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Editorial: A quest to fully understand precipitation: Novel methods to characterize, model, and detect precipitation processes

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Editorial on the Research Topic
A quest to fully understand precipitation: Novel methods to characterize, model, and detect precipitation processes

Precipitation processes are among the most complex manifestations of the Earth's climate system. As such, they are difficult to observe, model, and predict. At the same time, the importance of a better scientific and statistical grasp of the dynamics of precipitation on a global level cannot be overstated. Specifically, the proper characterization of precipitation and its variability stands out as a crucial task for Earth sciences today: it would lead to massive improvements in water resources management, monitoring and prediction of extreme weather events, climate and hydrologic modeling, and infrastructure design. In recent years, affordable computational resources and ever-evolving open source software solutions have resulted in a rapid expansion of advanced statistical techniques throughout the field, including a surge in artificial intelligence (AI)-based methods. Such approaches have the potential to meet increasing requirements for a wide range of hydrometeorological products. Yet, our ability to accurately monitor, understand, and model precipitation processes remains limited. This Research Topic collects five contributions on precipitation studies that investigate key issues, such as the impact of precipitation extremes on local communities, the space-time variability of precipitation and its predictability, as well as novel downscaling approaches for enhancing the simulation of rainfall systems.

Climate change projections suggest that droughts are to become more frequent and prolonged in semi-arid areas of the world. Therefore, studying how droughts can impact local communities' vulnerability and their coping strategies is of paramount importance. Mdemu adopted participatory vulnerability assessment tools to investigate food insecurity caused by prolonged droughts across several villages in Tanzania. Droughts in the central and north-eastern semi-arid areas of the country are shown to contribute toward crop failure, loss of pasture, and water scarcity, potentially causing food and water shortages. Thus, it is critical to highlight the need to build resources to cope with prolonged drought conditions and improve year-round access to water for domestic, sanitation, and livestock uses. Results from this study advocate for relevant policies on investments, both by the government and local organizations. More studies along the same lines are needed to quantify the impact of precipitation extremes on society and further develop adaptation strategies.

To devise effective strategies aimed at increasing our community's resilience to climate change, it is crucial to better understand and predict precipitation patterns and their variability at a sub-regional scale. Dollan et al. assessed the spatial-temporal variability of average and extreme precipitation in the Southern Mid-Atlantic United States during 1980–2018. An increasing trend of 4.3 mm/year in the annual average is identified, along with a positive trend in the annual maximum precipitation. Furthermore, an increase in the frequency of extreme precipitation events was observed in the region. Spatial and temporal information is relevant not only to understand but also to forecast precipitation processes at different scales. Goodwell and Chapagain introduced a novel information theory-based method to predict precipitation occurrence. Specifically, they constructed "chains of influence" of regions and timescales of precipitation occurrence predictability in the continental United States. Results showed clear geographic and seasonal patterns, with larger storm spatial extents during the summer and across the interior states.

Our ability to predict atmospheric processes may be challenged by unexpected events that halt "normal" human and/or natural activities and cause complex impacts on the atmosphere. For instance, the lockdowns imposed by several countries to fight the global COVID-19 pandemic led to a decrease in anthropogenic emissions in early 2020, which can potentially modify precipitation systems and their variability. Sharif et al. compared precipitation patterns during COVID-19 lockdowns to the previous 19 years in Northern Italy and the Chinese province of Hubei. They found that rainfall averages were higher in 2020 with respect to the climatological means with a larger number of rainy locations. Although, as highlighted by the authors, such anomalies could be caused by natural variations, precipitation patterns during these unprecedented times were on the extreme tails of the precipitation climatological distributions in both study regions.

Model simulations can be particularly useful to explore sources and reasons behind changes in precipitation patterns. However, the scale at which numerical model simulations are performed may be too coarse to fully capture such changes posing significant challenges to study these patterns at regional scale. Desamsetti et al. proposed a dynamical-downscaling technique, named Continuous Data Assimilation (CDA), to improve the simulation of Indian summer monsoons with the Weather Research and Forecasting (WRF) model. CDA was able to enhance some features over the Indian subcontinent by maintaining a better balance between the large- and small-scale features when compared to more traditional methodologies.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

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