Supplementary Material to:

Regional and Sub-basin Tropical Cyclone Activity in the CMCC Seasonal Forecast System 3.5

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Supplementary Texts

S.1 Tropical Cyclone Tracking

TRACK takes as input the vertical relative vorticity at several pressure levels (850 hPa, 700 hPa, 500 hPa, 300 hPa, 200 hPa) and spectrally filters it using a triangular T63 truncation (ζ_{T63}). This method filters out the wavenumbers related to large-scale background vorticity ($n \leq 5$) and small-scale noise at the other end ($n \geq 63$). In the first step, local maxima that attain a threshold of $5 \times 10^{-5} s^{-1}$ on the average (850 hPa, 700 hPa) ζ_{T63} field are detected. Feature points are clustered together by using a nearest-neighbor method and potential tracks are then optimized by minimizing a cost function for track smoothness [1]. After the tracking, the algorithm searches for ζ_{T63} maxima on the pressure levels available to verify the vertical structure of the potential TC. Vorticity maxima are added to the track if they lie within a 5° geodesic radius circle centered on the position of the extremum found at the level below [2]. The same method is applied to the mean sea level pressure minimum, using the vorticity center of the averaged ζ_{T63} field as the reference point. Eventually, TC identification of a potential track is performed, following the methodology used in [3]:

1. every TC is tracked up to 50° from the Equator and must originate within 30° from the Equator, to exclude potential extratropical cyclones;
2. ζ_{T63} at 850 hPa must be greater than $6 \times 10^{-5} s^{-1}$;
3. an inversion of the circulation between the lower and the upper level must hold to inform the presence of a warm core, that is, $\zeta_{T63}(850 \text{ hPa}) - \zeta_{T63}(200 \text{ hPa}) > 6 \times 10^{-5} s^{-1}$;
4. $\zeta_{T63} > 6 \times 10^{-5} s^{-1}$ at each pressure level considered to ensure coherence in the vertical structure of the cyclone;
5. conditions 2-4 must be jointly satisfied over the ocean for at least one day, i.e., two consecutive time steps.

S.2 The linear relationship between MSSS and PCOR

Here, we provide a detailed derivation of the linear relationship between MSSS and PCOR, which arises in case of standardized variables (zero mean and unit variance). Given the definition of MSSS:

$$MSSS = 1 - \frac{\frac{1}{N}\sum_{i=1}^{N}(f_i - o_i)^2}{\frac{1}{N}\sum_{i=1}^{N}(o_i - \overline{o})^2}, \tag{1}$$

we can note that the denominator of the fraction equals to 1, since it represents the variance of a standardized variable. Following [4], we can decompose the numerator as:

$$\begin{aligned}\frac{1}{N}\sum_{i=1}^{N}(f_i-o_i)^2 &= \frac{1}{N}\sum_{i=1}^{N}\left[(f_i-\overline{f})-(o_i-\overline{o})+(\overline{f}-\overline{o})\right]^2 \\ &= (\overline{f}-\overline{o})^2+(\sigma_f^2+\sigma_o^2)-2cov_{f,o} \\ &= 2(1-cov_{f,o})\end{aligned} \tag{2}$$

where $cov_{f,o} = \frac{1}{N}\sum_{i=1}^{N} f_i o_i$ is the covariance of the anomalies of the hindcasts and the observations. The Pearson correlation is generally defined as:

$$PCOR = \frac{cov_{f,o}}{\sigma_f \sigma_o} \tag{3}$$

Therefore, it reduces to the covariance of the anomalies of the hindcasts and the observations since the standard deviations σ_f, σ_o are unitary. Comparing the expressions obtained, it follows that the relationship between MSSS and PCOR is linear and can be expressed as:

$$MSSS = 1 - 2(1 - PCOR). \tag{4}$$

Supplementary Figures

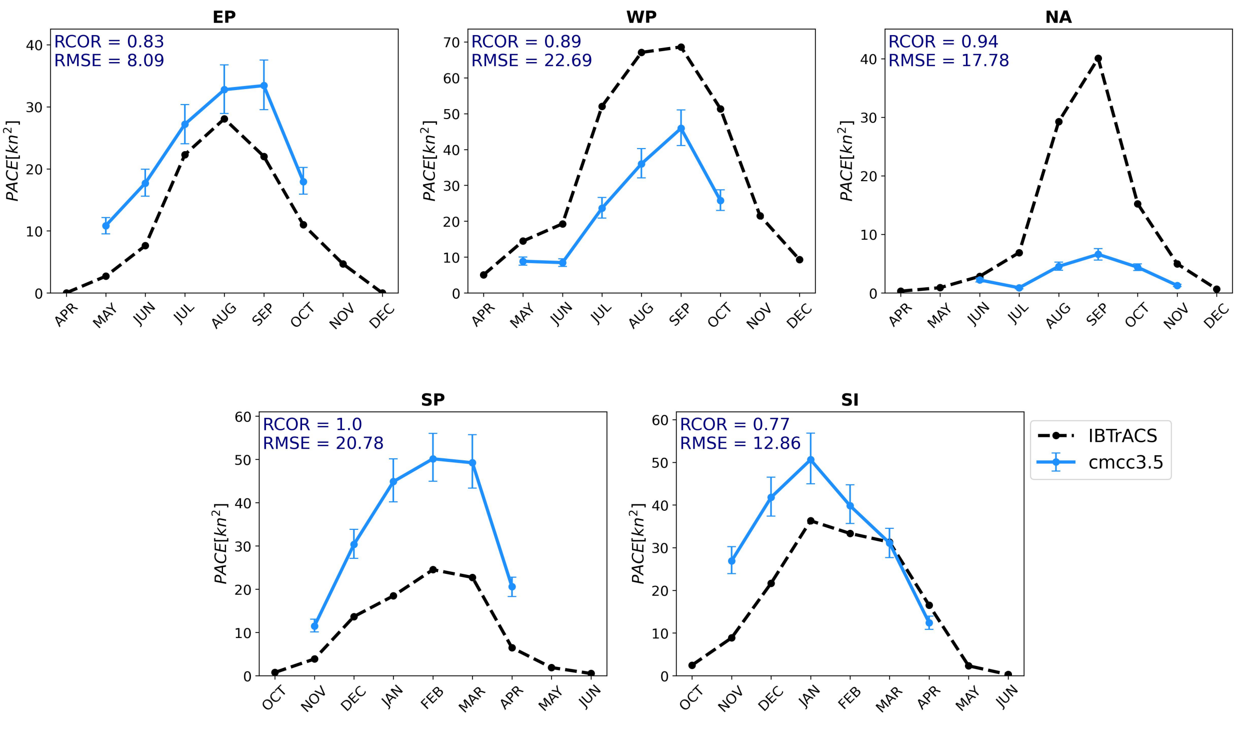

Figure S1: As fig.1 in the main text, but for Pressure Accumulated Cyclone Energy (PACE).

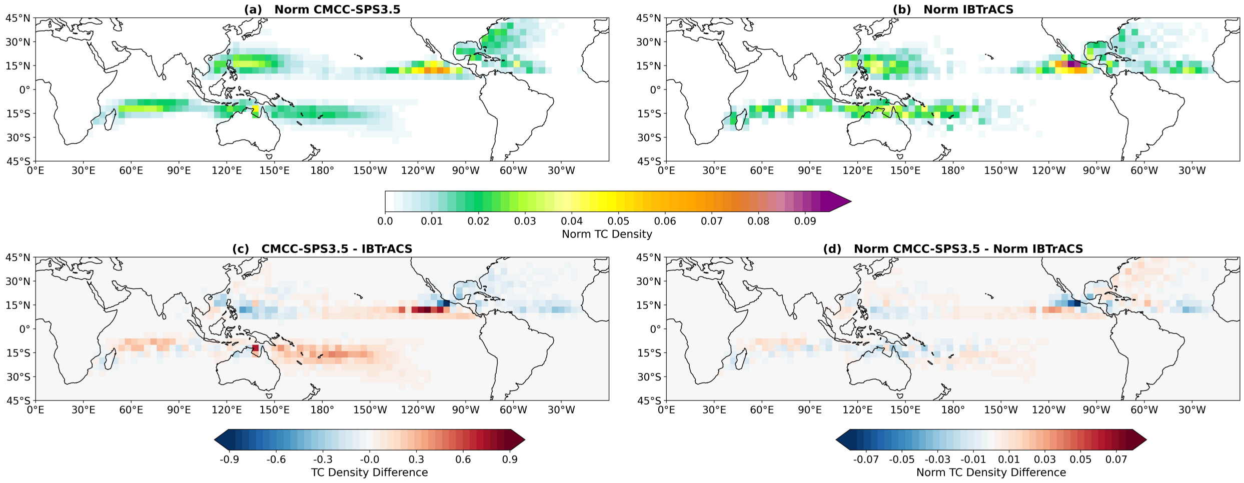

Figure S2: Maps of TC genesis density over $4^\circ \times 4^\circ$ boxes in CMCC-SPS3.5 hindcasts (a), in the observations (b), difference between hindcasts and observations (c, d). Genesis is defined as the first point of the track with tropical storm intensity. Values in (a), (b) and (d) are normalized over the area of each basin, as Fig.3 in the main text. Values in (c) are in storm genesis per year.

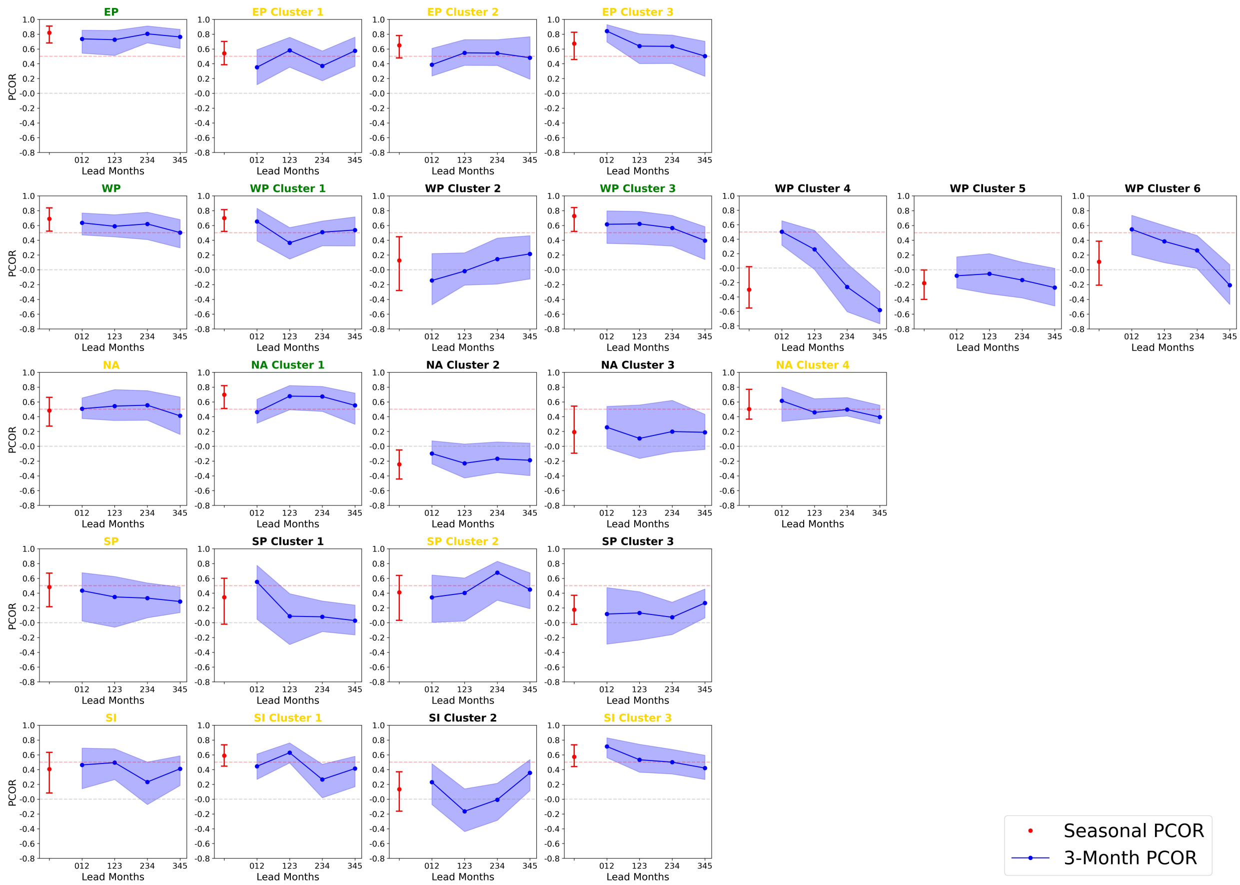

Figure S3: As fig.5 in the main text, but for PACE.

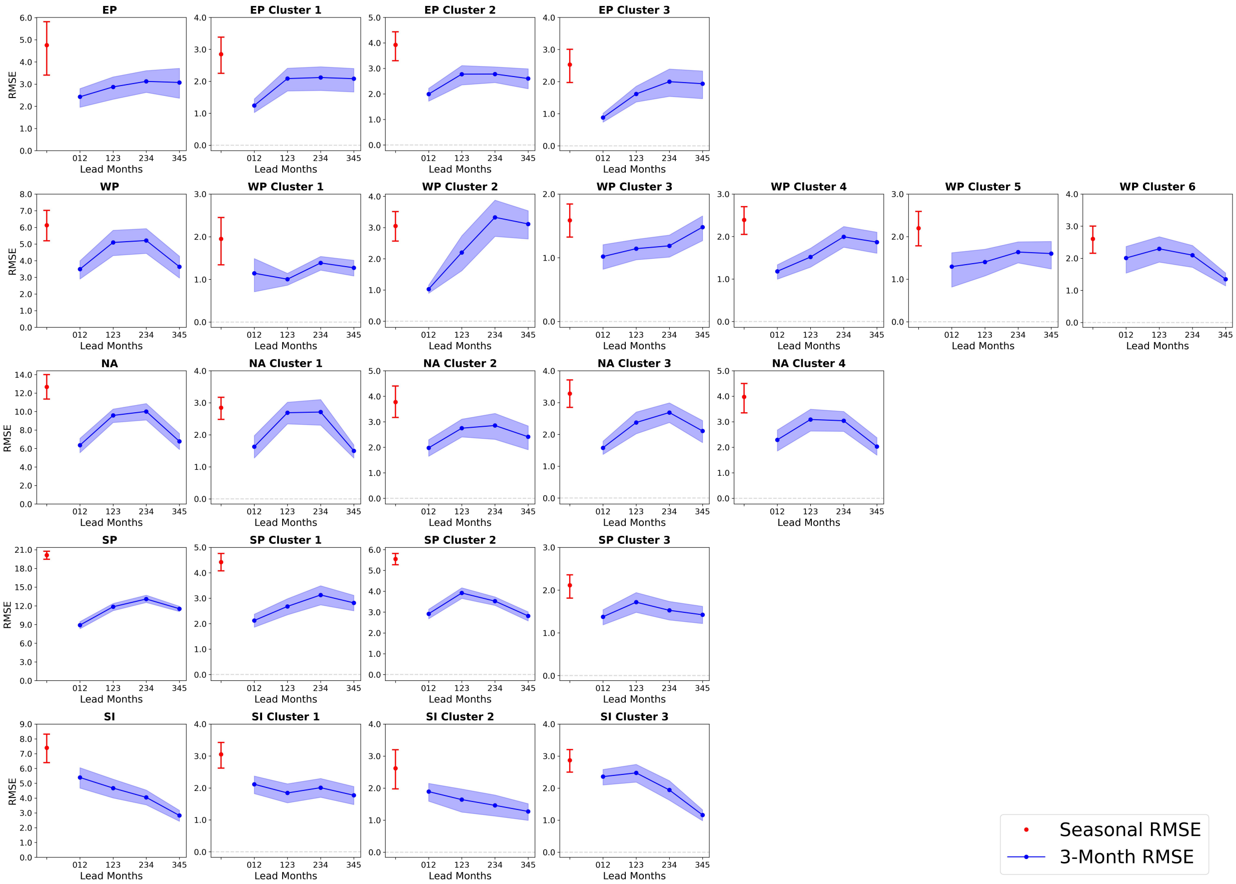

Figure S4: Root Mean Square Error (RMSE) between observed and predicted NTC. Each row corresponds to an ocean basin. RMSE computed over the whole seasonal cycle is displayed with the red dot, and RMSE over a 3-month window is displayed with the blue curve. The area between the 10^{th} and the 90^{th} percentile is displayed between the whiskers and within the shaded area, respectively.

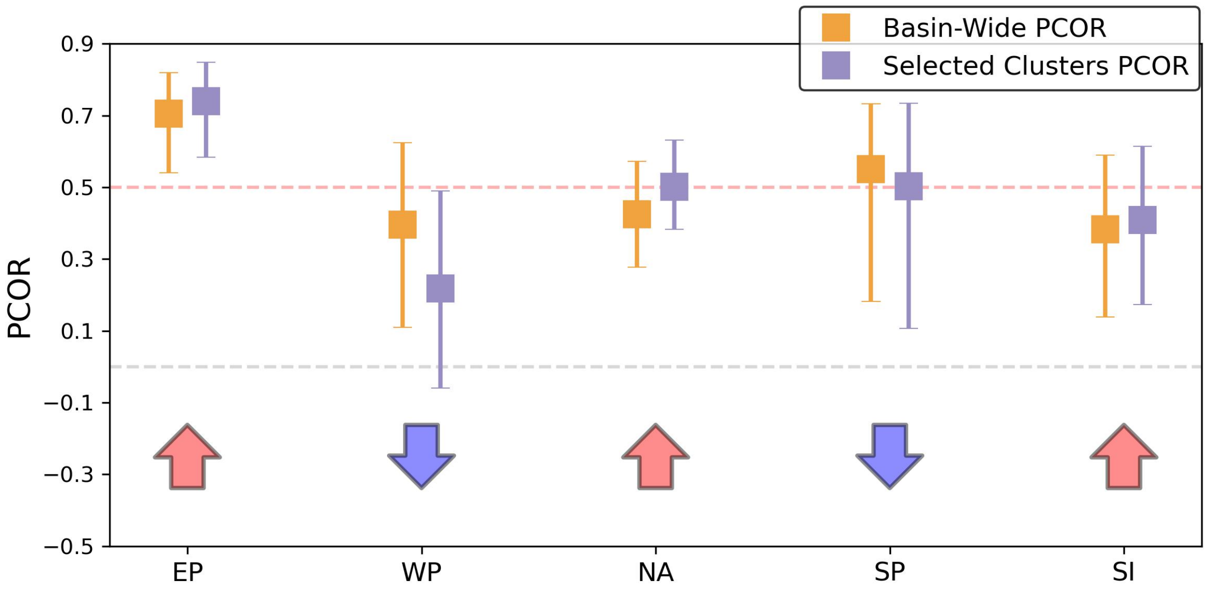

Figure S5: Comparison of correlation of NTC anomaly between basin-wide IBTrACS and basin-wide CMCC-SPS3.5 (orange) and between basin-wide IBTrACS and composite of selected clusters from CMCC-SPS3.5 (purple) over the 1993-2016 period. Red (blue) arrows indicate an improved (reduced) skill. Selected hindcast clusters are: 2+3 (EP), 1+3 (WP), 1+3+4 (NA), 1 (SP), 1+3 (SI). Selection is based on clusters skill score. Whiskers indicate the 10^{th} and the 90^{th} of the distribution obtained using a 1000 sample bootstrap.

References

[1] Hodges K 1999 *Monthly Weather Review* **127** 1362–1373

[2] Hodges K, Cobb A and Vidale P L 2017 *Journal of Climate* **30** 5243–5264

[3] Befort D J, Hodges K I and Weisheimer A 2022 *Journal of Climate* **35** 1385–1397

[4] Murphy A H 1988 *Monthly weather review* **116** 2417–2424