

Supplement to: A Process-Based Evaluation Metric for the Pacific–Japan Pattern (PJEM) and its Influence on Asian Summer Extreme

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This supplement provides additional figures and a table that support the results presented in the main manuscript. The supplementary material consists of one table listing the CMIP6 models used in this study (Table S1) and eleven figures (Fig. S1–S11) that show further details of the Pacific–Japan (PJ) pattern evaluation, including individual-model regression patterns, vertical structures, and additional sensitivity tests.

Supplementary Table

Table S1. List of CMIP6 historical simulations used for the analysis evaluated herein. The model name (acronym), institution, and list of available model variables are summarized. Variable codes follow CMIP6 conventions: *ua/va* (zonal/meridional wind), *zg* (geopotential height), *hus* (specific humidity), *pr* (precipitation), *tas* (near-surface air temperature), *rlut* (outgoing longwave radiation), *tos* (sea surface temperature).

No.	Model (acronym)	Institution	Variables					
			<i>ua/va</i>	<i>zg</i>	<i>hus</i>	<i>pr</i>	<i>tas</i>	<i>rlut/tos</i>
1	ACCESS-CM2	CSIRO/Bureau of Meteorology, Australia	o	o	o	o	o	o
2	BCC-ESM1	Beijing Climate Center, China	o	o	o	o	o	o
3	CESM2	NCAR, USA	o	o	o	o	o	o
4	CESM2-FV2	NCAR, USA	o	o	o	o	o	o
5	CESM2-WACCM	NCAR, USA	o	o	o	o	o	o
6	CanESM5	CCCma, Canada	o	o	o	o	o	o
7	EC-Earth3	EC-Earth Consortium, ECMWF	o	o	o	o	o	o
8	FGOALS-f3-L	IAP, Chinese Academy of Sciences	o	o	o	o	—	—
9	FGOALS-g3	IAP, Chinese Academy of Sciences	o	o	o	o	o	—
10	GFDL-CM4	NOAA/GFDL, USA	o	o	o	o	o	—
11	GISS-E2-1-G	NASA/GISS, USA	o	o	—	—	o	—

12	IITM-ESM	Indian Institute of Tropical Meteorology	o	o	o	o	o	—
13	INM-CM4-8	Institute for Numerical Mathematics, Russia	o	o	o	o	o	—
14	INM-CM5-0	Institute for Numerical Mathematics, Russia	o	o	o	o	o	—
15	IPSL-CM6A-LR	IPSL, France	o	o	o	o	o	o
16	IPSL-CM6A-LR- INCA	IPSL, France	o	o	o	—	o	—
17	MPI-ESM-1-2-HAM	MPI for Meteorology, Germany	o	o	o	o	o	o
18	MPI-ESM1-2-HR	MPI for Meteorology, Germany	o	o	o	o	o	o
19	MPI-ESM1-2-LR	MPI for Meteorology, Germany	o	o	o	o	o	o
20	MRI-ESM2-0	MRI, Japan	o	o	o	o	o	o
21	NorESM2-LM	Norwegian Climate Centre	o	o	o	—	—	o
22	NorESM2-MM	Norwegian Climate Centre	o	o	o	—	—	o
23	TaiESM1	Academia Sinica, Taiwan	o	o	o	o	o	—

Notes. The 'o' indicates that the variable is available for the model; '—' indicates the variable is unavailable. Only the first ensemble member (r1i1p1f1) was used for each model.

Supplementary Figures

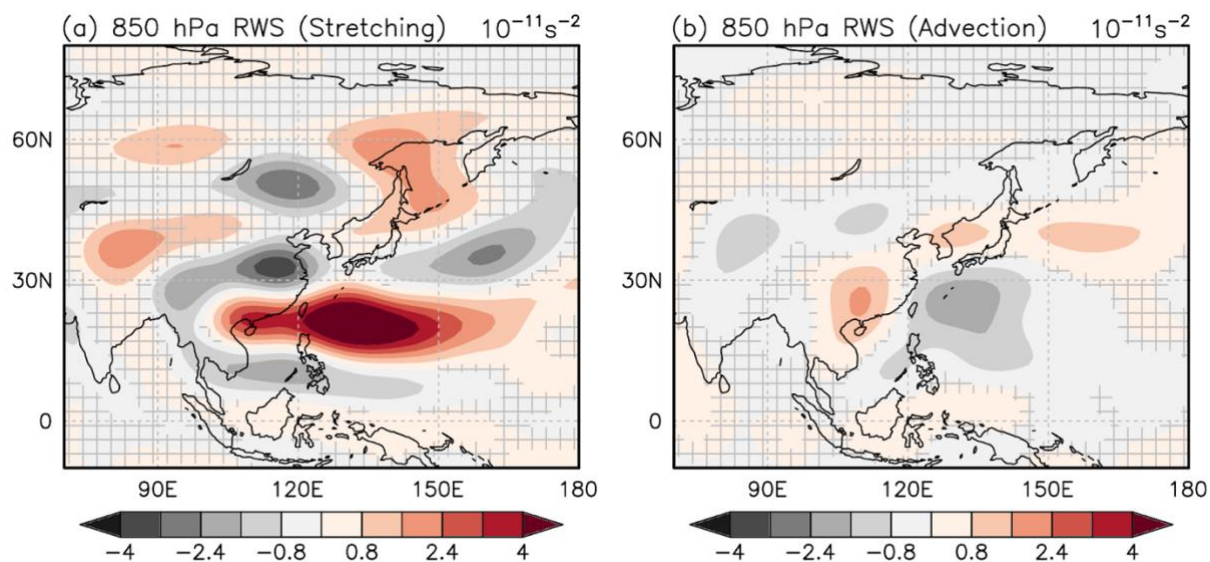


Figure S1. Regression coefficients of 850 hPa Rossby wave source onto the negative Pacific–Japan (PJ) index: (a) stretching component (10^{-11} s^{-2}) and (b) advection component (10^{-11} s^{-2}). The gray hatch represents statistically non-significant areas at the 95 % confidence level. The wave source is predominantly contributed by the stretching component over the subtropical western Pacific, indicating that convergent/divergent flow associated with deep convection is the dominant generator of PJ-related Rossby waves.

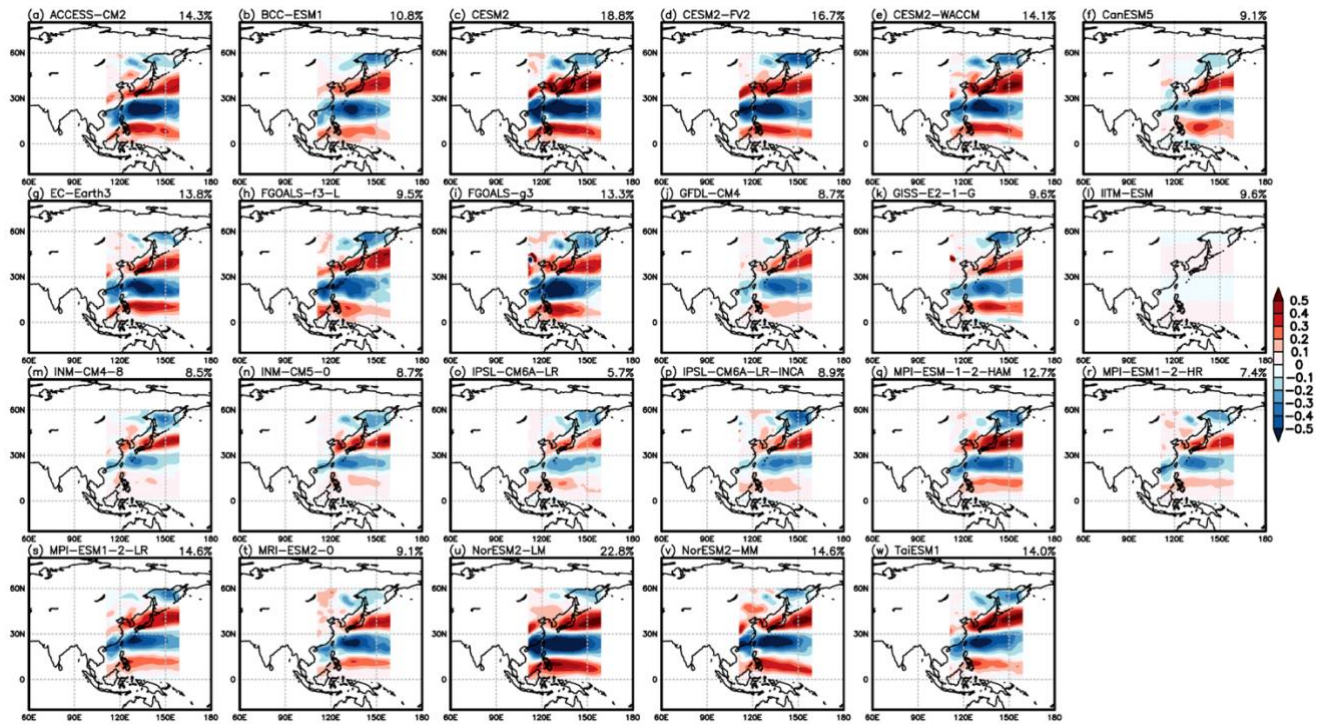


Figure S2. Regression coefficients of the Pacific–Japan (PJ) pattern for the interannual timescale obtained using the common basis function (CBF) approach for 23 CMIP6 models. Each panel represents a different model, showcasing the spatial distribution of the regression coefficients and highlighting the variability captured by each model in simulating the PJ pattern. The percentage variance explained by each model is indicated at the top-right of each panel.

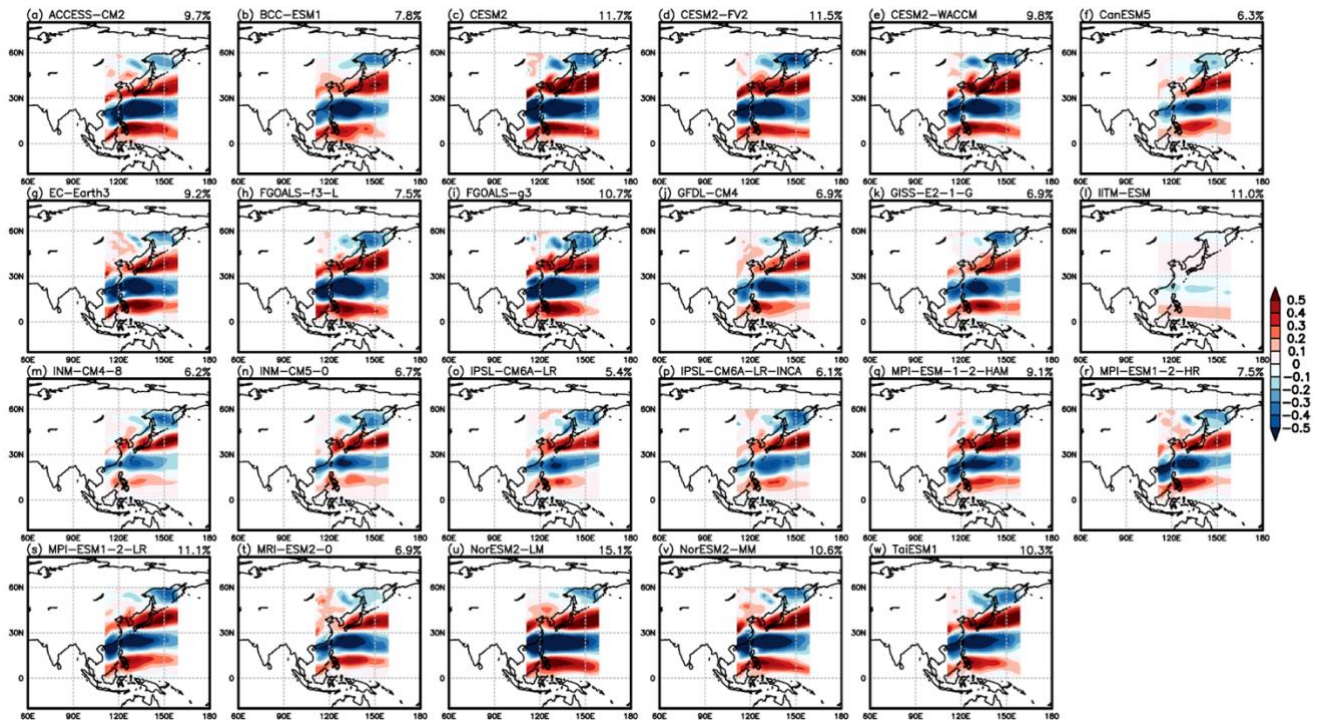


Figure S3. Same as Fig. S2, but for the intraseasonal timescale.

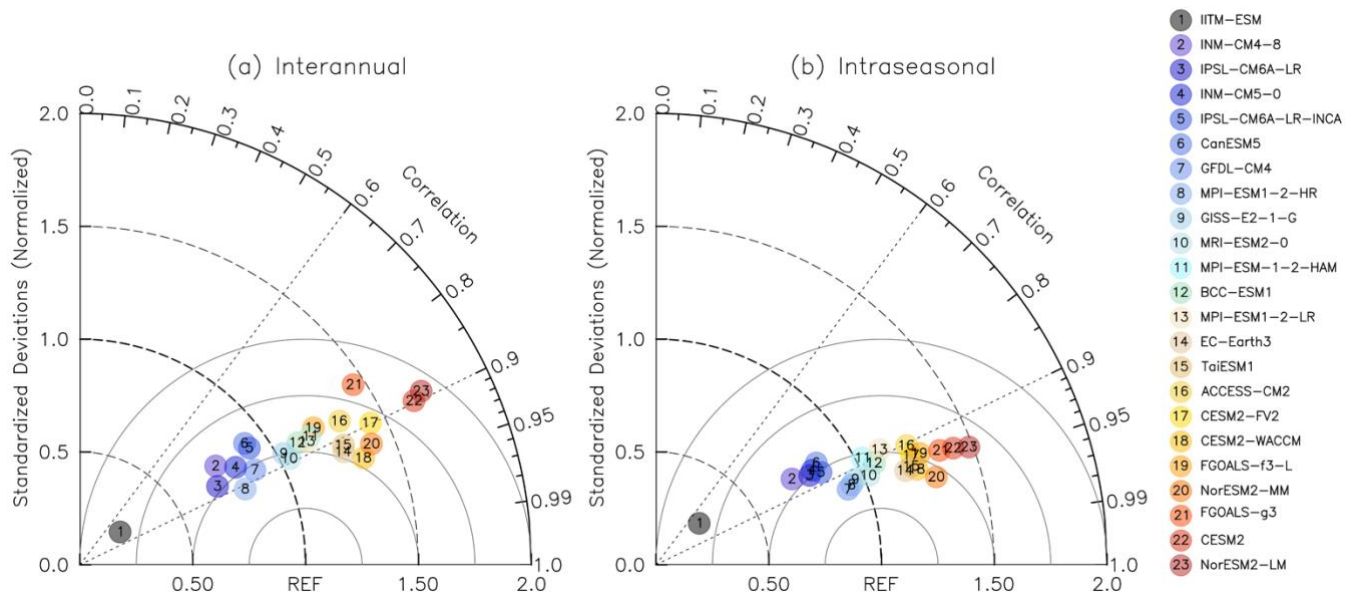


Figure S4. Taylor diagrams presenting the performance of 23 CMIP6 models at (a) interannual and (b) intraseasonal timescales based on the CBF approach. The diagrams depict the normalized standard deviations and pattern correlations of the simulated PJ relative to the ERA5 reference (REF). All models exhibit pattern correlations greater than 0.8, but amplitudes vary widely from 25 to 170 % of observations.

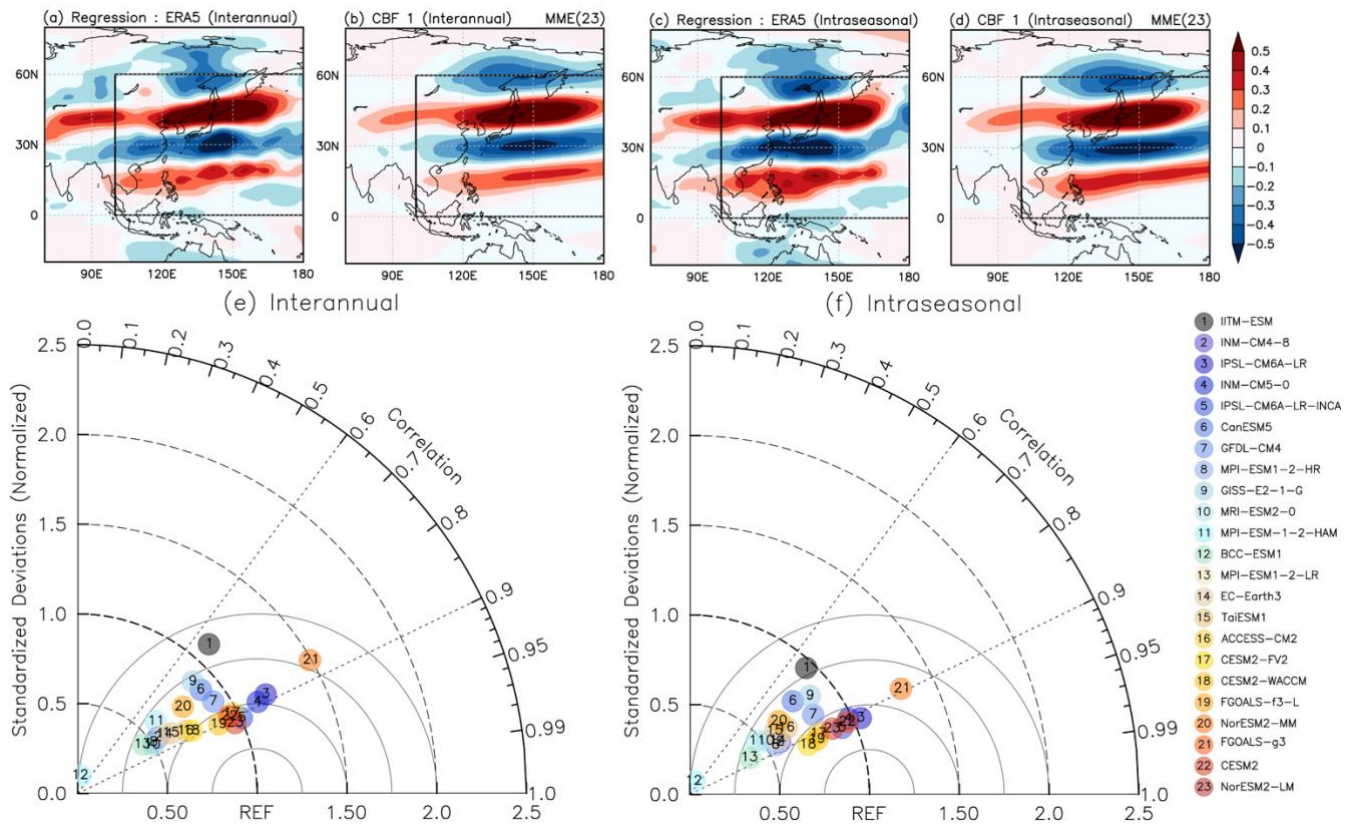


Figure S5. (a–d) Spatial distribution of 200 hPa geopotential height anomalies regressed onto the PJ PC time series for (a, b) interannual and (c, d) intraseasonal timescales. Panels (a, c) show ERA5, and (b, d) show the ensemble mean of the CMIP6 models. Taylor diagrams for the 200 hPa geopotential patterns of individual models on (e) interannual and (f) intraseasonal timescales. The properties of the Taylor diagrams are computed within the black box shown in panels (a–d).

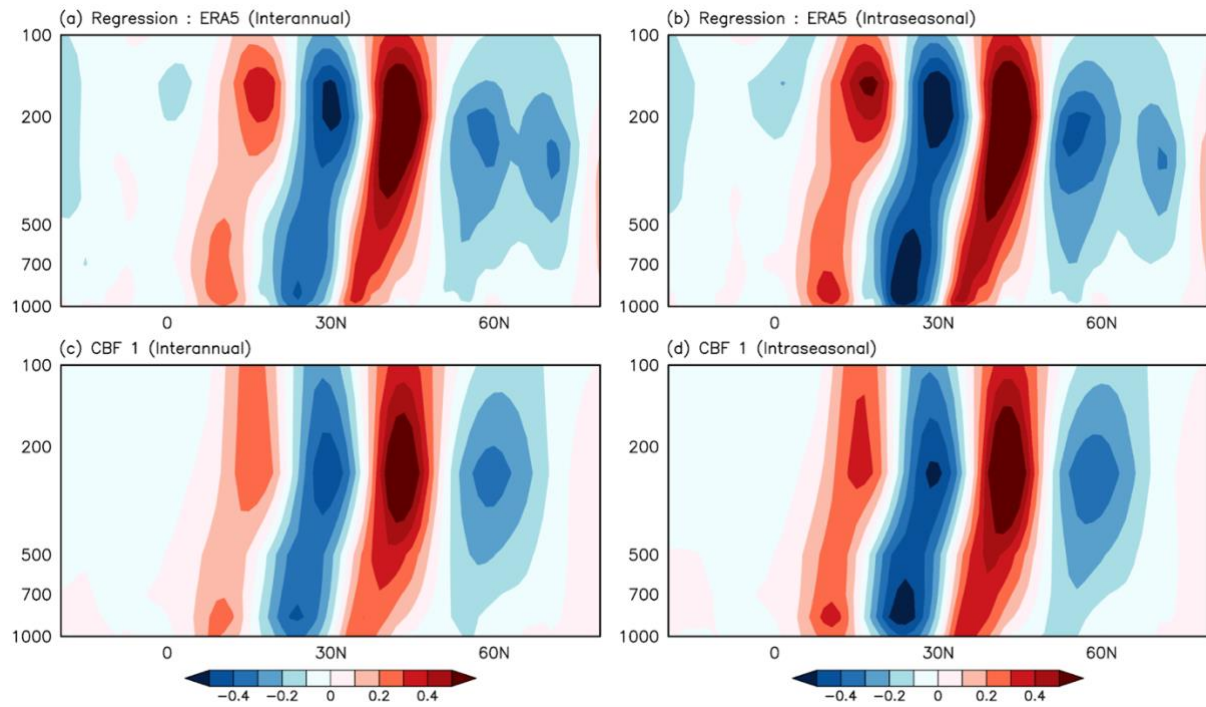


Figure S6. Meridional cross-sections of geopotential height regressed onto the PJ PC time series for (left) interannual and (right) intraseasonal timescales. The upper panels show ERA5, and the lower panels show the ensemble mean of CMIP6 models. The cross-sections are averaged over the longitude range of 120° – 150° E. The northward-tilted baroclinic structure is broadly reproduced by the MME, although with slight intensity underestimation and a northward shift in the upper troposphere.

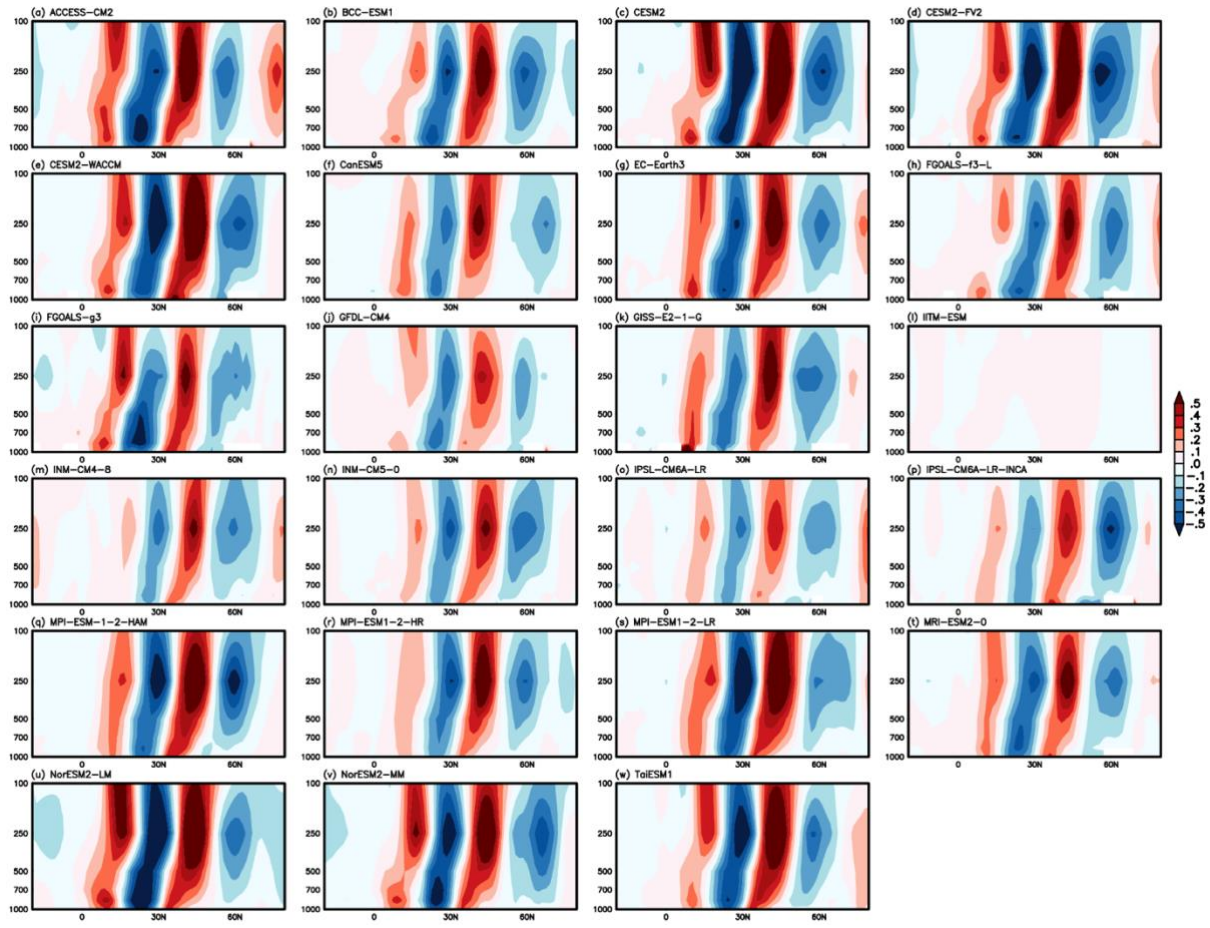


Figure S7. Vertical cross-section regression coefficients of the Pacific–Japan (PJ) pattern for the interannual timescale obtained using the CBF approach for 23 CMIP6 models. Each panel represents a different model, showcasing the spatial distribution of the regression coefficients and highlighting the diversity in the simulated vertical structure of the PJ pattern across models.

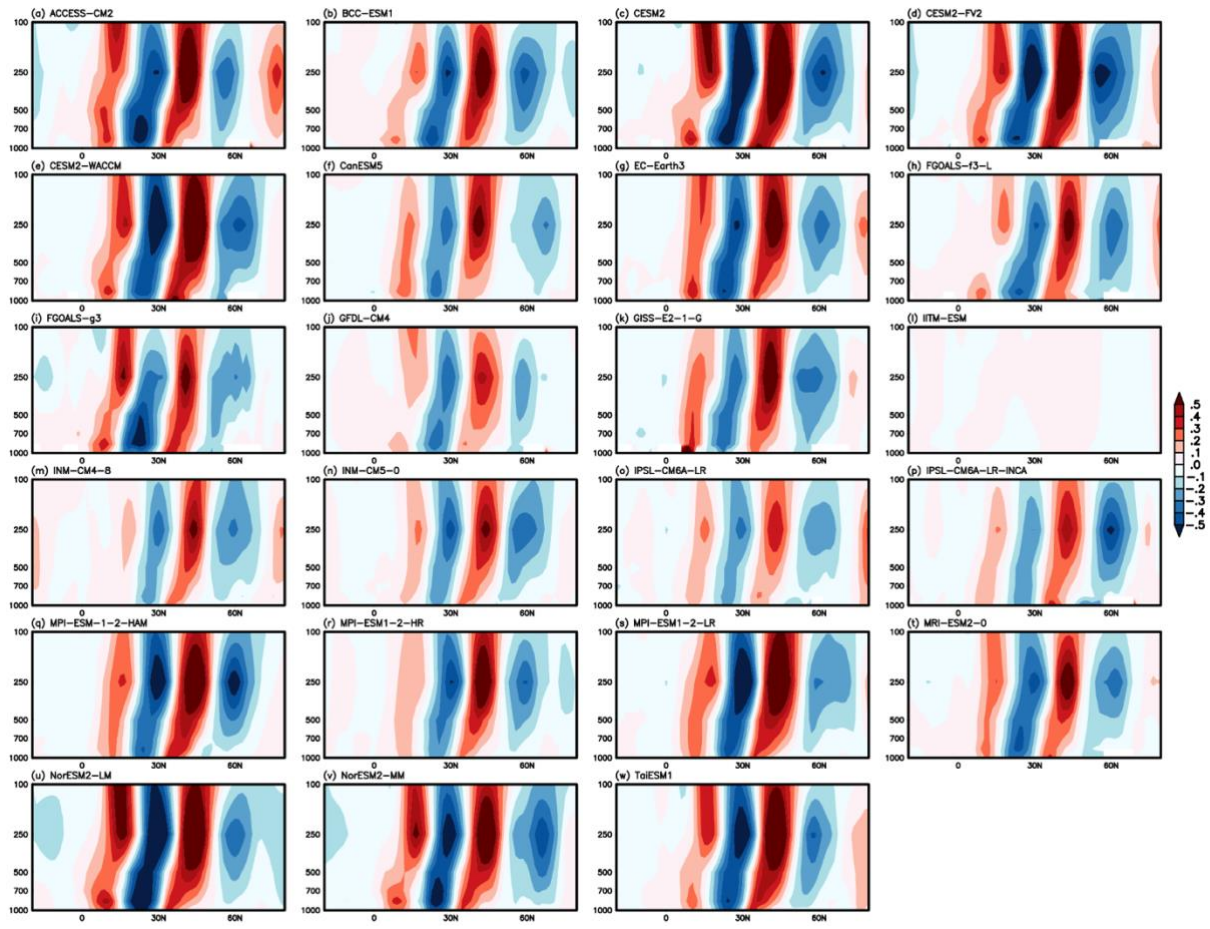


Figure S8. Same as Fig. S7, but for the intraseasonal timescale.

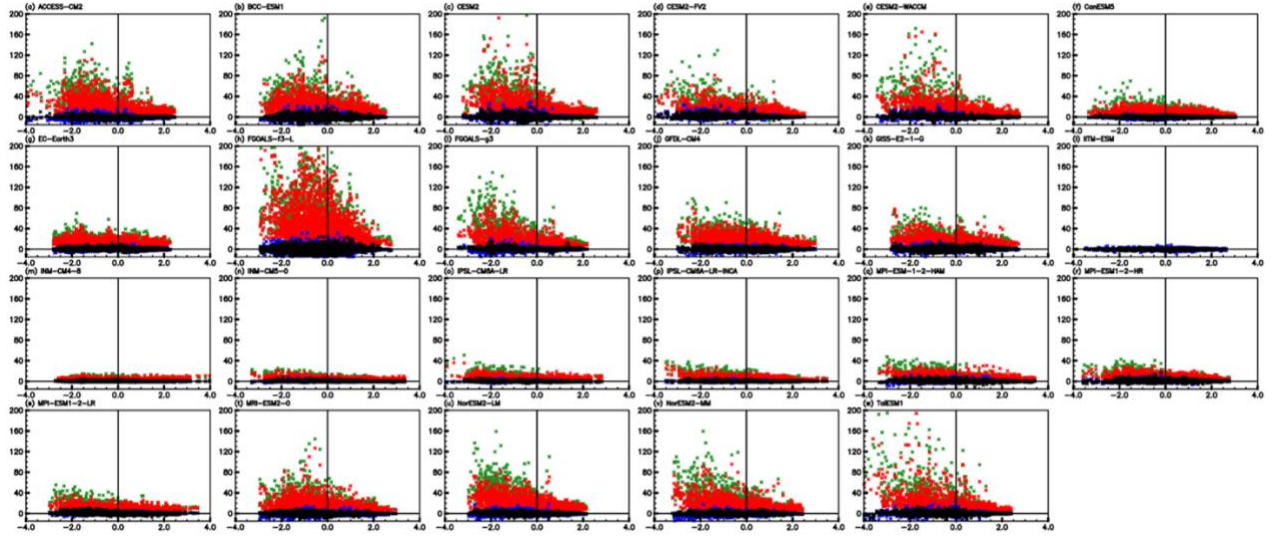


Figure S9. Scatter plots of the Pacific–Japan indices versus the meridional component of the 850 hPa wave activity flux (F_y , $\text{m}^2 \text{s}^{-2}$) over the Philippine Sea region (black box in Fig. 9c of the main text) for 23 CMIP6 models. Each panel represents a different model, with the model identifier shown in the top-left corner of each subplot. The colored dots represent different terms in the F_y decomposition: black and blue dots show the zonal momentum and geopotential flux terms, while red and green dots show the meridional momentum and geopotential flux terms, respectively. The phase-dependent asymmetry in wave propagation between positive and negative PJ phases is evident across most models.

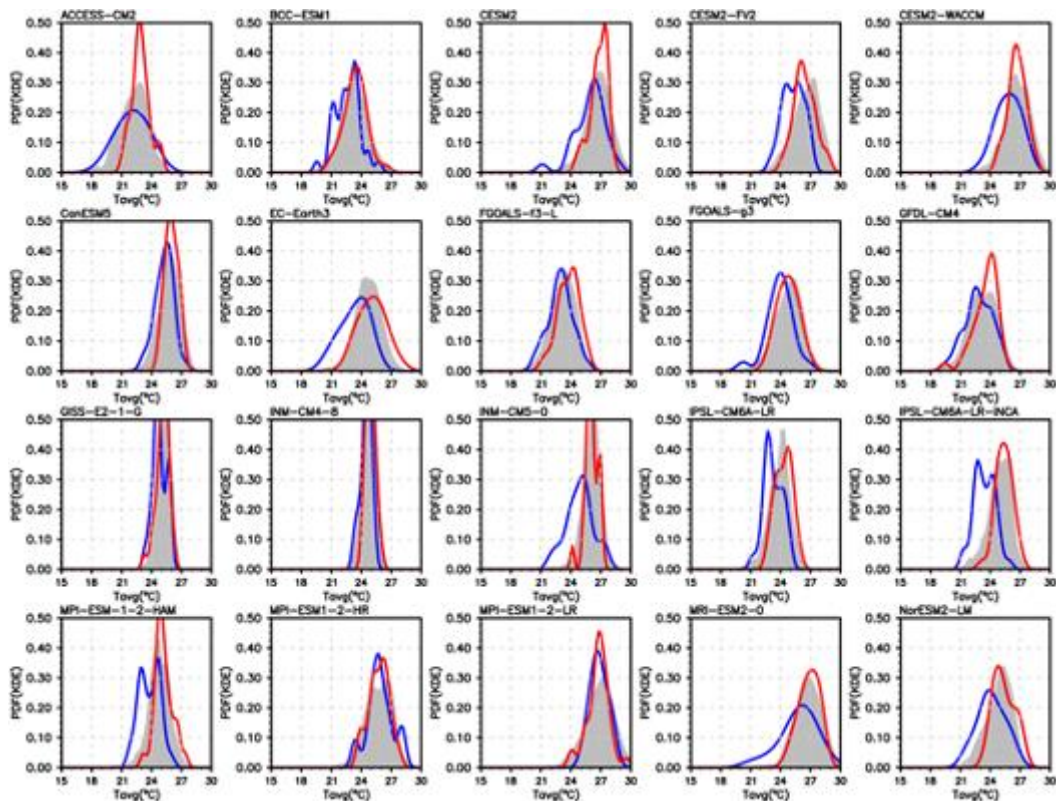


Figure S10. Probability density functions (PDFs) of surface temperature for 23 CMIP6 models. Each panel displays the PDF for a different model, showing the distribution of surface temperature averaged over the East Asian box region (30°–45° N, 120°–160° E). The gray shading represents the distribution under neutral PJ conditions, the blue lines indicate the distribution under positive PJ phases, and the red lines represent the distribution under negative PJ phases. The phase-dependent shift toward warmer values during negative PJ phases is consistently reproduced across most models.

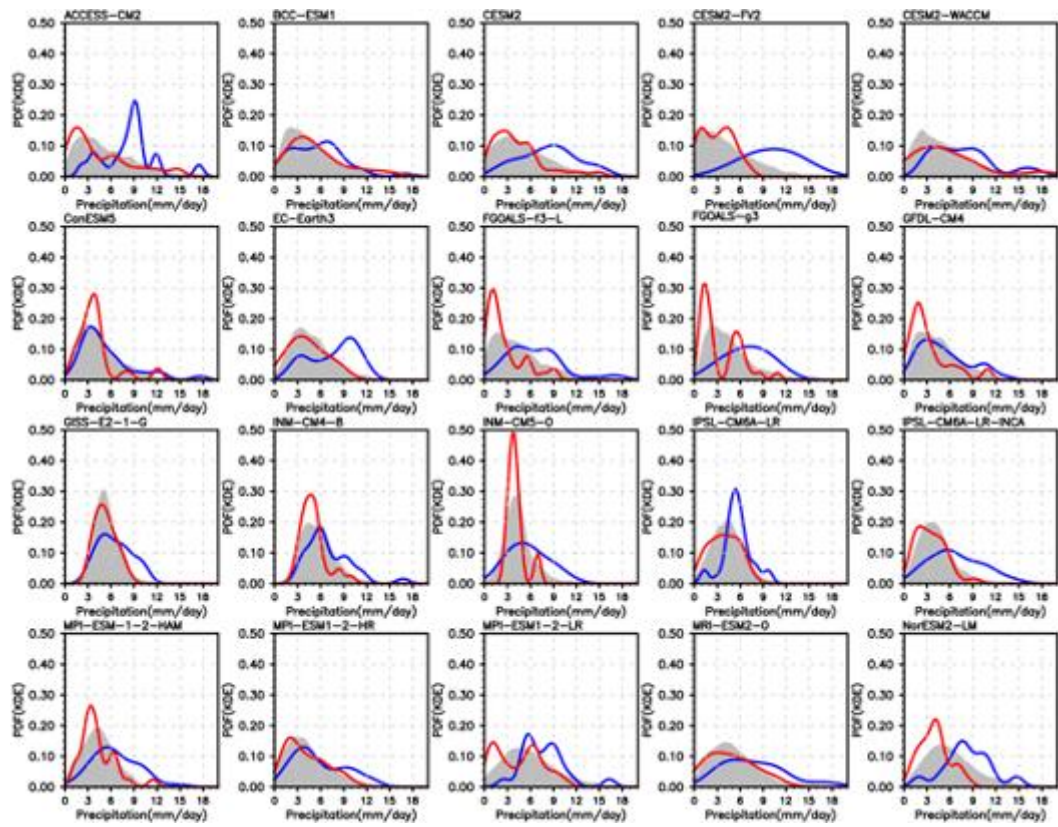


Figure S11. Same as Fig. S10, but for total precipitation (mm day^{-1}) averaged over the East Asian precipitation box region (30° – 40° N, 110° – 150° E).