Precipitation system observations in monsoon season around the East China Sea from 2006 to 2009

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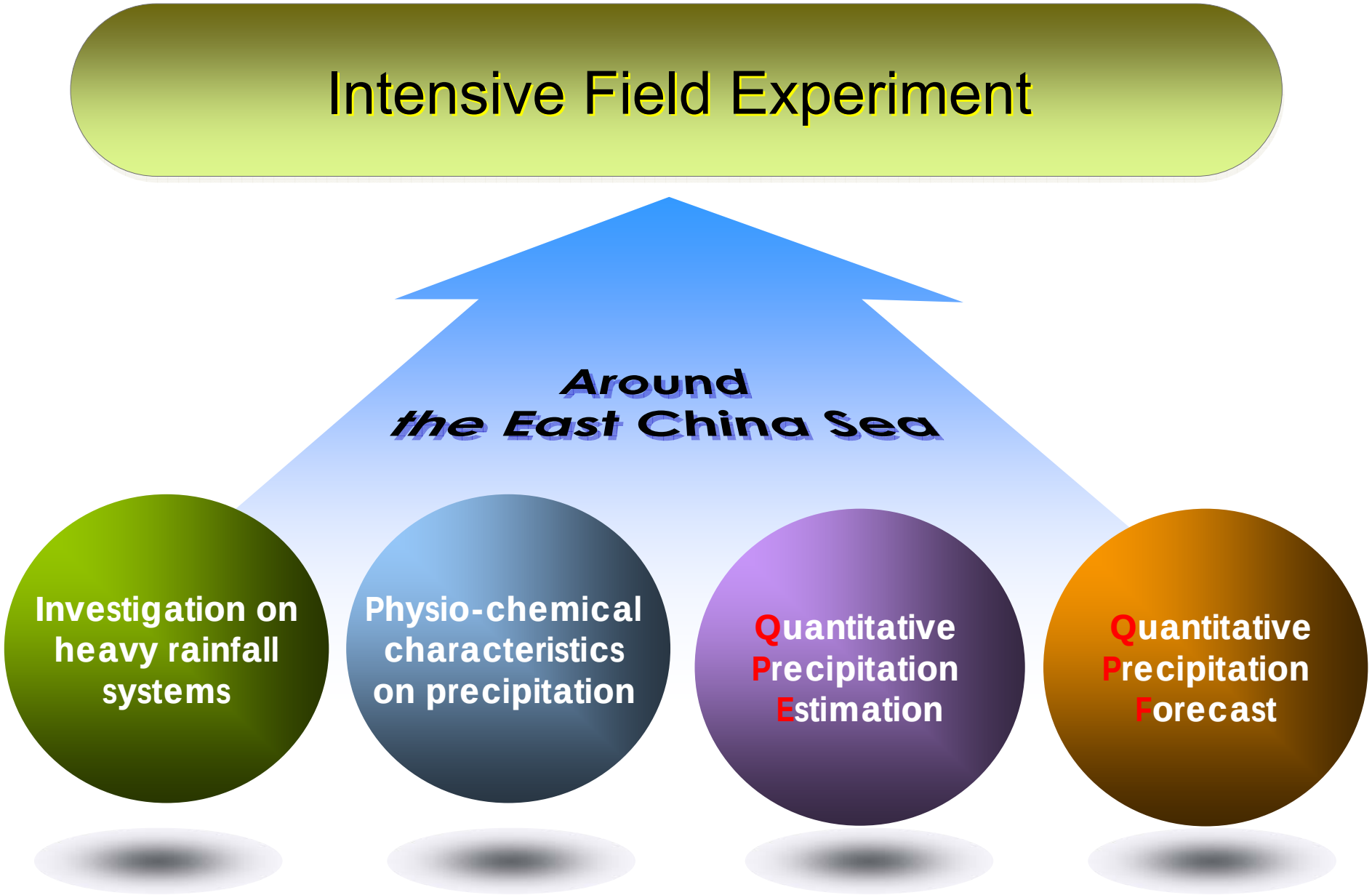
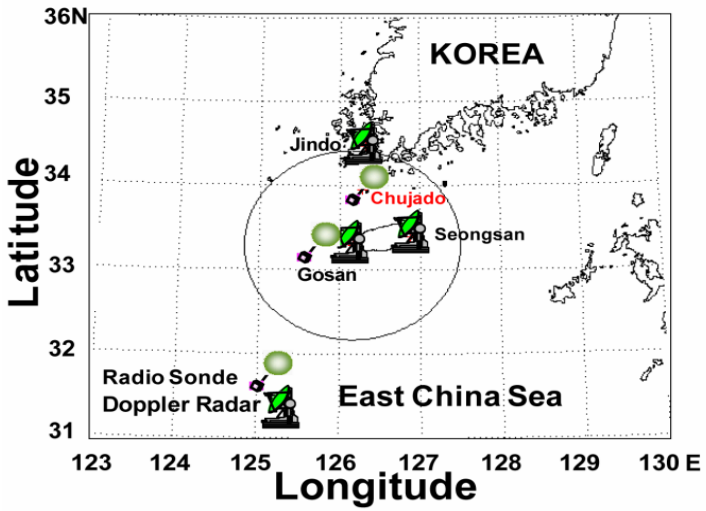
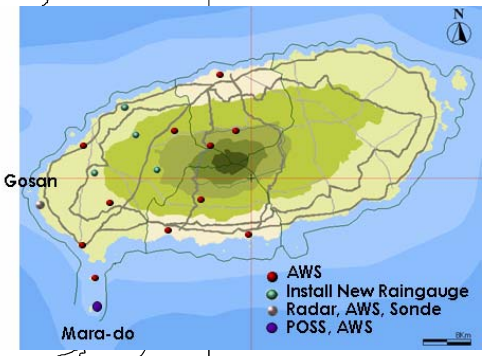
Global Research Laboratory

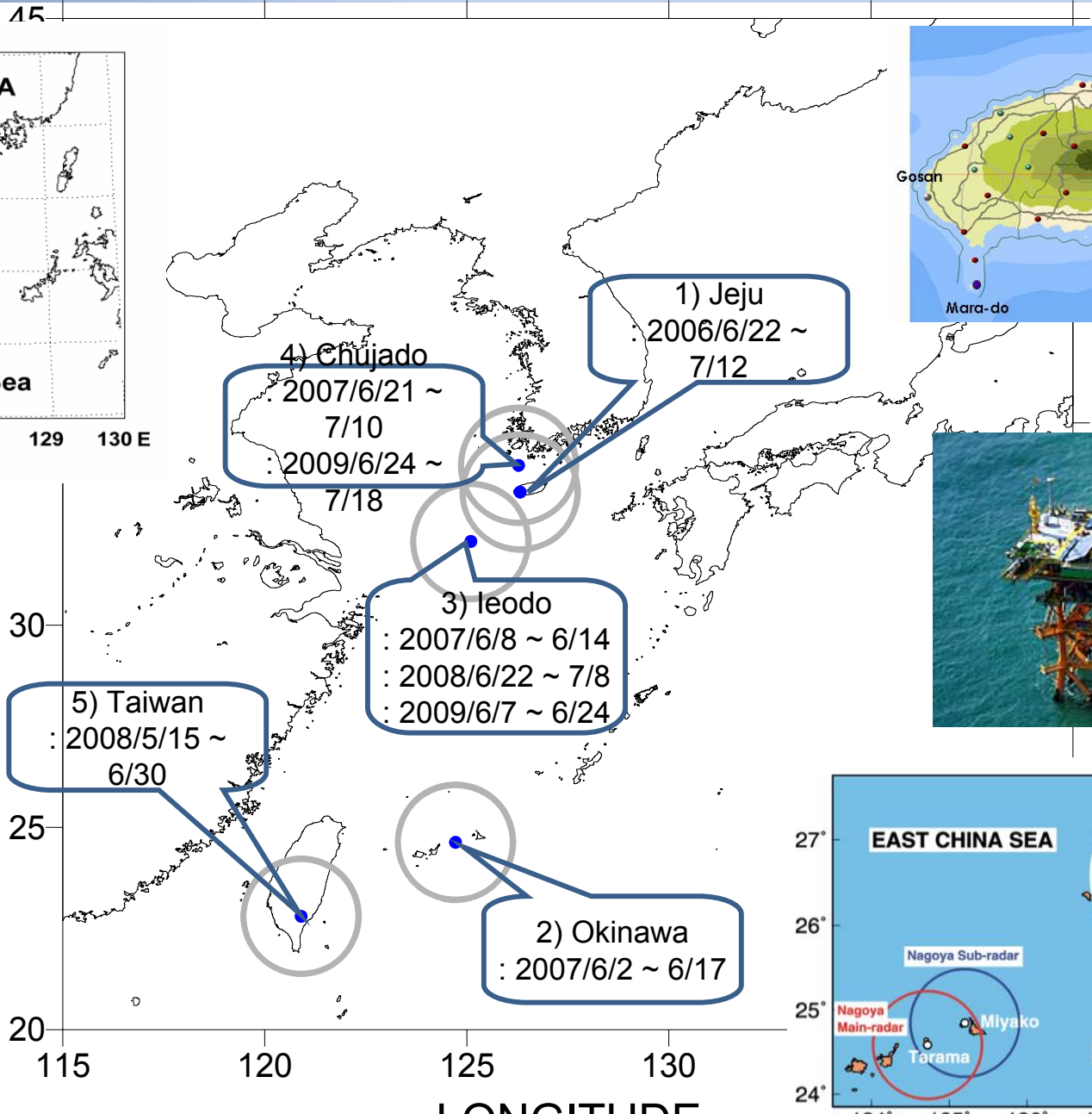
Purpose of Research

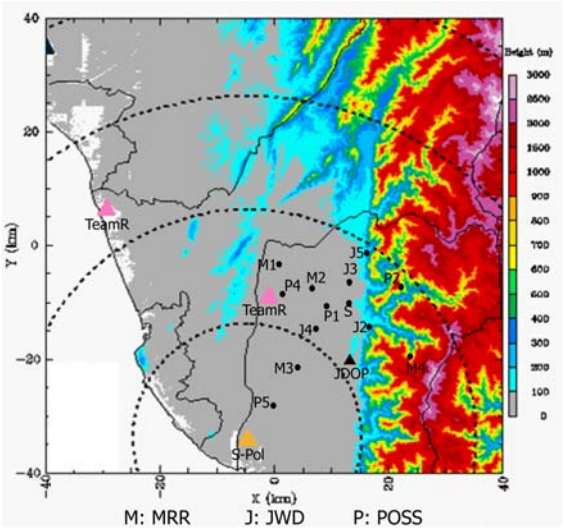


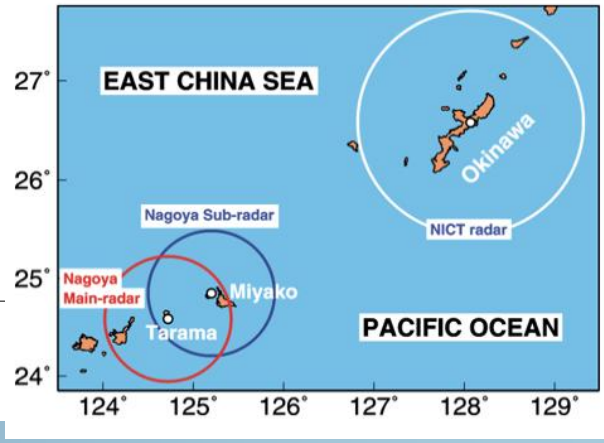
Location of experiment sites









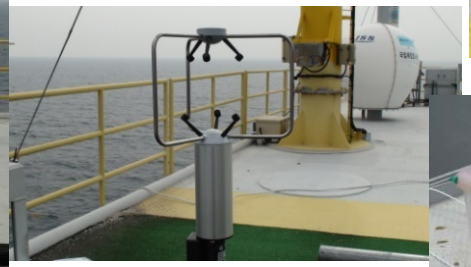


" Jeju and Marado " in 2006

- S-band radars(KMA)
- Rain gauge (type : 0.1 mm, 0.5 mm)
- Rain sampler
- Radio sonde
- POSS disdrometer and Filter papers
- AWS, LPC

" Ieodo " in 2007, 2008, and 2009

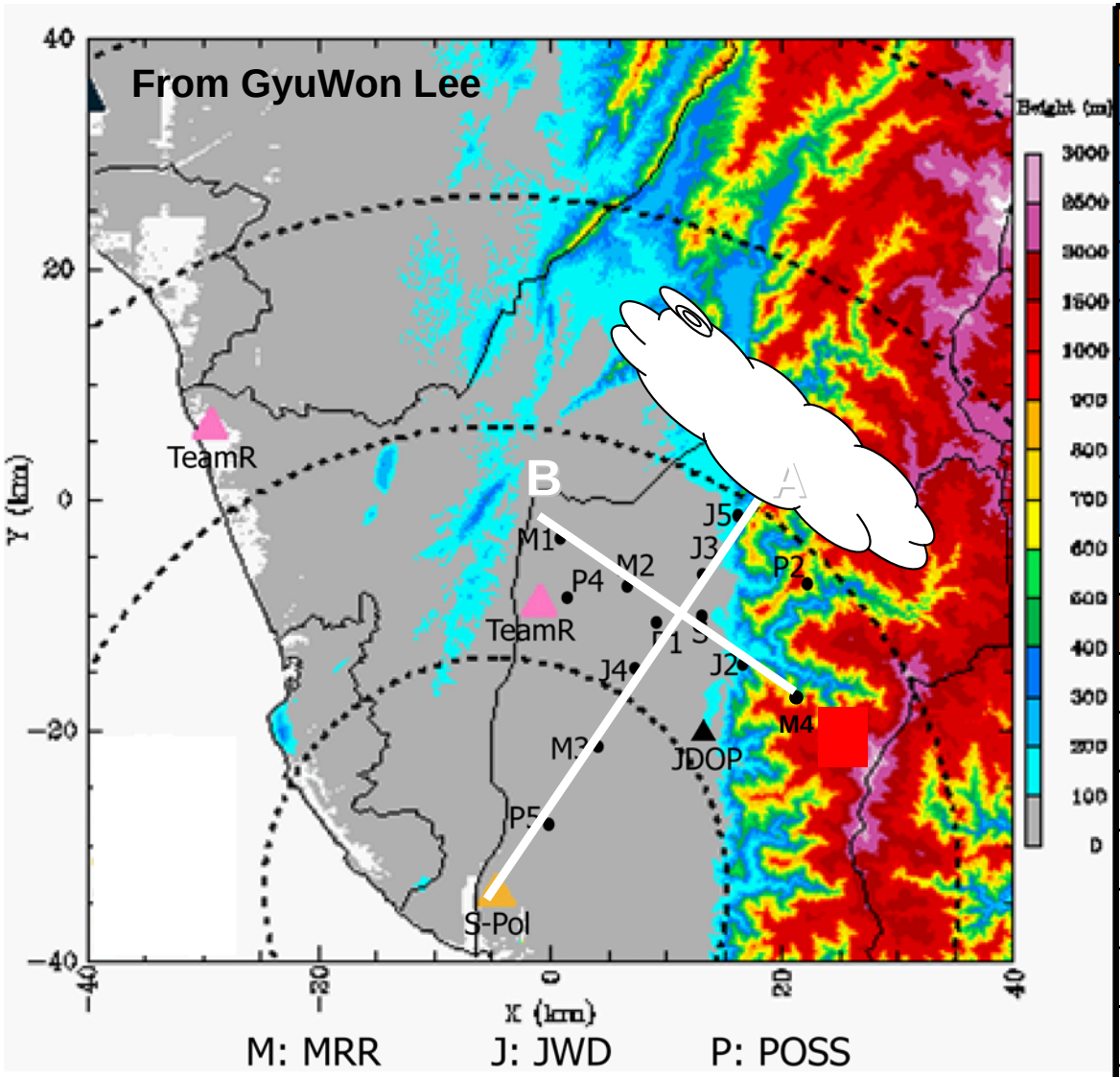
- Rain gauge (type : 0.1 mm, 0.5 mm)
- Parsivel (Optical Disdrometer), Filter paper
- Radio sonde
- Rain sampler, Eight-stage cascade impactor
- LPC, Mini volume air sampler
- AWS, UVW



" Chujado " in 2007 and 2009

- S-band radars (KMA)
- Rain gauge (type : 0.1 mm, 0.5 mm)
- Parsivel (Optical Disdrometer), Filter paper
- Radio sonde
- Rain sampler
- LPC, Mini volume air sampler
- AWS, UVW

" Taiwan " in 2008



INSTRUMENT	ORGANIZATION	STATION
VertiX	KNU (Korea)	SuperSite : Quan-Xin Elementary School
MRR(M5)	KNU (Korea)	
JWD(J1)	NCU1 (Taiwan)	
POSS(P3)	EC1 (Canada)	
2DVD	NCU (Taiwan)	
ISS	NCU (Taiwan)	
Tipping bucket raingauge	CWB (Taiwan)	
Traditional raingauge	NTU (Taiwan)	
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 (Taiwan)	Tu-Ku
MRR(M2)	CCU2 (Taiwan)	Lin-Luo
MRR(M3)	CCU3 (Taiwan)	Shi-Long
MRR(M4)	CCU4 (Taiwan)	Ma-Jia. V. O.
JWD(J2)	CCU (Taiwan)	Ma-Jia J. H. S
JWD(J3)	NCU2 (Taiwan)	Quan-Fu
JWD(J4)	NCU3 (Taiwan)	Fan-Hua
JWD(J5)	NCU4 (Taiwan)	Chin-San

Deployment of instruments in Supersite

2DVD : Sonic anemometer

ISS : surface tower

ISS

2DVD

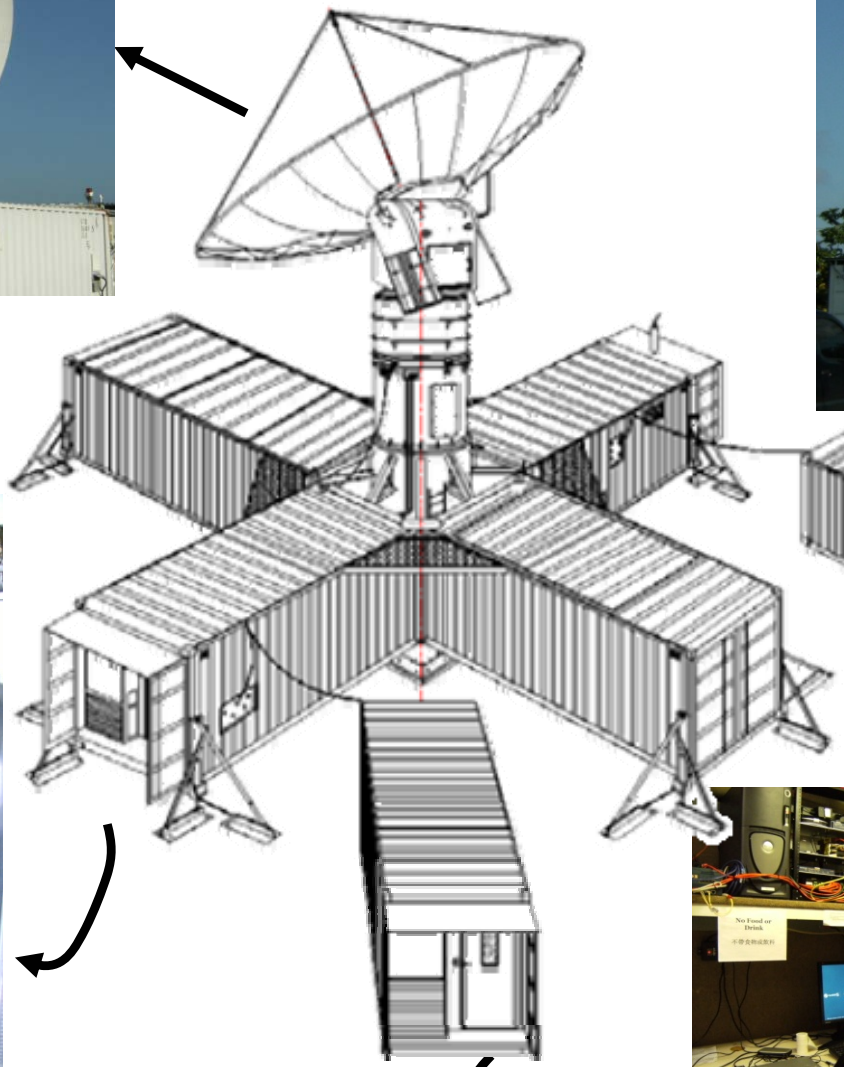
MRR-2

2DVD : Tipping Bucket Raingauge

Tipping Bucket Raingauge

JWD

Deployment of S-Pol. Radar



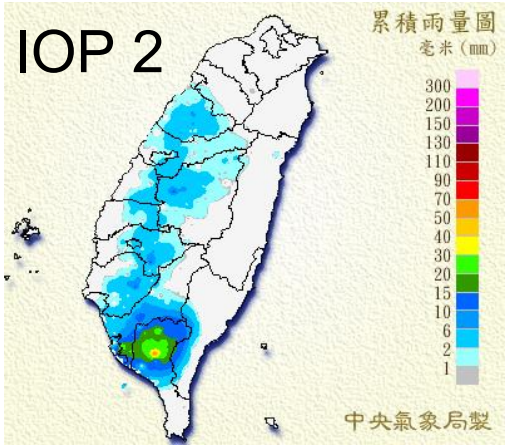
Summarize the event during IOP in Taiwan

	Date	Science Objectives	Begin (UTC)	End (UTC)	Dropsonde Mission
IOP-1	19-22 May	• Frontal circulation • Upstream environment for orographic convection • Model verification and data assimilation	19 May 06:00	22 May 00:00	mission #1 2008/05/20 21:00-24:00
IOP-2	27-29 May	• Southwest flow interacting with the terrain • Upstream condition for mountain convection • Lee side vortex/shear zone	27 May 06:00	29 May 21:00	mission #2 2008/05/28 21:00-23:30
IOP-3	29-31 May	• Island effects on SW (LLJ) and the Mei-Yu front • Upstream condition forheavy precipitation	29 May 21:00	31 May 21:00	mission #3 2008/05/29 21:00-23:30 mission #4 2008/05/30 21:00-23:30
IOP-4	01-03 Jun	• Mesoscale convective systems • Shallow surface front • Mesoscale convective vortex	01 Jun 21:00	03 Jun 15:00	mission #5 2008/06/03 09:00-11:30
IOP-5	03-04 Jun	• Mesoscale convective systems • Quasi-stationary front • Mesoscale convective vortex	03 Jun 18:00	04 Jun 12:00	mission #6, 2008/06/03 21:00-24:00 mission #7, 2008/06/04 05:00-07:00
IOP-6	04-06 Jun	• Mesoscale convective systems • Quasi-stationary front • Mesoscale convective vortex	04 Jun 18:00	06 Jun 12:00	mission #8, 2008/06/04 21:00-24:00 mission #9, 2008/06/05 05:00-07:00 mission #10, 2008/06/05 21:00-24:00
IOP-7	12-13 Jun	• Convection initiation • Orographic convection	12 Jun 00:00	13 Jun 12:00	Astra engine oil leakage and grounded for a few days
IOP-8	14-17 Jun	• Southwesterly flow interacting with the terrain • Upstream condition for mountain convection, low level jet • Mesoscale convective systems • Mesoscale convective vortex	14 Jun 00:00	17 Jun 12:00	mission #11, 2008/06/16 08:48-10:53 mission #12, 2008/06/16 21:00-23:53 mission #13, 2008/06/17 04:00-06:00
IOP-9	23-26 Jun	• Typhoon Fengseng track uncertainty • Typhoon induced southwesterly flow and related heavy rain systems	23 Jun 06:00	26 Jun 12:00	mission #14 2008/06/23 08:30-11:30 mission #15 2008/06/25 09:00-11:30

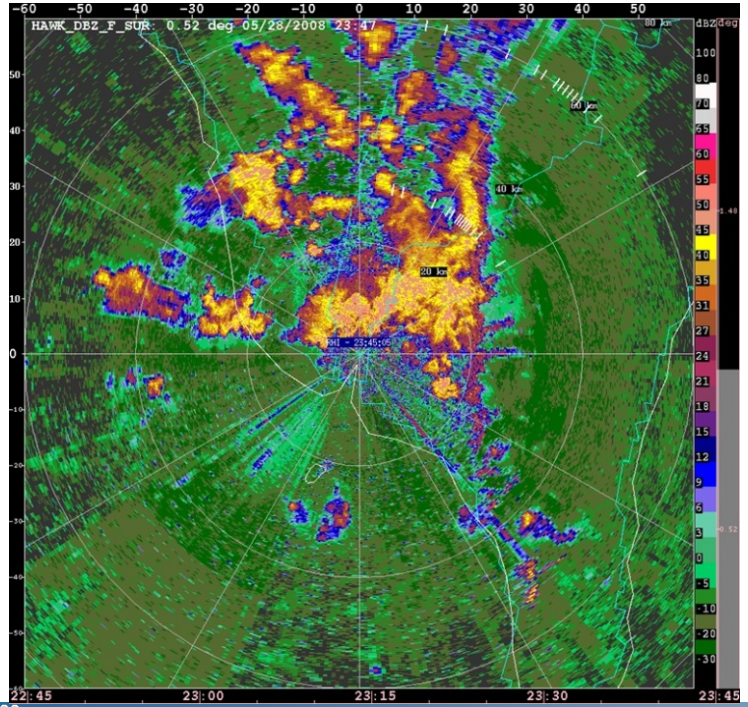
Study on classification of stratiform and convective system

05/28 23:00 UTC ~ 05/29 00:00 UTC

Accumulated Rainfall Amount :

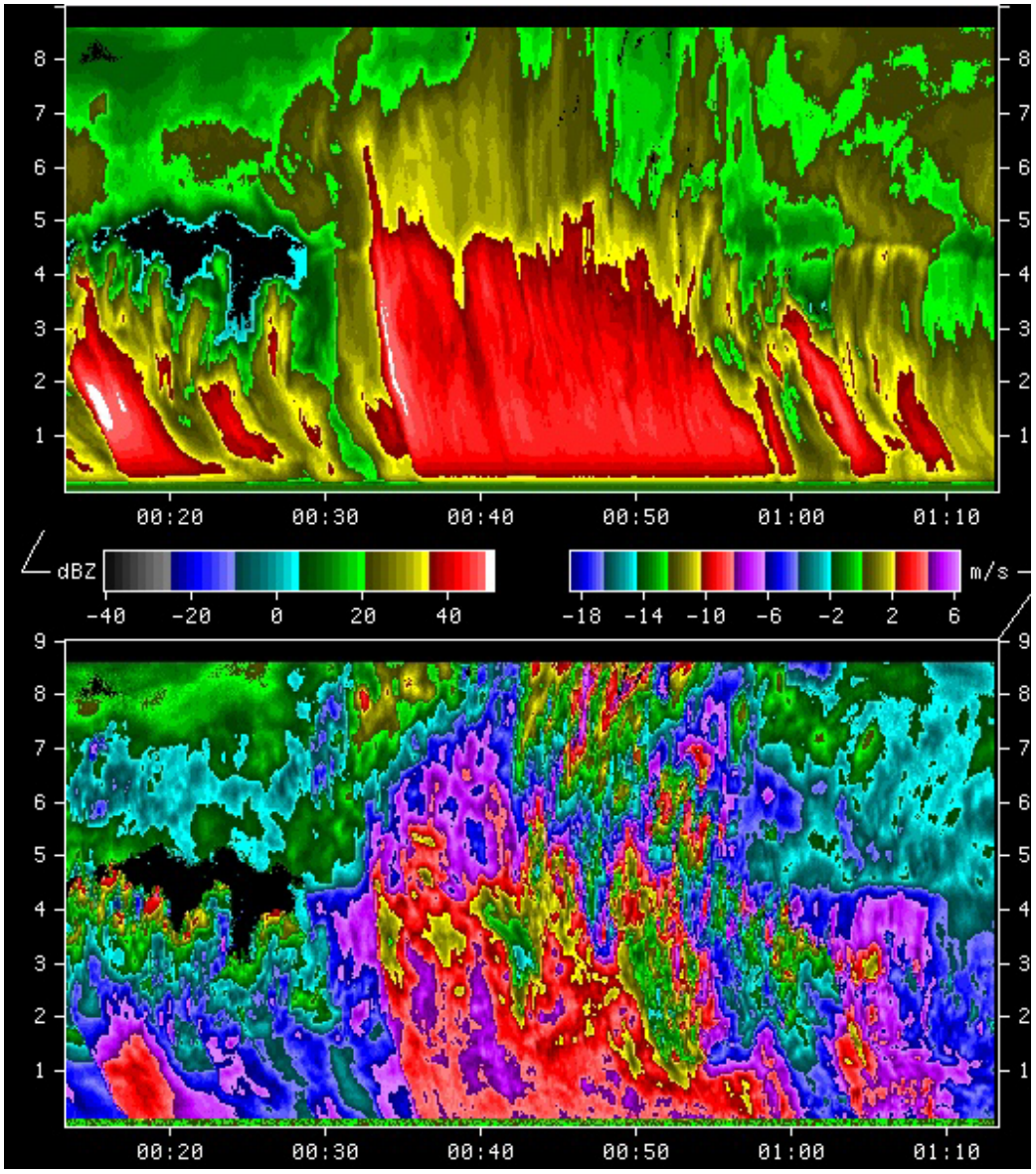


S-Pol. Radar reflectivity: 2008/05/28 23:47 UTC



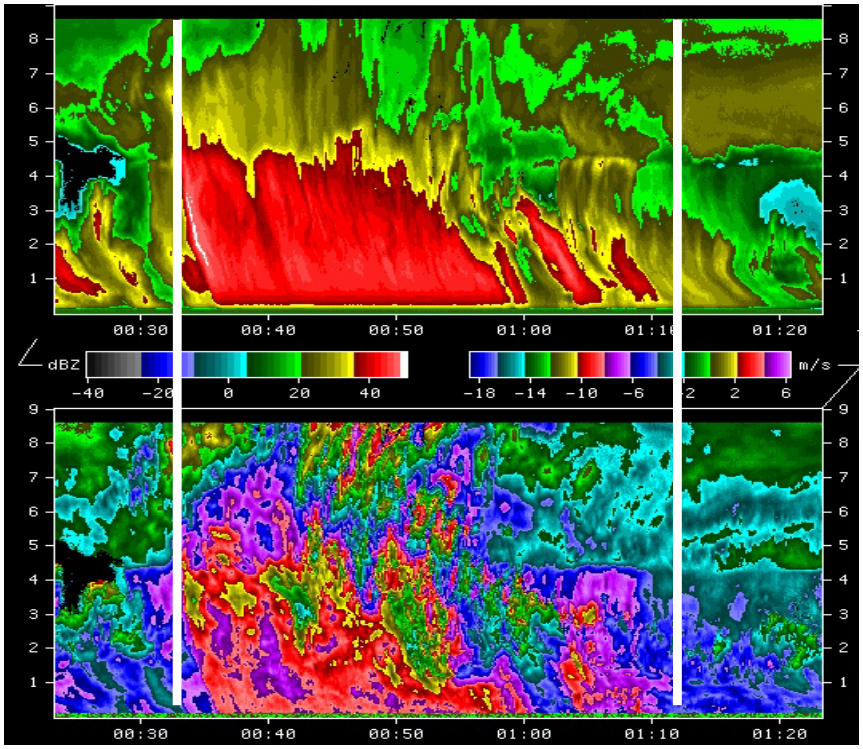
Vertical Pointing X-band (VPR : VertiX)

05/29 00:10 UTC ~ 01:20 UTC

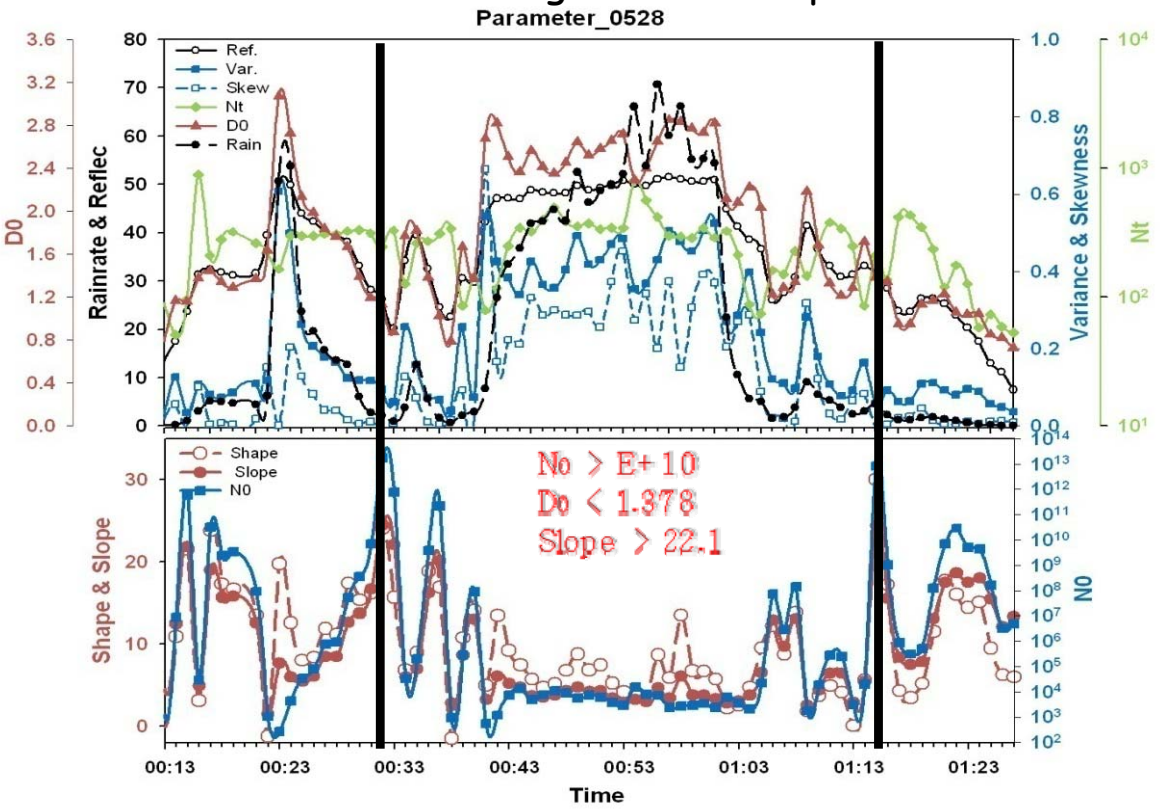


Study on classification of stratiform and convective system

Vertical Pointing X-band (VPR : VertiX)



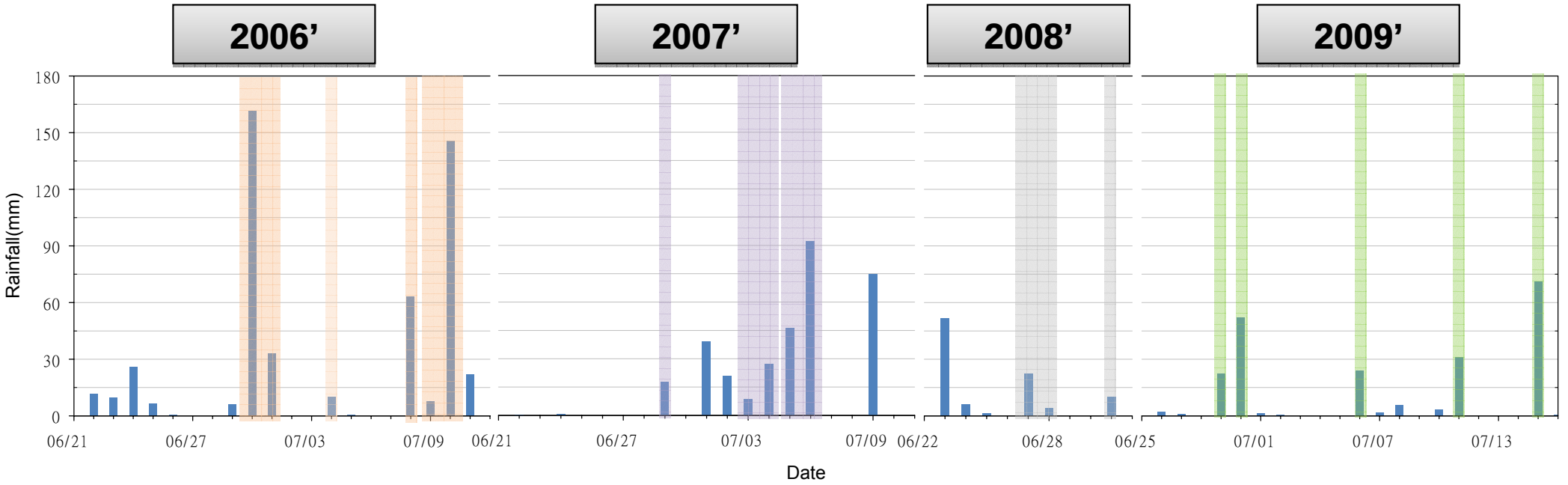
Line and scatter diagram of DSD parameters



DSD parameters.

Parameter	Equation	Parameter	Equation
Shape	$\mu = \frac{(8-11m)-(m^2+8m)^{1/2}}{2(m-1)}$	Reflectivity	$Z = \int_{D_{min}}^{D_{max}} D^6 N(D) dD$
Slope	$\Lambda = \frac{M_3}{M_4}(\mu+4)$	Variance	$\sigma^2 = \frac{\int (D-D_m)^2 N(D) dD}{M_0}$
Median volume diameter	$D_0 = \frac{(3.67+\mu)}{\Lambda}$	Skewness	$sk = \frac{\int (D-D_\mu)^3 N(D) dD}{\int N(D) dD}$
Intercept parameter	$N_0 = \frac{\Lambda^{(\mu+4)} M_3}{\Gamma(\mu+4)}$	Total number density	$N_t = \int N(D) dD$
Rainfall intensity	$R = \frac{\pi}{6} \int_{D_{min}}^{D_{max}} D^3 V_f N(D) dD$		(Kozu, and Nakamura, 1991)
			(Chu at al., 2008)

Observation of Precipitation Systems



Site	Gosan and Marado
Period	2006. 6. 22 ~ 7. 12
Case 1 : 1220 ~ 1630 LST 30 June, 1600 ~ 2300 LST 1 July	
Case 2 : 0800 ~ 1400 LST 4 July	
Case 3 : 0730 ~ 2400 LST 8 July	
Case 4 : 2100 LST 9 ~ 1000 LST 10 July	

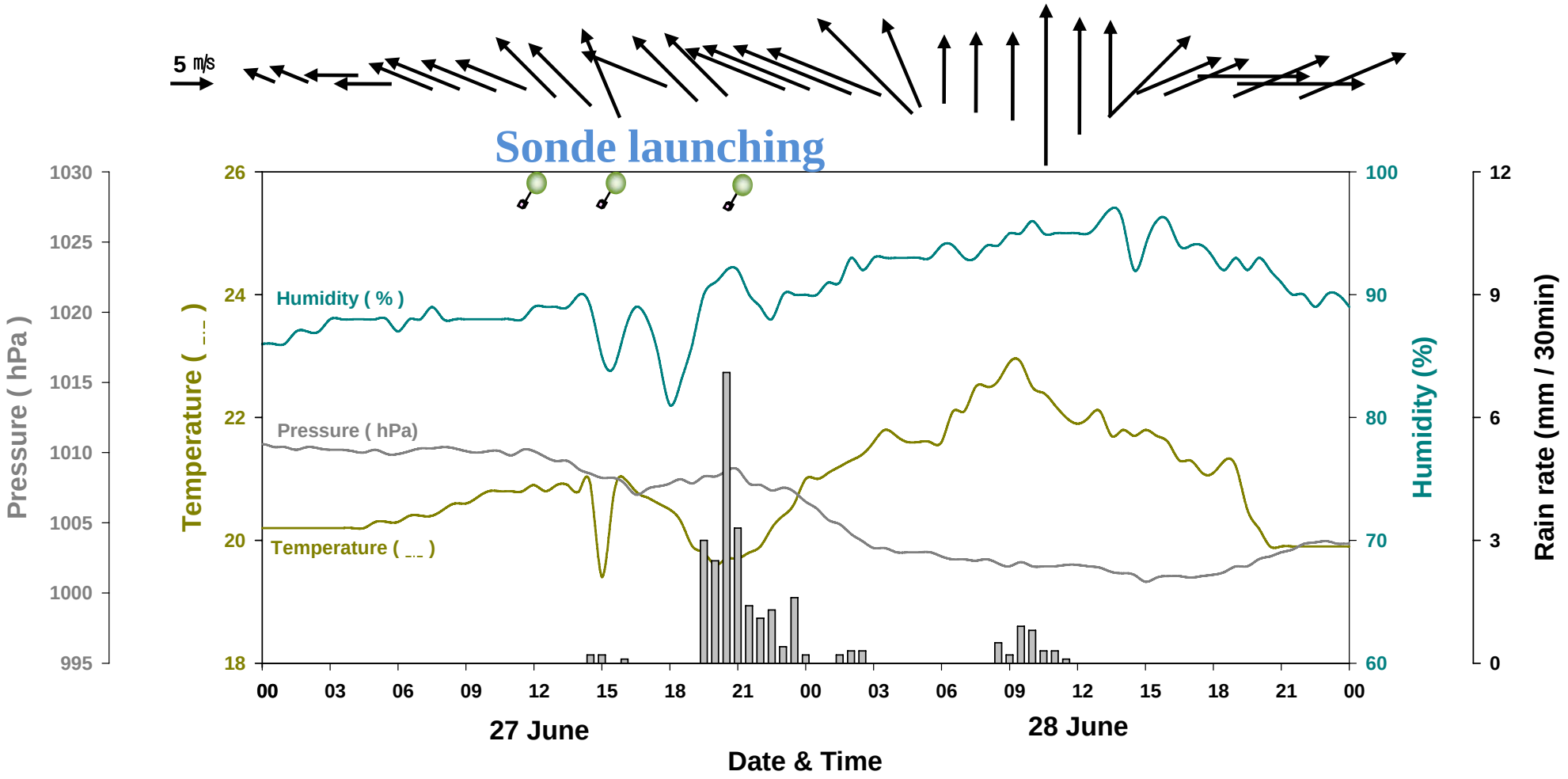
Site	Chujado
Period	2007. 6. 21 ~ 7. 10
Case 1 : 0300 ~ 1000 LST 29 June	
Case 2 : 2100 LST 3 ~ 0500 LST 4 July	
Case 3 : 1600 LST 5 ~ 1600 LST 6 July	

Site	Ieodo
Period	2008. 6. 22 ~ 7. 8
Case 1 : 1400 LST 27 ~ 1100 LST 28 June	
Case 2 : 2100 LST 30 June ~ 0800 LST 1 July	

Site	Chujado
Period	2009. 6. 24 ~ 7. 18
Case 1 : 0300 ~ 0830 LST 29 June	
Case 2 : 0430 ~ 2400 LST 30 June	
Case 3 : 2030 ~ 2400 LST 06 July	
Case 4 : 0300 ~ 1730 LST 11 July	
Case 5 : 0500 ~ 1700 LST 15 July	

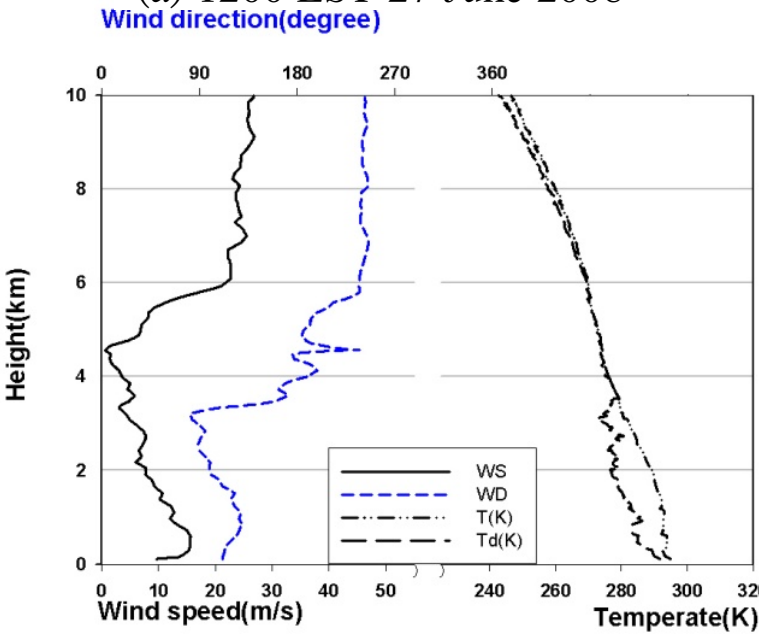
2008 Case 1 : 1400 LST 27 ~ 1100 LST 28 June 2008

- Changma Front
- Rainfall : 26.3 mm

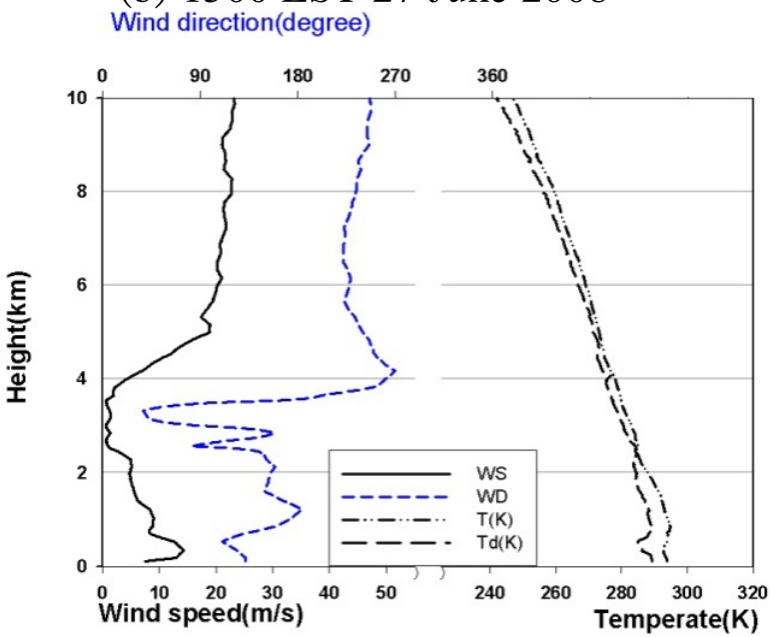


Vertical profile of sounding (Case 1)

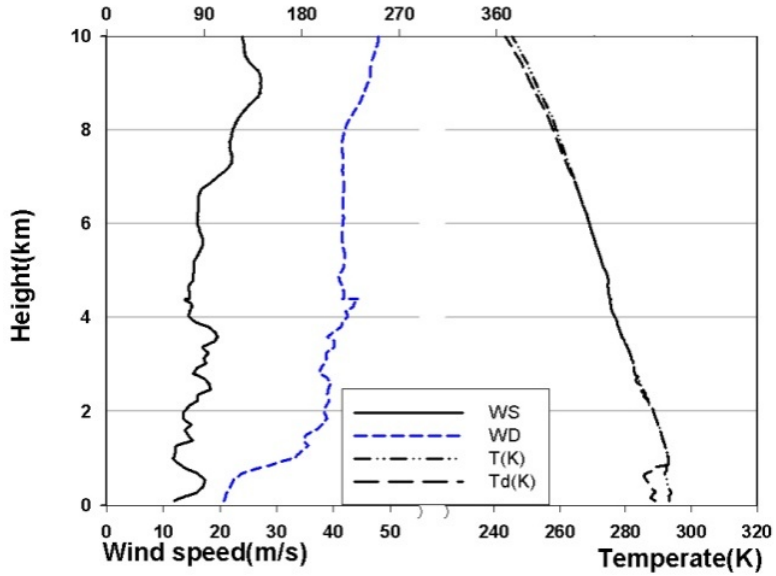
(a) 1200 LST 27 June 2008



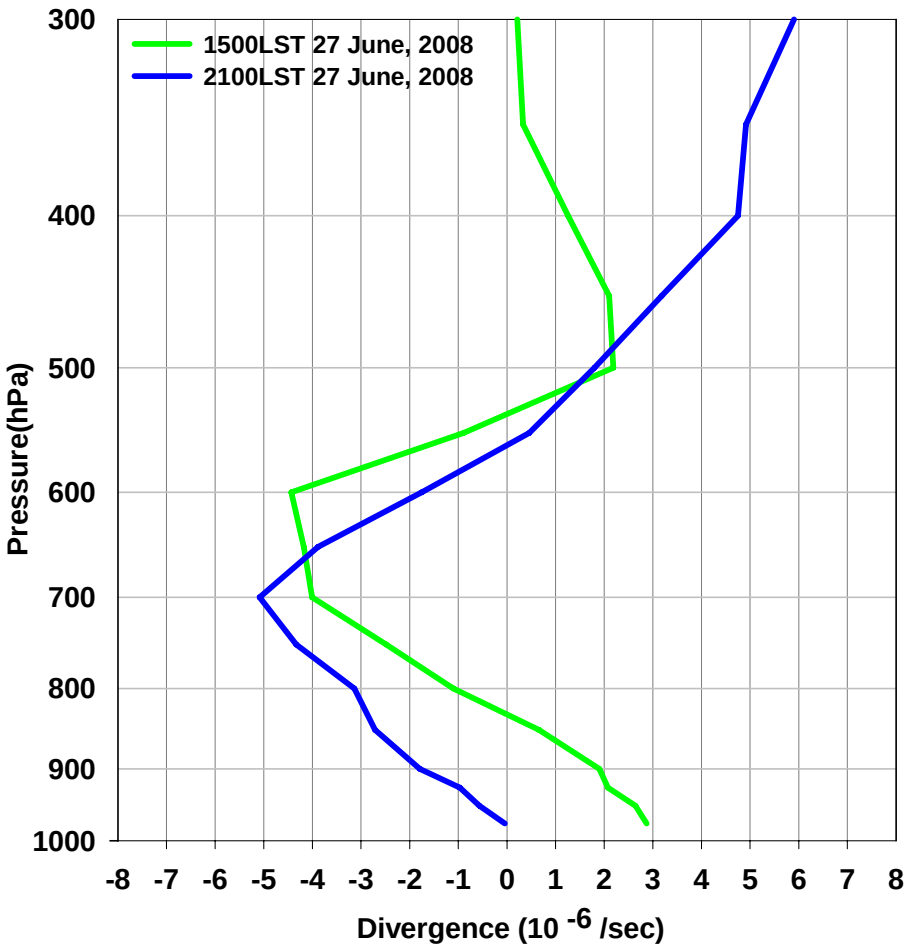
(b) 1500 LST 27 June 2008

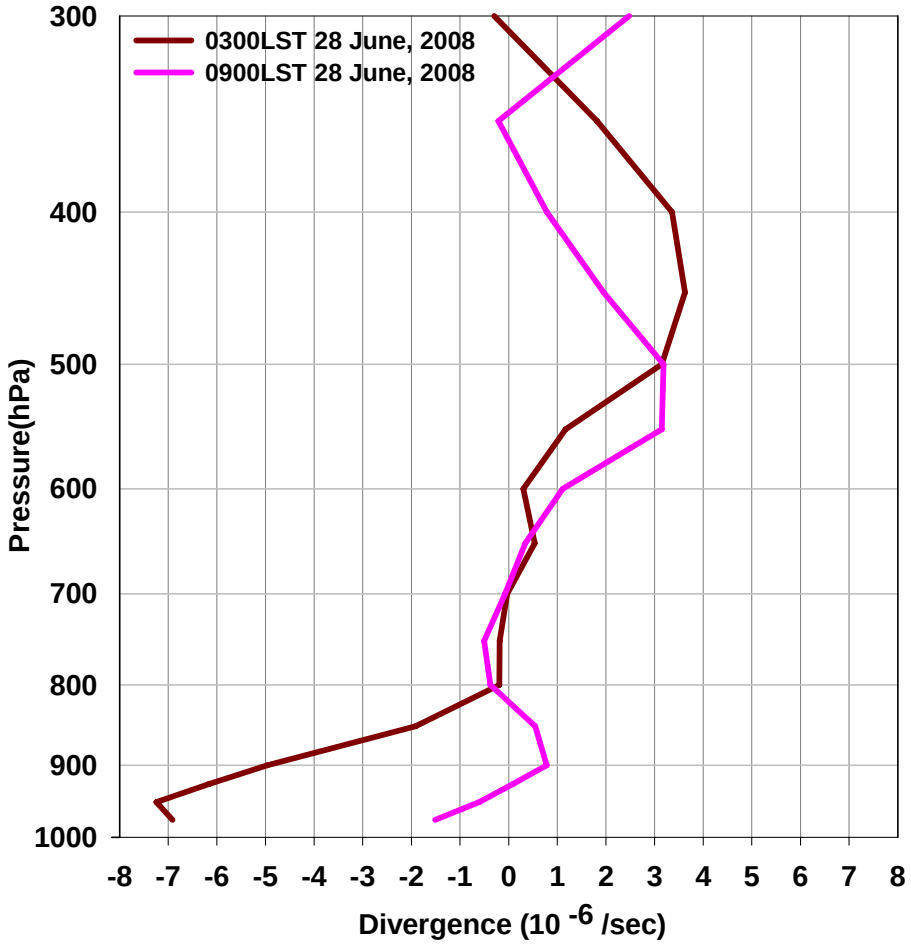


(c) 2100 LST 27 June 2008



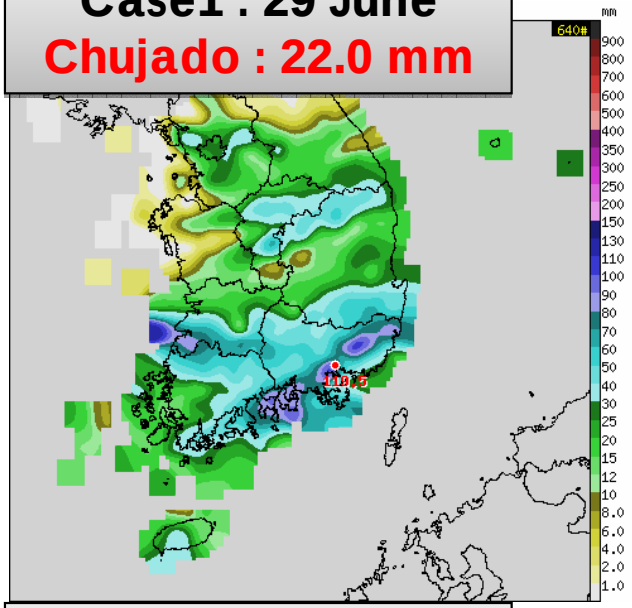
Divergence of horizontal wind (FNL NCEP/NCAR reanalysis data)



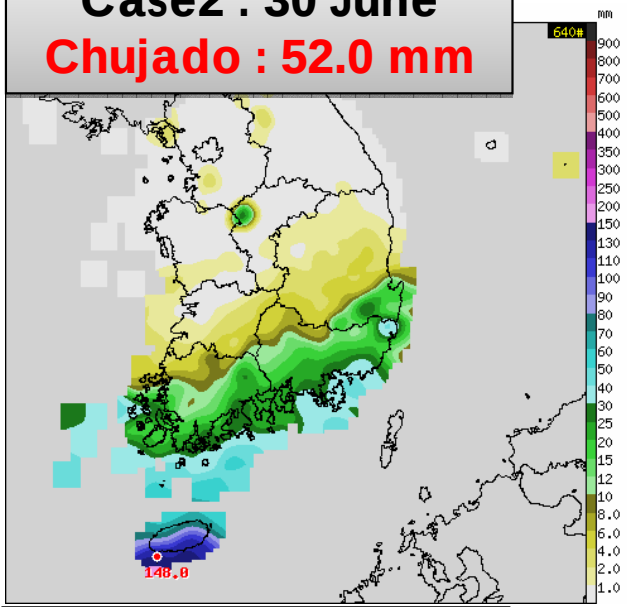


Daily accumulated rainfall amount during 2009 IOP

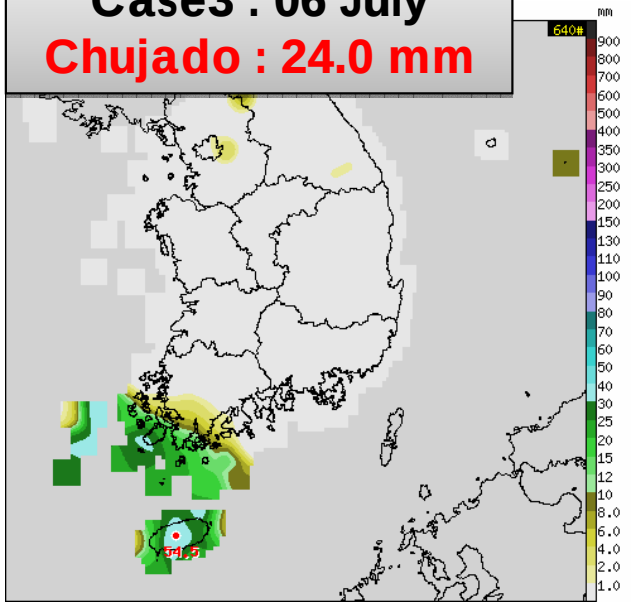
Case1 : 29 June
Chujado : 22.0 mm



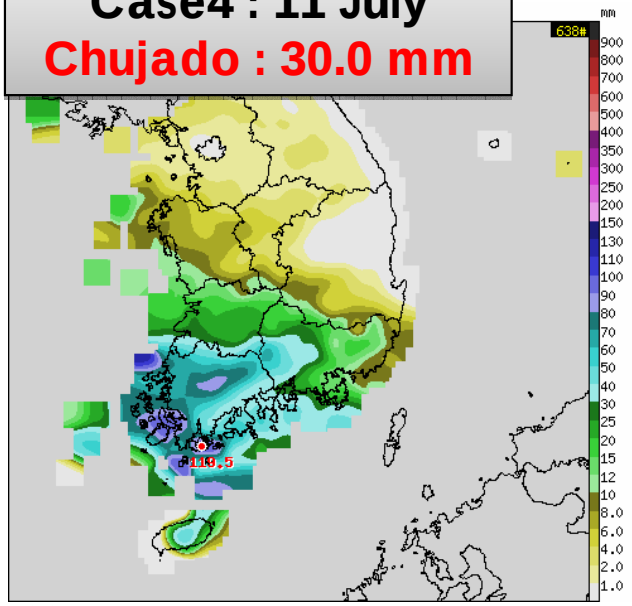
Case2 : 30 June
Chujado : 52.0 mm



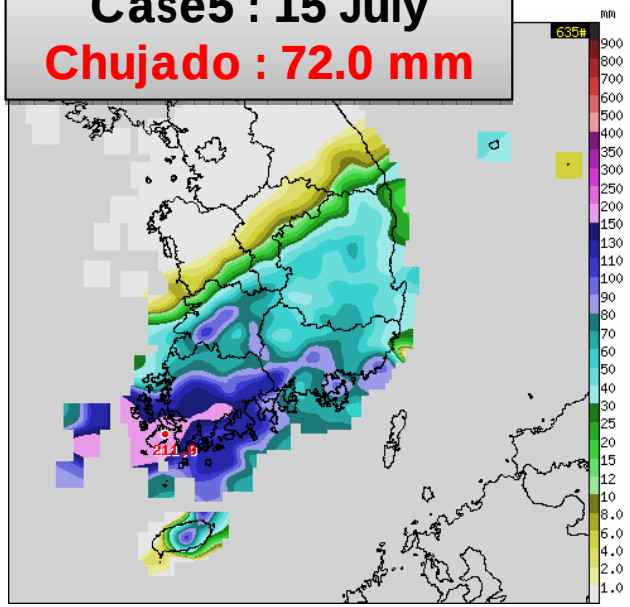
Case3 : 06 July
Chujado : 24.0 mm



Case4 : 11 July
Chujado : 30.0 mm



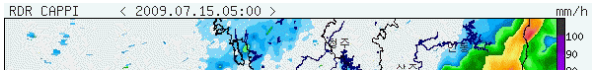
Case5 : 15 July
Chujado : 72.0 mm

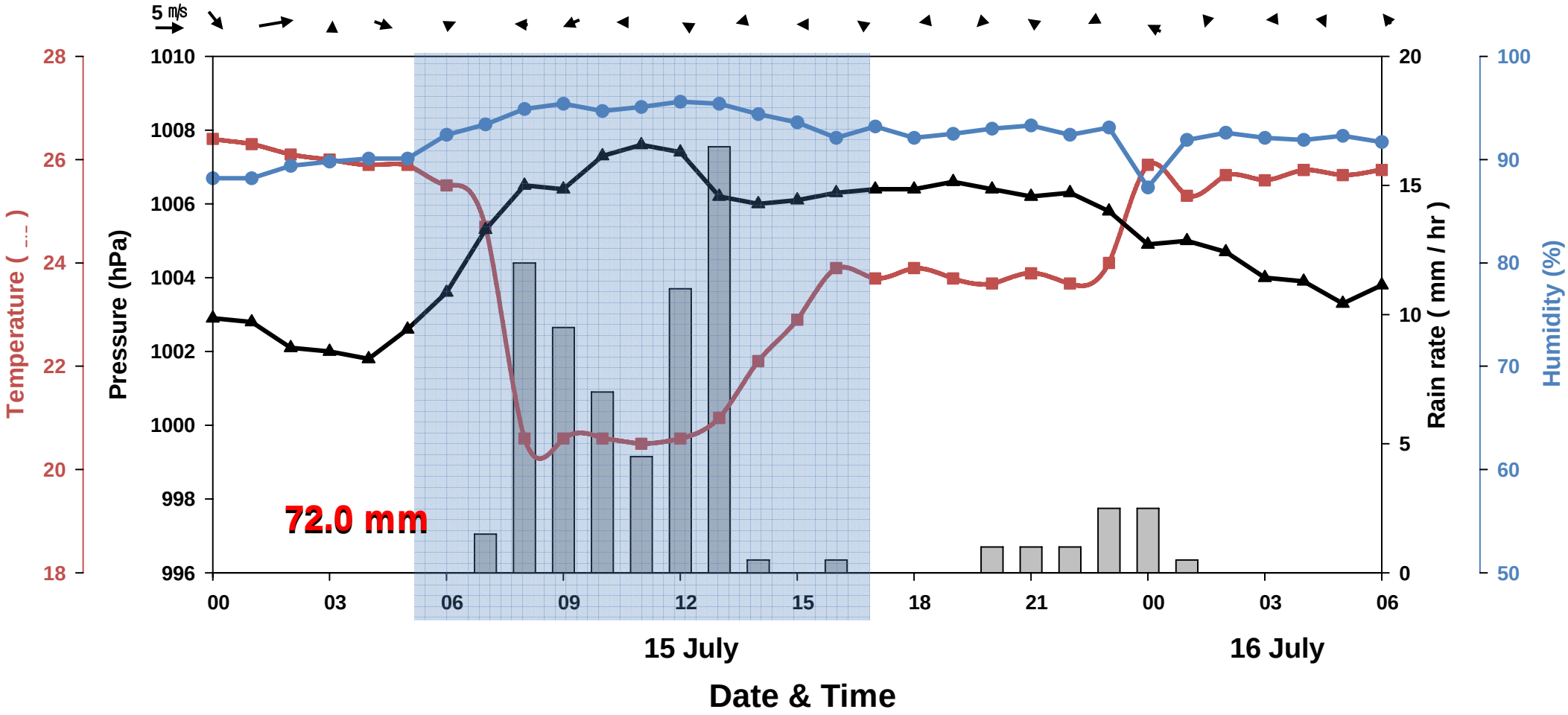


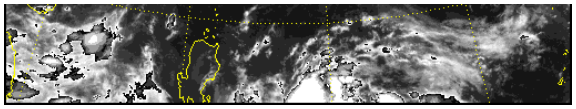
Precipitation were concentrated to the southern part of Korean peninsula

2009 Case 5 : 0500 ~ 1700 LST 15 July 2009

- Typical Changma Front
- Rainfall : Southern part of the Korean Peninsula



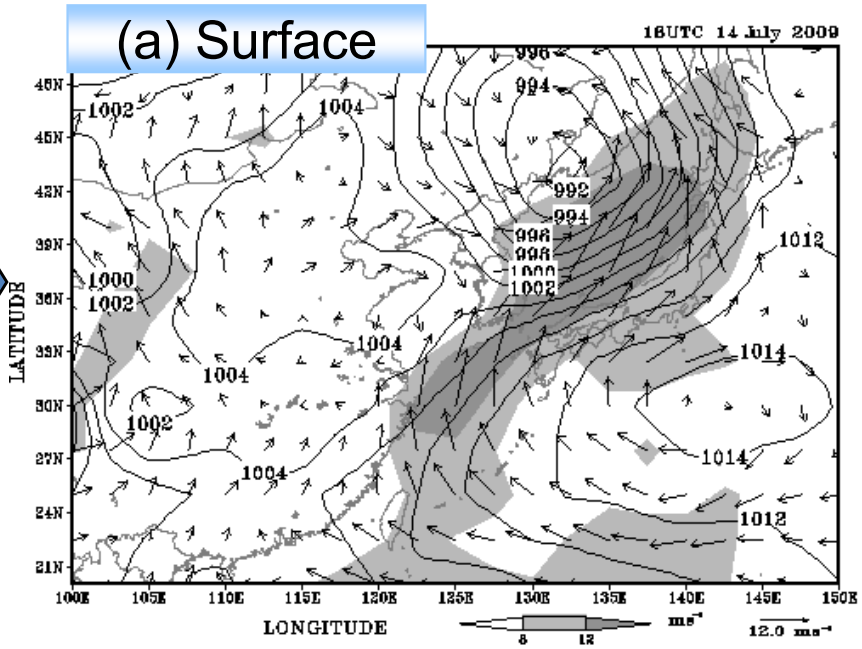


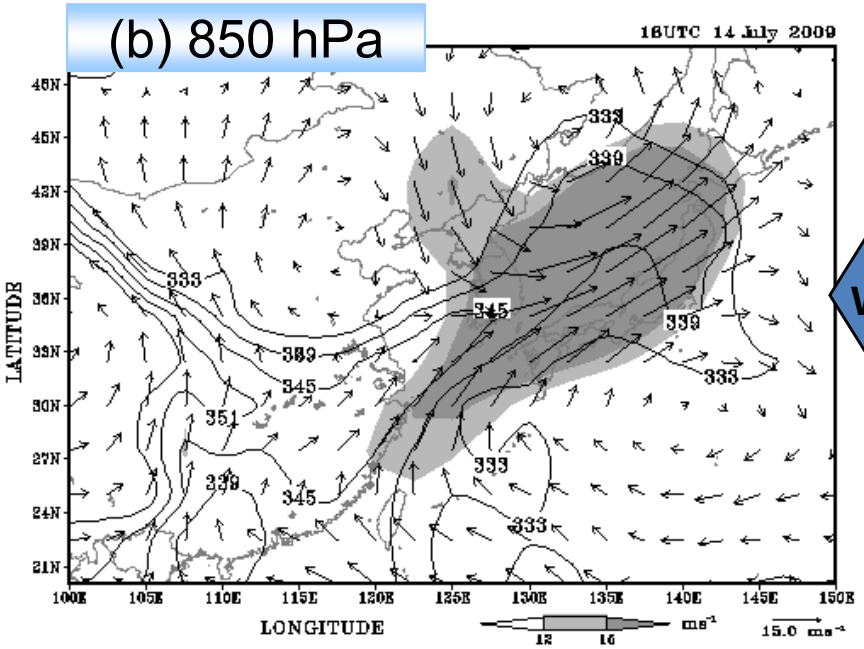


Synoptic Condition (NCEP/NCAR reanalysis data)

[03 LST 15 July 2009]

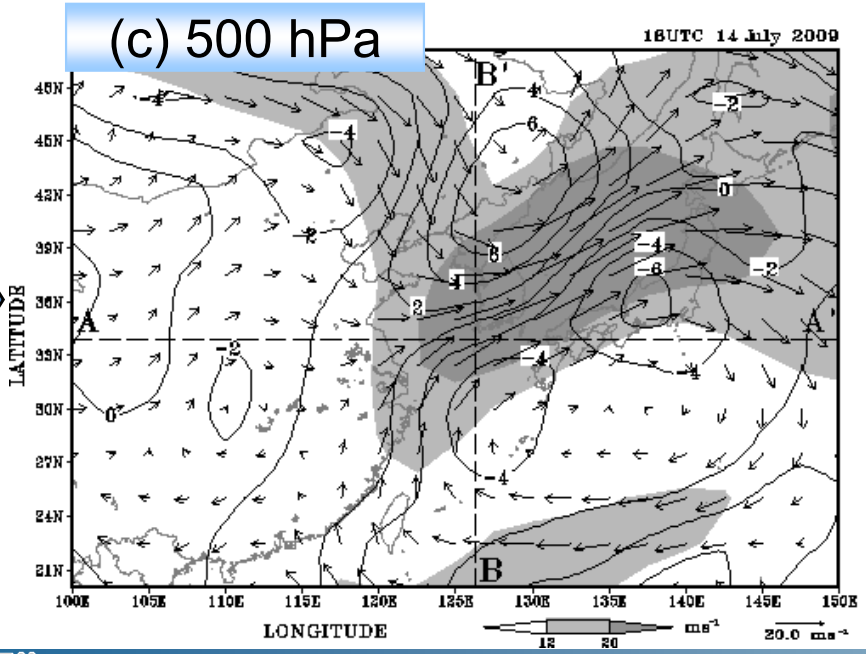
WS & P

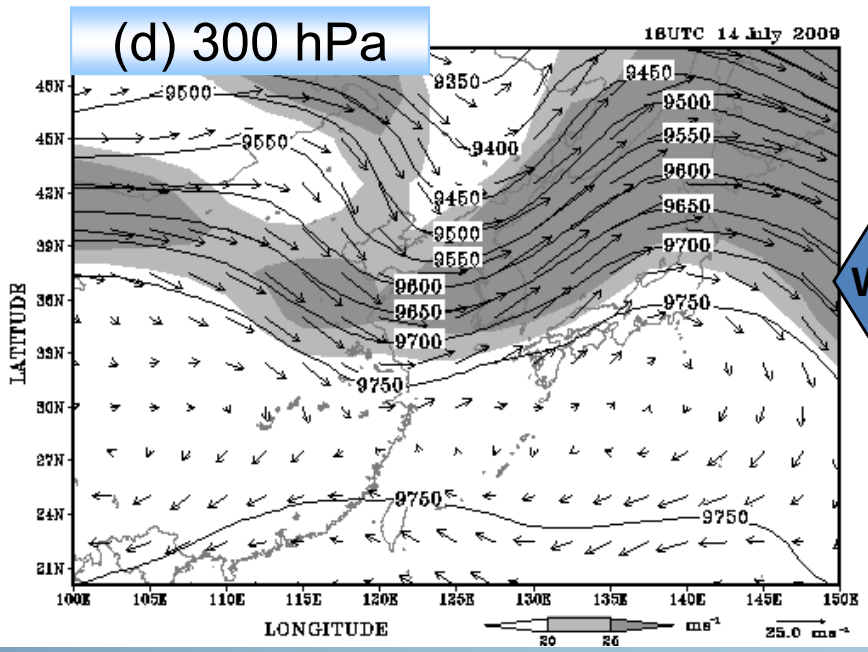




WS & θ_E

WS & RV



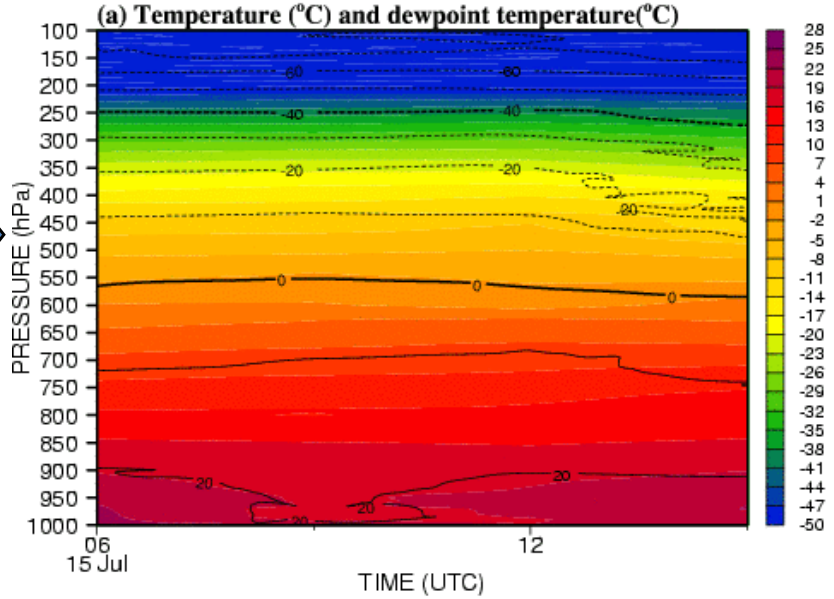


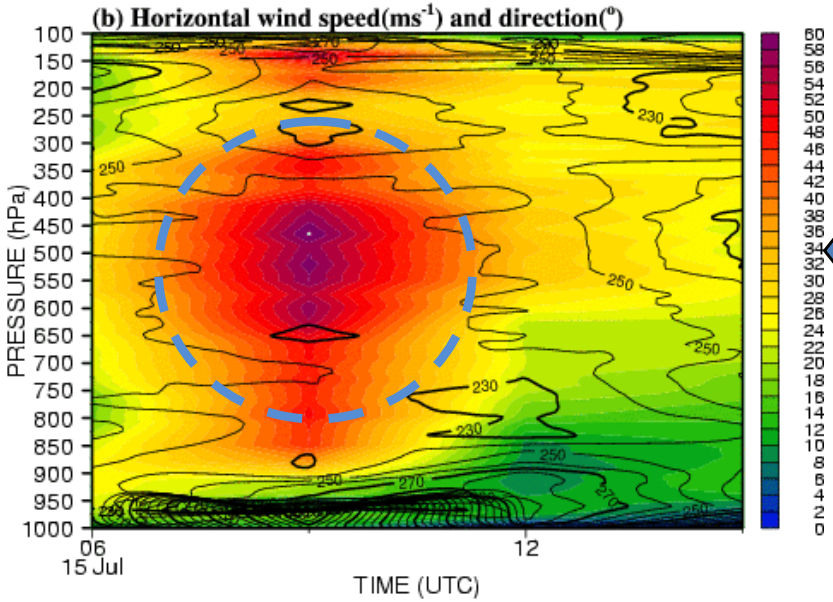
WS & hgt

Time series of sounding

0600 LST ~ 1500 LST 15 July 2009 (9 hour)

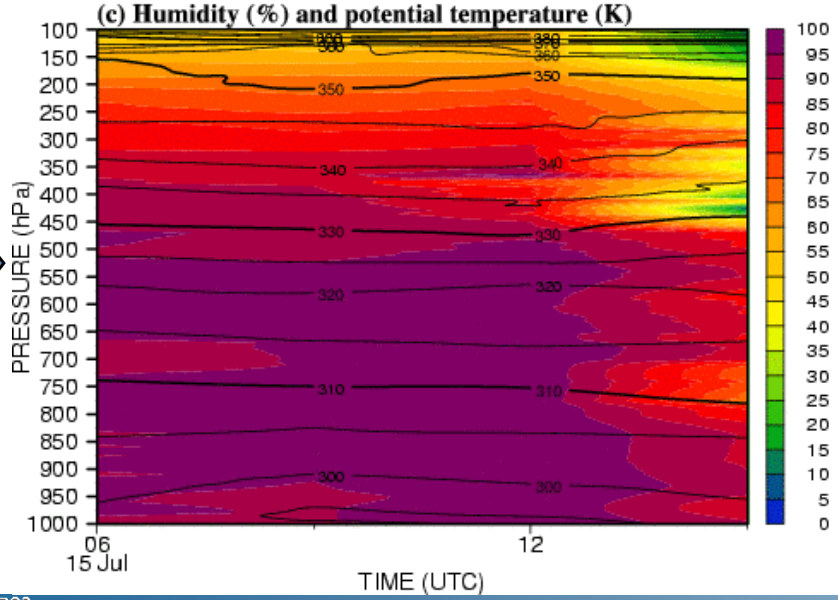
T & Td

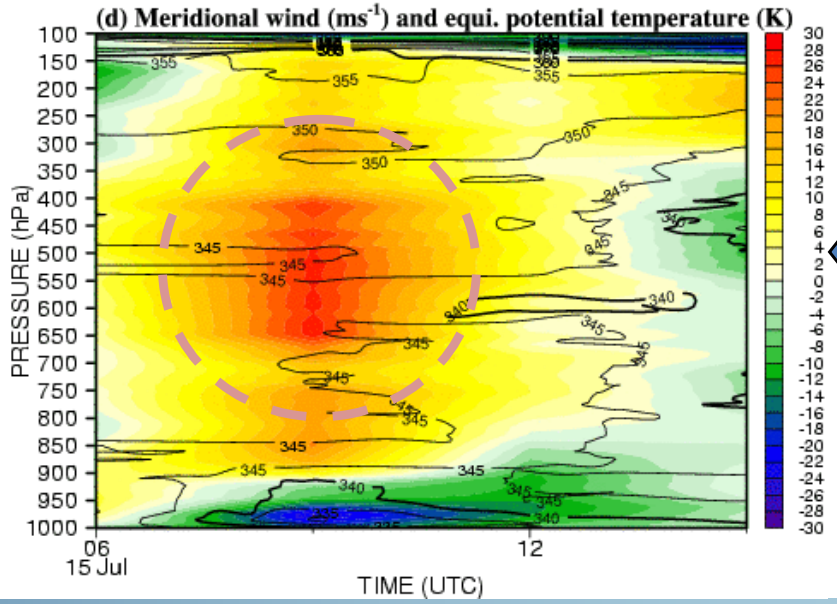




WS & WD

H(%) & θ

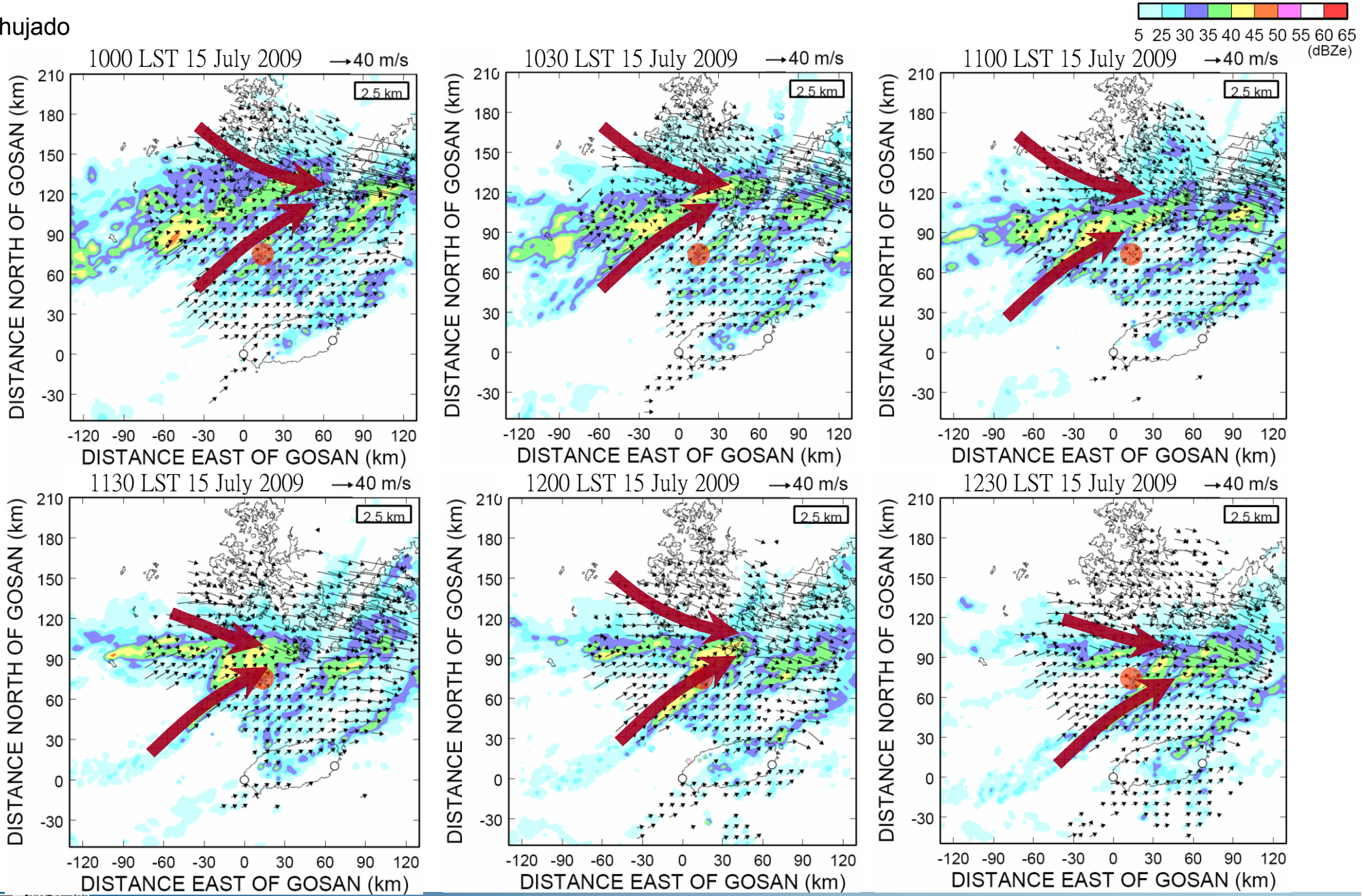




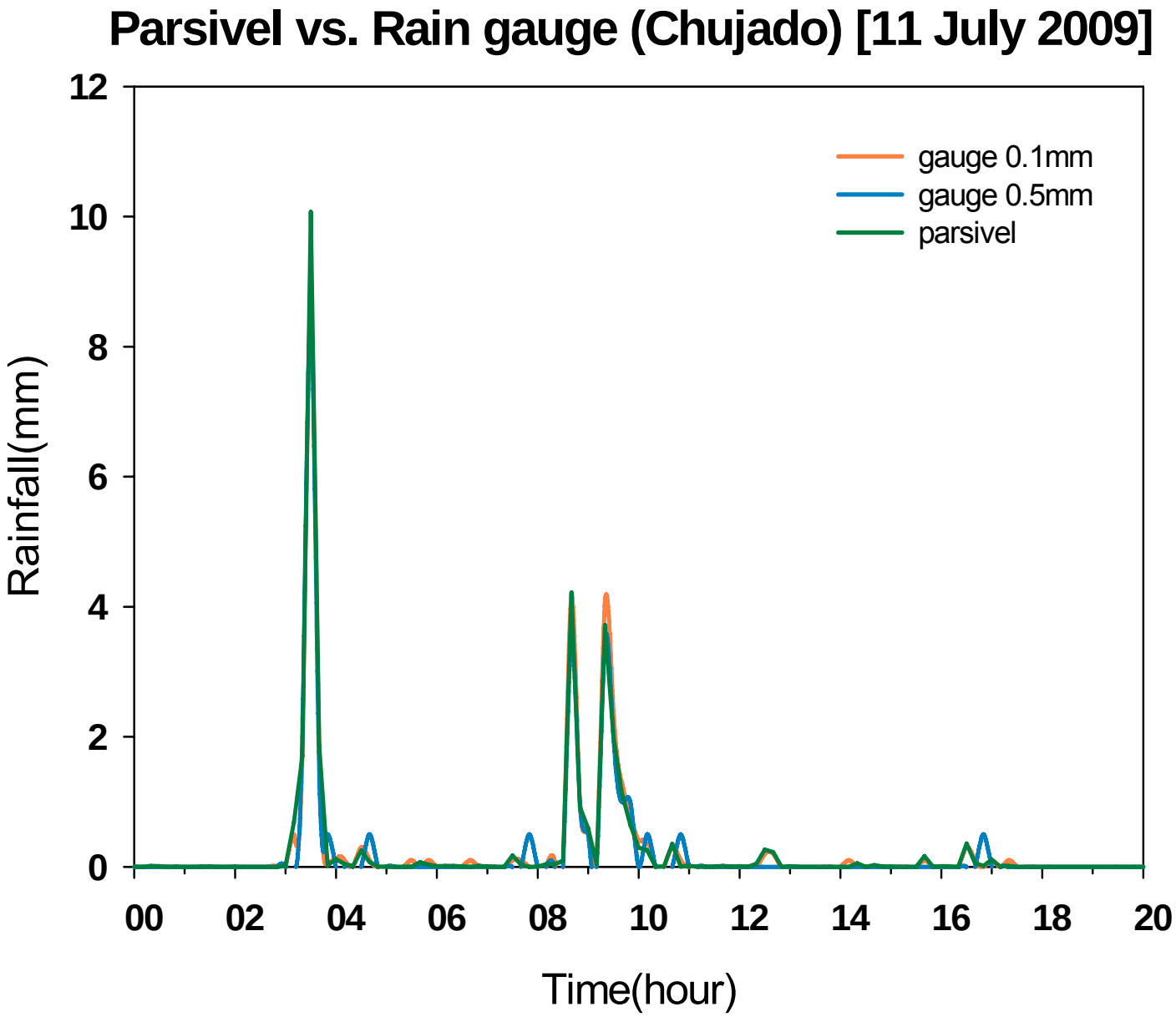
MS & θ_E

Dual Doppler analysis

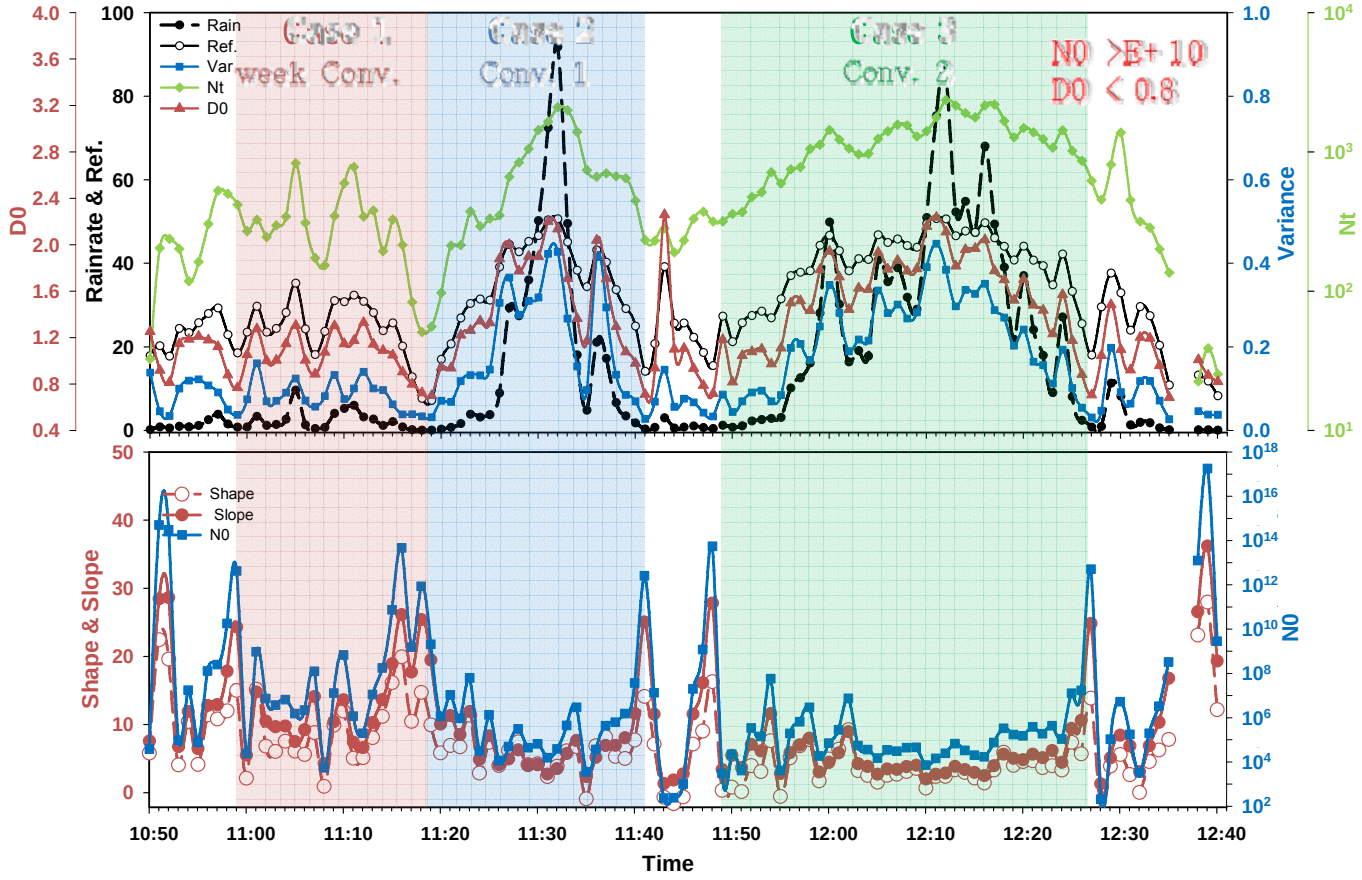
- Chujado

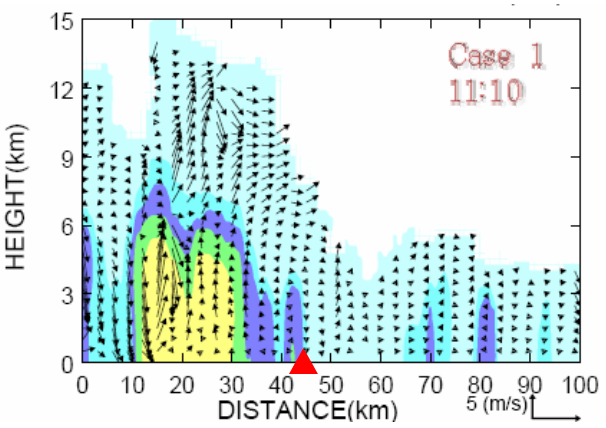


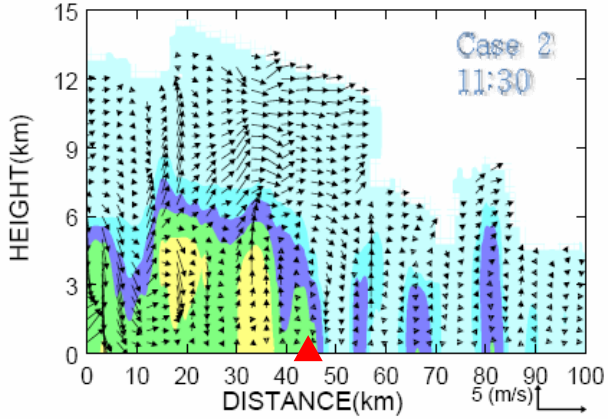
Parsivel

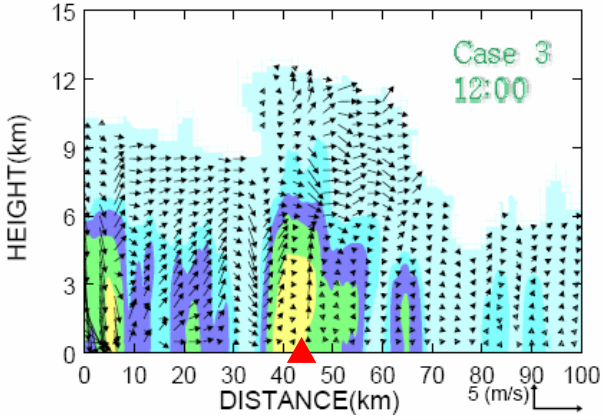

Parsivel vs. Rain gauge (Chujado) [11 July 2009]
Rainfall(mm)
0
2
4
6
8
10
12
00
02
04
06
08
10
12
14
16
18
20
Time(hour)
gauge 0.1mm
gauge 0.5mm
parsivel

Classification of stratiform and convective system using DSD parameter









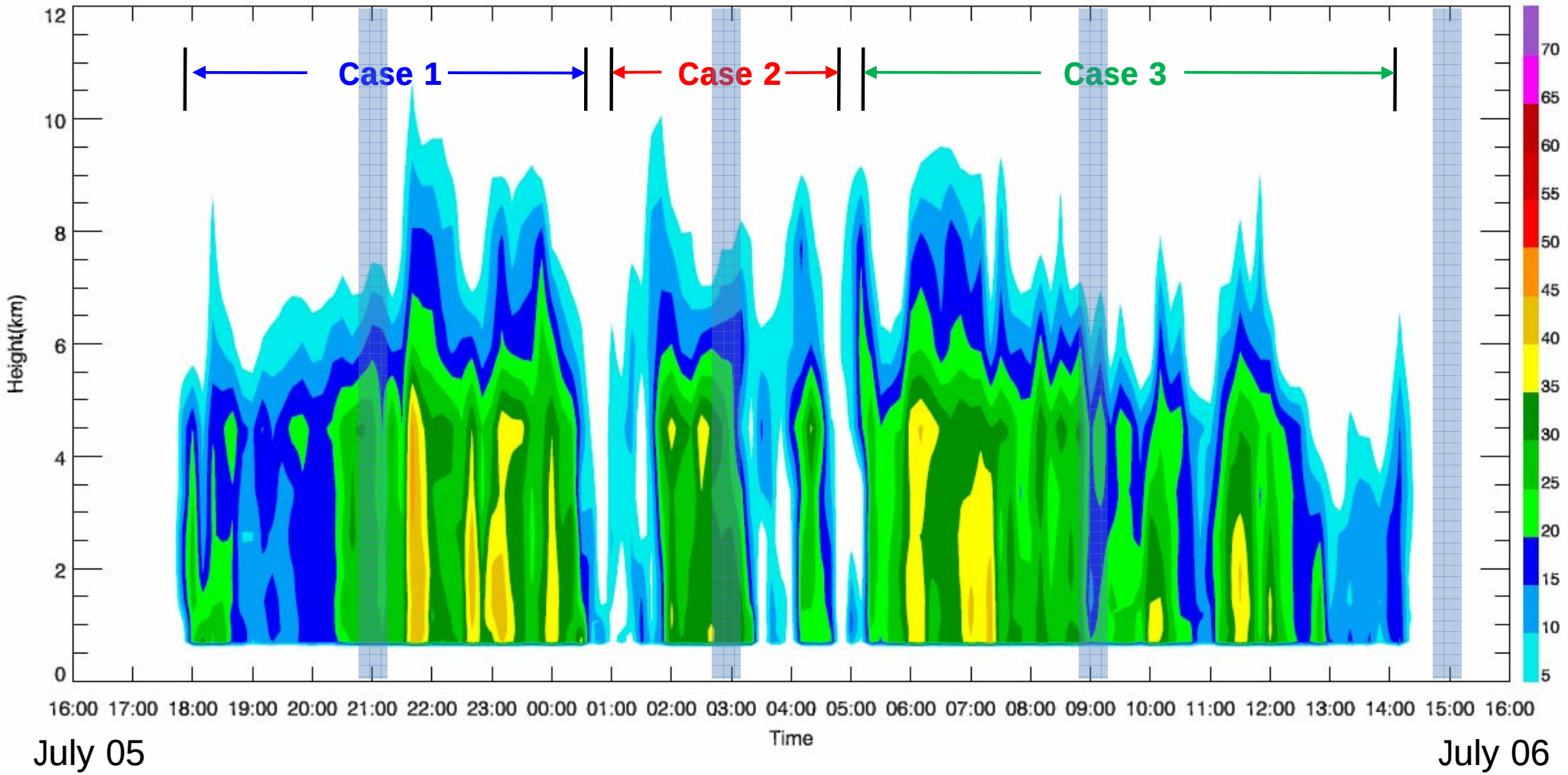
	rainrate	Refec	shape	slope	D0	variance	skewness	Nt	N0
Str. 1	1.33	22.81	11.57	15.76	**1.05**	0.08	0.02	270.36	**8.1E+13**
Week Conv.	2.49	24.96	9.03	12.39	**1.07**	0.09	0.02	329.19	**2.5E+12**
Conv. 1	20.56	35.14	5.83	7.22	**1.49**	0.21	0.11	767.78	**9.9E+07**
Str. 2	0.95	22.73	6.34	12.25	**1.07**	0.06	0.05	273.14	**7.2E+12**
Conv. 2	27.90	39.86	3.64	5.00	**1.57**	0.22	0.13	1233.19	**2.7E+06**
Str. 3	2.28	21.99	8.80	13.81	**1.00**	0.07	0.02	394.53	**1.5E+16**

5 25 30 35 40 45 50 55 60 65 (dBZe)

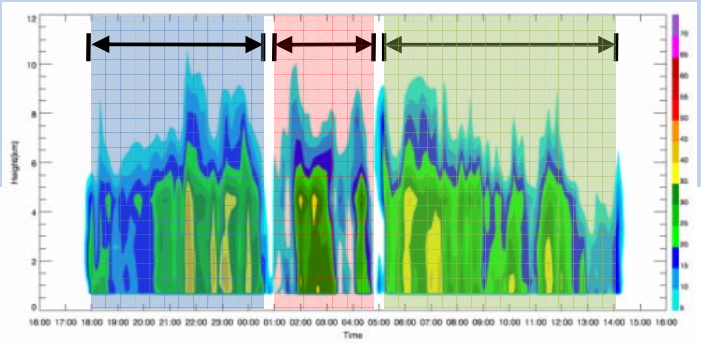
In the future,

- First, radar reflectivity correction to improve the radar rainfall estimation accuracy using a disdrometer
- Second, study on micro-physical characteristics of precipitation system using parameters derived from dual polarimetric radar and disdrometer (classification of stratiform and convective system)
- Third, clarify development characteristics of heavy rainfall using dual Doppler radar analysis and radiosonde
- Fourth, clarify MCS's characteristics developed around the Changma front

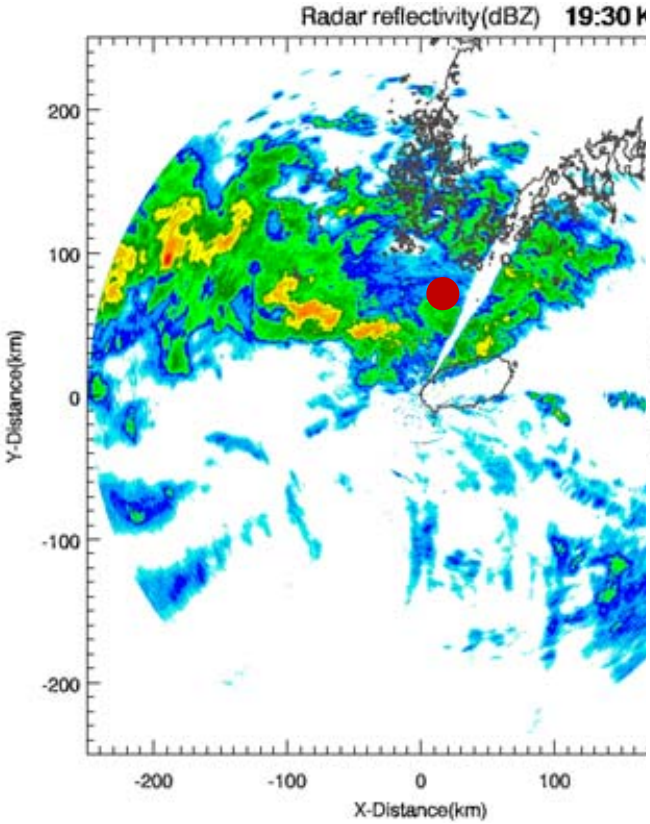
Vertical Profile of Reflectivity at Chujado (2007)



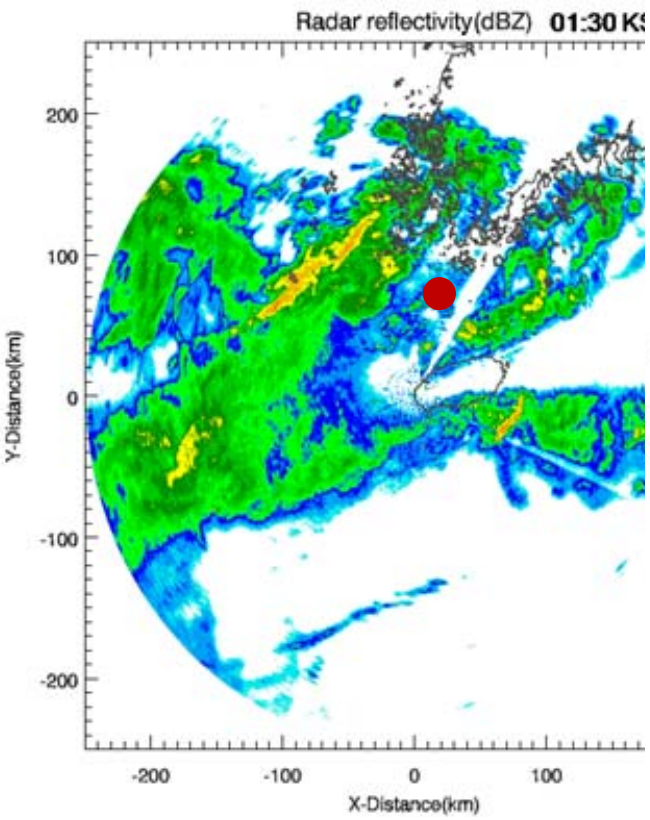
Radar Images with Case(2007)



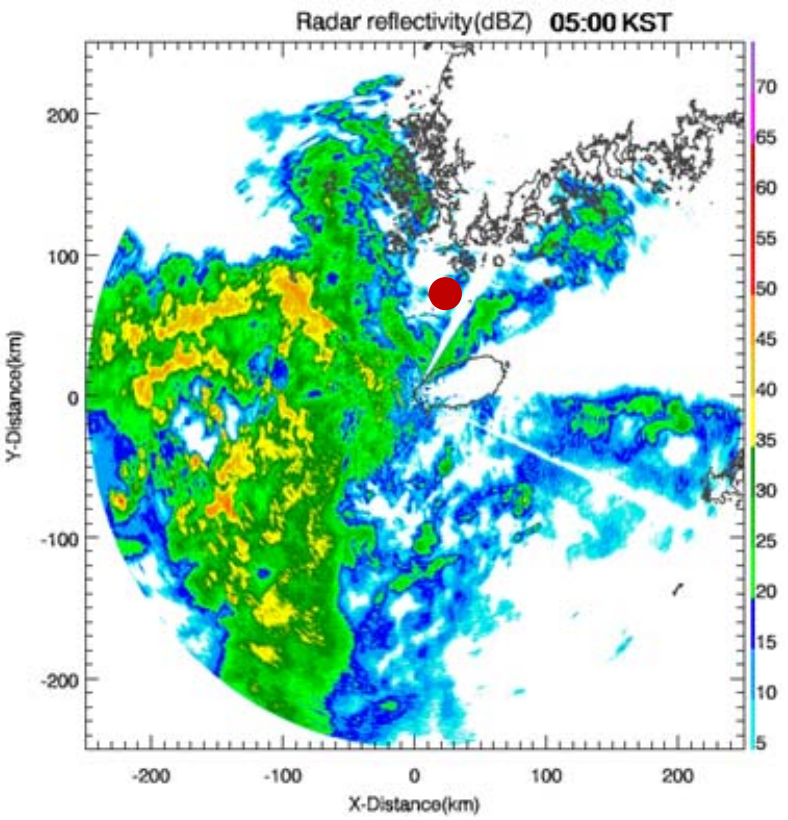
Case 1



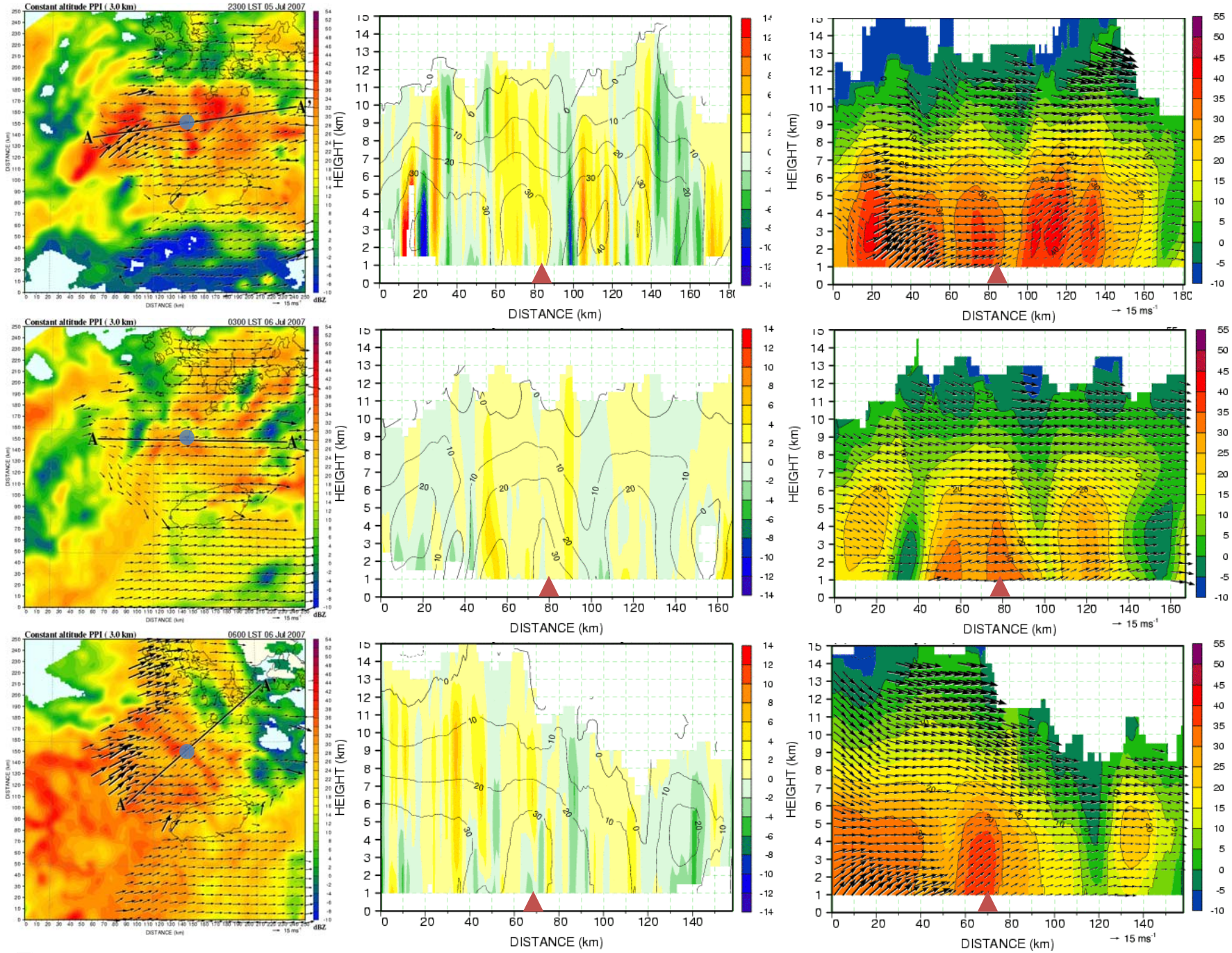
Case 2



Case 3



Dual Doppler analysis (2007)



Vertical wind shear analysis by sonde observation

a) TVWS

$$\left|\frac{dV}{dz}\right| \equiv \sqrt{(\frac{du}{dz})^2 + (\frac{dv}{dz})^2} \quad \textbf{(1)}$$

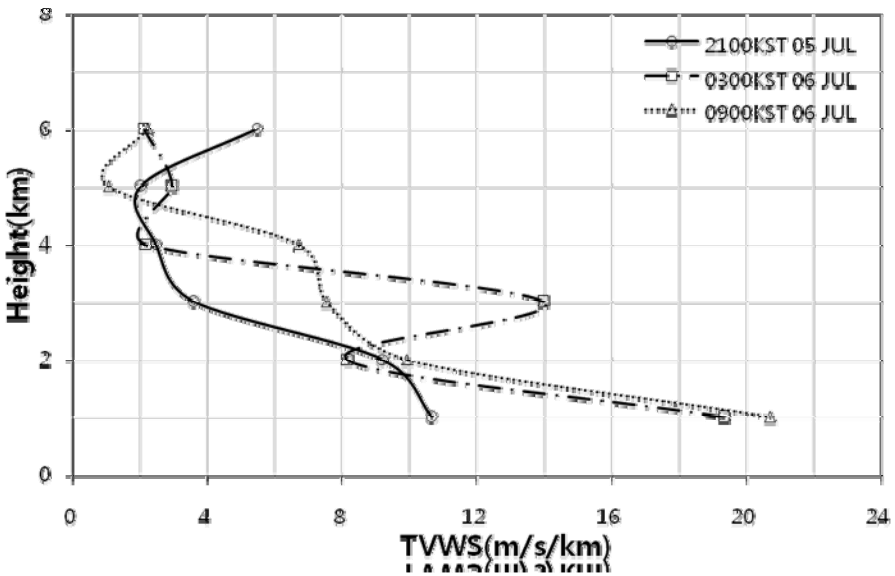
$$V = u\hat{i} + v\hat{j}$$

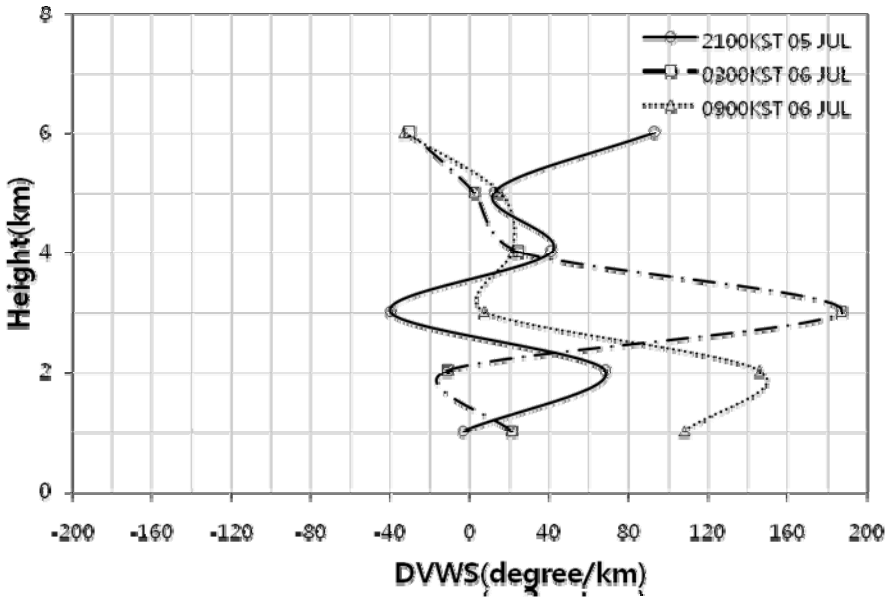
$$\bar{u} = (u(k+1) + u(k-1))/2$$

$$\bar{v} = (v(k+1) + v(k-1))/2$$

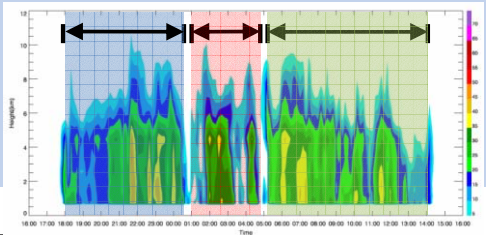
b) DVWS (Neiman, 2003)

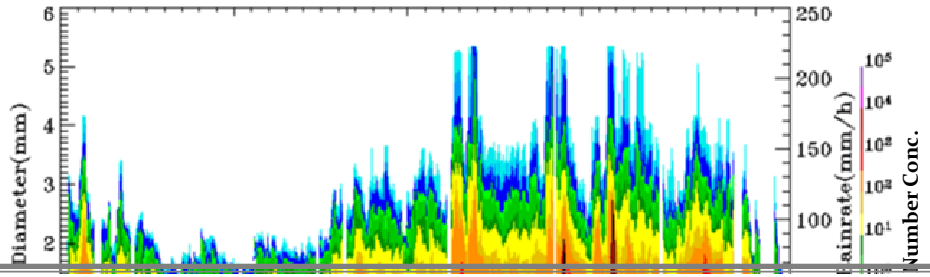
$$\frac{dD}{dz} \equiv -(\bar{u}\frac{dv}{dz} - \bar{v}\frac{du}{dz}) \quad \textbf{(2)}$$



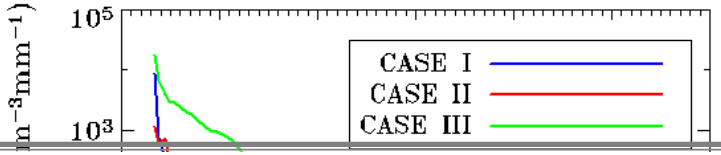


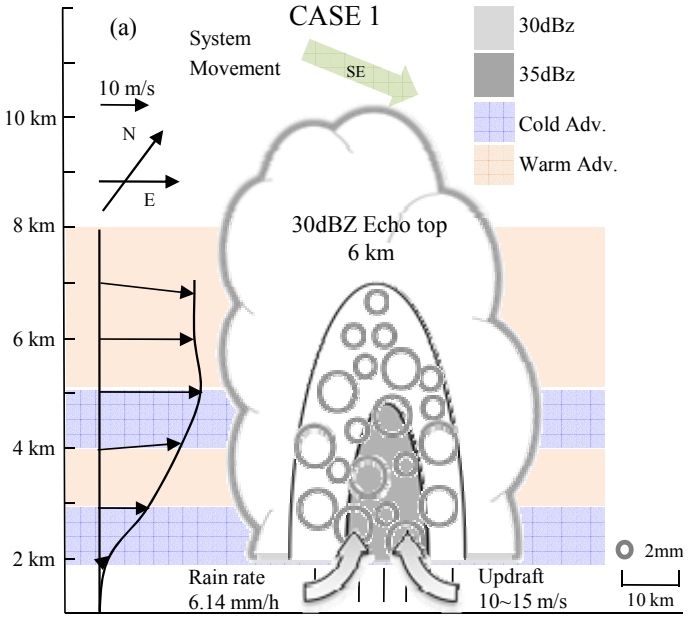
Raindrop size distributions (2007)

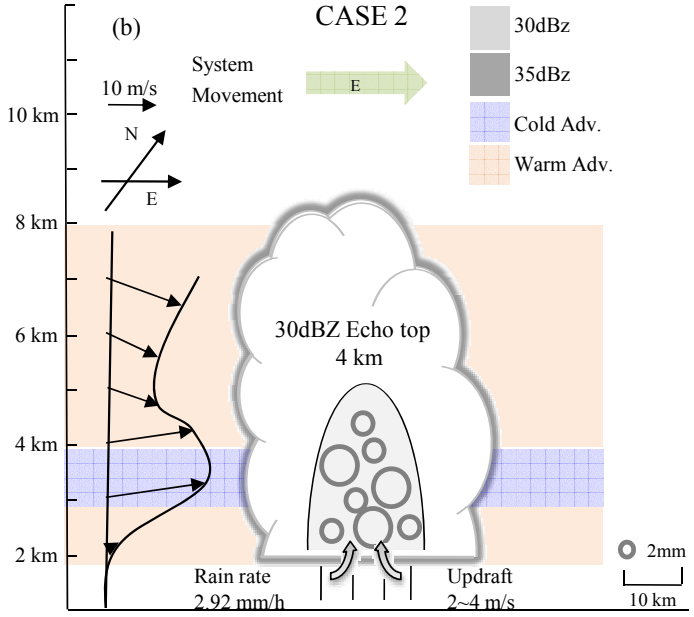


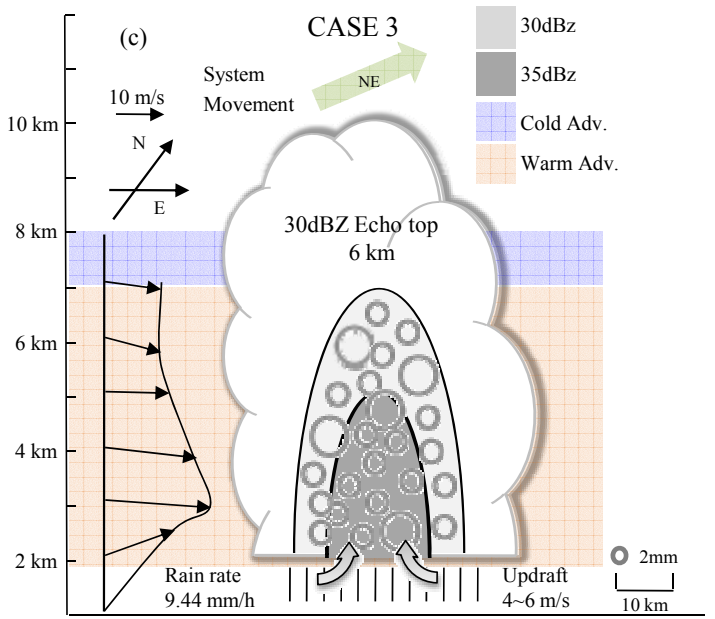


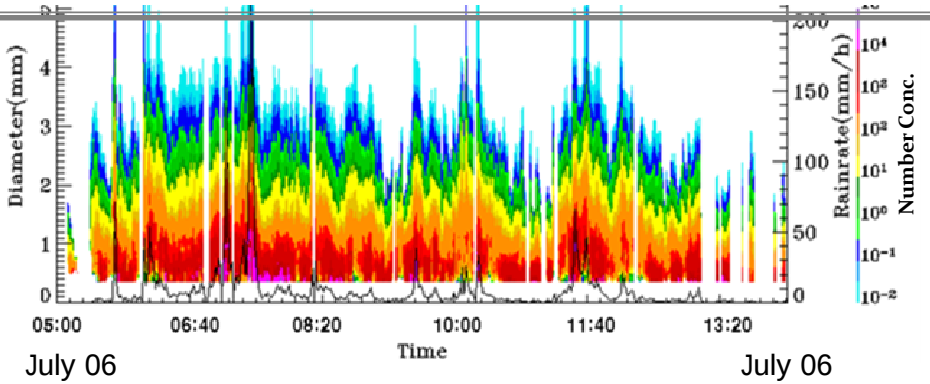
$$N(D) = N_0 D^{\mu} \exp(-\Lambda D)$$



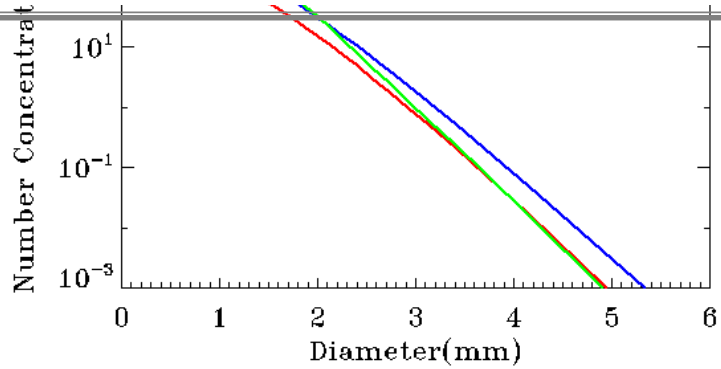








July 06

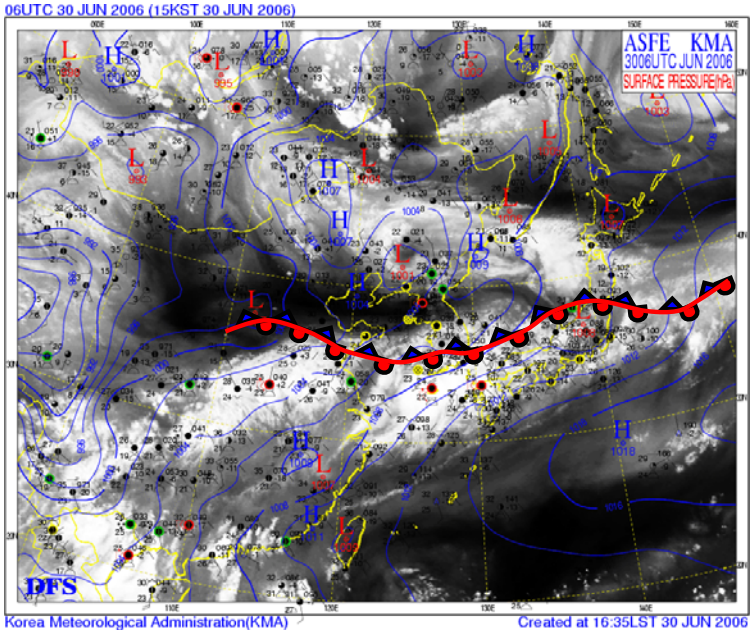


July 06

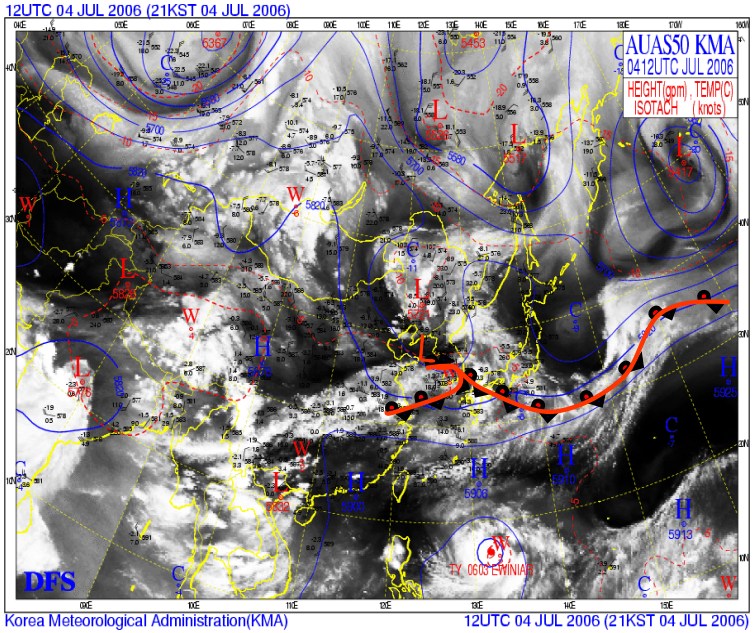
Thank you~

Weather chart (2006)

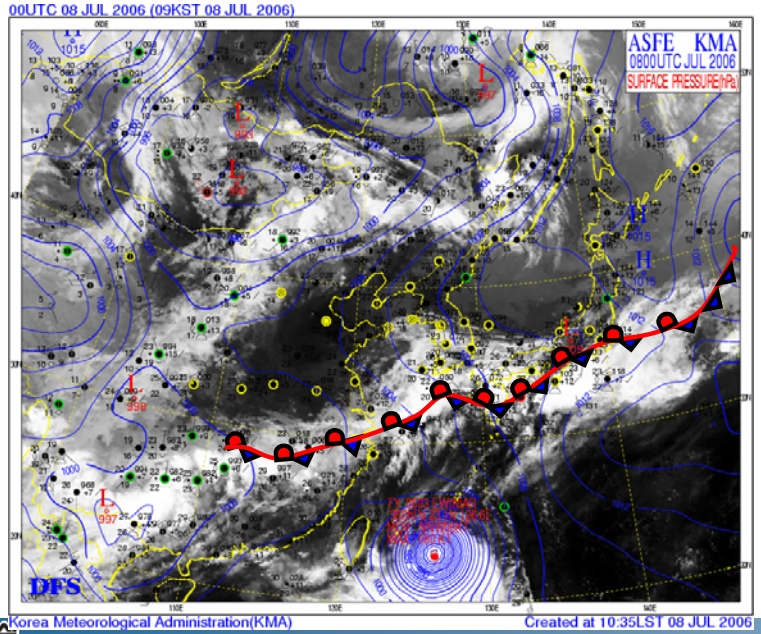
Case1



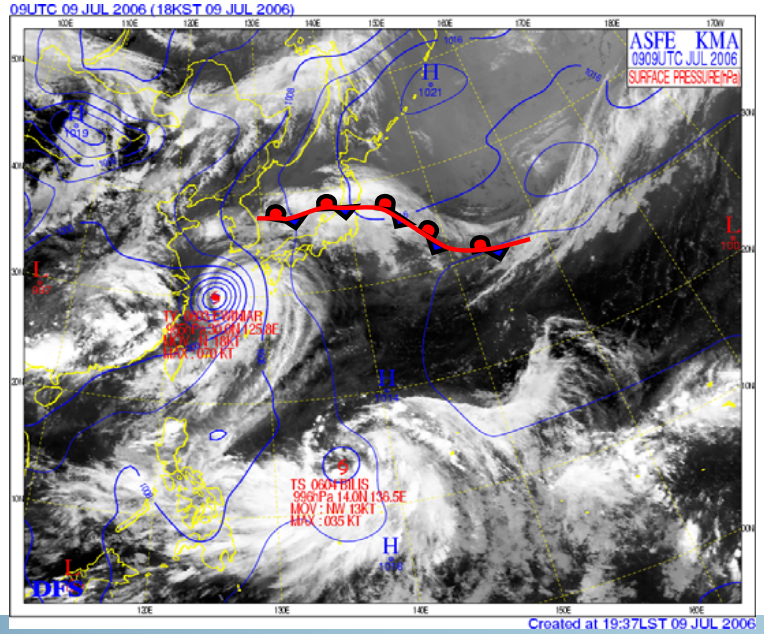
Case2



Case3

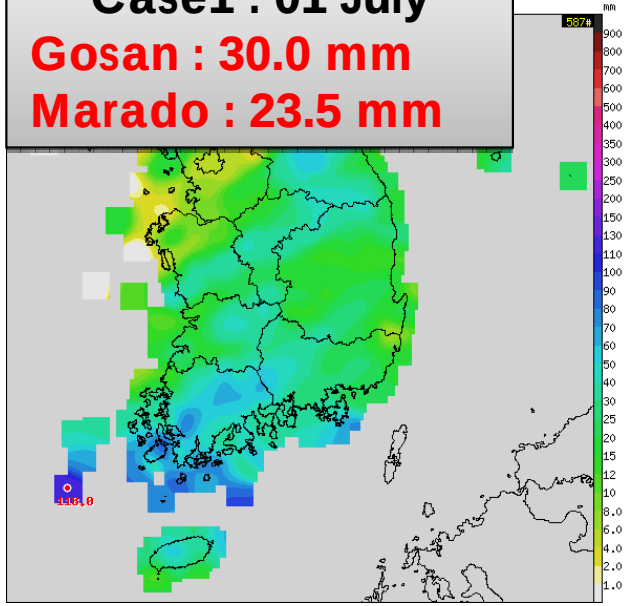


Case4

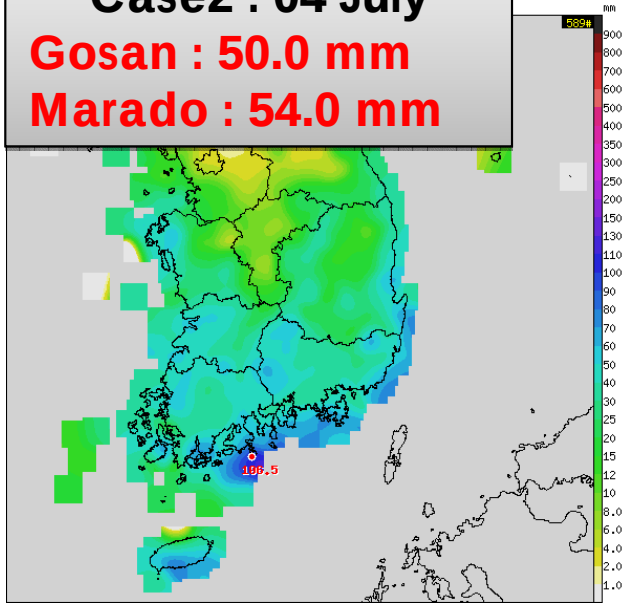


Daily accumulated rainfall amount during 2006 IOP

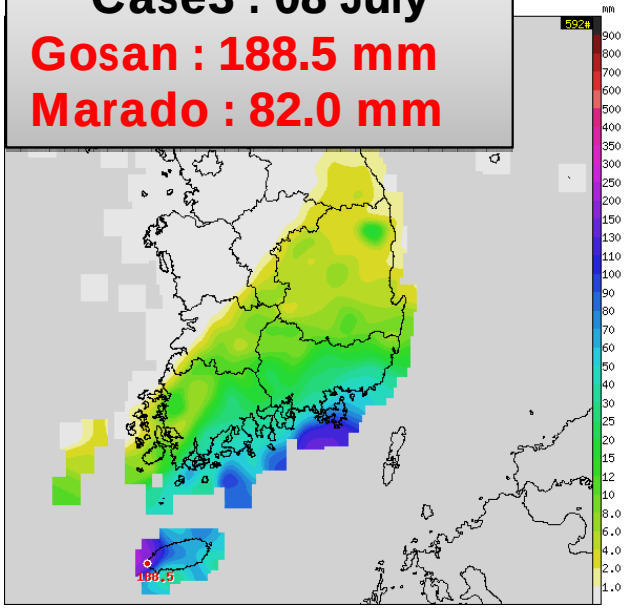
Case1 : 01 July
Gosan : 30.0 mm
Marado : 23.5 mm



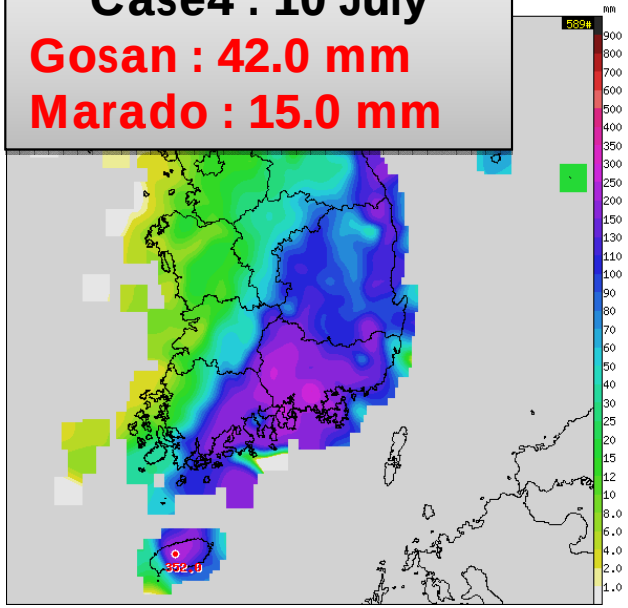
Case2 : 04 July
Gosan : 50.0 mm
Marado : 54.0 mm



Case3 : 08 July
Gosan : 188.5 mm
Marado : 82.0 mm

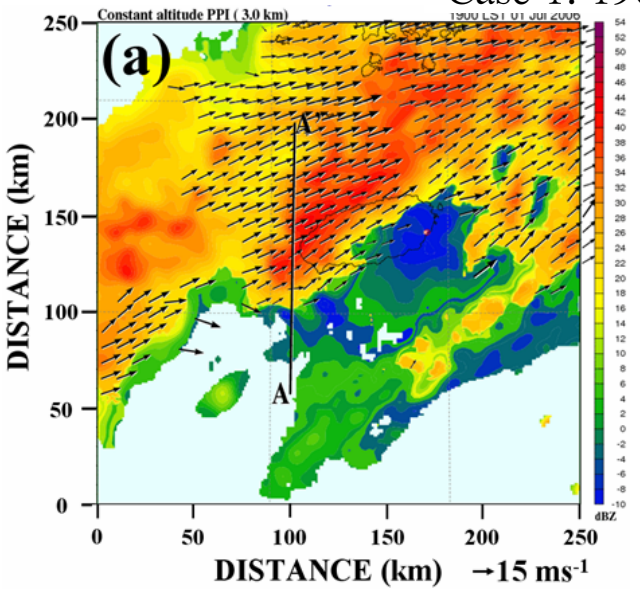


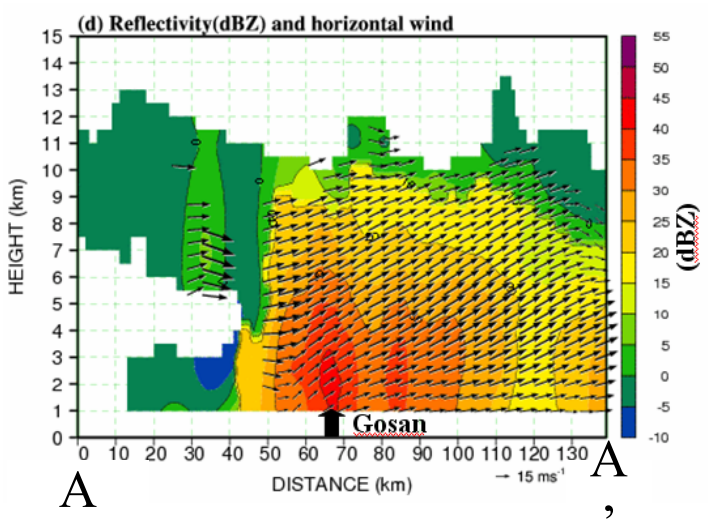
Case4 : 10 July
Gosan : 42.0 mm
Marado : 15.0 mm



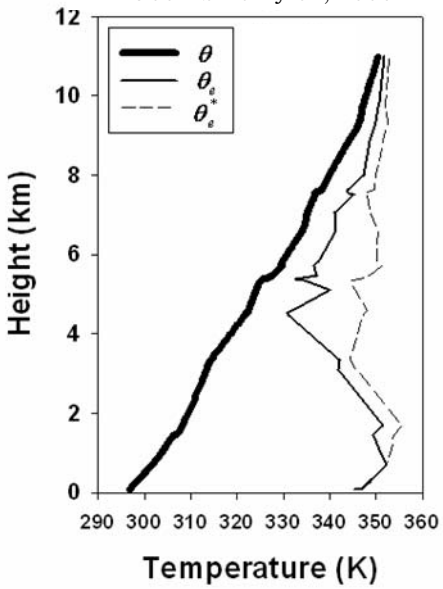
Dual Doppler analysis and sounding (2006)

Case 1: 1900 LST 01 Jul 2006

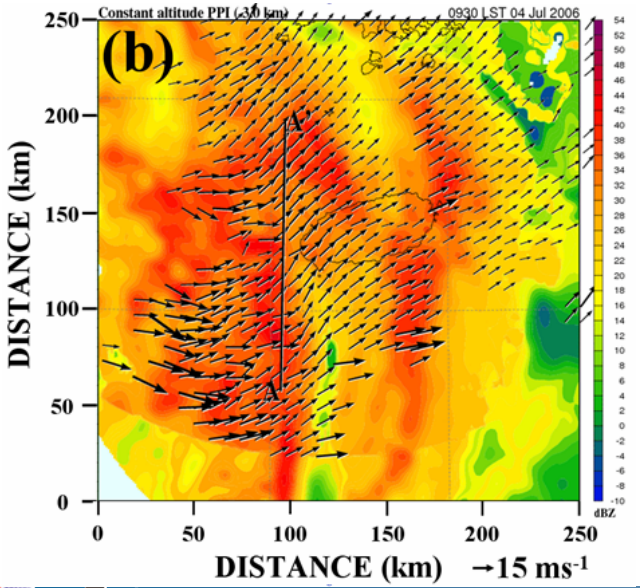


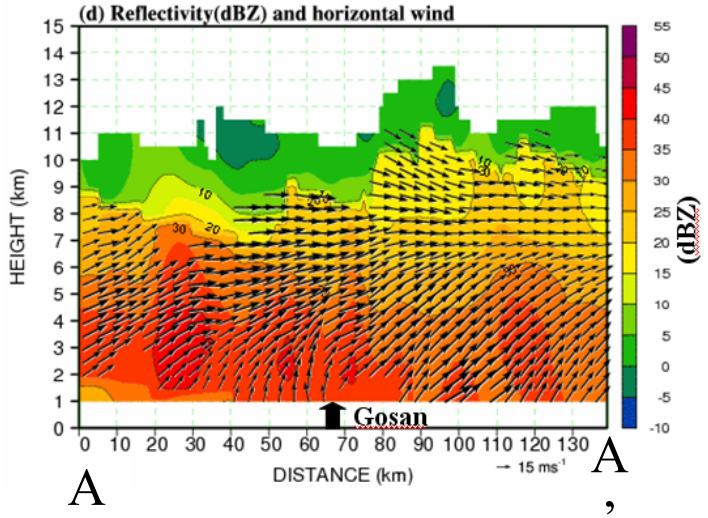


1500 LST July 01, 2006

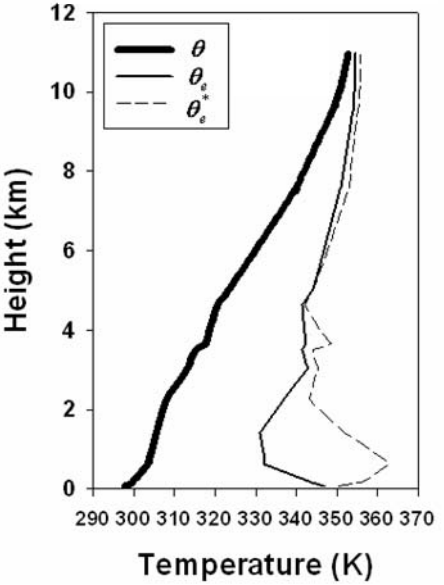


Case 2: 0930 LST 04 Jul 2006



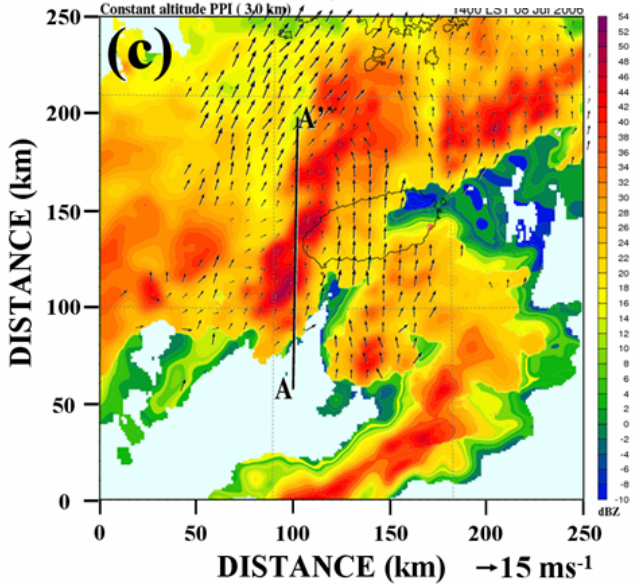


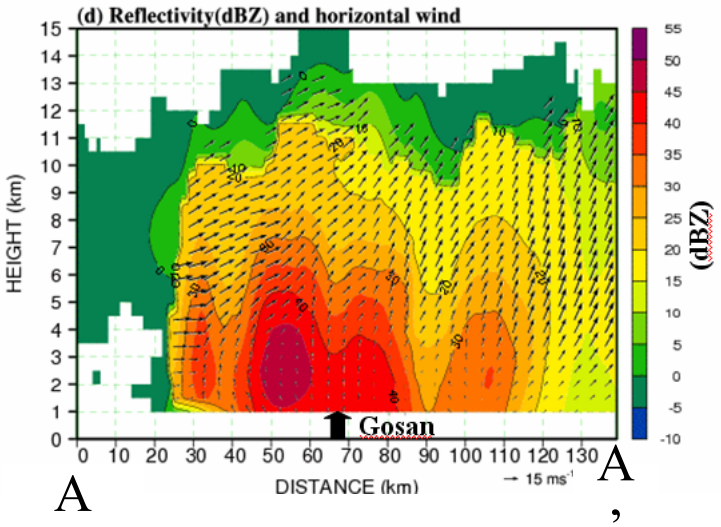
0900 LST July 04, 2006



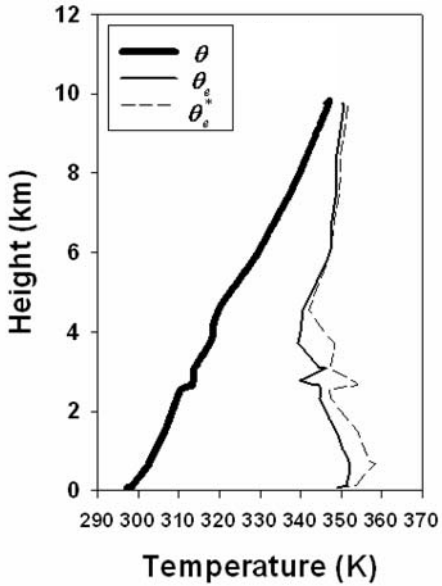
Dual Doppler analysis and sounding (2006)

Case 3: 1400 LST 08 Jul 2006

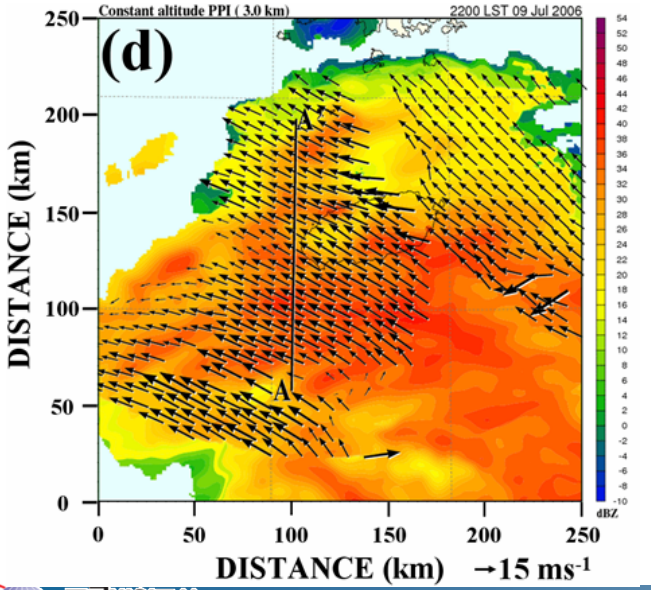


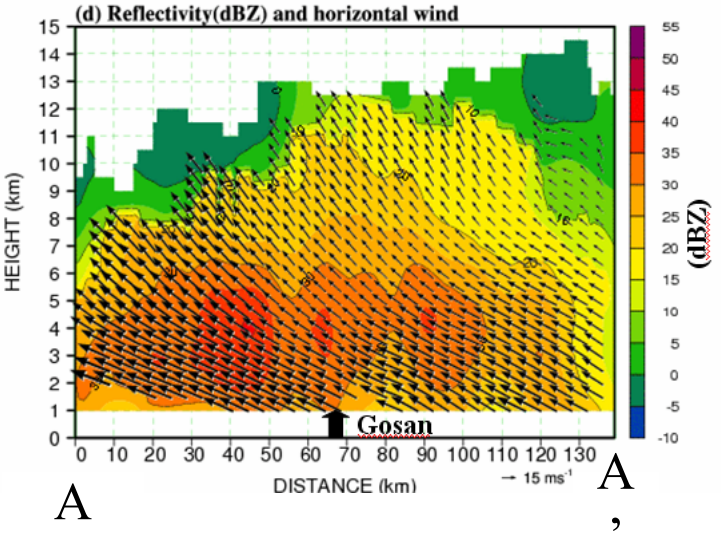


2100 LST July 08, 2006

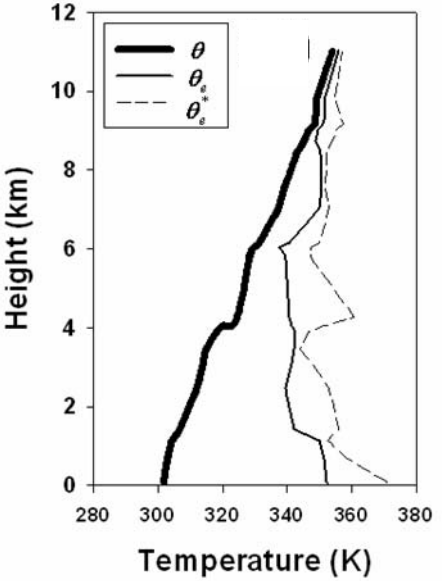


Case 4 : 2200 LST 09 Jul 2006





2100 LST July 09, 2006



Schematic diagram (2006)