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Editorial: Droughts in a changing climate: advances in modeling, forecasting and strategies for adaptation

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Editorial on the Research Topic
Droughts in a changing climate: advances in modeling, forecasting and strategies for adaptation

Droughts are complex and multifaceted natural hazards that have long impacted society, the economy and the environment (Raposo et al., 2023). Recent extreme events across the world have renewed researchers' interest in drought drivers (Brunner et al., 2023), propagation mechanisms (e.g., Costa et al., 2021), and spatiotemporal dynamics (e.g., Gesualdo et al., 2024). In parallel, anthropogenic climate change (ACC) has led to growing concerns about intensification of drought events, highlighting the need for adaptative water resources management to mitigate future risks. In this Research Topic, we sought to explore three of the main aspects of drought management under a changing climate: (i) novel or alternative approaches for estimating drought risks or describing drought propagation; (ii) short to long-term drought forecasting with empirical, physically-based, or climate-informed models; and (iii) adaptation strategies for future drought risks.

With respect to drought modeling, Milojevic et al. discussed an empirical approach for assessing the frequency of dry spells and low flows, which reflect meteorological and hydrological droughts. In a case study in Swiss, the authors highlighted the influence of seasonal characteristics on the stochastic behavior of such variables, as well as the potential benefits of utilizing intra-annual time scales in water resources management. They argue, however, that a broader comprehension of drought dynamics depends on annual analysis as it should properly describe the temporal evolution of longer dry spells or under-threshold flows. Yet, it is still challenging to account for potential random (e.g., long-range dependence) or predictable (e.g., trends) changes in the rainfall and streamflow from data alone (Serinaldi et al., 2018). Hence, process-based models or deductive reasoning might be required for estimating the time-varying probabilities of future drought events.

Rezende et al., in turn, evaluated the potential occurrence of "greening"—an increase in vegetation density stemming from enhanced atmospheric CO_2—across the Brazilian semiarid region, during a period with many extreme meteorological droughts (1961–2020). The authors concluded that, as opposed to other semiarid regions in the world, "greening" has been inhibited in most of the study area because of rainfall shortages, which propagates to the terrestrial phase of the water cycle and reduces soil moisture for vegetation growth. However, the study also suggests that water use efficiency, which translates the natural adaptation of plants to water scarcity, has a positive trend, mitigating the effects of droughts in agriculture.

As for drought forecasting, Toma et al. assessed the effects of ACC on future rainfall and temperatures—arguably, the main drivers of meteorological droughts—under two climate change scenarios in Ethiopia. For this, 5 global circulation models (GCM) and the resulting ensemble were downscaled and bias-corrected (with respect to the first moment). The study results suggested a declining trend in mean annual rainfall, whereas temperatures are expected to increase, decreasing water availability and leading the entire catchment to drier conditions. In addition, seasonal patterns for both variables might strongly change, with potentially large impacts on hydropower and irrigation. These conditions are critical for defining adaptation measures and effectively managing multiple water uses, particularly in vulnerable agricultural areas. Nonetheless, the extent to which simple bias correction techniques may underpin the estimation of extreme events is disputable, as the error structure of GCMs may depend on the process levels. Moreover, a proper account of uncertainty appears necessary as climate model estimates are often unable to reproduce the statistics of the observed time series (e.g., Koutsoyiannis and Montanari, 2022).

Still regarding long-term drought forecasting, Silva et al. utilized two regional circulation models (RCM) and two standardized indexes, namely, the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evaporation Index (SPEI), for assessing the future dynamics of meteorological droughts in the Pantanal wetland, in Brazil. The authors discussed the distinctions in drought characterization that arise from the different RCMs, particularly with respect to extreme events. They also highlighted the benefits of including potential evapotranspiration in the computation of the meteorological drought index—SPEI provided much closer approximations of observed extreme events during the projection period, mostly due to the sharp temperature rises. Although many studies converge on rising air temperature and their significant impact on drought development, further research accounting for the uncertainties of RCMs are needed across different regions worldwide before drawing definitive conclusions about drought behavior.

As an alternative, Santos et al. discussed a stochastic representation of climate model outputs—monthly rainfall and temperatures—for evaluating ACC-related drought effects, under three climate change scenarios, in Brazil. For this, the expanded Bluecat framework (Koutsoyiannis and Montanari, 2022), which retrieves the distribution functions of the observations conditioned to the GMC estimates, was utilized. The study findings suggest that, after bias correction, monthly rainfall amounts are not expected to change. Also, relatively smaller increases in temperatures should be anticipated for all scenarios. However, uncertainty, for both variables, is too large, which implicitly reflects the inability of GMCs in predicting the processes trajectories and summarizing the future drought dynamics.

Finally, Samuel et al. assessed the benefits of climate smart agriculture, mostly designed for increasing crop resilience, for mitigating drought impacts in India. The authors demonstrated that adaptation strategies, whether technological or from a political perspective, are paramount for avoiding crop loss and food insecurity during drought episodes, particularly for small agricultural units. The study also evaluated influential factors for the adaptation measures to succeed and provided insights on how the integration of sustainable policy making and structural interventions may underpin the resilience increase in farm households.

Among some points not addressed in the Research Topic, short-term drought forecasting and drought propagation have stood out in recent literature, but advances are desirable. For the former, machine learning models have comprised a promising research avenue, particularly with the advent of the "Explainable Artificial Intelligence," which aggregates physical constraints to model structures (Dikshit and Pradhan, 2021). Also, customized (Renard and Lall, 2014) or hidden climate indexes (Renard et al., 2022) may be useful tools for improving predictions. For the latter, a deeper understating of anthropogenic influence in the propagation mechanisms appears necessary for defining effective adaptation strategies (Raposo et al., 2023). These should comprise interesting developments for the Research Topic.

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Conflict of interest

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