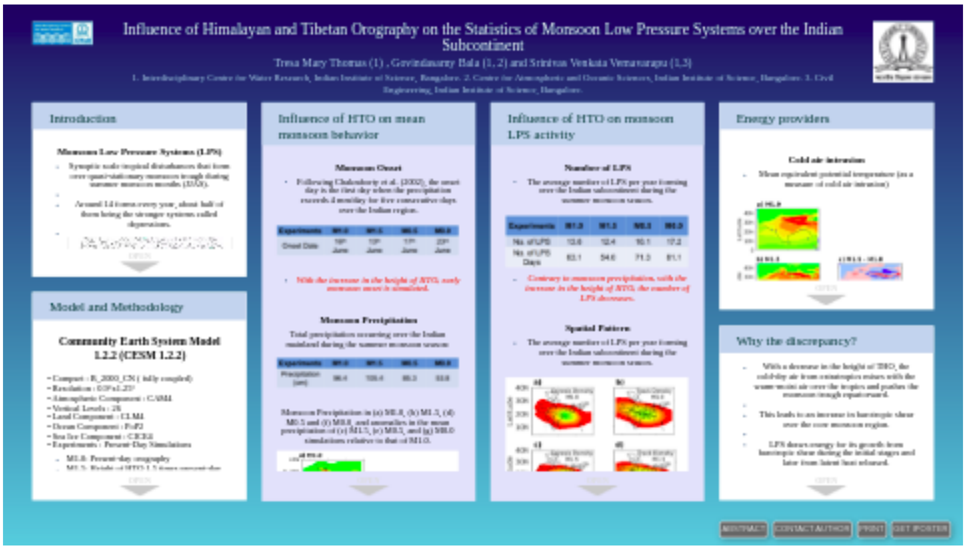
Influence of Himalayan and Tibetan Orography on the Statistics of Monsoon Low Pressure Systems over the Indian Subcontinent



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PRESENTED AT:

1. INTRODUCTION

1.1. Monsoon Low Pressure Systems (LPS)

- Synoptic scale tropical disturbances that form over quasi-stationary monsoon trough during summer monsoon months (JJAS).
- Around 14 forms every year, about half of them being the stronger systems called depressions.
  [VIDEO] https://res.cloudinary.com/amuze-interactive/image/upload/v1637995464/agu-fm2021/42-7F-23-C0-F0-D4-AF-73-C7-7E-41-04-99-95-A8-83/Image/LPS_yfqqy4.mp4
- Mostly form over the warm water of north BoB and move northwestwards.
- Primary rain bearer of the country associated with 60-70% monsoon rainfall.
- Also, trigger extreme precipitation events leading to disastrous floods at many locations.
- 78% of extreme precipitation events in the country are LPS related.

1.2. Himalayan and Tibetan Orography

- Himalayan and Tibetan orography (HTO) has a major influence on monsoon activity in India.
- Removal of HTO results in a late monsoon onset and reduction in summer monsoon precipitation over India.
- A southward latitudinal shift in the location of the monsoon trough axis is also found on the removal of HTO.

2. MODEL AND METHODOLOGY

2.1. Community Earth System Model 1.2.2 (CESM 1.2.2)

- Compset : B_2000_CN (fully coupled)
- Resolution : 0.9°x1.25°
- Atmospheric Component : CAM4
- Vertical Levels : 26
- Land Component : CLM4
- Ocean Component : PoP2
- Sea Ice Component : CICE4
- Experiments : Present-Day Simulations

  - ***M1.0***: *Present-day orography*
  - ***M1.5***: *Height of HTO 1.5 times present-day orography.*
  - ***M0.5***: *Height of HTO 0.5 times present-day orography.*
  - ***M0.0***: *Height of HTO 0.0 times present-day orography.*

- Time Scale : 6-hourly
- Time Period : 37 years

2.2. Tracking Algorithm

Automated Tracking Algorithm using Geopotential Criteria
(ATAGC; Thomas et al. 2021)

3. INFLUENCE OF HTO ON MEAN MONSOON BEHAVIOR

3.1. Monsoon Onset

- Following Chakraborty et al. (2002), the onset day is the first day when the precipitation exceeds 4 mm/day for five consecutive days over the Indian region:

Experiments	M1.0	M1.5	M0.5	M0.0
Onset Date	16th June	13th June	17th June	23rd June

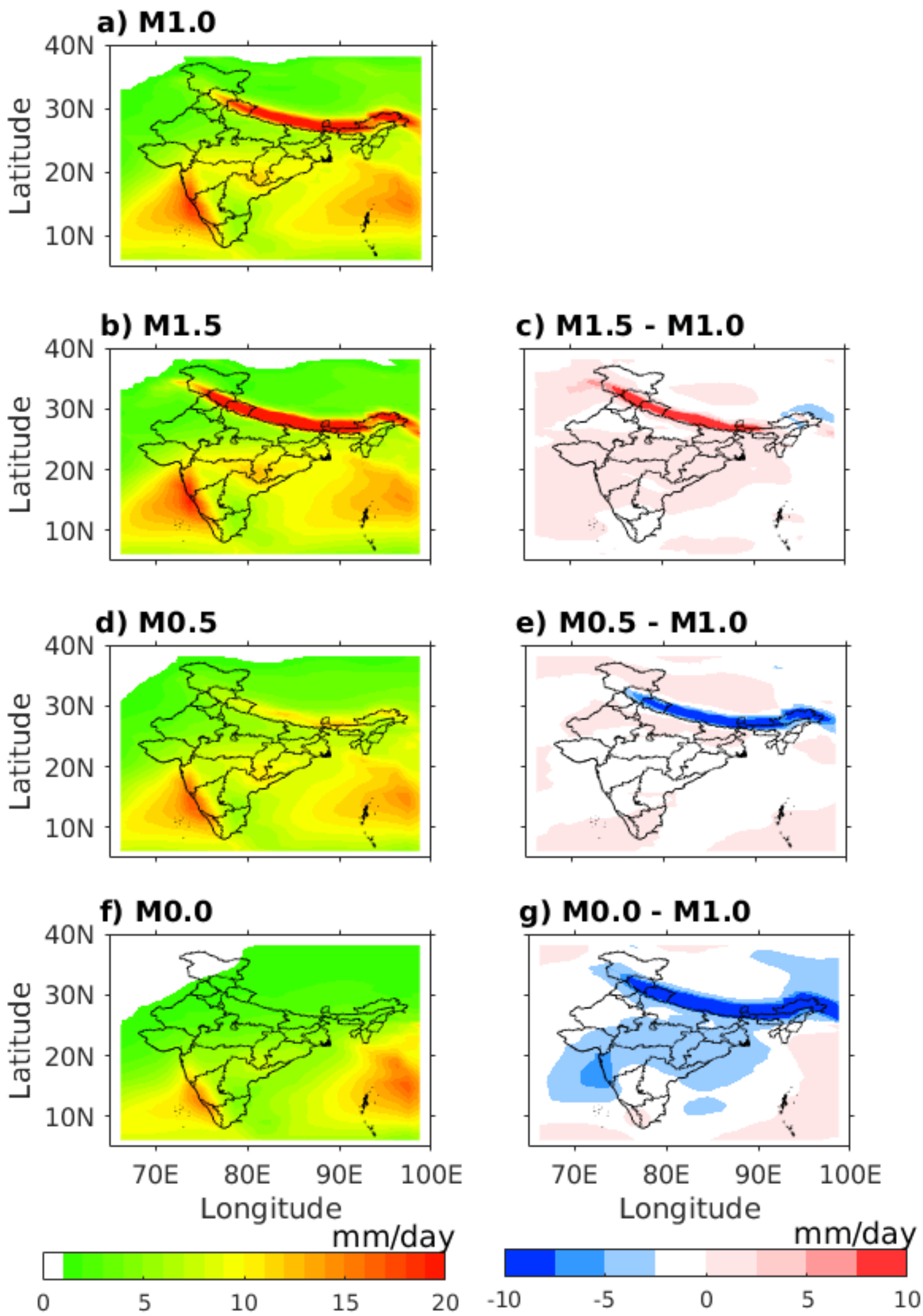
With the increase in the height of HTO, early monsoon onset is simulated.

3.2. Monsoon Precipitation

- Total precipitation occurring over the Indian mainland during the summer monsoon season:

Experiments	M1.0	M1.5	M0.5	M0.0
Precipitation (cm)	96.4	105.4	85.3	53.8

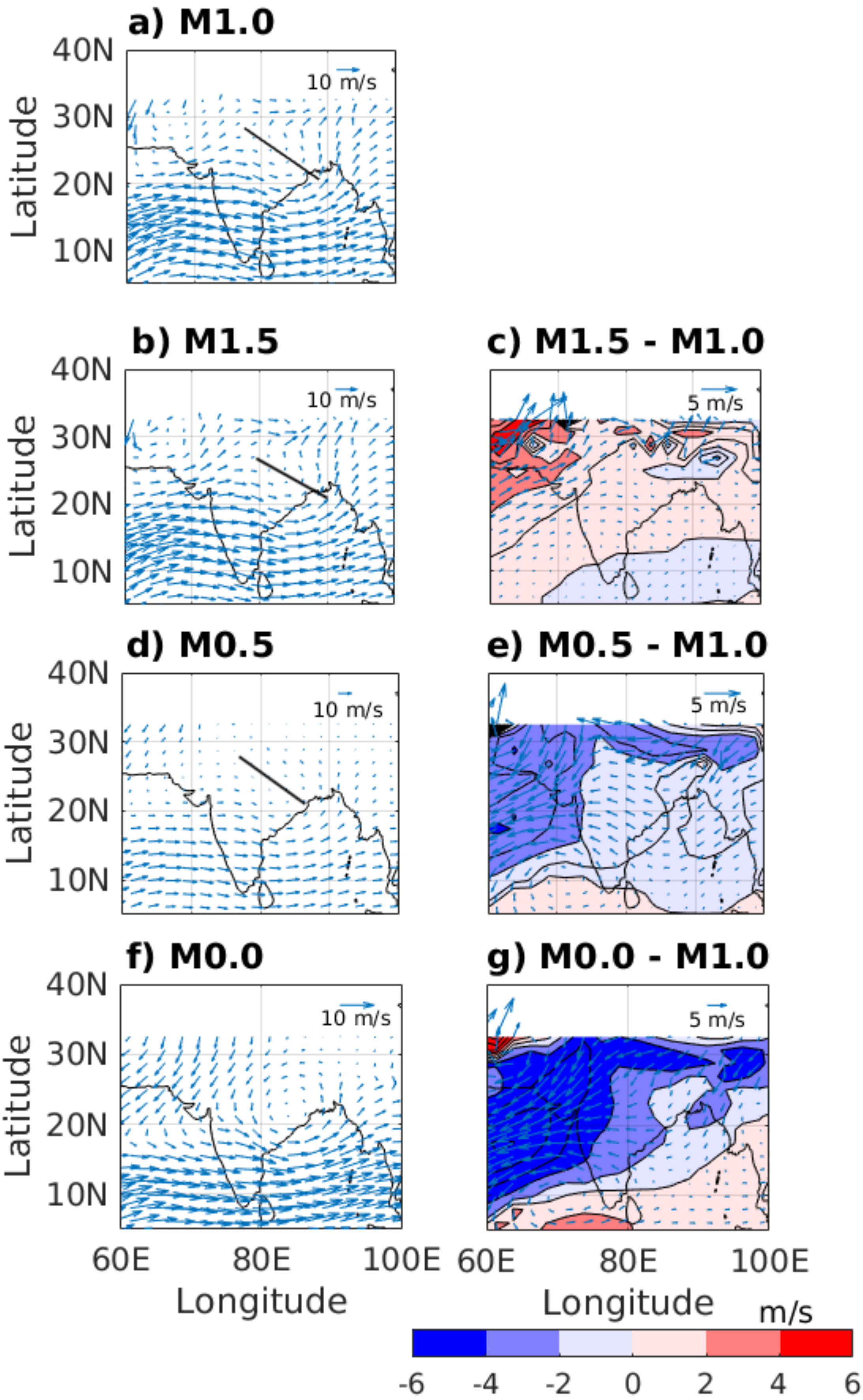
- Monsoon Precipitation in (a) M1.0, (b) M1.5, (d) M0.5 and (f) M0.0, and anomalies in the mean precipitation of (c) M1.5, (e) M0.5, and (g) M0.0 simulations relative to that of M1.0:



With the increase in the height of HTO, mean summer monsoon precipitation increases.

3.3. Monsoon Circulation

- The climatological mean of 850hPa wind during the summer monsoon season in (a) M1.0, (b) M1.5, (d) M0.5 and (f) M0.0, and anomalies in the mean precipitation of (c) M1.5, (e) M0.5, and (g) M0.0 simulations relative to that of M1.0:



With the increase in the height of HTO, mean monsoon circulation intensifies.

4. INFLUENCE OF HTO ON MONSOON LPS ACTIVITY

4.1. Number of LPS

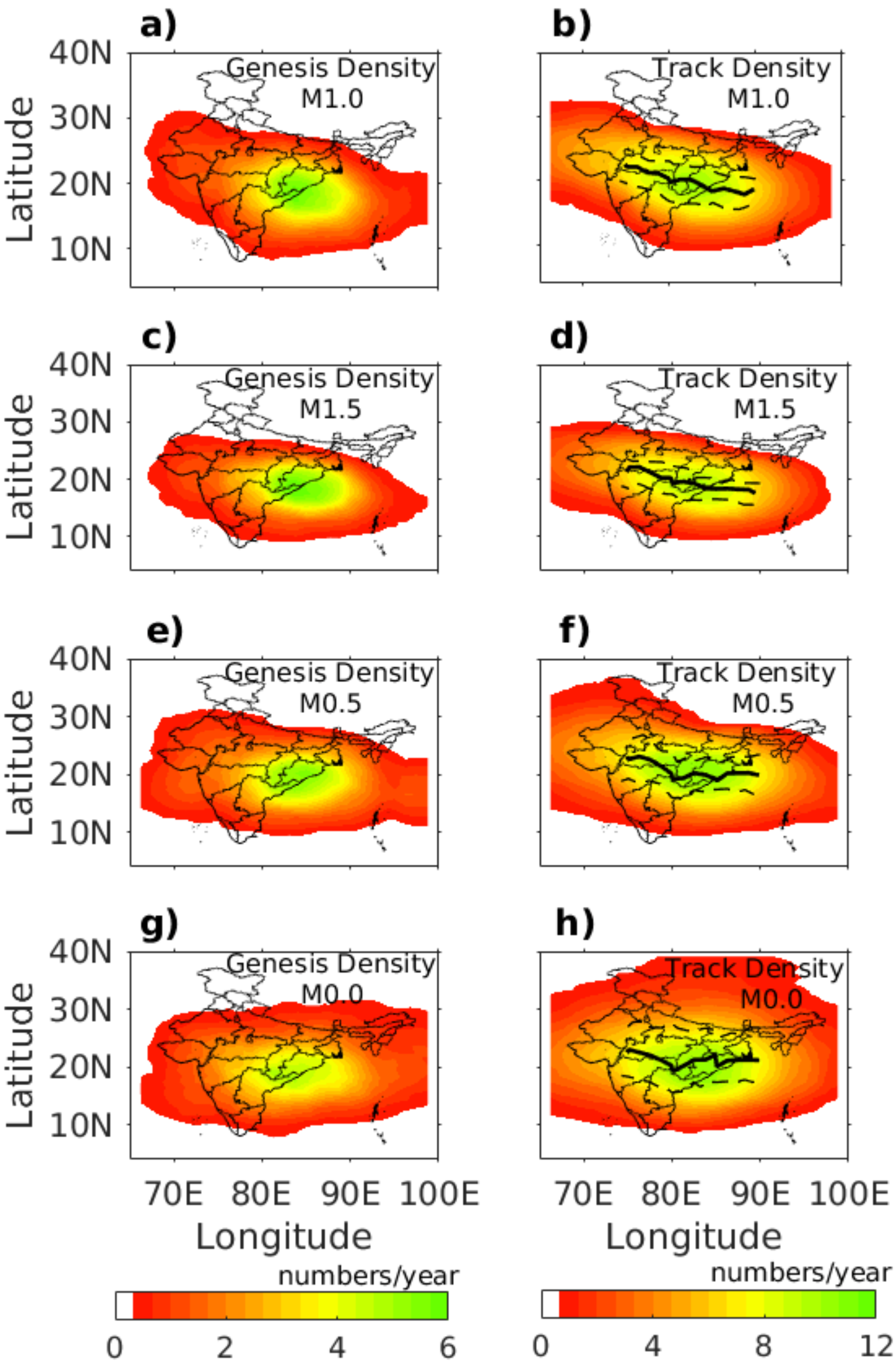
- The average number of LPS per year forming over the Indian subcontinent during the summer monsoon season:

Experiments	M1.0	M1.5	M0.5	M0.0
No. of LPS	13.6	12.4	16.1	17.2
No. of LPS Days	63.1	54.0	71.3	81.1

Contrary to monsoon precipitation, with the increase in the height of HTO, the number of LPS decreases.

4.2. Spatial Pattern

- The average number of LPS and LPS tracks per year forming over the Indian subcontinent during the summer monsoon season:

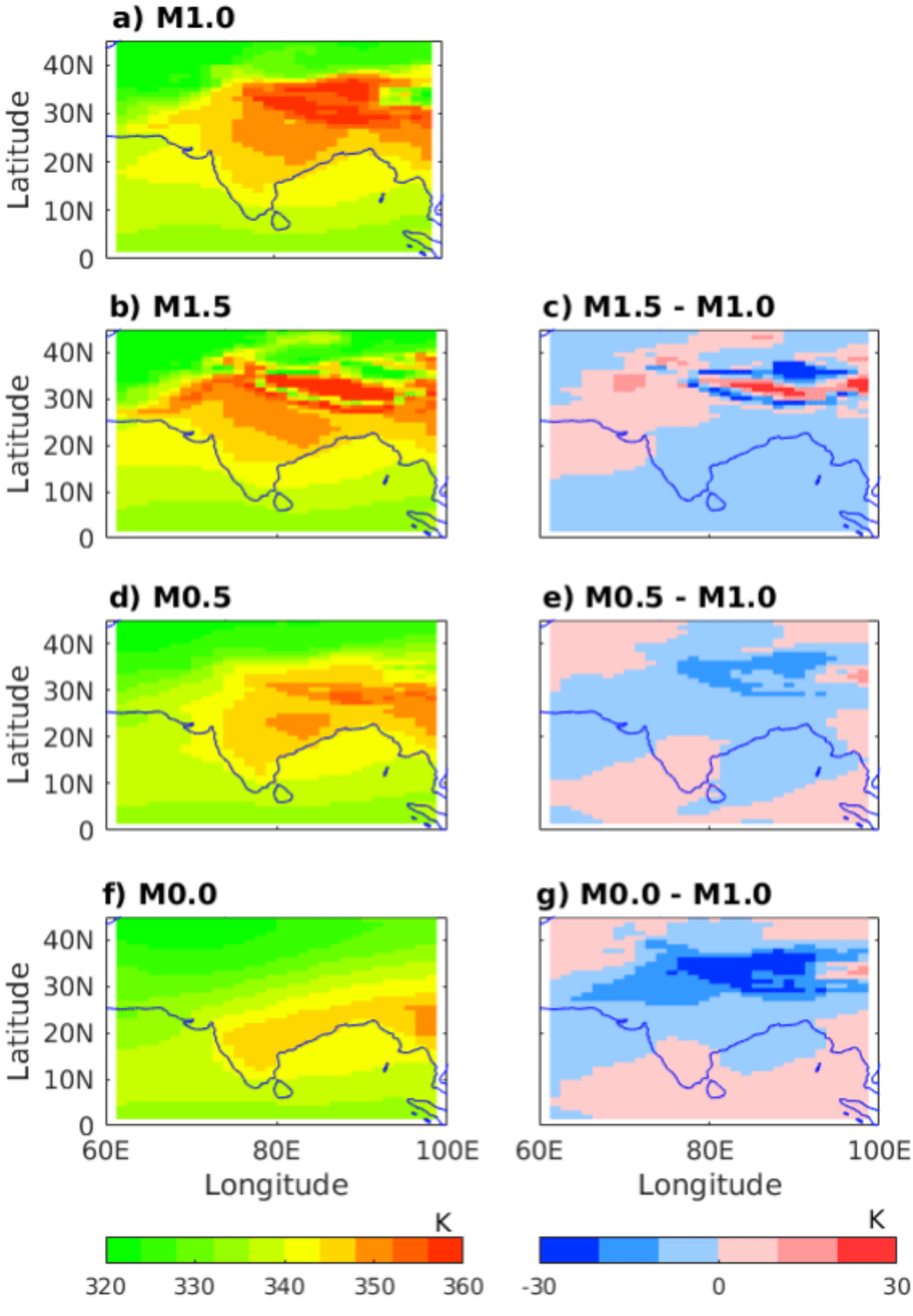


With an increase in the height of HTO, the LPS genesis and tracks shrink in spatial extend.

5. ENERGY PROVIDERS

5.1. Cold air intrusion

- Mean equivalent potential temperature (as a measure of cold air intrusion) in (a)M1.0, (b)M1.5, (c)M0.5, and (d)M0.0:



- With an increase in the height of HTO, the mixing of cold and dry air from extratropics with warm and moist air in the tropics is reduced.

The monsoon trough axis moves further northward when the height of HTO is increased.

5.2. Barotropic Shear

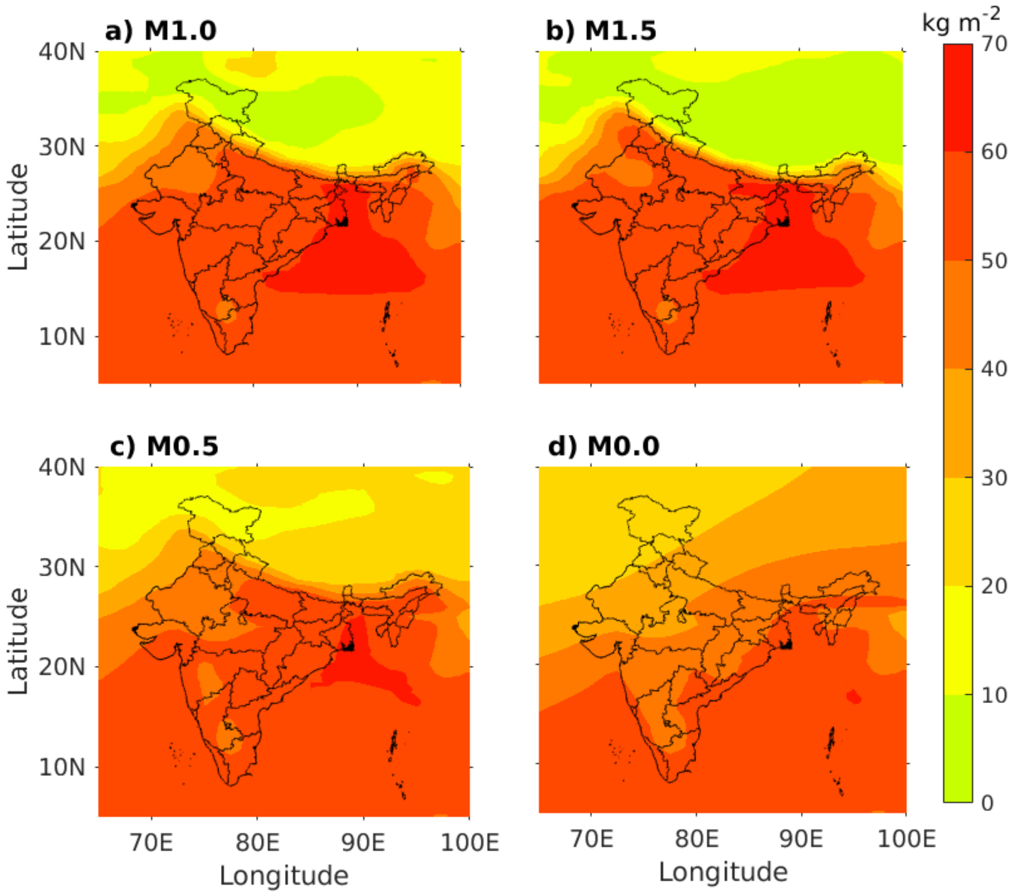
- Meridional shear of zonal wind (which indicates barotropic instability) is determined as the slope of the mean zonal wind between 10⁰N and 26⁰N:

Experiments	M1.0	M1.5	M0.5	M0.0
Barotropic shear (∂U/∂y) (s^{-1})	-0.7	-0.68	-0.73	-0.96

With an increase in the height of HTO, barotropic shear in the monsoon core region decreases.

5.3. Precipitable Water

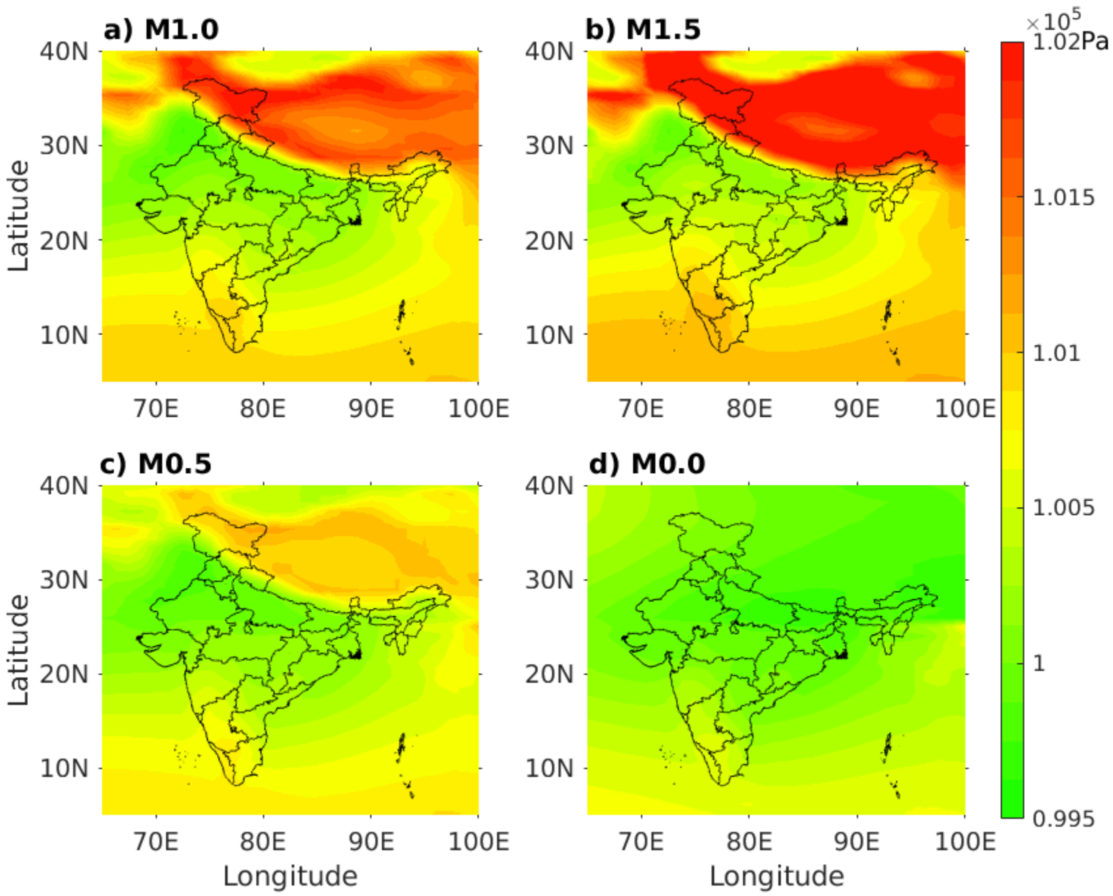
- Vertically integrated total column precipitable water in (a)M1.0, (b)M1.5, (c)M0.5, and (d)M0.0:



With a decrease in the height of HTO, precipitable water is advected into the HTO region.

5.4. Monsoon trough area

- Mean Sea level pressure in (a)M1.0, (b)M1.5, (c)M0.5, and (d)M0.0:



With a decrease in the height of HTO, an expansion in the low-pressure area occurs.

6. WHY THE DISCREPANCY?

- With a decrease in the height of THO, the cold-dry air from extratropics mixes with the warm moist air over the tropics and pushes the monsoon trough equatorward.
- This leads to an increase in barotropic shear over the core monsoon region.
- LPS draws energy for its growth from barotropic shear during the initial stages and later from latent heat released.
- The increase in barotropic shear results in an increase in the number of LPS over India when the height of HTO is reduced.
- Advection of moist air towards HTO provides energy for LPS during the later stages.
- Expansion of the monsoon trough with a decrease in the height of HTO leads to spatial spread in LPS genesis and track density.

Manuscript Submitted in PNAS titled: *'What is the influence of the height of Tibetan Plateau and Himalayas on Monsoon Low Pressure Systems over India?'*

ABSTRACT

Monsoon low pressure systems (LPS) are synoptic scale tropical disturbances that form over the Indian subcontinent along the quasi-stationary trough axis during the monsoon (June to September) period. Around 14 LPS form every year, accounting for around 44% of monsoon precipitation and 78% of extreme precipitation events over the country. Many past studies have investigated the influence of various topographical features on the Indian monsoon. This study investigates the influence of the Himalayan and Tibetan orography (HTO) on various LPS-related characteristics/features (genesis location, number, tracks, and intensity). The NCAR Community Earth System Model (CESM1.2.2) is used to study the influence of HTO on monsoon and LPS activity over India.

Simulations from CESM1.2.2 are obtained at 0.9°×1.25° horizontal resolution by considering the present-day height (*h*) of HTO, and altered heights (zero, 0.5*h*, and 1.5*h*). A 9.3% increase in the average monsoon precipitation is simulated over India when the height of HTO is increased to 1.5*h*, while a decrease in the same by 11.5% (44%) is simulated when the height of HTO is reduced to 0.5*h* (zero). These results are consistent with previous modeling studies. The changes in monsoon precipitation are attributed to a strong (weak) mean meridional temperature gradient (MTG) associated with an increase (a decrease) in the height of HTO and the prevention of cold dry mid-latitude air mixing with the warm humid air over India. Furthermore, we find that the simulated number of LPS per year increases when the height of HTO is reduced. The number of LPS is 17.2, 16.1, 13.6, and 12.4, respectively, in the simulations where the height of HTO is zero, 0.5*h*, *h*, and 1.5*h*. The mean meridional width of the LPS active region also increases when the height of HTO is reduced (Fig. 1).

Contrary to the expectation of a southward shift in the LPS median track with a decrease in MTG (when the height of HTO is reduced), a slight northward shift is simulated in the track's location. We attribute this to an increase (a decrease) in barotropic instability on reducing (increasing) the height of HTO, which results in a larger latitudinal spread in the location of genesis and tracks. The increased (decreased) barotropic instability also causes an increase (a decrease) in the frequency of LPS over the Indian subcontinent.

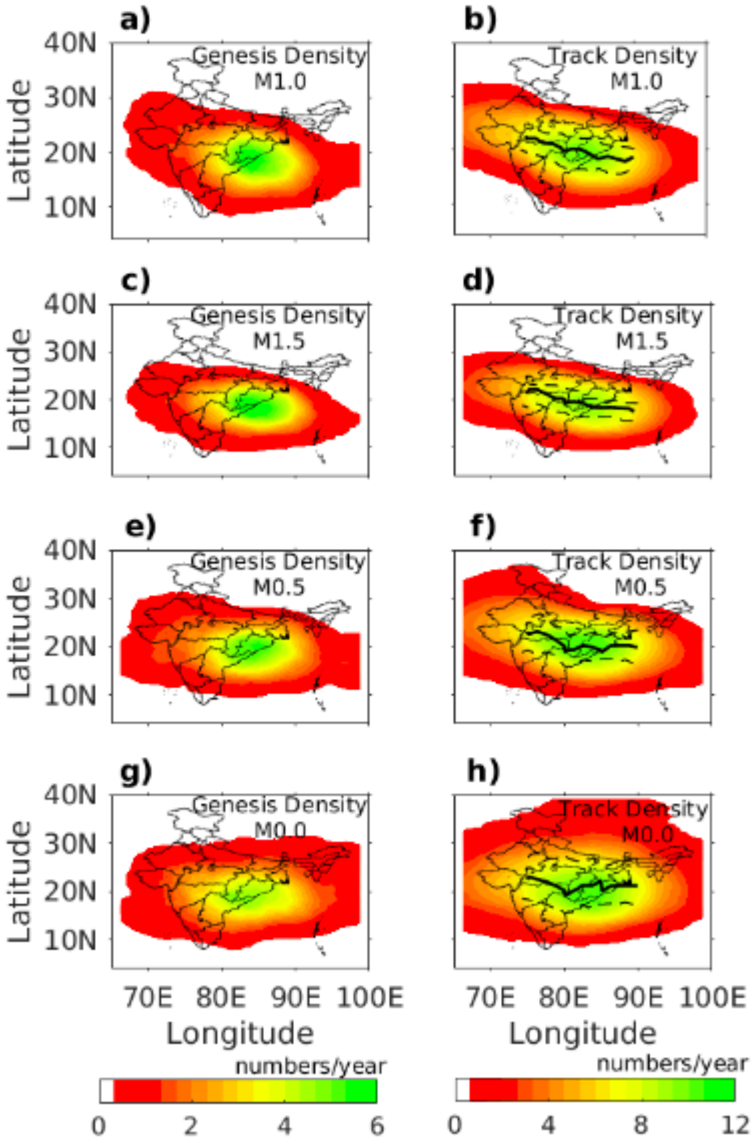


Fig. 1 LPS genesis density (i.e., number of genesis locations per year within 500km radius of a location) and LPS track density (i.e., number of tracks per year within 500km radius of a location) in CESM simulations obtained for 37 years by considering the height of Himalayan and Tibetan orography as unaltered (M1.0), and when it is altered by 1.5 (M1.5), 0.5 (M0.5) and zero (M0.0) times its height. The median track (black solid lines) and 66th percentile (black dashed lines) spread in tracks for all experiments are also shown.

(https://agu.confex.com /data/abstract/agu/fm21/8/7/Paper_829478_abstract_772043_0.png)

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