Spatial and Diurnal variation of Lightning activity and CAPE over Indian region and their correlation with various indices

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INTRODUCTION:

- Lightning is linked to thermodynamic variables such as instability, adequate moisture, and lifting force
- CAPE is an index that is used to evaluate atmospheric instability

$$CAPE = \int \frac{g\left(T_p - T_e\right) dz}{T_e}$$

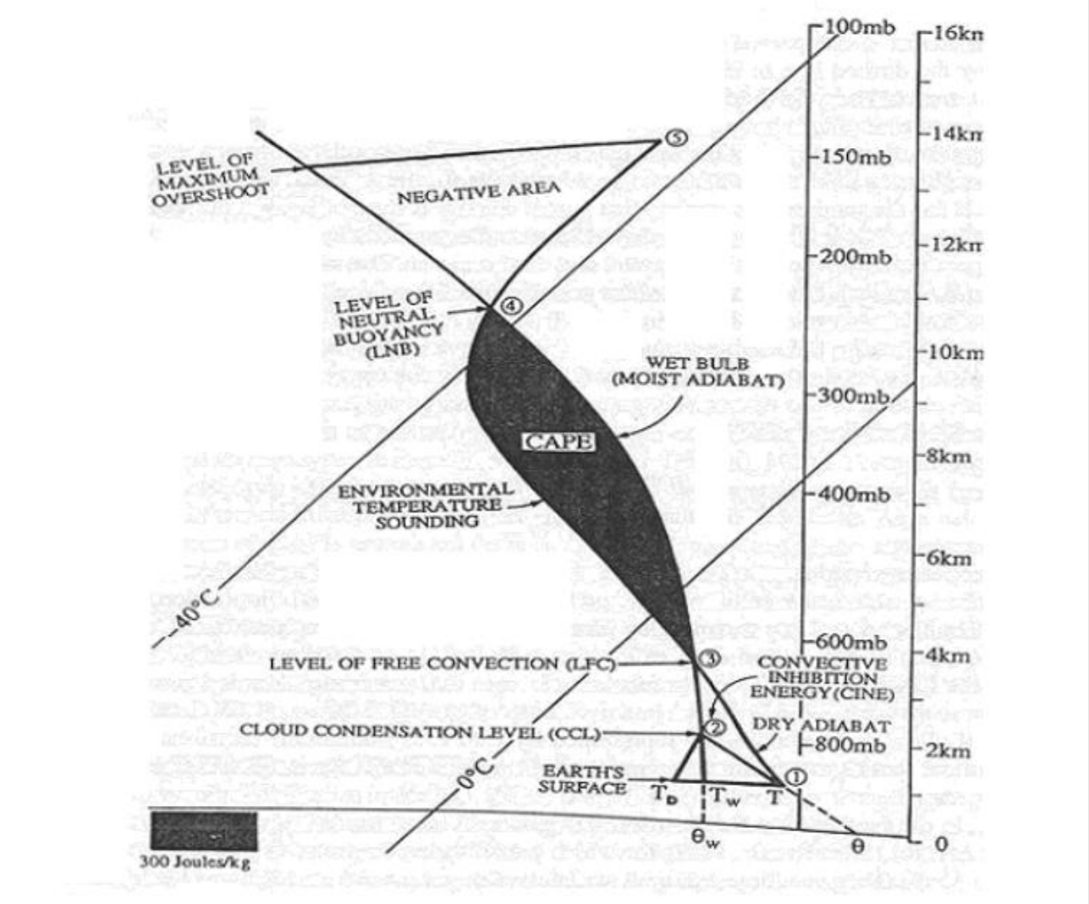
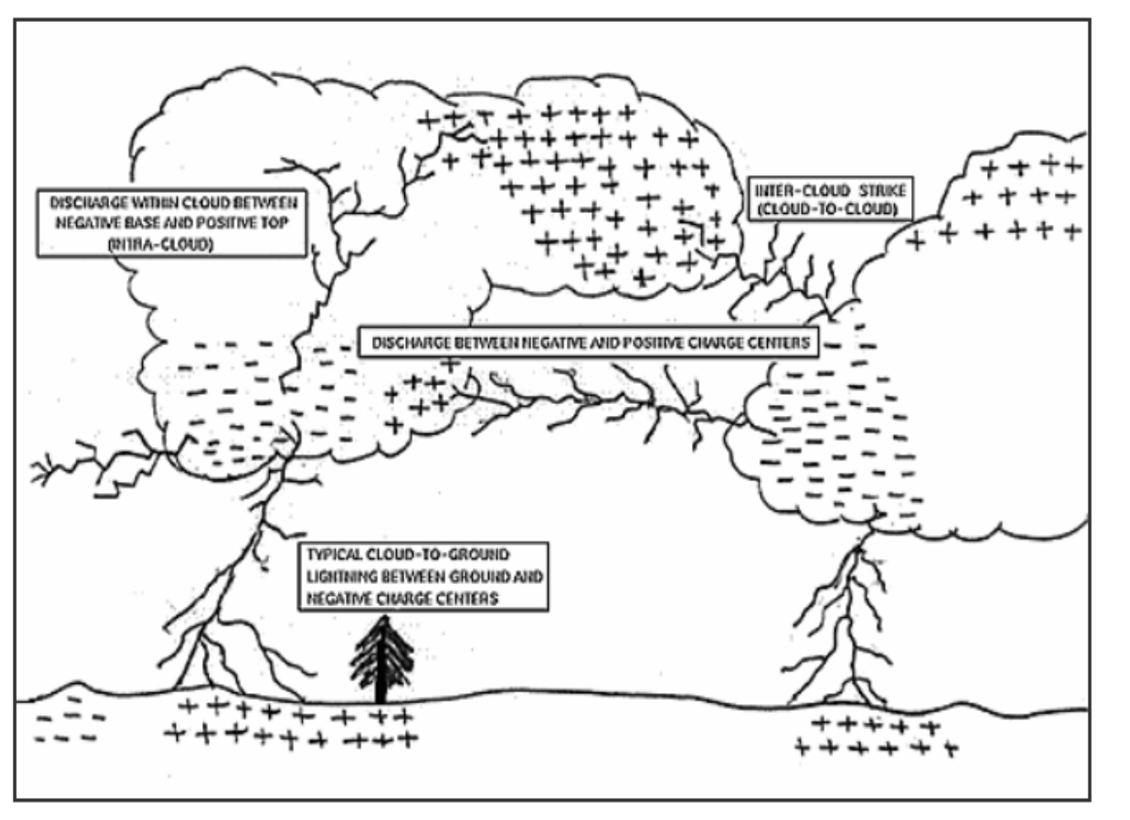


Figure 1.1 Illustration of ingredients of conditional instability on a thermodynamic digram (from Williams, 1995).



The lower part of a thundercloud is usually negatively charged. The upward area is usually positively charged. Lightning from the negatively charged area of the cloud generally carries a negative charge to Earth and is called a negative flash. A discharge from a positively-charged area to Earth produces a positive flash.

DATA:

IIT LLN currently consists 82 lightning-detecting sensors manufactured by the Earth Networks, USA).

Low frequency (1 kHz) - Detect CG discharges with 90% detection efficiency
Middle frequencies (1 kHz to 1 MHz): Used for locating return strokes
High frequencies (1 MHz to 12 MHz): Detect in-cloud pulses with 50% detection efficiency

When lightning occurs, electromagnetic energy is emitted in all directions. Each sensor records and send the waveforms to the central lightning detection server via the Internet. The precise arrival times are calculated by correlating the waveforms from all the sensors that detect the strokes of a flash. The waveforms, arrival time and signal amplitude can be used to determine the peak current of the stroke and its exact location (Location accuracy=300 m)including latitude, longitude and altitude. Lightning strokes are then clustered into a flash if they are within 700 ms and 10 km. A flash that contains at least one return stroke is classified as a CG flash.

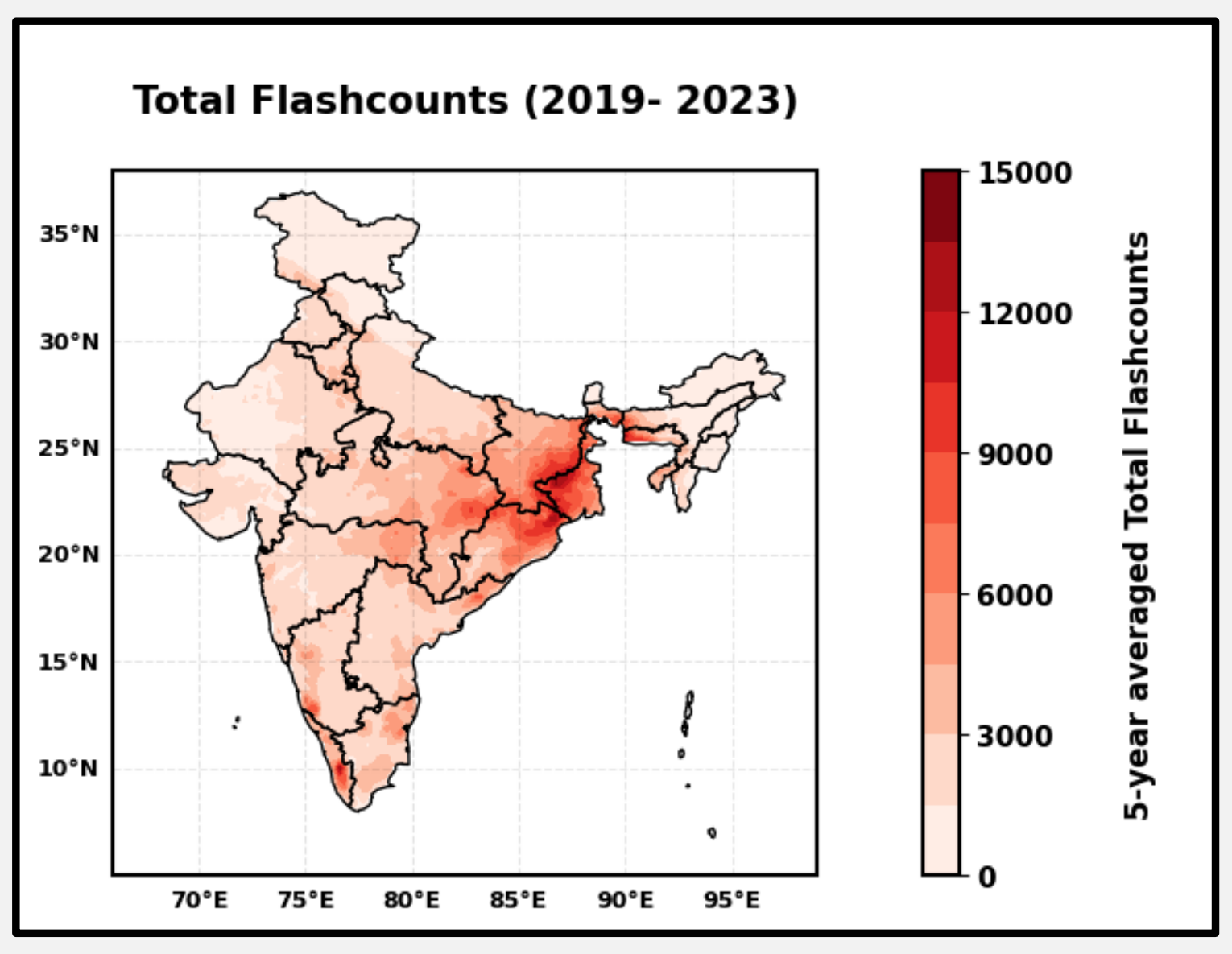
IITM LLN Sensor data with spatial resolution of 0.25° x 0.25° and temporal resolution in nanoseconds was used for the analysis.

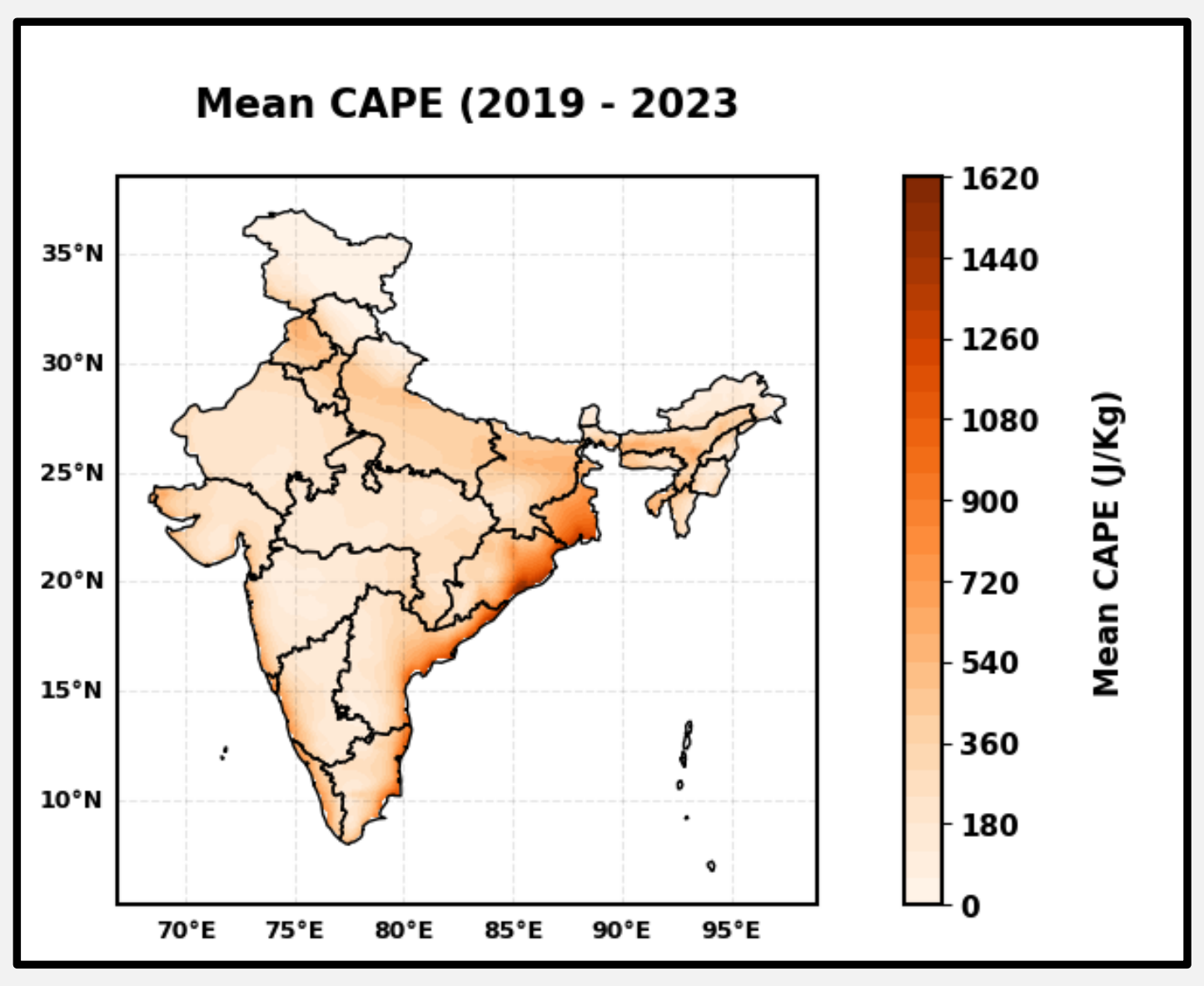
ERA5 is the fifth generation ECMWF reanalysis for the global climate and weather for the past 8 decades. Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset.

ERA5 Hourly Cape Data and Era5 Hourly Specific Humidity at 850 hPa with Spatial resolution 0.25° x 0.25° were used for the analysis.

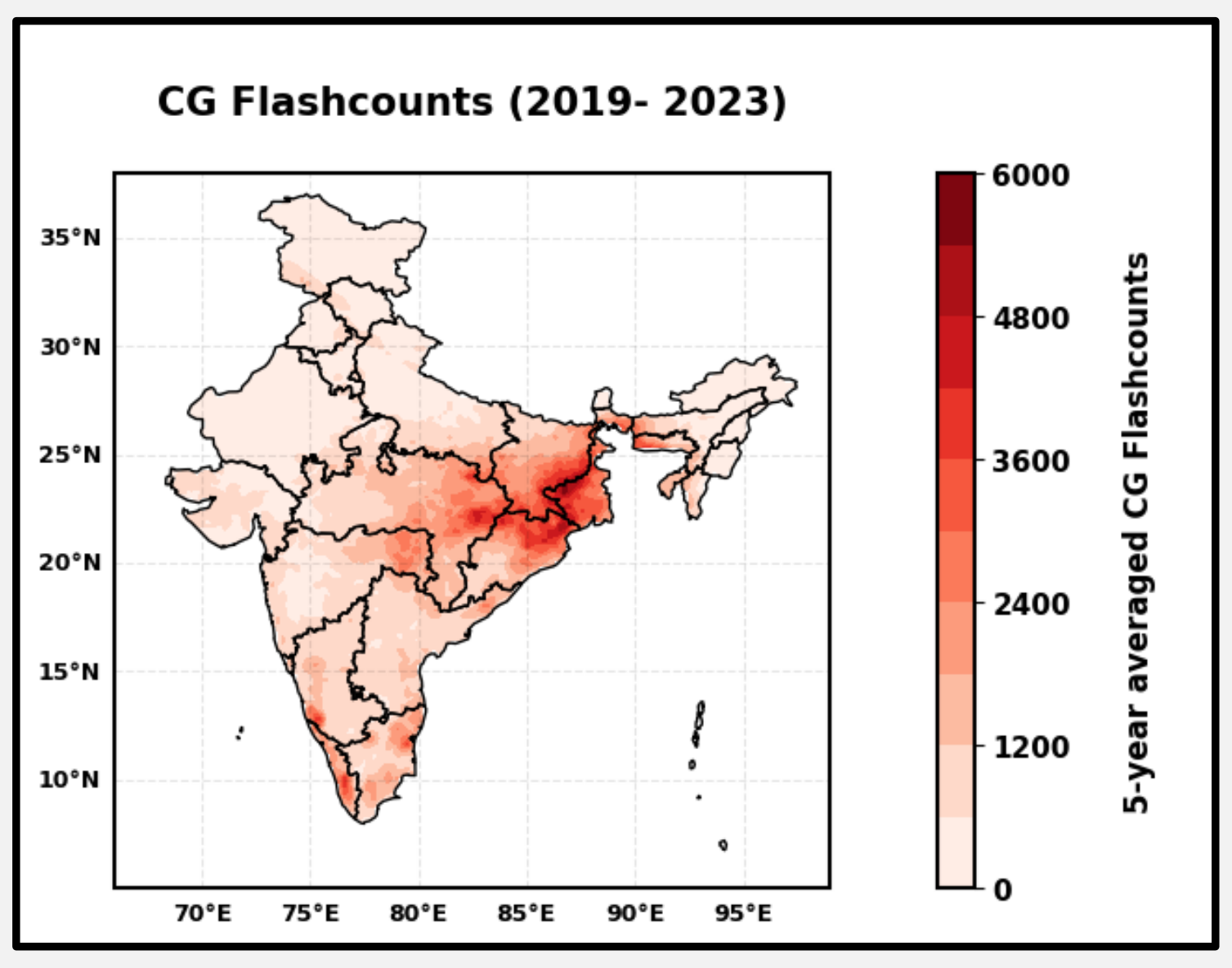
RESULTS:

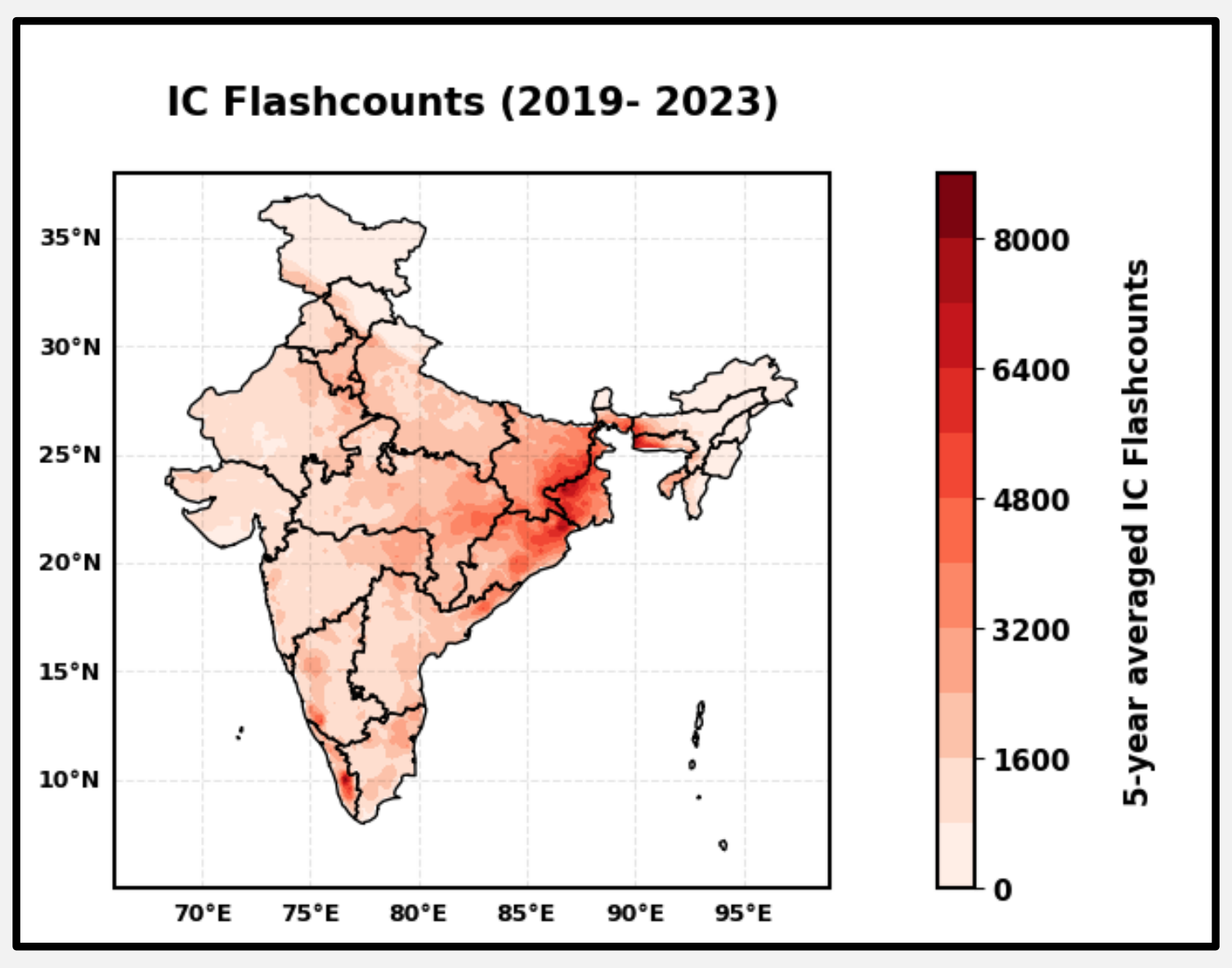
5 - Year Averaged Spatial Distribution of Flash counts and CAPE:



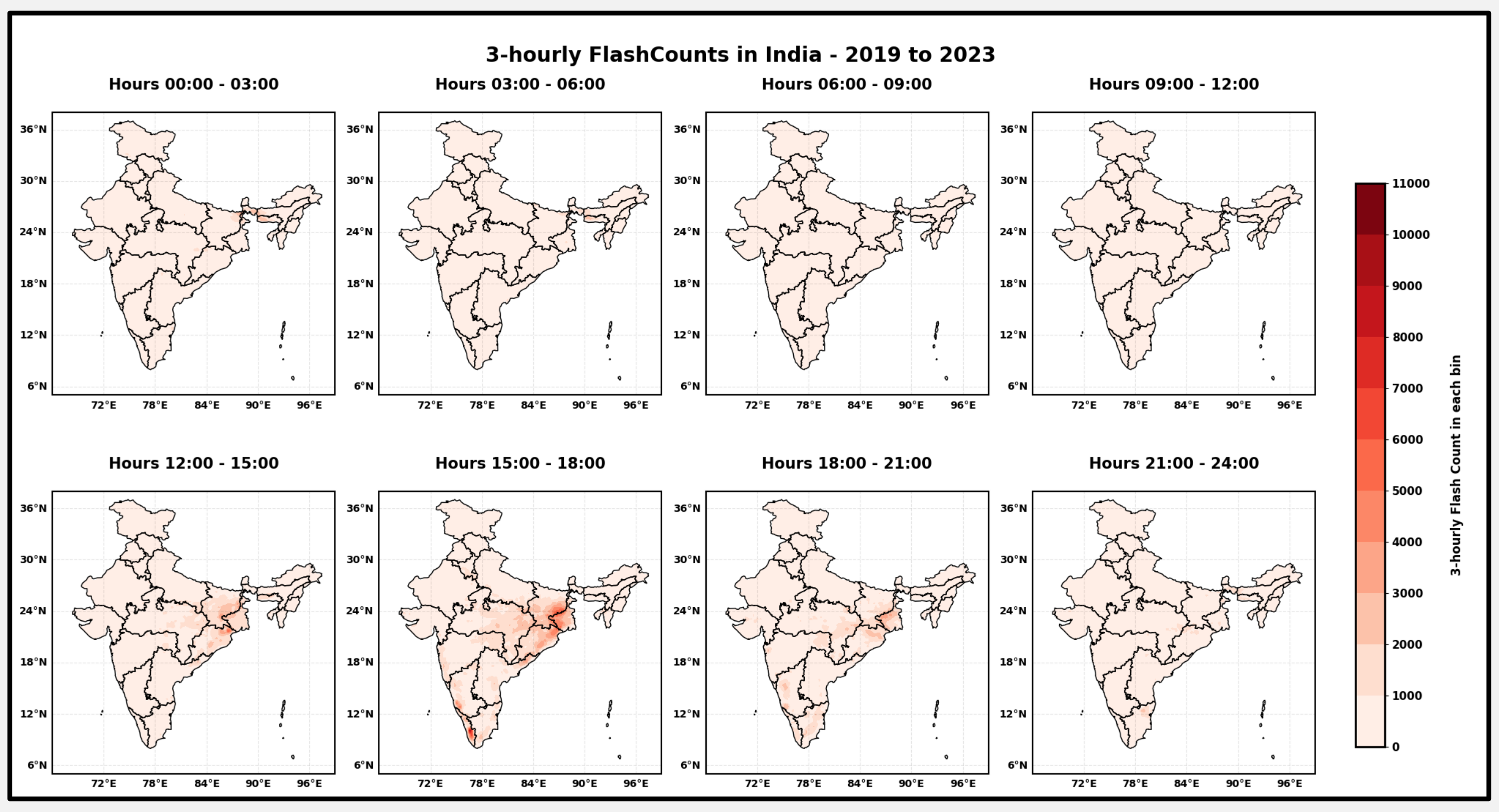


Spatial distribution of CG and IC Flashes:

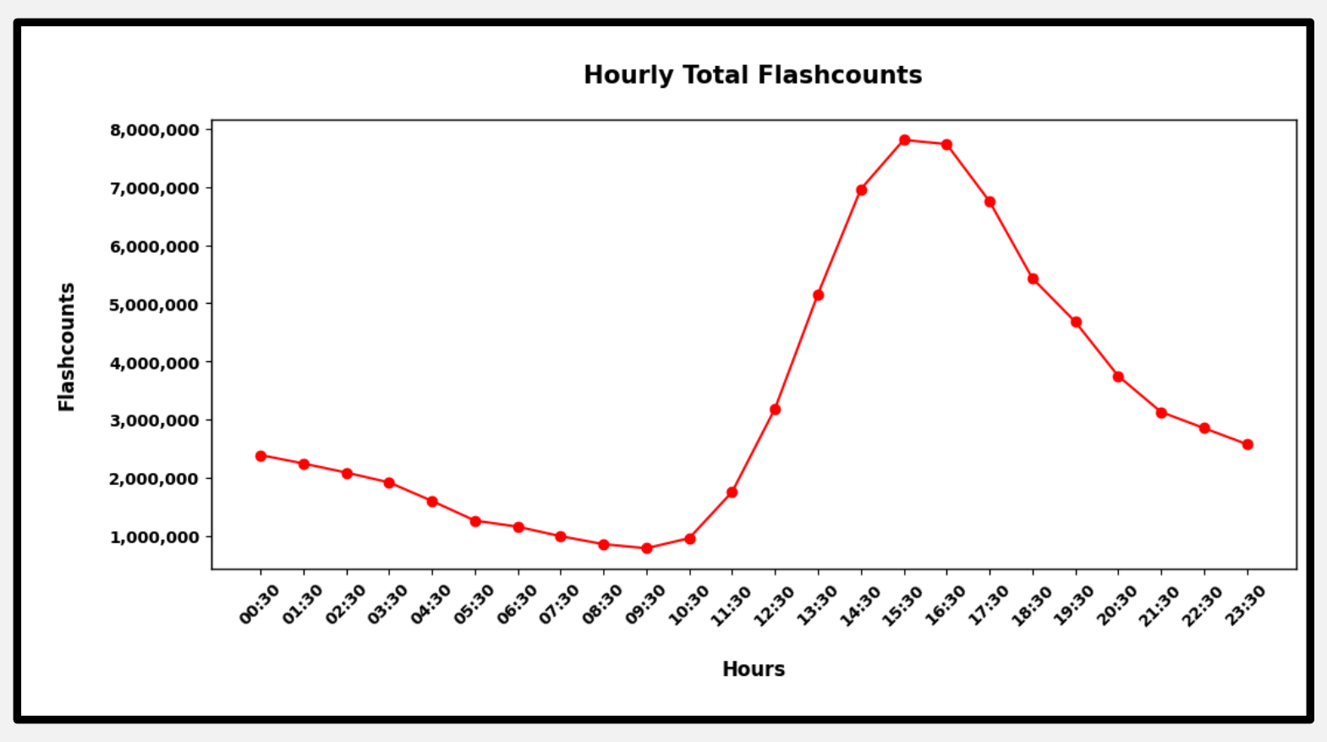


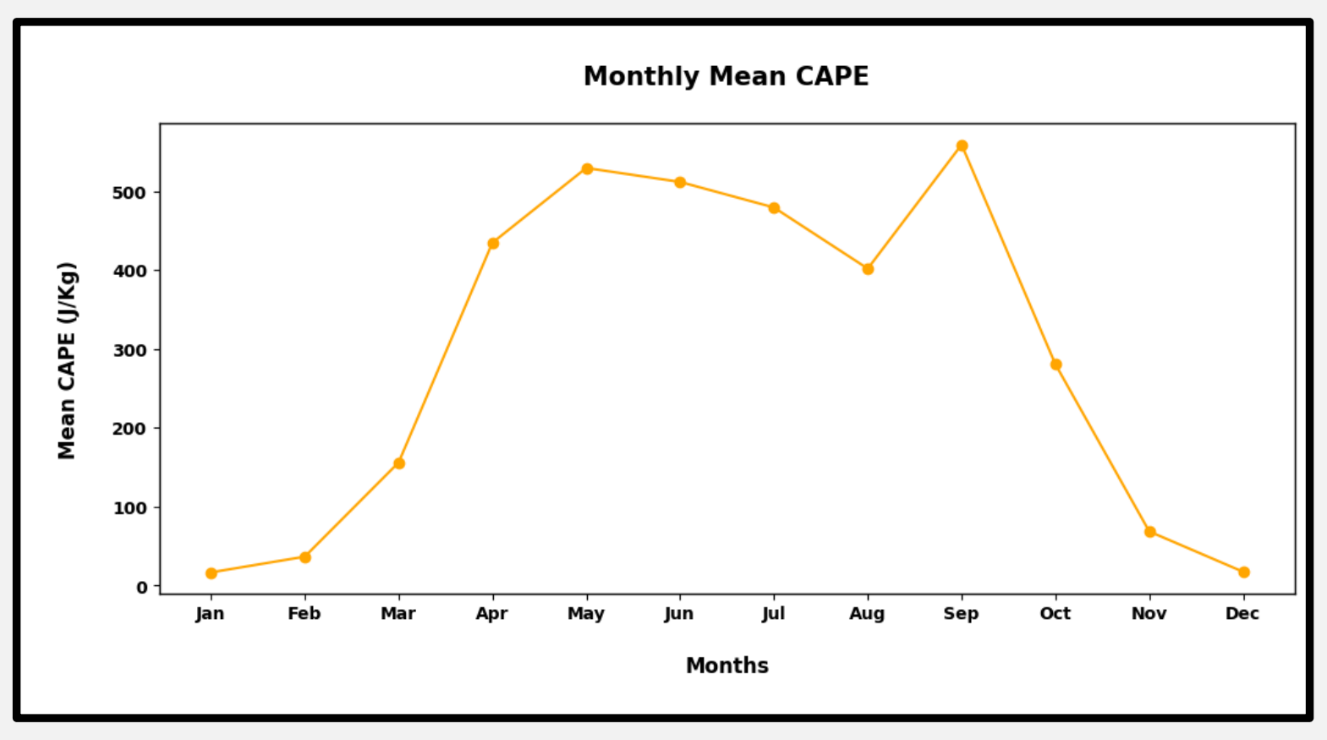


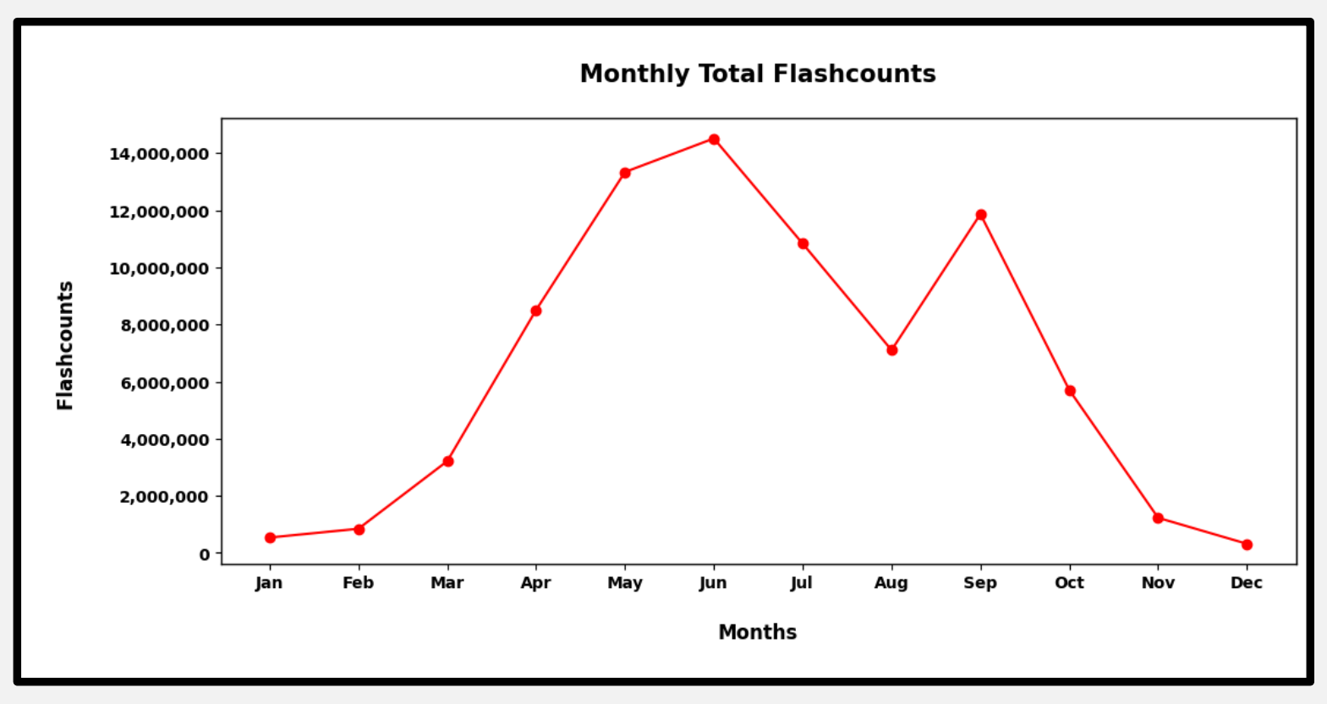
3 - Hourly Spatial distribution of Total Flash counts:

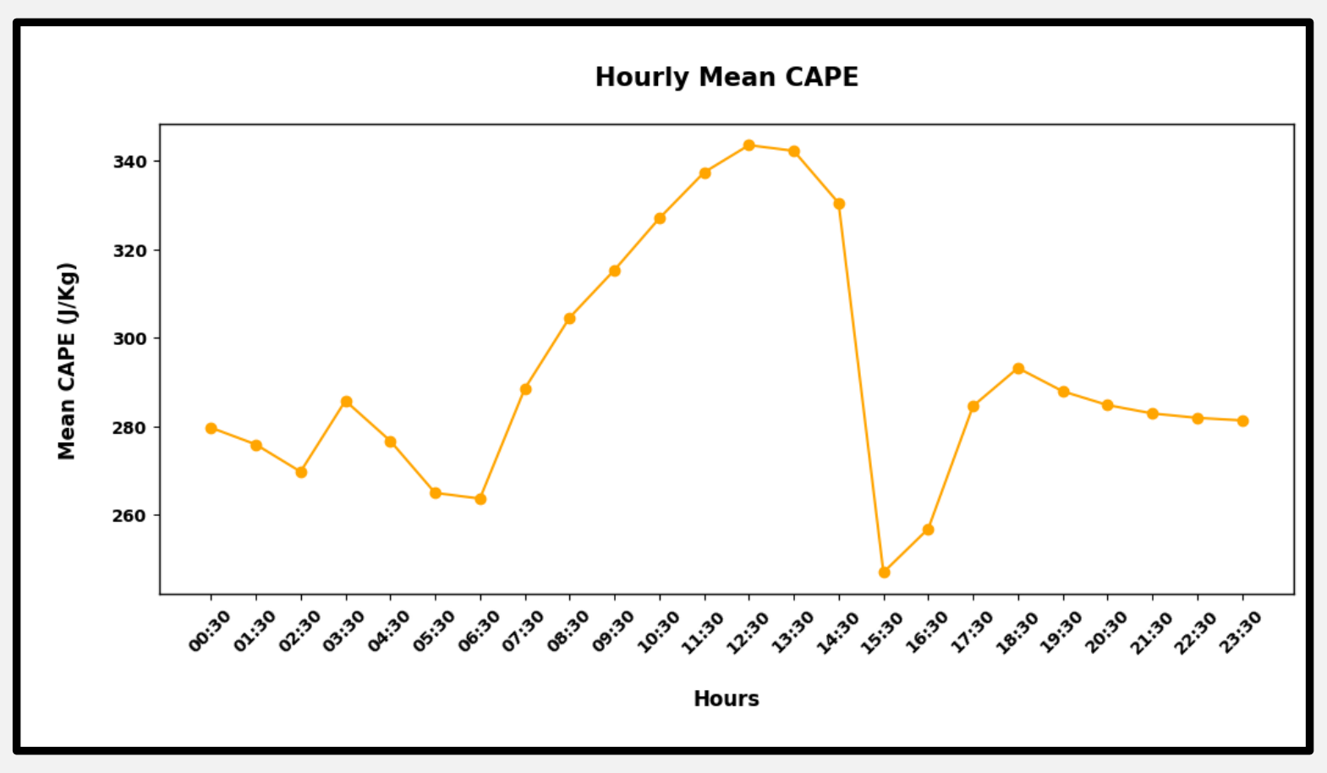


Temporal pattern of Flash counts and CAPE:

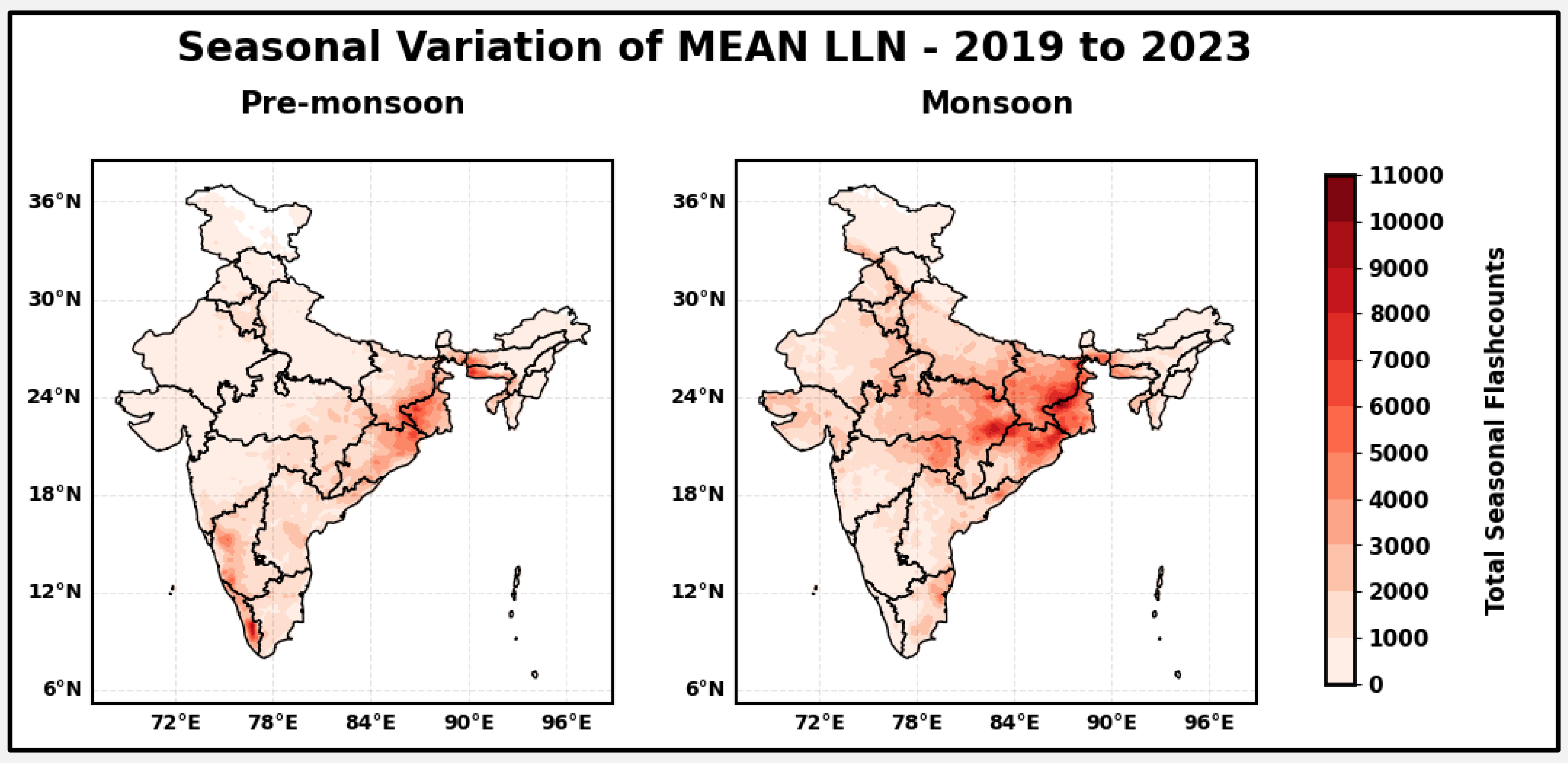


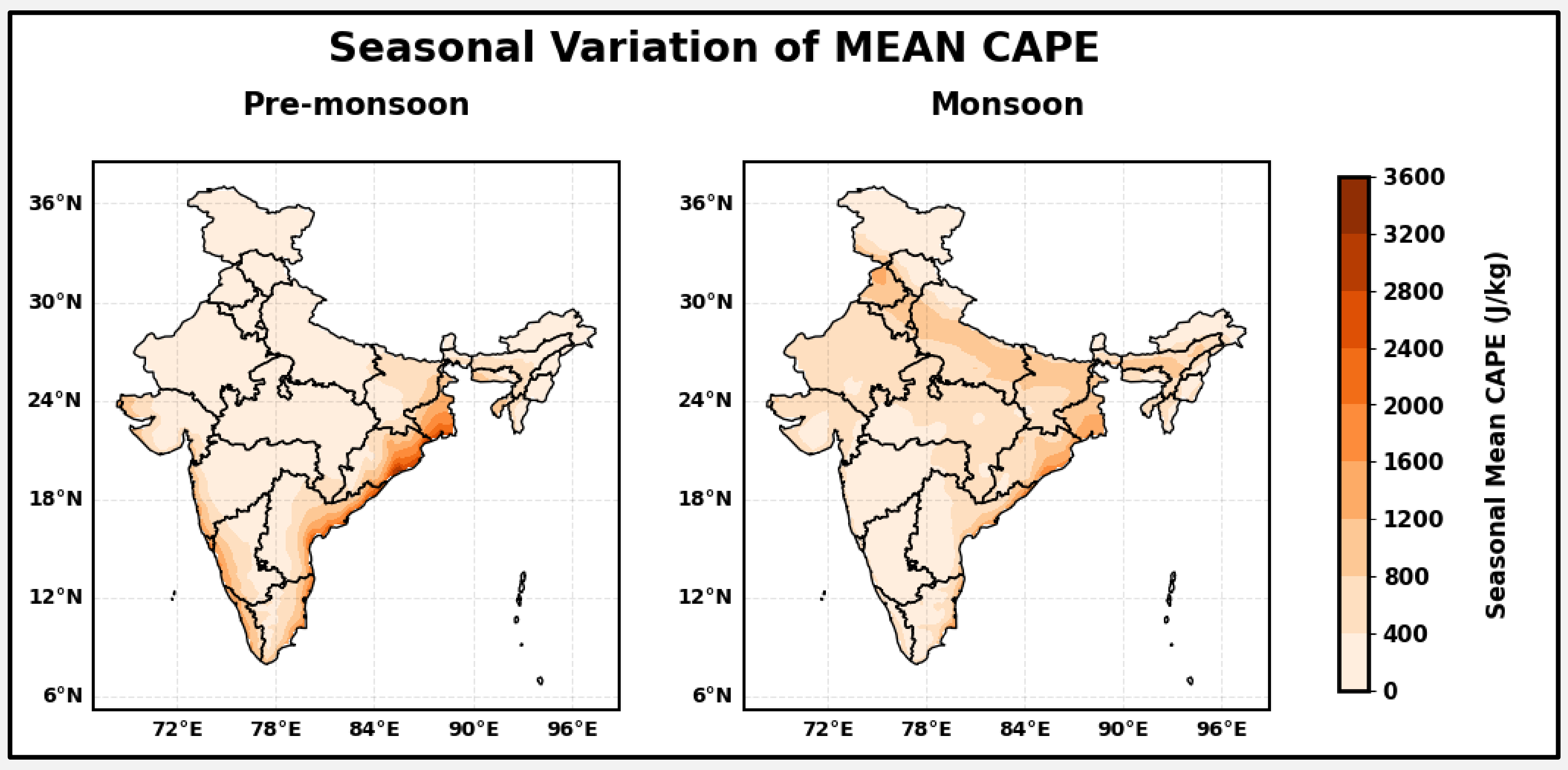






Seasonal pattern of Flash counts and CAPE:





CORRELATION CO-EFFICIENT FOR FLASH COUNT AND VARIOUS PARAMETERS

	Different Parameters	Yearly	Seasonwise	Monthly	Daily	Hourly
1.	Mean CAPE	0.5405	0.6422	0.6140	0.3166	0.2015
2.	Mean Conv. PPT	0.4845	0.5858	0.4471	0.2194	0.4603
3.	Mean Sp. Humidity (850 hPa)	0.4592	0.6316	0.5033	0.2375	0.2468
4.	CAPE x PPT INDEX	0.5901	0.7181	0.6073	0.3600	0.5497
5.	CAPE X SP.HUMIDTY INDEX	0.5794	0.7207	0.6638	0.3497	0.2760

CONCLUSIONS:

- For Indian region, Intra-cloud (IC) discharge are more than CG discharges
- Higher Thunderstorm and Lighting activity are observed higher in monsoon than pre-monsoon season and has peak activity in the afternoon (3 – 5 PM).
- We observe more Thunderstorms near West Bengal, Jharkhand, Chhattisgarh, Bihar, western ghats and near foothills of Himalayas.
- The prevailing meteorological conditions and orography provide favorable conditions for formation of thunderstorms, and hence, lightning activity is higher in spite of lower value of CAPE over few regions compared to other parts of India.
- In addition to high CAPE value, availability of moisture and some triggering mechanisms are necessary for initiation and maintenance of small-scale atmospheric convections
- We found higher correlation values for Flash count and CAPE x PPT and CAPE x Sp. Humidity than just CAPE alone.

Moving forward, we plan to study the role of orography in the spatial distribution of thunderstorm and lighting along with CAPE, and Sp. Humidity parameter to find an Index which can be used as a better proxy for Thunderstorms and Lightning.

References:

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- Romps, D. M., Charn, A. B., Holzworth, R. H., Lawrence, W. E., Molinari, J., & Vollaro, D. (2018). CAPE times P explains lightning over land but not the land-ocean contrast. Geophysical Research Letters, 45, 12,623–12,630.
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