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Attribution of the extreme heat wave of July-August, 2021, in Greece to human-induced climate change, employing a forecast-based storyline approach

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Situated in the eastern Mediterranean basin, Greece is characterized by pronounced increasing trends in heat waves intensity, duration and frequency of occurrence. This evidence-based fact is associated with the human-induced climate change (CC). However, CC is not responsible for every single extreme temperature event. Attributing weather extremes to manmade climate change is necessary for putting CC effects in context. It is also of paramount importance for addressing societal needs and providing actionable knowledge to governance authorities with respect to the CC impact on humanity. The traditional attribution processes that are based on climate modeling are computationally demanding and very challenging in terms of uncertainty quantification. For this, in the current work, we present a forecast-based storyline methodology and demonstrate its application for the extreme nine-day (July 25-August 08) heat wave that affected Greece in summer 2021. The method is based on the Weather Research and Forecasting (WRF) model, which is operationally applied over Greece and neighboring countries at high spatial resolution (2 km) for supporting the NOA (National Observatory of Athens) weather forecasting activities. WRF has successfully predicted the event of interest, providing robustness in the attribution analysis. We first define and simulate analogues of the examined episode under hypothetical climate settings. For the past experiment, this corresponds to the simulation of the heat wave under pre-industrial global CO_2 concentrations and historical simulated Sea Surface Temperature (SST). For the future experiment, the CO_2 concentrations during the forecast simulations were set equal to those anticipated on 2050 based on the shared socioeconomic pathway 2 - 4.5 (SSP2-4.5), while SST was set based on future simulations. Then, we compare the 2021 extreme heat wave to the past and future scenarios, and investigate differences in the heat wave amplitude, attributed to the anthropogenic forcing.