

Analysis of Precipitation Mechanisms of Tropical Cyclone Dana (2024) through GPM-DPR and IMERG Satellite Observations

Devashish Prakash Singh¹, Maheswaran Rathinasamy^{1 2}, Shruti Upadhyaya^{1 2}

¹ Department of Climate Change, ² Department of Civil Engineering, Indian Institute of Technology, Hyderabad, India
Contact: cc23resch11002@iith.ac.in; shrutiau@ce.iith.ac.in

1 Introduction

Tropical cyclones (TC) in the Bay of Bengal are among the most destructive weather systems in the North Indian Ocean, driven primarily by the region's high sea surface temperature. This intense ocean heat acts as fuel, feeding moisture into the atmosphere and triggering deep convection. Recently, this thermal energy has increased causing cyclones to intensify much more than in the past. To uncover how this rapid growth happens, we need to look inside the TC and track how its rain and ice particles form. But here is the problem: coastal land radars can only spot a TC when it gets close to shore, leaving its vital growth over the open ocean completely hidden from us. To solve this, we rely on space-borne instruments like the GPM Dual-frequency Precipitation Radar, which scans from above to reveal heavy convective storms tightly packed around the core and lighter stratiform rain stretching into the outer bands.

Severe Tropical Cyclone Dana (7th LPS of 2024) gives us the perfect window to watch this unfold. Because Dana travels 1,780 kilometers over a 120-hour lifespan nearly double what we typically see in post-monsoon storms it gives us an unprecedented, continuous view of how a cyclone's rain structure matures from its birth all the way to landfall.

2 Objectives

- How did Severe Cyclonic Storm Dana evolve structurally and thermodynamically throughout its lifecycle?
- What was the spatial and quantitative distribution of precipitation within the cyclone's core impact zone?
- How did the microphysical rain distribution shift as the storm transitioned between genesis and landfall?

Track: NW across the BoB to the Odisha, West Bengal coast. Track Length 1780 kms (climatological mean for SCS in October 970kms).

Life: 120 hrs life (mean life of SCS in October 100 hrs).

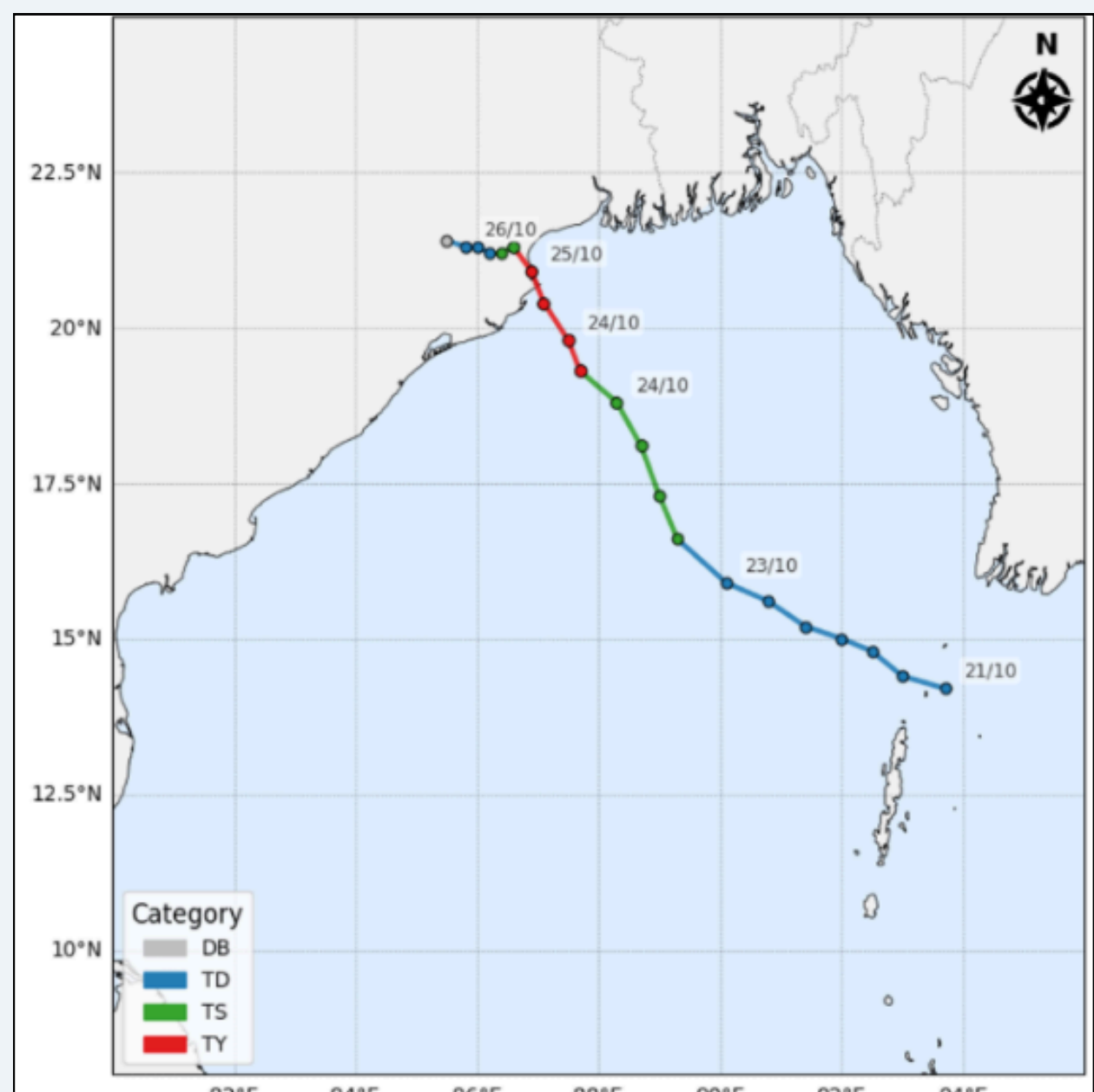


Fig. 1. IBTrACS best track, coloured by intensity category.

3 Data

IBTrACS v4r01
6-hourly best track

Wind Speed (Knots), Central Pressure (hPa), Radius of Maximum Wind (RMW)(Km), Eye Diameter (Km)

IMERG V07 Final
0.1°, 30 min → daily

Daily Mean Rainfall. Analysis of 200 km impact zone across the lifetime.

GPM-DPR 2ADPR V07
Ku-band, 13.6 GHz

Precipitation type, Surface Precipitation Rate, Mass-weighted mean diameter (Dm) profiles.

2 of 6 DPR overpasses crossed the eye: genesis (22 Oct, red) and landfall (25 Oct, blue).

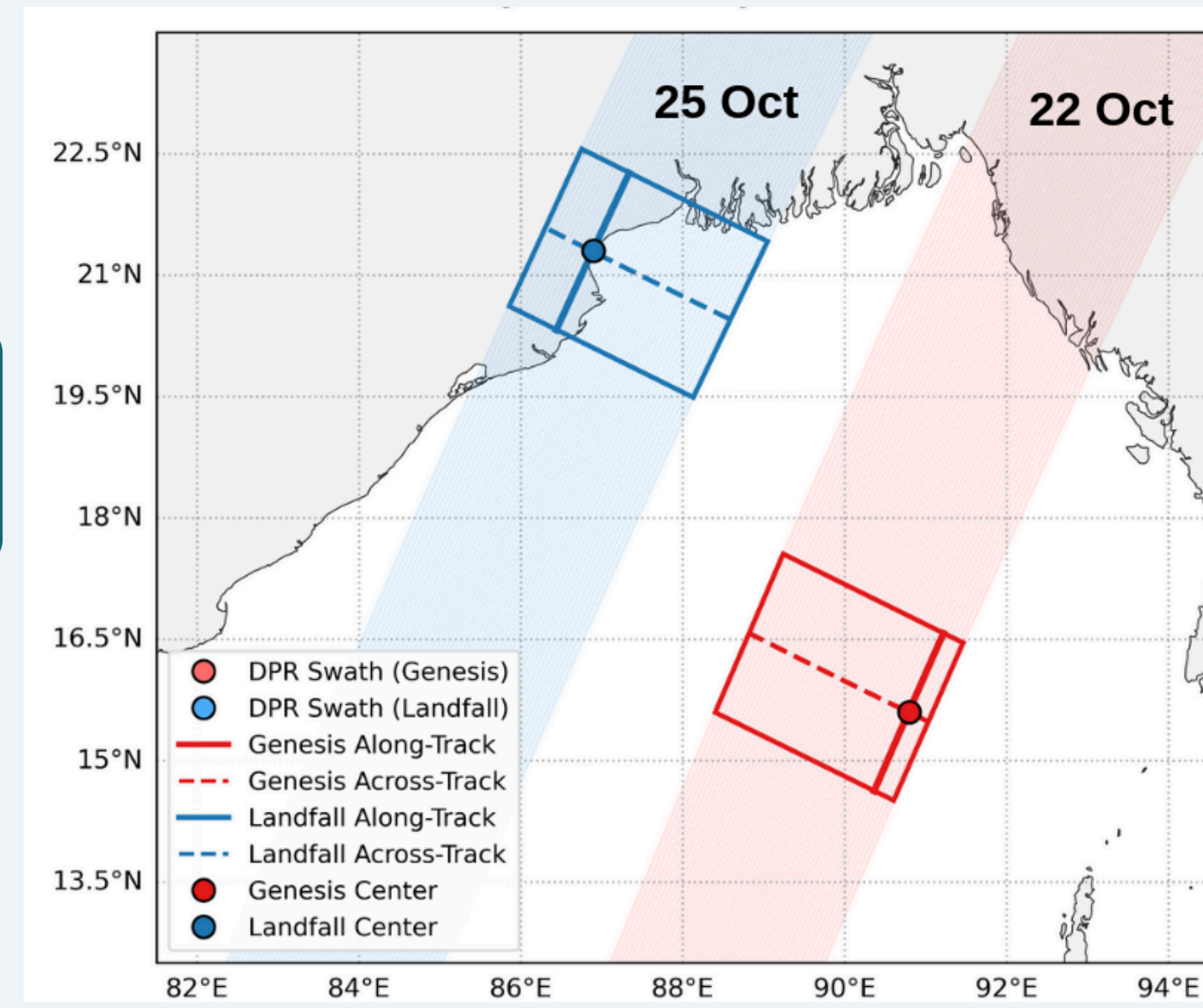
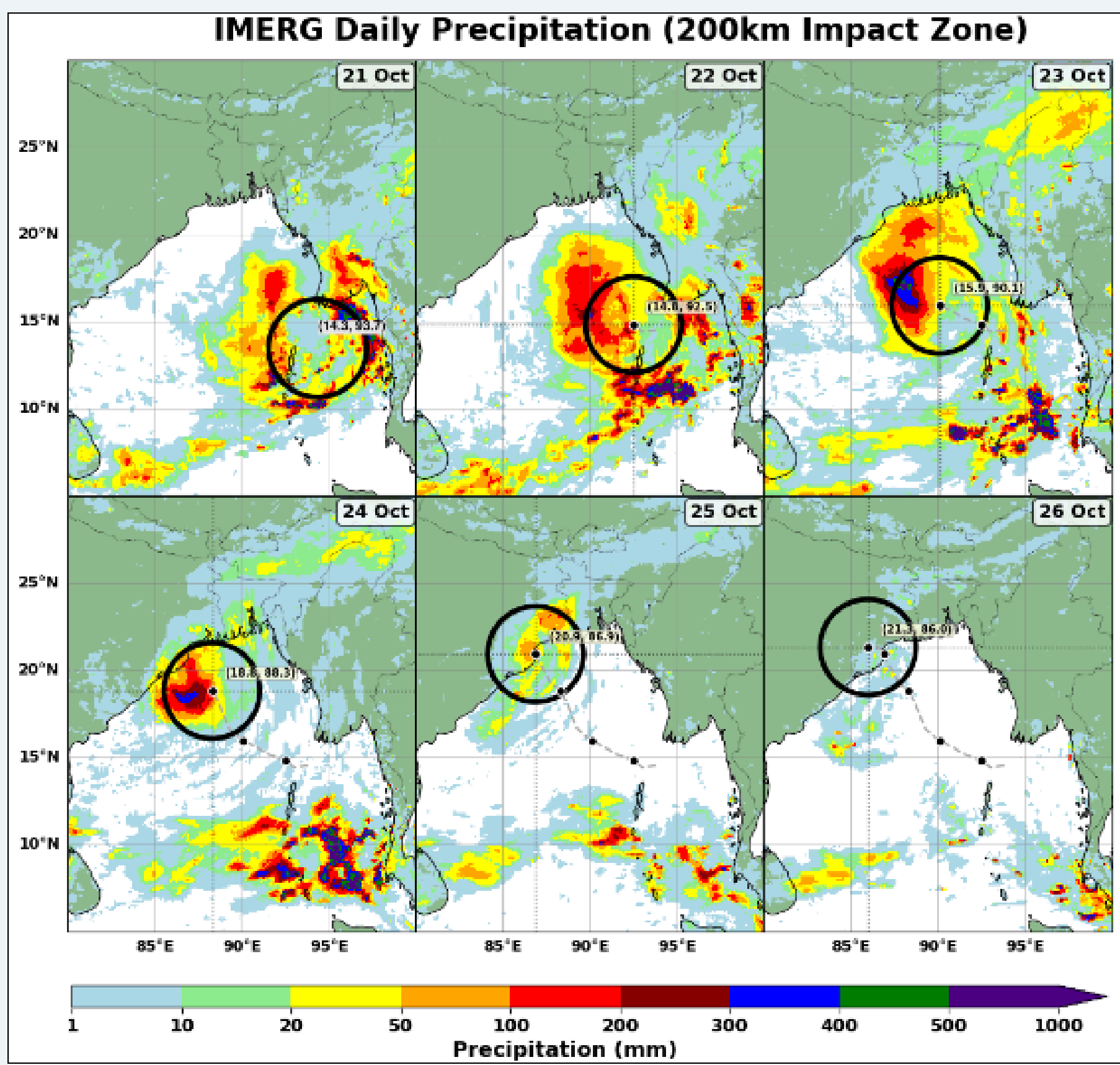
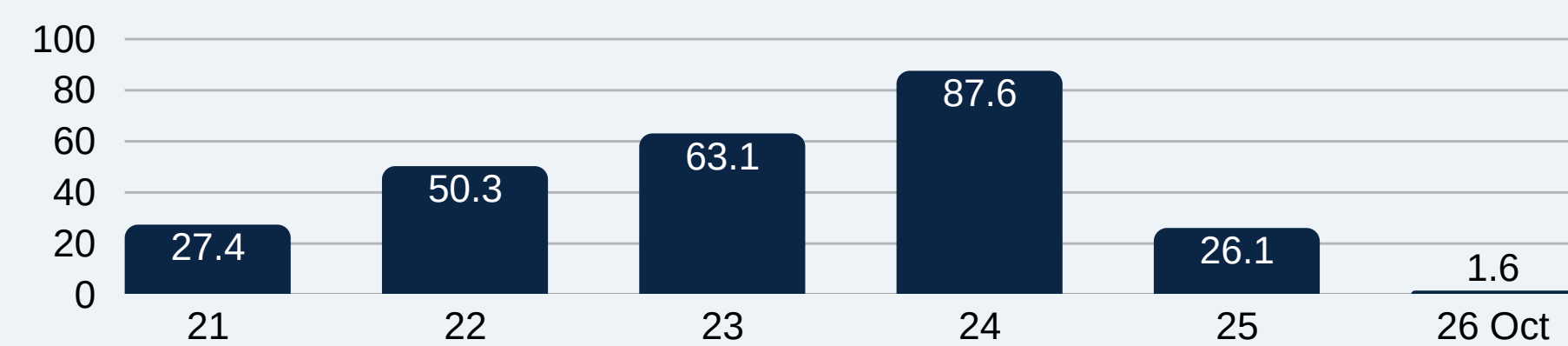


Fig. 2. DPR swaths and bounded analysis regions.

5 Daily Rainfall (IMERG)



Mean rain within 200 km (mm day^{-1})



Genesis Phase (21–22 Oct):

Rainfall was spatially disorganized and concentrated primarily outside the impact zone, shifting on 22 October toward the western quadrants with a mean areal rainfall of 27.4 & 50.3 mm.

Intensification Phase (23–24 Oct):

Precipitation contracted into the western quadrants with daily values exceeding 300 mm day^{-1} and mean areal rainfall reaching 87.6 mm on 24 October, consistent with inner-core convective organization.

Landfall and Post Landfall Phase (25–26 Oct):

As TC Dana approached Odisha and West Bengal, mean precipitation dropped to 26.1 mm, shifting to northern quadrants dominance due to asymmetric coastline interaction. 26 Oct the precipitation dropped to 1.6mm marking the end of the cyclone.

Fig. 4. Daily accumulated rain (mm day^{-1}); circle = 200 km impact zone.

4 Intensity Evolution

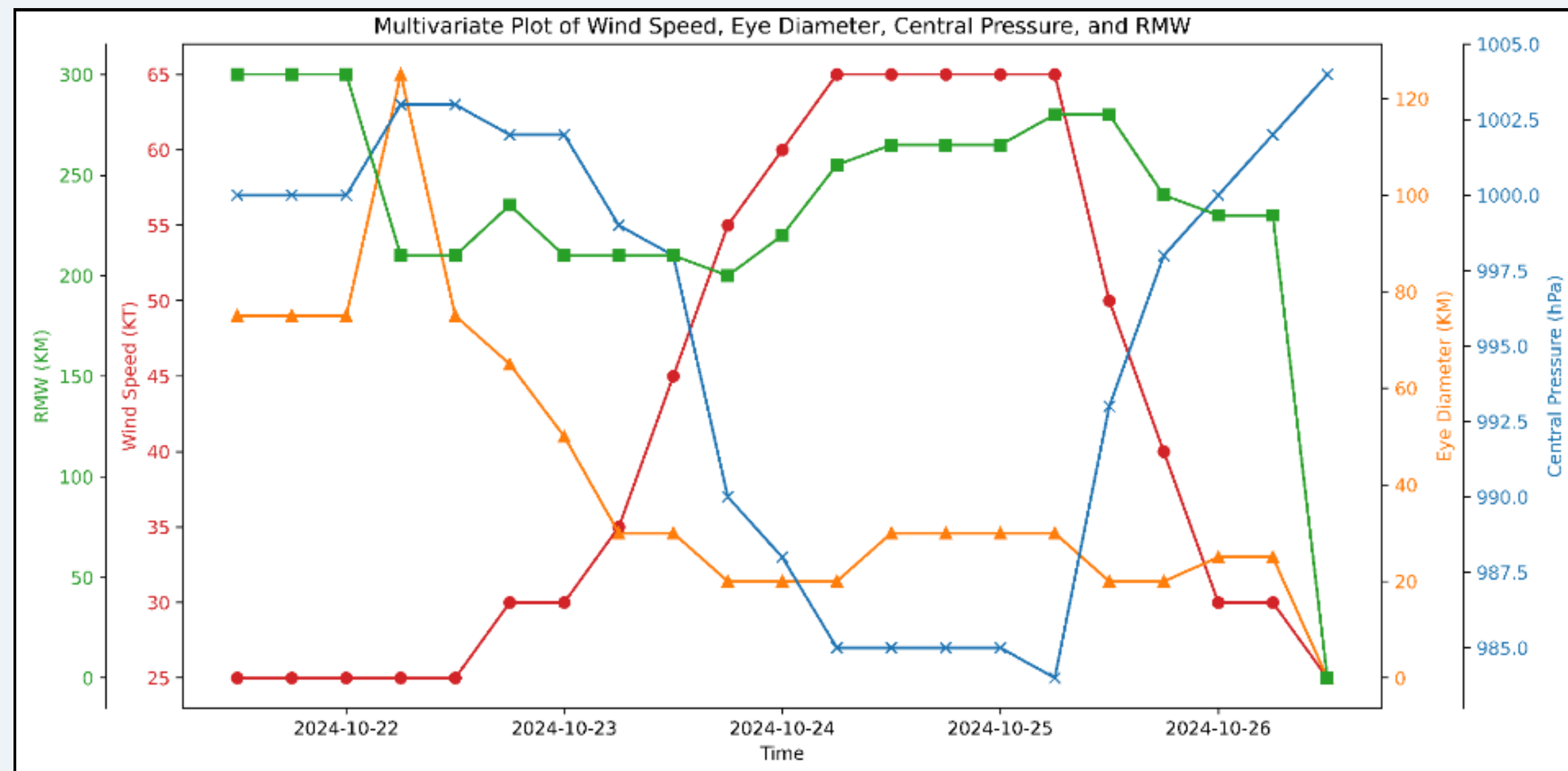


Fig. 3. Wind (red), central pressure (blue), RMW (green) and eye diameter (orange), 6-hourly. Eye contraction with rising winds reflects angular-momentum conservation.

Genesis: 21–23 Oct

25 to 30 kt; eye 80→50 km; RMW 300→200 km; CP 1000→1001 hPa

Mature: 24–25 Oct

Peak 65 kt; eye 20→30 Km; CP 988→985

Intensification: 23–24 Oct

30→60 kt; eye 50→20 Km; CP 1003→985 hPa

Decay: 25–26 Oct

65→25 kt; eye 30→0 Km; 1005 hPa

6 Radial Rain Structure

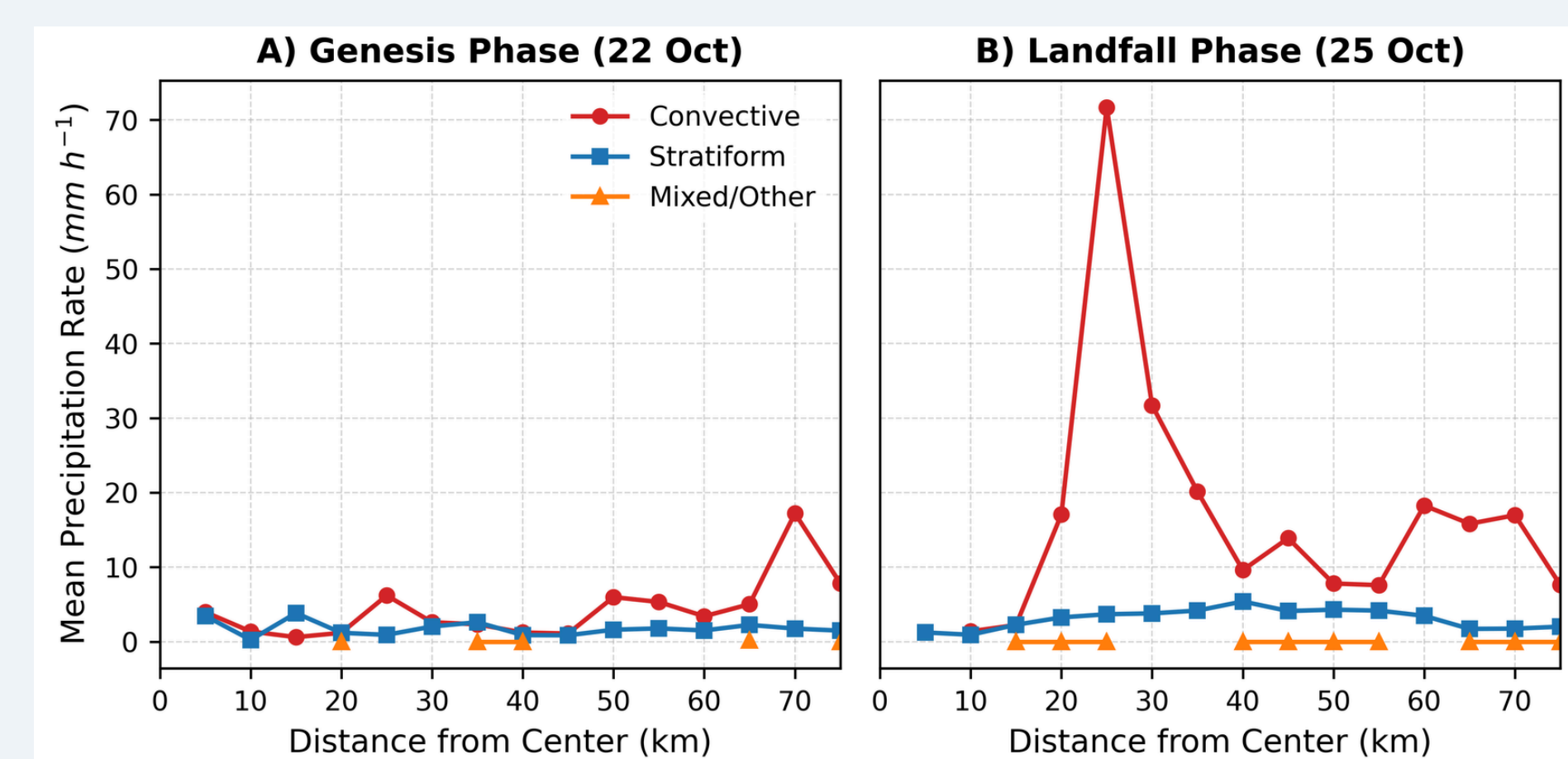


Fig. 5. Near-surface rain rate within 75 km: convective (red), stratiform (blue), mixed (orange).

Genesis: Weak convection displaced outward, $\sim 17 \text{ mm h}^{-1}$ at 70 km; stratiform peak 4 mm h^{-1} at 10–15 km.

Landfall: A compact convective core above 70 mm h^{-1} at 25 km; stratiform peak 7 mm h^{-1} at 40 km; mixed rain near-negligible during both the overpasses.

7 Vertical Rain Profiles

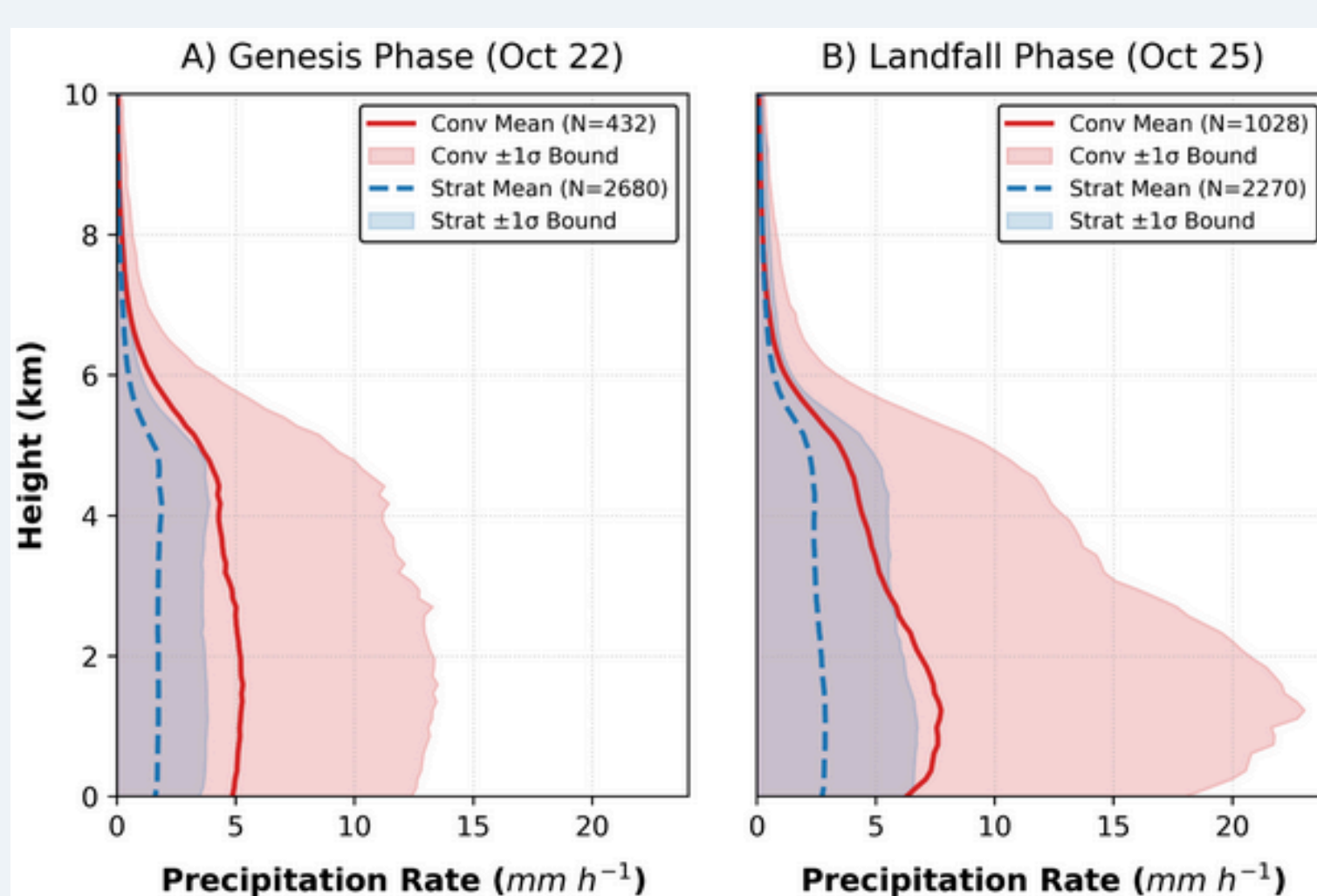


Fig. 6. Mean rain-rate profiles ($\pm 1\sigma$).

Convective mean rose $5.2 \rightarrow 7.6 \text{ mm h}^{-1}$, peaking near 1.5 km: rain keeps growing below the melting layer, over a convective observations twice as large (432 → 1028). **Stratiform** stayed below 3 mm h^{-1} ; its maximum descends from 4 km to 1.5 km.

8 Hydrometeor Profile

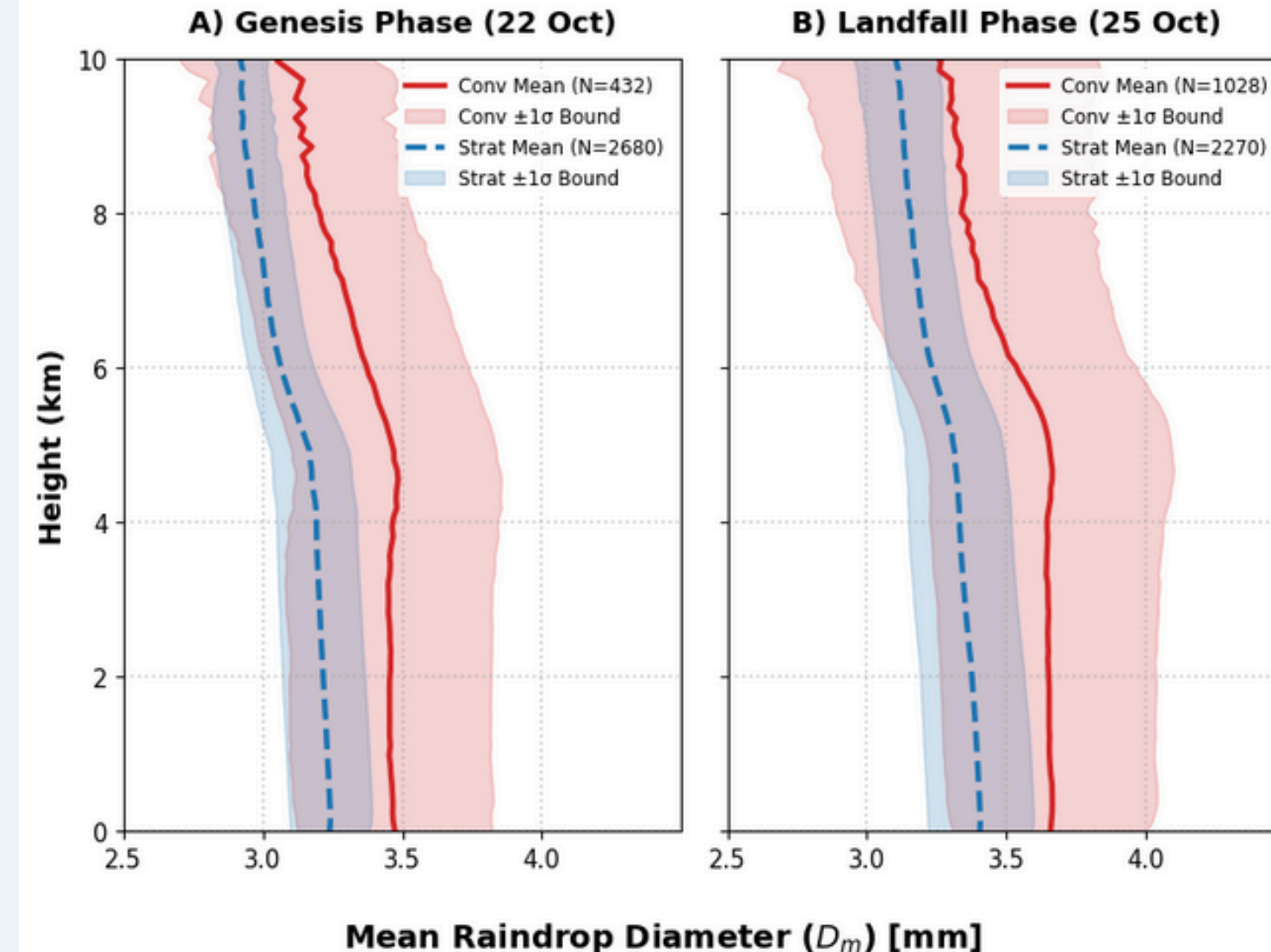


Fig. 7. Mass-weighted mean diameter (D_m) profiles.

Convective 3.1–3.5 mm at genesis; stronger eyewall updrafts at landfall raise surface D_m to $\sim 3.65 \text{ mm}$.

Stratiform 2.8–3.25 → 3.1–3.4 mm. Above the $\sim 5 \text{ km}$ melting layer, D_m reflects ice-phase particles.

9 Conclusions

- TC Dana was an exceptionally long-lived system with a 1,780 km track and 120-hour lifespan, far exceeding post-monsoon SCS averages. Daily rainfall was persistently concentrated in the North and west quadrants during intensification, peaking at a mean of 87.6 mm on 24 October in its impact zone.
- In the 75 km inner core, convective precipitation rate increased from genesis (17.5 mm h^{-1}) to landfall ($>70 \text{ mm h}^{-1}$), alongside a notable increase in stratiform rainfall at landfall.
- Vertical precipitation profiles (VPR) confirm intensified convective activity (mean core rates increasing from 5.2 to 7.6 mm h^{-1} peaking near 1.5 km altitude). Raindrop median diameter (D_m) increased during landfall, exhibiting a robust collision-coalescence equilibrium zone below 4 km altitude.
- Study Limitations & Future Work:** Results represent snapshots (lacking direct DPR coverage during peak intensification on 23–24 Oct). Generalization to other Bay of Bengal cyclones requires multi-case comparisons (e.g., Amphan, Yaas, Mocha).
- Implications:** Serves as a quantitative, observation-based benchmark to calibrate and validate cloud microphysics parameterizations in NWP models for post-monsoon tropical cyclones.