Supplementary material

1. Experimental setup

	Spin-up 1993-1999			Evaluation 1999-2019		
Experiment	LC	LAI	FCover	LC	LAI	FCover
CTR	ESA-CCI 1993	CGLS climatology 1993-2019	k=0.5	ESA-CCI 1993	CGLS climatology 1993-2019	k=0.5
IALC	ESA-CCI annually varying 1993-2019	CGLS climatology 1993-2019	k=0.5	ESA-CCI annually varying 1993-2019	CGLS climatology 1993-2019	k=0.5
IAK5	ESA-CCI annually varying 1993-2019	CGLS inter-annually varying 1993-2019	k=0.5	ESA-CCI annually varying 1993-2019	CGLS inter-annually varying 1993-2019	k=0.5
IAKV	ESA-CCI annually varying 1993-2019	CGLS inter-annually varying 1993-2019	k vegetation specific	ESA-CCI annually varying 1993-2019	CGLS inter-annually varying 1993-2019	k vegetation specific

Table S 1. Details of offline model experiments

2. Land Cover

Case	E CTR	E IALC	E DOLCEv3	Et CTR	Et IALC	Es CTR	Es IALC	Ei CTR	Ei IALC
Amazon	1174	1162	1160	633	615	156	183	384	363
Lapland	202	206	252	43	49	116	112	39	41
Central Asia	279	280	287	29	30	222	220	13	13

Table S 2. Annual mean (2014-2018) evaporation fluxes (mm/year) with E total evaporation, Et transpiration, Es soil evaporation and Ei interception evaporation in experiments CTR and IALC and DOLCEv3 (only E) for the three cases highlighted in Fig. 3

Case	r E CTR	r E IALC	RMSE E CTR	RMSE E IALC		r SMs CTR	r SMs IALC	RMSE SMs CTR	RMSE SMs IALC
Amazon	0.64	0.64	0.43	0.44		0.059	0.056	1.01	1.01
Lapland	0.56	0.56	0.28	0.27		0.034	0.034	1.33	1.33
Central Asia	0.76	0.76	0.33	0.33		0.24	0.24	0.81	0.81

Table S 3 Pearson correlation values (r) and root mean squared error (RMSE) of model monthly evaporation with respect to DOLCEv3 evaporation, and near-surface soil moisture with respect to ESA-CCI SM. For r inter-annual anomalies are used, for RMSE E the monthly values, and for RMSE SMs the standardized inter-annual anomalies. The cases are highlighted in Fig. 3, S1-S3
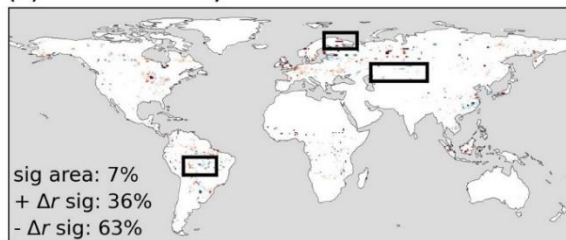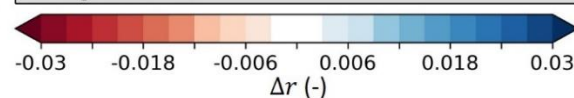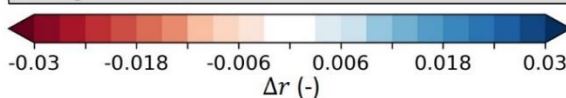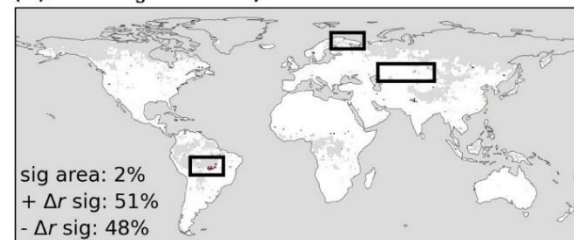
Figure S 1. Pearson correlation difference between experiment CTR and IALC (IALC-CTR) for (a) monthly anomaly total evaporation (E) with respect to DOLCEv3 evaporation and (b) monthly anomaly surface soil moisture (SMs) with respect to ESA-CCI SM. Blue (red) indicates an increased (reduced) correlation in IALC compared to CTR, white indicates small and/or insignificant r differences, and grey indicates no data points. The percentages indicate the areal percentage of significantly changing land points, and the areal percentage of positive and negative Δr for significant points. The boxes highlight the three regions Southern Amazon, Lapland and Central Asia with major land cover changes. See Table S1 for details of the experiments and Table S2 for values in the highlighted regions.
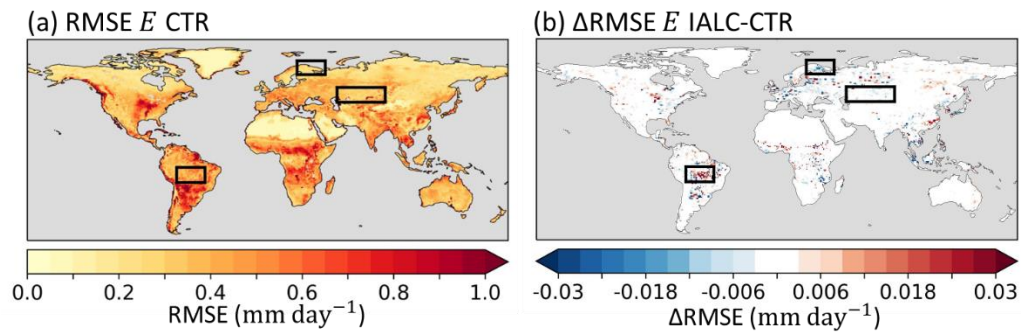
Figure S 2 (a) Root mean squared error (RMSE) of model monthly evaporation in experiment CTR with respect to DOLCEv3 with red indicating a larger RMSE. (b) The difference between RMSE in CTR and IALC (IALC–CTR) with blue (red) indicating a reduced (increased) RMSE. The boxes highlight the three regions Southern Amazon, Lapland and Central Asia with major land cover changes. See Table S1 for details of the experiments and Table S2 for values in the highlighted regions.
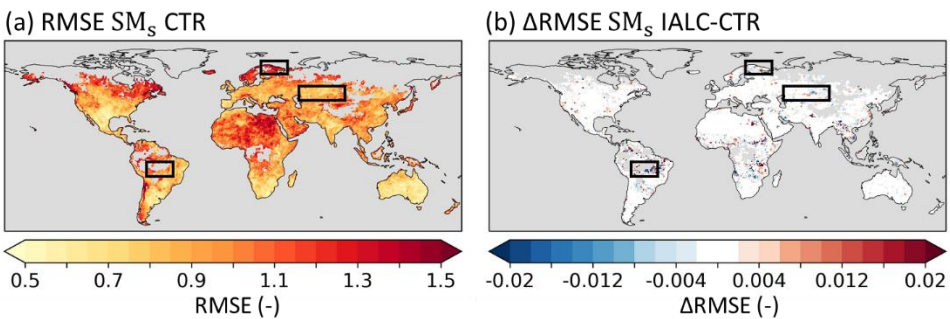
Figure S 3 (a) Root mean squared error (RMSE) of model monthly standardized anomalies of near-surface soil moisture (SMs) in experiment CTR with respect to ESA-CCI SM with red indicating a larger RMSE. (b) The difference between RMSE in CTR and IALC (IALC–CTR) with blue (red) indicating a reduced (increased) RMSE. The boxes highlight the three regions Southern Amazon, Lapland and Central Asia with major land cover changes. See Table S1 for details of the experiments and Table S2 for values in the highlighted regions.

3. LAI
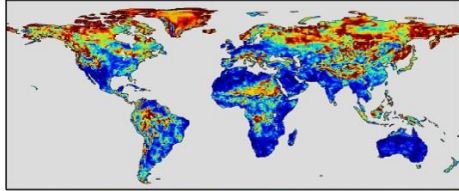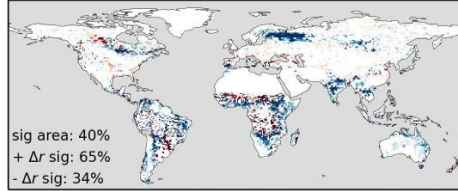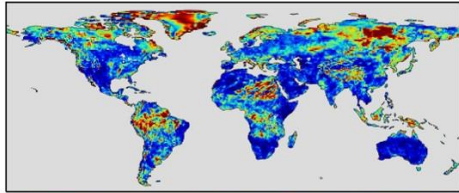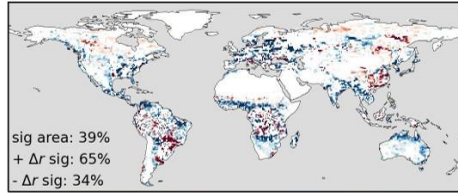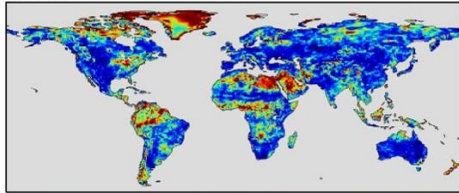
Figure S 4. (a,c,e,g) Pearson correlation of seasonal anomaly evaporation (E) with respect to DOLCEv3 evaporation in IALC and (b,d,f,h) seasonal correlation difference between IALC and IAK5 (IAK5-IALC). Blue (red) indicates an increased (reduced) correlation in IAK5 compared to IALC, white colors indicate small and/or insignificant differences, and grey indicates no data points. The percentages indicate the areal percentage of significantly changing land points, and the areal percentage of positive and negative Δr for significant points. See Table S1 for details of the experiments.
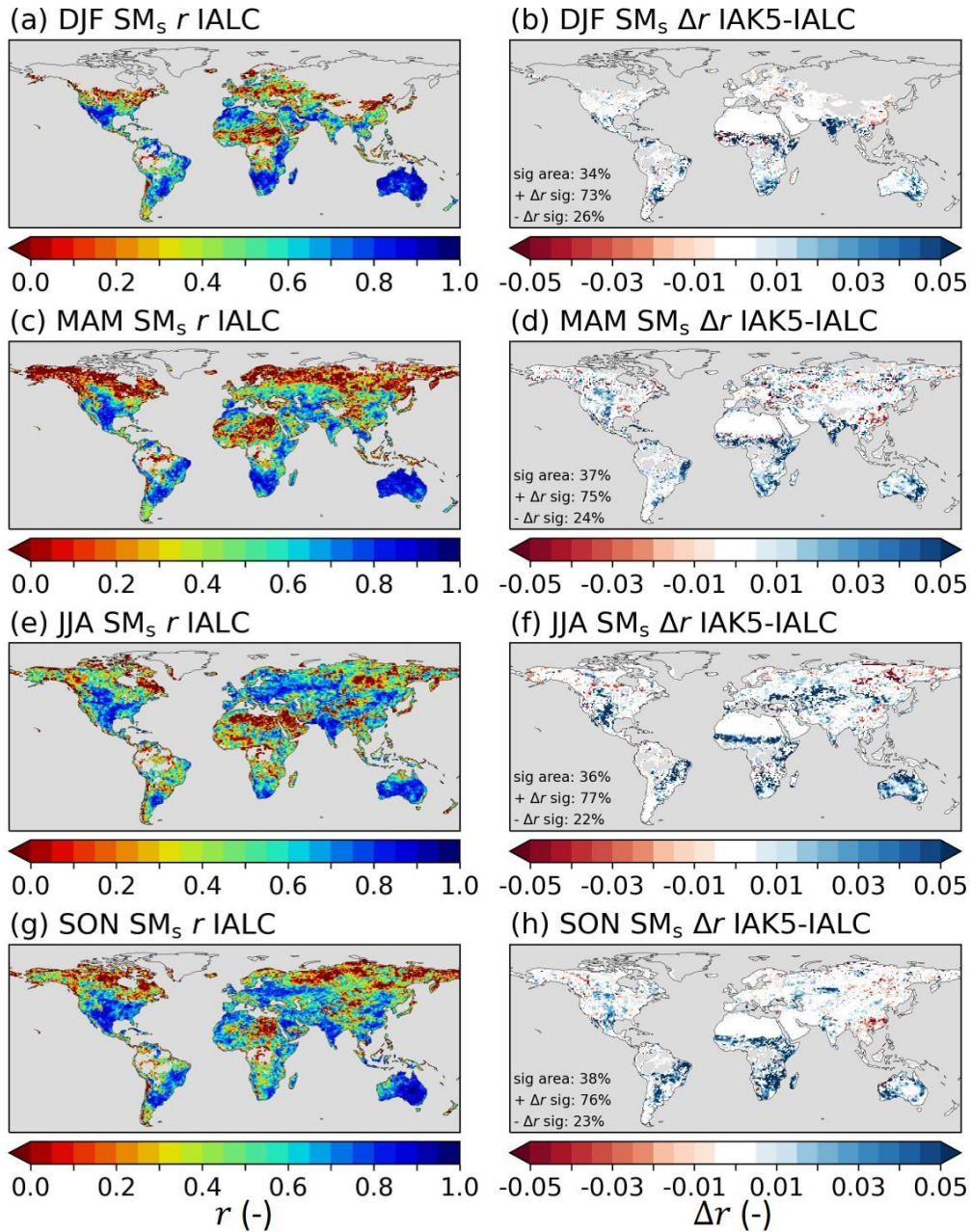
Figure S 5. (a,c,e,g) Pearson correlation of seasonal anomaly surface soil moisture (SMs) with respect to ESA-CCI SM in IALC and (b,d,f,h) seasonal correlation difference between IALC and IAK5 (IAK5-IALC). Blue (red) indicates an increased (reduced) correlation in IAK5 compared to IALC, white colors indicate small and/or insignificant differences, and grey indicates no data points. The percentages indicate the areal percentage of significantly changing land points, and the areal percentage of positive and negative Δr for significant points See Table S1 for details of the experiments.

4. Effective vegetation cover
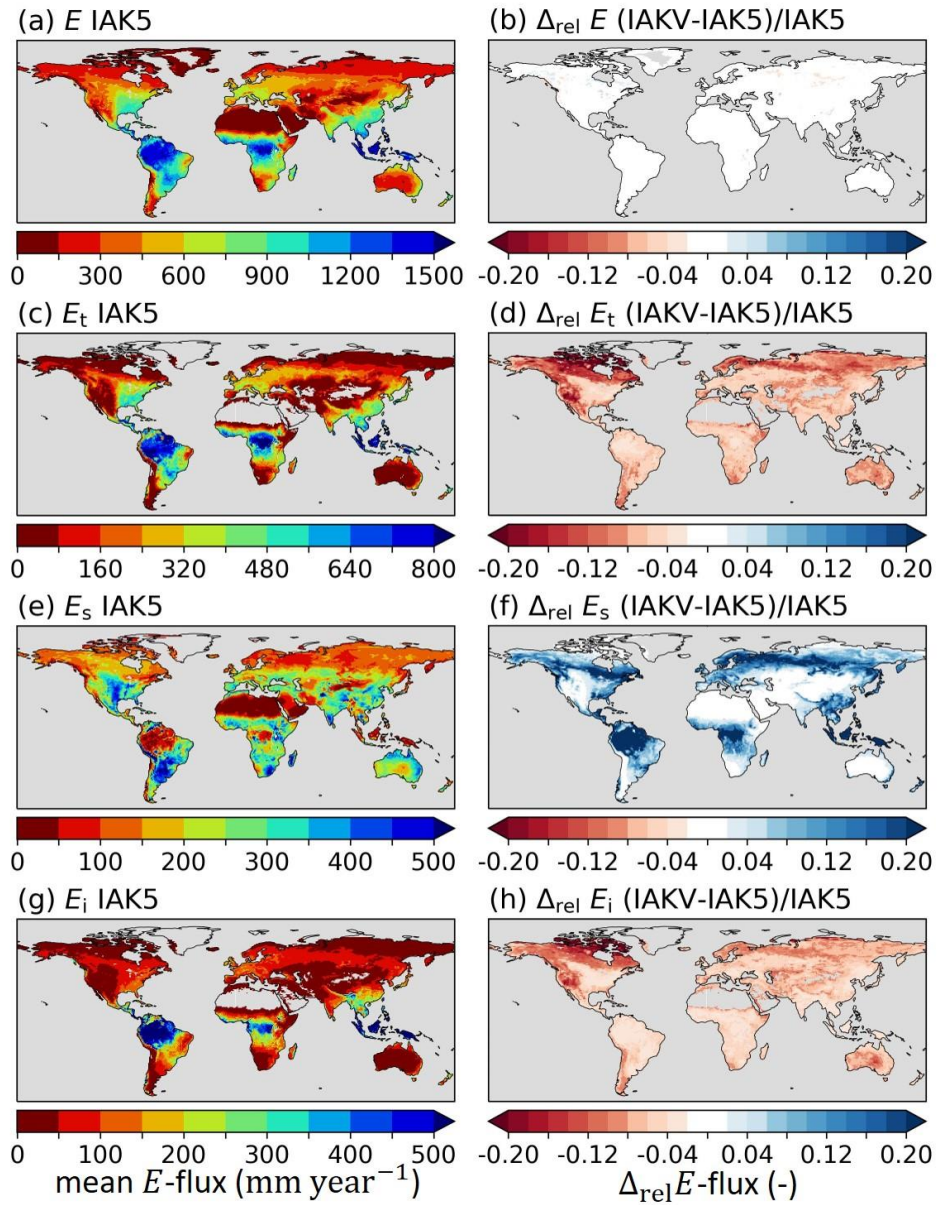
Figure S 6. Annual mean evaporation fluxes in experiment IAK5 with (a) total evaporation (E), (c) transpiration (Et), (e) soil evaporation (Es) and (g) interception evaporation (Ei) and the relative difference between annual mean evaporation fluxes in experiment IAKV and IAK5 ((IAKV-IAK5)/IAK5) for (b) E, (d) Et, (f) Es and (h) Ei. Blue (red) indicates an increased (reduced) flux. Grey land areas indicate regions with annual mean E-fluxes < 0.1 mm/year. See Table S1 for details of the experiments.
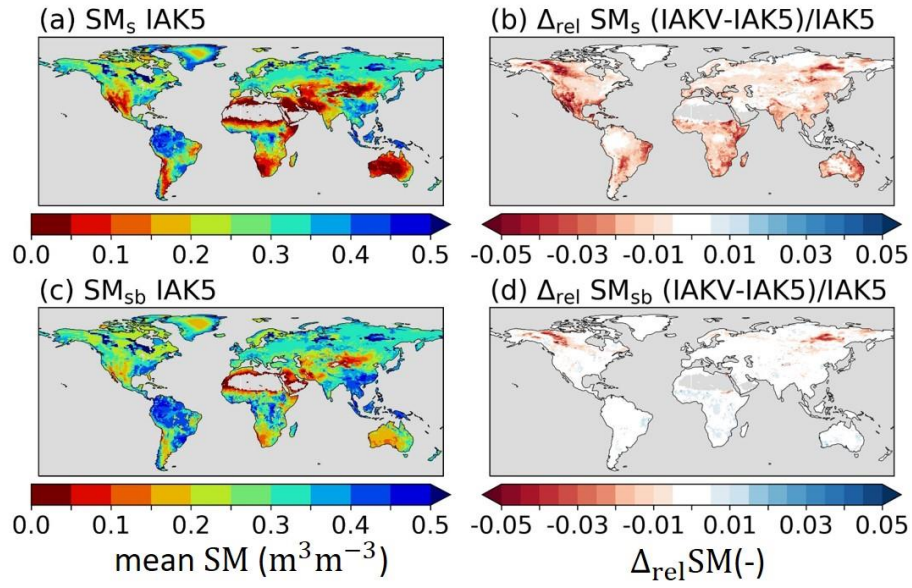
Figure S 7 Annual mean soil moisture in experiment IAK5 with (a) near-surface soil moisture (SMs) and (c) subsurface soil moisture (SMsb) and the relative difference between annual mean SM in experiment IAKV and IAK5 ((IAKV-IAK5)/IAK5) for (b) SMs and (d) SMsb. Blue (red) indicates an increased (reduced) soil moisture. Grey land areas indicate regions with annual mean SM < 0.01 m3/m3. See Table S1 for details of the experiments.
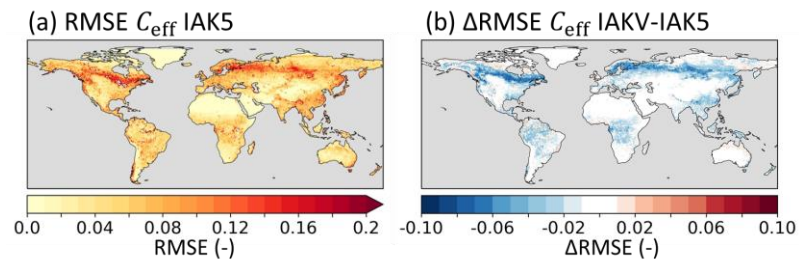
Figure S 8 (a) Root mean squared error (RMSE) of model monthly effective vegetation cover Ceff in experiment IAK5 with respect to CGLS FCover with red indicating a larger RMSE. (b) The difference between RMSE in IAK5 and IAKV (IAKV-IAK5) with blue (red) indicating a reduced (increased) RMSE. See Table S1 for details of the experiments.
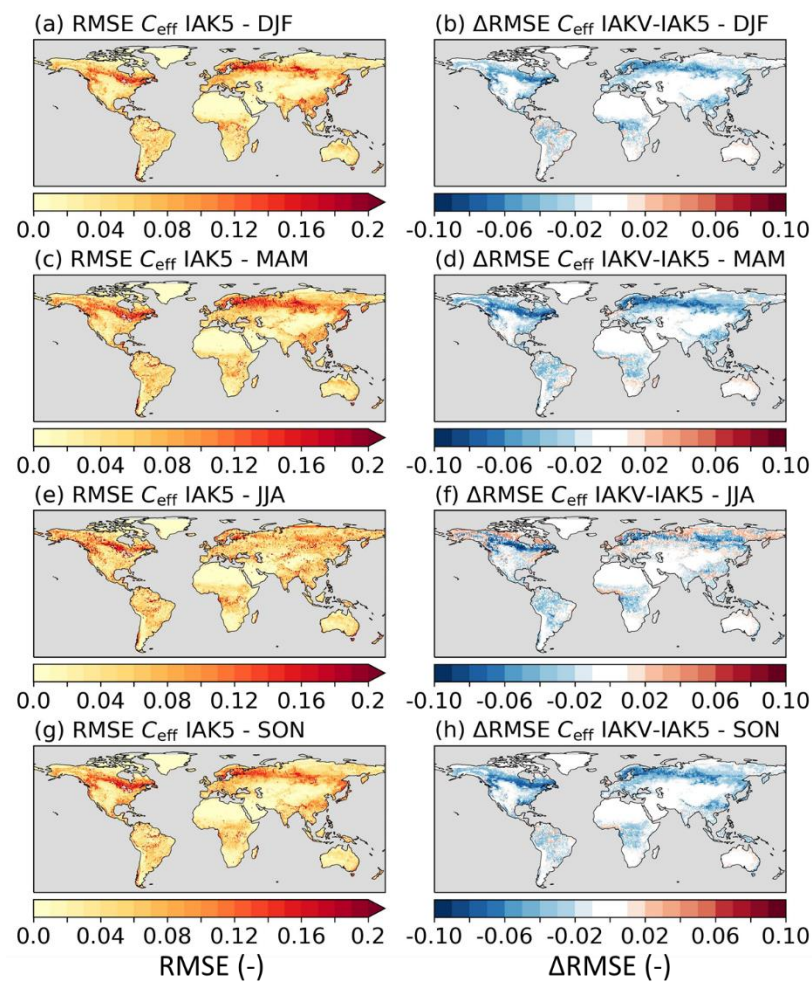
Figure S 9. Same as Fig. S8 for seasonal values
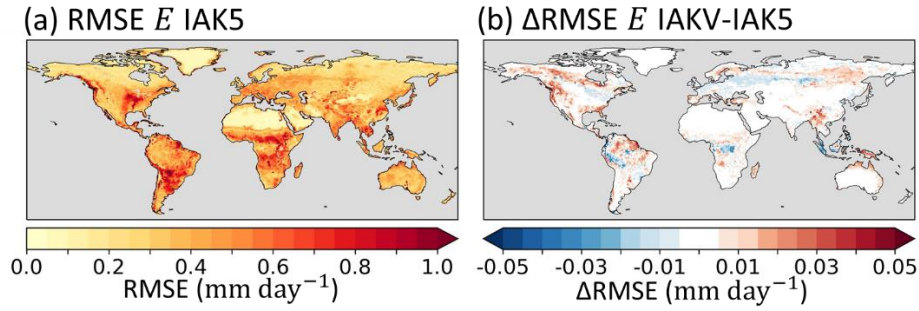
Figure S 10 (a) Root mean squared error (RMSE) of model monthly evaporation E in experiment IAK5 with respect to DOLCEv3 E with red indicating a larger RMSE. (b) The difference between RMSE in IAK5 and IAKV (IAKV-IAK5) with blue (red) indicating a reduced (increased) RMSE. See Table S1 for details of the experiments.
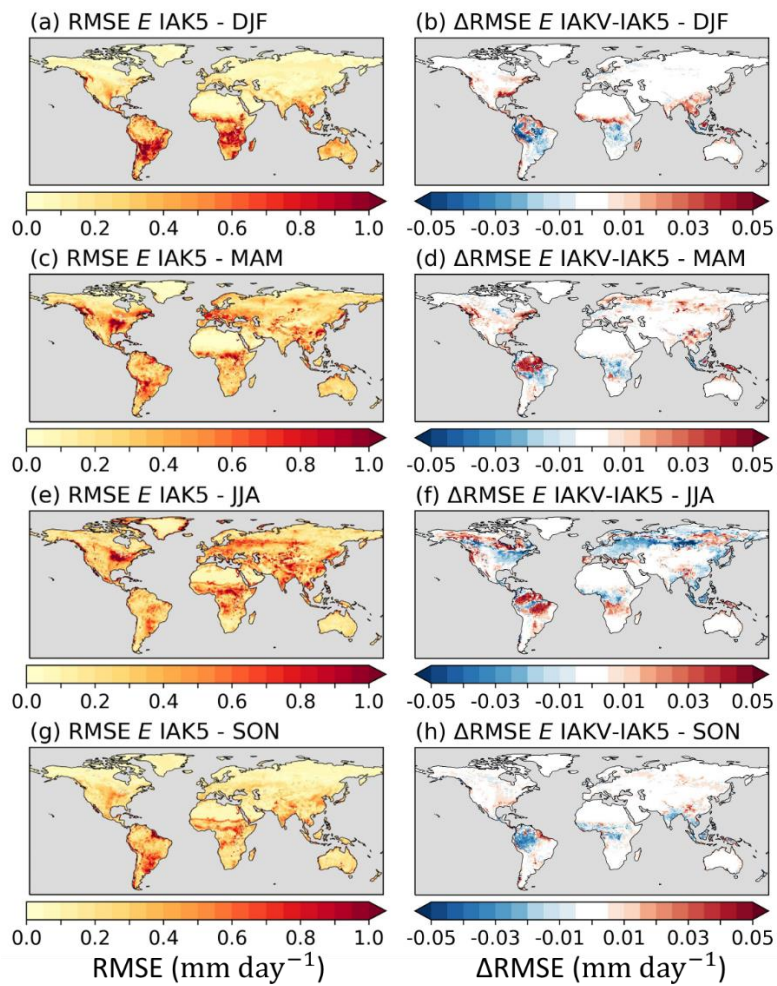
Figure S 11 Same as Fig. S10 for seasonal values
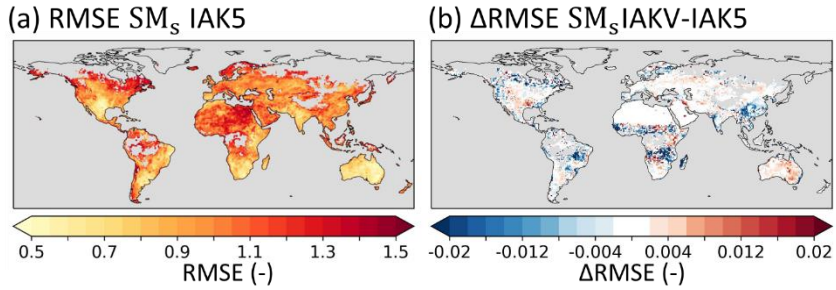
Figure S 12 (a) Root mean squared error (RMSE) of model monthly standardized anomalies of near-surface soil moisture in experiment IAK5 with respect to ESA-CCI SM with red indicating a larger RMSE. (b) The difference between RMSE in IAK5 and IAKV (IAKV-IAK5) with blue (red) indicating a reduced (increased) RMSE. See Table S1 for details of the experiments.
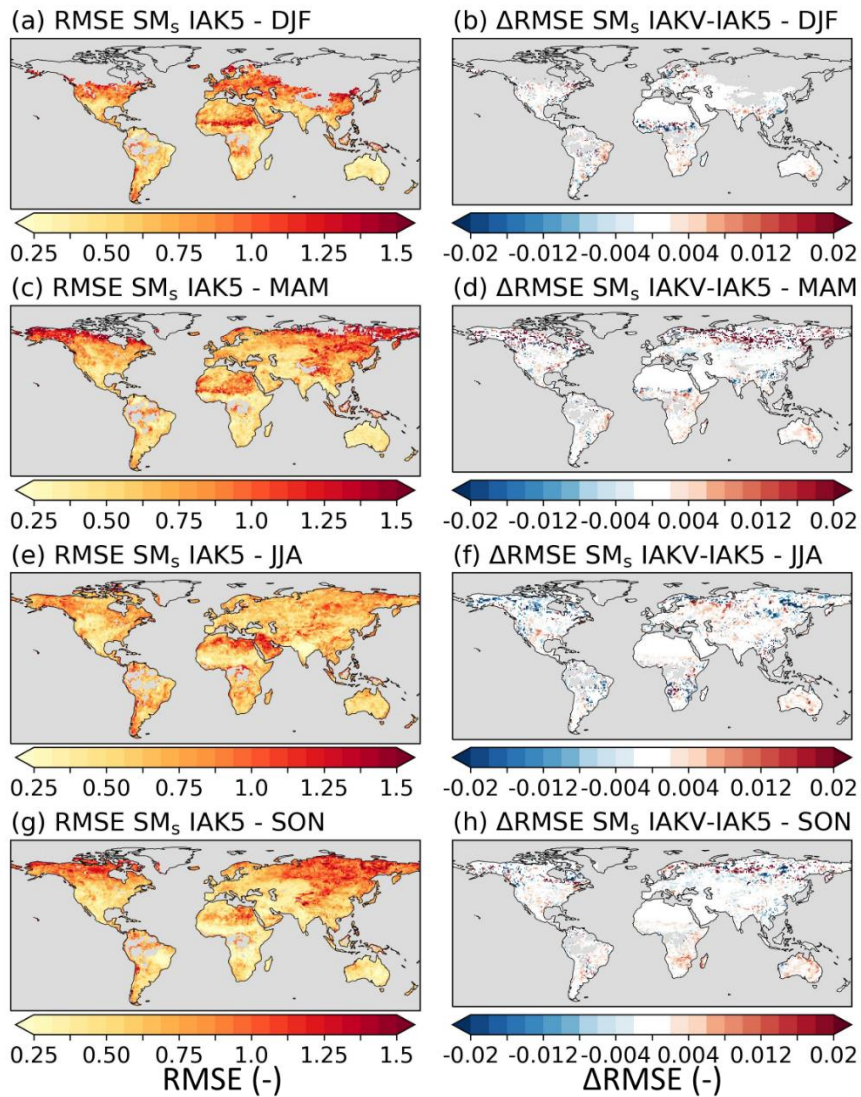
Figure S 13 Same as Fig. S12 for seasonal values
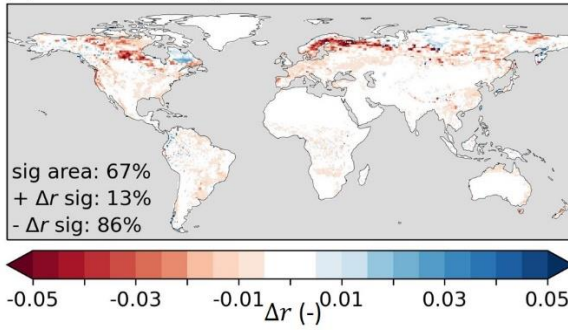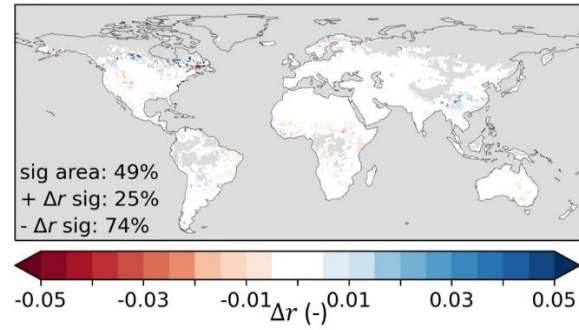
Figure S 14 Pearson correlation difference between experiment IAK5 and IAKV (IAKV-IAK5) for (a) monthly anomaly total evaporation (E) with respect to DOLCEv3 evaporation and (b) monthly anomaly surface soil moisture (SMs) with respect to ESA-CCI SM. Blue (red) indicates an increased (reduced) correlation in IAKV compared to IAK5, white indicates small and/or insignificant r differences, and grey indicates no data points. The percentages indicate the areal percentage of significantly changing land points, and the areal percentage of positive and negative Δr for significant points. See Table S1 for details of the experiments.
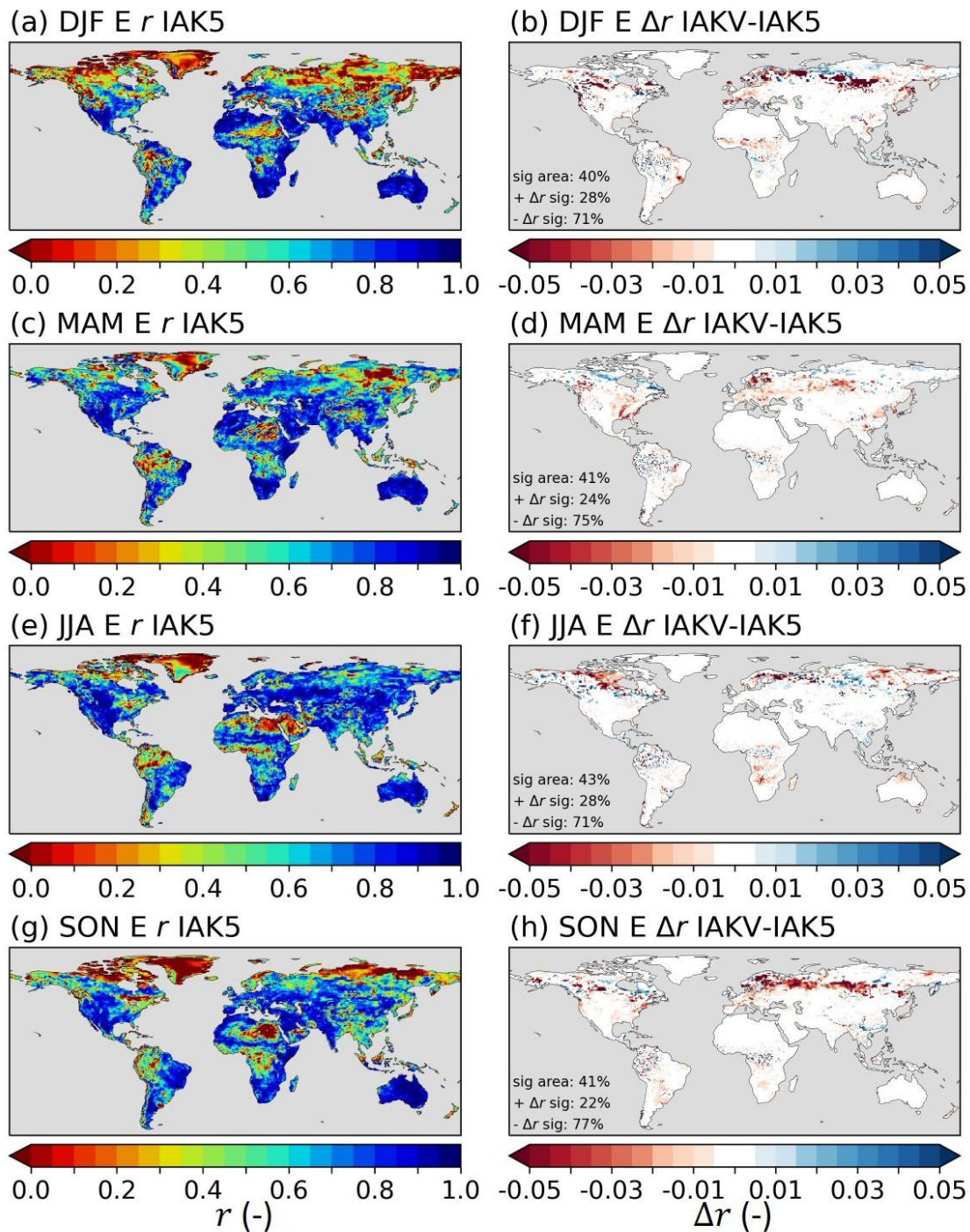
Figure S 15. (a,c,e,g) Pearson correlation of seasonal anomaly evaporation (E) with respect to DOLCEv3 evaporation in IAK5 and (b,d,f,h) seasonal correlation difference between IAK5 and IAKV (IAKV-IAK5). Blue (red) indicates an increased (reduced) correlation in IAKV compared to IAK5, white colors indicate small and/or insignificant differences, and grey indicates no data points. The percentages indicate the areal percentage of significantly changing land points, and the areal percentage of positive and negative Δr for significant points. See Table S1 for details of the experiments.
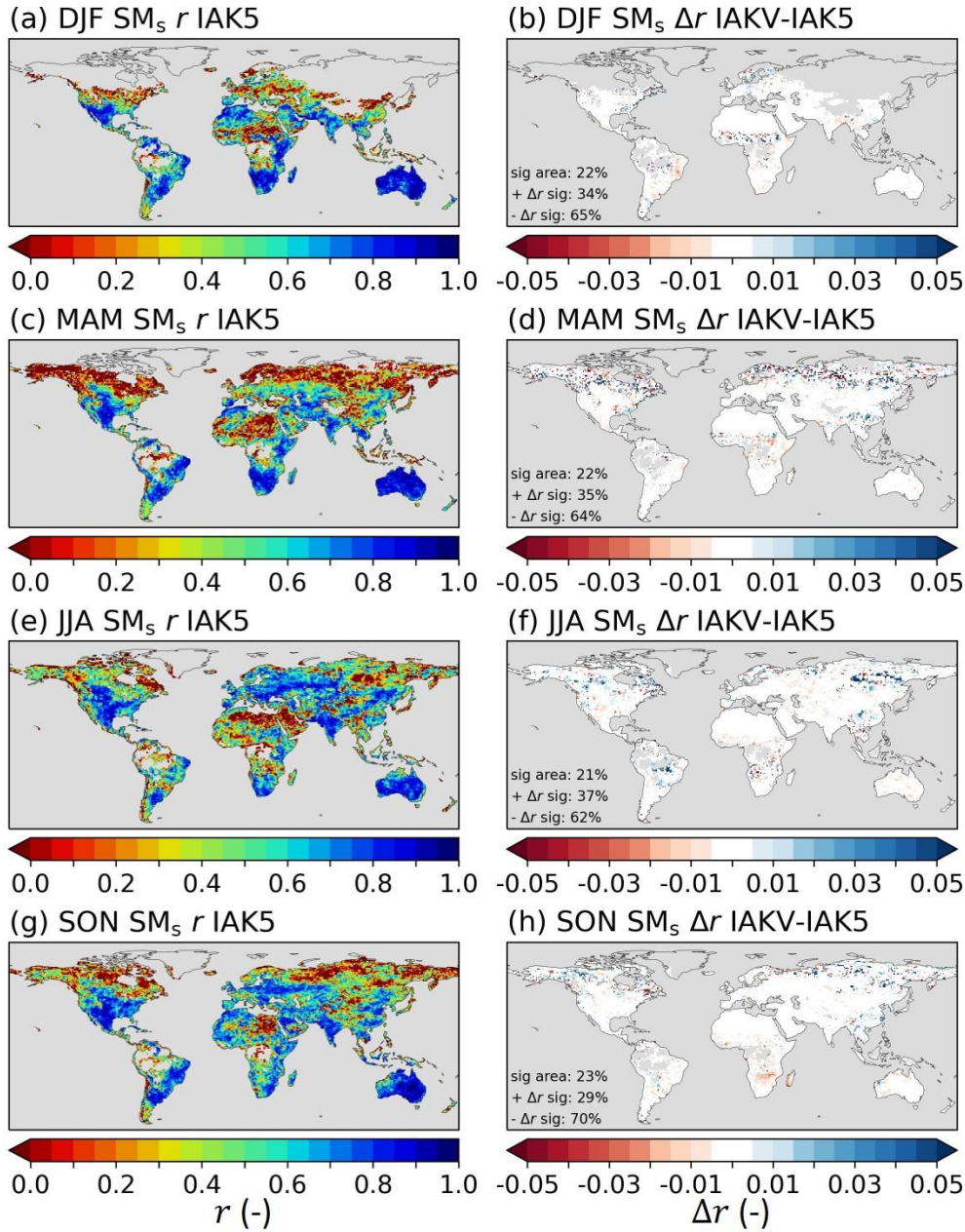
Figure S 16. (a,c,e,g) Pearson correlation of seasonal anomaly surface soil moisture (SMs) with respect to ESA-CCI SM in IAK5 and (b,d,f,h) seasonal correlation difference between IAK5 and IAKV (IAKV-IAK5). Blue (red) indicates an increased (reduced) correlation in IAKV compared to IAK5, white colors indicate small and/or insignificant differences, and grey indicates no data points. The percentages indicate the areal percentage of significantly changing land points, and the areal percentage of positive and negative Δr for significant points. See Table S1 for details of the experiments.

6. LC + LAI + effective vegetation cover
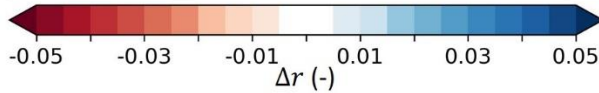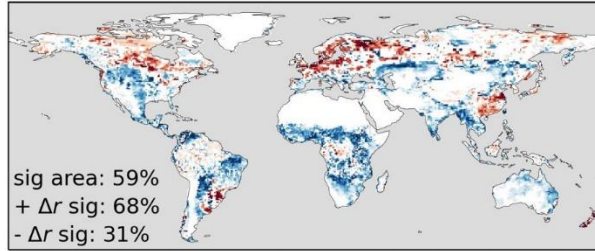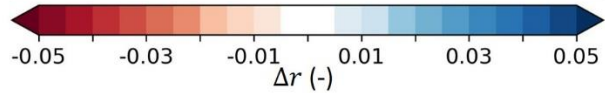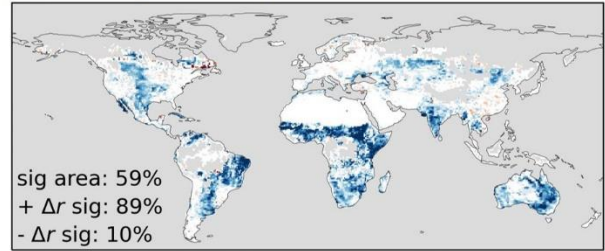
Figure S 17. Pearson correlation difference between experiment CTR and IAKV (IAKV-CTR) for (a) monthly anomaly total evaporation (E) with respect to DOLCEv3 evaporation and (b) monthly anomaly surface soil moisture (SMs) with respect to ESA-CCI SM. Blue (red) indicates an increased (reduced) correlation in IAKV compared to CTR, white indicates small and/or insignificant r differences, and grey indicates no data points. The percentages indicate the areal percentage of significantly changing land points, and the areal percentage of positive and negative Δr for significant points. See Table S1 for details of the experiments.
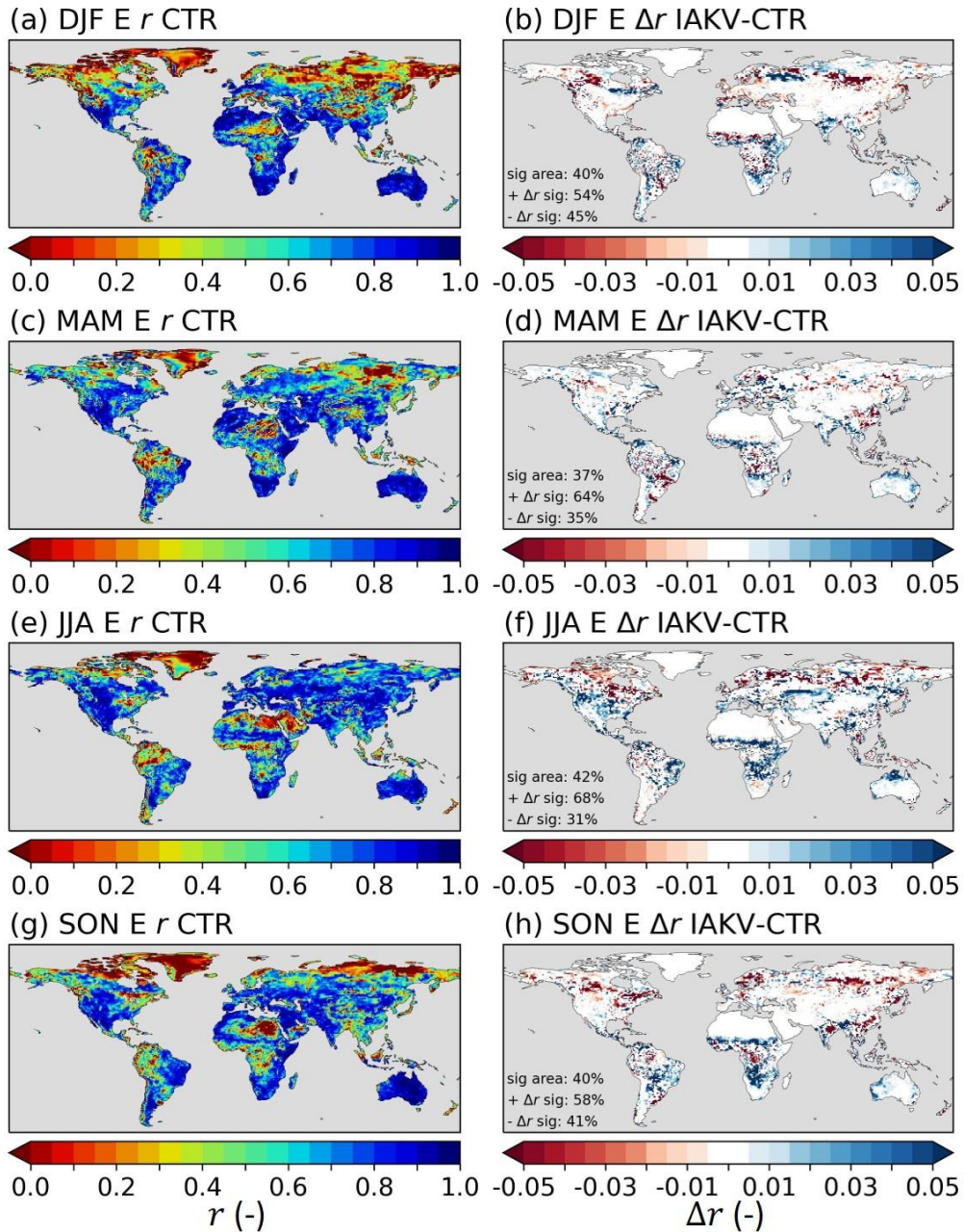
Figure S 18. (a,c,e,g) Pearson correlation of seasonal anomaly evaporation (E) with respect to DOLCEv3 evaporation in CTR and (b,d,f,h) seasonal correlation difference between CTR and IAKV (IAKV-CTR). Blue (red) indicates an increased (reduced) correlation in IAKV compared to CTR, white colors indicate small and/or insignificant differences, and grey indicates no data points. The percentages indicate the areal percentage of significantly changing land points, and the areal percentage of positive and negative Δr for significant points. See Table S1 for details of the experiments.
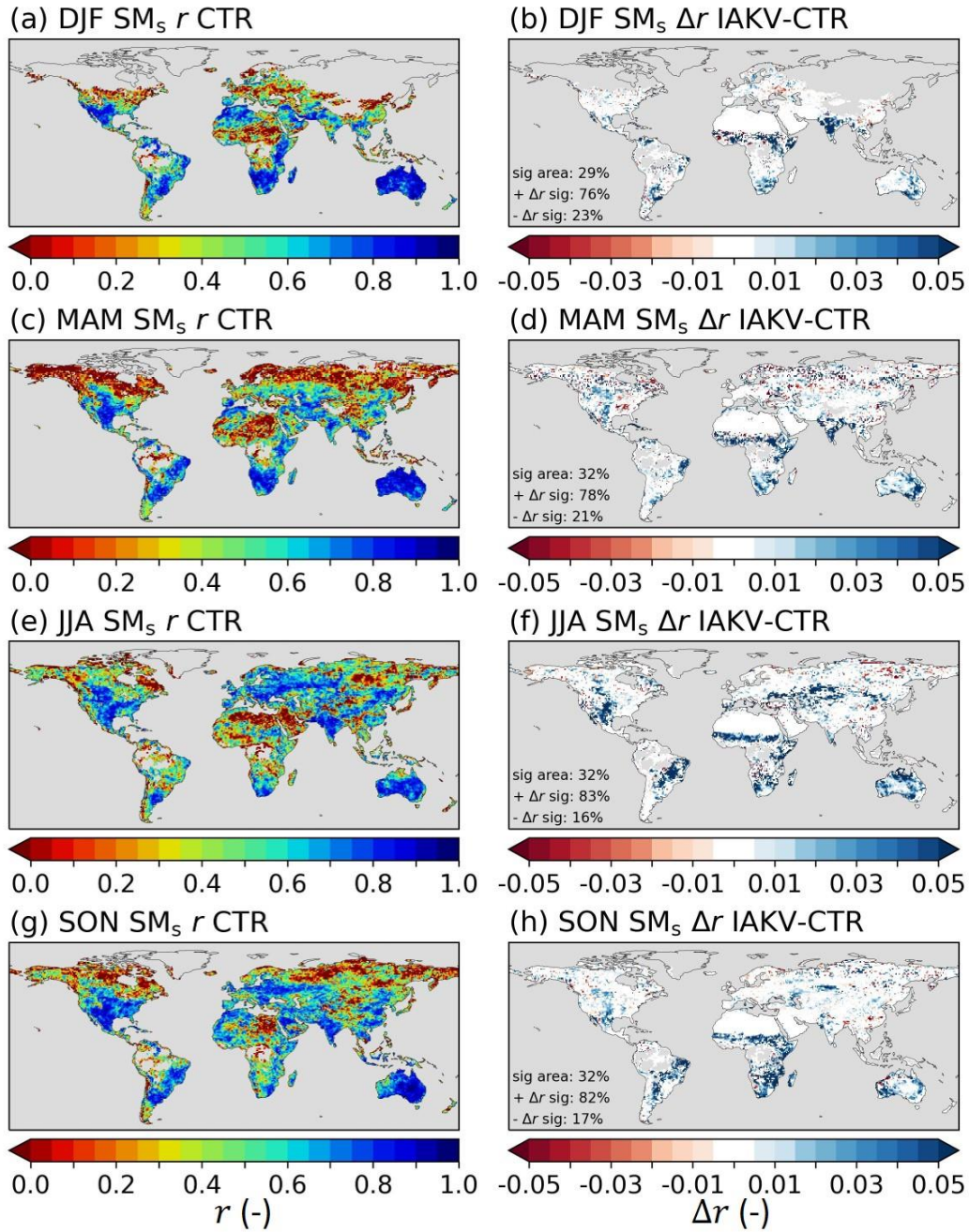
Figure S 19. (a,c,e,g) Pearson correlation of seasonal anomaly surface soil moisture (SMs) with respect to ESA-CCI SM in CTR and (b,d,f,h) seasonal correlation difference between CTR and IAKV (IAKV-CTR). Blue (red) indicates an increased (reduced) correlation in IAKV compared to CTR, white colors indicate small and/or insignificant differences, and grey indicates no data points. The percentages indicate the areal percentage of significantly changing land points, and the areal percentage of positive and negative Δr for significant points. See Table S1 for details of the experiments.