Evaluation of CASIM using DSD bulk parameters and its improvement for monsoon extremes

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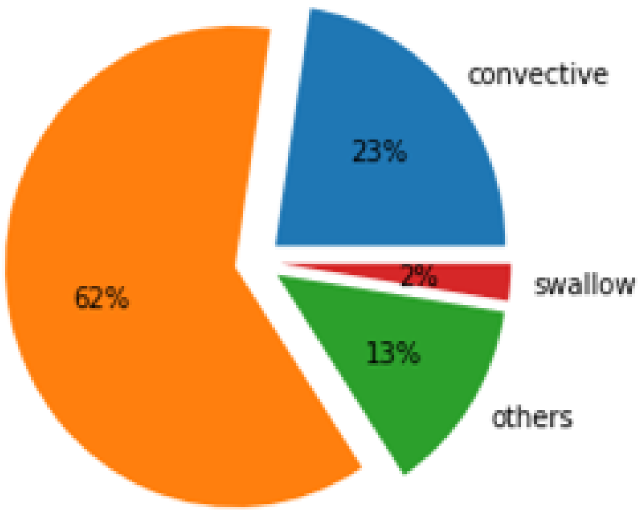
Outline

- ❑ **DSD diagnostic in CASIM : General characteristic of bulk parameters for tropical monsoon station.**
- ❑ **Extreme precipitation cases of 2018 and 2019 Kerala floods.**
- ❑ **Features of RA3 versions in convection permitted model, NCUM-R in compared to earlier operational science version (RA2)**

Monsoon cloud microphysics ?

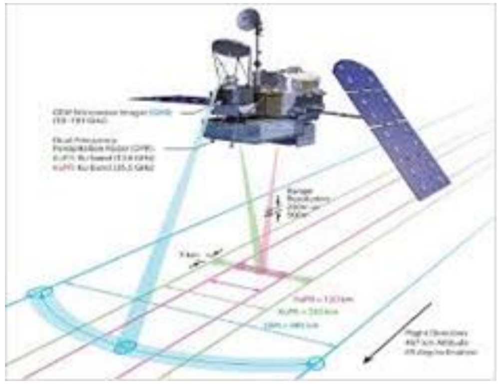
- Convective stratiform embedded systems - more prominent
- Stratiform rain occurrence is more than convective
- Microphysics can be interpreted using Drop Size Distribution DSD

Precipitation type clustering-GPM_CI(All).png



DSD Observations

GPM DPR ku band Radar Data



- 3d DSD data
- Swath path
- 1.5 hour sampling time
- Available all over tropics

Joss-Waldvogel Disdrometer

- Surface DSD data
- 1 minute sampling time
- Lesser availability

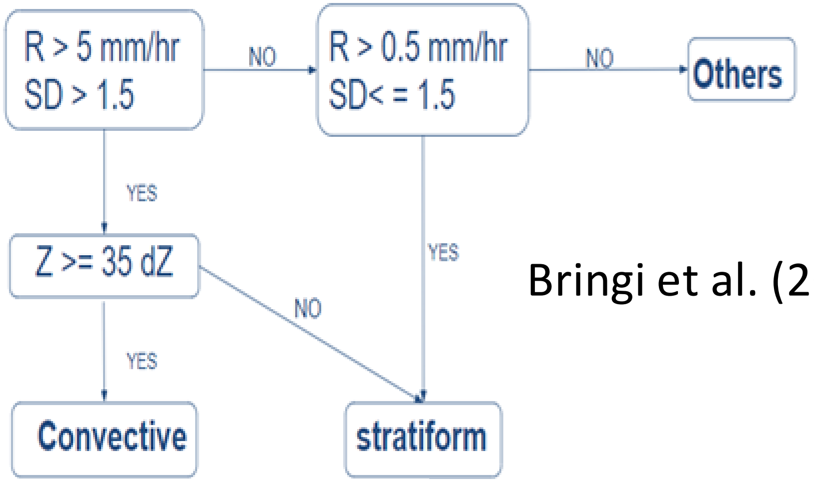
Sampling region : Tuljapur (Maharashtra)18.0087° N, 76.0709

Sampling time : June,July,August,September(2022)

Convective and Stratiform rain is from same system but different characteristics

- Intensity
- Areal extent
- DSD

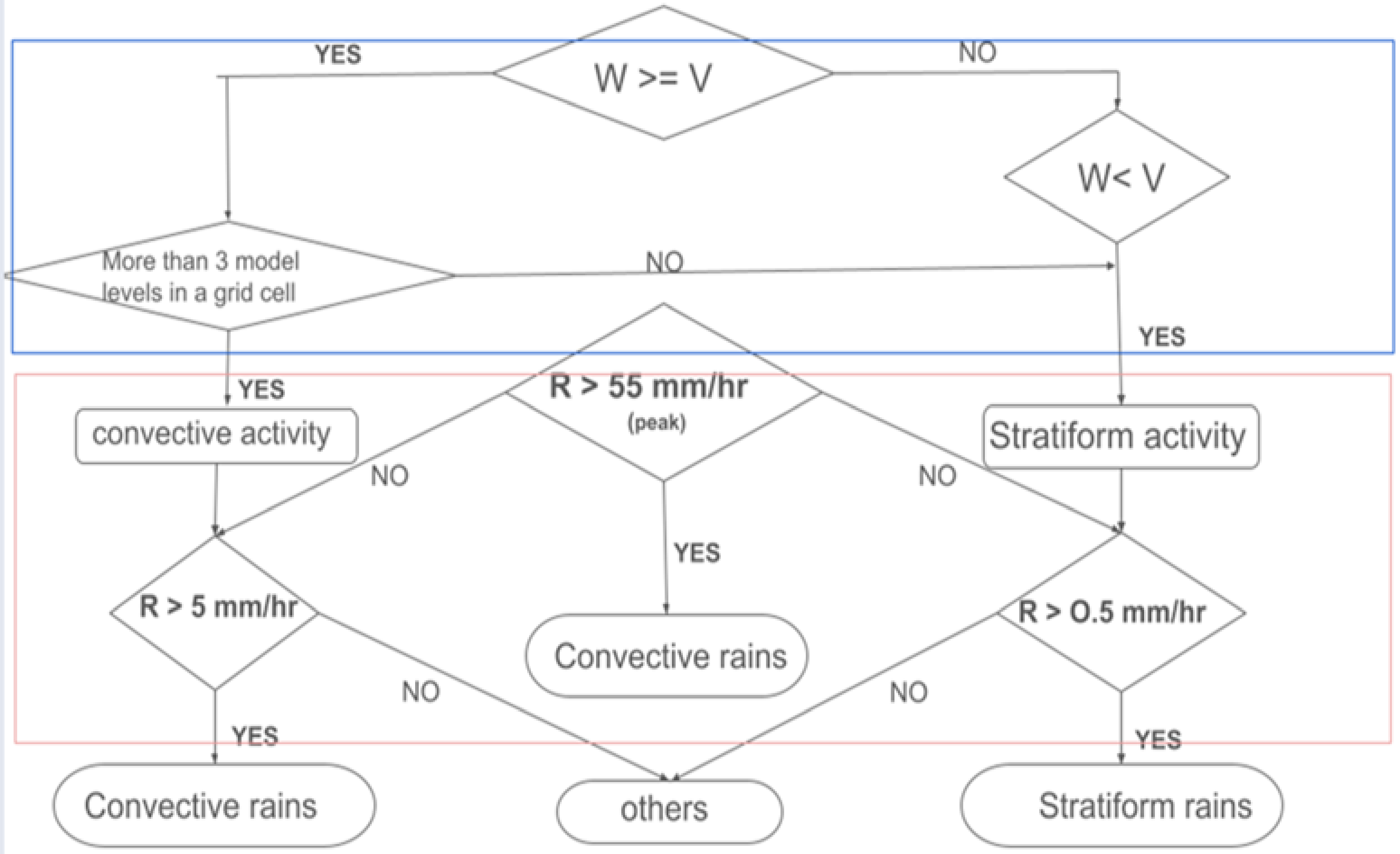
Raintype separation criteria used in JWD



Bringi et al. (2003)

$W_c = w + c\sqrt{tke}$ > V (Fall velocity)

Raintype separation criteria used in the NCUM-R



W = incloud vertical velocity , V = Fall velocity ,R = RainRate

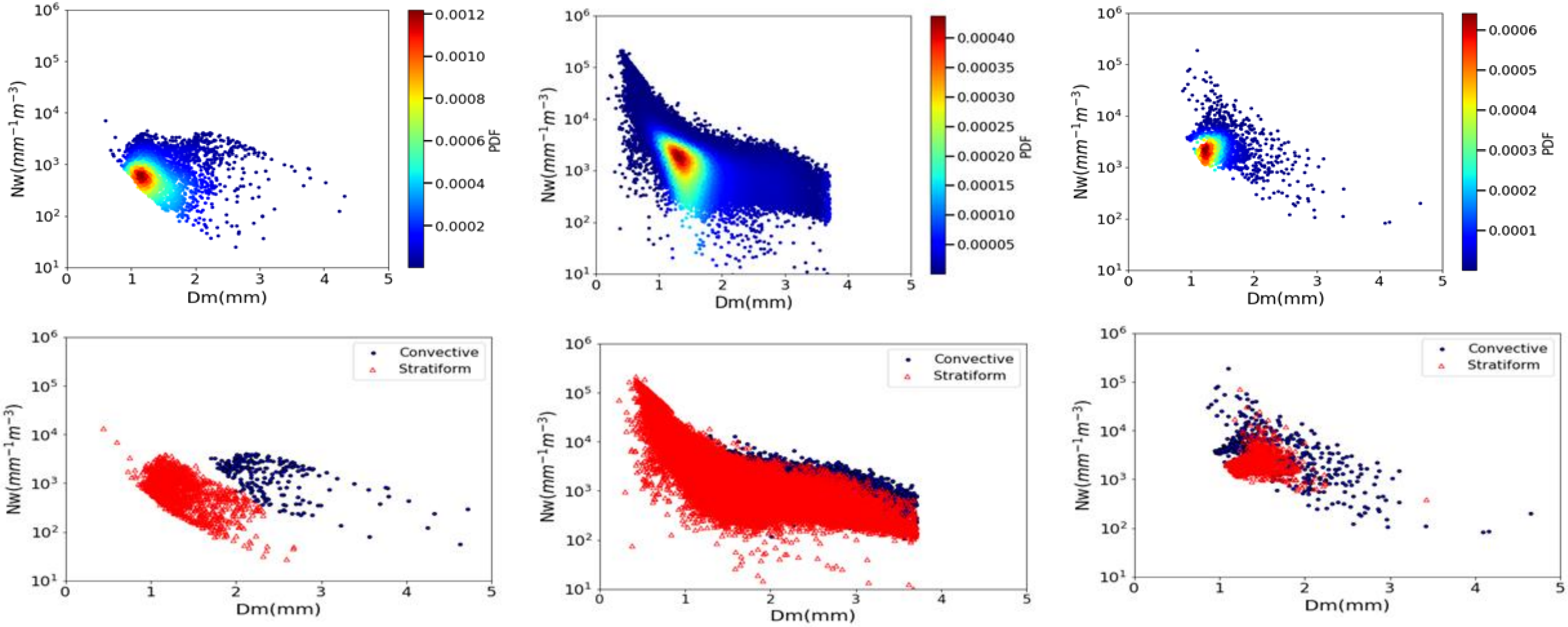
Gamma distribution parameterization in Observation and Model

Observation	Model
$N(D) = N_0 D^{\mu} \exp\left(-\frac{3.67+\mu}{D/D_0}\right)$	$N(D) = \frac{n_x}{\lambda^{1+\mu_x}} \frac{1}{\Gamma(1+\mu_x)} D^{\mu_x} \exp(-\lambda D)$
$(D_m) = \frac{\int_0^{\infty} D^4 N(D)\, dD}{\int_0^{\infty} D^3 N(D)\, dD}$	$(D_m) = \frac{\Gamma(5+\mu)}{\lambda \cdot \Gamma(4+\mu)}$
$LWC = \frac{10^{-3}\pi}{6} \rho_w \int_0^{\infty} D^3 N(D)\, dD$	$(LWC) = \frac{\Pi \cdot \rho_w \cdot M_3}{10^3 \cdot 6}$
$(N_w) = \frac{256 \cdot 10^3 \cdot LWC}{\pi \cdot \rho_w \cdot D_m^4}$	$N_w = \frac{256 \cdot nx \cdot \Gamma(4+\mu)}{6 \cdot \lambda^3 \cdot \Gamma(1+\mu) \cdot D_m^4}$

N(D) - Number distribution of drops in diameter intervals
μ = shape parameter
Λ = Slope parameter
Γ = gamma function
ρ_w = density of the drop
LWC = liquid water content
M = moment
D = Diameter
n_x = number concentration of drops after each timestep
N_0 = intercept parameter
D_0 = median diameter

N_w = Normalized Number concentration
D_m = Mass weighted Mean diameter

Analysation of DSD of the case events shows the overestimation of Nw in the NCUM-R for smaller drops (Dm < 3mm) and significant underestimation of larger drops (~ Dm> 4 mm) Convective-stratiform separation is minimum and overall domination of stratiform events in NCUM-R



JWD **NCUM-R** **GPM-DPR**

Sensitivity towards Autoconversion parameterization

KK00

$$A_u = 1350 \times q_c^{2.47} \left(N_c \times 10^{-6^{-1.79}} \rho_a^{-1.47} \right)$$

LD04

$$A_u = 1.1 \times 10^{13} \left[\frac{(1+3\varepsilon^2)(1+4\varepsilon^2)(1+5\varepsilon^2)}{(1+\varepsilon^2)(1+2\varepsilon^2)} \frac{q_c^3}{N_c} \right]$$

$$\times \frac{1}{2}(x_c^2 + 2x_c + 2)(1 + x_c)e^{-2x_c}$$

where, $x_c = 9.7 \times 10^{-14} N_c^{3/2} q_c^{-2}$.

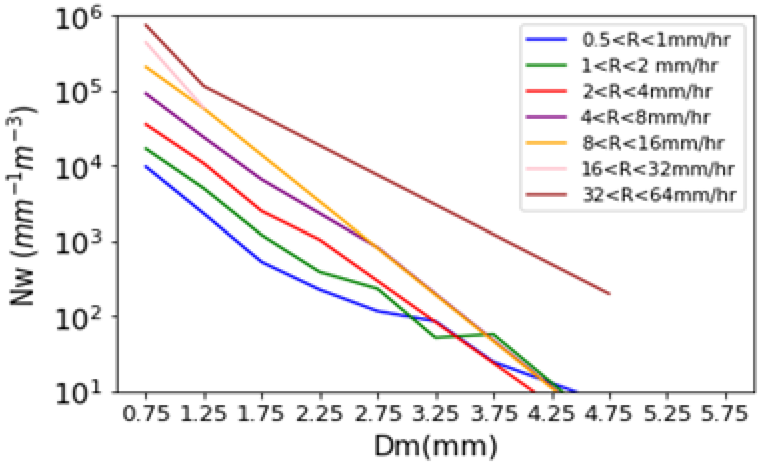
N_c is number concentration q_c is mixing ratio, ρ is density of hydrometeor and ε is the dispersion term fixed to be 0.5

References : *Liu and Daum 2004, xu 2020*

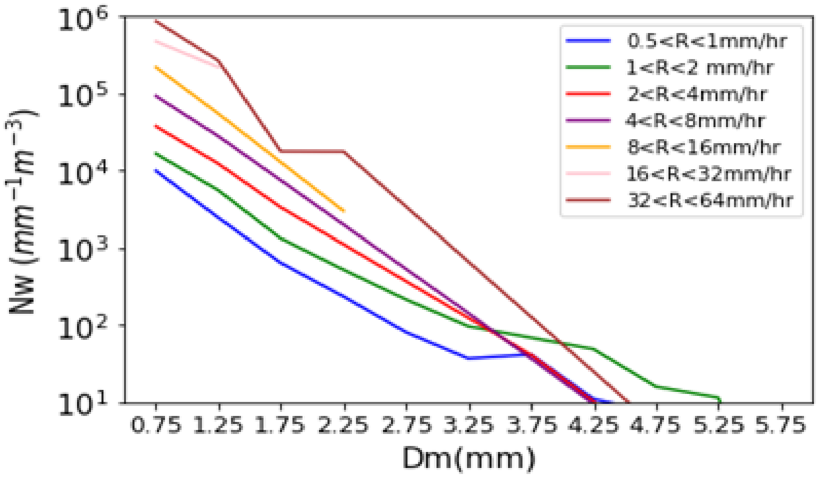
- LD scheme considered drop size dispersion ε on growth of drops which assist proper segregation of drops and regulate its growth.
- To evaluate this performance, Dmax is relaxed for further experiments.

Significance of dispersion term in LD scheme

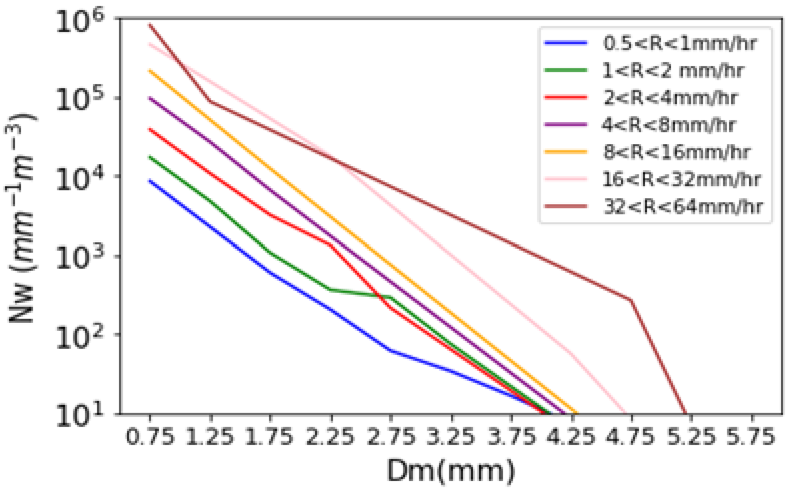
ε = 0.2(D = 3mm)



ε = 0.4(D = 3mm)



ε = 0.5(D = 3mm)

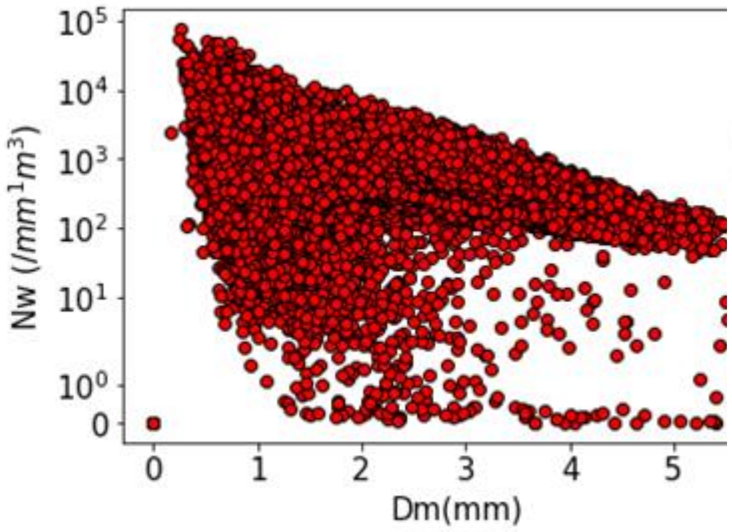


- Dynamic aggregation is invoked to visualize the effect of dispersion term on the DSD
- Drops are able to grow better in all rain rate intervals at dispersion term value 0.5.

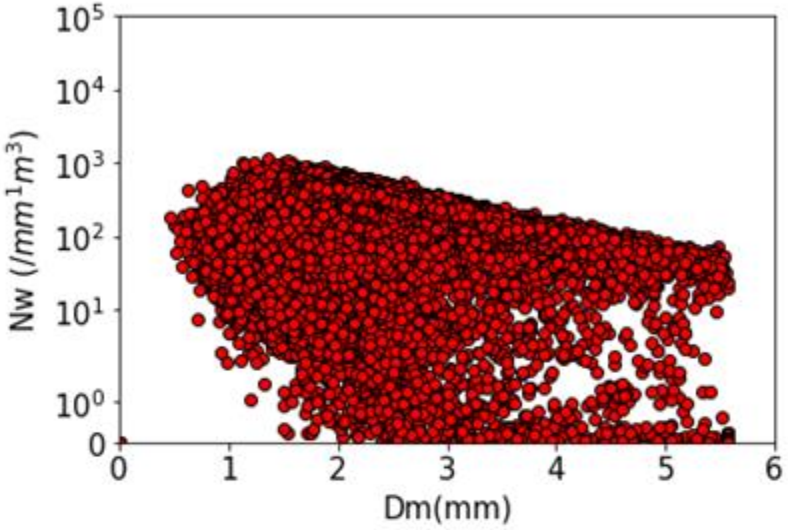
Significance of LD scheme over KK00

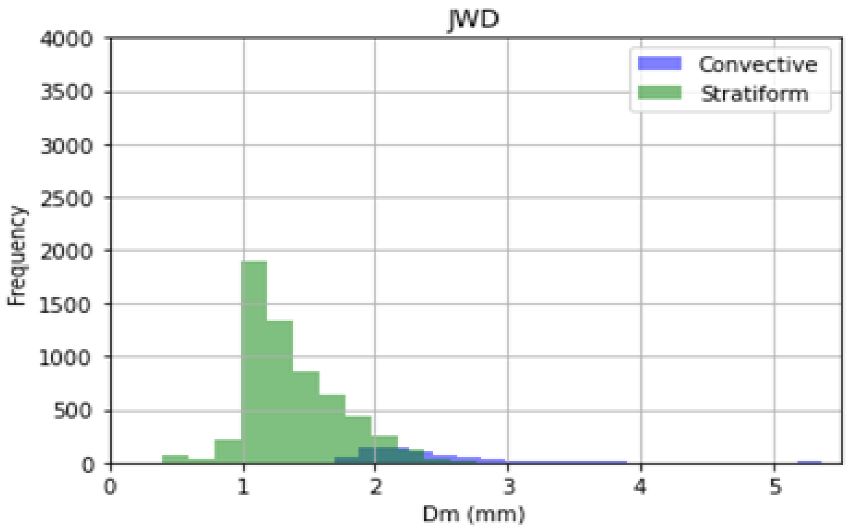
- LD scheme support growth of larger drops compared to KK00 scheme.
- Realistic segregation of convective and stratiform drops compared to KK00

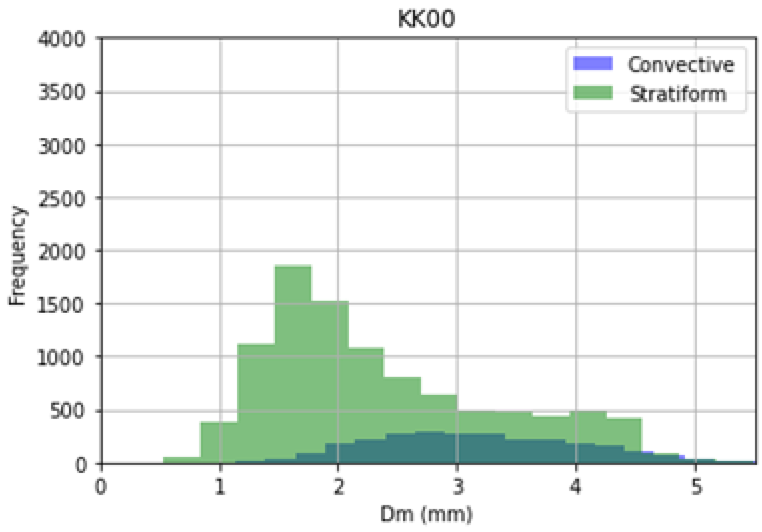
KK00

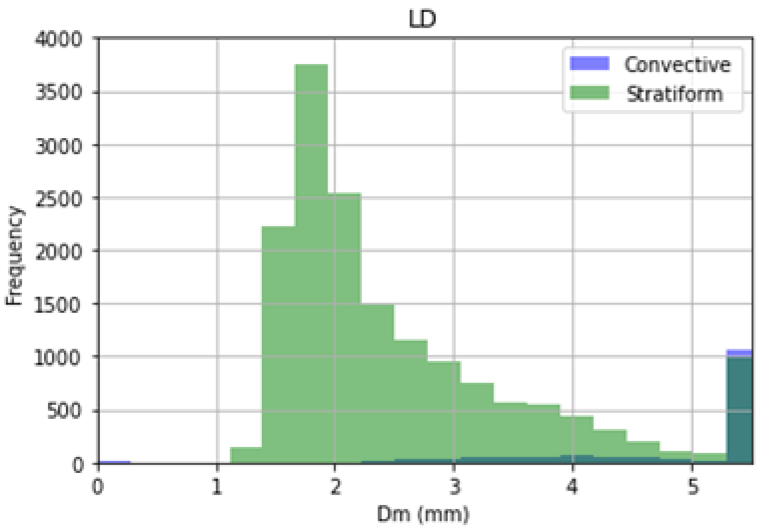


LD

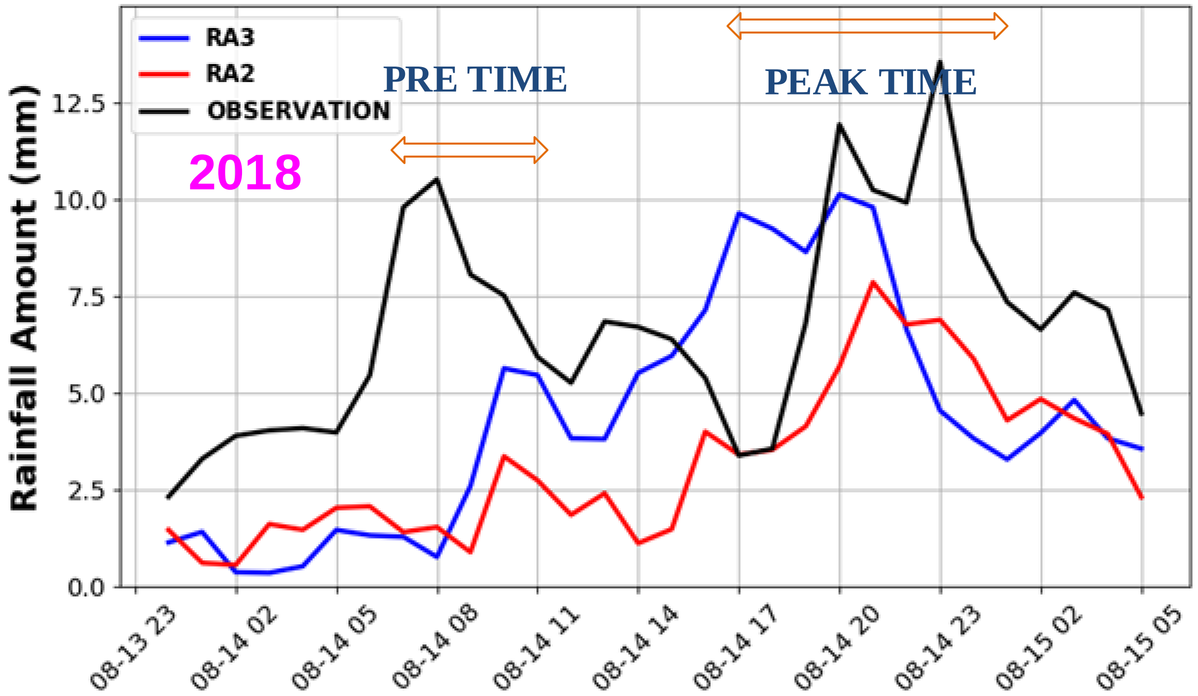


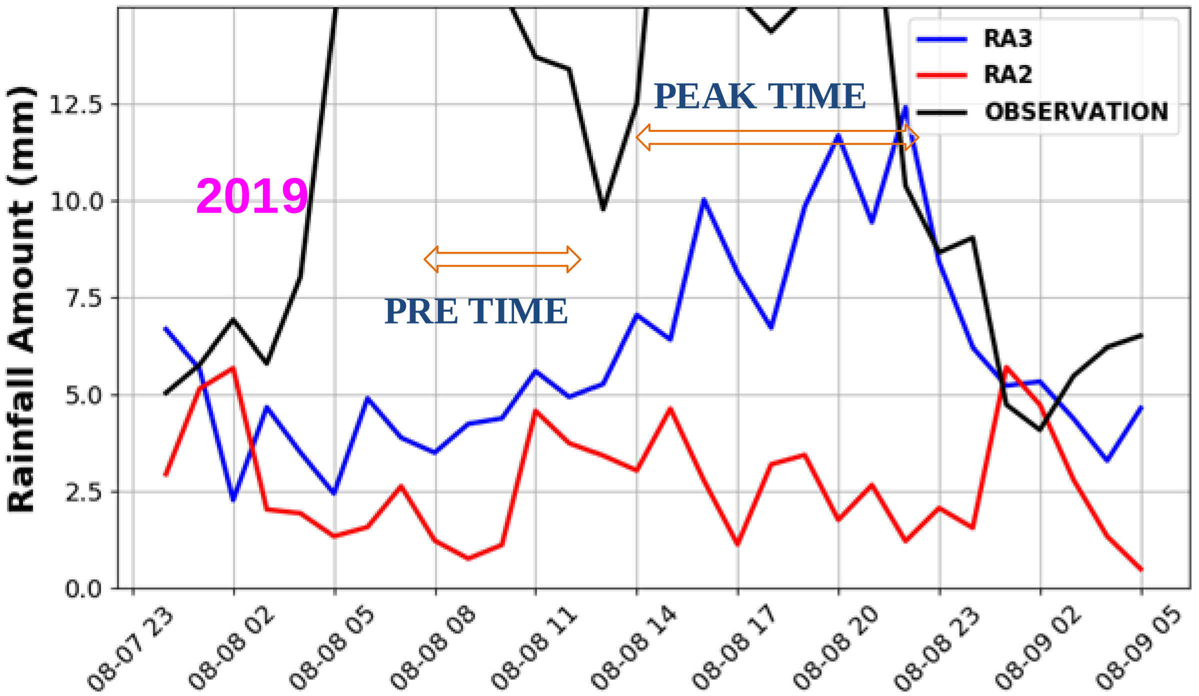






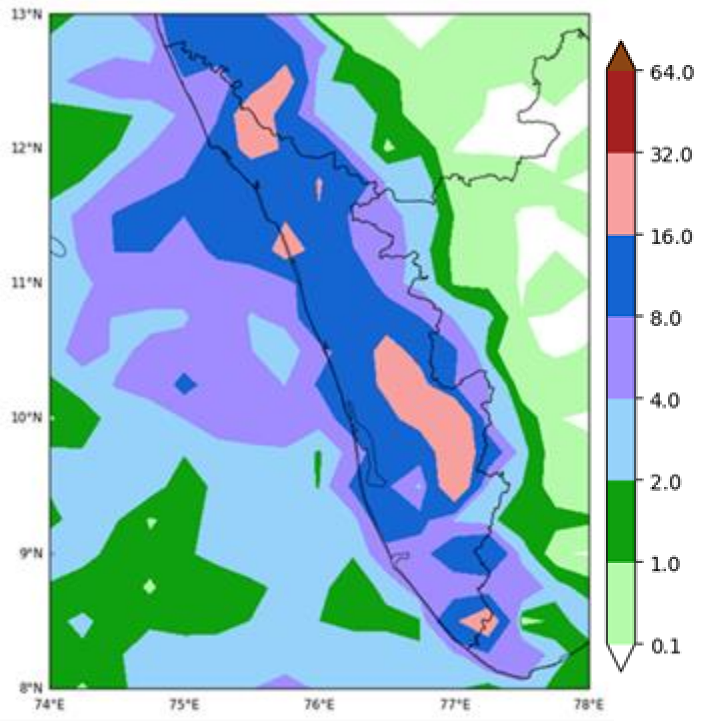
Kerala Flood: Extreme precipitation



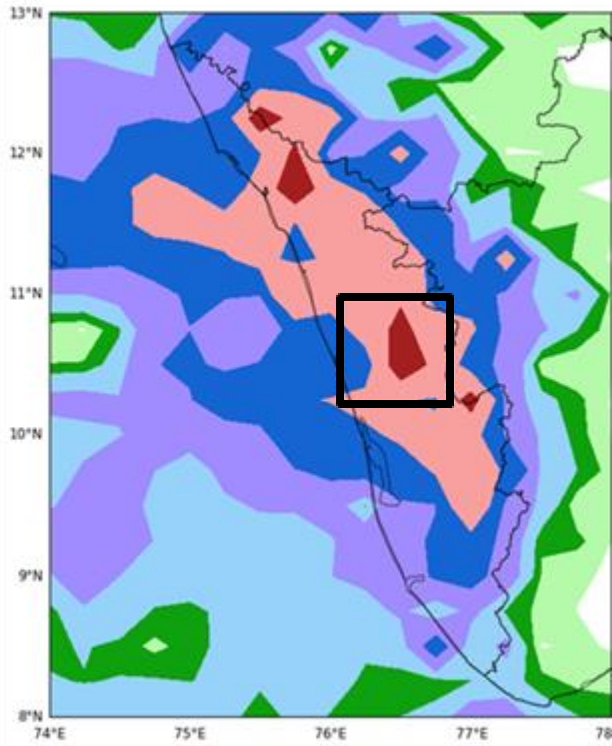


Horiz:76 – 77E and 10-11.5N

2018



2019



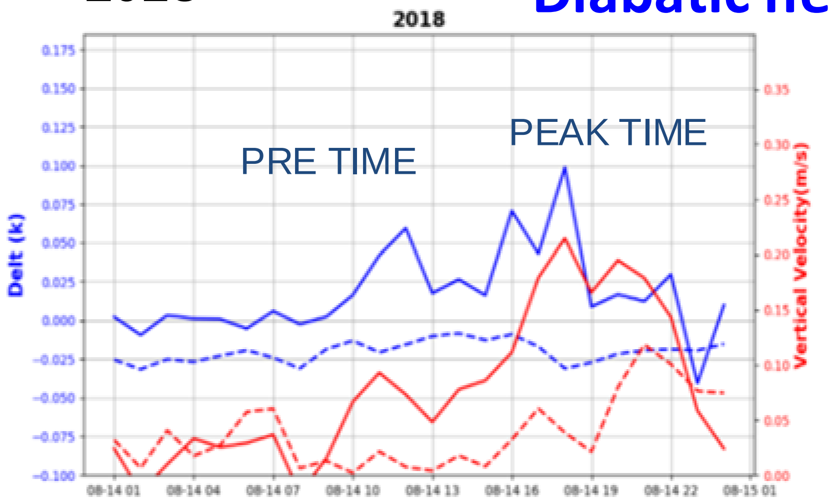
GPM + Gauge precipitation

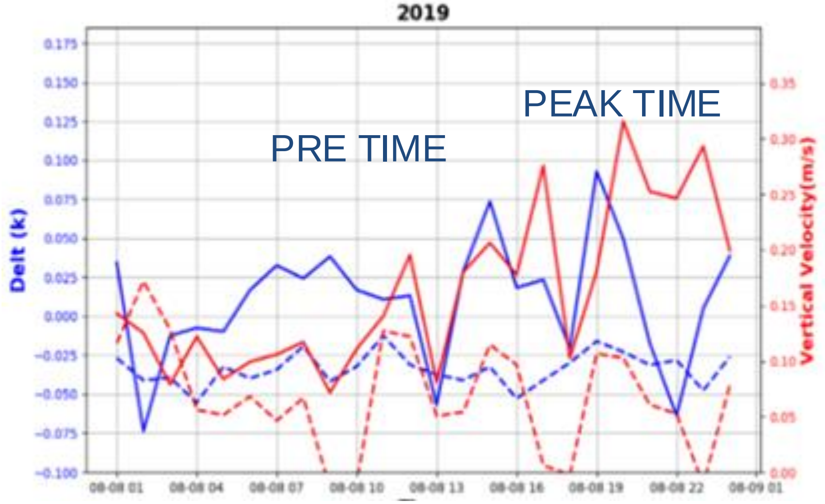
Deeper convective activity : cloud burst

- **~100 %** excess than the long period average rainfall over the state

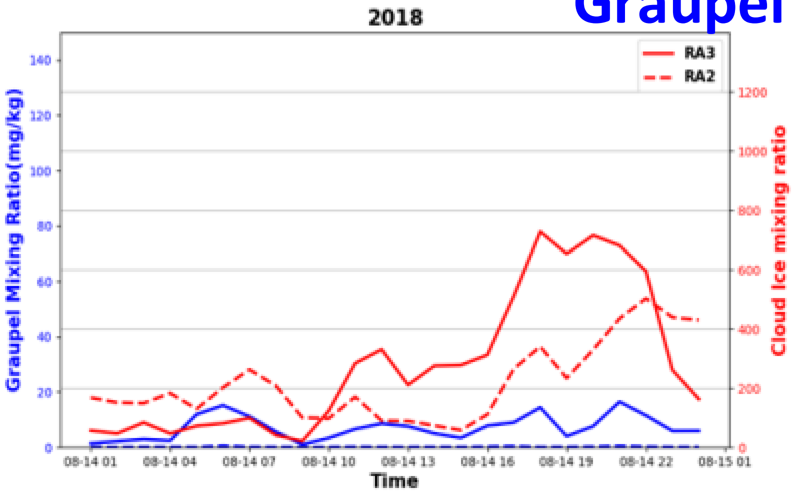
Twisting term for strong convective process

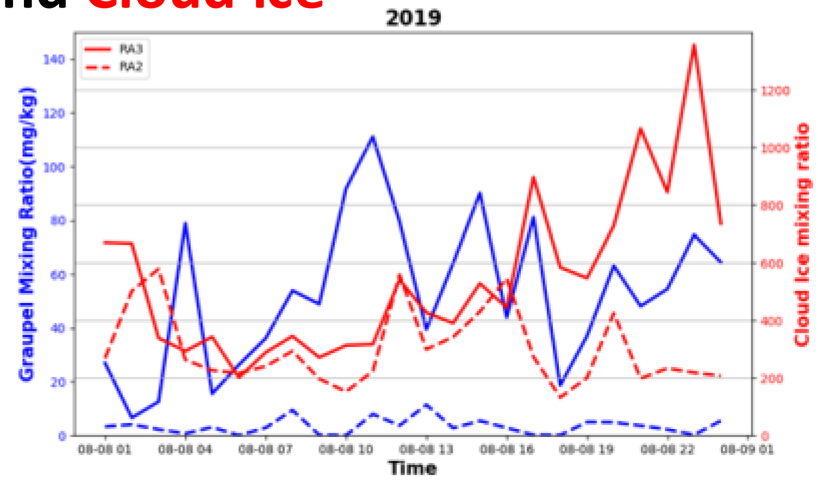
2018 **Diabatic heat term** and **W** 2019



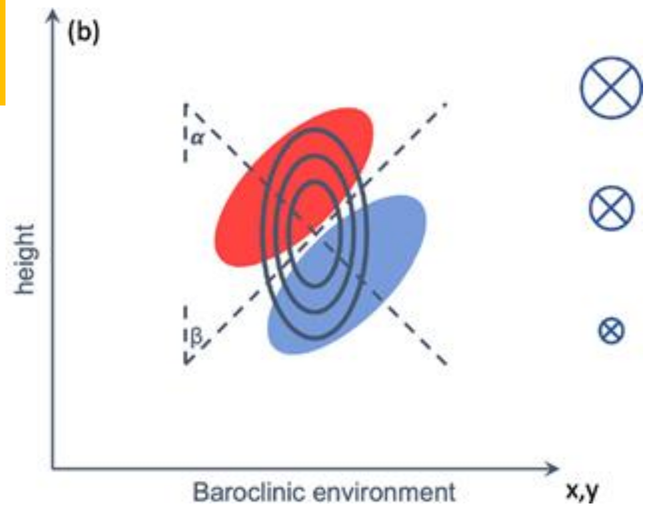


Graupel and **Cloud ice**





Horiz (76 – 77E and 10-11.5N), vertical (4-13 km)



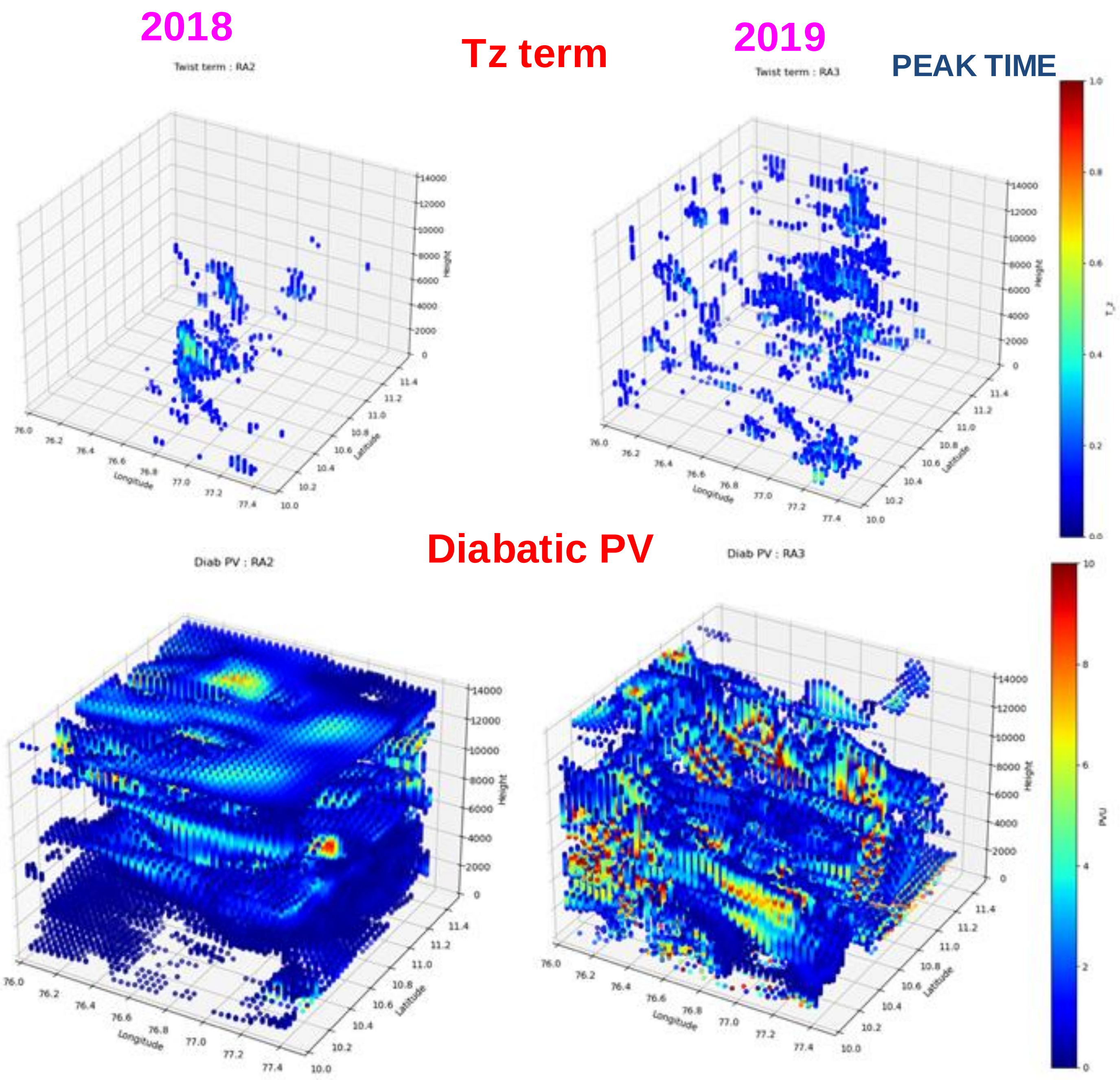
$$T_z = \mathbf{k} \cdot \left(\nabla_h w \times \frac{\partial \mathbf{v}_h}{\partial z} \right) = \frac{\partial w}{\partial x}\frac{\partial v}{\partial z} - \frac{\partial w}{\partial y}\frac{\partial u}{\partial z}$$

convective updraft in the small scales

Baroclinicity on the synoptic scale

Couples the dynamics on the convective scale with the dynamics on the synoptic scale.

3D structure of diabatic PV and twisting term at convective scale from RA3 for 2019

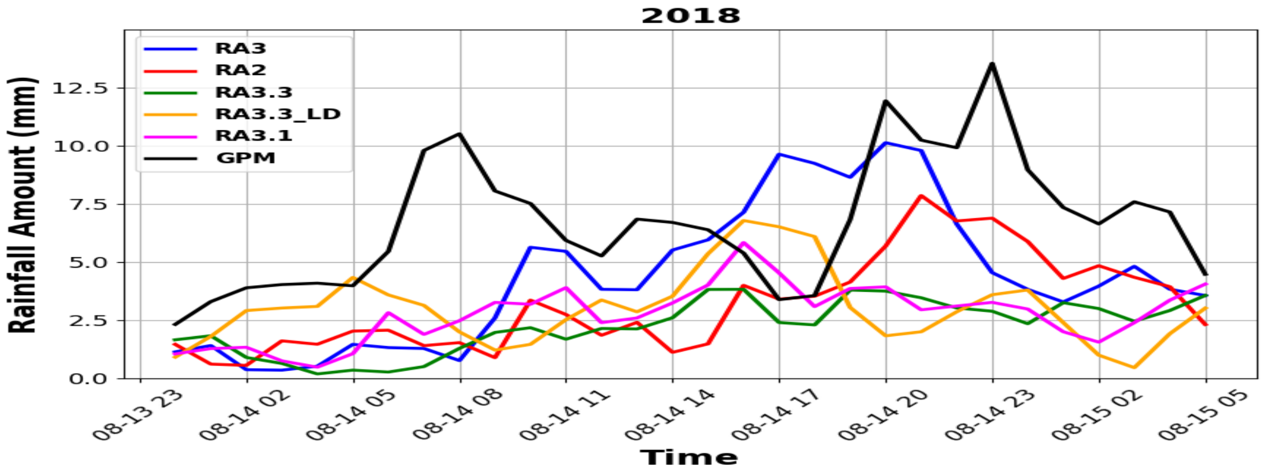


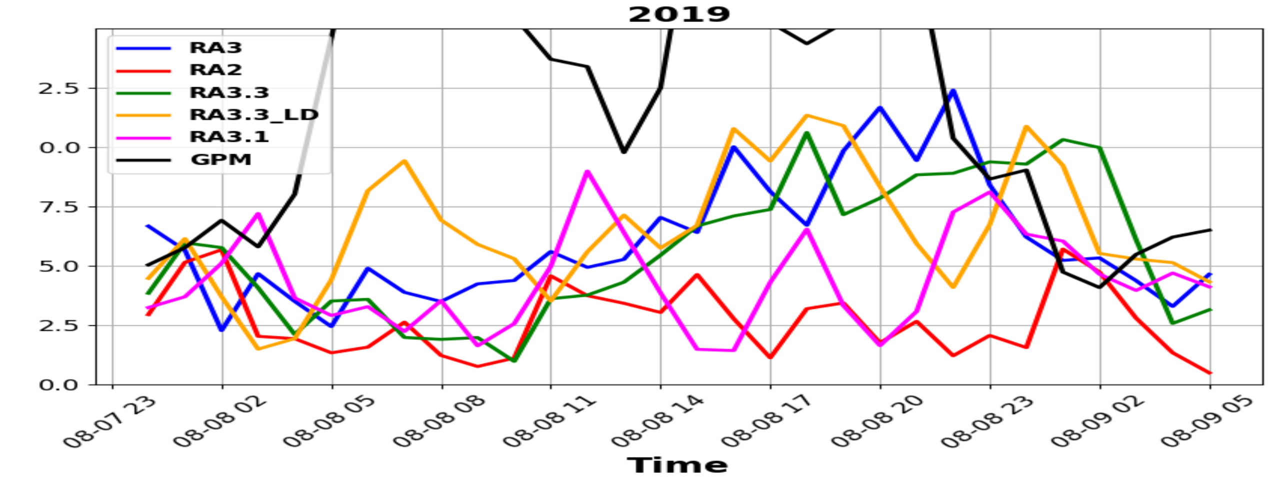
- Diabatic PV is correlated with the Tz term, which signifies the strong coupling of dynamics to heating distribution.
- Barotropic distortion due to mid level latent heat release from the graupel accretion process in the H-M zone.
- This reflect the strong baroclinicity from the mid-atmospheric horizontal distribution of latent heat release process.
- RA2 able to show only the barotropic structure in the diabatic PV term (similar to Global model)

Tendency equation for PV vorticity can be written as

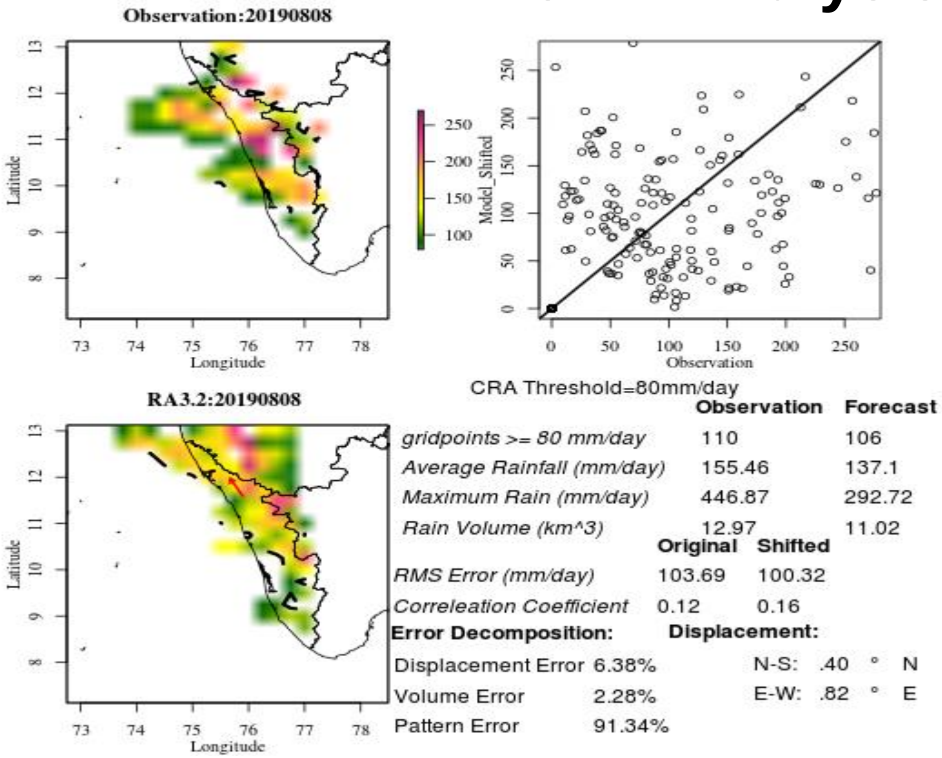
$$\frac{Dq}{Dt} = \left(\frac{\zeta}{\rho}\right) \cdot \nabla S_\theta + \frac{\nabla \theta}{\rho} \cdot \nabla \times \ S_u$$

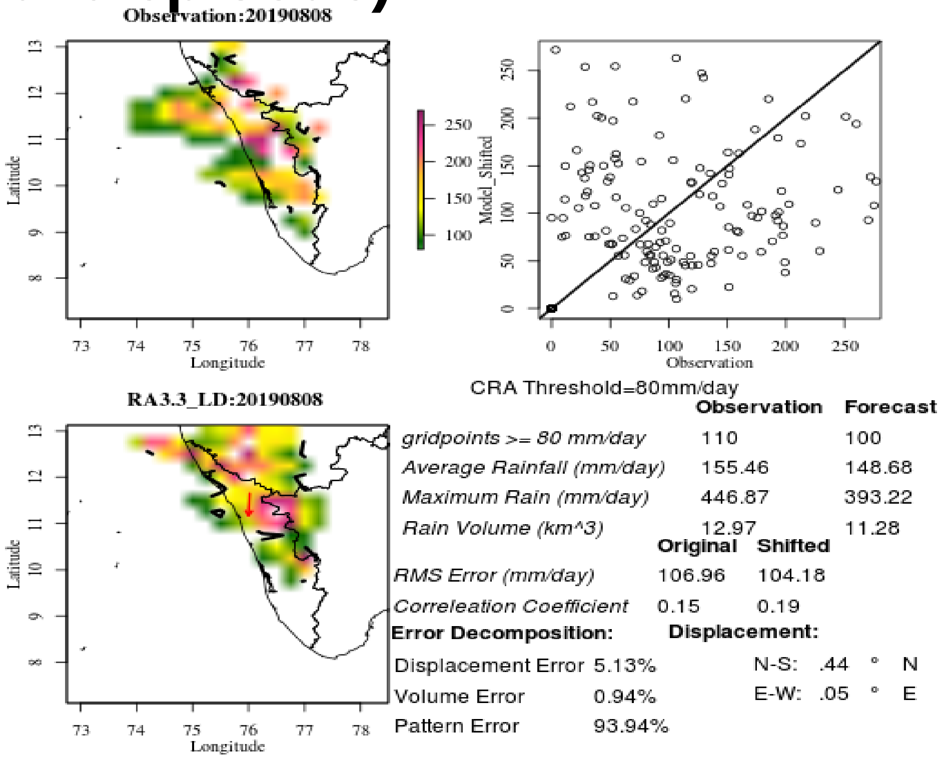
Sθ and Su represents the sources of diabatic heat and sources of friction respectively. Latent heat flux, sensible heat flux, radiation and heat release during the phase transitions of water are considered as the sources of diabatic heat (Hoskins, 2015).





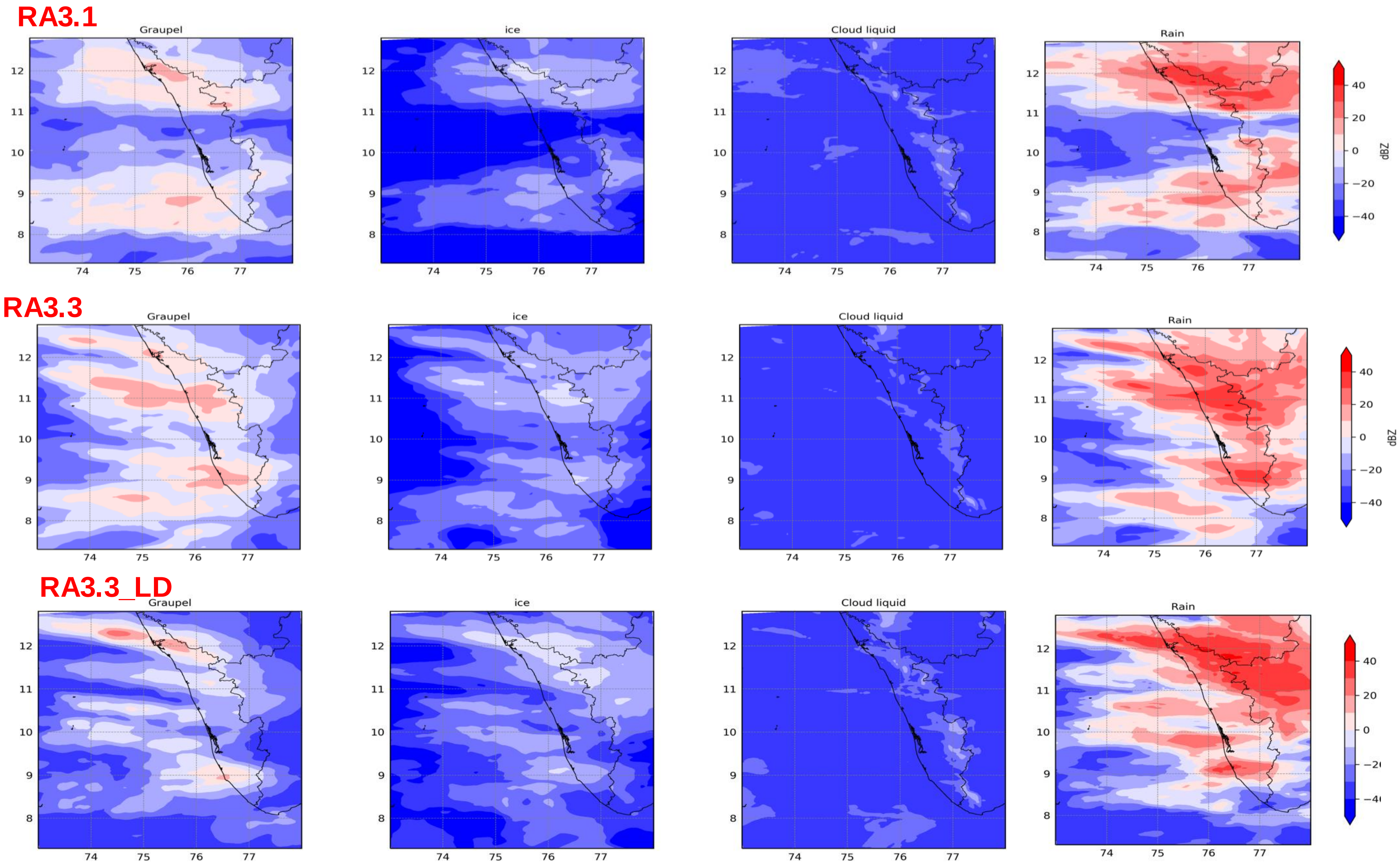
CRA Analysis (2019 episode)





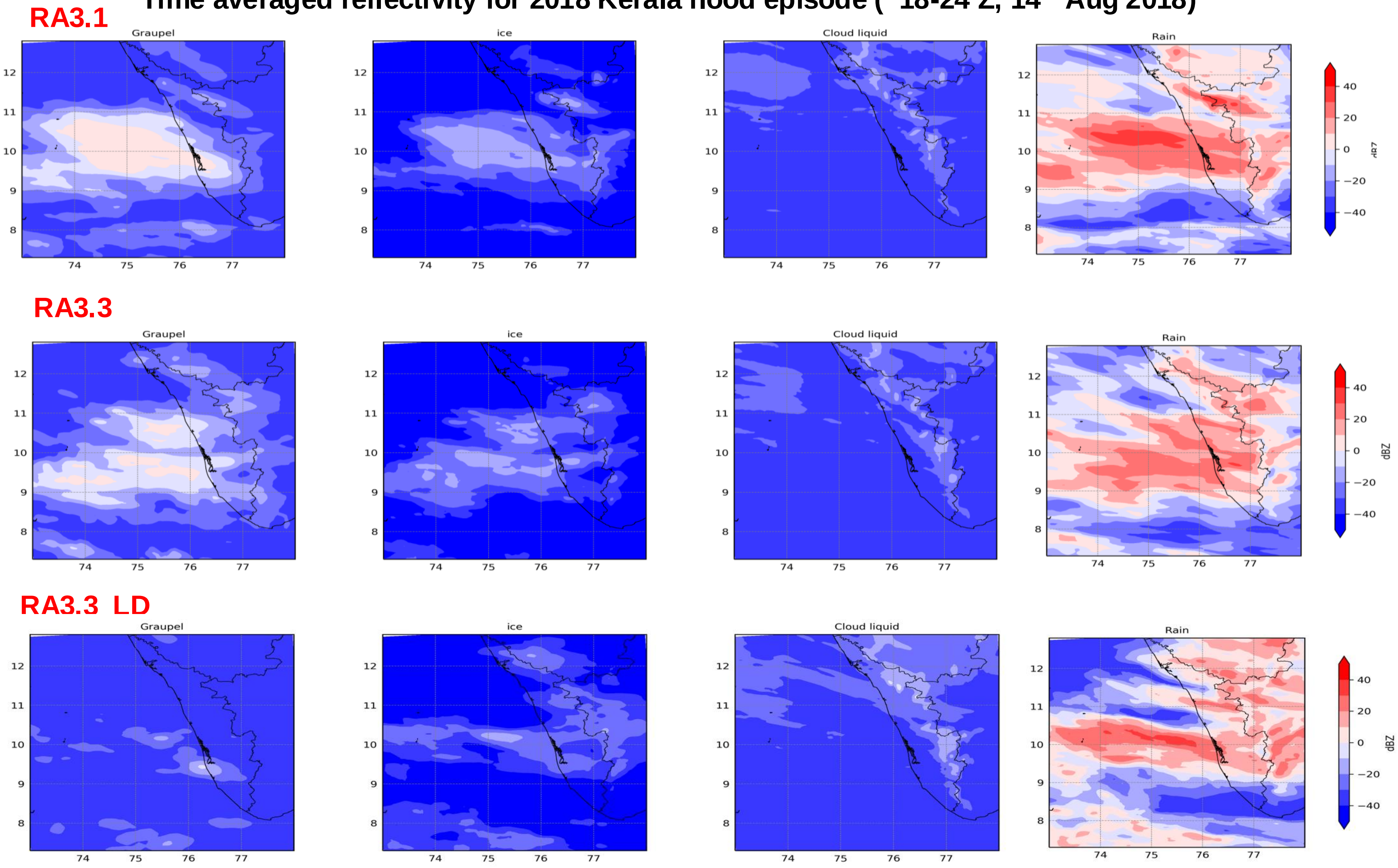
RA3.3 with LD autoconversion (RA3.3_LD) found to be better configuration for mix-phase and warm rain process in compared to RA3.3, but still requires improvement for the extreme rainfall cases for the tropics

Time averaged reflectivity for 2019 Kerala flood episode (18-24 Z, 8th Aug 2019)



Deep convective systems formed over center Kerala during 2019 is predicted well RA3.3 in compared to RA3.1. Rainfall is preceded by the higher amount of graupel in RA3.3, while higher contribution of LWC is found in RA3.3_LD. Rainfall observed in the GPM is generally consistent with the Reflectivity in RA3.3.

Time averaged reflectivity for 2018 Kerala flood episode (18-24 Z, 14th Aug 2018)



Mixed phase ice process has lesser role in 2018 episode. RA3.1 features higher amount of land precipitation in compared to RA3.3. 2018 heavy rain is not a convective driven episode, rather than governed by large scale dynamics.

Conclusion

- Advanced cloud-microphysical schemes (RA3) in convection permitted model able to represent baroclinicity contributed from mid-atmospheric heating. This feature is not evident in the RA2, reflected in the under-prediction of the deeper convective system .

- Graupel formation in the H-M zone and the associated latent heat release is exhibited in the RA3.

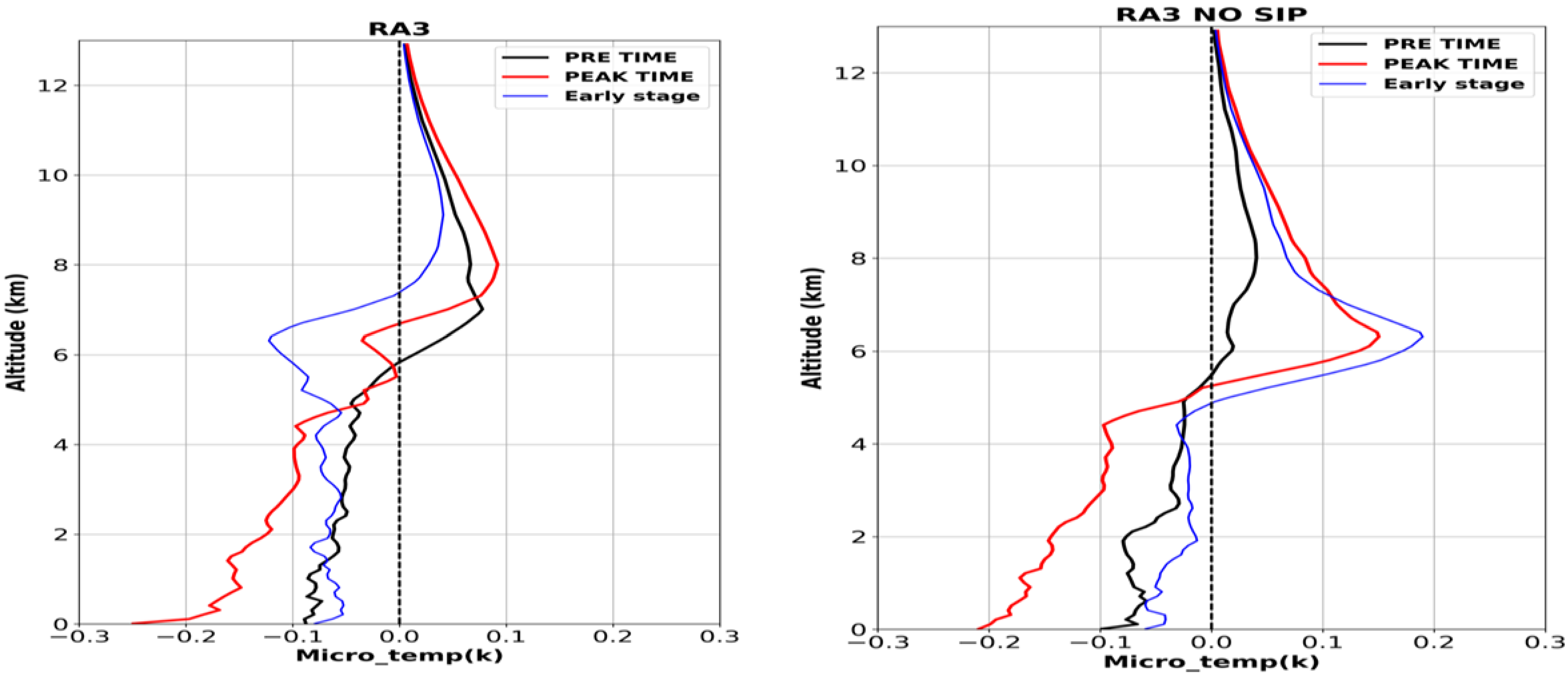
- Coupling of synoptic to convective scale measure the strength of model in predicting the convectively driven extreme events

- Configurations in the RA3 versions (RA3.1 .. RA3.3) is biased towards mixed phase ice process, which may not be ideal for large scale dynamically driven tropical extreme cases.


Q&A
THANK YOU !

Role of SIP process in the diabatic heating from RA3 for 2019

Temperature Increment due to Microphysics



Redistribution of heating in the mid-atmosphere along with the evolution of the convective system (early, pre to peak) is weaker in the model with the absence of SIP.