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Super Clausius-Clapeyron scaling of extreme hourly precipitation and its relation to large-scale atmospheric conditions

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Present-day precipitation-temperature scaling relations indicate that hourly precipitation extremes may have a response to warming exceeding the Clausius-Clapeyron (CC) relation; for The Netherlands the dependency on surface dew point temperature follows two times the CC relation corresponding to 14 % per degree. Our hypothesis – as supported by a simple physical argument presented here – is that this 2CC behaviour arises from the physics of convective clouds. So, we think that this response is due to local feedbacks related to the convective activity, while other large scale atmospheric forcing conditions remain similar except for the higher temperature (approximately uniform warming with height) and absolute humidity (corresponding to the assumption of unchanged relative humidity). To test this hypothesis, we analysed the large-scale atmospheric conditions accompanying summertime afternoon precipitation events using surface observations combined with a regional re-analysis for the data in The Netherlands. Events are precipitation measurements clustered in time and space derived from approximately 30 automatic weather stations. The hourly peak intensities of these events again reveal a 2CC scaling with the surface dew point temperature. The temperature excess of moist updrafts initialized at the surface and the maximum cloud depth are clear functions of surface dew point temperature, confirming the key role of surface humidity on convective activity. Almost no differences in relative humidity and the dry temperature lapse rate were found across the dew point temperature range, supporting our theory that 2CC scaling is mainly due to the response of convection to increases in near surface humidity, while other atmospheric conditions remain similar. Additionally, hourly precipitation extremes are on average accompanied by substantial large-scale upward motions and therefore large-scale moisture convergence, which appears to accelerate with surface dew point. This increase in large-scale moisture convergence appears to be consequence of latent heat release due to the convective activity as estimated from the quasi-geostrophic omega equation. Consequently, most hourly extremes occur in precipitation events with considerable spatial extent. Importantly, this event size appears to increase rapidly at the highest dew point temperature range, suggesting potentially strong impacts of climatic warming.