New dynamical prediction system for lightning flash over India using multi-physics parameterizations schemes

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Background

Thunderstorms (TS) are the source of lightning discharge, which is one of the major causes of natural calamity (i.e. damage of public properties and loss of life) across the globe. In India, the loss of human life due to lightning strike is particularly high over different parts of the sub-continent due to large occurrence of TS in pre-monsoon season (March-May). Unfortunately, besides some purely empirical methods, there is hardly any systematic mechanism involving dynamical model and suits of observational inputs which provides a reliable forecast to issue a warning prior to the occurrence of lightning.

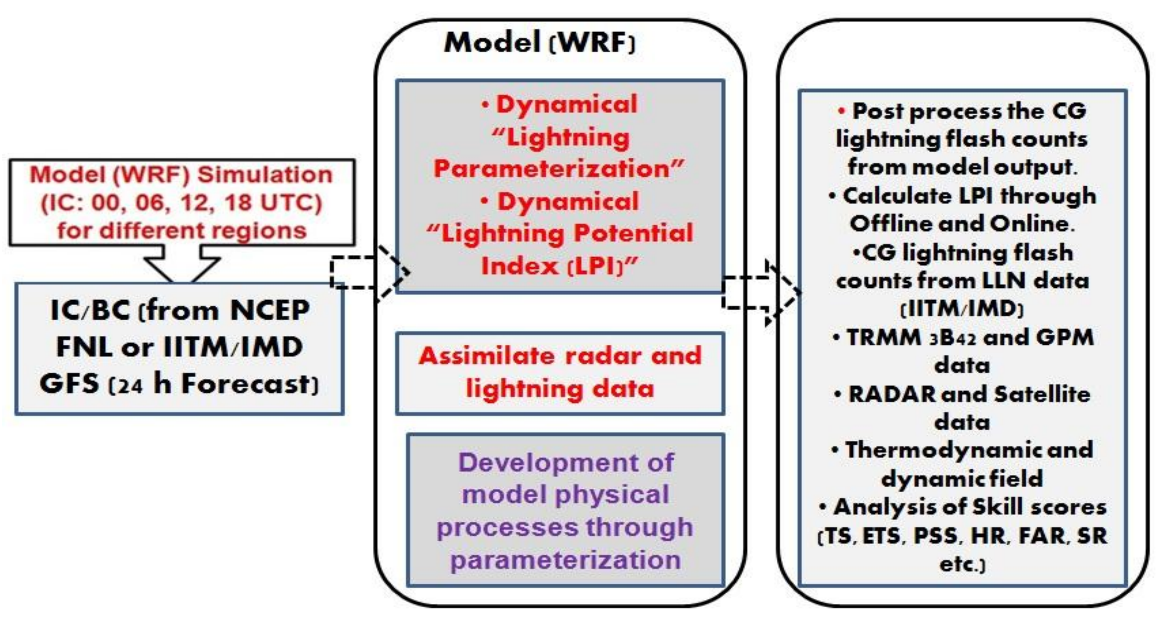
A system of modeling framework for thunderstorm/lightning prediction based on state-of-the-art dynamical model (e.g., WRF) as well as hybrid (Model and Statistics) methods need to be setup due to the high demand from the society.

This study evaluates the model performance in terms of model skill and biases. The model simulated lightning flash count results are compared with Maharashtra Lightning Detection Network (MLDN) data. Further, this study will extent to identify the causes of biases in the simulation of TS in numerical model (e.g., WRF) and develop/improve the physical processes.

Simulation of Lightning Flash Rate

- ✓ **Conventional approach for thunderstorm prediction using dynamical model and observations are well documented and have some limitations (*Mukhopadhyay et al., 2003,2005; Chaudhari et al., 2010, Ghosh et al., 2004, Rajeevan et al., 2010, Madhulata et al., 2013).***
- ✓ **Dynamical Lightning parameterization and dynamical lightning potential index should be tested in the dynamical model for convection over India along with microphysics for the proper feedback and coupling.**
- ✓ **Improvement of microphysical and lightning parameterization schemes need to be targeted for the extreme events associated with electric fields.**
- ✓ **More observed data are now used for the verification and for improving the modeling system.**

Proposed Roadmap of Lightning/Thunderstorm Nowcasting System



Lightning Parameterizations

The total (IC and CG) lightning flash density (f_T: in flashes km^{-2} day^{-1}), is determined as

$$f_T = \alpha Q_R \sqrt{CAPE}\, min(z_{base}, 1.8)^2$$

$$Q_R = \int_{z0}^{z-25} q_{graup}(q_{cond} + q_{snow})\bar{\rho}\, dz$$

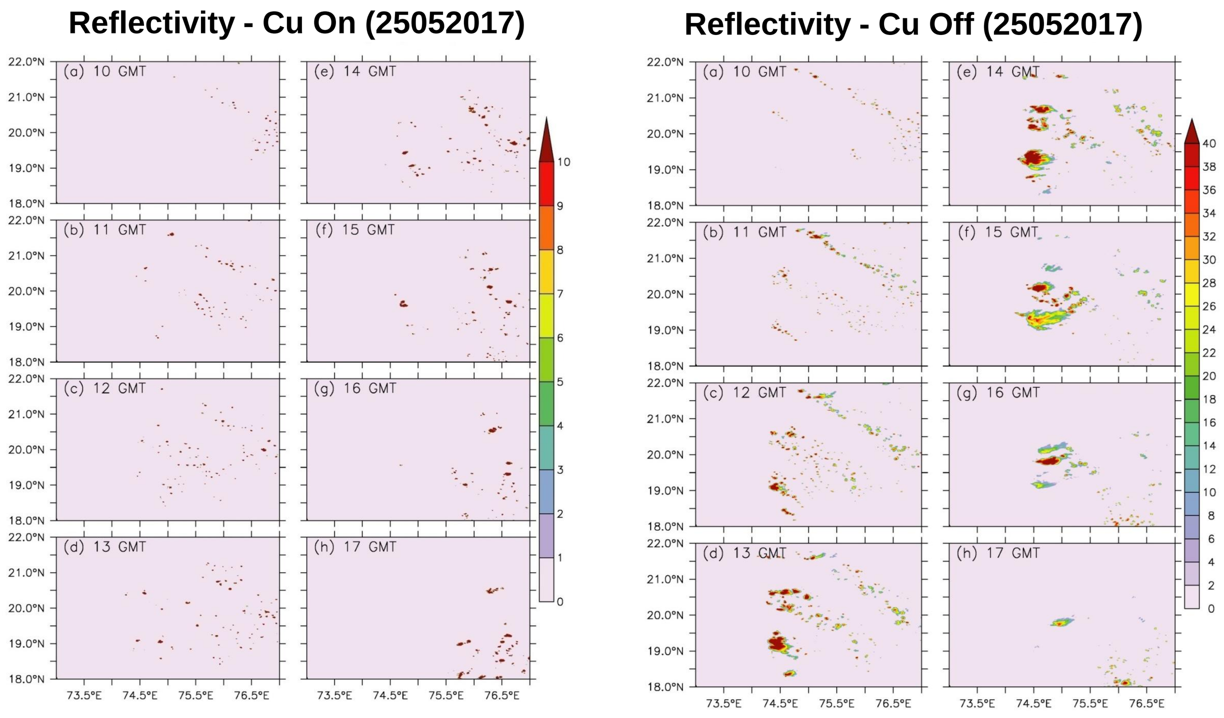
$$q_{graup} = \beta \frac{P_f}{\bar{\rho} V_{graup}} \quad ; \quad q_{snow} = (1-\beta)\frac{P_f}{\bar{\rho} V_{snow}}$$

- **DLP1: PR92 based on maximum vertical velocity, redistributes flashes within dBZ>20**
- **DLP2: PR92 based on 20 dBZ top, redistributes flashes within dBZ>20**
- **DLP3: PR92 based on level of neutral buoyancy from convective parameterization**

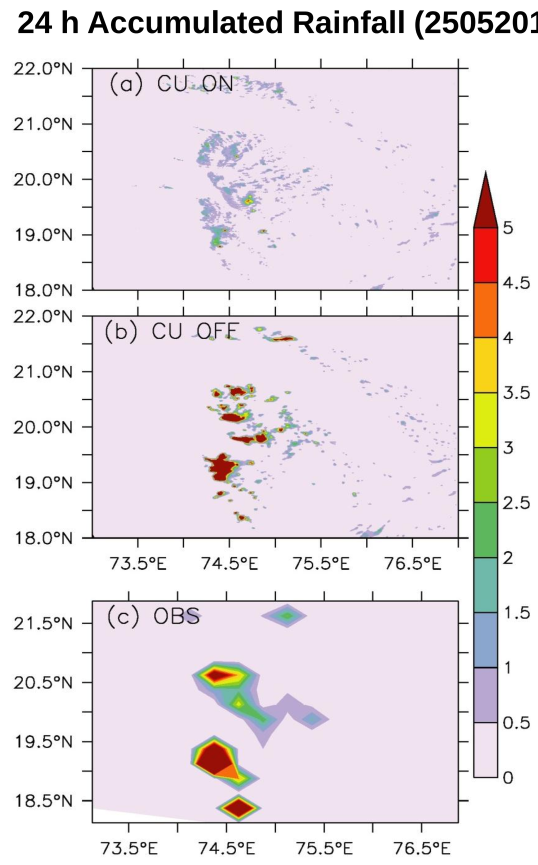
(PR92: Price, C., and D. Rind (1992), A simple lightning parameterization for calculating global lightning distributions, J. Geophys. Res., 97, 9919–9933,doi:10.1029/92JD00719)

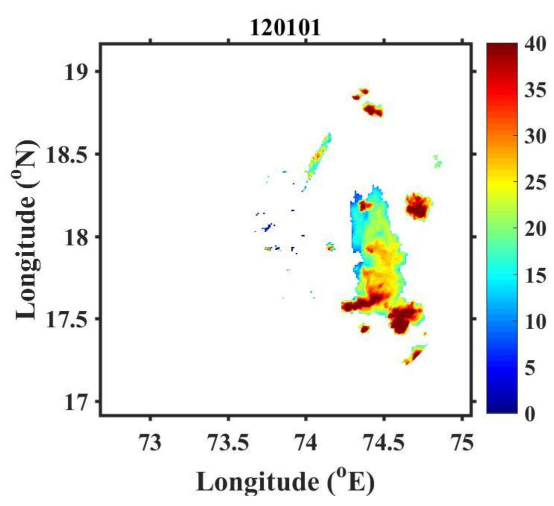
Basic Research: Importance of "Cumulus Parameterization" for Simulating Convective Events

Reflectivity - Cu On (25052017) **Reflectivity - Cu Off (25052017)**



24 h Accumulated Rainfall (25052017)



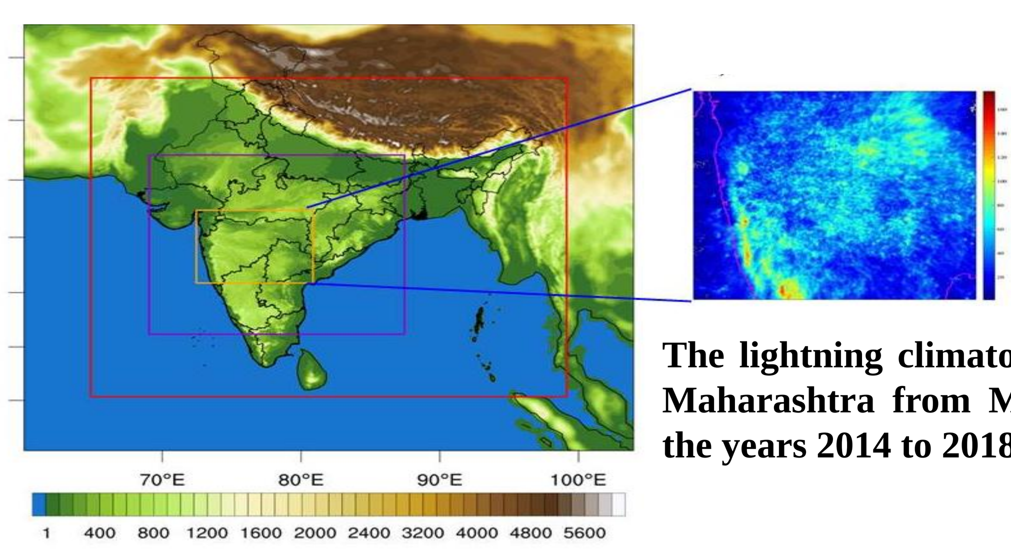


Observed X-band radar reflectivity

(Prepared by Dr. Subrata K. Das)

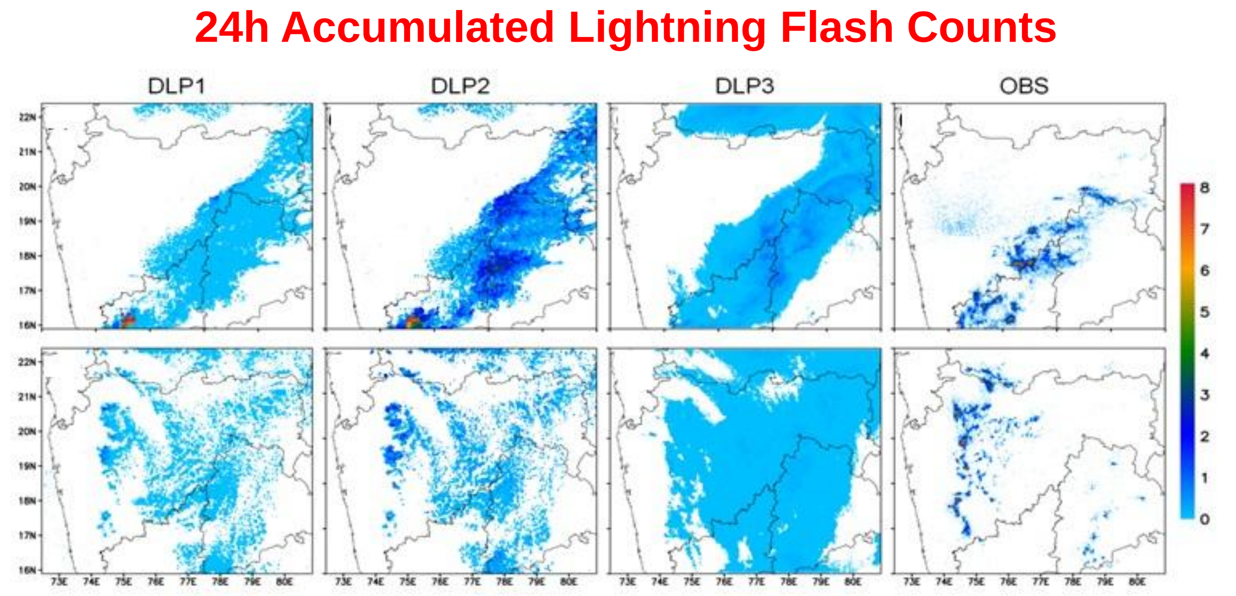
Results: Case Studies

Model Domain System

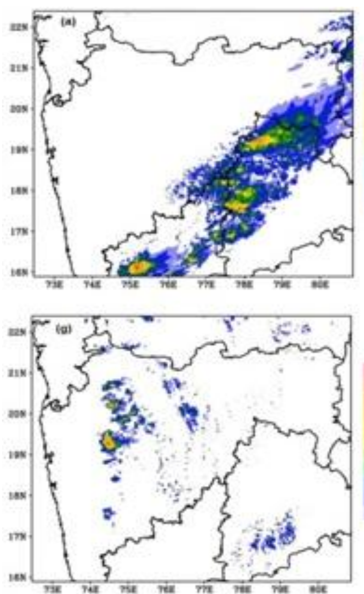


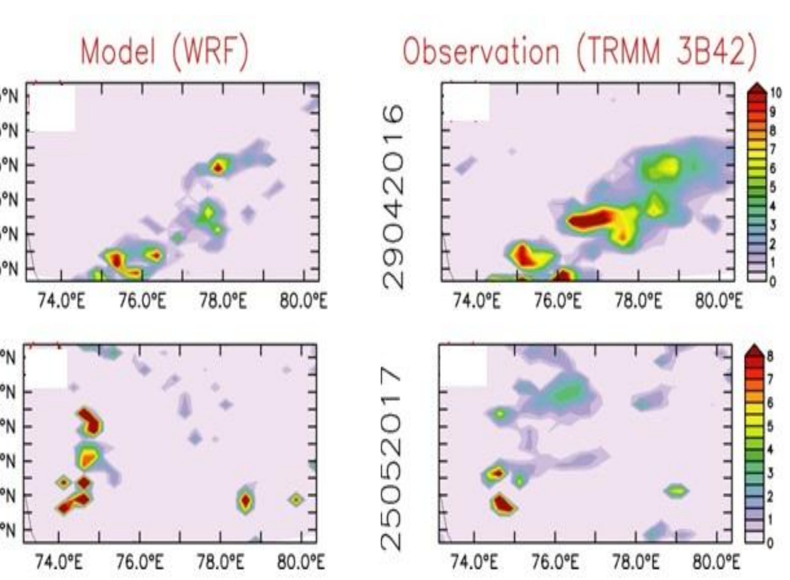
The lightning climatology over Maharashtra from MLDN for the years 2014 to 2018.

24h Accumulated Lightning Flash Counts



Max. Reflectivity **Accumulated Rainfall**

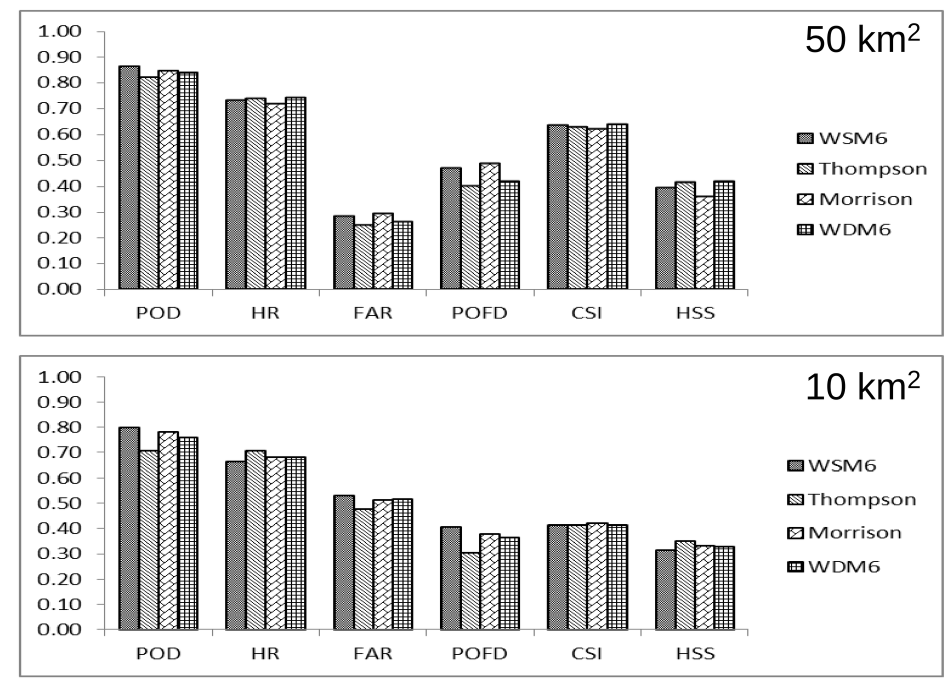


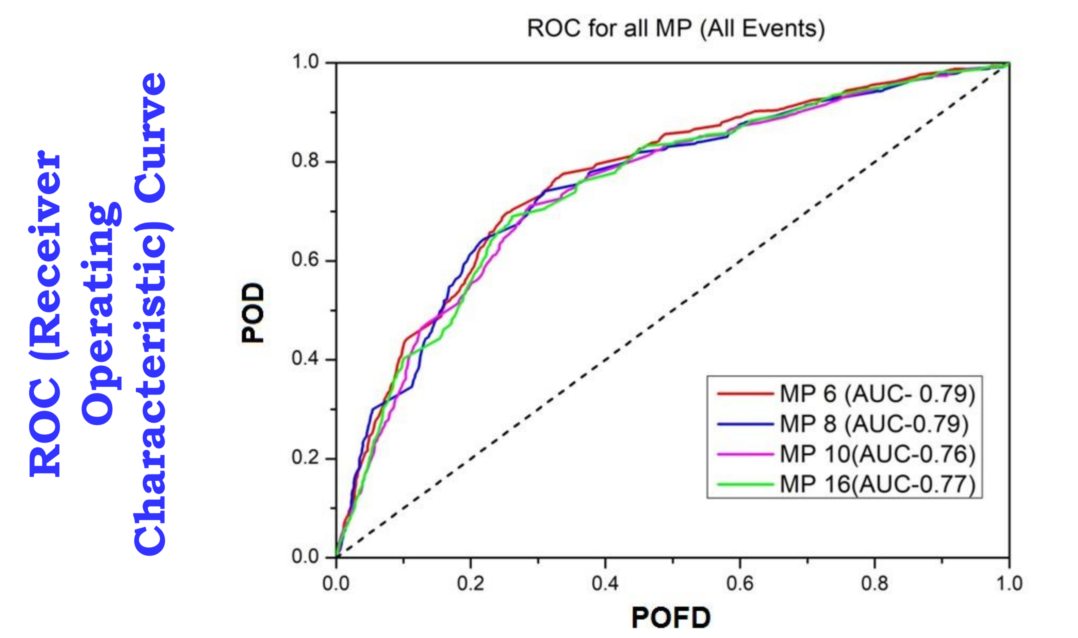


Greeshma, M., Gayatri, Vani K. , Hazra A., et al., (2020)

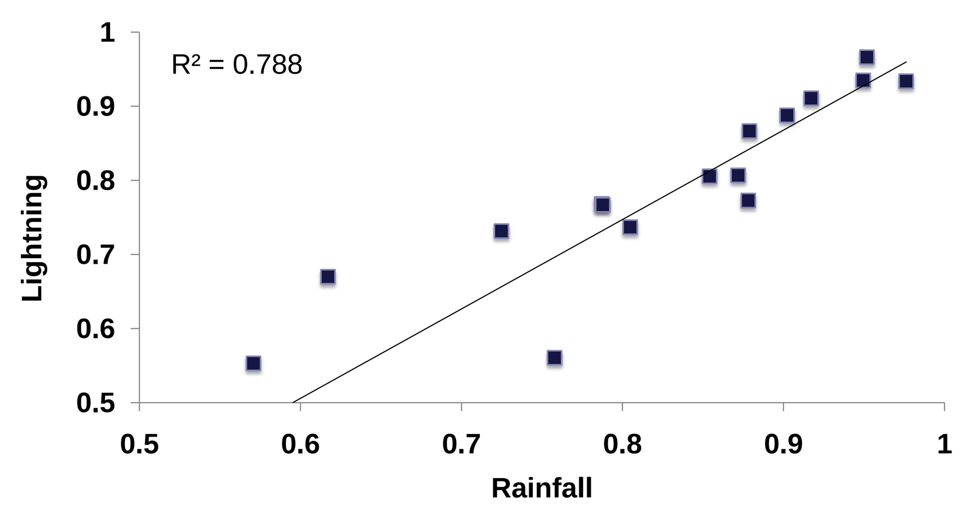
Verification and Usefulness

Skill Score (Lightning Flash Count)





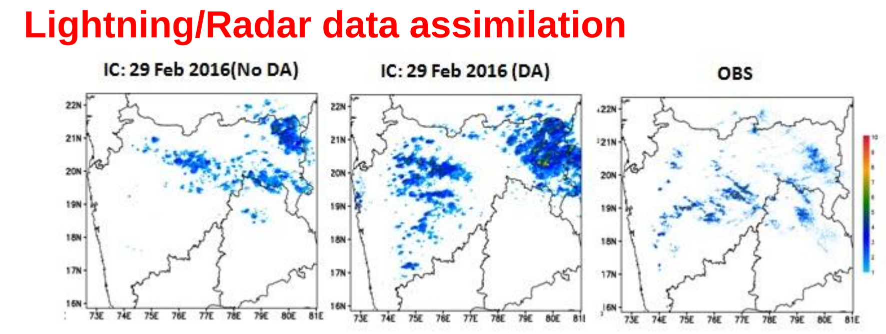
POD of Rainfall and Lightning Flash



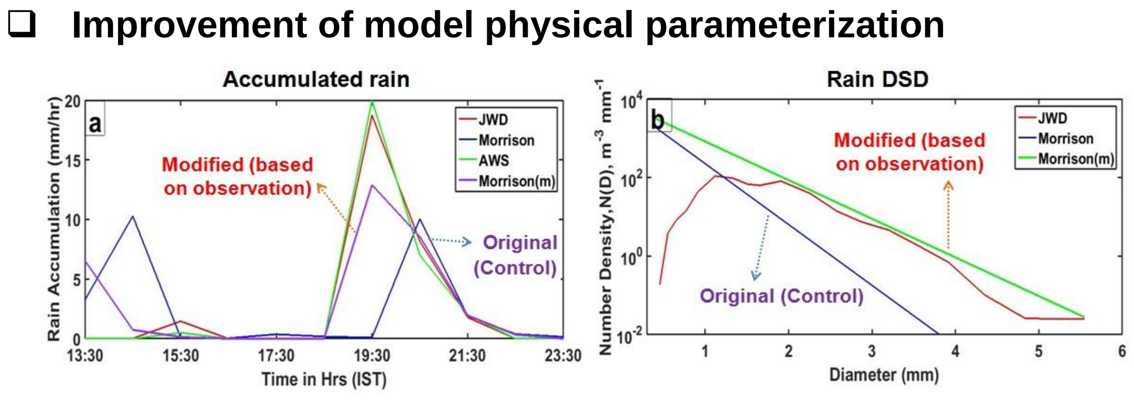
Gayatri, Vani K. , Greeshma, M., Hazra A., et al., (2020)

Model development (Ongoing)

- ❑ **Lightning/Radar data assimilation**



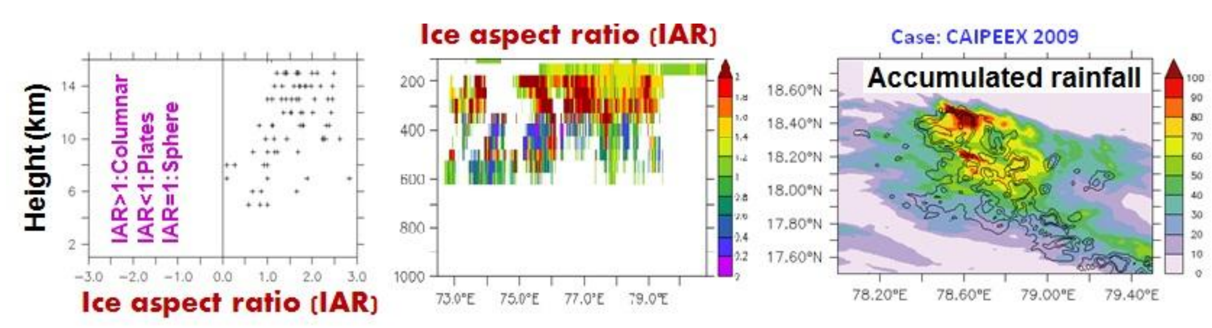
- ❑ **Improvement of model physical parameterization**



Mudier, Hazra, Pawar et al., 2020

- ❑ **Inclusion of shape parameterization (triple-moment microphysics) and improvement of lightning parameterization.**

Triple-Moment Microphysical Scheme (Shape Parameterization): Volume-Weighted Bulk Aspect Ratio: NTU Scheme (J.-P. Chen and Tsai 2016; Chen-Hazra-Levin, 2018)



Hazra, A. et al., (2019)

- ❑ **New 'Electric filed' parameterization along with cloud-aerosol interaction.**
- ❑ **Improvement through IC/CG ratio.**
- ❑ **Land-surface processes and interaction with convection.**

Acknowledgements: Indian Institute of Tropical Meteorology, Pune is supported by the Ministry of Earth Sciences, Govt. of India, New Delhi. Team sincerely thanks Director, IITM, Program manager, Aaditya HPCS, WG-TP, MoES, IMD, NCMRWF. We are grateful to Prof. Jen-Ping Chen and his group, National Taiwan University, Taipei, Taiwan, Dr. M. C. Barth, NCAR, Dr. Thomas Hopson and his group, NCAR for scientific collaboration, help and support.

TS- Lightning Modelling Team : Anupam Hazra (Lead), Greeshma M. Mohan, Gayatri. Vani K, S. Pokhrel, H. S. Chaudhari, S. K. Das, S. Deshpande

Lightning Observations: S. D. Pawar and Team; Cloud-aerosol-Land surface Team: M. Konwar, S. Ghude, S. K. Saha