Supplement of Earth Syst. Dynam., 17, 1687–1702, 2026
https://doi.org/10.5194/esd-17-1687-2026-supplement
© Author(s) 2026. CC BY 4.0 License.



Earth System Dynamics
Open Access
EGU

Supplement of

Climate suitability of East Asian mangroves for nature-based solutions is limited by climate extremes

Ran Chen et al.

Correspondence to: Jin-Soo Kim (jinsoo@kaist.ac.kr) and Jung-Eun Chu (jungeunchu@snu.ac.kr)

The copyright of individual parts of the supplement might differ from the article licence.

Supplementary Material

Table S1. Mangrove species combinations in the three zones

Zone	Species combination
Northern zone	*Kandelia obovata, Aegiceras corniculatum, Avicennia marina, Sonneratia apetala, Laguncularia racemosa*
Middle zone	*Bruguiera gymnorhiza, Sonneratia caseolaris, Rhizophora stylosa, K. obovata, A. corniculatum, A. marina, S. apetala, Lag. racemosa*
Southern zone	*Bruguiera sexangula, Rhizophora apiculata, Lumnitzera racemosa, Sonneratia alba, Ceriops tagal, B. gymnorhiza, S. caseolaris, R. stylosa, K. obovata, A. corniculatum, A. marina, S. apetala, Lag. racemosa*

*Data from Zhao, C., Jia, M., Zhang, R., Wang, Z., Ren, C., Mao, D., and Wang, Y.: Mangrove species mapping in coastal China using synthesized Sentinel-2 high-separability images, Remote Sensing of Environment, 307, 114151, https://doi.org/10.1016/j.rse.2024.114151, 2024.

Table S2. List of the CMIP6 ESMs used in this research

Model	Modelling Center (or Group)
ACCESS-CM2	Commonwealth Scientific and Industrial Research Organization, Australia
ACCESS-ESM1-5	Commonwealth Scientific and Industrial Research Organization, Australia
AWI-CM-1-1-MR	Alfred Wegener Institute, Germany
BCC-CSM2-MR	Beijing Climate Center, China
CAMS-CSM1-0	China Meteorological Administration, China
CAS-ESM2-0	Chinese Academy of Sciences, China
CESM2-WACCM	National Center for Atmospheric Research, USA
CMCC-CM2-SR5	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy
CMCC-ESM2	Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy
CanESM5	Canadian Centre for Climate Modelling and Analysis, Canada
EC-Earth3	EC-Earth Consortium, Europe
EC-Earth3-Veg	EC-Earth Consortium, Europe
EC-Earth3-Veg-LR	EC-Earth Consortium, Europe
FGOALS-f3-L	Chinese Academy of Sciences, China
FGOALS-g3	Chinese Academy of Sciences, China
GFDL-ESM4	NOAA Geophysical Fluid Dynamics Laboratory, USA
IITM-ESM	Indian Institute of Tropical Meteorology, India
INM-CM4-8	Russian Academy of Science, Russia

Model	Modelling Center (or Group)
INM-CM5-0	Russian Academy of Science, Russia
IPSL-CM6A-LR	Institut Pierre Simon Laplace, France
KACE-1-0-G	Korea Meteorological Administration, Korea
MIROC6	Japan Agency for Marine-Earth Science and Technology, Japan
MPI-ESM1-2-HR	Max Planck Institute for Meteorology, Germany
MPI-ESM1-2-LR	Max Planck Institute for Meteorology, Germany
MRI-ESM2-0	Meteorological Research Institute, Japan
NorESM2-LM	Norwegian Research Centre, Norway
NorESM2-MM	Norwegian Research Centre, Norway
TaiESM1	Research Center for Environmental Changes, Taiwan, China

Table S3. Comparison of time-lagged effects of climatic factors between mangroves and forests

Zone		Northern				Middle				Southern			
Lag (months)		0	1	2	3	0	1	2	3	0	1	2	3
Mean temperature	DJF	F	F										
	MAM		M	M					M		M	M	M
	JJA	F											
	SON	M	M										
Solar radiation	DJF									M			
	MAM	F					F				M		
	JJA	F		M	M	M							
	SON									F	M/F		

*This result is based on the time-lagged effect test for both mean temperature and solar radiation on mangroves and forests. Filled cells indicate significant lagged associations, with the letter and background color identifying the vegetation type: F with green background stands for forests, M with red background stands for mangroves, M/F with blue background stands for both mangroves and forests.

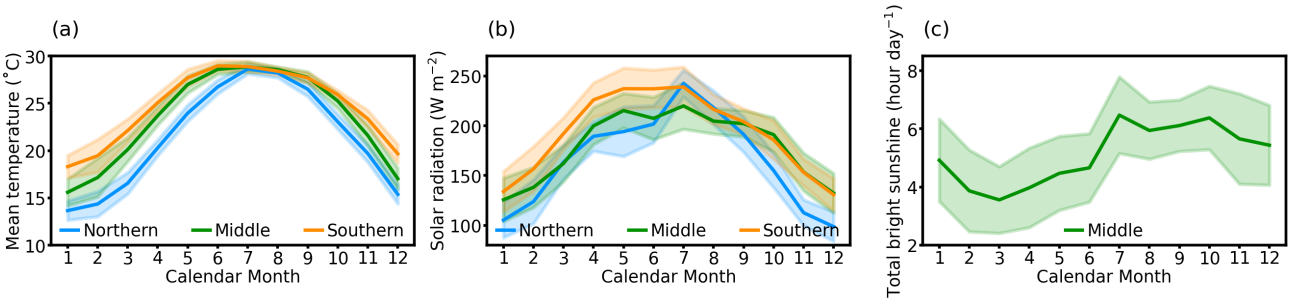


Figure S1. Seasonal cycles of climatic factors from 2001 to 2022. The three climatic factors are mean temperature (a), solar radiation (b) and total bright sunshine (c). Data for the first two climatic factors were obtained from ERA5 data, while the total bright sunshine data were accessed from the Hong Kong Observatory which is located in the middle zone.

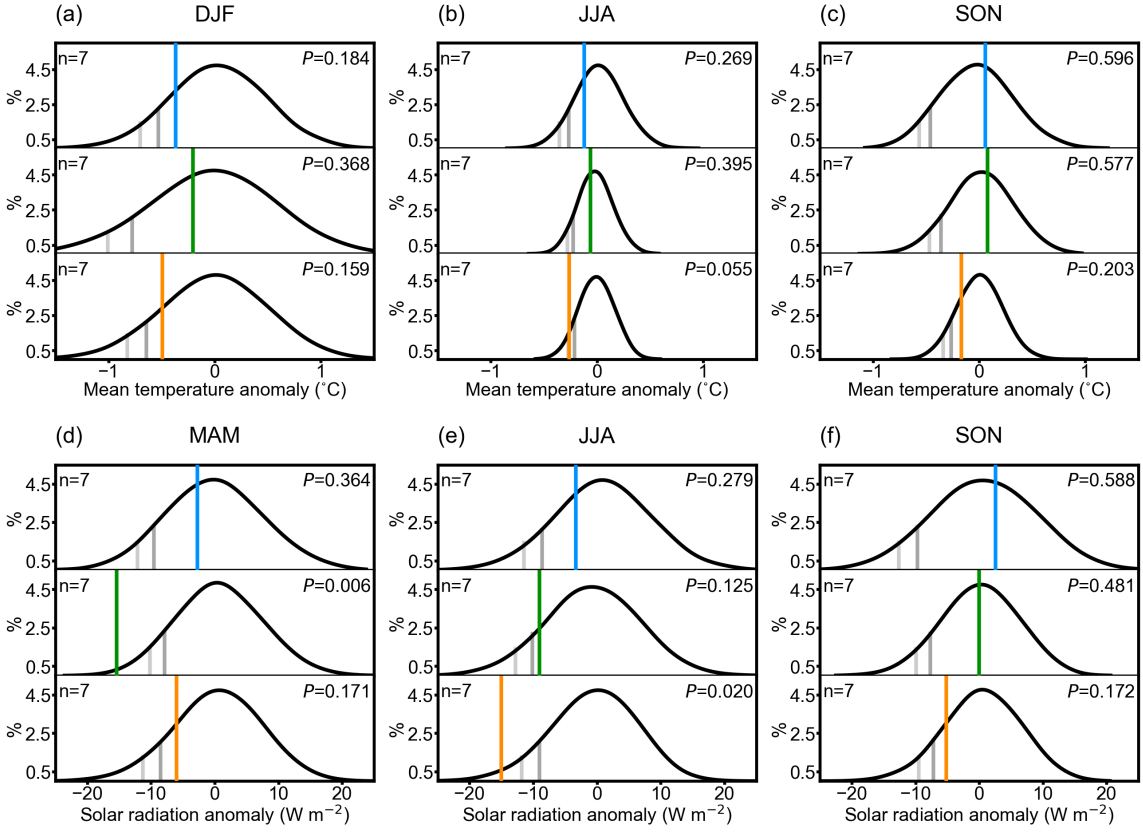


Figure S2. Simultaneous impact of mean temperature and solar radiation on mangrove greenness. Bootstrap distributions for mean temperature and the significance test for extreme low cases are shown for DJF (a), JJA (b), SON (c), while (d), (e) and (f) are for solar radiation. Light gray lines represent $P = 0.05$, and dark gray lines represent $P = 0.1$. In the top left corner, n represents the number of cases selected. In the top right corner, P indicates the P–value result for the cases and is rounded to three decimal places. Different colors indicate different zones: blue for the northern zone, green for the middle zone and orange for the southern zone.

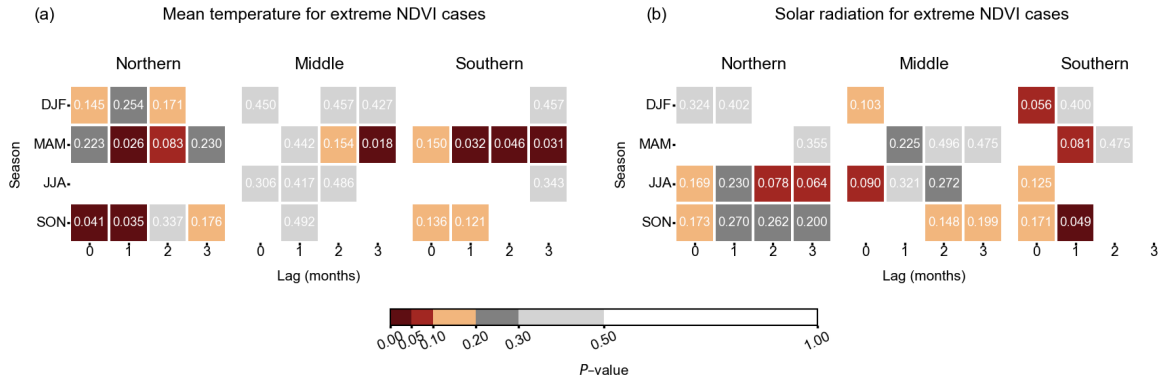


Figure S3. Time-lagged effect of mean temperature and solar radiation on mangrove canopy greenness in seasonal composites. Significance tests for differences in mean temperature (a) and solar radiation (b) between high and low NDVI cases. Lags (τ) on the *x*-axis represent a three-month period that occurs τ months prior to a given season (*y*-axis). Statistical significance ($P < 0.10$) indicates significant lagged associations between climate variables and NDVI extremes, with stronger evidence at $P < 0.05$. All *P*–values are rounded to three decimal places.

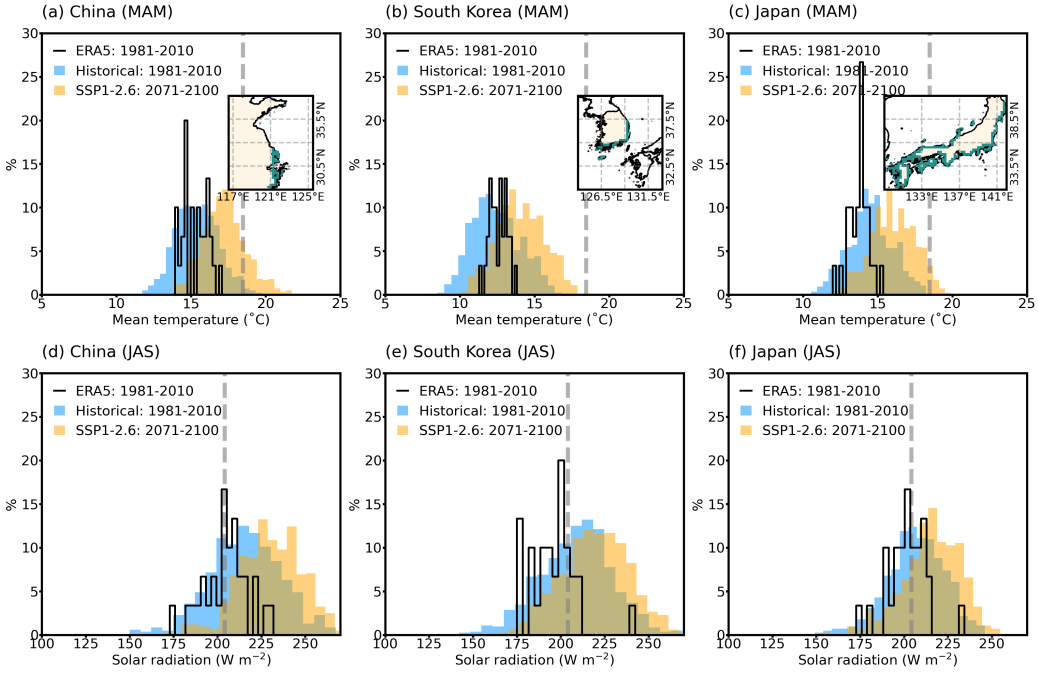


Figure S4. Changes in temperature and solar radiation within the future temperature-defined mangrove range. Histogram of mean temperature comparing ERA5 (1981–2010), CMIP6 historical (1981–2010) and SSP1-2.6 (2071–2100) for future potential mangrove habitats in China (a), South Korea (b) and Japan (c). Same but for solar radiation in China (d), South Korea (e) and Japan (f). The grey dashed lines represent the threshold criteria for high mean temperature (top row) and low solar radiation (bottom row), using the northern zone as the reference standard. The maps delineate potential mangrove habitats under SSP1-2.6 by integrating: (1) current non-mangrove shorelines, and (2) areas where winter (DJF) mean temperatures reach ≥ 10°C in SSP1-2.6 (2071–2100). Other constraints on realized mangrove establishment, including intertidal habitat availability, shoreline hardening, sea-level rise, and dispersal, were not assessed.