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Editorial: Application of artificial intelligence-supported process-based climate models to understand the atmosphere/weather patterns and their prediction

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Editorial on the Research Topic
Application of artificial intelligence-supported process-based climate models to understand the atmosphere/weather patterns and their prediction

Weather and climate related risks remains a significant challenge to address through conventional modeling techniques. These risks, including extreme weather events, temperature fluctuations, and precipitation variability, pose substantial threats to communities and ecosystems. Traditional models often struggle with the complexity and unpredictability of these phenomena. Artificial Intelligence (AI) offers promising solutions to enhance the accuracy and reliability of climate and weather predictions. By leveraging AI-supported process-based climate models, scientists can analyze vast amounts of historical and real-time environmental data to identify patterns and generate more precise forecasts. AI techniques, such as machine learning and neural networks, excel in handling the non-linear and dynamic nature of atmospheric processes. Recent advancements in AI have demonstrated significant improvements in climate and weather prediction. For instance, AI has been instrumental in air quality monitoring and management, optimizing forecasting by analyzing pollution patterns. These techniques, as discussed by Awasthi et al. (2024), highlight the potential of AI to revolutionize environmental monitoring.

This Research Topic focuses on the integration of AI with process-based climate models to enhance the understanding of atmospheric dynamics and improve prediction accuracy. Overall, the application of AI in climate modelling represents a significant step forward in mitigating the impacts of climate change and protecting communities from erratic weather patterns. The contributions of these studies improve the knowledge for the dynamics of the atmosphere and from a practical perspective for improving weather forecasting practices. As we continue to face the effects of a changing climate, AI-driven models will be essential for developing effective strategies to safeguard our environment and society.

In the first paper, Awasthi et al., studies the effect of climate change on temperature in Northern India using CMIP6 models under 1.5°C and 2.0°C warming scenarios. Surface temperature data from the Climatic Research Unit (CRU) and ensemble mean simulations from CMIP6 are compared. The study predicts that North India will experience more frequent and severe heatwaves in the future, even under moderate global warming scenarios. Temperatures are expected to rise significantly compared to historical levels, with the most extreme heat events becoming more common. The study shows that climate models are important for understanding how climate change will affect Northern India. To reduce the negative impacts of climate change, it is important to execute serious actions to limit temperature rise. This study provides valuable information to help policymakers and communities in North India for the development of effective strategies to adapt and mitigate climate change.

Sharma et al. highlight the enhancement of the convective-permitting regional ensemble prediction systems with the introduction of adaptive selection method. This method mainly targets a numerous challenge in ensemble forecast generations, specifically under-dispersiveness in which the variability of ensemble members is too low to depict the complexity of atmospheric processes. The study shows substantial improvements in skill of wind, temperature and precipitation fields with respect to the forecast accuracy using a sampling algorithm optimizing the selection of global ensemble members according to a fractions skill score (FSS). The findings show that adaptive selection provide higher ensemble spread, lower root-mean-square error (RMSE), and more reliable forecasts beyond 24 h. Results pointed out the need of additional development and implementation of ensemble methods which accurately represent the complex physical processes for more efficient flood management and disaster alertness strategies in vulnerable regions.

Bhanage et al., used datasets across 29 Indonesian cities of six global climate model (GCM) from CMIP6. Performance of simulating surface air temperature, precipitation, wind speed, and relative humidity has been compared with the Modern-Era Retrospective Analysis for Research Applications (MERRA-2). To detect the biases, statistical methods were used to measure the complete errors in the models and Analytical Hierarchy Process (AHP) with respect to the different cities. The analysis showed that different GCMs performed better for specific weather variables, such as MPI-HR for humidity and TaiESM for temperature. This approach identified the best GCM for each city, ensuring more accurate and efficient future weather data. This method supports urban planning and sustainable building designs modified to local climate needs. Based on the results, in future, it is important for the architectural researchers and policymakers for the generation of typical meteorological year datasets for city-specific GCMs.

Wang focused on improving the accuracy of miniature air quality monitors by calibrating their data using a combined Stepwise Regression Analysis and Support Vector Regression (SRA-SVR) model. First, stepwise regression identifies the linear relationships between the monitor's readings and pollutant concentrations. Then, support vector regression captures hidden non-linear patterns in the residual errors from the stepwise regression. These residual corrections are added to the stepwise model's results to produce final, calibrated outputs. The combined model's performance was evaluated using statistical measures like mean absolute error and root mean square error. It outperformed other common methods, delivering more accurate results across pollutants and indicators. The SRA-SVR model effectively combines the interpretability of stepwise regression with the precision of support vector regression, improving monitor accuracy by 61.33%–87.43%. This approach enhances the reliability of air quality measurements, ensuring better monitoring and sustainable air quality management.

Kumar et al., explores the before, during and after impacts of tropical cyclones (TC) Amphan and Nisarga through data analysis with respect to ECMWF Reanalysis v5 (ERA5) data. The results indicate positive agreement in cyclone characteristics between the model simulation and India Meteorological Department observations, including intensity, wind patterns, and warm-core structure. Many of these storms formed and strengthened in favourable conditions such as high wind speeds, low sea-level pressure, and warm sea surface temperatures in the Arabian Sea and Bay of Bengal. The ERA5 data correctly represented their tracks with a small error (weakness of ~31 km). The vorticity analysis showed that upward motion actually strengthens cycles during development but has the opposite effect during dissipation. The results highlight the benefit of using high-resolution reanalysis data to clarify the dynamics of extreme weather events such as tropical cyclones.

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