A Toy Model for the Global Annual Number of Tropical Cyclones

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Motivation

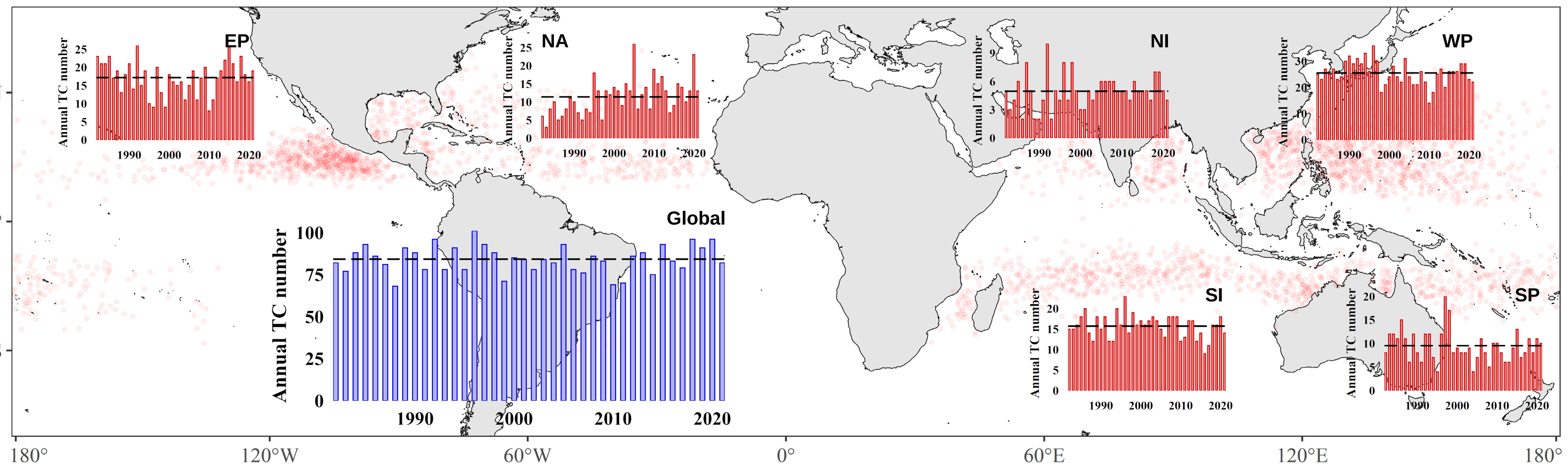


Figure 1. Spatial distribution of TC genesis (red points, 1982-2021). The annual number of TCs in each basin (red bar plots) and globally (blue bar plot) are denoted. The dashed lines indicate the average frequency (~90 globally).

- The annual number of global tropical cyclones (TCs) has remained stable ~90 in the past (Figure 1).
- Following TC passage, the atmosphere generally becomes more stable and drier, and the SST cools, lasting for 10-20 days (Figure 2). An inhibition on subsequent TC formation is observed in this period.
- **Here, we construct an idealized toy model to examine the impacts of TC-environment interactions on the annual TC number, with a particular focus on the environmental recovery.**

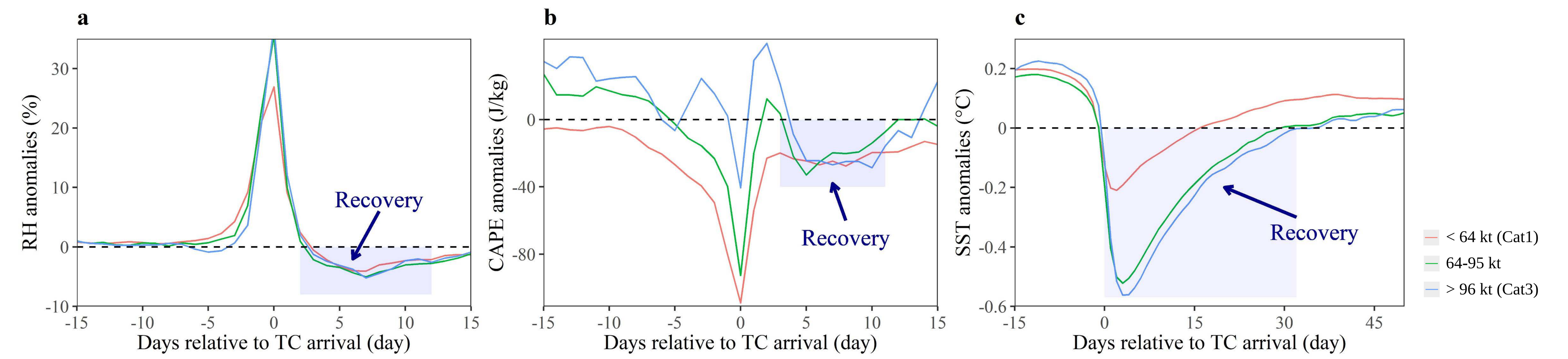


Figure 2. Timeseries of RH (a), CAPE (b) and SST (c) anomalies, with colors noting TC intensities. Anomalies are calculated as the mean within a 4°×4° area of the TC center (1982-2021). The blue shaded areas indicate the recovery process of environment.

Toy Model

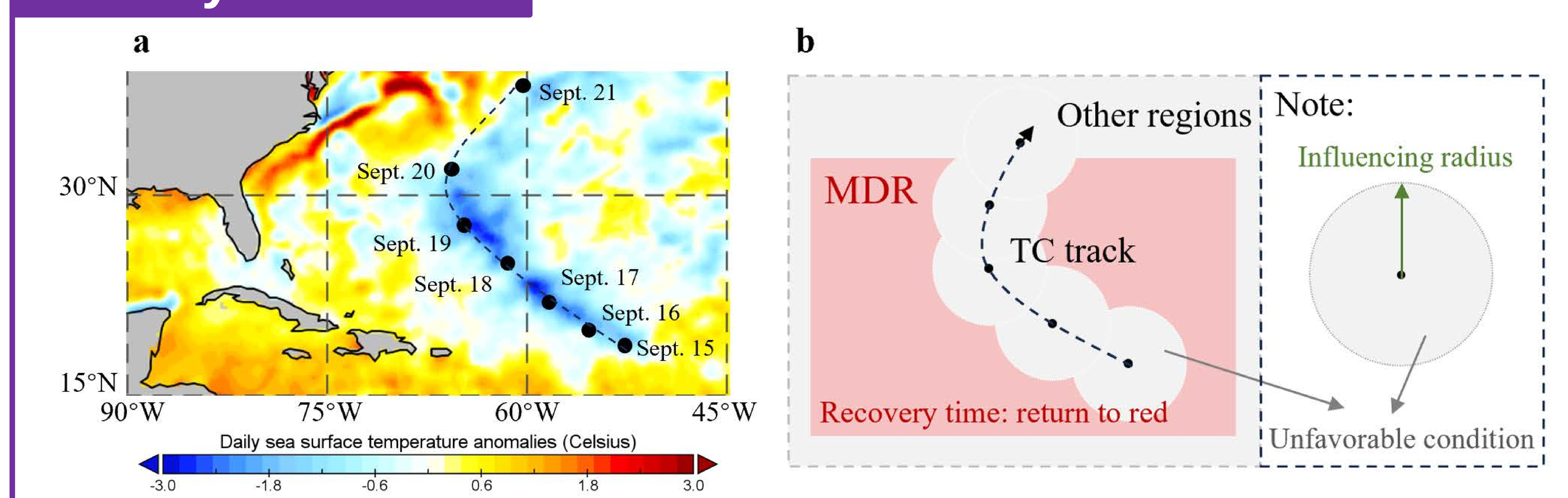


Figure 3. (a) Spatial distribution of SST anomalies showing the cold wake with TC track on Sept. 21, 2010 (TC Igor). (b) The schematic diagram of the toy model. The main development region (MDR, red areas) with the recovery time and influencing radius is shown.

- **Assumption:** the specific spatial and temporal extent after the passage of a TC does not support subsequent TC formation: grids within this radius and time frame are temporarily marked unfavorable (Figure 3).

Genesis part → Moving part → Lysis part

Incorporating the global MDR, recovery time and influencing radius

Using Monte Carlo sampling Based on observations

Table 1. Experimental design

Parameter	Unit	Range
Recovery time	Day	6, 10, 13, 15, 17, 19, 21, 23, 26, 30
Influencing radius	Degree	4, 6, 8, 10, 12, 14, 16
Speed coefficient	Unitless	0.4, 0.6, 0.8, 1 (reference), 1.2, 1.4, 1.6

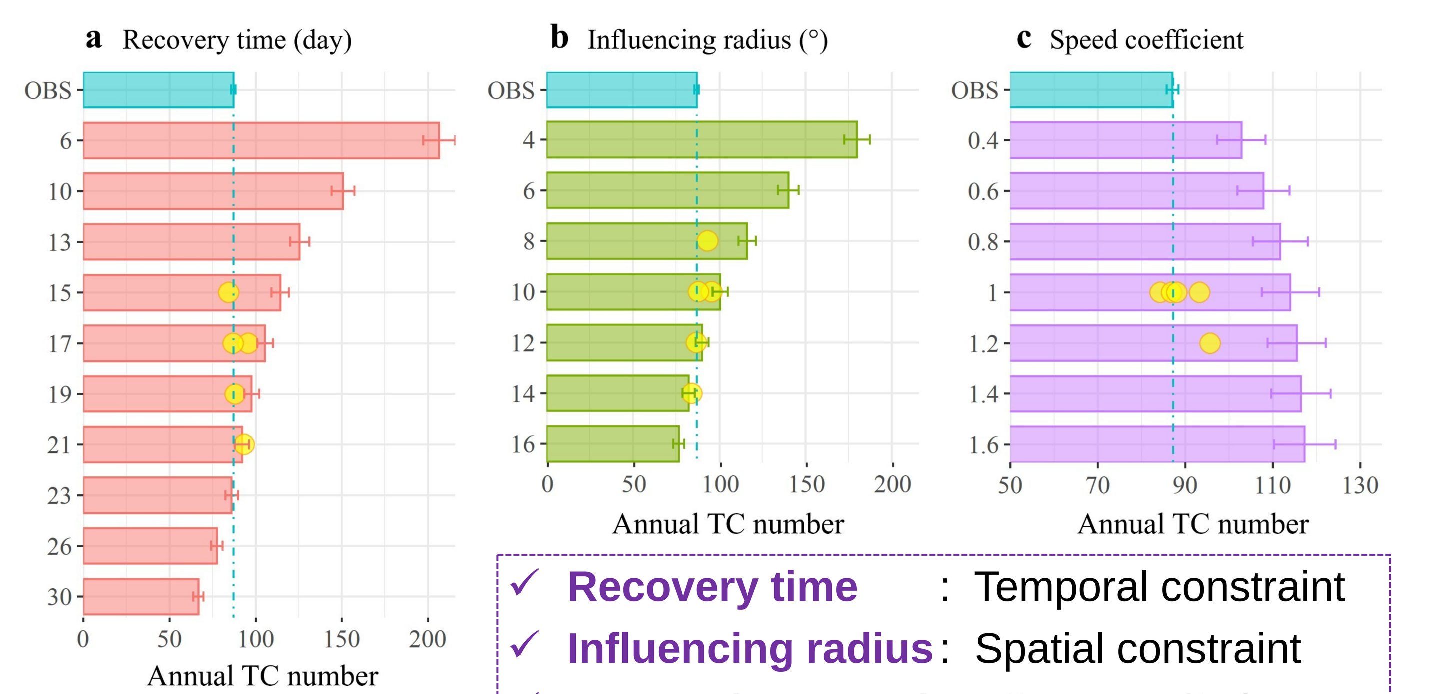
Reference

1. Emanuel, K. A. (2013). Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(30), 12219-12224. https://doi.org/10.1073/pnas.1301293110
2. Hoogewind, K. A., Chavas, D. R., Schenkel, B. A., & O'Neill, M. E. (2020). Exploring Controls on Tropical Cyclone Count through the Geography of Environmental Favorability. *Journal of Climate*, *33*(5), 1725-1745. https://doi.org/10.1175/jcli-d-18-0862.1
3. Vu, T. A., Kieu, C., Chavas, D., & Wang, Q. (2021). A Numerical Study of the Global Formation of Tropical Cyclones. *Journal of Advances in Modeling Earth Systems*, *13*(1). https://doi.org/10.1029/2020ms002207

Results

- Longer recovery times, larger influencing radii and slower translation speed lead to decreased TC numbers.

Figure 4. Histograms of annual TC numbers with each parameter in the toy model.



✓ **Recovery time** : Temporal constraint
✓ **Influencing radius**: Spatial constraint
✓ **Translation speed** : Affect TC Lifetime

- Parameter combinations producing reasonable TC activities are consistent with observational evidence (Table 2). Influencing radius of ~**10°** is similar to the ~900 km outer wind size of TCs, and the recovery time of **2-3 weeks** is consistent with the recovery time in observations.

Table 2. The results of parameter combinations that are consistent with the observed TC activity (by the K-S test, yellow points in Figure 4).

	Recovery time	Influencing radius	Speed coefficient	Annual number
1	15 days	14°	1	84.2
2	17 days	10°	1.2	95.6
3	17 days	12°	1	86.8
4	19 days	10°	1	88.0
5	21 days	8°	1	93.2

Scaling

- The proposed scaling of the global annual TC number (TCN) refines the approach by Hoogewind et al. (2020).

Sum of daily TC numbers Under densely-packed scenario

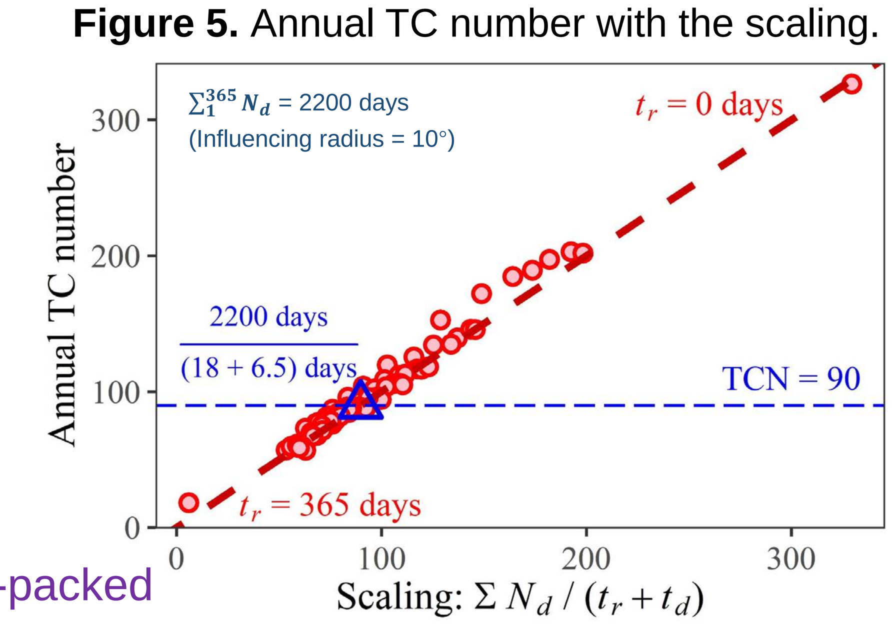
$$\boldsymbol{TCN} = \frac{\sum_1^{365} N_d}{t_d + t_r}$$

Typical lifetime

Added Recovery time

$t_r = 0$: densely-packed

Figure 5. Annual TC number with the scaling.



- ☐ Influencing radius ⇒ $\sum_1^{365} N_d(10°) \approx 2200$ days
- ☐ Recovery time ⇒ $t_r = 18$ days
- ☐ Typical lifetime ⇒ $t_d = 6.5$ days

⇒ $\boldsymbol{TCN \approx 90}$

Discussion

- **Future projection:** Increase in TC size, slowdown in translation speed, and prolonged recovery time (e.g., the increased saturation deficits with warming, Emanuel, 2013), would reduce the annual number of TCs.
- **Temporal constraint:** The cyclical pattern (recovery time) of TC genesis offers valuable insight into understanding the global TC number (Vu et al., 2021) and may be linked to the clustering of TC genesis.
- **Air-sea interactions:** It is advocated to run simulations in coupled modes to better capture TC-environment interactions, such as cold wakes and their associated environmental changes.