Supplementary Information for

Robustness of Dynamical Coupling between wintertime European Weather Extremes and the Large-Scale Circulation

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Submission to Climate Dynamics

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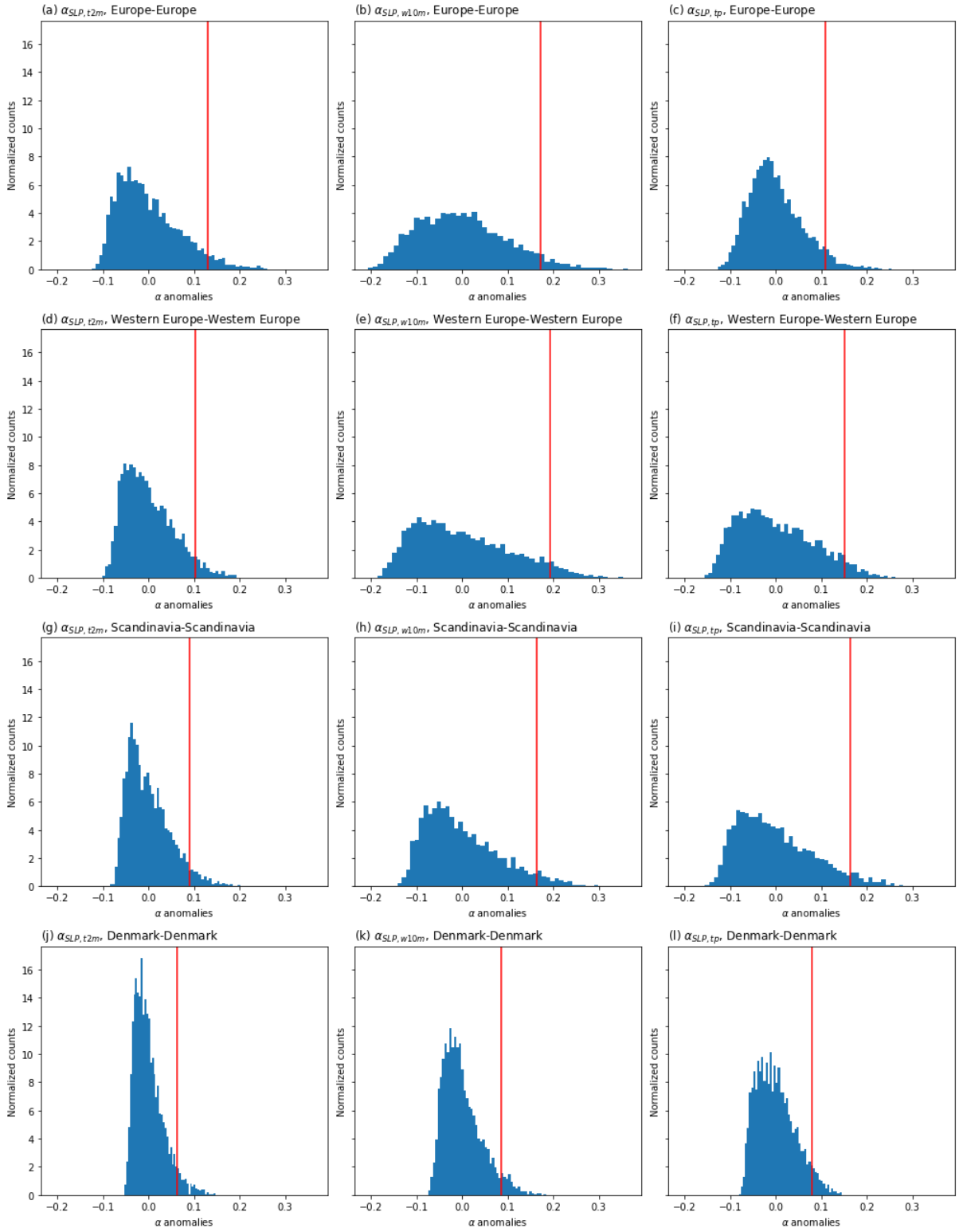

Figure S1: Histograms of $\alpha_{SLP,t2m}$ anomalies (a, d, g, j), $\alpha_{SLP,w10m}$ anomalies (b, e, h, k), and $\alpha_{SLP,tp}$ anomalies (c, f, i, l), computed for both variables in Europe (a-c), Western Europe (d-f), Scandinavia (g-i), and Denmark (j-l).

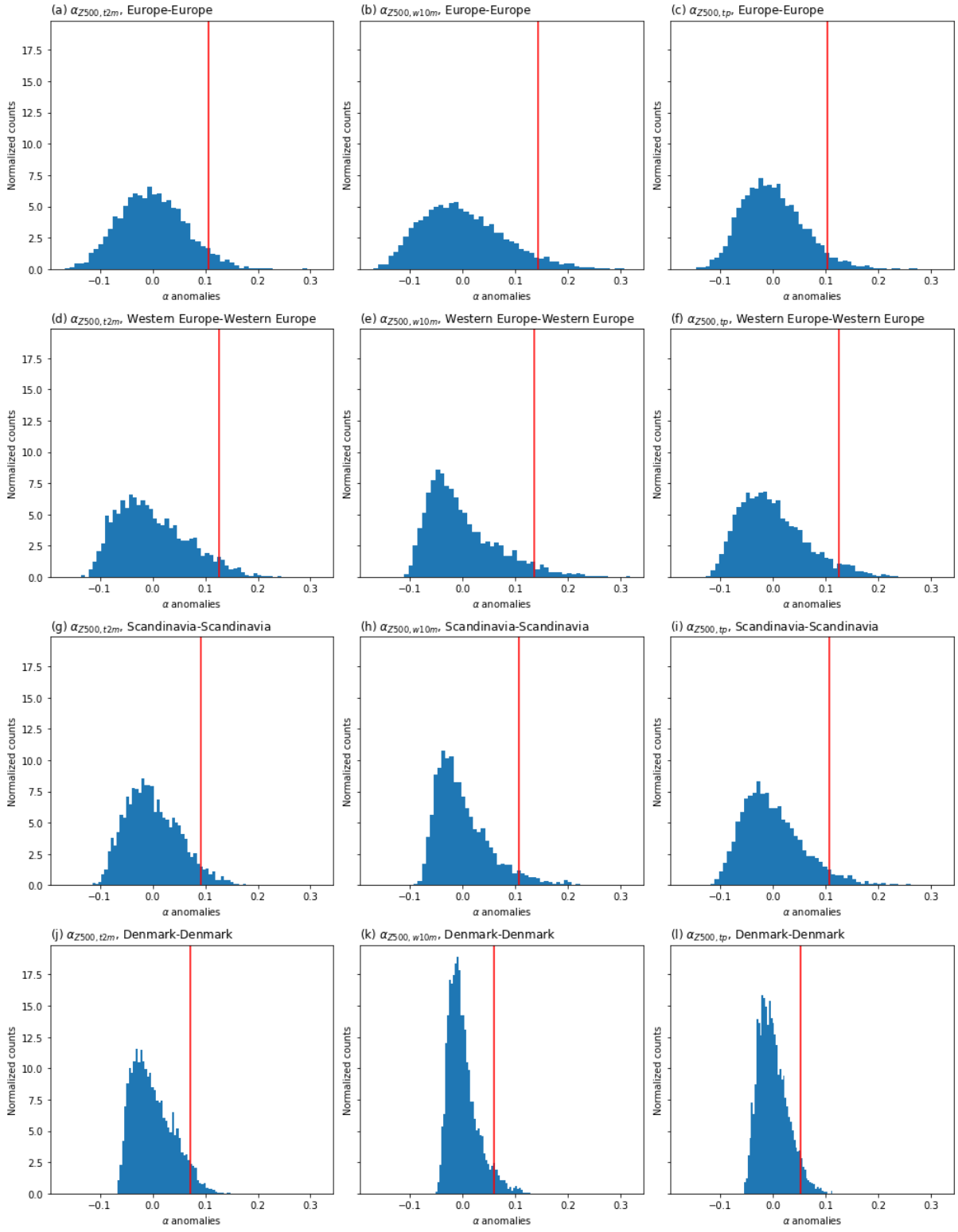

Figure S2: Histograms of $\alpha_{Z500,t2m}$ anomalies (a, d, g, j), $\alpha_{Z500,w10m}$ anomalies (b, e, h, k), and $\alpha_{Z500,tp}$ anomalies (c, f, i, l), computed for both variables in Europe (a-c), Western Europe (d-f), Scandinavia (g-i), and Denmark (j-l).

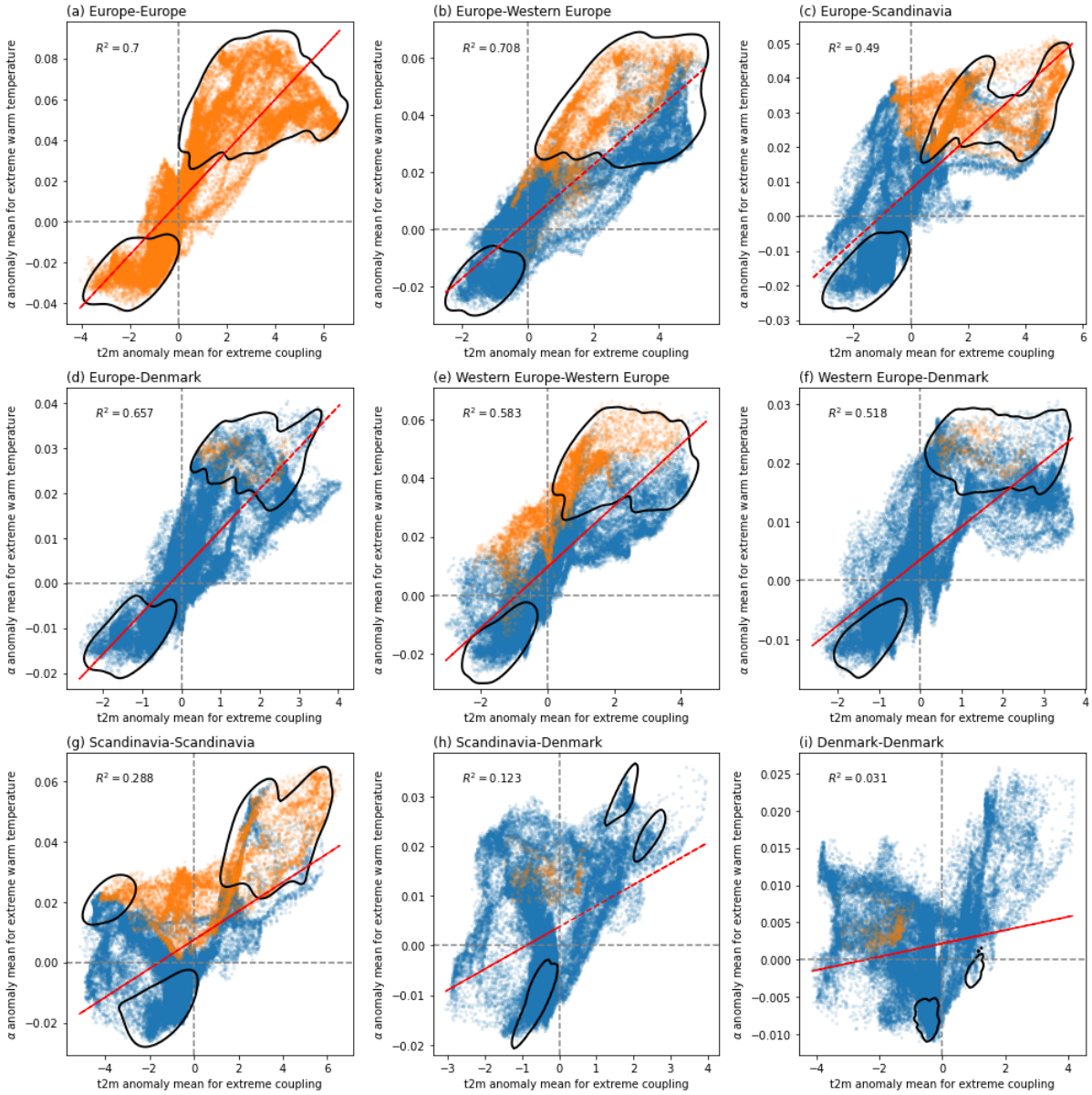

Figure S3: Scatterplots of composite t2m (K) anomalies for extreme coupling days (> 0.95-quantile) vs. composite $\alpha_{\mathrm{SLP,t2m}}$ anomalies for extreme warm days (> 0.95-quantile). The co-recurrence ratio is computed for SLP in Europe (a-d), Western Europe (e, f), Scandinavia (g, h), and Denmark (i) and for t2m in Europe (a), Western Europe (b, e), Scandinavia (c, g), and Denmark (d, f, h, i). Orange points represent grid points within the co-recurrence domain, and blue points represent grid points outside this domain. The black lines bound regions of high density, determined by the Kernel Density Estimate (KDE), where at least 2/3 of the composited anomalies, for both t2m and $\alpha_{\mathrm{SLP,t2m}}$, have the same sign. The dotted red line is a linear regression line of all grid points.

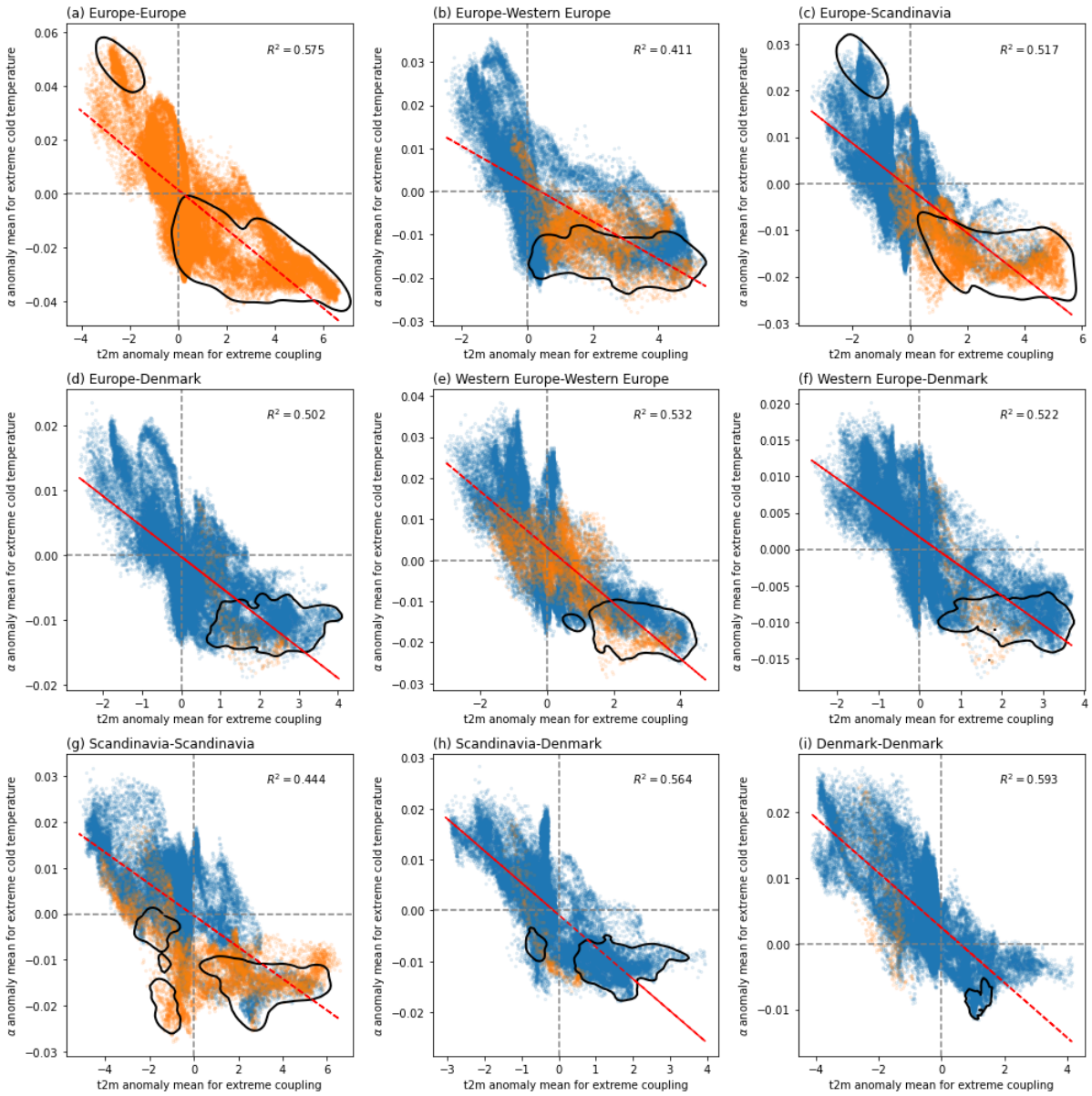

Figure S4: Scatterplots of composite t2m (K) anomalies for extreme coupling days (> 0.95-quantile) vs. composite $\alpha_{\mathrm{SLP,t2m}}$ anomalies for extreme cold days (< 0.05-quantile). The co-recurrence ratio is computed for SLP in Europe (a-d), Western Europe (e, f), Scandinavia (g, h), and Denmark (i) and for t2m in Europe (a), Western Europe (b, e), Scandinavia (c, g), and Denmark (d, f, h, i). Orange points represent grid points within the co-recurrence domain, and blue points represent grid points outside this domain. The black lines bound regions of high density, determined by the Kernel Density Estimate (KDE), where at least 2/3 of the composited anomalies, for both t2m and $\alpha_{\mathrm{SLP,t2m}}$, have the same sign. The dotted red line is a linear regression line of all grid points.

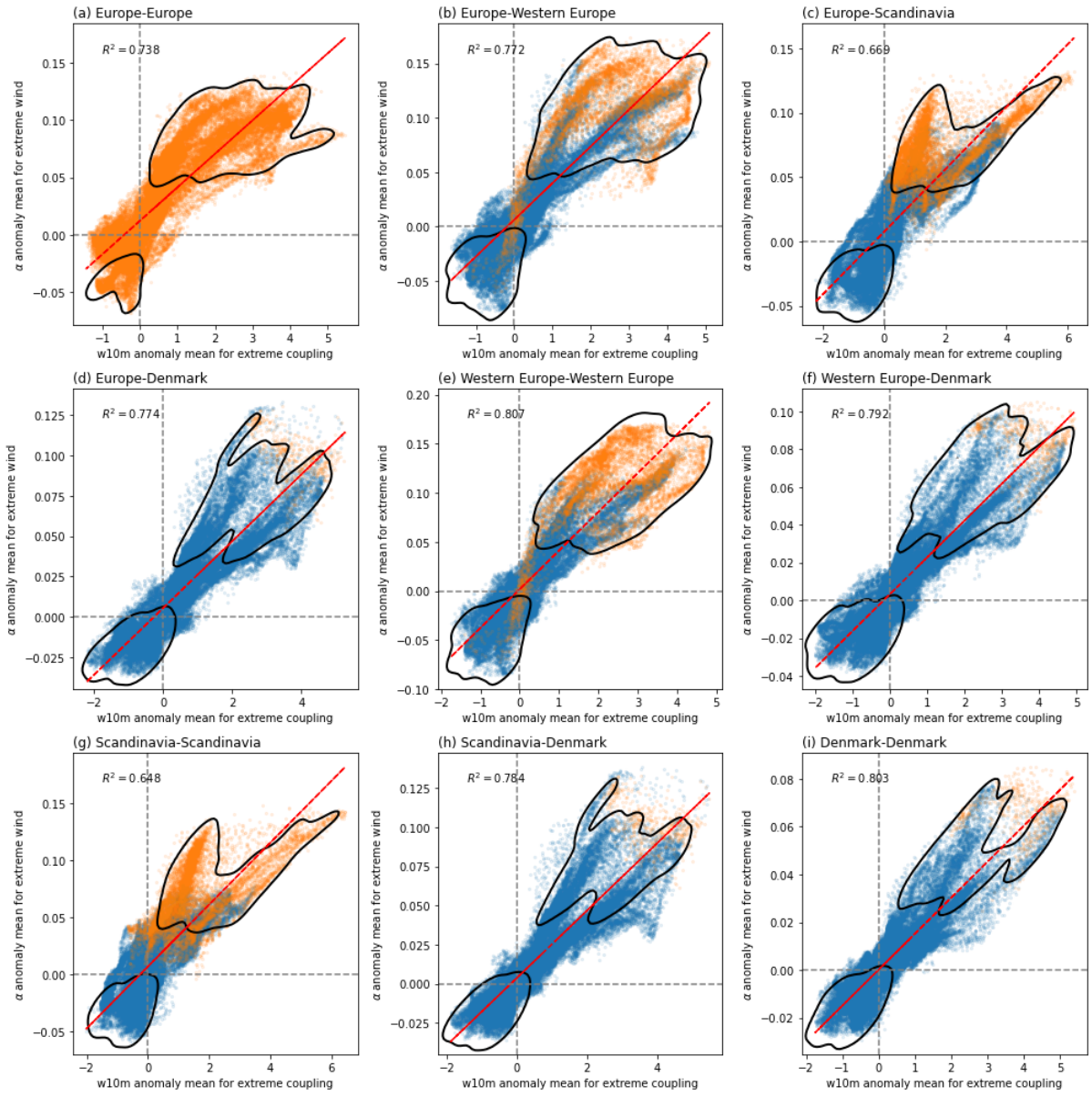

Figure S5: Scatterplots of composite w10m (m s^{-1}) anomalies for extreme coupling days (> 0.95-quantile) vs. composite $\alpha_{\mathrm{SLP,w10m}}$ anomalies for extreme windy days (< 0.05-quantile). The co-recurrence ratio is computed for SLP in Europe (a-d), Western Europe (e, f), Scandinavia (g, h), and Denmark (i) and for tp in Europe (a), Western Europe (b, e), Scandinavia (c, g), and Denmark (d, f, h, i). Orange points represent grid points within the co-recurrence domain, and blue points represent grid points outside this domain. The black lines bound regions of high density, determined by the Kernel Density Estimate (KDE), where at least 2/3 of the composited anomalies, for both tp and $\alpha_{\mathrm{SLP,w10m}}$, have the same sign. The dotted red line is a linear regression line of all grid points.

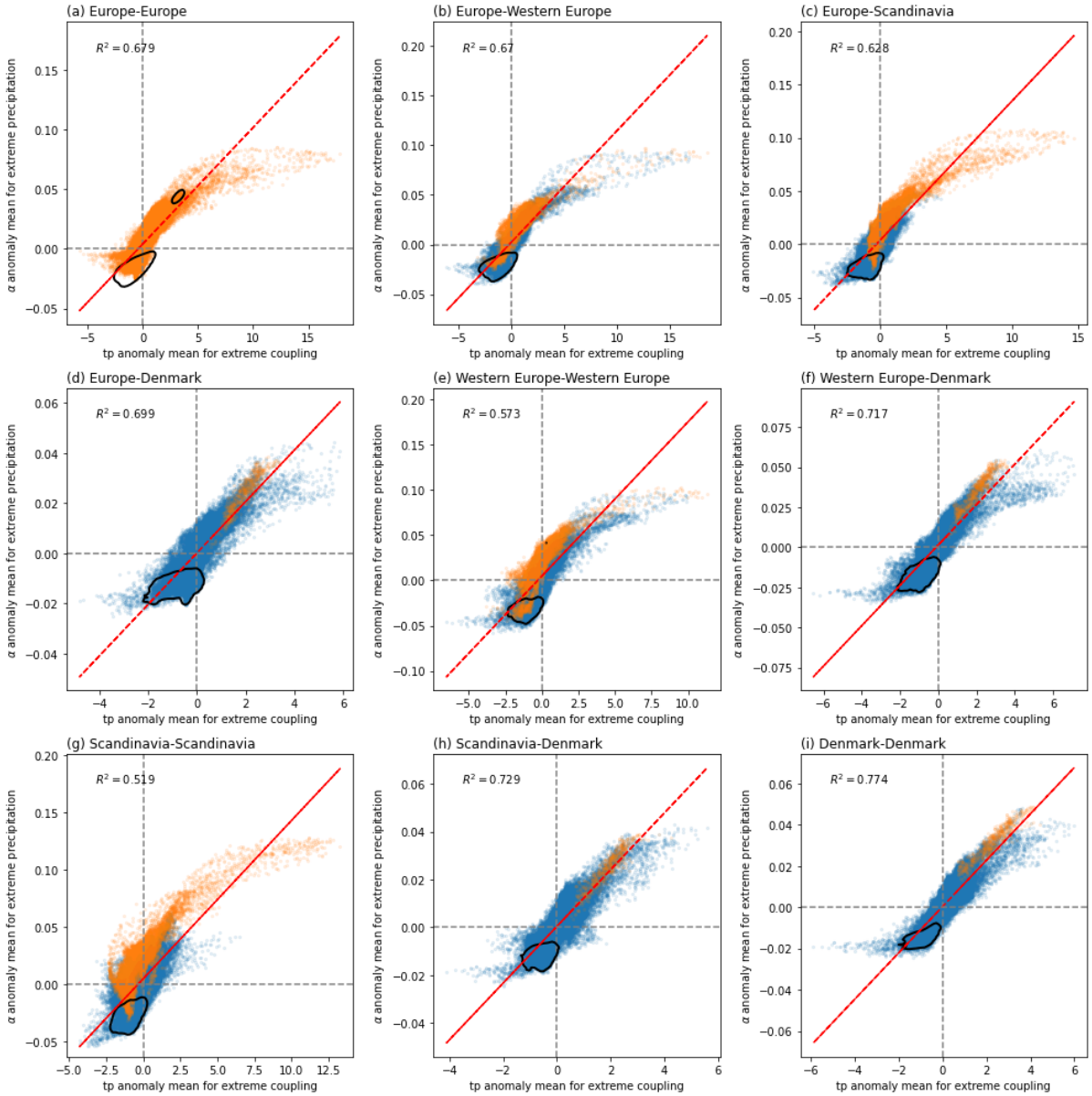

Figure S6: Scatterplots of composite tp (mm day^{-1}) anomalies for extreme coupling days (> 0.95-quantile) vs. composite $\alpha_{\mathrm{SLP,tp}}$ anomalies for extreme windy days (< 0.05-quantile). The co-recurrence ratio is computed for SLP in Europe (a-d), Western Europe (e, f), Scandinavia (g, h), and Denmark (i) and for tp in Europe (a), Western Europe (b, e), Scandinavia (c, g), and Denmark (d, f, h, i). Orange points represent grid points within the co-recurrence domain, and blue points represent grid points outside this domain. The black lines bound regions of high density, determined by the Kernel Density Estimate (KDE), where at least 2/3 of the composited anomalies, for both tp and $\alpha_{\mathrm{SLP,tp}}$, have the same sign. The dotted red line is a linear regression line of all grid points.

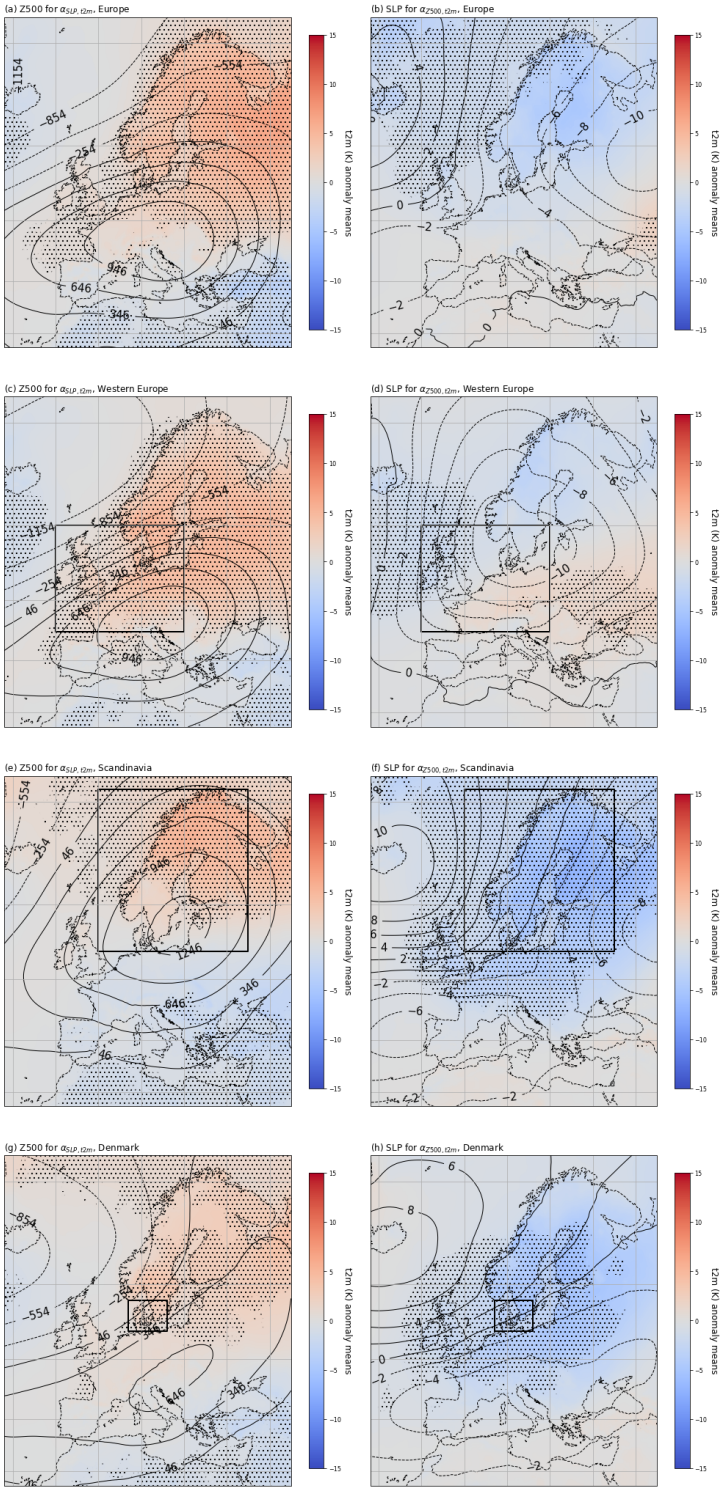

Figure S7: Composite t2m (K, colors) and Z500 (m^2 s^{-2}, contours), respectively, SLP (hPa, contours) anomalies for extreme coupling days (> 0.95-quantile), computed for the other circulation variable (a, c, e, g respectively b, d, f, h). The co-recurrence ratio is computed for both variables in Europe (a-b), Western Europe (c-d), Scandinavia (e-f), and Denmark (g-h). Stippling indicates regions where at least 2/3 of the composited anomalies share the same sign.

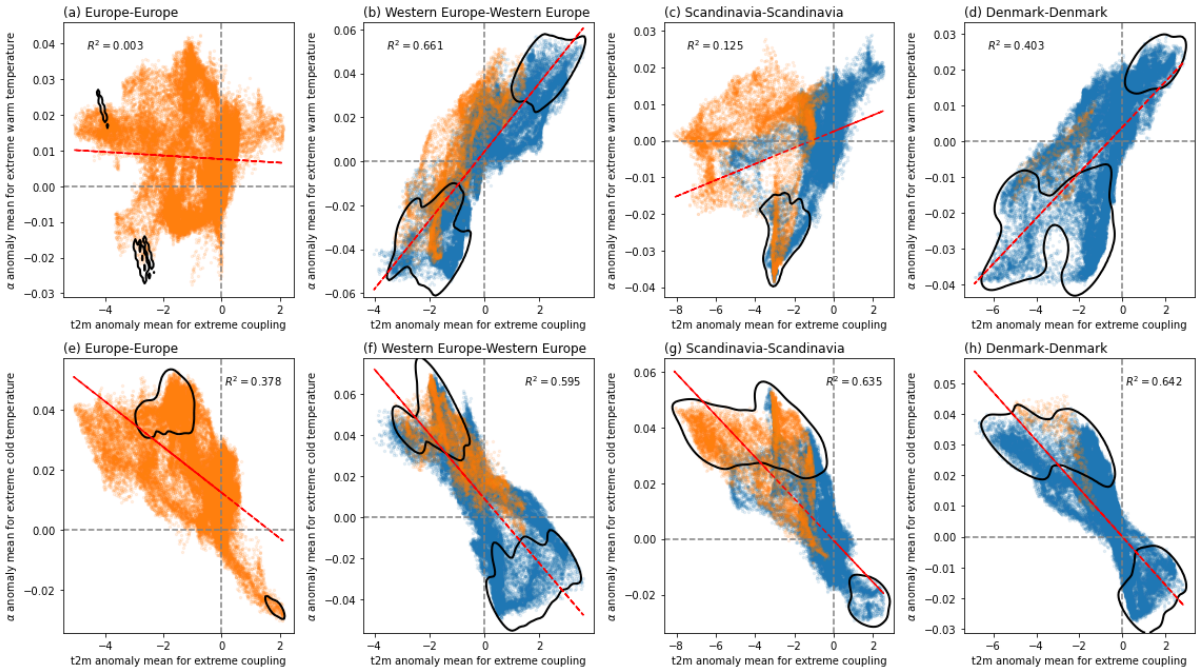

Figure S8: Scatterplots of composite t2m (K) anomalies for extreme coupling days ($>$ 0.95-quantile) vs. composite $\alpha_{\mathrm{Z500,t2m}}$ anomalies for extreme warm days ($>$ 0.95-quantile) (a-d) and extreme cold days ($<$ 0.05-quantile) (e-h). The co-recurrence ratio is computed for Z500 and t2m in Europe (a, e), Western Europe (b, f), Scandinavia (c, g), and Denmark (d, h). Orange points represent grid points within the co-recurrence domain, and blue points represent grid points outside this domain. The black lines bound regions of high density, determined by the Kernel Density Estimate (KDE), where at least 2/3 of the composited anomalies, for both t2m and $\alpha_{\mathrm{Z500,t2m}}$, have the same sign. The dotted red line is a linear regression line of all grid points.

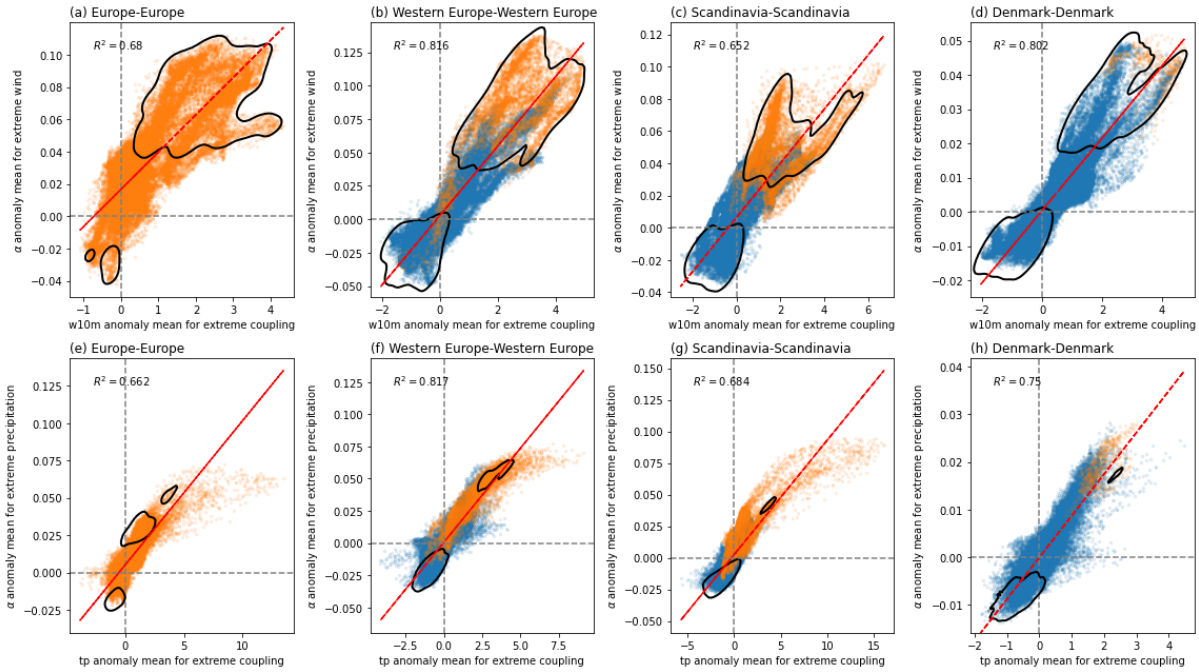

Figure S9: Scatterplots of composite w10m (m s^{-1}) (a-d) and tp (mm day^{-1}) (e-h) anomalies for extreme coupling days (> 0.95-quantile) vs. composite $\alpha_{\mathrm{Z500,w10m}}$ respectively $\alpha_{\mathrm{Z500,tp}}$ anomalies for extreme windy and extreme precipitation days (> 0.95-quantile). The co-recurrence ratio is computed for Z500, w10m, and tp in Europe (a, e), Western Europe (b, f), Scandinavia (c, g), and Denmark (d, h). Orange points represent grid points within the co-recurrence domain, and blue points represent grid points outside this domain. The black lines bound regions of high density, determined by the Kernel Density Estimate (KDE), where at least 2/3 of the composited anomalies, for both w10m and $\alpha_{\mathrm{Z500,w10m}}$ respectively tp and $\alpha_{\mathrm{Z500,tp}}$, have the same sign. The dotted red line is a linear regression line of all grid points.

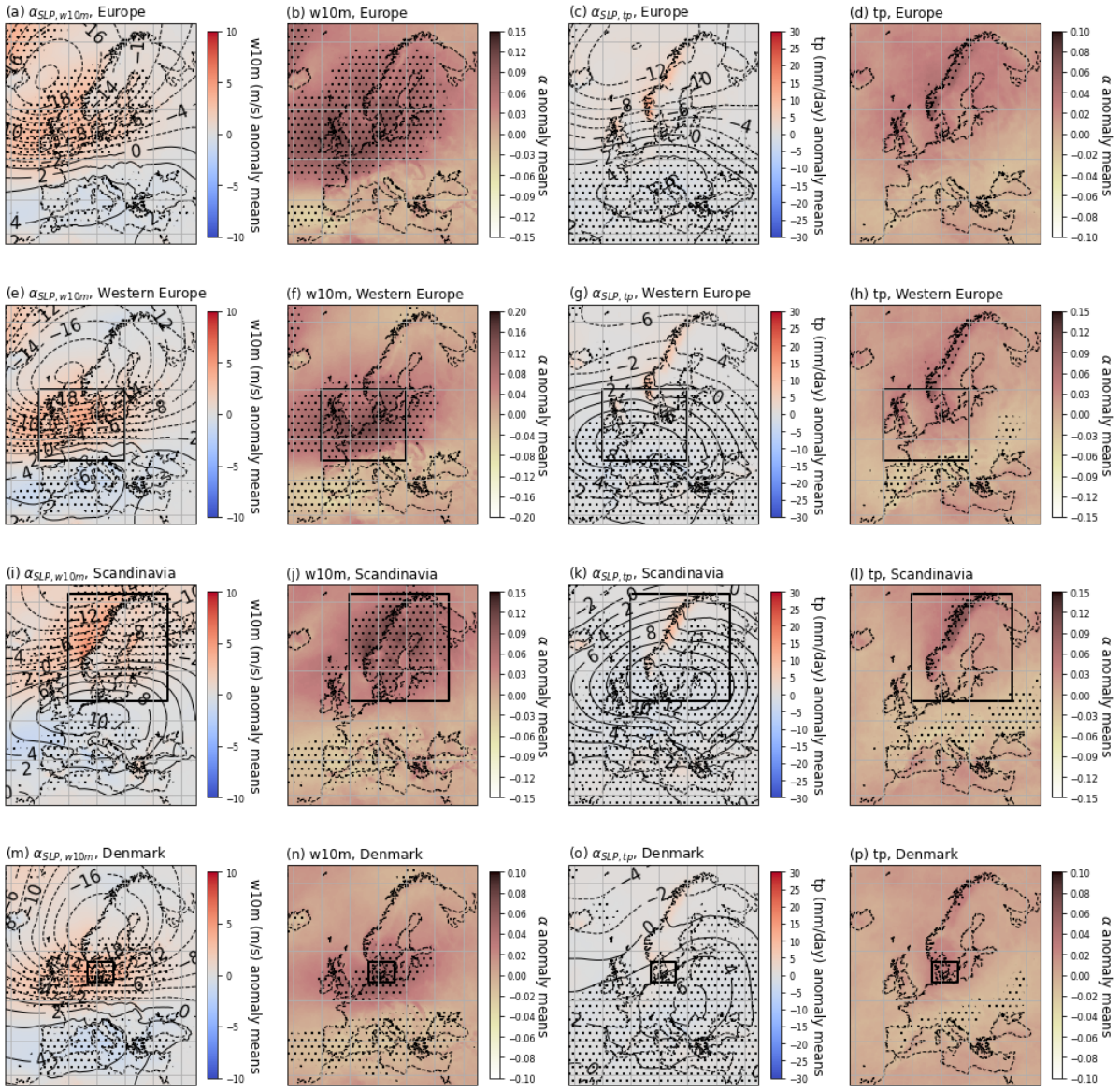

Figure S10: Composite SLP (hPa, contours) and t2m (K, colors) anomalies for extreme coupling days (> 0.9-quantile) (a, d, g, j) and composite $\alpha_{\mathrm{SLP,t2m}}$ anomalies for extreme warm days (> 0.9-quantile) (b, e, h, k) and extreme cold days (< 0.1-quantile) (c, f, i, j). The co-recurrence ratio is computed for SLP and t2m in Europe (a-c), Western Europe (d-f), Scandinavia (g-i), and Denmark (j-l). Stippling indicates regions where at least 2/3 of the composited anomalies share the same sign. To ensure consistency, the colorbar limits correspond to approximately the 95th percentile of α anomalies (see Figures S1, 2 for the full distributions).

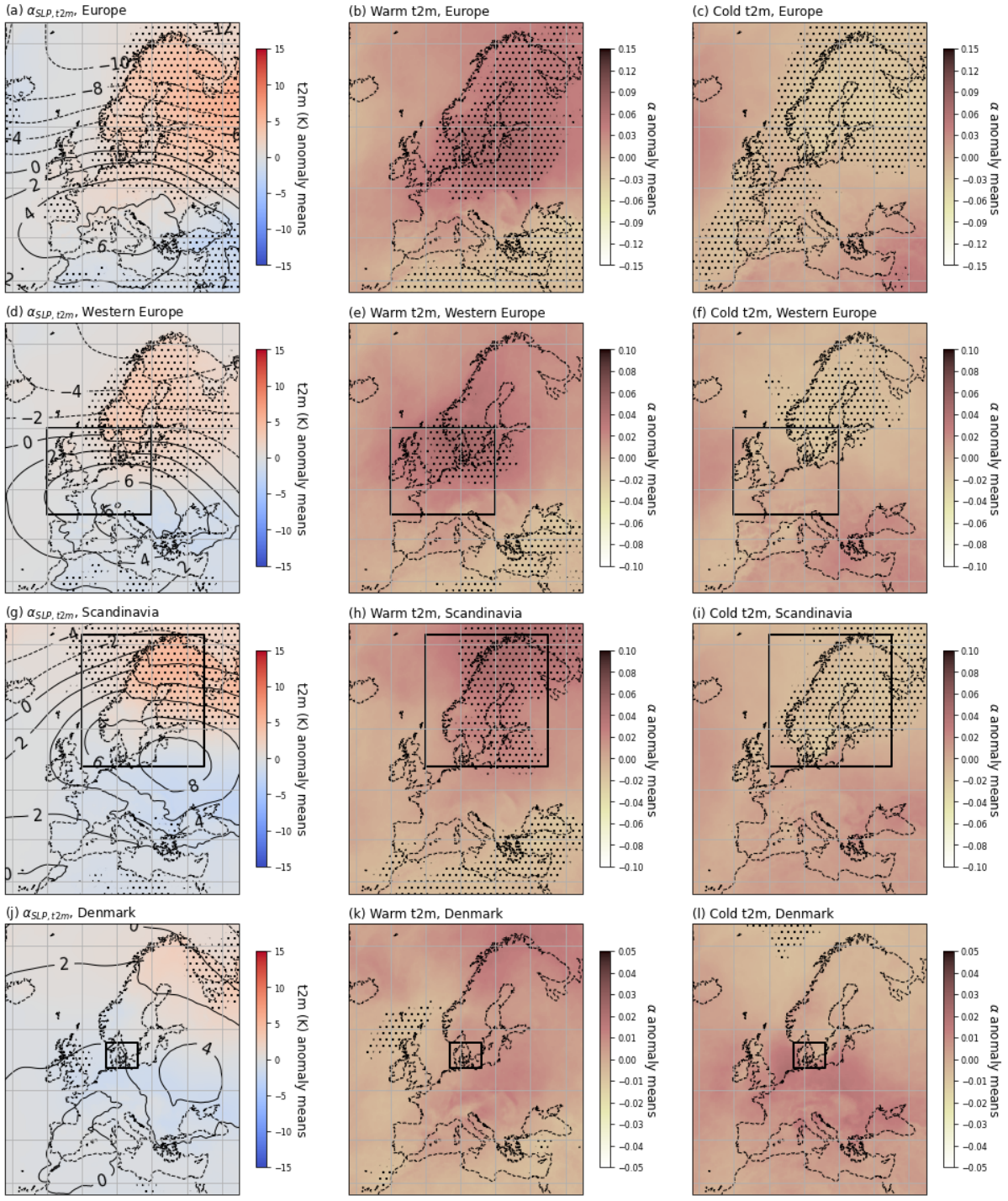

Figure S11: Composite SLP (hPa, contours) and w10m (m s^{-1}, colors), respectively, tp (mm day^{-1}) anomalies for extreme coupling days (> 0.9-quantile) (a, e, i, m, respectively c, g, k, o) and composite $\alpha_{\text{SLP,w10m}}$ anomalies for extreme windy days (> 0.9-quantile) (b, f, j, n) and $\alpha_{\text{SLP,tp}}$ anomalies for extreme precipitation days (> 0.98-quantile) (d, h, l, p). The co-recurrence ratio is computed for SLP, w10m, and tp in Europe (a-d), Western Europe (e-h), Scandinavia (i-l), and Denmark (m-o). Stippling indicates regions where at least 2/3 of the composited anomalies share the same sign. To ensure consistency, the colorbar limits correspond to approximately the 95th percentile of α anomalies (see Figures S1, 2 for the full distributions).

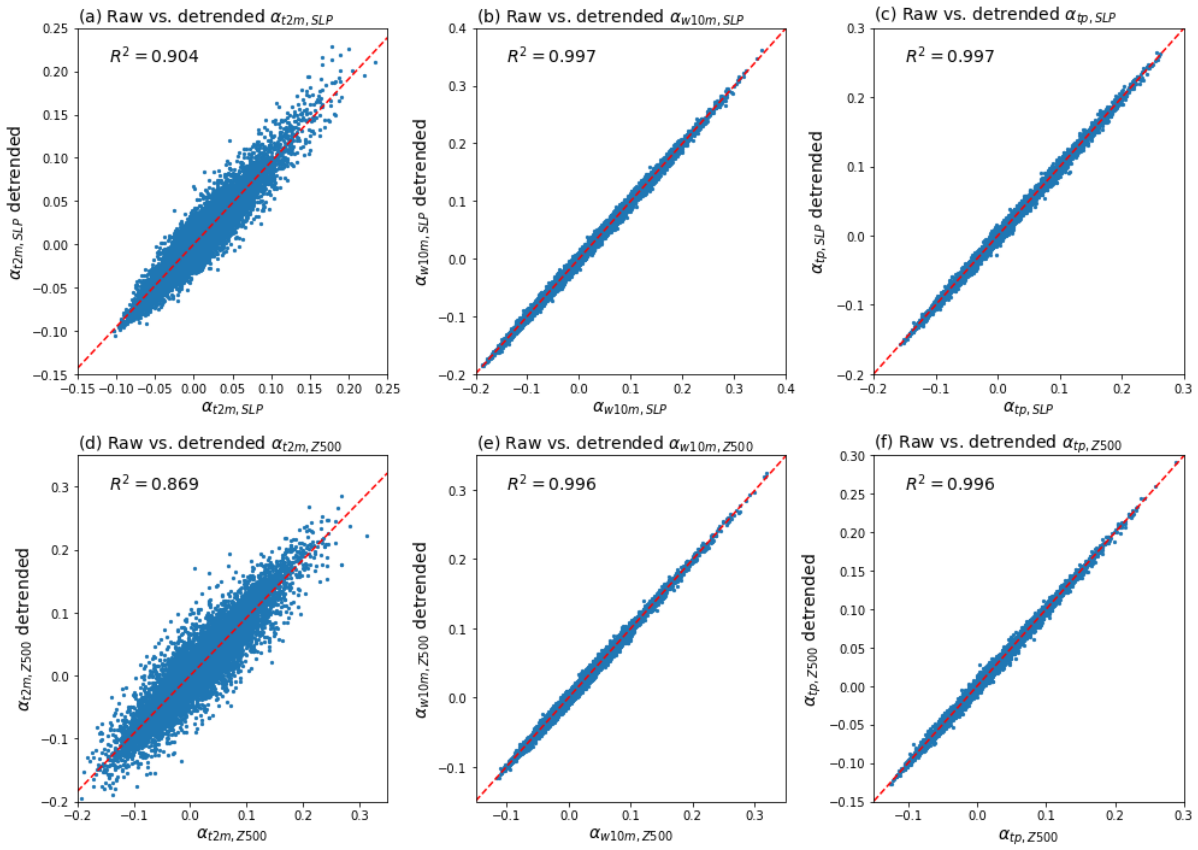

Figure S12: Scatterplots of α anomalies computed on raw data vs. detrended climate data in Western Europe for the hazard variables t2m (a, d), w10m (b, e), and tp (c, f), and the large-scale circulation variables SLP (a-c) and Z500 (d-f).