The vertical Structure and Drop Size Distribution of Different Precipitation Systems in Taiwan

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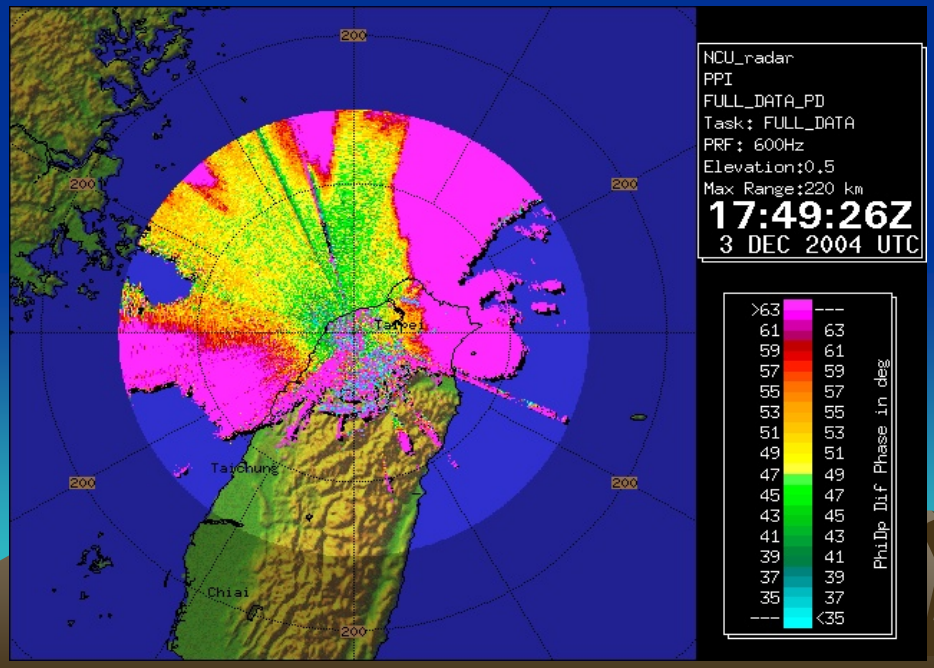


Motivation:

- Is there any difference in DSD between precipitation type?
- What kind of the vertical structure ?

- What mechanism causes the difference?

- Is there any dependence of the relationship between integrated rain parameters on precipitation type?

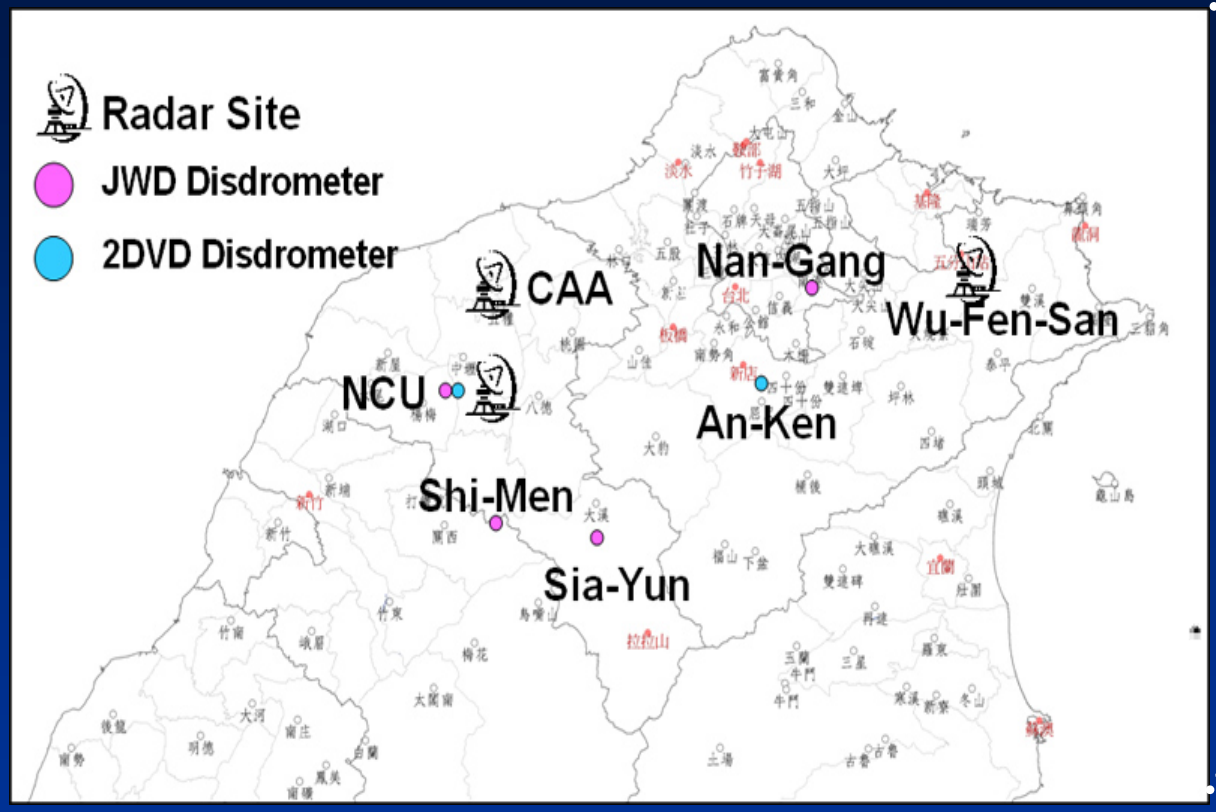
Introduction

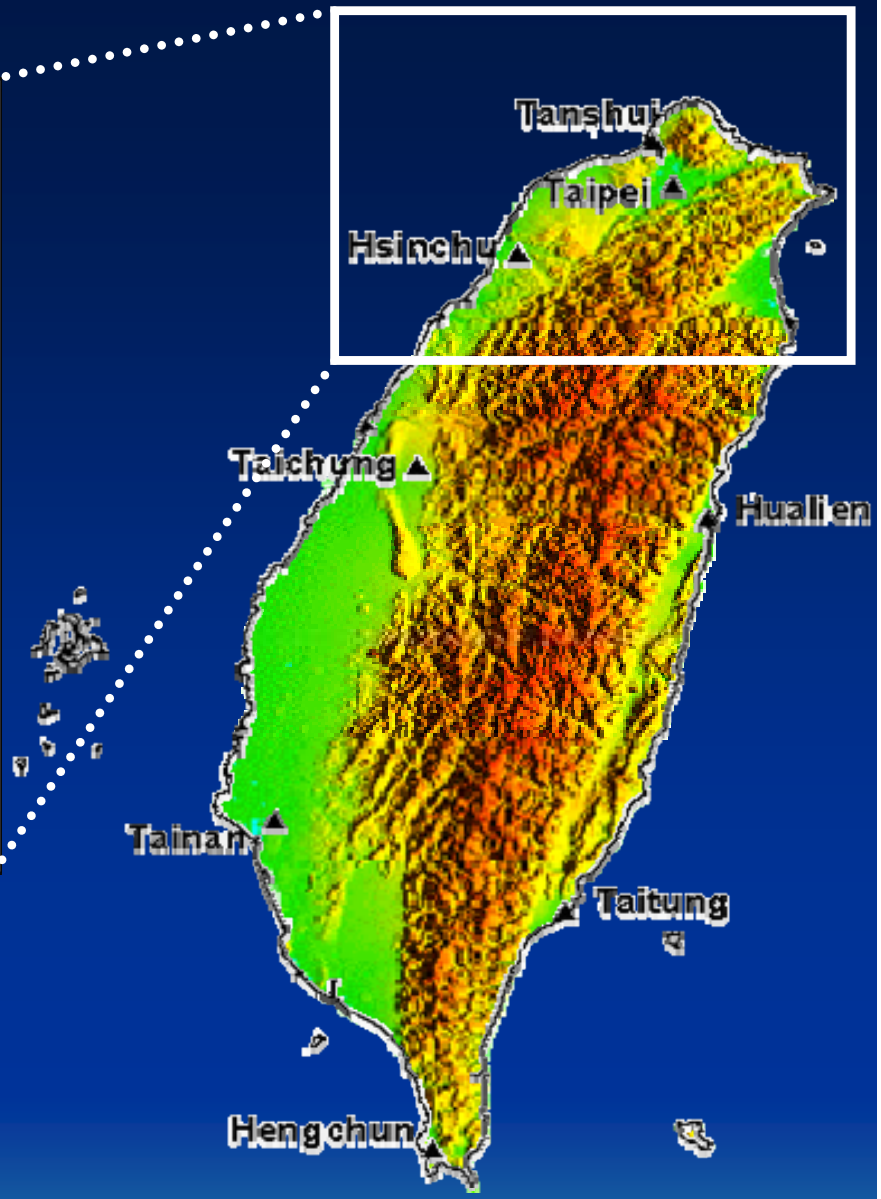
The measurements of drop-size distributions are important for many meteorological applications, including estimation of rainfall, precipitating cloud microphysics studies, and cloud model initialization and verification

(Cifelli et al., 2000; Tokay et al., 2003).

In particular, accurate estimates of area rainfall through radar measurements benefit from the knowledge of the drop size distribution

(Tokay et al., 2001) .





A network of disdrometer, rain gauge and Doppler radar site in the northern area of Taiwan.

Methodology

- Ulbrich et. al(1983)：Gamma Distribution

$$N(D) = N_0 D^{\mu} e^{-(\Lambda D)}$$

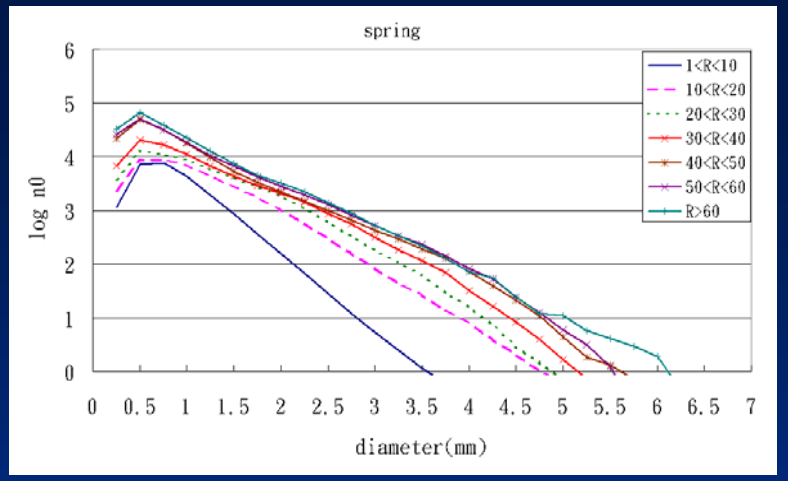
- Testud et. al(2001)：Normolized N0

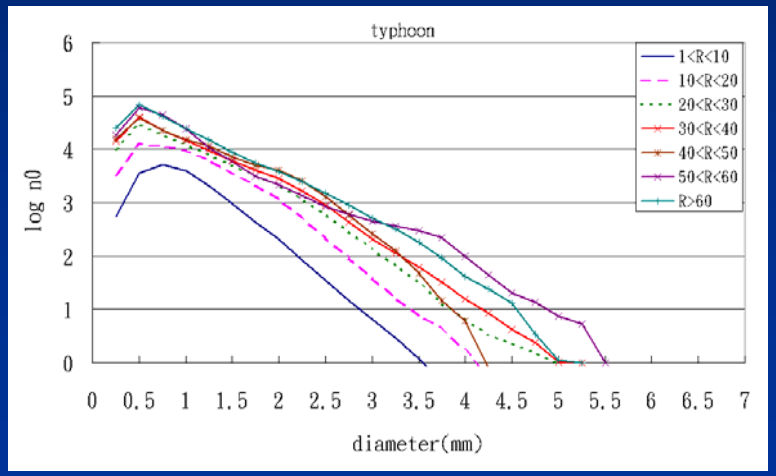
$$N(D) = N_w f(\mu) \left(\frac{D}{Dm}\right)^{\mu} \exp\left[-(4+\mu)\frac{D}{Dm}\right]$$

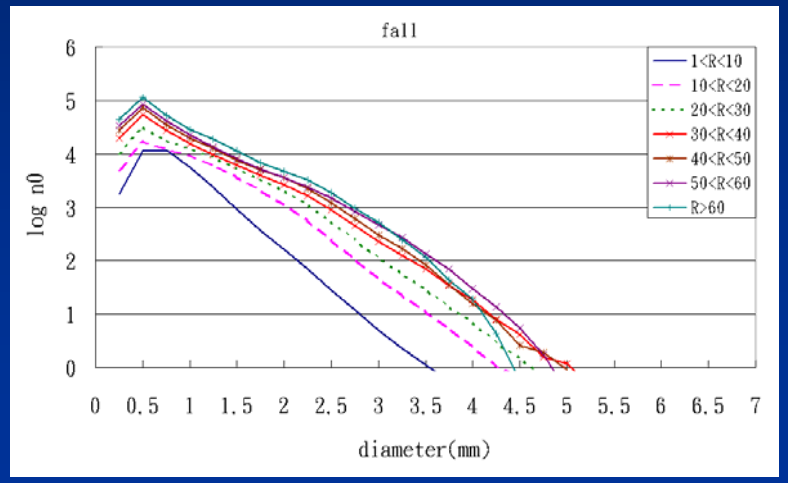
$$f(\mu) = \frac{6(4+\mu)^{4+\mu}}{4^4 \Gamma(\mu+4)}$$

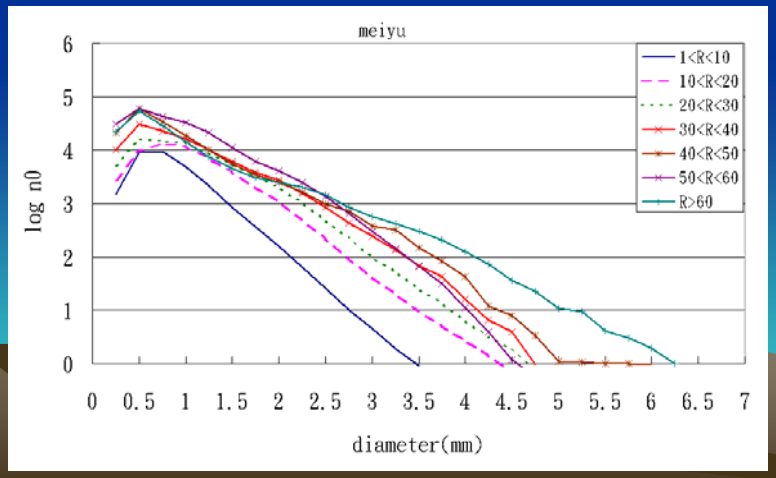
$$Nw = \frac{4^4}{\pi \rho_w} \left(\frac{LWC}{D_m^4}\right)$$

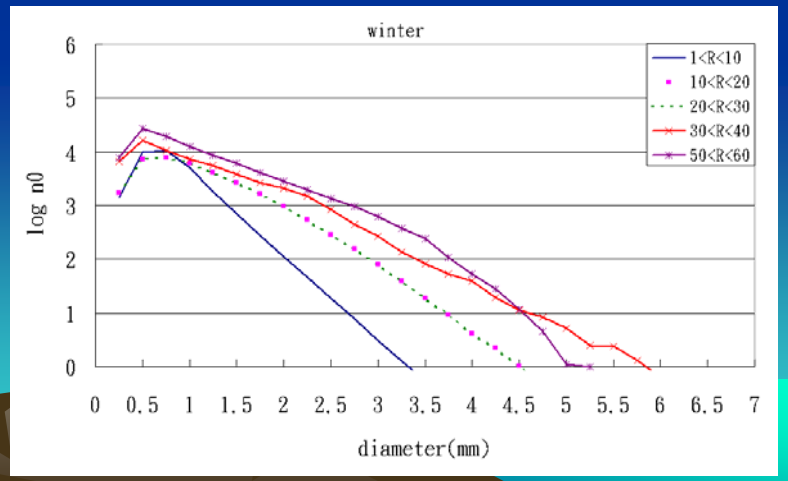
DSD observed at NCU with 2DVD in different rainfall rate and different seasons in Taiwan.



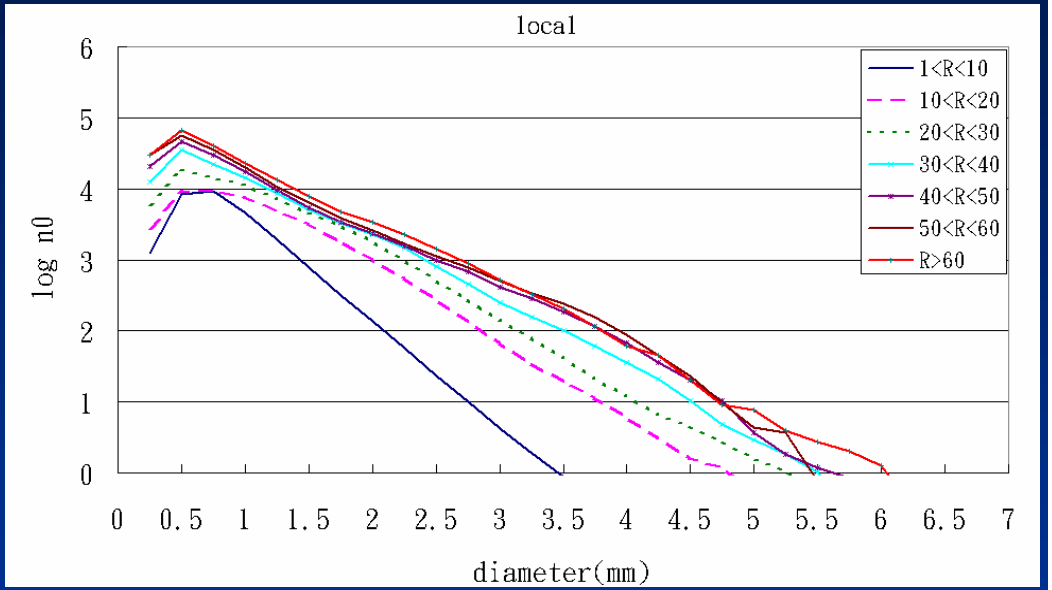


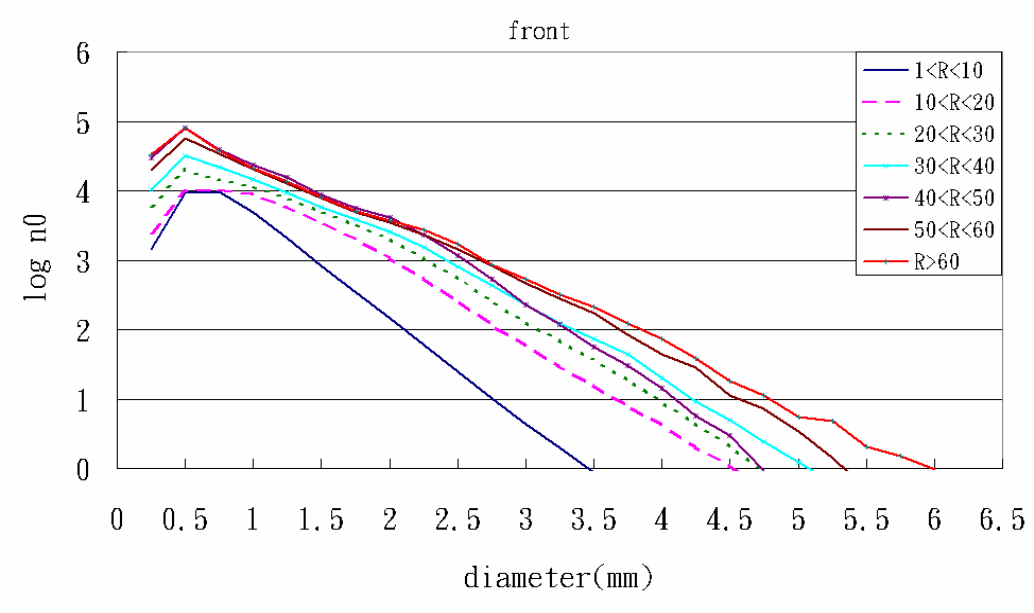


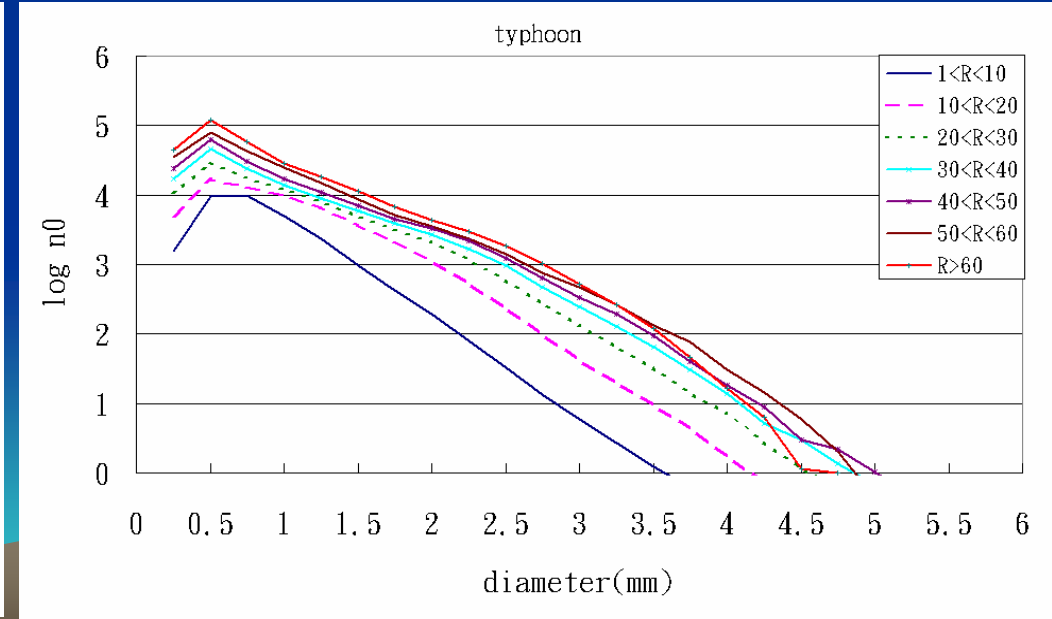




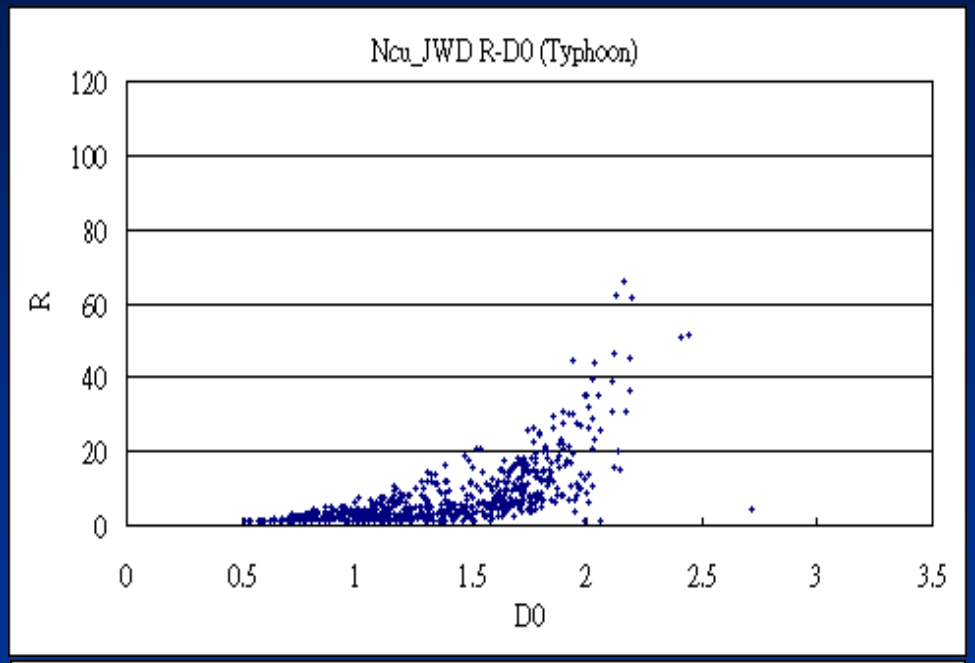
DSD observed at NCU with 2DVD in different rainfall rate and different weather systems in Taiwan.

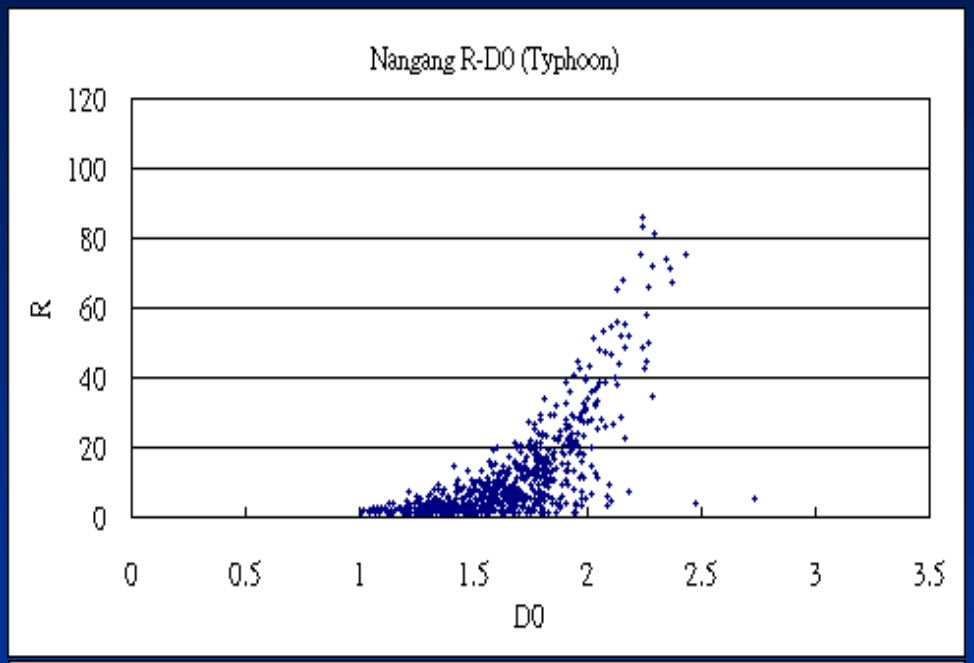


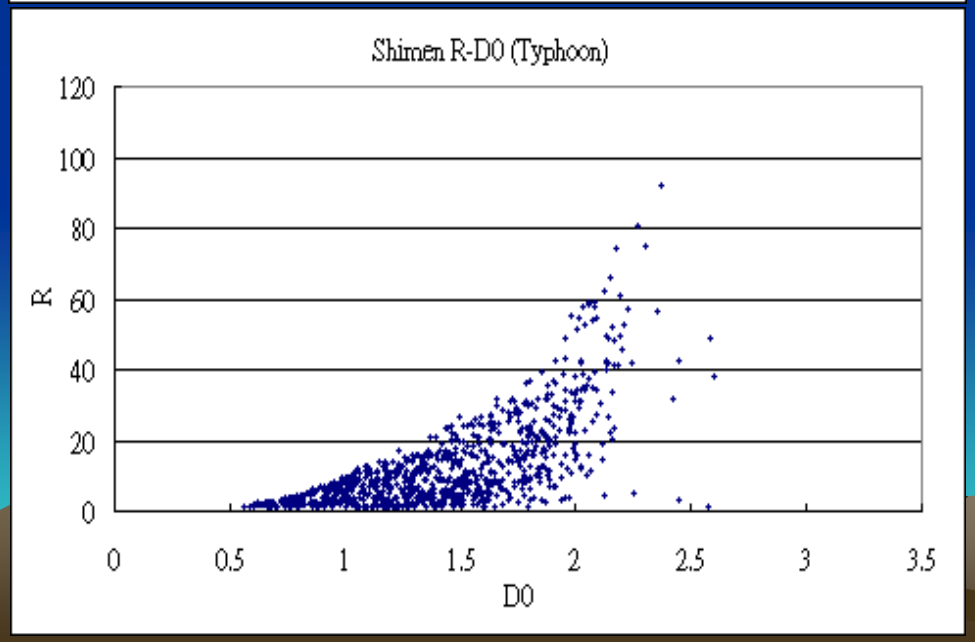


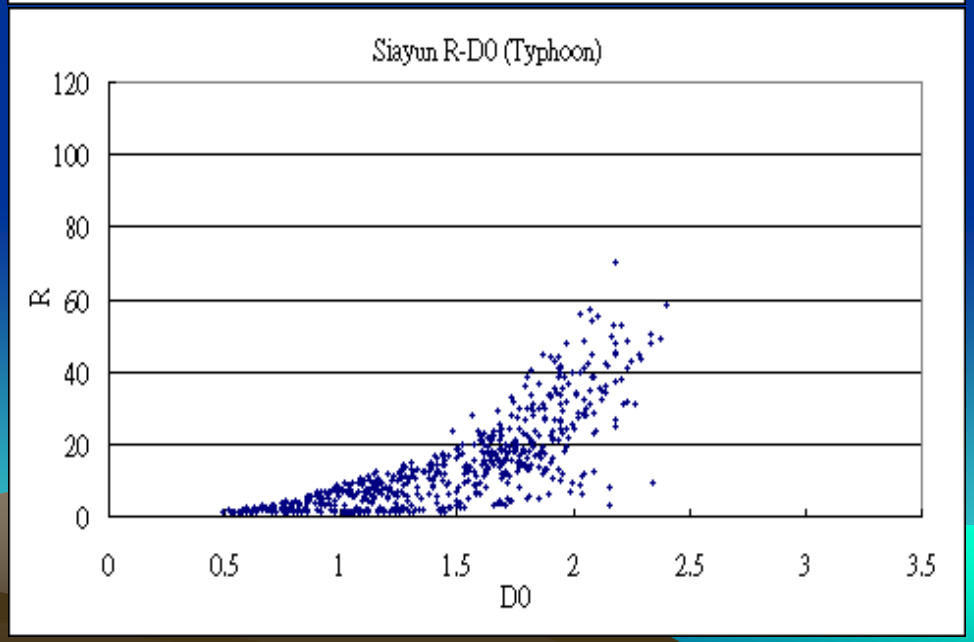


D_0-R Scatter diagrams with JWD at NCU, Nan-Gang, Shi-Men and Sia-Yun Stations during 2004 Typhoon season.

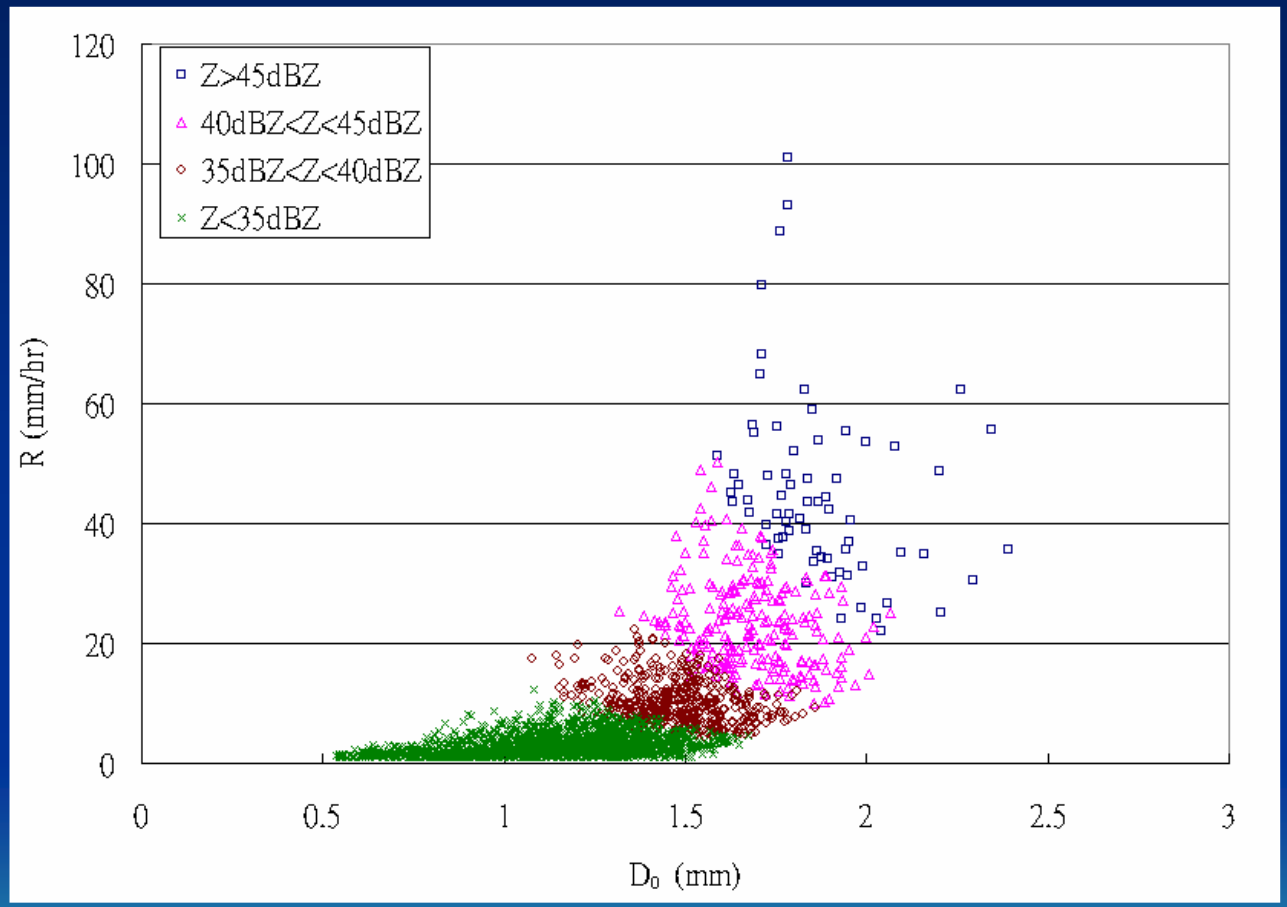








D_0 increases with increasing rainfall rate. However, the D_0 remains the value about 1.7 mm when the rainfall rate is greater than 60 mm/hr.



The median volume diameter (D_0) vs rainfall rate (mm/hr) in different reflectivity.

Disdrometer and Z-R Relation

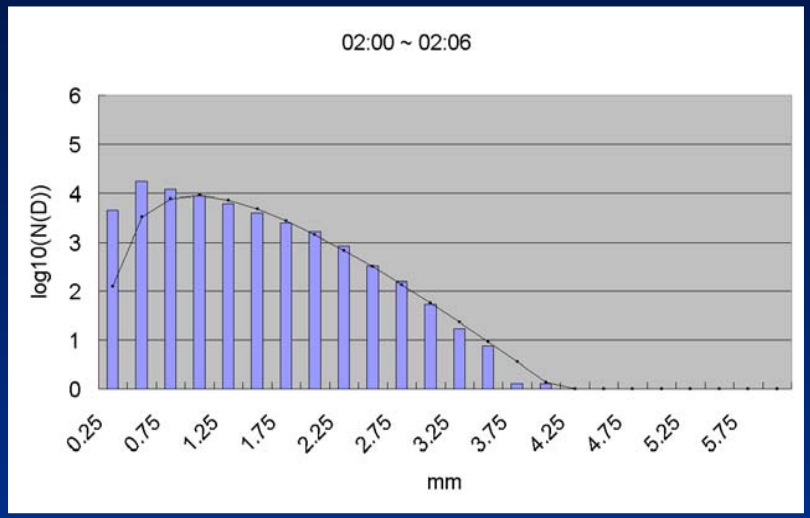
$$Z = AR^b$$

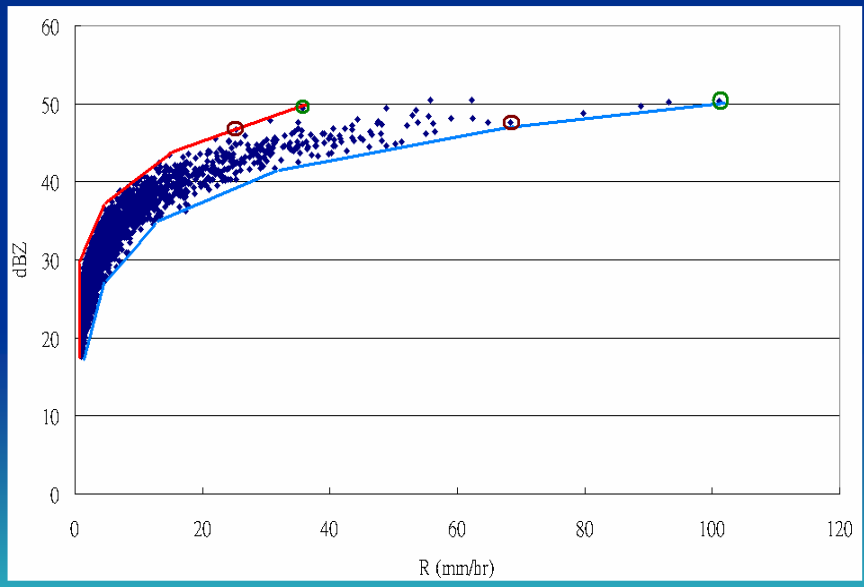
DSD Gamma Distribution

$$N(D) = N_O D^{\mu} \exp(-\Lambda D)$$

$$A = \frac{10^6 \Gamma(6+\mu+1) N_0^{1-b}}{\left[33.31\Gamma(3.67+\mu+1)\right]^b}$$

$$b = \frac{6+\mu+1}{3.67+\mu+1}$$





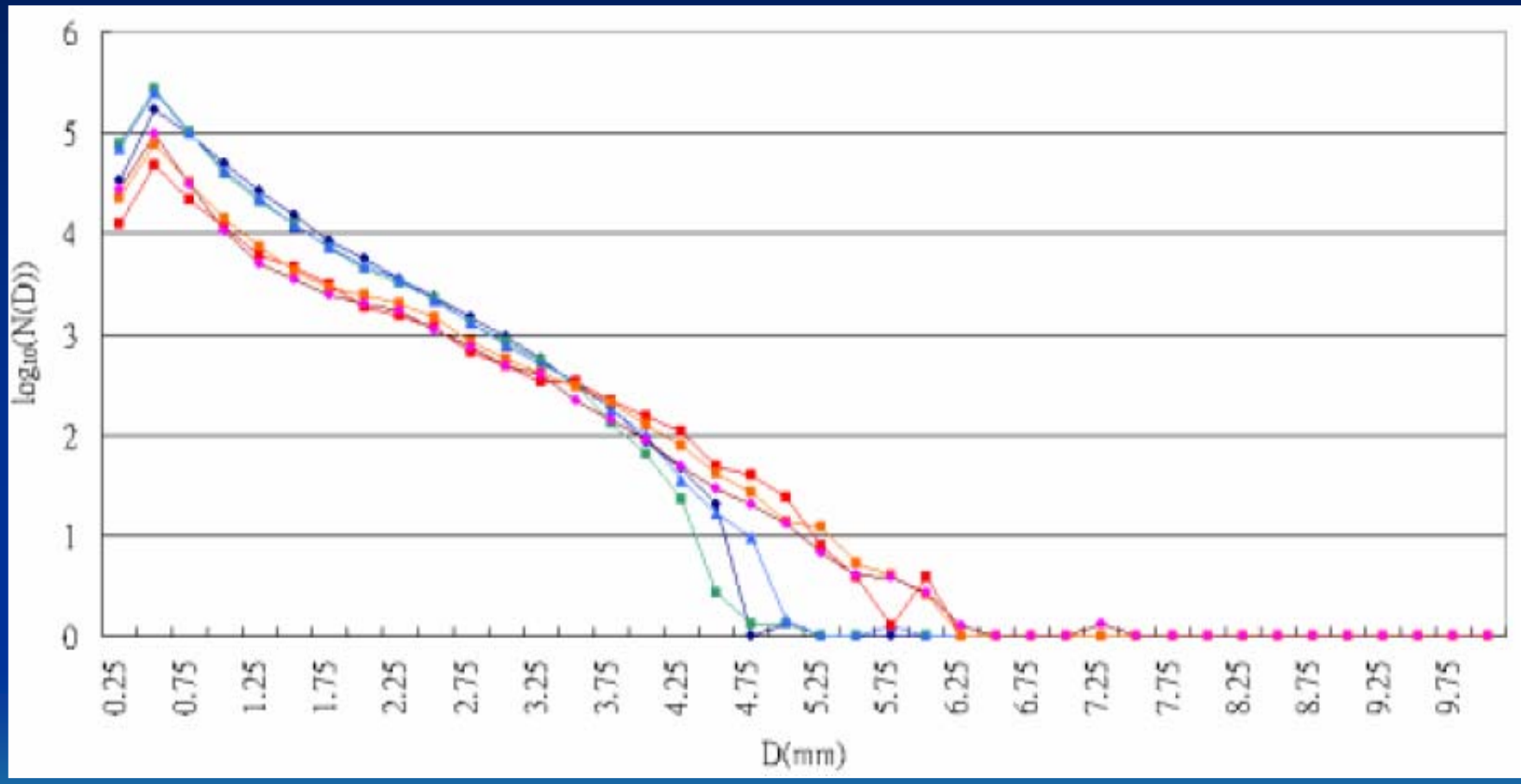
Six DSD data sets with reflectivity near 50 dBZ were divided into two groups according to their rainfall rate. (Type A> 85mm/hr, type B< 65mm/hr).

Type A has more raindrops with higher NW than type B. Type A has more small raindrops than type B, and the rainfall rate of type B are only half to type A.

	dBZ	R	m	Λ	A	b	D_0	N_W
	50.4	101.1	0.9	2.57	158.8	1.42	1.778	2.84E+04
A	49.7	88.8	0.691	2.51	152.7	1.43	1.738	2.74E+04
	50.2	93.2	0.48	2.35	147.9	1.45	1.765	2.66E+04
	50.8	55.8	1.39	2.11	435.2	1.38	2.401	4.03E+03
B	50.7	62.2	1.13	2.11	359.3	1.40	2.274	5.52E+03
	49.8	48.8	0.61	1.92	340.2	1.44	2.223	4.97E+03

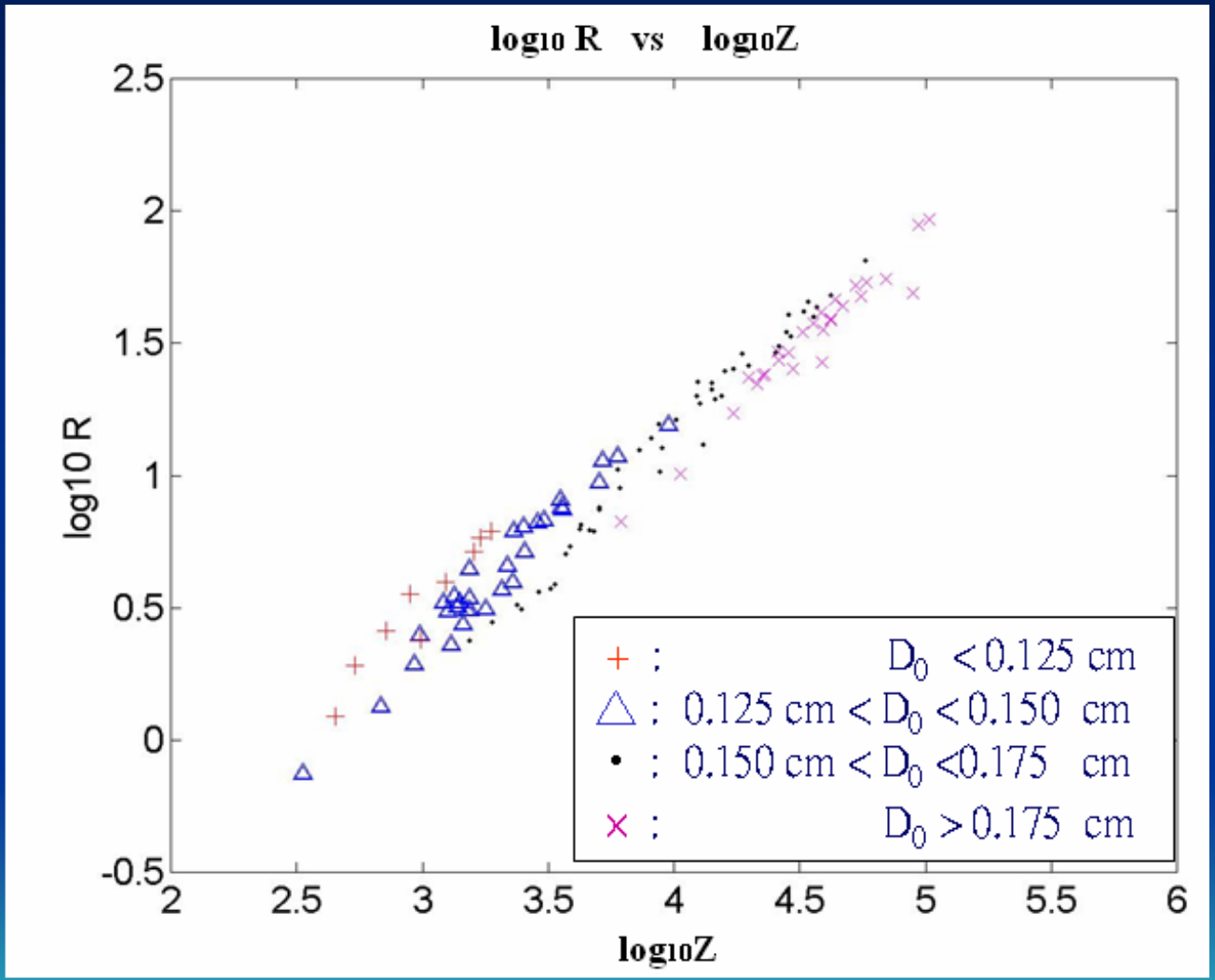
The reflectivity, rainfall rate, N0, μ, Λ, A, b, D0 and NW for type A and B.

Type A has more raindrops with higher NW than type B. Type A has more small raindrops than type B, and the rainfall rate of type B are only half to type A.



The raindrop size distribution of type A and B (blue and red solid line).

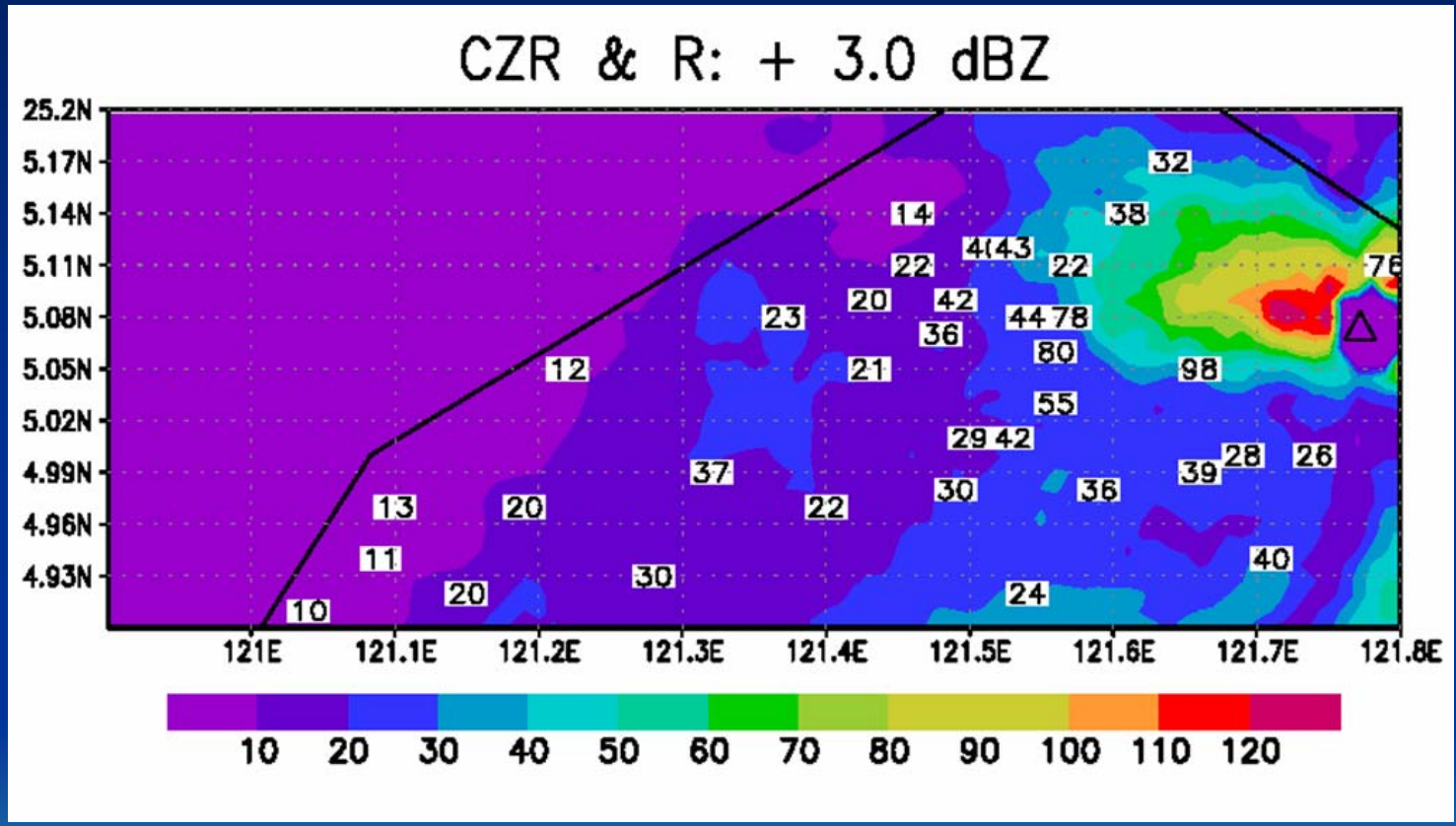
The Z-R relations are function of the variety of medium volume diameter distribution



The scatterplot of rainfall rate and reflectivity calculated from DSD and classified by D_0 .

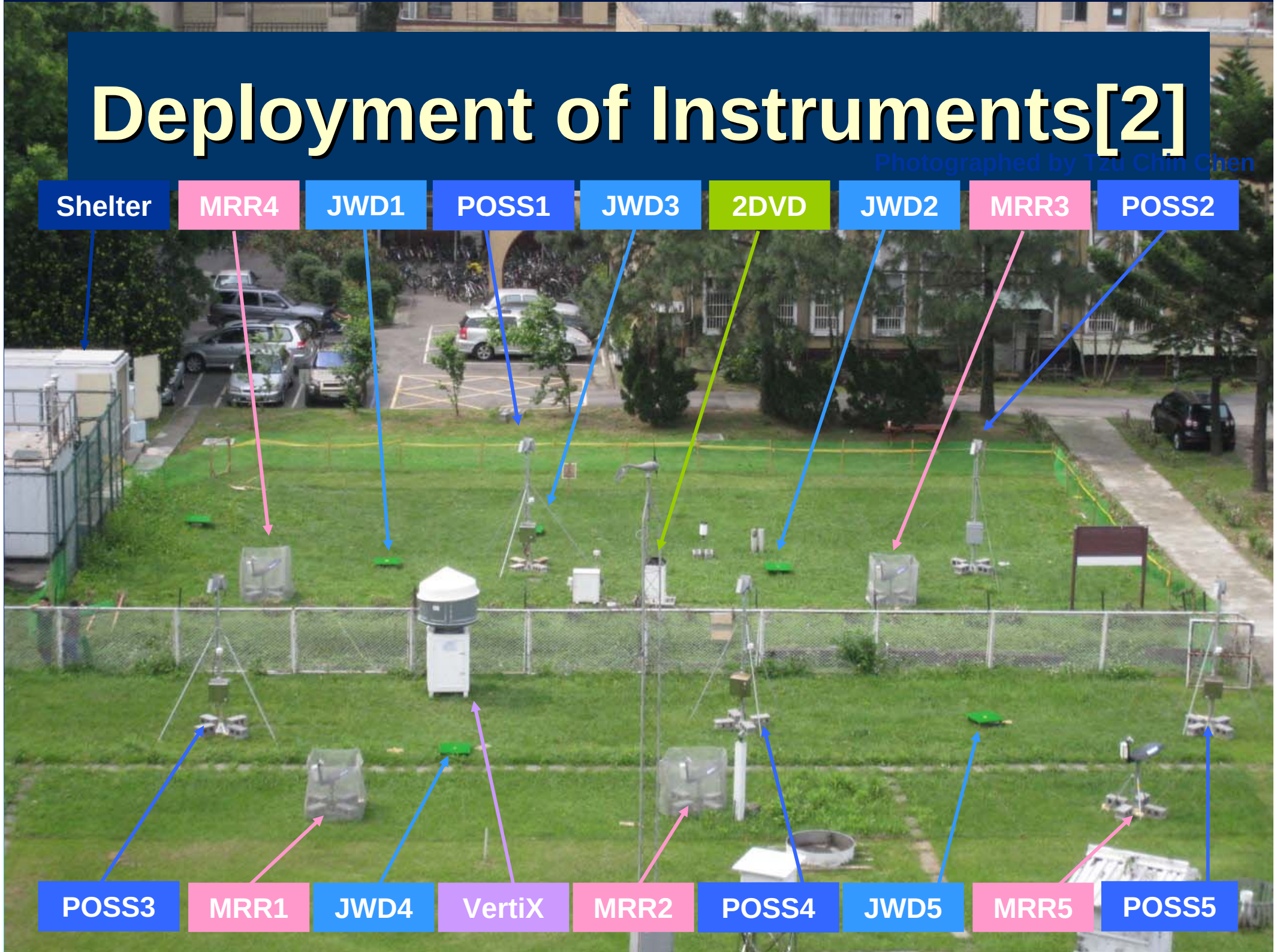
The classified Z-R relations derived from disdrometer was applied to estimate the rainfall rate from the radar reflectivity

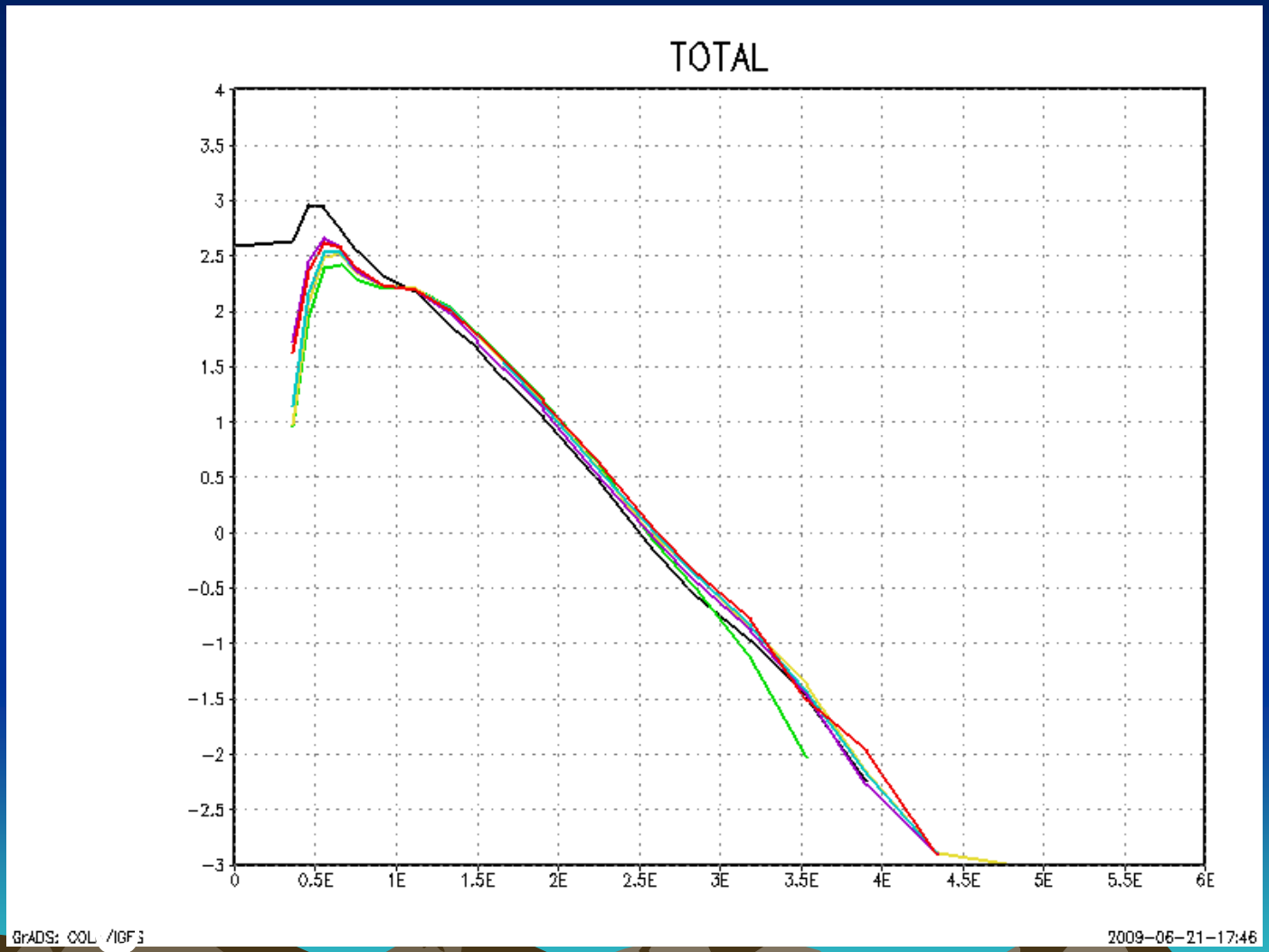
The area rainfall accumulation is quite satisfactory by using the disdrometer derived Z-R relation and corrected radar reflectivity.



The one hour precipitation accumulation derived from corrected Z-R and corrected reflectivity (color shaded), and the surface rainfall rate observation (digital numbers).

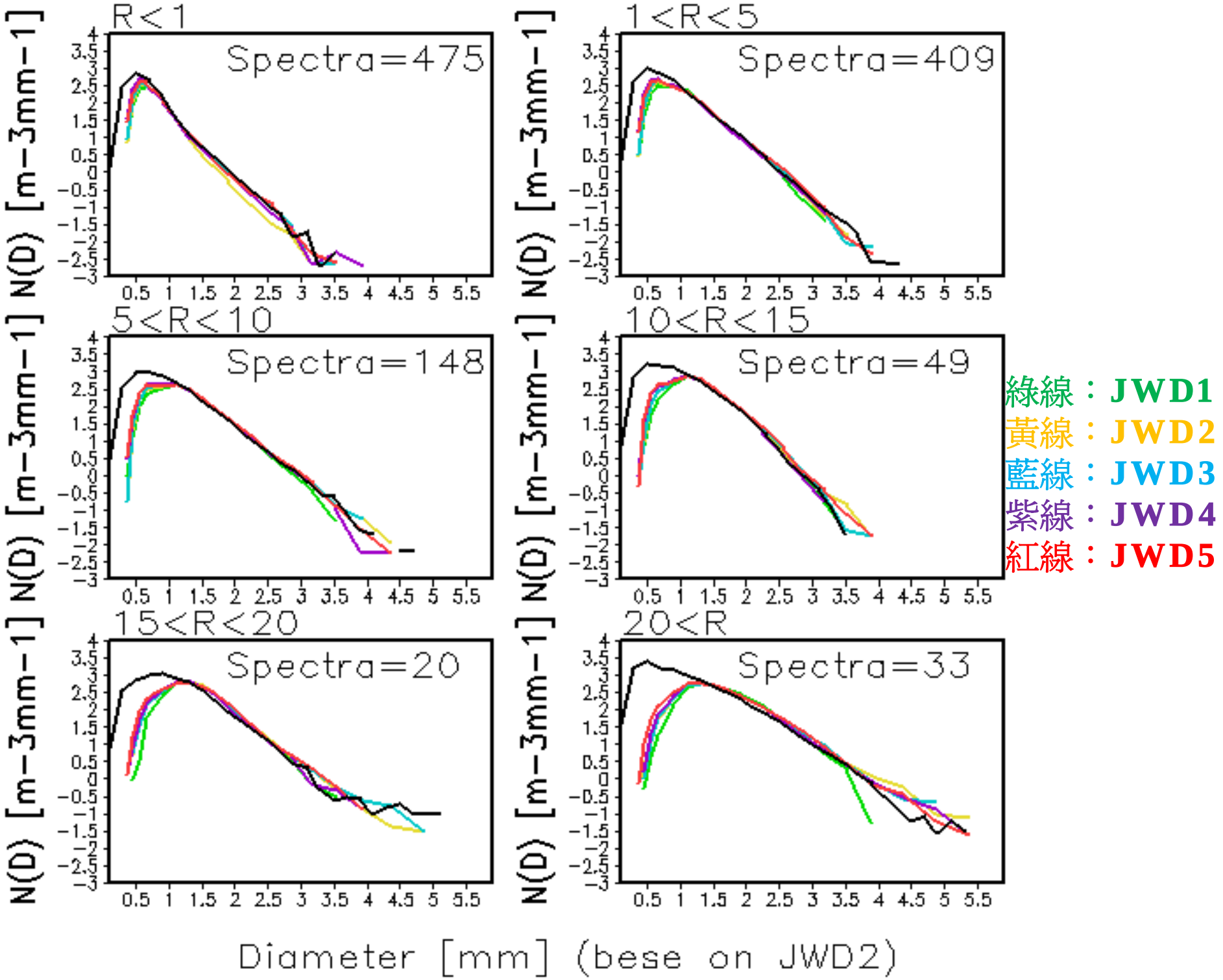
Deployment of Instruments[2]



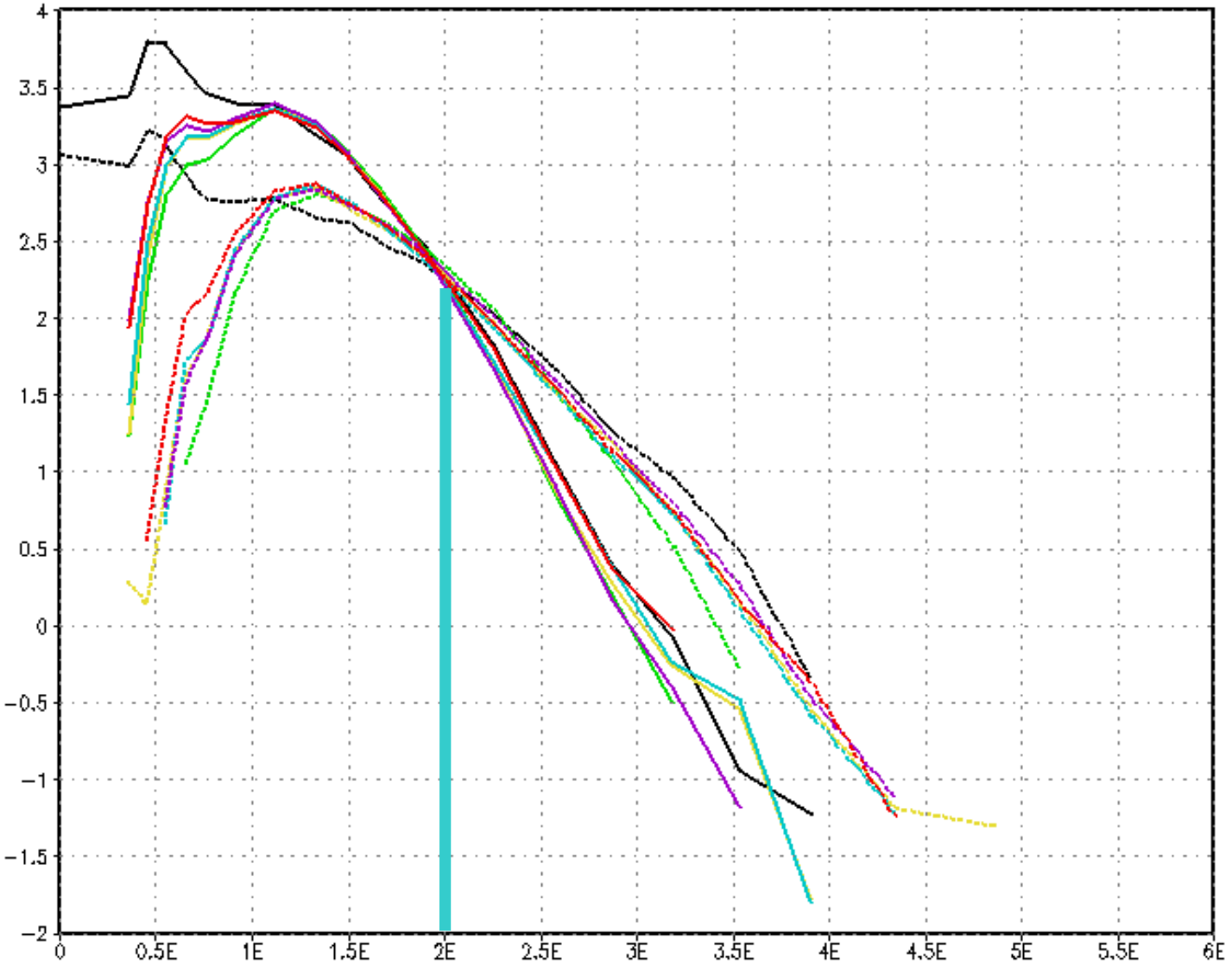


黑線：2DVD
綠線：JWD1
黃線：JWD2
藍線：JWD3
紫線：JWD4
紅線：JWD5

Drop Size Diameter [mm]


R<1
Spectra=475
1<R<5
Spectra=409
5<R<10
Spectra=148
10<R<15
Spectra=49
15<R<20
Spectra=20
20<R
Spectra=33
N(D) [m-3mm-1]
Diameter [mm] (bese on JWD2)
綠線：JWD1
黃線：JWD2
藍線：JWD3
紫線：JWD4
紅線：JWD5

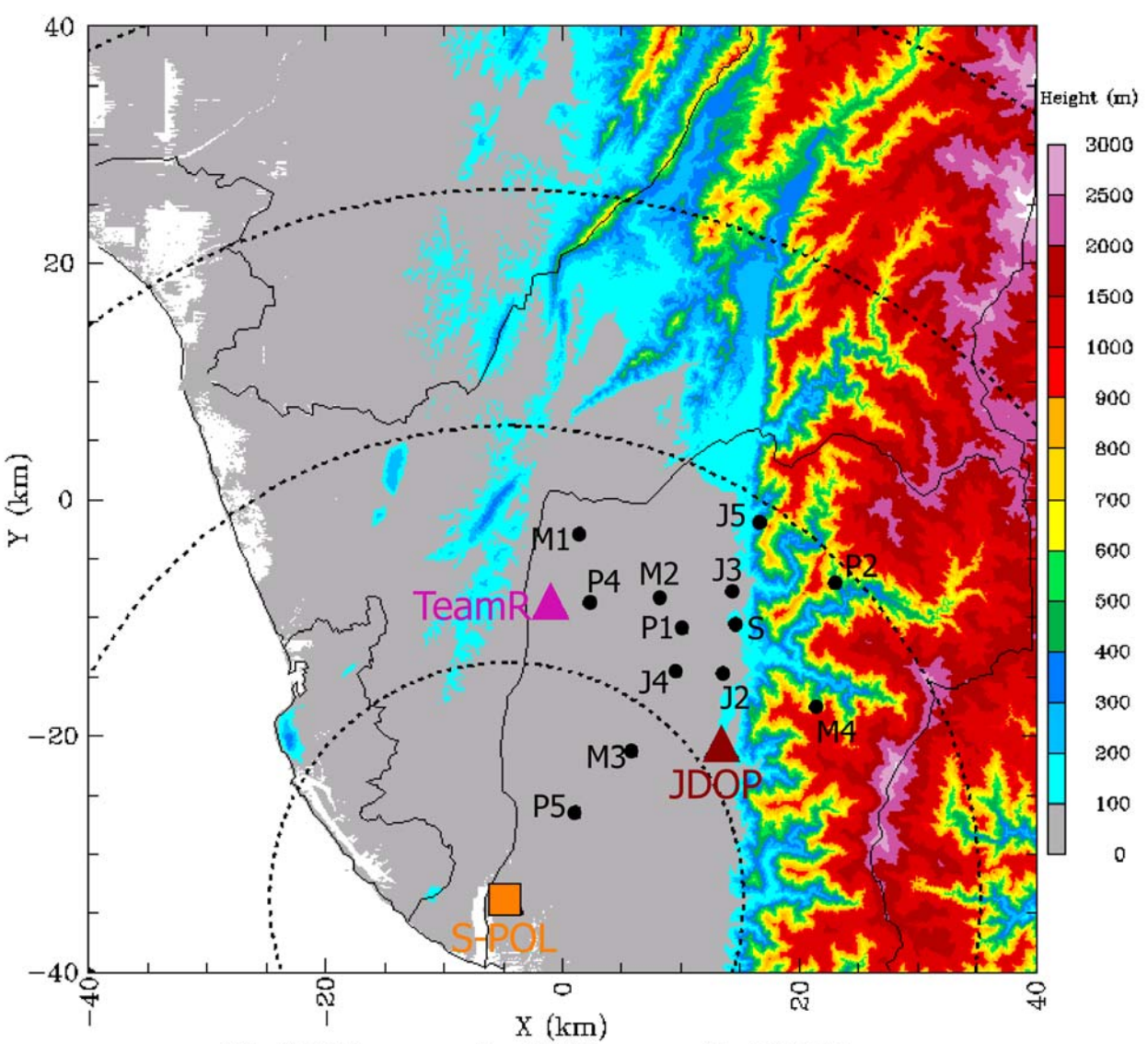
May 6 case



線：2DVD
綠線：JWD1
黃線：JWD2
藍線：JWD3
紫線：JWD4
紅線：JWD5

lid：strati.
sh：convec.

Spatial deployment



M: MRR J: JWD P: POSS

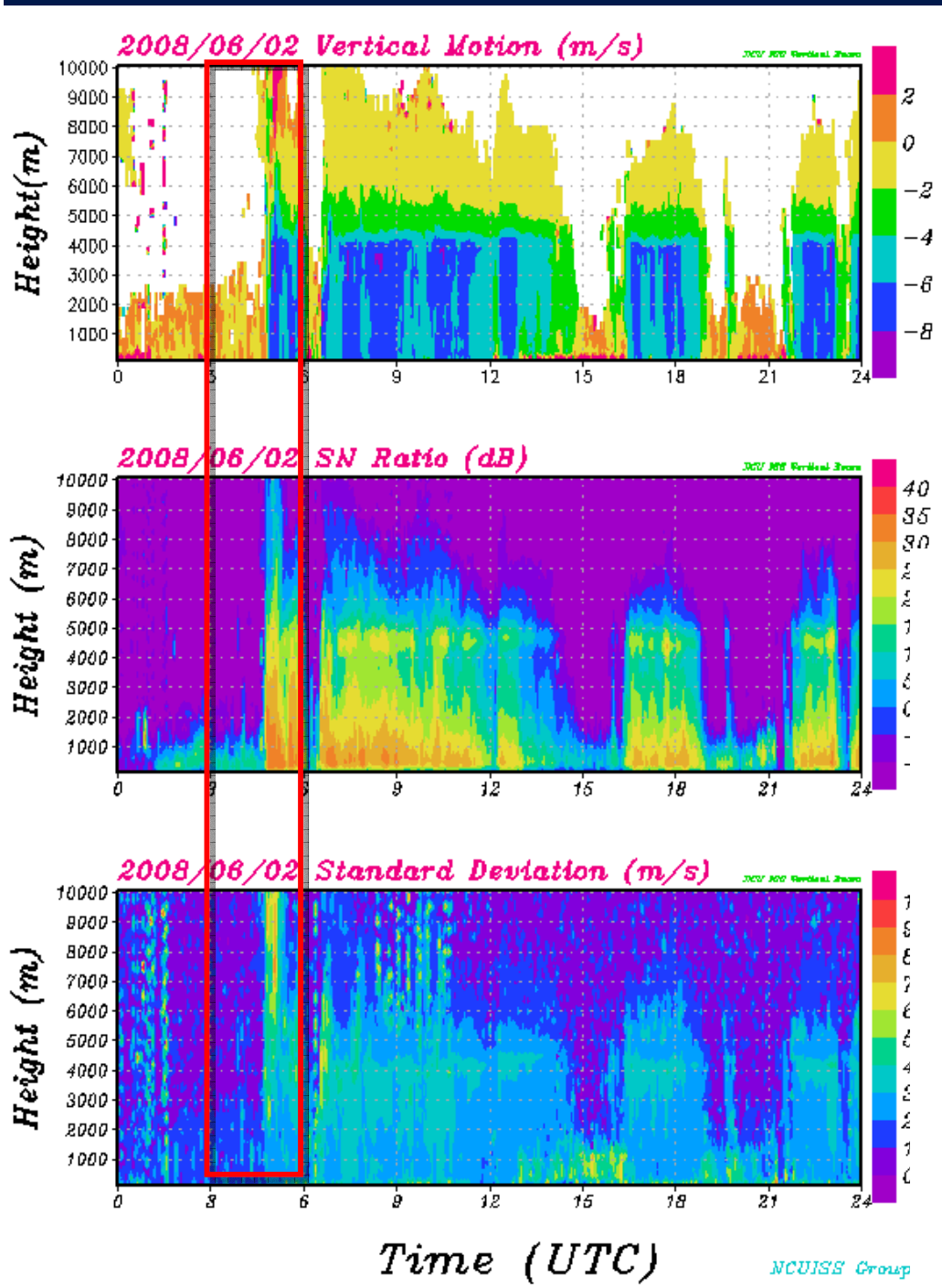
S: Supersite (VertiX, ISS, 2DVD, J1, P3, M5)

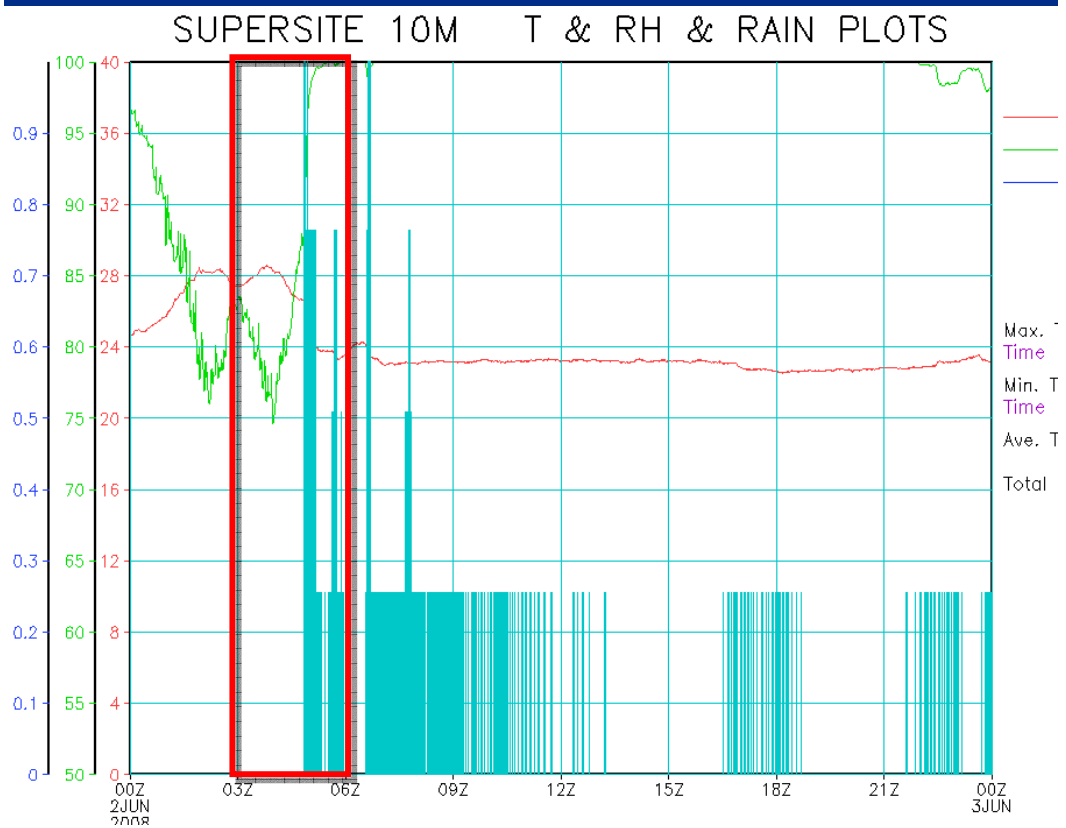
INSTRUMENT	Provider	STATION
VertiX	KNU (Korea)	Supersite (Quan-Xin)
2DVD	NCU	
JWD(J1)	NCU1	
MRR(M5)	KNU (Korea)	
POSS(P3)	EC1 (Canada)	
ISS	NCU	
Raingauge (tipping)	CWB	
Raingauge (traditional)	CWB	
POSS(P1)	McGill (Canada)	Gau-Lan
POSS(P2)	PKNU (Korea)	Te-Wen
POSS(P4)	EC2 (Canada)	Ho-Juan
POSS(P5)	EC3 (Canada)	Si-Wei
MRR(M1)	CCU1	Tu-Ku
MRR(M2)	CCU2	Lin-Luo
MRR(M3)	CCU3	Shi-Long
MRR(M4)	CCU4	Ma-Jia. V. O.
JWD(J2)	CCU	Ma-Jia J. H. S
JWD(J3)	NCU2	Quan-Fu
JWD(J4)	NCU3	Fan-Hua
JWD(J5)	NCU4	Chin-San

Stage 2: Supersite

Deep Convective

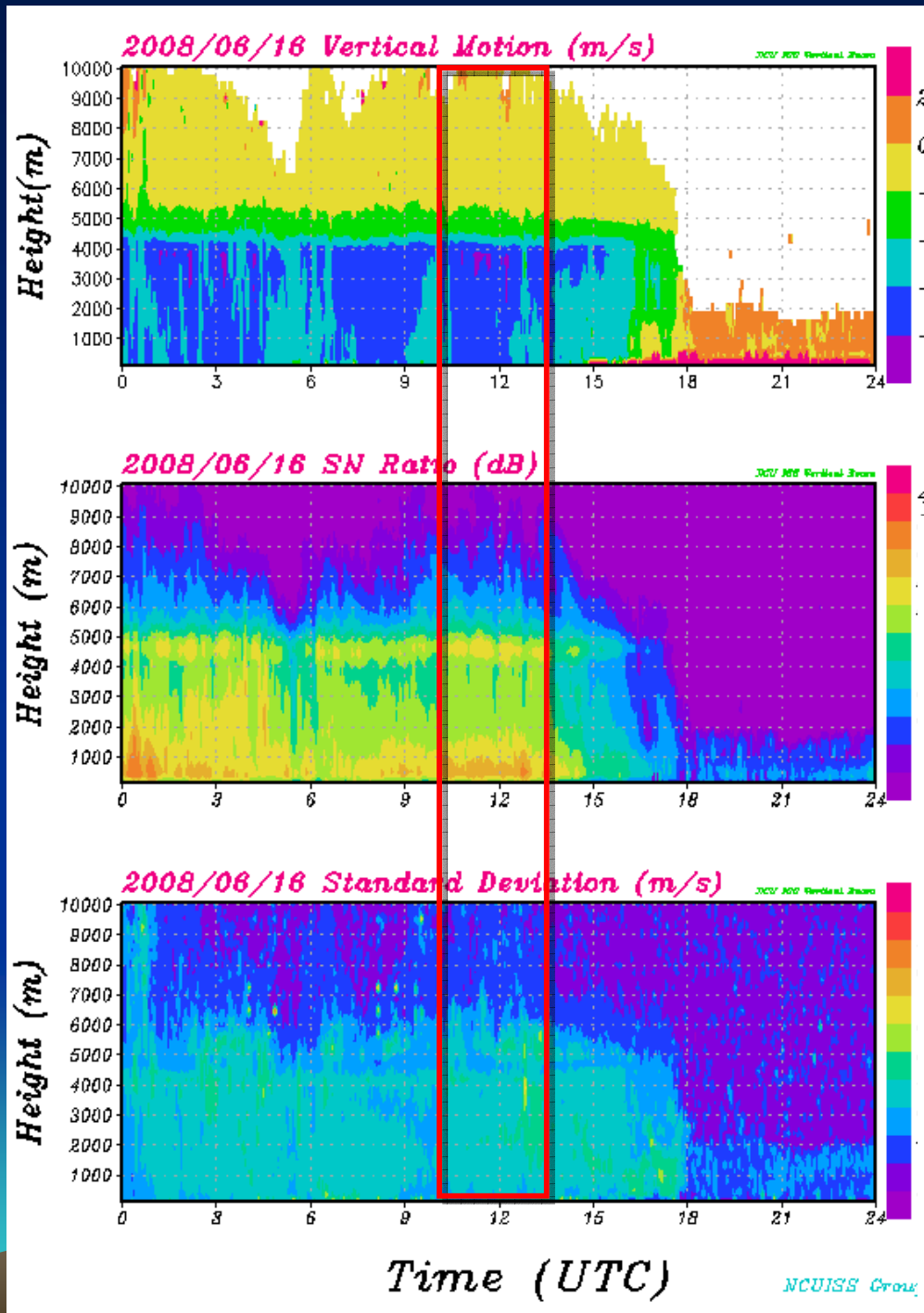
2008/06/02

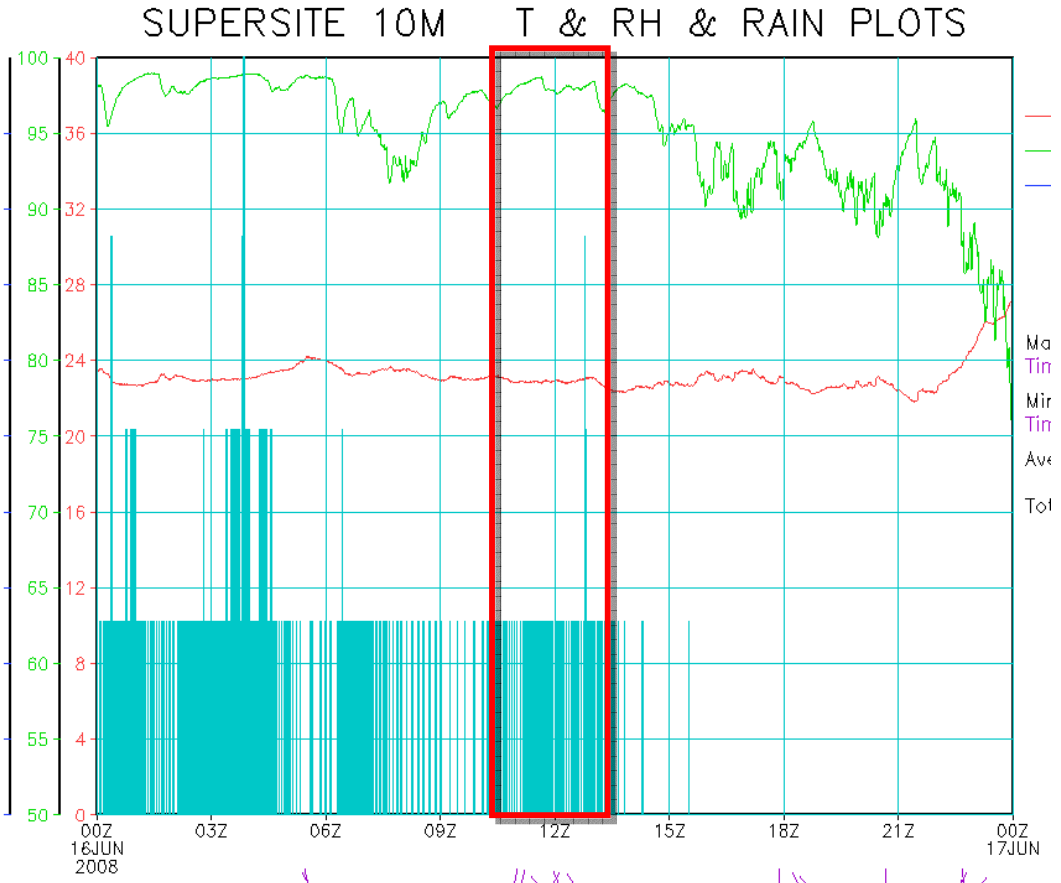




Stratiform Precipitation

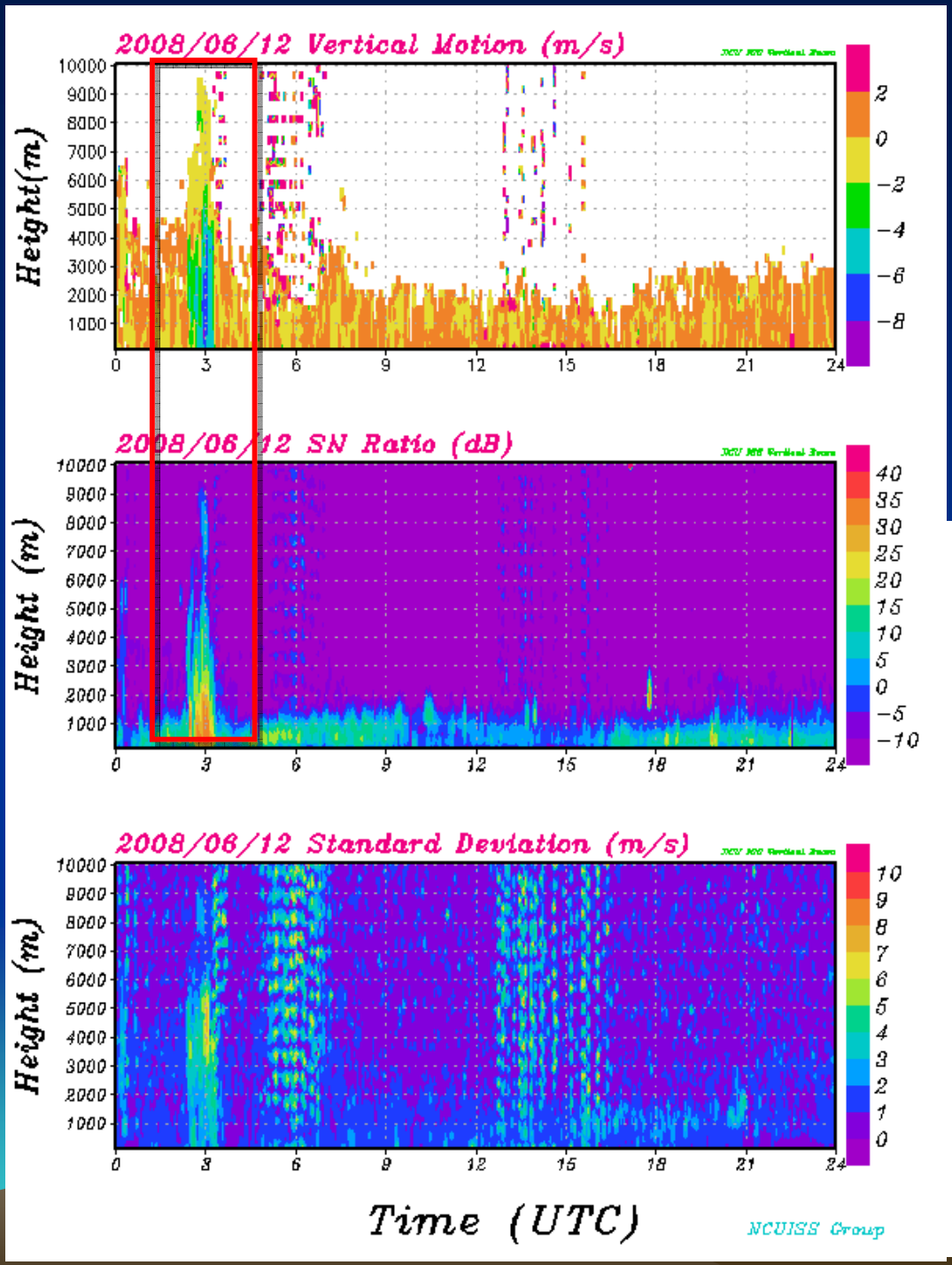
2008/06/16

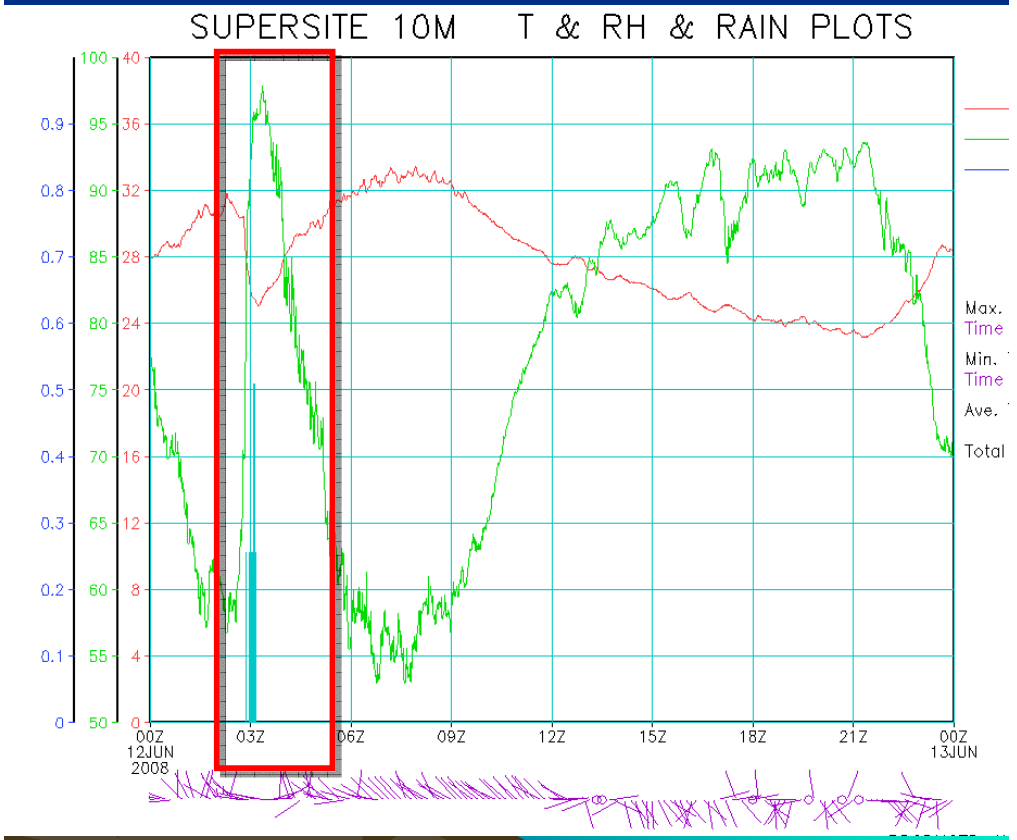




Shallow Convective

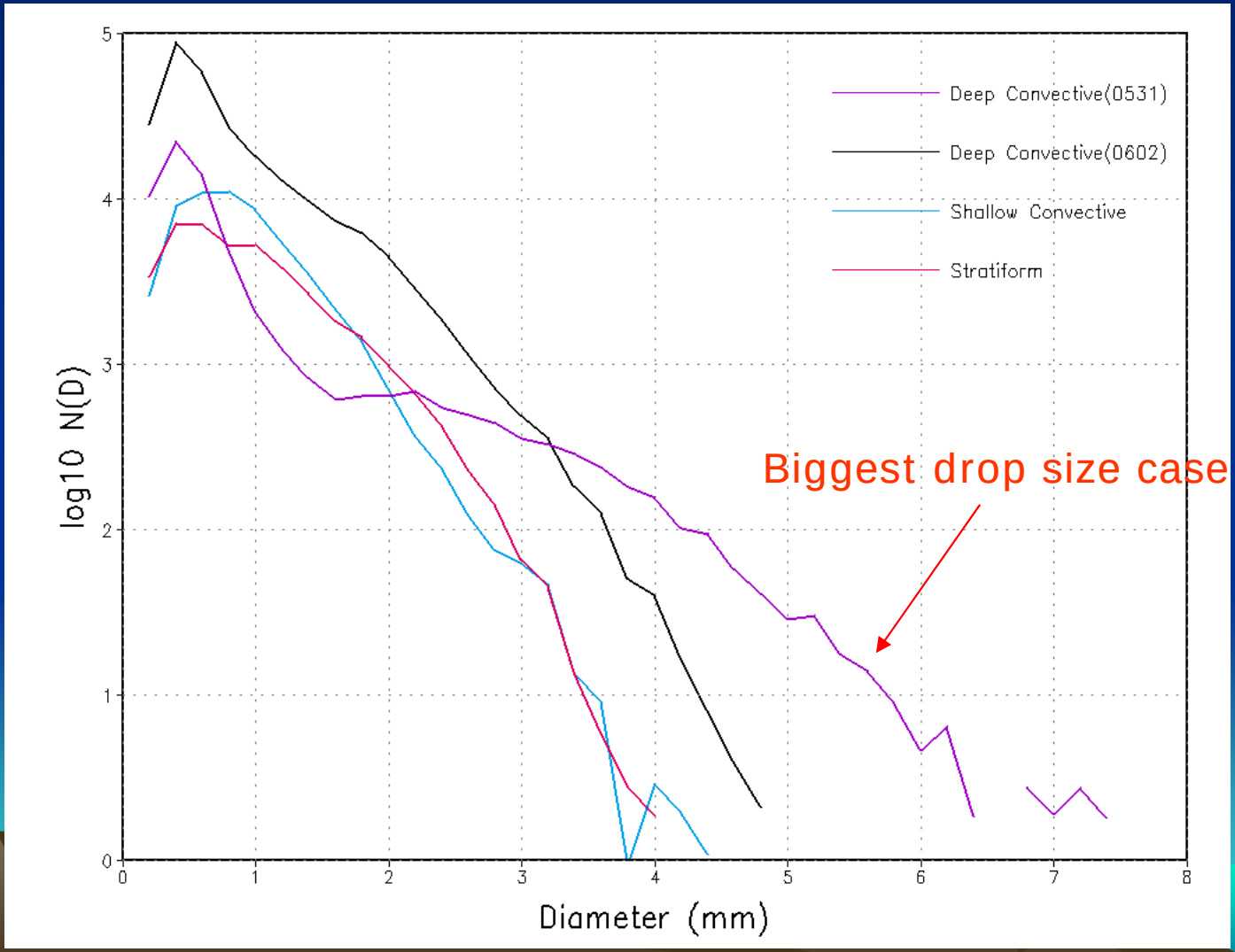
2008/06/12

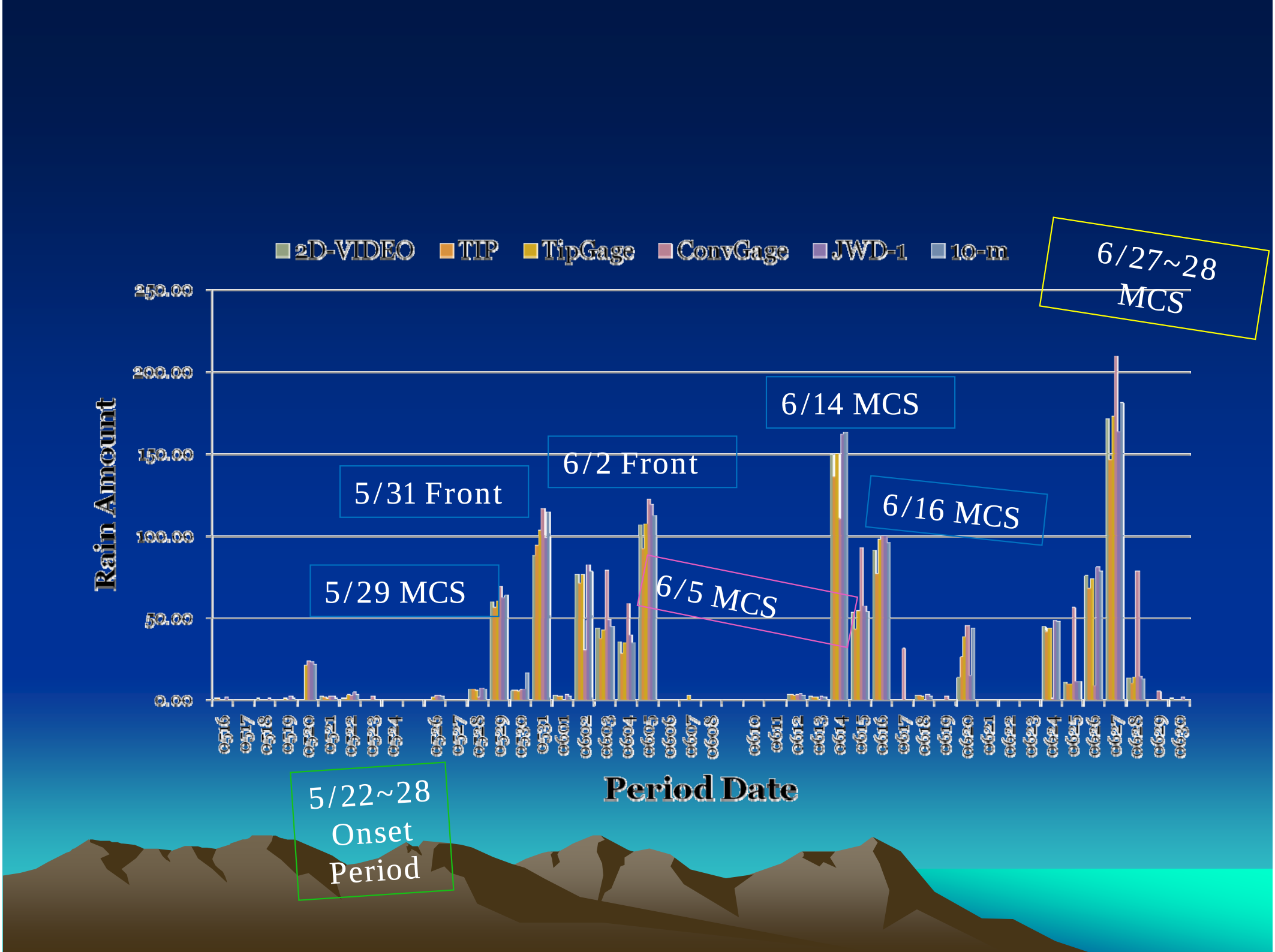




Drop size Distribution of Different Precipitation Type

Biggest drop size case (2008/05/31) : exceed 7 mm




2D-VIDEO
TIP
TipGage
ConvGage
JWD-1
10-m
Rain Amount
250.00
200.00
150.00
100.00
50.00
0.00
Period Date
6/27~28 MCS
6/14 MCS
6/2 Front
5/31 Front
6/16 MCS
6/5 MCS
5/29 MCS
5/22~28 Onset Period

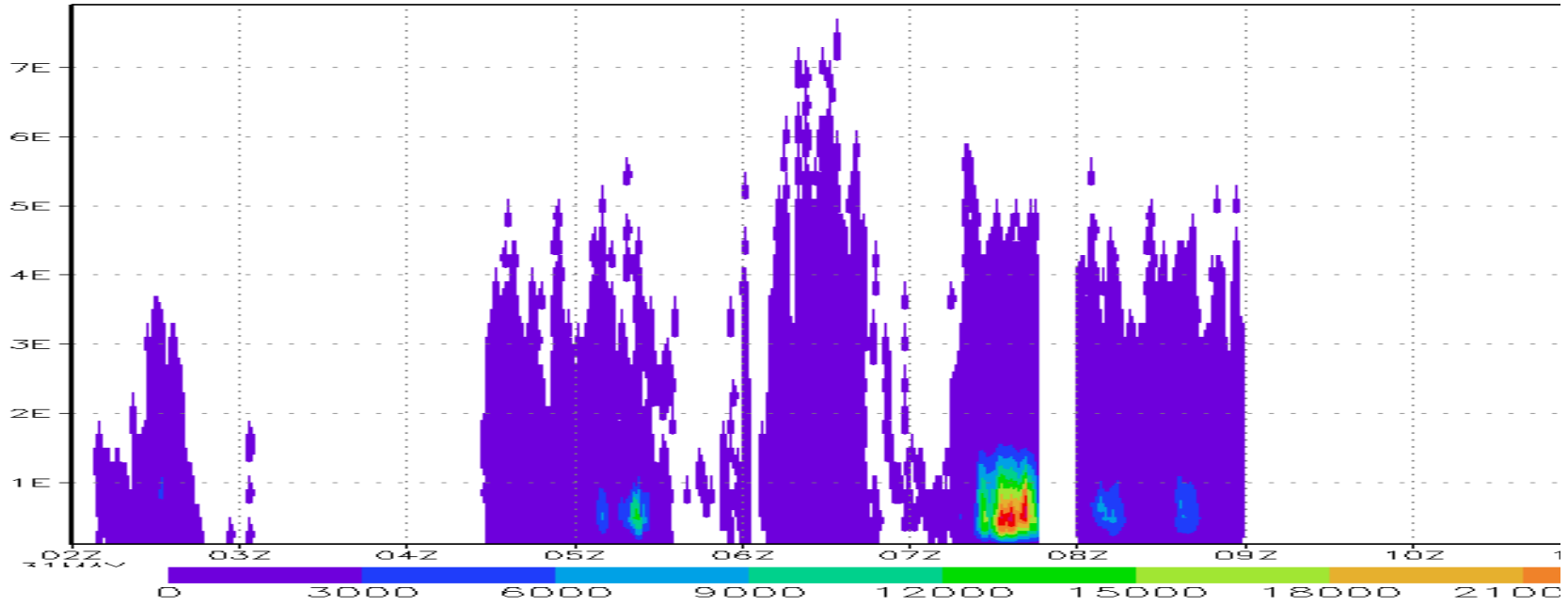
Precipitation Classification

- Tokay et. al(1996) ：N0-R
- Bringi et. al(2003)：SD
- Testud et. al(2001)：10 minutes data
- Chang et. al(2009)：

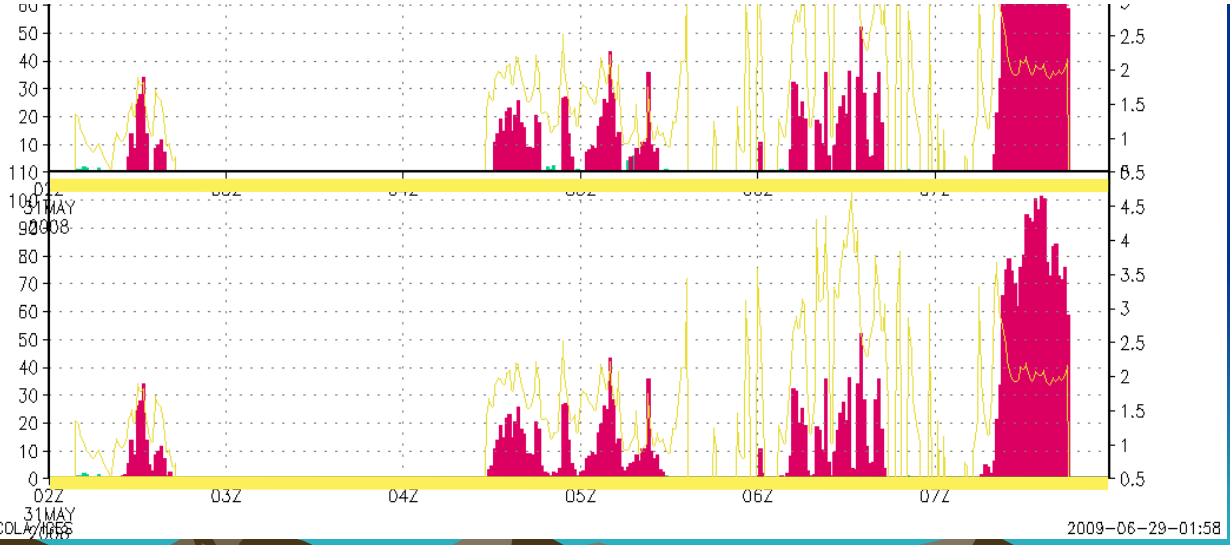
stratiform：**R < 20 mm/hr**
convective： **R > 20 mm/hr**

個案討論(1)5/31

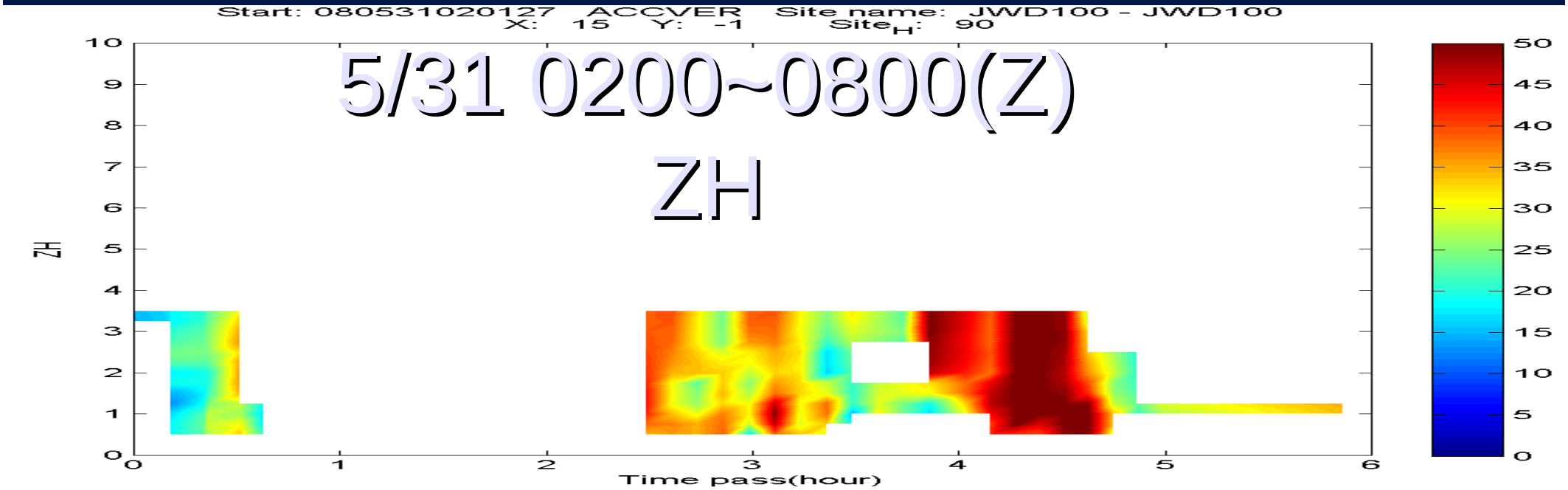
(a)

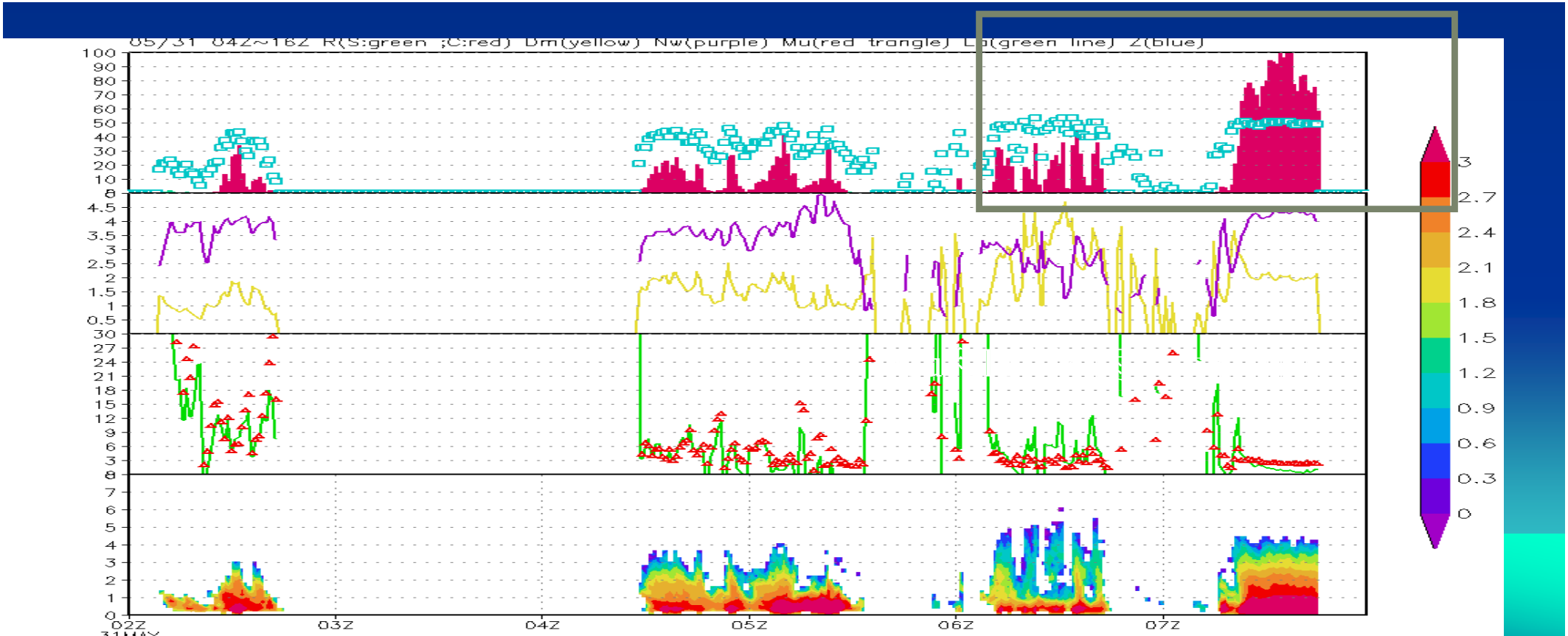


(b) Bring

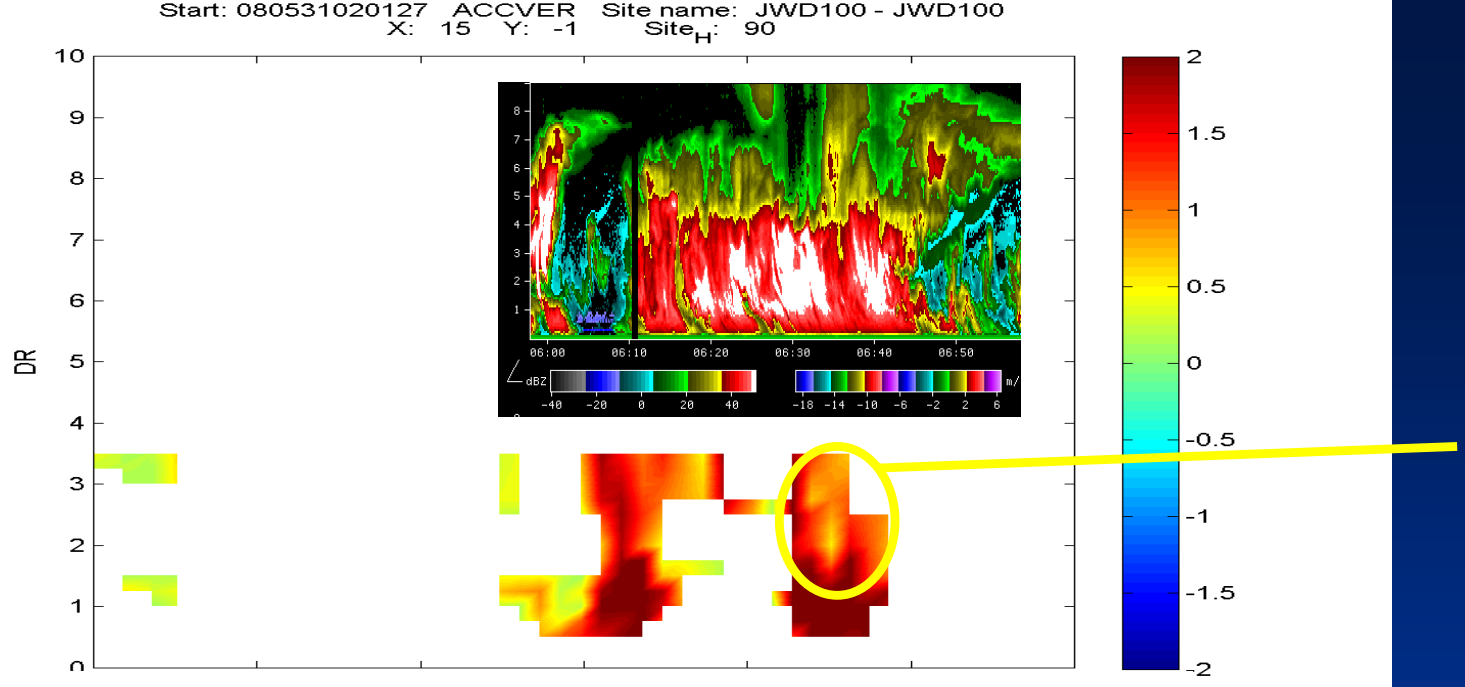


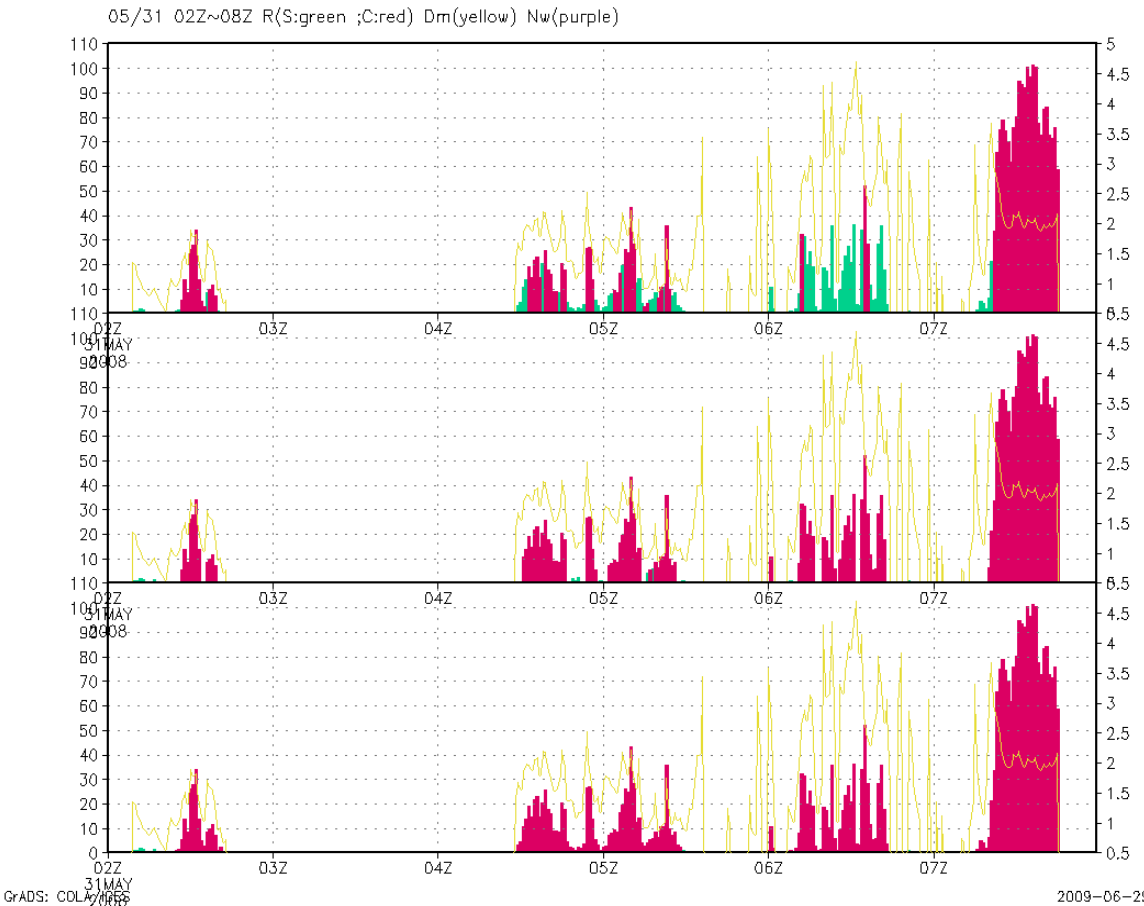
(c) Testu


Start: 080531020127 ACCVER Site name: JWD100 - JWD100
X: 15 Y: -1 Site_H: 90
5/31 0200~0800(Z)
ZH
ZH
Time pass(hour)


05/31 04Z~16Z R(S:green ;C:red) Dm(yellow) Nw(purple) Mu(red trangle) La(green line) Z(blue)
02Z
03Z
04Z
05Z
06Z
07Z

5/31 0200~0800 ZDR

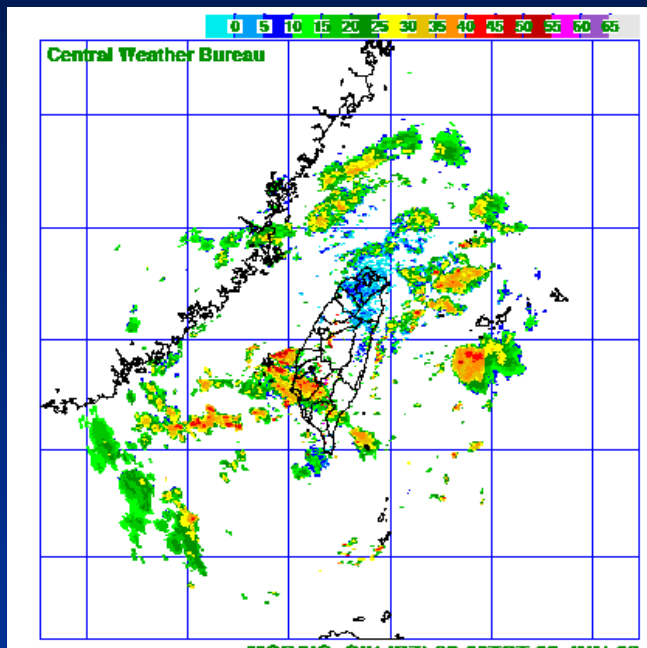


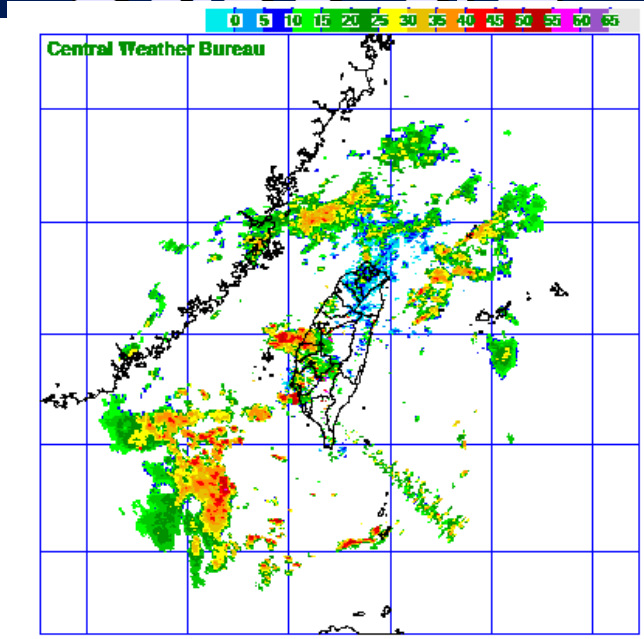


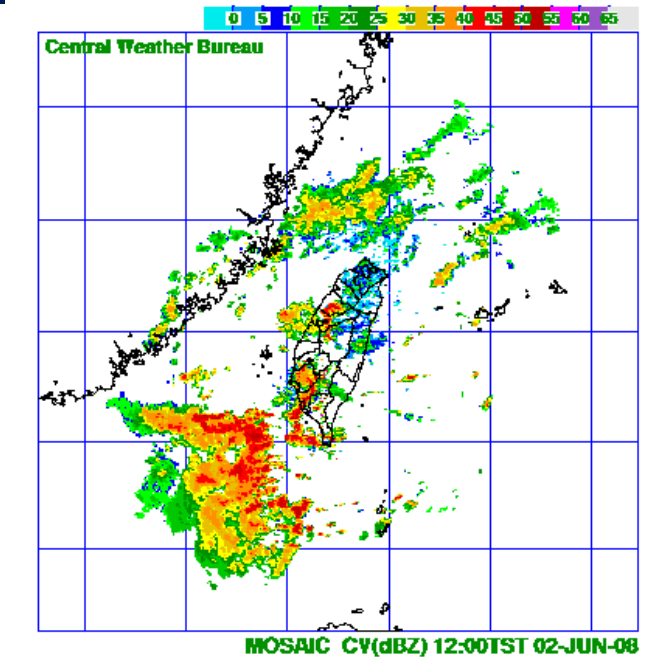
GrADS: COLA/IGES

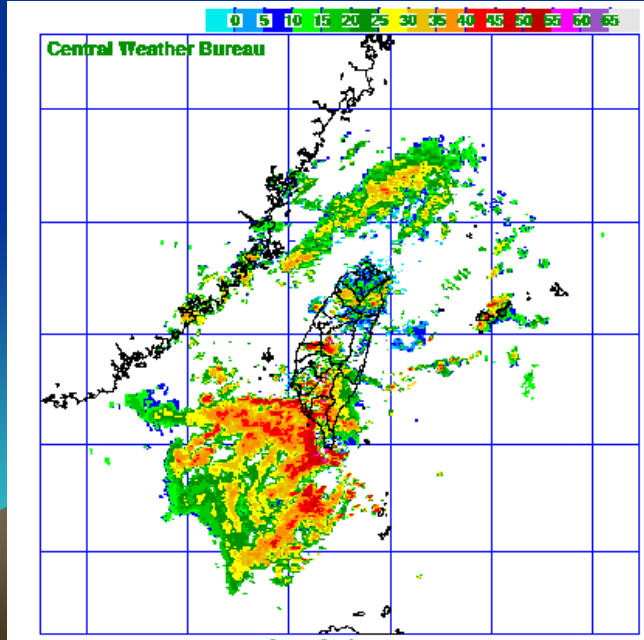
2009-06-29-01:58

Case 6/2


Central Weather Bureau
MOSAIC CV(dBZ) 08:00TST 02-JUN-08


Central Weather Bureau
MOSAIC CV(dBZ) 10:00TST 02-JUN-08


Central Weather Bureau
MOSAIC CV(dBZ) 12:00TST 02-JUN-08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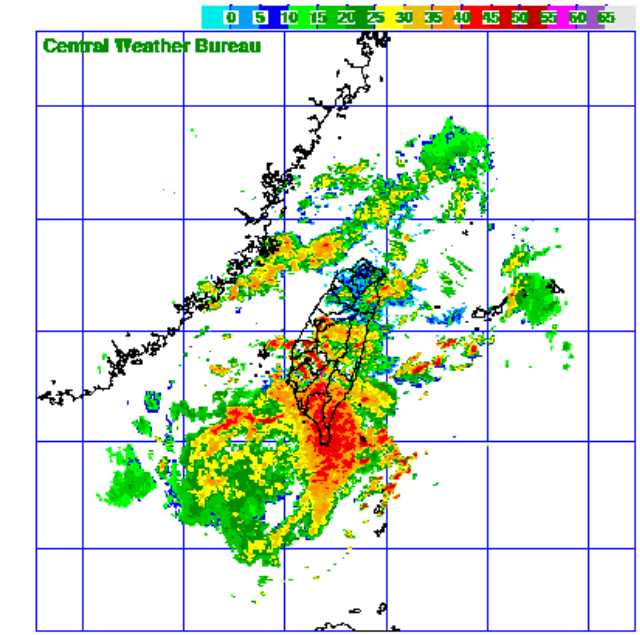
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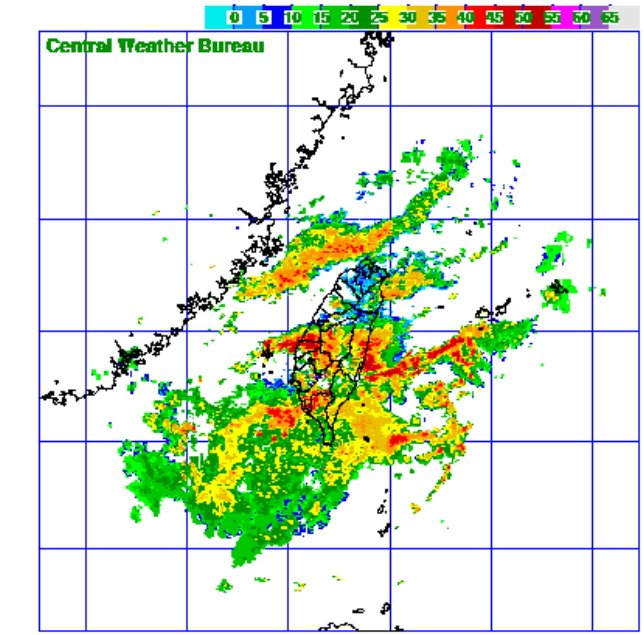
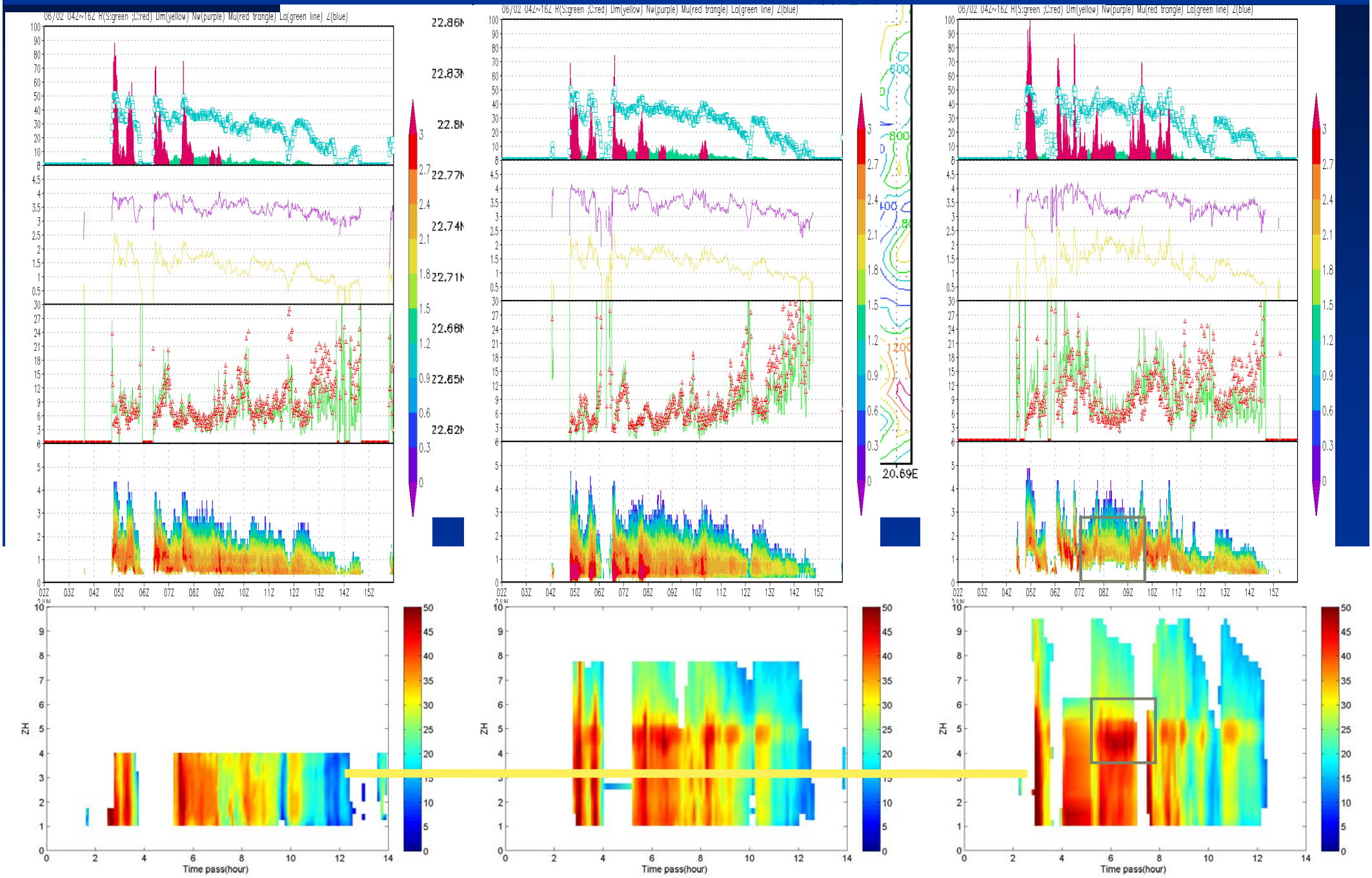

Central Weather Bureau
MOSAIC CV(dBZ) 18:00TST 02-JUN-08

▲ : mu --- : lambda -- : Nw -- : Dm -- : Z

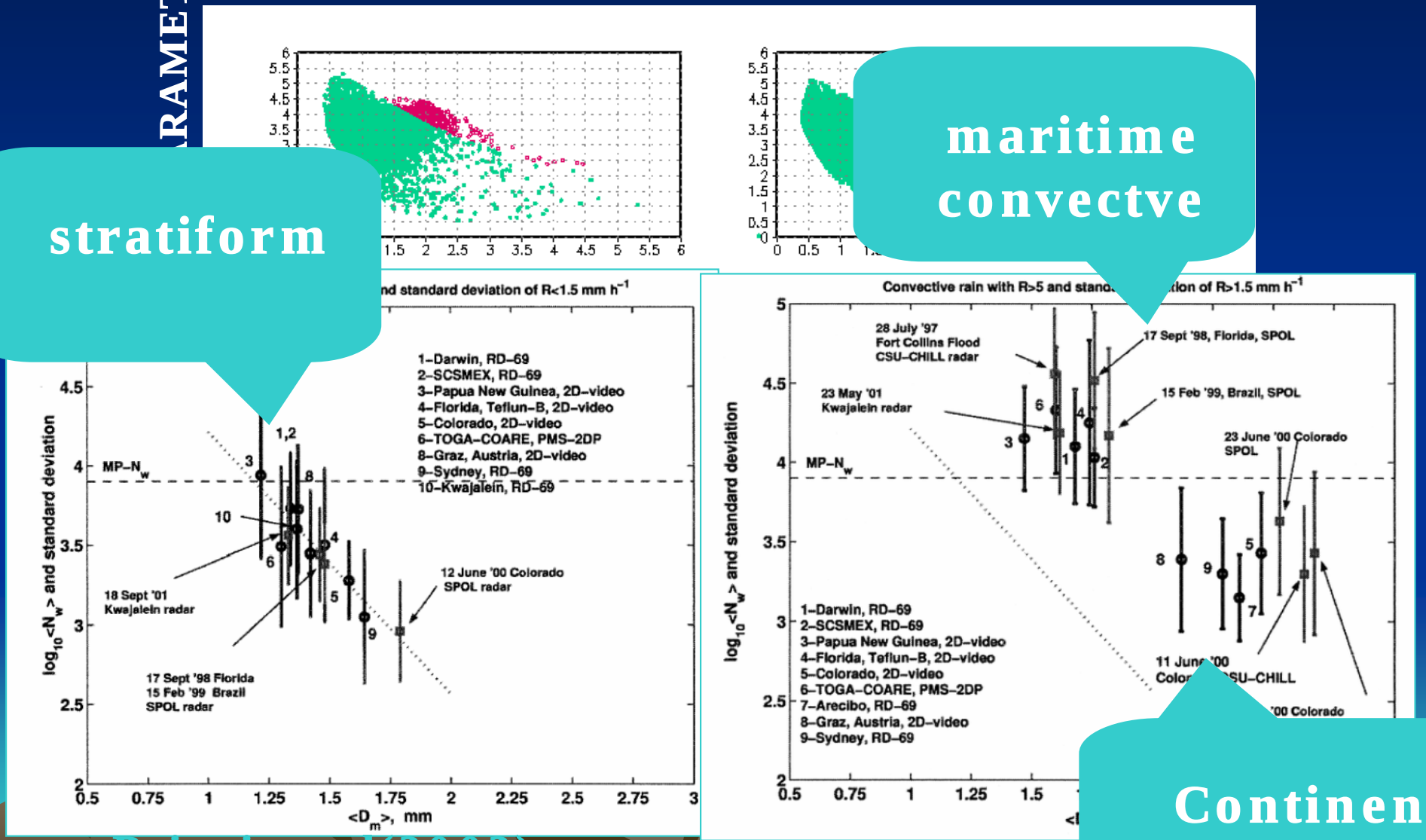


Dm-Nw

RAMETER

stratiform

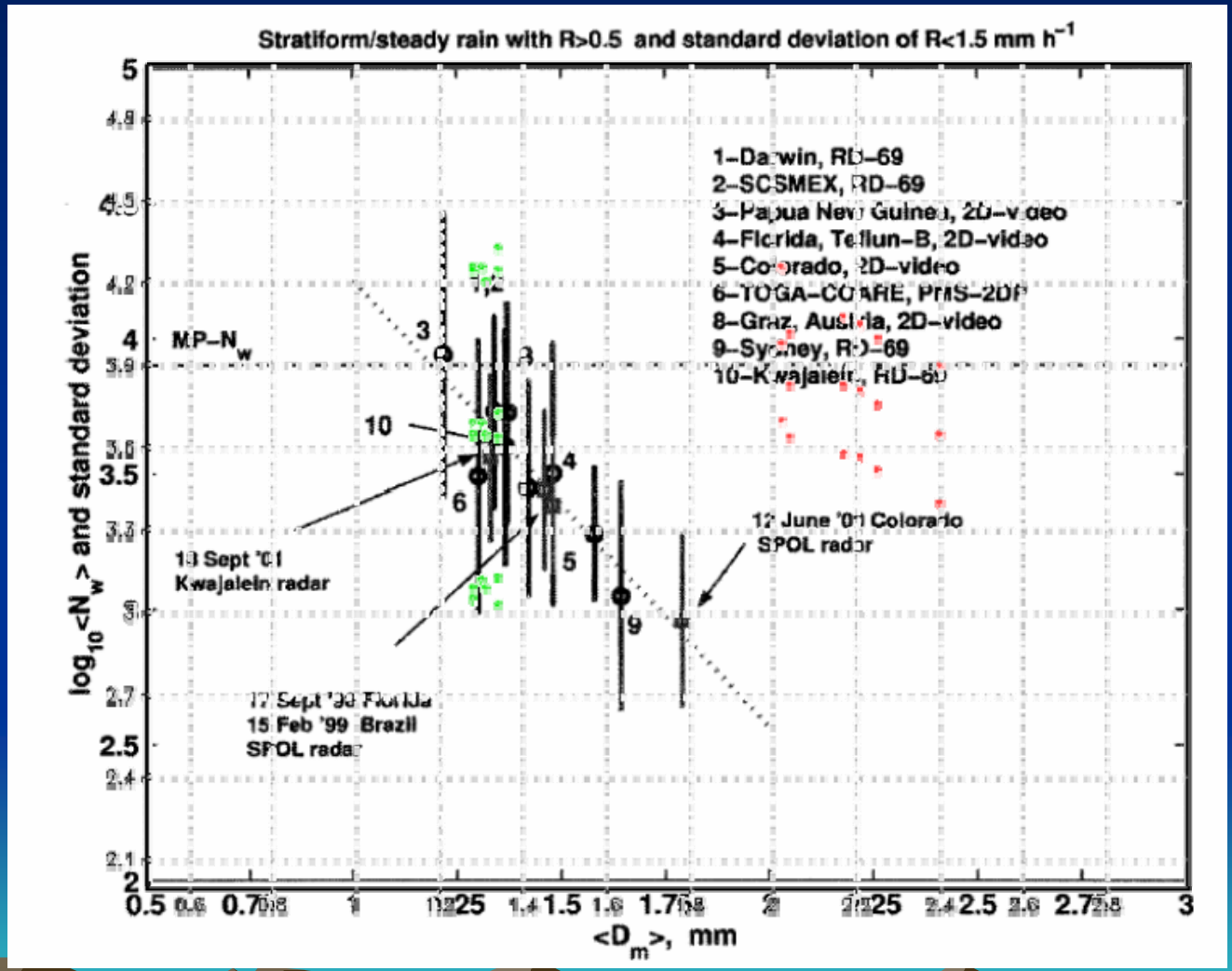
maritime convectve



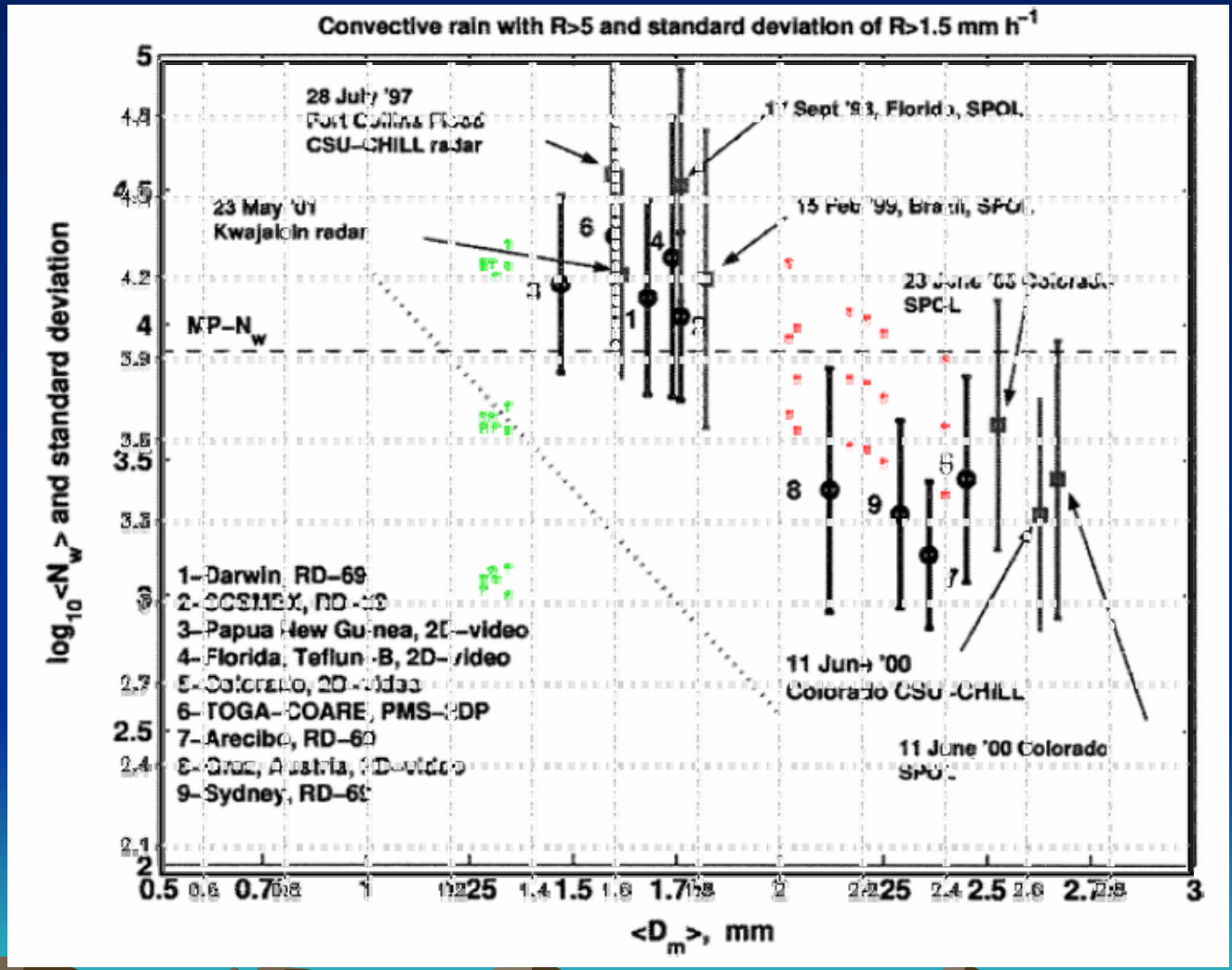
Bringi et. al(2003)

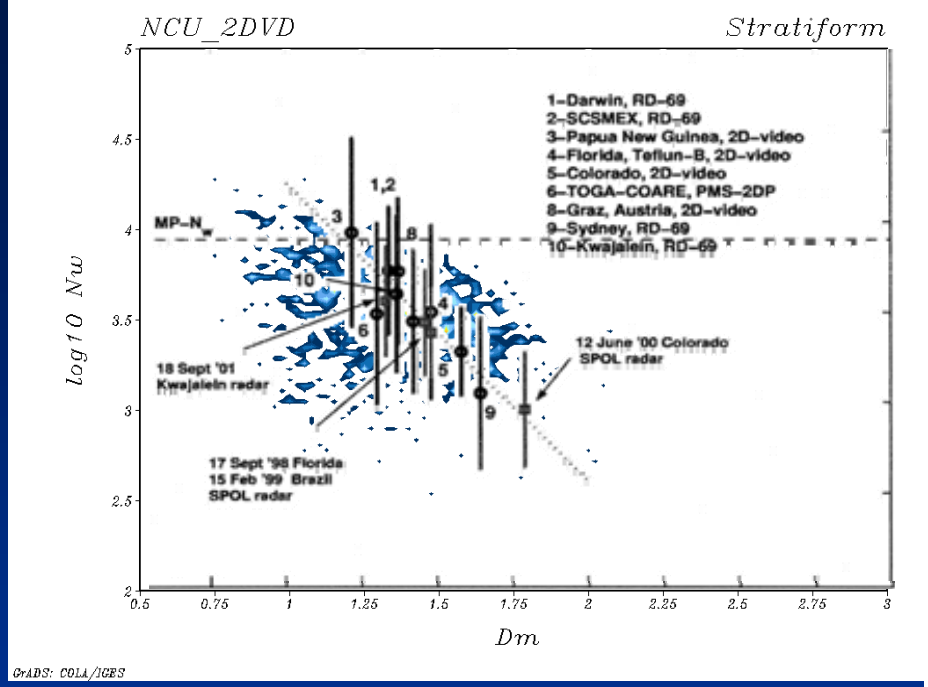
Continental convective

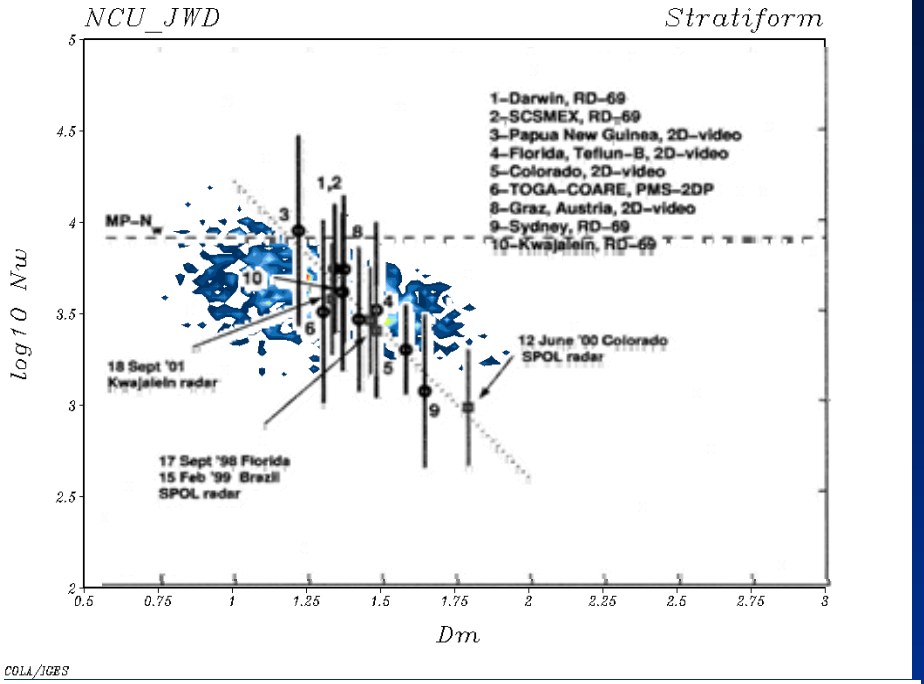
STRAITIFORM

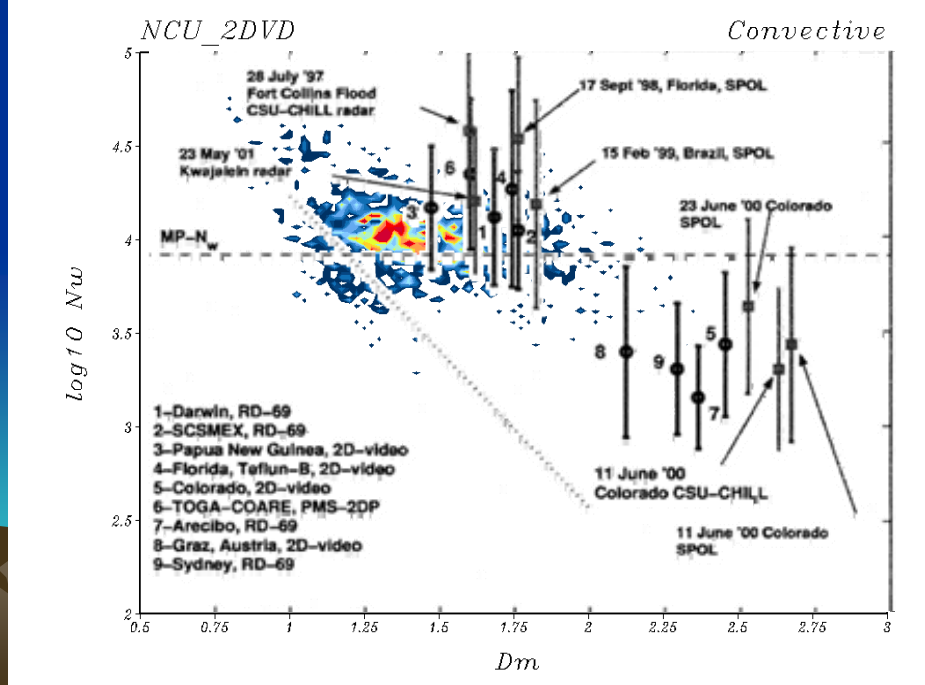


CONVECTIVE


Convective rain with R>5 and standard deviation of R>1.5 mm h^{-1}
28 July '97
Fort Collins flood
CSU-CHILL radar
23 May '01
Kwajalein radar
MP-N_w
1-Darwin, RD-69
3-Papua New Guinea, 2D-video
4-Florida, Teflun-B, 2D-video
6-TOGA-COARE, PMS-2DP
7-Arecibo, RD-69
9-Sydney, RD-69
11 June '00
Colorado CSU-CHILL
11 June '00 Colorado
SPOL
$\log_{10}\langle N_w \rangle$ and standard deviation
$\langle D_m \rangle$, mm


NCU_2DVD
Stratiform
1–Darwin, RD–69
2–SCSMEX, RD–69
3–Papua New Guinea, 2D–video
4–Florida, Teflun–B, 2D–video
5–Colorado, 2D–video
6–TOGA–COARE, PMS–2DP
8–Graz, Austria, 2D–video
9–Sydney, RD–69
10–Kwajalein, RD–69
MP–N_w
18 Sept '01
Kwajalein radar
12 June '00 Colorado
SPOL radar
17 Sept '98 Florida
15 Feb '99 Brazil
SPOL radar
Log10 Nw
Dm
GrADS: COLA/IGES


NCU_JWD
Stratiform
1–Darwin, RD–69
2–SCSMEX, RD–69
3–Papua New Guinea, 2D–video
4–Florida, Teflun–B, 2D–video
5–Colorado, 2D–video
6–TOGA–COARE, PMS–2DP
8–Graz, Austria, 2D–video
9–Sydney, RD–69
10–Kwajalein, RD–69
MP–N_w
18 Sept '01
Kwajalein radar
12 June '00 Colorado
SPOL radar
17 Sept '98 Florida
15 Feb '99 Brazil
SPOL radar
Log10 Nw
Dm
GrADS: COLA/IGES


NCU_2DVD
Convective
28 July '97
Fort Collins Flood
CSU–CHILL radar
17 Sept '98, Florida, SPOL
23 May '01
Kwajalein radar
15 Feb '99, Brazil, SPOL
23 June '00 Colorado
SPOL
MP–N_w
1–Darwin, RD–69
2–SCSMEX, RD–69
3–Papua New Guinea, 2D–video
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5–Colorado, 2D–video
6–TOGA–COARE, PMS–2DP
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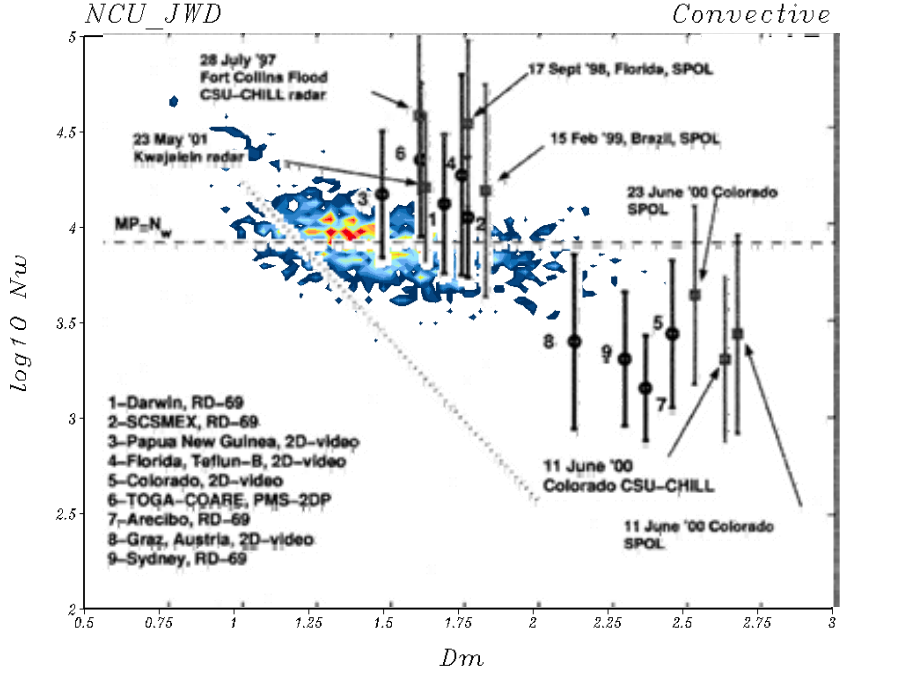
8–Graz, Austria, 2D–video
9–Sydney, RD–69
11 June '00
Colorado CSU–CHILL
11 June '00 Colorado
SPOL
Log10 Nw
Dm
GrADS: COLA/IGES


NCU_JWD
Convective
28 July '97
Fort Collins Flood
CSU–CHILL radar
17 Sept '98, Florida, SPOL
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Kwajalein radar
15 Feb '99, Brazil, SPOL
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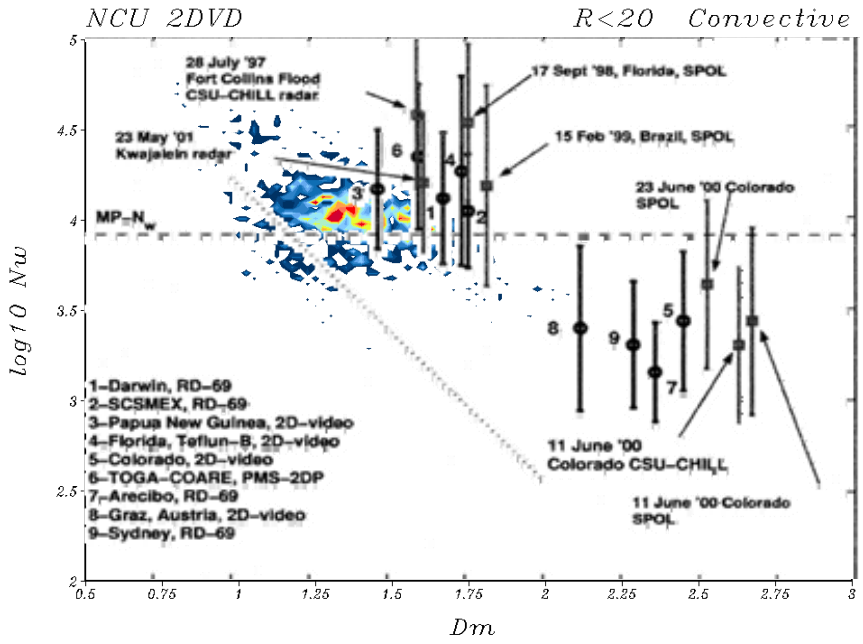
9–Sydney, RD–69
11 June '00
Colorado CSU–CHILL
11 June '00 Colorado
SPOL
Log10 Nw
Dm
COLA/IGES


NCU 2DVD
R<20 Convective
28 July '97
Fort Collins Flood
CSU-CHILL radar
17 Sept '98, Florida, SPOL
23 May '01
Kwajalein radar
15 Feb '99, Brazil, SPOL
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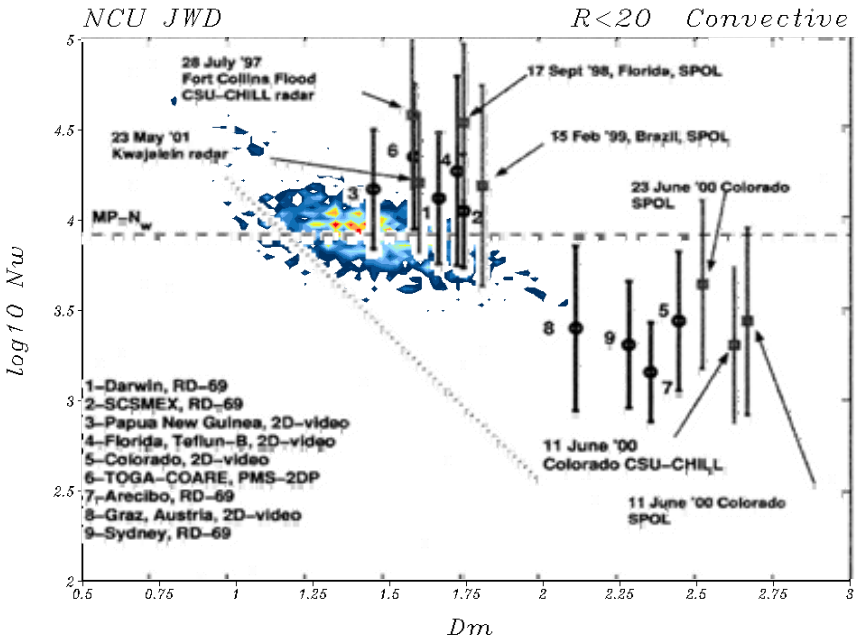
11 June '00
Colorado CSU-CHILL
11 June '00 Colorado
SPOL
log10 Nw
Dm


NCU JWD
R<20 Convective
28 July '97
Fort Collins Flood
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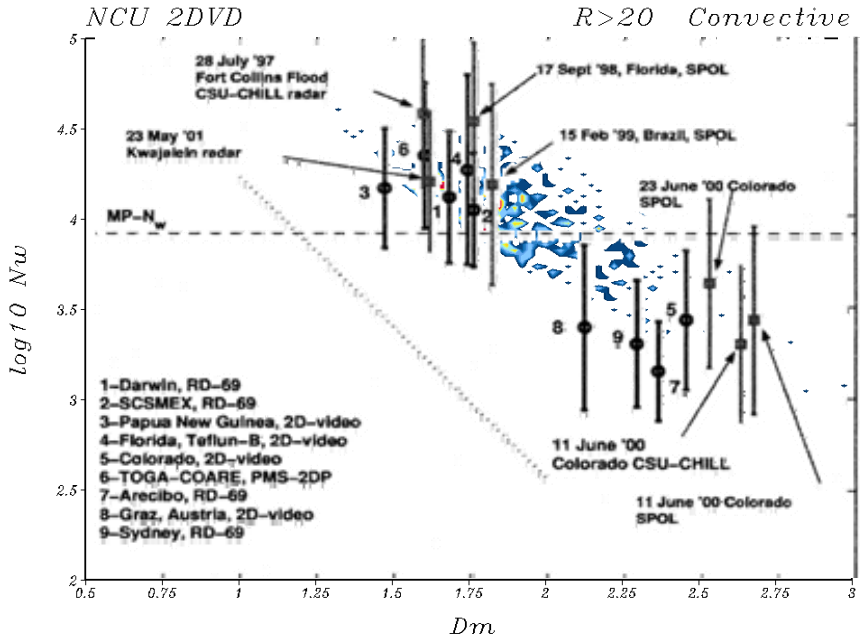
11 June '00
Colorado CSU-CHILL
11 June '00 Colorado
SPOL
log10 Nw
Dm


NCU 2DVD
R>20 Convective
28 July '97
Fort Collins Flood
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11 June '00
Colorado CSU-CHILL
11 June '00 Colorado
SPOL
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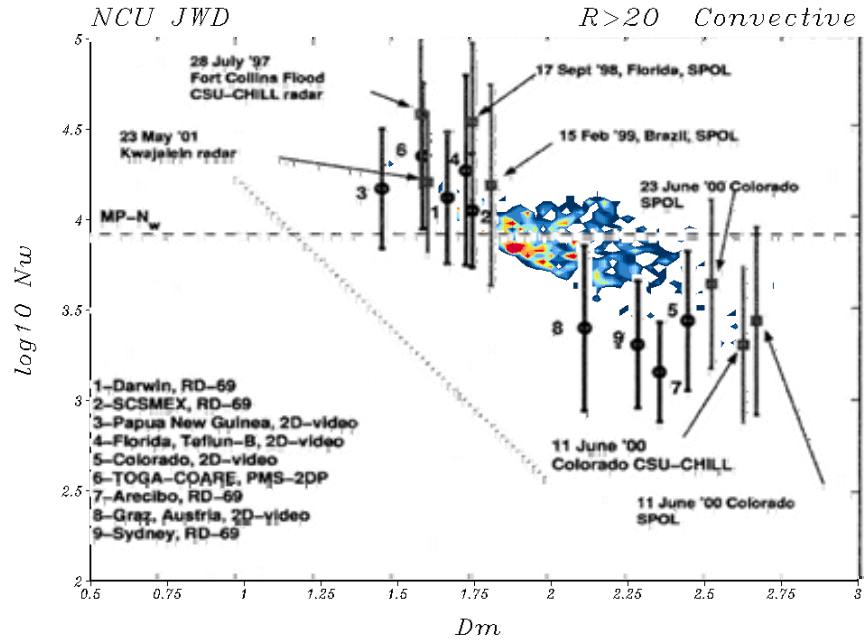
NCU JWD
R>20 Convective
28 July '97
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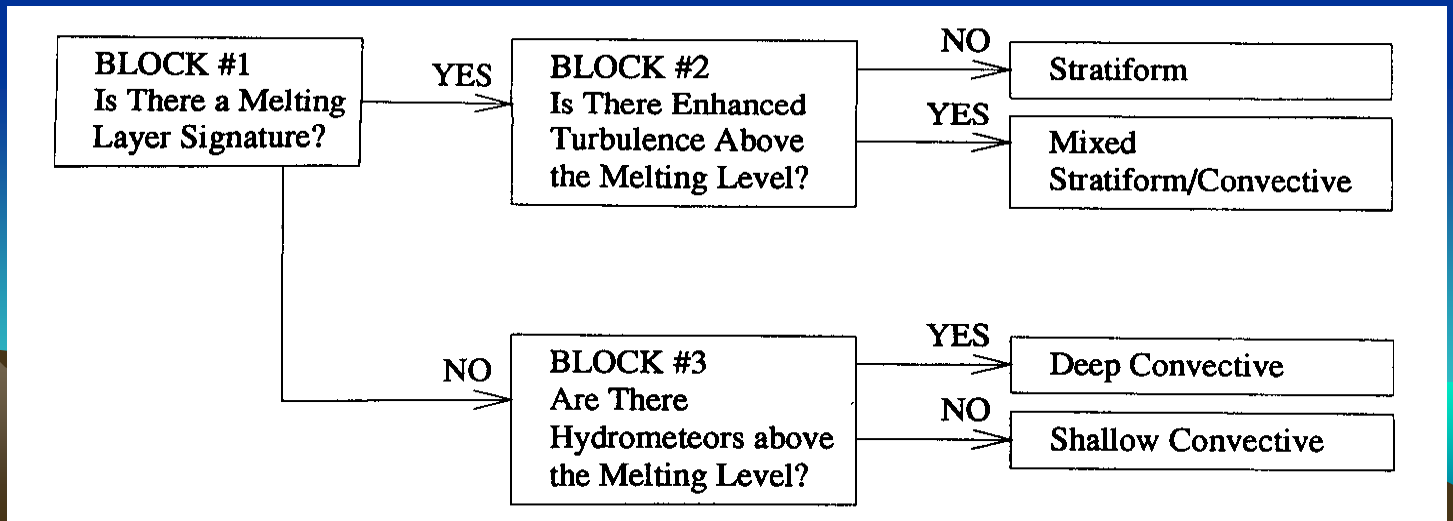
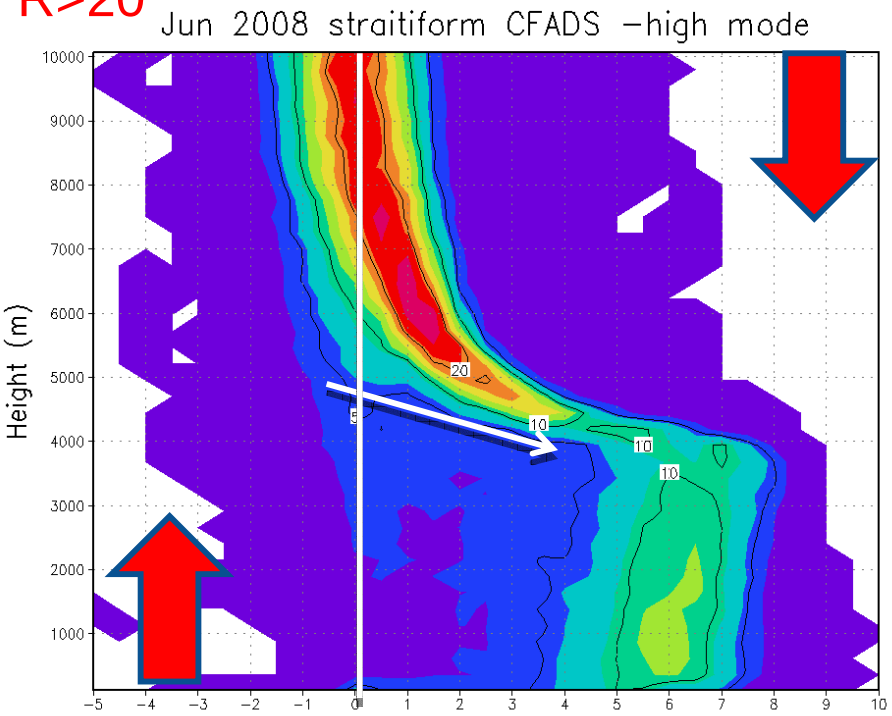
8-Graz, Austria, 2D-video
9-Sydney, RD-69
11 June '00
Colorado CSU-CHILL
11 June '00 Colorado
SPOL
log10 Nw
Dm

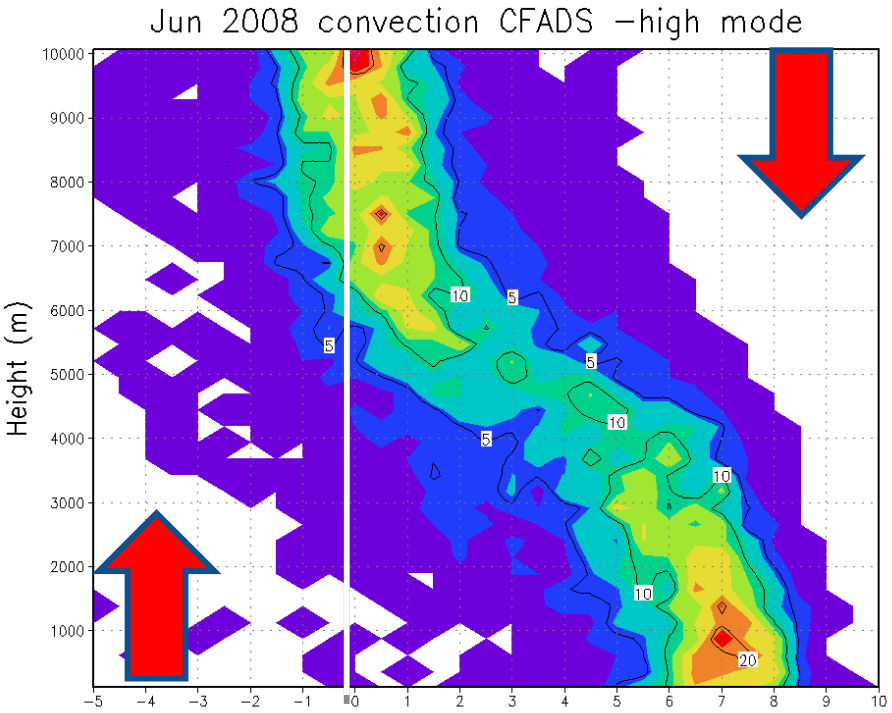
Precipitation Classification

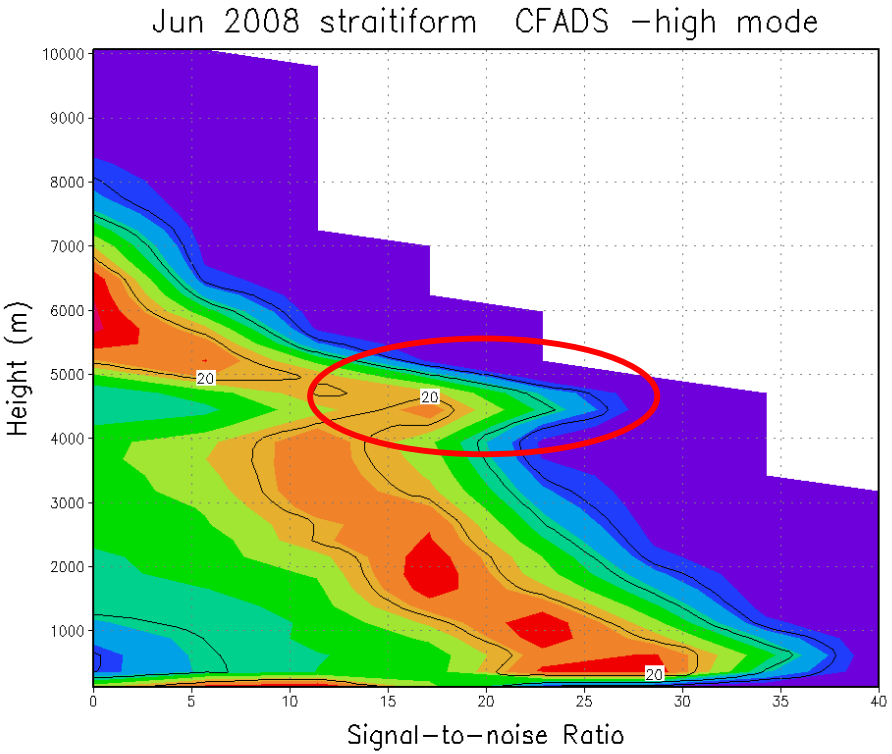
- Rain rate R > 20 (Tokay et al, 1999)
- NO-R (Tokay and Short, 1996)
- DVG(Doppler velocity gradient) and MSW(maximum spectral width) (Williams et al. 1995)

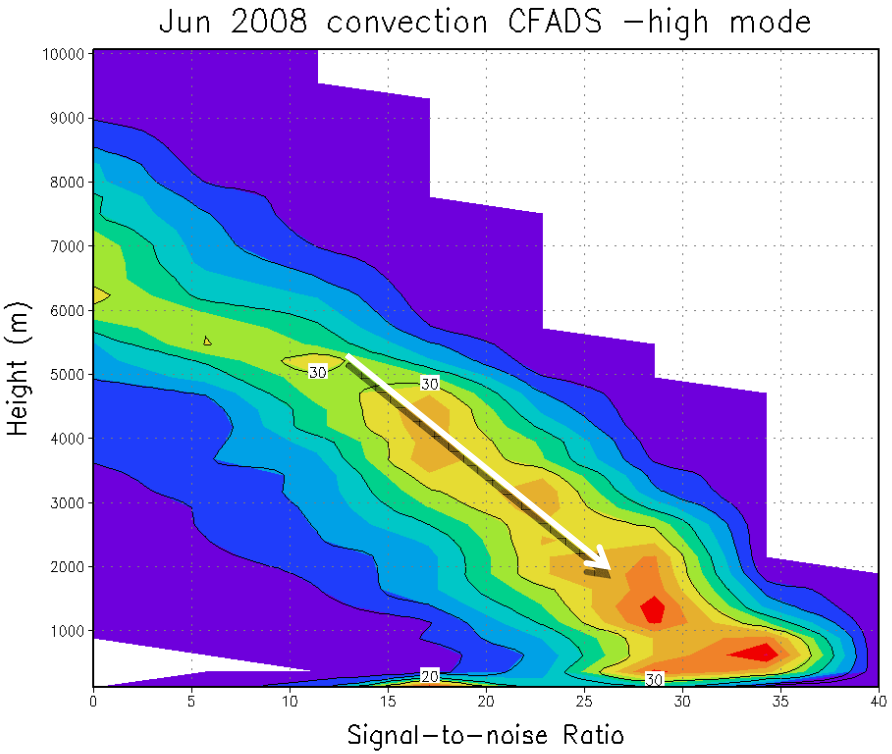


R>20

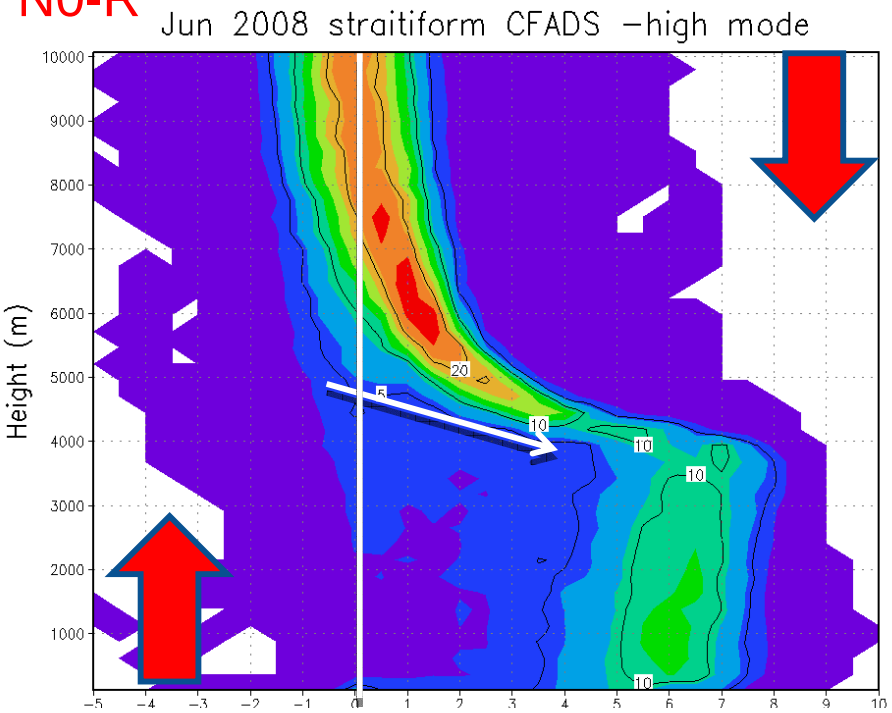

Jun 2008 straitiform CFADS −high mode
Height (m)
(%)

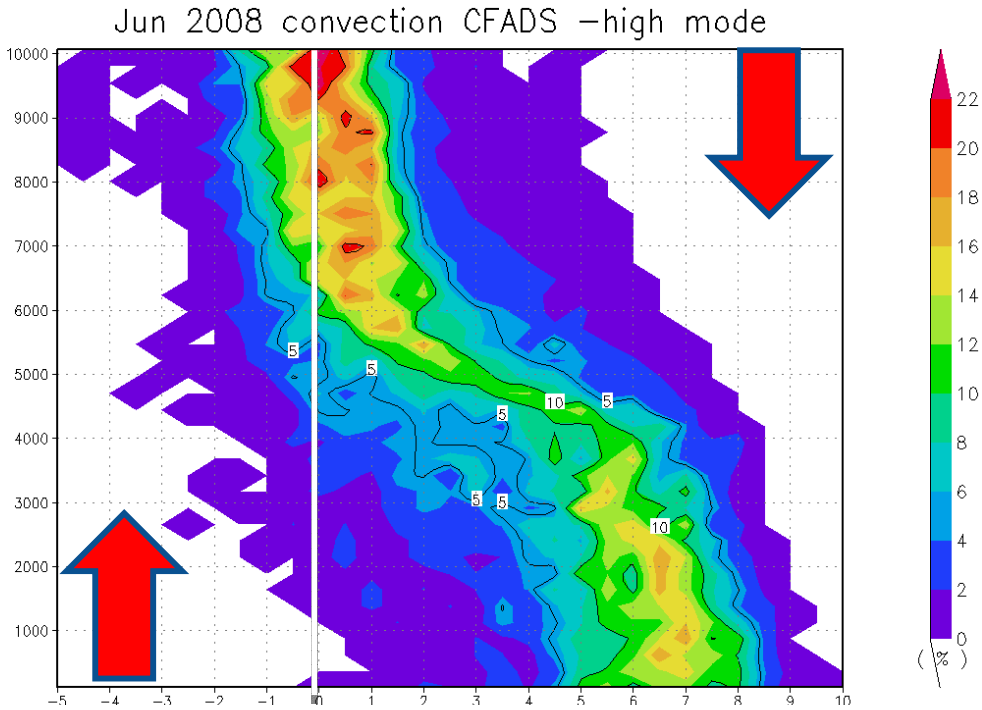

Jun 2008 convection CFADS −high mode
Height (m)
(%)

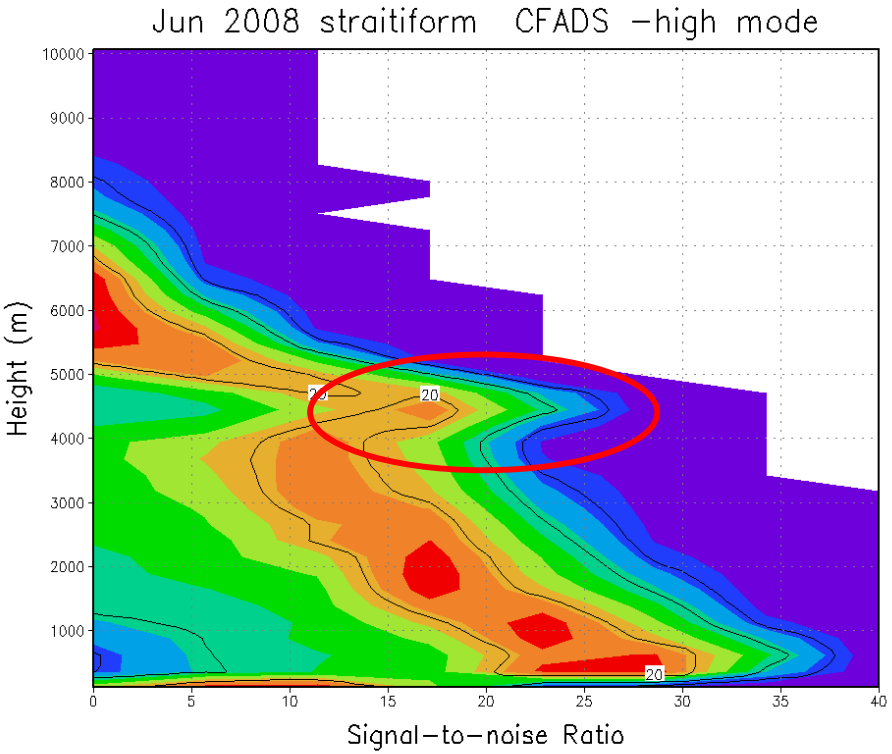

Jun 2008 straitiform CFADS −high mode
Height (m)
Signal−to−noise Ratio
(%)

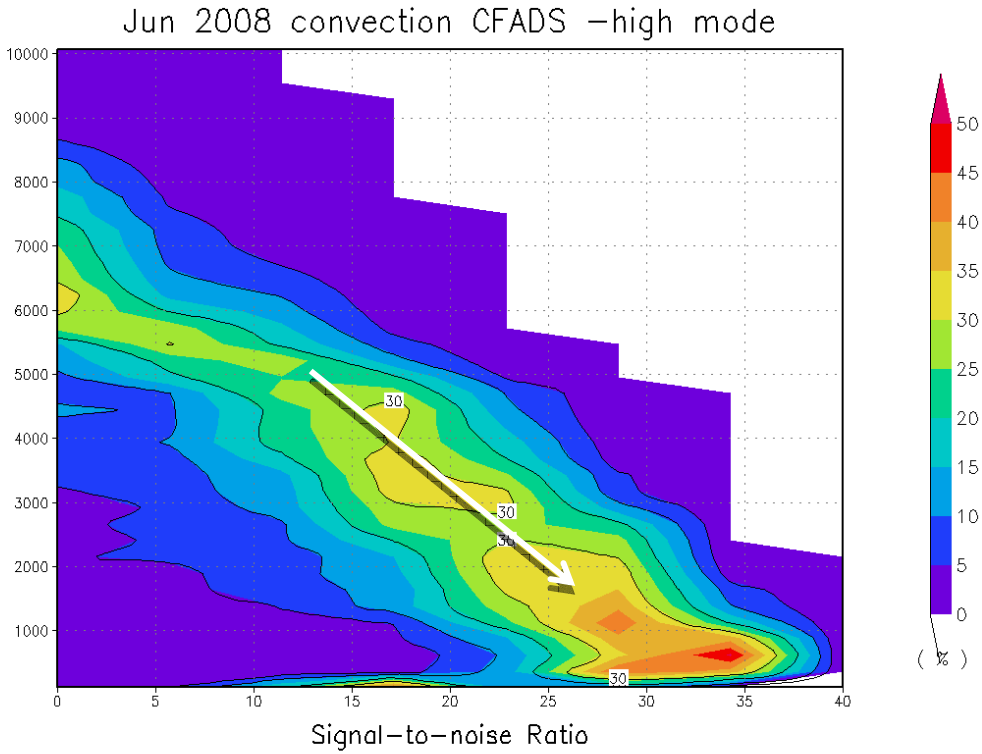

Jun 2008 convection CFADS −high mode
Height (m)
Signal−to−noise Ratio
(%)

N0-R


Jun 2008 straitiform CFADS −high mode
Height (m)
(%)


Jun 2008 convection CFADS −high mode
(%)


Jun 2008 straitiform CFADS −high mode
Height (m)
Signal−to−noise Ratio
(%)

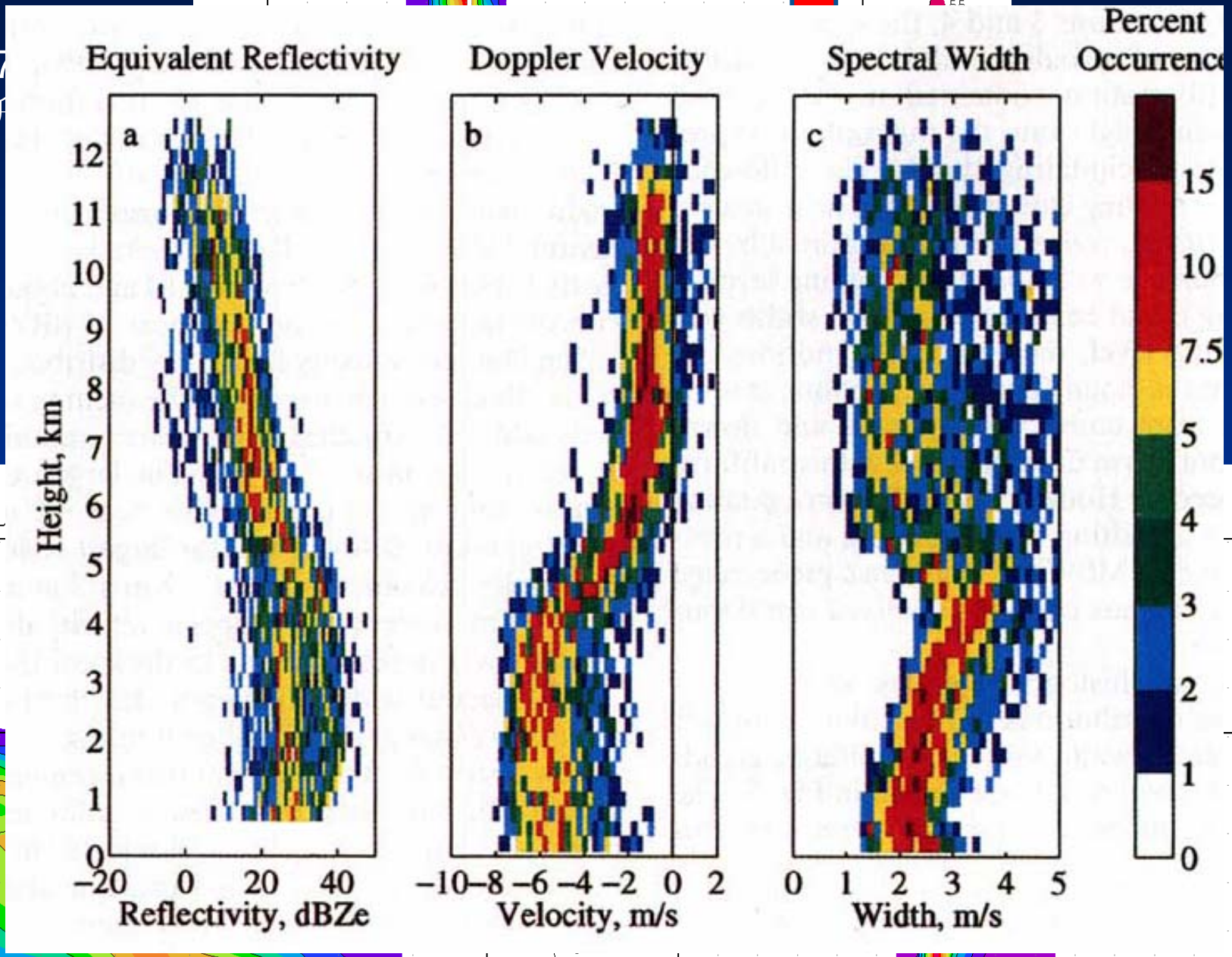

Jun 2008 convection CFADS −high mode
Signal−to−noise Ratio
(%)

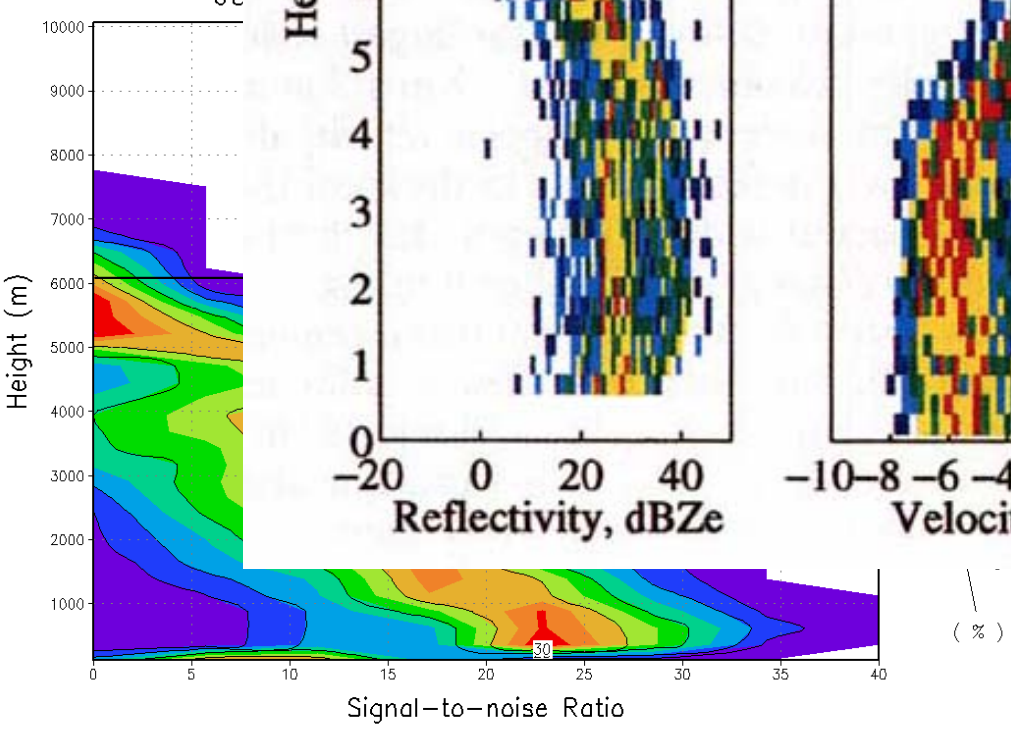
DVG 1 MSW3.5

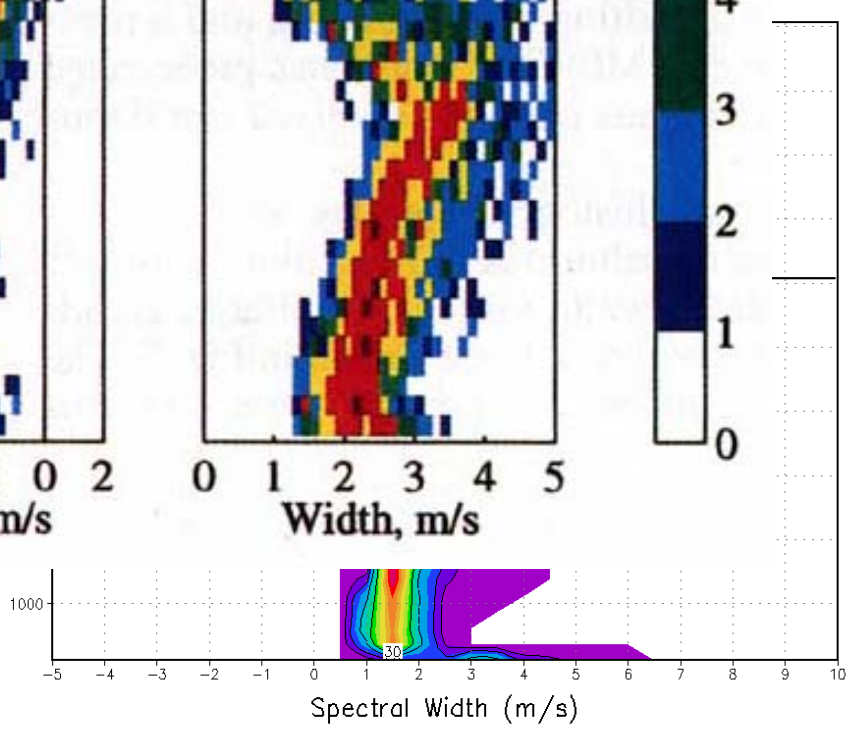
六月份混合降水

6~7

上升

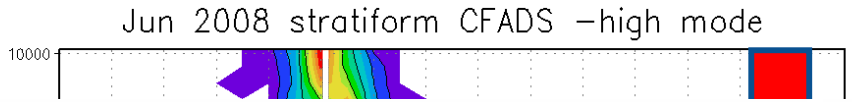


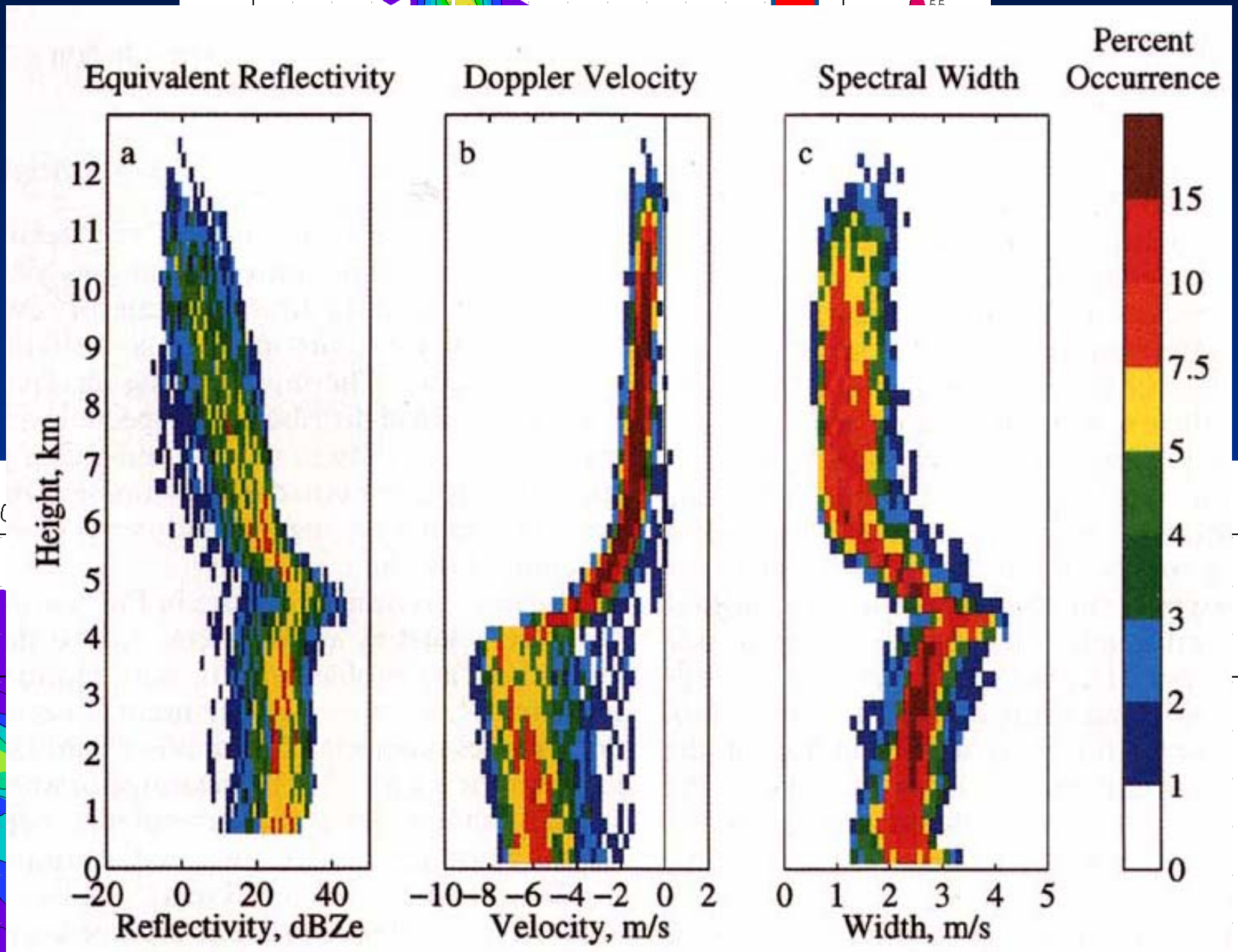


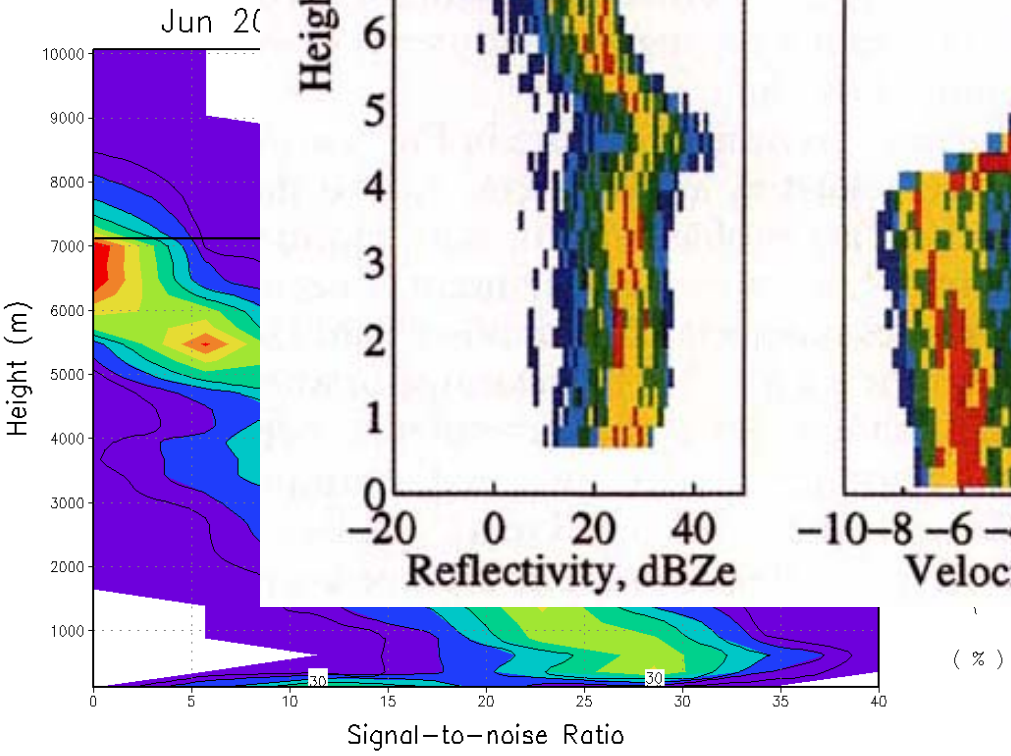


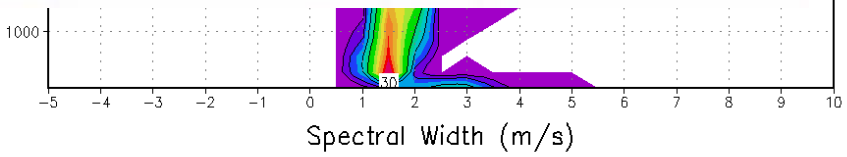
DVG 1 MSW3.5

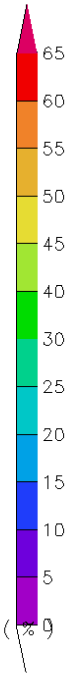
六月份層狀降水





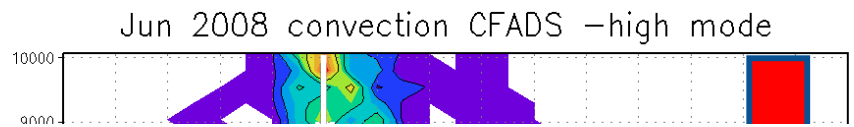


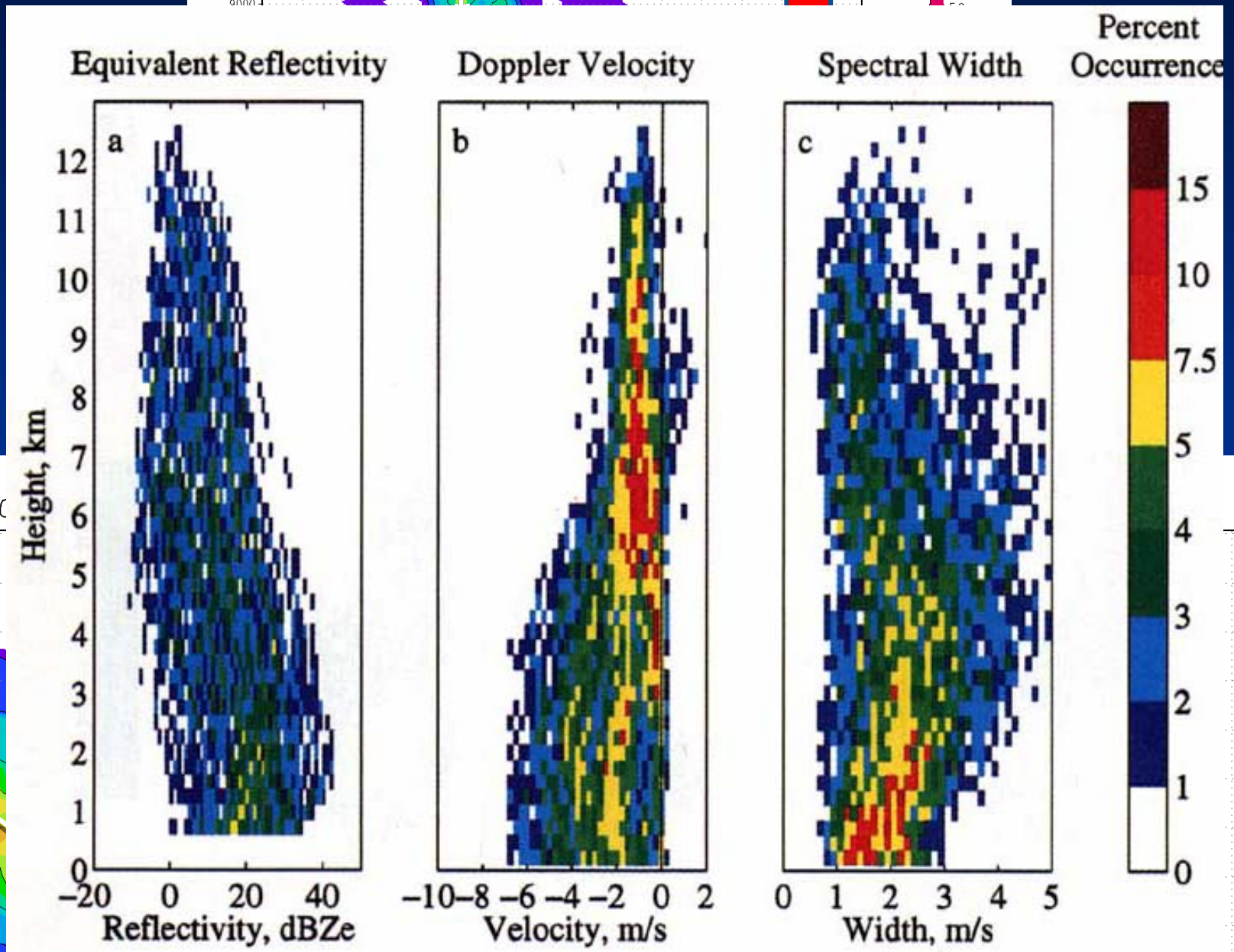


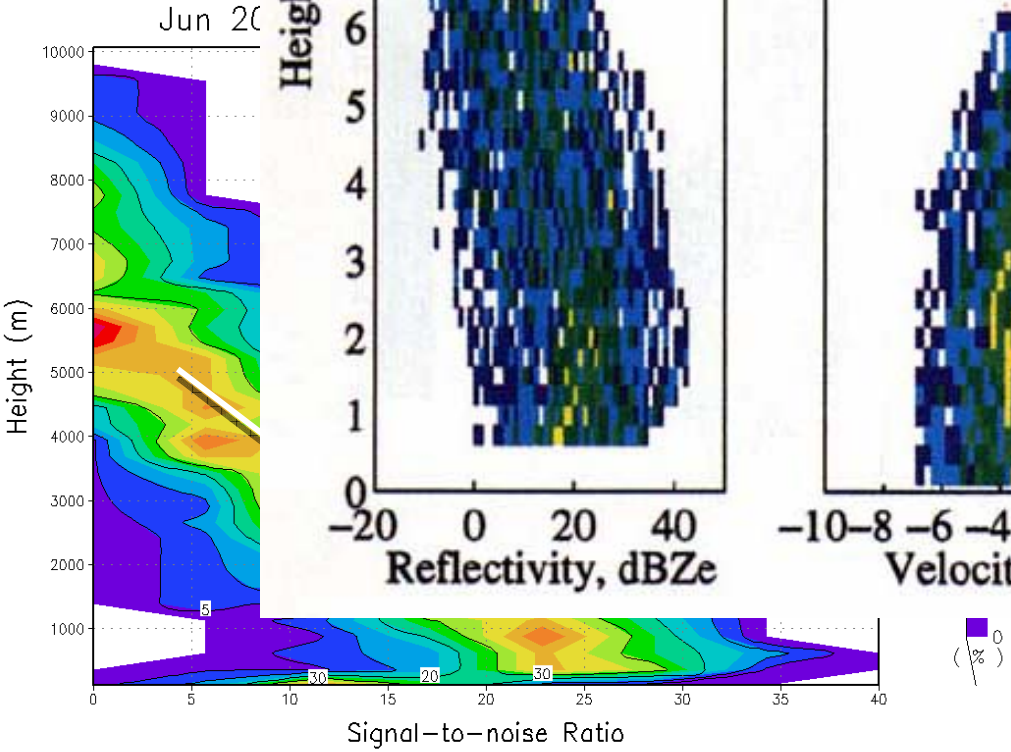


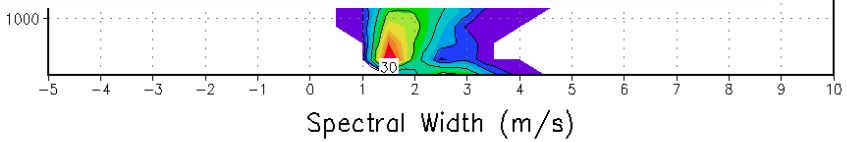
DVG 1 MSW3.5

六月份對流降水









Summary

- The heavy rain events are mostly composed of small and median raindrops rather than big raindrops.
- The median volume diameter increases with increasing rainfall rate, but the median volume diameter remains about 1.7 mm when the rainfall rate greater than 60 mm/hr.
- The microphysics process of collision and breakup may be the main reason for this unique D0 value.
- The modified Z-R relations were applied to the corrected reflectivity to improve the Z-R relation rainfall estimations.
- The area rainfall accumulation is quite satisfactory by using the disdrometer derived Z-R relation and corrected radar reflectivity.

Summary

- We use the NCUISS/UHF radar to collect very useful data for the study of monsoon flow and precipitating cloud microphysical processes.
- Some types of precipitation (Deep convective, shallow convective, stratiform precipitation and cumulus cloud) were observed in TIMREX using UHF radar and distrometers, and show some quite different vertical structure of refrectivity , vertical motion and surface DSDs distribution.
- Future work
  - quality control of other JWD distrometers
  - Compare the rainfall spacial characters using different distrometers.
  - Microphysical process accompanied with precipitatig cloud development will be investigaated using profiler , TEAM-R , S-Pol and disdrometer network.
  - The structure of boundary layer and local circulation associated with different weather regimes will be discussed in the coming days.