and tide gauge data.



Buoy data of ocean wave in the coastal area of the China Sea



NDBC buoy data of ocean wave



Tide gauge data from UHSLC

European Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Bjarke Nilsson	Technical University of Denmark – National Space Institute	Consolidating ICESat-2 Ocean Wave Characteristics With CryoSat-2 During The CRYO2ICE Campaign	Analysis, validation, data curation, writing
Mads Ehrhorn	Technical University of Denmark – National Space Institute	Predicting Future Sea Level from Satellite Altimetry	Analysis, model creation, data handling, writing

Chinese Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Zhiheng Hong	First Institute of Oceanography, Ministry of Natural Resources	The Improvement of HY-2B Satellite Altimetry Range Corrections in Coastal Area	Analysis, validation, data curation, writing
Jiaju Ren	First Institute of Oceanography, Ministry of Natural Resources	Optimization Of Waveform Retracking Algorithm For Sentinel-3 SAR Altimeter In Coastal Altimetry	Analysis, validation, data curation, writing

2. The main results after 2 years' activities

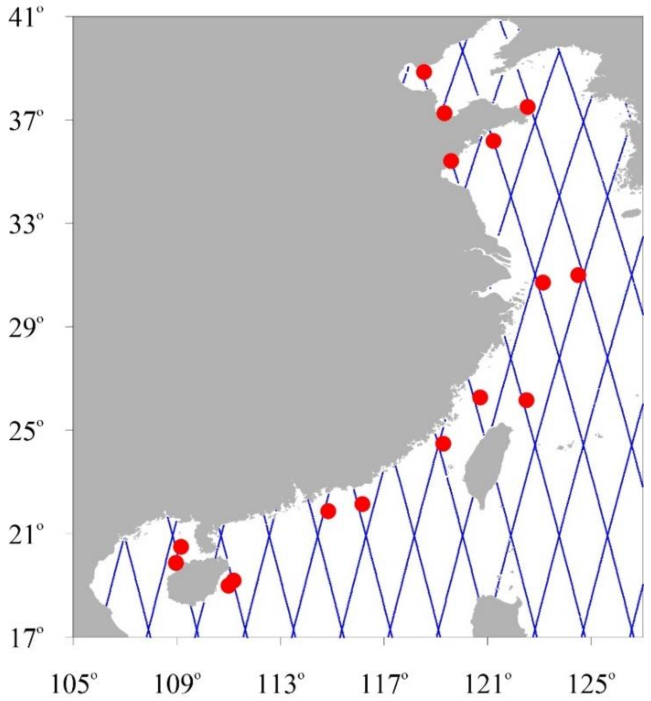
The following three tasks were carried out:

- The waveform retracking of HY-2B ALT in the coastal areas by two methods. One is the two-pass waveform retracker (Sandwell and Smith, 2005). The other is the effective trailing edge determining retracker presented in the study of this project.
- Generation of sea surface current data by combing the altimeter, sea surface wind and SST data in the global ocean.
- The studies on ocean wave: accuracy evaluation of CFOSAT SWIM data, data fusion of Significant Wave Height by multi-source remote sensing data, characteristics analysis of ocean wave in global ocean.

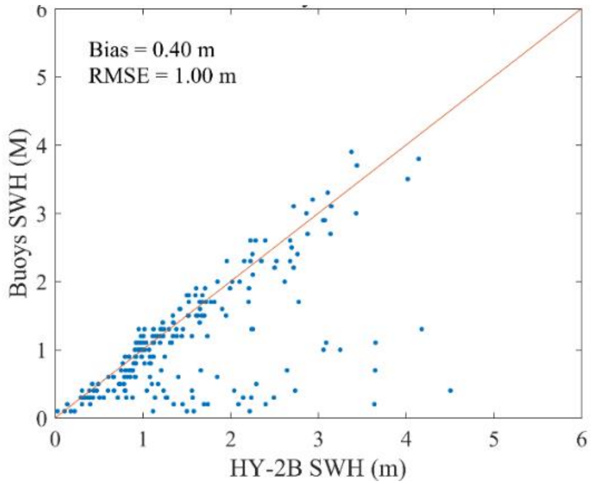
1) Coastal Waveform Retracking of HY-2B ALT

➢ By two-pass retracker

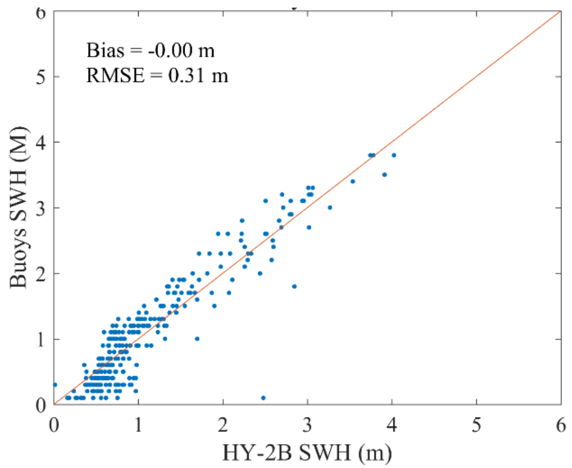
The waveforms of HY-2B altimeter data in the coastal areas are retracked by the two-pass retracker. The SWH between GDR data and retracked results are compared to buoys data.



16 buoys in the coastal waters of China



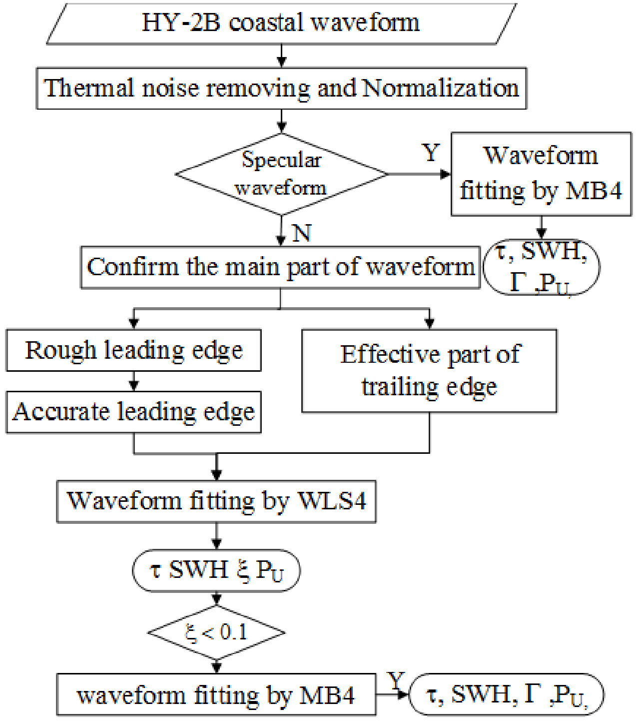
GDR data



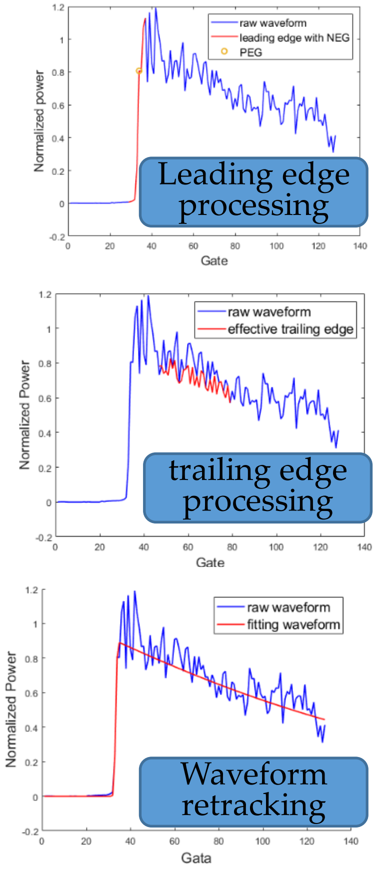
Retracking results

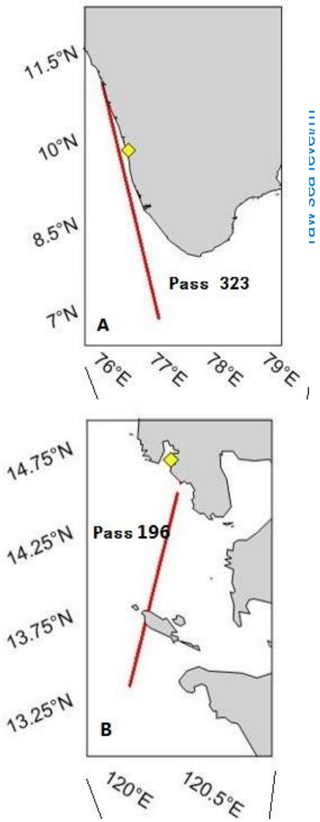
- RMSE reduced from 1.0m to 0.31m.
- The results show that the retracking of waveform improves the data precision of HY-2B ALT.

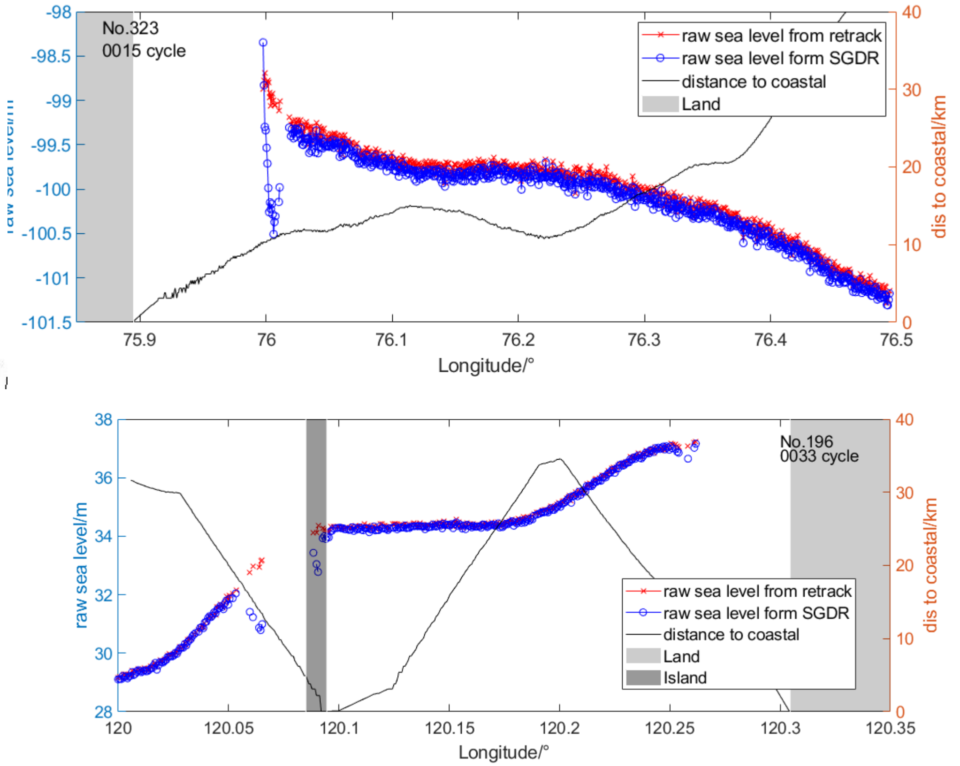
➢ by the effective trailing edge determining retracker



The flow chart of waveform retracking







The accuracy of the reprocessing results in the range of 0-40 km offshore is validated against the tide gauge data. The results show that the accuracy of the reprocessed data is higher than that of the SGDR data and has good performance within 15 km offshore.

2) Generation of sea surface current data

Sea surface current data are generated by combing the altimeter, sea surface wind and SST data.

CMEMS Sea surface height data from the multi-source altimeters merging(0.25°, daily, 1993-2020)

$$\begin{cases} u = -\dfrac{g}{f}\dfrac{\partial h}{\partial y} \\ v = \dfrac{g}{f}\dfrac{\partial h}{\partial x} \end{cases}$$

Geostrophic equilibrium relation

Geostrophic Current *Ug*

CCMP (Cross-Calibrated Multi-platform Wind Vector Analysis) wind data (0.25°, daily, 1993-2020)

Two parameter model

$$\tau = [\tau_x, \tau_y] = \rho_a C_D V_{10}[u_{10}, v_{10}]$$

Ekman Current *Ue*

$$U_{sfc} = U_g + U_e$$

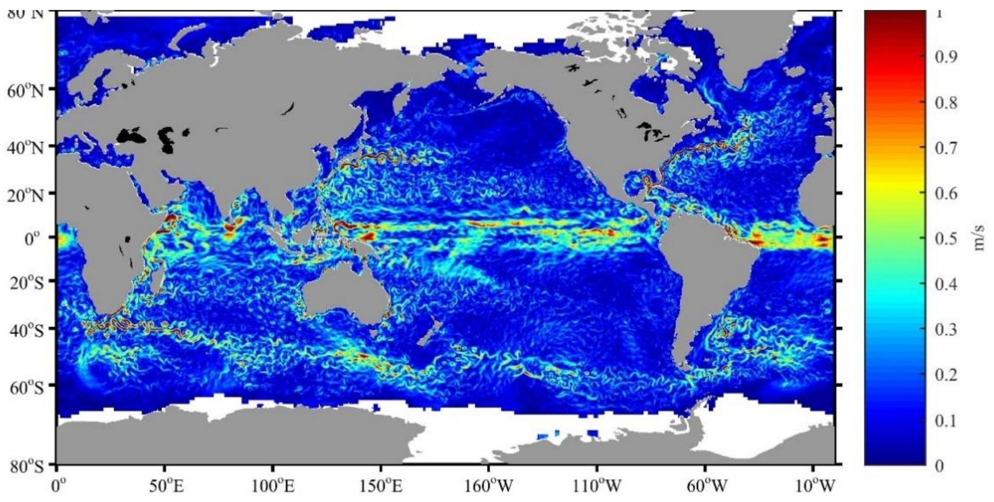
Initial Sea Surface Current

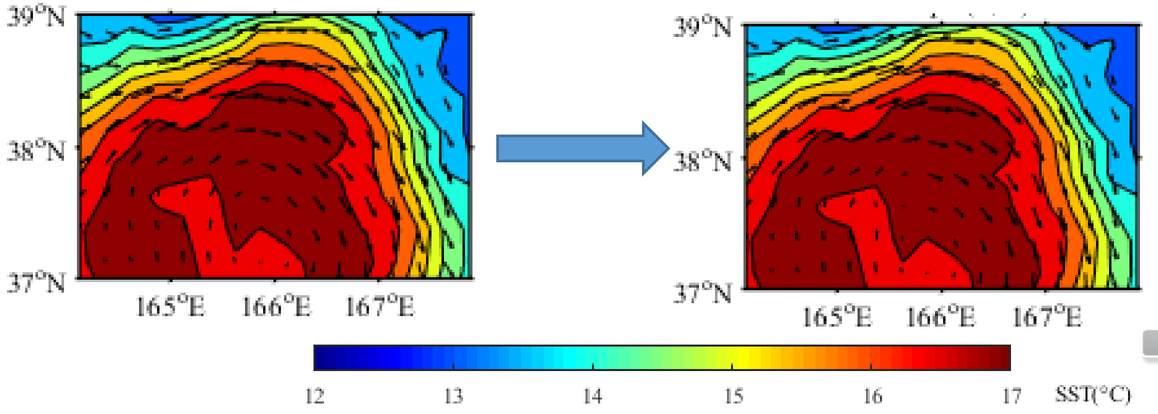
$$\frac{\partial SST}{\partial t} + u\frac{\partial SST}{\partial x} + v\frac{\partial SST}{\partial y} = F$$

Modified by SST

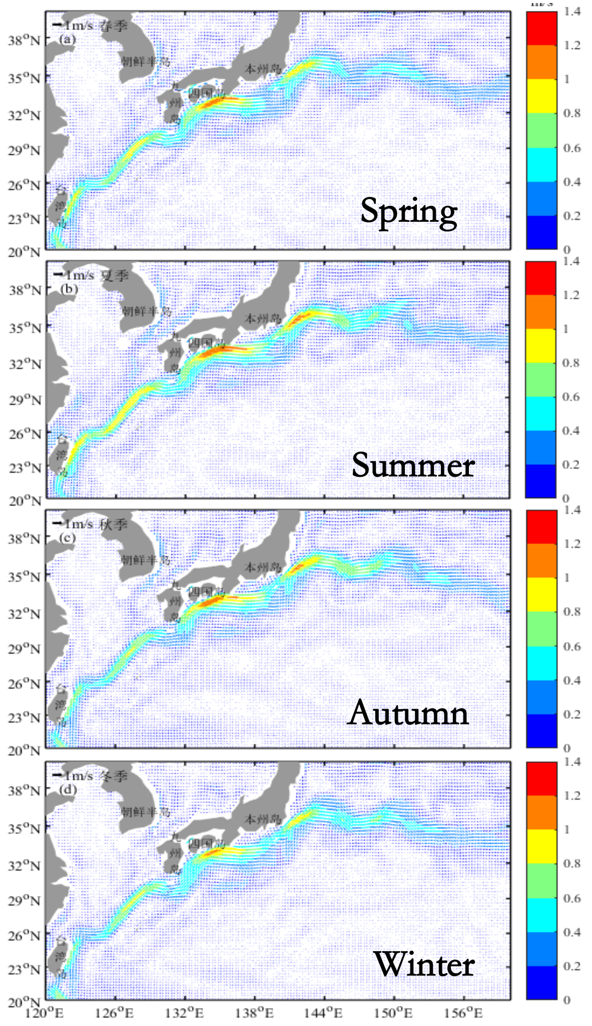
Sea Surface Current

The flow chart of generating sea surface current

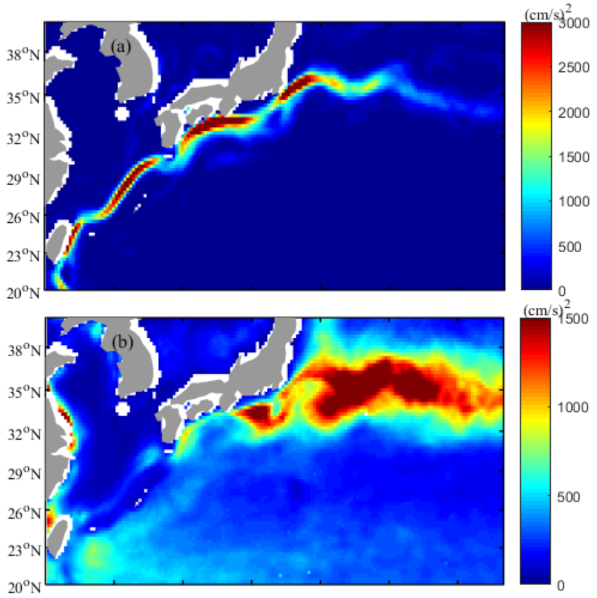




➢ Sea surface current data application on the Kuroshio

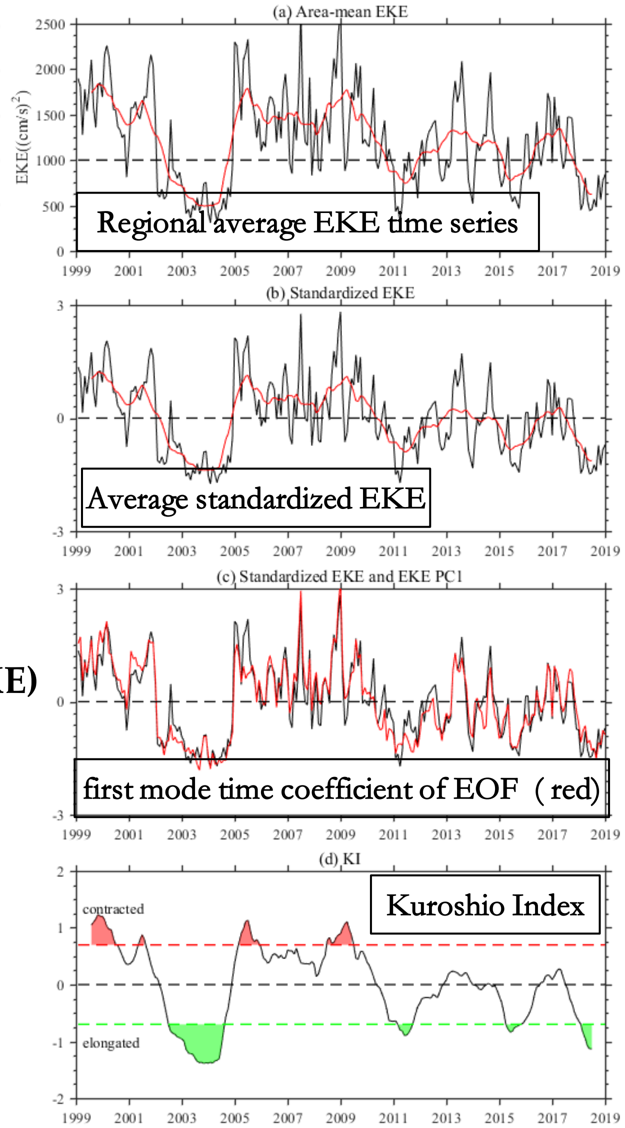


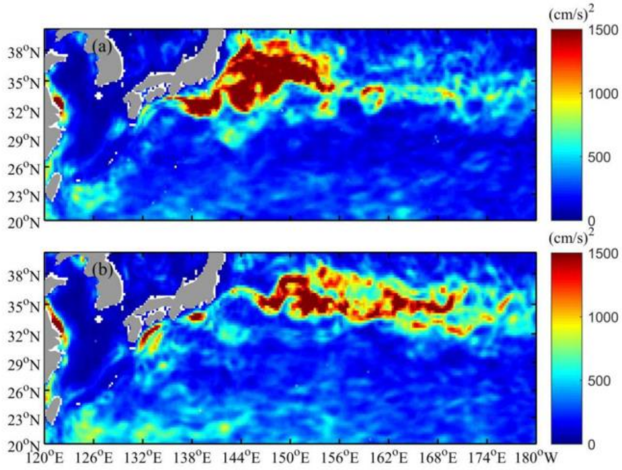
Multi year seasonal average flow field



Multi year mean kinetic energy (MKE) and eddy kinetic energy (EKE)

- Strong in summer and weak in winter;
- Alternating distribution of low velocity area and high velocity area.





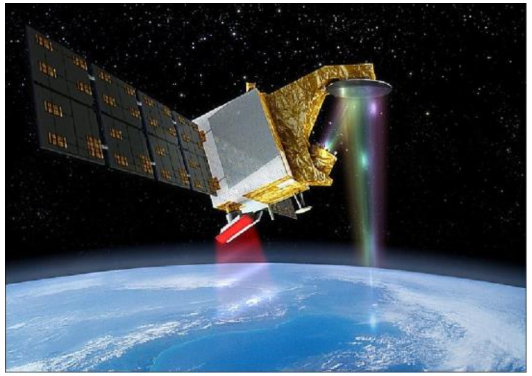
eddy kinetic energy (EKE) of Kuroshio Extension

Contraction period:
1999-2001,2009;
Extension period:
2002-2004, 2011,2015, 2018.

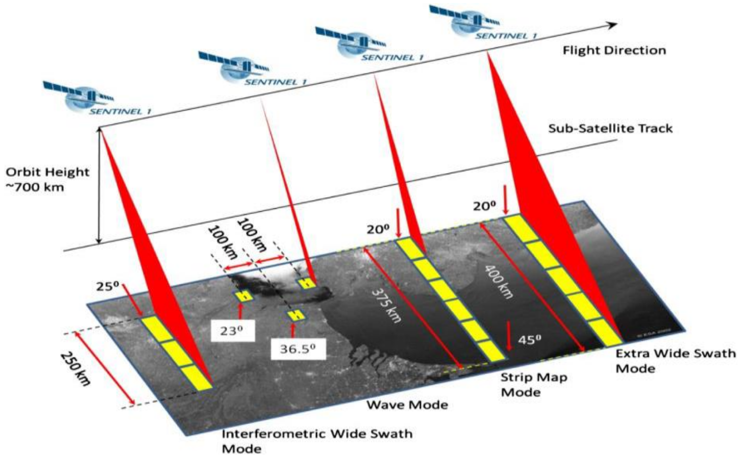
KI shows that the Kuroshio Extension has significant low-frequency oscillation on the interdecadal time scale.

3. Research on ocean wave satellite remote sensing products based on altimeters, CFOSAT SWIM and Sentinel-1 SAR data

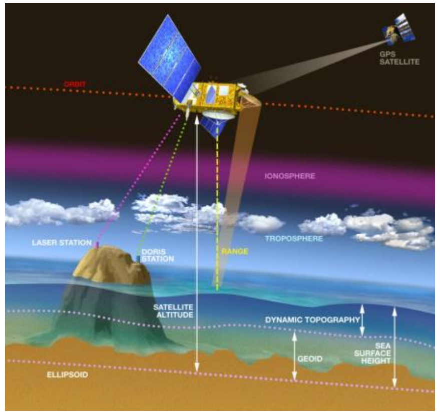
- Evaluation of CFOSAT SWIM ocean wave data by comparing to buoys and altimeters data
- Generation of ocean wave grid data by merging multi-platform remote sensing data
- Characteristics analysis of global ocean wave



CFOSAT (Chinese-French Oceanography Satellite)
SWIM (Surface Waves Investigation and Monitoring instrument)

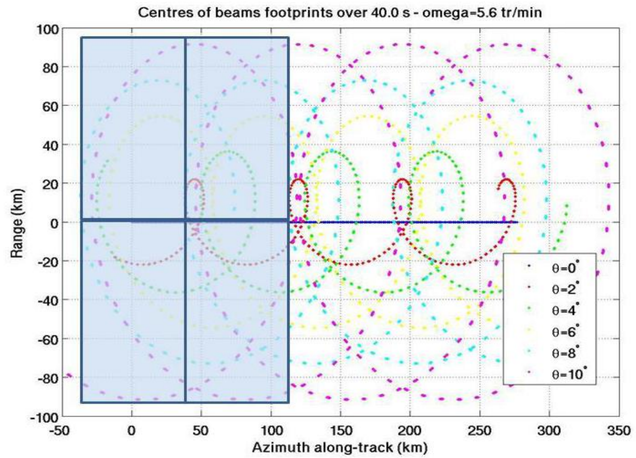


Sentinel-1A/B SAR OCN data

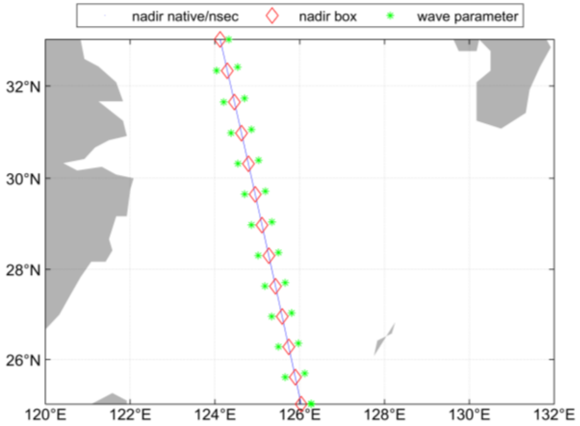


Altimeters: Sentinel-3A/B, HY-2A/B/C
Jason-2/3, SARAL

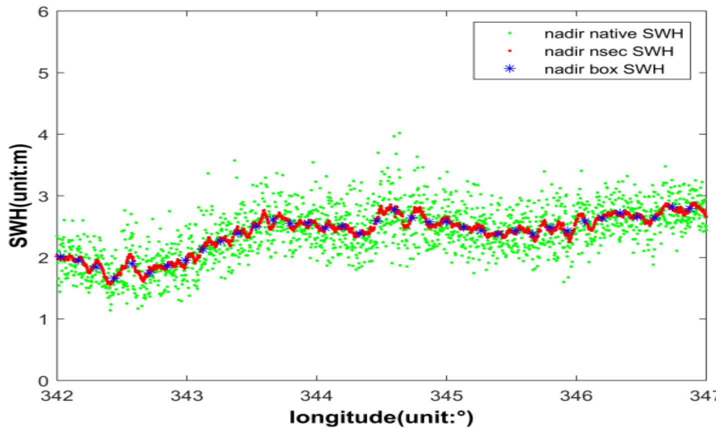
1) Evaluation of CFOSAT SWIM ocean wave data



SWIM working principle



Example of the location of nadir and off-nadir SWH data

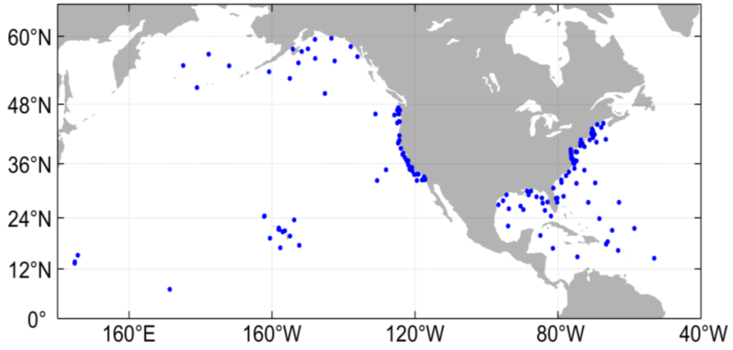


Example of the comparison of three kinds of nadir SWH

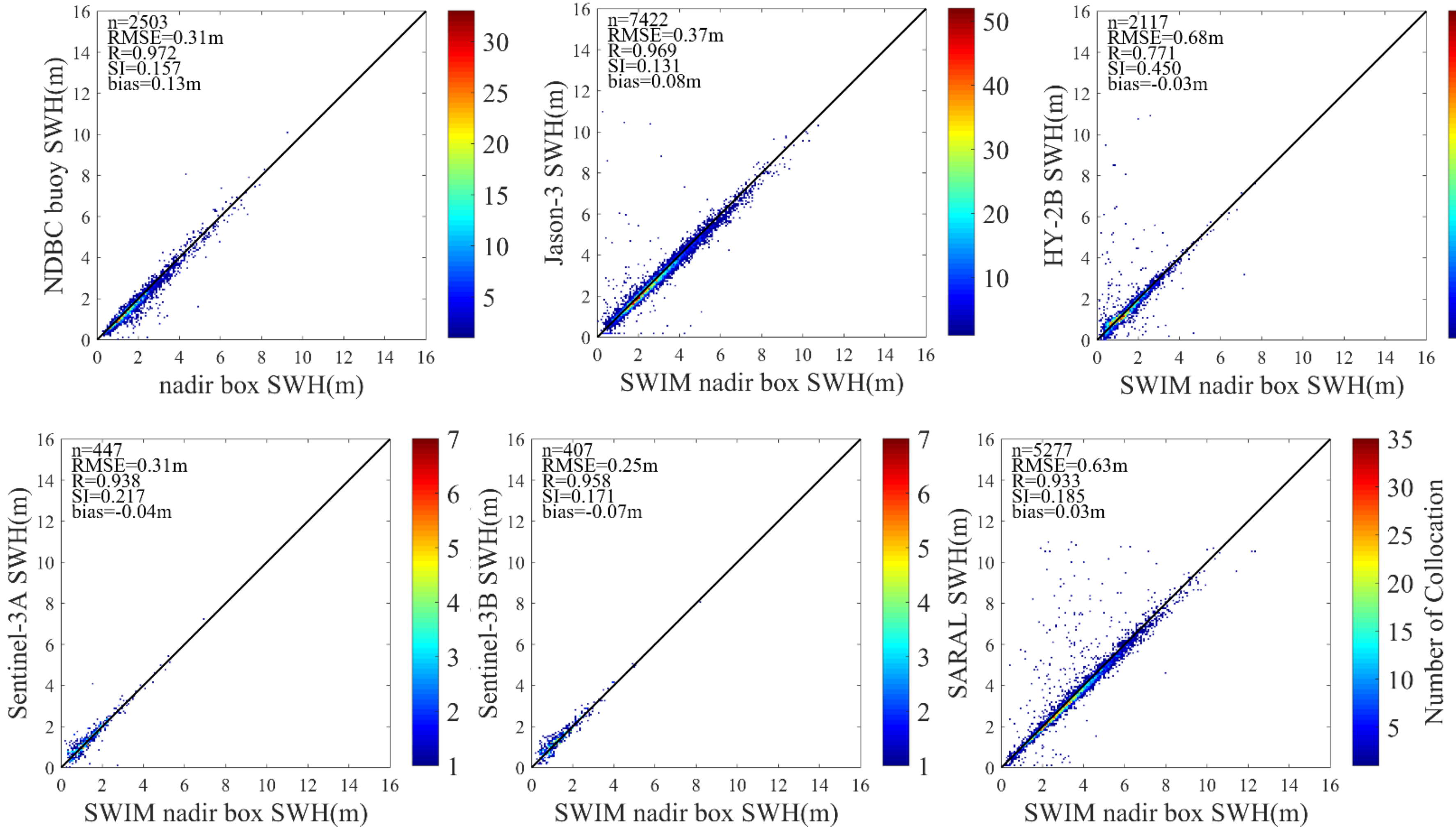
The CFOSAT SWIM data during the period from April 25 2019 to Dec. 31 2021 are evaluated by compared to NDBC Buoys data and altimeters data. SWIM data includes three kinds of nadir SWH (native, nsec, box) and off-nadir SWH data of different incidence angle (6°, 8, 10 and combined).

- NDBC buoys data: 148 buoys are used.
- Altimeters data: Jason-3, HY-2A/B/C, Sentienl-3A/B, SARAL .

Matching criteria: The spatial and temporal scales is 25 km and 30 min.

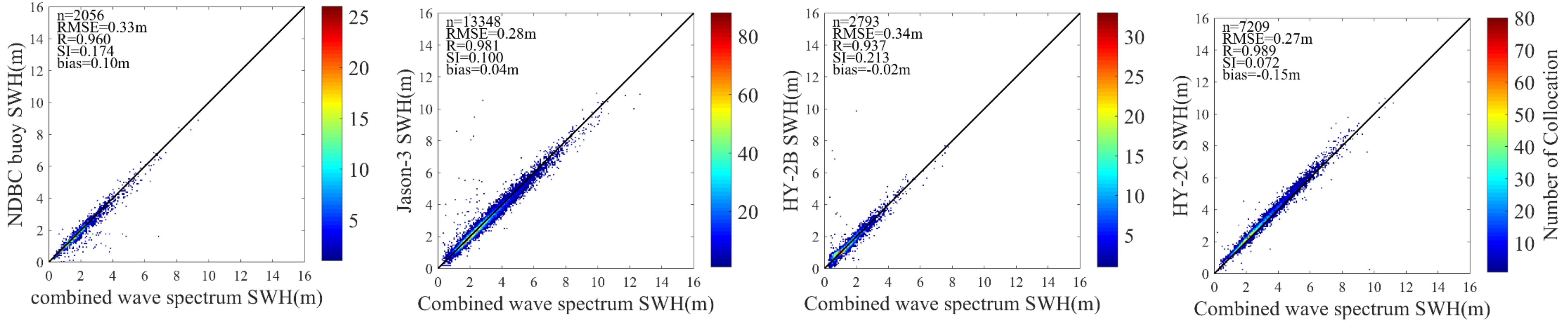


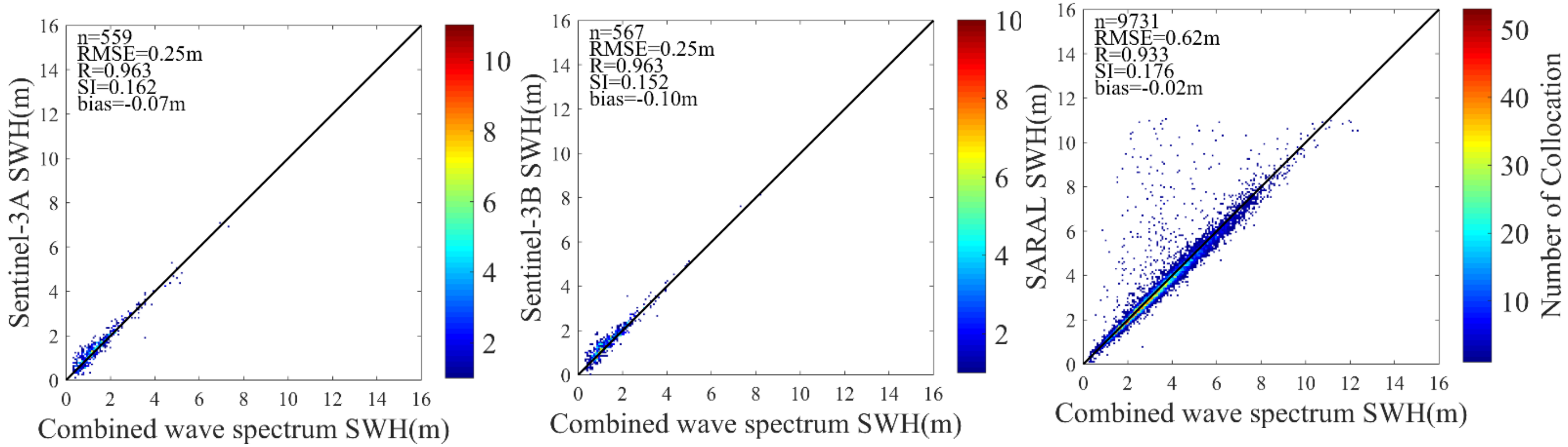
➢ The evaluation of SWIM nadir SWH data by comparing to buoys and altimeters data



	n	bias	RMSE	R
Buoys	2503	0.13m	0.31m	0.972
Jason-3	7422	0.08m	0.37m	0.969
HY-2B	2127	-0.03m	0.68m	0.771
HY-2C	3930	-0.12m	0.35m	0.975
Sentinel-3A	447	-0.04m	0.31m	0.938
Sentinel-3B	407	-0.07m	0.25m	0.958
SARAL	5277	0.03m	0.63m	0.933

➢ The evaluation of SWIM off-nadir SWH data by comparing to buoys and altimeters data





	n	bias	RMSE	R
Buoy	2056	0.10m	0.33m	0.960
Jason-3	13348	0.04m	0.28m	0.981
HY-2B	2793	-0.02m	0.34m	0.937
HY-2C	7209	-0.15m	**0.27m**	0.989
Sentinel-3A	559	-0.07m	**0.25m**	0.963
Sentinel-3B	567	-0.10m	**0.25m**	0.963
SARAL	9731	-0.02m	0.62m	0.933

2) Generation of ocean wave grid data by merging multi-platform remote sensing data

➢ The merging of global SWH data

Data:

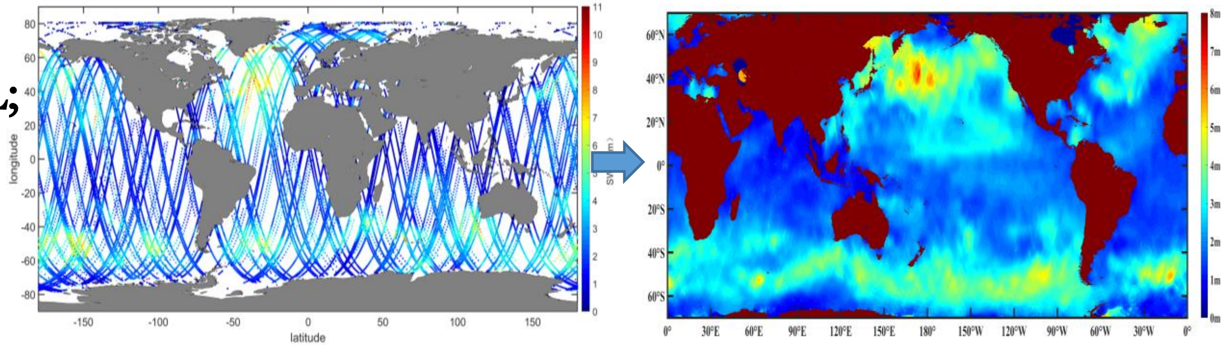
- ALT: Sentinel-3A/B, HY-2A/B/C, Jason-2/3, SARAL;
- SAR: Sentinel-1A/B ;
- CFOSAT SWIM;

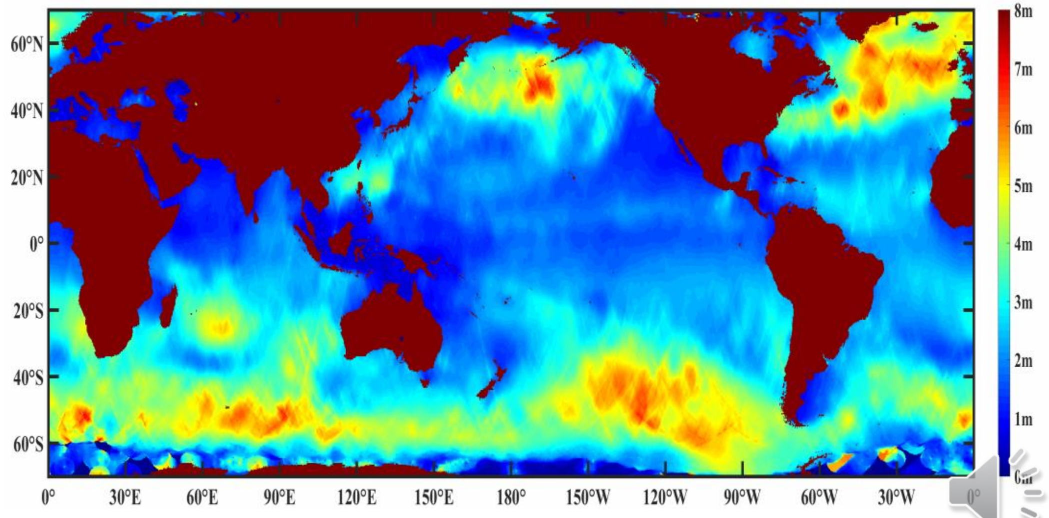
Method: Inverse distance weighting method.

$$Z_{xy} = \frac{\sum_{i=1}^{n} Z(i)\omega_i}{\sum_{i=1}^{n} \omega_i}$$

The spatial and temporal resolution of SWH gridding data is 0.25° ×0.25° and daily. The spatial and temporal scales are 300/400km and 3 days.

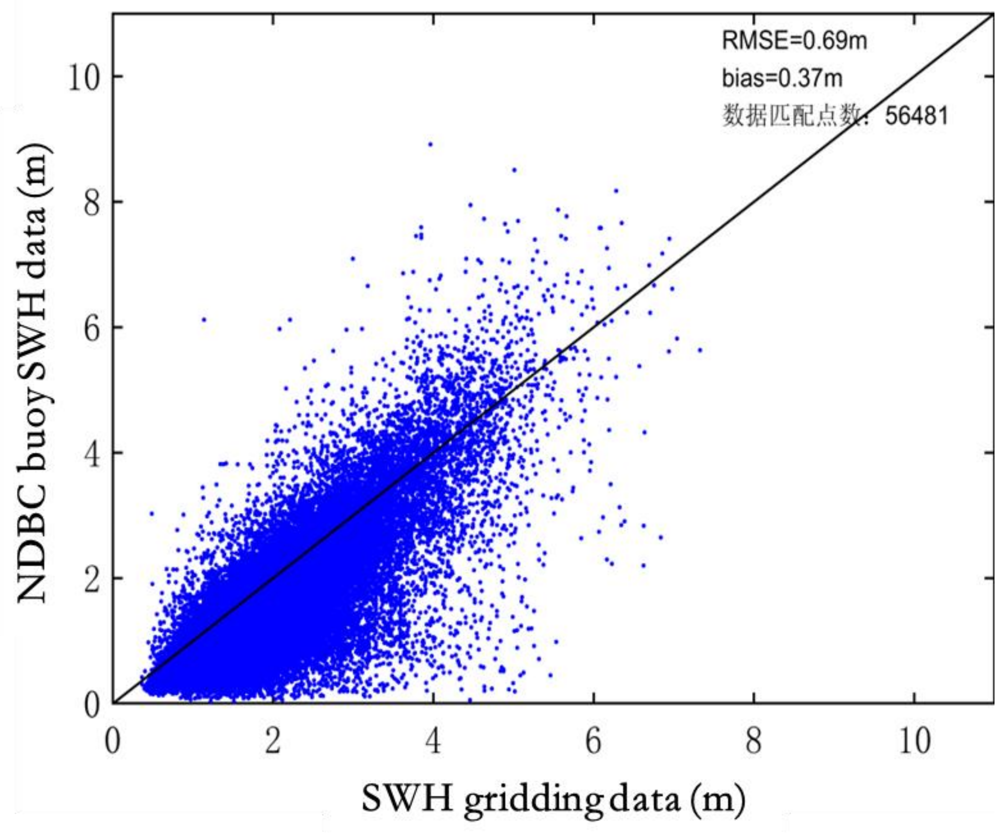
To generate 2016-2020 global ocean wave SWH gridding data.



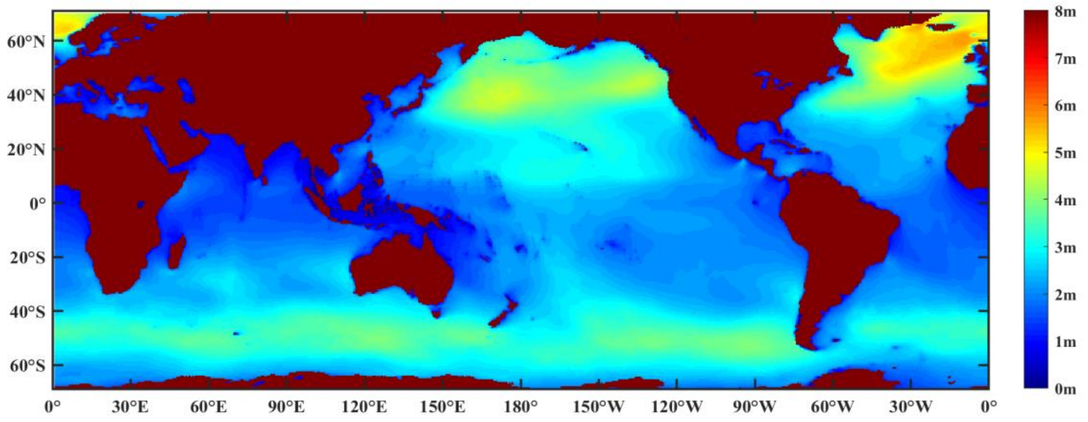


The distribution of SWH in Dec. 2020

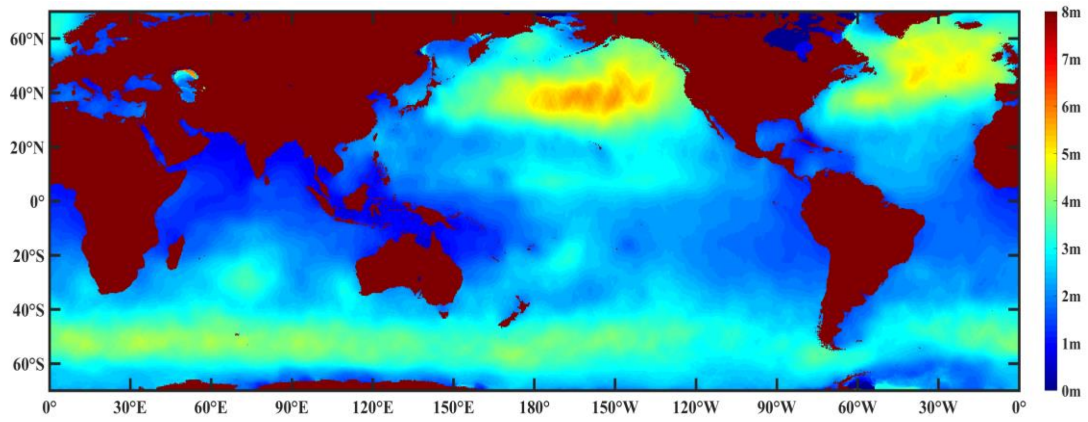
SWH gridding data are compared to NDBC buoy data and ERA5 re-analysis data.



The SWH comparison between gridding data and NDBC buoy data



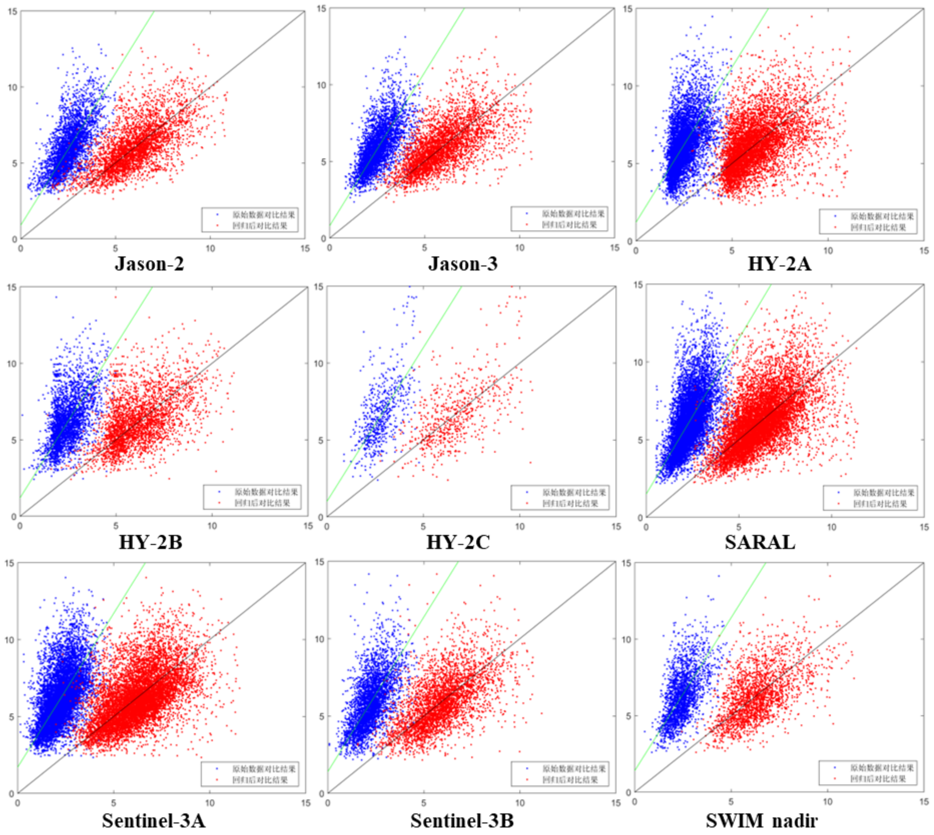
ERA5 re-analysis monthly average SWH data



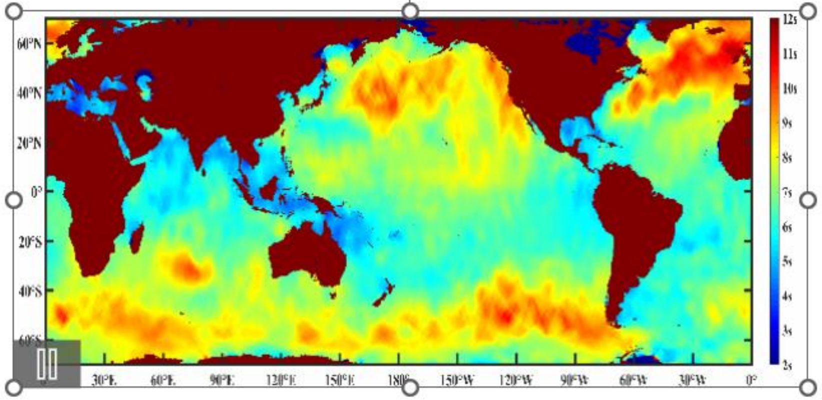
SWH gridding data

The merging of global MWP data

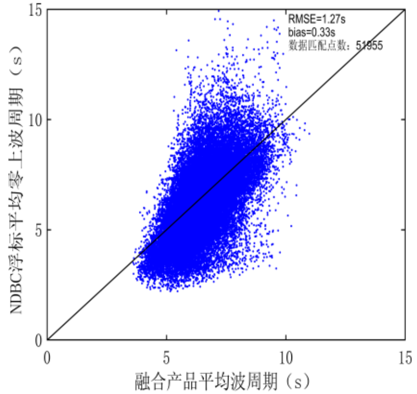
Wave Period empirical relationship: $T \sim (\sigma^0 SWH^2)^{0.25}$



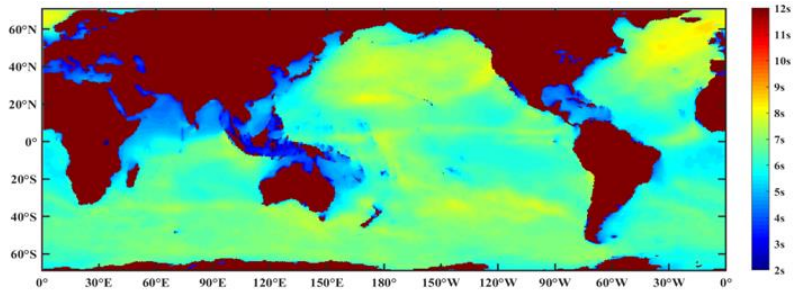
The determination of regression relationship of WP based on the buoy data



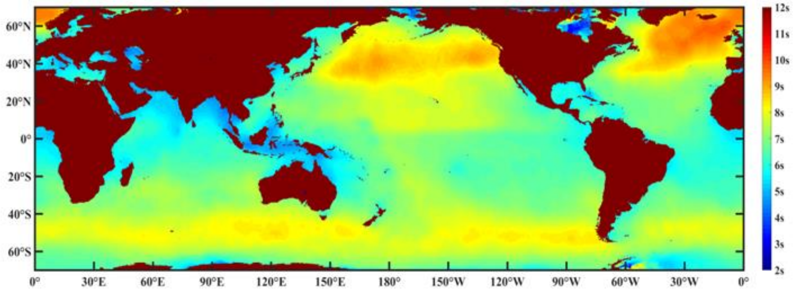
The distribution of global ocean wave MWP



MWP comparison between merging data and buoy data



ERA5 re-analysis monthly average MWP data



The merging MWP data

- After regression, the bias between altimeters and buoys reduced from 1.26~1.66s to -0.01~0.06s.
- The RMSE between merging MWP results and buoy data is 1.33s.

➢ The merging of global Swell data based on Sentinel-1 and SWIM

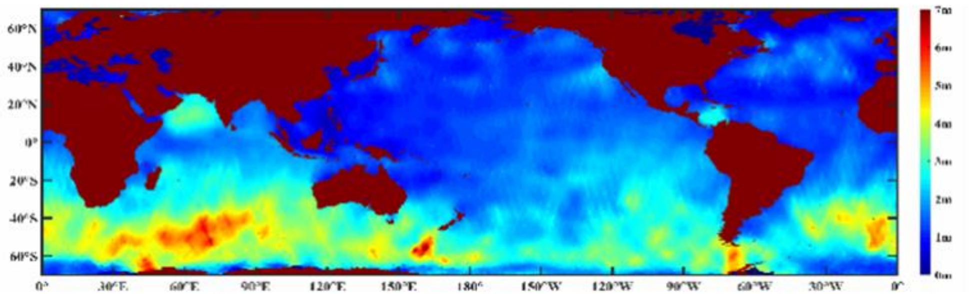
Wind wave and swell are separated by using wave age. Defined by:

$$\beta = \frac{C_p}{u} = \frac{1}{1.82\pi}\left(\frac{gH_s}{BC_D U_{10}^{2}}\right)^{\frac{2}{3}}$$

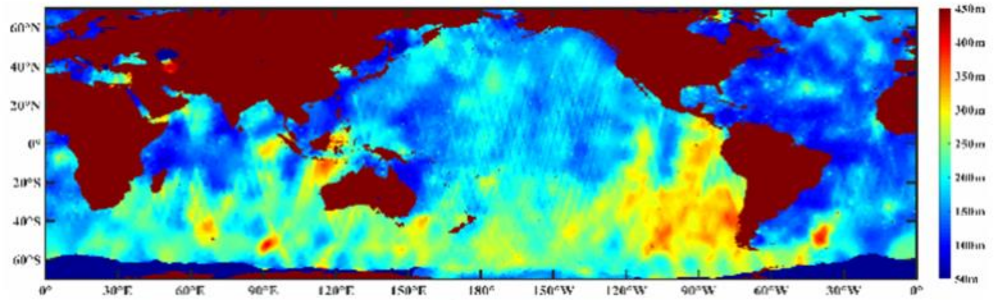
β is wave age, C_p is phase velocity, B is 0.062， $U_{10}$is wind speed at 10m above sea level ，$C_D$is wind drag coefficient.

$$C_D = \begin{cases} 1.2875*10^{-3}(U_{10} < 7.5m/s) \\ (0.8+0.065*U_{10})*10^{-3}(U_{10} > 7.5m/s) \end{cases}$$

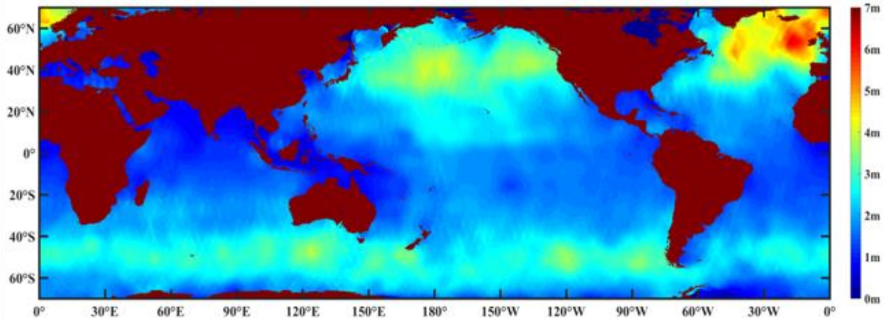
Combing SWH gridding data and CCMP wind data, wave age data are obtained, and ocean wave of wave age larger than 32 is regarded as wind wave.



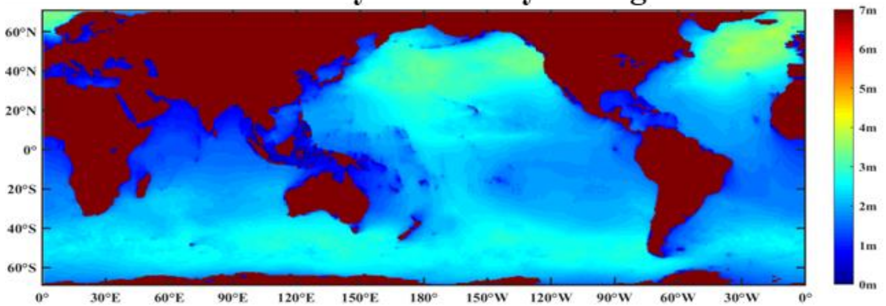
SWH of swell



wavelength of swell

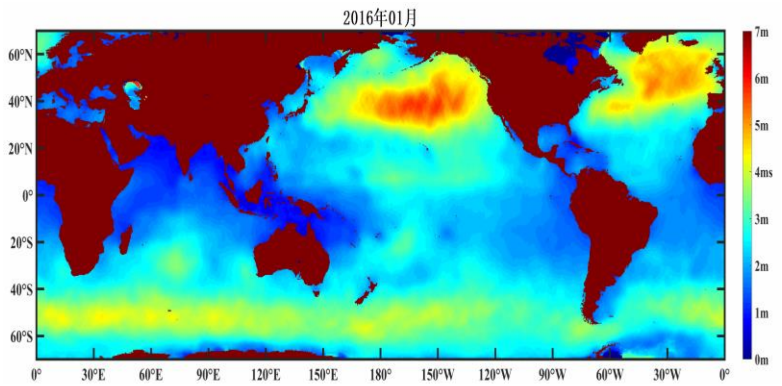


ERA5 re-analysis monthly average SWH

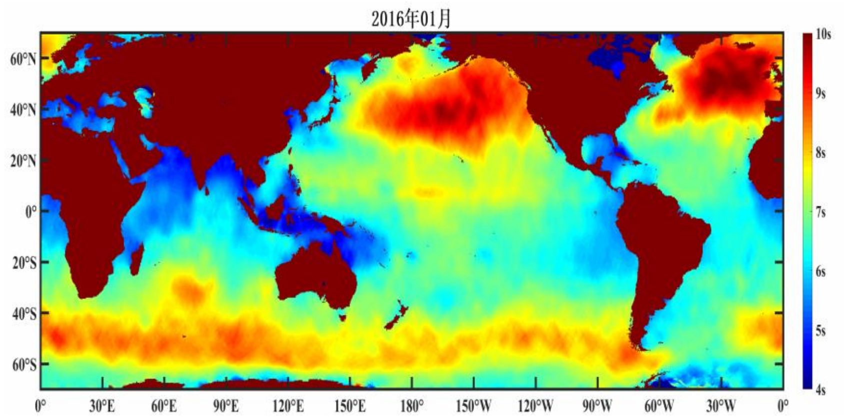


SWH of swell

3) Characteristics analysis of global ocean wave

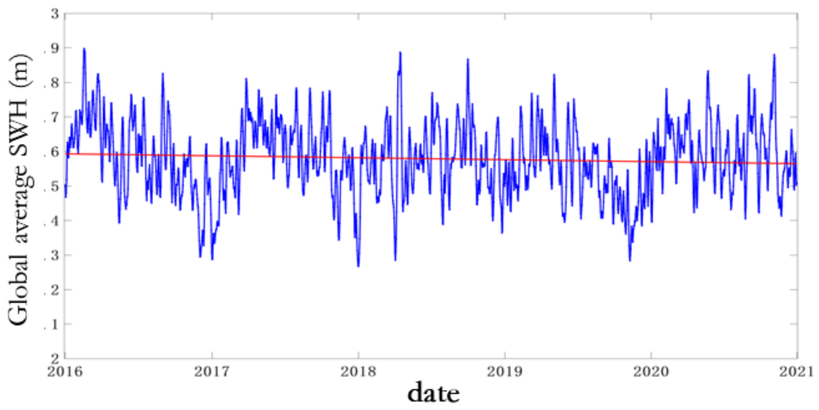


The distribution of global ocean wave monthly SWH

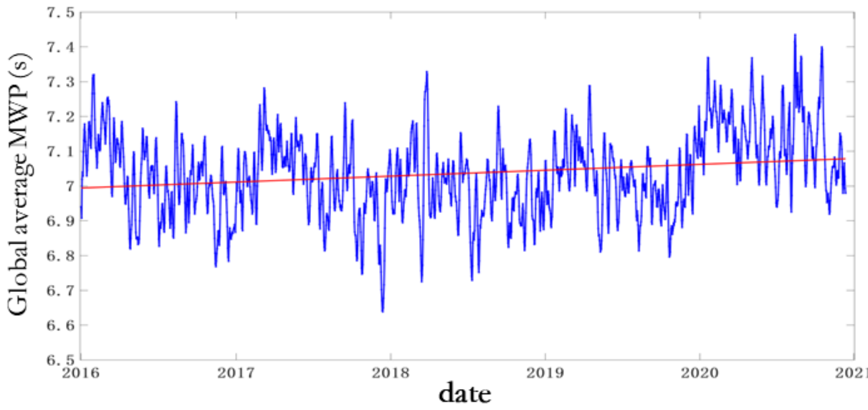


The distribution of global ocean wave monthly MWP

- Three areas of large SWH: the North Atlantic, the North Pacific and the Southern Ocean.
- From winter to summer, SWH decreases and MWP increases.
- From summer to winter, SWH increases and MWP decreases.



The temporal variations of global ocean wave monthly SWH



The temporal variations of global ocean wave monthly MWP

- SWH has the decreasing trend with time.
- MWP has the increasing trend with time.

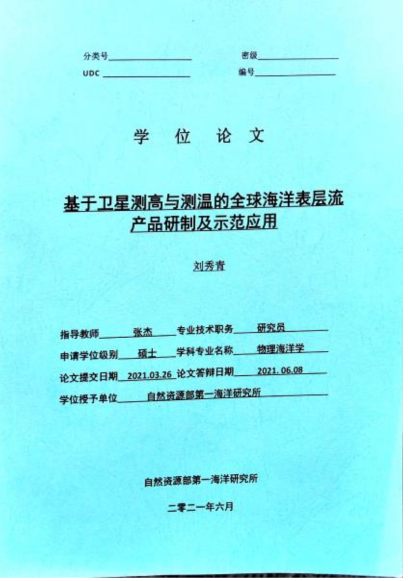
4. Training of young scientists on the project

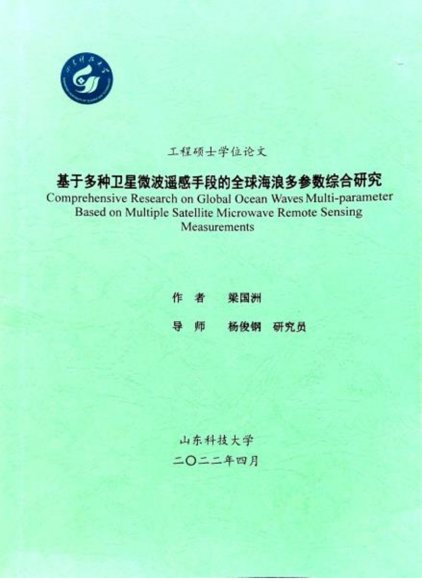
Five young scientists from FIO take part in the study, and two had graduated.

- Xiuqing LIU: graduated Major, data oceanic application on ocean circulation.
- Guozhou Liang: graduated Master, Major: data application on ocean wave.
- Zhihong Heng: Master Student, retracking of waveform.
- Fengjia Sun: Master Student, ocean wave.
- Jie sun: Master Student, tropospheric correction of altimeter.

Two young scientists from DTU space take part in the study.

The Chinese young scientists have be trained on the data processing of altimeters and data application including the study on ocean wave, sea surface current. The European young scientists contributes to the data processing of altimeter.





Thesis Titles are:

- ➢ Application and Evaluation of Surface currents Product Generation Method Based on Satellite Altimetry and Satellite Temperature Measurement.
- ➢ Comprehensive Research on Global Ocean Waves Multi-parameter Based on Multiple Satellite Microwave Remote Sensing Measurements.

5. The planning of the following 2 years

- To continue waveform retracking of HY-2 and Sentinel-3A/3B in the coastal area of the China.
- To obtain the retracked SSH and SWH data of HY-2 and Sentinel-3 series.
- Data applications on ocean wave, ocean current and mesoscale eddy in the study area.
- spatial-temporal characteristics analysis of marine dynamic environment in the China seas and western Pacific Ocean, such as ocean wave, ocean circulation and mesoscale eddies.

Thanks for your attentions