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Supplement of

Decadal variability and trends in extratropical Rossby wave packet amplitude, phase, and phase speed

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Contents

1 Annual time series of RWP amplitude over N America, Europe, C Asia, and NW Pacific

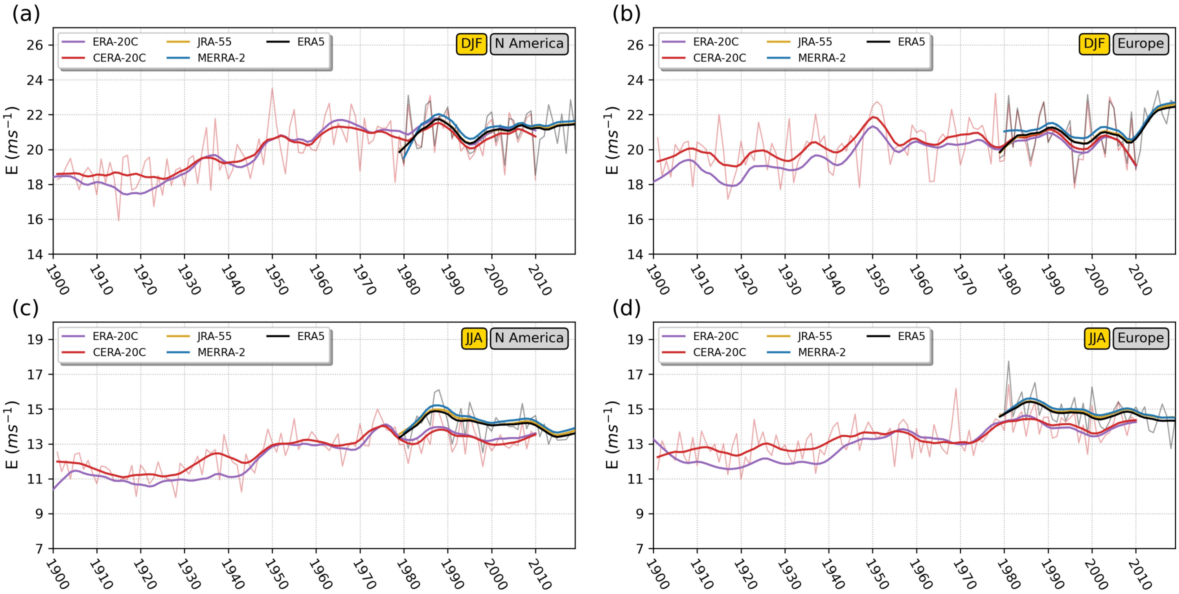

Fig. S1: (a) LOWESS time series of DJF-mean E at 300 hPa over N America (Fig. 2) based on the CERA-20C (red), ERA-20C (purple), JRA-55 (yellow), MERRA-2 (blue), and ERA5 (black) reanalysis. The thin red and black lines correspond to the original DJF-mean time series in CERA-20C and ERA5, respectively. (b) Same as (a), but for the Europe region. (c,d) Same as (a,b), but for the JJA season.

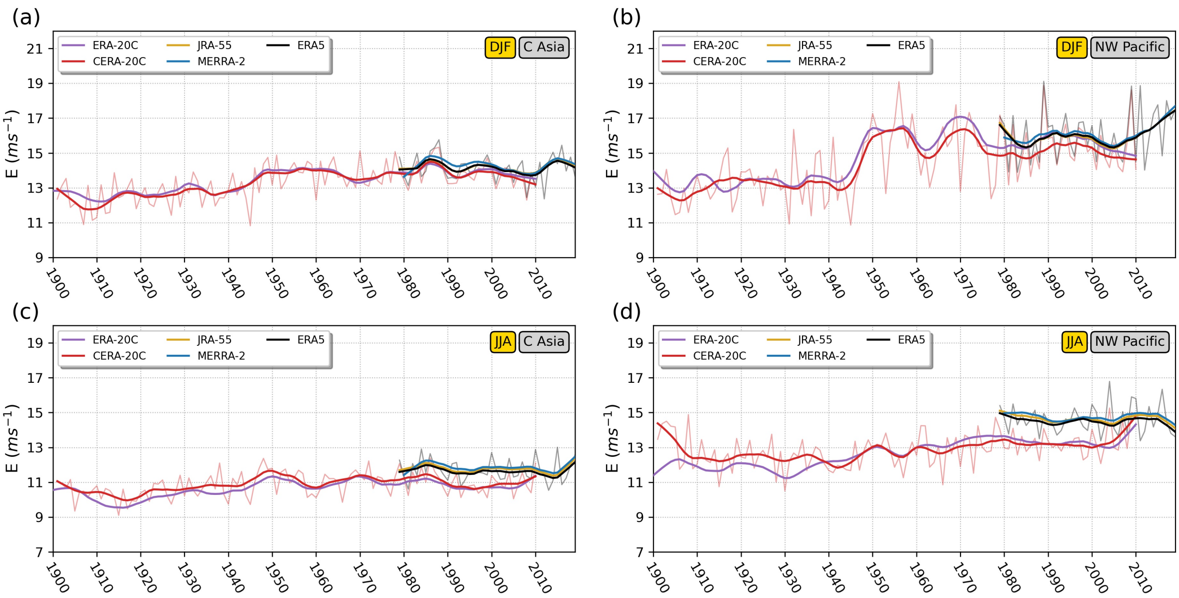

Fig. S2: Same as Fig. S1, but for the C Asia (a,c) and NW Pacific (b,d) regions.

2 Annual time series of RWP amplitude over NE Pacific and N Atlantic: Comparison between CERA-20C members

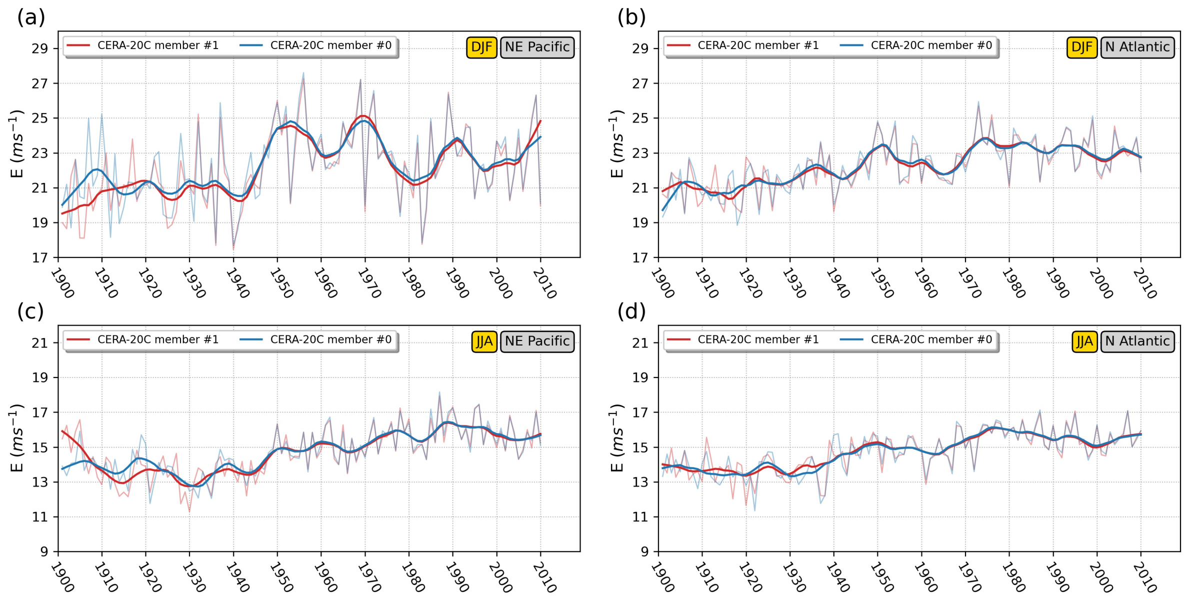

Fig. S3: (a) LOWESS time series of DJF-mean E at 300 hPa over NE Pacific (Fig. 2) based on two CERA-20C members (member #1 corresponds to the one used in Fig. 3 of the paper). The thin lines correspond to the original DJF-mean time series. (b) Same as (a), but for the N Atlantic region. (c,d) Same as (a,b), but for the JJA season.

3 Annual time series of RWP phase speed over NE Pacific and N Atlantic

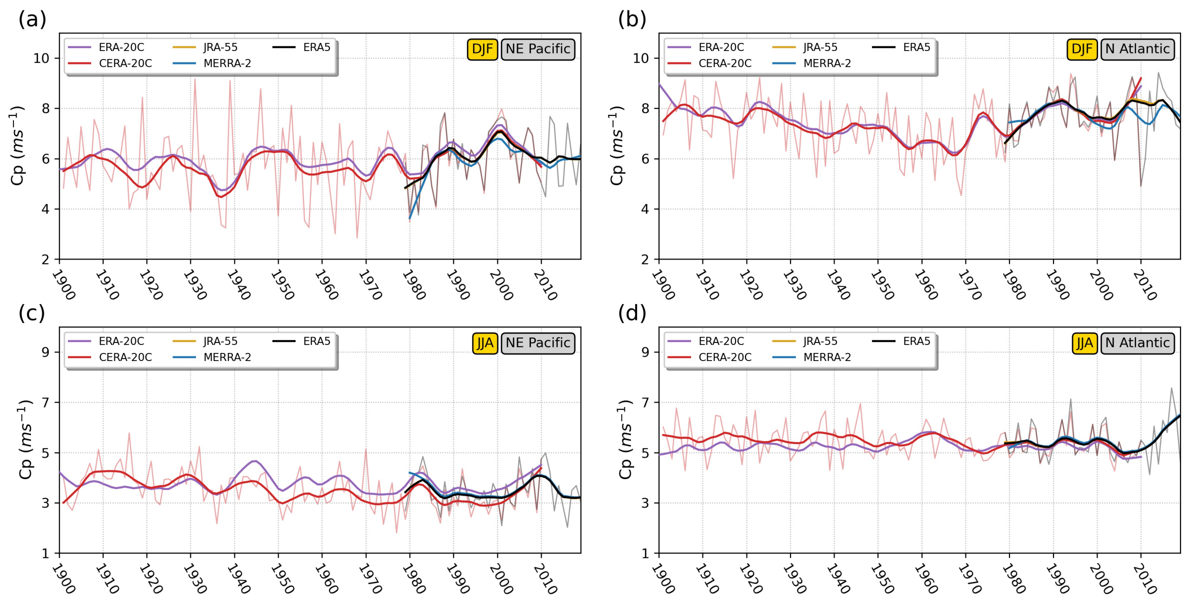

Fig. S4: (a) LOWESS time series of DJF-mean c_p at 300 hPa over NE Pacific (Fig. 2) based on CERA-20C (red), ERA-20C (purple), JRA-55 (yellow), MERRA-2 (blue), and ERA5 (black). The thin red and black lines correspond to the original DJF-mean time series in CERA-20C and ERA5, respectively. (b) Same as (a), but for the N Atlantic region. (c,d) Same as (a,b), but for the JJA season.

4 Decadal trends in 300 hPa zonal wind

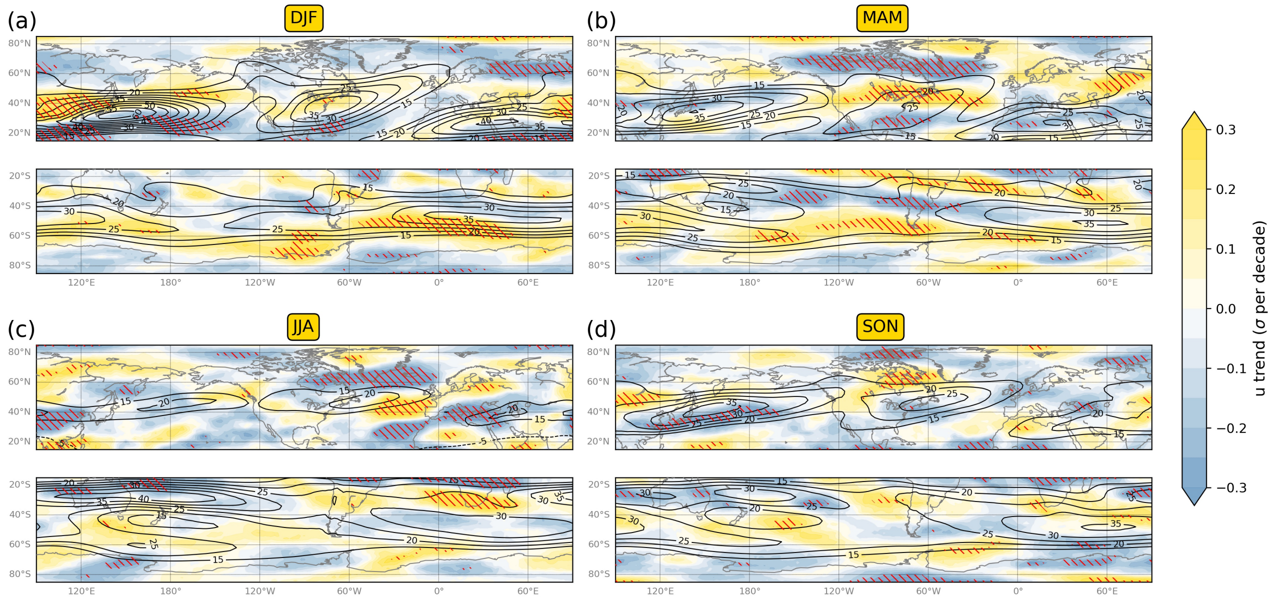

Fig. S5: Maps of 1979–2019 linear trends (Theil-Sen estimator; colour shading) in the standardized seasonal-mean zonal wind (u) at 300 hPa for (a) DJF, (b) MAM, (c) JJA, and (d) SON in ERA5. Red hatching indicates areas where the monotonicity of the trend is statistically significant at the 0.10 significance level. Black contours correspond to the multi-year mean u values of the respective season.

5 Decadal trends in high-E extremes

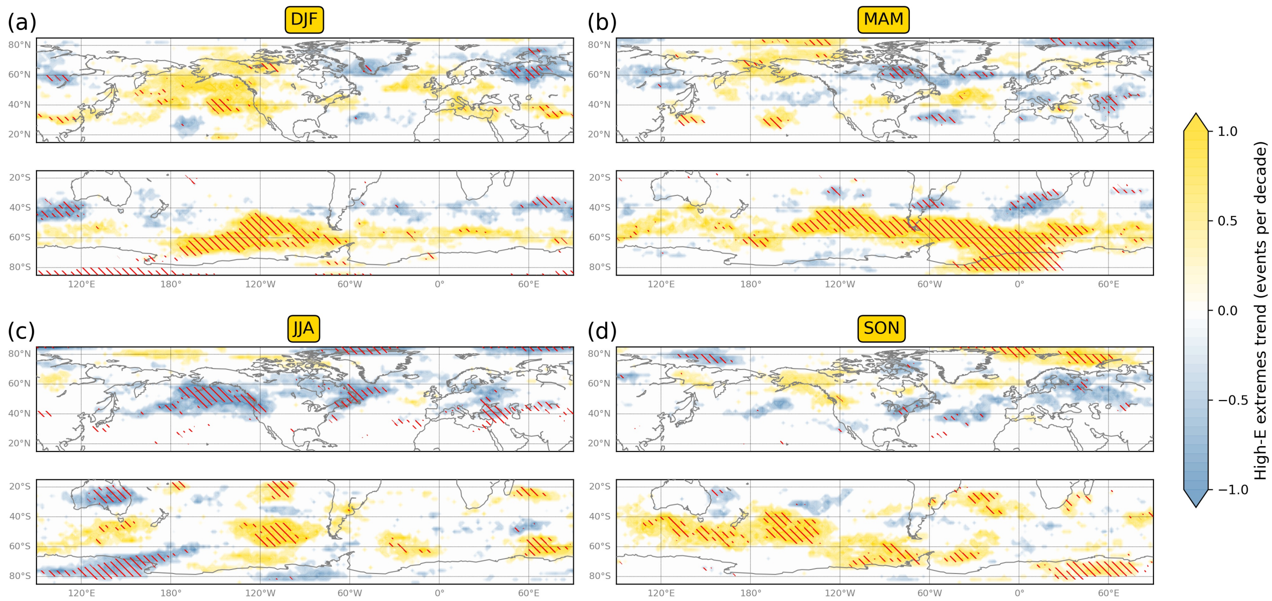

Fig. S6: Maps of 1979–2019 linear trends (Theil-Sen estimator; colour shading) in the number of high-E extremes at 300 hPa for (a) DJF, (b) MAM, (c) JJA, and (d) SON in ERA5. Red hatching indicates areas where the monotonicity of the trend is statistically significant at the 0.10 significance level.

6 Decadal trends in low-c_p extremes

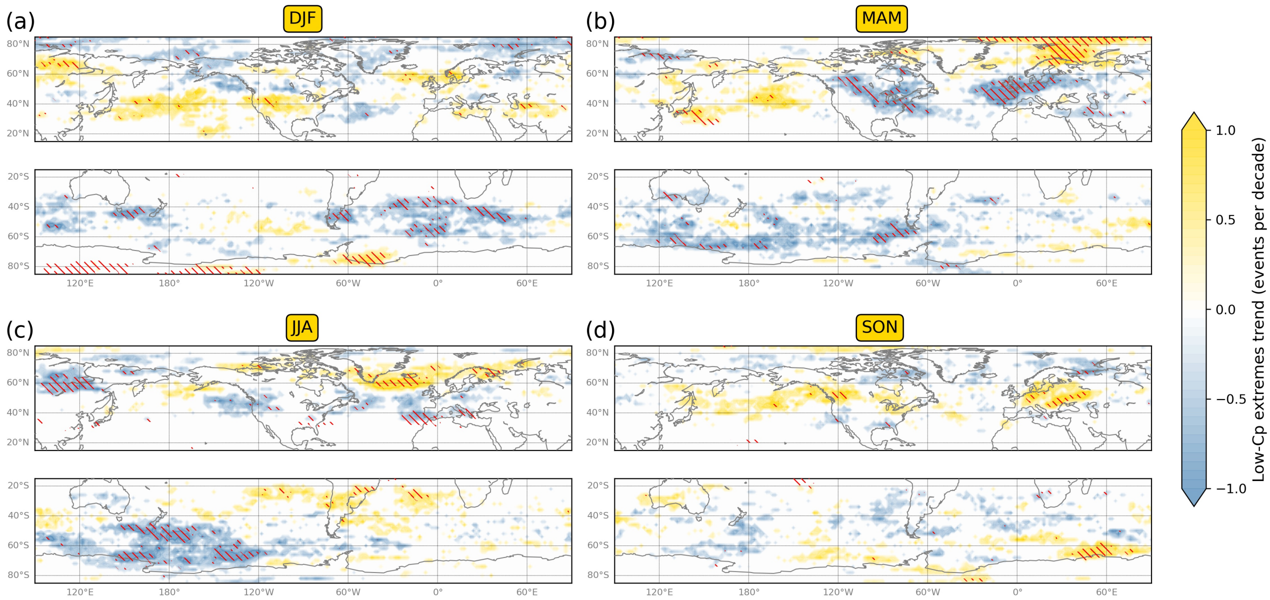

Fig. S7: Same as Fig. S6, but for low-c_p extremes at 300 hPa.

7 Decadal trends in compound extremes

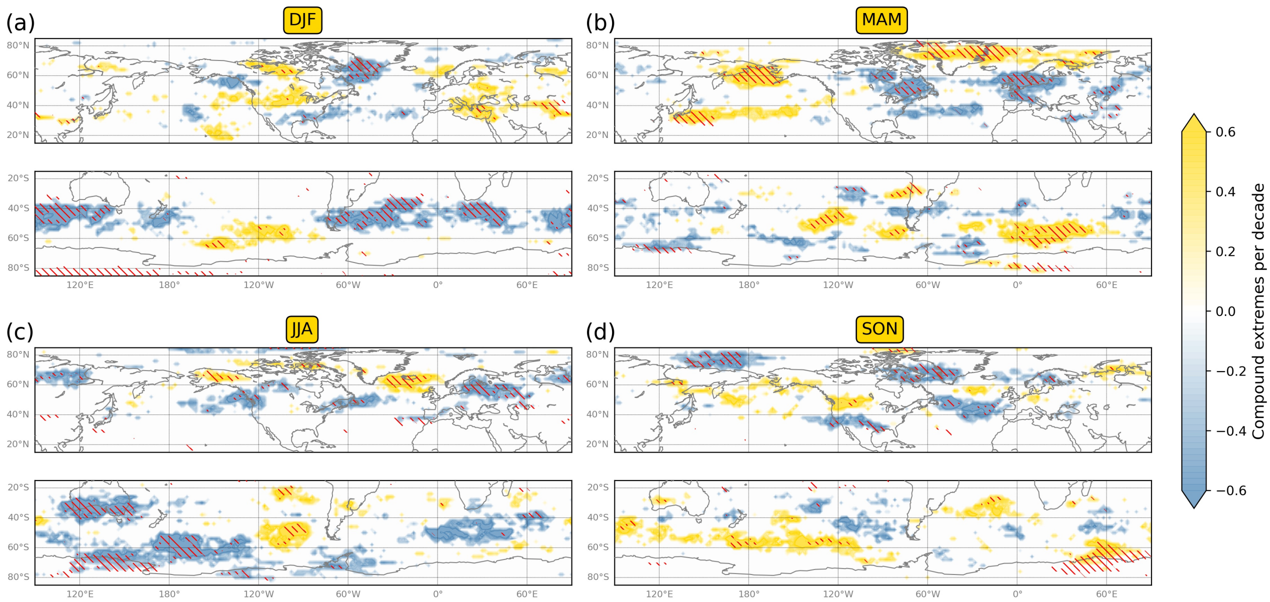

Fig. S8: Same as Fig. S6, but for compound extremes at 300 hPa.

8 Temporal variation of trends in RWP extremes

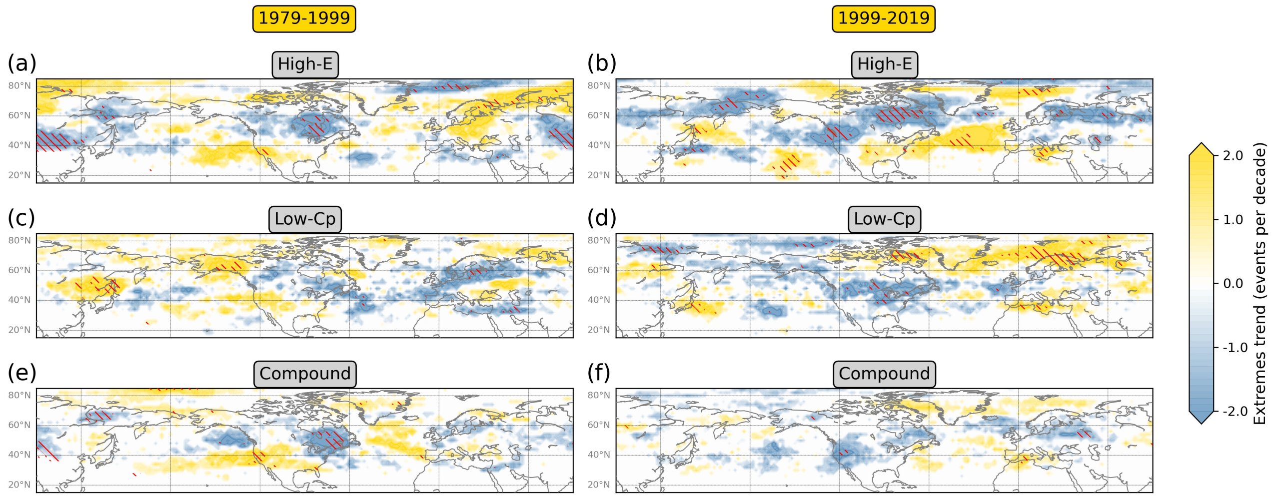

Fig. S9: Maps of 1979–1999 linear trends (Theil-Sen estimator; colour shading) in the number of MAM (a) high-E extremes, (c) low-c_p extremes, and (e) compound high-E/low-c_p extremes at 300 hPa in ERA5. (b),(d),(f) Same as (a),(c),(e), but for 1999–2019. Red hatching indicates areas where the monotonicity of the trend is statistically significant at the 0.10 significance level.

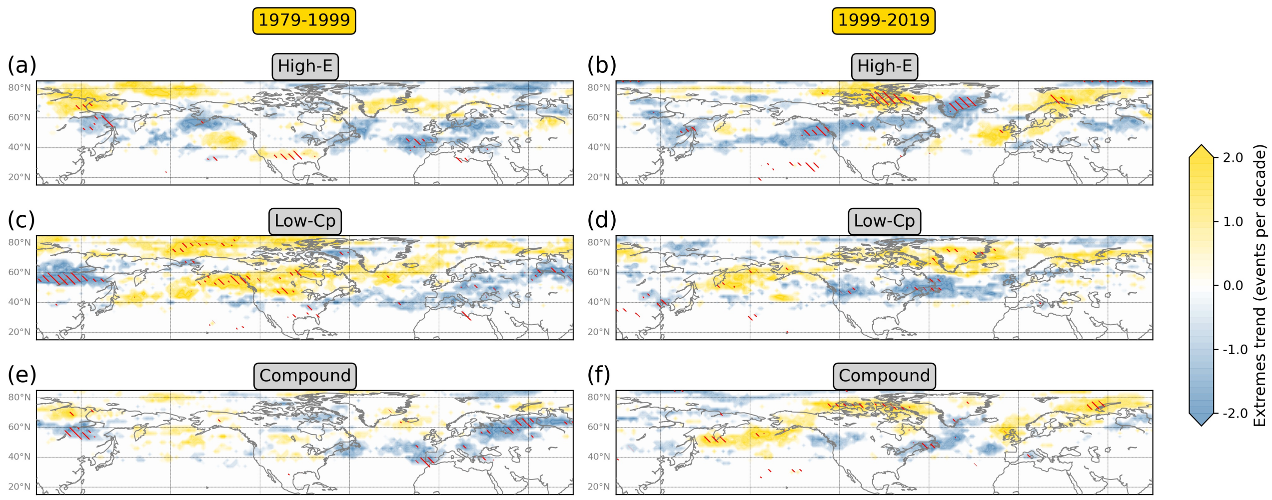

Fig. S10: Same as Fig. S9, but for JJA.

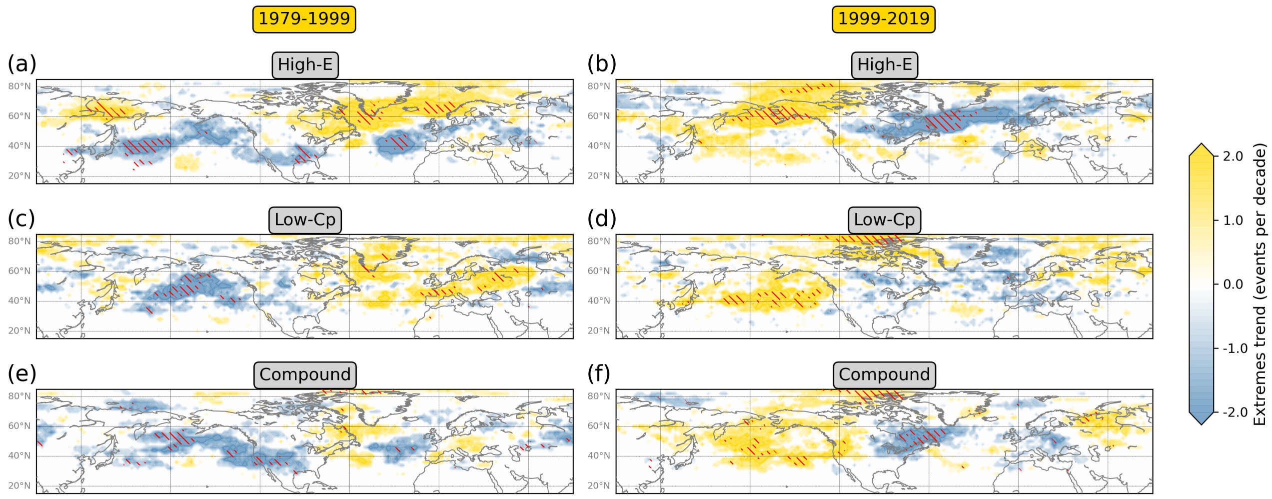

Fig. S11: Same as Fig. S9, but for SON.

9 Reanalysis data retrieval

The reanalysis datasets used in this study are described and referenced in section 2.1 of the paper. They have been freely retrieved from the online sources listed in Table S1.

	Dataset	Citation & Online Source	Web Address
1	`ERA5/ERA5.1`	Hersbach et al. (2018). Source: Copernicus Climate Change Service (C3S) Climate Data Store (CDS).	`https://doi.org/10.24381/cds.bd0915c6`, `https://confluence.ecmwf.int/pages/viewpage.action?pageId=181130838`
2	`MERRA-2`	NASA Global Modeling and Assimilation Office (GMAO) (2015). Source: Goddard Earth Sciences Data and Information Services Center (GES DISC).	`https://disc.gsfc.nasa.gov/datasets/M2I6NPANA_5.12.4/summary`
3	`JRA-55`	Japan Meteorological Agency, Japan (2013). Source: Research Data Archive at NCAR/CISL.	`https://rda.ucar.edu/datasets/ds628.0/`
4	`ERA-20C`	ECMWF Public Datasets	`https://apps.ecmwf.int/datasets/data/era20c-daily/levtype=sfc/type=an/`
5	`CERA-20C`	ECMWF Public Datasets	`https://apps.ecmwf.int/datasets/data/cera20c/levtype=sfc/type=an/`

Table S1: List of reanalysis datasets used in this study and their online sources.

10 Computation methods

The computations in this study were conducted in Python 3.9.7. The Climate Data Operators (CDO) 1.9.8 (Schulzweida 2021) was used for basic handling of the reanalysis data files. In terms of Python libraries, netCDF4 1.5.4 (Unidata 2018) was used for reading the data, Matplotlib 3.3.3 (Hunter 2007) was used for plotting, while NumPy 1.22.0 (Harris et al. 2020) and SciPy 1.5.3 (Virtanen et al. 2020) were used for routine array operations and data analysis. Finally, Table S2 lists the main Python modules/functions that were used in this study.

	Module (version)	Notes	More info
1	`scipy.fft` (1.5.3)	1-D discrete Fourier Transform (Fast Fourier transform algorithm)	`https://docs.scipy.org/`
2	`scipy.stats.gaussian_kde` (1.5.3)	1-D and 2-D kernel-density estimate using Gaussian kernels (Figs. 4,9)	`https://docs.scipy.org/`
3	`pyMannKendall` (1.4.1)	Mann-Kendall trend test and Theil-Sen estimator (Hussain and Mahmud 2019)	`https://github.com/mmhs013/pymannkendall`

Table S2: List of Python modules used in this study. In the Notes column we indicate their specific application in the paper.

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