Evaluating microphysics schemes of WRF model in simulating Lightning and Thunderstorm events

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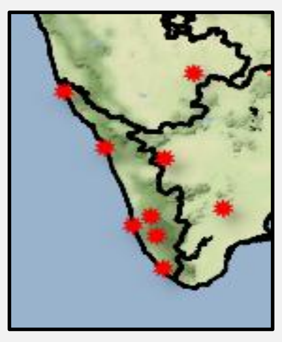
INTRODUCTION:

- Lightning is a complex phenomenon, influenced by microphysical processes like cloud droplet formation and ice crystal growth within thunderstorms. Understanding these processes is crucial for accurate lighting simulations (Lynn et al., 2005).
- The WRF model offers various microphysics schemes, each representing cloud microphysics differently. Evaluating these schemes' ability to capture lightning activity is essential for model improvement.
- Accurate lightning prediction through WRF can enhance thunderstorm hazard warnings and nowcasting, leading to increased public safety and improved preparedness (Wang et al., 2013).

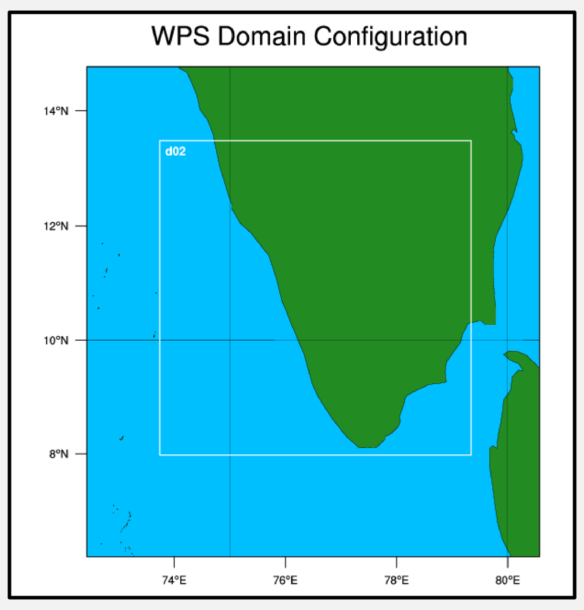
DATA AND MODEL CONFIGURATION

1. IITM LLN: Currently consists of 82 lighting detecting sensors all over India (as of 2024). It uses Low frequency (1 kHz) to detect CG discharges with 90 % detection efficiency. Spatial resolution of 0.03° x 0.03° and temporal resolution of 30 minutes was used for the analysis.
2. IMD DAILY RAINFALL DATA: 0.25° x 0.25° - Daily data



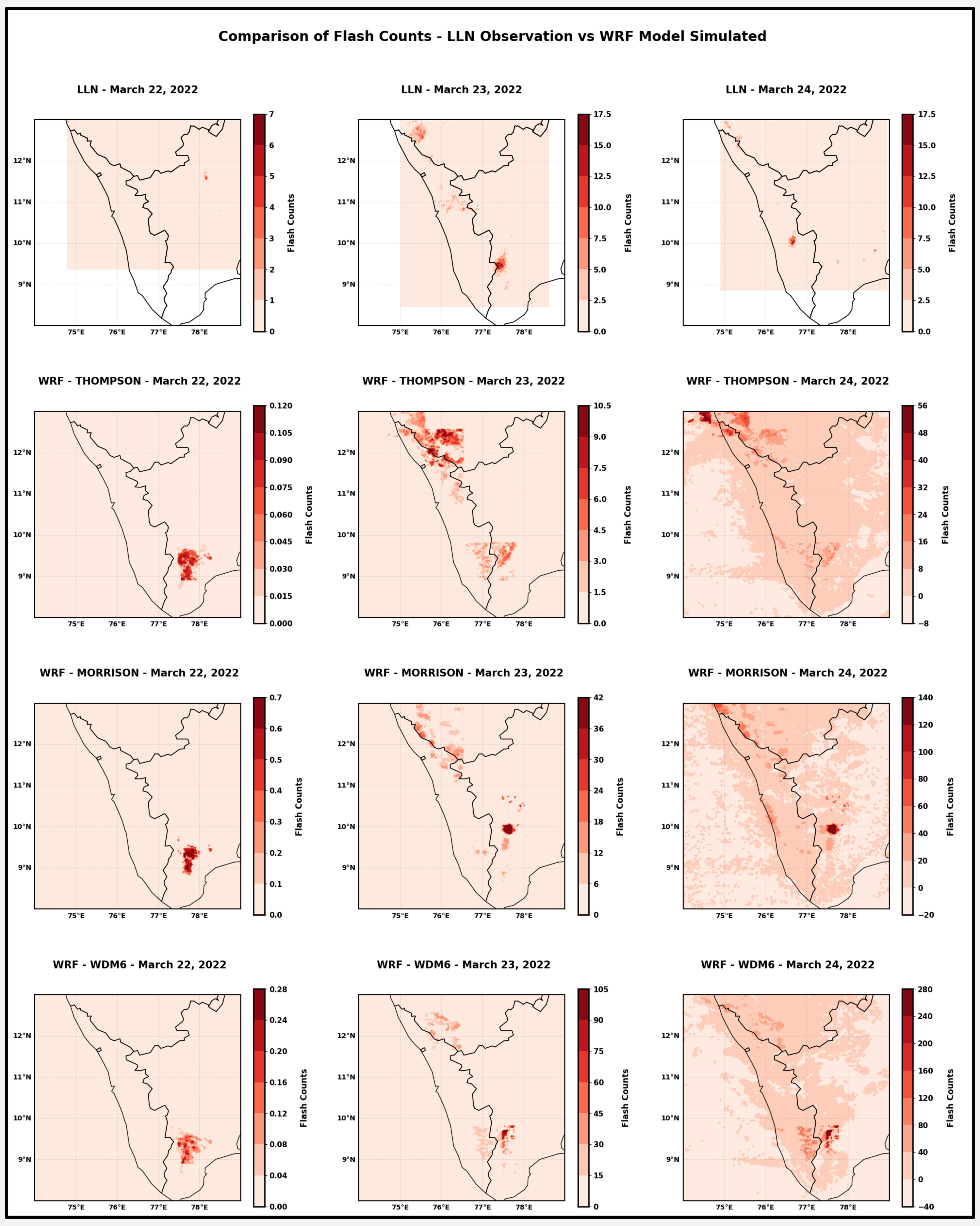
WRF MODEL CONFIGURATION:

- IC/BC - GFS Data
  27 km * 27 km – 6 hourly
- Domain – 2 domain
  9 km , 3 km – 30 minutes
- Microphysics parameterizing Scheme:
  Thompson, Morrison, and WDM6
- Cumulus parameterizing Scheme:
  Multiscale Kain-Fritsch
- Lightning parameterizing Scheme:
  Price and Rind, 92

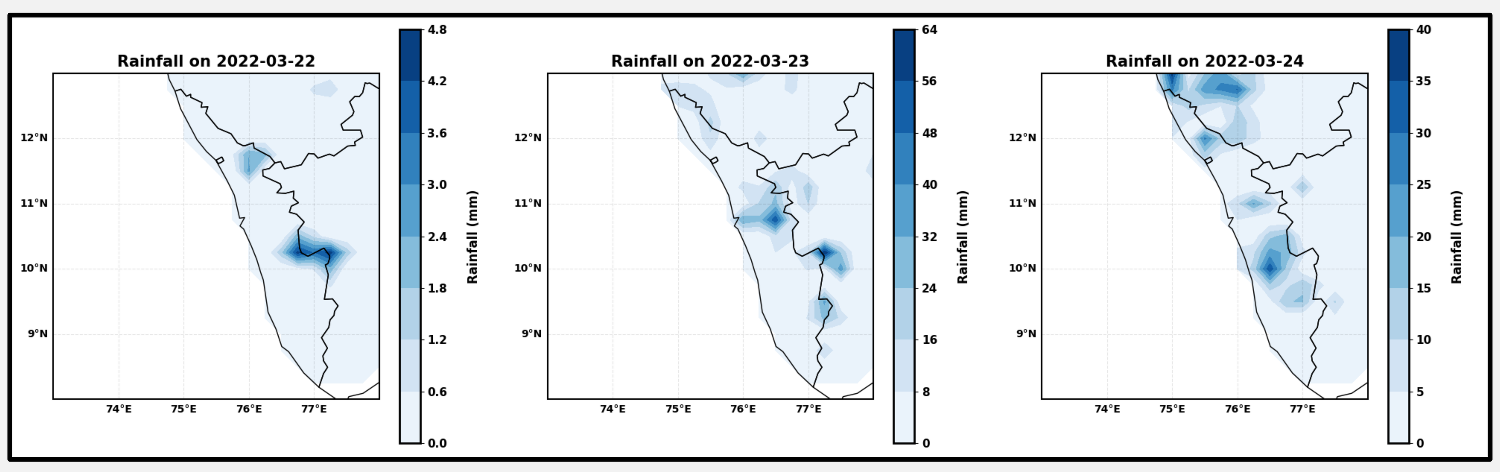


RESULTS:

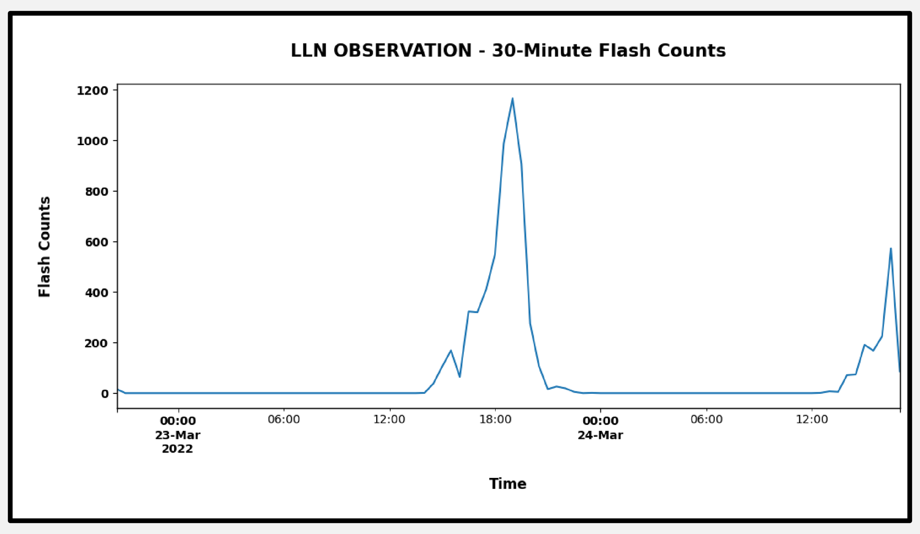
Observed and Model simulated Flash counts:

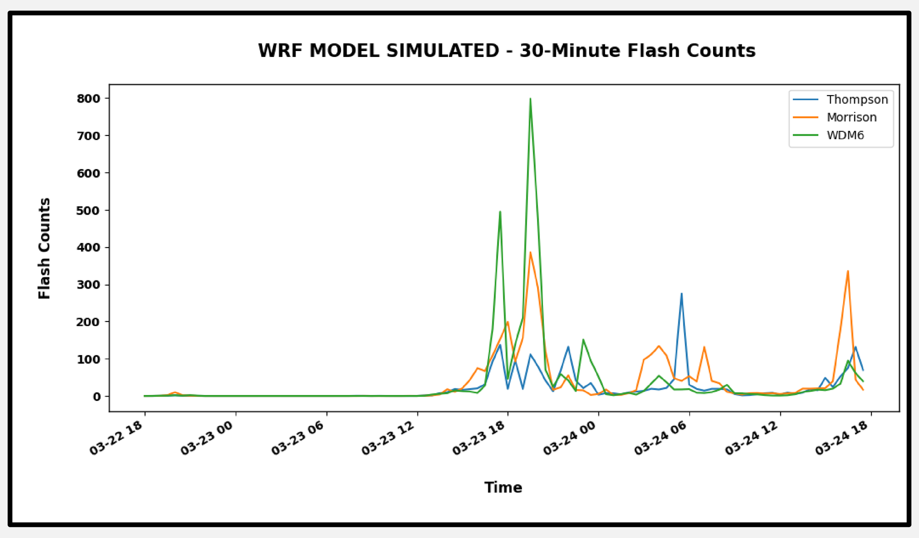


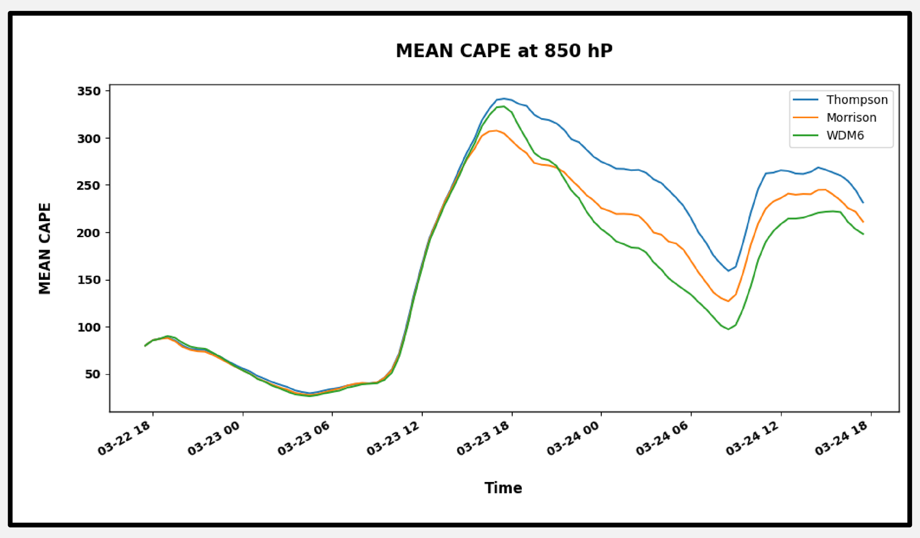
Observed IMD Rainfall:

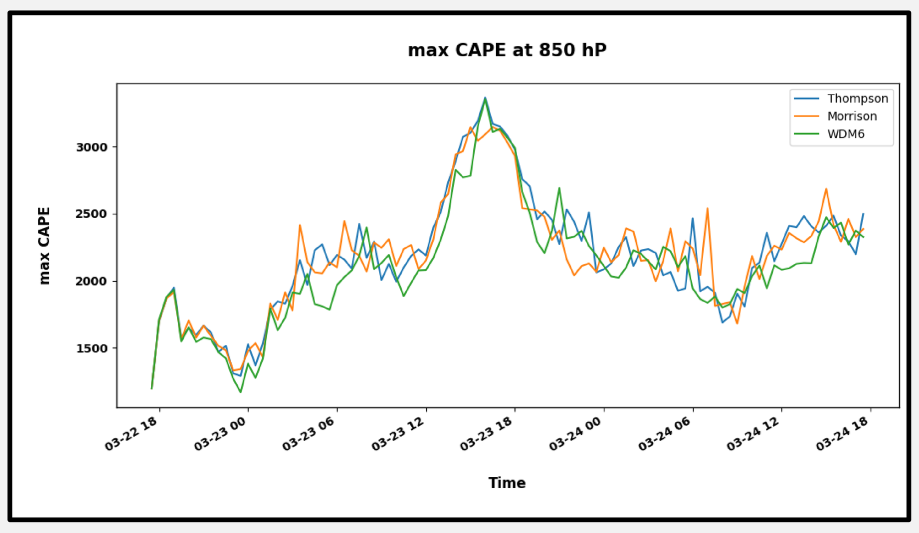


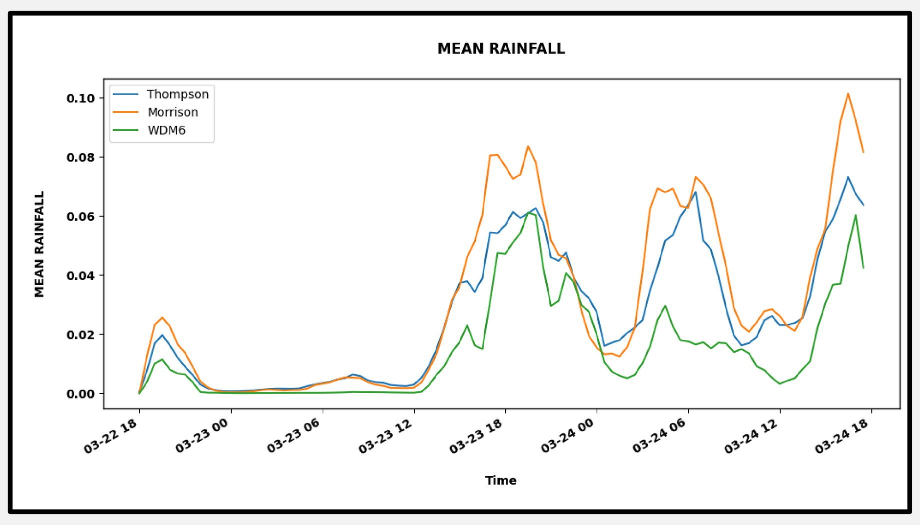
Temporal Variation of Flash counts, CAPE and Rainfall:

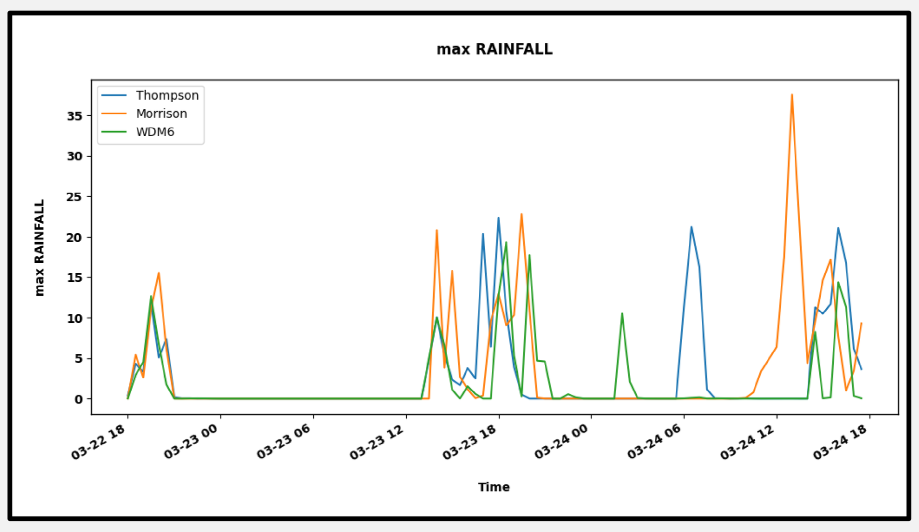




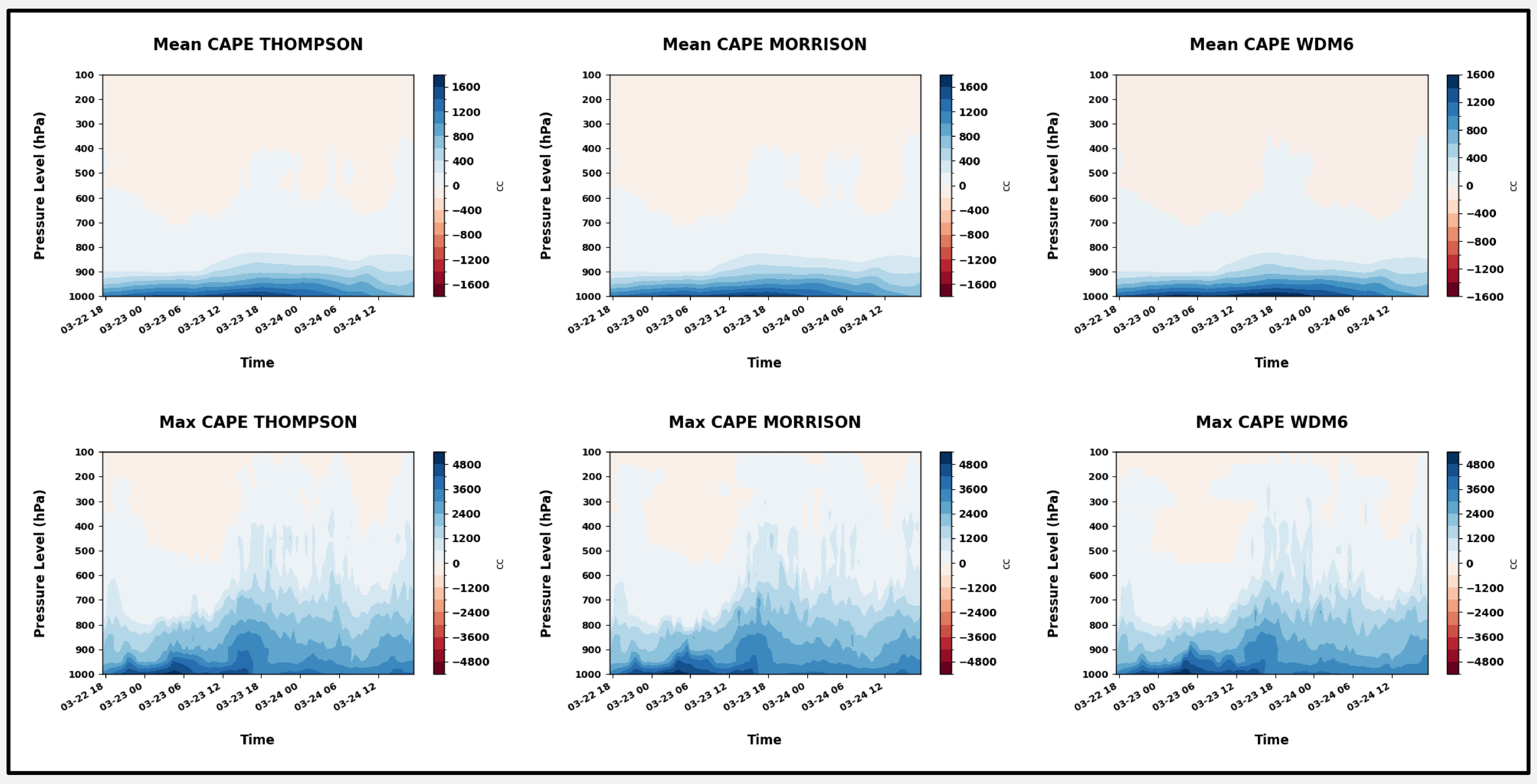








Vertical Distribution of CAPE over different pressure levels:



CONCLUSIONS:

- WDM6 and Morrison schemes matches the observed lightning distribution (both spatially and temporally, with WDM6 capturing flash magnitude).
- All microphysics schemes underestimates the total number of lightning flashes compared to observations.
- All schemes occasionally simulates lightning flashes when none were observed.
- While all microphysics schemes captured similar variations in CAPE, there were slight differences in the simulated magnitudes.
- The vertical distribution of CAPE also showed minimal variation between the different schemes.
- Further research is ongoing to understand how other factors, including thermodynamic parameters beyond CAPE, microphysical processes in more detail, and dynamical factors influencing cloud development and electrification, contribute to discrepancies between simulated and observed lightning.

FUTURE DIRECTIONS:

1. Model Efficiency: We will explore methods to improve model efficiency by increasing spatial resolution while maintaining computational feasibility.

2. Sensitivity to Initial and Boundary Conditions (IC/BC): A further investigation will be conducted to assess the impact of different IC/BC on the performance of various microphysics schemes in simulating lightning.

3. Cumulus Parameterization Schemes: We plan to study the role of various cumulus parameterization schemes in WRF and their interaction with microphysics schemes in representing lightning activity.

References:

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2. Vani, K., Mohan, G. M., Hazra, A., Pawar, S. D., Pokhrel, S., Chaudhari, H. S., et al. (2022). Evaluation and usefulness of lightning forecasts made with lightning parameterization scheme coupled with WRF model. Weather and Forecasting. https://doi.org/10.1175/WAF- D-21-0080.1
3. Biswasharma, Rupraj & Sharma, Sanjay & Satyanarayana, Gubbala. (2019). Sensitivity analysis of microphysics and cumulus schemes of WRF model for simulation of extreme rainfall events over Nagaland in the North East Indian region.