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TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

Inferring Center Location and Wind Radii of Tropical Cyclones from Satellite Scatterometer Winds

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Outline

1. Motivation
2. Data and method
3. Results
4. Conclusions

1. Motivation

- Monitoring the location and the intensity of tropical cyclones (TCs) is of great significance for improving the accuracy of TC forecast and for reducing the impact of TC disasters.

- Satellite scatterometers generally provide high-quality vector winds over the global ocean surface, such that they have been widely used in the study of TC structure and location.

- Due to rain contamination, signal saturation, and lack of proper extreme-wind reference for calibration, the scatterometer-derived extreme winds are usually underestimated, notably for the Ku-band systems, therefore limiting the application of its data in determining the TC intensity. A novel method to determine TC location and intensity needs to be proposed.

2. Data and Method

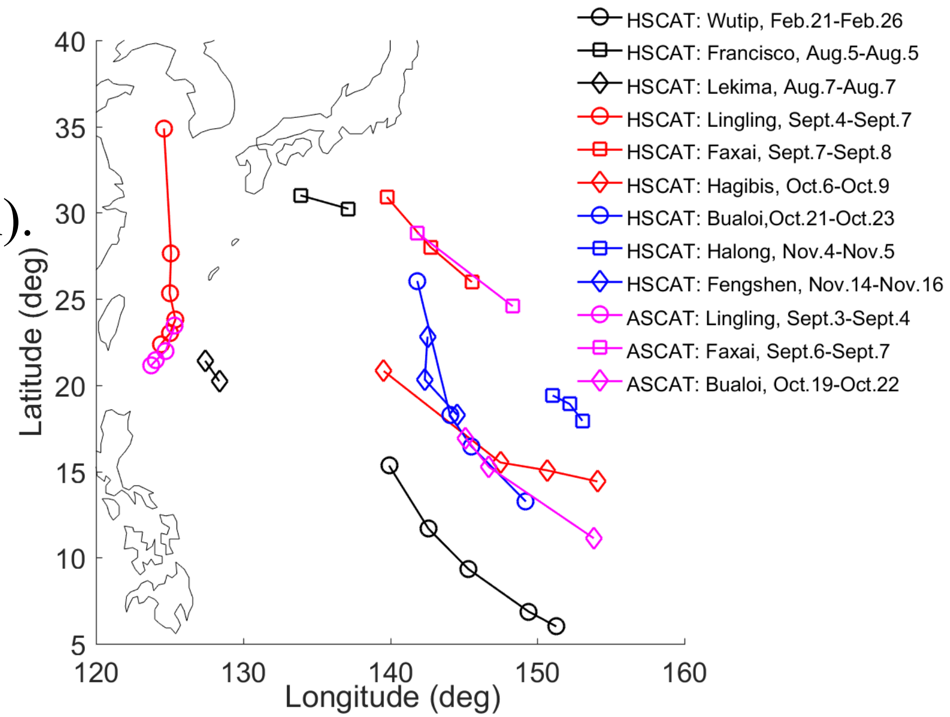
- **Data & TC cases**

1) Sea surface wind field data from HSCAT (HY-2B) level 2B (L2B) data of western Pacific TCs in 2019 (25-km grid resolution).

2) Advanced Scatterometers (ASCAT) wind field data (12.5-km grid resolution).

3) Collocated ECMWF forecast winds.

4) Best-track data from China Meteorological Administration (CMA).

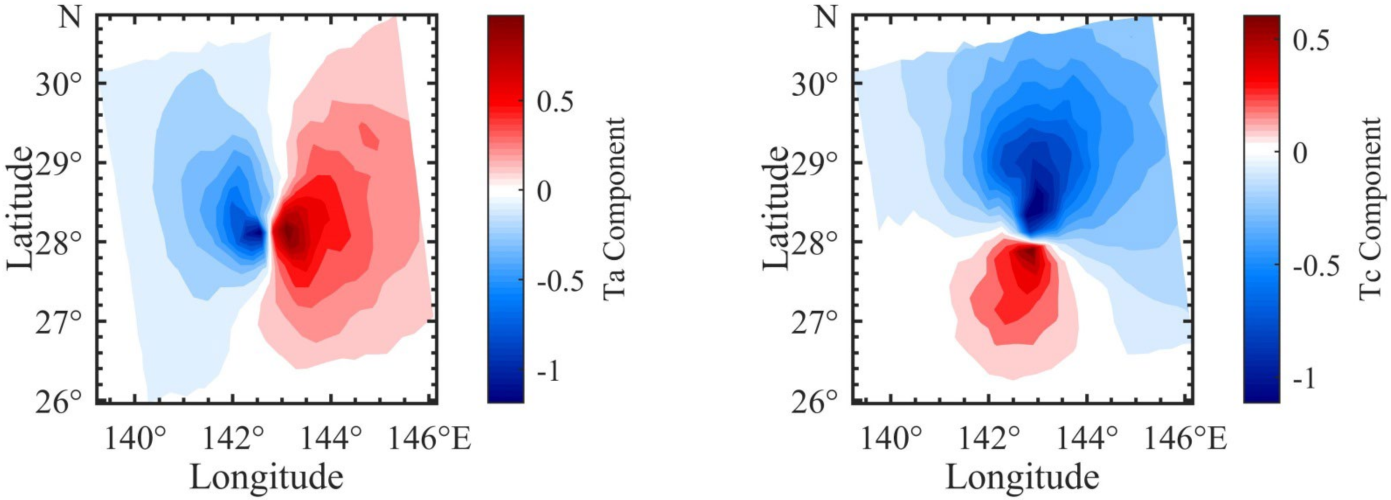


2. Data and Method

- **TC center location estimation method** **(previous studies – case #1)**
- Using the geometric signatures of wind stress component to determine the TC center.

$$\begin{cases} \tau_c = \rho_a C_D |u_c| u_c \\ \tau_a = \rho_a C_D |v_a| v_a \end{cases}$$

The meridional (zonal) wind component has a maximum and a minimum on either side of the TC center.



2. Data and Method

- **TC center location estimation method (previous studies – case #2)**

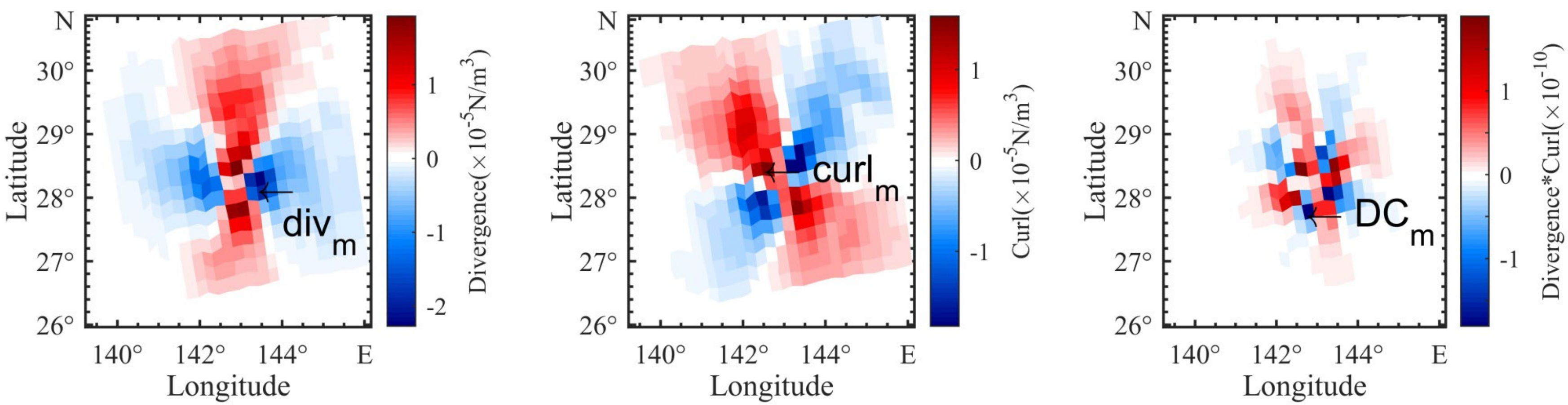
1) Calculate the wind stress curl, divergence, and their product (DC);

$$DC = div\vec{V} * curl\vec{V}$$

2) Evaluate the characteristics of curl/div/DC near the TC center;

3) Determine the TC center following the local maxima/minima of wind curl/div/DC

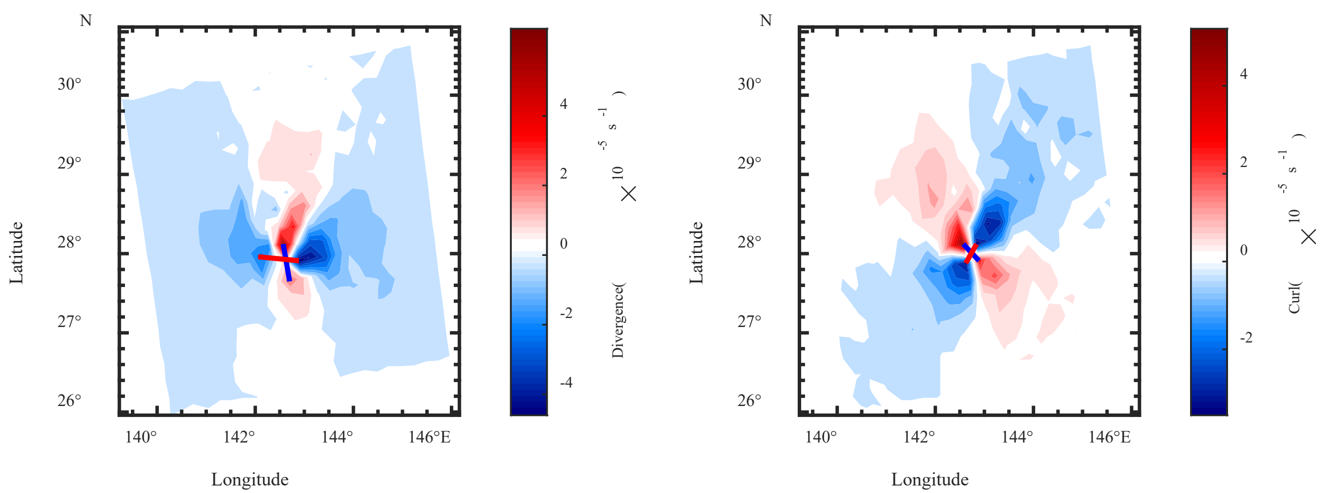
DC field location method has a better accuracy than the other methods (*Zhao et al., 2007*, *Wang et al., 2020*).



2. Data and Method

- **TC center location estimation method (our method – case #3)**

Two positive local maxima and two negative local minima appear symmetrically near the TC core.



As such one can take the intersection of the two lines constructed separately by the local maxima and the local minima as the TC center.

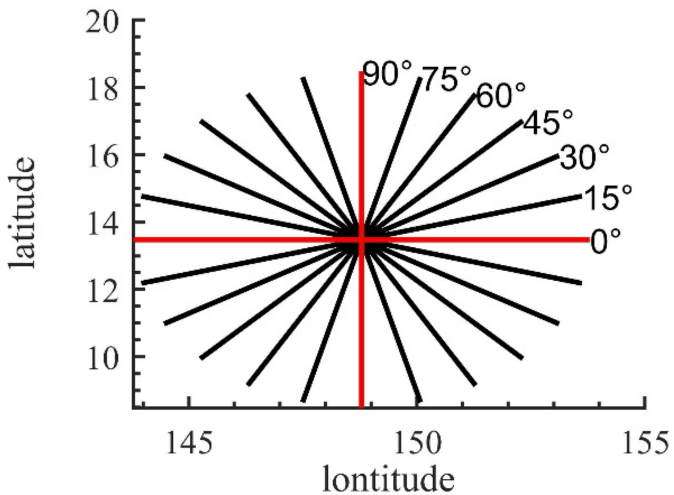
2. Data and Method

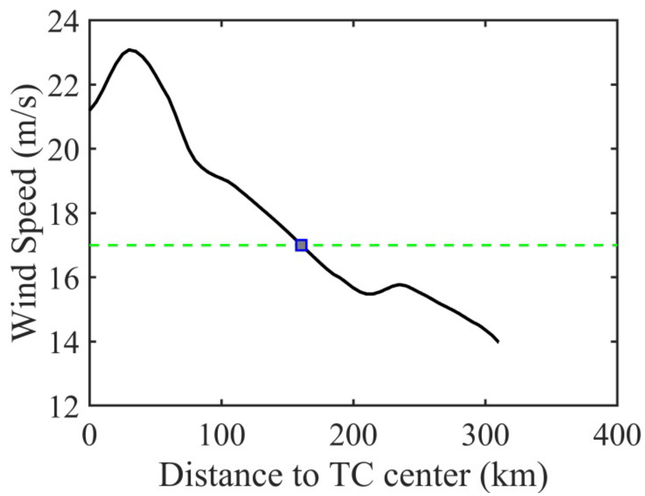
- **TC wind radii estimation method**

Taking the identified HSCAT TC center as the origin of Polar coordinates, the wind speed profiles along a set of equally spaced azimuth angles (e.g., Δφ = 15° , 24 intervals in total) are calculated and recorded as d_i .

As such, the azimuthally averaged radius (R17) is given by,

$$R17 = \sum_{i=1}^{24} d_i / 24 \, (i = 1, 2, \cdots, 24)$$

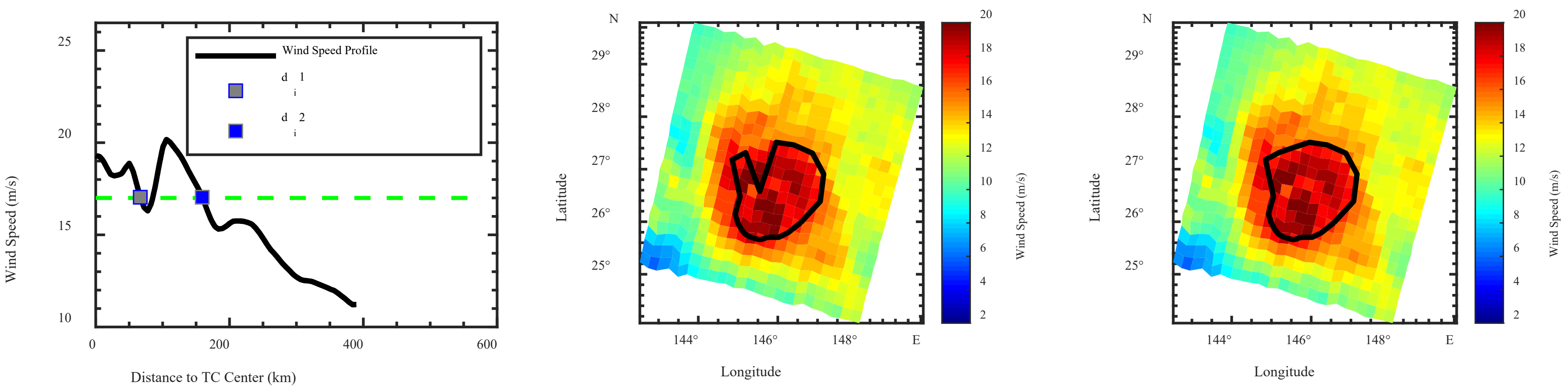




2. Data and Method

- **TC wind radii estimation method**

  Due to rain contamination and radar measurement noise, the wind speed profile may have spurious oscillations, leading to multiple peaks, and, therefore, multiple 17-m/s intersections. In this case, the 17-m/s intersection whose distance to the TC center is closer to the 17-m/s radial extent at neighboring azimuth angles is selected.



3. Results

- **Method A – case #2**
- **Method B – case #3**

D1 (D2) : The difference between the identified HSCAT (ECMWF) TC center and the interpolated best-track positions.

HSCAT		Method A			Method B		
		Divergence	Curl	DC	Wind stress component	Divergence	Curl
$D_1(km)$	Mean	57.75	72.66	67.72	29.67	23.15	27.05
	Std	26.78	38.62	25.19	16.37	13.32	16.68
$D_2(km)$	Mean	77.32	80.50	80.58	29.30	29.20	30.53
	Std	28.40	41.41	31.54	17.97	15.19	19.00

- Scatterometer-derived TC center closer to the best-track than that of ECMWF

3. Results

- **Method A – case #2**
- **Method B – case #3**

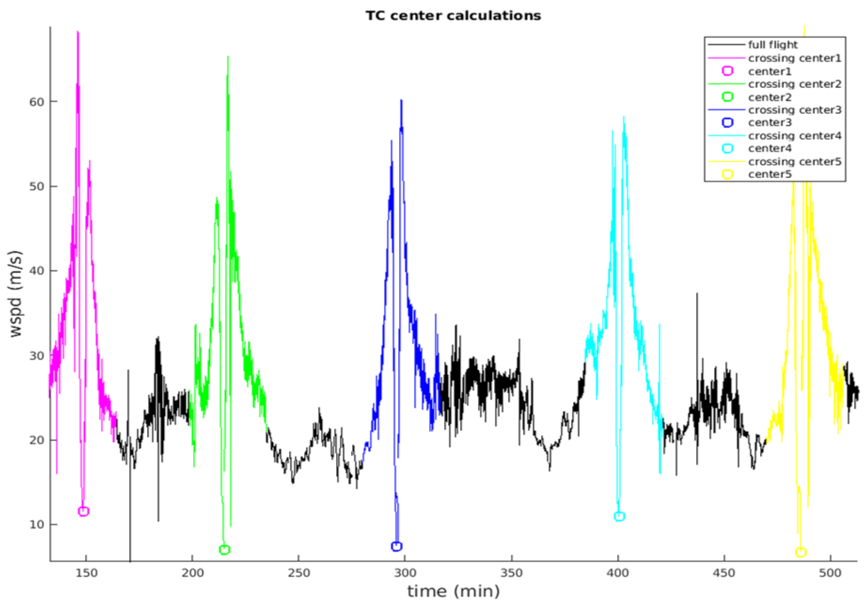
D1 (D2) : The difference between the identified ASCAT (ECMWF) TC center and the interpolated best-track positions.

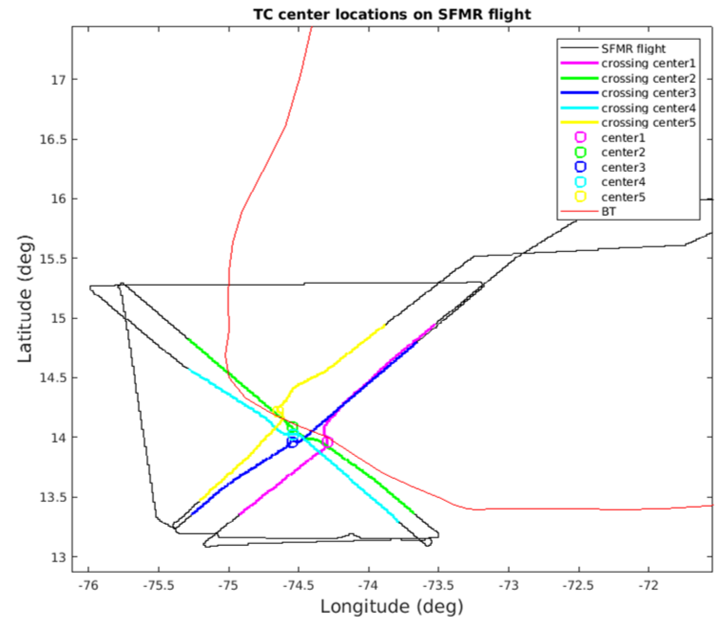
ASCAT		Method A Divergence	Method A Curl	Method A DC	Method B Wind stress component	Method B Divergence	Method B Curl
$D_1(km)$	Mean	44.04	62.18	51.36	23.48	17.27	18.10
	Std	26.85	23.24	30.23	15.10	8.56	12.03
$D_2(km)$	Mean	51.02	56.83	65.28	38.88	35.23	38.28
	Std	31.20	28.59	21.68	16.04	20.77	14.35

- This method is also valid for the C-band ASCAT wind fields

3. Results

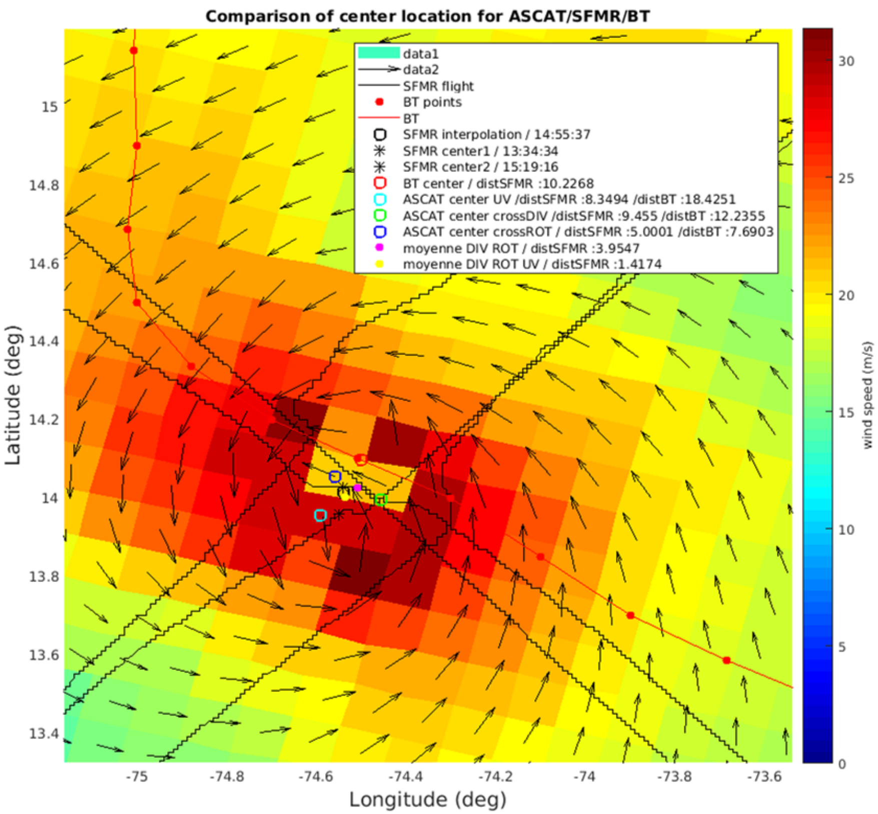
- **Same analysis but with BT & SFMR data**





SFMR based TC centre estimates, by simply depicting the location of the minimum wind speed inside the eyewall

3. Results

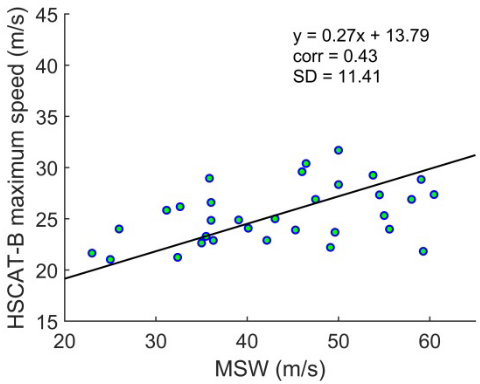


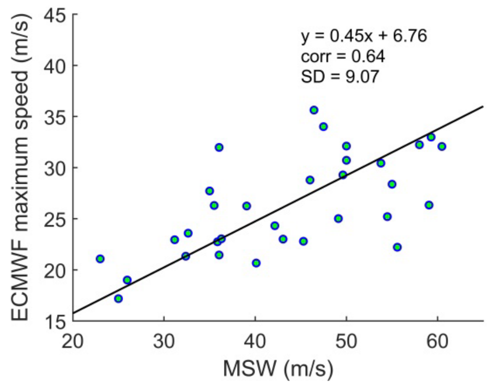
Distance to SFMR center	Mean of the 16 examples
From BT center	10.345 km
From crossTx/Ty center	14.533km
From crossDIV center	12.305 km
From crossROT center	12.956 km
From DIV/ROT centers average	10.156 km
From DIV/ROT/Txy centers average	9.571 km
From DIV/ROT/Txy/BT centers average	7.826 km
From minDC center	30.065 km
From minDIV center	30.468 km
From maxROT center	32.213 km

- **Method #3 leads to the best agreement with SFMR TC centre estimates**
- **Method #3 + BT estimates leads to most accurate TC centre estimation**

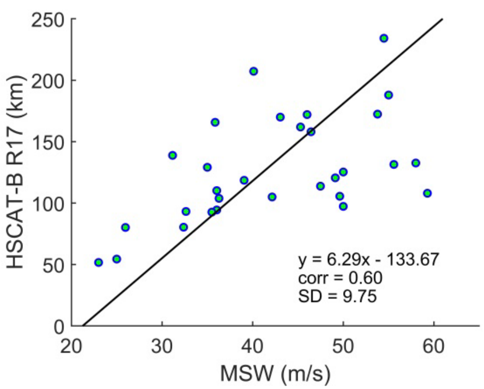
3. Results   TC intensity Evaluation

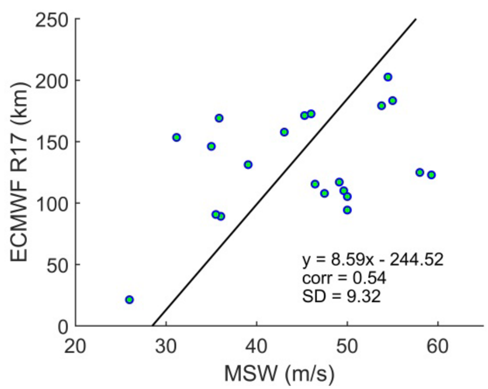
HSCAT/ECMWF **maximum wind speed** & best-track MSW (overall evaluation)





HSCAT/ECMWF **R17** & best-track MSW



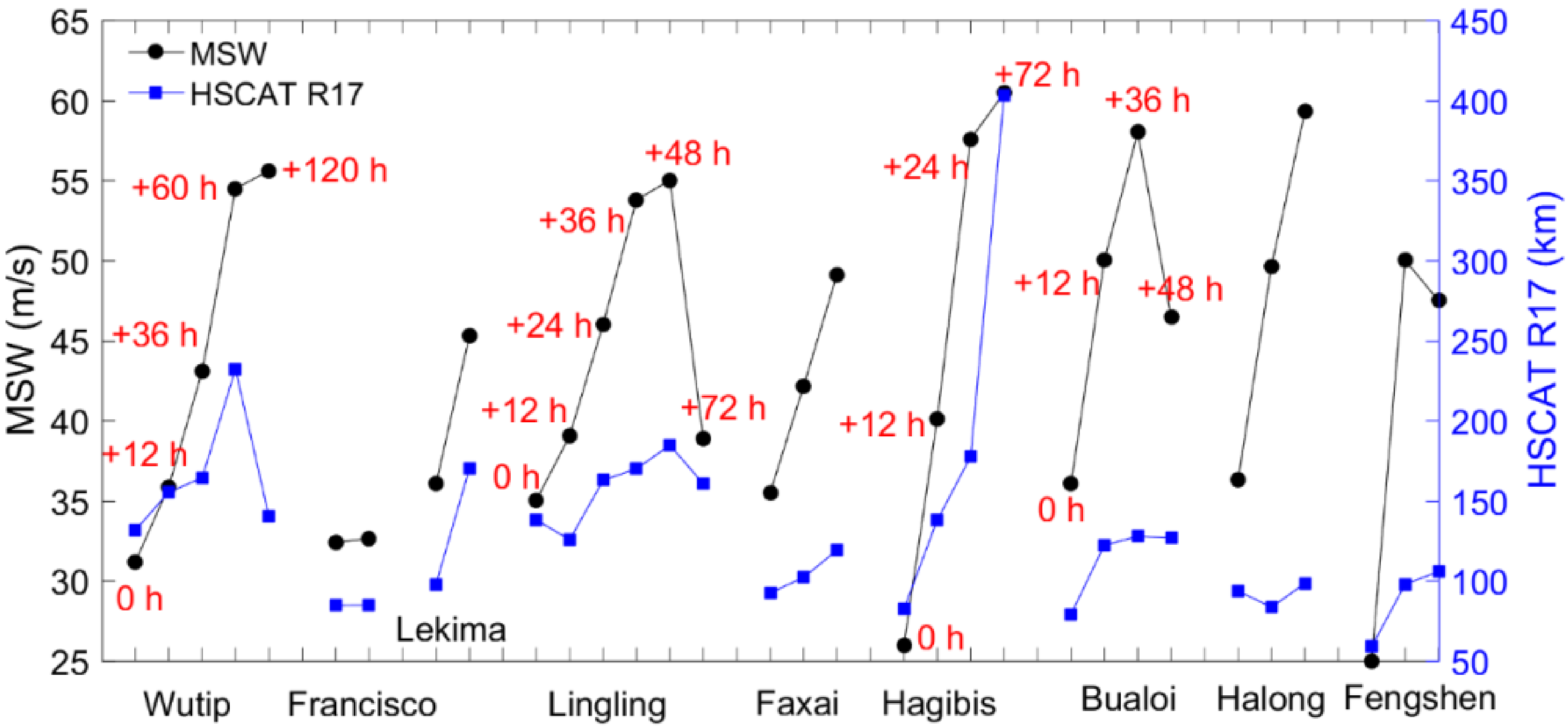


- Compared to the maximum wind speed, the HSCAT wind radii show better correlation with best-track MSW.
- ECMWF R17 is less effective than the ECMWF maximum wind speed in terms of representing TC intensity (ECMWF has a much coarser spatial resolution).

3. Results

TC intensity Evaluation

Case by case correspondence between the **HSCAT R17** and best-track **MSW**

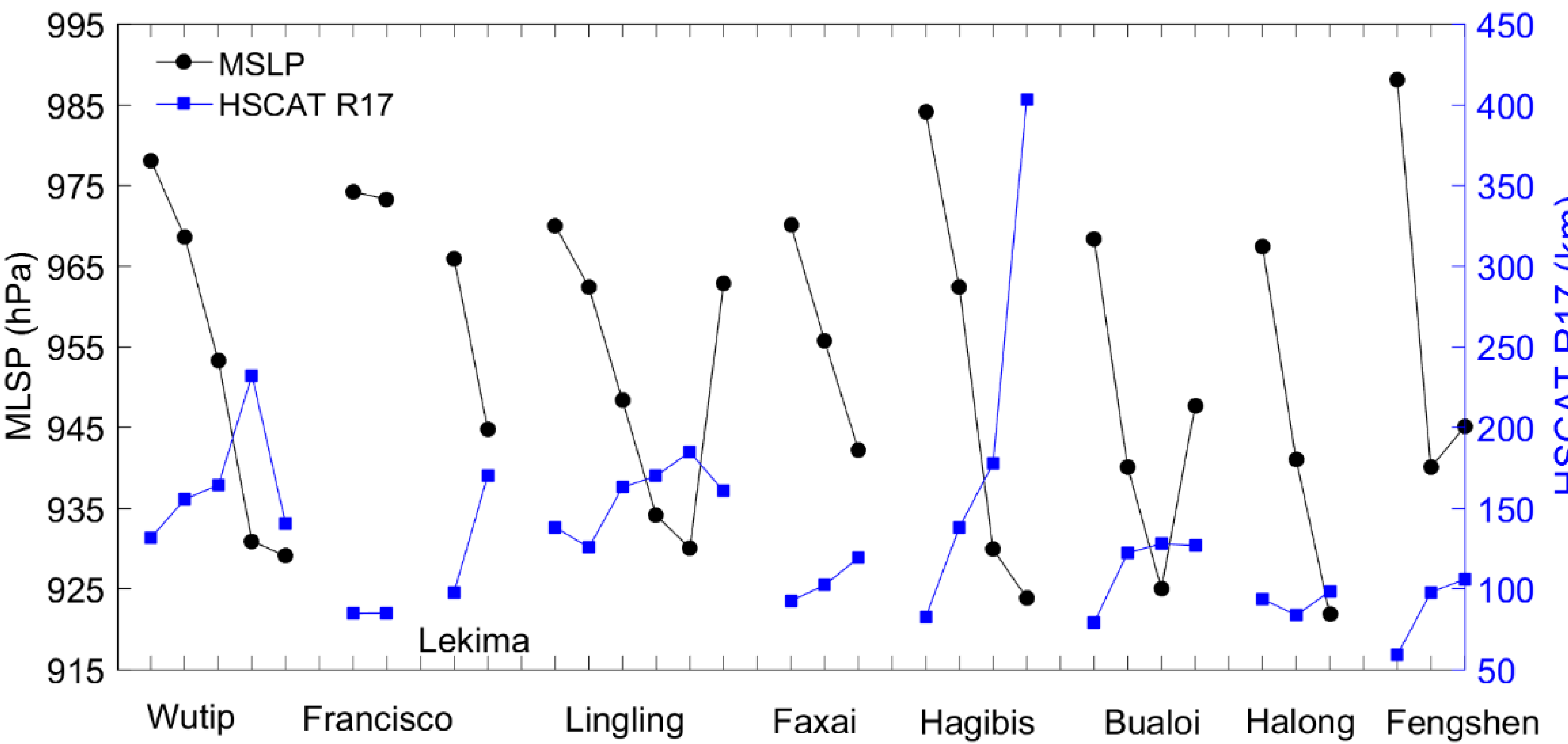


- For a certain Tropical cyclone, Ku-band R17 shows good correlation with best-track MSW

3. Results

TC intensity Evaluation

Case by case correspondence between the **HSCAT R17** and best-track **MSLP**



- For a certain Tropical cyclone, Ku-band R17 shows good correlation with best-track MSLP

3. Results

TC intensity Evaluation

The correlation coefficient is calculated for each TC events with more than three HSCAT acquisitions.

TC Name	Correlation Coefficient					
	R17 vs. MSW	HSCAT W_{max} vs. MSW	ECMWF W_{max} vs. MSW	R17 vs. MSLP	HSCAT W_{max} vs. MSLP	ECMWF W_{max} vs. MSLP
Wutip	0.53	−0.36	0.33	−0.54	0.36	−0.34
Wutip (<72 h)	0.97	0.04	0.89	−0.97	−0.02	−0.88
Lingling	0.83	0.63	0.56	−0.84	−0.61	−0.54
Hagibis	0.79	0.76	0.91	−0.81	−0.78	−0.92
Bualoi	0.86	0.16	−0.08	−0.87	−0.17	0.09

- For a certain Tropical cyclone, Ku-band R17 generally shows better correlation with best-track MSW/MSLP than Ku-band (ECMWF) maximum wind speed.

4. Conclusions

- The divergence or curl of the wind field near the TC center shows remarkable signatures, such that a new method is proposed to identify the TC center.
- The mean difference between the identified HSCAT/ASCAT TC center and the interpolated best-track positions is about one wind vector cell (~25 km).
- When the new method is combined with independent BT estimates, the TC centre estimation is in best agreement with that based on SFMR winds.
- A new method is developed to estimate the azimuthally averaged radius of 17 m/s scatterometer winds (R17). Compared to the maximum wind speed, the R17 value show a significantly better correlation with best-track MSW.
- Through case-by-case analysis, we find that the R17 value is highly correlated with the best-track MSW for each single TC event (>0.8), implying that the scatterometer wind radii are useful in estimating TC intensity by limiting the concerned spatial region and temporal duration.
- In the context of the ESA MAXSS project, a new SFMR-based (non-linear) recalibration of scatterometer & radiometer extreme winds have been carried out; we plan to repeat the analysis with both ASCAT & HSCAT recalibrated winds.