Towards Improved Flash Flood Forecasting over Dire Dawa,Ethiopia Using WRF-Hydro

Addisu Semie, Gulilat Diro, Teferi Demissie, Yonas Yigezu, Binyam Hailu

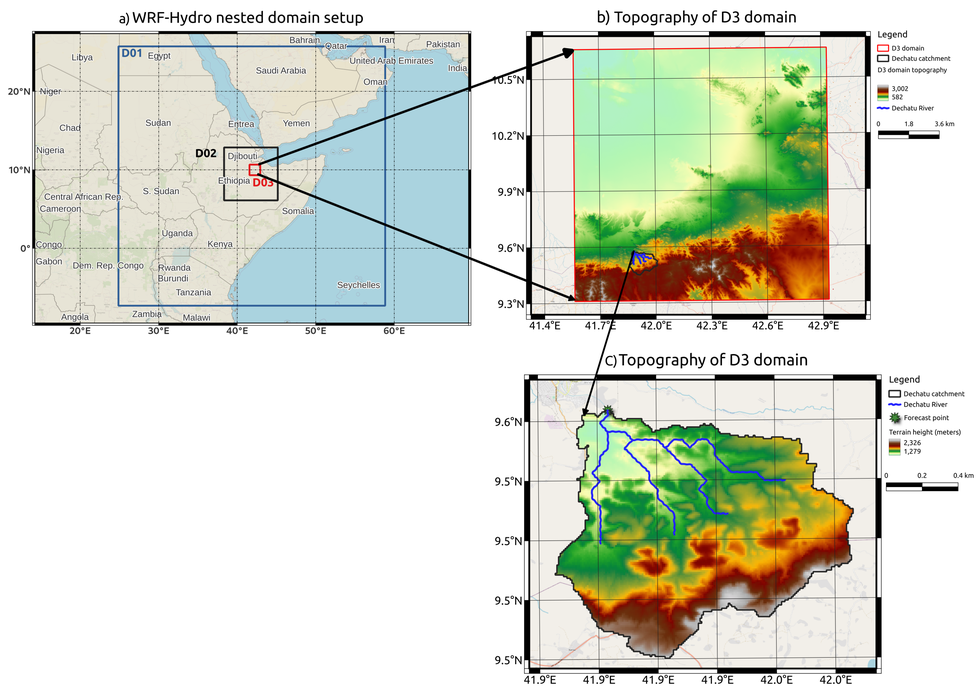
addisu.semie@aau.edu.et

Computational Data Science Program, Addis Ababa University, Addis Ababa, Ethiopia

Abstract

Flash floods, such as those recently experienced in eastern Ethiopia, are becoming more common globally, causing casualties, property damage, and service disruptions. Current national flash flood forecasts primarily focus on precipitation, neglecting surface processes. Improving forecast accuracy requires integrating surface processes and hydrological models with a better understanding of heavy precipitation mechanisms. In this study, an uncoupled WRF-Hydro model was calibrated for eastern Ethiopia to simulate extreme floods. Sensitivity analysis identified key parameters for realistic streamflow distribution. Further analysis of extreme floods in 2005 and 2007 showed that the model accurately replicates temporal and spatial patterns. These heavy precipitation events are associated with strong upper-level westerly jet streams and conducive circulation anomalies at lower levels. Implementing the WRF-Hydro model operationally in forecasting centers could enhance flood monitoring and early warning systems.

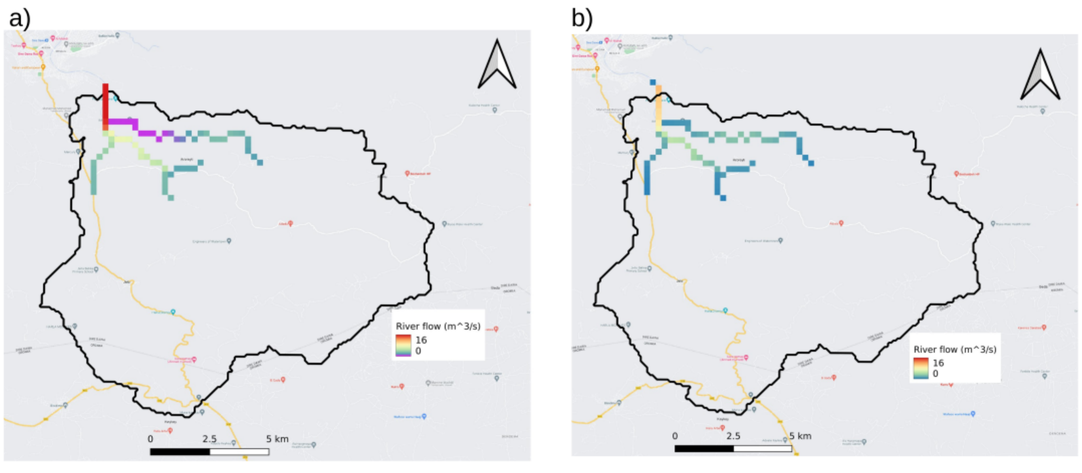
Study Area



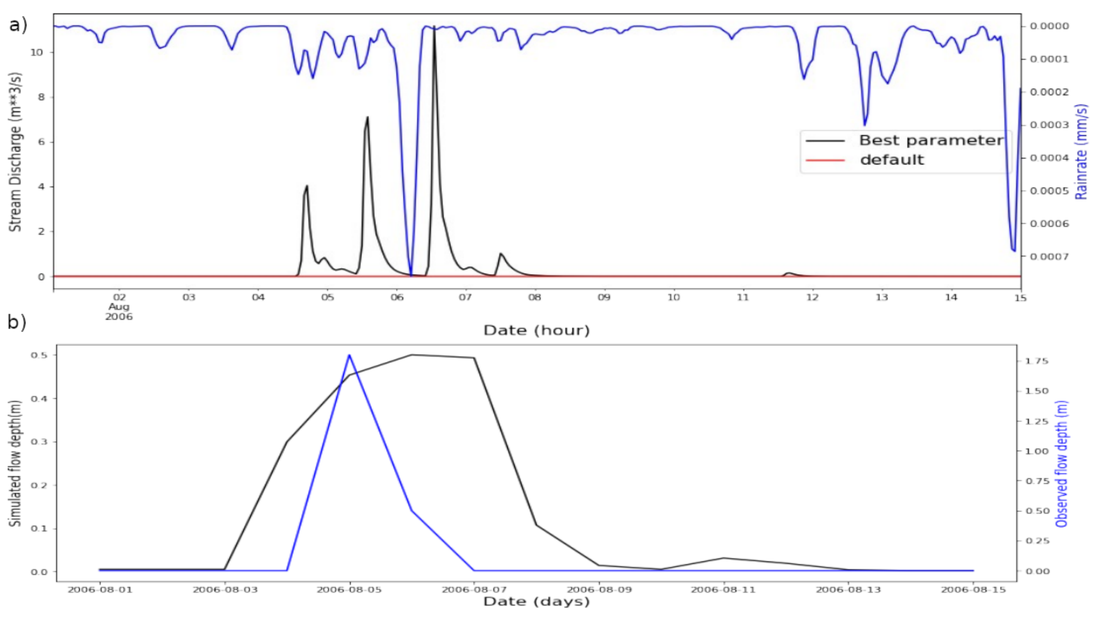
a) Map of East Africa showing the location of model domains at 25, 5 and 1 km horizontal resolution (D1, D2 and D3, respectively). D1 is defined by 150 × 150 grid points and extends 0 to 17◦ N and 30 to 55◦ E); D2 and D3 are defined with 150 × 150 grid points; b) topography of D3 domain; c) river channels in D3 domain with the focus of Dechatu River catchment and forecast point.

Calibration of the Uncopuled WRF-Hydro Model

Many parameters in the uncoupled WRF-Hydro model have significant uncertainty that can potentially alter the calculation of the runoff. Sensitivity analysis for August 2006 showed that infiltration runoff (REFKDT), hydraulic soil conductivity (DKSAT) and saturated volumetric soil moisture (SMCMAX) with parameter values of 0.1, 1.5 and 1.0 produced realistic streamflow distribution.

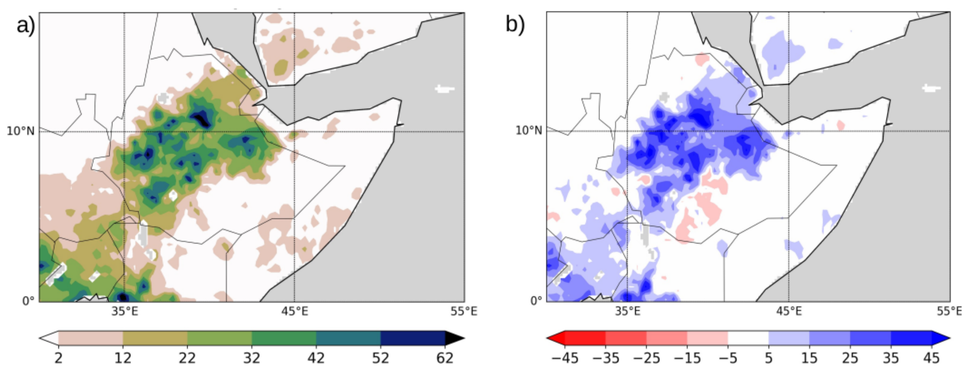


[m^3s^{-1}] that contributes to the Dechatu River at the forecast point a) 6 August 2006 at 13 h; b) 6 August 2006 at 14 h.

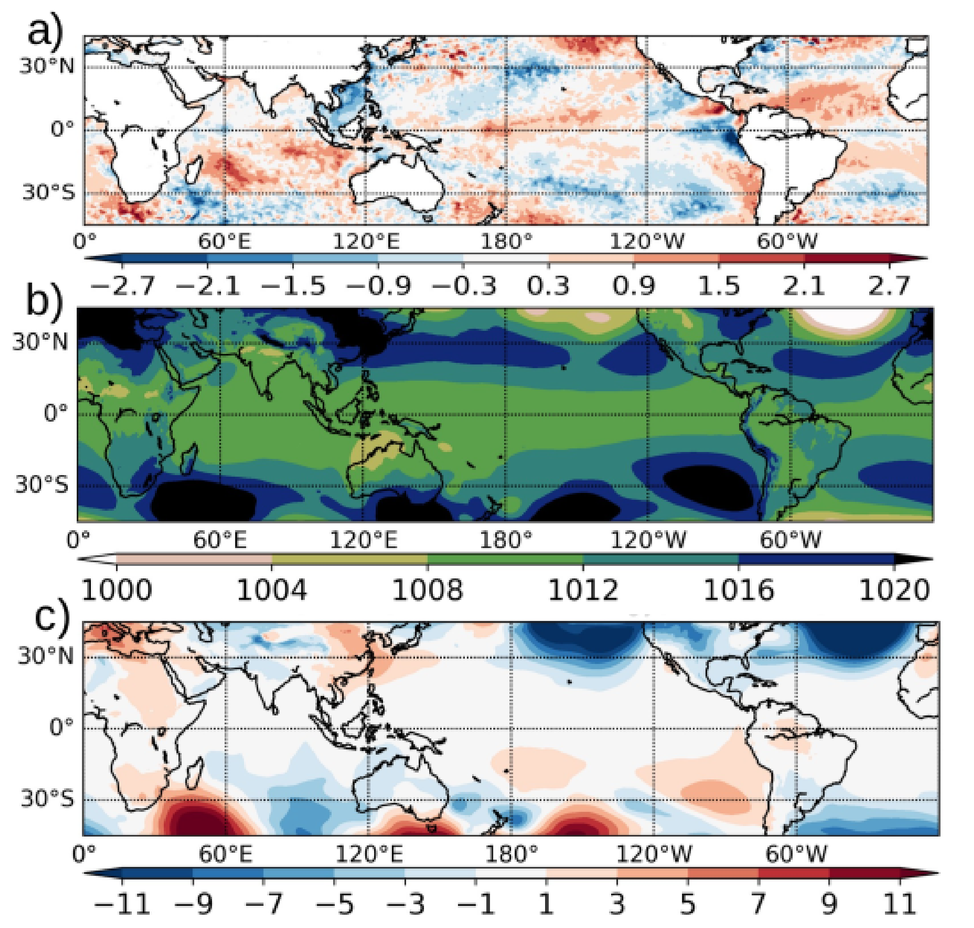


a) WRF-Hydro hourly stream discharge [m^3s^{-1}] of default and calibrated parameters compared with the rainrate [mms^{-1}] obtained from ERA5 data for the period of 1–15 August 2006; b) daily simulated flow depth [m] is compared with observed flow depth [m] for the duration of 1–15 August 2006.

Extreme Precipitation Event and Its Association with Circulation Anomalies of the Case Study of March 2005

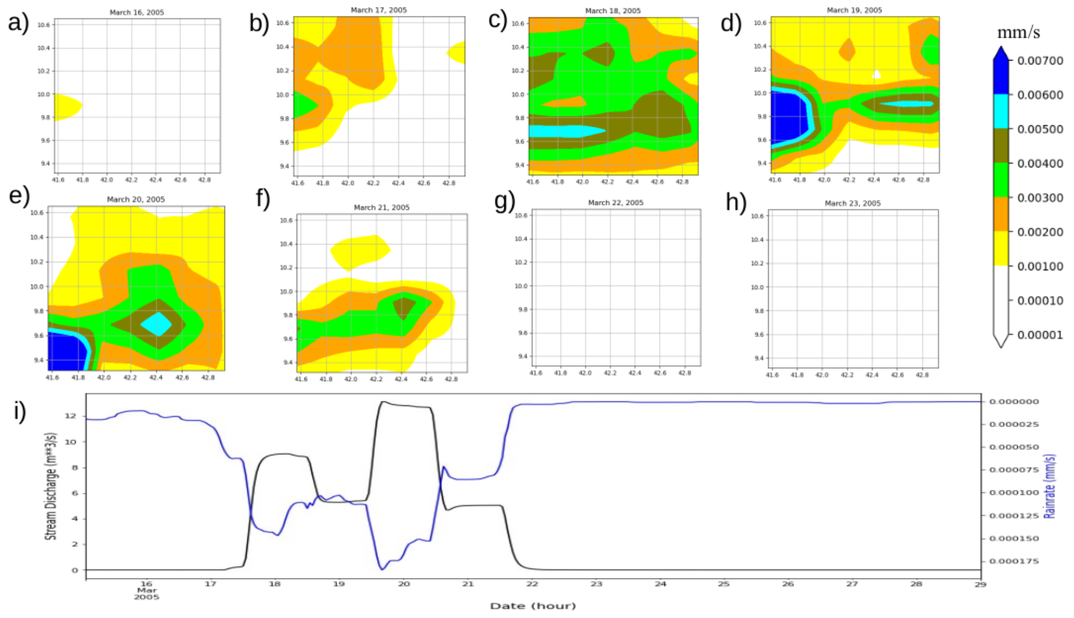


a) CHIRPS precipitation (mm) [17–20] March 2005; b) CHIRPS precipitation anomaly [17–20] March 2005—Climatology [1991–2020].



a) OI SST anomaly [°C] , [17–21] March 2005—climatology [1991–2020]; b) ERA5 SLP [hPa] [17–21] March 2005; c) ERA5 SLP anomaly [hPa] [17–21] March 2005—climatology [1991–2020].

WRF-Hydro Simulation for the Case Study of March 2005



Spatial distribution of daily cumulative precipitation [mms^{-1}] obtained from ERA5 reanalysis precipitation data for duration of 15–30 March 2005, (a –h), respectively. i) Time series with running mean of 24 h of stream discharge [m^3s^{-1}] (black) and rainrate [mms^{-1}] (blue) for the period of 15–30 March 2005.

Summary and Conclusions

- The key large scale and regional circulation anomalies associated with heavy precipitation are assessed using analysis of observational and reanalysis dataset to gain an insight into the atmospheric processes and mechanisms causing the heavy precipitation events across the region.
- Uncoupled WRF-hydro model over the Eastern Ethiopia domain at a resolution of 1km (250m) is conducted and several sensitivity experiments have been carried out to obtain appropriate parameters for hydraulic conductivity and surface infiltration coefficient
- Our result shows that the WRFhydro model is able to capture the timing and peaks of flood events reasonably well when it is driven with ECMWF reanalysis.