



Spatiotemporal variability and future projections of compound climate events in the eastern part of the Baltic Sea region

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In a rapidly changing climate, various types of compound climate events (CCEs) have been widely analysed at both global and regional scales recently. Yet in the Baltic States, they have scarcely been studied. In this research three different CCEs were analysed: compound drought and heatwave events (CDHE), late spring frost events (FS events), and compound precipitation amount and wind speed extremes (CPWE). The aim of this study was to examine the recurrence, intensity, and spatial distribution of these CCEs from 1950 to 2022, and to assess projected changes in their characteristics by the end of the 21st century in the eastern part of the Baltic Sea region.

ERA5 reanalysis data were used to identify CDHEs, FS events, and CPWEs during the 1950–2022 period. Future projections were derived from five CMIP6 climate models using the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6) dataset under the SSP2–4.5 and SSP5–8.5 scenarios. Changes were assessed by comparing the period from 2081 to 2100 with a baseline period from 1995 to 2014. CDHEs were identified by calculating daily Standardised Precipitation Index (SPI) values to distinguish droughts and by defining heatwaves using the 90th percentile of daily maximum air temperature. CDHEs occurred when drought and heatwave conditions coincided. FS events were detected when the last spring frost occurred after the start of the growing season. Finally, CPWEs were defined as days when both precipitation and maximum wind speed exceeded their respective 98th percentiles at the same grid cell.

During 1950–2022, the number of CDHE days increased in over 75% of grid cells, mainly driven by a widespread rise in heatwave days (> 99% of grid cells). Also, FS events increased across more than 80% of the study area, while CPWEs became more frequent in 70.2% of grid cells. However, in most cases, the observed changes were small. They were statistically significant ($p < 0.05$) in less than 10% of the study area. Depending on the model and scenario, future projections indicate an increase in the number of days with CDHEs by the end of the century, with an average rise of 0.8–18.3 days/year. These events are also projected to become longer and more intense. CPWEs are expected to increase by 0.7–4.5 events/decade. Only the projections for FS events are uncertain, with different models indicating either increases or decreases in both frequency and intensity.

Distance from the Baltic Sea was found to have a strong influence on the spatial distribution of CCEs, with the highest number of CPWEs occurring in the western part of the study area. On the

contrary, FS events and CDHEs occurred more frequently farther from the Baltic Sea coast. The results of this study suggest a potential increase in risks associated with CCEs in the Baltic States, underscoring the need for evaluations of climate adaptation strategies.