Program: Radar and Satellite Meteorology

Research Highlights

Precipitation Estimates over the Western Ghats

Precipitation estimates from Cloud Radar

Background

- ❖ Rainfall pattern over the Western Ghats (WGs) is complex, where topography plays an important role. The major challenges in rainfall study over the WGs are the unavailability of measurement stations on the windward and leeward sides of the mountains. Weather radars are the only instrument to measure the rainfall pattern over a given region with high temporal resolution.
- ❖ Cloud radars are primarily designed to observe only clouds, as their application to examine the precipitation is limited due to strong attenuation by raindrops.

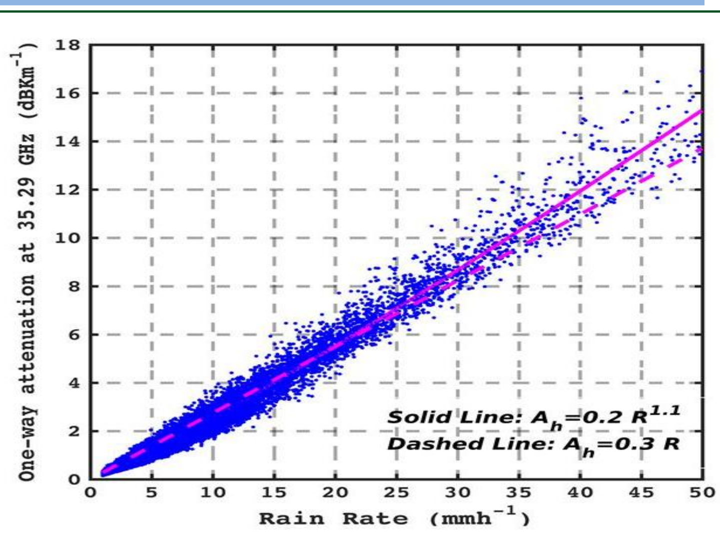
Significance

- ➢ Attenuation-based retrievals of rainfall does not require absolute radar calibration.
- ➢ Rainfall retrieval is independent of empirical relationships *(Ze − R)* that are sensitive to variations in the raindrops size distribution.
- ➢ Provide vertically resolved information.
- ➢ Vertical profile of rain is associated with variation in the microphysical and thermodynamical process, and hence, indicates the changes of phase, size, and concentration of hydrometeors in the vertical.

System Description

Parameters	KaSPR Specifications
Frequency	35.29 GHz
Peak Power	2.2 kW
Average Power	~110 W
Antenna aperture	~1.2 m
Antenna gain	49 dB
Beam width	0.5º
Pulse length	3.3 μs
Pulse repetition rate	~4960 Hz
Range resolution	~25 m

T-matrix Microwave Scattering Simulations



T-matrix scattering simulation (TSS) is used to derive specific attenuation (A_h) at Ka-band from JWD data.

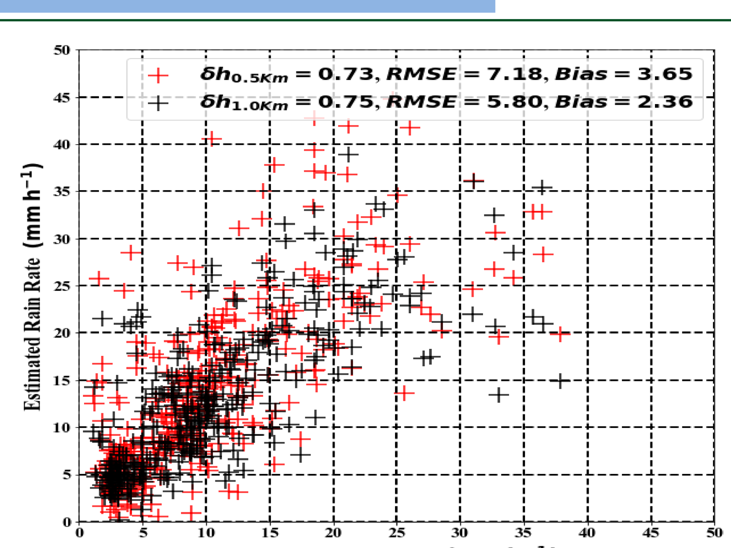
$$\kappa(h) = 1.1\,\rho(h)^{-0.45}$$

$$A_h = c\,R \;;\; c = 0.3$$

$$R = \frac{\kappa}{2c}\left(\frac{\partial Z_{el}}{\partial h}\right)$$

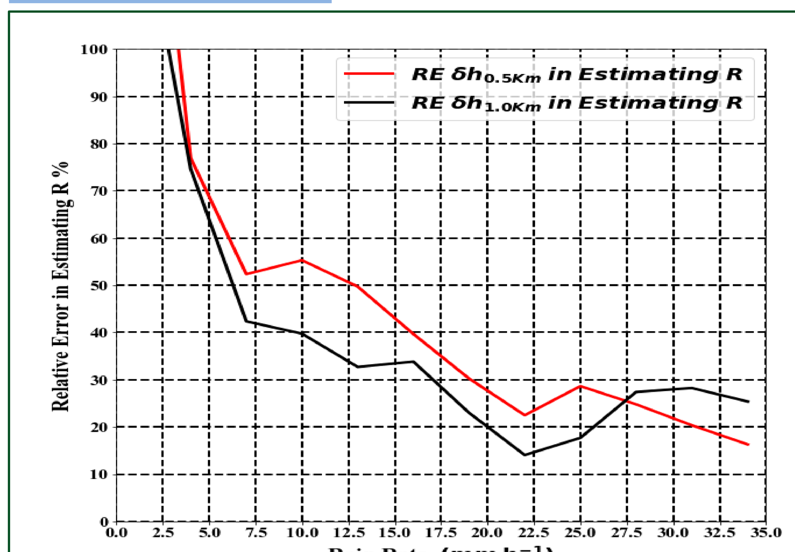
κ = Dimensionless coefficient accounts for the raindrop fall velocity.
ρ = Air density
Z_{el} = Reflectivity
c = Coeff. derived using TSS.
R = Rain rate (mm hr^{-1})

Evaluation of rain rate retrieval



Scatter plot of rain rate between JWD measured versus Ka-band radar retrieved for all 11 cases

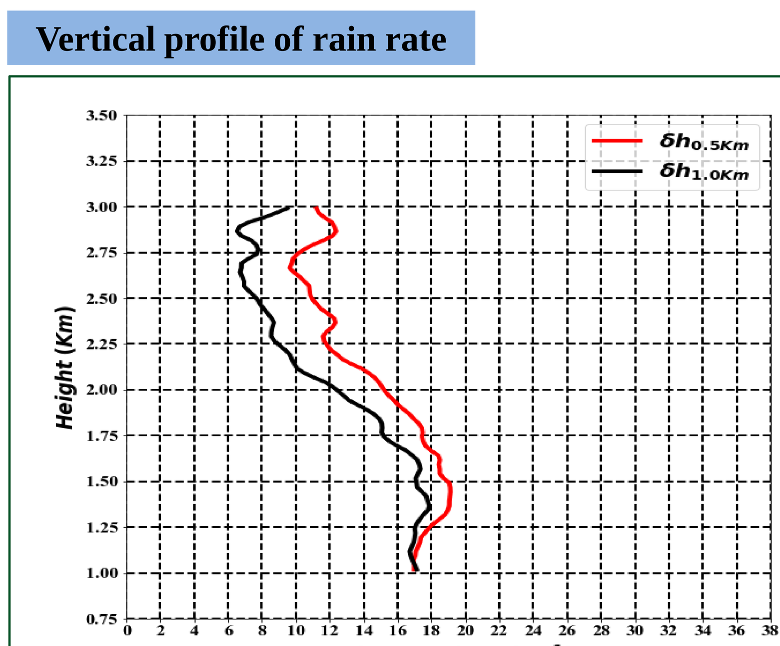
Error Estimation



Retrieval error (%) in rain rate estimation from Ka-band radar

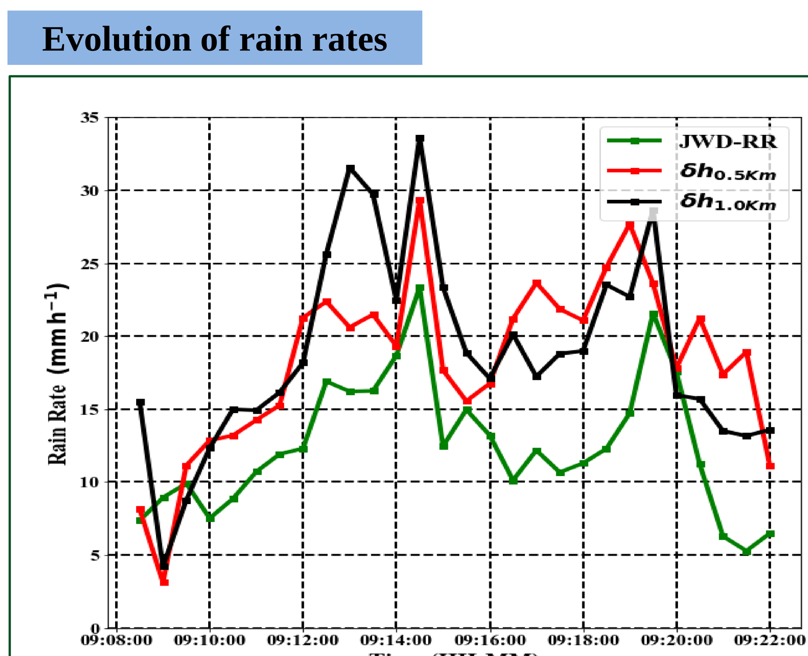
- ❖ Rain rates retrieved from 1-km rain layer depth shows better comparison with JWD observations.
- ❖ Retrieval error decreases with the increase in rain rate due to increase in attenuation with rain rate.
- ❖ Rain rate retrieval from an attenuation-based method is independent of errors in radar calibration.

Vertical profile of rain rate



- ❖ The vertical profile of *R* is constructed using a sliding window of 0.025 km height for both 0.5-km and 1-km rain layer depths
- ❖ Bias is small below 1.5-km altitude and increases with height above 1.5-km

Evolution of rain rates



- ❖ Ka-band radar data are averaged for every 30-s time interval to match with the JWD measurements
- ❖ Time of JWD measured rain has been shifted by 1 min to match with the time of the Ka-band radar retrieved rain rate

Summary

- ✓ **Both the information on clouds and precipitation can be obtained from cloud radars.**
- ✓ **The main advantage of this study is its utilization in the numerical models to validate the representation of clouds and rain over complex terrain.**

Subrata K. Das, Y. K. Kolte, U. V. Murali Krishna, S. M. Deshpande, A. K. Jha, and G. Pandithurai (2019), Estimation of Layer-Averaged Rain Rate From Zenith Pointing Ka-Band Radar Measurements Using Attenuation Method, *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, 12(9), 3178–3183, doi:10.1109/jstars.2019.2929327

Behaviour of raindrops fall speed

Background

Raindrop fall speeds depends on air density in the atmosphere. Due to topography, the raindrops fall speeds over Western Ghats differ from the terminal velocity of Gunn and Kinzer (1949).

Significance

- ❖ Knowledge of raindrop terminal velocities is important in cloud physics for modelling different micro-physical processes like breakup and coalescence. These precipitation processes are important in the parameterization schemes in the GCM's because these processes occur at smaller scales than the typical model grid size.
- ❖ Useful in rainfall retrievals from remote sensing instruments (e.g., ground-based and space-borne weather radars), hydrological and climate modelling, rain scavenging of aerosol particles.

Effect of air density on Raindrop Fall Velocity

Effect of air density on raindrop terminal velocity is not negligible and needs to be accounted.

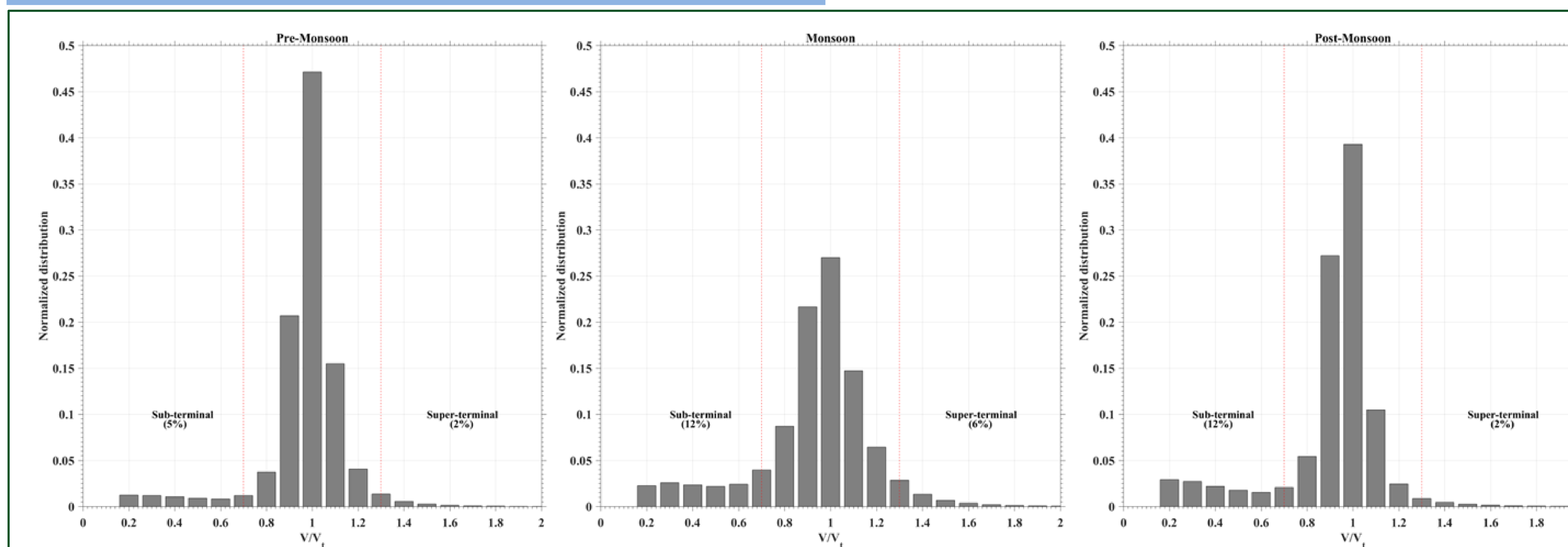
Raindrop terminal velocity at higher altitude is

$$V_t = V_0\left(\frac{\rho_0}{\rho_a}\right)^m$$

V_0 (m s^{-1}) is the fall velocity of a raindrop at diameter *D* (mm) in the standard atmosphere at the sea level.
ρ_a is the air density at the Mahabaleshwar site
ρ_0 is the air density at the sea level.

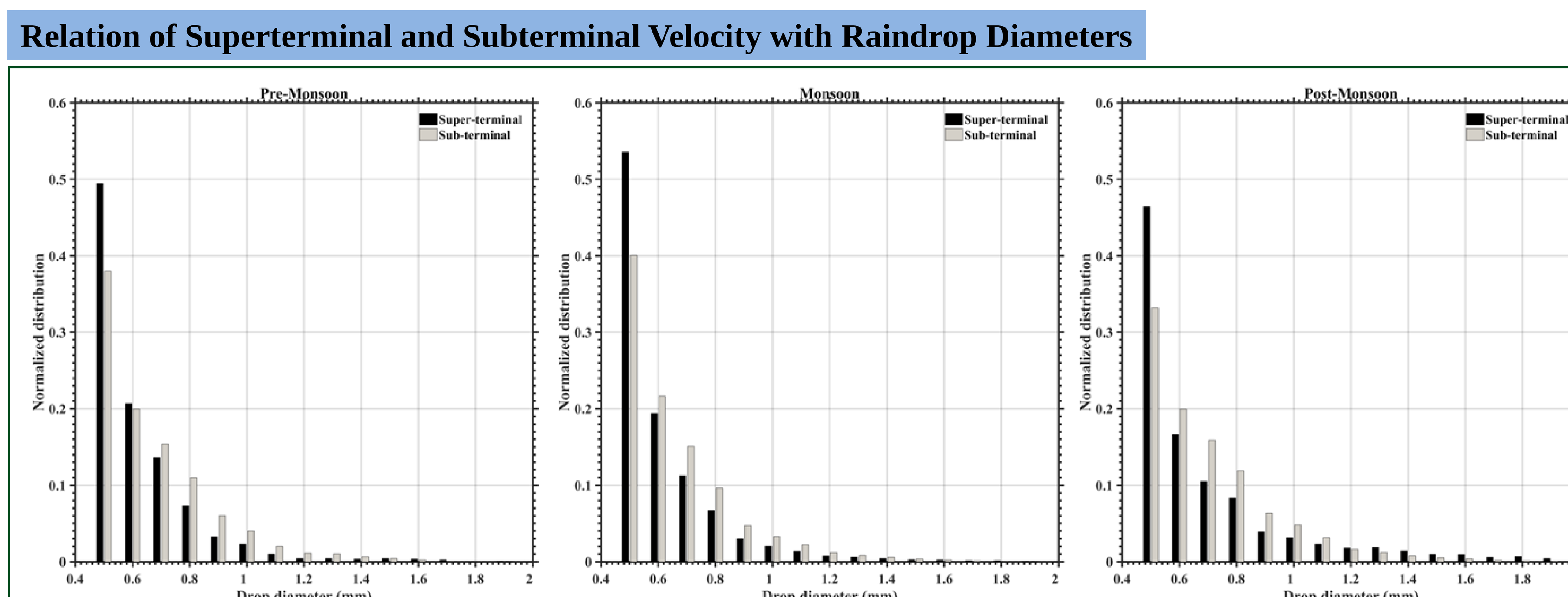
$$m(D) = 0.375 + 0.025D$$

Evidence for Raindrops deviate from Terminal Velocity



Normalized distribution of (V_{2DVD}/Vt) for the different seasons. The dashed red line marked the boundary for the super- and sub-terminal velocity of raindrops

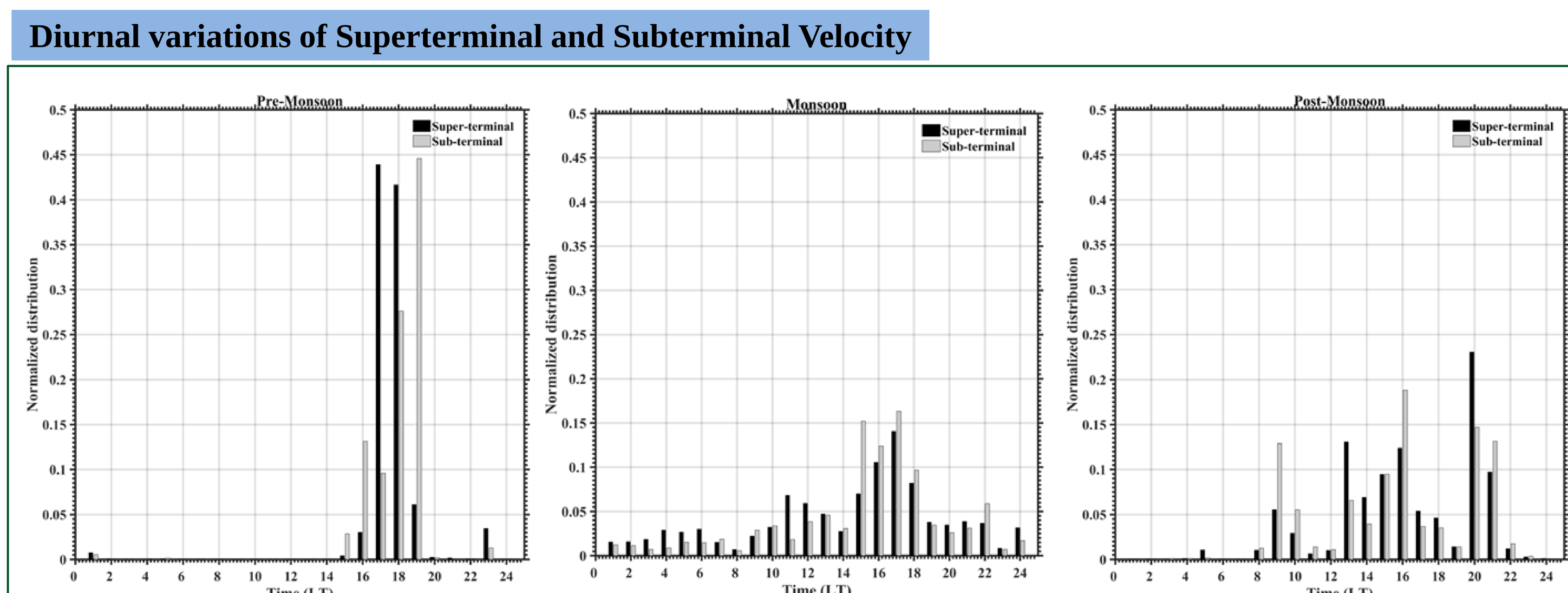
Relation of Superterminal and Subterminal Velocity with Raindrop Diameters



Normalized distribution of fall velocity against the raindrop diameter (mm) for super- and sub-terminal raindrops during the different monsoon seasons

- ❖ Super-terminal raindrops are dominant below 0.6 mm during pre-monsoon.
- ❖ Super- and sub-terminal raindrops exist below 1 mm, and shows a decreasing trend with increase in diameter during monsoon.

Diurnal variations of Superterminal and Subterminal Velocity



- ❖ Super-terminal and sub-terminal raindrops mainly occurs in the evening hours with a duration of 4-5 hours during pre-monsoon.
- ❖ Super-terminal and sub-terminal raindrops occurs throughout the day during monsoon season. Both super-terminal and sub-terminal raindrops are equally distributed during monsoon season.
- ❖ Super-terminal and sub-terminal drops usually occurs during daytime in the post-monsoon season.

Summary

- ✓ **Terminal velocity of raindrops is calculated by correcting the effect of air density at high altitude station in the Western Ghats, and these velocity criteria are applied in most of the fields like numeric modeling, DSD from impact disdrometer, and erosion parameterization.**

Subrata Kumar Das, Sibin Simon, Y. K. Kolte, U.V. M. Krishna, S. M. Deshpande and A. Hazra (2020), Investigation of raindrops fall velocity during different monsoon seasons over the Western Ghats, India, *Earth and Space Science, 7*, e2019EA000956. https://doi.org/10.1029/2019EA000956