Effects of Long-term Climate Change on Typhoon Rainfall near Taiwan (Morakot、Mindulle)

長期氣候變遷對於侵台颱風個案降雨影響之探討（莫拉克、敏督利）

Supervisor: Prof. Chung-Chieh Wang (王重傑教授)
Prof. Li-shan Tseng (曾莉珊教授)

Student: Chien-Chang Huang (黃建彰)

Contents

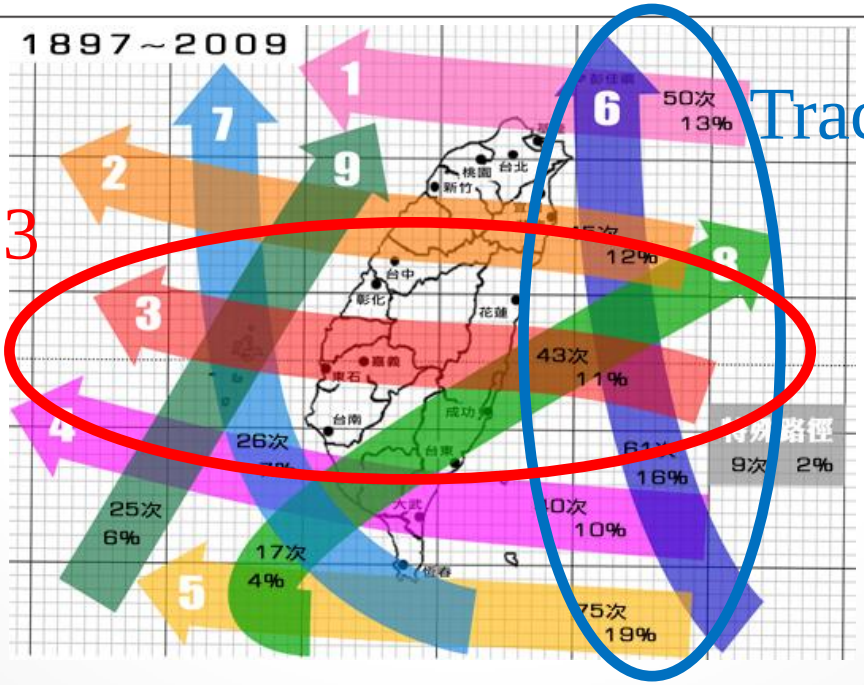
Research Motivation

- Typhoon is a disastrous or extreme weather. For Taiwan, the biggest threat is heavy rainfall of Typhoon.
- In recent years, the accumulated rainfall brought by typhoons have clearly increasing trend, some of the media and the people will be attributed on global warming.
- We want to understand the long-term climate change can have how much influence on the typhoon rainfall.

TABLE 1. The 12 typhoons in 1960–2011 with total rainfall over Taiwan exceeding 3500 mm during the three phases, ranked according to total rainfall amount. The eight since 2004 are highlighted in boldface.

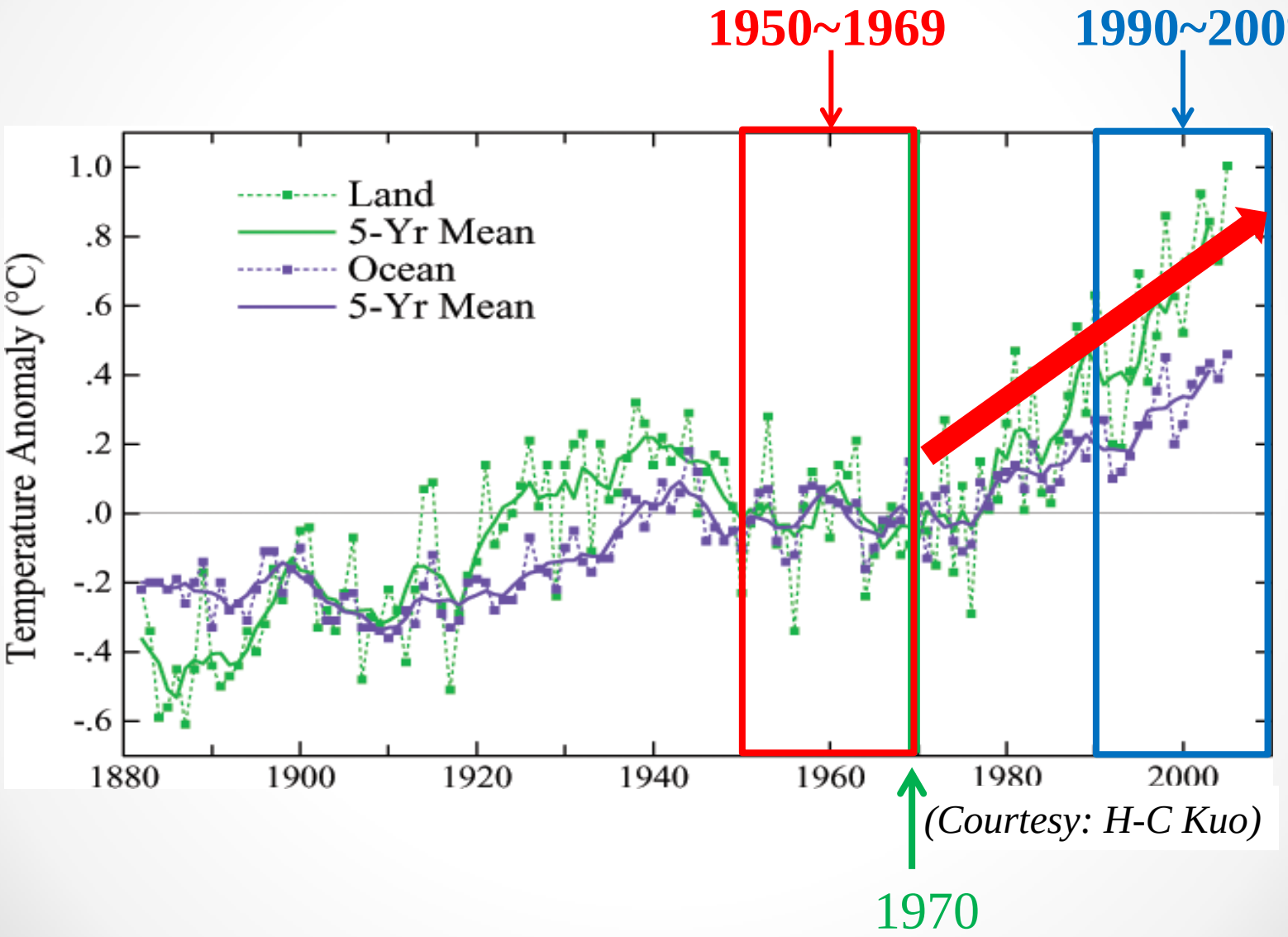
Rank	Year	Typhoon name	PR (h)	OL (h)	EX (h)	Total duration (h)	Rainfall (mm)	Type of track
1	**2009**	**Morakot**	**12**	**15**	**18**	**45**	**8996**	**CWB 3 (C)**
2	2001	Nari	10	51	14	75	8108	CWB Special
3	**2008**	**Sinlaku**	**16**	**10**	**22**	**48**	**8105**	**CWB 2 (N)**
4	**2005**	**Haitang**	**11**	**9**	**12**	**32**	**5589**	**CWB 3 (C)**
5	1996	Herb	5	7	4	16	4836	CWB 2 (N)
6	1989	Sarah	5	20	13	38	4655	CWB 3 (C)
7	1960	Shirley	3	11	10	24	4637	CWB 2 (N)
8	**2007**	**Krosa**	**12**	**1**	**10**	**23**	**3936**	**CWB 2 (N)**
9	**2004**	**Mindulle**	**16**	**18**	**7**	**41**	**3856**	**CWB 6**
10	**2008**	**Jangmi**	**4**	**13**	**8**	**25**	**3800**	**CWB 2 (N)**
11	**2008**	**Kalmaegi**	**8**	**10**	**5**	**23**	**3763**	**CWB 2 (N)**
12	**2005**	**Talim**	**4**	**9**	**4**	**17**	**3526**	**CWB 3 (C)**

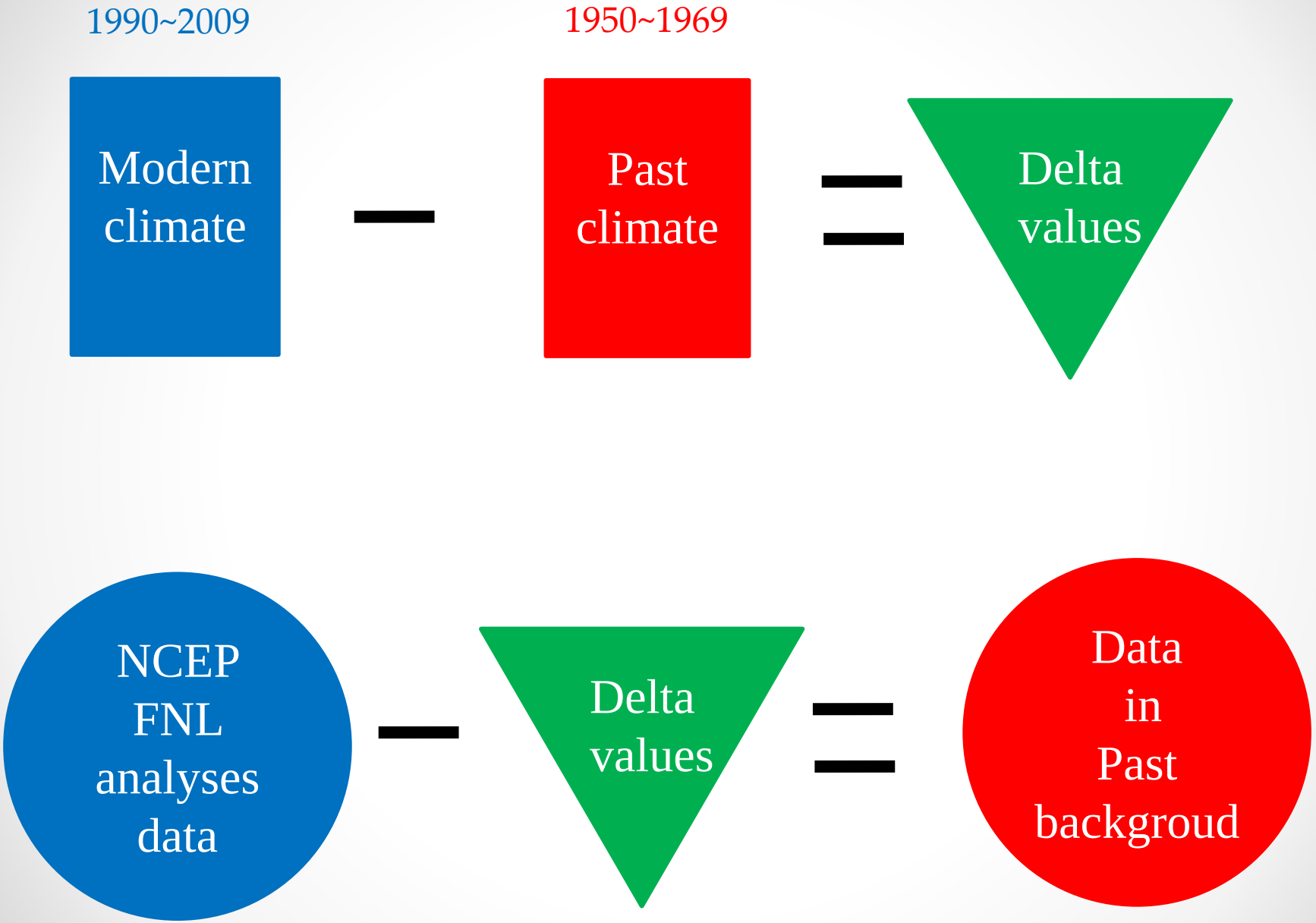
Track 3

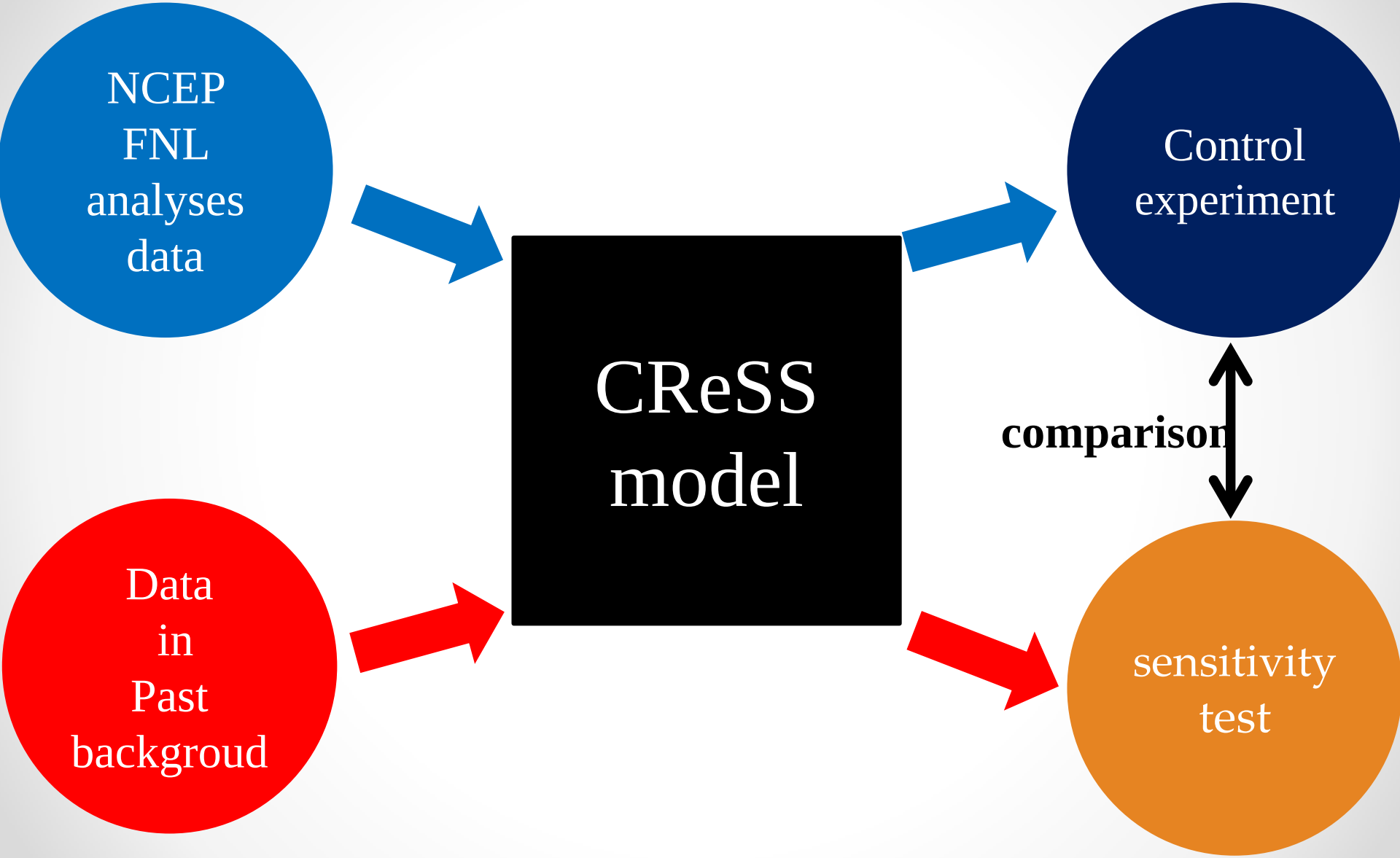


Track 6

Method


1950~1969
1990~2009
Land
5-Yr Mean
Ocean
5-Yr Mean
Temperature Anomaly (°C)
1.0
.8
.6
.4
.2
.0
-.2
-.4
-.6
1880
1900
1920
1940
1960
1980
2000
(Courtesy: H-C Kuo)
1970


1990~2009
1950~1969
Modern climate
Past climate
Delta values
NCEP FNL analyses data
Delta values
Data in Past backgroud


NCEP
FNL
analyses
data
Data
in
Past
backgroud
CReSS
model
Control
experiment
comparison
sensitivity
test

Data Source

Climate average

- National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) monthly-mean global gridded reanalysis data(2.5°×2.5°)
- the Hadley Centre Sea Ice and Sea Surface Temperature (HadISST)data (1.0^o x1.0^o)

Typhoon data

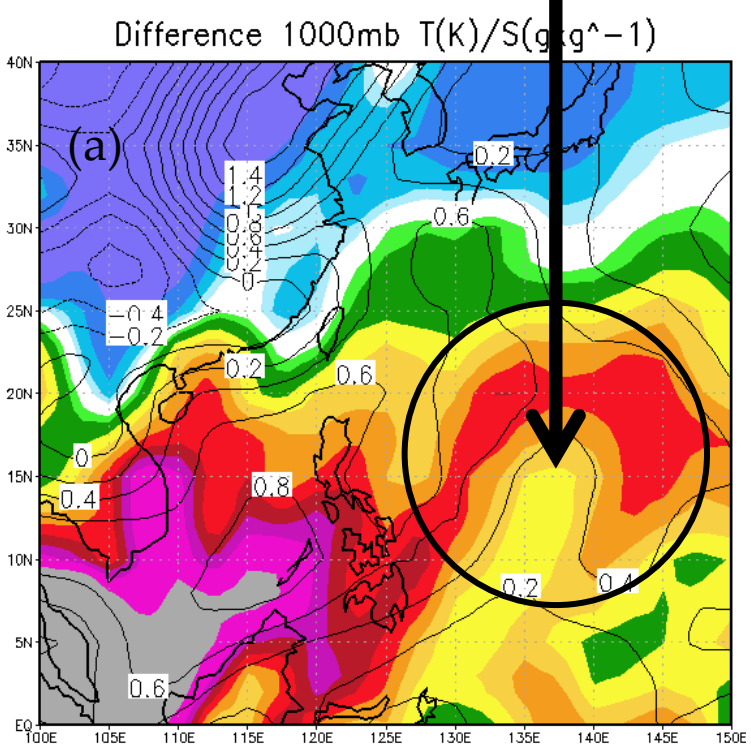
- NCEP FNL Operational Model Global Tropospheric Analyses data(1.0^o x1.0^o)
- NOAA Optimum Interpolation (OI) Sea Surface Temperature (SST) V2(1.0^o x1.0^o)

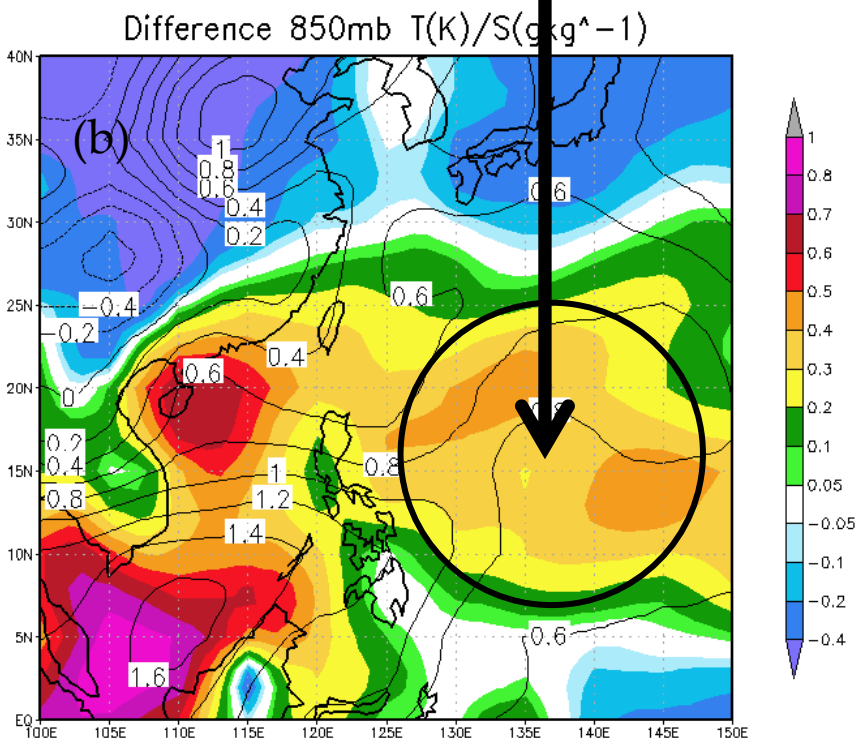
Delta values

Temperature + Humidity

+ ~0.5K
+ ~0.4g/kg

+ ~0.7K
+ ~0.3g/kg



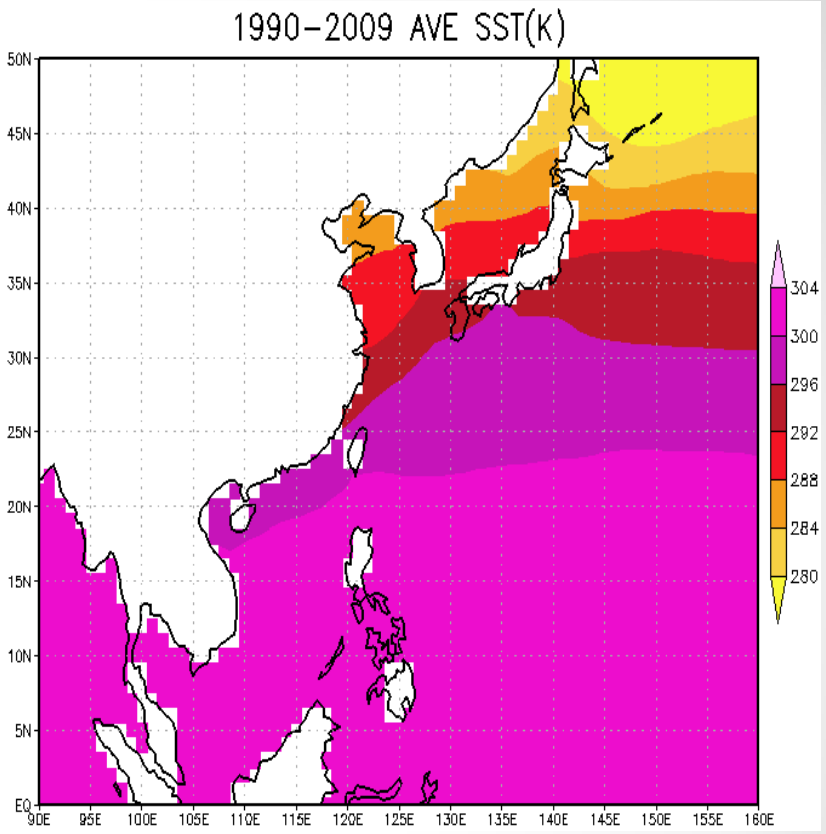


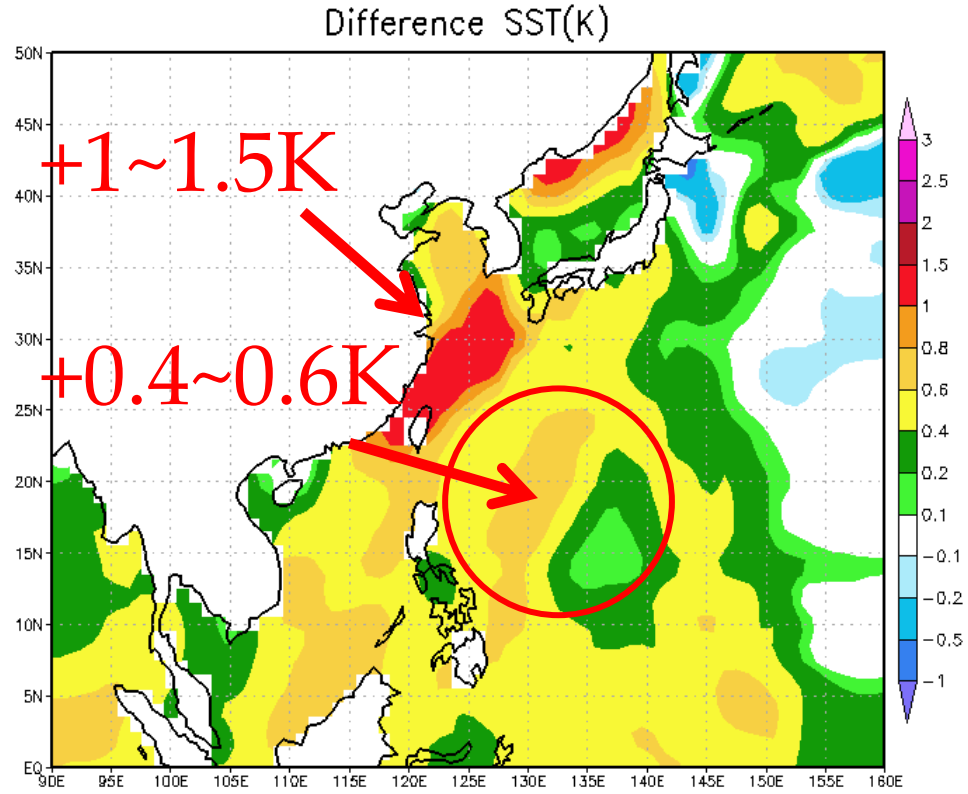
The contours is temperature and the color bar is humidity. there is a warming and moistening trend of roughly 0.5K and 0.4g/kg at 1000hpa in western pacific region . And figure(b) is the level in 850mb ,the temperature increase about 0.7K and humidity increase 0.3 g/kg.

Delta values

Sea Surface Temperature

This figure shows sea surface temperature average of 1990 to 2009

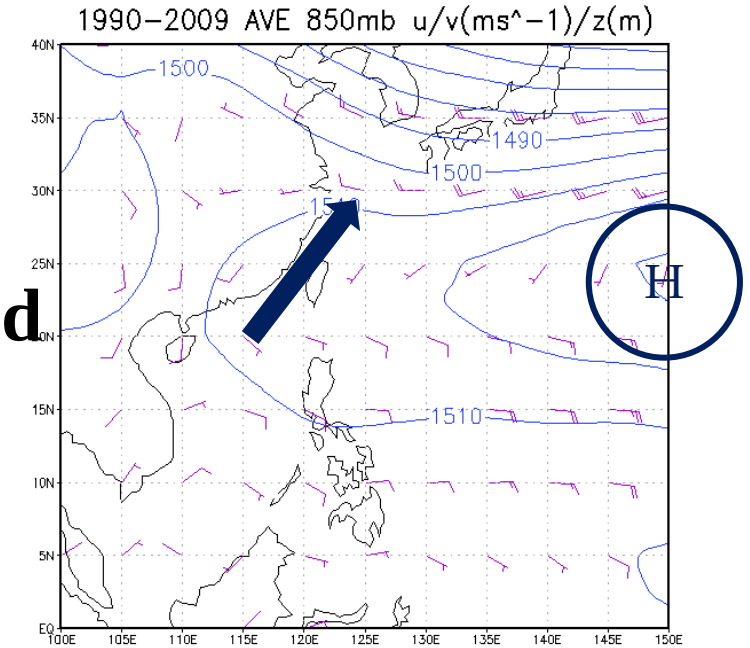


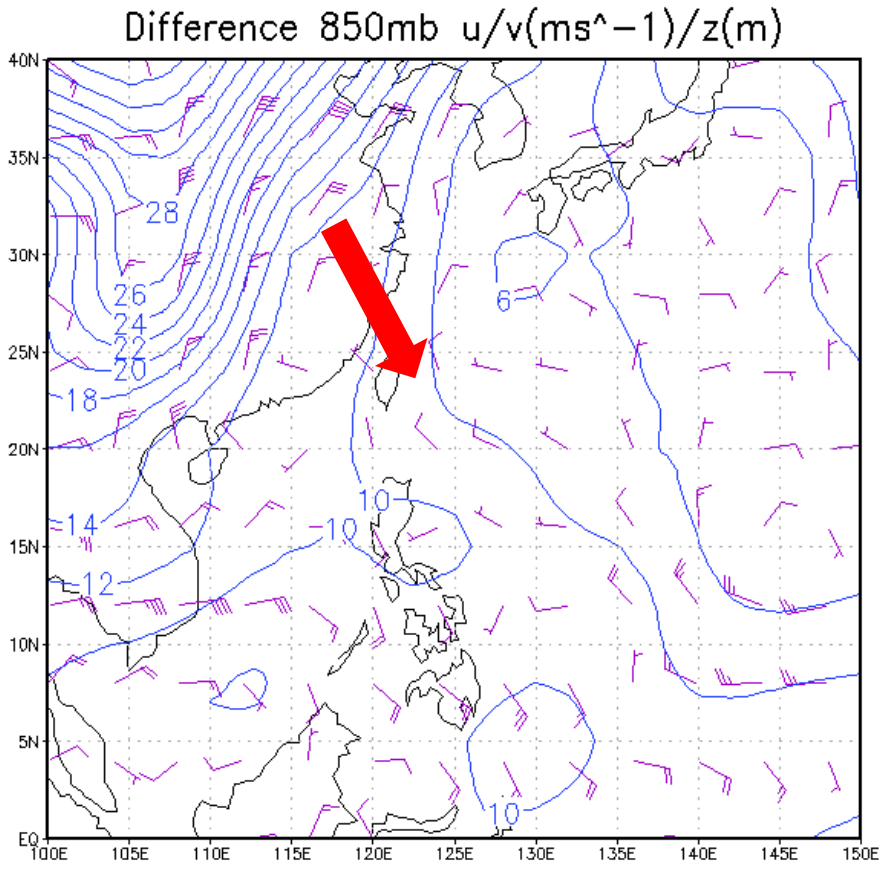


This figure is delta value of sea surface temperature.
There is an increase about 1 to 1.5 K near Taiwan.About 0.4 to 0.6K in western pacific.

Delta values

850mb Geopotential height + Wind

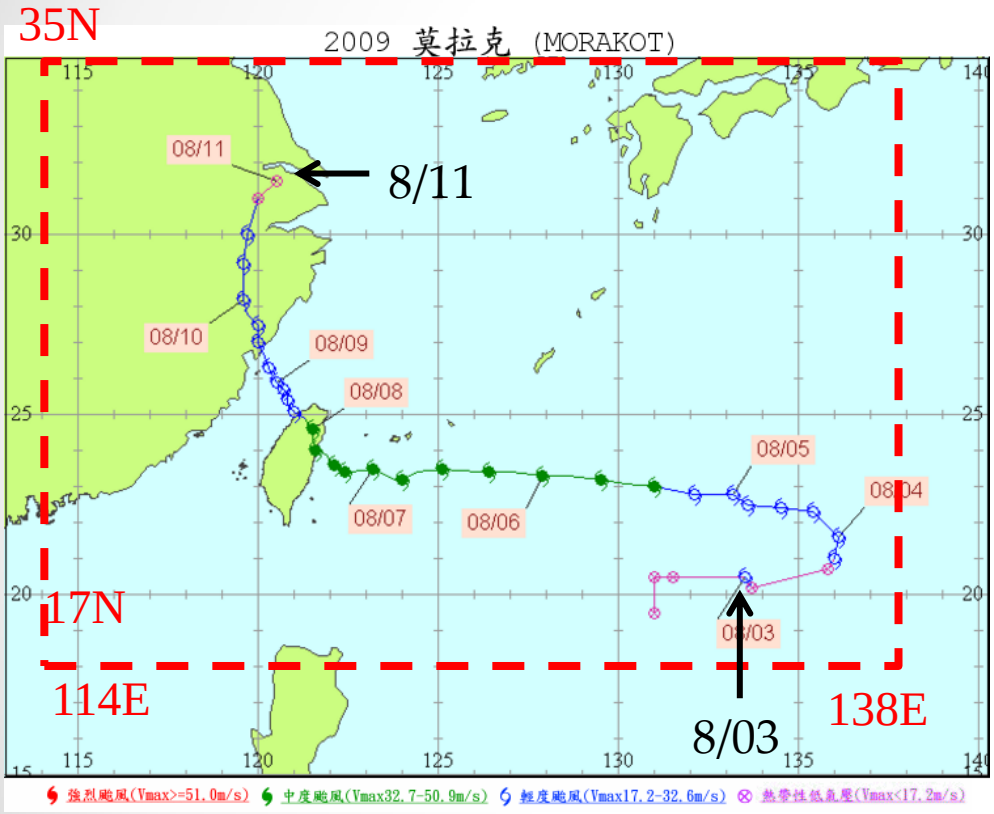




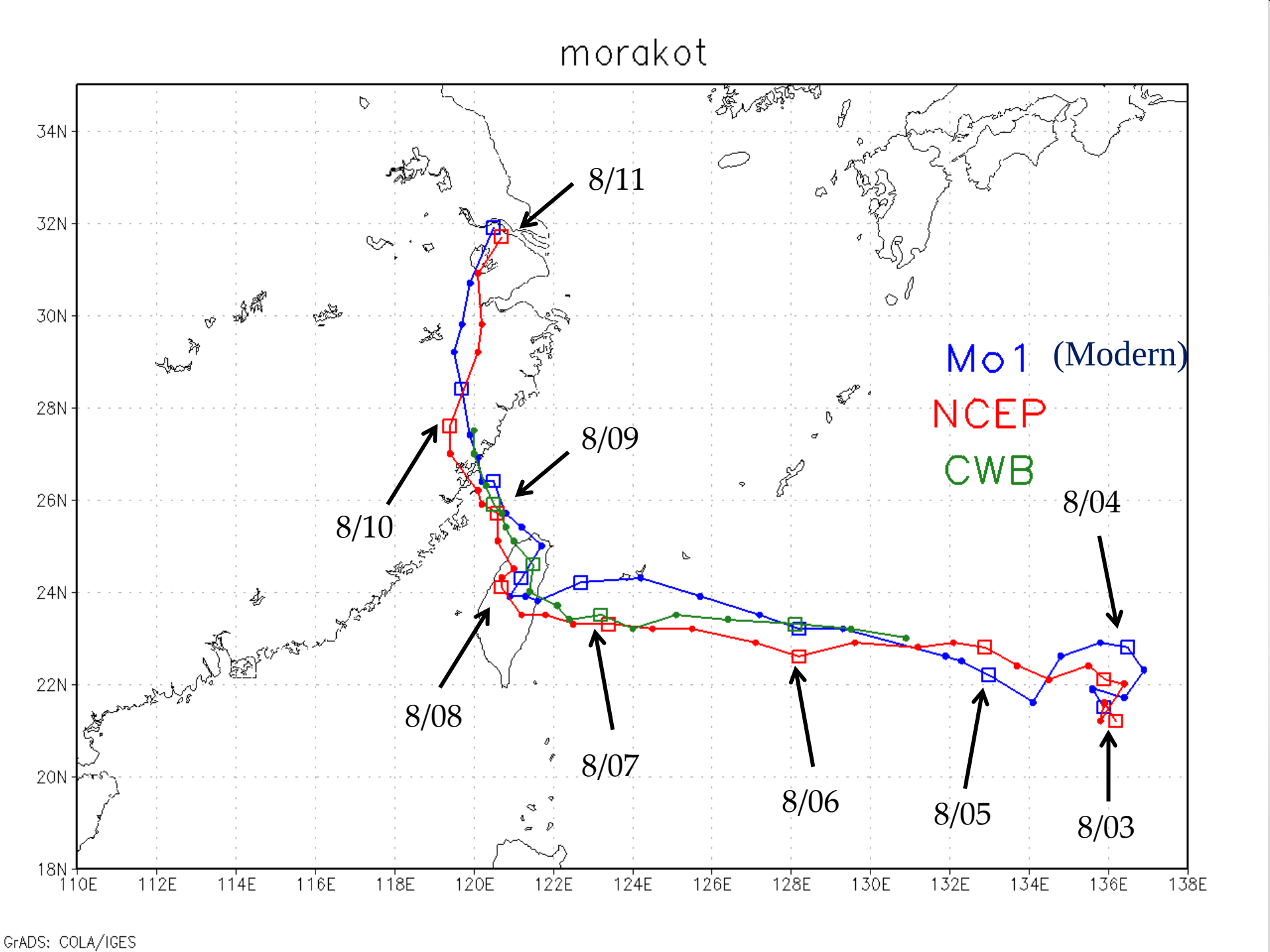
Upper figure is geopotential height and winds average of 1990 to 2009 at 1000mb. The wind field is dominated by subtropical high.So,the winds field is almost easterly or southeasterly component near Taiwan.

But in the delta value,can find the difference slight increase in westerly or northwesterly wind component near Taiwan.It represent steering flow of subtropical high is weakened.

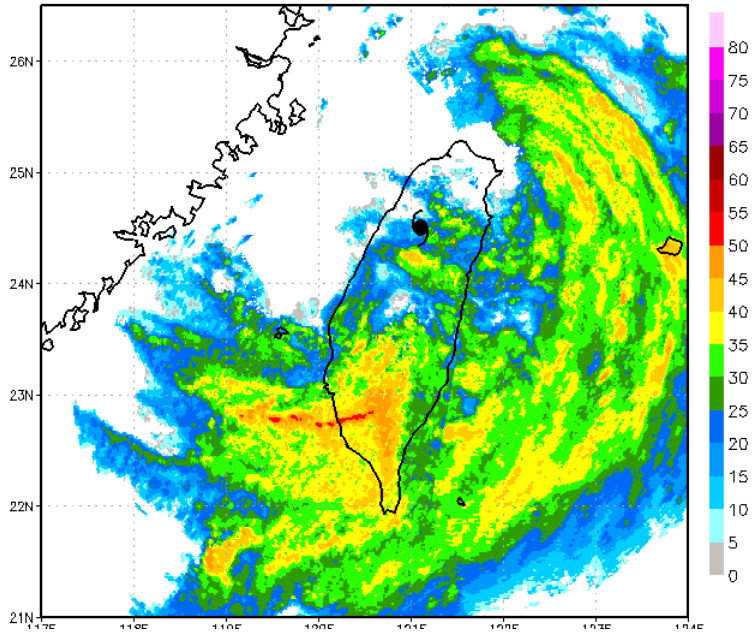
Case 1 : Morakot



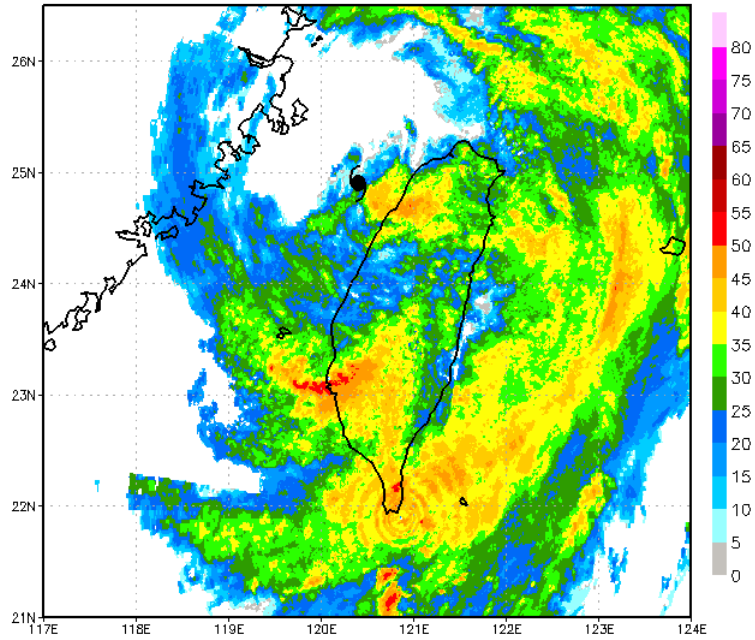
Configuration	Case1:Morakot
Domain size	800×600×40
Horizontal grid size	3000m
Vertical grid size	500m
Integration length	192 hr (8day)
Initial time and end time	2009/8/03 0000UTC ~ 08/11 0000UTC
Cloud microphysics	Bulk cold rain scheme


morakot
34N
32N
30N
28N
26N
24N
22N
20N
18N
110E
112E
114E
116E
118E
120E
122E
124E
126E
128E
130E
132E
134E
136E
138E
8/11
8/10
8/09
8/08
8/07
8/06
8/05
8/04
8/03
Mo1 (Modern)
NCEP
CWB
GrADS: COLA/IGES

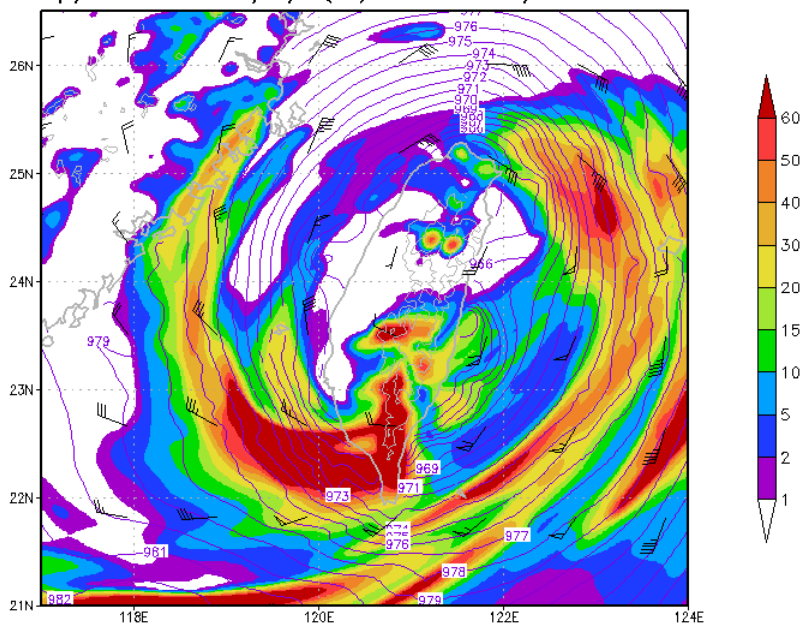
00Z08AUG2009



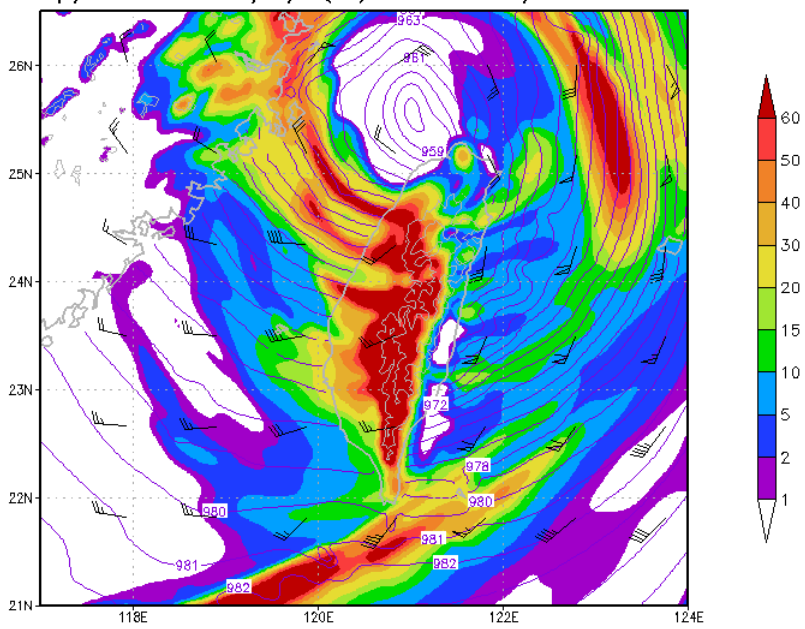
12Z08AUG2009



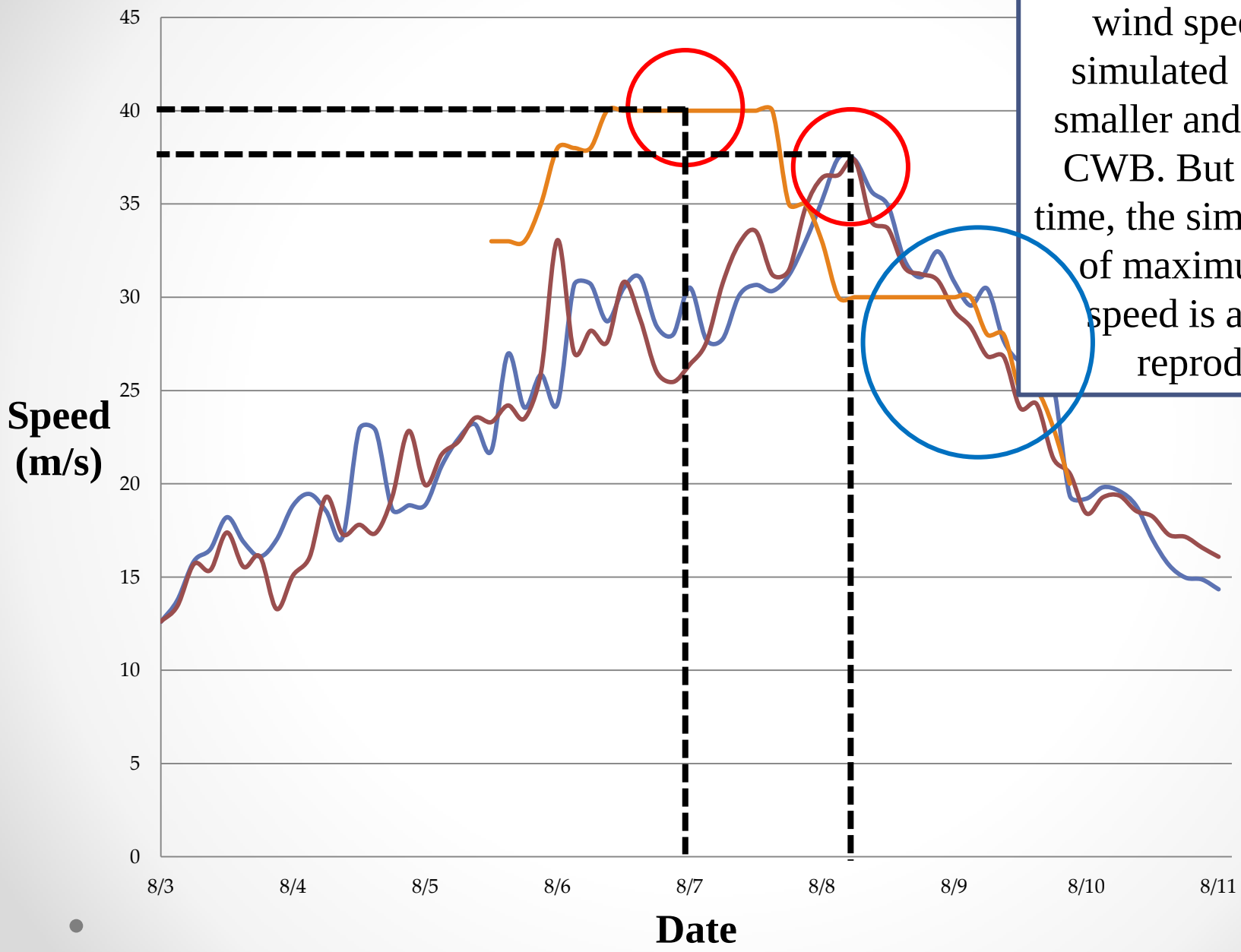
sfc p/60min-rain/u/v(kt) 2009 08/08 0000 UTC



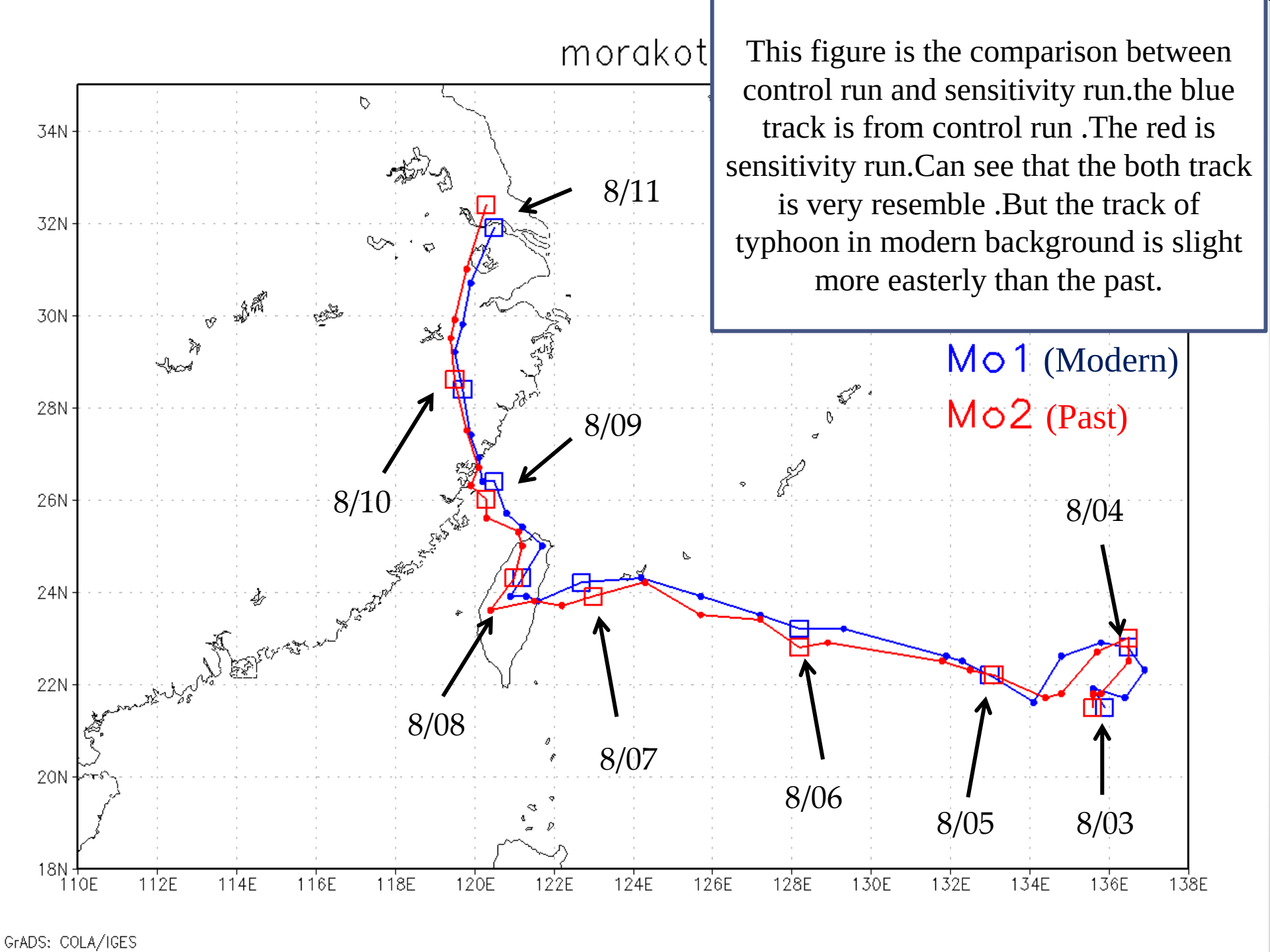
sfc p/60min-rain/u/v(kt) 2009 08/08 1200 UTC

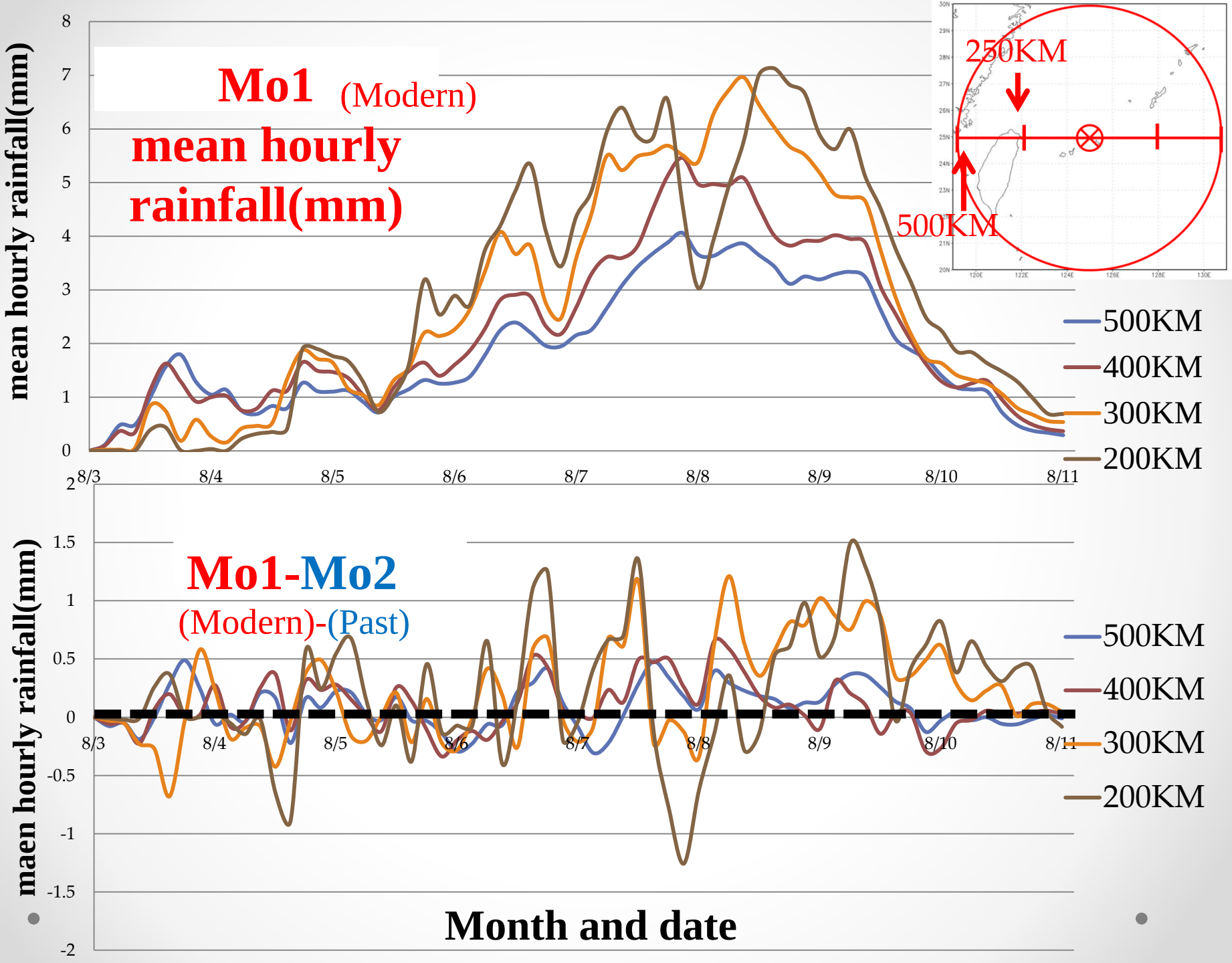


Wind Speed Max



This pattern show the peak of maximum wind speed from simulated result is smaller and later than CWB. But in almost time, the simulate result of maximum wind speed is also well reproduced


morakot
This figure is the comparison between control run and sensitivity run.the blue track is from control run .The red is sensitivity run.Can see that the both track is very resemble .But the track of typhoon in modern background is slight more easterly than the past.
Mo1 (Modern)
Mo2 (Past)
8/11
8/10
8/09
8/08
8/07
8/06
8/05
8/04
8/03
34N
32N
30N
28N
26N
24N
22N
20N
18N
110E
112E
114E
116E
118E
120E
122E
124E
126E
128E
130E
132E
134E
136E
138E
GrADS: COLA/IGES


Mo1 (Modern)
mean hourly rainfall(mm)
250KM
500KM
mean hourly rainfall(mm)
500KM
400KM
300KM
200KM
8/3
8/4
8/5
8/6
8/7
8/8
8/9
8/10
8/11
Mo1-Mo2
(Modern)-(Past)
maen hourly rainfall(mm)
Month and date

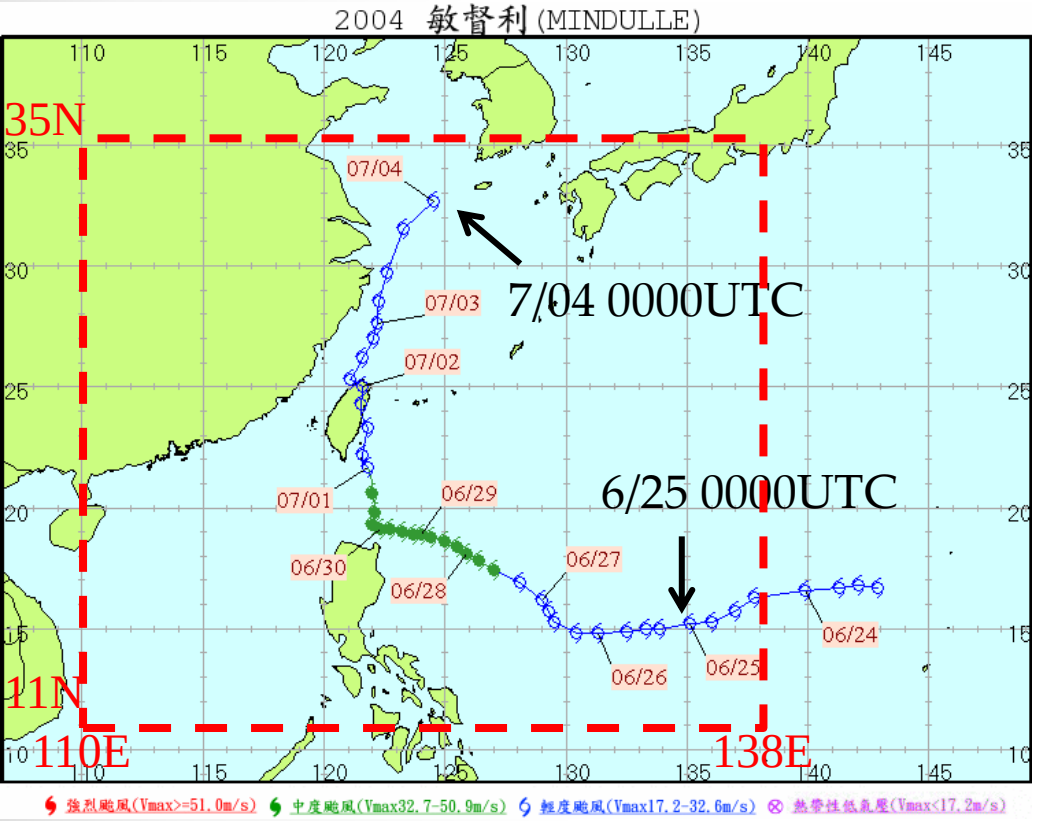
the radius of 500 km for 3-10 Aug and Mo1,Mo2, their difference (Mo1 - Mo2), and the difference in percent change [%, (Mo1 - Mo2)/Mo1] for Morakot (2009).

500 km	8/03	8/04	8/05	8/06	8/07	8/08	8/09	8/10	8/03~09
Mo1(mm) (Modern)	23.27	23.04	26.23	48.18	80.05	83.81	58.71	16.86	45.02
Mo2(mm) (Past)	21.32	21.23	26.53	46.34	77.53	79.02	54.74	17.18	42.99
Mo1-Mo2	2.12	0.98	1.25	1.22	2.06	4.59	4.46	-0.37	2.03
Percent Change	8.38%	7.89%	-1.15%	3.82%	3.15%	5.71%	6.77%	-1.88%	4.52%

Model areal-mean daily rainfall(mm) inside different radii of 200-500 km from the TC center for the period of 3-10 Aug

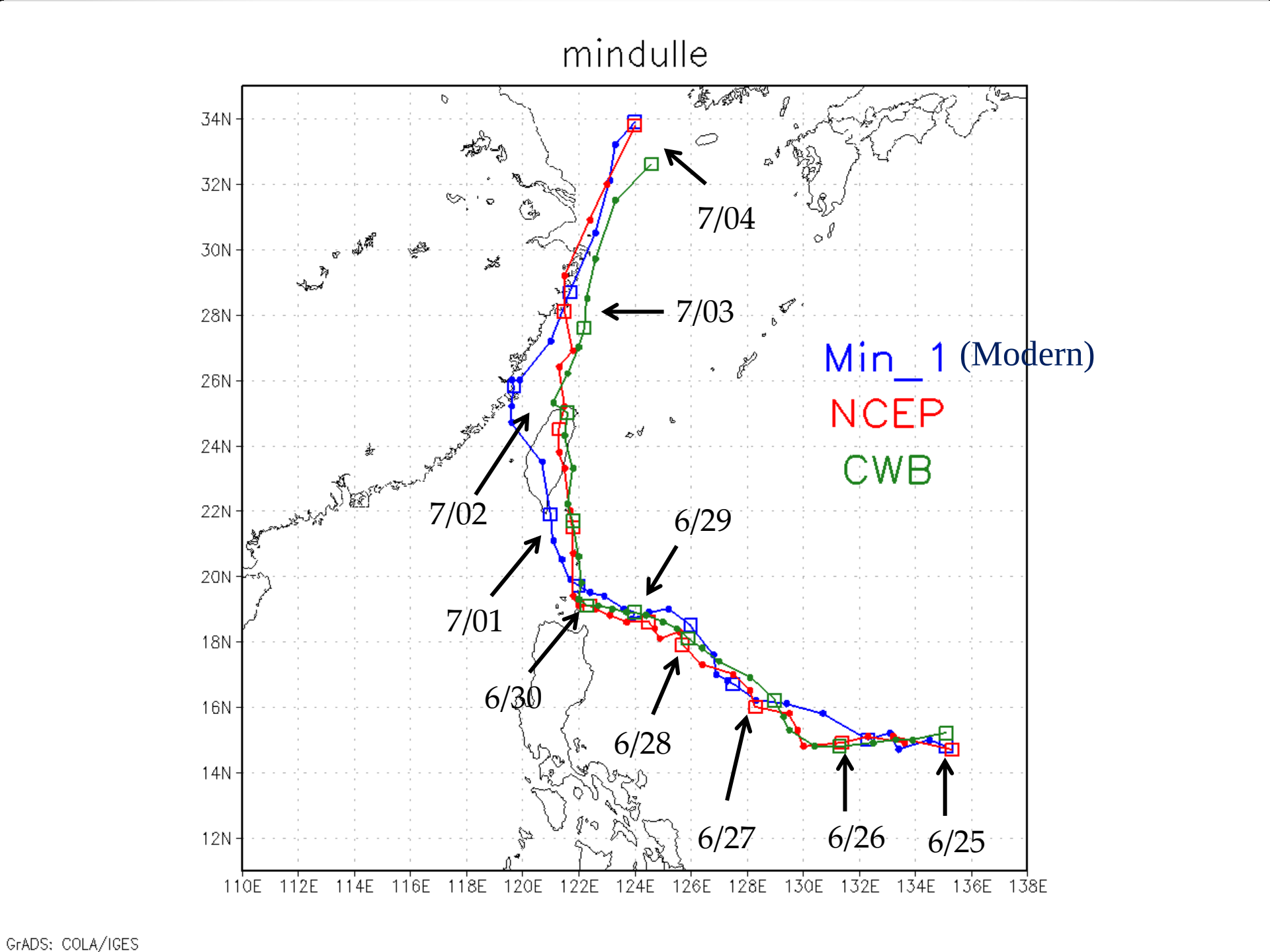
	500 km	400 km	300 km	200 km
Mo1 (mm) (Modern)	45.02	54.43	65.68	71.19
Mo2 (mm) (Past)	42.99	52.04	60.17	65.64
Mo1-Mo2	2.034	2.39	5.504	5.553
Percent Change	**4.52%**	**4.39%**	**8.38%**	**7.80%**

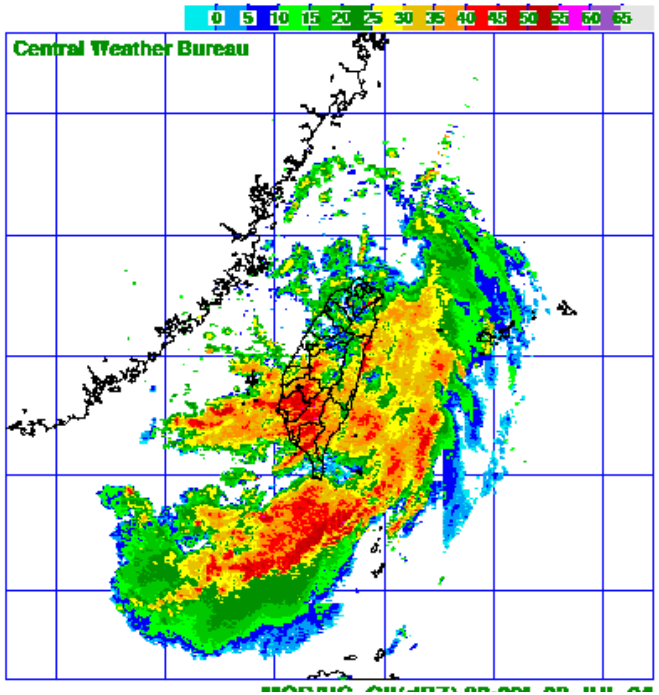
Case 2 : Mindulle

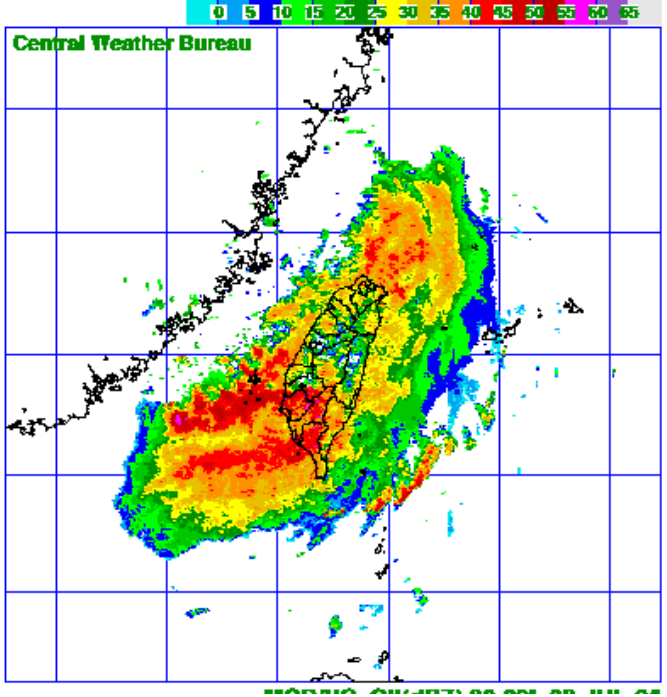


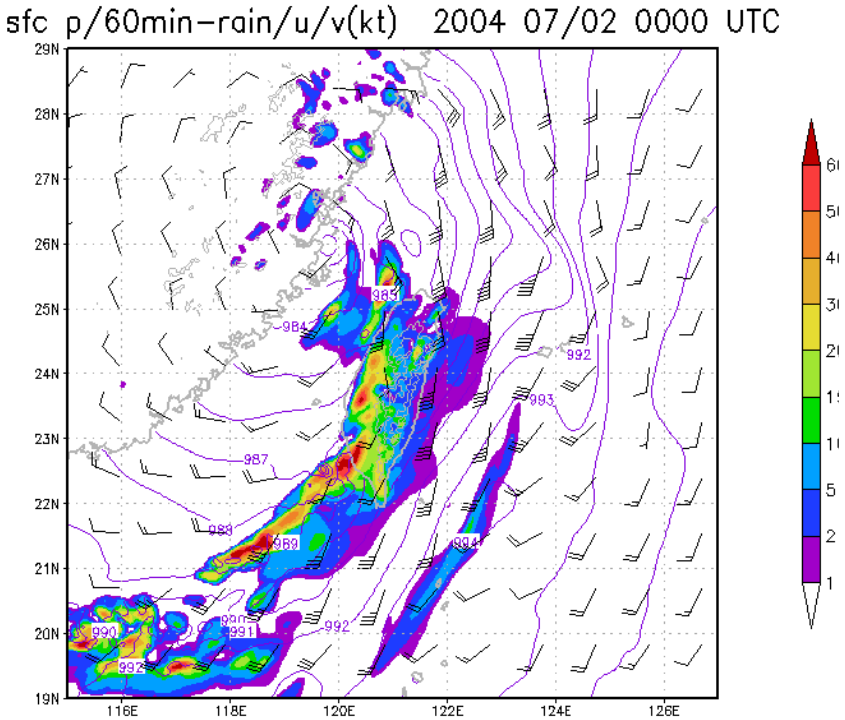
From CWB

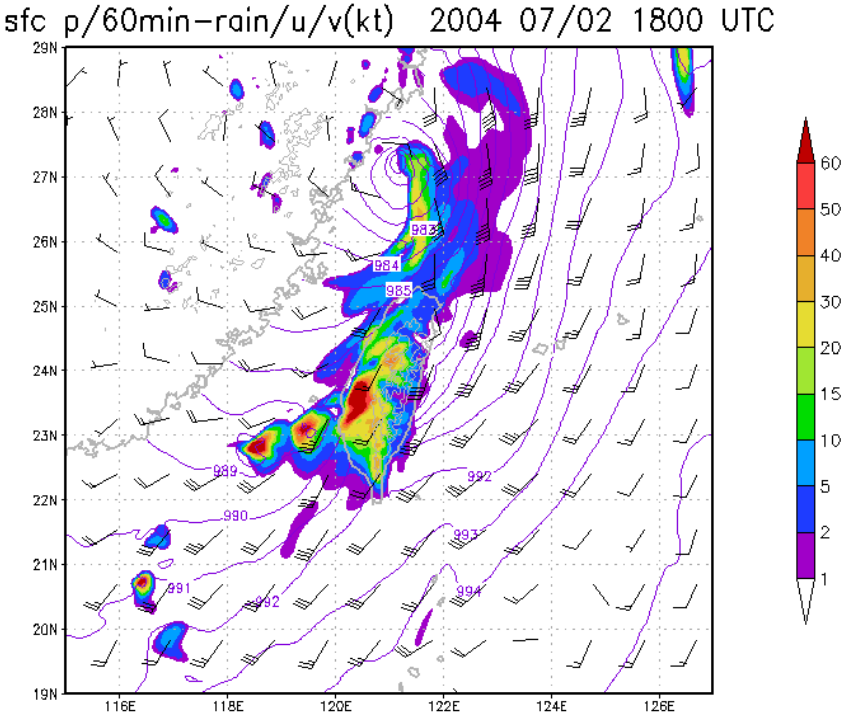
	Case2:Mindulle
Domain size	960×840×50
Horizontal grid size	3000m
Vertical grid size	500m
Integration length	216 hr (9day)
Initial time and end time	2004/6/25 0000UTC ~ 7/04 0000UTC
Cloud microphysics	Bulk cold rain scheme


mindulle
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
110E
112E
114E
116E
118E
120E
122E
124E
126E
128E
130E
132E
134E
136E
138E
7/04
7/03
7/02
7/01
6/30
6/29
6/28
6/27
6/26
6/25
Min_1 (Modern)
NCEP
CWB
GrADS: COLA/IGES

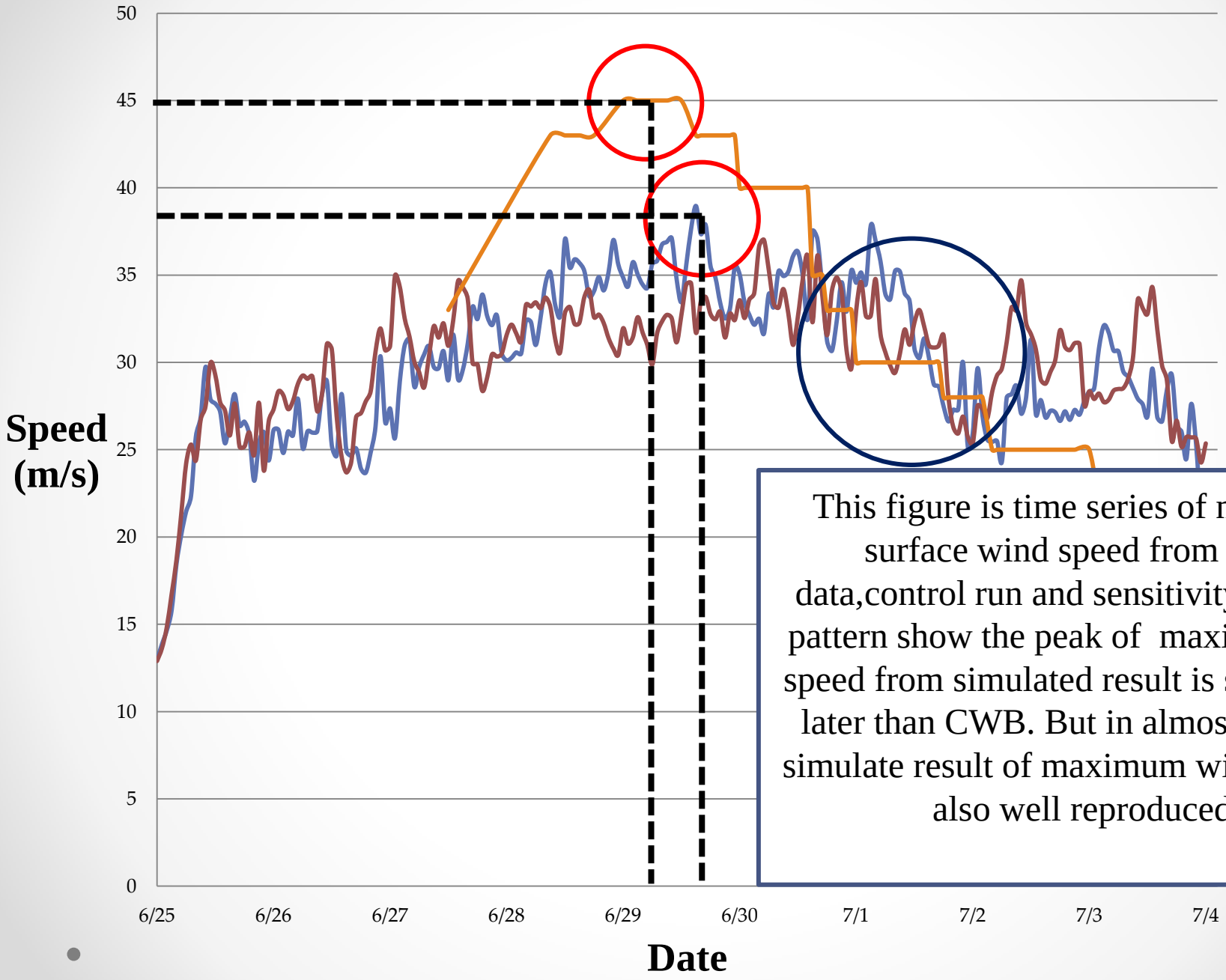

Central Weather Bureau
0 5 10 15 20 25 30 35 40 45 50 55 60 65


Central Weather Bureau
0 5 10 15 20 25 30 35 40 45 50 55 60 65

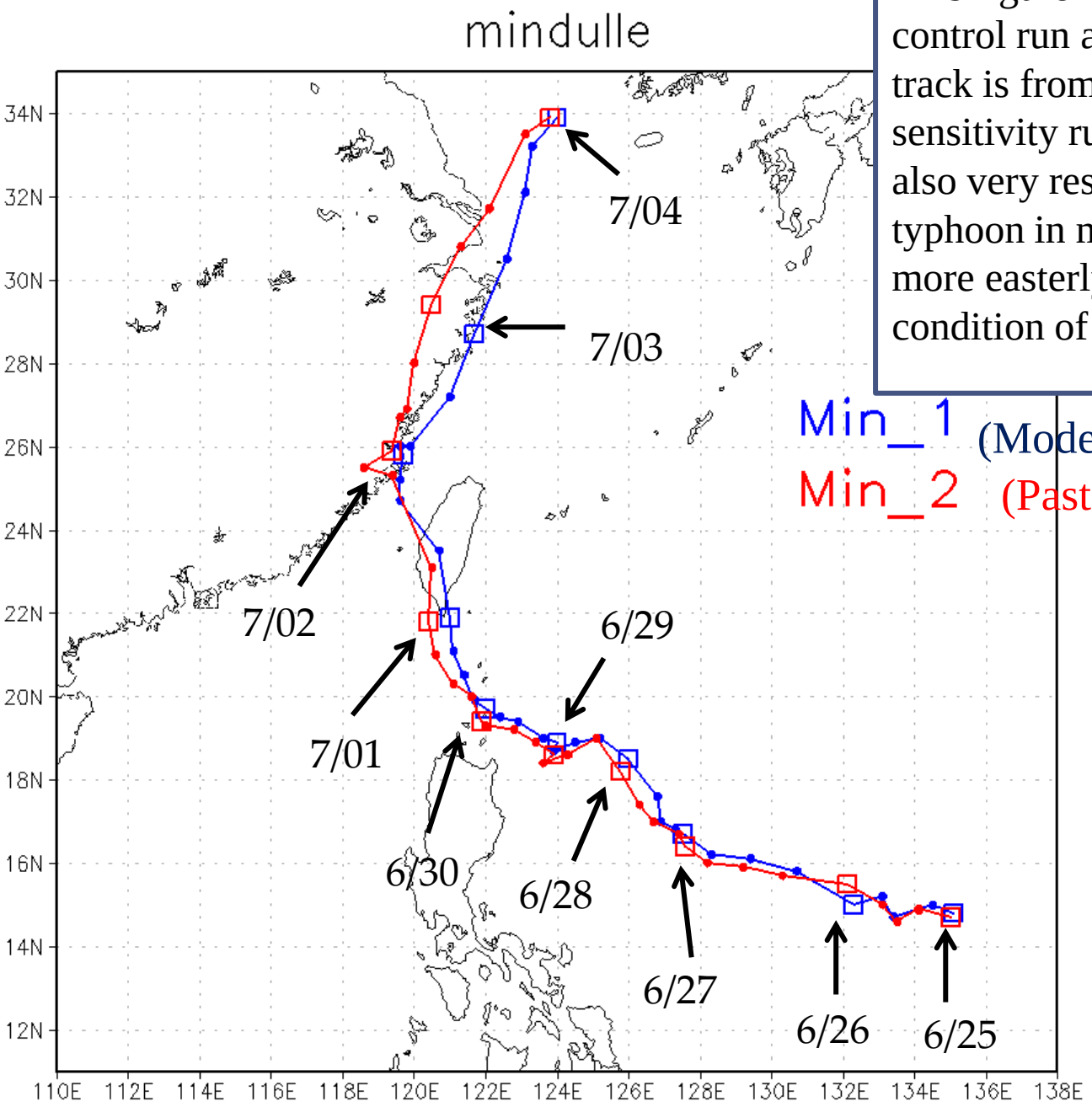

sfc p/60min-rain/u/v(kt) 2004 07/02 0000 UTC
29N
28N
27N
26N
25N
24N
23N
22N
21N
20N
19N
116E
118E
120E
122E
124E
126E
984
992
993
987
988
989
994
990
991
992
60
50
40
30
20
15
10
5
2
1


sfc p/60min-rain/u/v(kt) 2004 07/02 1800 UTC
29N
28N
27N
26N
25N
24N
23N
22N
21N
20N
19N
116E
118E
120E
122E
124E
126E
983
984
985
989
990
991
992
993
994
60
50
40
30
20
15
10
5
2
1

Wind Speed Max



This figure is time series of maximum surface wind speed from CWB data,control run and sensitivity run. This pattern show the peak of maximum wind speed from simulated result is smaller and later than CWB. But in almost time, the simulate result of maximum wind speed is also well reproduced.



This figure is the comparison between control run and sensitivity run.the blue track is from control run .The red is sensitivity run.Can see that the both track is also very resemble .and the track of typhoon in modern background is slight more easterly than the past. Just like the condition of morakot.

the radius of 400 km for 25 Jun ~ 3 Jul and Min1,Min2, their difference (Min1 - Min2), and the difference in percent change [%, (Min1 - Min2)/Min1] for Mindulle (2009).

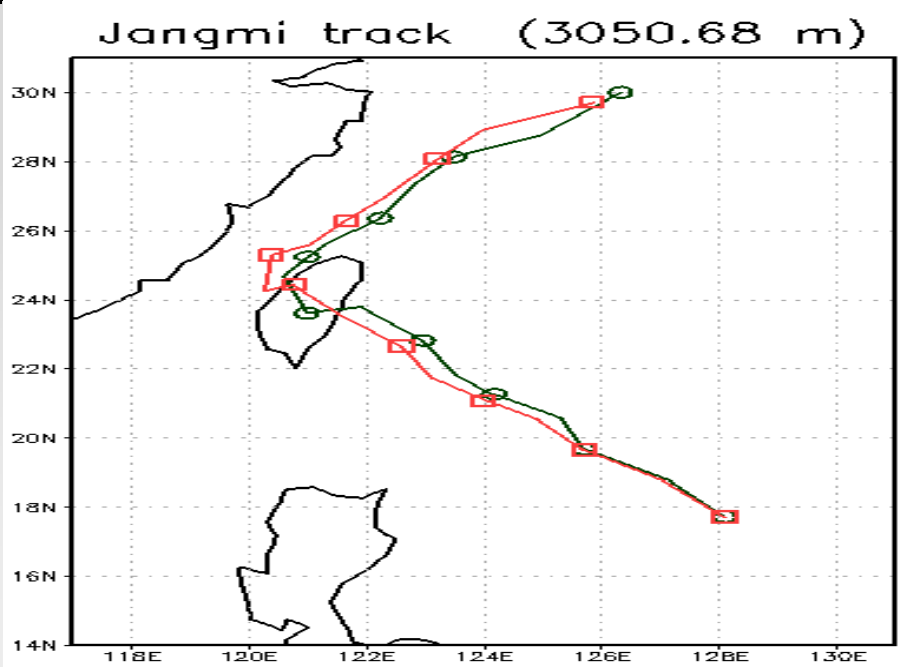
400 km	6/25	6/26	6/27	6/28	6/29	6/30	7/01	7/02	7/03	6/25~7/3
Min1(mm) (Modern)	36.34	56.16	77.00	96.13	89.99	91.06	46.56	40.20	38.58	63.56
Min2(mm) (Past)	39.22	56.36	70.67	92.70	79.17	78.57	43.31	34.06	32.29	58.48
Min1-Min2	-2.88	-0.20	6.34	3.43	10.82	12.49	3.26	6.13	6.28	5.08
Percent Change	-7.92%	-0.35%	8.23%	3.57%	12.02%	13.71%	7.00%	15.26%	16.29%	7.98%

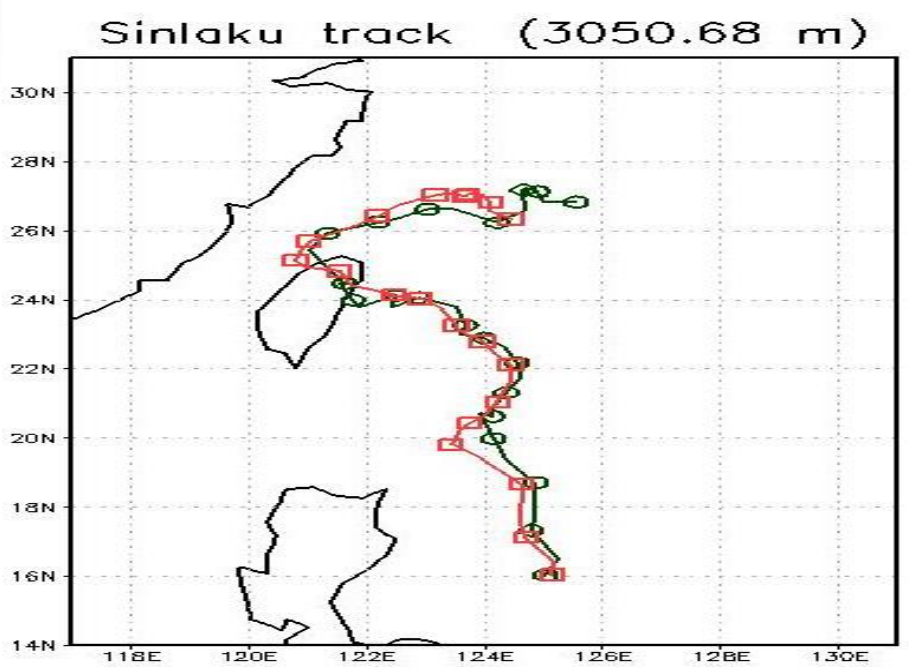
Model areal-mean daily rainfall(mm) inside different radii of 200-500 km from the TC center for the period of 25 Jun ~ 3 Jul

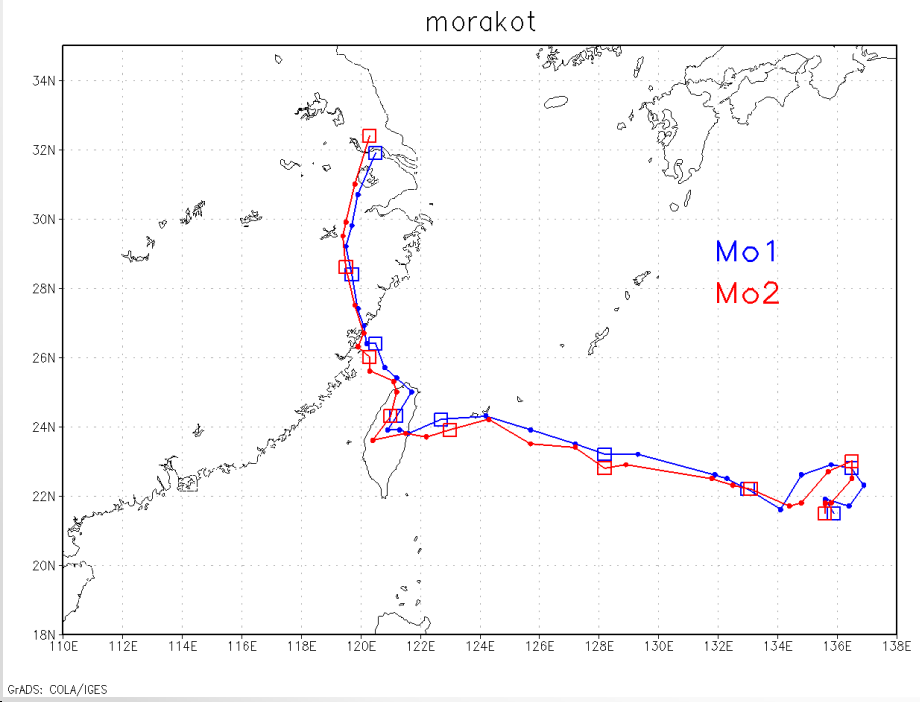
	500 km	400 km	300 km	200 km
Min1 (mm) (Modern)	52.42	63.56	71.56	86.79
Min2 (mm) (Past)	51.93	58.48	70.08	86.21
Min1-Min2	0.488	5.075	1.476	0.583
Percent Change	**0.93%**	**7.98%**	**2.06%**	**0.67%**

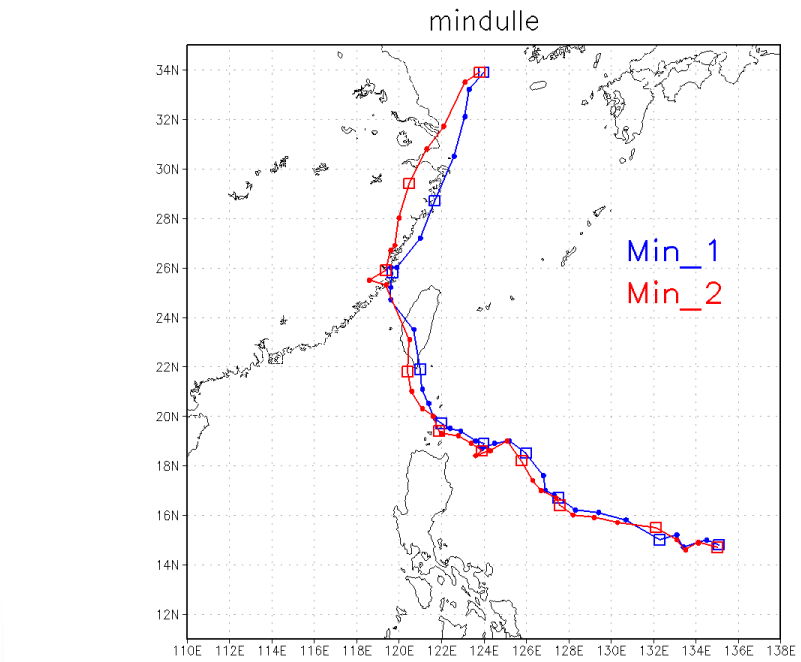
Conclusion

- The simulated track and rainfall are well reproduced for both case.
- According to the long-term change in wind field, we can anticipate that modern-day typhoons might move more easterly and the difference of track is very small. (p.26)
- The long-term climate change in temperature and humidity show that modern-day typhoons might stay in a environment which is more humid and warmer than the past climate.
- Both modern-day typhoon yield more rainfall than their counterpart in past climate(about 4~8%). (p27)


Jangmi track (3050.68 m)
30N
28N
26N
24N
22N
20N
18N
16N
14N
118E
120E
122E
124E
126E
128E
130E


Sinlaku track (3050.68 m)
30N
28N
26N
24N
22N
20N
18N
16N
14N
118E
120E
122E
124E
126E
128E
130E


morakot
Mo1
Mo2
34N
32N
30N
28N
26N
24N
22N
20N
18N
110E
112E
114E
116E
118E
120E
122E
124E
126E
128E
130E
132E
134E
136E
138E
GrADS: COLA/IGES


mindulle
Min_1
Min_2
34N
32N
30N
28N
26N
24N
22N
20N
18N
16N
14N
12N
110E
112E
114E
116E
118E
120E
122E
124E
126E
128E
130E
132E
134E
136E
138E
GrADS: COLA/IGES

	500 km	400 km	300 km	200 km
J1 (mm)	45.975	53.441	63.738	76.930
J2 (mm)	45.242	52.370	59.315	73.537
J1-J2	0.733	1.071	4.423	3.392
Percent Change	**1.59%**	**2.00%**	**6.94%**	**4.41%**
S1 (mm)	37.43	50.70	71.46	102.46
S2 (mm)	35.03	47.61	67.67	101.07
S1-S2	2.40	3.08	3.78	1.39
Percent Change	**6.41%**	**6.08%**	**5.29%**	**1.36%**
Mo1 (mm)	45.02	54.43	65.68	71.19
Mo2 (mm)	42.99	52.04	60.17	65.64
Mo1-Mo2	2.034	2.39	5.504	5.553
Percent Change	**4.52%**	**4.39%**	**8.38%**	**7.80%**
Min1 (mm)	52.42	63.56	71.56	86.79
Min2 (mm)	51.93	58.48	70.08	86.21
Min1-Min2	0.488	5.075	1.476	0.583
Percent Change	**0.93%**	**7.98%**	**2.06%**	**0.67%**

致謝

感謝王重傑教授與曾莉珊教授的指導並提供了許多改進的意見。感謝林伯勳學長提供研究所需的資料與指導。感謝指導我使用CReSS模式與工作站的學長姐們。使得此次暑期研究得以順利完成。

END