Supplementary material to:

Past warm climate conditions show a shift in Northern Hemisphere winter variability towards a dominant North Pacific Oscillation

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S1 Spin up of simulations

The equilibration of the CCSM4-Utr simulations presented and analysed in this study is assessed by means of time evolution of the global mean surface temperatures (GMST), shown in Figure S1. The original E^{280} (in gray, before year 0) has had 2,500 years of spin-up, which can be found in the Supplementary material of Baatsen et al. (2022). The E^{280} and E^{560} simulations analysed in this study are denoted as $E^{280,p}$ and $E^{560,p}$, respectively, following the naming convention in Baatsen et al. (2022). It indicates the simulations have been run with a 'paleo' vertical mixing parametrisation that is also employed in the Eoi^{400} and Eoi^{280} simulations (more on that in the Methods section of the main paper).

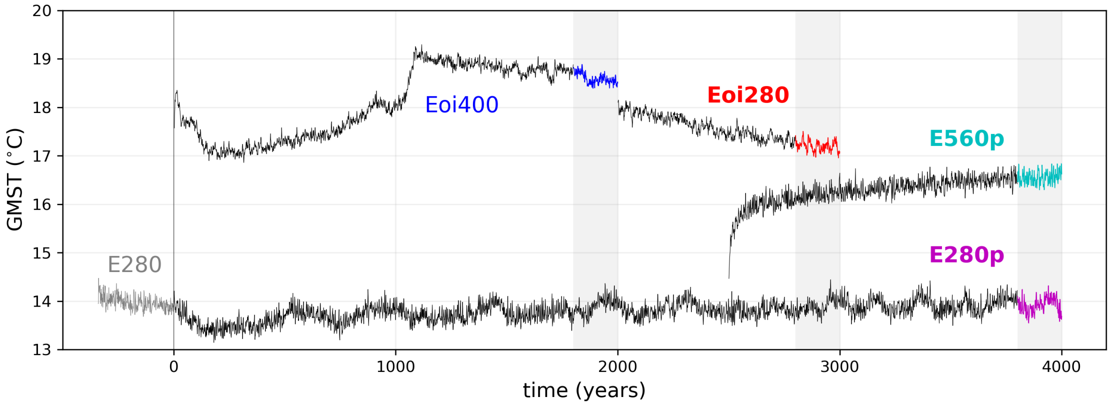

Figure S1: Annual mean global mean surface temperatures (GMST) over simulation years. The colored parts with grey shading are the 200 years that have been used for analysis in this study. In **bold** the simulations presented in the main paper.

S2 Eoi400 January SLP results

We will briefly look at winter sea-level pressure (SLP) results for the simulation with mid-Pliocene boundary conditions and mid-Pliocene CO_2 levels, i.e. the Eoi^{400} experiment, that has been featured in many PlioMIP2 studies. Figure S2 show mean SLP (a) and SLP standard deviation (SD, b) for Eoi^{400}, as well as the difference with the E^{280}. The patterns of MSLP increase and decrease are similar to the Eoi^{280} results presented in Figure 2 in the main study. The amplitude of the higher SLP over the North Pacific (up to 16 hPa) is high, considering that the SD of SLP (Figure S2b) in the E^{280} in this region is around 8 hPa. The SLP increase over the North Pacific is also present in the annual mean (as shown by Baatsen et al. (2022)), but with a smaller amplitude (up to 7 hPa). For comparison, the Eoi^{400} simulation performed with CCSM4-UoT also shows a region of higher SLP over the North Pacific in the winter (DJF) mean, that is very similar in amplitude (up to 16 hPa) and spatial extent (Menemenlis et al., 2021).

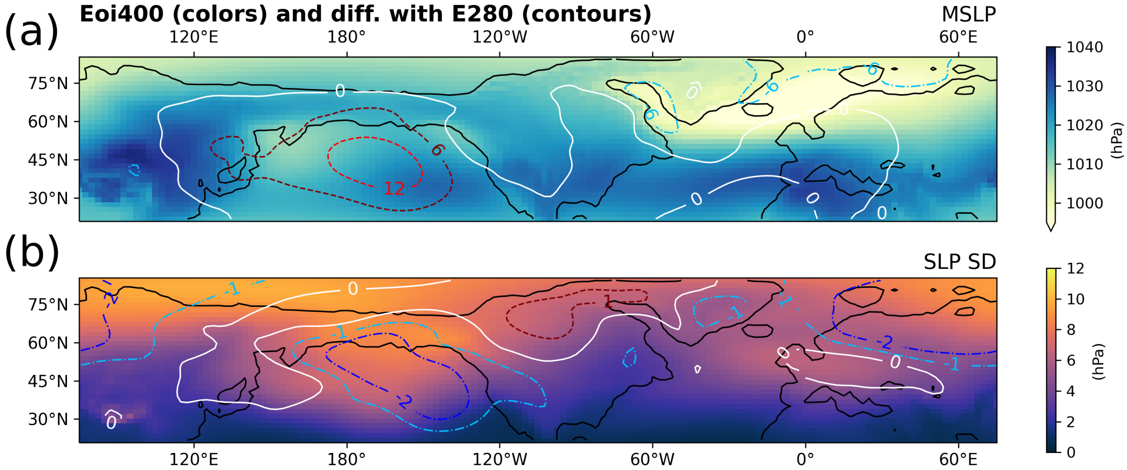

Figure S2: January mean SLP (MSLP, a) and SLP standard deviation (SLP SD, b) for the Eoi^{400} (colors) as well as the difference with E^{280} (contours).

S3 The NHem mode and jet variations

The analysis of the variations in (latitude of the) jet maximum in the North Pacific as presented in the main paper in Figure 8 is repeated here, but for the global zonal mean zonal wind and the NHem mode of variability (Figure S3). The (latitude of the) max jet (Figure S3c and d) is determined per longitude and then averaged to obtain a zonal mean value. Like in the North Pacific, the Eoi^{280} has a smaller range of jet intensities than the E^{280} (Figure S3c). In both climates the NHem shows a positive correlation with the jet intensity, and a weak negative correlation with jet latitude. The Eoi^{280} shows a distribution of slightly more poleward latitudes of the strongest jet in Figure S3d when compared to the E^{280}.

S4 Surface impacts of the NPac-z phases

Figure S4 is an extension of Figure 9 in the main study, showing the surface impacts of the NPac-z MIN and PLUS phases in the E^{280} and Eoi^{280} simulations by means of SAT, SIE and SLP anomalies. The PLUS phase is defined as the average of the top 5% (or ten Januaries) NPac-z PC values, and the MIN phase as the average of the bottom 5% NPac-z PC values.

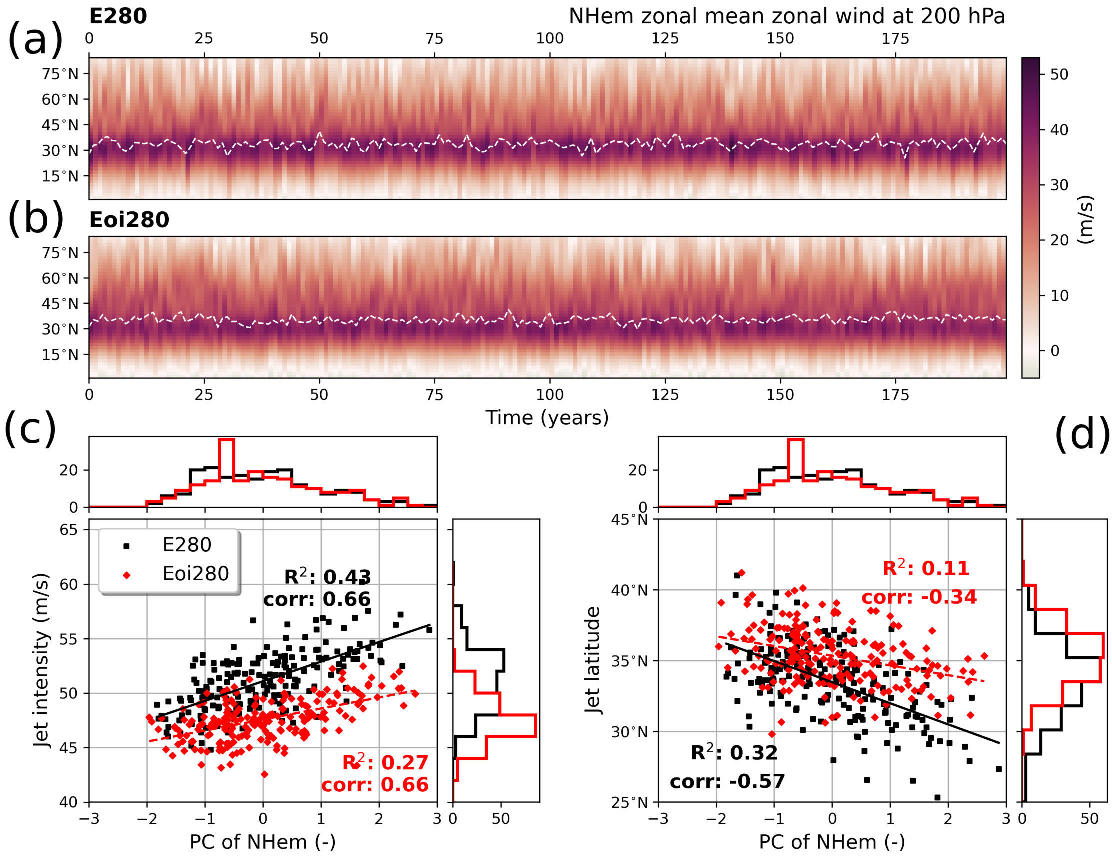

Figure S3: (a,b) Hovmöller diagrams showing global zonal mean zonal wind at 200 hPa for every January for the E^{280} (a) and Eoi^{280} (b). The white dashed line follows the maximum of zonal wind. (c) Scatter plot including histograms of counts for the Principal component (PC) of the NHem mode versus the jet intensity (defined as mean of the max zonal wind per longitude). R^2 of linear fit and correlation coefficient are shown. For E^{280} (black squares) and Eoi^{280} (red diamonds). (d) Same, but for PC of NHem mode versus jet latitude (defined at mean latitude of max zonal wind per longitude).

References

Baatsen, M. L. J., von der Heydt, A. S., Kliphuis, M. A., Oldeman, A. M., and Weiffenbach, J. E. (2022). Warm mid-Pliocene conditions without high climate sensitivity: the CCSM4-Utrecht (CESM 1.0.5) contribution to the PlioMIP2. *Climate of the Past*, 18(4):657–679.

Menemenlis, S., Lora, J. M., Lofverstrom, M., and Chandan, D. (2021). Influence of stationary waves on mid-Pliocene atmospheric rivers and hydroclimate. *Global and Planetary Change*, 204(July):103557.

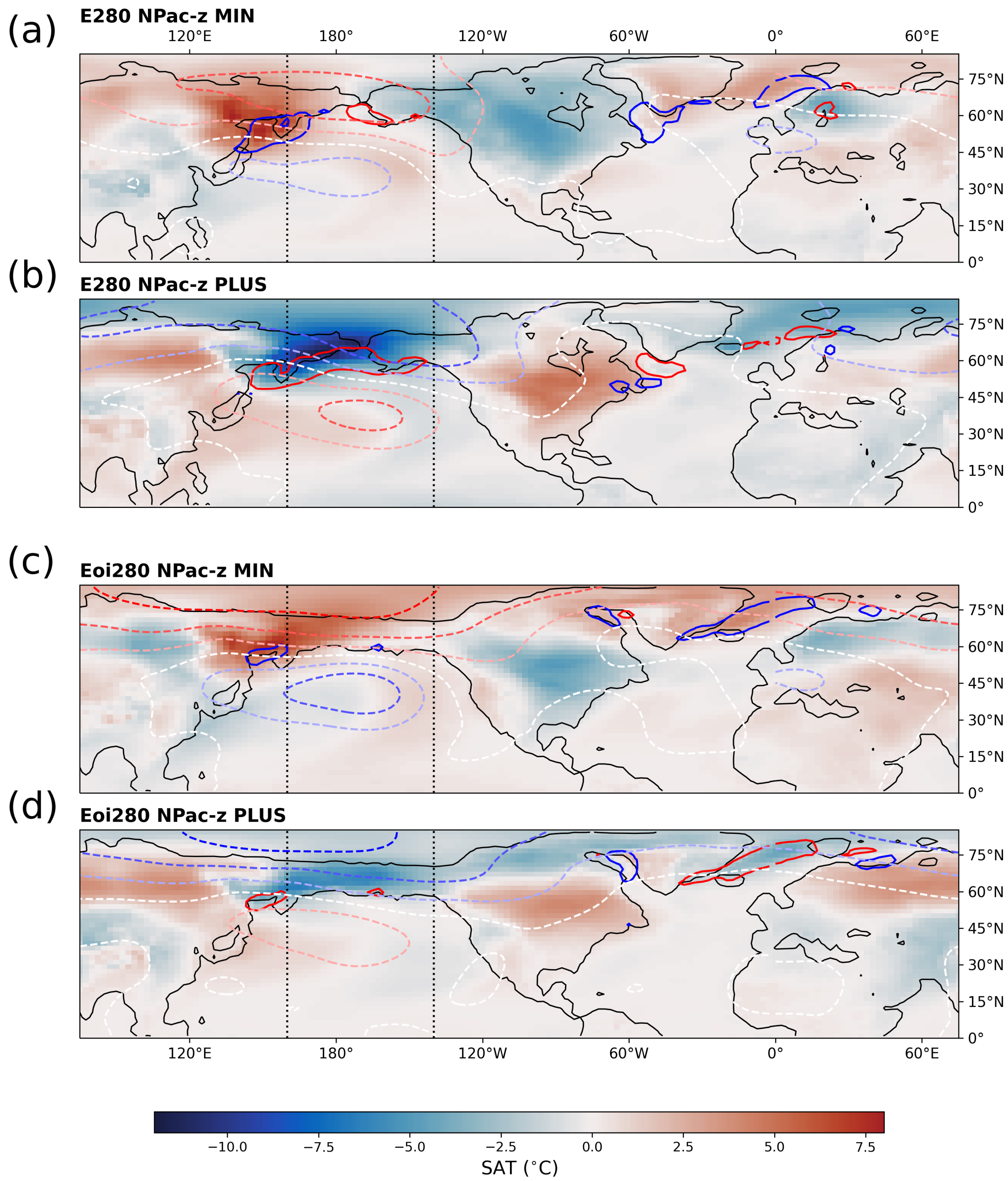

Figure S4: Surface air temperature (SAT, colors), sea-ice extent (SIE, solid contours) and sea-level pressure (SLP, dashed contours) anomalies (to the January mean). For the E^{280} (a, b) and Eoi^{280} (c, d), representing the NPac-z MIN phases (a, c) and PLUS phases (b, d). SIE anomalies represent +/- 3%, SLP anomalies in steps of 5 hPa, for both contours blue means negative, red means positive.