

INSIGHTS INTO MICROPHYSICS AND DYNAMICS OF PRE-MONSOON HAILSTORMS OVER EASTERN INDIA USING WRF SIMULATIONS



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Theme 1 : 23

Introduction

Hailstorms are a distinctive form of solid precipitation characterized by ice particles with diameters ranging from 5 to 50 mm, developing in highly unstable environments with strong vertical wind shear and high Convective Available Potential Energy.



- Over India, the eastern region is more prone to hailstorms during the pre-monsoon season.
- Radars serve as an important tool to study the structural and temporal evolution of hailstorms by providing intensity, track and 3D measurements at high resolutions.

Lacunae

- Radars observations lack information on hydrometeor classification and microphysical processes behind these convective systems.
- The ability of high resolution numerical models Weather Research and Forecasting (WRF) model such as to reproduce the observed structure and microphysical characteristics of such hailstorms requires further evaluation using appropriate parameterization schemes



Objectives

- To examine the dynamical and microphysical characteristics of hailstorms that had varying hail sizes.
- To investigate the spatial and temporal evolution of hydrometeors during the selected hailstorm events.

Data

Case events

- Hailstorm occurred over **Sriniketan** (23.5°N, 87.67°E) on 04 April 2015 with a hail size of 1.5 cm and **Digha** (21.62°N, 87.5°E) on 19 March 2017 with hail size of 5-10 cm are chosen.

Data

- ERA 5 data is used as the initial and boundary conditions for the model.
- CMORPH Climate Data Record and Doppler Weather Radar observations are used to compare the model output.

Model

- The Advanced Research Weather Research and Forecasting (ARW) version 4.5 is used.
- The model configuration is given in the table below.

Model Version	WRF 4.6
Horizontal resolution	9 km (D01), 3 km (D02)
Temporal resolution	360 min, 60 min
Integrated time step	36 s
Map projection	Mercator
Vertical levels	34
Microphysics scheme	Milbrandt-Yao Double-moment 7-class
Cumulus scheme	Kain Fritsch scheme
PBL scheme	Mellor-Yamada Nakanishi and Niino Level 2.5
Longwave radiation scheme	BRTM scheme
Shortwave radiation scheme	Dudhia scheme
Land surface scheme	NOAH
Surface layer scheme	Revised MM5

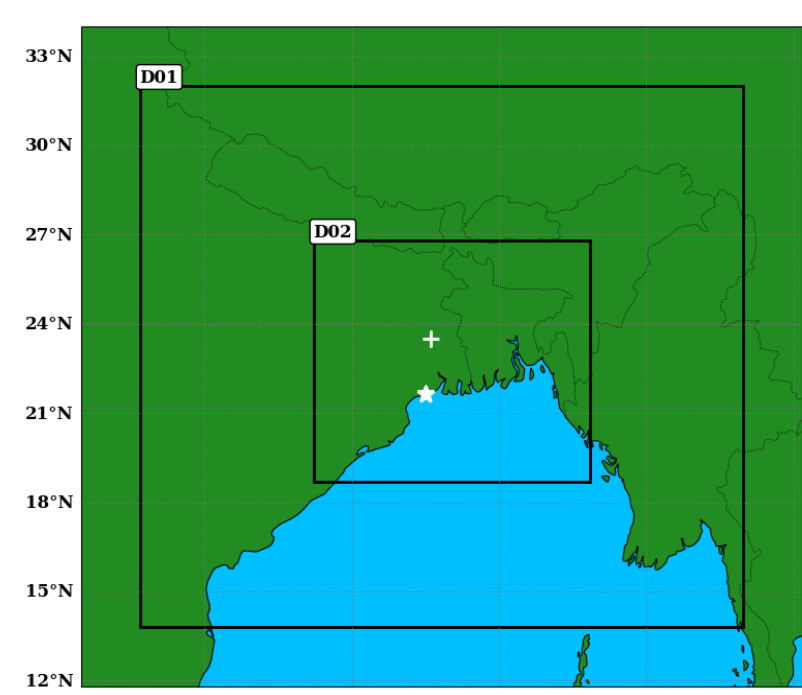


Fig 1 Model Domain

Results and Discussion

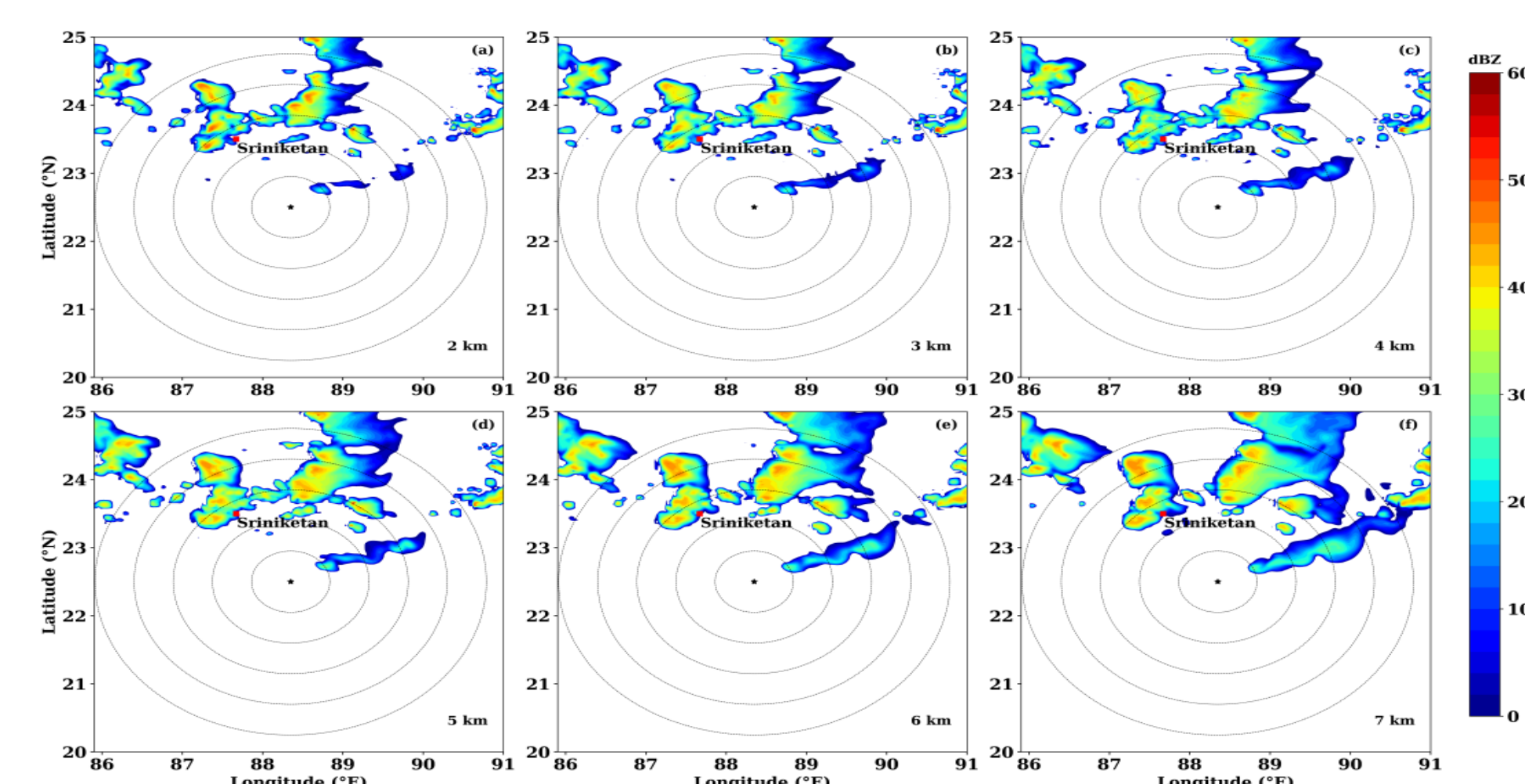


Fig 2 Spatial distribution of reflectivity (dBZ) over Sriniketan at a 2 km, b 3 km, c 4 km, d 5 km, e 6 km, f 7 km at 13 UTC on 04 April 2015.

- A squall line structure with reflectivity <50 dBZ observed
- A weak and short lived convective structure with limited vertical development

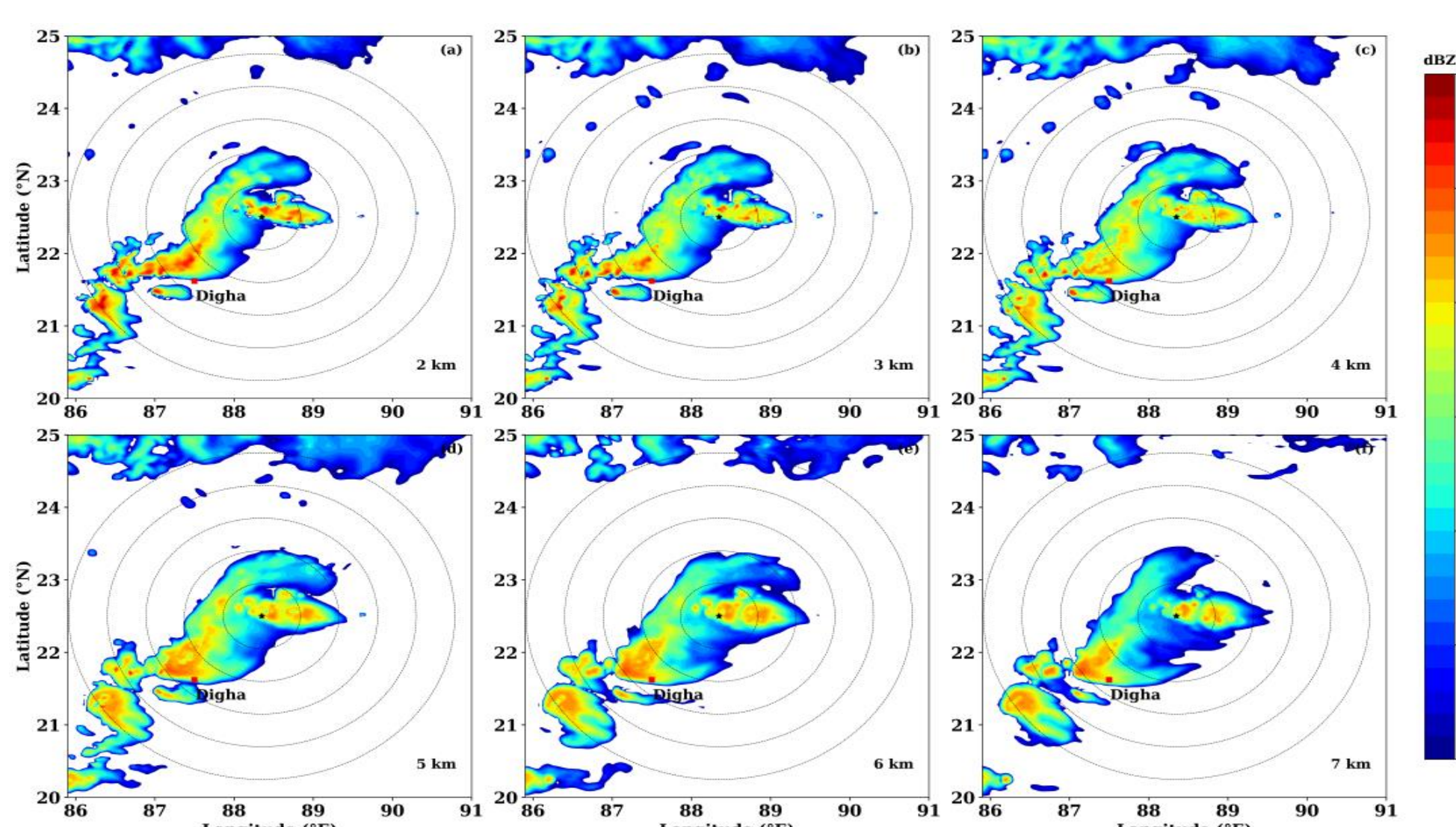


Fig 3 Spatial distribution of reflectivity (dBZ) over Digha at a 2 km, b 3 km, c 4 km, d 5 km, e 6 km, f 7 km at 12 UTC on 19 March 2017

- Model simulated multi cellular structure with reflectivity values exceeding 55 dBZ.

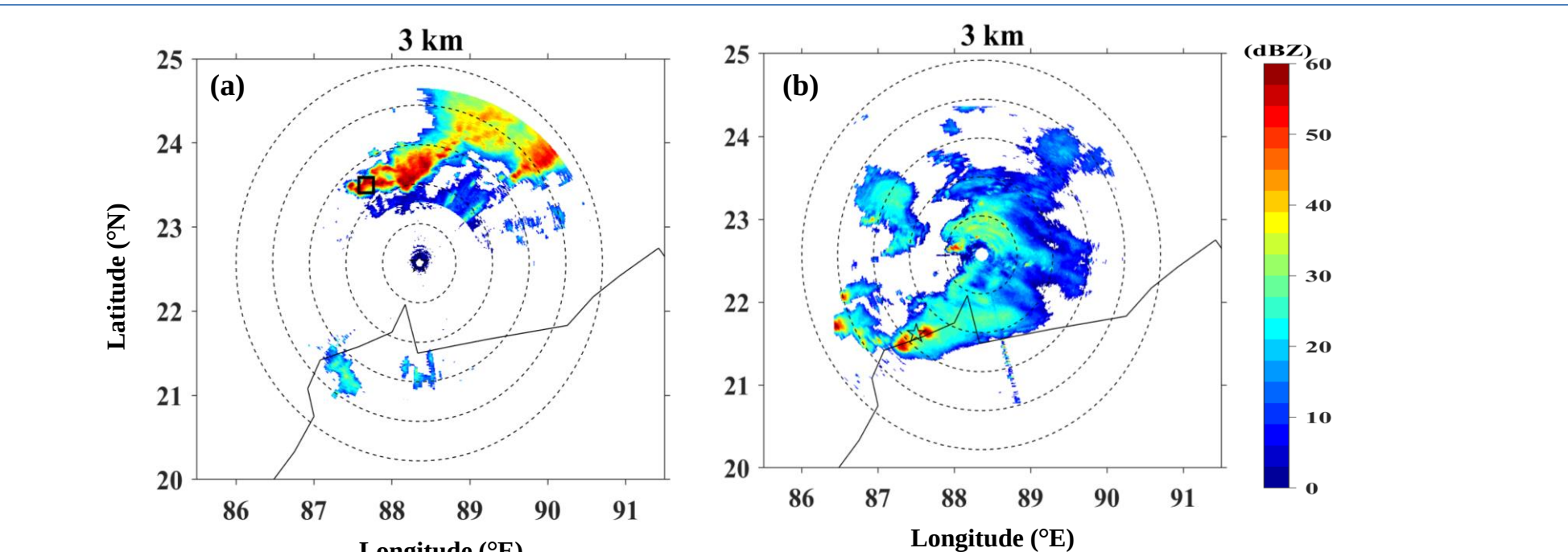


Fig 4 Spatial distribution of DWR reflectivity (dBZ) at 3 km over a Sriniketan and b Digha

- Model captured structure and location of the storm over Sriniketan though the simulated peak reflectivity values fall slightly short of radar observation while model simulated reflectivity over Digha is well consistent with DWR reflectivity.

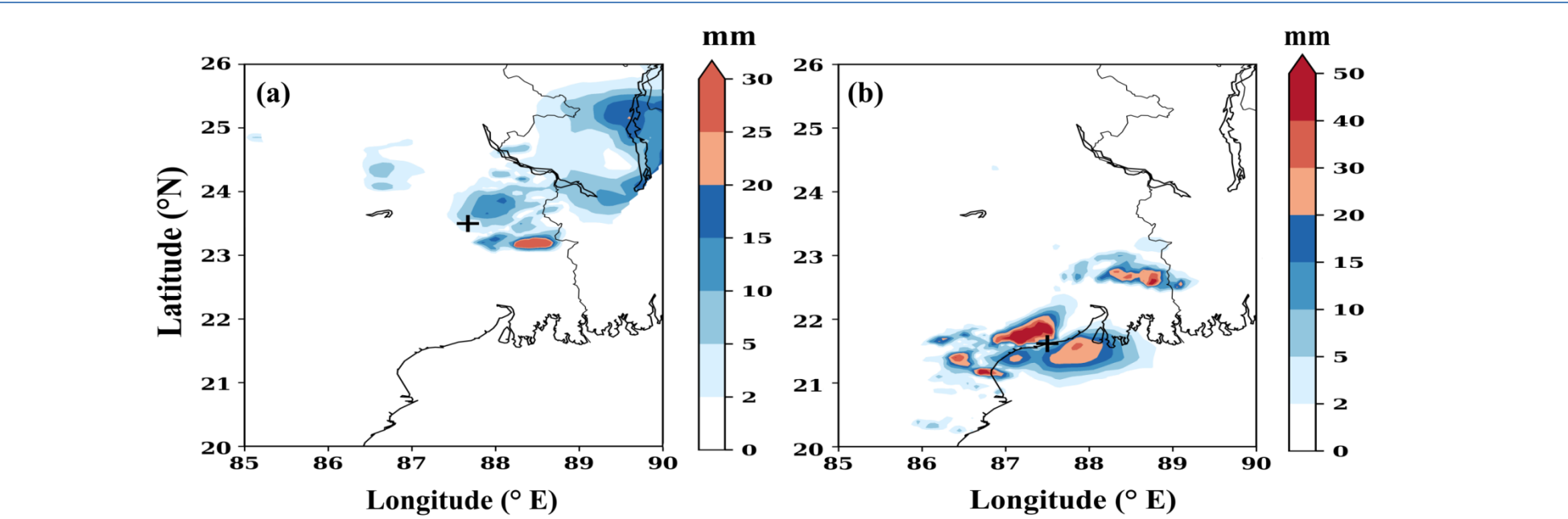


Fig 5 Root Mean Square of rainfall (mm) (WRF- CMORPH) over a Sriniketan at 13 UTC, b Digha at 12 UTC

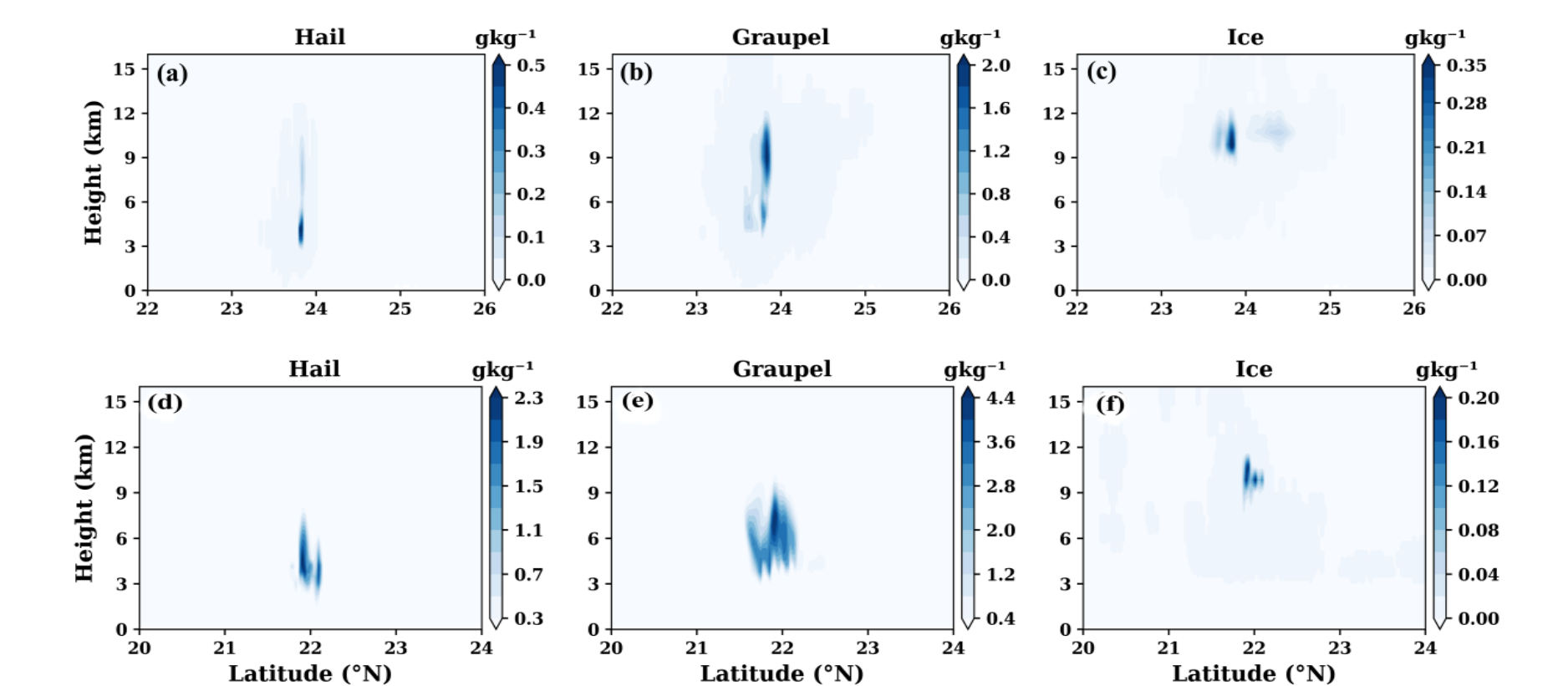


Fig 6 Latitudinal cross section of mixing ratios ($g\ kg^{-1}$) of a hail, b graupel, and c ice over Sriniketan at longitude 87.67° E at 13 UTC, d-f are same as a-c but for Digha at longitude 87.5° E at 12 UTC

- Hail and graupel mixing ratios around 0.5 and 2 $g\ kg^{-1}$ simulated over Sriniketan at mid-altitudes.
- Active growth of hail and graupel (~ 2.2 and $4.5\ kg^{-1}$) over Digha reflects the severity of the storm.

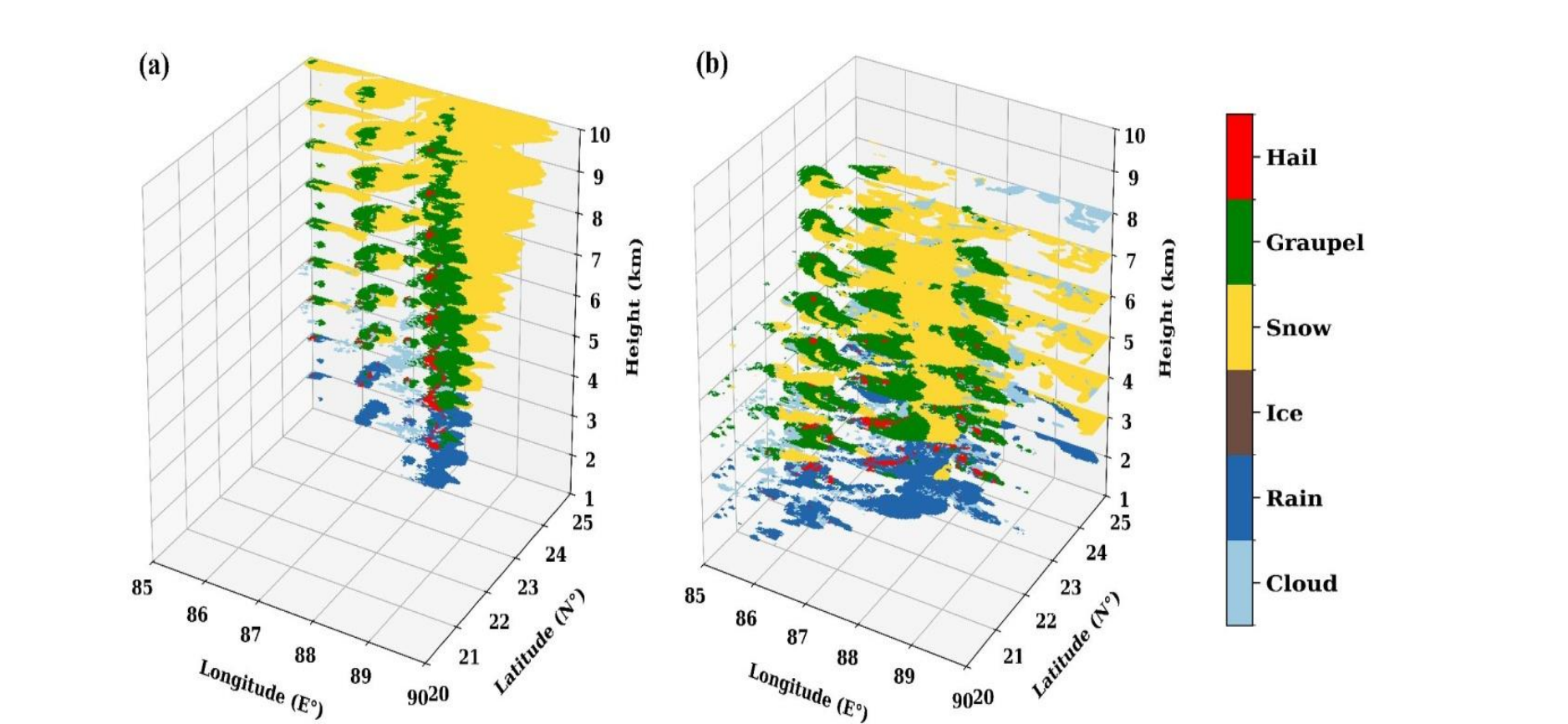


Fig 7 3D cross section of hydrometeors at different heights for a Sriniketan at 13 UTC, b Digha at 12 UTC

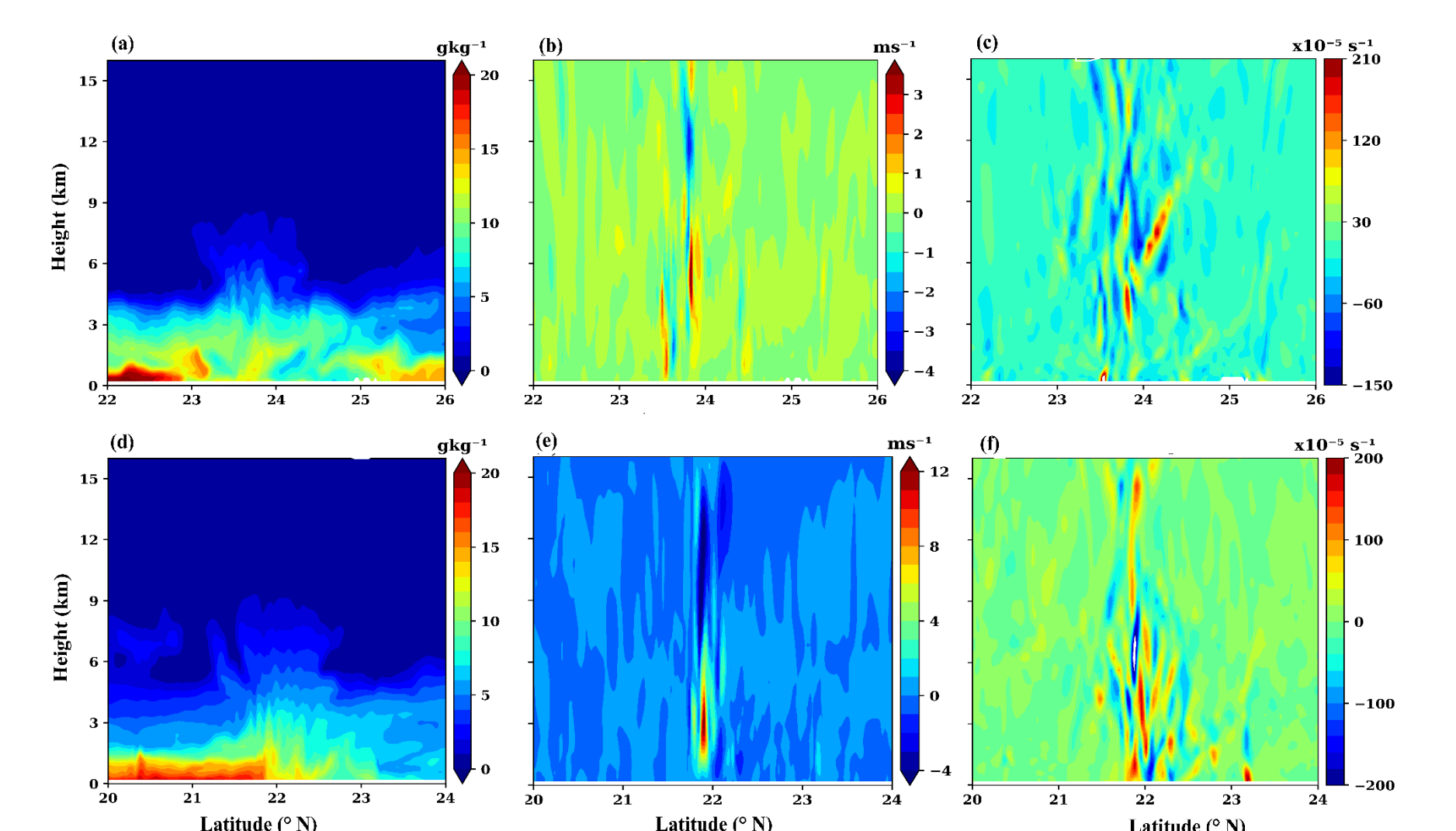


Fig 8 Latitudinal cross section of a specific humidity ($g\ kg^{-1}$), b vertical wind ($m\ s^{-1}$), c convergence (s^{-1}) over Sriniketan at a longitude 87.67°E at 13 UTC, d-f same as a-c but over Digha at a longitude 87.5°E at 12 UTC

- Model simulated updraft velocities of $12\ m\ s^{-1}$ over Digha simulation while $3\ m\ s^{-1}$ seen over Sriniketan .

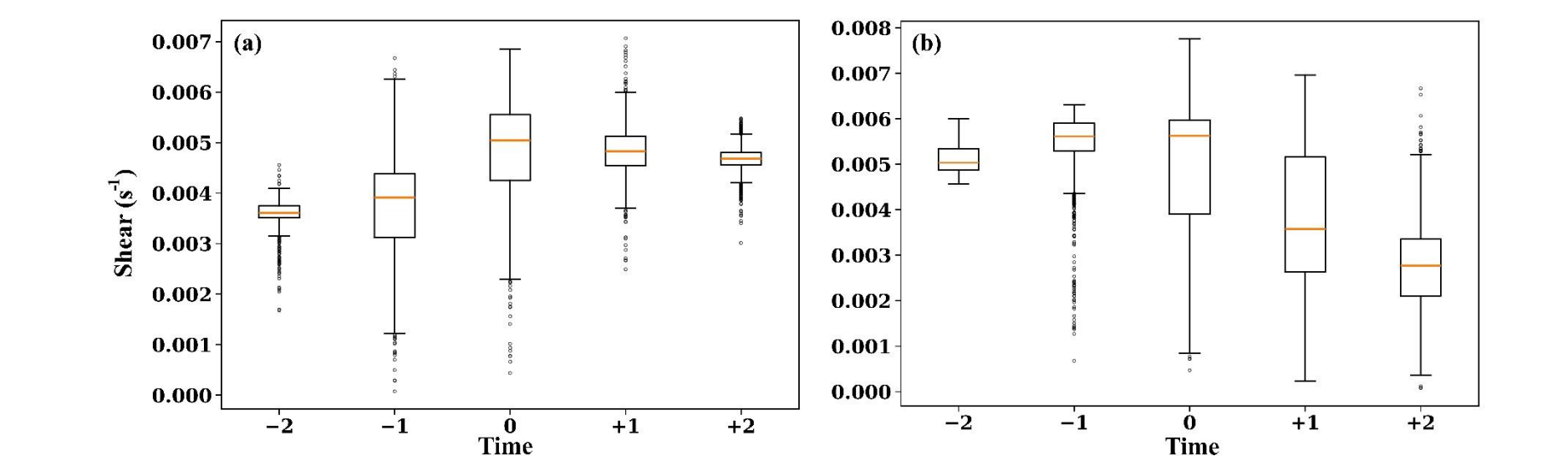


Fig 9 shear (s^{-1}) a for Sriniketan at 13 UTC and b for Digha at 12 UTC.

- Strong vertical wind shear during hail occurrence over Digha observed, followed by significant decrease.

Conclusions

- WRF model effectively reproduced the dynamics and microphysics of Digha hailstorm which produced larger hail rather than Sriniketan that shown comparatively smaller hail size.
- Sriniketan exhibited squall line structure with low reflectivity (<50 dBZ) while multi-cellular structure is observed over Digha with reflectivity exceeding 55 dBZ. WRF exhibited a reflectivity structure consistent with the observed DWR reflectivity.
- WRF underestimated the spatial extend and intensity of rainfall over Sriniketan while it overestimated over Digha.
- Higher growth of hail and graupel is observed in the simulation over Digha.
- Model reproduced high wind shear before and during the hailstorm in both the events, after which shear decreased.
- Model captured dynamical and microphysical features of the two hailstorms though with notable biases in reflectivity and precipitation.

References

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