Supporting Information for "Resolving weather fronts increases the large-scale circulation response to Gulf Stream SST anomalies in variable resolution CESM2 simulations"

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Text S1. Initialization, Spinup, and Stratospheric Anomalies The NATLx8 simulations exhibit drift in the global-mean stratospheric temperature over the first decade of the simulation, whereas global-mean stratospheric temperature appears spun up in the NE30 simulations within the first year or two of the simulation (Fig. S1a). This drift also occurs in NATLx4, though it is of a much reduced magnitude. This stratospheric drift is particularly large within the first 4 years of the NATL simulations, and we therefore exclude the first 4 years of all simulations from the analysis in the rest of the paper, taking March 1st of model year 5 as the beginning of the analysis period.

The drift in NATLx8 and NATLx4 stems from large stratospheric temperature anomalies at the beginning of the simulation compared to the eventual long-term mean. This anomaly occurred in NATLx8 and NATLx4, but not NE30, despite a similar initialization procedure for all grids. For NATLx8 and NATLx4, spin-up simulations were performed starting from US Standard Atmosphere conditions. The runs were performed with increased hyperviscocity and reduced timestep, then the hyperviscocity and timestep were gradually adjusted towards their default values until a stable initial condition was achieved. This process took ∼75 model days for NATLx8 and ∼55 model days for NATLx4. The main simulations were then started from January 1st using the end of these spin-up simulations as initial conditions. NE30 started directly from the US Standard Atmosphere

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initial conditions with no additional spin-up simulation required. We think it is this spin-up procedure, and in particular running with the model with reduced dynamics time step, that led to the large stratospheric anomalies at the beginning of the NATLx8 and NATLx4 simulations relative to their eventual long-term mean. However, we were unable to investigate further because output was not saved for the initialization simulations, and we were unable to reproduce these anomalies by redoing the same initialization procedure.

In addition to the large anomalies in the spin-up period, there is a large negative excursion in the global-mean stratospheric temperature in the NATLx8-WARM simulation, which extends from model year 10 to model year 16 (blue dot-dashed line in Fig. S1a). During this period, the summer stratospheric polar vortex (characterized by the geopotential at 10 hPa averaged over the Northern Hemisphere polar cap) strengthens to be nearly as strong as its typical winter state (blue dot-dashed line in Fig. S1b). The winter stratospheric polar vortex also strengthens by a similar amount during this period, but it is not nearly as anomalous compared to the winter internal variability in the polar vortex as it is compared to the summer internal variability in the polar vortex. We have tested the sensitivity of our key SLP response figure to the exclusion of the 6 winters during the affected period and found that excluding this period has minimal impact on our results (Fig. S2). We therefore keep this period in our figures in the main text.

The stratospheric excursion in NATLx8-WARM and a smaller one in NATLx8-REF immediately follow model crashes, on January 26th of model year 10 and January 27th of model year 11, respectively. These crashes were tracked down to instabilities that developed near the surface in the 8× refinement region near the southeast coast of Baffin Island. To get the model through these crashes, the *se_nsplit* parameter was increased for a single day by a factor of 30 and 8, respectively, corresponding to reductions in the dynamics timestep by the same factors. It thus appears that the stratospheric temperature is strongly sensitive to the dynamics timestep, which is likely also the explanation for the large anomalies in the spin-up period. Strong caution is therefore urged in using such a timestep reduction approach to get through model crashes in future simulations.

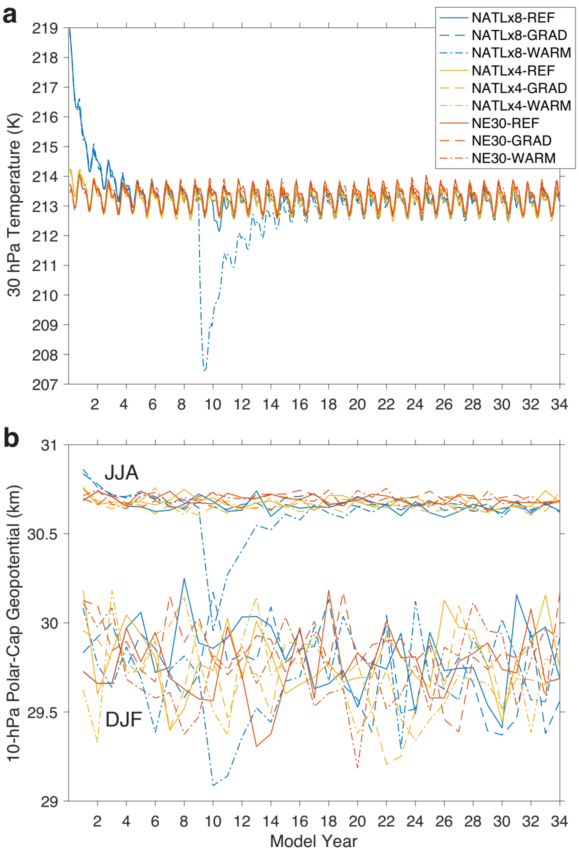

Figure S1. (a) Global-mean stratospheric temperature at model level 5 (approx. 30 hPa), showing large drift over the first 4 model years, particularly in the 14-km configuration (blue lines). A large excursion can also be seen in model years 10 through 15 of NATLx8-WARM, and a smaller excursion in model year 10 of NATLx8-REF. (b) Geopotential height averaged over model levels 2 and 3 (approx. 10 hPa) and over the Northern Hemisphere polar cap (60-90°N), shown separately for JJA (top) and DJF (bottom). The JJA geopotential shows positive anomalies in the spinup period in all 3 NATLx8 simuations and a large negative anomaly beginning in year 10 in NATLx8-WARM.

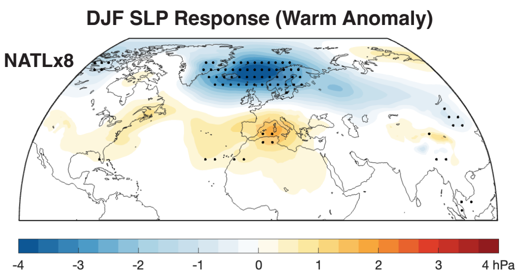

Figure S2. As in Fig. 3b, but excluding 6 DJFs of the NATLx8-WARM simulation during the period affected by large stratospheric anomalies.

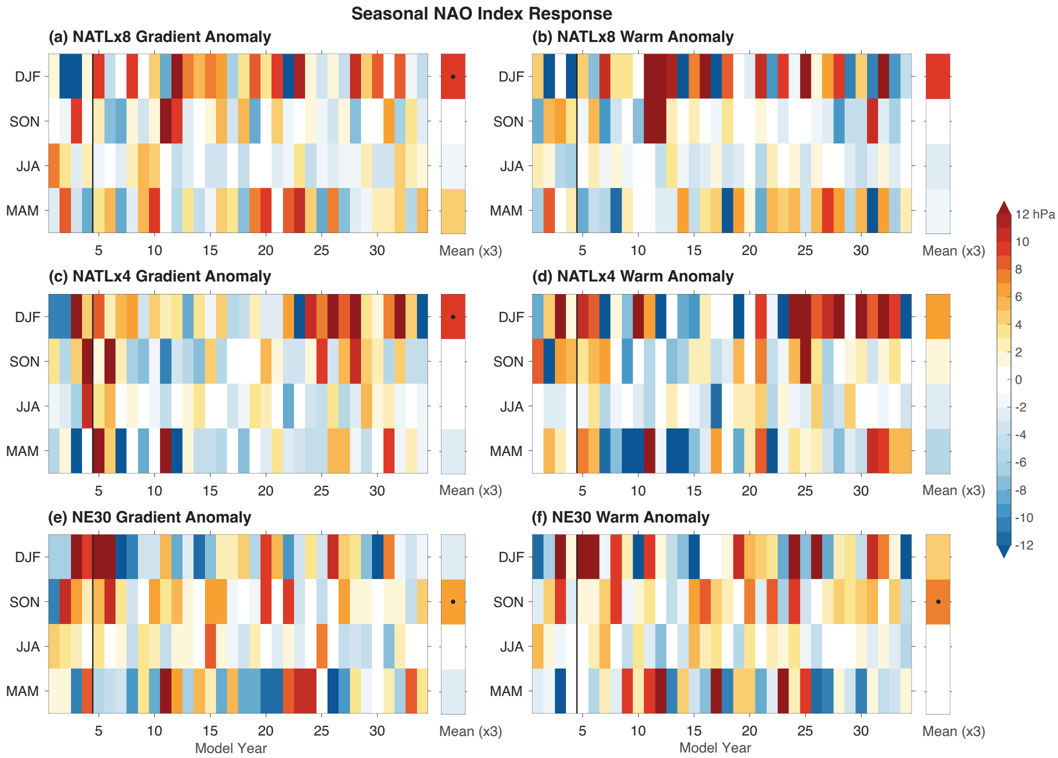

Figure S3. NAO index anomaly in each season and model year: (a) NATLx8 SST-GRAD minus NATLx8-REF, (b) NATLx8-WARM minus NATLx8-REF, (c) NATLx4-GRAD minus NATLx4-REF, (d) NATLx4-WARM minus NATLx4-REF, (e) NE30 SST-GRAD minus NE30-REF, (f) NE30-WARM minus NE30-REF. Here, the NAO index is defined as the SLP anomaly in the box defined by 60°W-10°E, 35-45°N (including Lisbon) minus the SLP anomaly in the box defined by 5-35°W, 62-72°N (including Reykjavik); these boxes were defined based on Fig. 7a. A black line separates the first 4 years of each simulation, which are excluded from the analysis in the remainder of the paper due to stratospheric spinup issues. An average over the following 30 years is shown on the right side of each panel, with values multiplied by 3 and statistical significance at the 0.1 significance level, assessed by bootstrap resampling and applying a two-tailed t-test, indicated with a black dot.

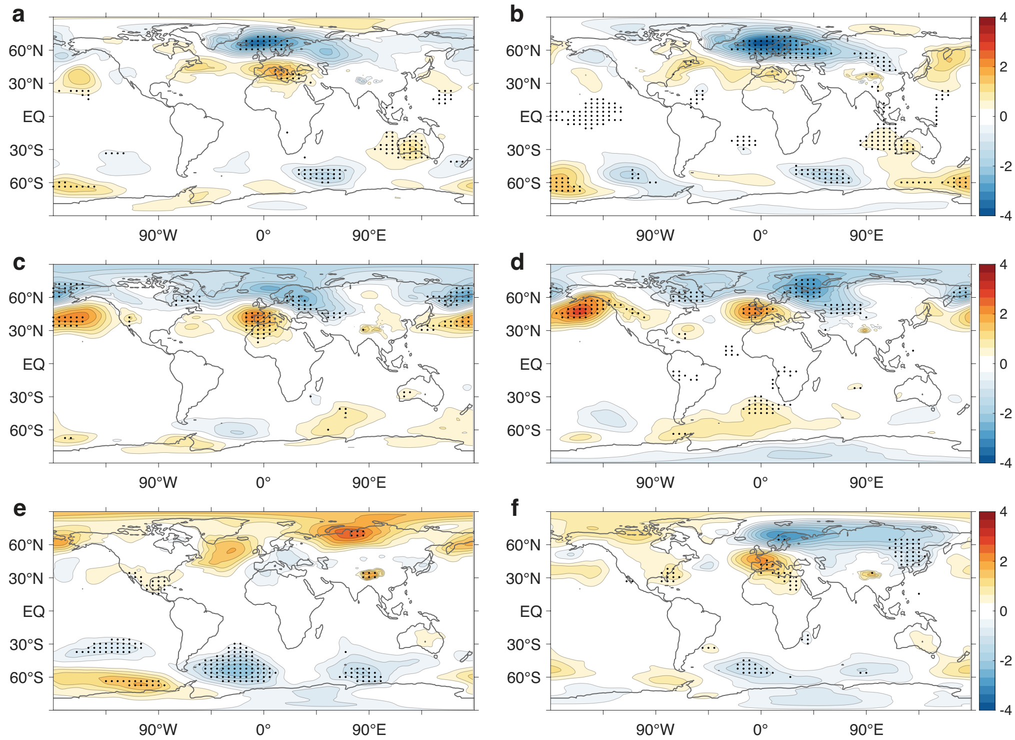

Figure S4. Same as Fig. 3, but using 30-year averages instead of 50-year averages for NE30 (panels e and f) and showing the full globe.

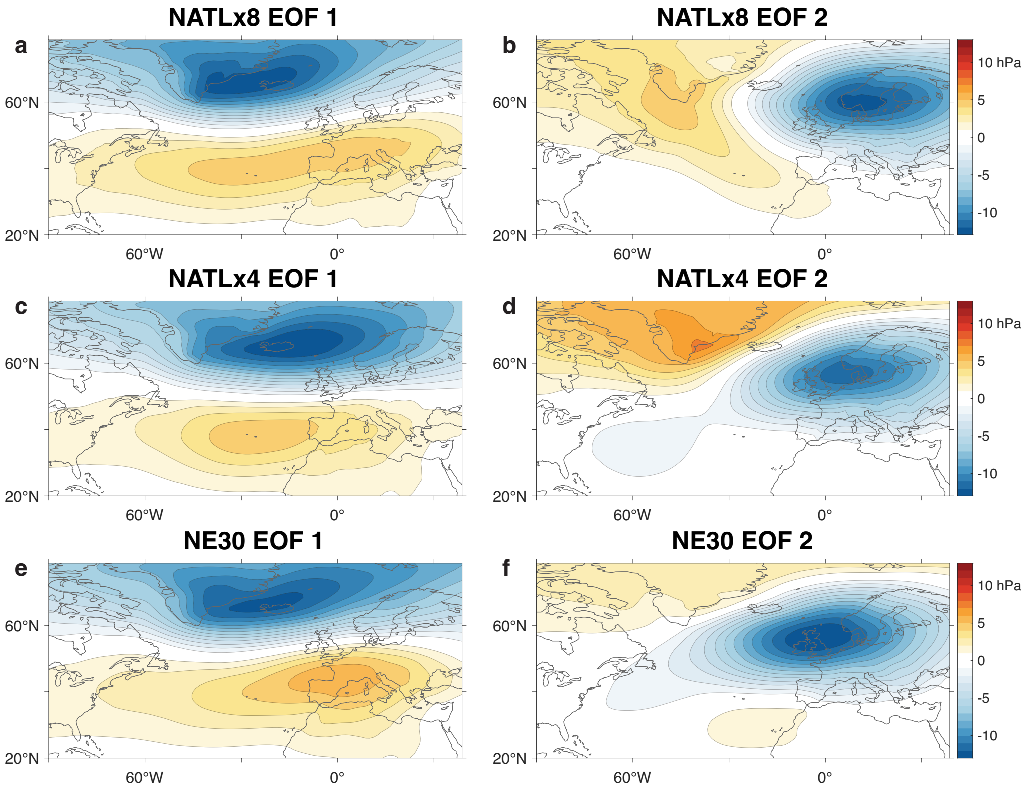

Figure S5. Same as Fig. 7a,b, but separately for each grid: (a,b) NATLx8, (c,d) NATLx4, (e,f) NE30.

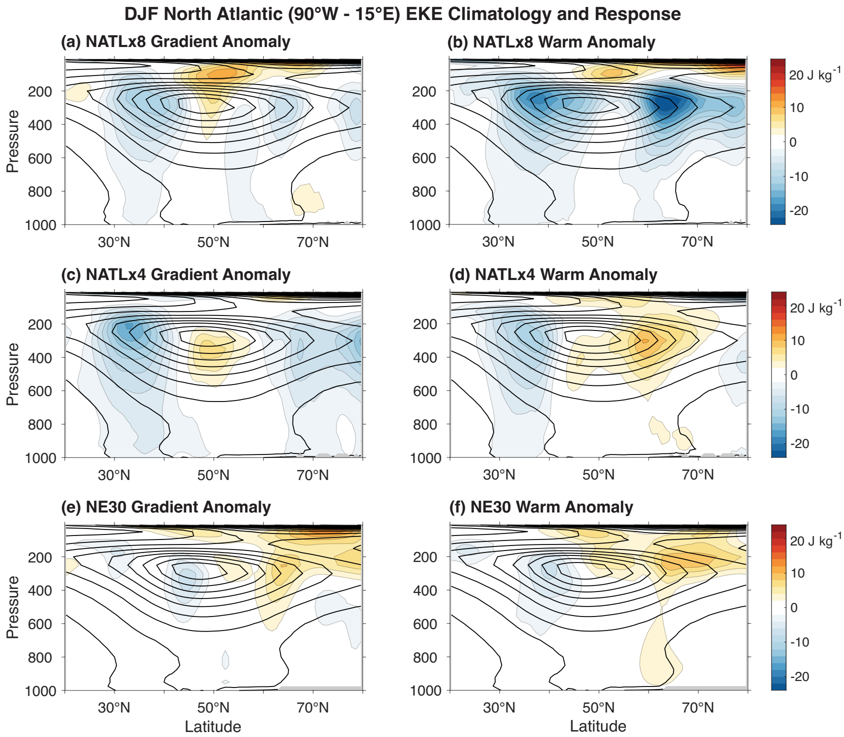

Figure S6. Same as Fig. 6, but for the zonal-mean eddy kinetic energy (EKE) over the Atlantic sector (90°W-15°E) as a function of latitude and pressure. The contour interval for the climatology is 30 m s^{-1}.