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環境

Coupled WRF–WRF–Hydro Modeling of the 2020 Upper Blue Nile Flood: Sensitivity to Physics Schemes and Coupling Modes

■ Introduction

Floods in the Upper Blue Nile Basin (UBNB) are among the most damaging natural hazards in East Africa, with the 2020 event causing significant socio-economic impacts. Accurate simulation of such extreme events is essential for improving flood forecasting and early warning systems. This study investigates the performance of the Weather Research and Forecasting (WRF) model and its hydrological extension, WRF-Hydro, in simulating the 2020 flood event. The focus is on understanding the sensitivity of precipitation simulation to different physics parameterization schemes and evaluating the impact of one-way and two-way coupling on hydrological response.

■ Research Activity

1. Data

The simulations were driven by two atmospheric datasets: the ERA5 reanalysis and NCEP GFS, while CHIRPS, MSWEP, and TAMSAT satellite-based products were used as reference datasets for precipitation validation. Streamflow data from the basin were used to assess WRF-Hydro's hydrological performance.

2. Methods

A nested WRF model configuration (9 km outer and 3 km inner domain) was applied using 21 combinations of microphysics, planetary boundary layer (PBL), and land surface models. These included WSM5, WDM5, Thompson, and Morrison double-moment (Morr2) microphysics schemes; MYJ and YSU PBL schemes; and Noah and NoahMP land surface models.

The study employed a comprehensive set of metrics to evaluate the sensitivity of WRF simulations to different parameterization schemes. These included statistical metrics (Correlation Coefficient, Root Mean Square Error, and Bias) to assess the overall accuracy and systematic differences, and categorical statistical metrics (Probability of Detection, False Alarm Ratio, and Threat Score) to evaluate the model's forecasting capabilities (Deng et al., 2023).

WRF-Hydro was used in both offline and online coupling modes. The one-way mode forced the hydrological model with atmospheric outputs, while the two-way mode allowed for dynamic land-atmosphere feedback during the simulation. Hydrological results were assessed through comparison with observed streamflow to evaluate the impact of coupling strategies on flood representation (Dixit et al., 2025).

■ Contribution of the study

This study demonstrates that high-resolution WRF simulations are highly sensitive to physics parameterizations, especially in complex topographic regions like the Upper Blue Nile Basin. More importantly, coupling WRF with WRF-Hydro in an online framework improves the realism of hydrological simulations and better captures the dynamics of extreme flood events. These findings are critical for advancing flood modeling, early warning systems, and water resource planning in data-scarce but vulnerable regions.

■ References

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