Supplementary information for:

Constraining low-frequency variability in climate projections to predict climate on decadal to multi-decadal time scales - a 'poor-man' initialized prediction system

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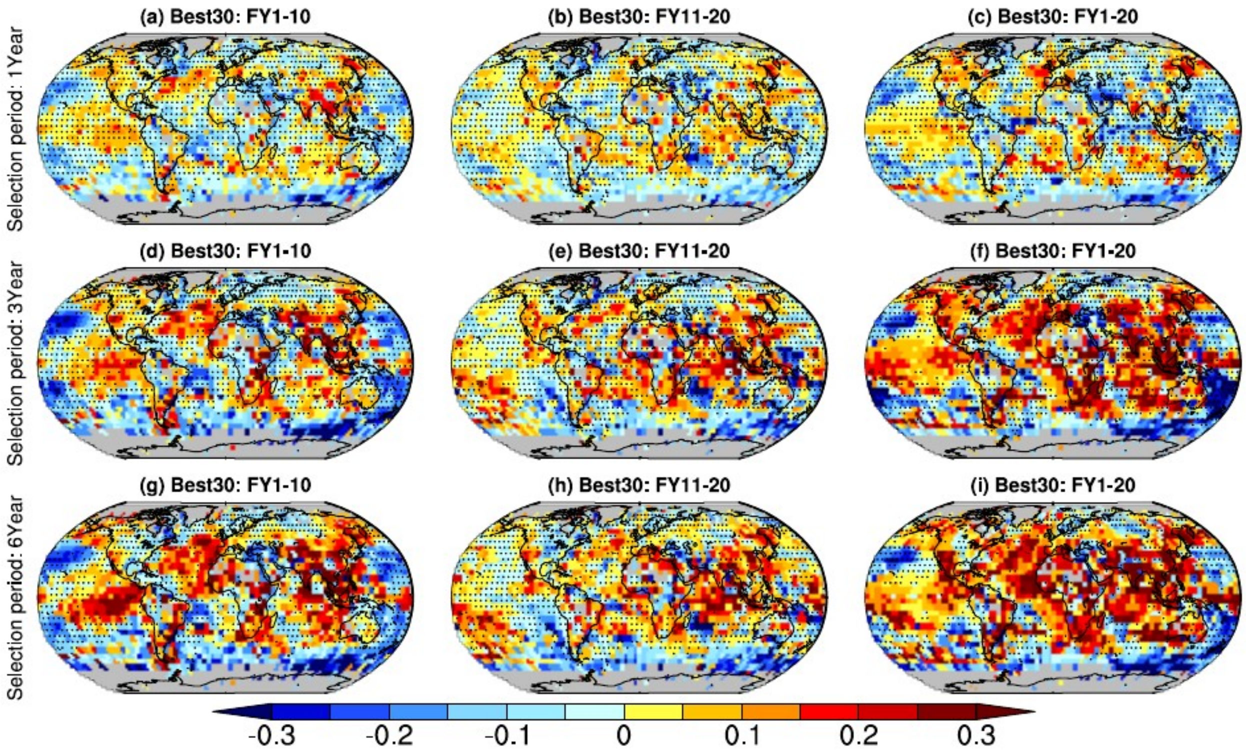

Figure S1: RPSS for Best30 ensemble against the unconstrained CMIP6 ensemble of 212 members as reference. Best30 ensemble is constrained by one year average SST anomaly patterns (a-c), three year average SST anomaly patterns (d-f), and six year average SST anomaly patterns (g-i). Stipplings indicate regions where RPSS is statistically not significant at 95% confidence level.

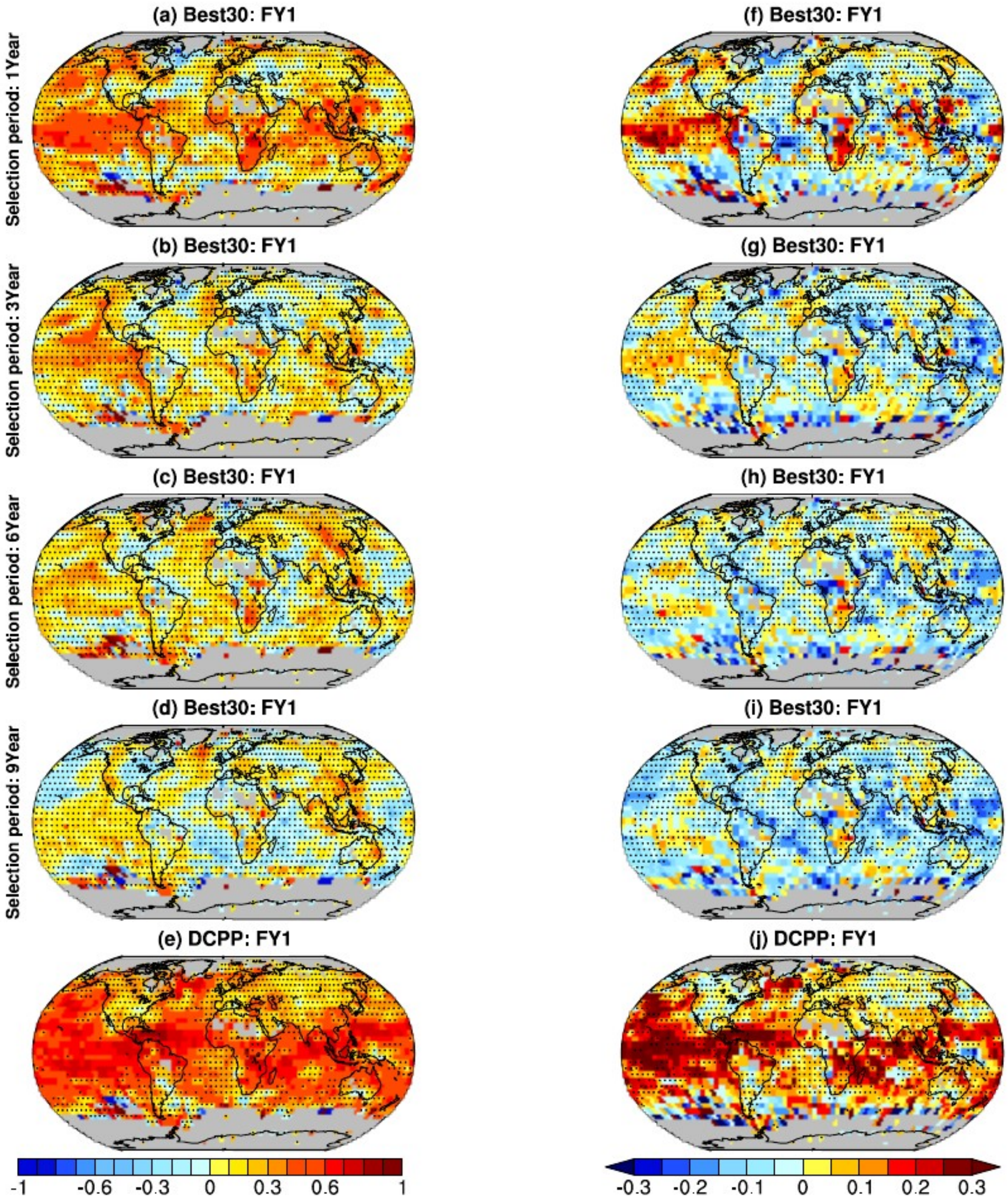

Figure S2: Residual correlation (a-e) and RPSS (f-j) for the forecast year 1. (a-d) and (f-i) show added value for the Best30 ensemble selected based on SST anomalies of different time periods (i.e. using 1, 3, 6, and 9 year average SST anomaly patterns). (e) and (f) show added value for DCPP. Stipplings indicate regions where the residual correlations and RPSS are statistically not significant at 95% confidence level.

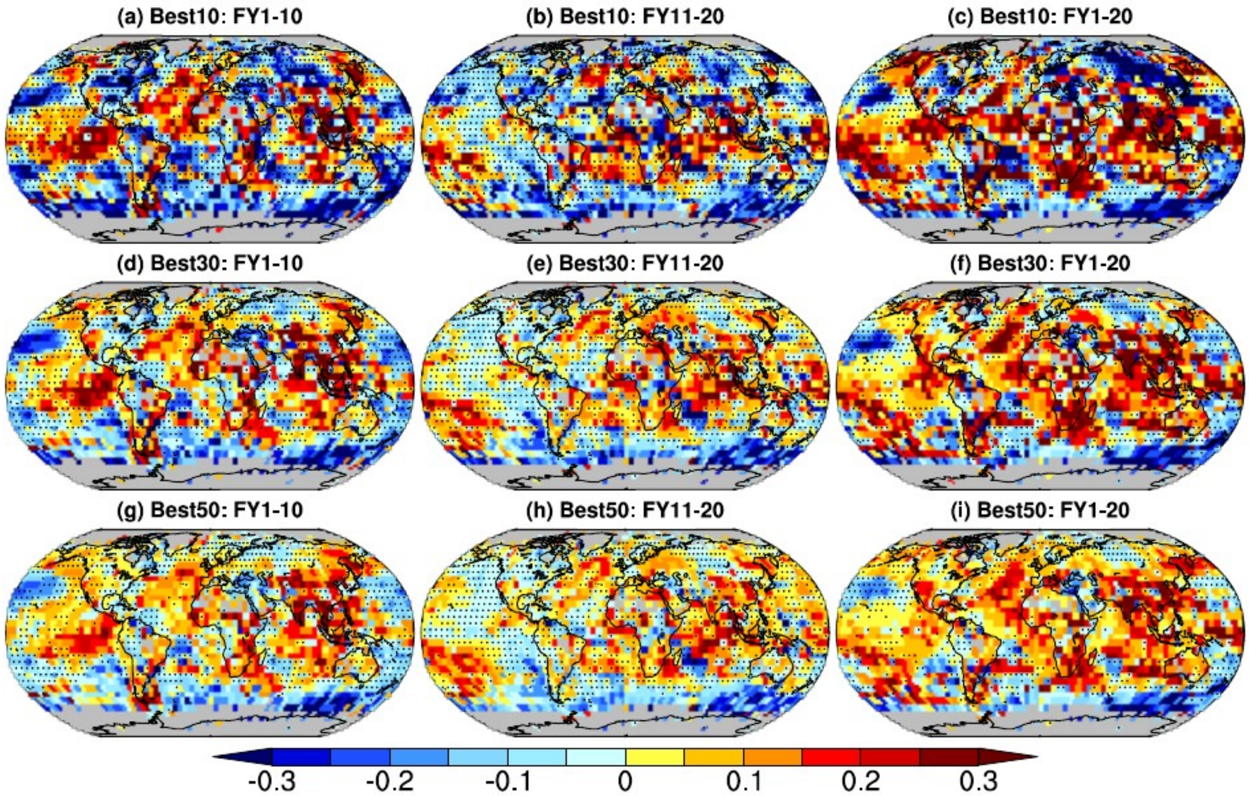

Figure S3: RPSS for Best10 (a-c), Best30 (d-f) and Best50 (g-i) against the unconstrained CMIP6 ensemble of 212 members as reference. Note that panel (d-f) are the same as in Figure 2 (h-j). Stipplings indicate regions where the results are statistically not significant at 95% confidence level.

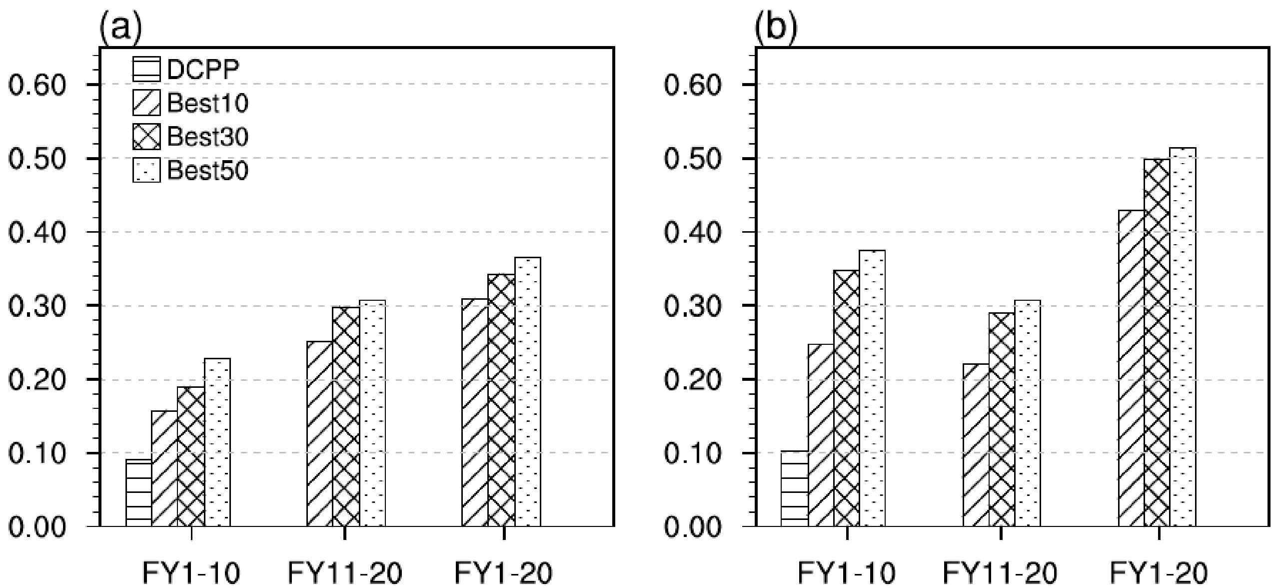

Figure S4: Fraction of global area where the added skill of DCPP, and the global SST based constrained ensembles (i.e. Best10, Best30 and Best50) is positive and statistically significant for 95% confidence level for residual correlation (a) and for RPSS (b).

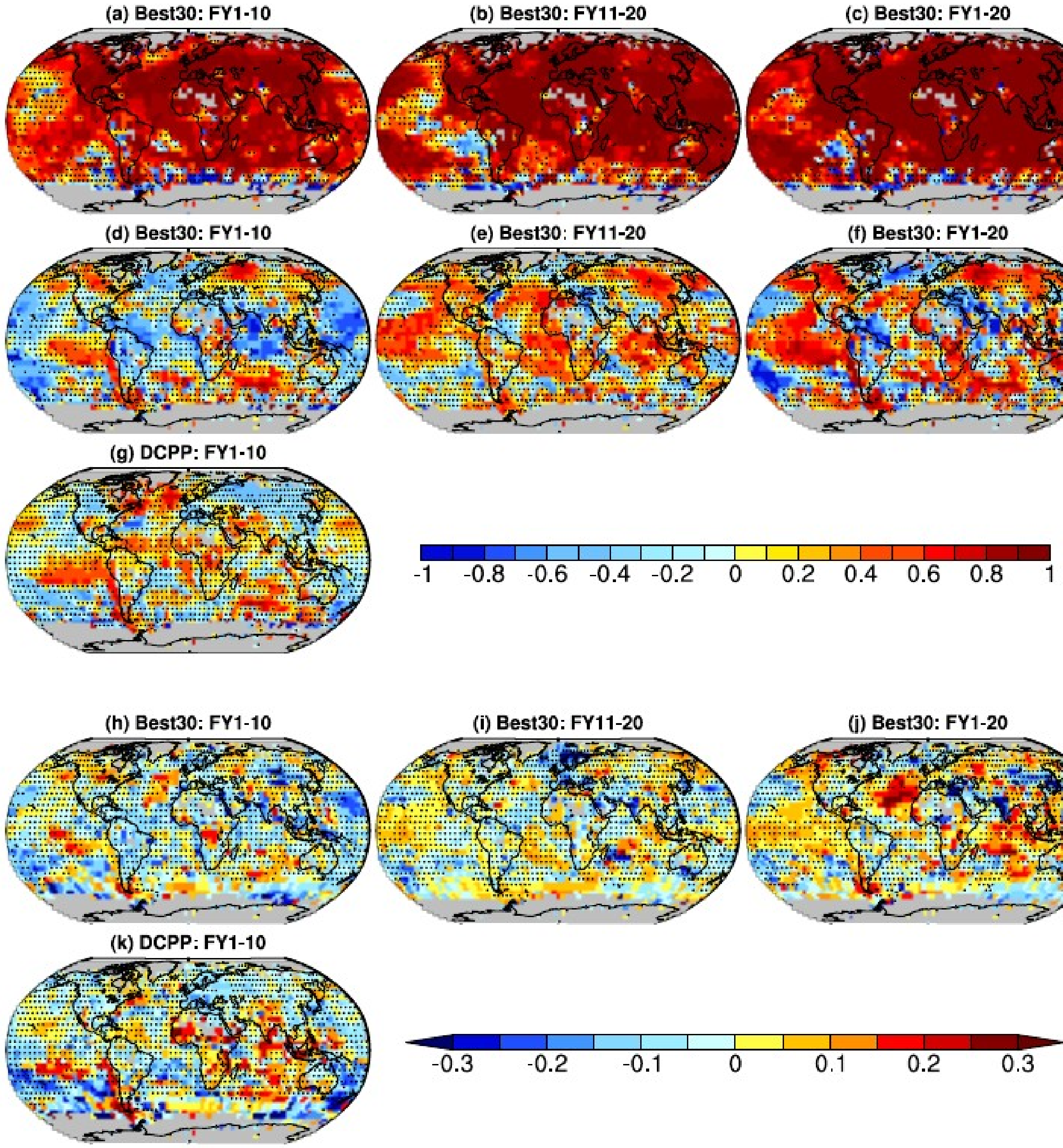

Figure S5: Same as Figure 2 in the main text but for the selection of Best30 based on ranking the projection members with least root mean square error. Stipplings indicate regions where the results are statistically not significant at 95% confidence level.

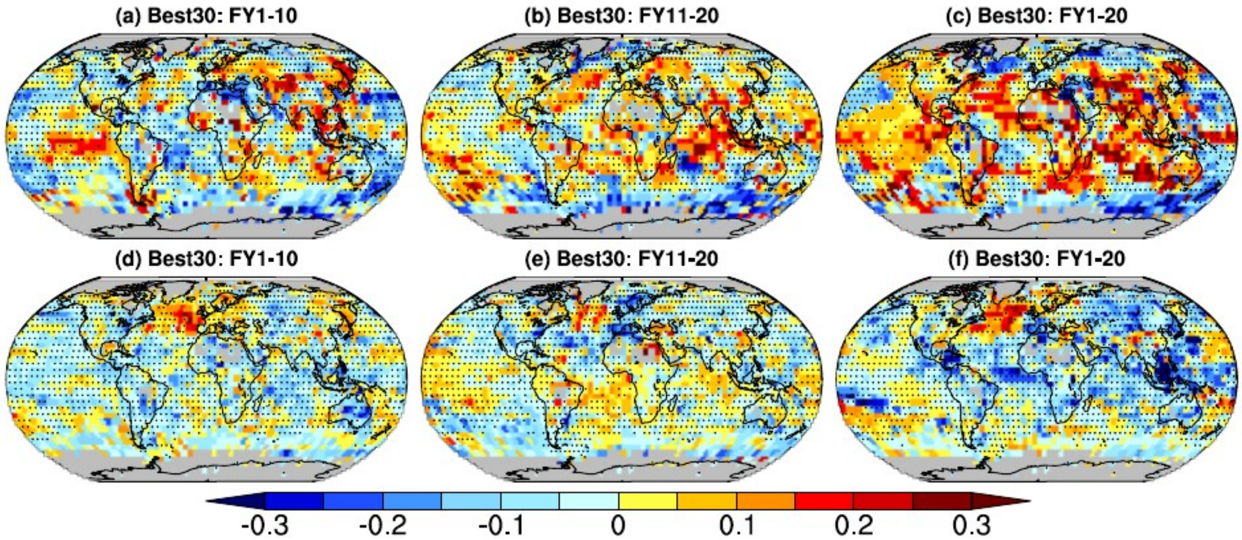

Figure S6: RPSS for Best30 ensemble against the unconstrained CMIP6 ensemble of 212 members as reference. Best30 is constrained by nine year average SST anomaly patterns in the Pacific basin (a-c) and in the North Atlantic basic (d-f). Stipplings indicate regions where the results are statistically not significant at 95% confidence level.

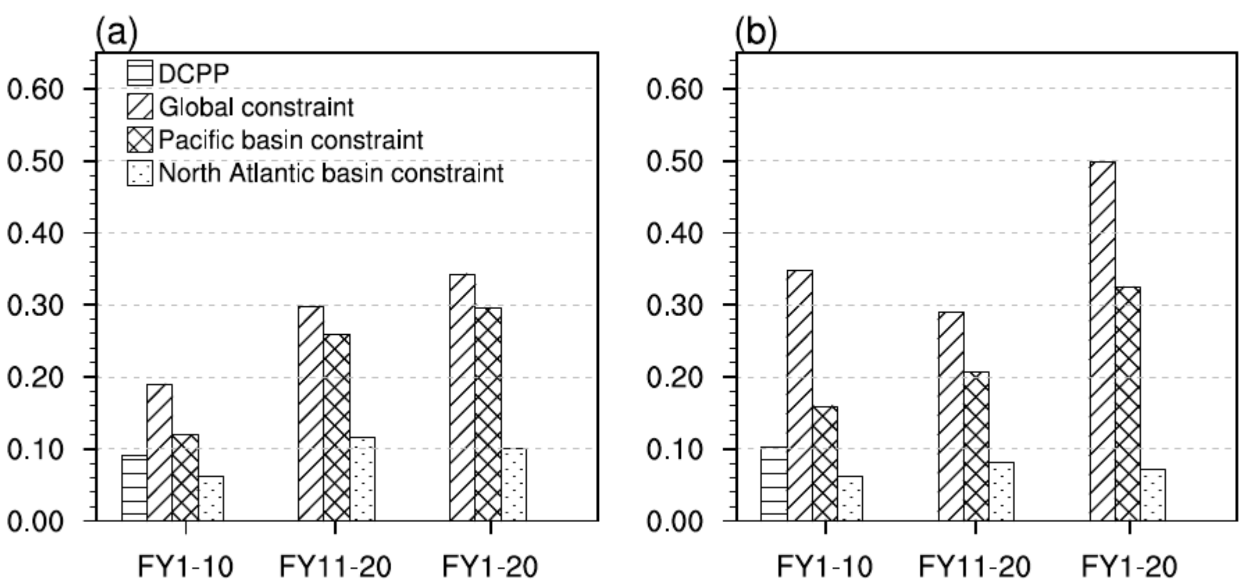

Figure S7: Fraction of global area where the added skill of DCPP and the Best30 constrained by different SST basins is positive and statistically significant for 95% confidence level for residual correlation (a) and for RPSS (b).

Text S1 Evaluating the hindcasts using different observational data sets.

This section evaluates the constrained ensembles and the DCPP using alternative observational reference data sets. For this we used surface air temperature from the Merged Land and Ocean Global Surface Temperature Analysis by NOAA (NOAAGlobalTemp, Huang et al., 2020), sea level pressure from the European Centre for Medium-Range Forecasts (ECMWF) Reanalysis Version 5 (ERA5; Hersbach et al., 2020) and precipitation data from the CRU TS 4.0.4 dataset (Harris et al., 2020). Overall the results shown in Figures S8-10 compare well with the results shown in the main text Figures 2-4. For example, for the surface temperature the Best30 ensemble shows high skill in terms of ACC and significant added value over the unconstrained ensemble in terms of residual correlations and RPSS in many global regions including the tropical Pacific, the Indian Ocean, north and south America and parts of Asian and Africa, (Figure S8). These results also suggest even higher added values than shown in Figure 2 especially over the southern Indian ocean with similar results for the Best30 and DCPP. The SLP and precipitation prediction skill of the constrained ensemble in Figures S9 and S10 respectively are generally similar to the results shown in Figures 3 and 4. The results based on these alternative observational datasets confirm the robustness of the skill of the constrained ensembles to the choice of reference dataset used for skill evaluation.

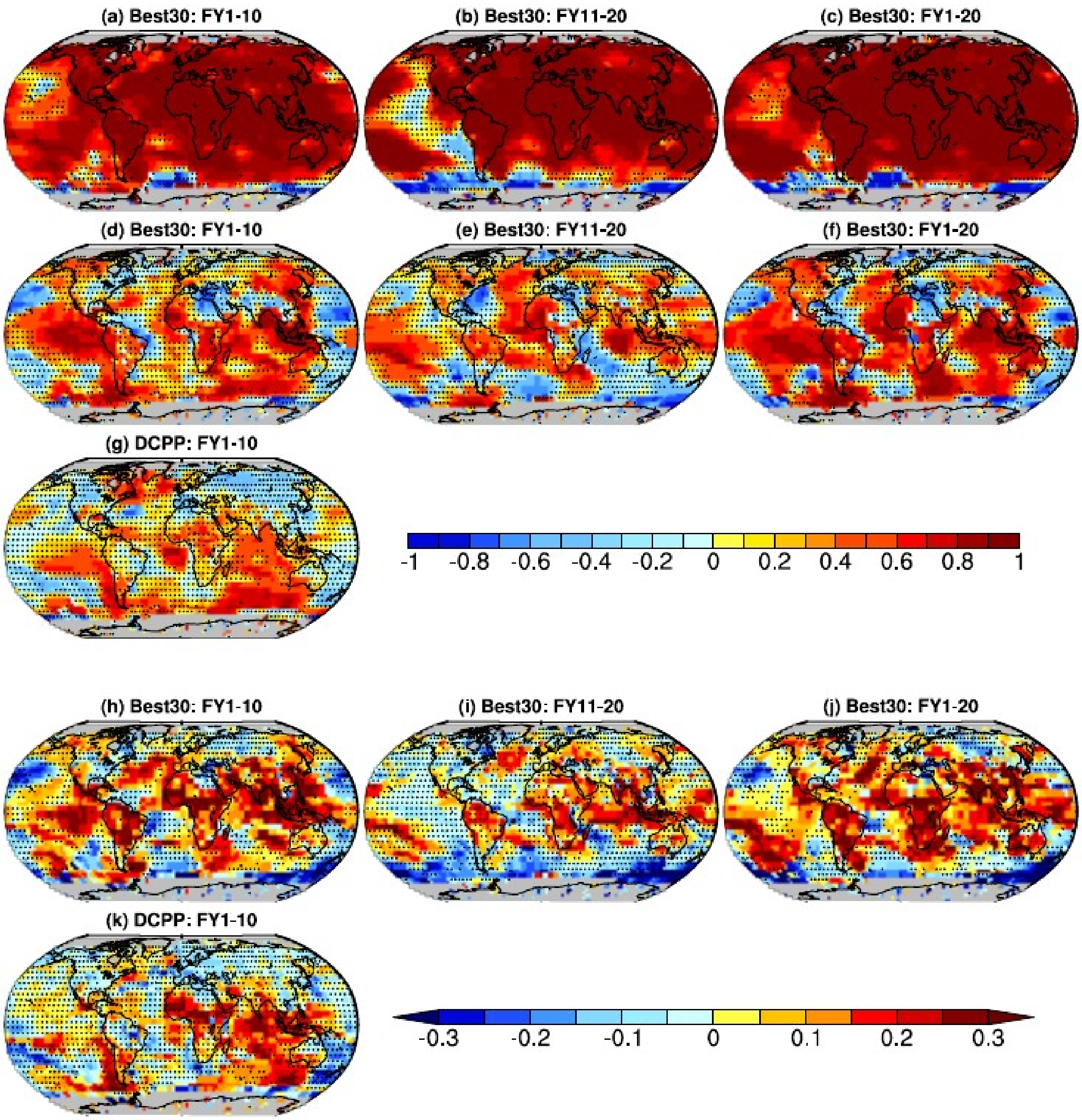

Figure S8: **Same as Figure 2 but using NOAAGlobalTemp as observation.** Anomaly correlation coefficient (ACC) between observed and predicted surface temperature anomalies for three forecast periods, average of forecast years 1-10, 11-20 and 1-20 (a-c). Residual correlations for Best30 (d-f) and for DCPP (g) ensemble means after removing the forced signal (estimated based on ensemble mean of the unconstrained CMIP6 212 members following Smith et al. (2019). RPSS for Best 30 (h-j) and for DCPP (k) against the unconstrained CMIP6 ensemble of 212 members as reference. Stipplings indicate regions where the ACC, residual correlation and RPSS are statistically not significant at 95% confidence level.

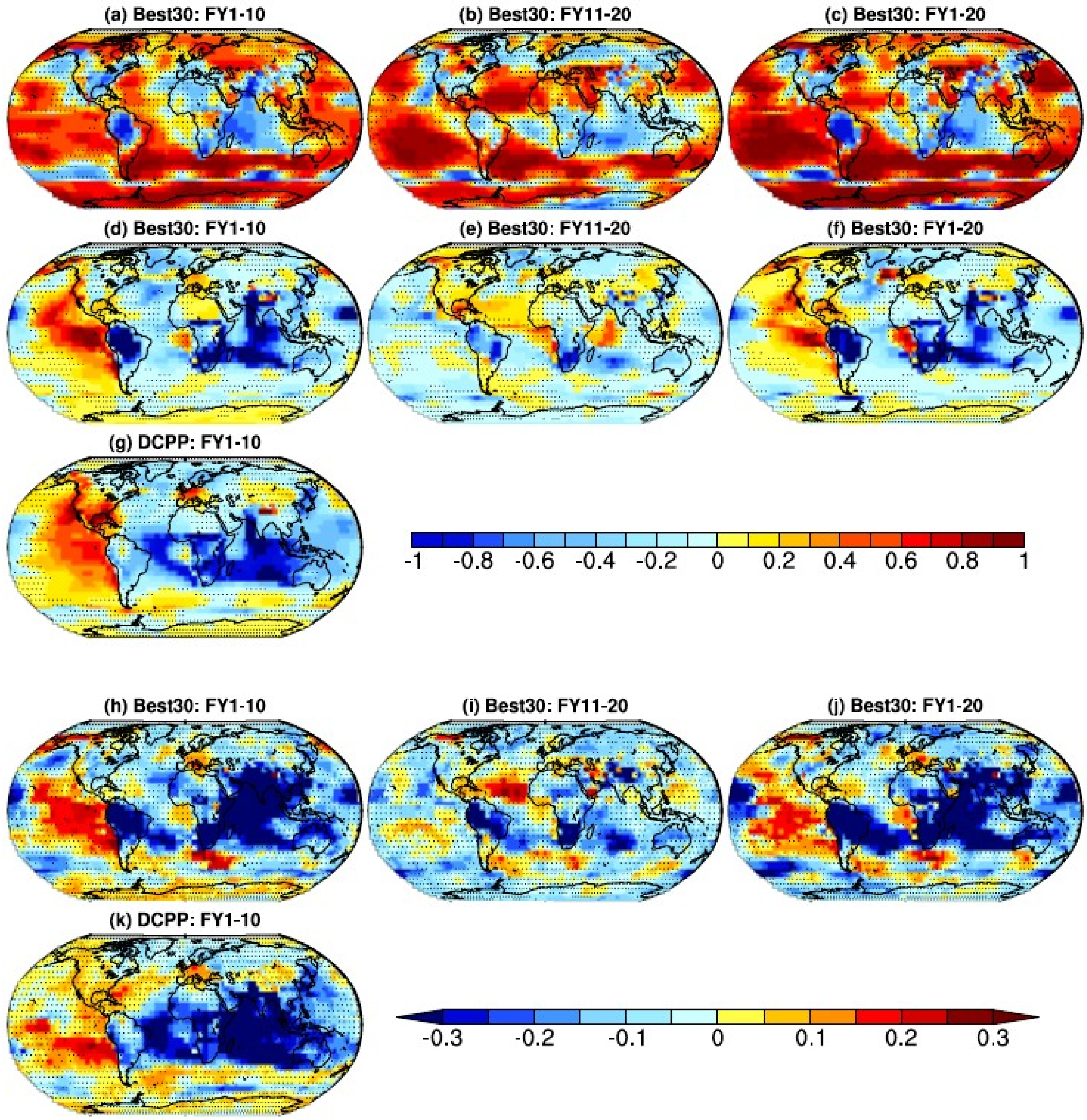

Figure 9: **Same as Figure 3 but using ERA5 SLP**. (a-c) Anomaly correlation coefficient (ACC) between observed and predicted SLP anomalies for Best30 ensemble mean. (d-f) ACC difference between Best30 and UNINIT ensembles means. (g) ACC difference between DCPP and UNIIT ensemble means. (h-j) RPSS for Best 30 and (k) for DCPP against the unconstrained CMIP6 ensemble of 212 members as reference. Stipplings indicate regions where the ACC, ACC difference and RPSS are statistically not significant at 95% confidence level.

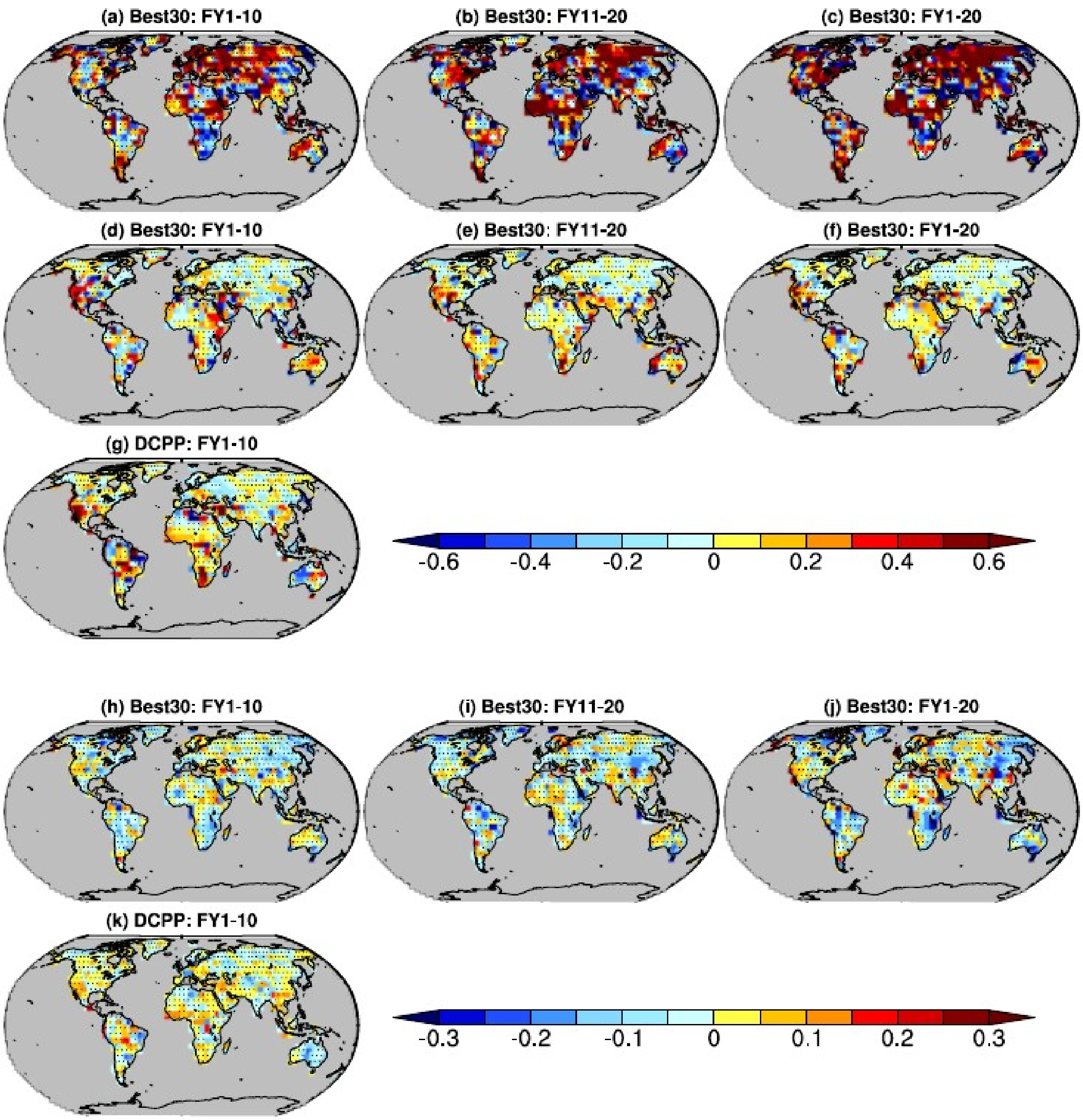

Figure 10: **Same as Figure 4 but using CRU precipitation**. (a-c) Anomaly correlation coefficient (ACC) between observed and predicted precipitation anomalies for Best30 ensemble mean. (d-f) Correlation difference between Best30 and UNINIT ensembles means. (g) Correlation difference between DCPP and UNIIT ensemble means. (h-j) RPSS for Best 30 and (k) for DCPP against the unconstrained CMIP6 ensemble of 212 members as reference. Stipplings indicate regions where the ACC, ACC difference and RPSS are statistically not significant at 95% confidence level. Stipplings indicate regions where the ACC, ACC difference and RPSS are statistically not significant at 95% confidence level.

Table S1: CMIP6 model simulations used in this study.

Model	Institution	# of DCPP-A members	# of unconstrained members	Reference
ACCESS-CM2	CSIRO-ARCCSS	-	3	Bi et al. (2020)
ACCESS-ESM1-5	CSIRO	-	6	Ziehn et al. (2020)
BCC-CSM2-MR	BCC	8	1	Wu et al. (2019)
CAMS-CSM1-0	CAMS	-	2	Rong et al. (2019)
CAS-ESM2-0	CAS	-	2	Guangqing et al. (2020)
CESM2	NCAR	-	1	Danabasoglu et al. (2020)
CESM2-WACCM	NCAR	-	3	Gettelman et al. (2019)
CMCC-CM2-SR5	CMCC	6	1	Cherchi et al. (2019)
CMCC-ESM2	CMCC	-	1	Lovato et al. (2022)
CanESM5	CCCma	20	25	Swart et al. (2019)
CanESM5-CanOE	CCCma	-	3	Swart et al. (2019)
CNRM-CM6-1	CNRM-CERFACS	-	6	Voldoire et al. (2019)
CNRM-CM6-1-HR	CNRM-CERFACS	-	1	Voldoire et al. (2019)
CNRM-ESM2-1	CNRM-CERFACS	-	10	Séférian et al. (2019)
EC-Earth3	EC-Earth consortium	10	13	Bilbao et al. (2021)
FGOALS-f3-L	CAS	-	1	He et al. (2019)
FGOALS-g3	CAS	-	3	Pu et al. (2020)
FIO-ESM-2-0	FIO-QLNM	-	3	Bao et al. (2020)
GISS-E2-1-G	NASA-GISS	-	10	Kelley et al. (2020)
HadGEM3-GC31-LL	MOHC	-	1	Andrews et al. (2020)
HadGEM3-GC31-MM	MOHC	10	-	Sellar et al. (2020)
IITM-ESM	CCCR-IITM	-	1	Krishnan et al. (2019)
INM-CM5-0	INM	-	1	Volodin et al. (2017)
IPSL-CM6A-LR	IPSL	10	11	Boucher et al. (2020)
KIOST-ESM	KIOST	-	1	Pak et al. (2021)
MIROC-ES2L	MIROC	-	30	Hajima et al. (2020)
MIROC6	MIROC	10	50	Tatebe et al. (2019)
MPI-ESM1-2-HR	MPI-M	9	-	Müller et al. (2018)

MPI-ESM1-2-LR	MPI-M	-	10	Mauritsen et al. (2019)
MRI-ESM2-0	MRI	-	1	Yukimoto et al. (2019)
NESM3	NUIST	-	2	Cao et al. (2018)
NorESM2-LM	NCC	-	3	Seland et al. (2020)
NorESM2-MM	NCC	-	1	Seland et al. (2020)
NorCPM1	NCC	10	-	Bethke et al. (2021)
UKESM1-0-LL	NIMS-KMA	-	5	Sellar et al. (2019)

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