Influence of coastal topography on the South Asian Summer Monsoon

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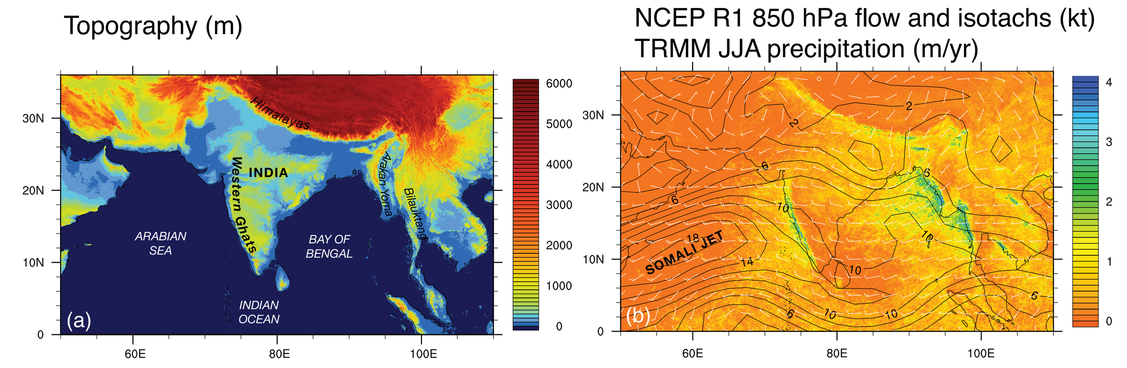
Introduction

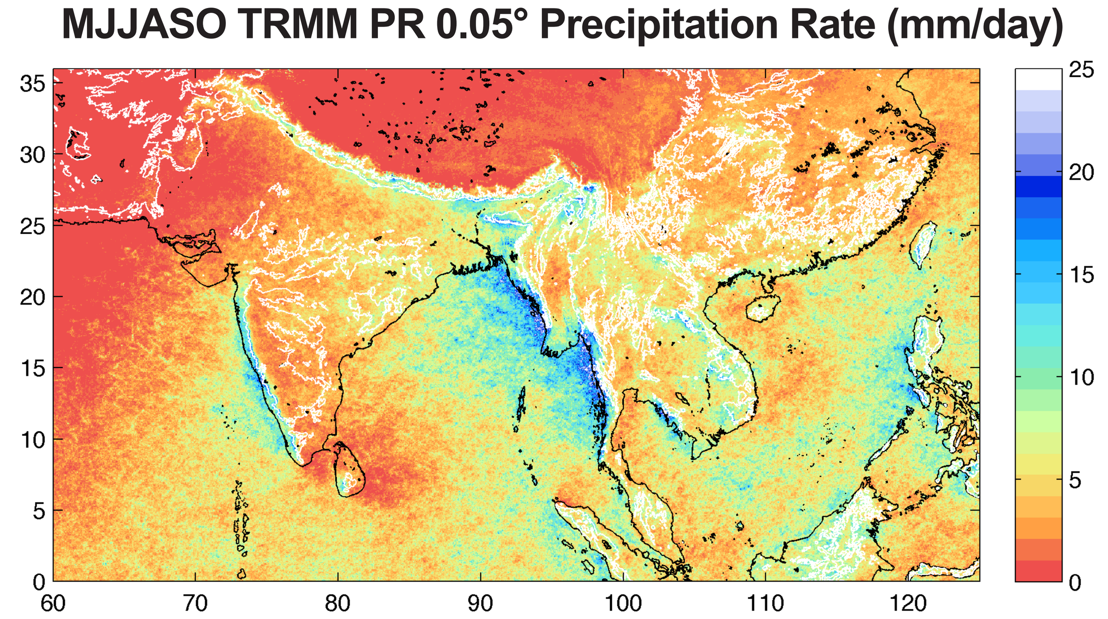
Recent high-resolution precipitation observations from the Tropical Rainfall Measuring Mission have exemplified narrow, extremely heavy precipitation zones near and upstream of the coastal mountain ranges in South Asia (the Western Ghats in India and the Arakan Mountains in Myanmar). These narrow precipitation zones, and associated downstream rain shadows, play an important role in the ecoclimatological stability of the region, while modulating atmospheric heating and water and energy cycles of the South Asian Monsoon. While the role of the Tibetan Plateau has been shown by Yanai and others to be an important driver for the large scale circulation of the South Asian Monsoon, these smaller mesoscale mountain ranges may also play an important role in driving onshore moisture flows through wind-terrain interaction.



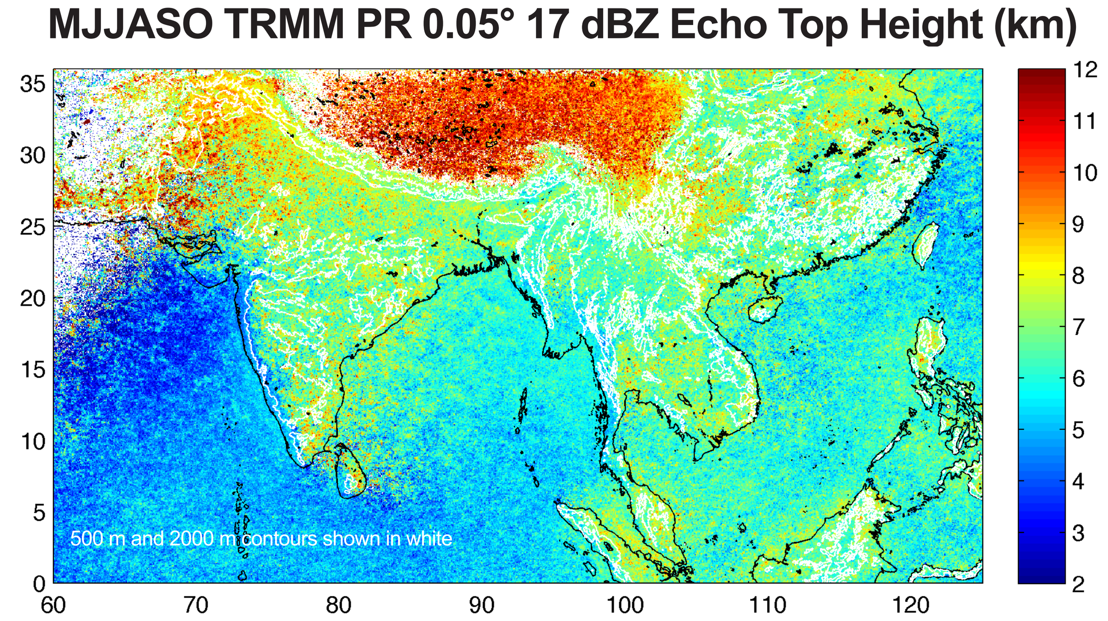
TRMM puts tropical orographic precipitation under the microscope

The high spatial resolution of the TRMM precipitation radar (5 km) and long data record allows us to generate very high resolution composites of precipitation and precipitation characteristics, revealing the small scale variability of orographic precipitation, as discussed by Xie et al. (2006, J. Climate); our analysis is 10x finer resolution (Nesbitt and Anders, 2008, GRL).

MJJASO TRMM PR 0.05° Precipitation Rate (mm/day)



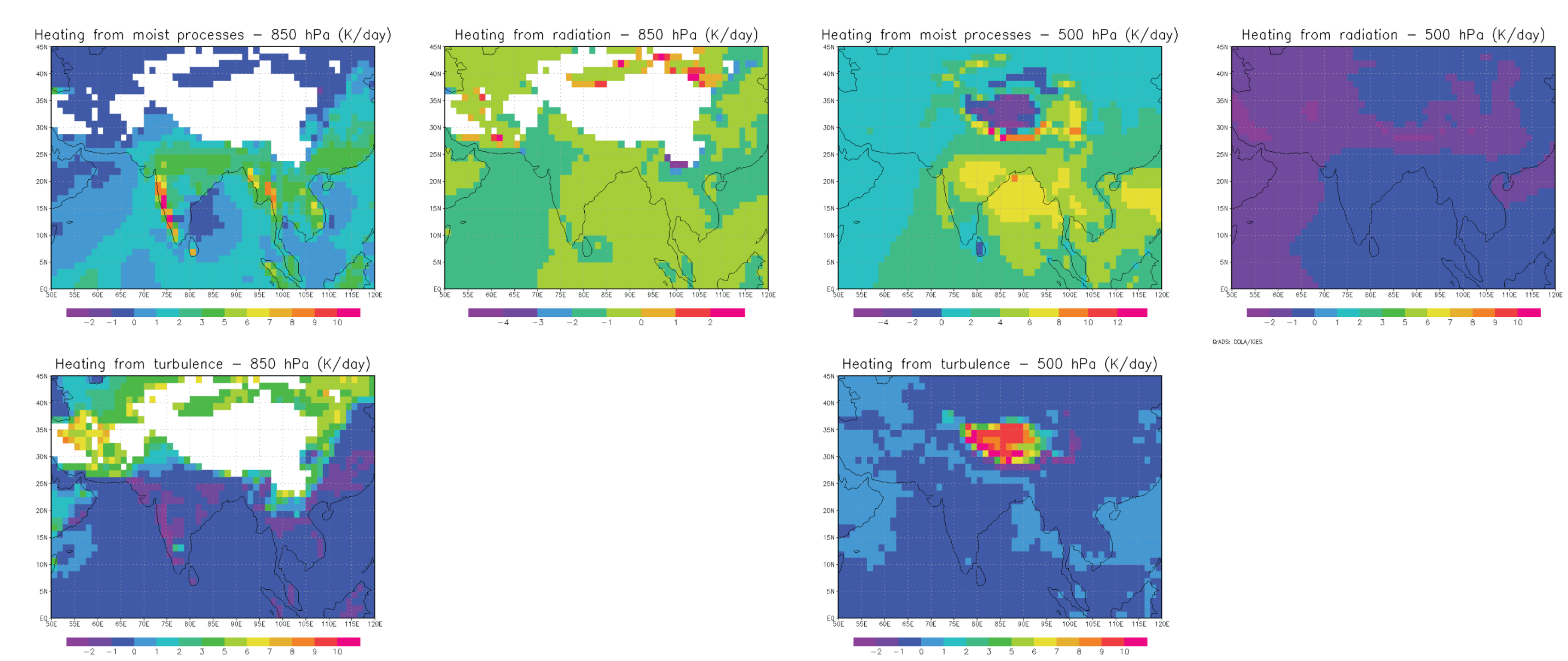
MJJASO TRMM PR 0.05° 17 dBZ Echo Top Height (km)



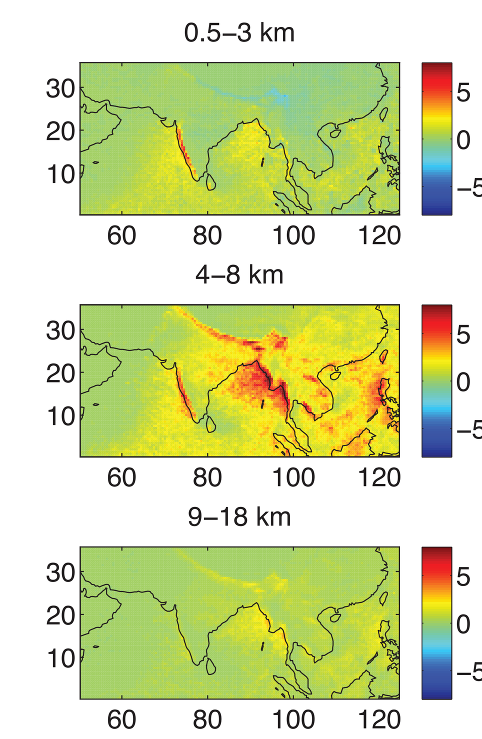
How important is heating from precipitation on coastal ranges?

NASA Modern Era Retrospective Reanalysis (MERRA) heating term output (June-September 1998-2009)

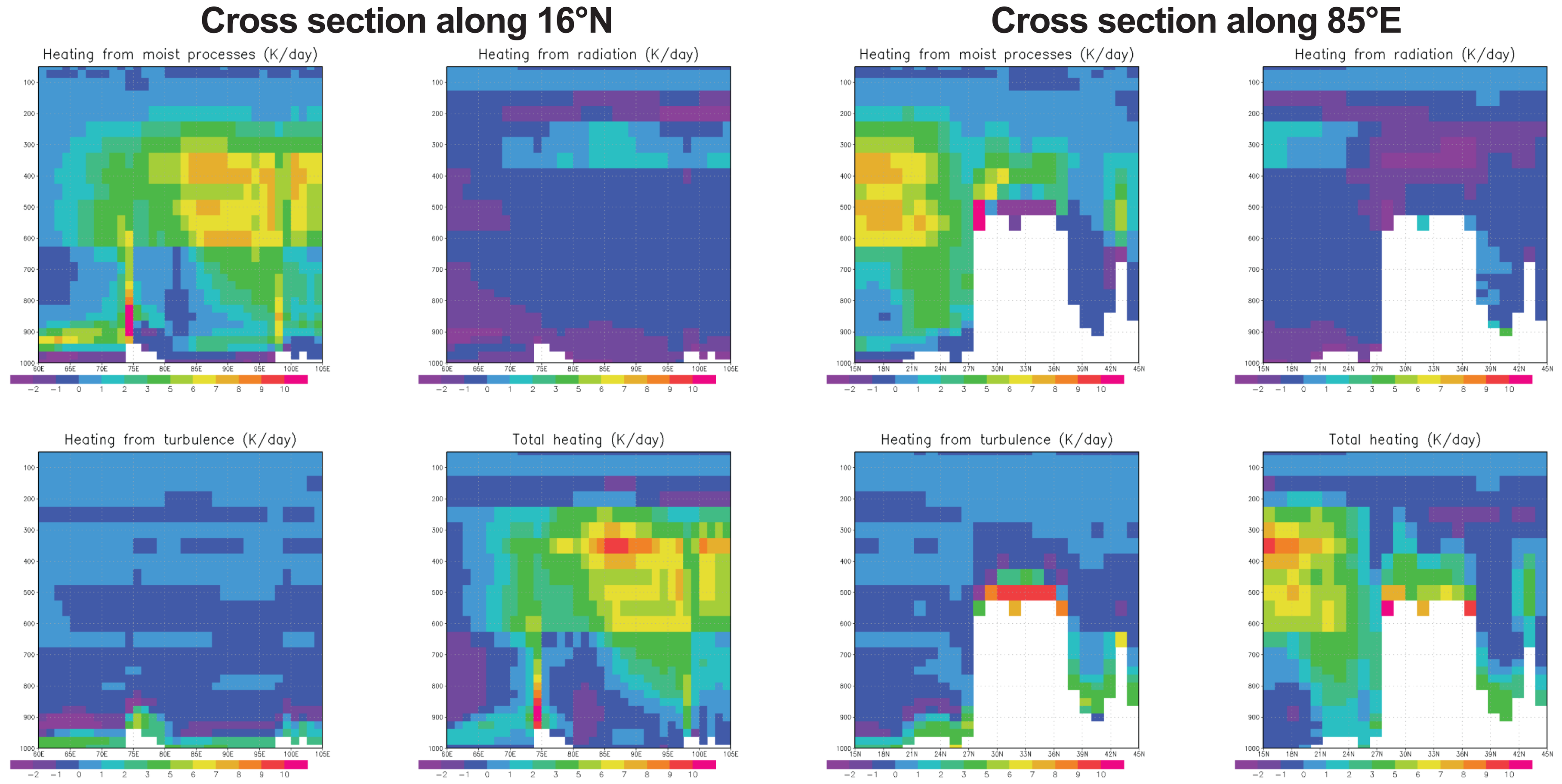
850 hPa **300 hPa**



TRMM CSH LH (K/dy)



Cross section along 16°N **Cross section along 85°E**

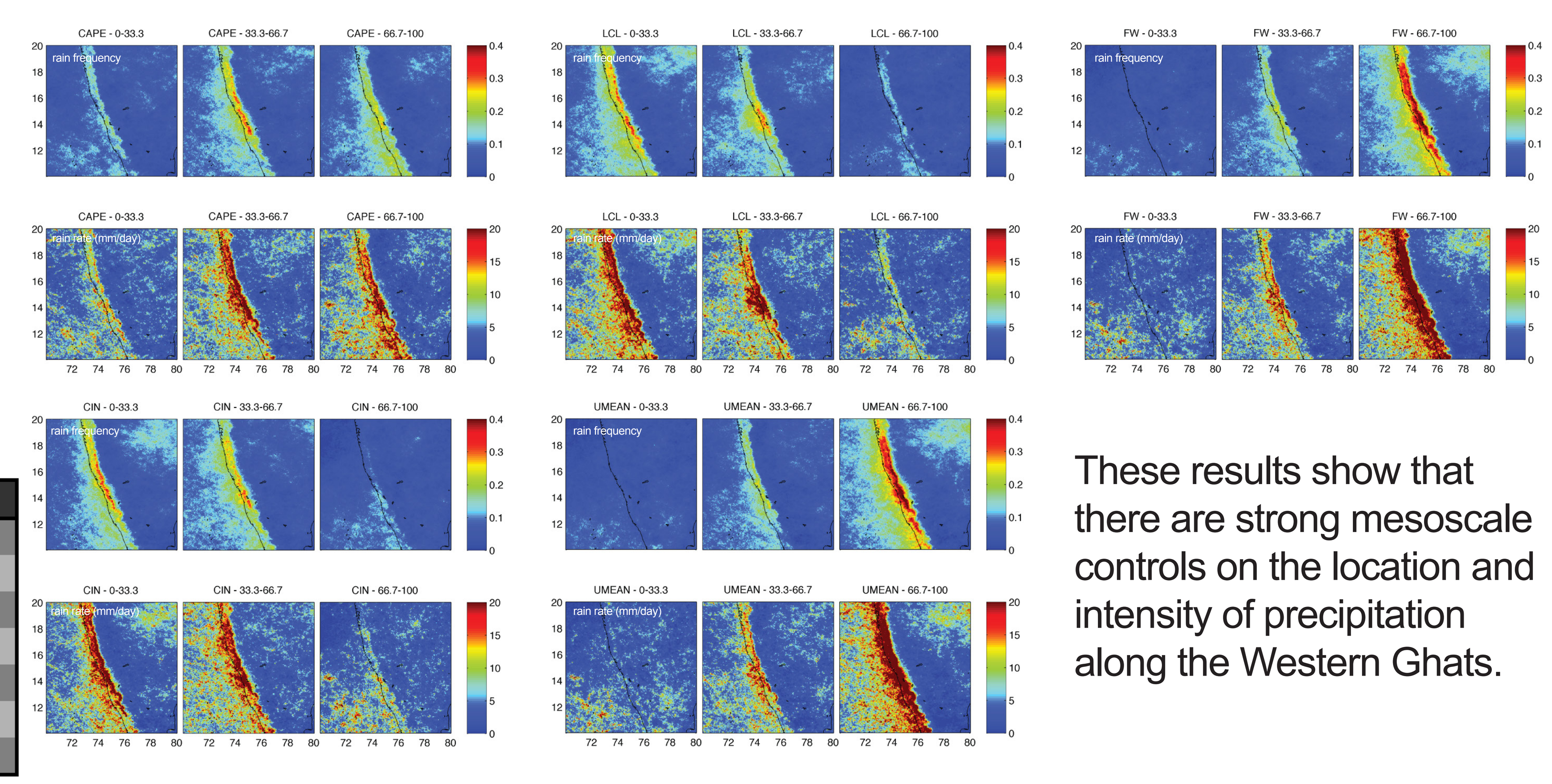


These results show that the peak magnitude of heating (primarily from moist processes in coastal mountain precipitation), nearly equals that over the Tibetian Plateau (primarily due to PBL heating due to sensible heating). Shallow heating over the Western Ghats contrasts the deep heating occurring over India and the Bay of Bengal in MERRA and TRMM heating. In MERRA, heating over the Tibetan Plateau is offset by strong near-surface latent cooling.

Forcing for precipitation variability along the Western Ghats

To investigate mesoscale controls on precipitation in the Western Ghats, selected MERRA fields known to modulate orographic precipitation in conditionally unstable flow were composited in the “upstream region” for May-September 1998-2008 into thirds, the range of those composites are shown in the table below; TRMM PR rain frequency and rain rate composites are presented for each of these composites.

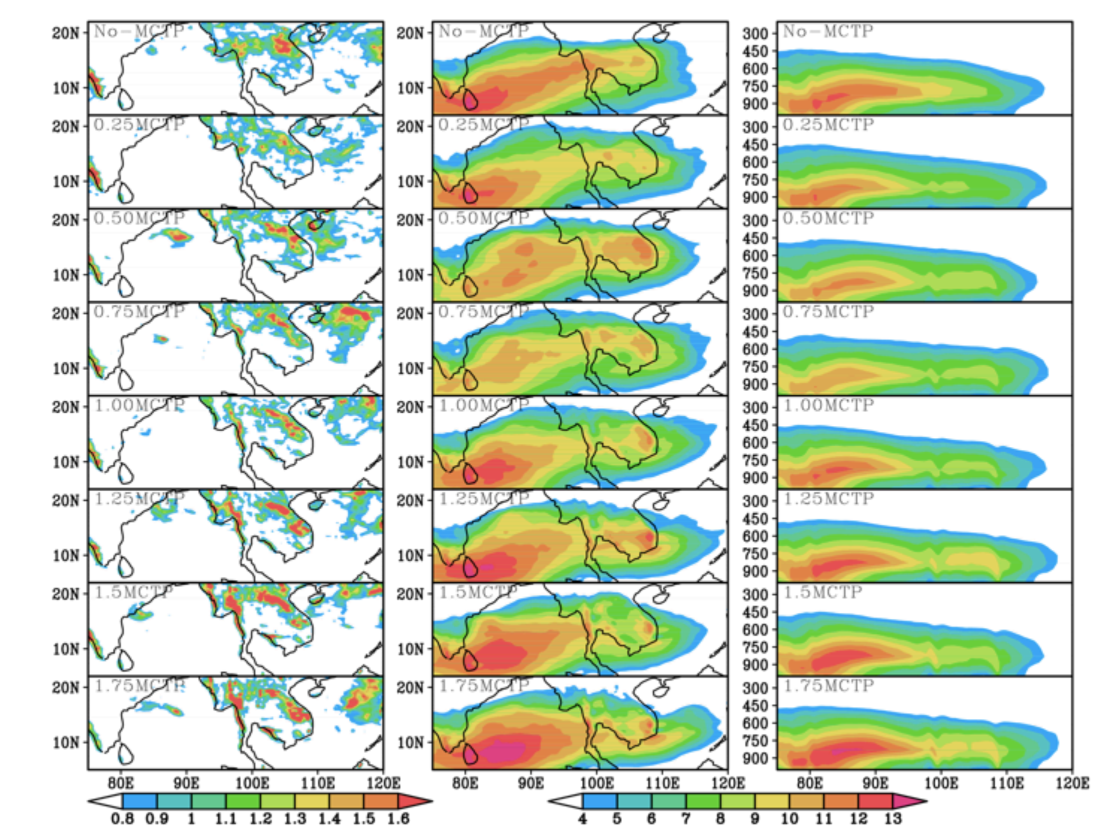
Variable/Parameter	0 - 33.3%	33.3 - 66.7%	66.7 - 100%
CAPE ($J\ kg^{-1}$)	8 - 1063	1063 - 1513	1513 - 3322
CIN ($J\ kg^{-1}$)	0 - 1	1 - 6	6 - 329
LCL (m)	377 - 520	520 - 618	618 - 1455
LFC (m)	414 - 625	625 - 1061	1061 - 2538
F_w	-0.67 - 0.30	0.30 - 0.61	0.61 - 1.32
N_w ($s^{-1}\ km^{-1}$)	7.8 - 10.4	10.4 - 10.9	10.9 - 12.2
U Mean ($m\ s^{-1}$)	-9.4 - 5.3	5.3 - 9.9	9.9 - 21.4



These results show that there are strong mesoscale controls on the location and intensity of precipitation along the Western Ghats.

Wind-terrain interaction caused by coastal precipitation

An idealized version of WRF was run at regional climate model resolution from April 20 - June 30, varying the height of the terrain from 0 to 1.75 times the real topography. The results show that the precipitation over the Western Ghats is not modified by the height of the terrain, but the resultant enhancement caused by the wind-terrain interaction increases dramatically as the model topography increases.



Precipitation (left panels), 850 mb zonal wind (middle panels) and vertical profile of zonal wind averaged between 5-15N in the regional climate model simulations, where the terrain height over Southeast Asia changes from zero to 1.75 times of that observed from the top to the bottom panels. All variables are averaged from April 20 to June 30 in the model simulations.

Summary

TRMM PR precipitation composites reveal intense zones of heavy precipitaion along the coastal mountain ranges of South Asia during the Summer Monsoon. This preciptiaion typically is caused by shallow convection which provides intense heating in the lowest 6 km according to MERRA and observations from the TRMM PR, in contrast to deep stratiform heating occurring elsewhere in the Asian Monsoon. Idealized WRF simulations reveal that this heating may play a major role in the large scale flow patterns in the region.

Acknowledgements

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