Supporting Information for

MESMER-RCM: A Probabilistic Climate Emulator for Regional Warming Projections

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Contents of this file

Introduction

This supplementary material provides additional information about MESMER-RCM development. Figure S1 and S2 provides a summary of calibration results of the Deterministic response module. Figure S3 shows an example of insights from calibration results. Figure S4 further provides an example of calibration results of residual variability module. Table S1 summarizes the available GCM-RCM simulations used in this study.
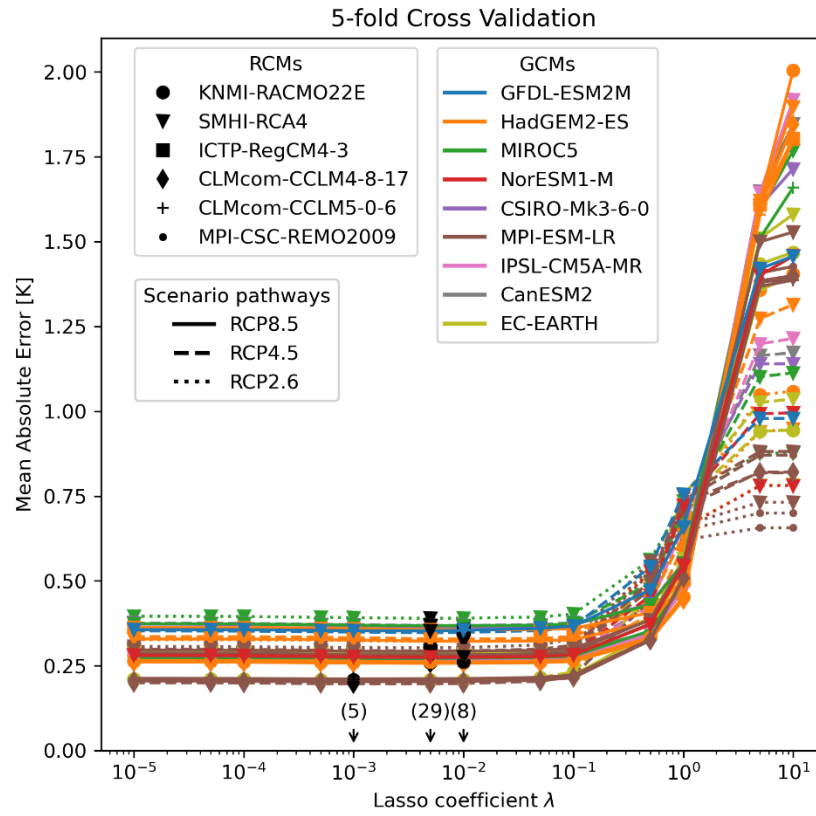
Figure S1. Searching for the optimum Lasso coefficient λ using 5-fold cross-validation based on the spatial mean MAE. Each line represents the cross-validation results for a GCM-RCM model chain simulation, with colors, markers, and linestyles representing GCMs, RCMs, and scenario pathways, respectively. The frequency of the optimum Lasso coefficient is shown in brackets above the x-axis.
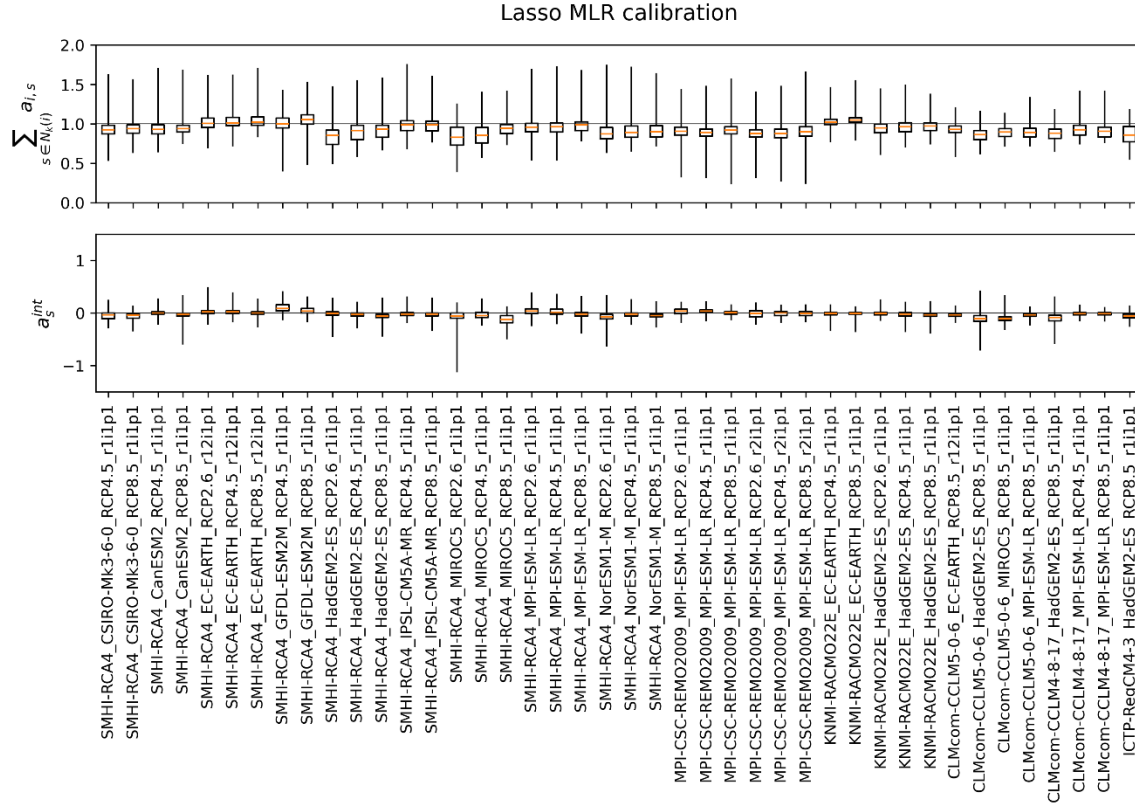
Figure S2. Calibration results of Lasso MLR across GCM-RCM model chain simulations: the summation of scaling coefficients over a **3 × 3** grid (top) and the intercepts (bottom). GCM-RCM model chains are labeled in the format: RCM_GCM_Scenario_Ensemble.

Training data [GCM:CanESM2, RCM:SMHI-RCA4, Scenario pathways:RCP4.5, Ensemble: r1i1p1]
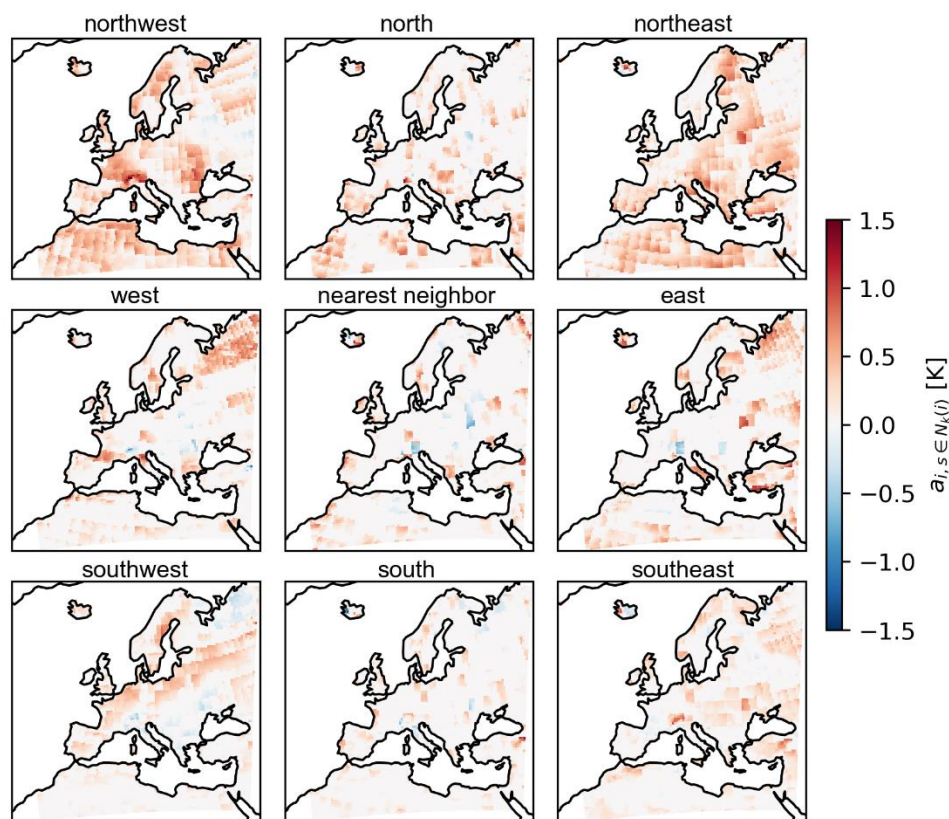
Figure S3. An example of the individual scaling coefficients in Lasso MLR. Subtitles on each map indicate the relative location of GCM grid point predictors with respect to RCM grid point predictands. For example, the center map represents the scaling factor for the nearest GCM grid temperature predictor to each RCM grid point temperature predictand.
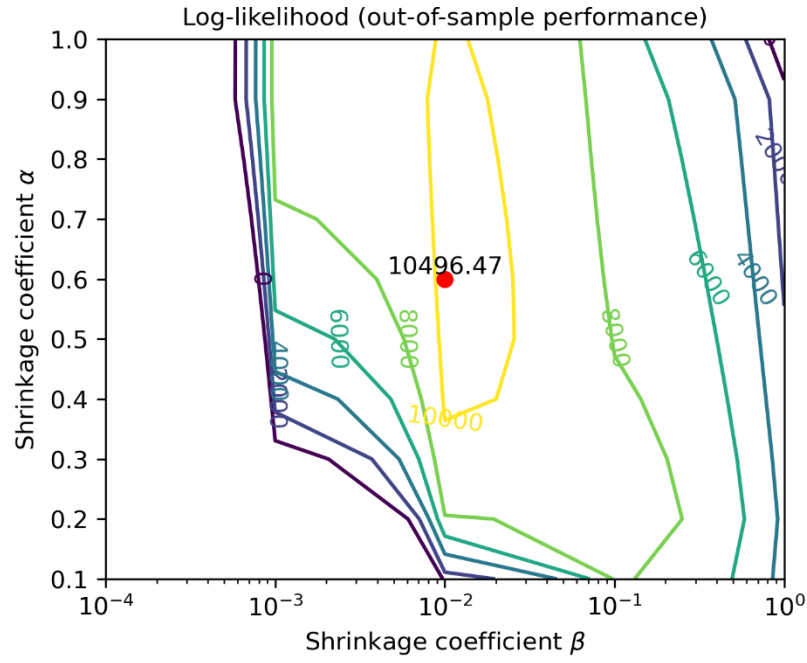
Figure S4. Example of the log-likelihood field associated with shrinkage coefficients α and β (out-of-sample performance, showing only log-likelihood values greater than 0). The red dot indicates the maximum log-likelihood location, corresponding to the optimal set of shrinkage coefficients in this validation experiment: $\alpha = 0.6$ and $\beta = 0.01$.

GCM	Initial condition	RCM	RCP8.5	RCP4.5	RCP2.6
EC-EARTH	r1i1p1	KNMI-RACMO22E	✓	✓	
	r12i1p1	CLMcom-CCLM5-0-6	✓		
		SMHI-RCA4	✓	✓	✓
HadGEM2-ES	r1i1p1	CLMcom-CCLM4-8-17	✓		
		CLMcom-CCLM5-0-6	✓		
		ICTP-RegCM4-3	✓		
		KNMI-RACMO22E	✓	✓	✓
		SMHI-RCA4	✓	✓	✓
MPI-ESM-LR	r1i1p1	CLMcom-CCLM4-8-17	✓	✓	
		CLMcom-CCLM5-0-6	✓		
		MPI-CSC-REMO2009	✓	✓	✓
		SMHI-RCA4	✓	✓	✓
	r2i1p1	MPI-CSC-REMO2009	✓	✓	✓
MIROC5	r1i1p1	CLMcom-CCLM5-0-6	✓		
		SMHI-RCA4	✓	✓	✓
CanESM2	r1i1p1	SMHI-RCA4	✓	✓	
CSIRO-MK3-6-0	r1i1p1	SMHI-RCA4	✓	✓	
IPSL-CMSA-MR	r1i1p1	SMHI-RCA4	✓	✓	
NorESM1-M	r1i1p1	SMHI-RCA4	✓	✓	✓
GFDL-ESMS	r1i1p1	SMHI-RCA4	✓	✓	

Table S1. GCM/RCM Matrix for training and testing RCM emulator in this study. Adapted from CH2018 Technical Report (2018)