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

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³Atmospheric Environmental Research Institute, Pukyong National University, Busan, Korea
1) Jeju: 2006/6/22 ~ 7/12
2) Okinawa: 2007/6/2 ~ 6/17
3) Ieodo: 2007/6/8 ~ 6/14; 2008/6/22 ~ 7/8; 2009/6/7 ~ 6/24
4) Chujado: 2007/6/21 ~ 7/10; 2009/6/24 ~ 7/18
5) Taiwan: 2008/5/15 ~ 6/30; 2008/6/22 ~ 7/8; 2009/6/7 ~ 6/24
“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

- 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

From GyuWon Lee

**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

**Legend**
- M: MRR
- J: JWD
- P: POSS
- S: Supersite (VertiX, ISS, 2DVD, J1, P3, M5)
Deployment of instruments in Supersite

POSS

2DVD : Sonic anemometer
ISS : surface tower
2DVD

ISS

MRR-2

VertiX

2DVD : Tipping Bucket Raingauge

Tipping Bucket Raingauge

JWD
Deployment of S-Pol. Radar
<table>
<thead>
<tr>
<th>Date</th>
<th>Science Objectives</th>
<th>Begin (UTC)</th>
<th>End (UTC)</th>
<th>Dropsonde Mission</th>
</tr>
</thead>
</table>
| 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 for heavy precipitation | 29 May 21:00 | 31 May 21:00 | mission #3 2008/05/29 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 |
| IOP-6 04-06 Jun | • Mesoscale convective systems  
• Quasi-stationary front  
• Mesoscale convective vortex | 04 Jun 18:00 | 06 Jun 12:00 | mission #7 2008/06/04 05:00-07:00 |
| 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 |
| 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 |

Summarize the event during IOP in Taiwan.
Study on classification of stratiform and convective system

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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>$\mu = \frac{(8-11m) - (m^2 + 8m)^{1/2}}{2(m-1)}$</td>
</tr>
<tr>
<td>Slope</td>
<td>$\Lambda = \frac{M_x}{m} (\mu + 4)$</td>
</tr>
<tr>
<td>Median volume diameter</td>
<td>$D_0 = \frac{(3.67 + \mu)}{\Lambda}$</td>
</tr>
<tr>
<td>Intercept parameter</td>
<td>$N_0 = \frac{\Lambda^{1/4} M_x}{\Gamma(\mu + 4)}$</td>
</tr>
<tr>
<td>Rainfall intensity</td>
<td>$R = \frac{\pi}{6} \int_{D_{Max}}^{D_{Min}} D^3 V_r N(D) dD$</td>
</tr>
<tr>
<td>Reflectivity</td>
<td>$Z = \int_{D_{Max}}^{D_{Min}} D^3 N(D) dD$</td>
</tr>
<tr>
<td>Variance</td>
<td>$\sigma^2 = \frac{M_0}{\int N(D) dD}$</td>
</tr>
<tr>
<td>Skewness</td>
<td>$sk = \frac{\int (D - D_0)^3 N(D) dD}{\int N(D) dD}$</td>
</tr>
<tr>
<td>Total number density</td>
<td>$N_0 = \int N(D) dD$</td>
</tr>
</tbody>
</table>

(Kozu, and Nakamura, 1991)

(Chu at al., 2008)
Observation of Precipitation Systems

**2006’**
- 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

**2007’**
- 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

**2008’**
- Site: Chujado
  - Period: 2007. 6. 21 ~ 7. 10
  - Case 1: 0300 ~ 1000 LST 29 June
  - Case 2: 2100 LST 30 June ~ 0800 LST 1 July

**2009’**
- 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

![Sonde launching diagram]

**Graph Details**:
- **Pressure (hPa)**
- **Temperature (°C)**
- **Humidity (%)**
- **Rain rate (mm/30min)**

**Dates & Times**:
- 27 June
- 28 June
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)
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

![Graph showing temperature, pressure, and humidity over 15 July 2009]

**Rainfall:** 72.0 mm

**Date & Time:**
- 00:00 to 03:00
- 06:00 to 09:00
- 12:00 to 15:00
- 18:00 to 21:00
- 00:00 to 03:00

**Rain Rate (mm/hr):**
- 0
- 5
- 10
- 15

**Temperature (°C):**
- 18
- 20
- 22
- 24
- 26
- 28

**Pressure (hPa):**
- 996
- 998
- 1000
- 1002
- 1004
- 1006
- 1008

**Humidity (%):**
- 50
- 60
- 70
- 80
- 90
- 100
Synoptic Condition (NCEP/NCAR reanalysis data)

(a) Surface
(b) 850 hPa
(c) 500 hPa
(d) 300 hPa

[03 LST 15 July 2009]
Time series of sounding

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

(a) Temperature (°C) and dewpoint temperature (°C)
(b) Horizontal wind speed (m/s) and direction (°)
(c) Humidity (%) and potential temperature (K)
(d) Meridional wind (m/s) and equi. potential temperature (K)

T & Td
WS & WI
H(%) & θ
MS & θE
Dual Doppler analysis

Chujado

1000 LST 15 July 2009 → 40 m/s
1030 LST 15 July 2009 → 40 m/s
1100 LST 15 July 2009 → 40 m/s
1130 LST 15 July 2009
1200 LST 15 July 2009
1230 LST 15 July 2009

DISTANCE EAST OF GOSAN (km)
DISTANCE NORTH OF GOSAN (km)

2.5 km

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

- Laser-based optical disdrometer
- Measurement of particle size and velocity in precipitation
- Types of precipitation: Drizzle, Rain, Ice pellets, Hail, Snow, Mixed precipitation

Parsivel vs. Rain gauge (Chujado) [11 July 2009]

Time(hour)

Rainfall(mm)

- orange: gauge 0.1mm
- blue: gauge 0.5mm
- green: parsivel

Rainfall vs. Time graph showing comparisons between parsivel and rain gauges.
Classification of stratiform and convective system using DSD parameter

<table>
<thead>
<tr>
<th>Case</th>
<th>rainrate</th>
<th>Refec</th>
<th>shape</th>
<th>slope</th>
<th>D0</th>
<th>variance</th>
<th>skewnes</th>
<th>Nt</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Str. 1</td>
<td>1.33</td>
<td>22.81</td>
<td>11.57</td>
<td>15.76</td>
<td><strong>1.05</strong></td>
<td>0.08</td>
<td>0.02</td>
<td>270.36</td>
<td><strong>8.1E+13</strong></td>
</tr>
<tr>
<td>Week Conv.</td>
<td>2.49</td>
<td>24.96</td>
<td>9.03</td>
<td>12.39</td>
<td><strong>1.07</strong></td>
<td>0.09</td>
<td>0.02</td>
<td>329.19</td>
<td><strong>2.5E+12</strong></td>
</tr>
<tr>
<td>Conv. 1</td>
<td>20.56</td>
<td>35.14</td>
<td>5.83</td>
<td>7.22</td>
<td><strong>1.49</strong></td>
<td>0.21</td>
<td>0.11</td>
<td>767.78</td>
<td><strong>9.9E+07</strong></td>
</tr>
<tr>
<td>Str. 2</td>
<td>0.95</td>
<td>22.73</td>
<td>6.34</td>
<td>12.25</td>
<td><strong>1.07</strong></td>
<td>0.06</td>
<td>0.05</td>
<td>273.14</td>
<td><strong>7.2E+12</strong></td>
</tr>
<tr>
<td>Conv. 2</td>
<td>27.90</td>
<td>39.86</td>
<td>3.64</td>
<td>5.00</td>
<td><strong>1.57</strong></td>
<td>0.22</td>
<td>0.13</td>
<td>1233.19</td>
<td><strong>2.7E+06</strong></td>
</tr>
<tr>
<td>Str. 3</td>
<td>2.28</td>
<td>21.99</td>
<td>8.80</td>
<td>13.81</td>
<td><strong>1.00</strong></td>
<td>0.07</td>
<td>0.02</td>
<td>394.53</td>
<td><strong>1.5E+16</strong></td>
</tr>
</tbody>
</table>
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**
Radar reflectivity (dBZ) 19:30 h

**Case 2**
Radar reflectivity (dBZ) 01:30 K

**Case 3**
Radar reflectivity (dBZ) 05:00 KST
Dual Doppler analysis (2007)
Vertical wind shear analysis by sonde observation

a) TVWS

\[
\left| \frac{dV}{dz} \right| = \sqrt{\left( \frac{du}{dz} \right)^2 + \left( \frac{dv}{dz} \right)^2} \quad (1)
\]

\[
V = u\hat{i} + v\hat{j}
\]

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

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

b) DVWS

(\text{Neiman, 2003})

\[
\frac{dD}{dz} \equiv -(\bar{u} \frac{dv}{dz} - \bar{v} \frac{du}{dz}) \quad (2)
\]
Raindrop size distributions (2007)

\[ N(D) = N_0D^\mu \exp(-\Lambda D) \]

CASE 1
- System Movement: SE
- 30dBZ
- 35dBZ
- Cold Adv.
- Warm Adv.
- Rain rate: 6.14 mm/h
- Updraft: 10~15 m/s
- 30dBZ Echo top: 6 km

CASE 2
- System Movement: E
- 30dBZ
- 35dBZ
- Cold Adv.
- Warm Adv.
- Rain rate: 2.92 mm/h
- Updraft: 2~4 m/s
- 30dBZ Echo top: 4 km

CASE 3
- System Movement: NE
- 30dBZ
- 35dBZ
- Cold Adv.
- Warm Adv.
- Rain rate: 9.44 mm/h
- Updraft: 4~6 m/s
Thank you~
Weather chart (2006)

Case 1

Case 2

Case 3

Case 4
Daily accumulated rainfall amount during 2006 IOP

Case 1: 01 July
Gosan: 30.0 mm
Marado: 23.5 mm

Case 2: 04 July
Gosan: 50.0 mm
Marado: 54.0 mm

Case 3: 08 July
Gosan: 188.5 mm
Marado: 82.0 mm

Case 4: 10 July
Gosan: 42.0 mm
Marado: 15.0 mm
Dual Doppler analysis and sounding (2006)

Case 1: 1900 LST 01 Jul 2006

Case 2: 0930 LST 04 Jul 2006
Schematic diagram (2006)