The Airflow and Precipitation Characteristics of Typhoon Morakot (2009) from radar analyses and Modelling Study

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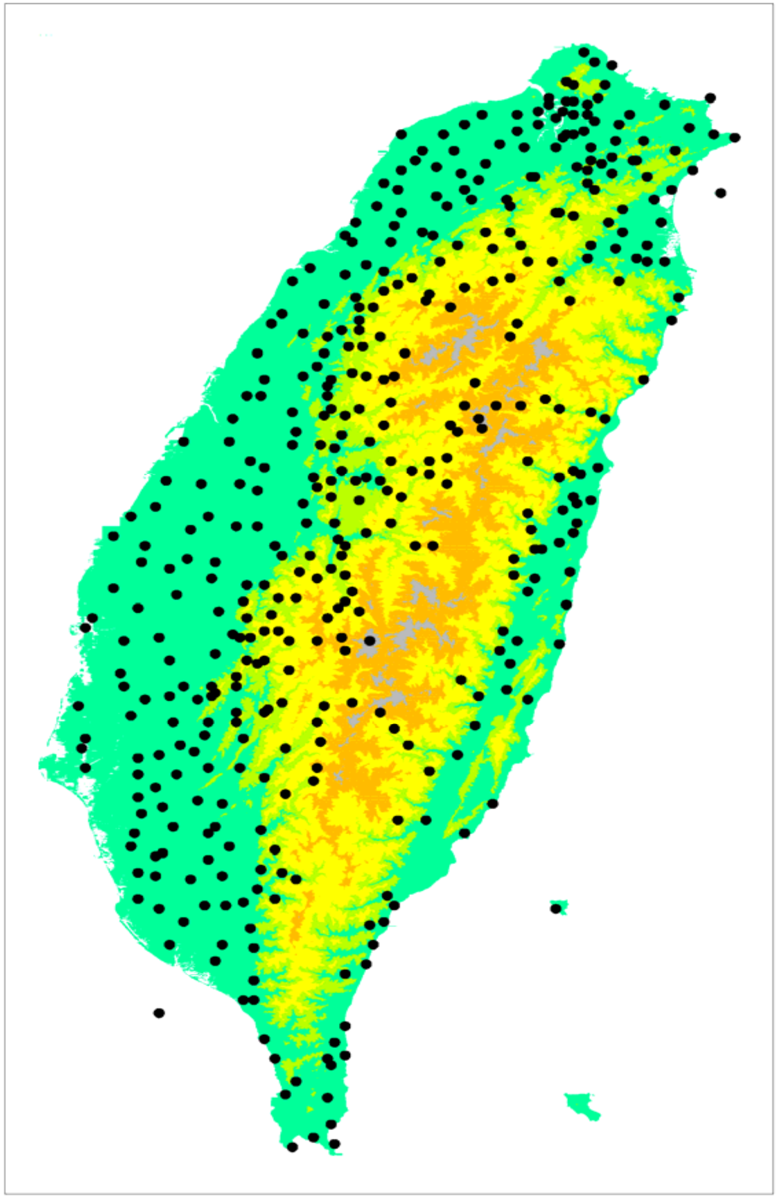
Typhoon Morakot (2009)

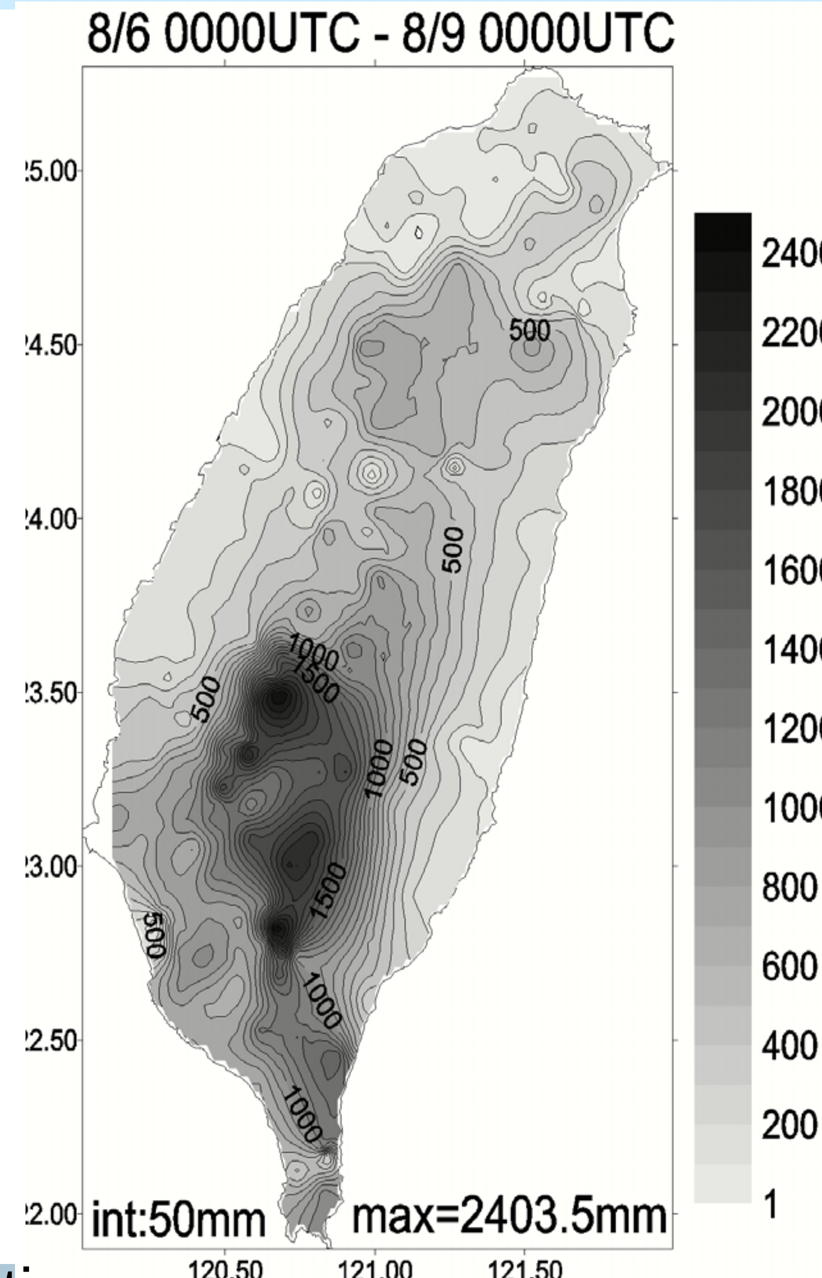
after

before

Over all in Taiwan: more than 25,000 persons were evacuated before heavy rainfall associated with TY Morakot. However, the life losses close to 700.

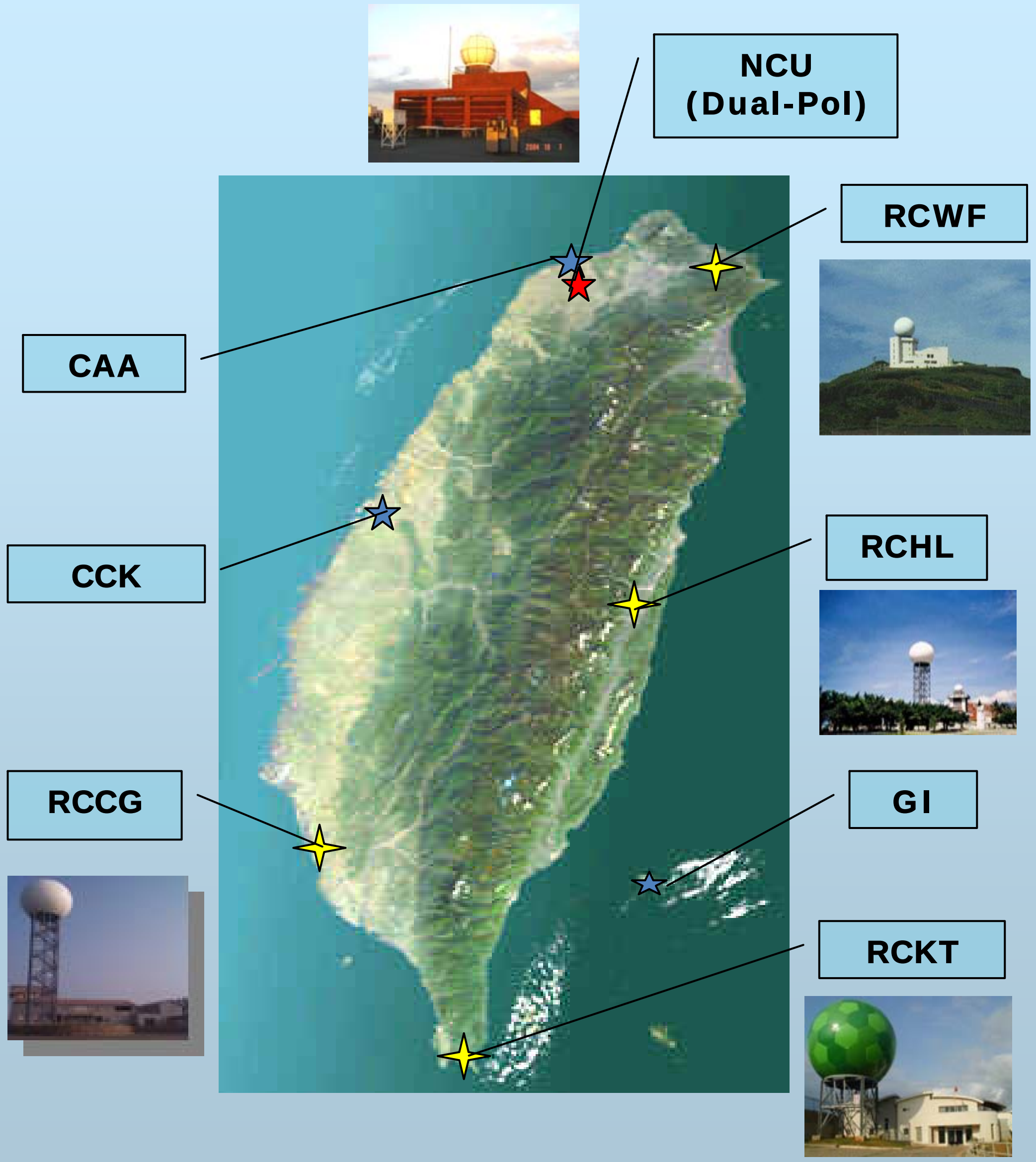
MORAKOT





432 Rain Gauge Station

Taiwan radar network



CWB	(4)
AF	(2)
CAA	(1)
NCU dual-pl.	(1)
----------------------------------	
ground-based radars	(8)

NCU C-band

Dual-pol & Doppler radar
- Full PPI scans

TEAM-R X-band

Dual-pol & Doppler radar
- Sector scans
- RHI scans

Fig.1: 2008/5/1, Training at NCU

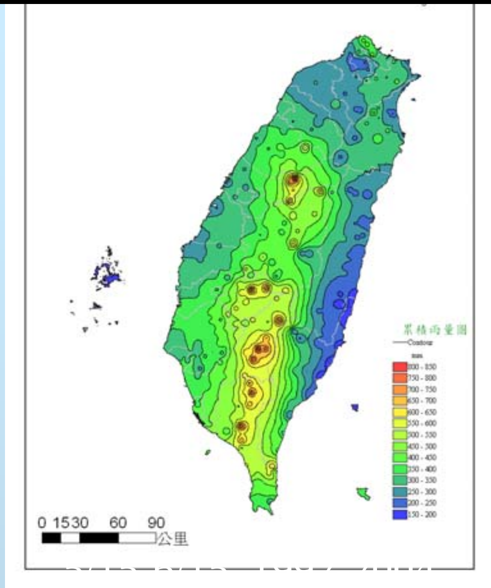
Fig.2: 2008/5/10-29, at Hsin-Yuan Levee with S-POL

Fig 3：2008/5/28 at Golden Beach。

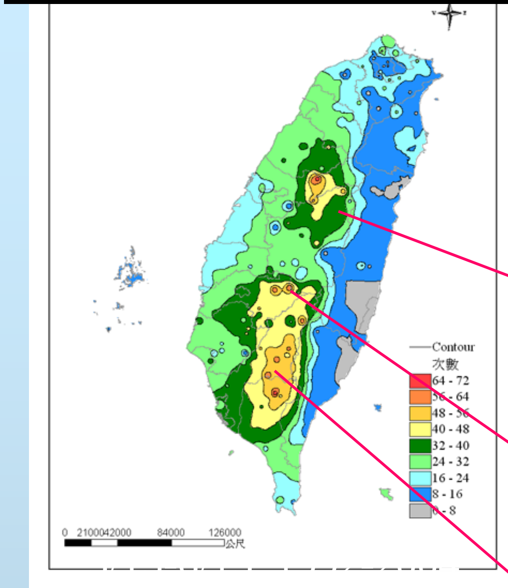
Fig. 4：2008 5/30-6/28 at Jou-Ru Levee

Rainfall statistics of May 15-June 15, 1992-2004.

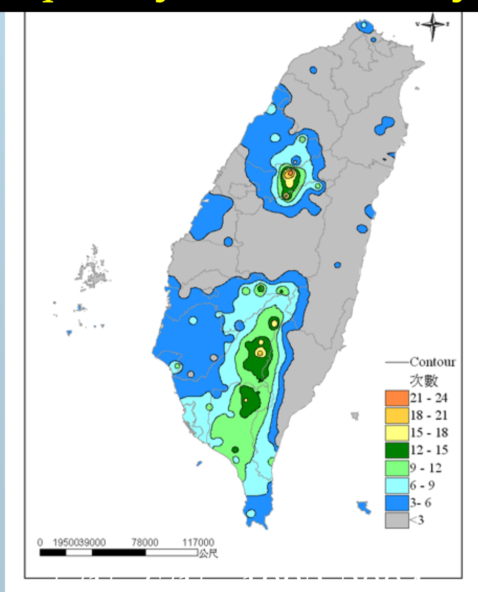
Averaged rainfall



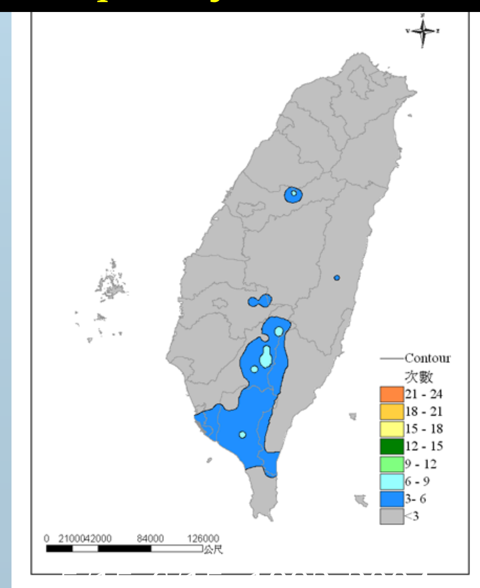
Frequency ≥50mm/day

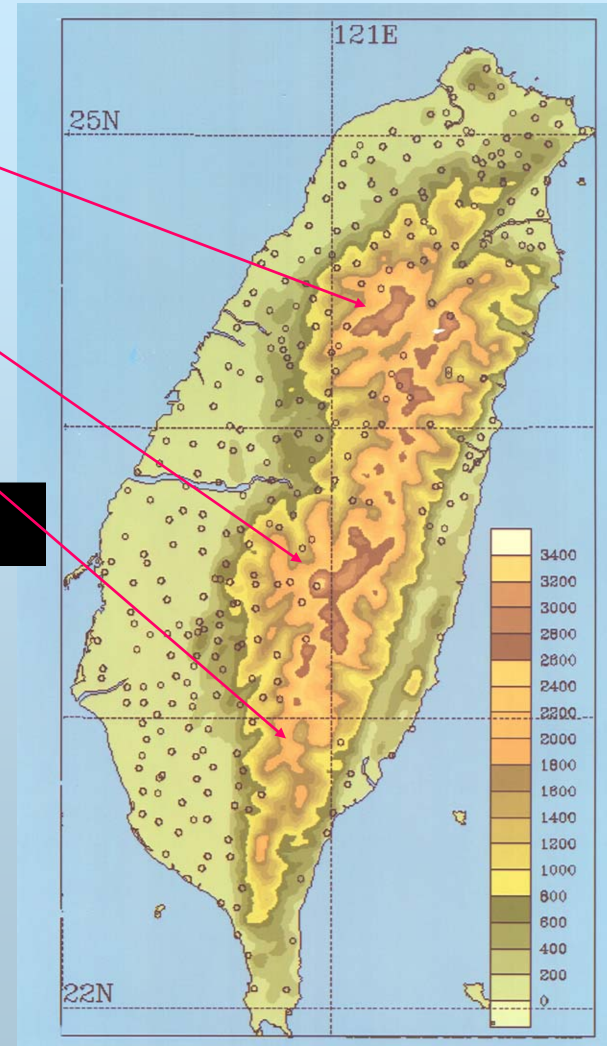


Frequency ≥130mm/day

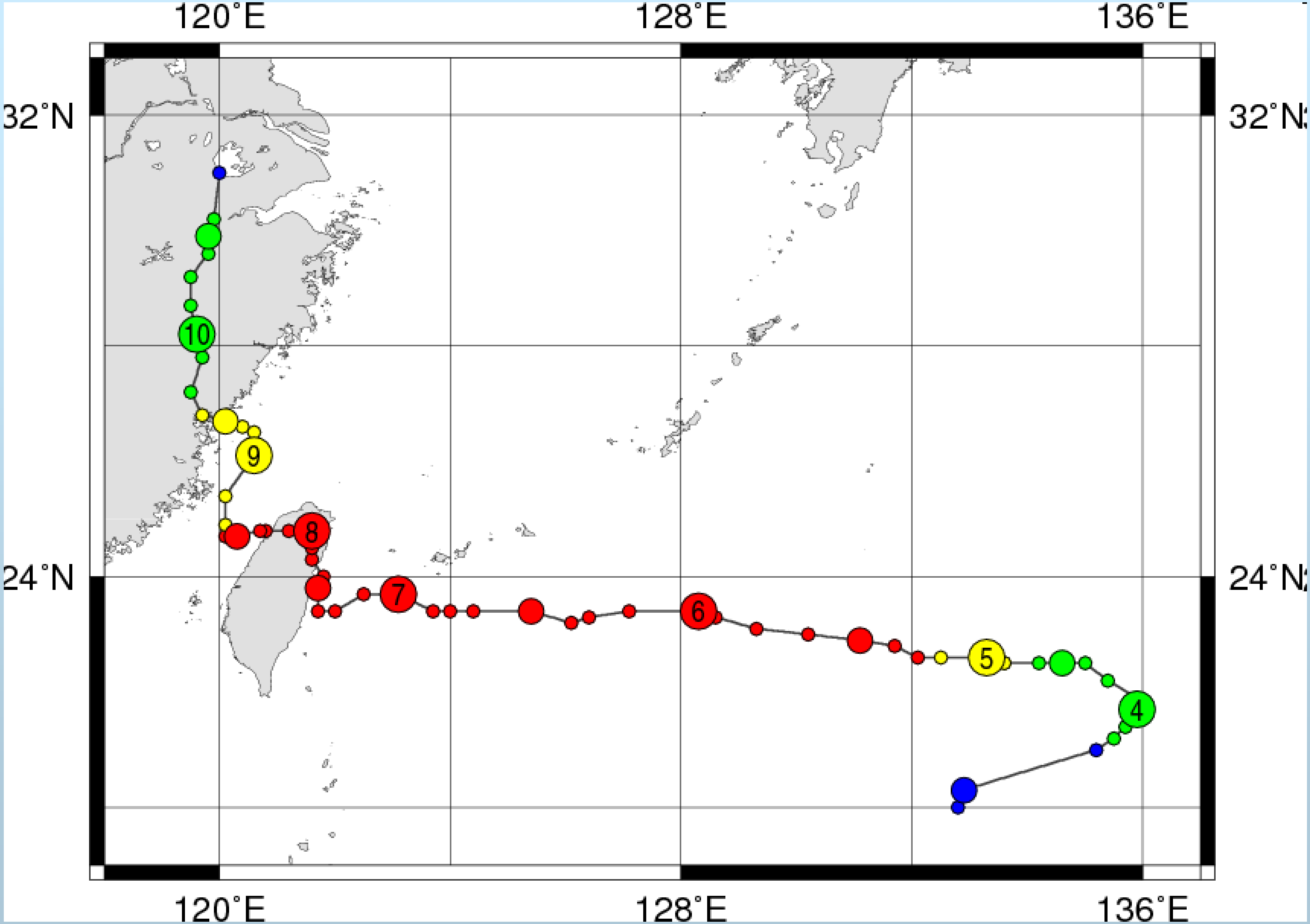


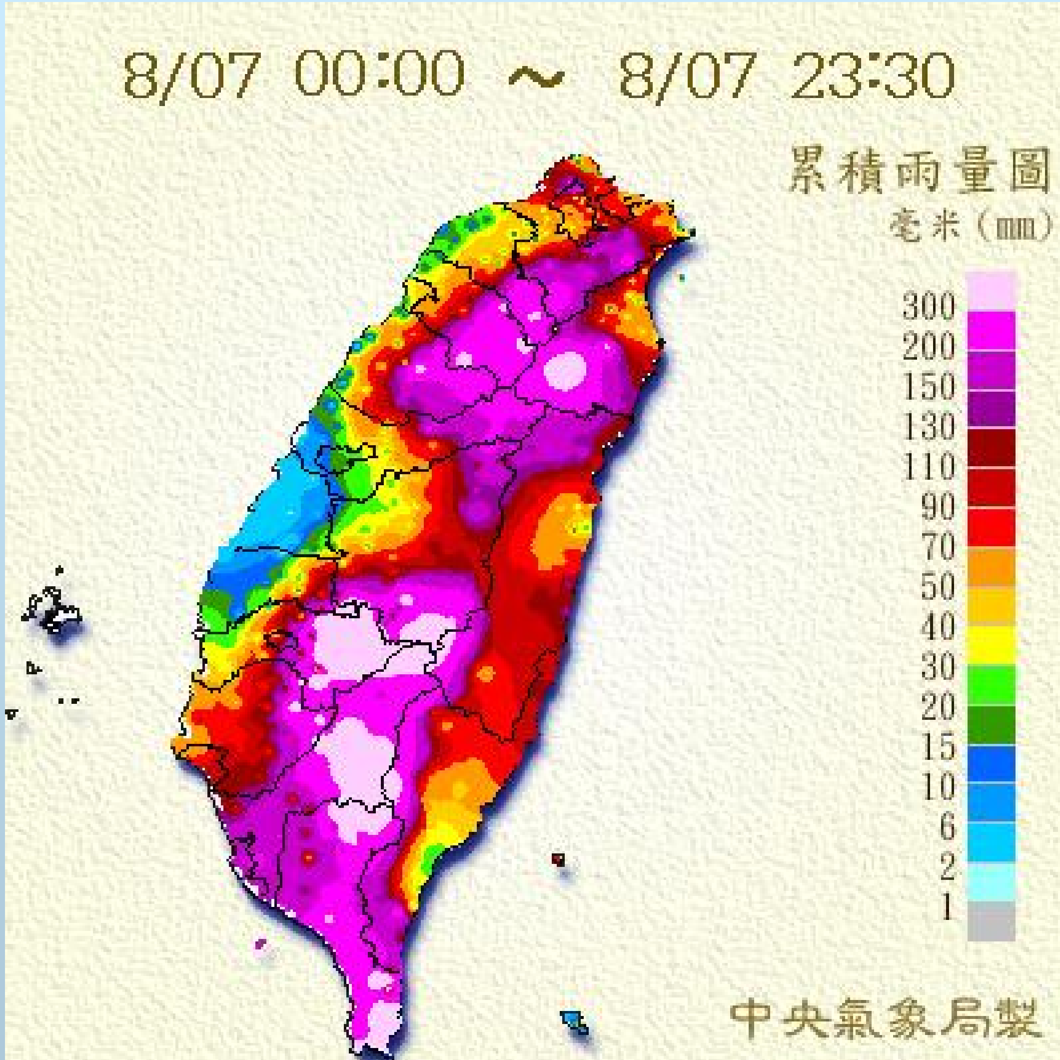
Frequency ≥200mm/day





Topography of Taiwan


120˚E
128˚E
136˚E
32˚N
24˚N
10
9
8
7
6
5
4


8/07 00:00 ～ 8/07 23:30
累積雨量圖
毫米（mm）
300
200
150
130
110
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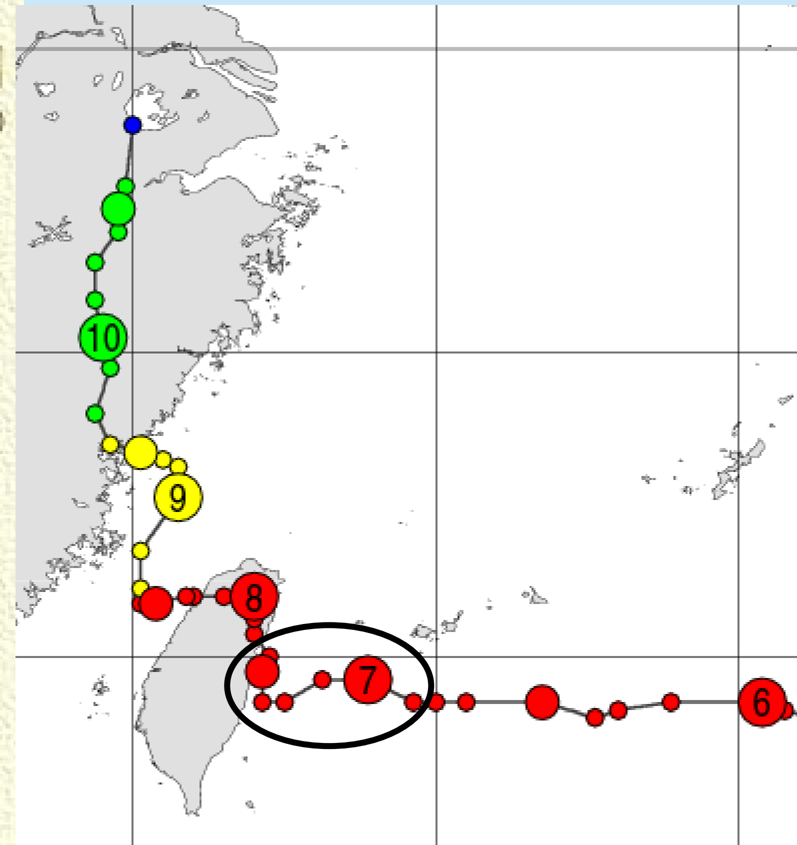
2
1
中央氣象局製

10
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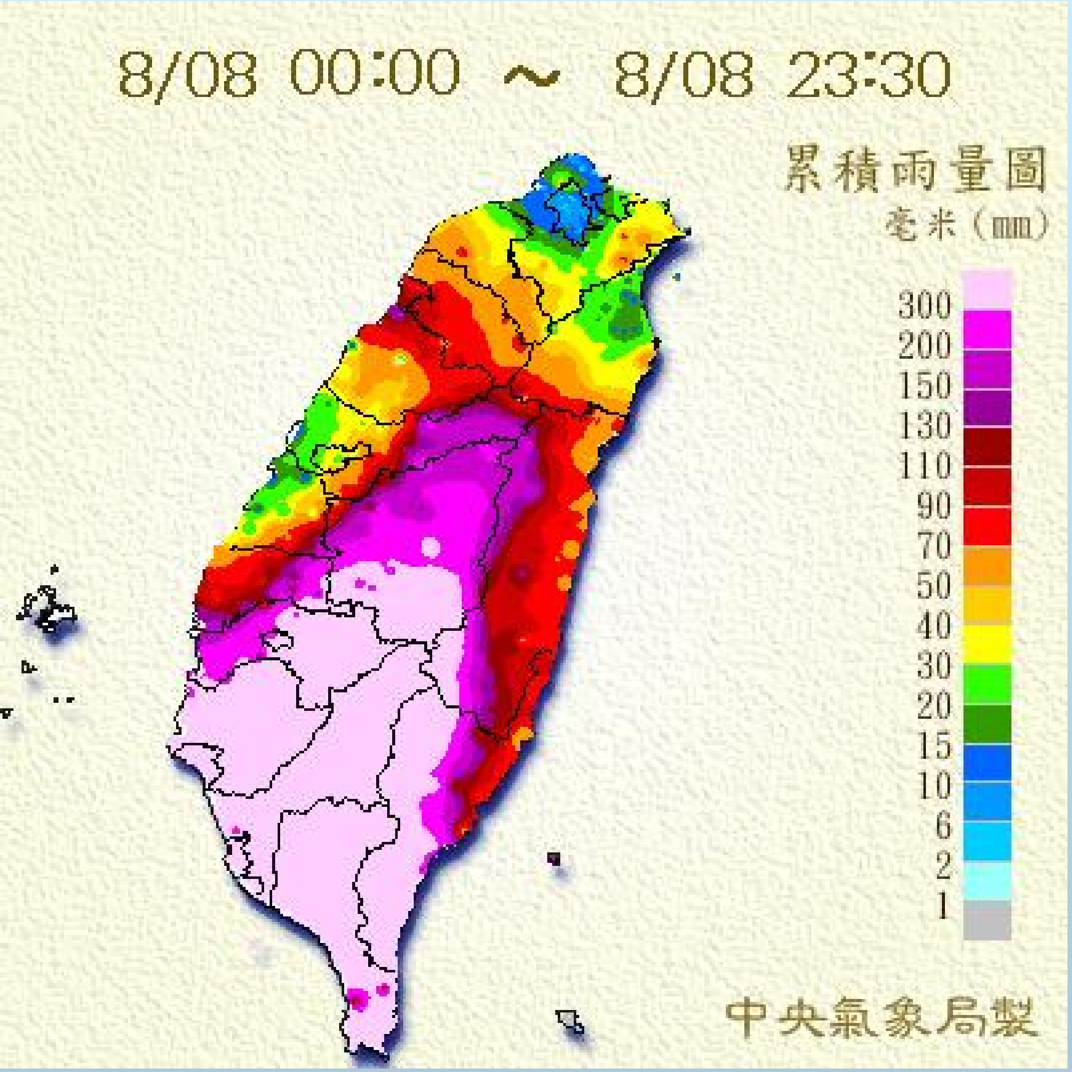

8/08 00:00 ~ 8/08 23:30
累積雨量圖
毫米 (mm)
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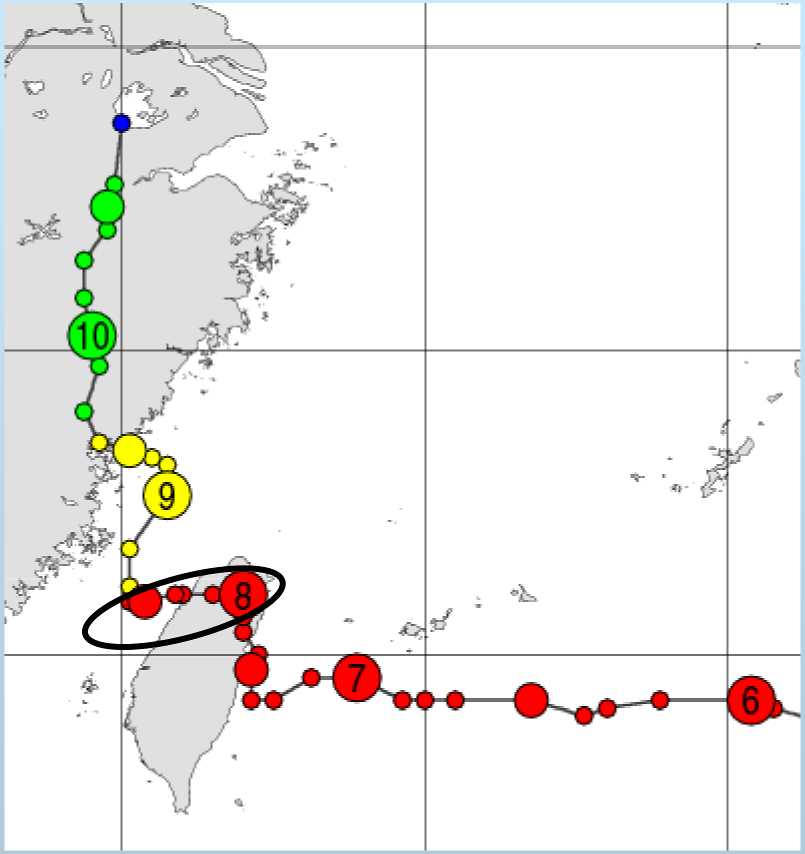
1
中央氣象局製



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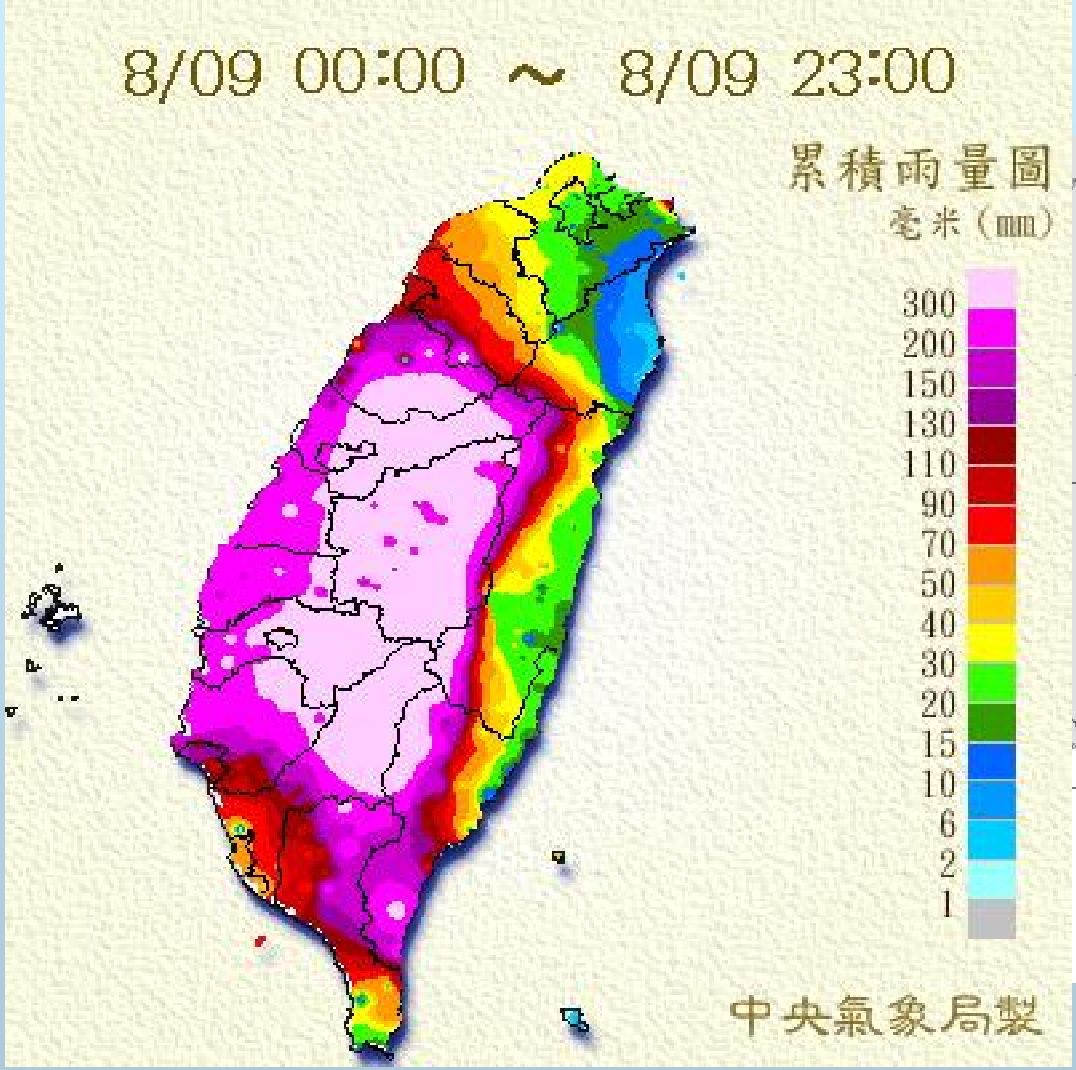
8/09 00:00 ~ 8/09 23:00
累積雨量圖
毫米（mm）
300
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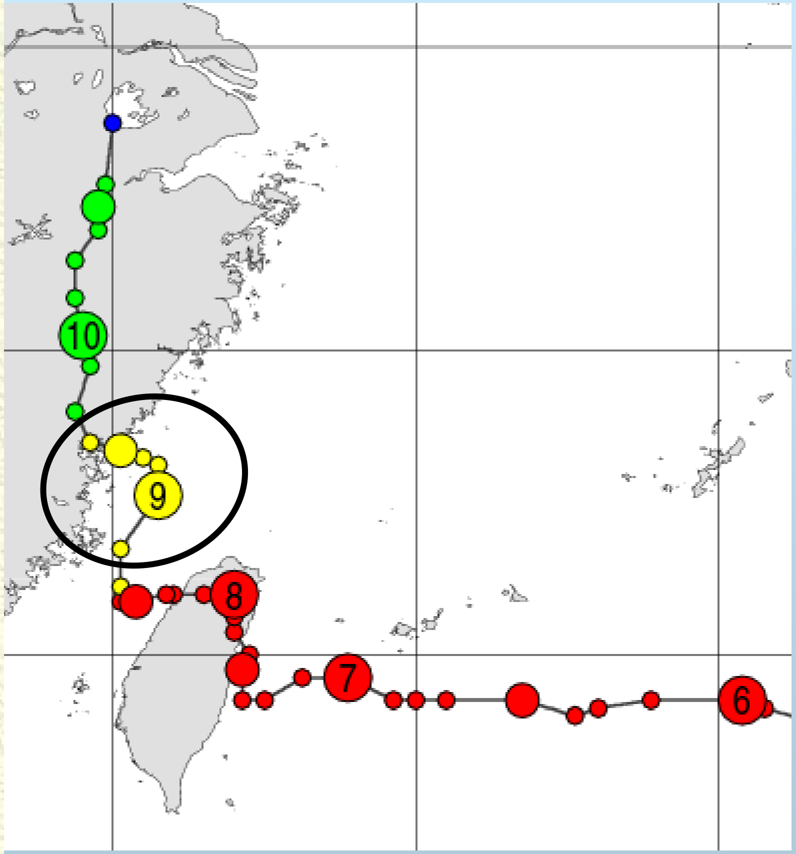
中央氣象局製


10
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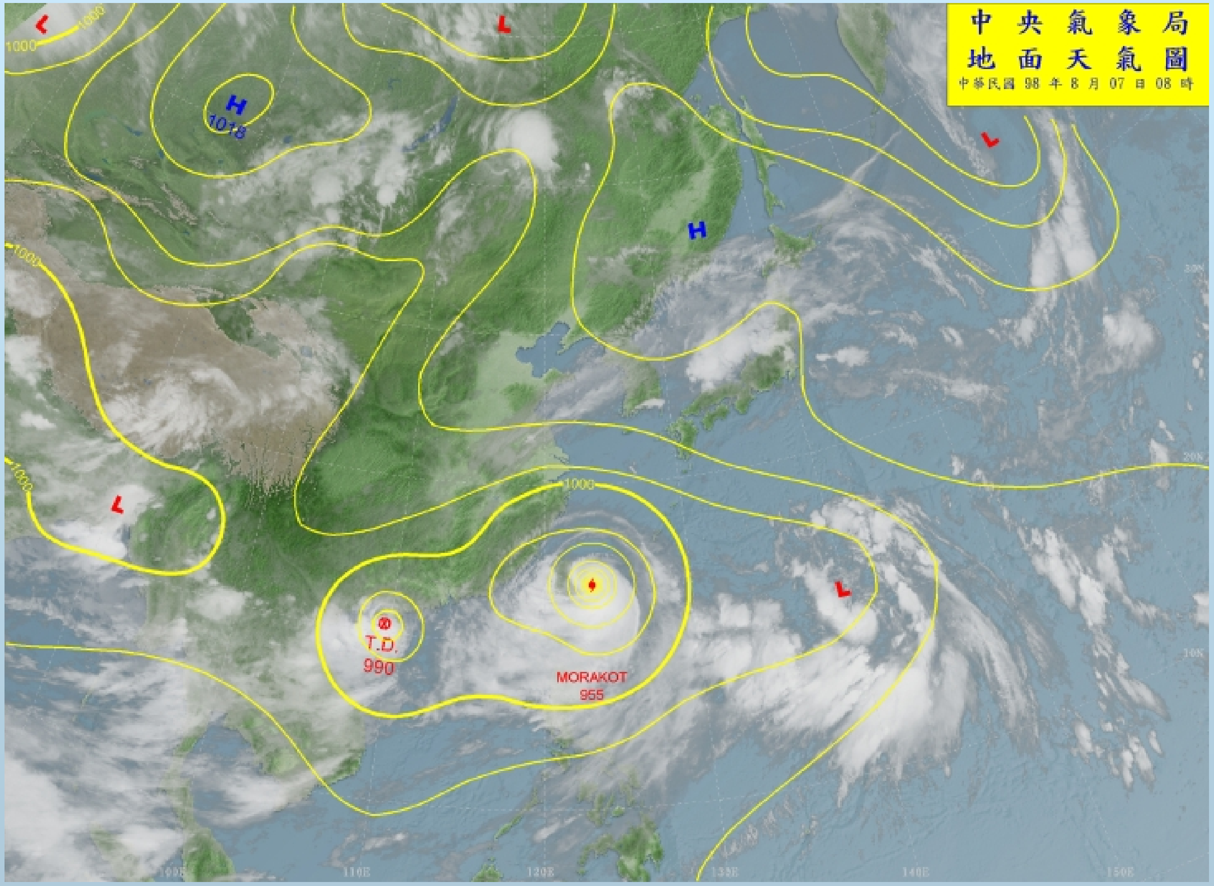
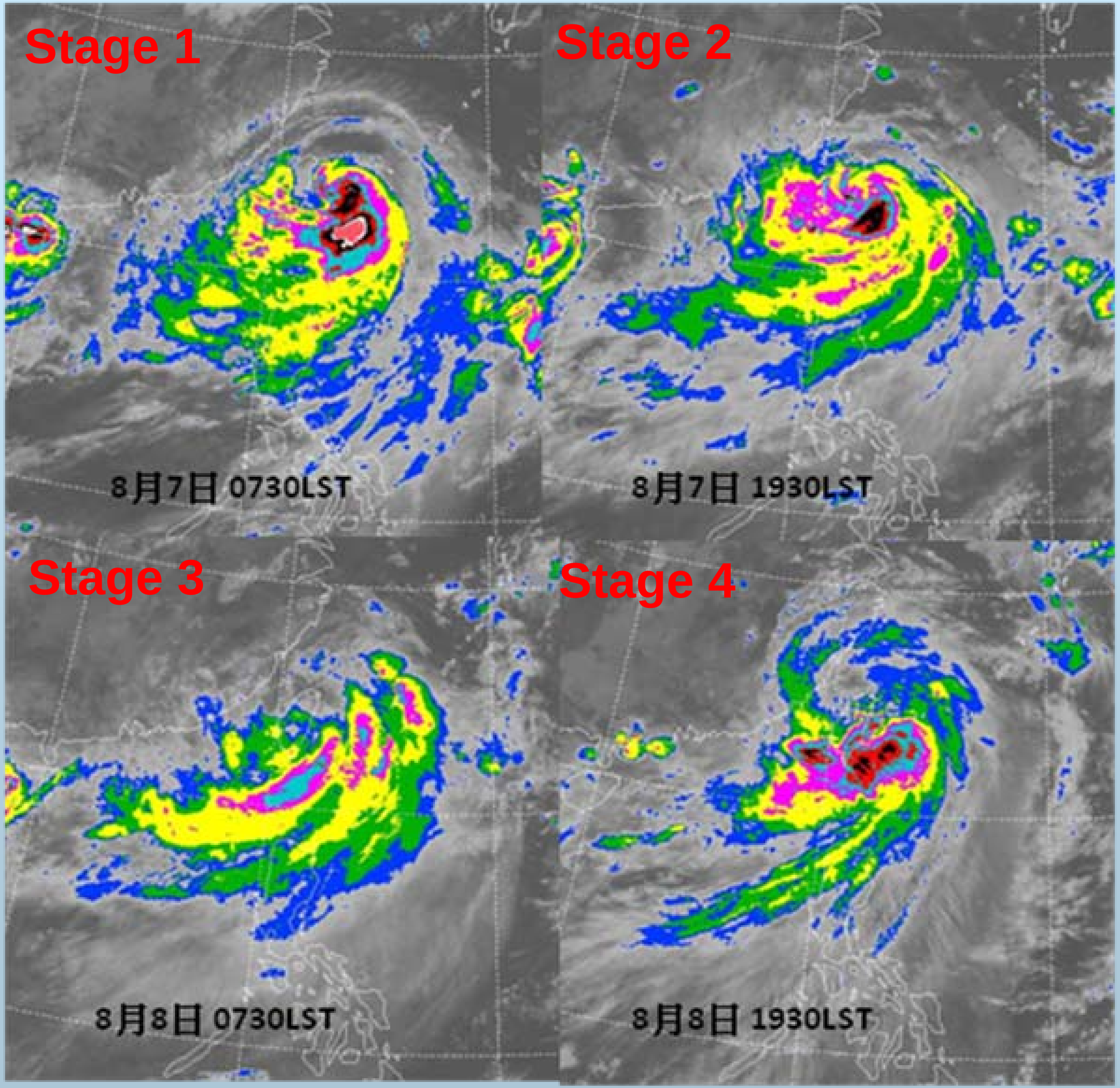


8月7日:颱風後方的熱帶雲簇持續發展且位置向北移動。北方的太平洋副熱帶高壓勢力減弱，再加上地形阻擋，導致颱風移速減慢。

Set up the stage



- Weak steering flow
- Large circulation size
- weak core
- Strong convective principal rain band

Bounty moisture around the surrounding area of Taiwan Island

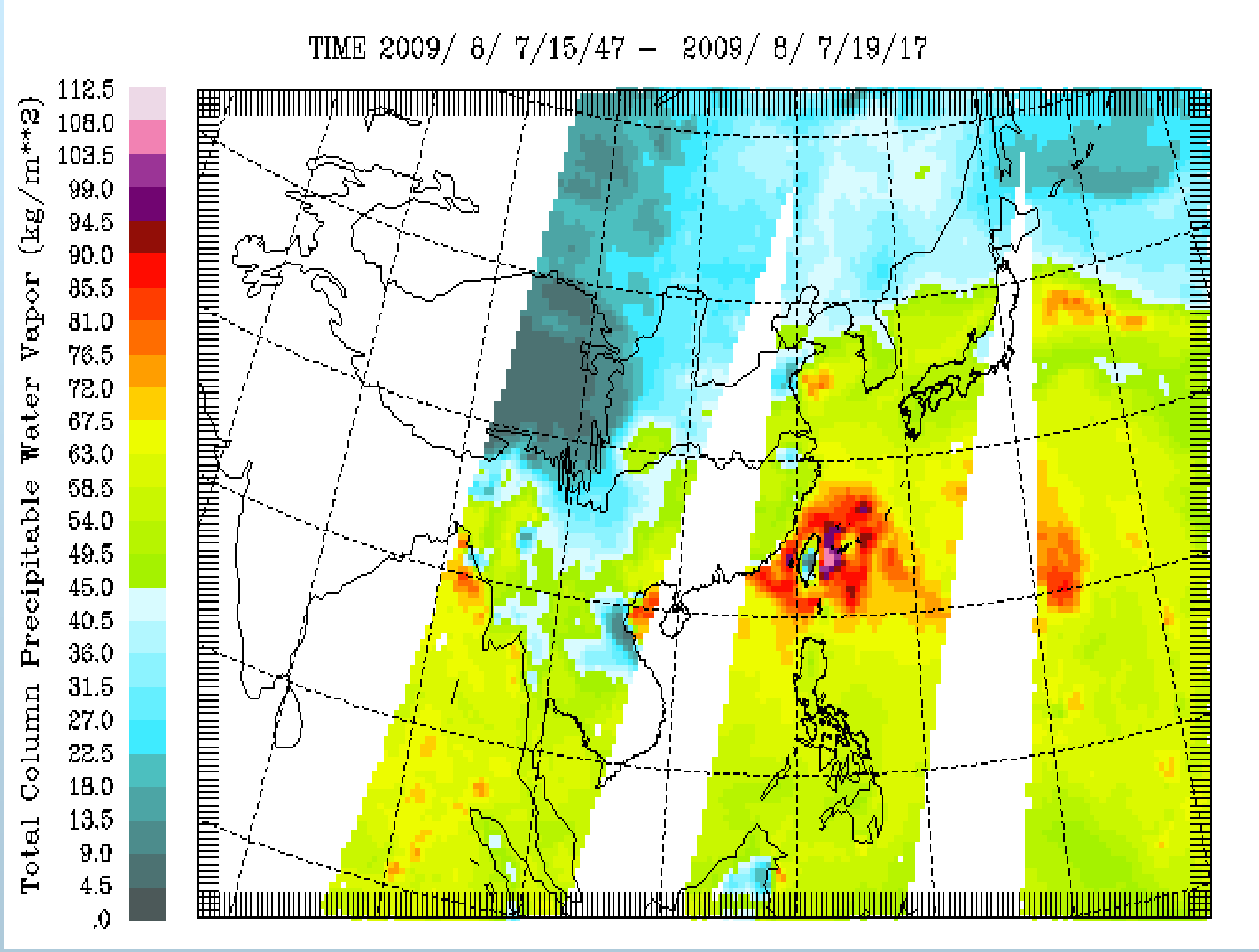
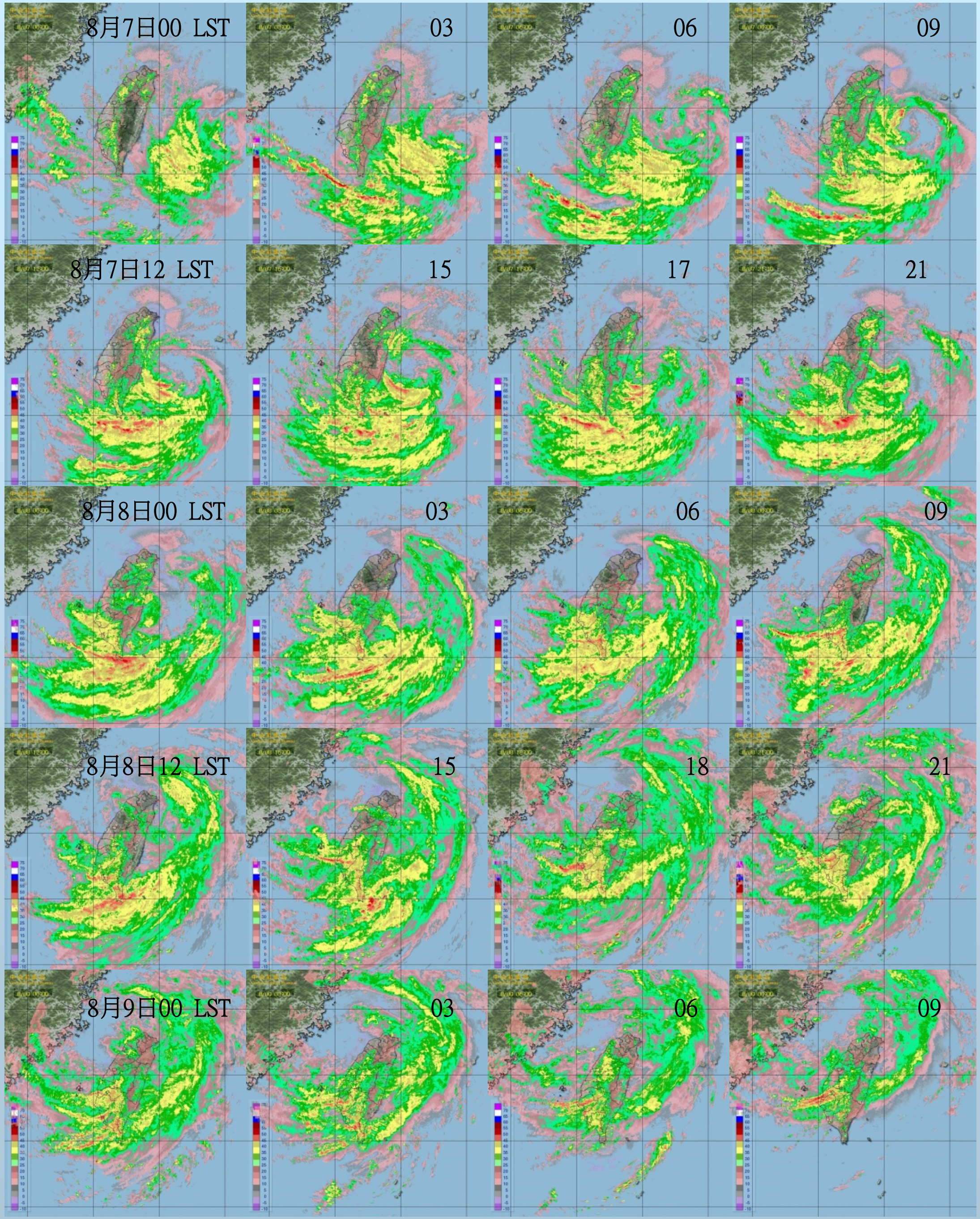


圖1(b)：8月7日12時、8月8日凌晨、8月9日凌晨、8月9日12時附近 時間微波頻道可降水量，單位爲(kg/m^2)(周等，2010)。



Stage 1: Aug. 7, 00-12 LST
TC approaching

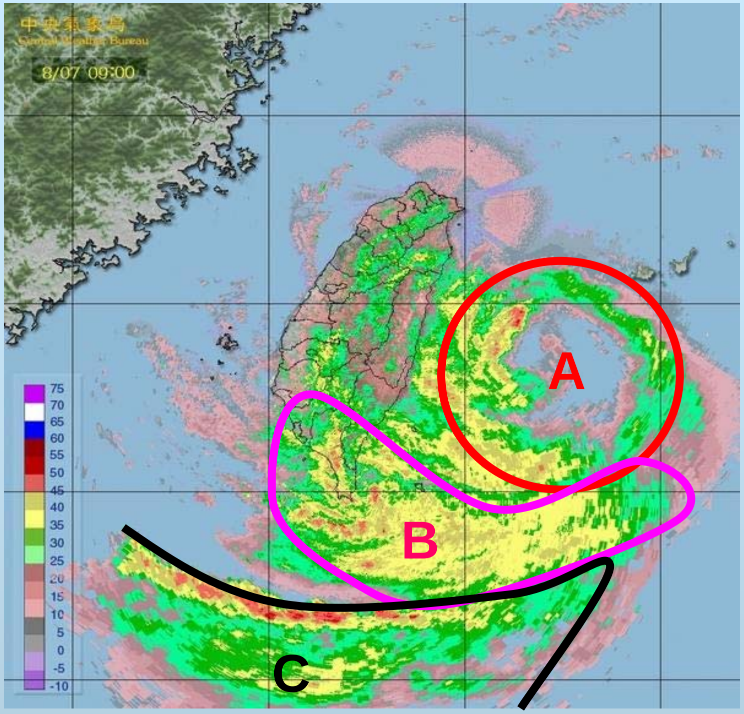
Stage 2: Aug. 7, 12 - 24 LST
TC very slowly approaching

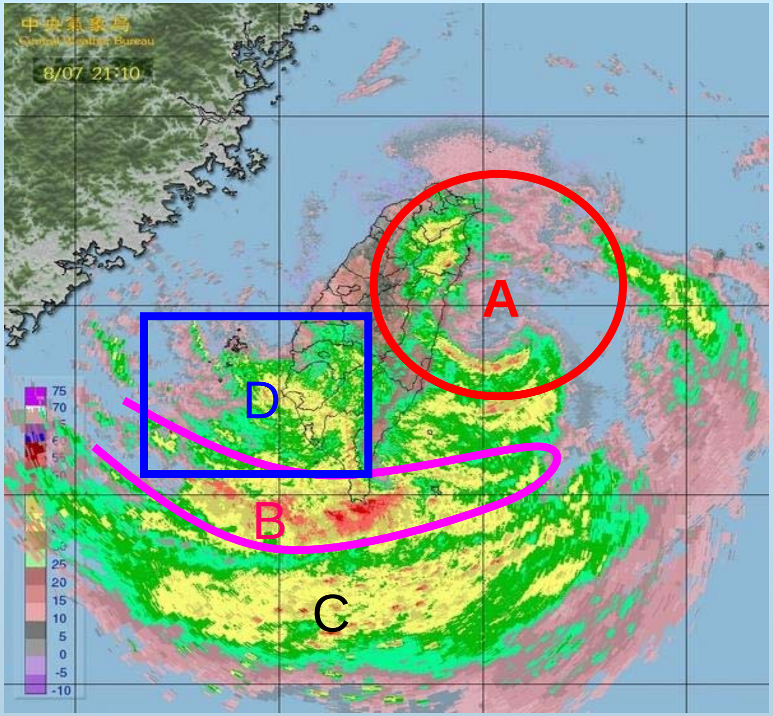
Stage 3: Aug. 8, 00-12 LST
TC landing and across the island

Stage 4: Aug. 7, 12 - 24 LST
TC in the Taiwan strait

Stage 5: TC approaching FuJeng

Multiscale interaction and movement





The maximum reflectivity maps from CWB QPESUMS

圖2：氣象局全省雷達網最大回波圖(a)8月7日09時降水特徵分區。(b)8月7日21時降水特徵分區。

Region C

Rain band along the convergence zone between Typhoon circulation and Southwesterly. (Thermodynamic characteristics?)

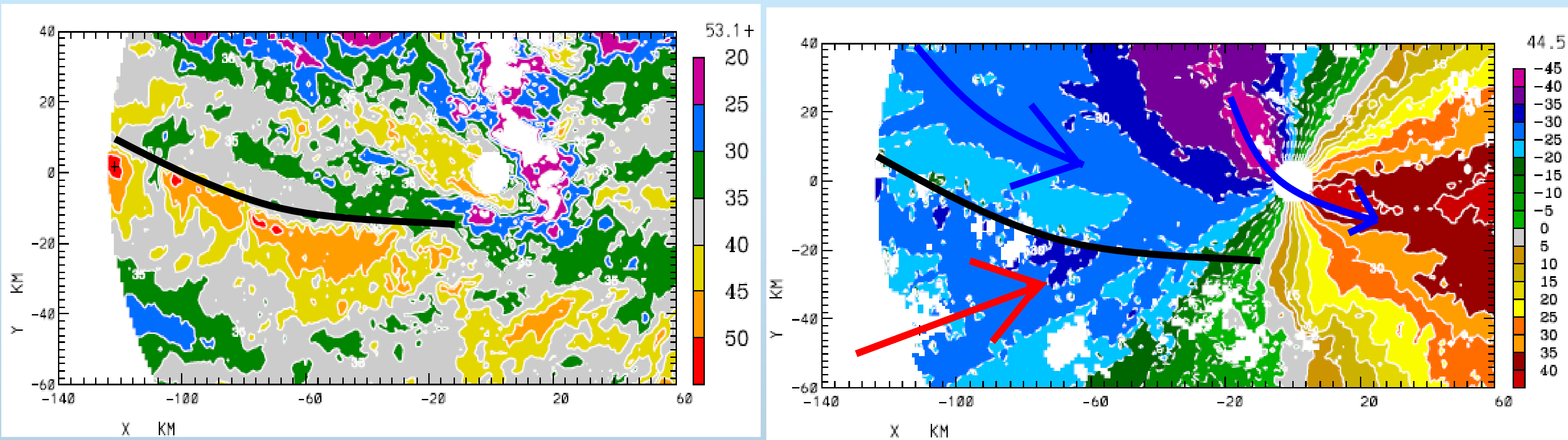
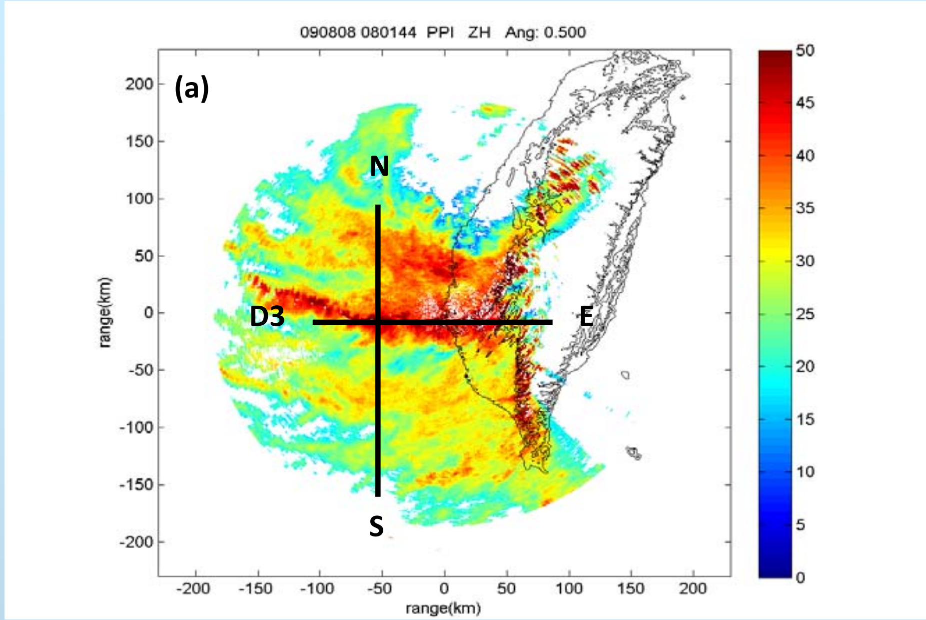


圖9：8月7日1700LST墾丁雷達站B區雨帶單都卜勒(a)回波場分布，(b)單雷達徑向風場，其中黑線代表雨帶對流區前緣，也是颱風西北西的風場(藍色箭頭)與西南氣流(紅色箭頭)輻合區(唐,2010)。

Multiple bands in D region



The behaviors of the devastation rain bands

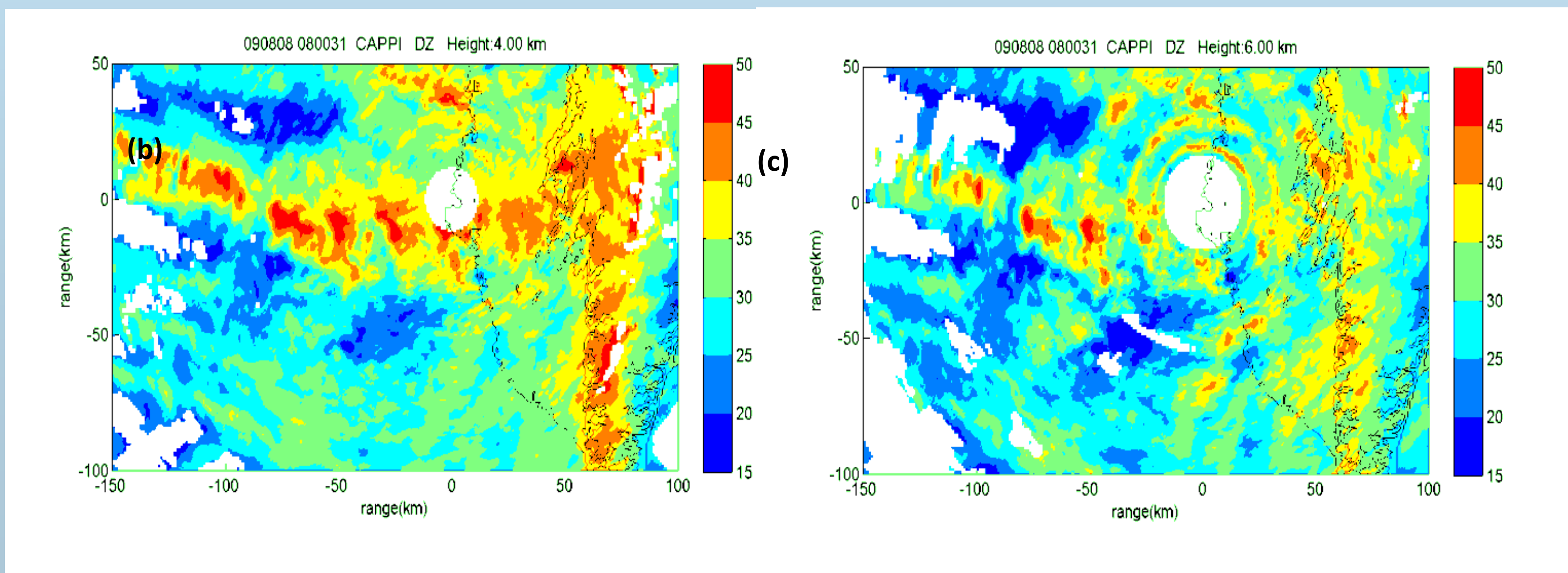
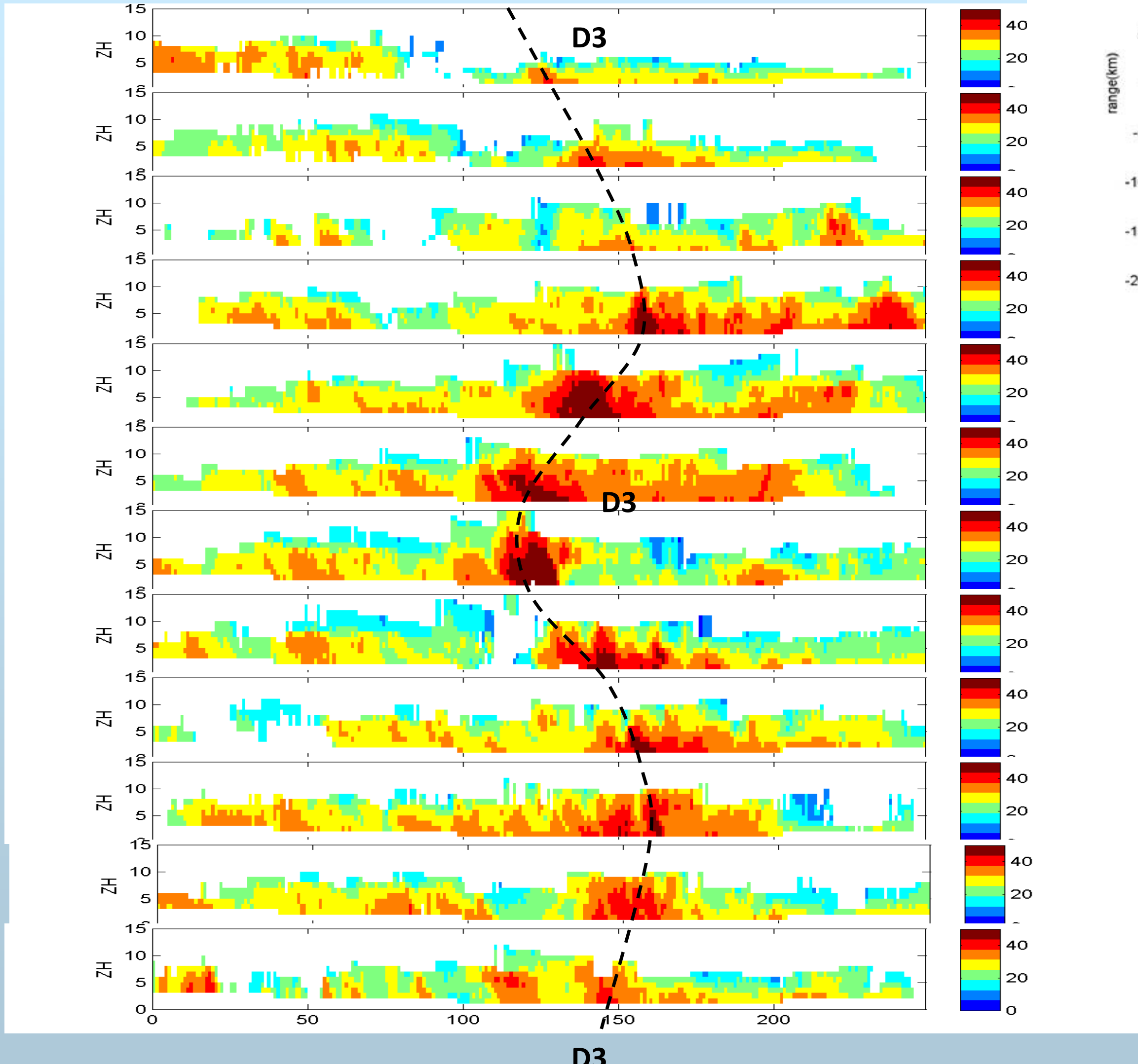
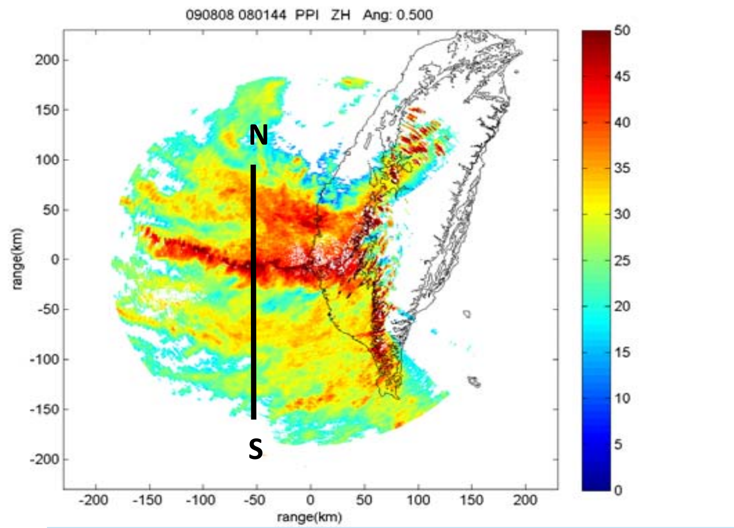


圖6：8月8日1600LST(a)七股0.5高度角的回波圖，其中黑線爲圖8的剖面位置。
(b)4公里等高面回波圖(c)6公里等高面(唐,2010)

Stage 4: Aug.8 12-23 LST





The heaviest rain period

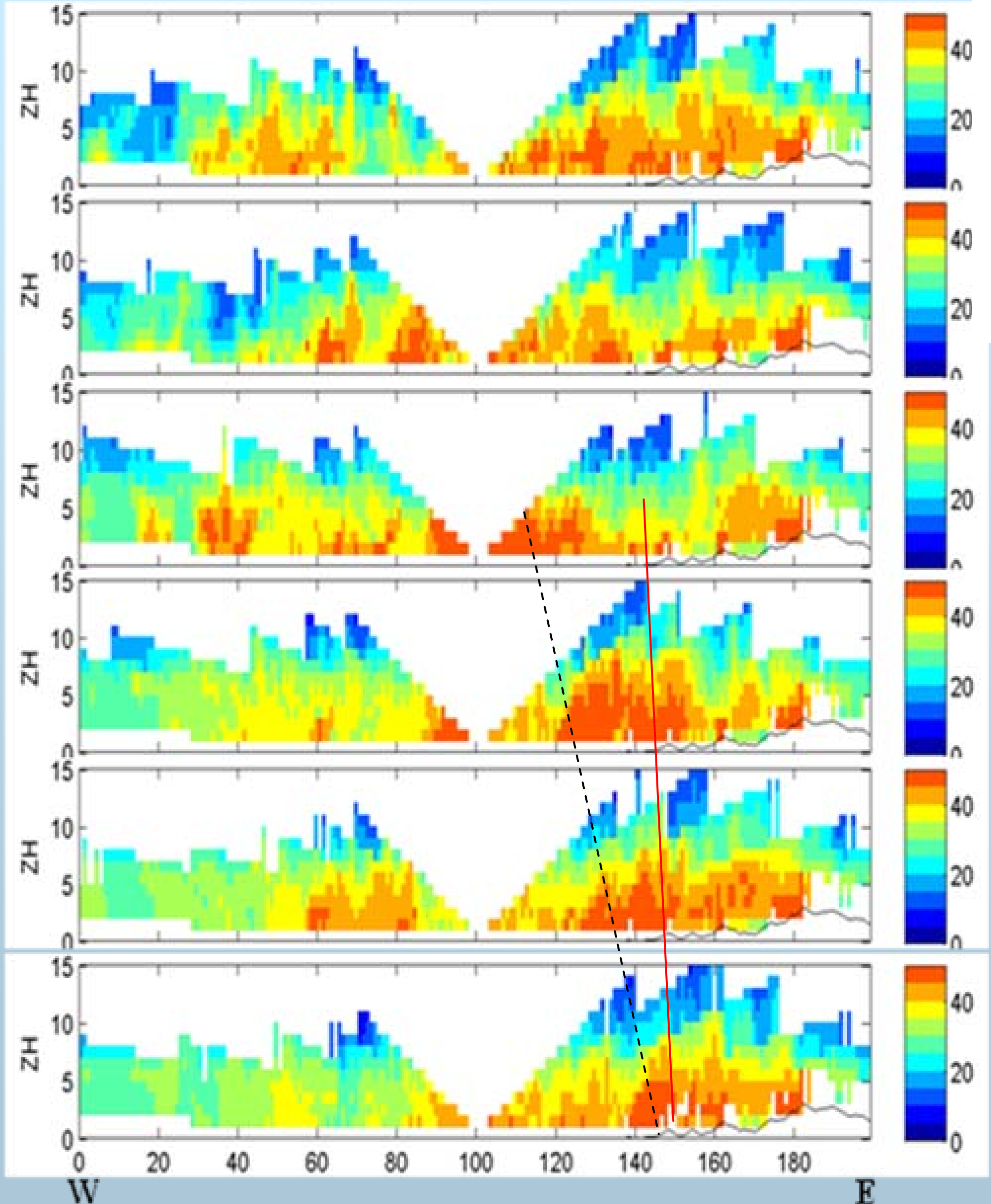
Rain band D3 oscillate between 22.5 to 23.5N

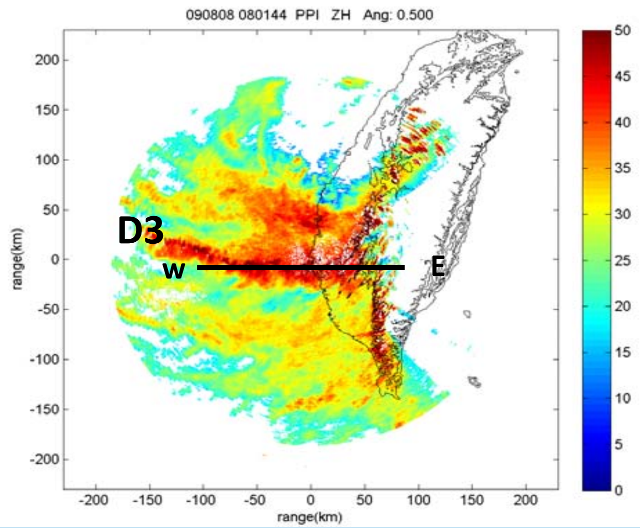
Very high hot towers were observed within the rain band

Line echo wave pattern

圖8(a)：同圖7的配置，8月8 日12LST~23LST的七股外海50公里的南北回波剖面圖時間序列，每一張間隔一小時，其中黑線爲對流雨帶D3的連結線(唐,2010)。此D3東西走向雨帶在12小時內南北震盪推移，影響的緯度即爲南部山區最大雨量的位置。

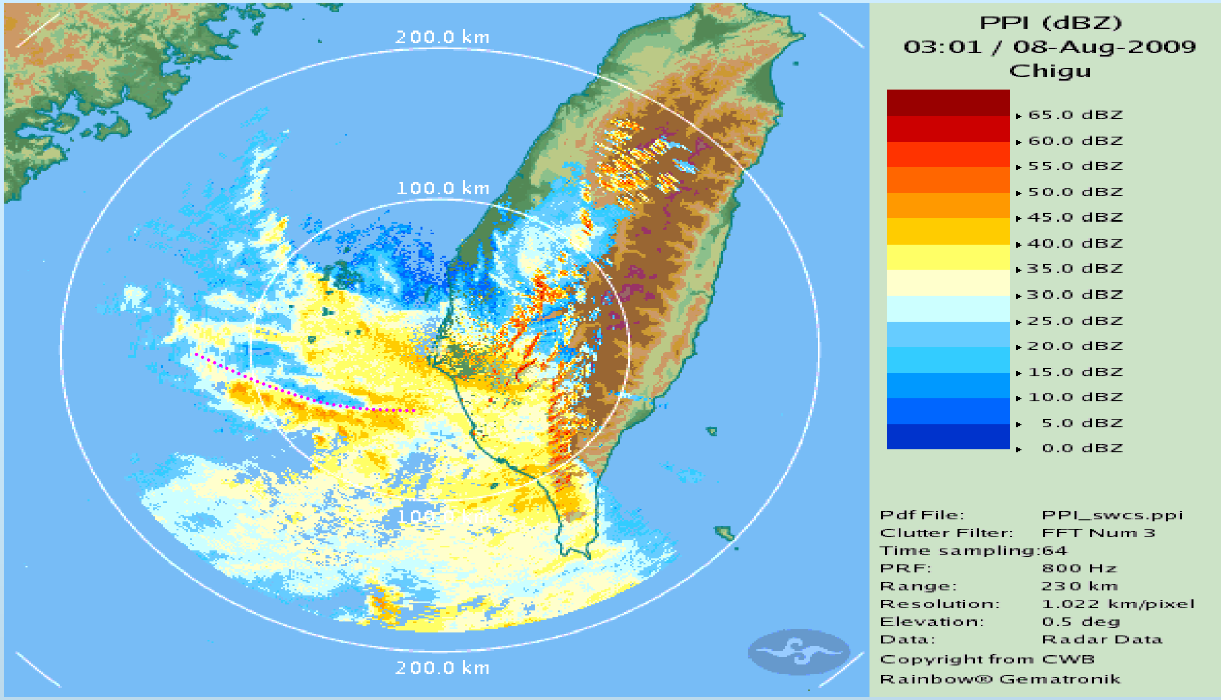
Aug.8 2101~2331 LST





Deep convection cells moving into mountain area

圖8(b)：8月8 日2101LST~2331LST的通過七股雷達站及甲仙雨量站的東西回波剖面圖時間序列，每一張間隔30分鐘(唐,2010)。圖中座標140到160公里處爲高屏溪上游山區位置。圖中可看出強對流胞自外海移入山區附近後滯留造成強降雨延時較久的現象。



Jet streaks along the rain bands

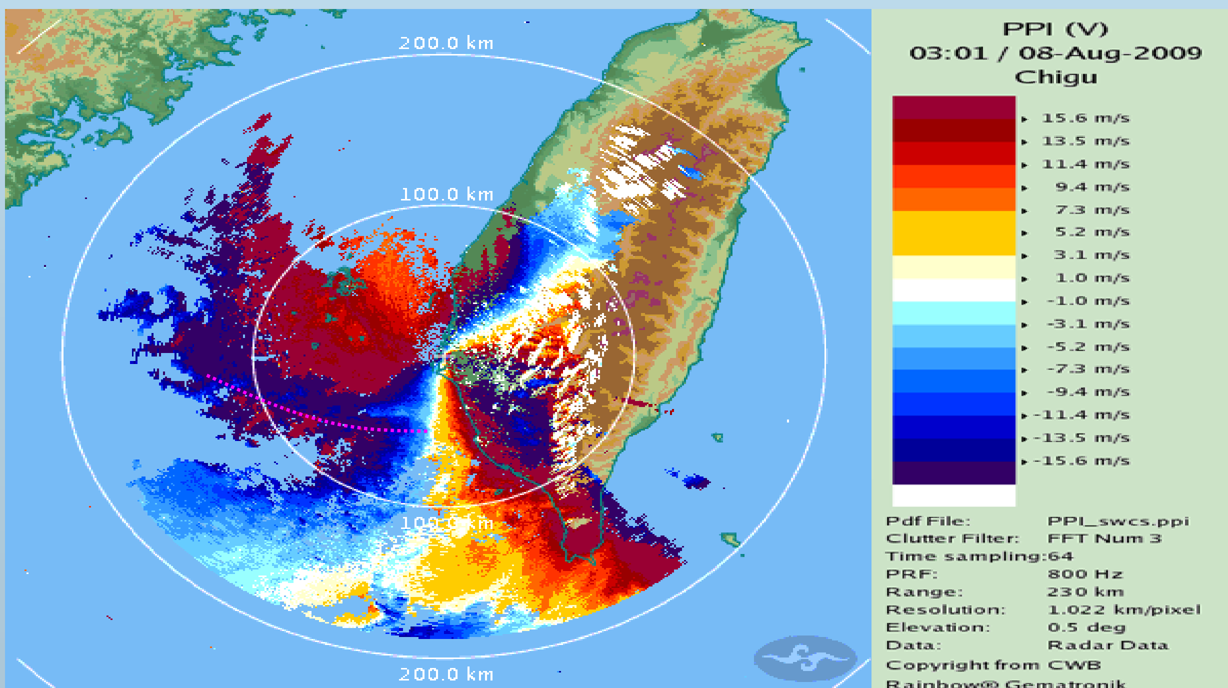
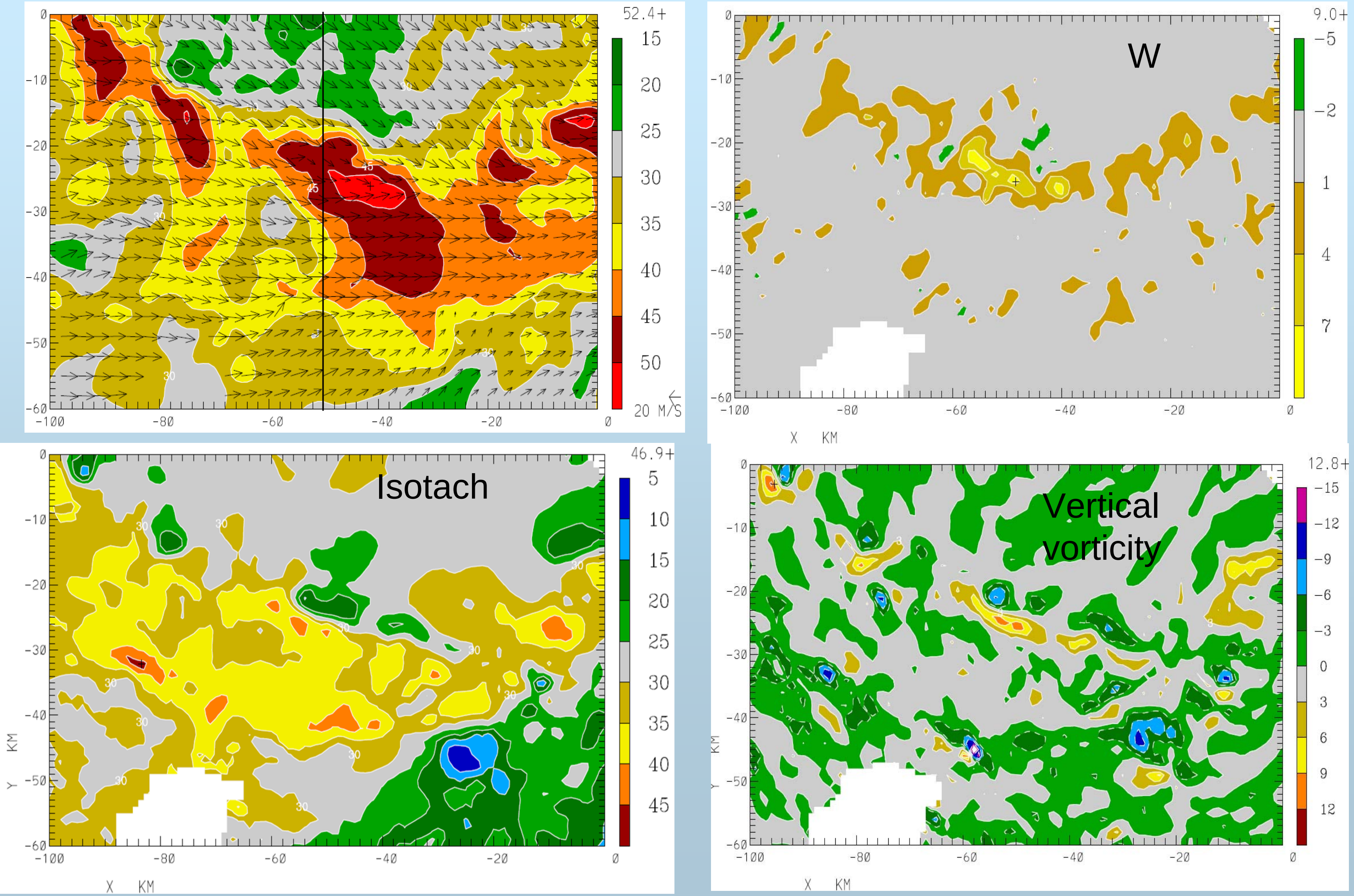
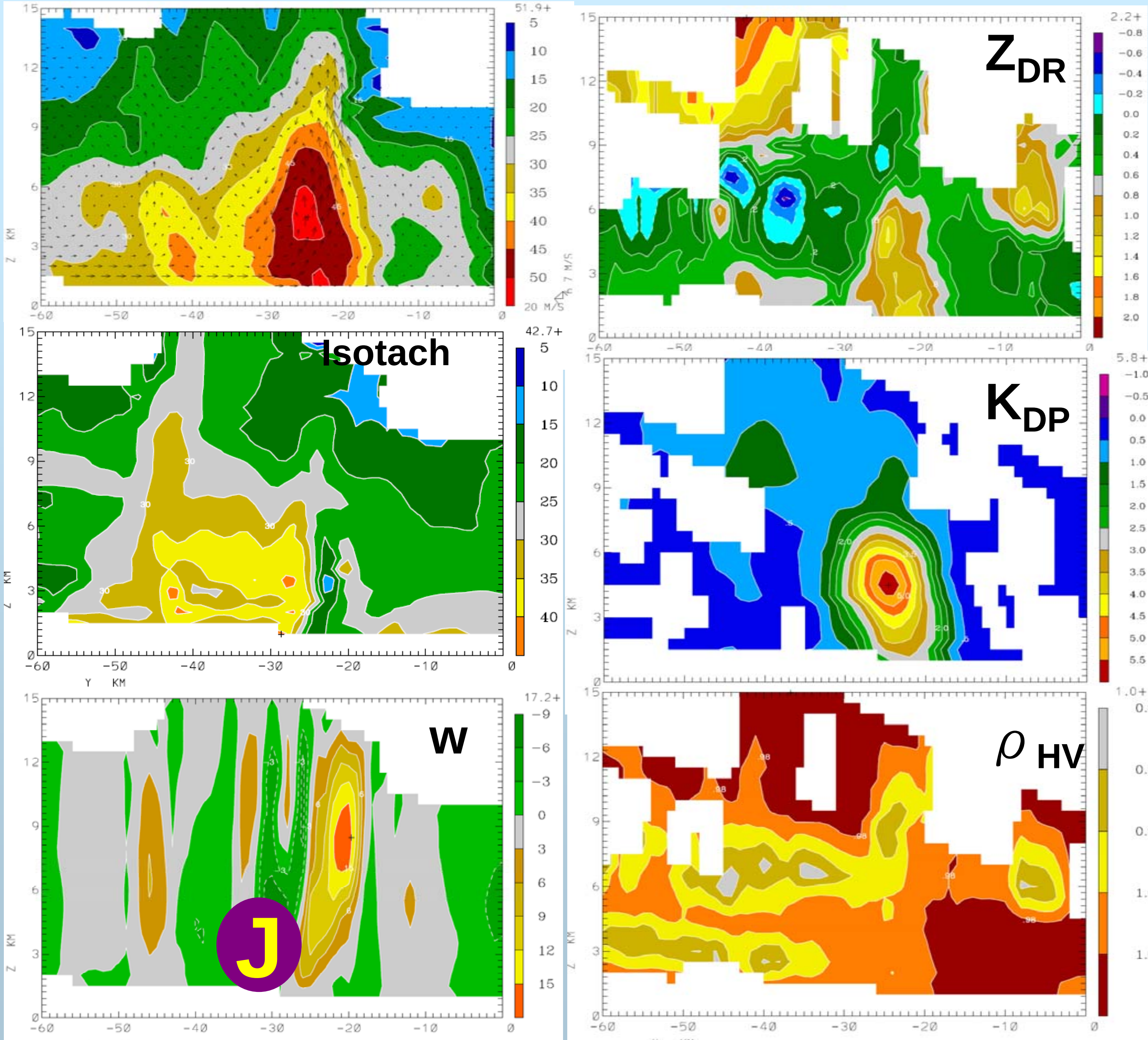


圖10：8月8日0300LST七股雷達站D區雨帶單都卜勒(a)回波場分布，(b)單雷達徑向風場，其中桃紅色虛線代表雨帶對流區前緣，也是颱風西北西的風場與西南氣流輻合區。

Kinematic structure of the rain band



Vertical Structure



Median diameter 1.5 1.8mm

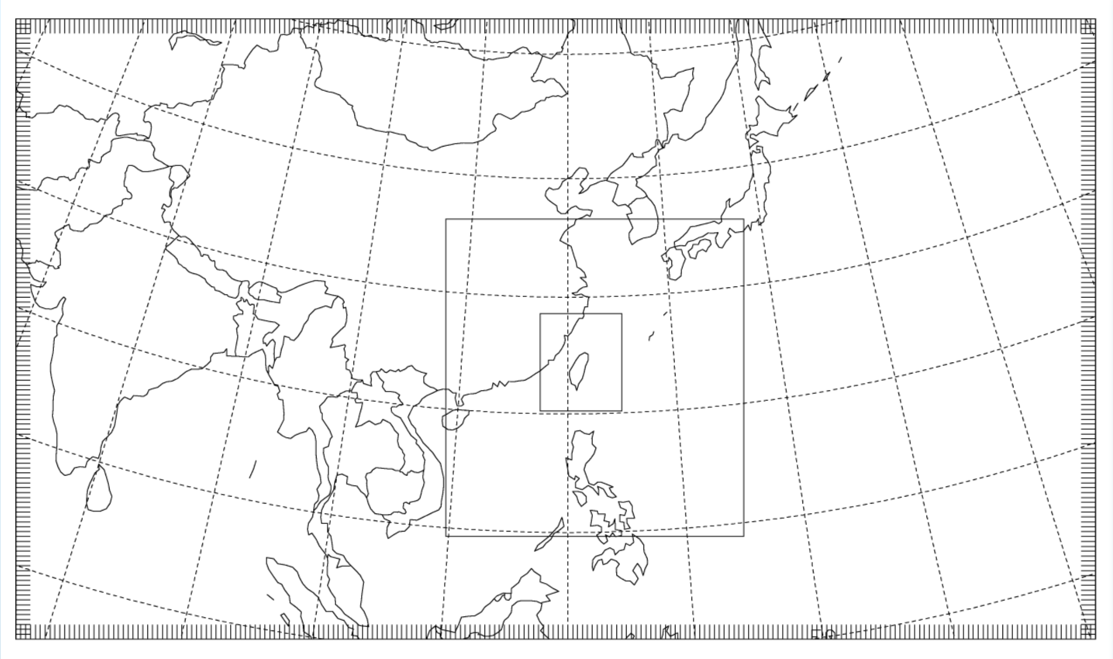
Liquid water content 10g/kg

Mixing phases

Some thoughts from radar observation

- The jet enhanced by the convections along the rain band impinging the high mountain.
- The oscillation movement of the rain band caused long period influence to the mountain area.
- Beside the kinematic analysis , thermodynamic retrieval and model studies are necessary to understand the movement of rain band.
- The roles of the hot towers need to be further studied through the polarimetric variables analyses.

WRF V3.1 at TTFRI



Input Data :

NCEP Global Forecast System (*GFS*)

1.0 deg in GRIB2 format

Domain :

D01 : 222 ×128 ×45 (45 km)

D02 : 184 ×196 ×45 (15 km)

D03 : 151 ×181 ×45 (5 km)

Starting Time :

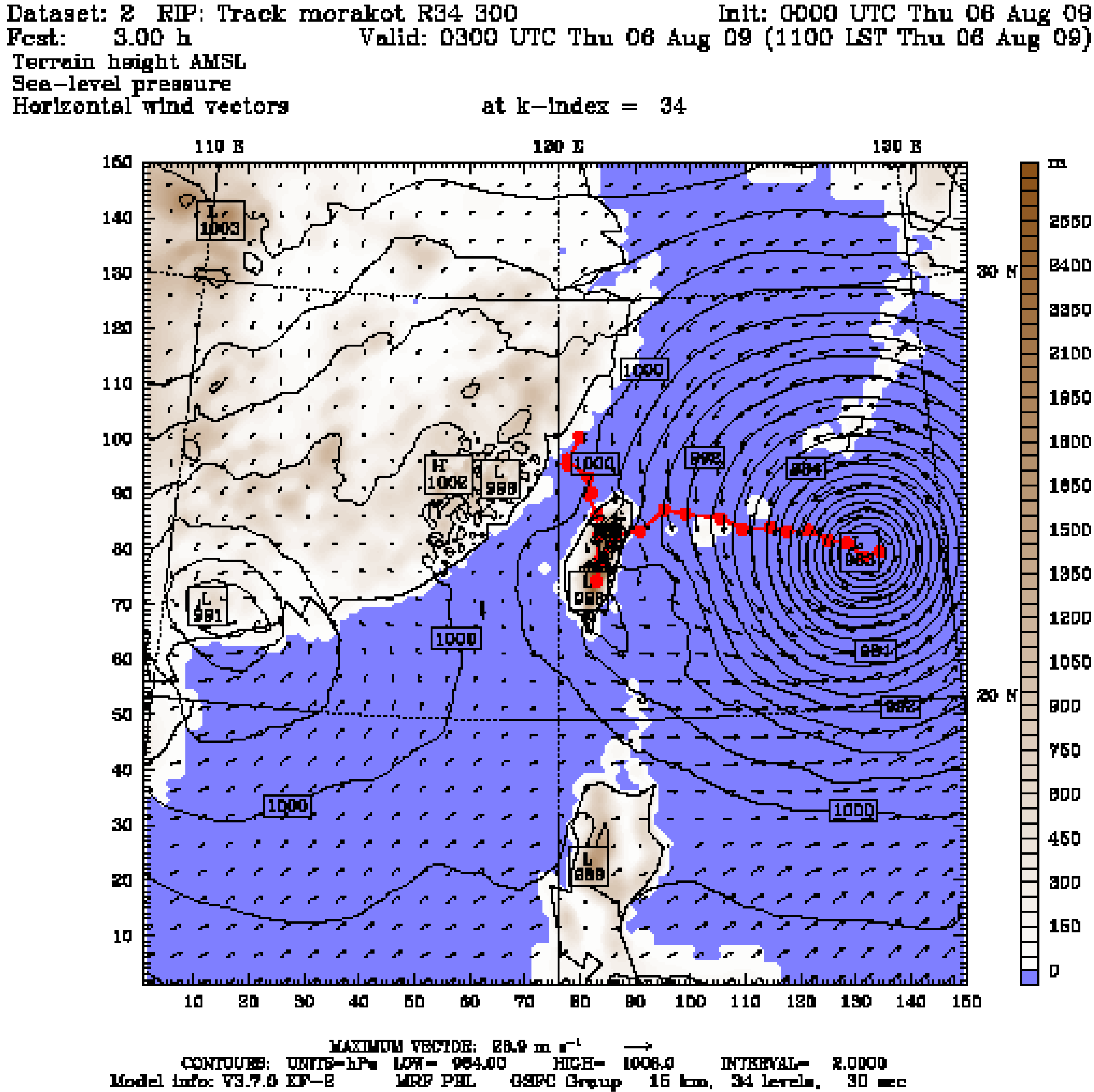
2009/08/06 00UTC

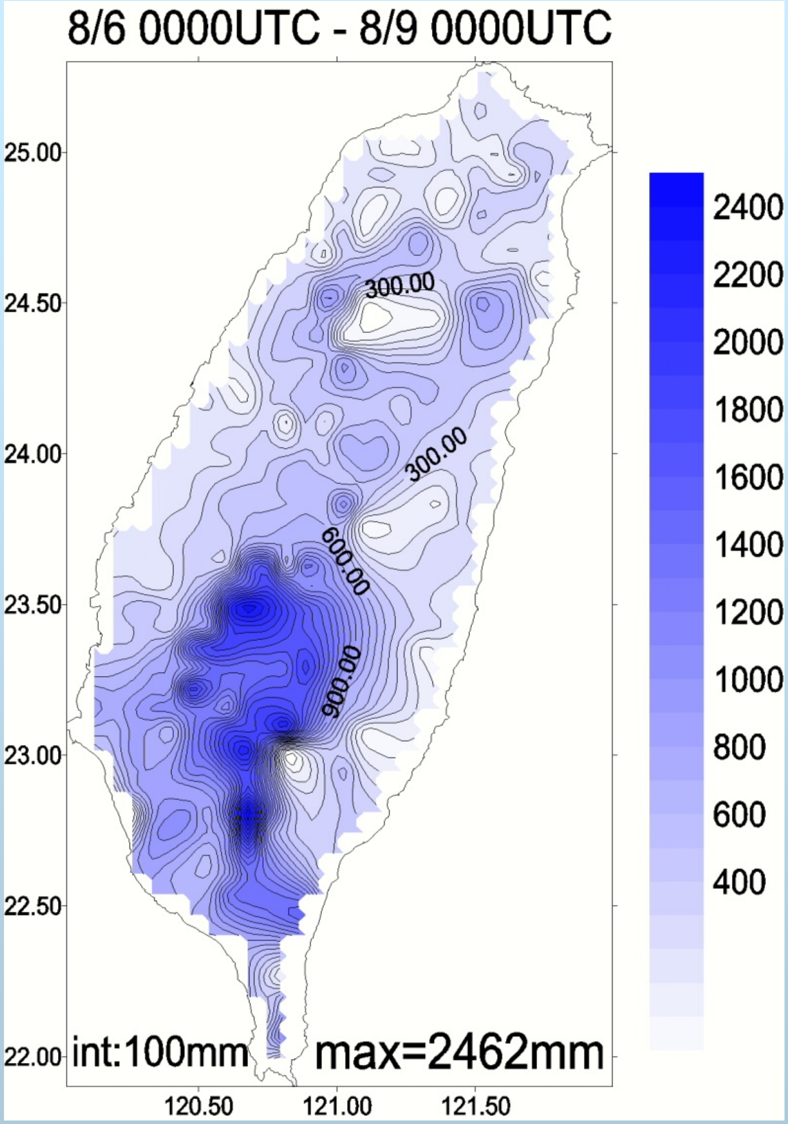
Ending Time :

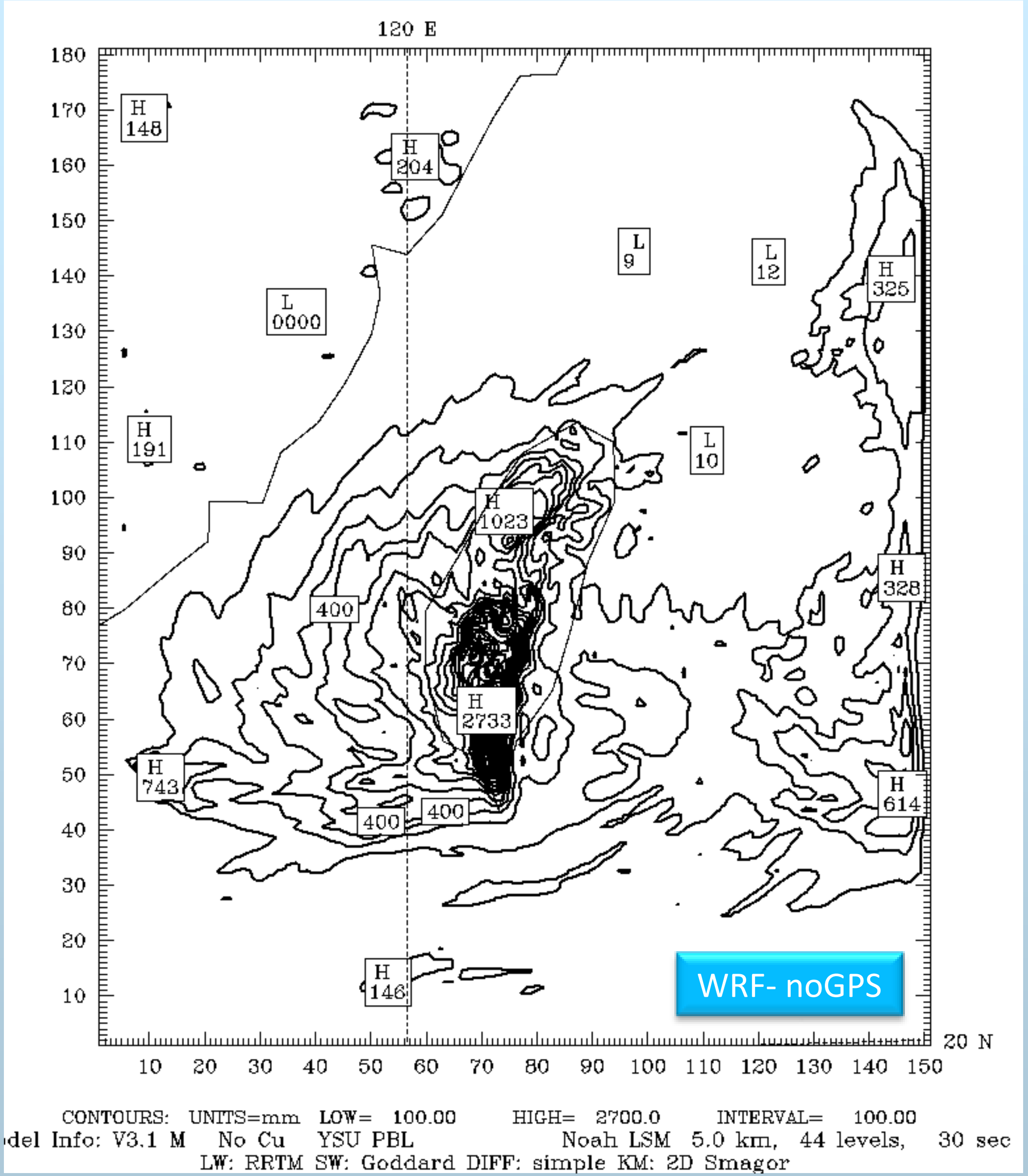
2009/08/09 00UTC

Physics Options in WRF :	
Microphysics scheme	Goddard GCE scheme
Longwave radiation scheme	RRTM scheme
Shortwave radiation scheme	Goddard short wave
Boundary layer parameterization	YSU scheme
Cumulus parameterization	Grell-Devenyi ensemble scheme
Surface-layer scheme	Monin-Obukhov similarity scheme
Land-surface parameterization	Unified Noah land-surface model

Radiation Schemes	cloud(D01)

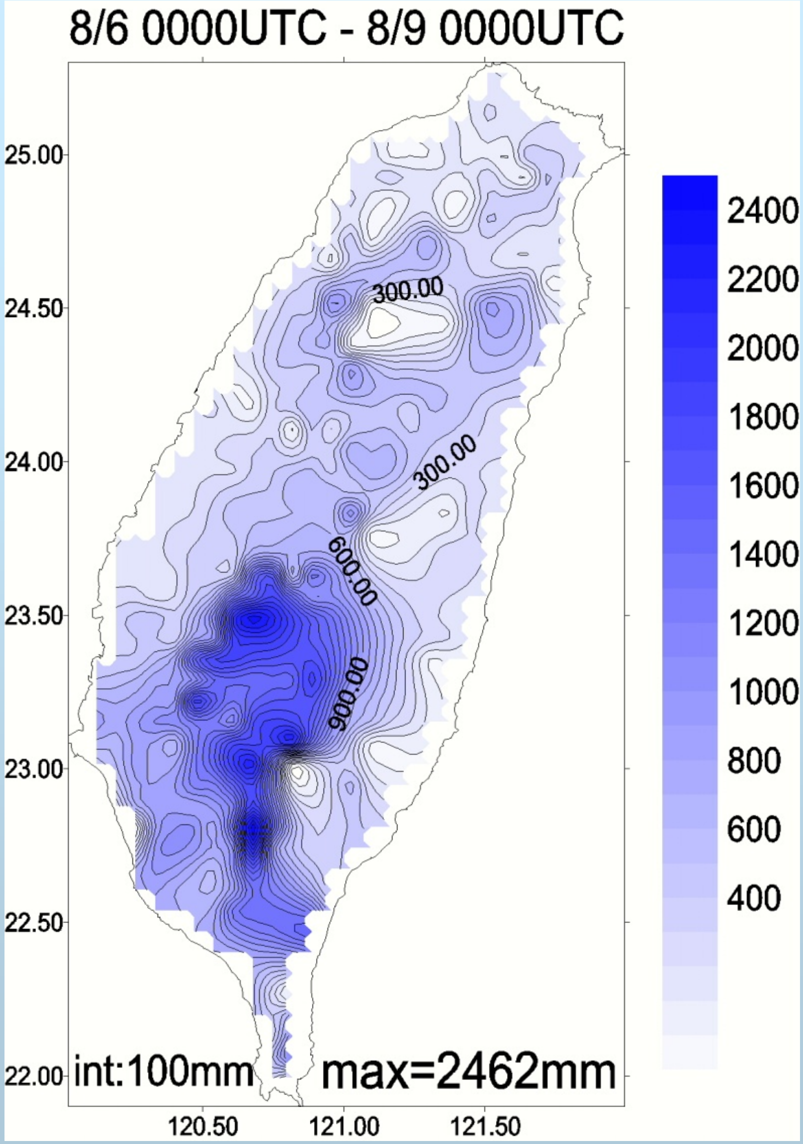

Dataset: 2 RIP: Track morakot R34 300
Init: 0000 UTC Thu 06 Aug 09
Fcst: 3.00 h
Valid: 0300 UTC Thu 06 Aug 09 (1100 LST Thu 06 Aug 09)
Terrain height AMSL
Sea-level pressure
Horizontal wind vectors
at k-index = 34
110 E
120 E
130 E
30 N
20 N
1000
992
984
L
H
m
MAXIMUM VECTOR: 29.9 m s⁻¹
CONTOURS: UNITS=hPa LOW= 964.00 HIGH= 1006.0 INTERVAL= 2.0000
Model info: V3.7.0 KF-2 MRF PBL GSFC Group 15 km, 34 levels, 30 sec

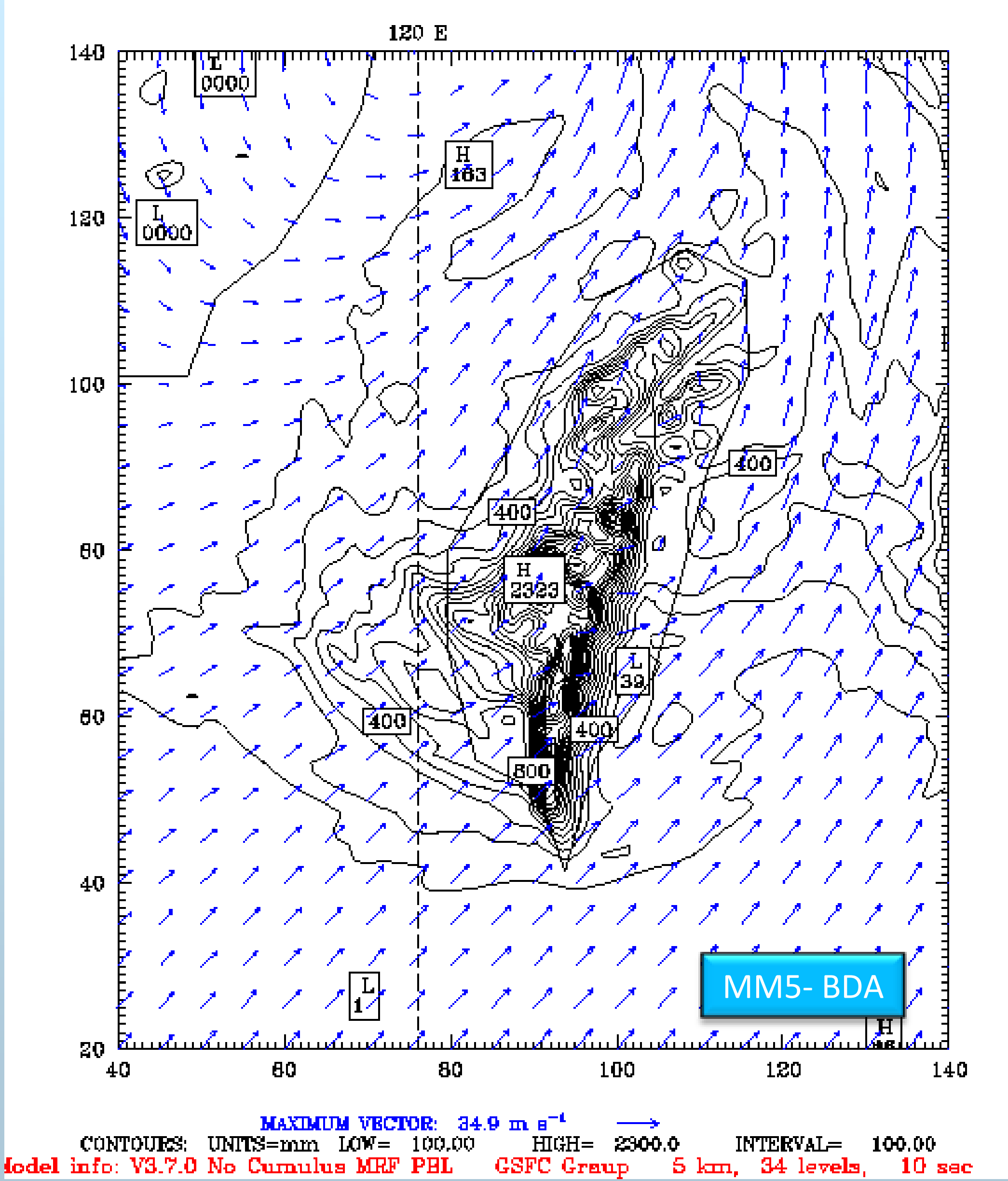




0600-0900UTC 觀測雨量

0600-0900UTC 預報雨量





0600-0900UTC 觀測雨量

0600-0900UTC 預報雨量

High-resolution WRF Experiments

- Performed high-resolution (WRF experiments with NCEP FNL initial conditions at 0000 UTC, 0600 UTC
- WRF experiments with either experiments under-predicted rainfall after landfall.
- Clear more improvements are needed on better modeling and prediction of orographic precipitation associated with typhoon interacting with the island of Taiwan

- We need more data over the ocean – COSMIC-II will be very helpful. But, that is not enough:
- We still need to:
  - Continued improvement in data assimilation systems (ECMWF has an edge over NCEP because of the use of more advanced data assimilation)
  - Continued improvement in the modeling the typhoon-mountain interaction
  - Continued improvement in model physics

Factors influenced the heavy precipitation for Morakot

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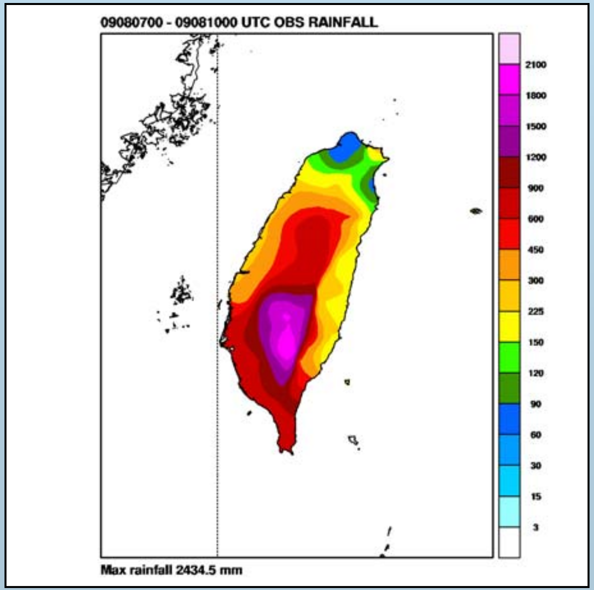
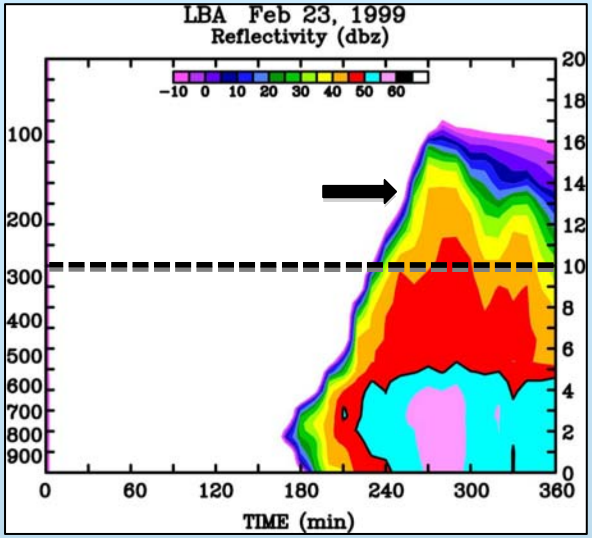
[3]Science Systems and Applications, Inc., Lanham, Maryland, USA
[4]National Central University, Chung-Li, Taiwan, R.O.C.
[5]National Taiwan University, Taipei, Taiwan, R.O.C.

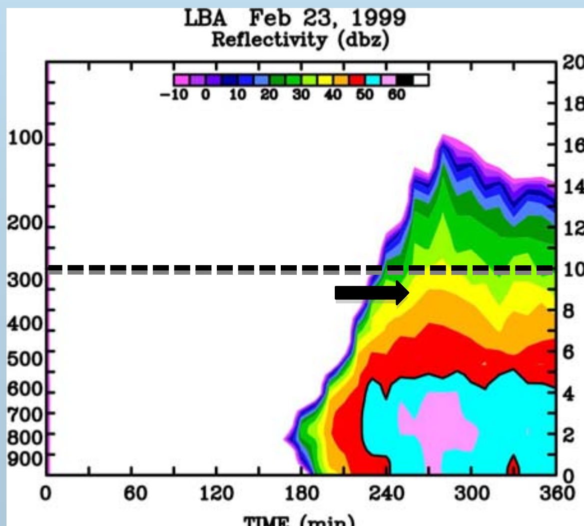
Typhoon's circulation
Microphysical processes
Sea Surface Temperature (+-2^o)
Terrain (height)
South-west flow
Others



2434 mm

Improved Performance of the GCE Bulk Microphysics

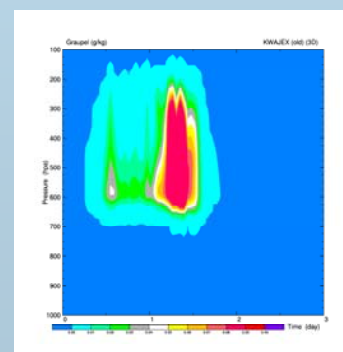


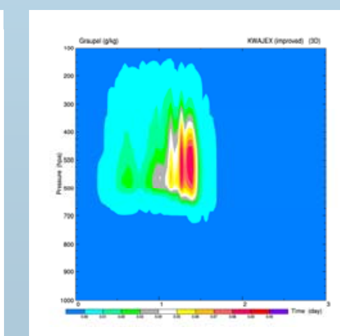


Lang, Tao, Zeng and Matsui (2010, MWR)

Climatologically, penetrations of 40-dBZ radar echoes above 10 km are rare even over land (Zipser et al. 2006; Liu et al. 2008)

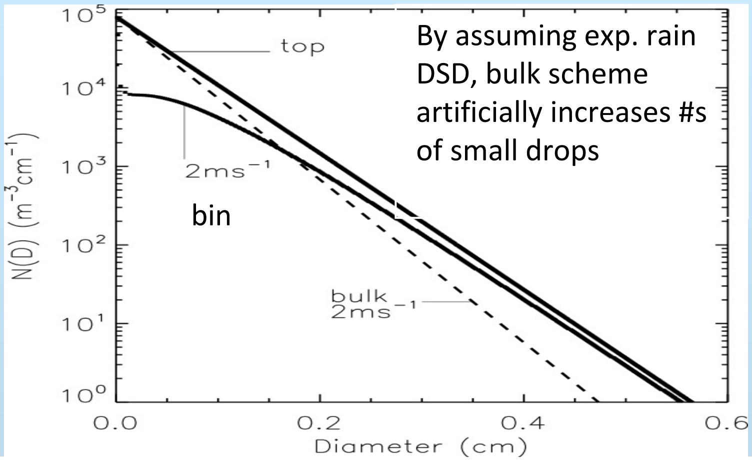
Through a series of improvements to the ice processes in the GCE model's bulk microphysics scheme, the bias in the penetration of excessively high reflectivity values to upper levels due to overly large amounts of precipitation ice particles was significantly reduced (see below).





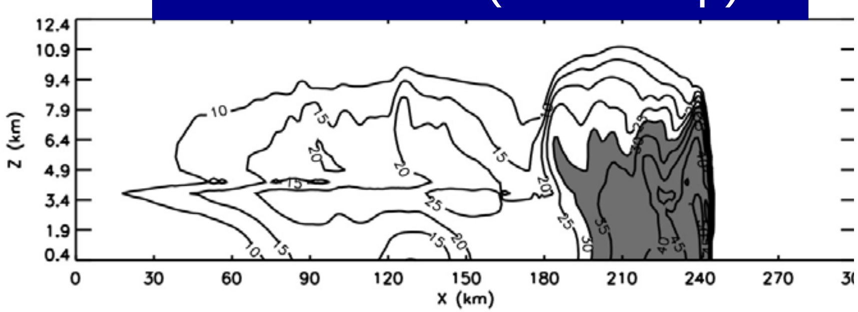
Time-height cross sections of maximum radar reflectivity obtained from 3D simulations of the 23 February 1999 easterly regime event observed during TRMM LBA (Large Scale Biosphere-Atmosphere Experiment in Amazonia) using the original Rutledge and Hobbs (1984) based bulk microphysics formulation (top panel) and an improved version (bottom panel). Ground-based radar data for this case indicated 40-dBZ echoes reached to approximately 8 km.

Improving Bulk Microphysics in GCE Using Bin Spectral Scheme (Li, Tao et al., JAS, 2009)

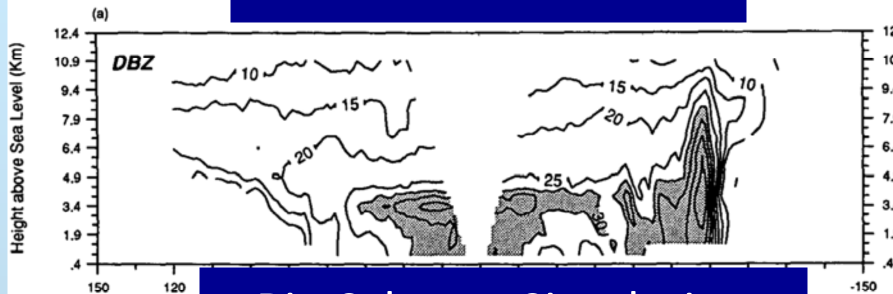


Bin Scheme is used to correct the overestimation of rain evaporation in bulk scheme and the density and fall speed of graupel in bulk scheme

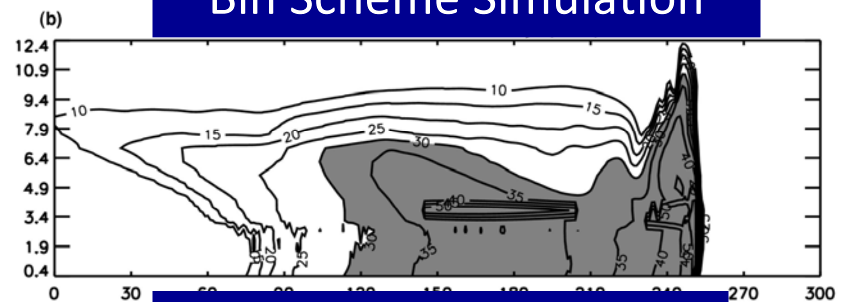
Bulk Scheme (Red Evap)



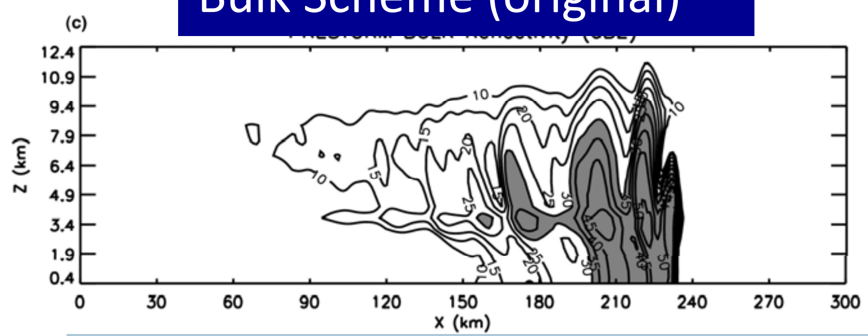
Radar Observation

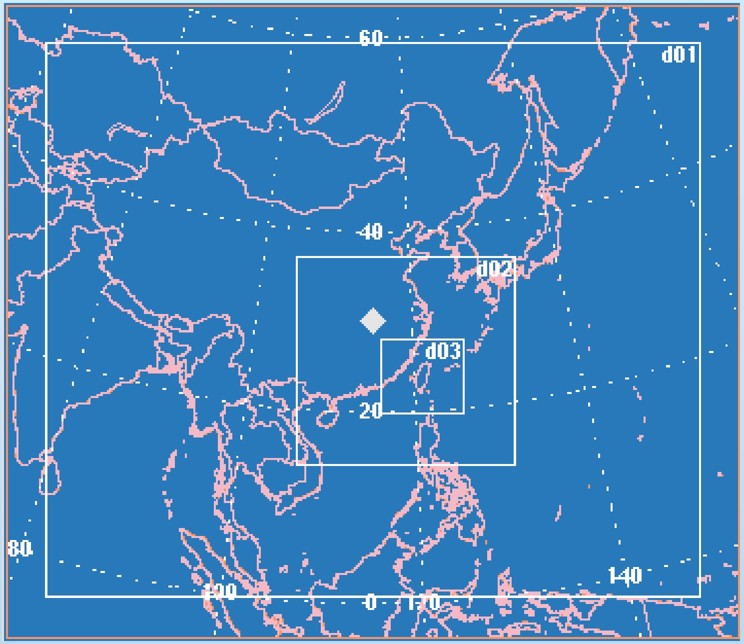


Bin Scheme Simulation



Bulk Scheme (original)





391x322, 475x427, and 538x439
18, 6 and 2 km

61 vertical layers

Initial condition: NCEP GFS 1^0 global analysis

72 h integration starting at 00Z August 7 - 00Z August 10 2009

Physics:

- **Cu parameterization: Grell-Devenyi scheme (for the outer grid only)**
- **Cloud microphysics:**

  Goddard microphysics 3ice-Graupel
- **Radiation:**

  Shortwave: New Goddard

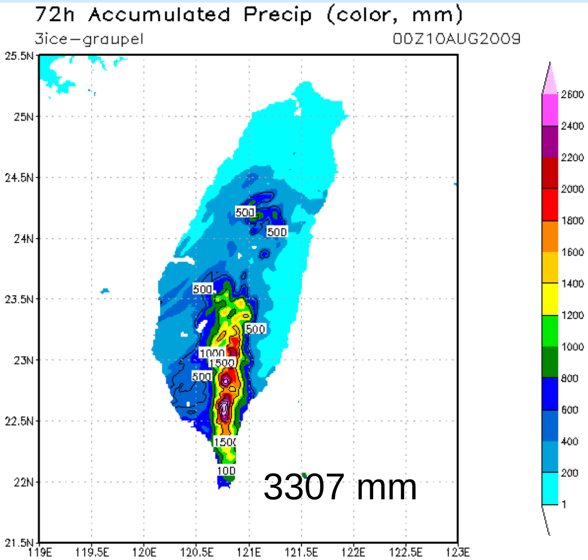
  Longwave: New Goddard
- **PBL parameterization:**

  Mellor-Yamada-Janjic TKE scheme
- **Surface Layer: Monin-Obukhov (Janic)**
- **Land Surface Model: Noah land-surface**

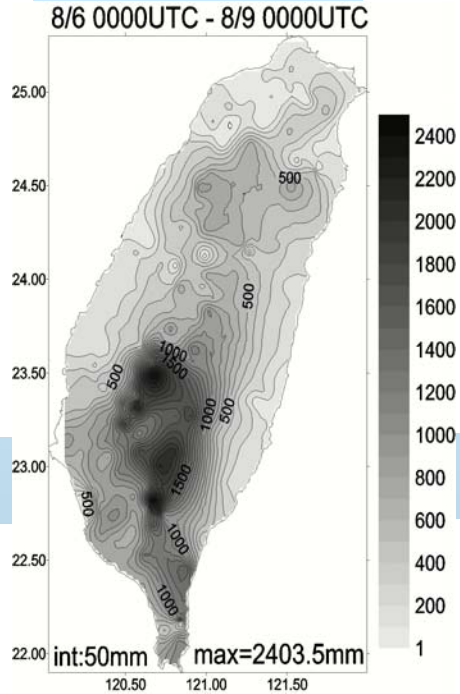
1	Goddard 3Ice-Hail (new Evap, Li et al. 2009)
2	Goddard 3ice-graupel (Lang et al. 2007)
3	Goddard 3ice-graupel (Lang et al. 2010)
4	Goddard Warm only

Red: Not in NCAR WRF 3.1 yet

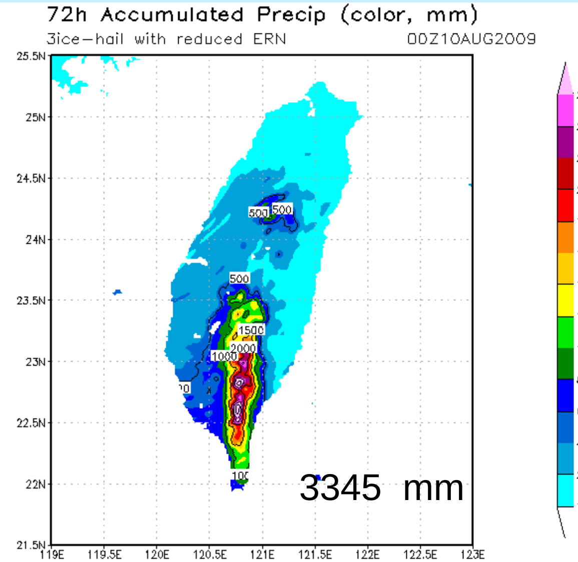
Microphysics



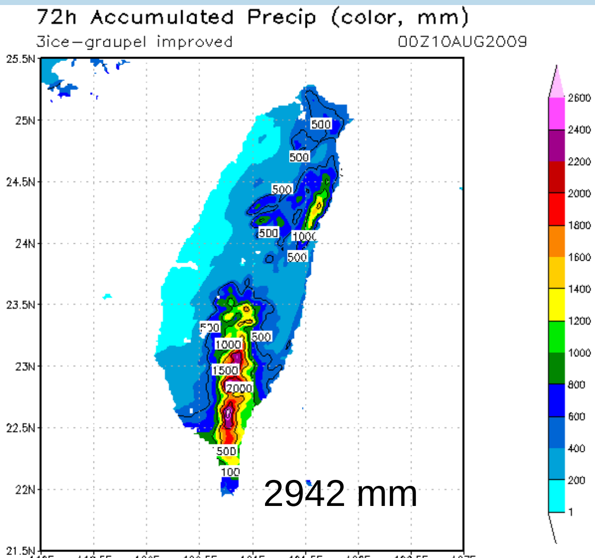
3ice-graupel



2434 mm

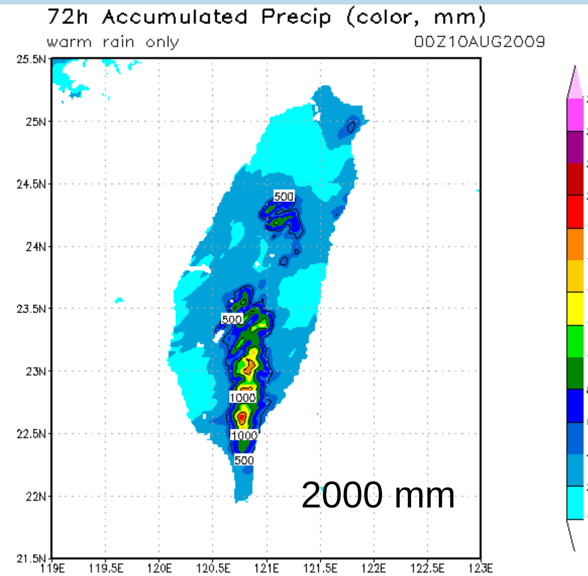


3ice-hail
reduced evaporation



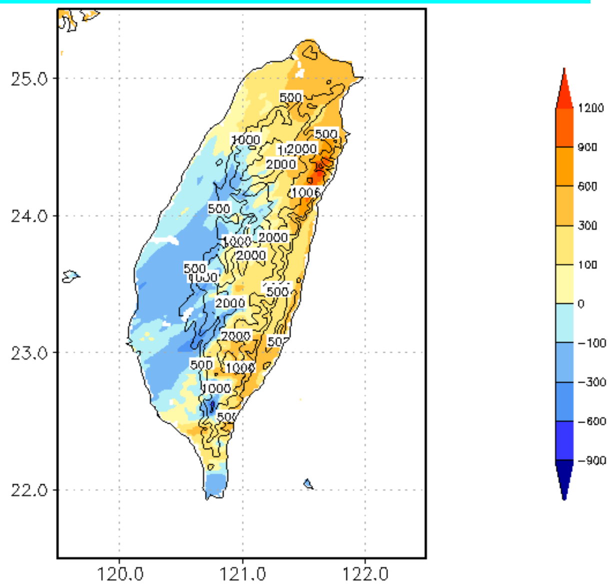
improved 3ice-graupel

Microphysical processes cannot determine the location of heavy precipitation, but it can affect the intensity and total amount of rainfall.

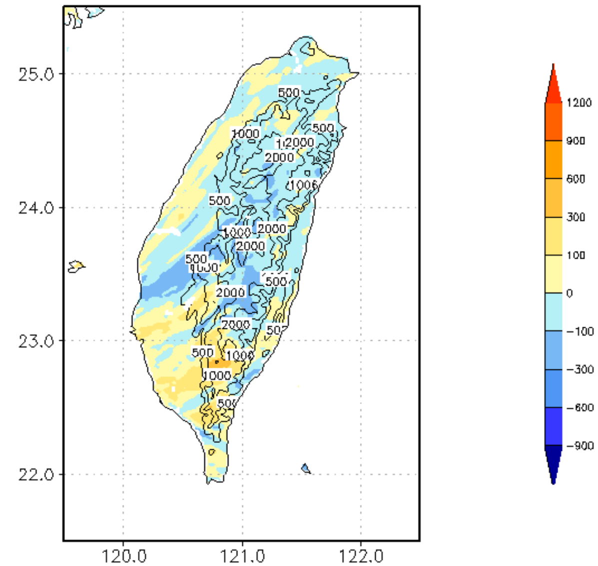


warm rain only

Improved graupel - Original

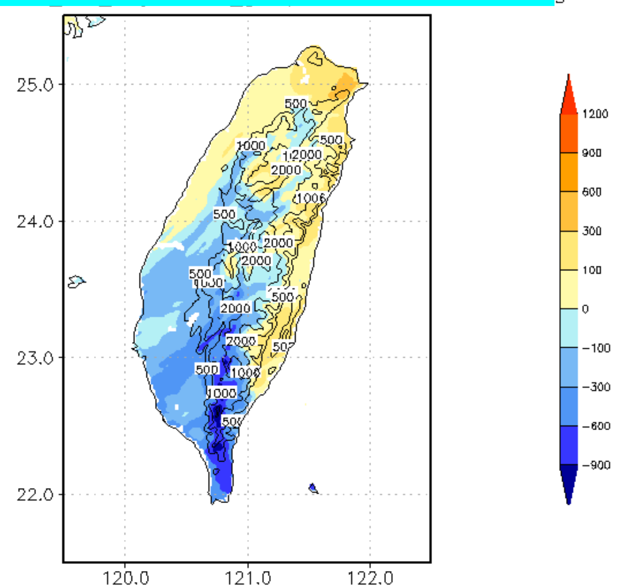


Improved evap - Original



	Accumulated Rainfall over S. Taiwan
3-ICE with graupel (conrol)	739.514
Improved 3-ICE with graupel	771.269
Improved 3-ICE with Hail	756.735
Warm rain only	462.102

Warm Rain - 3ICE



Improved microphysics (reduced 40 dBZ aloft and amount graupel) could reduce (increase) the amount of precipitation over the plain and low terrain region (high terrain and east side) of S. Taiwan.

The ice processes are important for heavy precipitation over S. Taiwan (accounting about 36%).

Summary

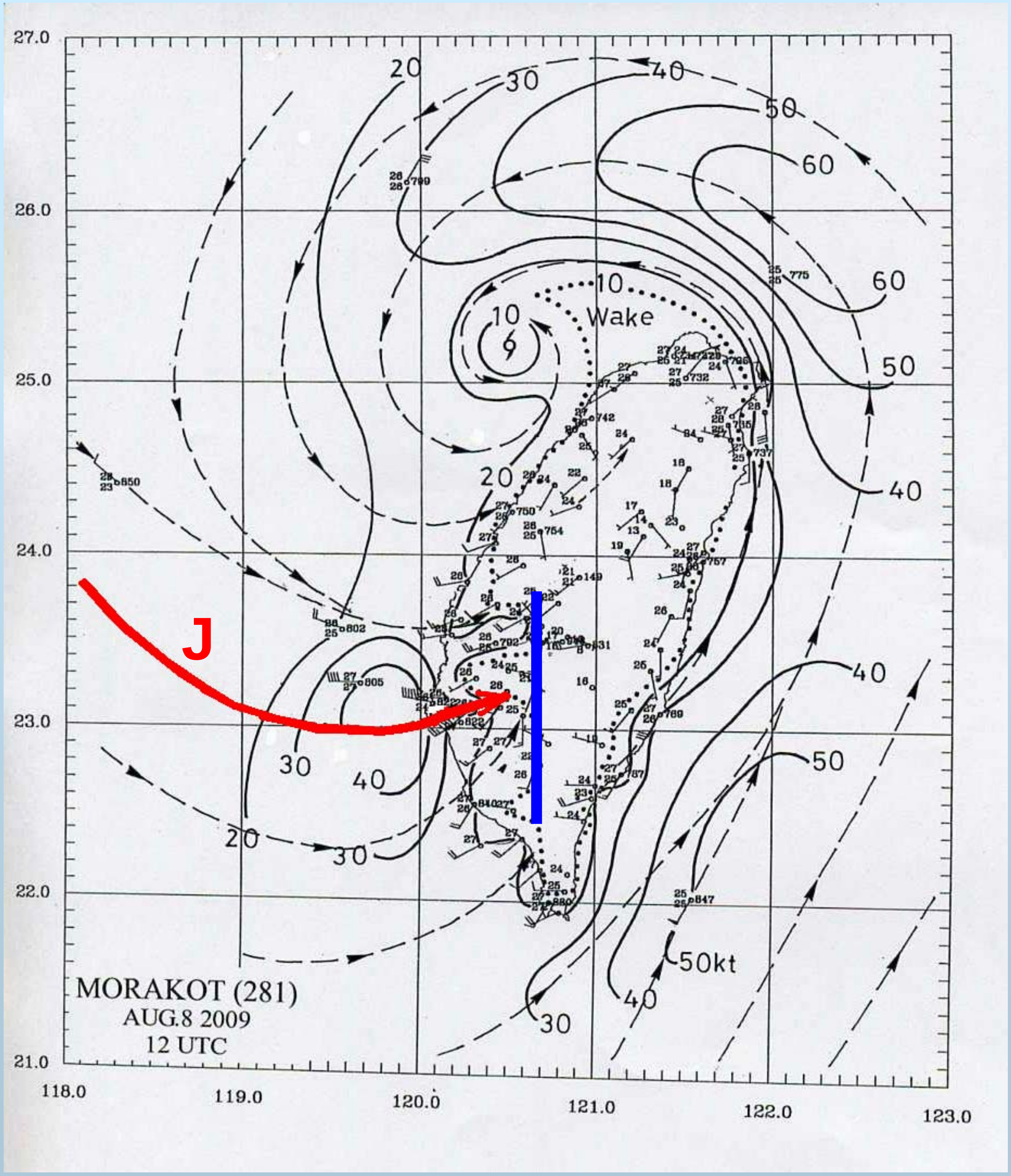
- Microphysical processes cannot determine the location of heavy precipitation, but it can affect the intensity and total amount of rainfall.
- Improved microphysics (reduced 40 dBZ aloft and amount graupel) could reduce (increase) the amount of precipitation over the plain and low terrain region (high terrain and east side) of S. Taiwan.
- The ice processes are important for heavy precipitation over S. Taiwan (accounting about 36%). Note that cloud tops are not very tall.
- Sea surface temperatures (SSTs) cannot determine the location of heavy precipitation, but they too can affect the total amount of rainfall. SSTs on the south-west side of Taiwan have more impact on the rainfall over southern Taiwan than those east of the island.
- A 2 degree increase (decrease) in SST can increase (decrease) rainfall over southern Taiwan by 16-20% (6-16%).
- Terrain height can also affect the amount of rainfall over southern Taiwan. Reducing the terrain height by 25, 50, and 75% reduces the amount of heavy rainfall by 16, 27 and 39%, respectively. Topographic areas seem to be affected more by reductions in the terrain height.
- Both (eastern and western) coastal regions generally have more rainfall when the terrain height is reduced.
- The typhoon-induced circulation and Taiwan's unique terrain determined the location of heavy precipitation

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

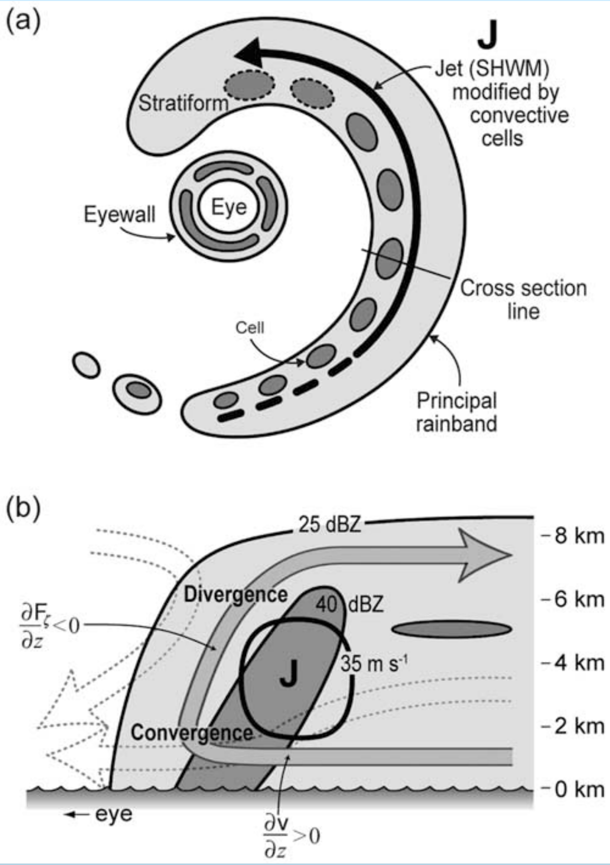
Surface Rainfall

Website for Goddard Mesoscale Modeling Group and Cloud Library

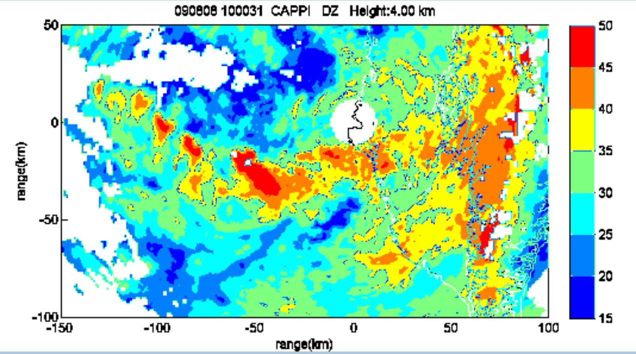
http://portal.nccs.nasa.gov/cloudlibrary/index2.html



MORAKOT (281)
AUG.8 2009
12 UTC
J
Wake
50kt
27.0
26.0
25.0
24.0
23.0
22.0
21.0
118.0
119.0
120.0
121.0
122.0
123.0



(a)
J
Jet (SHWM) modified by convective cells
Stratiform
Eyewall
Eye
Cross section line
Cell
Principal rainband
(b)
25 dBZ
Divergence
40 dBZ
35 m s-1
J
Convergence
eye
8 km
6 km
4 km
2 km
0 km



090808 100031 CAPPI DZ Height:4.00 km
range(km)
range(km)