Assimilate the ground-base GPS ZTD/PWV observations in CWB WRF

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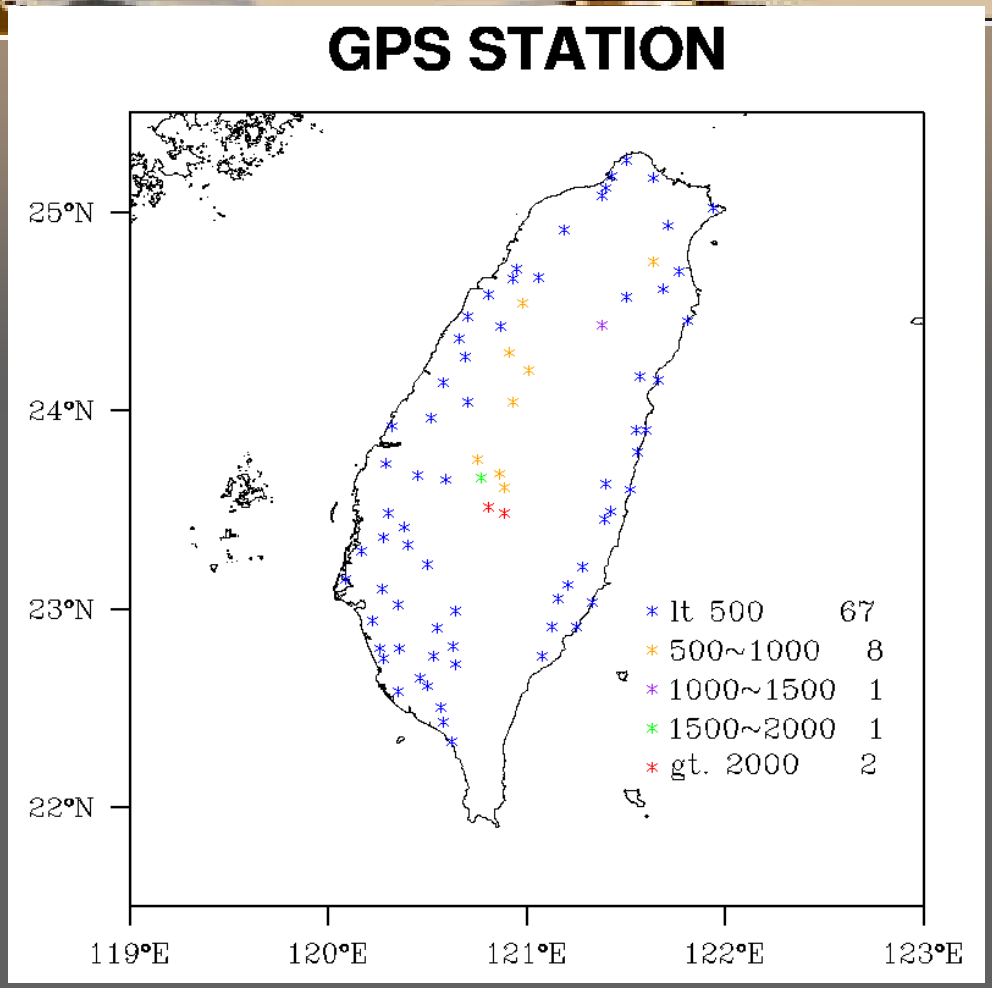
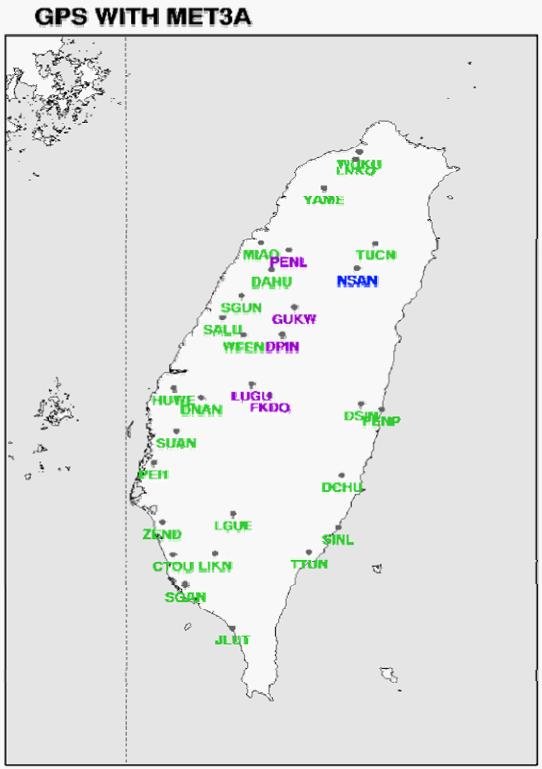
Special thanks to:

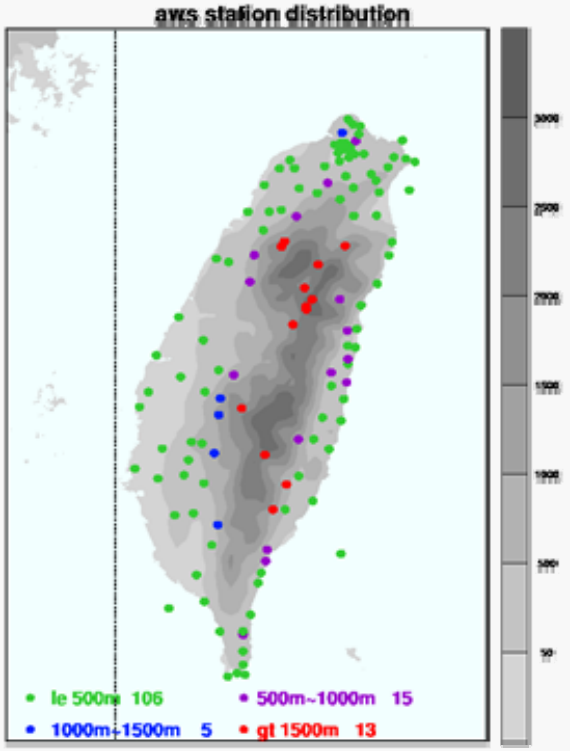
- The SoWMEX project office for the funding support to re-construct part of the observation facilities.
- The Seismological Center of CWB to provide the realtime GPS data.
- Dr. J. Braun and TACC/COSMIC to support the realtime operation of ZTD data process.

Outline

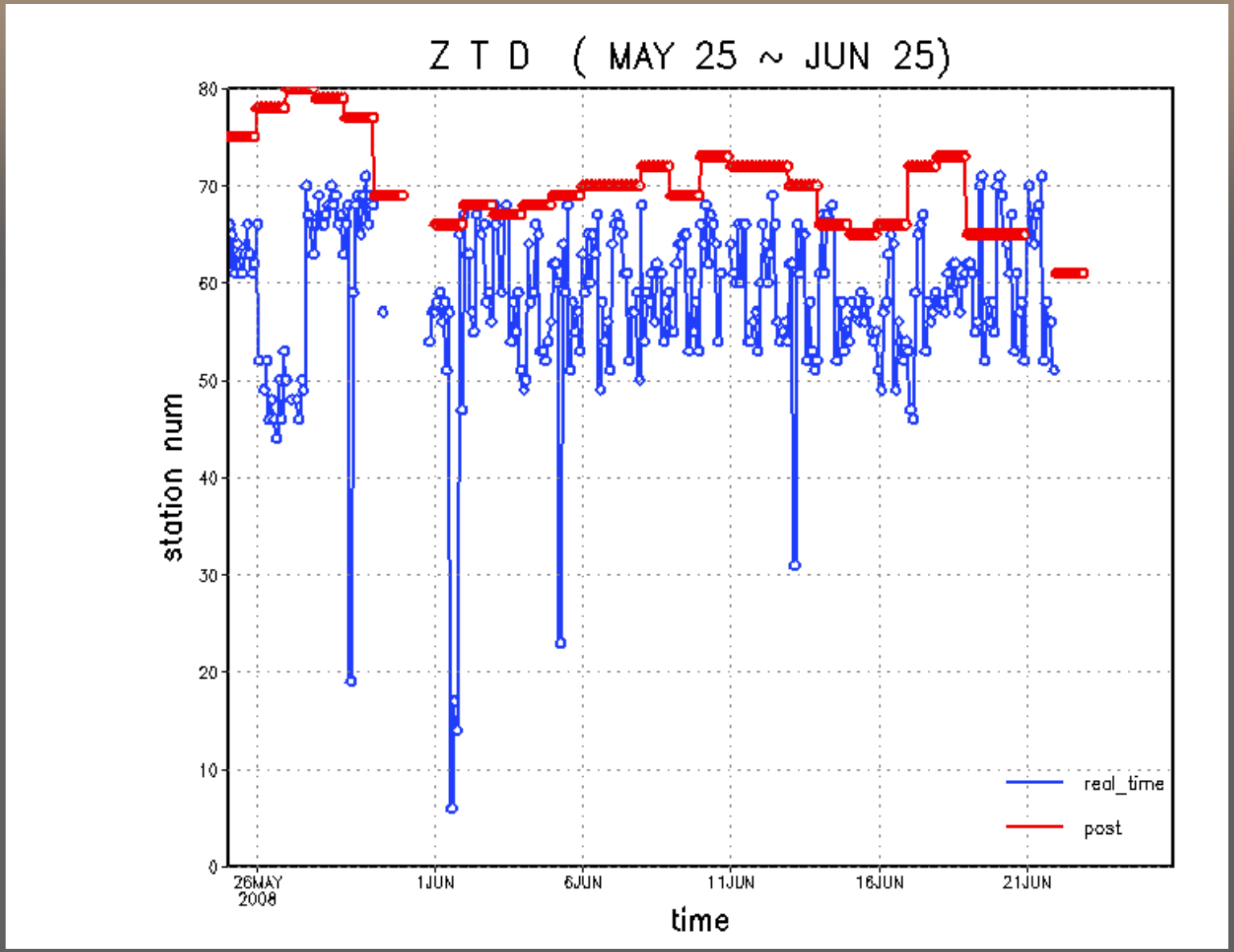
- Introduction to the ground-base GPS observations in Taiwan
- Impact of GPS-PWV and ZTD in CWB WRF data assimilation system
  - Typhoon Kalmaegi
  - SoWMEX case







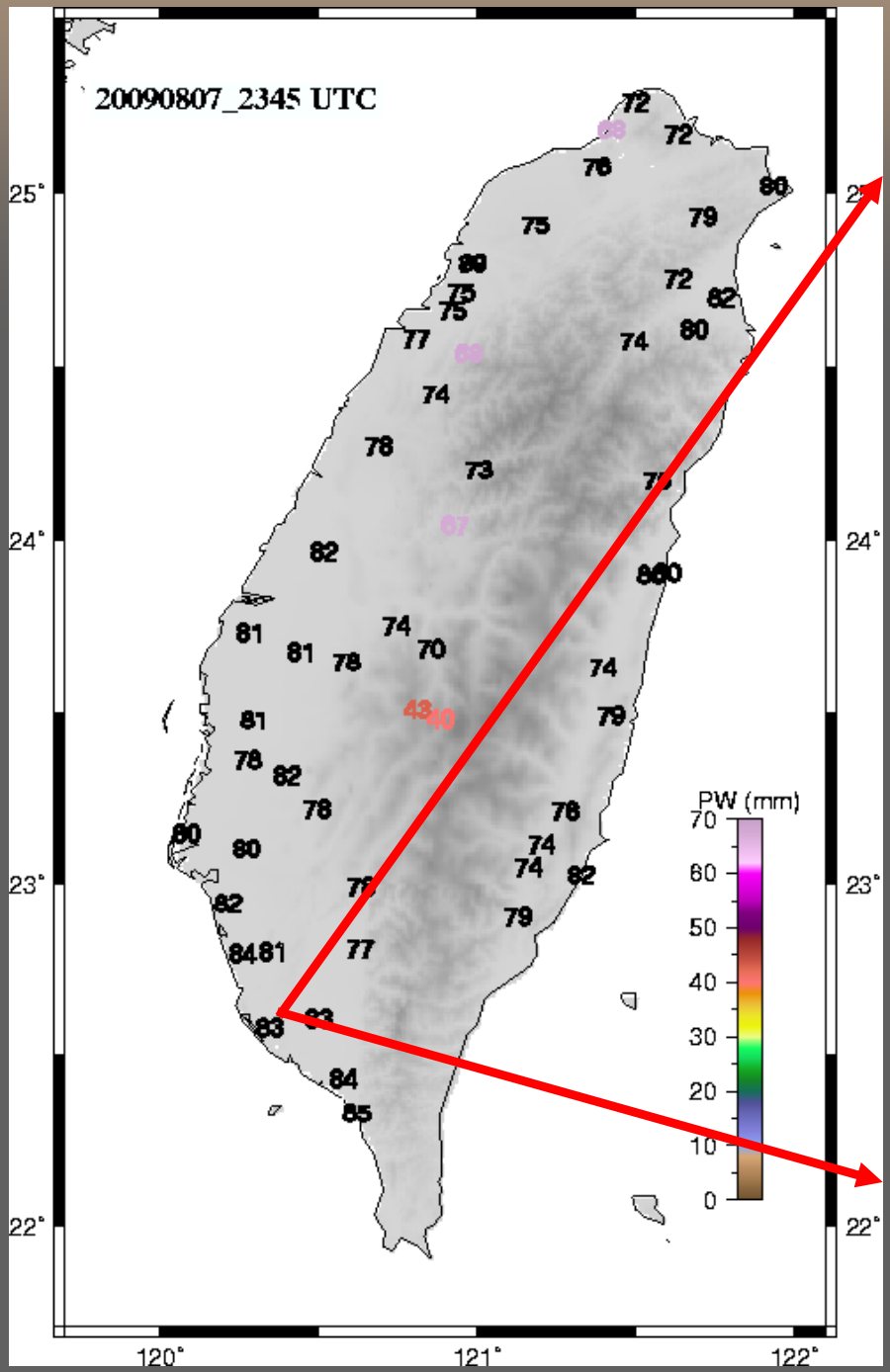
- A total of 80 GPS stations
- 30 of 80 GPS stations accompanied the surface observations
- A total of 139 mesonet provide additional surface observations
- To provide the ZTD and PWV products.

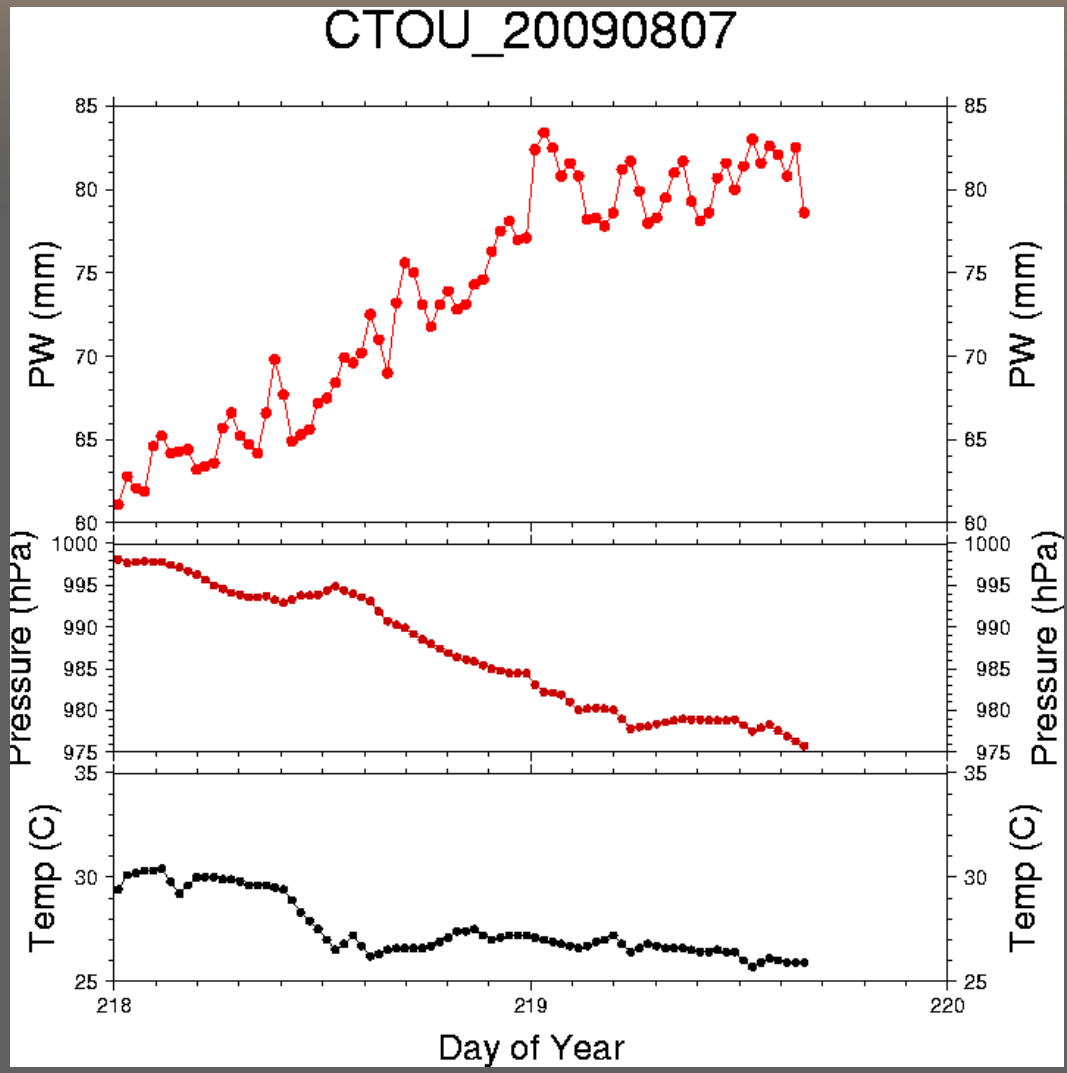


~60 stations in near-realtime with 3.5 hour delay

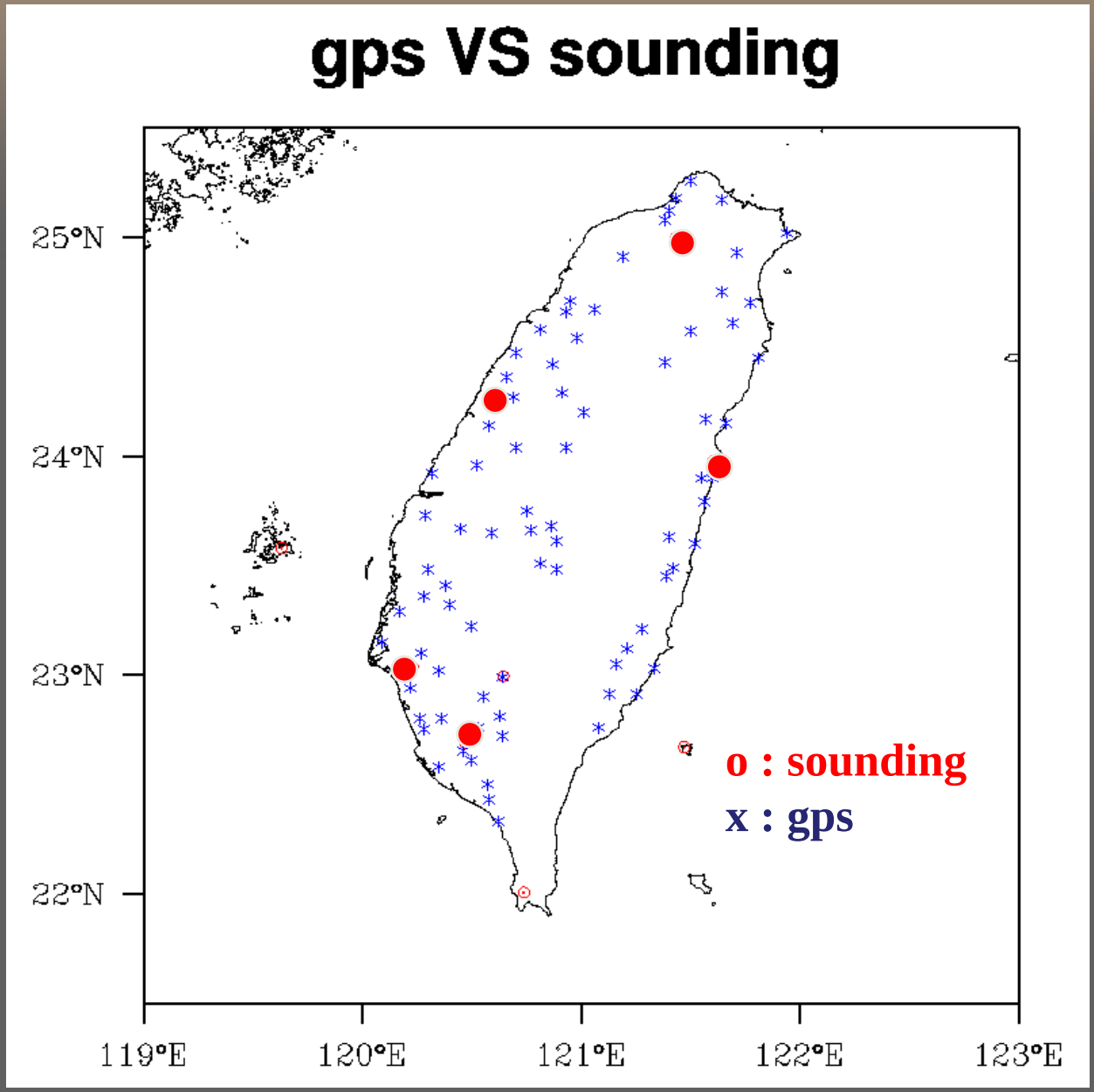
~70 stations available for daily post analysis

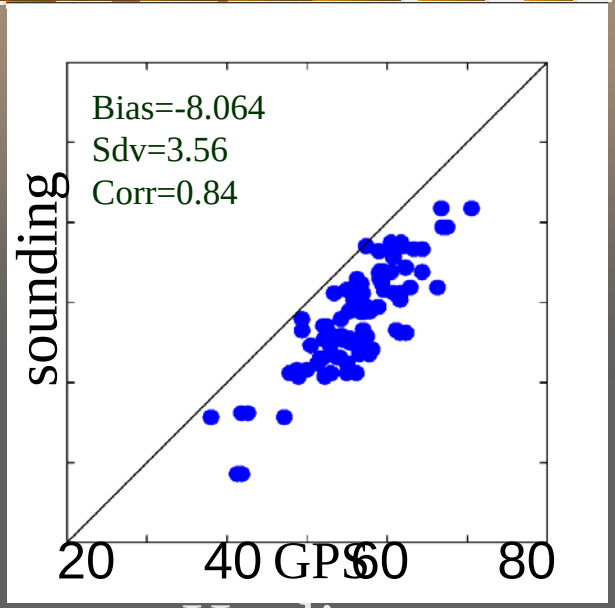
A realtime system with 30-min delay is implementing


20090807_2345 UTC
PW (mm)
70
60
50
40
30
20
10
0
25°
24°
23°
22°
120°
121°
122°

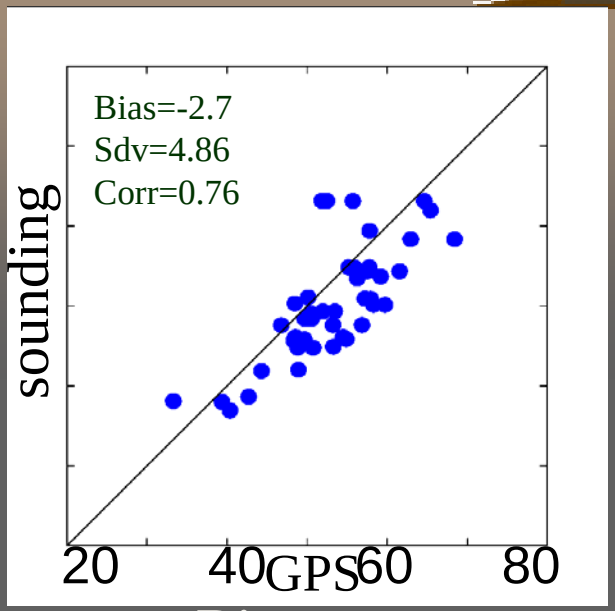

CTOU_20090807
PW (mm)
Pressure (hPa)
Temp (C)
Day of Year
218
219
220

gps VS sounding

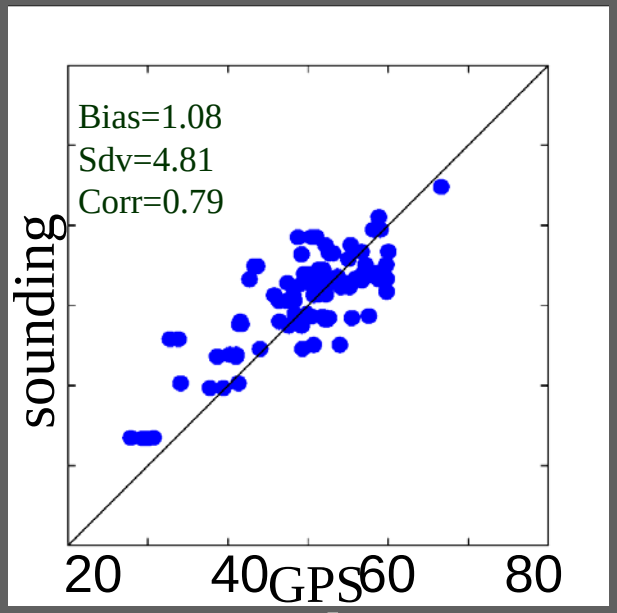




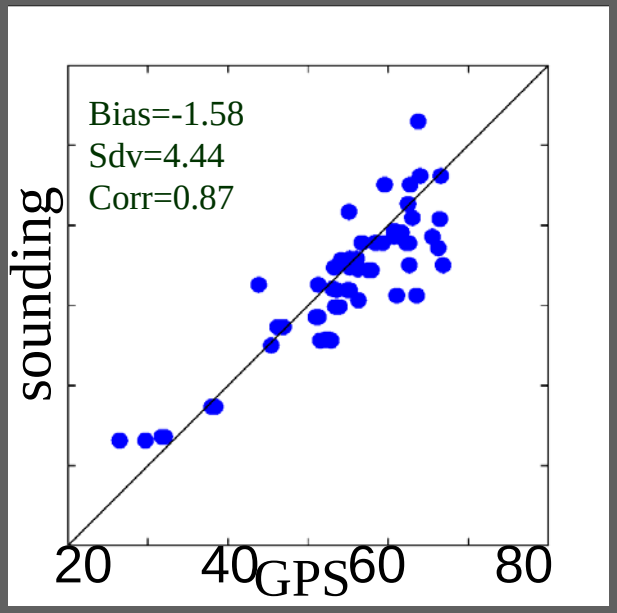
Hualian



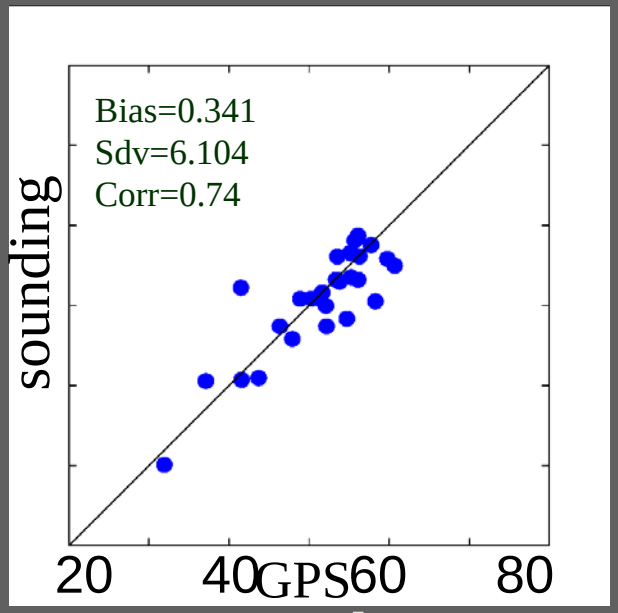
Pingtung



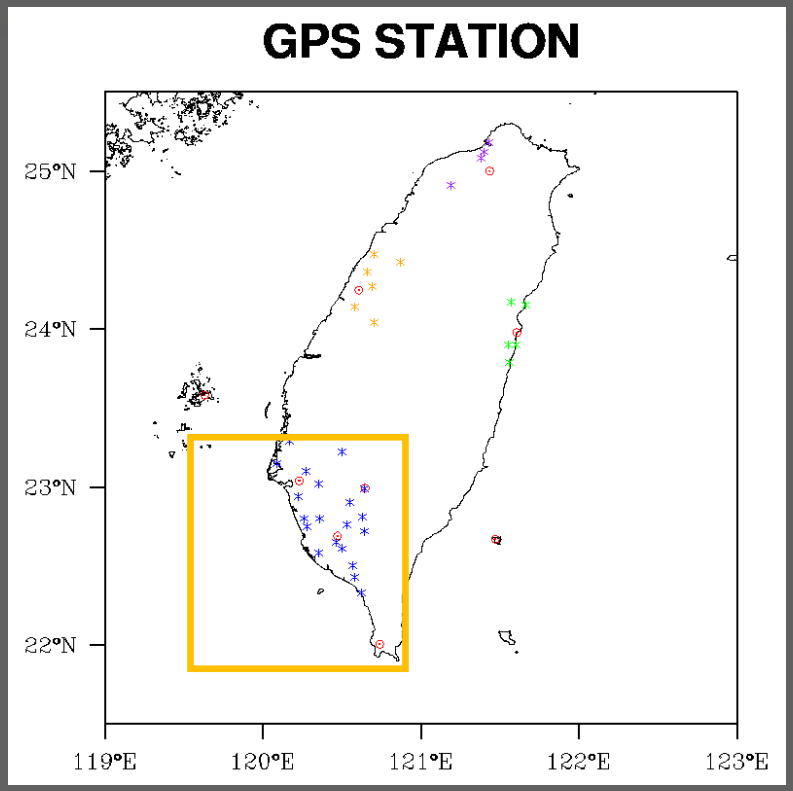
Banchiao

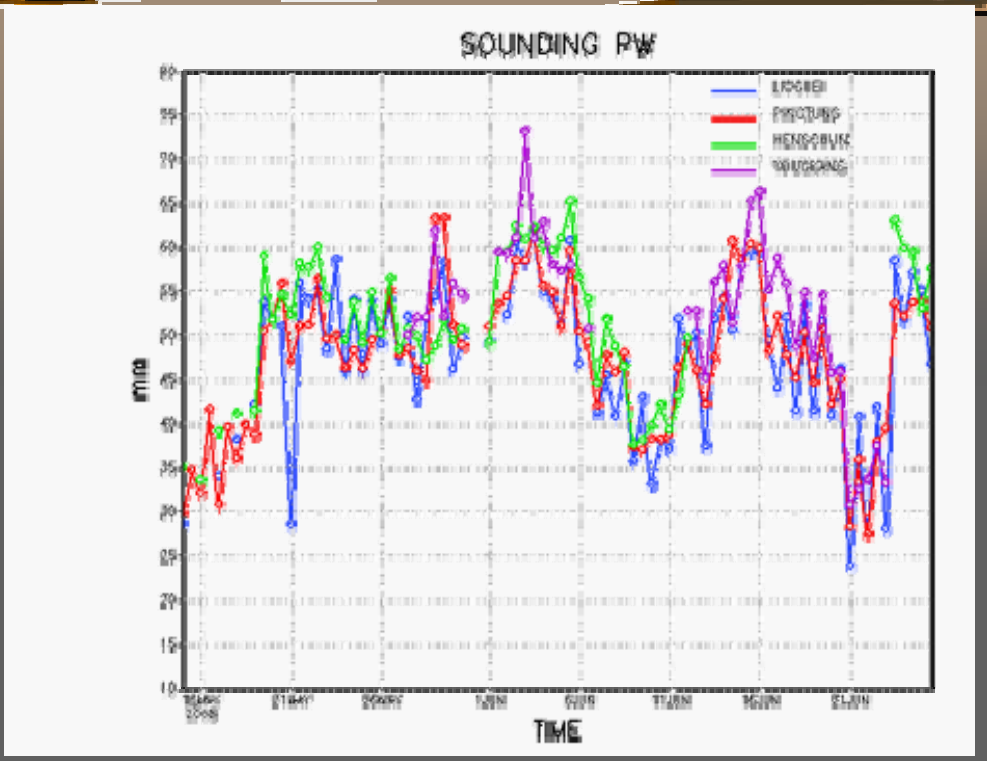


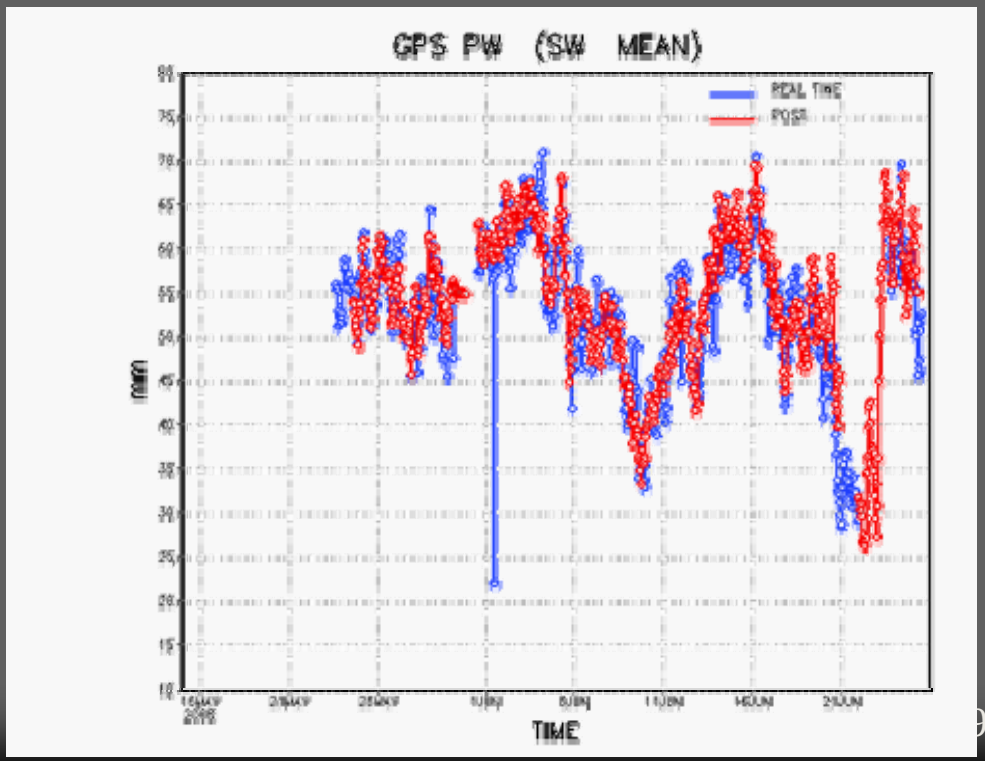
Yongkang



Taichun



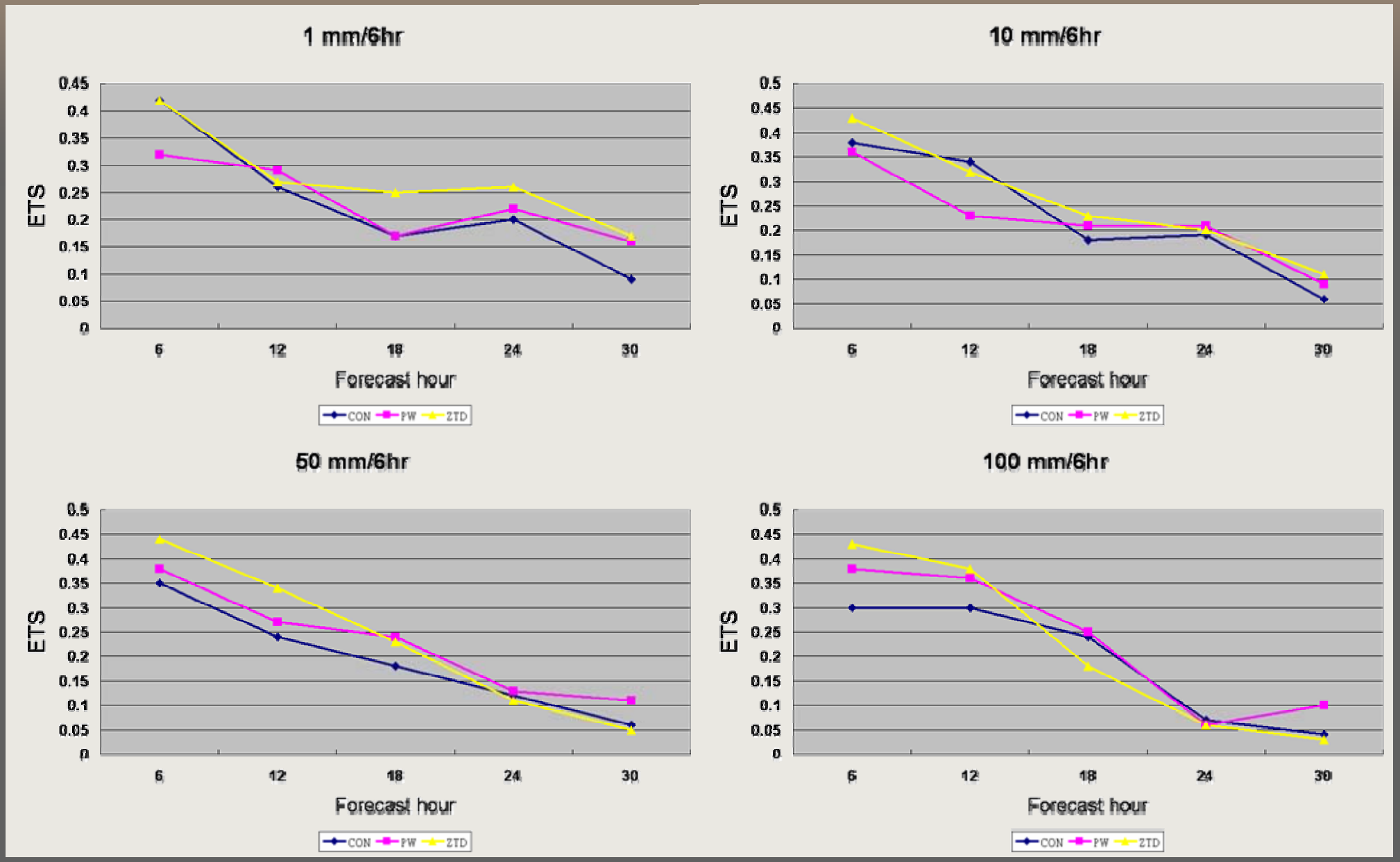




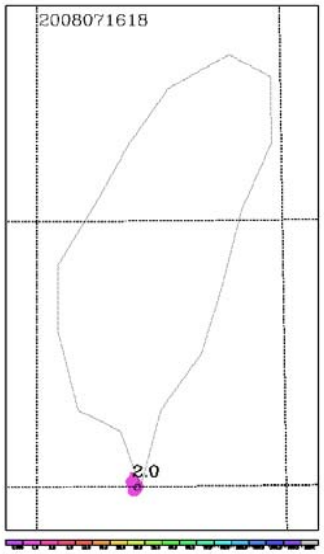
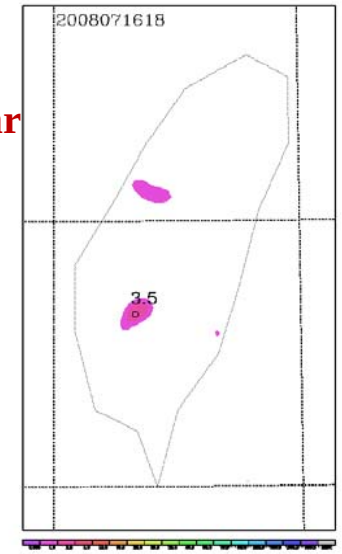
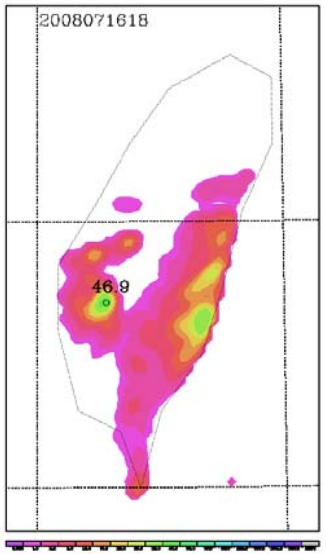
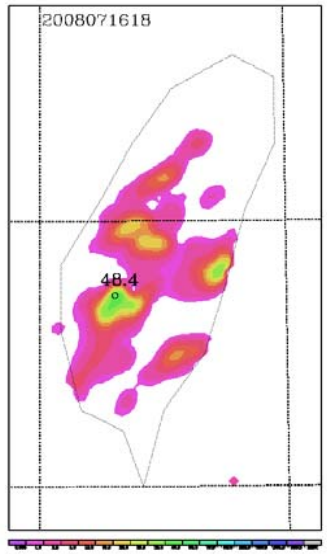
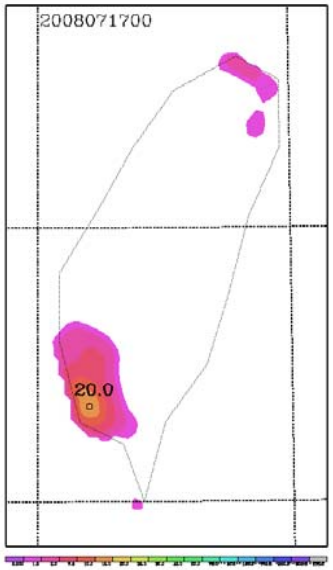
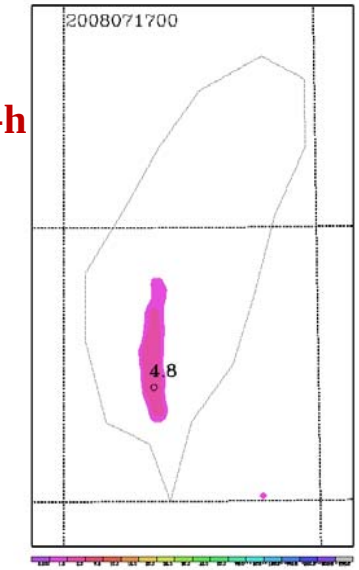
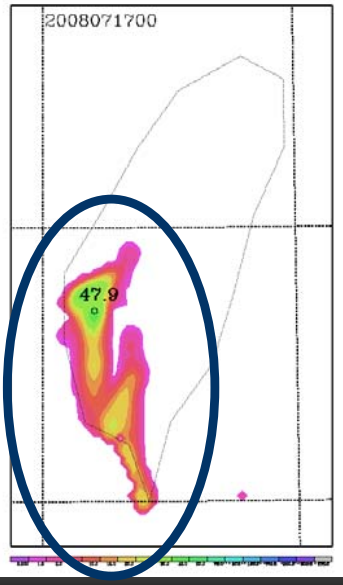
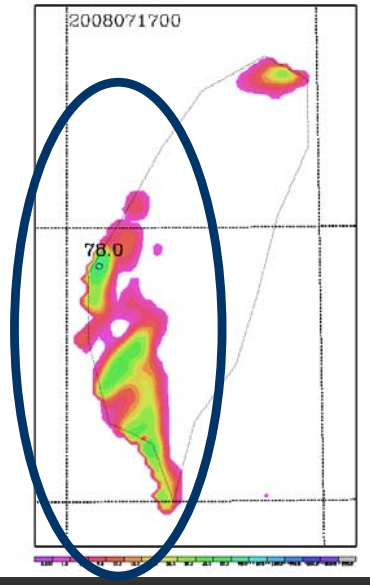
Sounding : 4
GPS station: 20

Assimilation of the GPS observations in Typhoon Kalmaegi

- Assimilation experiment period
  - 0000 UTC 16 July ~ 0000 UTC 18 July 2008
  - Update every 3-hr
- WRF 3DVAR/WRF
  - 45/15/5-km nested domain, 45 levels in the vertical
  - Full cycle, a total of 17 forecast cases
- Exp design
  - CON: Assimilate all the GTS observations
  - PW: CON + GPS-PW
  - ZTD: CON + GPS-ZTD


1 mm/6hr
ETS
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6
12
18
24
30
Forecast hour
CON
PW
ZTD
10 mm/6hr
ETS
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6
12
18
24
30
Forecast hour
CON
PW
ZTD
50 mm/6hr
ETS
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6
12
18
24
30
Forecast hour
CON
PW
ZTD
100 mm/6hr
ETS
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6
12
18
24
30
Forecast hour
CON
PW
ZTD

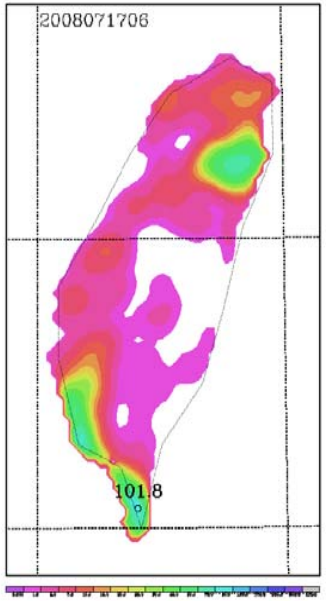
6-hourly Rainfall forecast initiated at 2008071612Z (4 cycles)

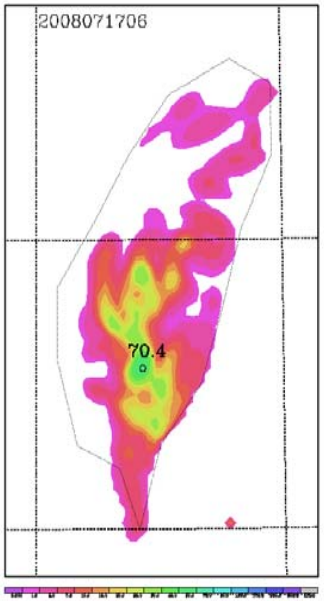
	OBS	CON	PW	ZTD
0-6-hr fcst				
6-12-h fcst				

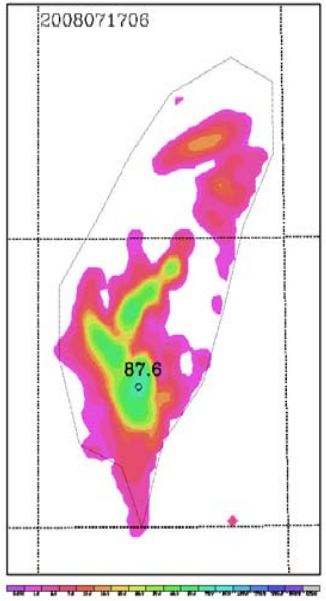
6-hourly Rainfall forecast initiated at 2008071612Z (4 cycles)

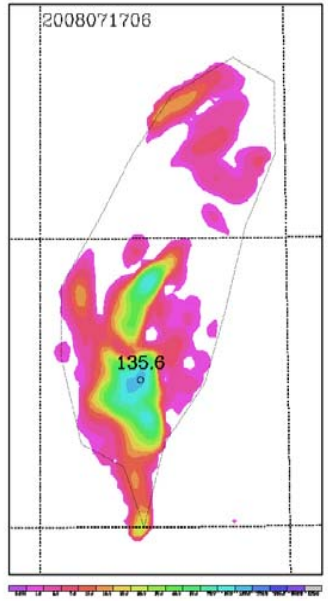
OBS CON PW ZTD

12-18-h fcst

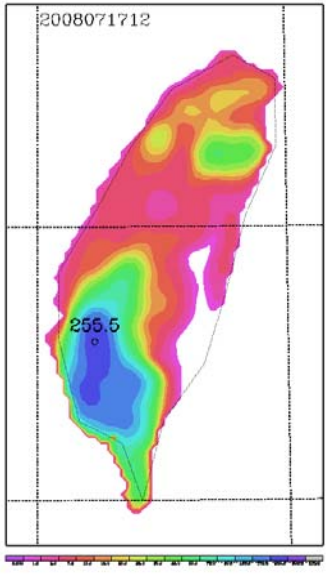


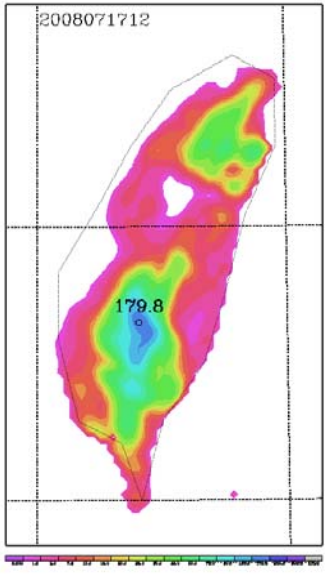


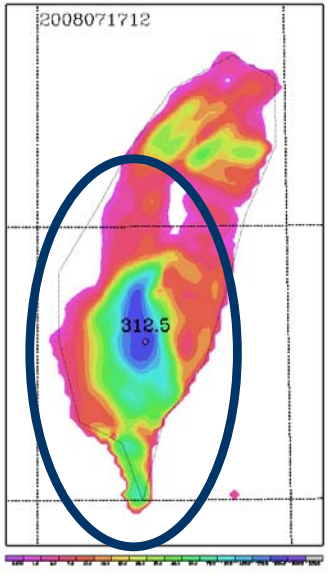


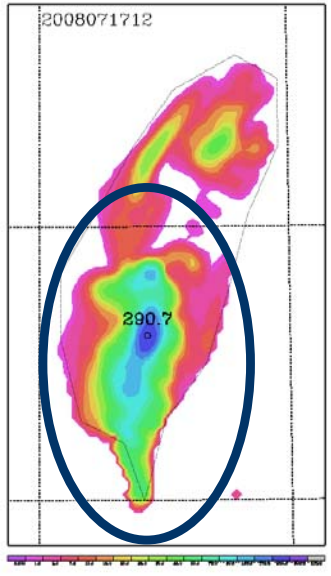


18-24-h fcst



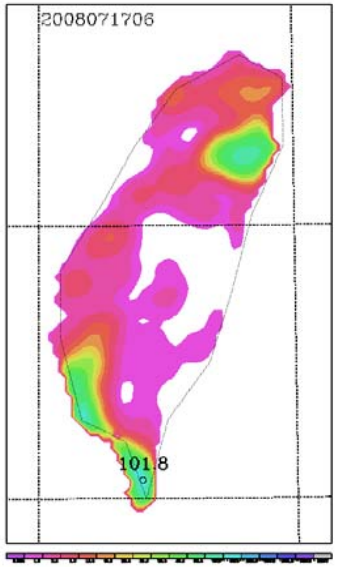




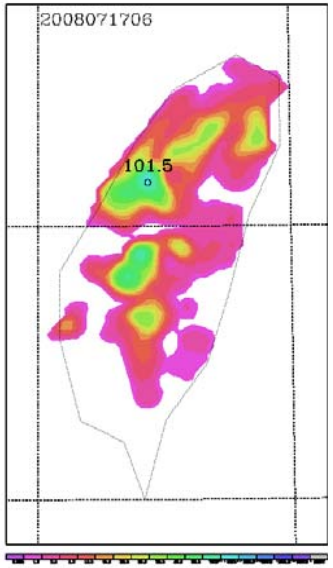


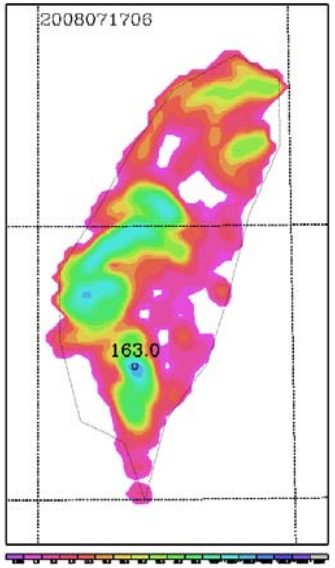
6-hourly Rainfall forecast initiated at 2008071700Z (8 cycles)

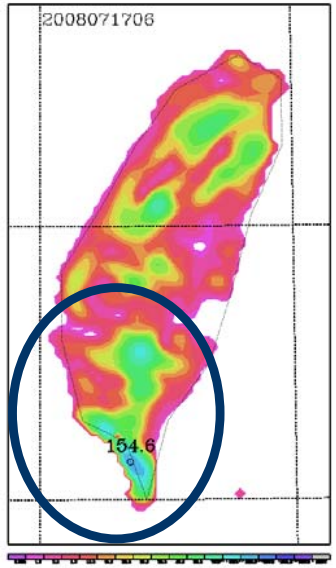
OBS CON PW ZTD

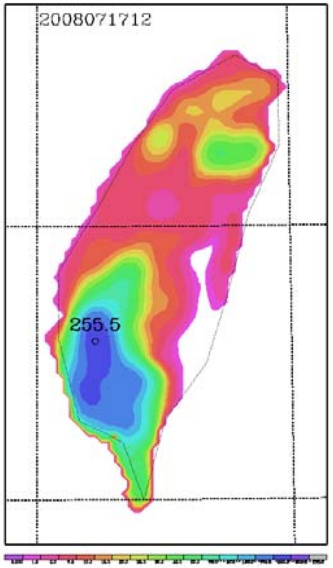


0-06-h fcst

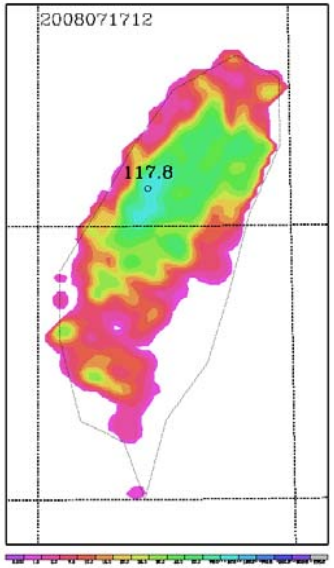


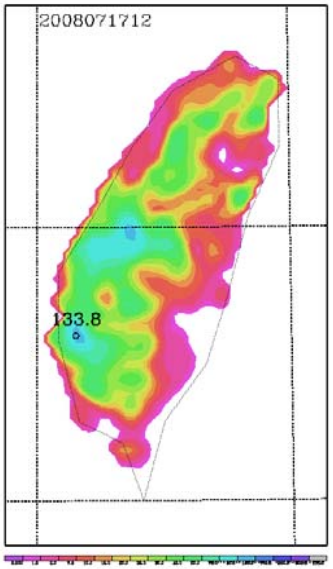


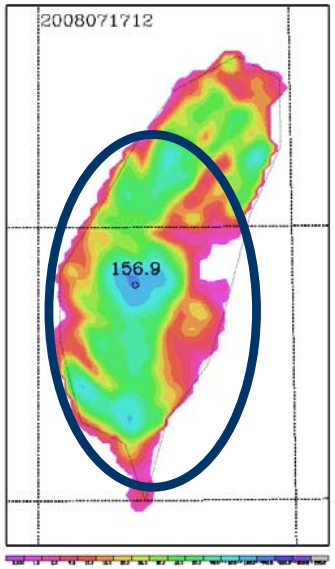




6-12-h fcst







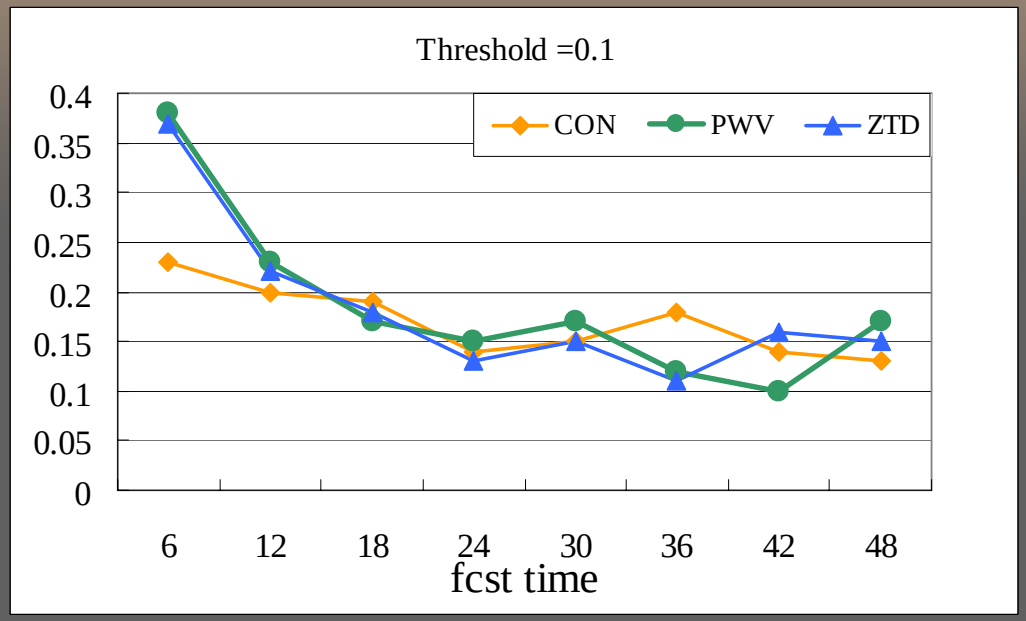
Averaged errors of track forecast over 60-h period for Typhoon Kalmaegi

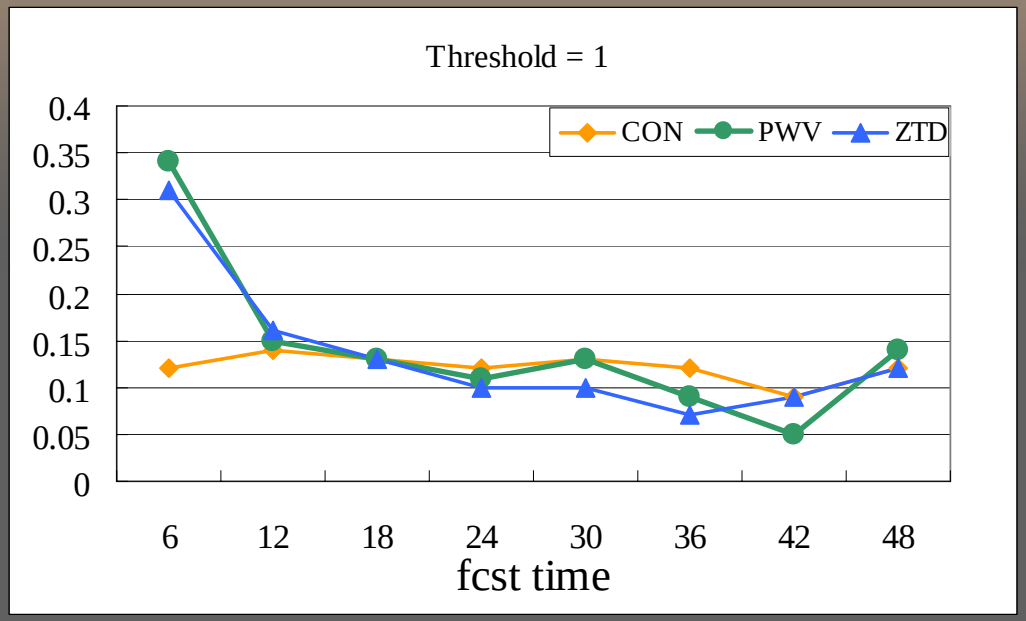
Init. Times \ Exp.	CON	PW	ZTD
1600Z	434.0	283.4	250.4
1606Z	153.4	151.2	145.5
1612Z	158.1	153.3	145.5
1618Z	215.6	181.8	118.6
1700Z	210.1	166.3	160.0
1706Z	150.5	142.8	128.7
1712Z	207.6	155.9	140.9
Mean	218.5	176.4	155.7

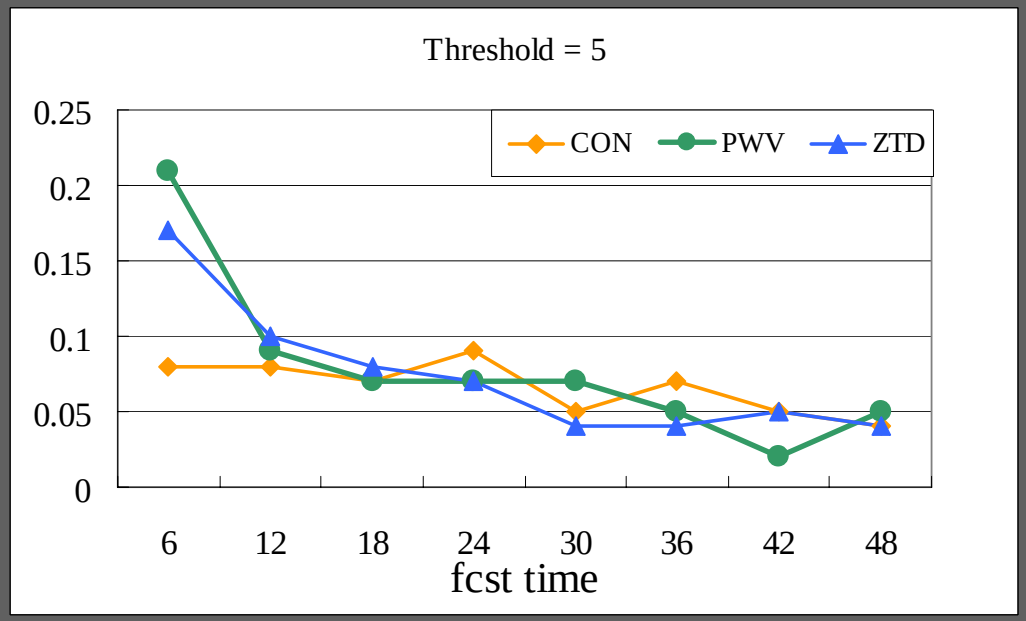
Assimilation of GPS ZTD got 29% reduction of the track forecast error compared to the CON

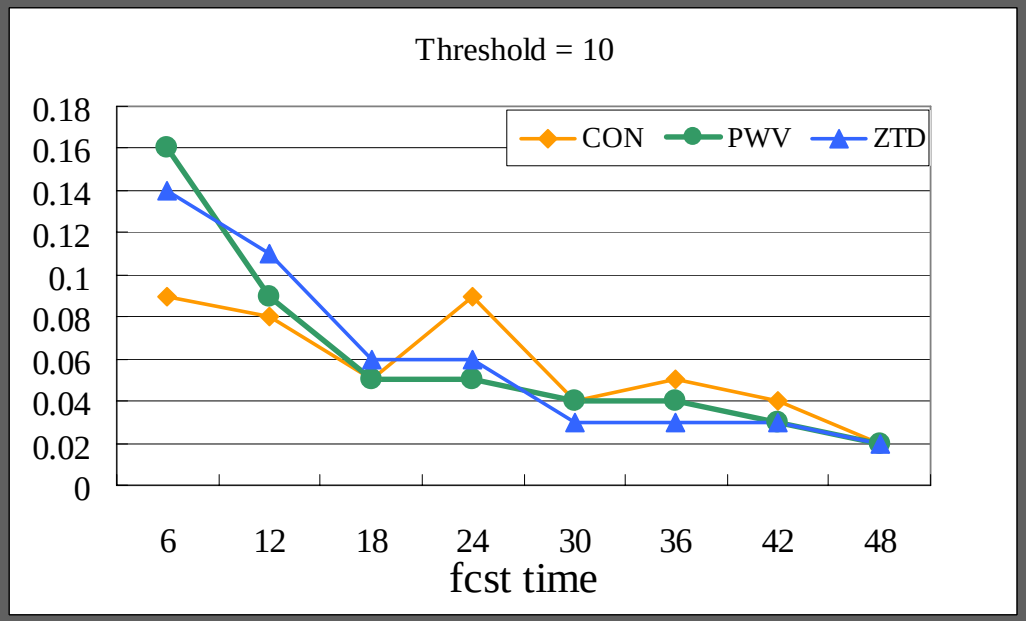
Assimilation of the GPS observations in SoWMEX case

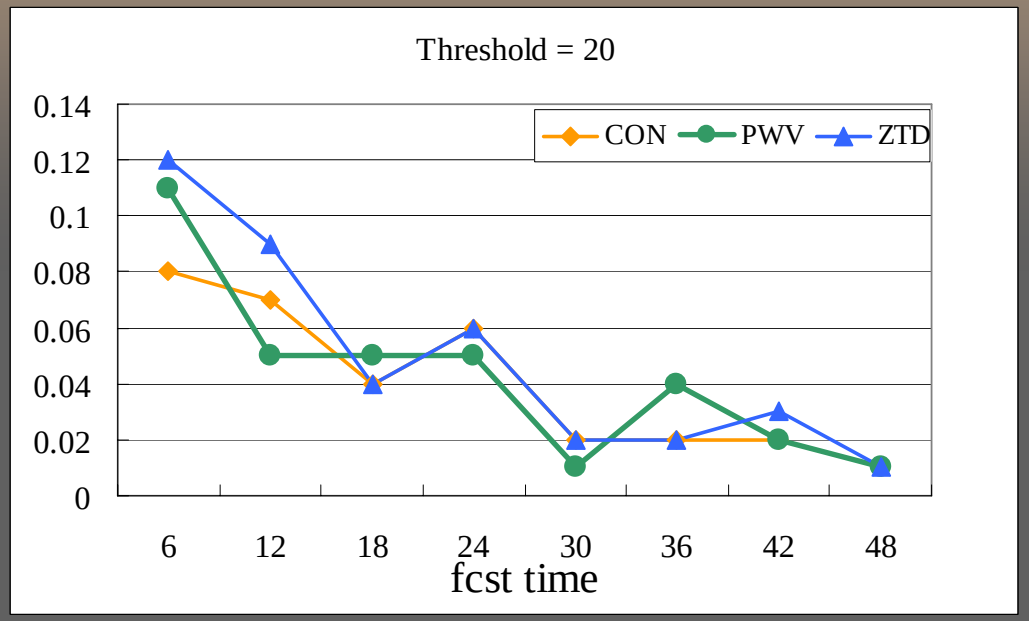
- Assimilation experiment period
  - 1800 UTC 31 May ~ 0600 UTC 4 June 2008
  - Update every 6-hr
- WRF 3DVAR/WRF
  - 45/15/5-km nested domain, 45 levels in the vertical
  - Full cycle, a total of 14 forecast cases
- Exp design
  - CON: Perform 3DVAR analysis with the GTS observations
  - PWV: CON +GPS-PW
  - ZTD: CON + GPS-ZTD

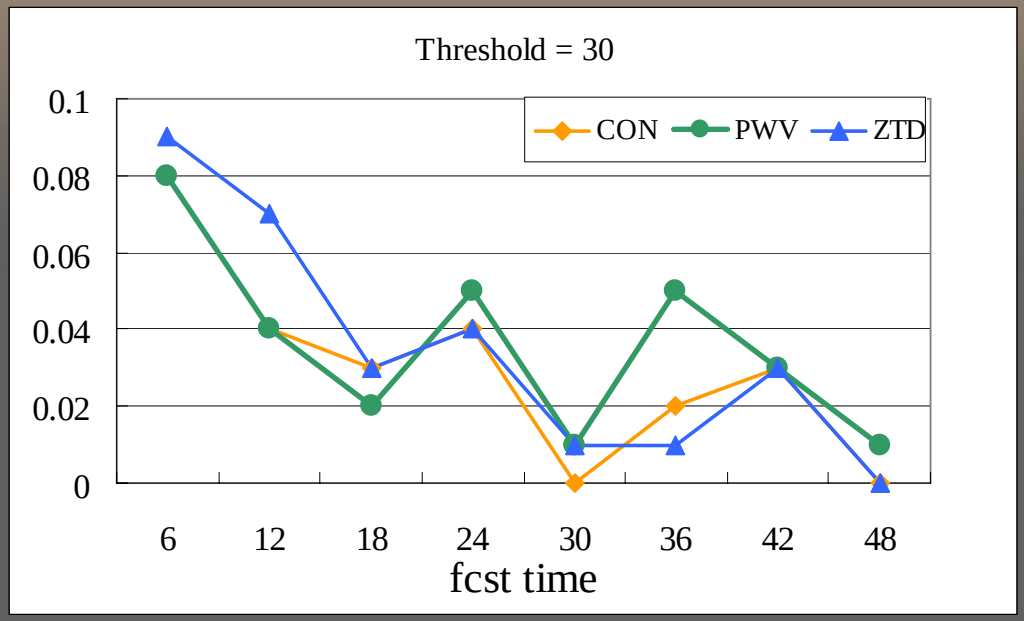

Threshold =0.1
CON
PWV
ZTD
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6
12
18
24
30
36
42
48
fcst time


Threshold = 1
CON
PWV
ZTD
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6
12
18
24
30
36
42
48
fcst time


Threshold = 5
CON
PWV
ZTD
0.25
0.2
0.15
0.1
0.05
0
6
12
18
24
30
36
42
48
fcst time

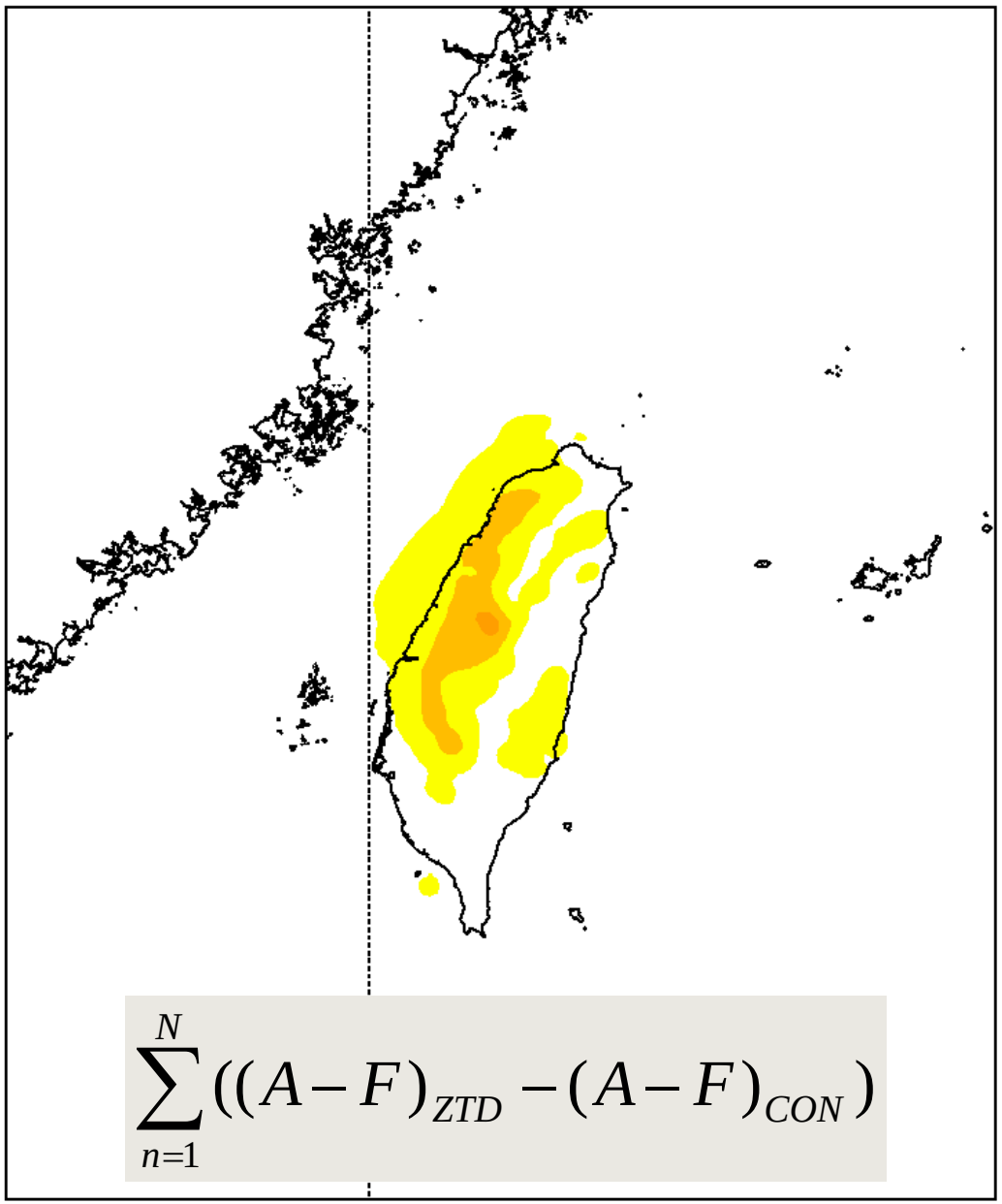

Threshold = 10
CON
PWV
ZTD
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
6
12
18
24
30
36
42
48
fcst time



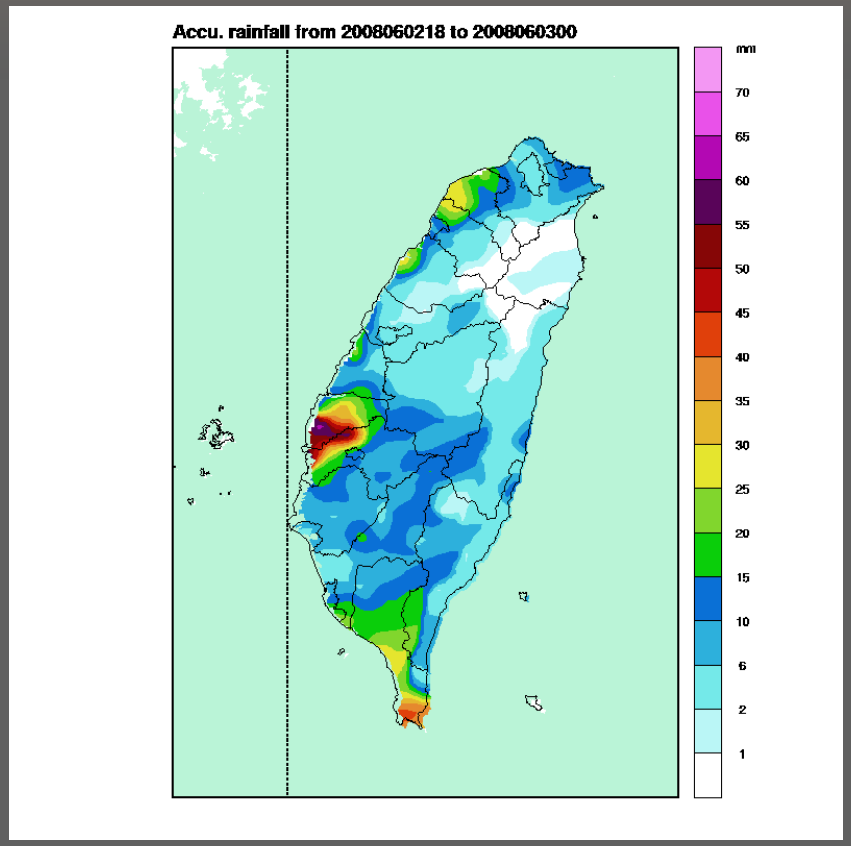


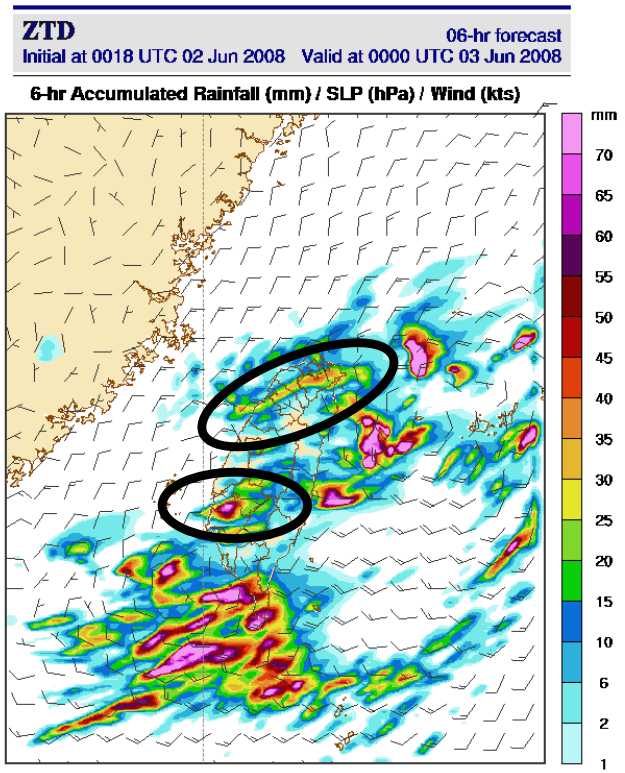
EXP \ Fcst hr	6	12	18	24
CON	0.08	0.07	0.06	0.07
PWV	0.15	0.077	0.058	0.07
ZTD	0.14	0.089	0.06	0.06

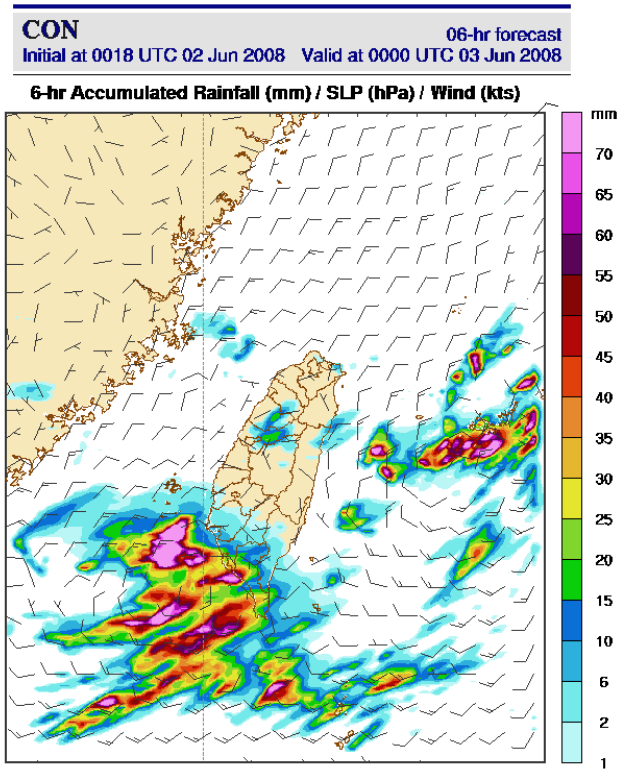
Averaged ETS score over all thresholds

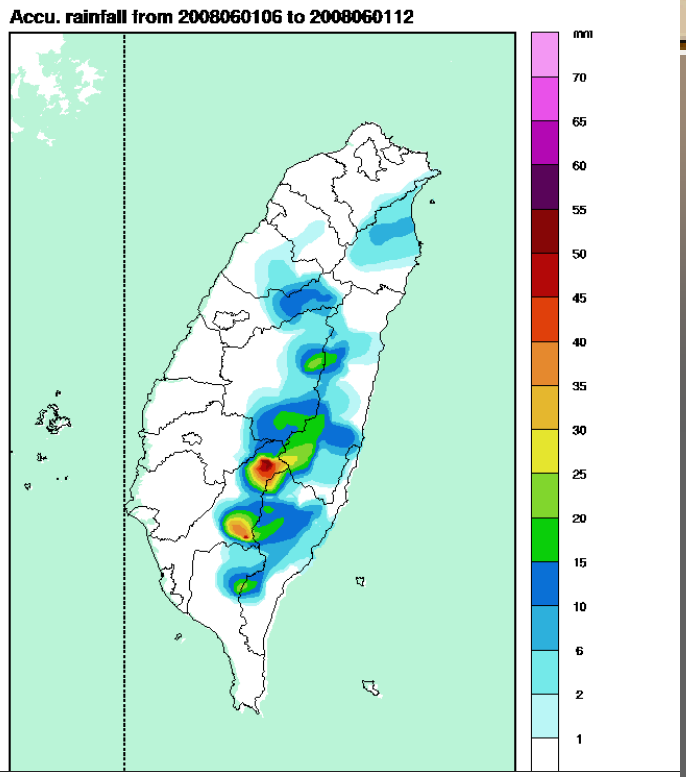


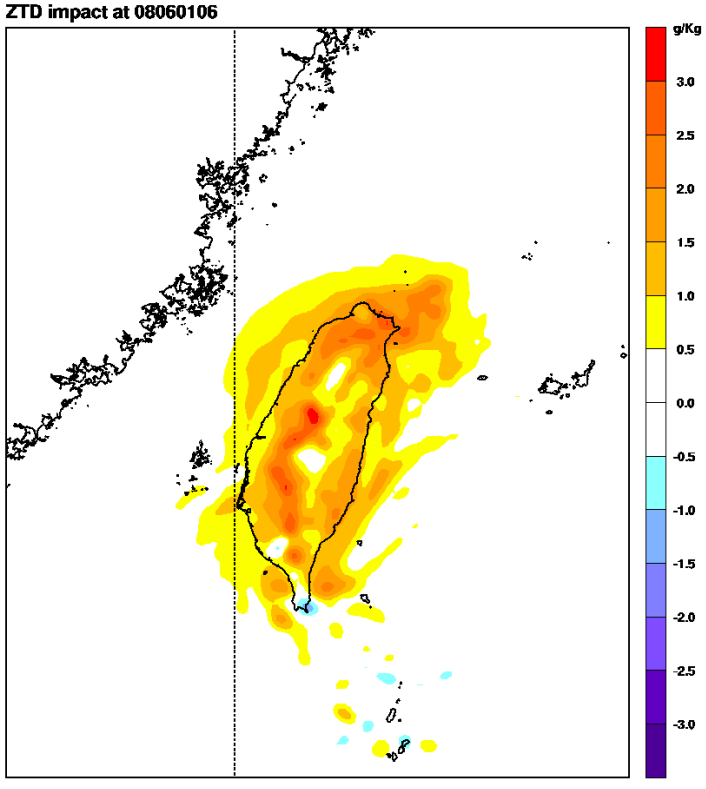
Impact of ZTD for the surface mixing ratio during the assimilation period

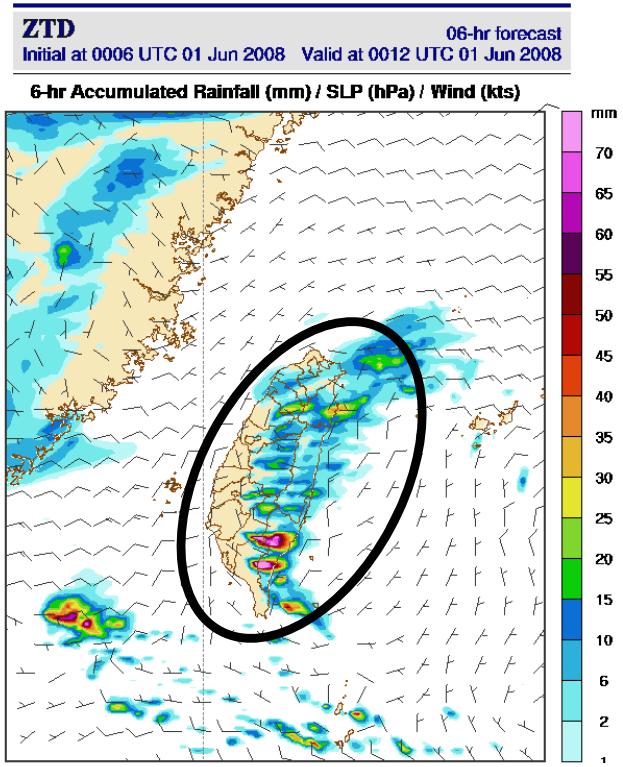

Accu. rainfall from 2008060218 to 2008060300
mm
70
65
60
55
50
45
40
35
30
25
20
15
10
6
2
1

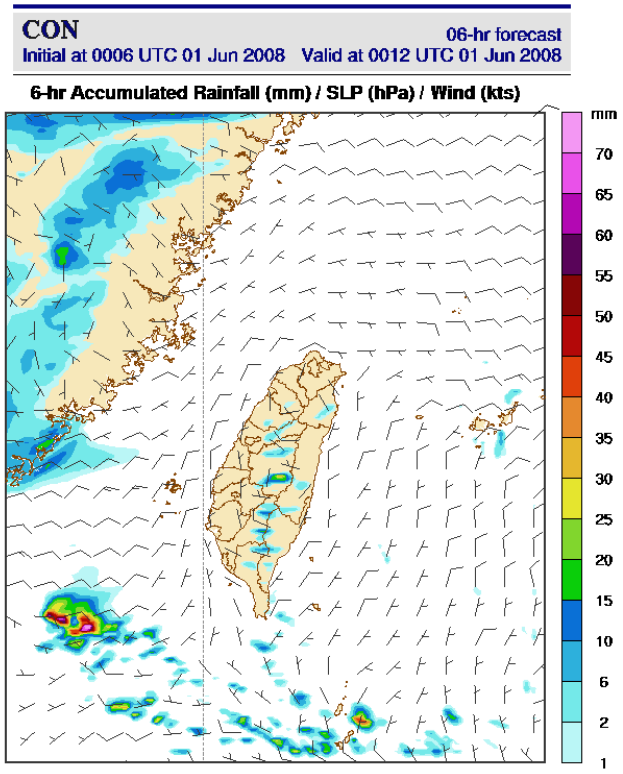

ZTD
06-hr forecast
Initial at 0018 UTC 02 Jun 2008 Valid at 0000 UTC 03 Jun 2008
6-hr Accumulated Rainfall (mm) / SLP (hPa) / Wind (kts)
mm
70
65
60
55
50
45
40
35
30
25
20
15
10
6
2
1

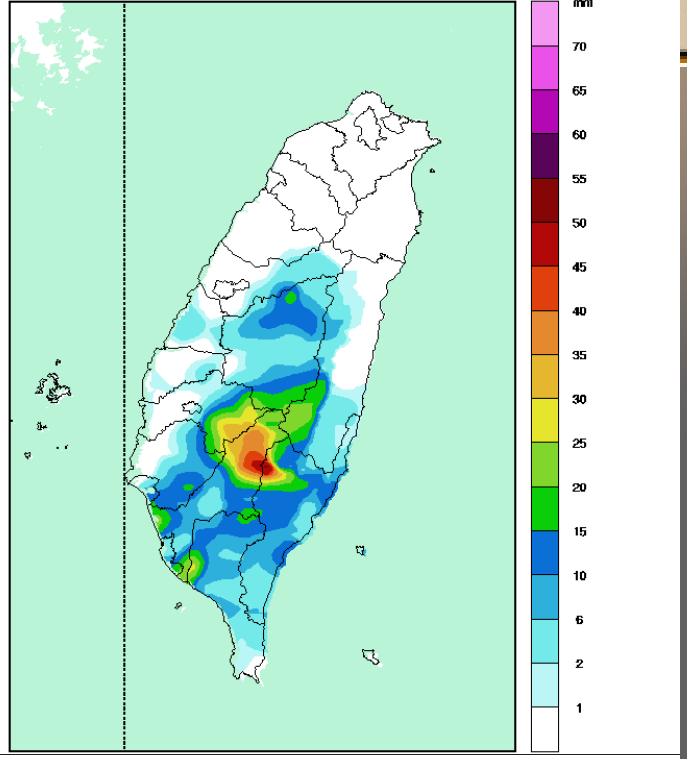

CON
06-hr forecast
Initial at 0018 UTC 02 Jun 2008 Valid at 0000 UTC 03 Jun 2008
6-hr Accumulated Rainfall (mm) / SLP (hPa) / Wind (kts)
mm
70
65
60
55
50
45
40
35
30
25
20
15
10
6
2
1


Accu. rainfall from 2008060106 to 2008060112
mm
70
65
60
55
50
45
40
35
30
25
20
15
10
6
2
1


ZTD impact at 08060106
g/Kg
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0

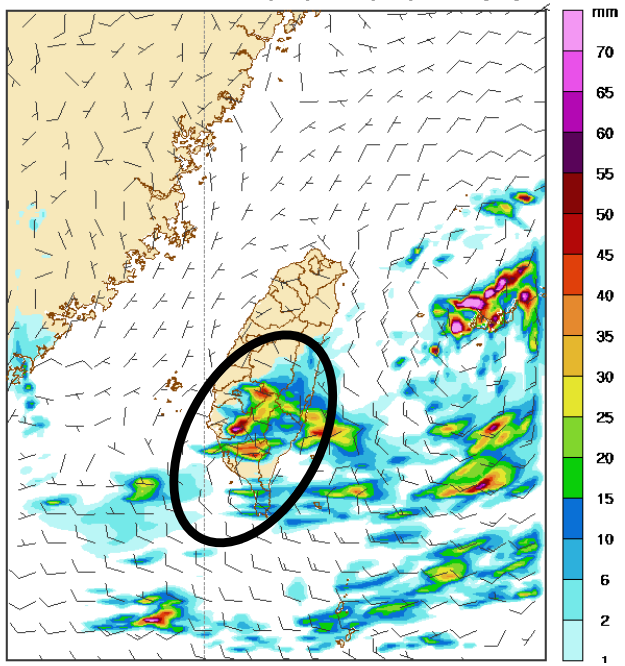

ZTD
06-hr forecast
Initial at 0006 UTC 01 Jun 2008 Valid at 0012 UTC 01 Jun 2008
6-hr Accumulated Rainfall (mm) / SLP (hPa) / Wind (kts)
mm
70
65
60
55
50
45
40
35
30
25
20
15
10
6
2
1


CON
06-hr forecast
Initial at 0006 UTC 01 Jun 2008 Valid at 0012 UTC 01 Jun 2008
6-hr Accumulated Rainfall (mm) / SLP (hPa) / Wind (kts)
mm
70
65
60
55
50
45
40
35
30
25
20
15
10
6
2
1

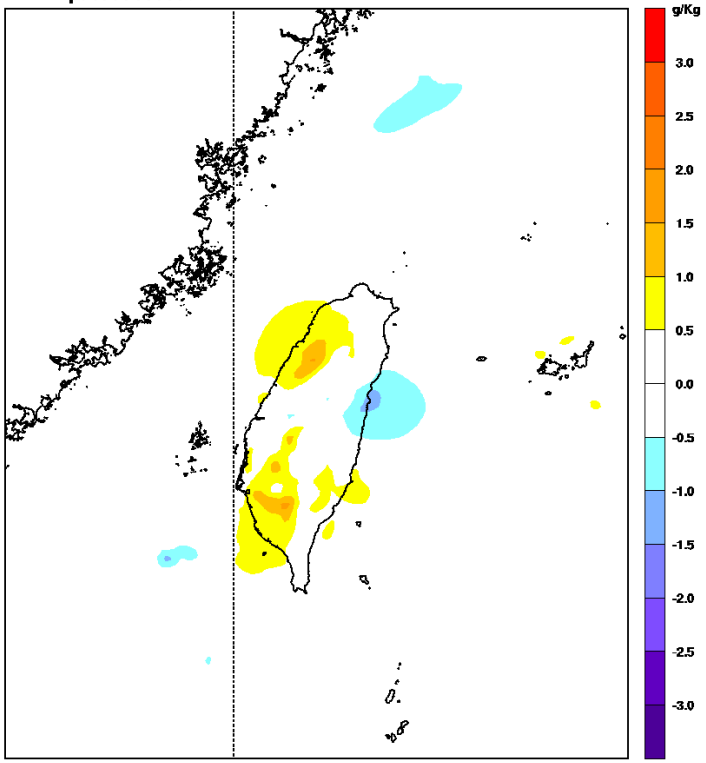


ZTD
Initial at 0012 UTC 03 Jun 2008 Valid at 0018 UTC 03 Jun 2008
06-hr forecast

6-hr Accumulated Rainfall (mm) / SLP (hPa) / Wind (kts)

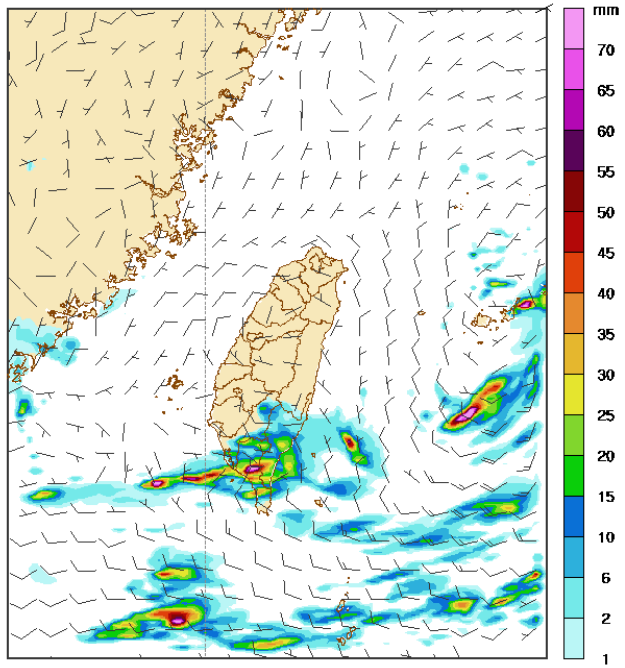


ZTD impact at 08060312



CON
Initial at 0012 UTC 03 Jun 2008 Valid at 0018 UTC 03 Jun 2008
06-hr forecast

6-hr Accumulated Rainfall (mm) / SLP (hPa) / Wind (kts)



Conclusion

- A realtime ground-base GPS process system has been established in CWB, provide the ZTD and PWV products in 2-hr frequency with 3.5-hr delay.
  - An hourly system with 0.5-hr delay is implementing
- Good match in between the GPS PWV and sounding derived PWV.
- Compared to the control run, assimilation of ground base GPS observations increase the moisture over Taiwan and then improve the QPF performance both in typhoon Kalmaegi and SoWMEX cases.
  - Most significant in the first 6-hr rainfall forecast
- Assimilation of ZTD performed better than that of PWV, probably due to the well control of the observation error for ZTD.