Supporting Information for

A Spontaneous Synthetic Tropical Cyclone Model Empowered by NeuralGCM for Hazard Assessment

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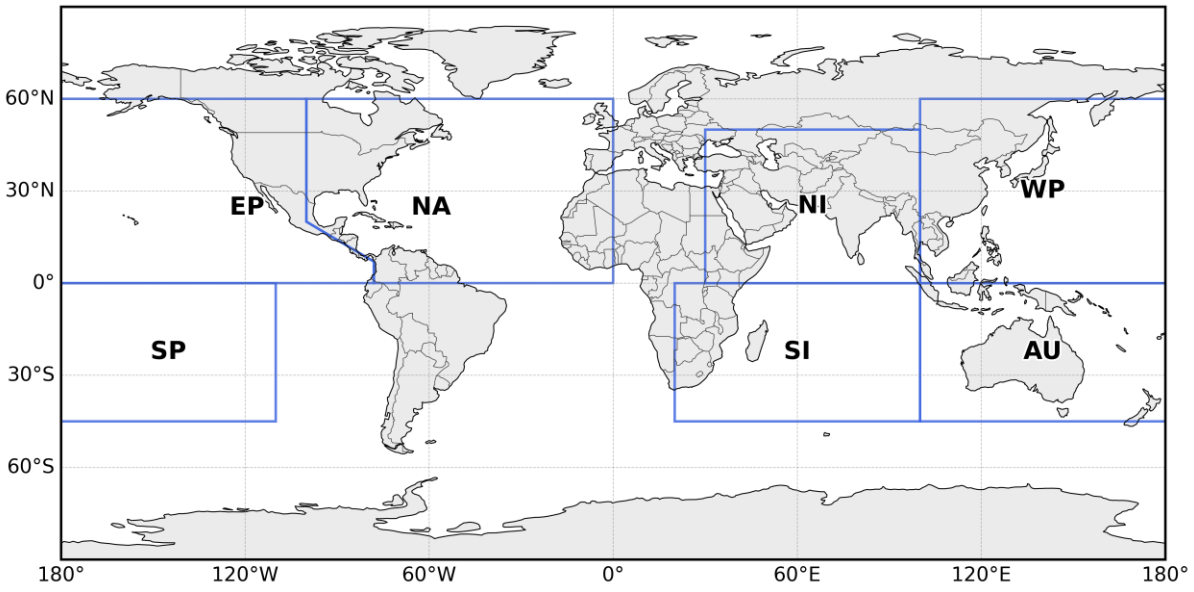

Figure S1. Basin boundaries as defined in this study.

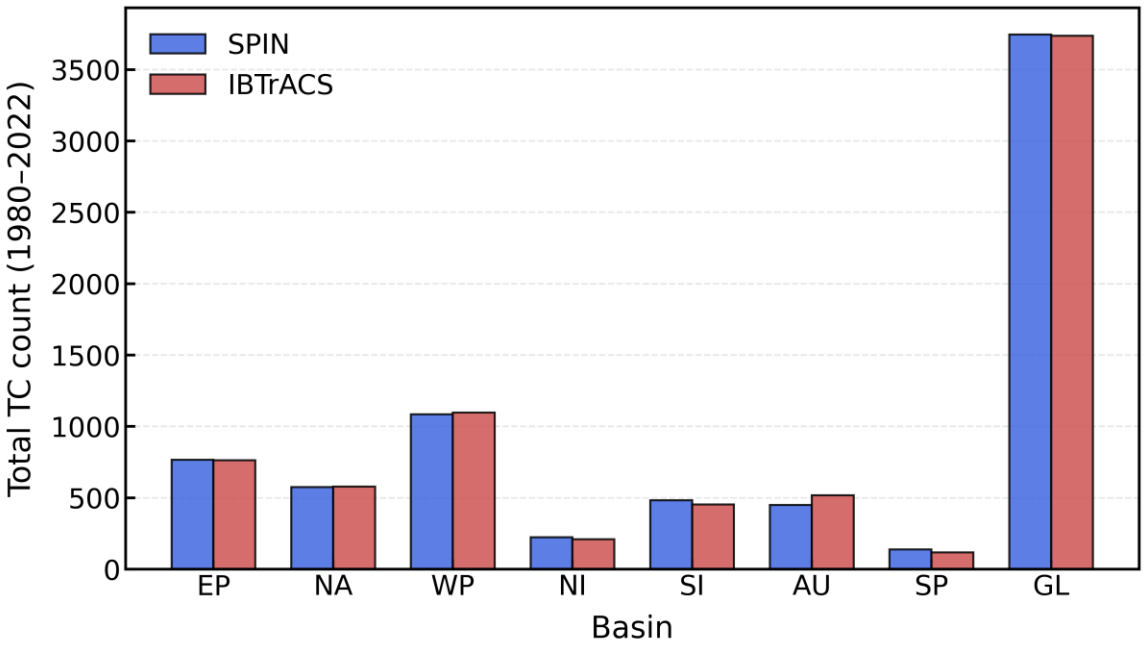

Figure S2. Comparison of total tropical cyclone (TC) counts from 1980–2022 between IBTrACS (red) and the 14-member SPIN ensemble mean (blue) across basins.

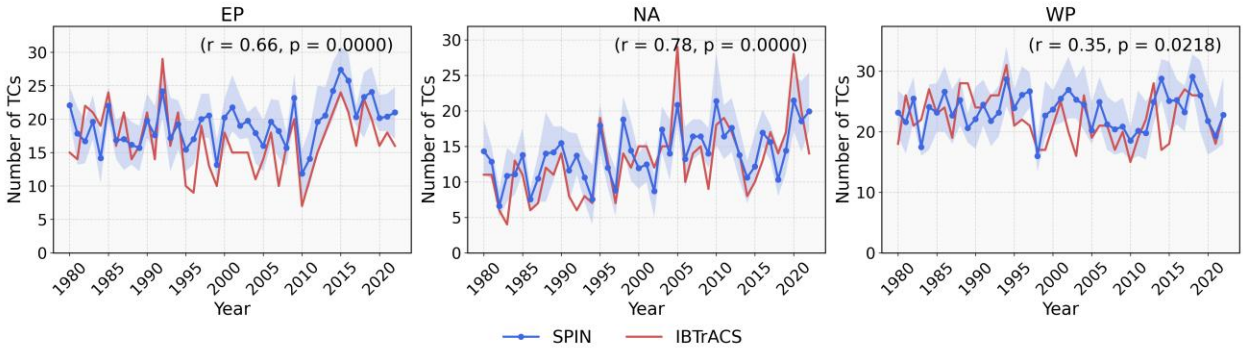

Figure S3. Interannual variability of TC counts by basin during June–December for 1980–2022. The blue line shows the ensemble mean of 14-member SPIN simulations initialized in early April at 6-hour intervals, with shading indicating the 10th–90th percentile range, and observations are shown in red. Pearson correlation coefficients (with significance levels) are reported in the upper-right of each panel.

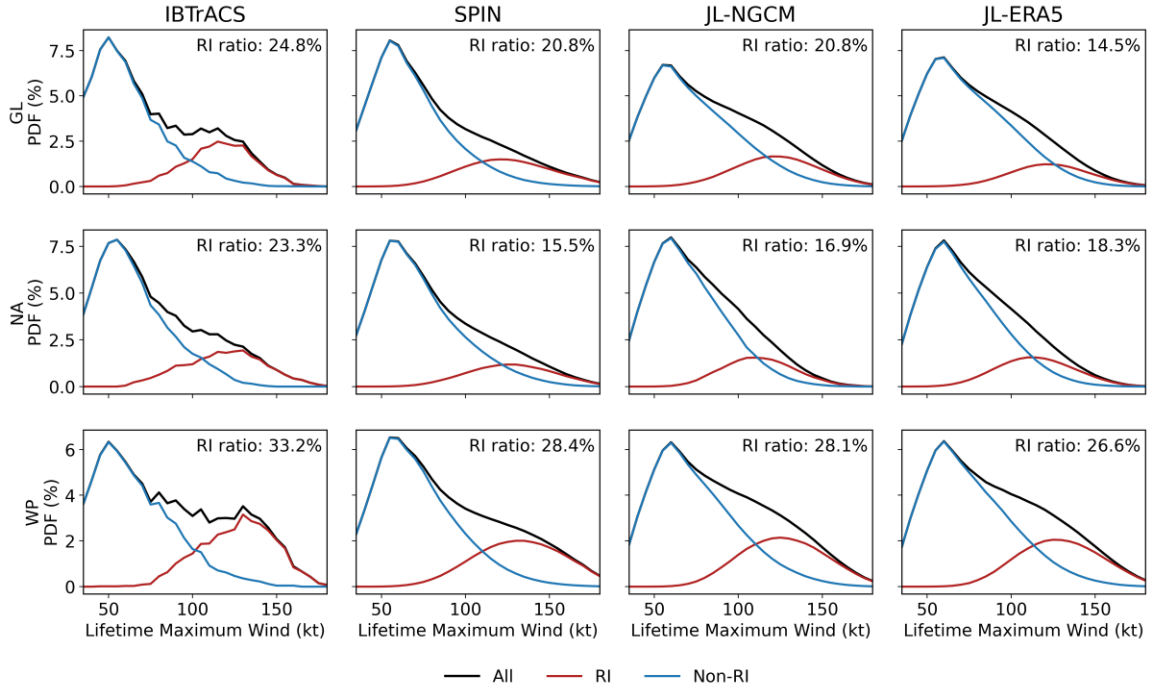

Figure S4. Distributions of TC lifetime maximum intensity (LMI) for rapid intensification (RI) and non-RI cases (1980–2022). Columns show IBTrACS, SPIN ensemble mean, JL23-downscaled NeuralGCM, and JL23-downscaled ERA5. For both JL-downscaled NeuralGCM and ERA5, the number of TCs is obtained by sub-sampling the downscaling events to match the number of observed events. Rows correspond to GL, NA, and WP basins. RI ratios are given in the upper-right of each panel.

Basin	Model	$D_{\mathrm{KL}}(M \parallel O)$	ACDFs
GL	SPIN	0.029	-1.207
	JL-ERA5	0.034	-1.009
	JL-NGCM	0.026	-1.071
NA	SPIN	0.009	-3.353
	JL-ERA5	0.029	-3.133
	JL-NGCM	0.035	-1.385
WP	SPIN	0.027	-0.853
	JL-ERA5	0.029	-1.355
	JL-NGCM	0.027	-1.414

Table S1. Evaluation of model-simulated LMI (1980-2022) using the Kullback–Leibler (KL) divergence $\boldsymbol{D_{\mathrm{KL}}(M \parallel O)}$ and the area between cumulative distribution functions (ACDFs) of the model and observations, shown across basins for SPIN, JL23-downscaled ERA5, and JL23-downscaled NeuralGCM.

Basin	Model	$D_{\mathrm{KL}}(M \parallel O)$	ACDFs	ACDFs (0-5 day)
EP	SPIN	0.032	1.17	0.31
	IBTrACS (uniform)	0.031	0.46	0.47
NA	SPIN	0.018	0.86	-0.06
	IBTrACS (uniform)	0.019	1.35	0.28
WP	SPIN	0.007	-0.33	-0.02
	IBTrACS (uniform)	0.027	0.61	0.48
NI	SPIN	0.056	0.57	-0.05
	IBTrACS (uniform)	0.168	5.44	0.63
SI	SPIN	0.021	1.26	0.22
	IBTrACS (uniform)	0.055	2.06	0.50
AU	SPIN	0.014	-0.53	-0.24
	IBTrACS (uniform)	0.031	1.36	0.25
SP	SPIN	0.062	-0.79	-0.18
	IBTrACS (uniform)	0.073	2.89	0.27

Table S2. Evaluation of model-simulated TC inter-genesis dates (1980-2022) using the Kullback–Leibler (KL) divergence $\boldsymbol{D_{\mathrm{KL}}(M \parallel O)}$, and the area between cumulative distribution functions (ACDFs) of the model and observations for all bins and 0-5day bin. Results are shown across basins for SPIN and IBTrACS with uniformly sampled dates.