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Understanding and quantifying recent and potential future record-shattering extremes

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Recent land and marine heatwaves, extreme precipitation events and even monthly global mean temperature anomalies shattered previous observed records by large margins and reached intensities that many would have conceived impossible based on observations so far.

Here, I first demonstrate how in recent decades the frequency of such record-breaking and record-shattering extremes strongly deviates from expectations in a stationary climate and demonstrate how the current high rate of forced warming contributes to the current high occurrence record-shattering extremes. I further identify and discuss the extremes of the last two decades with the highest record margins.

Furthermore, I review different ways of estimating the probability and potential intensity of future record-shattering extremes. Different approaches including statistical approaches, such as Statistical Weather Generators or the use of Generalized Extreme Value distributions with process-based covariates as well as climate model-based approaches such as initialized hindcasts, single-model initial condition large ensembles and ensemble boosting have been proposed to estimate the potential intensity of future record-shattering extremes. I review the strengths and weaknesses of these approaches and argue that combining different lines of evidence is crucial to increase confidence in such estimates.

Finally, I will discuss how some of these methods also reveal how physical mechanisms differ between very extreme events and more moderate ones, and how they help to evaluate potential process-based constraints to upper bounds of the intensity of future record-shattering extremes.