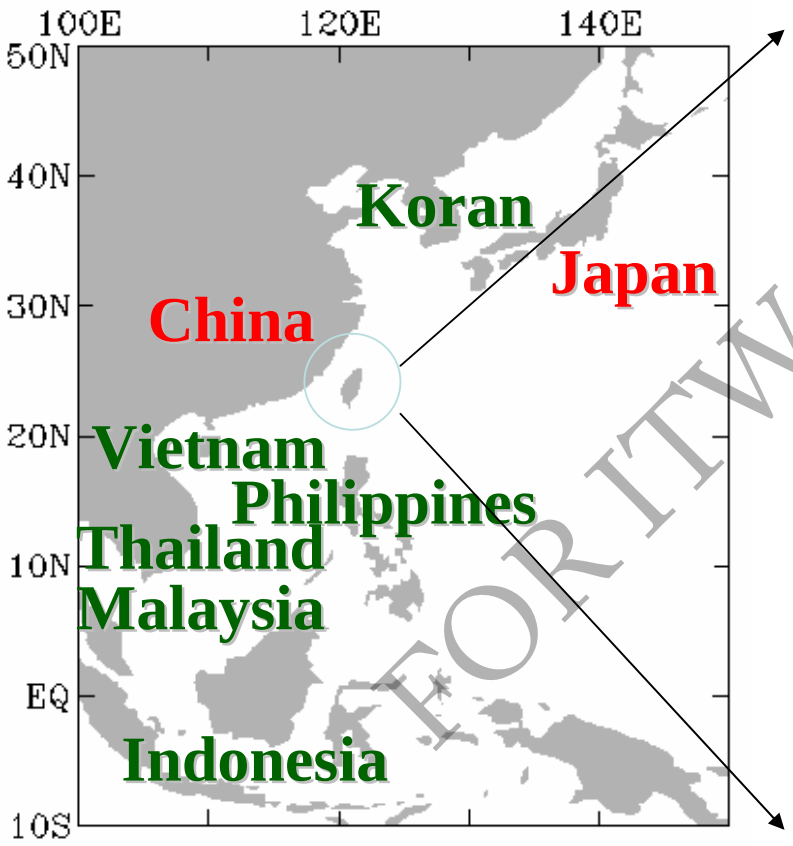
ITW on Natural Disaster Reduction 2010, NCDR
Taipei, Taiwan, ROC.

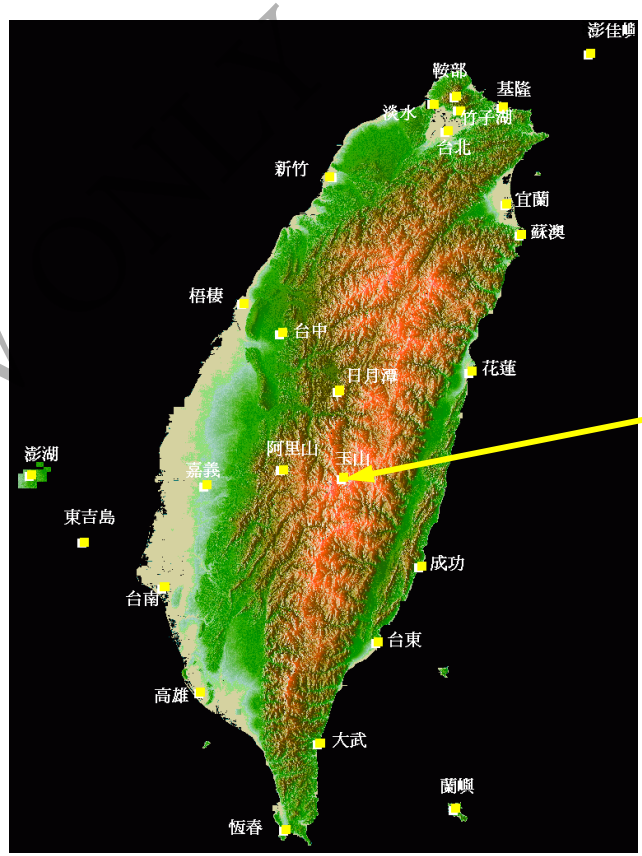
An Introduction on the extreme weather in Taiwan and the forecast at the Central Weather Bureau

FOR ITW ONLY

Tien-Chiang Yeh
Central Weather Bureau
May 12, 2010

Taiwan





Jade Mt
3952 m

36,000 km^2

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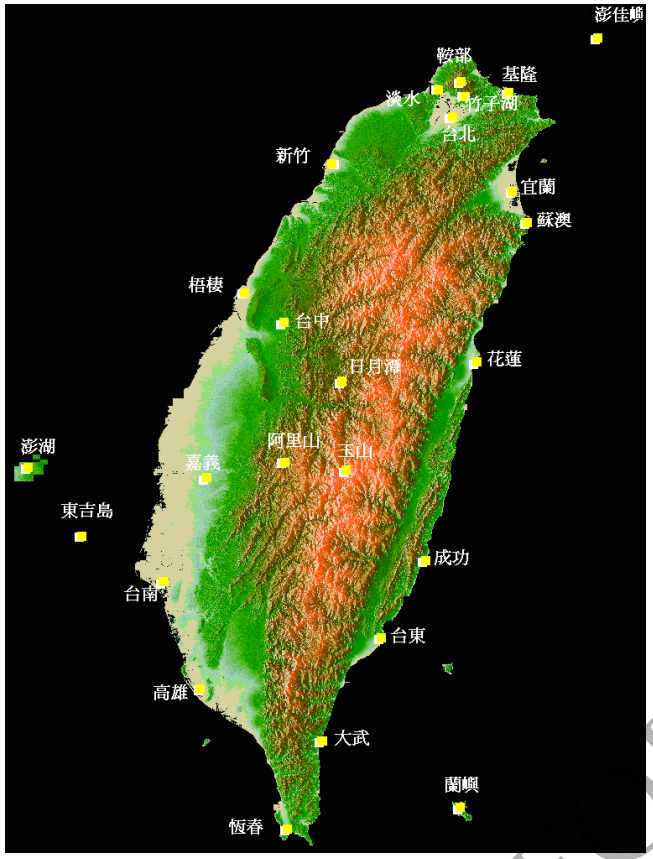
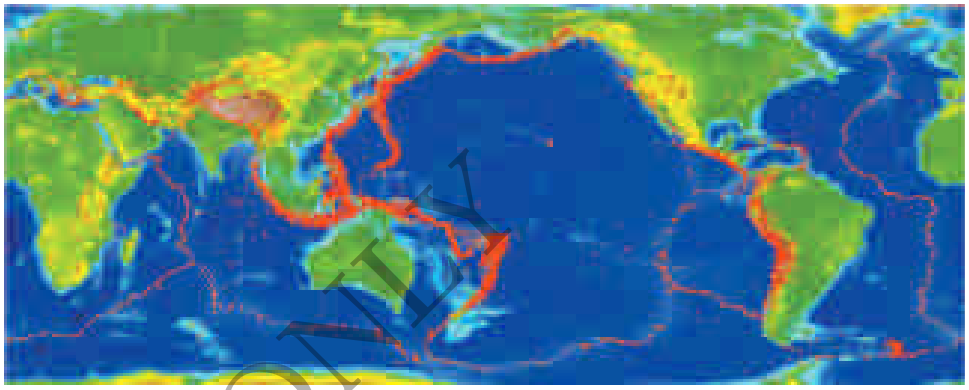
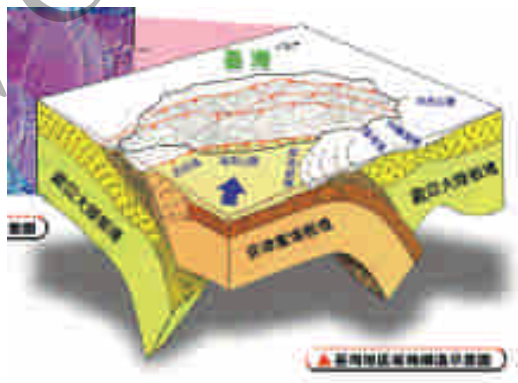
Jade Mt.

OTTW ONLY







32% of the area with elevation higher than 1,000 m

Locate at the **convergent boundary** of the Eurasian plate and the Philippine Sea plate. There are about 1,000 felt quakes yearly.

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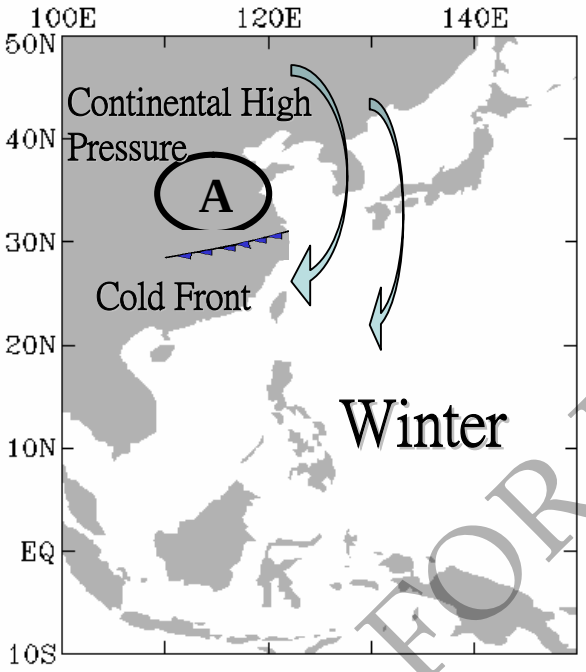
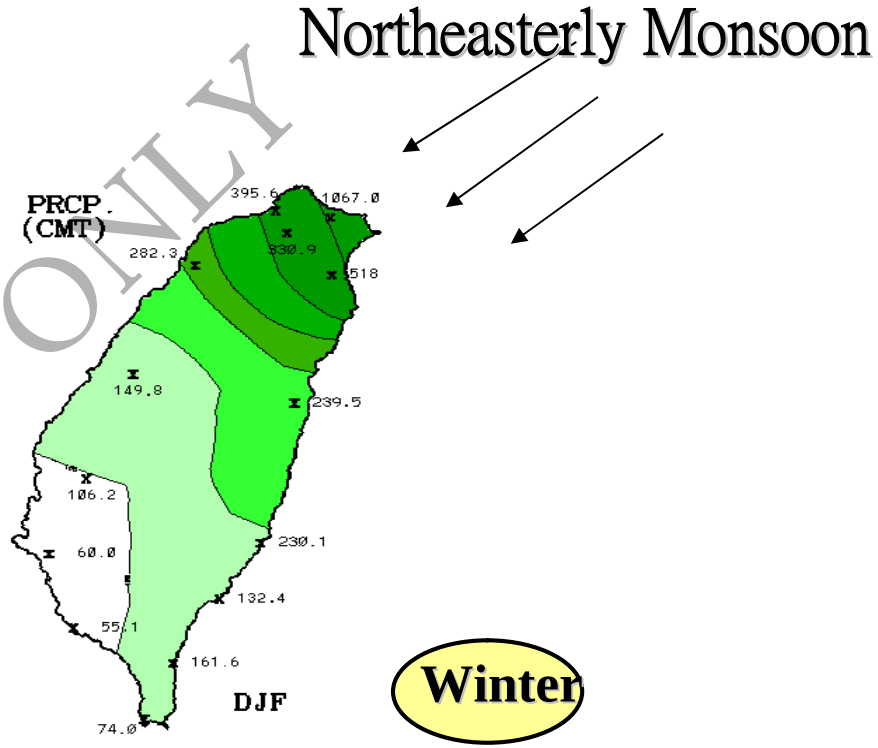
Climate in Taiwan





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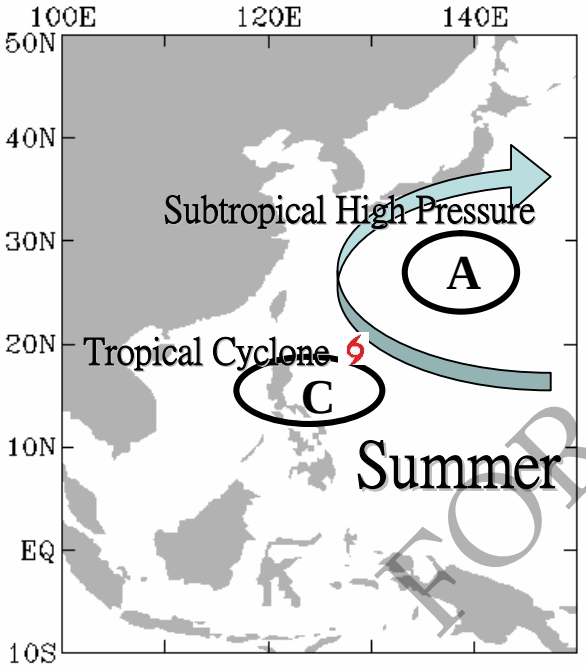
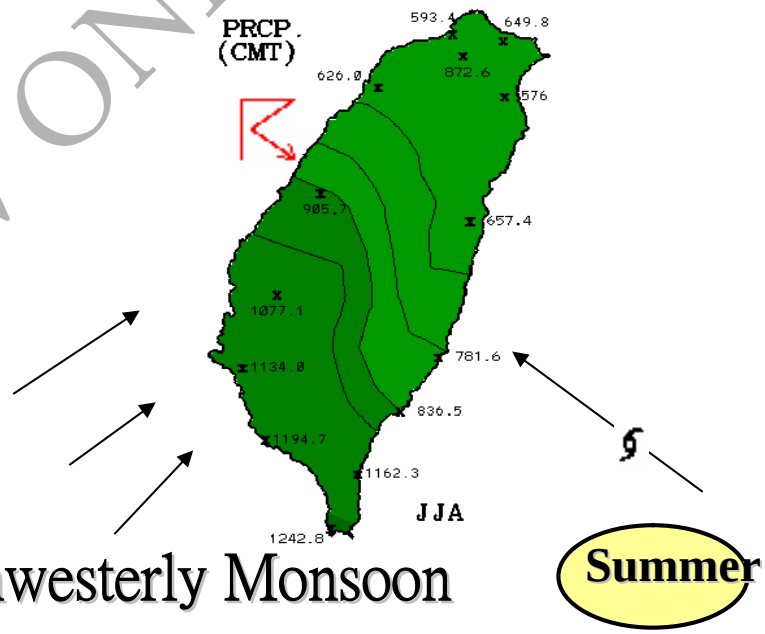
Climate in Taiwan





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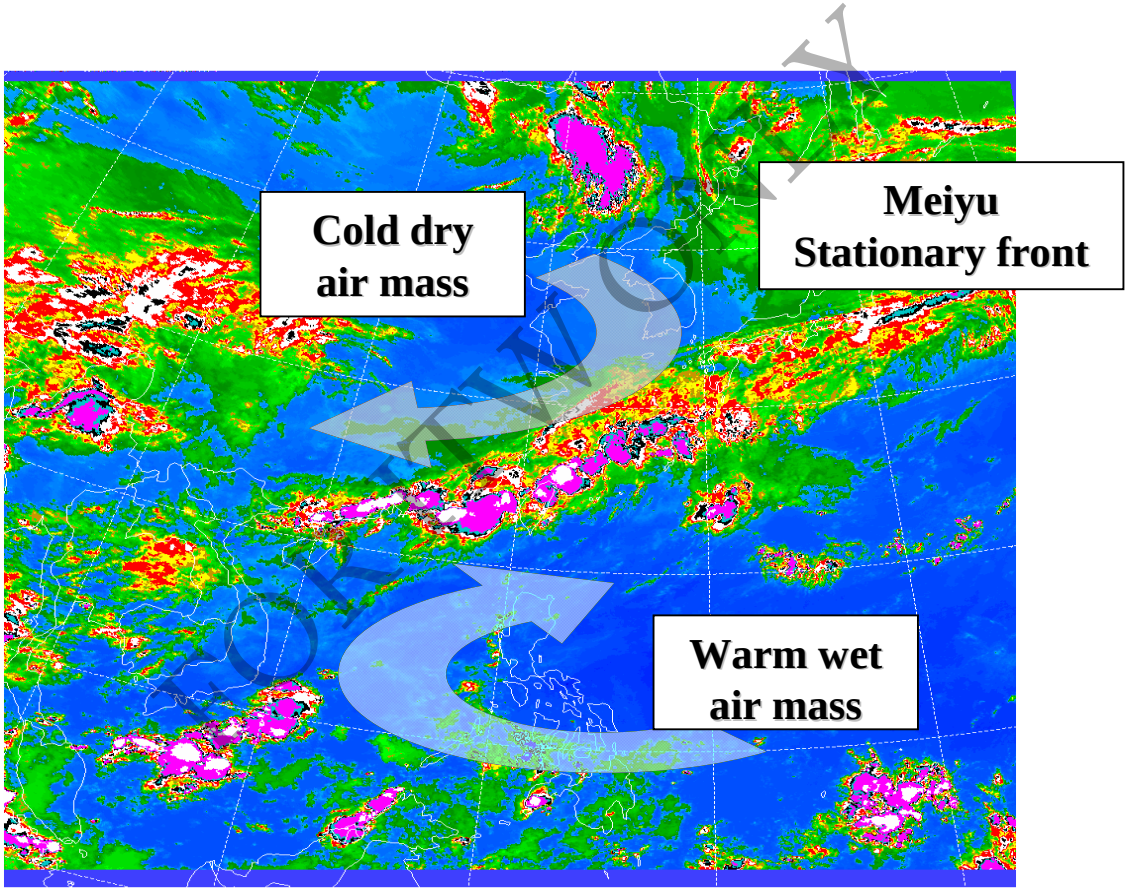
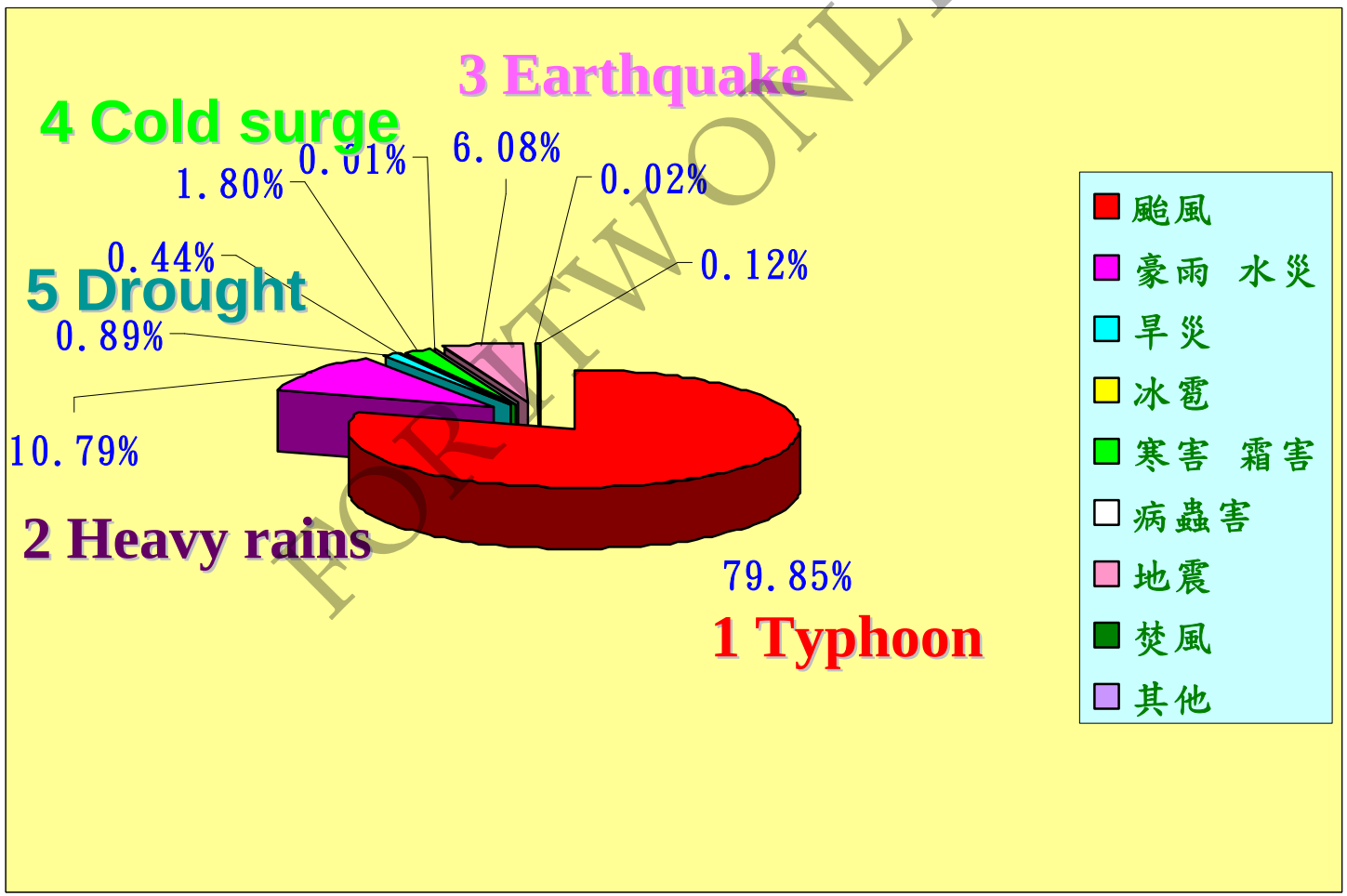


In Spring

Percentage Distribution Among Natural Disaster Losses

Total direct losses due to the Weather and earthquake related disasters from 1985 to 2005 is about NT$ 332 B. (US$ 0.5 B per year)



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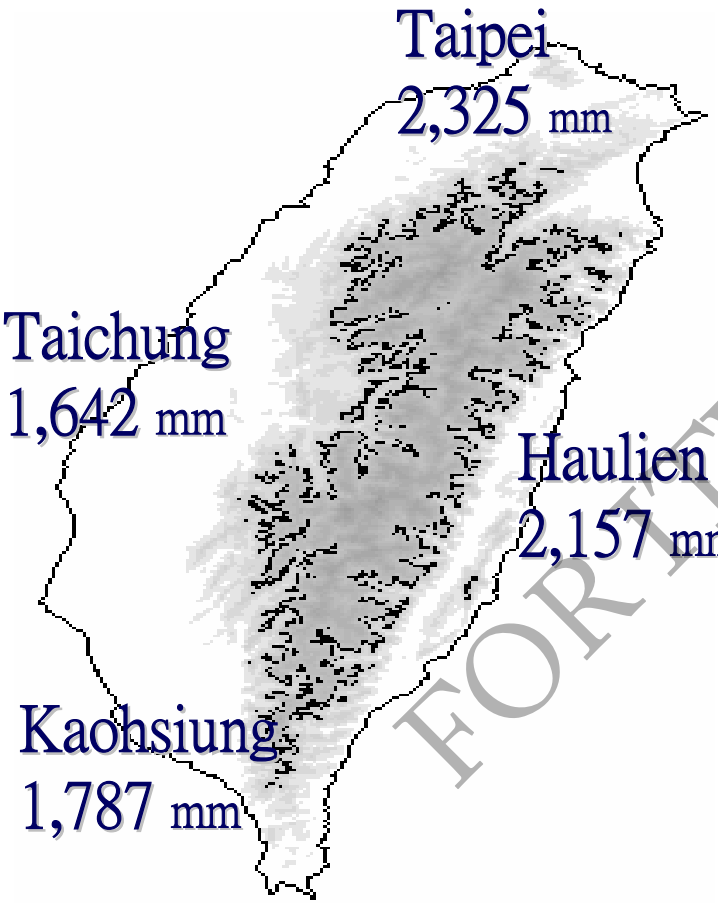
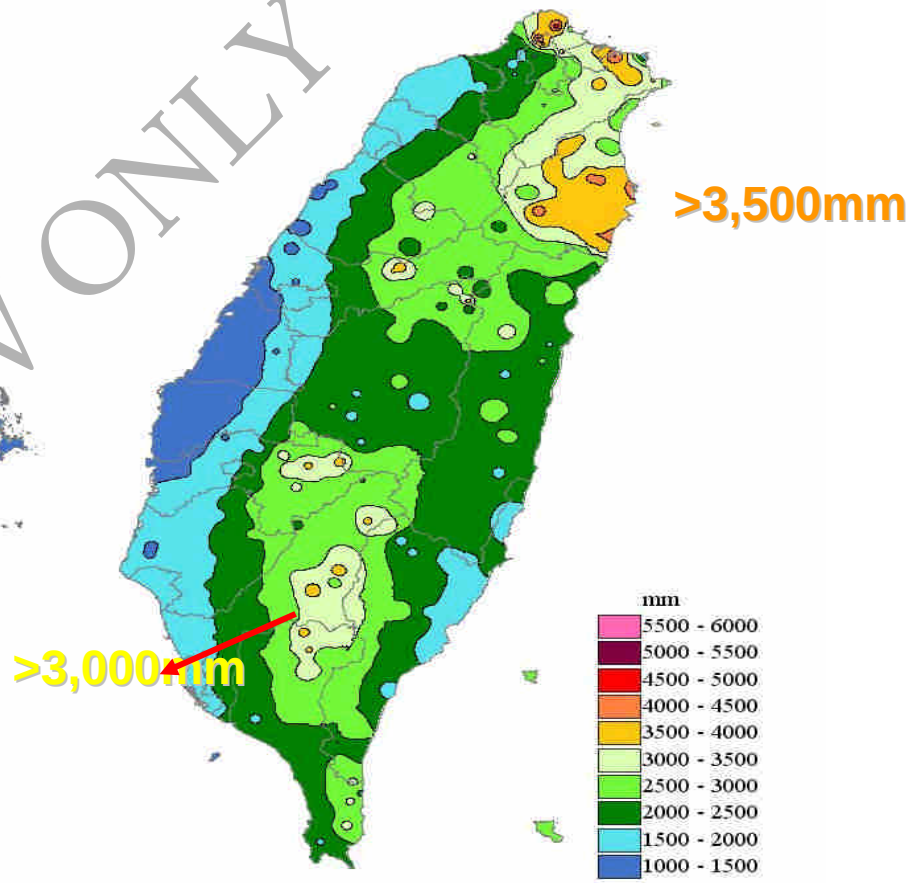
Annual Rainfall



(data period 1971-2000)



(data period 1992-2006)

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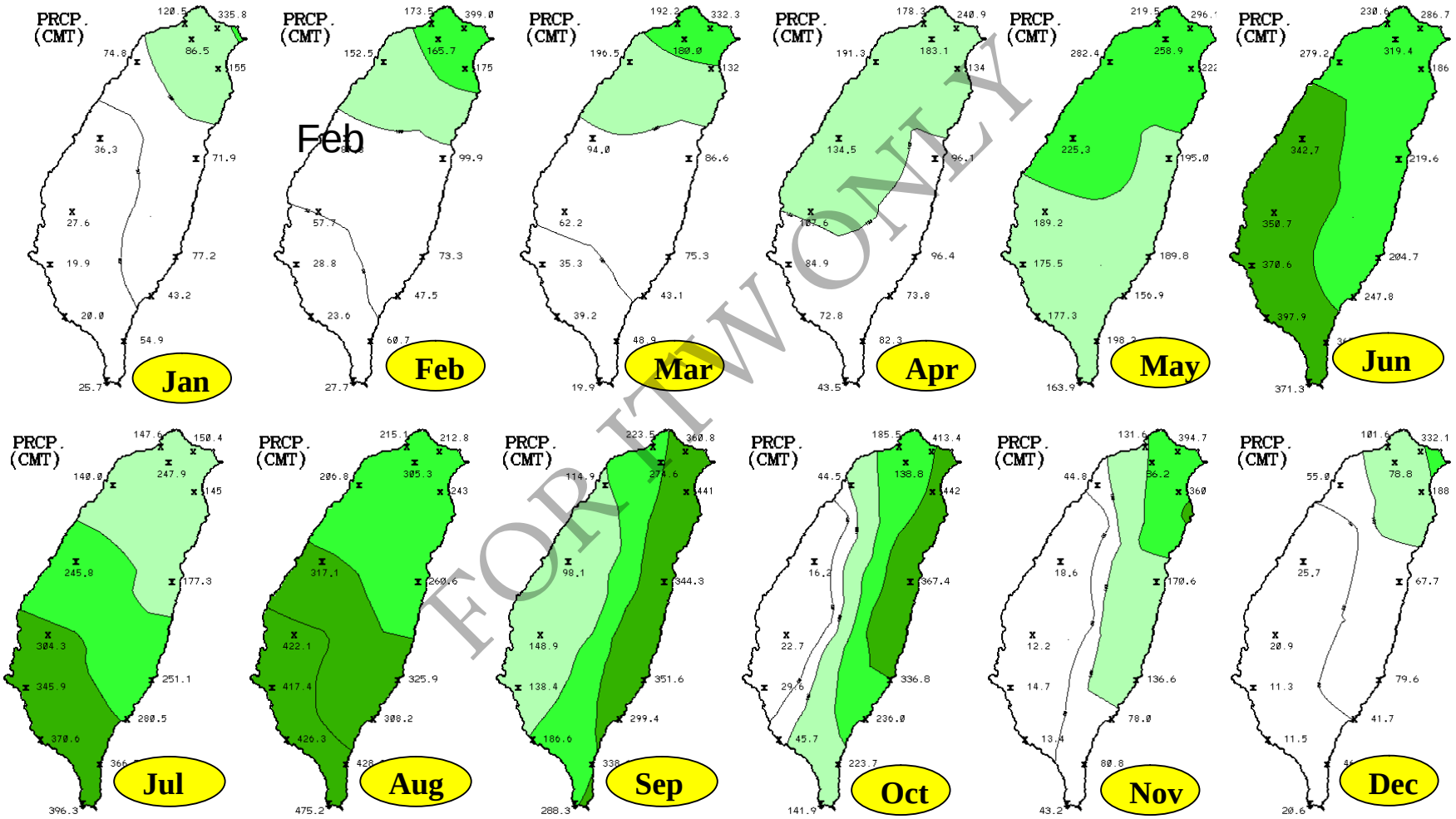
Monthly Rainfall (data period 1971-2000)

Jan



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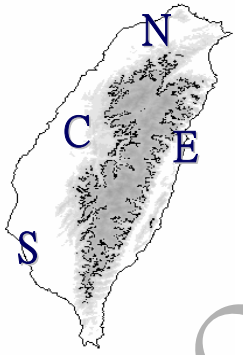
Rainfall Distribution



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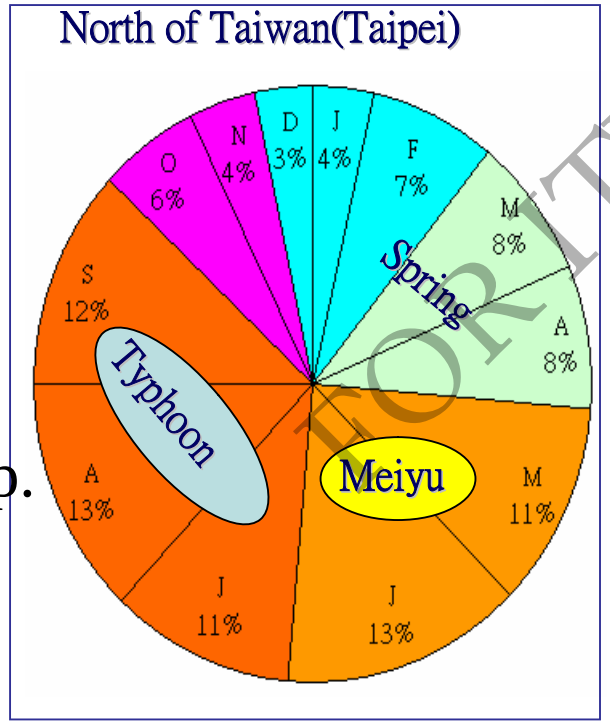
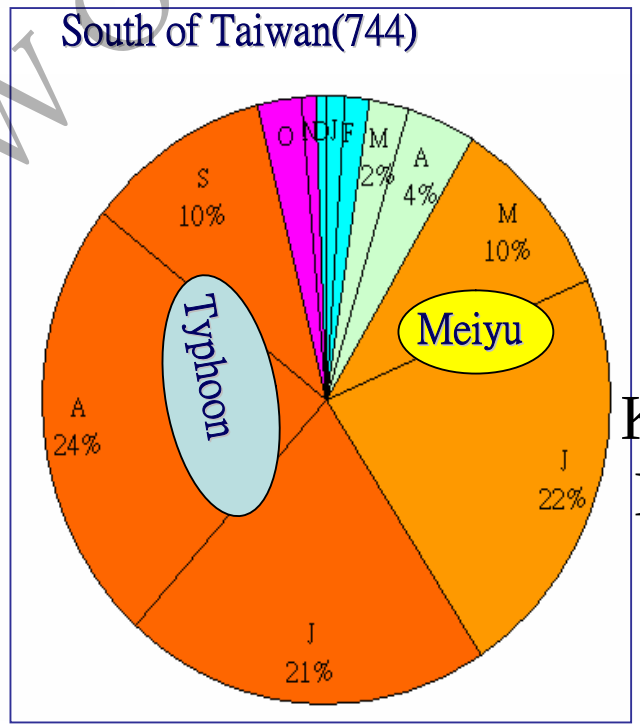
Taipei
May-Sep.
60%





Kaohsiung
May-Sep.
87%

FOR TW ONLY

Typhoon Morakot (2009)

after

before

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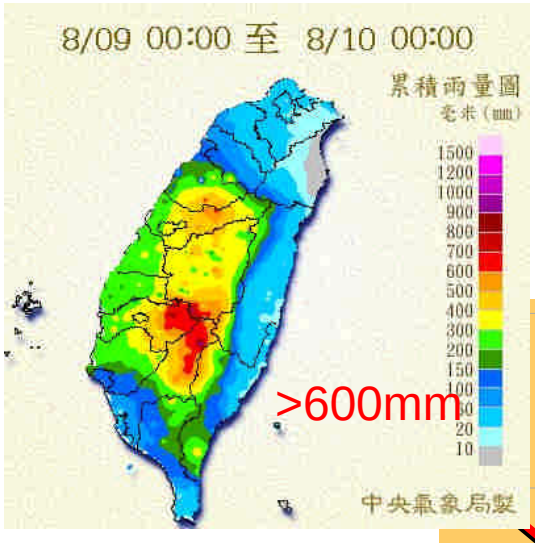
More than 100 houses affected

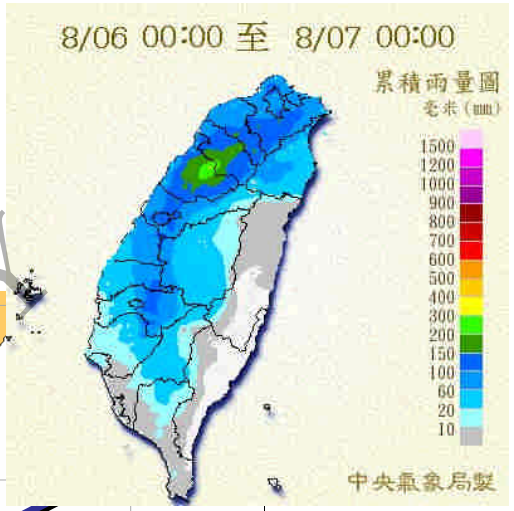
Over all in Taiwan: Evacuated more than 25,000 persons, life losses close to 700.

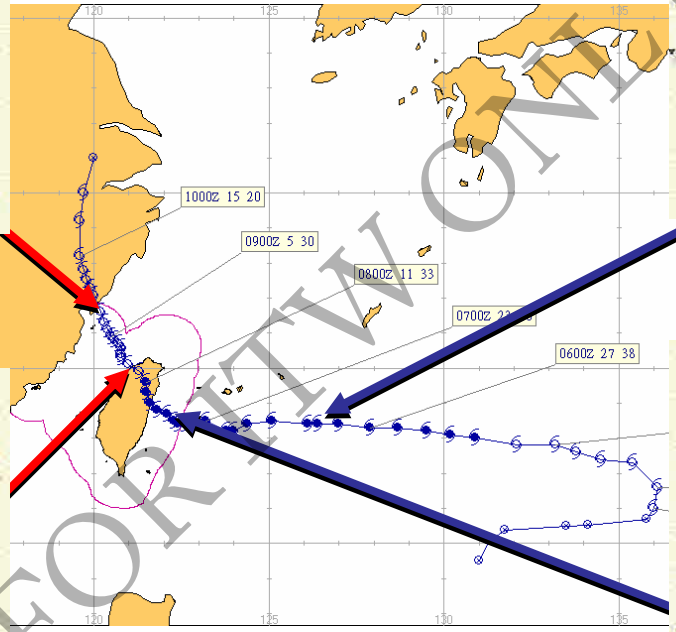
FOR DEMO ONLY

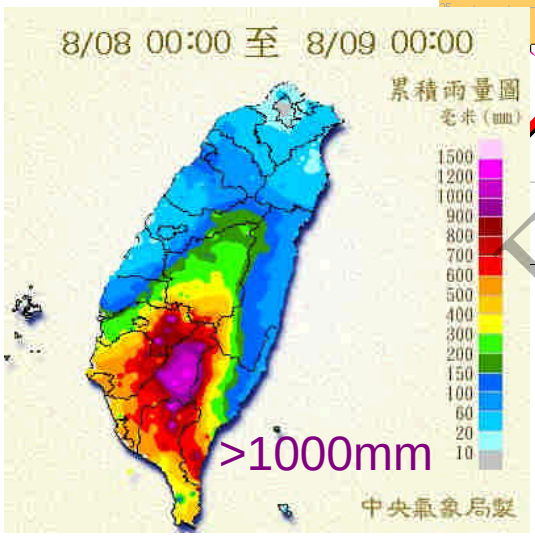
LST=UTC+8



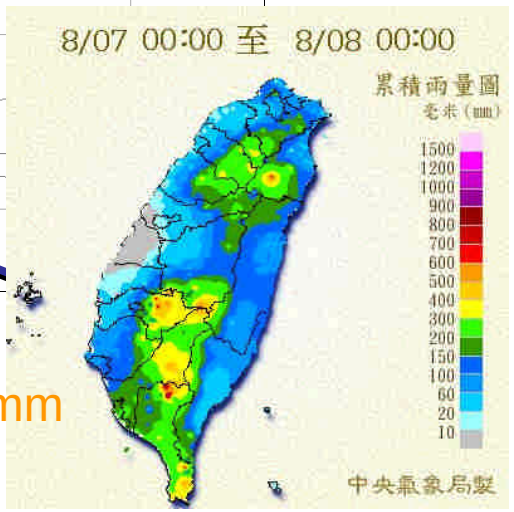
>600mm







>1000mm



>400mm

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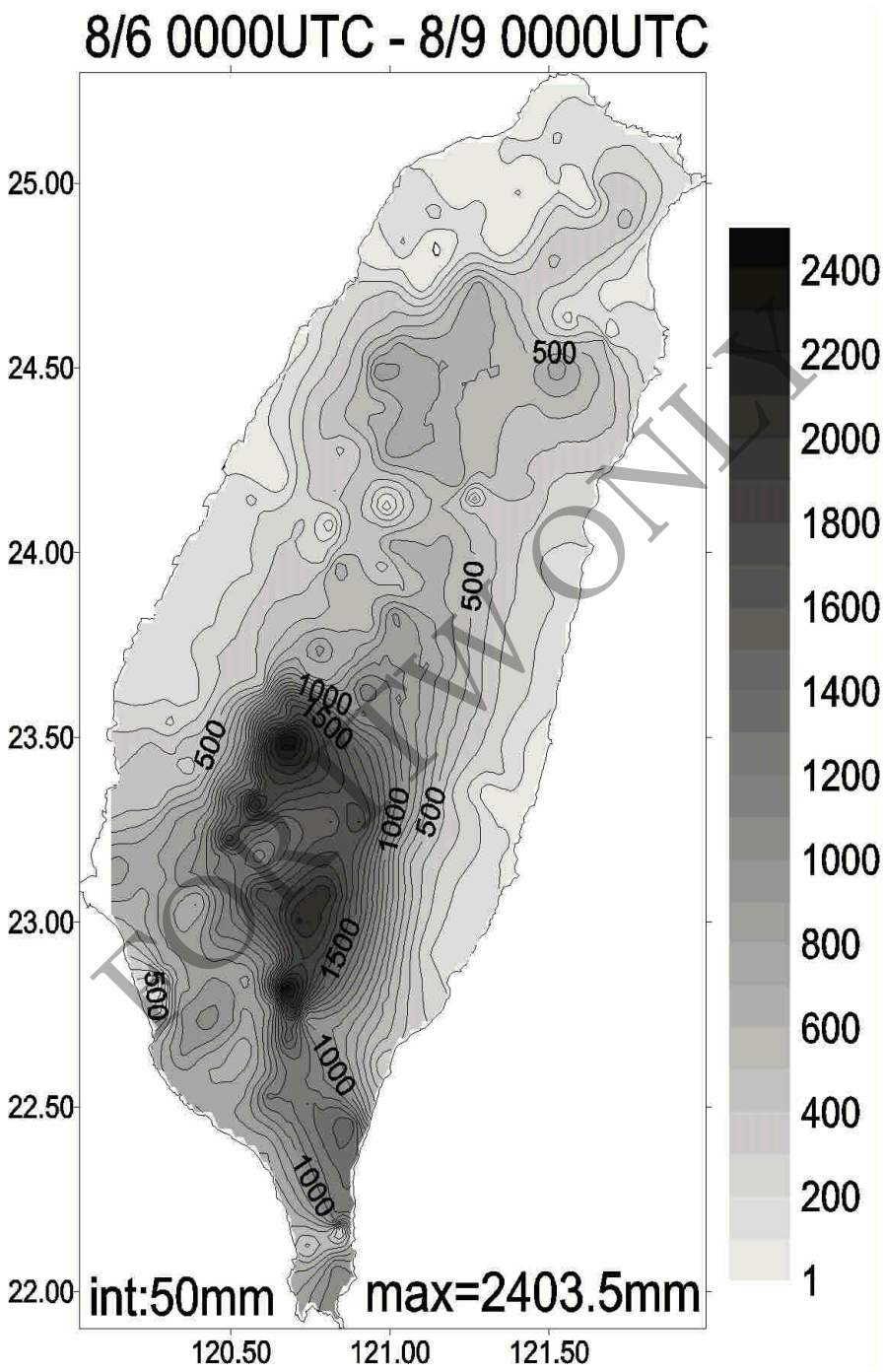
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25.00
24.50
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23.50
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int:50mm
max=2403.5mm
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1
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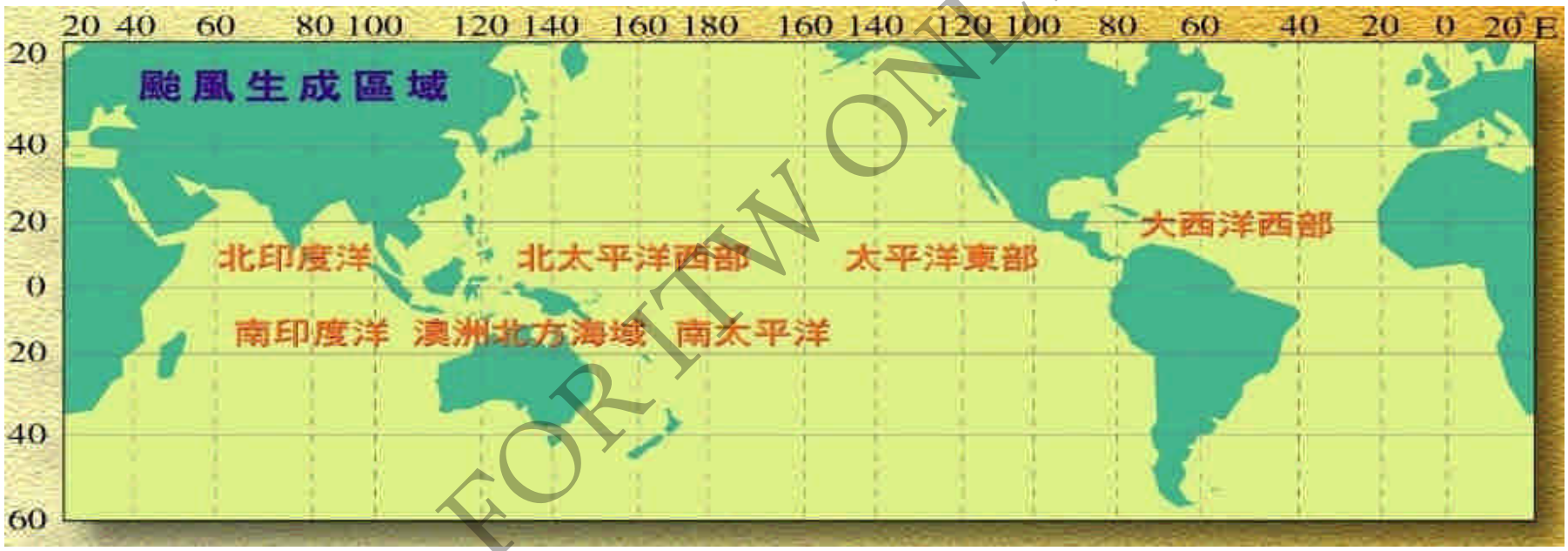
Tropical cyclones (typhoons)



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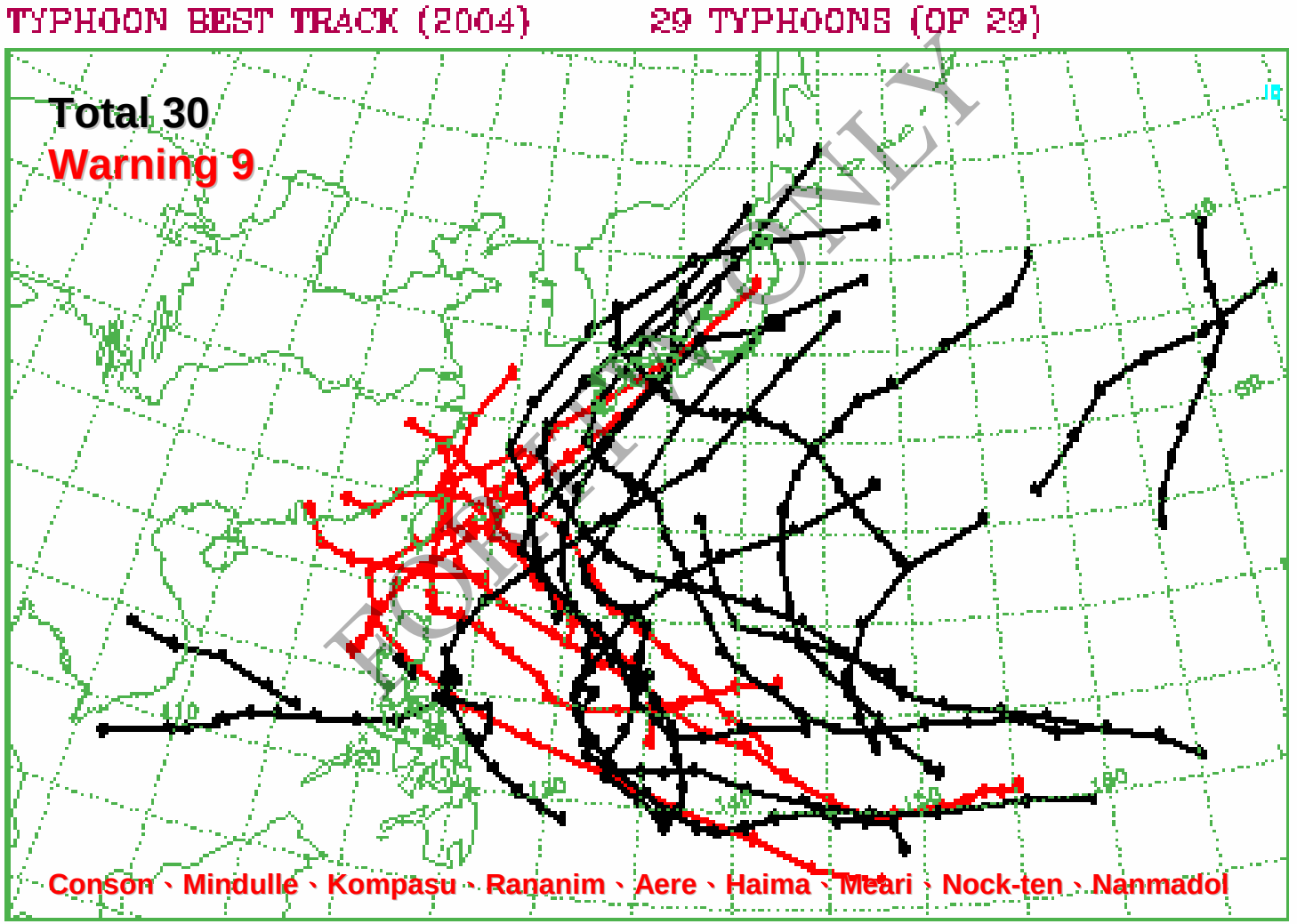
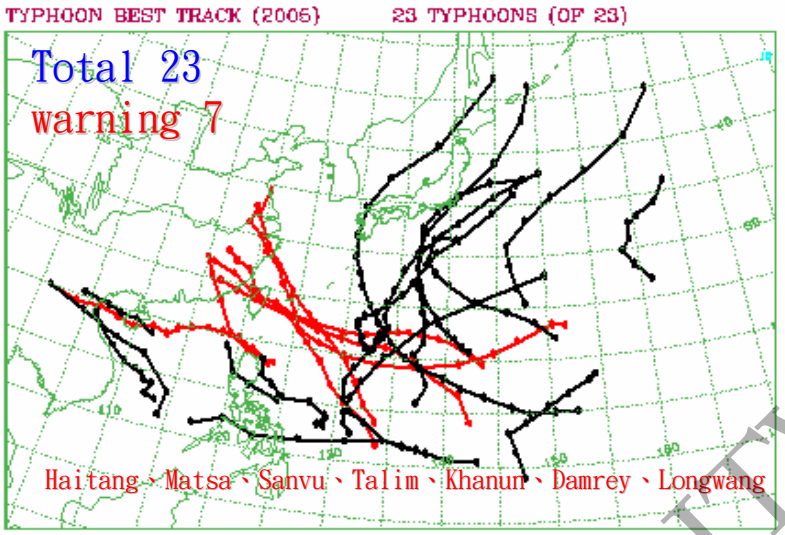
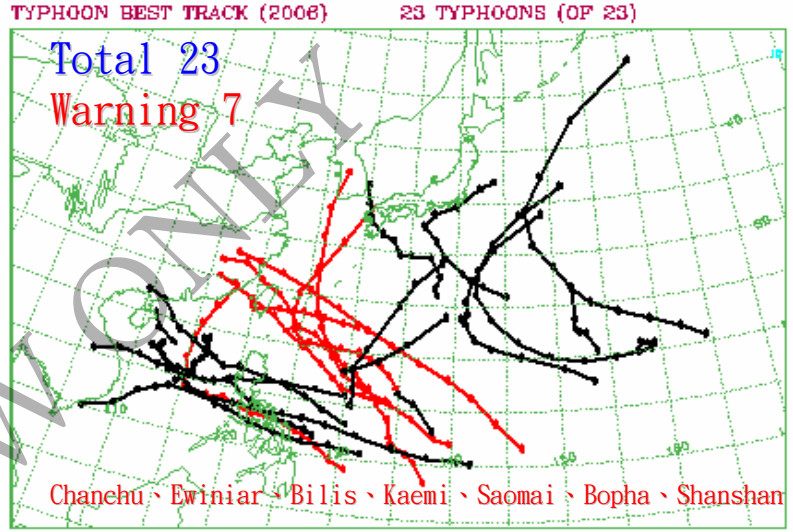
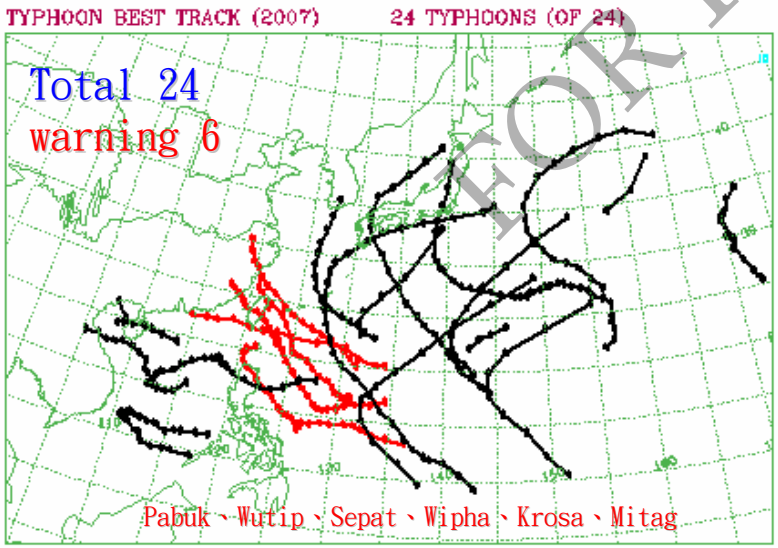
NWP Tropical cyclone tracks 2004

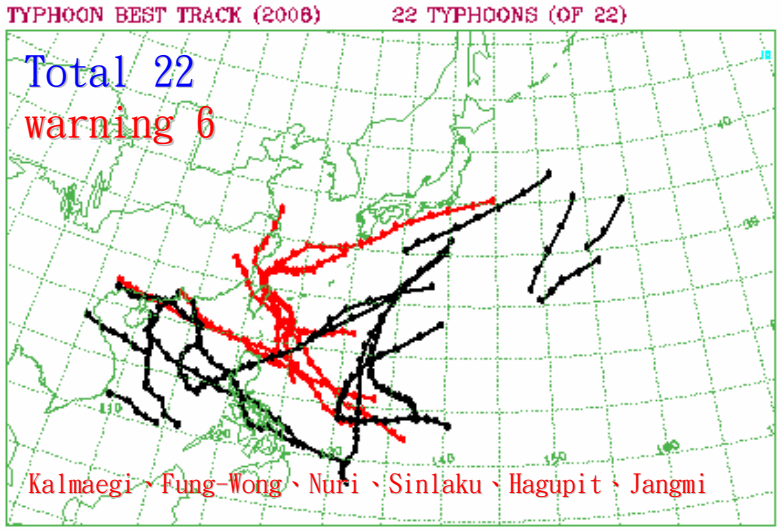


2005-2008 TC tracks
(CWB issued warnings)









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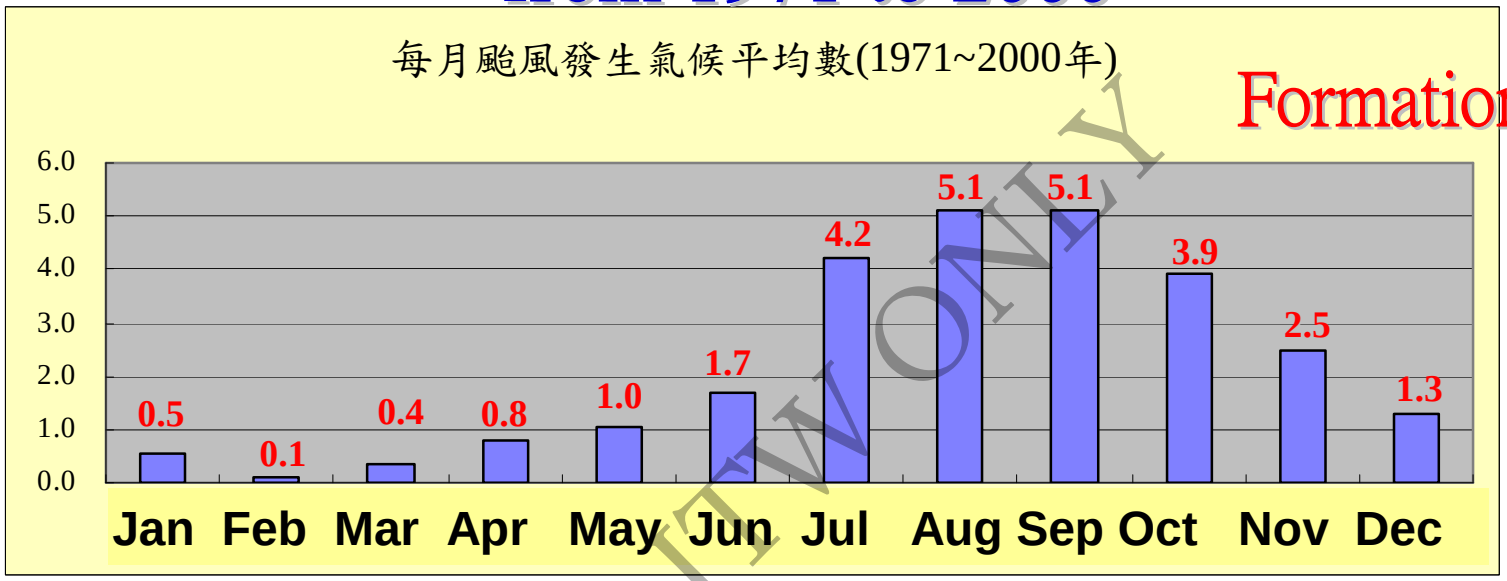
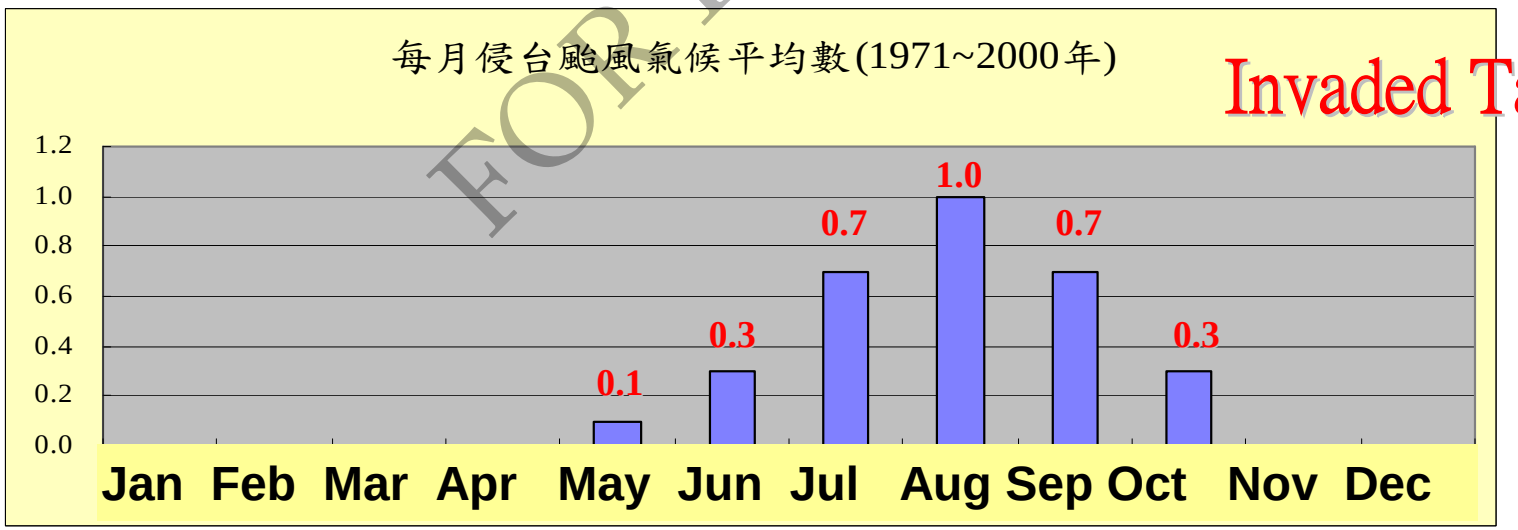
Number of tropical cyclones in NW Pacific ocean from 1971 to 2000



Formation

26.6



Invaded Taiwan

3.1

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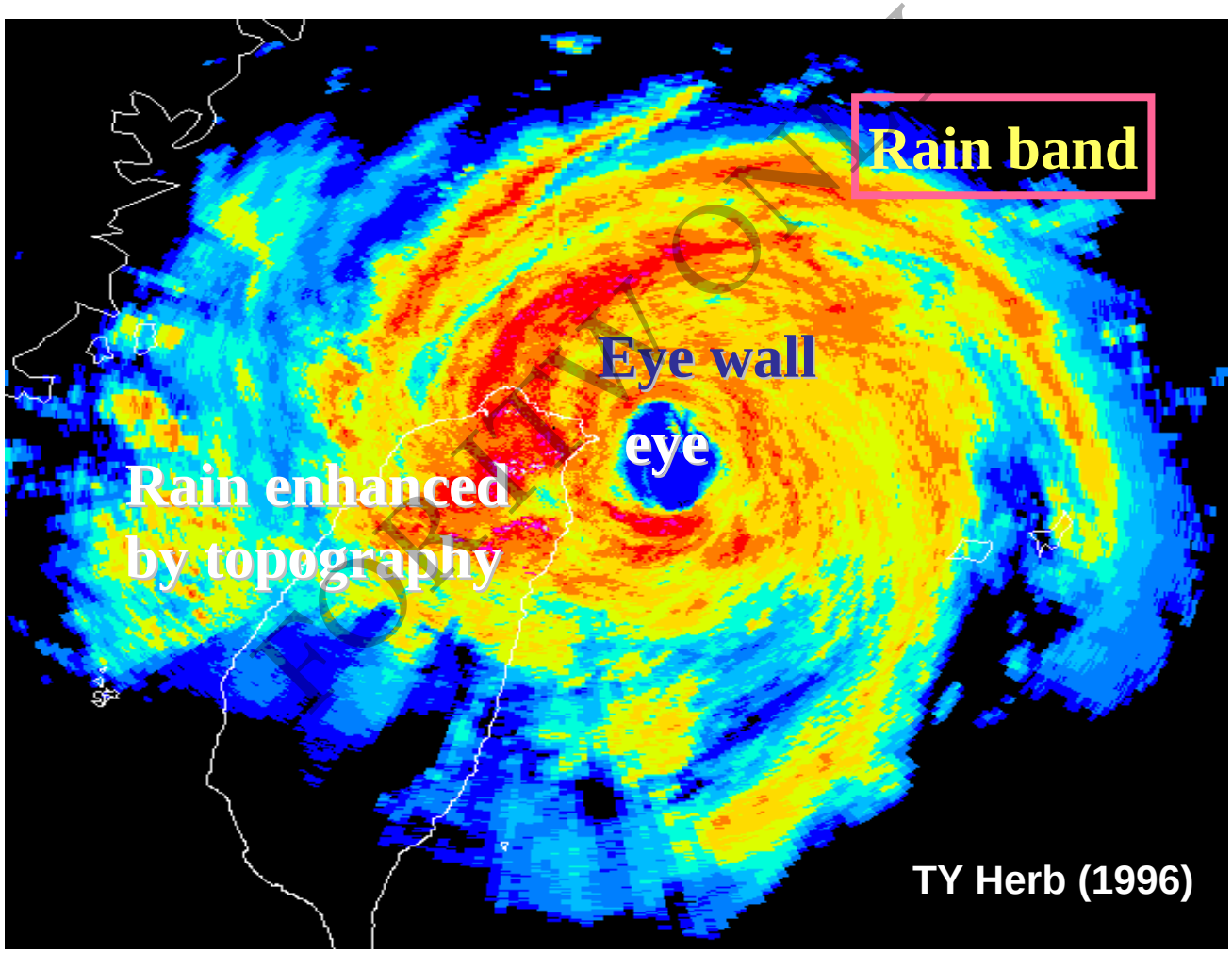
Typhoon Near Taiwan



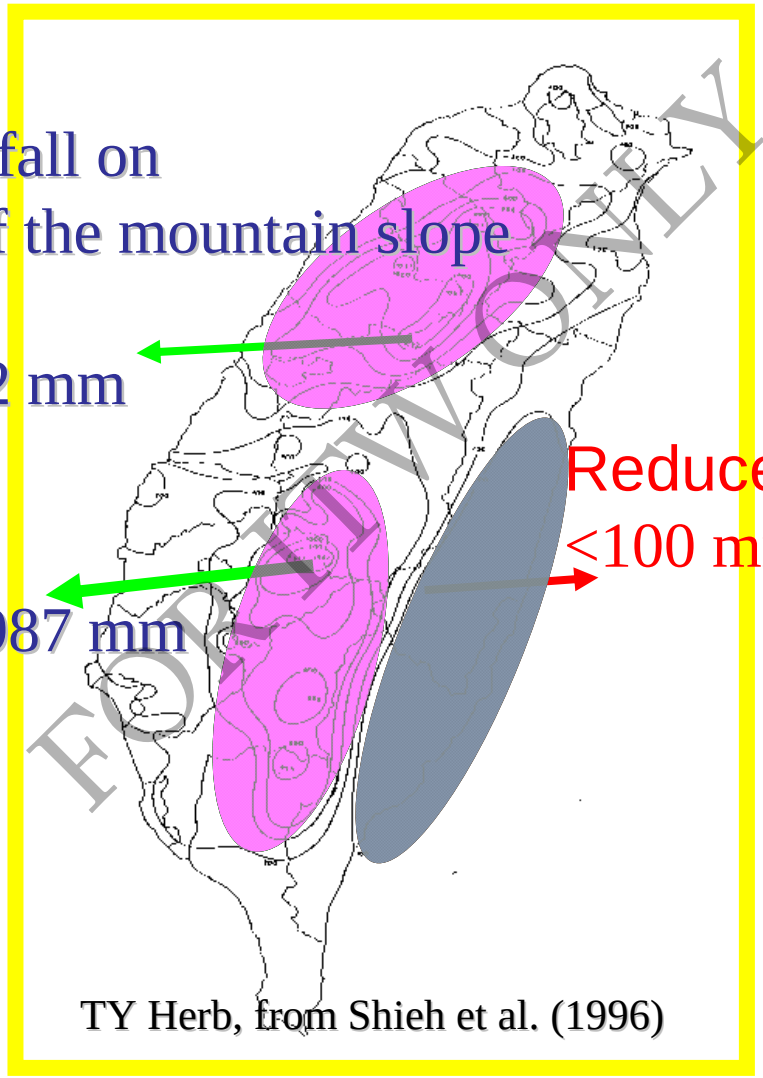
Terrain redistributes tropical cyclone rainfall

Enhanced rainfall on
upwind side of the mountain slope

Max:1,082 mm

Max:1,987 mm

Reduced rainfall on leeside
<100 mm



TY Herb, from Shieh et al. (1996)

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Torrential rains associating with tropical cyclones

Liao (1960) showed that there were more than 20 tropical cyclones that each caused more than 700 mm rainfall in Taiwan from 1911 to 1959.

-- experienced a very heavy rainfall event per 2-year.

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Damages caused by torrential rains of typhoon

FOR FM ONLY

Damages caused by torrential rains of typhoon

FOR REVIEW ONLY

Damages caused by strong winds of TY Longwang (2005)

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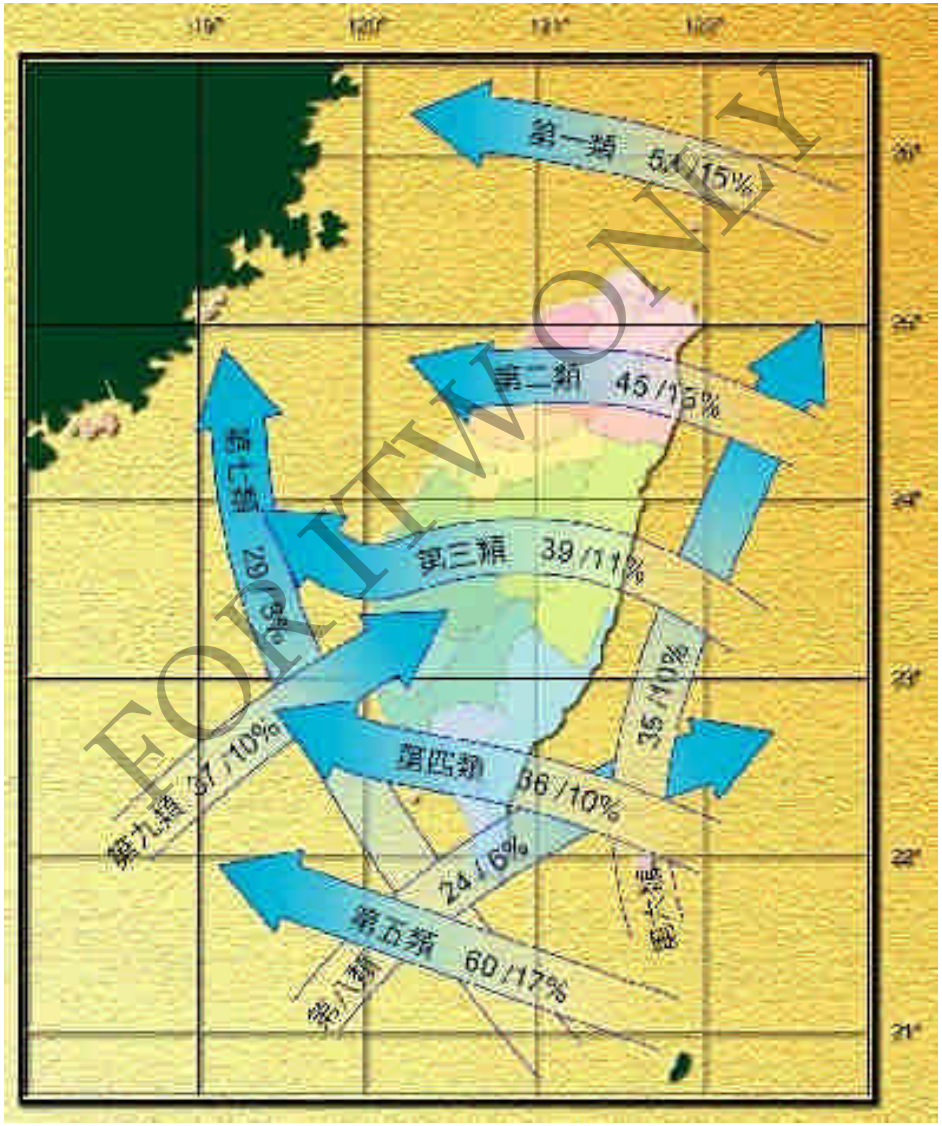
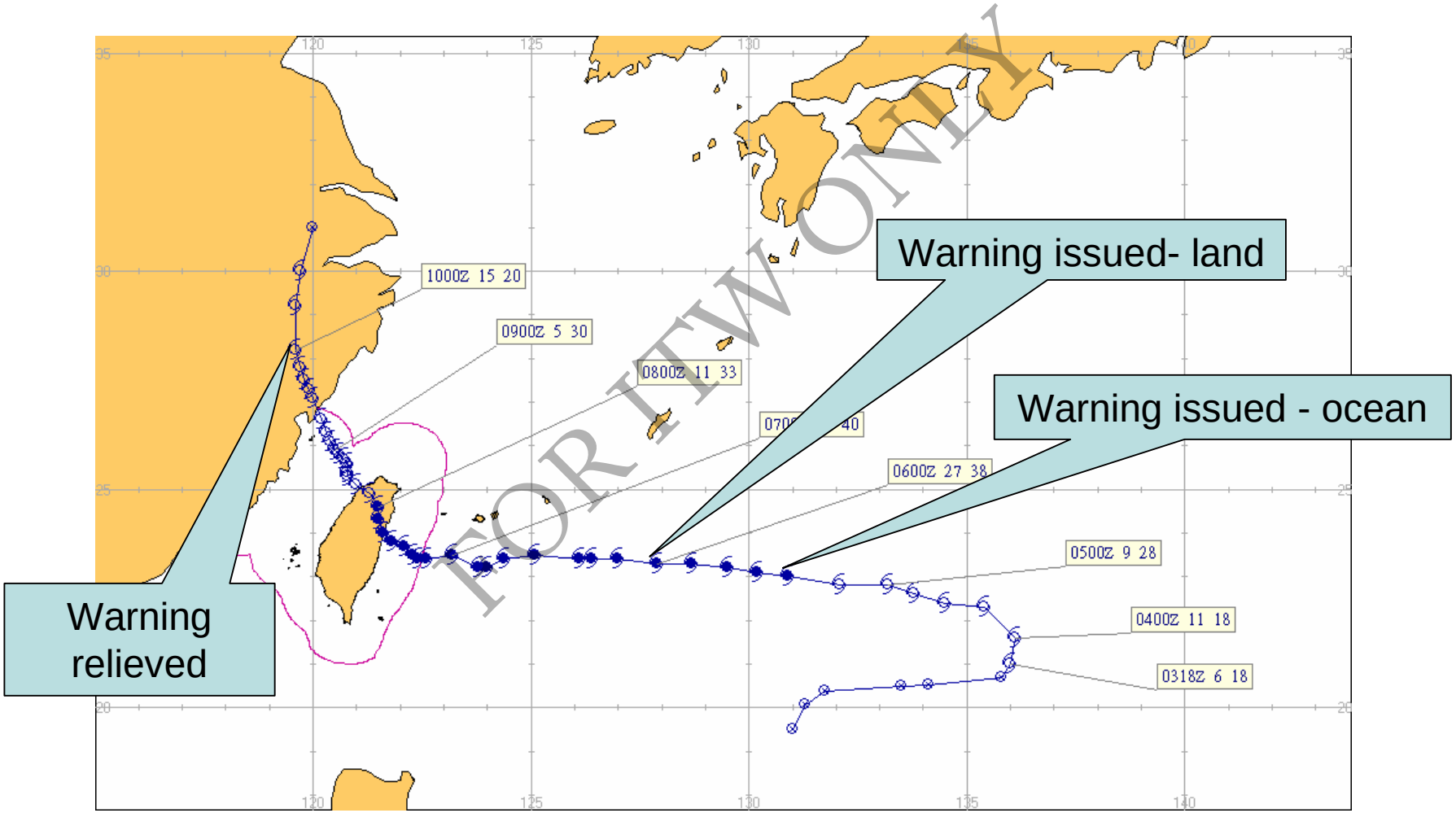
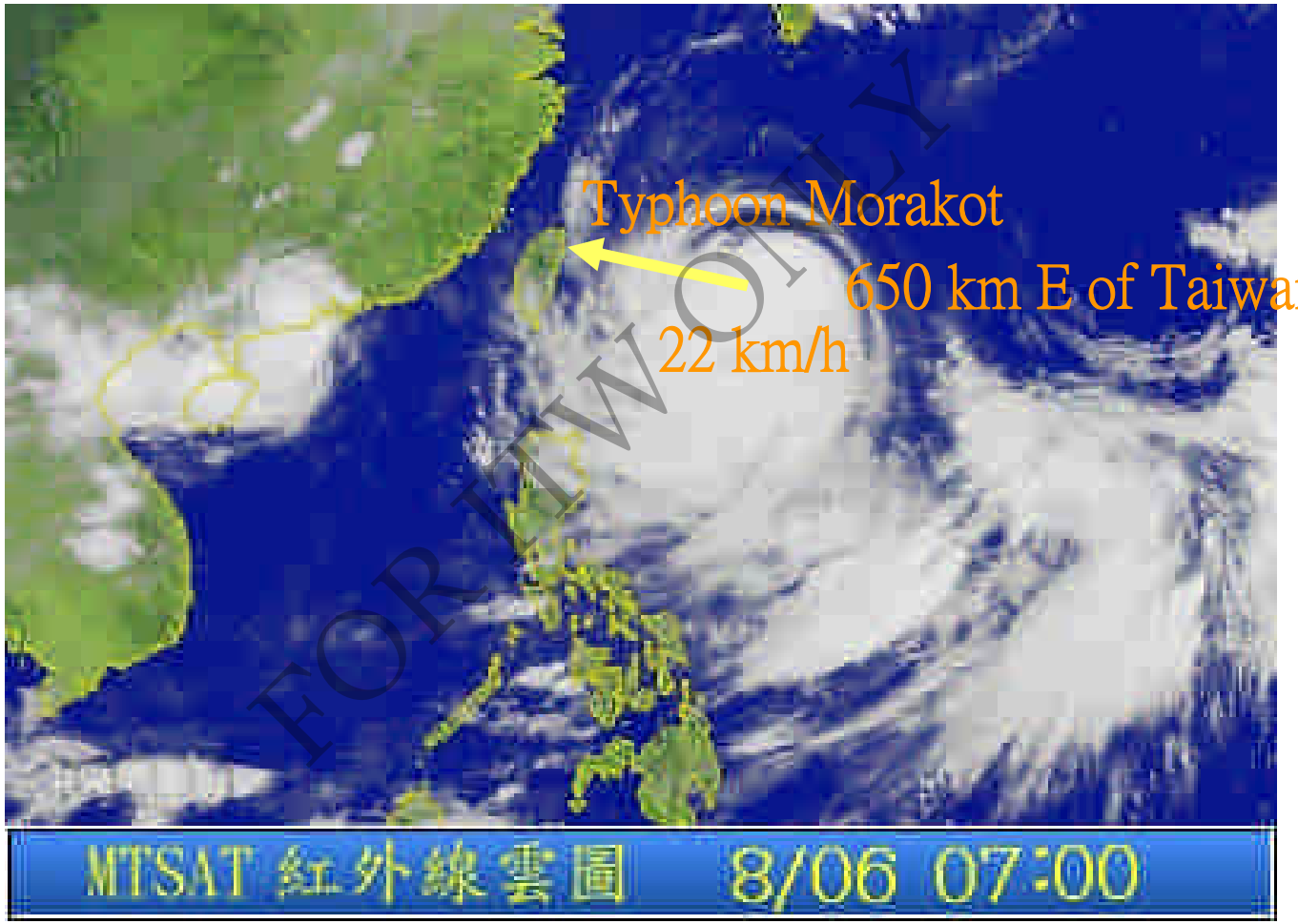
Major track types of tropical cyclones invaded Taiwan



Typhoon Morakot (2009)





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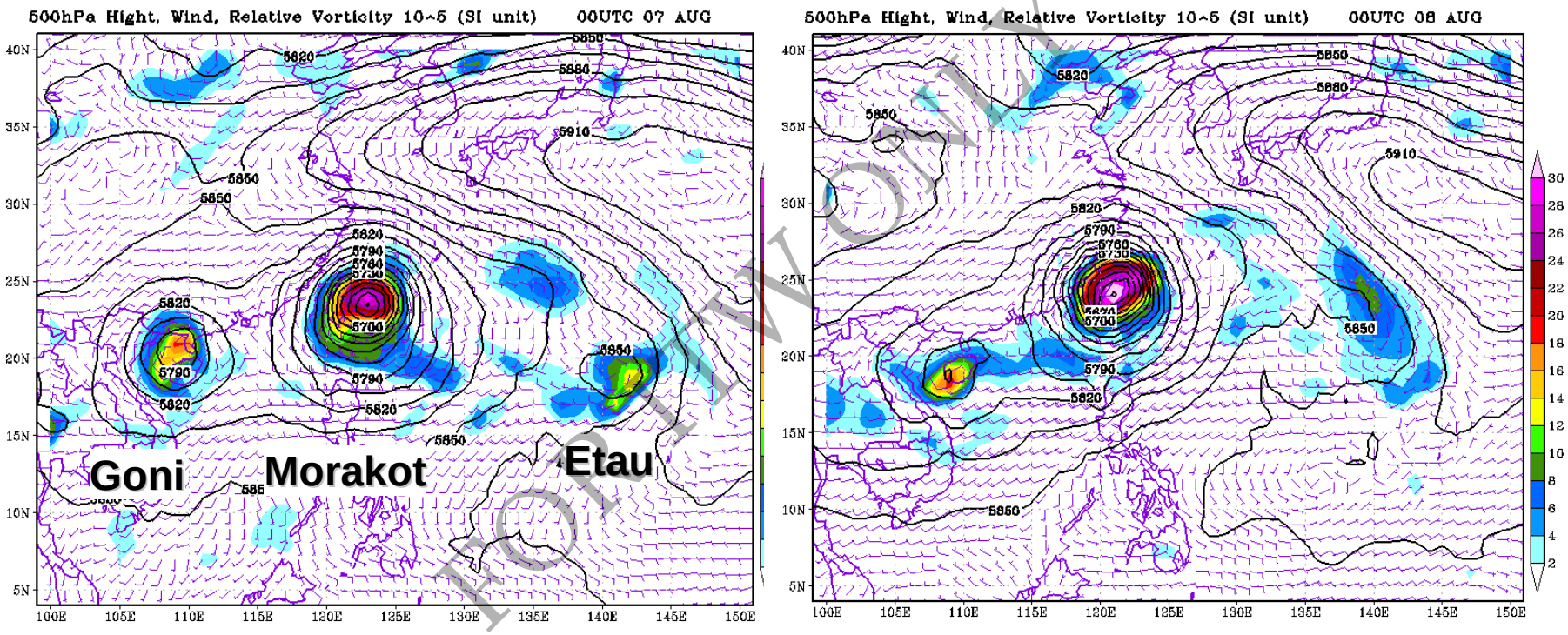
500 hPa analyses (geopotential height/winds/vorticity)

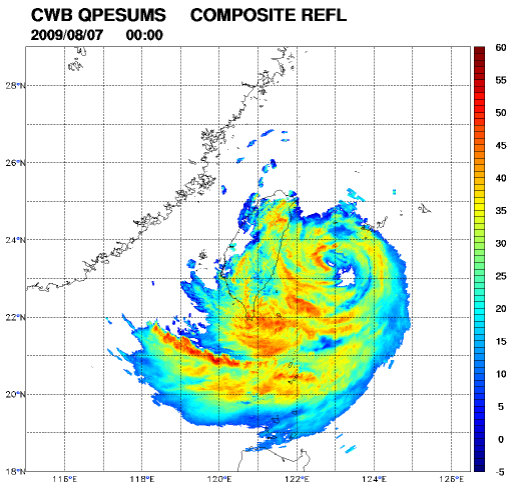


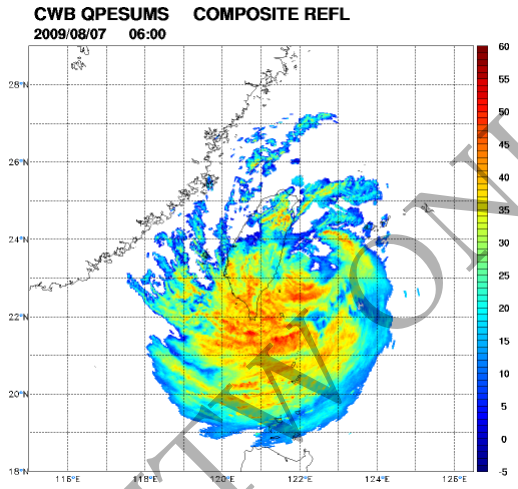
2009/10/07 08:00 **2009/10/08 08:00**

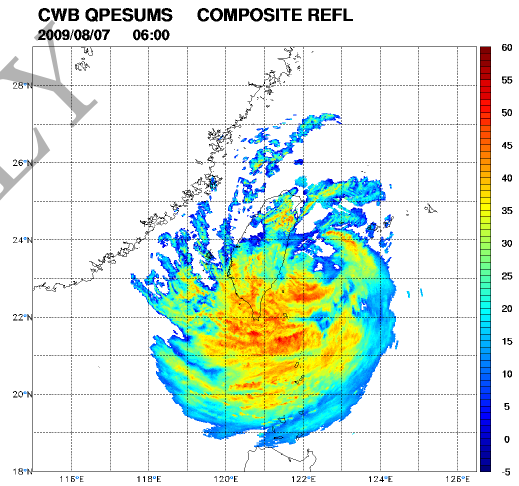
Jou et al.

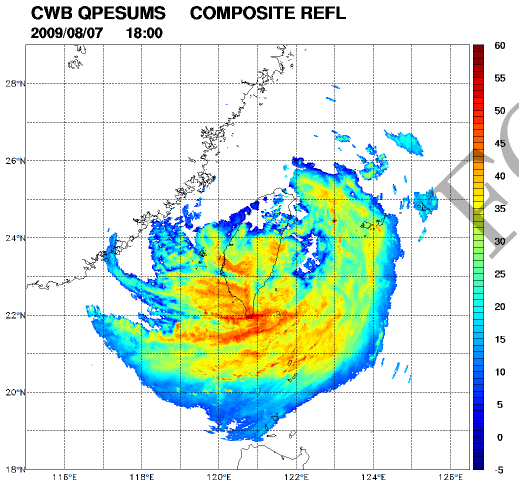
FOR ITW ONLY

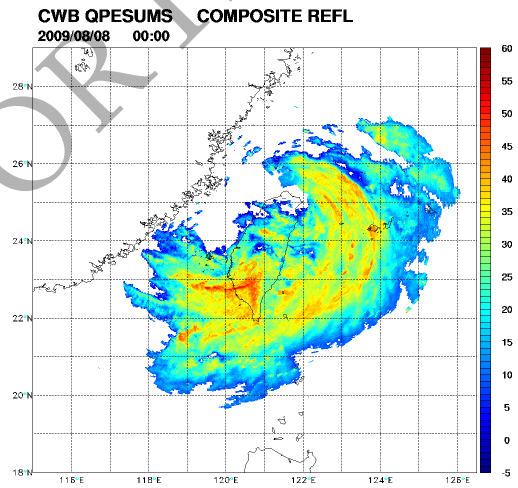
Reflectivity 2009/08/07 00UTC--2009/08/08 12UTC

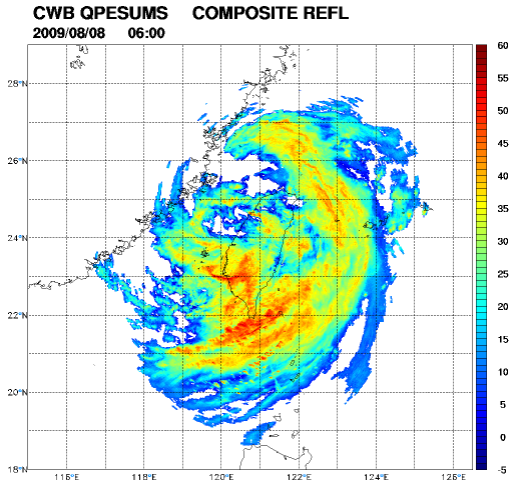






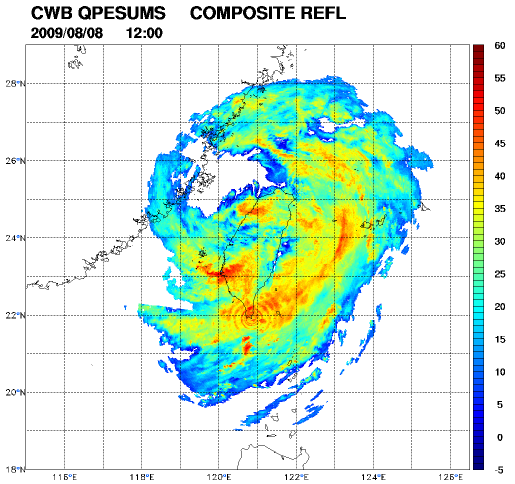


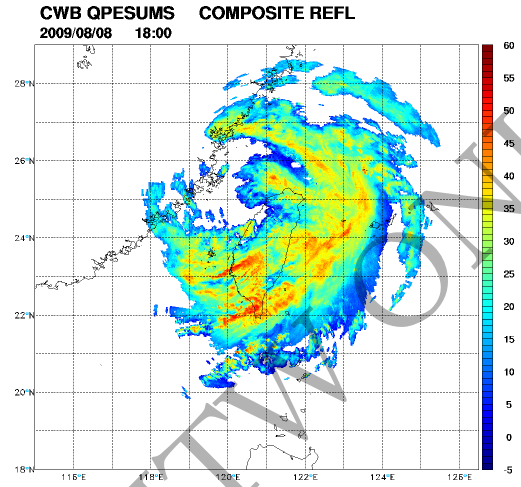


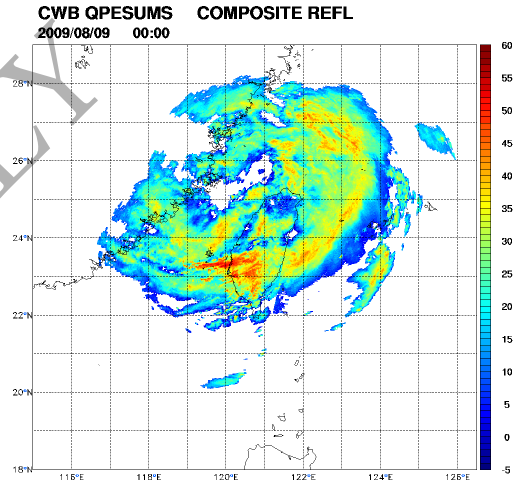


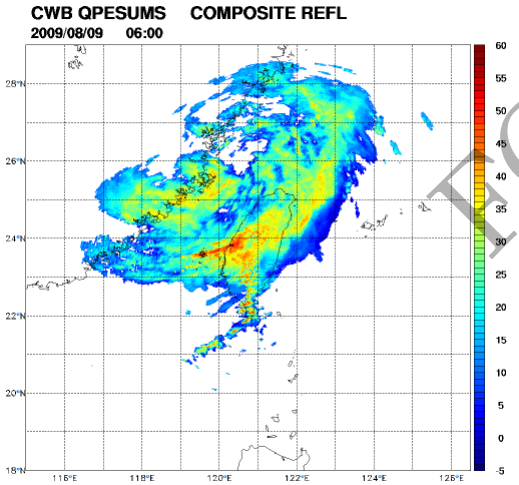
FOR ITWO ONLY

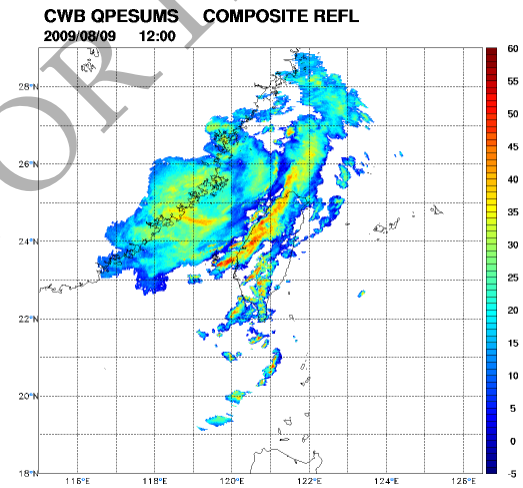
Reflectivity 2009/08/08 18UTC--2009/08/09 12UTC

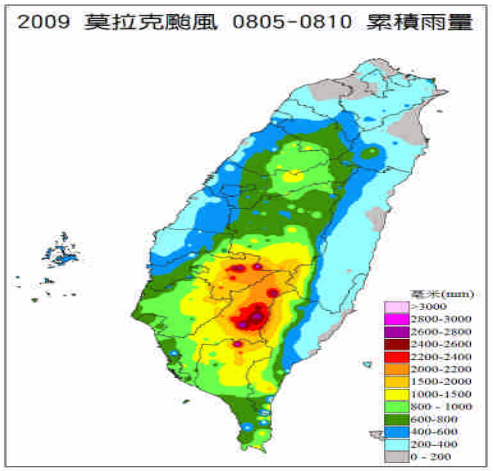












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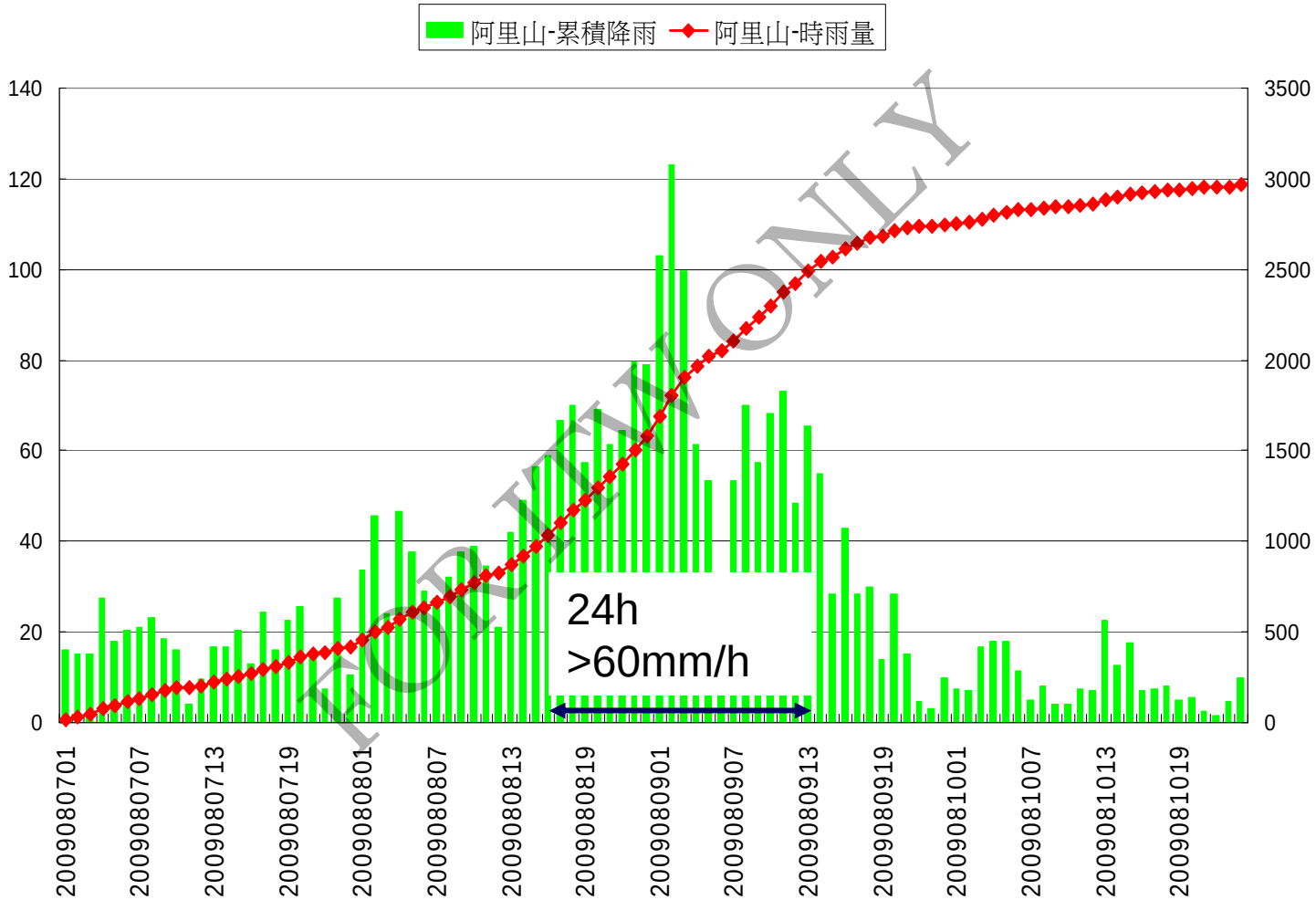
Hourly and accumulated rainfall at Central Taiwan (Alisam)



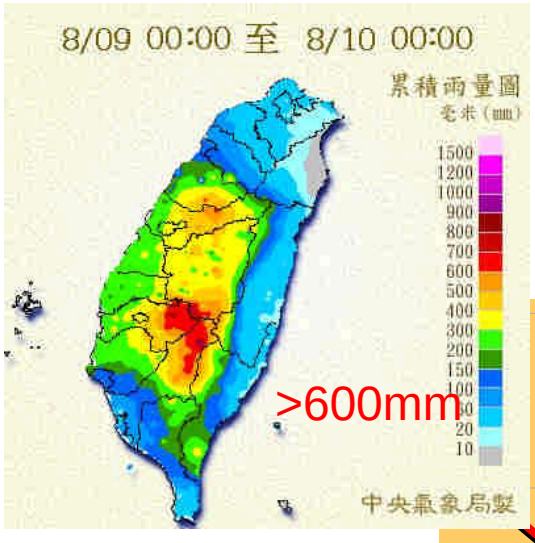
FOR REVIEW ONLY

Top-10s of daily rainfall in Taiwan

rank	station	Date(Y/M/D)	Daily rainfall	typhoons
1	尾寮山	2009/08/08	1402.0	Morakot
2	溪南	2009/08/08	1301.5	Morakot
3	御油山	2009/08/08	1283.0	Morakot
4	布洛灣	1997/08/29	1222.5	Amber
5	馬頭山	2009/08/08	1213.5	Morakot
6	新發	2009/08/08	1190.0	Morakot
7	奮起湖	2009/08/08	1185.5	Morakot
8	石磐龍	2009/08/08	1182.0	Morakot
9	瑪家	2009/08/08	1181.0	Morakot
10	小關山	2009/08/08	1178.0	Morakot

FOR ITW ONLY

LST=UTC+8



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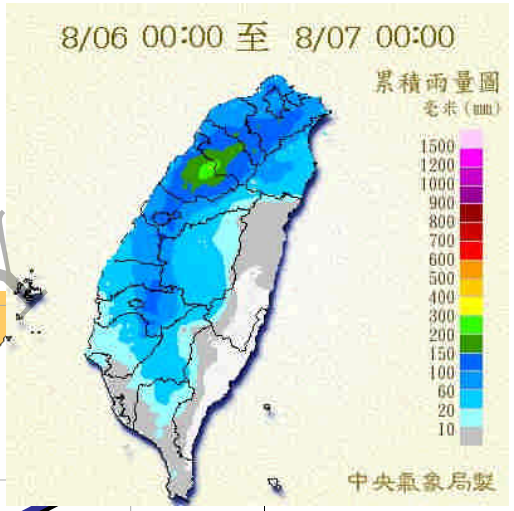

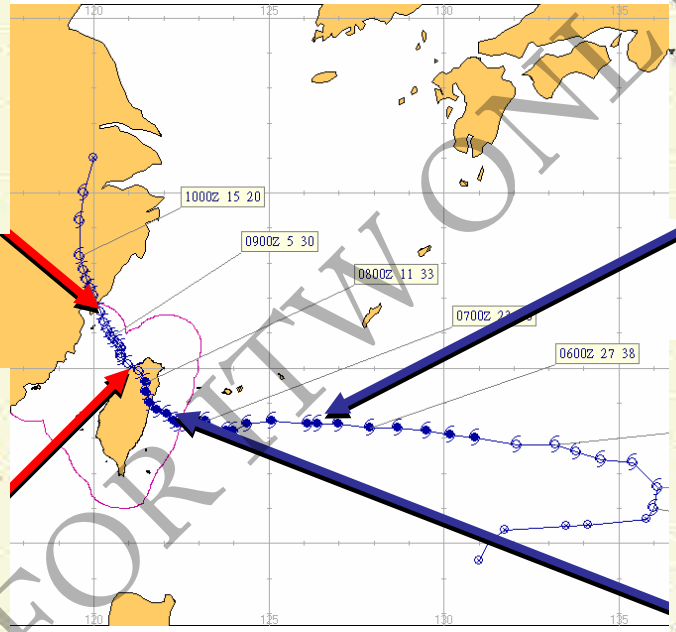

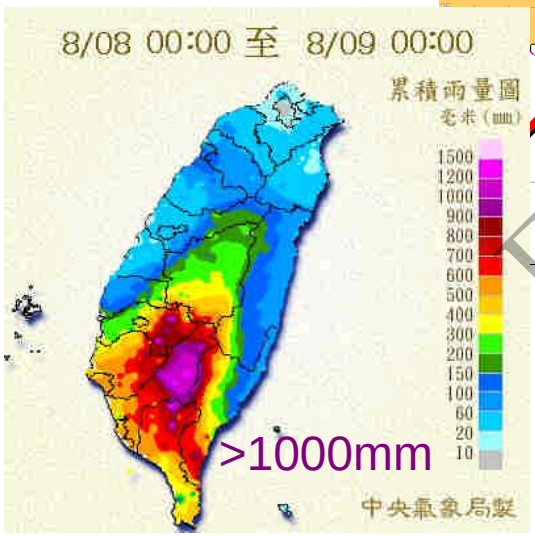

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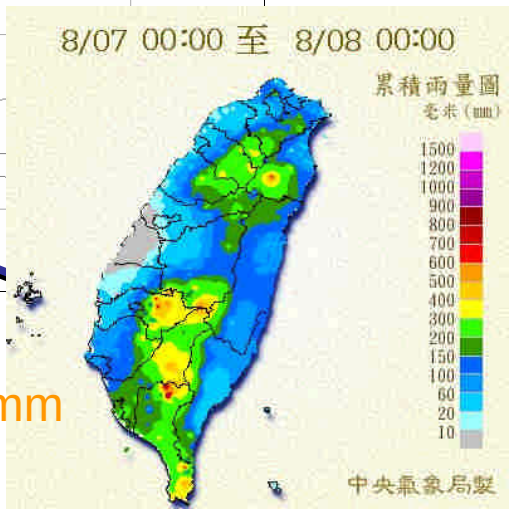

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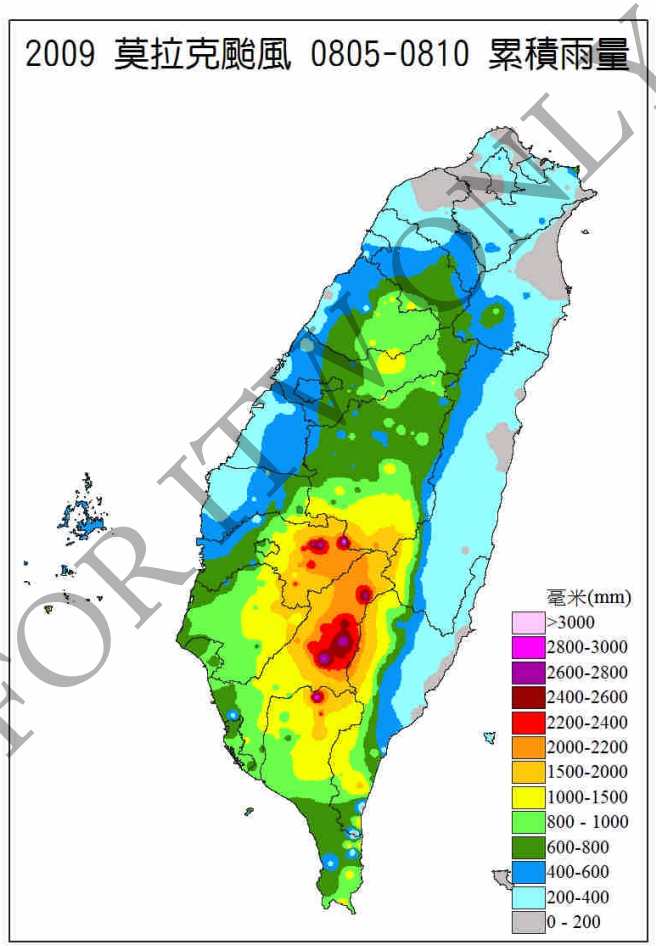
FOR ITW ONLY


2009 莫拉克颱風 0805-0810 累積雨量
毫米(mm)
>3000
2800-3000
2600-2800
2400-2600
2200-2400
2000-2200
1500-2000
1000-1500
800 - 1000
600-800
400-600
200-400
0 - 200

FOR ITW ONLY

Tropical Cyclone Warnings

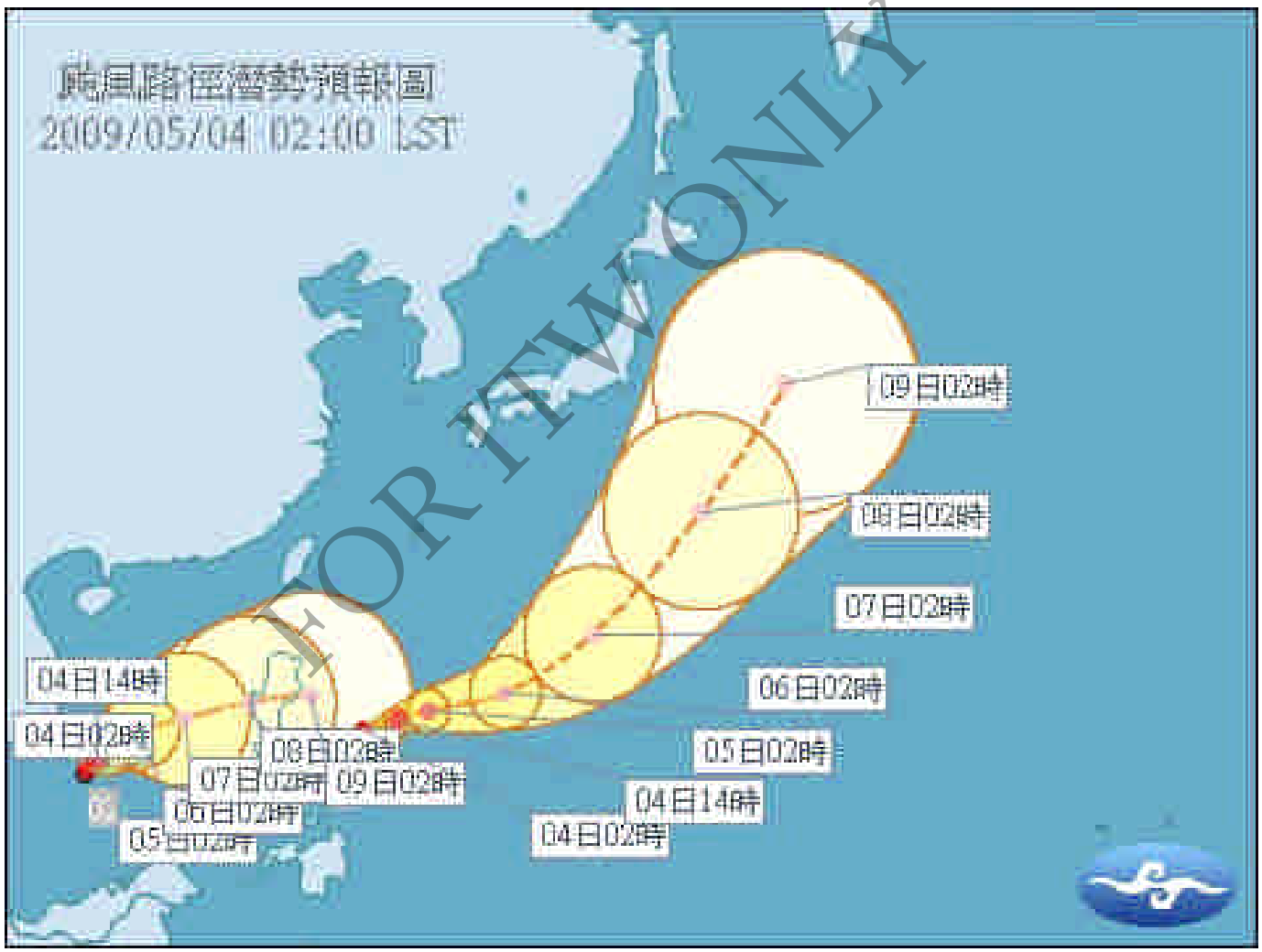
Provided every 3-hour

Update center location every hour during inland warnings

Includes current location, intensity, rainfall, 24-hour forecasted center location, trend of intensity change, probability track forecast, warning area, and remarks.

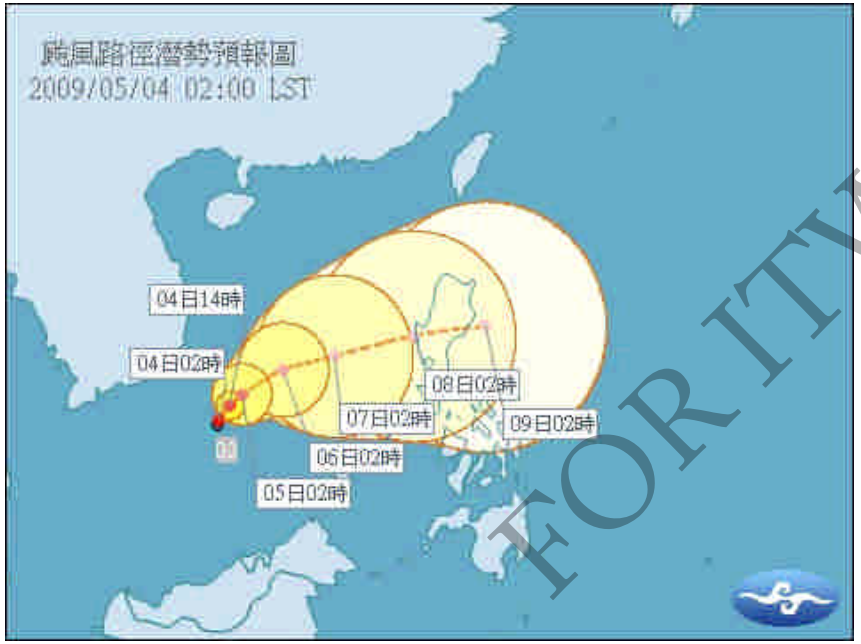
FOR TTN ONLY

An example of the 5 days track forecast

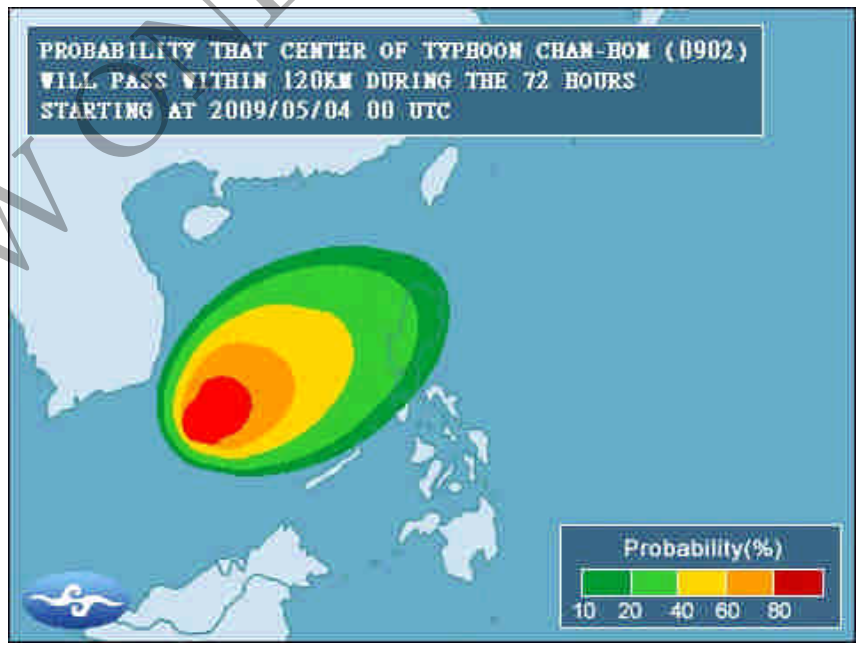


FOR ITW ONLY

An example of the probability forecast



5 days center location



72 hours strike probability

FOR ITW ONLY

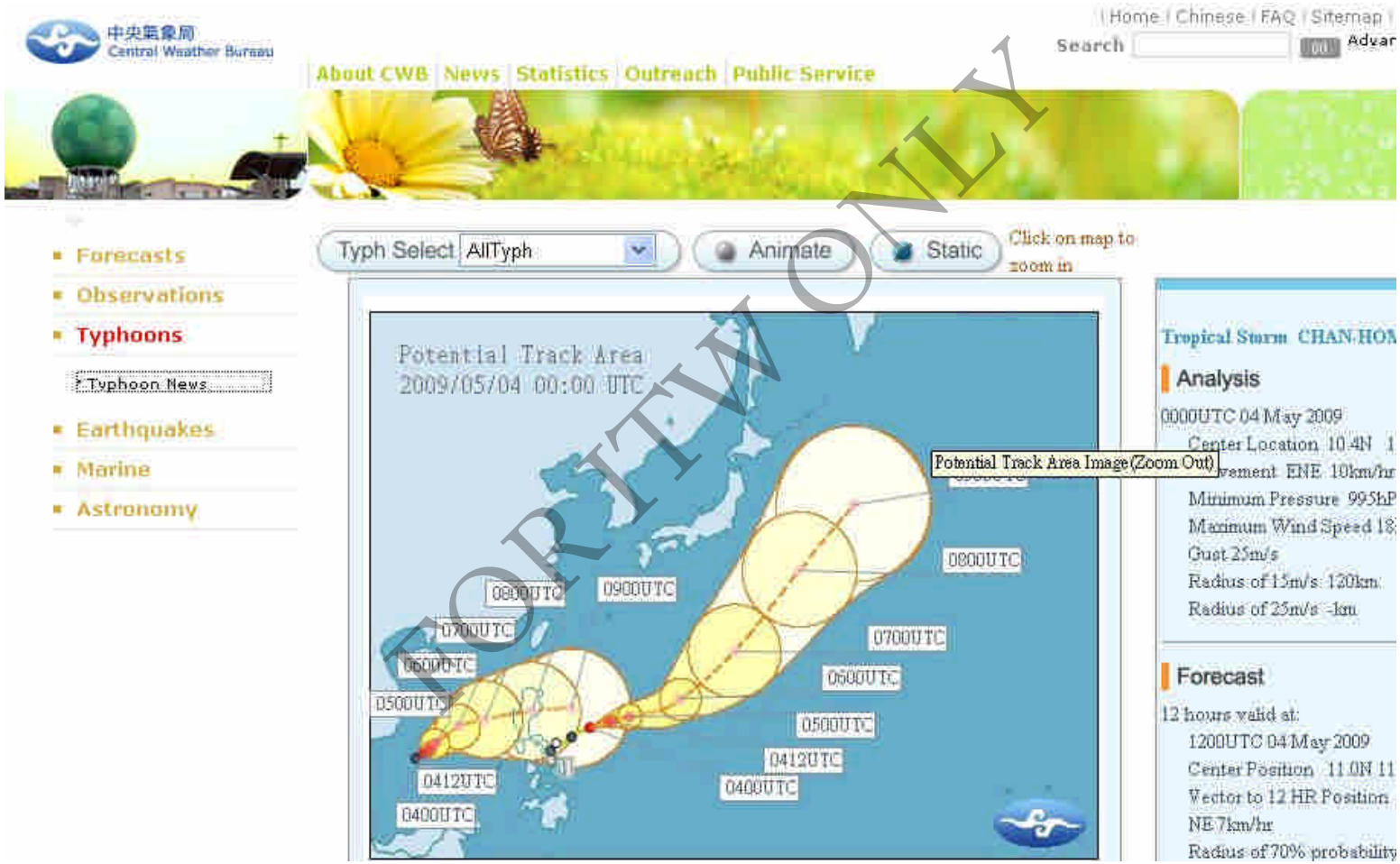
Rainfall forecasts

Rainfall forecasts are provided every 3 hours.

The rainfall forecasts include the total accumulation rainfall for the whole period of typhoon invasion and the next 24-h accumulation rainfall for each county.

FOR ITV ONLY

http://www.cwb.gov.tw/eng/index.htm



FOR JTW ONLY

Channels of Services

Cell Phone Short Message
Press Conference/Interview
Telephone Interview
FAX
WWW

Press

Cell Phone Short Message
FAX
Disaster Mitigation System
Phone
WWW

EMO

Cell Phone Short Message
FAX
Disaster Mitig. Sys
Phone
WWW

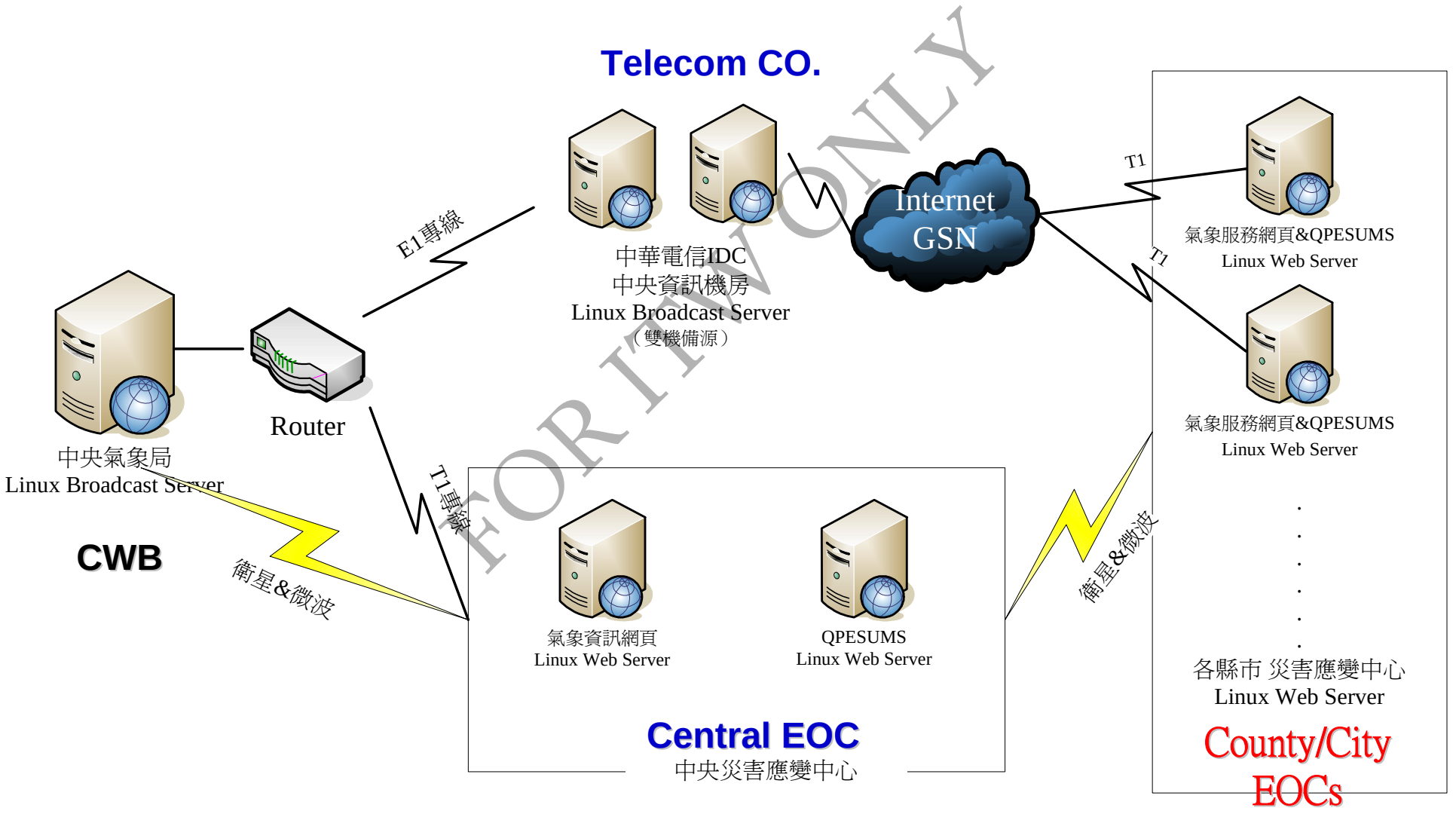
Government

Newspaper、166/167
FOD、WWW
email 、SSB
Consultation Phone
Television & Radio

Public

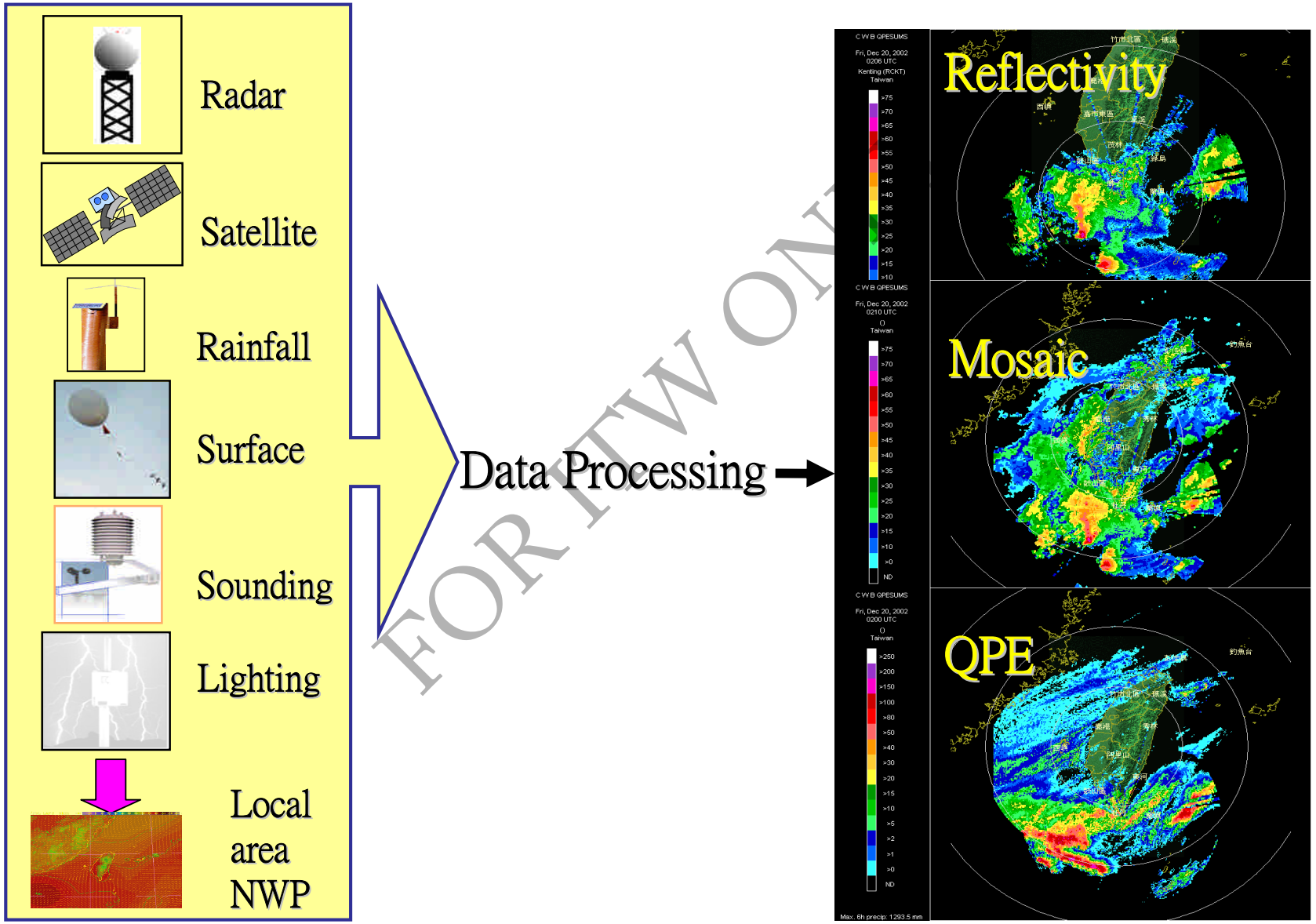
FOR ITWONLY

Framework of the Service System For Disaster Mitigation



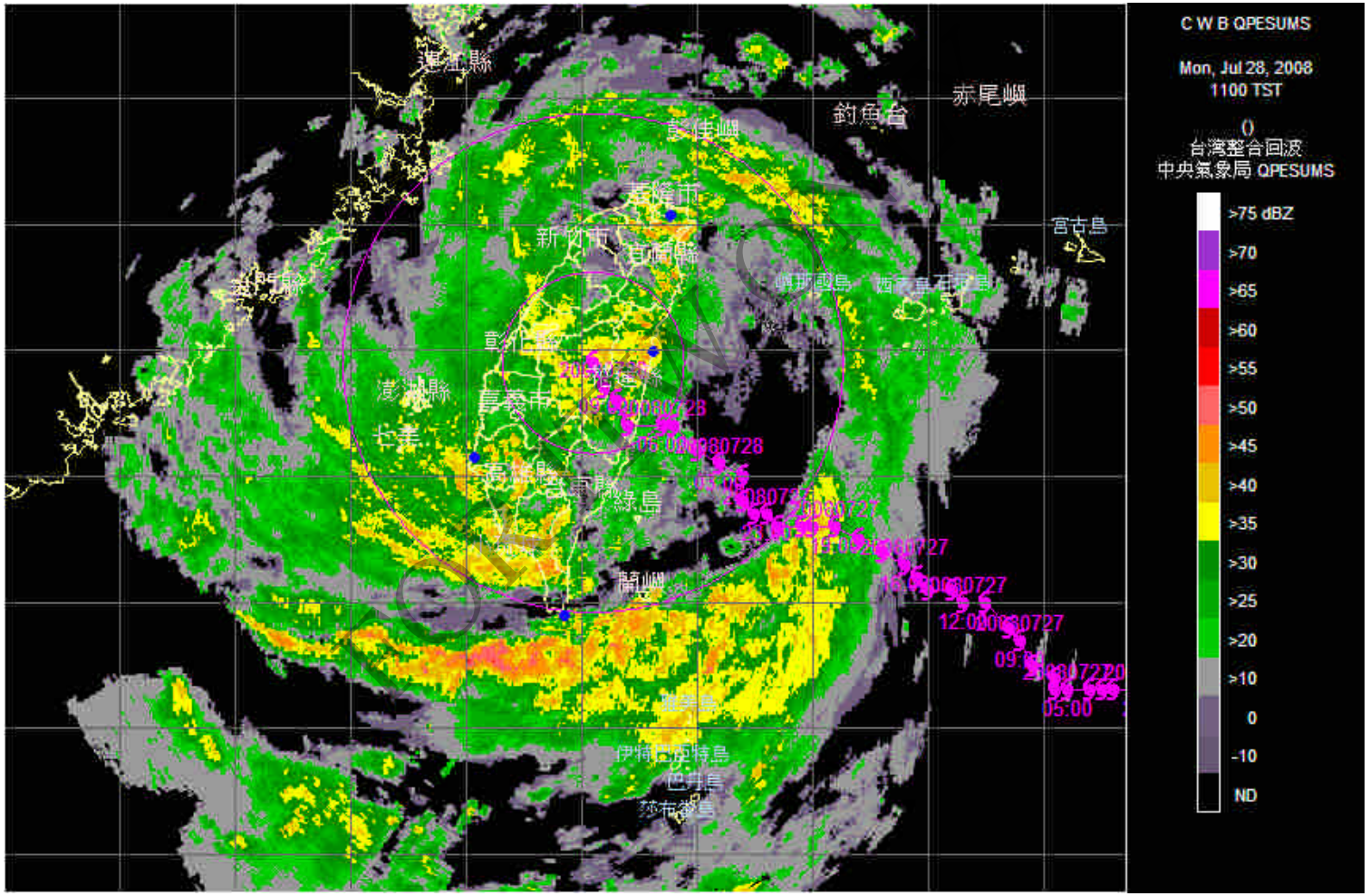
FOR ITW ONLY

QPESUMS (Quantitative Precipitation Estimation)

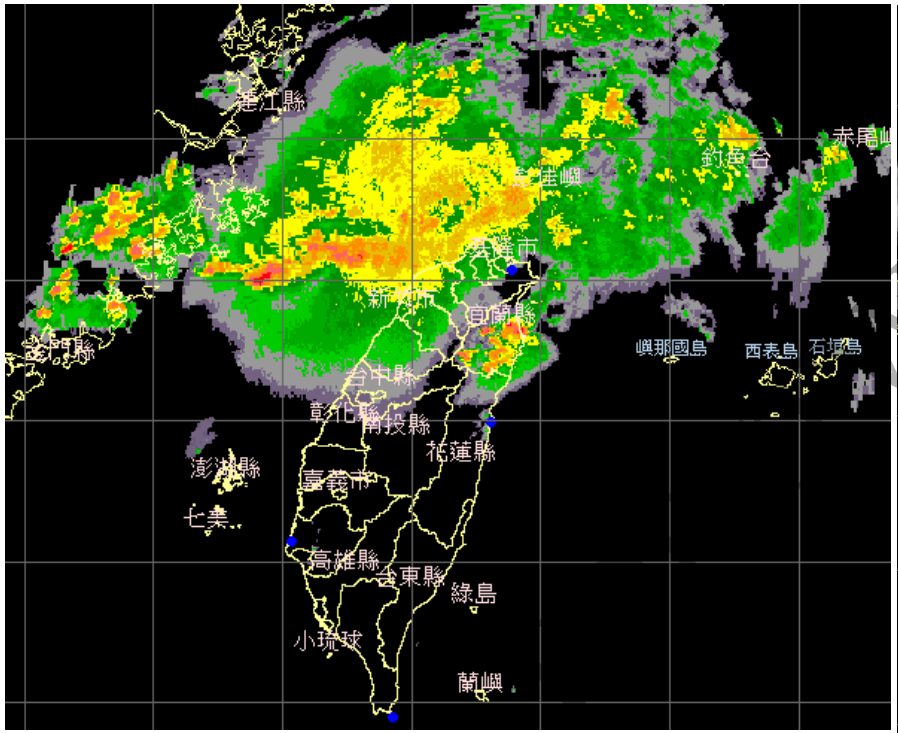


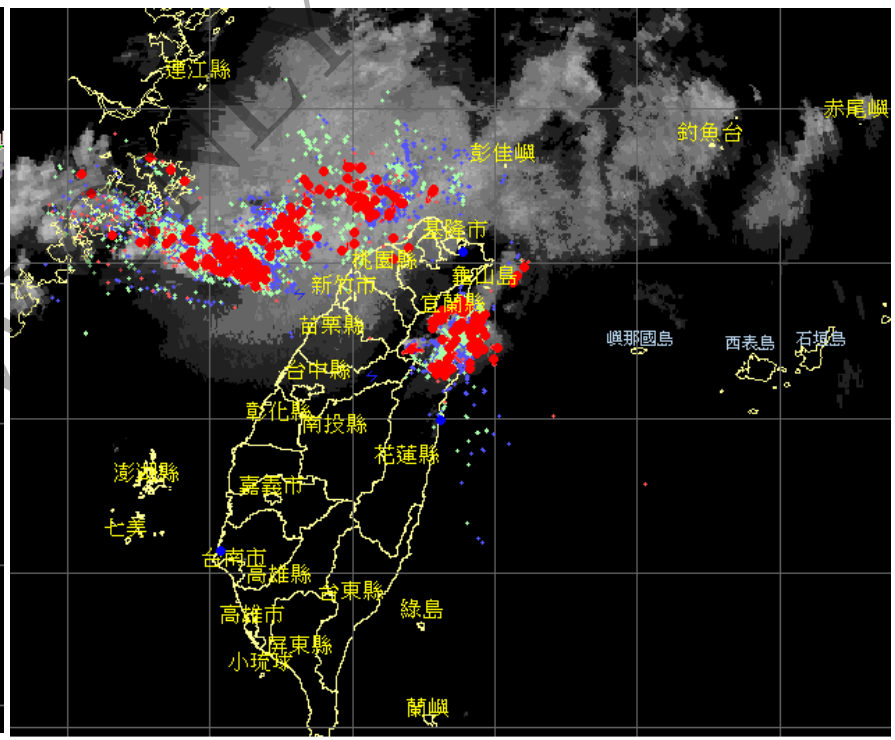
FOR ITW ONL

Reflectivity and typhoon track

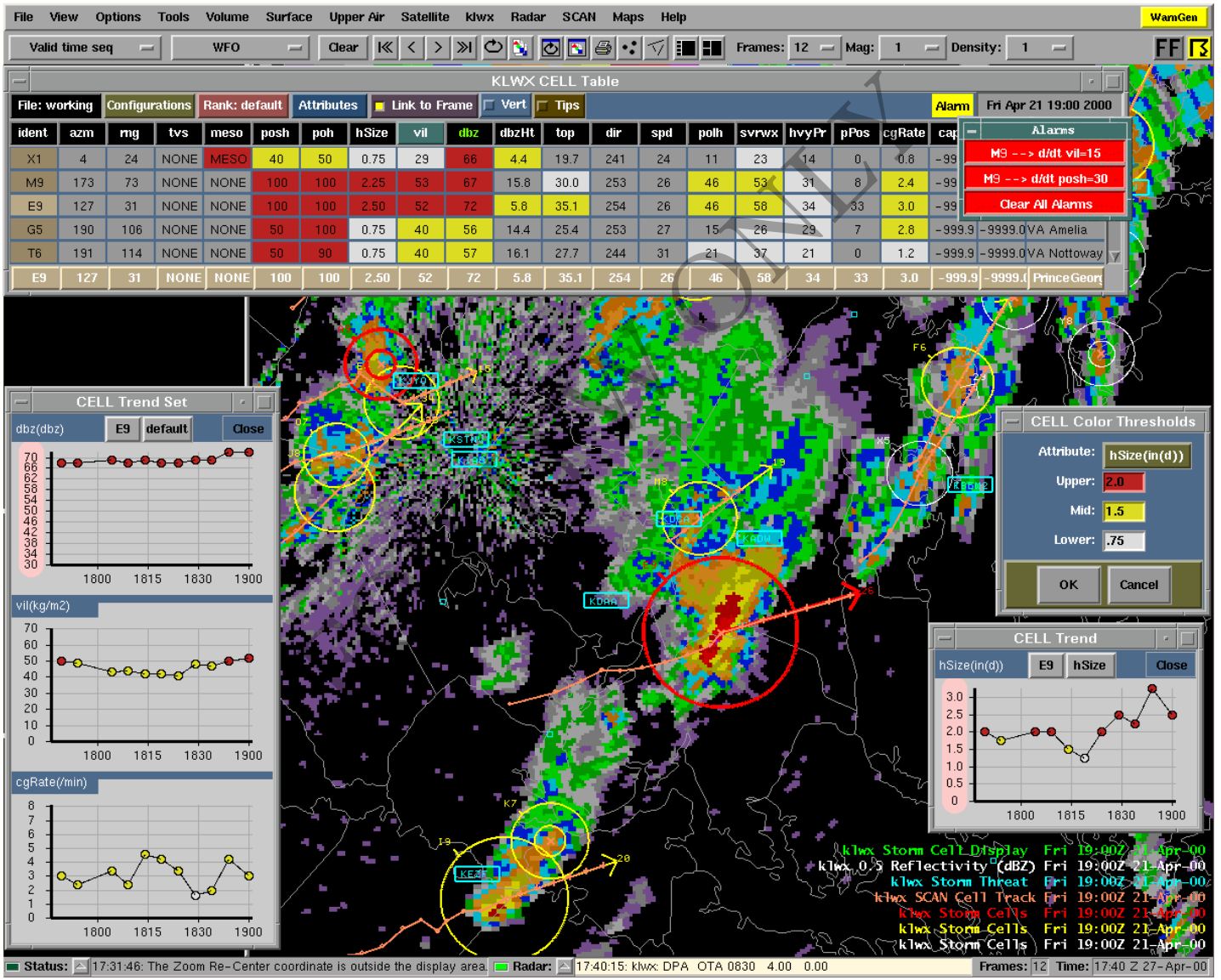


Reflectivity and lightings

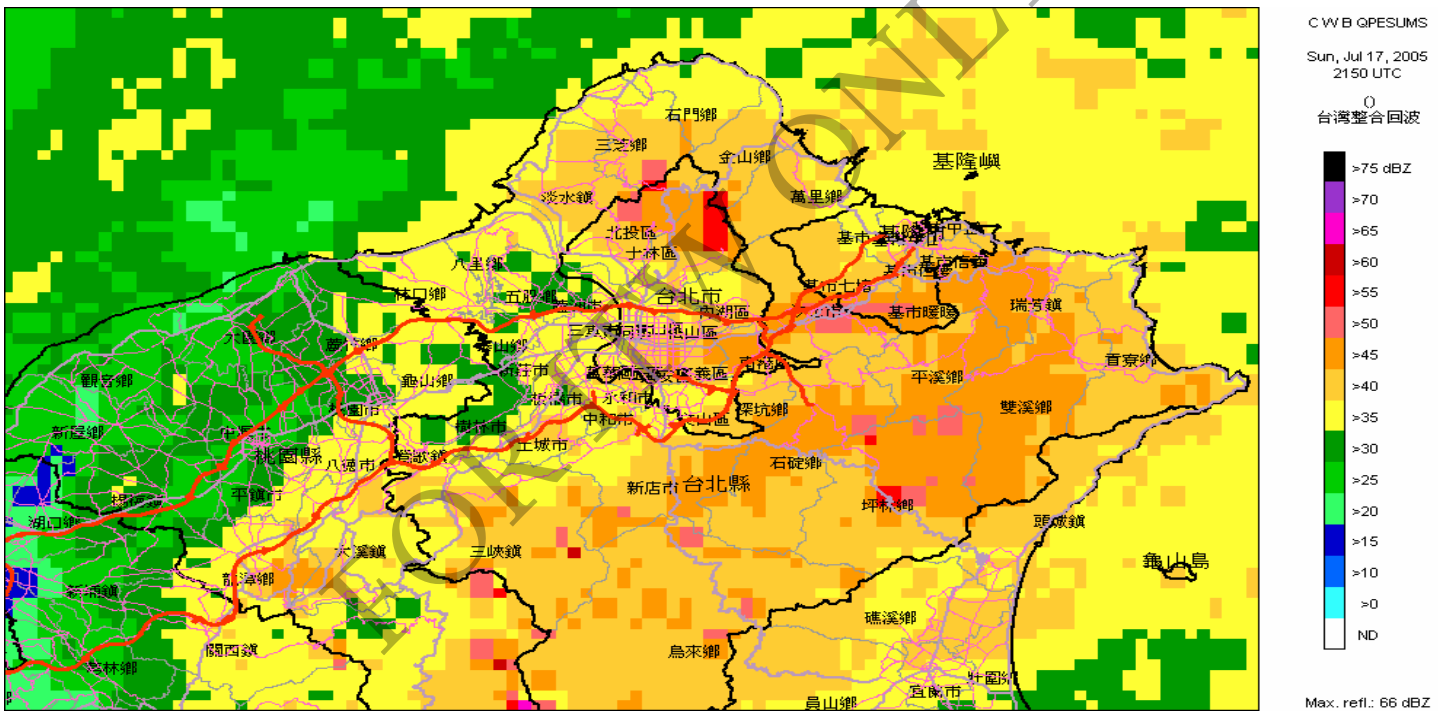




Convective Analysis and Nowcasting



Display rainfall on GIS

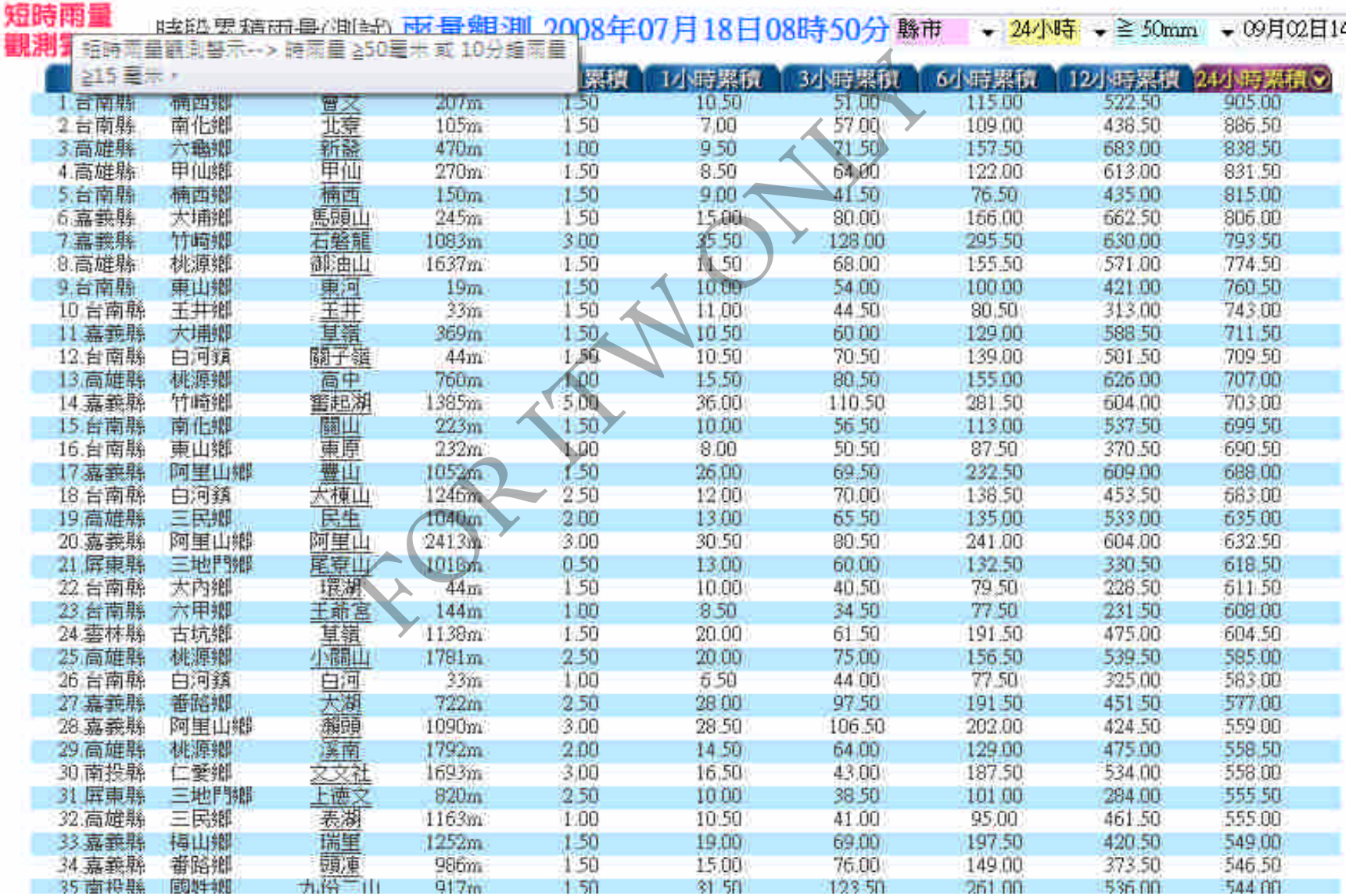


FOR TRAINING ONLY

Display rainfall near the major bridges

FOR ITW ONLY

List of station rainfall
(sorting by selected time range)



短時雨量觀測

時段累積雨量(測試) 雨量觀測 2008年07月18日08時50分 縣市 24小時 ≧ 50mm 09月02日14

短時雨量觀測警示--> 時雨量 ≥50毫米 或 10分鐘雨量 ≥15 毫米，

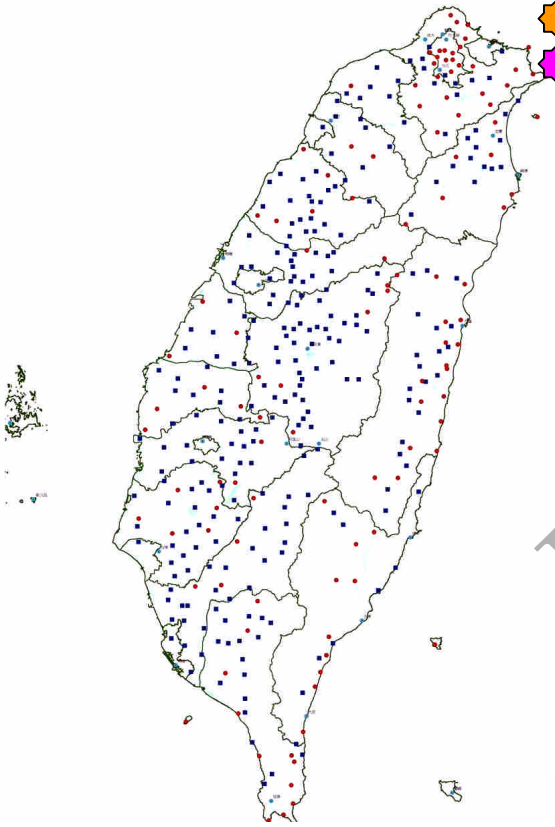
				累積	1小時累積	3小時累積	6小時累積	12小時累積	24小時累積
1.台南縣	楠西鄉	曾文	207m	1.50	10.50	51.00	115.00	522.50	905.00
2.台南縣	南化鄉	北寮	105m	1.50	7.00	57.00	109.00	438.50	886.50
3.高雄縣	六龜鄉	新發	470m	1.00	9.50	71.50	157.50	683.00	838.50
4.高雄縣	甲仙鄉	甲仙	270m	1.50	8.50	64.00	122.00	613.00	831.50
5.台南縣	楠西鄉	楠西	150m	1.50	9.00	41.50	76.50	435.00	815.00
6.嘉義縣	大埔鄉	馬頭山	245m	1.50	15.00	80.00	166.00	662.50	806.00
7.嘉義縣	竹崎鄉	石磐龍	1083m	3.00	35.50	128.00	295.50	630.00	793.50
8.高雄縣	桃源鄉	御油山	1637m	1.50	11.50	68.00	155.50	571.00	774.50
9.台南縣	東山鄉	東河	19m	1.50	10.00	54.00	100.00	421.00	760.50
10.台南縣	玉井鄉	玉井	33m	1.50	11.00	44.50	80.50	313.00	743.00
11.嘉義縣	大埔鄉	草嶺	369m	1.50	10.50	60.00	129.00	588.50	711.50
12.台南縣	白河鎮	關子嶺	44m	1.50	10.50	70.50	139.00	501.50	709.50
13.高雄縣	桃源鄉	高中	760m	1.00	15.50	80.50	155.00	626.00	707.00
14.嘉義縣	竹崎鄉	奮起湖	1385m	5.00	36.00	110.50	281.50	604.00	703.00
15.台南縣	南化鄉	關山	223m	1.50	10.00	56.50	113.00	537.50	699.50
16.台南縣	東山鄉	東原	232m	1.00	8.00	50.50	87.50	370.50	690.50
17.嘉義縣	阿里山鄉	豐山	1052m	1.50	26.00	69.50	232.50	609.00	688.00
18.台南縣	白河鎮	大棟山	1246m	2.50	12.00	70.00	138.50	453.50	683.00
19.高雄縣	三民鄉	民生	1040m	2.00	13.00	65.50	135.00	533.00	635.00
20.嘉義縣	阿里山鄉	阿里山	2413m	3.00	30.50	80.50	241.00	604.00	632.50
21.屏東縣	三地門鄉	尾寮山	1016m	0.50	13.00	60.00	132.50	330.50	618.50
22.台南縣	大內鄉	環湖	44m	1.50	10.00	40.50	79.50	228.50	611.50
23.台南縣	六甲鄉	王爺宮	144m	1.00	8.50	34.50	77.50	231.50	608.00
24.雲林縣	古坑鄉	草嶺	1138m	1.50	20.00	61.50	191.50	475.00	604.50
25.高雄縣	桃源鄉	小關山	1781m	2.50	20.00	75.00	156.50	539.50	585.00
26.台南縣	白河鎮	白河	33m	1.00	6.50	44.00	77.50	325.00	583.00
27.嘉義縣	番路鄉	大湖	722m	2.50	28.00	97.50	191.50	451.50	577.00
28.嘉義縣	阿里山鄉	瀨頭	1090m	3.00	28.50	106.50	202.00	424.50	559.00
29.高雄縣	桃源鄉	溪南	1792m	2.00	14.50	64.00	129.00	475.00	558.50
30.南投縣	仁愛鄉	文文社	1693m	3.00	16.50	43.00	187.50	534.00	558.00
31.屏東縣	三地門鄉	上德文	820m	2.50	10.00	38.50	101.00	284.00	555.50
32.高雄縣	三民鄉	表湖	1163m	1.00	10.50	41.00	95.00	461.50	555.00
33.嘉義縣	梅山鄉	瑞里	1252m	1.50	19.00	69.00	197.50	420.50	549.00
34.嘉義縣	番路鄉	頭溝	986m	1.50	15.00	76.00	149.00	373.50	546.50
35.南投縣	國性鄉	九份二山	917m	1.50	31.50	123.50	261.00	536.00	544.00

FOR ITW ONLY

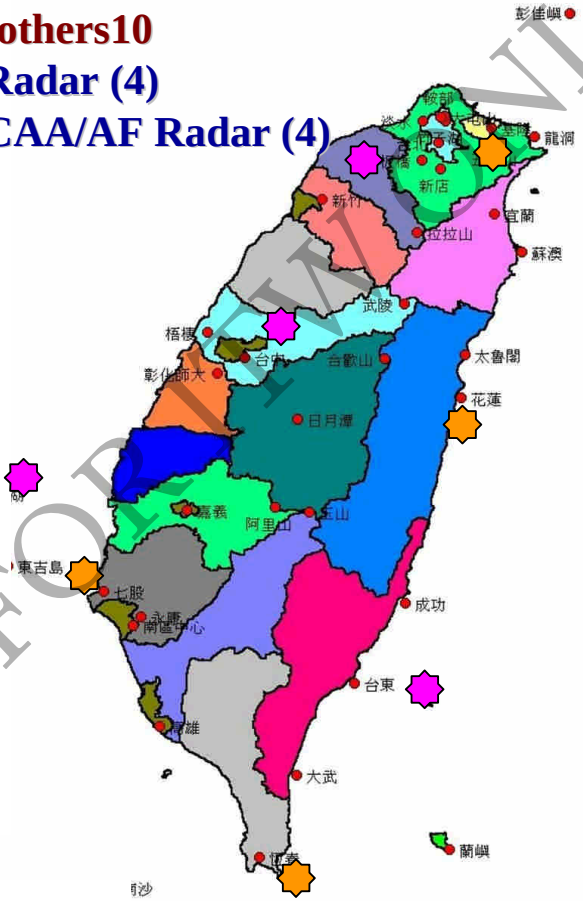
To improve users' understanding -- Outreach Programs

Observation stations

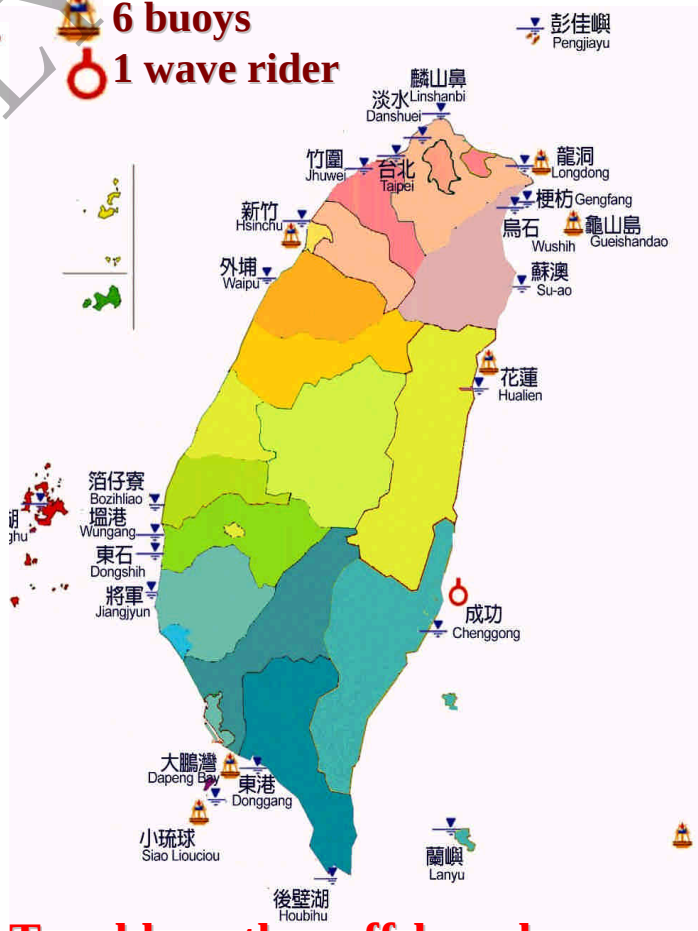
136 auto-met stations
249 auto-rain gauge



■Surface station (42)
CWB 32
others10
Radar (4)
CAA/AF Radar (4)



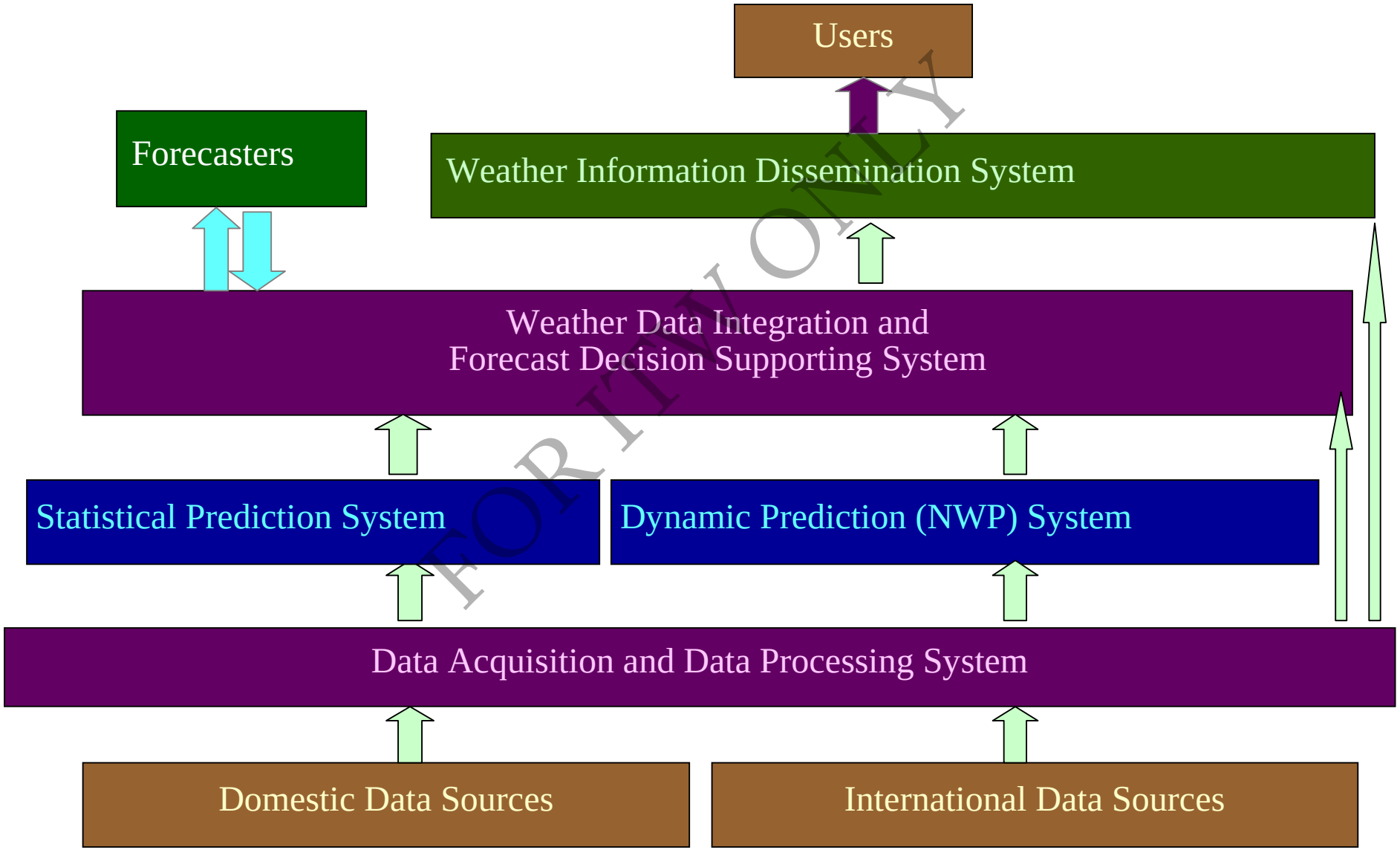
■ Marine Met observation
23 Tidal
6 buoys
1 wave rider



To add another offshore buoy later this year at SW of Taiwan

FOR REVIEW ONLY

The CWB Weather Forecast System Framework

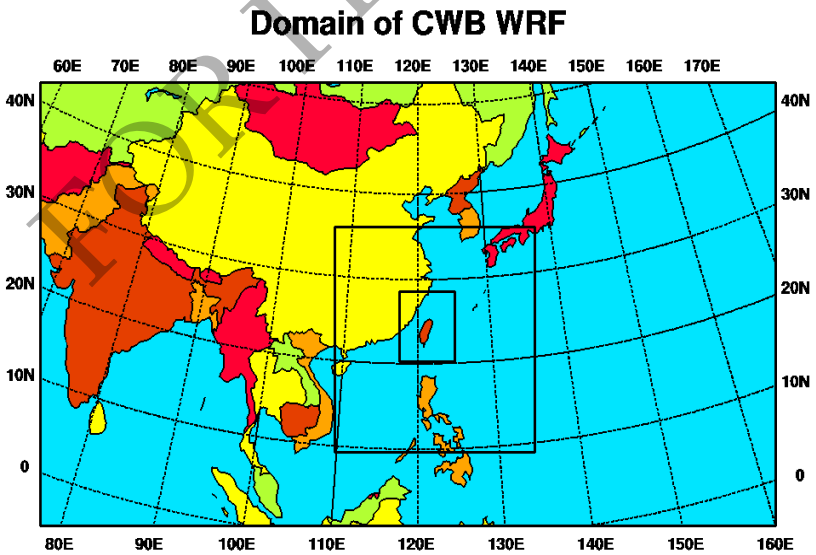


FOR ITW ONLY

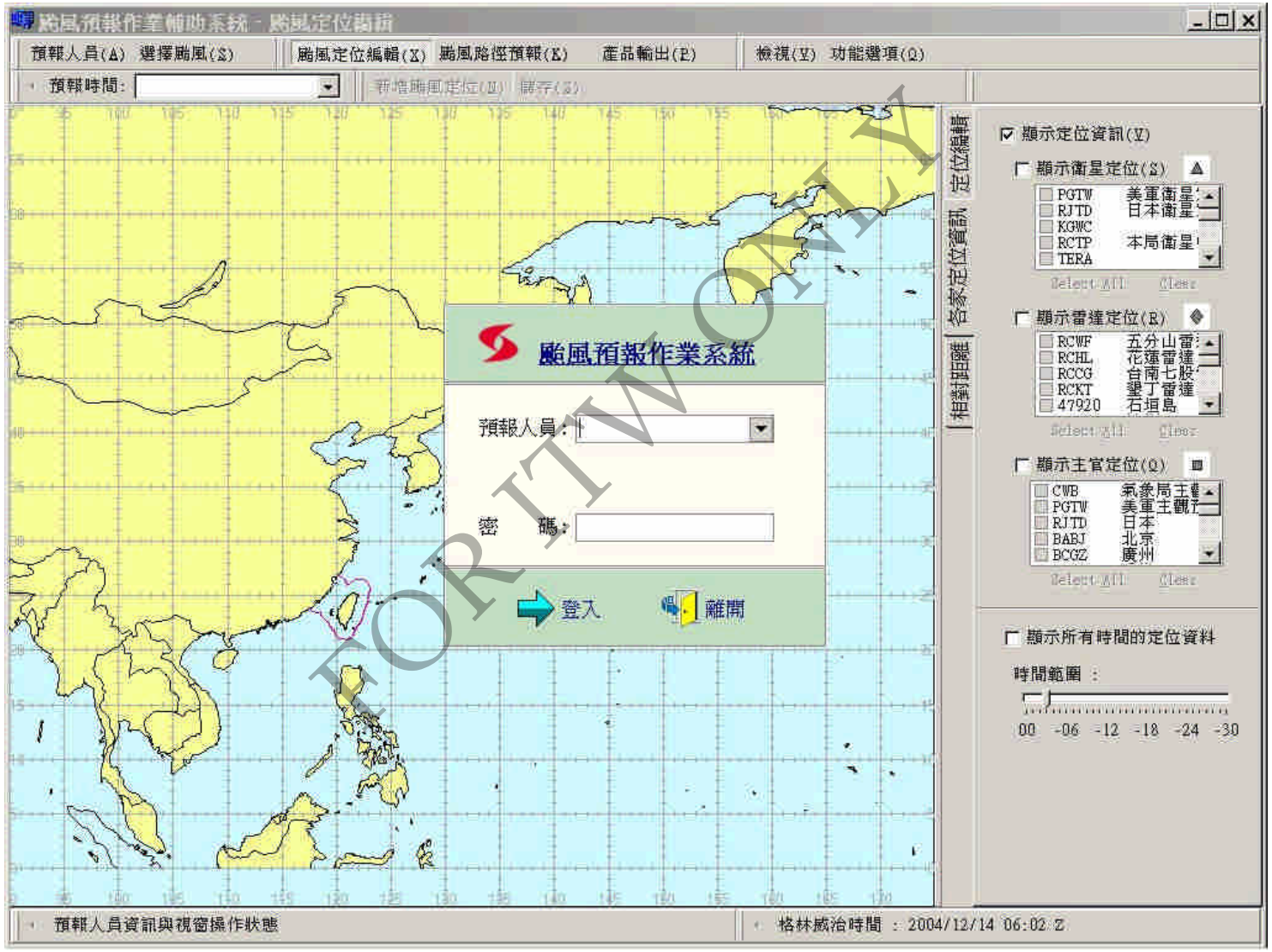
CWB numerical weather prediction system

-- High performance computation system:
IBM P5-575 Cluster 1600 (2496 CPUs)
-- Global Spectral Model CWBGFS T239L30(55km)
-- Regional Model NFS 45/15/3 km
-- Regional Model WRF 45/15/3 km

FOR ITV ONLY

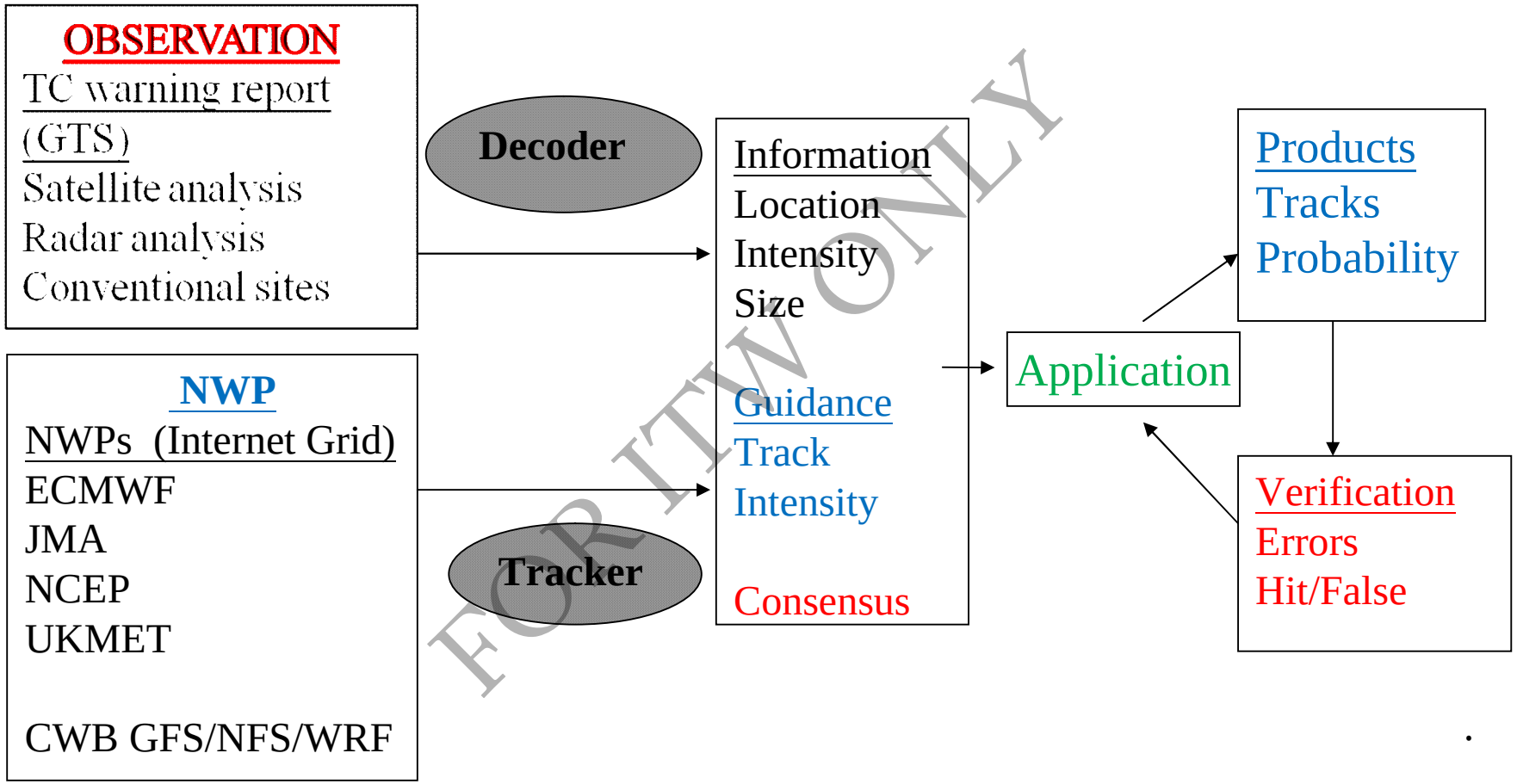


TAFIS (Typhoon Analysis and Forecast Information System)



TAFIS

(Typhoon Analysis and Forecast Information System)



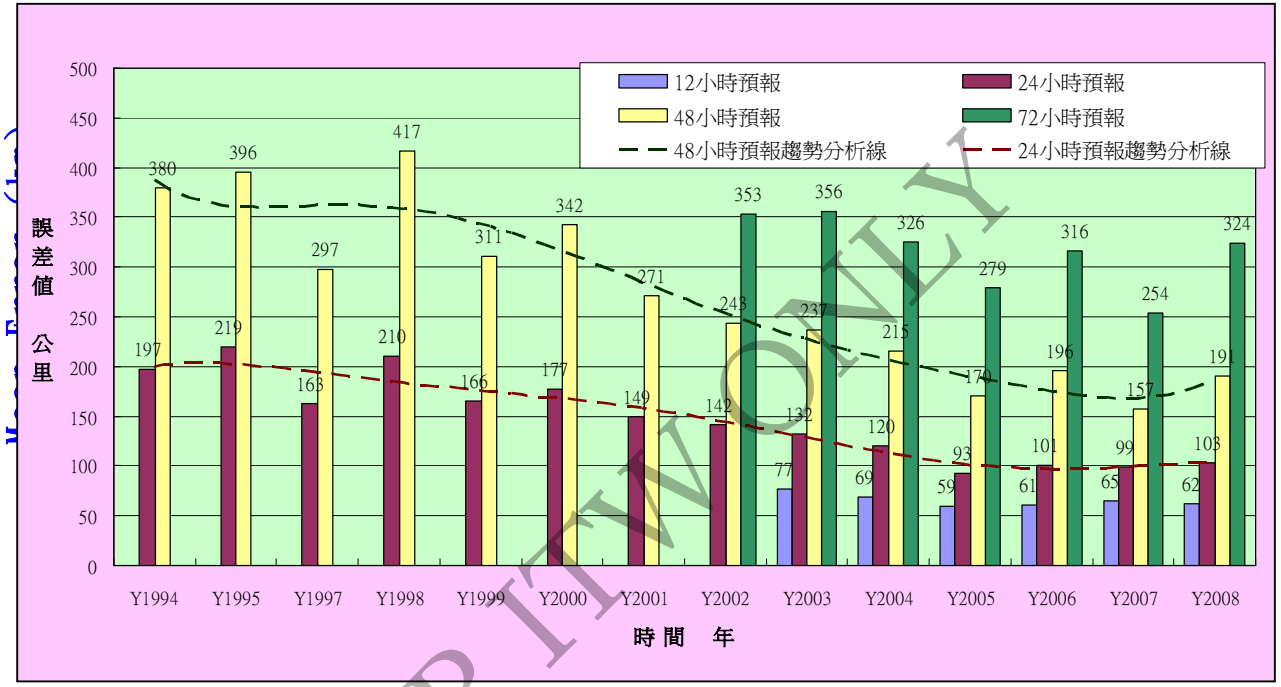
FOR ITW ONLY

Observations + NWP Models + Real time verification

⇩

Better TC track forecast

Typhoon Track Forecast Error



FOR ITWG ONLY

Typhoon Track 24-hour Forecast Error (km)

	2004	2005	2006	2007	2008	Morakot
CWB	120	95	101	99	103	87
JMA	125	104	105	111	112	93
JTWC	130	104	104	100	103	91

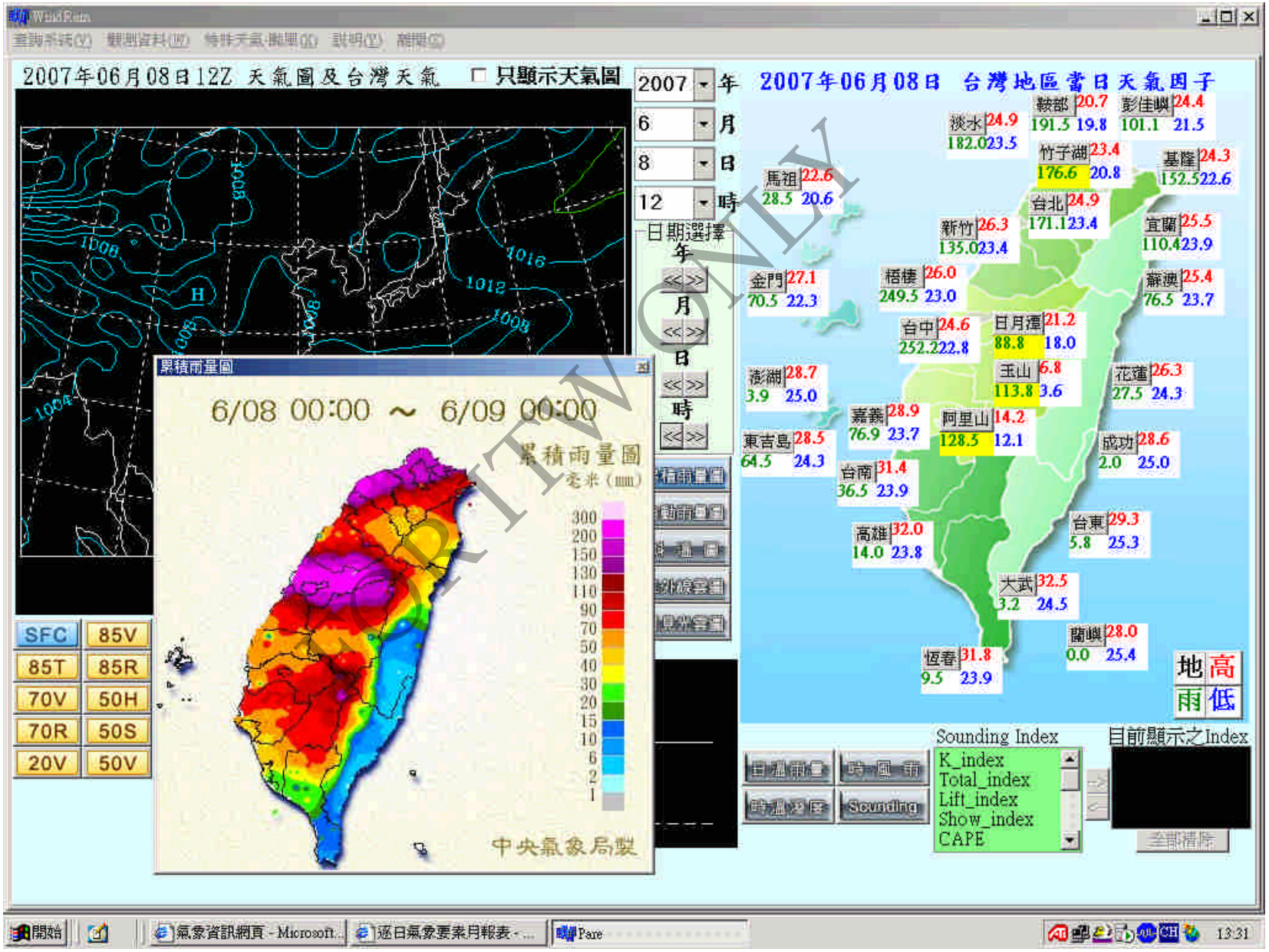
Forecast data from GTS and verified against the CWB track

Typhoon rainfall forecast

Analog and climatology approach

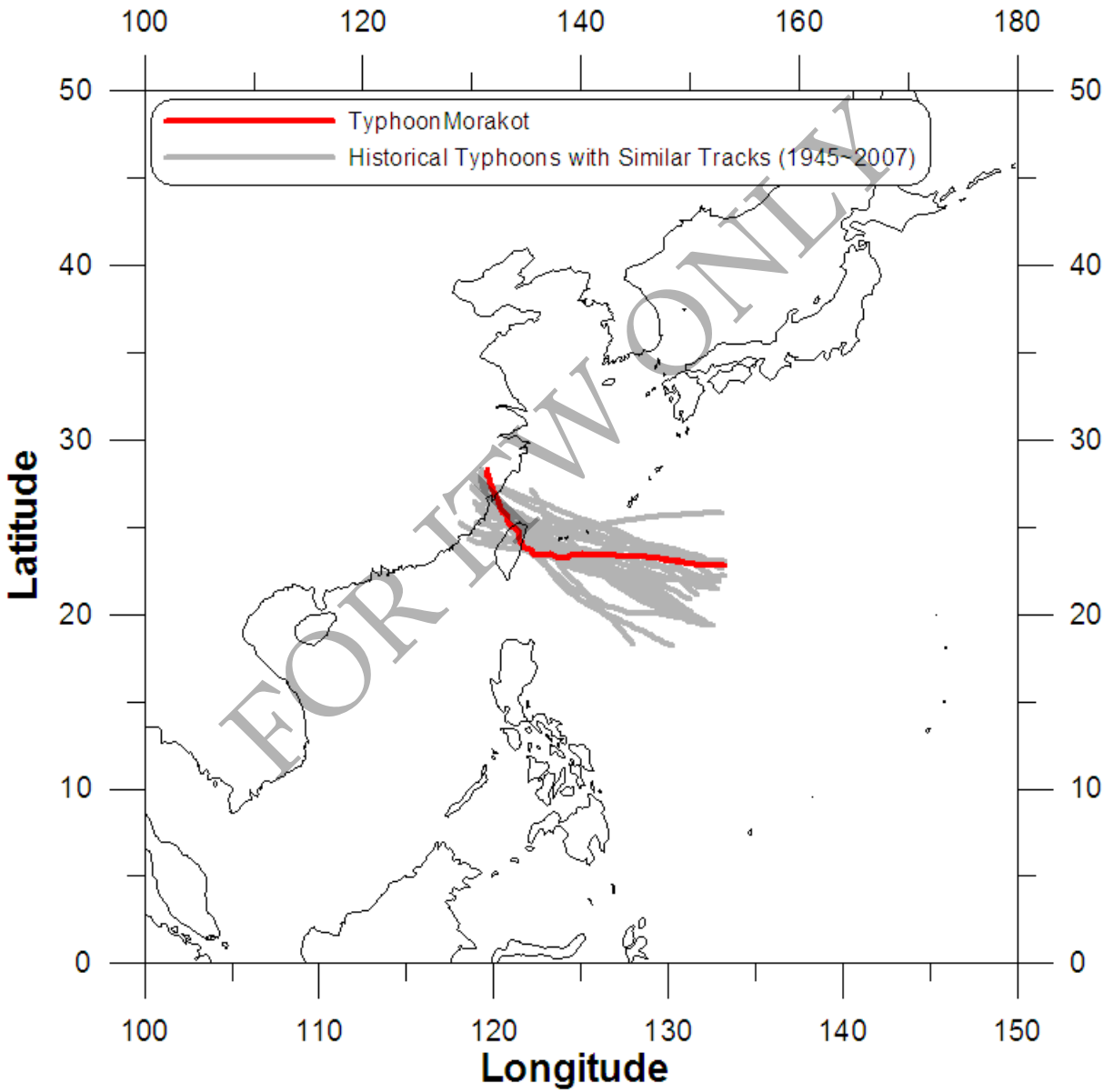
FOR ITW ONLY

Historical data set and computerization system



NOT FOR PUBLIC VIEW ONLY

Search for analog cases (track/intensity/season/speed)



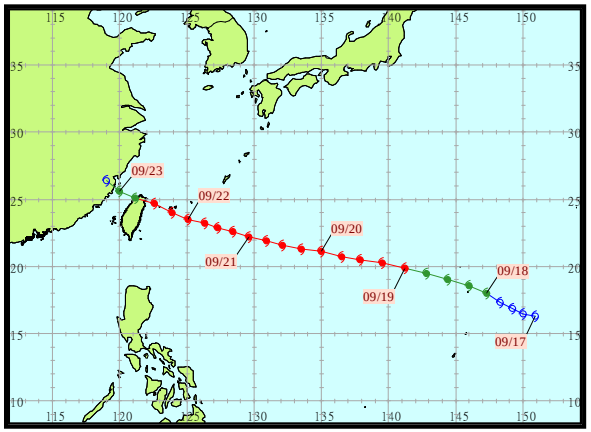
Analog cases (1945~2007) of TY Morakot

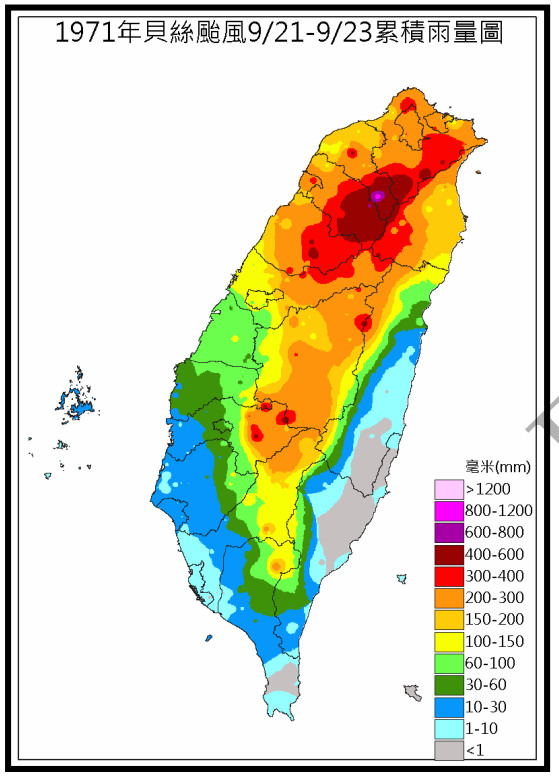
名次	颱風名稱	距離差距(度)	日期差距(日)
1	1971BESS	0.863225	46
2	1976BILLIE	0.964	2
3	1961PAMELA	1.00859	36
4	1969ELSIE	1.053475	50
5	1980NORRIS	1.17863	20
6	1969BETTY	1.19193	1
7	1972WINNIE	1.257044	-6
8	1960TRIX	1.268515	1
9	1975NINA	1.316889	-4
10	1967NORA	1.396228	22
11	1963WENDY	1.39637	-23
12	2005LONGWANG	1.448746	55
13	2006SAOMAI	1.449495	3
14	1966NINA	1.501336	-19
15	1985NELSON	1.55401	14
16	1962OPAL	1.603029	-2
17	1967CLARA	1.64555	-28
18	1991ELLIE	1.654599	10
19	1960SHIRLEY	1.713983	-7
20	1963GLORIA	1.738544	33
21	2006BILIS	1.741698	-25
22	1984FREDA	1.744456	0
23	1959BILLIE	1.782414	-23
24	1990ABE	1.798237	23
25	1958GRACE	1.803255	27

名次	颱風名稱	距離差距(度)	日期差距(日)
26	1947FAITH	1.82571	-9
27	1949NELLY	1.850519	38
28	1989TD12W	1.877136	-9
29	1956FREDA	1.917298	39
30	1972BETTY	1.920266	8
31	1992OMAR	1.991008	27
32	1959JOAN	1.992481	22
33	1966ALICE	1.994789	26
34	2005TALIM	2.027034	24
35	1947INEZ	2.034721	22
36	1975BETTY	2.049771	46
37	2003VAMCO	2.053851	14
38	1966CORA	2.063647	28
39	2004NOCK-TEN	2.068299	79
40	1953NINA	2.097742	9
41	1989VERA	2.100713	39
42	1971AGNES	2.110975	42
43	2004AERE	2.11345	16
44	1948PEARL	2.134183	-32
45	1978DELLA	2.149298	6
46	1945HELEN	2.15712	26
47	1985JEFF	2.157929	-9
48	1959LOUISE	2.186522	28
49	1992POLLY	2.194487	21
50	2005KHANUN	2.213225	35

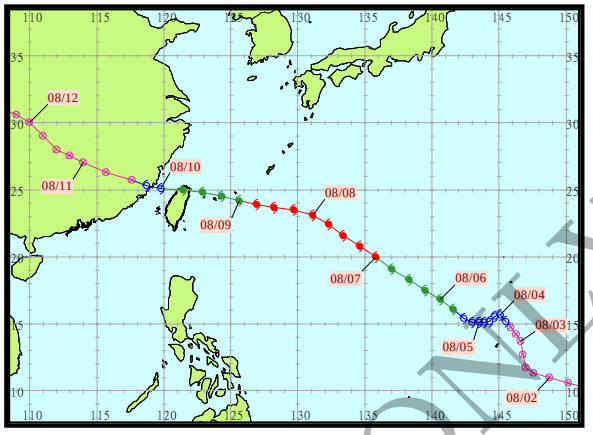
FOR ITWONLY

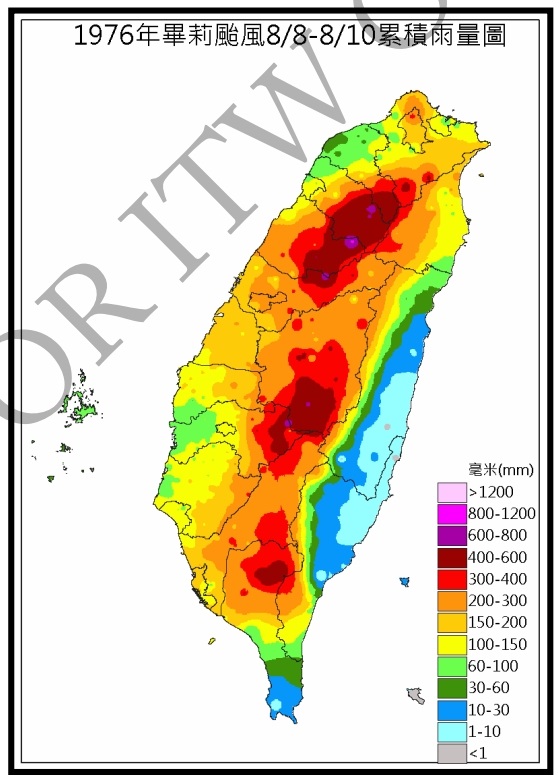
1971 BESS



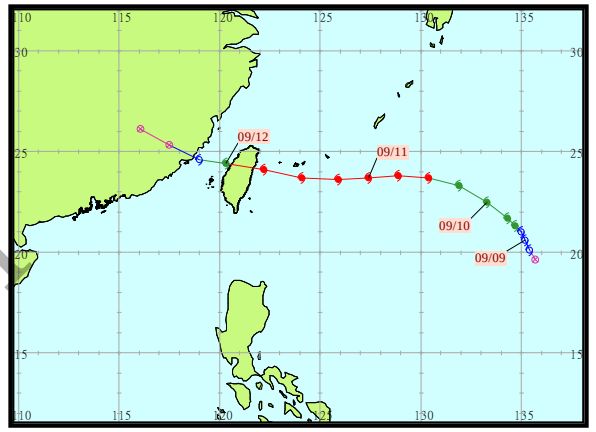


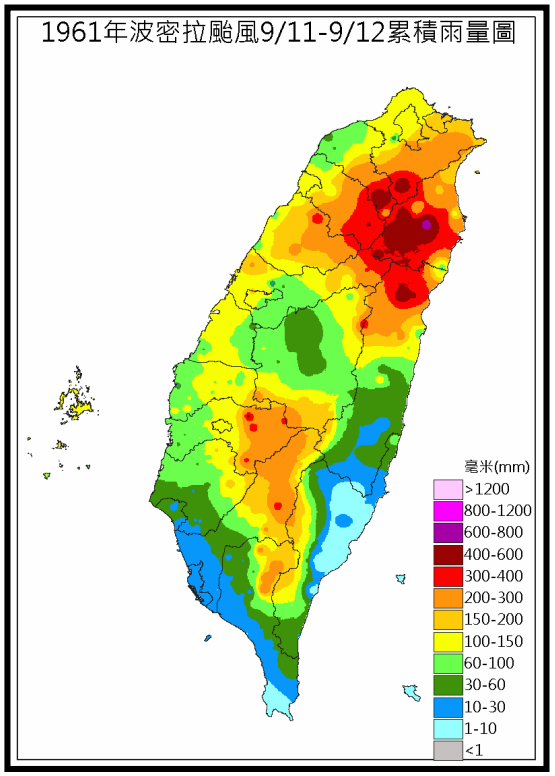
1976 BILLIE





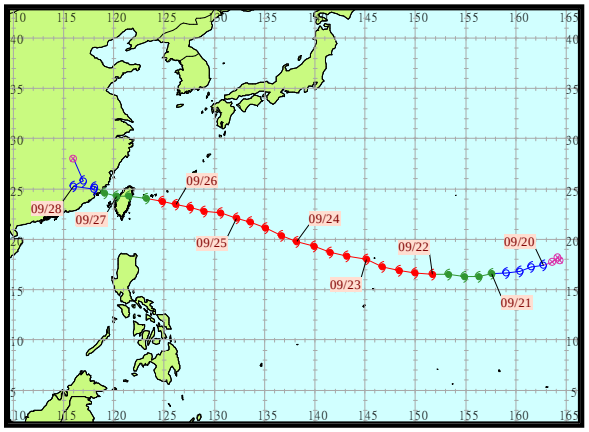
1961 PAMELIA

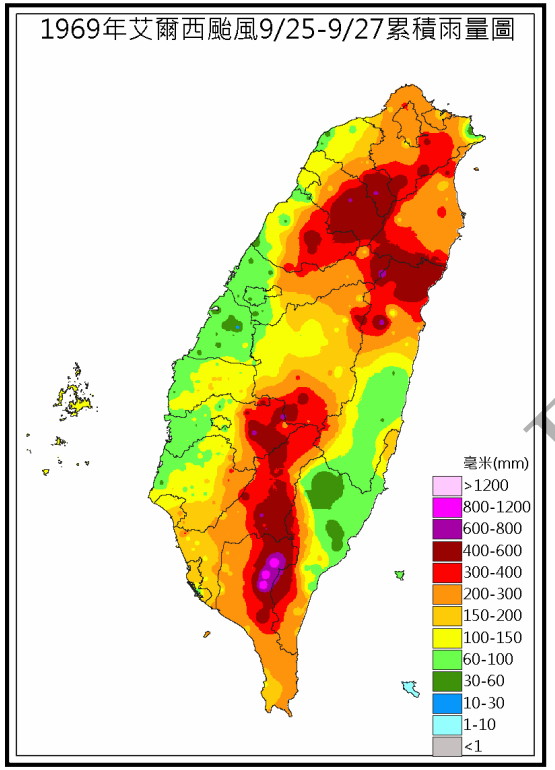




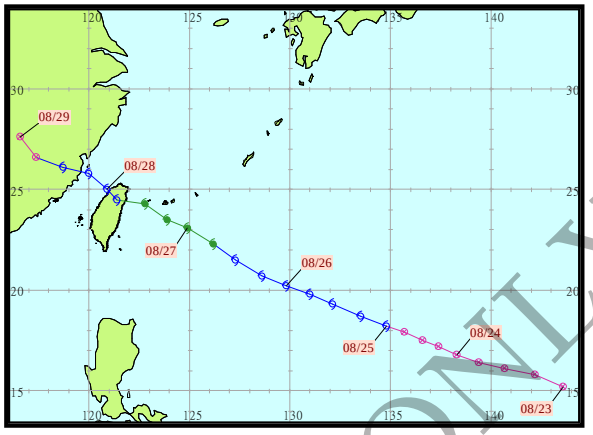
FOR ITW ONLY

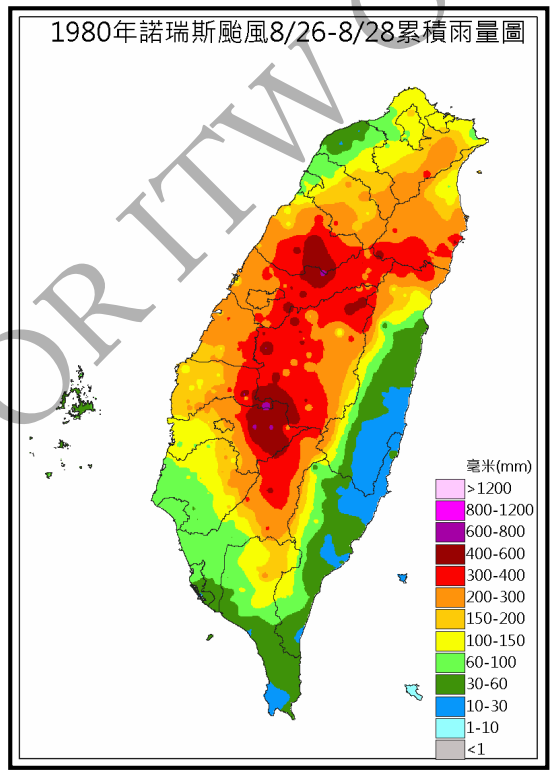
1969 ELSIE



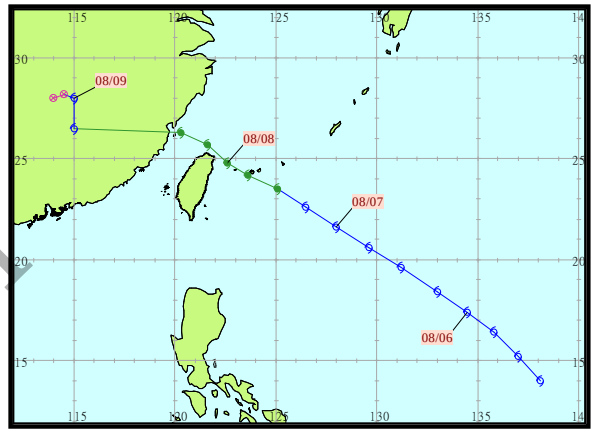


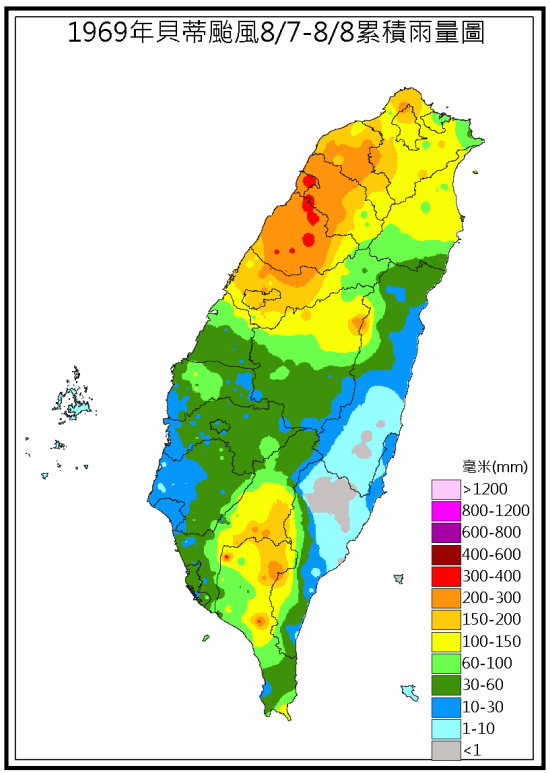
1980 NORRIS





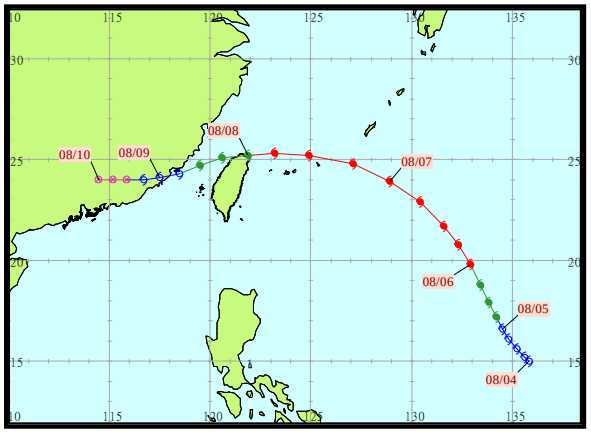
1969 BETTY

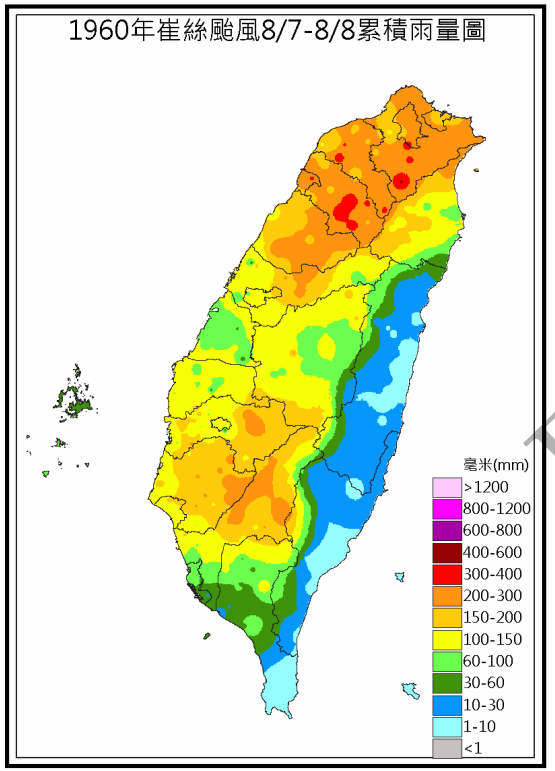




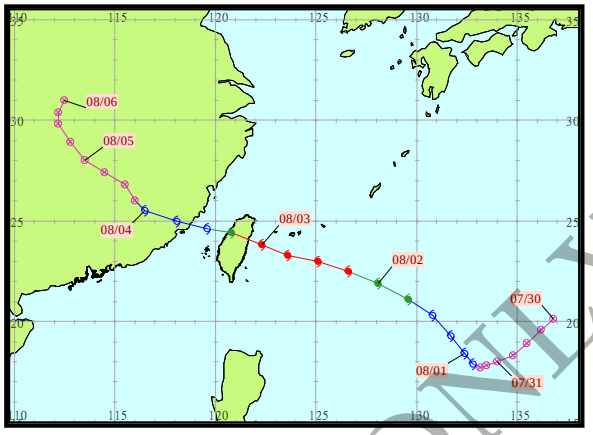
FOR ITW ONLY

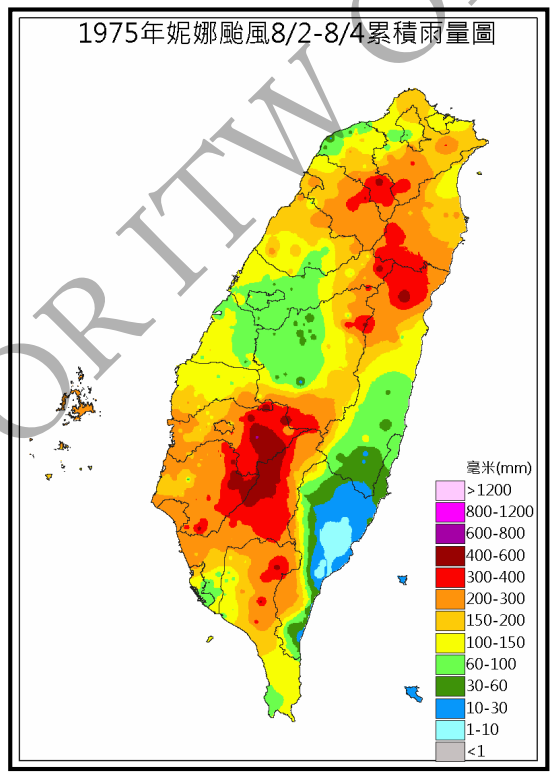
1960 TRIX



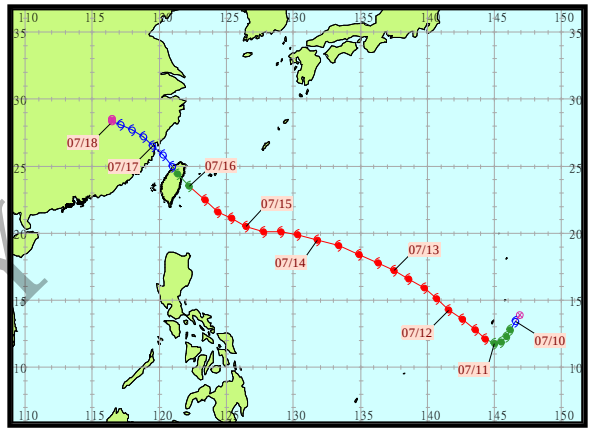


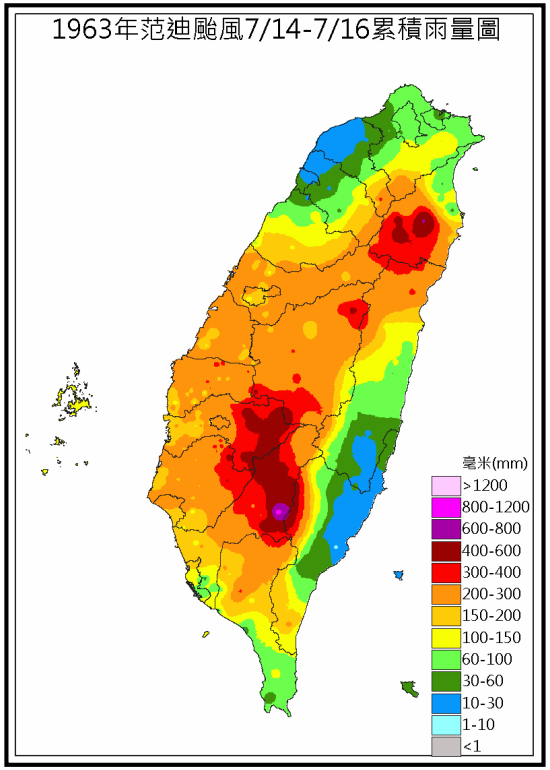
1975 NINA



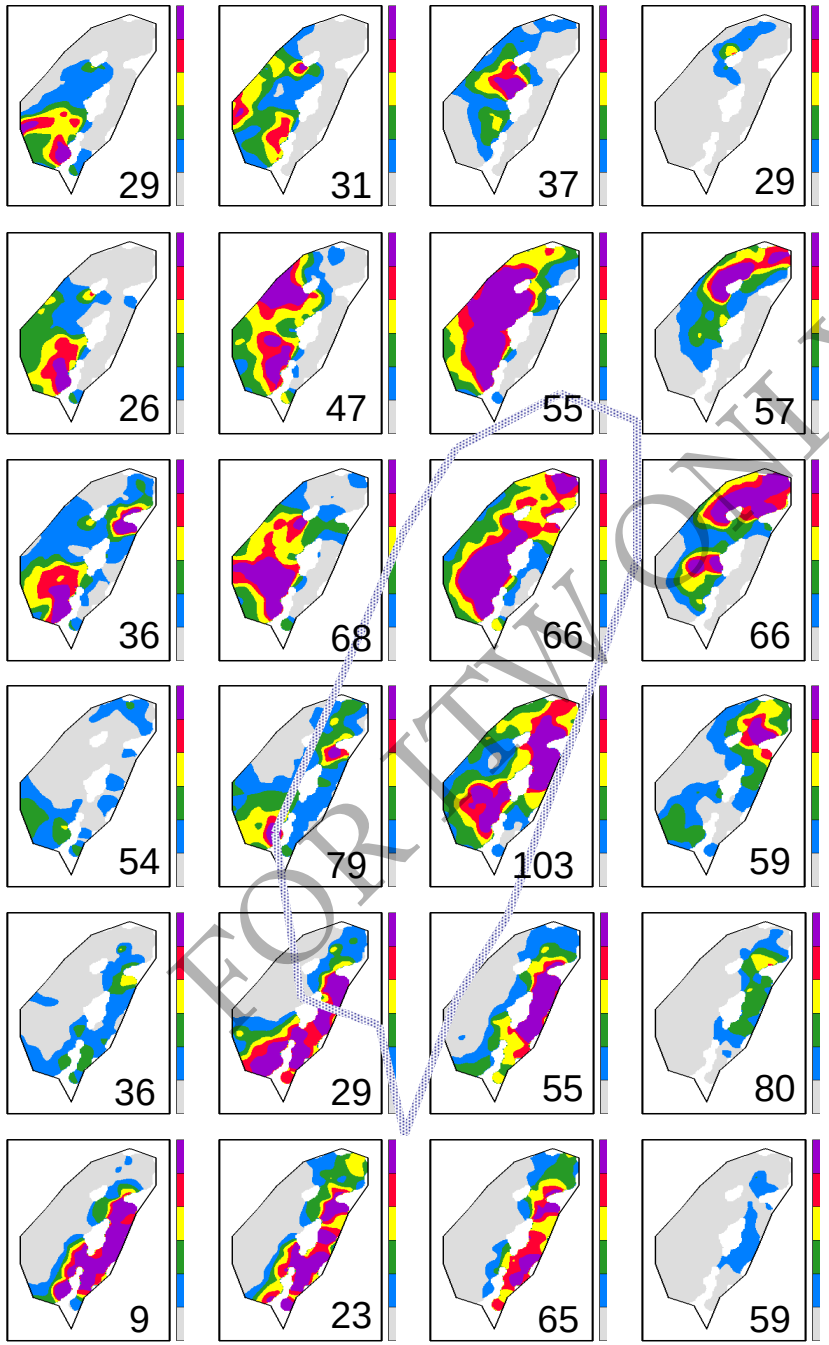


1963 WENDY





FOR ITW ONLY

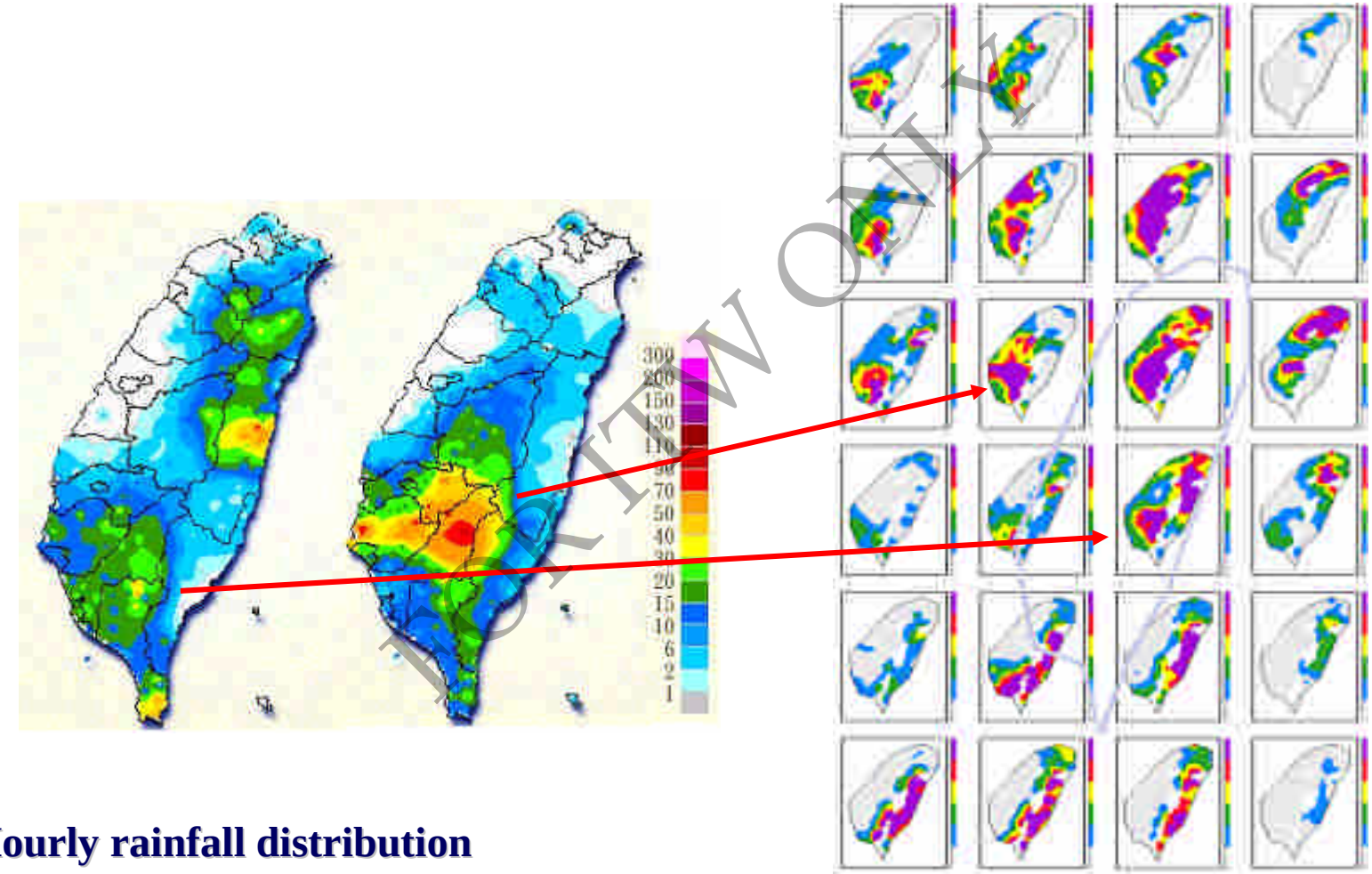


Climatology Approach

FOR ITV ONLY

1° x 1° Mean rainfall rate

Comparison of the rainfalls from the observation and the estimation from climatology approach

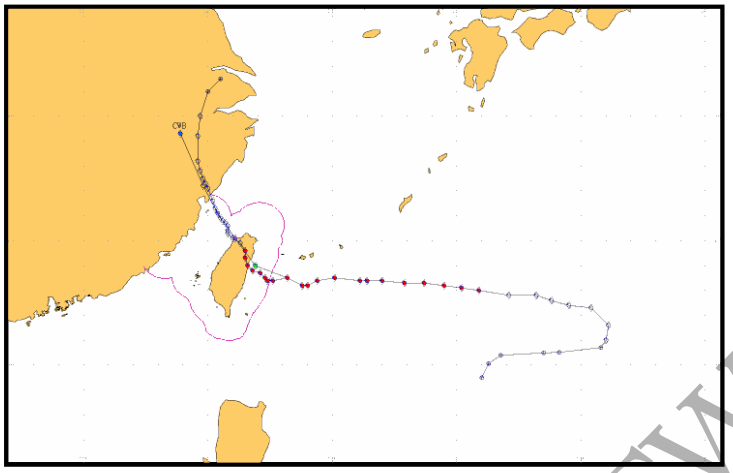


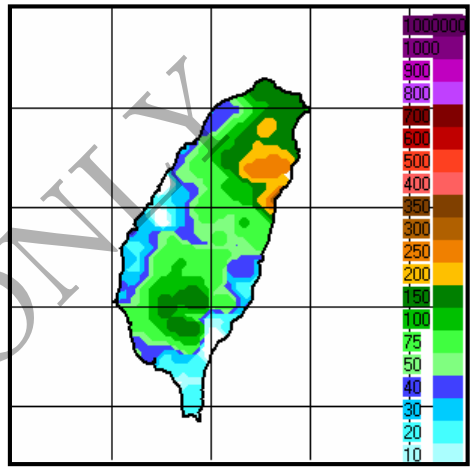
FOR TFW ONLY

Hourly rainfall distribution
00LST (left) and 18LST (right), 8 August, 2009.

Rainfall estimation based on climatology rainfall forecast and CWB 120-h track forecast

2009080700UTC





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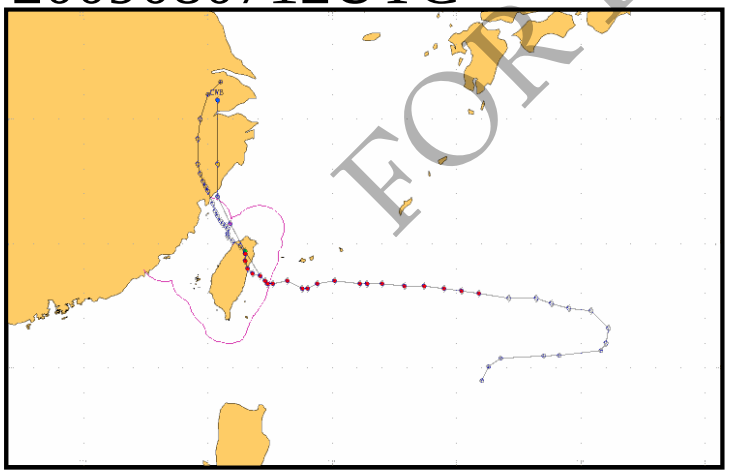
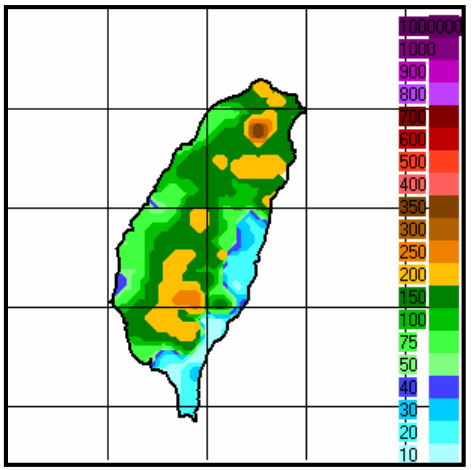
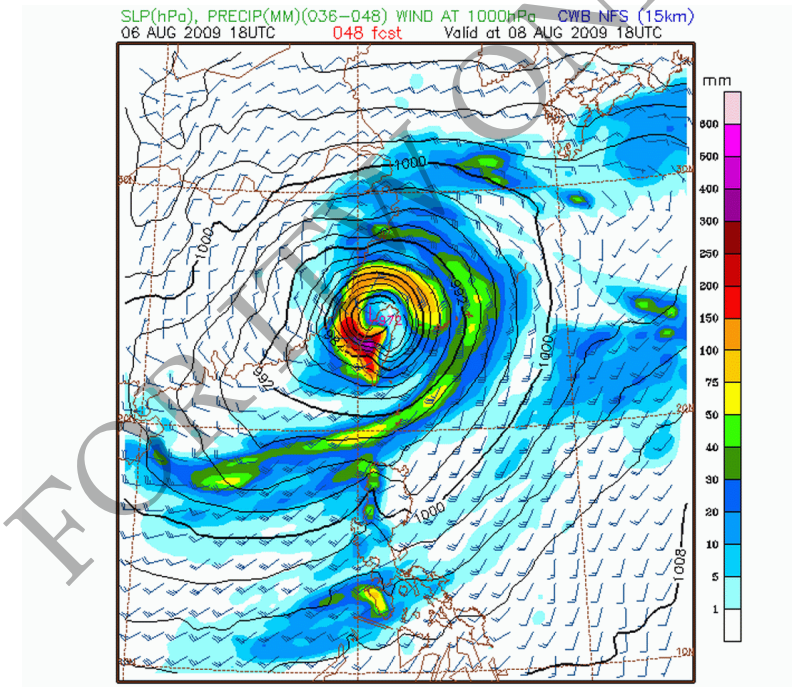




FOR ITW ONLY

NWP model rainfall forecast

-- High performance computation system:
IBM P5-575 Cluster 1600 (2496 CPUs)
-- Global Spectral Model CWBGFS T239L30(55km)
-- Regional Model NFS 45/15/3 km
-- Regional Model WRF 45/15/3 km



FOR REVIEW ONLY

CWBNFS(15km) Morakot 12-h rainfall

Typhoon rainfall forecast

Analog and climatology approach

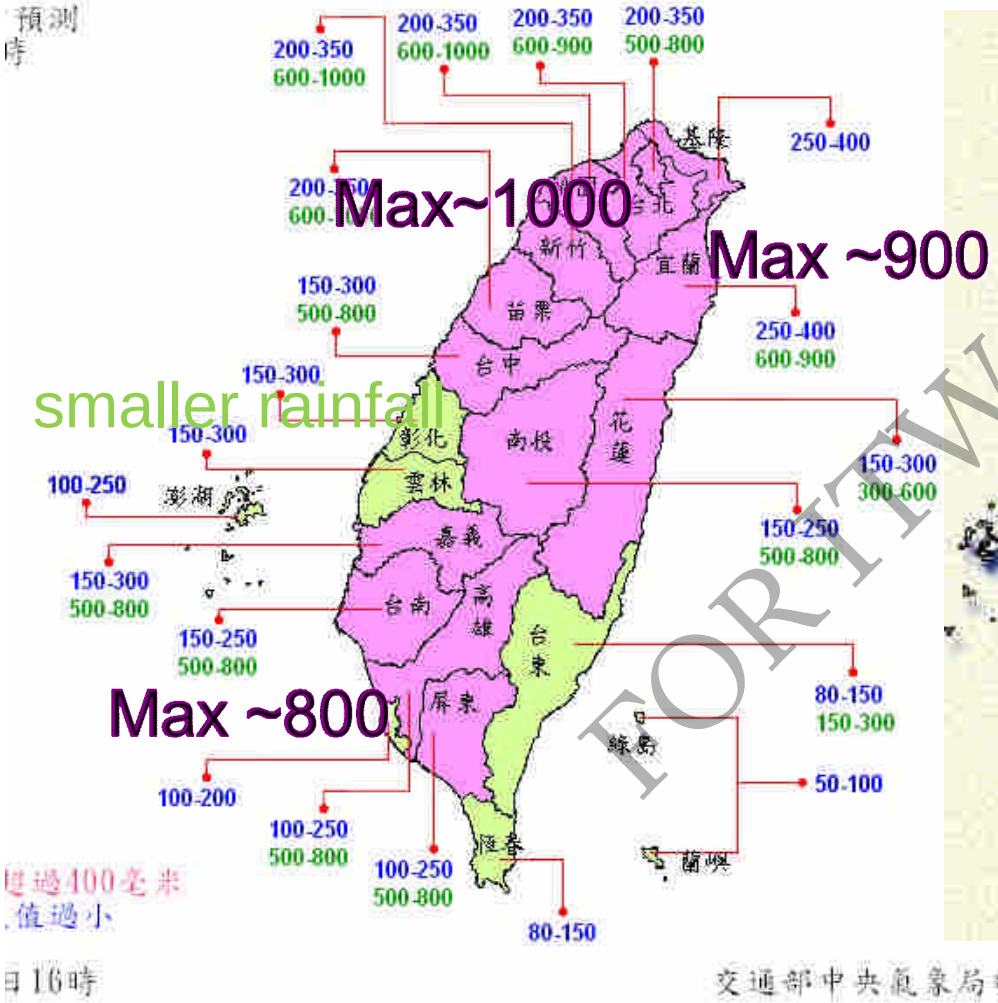
Numerical model forecast

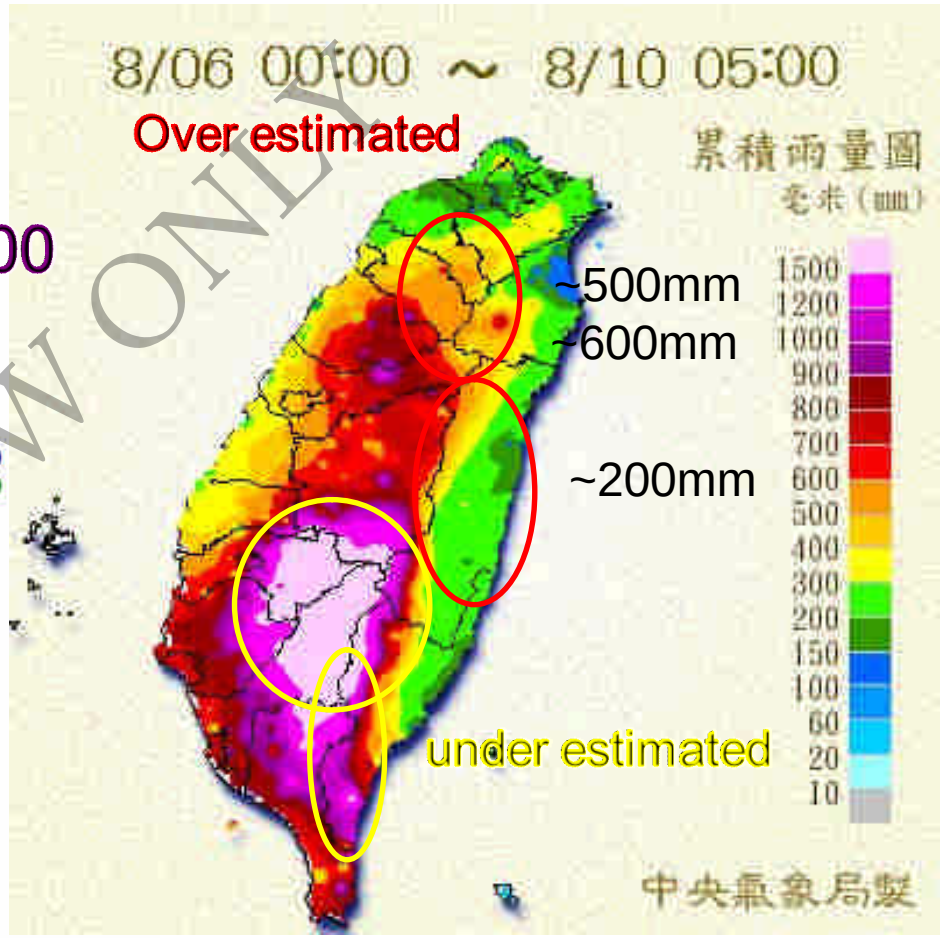
Satellite estimation

Adjust the forecast subjectively by the forecasters

FOR ITW ONLY

CWB Rainfall forecast for TY Morakot (2009)

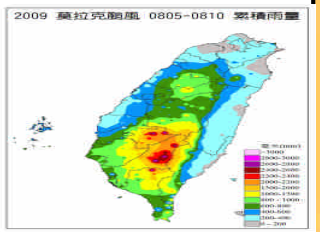




FOR TW ONLY

Forecast at 6 Aug, 1600LST

rainfall



9日23時
宜蘭 -- / 822 (- / -)
新竹 -- / 1013 (- / -)
高雄 -- / 2392 (-- / 2700)
屏東 -- / 2569 (-- / 2700)
台東 -- / 1605 (-- / 1600)
嘉義 -- / 2777 (-- / 2900)
台南 -- / 1919 (-- / 2200)

9日4時
高雄 897/1935 (1400/2700)
屏東 879/2279 (1400/2700)
台東 1052/1385 (1200/1600)
嘉義 358/2163 (1400/2900)
台南 900/1652 (1200/2200)

8日16時
高雄 736/1325 (800/1800)
屏東 693/1797 (900/2500)
台東 741/965 (900/1200)
嘉義 167/1246 (700/1800)
台南 464/998 (800/1600)

8日8時
高雄 515/906 (800/1400)
屏東 532/1401 (900/2000)
台東 474/662 (600/1000)
嘉義 99/1008 (700/1400)
台南 324/748 (800/1400)

7日16時
高雄 132/519 (700/1400)
屏東 111/670 (500/1400)
台東 83/158 (200/400)
嘉義 38/618 (700/1400)
台南 65/331 (700/1400)

9日 8時

8日 8時

7日 8時

實際雨量
平地 / 山區

預測總雨量
(平地 / 山區)

7日22時
高雄 216/676 (700/1400)
屏東 208/936 (500/1400)
台東 129/292 (200/400)
嘉義 47/759 (700/1400)
台南 104/435 (700/1400)

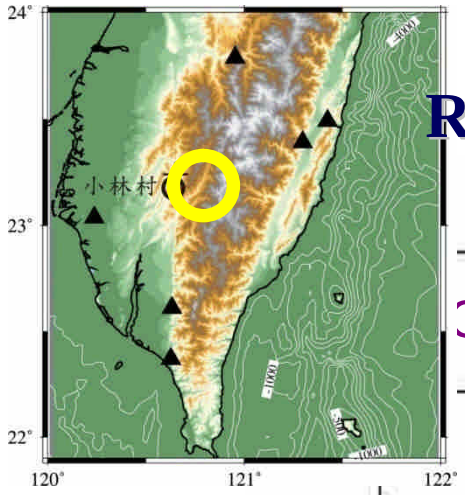
6日8時30分
發布陸上颱風警報

7日7時
高雄 31/248 (500/1100)
屏東 26/265 (350/1100)
台東 12/17 (200/350)
嘉義 38 / 354 (500/1200)
台南 26 / 204 (500/1100)

6日10時
宜蘭 0 (400/900)
新竹 0 (350/1000)
高雄 0 (250/800)
屏東 0 (250/800)
台東 0 (150/300)
嘉義 0 (300/800)
台南 0 (250/800)

AUTHORITY ONLY

Rainfall and rainfall forecast at Sauling



CWB forecasted rainfall ranges

3000 mm

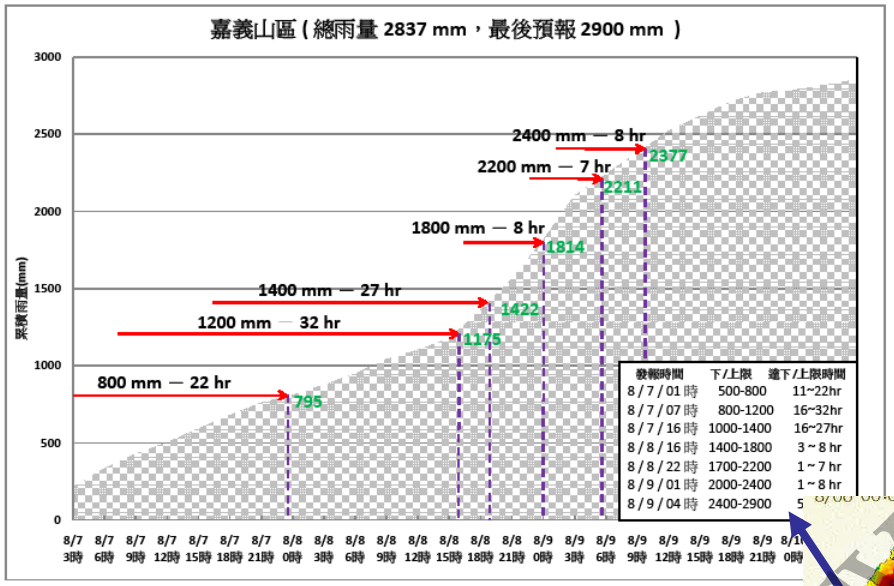
2500 mm

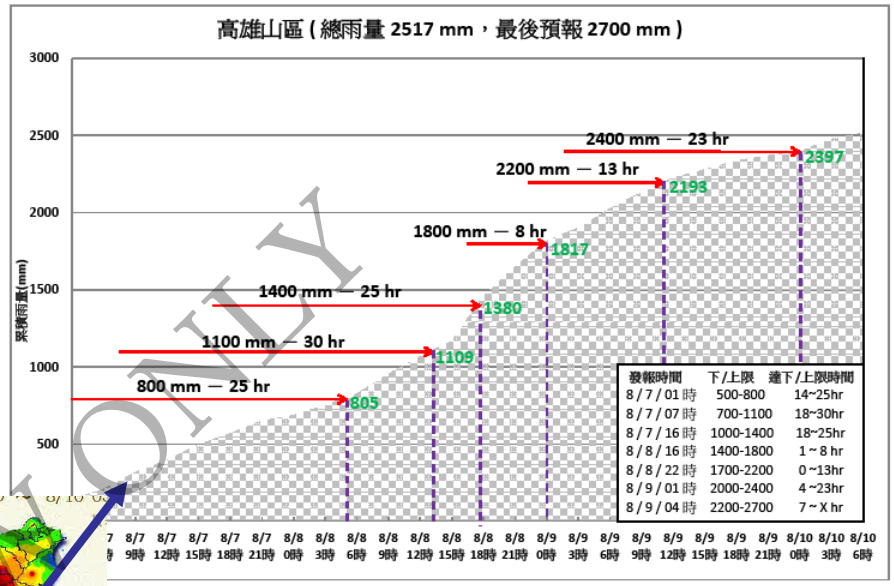
accumulated rainfall

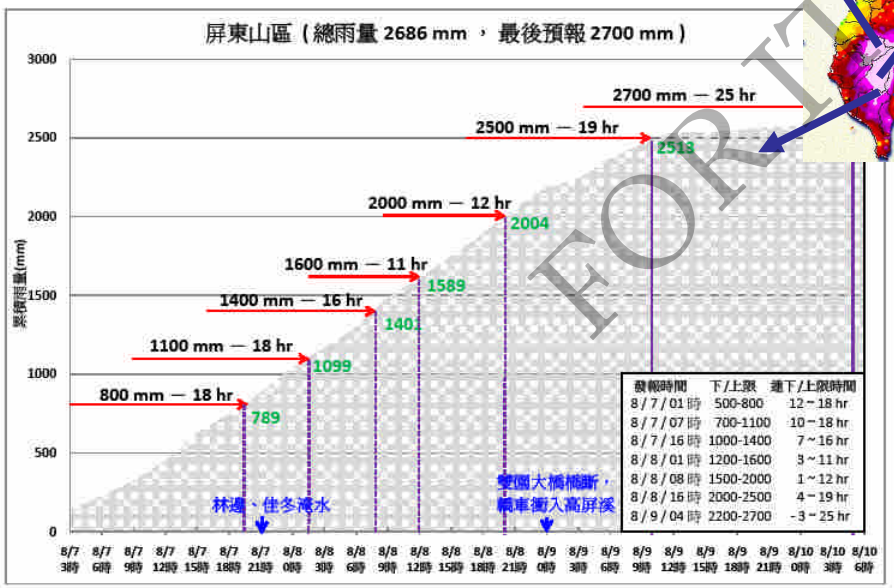
FOR ITW ONLY

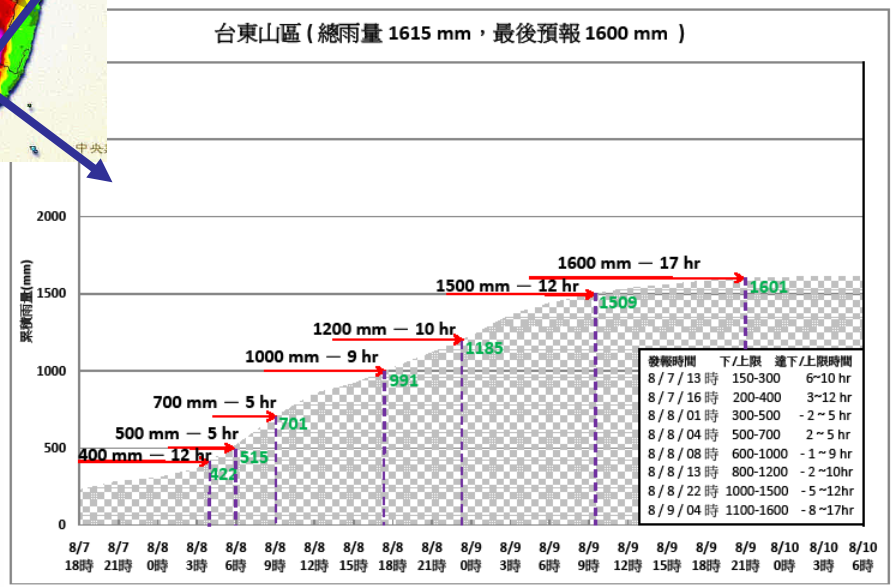
Time from 1 AM 6 Aug to 1 AM 10 August, 2009

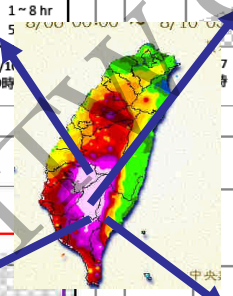
Lead time of the rainfall forecast





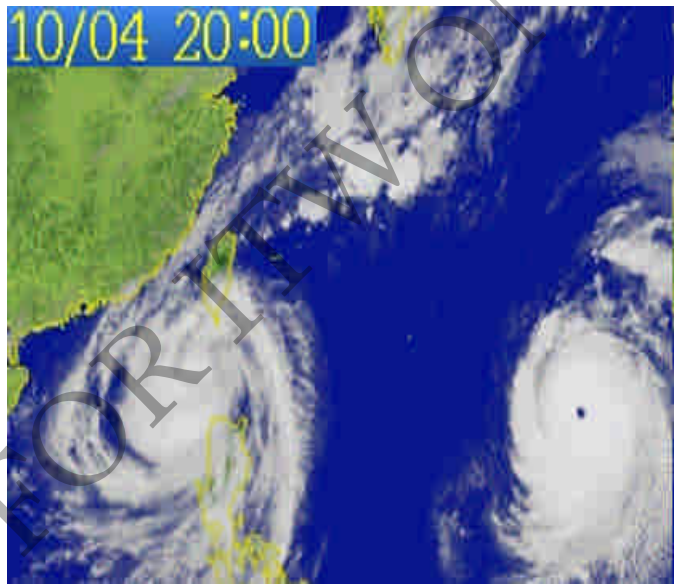






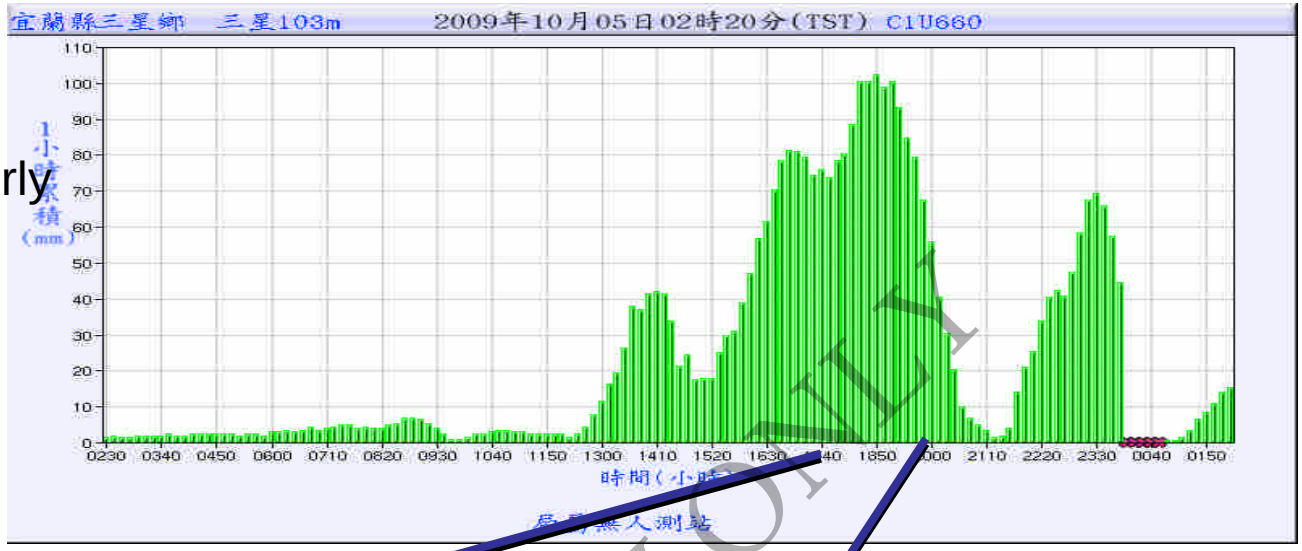
FOR ITU ONLY

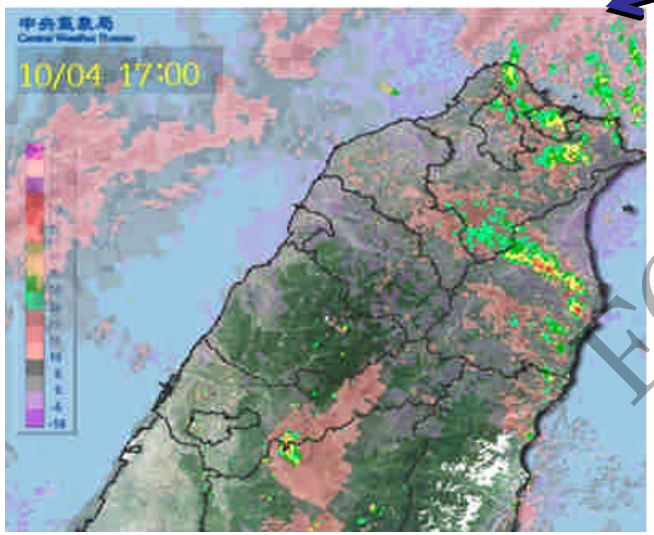
Another case – Tropical storm Prama

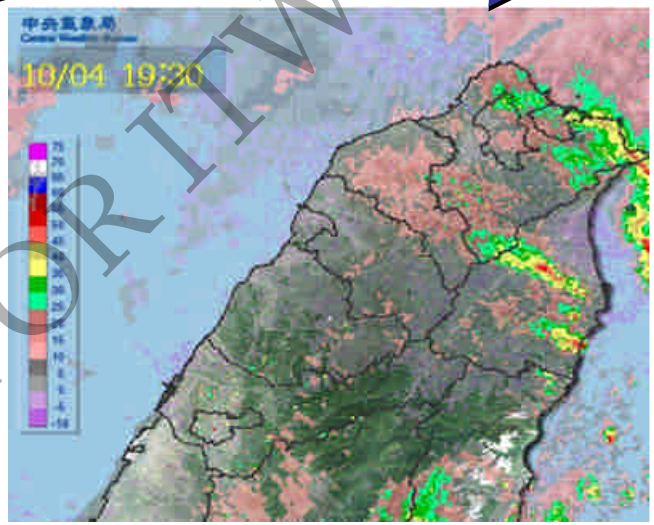


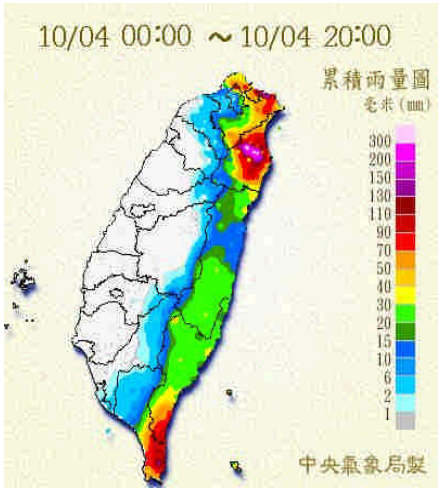
FOR ITWO ONLY

hourly





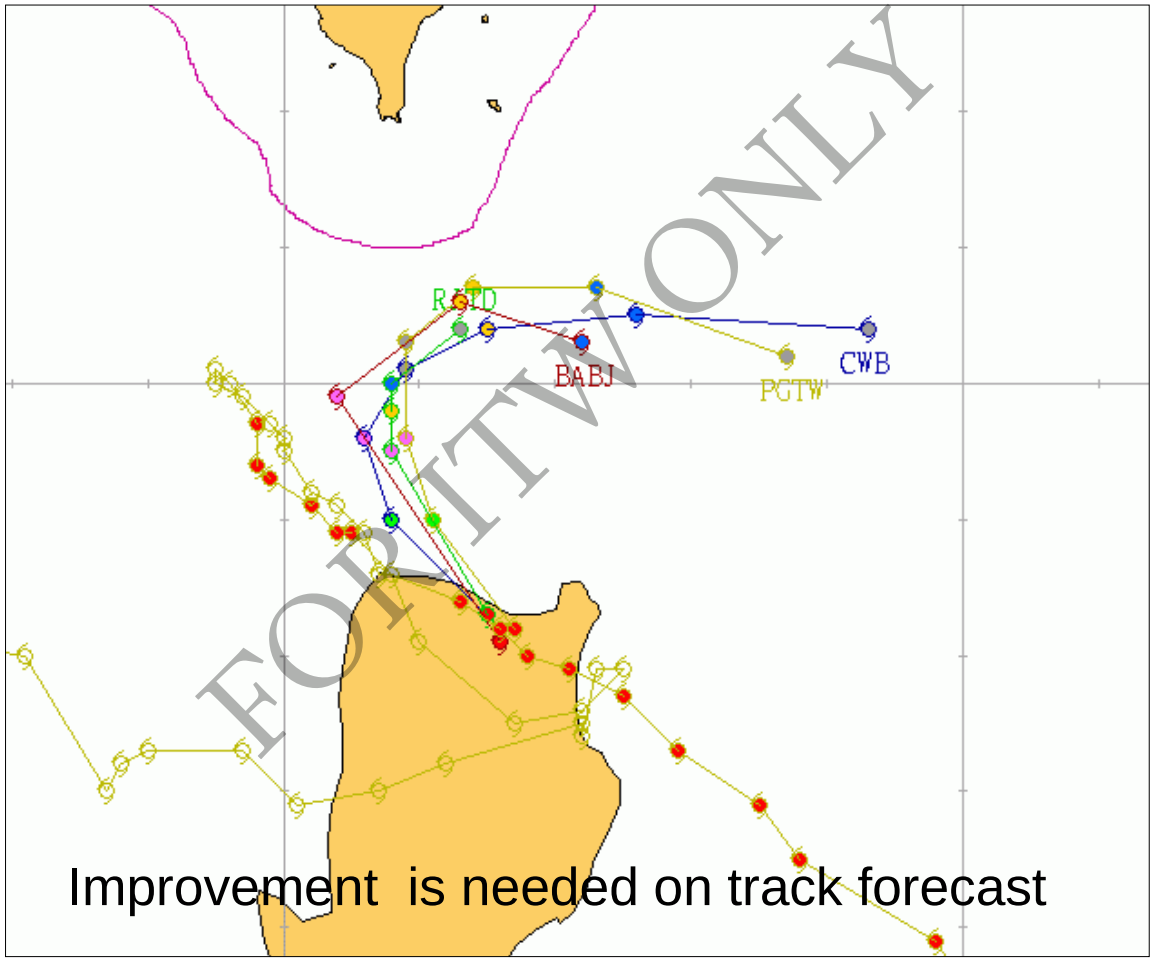




FOR ITW ONLY

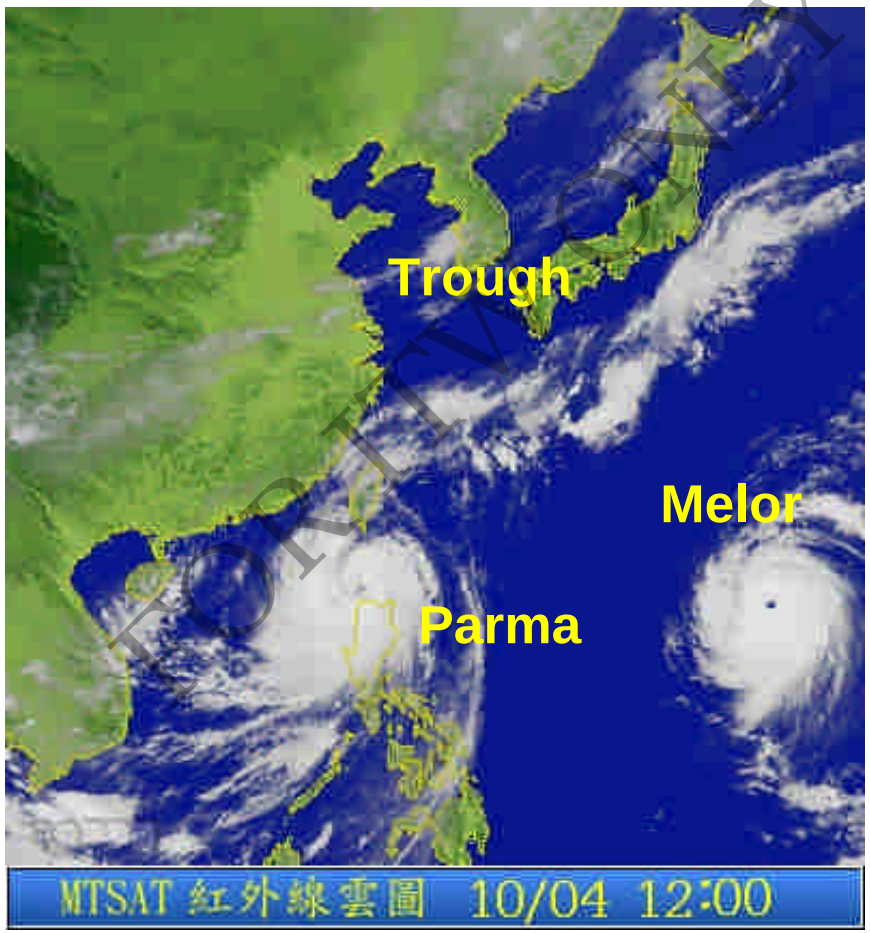
Very intensive
small scale heavy rainfall event

Challenge on typhoon forecast



FOR TTW ONLY

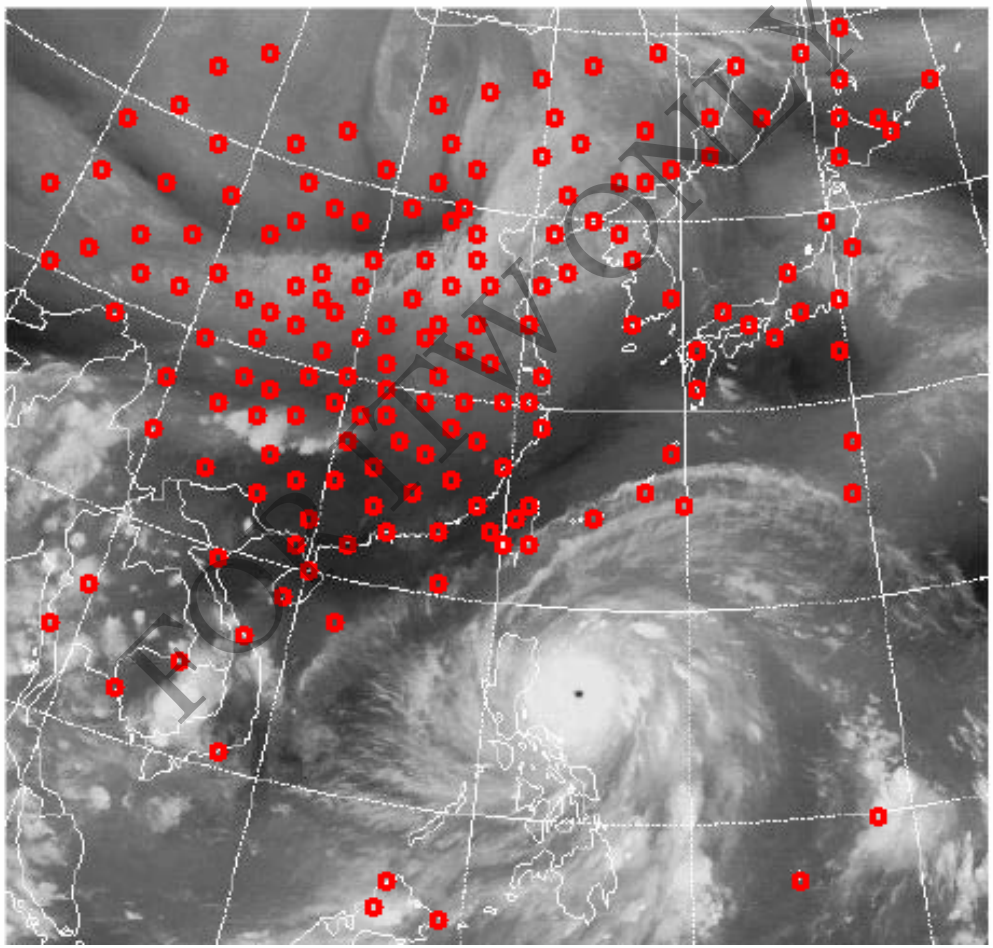
Improvement is needed on track forecast



FOR TV ONLY

Challenge

- Poor data coverage

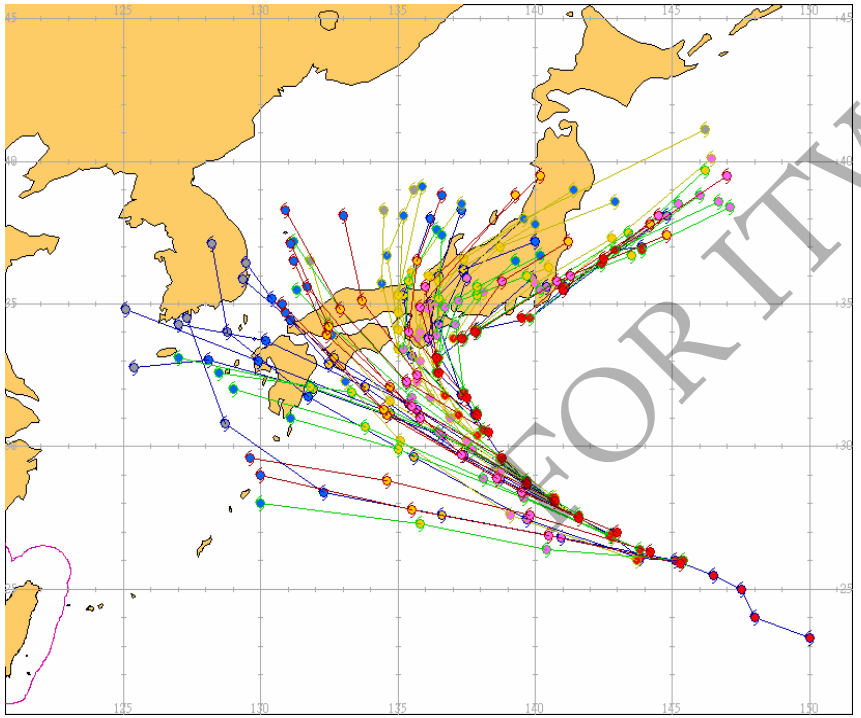


PREVIEW ONLY

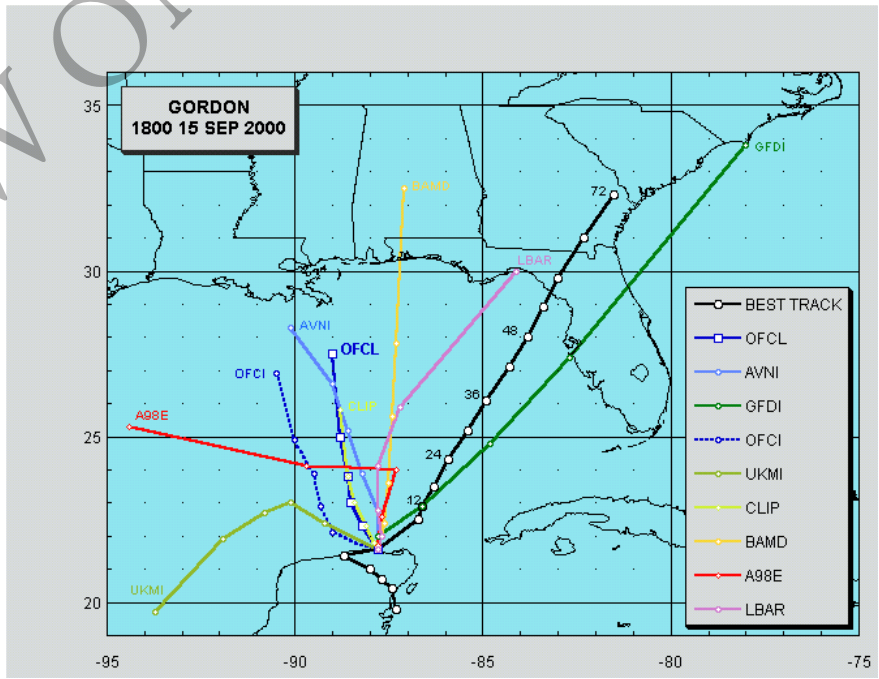
Challenge

- Not fully understand the mechanism of the typhoon motion and structure change

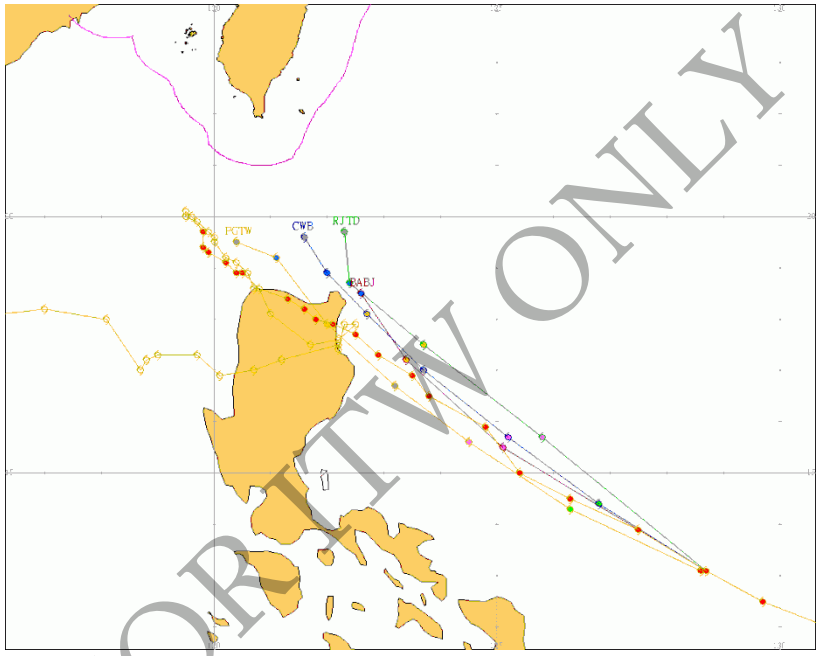
Different forecasts for NWP TC Maria (2006)



Different forecasts for NWA TC Gordon (2000)



FOR ITW ONLY

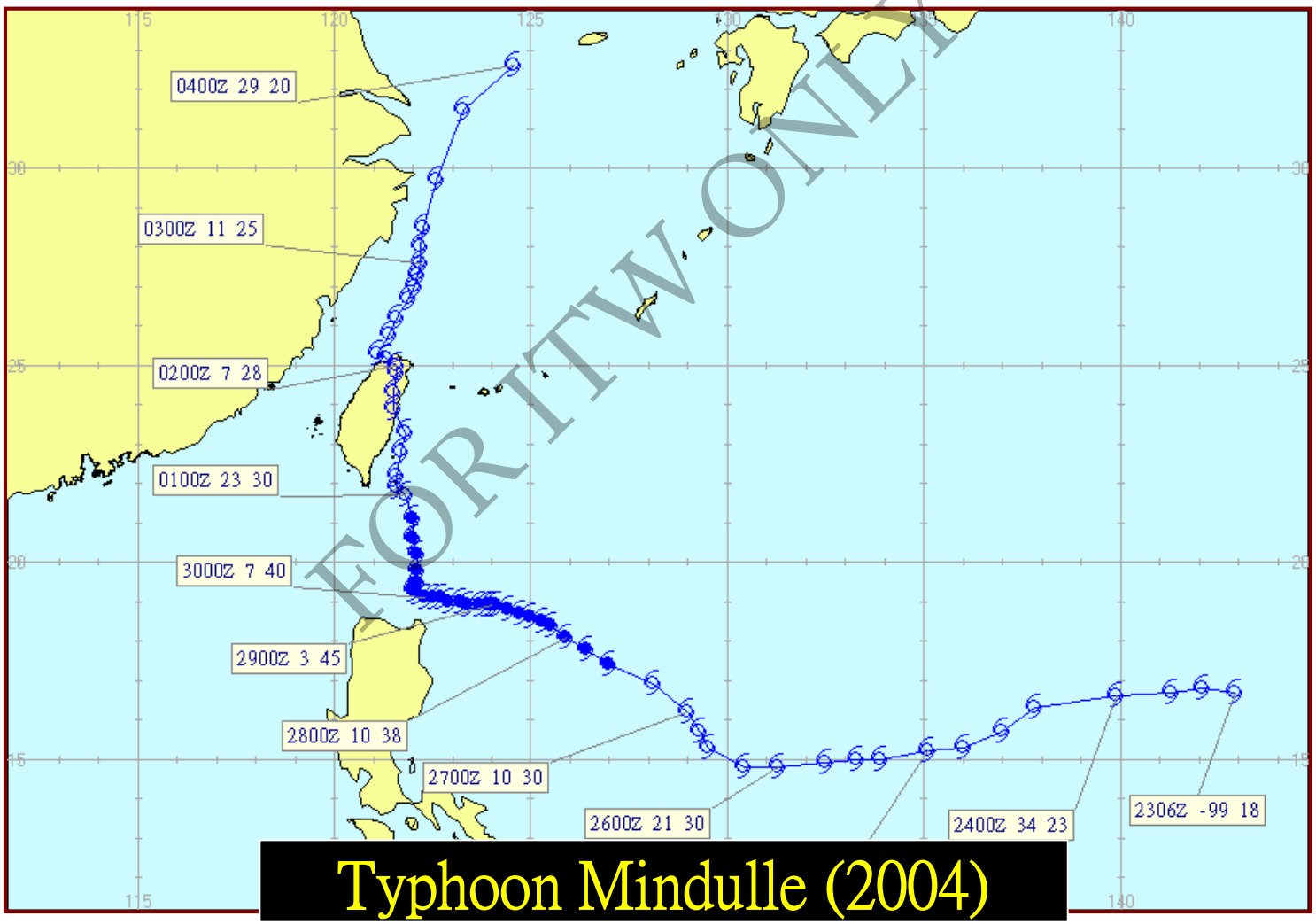


FOR TTW ONLY

Different official 96-h forecasts
for TC Prama (09100112UTC)

Challenge

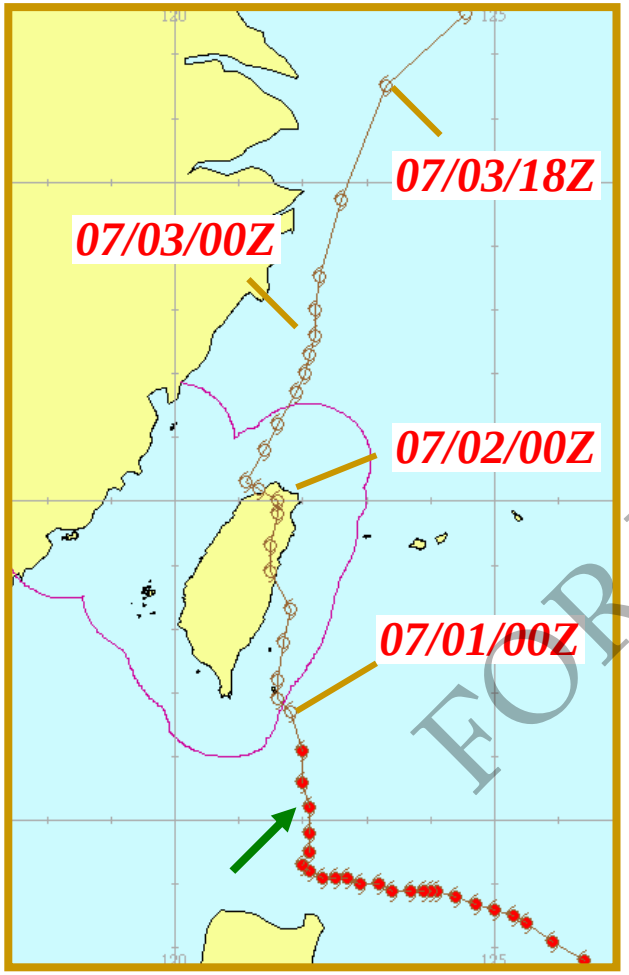
- Not fully understand the mechanism of the typhoon motion and structure change

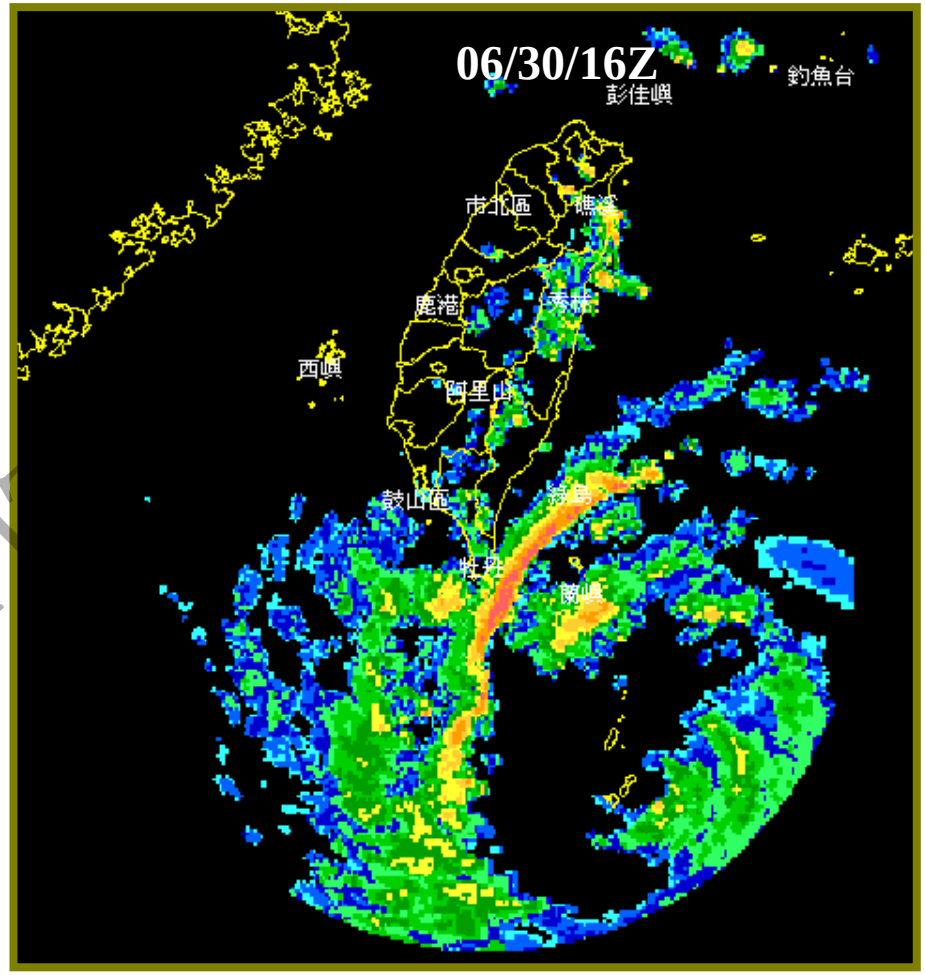


Typhoon Mindulle (2004)

FOR ITW ONLY

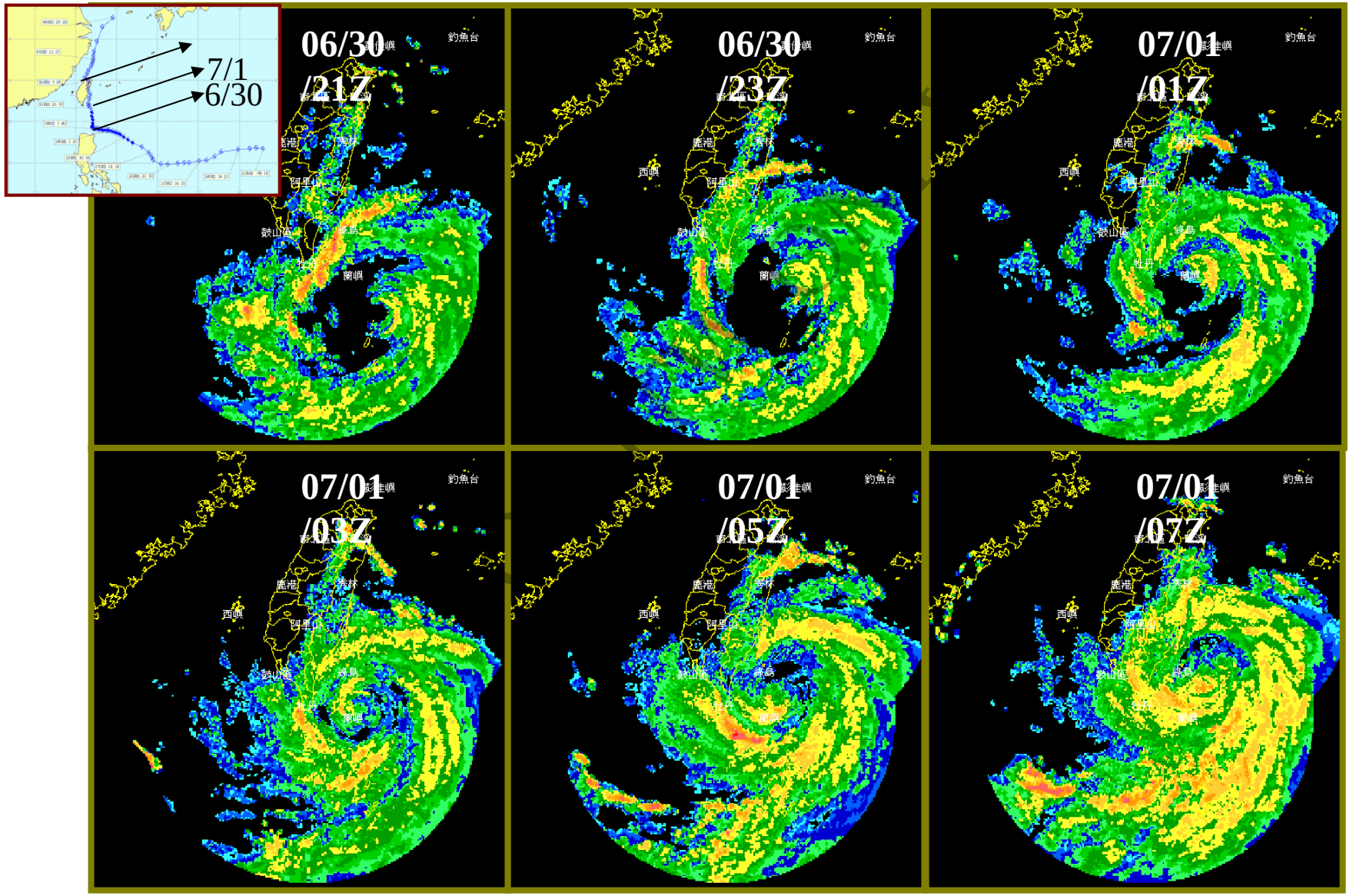
Structure of Mindulle Observed from CWB Radars



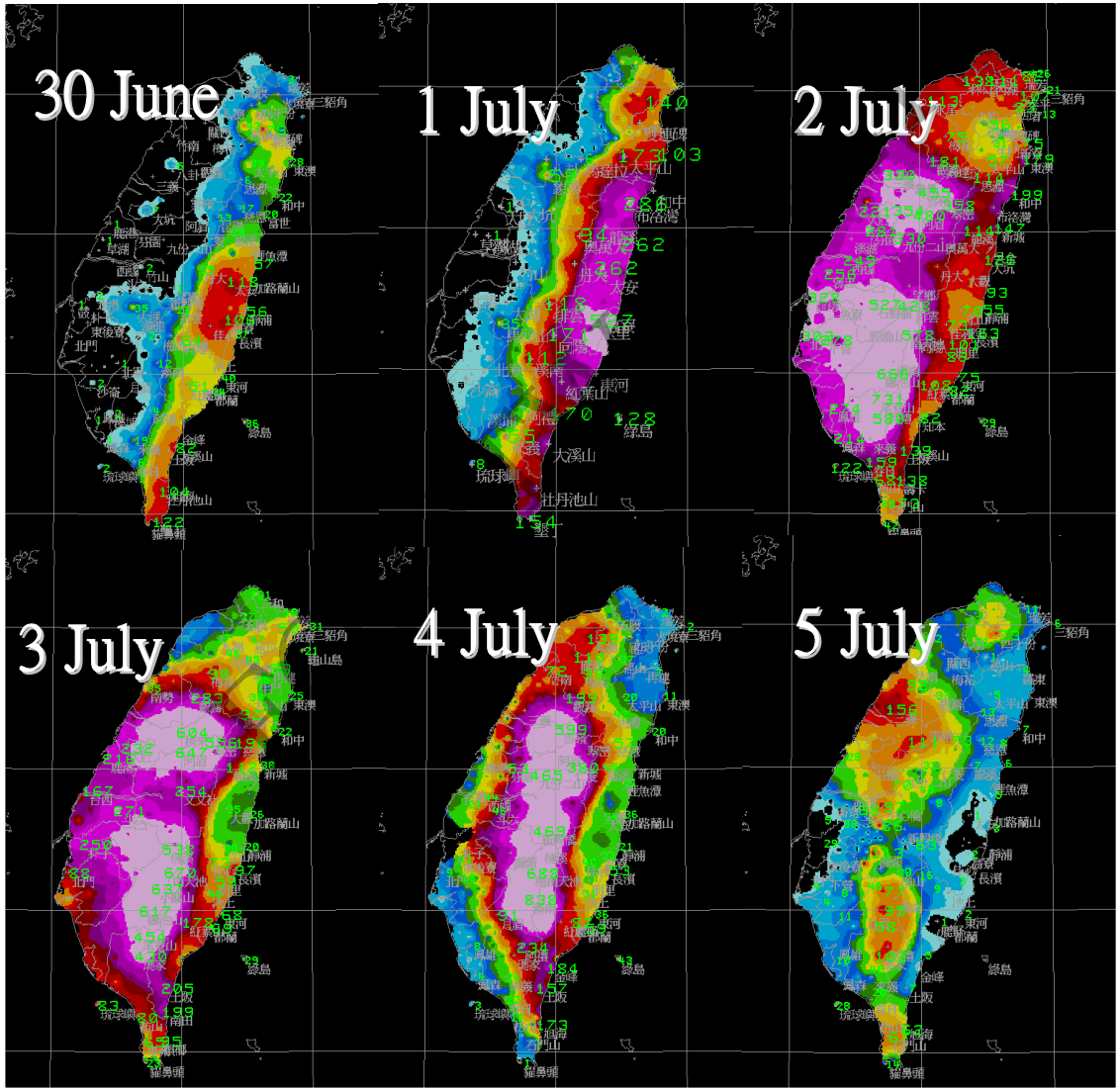


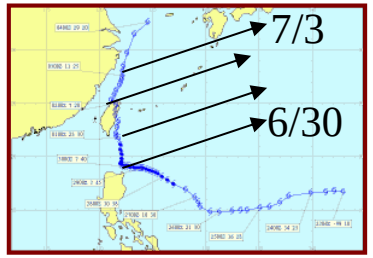
FOR

Structure of Mindulle Observed from CWB Radars



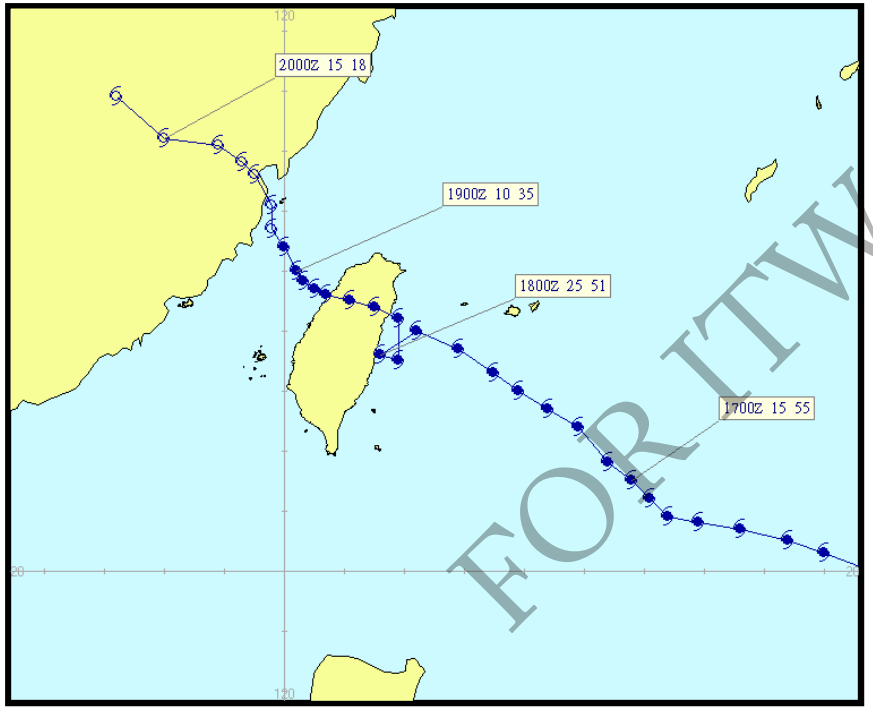
Rainfall on 30 June to 5 July
(under the influence of Typhoon Mindulle)

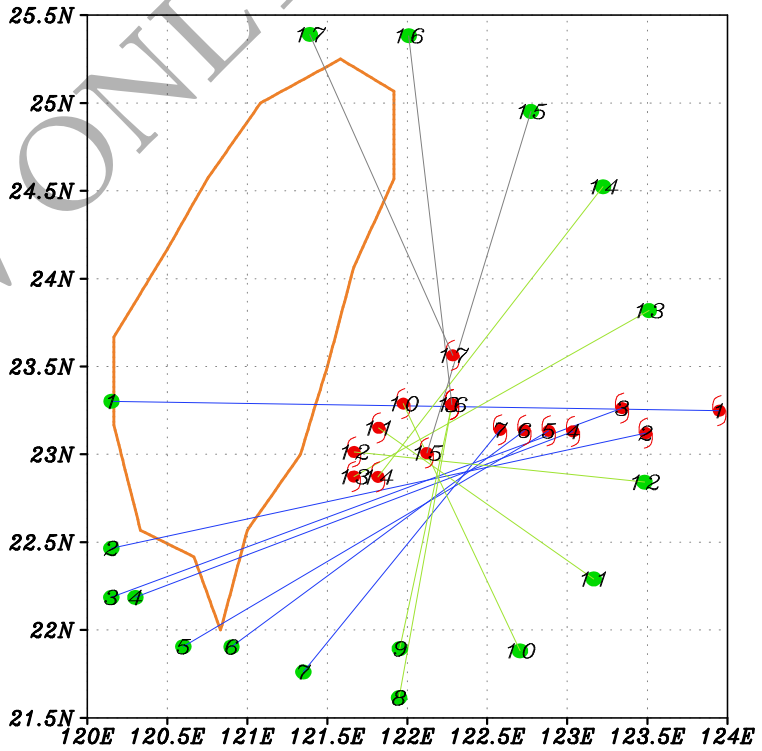




Challenge

– Topography effect on tropical cyclones – Track change



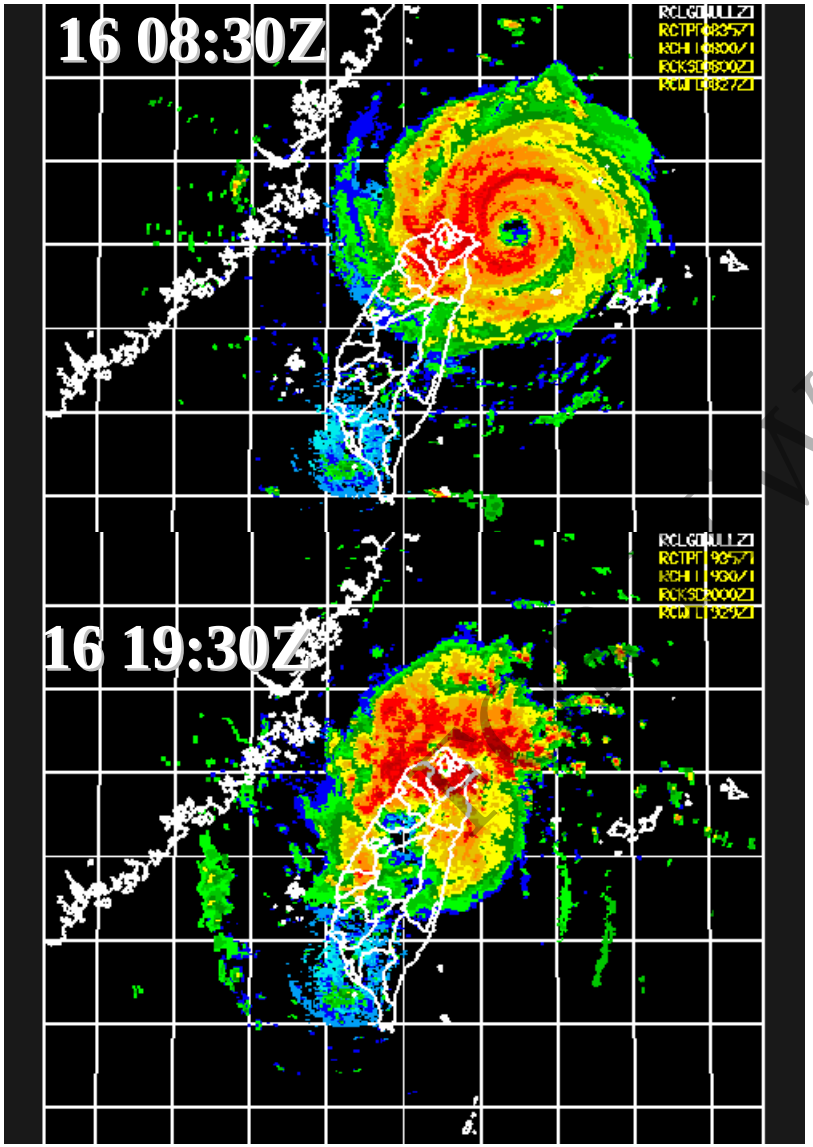


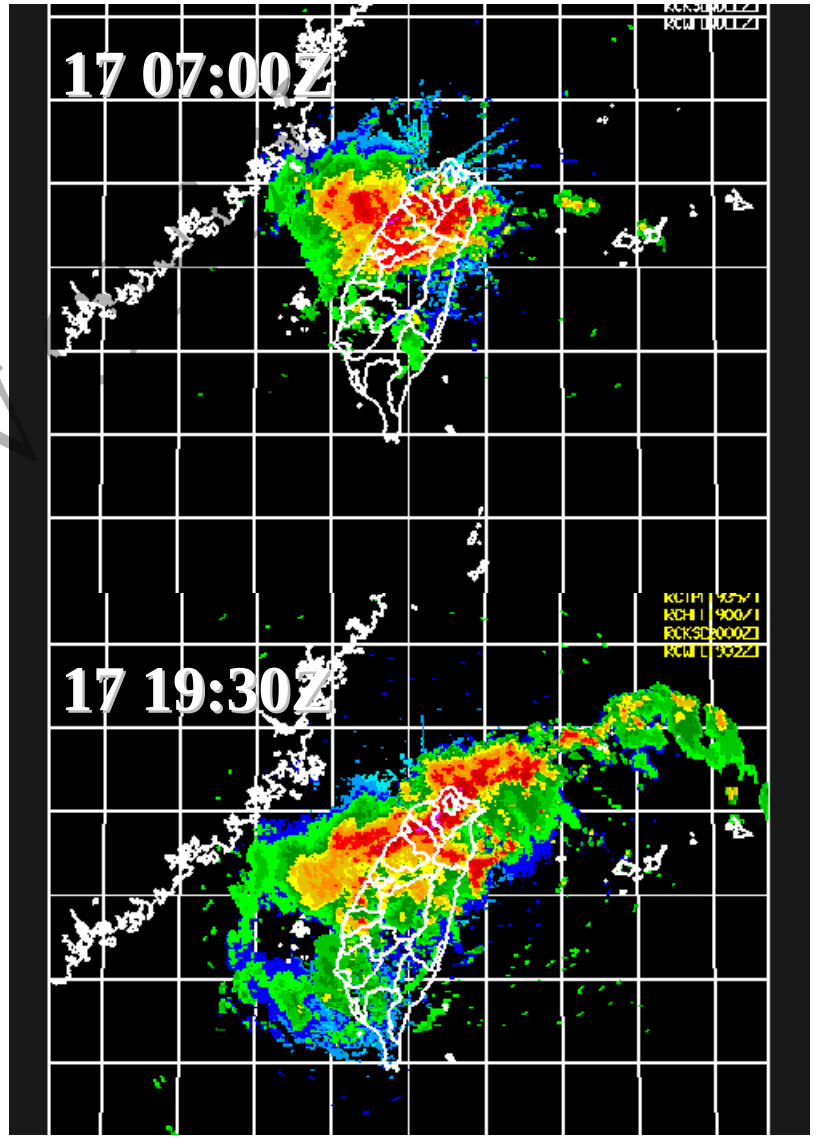
FOR ITW ONLY

Typhoon Haitang 2005

Challenge

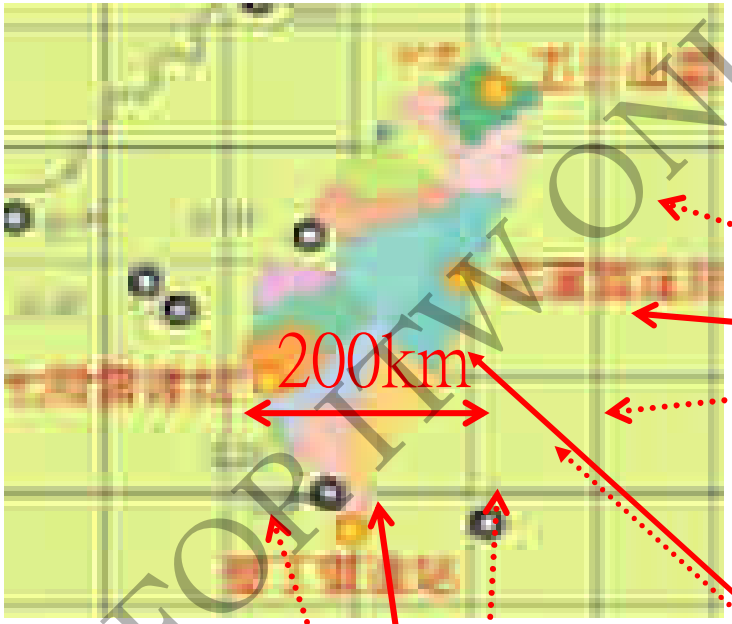
– Topography effect on tropical cyclones - Structure change





Challenge

- Small track forecasting error maybe result in completely different scenarios



Wind could be strong or weak depends on whether it is at the Leeside or upwind side of the mountain

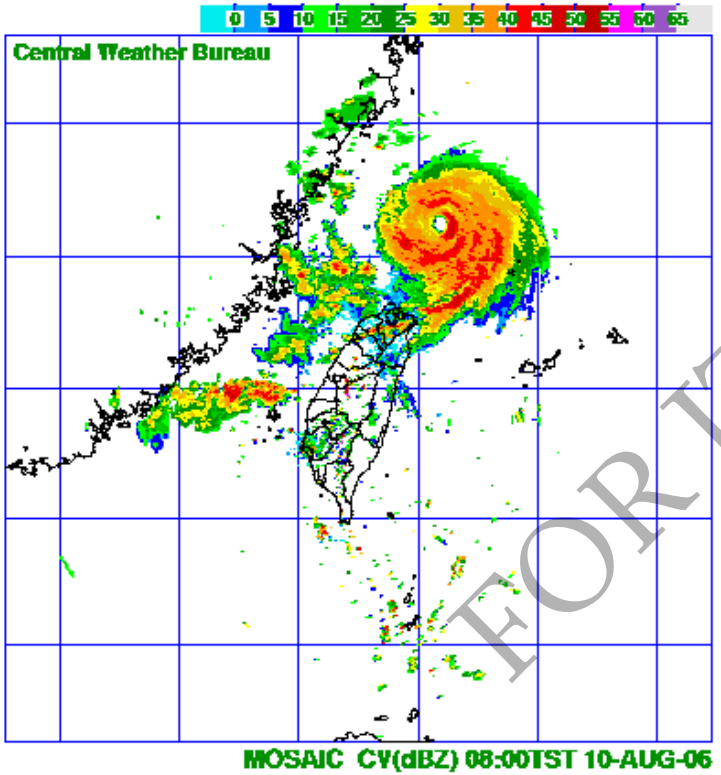
Could passes by either sides of CMR

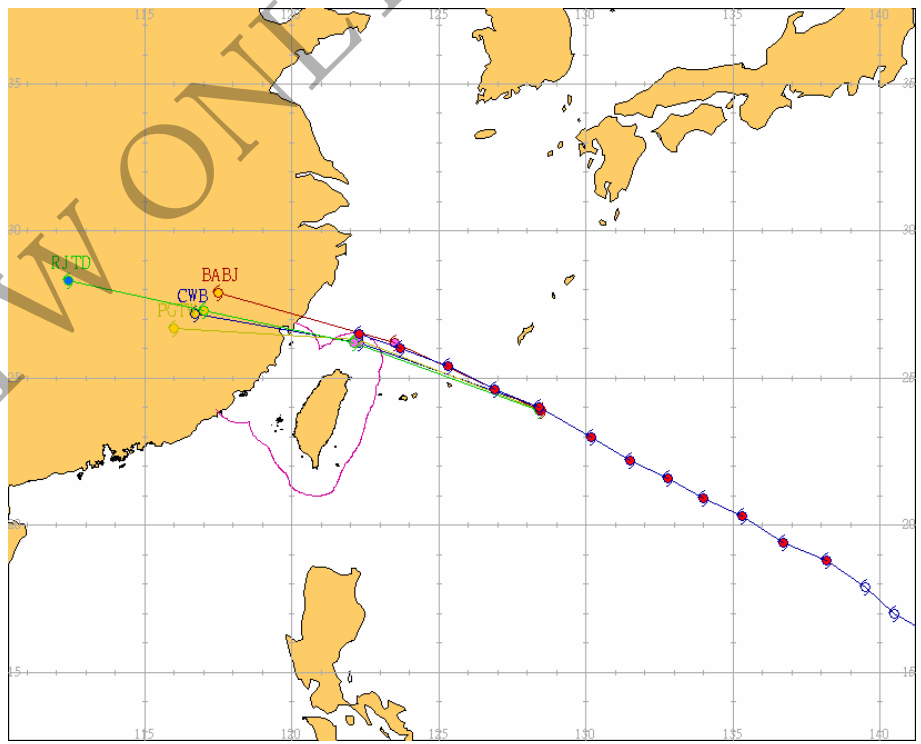
Time can be a couple of hours of difference even direction is correct

FOR TFW ONLY

Challenge

- Small track different results in completely different scenarios



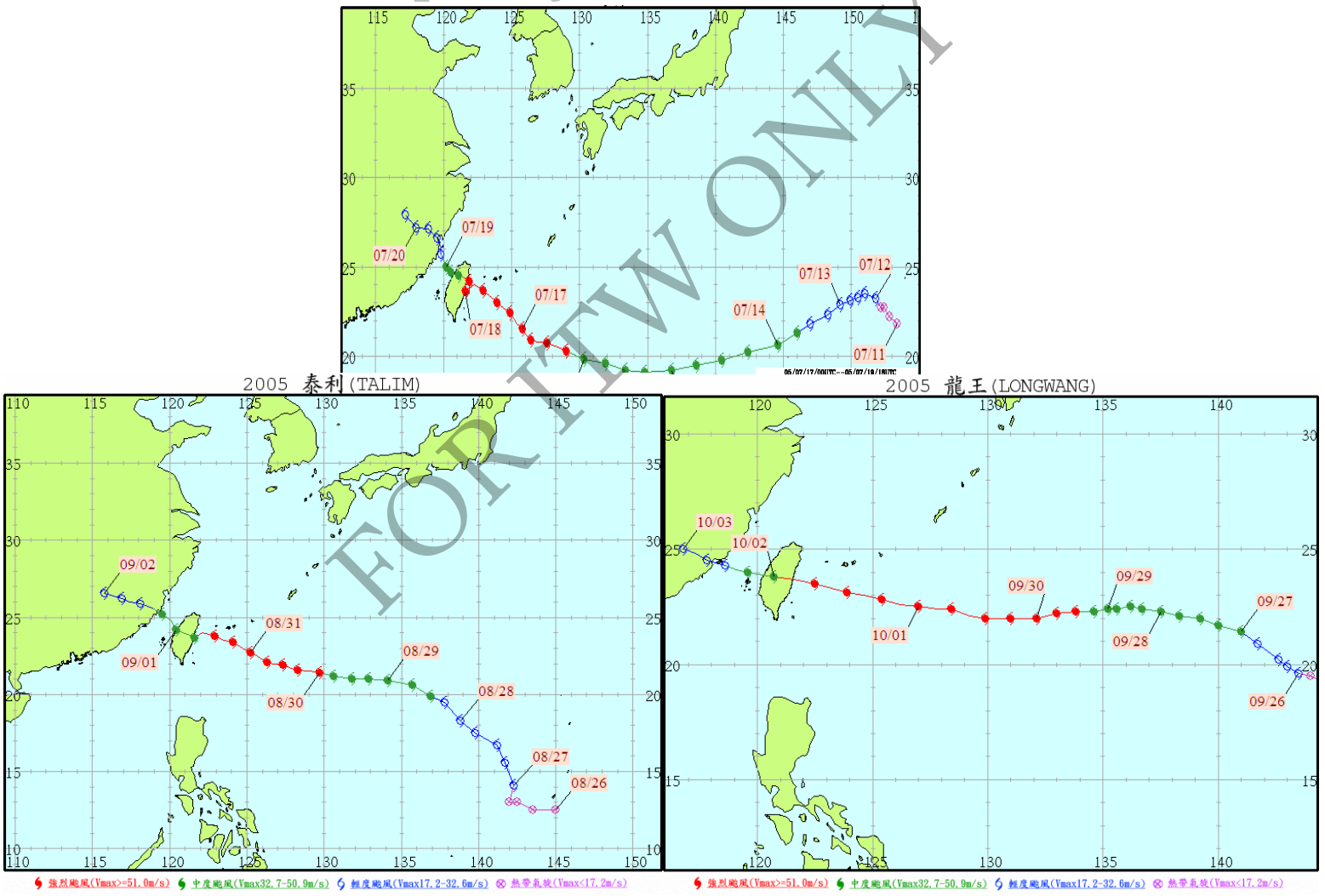


FOR ITW ONLY

Songmei caused many casualties in China.
Could cause serious damage in Northern Taiwan with the track shift southward only a few 10s km.

Challenge

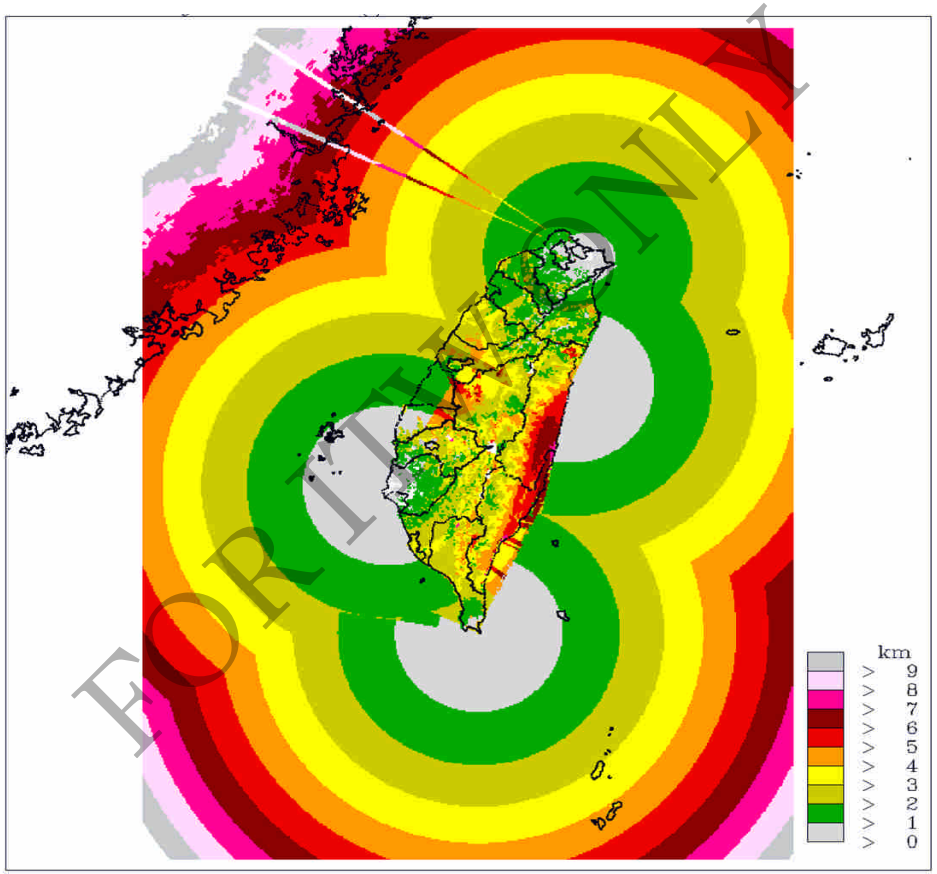
- Environment and cyclone structure different results in completely different scenarios



FOR ITW ONLY

Challenge

- With the best observation system is still not enough

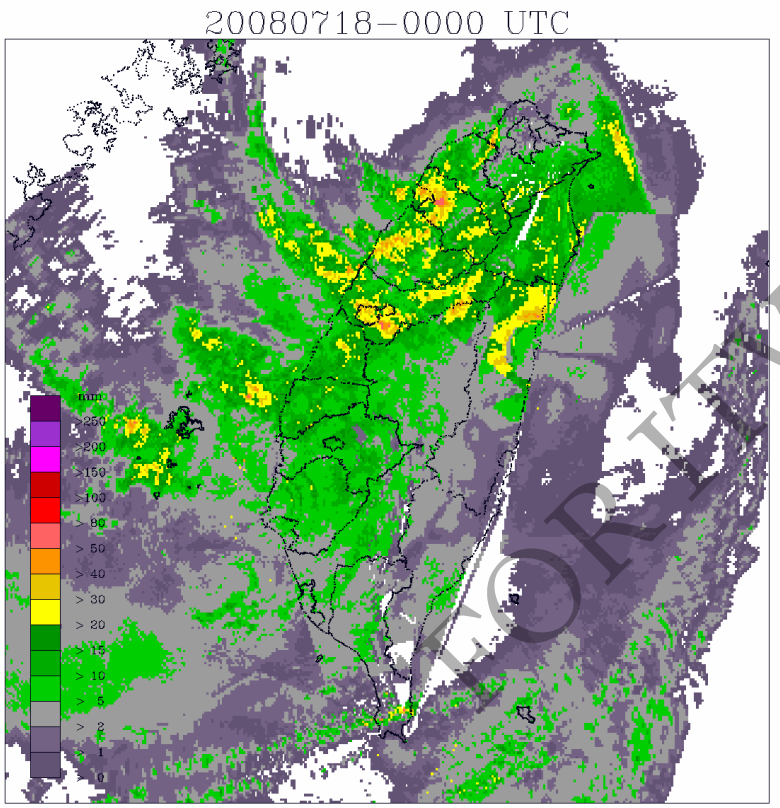


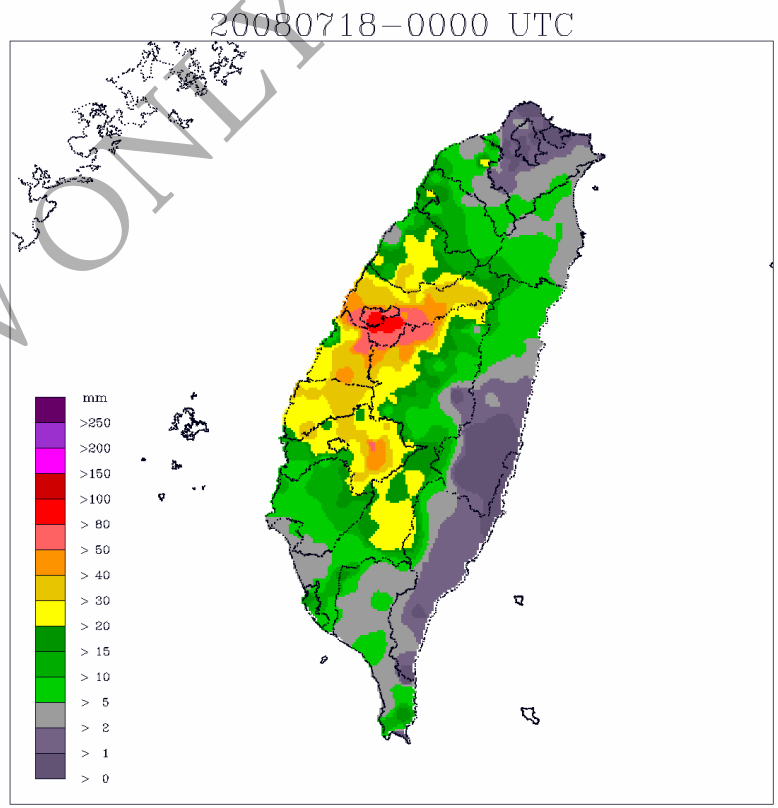
FOR ITRI ONLY

Radar could not detect the lower layer of atmosphere

Challenge

- With the best observation system is still not enough



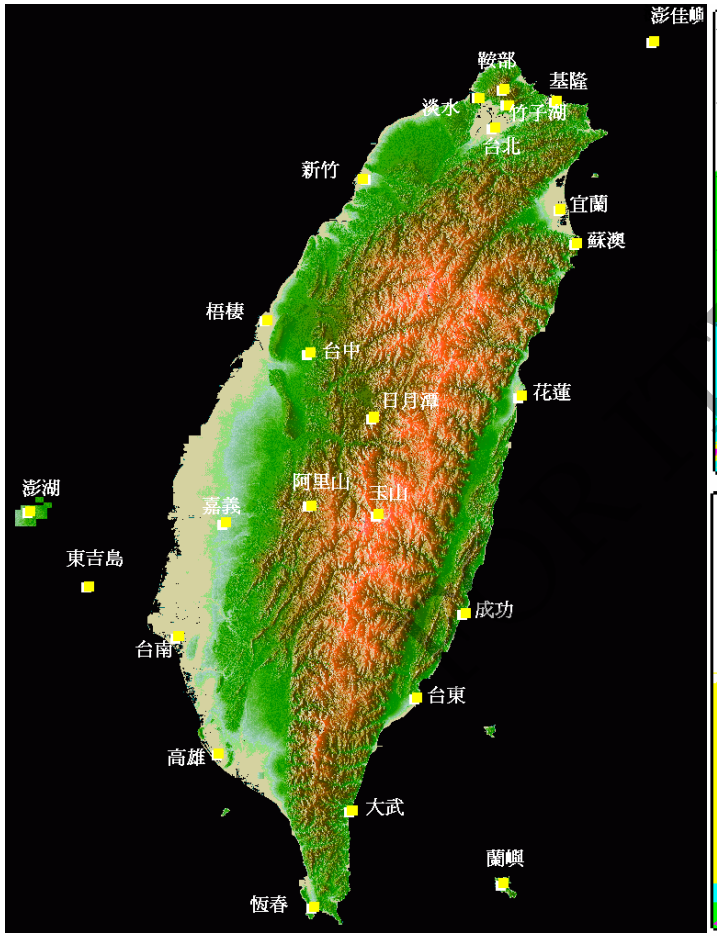


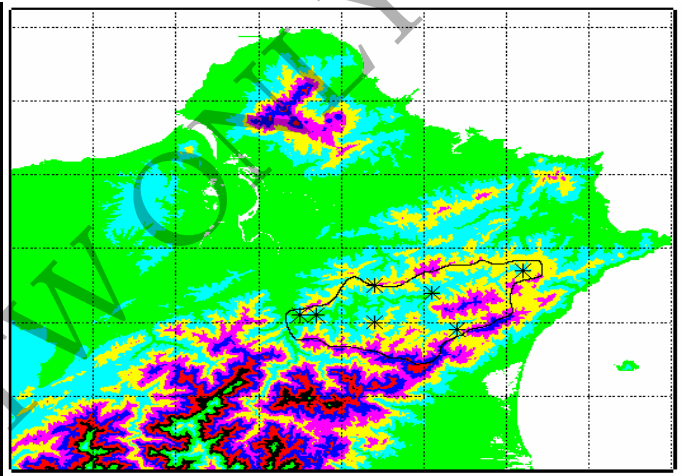
FOR REVIEW ONLY

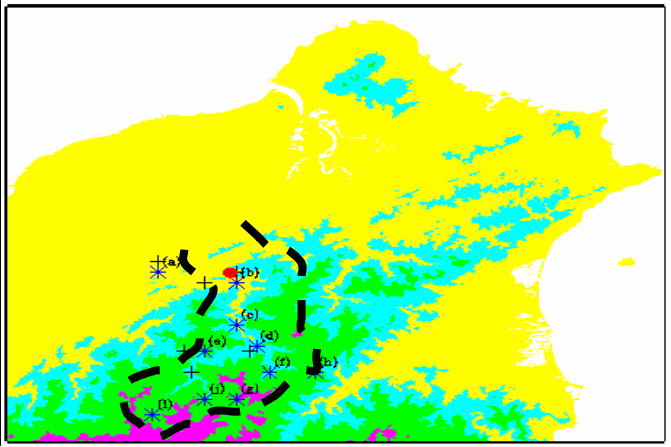
Radar estimated rainfall may different from sit observations

Challenge

- Steep slop, small reservoirs, small watersheds with high water demand result in great challenge of water management in Taiwan







303 km^2

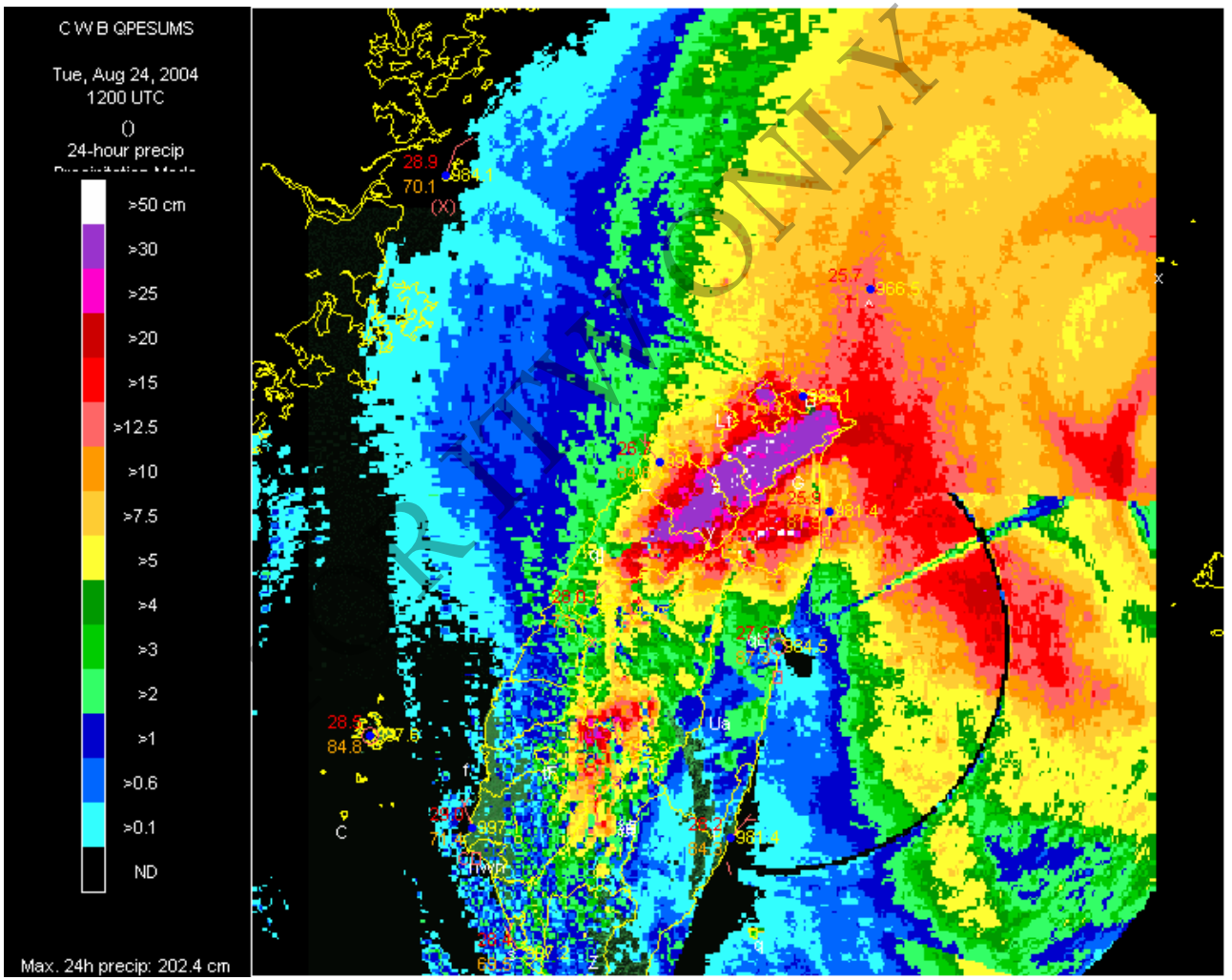
10 km^2

400 M m^3

FOR DEMONSTRATION ONLY

Future Work

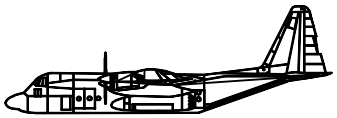
-- Improve short range forecast

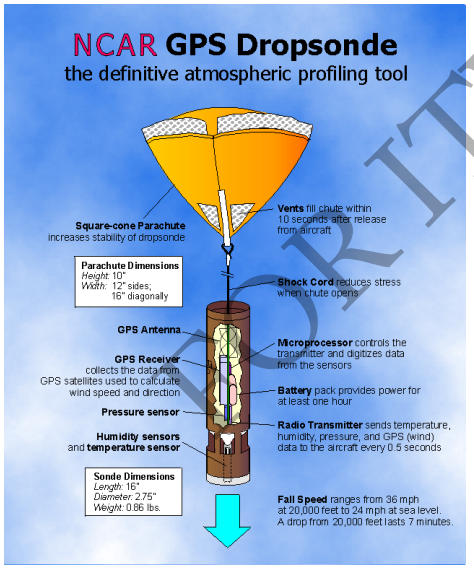


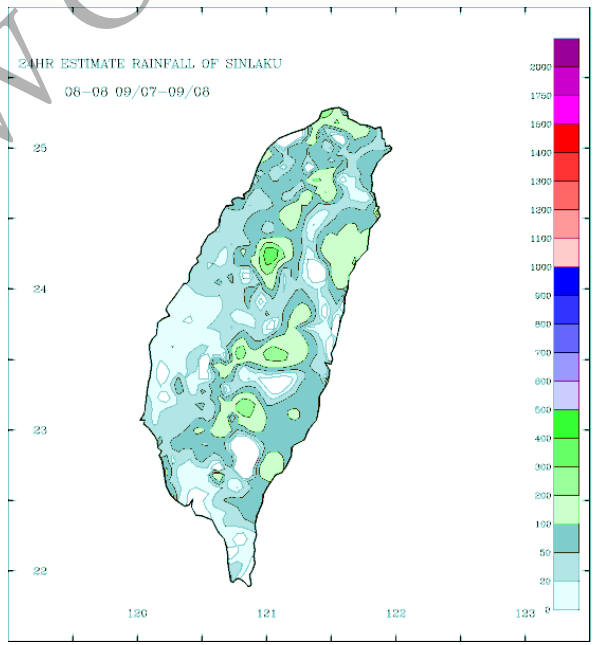
RTN ONLY

Future Work

-- More studies such as tyhoon dropsonde observation experiment





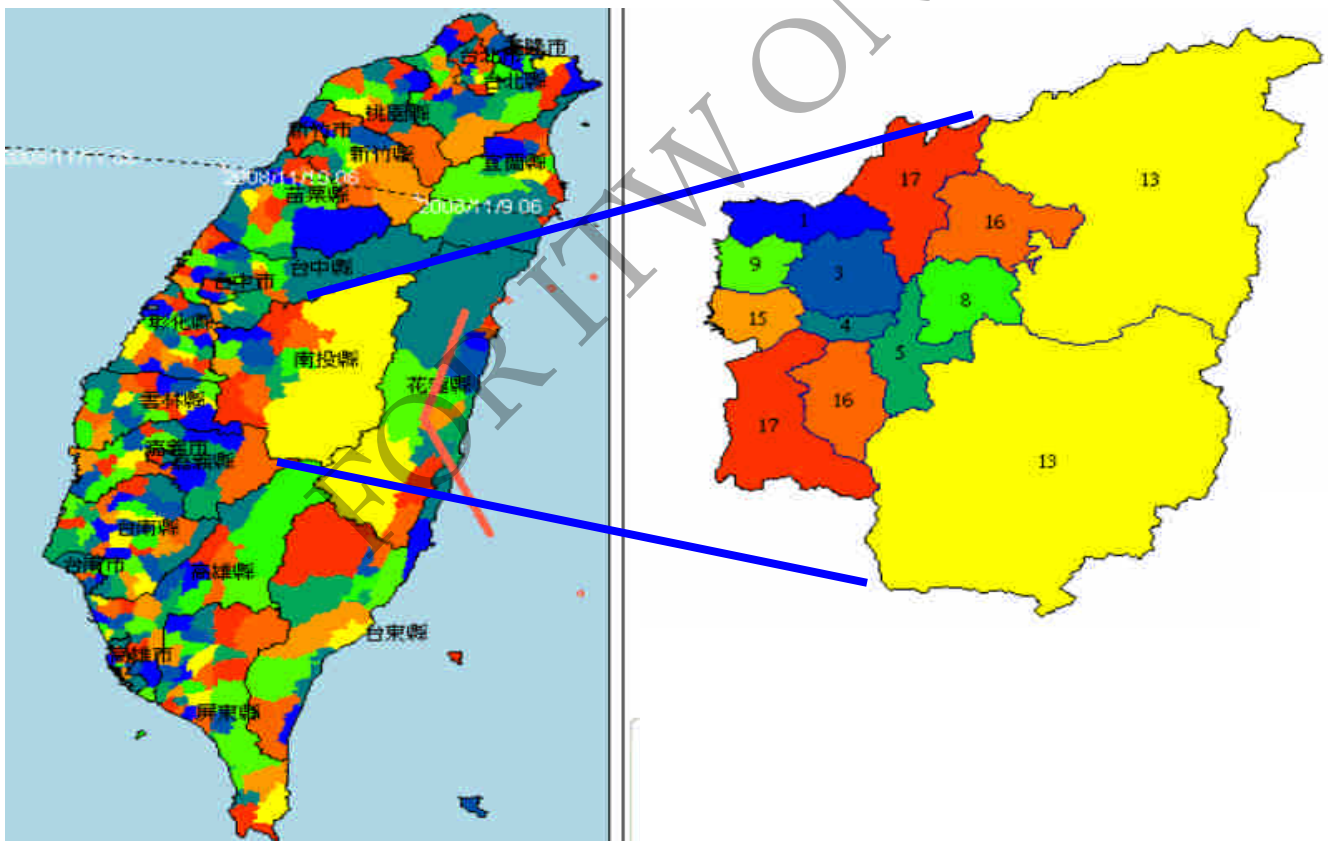


FOR ITW ONLY

Future Work

-- More studies such as development of finer scale forecast

- forecasts for 22 counties/cities ➔ for 368 townships

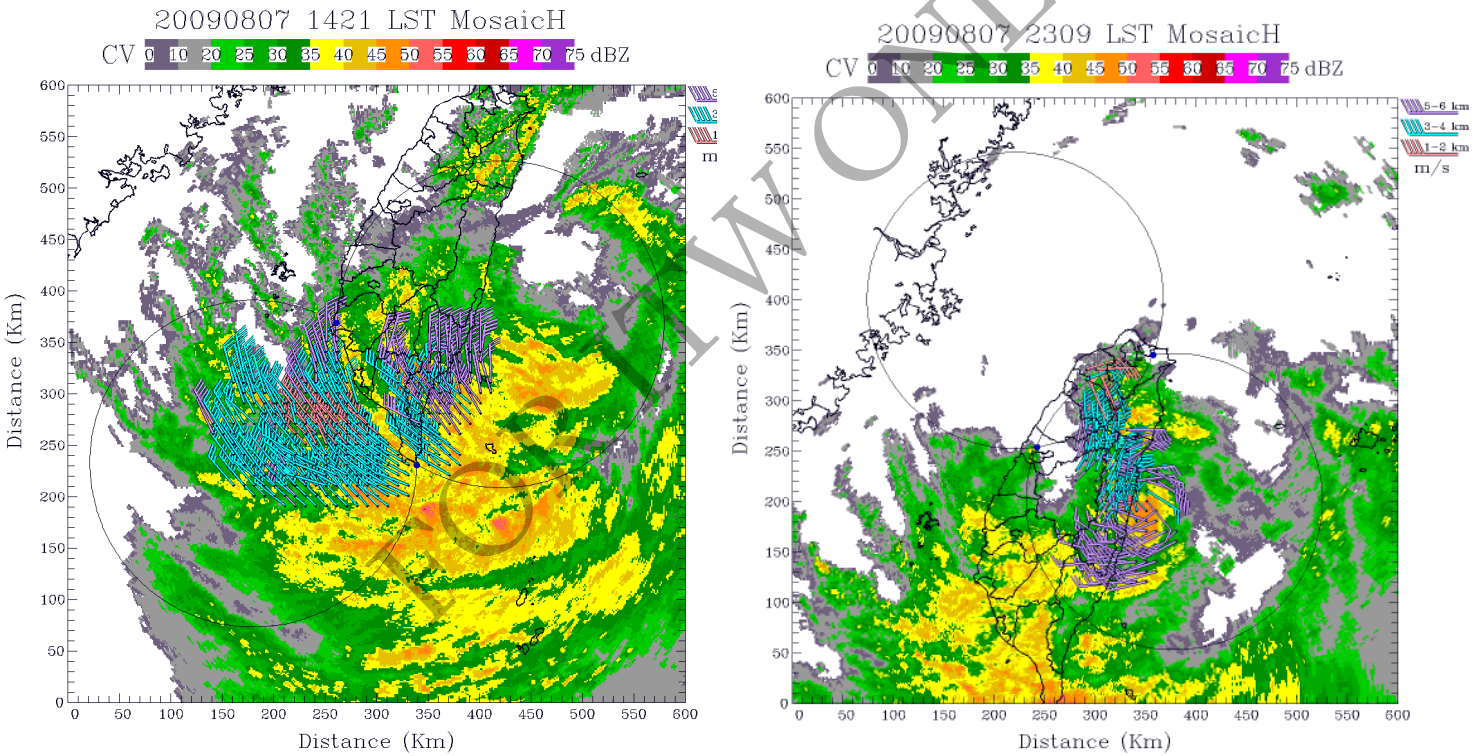


FOR ITW ONLY

Improve real time monitoring and short time forecast

More complete coverage of the radar observation

Dual-Doppler wind analyses: RCWF–RCHL, RCWF–RCCK, RCCG–RCCK, RCCG–RCKT, RCKT–RCHL, and RCCK–RCMK 6-pairs

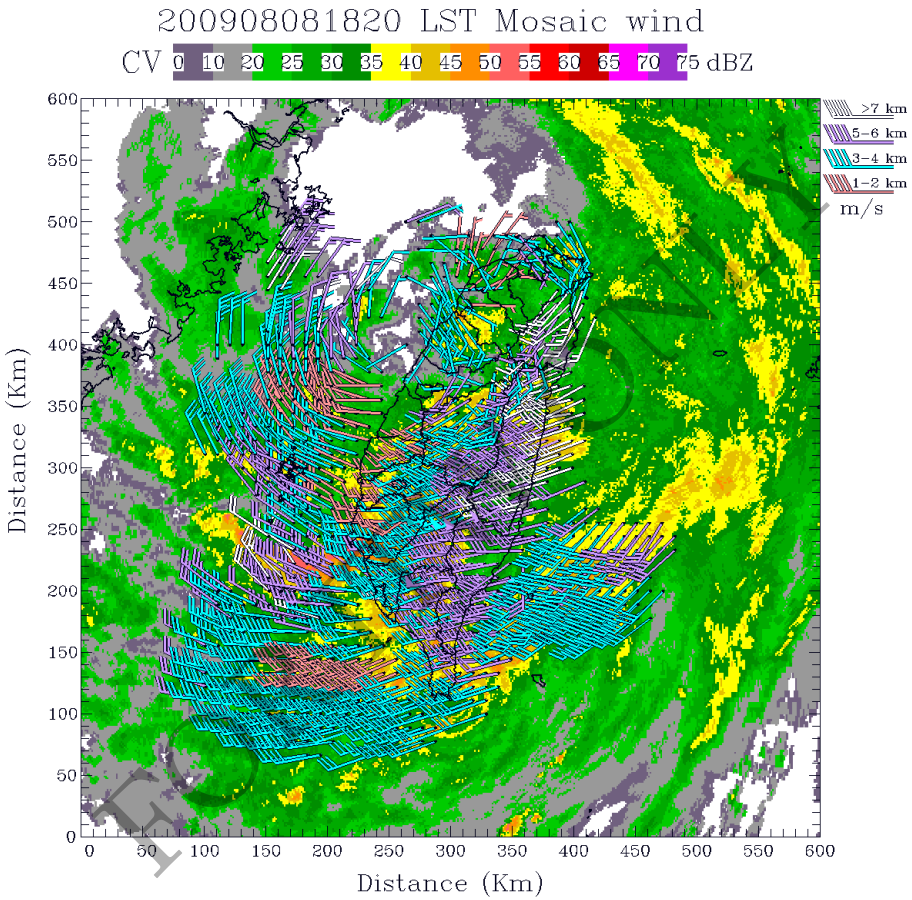


FOR NWOLY

Dual-Doppler winds

2009 0807 14:21 LST RCCG-RCKT and 0723:09 LST RCWF-RCCK

P.-L. Chang

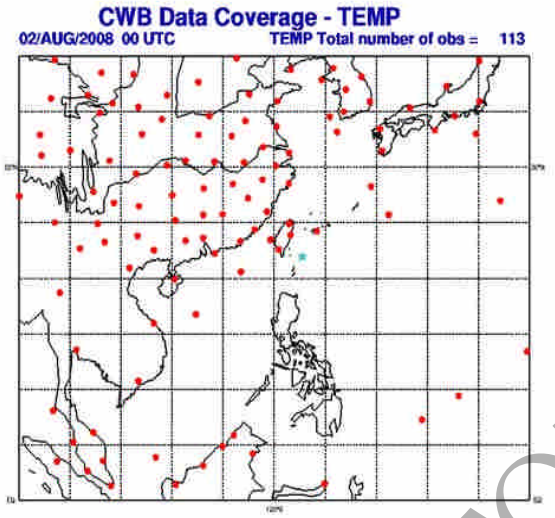


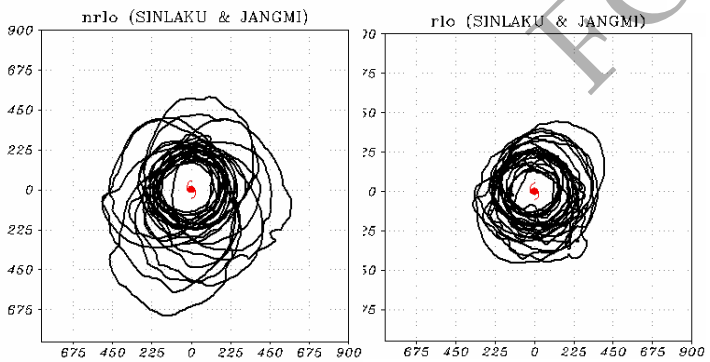
Compose of the Dual-Doppler winds at 20090808 18:20 LST

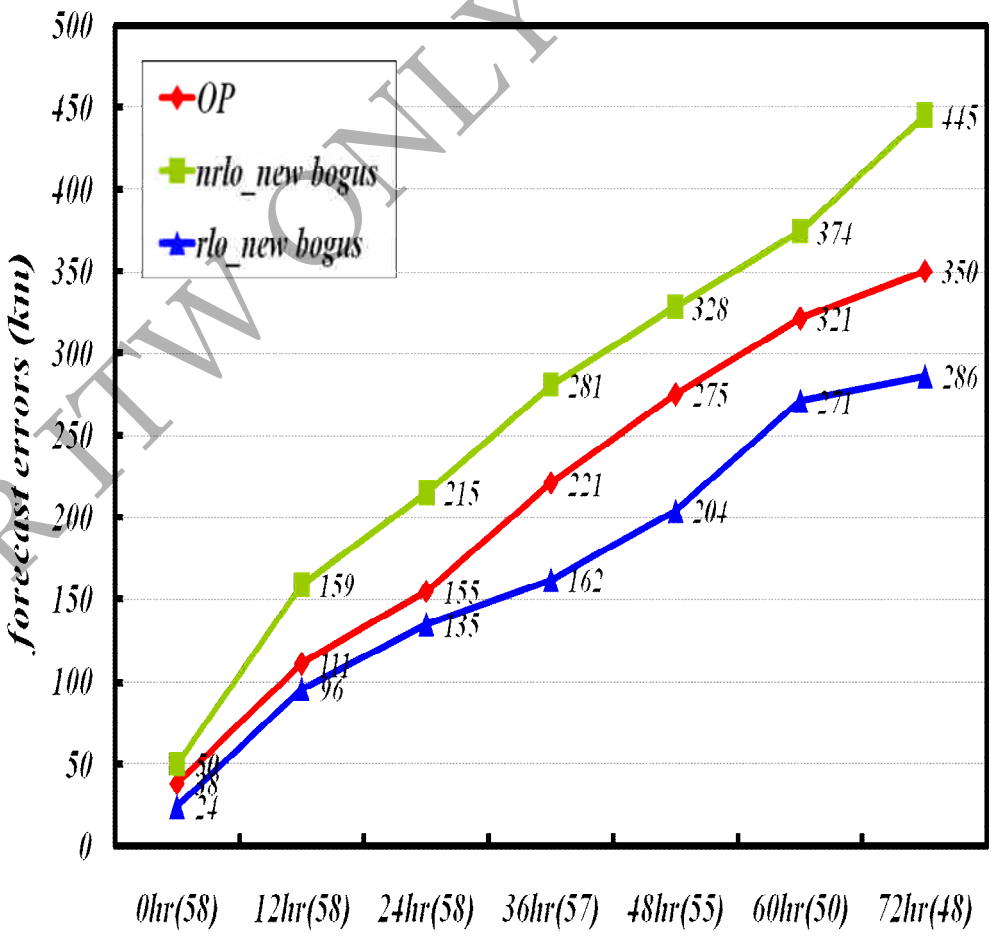
P.-L. Chang

Improve NWP model forecast

Reduce model track forecasting error by developing a better typhoon vortex bogussing method on WRF model





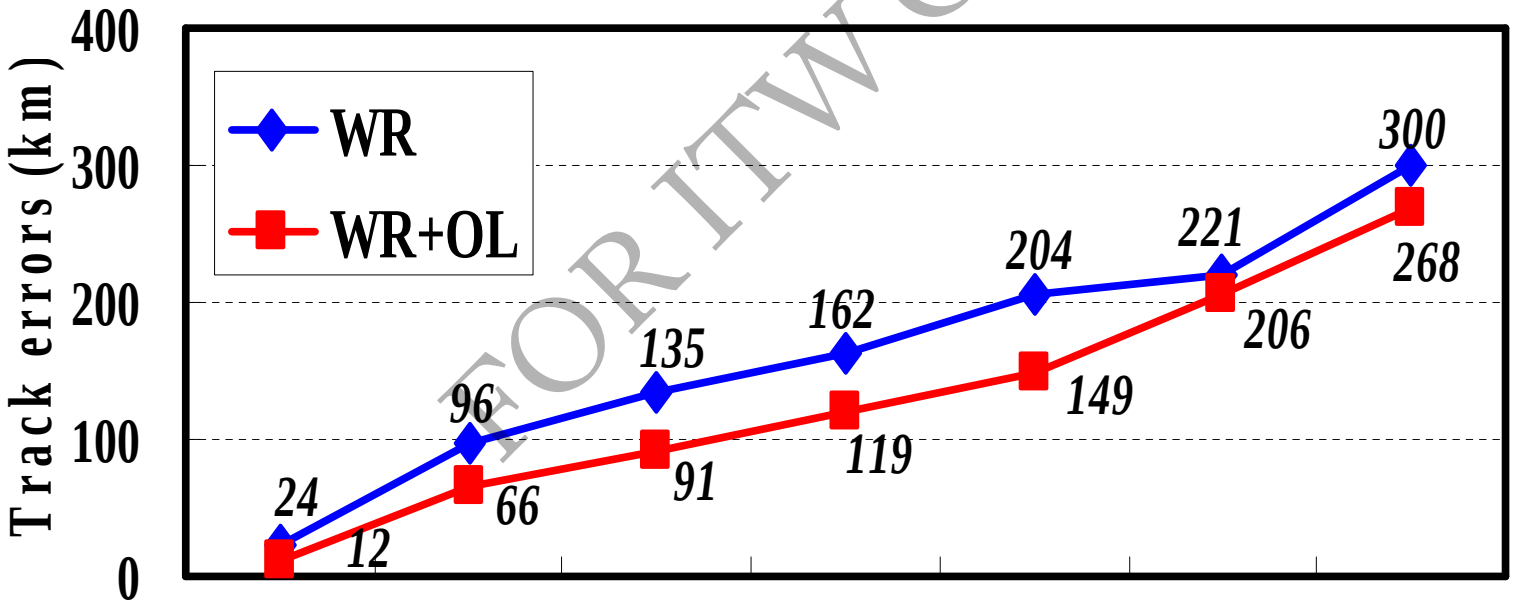


FOR ITW ONLY

Hsiao et al.

Reduce model track forecasting error by better understanding the function of the outer loop of WRF 3Dvar

- **Include the non-linearities in the observation operators via outerloop**
- **Introduces non-linear effects in the form of a first-order Taylor series expansion multiple times, the analysis is more and more accurate**
- **The assimilation system is able to utilize more observations**
- **Produce the best possible estimate of the model initial state**

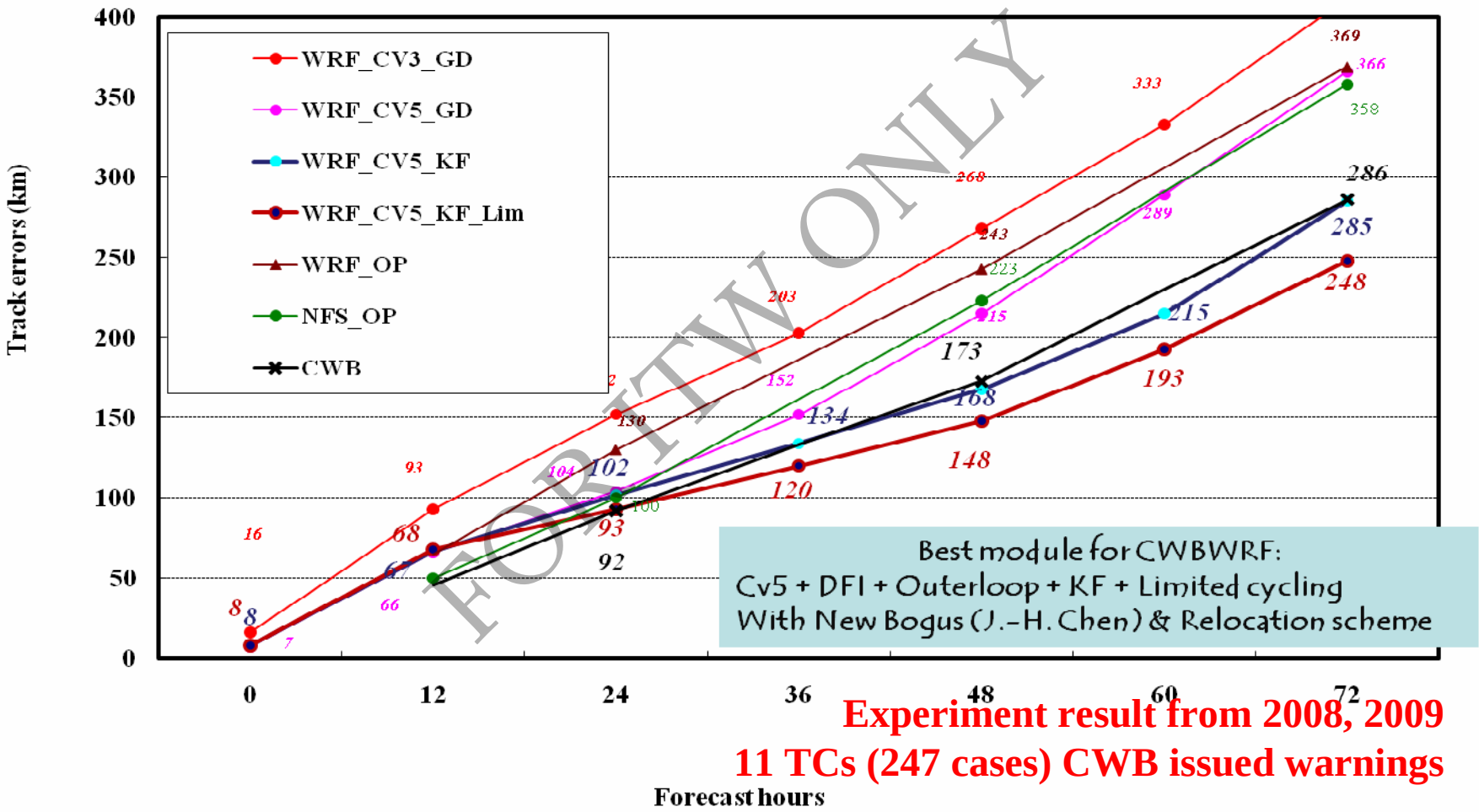


Track Forecasts Error for Sinlaku & Jangmi (58 cases)

Hsiao et al.

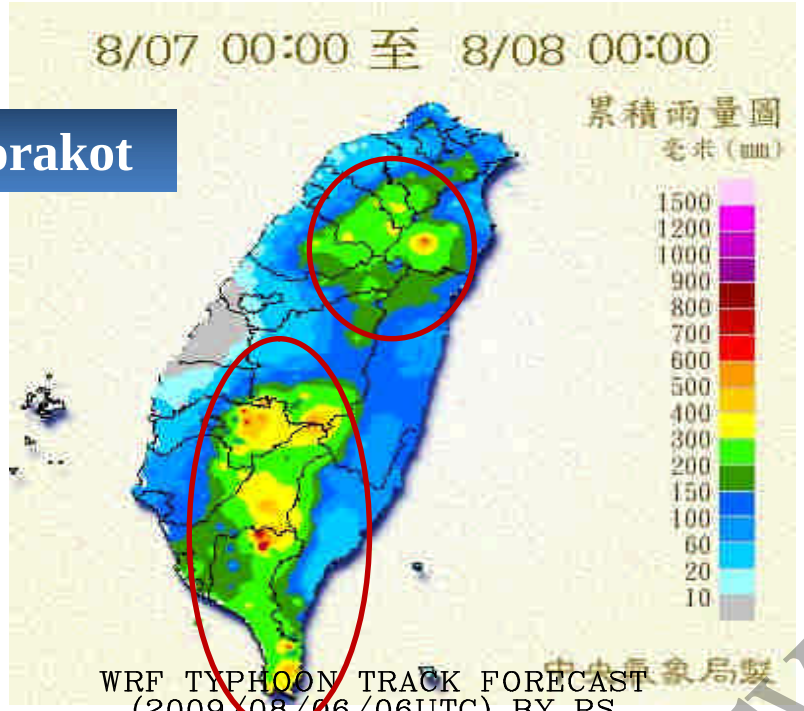
FOR ITW ONLY

Reduce model track forecasting error by better combination of physics package, analysis scheme, and initial data processing

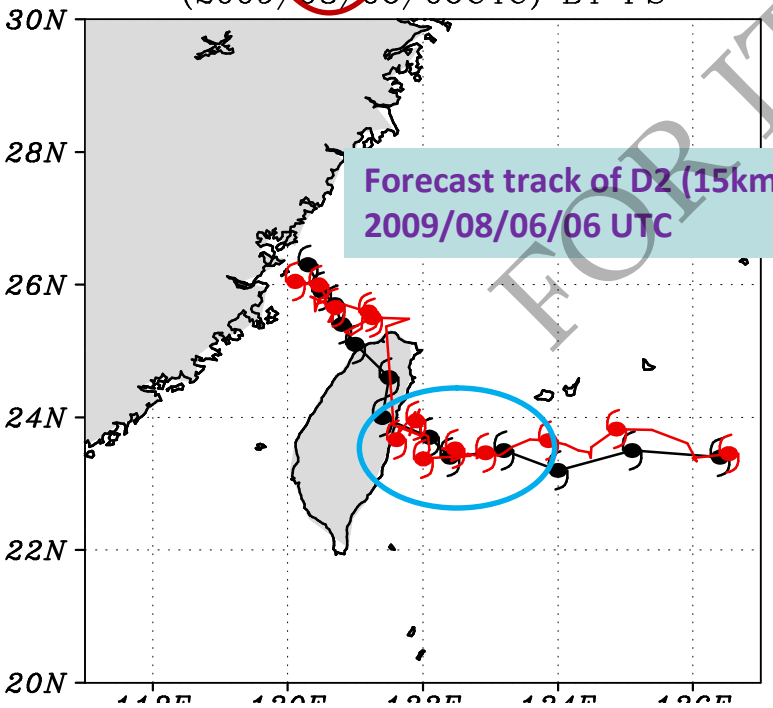


Experiment result from 2008, 2009

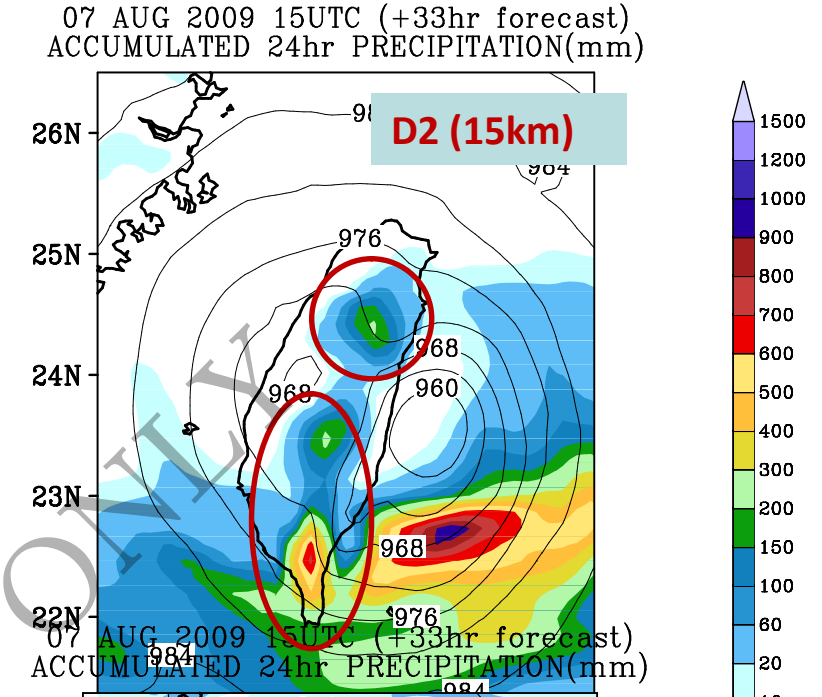
11 TCs (247 cases) CWB issued warnings



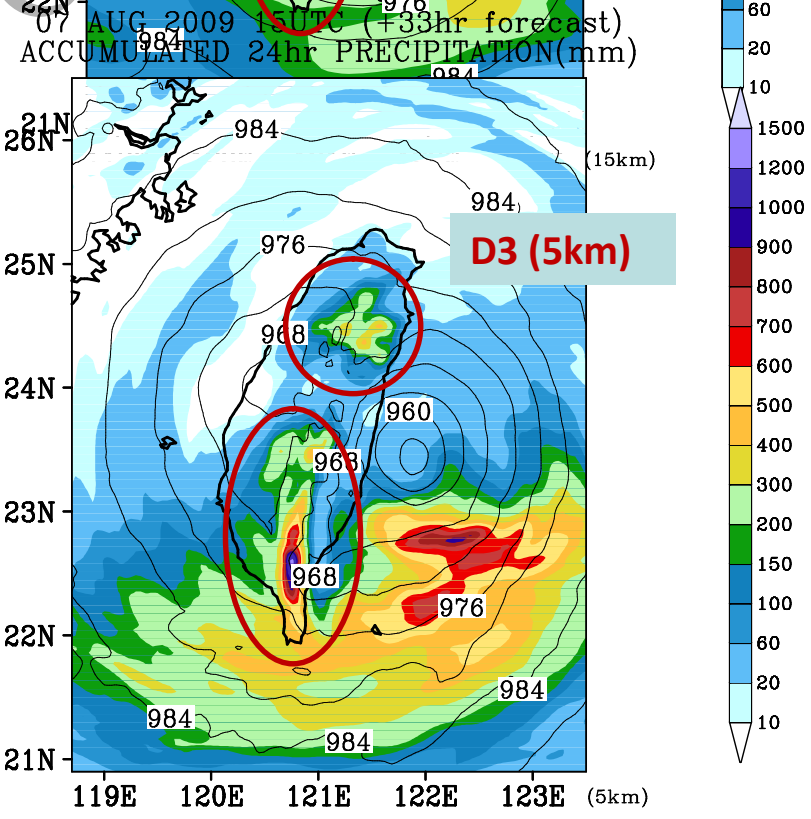
Morakot



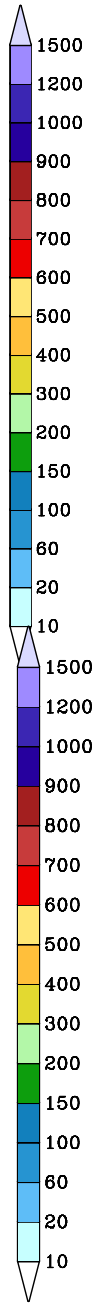
Forecast track of D2 (15km) on 2009/08/06/06 UTC



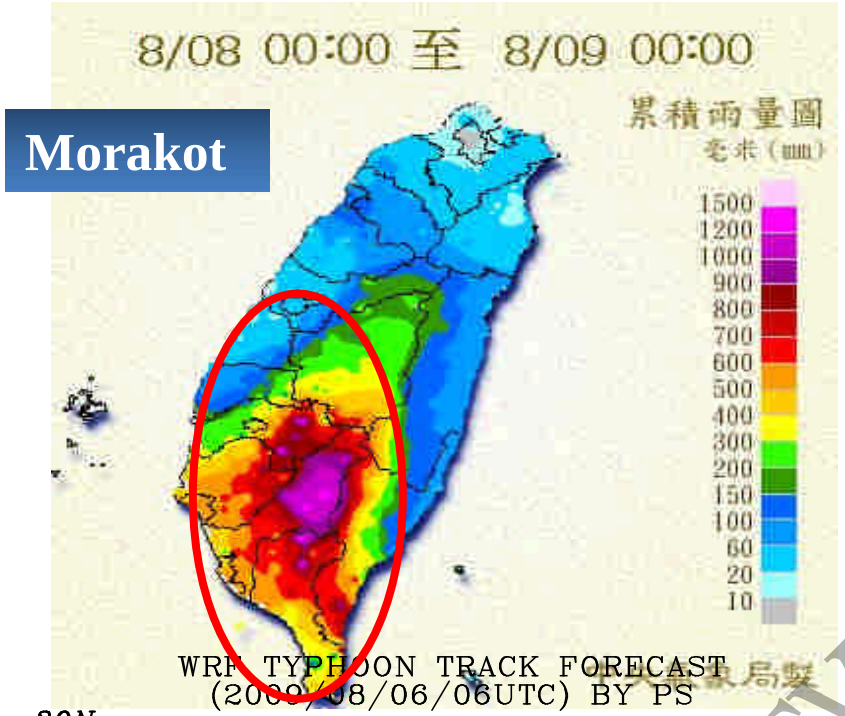
D2 (15km)

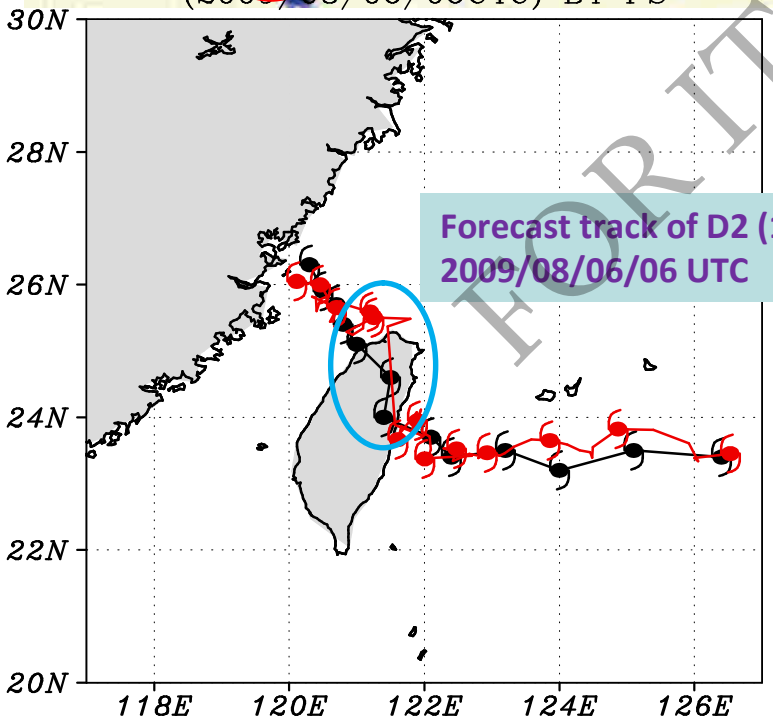


D3 (5km)

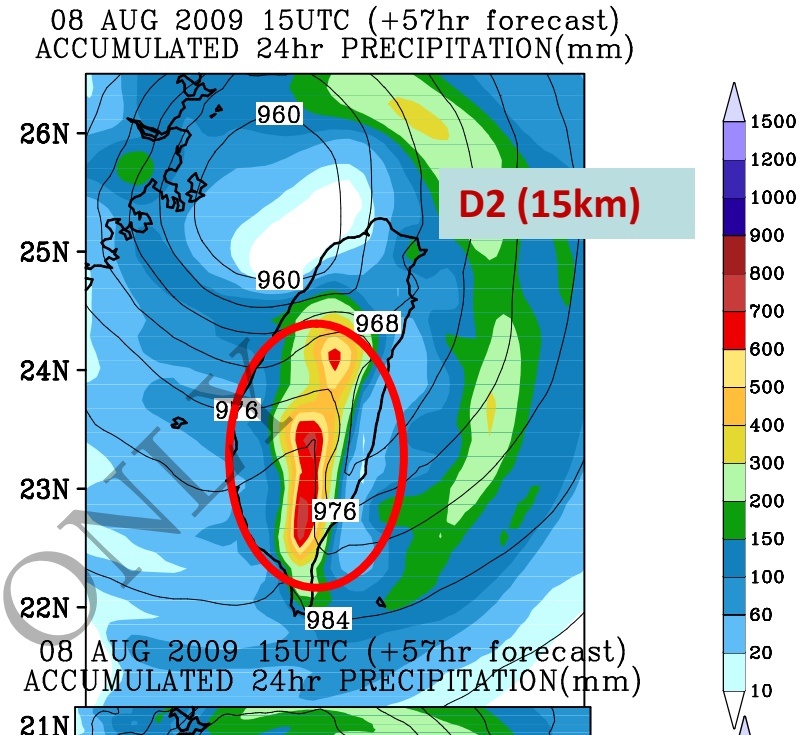


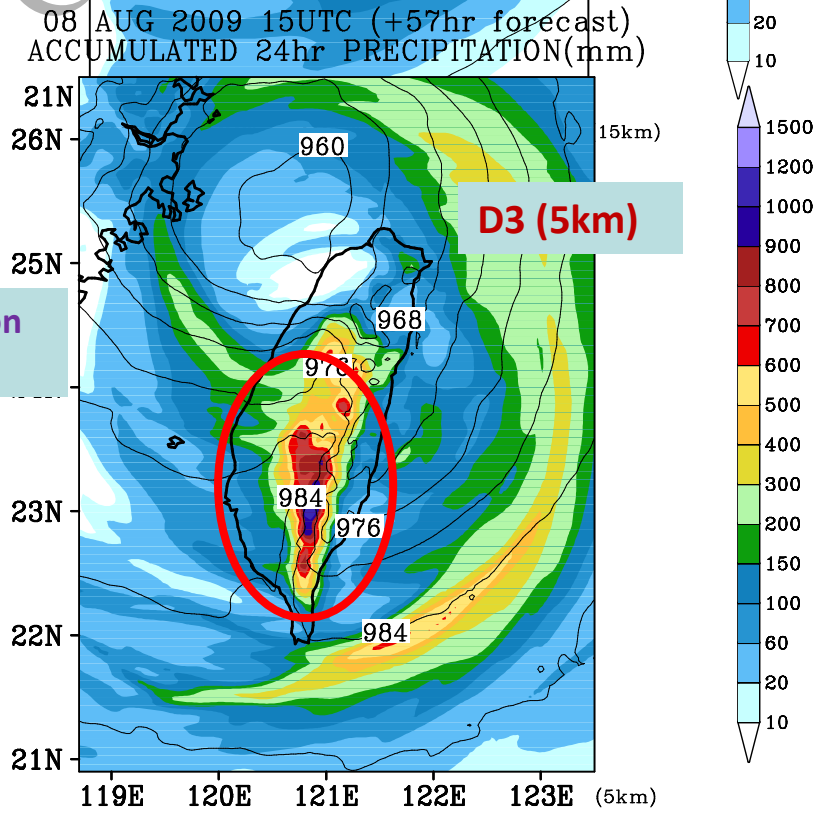
FOR ITW ONLY



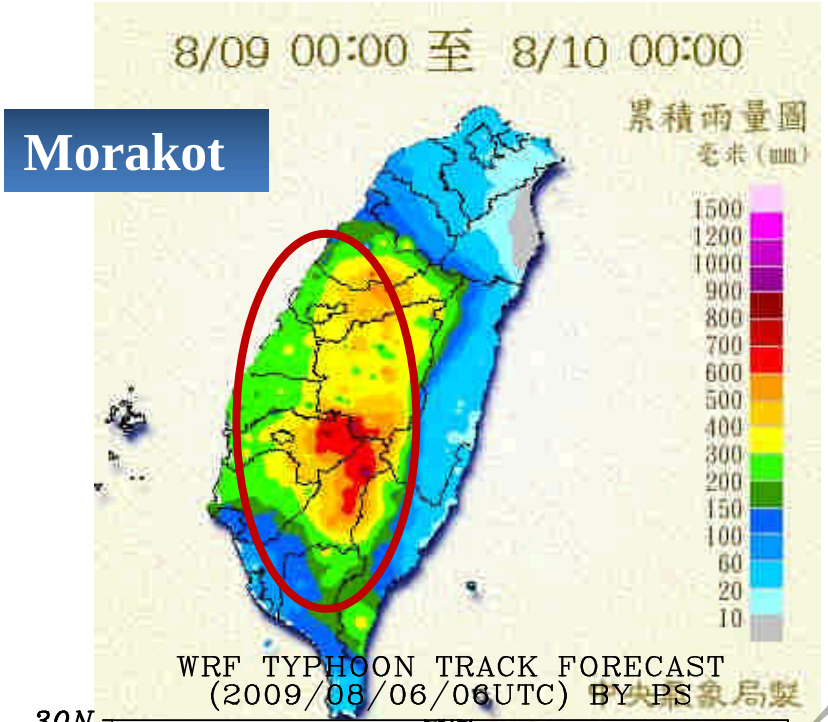


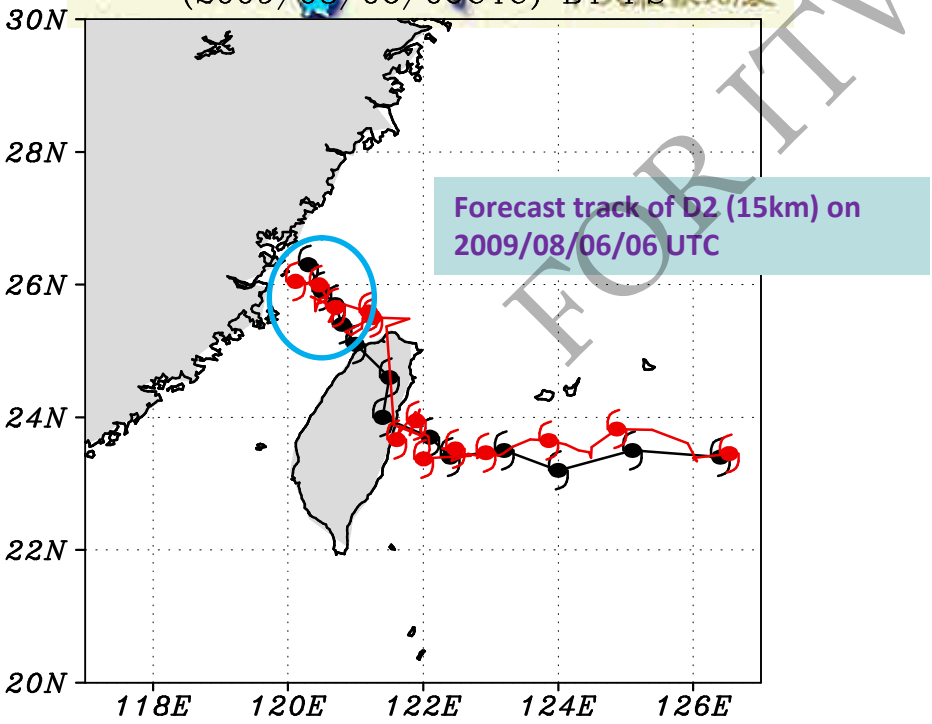
Forecast track of D2 (15km) on 2009/08/06/06 UTC

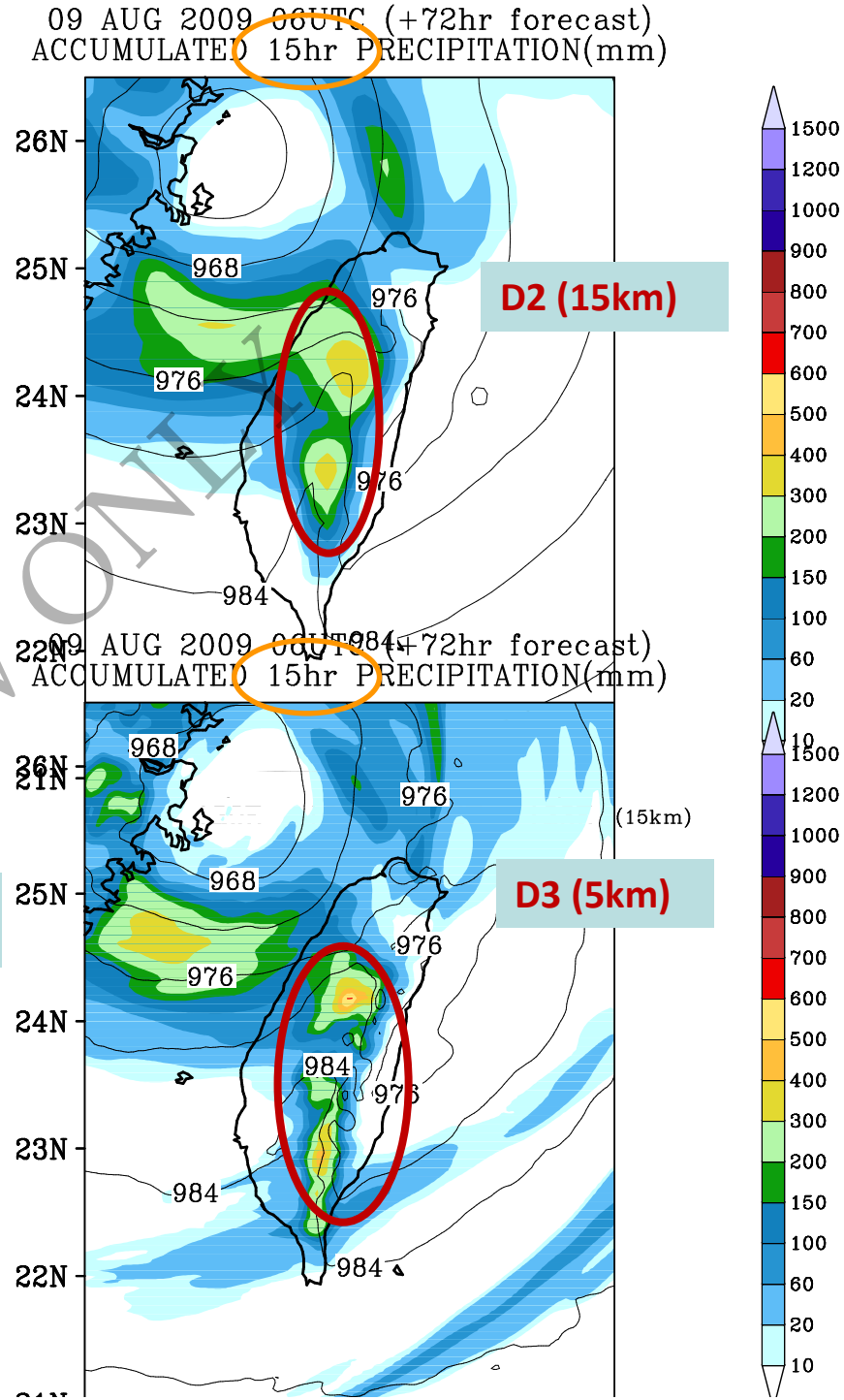




FOR ITW ONLY

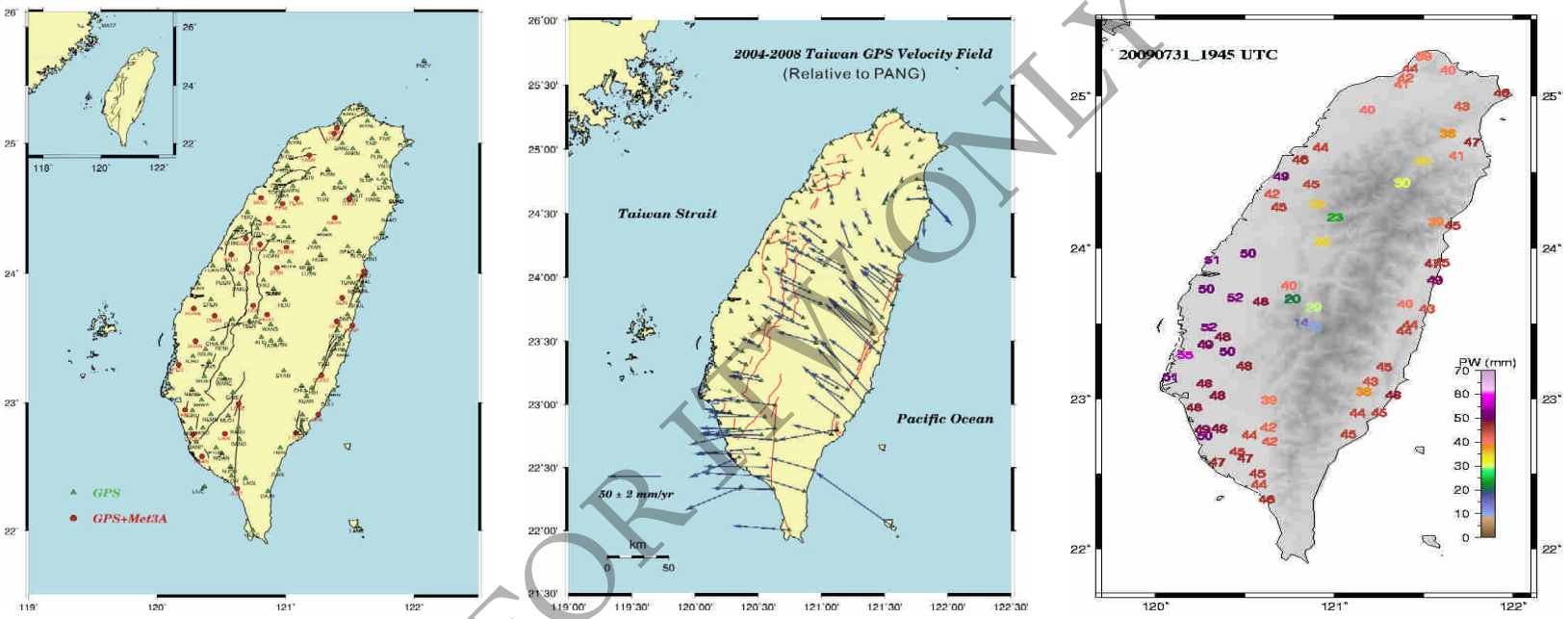

Morakot
8/09 00:00 至 8/10 00:00
累積雨量圖
毫米(mm)
1500
1200
1000
900
800
700
600
500
400
300
200
150
100
60
20
10


WRF TYPHOON TRACK FORECAST
(2009/08/06/06UTC) BY PS
30N
28N
26N
24N
22N
20N
118E
120E
122E
124E
126E
Forecast track of D2 (15km) on
2009/08/06/06 UTC


09 AUG 2009 06UTC (+72hr forecast)
ACCUMULATED 15hr PRECIPITATION(mm)
D2 (15km)
968
976
984
26N
25N
24N
23N
22N
21N
(15km)
D3 (5km)
1500
1200
1000
900
800
700
600
500
400
300
200
150
100
60
20
10

FOR ITW ONLY

Usage of remote sensing data

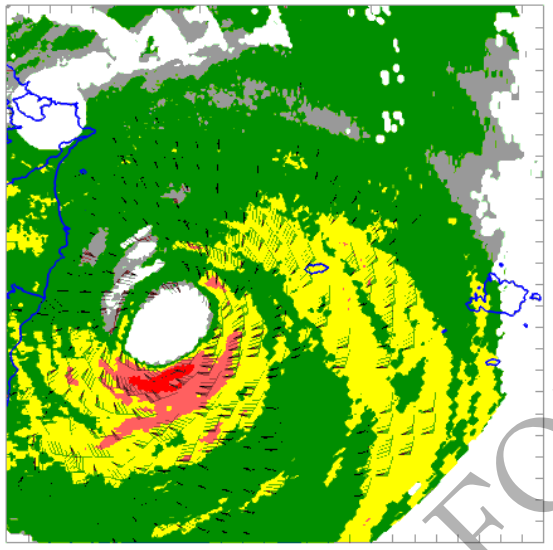


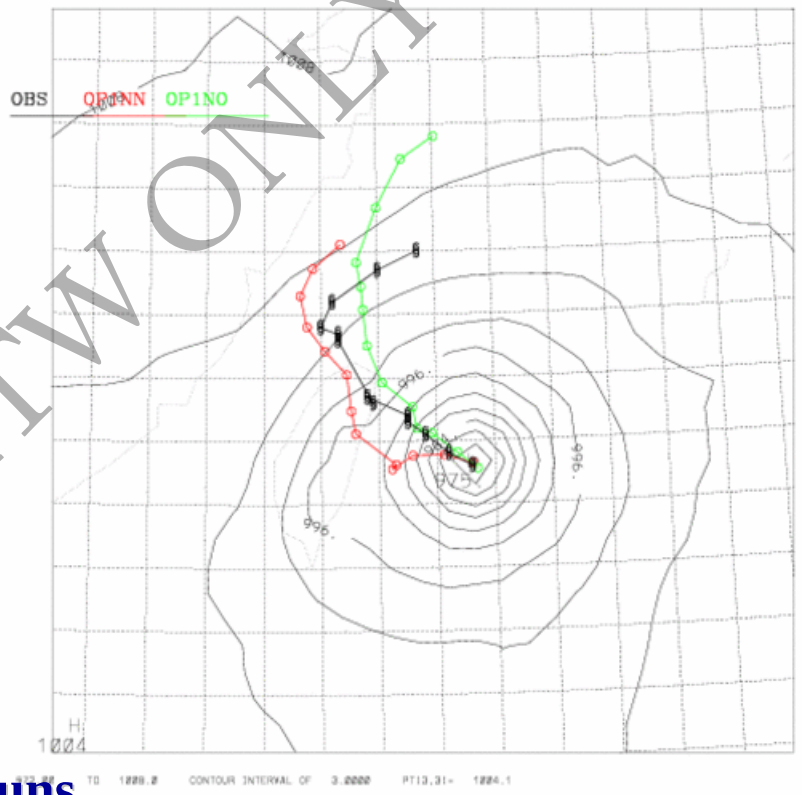
FOR IT ONLY

Data at 80 of 154 GPS stations are transmitted real time to CWB that allow to develop algorithm retrieving perceptible water vapor content.

Improve data assimilation by executing 4 dimensional data assimilation studies

Typhoon Sinlaku (2008)
12 UTC on 12 September





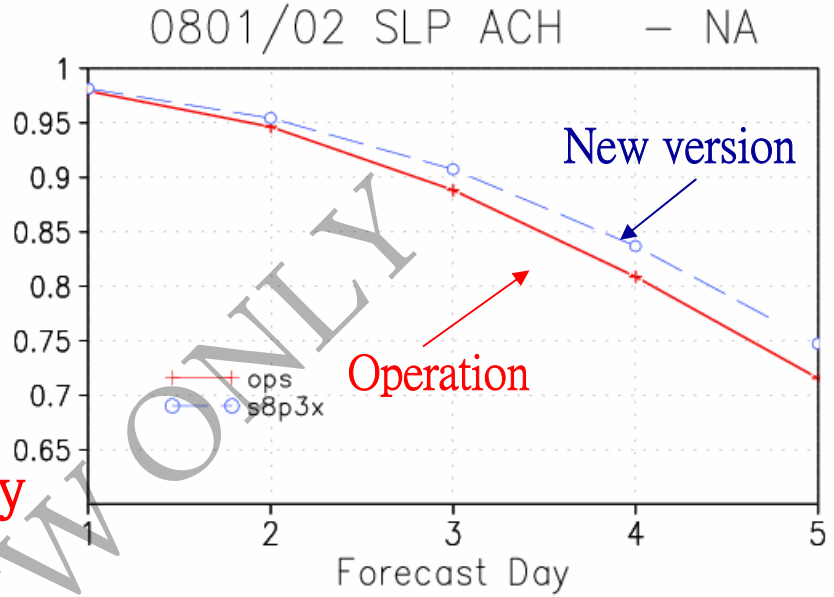
FOR ITW ONLY

Successfully performed some test runs on ensemble Kalman filter and WRF 4Dvar, will apply to operation after more tests.

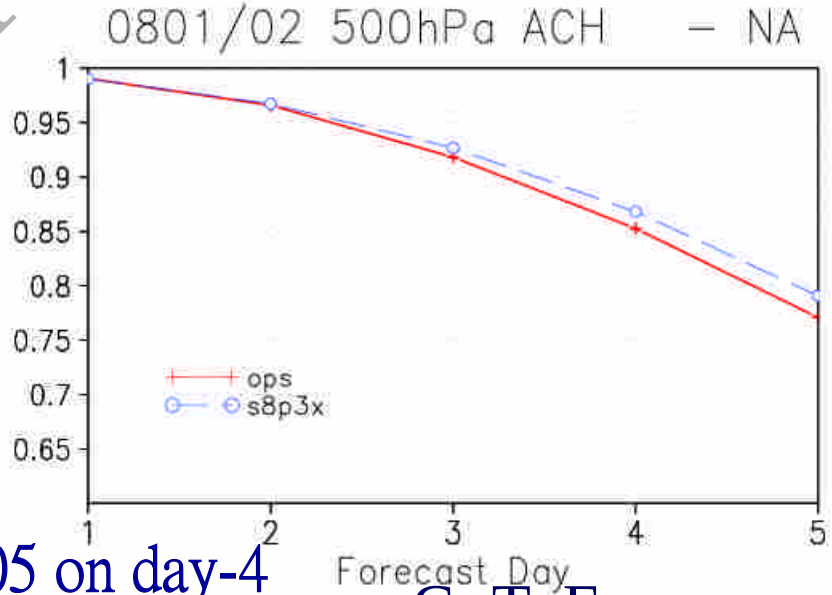
New vortex bogussing + relocation

Hsiao et al.

Improve CWBGFS forecasts by improving the cumulus parameterization and planetary boundary layer treatment in CWBGFS



CWBGFS provides lateral boundary values for regional model forecast



Anomaly correlations on
Sea level pressure
and
500hPa geopotential height

Improve ACH of SLP FCST by ~.05 on day-4

C.-T. Fong

FOR ITW ONLY

Thank you for your attention

FOR ITW ONLY