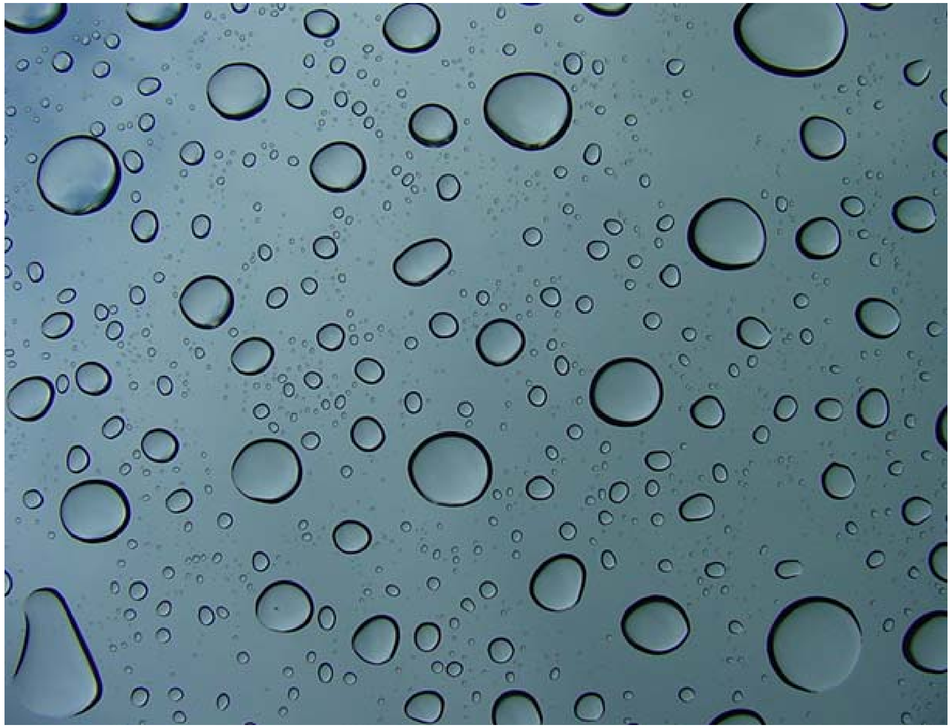
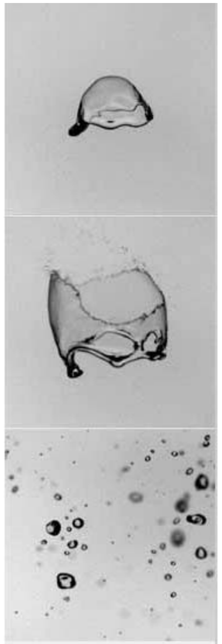
Characteristics of the raindrop size distribution in maritime squall line observed in Taiwan (Case study)

Pukyong National University, Korea
Master's course, Sung-A Jung

Introduction





In every drop of rain, a shower.

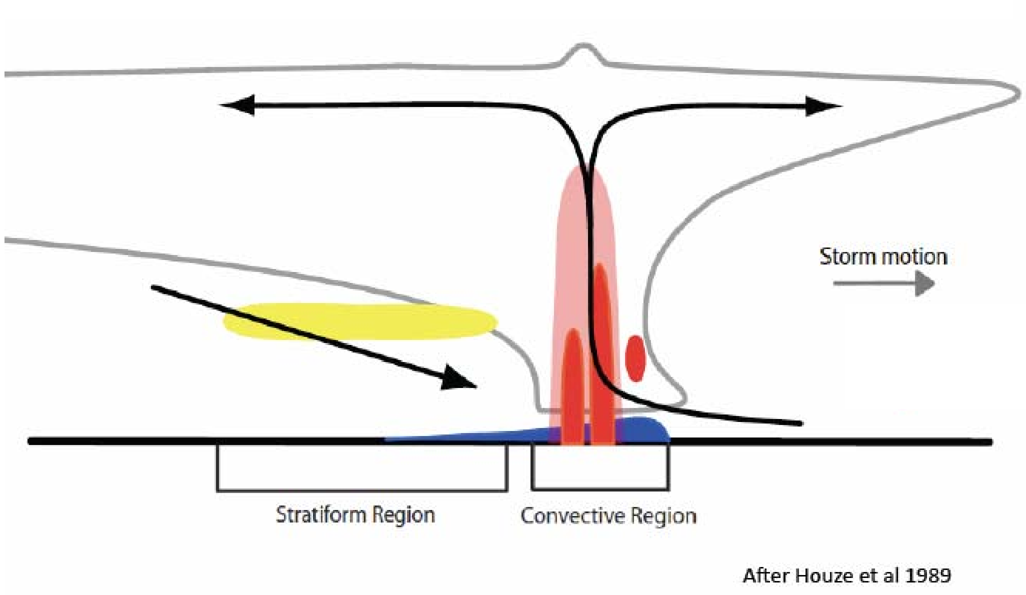
Emmanuel Villermaux

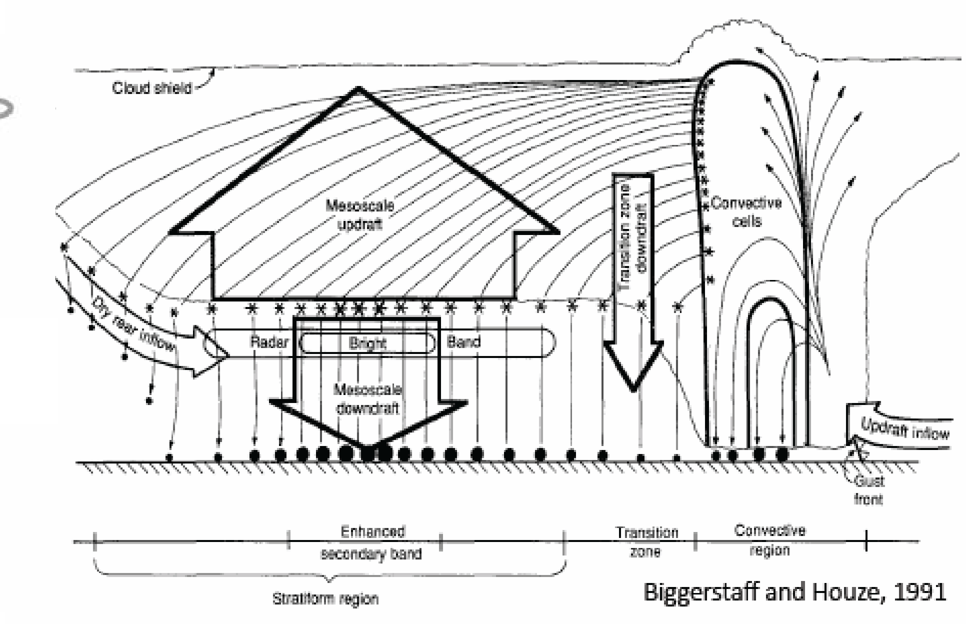
Raindrop size distribution (RDSD, N(D))

- The end of the products of all of **the cloud microphysical processes**, **cloud dynamical processes and interaction**s that affect the formation and growth of liquid precipitation.
- The spatial and temporal variability of RDSD reflects variations in the **microphysical processes** (e.g. coalescence, break-up, and evaporation)
- Which may be related to differences in the observed **ground rainfall integral variables** and **RDSD parameters**.

(Caracciolo et al., 2008)

Introduction





❖ Squall line system

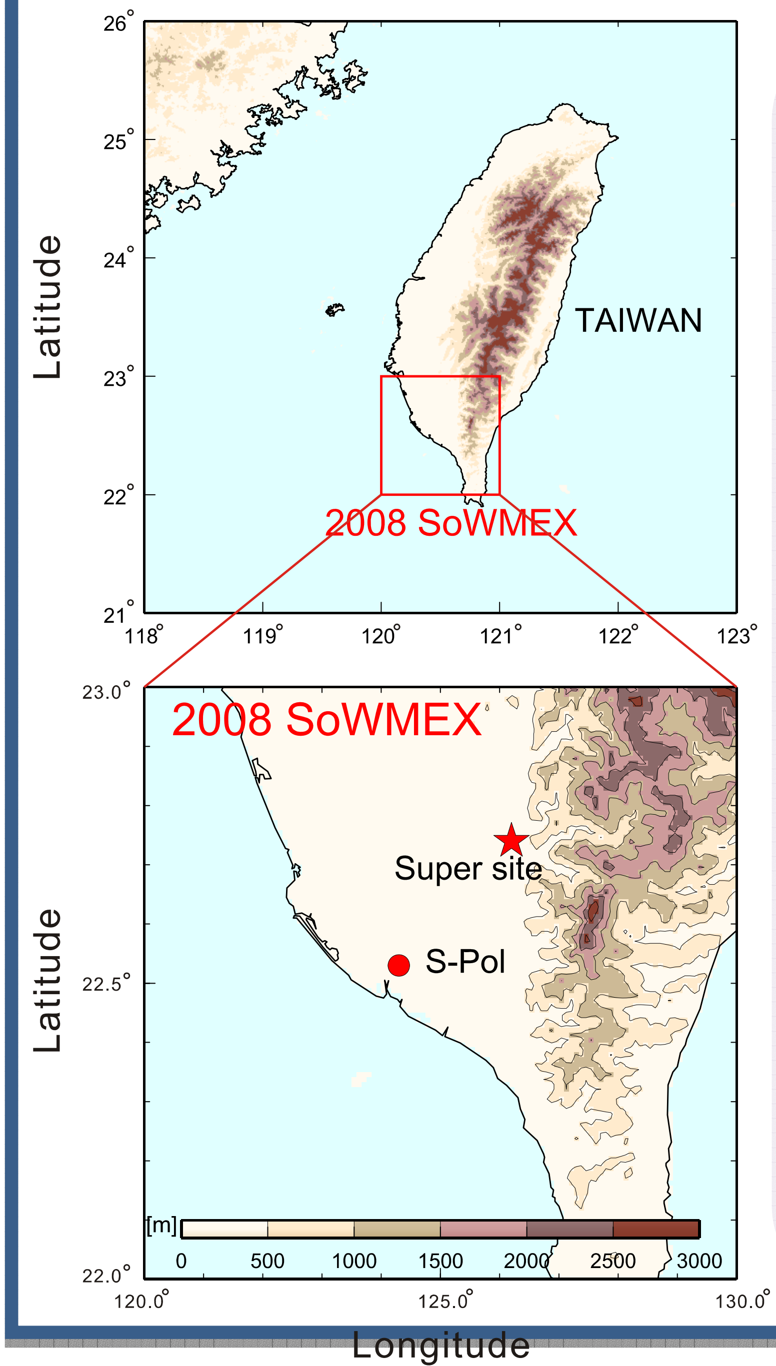
- Property of cells and system scale circulation features are <u>similar along the line</u>.
- Distinctive structure, which consists of **leading convective line, trailing stratiform region, and reflectivity trough.**

Good to examine dependence of RDSD characteristics on precipitation types

❖ The purpose of this study is

➢ to identify the characteristics of RDSD and the microphysical process on maritime squall line system on Taiwan.

Observation



- **Period**

  SoWMEX/TiMREX in 2008

  (Southwest Monsoon Experiment
  Terrain-influenced Monsoon Rainfall
  Experiment)
  period of May 15 to Jun

  2 June 2008

- **Observation Site**

  - **Disdrometer site (Super site)**

    Below the western mountain slope
    [Location : Lat. 22.73 and Lon. 120.62]

  - **S-Pol site**

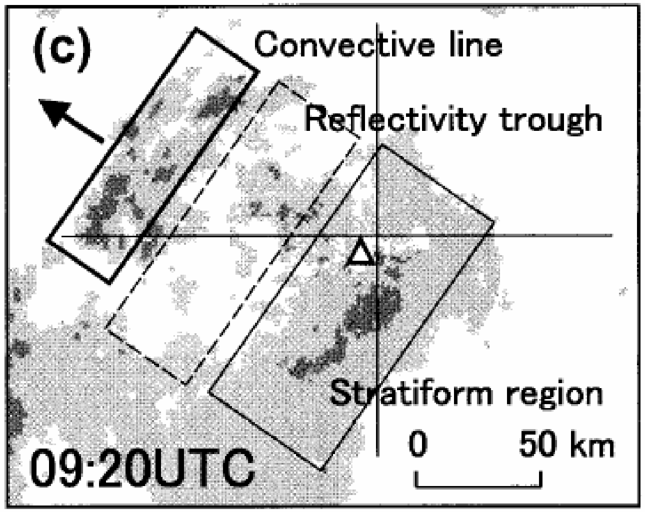
    western coastal plain
    [Location : Lat. 22.52 and Lon. 120.43]

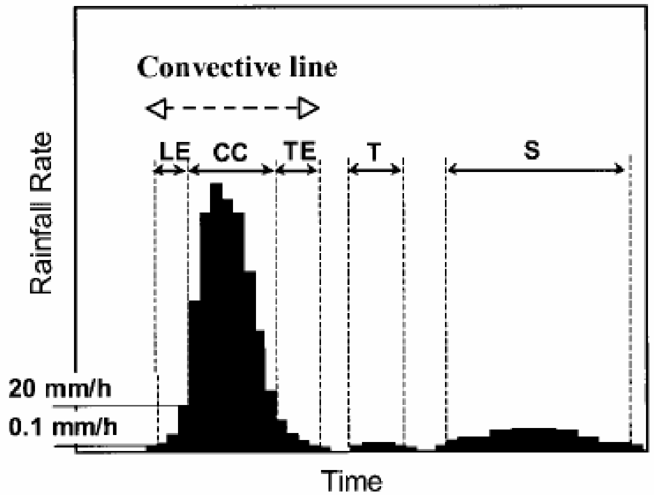
Instruments and Classification

- **Instruments**
  - a) Precipitation Occurrence Sensing System (**POSS**)
  - b) S-band Polarimetric Radar (**S-Pol**)
  - c) Vertical Pointing X-band Radar (**VertiX**)

- **Classification**

A squall line accompanied with trailing stratiform precipitation, which was partitioned into the three regions based on radar reflectivity patterns and vertical radial velocity
→ **Convective line,** **Stratiform** and **Reflectivity trough**





The **convective line** was subdivided using threshold rain rate **20mm/h**.

- **Convective center (CC)**
- **Leading edge (LE)**
- **Trailing edge (TE)**

(Maki et al., 2001)

Method : Normalized gamma RDSD Model

- The **gamma distribution function** was employed for modeling the RDSD.

(Ulbrich, 1983)

$$N(D) = N_0 D^{\mu} \exp(-\Lambda D) = N_0 D^{\mu} \exp(-(3.67+\mu)(D/D_0))$$

- The **normalized gamma RDSD** was employed for independent from any assumption.

$$N(D) = N_w f(\mu)(D_0)^{\mu} \exp(-(3.67+\mu)(D/D_0))$$

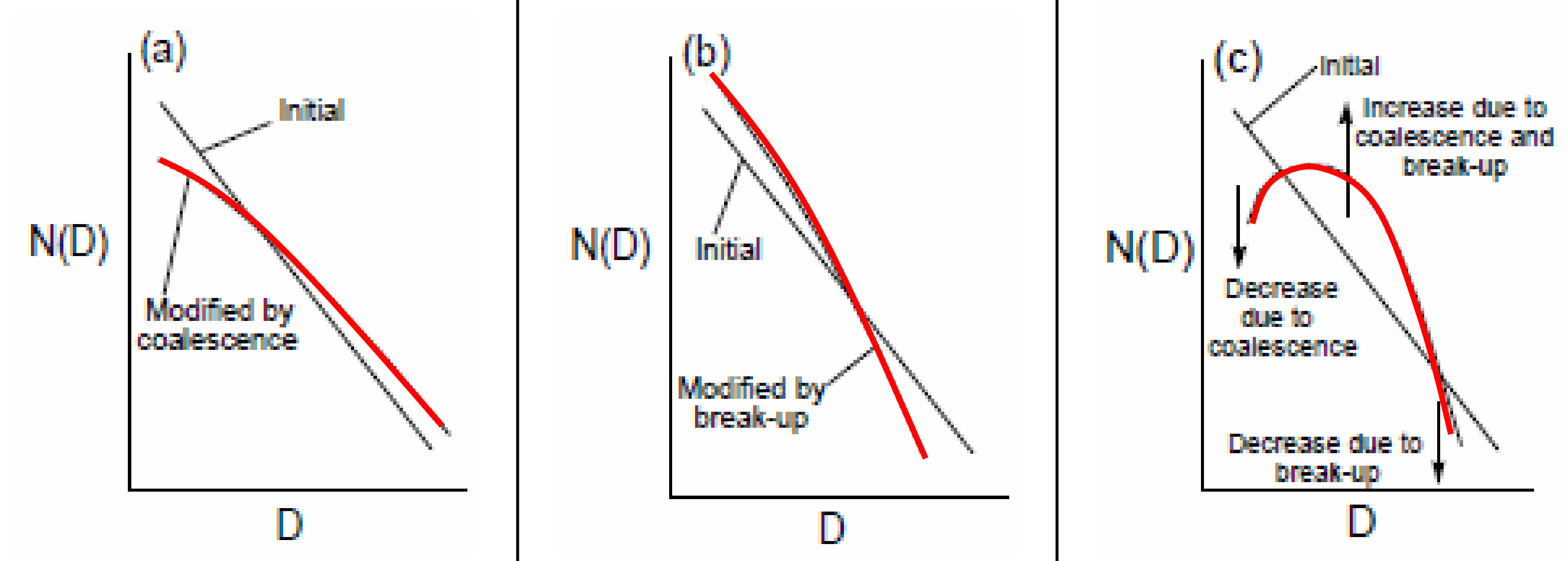
(Testud et al., 2001)

Table 1. RDSD parameters.

Parameter	Equation	Parameter	Equation
Rainfall intensity	$R = \frac{\pi}{6}\int_{D_{min}}^{D_{max}} D^3 V_f N(D)dD$	Reflectivity	$Z = \int_{D_{min}}^{D_{max}} D^6 N(D)dD$
Shape	$\mu = \frac{(8-11m)-(m^2+8m)^{1/2}}{2(m-1)}$	Median volume diameter	$D_0 = \frac{(3.67+\mu)}{\Lambda}$
Slope	$\Lambda = \frac{M_3}{M_4}(\mu+4)$	Intercept parameter	$N_0 = \frac{\Lambda^{(\mu+4)} M_3}{\Gamma(\mu+4)}$
Generalized intercept parameter	$N_w = \frac{N_0}{f(\mu)} D_0^{\mu}$		

Method : Microphysical processes

❖ The shape of the drop size distribution reflects the microphysics of rain.



Coalescence Small drops ↓ Large drops ↑ Increase : D_0, μ Decrease : Total number density N_t, N_0	**Breakup** Small drops ↑ Large drops ↓ Increase : N_t, N_0 Decrease : D_0, μ	**Coalescence and Breakup** **Coalescence** is more important at **large drops** **breakup** is more important at **small drops** **Increase :** μ

Fig. Schematic diagrams the effects on RDSD of microphysical process. (Rosenfeld and Ulbrich 2002)

Results

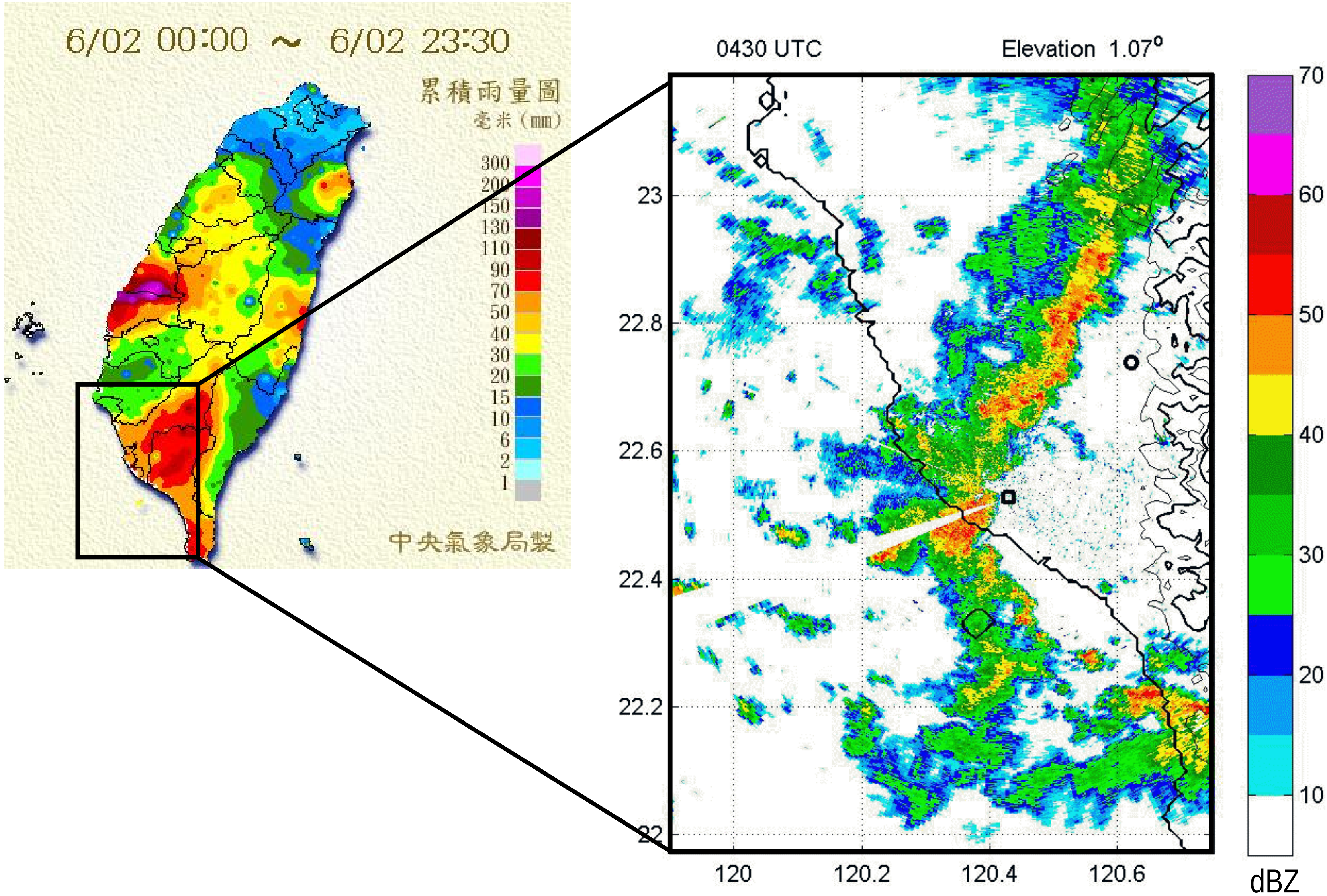
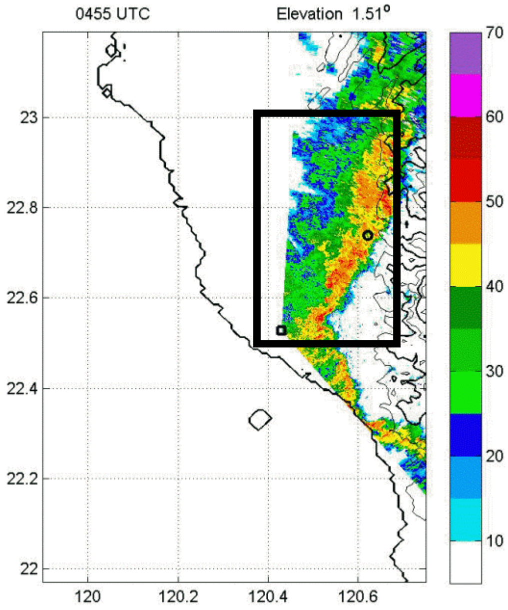


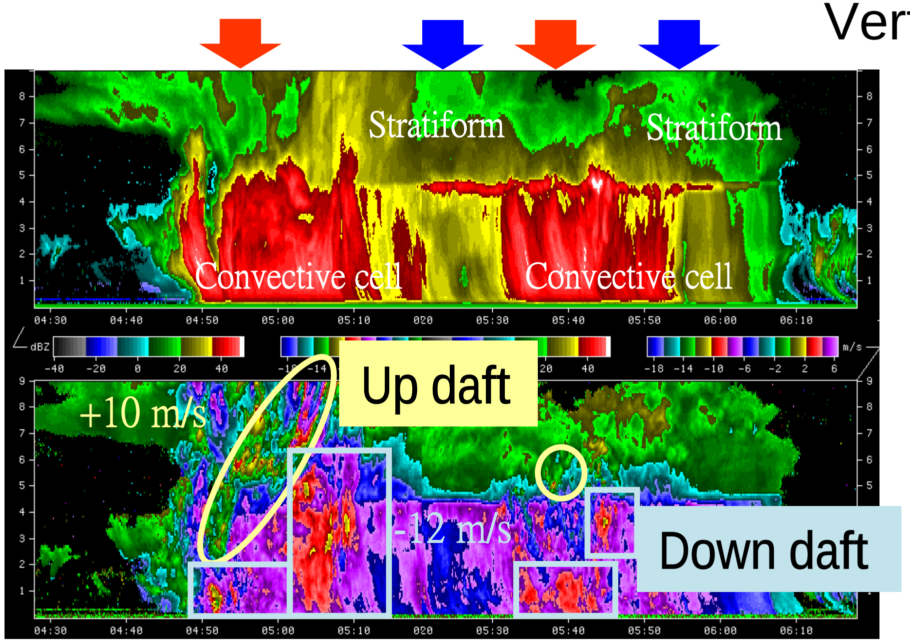
Fig. (a) Accumulated precipitation during 2 June 2008. (b) PPI image of maritime squall line observed 2 June 2008 in Taiwan. The small white triangle shows the location of S-Pol. The small white circle shows the location of the POSS and VertiX.

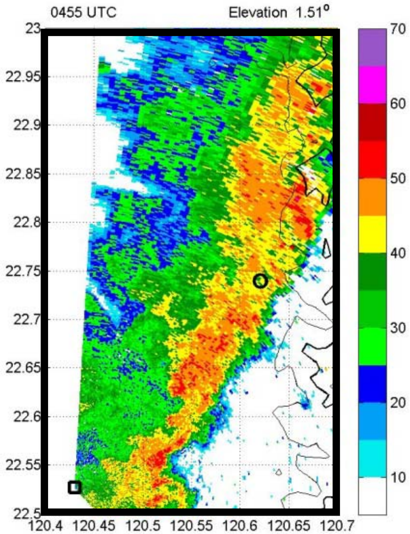
Classification

PPI

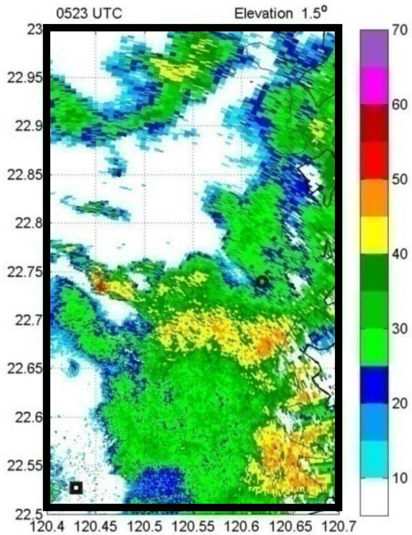


VertiX

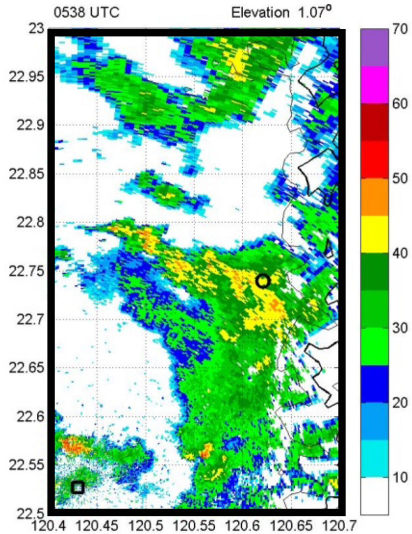




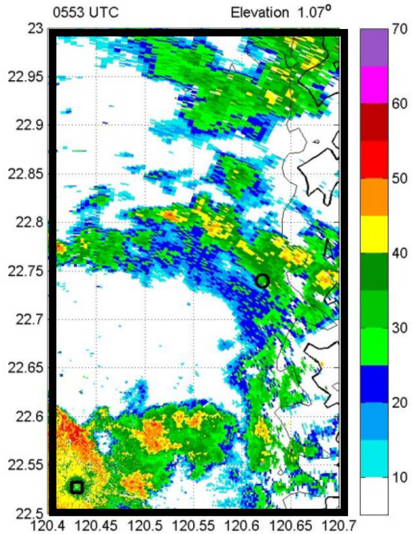
Convective cell



Stratiform



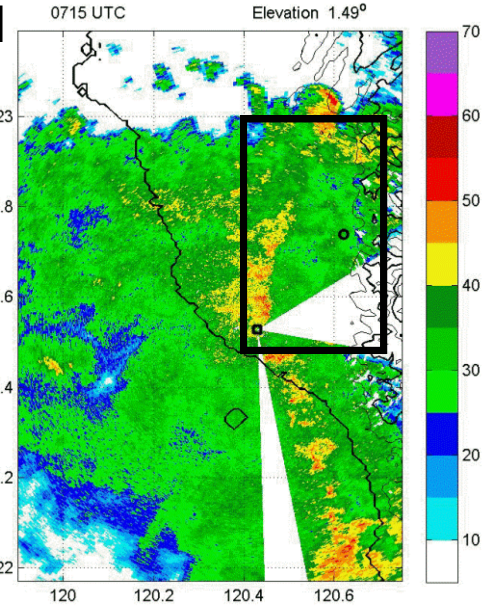
Convective cell



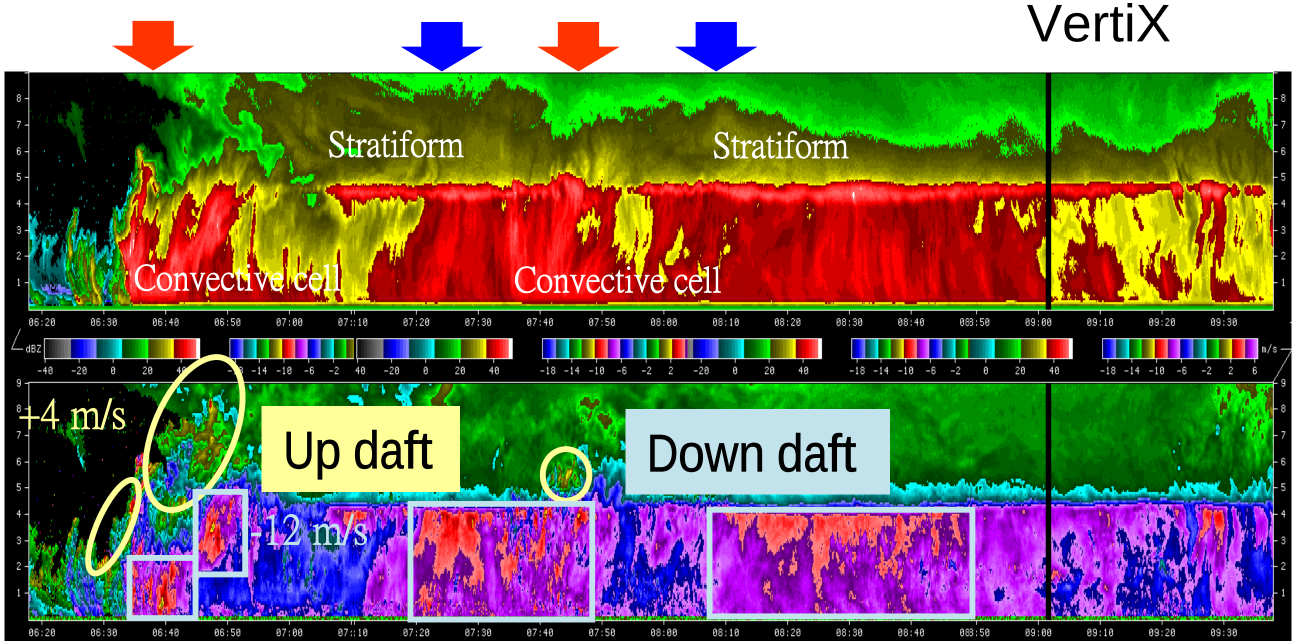
Stratiform

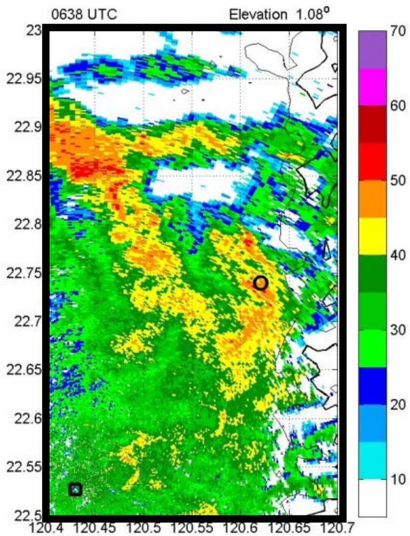
Classification

PPI

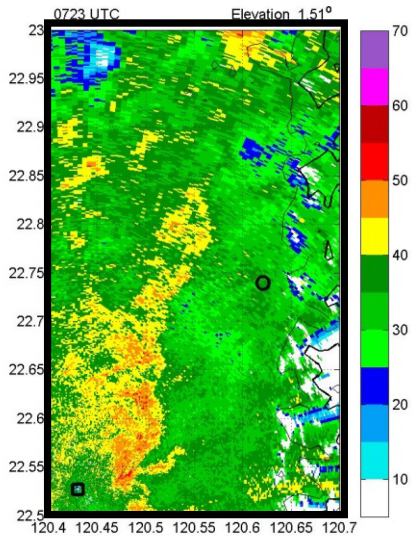


VertiX

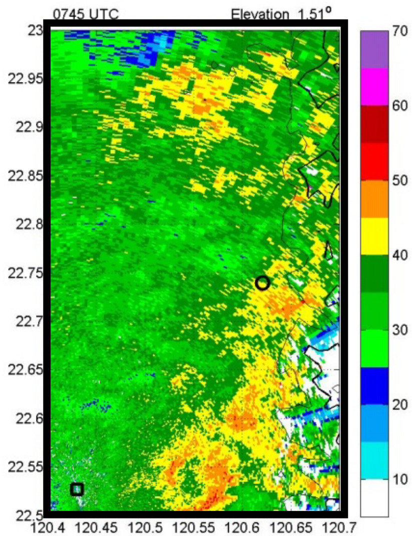




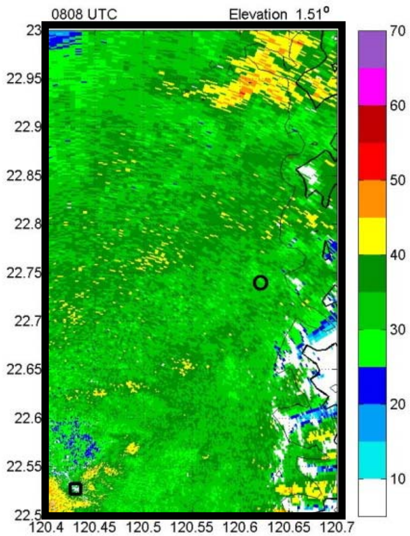
Convective cell



Stratiform



Convective cell



Stratiform

RDSD Analysis

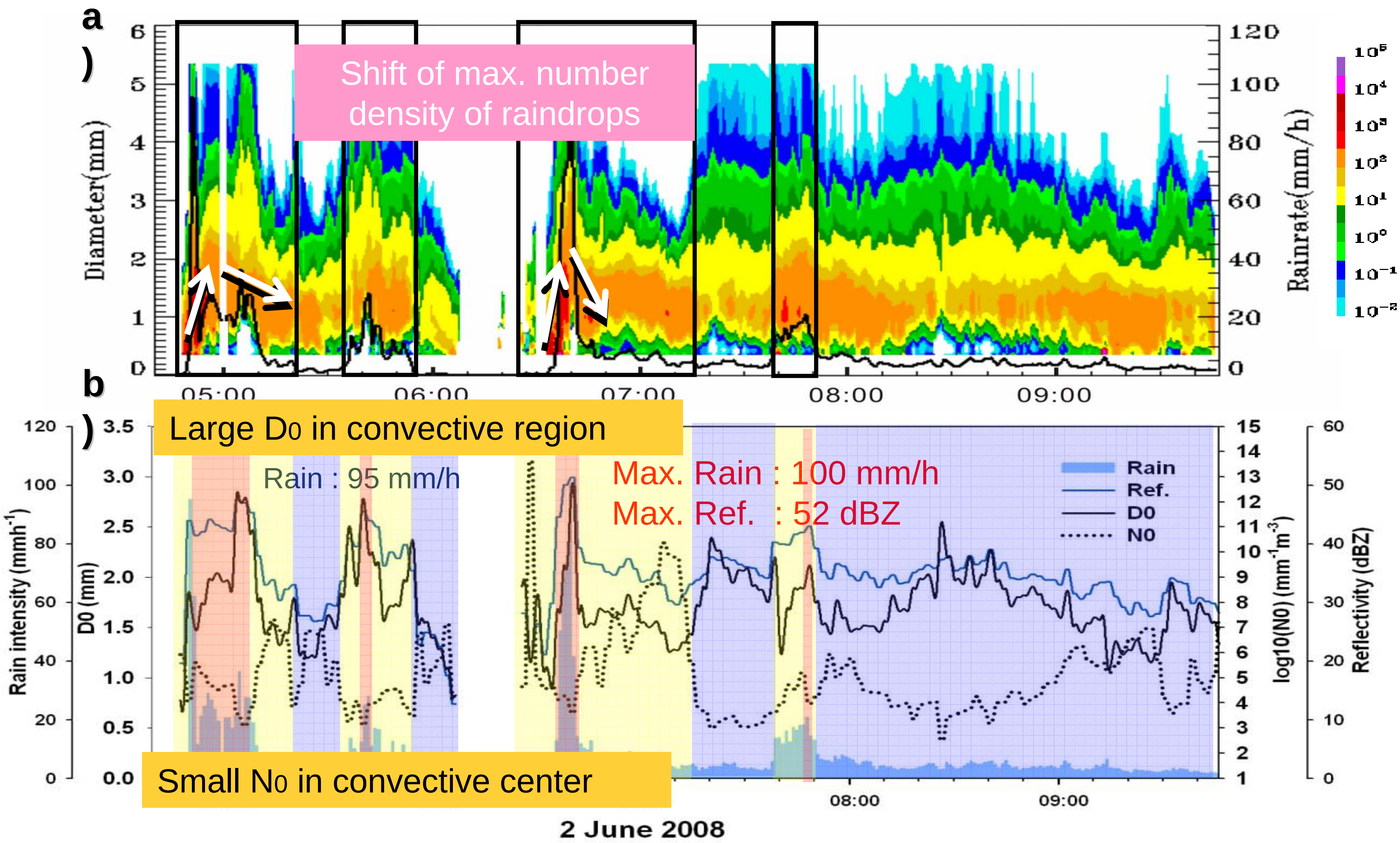


Fig.(a) The time series of RDSDs measured by POSS in 2 June 2008.
(b) The comparison of distribution among rainfall rate, reflectivity and RDSD parameters.

RDSD Analysis

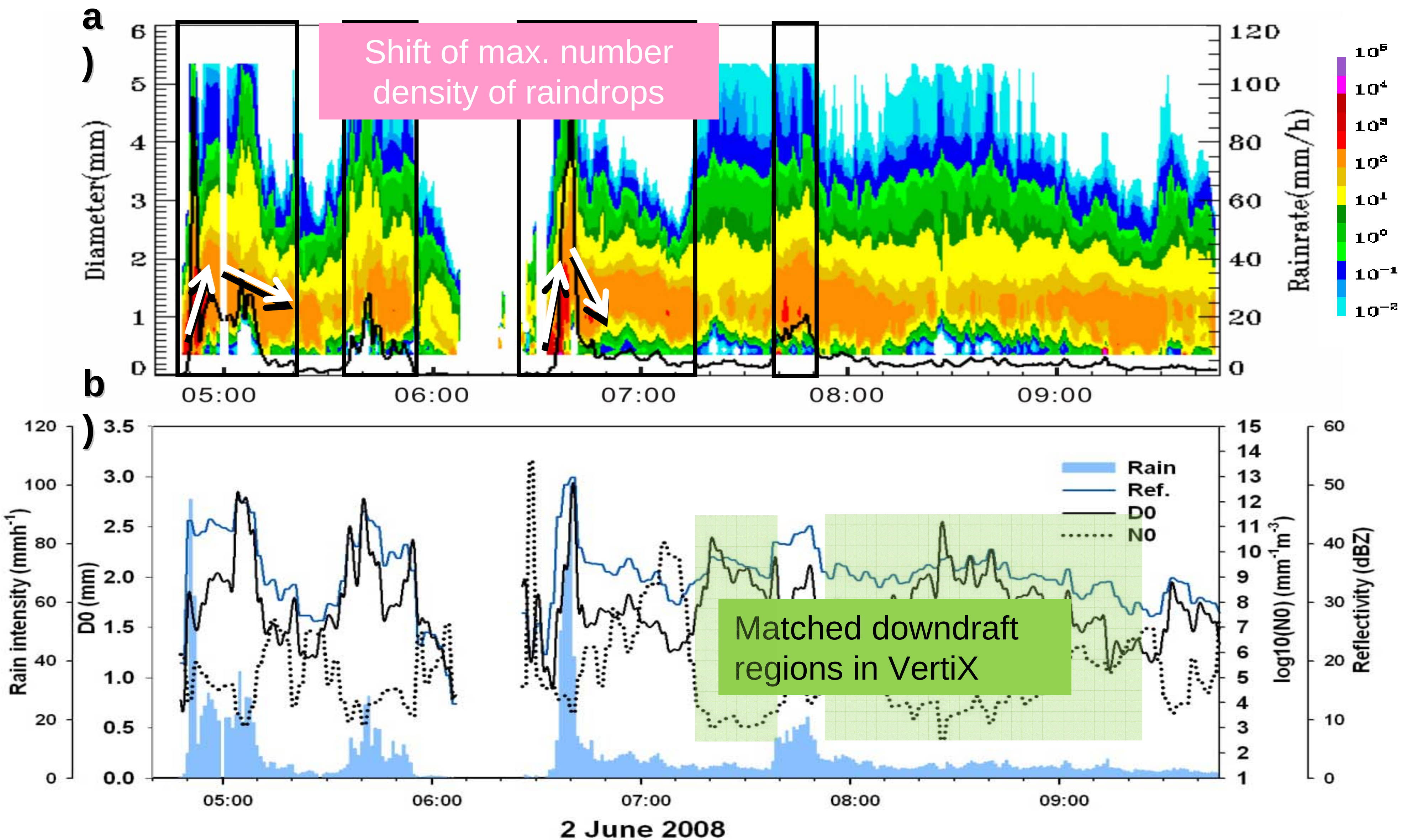


Fig.(a) The time series of RDSDs measured by POSS in 2 June 2008.
(b) The comparison of distribution among rainfall rate, reflectivity and RDSD parameters.

RDSD Analysis

Case 1	Case 2	Case 3	Case 4

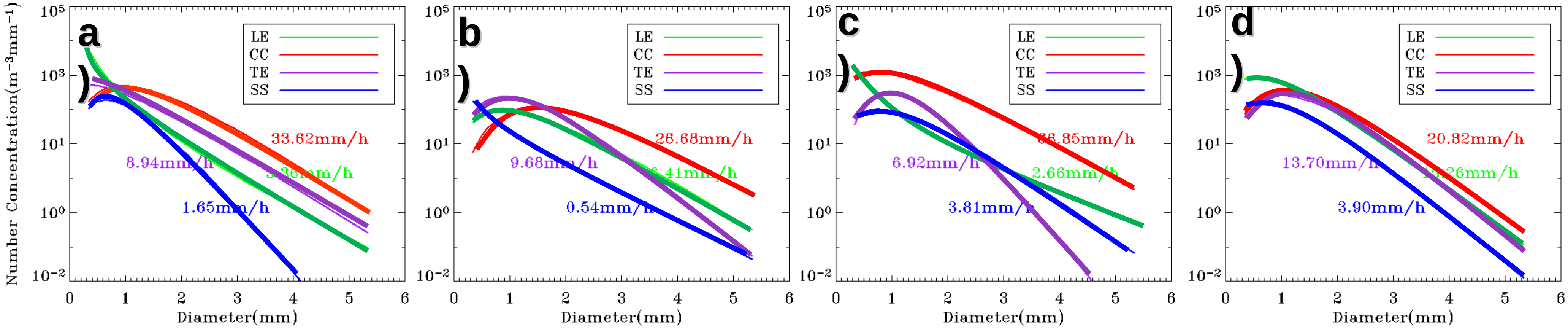


Fig. Averaged gamma RDSD for leading edge LE, Convective center CC, trailing edge TE, and stratiform SS of different developmental stage show in maritime squall line. The period of developmental stage are (a) from 0448 to 0531 UTC, (b) from 0532 to 0606 UTC, (c) from 0639 to 0946 UTC, and (d) from 0739 to 0946 UTC.

- ✓ From leading edge to convective center
  small drops decreased and large drops increased.
- ✓ From convective center to trailing edge
  the small drops increased and large drops decreased.
- ✓ In stratiform region
  there are **many drops in nearby 1mm** compared with small and large drops.

RDSD Analysis

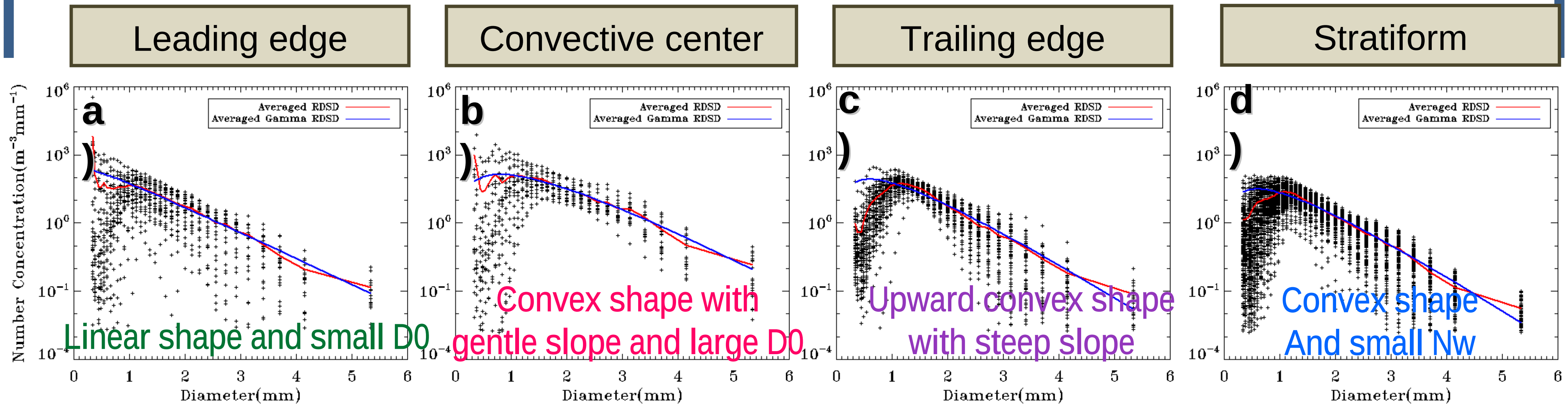


Fig. RDSDs, averaged RDSD and averaged gamma RDSD for leading edge LE, Convective center CC, trailing edge TE, and stratiform SS in maritime squall line. The numbers of stages are (a) 29 minutes, (b) 21 minutes, (c) 62 minutes, and (d) 164 minutes.

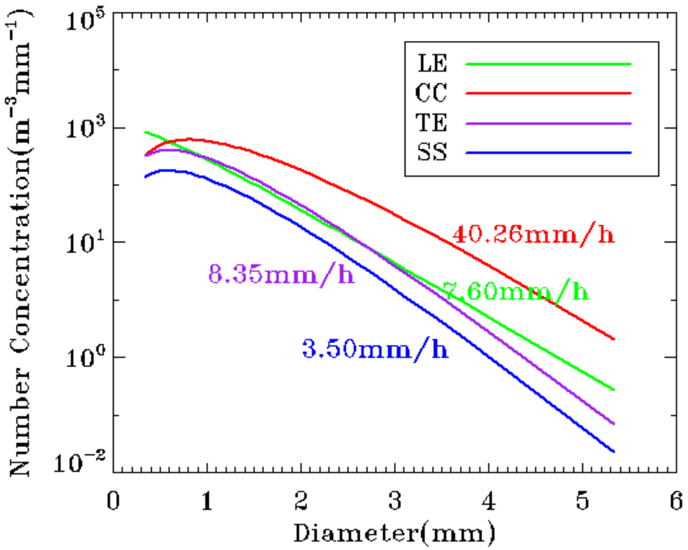


Table 2. Averaged RDSD parameters

	R	μ	Λ	D0	Nw
LE	7.6	**5.1**	5.5	**1.6**	5×10^3
CC	**40.3**	5.5	**4.1**	**2.3**	7×10^3
TE	8.4	**9.5**	**8.3**	1.7	4×10^3
SS	**3.5**	5.9	5.9	1.7	2×10^3

RDSD Analysis

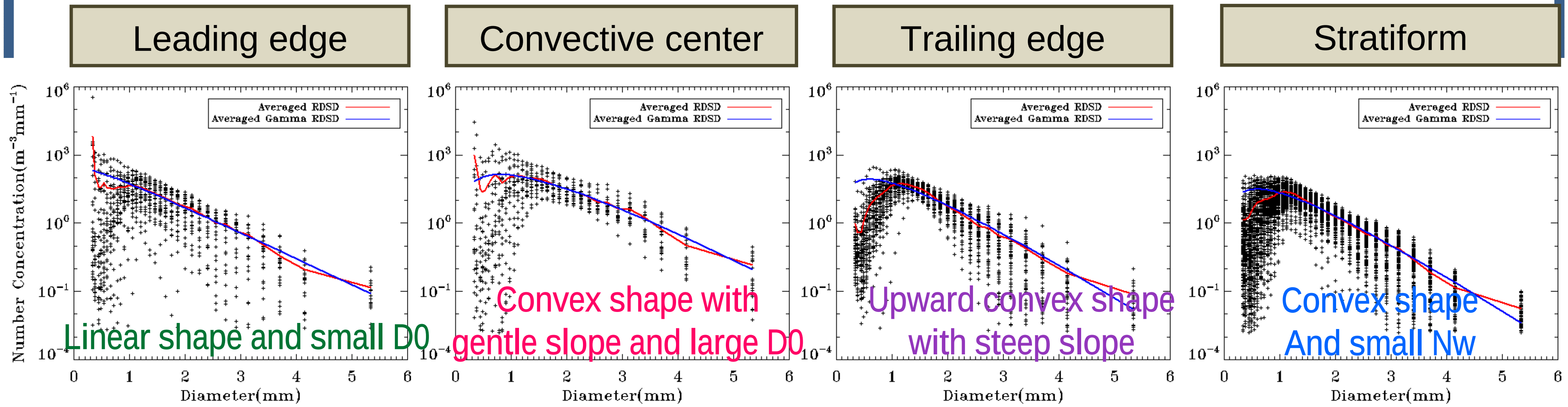


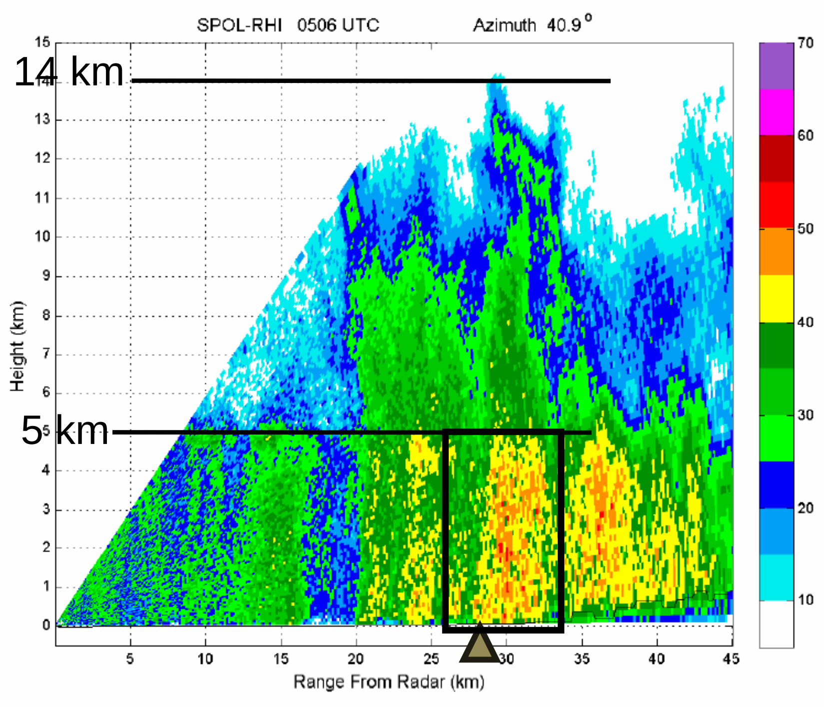
Fig. RDSDs, averaged RDSD and averaged gamma RDSD for leading edge LE, Convective center CC, trailing edge TE, and stratiform SS in maritime squall line. The numbers of stages are (a) 29 minutes, (b) 21 minutes, (c) 62 minutes, and (d) 164 minutes.

- From leading edge to convective center — **coalescence process**
- From convective center to trailing edge — **coalescence and breakup process**
- In stratiform region — **coalescence process**

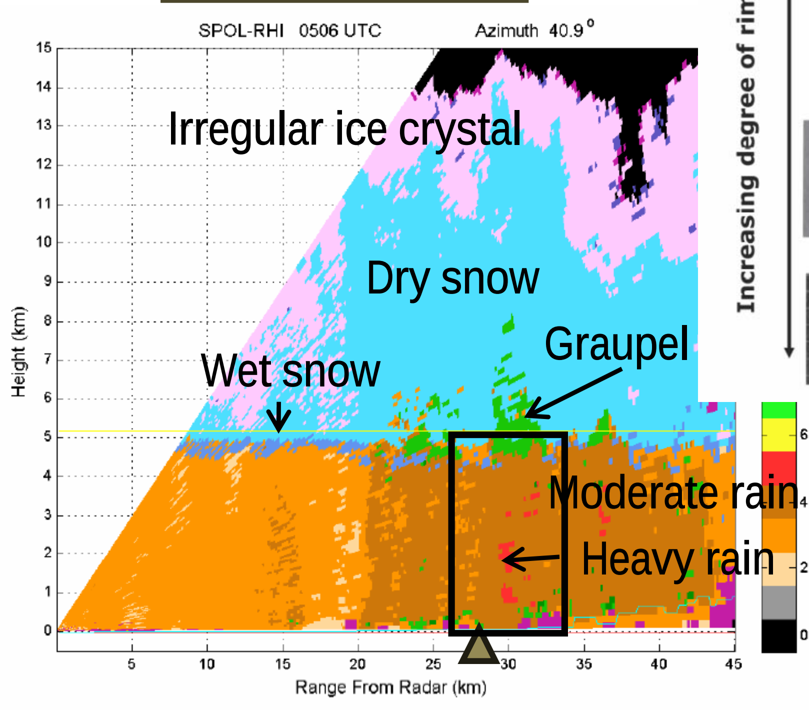
Radar Analysis

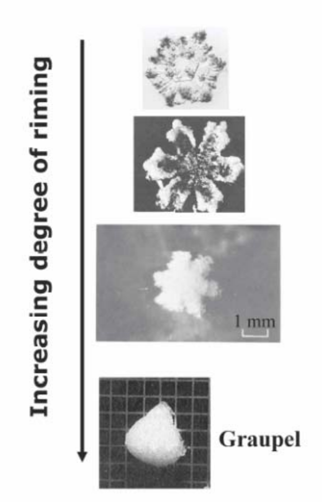
Convective cell
(0506 UTC)

dBZ



Classification





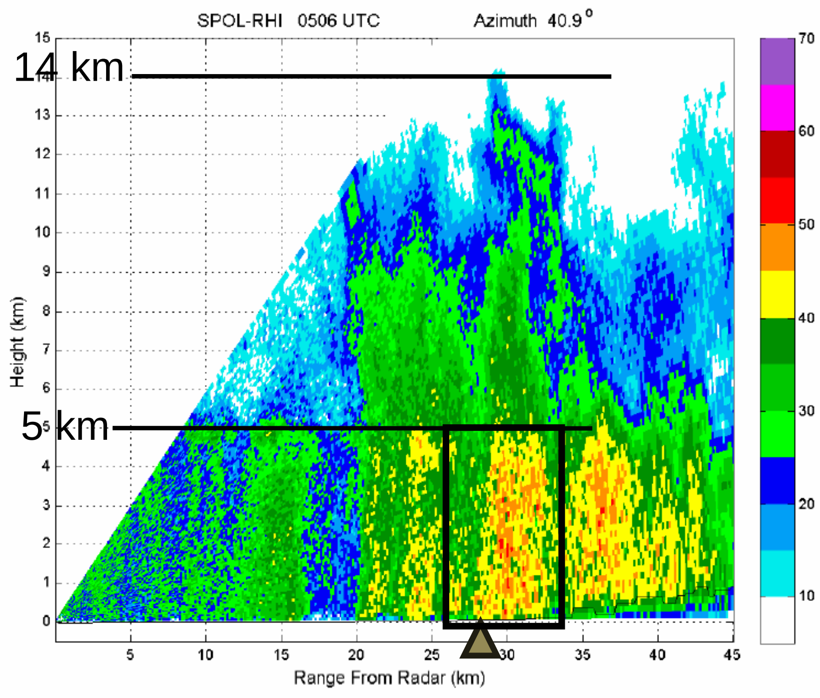
- ✓ The top of the cell reached an altitude of 14km.
- ✓ The thick graupel region appeared under the highest echo top.
- ✓ The graupel located between dry and wet snow.
- ✓ The heavy rain was appeared in the altitude from 1 to 4 km.

The thick graupel region matched large drop spectra and strong up and downdraft region in VertiX

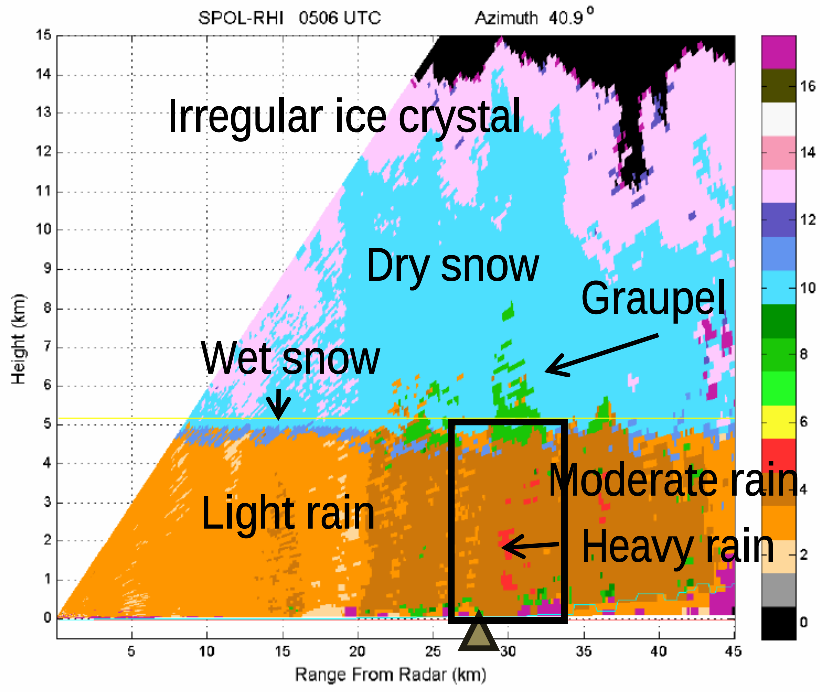
Radar Analysis

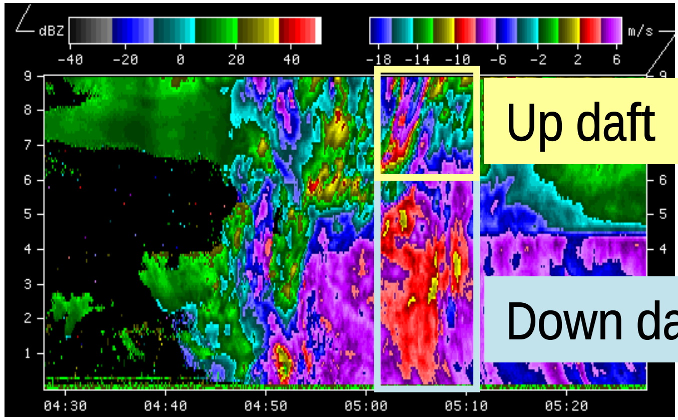
First convective line
(0506 UTC)

dBZ

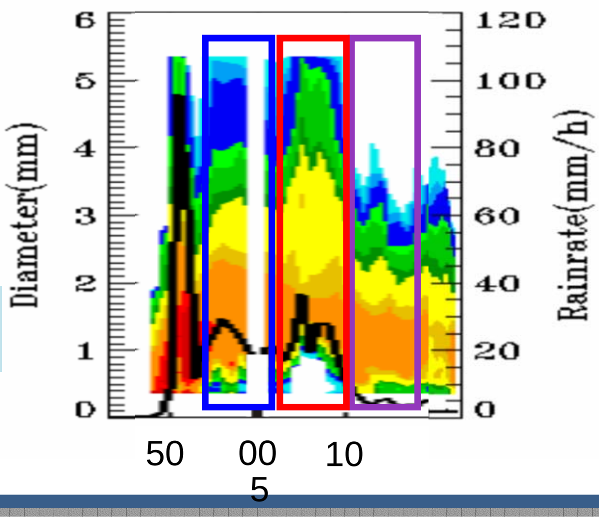


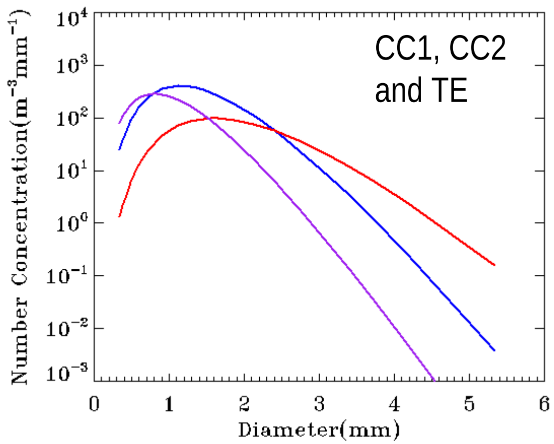
Classification





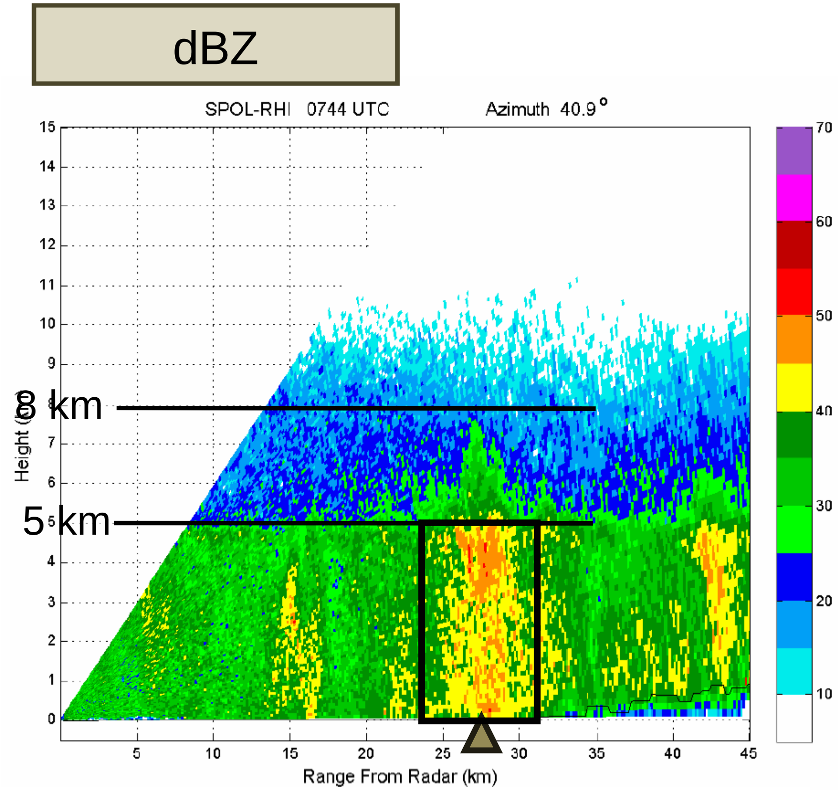
CC1 CC2 TE

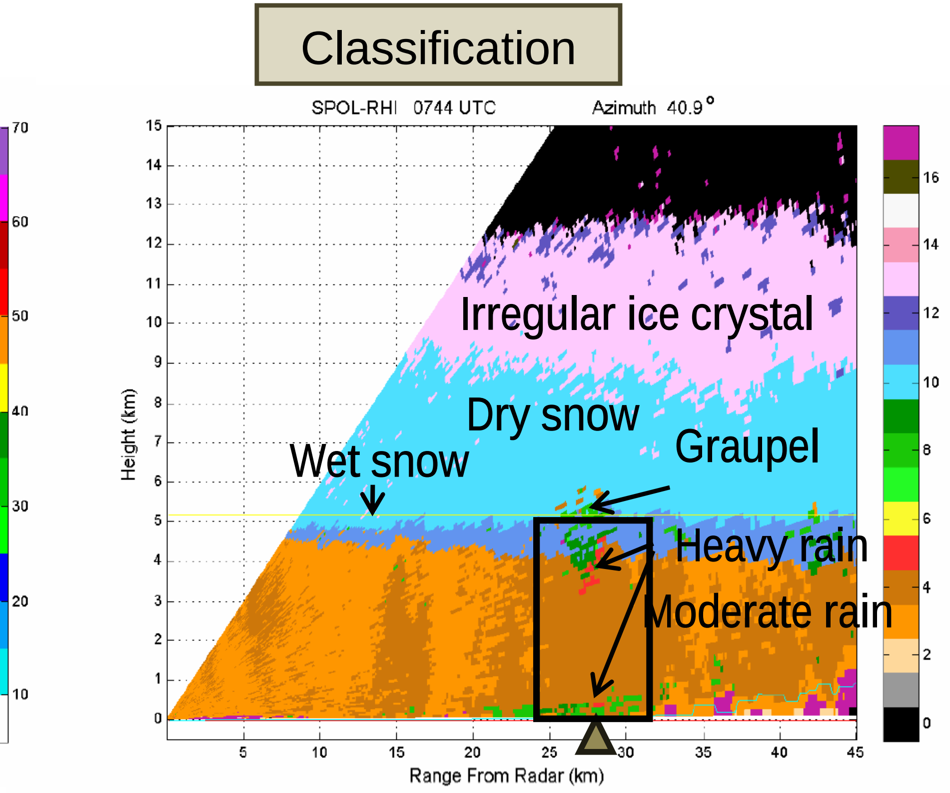




Radar Analysis

Small Convective cell
(0744 UTC)





- ✓ The top of the cell reached an altitude of 8km.
- ✓ The graupel appeared under the highest echo top.
- ✓ The graupel located between dry and wet snow.
- ✓ The heavy rain was classified in the altitude nearby 4km and ground.

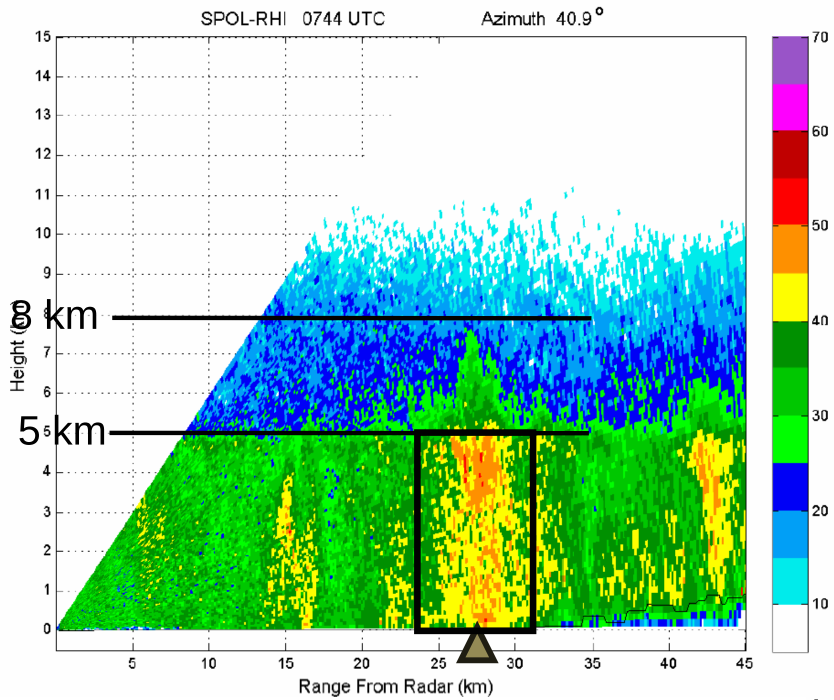
The graupel region matched large drop spectra and

up and down draft region in VertiX

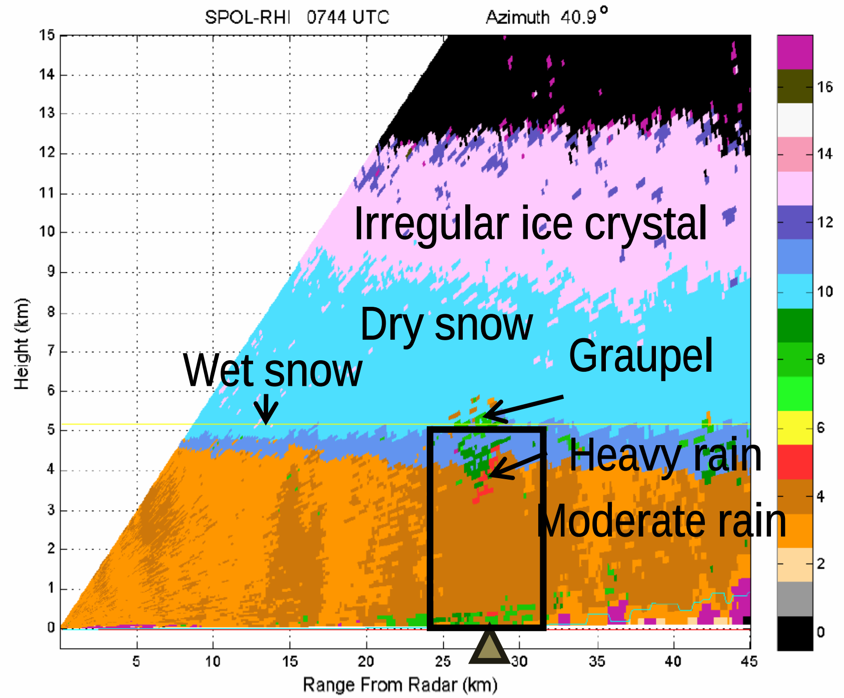
Radar Analysis

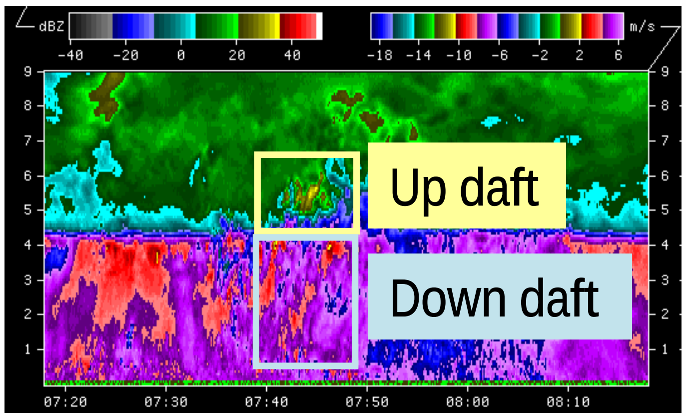
Convective cell
(0506 UTC)

dBZ

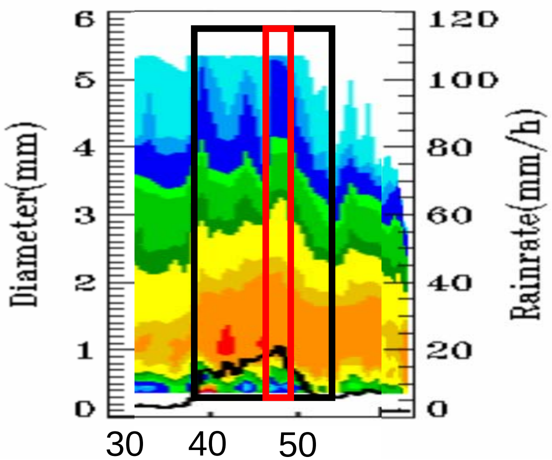


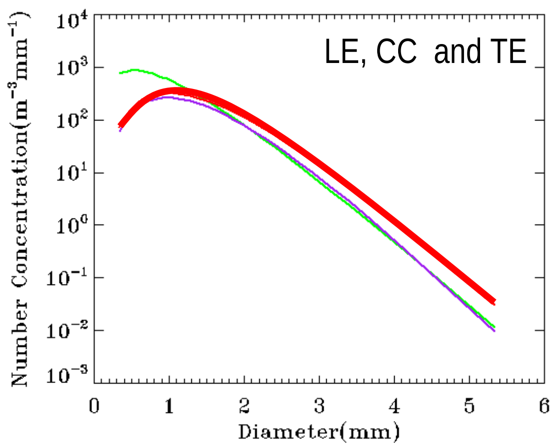
Classification





LE CC TE

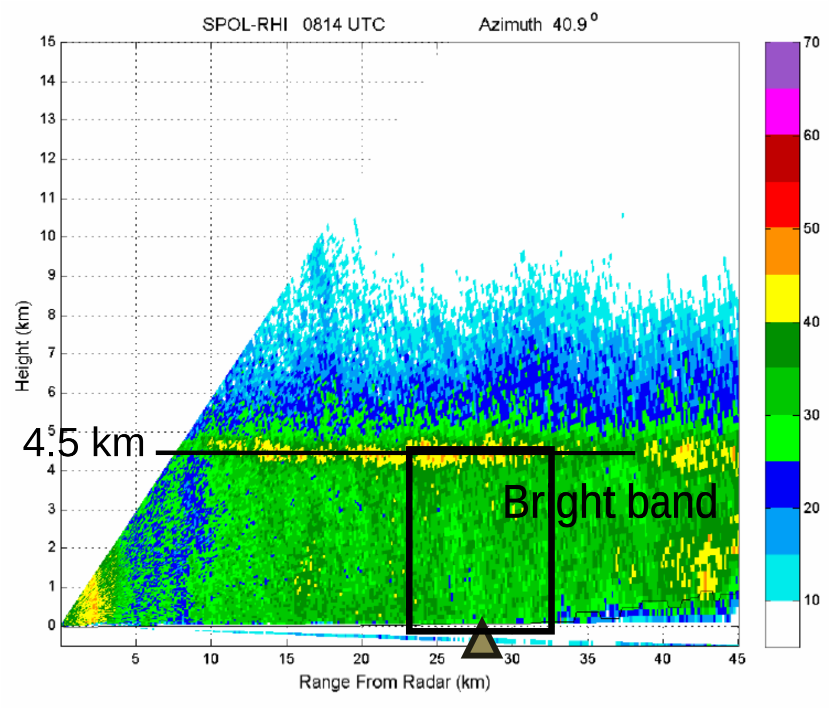




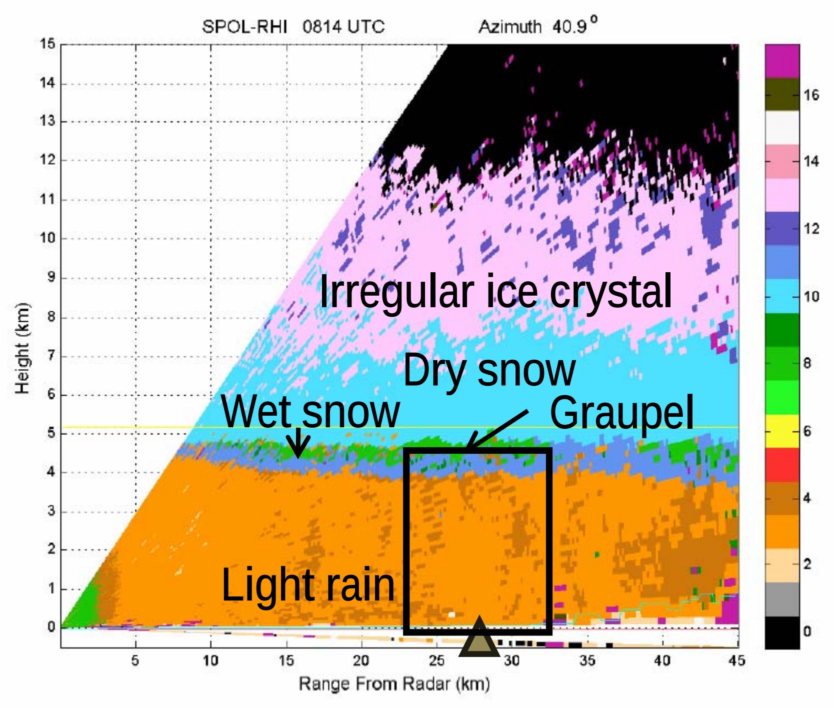
Radar Analysis

Stratiform
(0814 UTC)

dBZ



Classification



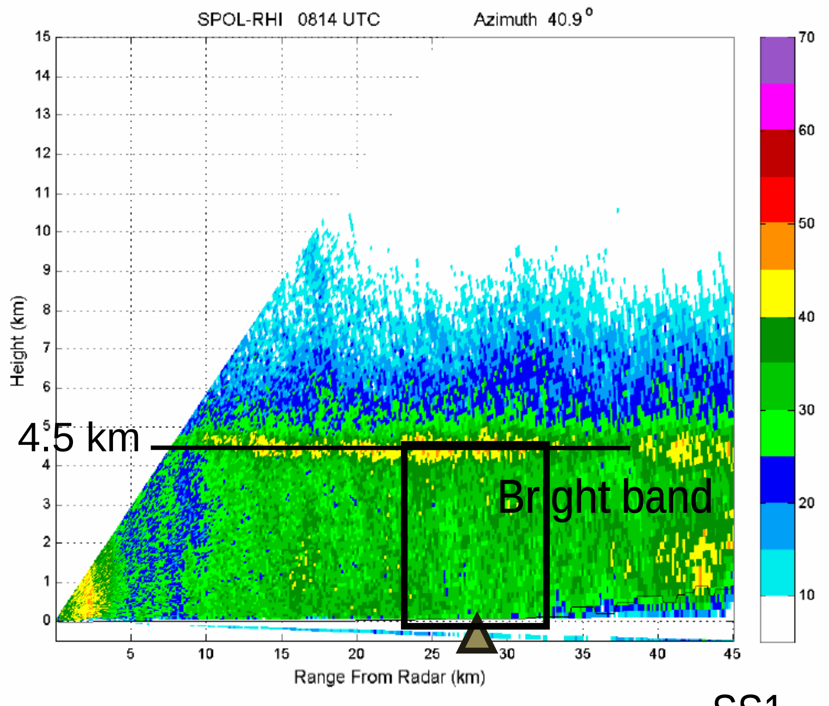
- ✓ The bright bad appeared in an altitude of 4.5km.
- ✓ Graupel located under the bright band region and positioned between dry and wet snow.
- ✓ The moderate rain scattered in the light rain.

The graupel region matched large drop spectra and downdraft regions in VertiX

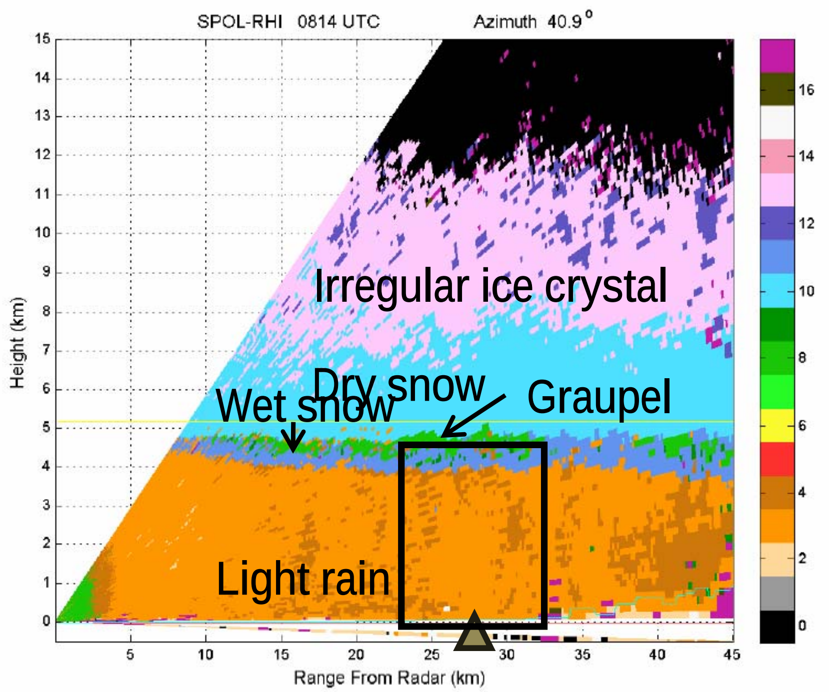
Radar Analysis

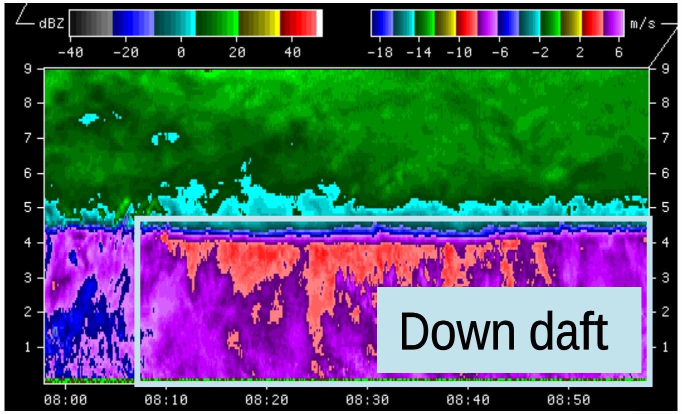
Stratiform
(0814 UTC)

dBZ

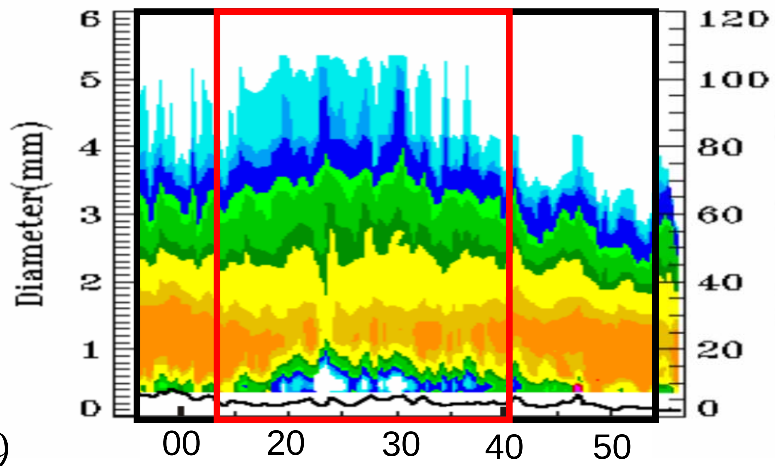


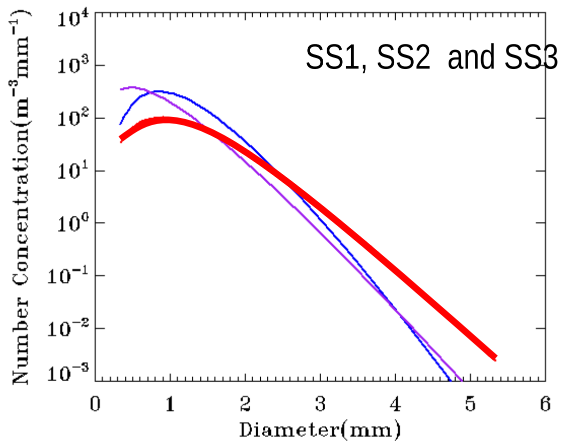
Classification





SS1 SS2 SS3





Summary and Conclusion

Comparison of maritime squall line system with each stage

	Leading edge	Convective center	Trailing edge	Stratiform
Characteristics of RDSD	small D0 and μ	large D0 and Nw	Large μ and Λ	small D0 and Nw
	Linear shape	upward convex shape	More upward convex shape	upward convex shape
Microphysical process (under cloud)	Coalescence		Coalescence-breakup	coalescence

- ➢ **In cloud, the graupel from riming helped to make large drop spectra on the ground.**
- ✓ In convective region, graupel was formed from falling ice particles under the updraft region.
- ✓ In stratiform region, graupel was formed from the ice particles, which were supplied by the convective region.


Thank you for listning

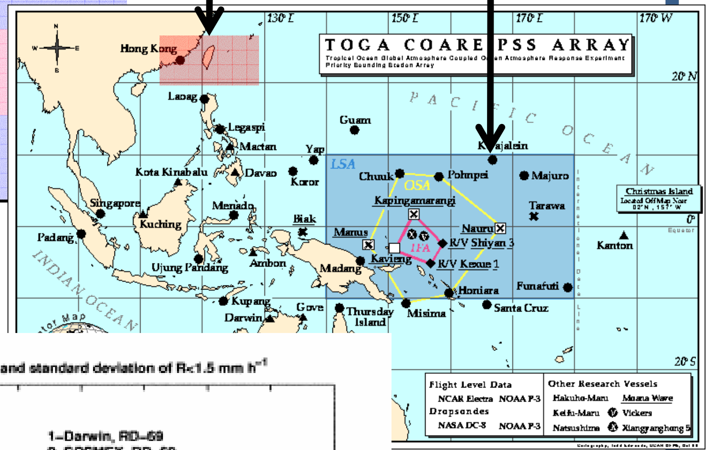
Summary and Conclusion

Comparison of convective region between Taiwan squall line and maritime storms

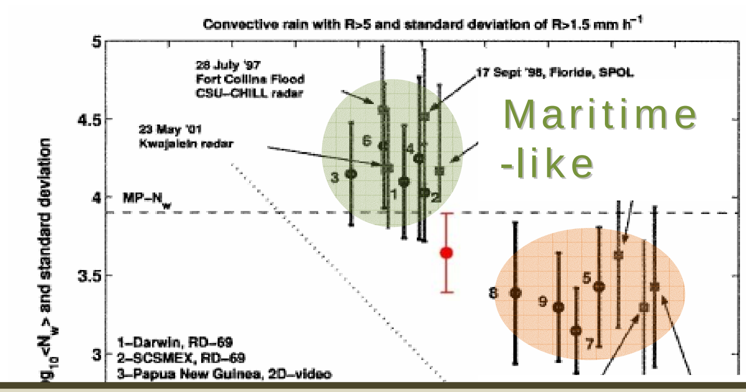
Convective region	Maritime storms	Taiwan Squall line system
μ	3 – 15	-0.5 – 11.4
Λ (mm-1)	4 – 12	2.1 – 5.8
D_0 (mm)	1.3 – 1.7	1.4 – 3.2
N_w (m-3mm-1)	2×10^4	7×10^3

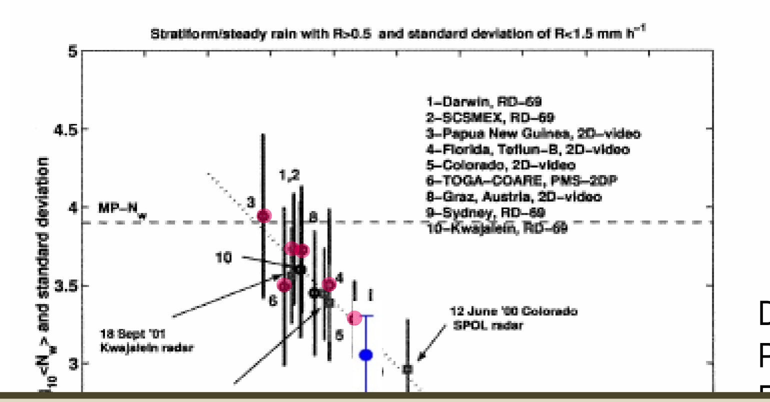
(Ulbrich and Atlas, 2007)

Taiwan TOGA COARE



TOGA COARE (Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment)





Darwin
Papua New Guinea

- ✓ The point of **convective region** was **plotted below maritime-like cluster**
- ✓ The point of **stratiform region** was **plotted in the low part of the fitted line of stratiforms**

(Bringi et al., 2003)