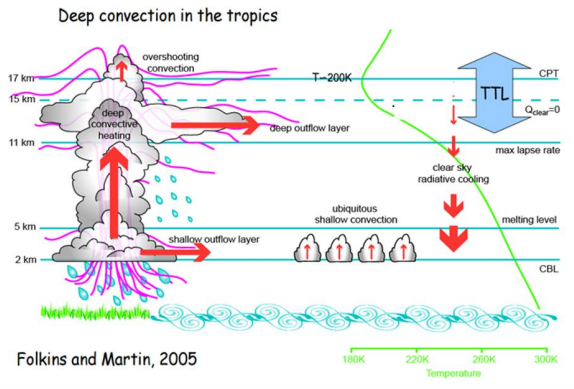
THE IMPACT OF THE MESOSCALE CONVECTIVE SYSTEM ON THE UPPER TROPOSPHERE LOWER STRATOSPHERE (UTLS) COMPOSITION OVER THE ASIAN MONSOON REGION

Tesna Maria[1], Ajil Kottayil[1], Prince Xavier[2]

[1] Satellite Remote Sensing and Application (SRA) Group,
Advanced Centre for Atmospheric Radar Research (ACARR),
Cochin University of Science and Technology (CUSAT), Kerala, India
[2] Met Office, Exeter, United Kingdom.

INTRODUCTION

Convective Processes and UTLS

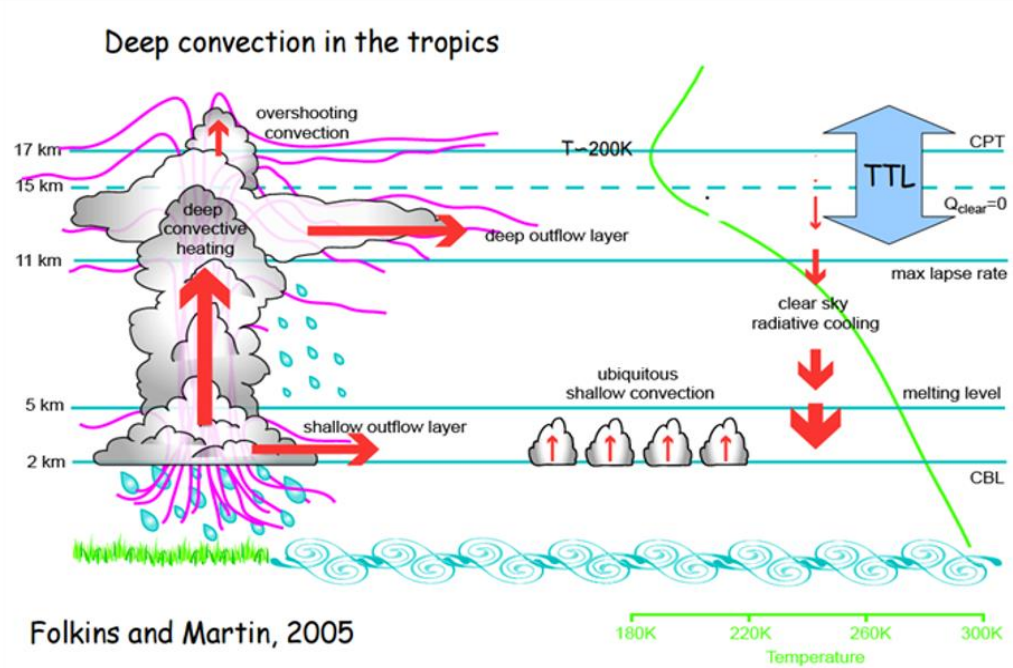


- The global climate is also influenced by the small variations in the stratospheric humidity.
- Deep convective clouds that rapidly transport humid air up to the tropical upper atmosphere region could potentially influence the stratospheric water vapour.
- Processes associated with atmospheric waves and convection also play a role in the dehydration of air entering the stratosphere through the tropical tropopause layer (TTL).
- Several studies using storm-resolving models have indicated that tropopause-overshooting convection can hydrate the lower stratosphere, but the impact of overshooting convection on the global stratospheric water vapour budget based on observations is unclear.
- Deep convective sources of stratospheric water vapour are generally small; a quantitative assessment of the convective impact on a global scale, such as for the boreal summer, requires further investigation.
- The deep convection hydrates or dehydrates the TTL is one of the debatable topics.

INTRODUCTION

TROPICAL TROPOPAUSE LAYER (TTL)

- Zone with properties of both the troposphere and stratosphere
- Bounded by the region of strong convective outflow to the highest altitudes influenced by convective overshooting and tropical tropospheric processes (12-19 km) (215 - 56 hPa)



Tropical Tropopause Layer can influence climate **:**
Long-term variation in the TTL can be taken as the indicator of climate change.
It has also crucial impact in the radiative processes of the atmosphere.

Climate Influence: Changes in the TTL temperature can impact the water vapor content in the stratosphere, in turn influencing climate patterns and processes.

Indicator of Climate Change: Long-term variations in the temperature and altitude of the tropopause are considered sensitive indicators of climate change.

Radiative Processes: Understanding the radiative processes in the TTL is important for comprehending the overall energy budget of the Earth's atmosphere.

Convective and Thermodynamic Processes: Studying these processes in the TTL contributes to a deeper understanding of atmospheric dynamics, especially in tropical regions.

DATASETS

Precipitation data

GPM IMERG data

The Precipitation feature detection method : **Xavier et al (2024)**

- Threshold-based detection of contiguous grid points that exceed precipitation values greater than 5, 10, 15, and 20 mm per day.
- Precipitation object attributes: mean, **maximum**, and **minimum precipitation** within the object **area**; standard deviation, their geometric coordinates, area, perimeter, orientation, eccentricity, centroid, effective radius, etc.
- The object area: Number of grid points
- Area of MCS = No of grids x 100 km^2

AURA MLS data (2004-2019)

- **H_2O**

Spatial: 165 km x 3 km, Vertical: 1.5 - 6 km

- **CO :**

Spatial: 165 km x 3 km, Vertical: 3 - 6 km

- **SO_2 :**

Spatial: 165 km x 3 km, Vertical: 3 - 6 km

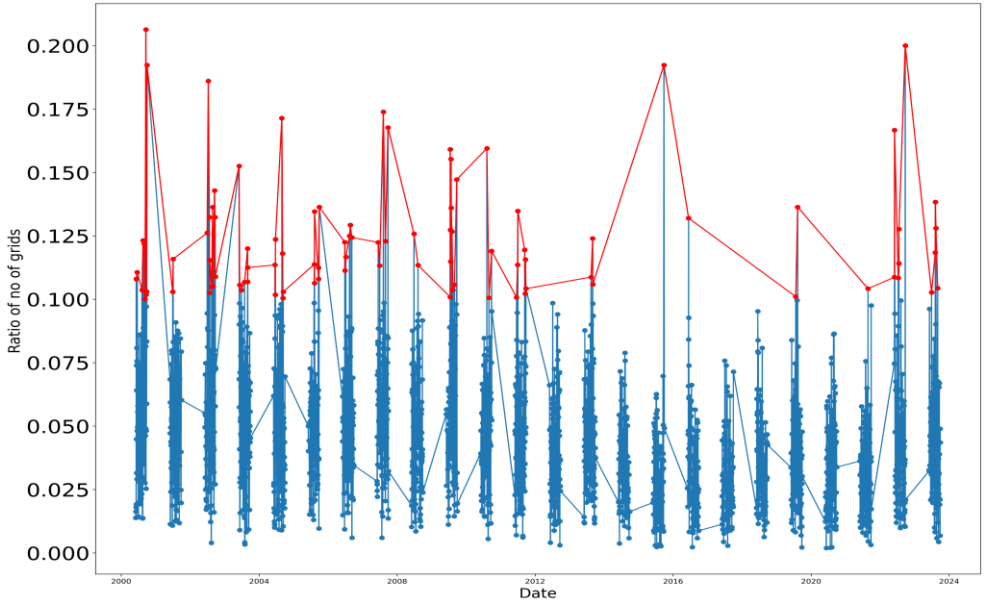
Re-gridded data : 0.5^o x 0.5^o spatial resolution

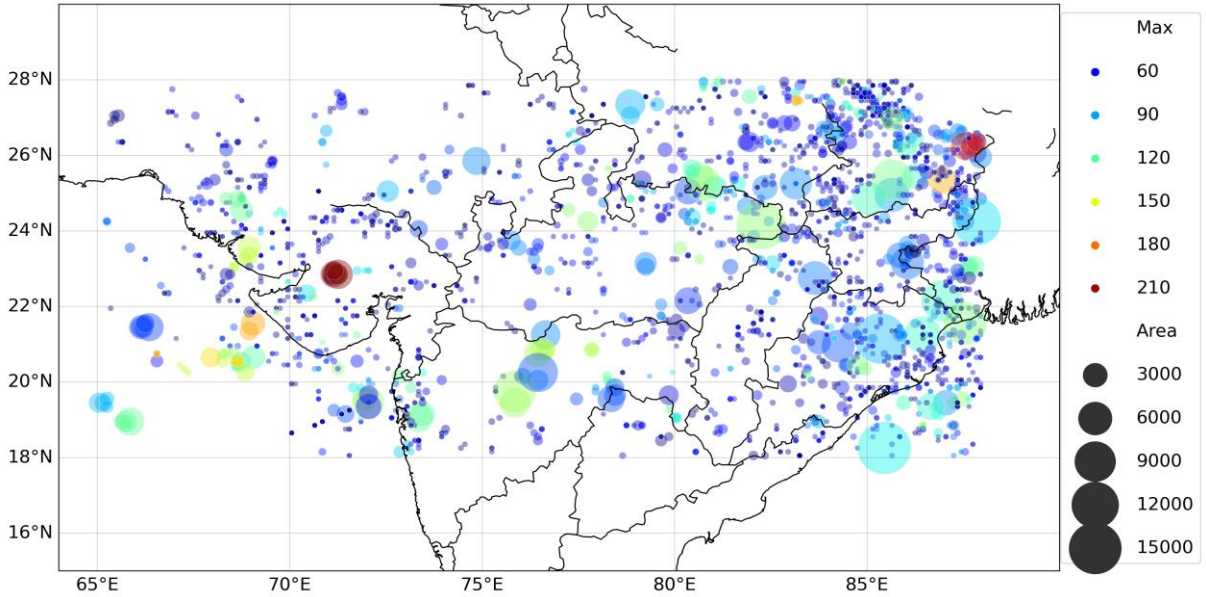
METHODOLOGY

MCS Phase

The precipitation object where the ratio of the number of grids above **0.10 for MCS phase** over the core monsoon region are selected for further studies.

$$\text{Ratio of MCS} = \frac{\text{No. of features} > 40 \text{ mm/day}}{\text{Total no of features}}$$



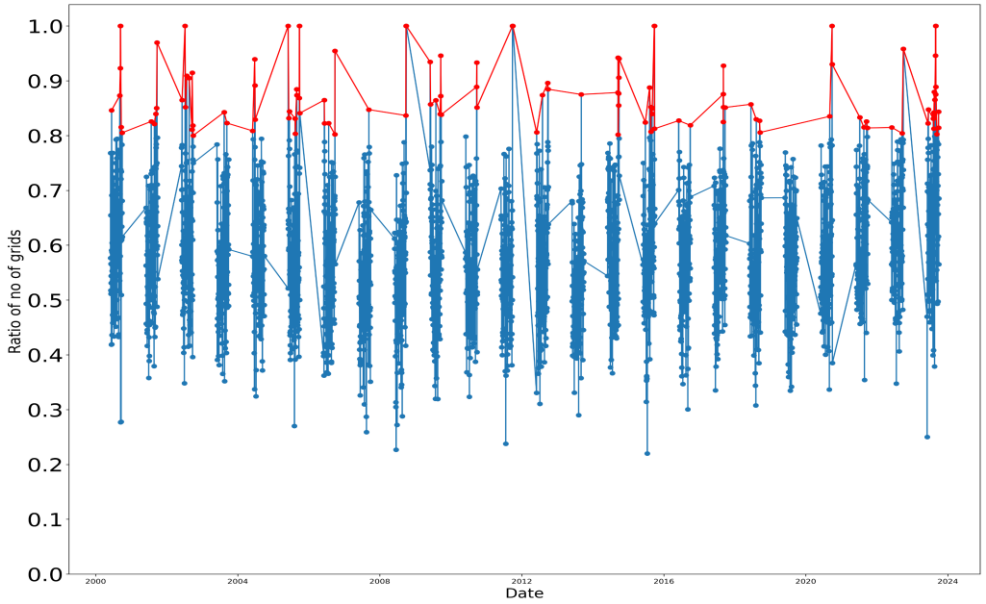


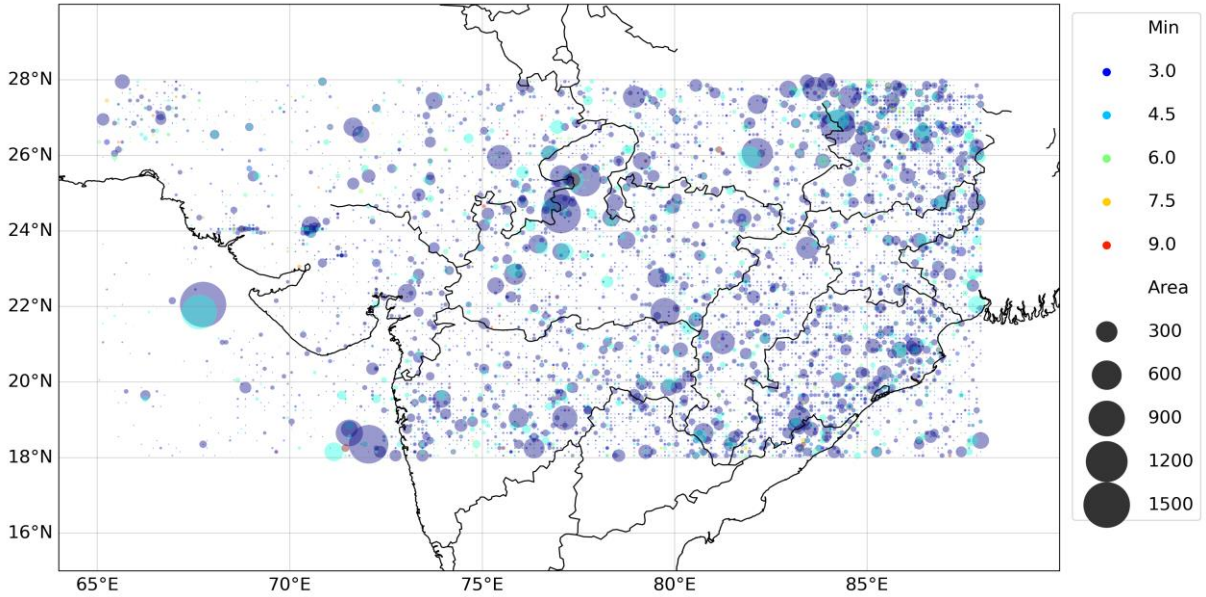
METHODOLOGY

Non-MCS Phase

The precipitation object where the ratio of the number of grids above **0.80 for non MCS phase** over the core monsoon region are selected for further studies.

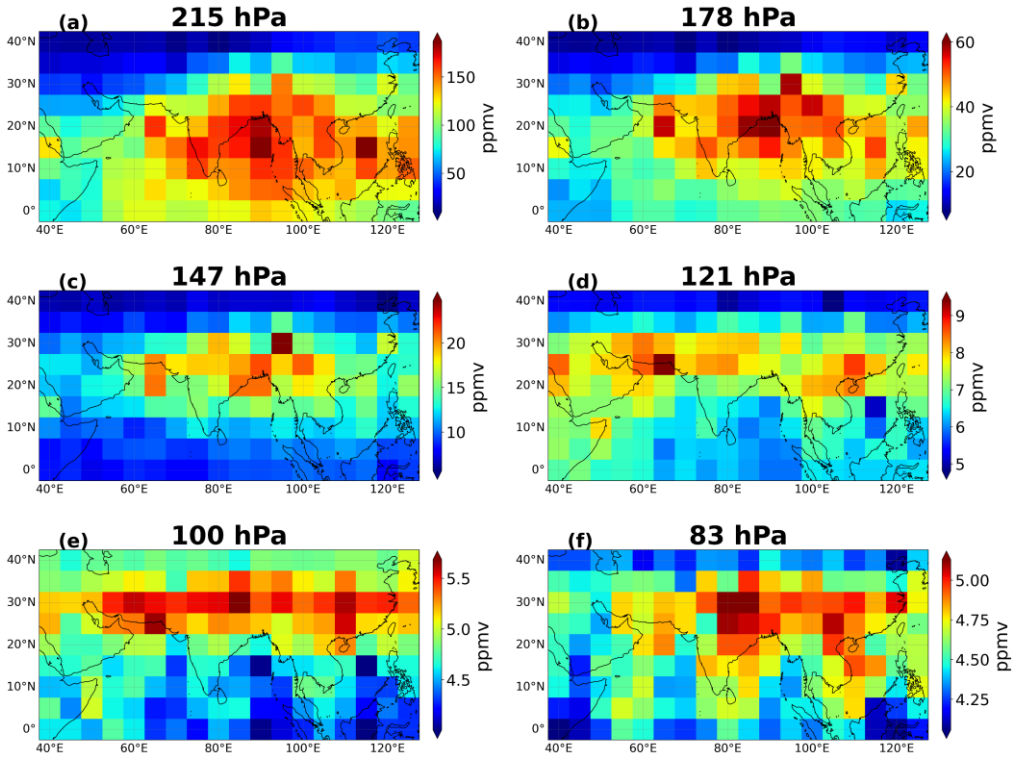
$$\text{Ratio of non-MCS} = \frac{\text{No of features} < 10 \text{ mm/day}}{\text{Total no of features}}$$



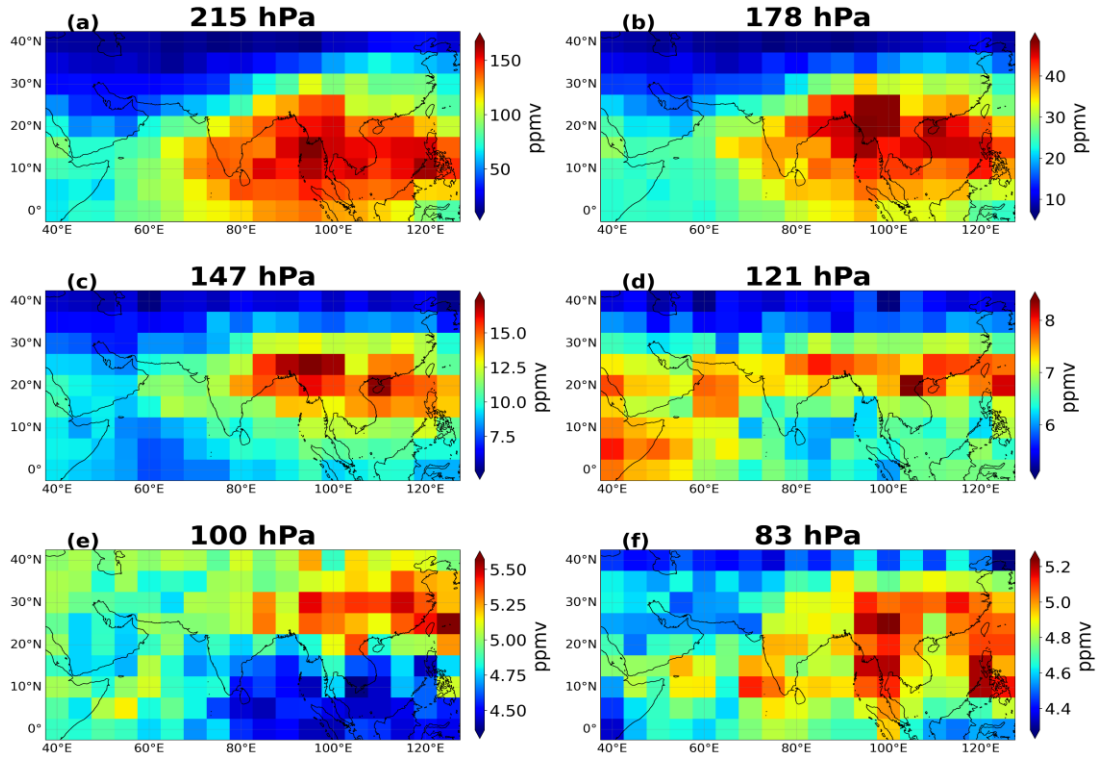


Water Vapour (H_2O)

- Water vapor is one of the key tracers for troposphere-stratosphere exchange and the processes that control water vapor in the TTL are of importance to the global climate system.
- Enhanced water vapor over the Asian summer monsoon region appears to be collocated with a region of deep convective activity.



*Water vapour mixing ratio (ppmv) during the **MCS** phase*



*Water vapour mixing ratio (ppmv) during the **non-MCS** phase*

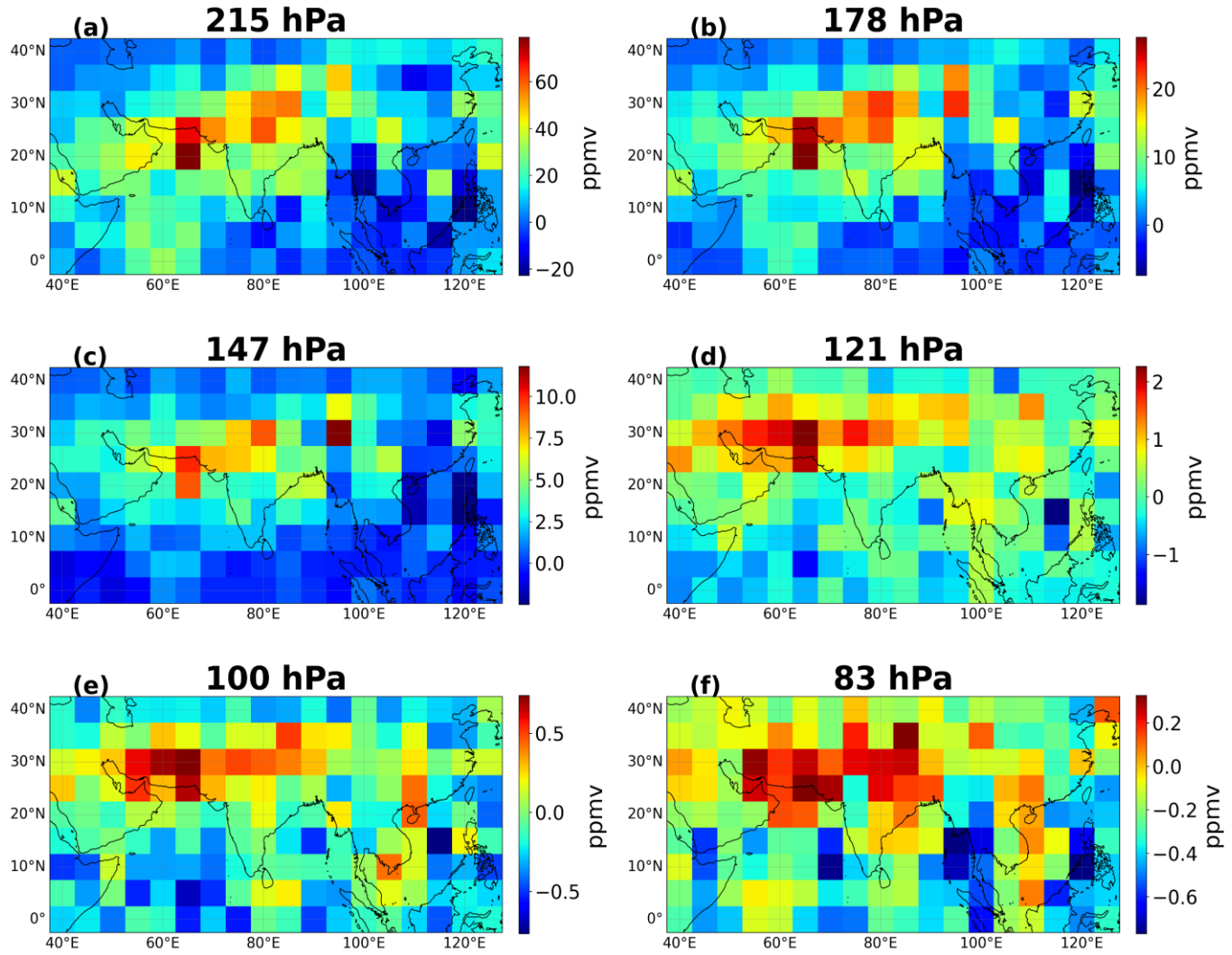
RESULTS

Water Vapour (H_2O)

- Hydration signature in the TTL over the Indian core monsoon zone

- Water vapour mixing ratio difference of >45 ppmv is observed at 215 hPa, > 15 ppmv at 178 hPa, and > 7 ppmv at 147 hPa over the monsoon region.

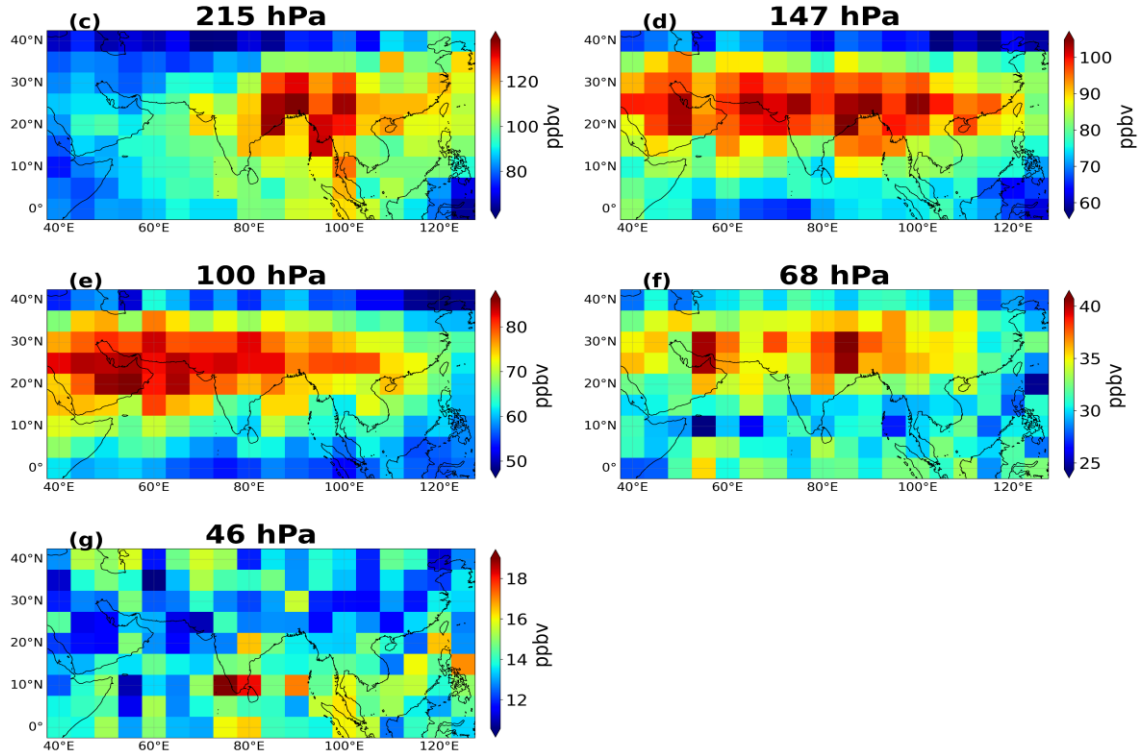
- Convection reaching the upper troposphere hydrates the lower stratosphere.



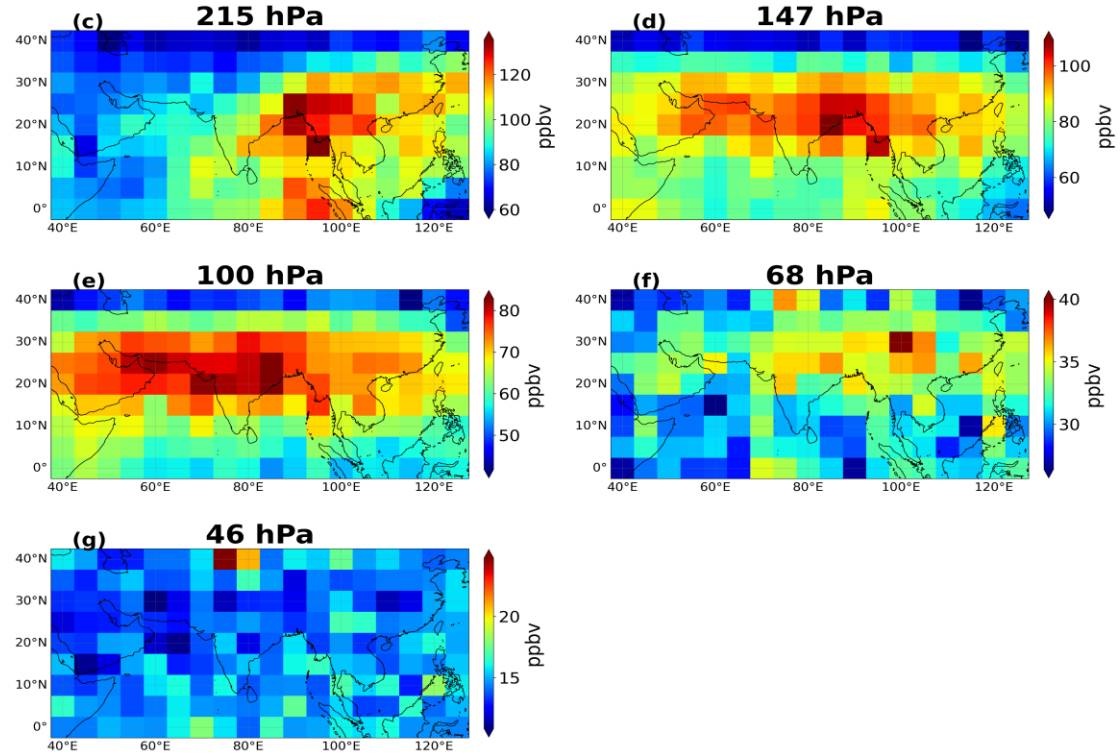
*Difference between the water vapour mixing ratio (ppmv) during the **MCS** phase and **non-MCS** phase.*

Carbon monoxide (CO)

- The dominant source of CO to the TTL is transport from the troposphere
- Because the chemical lifetime of CO is comparable with dynamical time scales in the TTL, it has often been used to help quantify convective transport in the TTL
- The distribution of CO is large over the Asian summer monsoon region due to the presence of Asian monsoon anticyclone at that level over the region.



*CO mixing ratio (ppbv) during the **MCS** phase*

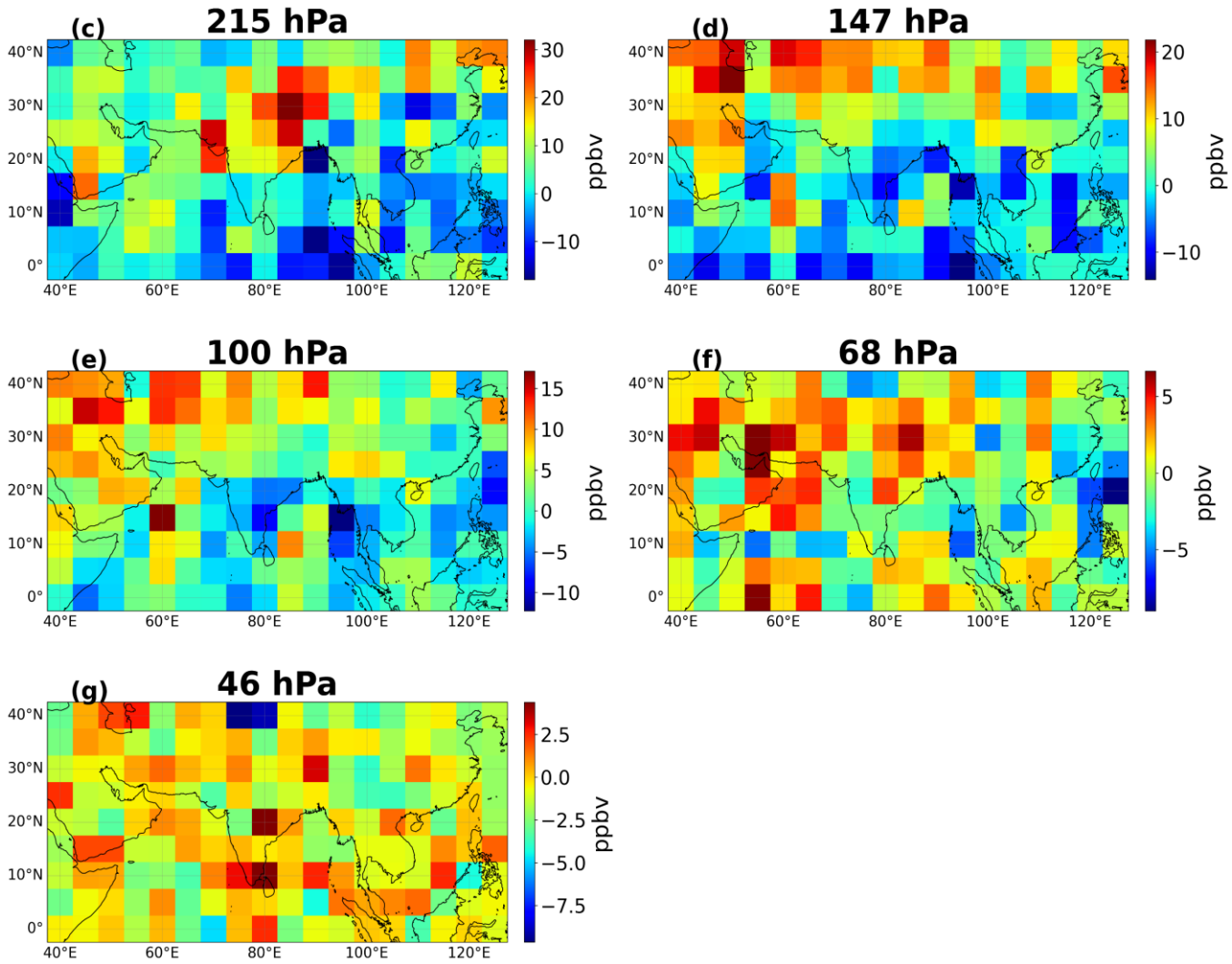


*CO mixing ratio (ppbv) during the **non-MCS** phase*

RESULTS

Carbon monoxide (CO)

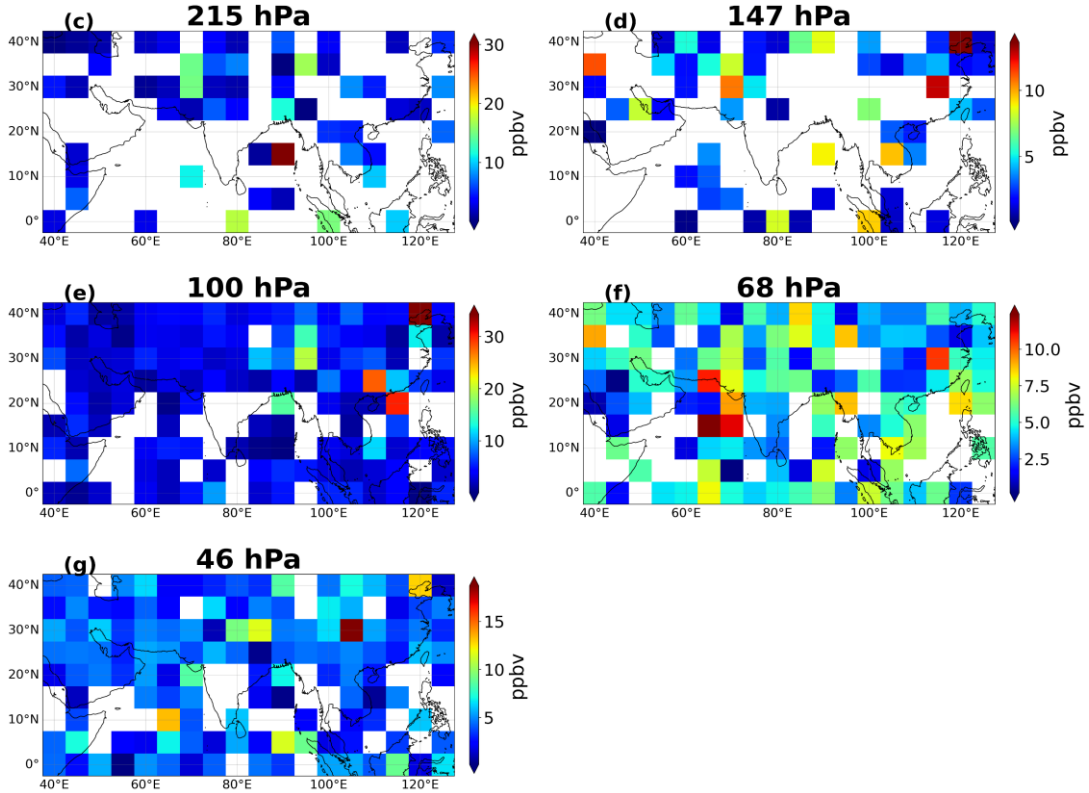
- The concentration of CO over the Asian Summer Monsoon Anticyclone (AMA) region (mainly over S. China and N. Indian region) is evident during the extreme MCS events
- The result is suggested in the StratoClim Campaign.



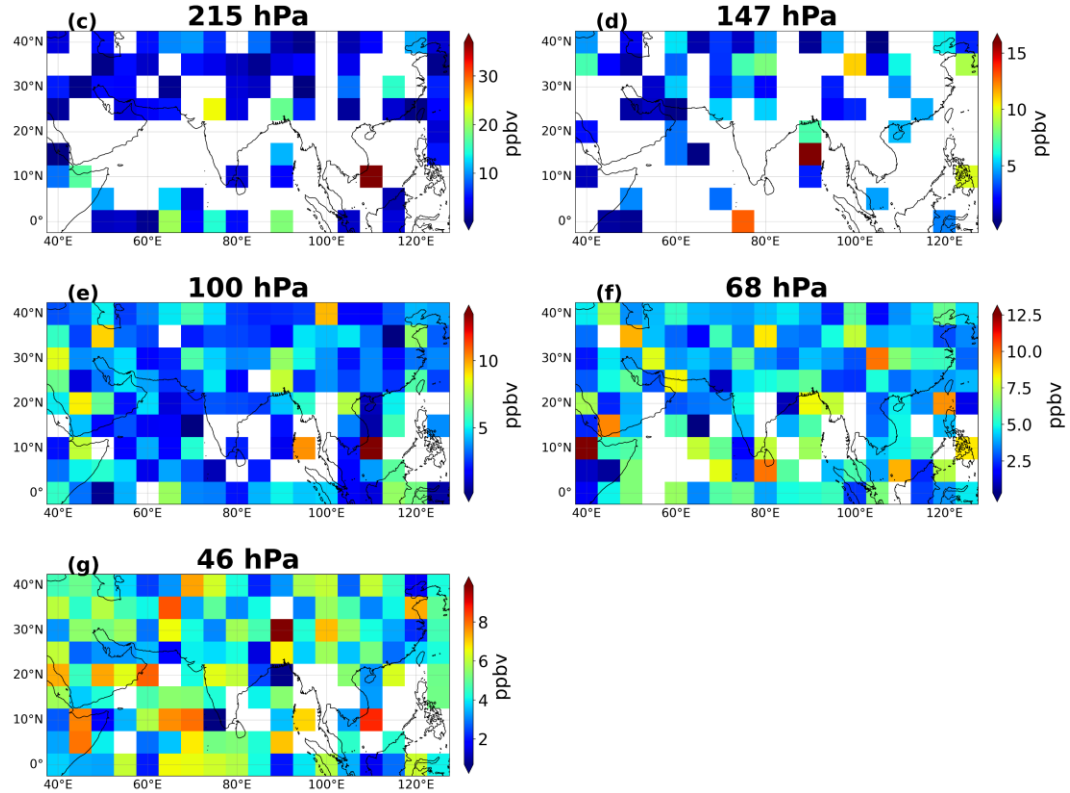
*Difference between the mixing ratio of CO (ppbv) during the **MCS** phase and **non- MCS** phase.*

Sulphur dioxide (SO_2)

- Anthropogenic SO_2 emissions alter the global sulphate aerosol distribution which in turn significantly impacts the radiative forcing of Earth's atmosphere.
- Since the concentration of SO_2 is less compared to CO in TTL we are unable to access the sensitivity of the SO_2 over the core monsoon region.



*Mixing ratio of SO_2 (ppbv) during the **MCS** phase*

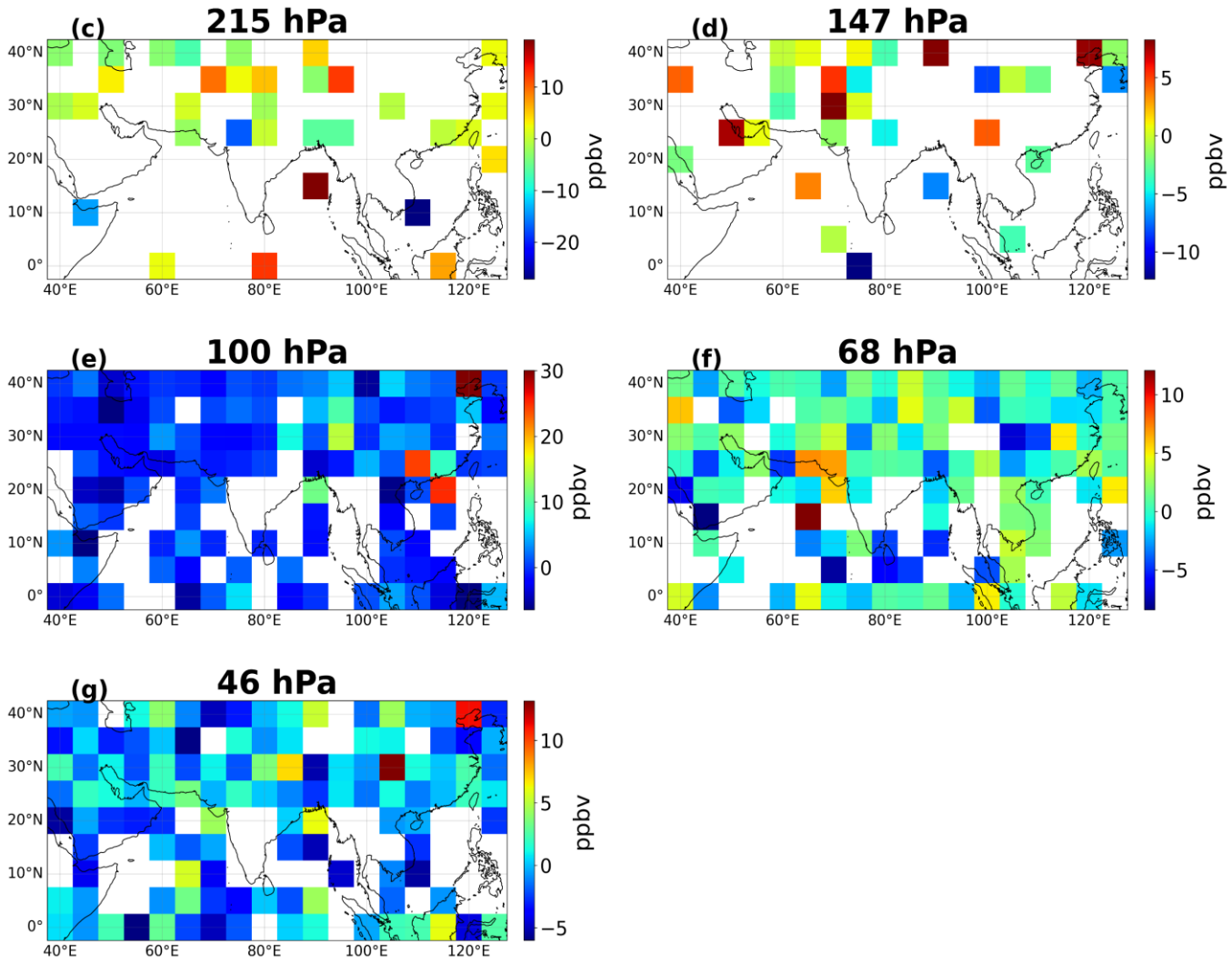


*Mixing ratio of SO_2 (ppbv) during the **non-MCS** phase*

RESULTS

Sulphur dioxide (SO_2)

- The enhancement in the concentration of SO_2 due to convective activity over the TTL is not so evident compared to water vapour and CO.
- SO_2 is distributed uniformly between these two MCS extremes.



Difference between mixing ratio of SO_2 (ppbv) during the MCS phase and non- MCS phase.

SUMMARY & FUTURE WORK

SUMMARY

- The hydration signature of water vapour over the TTL is quite evident from the Mesoscale Convective events
- The concentration of CO is high over the region of Asian monsoon anticyclone (AMA) region (Asia to Middle East) in UTLS during deep Convective events.
- Enhancement of pollutants especially CO in the UTLS over the AMA domain due to deep convective processes evident over land regions.

FUTURE PLAN

- Detailed study of the factors governing the hydration in the TTL during convective events.
- The role of upper level dynamics for constituents distribution in the UTLS
- To check the impact of TTL temperature for the gaseous distribution.


THANK YOU