Supplementary material for *Generating samples of extreme winters to support climate projections*

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S.1 Comparison of large-scale Euro-Atlantic dynamics in HadAM4 and HadGEM3-GC3.05

We used a principal component analysis to check whether the differences in DJF mean rainfall between the HadGEM3-GC3.05 and HadAM4 models over the baseline period (as described in the Results section) are due to differences in the simulated large-scale dynamics. Significant differences in these dynamics would be a concern, as it would represent a fundamental difference between the two models, and would make the ensemble comparisons in the main text less meaningful.

We computed the principal components (PCs) and corresponding empirical orthogonal functions (EOFs) of DJF mean mean sea level pressure (MSLP) anomaly data from the UKCP18 PPE 1997-2016 over the region bounded by 35:70N, -30:20E (Neal et al., 2016). We then determined which PCs were most important in explaining UK rainfall variance using an ordinary least-squares regression cross-validation. We regressed the top 20 (here we denote the PCs by their rank in terms of MSLP variance explained) MSLP PCs against DJF mean rainfall averaged over the UK from the same simulations, excluding one PC at a time, and observed which exclusions reduced the total rainfall variance explained by the regression model by the largest amount. Three PCs were clearly more important than the rest: 0, 1 and 4. The regression model using these three PCs as the predictors explains 71 % of the total variance in UK rainfall. Their corresponding EOFs are shown in Figure S1.

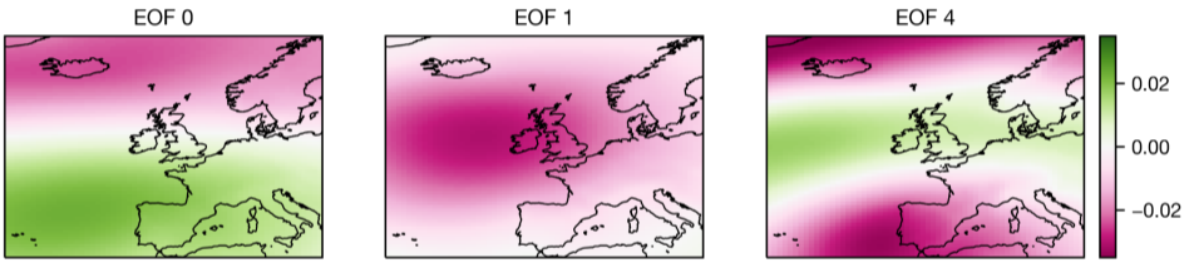

FIG S1: empirical orthogonal functions of UKCP18 PPE 1997-2026 Euro-Atlantic DJF mean sea level pressure. EOFs 0, 1 and 4 explain 43, 33 and 2.3 % of the overall variability in MSLP over the region shown.

Next, we compared the distribution of these chosen PCs to their distribution within the aggregated ExSamples baseline ensemble. The distribution of these PCs within the ExSamples baseline ensemble was computed by projecting their EOFs onto the simulated DJF mean MSLP anomalies, thereby generating a set of pseudo-PCs. We find no significant differences between the distributions of these PCs within the UKCP and ExSamples baseline ensembles, using a two-sample Kolmogorov-Smirnoff test (Hodges, 1958; Kolmogorov, 1933; Smirnoff, 1939a, 1939b). These distributions are shown in Figure S2.

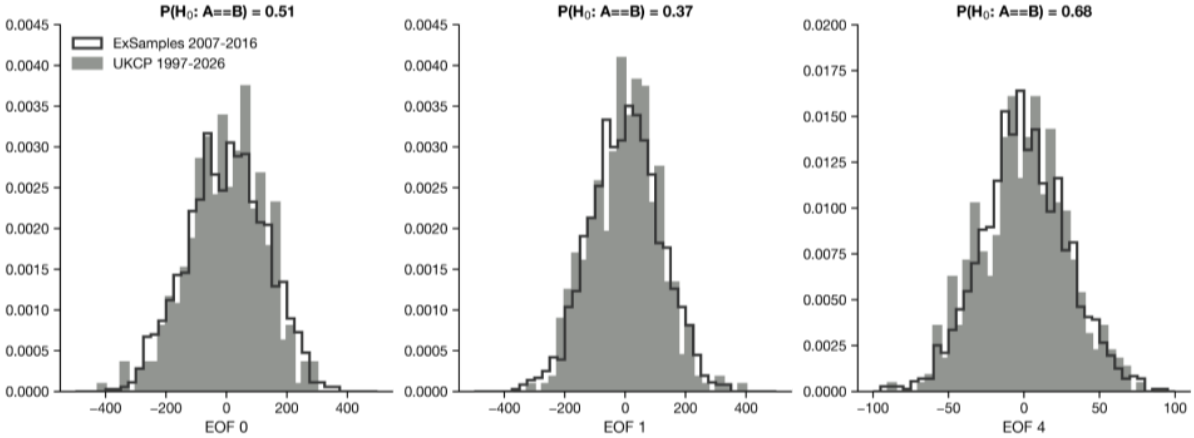

FIG S2: histograms of unscaled principal components associated with EOFs 0, 1 and 4. Grey filled histogram shows original PCs from decomposition of UKCP18 PPE 1997-2026. Black line histogram shows pseudo-PCs from EOF projection onto aggregated ExSamples 2007-2016 baseline. The subplot titles state the p-value of a two sample K-S test.

This analysis suggests that the difference in mean rainfall intensity between the two models is not due to differences in their simulation of large-scale mid-latitude dynamics. We suggest that these differences may be caused by differences in the parameterisation of precipitation or convection between the two models.

S.2 Analog frequency in ExSamples ensembles

Figure S3 displays the distribution of euclidean MSLP distances between the study winters and their corresponding ExSamples ensembles. This illustrates the slight increase in average distance to the study winter for the HOT1 ensemble compared to its corresponding baseline (and corresponding decrease in analog frequency), and vice versa for the HOT2 ensemble.

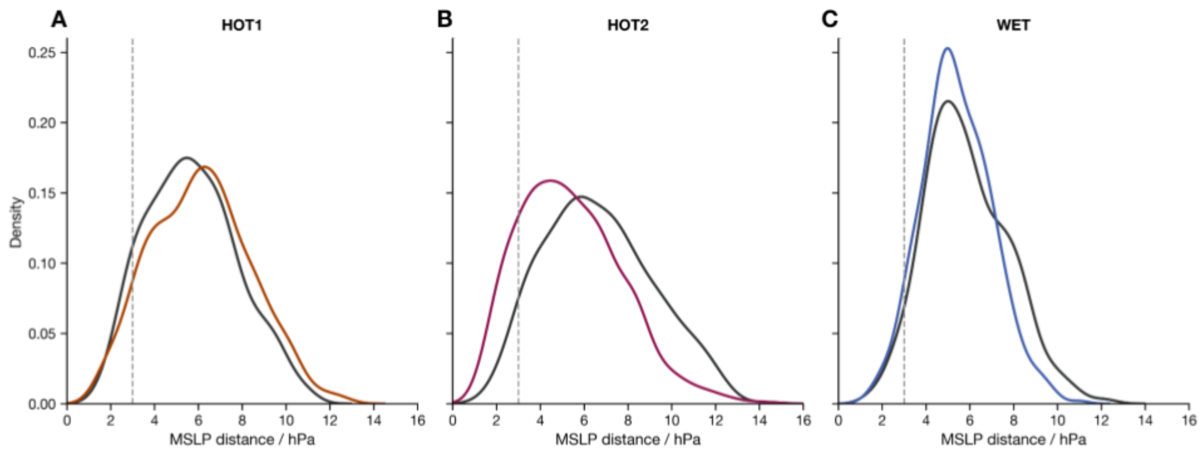

FIG S3: PDFs of euclidean MSLP distance between ExSamples ensemble members and corresponding UKCP18 extreme winters. Coloured lines show PDFs of ExSamples future ensembles, black lines show corresponding baseline ensembles. Dashed grey line indicates a distance of 3 hPa, the bounding limit of the analog selection criterion.

S.3 Comparison figures for additional variables

This section contains figures as Figure 3 for all the variables discussed in the main text.

TXm

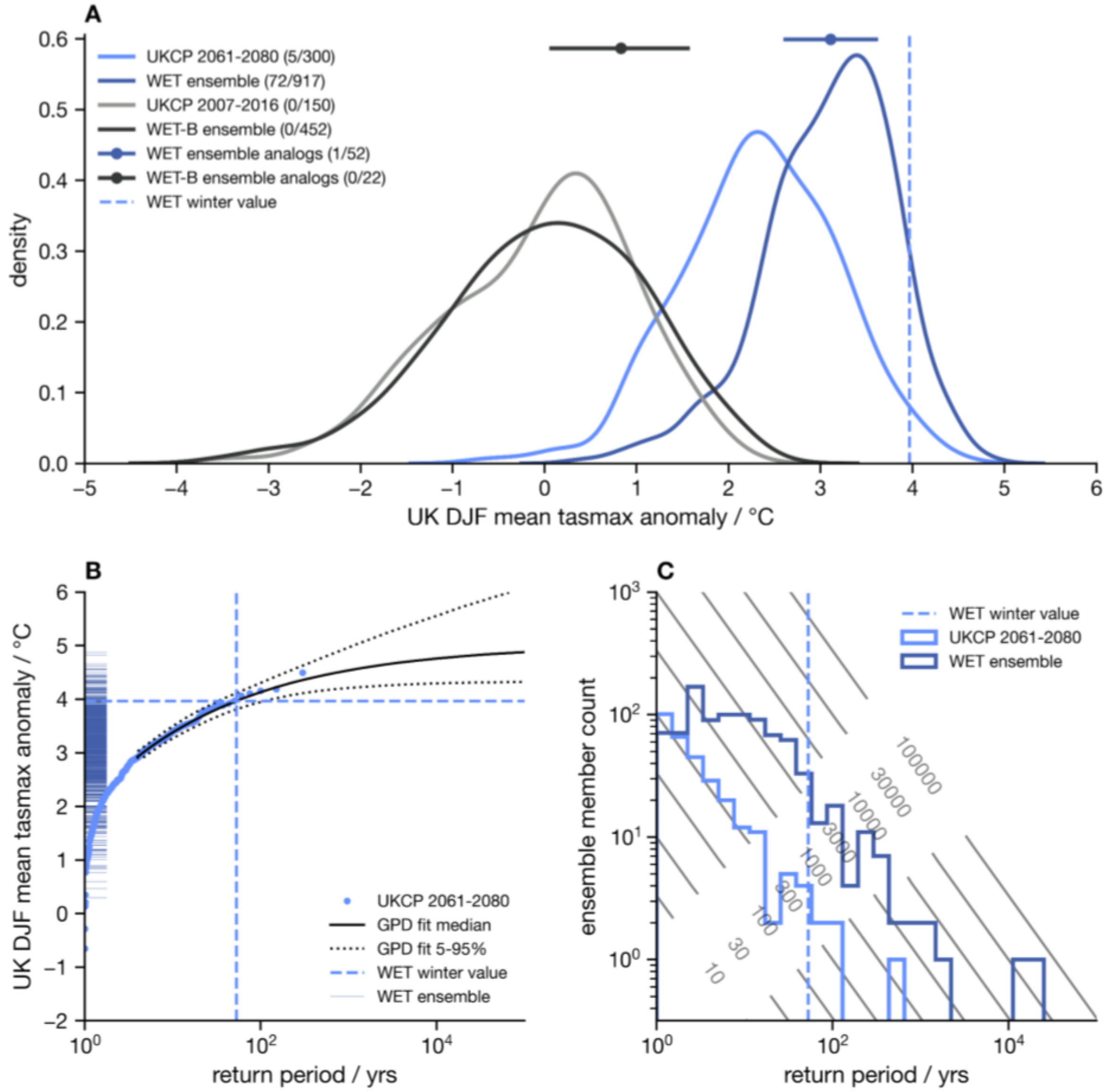

FIG S4: as FIG 3, but for the WET winter.

PRm

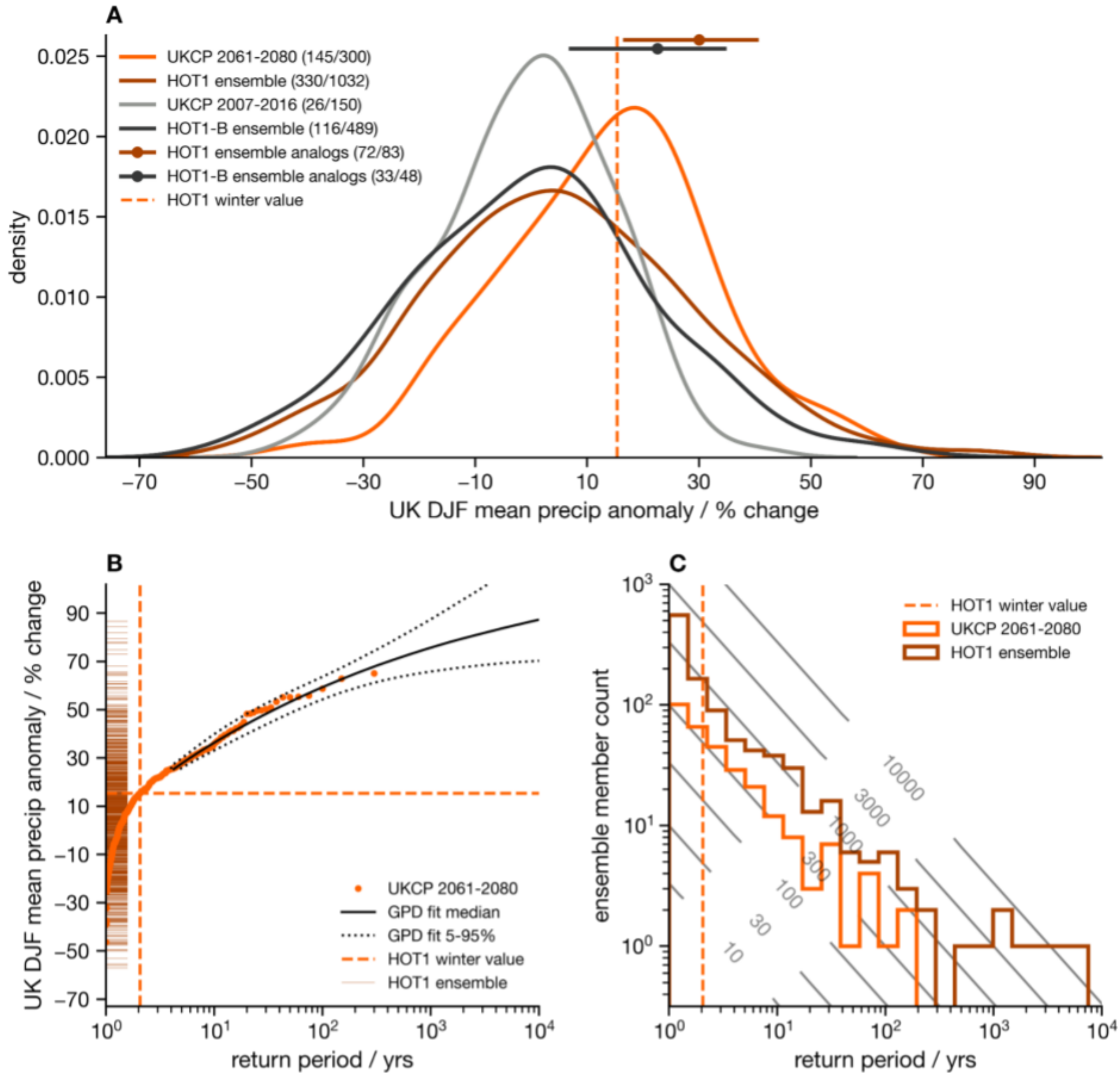

FIG S5: as FIG 3, but of DJF mean precipitation averaged over the UK region.

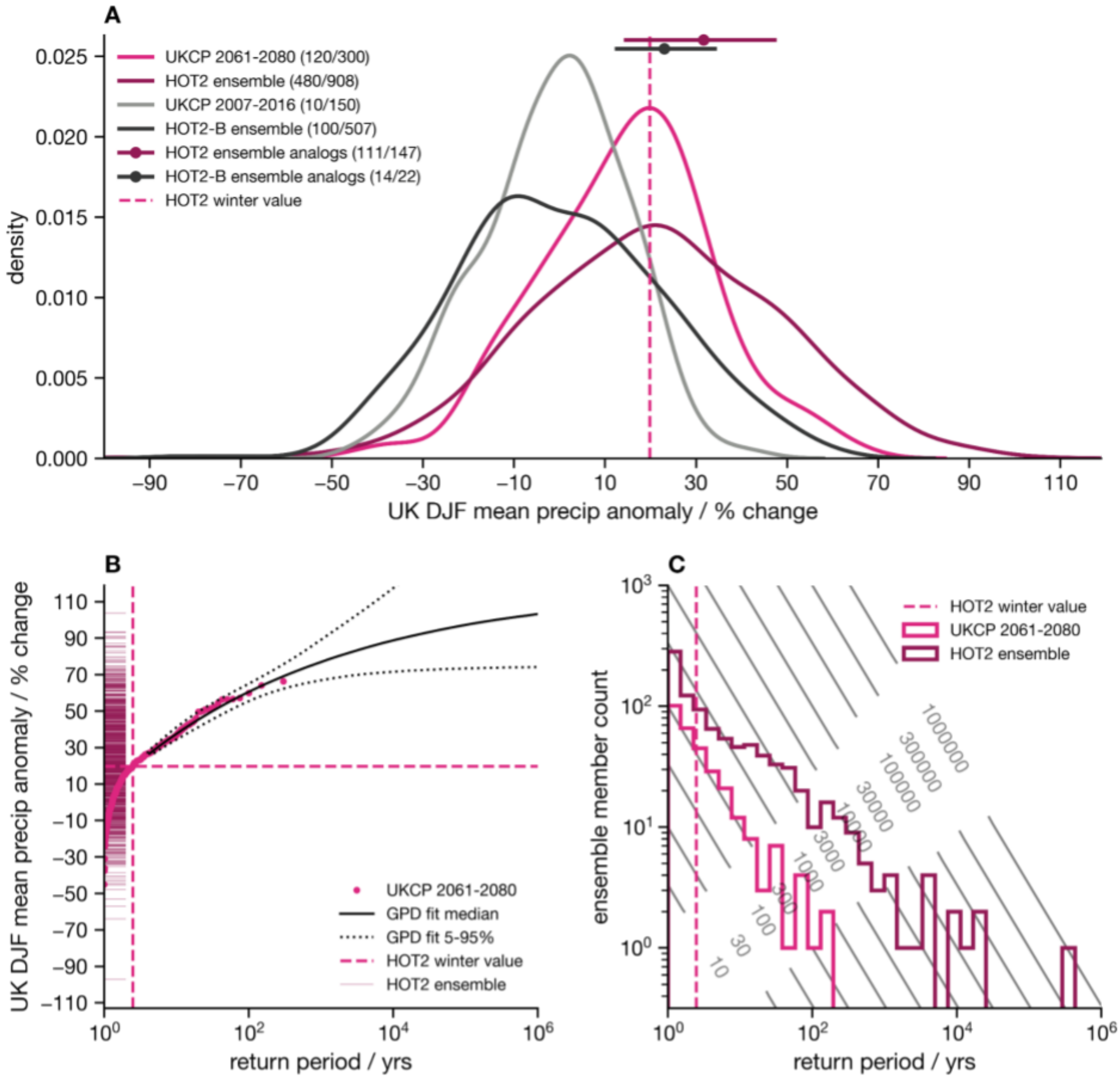

FIG S6: as FIG 3, but of DJF mean precipitation averaged over the UK region and for the HOT2 winter.

TXx

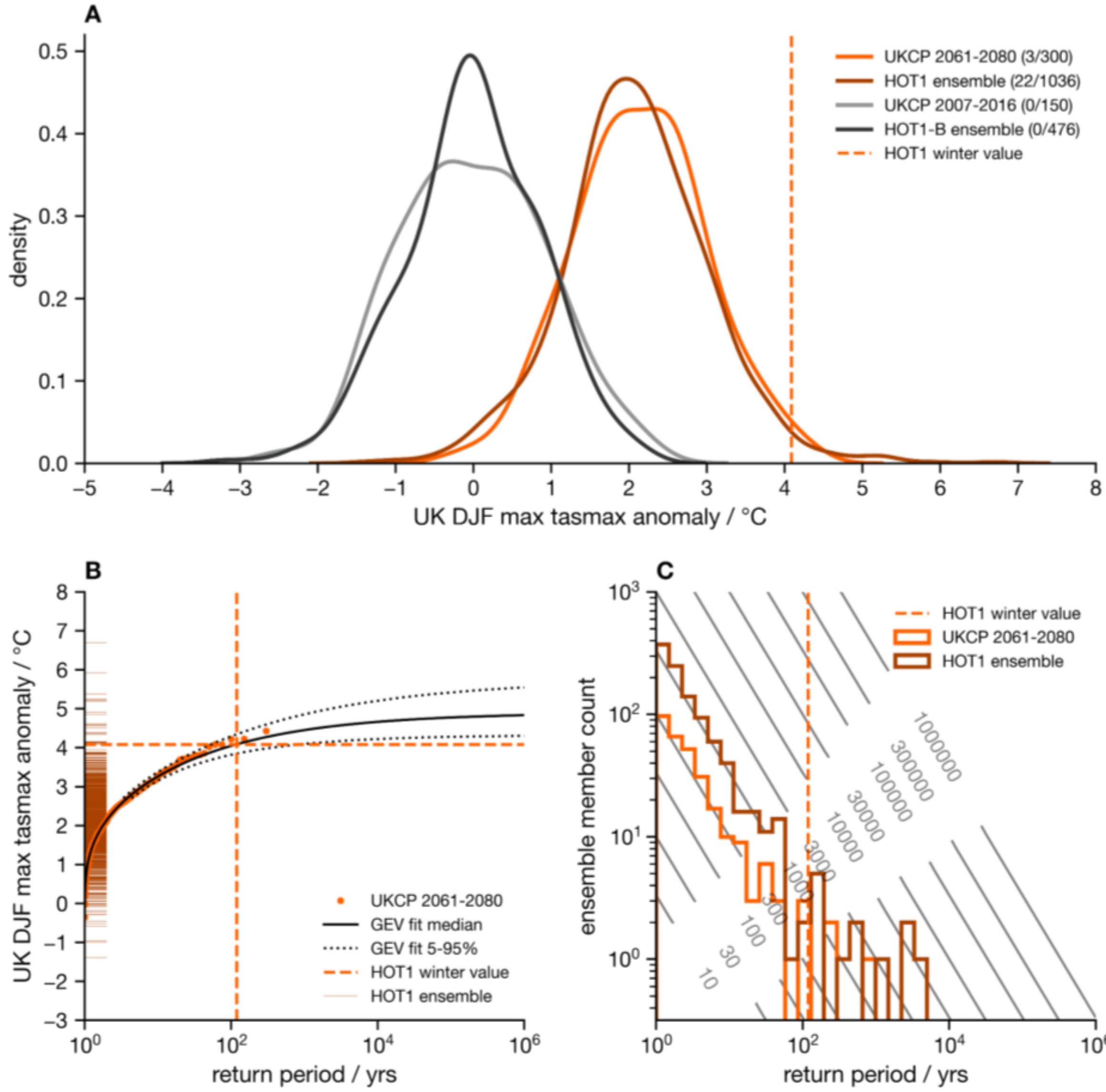

FIG S7: as FIG 3, but of DJF max of daily tasmax averaged over the UK region.

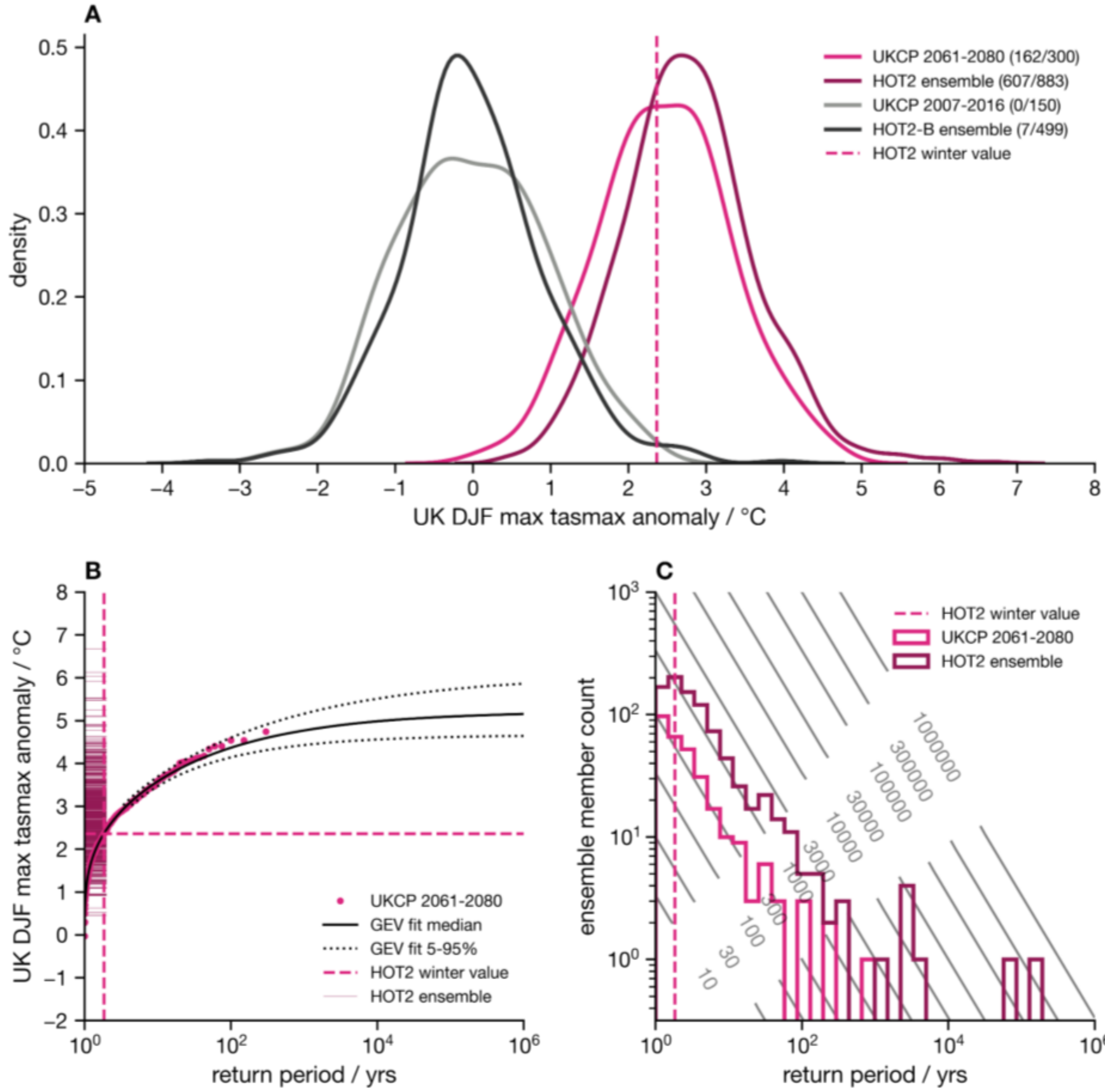

FIG S8: as FIG 3, but of DJF max of daily tasmax averaged over the UK region and for HOT2 winter.

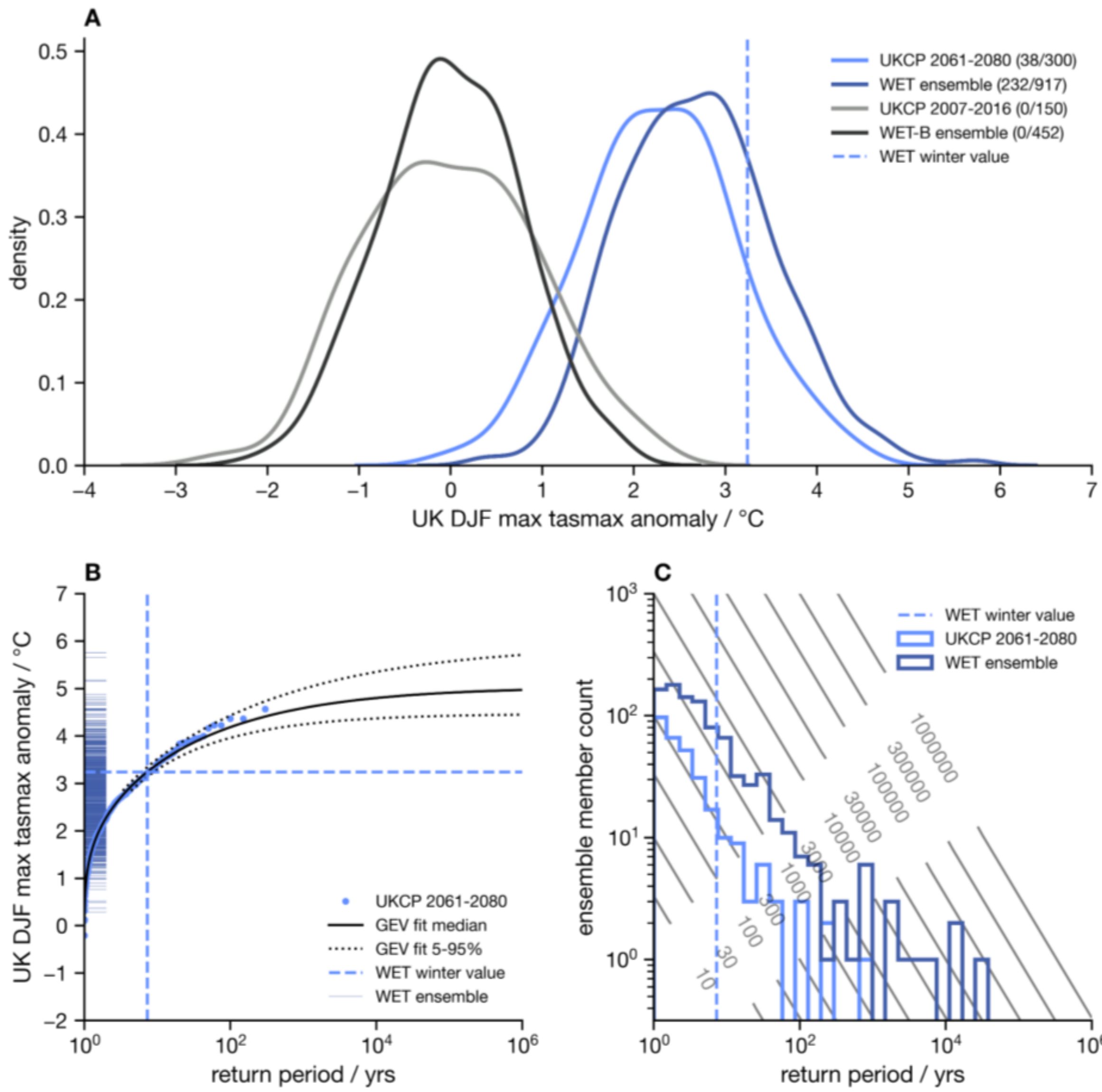

FIG S9: as FIG 3, but of DJF max of daily tasmax averaged over the UK region and for WET winter.

PRx

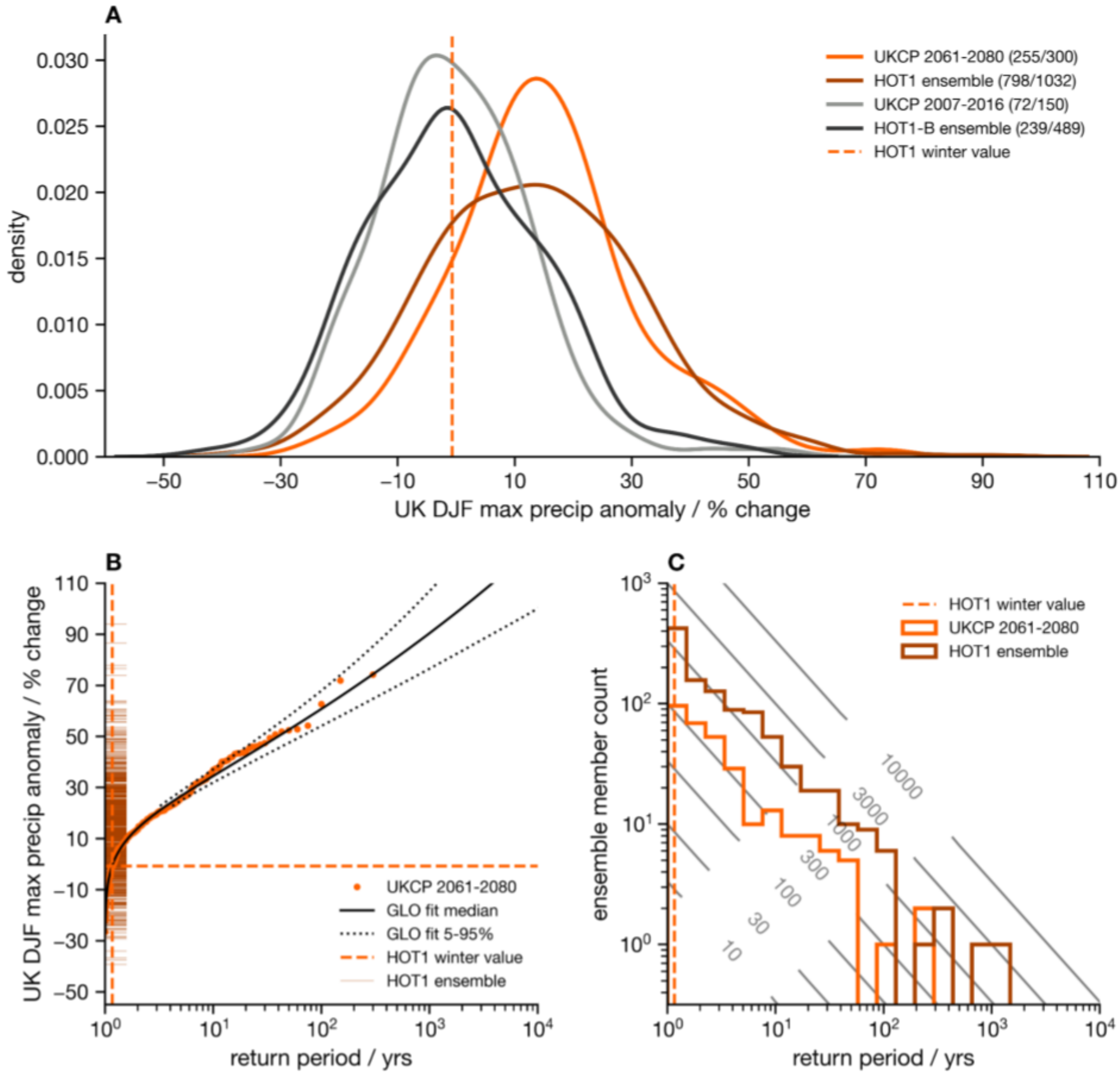

FIG S10: as FIG 3, but of DJF max of daily precipitation averaged over the UK region.

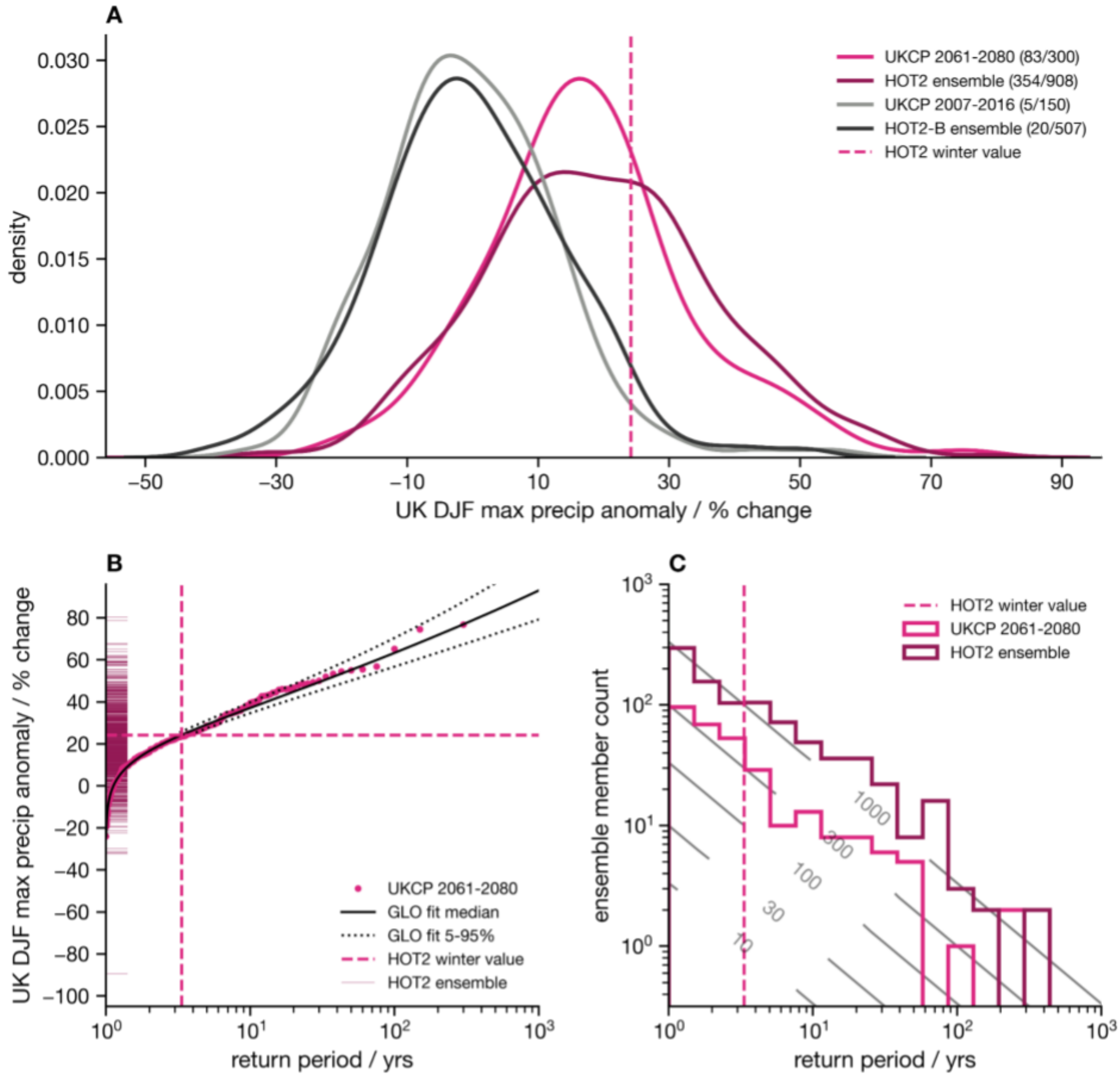

FIG S11: as FIG 3, but of DJF max of daily precipitation averaged over the UK region and for HOT2 winter.

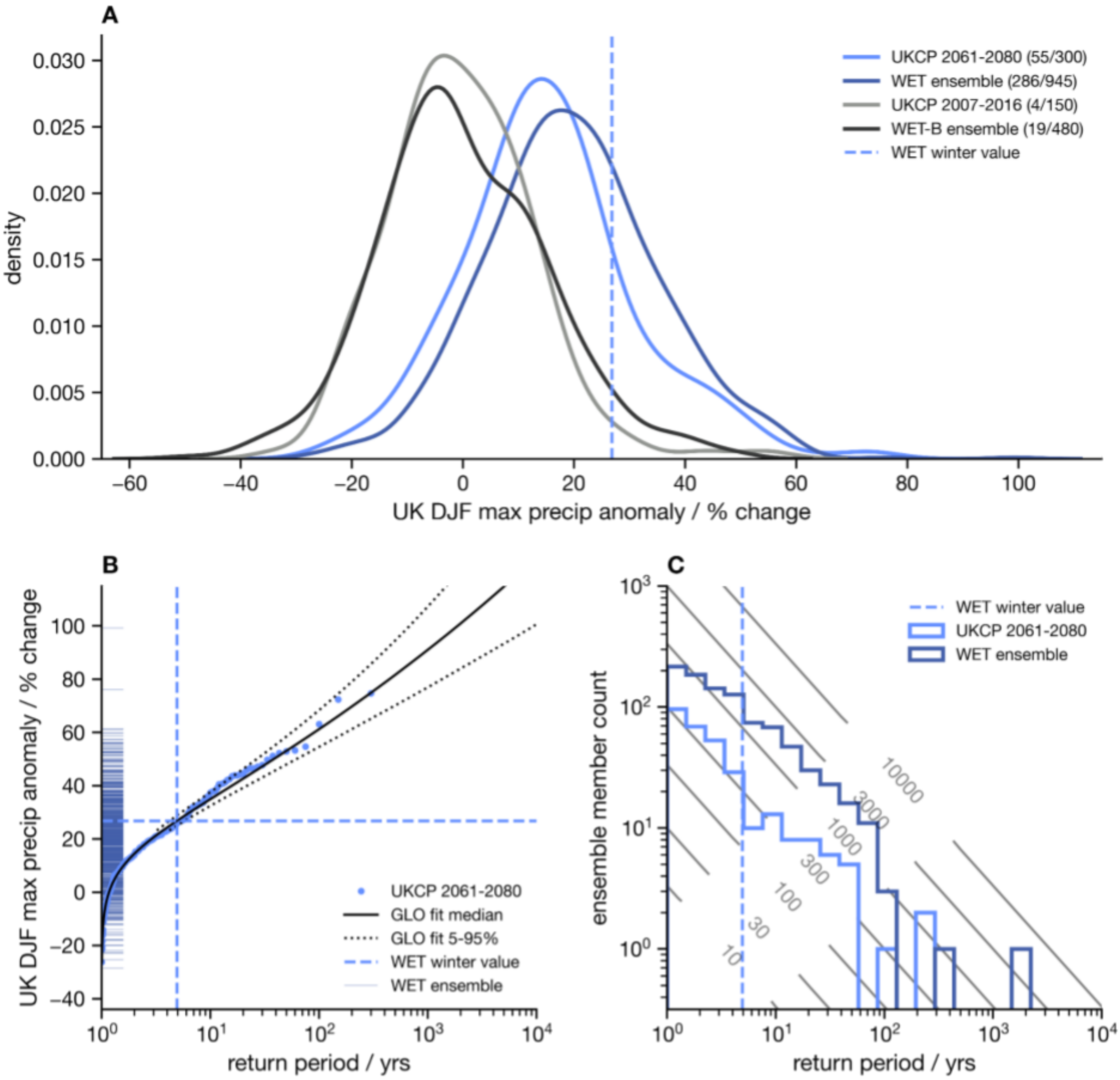

FIG S12: as FIG 3, but of DJF max of daily precipitation averaged over the UK region and for WET winter.

References

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