CFOSAT Second International Science Team Meeting

(15-18 March 2021)

Asymmetric wave distributions of tropical cyclones based on CFOSAT observations

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Guangzhou 2021.3.17

Contents

1. Research background **CFOSAT (Chinese-French Oceanic SATellite)**

- CFOSAT carries two radar instruments, including a wind scatterometer (SCAT) developed by the National Space Science Center (NSSC) of the Chinese Academy of Sciences
- and a wave spectrometer (Surface Wave Investigation and Monitoring, SWIM) provided by CNES

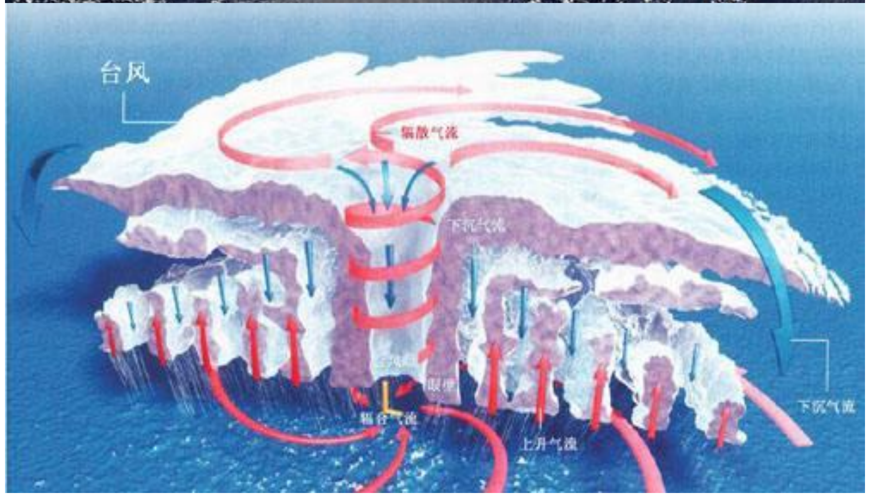
- Simultaneously observe ocean surface wind at 10 m height and surface wave spectra

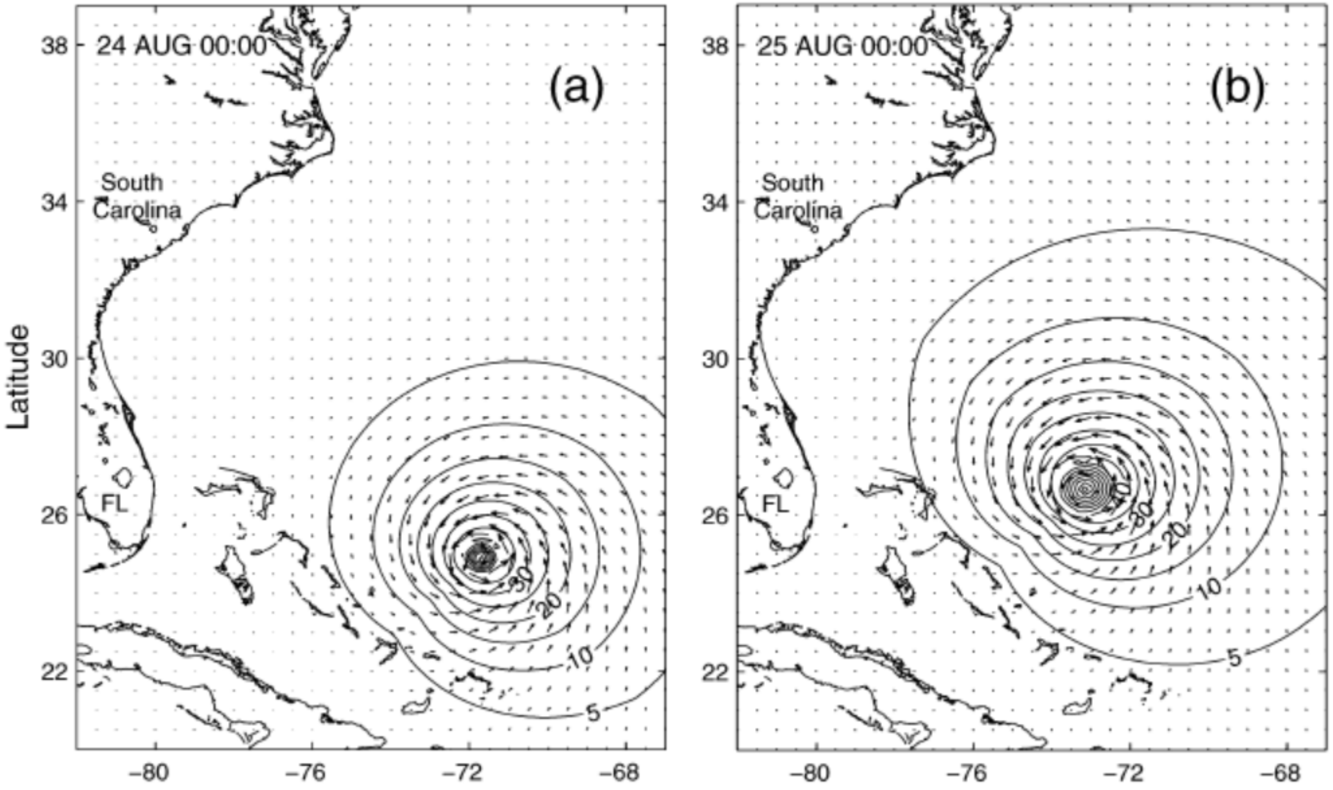
Nation:	China, France
Type / Application:	Earth Science
Operator:	CNSA, CNES
Contractors:	CAST
Equipment:	SWIM, SCAT
Configuration:	CAST2000 bus
Propulsion:	
Power:	Deployable solar array, batteries
Lifetime:	3 years
Mass:	~600 kg
Orbit:	509 km × 523 km, 97.53°

	Time	Resolution
Wind data	2018.12-present	0.125° × 0.125° 0.25° × 0.25°
Wave data	2019.7-present	70km × 90km

1. Research background **Tropical cyclone structure**

Wind field





The strong cyclonic wind field during typhoon is asymmetric structure with higher wind speed on the right side of typhoon track in the Northern Hemisphere. (e.g. Bender, 1997; Young et al., 2003; Xie et al., 2006; Uhlhorn et al., 2013; Huang et al., 2013)

Wave field Case study: Hurricane Bonnie (1998)

Observation result (Wright et al., 2001, JPO)

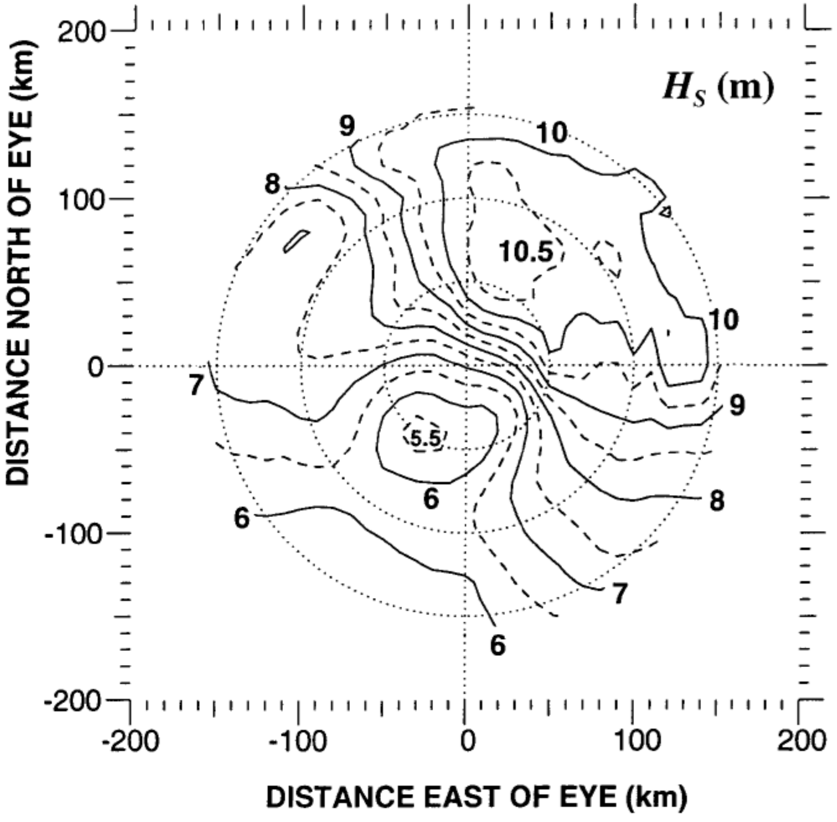
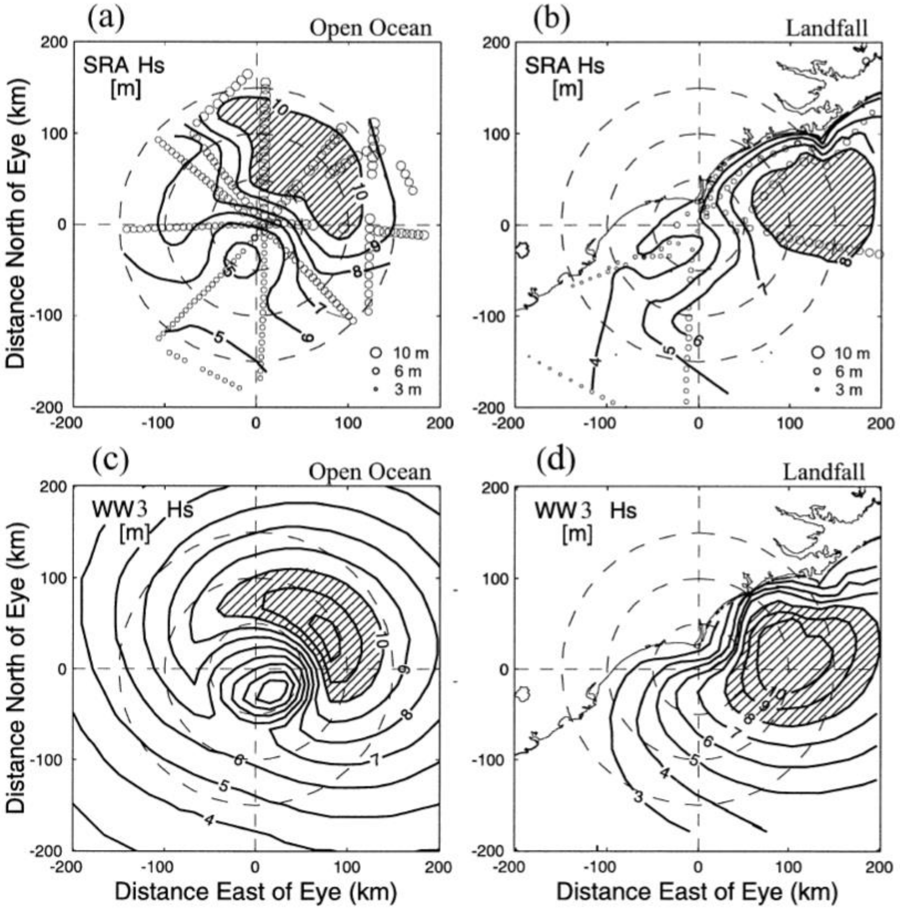


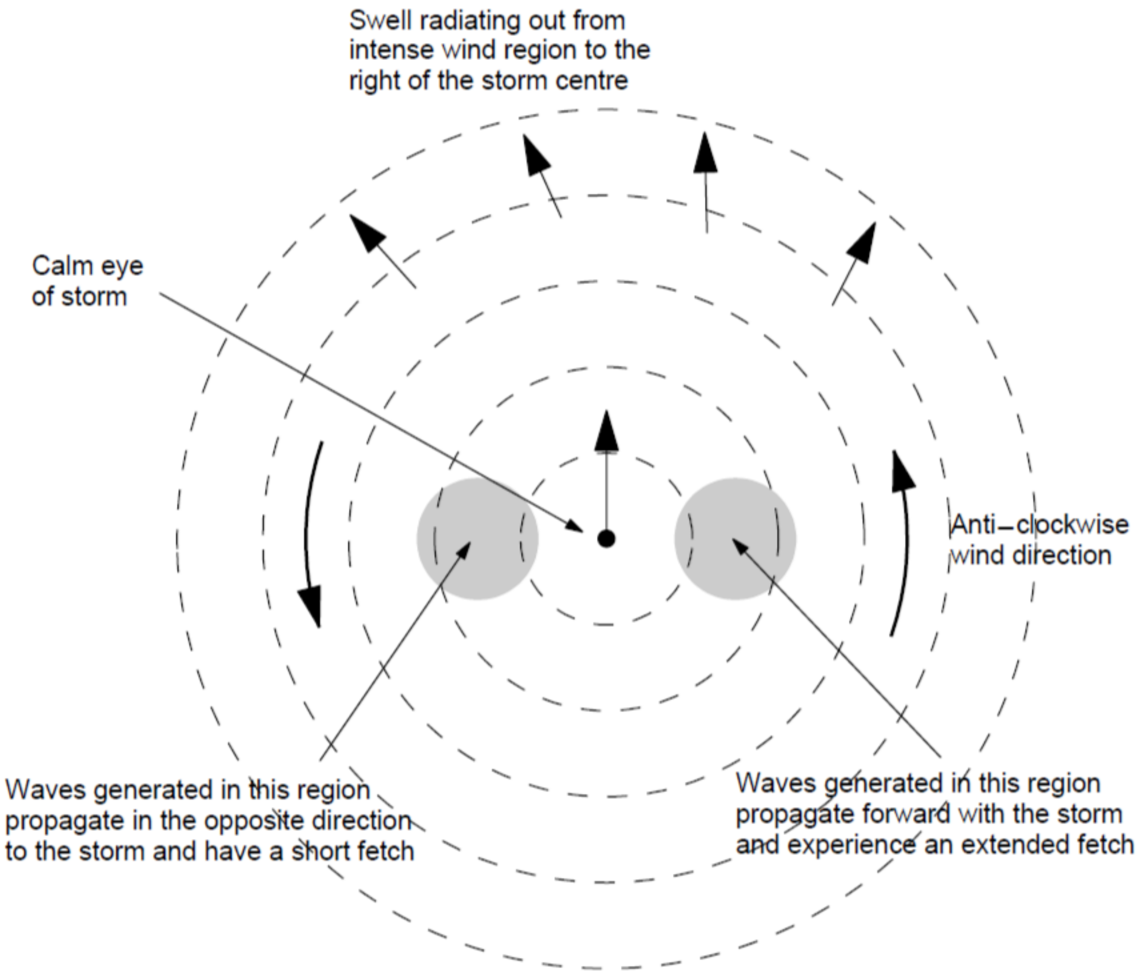
FIG. 5. Spatial variation in H_S measured by the SRA in Hurricane Bonnie on 24 Aug 1998. Contours for integer values of wave height (in meters) are solid and contours for integer values plus 0.5 m are dashed.

Model result (Moon et al.,2003,JPO)



Ocean wave height was asymmetric structure under the TCs conditions. (e.g. Wright et al., 2001; Moon et al.. 2003; Liu et al., 2007; Chu & Cheng, 2008; Mori, 2012; Xu et al., 2017).

Relation of Wind & Wave



(Young, 2003, in Marine Structures)

1. Research background

TC Waves disasters

Most of the above studies about TCs wave distributions are based on numerical simulation. However, there are a few investigations of ocean wave depictions using observed data under the TCs conditions due to the lack of observations.

Questions:

1. **Whether the asymmetric wave distribution during TC is depicted by CFOSAT observations?**
2. **Is it a general phenomenon that asymmetry of wave height distribution during TC?**

2. Data and methods

2.1 Data:

TCs data :IBTrACS, Version 04

Wind and wave data : CFOSAT

Others: CCMP wind data; model wave data from MFWAM (for comparison)

2.2 Methods:

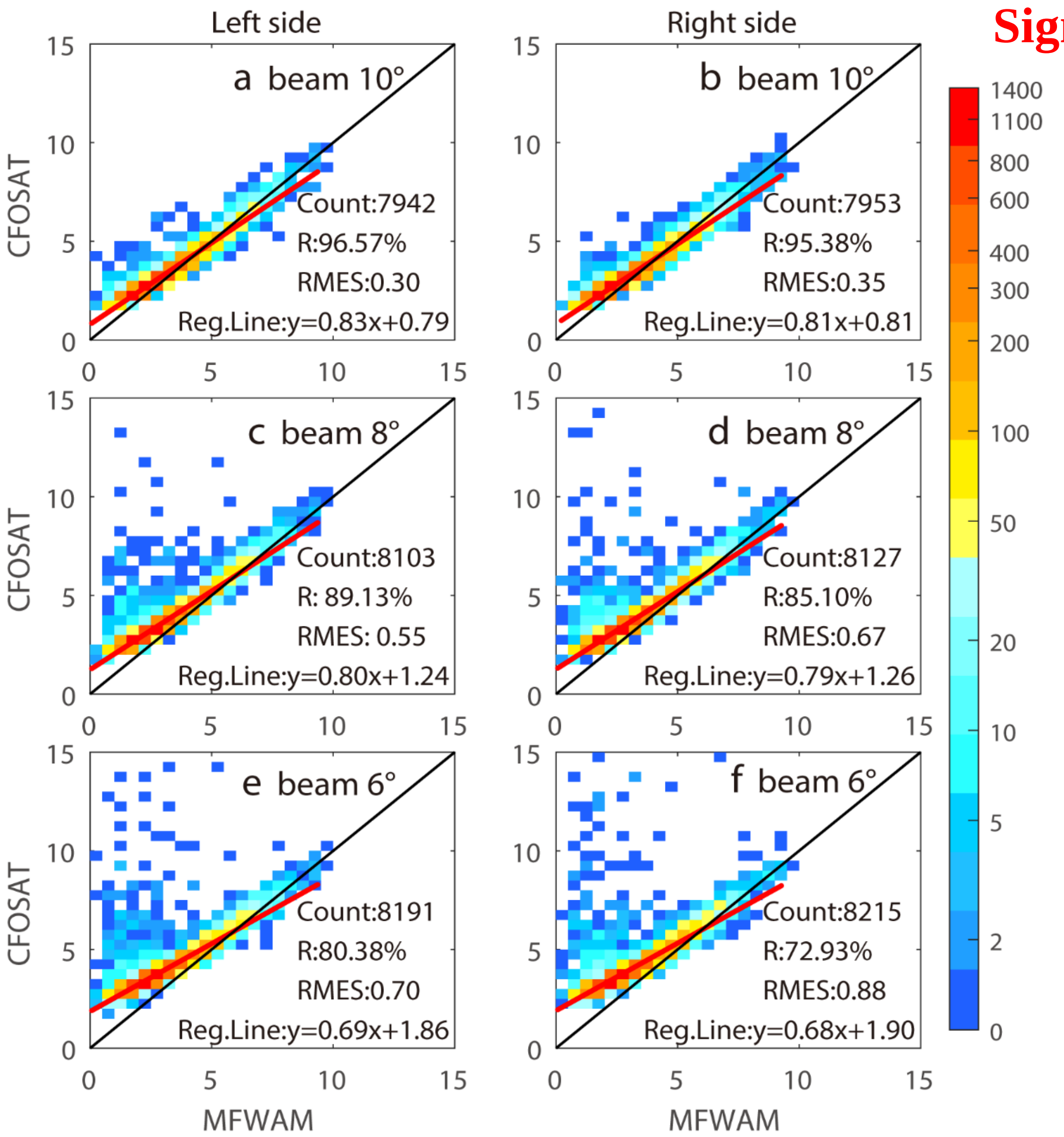
Linear regression: $y_i = ax_i + b; i = 1, 2, 3, \dots, n$

Gaussian model simulation: $y = \sum_{i=1}^{2} a_i \times e^{\left[-\left(\frac{x-b_i}{c_i}\right)^2\right]}$

Wave dispersion relation formulation: $\sigma^2 = gktanh(kh)$

Dominant wavenumber : $k = \frac{2\pi}{L}$; Dominant wave period: $T = \frac{2\pi}{\sigma}$.

2.3 Data comparison



Significant Wave Height (SWH): CFOSAT VS. MFWAM

	correlation coefficients (%)		root mean square error (RMSE, m)	
	Left	Right	Left	Right
Beam 10°	96.57	95.38	0.30	0.35
Beam 8°	89.13	85.10	0.55	0.67
Beam 6°	80.38	72.93	0.70	0.88

- The result obtained from beam 10° is more convinced due to the less bias and higher correlation.

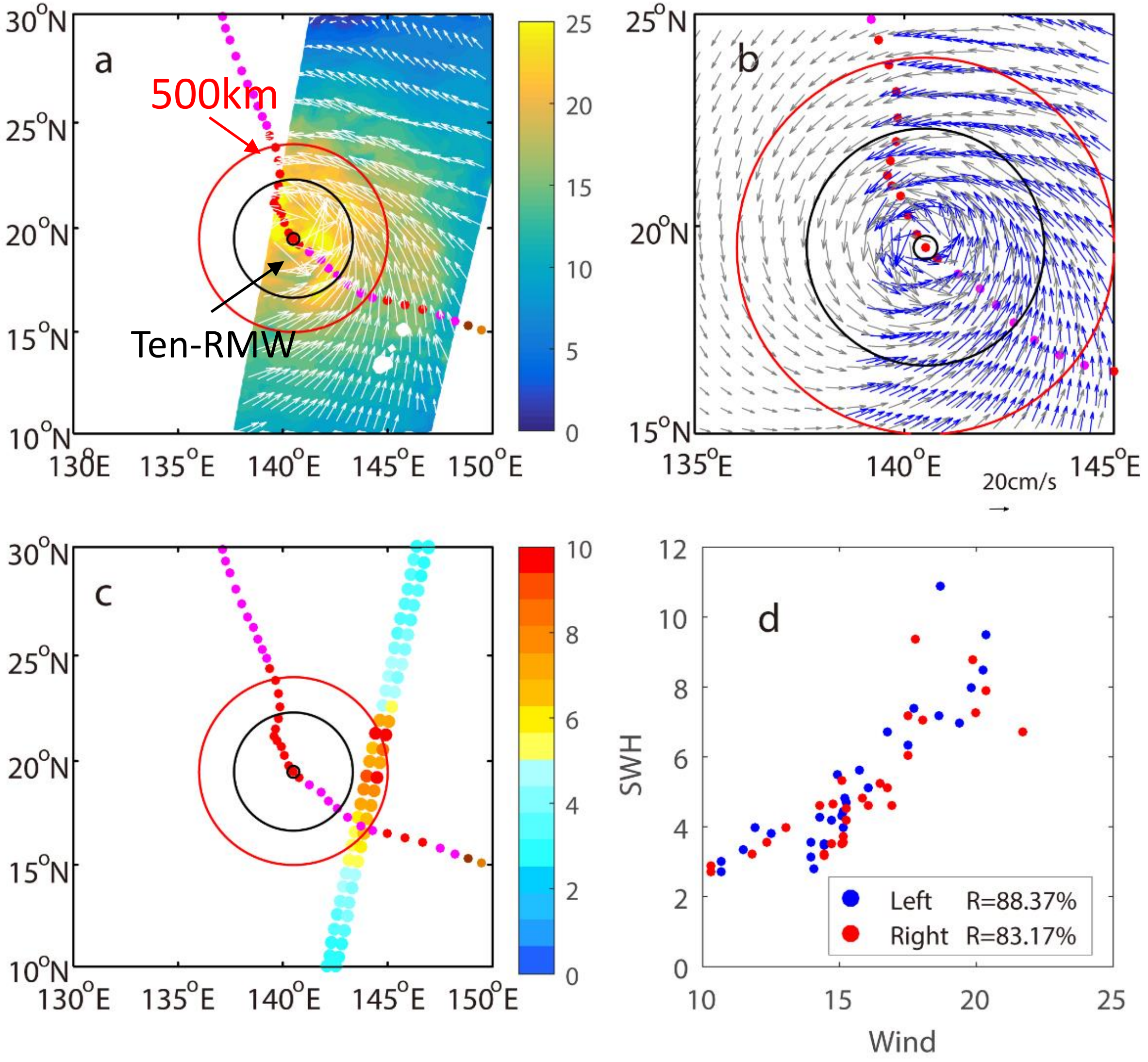
Beam 10°

Smallest speckle noise perturbation

Largest observed range

3. Results (Case study)

Super typhoon Hagibis (Oct. 8, 2019)



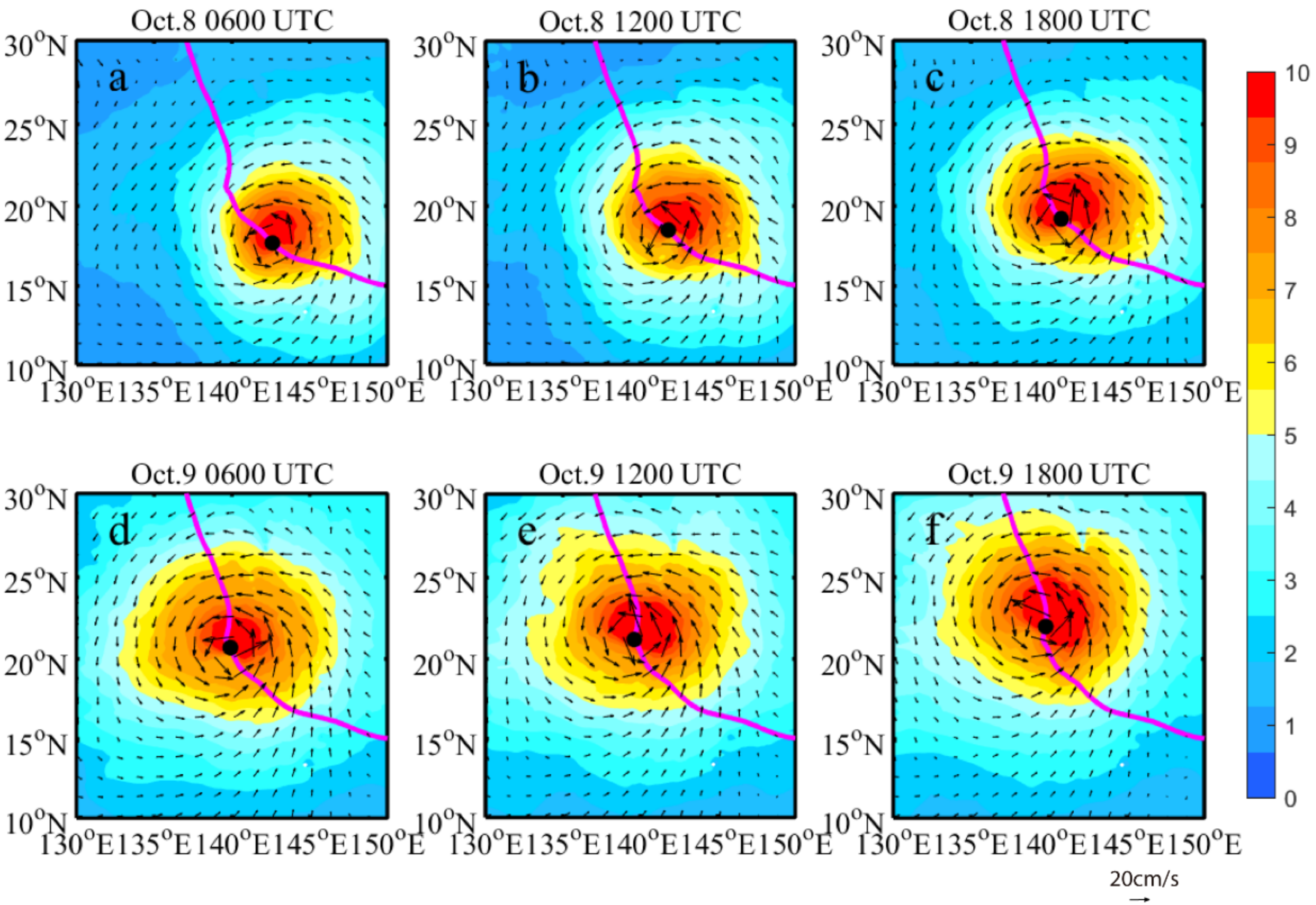
(a) Wind field
(b) A comparison of wind between CFOSAT & CCMP
(c) Wave field
(d) SWH-wind diagram

CFOSAT observations:

- Cyclonic and asymmetric wind field
- Maximum SWH appears on the right side of typhoon track.

3. Results (Case study)

Super typhoon Hagibis (Oct. 8, 2019)

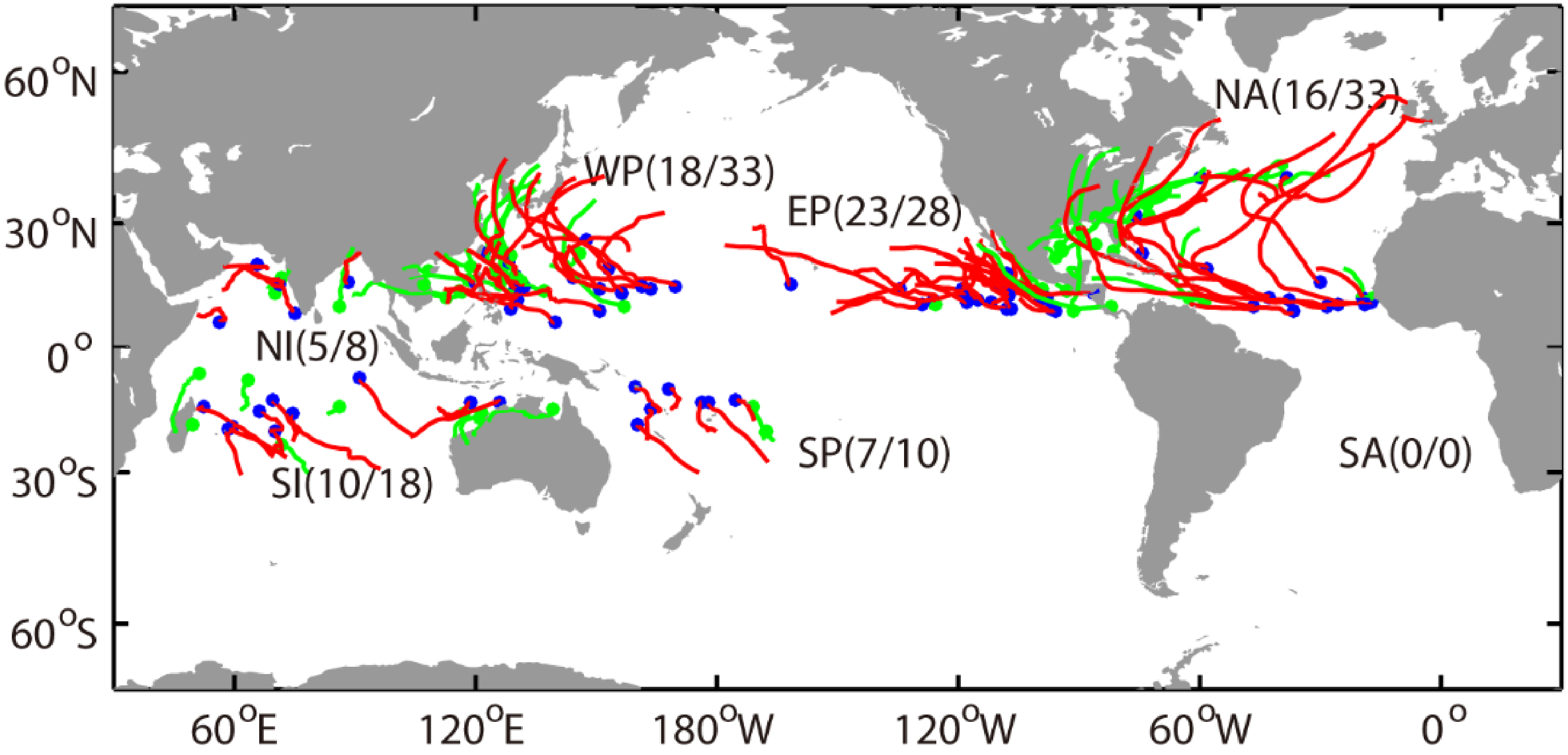


MFWAM Model

Highest SWH is located on the right side of typhoon track.

Asymmetric wave distribution during TC based on the observed and model data is consistent with the previous studies (e.g. Moon et al., 2003; Mori, 2012; Huang et al., 2013).

3. Results (Composite analyses)

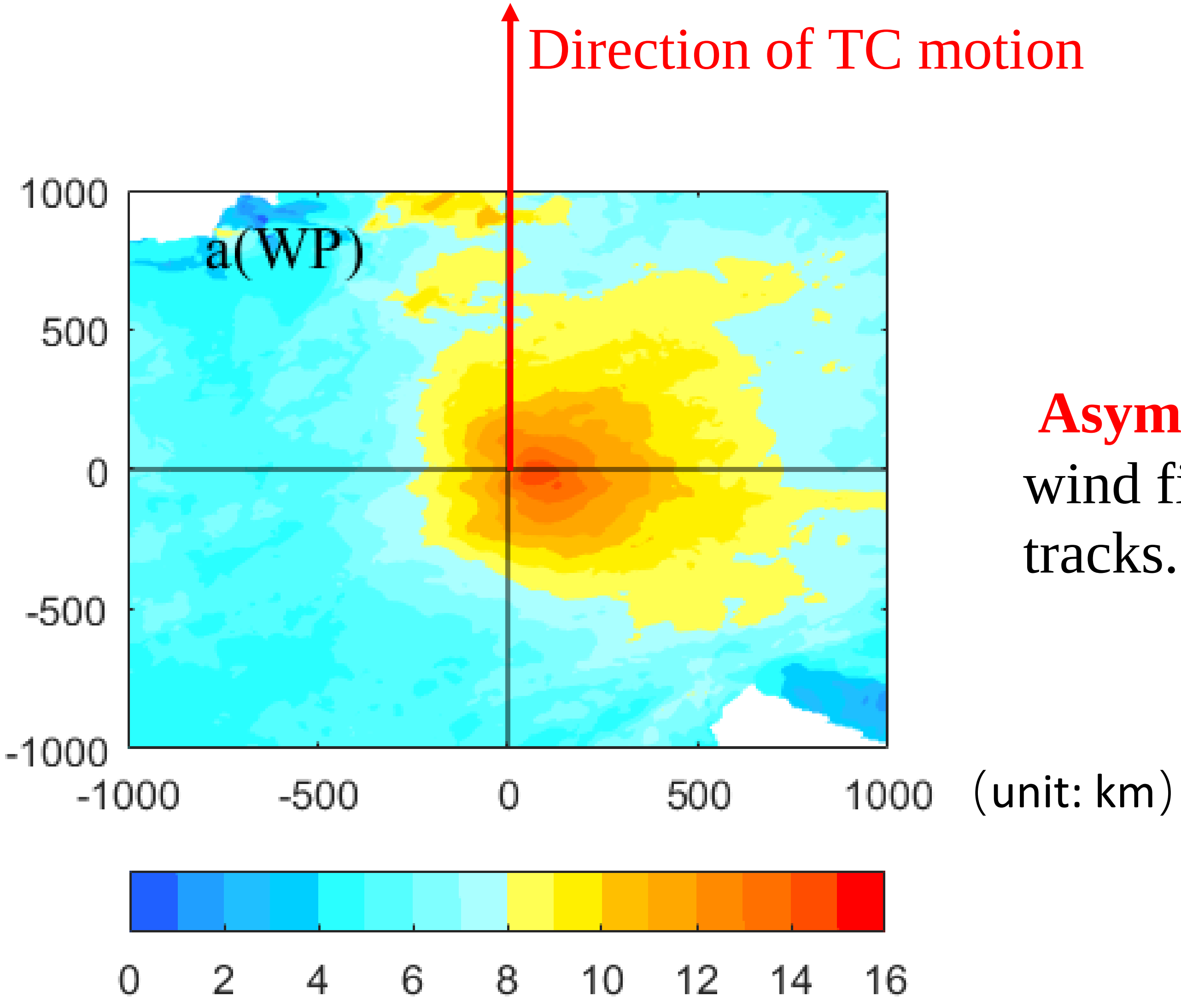


It has a total of 79 TCs that CFOSAT successfully measured during TCs from August, 2019/08 to August, 2020.

3. Results (In the Northern hemisphere)

In the WNP (18 TCs)

Composite Wind field

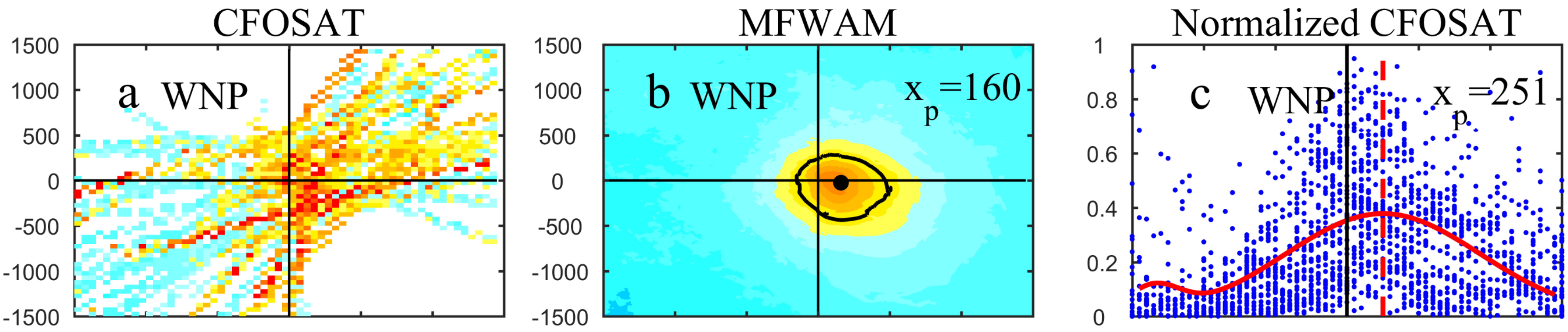


Asymmetric wind structure with higher wind field located on the right side of TCs tracks.

3. Results (In the Northern hemisphere)

In the WNP (18 TCs)

Wave field



Similar to distribution of wind speed, the wave distribution is also asymmetric with highest SWH on the right side of TCs tracks.

Gaussian Fitting:

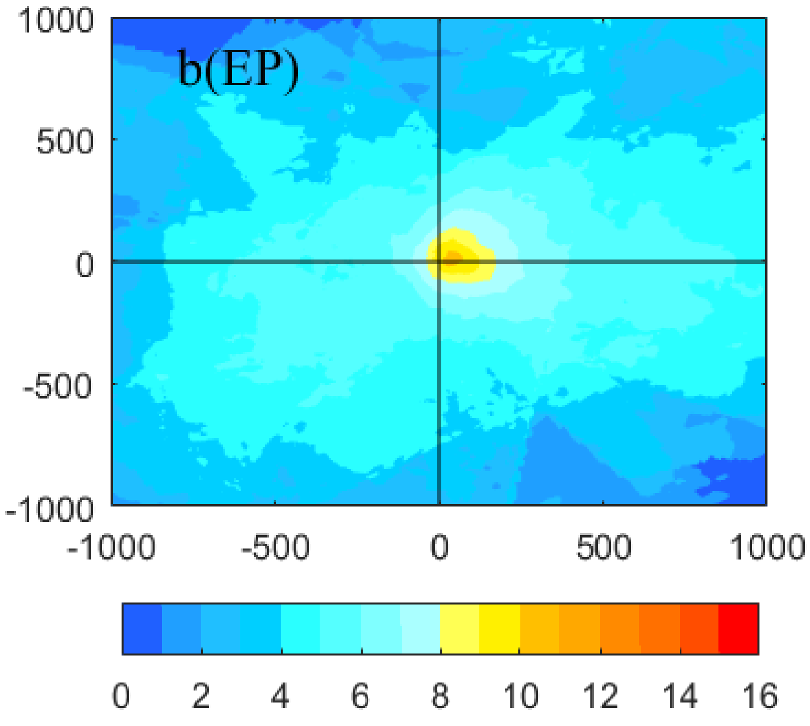
The closer to the typhoon, the greater SWH appearing.

Positive value of the expectation reveals the peak SWH is on the right side about 251 km of the typhoon track.

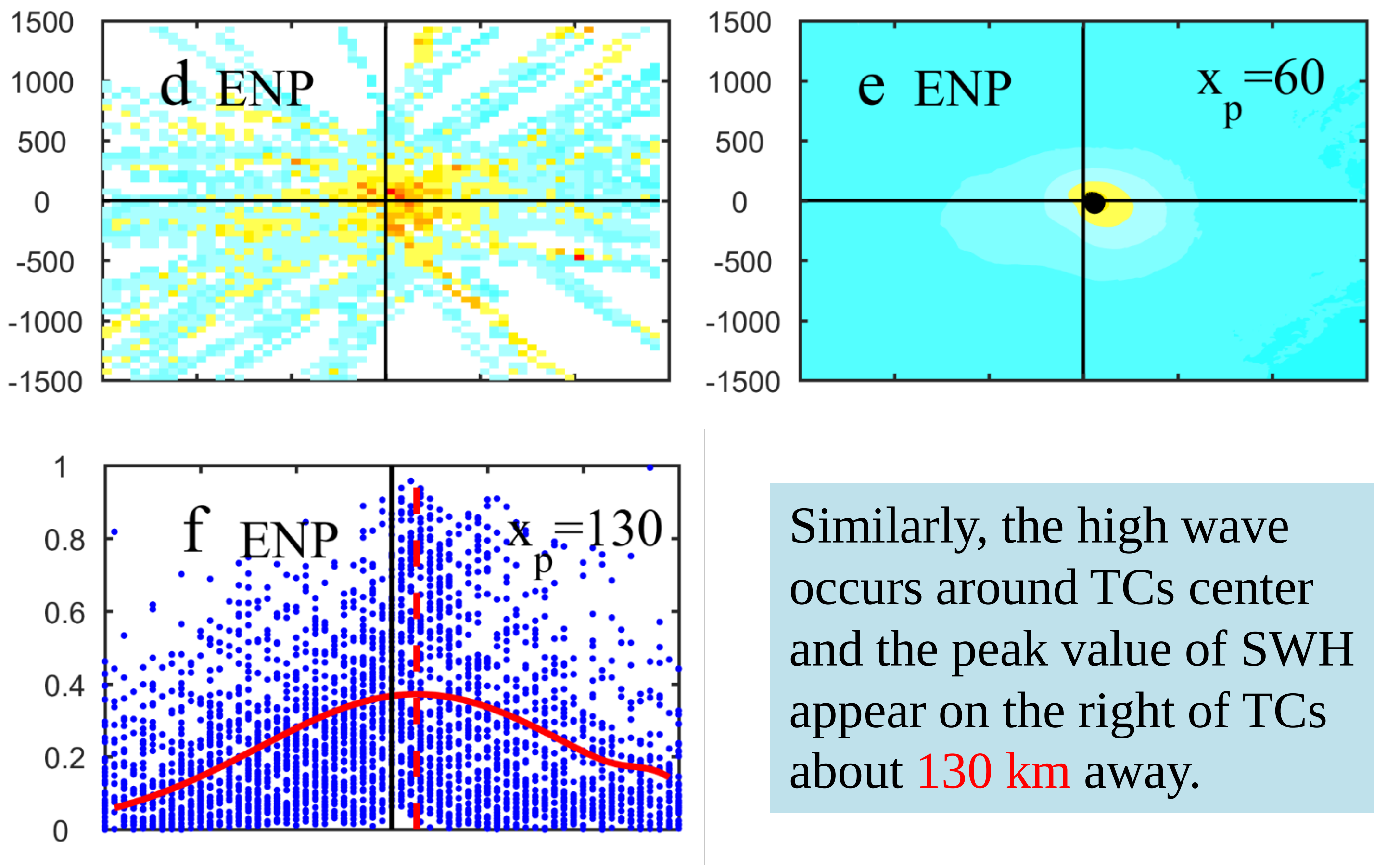
3. Results (In the Northern hemisphere)

In the ENP (23 TCs)

Wind field



Wave field



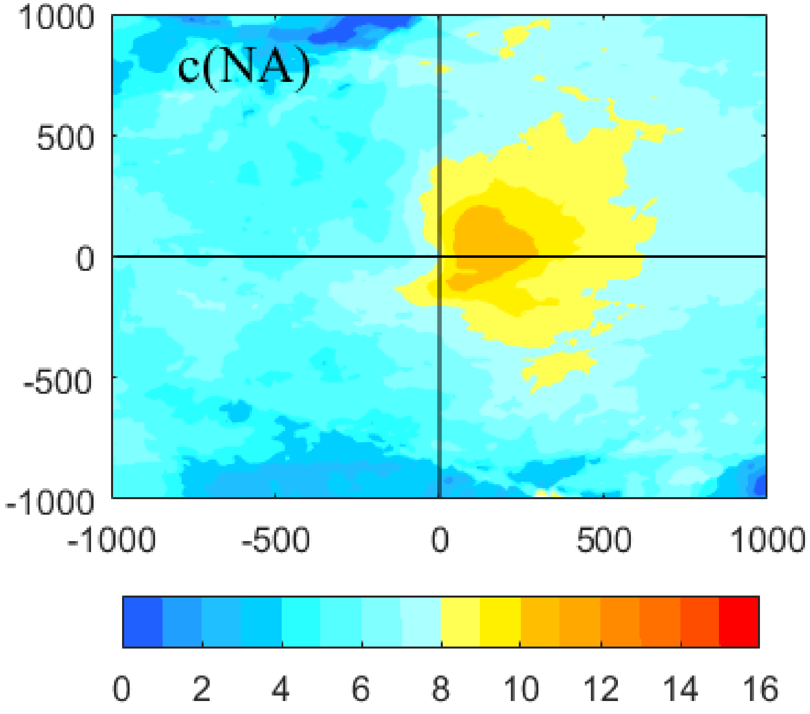
Wind field is small due to smallest TC size in the ENP (Knaff et al., 2007, 2014).

Similarly, the high wave occurs around TCs center and the peak value of SWH appear on the right of TCs about 130 km away.

3. Results (In the Northern hemisphere)

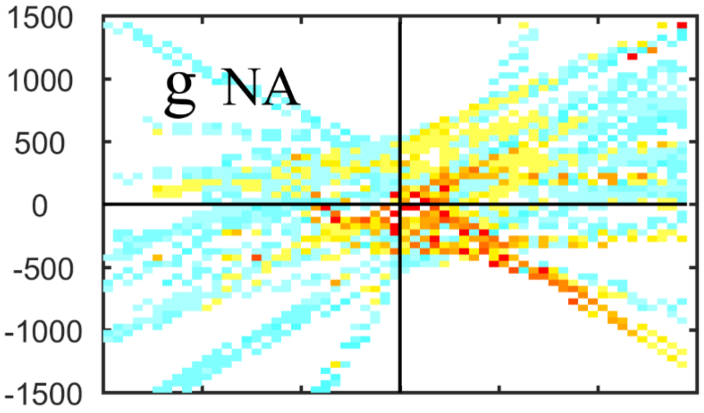
In the NA (16 TCs)

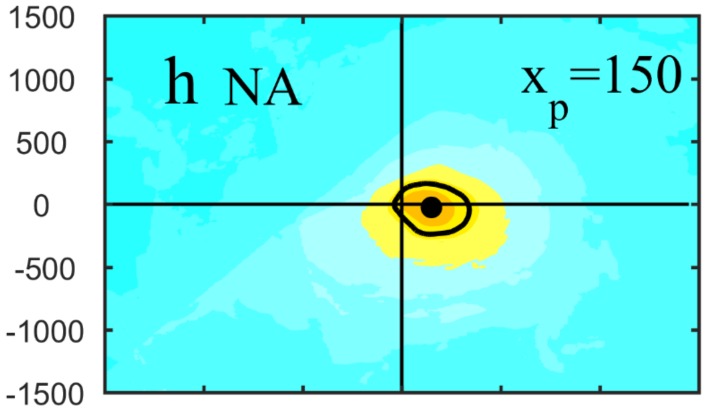
Wind field

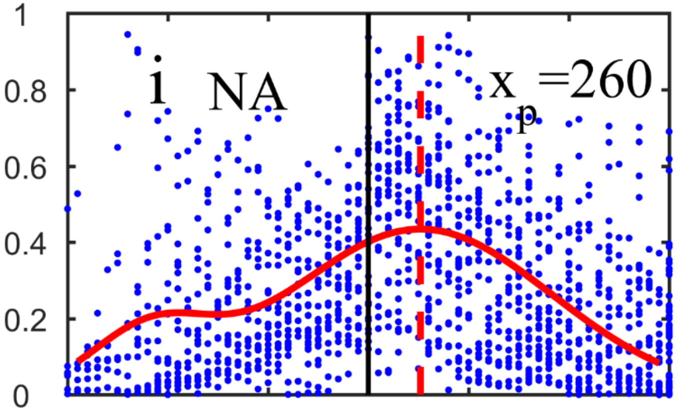


Wind field is obvious asymmetric with high wind speed on the right of TC in the NA.

Wave field





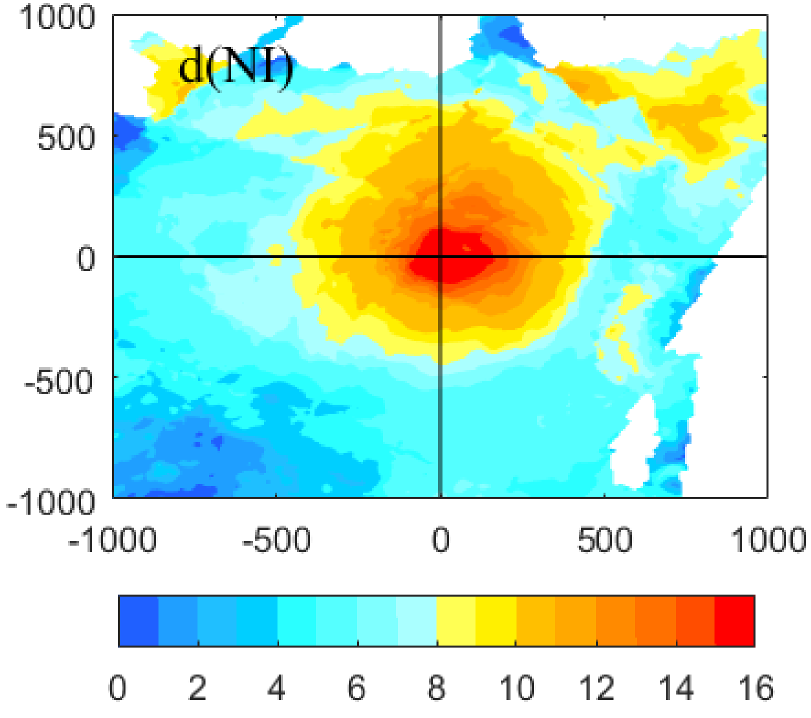


The asymmetry of wave distribution is more obvious in the NA.
Highest SWH value is located on the right approximately 260 km from the TCs center.

3. Results (In the Northern hemisphere)

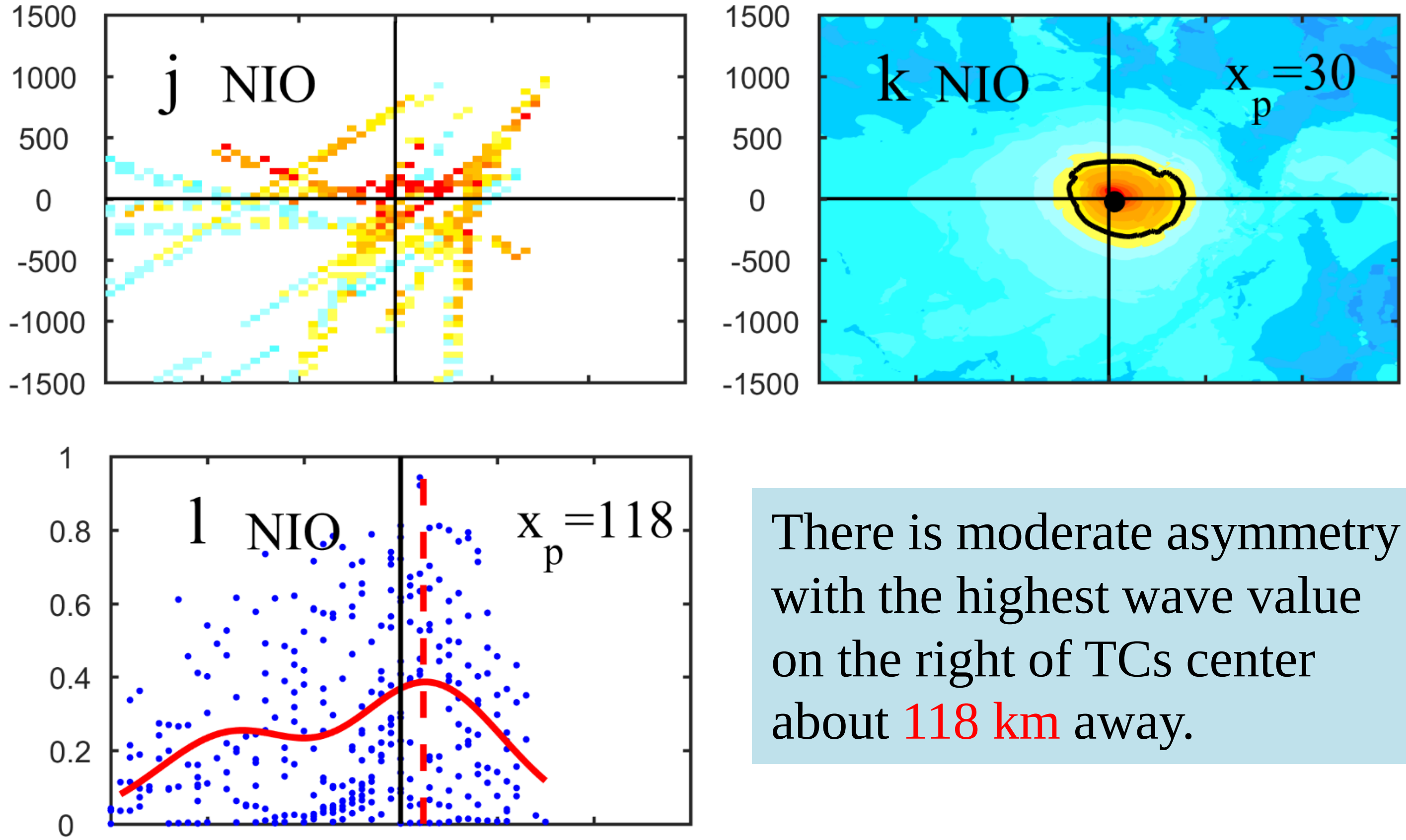
In the NI (5 TCs)

Wind field



NIO has fewer TC activities, contributing ~7% of global TC counts.

Wave field



There is moderate asymmetry with the highest wave value on the right of TCs center about 118 km away.

3. Results (In the Northern hemisphere)

Basins	WNP	ENP	NA	NI
Right-bias (~km)	251	130	260	118

Open ocean

Coastal area

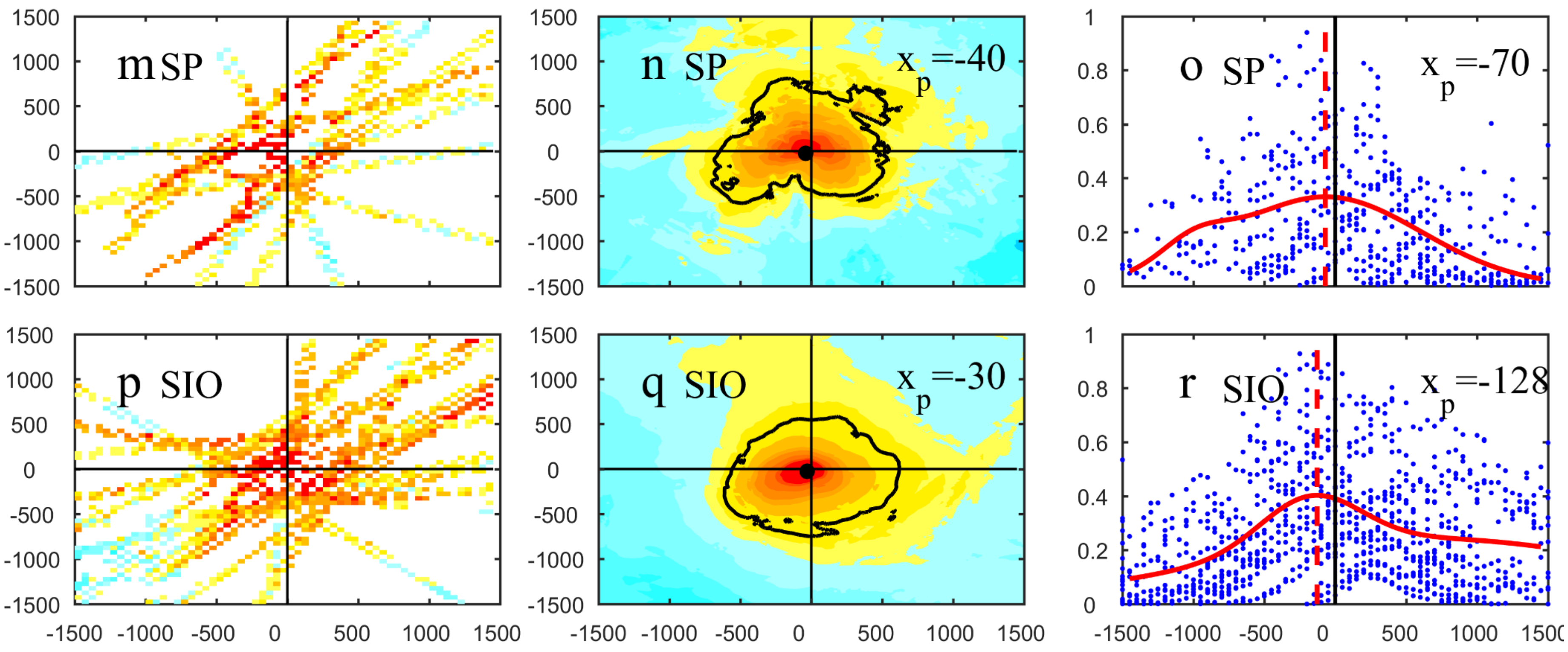
- Wind effect
- Continent-ocean configuration

A hypothesis

In the SH, the distribution of TCs wave is asymmetric with the highest wave field is located on the left side of TCs tracks in the SH, analogously to that in the NH.

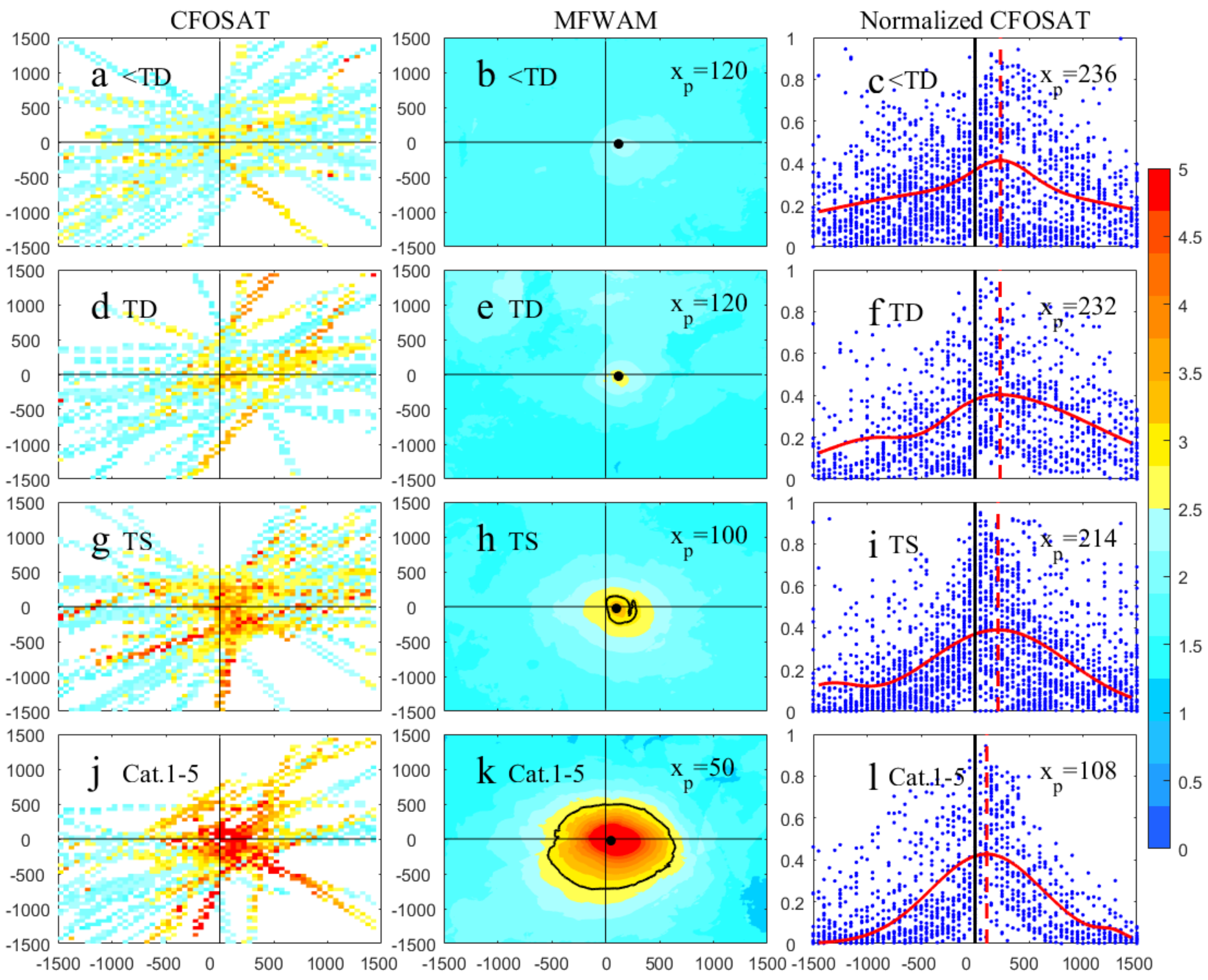
3. Results (In the Southern hemisphere)

Wave field



In the SH, there are 7 TCs in the SP and 10 in the SIO, the highest SWH is on the left side of ~70 km and 128 km.

3. Results (Asymmetric distributions based on TC categories)



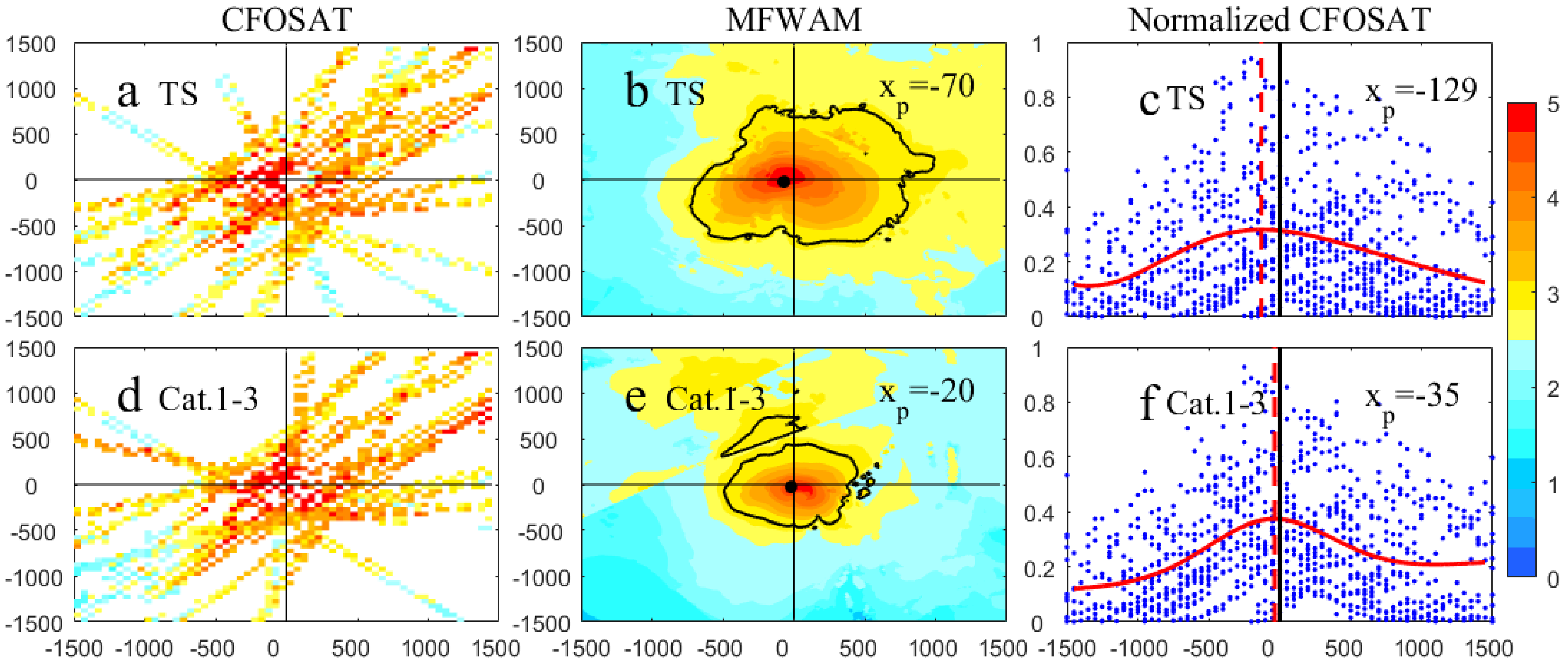
In the Northern hemisphere

<TD	TD	TS	Cat.1-5
236km	232km	214km	108km

According to the TC categories, the largest (smallest) asymmetry happens during the weakest (strongest) TC.

3. Results (Asymmetric distributions based on TC categories)

In the Southern hemisphere

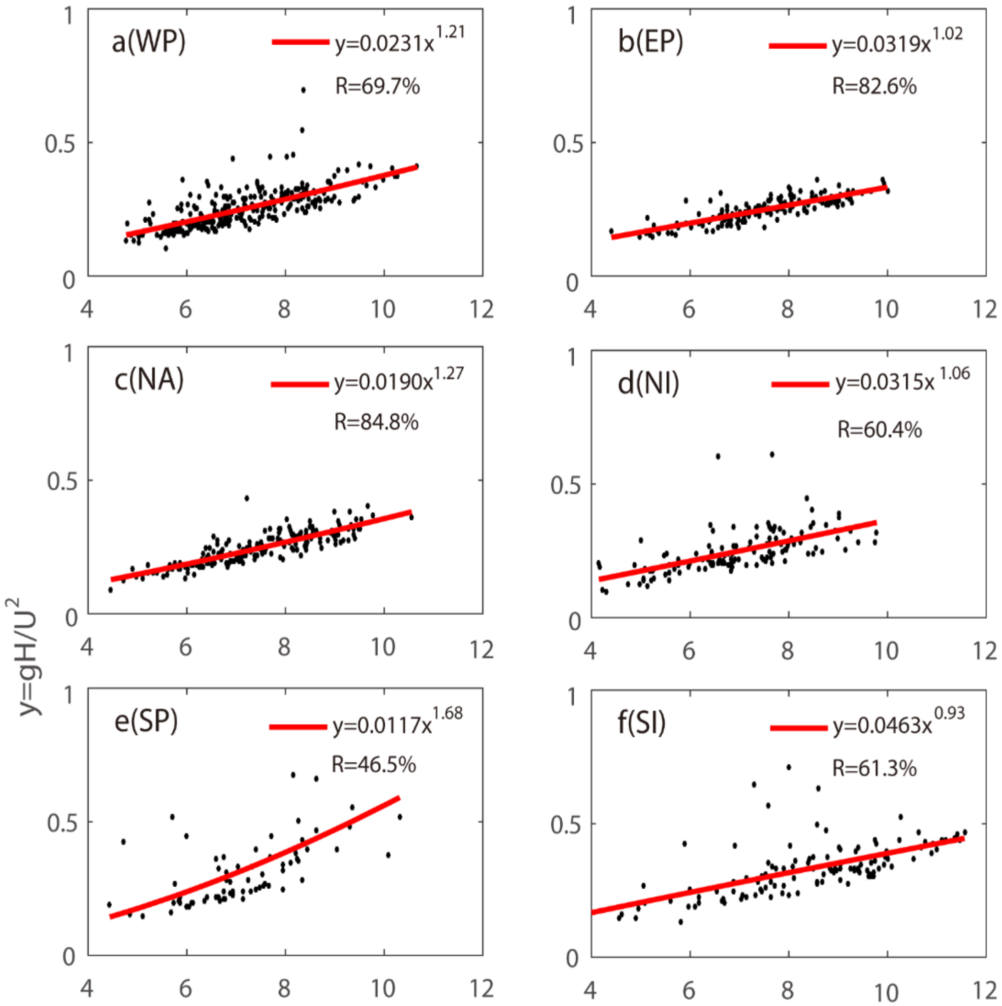


TS	Cat.1-3
-129km	-35km

Based on the TC categories, the largest (smallest) asymmetry happens during the weakest (strongest) TC. The intensifying of TC favors the wave field's growth and reduces the asymmetry of the wave height's distribution.

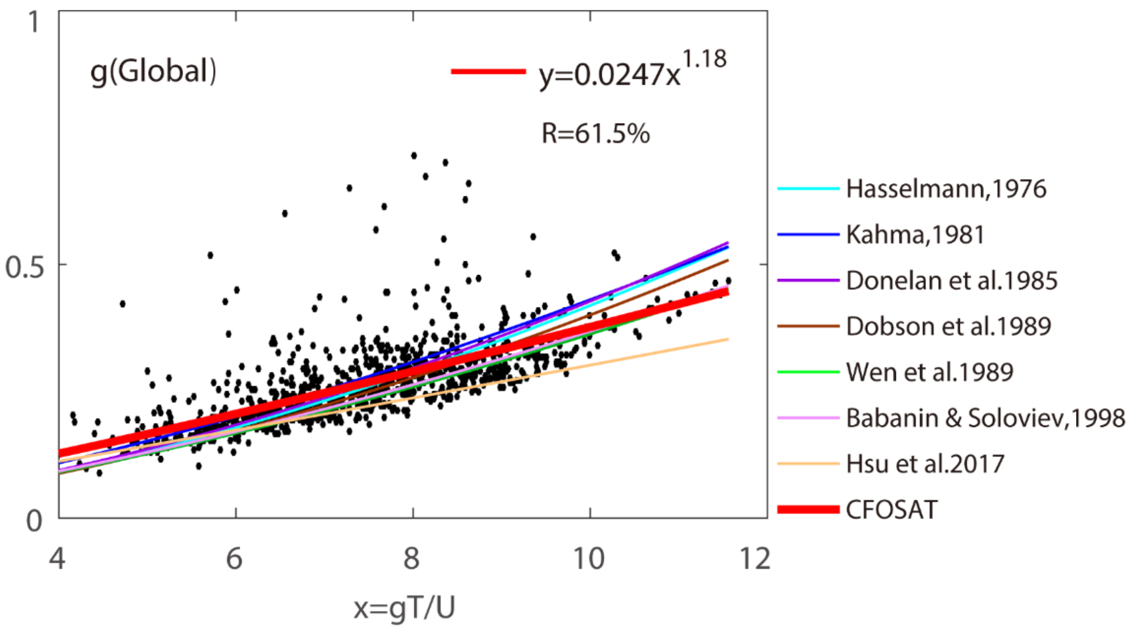
4. Discussion

The wave under the TC condition is a wind wave, and the spectrum is not fully developed, which is empirically depicted in the JONSWAP spectrum (Hasselmann et al., 1973; Stewart, 2008).



Power-law relation of wind and wave height during TCs over the WNP, ENP, NA, NIO, SP, SIO (e-f) and global TC (g).

Wind effect



5. Conclusion

- The TC waves' asymmetry is investigated based on six ocean basins. In the NH (SH), the spatial distribution of wave height during TCs is asymmetric, with the highest wave on the right (left) side of TCs, which agrees well with previous studies.
- According to the TC categories, the largest (smallest) departure happens during the weakest (strongest) TC. The intensifying of TC favors the wave field's growth and reduces the asymmetry of the wave height's distribution.
- The asymmetric wind fields, as well as the orographic effects by the nearby continent, have a dominant impact on the asymmetry of wave distribution during TCs.

TC intensity increases under global warming (e.g., Sobel et al., 2016; Oouchi et al., 2006; Emanuel et al., 2013; Lim et al., 2018). Furthermore, oceanic warming affects ocean waves globally. Reguero et al. (2019) indicated that global wave power has consequently increased due to oceanic warming.

Asymmetric wave distributions of tropical cyclones based on CFOSAT observations

Thanks for your attention.
谢 谢!

Reporter: Yanping SHI (Email: ypshi@scsio.ac.cn)