

The relationship between the VAD wind and orographic heavy rainfall of southwestern Taiwan induced by typhoon circulation

Lei Feng¹, Ben Jong-Dao Jou², Pao-Liang Chang³

¹Taiwan Typhoon and Flood Research Institute (TTFRI)

²National Taiwan University (NTU)

³Central Weather Bureau (CWB)

- More understanding on orographic heavy rainfall that cause damage.
 - 3hr > 200mm
 - 6hr > 400mm
 - 12hr > 800mm
 - Each situation means different disaster scale !
- FAQ: The heavy rain will persist how many hours ?

Landslide and debris flow



影像來源:飛虎、元智大學

台東太麻里



mountain torrents

資料來源：屏東科技大學

flood



照片取自網路

屏東：林邊、佳冬、東港、新園

Heavy rainfall (conceptual)

total rainfall = rain rate × duration

$$P = RD$$

$$P = E(\mathbf{V}_H \cdot \nabla h + w_{env})qL_s/c_s$$

$$R = E(wq)$$

$$D = L_s/c_s,$$

duration

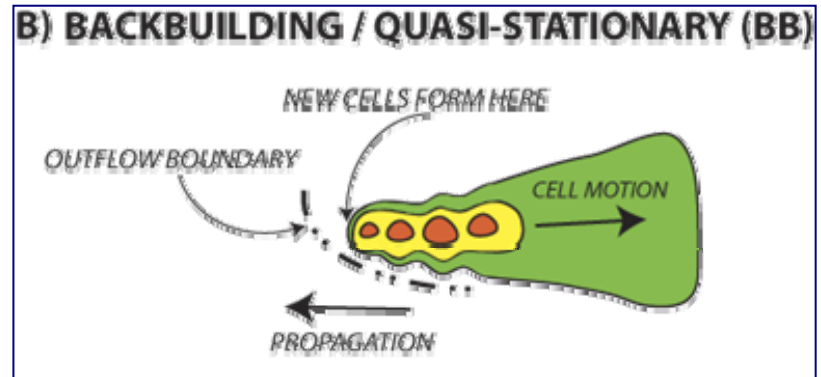
Water content

vertical velocity

synoptic
C
(短波槽)

$$w = w_{oro} + w_{env}$$

$$w_{oro} = \frac{Dh}{Dt} = \mathbf{V}_H \cdot \nabla h,$$



Precipitation Efficiency

Precipitation Efficiency

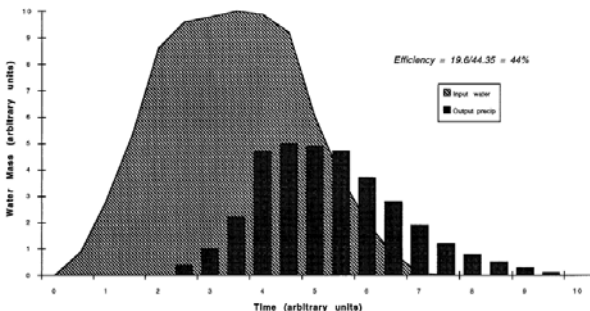
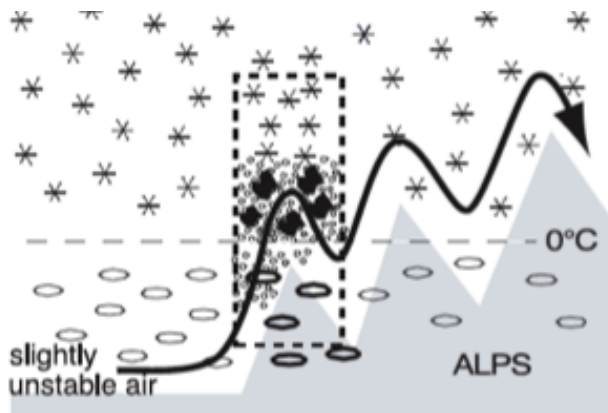
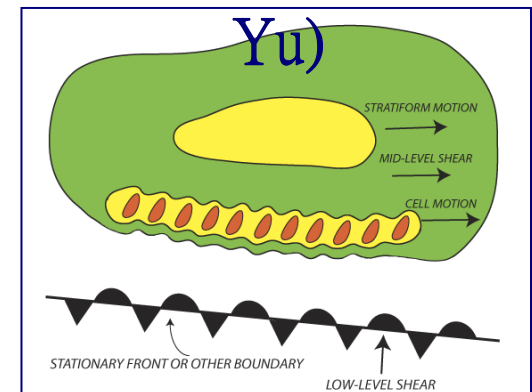


FIG. 1. Schematic illustration of the time variation of water vapor input (cross-hatched area) and the precipitation output (vertical bars) over the lifetime of a precipitation system. The units are arbitrary, so the system being portrayed can be any precipitating process with a developing phase (time = 0–3 units), a mature phase (time = 3–6 units), and a dissipating phase (time = 6–10 units). For this example, the areas under the respective curves give a precipitation efficiency of about 44%.

terrain enhanced rainfall



stationary front (Mei-Yu)



Orographic heavy rainfall

總雨量 = 降雨率 × 延時

$$P = RD$$

效率 × 垂直速度 × 水汽 × 延時

$$P = E(\mathbf{V}_H \cdot \nabla h + w_{env})qL_s/c_s$$

TABLE 1. An estimate of the contributions from some common ingredients.

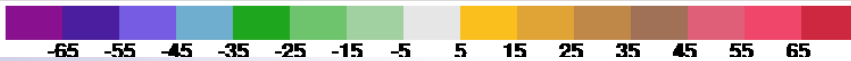
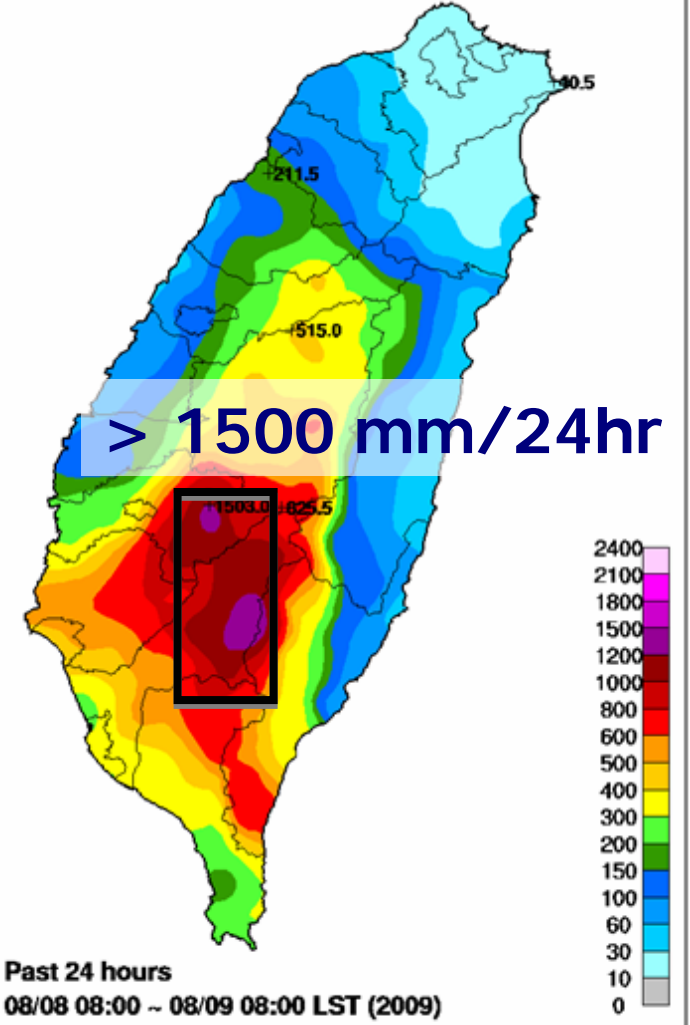
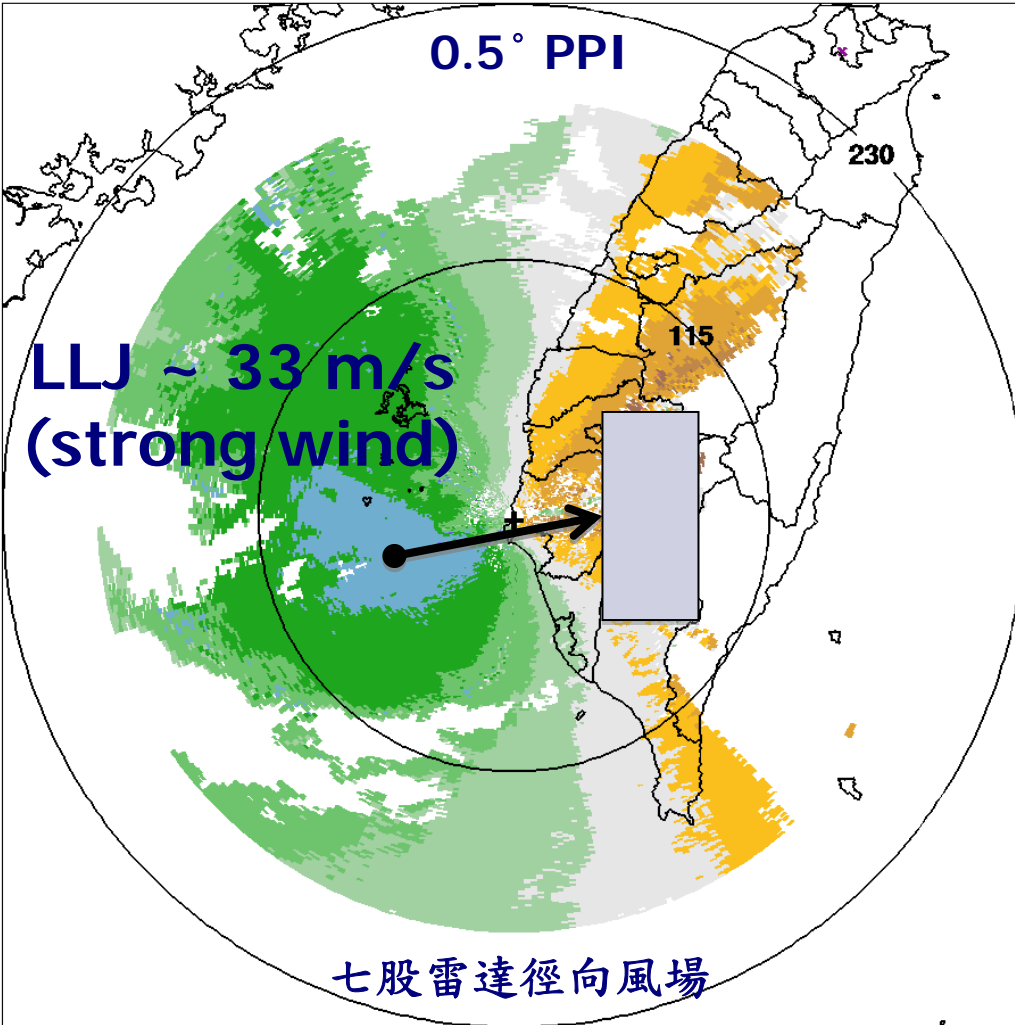
Event	NLLJ (U in m s)	Mountain slope ($\delta h/\delta x$)	q (g kg ⁻¹)	Index [$U (\delta h/\delta x)q$]	w_{env} (synoptic system)	Max rainfall rate	CAPE (J kg ⁻¹) (selected)
Big Thompson, CO	12.5	0.025	16	5.0+*	Trough	915 mm day ⁻¹ [305 mm (4 h) ⁻¹]	2526
Rapid City, SD	12.5	0.020	13.5	3.4+	Trough	1143 mm day ⁻¹ [381 mm (4 h) ⁻¹]	— (<2180)
Fort Collins, CO	10	0.021	13	2.7+	Trough	519 mm day ⁻¹ [259 mm (6 h) ⁻¹]	628
Madison County, VA	12.5	0.025	16	5.0+	Trough	600 mm day ⁻¹	286
Vaison-la-Romaine, France	15	0.027	15	6.1+	Trough	300 mm day ⁻¹	2662
Piedmont, Italy	13	0.033	11	4.7+	Trough	250 mm day ⁻¹	212
South Ticino, Switzer- land	10	0.033	9.3	3.1+	Trough	260 mm day ⁻¹ [130 mm (6 h) ⁻¹]	383
Lago Maggiore, Italy (IOP2)	12.5	0.033	11.5	4.74+	Trough	300 mm (36 h) ⁻¹	90

* Plus signs indicate that the index may be higher with the addition of w_{env} associated with an approaching synoptic system.

Morakot typhoon (2009)

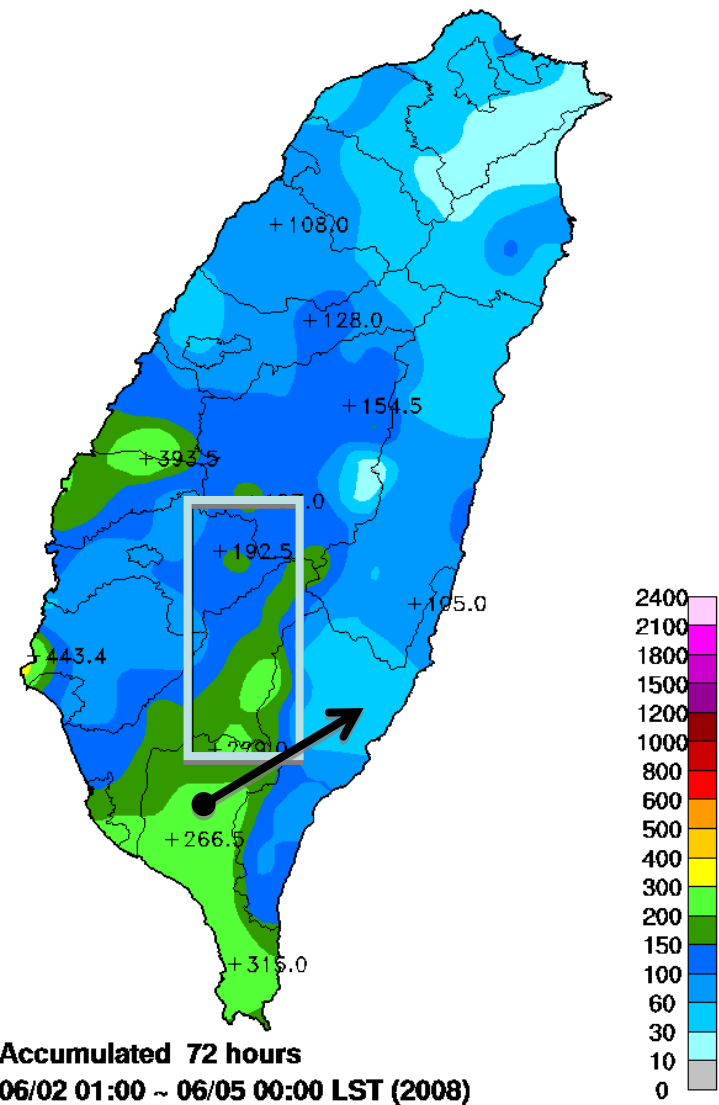
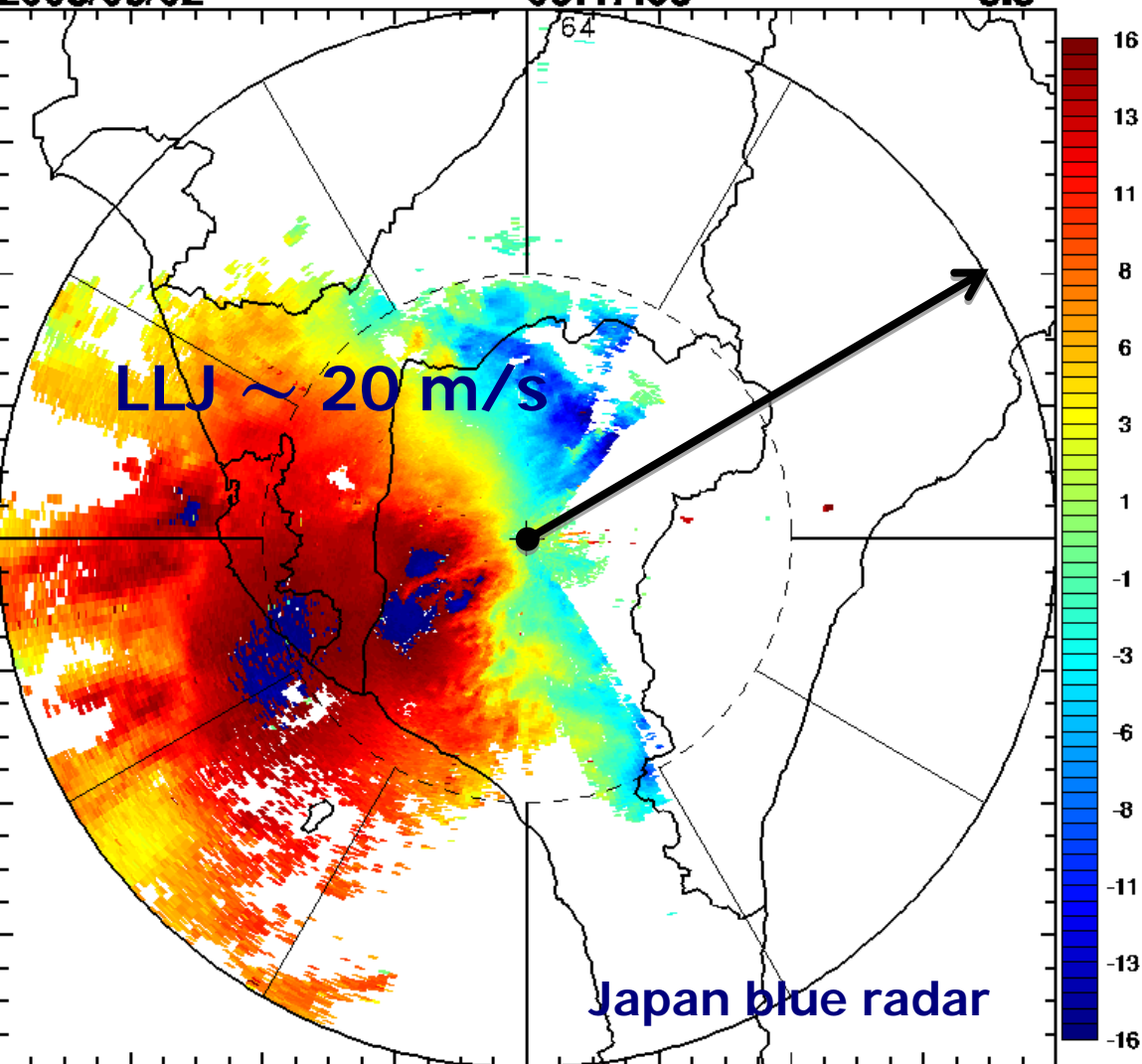
8月8日 20:00 LST

RCCG200908081206_ppi_da01



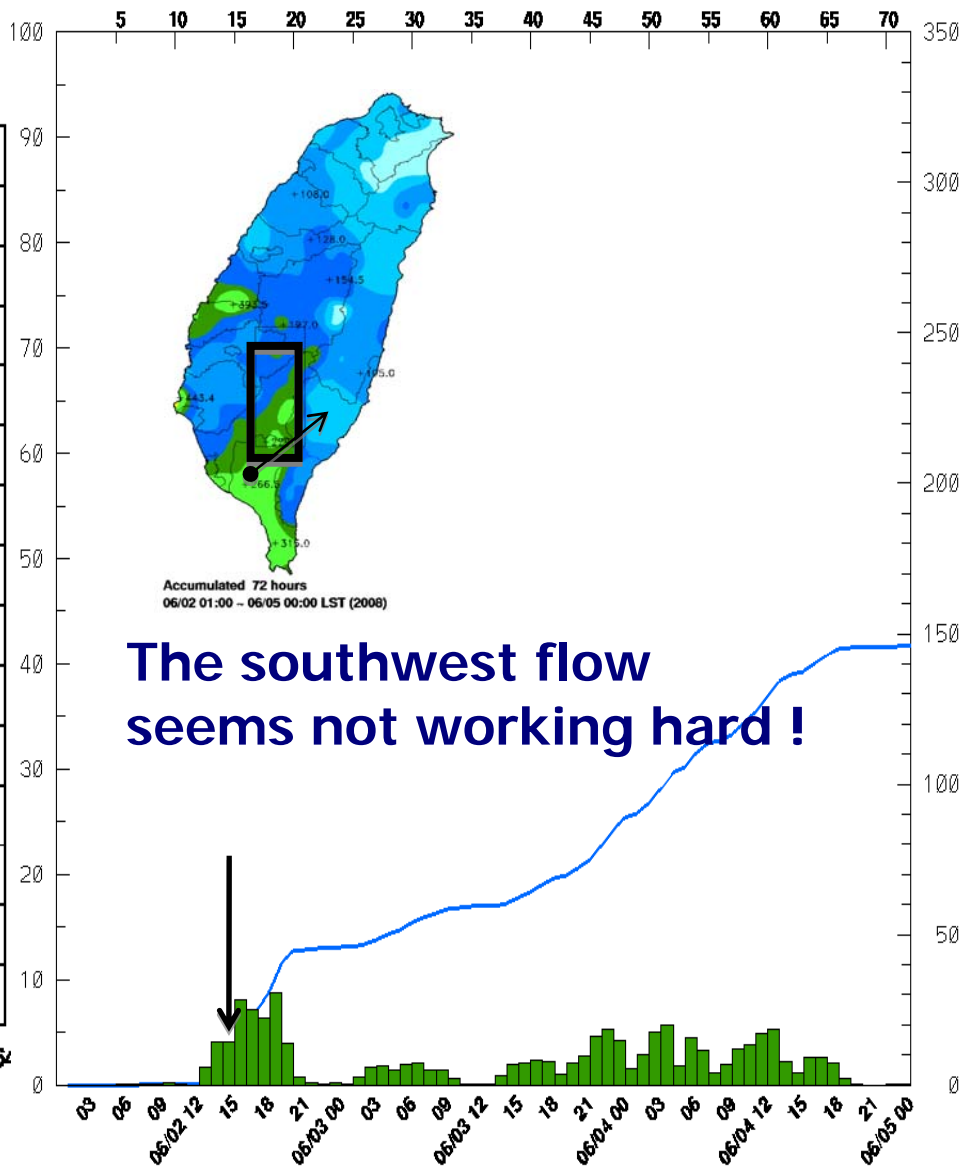
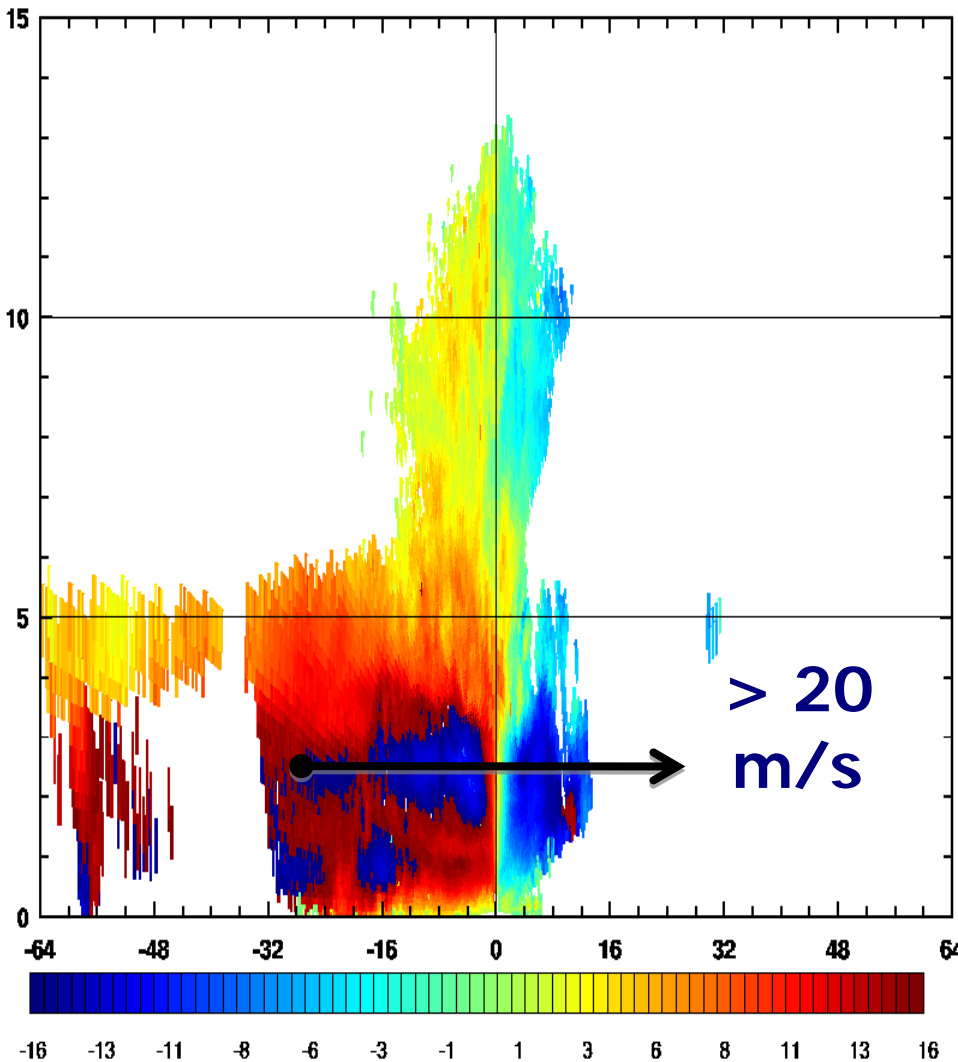
Mei-Yu front (IOP#4)

SoWMEX/TiMREX Nagoya Blue Radar
2008/06/02 06:47:06 3.5°



Mei-Yu front (IOP#4)

SoWMEX/TiMREX Nagoya Blue Radar
 2008/06/02 06:36:03 239.9°



Morakot typhoon rainfall

(a) max. hourly rainfall
136 mm

(b) max. 12 hour rainfall
965 mm

(c) 95 hours total rainfall
2767 mm

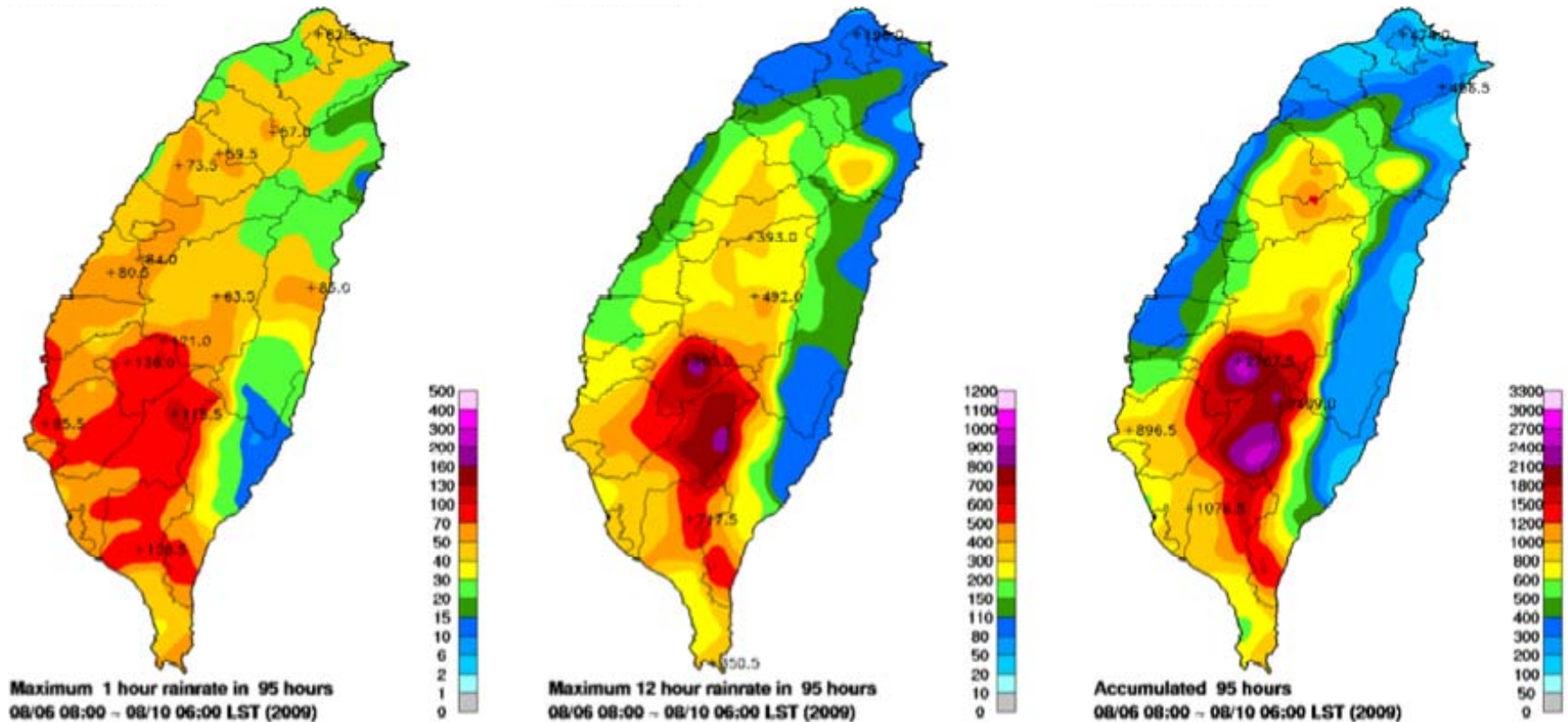
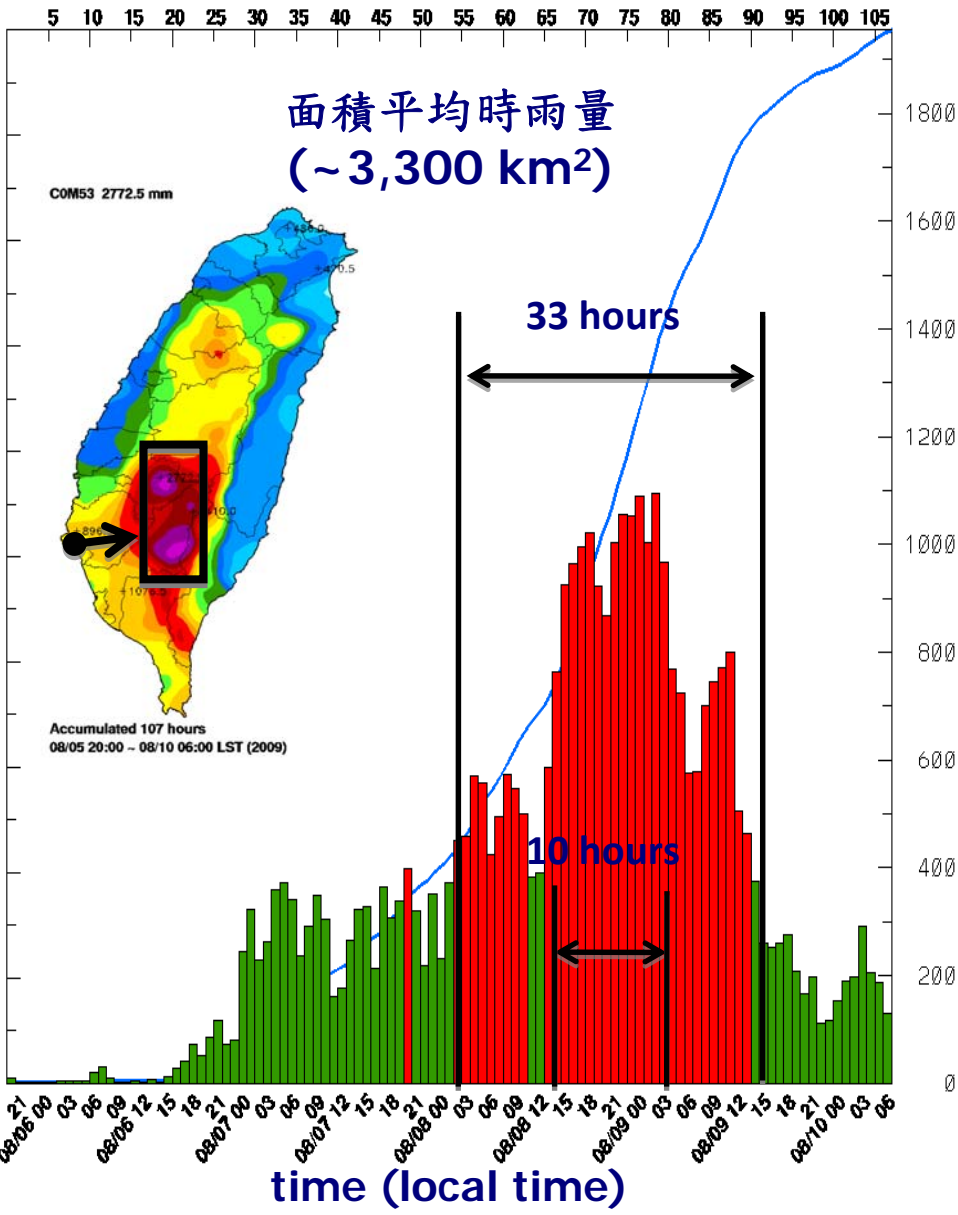
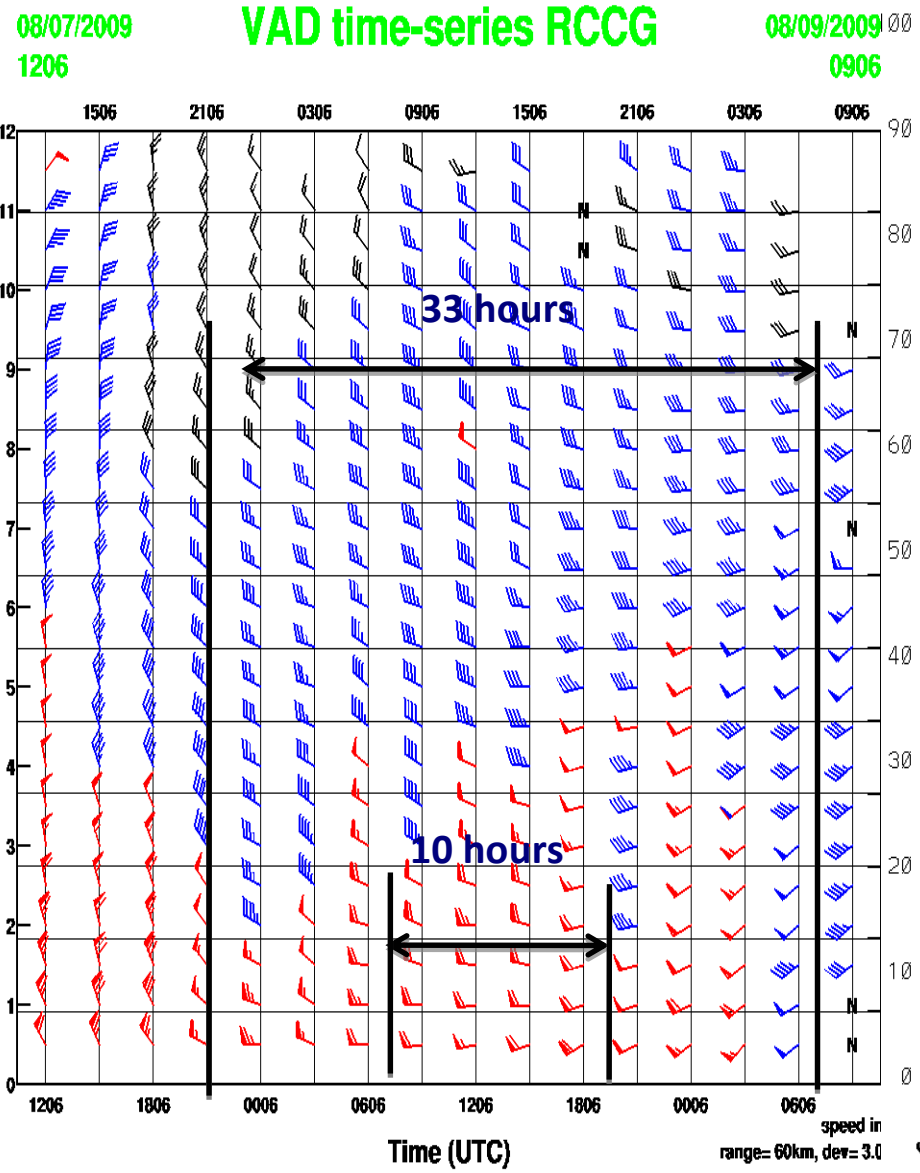


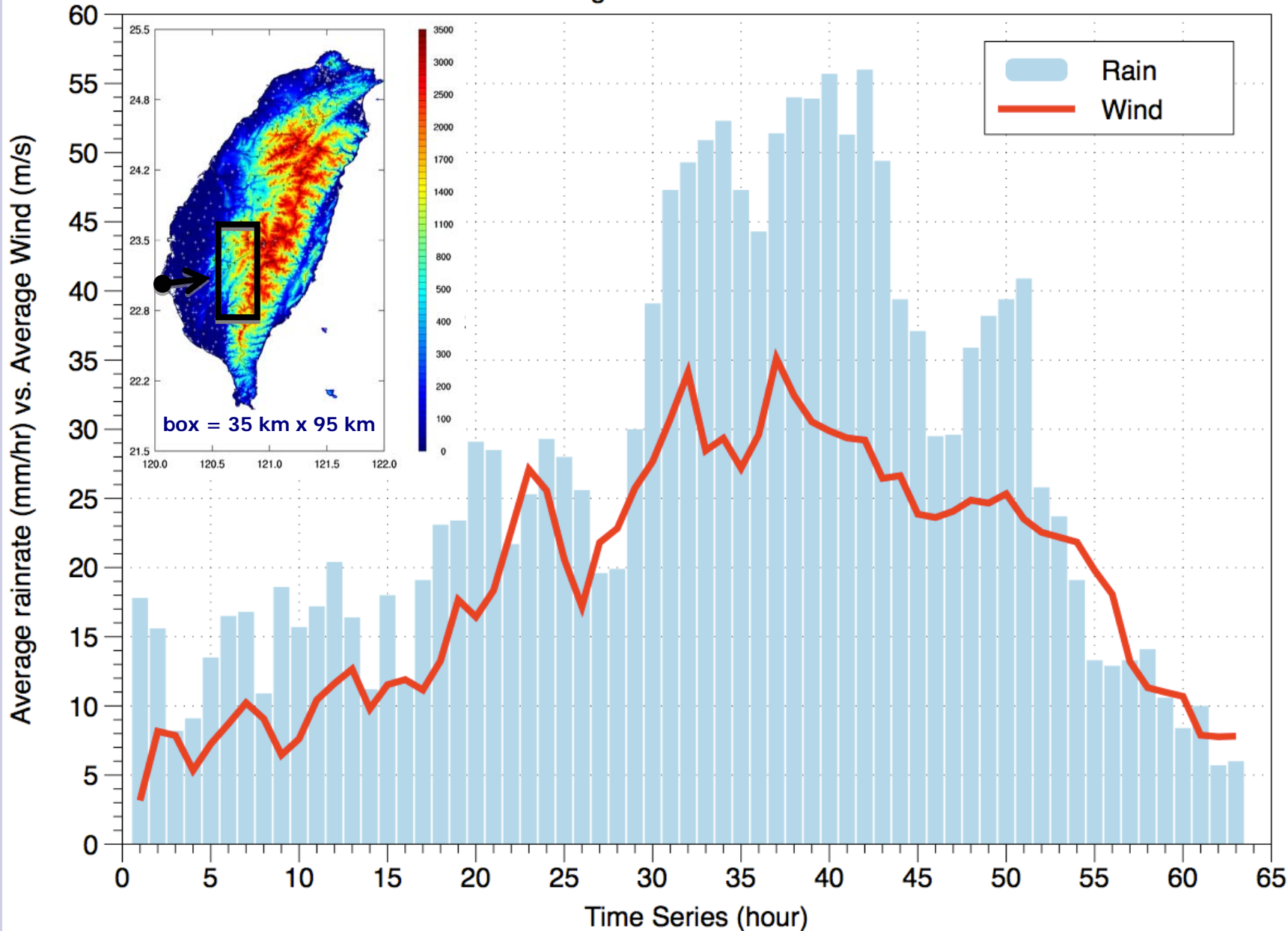
Fig. 1. Rainfall statics of Morakot typhoon in warning stage (95 hours) using surface raingauge network: (a) maximum hourly rainrate; (b) maximum 12 hours accumulation; (c) even total rainfall.

Morakot typhoon U vs. R



莫拉克颱風平均西風與降雨關係

Average Wind vs. Rainrate



- **Does the upstream rainband common occur for other typhoons ?**

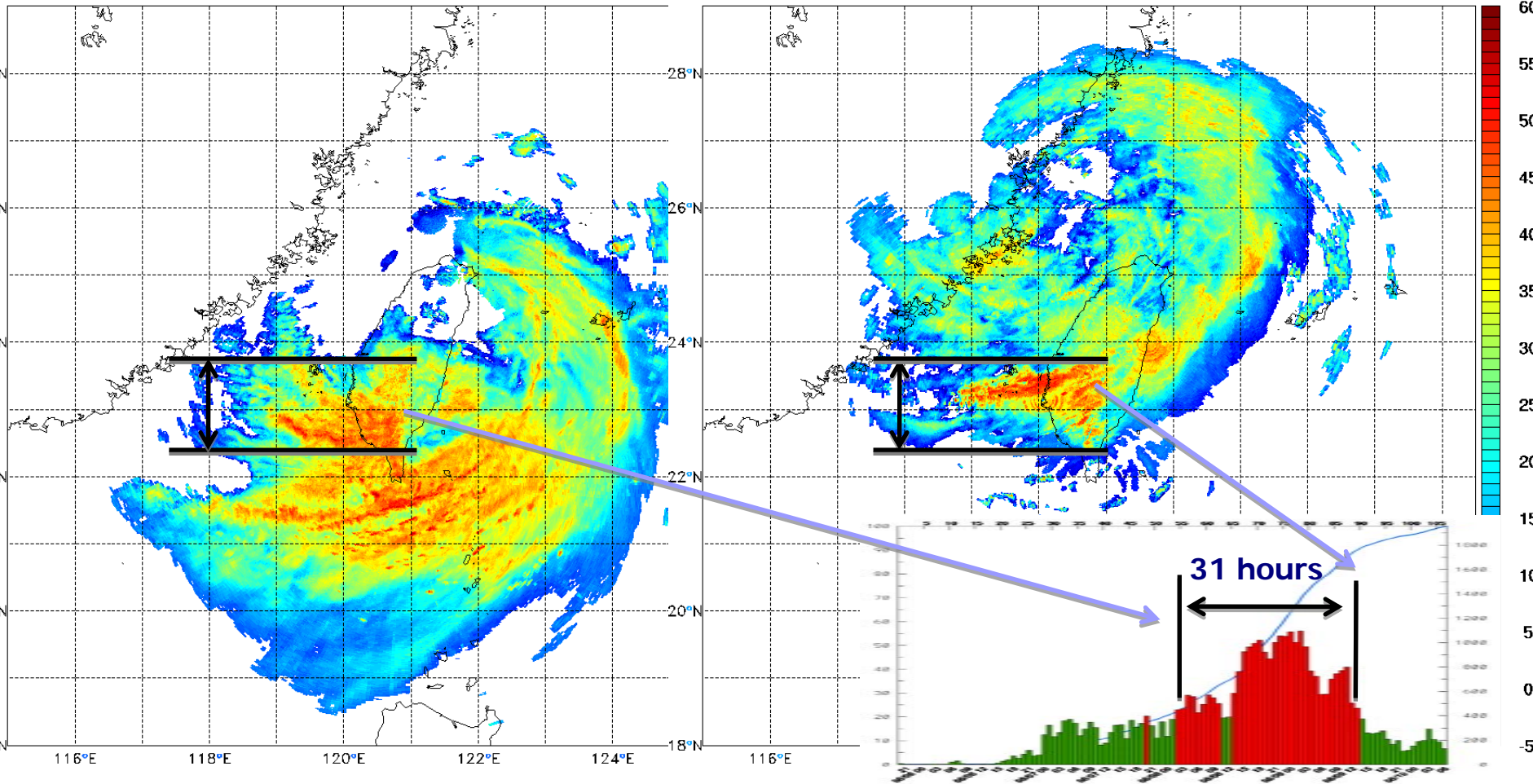
- **Are all upstream rainband associate with strong and deep westly wind ?
(still in working no answer this time)**

2009 Morakot

upstream horizontal rainband persistent more than 31 hours

CWB QPESUMS COMPOSITE REFL
2009/08/07 20:00 UTC

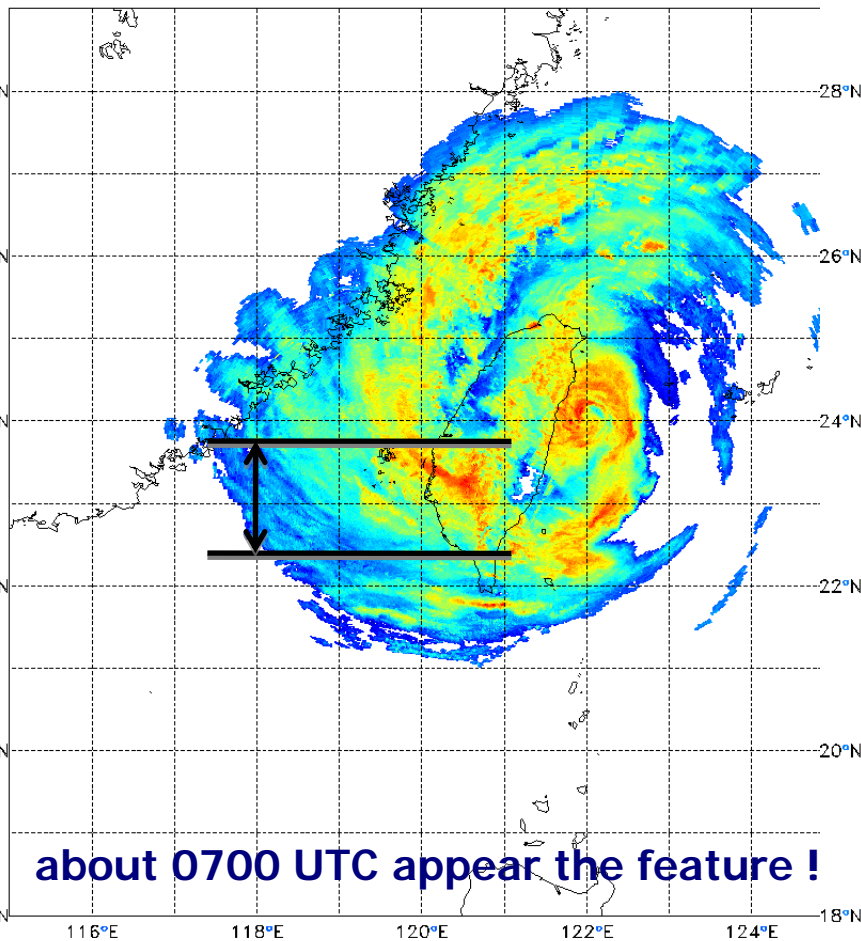
CWB QPESUMS COMPOSITE REFL
2009/08/09 03:00 UTC



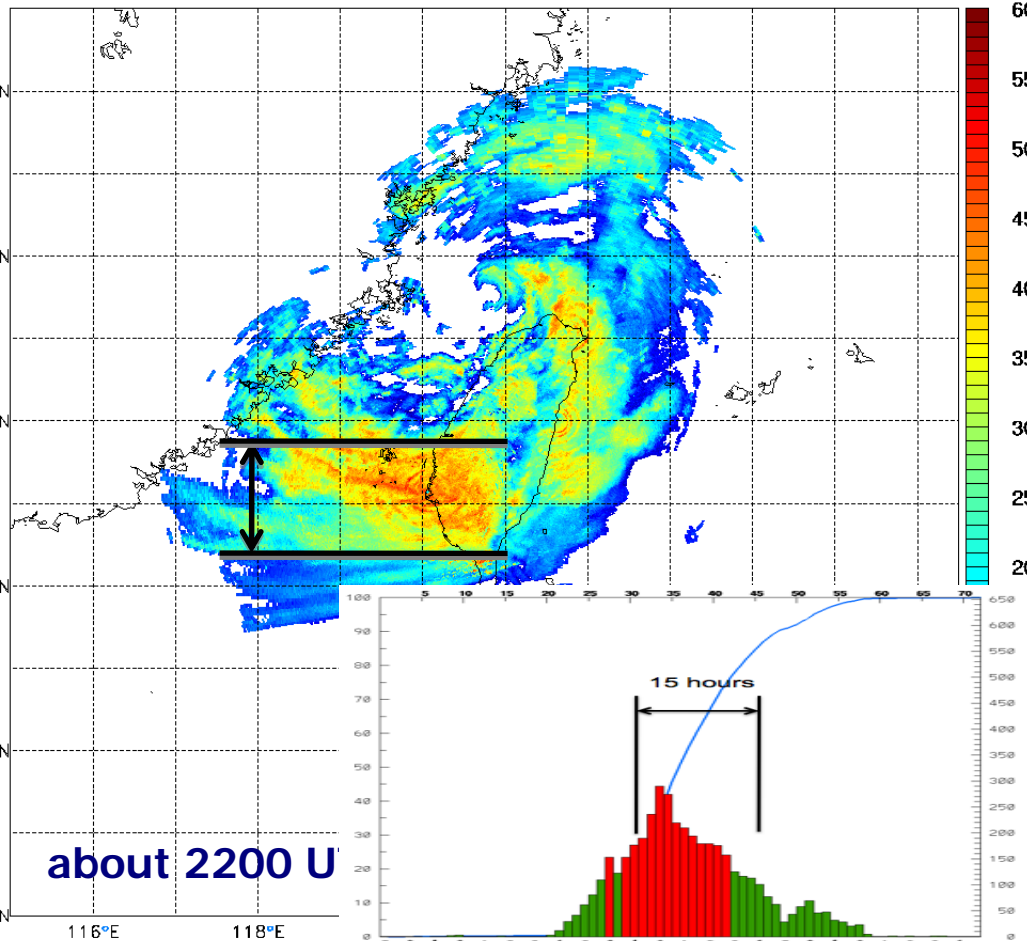
2007 Krosa

upstream horizontal rainband persistent more than 15 hours

CWB QPESUMS COMPOSITE REFL
2007/10/06 11:30 UTC



CWB QPESUMS COMPOSITE REFL
2007/10/06 20:00 UTC

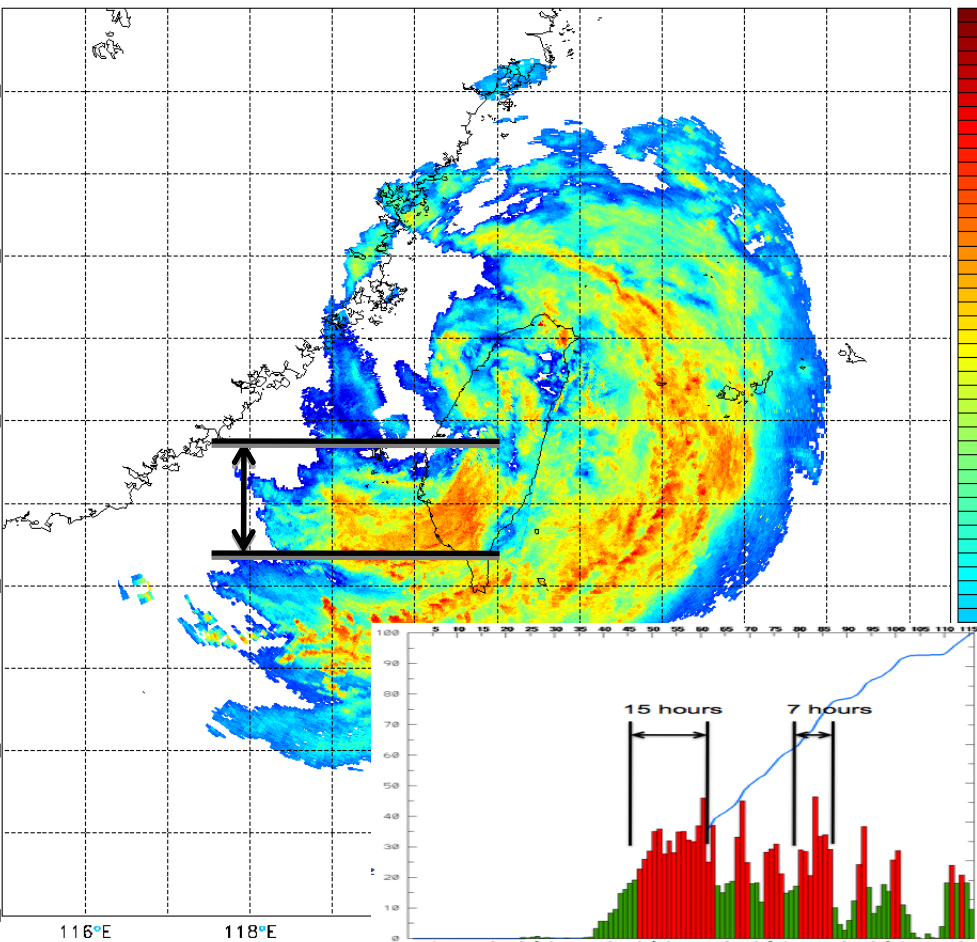
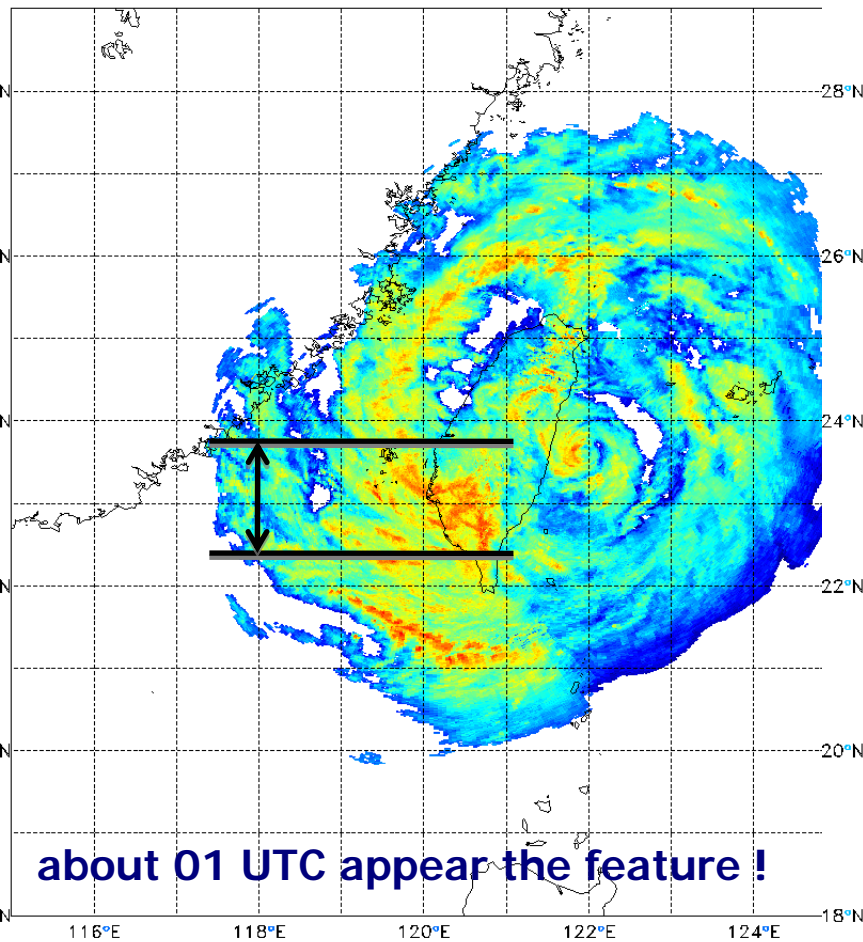


2005 Haitang

upstream horizontal rainband persistent more than 15 hours

CWB QPESUMS COMPOSITE REFL
2005/07/18 04:00 UTC

CWB QPESUMS COMPOSITE REFL
2005/07/18 16:00 UTC

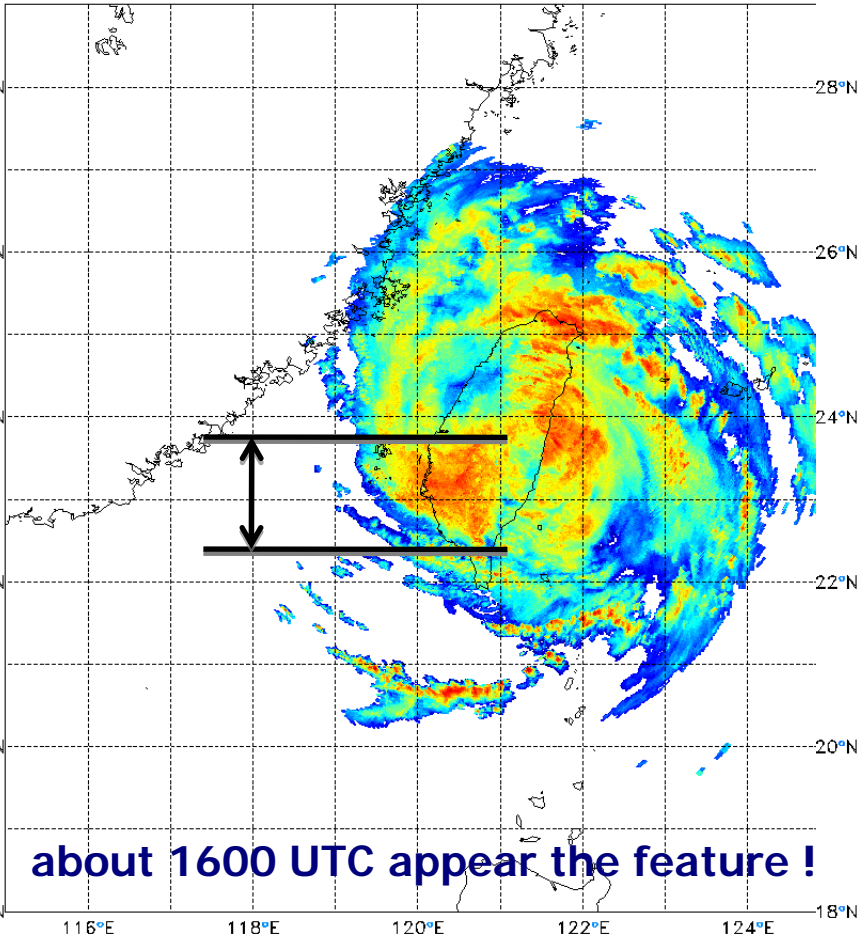


about 01 UTC appear the feature !

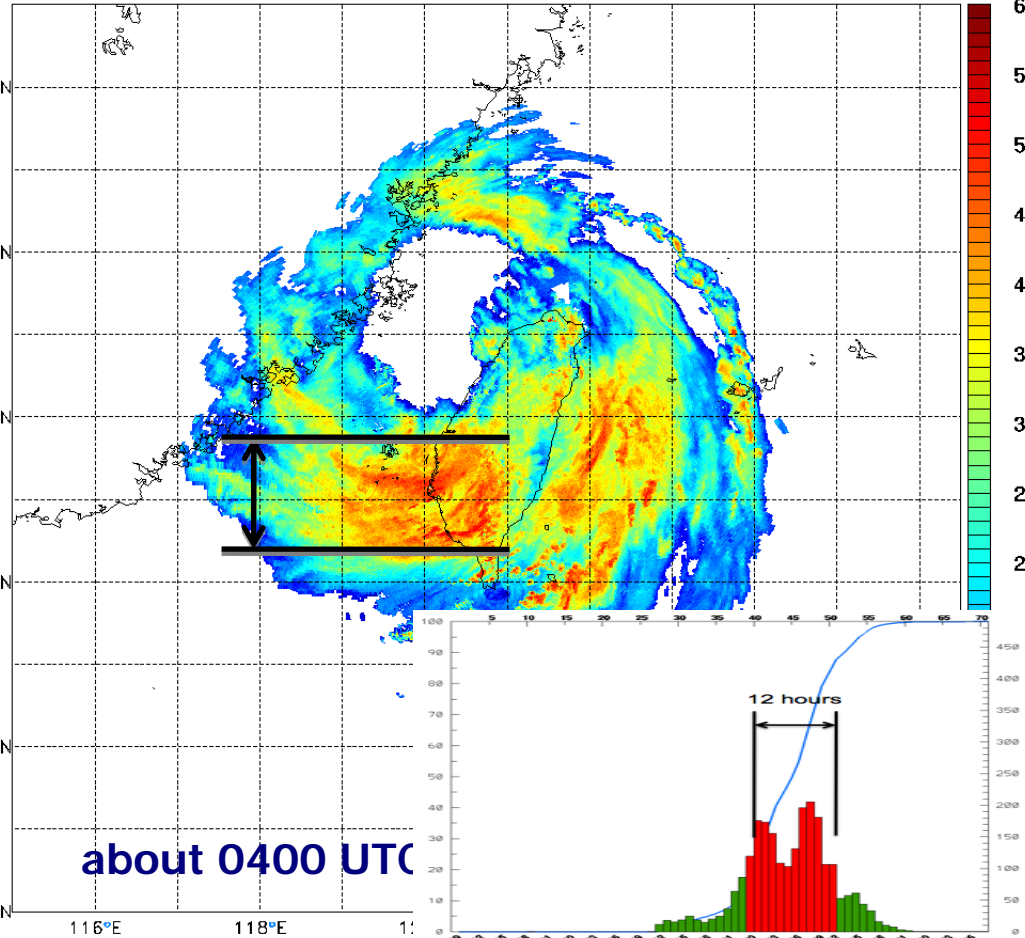
2005 Talim

upstream horizontal rainband persistent more than 12 hours

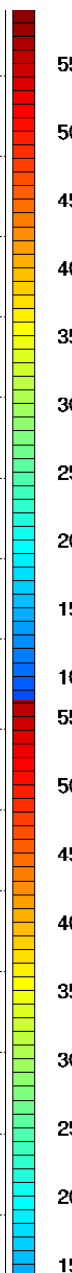
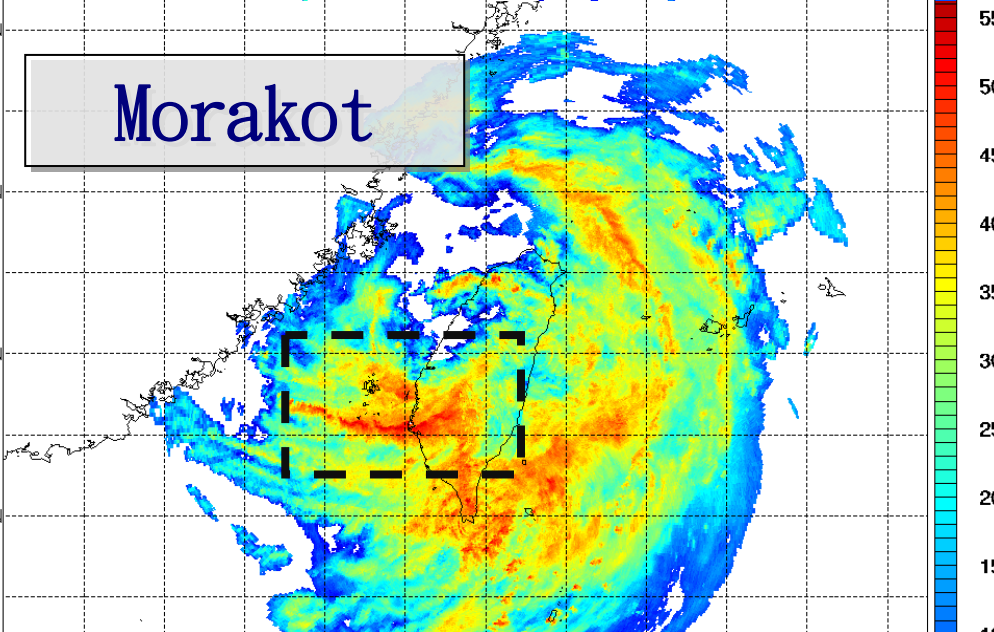
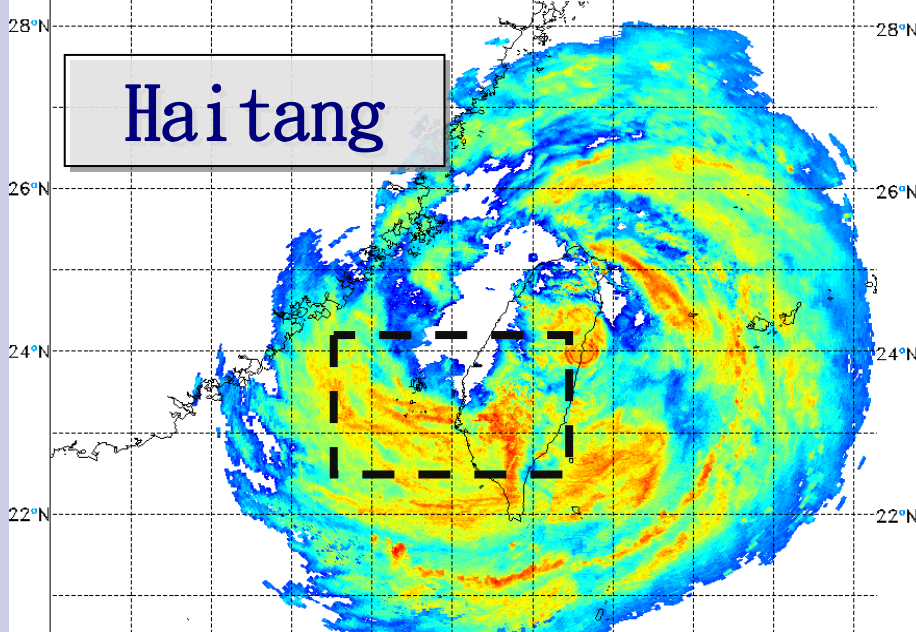
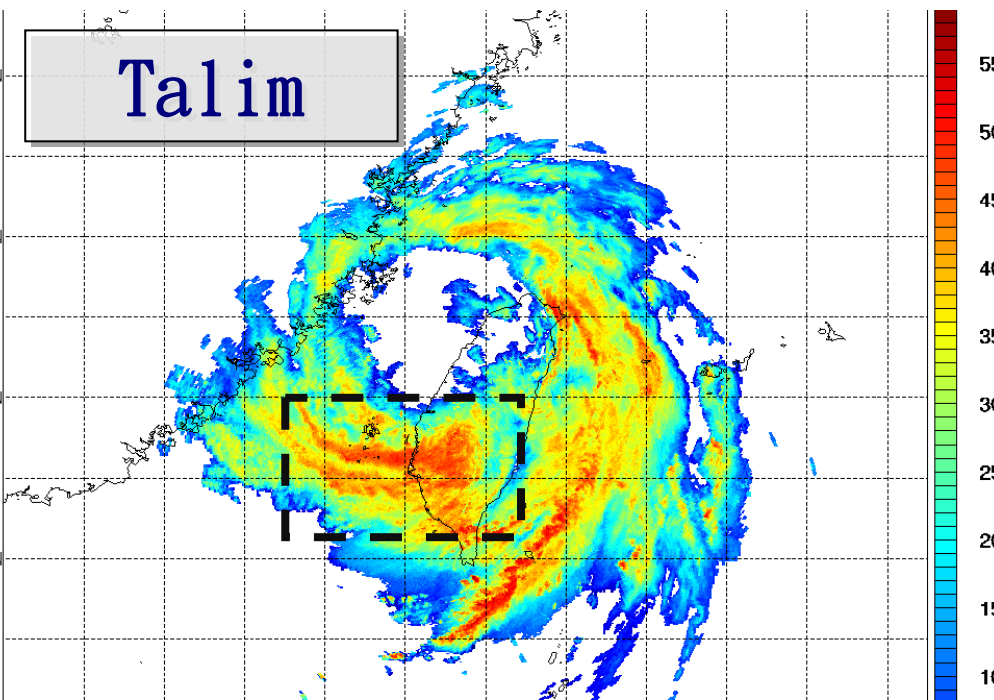
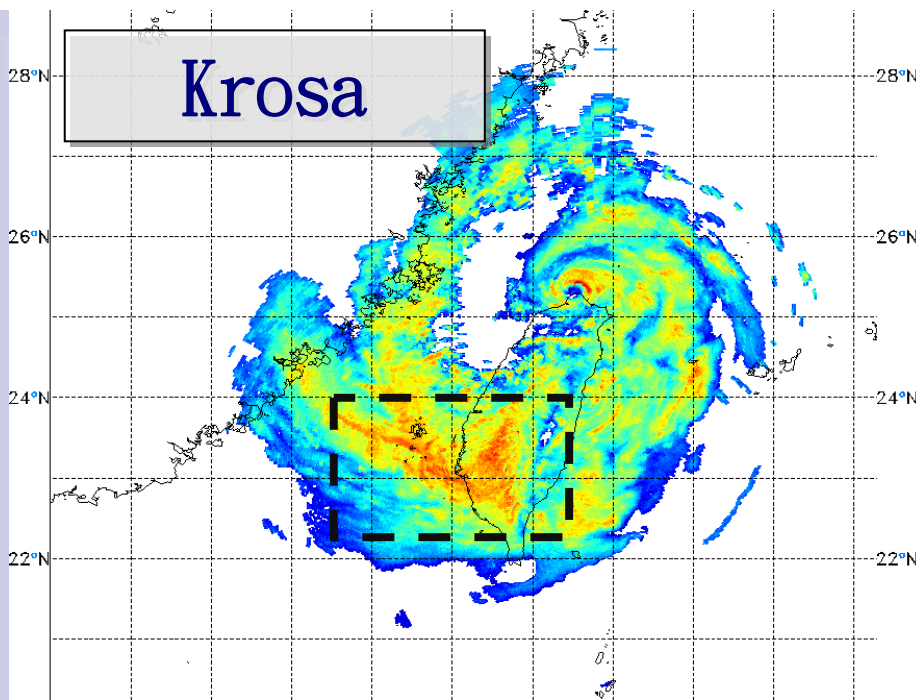
CWB QPESUMS COMPOSITE REFL
2005/08/31 17:30 UTC



CWB QPESUMS COMPOSITE REFL
2005/09/01 01:30 UTC

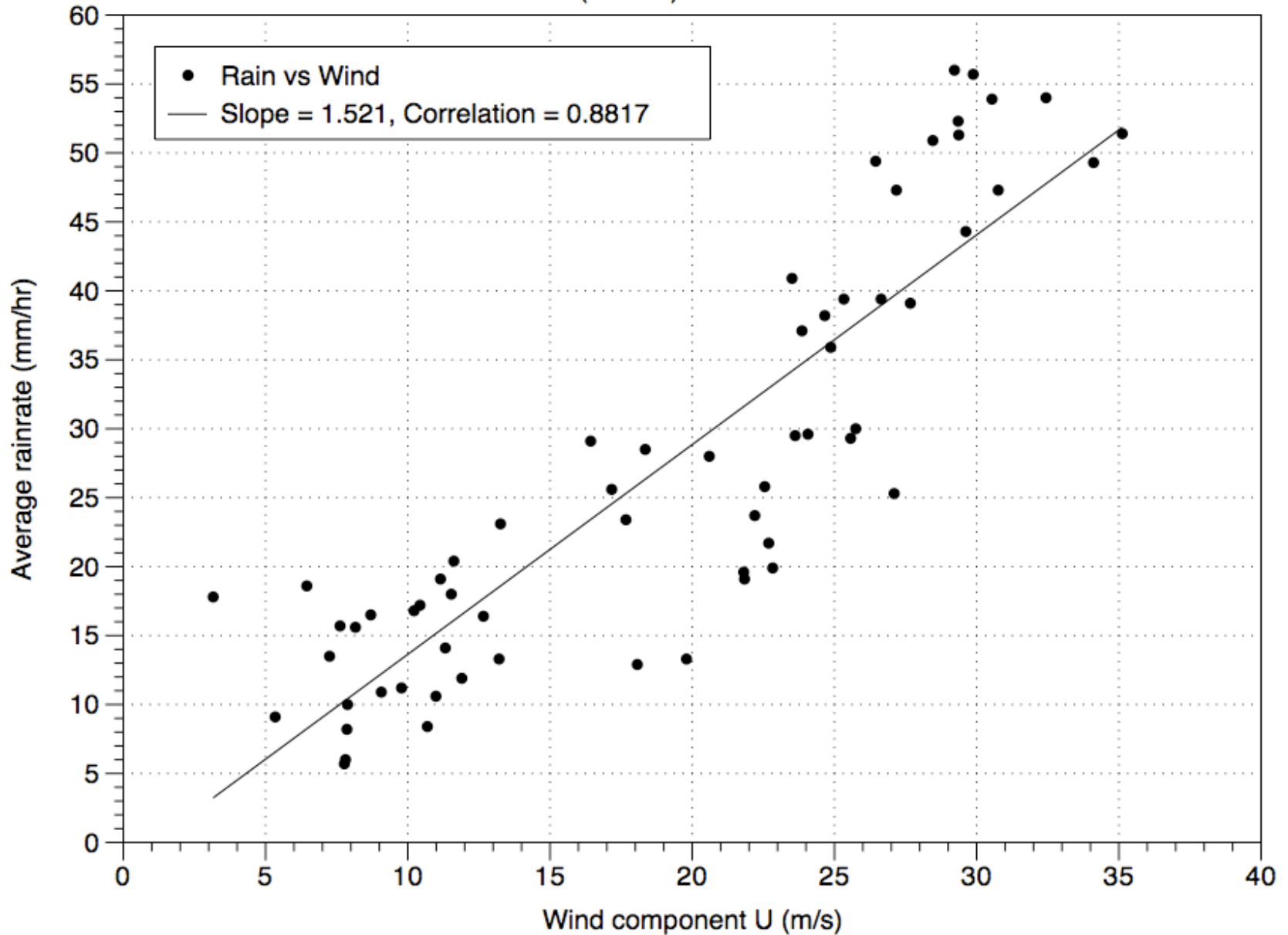


Use the similarity to build conceptual model

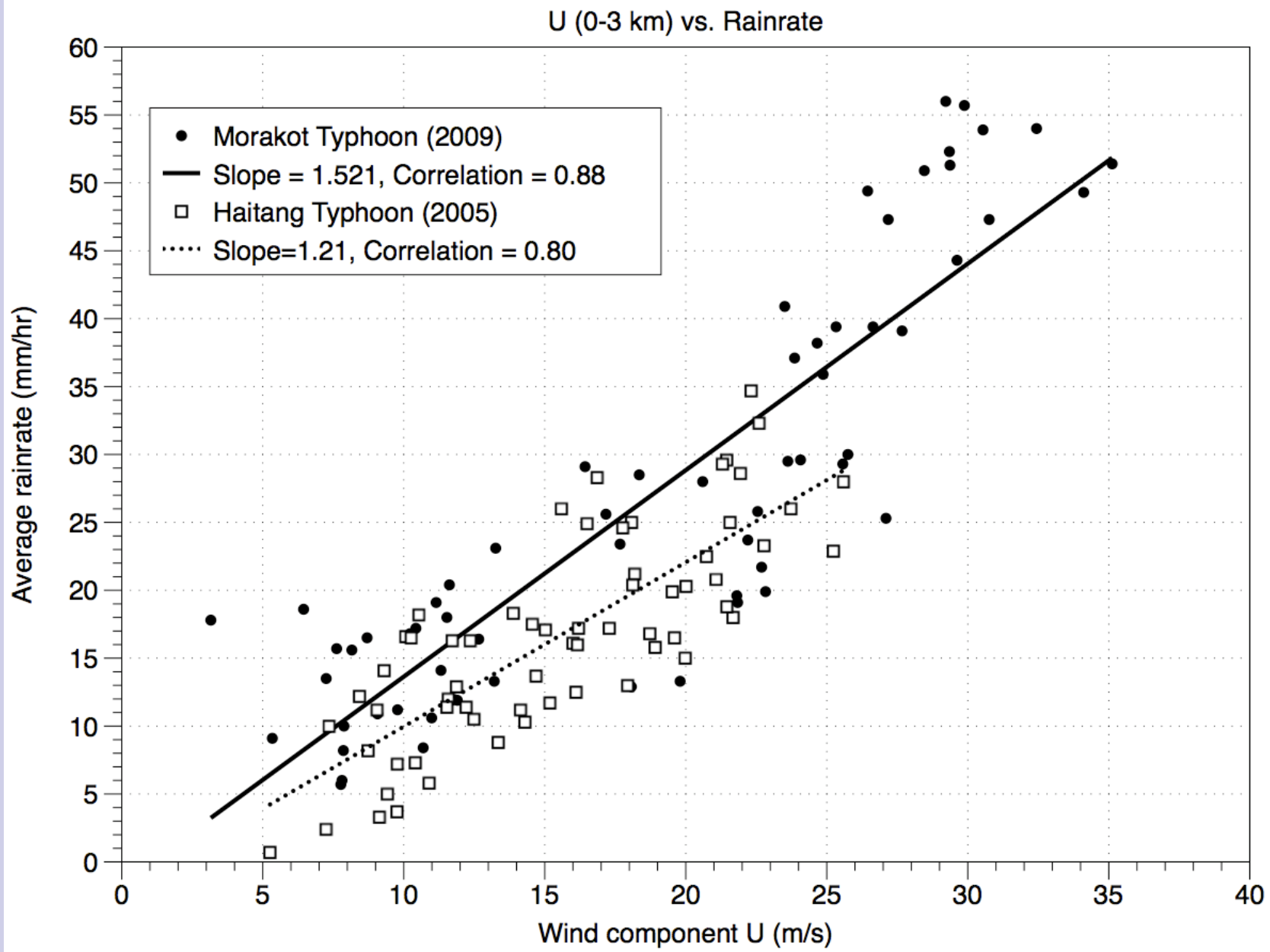


Morakot

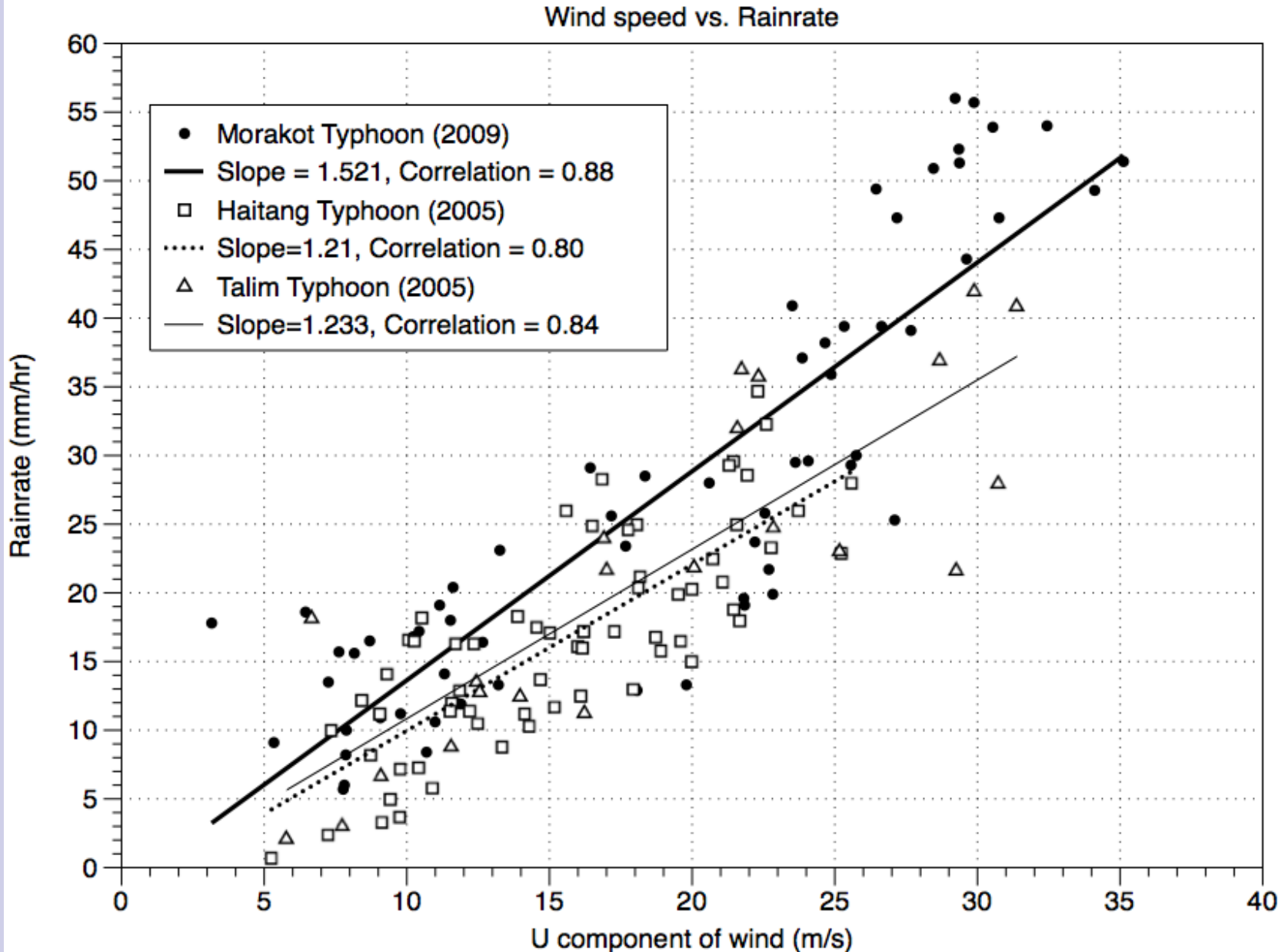
U (0-3 km) vs. Rainrate



Morakot, Haitang



Morakot, Haitang and Talim



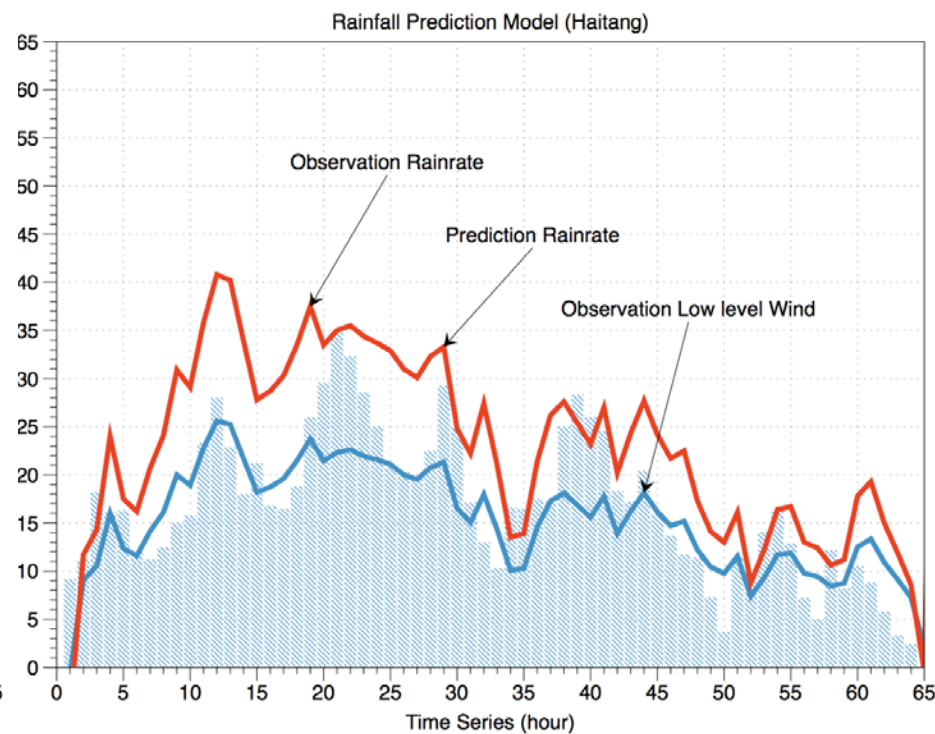
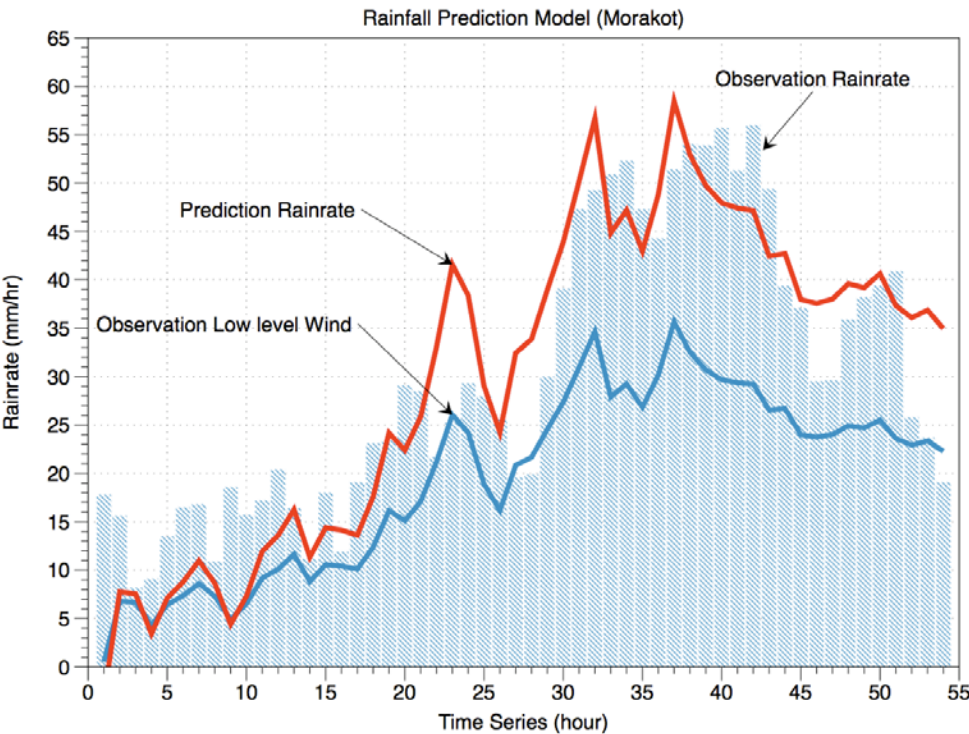
Linear Regression Model

Use the Morokat typhoon data to build a Rainfall Prediction Model

$$R \text{ (mm/hr)} = 1.756 \times U(1-3\text{km}) - 4.16$$

莫拉克颱風的雨量預報結果

海棠颱風的雨量預報結果

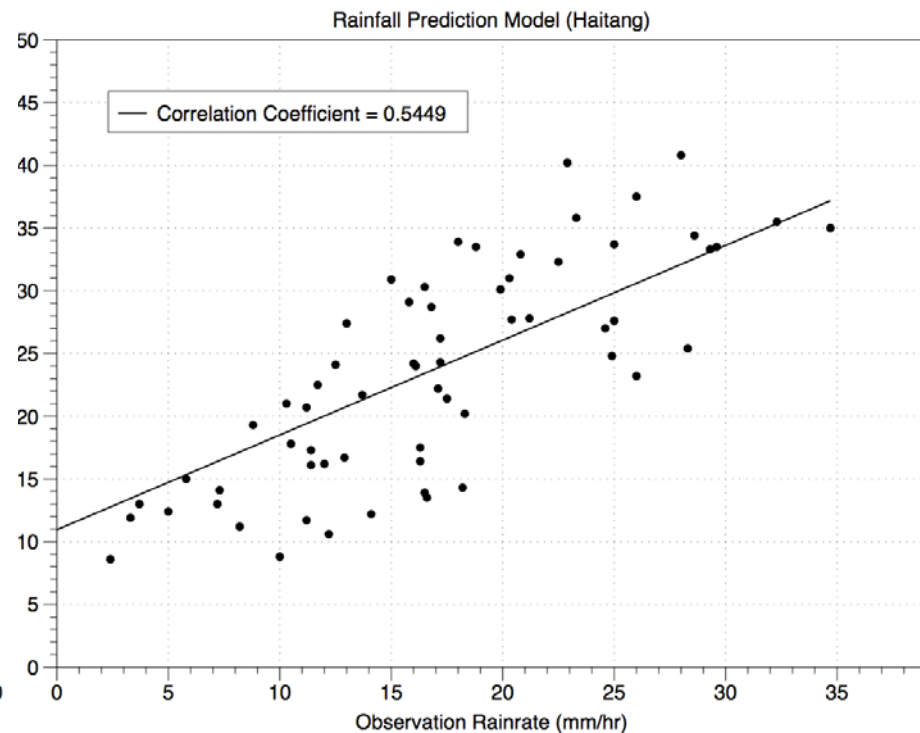
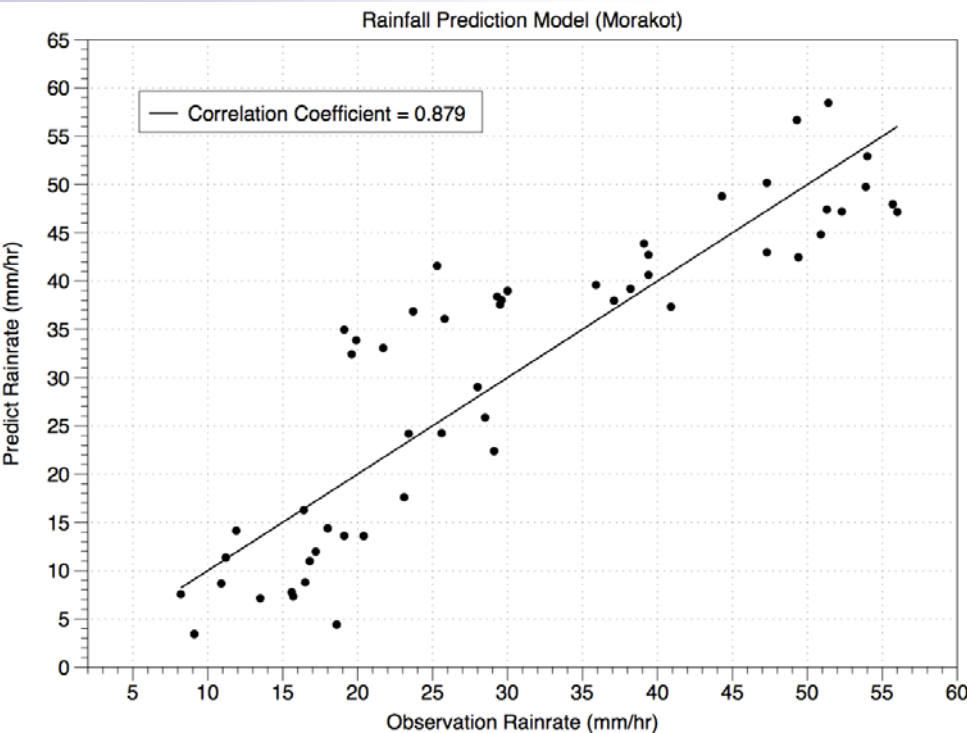


Linear Regression Model

Use the Morakot regression model to predict Morakot and Haitang typhoon, it is very good for Morakot but not so good for Haitang

預報莫拉克很好 ($R = 0.879$)

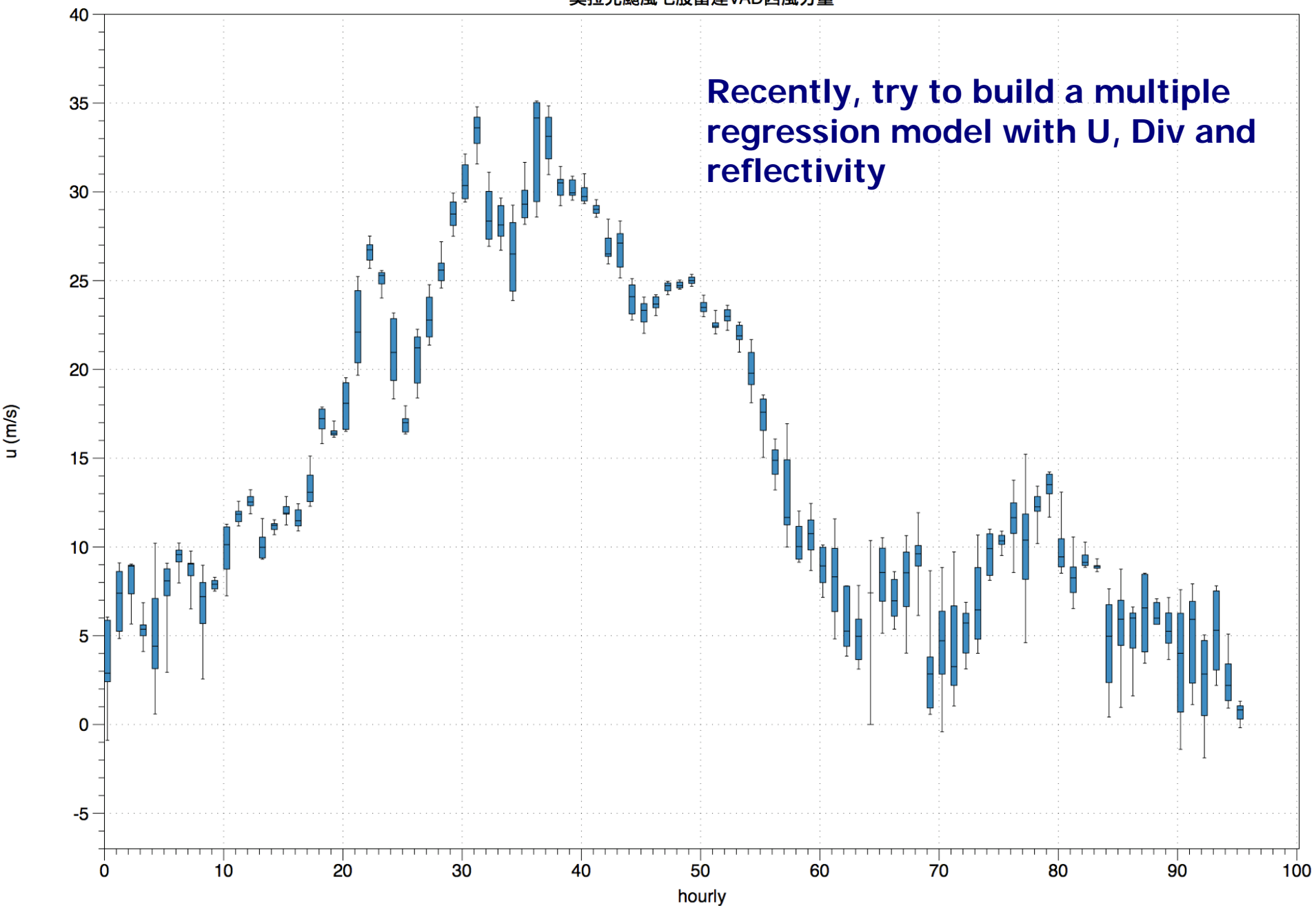
預報海棠比較差 ($R = 0.545$)



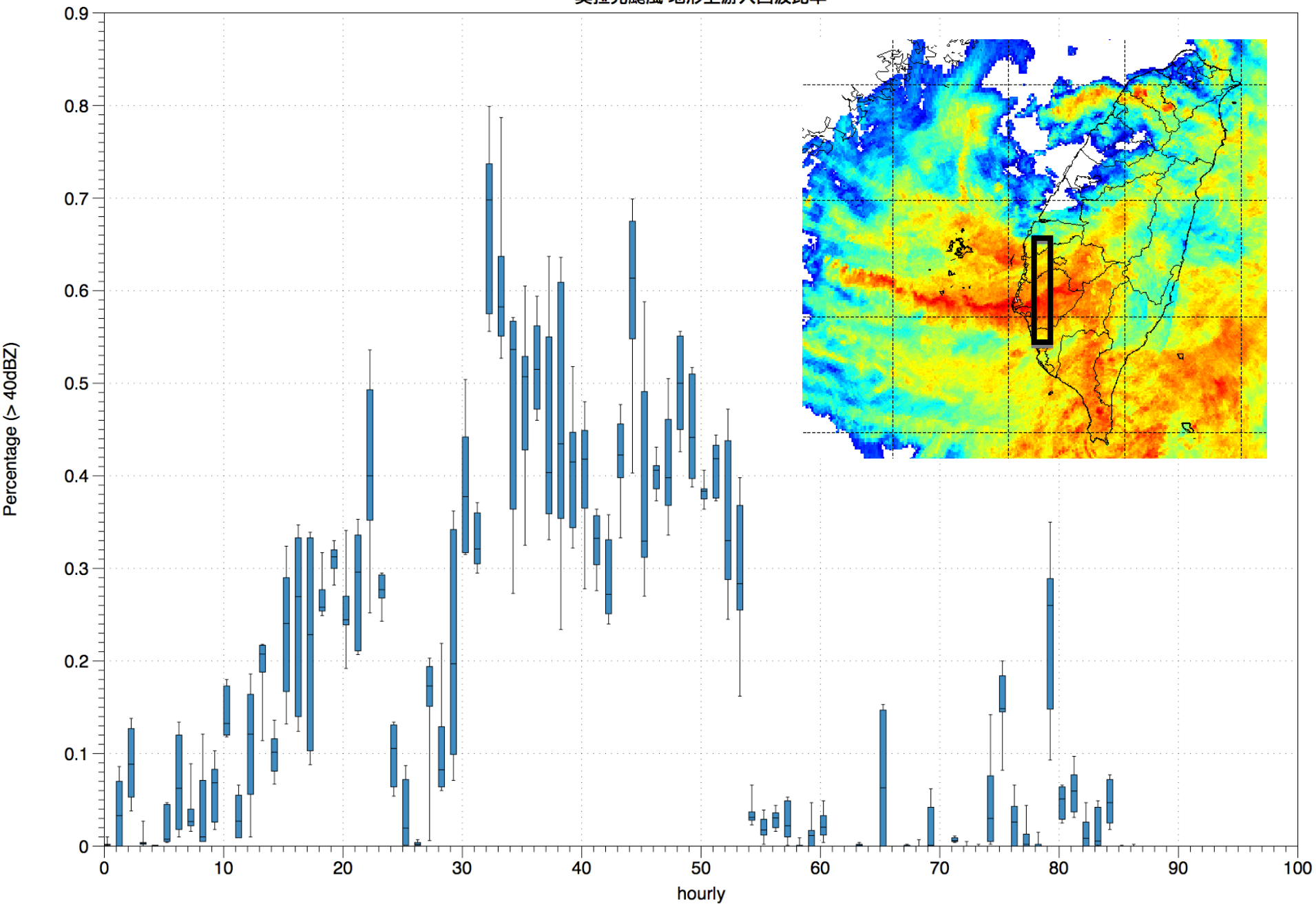


U (1-3km)

莫拉克颱風七股雷達VAD西風分量



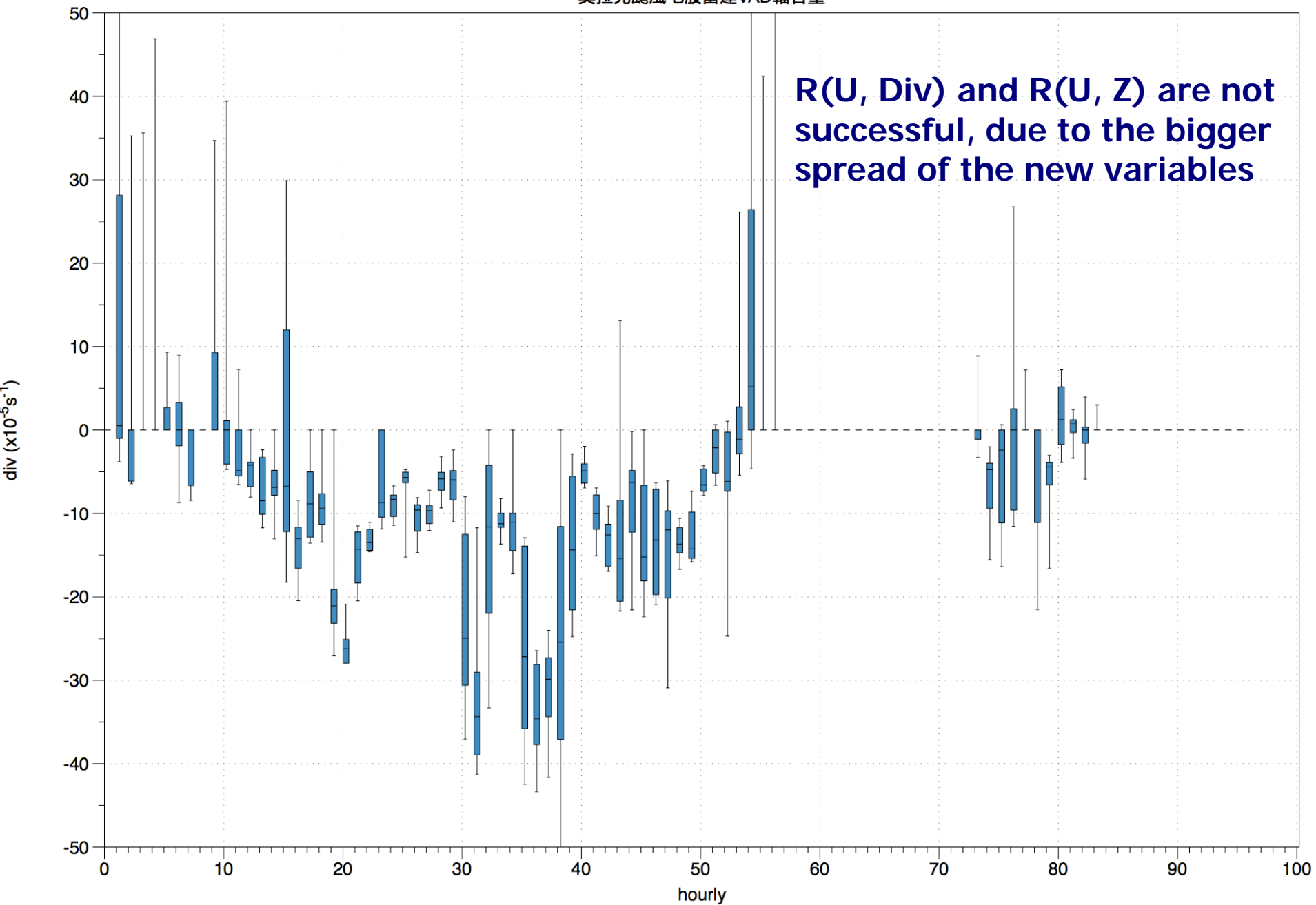
莫拉克颱風 地形上游大回波比率



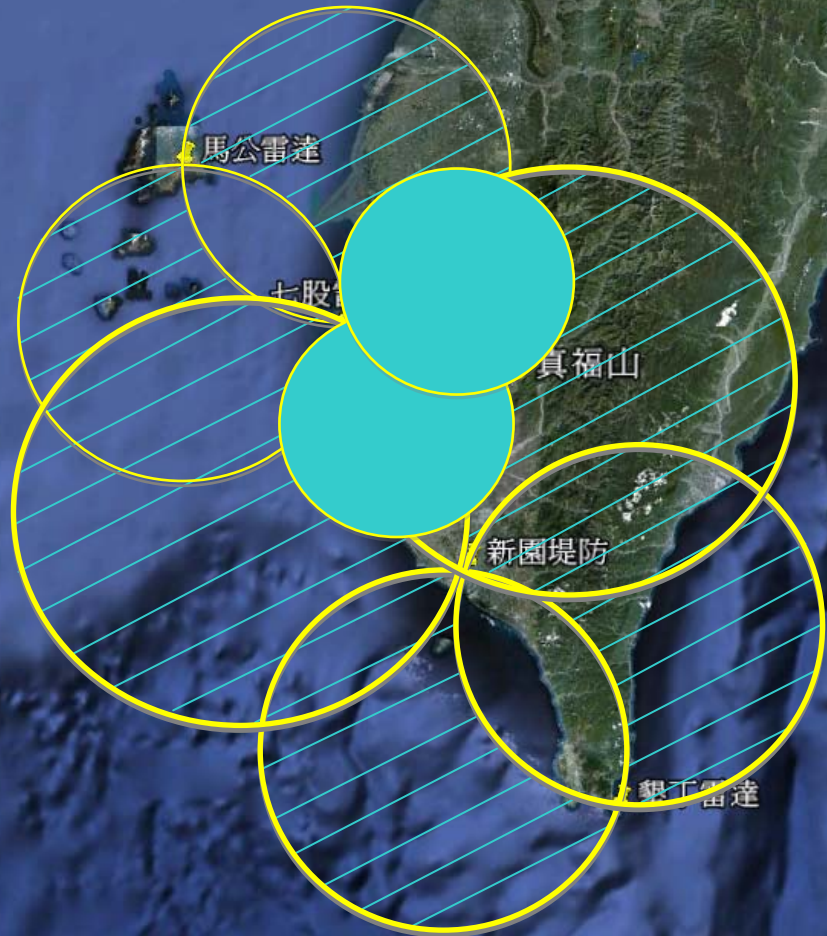


Div (1-3km)

莫拉克颱風七股雷達VAD輻合量



Observation in Planning



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 Cnes/Spot Image
Image © 2010 DigitalGlobe
Data © 2010 MIRC/IHA

©2009 Google

23°28'16.05" 北 121°38'16.24" 東 海拔高度 0 公尺

視角海拔高度 429.70 公里

Orographic Heavy Rain Obs. (旗山溪)



那瑪夏鄉
(三民)

五里埔
(小林村)

關山村
(中興國小)

杉林鄉
(大埔山/真福山)

地面雲物理
整合站

可移動式
偏極化雷達

Shanlin

杉林鄉

六龜鄉

六龜鄉 Liouguci

© 2010 Cnes/Spot Image
© 2010 Kingway Ltd.
© 2010 Europa Technologies
© 2010 ZENRIN

©2009 Google

Orographic Heavy Rain Obs. (荖濃溪)



地面雲物理
整合站

寶來溫泉

可移動式
偏極化雷達
荖濃村

六龜鄉

車載式偏極化雷達合作觀測(高雄)

- 第一次「西南氣流觀測實驗」(5月27日~ 6月16日)
- 第二次「萊羅克颱風觀測」(8月31日~ 9月02日)
- 第三次「凡那比颱風觀測」(9月18日~ 9月21日)

颱風中心18米
陸氣水文通量塔

中央大學
10米氣象站

中央大學
雨滴譜儀

人員作業室

中央大學(國科會)
移動式氣象雷達

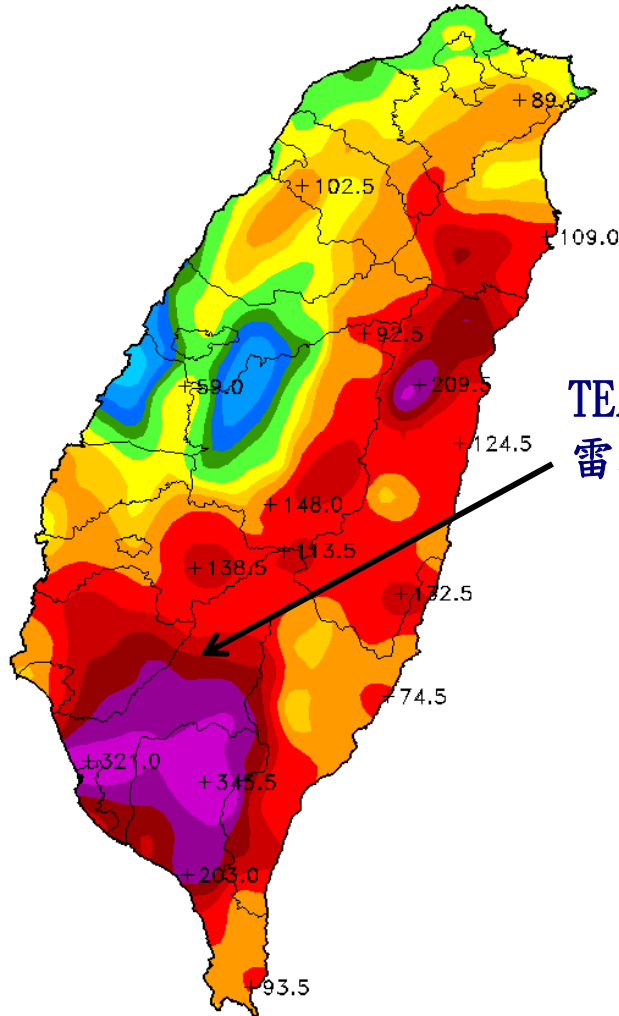
氣象局
自計雨量筒



凡那比颱風雨量圖 (9/18~9/20)

最大累積3小時雨量圖

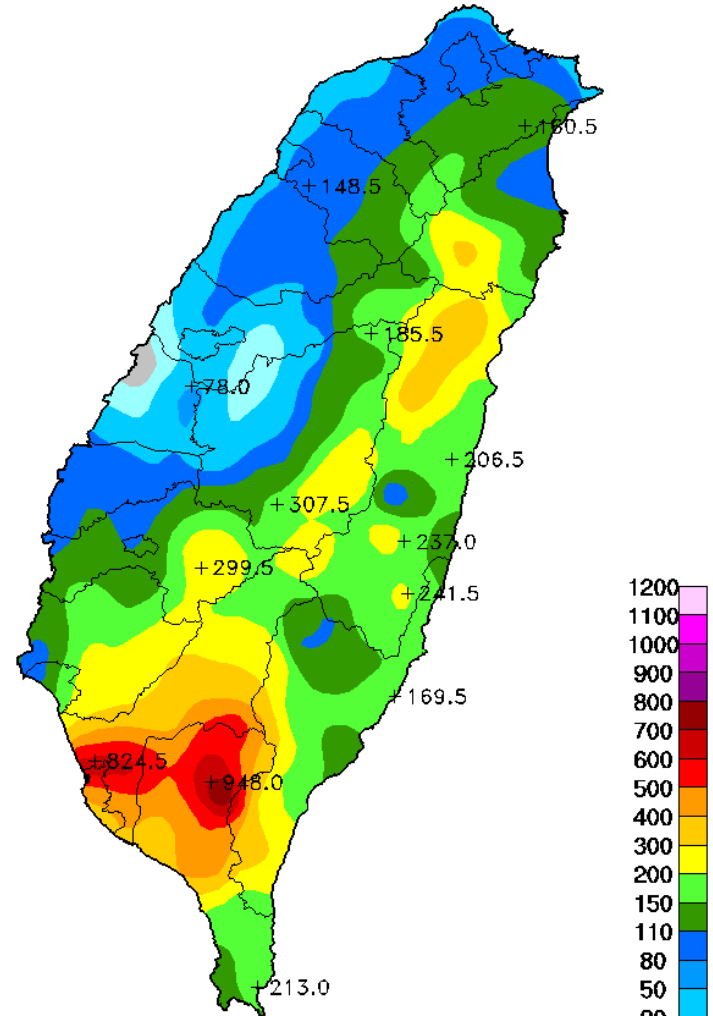
C1R14 345.5 mm



Maximum 3 hour rainrate in 72 hours
09/18 08:00 ~ 09/21 07:00 LST (2010)

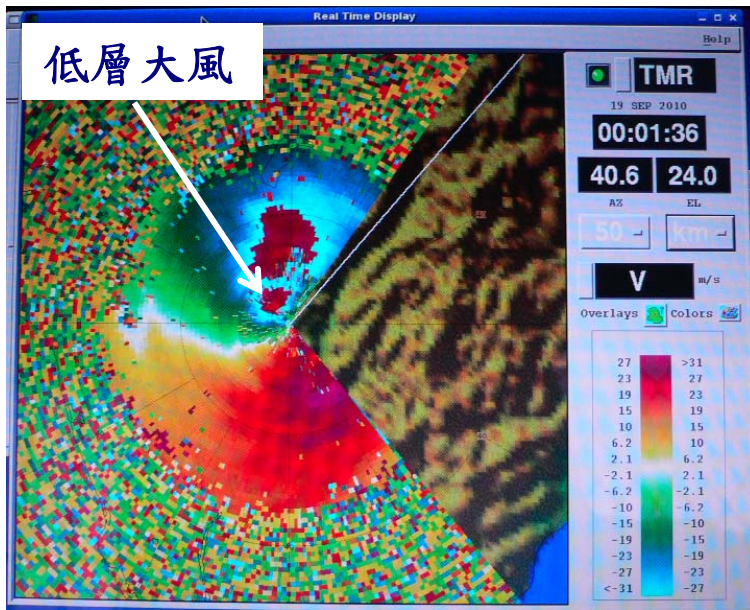
最大累積12小時雨量圖

C1R14 948.0 mm



Maximum 12 hour rainrate in 72 hours
09/18 08:00 ~ 09/21 07:00 LST (2010)

凡那比(Fanapi)颱風聯合觀測

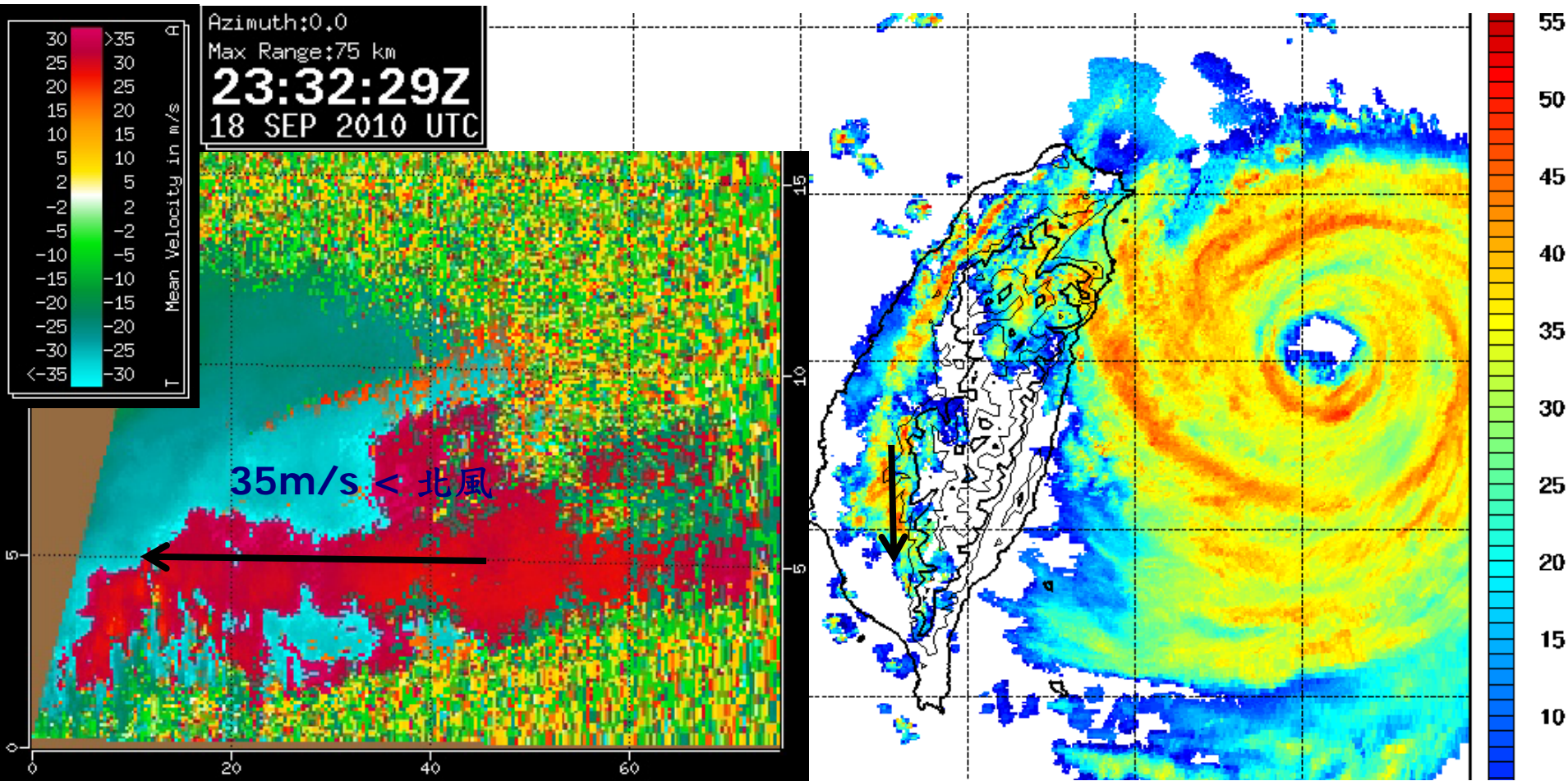


參與人員：颱洪中心5員、中央大學3員(含教授乙員)及台灣大學3員(研究生)
設備：車載偏極化雷達、日本小型都卜勒雷達、中央大學雨滴譜儀3套及地面氣象站3套

9月19日早上8點的雷達徑向風場顯示低層北風風速超過35m/s，造成雷達車前方50米的樹木及作業室後方的老樹攔腰折斷。強風造成杉林鄉大愛村附近路樹折斷倒塌超過百棵以上，路旁40呎貨櫃屋被吹落大水溝。



中央山脈西側的風雨比預期早發生



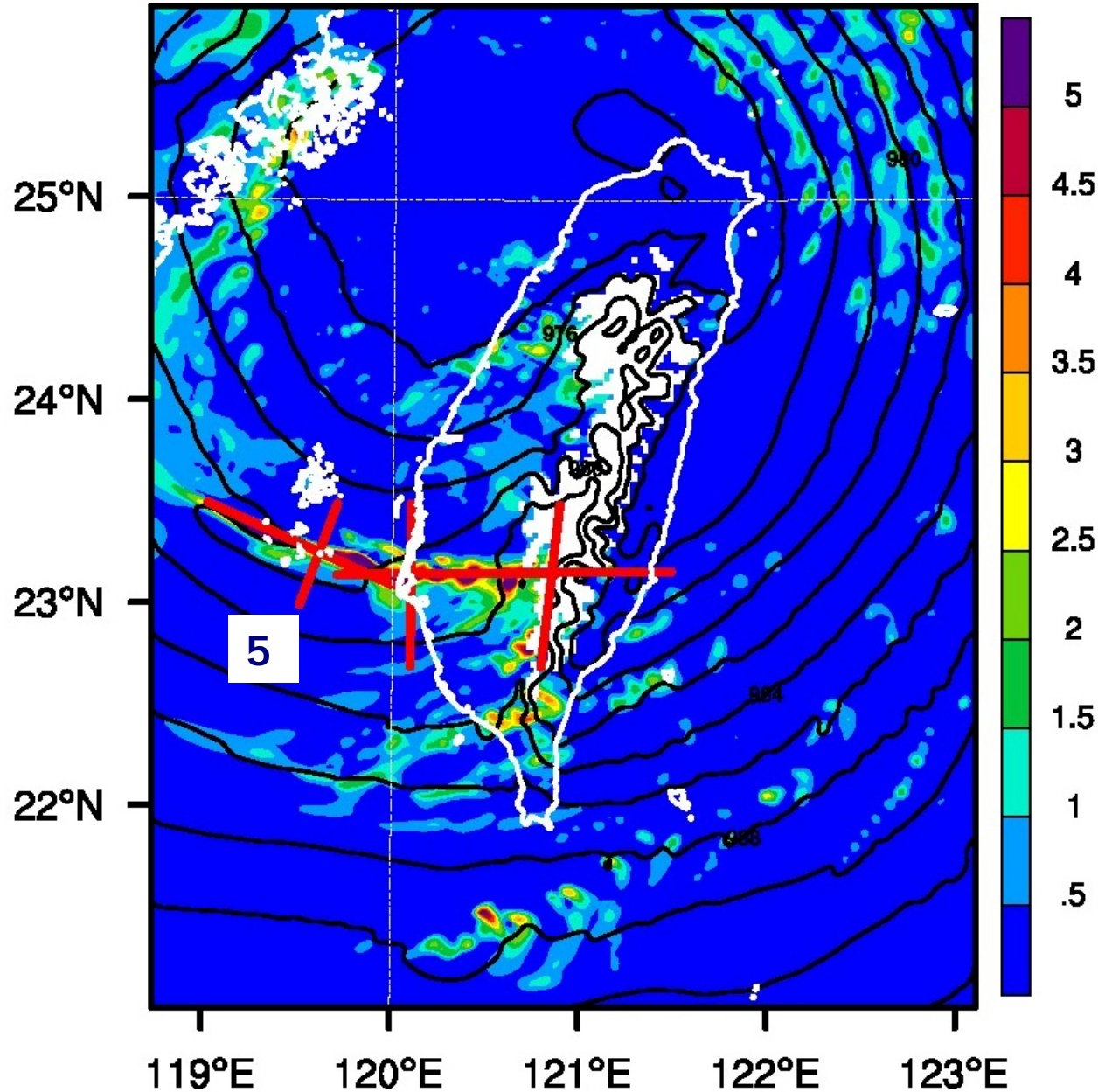
凡那比颱風暴風圈尚未接觸陸地(9/19 AM1:00)，中央山脈西側山麓就起括風下雨比預期早許多，至使觀測作業準備時間不足

summary

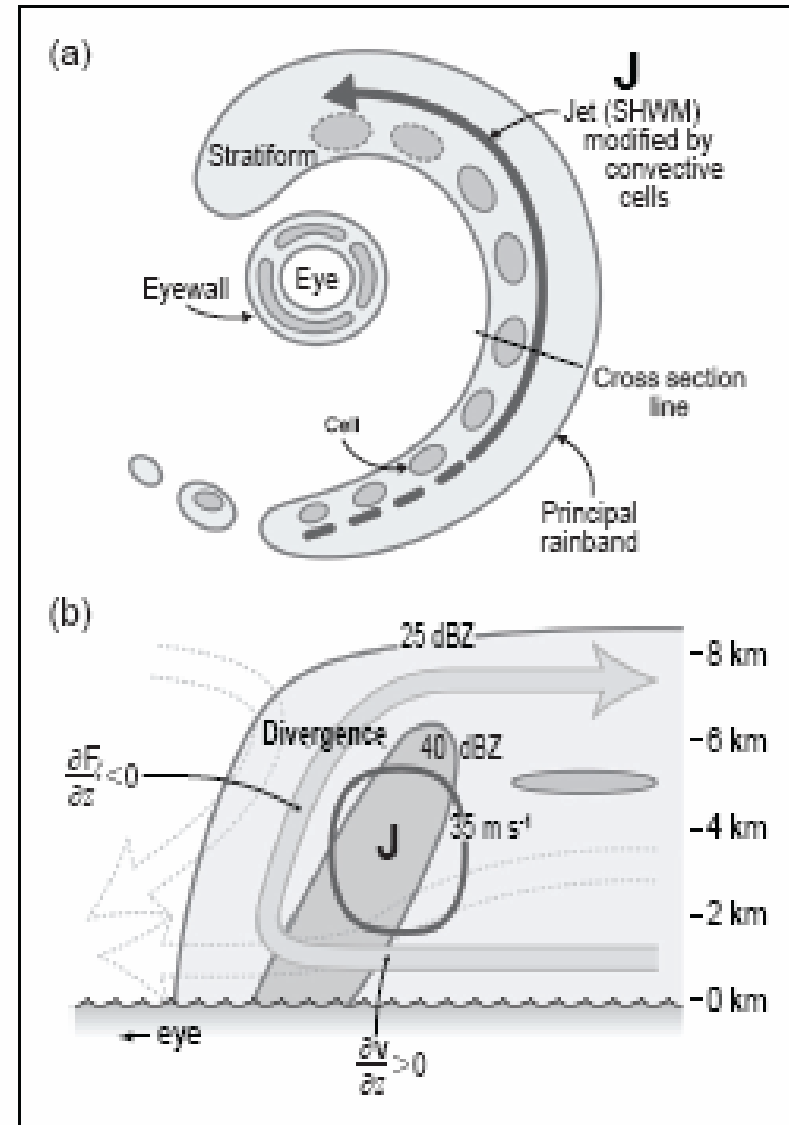
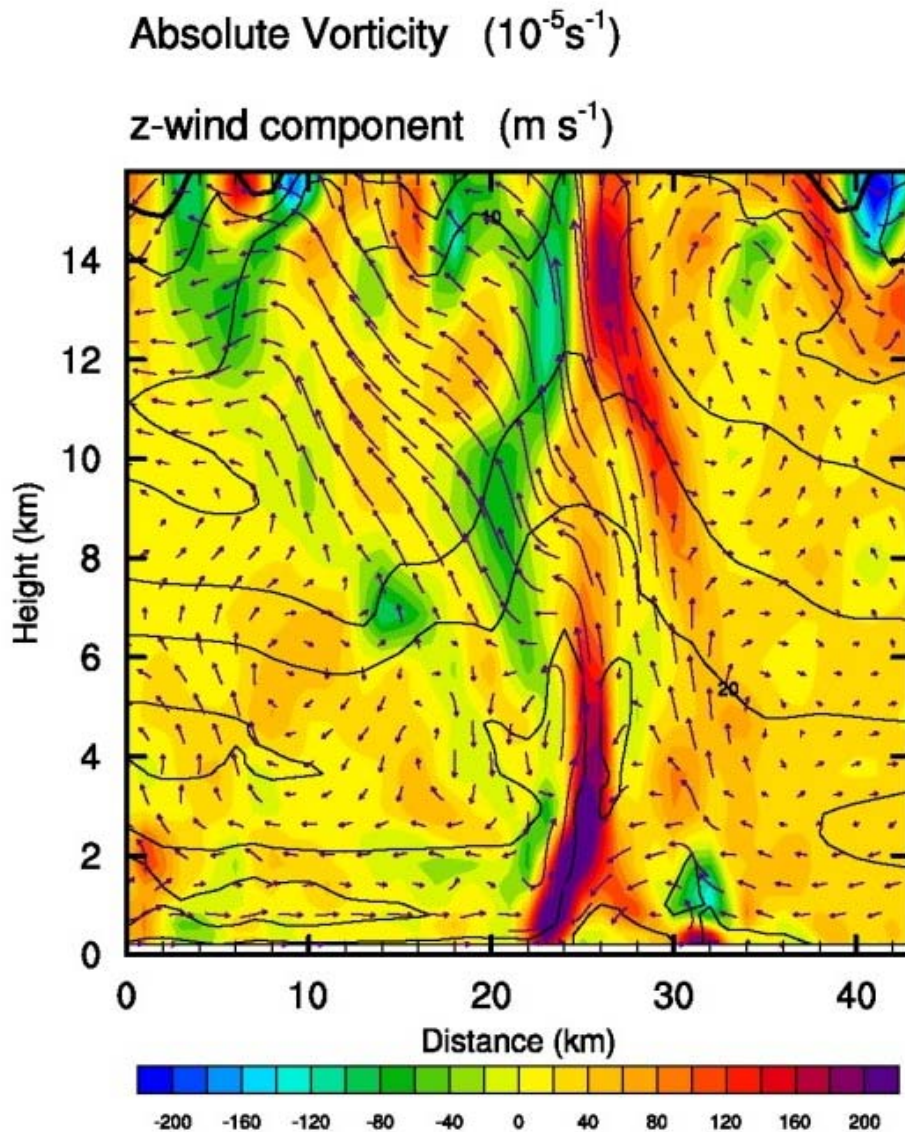
1. Heavy orographic rainfall need a strong upslope wind that perpendicular to mountain and need the pre-exist convection (line or cells) in the upstream side.
2. Typhoons in northern part of Taiwan can form a convergence zone in the southwest part of Taiwan.
3. The Linear regression model that use the $U(1-3\text{km})$ can predict the average rainfall amount not too bad, the Multiple regression model not improve anymore.

**Thanks
for your attention**

a snapshots of upstream rainband



upstream rainband vs. typhoon main rainband



Didlake and Houze (2009)