# Supplementary Material

# Seamless climate information for the next months to multiple years: merging of seasonal and decadal predictions, and their comparison to multi-annual predictions

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**Table S1.** Forecast systems and their ensemble members of seasonal, multi-annual and decadal predictions.

| Timescale | Forecast months | Total members | Forecast system | Ensemble members | Reference |
|---|---|---|---|---|---|
| Seasonal | 1–6 | 25 | SEAS5 | 1-–25 | Johnson et al. (2019) |
| Multi-annual | 1–24 | 70 | CMCC-CM2-SR5-i5 | r1–10i5p1f1 | Nicolì et al. (2023) |
| | | | EC-Earth3 | r1–20i5p1f1 | Bilbao et al. (2021) |
| | | | EC-Earth3-HR | r1–15i1p1f1 | Döscher et al. (2022) |
| | | | SEAS5 | 1–25 | Johnson et al. (2019) |
| Decadal | 1–60 | 197 | BCC-CSM2-MR | r1–8i1p1f1 | Wu et al. (2019) |
| | | | CanESM5 | r1–20i1p2f1 | Swart et al. (2019) |
| | | | CESM1-1-CAM5 | 1–40 | Yeager et al. (2018) |
| | | | CMCC-CM2-SR5 | r1–10i1p1f1 | Nicolì et al. (2023) |
| | | | CNRM-ESM2-1 | r1–10i1p1f2 | Séférian et al. (2019) |
| | | | EC-Earth3 | r1–10i1p1f1 | Bilbao et al. (2021) |
| | | | EC-Earth3 | r6–10i2p1f1 | Tian et al. (2021) |
| | | | EC-Earth3 | r1–10i4p1f1 | Bilbao et al. (2021) |
| | | | FGOALS-f3-L | r1–3i1p1f1 | Hu et al. (2023) |
| | | | HadGEM3-GC3.1-MM | r1–10i1p1f2 | Sellar et al. (2020) |
| | | | IPSL-CM6A-LR | r1–10i1p1f1 | Boucher et al. (2020) |
| | | | MIROC6 | r1–10i1p1f1 | Tatebe et al. (2019) |
| | | | MPI-ESM1.2-HR | r6–10i1p1f1 | Müller et al. (2018) |
| | | | MPI-ESM1.2-LR | r1–16i1p1f1 | Mauritsen et al. (2019) |
| | | | MRI-ESM2-0 | r1–10i1p1f1 | Yukimoto et al. (2019) |
| | | | NorCPM1 | r1–10i1p1f1 | Bethke et al. (2021) |
| | | | NorCPM1 | r1–10i2p1f1 | Bethke et al. (2021) |

**Table S2.** Climate models and their ensemble ensembles of historical forcing simulations and climate projections (historical + SSP2-4.5).

| Total members | Climate model | Members | Reference |
|---|---|---|---|
| | ACCESS-CM2 | r1–5i1p1f1 | Bi et al. (2020) |
| | ACCESS-ESM1-5 | r1–12i1p1f1 | Ziehn et al. (2020) |
| | BCC-CSM2-MR | r1i1p1f1 | Wu et al. (2019) |
| | CAMS-CSM1-0 | r1–2i1p1f1 | Rong et al. (2019) |
| | CAS-ESM2-0 | r(1,3)i1p1f1 | Li et al. (2023) |
| | CESM1-1-CAM5-CMIP5 | 1–40 | Yeager et al. (2018) |
| | CESM2-WACCM | r1–3i1p1f1 | Liu et al. (2019) |
| | CMCC-CM2-SR5 | r1i1p1f1 | Cherchi et al. (2019) |
| | CMCC-ESM2 | r1i1p1f1 | Lovato et al. (2022) |
| | CNRM-CM6-1-HR | r1i1p1f2 | Saint-Martin et al. (2021) |
| | CNRM-CM6-1 | r1–6i1p1f2 | Voldoire et al. (2019) |
| | CNRM-ESM2-1 | r1–10i1p1f2 | Séférian et al. (2019) |
| | CanESM5-CanOE | r1–3i1p2f1 | Swart et al. (2019) |
| | CanESM5 | r1–25i1p2f1 | Swart et al. (2019) |
| 264 | EC-Earth3 | r(2,7,10,12,14,16–25)i1p1f1 | Döscher et al. (2022) |
| | FGOALS-f3-L | r1i1p1f1 | Guo et al. (2020) |
| | FGOALS-g3 | r4i1p1f1 | Pu et al. (2020) |
| | FIO-ESM-2-0 | r1–3i1p1f1 | Bao et al. (2020) |
| | GISS-E2-1-G | r1–10i1p1f2 | Miller et al. (2021) |
| | HadGEM3-GC3.1-LL | r1i1p1f3 | Andrews et al. (2020) |
| | INM-CM5-0 | r1i1p1f1 | Volodin et al. (2017) |
| | IPSL-CM6A-LR | r(1–6,10–11,14,22,25)i1p1f1 | Boucher et al. (2020) |
| | KIOST-ESM | r1i1p1f1 | Pak et al. (2021) |
| | MIROC-ES2L | r1–30i1p1f2 | Hajima et al. (2020) |
| | MIROC6 | r1–50i1p1f1 | Tatebe et al. (2019) |
| | MPI-ESM1-2-HR | r1–2i1p1f1 | Müller et al. (2018) |
| | MPI-ESM1-2-LR | r1–10i1p1f1 | Mauritsen et al. (2019) |
| | MRI-ESM2-0 | r1–5i1p1f1 | Yukimoto et al. (2019) |
| | NESM3 | r1–2i1p1f1 | Cao et al. (2018) |
| | NorESM2-LM | r1–3i1p1f1 | Seland et al. (2020) |
| | NorESM2-MM | r1i1p1f1 | Seland et al. (2020) |
| | UKESM1-0-LL | r(1–4,8)i1p1f2 | Sellar et al. (2020) |

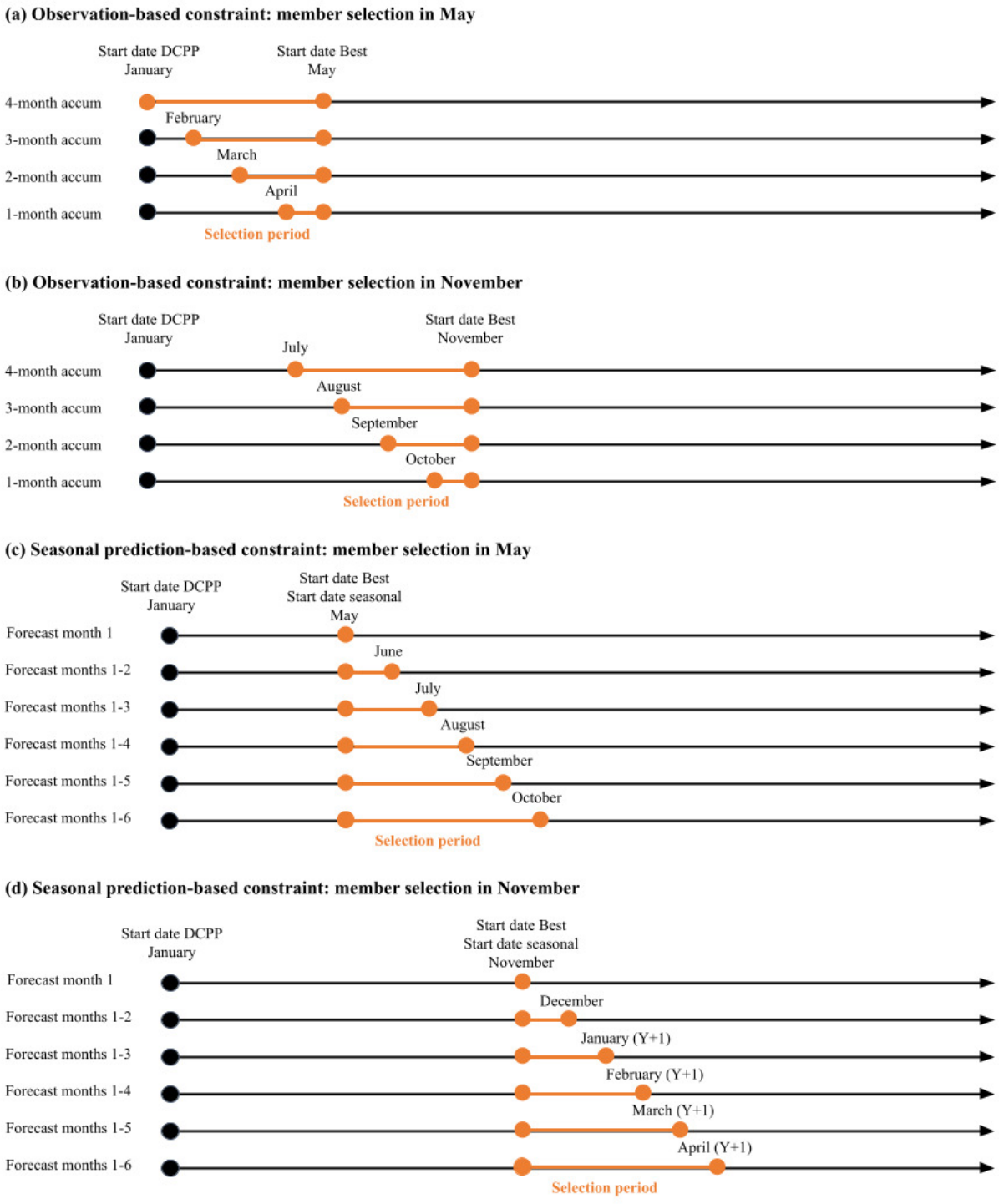


**Figure S1.** Illustration of the periods for observation-based and seasonal prediction-based constraints.

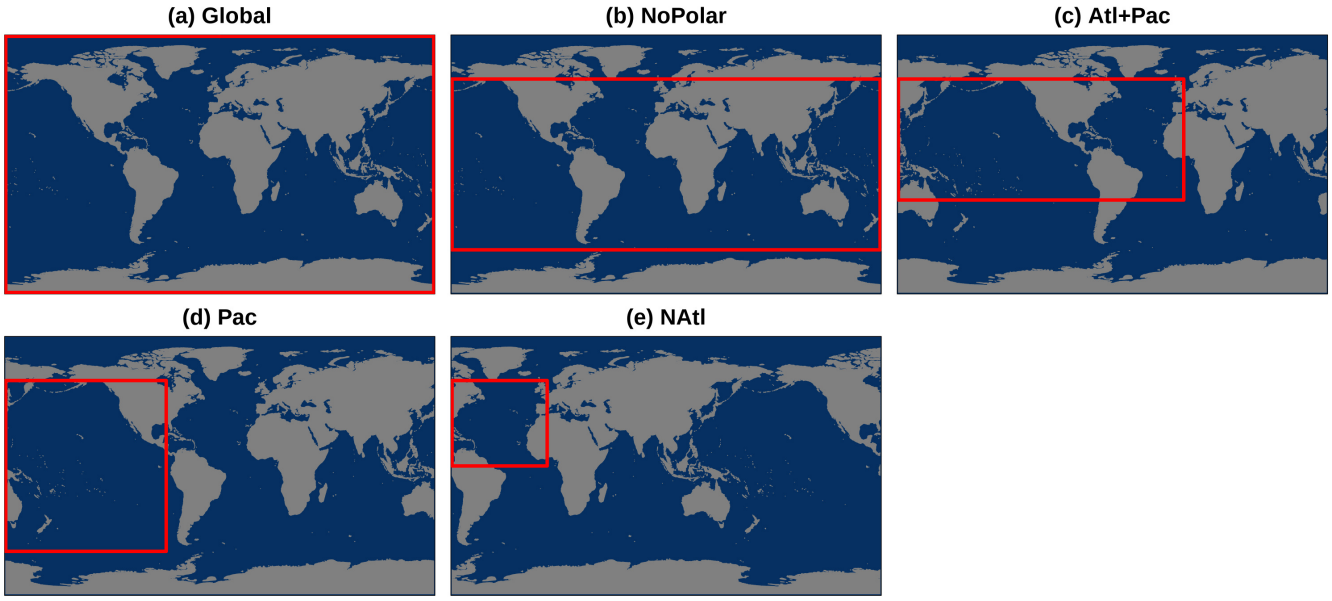


**Figure S2.** Constraining regions used to rank the ensemble members. The coordinates of the regions limits are: Global (180ºW-180ºE, 90ºS-90ºN), Global without the poles (NoPolar; 180ºW-180ºE, 60ºS-60ºN), Atlantic and Pacific Oceans (Alt+Pac; 120ºE-0ºE, 25ºS-60ºN), Pacific Ocean (Pac; 140ºE-85ºW, 60ºS-60ºN) and North Atlantic Ocean (NAtl; 80ºW-0ºE, 0ºN-60ºN).

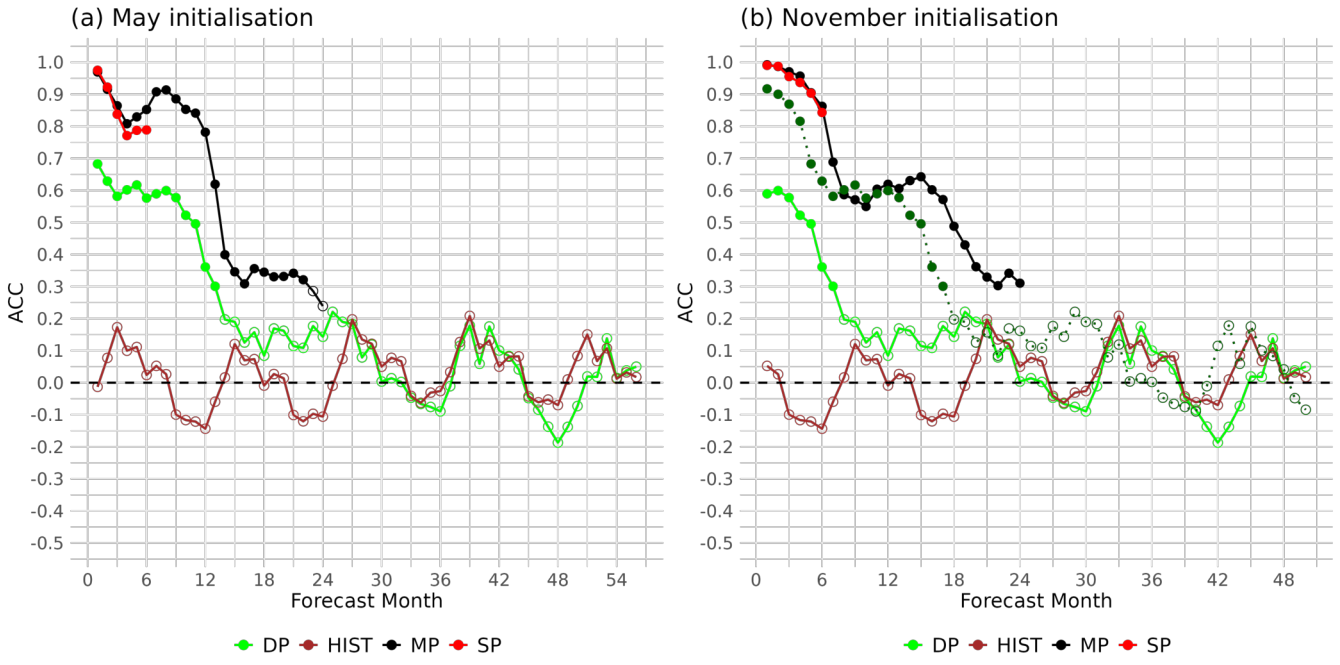


**Figure S3.** Forecast quality for the Niño3.4 index. ACC as a function of the forecast month for predictions issued in May (left) and November (right). The forecast quality is shown for SP (red), MP (black), DP (green). In the case of the November initialisation (right), the skill for DP is also shown from the first forecast months after initialisation (i.e. from January; dark green) for comparison to the skill for DP initialised at the end of the previous year (i.e. previous January; green). The ERA5 reanalysis has been used as the reference dataset. Filled dots indicate statistically significant ACC using a one-sided t-test at the 95% confidence level accounting for timeseries autocorrelation.

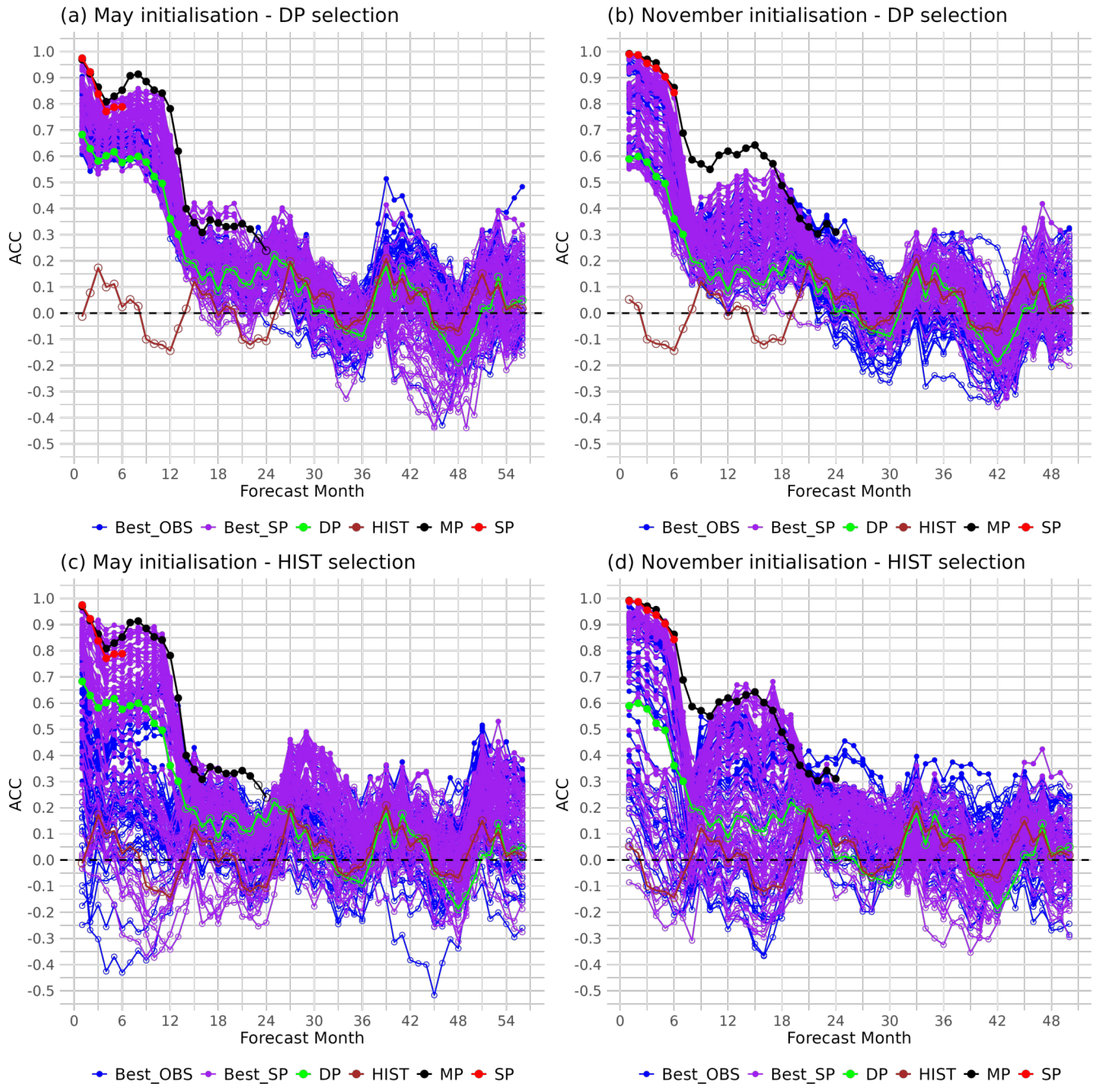


**Figure S4.** Same as Figure 1, but when the best members are selected only from the DP ensemble (top) or HIST ensemble (bottom) for predictions issued in May (left) and November (right).

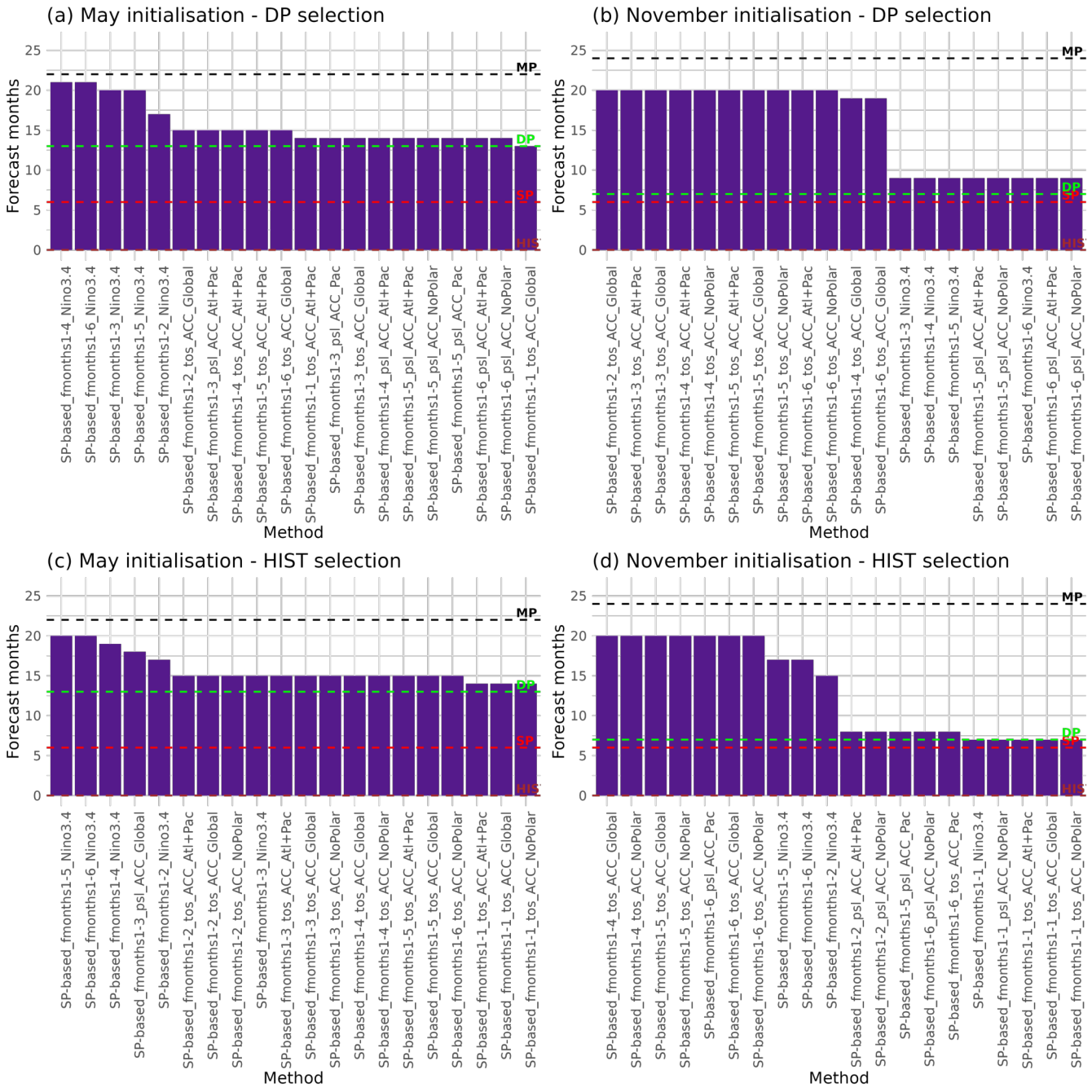


**Figure S5.** Same as Figure 2, but for when the best members are selected only from the DP ensemble (top) or HIST ensemble (bottom) for predictions issued in May (left) and November (right).

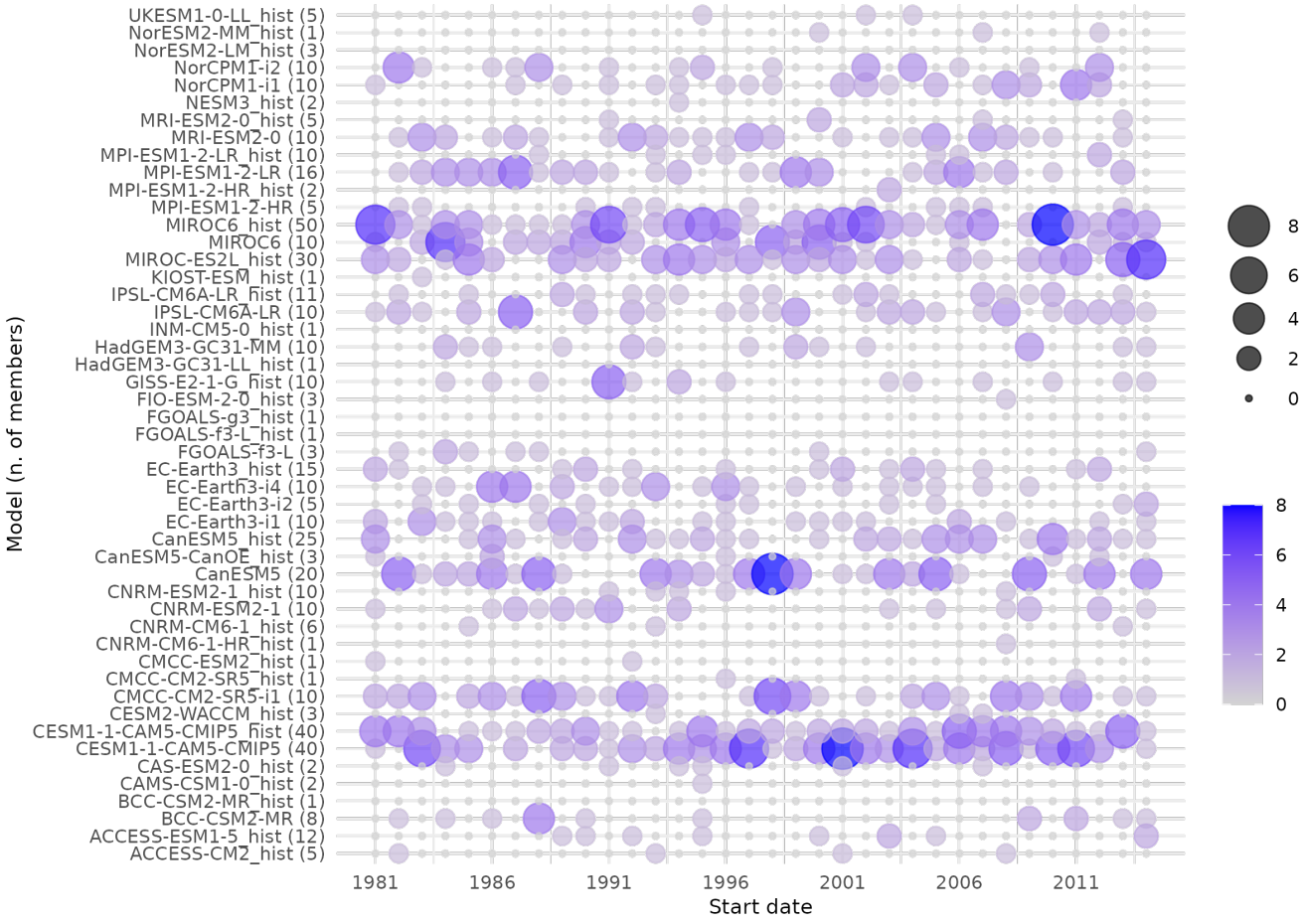


**Figure S6.** Number of selected members per model for each start date for May initialisation. Model names ending with "_hist" correspond to the HIST ensemble, while the rest correspond to the DP ensemble. The constraining method is based on SP of the Niño3.4 index for the forecast months 1-6.

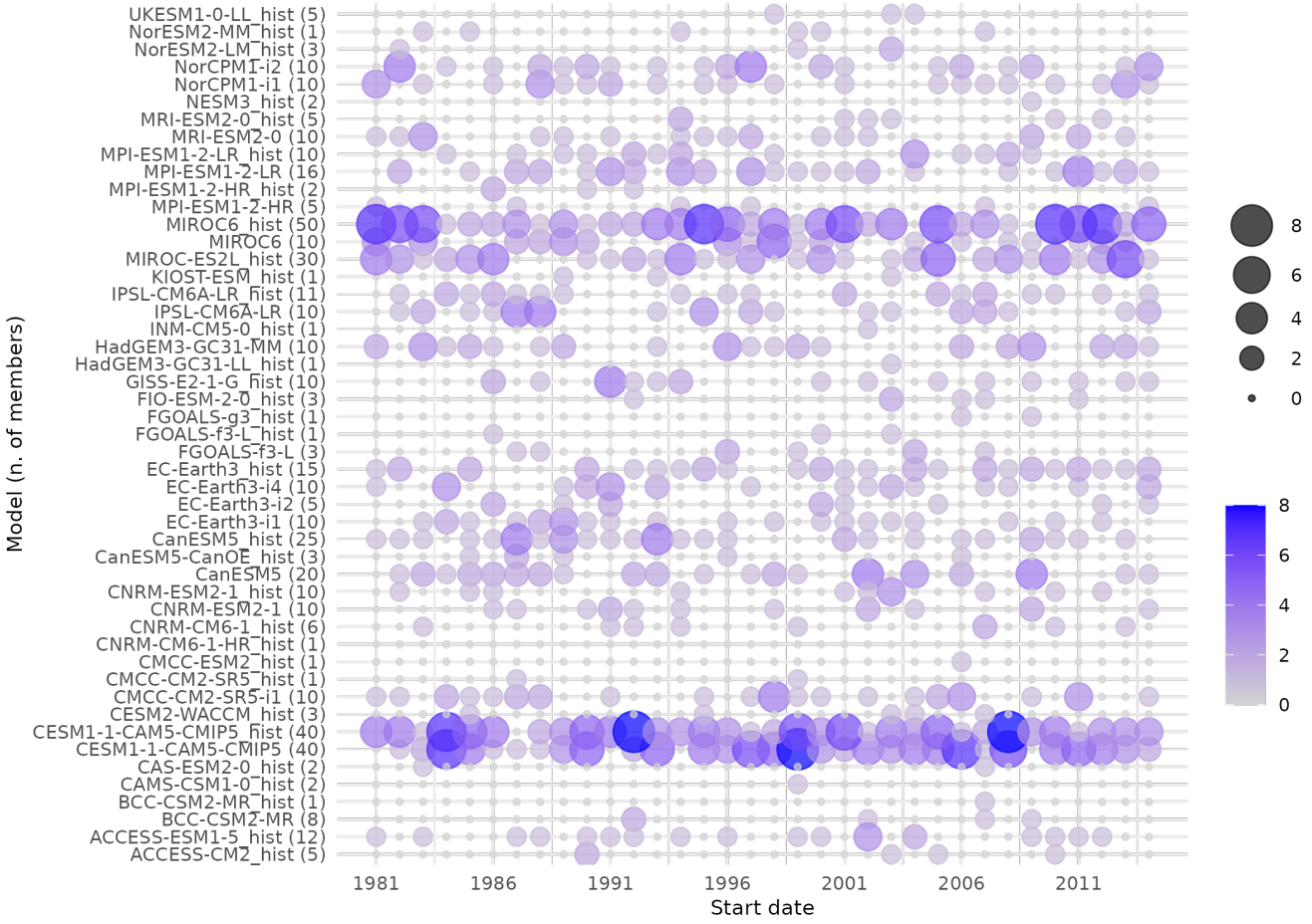


**Figure S7.** Same as Figure S6, but for November initialisation.

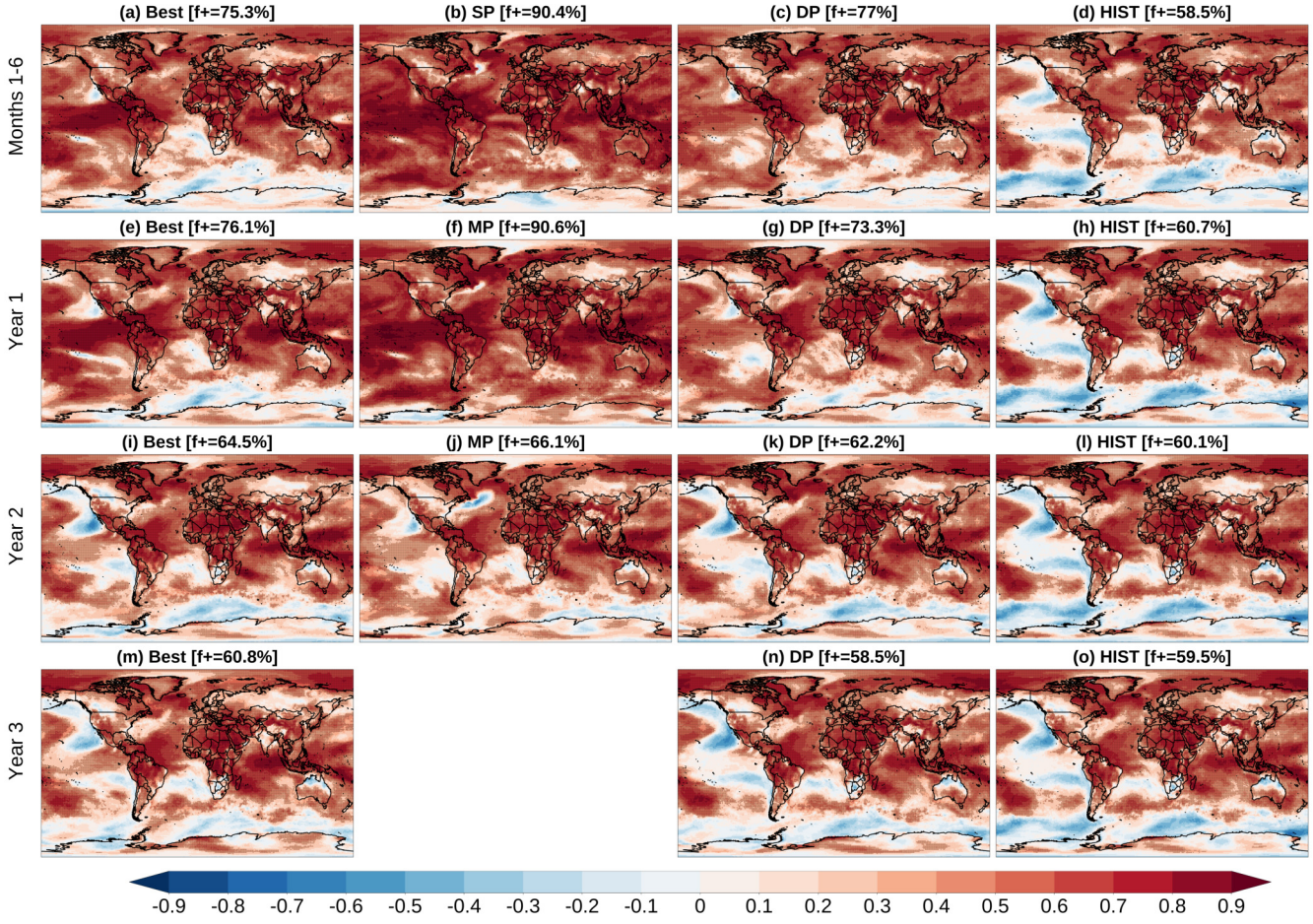


**Figure S8.** Same as Figure 3, but showing the ACC for all ensembles and forecast periods.

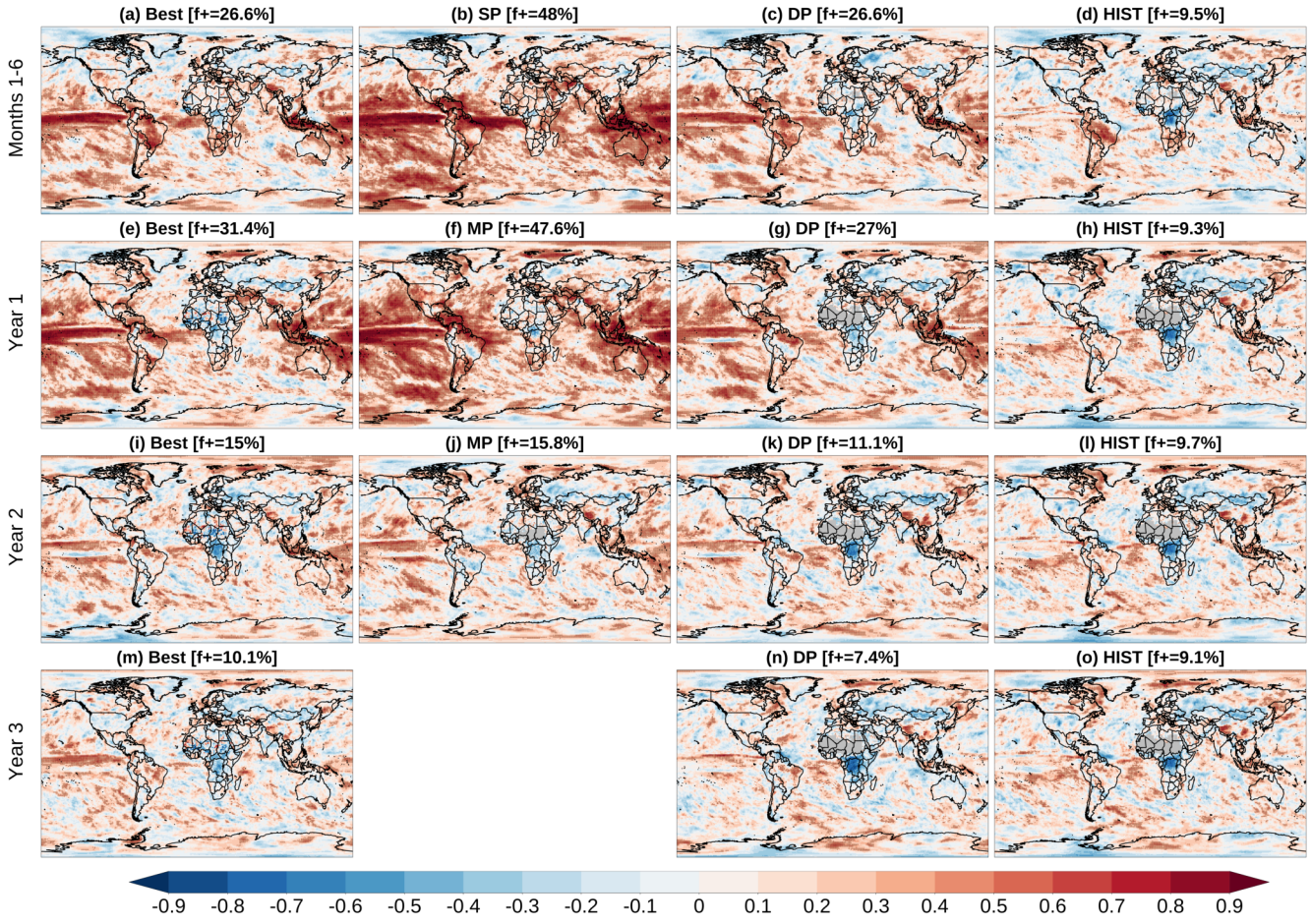


**Figure S9.** Same as Figure 4, but showing the ACC for all ensembles and forecast periods.

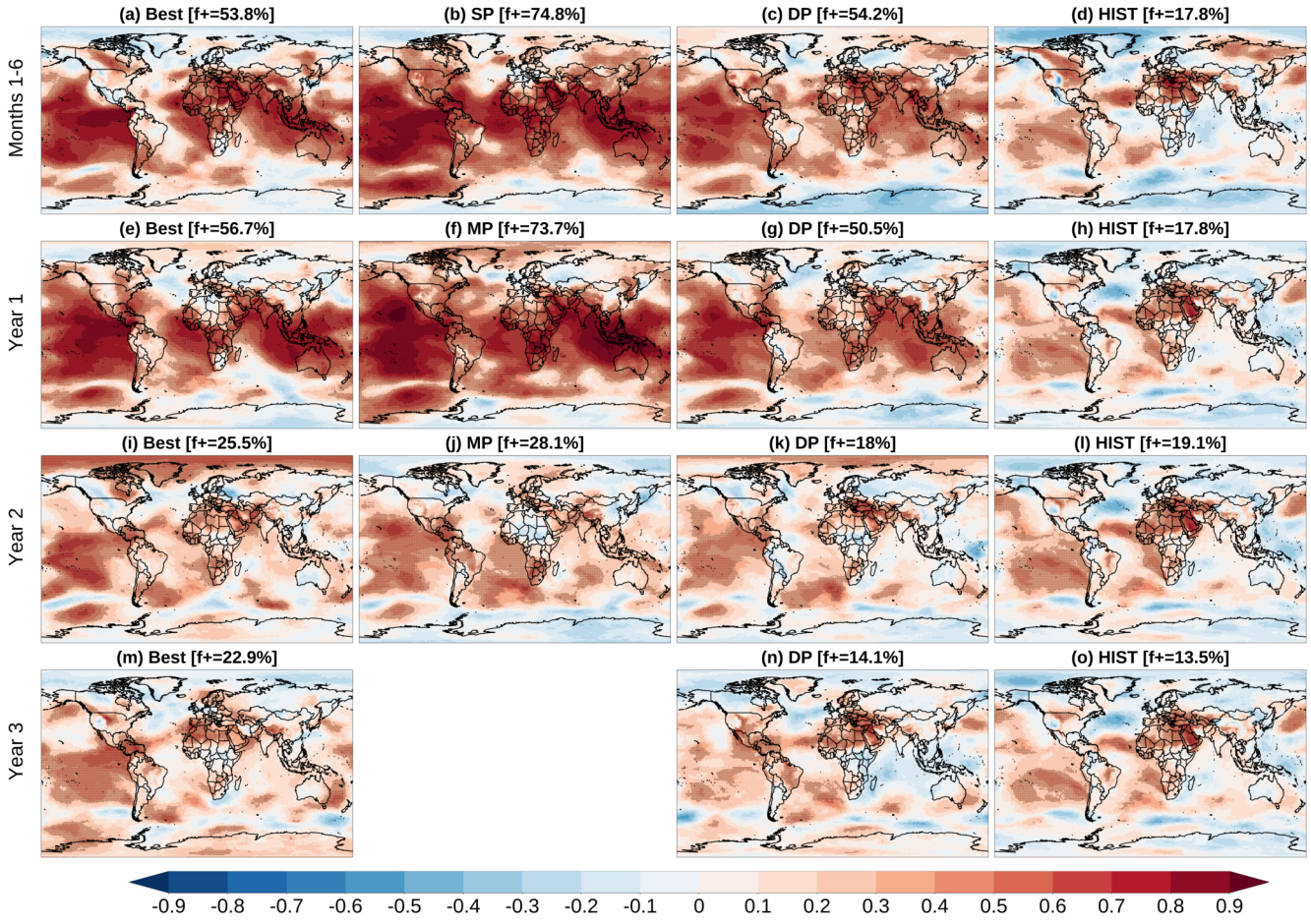


**Figure S10.** Same as Figure 5, but showing the ACC for all ensembles and forecast periods.

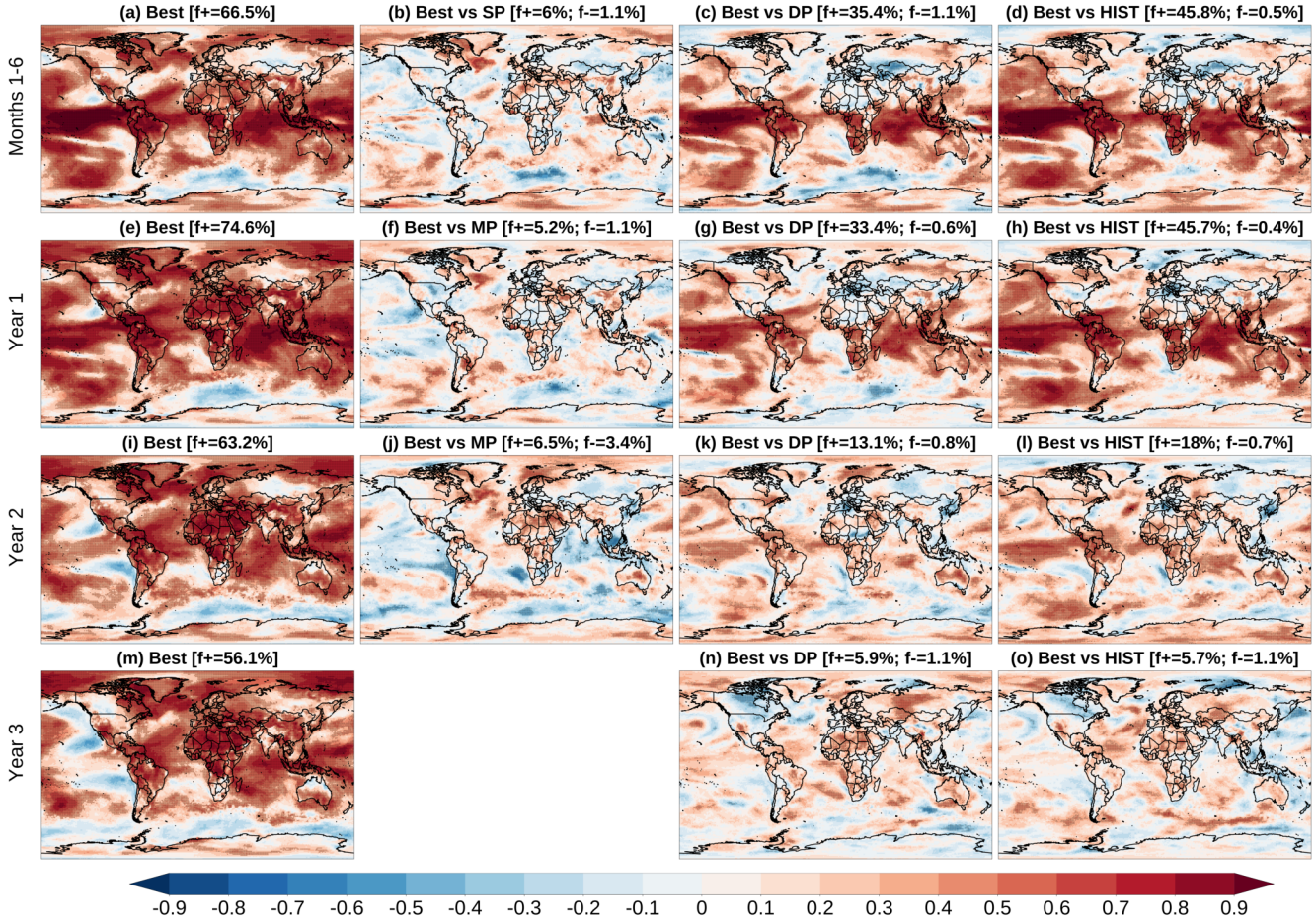


**Figure S11.** Same as Figure 3, but for the November initialisation.

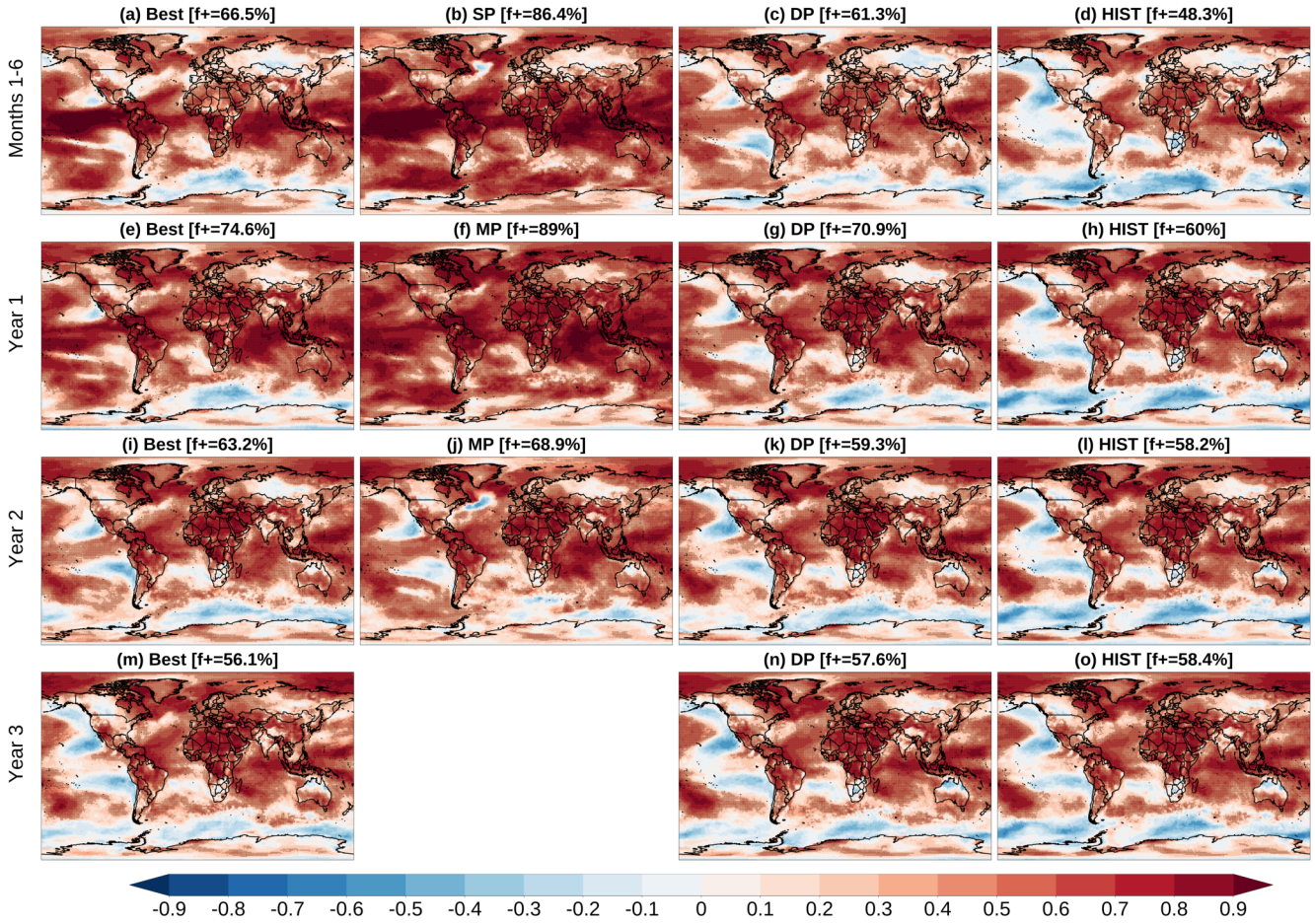


**Figure S12.** Same as Figure S8, but for the November initialisation

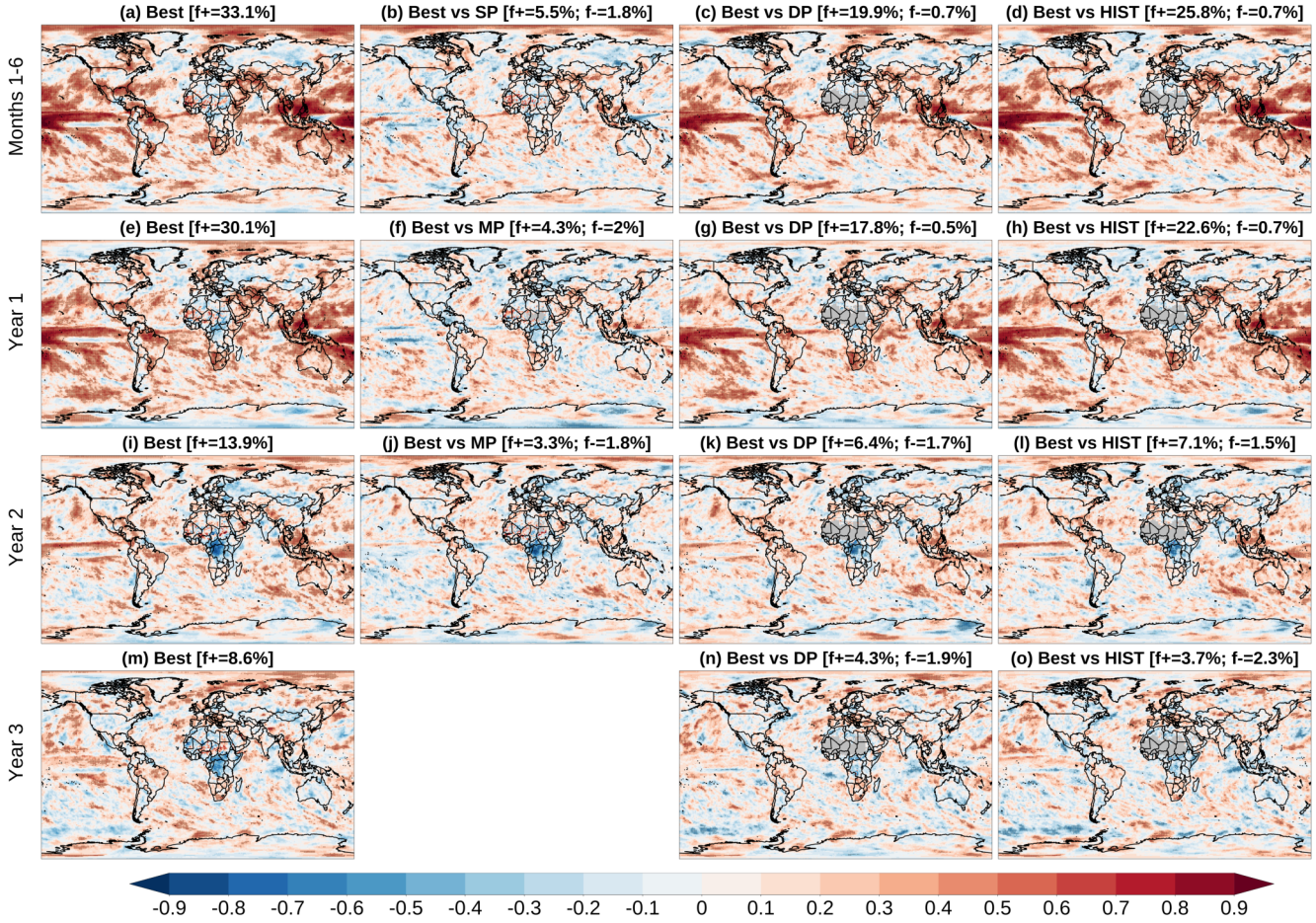


**Figure S13.** Same as Figure 4, but for the November initialisation.

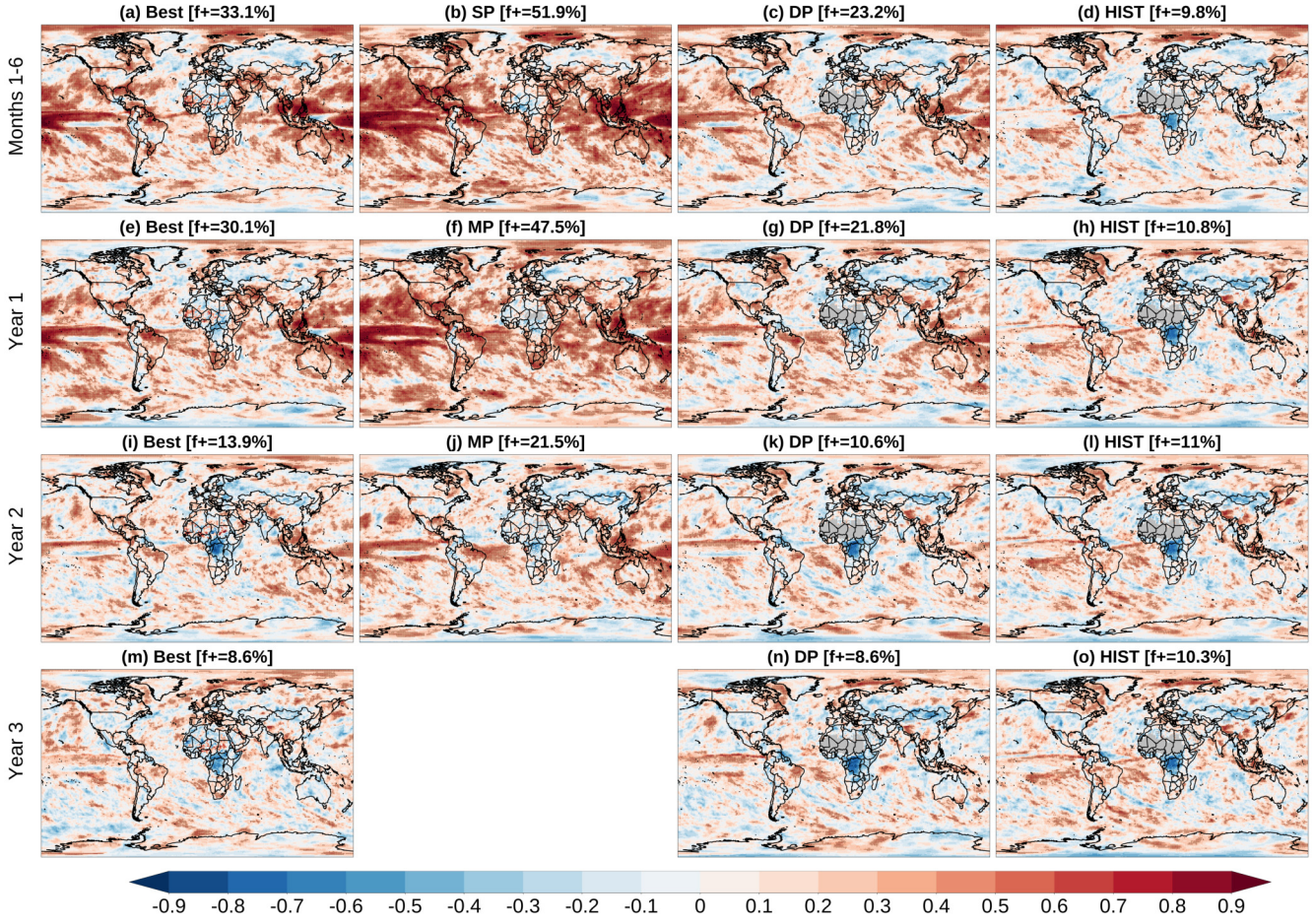


**Figure S14.** Same as Figure S9, but for the November initialisation.

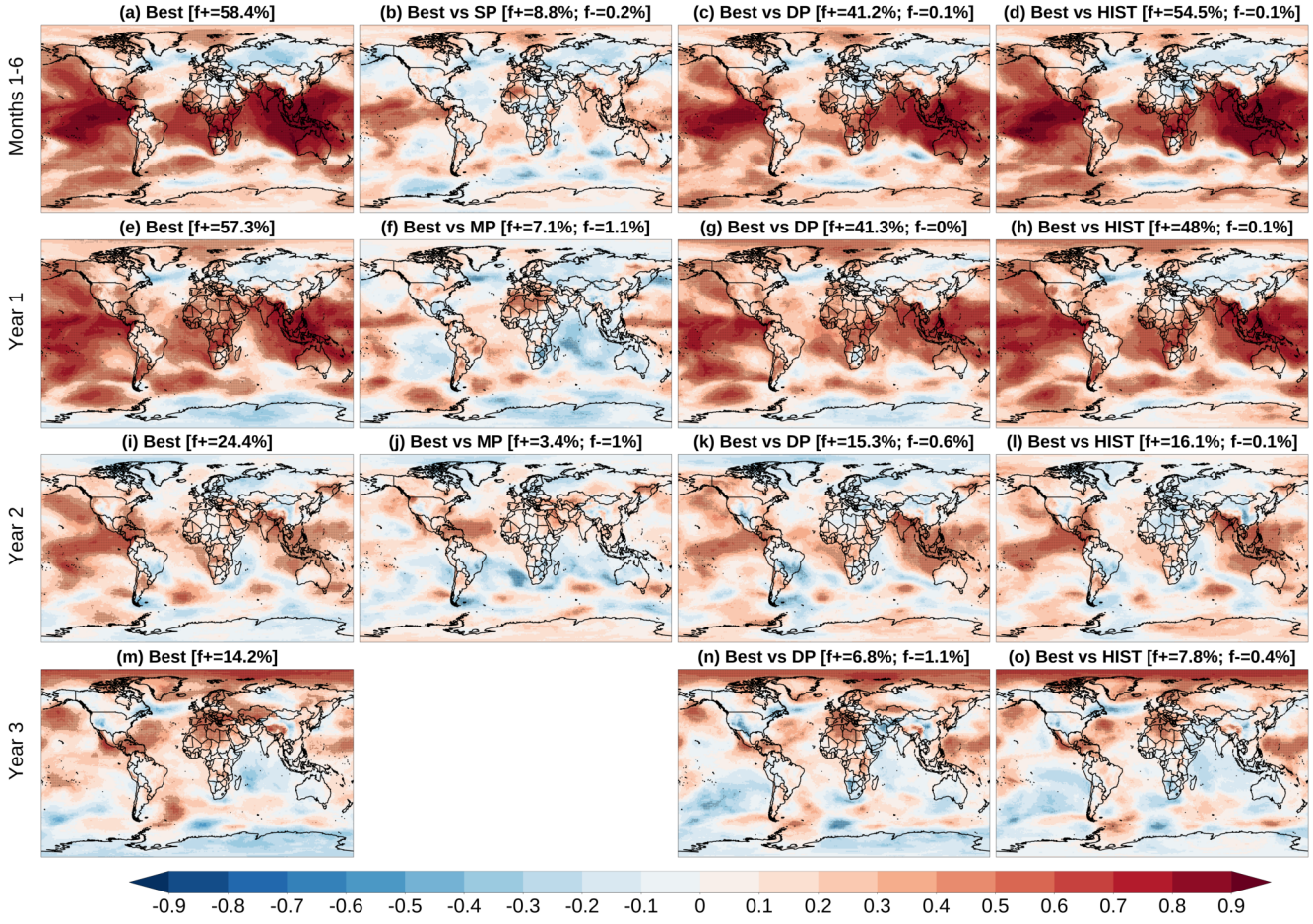


**Figure S15.** Same as Figure 5, but for the November initialisation.

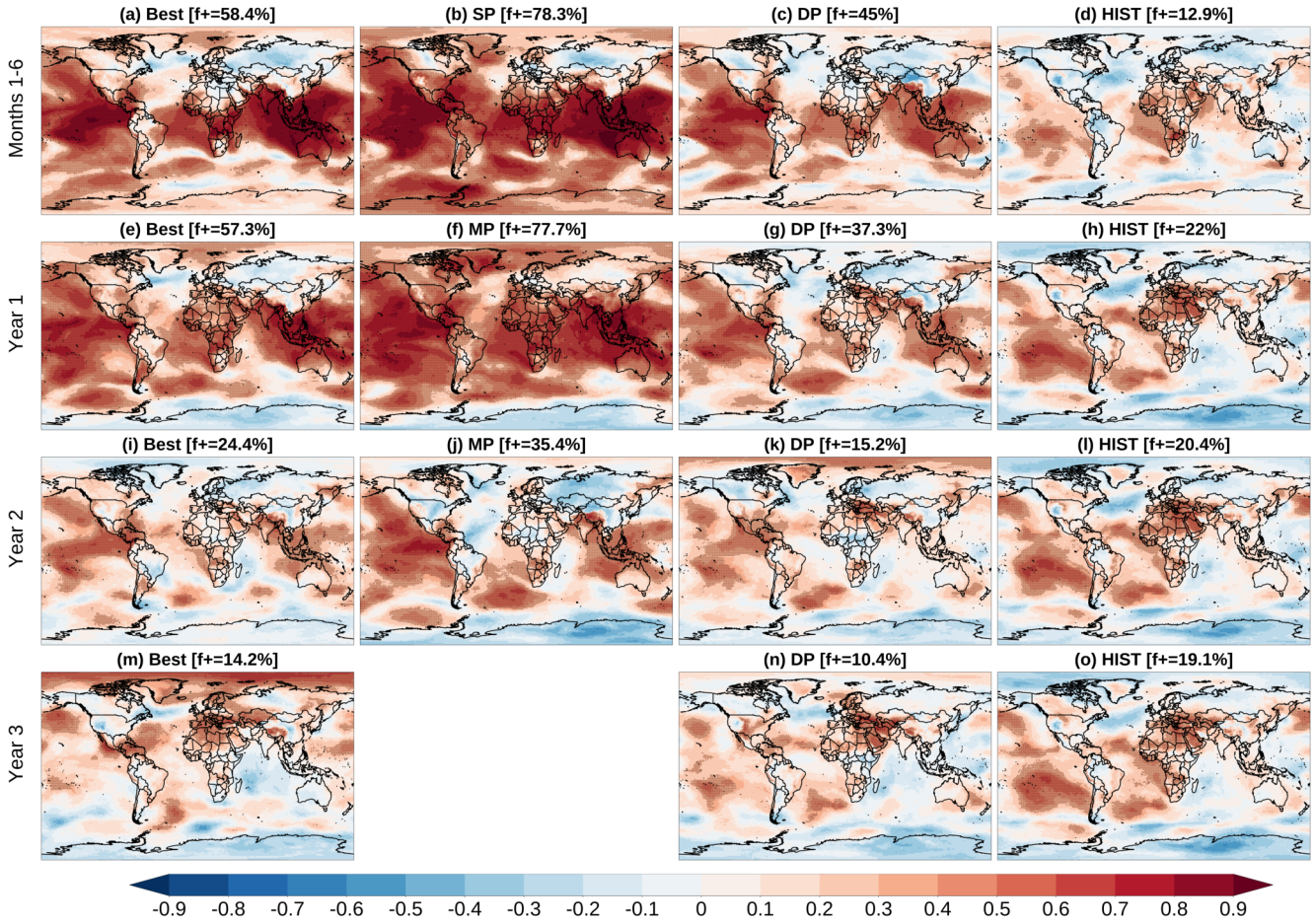


**Figure S16.** Same as Figure S10, but for the November initialisation.

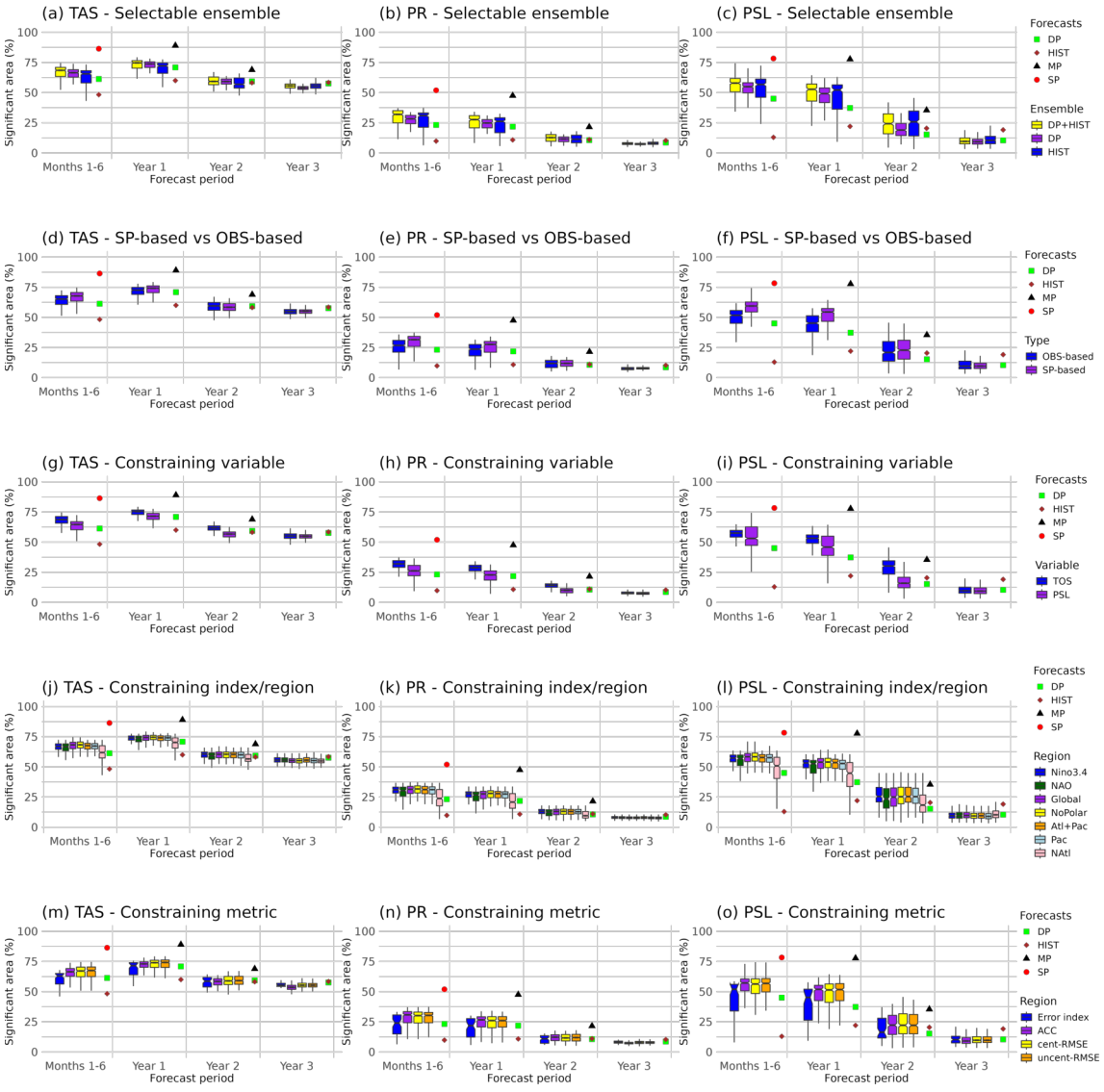


**Figure S17.** Same as Figure 6, but for the November initialisation.

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