Comparison of Orographic and Convective Driven Gravity Waves over the Western Ghats

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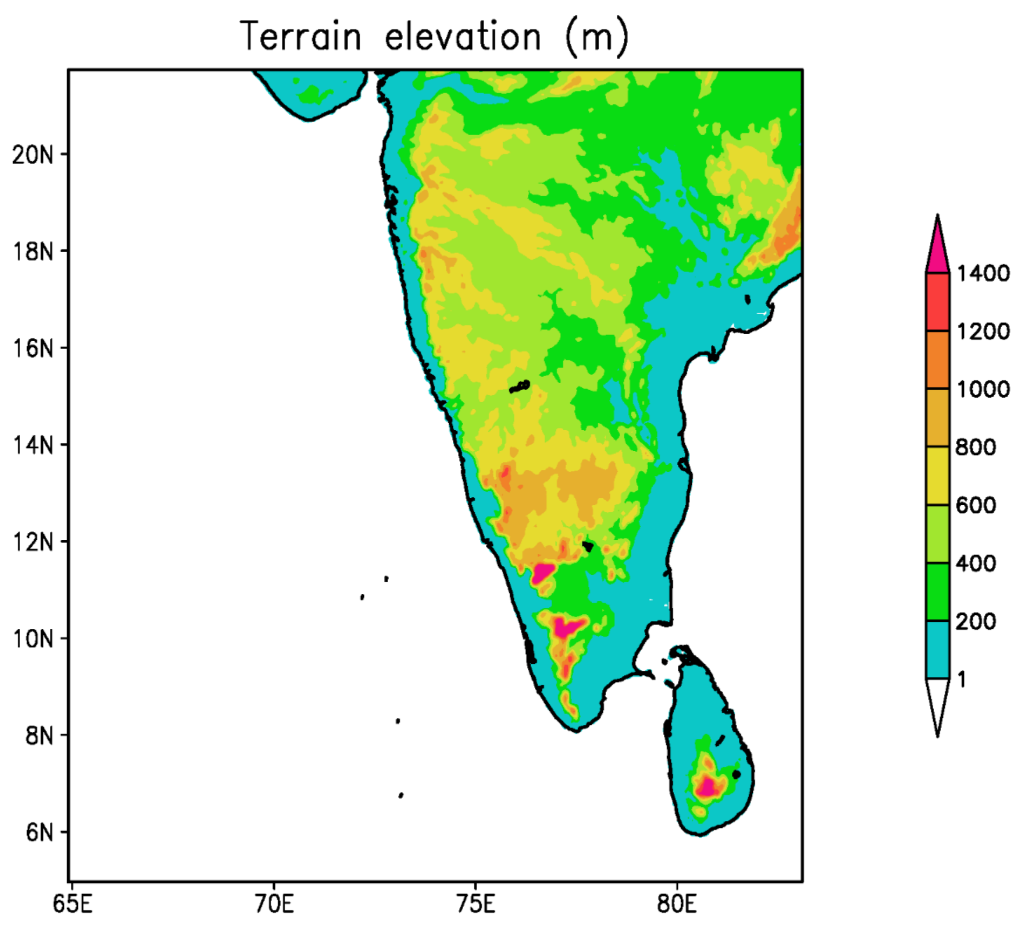
Introduction

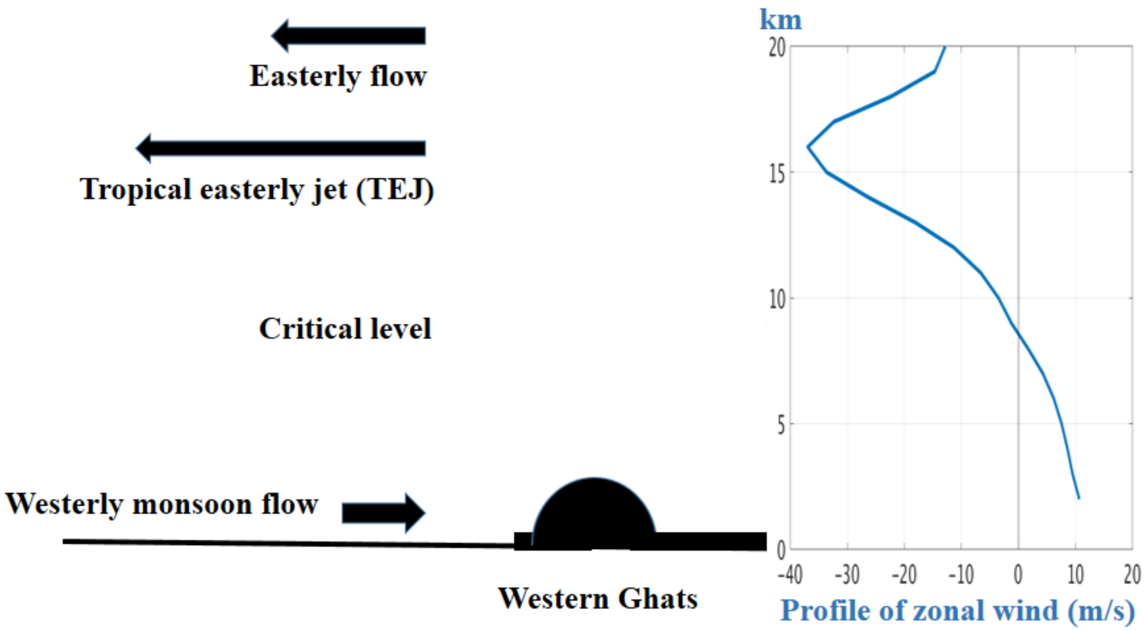
This presentation is focused on the Western Ghats in India.

What are the roles of mountains and deep moist convection in generating gravity waves?



Introduction

The Environment

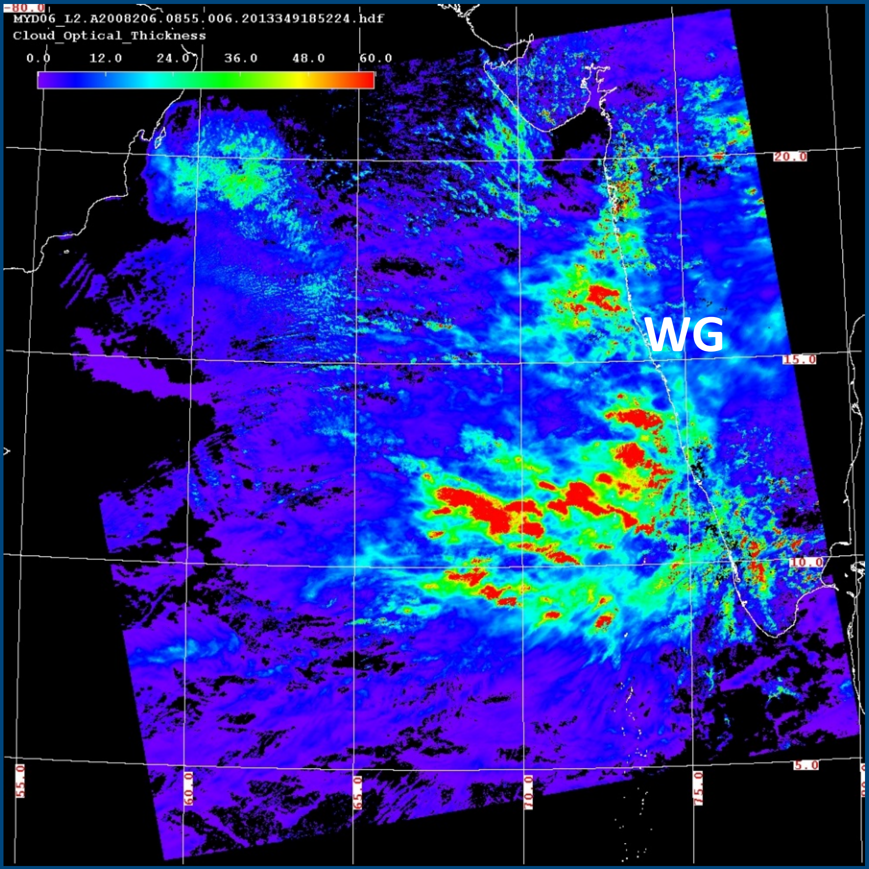


The Western Ghats mountain can trigger gravity waves, and our hypothesis is that these vertically-propagating mountain waves dissipate below the critical level.

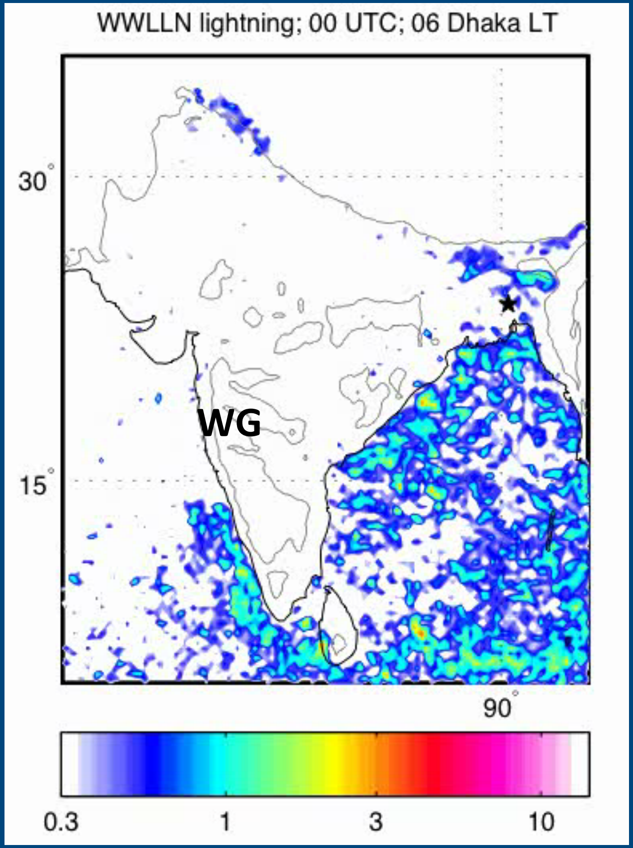
Introduction

A substantial amount of convection over the Western Ghats and the Indian Ocean during the boreal summer monsoon season. Deep convection can reach over tropopause to the stratosphere. The convection is another triggering factor of gravity waves.

MODIS Aqua cloud optical depth on July 25, 2008



World Wide Lightning Location Network (wwlln.net)



Methodology

A real case 3-D modeling approach

- Cloud resolving simulations using the Weather Research and Forecasting (WRF) model
- Initial and lateral boundary conditions from NCEP CFSR
- Selected periods in the rainy season in 2008-2010 (the "Years" of Tropical Convection, YOTC). Presented a 10-day simulation of July 20 – 30, 2008.
- 6 km resolution
- convective cumulus parameterization deactivated.

Set of simulations:

1. **Control**
2. **No mountain**
3. **No latent heating**
4. **No mountain and no latent heating**

Methodology

Filter methods to calculate perturbations for gravity wave diagnostics

Procedure:

- Step 1: Deplaning: subtracting the best-fit plane
- Step 2: High-pass spatial filtering
- Step 3: quadratic diagnostic quantities

$$EF_z = p'w' \qquad EF_x = p'u'$$

$$MF_x = \overline{\rho} u'w' \qquad HF_z = \overline{\rho} c_p w'T'$$

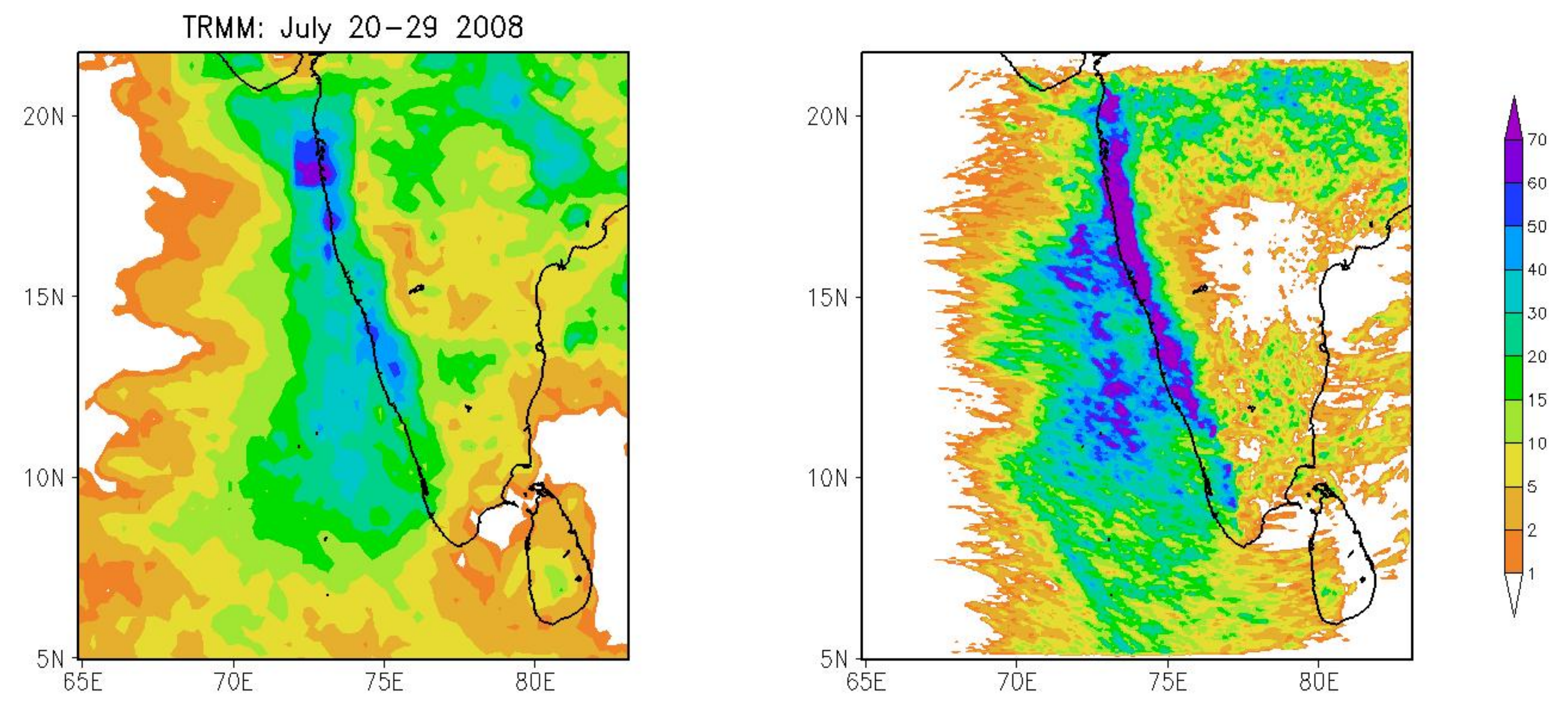
- Step 4: Low-pass spatial filtering (optional)

Reference: Kruse and Smith (2015)

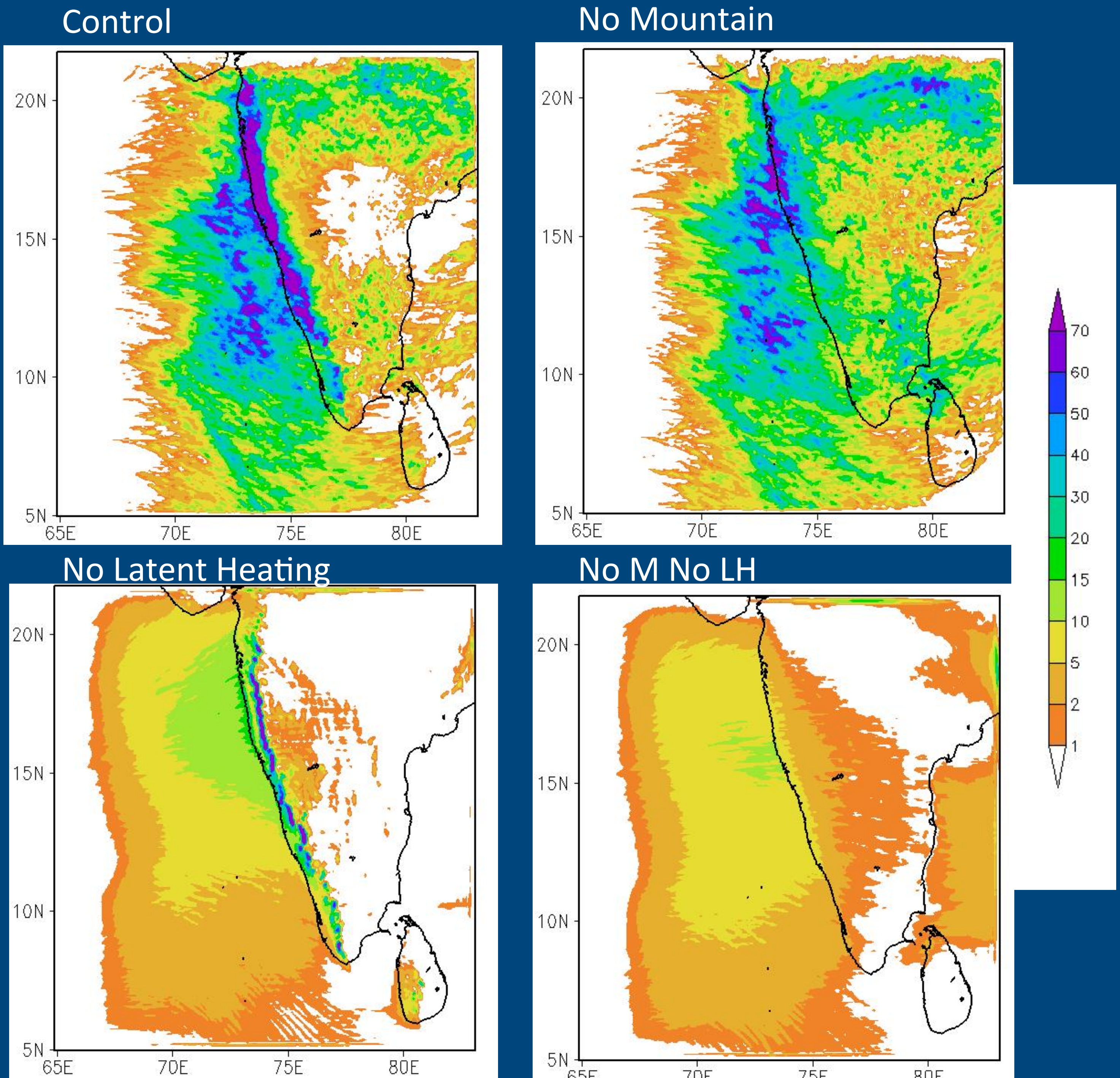
Results

TRMM

WRF



Mean rainfall rate (mm/day) in TRMM 3B43 product (left panel) and WRF control simulation (right panel) for 00 UTC 20 July 2008 – 00 UTC 30 July 2008



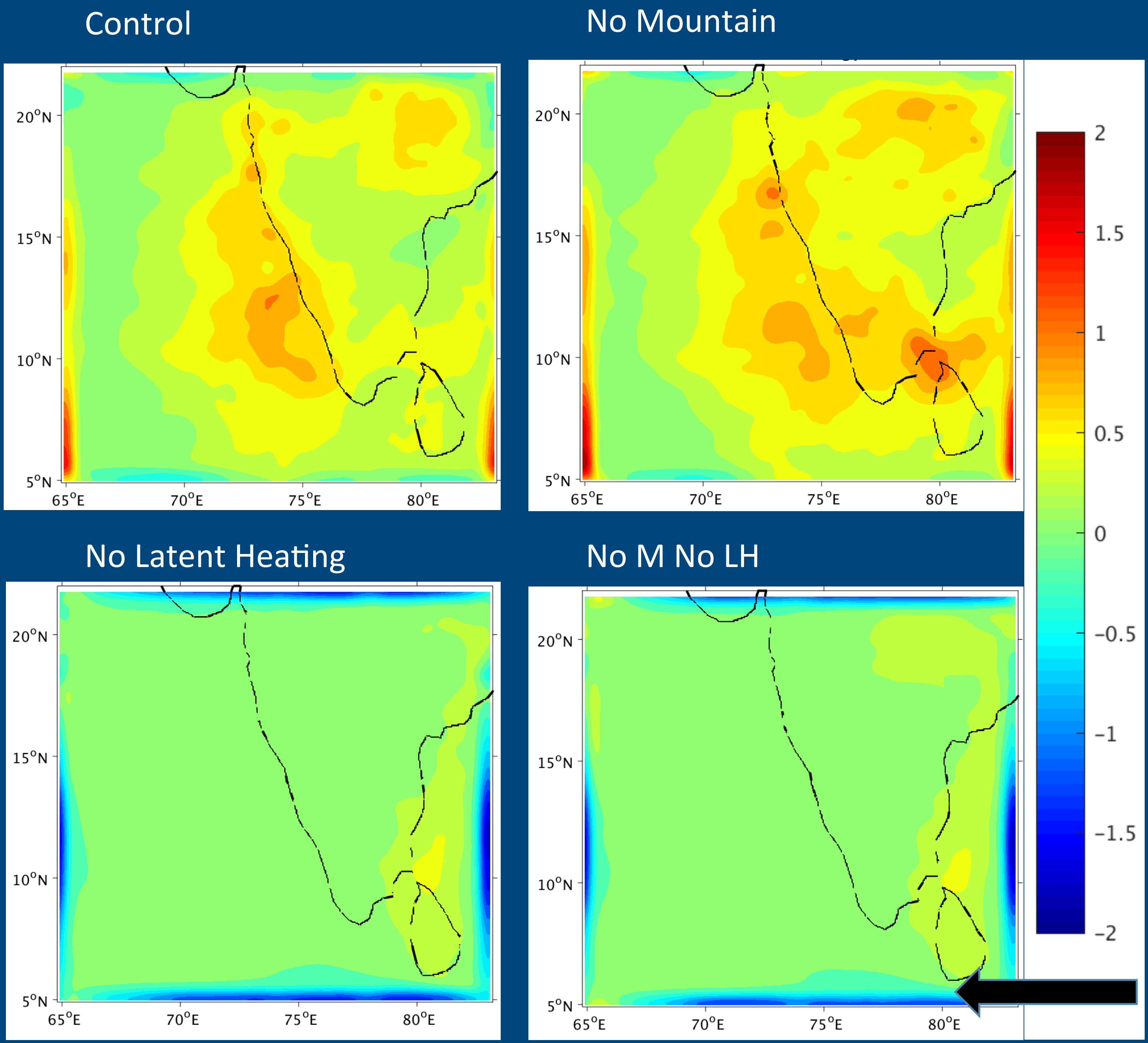
Control

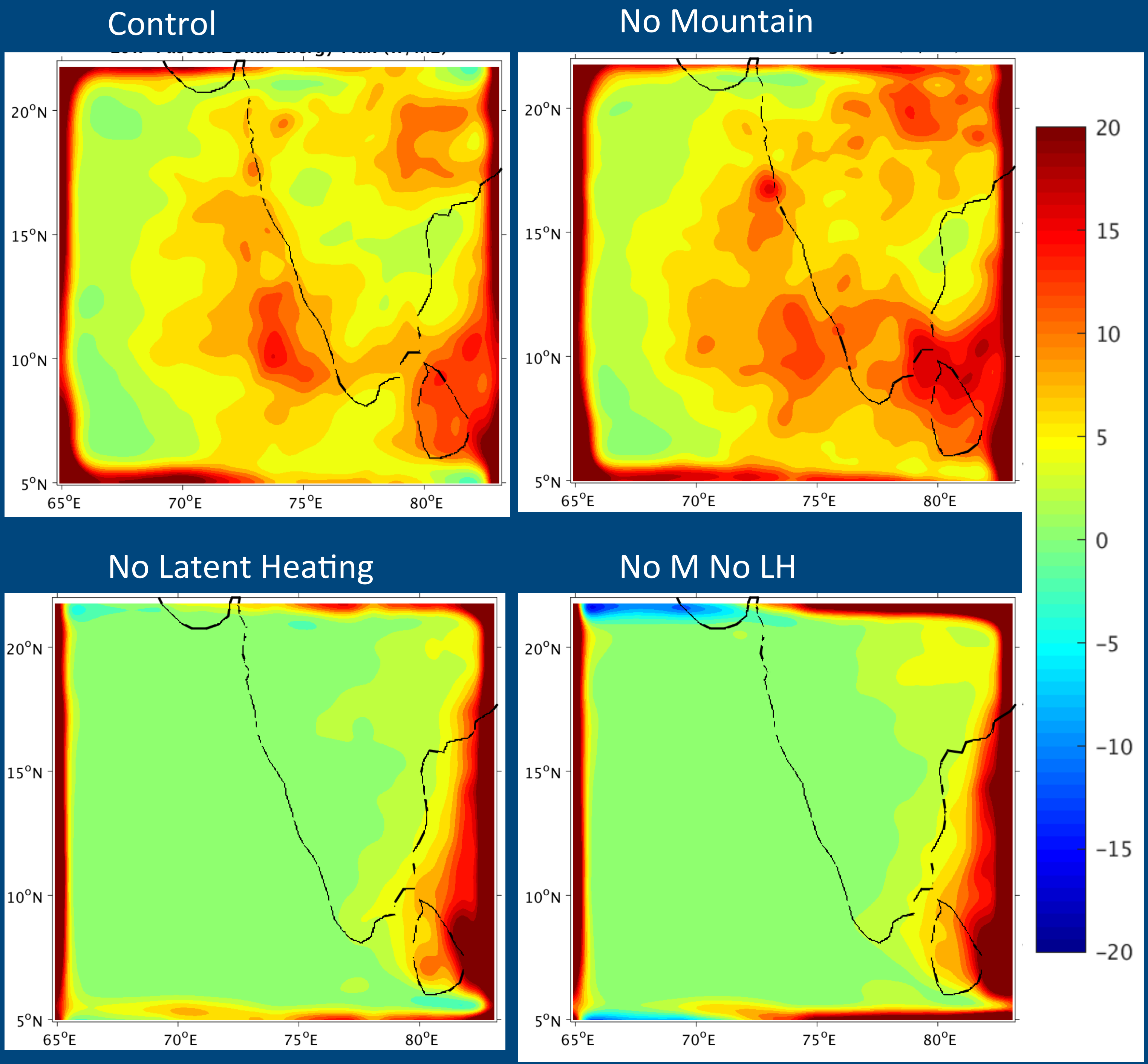
No Mountain

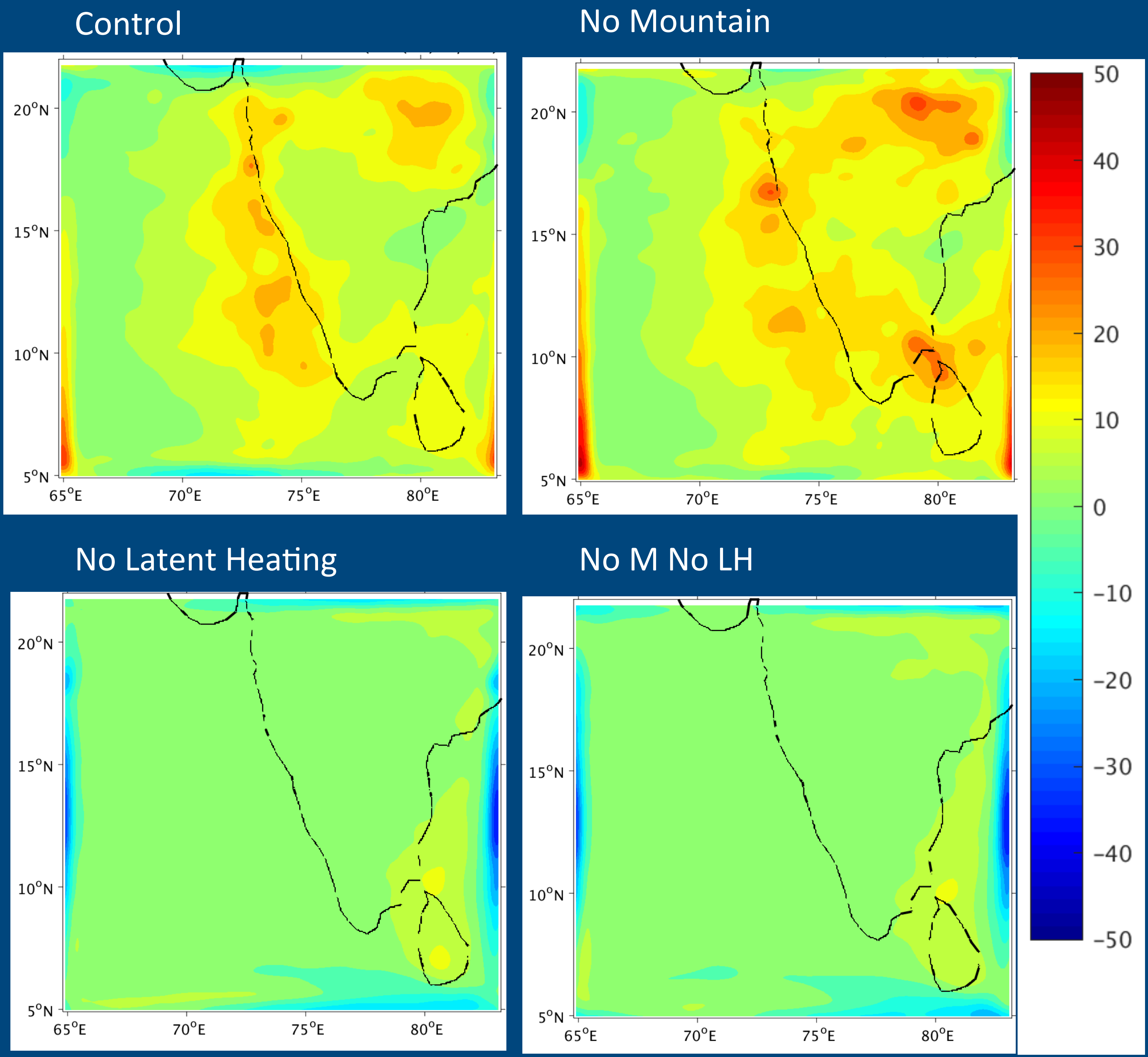
No Latent Heating

No M No LH

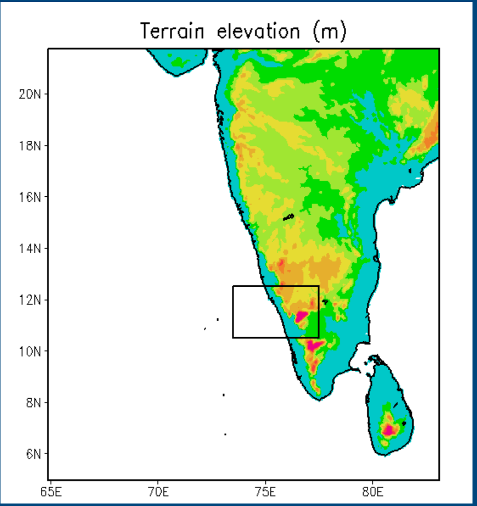
Mean rainfall rate (mm/day) in WRF simulations





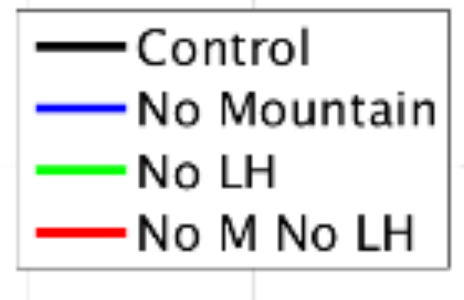


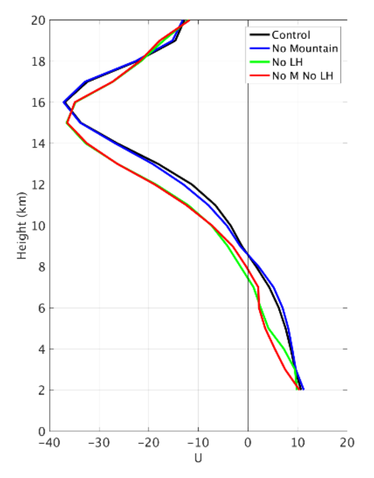
Smoothed zonal momentum flux (MFx, mPa) at 16 km level.



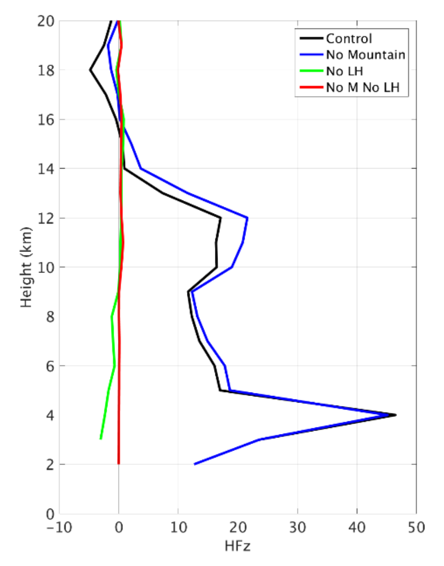
Box of averaging domain

Vertical profiles of gravity wave diagnostics averaged over southern Western Ghats region, averaged during simulation period.

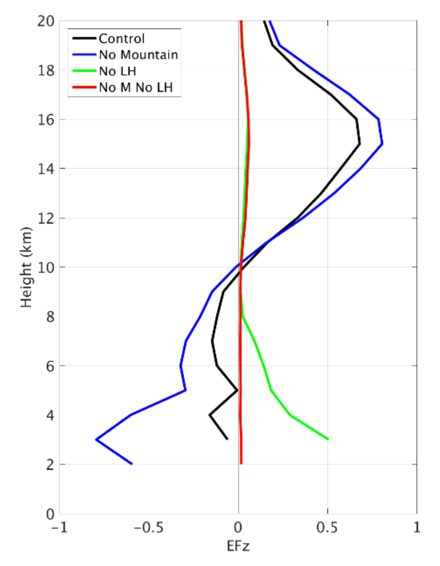




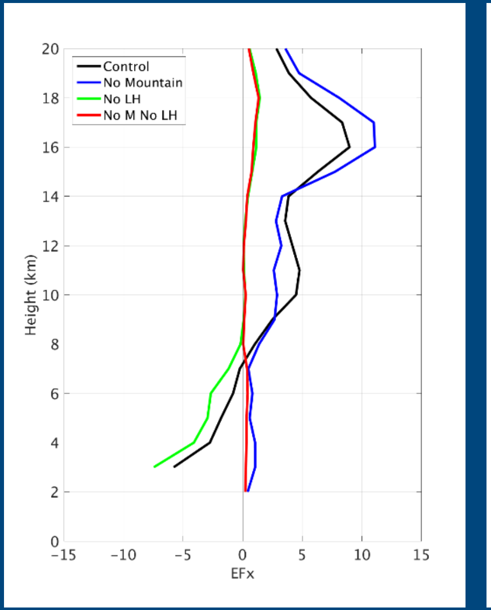
zonal wind (m/s)



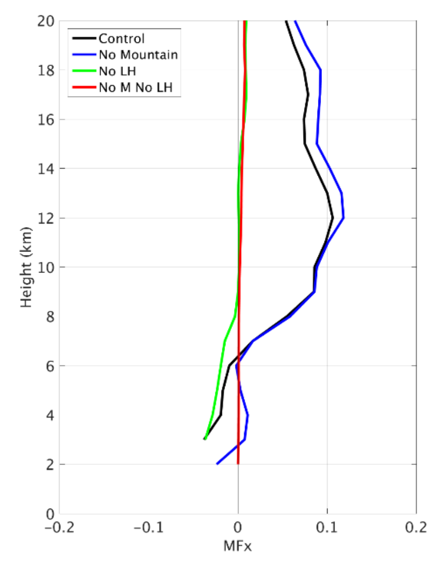
vertical heat flux (HFz, W/m^2)



vertical energy flux (EFz, W/m^2)



zonal energy flux (EFx, W/m^2)



zonal momentum flux (MFx, Pa)

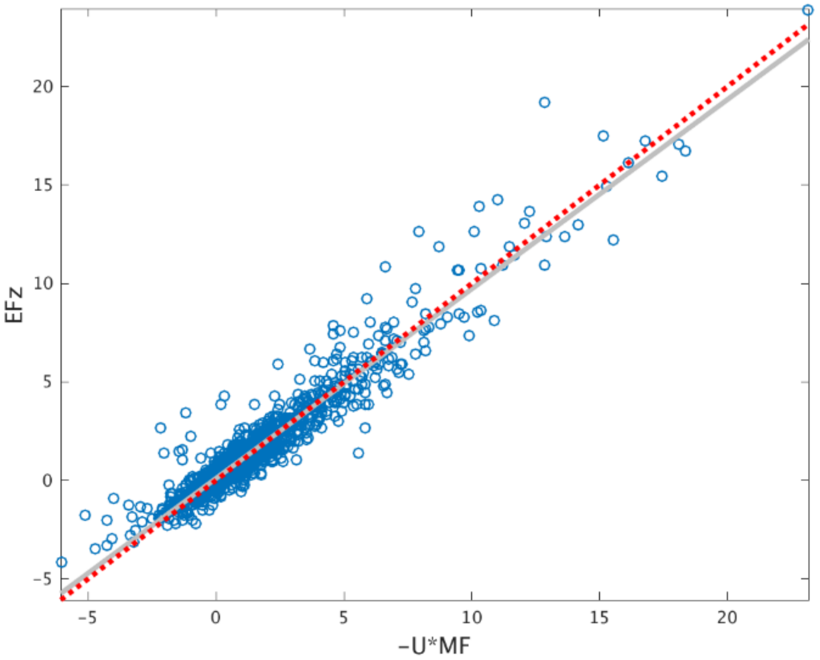
Convectively generated waves at 16km are nearly steady “mountain waves”

Vertical energy flux and horizontal momentum fluxes are related by Eliassen-Palm (E-P) relation, valid for steady, linear and nonrotating mountain waves. (Eliassen and Palm, 1960)

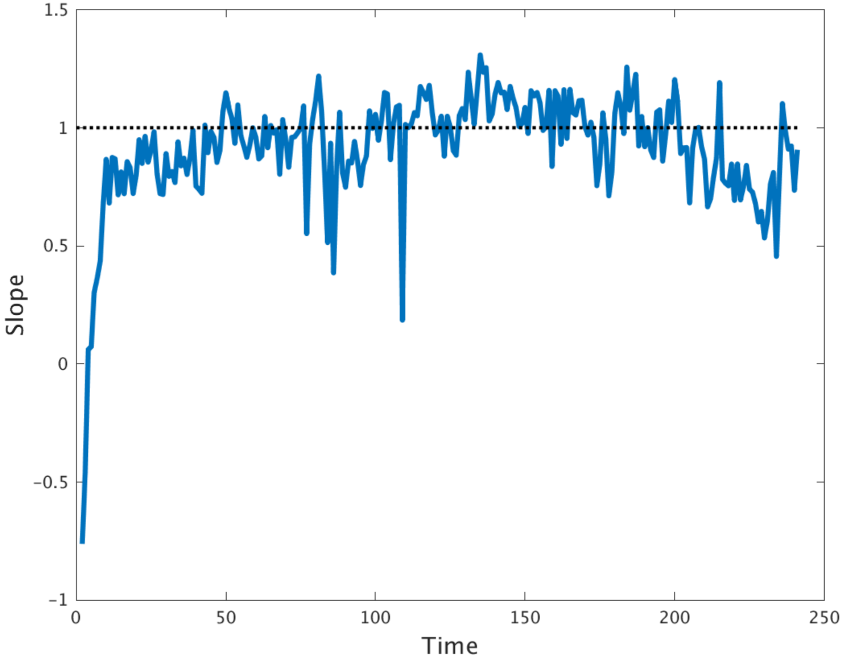
$$EF_z = -U \bullet MF$$

Pointwise evaluation of E-P relation at 16 km, which is above the critical level.

The gravity waves triggered by deep convection are similar to steady mountain waves.

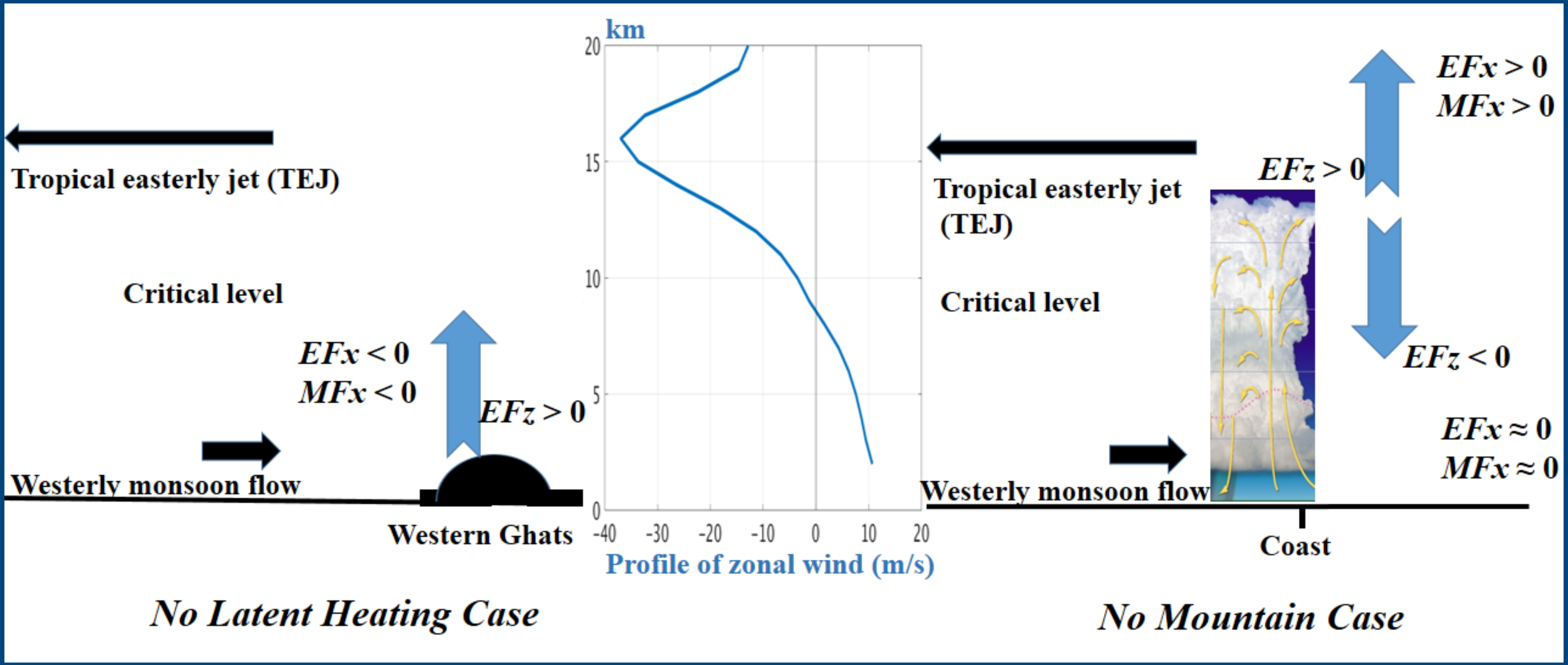


Snapshot of E-P relation (units: W/m^2)



Hourly time series of fitting slope of E-P relation at 16 km during the simulation period.

Conclusions



- In the absence of deep convection in the No Latent Heating simulation, mountain waves are generated up to the critical level.
- In the No Mountain simulation, convection produces negative *EFz*.
- In upper troposphere and lower stratosphere, deep convection generate upward propagating gravity waves, due to obstacle effect of convective element. These waves propagate eastward, against the easterly flow.
- The fluxes in the control simulation case are approximately represented by the sum of those in No Mountain case and No Latent Heating case.

Thank you!

Acknowledgment

- Supported by NSF-AGS-1338655: Deep Propagating Gravity Wave (DEEPWAVE)
- NCAR Yellowstone Supercomputer
- Discussion with Christopher Kruse at Yale University and René Garreaud at Universidad de Chile.

Methodology

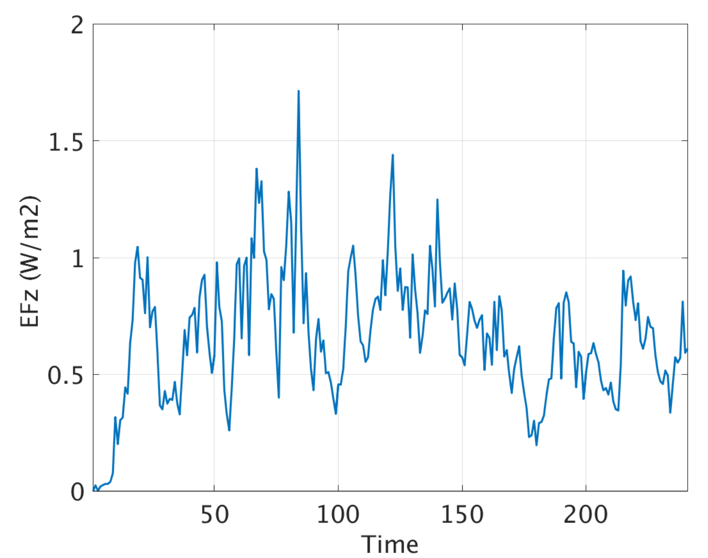
WRF model configuration

- 6 km resolution
- convective cumulus parameterization deactivated.
- Time step is 20 s.
- 80 vertical levels, with model top at 5 hPa
- A 5 km damping layer below the model top, with w-Rayleigh damping (coefficient 0.2)
- YSU PBL scheme
- Noah LSM land surface scheme
- Lin et al. microphysics scheme
- RRTM longwave radiation scheme
- Dudhia shortwave radiation scheme

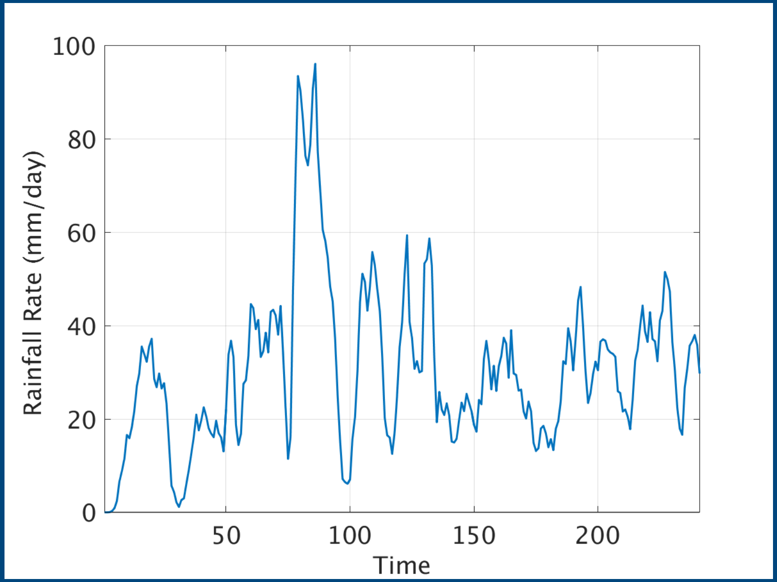
Results

Hourly time-series from the WRF control simulation

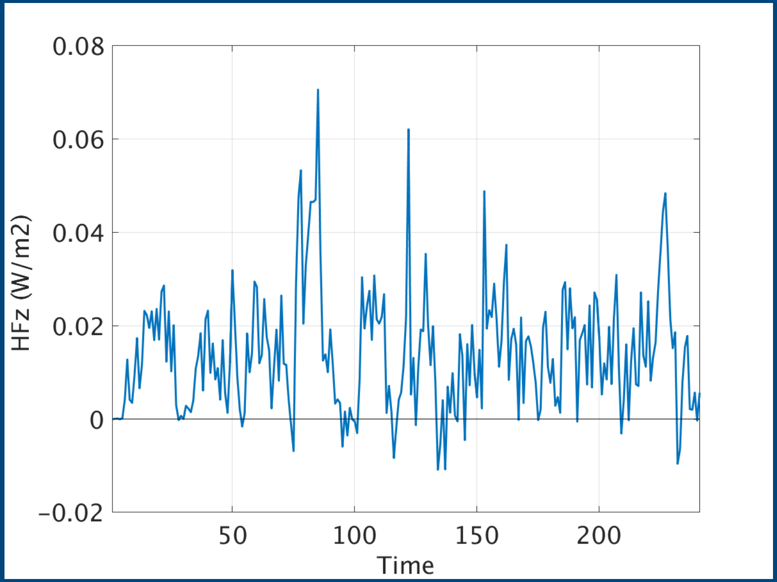
vertical energy flux at 16 km



Rainfall rate



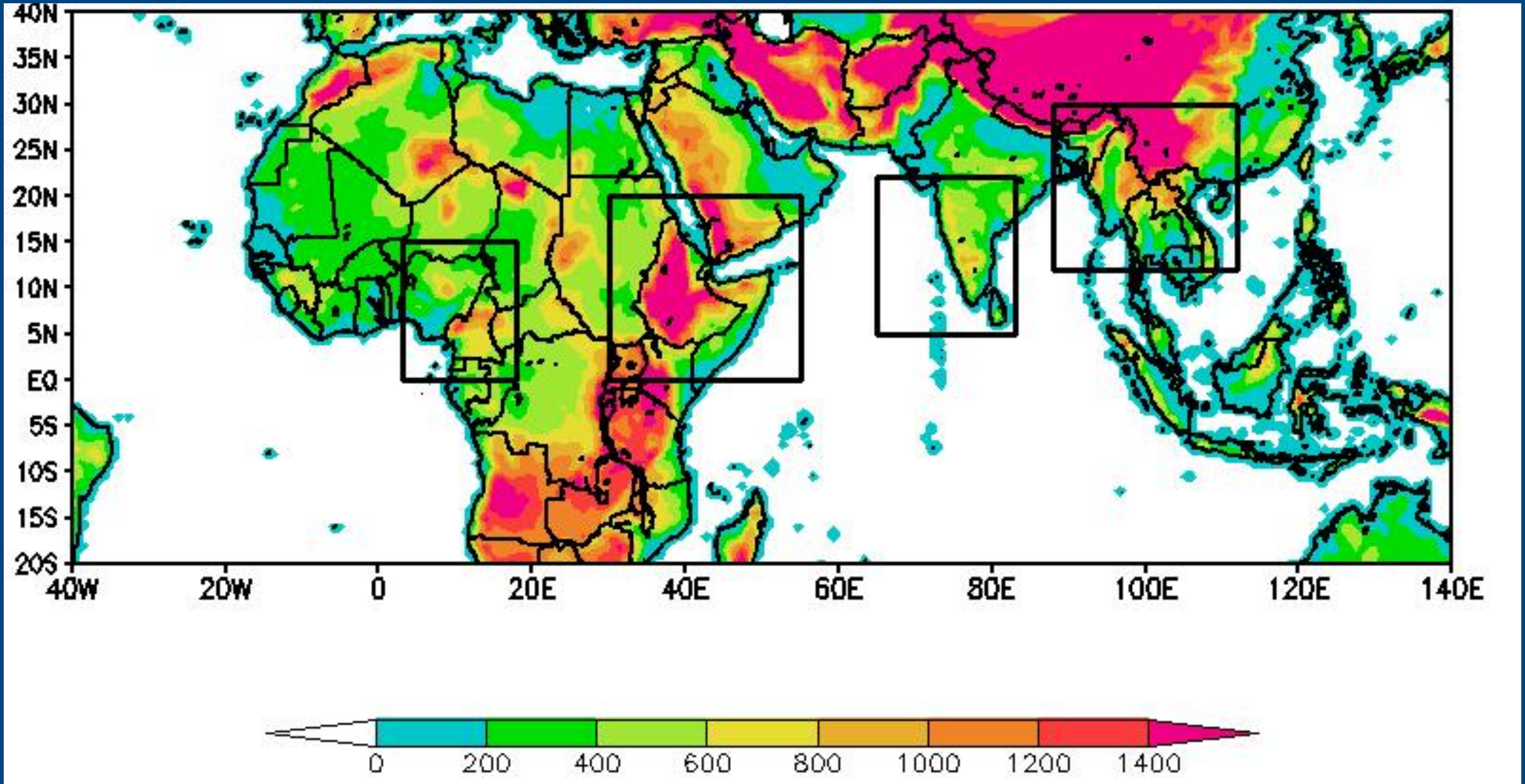
vertical heat flux at 5 km



Introduction

A comparative study of gravity waves over tropical mountain regions, including West Africa, East Africa, India, and Myanmar.

The objective is to better understand the gravity waves generated by mountains versus by convection and compare with those in DEEPWAVE studies.



Elevation (m) of four proposed study domains