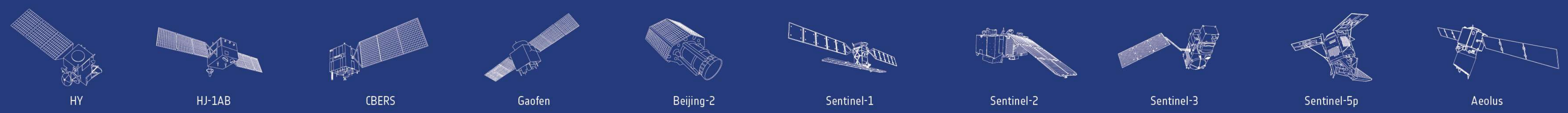

2023 DRAGON 5 SYMPOSIUM

3rd YEAR RESULTS REPORTING

11-15 SEPTEMBER 2023

[PROJECT ID. 58009]

[SYNERGISTIC MONITORING OF OCEAN DYNAMIC ENVIRONMENT FROM MULTI-SENSORS]

<2:00-2:45PM,WEDNESDAY, 13/SEP/2023>

ID. 58009

PROJECT TITLE: SYNERGISTIC MONITORING OF OCEAN DYNAMIC ENVIRONMENT FROM MULTI-SENSORS

PRINCIPAL INVESTIGATORS: [JINGSONG YANG & BERTRAND CHAPRON]

CO-AUTHORS: [HE WANG, HUIMIN LI, XIAOHUI LI, HAOYU JIANG, LIN REN, ROMAIN HUSSON, BERTRAND CHAPRON]

PRESENTED BY: [JINGSONG YANG]

Dragon 5 3rd Year Results Reporting

- Inform on the project's objectives
- Detail the Copernicus Sentinels, ESA, Chinese and ESA Third Party Mission data utilised after 3 years (complete slide 4)
- Detail the in-situ data measurements and requirements
- Provide details on field data collection campaigns and periods in P.R. China or other study areas
- Inform on the results after 3 years of activity
- Inform on the project's schedule, planning & contribution of the partners for the following year
- Report on the level and training of young scientists on the project achievements, including plans for academic exchanges
- Report on the peer reviewed publications (nr. of papers, journal name and publication title) after 3 years of activity

Some Progresses of Synergistic Monitoring of Ocean Dynamic Environment from Multi-Sensors

Jingsong Yang[1], He Wang[2], Huimin Li[3], Xiaohui Li[1], Haoyu Jiang[4], Lin Ren[1], Romain Husson[5], Bertrand Chapron[6]

[1]State Key Laboratory of Satellite Ocean Environment Dynamics (SOED), Second Institute of Oceanography, MNR, Hangzhou, China
[2]National Ocean Technology Center, MNR, Tianjin, China
[3]Nanjing University of Information Science and Technology, Nanjing, China
[4]China University of Geosciences, China,
[5]Collecte Localisation Satellites (CLS), Plouzané, France
[6]Laboratoire d'Océanographie Physique et Spatiale (LOPS), IFREMER, Plouzané, France

Project's objectives

(1) Assimilation studies of wind, waves and sea level in the context of hurricanes forecasts;

(2) The influence of swell on the studies of coastal extremes;

(3) Studies of vortex Rossby waves, asymmetric TC structures, rain bands, and sub-scale circulations by using high spatial resolution ocean wind data;

(4) Analysis of relationship between the above internal dynamical processes and TC intensity changes;

(5) Consistent analysis on winds, waves and storm surges in the context of hurricanes; and

(6) Consistent monitoring of ocean surface current and internal waves using multi-source satellite data.

Project's schedule

The overall progress of this project will be coordinated by the two PIs: Dr. Bertrand CHAPRON and Prof. Jingsong YANG. The obtained results are accordingly reported at each annual symposium.

Current progresses: 5+1 joint publications

Year 1: Data preparation, methodology development;
Year 2: Data preparation, methodology development, calculation, analysis;
Year 3: Calculation, analysis, validation;
Year 4: Analysis, validation, pre-operation and demonstration.

Training of young scientists and academic exchanges

The online training of young scientists and academic exchanges with European scientist are still carried out during COVID-19.

EO Data Delivery

Data access (list all missions and issues if any). NB. in the tables please insert cumulative figures (since July 2020) for no. of scenes of high bit rate data (e.g. S1 100 scenes). If data delivery is low bit rate by ftp, insert "ftp"

ESA /Copernicus Missions	No. Scenes
1. Sentinel-1A WV	FTP
2. Sentinel-1B WV	FTP
3.	
4.	
5.	
6.	
Total:	
Issues:	

ESA Third Party Missions	No. Scenes
1. CYGNSS	FTP
2.	
3.	
4.	
5.	
6.	
Total:	
Issues:	

Chinese EO data	No. Scenes
1. CFOSAT SCAT	FTP
2. CFOSAT SWIM	FTP
3. HY-2 SMR	FTP
4. HY-2 SCAT	FTP
5. HY-2 ALT	FTP
6.	
Total:	
Issues:	

European Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Alexey MIRONOV	eOdyn, France	Validation of Wave Spectral Partitions From SWIM Instrument On-Board CFOSAT Against In Situ Data **Presented in the 2nd YEAR RESULTS SYMPOSIUM**	Second Author
Romain Husson	CLS, France	Deep Learning-Based Model for Reconstructing Inner-Core High Winds in Tropical Cyclones Using Satellite Remote Sensing **Presented in the 3rd YEAR RESULTS SYMPOSIUM**	Ninth Author

Chinese Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Xiaohui LI	State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, MNR, China	Analysis of coastal wind speed retrieval from CYGNSS mission using artificial neural network **Presented in the 1st YEAR RESULTS SYMPOSIUM**	First Author & Presenter
		Deep Learning-Based Model for Reconstructing Inner-Core High Winds in Tropical Cyclones Using Satellite Remote Sensing **Presented in the 3rd YEAR RESULTS SYMPOSIUM**	First Author & Presenter
He WANG	National Ocean Technology Center, China	Characterizing Errors in the Swell Height Data Derived from Directional Buoys Via the Joint Analysis of Sentinel-1 SAR, CFOSAT/SWIM and WaveWatch III Simulations **Presented in the 2nd YEAR RESULTS SYMPOSIUM**	First Author & Presenter
		Quality Assessment Of CFOSAT SCAT Wind Products Using In Situ Measurements From Buoys And Research Vessels **Presented in the 3rd YEAR RESULTS SYMPOSIUM**	First Author & Presenter
Huimin LI	School of Marine Sciences, Nanjing University of Information Science and Technology, China	Up-to-Downwave Asymmetry of the CFOSAT SWIM Fluctuation Spectrum for Wave Direction Ambiguity Removal **Presented in the 2nd YEAR RESULTS SYMPOSIUM**	First Author & Presenter
		Direct Ocean Surface Velocity Measurements From Space In Tropical Cyclones **In the 3rd YEAR RESULTS SYMPOSIUM (Canceled)**	First Author & Presenter

Chinese Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Haoyu JIANG	China University of Geosciences, China	Validation of Wave Spectral Partitions From SWIM Instrument On-Board CFOSAT Against In Situ Data **Presented in the 2nd YEAR RESULTS SYMPOSIUM**	First Author & Presenter
		Accurate Mean Wave Period from SWIM Instrument On-Board CFOSAT **Presented in the 3rd YEAR RESULTS SYMPOSIUM**	First Author & Presenter
Lin REN	State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, MNR, China	Validation of Wave Spectral Partitions From SWIM Instrument On-Board CFOSAT Against In Situ Data **Presented in the 2nd YEAR RESULTS SYMPOSIUM**	Third Author

Chinese Young scientists contributions in Dragon 5

Dragon 4 (id. 32249) & Dragon 5 (id. 58009)

DRAGON 5 1st YEAR RESULTS SYMPOSIUM

Analysis of coastal wind speed retrieval from CYGNSS mission using artificial neural network

Poster

ID: 237

Dr4 YSPS.2.1:

Time: Monday, 19/July/2021: 10:15am - 1:00pm

Xiaohui Li[1,2], Dongkai Yang[1], Jingsong Yang[2,3], Gang Zheng[2,3], Guoqi Han[4], Yang Nan[5], Weiqiang Li[6,7]

[1] School of Electronic and Information Engineering, Beihang University, Beijing, China
[2] State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China
[3] Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), Zhuhai, China
[4] Fisheries and Oceans Canada, Institute of Ocean Sciences, Canada,
[5] Wuhan University, Wuhan, China
[6] Institute of Space Sciences (ICE, CSIC), Spain
[7] Institut d'Estudis Espacials de Catalunya, Spain

ABSTRACT

This paper demonstrates the capability and performance of sea surface wind speed retrieval in coastal regions (within 200 km away from the coastline) using spaceborne Global Navigation Satellite System Reflectometry (GNSS-R) data from NASA's Cyclone GNSS (CYGNSS) mission. The wind speed retrieval is based on the Artificial Neural Network (ANN). A feedforward neural network is trained with the collocated CYGNSS Level 1B (version 2.1) observables and the wind speed from European Centre for Medium-range Weather Forecast Reanalysis 5th Generation (ECMWF ERA5) data in coastal regions. An ANN model with five hidden layers and 200 neurons in each layer has been constructed and applied to the validation set for wind speed retrieval. The proposed ANN model achieves good wind speed retrieval performance in coastal regions with a bias of −0.03 m/s and a RMSE of 1.58 m/s, corresponding to an improvement of 24.4% compared to the CYGNSS Level 2 (version 2.1) wind speed product. The ANN based retrievals are also compared to the ground truth measurements from the National Data Buoy Center (NDBC) buoys, which shows a bias of −0.44 m/s and a RMSE of 1.86 m/s. Moreover, the sensitivities of the wind speed retrieval performance to different input parameters have been analyzed. Among others, the geolocation of the specular point and the swell height can provide significant contribution to the wind speed retrieval, which can provide useful reference for more generic GNSS-R wind speed retrieval algorithms in coastal regions.

Keywords: Global navigation satellite system reflectometry (GNSS-R); Cyclone GNSS (CYGNSS); Sea surface wind speed; Coastal; Artificial neural network (ANN)

Wednesday, 19/Oct/2022 9:50am - 10:00am
ID: 186 / P.2.1: 9
Poster Presentation
Ocean and Coastal Zones: 58009 - Synergistic Monitoring of Ocean Dynamic Environment From Multi-Sensors

Characterizing Errors in the Swell Height Data Derived from Directional Buoys Via the Joint Analysis of Sentinel-1 SAR, CFOSAT/SWIM and WaveWatch III Simulations

He Wang, Jingsong Yang, Bertrand Chapron, Jianhua Zhu

National Ocean Technology Center, China, People's Republic of

Characterizing the uncertainties in buoy ocean wave records is critical not only for understanding the limitations of in situ wave measurements, but also for interpreting the implied accuracies of the remotely sensed products in which these buoy data are used as validation references. This letter preliminarily assesses the error of long-period swell heights (Hss) representing specific directional wave partition energy observed from deep-water buoys moored in the northeast Pacific. We propose a buoy Hss error estimation method by combining dual and triple collocation using data derived from buoys, two kinds of space-borne radars and numerical simulations. Compared to traditional methods, the proposed approach can reveal "absolute" errors (with respect to the underlying truth) from buoy Hss, accepting and then confirming that swell heights from buoy, satellite and model are all uncertain. This study simultaneously employs ocean swell products derived from synthetic/real aperture radars (Sentinel-1A/B and CFOSAT/SWIM) and WaveWatch III ocean wave model hindcasts to diagnose the accuracy of the Hss values observed by buoys of National Data Buoy Center (NDBC) and Coastal Data Information Program (CDIP) during the period from July 2019 to October 2021. We quantify that the NDBC's 3-m heave-pitch-roll buoy (CDIP's Waverider buoy) recorded Hss have root-mean-square error of 0.17 m (0.12 m), or have about 10.65% (7.06%) uncertainty relative to the mean Hss value (approximately 1.6 m). Our findings imply that the reference value uncertainties should be taken into account when understanding direct satellite Hss validation against buoy in situ.

Wednesday, 19/Oct/2022 9:30am - 9:40am
ID: 108 / P.2.1: 7
Poster Presentation
Ocean and Coastal Zones: 58009 - Synergistic Monitoring of Ocean Dynamic Environment From Multi-Sensors

Up-to-Downwave Asymmetry of the CFOSAT SWIM Fluctuation Spectrum for Wave Direction Ambiguity Removal

Huimin Li1, Daniele Hauser2, Bertrand Chapron3, Biao Zhang1, Jingsong Yang4, Yijun He1

1School of Marine Sciences, NUIST, China, People's Republic of; 2Laboratoire Atmosphère, Observations Spatiales (LATMOS), UVSQ, Centre National de la Recherche Scientifique (CNRS), Université Paris-Saclay, Sorbonne Université, 78280 Guyancourt, France; 3IFREMER, Univ. Brest, CNRS, IRD, L aboratoire d' Oceanographie P hysique et Spatiale (LOPS), 29280 Plouzané, France; 4State Key Laboratory of Satellite Ocean Envi- ronment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou 310012, China

The surface wave investigation and monitor- ing (SWIM) aboard the China-France Oceanography Satellite (CFOSAT), a pioneer conically scanning wave spectrometer, was successfully launched on October 29, 2018. Its innovative configuration composed of one nadir and five rotating near-nadir beams is designed to simultaneously observe the directional wave spectrum at a global scale. In this study, we systematically implement the spectral analysis of the radar backscattering with the periodogram technique to obtain the fluctuation spectrum for each azimuth direction. The 2-D fluctuation spectrum of the three spectral beams (θ = 6◦, 8◦, and 10◦) combines all the azimuth directions within one entire rotation of 360◦. The case study demonstrates that the wave features (peak wavelength and direction) are roughly consistent between the estimated fluctuation spectrum and the collocated WaveWatch III wave slope spectrum. A marked up-to-downwave asymmetry of the fluctuation spectrum with larger spectral level in the upwave direction for all the three spectral beams is observed. A ratio is defined between the fluctuation spectrum within the [0◦, 180◦] sector relative to the [180◦, 360◦] sector. Statistics display that this ratio is greater than 1 when it denotes the up-to-downwave ratio and smaller than 1 for the down-to-upwave ratio. This observed spectrum asymmetry is linked to the asymmetric modulation from upwind to downwind. In addition, we employ such finding to help remove the 180◦ wave direction ambiguity from a practical point of view. Preliminary results of the direction ambiguity removal display a bias of 41.3◦, 40.6◦, and 36.7◦ for the beams. The 10◦ beam shows slightly better performance compared to the other two beams in terms of bias and standard deviation. This shall lay a strong basis for the operational implementation of such algorithm to resolve the direction ambiguity.

Wednesday, 19/Oct/2022 9:40am - 9:50am
ID: 109 / P.2.1: 8
Poster Presentation
Ocean and Coastal Zones: 58009 - Synergistic Monitoring of Ocean Dynamic Environment From Multi-Sensors

Validation of Wave Spectral Partitions From SWIM Instrument On-Board CFOSAT Against In Situ Data

Haoyu Jiang1, Alexey Mironov2, Lin Ren3, Alexander Babanin4

1China University of Geosciences, China, People's Republic of; 2eOdyn, France; 3State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, China; 4The University of Melbourne, Australia

The Surface Waves Investigation and Monitoring (SWIM) instrument onboard the China France Oceanography Satellite (CFOSAT) can retrieve directional wave spectra with a wavelength range of 70~500 m. This study aims to validate the partitioned integrated wave parameters (PIWPs) from SWIM, including partitioned significant wave height (PSWH), peak wave period (PPWP), and peak wave direction (PPWD), against those from National Data Buoy Center (NDBC) buoys. With quasi-simultaneous spectra from two NDBC buoys 13 km away from each other near Hawaii, the methods of comparing PIWPs from two sets of spectra were discussed first. After cross-assigning partitions according to the spectral distance, it is found that wrong cross-assignments lead to many outliers strongly impacting the estimate of error metrics. Three methods, namely comparing only the best-matched partition, changing the threshold of spectral distance during cross-assignment, and maximum likelihood estimation of root-mean-square error (RMSE) of PIWPs, were used to reduce the impact of potential wrong cross-assignments. Using these methods, the SWIM PIWPs were validated against NDBC buoys. The results show that SWIM performs well at finding the spectral peaks of different partitions with the RMSE of PPWPs and PPWDs of 0.9 s and 20°, respectively, which can be a useful complement for other wave observations. However, the accuracy of PSWH from SWIM is not that good at this stage, probably because the high noise level in the spectra impacts the result of the partitioning algorithm. Further improvement is needed to obtain better PSWH information.

Tuesday, 12/Sep/2023 3:45pm - 3:53pm

ID: 104 / P.2.2: 1

Poster Presentation

Ocean and Coastal Zones: 58009 - Synergistic Monitoring of Ocean Dynamic Environment From Multi-Sensors

Direct Ocean Surface Velocity Measurements From Space In Tropical Cyclones

Huimin Li1, Alexis Mouche2, Biao Zhang1, Jingsong Yang3, Yijun He1, Bertrand Chapron2

1NUIST, China, People's Republic of; 2LOPS, Ifremer, France; 3State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, China, People's Republic of

Synthetic aperture radar (SAR) is broadly known for its high-resolution imaging of the ocean surface under all weather conditions during day and night. The Doppler centroid anomaly (DCA) derived from SAR imagettes has been evidenced to well capture the line-of-sight component of ocean current velocity. Several studies have reported the analytical basis of DCA method and the monitoring of major current systems. Its applicability under tropical cyclone (TC) events is not yet examined. In this study, we focus on demonstrating the spatial features of DCA obtained over TC Maria (2017) and Cimaron (2018) as well as it relation to the surface winds. We found that the Doppler velocity provides a promising spatial representation of the surface flow under tropical cyclone wind forcing. The Doppler velocity exhibits an asymmetric feature similar to the radial wind speed with larger velocity-to-winds ratio in the front than in the rear quadrant. The combined Doppler velocity resulted from a tropical cyclone and the Kuroshio Current is distinct, particularly over the regions of encountering flow. The results shall shed light on the SAR observational capability of TC-induced surface velocity and extends our understanding of how the winds and current are coupled under TC.

Tuesday, 12/Sep/2023 3:53pm - 4:01pm
ID: 150 / P.2.2: 2
Poster Presentation
Ocean and Coastal Zones: 58009 - Synergistic Monitoring of Ocean Dynamic Environment From Multi-Sensors

Deep Learning-Based Model for Reconstructing Inner-Core High Winds in Tropical Cyclones Using Satellite Remote Sensing

Xiaohui Li1, Jingsong Yang1, Guoqi Han2, Xinhai Han3, Peng Chen1, Gang Zheng1, Lin Ren1, Lizhang Zhou1, Romain Husson4, Alexis Mouche5, Bertrand Chapron5

1State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou 310012, China; 2Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada, V8L 4B2, Canada; 3School of Oceanography, Shanghai Jiao Tong University, Shanghai 200240, China; 4Collecte Localisation Satellites, F-31520 Brest, France; 5Laboratoire d'Oceanographie Physique et Spatiale, Institut français de recherche pour l'exploitation de la mer, F-31520 Brest, France

Due to signal degradation or saturation within tropical cyclones, accurate estimation of inner-core high winds using satellite remote sensing is still challenging. To address this, we propose a deep learning-based approach that leverages generative adversarial networks (GANs) to reconstruct the inner-core high winds from satellite remote sensing data. Our deep learning-based model integrates dilated convolution and attention mechanisms to improve this underestimation issue of synthetic-aperture radar (SAR) data in tropical cyclones. We also tackle the scarcity of SAR data by developing a GAN model that uses Hurricane Weather Research and Forecasting (HWRF) data as a proxy to simulate missing SAR data via transfer learning. To improve the transfer learning process, we explore different pre-trained models and expand the HWRF dataset used for training the deep learning-based models. Additionally, we aim to investigate other machine learning algorithms to enhance the accuracy of scatterometer wind products (e.g. Chinese Haiyang-2 and CFOSAT). We also employ machine learning approach to fuse multi-source data for synergistic monitoring of ocean dynamic environment, specifically in the context of tropical cyclones. In summary, our study demonstrates the potential of deep learning technology for tropical cyclone reconstruction and monitoring using satellite remote sensing data， which can contribute to improving the accuracy of wind products in the context of tropical cyclones.

Tuesday, 12/Sep/2023 4:01pm - 4:09pm
ID: 157 / P.2.2: 3
Poster Presentation
Ocean and Coastal Zones: 58009 - Synergistic Monitoring of Ocean Dynamic Environment From Multi-Sensors

Quality Assessment Of CFOSAT SCAT Wind Products Using In Situ Measurements From Buoys And Research Vessels

He Wang1, Jingsong Yang2, Jianhua Zhu1, Bing Han1, Bertrand Chapron3

1National Ocean Technology Center, China, People's Republic of; 2State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography; 3Ifremer

The CFOSAT (Chinese-French Oceanic SATellite), carrying the first Ku-band scatteromenter (SCAT) with rotating fan beam, was successfully launched in October 2018. The preliminary quality assessment of CFOSAT SCAT wind data is carried out through the comparison for the period from Jan 2019 to Jun 2021 operationally released products with in situ measurements. The reference winds include in situ measurements from offshore (> 50 km) meteorological buoys of the National Data Buoy Center (NDBC) and serval research vessels. All in situ winds were converted to the 10 m equivalent neutral winds using the coupled ocean atmosphere response experiment (COARE) bulk algorithm. The temporal and spatial differences between the CFOSAT SCAT and the in situ observations were limited to less than 30 min and 12.5 km. For CFOSAT SCAT wind speed products, the comparison and analysis using the NDBC buoys yield a bias of 0.34 m/s, a root mean square error (RMSE) of 1.24 m/s. Although less accurate of CFOSAT SCAT wind direction at low winds, the RMSE of 19.76 deg with a bias of 1.13 deg is found for wind speeds higher than 4 m/s. Moreover, CFOSAT SCAT winds were evaluated against anemometers in situ onboard R/Vs , whose cruise were distributed globally. The comparison results against R/V winds are found consistent with those by the widely used NDBC buoys. The encouraging assessment results show that wind products from CFOSAT SCAT satisfy the mission specification and will be useful for scientific community.

Tuesday, 12/Sep/2023 4:09pm - 4:17pm
ID: 239 / P.2.2: 4
Poster Presentation
Ocean and Coastal Zones: 58009 - Synergistic Monitoring of Ocean Dynamic Environment From Multi-Sensors

Accurate Mean Wave Period from SWIM Instrument On-Board CFOSAT

Haoyu Jiang

China University of Geosciences, People's Republic of China

The Surface Waves Investigation and Monitoring (SWIM) instrument onboard the China–France Oceanography Satellite (CFOSAT) can provide wave spectra using its off-nadir beams. Although SWIM shows a reasonable performance for capturing spectral peak, the accuracy of mean wave periods (MWPs) computed directly from the SWIM spectra is not satisfying due to the high noise level of the spectra. SWIM can also provide good-quality simultaneous wind speed (U10) and significant wave height (SWH) like an altimeter. The MWP can also be estimated using a U10-SWH look-up table presented in previous studies. However, the accuracy of this method is also limited as the U10-SWH look-up table is only applicable for wind-sea-dominated conditions. The two MWP retrieval methods are independent of each other, and their error properties are complementary to each other. Therefore, this study further presents a merged MWP retrieval model combining the nadir U10-SWH and the MWP from the off-nadir spectrum of SWIM using a simple artificial neural network. After training against some buoy data, the model reaches unprecedented accuracy for MWP retrievals (RMSEs of ~0.36 s for zero up-crossing periods, ~0.41 s for mean periods, and ~0.60 s for energy periods), demonstrating the usefulness of SWIM in the studies of ocean waves.

Progress 1/6

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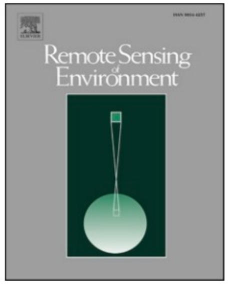


Analysis of coastal wind speed retrieval from CYGNSS mission using artificial neural network

Xiaohui Li [a,b], Dongkai Yang [a], Jingsong Yang [b,c], Gang Zheng [b,c], Guoqi Han [d], Yang Nan [e], Weiqiang Li [f,g,*]

[a] *School of Electronic and Information Engineering, Beihang University, Beijing 100191, China*
[b] *State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou 310012, China*
[c] *Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), Zhuhai 519082, China*
[d] *Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC V8L 4B2, Canada*
[e] *GNSS Research Center, Wuhan University, Wuhan 430079, China*
[f] *Institute of Space Sciences (ICE, CSIC), Barcelona 08193, Spain*
[g] *Institut d'Estudis Espacials de Catalunya (IEEC), Barcelona 08034, Spain*

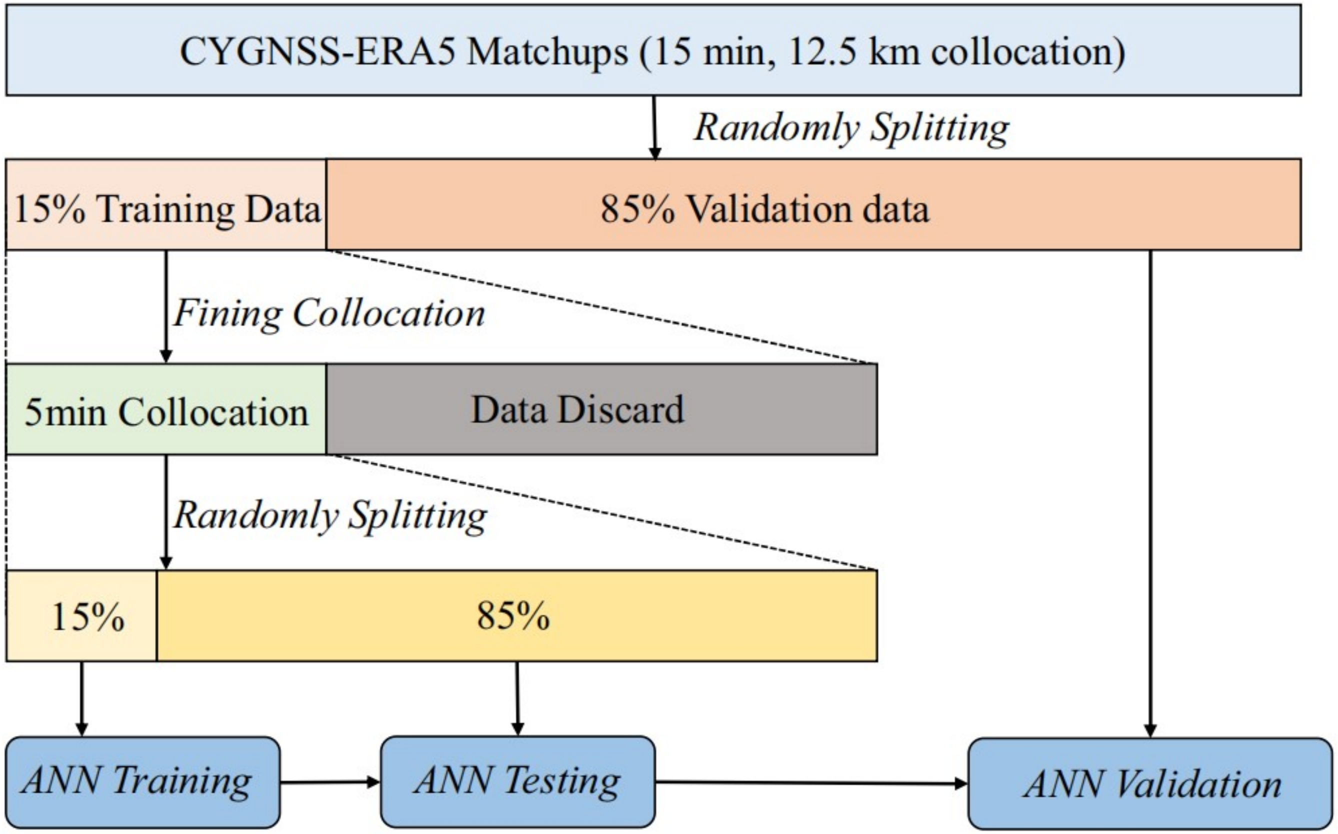
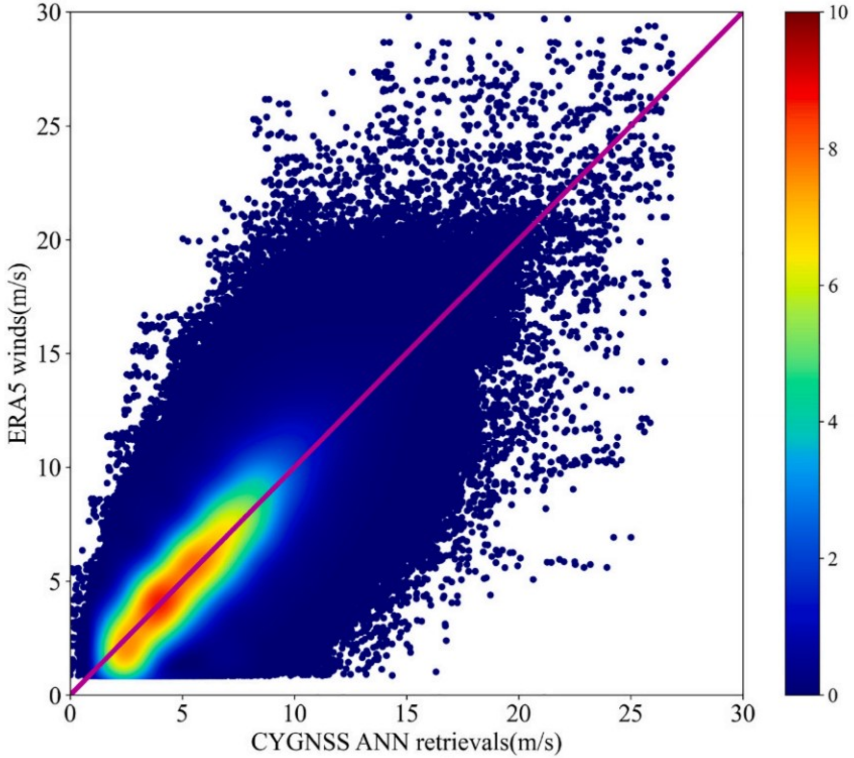


Fig. 2. Subsets selection of the CYGNSS-ERA5 matchups for ANN training and validation.



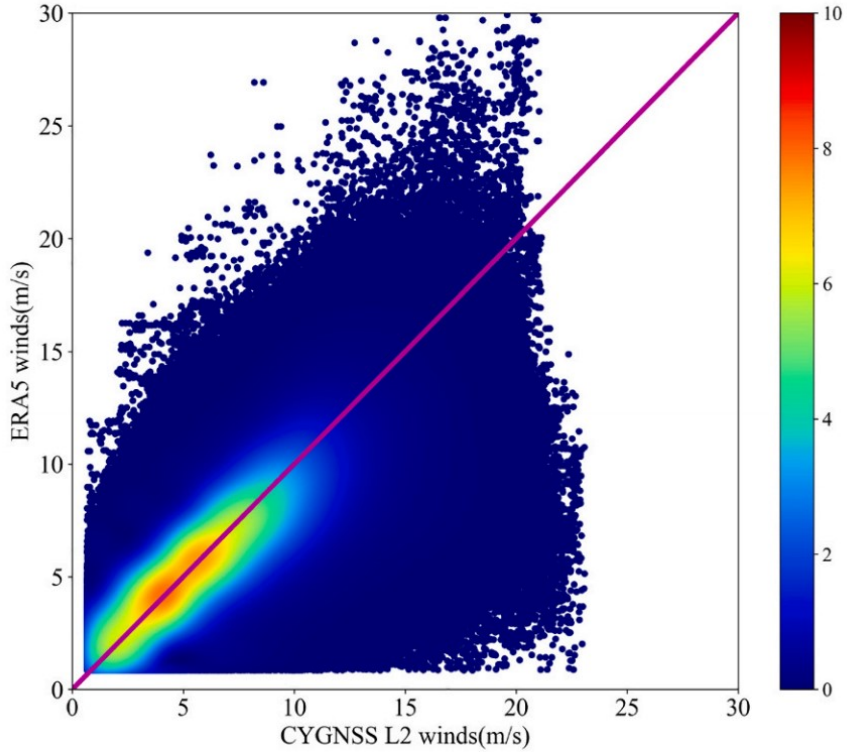


Fig. 4. Comparison between the CYGNSS ANN retrieved wind speed and the ECMWF/C3S ERA5 wind speed values (left). Comparison between the CYGNSS baseline L2 v2.1 wind speed and the ECMWF/C3S ERA5 wind speed values (right). The color scale is 1/100000 of the density of points. The purple line shows the 1:1 diagonal. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

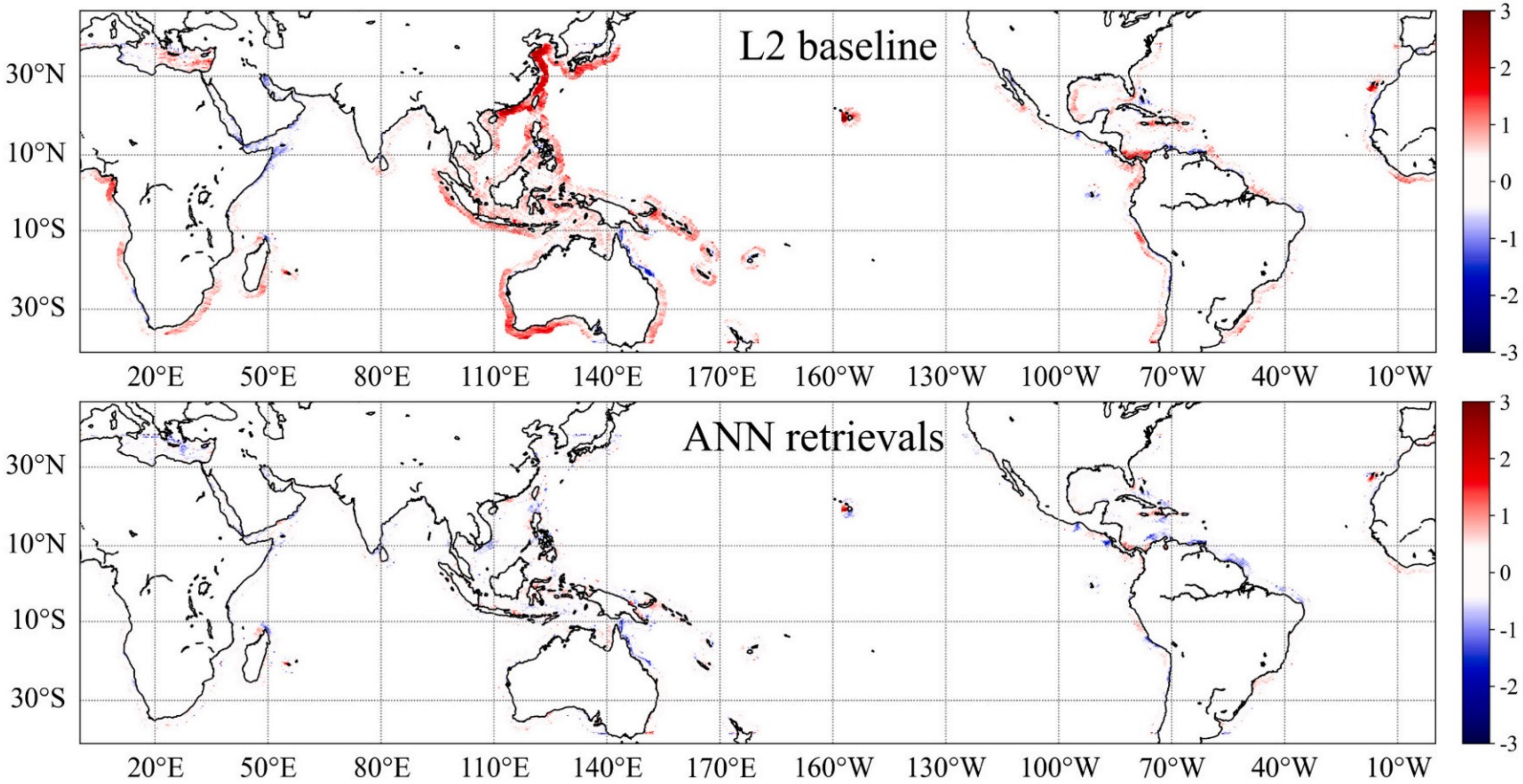


Fig. 7. Geographical map of the wind speed biases (CYGNSS wind speed - ERA5 wind speed) along the coastlines. Top: Wind speed bias of the CYGNSS Level 2 v2.1 products. Bottom: Wind speed bias of the ANN based retrieval.

Progress 2/6

remote sensing MDPI

Article

Assessment of Ocean Swell Height Observations from Sentinel-1A/B Wave Mode against Buoy In Situ and Modeling Hindcasts

He Wang [1,2,*], Alexis Mouche [2], Romain Husson [3], Antoine Grouazel [2], Bertrand Chapron [2] and Jingsong Yang [4]

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[2] Laboratoire d'Océanographie Physique Spatiale, Centre de Brest, Ifremer, 29280 Plouzané, France; alexis.mouche@ifremer.fr (A.M.); antoine.grouazel@ifremer.fr (A.G.); bertrand.chapron@ifremer.fr (B.C.)
[3] Collecte Localisation Satellites, 29280 Plouzané, France; rhusson@groupcls.com
[4] State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou 310012, China; jsyang@sio.org.cn
* Correspondence: wanghe_sio@126.com; Tel.: +86-22-2753-0334

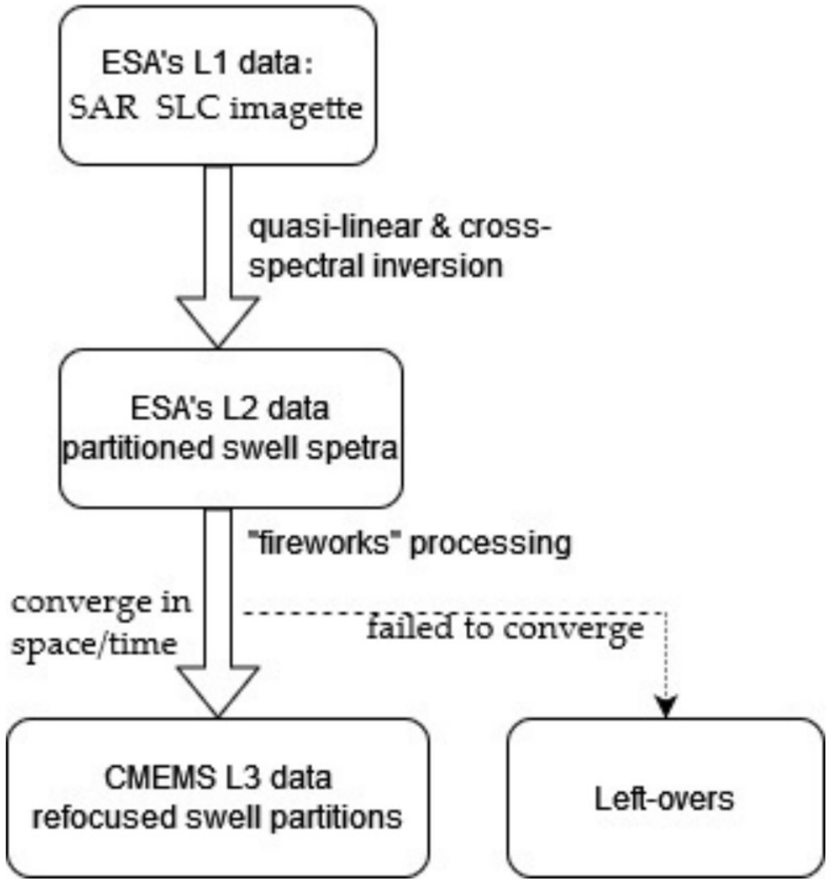


Figure 1. Flow chart of the processing of Sentinel-1A/B wave mode products from L1 to L3.

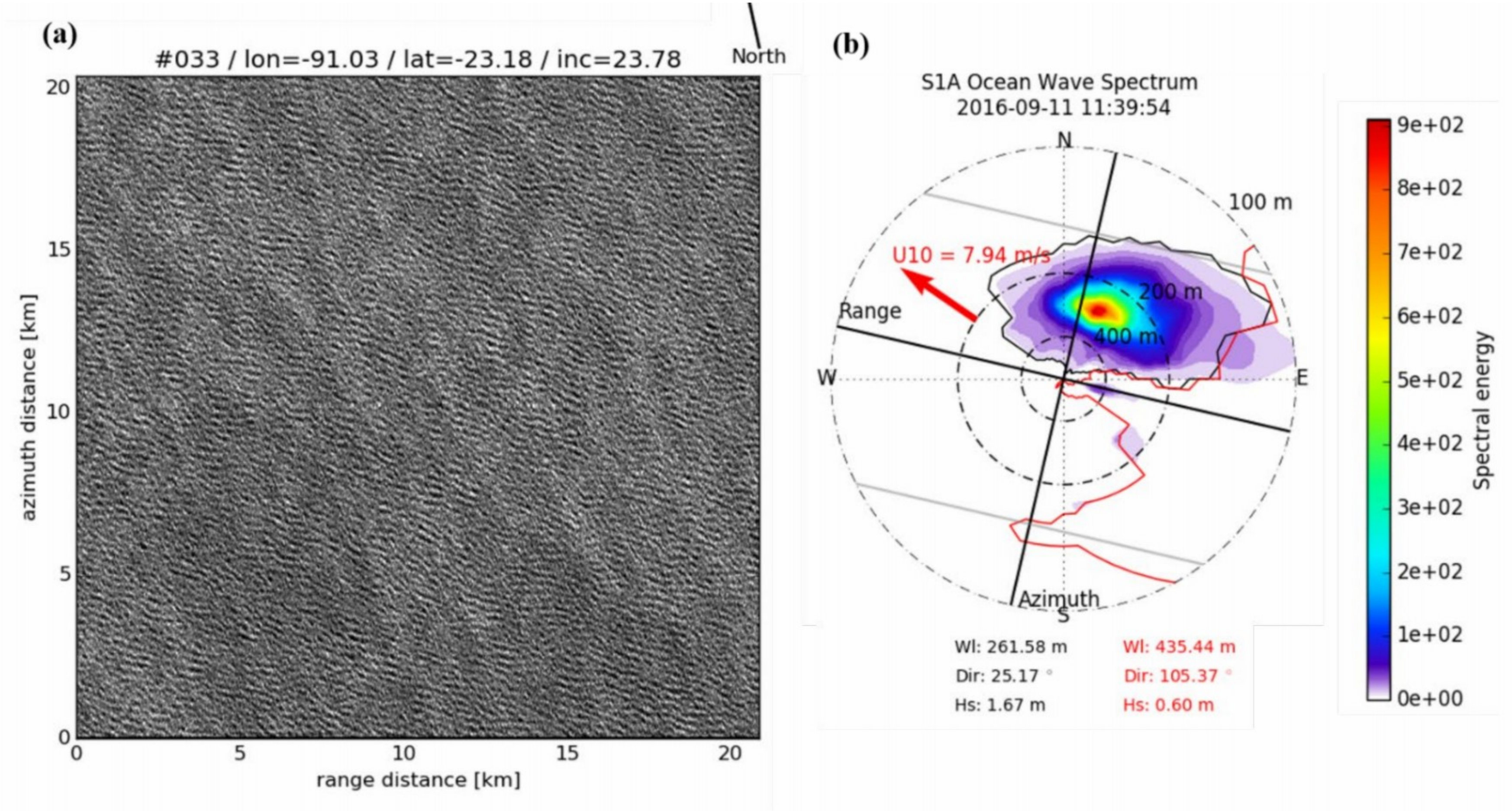


Figure 2. (**a**) Sentinel-1A wave mode roughness image acquired on 11:39:54 UTC 11 September 2016 at 23.18° S/91.03° W, and (**b**) corresponding Level-2 ocean swell spectrum.

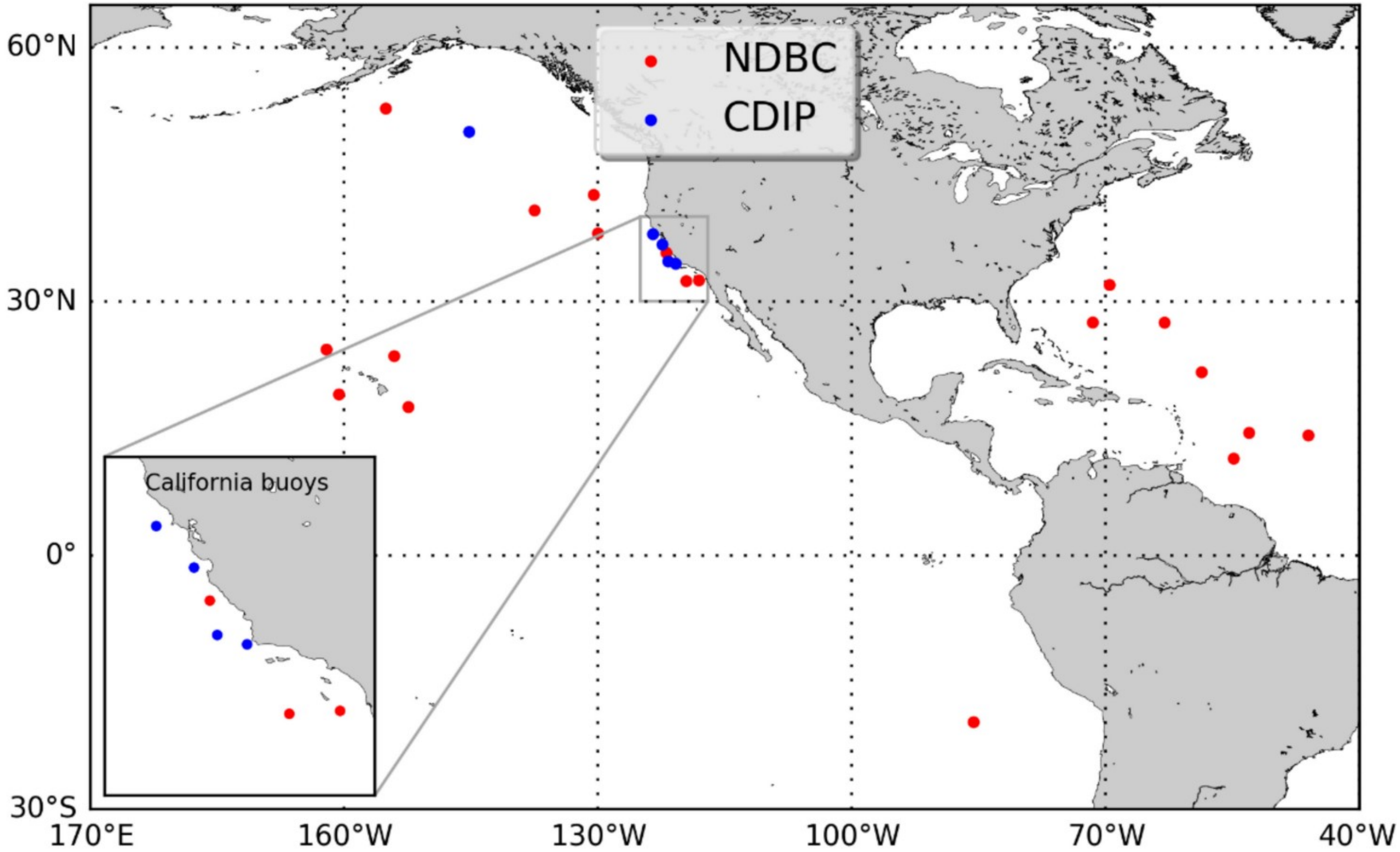


Figure 6. Location of directional wave buoys from the NDBC and CDIP networks.

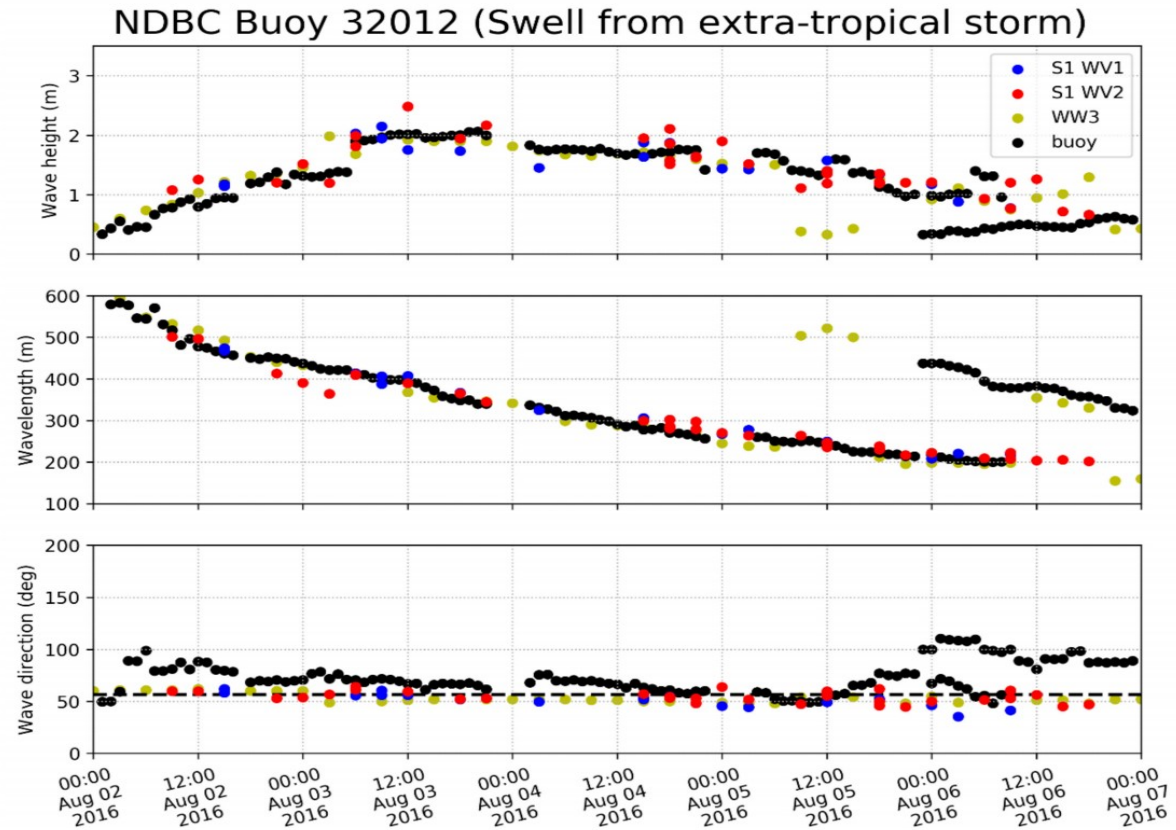


Figure 16. Comparison of significant wave height (**top**), peak wavelength (**middle**), and peak direction (**bottom**) from Level-3 CMEMS "fireworks" SAR products (red and blue dots representing Sentinel-1 SAR data in WV1 and WV2, respectively), buoy measurements (black dots) and WW3 model (yellow dots) at the Stratus buoy station #32012 (19.63° S/84.95° W) during the swell event generated by an extra-tropical storm on 28 July 2016.

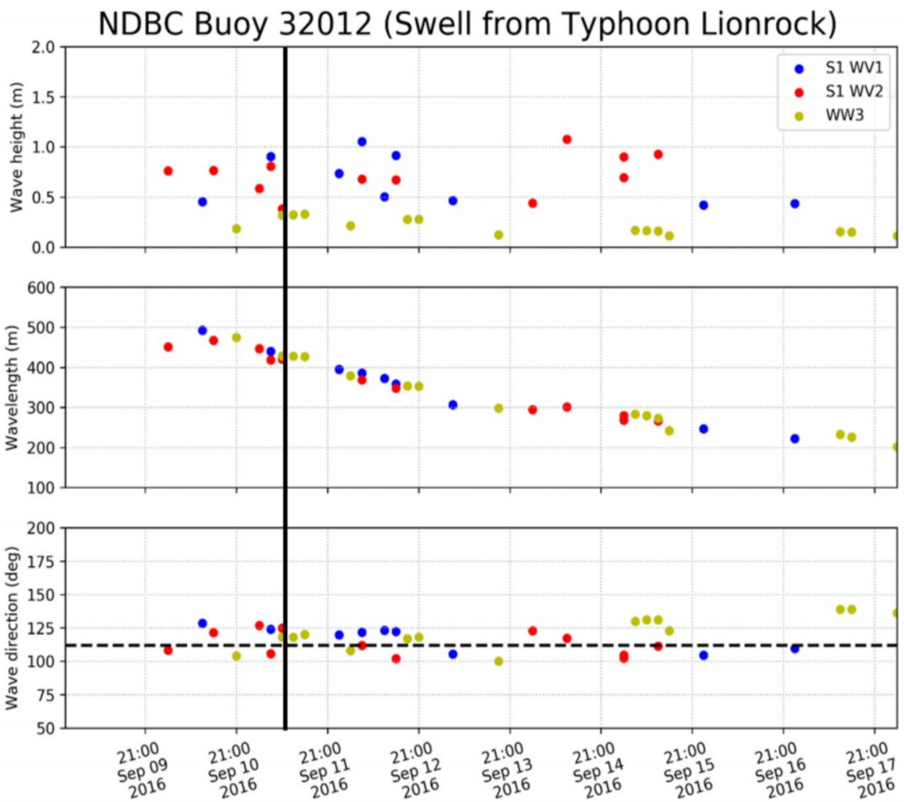


Figure 17. As in Figure 16, but for the case of a swell event originated from Typhoon Lionrock on 29 August 2016. The vertical black line corresponds to 12:00:00 UTC 11 September 2016 (the time of buoy observation presented in Figure 7).

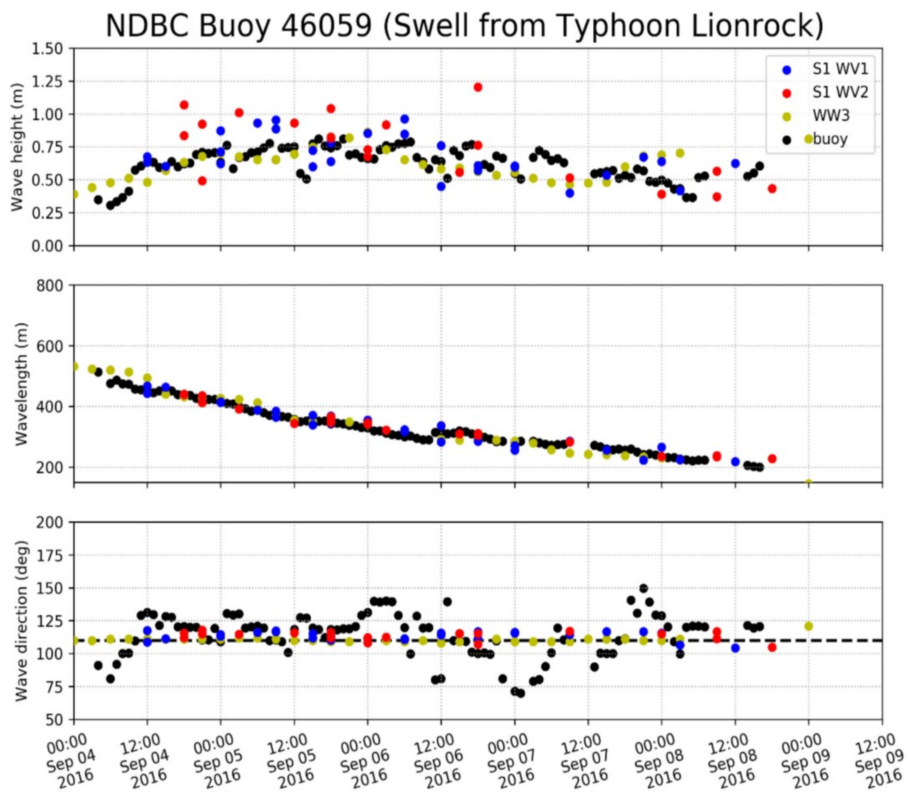


Figure 18. As in Figure 16, but for the case of a swell event originated from Typhoon Lionrock on 29 August at the buoy #46059 (38.05° N/129.90° E).

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 60, 2022 4207716

Progress 3/6

Quantifying Uncertainties in the Partitioned Swell Heights Observed From CFOSAT SWIM and Sentinel-1 SAR via Triple Collocation

He Wang, Alexis Mouche, Romain Husson, Bertrand Chapron, Jingsong Yang, Jianqiang Liu, and Lin Ren

***Abstract*—Nowadays, Sentinel-1 (S-1) synthetic aperture radars (SARs) operating in wave mode and the real aperture radar (RAR) called Surface Waves Investigation and Monitoring (SWIM) onboard the China-France Oceanography SATellite (CFOSAT) are the only two kinds of spaceborne radars providing directional ocean wave information globally. To quantify the absolute uncertainties in the swell wave heights of a specific wave system (Hss) observed from these two spaceborne sensors, a triple colocation error model is exploited via WaveWatch III (WW3) cussed with respect to regional error characteristics along with a feasible explanation of error sources. The findings could be helpful for better understanding and synergistically exploiting the Hss datasets from these two spaceborne radars.**

***Index Terms*—China-France Oceanography SATellite (CFOSAT), Sentinel-1 (S-1), swell wave height, synthetic aperture radar (SAR), triple collocation, validation, WaveWatch III (WW3).**

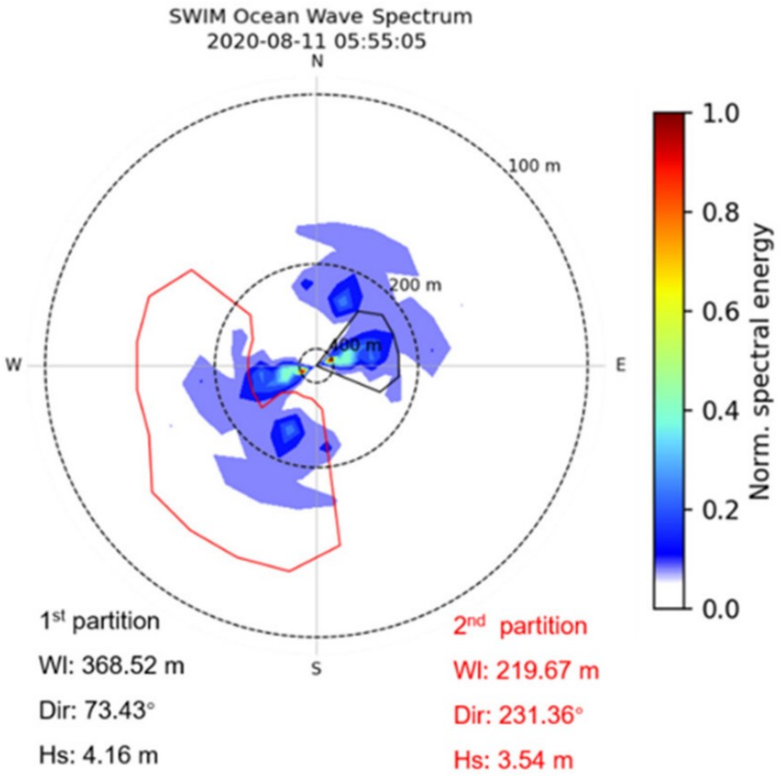


Fig. 2. Example of the SWIM (10° beam)-derived ocean wave spectrum on August 11, 2020, at 05:55:05 (UTC) at 57.29° S/150.0° W.

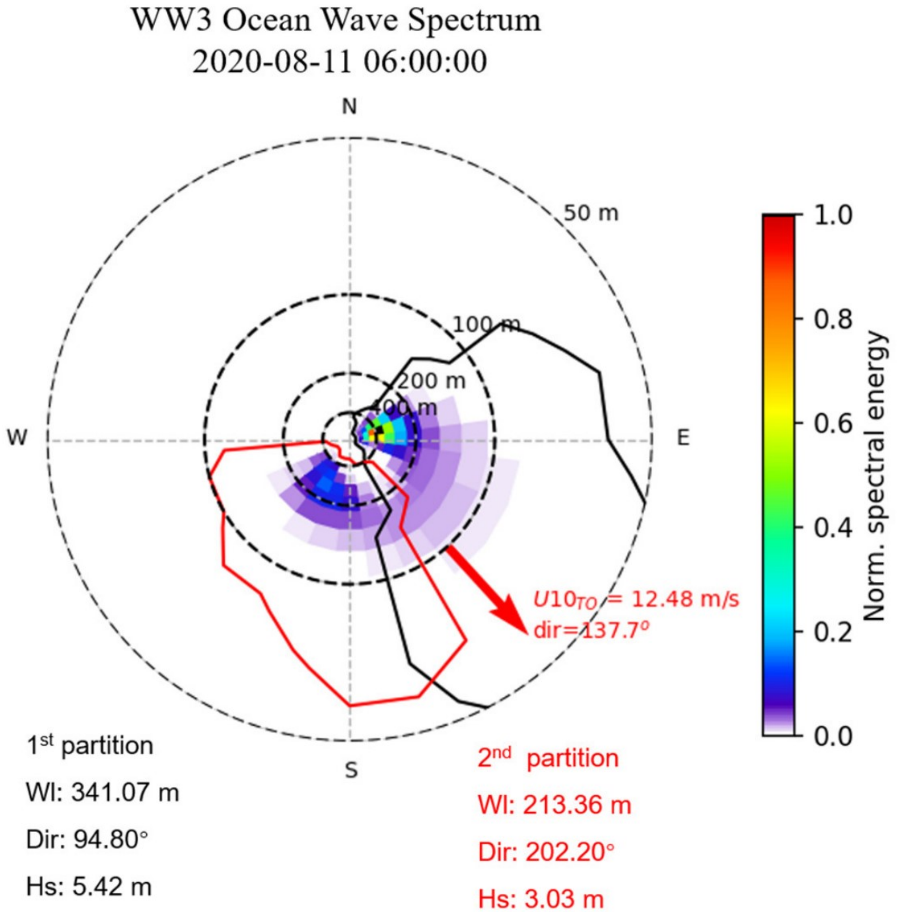


Fig. 3. Example of the WW3 hindcast spectrum on August 11, 2020, at 06:00 (UTC) at 57.5° S/150.5° W.

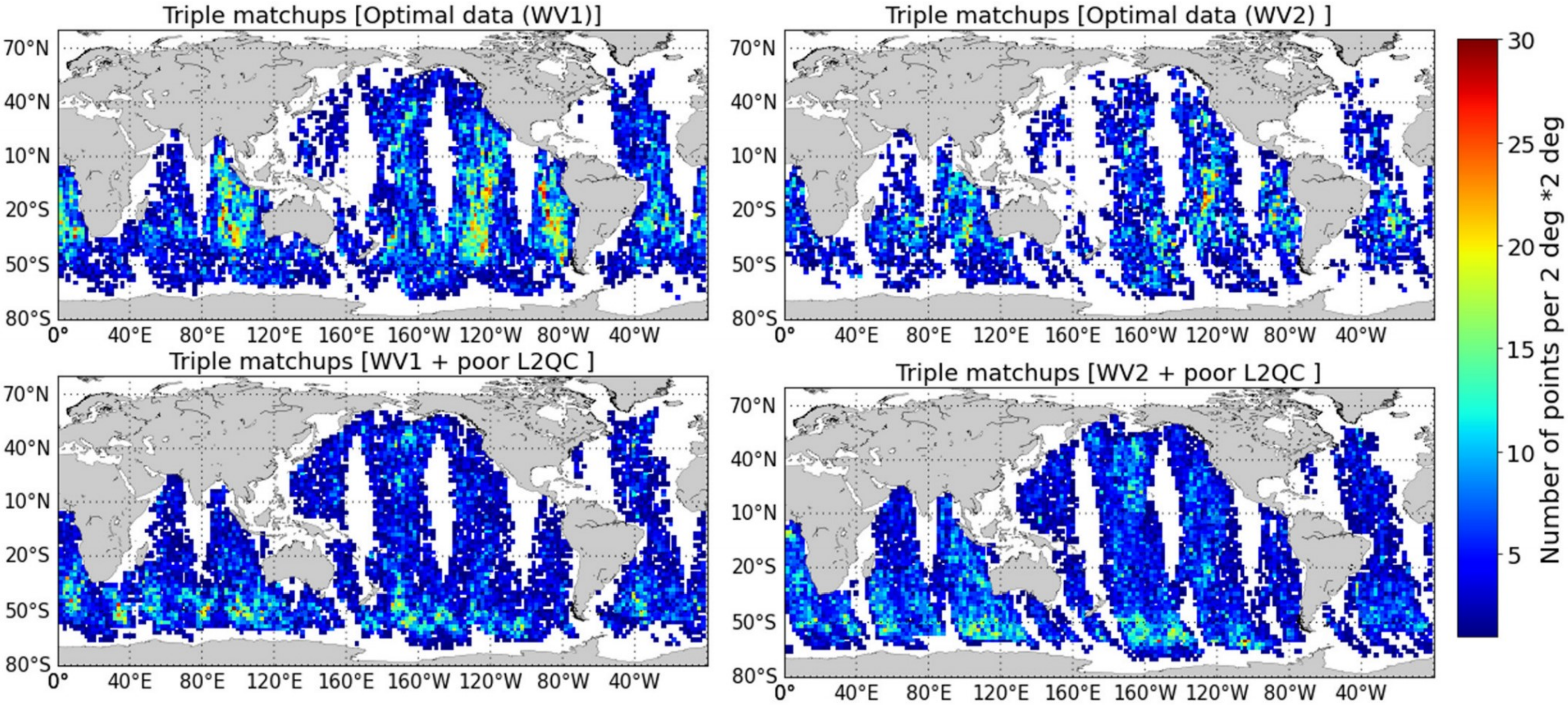


Fig. 9. Distributions of triplets (S-1 SAR WV, CFOSAT SWIM, and WW3) on a 2° × 2° grid.

TABLE II

ESTIMATES OF THE UNCERTAINTY METRICS FROM THE TRIPLE COLLOCATION ANALYSIS ON THE OPTIMAL-MATCHED HSS WITH THE LIMITS WITHIN 95% CONFIDENCE INTERVALS FOR THE CORRESPONDING VALUES GIVEN IN PARENTHESES

Datasets	RMSE (m)			Scatter index (%)			SNR (dB)		
	SAR	SWIM	WW3	SAR	SWIM	WW3	SAR	SWIM	WW3
SAR(**WV1**)-SWIM-WW3	0.35 (0.34, 0.37)	0.23 (0.21, 0.25)	0.42 (0.40, 0.44)	17.35 (16.71, 18.05)	11.32 (10.27, 12.38)	20.73 (19.77, 21.69)	6.34 (5.90, 6.79)	10.92 (10.06, 11.83)	7.88 (7.38, 8.39)
SAR(**WV2**)-SWIM-WW3	0.49 (0.48, 0.51)	0.22 (0.20, 0.24)	0.41 (0.39, 0.43)	23.58 (22.86, 24.30)	10.99 (9.88, 12.04)	19.42 (18.28, 10.61)	3.88 (3.46, 4.31)	11.22 (10.32, 12.24)	7.88 (7.27, 8.48)

TABLE III

SAME AS TABLE II BUT FOR THE SOUTHERN OCEAN (LATITUDES $< -45°$)

Datasets	RMSE (m)			Scatter index (%)			SNR (dB)		
	SAR	SWIM	WW3	SAR	SWIM	WW3	SAR	SWIM	WW3
SAR(**WV1**)-SWIM-WW3	0.49 (0.47, 0.51)	0.37 (0.34, 0.40)	0.66 (0.63, 0.70)	15.63 (15.02, 16.25)	11.93 (10.97, 12.88)	21.31 (20.16, 22.48)	4.65 (4.15, 5.17)	8.46 (7.68, 9.29)	6.03 (5.45, 6.62)
SAR(**WV2**)-SWIM-WW3	0.83 (0.80, 0.85)	0.33 (0.29, 0.38)	0.67 (0.64, 0.71)	25.00 (24.30, 25.73)	10.11 (8.71, 11.37)	20.22 (18.99, 21.41)	-2.89 (-3.27, -2.38)	9.20 (8.05, 10.62)	5.54 (4.90, 6.21)

Progress 4/6

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 60, 2022 5103012

Up-to-Downwave Asymmetry of the CFOSAT SWIM Fluctuation Spectrum for Wave Direction Ambiguity Removal

Huimin Li, Danièle Hauser, *Member, IEEE*, Bertrand Chapron, Frédéric Nouguier, Patricia Schippers, Biao Zhang, *Senior Member, IEEE*, Jingsong Yang, and Yijun He, *Member, IEEE*

***Abstract*—The surface wave investigation and monitoring (SWIM) aboard the China-France Oceanography Satellite (CFOSAT), a pioneer conically scanning wave spectrometer, was successfully launched on October 29, 2018. Its innovative configuration composed of one nadir and five rotating near-nadir beams is designed to simultaneously observe the directional wave spectrum at a global scale. In this study, we systematically implement the spectral analysis of the radar backscattering with the periodogram technique to obtain the fluctuation spectrum for each azimuth direction. The 2-D fluctuation spectrum of the three spectral beams ($\theta = 6°$, 8°, and 10°) combines all the azimuth directions within one entire rotation of 360°. The case study demonstrates that the wave features (peak wavelength and direction) are roughly consistent between the estimated fluctuation spectrum and the collocated WaveWatch III wave slope spectrum. A marked up-to-downwave asymmetry of the fluctuation spectrum with larger spectral level in the upwave direction for all the three spectral beams is observed. A ratio is defined between the fluctuation spectrum within the [0°, 180°] sector relative to the [180°, 360°] sector. Statistics display that this ratio is greater than 1 when it denotes the up-to-downwave ratio and smaller than 1 for the down-to-upwave ratio. This observed spectrum asymmetry is linked to the asymmetric modulation from upwind to downwind. In addition, we employ such finding to help remove the 180° wave direction ambiguity from a practical point of view. Preliminary results of the direction ambiguity removal display a bias of 41.3°, 40.6°, and 36.7° for the beams. The 10° beam shows slightly better performance compared to the other two beams in terms of bias and standard deviation. This shall lay a strong basis for the operational implementation of such algorithm to resolve the direction ambiguity.**

***Index Terms*—China–France Oceanography Satellite (CFOSAT) surface wave investigation and monitoring (SWIM), up-to-downwave asymmetry of fluctuation spectrum, wave direction ambiguity removal.**

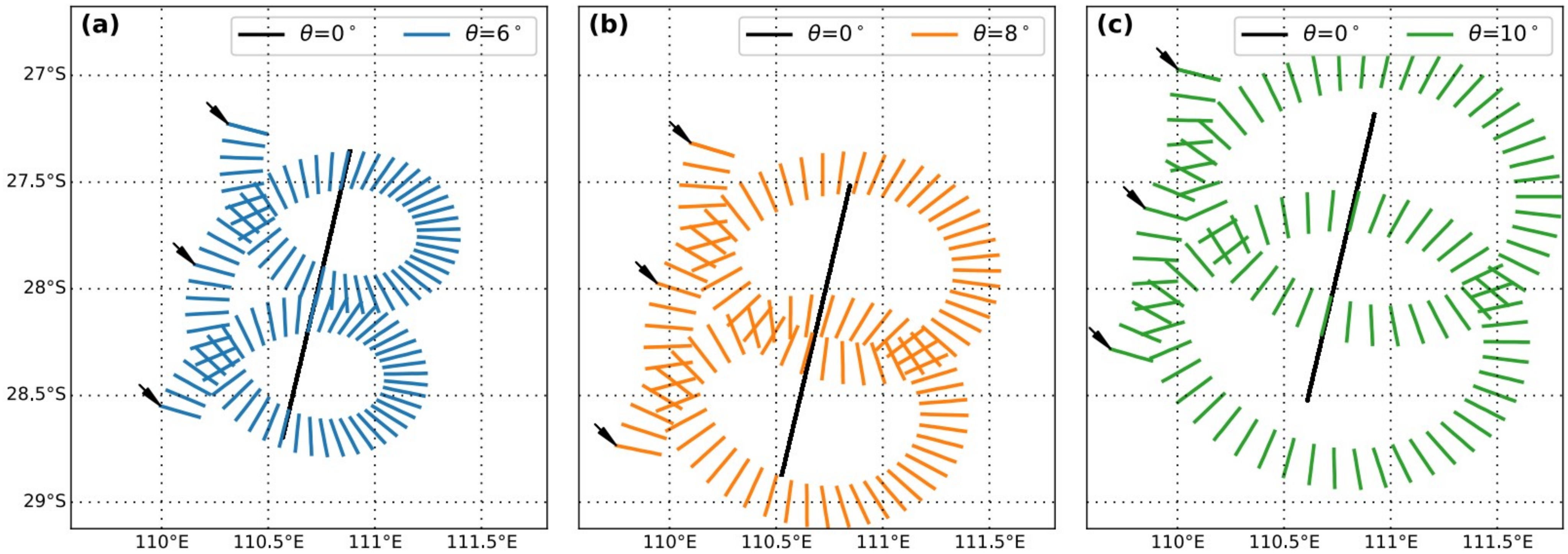


Fig. 1. Example for acquisition pattern of (a) 6°, (b) 8°, and (c) 10° beams within two rotations of 360°. Black curve denotes the footprint of the nadir beam. Note that the slightly varying coverage of these three incidence angles is due to their incontiguous azimuth directions at a given moment. The black arrow indicates the starting position of one entire rotation.

TABLE I

DETAILS OF SWIM OBSERVATION SWATH R_{SWATH} AND GROUND-RANGE RESOLUTION L_r

INC[°]	R_{swath} [km]	N_r	L_r [m]
2	18.1	4	53.9
4	36.3	4	27.0
6	54.5	2	9.0
8	72.9	3	10.1
10	91.5	3	8.1

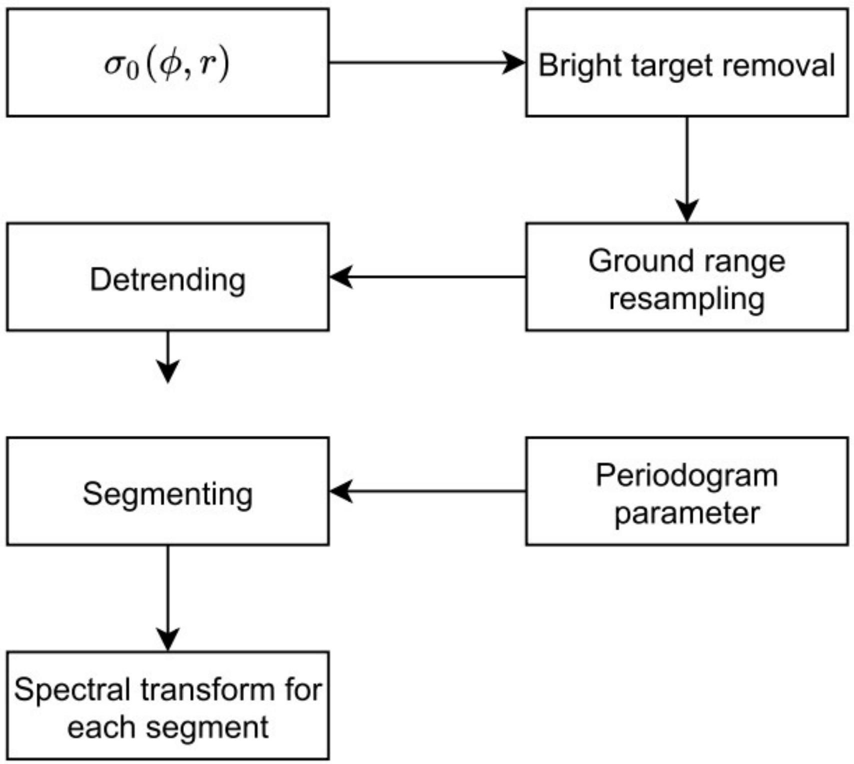


Fig. 2. Flowchart of the fluctuation spectrum estimate along each azimuth direction. The ground-range resampling spacing is set to be 5 m and the periodogram window is 512 pixels with 256 pixels overlapping.

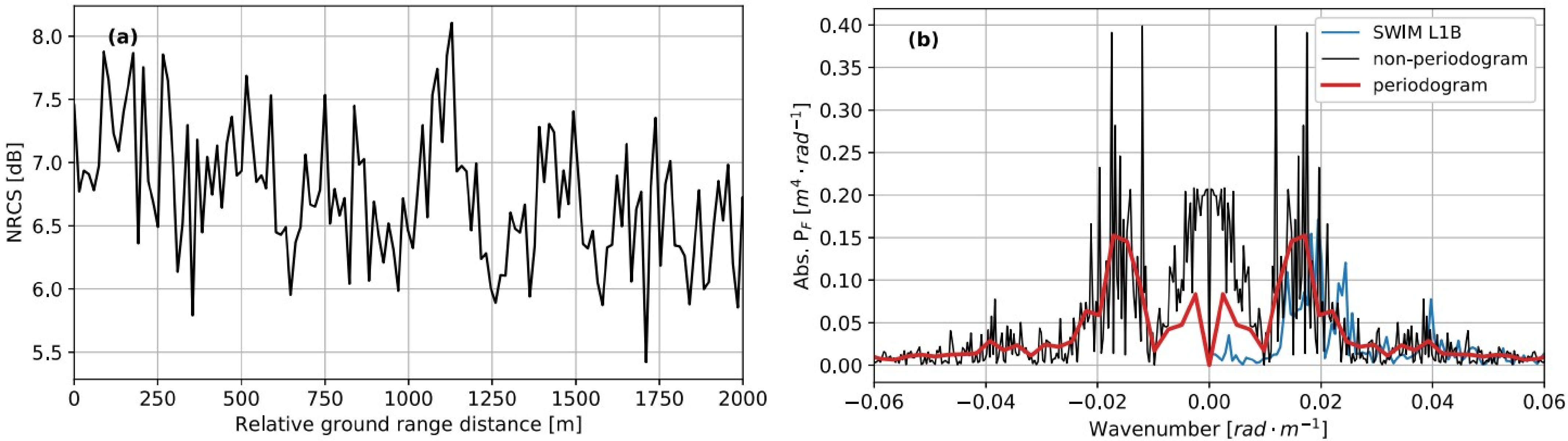


Fig. 3. Example for (a) SWIM measured σ_0 profile of 10° beam with respect to the relative ground-range distance. (b) Comparison of the obtained fluctuation spectrum using periodogram algorithm in Fig. 2 (red curve) and nonperiodogram method (black curve) and the results annotated in SWIM level-1B products (blue curve).

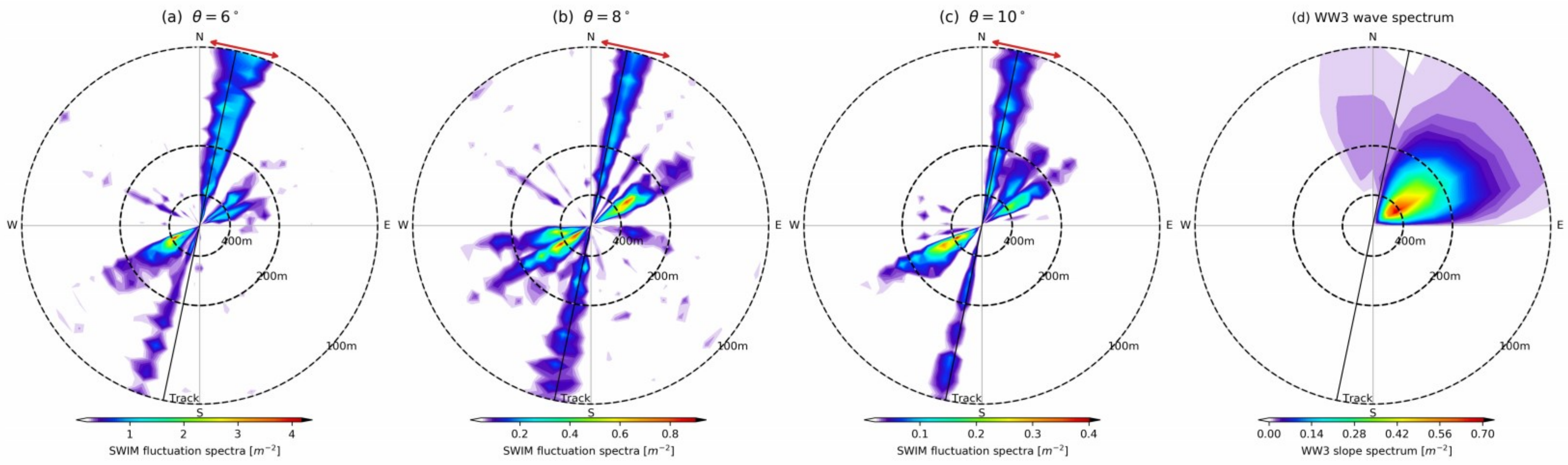


Fig. 4. 2-D fluctuation spectrum constructed from one rotation of 360° for the beam of (a) 6°, (b) 8°, and (c) 10°. (d) Collocated WW3 wave slope spectrum is shown for comparison. The WW3 spectra direction corresponds to the direction that the waves travel to. The red arrow denotes the directional sector where the signal is strong affected by the instrument noise.

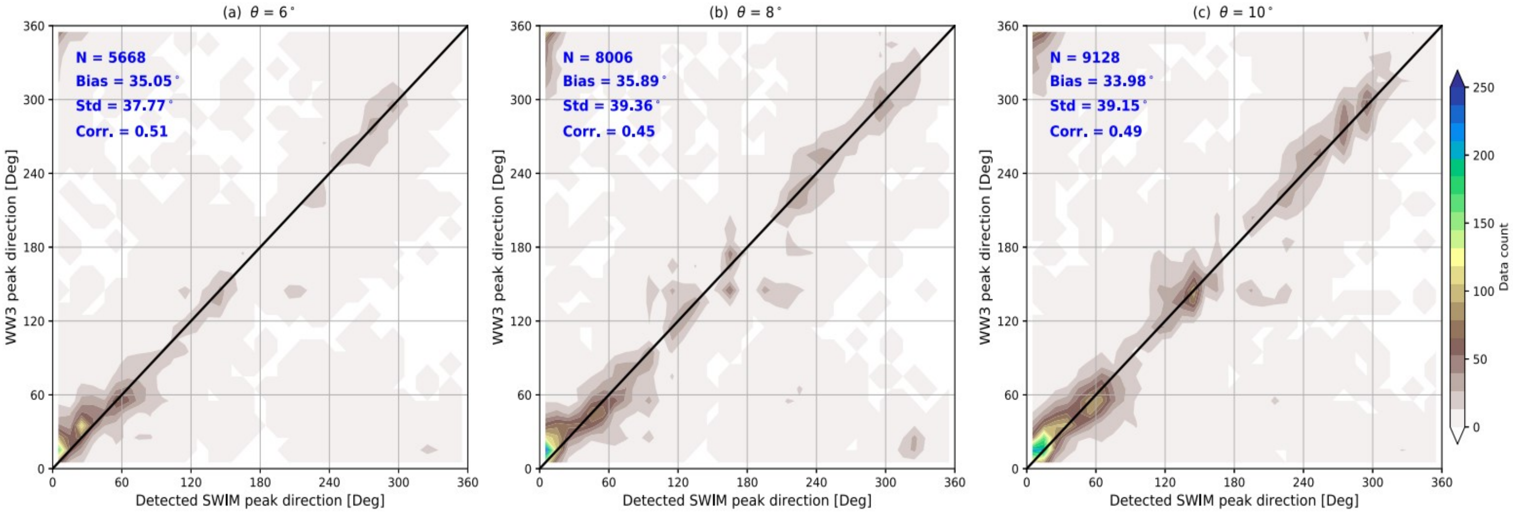


Fig. 9. Comparison of SWIM resolved wave peak direction with respect to the collocated WW3 wave peak direction for (a) 6°, (b) 8°, and (c) 10° beams. "N" annotated in each plot denotes the total number of valid peak pairs. Colors are the data count with directional bins of 10° for both axes. Result metrics are given on the top-left corner of each plot.

TABLE II

METRICS OF AMBIGUITY REMOVAL

INC [°]	Total			U10<15m/s			U10>15m/s			corr.
	N	Bias	STD	N	Bias	STD	N	Bias	STD	
6	6442	34.99°	37.69°	6195	34.28°	37.05°	247	52.83°	47.99°	0.51
8	8779	35.42°	38.90°	8543	34.94°	38.47°	236	52.84°	48.88°	0.46
10	8978	33.86°	39.25°	8798	33.40°	38.74°	180	56.40°	54.64°	0.50

Progress 5/6

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 60, 2022 4204013

Validation of Wave Spectral Partitions From SWIM Instrument On-Board CFOSAT Against *In Situ* Data

Haoyu Jiang, Alexey Mironov, Lin Ren, Alexander V. Babanin, Jiuke Wang, and Lin Mu

***Abstract*—The surface waves investigation and monitoring (SWIM) instrument onboard the China–France Oceanography Satellite (CFOSAT) can retrieve directional wave spectra with a wavelength range of 70–500 m. This study aims to validate the partitioned integrated wave parameters (PIWPs) from SWIM, including partitioned significant wave height (PSWH), partitioned peak wave period (PPWP), and partitioned peak wave direction (PPWD), against those from National Data Buoy of PSWH from SWIM is not that good at this stage, probably because the high noise level in the spectra impacts the result of the partitioning algorithm. Further improvement is needed to obtain better PSWH information.**

***Index Terms*—China–France oceanography satellite (CFOSAT), spectral partition, surface waves investigation and monitoring (SWIM), validation.**

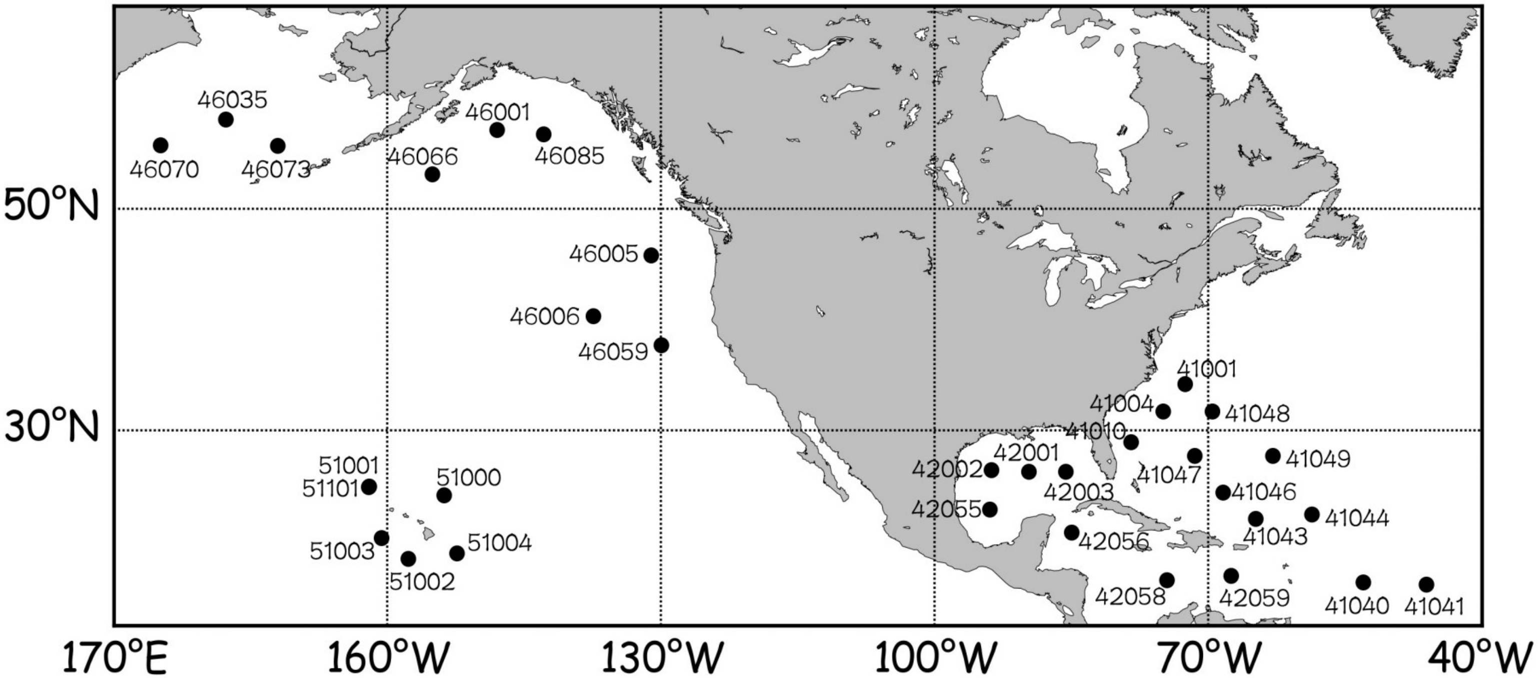
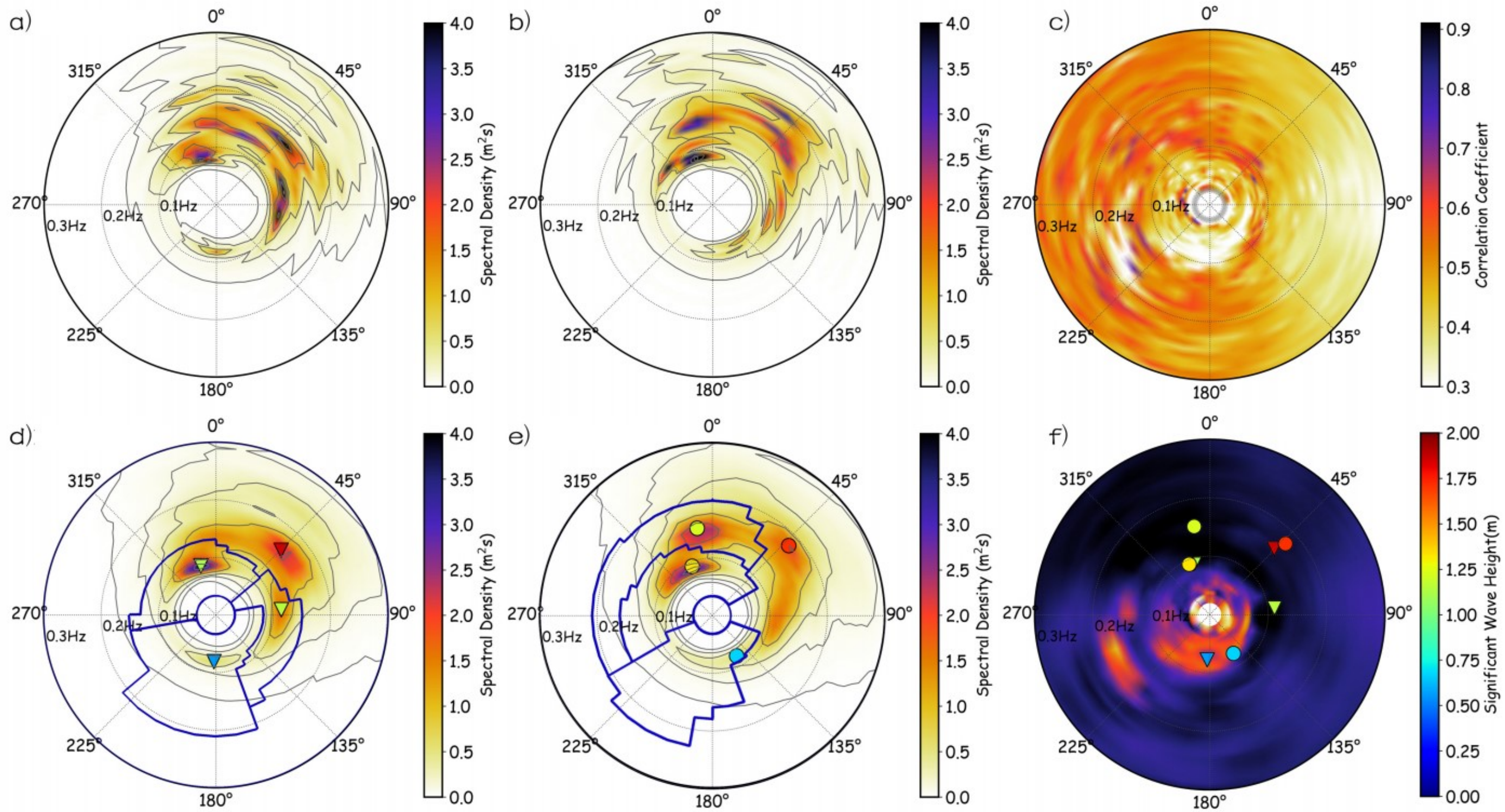


Fig. 1. Locations of the NDBC buoys used in the study.



correlation coefficient (CC).

Fig. 2. Directional wave spectra obtained at UTC1700 May 9, 2019 from the buoy (a) 51 001, (b) 51 101, and (c) CC of spectral density between spectra from the two buoys over the period from May 2019 to April 2020. (d)–(f) is the same as (a)–(c), but after smoothing in spectral space. Subplot (c) and (f) use the same color bar in (c). Triangles in (d) and (f) and circles in (e) and (f) represent the partitions derived from the spectra from buoy 51 001 and 51 101, respectively. The colors of triangles and circles indicate PSWHs and the locations of them indicate PPWPs and PPWDs, and all PSWHs indicated by triangles and circles use the same color bar in (f). The blue solid lines in (d) and (e) are the boundaries on different identified partitions.

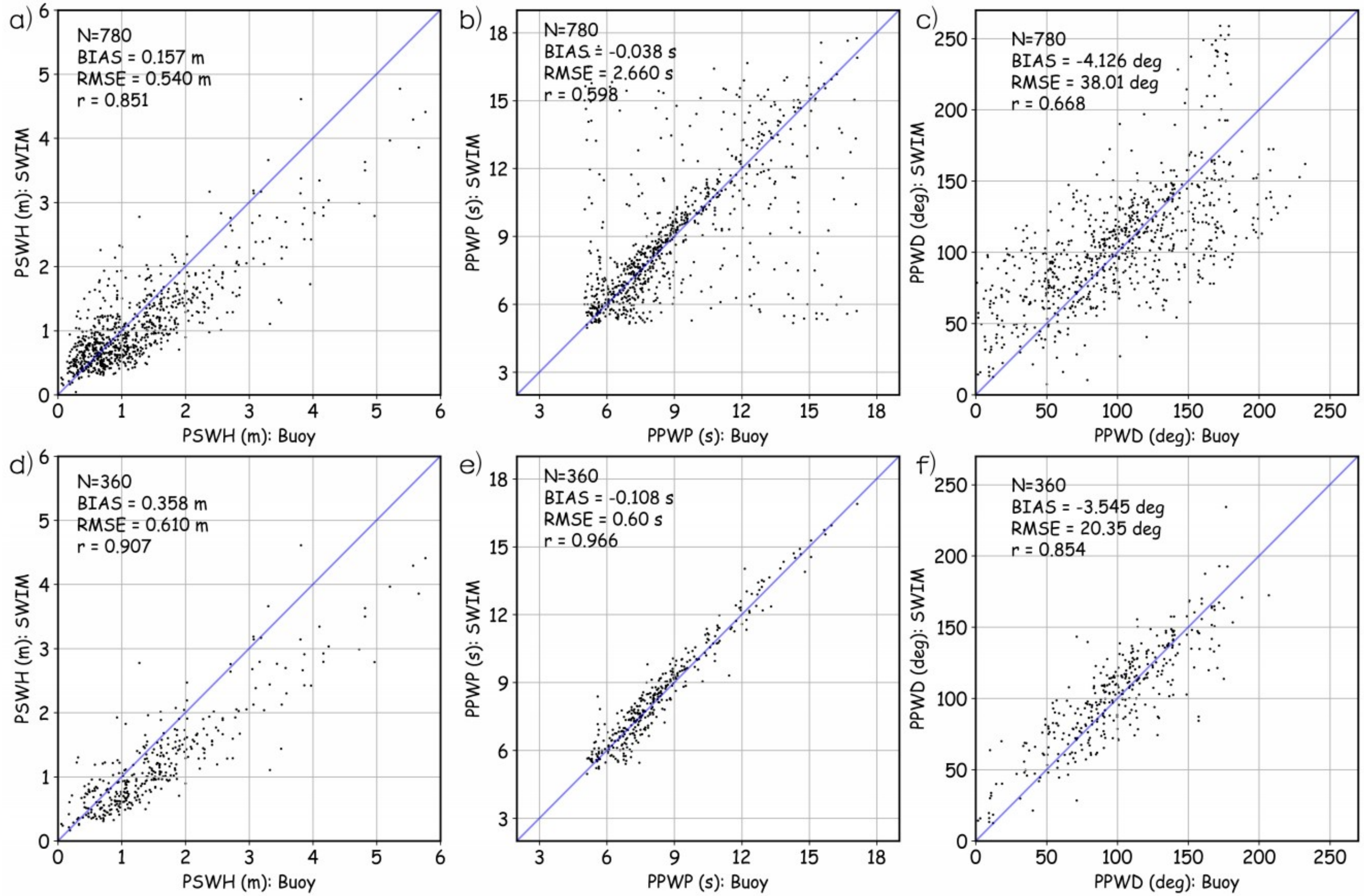


Fig. 8. Comparison of PIWPs (left column: PSWH, middle column: PPWP, right column: PPWD) between SWIM 10° beam and buoys over the period from May 2019 to April 2020. (a)–(c) All partitions are cross-assigned. (d)–(f) Only partitions with the minimum spectral distance for each pair of spectra are cross-assigned.

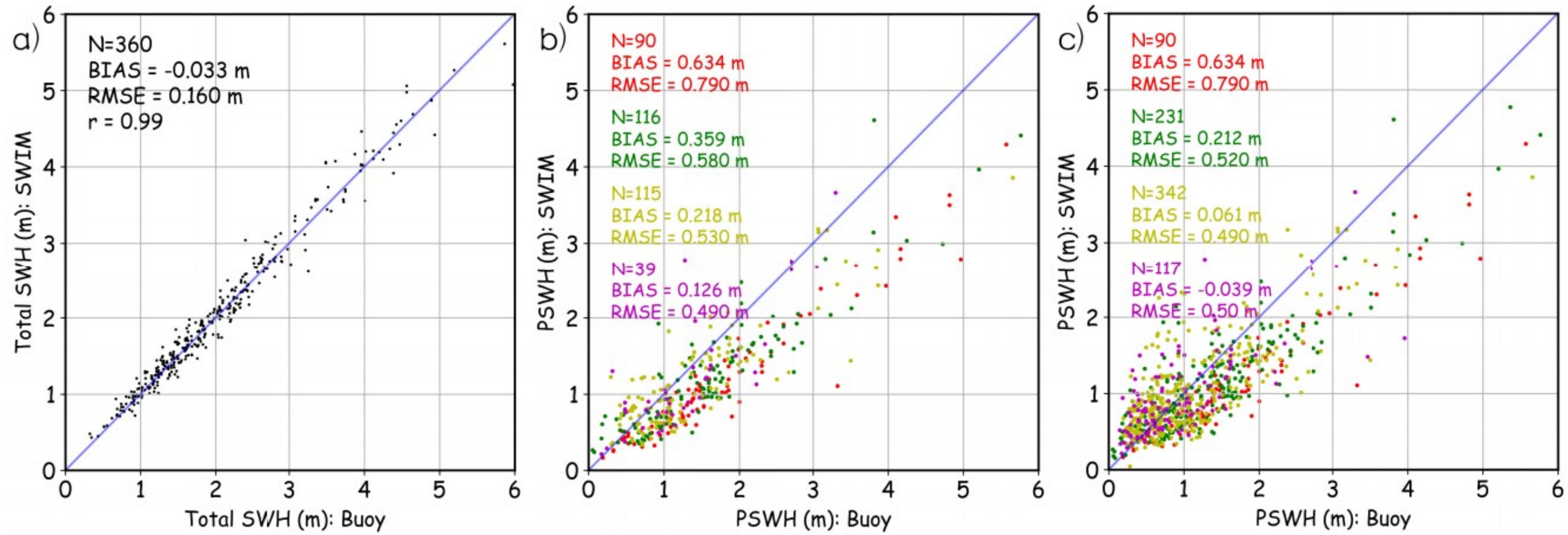


Fig. 12. Comparison of SWH between SWIM 10° beam and buoys. (a) Total SWH. (b) PSWH for best-matched partitions. (c) PSWH for all cross-assigned partitions. The colors of dots and texts in (b) and (c) indicate the number of partitions identified in the collocated buoy spectra (red: one partition, green: two partitions, yellow: three partitions, and purple: four partitions).

TABLE I

ERROR METRICS OF PIWPS FROM DIFFERENT BEAMS AND THE "WAVE BOX" OF SWIM FOR THE BEST-MATCHED PARTITIONS (ONLY PARTITIONS WITH THE MINIMUM SPECTRAL DISTANCE FOR EACH PAIR OF SPECTRA ARE CROSS-ASSIGNED) COMPARED WITH BUOY DATA FROM MAY 2019 TO APRIL 2020

	Beam 6°	Beam 8°	Beam 10°	Wave Box
No. Collocation	371	367	360	391
PSWH RMSE	0.66 m	0.60 m	0.61 m	0.63 m
PPWP RMSE	0.74 s	0.62 s	0.60 s	0.69 s
PPWD RMSE	23.2°	20.4°	20.4°	21.3°
PSWH Bias	0.46 m	0.35 m	0.36 m	0.33 m
PPWP Bias	-0.16 s	-0.16 s	-0.11 s	-0.19 s
PPWD Bias	-2.5°	-2.9°	-3.5°	-2.7°
PSWH CC	0.92	0.91	0.91	0.92
PPWP CC	0.96	0.97	0.97	0.96
PPWD CC	0.86	0.85	0.85	0.86

Progress 6/6 Under review (Geo-spatial Information Science)

Advanced Deep Learning Model for Spatiotemporal Sequence Forecast of Tropical Cyclone Motion and Wind Speed

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Tropical cyclones; generative adversarial network (GAN); deep learning

ABSTRACT

Tropical cyclones are complex and powerful weather systems, and forecasting their path, structure, and intensity is currently a focus and challenge of meteorological research. In this paper, we propose an Attention Spatio-Temporal Predictive Generative Adversarial Network (AST-GAN) for predicting the time and spatial distribution of tropical cyclones. The predicted results include the structure, path, and maximum wind speed of typhoons for the next 15 hours (with a time interval of 3 hours). To address the spatiotemporal feature transfer at different time steps in the model, we use a channel attention mechanism for feature channel selection to further improve model performance and reduce parameter redundancy. The model is applicable to various special scenarios, such as multiple tropical cyclones moving simultaneously, or tropical cyclones approaching or landing. Our model was evaluated using CMA best track data, and achieved an RMSE of 1.33 m/s for wind speed and 1.75 m/s for maximum wind speed in the Northwest Pacific. In a 99-hour loop prediction of Super Typhoon Mangkhut in 2018, the predicted center position had an absolute error of 41.16 Km. Our proposed deep learning model provides an effective means for spatiotemporal prediction of tropical cyclones.

Project's schedule

The overall progress of this project will be coordinated by the two PIs: Dr. Bertrand CHAPRON and Prof. Jingsong YANG. The obtained results will be accordingly reported at each annual symposium.

Year 1: Data preparation, methodology development;
Year 2: Data preparation, methodology development, calculation, analysis;
Year 3: Calculation, analysis, validation;
Year 4: Analysis, validation, pre-operation and demonstration.

Future plan

Thanks for your attention