Impact of Western Ghats Orography on Simulation of Extreme Precipitation over Kerala, India

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Sessions XII
AI/ML in Weather prediction

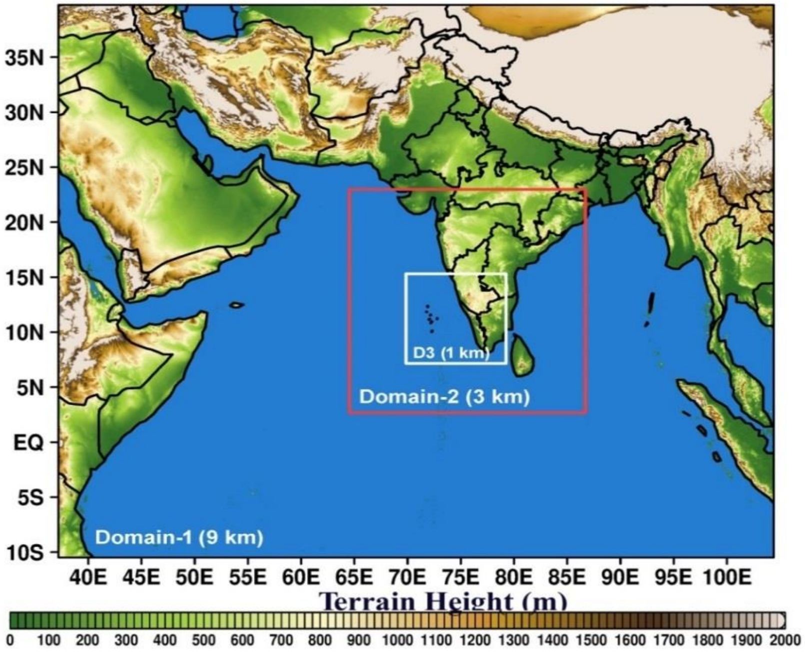
Stratosphere-Troposphere Interactions and Prediction of Monsoon weather EXtremes (STIPMEX)

Motivation

- **Mountains have significant influence on summer monsoon circulation and rainfall**
- **The length and width of mountains, along with their steepness and altitude, significantly modulate the rainfall on the windward side of mountains.**
- **Here, we examined the impact of different topographic configurations, including no-mountain, plateau, moderate, and steep mountain settings.**
- **Kerala has experienced a series of extremely heavy rainfall events in the past few years, resulting in severe flooding and landslides.**
- **Among these events, the exceptional heavy rainfall events during August 14-17 over Kerala is most intense which we have considered as a case day**
- **Four model numerical simulations using the Advanced Research WRF (ARW) model**

WRF Model configuration

Short wave radiation scheme	RRTMG
Long wave radiation scheme	RRTMG
Cloud Microphysics	Thompson Aerosol-Aware
Scheme for PBL process	MYNN 2.5 non-local scheme
Scheme for Land Surface processes	NOAH-MP scheme
Cumulus convection	Kain-Fritsch (KF-Eta) (configured for only domain 1)



Spatial extents of three model domains with terrain height

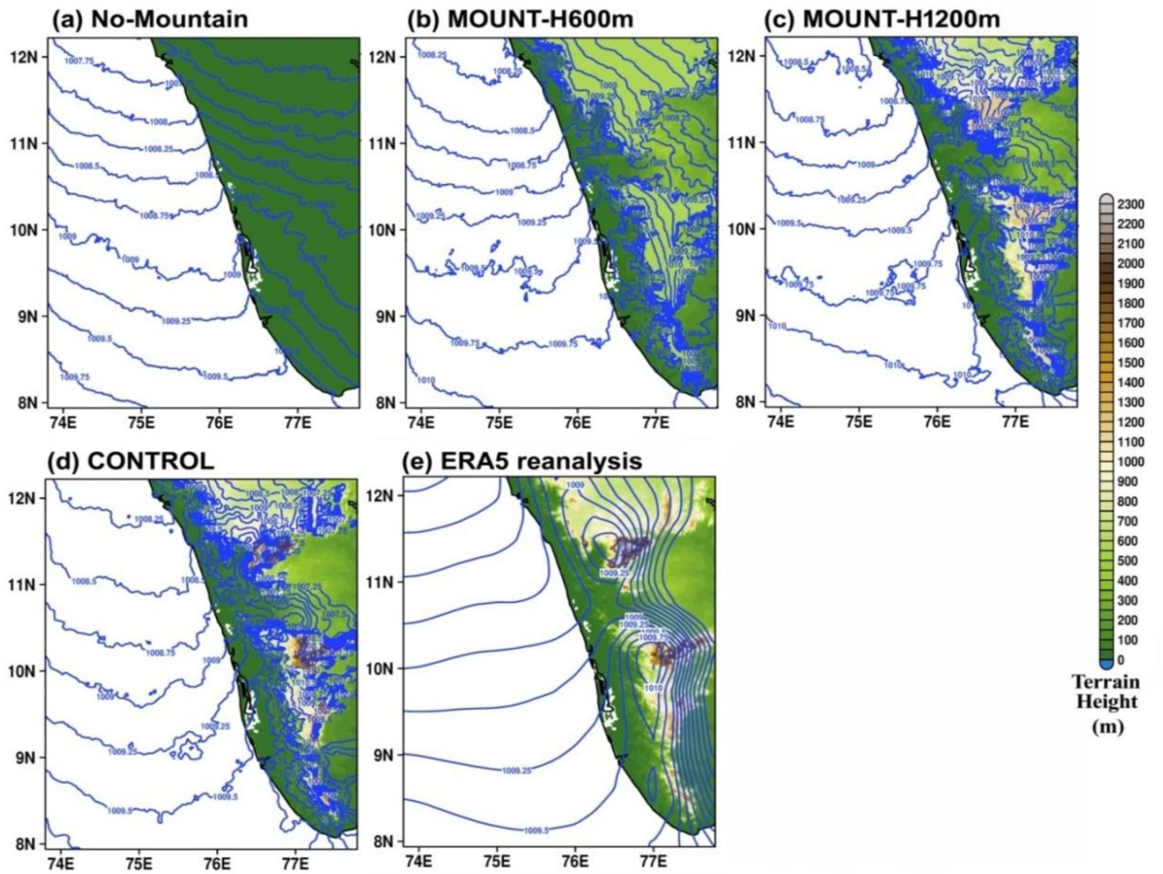
Numerical initializtion and physics cofigured based on the previous studies by Viswanadhapalli et al., (2019), Thomas et al., (2022) and Gorja et al., (2023)

Details on model experiments conducted

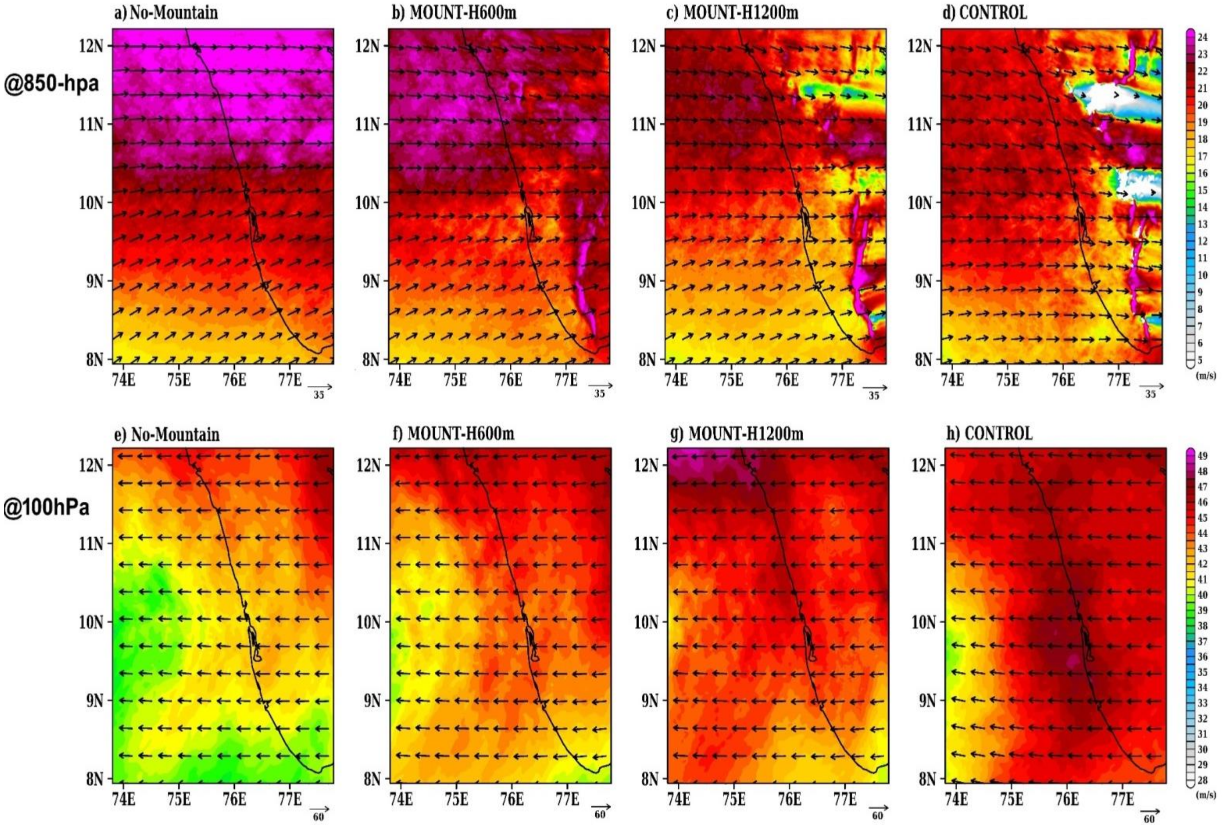
Experiment	Model initialization time	Model integration End time	Details in terrain variations
CONTROL	0000 UTC 13 August 2018	0000 UTC 17 August 2018	It is conducted with real topography using WRF-ARW model
No-Mountain	0000 UTC 13 August 2018	0000 UTC 17 August 2018	Conducted by removing mountain topography.
MOUNT-H600m	0000 UTC 13 August 2018	0000 UTC 17 August 2018	Conducted by limiting terrain height to 600m to test sensitivity of low or plateau type of terrain.
MOUNT-H1200m	0000 UTC 13 August 2018	0000 UTC 17 August 2018	Conducted by limiting terrain height to 1200m to test sensitivity of moderate mountain terrain.

Results: Changes in dynamical fields

Spatial distributions of daily mean Sea Level Pressure (shown in contour) along with the ERA5 reanalysis 15 August 2018. Terrain height is plotted in shaded color

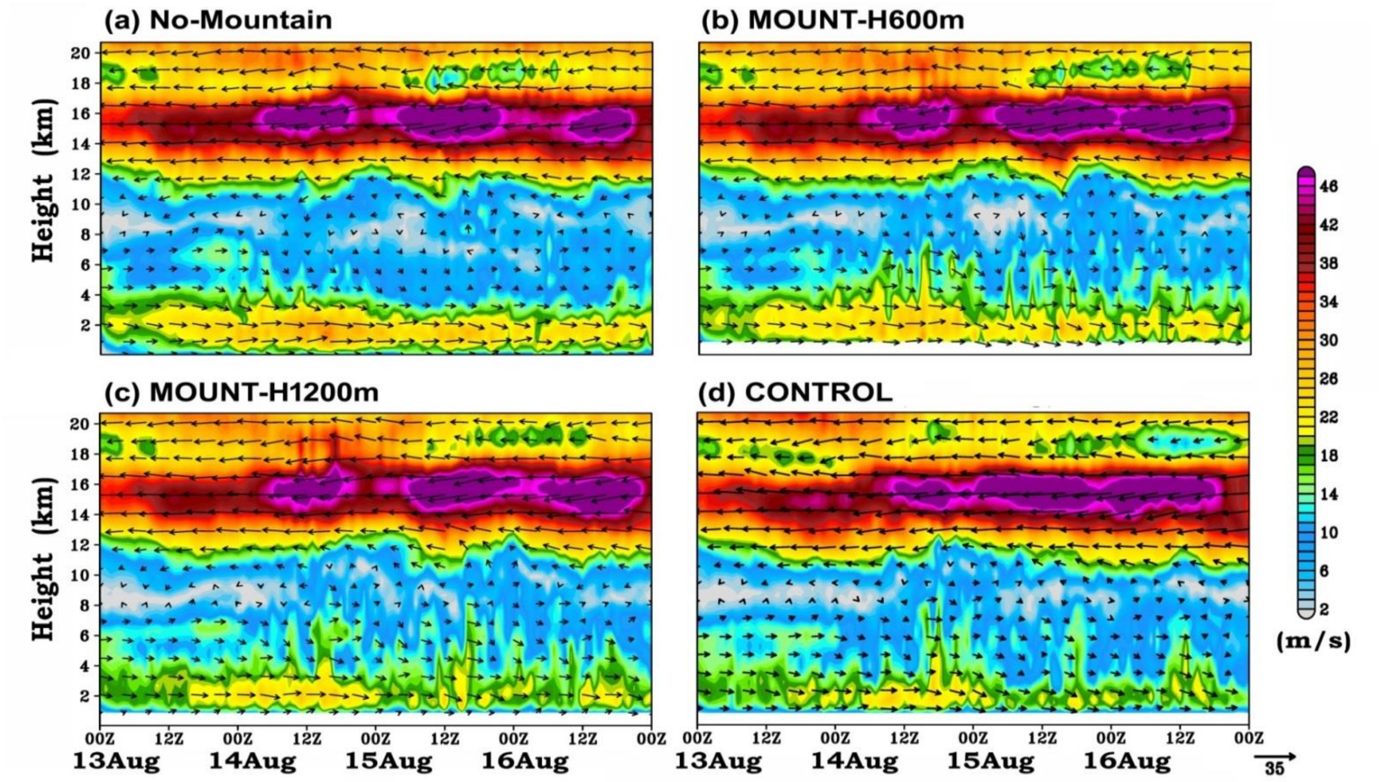


Simulated winds at lower and upper-troposphere



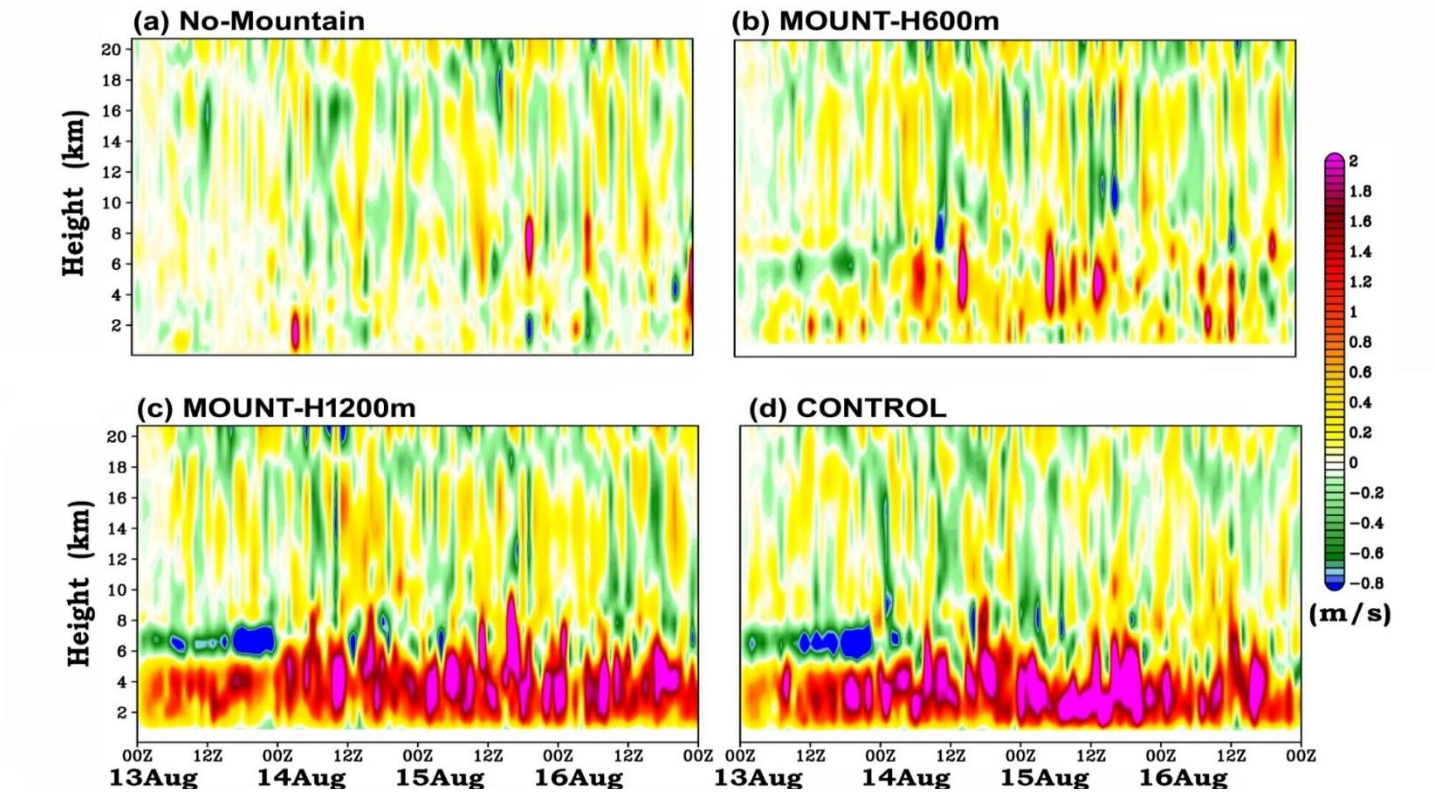
Simulated day mean winds on 15 August 2018 from different mountain experiments

Time-height variation of winds at heavy rainfall location



Time-height variation of simulated winds averaged over 1° x 1° region (11°N - 12°N; 75°E - 76°E) close to the heavy rainfall location

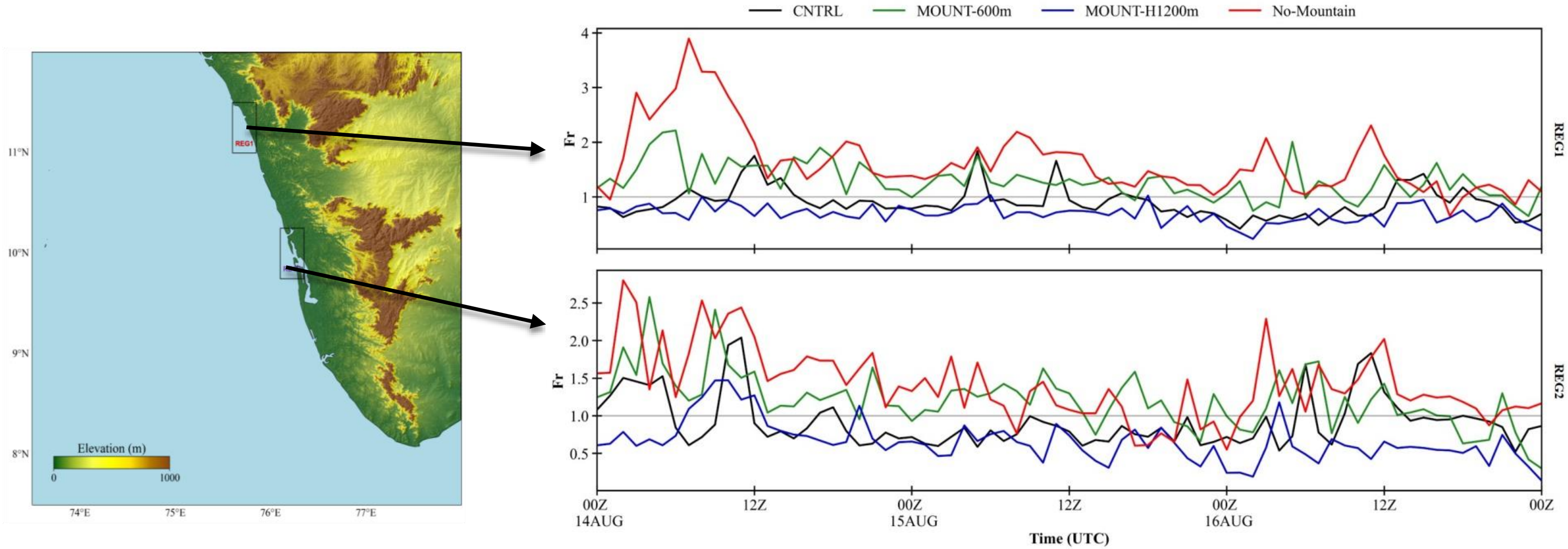
Time-height variation of vertical velocities over study location



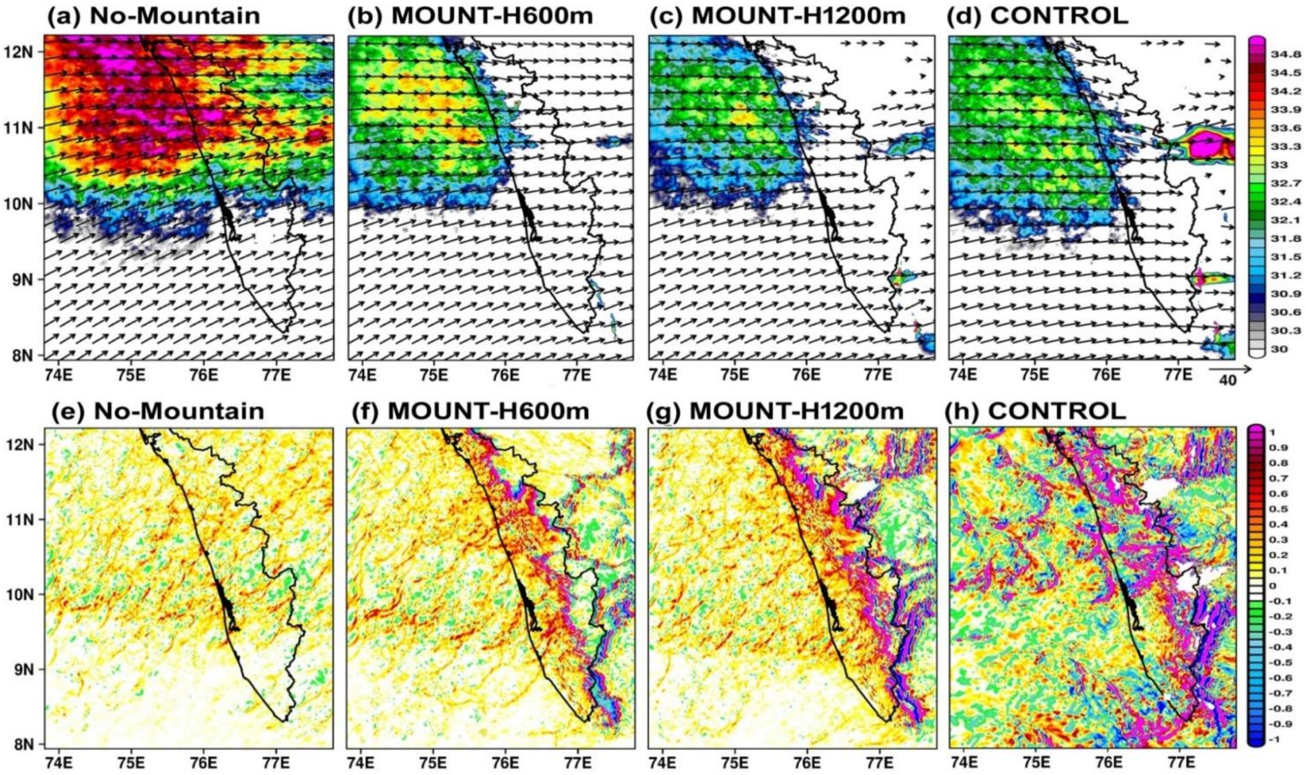
Time-height variation of vertical velocities averaged over 1° x 1° region (11°N - 12°N; 75°E - 76°E) close to the heavy rainfall location

Variations in Froude number with mountain height

- ❑ Froude number Fr = [UI(NH)], we adopted the methodology from Phadtare et al., (2018) where U is the mean wind speed normal to the orography, N is the Brunt-Väisälä frequency of atmosphere, H is the height of the orography
- ❑ $Fr < 1$, the flow is blocked and deflected by orography, it is $Fr > 1$, the flow overcomes the orographic barrier and moves to the leeward side



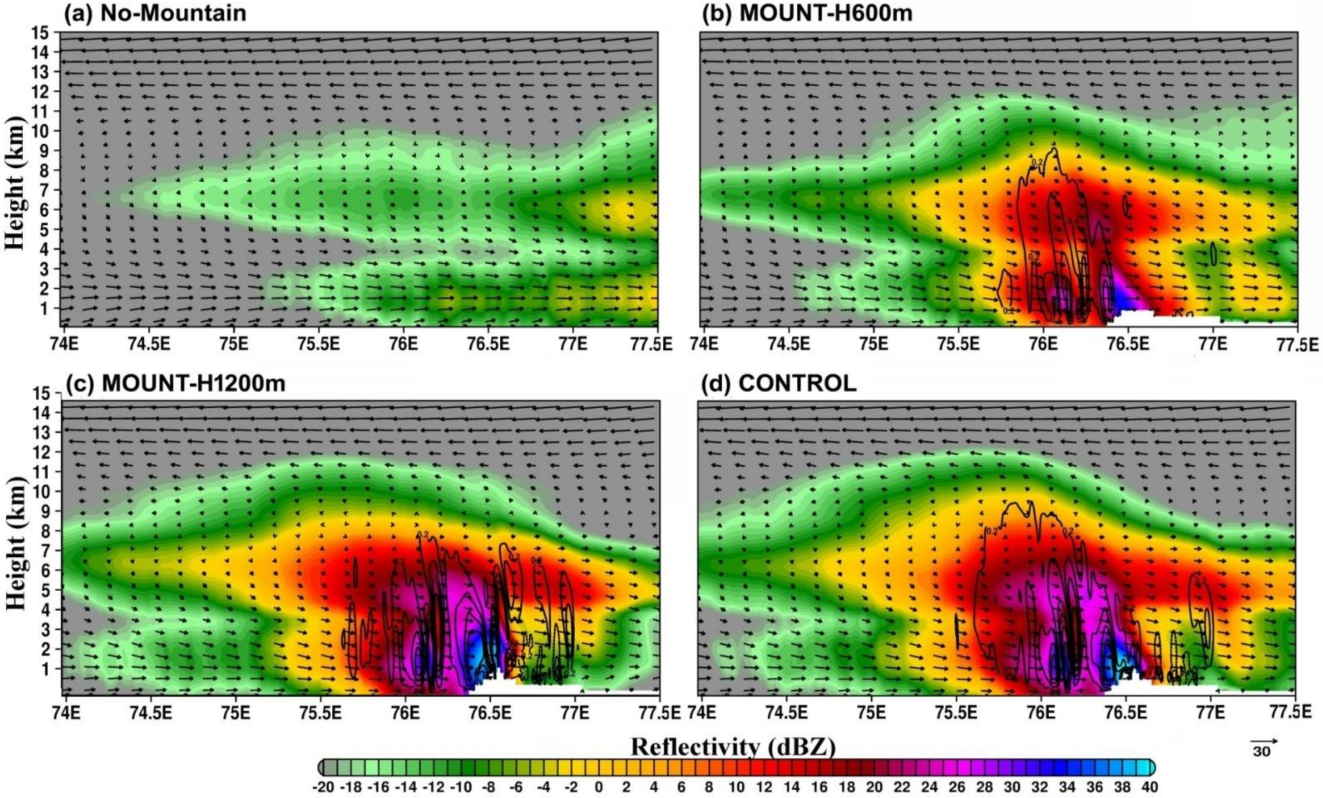
Changes in moisture transport and convergences



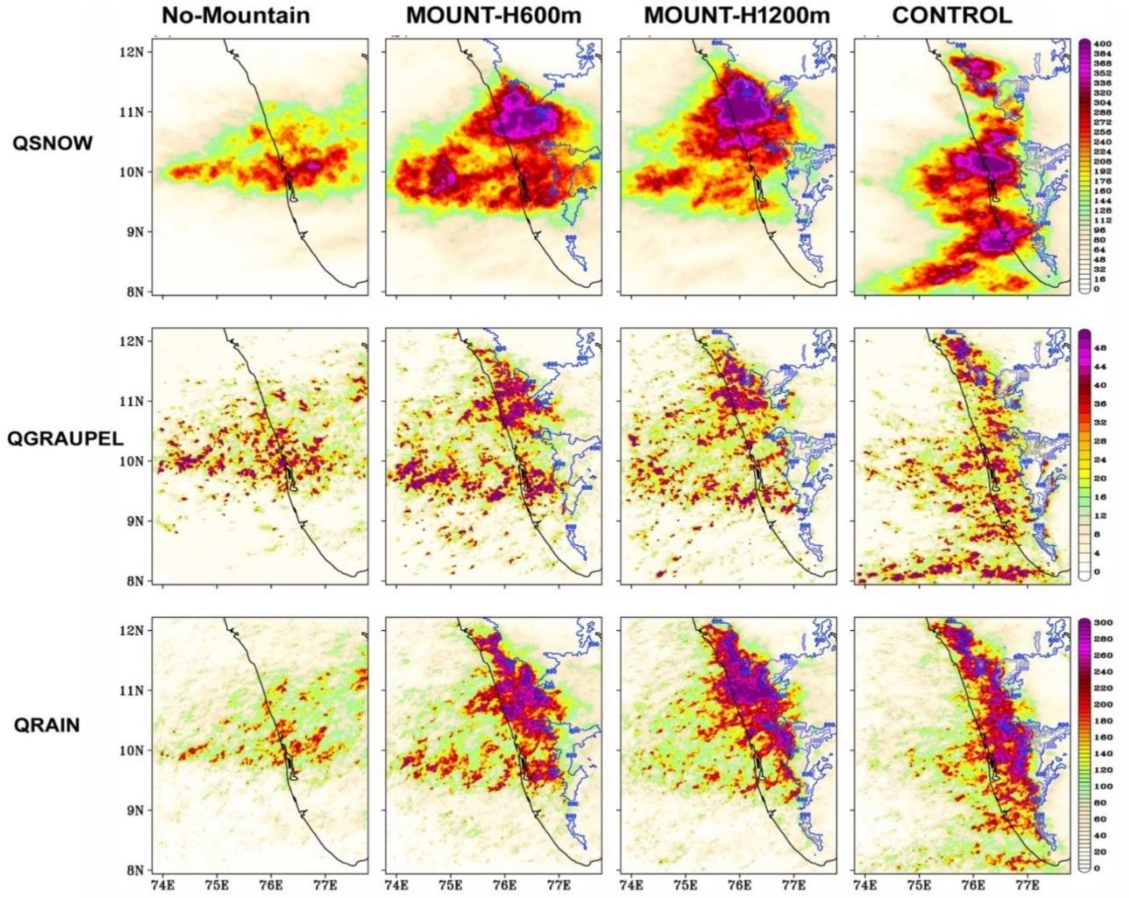
Spatial distribution of moisture transport (in kg $m^{-1}s^{-1}$; top panels) and moisture convergence (in 10^{-4} kg $m^{-2}s^{-1}$; bottom panels) averaged for heavy rainfall day

Changes in simulated hydrometeors

Longitudinal-height section of simulated mean reflectivity (shaded) and vertical winds (contours) along longitudes (74°E-77.5°E) on 15 August 2018

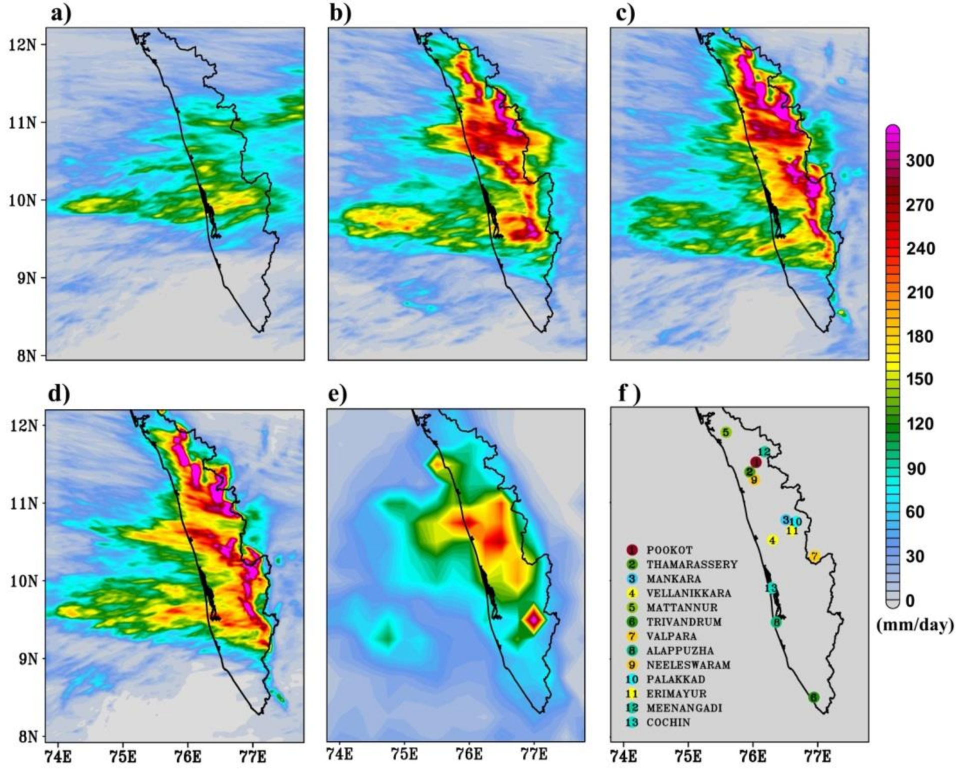


Time-averaged and vertically integrated hydrometeors



(units: 10^{-5} kg/m^{2})

Spatial rainfall distribution on 15 August, 2018



Spatial distribution of daily rainfall from a) No-Mountain, b) MOUNTHGTL-600m, c) MOUNTHGTL-1200m, d) CONTROL, e) IMD gridded rainfall product, and f) Station observations.

Summary

- Variations in mountain height have a direct impact on the tropospheric dynamics.
- Intensification offshore trough is observed with an increase in the mountain heights.
- An increased blocking effect lead to deceleration of low-level winds.
- Gradual increase in moisture transport and convergence is seen in the southeast and southern parts of Kerala in the presence of WG mountains.
- Simulated hydrometeors are highly sensitive to the underlying orography.
- Simulated rainfall progressively increases and shifts closer to elevated mountain topography and central parts of Kerala.

THANK YOU

Reference

Viswanadhapalli Y., Biyo Thomas, C.V. Srinivas, Ghouse Basha, Ravi Kumar Kunchala (2024) Impact of Western Ghats orography on the simulation of extreme precipitation over Kerala, India during 14–17 August 2018, Atmospheric Research, 299,107211, https://doi.org/10.1016/j.atmosres.2023.107211