Supplementary Information: Winter stratospheric extreme events impact European storm damage

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1 Surface response to weak and strong vortex states

To further establish the connection between stratospheric variability and storm impacts in the Euro-Atlantic region, we repeat the analysis using a broader definition of stratospheric events (as described in the Methods section), providing a larger number of weak and strong vortex states, including moderate states. Similar to the surface response associated with SSW and extremely strong vortex (see the Methods section for the definition), weak and strong states of the stratospheric vortex are followed by latitudinal shifts in the position of the midlatitude storm tracks (Figure S1).

2 Anomalous storm counts response following stratospheric extremes

To quantify the changes in high-impact storm counts, as recorded by the EM-DAT dataset, following stratospheric extremes, we compute the monthly anomalies in high-impact storm counts with respect to their climatological frequency. Climatology is defined as the monthly averaged storm counts between 1998 and 2023. Fig. S3 shows NDJFM climatology of storm counts, and their corresponding anomalies over Europe for periods of 30 days after SSW and SPV events.

3 Availability of economic damage data

For the calculation of total damage associated with European storm disasters shown in Fig.5a,b, we used available data from the EM-DAT dataset (as described in the Methods section). However, complete information on economic damage of known disasters and extreme events is not available for all events and in all countries.

Here, we provide details on the percentage of data availability by country (Fig. S4) based on all the storm events that were recorded between 1998–2023.

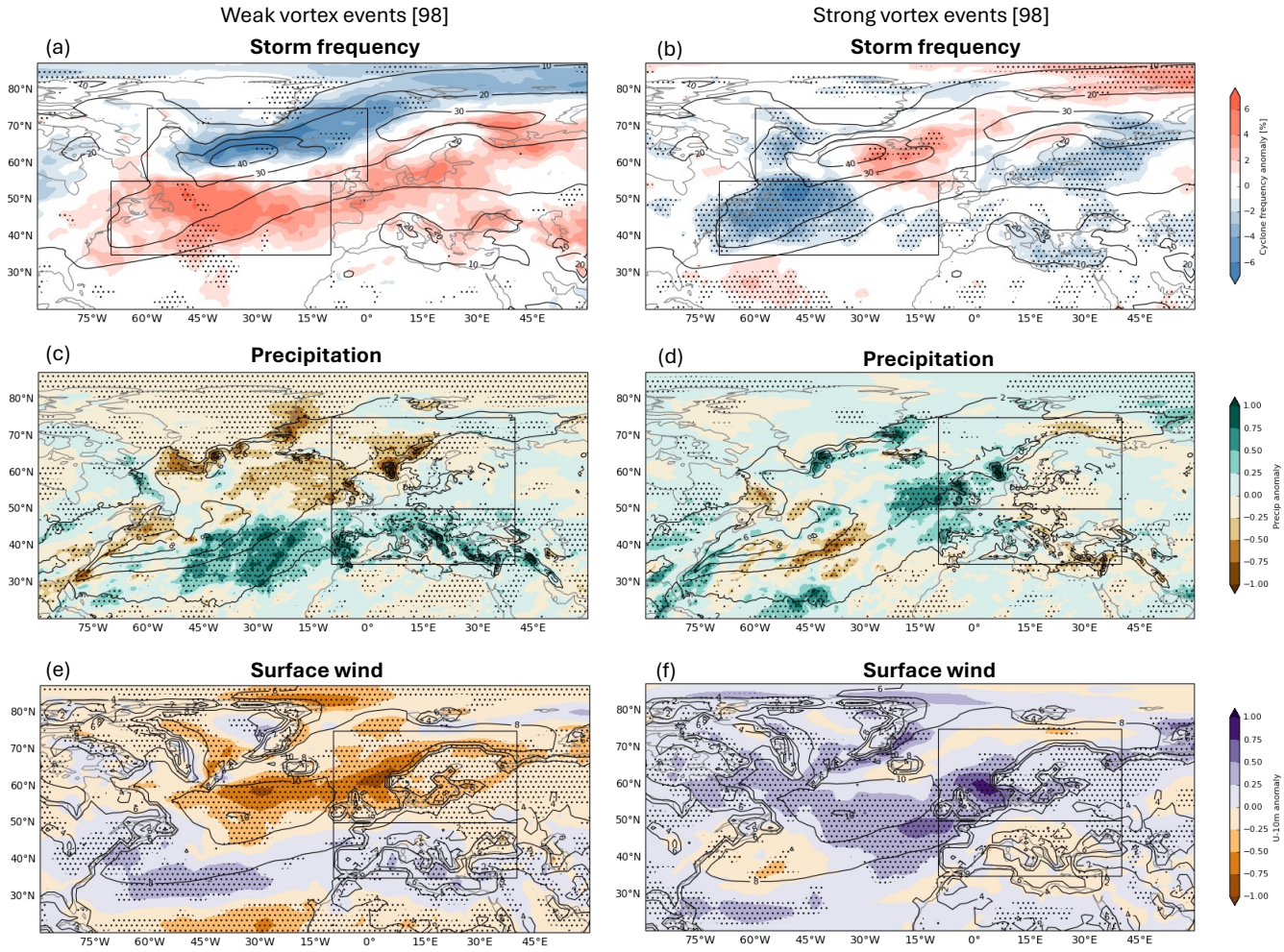

Figure S1. Same as Fig. 1, but for weak and strong vortex states.

4 Occurrence of combined storm and flood events

We further analyze the occurrence of compound events combining wind damage and flood events. A compound event can be associated with a single driver (an extreme cyclone) which potentially leads to multiple hazards. For this purpose, we use flood data from the EM-DAT dataset. In addition, we include in this analysis flood events documented in the Historical Analysis of Natural Hazards in Europe (hereinafter HANZE) dataset (Paprotny et al., 2023). HANZE covers riverine, pluvial, coastal and compound floods that have occurred in 42 European countries. The dataset includes 2521 events characterized by at least one impact statistic: area inundated, fatalities, persons affected or economic loss. Here, we use flood data between 1998 and 2023, focusing on flood count per country and associated economic damage.

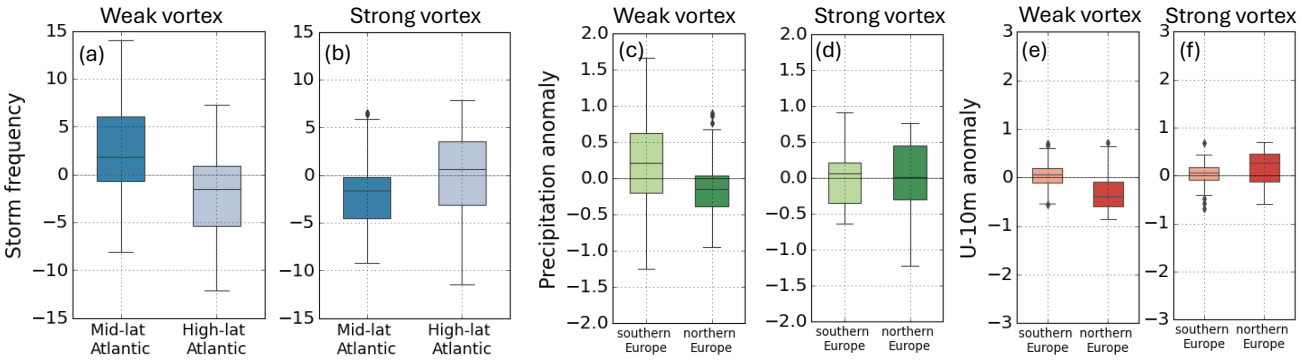

Figure S2. Same as Fig. 2, but for weak vortex (a,c,e) and strong vortex (b,d,f) in the reanalysis.

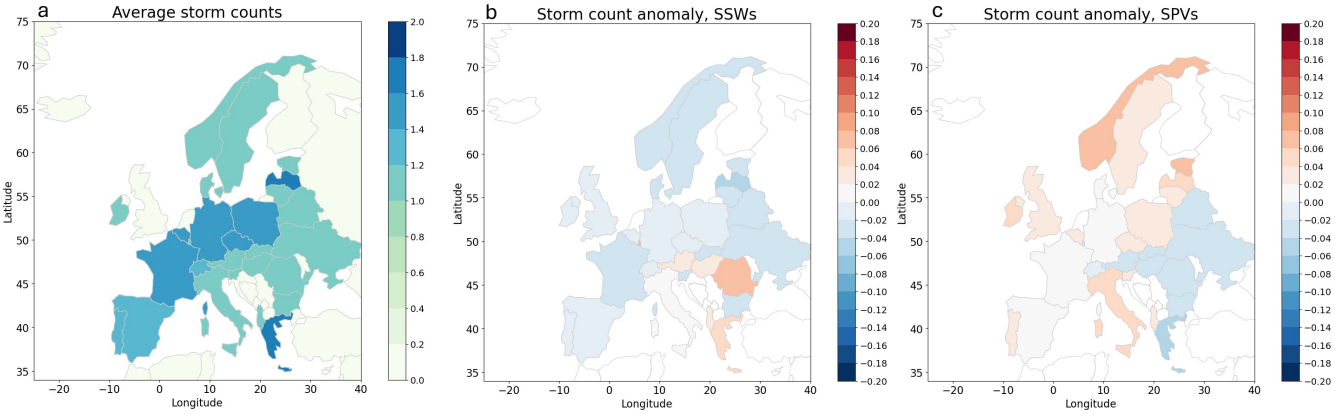

Figure S3. (a) Climatology of high-impact storm events per winter season, based on average number of storm events reported in the EM-DAT dataset for NDJFM between the years 1998 and 2023. (b,c) Anomalies of storm counts with respect to climatology (shown in panel a) for SSW and SPV events, respectively.

Fig. S5 shows the occurrence of compound events combining storm and flood impacts within a close time frame of 30 days after SSW and SPV events. We find that after SSW events, storm-related compound events occur in the western part of Europe (Fig. S5a), whereas after SPV events such compound events are found mostly in northern Europe and Scandinavia (Fig. S5b).

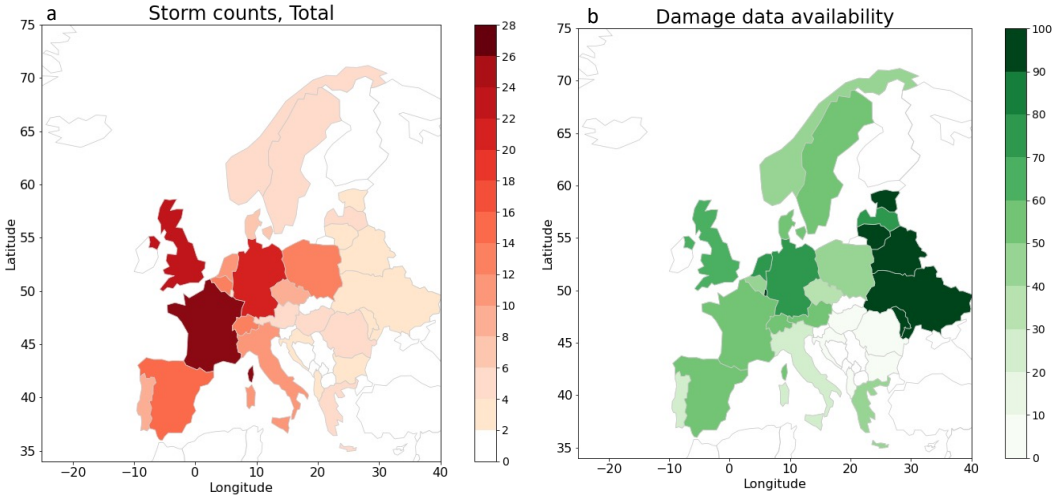

Figure S4. (a) Total number of storm events in NDJFM, based on the EM-DAT dataset between 1998 to 2023. (b) Availability of economic loss data by country (in %) during the same period. Availability is presented as the percentage of storm records with available damage data divided by the total number of storm events in the dataset.

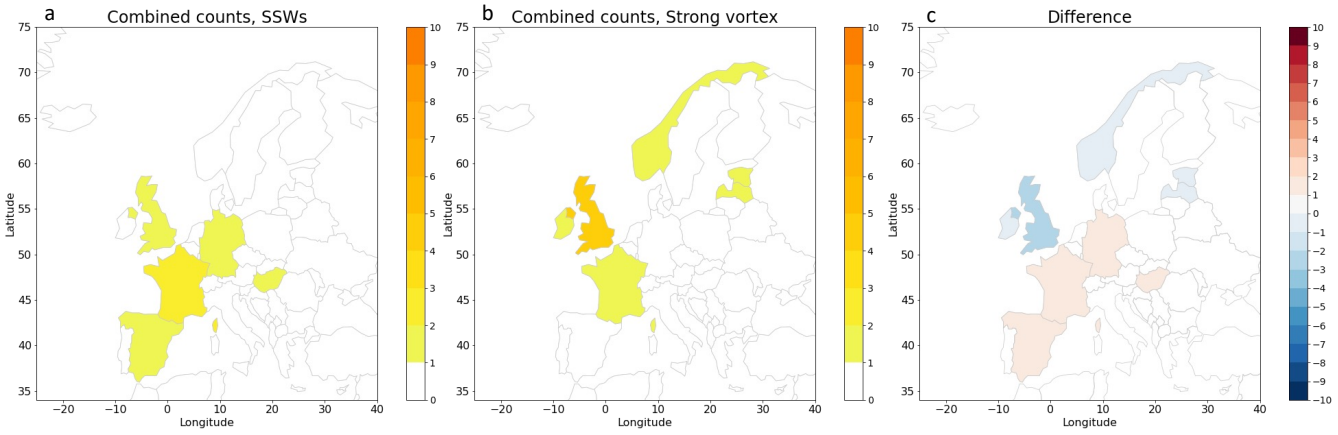

Figure S5. Same as Fig. 3, but for counts of compound events of combined storm and flood events. Values are based on records from both the EM-DAT and HANZE datasets.

References

Paprotny, D., Terefenko, P., and Śledziowski, J.: An improved database of flood impacts in Europe, 1870–2020: HANZE v2. 1, Earth System Science Data Discussions, 2023, 1–37, 2023.