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Extreme Hourly Precipitation in Portugal: Spatio-Temporal Variability and Case Studies in Major Wine Regions

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This study provides the first comprehensive analysis of extreme precipitation events in mainland Portugal, based on sub-hourly observations. Using 10-minute precipitation data from 71 weather stations for a period from 2000 to 2022, we assess the spatial and temporal variability of these events, including their seasonality, diurnal cycle and synoptic-scale drivers. The mean ratio of seasonal precipitation to total annual precipitation, considering different thresholds (10–20 mm h^{-1} for yellow warnings and greater than 20 mm h^{-1} for orange and red warnings), shows a large spatial variability. This ratio is higher in winter, reflecting a greater contribution of intense precipitation to the annual total. This is associated with the frequent passage of low-pressure systems across the Atlantic. In contrast, the contribution is lower in autumn and decreases further in spring, with the lowest values observed in summer. Extreme precipitation events peak between September and December, with a secondary maximum in April and May, especially in the Alentejo region. The diurnal cycle shows an afternoon peak, consistent with thunderstorms. Extreme precipitation events tend to make a greater contribution to total daily precipitation, mostly in spring and summer. Two extreme events were selected not only as case studies of heavy precipitation, hail and lightning but also as examples of understanding the specific weather conditions and atmospheric dynamics associated with such severe weather patterns. These events were selected in close collaboration with two winemaking companies, due to their reported severity. In the first case, the event of 28 May 2018 in the Douro region was associated with a cut-off low, while in the second case, the event of 14 September 2021 in the Alentejo region was associated with a frontal system in the final phase of its life cycle. ERA5 instability indices show a good agreement with observed lightning patterns. These results, especially on a regional scale, provide valuable insights for climate research and socio-economic sectors such as viticulture, where extreme precipitation and hailfall pose significant risks.

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