Precipitation system observations in monsoon season around the East China Sea from 2006 to 2010

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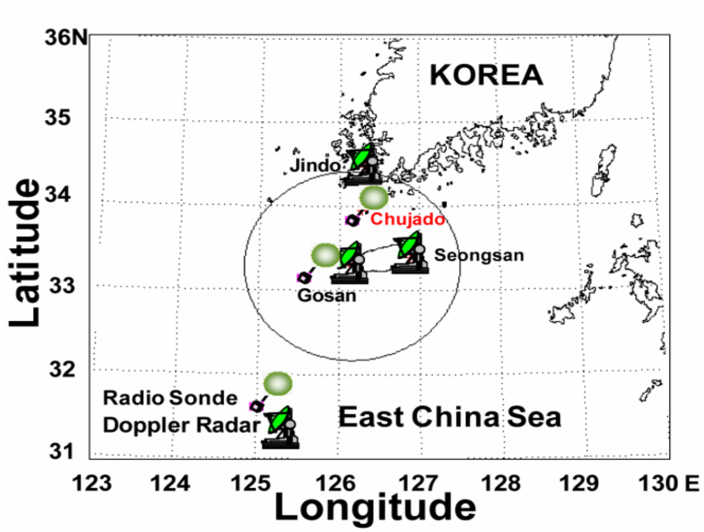
Purpose of Research

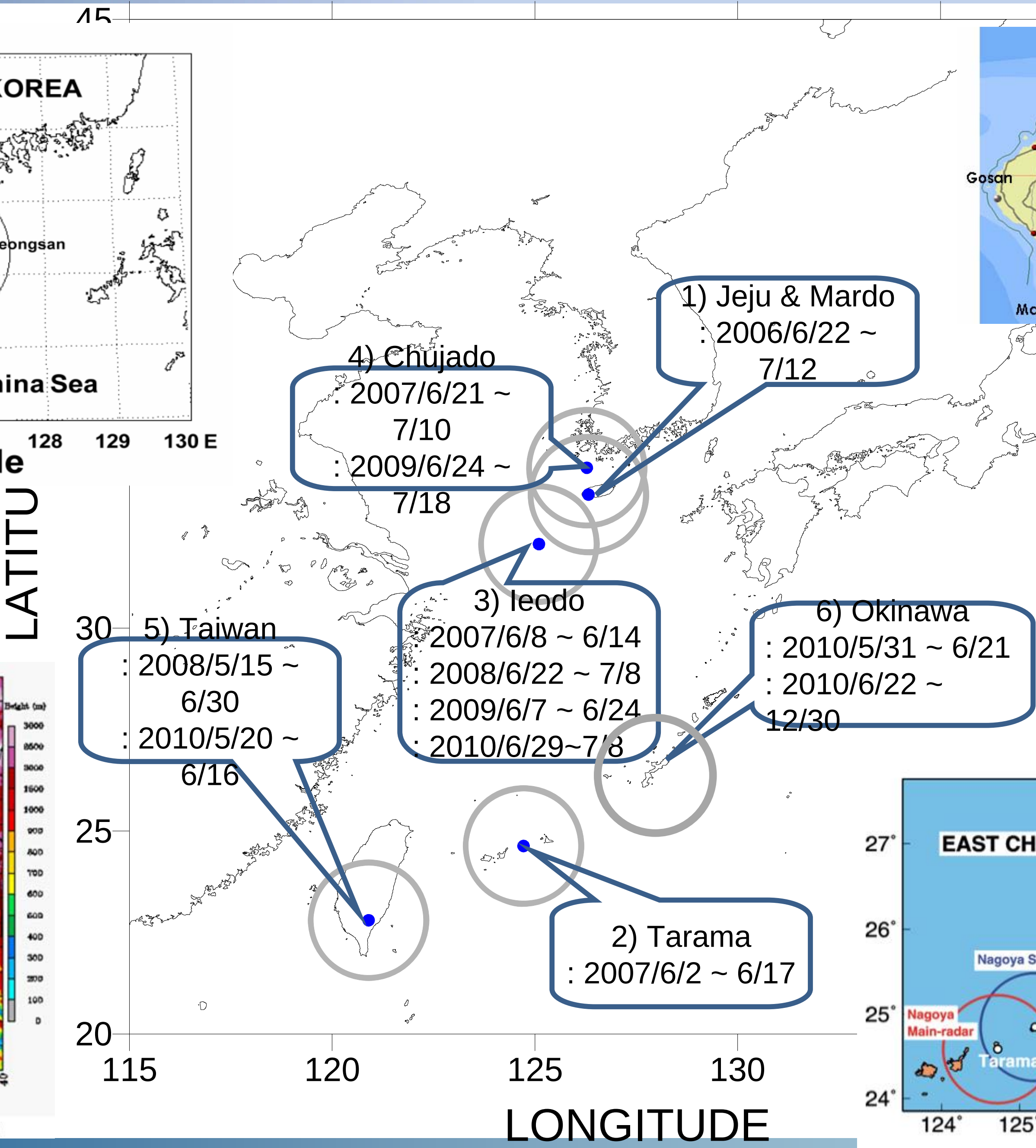
Intensive Field Experiment in Monsoon Season

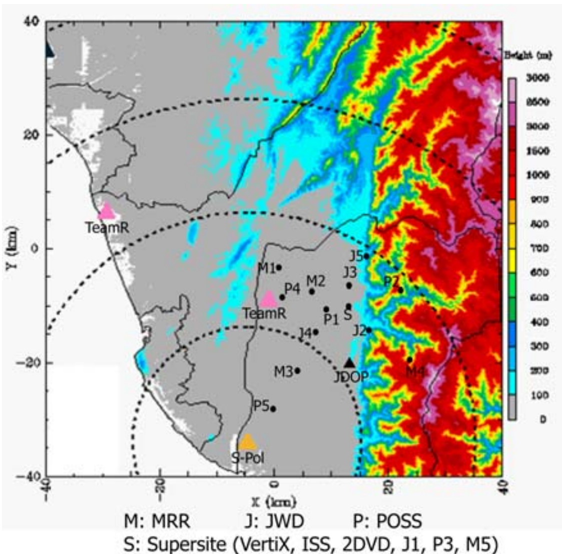
Frontal system occurred around the East China Sea

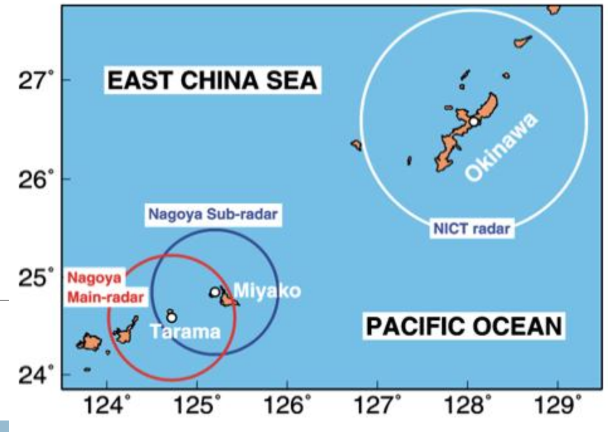
- Investigation on heavy rainfall systems
- Physio-chemical characteristics on precipitation
- **Q**uantitative **P**recipitation **E**stimation
- **Q**uantitative **P**recipitation **F**orecast

Location of experiment sites









Instruments installed- in Chujado (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

GPS Sonde Observation in Chujado (2009)

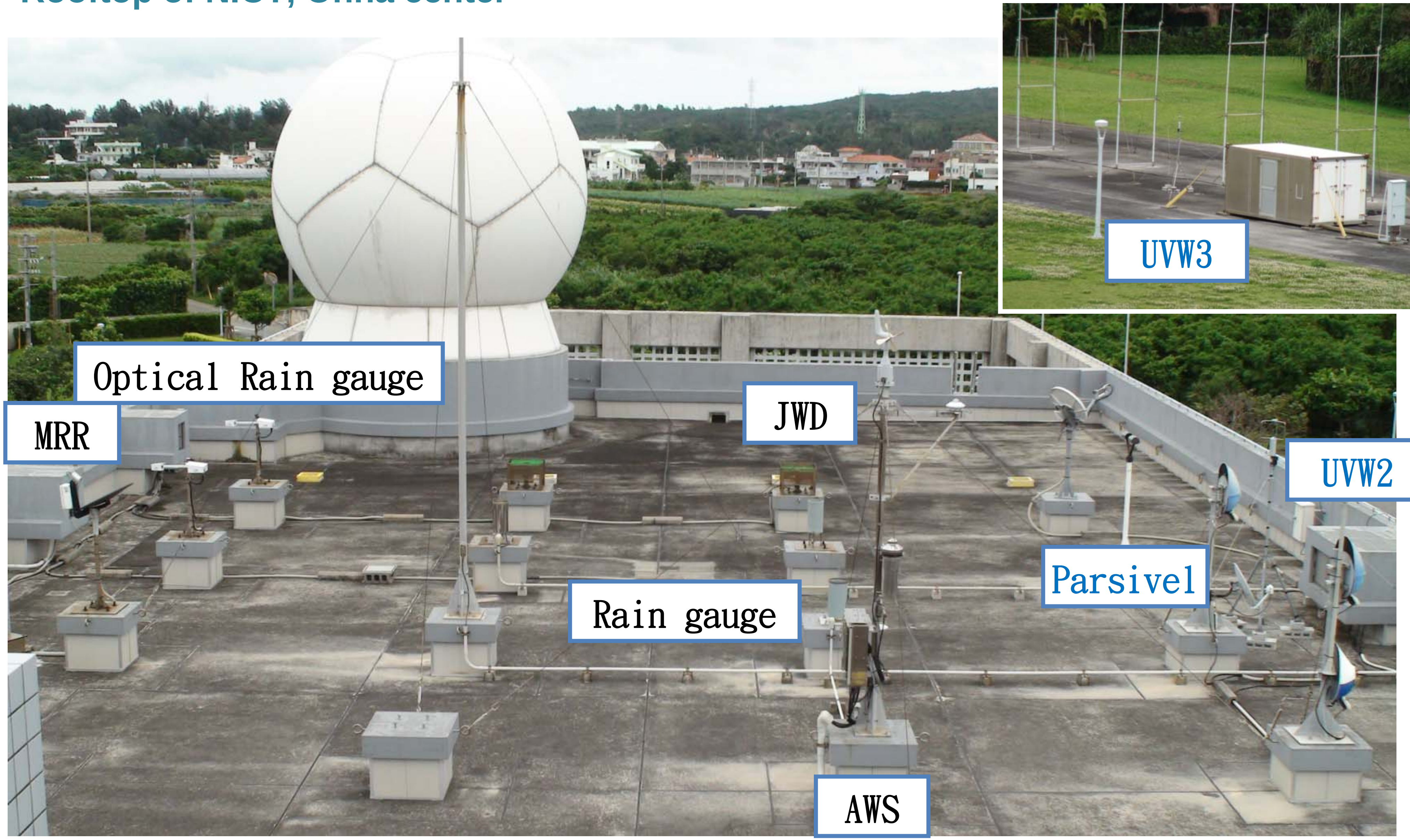
- **Radio sonde**

  :Discussion and report for every sonde observations (total 32)

GPS sonde	00h	03 h	06 h	09 h	12h	15h	18h	21h
2009-06-27 (Sat)			1	2				
2009-06-28 (Sun)							3	
2009-06-29 (Mon)			4	5	6	7		8
2009-06-30 (Tue)	9	10		11	12	13	14	15
2009-07-01 (Wed)	16							
2009-07-02 (Thu)								
2009-07-03 (Fri)								
2009-07-04 (Sat)								
2009-07-05 (Sun)								
2009-07-06 (Mon)								17
2009-07-07 (Tue)	18	19	20	21	22			
2009-07-08 (Wed)								
2009-07-09 (Thu)								
2009-07-10 (Fri)		23						
2009-07-11 (Sat)		24	25		26			
2009-07-12 (Sun)						27		
2009-07-13 (Mon)								
2009-07-14 (Tue)								
2009-07-15 (Wed)			28	29	30	31		
2009-07-16 (Thu)	32							

Instruments installed- in NiCT Center, Okinawa (2010)

Rooftop of NICT, Onna center



GPS Sonde Observation in Okinawa (2010)

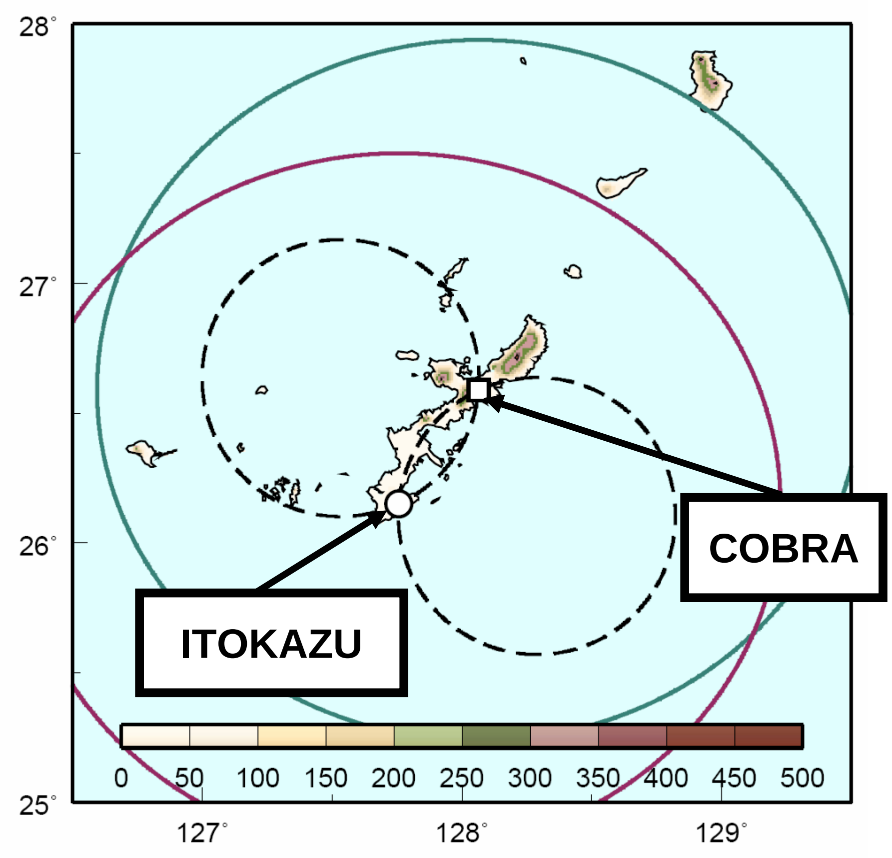
- Radio sonde

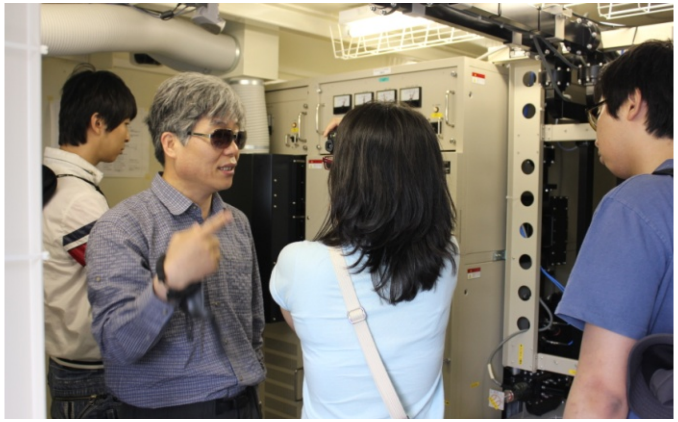
:Discussion and report
for every sonde observations
(total 40)

GPS sonde	03 h	09 h	15 h	21 h
2010-05-31 (Mon)				
2010-06-01 (Tue)				1
2010-06-02 (Wed)			2	3
2010-06-03 (Thu)			4	5
2010-06-04 (Fri)	6	7	8	9
2010-06-05 (Sat)	10	11	12	13
2010-06-06 (Sun)		14	15	
2010-06-07 (Mon)	16			
2010-06-08 (Tue)				
2010-06-09 (Wed)				17
2010-06-10 (Thu)	18	19	20	21
2010-06-11 (Fri)	22	23	24	25
2010-06-12 (Sat)	26	27		
2010-06-13 (Sun)				
2010-06-14 (Mon)		28	29	30
2010-06-15 (Tue)	31	32	33	34
2010-06-16 (Wed)	35	36	37	38
2010-06-17 (Thu)	39	40		
2010-06-18 (Fri)				
2010-06-19 (Sat)				
2010-06-20 (Sun)				
2010-06-21 (Mon)				

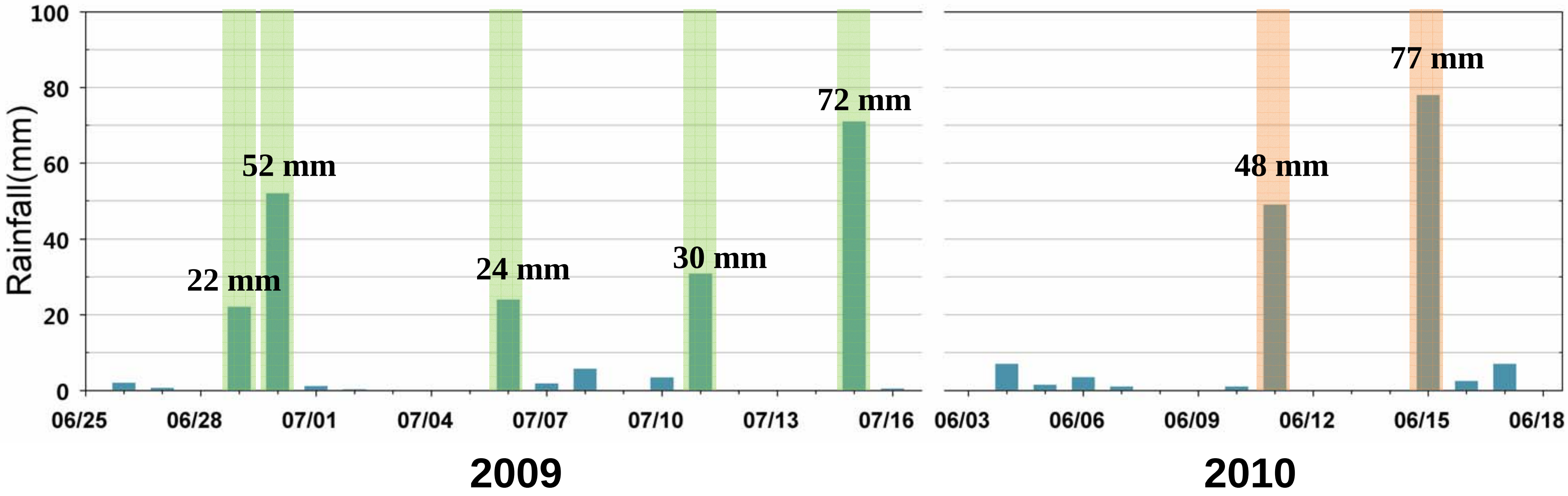
Instruments- COBRA site in Okinawa (2010)

Surface weather condition	AWS
Precipitation	Radar(COBRA)





Observation of Precipitation Systems



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

80 mm/hr

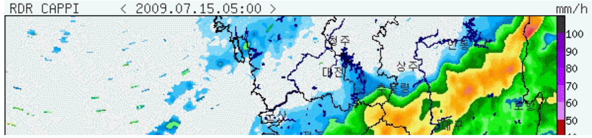
Site	Okinawa
Period	2010. 5. 31 ~ 6. 21

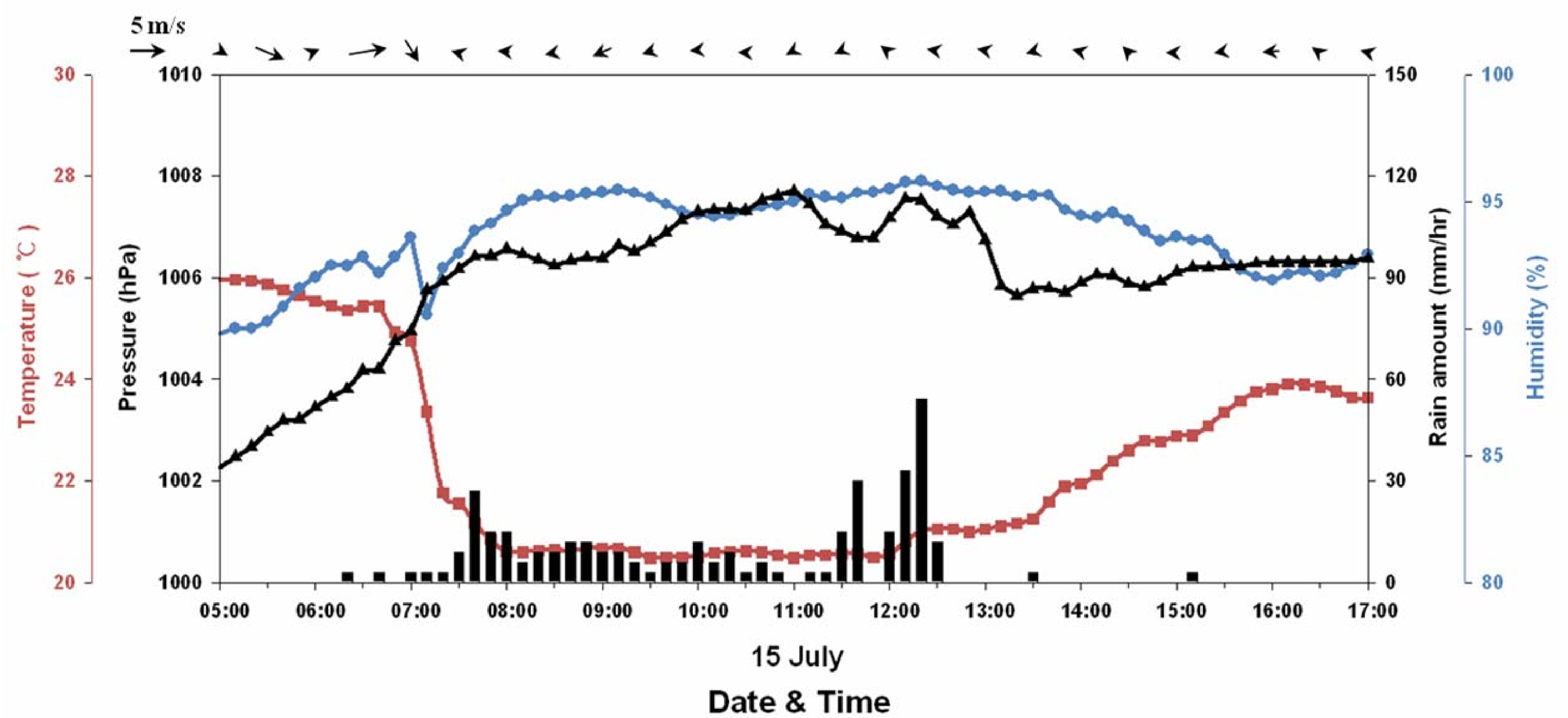
Case 1 : 0300 ~ 2300 LST 11 June
Case 2 : 1300 ~ 2100 LST 15 June

224 mm/hr

Chujado Case 5 : 0500 ~ 1700 LST 15 July (2009)

- Strong precipitation system developed at the rear side of Changma front moved eastward.
- Rainfall : Southern part of the Korean Peninsula





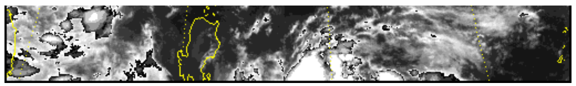
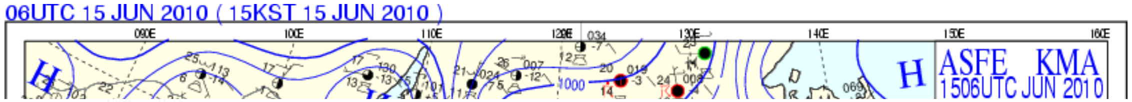


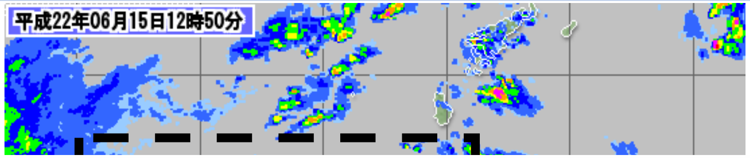
Fig. 1. Surface weather map(left), radar images (right upper) and satellite images (right bottom) at 0900 LST on 15 July 2009. The red circle shows the location of Chujado.

Okinawa Precipitation System #2

1300 ~ 2100 LST 15 June 2010

- Line-shape Convective system





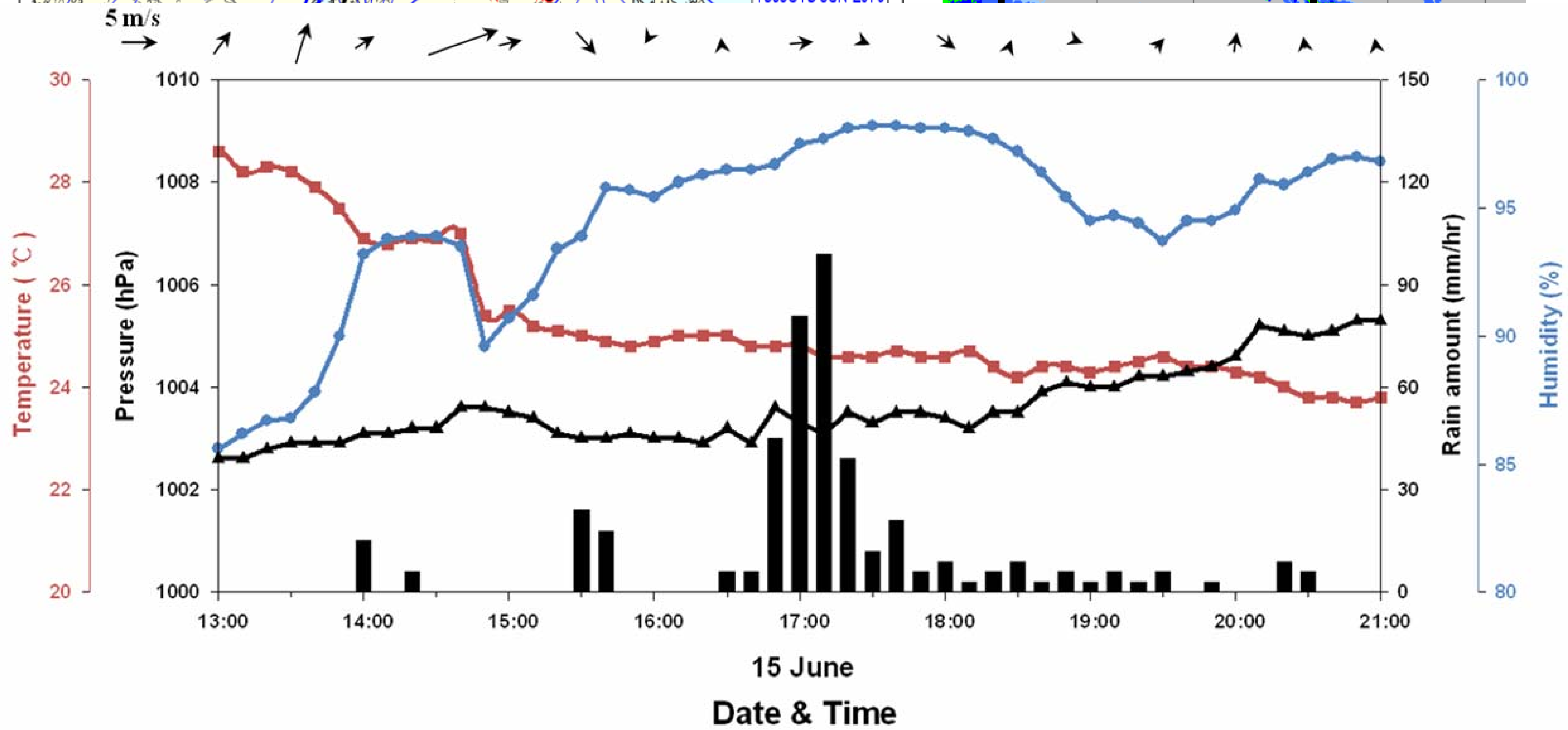
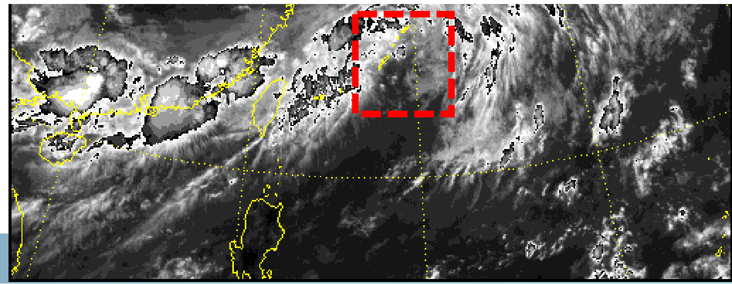


Fig. 2. Surface weather map(left), radar images (right upper) and satellite images (right bottom) at 1500 LST on 15 June 2010. The red circle shows the location of Okinawa.



NCEP/NCAR reanalysis data [0900 LST 15 July 2009]

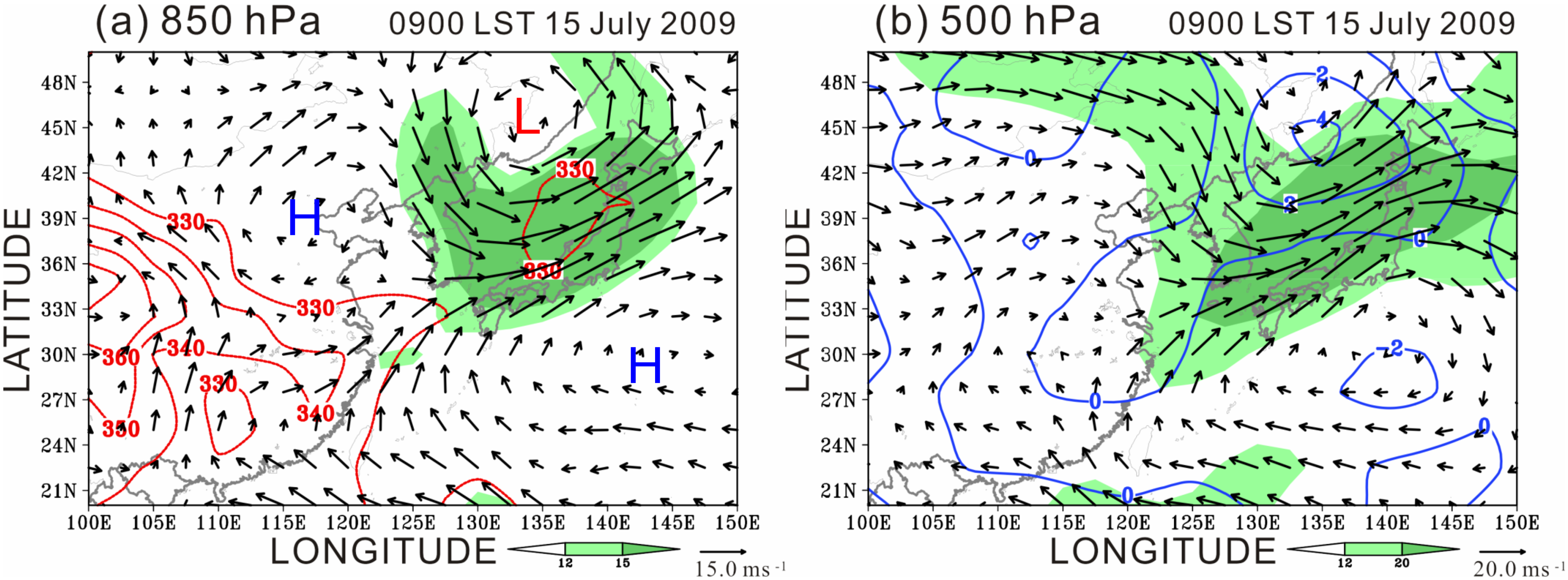


Fig. 3. (a) Equivalent potential temperature and wind vector at 850 hPa, (b) relative vorticity and wind vector at 500 hPa at 0900 LST on 15 July 2009.

- ✓ NW, W, SW and S wind were converged in the southern part of Korean peninsular.
- ✓ SW and S transported warm and moist air.
- ✓ Strong wind band located in the southern part of Korean peninsular.

NCEP/NCAR reanalysis data [1500 LST 15 June 2010]

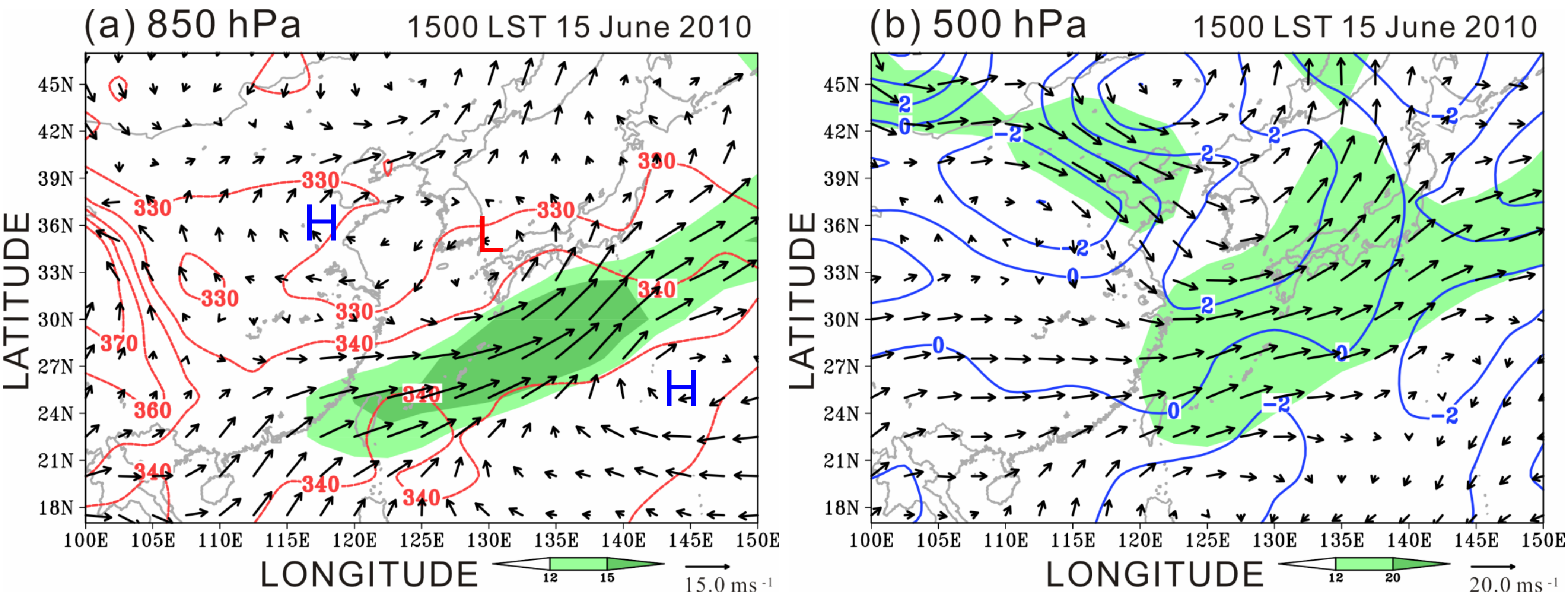


Fig. 4. (a) equivalent potential temperature and wind vector at 850 hPa, (b) relative vorticity and wind vector at 500 hPa at 1500 LST on 15 June 2010.

- ✓ W and SW wind were converged in the Okinawa at 850 hPa.
- ✓ W and SW transported warm and moist air.
- ✓ Strong wind band located in the Okinawa.

MSM - Divergence

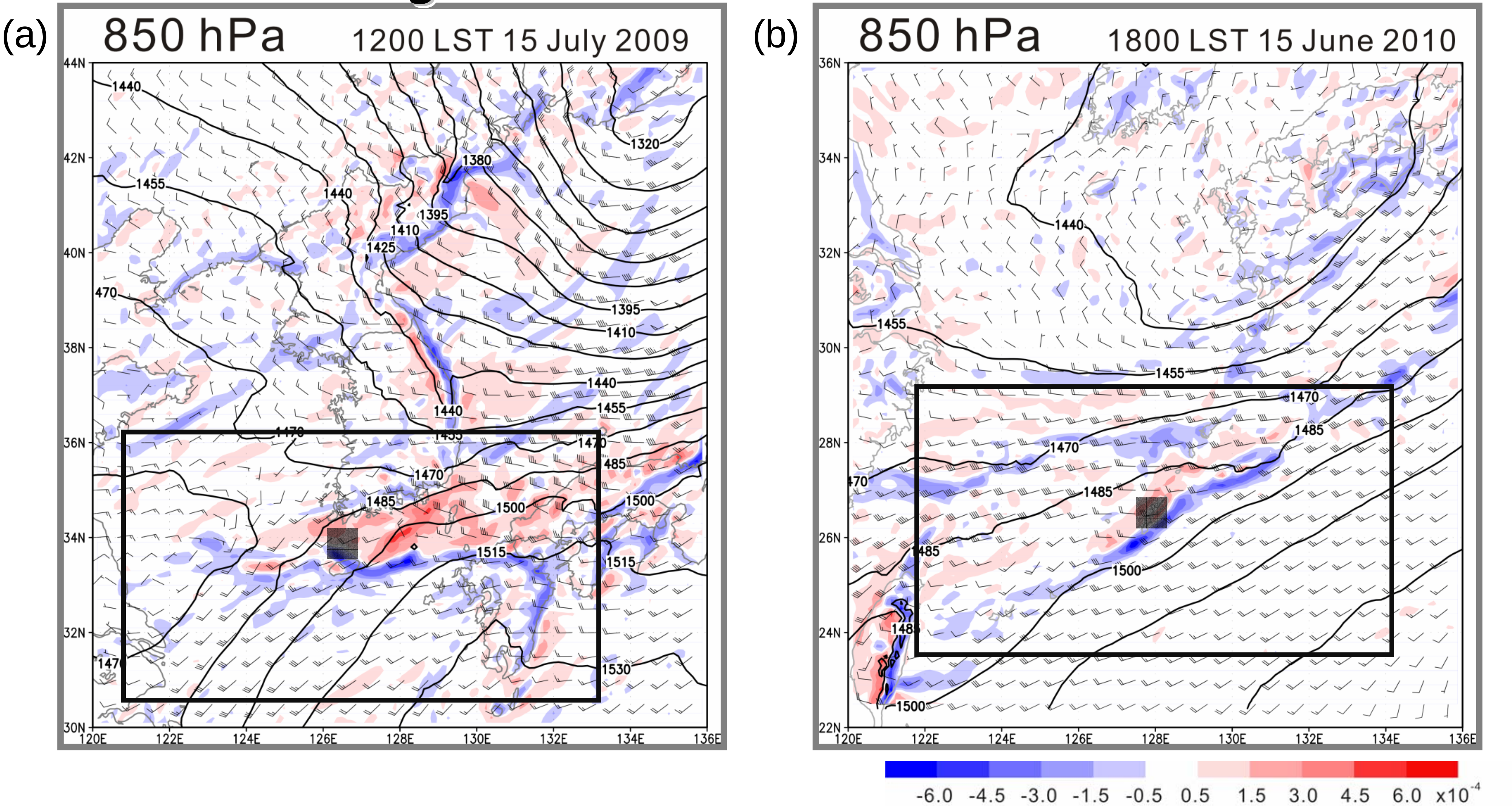


Fig. 5. Divergence, geopotential height (gpm) and wind at 850 hPa of (a) 1200 LST on 15 July 2009 and (b) 1800 LST on 15 June 2010.

- ✓ Strong convergence area represented in the southern part of Korean peninsular at 850 hPa at 1200 LST on 15 July 2009.
- ✓ Strong convergence area is represented along with the front at 850 hPa from 1800 LST on 15 June 2010.

MSM – Relative Humidity(%)

(a) (b)

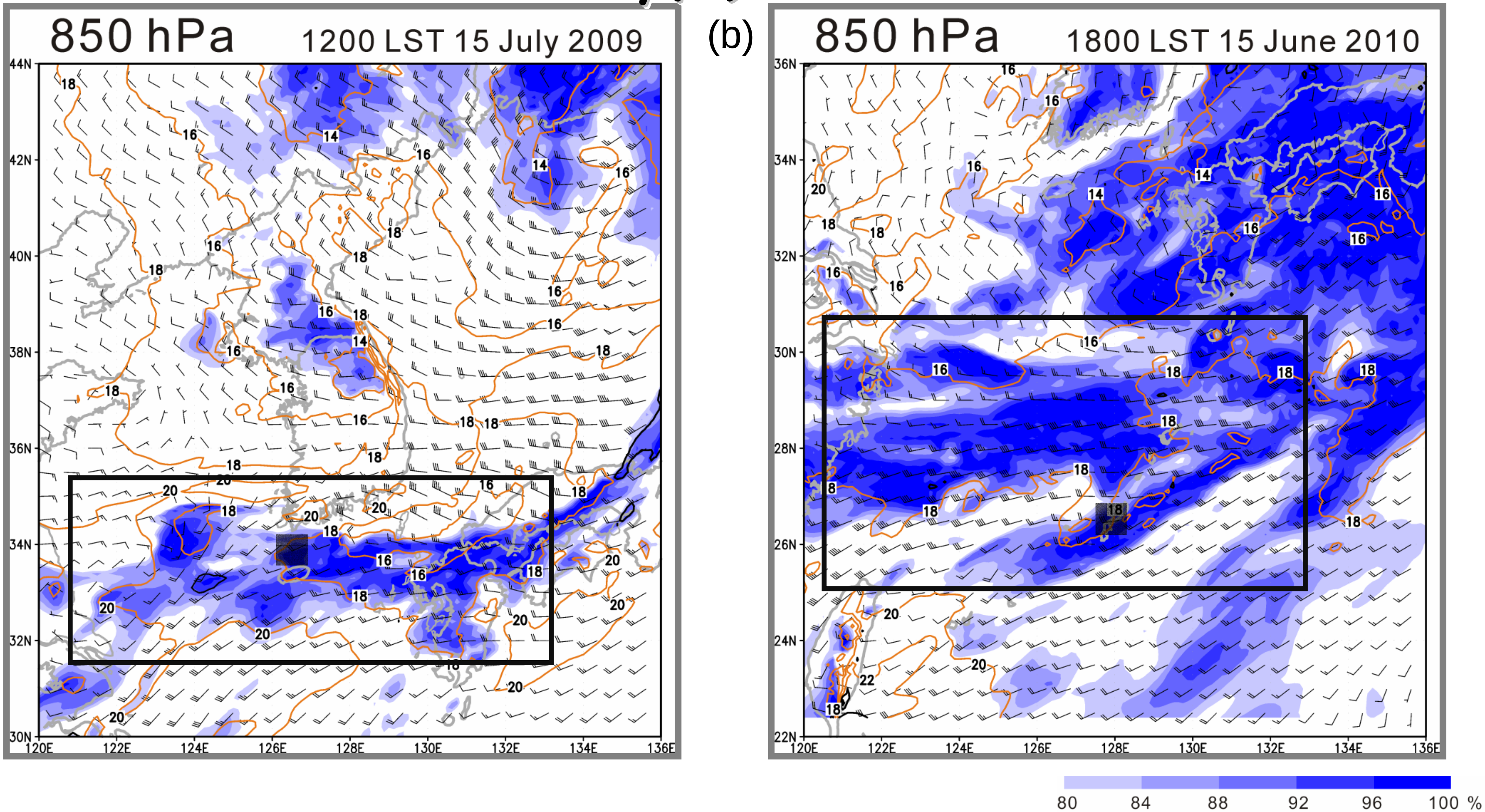


Fig. 6. Relative humidity (%), temperature (℃) and wind at 850 hPa of (a) 1200 LST on 15 July 2009 and (b) 1800 LST on 15 June 2010.

- ✓ SW wind transported warm and moist air
- ✓ In Fig. 6(a), warm and moist band indicated around front.
- ✓ In Fig. 6(b), high humidity region (25N ~ 30N) is widely distributed over East China Sea.

Sounding

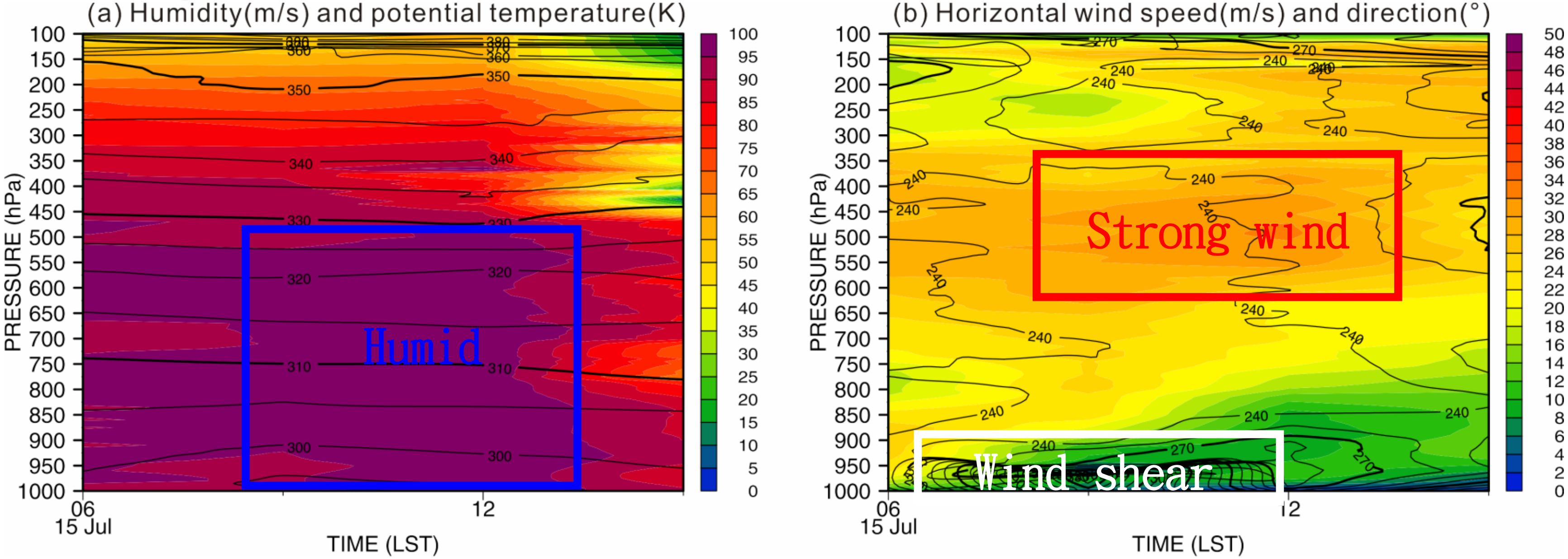


Fig. 7. Time series of vertical profile of (a) Humidity (%) and potential temperature, (b) horizontal wind speed (ms^{-1}) and direction (°) obtained from radiosonde from 0600 LST to 1500 LST on 15 July 2009.

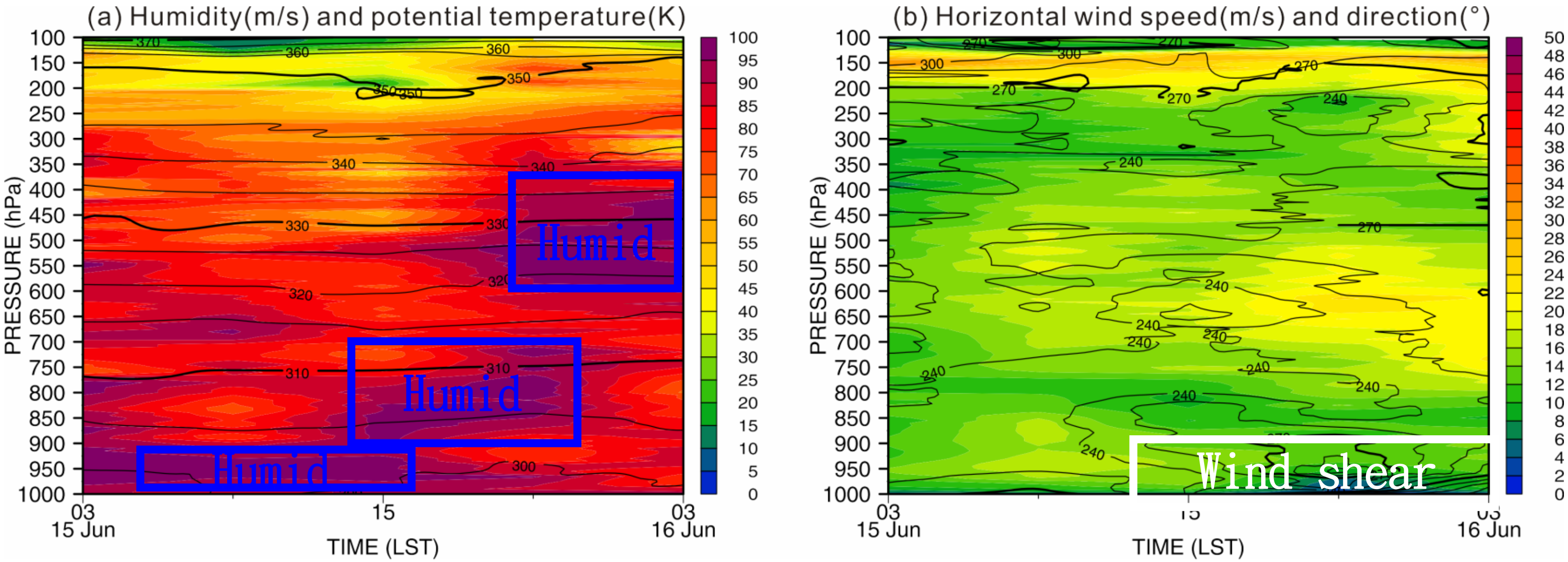


Fig. 8. The same as Fig. 5 but for from 0300 LST on 15 June to 0300 LST on 16 June 2010.

Sounding

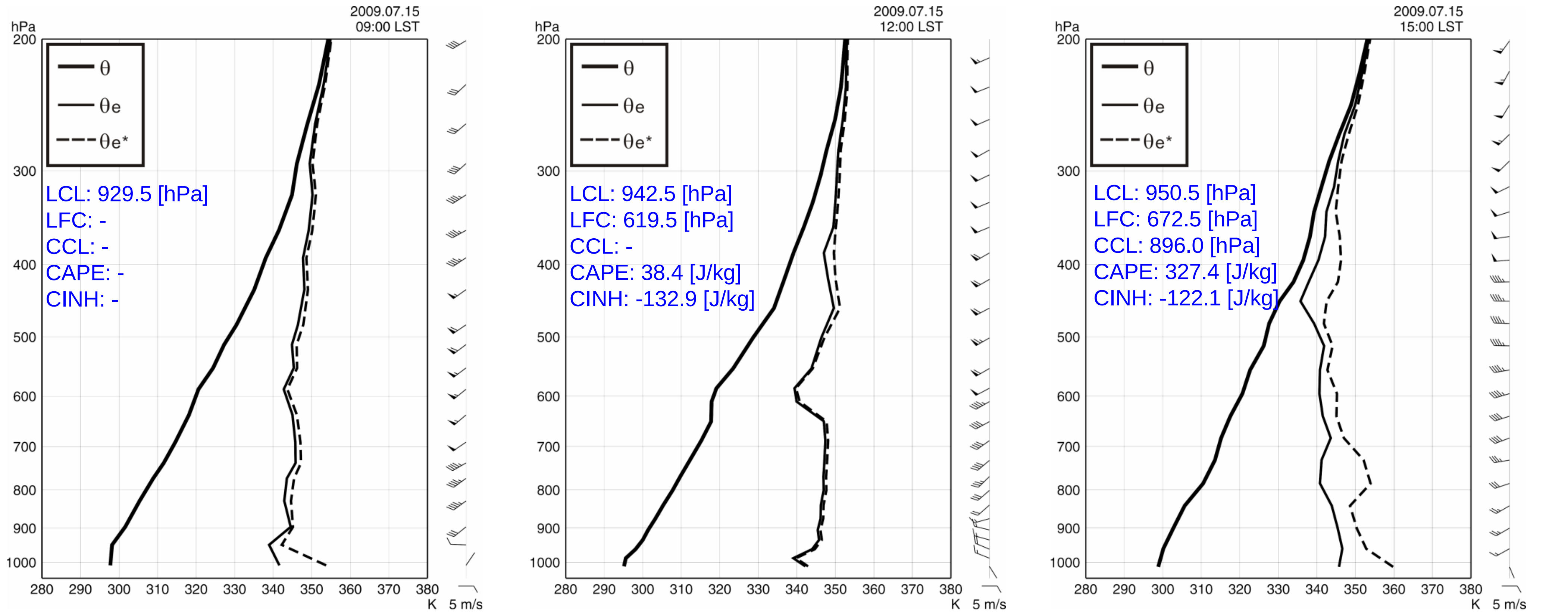


Fig. 9. Vertical profile of potential temperature (K), equivalent potential temperature (K) and saturated equivalent potential temperature (K) at 0900 LST, 1200 LST and 1500 LST on 15 July 2009.

- ✓ Humid air condition (0900 LST, 1200 LST).
- ✓ Equivalent potential temperature and saturated equivalent potential temperature are decreased at 500 hPa – 600 hPa.
- ✓ Strong wind is represented at 400 hPa – 900 hPa (0900LST) and wind direction is sharply changed at low level.
- ✓ Convective parameters did not provide favorable condition for convective cells.

Sounding

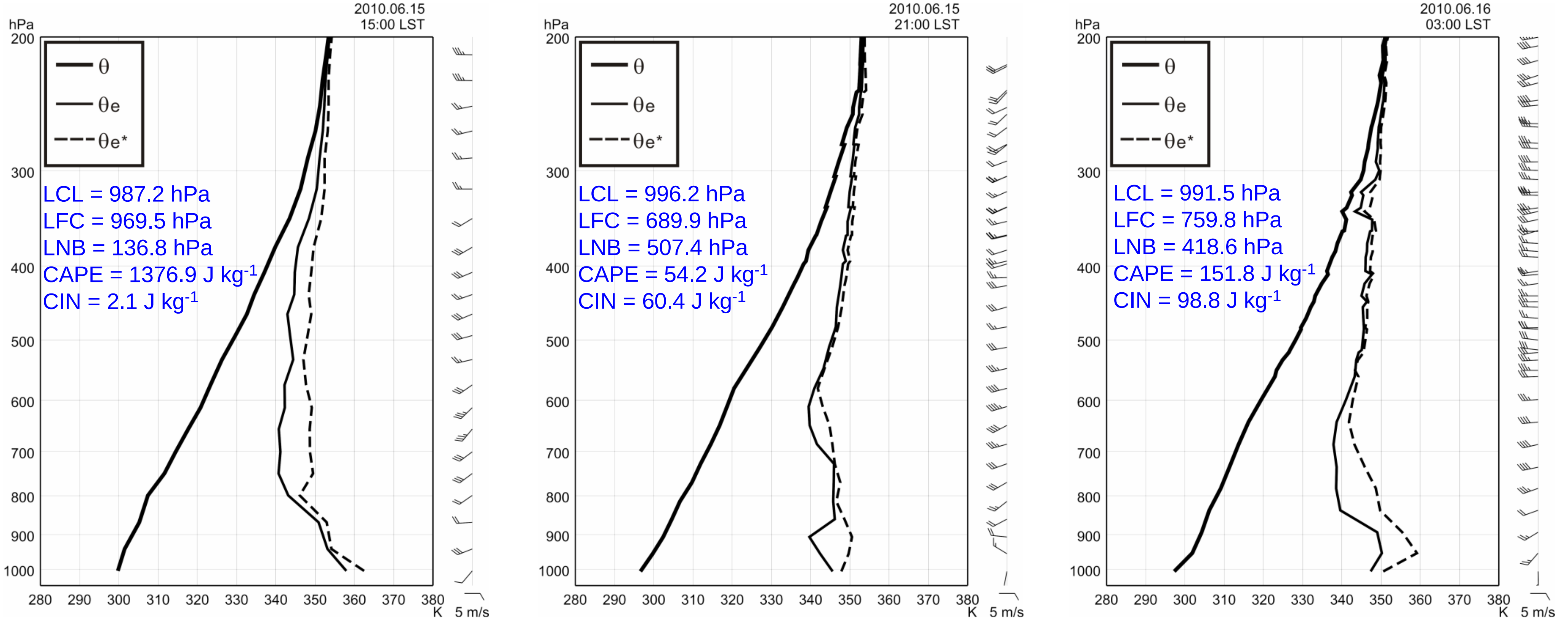


Fig. 10. Vertical profile of potential temperature (K), equivalent potential temperature (K) and saturated equivalent potential temperature (K) at 1500 LST, 2100 LST on 15 and 0300 LST on 16 June 2010.

- ✓ At 1500 LST on 15, Humid air is represented at 800 hPa – 1000 hPa, since then air is gradually dried under 600 hPa.
- ✓ Equivalent potential temperature and saturated equivalent potential temperature are decreased at 800 hPa – 1000 hPa (1500 LST) and at 600 – 950 hPa (0300 LST on 16).
- ✓ Wind direction is sharply changed under 900 hPa (1500 LST, 2100 LST on 15 and 0300 LST on 16).

Dual Doppler analysis

- Convective cells developed around the main front.
- Convective cells developed newly and continuously as a line shape.

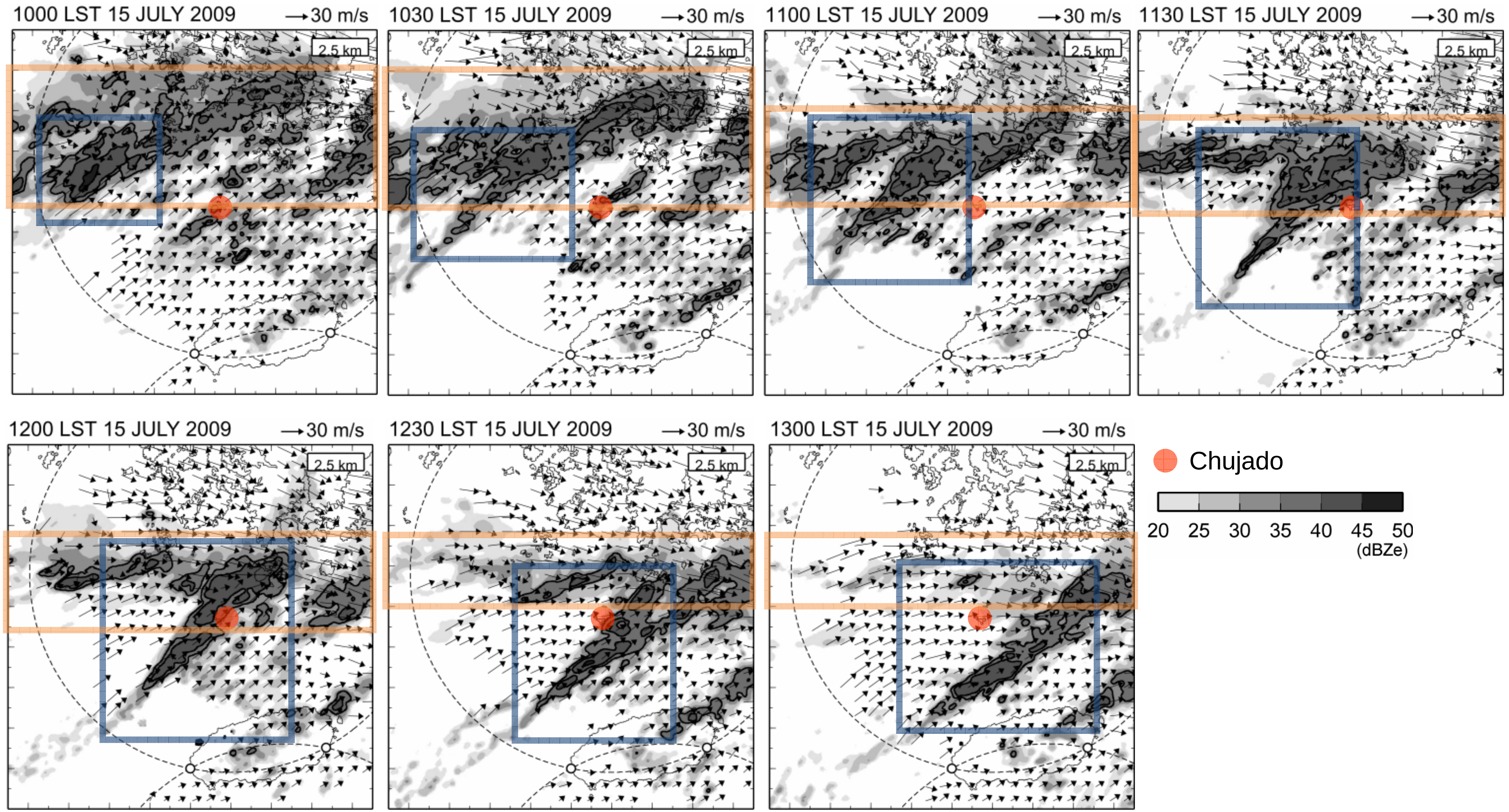
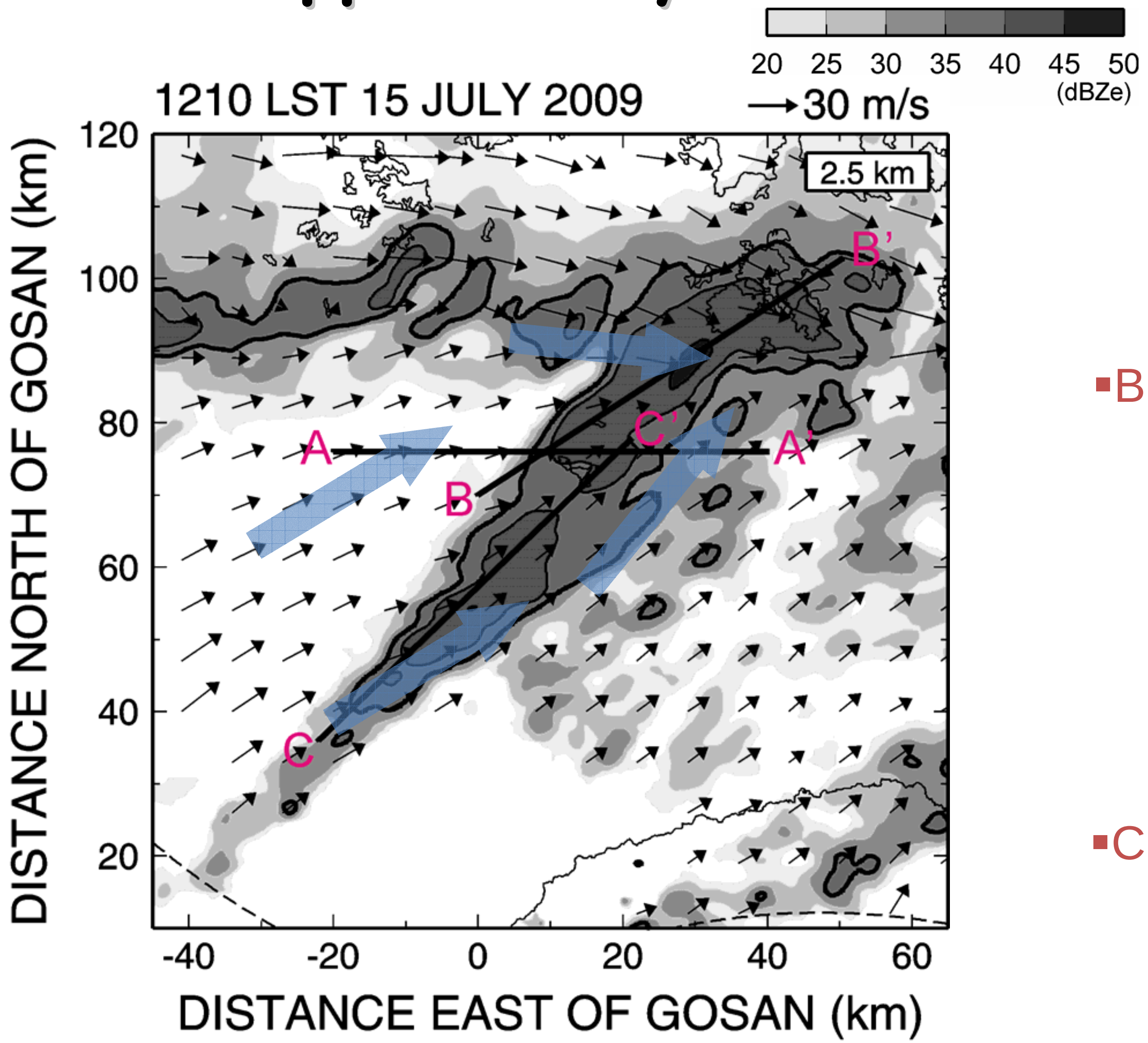
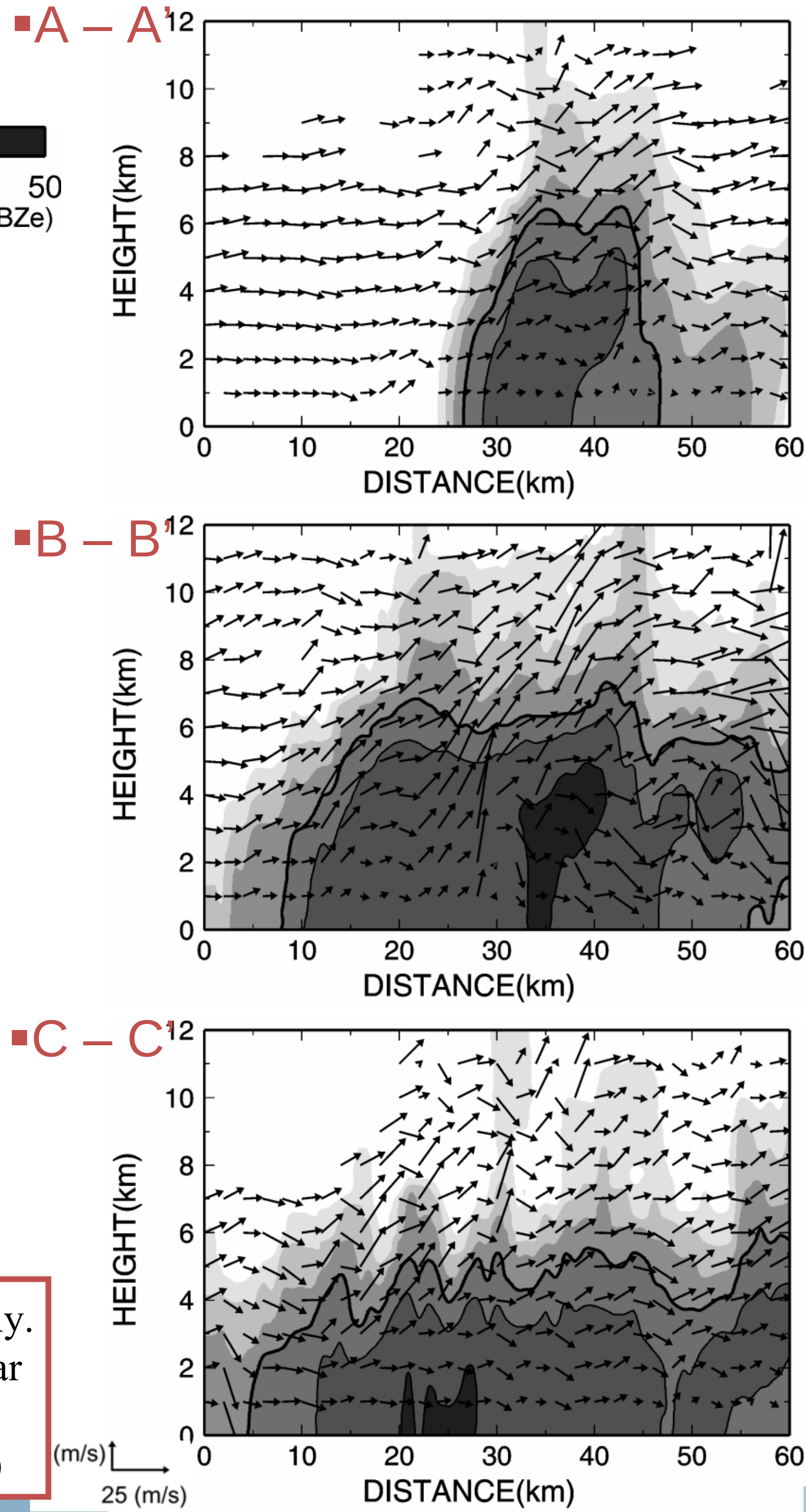


Fig. 11. Horizontal section of radar reflectivity and cell-relative wind fields at 2.5 km AGL (Above Ground Level) from 1000 LST to 1300 LST on 15 July 2009. Orange color box shows mainly precipitation system area, and blue color box means convective cells area newly developed.

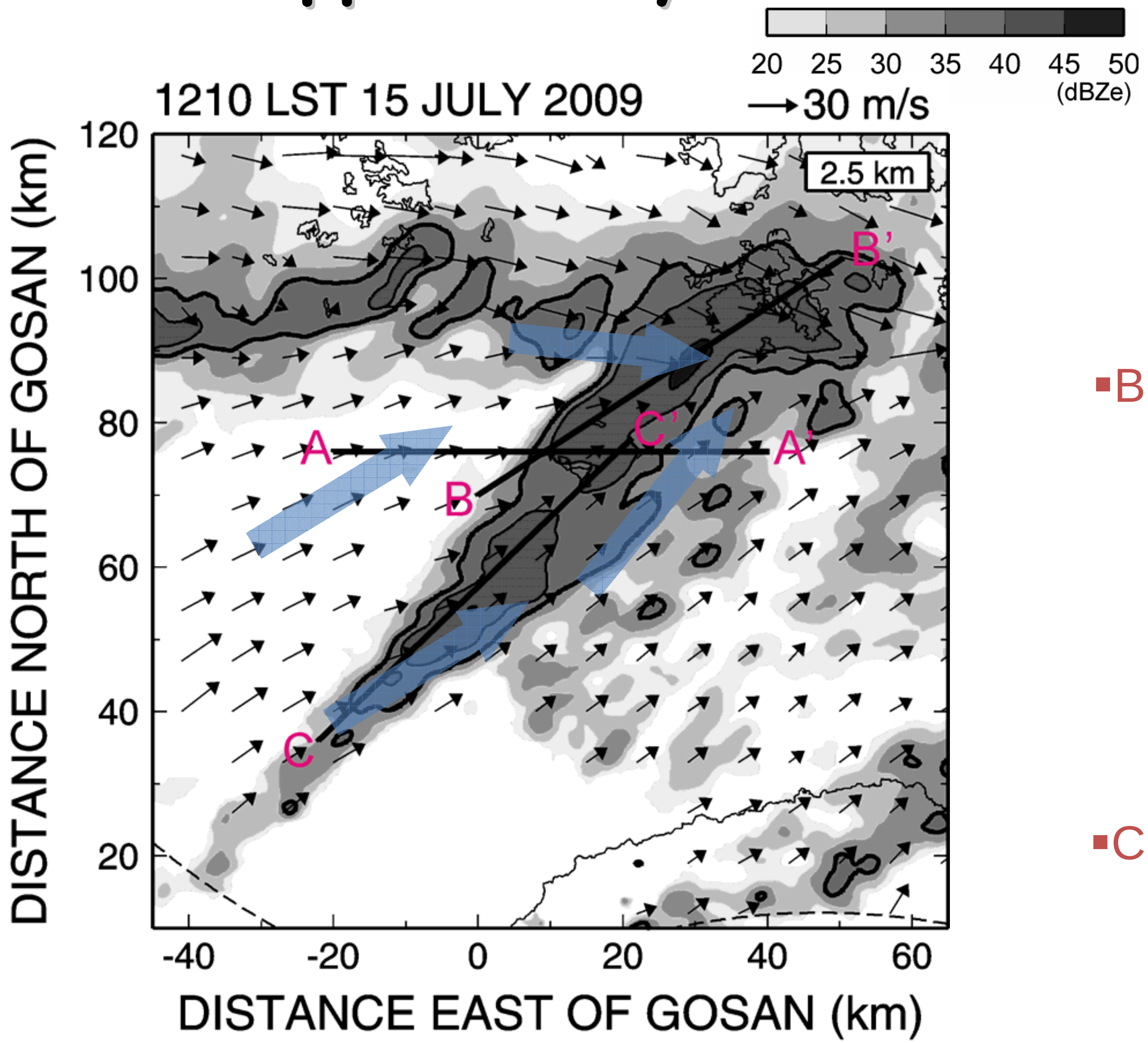
Dual Doppler analysis

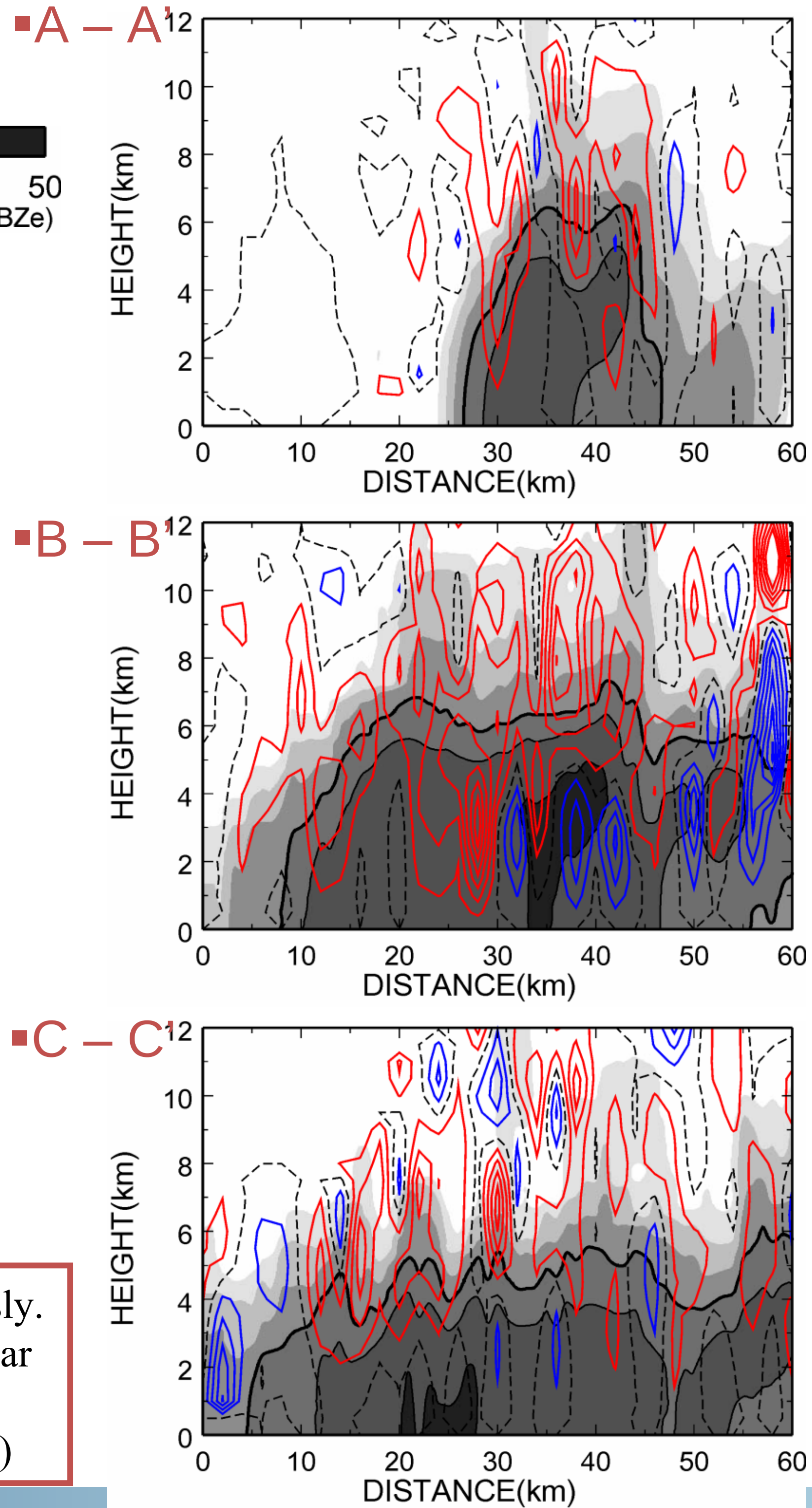




- Mainly SW winds flow at rear side of the convective cells, continuously.
- Strong updraft intensified at the newly developed cell (C-C') and at rear side of convective cell (B-B') developed around the main front.
- Strong convective region (≥45 dBZ) up to 5 km(B-B') and 2 km(C-C')

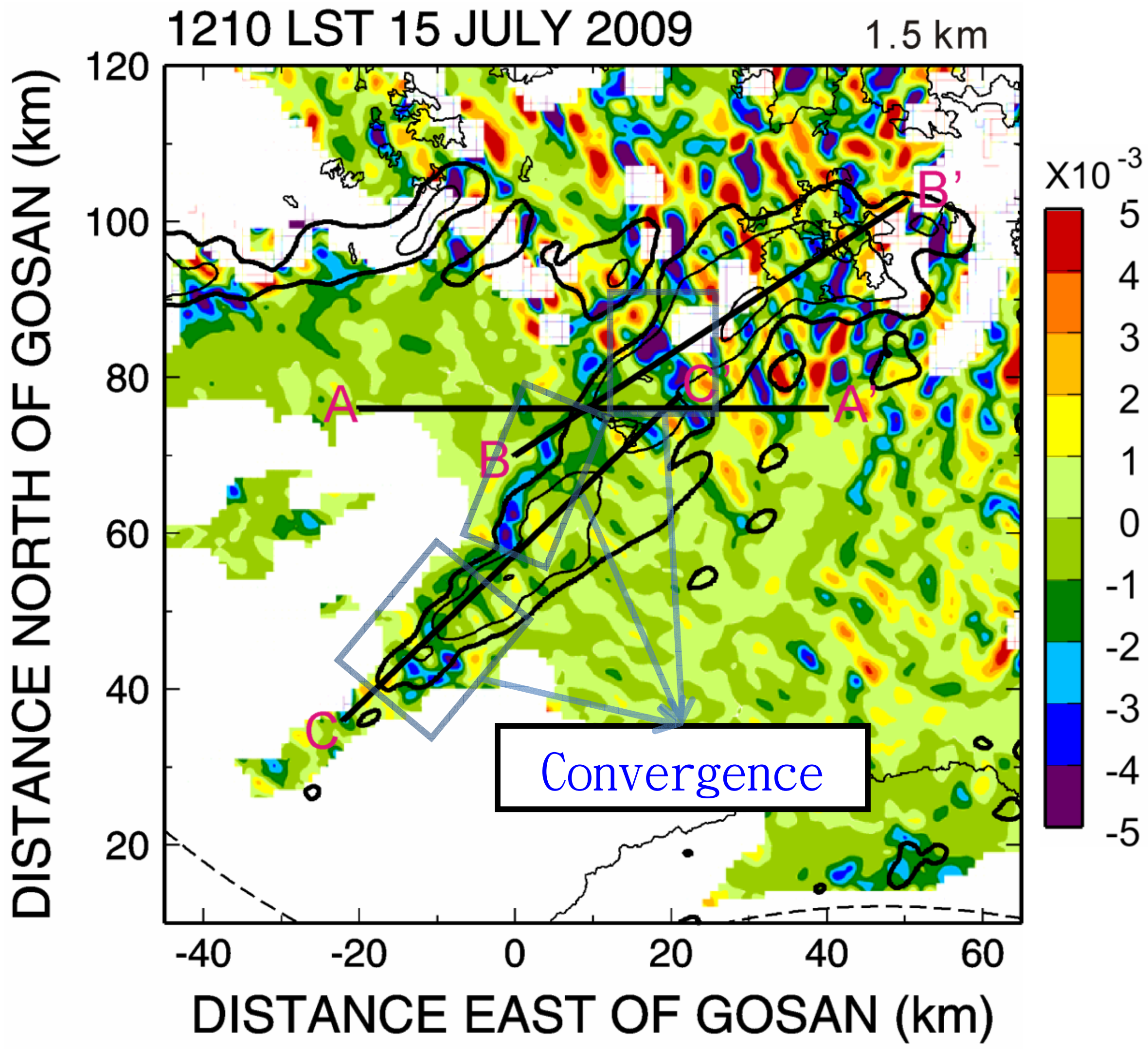
Dual Doppler analysis





- Mainly SW winds flow at rear side of the convective cells, continuously.
- Strong updraft intensified at the newly developed cell (C-C') and at rear side of convective cell (B-B') developed around the main front.
- Strong convective region (≥45 dBZ) up to 5 km(B-B') and 2 km(C-C')

Dual Doppler analysis



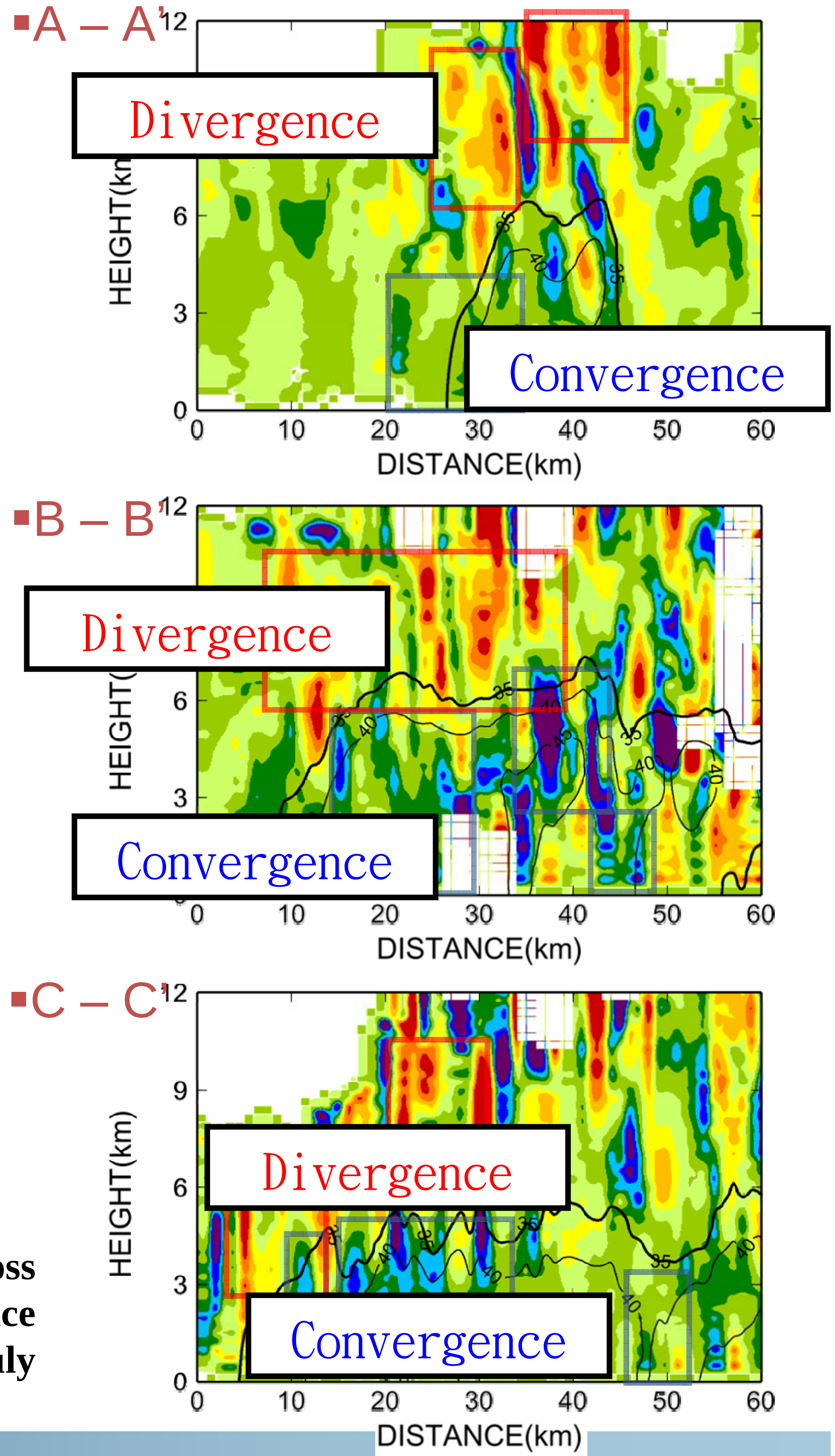


Fig. 12. (c) Horizontal section (left) at 1.5 km AGL and vertical cross section (right) along the lines (A-A', B-B', C-C') of divergence (color shaded) and reflectivity (> 35 dBZ) at 1210 LST on 15 July 2009.

Radar CAPPI (2.5km)

- Convective cells developed around the main front.
- Convective cells developed newly and continuously as a line shape.

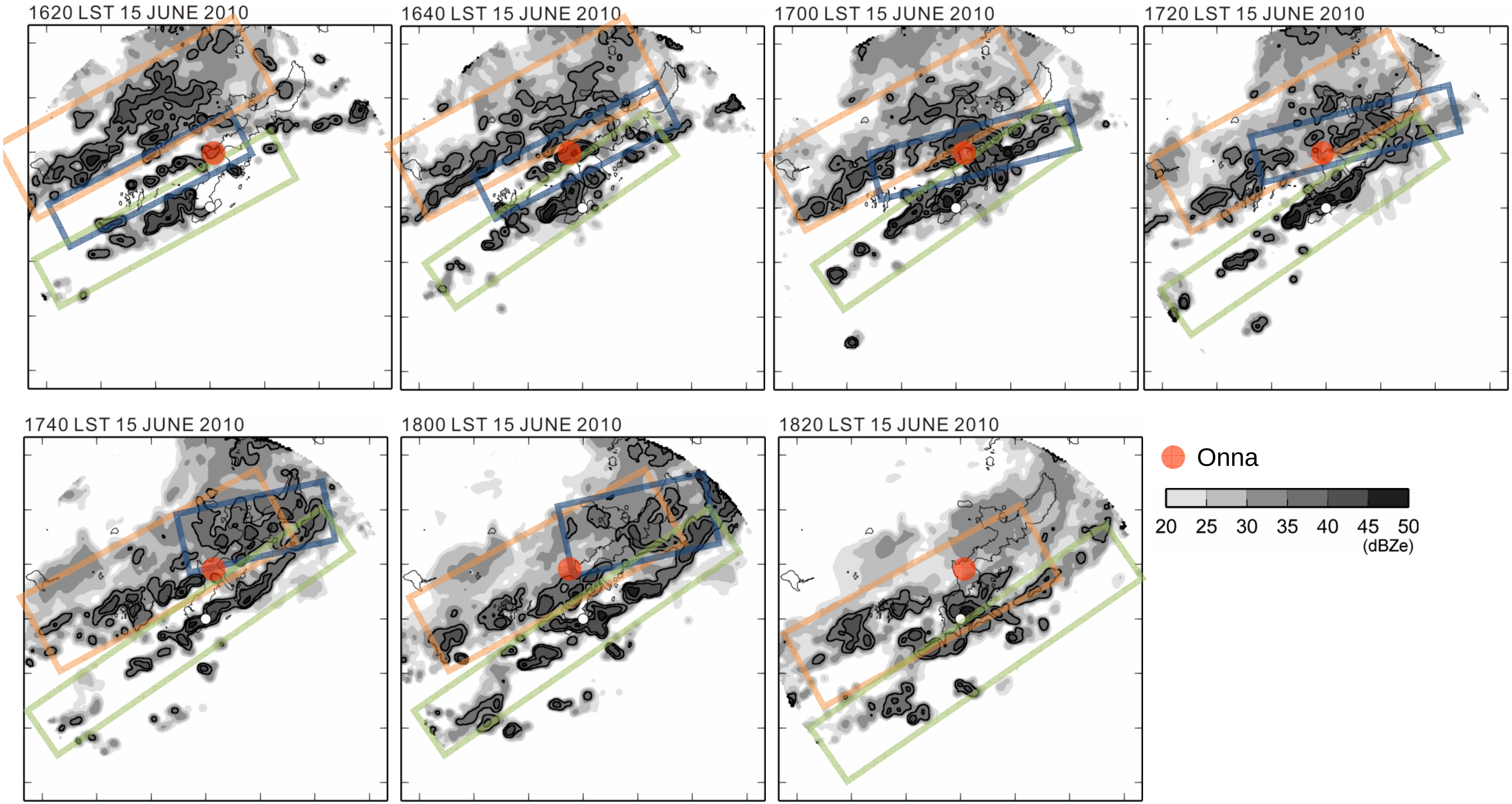
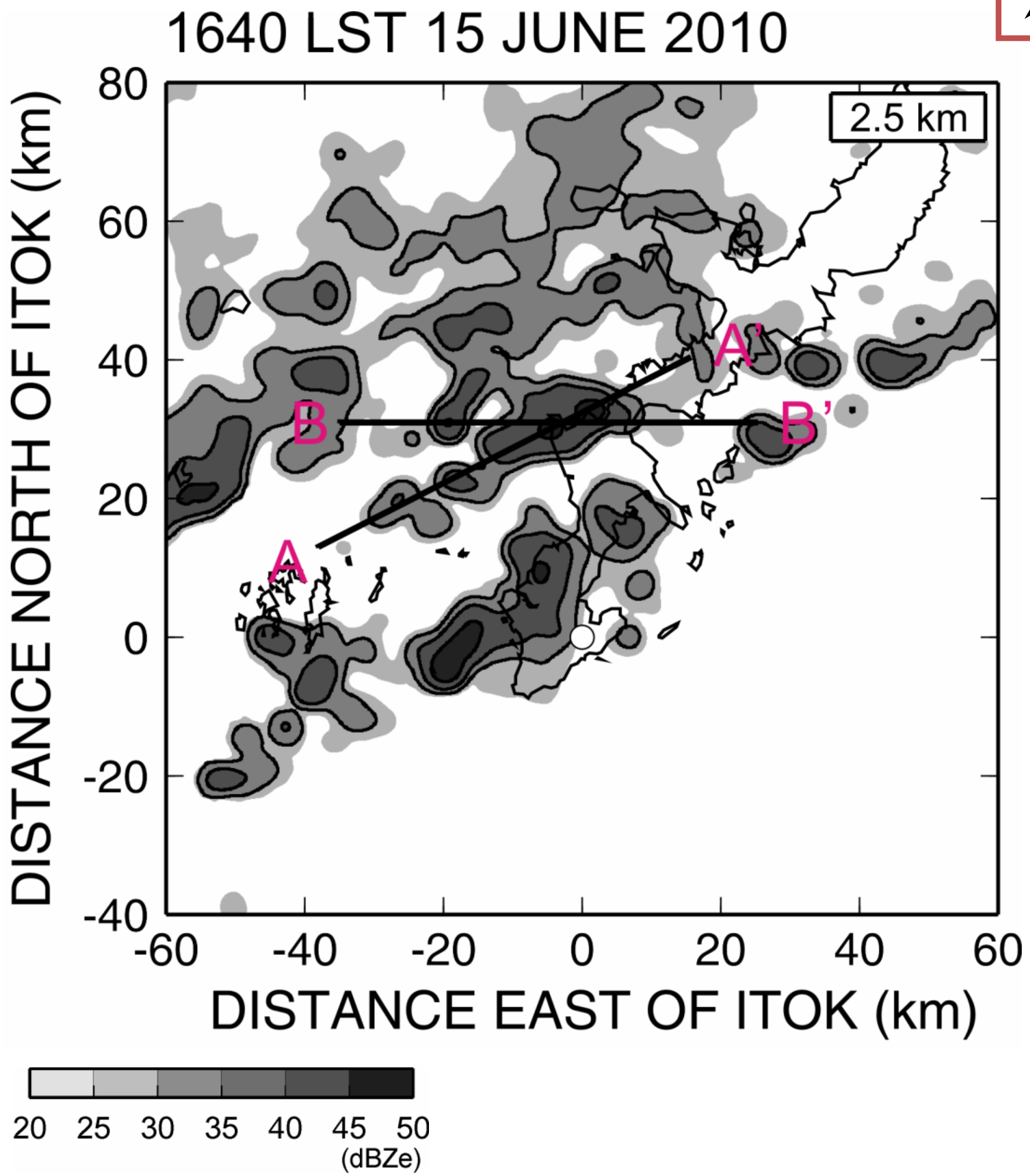


Fig. 13. Horizontal section of radar reflectivity (CAPPI) at 2.5 km AGL (Above Ground Level) from 1620 LST to 1820 LST on 15 June 2010. Orange color box shows mainly precipitation system area, and blue and green boxes mean convective cells area newly developed.

Radar analysis

- Core of the newly developed cell intensified.
- Strong convective region (≥45 dBZ) up to 3 km.
- New convective cell is developed, continuously.



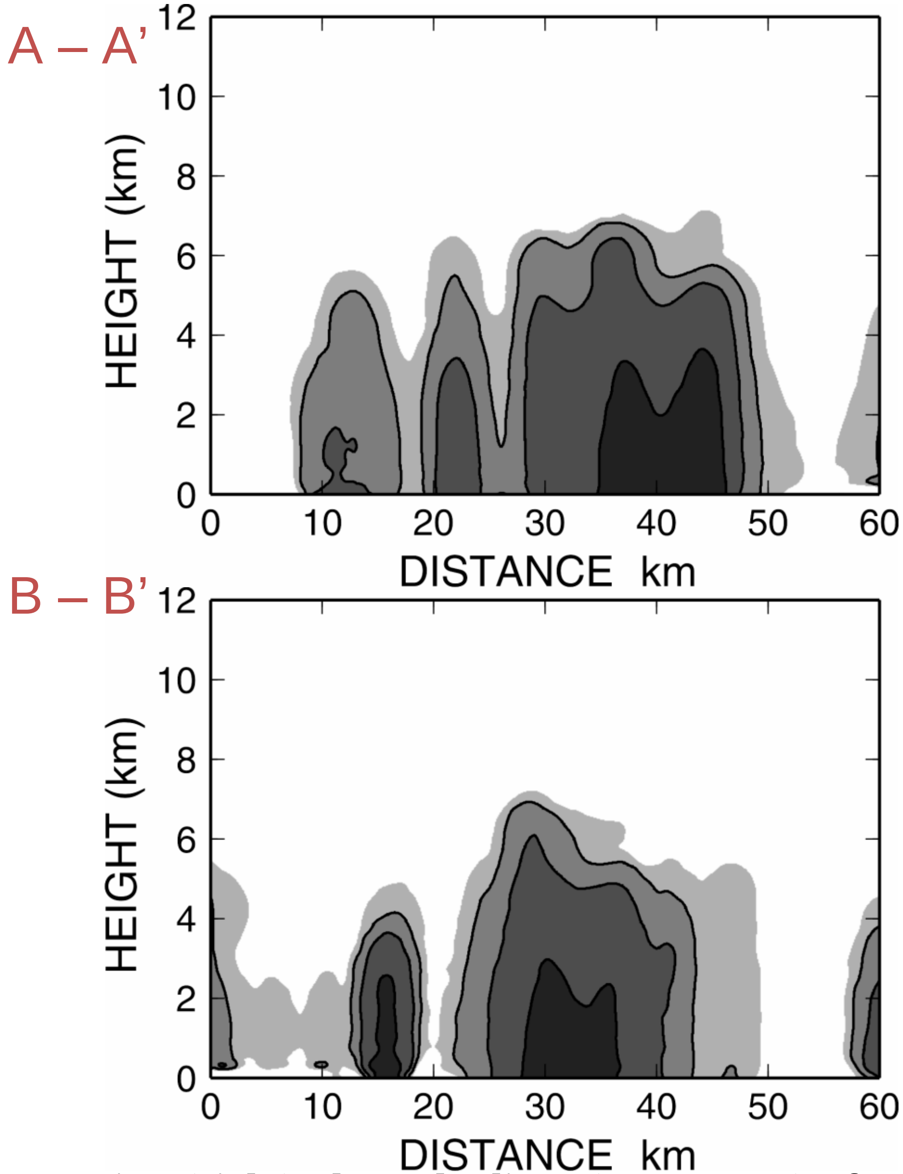


Fig. 14. Horizontal section (left) at 2.5 km AGL and vertical cross section (right) along the lines (A-A', B-B') of radar reflectivity at 1640 LST on 15 June 2010.

Raindrop size distributions

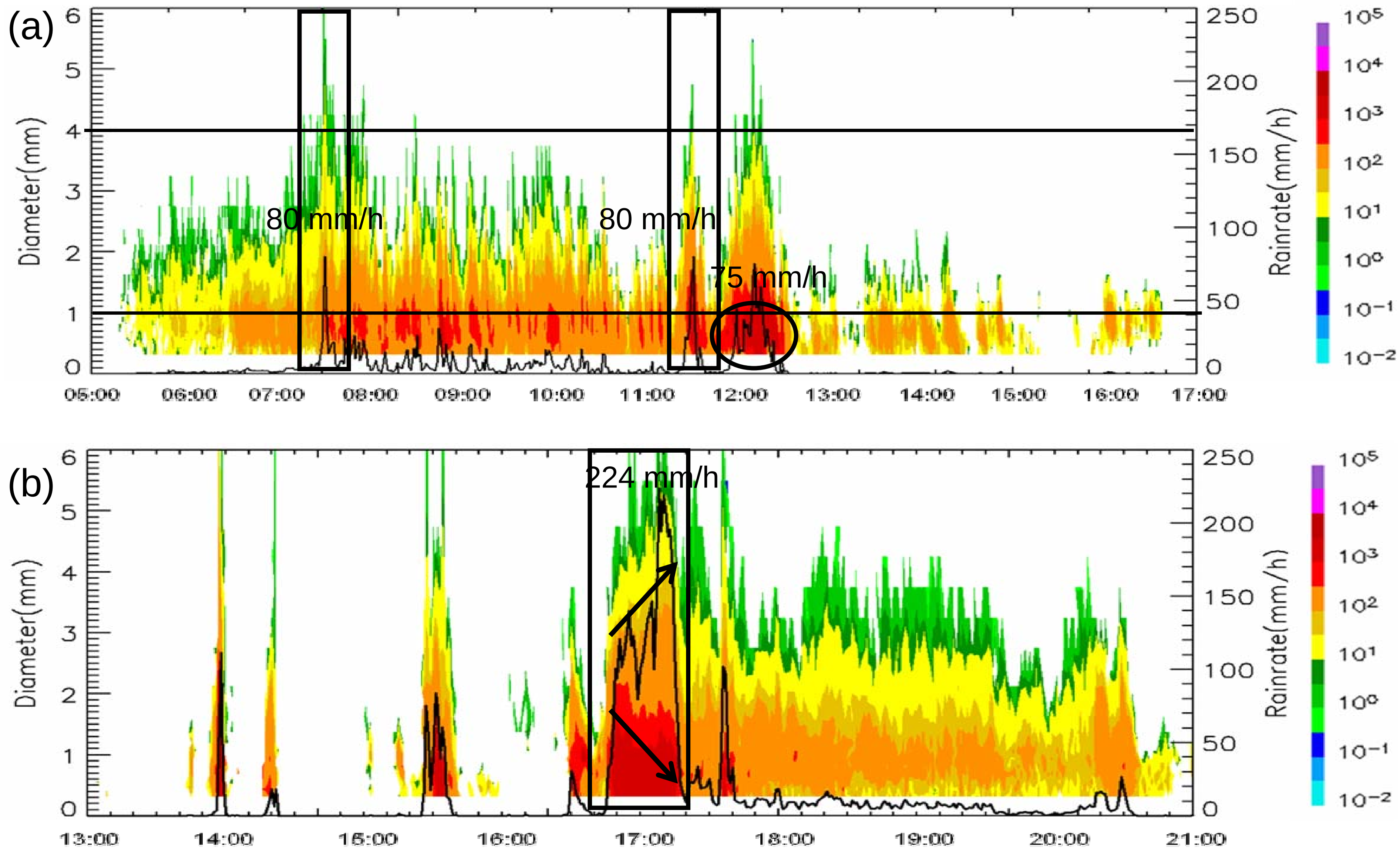


Fig. 15. The time series of rain drop size (left axis) and rainrate (right axis) of Case 1(0500 LST ~ 1700 LST on 15 July 2009) and Case 2 (1300 LST ~ 2100 LST on 15 June 2010) derived from Parsivel.

Vertical wind shear analysis by sonde observation

a) TVWS b) DVWS (Neiman, 2003)

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

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

$$V = u\hat{i} + v\hat{j}\,,\quad \bar{u} = (u(k+1) + u(k-1))/2\,,\quad \bar{v} = (v(k+1) + v(k-1))/2$$

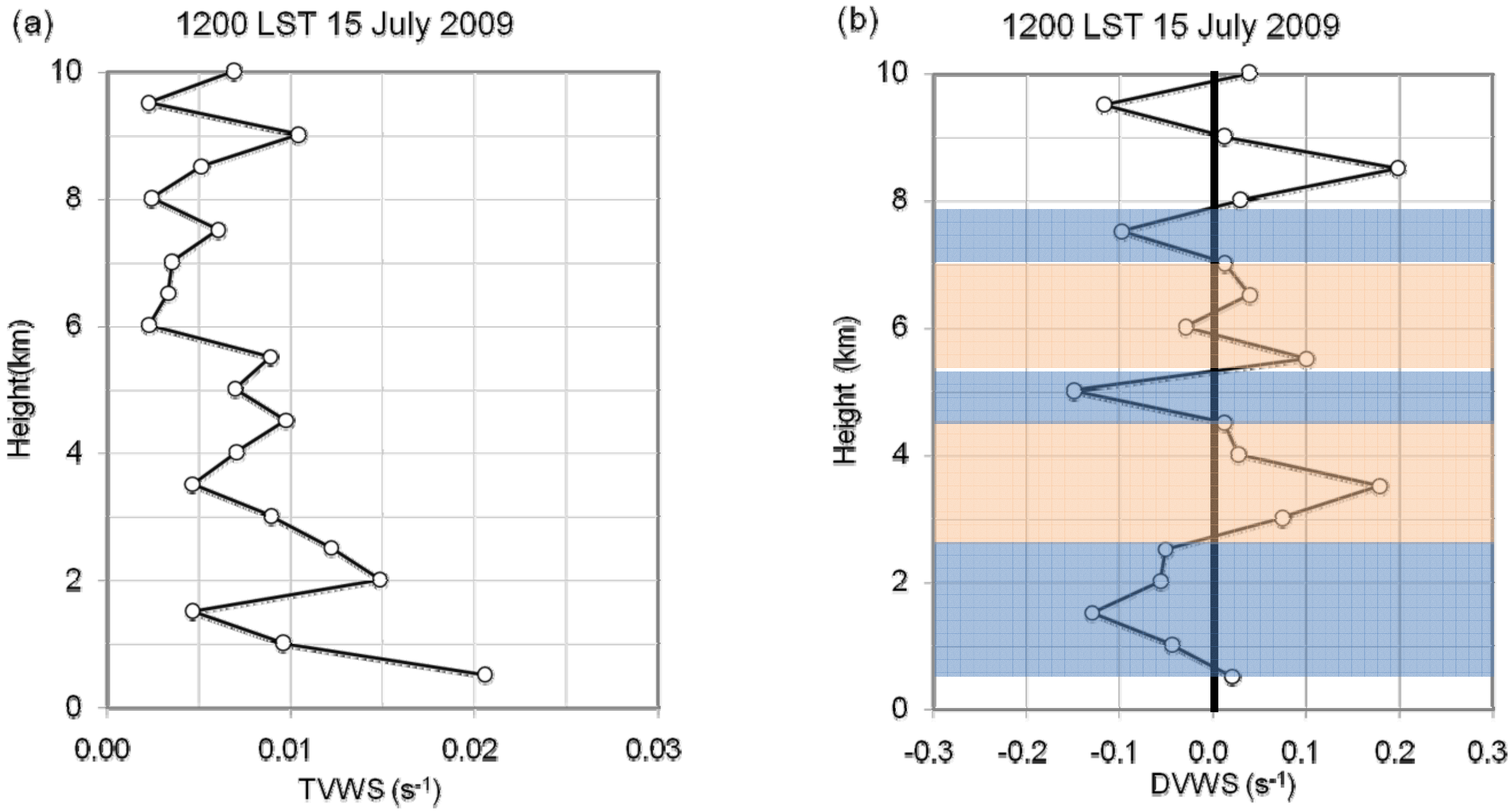


Fig. 16. The total vertical wind shear (TVWS, (a)) and directional vertical wind shear (DVWS, (b)) obtained from radiosonde at 1200 LST on 15 July 2009.

Vertical wind shear analysis by sonde observation

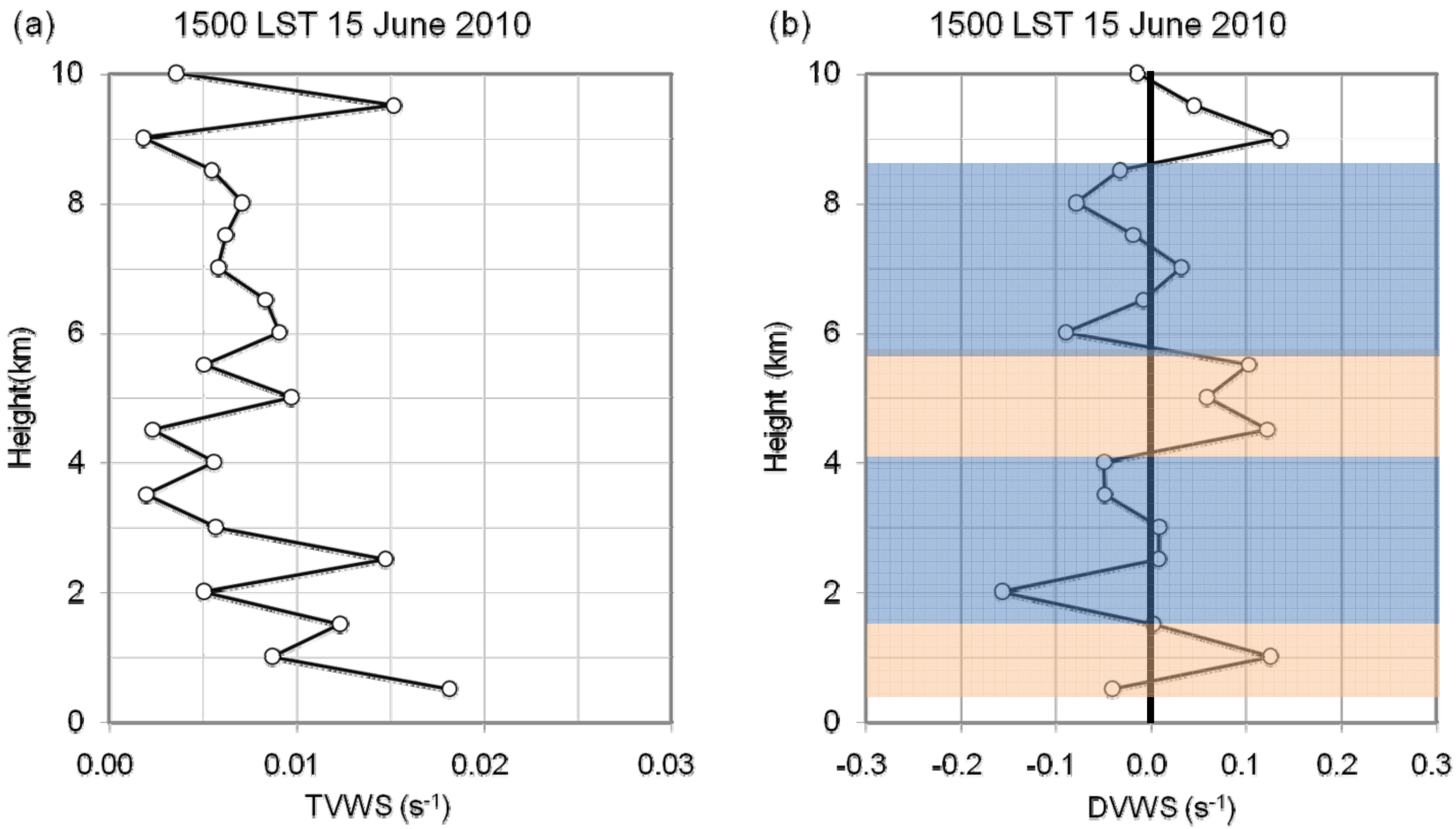
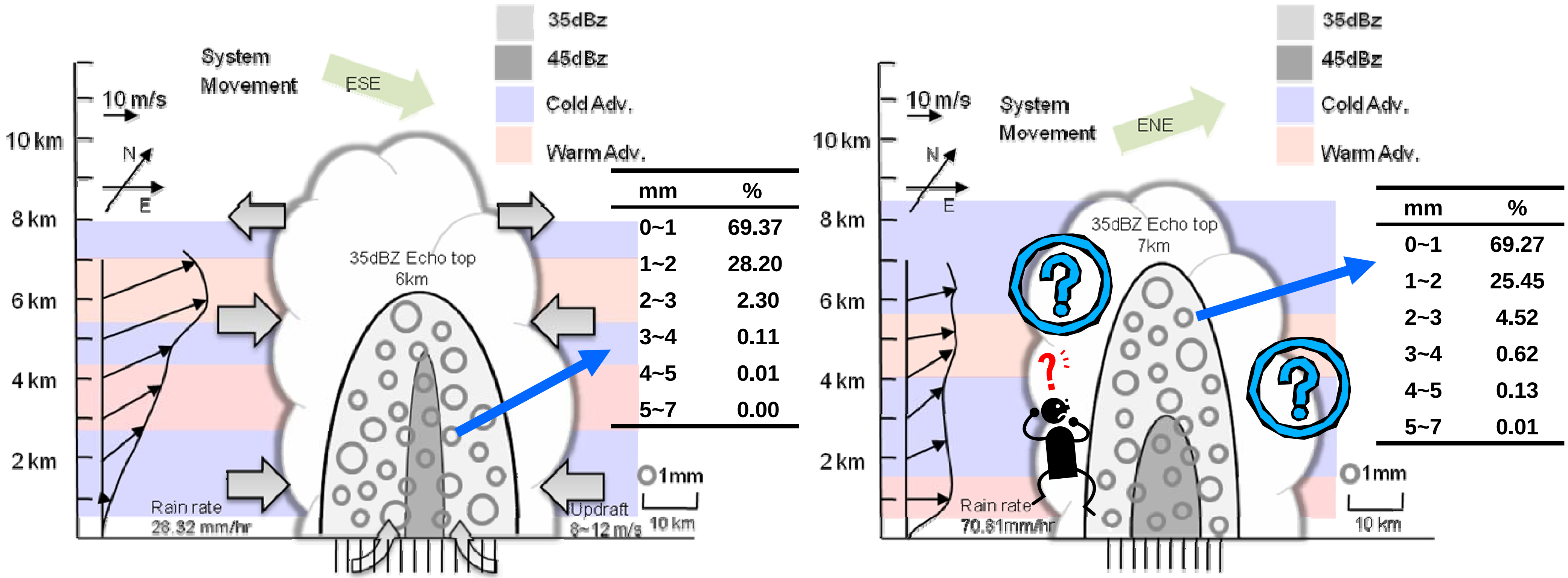


Fig. 17. The total vertical wind shear (TVWS, (a)) and directional vertical wind shear (DVWS, (b)) obtained from radiosonde at 1500 LST on 15 June 2010.

Schematic diagram (2009 and 2010)

2009 Chujado | **2010 Okinawa**

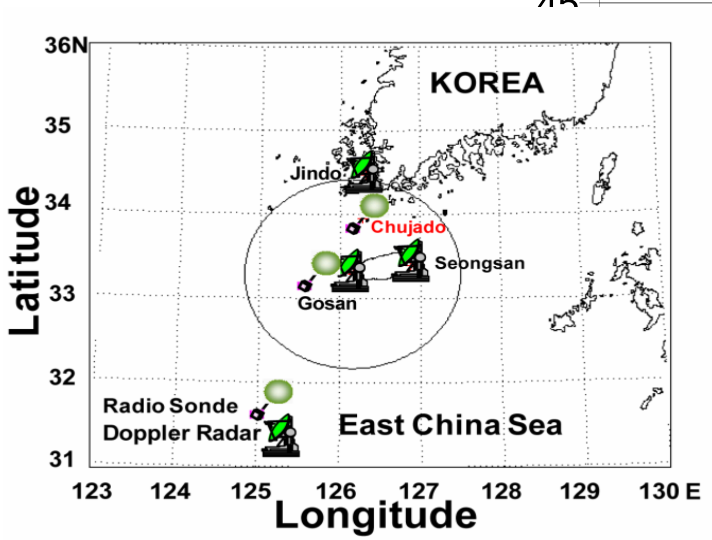


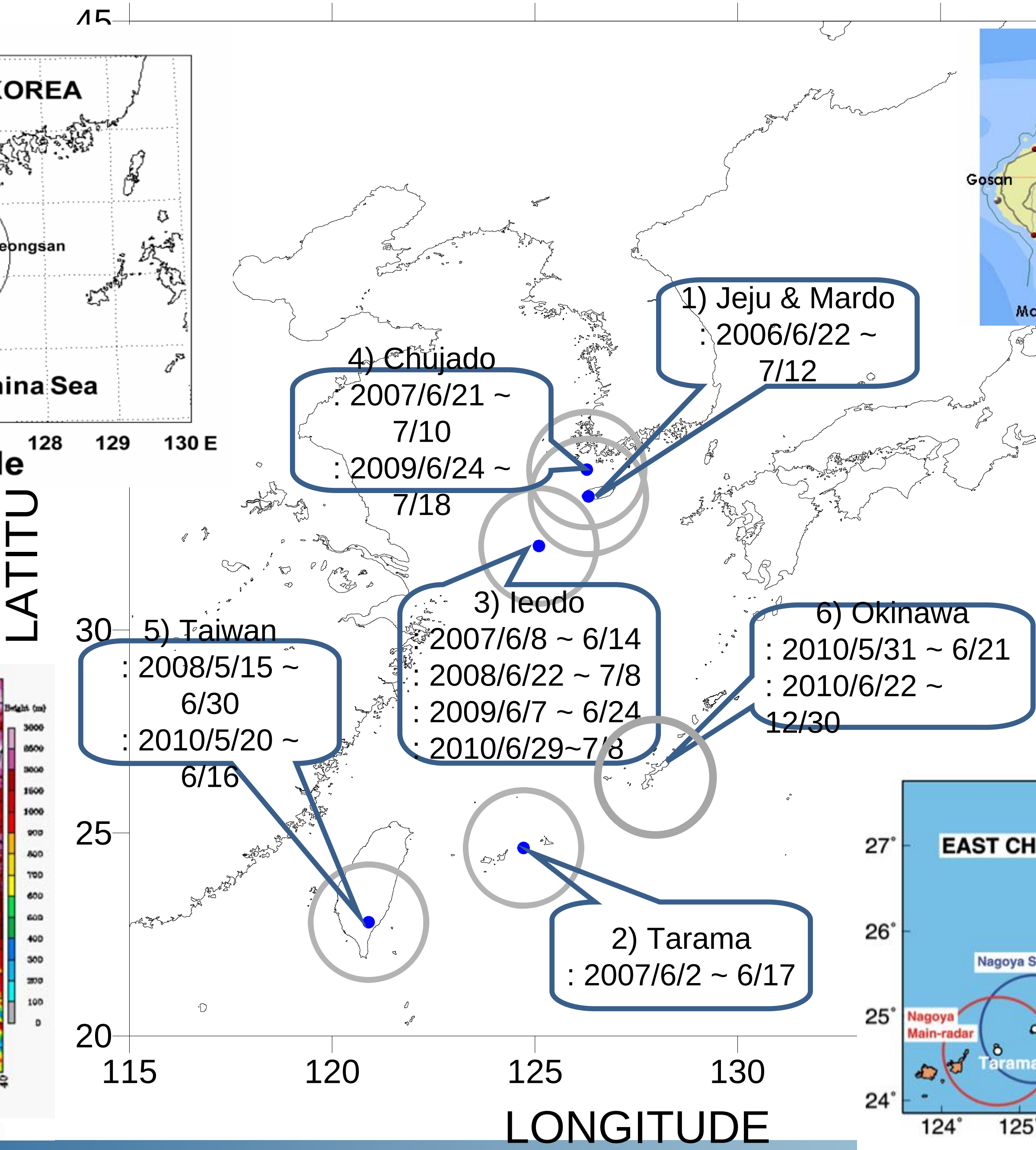
mm	%
0~1	69.37
1~2	28.20
2~3	2.30
3~4	0.11
4~5	0.01
5~7	0.00

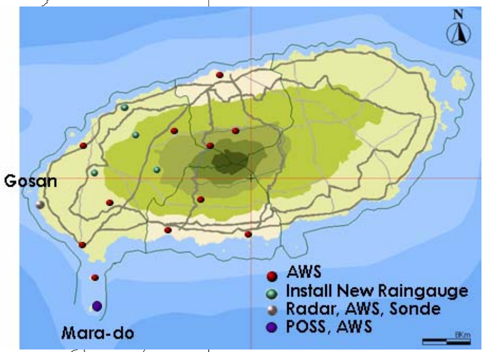
mm	%
0~1	69.27
1~2	25.45
2~3	4.52
3~4	0.62
4~5	0.13
5~7	0.01

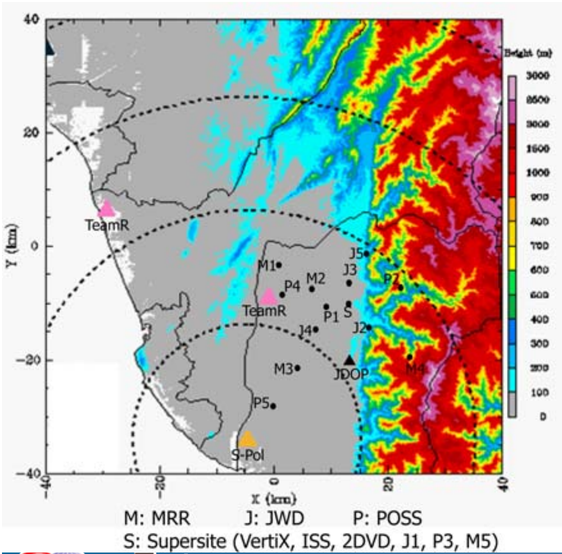
Fig. 18. The schematic diagram of Case 1 (15 July 2009) and Case 2 (15 June 2010).

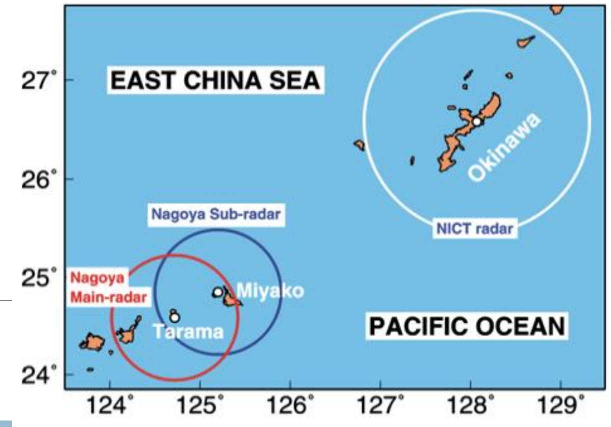
Observation sites for Monsoon study











Thank you