Linking Ice-Phase Microphysics to Raindrop Characteristics, and Extreme Rainfall in Two Deep Convection Events in China

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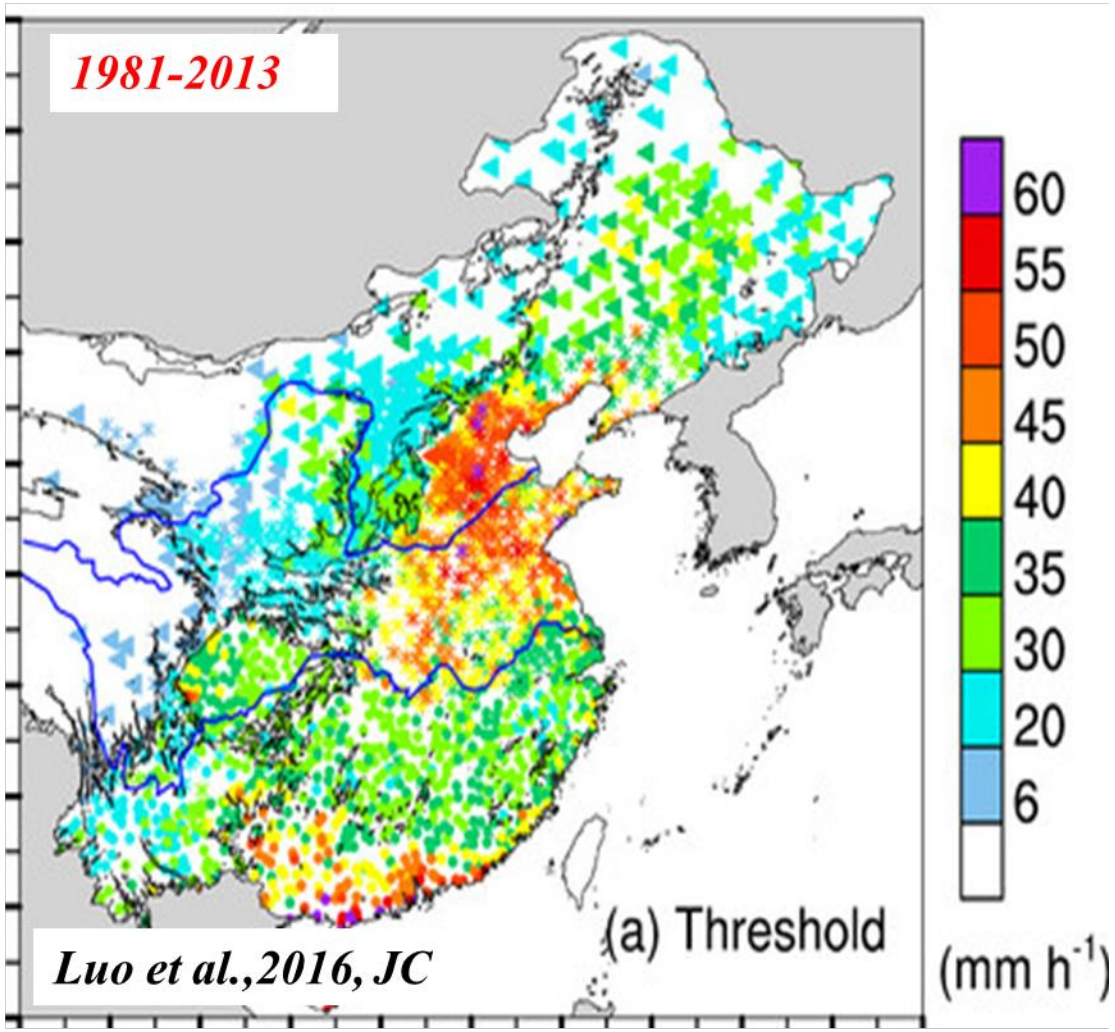
Outline

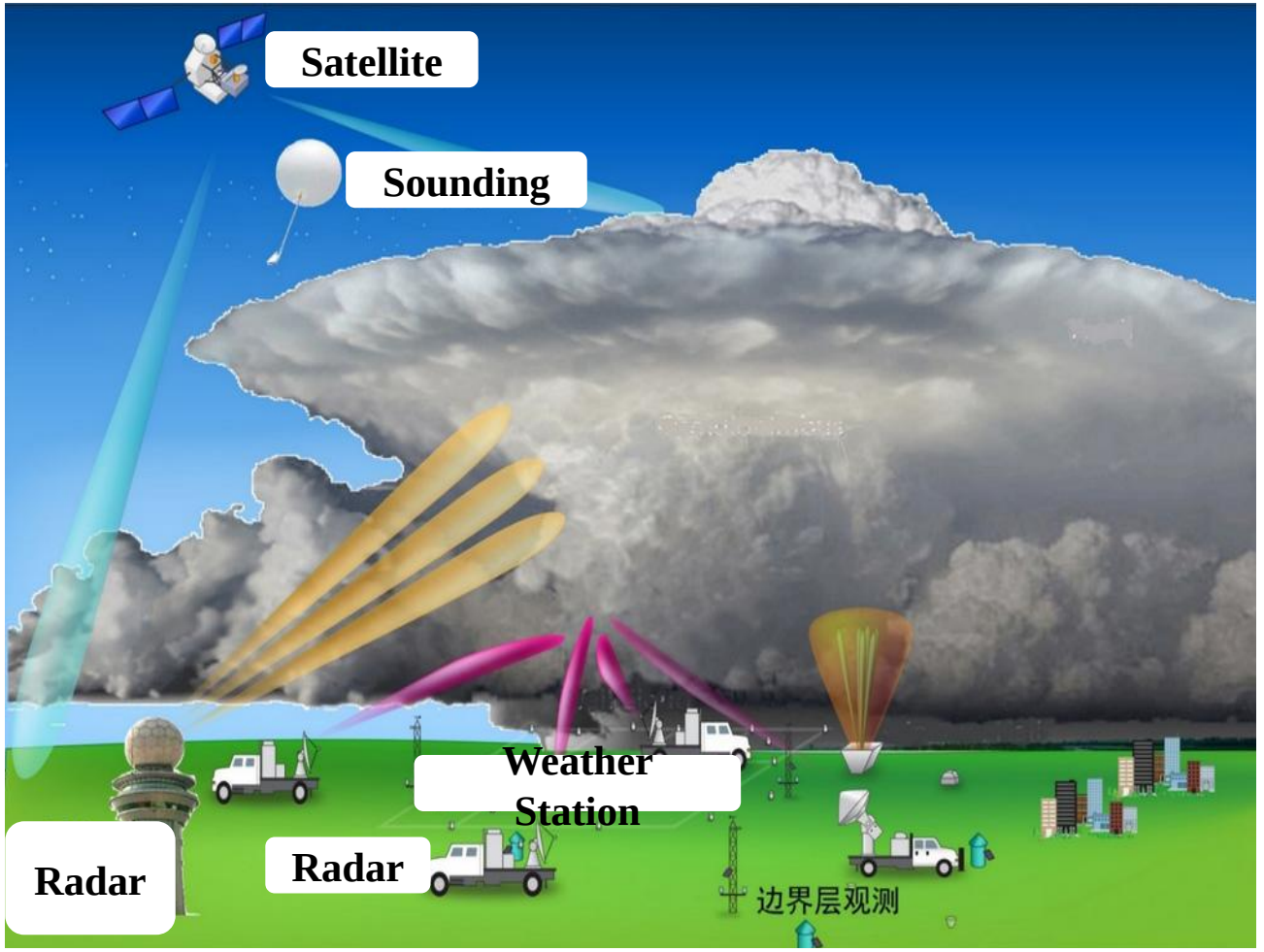
1. **Background**
2. **Data and Method**
3. **Microphysical Characteristics**
4. **Conclusion and Discussion**

Background

Distribution of extremely hour rainfall (0.1%)

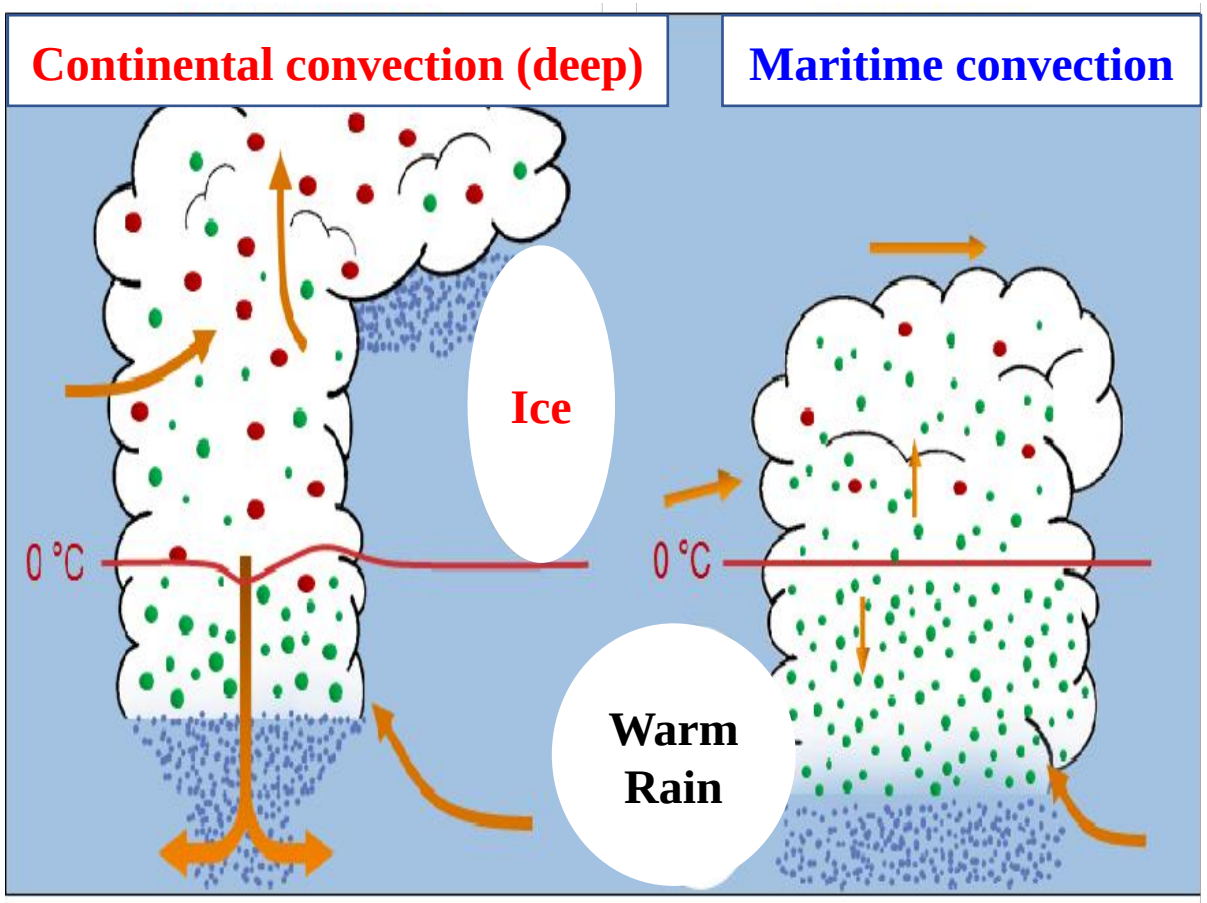


Radar: three-dimensional structure



Convection Depth and Extreme Rainfall

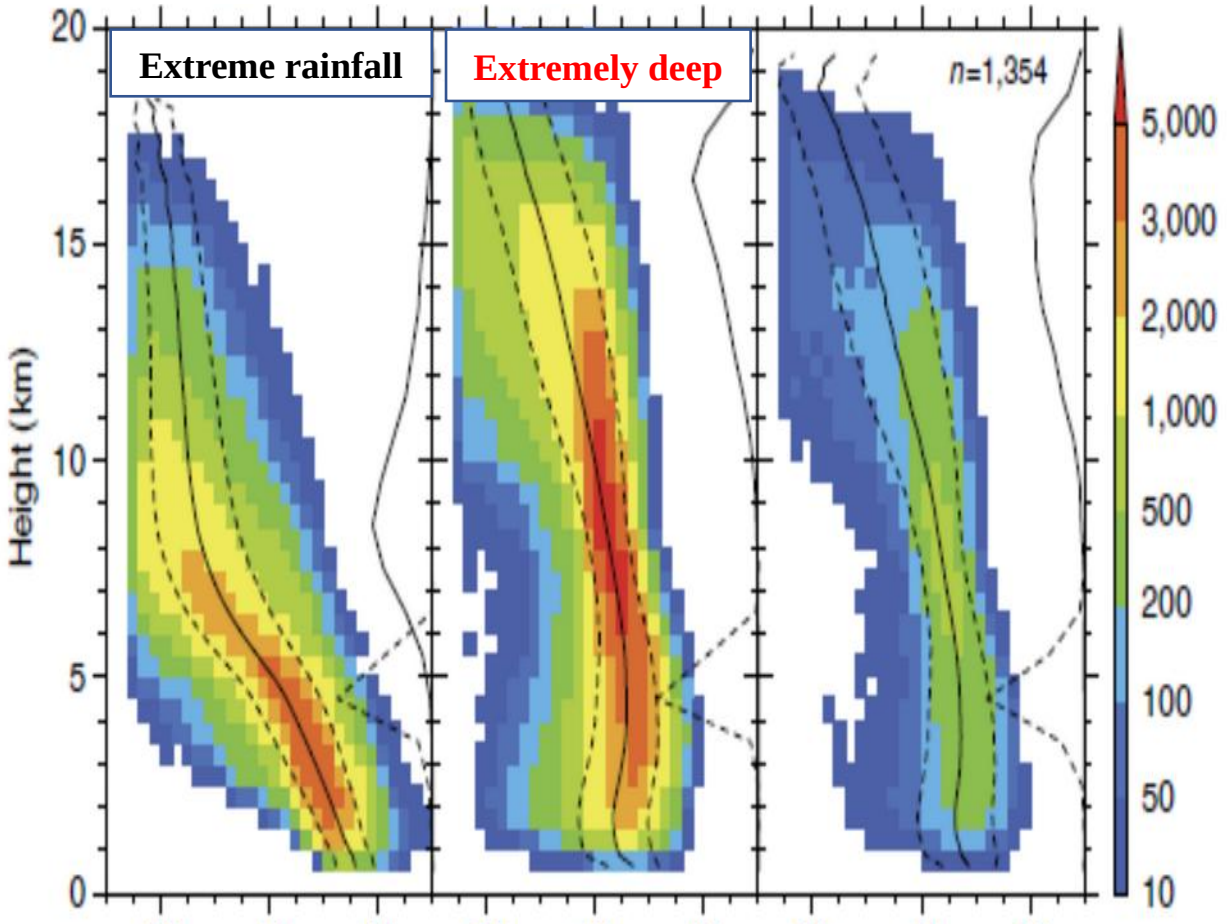
Extreme rainfall convection



Large mean size in continental convection
High number concentration in maritime convection

Bringi et al.,2003, JAS; Ryu et al., 2021, GRL

Deep and extreme rainfall convection



Extreme rainfall contributed by extreme deep convection on land is less than 30%

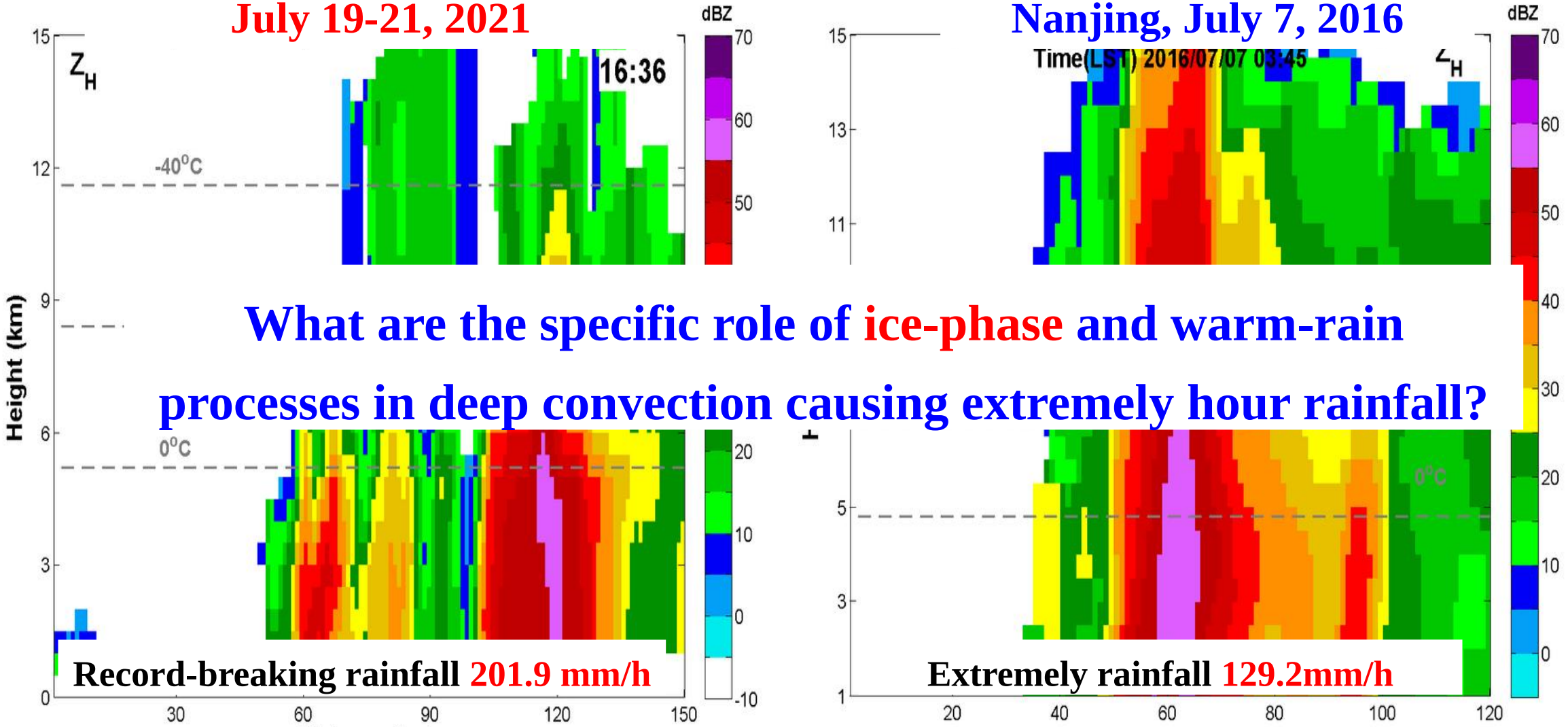
Hamada et al., 2015, NC; Xu et al.,2022, GRL

Two Extremely Deep Convection Events

Extreme rainfall in Henan, July 19-21, 2021

Extreme rainfall in Nanjing, July 7, 2016

What are the specific role of ice-phase and warm-rain processes in deep convection causing extremely hour rainfall?



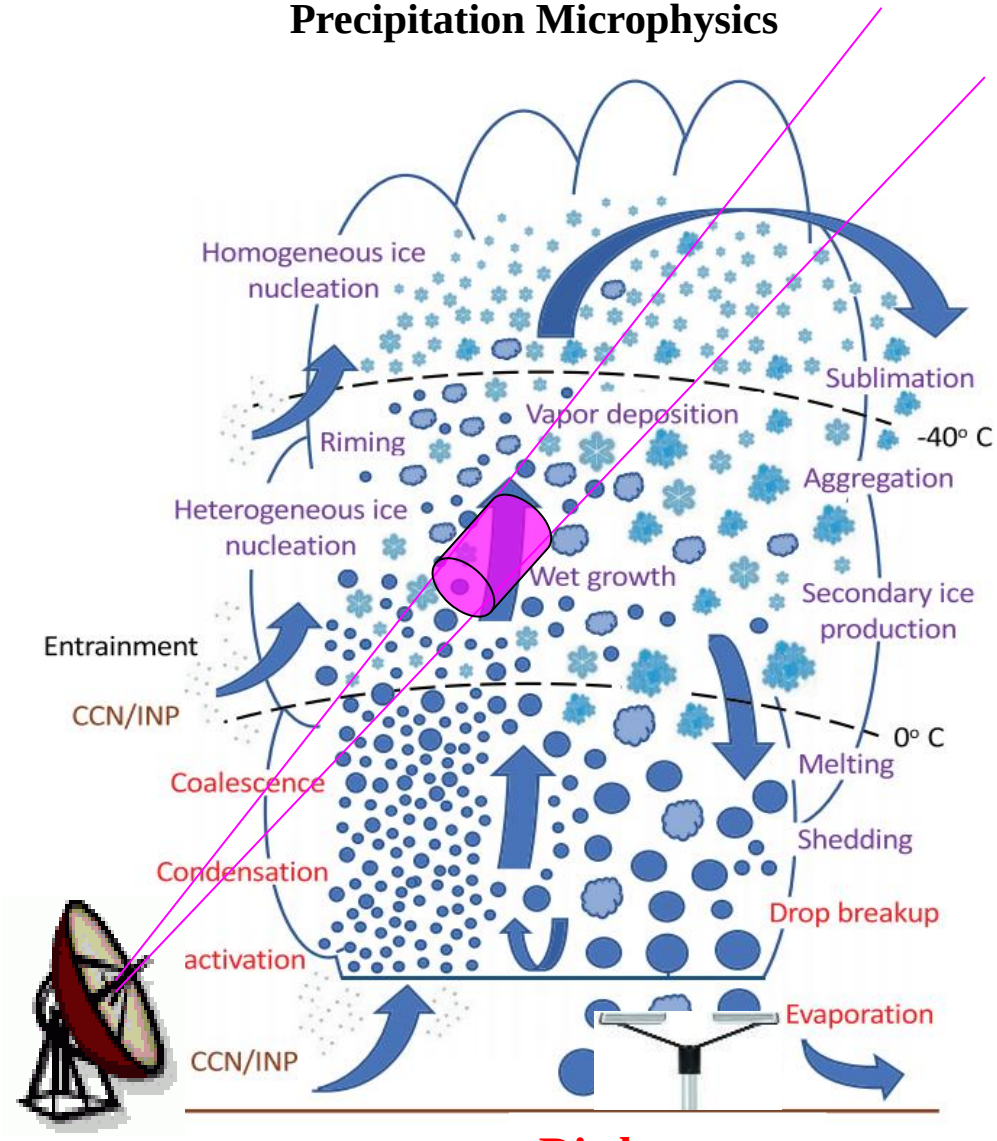
Record-breaking rainfall 201.9 mm/h

Extremely rainfall 129.2mm/h

Zhao et al., 2023, RS Chen et al. 2022, ESS

Data and method

Precipitation Microphysics

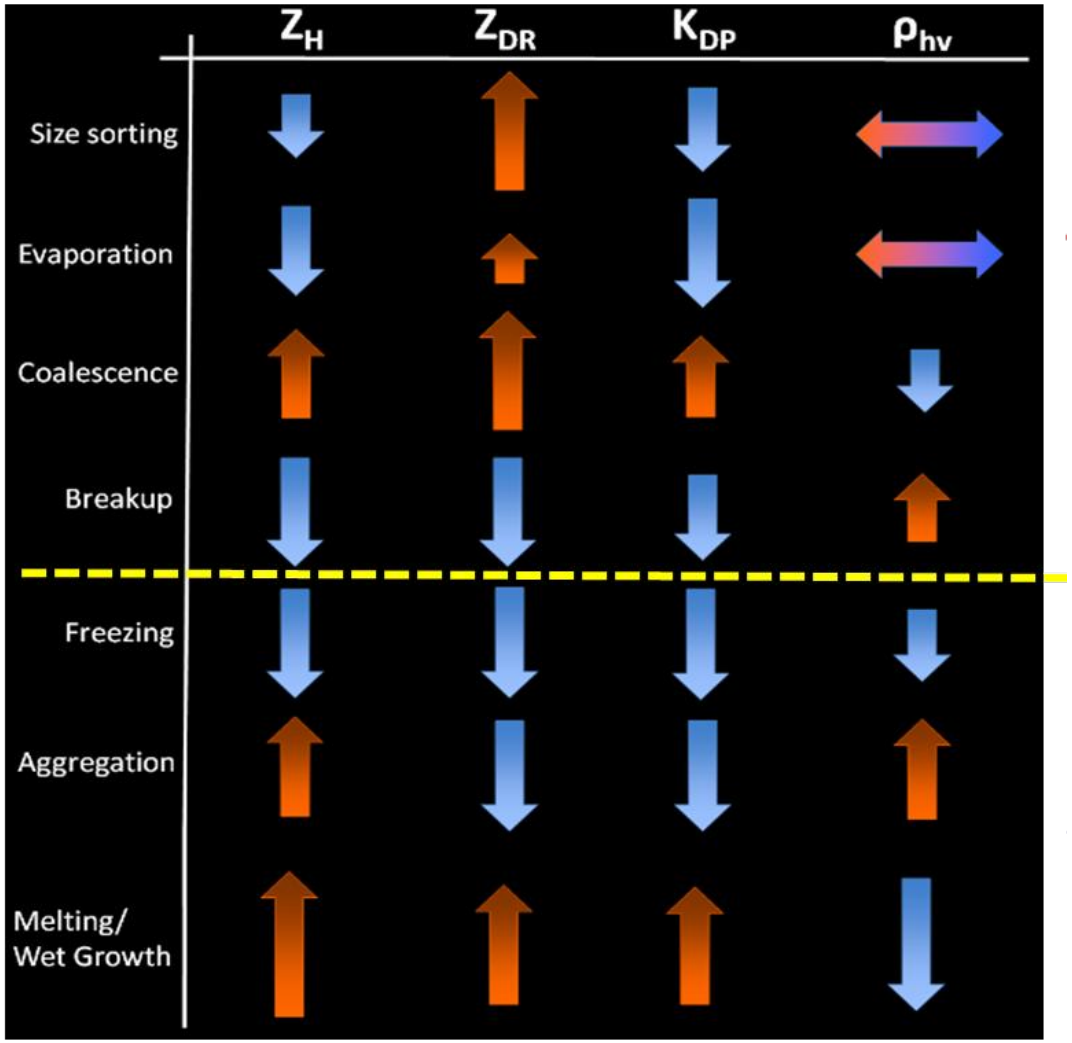


Polarimetric Radar

Disdrometer

Morrison et al., 2020, JAMES

Polarimetric Radar Fingerprints of Precipitation Microphysics



Warm Rain

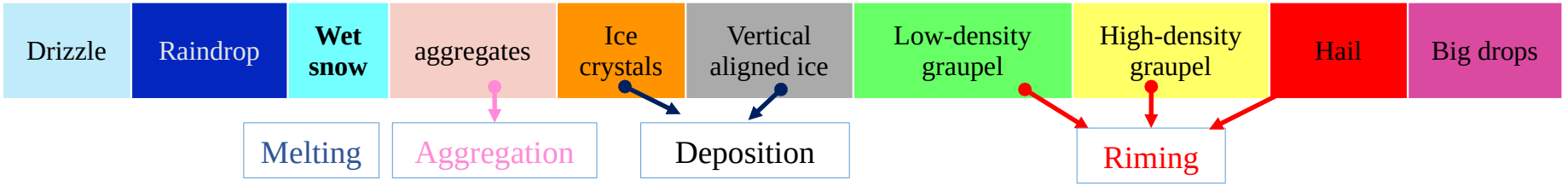
Ice

Changes in the variables indicate specific microphysical process

Kumjian et al., 2012,ERAD; 2022,RS

Data and method

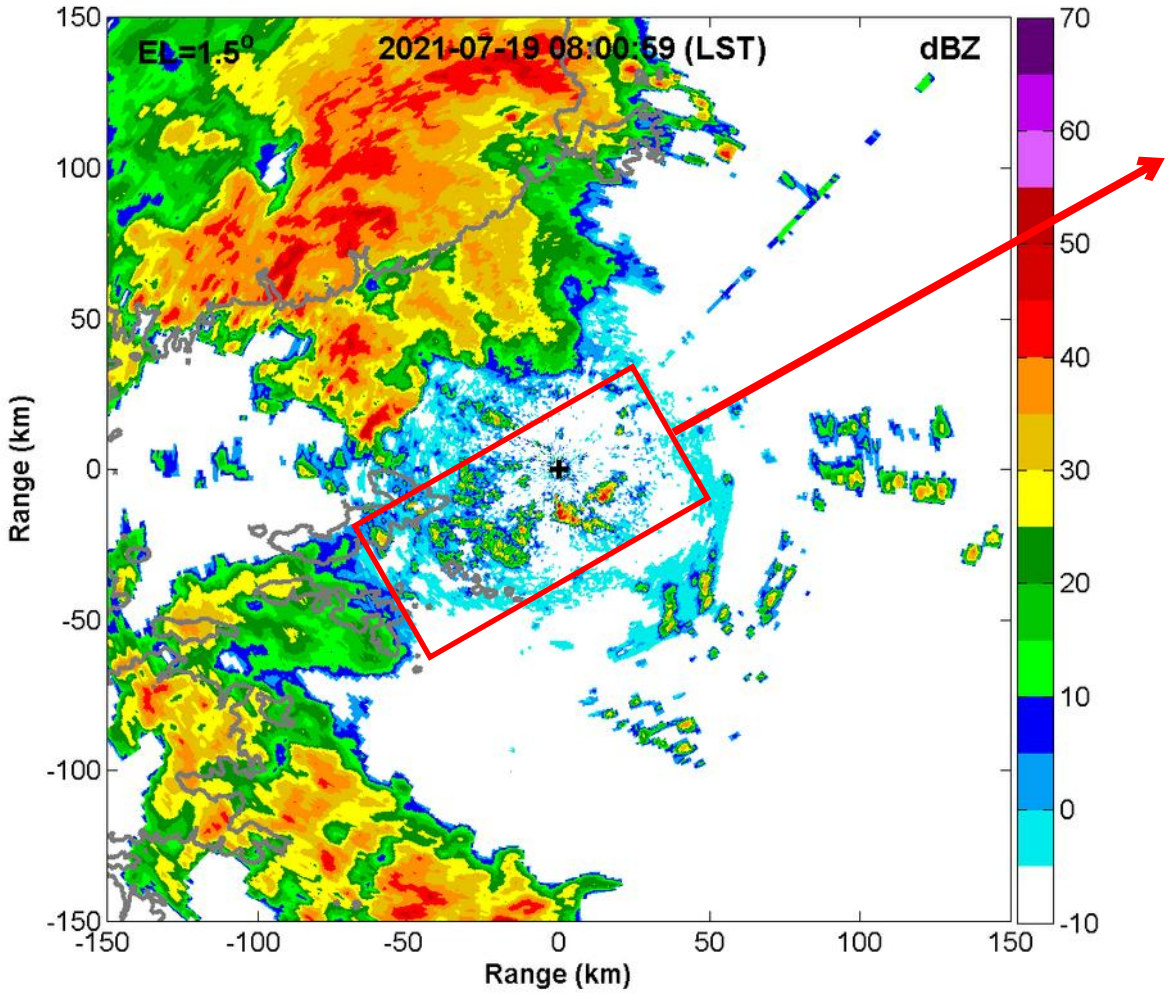
- Polarimetric radar variables from ZZRD 、 LYRD and NJ CPOL ($\mathbf{Z_H}$ –Intensity of convection, $\mathbf{Z_{DR}}$ – Mean raindrop size, $\mathbf{K_{DP}}$ –Liquid water content)
- 50 OTT PARSIVEL disdrometers in Henan and a 2DVD in JN station (**DSD, $\mathbf{D_m}$, $\mathbf{N_w}$, R)**.
- Retrieval of DSD parameters and rain rate using polarimetric radar (*Huang et al.,2020; Chen et al.,2017)*
- Retrieval of liquid and ice water content (*Carey and Rutledge., 2000; Ryzhkov et al., 2018)*
- Hydrometeor identification algorithm (**HID**, Dolan et al., 2013) to identify the dominant hydrometeor type in each radar sample volume

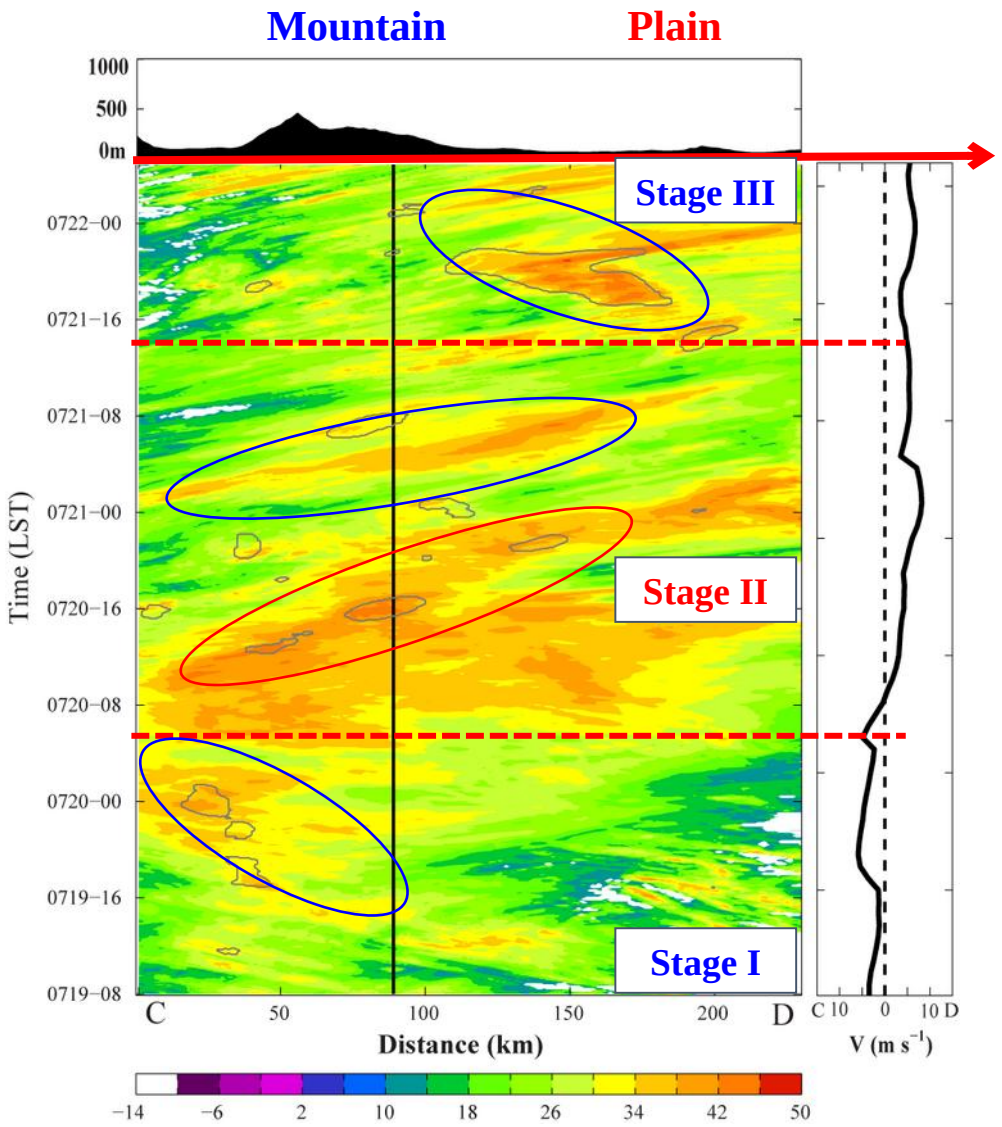


- **K-means** clustering algorithm (Anderberg 2014) to objectively classify the OTT-observed DSD datasets into separate groups
- The four-dimensional Variational Doppler Radar Analysis System (**VDRAS**, Chen et al., 2016) to provide three-dimensional wind and thermodynamic fields.

Case 1: Extremely Heavy Rainfall Event in Henan

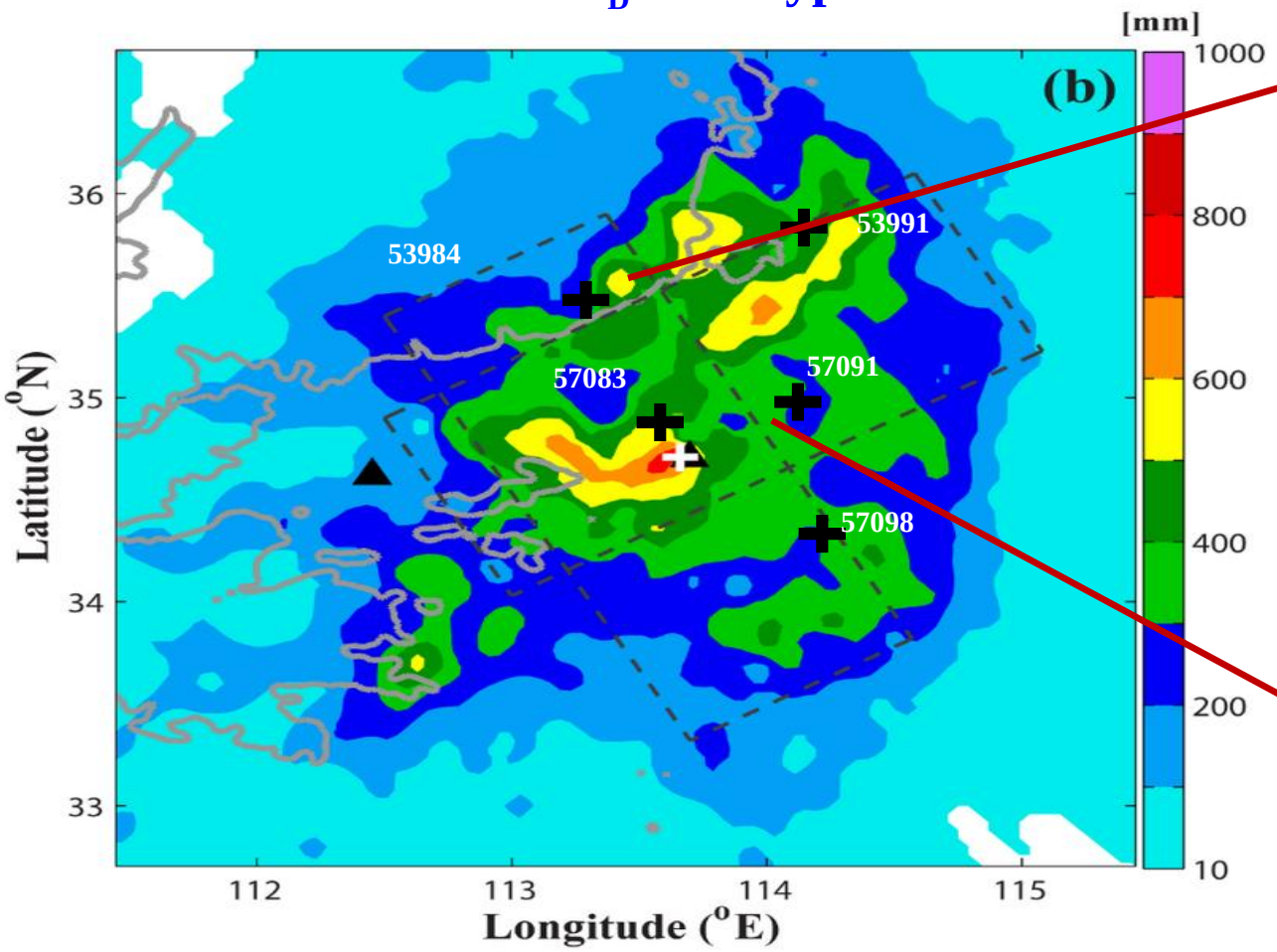
Evolution of the convective systems

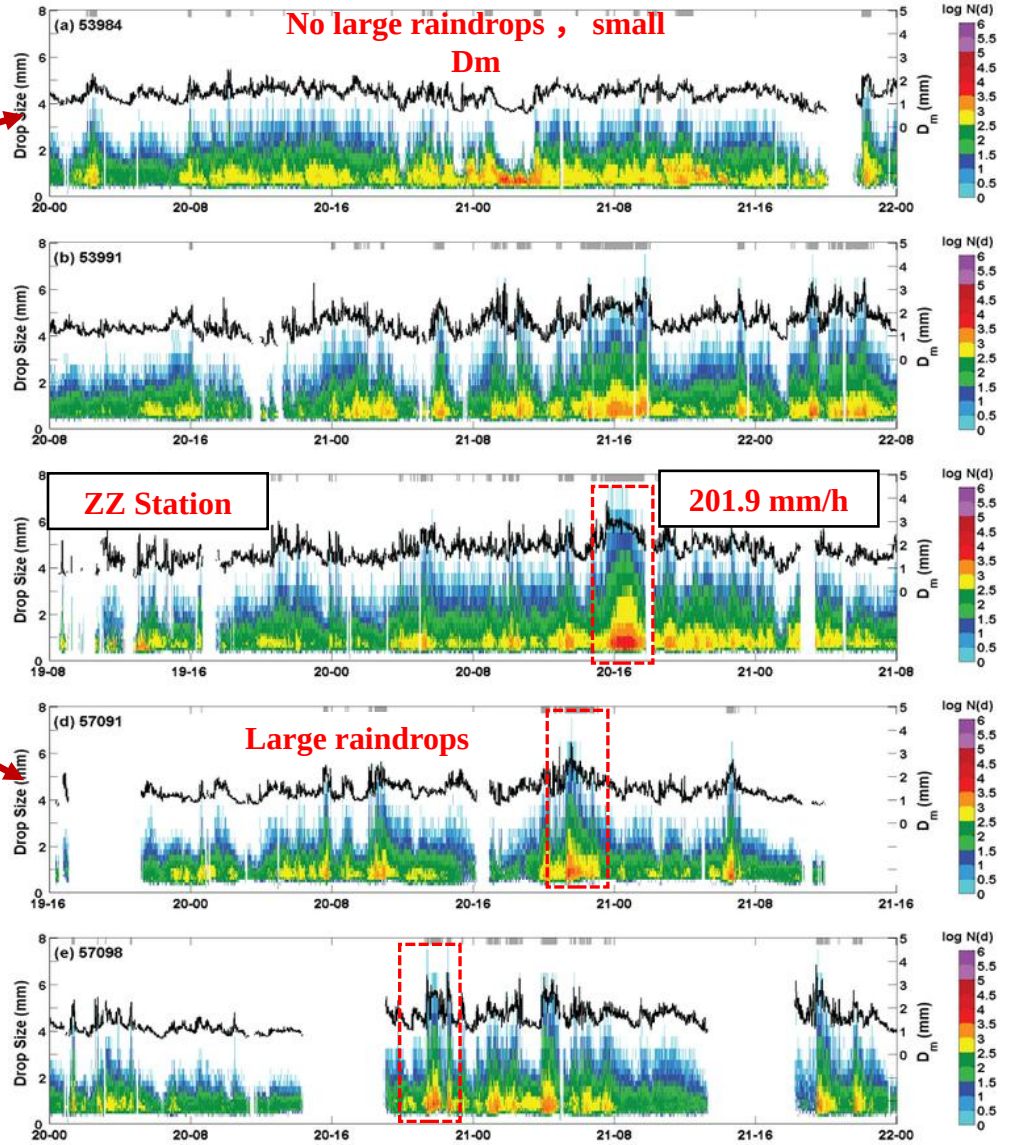




Extremely Heavy Rainfall Event in Henan

Time series of D-N_D from typical stations

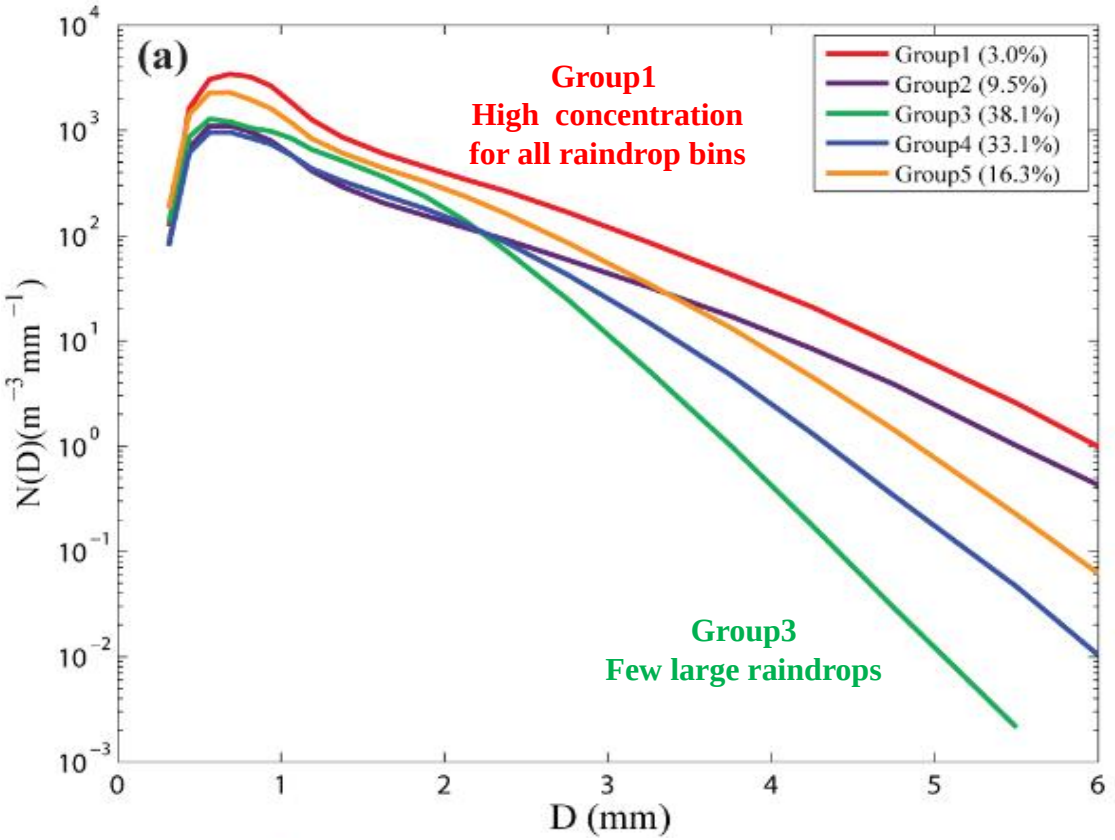


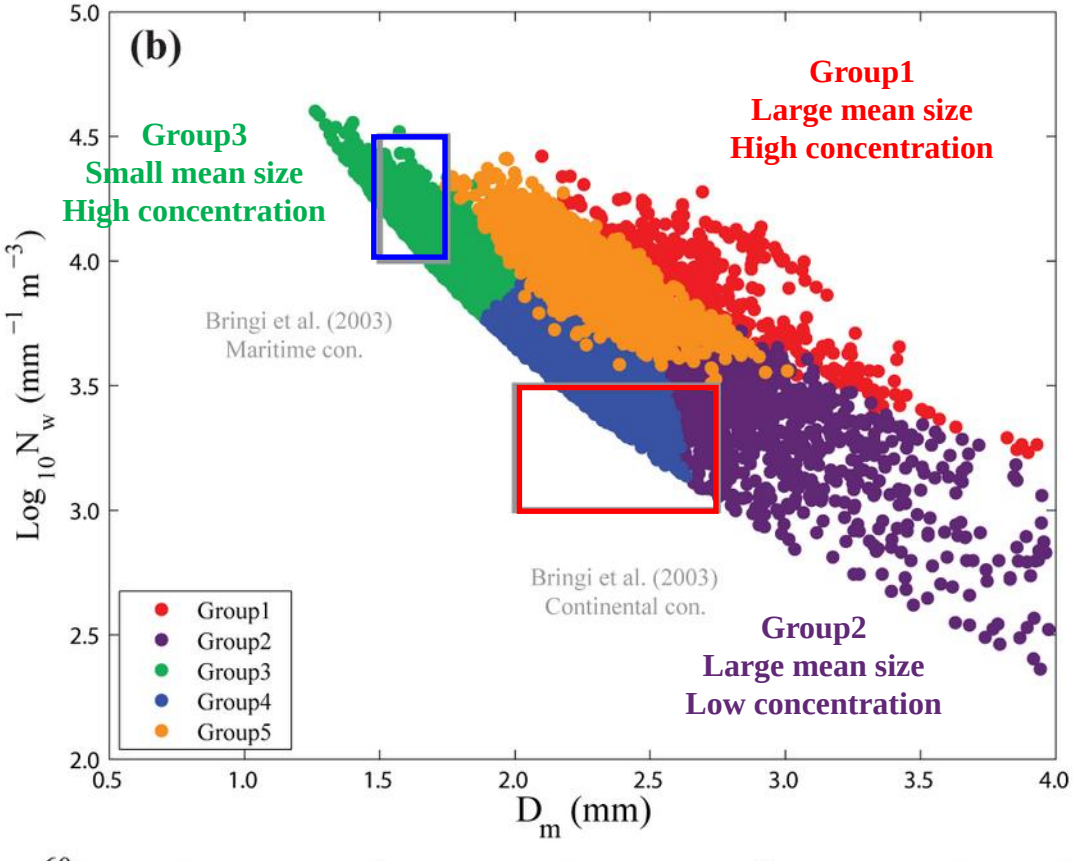


The spatial and temporal variability of DSD characteristics

DSD Characteristics

Based on the DSD characteristics, all heavy rainfall samples (11418) are clustered into **five groups** using the **K-means algorithm**





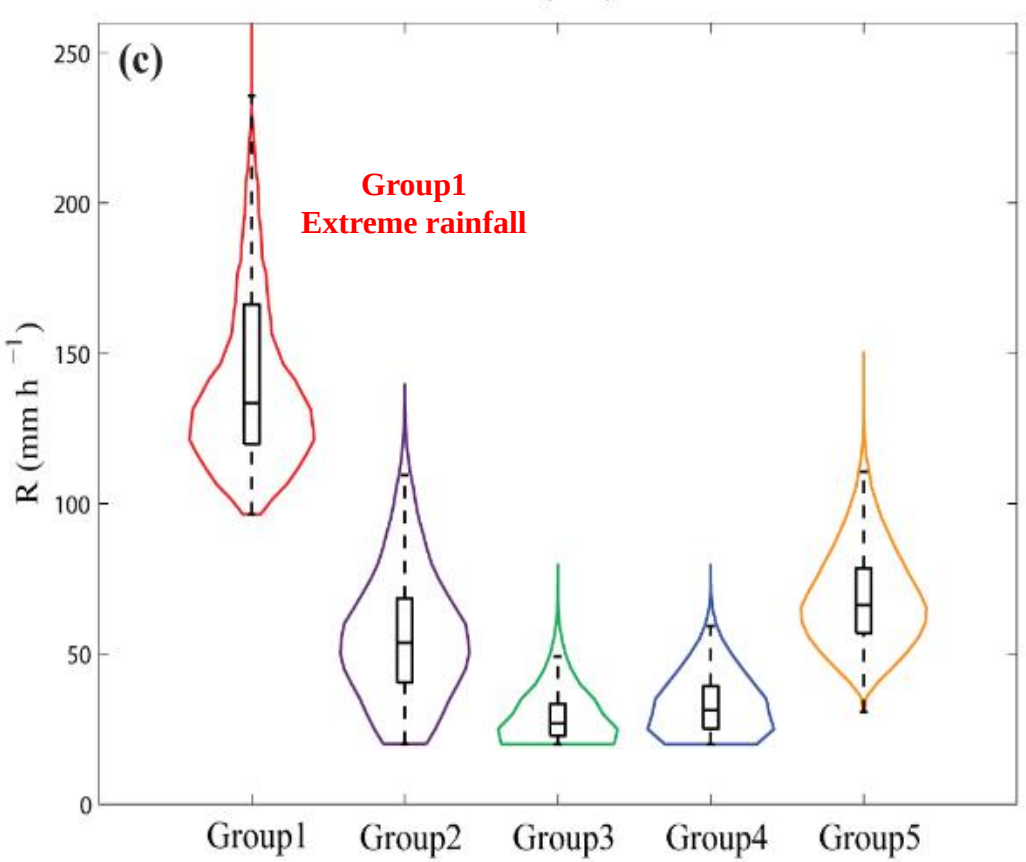
Group1: large mean size high number concentration, maritime and continental convection

Group2: large mean size low number concentration, typical continental convection

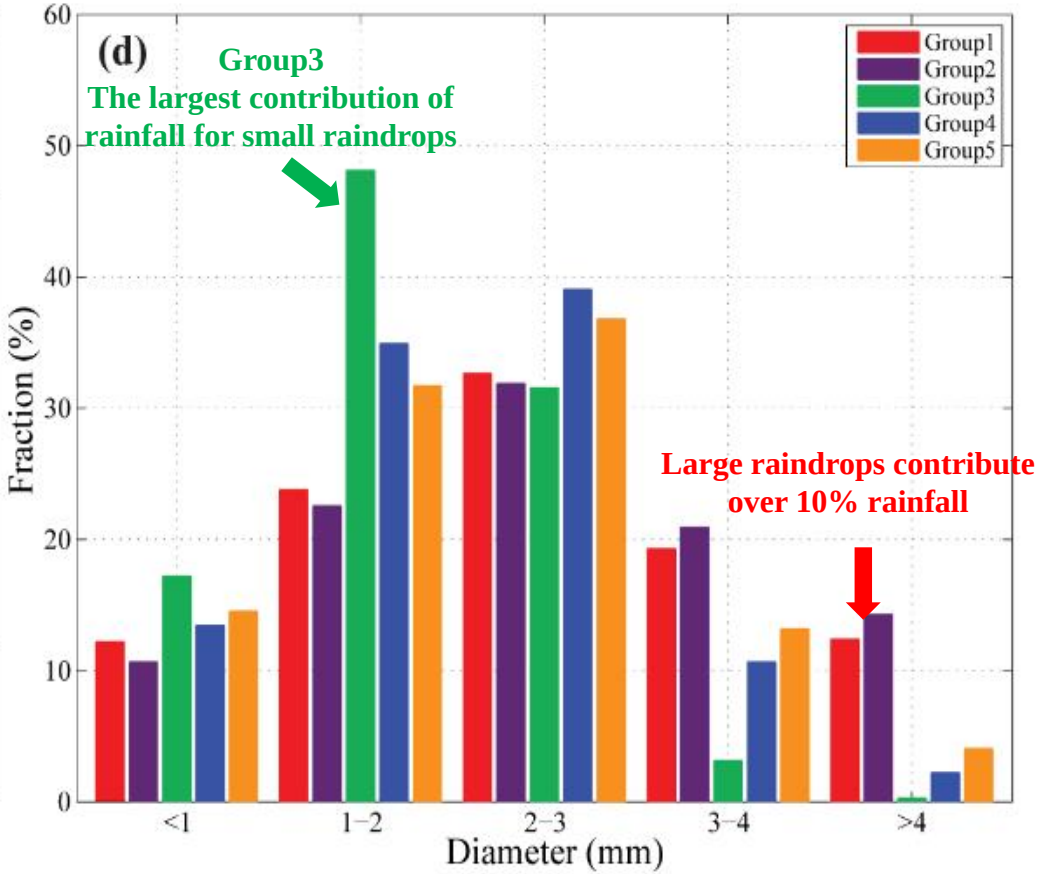
Group3: small mean size high number concentration, typical maritime convection

DSD Characteristics

Boxplots of rain rate



Contribution to total rainfall from selected diameter intervals

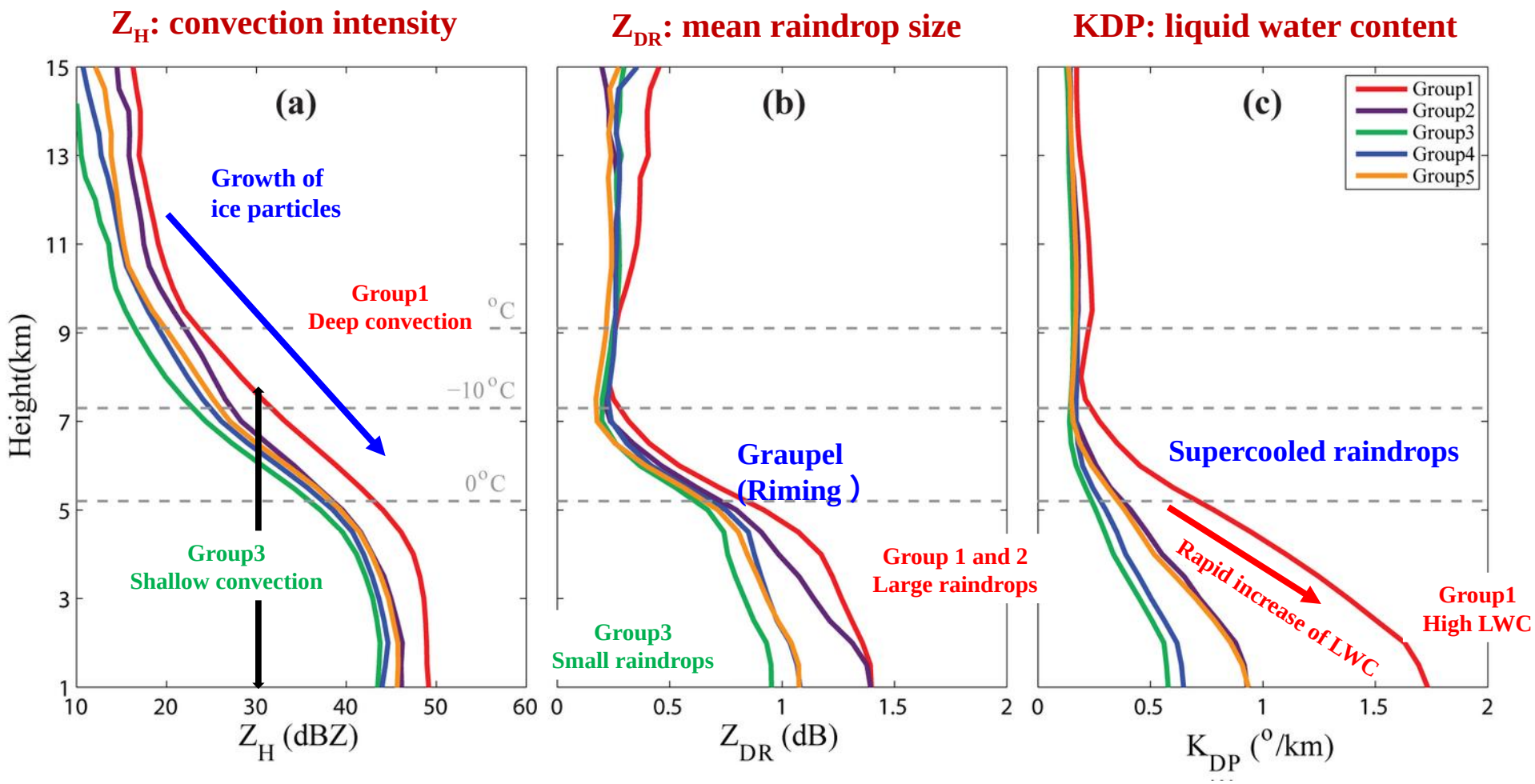


Group1: mean rain rate exceeds 100 mmh^{-1}, over 60% rainfall is contributed by raindrops with diameter >2 mm

Group3: rain rates basically lower than 50 mmh^{-1}, over 60% rainfall is contributed by raindrops with diameter <2 mm

Microphysical Structure

The average profiles of polarimetric radar variables

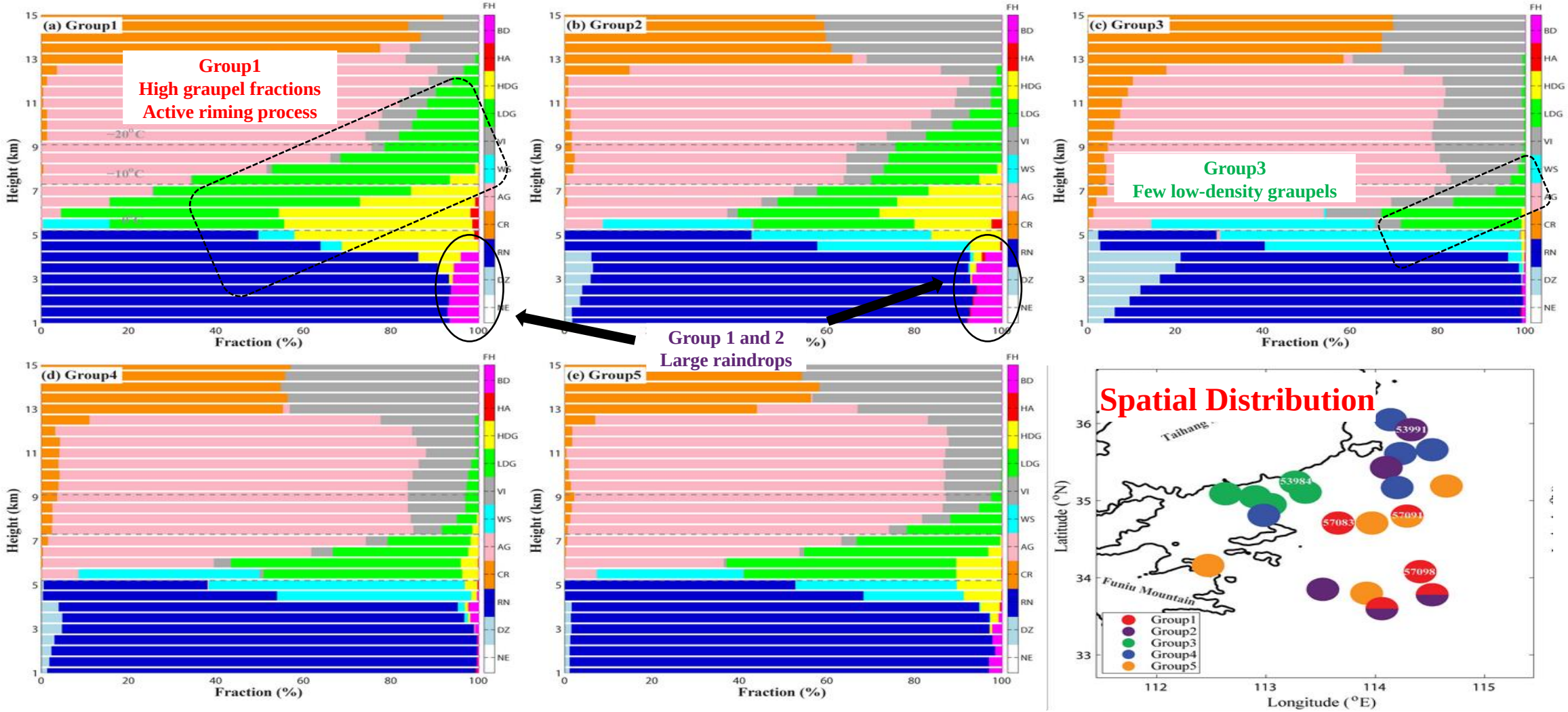


Group1: the deepest convection, both active ice-phase and warm-rain coalescence processes

Group3: shallow convection, active warm-rain coalescence processes

Microphysical Structure

Occurrence fractions of identified hydrometeors in vertical layers

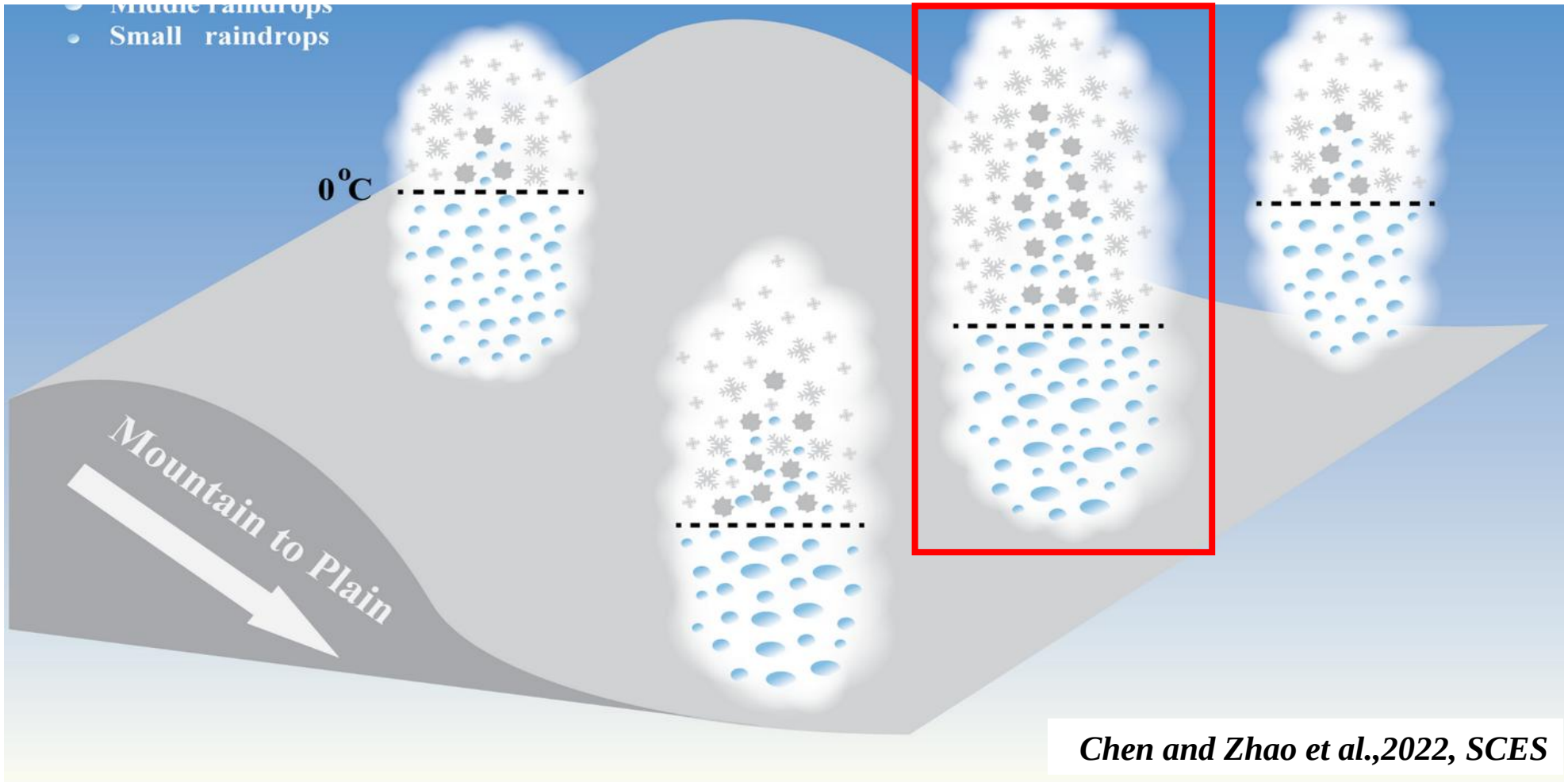


Group1: the highest graupel fraction, active ice-phase processes

Group3: the lowest graupel fraction, suppressed ice-phase processes

Conceptual Model

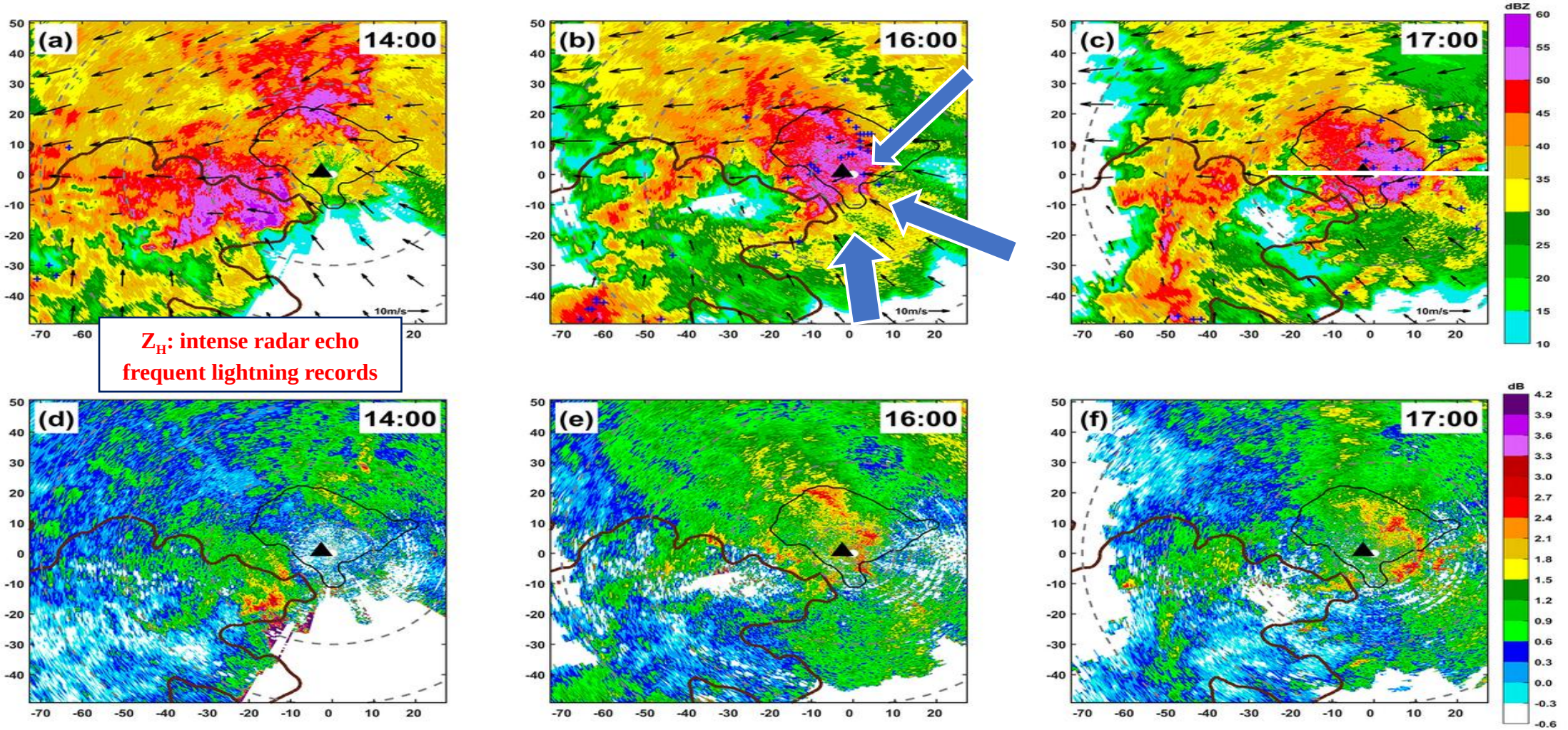
- **Significant microphysical variability is revealed, shallow (deep) convection with active warm-rain (ice-phase) processes is generated near mountain (plain) area.**
- **Extreme rainfall is produced by convection possessing both active ice-phase and efficient warm-rain coalescence processes, raindrops are characterized by high number concentration and large mean sizes.**



Chen and Zhao et al.,2022, SCES

Typical group1 convection

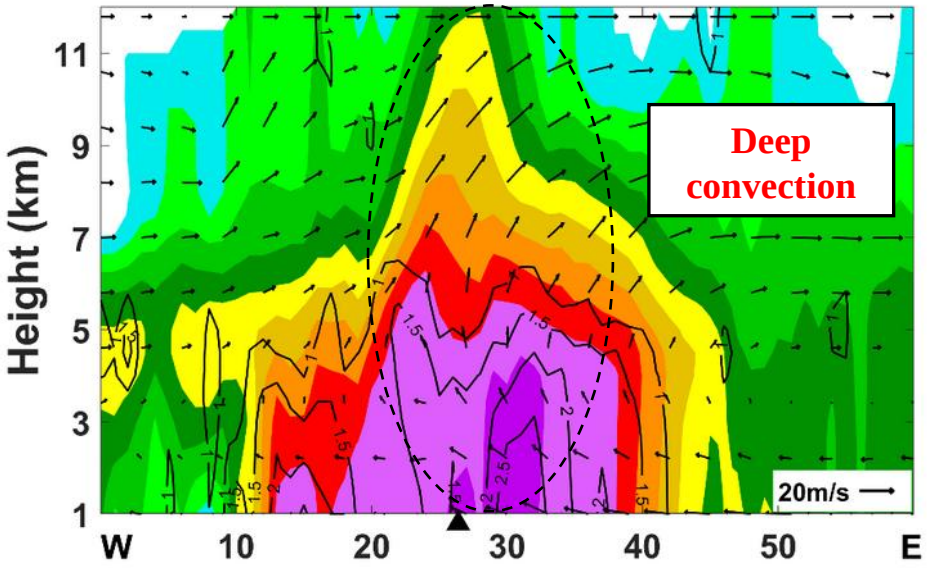
Convection causing the record breaking hourly rainfall (201.9mm/h) in the plain (Zhengzhou city)

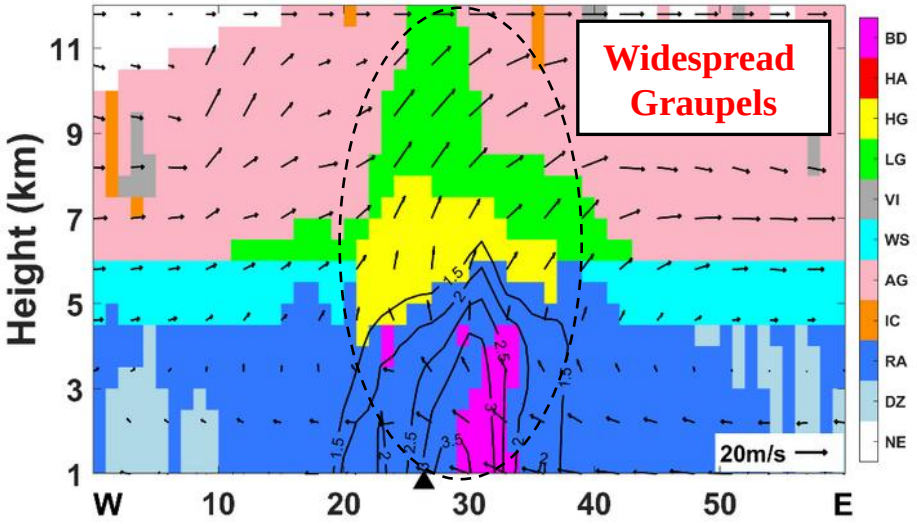


▲: Zhengzhou Station +: Lightning records Brown contours: terrain height

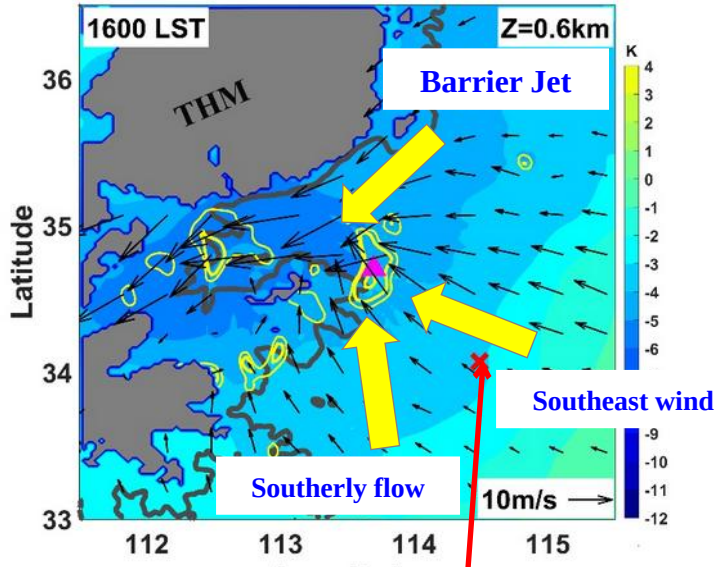
Typical group1 convection

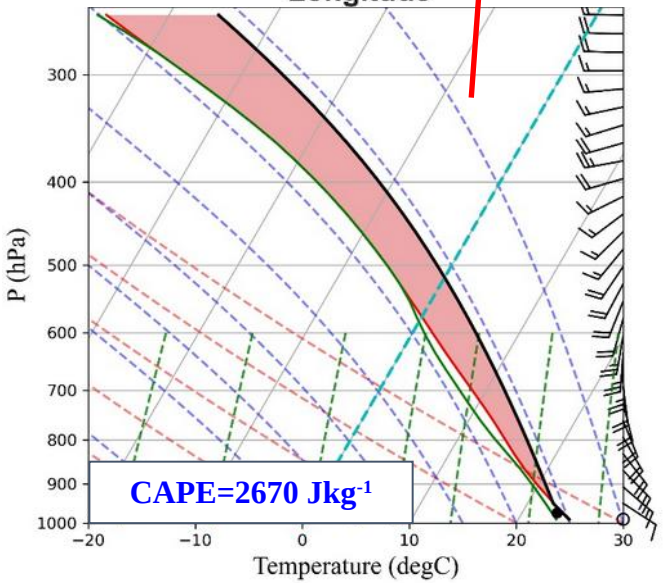
Cross section of the convection



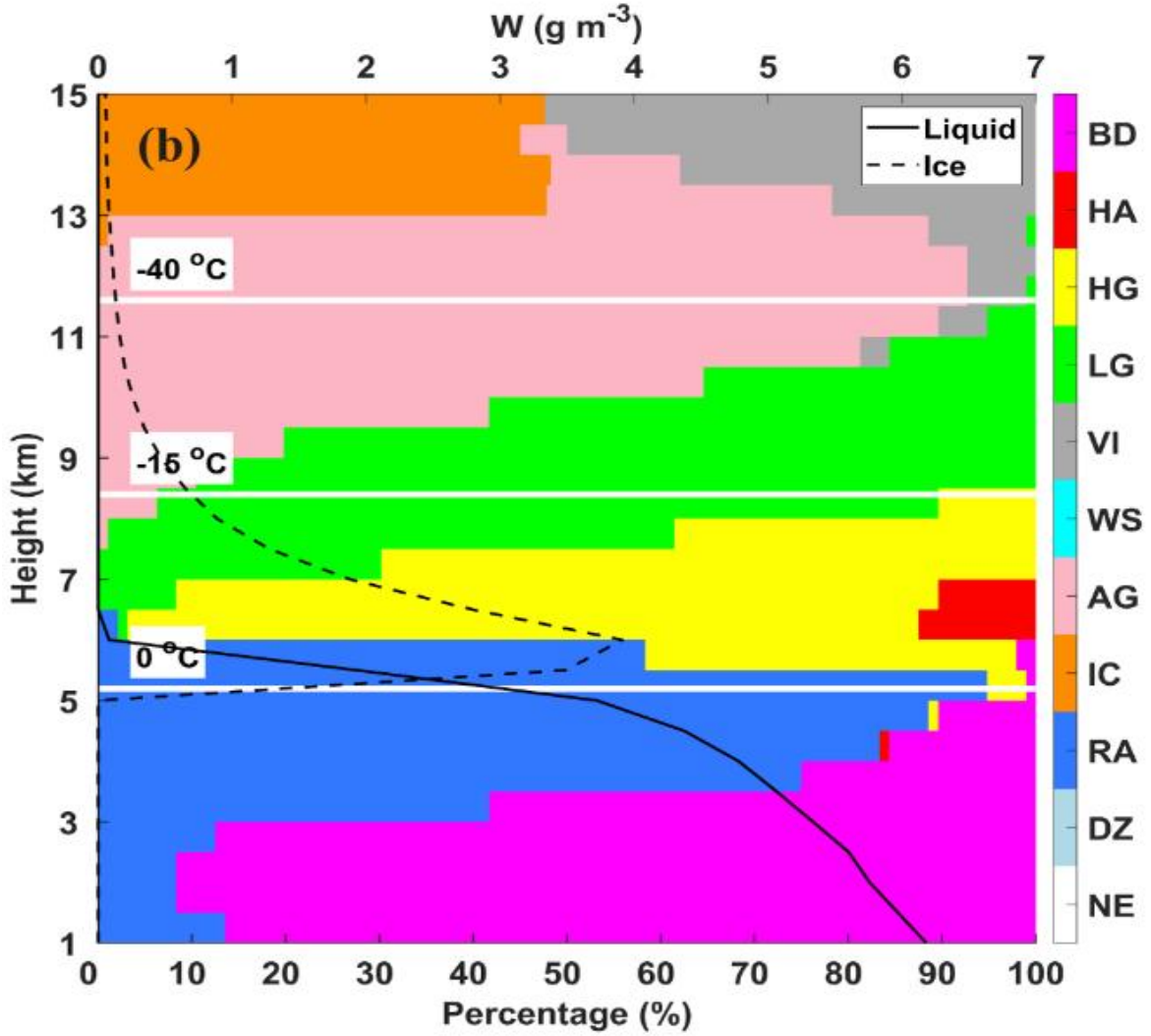


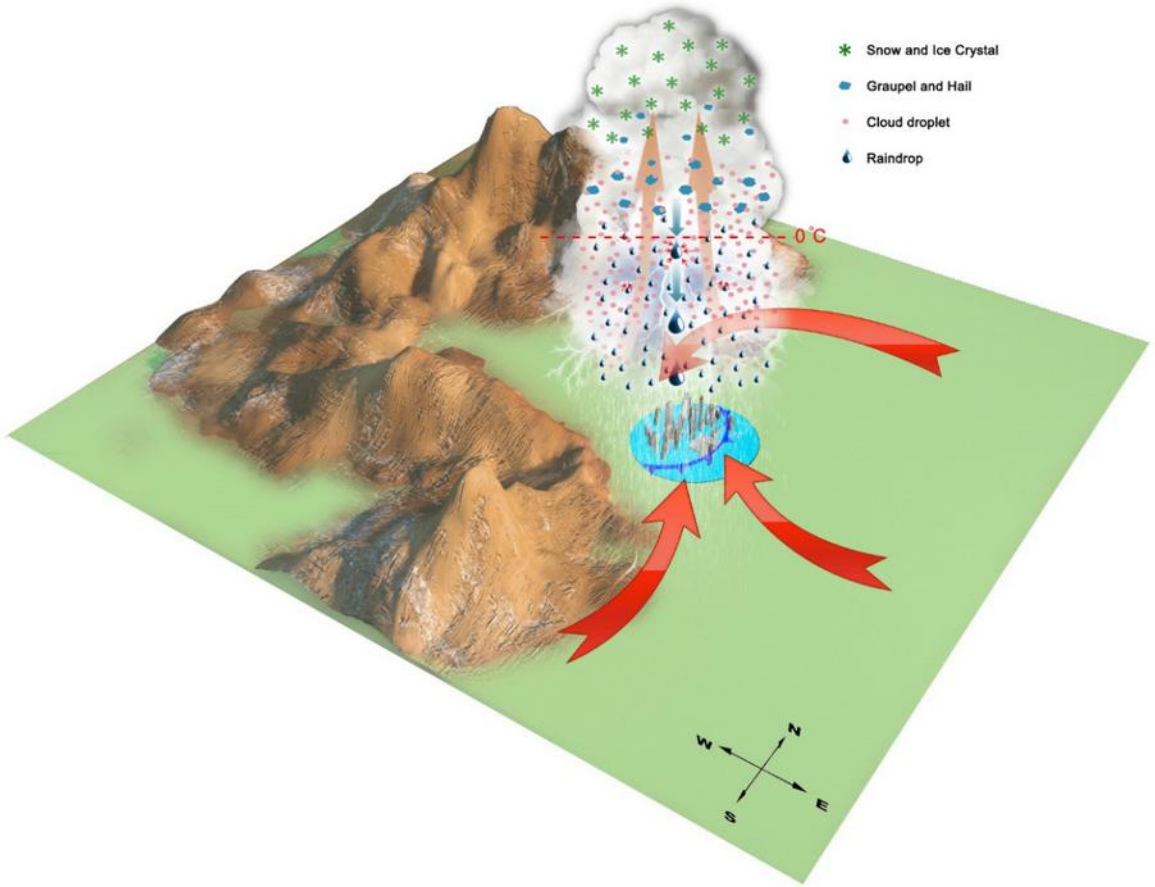
Synoptic conditions





Conceptual model of the record-breaking hour rainfall



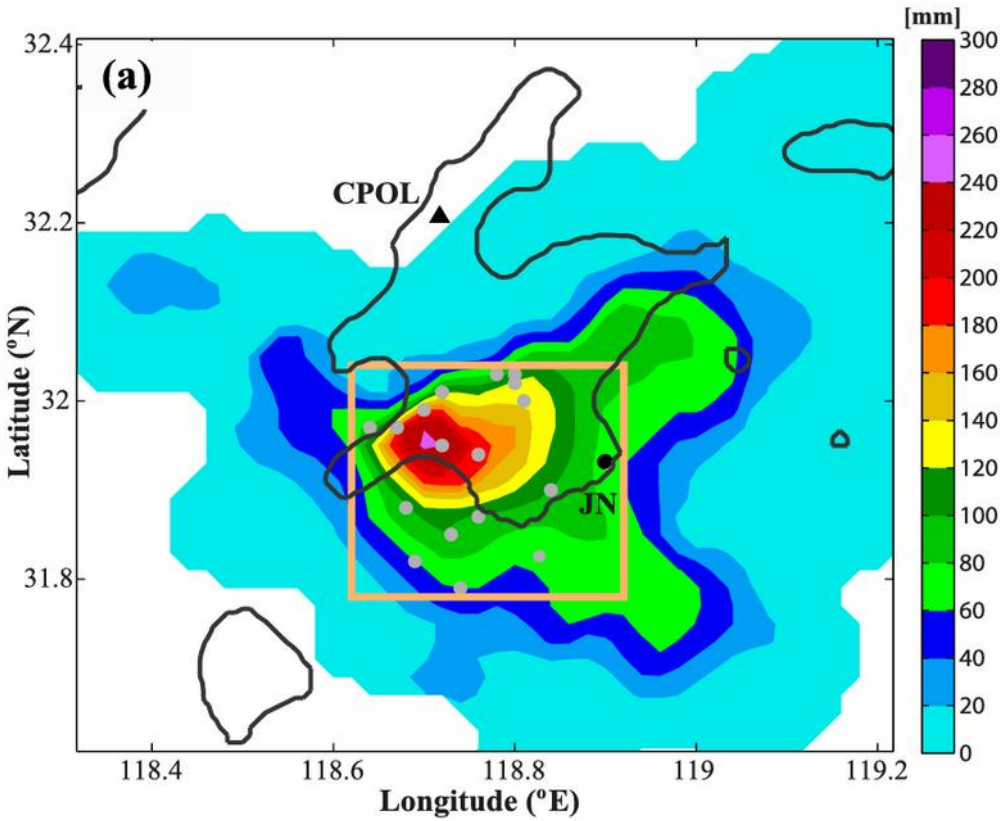


The combined active ice-phase and warm-rain processes in deep convection cause the extremely hour rainfall

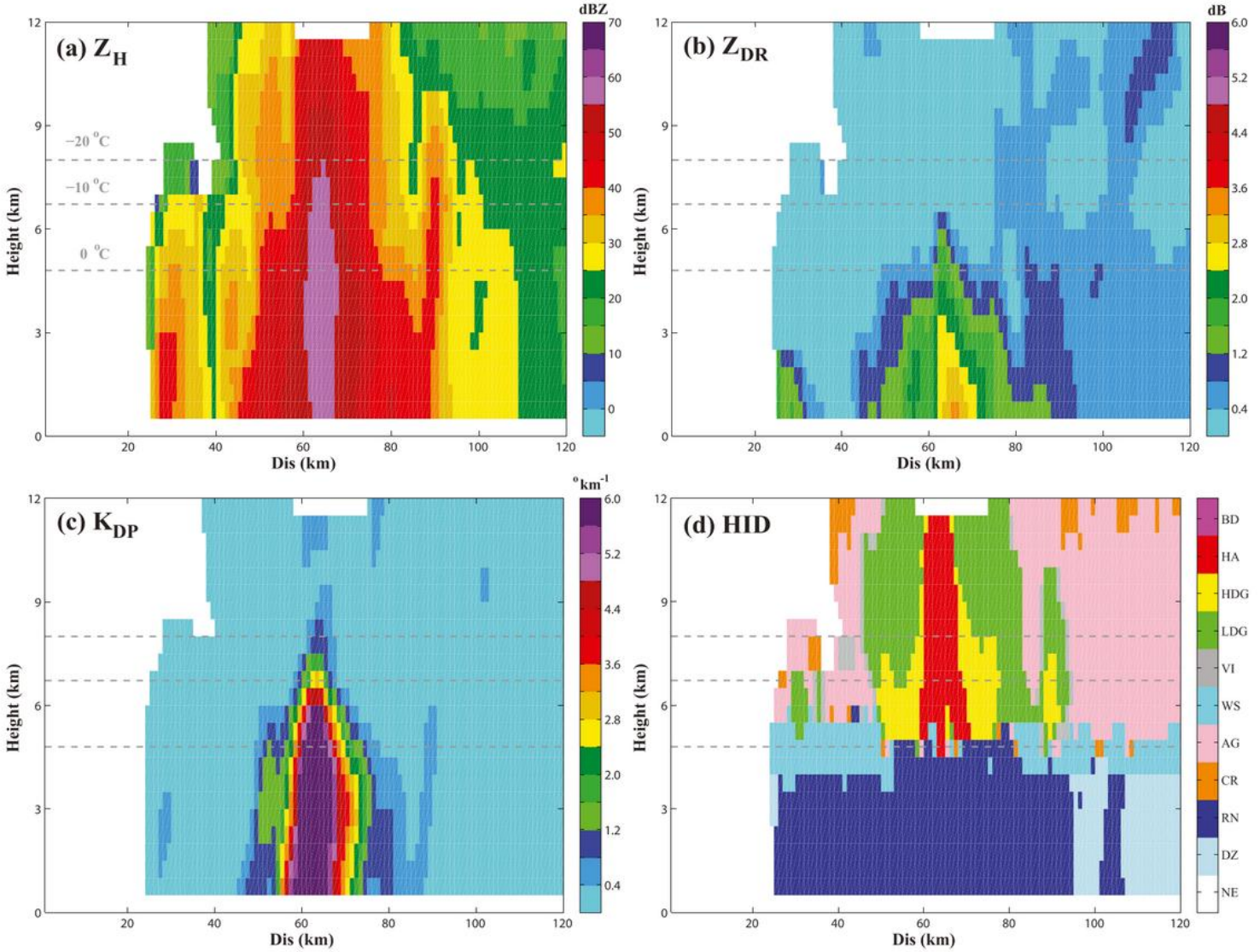
Zhao et al., 2023, RS

Case 2: Extreme Rainfall Event in Nanjing

The maximum 6-h rainfall (00-06): 258 mm
The maximum hour rainfall (02-03): 129.2 mm

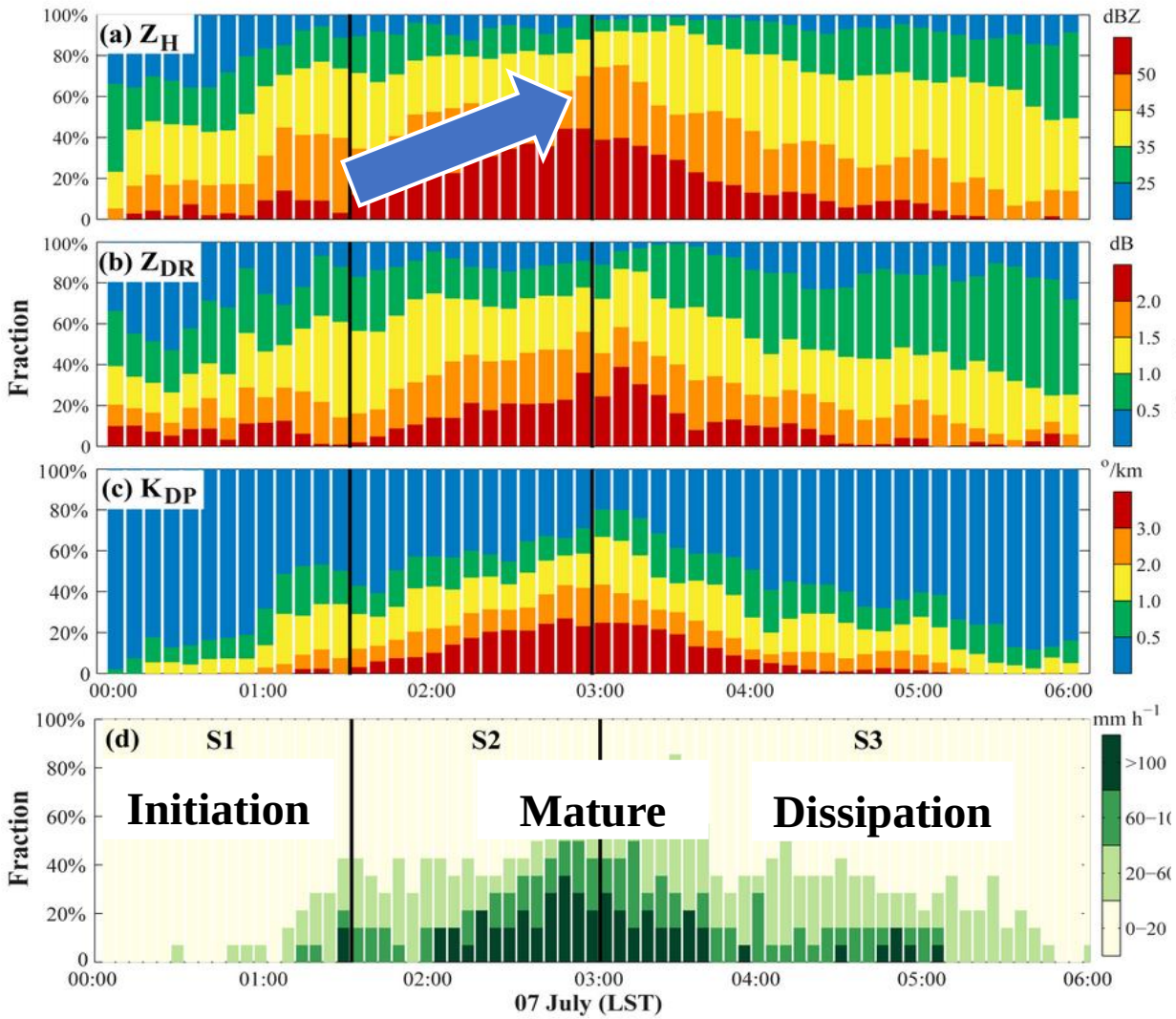


Vertical structure of mature convection

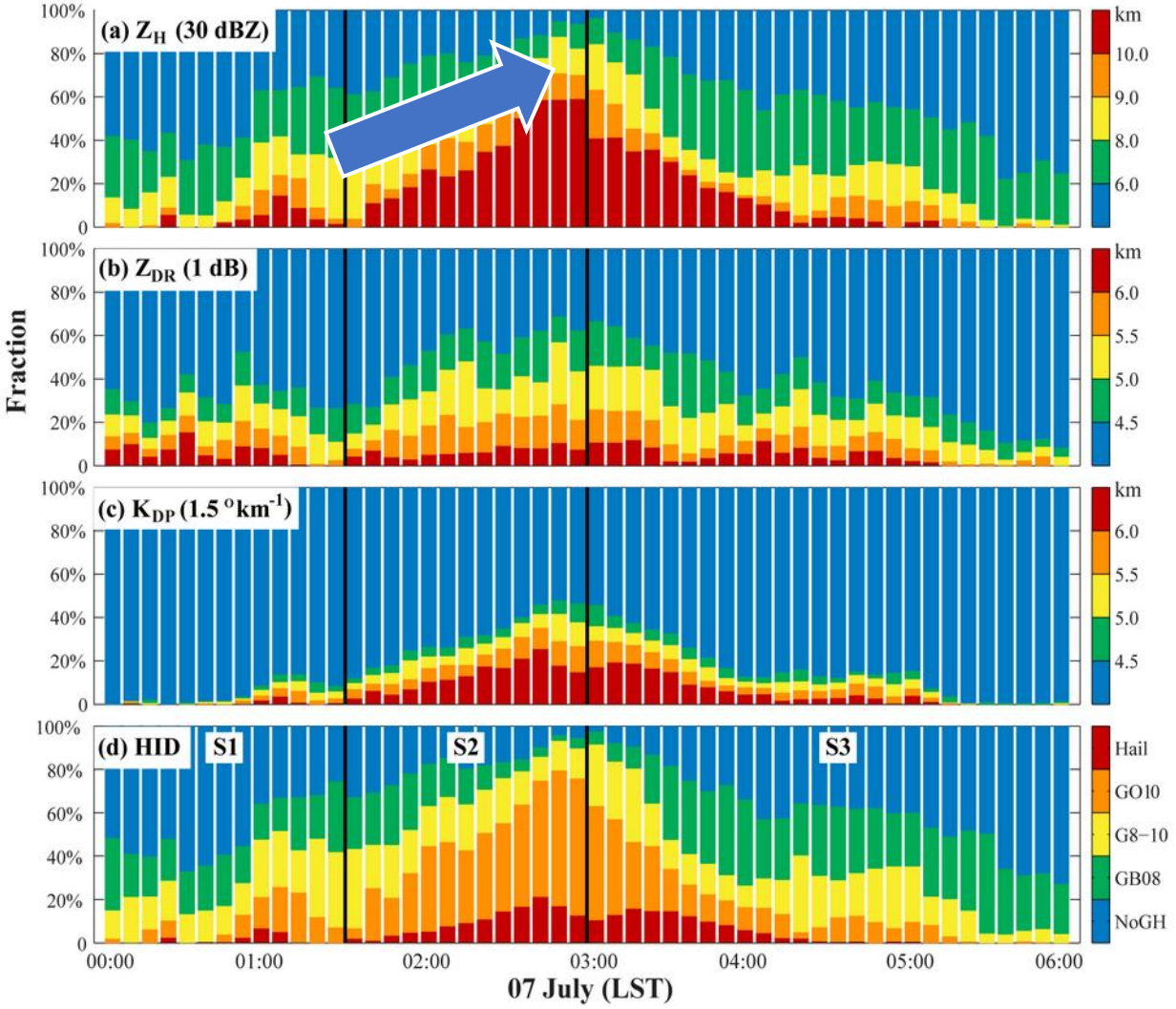


Evolution of Ice-phase Processes and DSD Characteristics

Polarimetric radar features at 1 km AGL



Ice-phase microphysics

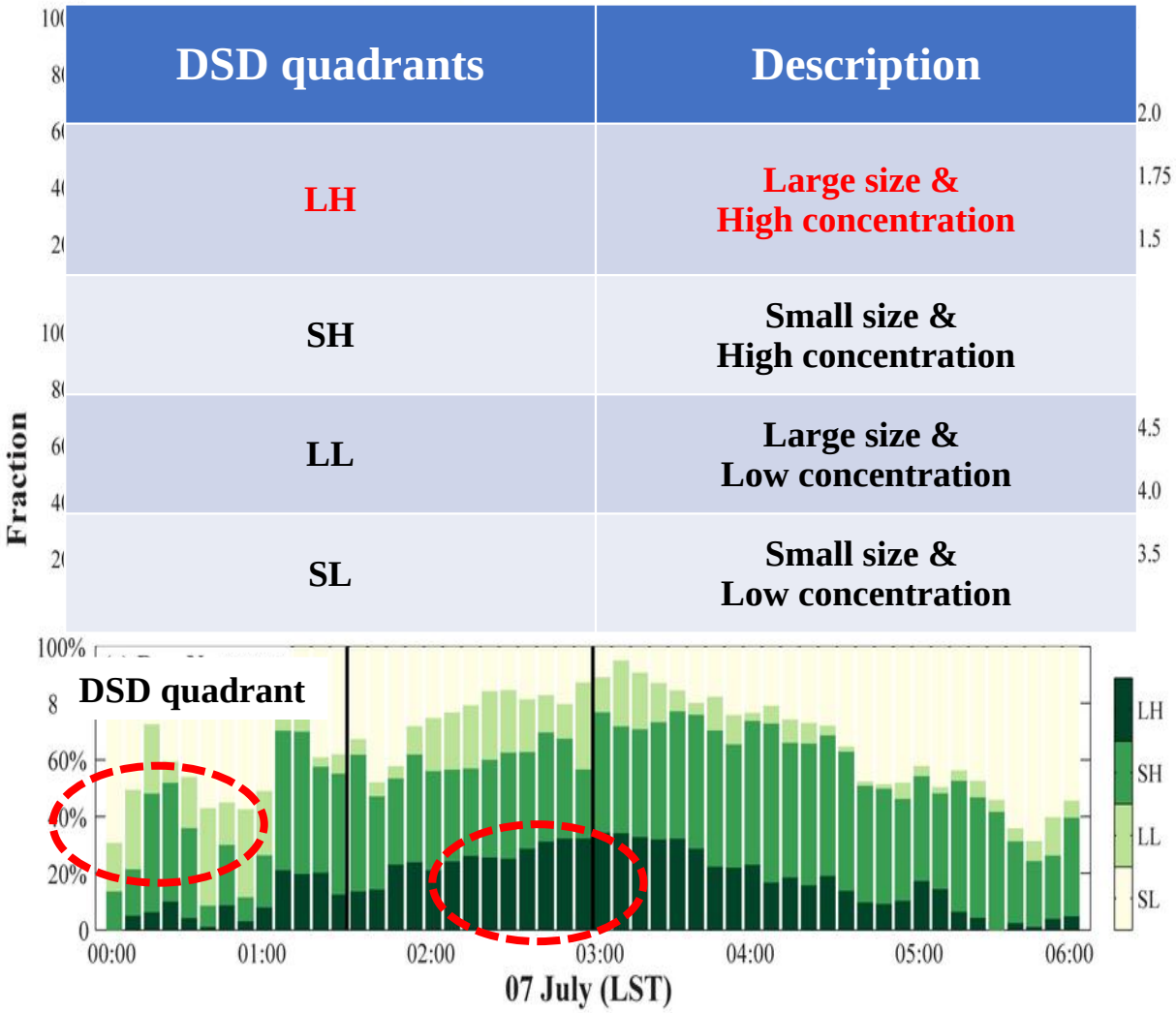


Deep convection in the mature stage, obvious K_{DP} column, maximum graupel exceeding 10 km AGL, heavy rainfall at surface

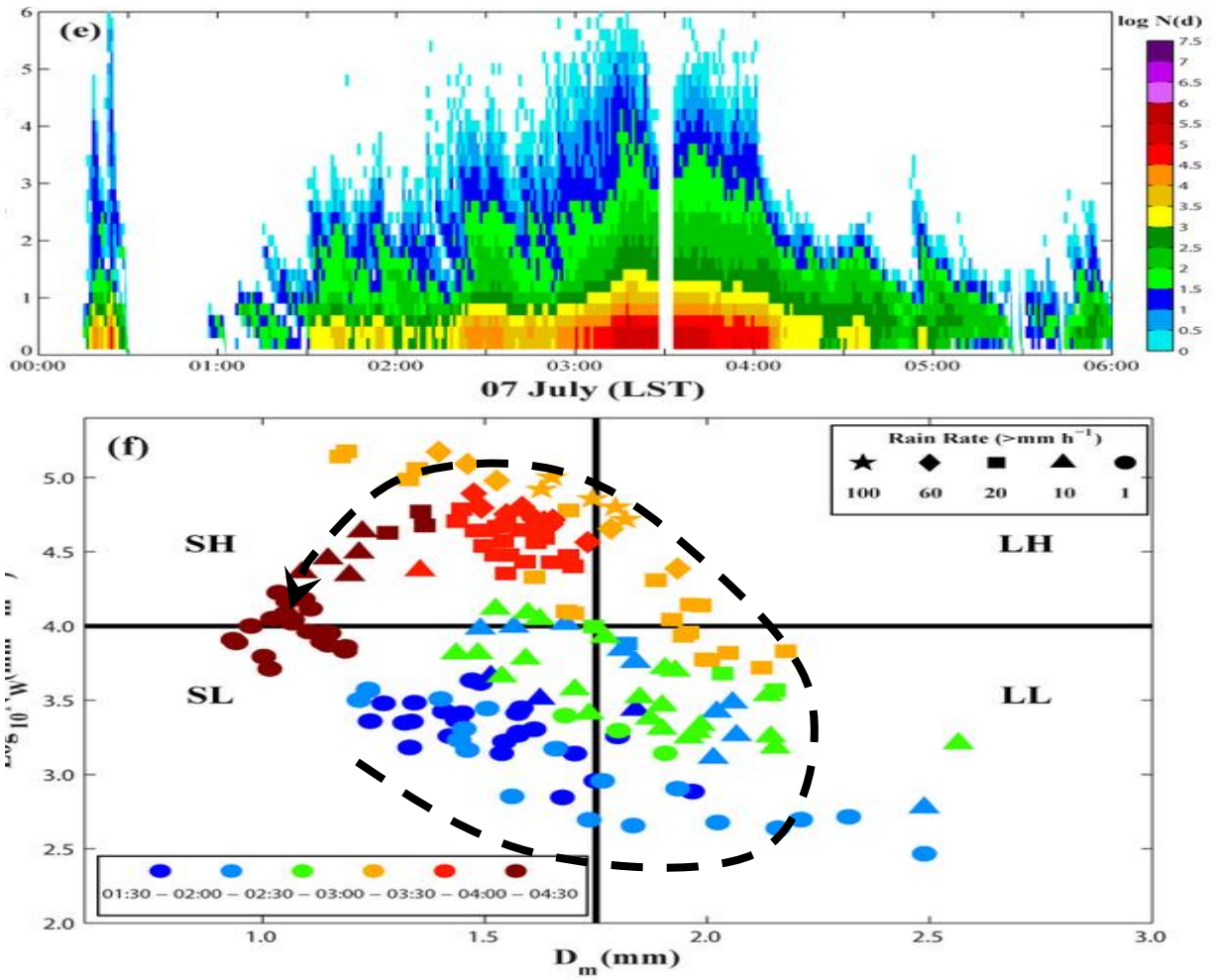
Evolution of DSD Characteristics

Retrieved DSD characteristics at 1 km AGL

DSD quadrants	Description
LH	Large size & High concentration
SH	Small size & High concentration
LL	Large size & Low concentration
SL	Small size & Low concentration



2DVD observation at JN station

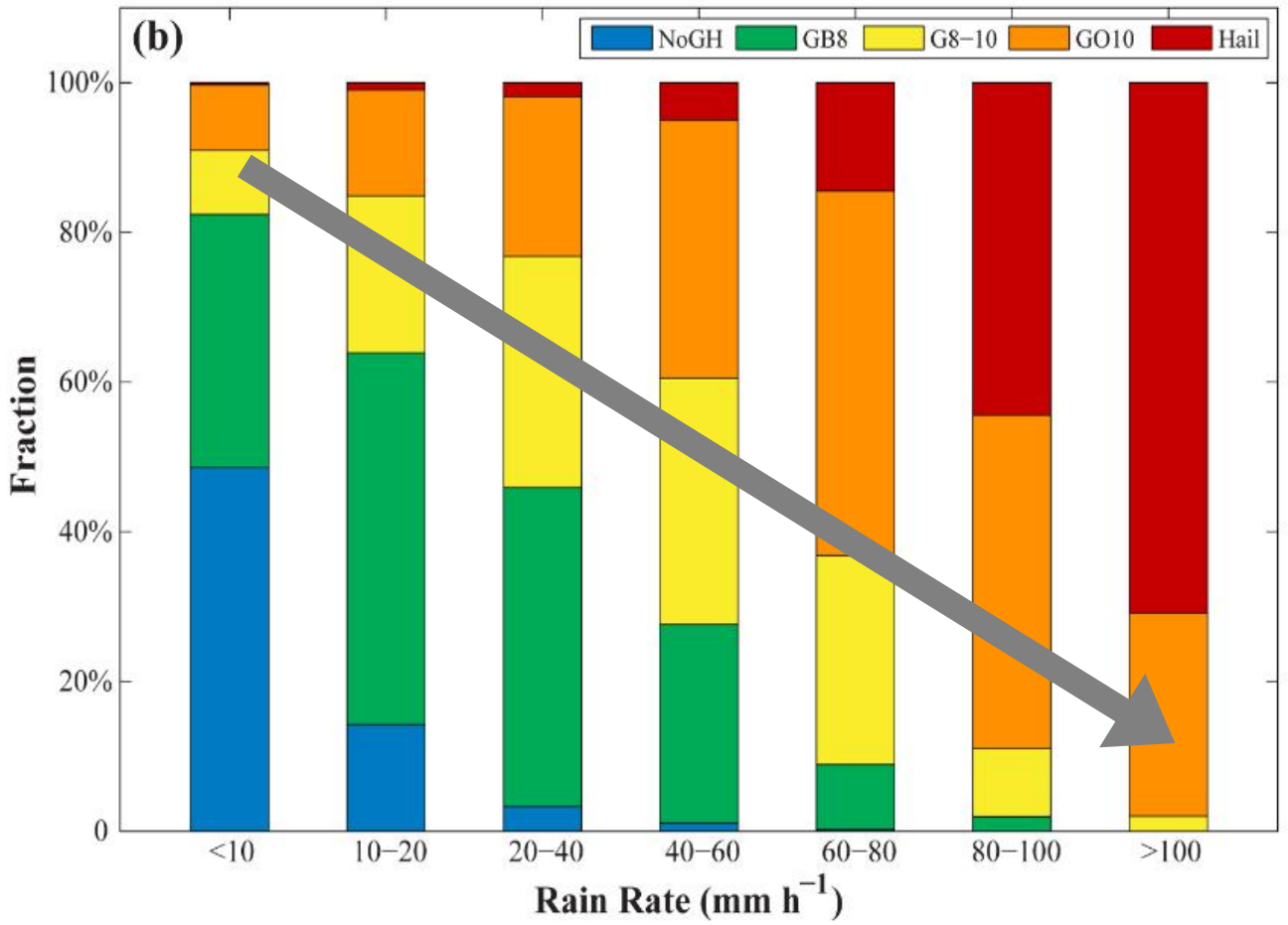


The maximum fraction of LH samples in the mature stage

Link between GH Distributions and DSD Characteristics

Type	Identification
Hail	With hail identified aloft
GO10	No hail, but with the maximum height of graupel over 10 km AGL
G8-10	No hail, but with the maximum height of graupel between 8 and 10 km AGL
GB08	No hail, but with the maximum height of graupel below 8 km AGL
NoGH	No hail or graupel identified aloft

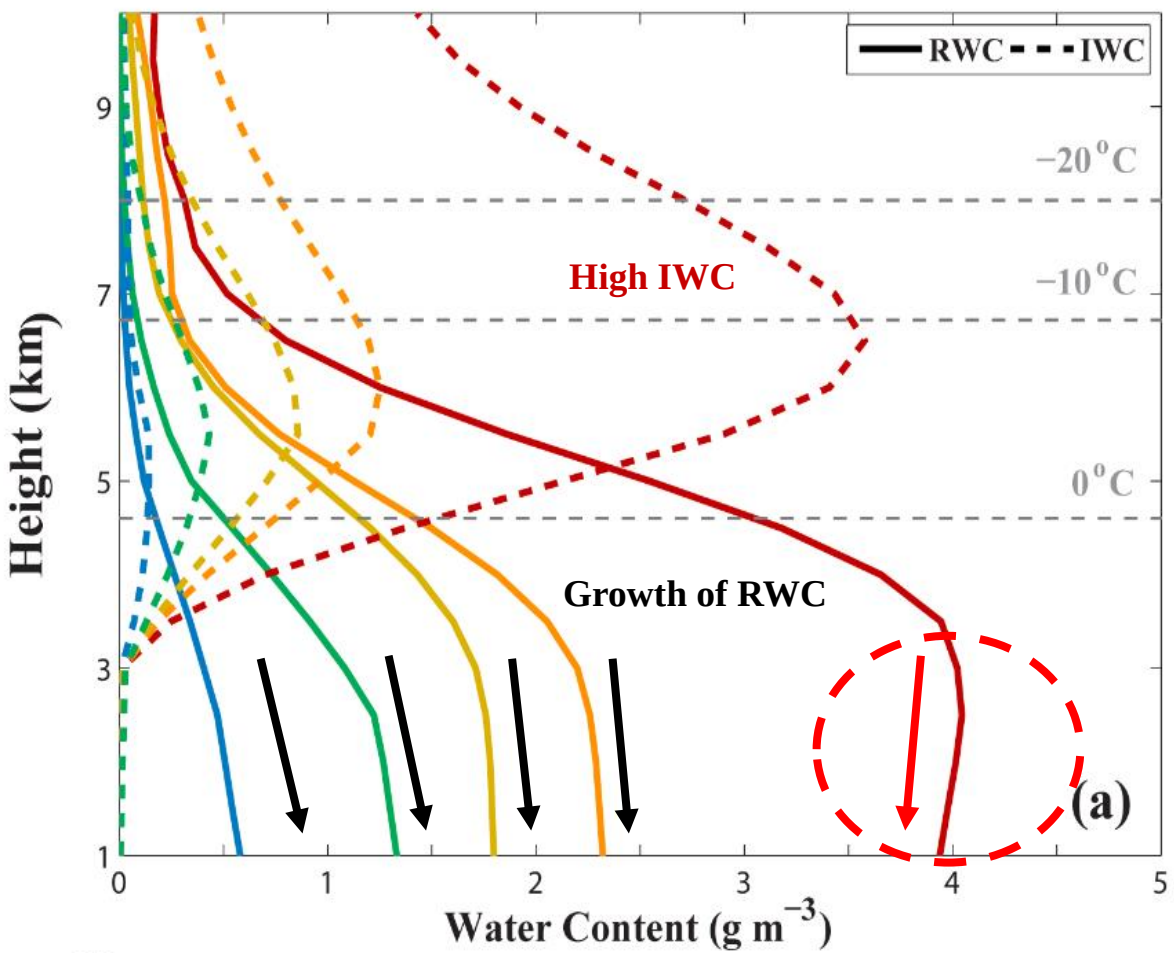
Fraction of GH conditions in different RR ranges



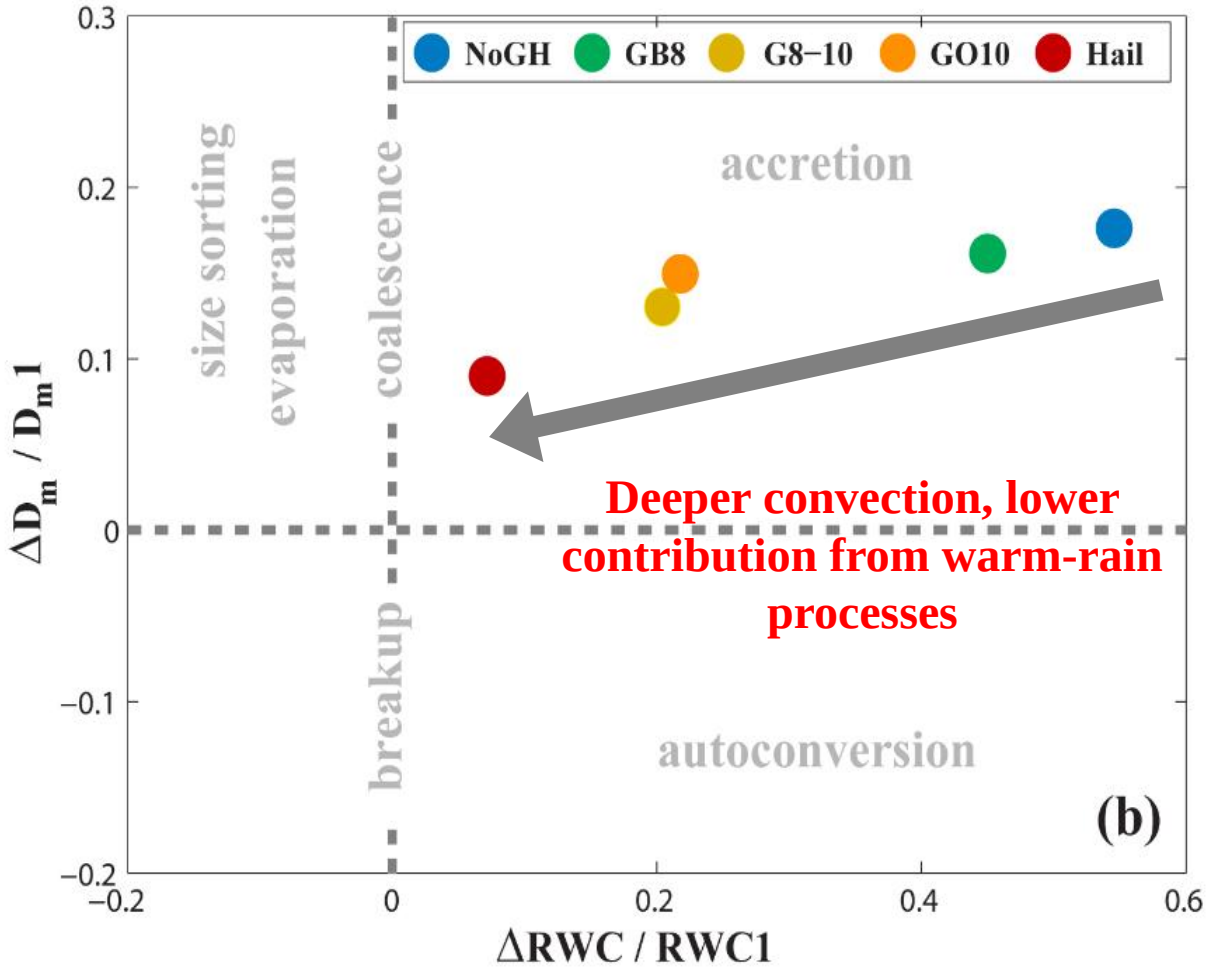
Positive correlation between RR & GH height

Link between GH Distributions and DSD Characteristics

Mean profiles of ice/rainfall water content



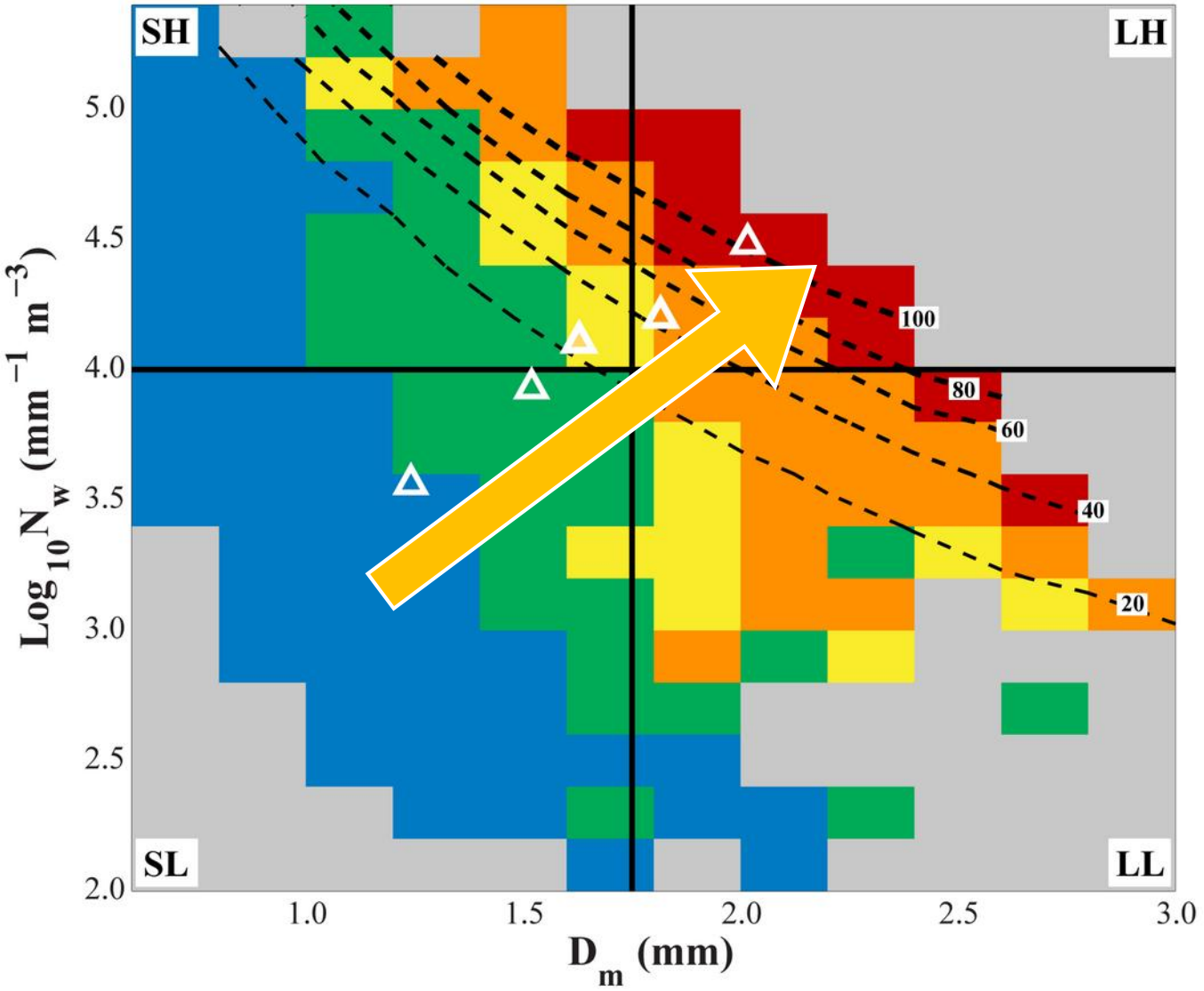
Growth of RWC-Dm within the warm-cloud layer

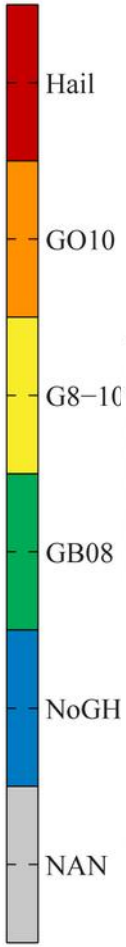


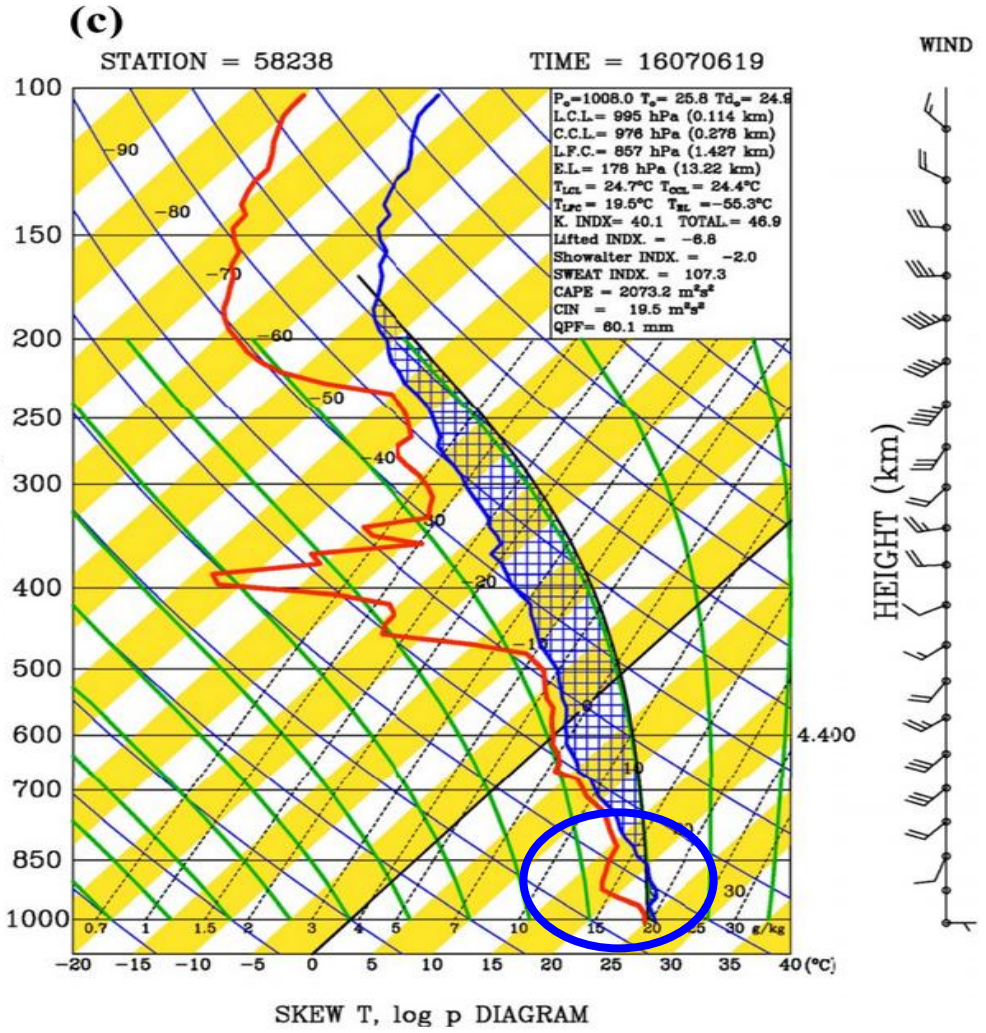
RWC is mainly contributed by ice-phase (warm-rain) processes in deep (shallow) convection

Link between GH Distributions and DSD Characteristics

The quantitative link between GH height and 1-km AGL DSD







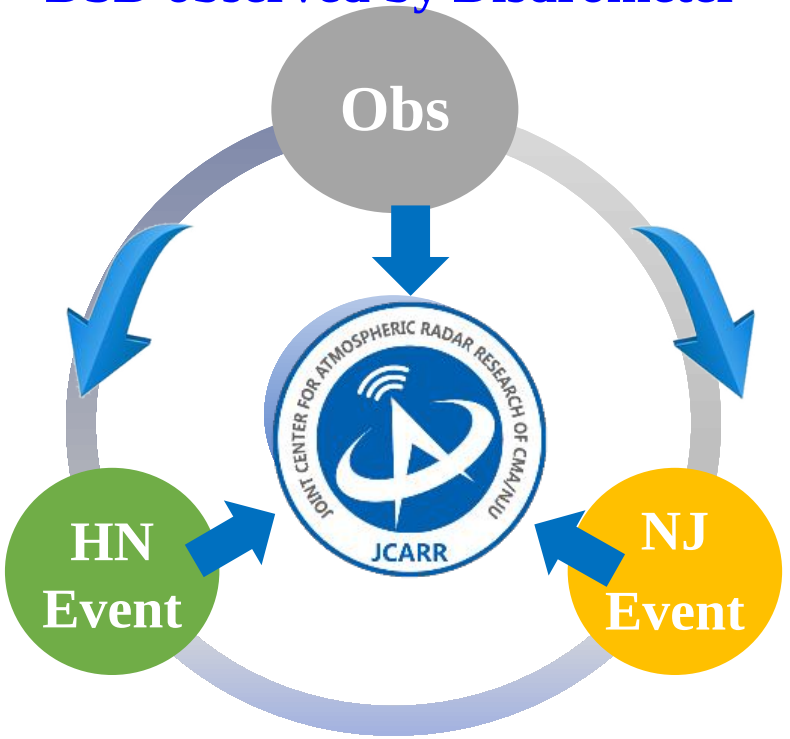
Chen and Zhao et al.,2023, ESS

Conclusion and Discussion

Microphysical structure of deep convection causing extreme rainfall

Hydrometeor type and DSD retrieved from polarimetric radar

DSD observed by Disdrometer



Deep convection

Large mean size &

High number concentration

（continental + maritime convection）

Both active in ice-phase and warm-rain processes(>200mm/h）

Extremely deep convection

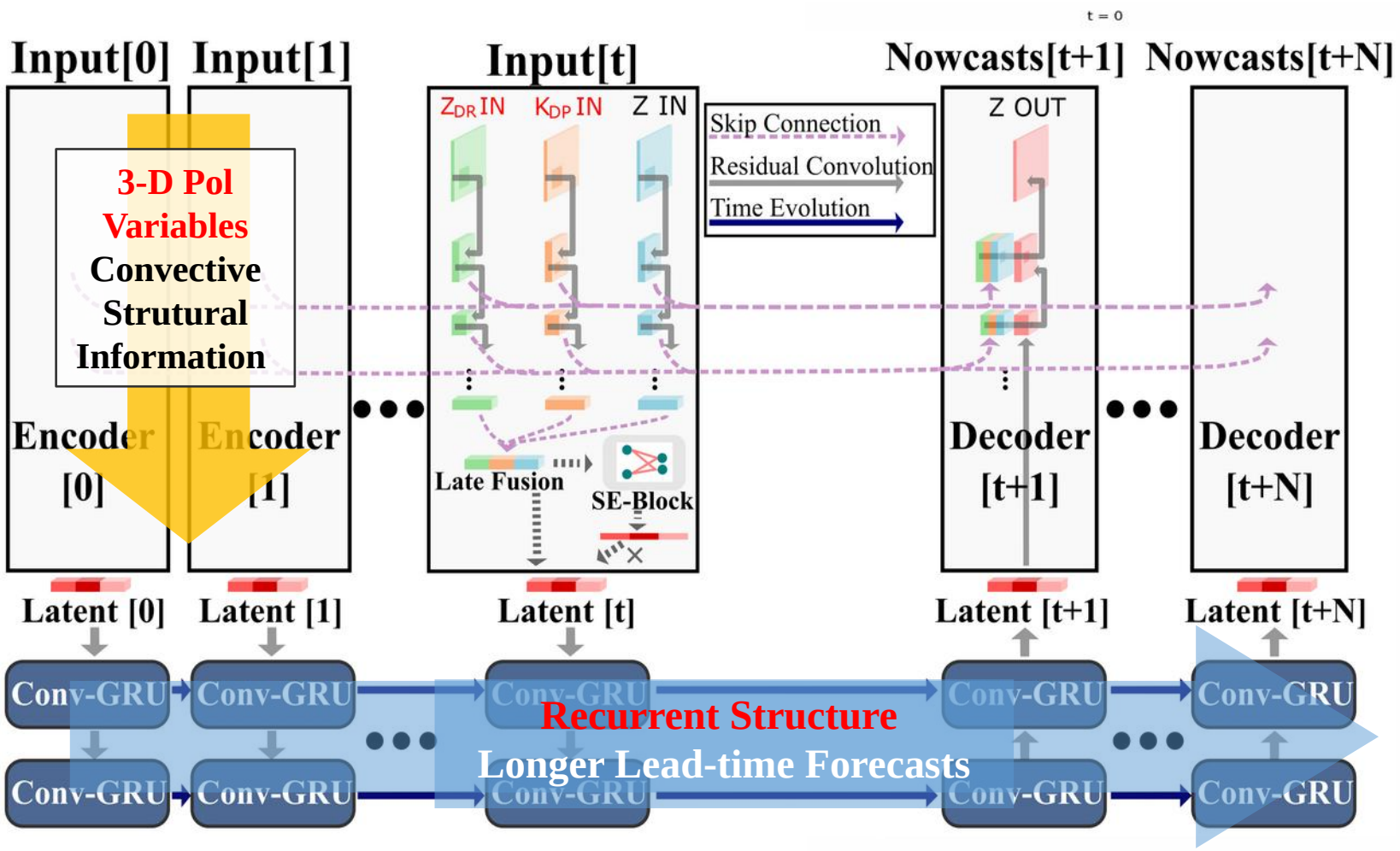
Low-level DSDs are indicated by GH distribution height

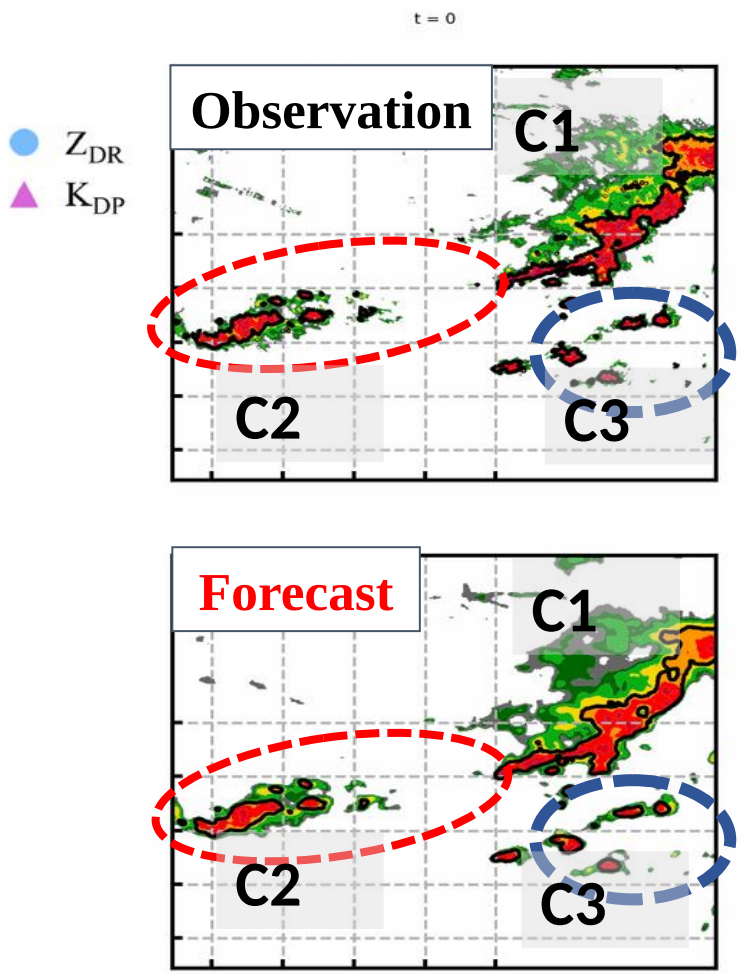
Extreme RR (>100 mm/h) is mainly caused by convection with hail identified aloft

Active ice-phase processes

Ongoing Work

AI-Based Nowcasting Model with Polarimetric Radar Variables





Pan and Zhao, GRL, 2021 ， 2025 (In Preparation)

Related papers

- Chen Gang, Zhao Kun(*), Wen Long., et al, 2023, Linking Ice-Phase Microphysics to Raindrop Characteristics in Deep Convection: A Warm-Sector Extreme Rainfall Case Study in Eastern China, *Earth and Space Science*, **10(2)**.
- Chen Gang, Zhao Kun(*), Lu Yinghui., et al, 2022, Variability of microphysical characteristics in the “21.7” Henan extremely heavy rainfall event, *Science China Earth Sciences*, **65(10)** , 1861–1878
- Wei Peng, Xu Xin(*), Xue Ming., et al, 2023, On the Key Dynamical Processes Supporting the 21.7 Zhengzhou Record-breaking Hourly Rainfall in China , *Advances in Atmospheric Sciences* , **40**, 337-349
- Wen Long, Zhao Kun(*), Yang Zhonglin., et al, 2020, Microphysics of Stratiform and Convective Precipitation during Meiyu Season in Eastern China, *Journal of Geophysical Research: Atmospheres*, **125**
- Huang Hao, Zhao Kun(*), Chan Johnny C.L., et al, 2022, Microphysical characteristics of extreme-rainfall convection over the Pearl River Delta region, South China from polarimetric radar data during the pre-summer rainy season, *Advances in Atmospheric Sciences* , **39**, 1-13.
- Yang Zhonglin, Zhao Kun (*), Xu Kun., et al, 2019, Microphysical characteristics of extreme convective precipitation over the Yangtze-Huaihe river basin during the Meiyu season based on polarimetric radar data. *Acta Meteorologica Sinica*. 77(1): 58-72

Thank you!

Any questions?