

EGU24-6559, updated on 20 May 2024

<https://doi.org/10.5194/egusphere-egu24-6559>

EGU General Assembly 2024

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Compound hot extremes at an urban site based on climatic and bioclimatic indices

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Over the past decades, extreme weather phenomena like hot extremes and heat waves (HWs) stand out as a major threat for humans and ecosystems. Compound extremes are understood as simultaneous, concurrent or sequential extreme events, taking place at a single or different locations. Compound extreme events may exacerbate the risk and increase associated adverse impacts, compared to individual events.

In the study, we examined the occurrence of compound hot extremes at an urban site of the eastern Mediterranean over a century-long period, using the historical climatic records of the National Observatory of Athens (NOA, 1897-2023). Compound hot extremes are defined as concurrent daytime and nighttime hot extremes, namely cases when both, daily maximum (T_{\max}) and daily minimum (T_{\min}) air temperatures are above a predefined threshold value. The threshold values for T_{\max} and T_{\min} were set equal to 36.7 °C and 25.9 °C respectively, corresponding to the 90th percentile of the summer T_{\max} and T_{\min} distributions at NOA, over the reference period 1981-2010. Likewise, we examined compound heat waves, defined as sequences of at least 3 consecutive days when both T_{\max} and T_{\min} exceed the predefined thresholds. Analysis has shown that 60% of the total number of compound hot extremes and compound heat waves in Athens (NOA) was observed from 2000 onwards. Besides, 57% of the daytime HWs over the whole study period constitute also compound HWs, while this percentage increases to 72% after the 2000s, indicating an increase in nighttime HWs, very likely related to the urban heat island effect.

In addition to the hot extremes based on air temperature, we have also estimated compound daytime and nighttime extremes related to human thermal comfort, using the bioclimatic index UTCI (Universal Thermal Climate Index), accounting also for relative humidity, solar radiation and wind speed conditions. Compound hot extremes based on UTCI were defined as the cases when the daily maximum UTCI value was above the index threshold indicating 'at least very strong heat stress' ($UTCI > 38$), and simultaneously, the daily minimum UTCI value was above the index threshold indicating 'at least moderate heat stress' conditions ($UTCI > 26$). The analysis detected 45 compound hot extremes based on UTCI from 1960-2023, with 34 of them occurring after the 2000s, suggesting a dramatic increase in the frequency of cases with heat-related thermal discomfort throughout the whole day and night. The higher frequency of compound hot events was observed during the extreme years 2007, 2021 and 2023.

