Supplementary Material of
“Dominant patterns of interaction between the tropics and mid-latitude in
boreal summer: Causal relationships and the role of timescales”

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Figure S1. MCA of mid-latitude Z200 and tropical OLR at intraseasonal time scales. Panels (a) and (b) show the first MCA mode for mid-latitude Z200 (25-75° N) and tropical OLR (15°S-30°N), respectively, at the 4-weekly time scale. This mode depicts the North Pacific high (NPH) in the mid-latitudes and the western North Pacific summer monsoon (WNPSM) in the tropical belt. Panels (c) and (d): Same as for panel (a) and (b) but for the second MCA mode. The second MCA highlights the circumglobal teleconnection (CGT) pattern in the mid-latitudes and the South Asian monsoon (SAM) in the tropical belt. The squared covariance fraction (SCF) of each MCA mode is given on top of the panels. Panel (e) shows the time series of MCA scores for the two MCA modes at 4-weekly time scale. Each MCA pattern has its own time series, i.e. one for tropical OLR and one for mid-latitude Z200 (note the different y-axes are used). Panel (f): Same as panel (e) but for weekly time series obtained by projecting the 4-weekly MCA modes on weekly OLR and Z200 3D fields.

Figure S2. Time evolution of weekly tropical and mid-latitude anomalies. Composites of weekly OLR (left column), Z200 (central column) and V200 (right column) fields are calculated for weeks with high MCA mode 1 OLR scores (M1OLR) and $M1OLR > M1OLR_{std}$ minus weeks with low M1OLR ($M1OLR < M1OLR_{std}$). Here, lag 0 refers to the weeks where the M1OLR anomalies larger or smaller than $M1OLR_{std}$ are identified. Lags -1 and -2 are defined as 1 and 2 weeks prior lag 0, while lags +1 and +2 are defined as 1 and 2 weeks following lag 0.

Figure S3. BSISO time evolution. BSISO data from Kikuchi et al. 2010 weekly averaged. The colour of each point in the Wheeler-Hendon diagram represents different lags defined as in Fig. S2. For simplicity, overlapping events are shown only once (only the event that stars first in time is shown).

Figure S4. Influence of MCA mode 2 on Northern Hemisphere circulation. Panel (a): correlation map between the weekly SAM time series (obtained from 4-weekly MCA modes, see SI Fig. S1) and the Z200 field. Panel (b): Same as panel (a) but for the correlation between weekly CGT time series and the Z200 field. Panel (c): path coefficient β for link $\text{SAM}_{\tau=-1} \rightarrow \text{Z200}_{\tau=0}$ for a 3-actors CEN built with SAM, CGT and Z200. Panel (d): Same as panel (c) but for the link $\text{CGT}_{\tau=-1} \rightarrow \text{Z200}_{\tau=0}$. Panels (e) and (g): Same as panel (c) but for the influence of SAM on OLR and T2m fields respectively. Panels (f) and (h): Same as panel (d) but for the influence of CGT on OLR and T2m fields respectively. Only path coefficients β with $p < 0.05$ are shown (accounting for the effect of serial correlations) are shown by black contours, while grid points which are found significant only with non-corrected p values are shaded. The dashed black line located at 30°N shows the border between the tropical and the mid-latitude belt.

Figure S5. Influence of MCA mode 1 on Northern Hemisphere circulation. Panel (a): correlation between the weekly WNPSM time series (obtained from 4-weekly MCA modes, see SI Fig. S1) and the Z200 field. Panel (b): As panel (a) but for the correlation between weekly NPH time series and the Z200 field. Panel (c): path coefficient β for the link $\text{WNPSM}_{\tau=-1} \rightarrow \text{Z200}_{\tau=0}$ in a 3-actors CEN built with WNPSM, NPH and Z200. Panel (d): Same as panel (c) but for the link $\text{NPH}_{\tau=-1} \rightarrow \text{Z200}_{\tau=0}$. Panels (e) and (g): Same as panel (c) but for the influence of WNPSM on OLR and T2m fields respectively. Panels (f) and (h): Same as panel (d) but for the influence of NPH on OLR and T2m fields respectively. Only path coefficients β with $p < 0.05$ (accounting for the effect of serial correlations) are shown by black contours, while grid points which are found significant only with non-corrected p -values are shaded. The dashed black line located at 30°N shows the border between the tropical and the mid-latitude belt.

SST 1979-2018 composite anomalies

Figure S6. Composites of seasonal averaged SST anomalies for summer JJAS preceding El Niño, winter (DJF) with El Niño peak and summers following El Niño (left column). Right column: Same as left column but for La Niña years.

Figure S7. MCA modes during different ENSO phase. Panels (a) and (b) show the first MCA mode for mid-latitude Z200 (25-75° N) and tropical OLR (15°S-30°N), respectively, at the weekly time scale and during La Nina years only. Panels (c) and (d): Same as for panel (a) and (b) but for the second MCA mode. Panels (e) to (h): Same as panels (a) to (d) but for El Niño summers.

Figure S8. Histograms for spatial correlation between each weekly MCA mode and the Z200/OLR fields. Panel (a): histogram for the spatial correlation between the weekly MCA mode 1 Z200 pattern and the Z200 weekly field. Panel (b): Same as panel (a) but for the weekly MCA mode 1 OLR pattern and the weekly OLR fields. Panel (c): Same as panel (a) but for MCA mode 2. Panel (d): Same as panel (b) but for MCA mode 2.

Figure S9. Causal maps: ENSO influence. Panel (a) shows the β values for the link $WNPSM_{\tau=-1} \rightarrow Z200_{\tau=0}$ a 3-actors CEN built with WNPSM, NPH and Z200 during El Niño years. Panel (b): Same as panel (a) but for La Niña years. Panel (c) and (d): Same as panels (a) and (b) but for the link $NPH_{\tau=-1} \rightarrow Z200_{\tau=0}$. Panel (e) and (f): Same as panels (a) and (b) but for the link $SAM_{\tau=-1} \rightarrow Z200_{\tau=0}$ from a 3-actors CEN built with SAM, CGT and Z200. Panel (g) and (h): Same as panels (e) and (f) but for the link $CGT_{\tau=-1} \rightarrow Z200_{\tau=0}$. Only β values with $p < 0.05$ are shown.

Figure S10. Same as Figure 2 but for time series obtained from OLR and Z200 fields with removed 4-weekly variability.