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Stratospheric circulation response to large Northern Hemisphere high-latitude volcanic eruptions in a global climate model

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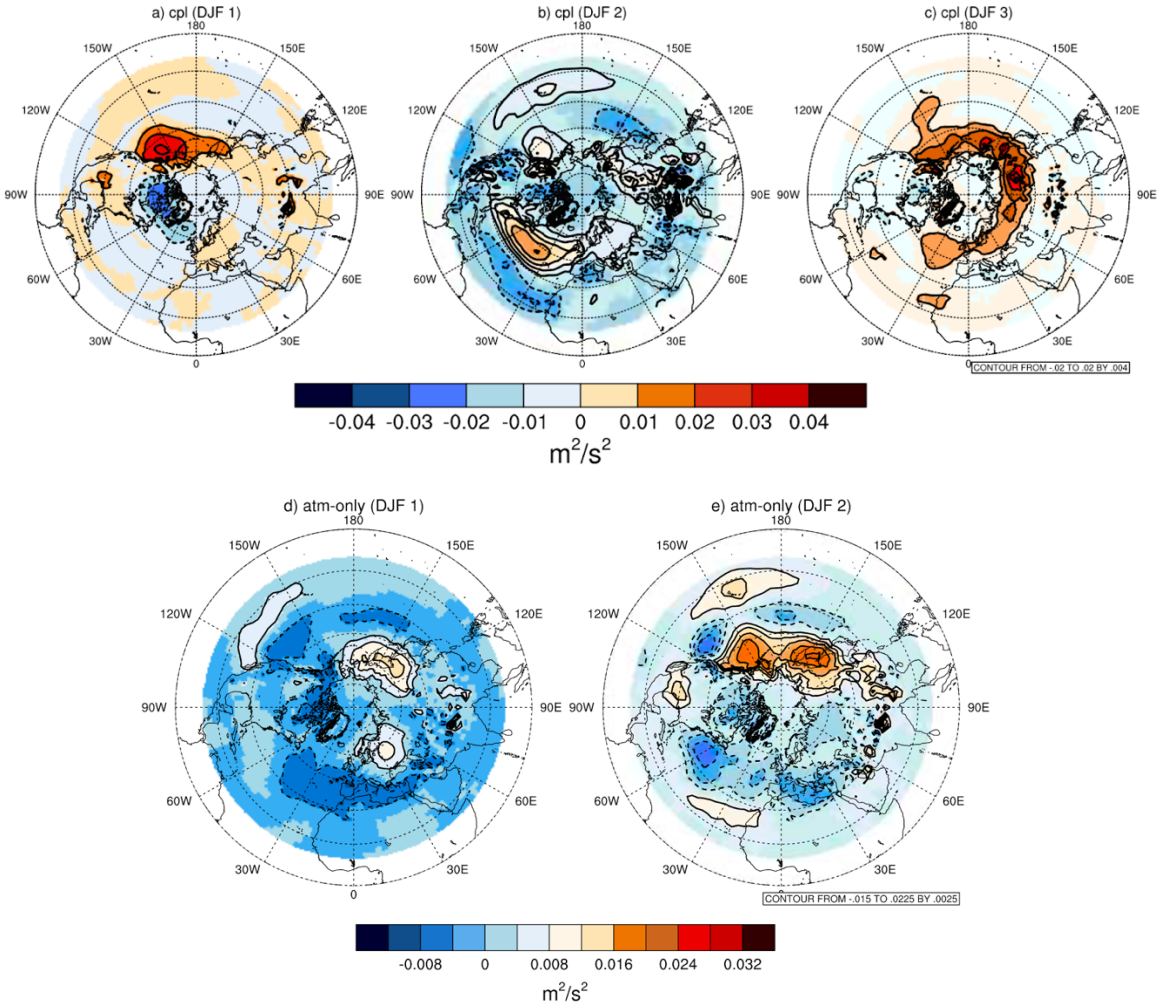

Figure S1: a-c) Coupled and d-e) atm-only vertical wave activity flux (Plumb flux) at 150 hPa for winters 1-3 and 1-2, respectively. Contours indicate 95% significance according to a Student's t-test.

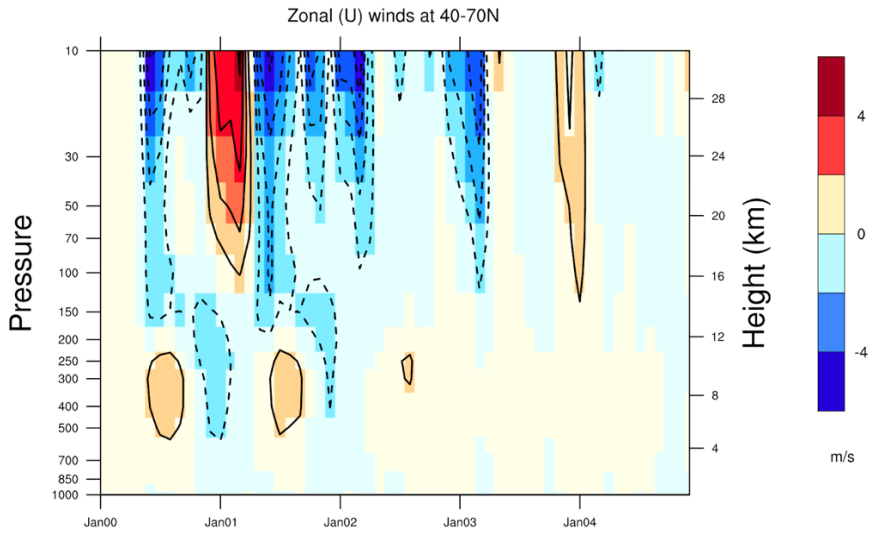

Figure S2: The vertical profile of the time evolution of zonal-mean zonal wind (U) averaged over 40-70N for years 0-4. Contours indicate significance in 95% confidence intervals according to a two-tailed Student's t-test.

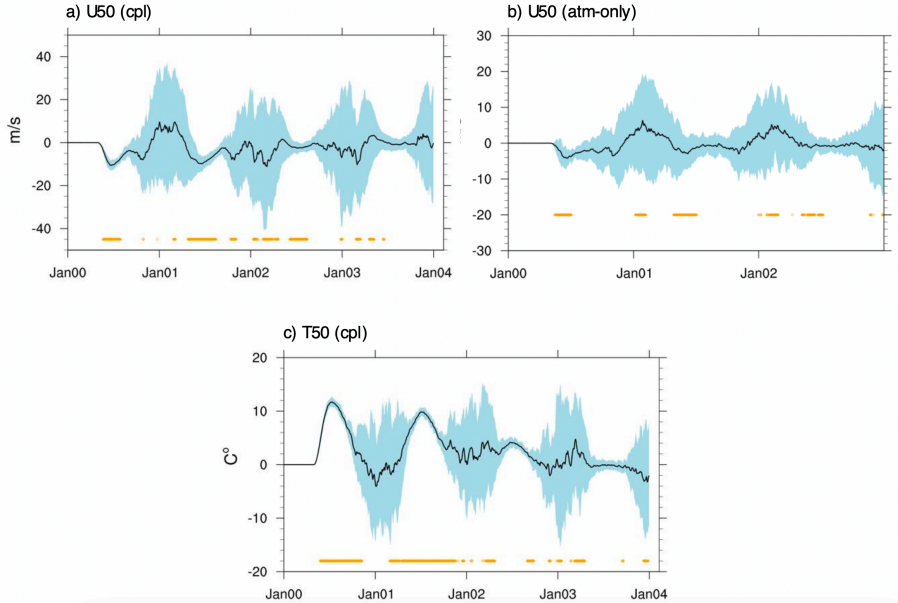

Figure S3: The stratospheric polar vortex is shown here as the zonal winds at 50 hPa (U50) between 70 and 80°N for a) *cpl* (spanning 4 years) and b) *atm-only* (spanning 3 years). d) The temperature at 50 hPa in *cpl* (also spanning 4 years) between 70-90°N and 0-200°E (due to the asymmetric nature of the warming). Black lines show ensemble mean and blue shadings show ensemble mean +/- 2 standard deviation. Orange markers indicate when the difference between perturbed and unperturbed experiments becomes significant ($p<0.05$) according to a Kolmogorov-Smirnov test.

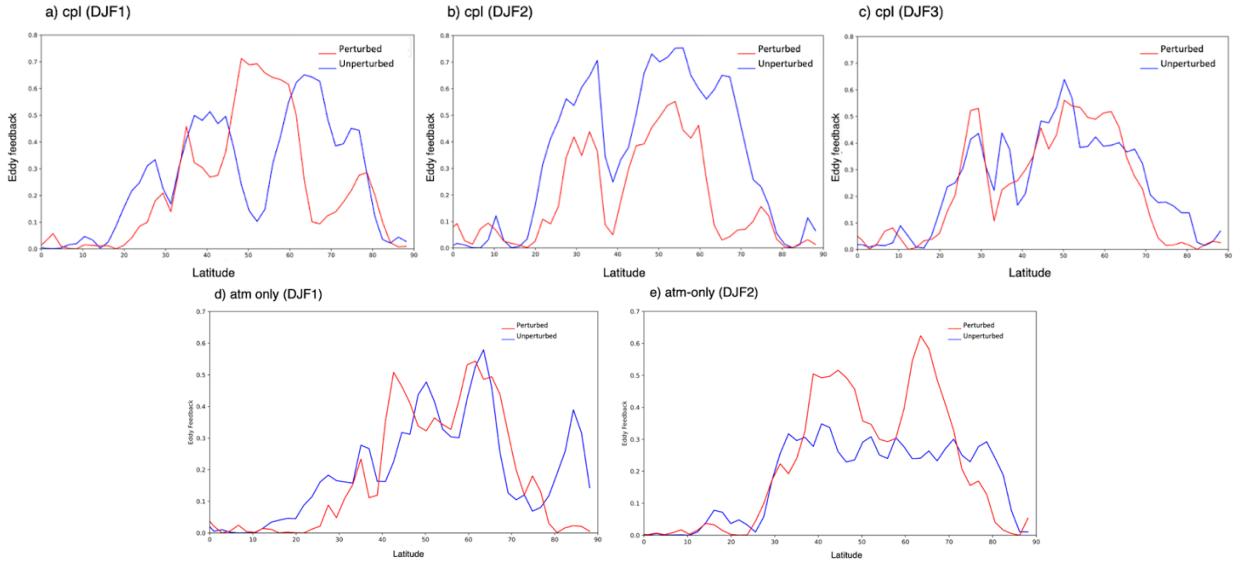

Figure S4: The eddy feedback evolution in the lower atmosphere (200-600hPa) in *cpl* winters 1-3 (a-c) and *atm-only* winters 1-2 (d-e) where the eddy feedback is calculated as the squared correlation of zonal mean zonal winds and the divergence.

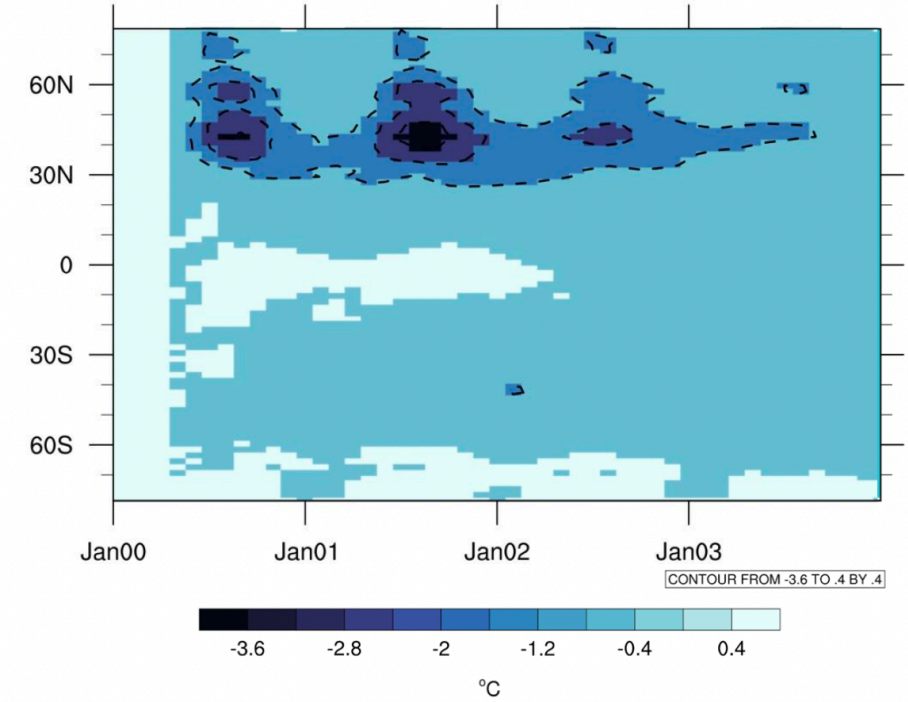

Figure S5: Time evolution of the zonally averaged SST anomalies in the *cpl* experiment during years 0-3. Contours indicate 95% significance according to a two-tailed Student's t-test.

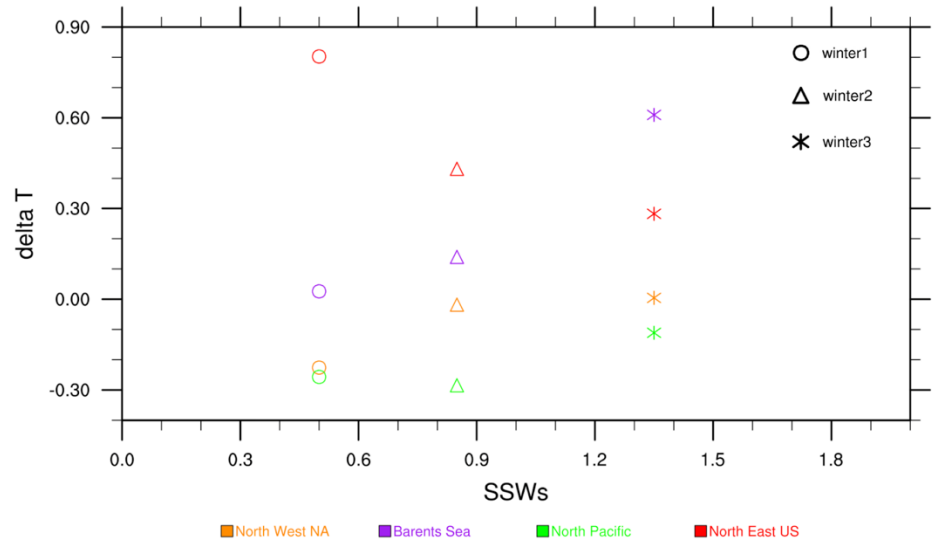

Figure S6: Mean meridional T2m gradient vs. mean SSWs for: North Pacific (50-60N, 150-180E), North-East US (44-50N, 300-315E), North-West NA (60-70N, 310-330E) and Barents sea (70-75N, 30-75E).

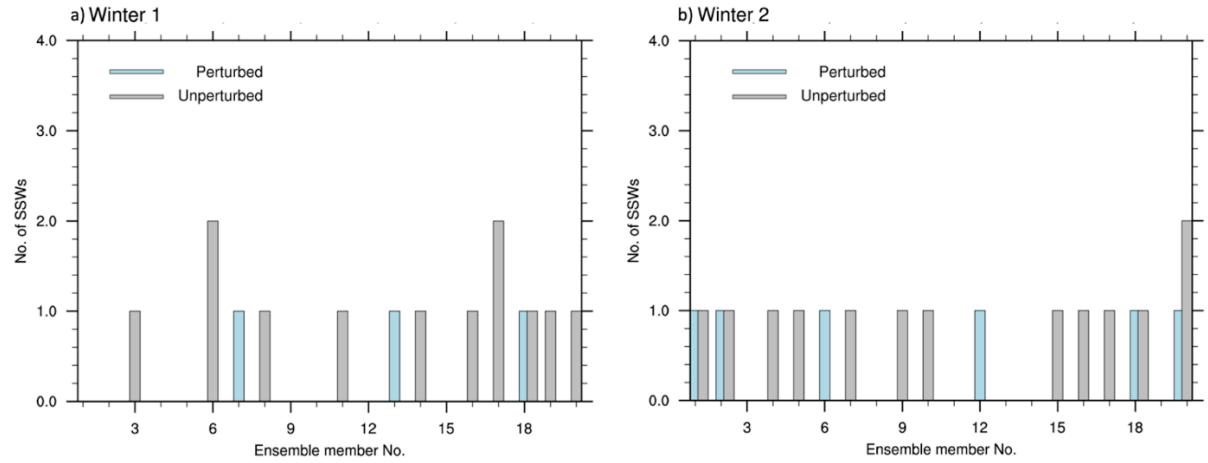

Figure S7: a-b) The number of SSWs during winters 1-2 for each ensemble member in *atm-only*.

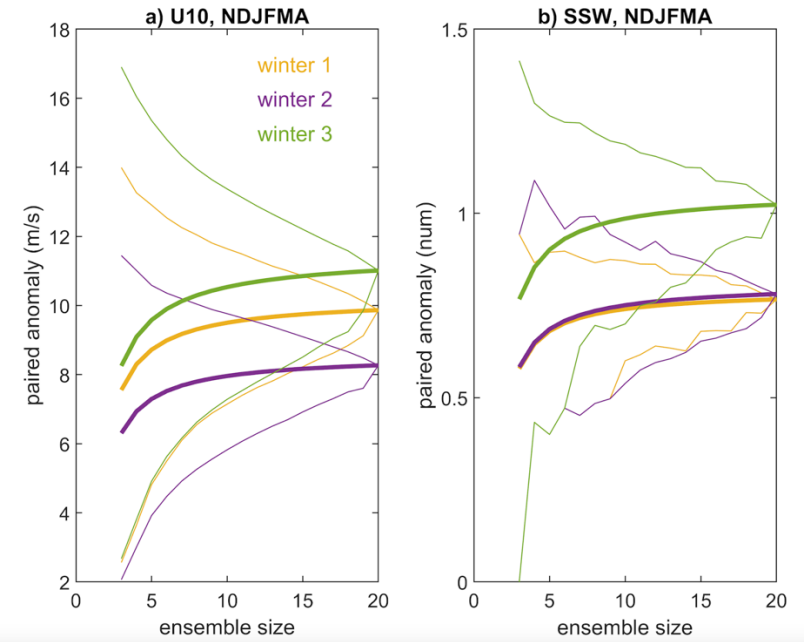

Figure S8: Impacts of ensemble size and spread on the volcanic signal. Ensemble mean (thick lines) and associated standard errors (thin lines, 5-95 percentile range) of paired anomalies calculated for different ensemble sizes and for the first three post-eruption extended winter seasons (November to April) for stratospheric zonal-mean zonal wind (a) and number of sudden stratospheric warming events (b). For each ensemble size from 3 to 20, the mean and the standard error of the mean are calculated for all sub-ensembles determined by all possible permutations of the full ensemble for the considered size. Then, means and 5th and 95th percentiles of the so-obtained standard errors for each ensemble size are plotted.