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Recent extreme heatwaves dwarfed by projected future events

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In recent decades, unprecedented heatwaves have resulted in substantial impacts on human health and their environment. Previously, heatwave trend analysis has largely focused on trends across global warming thresholds or on specific regions. Furthermore, a variety of diverse heatwave parameters has been applied across separate studies, hampering direct comparison. What is more, there has been limited information on how future projections of individual events compare to recent extreme heatwaves.

In our study, we define heatwaves as periods of at least three consecutive days where daily area-weighted mean temperature exceeds the regional 90th percentile. We utilize a comprehensive analysis framework based on four heatwave parameters and additional sub-parameters where appropriate: (1) heatwave duration in days, (2) heatwave severity, an intensity index enabling interpreting excess heat relative to the regional climatology, (3) cumulative heat, and (4) percentage of locally affected area. The latter is an area-based parameter providing information on the exceedance of local (grid cell level) climatology thresholds during the course of an individual heatwave in percent of the respective region's overall area. For parameters (2) and (4) we, moreover, investigate two sub-parameters, namely median and maximum values. The first sub-parameter refers to the median value of the entire heatwave, whereas the second indicates that this maximum value is being reached for at least one day during the event. This analysis framework greatly increases the ability for individual heatwave-based and regional intercomparison, and, furthermore, explores both regional as well as local scale trends, thereby providing critical human-impact-oriented information. In addition to daily output from multi-model ensembles from models taking part in the Coupled Model Intercomparison Project Phase 5 and 6 and large initial-condition ensembles (CanESM5 and ACCESS-ESM1-5), we employ our framework to 14 regional events observed during the period of 2010-2021 and analyzed based on Berkeley Earth and ERA5. This provides crucial insights into how future heatwaves compare to recent events.

Our results indicate that recently observed extreme heatwaves are dwarfed by projected 21st century events. Moreover, without even moderate reduction in greenhouse gas emissions the probability of reoccurrence or exceedance of these recent extreme reference values is significantly increasing, and they are still plausible under aggressive emission reduction scenarios.

In conclusion, we can see that a lack of mitigation and adaptation measures could considerably increase human exposure to extreme heat. In particular as we found, depending on the scenario, significant increases in the percentage of locally affected area and the heatwave severity. Thus, these findings stress the necessity for substantial and ambitious mitigation efforts and for considering heatwaves well outside the lived experience for effective adaptation measures.