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Spatial and temporal analysis of deep convection activity over Tibetan plateau and the Himalayan Mountain region.

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Motivation

The Tibetan Plateau (TP) known as the “roof of the world” plays a vital role in weather and climate on a regional and global scale. The exchange of aerosols and water vapor to the upper troposphere and lower stratosphere (UTLS) significantly affects the climate.

- ✓ Monsoon anticyclonic dynamics play an important role in transport of convectively pumped aerosols and trace gases from planetary boundary (PBL) layer to UTLS region. [1,3]
- ✓ Lightning/Thunderstorm is considered as signature of deep convection. [2]
- ✓ This study try to analyse spatial and temporal variation of lightning activity over TP and the Himalayan Mountain (HM) using Tropical Rainfall Measuring Mission (TRMM) data.
- ✓ Simulations using Icosahedral Nonhydrostatic Weather and Climate Model (ICON) at convection resolving scale is used to analyze water vapor transport during lightning events over TP.

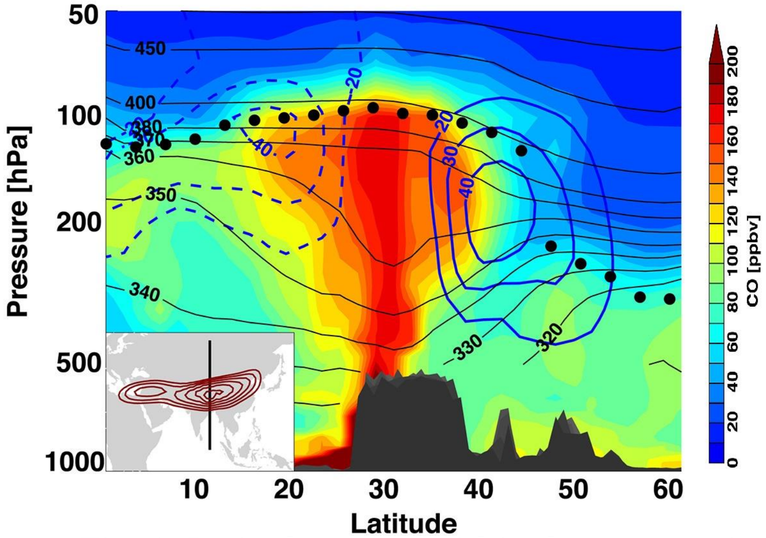


Fig. 1: Latitude-pressure/altitude cross section of CO (ppbv) along 90º E (Pan et al., 2014) [1]

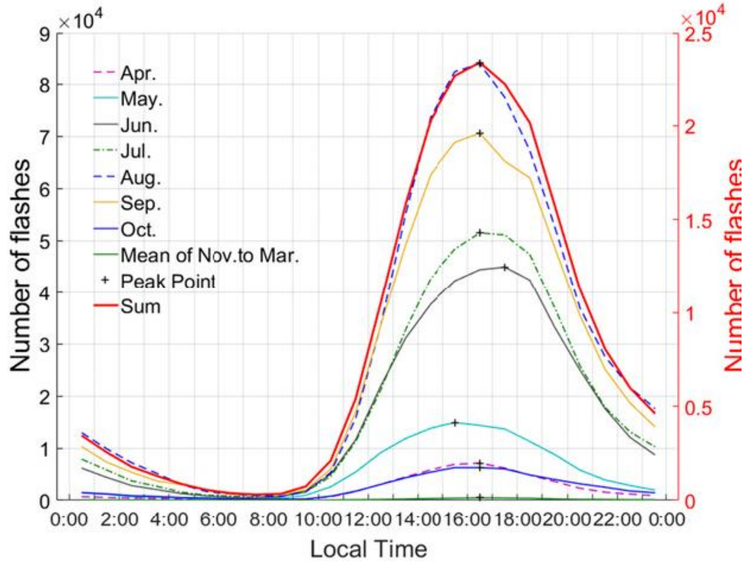


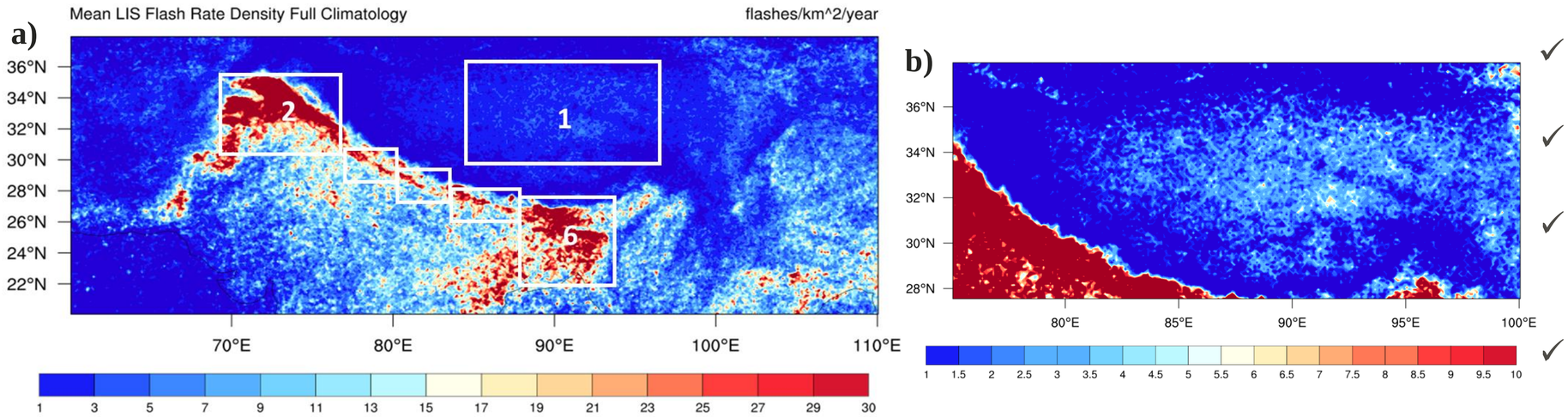
Fig. 2: Diurnal variation in the WWLLN lightning data over Tibetan Plateau from 2010 to 2018 (Ma et al., 2021) [2]

[1] *Pan, Laura L., et al. "Transport of chemical tracers from the boundary layer to stratosphere associated with the dynamics of the Asian summer monsoon." Journal of Geophysical Research: Atmospheres 121.23 (2016): 14-159.*

[2] Ma, Ruiyang, et al. "Spatiotemporal Lightning Activity Detected by WWLLN over the Tibetan Plateau and Its Comparison with LIS Lightning." Journal of Atmospheric and Oceanic Technology 38.3 (2021): 511-523.

[3] Singh, Prashant et al., "Transport of black carbon from planetary boundary layer to free troposphere during the summer monsoon over South Asia." Atmospheric Research 235 (2020): 104761.

Lightning activity over TP and the Himalaya using TRMM data



- ✓ Lightning peak in different period, depends on different circulations over region like monsoon, westerlies.
- ✓ May & June have higher lightning in comparison with rest of the year.
- ✓ Easter HM shows high deep convection activity during March-April.
- ✓ Western HM during September-October.
- ✓ The Southern TP faces maximum disturbance during June-August (12:00-16:00 Local Time (LT)).
- ✓ Eastern and Western HM region peak hours are between 22:00-04:00 LT and 15:00-20:00 LT.
- ✓ The Central HM peaks are between 14:00-19:00 LT.

Fig. 3: TRMM derived lightning climatology from 1995-2014 over a) TP and the Himalaya a) Annual, b) TP

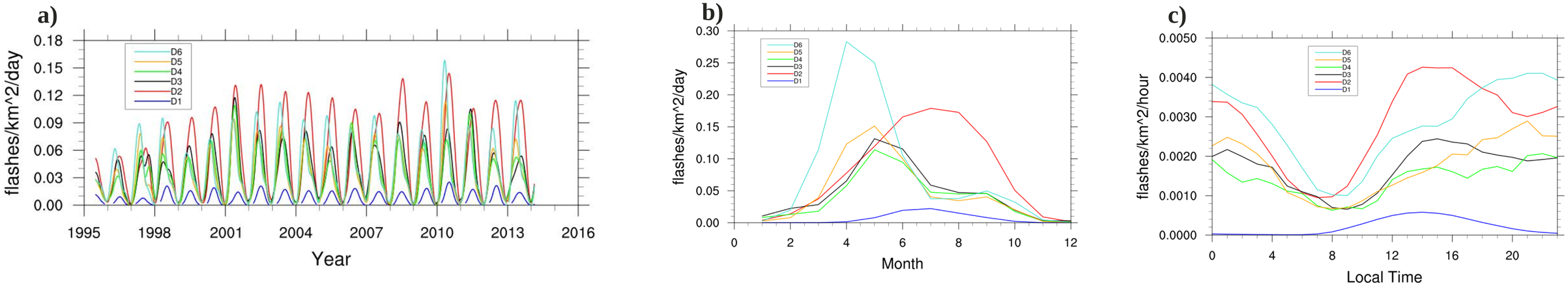
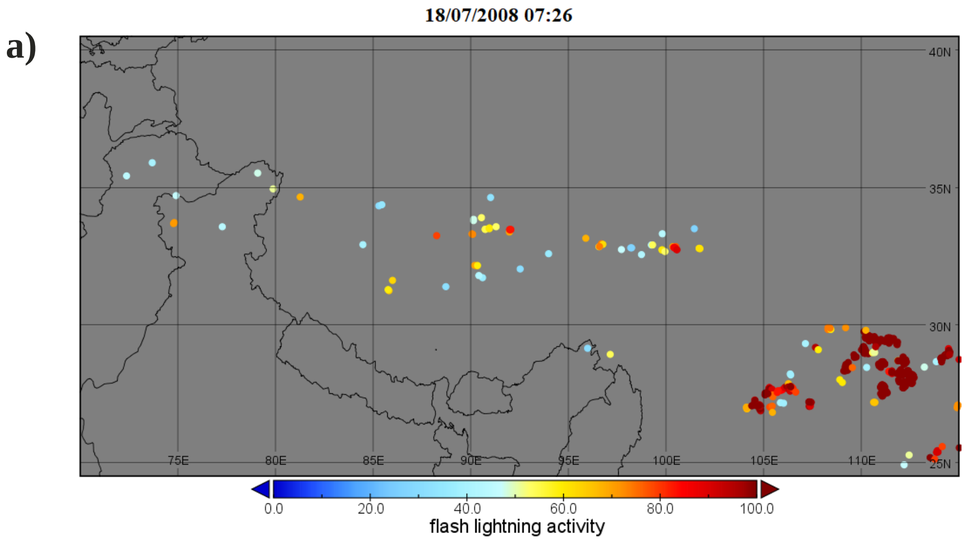
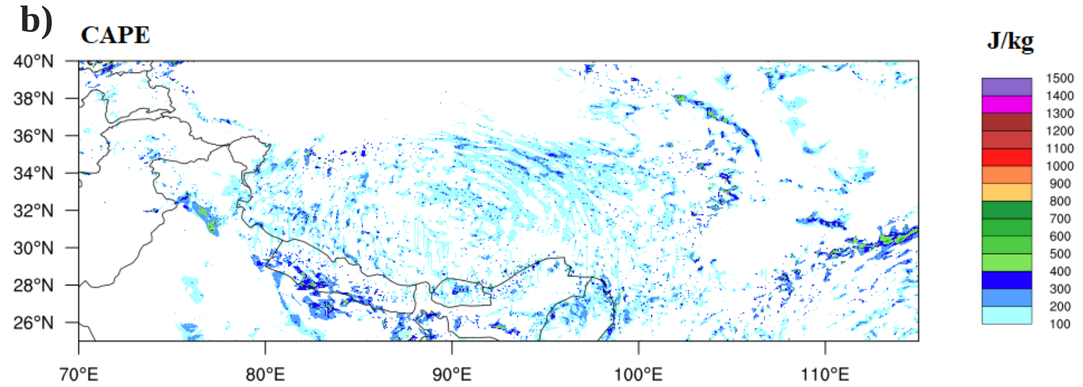


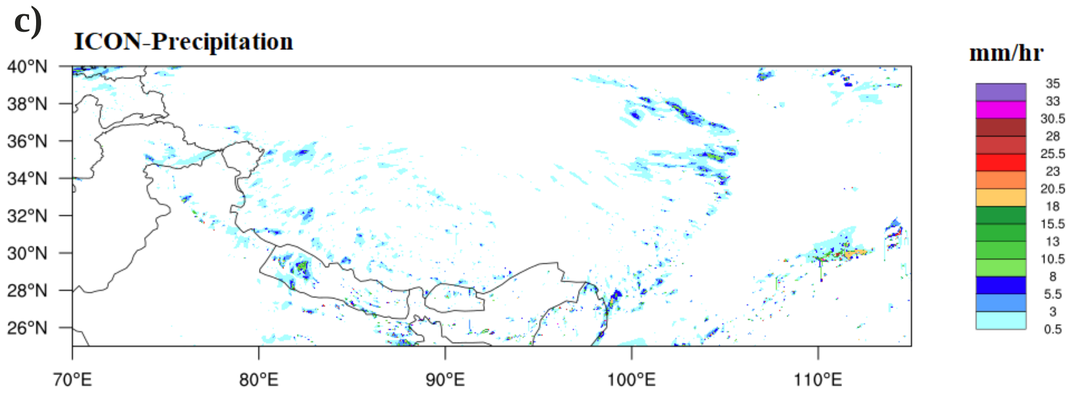
Fig. 4: TRMM derived lightning temporal trend from 1995-2014 over TP and the Himalaya a) Annual, b) Monthly, and c) diurnal

ICON-LAM simulation over TP and the Himalaya Mountain region

- ✓ Various deep convection events are simulated using ICON-LAM at a convection-permitting scale (~3.3 km) covering the domain 25ºN to 40ºN, and 70ºE to 115ºE (Domain can be referred to Fig 5b).
- ✓ We tried to analyse a long-lived mesoscale convective system (MCS) developed over the TP in mid-July 2008.
- ✓ In the area with higher lightning activity (5a), the ICON-LAM simulation shows higher CAPE values (5b), and higher precipitation (5c) which is further supported by TRMM 3 hourly precipitation data (5d).







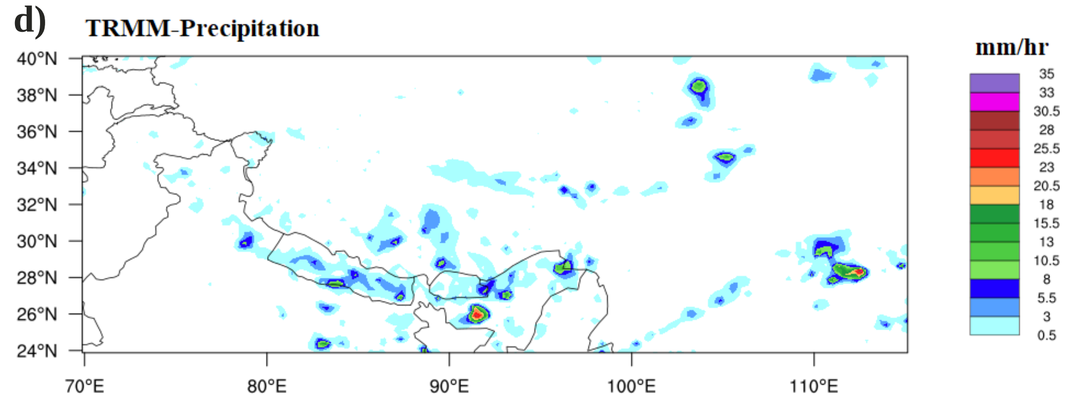


Fig. 5: a) Lightning flashes from TRMM, ICON simulated b)CAPE, c) Precipitation, and d) Precipitation from TRMM on 18/07/2008 ~8 am

Water Vapor Exchange PBL to UTLS during deep convection event

- ✓ Specific Humidity (ICON-LAM) at 100 hPa over the area of deep convection, which is further supported by satellite observation of the H_2O mixing ratio at 100 hPa (AIRS). (fig. 6a& 6b)
- ✓ The western Himalayan region (Karakoram ranges) also shows much higher Specific Humidity.
- ✓ Orography of Karakoram in combination with deep convection might be one of the reason.
- ✓ H_2O vapor pressure from Radio Occultation (RO) MetOp-A satellite shows significant variation in the mid-troposphere during the event from 12 hours (red) and 24 hours (blue) before the event. (Fig. 7) .

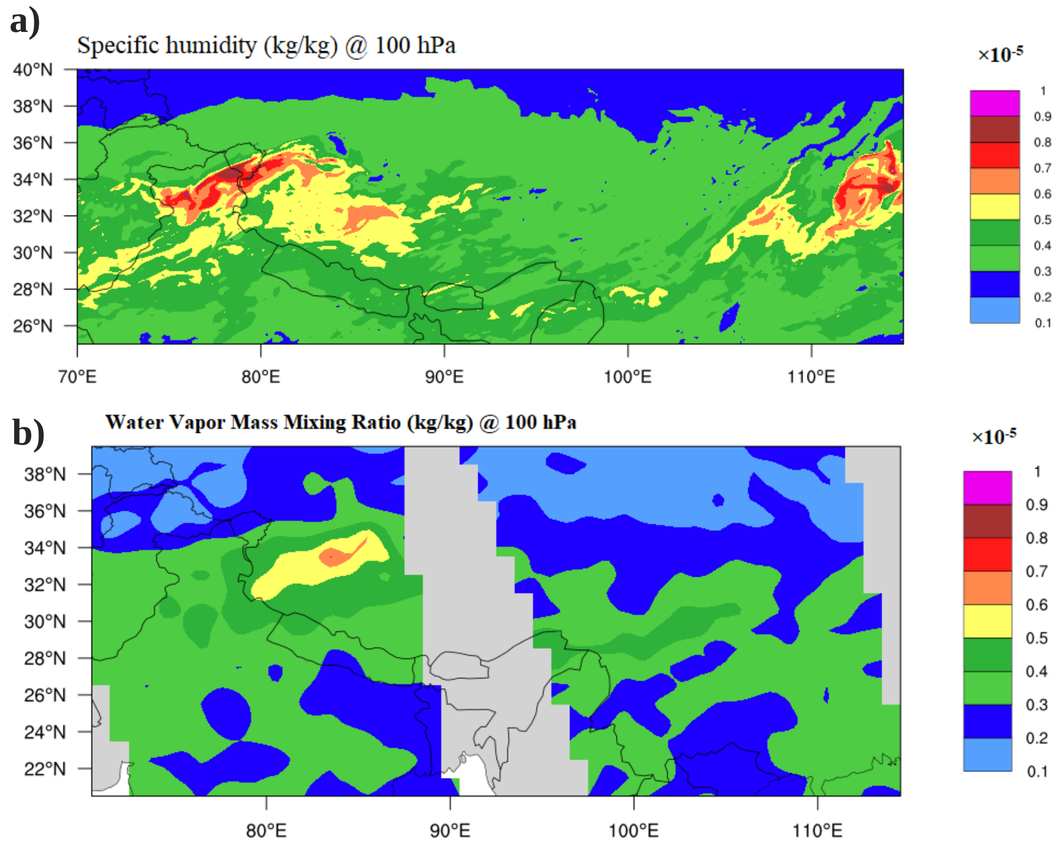


Fig. 6: a) ICON simulated Specific Humidity, and d) H_2O mixing ratio from AIRS on the event day

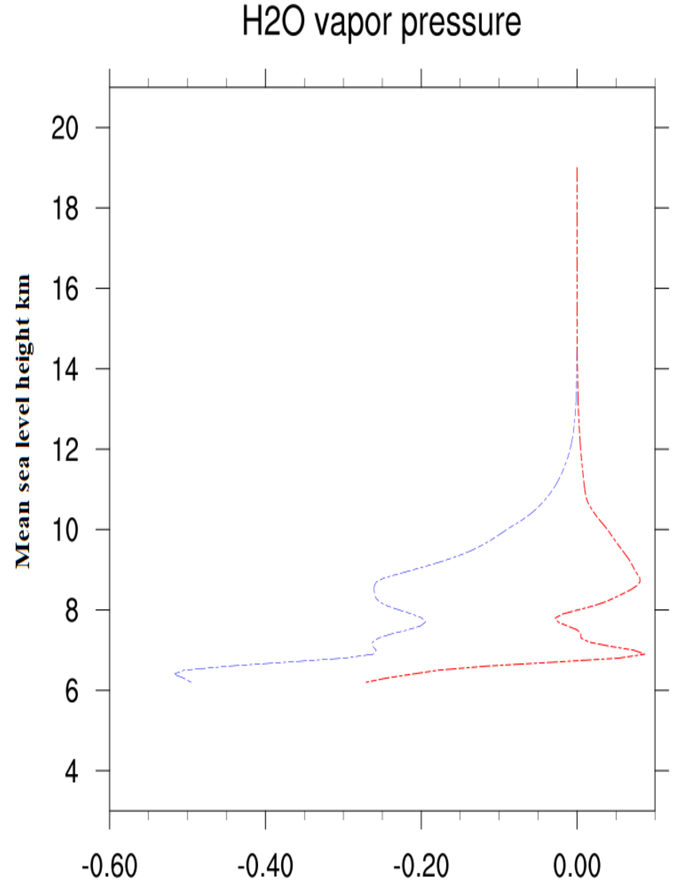


Fig. 7: Change in H_2O vapor pressure from radio occultation (MTPA Satellite), (red) 12 hour and (blue) >24 hour before the lightning event

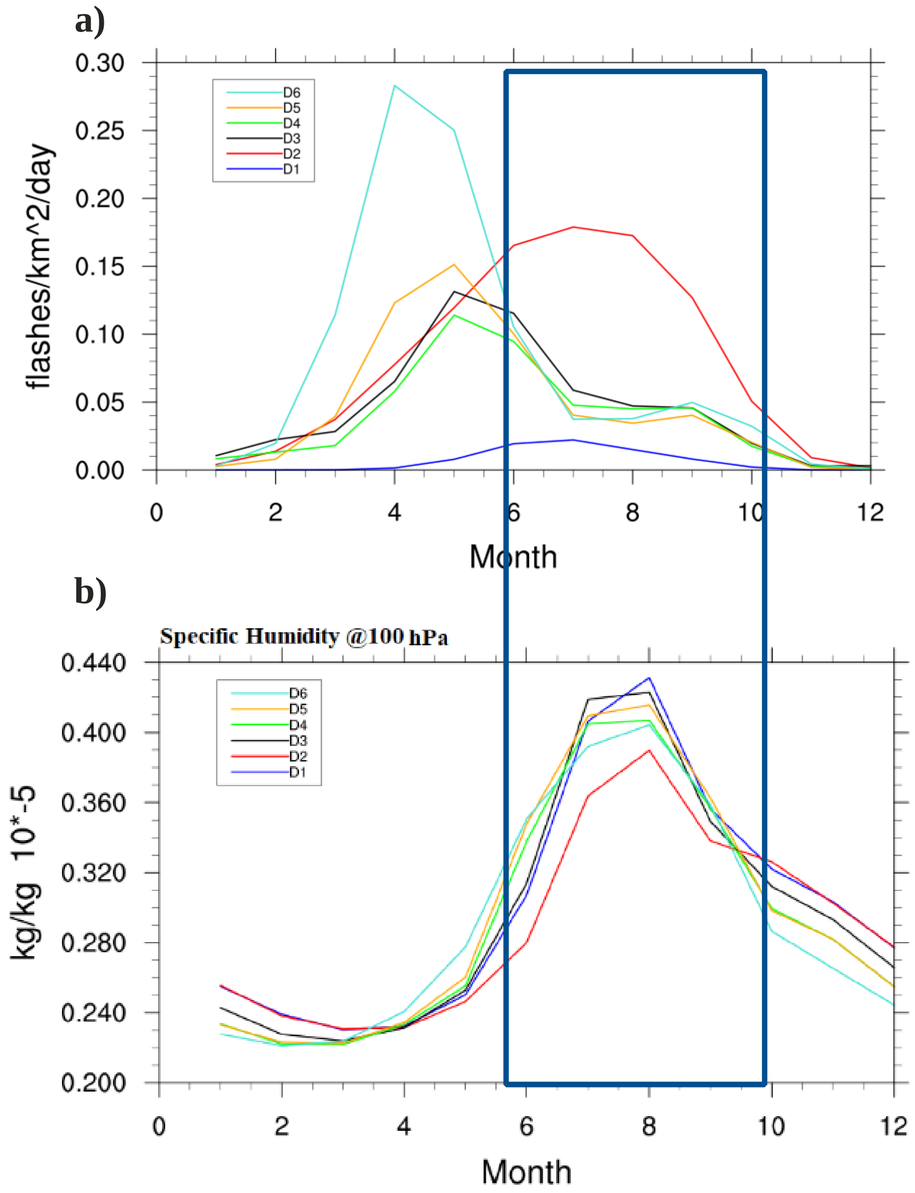


Fig. 8: a) Lightning monthly climatology over selected domain from TRMM data b) Specific Humidity monthly climatology at 100 hPa from ERA5

Conclusion and Way forward ..!!

Preliminary analysis using combination of data from satellite and ICON-LAM suggest ..

- ✓ Lightning activity over the Tibetan Plateau, Western, Central, and Eastern Himalayan Mountain shows different spatial and temporal pattern depending upon different circulation pattern.
- ✓ ICON-LAM at convection resolving scale able to capture long-lived mesoscale system development over the Tibetan Plateau.
- ✓ Model simulation shows significant changes in Specific Humidity at 100 hPa during deep convection events.
- ✓ Whereas Radio Occultation suggest major changes in water vapor during this event is in mid-troposphere.
- ✓ Therefore, deep convection in combination with anticyclonic monition motion and/or orographic lifting plays an important role in water vapor transport in UTLS region (Fig. 8).
- ✓ Further long simulation need to perform and analyse to quantify the role of monsoon, westerlies, orography etc in transport of convectively pumped water vapor from PBL to UTLS region.

Thank You ..!!