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Regional modelling of aerosol-cloud interactions (ACI) in extreme precipitation events: the Emilia-Romagna May 2023 floods case study

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Aerosol–cloud interactions (ACI) represent the main source of uncertainty in estimating global radiative forcing, and the processes driving these interactions are still poorly understood. This is particularly relevant in the context of extreme precipitation events, where ACI can have a decisive impact, especially over polluted regions.

The Po Valley is one of the most polluted regions in Europe, due to its intense anthropogenic emissions combined with unique topography (flat terrain enclosed by the Alps and Apennines mountain chains), which promotes aerosol accumulation due to low dispersion capabilities.

In May 2023, Northern Italy experienced two extreme precipitation events, occurring in close succession, both characterized by exceptionally heavy precipitation exceeding 200 mm within 48 hours over the Apennines slopes. More than 21 rivers flooded in the Po Valley, causing over €8.5 billion in damages and widespread landslides and flooding, resulting in several deaths. The present work seeks to estimate the role of aerosols in this extreme precipitation event.

In this study, we have performed high-resolution regional chemical transport model simulations with the WRF-CHIMERE model to evaluate the impact of ACI during the 2–3 May 2023 and 16–17

May 2023 precipitation events. Both events were characterized by strong water vapour advection from the southern Mediterranean, North Africa and the Adriatic Sea, increasing moisture availability over the region. Simulations including online ACI were conducted to assess the aerosol impact on precipitation. Precipitation patterns were then compared to rain gauges, radar, and satellite observations to accurately evaluate the simulated spatial variability and intensity during the events. Sensitivity tests reveal that ACI from anthropogenic emissions resulted in significant reductions in precipitation of up to 30–40 mm locally, and 10 mm regionally, accompanied by a temporal shift of the precipitation peak by approximately 3 hours.

This work demonstrates that aerosols can play an important role in extreme precipitation events, and need to be taken into account to better forecast the intensity and timing of such events.

Keywords: aerosol-cloud interactions, anthropogenic aerosols, regional modelling