# Observational atmospheric vertical structure of Core monsoon zone in Central India

*Meenu R Nair[1], Sunilkumar Khadgarai[1], M.C.R. Kalapureddy[1], Ved Prakash S. Chandel[2]*

[1]Radar and Satellite Meteorology, IITM, Dr. Homi Bhabha Road, Pashan, Pune-411008, India.

[2]India Meteorological Department, Bhopal, India.

Email contact: meenurnair4@gmail.com

## Introduction

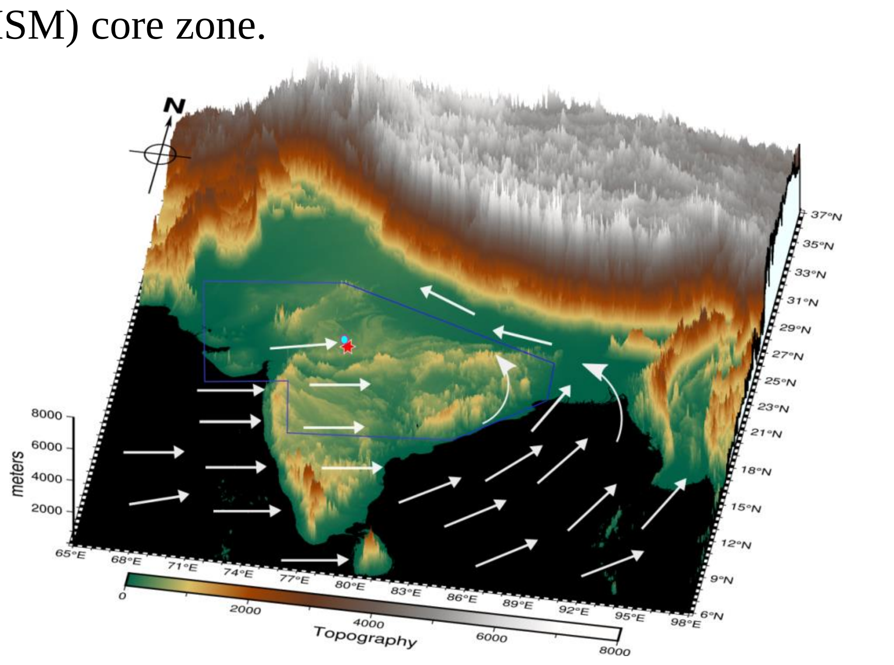
The Indian Summer Monsoon (ISM) core zone is characterized the establishment of inter tropical convergence zone (ITCZ) during the end of onset of ISM. During the monsoon months in India, oscillation of ITCZ happens in this core zone. The rainfall in the core zone aids in the identification of active and break spells by average rainfall throughout the region. Observations of environment vertical structures of turbulence (VST), atmospheric parameters, stability parameters, and cloud vertical structure over Bhopal in Central India, a vital core monsoon zone, can bring new insights on better ISM understanding and predictability. Turbulence in the atmosphere can be parameterized by the refractive index structure parameter ($C_n^2$) which depends on humidity and temperature profiles.

## Objectives

The study uses Bhopal's GPS-Radiosonde data for 2011-2020 (10 years) to study the features of atmospheric vertical structure including turbulence (VST) in the atmosphere, parameterized by turbulence structure parameter of refractive index; $C_n^2$ and other thermodynamic and dynamic conditions. The difference in VST during active and break period is brought out with their background features

## Data & Methodology

The study area is a tropical site in Central India, Bhopal. Bhopal (23.30°N, 77.30°E, and 530 m AMSL) is situated in the Indian Summer Monsoon (ISM) core zone.



In homogeneous isotropic turbulence, the turbulence structure constant for radio refractivity can be expressed as (Tatarskii, 1971)

$$C_n^2 = a^2\alpha' Lo^{4/3} M^2$$

$a^2$ is a universal constant taken as 2.8 (Ottersten, 1969), $\alpha'$ is the ratio eddy diffusivities taken as unity, $Lo$ is the outer scale of turbulence spectrum and considered to be 10 m and M is the vertical gradient of potential refractive index fluctuations.

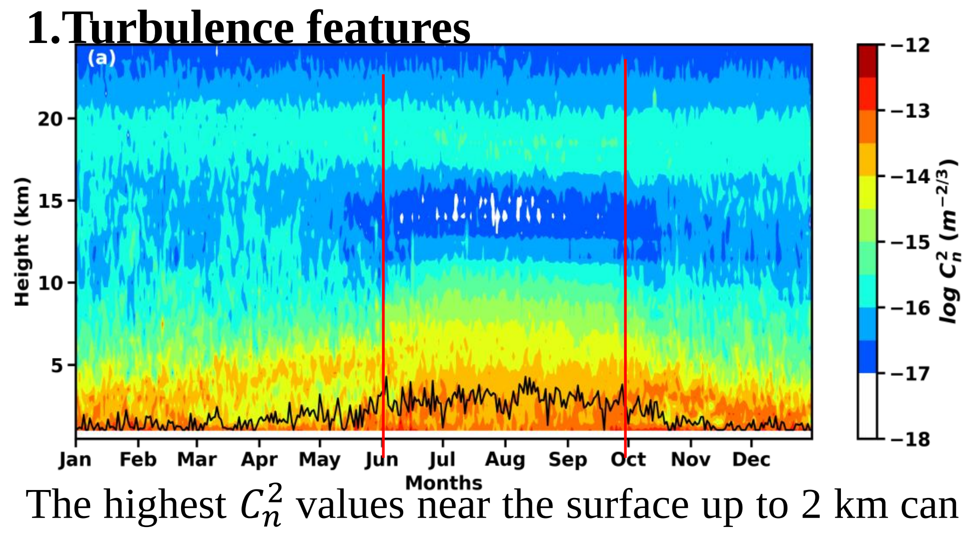
M is defined as (Van Zandt et al., 1978)

$$M = -77.6\ X\ 10^{-6}\frac{p}{T}\frac{\delta ln\theta}{\delta z}\left[1+\frac{15500q}{T}\left(1-\frac{1}{2}\frac{\delta lnq/\delta z}{\delta ln\theta/\delta z}\right)\right]$$

where p is pressure in hPa, T is the absolute temperature(K), $\theta$ is the potential temperature (K), q is specific humidity (g kg$^{-1}$) and z is the altitude in meters (m).

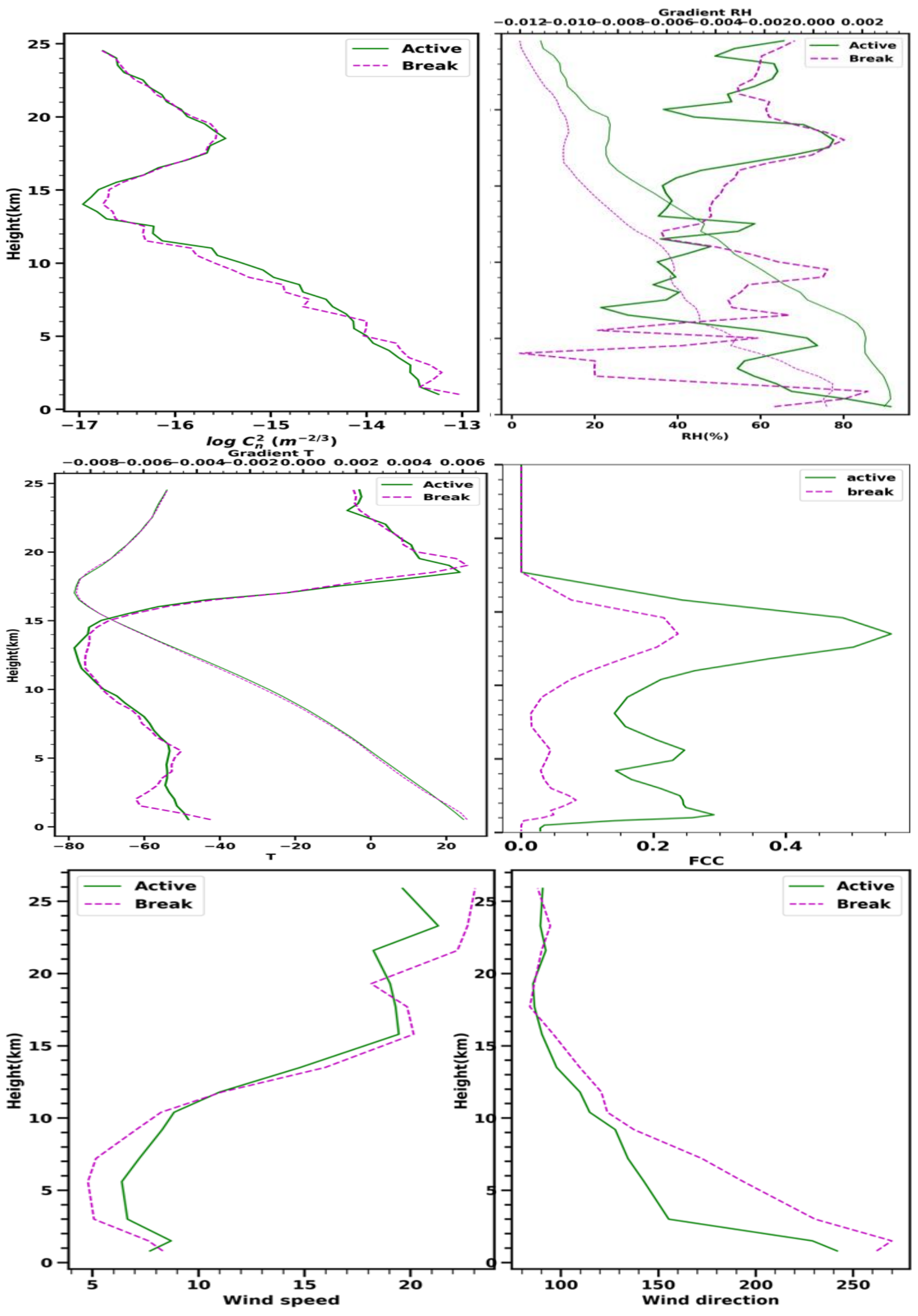
## Results & Discussion

### 1.Turbulence features



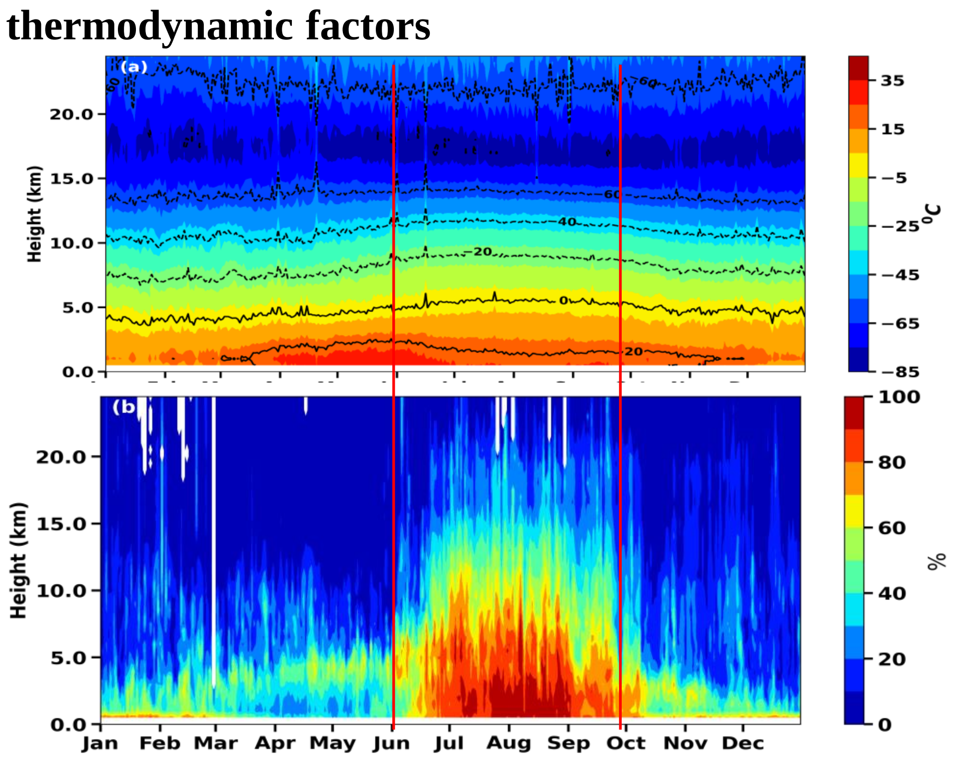
The highest $C_n^2$ values near the surface up to 2 km can be attributed to the turbulence created by thermal within the PBL. Even before the onset of monsoon, an early signature of weakest turbulence zone over Bhopal is seen at an altitude of 13-15 km. Monsoon turbulence is more homogeneous in nature. The weakest turbulence zone is attributed to the presence of higher cold cloud fraction.

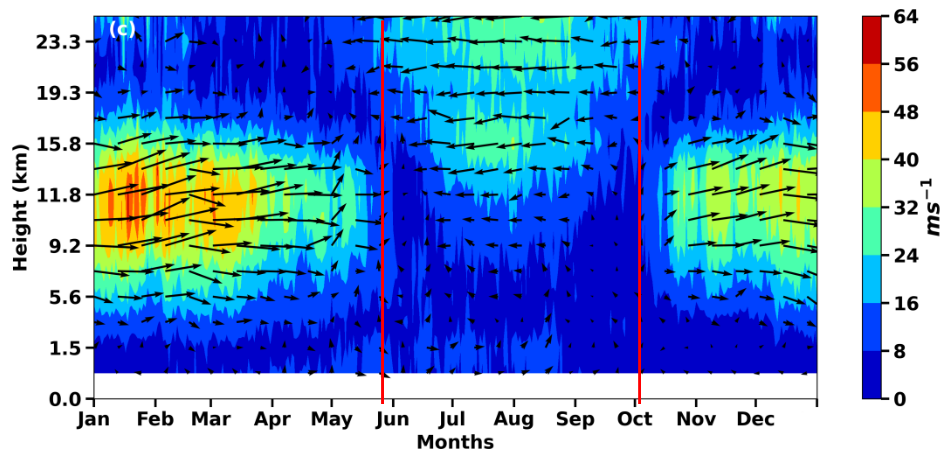
### 2.Active and break



Intra-seasonal analysis on active and break during monsoon displays the characteristic difference between them. The difference in RH and temperature and its gradients are the main reasons for the $C_n^2$ distinction between both. The fractional cloud cover (FCC) show a significant reduction during break throughout the height range. The weakest turbulence zone near 14 km larger value in break is due to the lower FCC near that height. Wind speed and direction also show significant differences during active and break days.

### 3.Climatological vertical structure of dynamic and thermodynamic factors





ISM brings a copious moisture to the study region. Elevation of isotherms above 10 ºC provide a warm atmospheric column for ISM.A flip-flop pattern of mid-tropospheric wind from non-monsoon westerly to monsoon easterly is observed. Strong wind shears at the upper flank of non-monsoon subtropical westerly jet streams/winds (STJ) and lower flank of monsoon TEJ are responsible for the persistence of secondary $C_n^2$ maximum zone, above 16 km altitude throughout the year.

## Summary and Conclusion

Present study characterized the evolution of vertical structure of turbulence by employing the GPS-RS measurements during 2011-2020. The important results are summarized as below.

- $C_n^2$ profiles values are from -18 to -12 m$^{-2/3}$ in the height range 0.5 – 25.0 km.
- An early signature of weakest turbulence band is noticed even before the onset of monsoon. This can act as a precursor for ISM .
- Monsoon season VST is seen to be more homogeneous.
- Active and break show significant difference in $C_n^2$ profile due to its variation in its controlling factors, thus suggesting intra-seasonal variation in homogeneous monsoon.
- The higher cold cloud fraction is responsible for the weak turbulence zone centered at 14 km altitude.
- Strong wind shears at the upper flank of non-monsoon STJ and lower flank of monsoon TEJ are responsible for the persistence of secondary $C_n^2$ maximum zone, above 16 km altitude throughout the year over Bhopal latitude.
- A flip-flop pattern of mid-tropospheric wind from non-monsoon to monsoon and moisture holds the key for ISM vigor over monsoon core zone.

## Acknowledgements & References

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