On the Observed Relationships Between Lightning Flash Rates and Radar Echo Volumes of Thunderstorms

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Introduction and Motivation

- Radar observations of deep convective clouds provide critical insights into atmospheric dynamics, microphysics, and lightning parameterizations for numerical weather prediction **of thunderstorms.**
- Current lightning parameterization schemes (e.g., PR92) rely on proxies like cloud tops and vertical velocities. They do not consider **volumetric information of convective cells**.
- This study investigates 3D structures of lightning-producing DCCs using C-band polarimetric radar, Indian Lightning Location Network, satellite imagery, and WRF model simulations.
- By analyzing 6-minute volumetric scans of CPOL radar, we identify DCCs exceeding reflectivity thresholds and associated lightning flashes. A new method has been implemented to estimate Echo Top Heights (ETHs) and Echo Volumes (EVs) with various thresholds for lightning estimation

Objectives

- **Integration of radar and lightning observations to characterize the 3-D structures of Thunderstorms.**
- **Establishing relationships between radar-derived Echo Volumes and lightning flash rates.**
- **To implement the derived relationship in the WRF model for lightning estimation.**

Methodology & Study Area

- **The 3D structures of the lightning-producing deep convection are investigated using CPOL radar at the Atmospheric Research Testbed (ART) facility of IITM, and Indian Lightning Location Network (ILLN)**. The study is conducted at ART Silkheda and adjoining regions in India's monsoon core region (**Figure 1**).

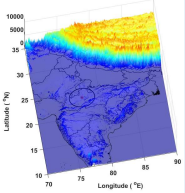
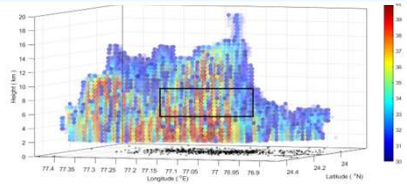


Fig. 1: Map of the study region with enclosed radar coverage. The asterisk symbol denotes the ground station located at Silkheda.

- DCCs are investigated using Doppler and polarimetric variable measurements.
- 3-D structures of DCCs are identified using contiguous regions of pixels that exceed a threshold value of reflectivity and have at least one lightning flash.

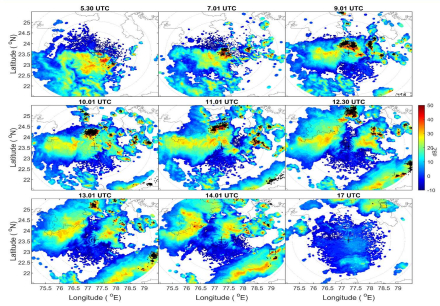
Illustration of Radar Echo Volume in Deep Convective System



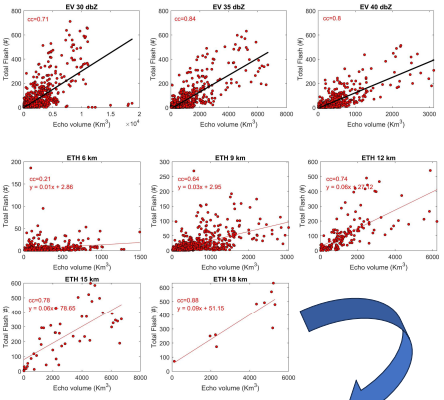
Circular points denote connected 26-bit pixels, with color indicating dBZ values. black points mark the positions of lightning flashes.

Results: Integrating Radar and Lightning Observations

Geolocation of Radar reflectivity and lightning flashes



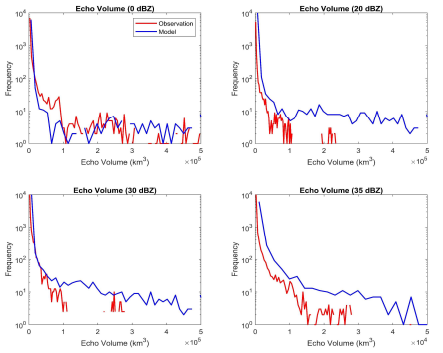
Observed Relationships: Flash, Echo Volumes and Echo Top Heights



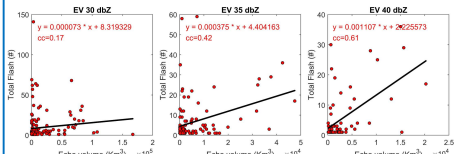
Derived relationship

For h=6 km: flash=0.01v+2.86
For h=9 km: flash=0.03v+2.95
For h=12 km: flash=0.06v+27.12
For h=15 km: flash=0.06v+78.65
For h=18 km: flash=0.09v+51.15
Where, h= Echo top heigh, v= Echo Volume

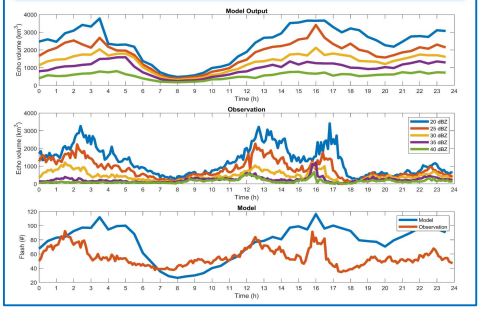
Distributions of Echo Volumes in Radar OBS and WRF model



WRF Model derived Echo Volume & OBS Flash



Evolution of Echo Volumes and Lightning Flash: Radar OBS and WRF model estimated



Summary and Future Scopes

- **Echo Volumes and Echo Top Height were calculated from 3D reflectivity profiles of CPOL radar at ART.**
- **Relationships of observed Echo Volumes and Echo Top Height with lightning were analyzed.**
- **Lightning flashes are found to be highly correlated (CC: 0.84) with the observed 35 dBZ Echo Volumes.**
- **35 dBZ Echo Volumes having ETH >= 12 km show the highest correlation (CC: 0.78) with the total flash.**
- **The obtained relationships were implemented in the WRF model, and the performance was analyzed.**
- **Simulation shows comparable lightning flashes with the IITM-ILLN observation, showing the potential for using in lightning parameterization.**

Future directions

- **Exploring polarimetric observations and their relationships with Lightning/Microphysics**
- **Validation of the derived relationship over various locations from observation and simulations.**

Acknowledgements & References

Acknowledgments

- Authors express their gratitude to Director, IITM for his support for study. Authors are thankful to Indian Lightning Location Network (ILLN) team and ART CPol radar team for providing the data for this work.

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Eighth International Workshop on Monsoons (IWM-8)
02-07 17-21 March 2025, IITM PUNE