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Evaluation of CFOSAT scatterometer wind data in global oceans

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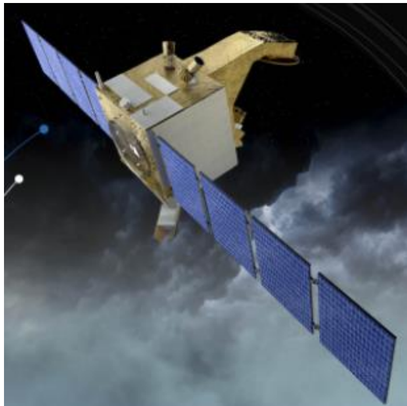
2021.03.15

中国科学院热带海洋环境国家重点实验室 LTO



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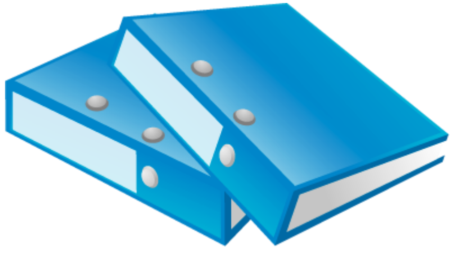
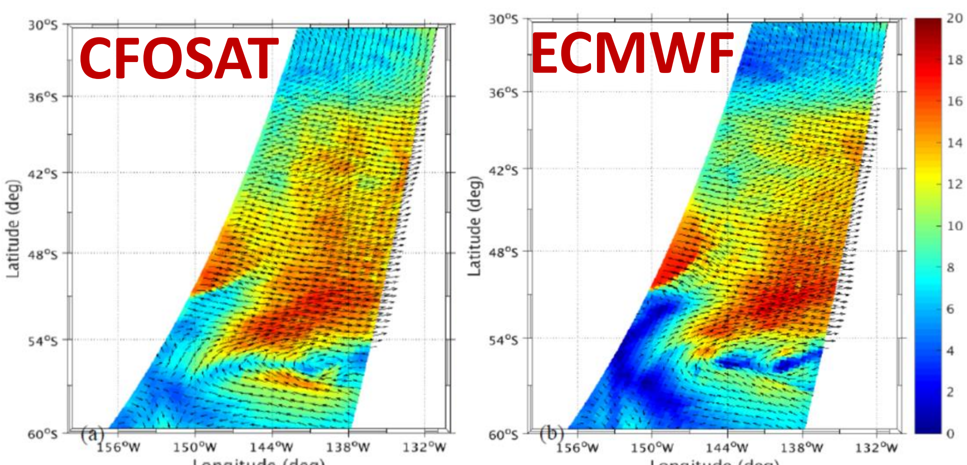


1. Introduction

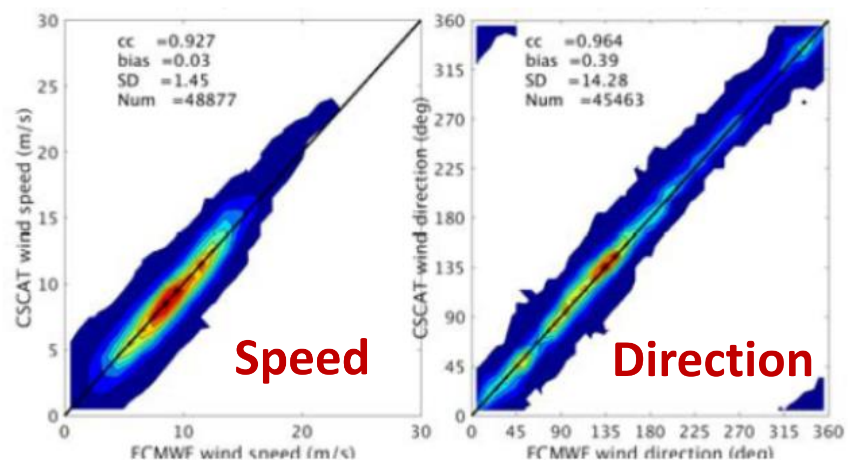
- Ocean surface **wind vectors** are **essential parameters** in fields of meteorology, oceanography, and climate studies.
- **Satellite** observations have the advantages of observing a **wide area** simultaneously and regularly with a width of 550 km (ASCAT) to 1800 km (QuikSCAT) and a **period of years**.
- However, satellite do not measure wind vectors directly but measure **radiation signals** from the sea surface.
- Therefore, it is necessary to evaluate the overall **accuracy** and precision of satellite wind data.

1. Introduction

- Many studies have been conducted by **comparing** scatterometer, radiometer and altimeter satellite wind retrievals with **in situ buoy measurements** and ECMWF, and cross validation between different satellite retrievals.
- Two preliminary evaluation studies reported that the CFOSAT wind vectors agree well with the **ECMWF reanalysis data.**
- In this study, CFOSAT wind retrievals are compared with near shore and offshore **in situ** buoy measurements to evaluate the performance of CFOSAT wind retrievals.



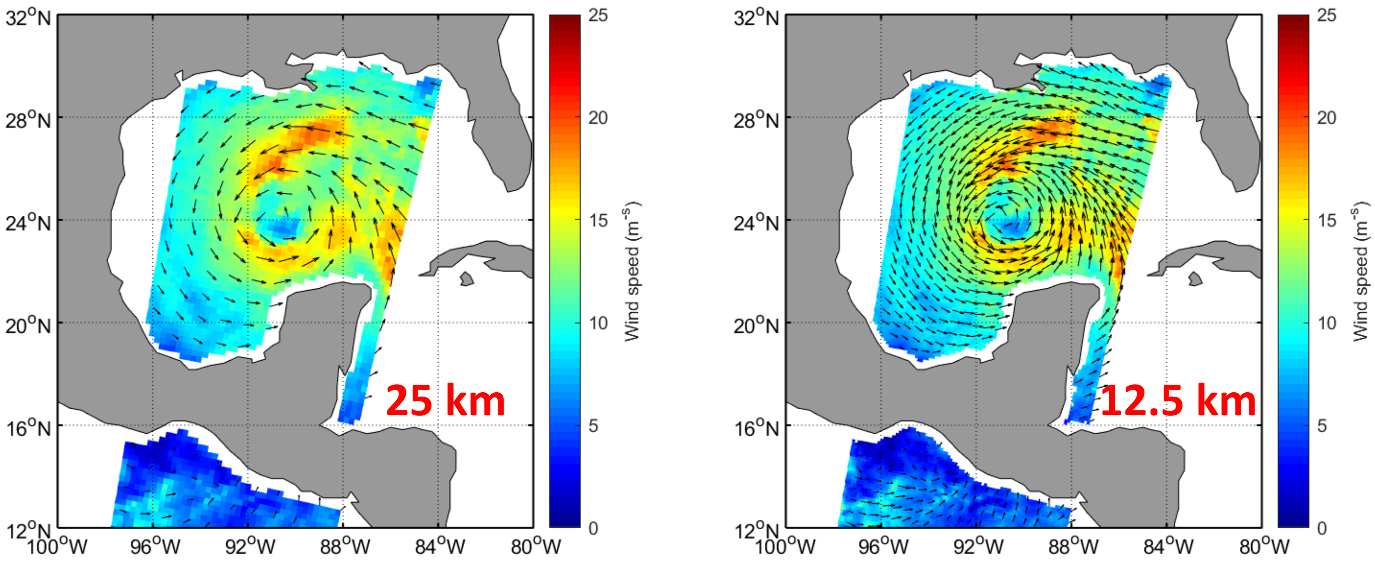
Lin et al., 2019



Zhu et al., 2019

2. Data and Methods

CFOSAT SCAT wind data



- The CFOSAT team has published L2 data products with spatial resolutions of **12.5 km** and **25 km** for scientific research.
- As swath products with a 12.5 km resolution are available only after September 2019, to obtain more collocations**, L2B swath data with a spatial resolution of 25 km** were used.
- **Data period**: December 2018 – December 2020.

2. Data and Methods

CFOSAT SCAT wind data

All swath data are freely available at the China Ocean Satellite Data Service Center and from AVISO.

L2B swath data specification and quality flag

变量名	有效范围	填充值	尺度因子
row_time	2000-01-01T00:00:00Z 2099-12-31T23:59:59Z	0000-00-00T00:00:00Z	N/A
wvc_lat	[-90.0 90.0]	-1.7E38	1.0
wvc_lon	[-180.0 360.0]	-1.7E38	1.0
wvc_quality	[0 2147483646]	-2147483648	1
wind_speed	[0 5000]	-32768	0.01
wind_dir	[0 3600]	-32768	0.1

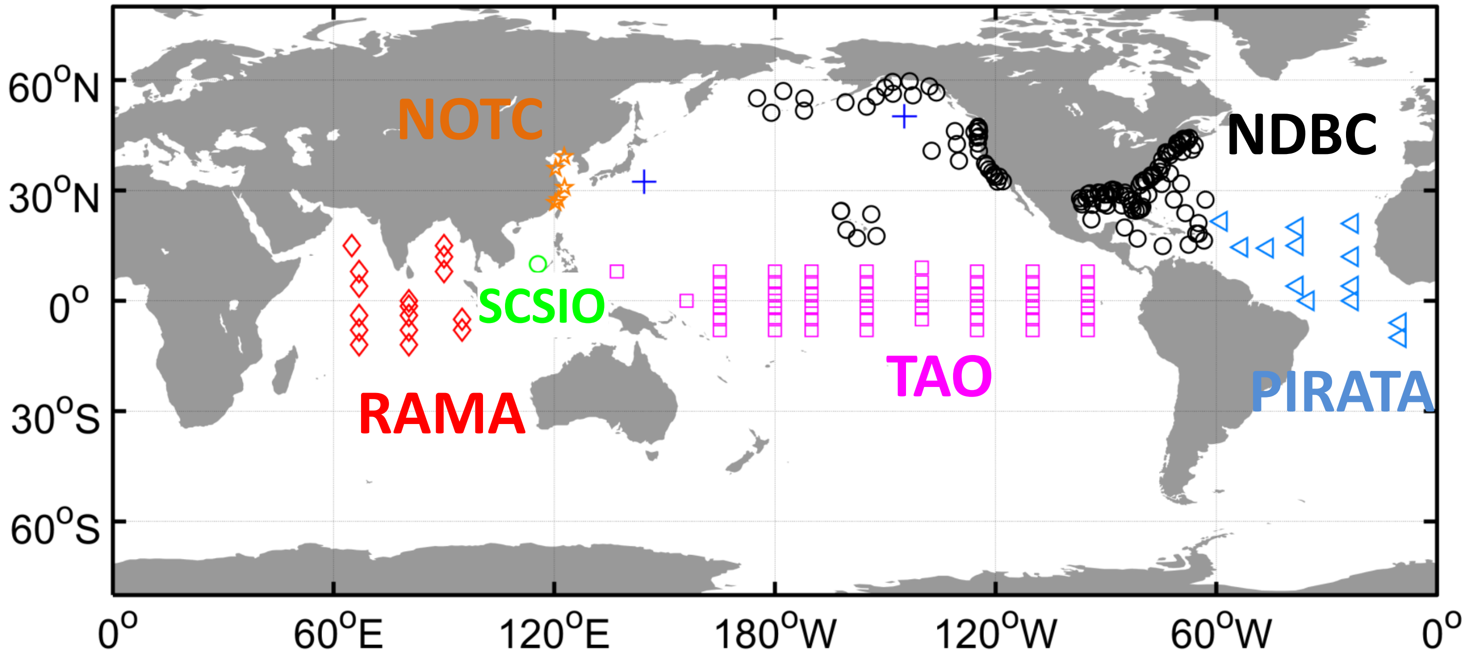
14	ice	风单元的一部分海冰数据
13	inversion	风场反演不成功
12	large	风速超过 30 m/s
11	small	风速小于 3 m/s
10	rain_fail	降雨标识不可用
9	rain_detect	降雨
8	no_background	未使用背景场数据

Rain

2. Data and Methods

Buoys

217 buoys from seven different buoy platforms.



Locations of the buoys used to evaluate the CFOSAT wind retrievals.

Among all 217 buoys, 81 buoys are coastal stations (within 100 km from the shore) and 136 are offshore stations

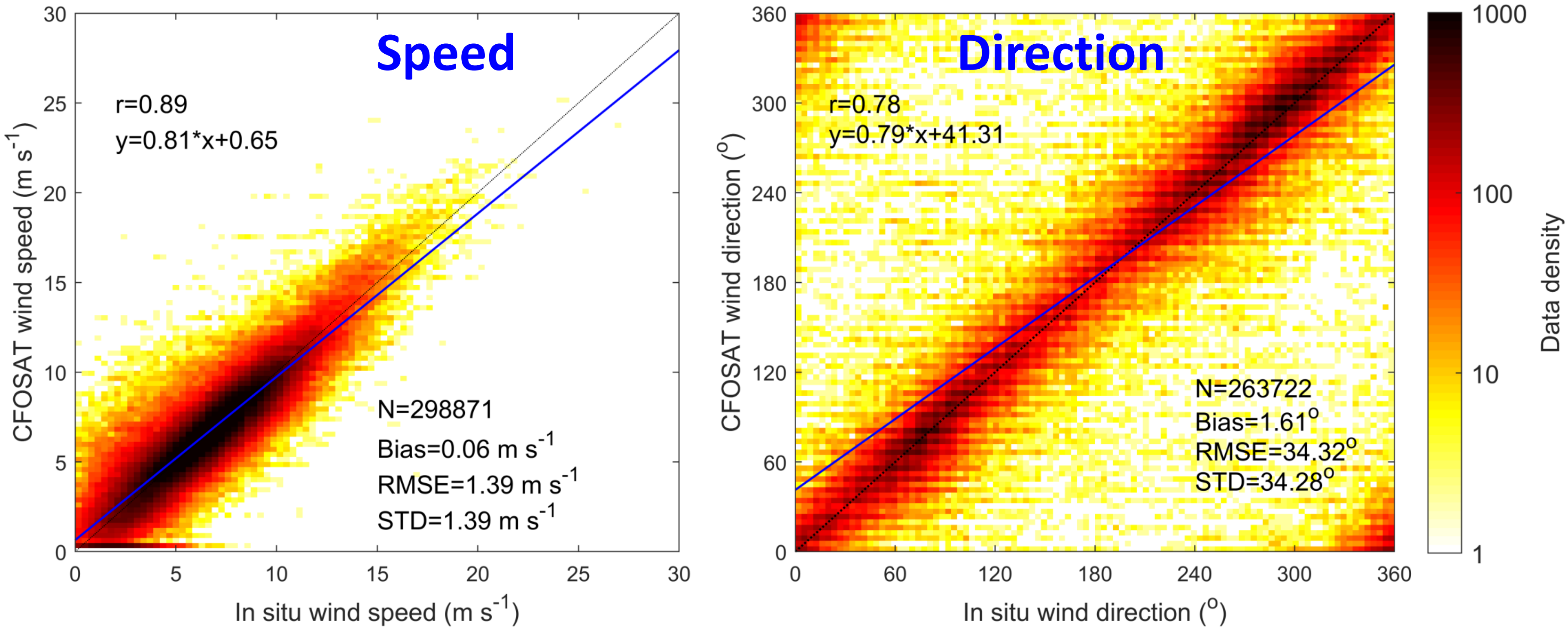
Wind conversion: $U_z = \ln(z/z_0)/\ln(z_m/z_0) \times U(z_m)$ A simple logarithmic method

To compare with other satellite products, the frequently used criteria of 25^0 and 30 min were used in this study.

3. Results and discussion

Overall

RMSE=**1.39**, Bias=0.06, N=298871 RMSE=**34.32**, Bias=1.61, N=263722



Scatter density plots of collocations for wind speeds and directions

Offshore: more than 100 km away from the shore and in water depth > 50 m

3. Results and discussion

offshore

RMSE= 1.32 2.40 1.16

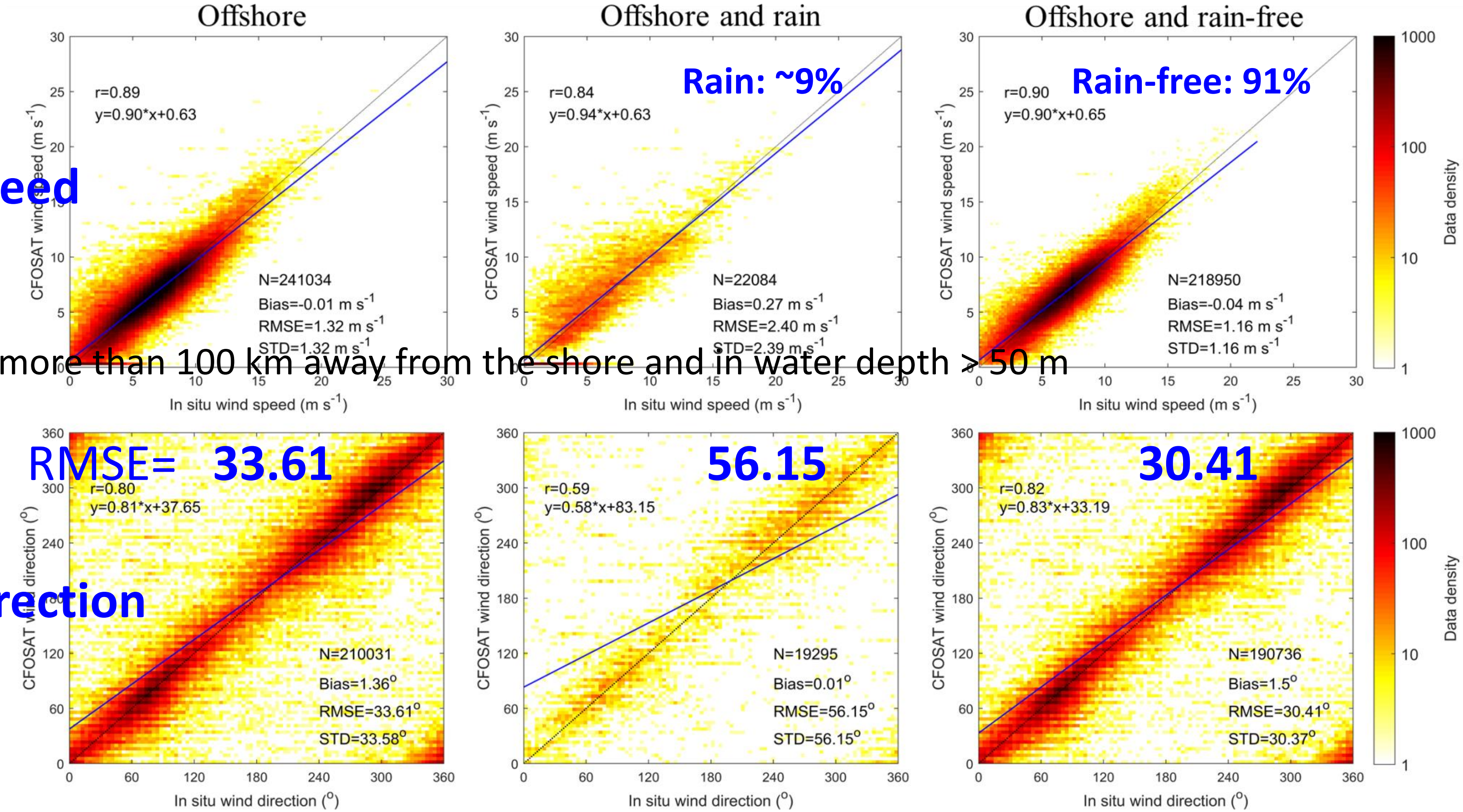
Rain: ~9% Rain-free: 91%

Speed

more than 100 km away from the shore and in water depth > 50 m

RMSE= 33.61 56.15 30.41

Direction



Density plots under all-weather, rain and rain-free conditions in the **offshore areas**

3. Results and discussion

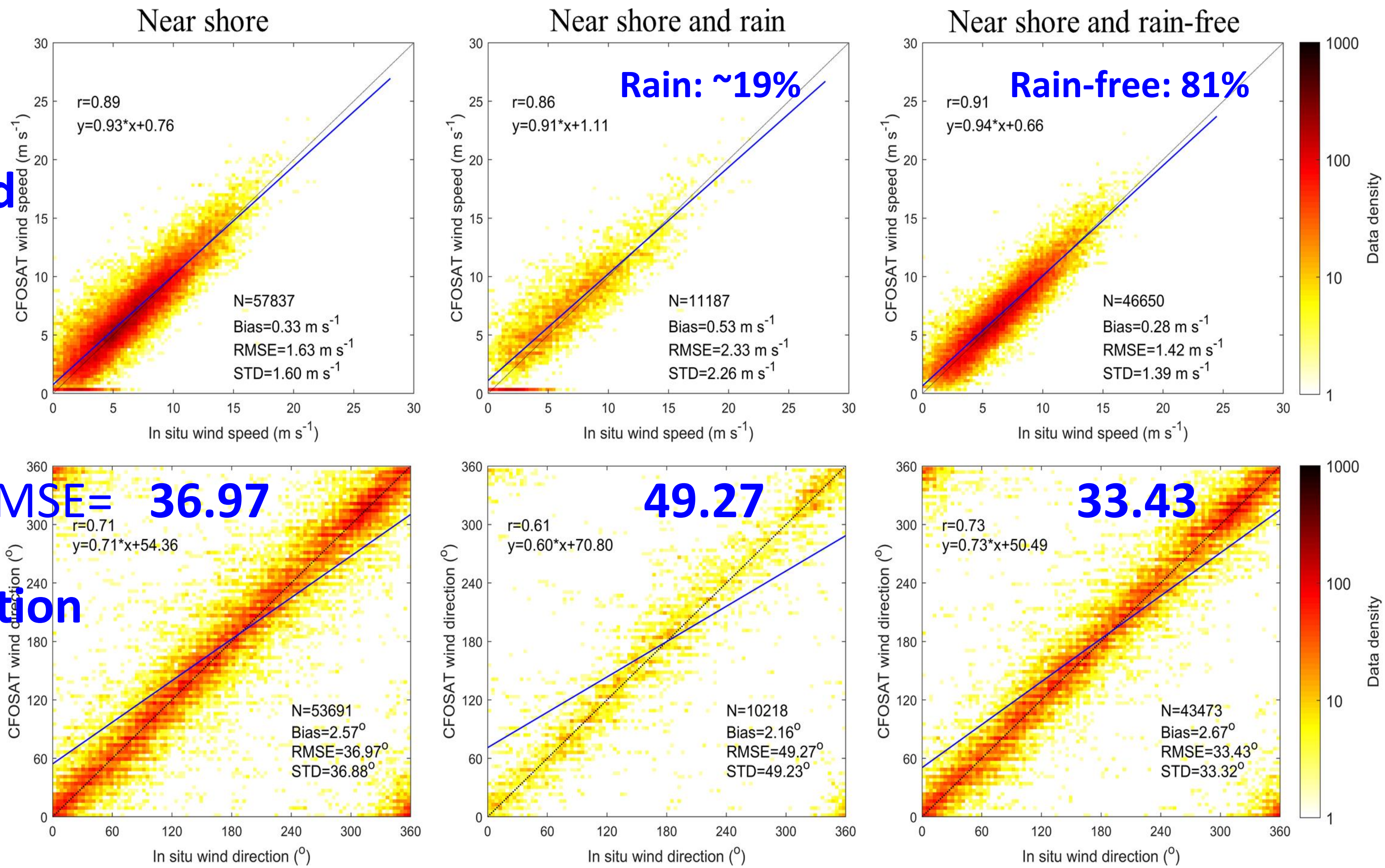
Near shore

RMSE= **1.63** **2.33** **1.42**

Speed

Direction

RMSE= **36.97** **49.27** **33.43**



Density plots under all-weather, rain and rain-free conditions in the **near shore areas**

3. Results and discussion

Summary of all statistical parameters of wind speed and direction

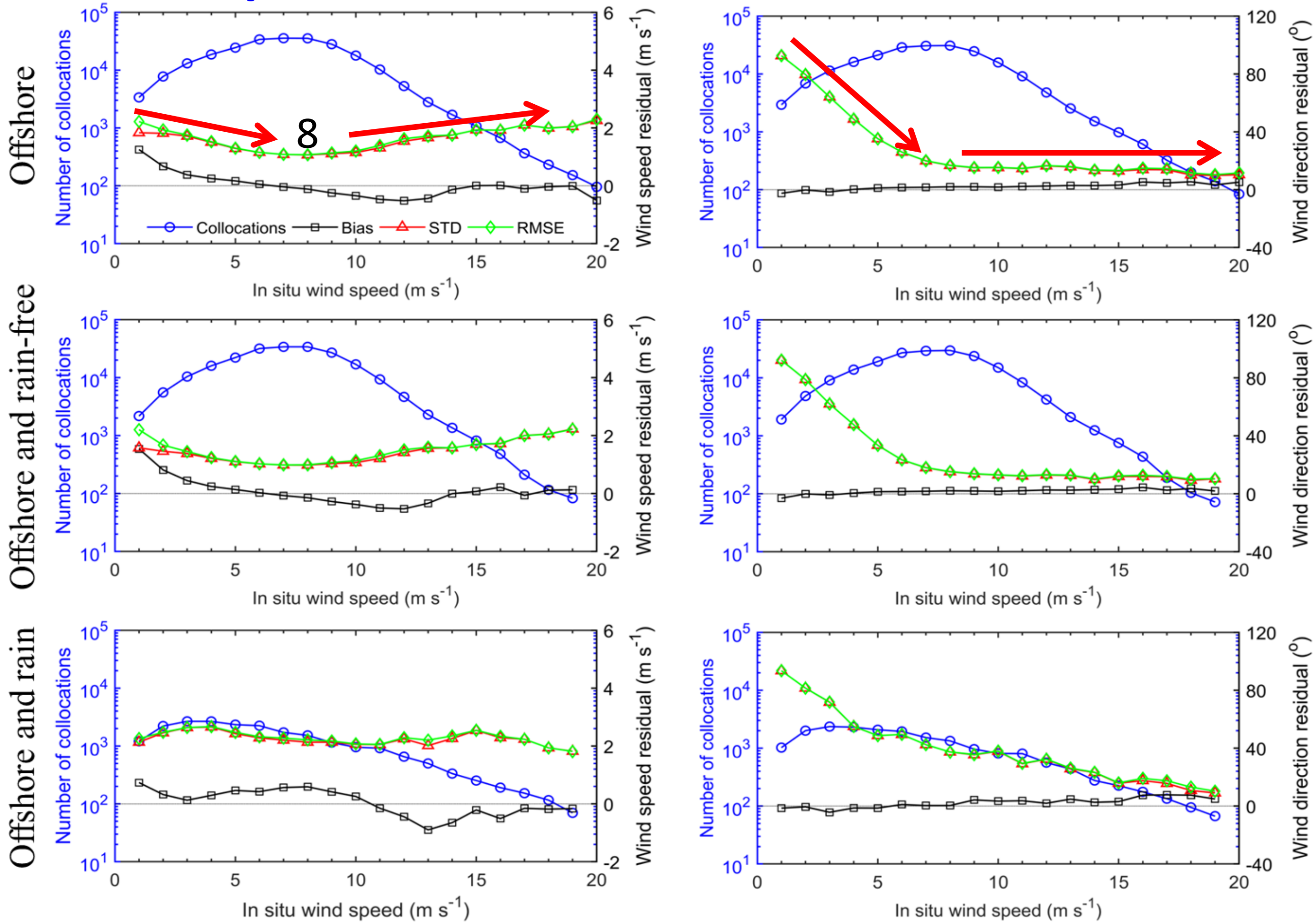
	Mean Bias		RMSE		r		Collocation	
	Speed ($m\ s^{-1}$)	Direction (°)	Speed ($m\ s^{-1}$)	Direction (°)	Speed	Direction	Speed	Direction
All	0.06	1.61	1.39	34.32	0.89	0.78	298871	263722
Near shore								
All	0.33	2.57	1.63	36.97	0.89	0.71	57837	53691
Rain	0.53	2.16	2.33	49.27	0.86	0.61	11187	10218
No Rain	0.28	2.67	1.42	33.43	0.91	0.73	46650	43473
Offshore								
All	-0.01	1.36	1.32	33.61	0.89	0.80	241034	210031
Rain	0.27	0.01	2.40	56.15	0.84	0.59	22084	19295
No Rain	-0.04	1.50	1.16	30.41	0.90	0.82	218950	190736

The performance of the CFOSAT wind retrievals is **better than** that of the OSCAT, HY-2A, RapidScat, SSMIS series, AMSR series, and TMI wind products and approximately **equal to** that of the QuikSCAT, ASCAT, HY-2B, WindSat, Sentinel-3 and Jason-3 wind products.

3. Results and discussion

Residuals in 1 m s^{-1} bins

Speed **Direction**



91%
Rain-free

9%
Rain

15.11°
Speed>6

The errors of the wind **speed first increase** and then **decease,** and the errors of the wind **direction decrease** with the increasing wind speed.

Under rainy conditions, the RMSE was both highly enhanced at all wind speeds except for wind speeds > 17 m

3. Results and discussion

Errors versus buoy location

In the offshore

Rain-free

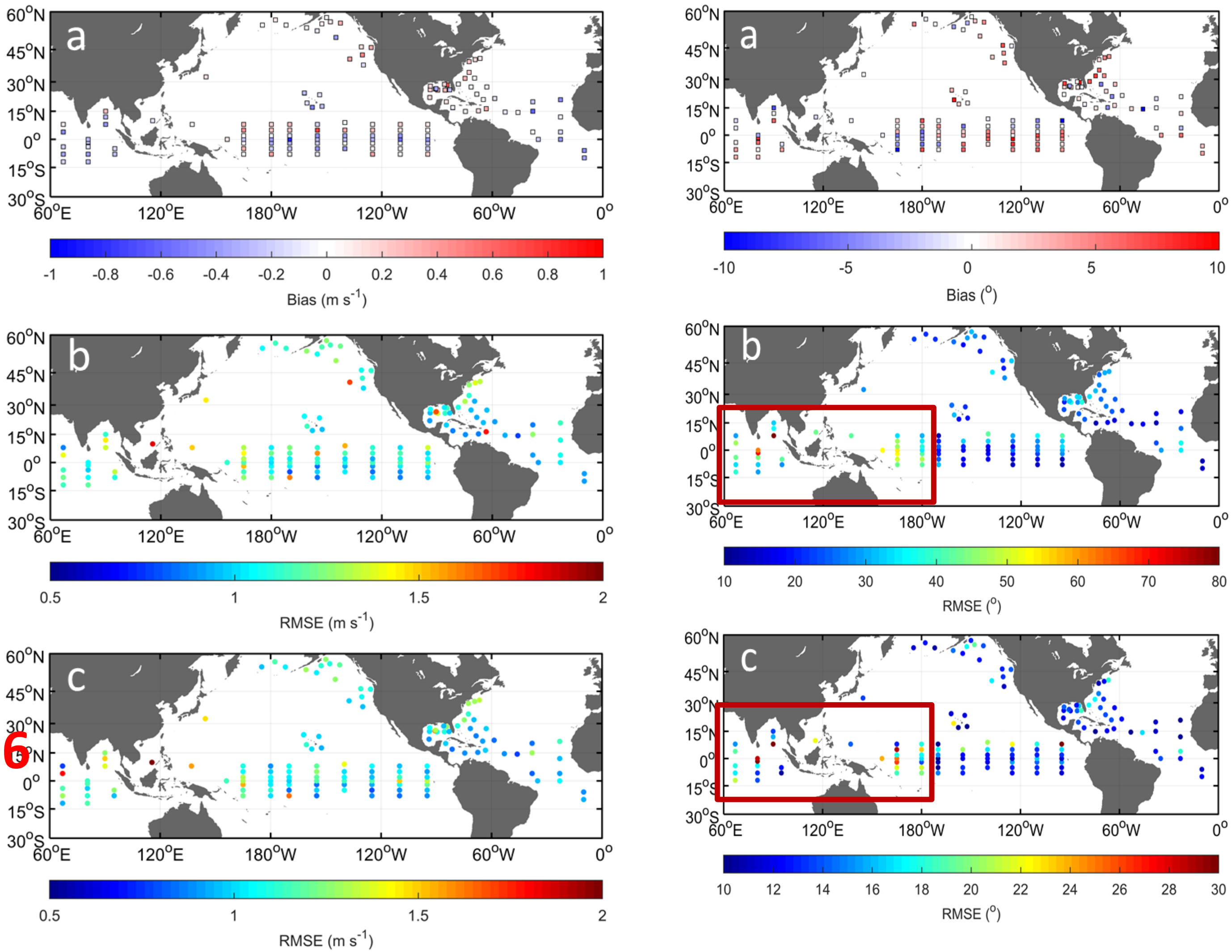
Speed **Direction**

Bias

RMSE

RMSE

Speed > 6



- Only 7 stations had RMSEs larger than 1.5 m s^{-1}, and they were uniformly distributed in the global oceans.

3. Results and discussion

Errors versus buoy location

In the near shore

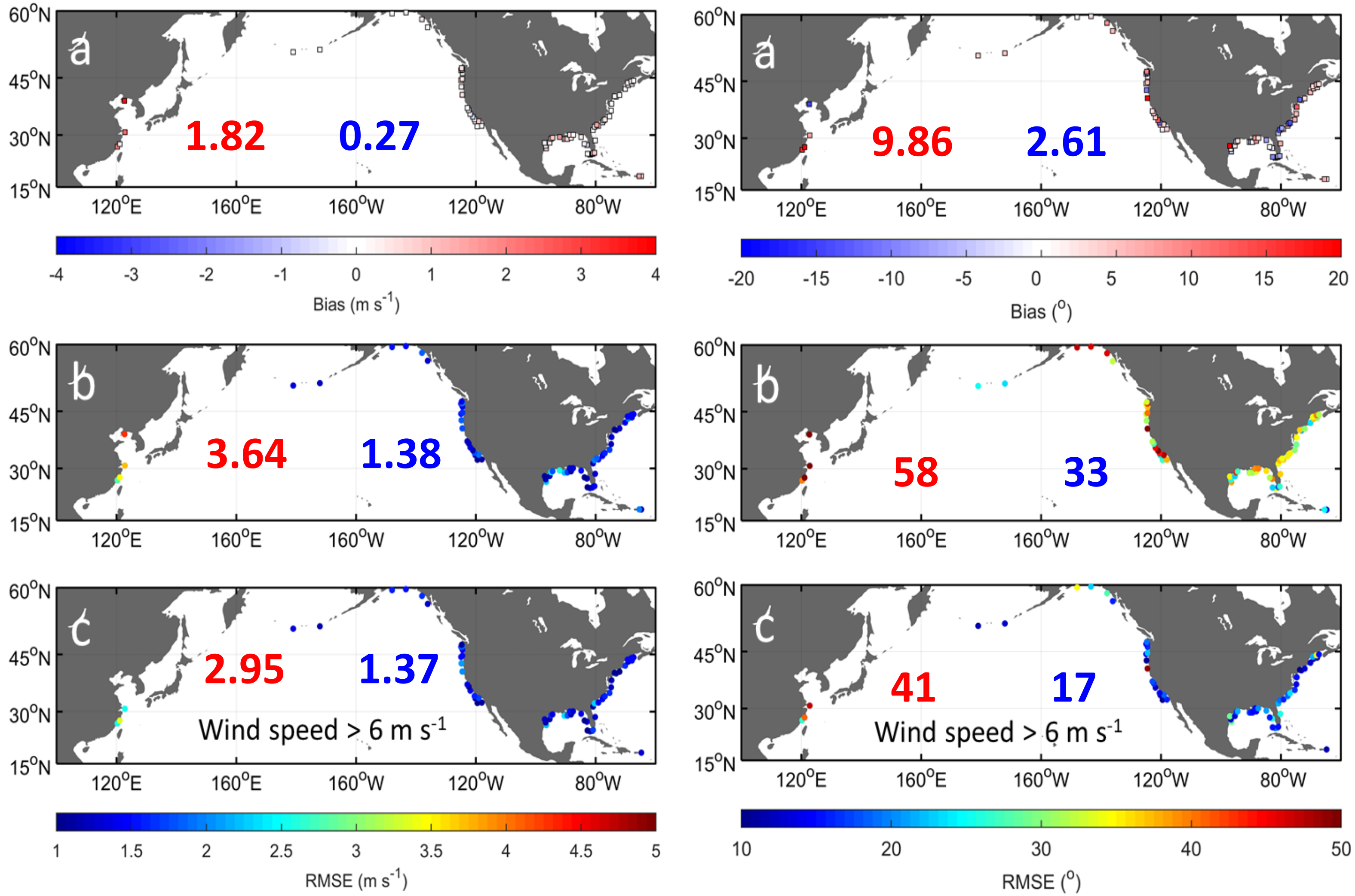
Rain-free

Speed **Direction**

Bias

RMSE

RMSE Speed > 6



The overall result near the US coast is better than the China coast, which is mainly due to the buoy site being **closer to the shore** (12.6 ± 9.3 km vs 35.9 ± 24.7 km).

3. Results and discussion

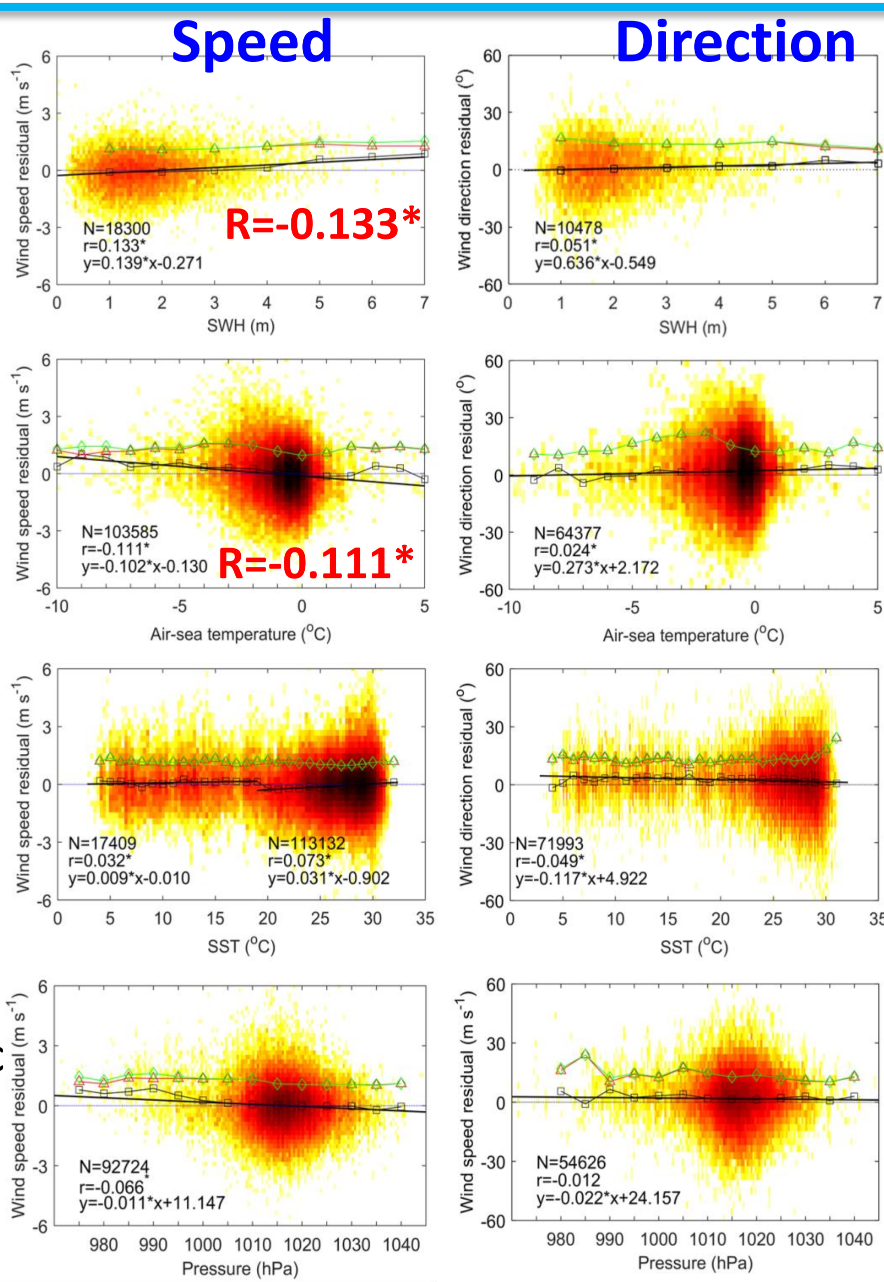
Atmospheric and oceanic parameters

Significant Wave Height

Air-sea temperature

SST

Atmospheric pressure



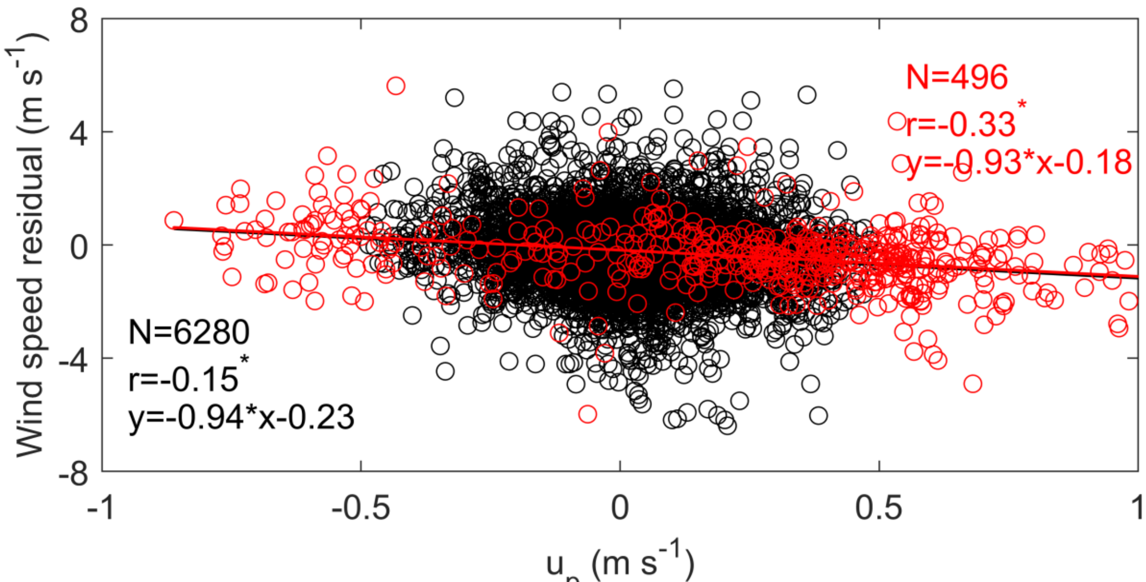
The correlation coefficients between the wind residuals and various buoy measured parameters were calculated to examine the impact factors on the CFOSAT wind retrievals. Although the correlation coefficients is very small for all parameters, the residual is significantly correlated to most parameters.

A positive relationship between wind speed residual and SWH was found in the Scatterometer and Altimeter retrievals [*Stopa et al.*, 2017; *Jiang et al*., 2020; *Wang et al*., 2021].

3. Results and discussion

Ocean surface currents

The winds retrieved by scatterometers represent the winds relative to the moving ocean surface.



The **effective ocean surface current** (u_p) is computed as:

$$u_p = |U_s|\cos(\theta_s - \theta_{buoy-wind})$$

where $|U_s|$ is the ocean surface current magnitude, θ_s is the current direction, and $\theta_{buoy-wind}$ is the buoy wind direction.

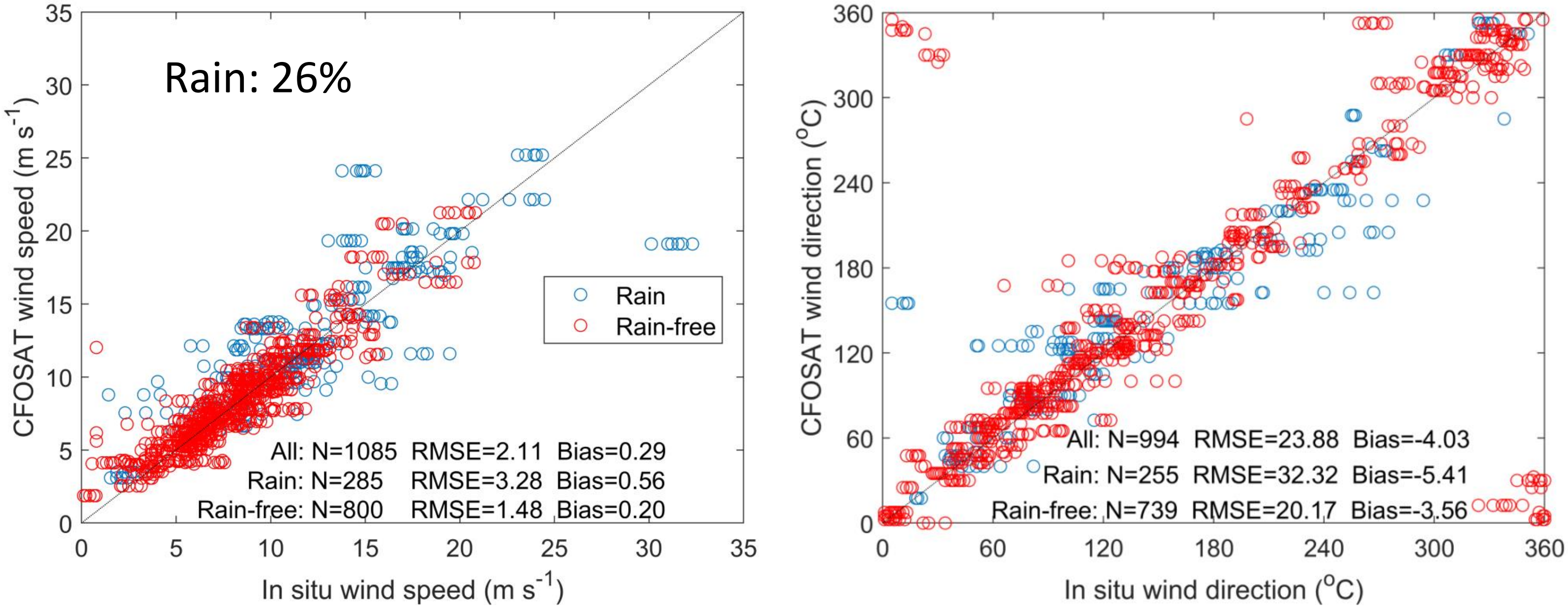
The ***r* is -0.15** which is similar as found by ASCAT, QuikSCAT, SCATSAT and less than that of ERS and AltiKa.
A negative correction indicating that the CFOSAT wind exceeds the in situ measurement in the event of an opposite current.

In high ocean current (> 0.5 m s^{-1}, red circles), the ***r* enhanced to -0.33**.

3. Results and discussion

Tropical cyclone

TC's impact: distance < 200 km Time < 24 hrs



Wind performance during the passage of tropical cyclones

1. The collocations resulted in a wind speed bias of 0.29 m s^{-1} and **RMSE of 2.11** m s^{-1}, which were much higher than those in the offshore area.

2. Low RMSE of direction (**20.17** vs **30.41**) was due to the higher **mean wind speed** (**9.34 vs 6.56** m s^{-1}).

3. Therefore, this is might be due to the large RMSE in high wind speeds [*Chou et al.*, 2013; *Zabolotskikh et al.*, 2014] and the **reduction of maximum wind** speed due to the spatial averaging [*Yueh et al.*, 2003].

4. Conclusions

1. Approximately **300000 collocations** were obtained within the spatial and temporal separations and were limited to less than **0.25° and 30 min**.
2. The overall RMSEs of wind vectors were 1.39 m s^{-1} and 34.32°, and reduced to **1.16 m s^{-1}** and 30.41° in the offshore under rain-free conditions. After removing winds less than 6 m s^{-1}, the RMSE of wind directions was reduced to **15.11°**.
3. **The performance** of the CFOSAT wind retrievals is **better than** that of the OSCAT, HY-2A, RapidScat, SSMIS series, AMSR series, and TMI wind products and approximately **equal to** that of the QuikSCAT, ASCAT, HY-2B, WindSat, Sentinel-3 and Jason-3 wind products.
4. The analyses of errors in bins of wind speeds reveal that the **errors of the wind speeds** decrease first and then increase with increasing in situ wind speed, and the **errors of wind directions** decrease with increasing in situ wind speed.
5. The results indicated that the retrievals are the most significantly effected by the **SWH,** air-sea **temperature difference** and **sea surface currents**.
6. In general, the accuracies of the CFOSAT wind vectors **satisfy** the general scatterometer **mission requirements**.

Many thanks for your comments and suggestions!