Ocean Coupling and High-Impact Tropical Cyclones (TCs)

Part 1: Category '6' Tropical Cyclone and Ocean Heat Content (Lin et al., to be submitted 2026)

Part 2: Guan et al. Nature Communications 2024: Ocean Internal Tides as an effective damper to suppress TCs

Part 3: Guan et al. Nature Geoscience 2026: Large Amount of Global Drifters for Quantification of TC-induced Cooling effect

Category ‘6’ Tropical Cyclones and OHC

I-Lin[1], Maggie Lien[1], Yating Chang[1], I-Chun Liao[1], Chun-Chieh Wu[1], Yuqing Wang[3], Hsiao-Ching Huang[1], Iam-Fei Pun[3]

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to be submitted 2026

Category '6' TCs: Lin et al. 2014; 2021; Wehner and Kossin 2023; Lin et al. in prep. 2026

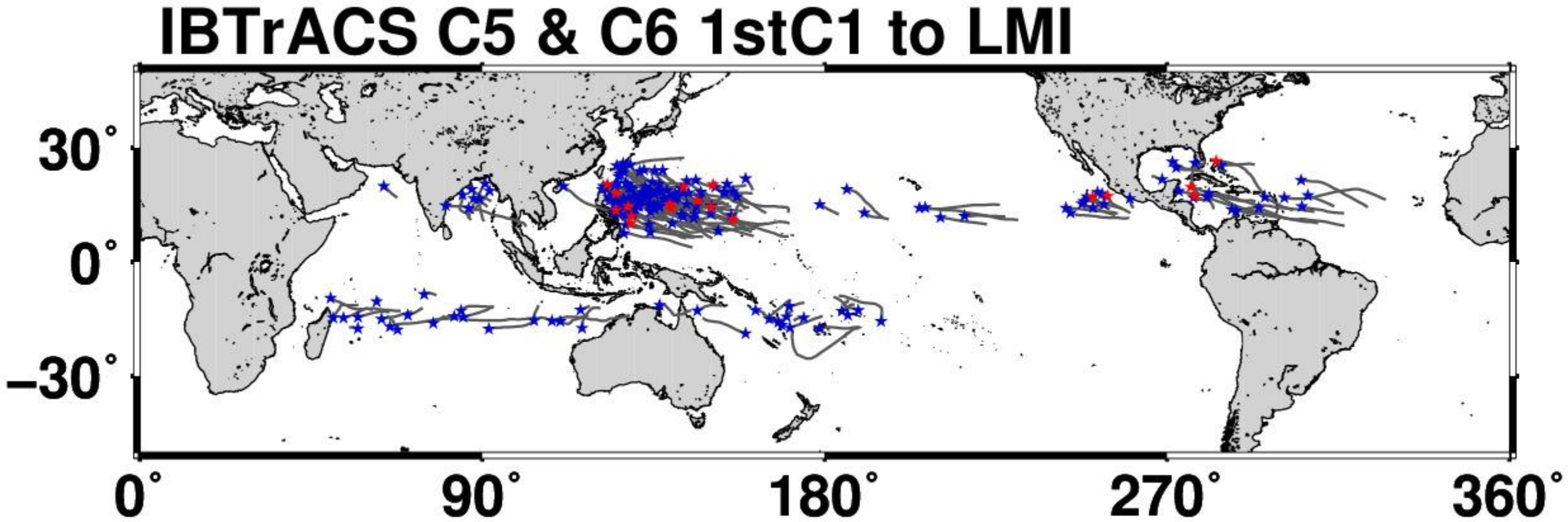
Category	Winds (knots)	V^2 (fcn. of ACE, k. energy)	V^3 (fcn. of PDI, destructiveness)
1	64-82	4,096	262,144
19		x1.7	x2.2
2	83-95	6,889	571,787
13		x1.3	x1.5
3	96-113	9,216	884,736
18		x1.4	x1.7
4	114-137	12,996	1,481,544
22		x1.4	x1.7
5 (Katrina)	>137 - 159	18,225	2,460,375
23		x1.5-1.6-1.9	x1.8-2.0-2.6
'Cat 6'? Haiyan, Hagibis, Patricia	**>=160 (160-170-185)**	**25,600-28,900-34,225**	**4,096,000-4,913,000-6,331,625**

Objective

Category ‘6’ vs. Category ‘5’ TCs

Category 6 Hot Spot Predictor

Lin et al. in prep. 2026



T-test (Pre SST)

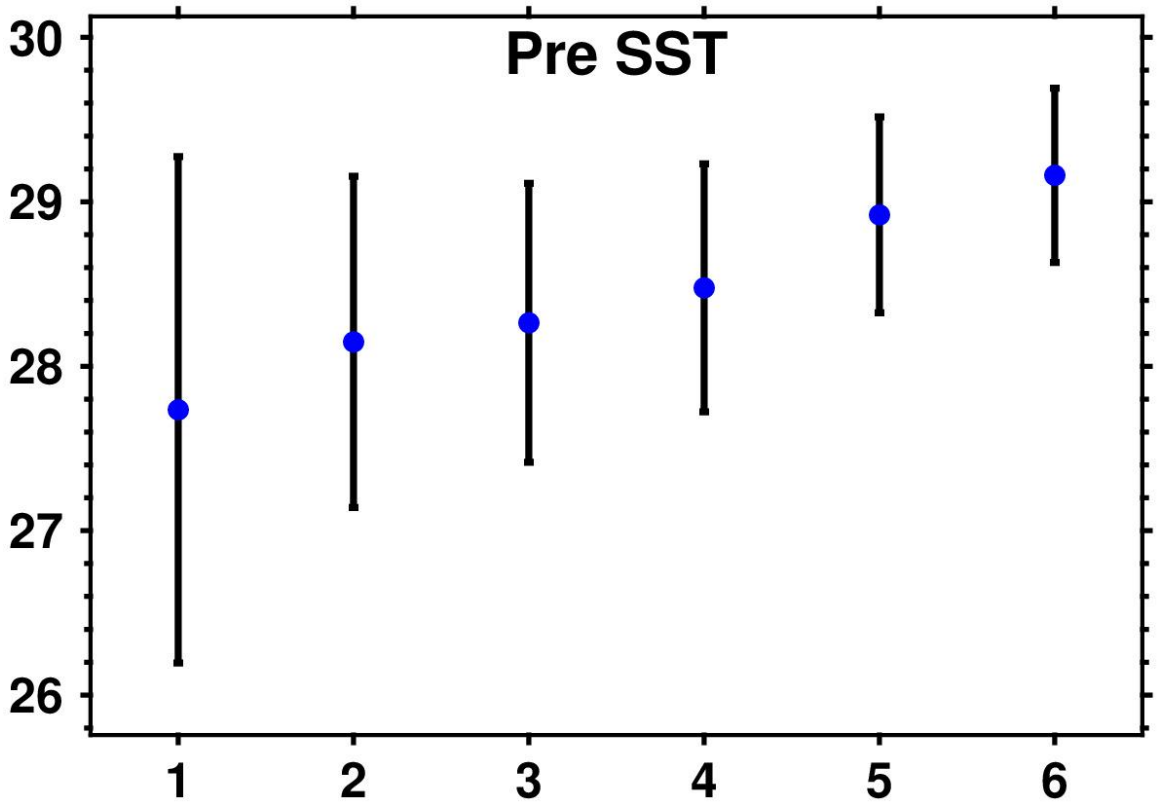
Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C1	27.73504	2.37195	613	-4.93302	99.99991
C2	28.14775	1.0142	324		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C2	28.14775	1.0142	324	-1.56661	88.22855
C3	28.26366	0.71941	307		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C3	28.26366	0.71941	307	-3.62077	99.96809
C4	28.47667	0.56891	509		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C4	28.47667	0.56891	509	-8.03613	100
C5	28.92017	0.35476	184		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C5	28.92017	0.35476	184	-1.81992	91.72327
C6	29.16109	0.28073	18		



T-test (Pre-OHC)

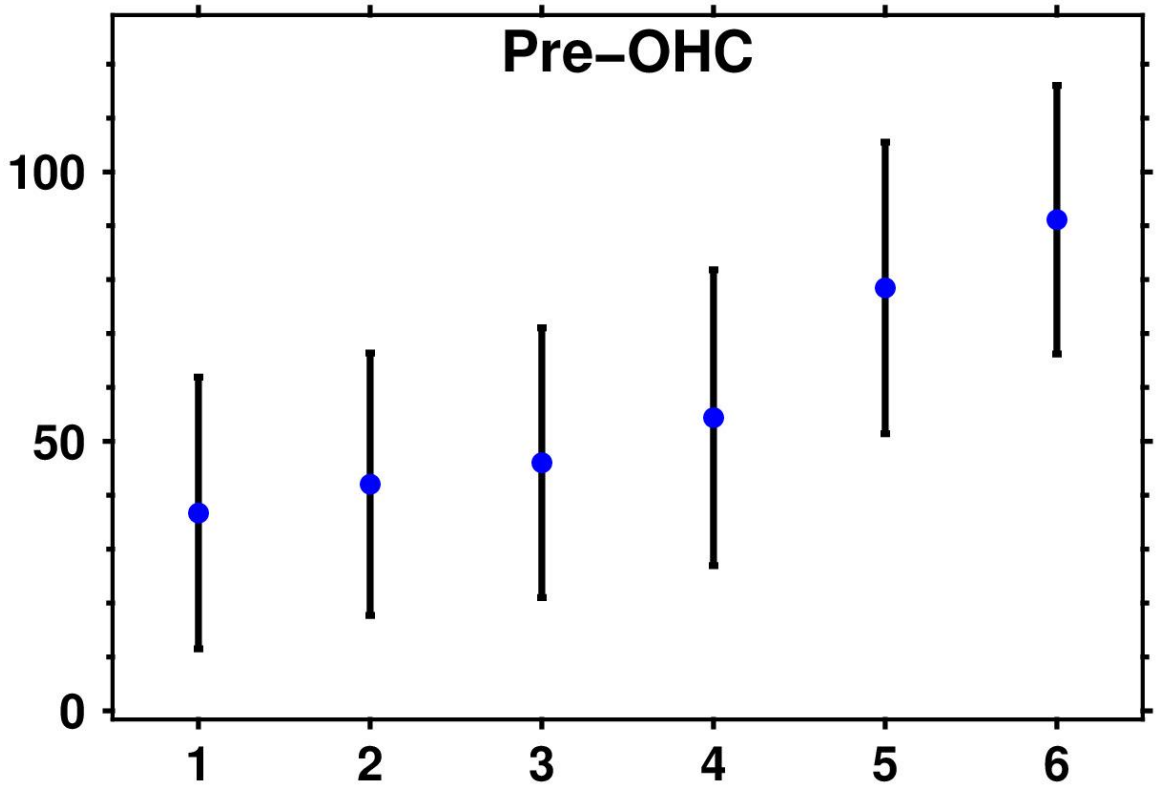
Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C1	36.68597	635.45459	551	-3.07379	99.78015
C2	42.03368	593.91736	317		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C2	42.03368	593.91736	317	-2.01393	95.55485
C3	46.02876	626.72571	304		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C3	46.02876	626.72571	304	-4.43054	99.9989
C4	54.38178	753.89874	505		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C4	54.38178	753.89874	505	-10.29763	100
C5	78.46682	731.8681	184		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C5	78.46682	731.8681	184	-2.04067	94.6019
C6	91.12548	621.0379	18		



T-test (vertical wind shear)

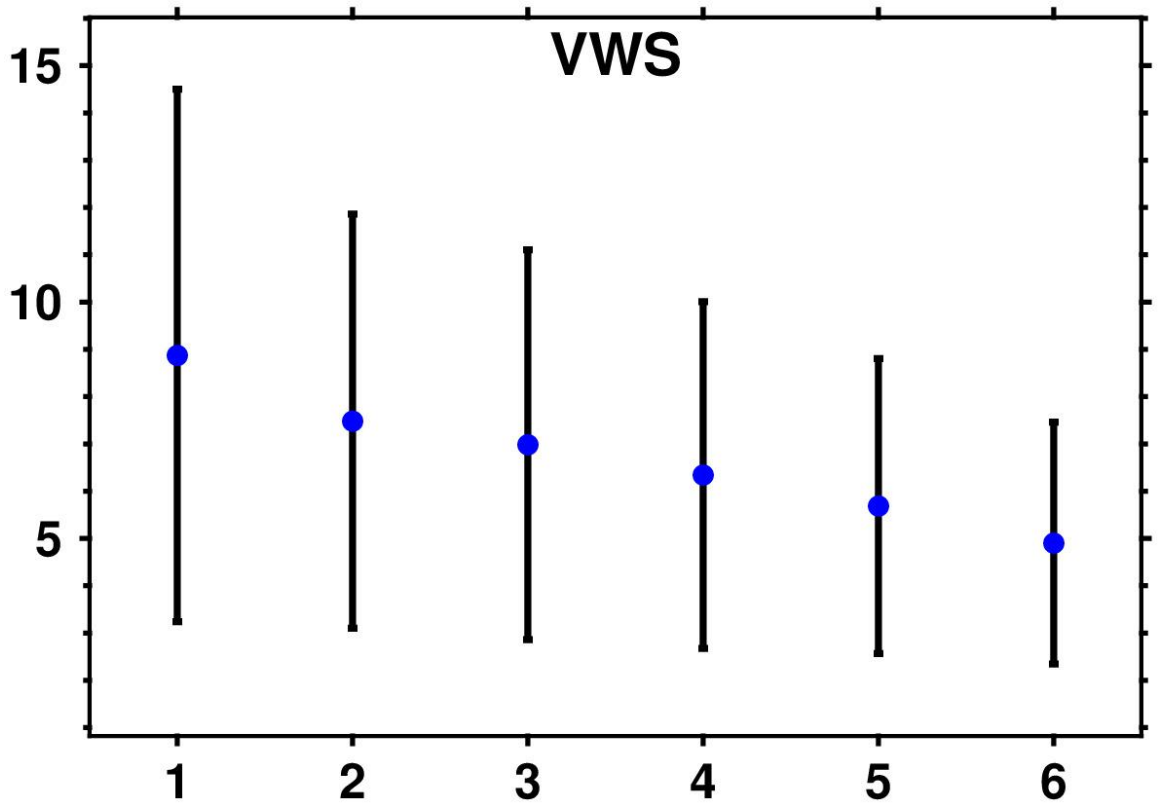
Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C1	8.87071	31.71413	621	4.18714	99.99686
C2	7.48033	19.17867	324		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C2	7.48033	19.17867	324	1.47088	85.81775
C3	6.98241	17.00846	307		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C3	6.98241	17.00846	307	2.24494	97.48563
C4	6.34028	13.44414	509		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C4	6.34028	13.44414	509	2.32931	97.9631
C5	5.68453	9.72272	184		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C5	5.68453	9.72272	184	1.21478	76.28201
C6	4.90088	6.53958	18		



T-test (Qa@500hPa)

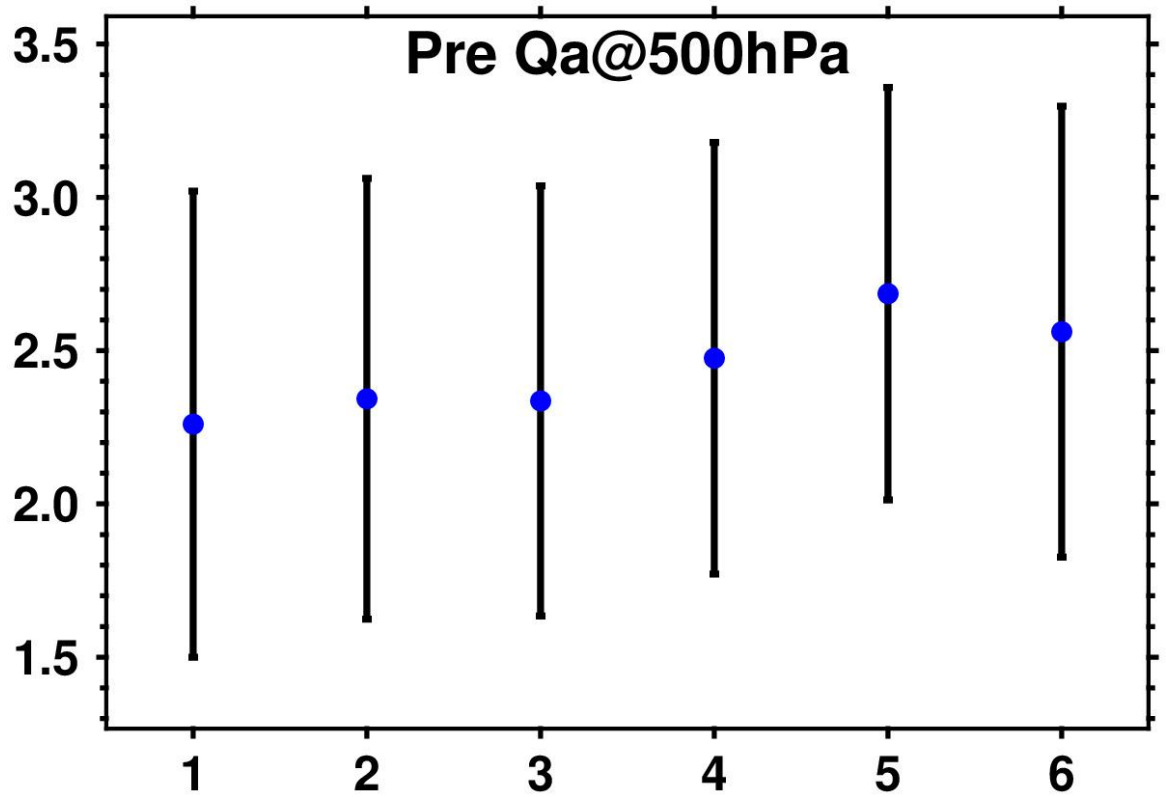
Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C1	2.26007	0.57841	621	-1.64658	89.99
C2	2.34286	0.51719	324		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C2	2.34286	0.51719	324	0.12351	9.82304
C3	2.33587	0.49216	307		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C3	2.33587	0.49216	307	-2.74575	99.3795
C4	2.47523	0.49524	509		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C4	2.47523	0.49524	509	-3.59155	99.96224
C5	2.6857	0.45286	184		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C5	2.6857	0.45286	184	0.68858	50.09595
C6	2.56157	0.54069	18		



T-test (Pre-SSS)

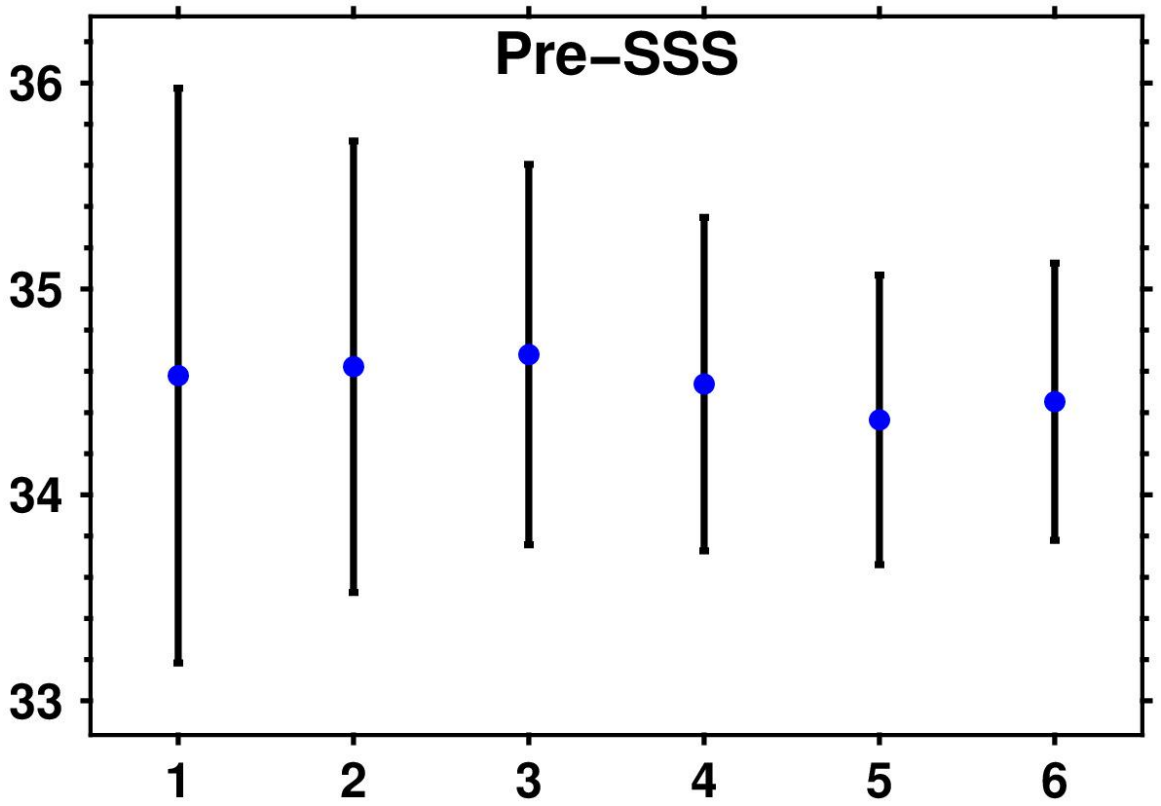
Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C1	34.579	1.94825	617	-0.52552	40.06404
C2	34.62254	1.20111	324		

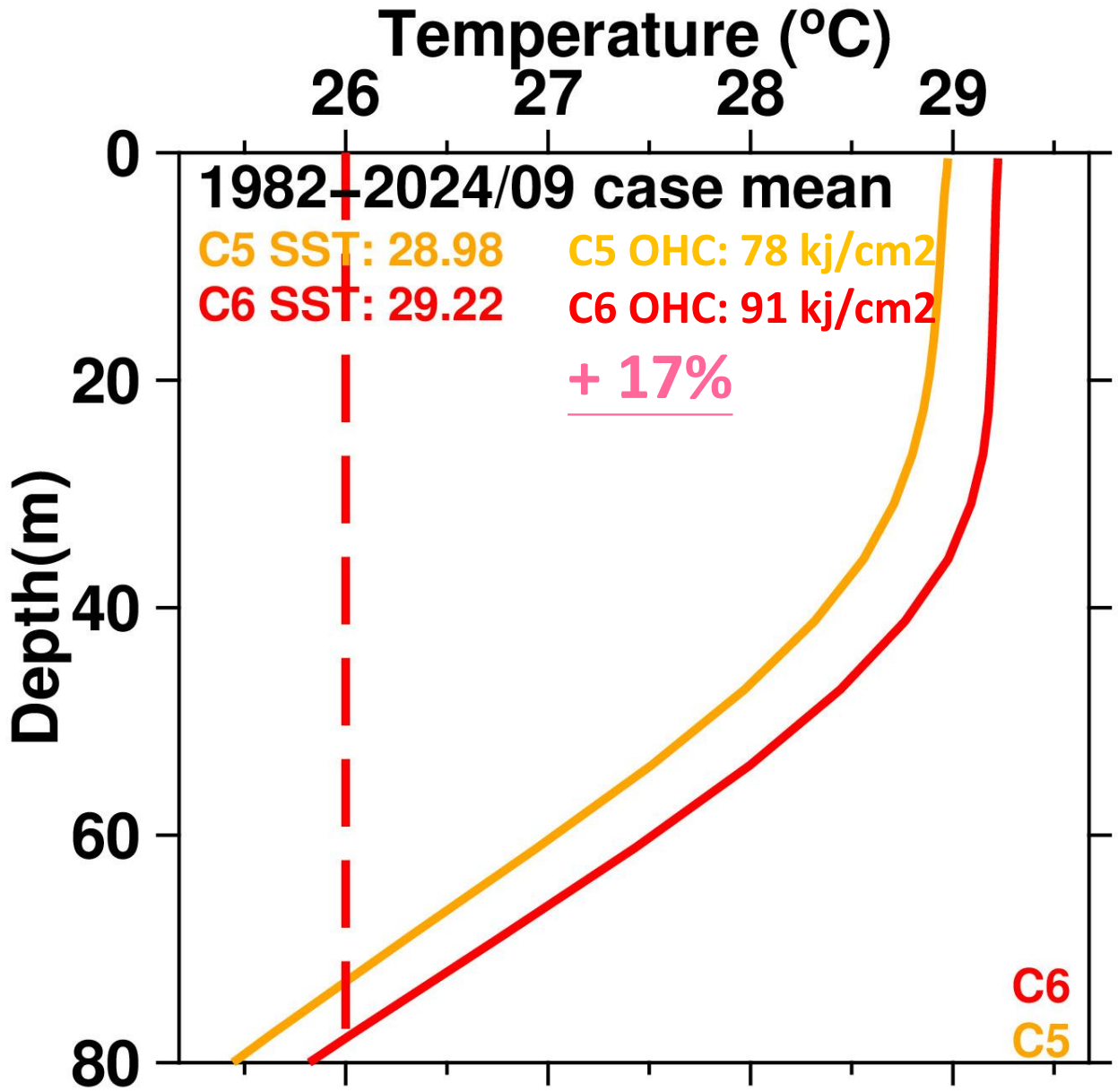
Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C2	34.62254	1.20111	324	-0.72877	53.3587
C3	34.68122	0.85266	307		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C3	34.68122	0.85266	307	2.2482	97.50624
C4	34.53791	0.65478	509		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C4	34.53791	0.65478	509	2.7557	99.3853
C5	34.3641	0.49528	184		

Category	Mean	Variance	Sample number	T value	Confidence Level (two-tailed)
C5	34.3641	0.49528	184	-0.52941	39.78785
C6	34.45246	0.453	18		




Temperature (°C)
26
27
28
29
0
20
40
60
80
Depth(m)
1982–2024/09 case mean
C5 SST: 28.98
C6 SST: 29.22
C5 OHC: 78 kj/cm2
C6 OHC: 91 kj/cm2
+ 17%
C6
C5

Potential Intensity (PI, Bister and Emanuel 1998, SST based)

Ocean Coupling Potential Intensity (OCPI, include subsurface contribution in PI) (Lin et al. GRL 2013)

Pre SST vs. Coupled_SST (i.e., PreSST-Cooling)

$$V_{OC_PI}{}^2 = \frac{\bar{T} - T_0}{T_0} \frac{C_k}{C_D} (k^* - k)$$

nature communications

May 2024

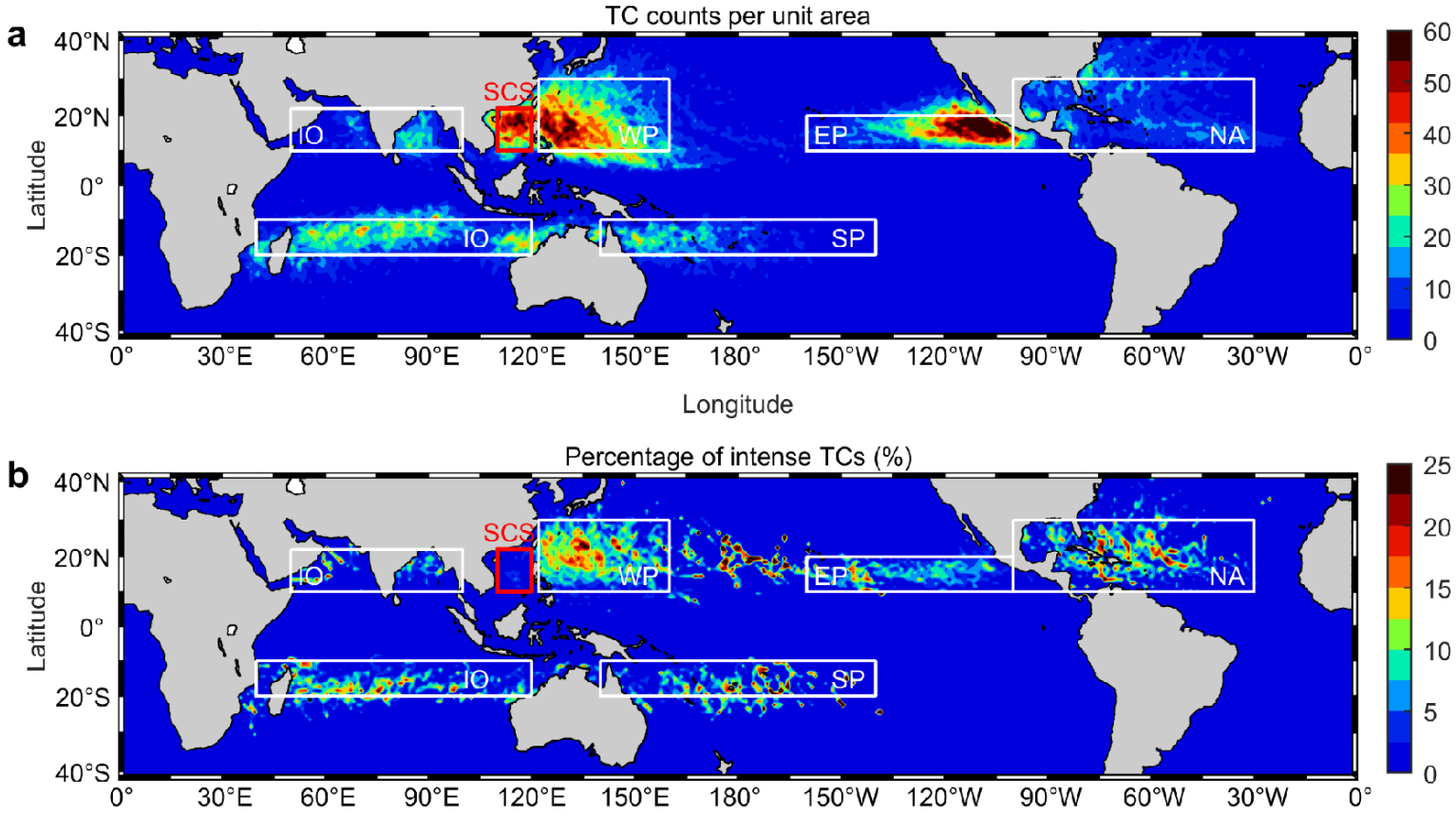
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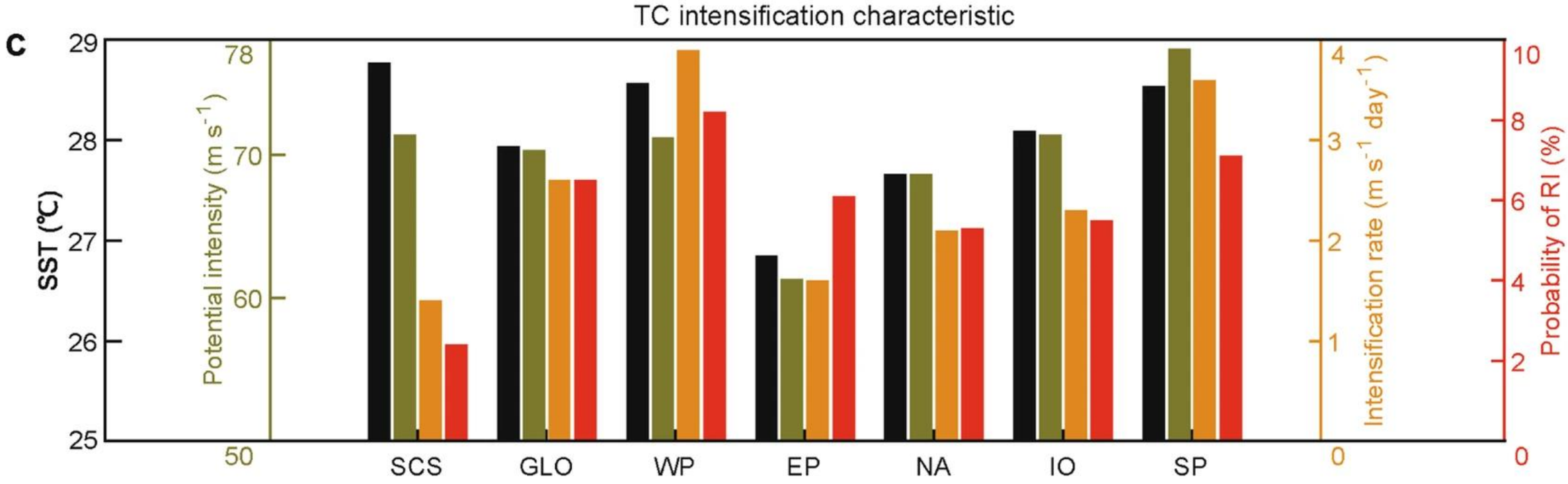
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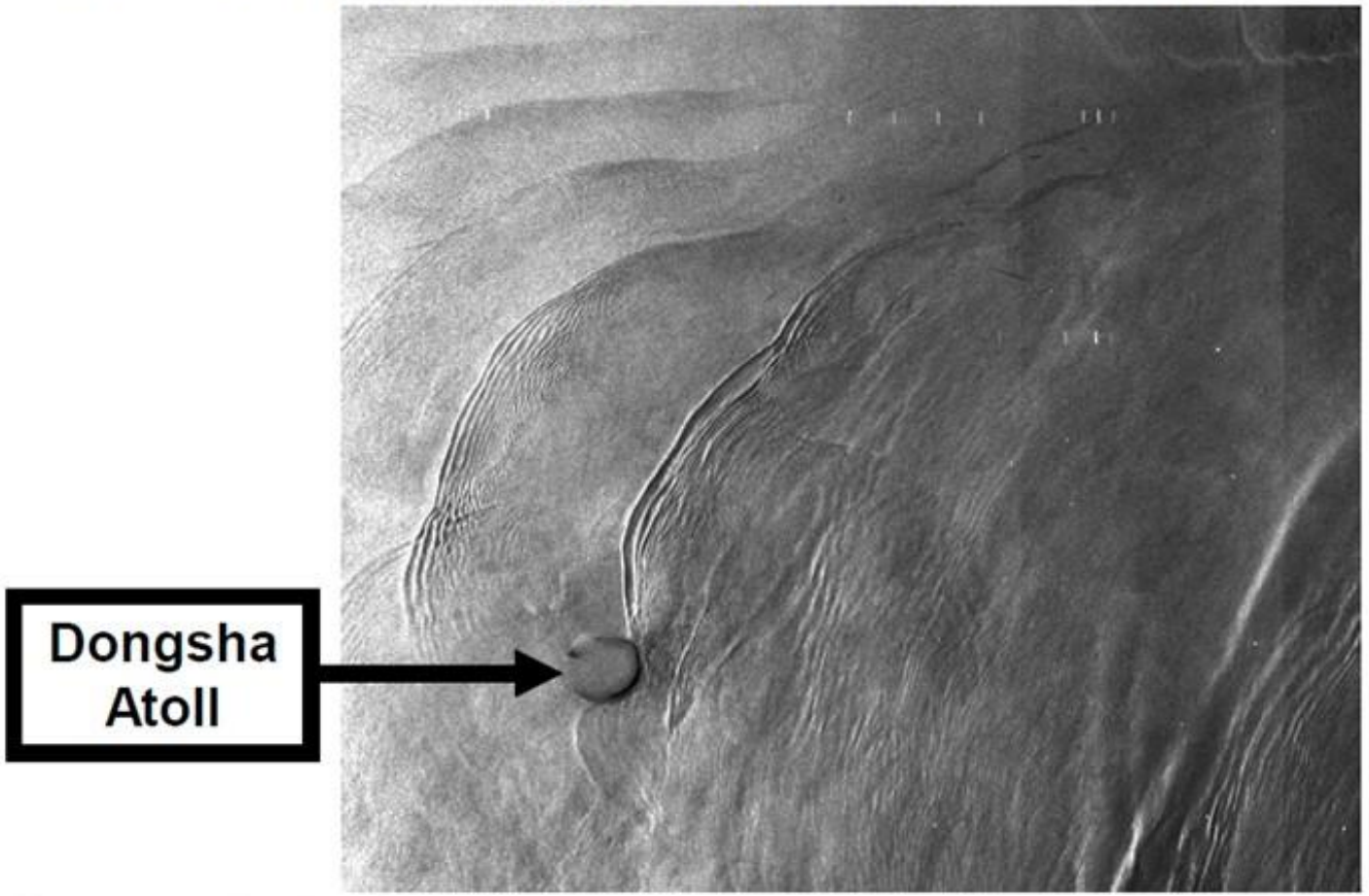
Ocean internal tides suppress tropical cyclones in the South China Sea

Shoude Guan, Fei-Fei Jin ✉, Jiwei Tian ✉, I-I Lin ✉, Iam-Fei Pun, Wei Zhao, John Huthnance, Zhao Xu, Wenju Cai, Zhao Jing, Lei Zhou, Ping Liu, Yihan Zhang, Zhiwei Zhang, Chun Zhou, Qingxuan Yang, Xiaodong Huang, Yijun Hou & Jinbao Song

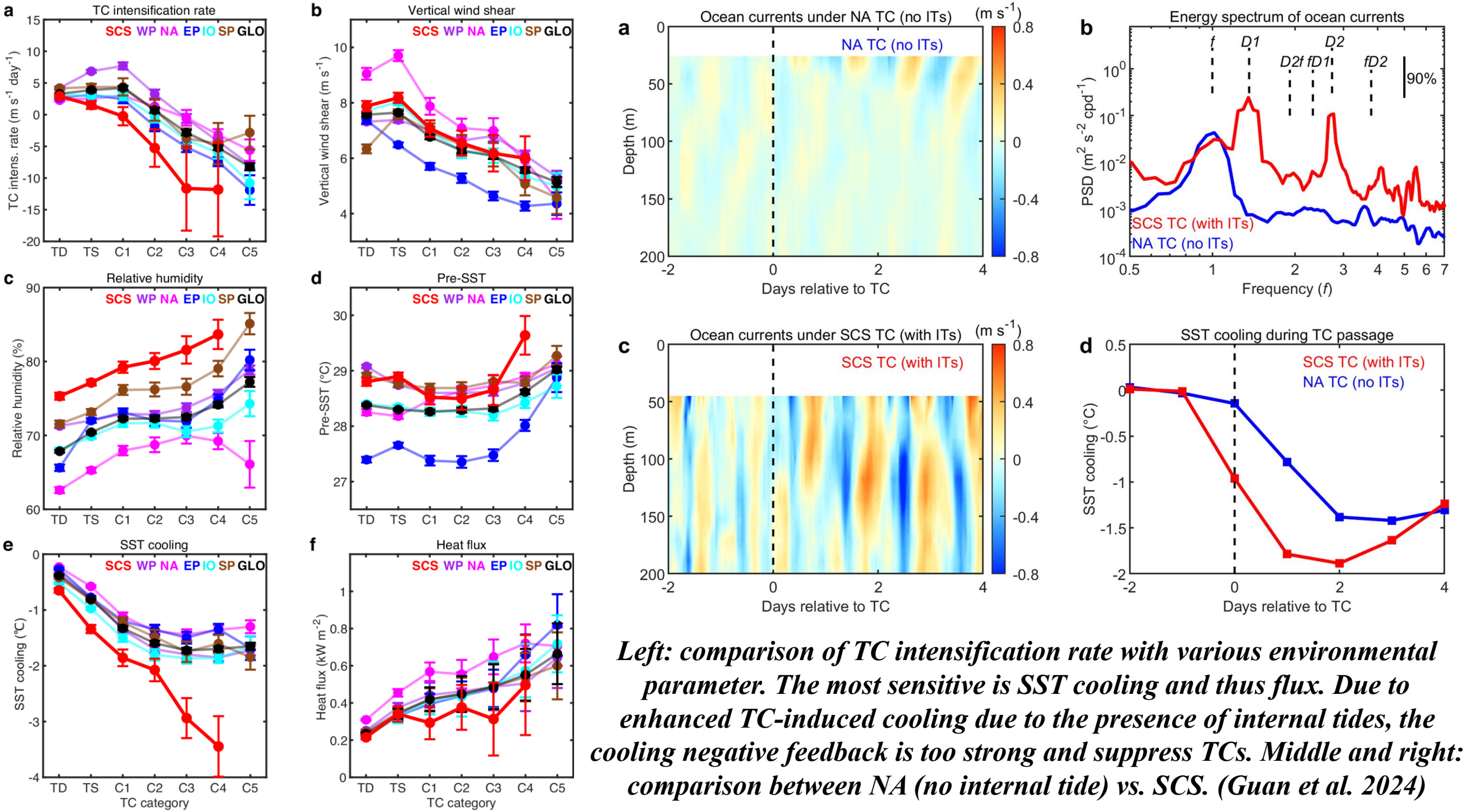



c
TC intensification characteristic
SST (℃)
29
28
27
26
25
Potential intensity (m s-1)
78
70
60
50
Intensification rate (m s-1 day-1)
4
3
2
1
0
Probability of RI (%)
10
8
6
4
2
0
SCS
GLO
WP
EP
NA
IO
SP

Sea surface signatures of oceanic internal waves



Envisat SAR Wide Swath image acquired over the South China Sea on 18-06-2005, 021:3UTC showing sea surface signatures of oceanic internal waves. Swath widths: 400 km.



Left: comparison of TC intensification rate with various environmental parameter. The most sensitive is SST cooling and thus flux. Due to enhanced TC-induced cooling due to the presence of internal tides, the cooling negative feedback is too strong and suppress TCs. Middle and right: comparison between NA (no internal tide) vs. SCS. (Guan et al. 2024)

All drifters from 1992-2021

nature geoscience

Article

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Weak self-induced cooling of tropical cyclones amid fast sea surface warming

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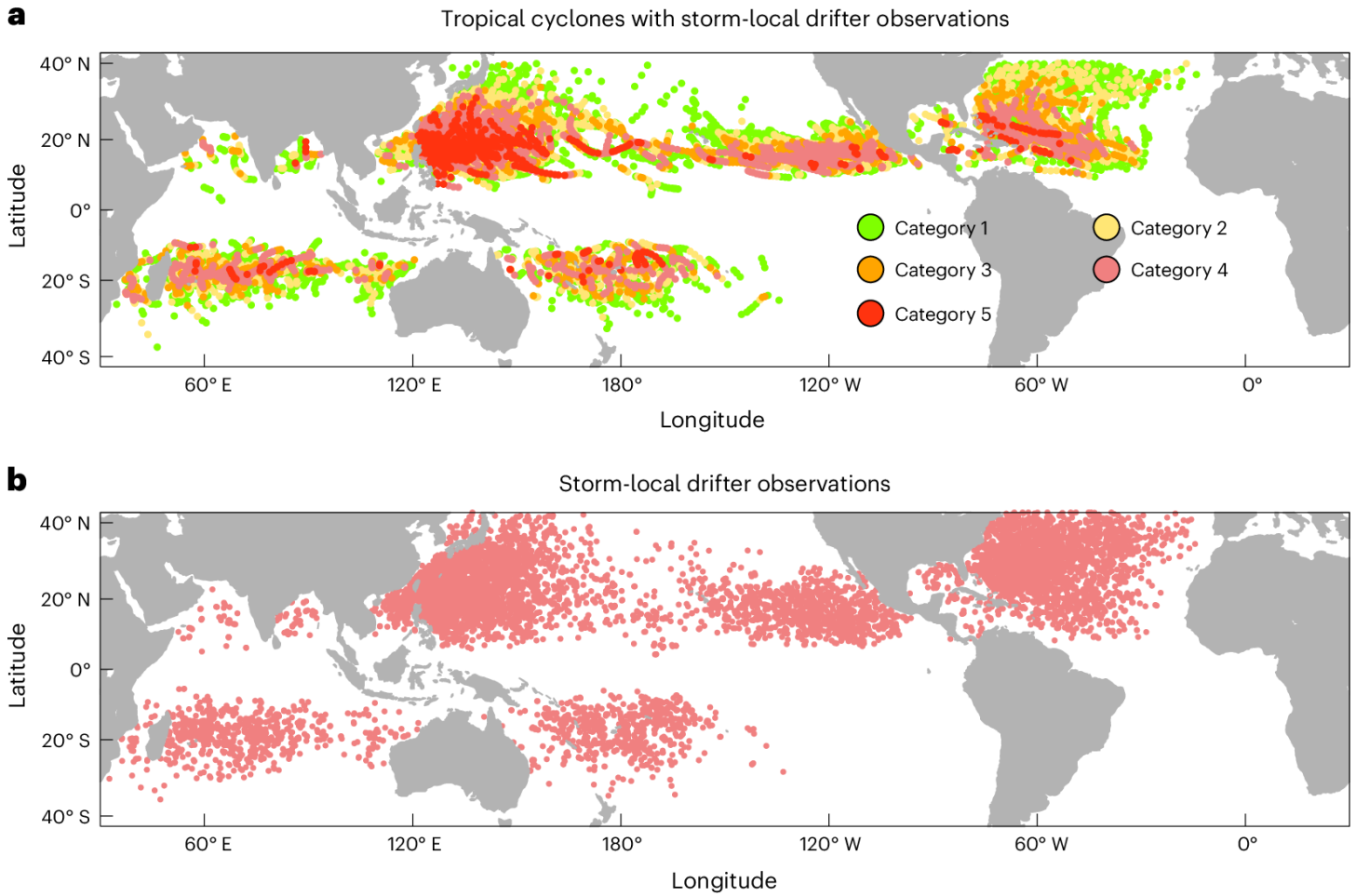
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Shoude Guan[1,2,3,14], Mengya Huang[1,14], Wenju Cai[1,4,5,6] ✉, Zhengguang Zhang[1,3], I-I Lin[7] ✉, Hyun-Sook Kim[8], Lei Zhou[9], Xiaopei Lin[1,3], Zhao Xu[1,3], Fei-Fei Jin[10], Wei Mei[11], Qian Wang[12], Chun Zhou[1,2,3], Ze Meng[11,13], Jiwei Tian[1,2,3] & Wei Zhao[1,2,3] ✉

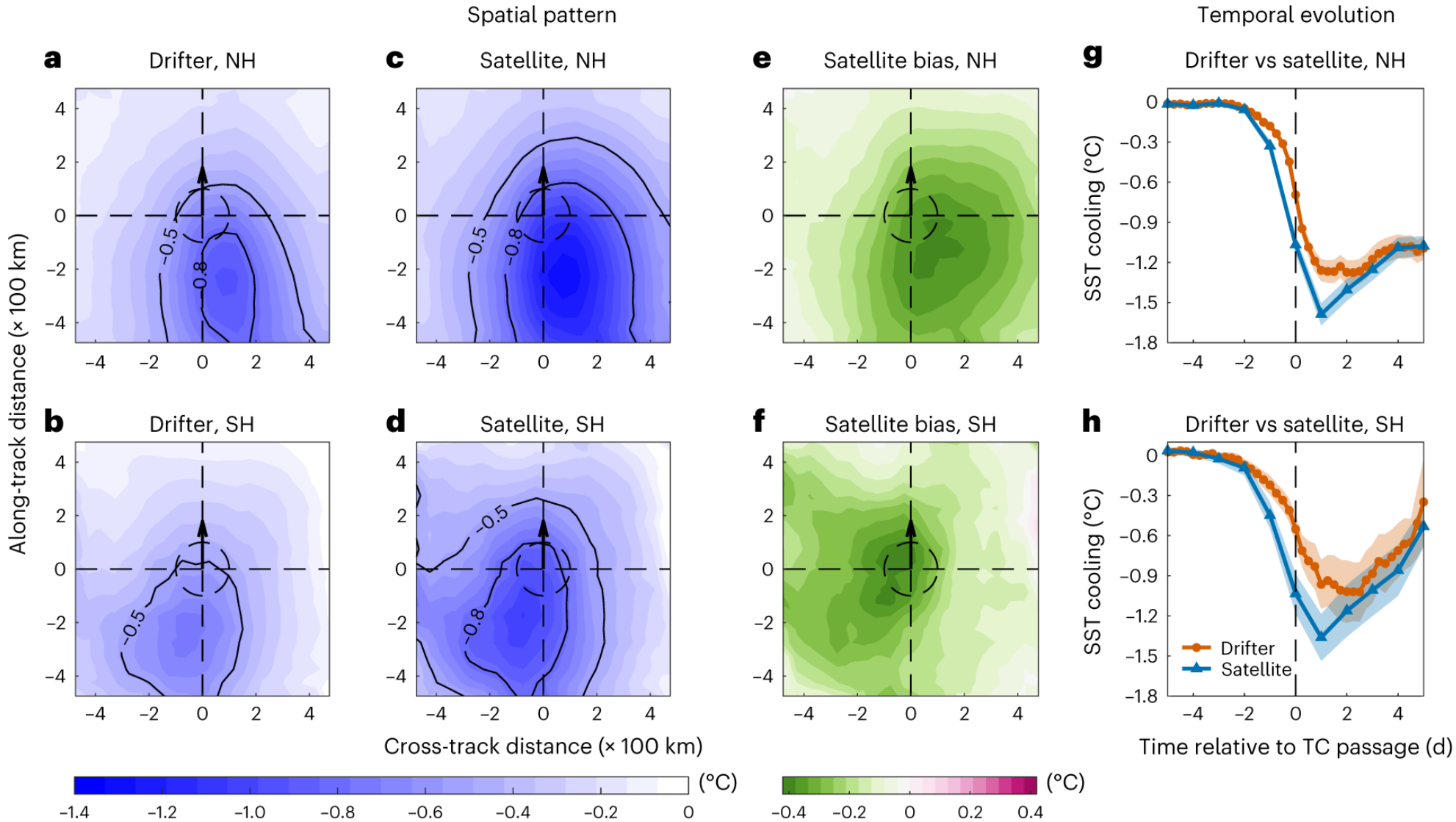
Sea surface temperature directly beneath tropical cyclones is crucial for their intensification. In the long term, global warming heats the surface oceans, intensifying tropical cyclones, whereas concurrently with a cyclone, inner-core surface cooling is induced by the cyclone itself curtailing its intensification. However, the magnitude of cyclone-induced cooling, or the trend in storm-local sea surface temperature, remains uncertain. Here we provide a quantification using global surface drifter data from 1992 to 2021. We find that storm-local sea surface temperatures are rising at 0.29 ± 0.07 °C per decade—about twice the average rate in tropical cyclone-active regions despite enhanced cyclone-induced cooling; furthermore, the magnitude of cyclone-induced inner-core cooling is far smaller than previous estimates. The inner-core cooling measured by drifters is −0.68 ± 0.04 °C, substantially less than microwave satellite estimates (−1.05 ± 0.06 °C). State-of-the-art climate models tend to overestimate inner-core cooling while underestimating storm intensity. These findings offer observational benchmarks for models and suggest that current projections may underestimate the strength, frequency and impacts of major tropical cyclones.

Tropical cyclones (TCs) are among the most devastating natural disasters on Earth[1]. Under greenhouse warming, TCs have been shifting towards higher intensities[2–5]. The increasing TC intensity, combined with its poleward and coastal migration[6–11], poses rising risks to affected communities. Therefore, a better understanding of environmental factors controlling TC intensities and consequent improvements in forecasts and future projections to mitigate their impacts are of great importance to society[12]. Among atmosphere–ocean factors, storm-local sea surface temperature (SST) directly beneath TCs (defined as SST within 500 km around TC centre) is crucial as it determines TCs' enthalpy supply and thus is pivotal in controlling TC intensity[13,14]. In recent decades, despite efforts to measure storm-local SST using fixed buoys, ship- or aircraft-based expendables[15–23], the collected observations have covered limited intense Category 1–5 TCs and mostly concentrated in the North Atlantic. Consequently, an understanding of storm-local SST on a global scale is not previously available.

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Guan et al. Nature Geoscience 2026



Guan et al. Nature Geoscience 2026

Conclusions

Part 1: Category ‘6’ TCs and OHC (Lin et al. to be submitted 2026)

a. Pseudo-Warm vs. Robust-Warm Ocean

b. Ocean Coupling Potential Intensity (OCPI Lin et al. 2013) for Category ‘6’ hot spot detection

c. Hot Spot has expanded significantly

Conclusions

Part 2: Guan et al. Nature Comm. 2024: Ocean Internal Tides as an effective damper to suppress TCs

Part 3: Guan et al. Nature Geoscience 2026: Large Amount of Global Drifters for Quantification of TC-induced Cooling effect