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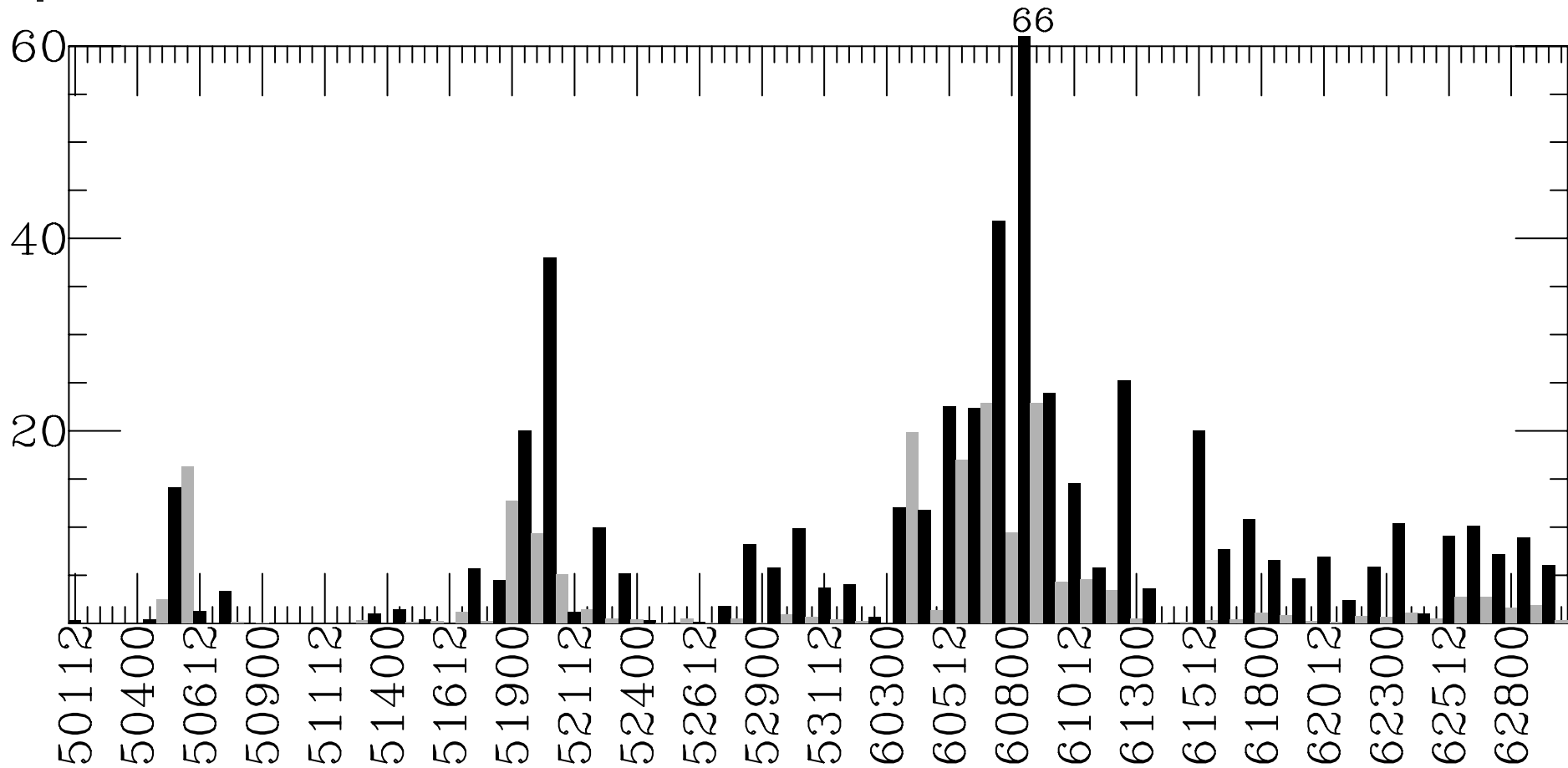
# An Impact Study of FORMOSAT-3/ COSMIC GPS Radio Occultation and Dropsonde Data on WRF Simulations

**2007 Mei-yu season**

Chien and Kuo (2009), GPS Solutions

**2008 Mei-yu season, SoWMEX**

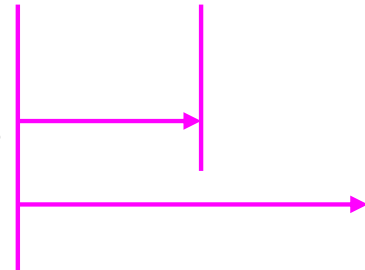
# 12-h rainfall average over Taiwan (May 1-June 30 2007)



Pre-SoWMEX

FORMOSAT-3/COSMIC GPS

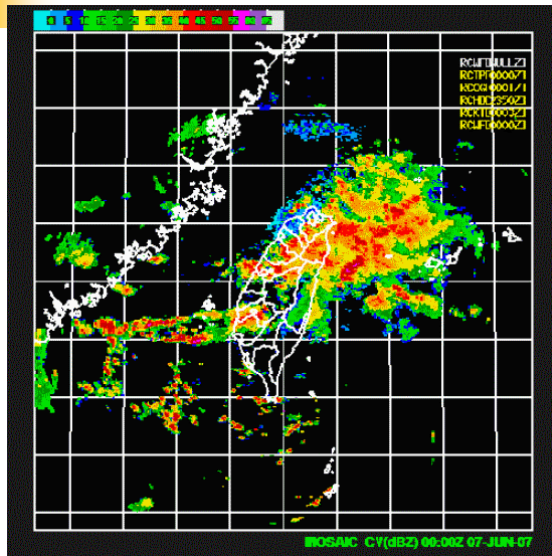
Dropsonde obs  
Simulation period



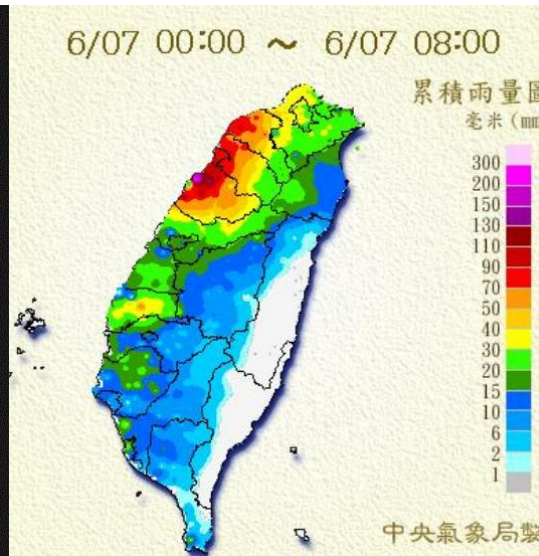


# Case Review

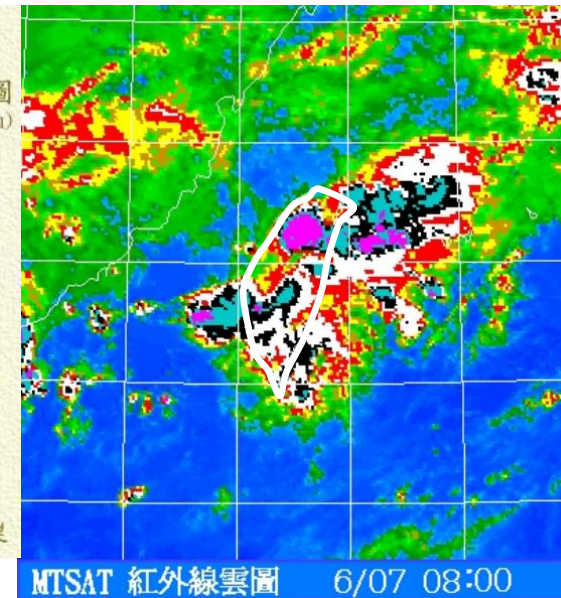
20070607 0000UTC



Radar

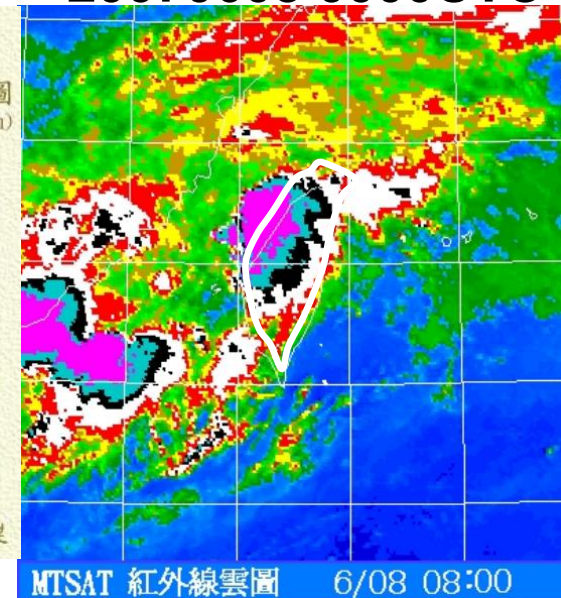
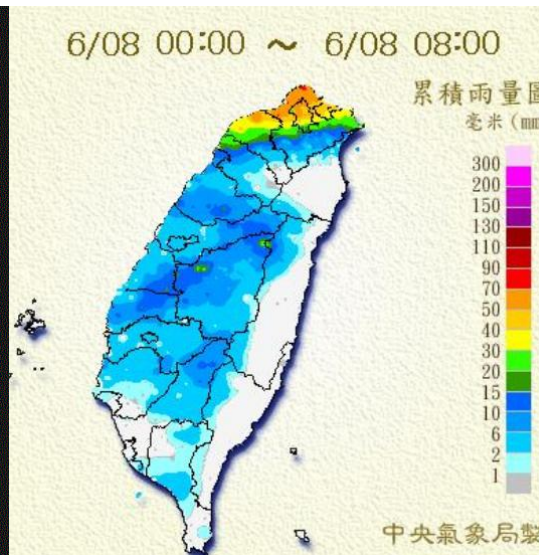
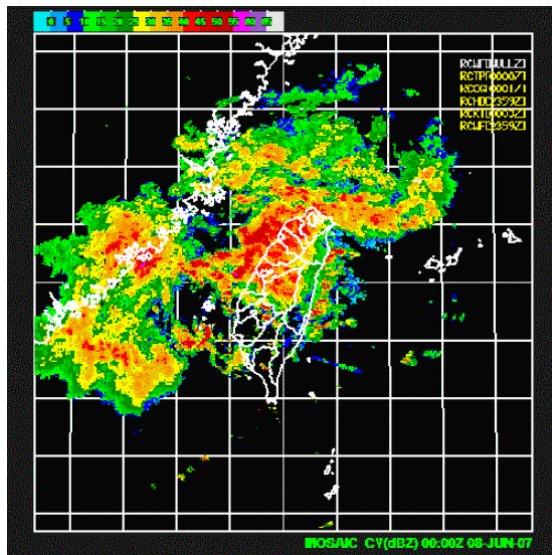


Accumulated rain

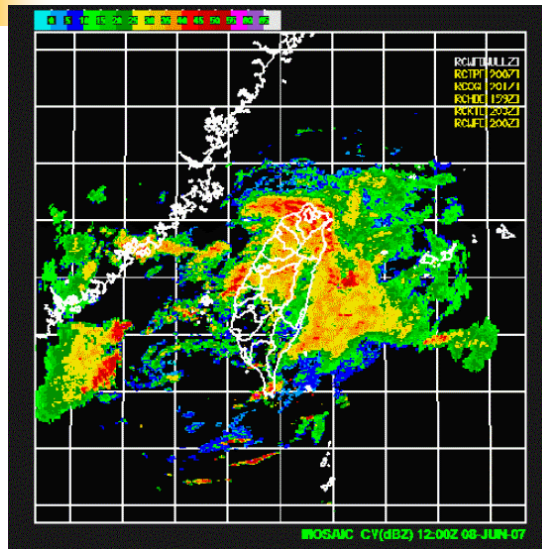


IR satellite picture

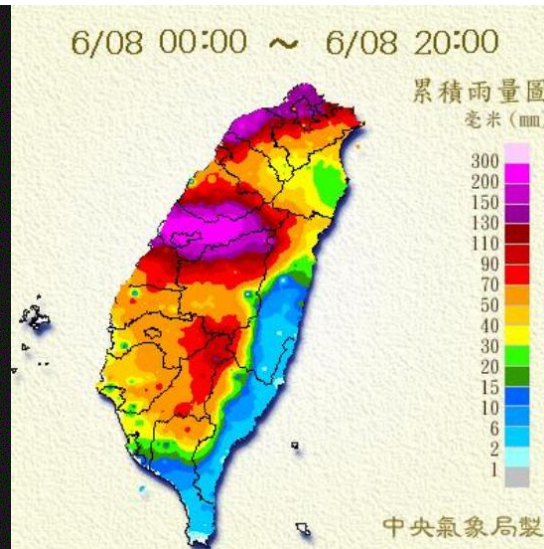
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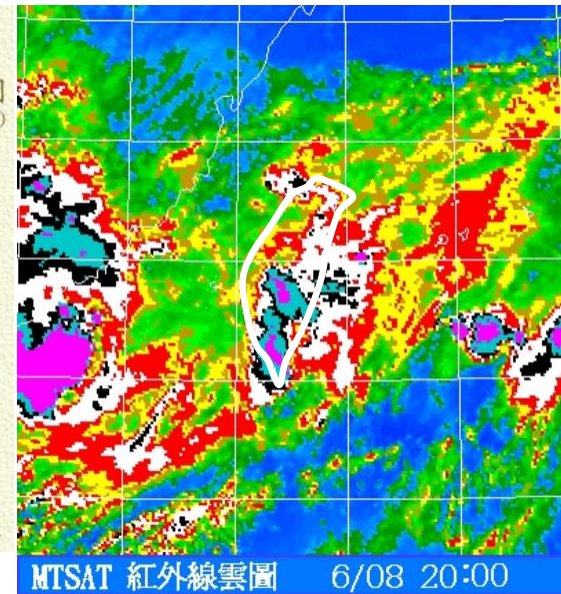
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Radar

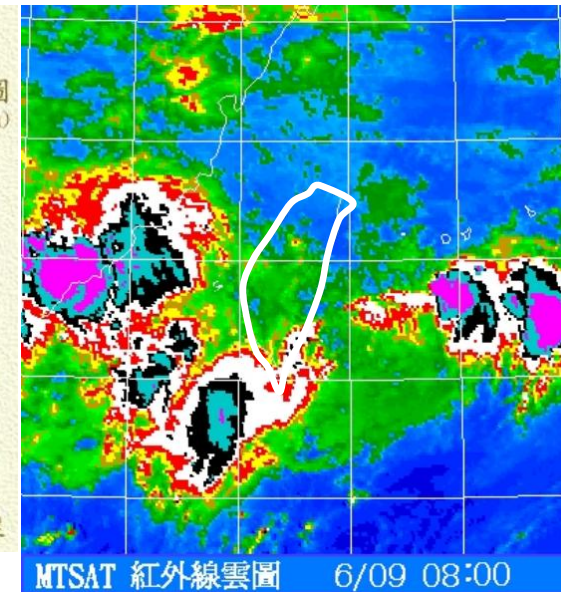
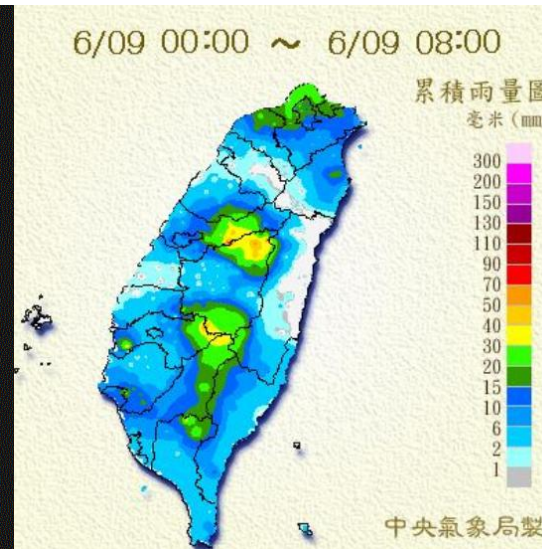
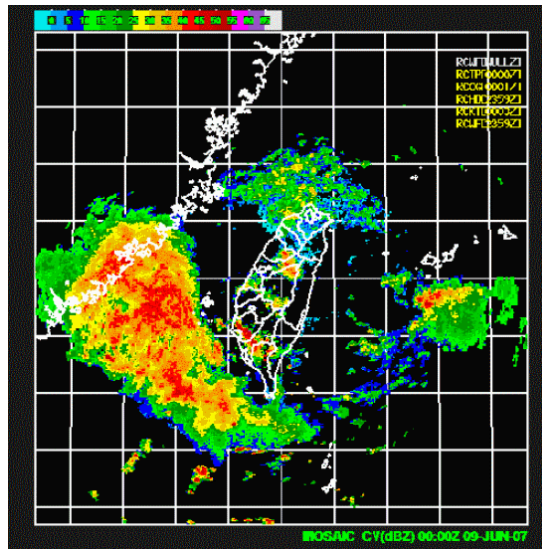


Accumulated rain



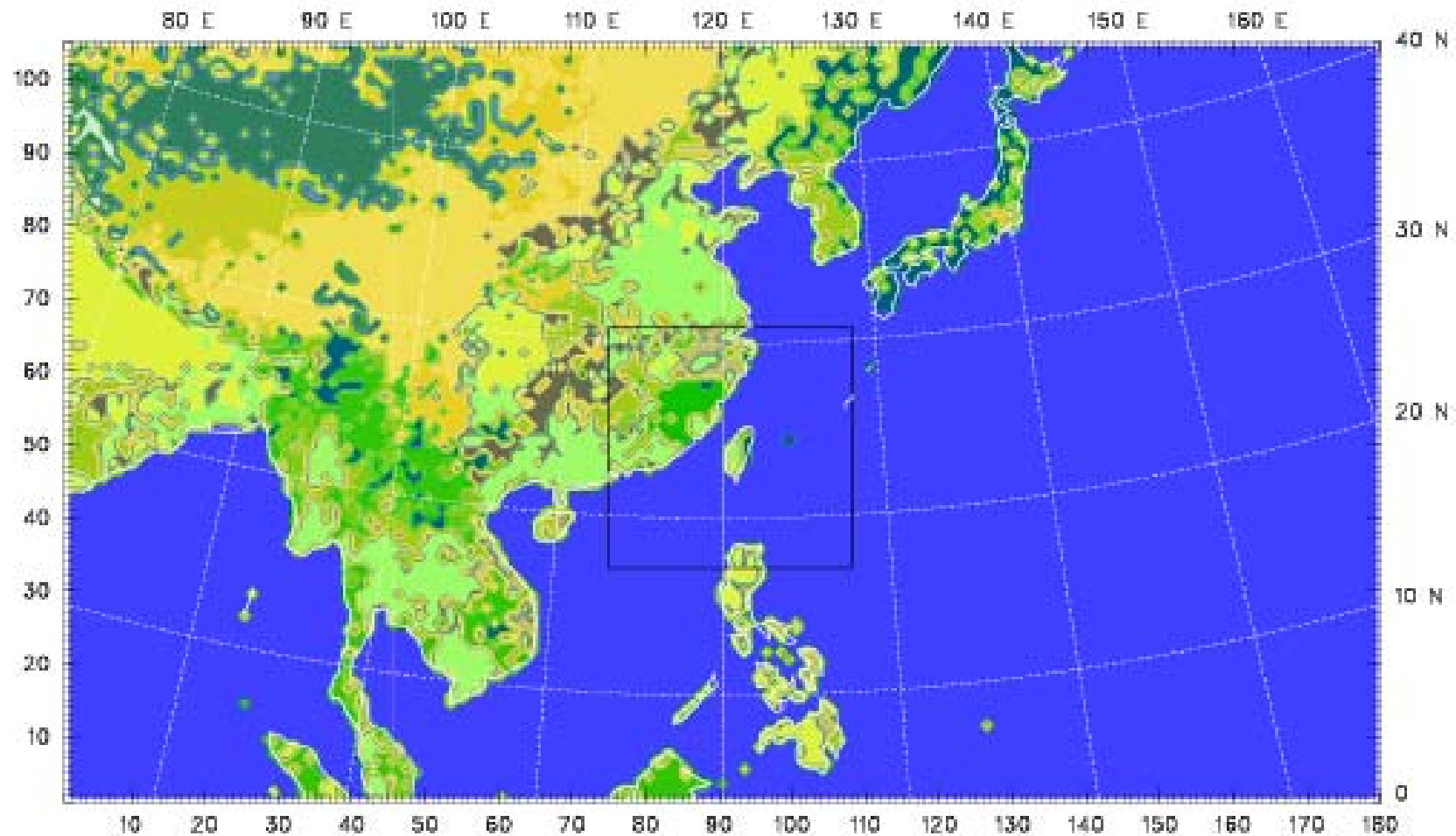
IR satellite picture

20070609 0000UTC



# WRF Domain settings

D1: 45 km; D2: 15 km





# WRF settings

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- Model settings for the control experiment (CON)
  - WRF V2.2: WSM 5-class microphysics, Kain-Fritsch cumulus parameterization scheme, and YSU PBL scheme
  - WRF Var v2.2 beta (surface obs and soundings)
  - Contains 22 runs of 72-h simulation that are initialized twice daily from 0000 UTC 5 June to 1200 UTC 15 June 2007.
  - The initial data of the first run at 0000 UTC 5 June 2007 are obtained from the NCEP GFS + WRF Var.
  - The initial data of the other 21 runs are obtained from the 12-h update cycle of the previous WRF run + WRF Var.
- The GPS experiment (GPS)
  - CON + GPS RO data assimilation
- The DRP experiment (DRP)
  - CON + dropsonde data assimilation
- The ALL experiment (ALL)
  - CON + GPS RO + dropsonde data assimilation

# Amounts of OBS used in WRF Var

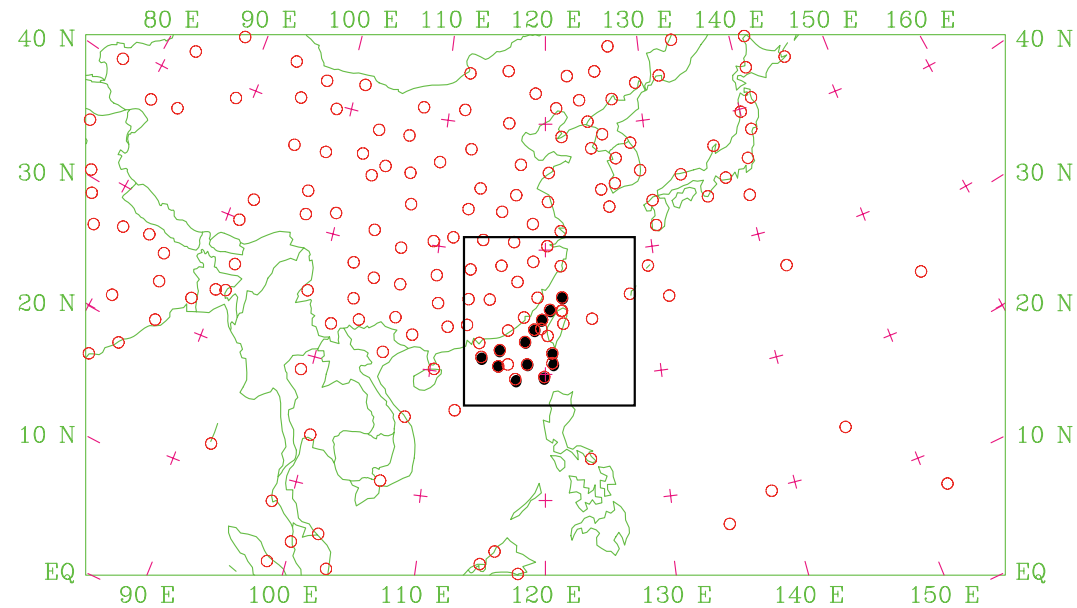
Init time ( dd/hh )	05/ 00	05/ 12	06/ 00	06/ 12	07/ 00	07/ 12	08/ 00	08/ 12	09/ 00	09/ 12	10/ 00	10/ 12
SYNOP	914	964	877	882	898	973	902	902	917	915	916	959
SOUND	155	140	155	141	153	140	153	138	151	141	152	140
GPS	9	17	10	20	5	14	10	28	15	20	11	24
Dropsonde	13	0	13	0	8	0	8	0	13	0	7	0
Init time ( dd/hh )	11/ 00	11/ 12	12/ 00	12/ 12	13/ 00	13/ 12	14/ 00	14/ 12	15/ 00	15/ 12		
SYNOP	904	908	899	914	898	900	891	900	892	927		
SOUND	152	132	152	138	155	139	151	136	153	135		
GPS	9	21	8	18	4	20	17	24	12	22		
Dropsonde	0	0	0	0	0	0	0	0	0	0		

**GPS RO:  $\Phi$ , T, and q**

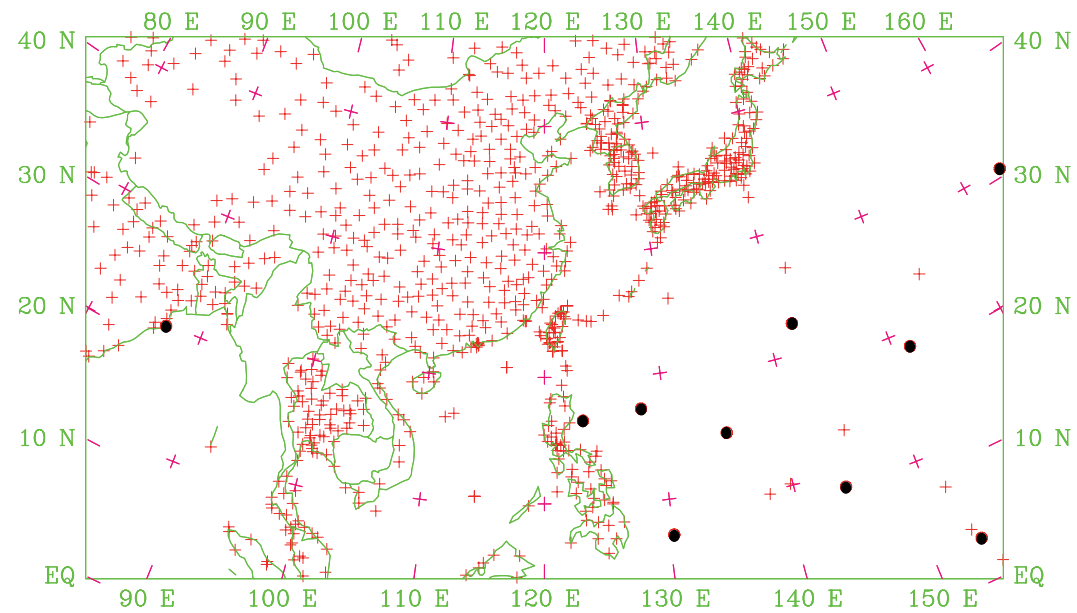
**Dropsonde:  $\Phi$ , T, q, and wind**



0000 UTC 2007.6.6



- Sounding
- Dropsondes



- + Synop
- GPS RO

# Verification on pressure levels

- Verification method:

- Root-mean-square error (RMSE)
- Mean error (ME)
- Correlation coefficient (CC)
- Skill score (SS)

$$SS = \frac{RMSE_{CON} - RMSE_{GPS}}{RMSE_{CON}} \times 100\%$$

- Averaged on (1) grid points of the 15-km domain against NCEP GFS analyses + WRF Var with sounding and surface obs, (2) traditional sounding stations inside the 15-km domain. Averaged for all the 22 runs of each experiment.

- Variables:

- H, T, RH, U, V

- Pressure levels:

- 850 hPa, 500 hPa, 300 hPa

- Times:

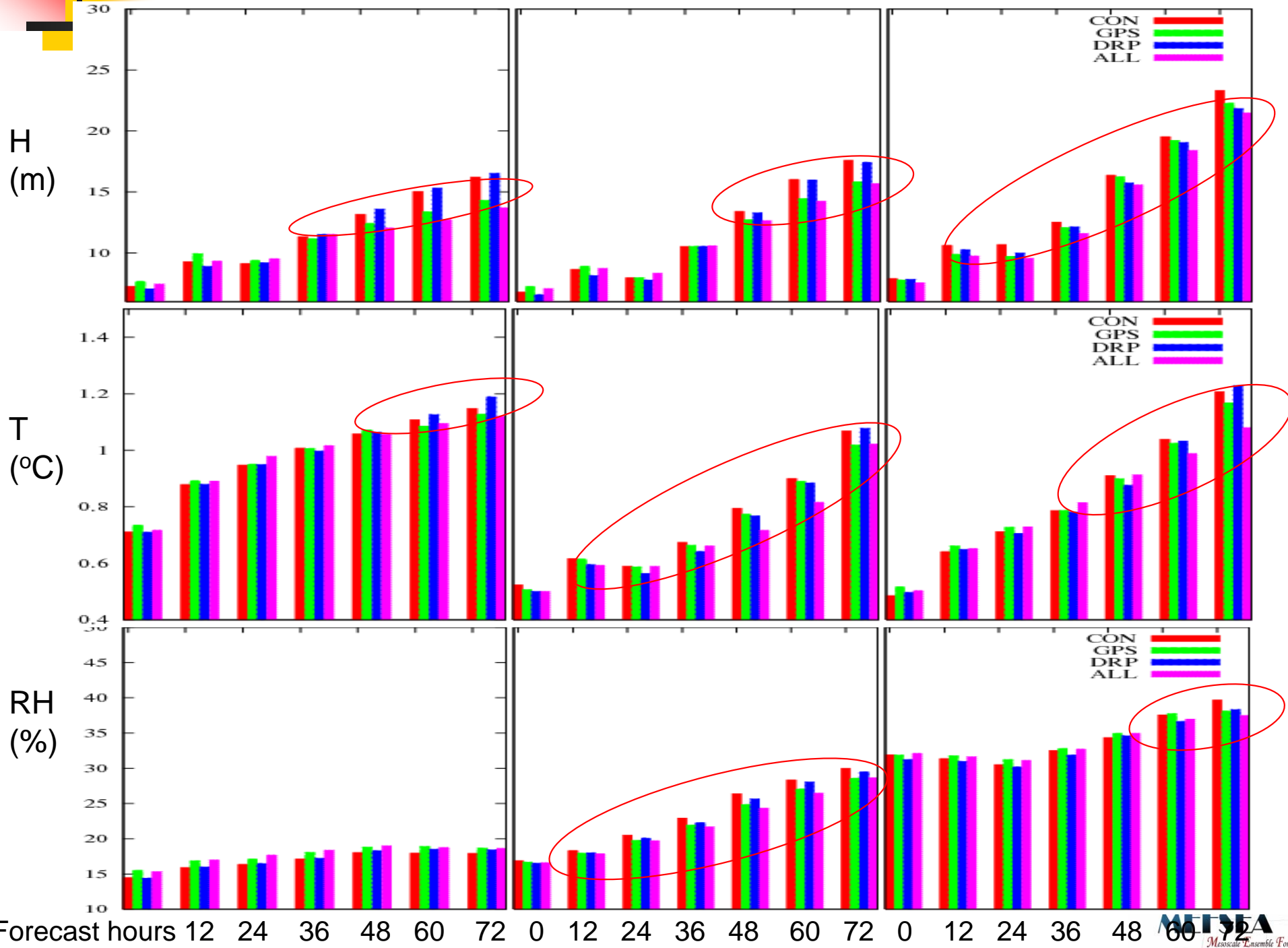
- 0, 12, 24, 36, 48, 60, 72 h

# RMSE averaged on grid points of D2

850hPa

500hPa

300hPa



# RMSE

850hPa

500hPa

300hPa

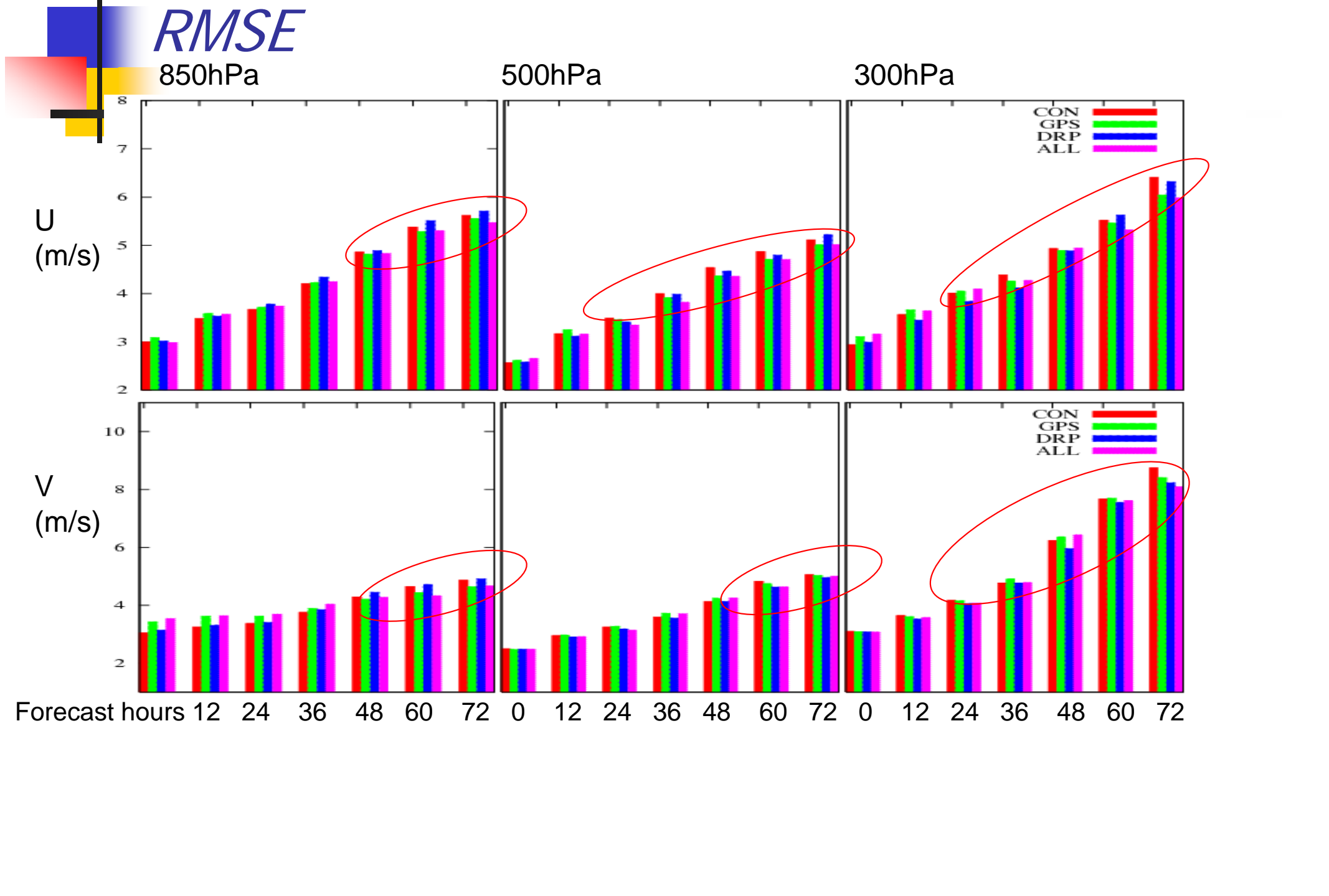
U  
(m/s)

V  
(m/s)

CON  
GPS  
DRP  
ALL

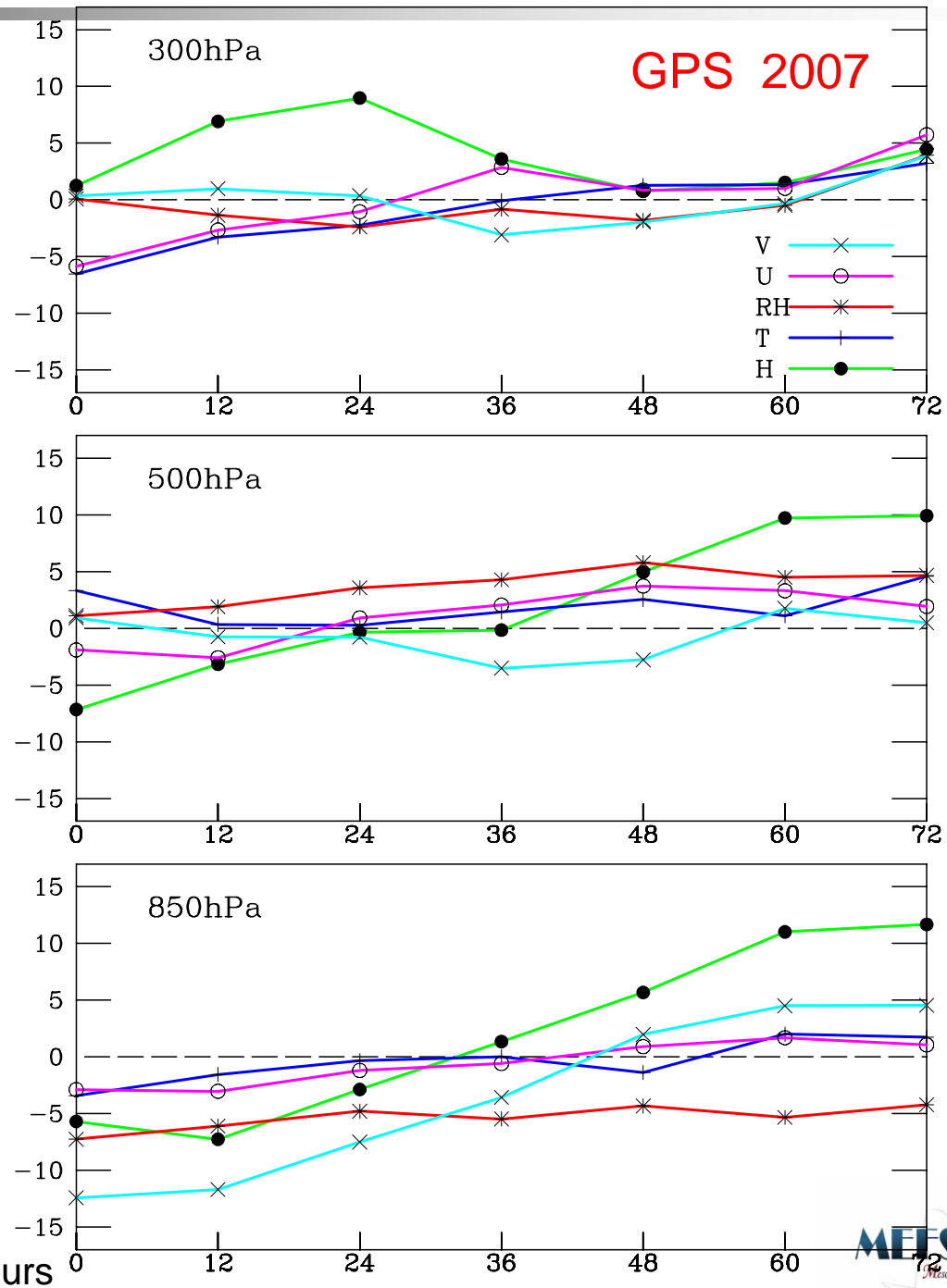
CON  
GPS  
DRP  
ALL

Forecast hours 12 24 36 48 60 72 0 12 24 36 48 60 72 0 12 24 36 48 60 72



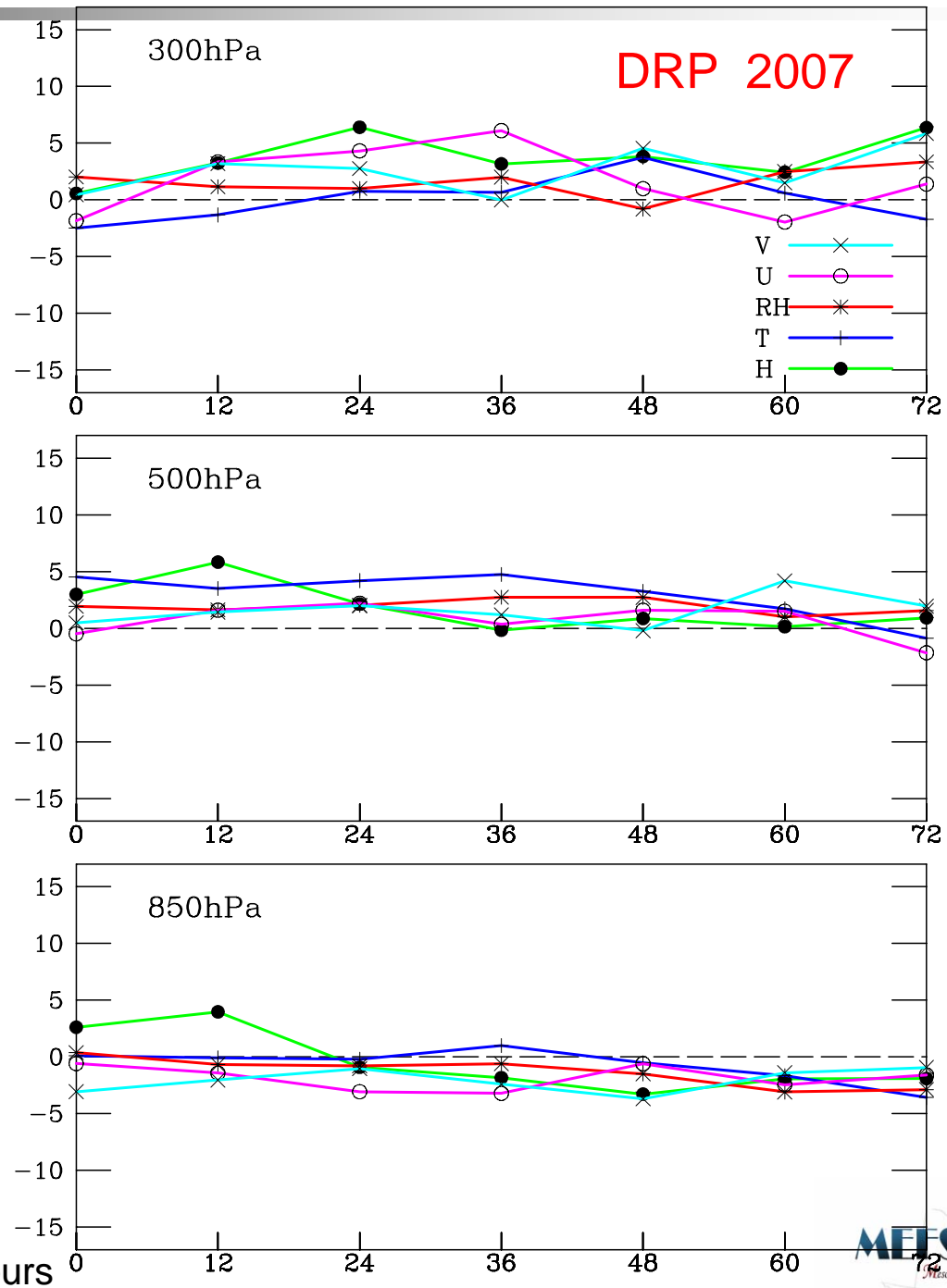
# Skill Score of GPS against CON

$$SS = \frac{RMSE_{CON} - RMSE_{GPS}}{RMSE_{CON}} \times 100\%$$

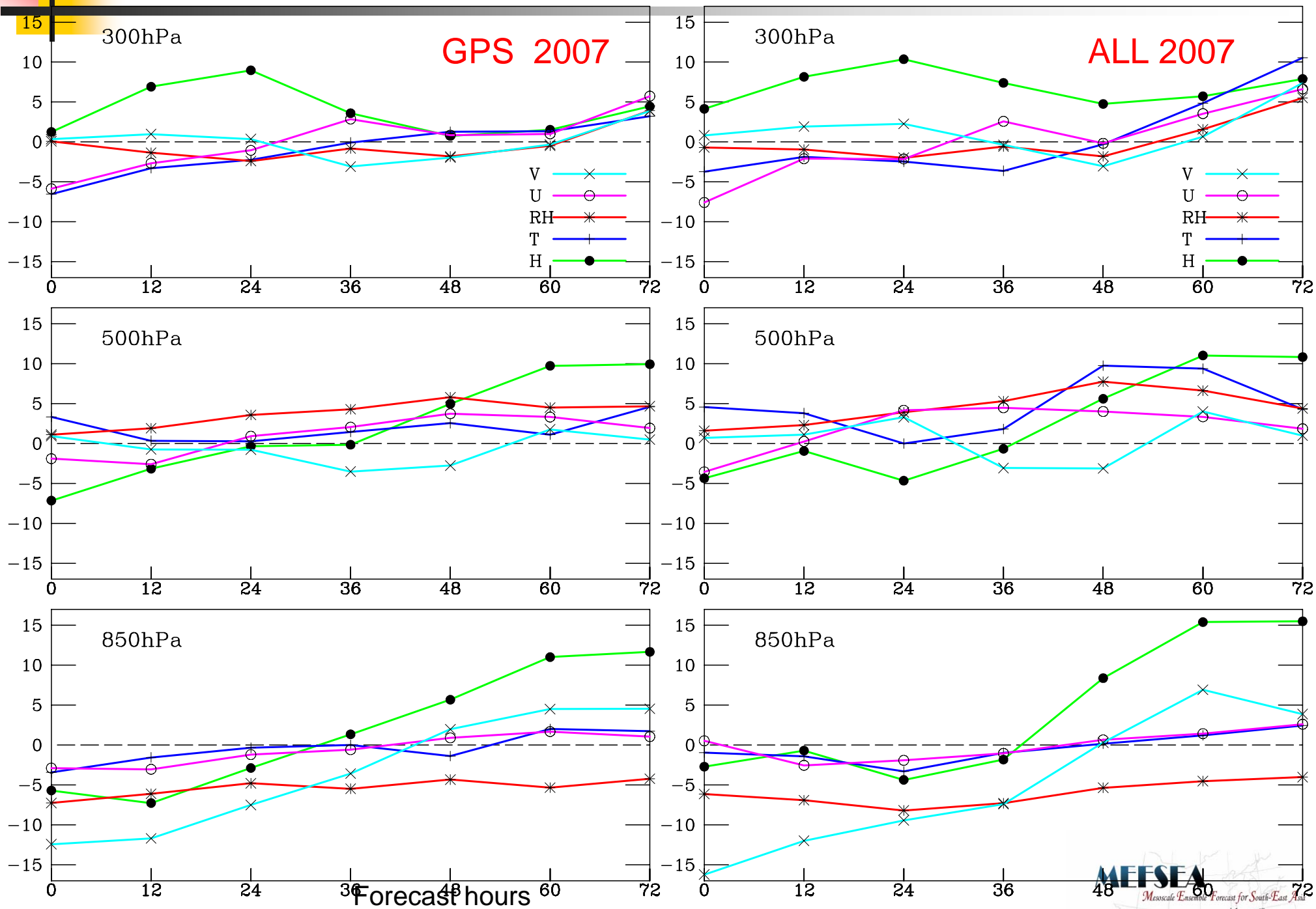


# Skill Score of DRP against CON

$$SS = \frac{RMSE_{CON} - RMSE_{DRP}}{RMSE_{CON}} \times 100\%$$

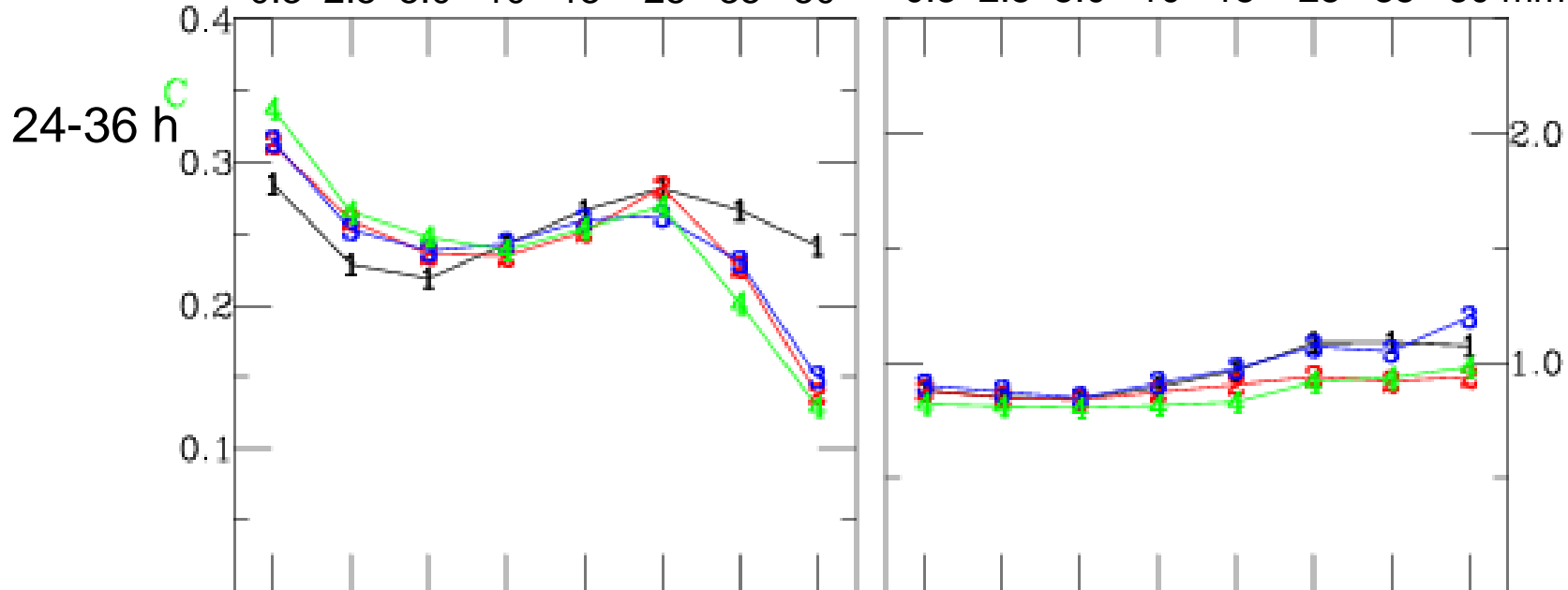
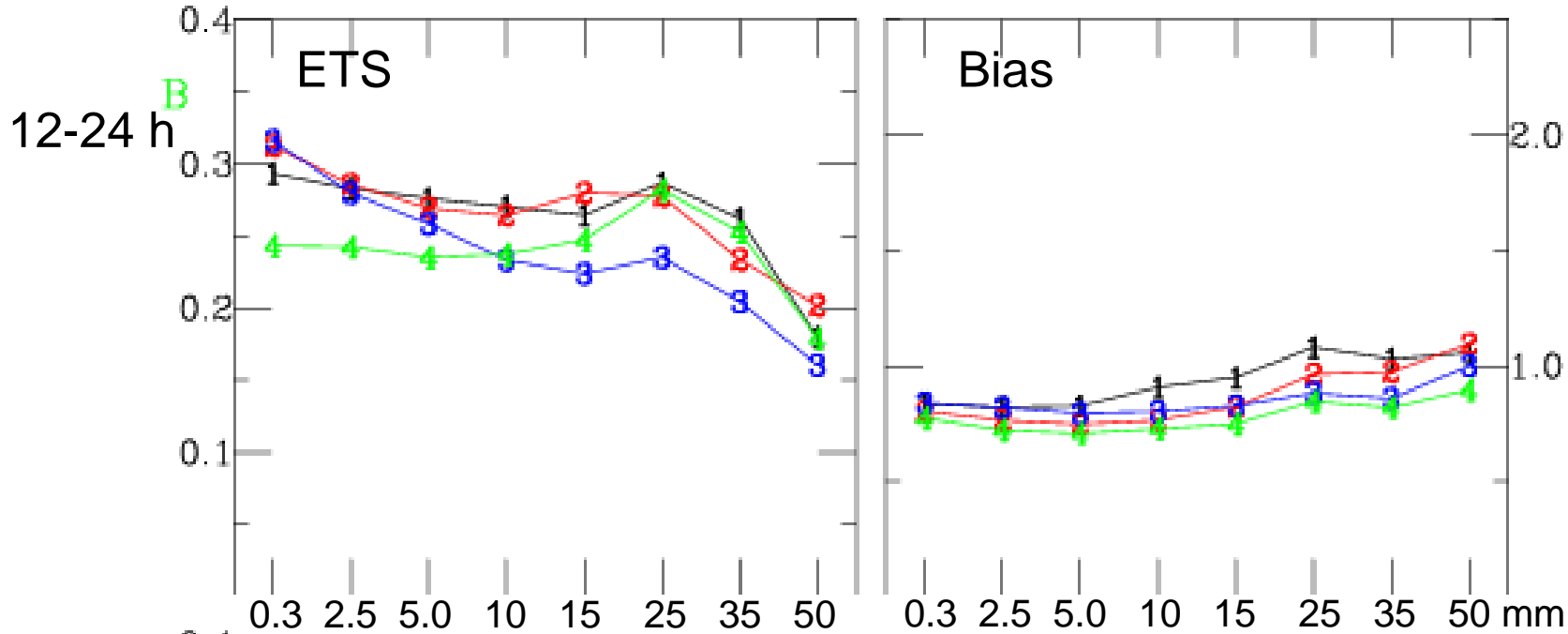


# Skill Score of ALL against CON



# ETS and bias, verified against rain gauges

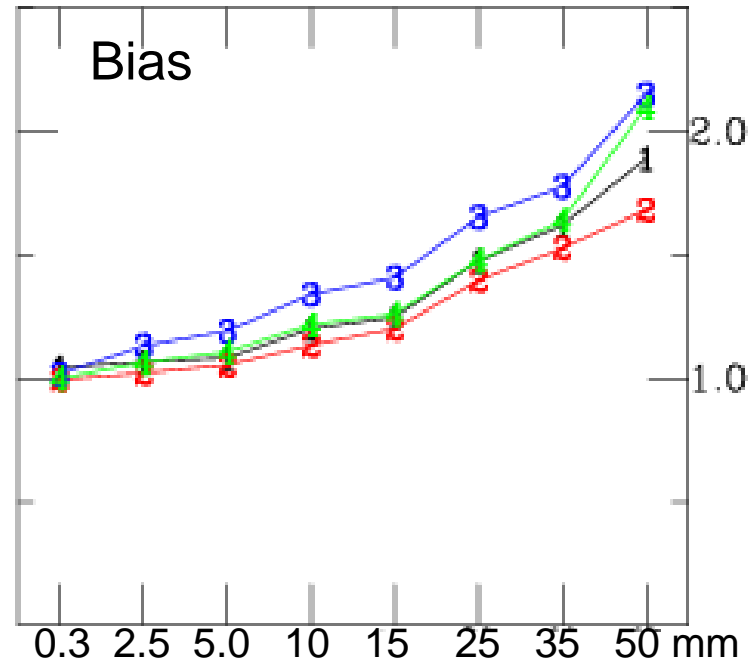
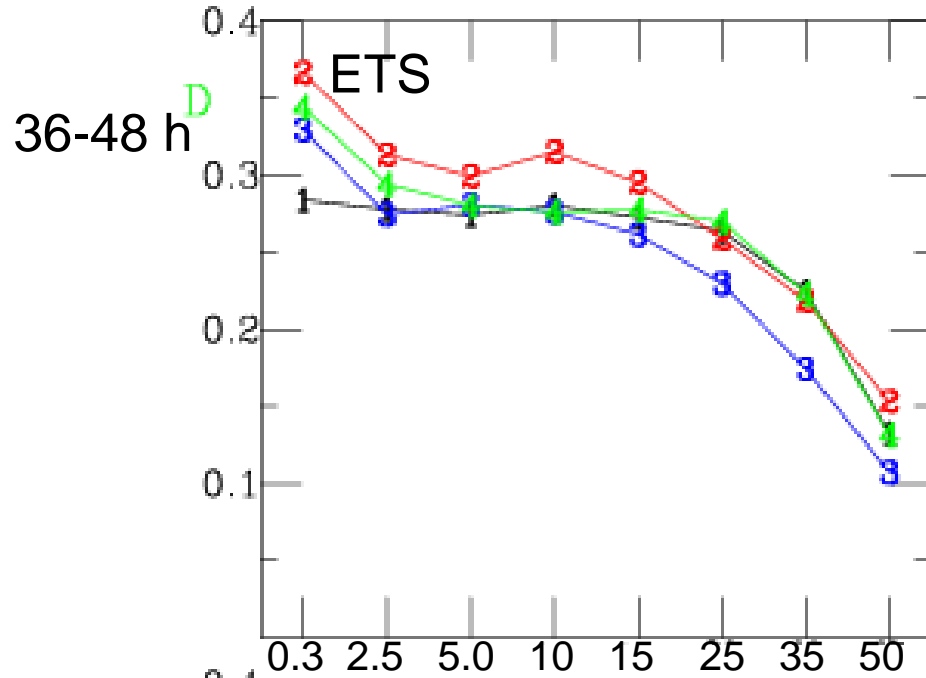
12-h accumulated rainfall



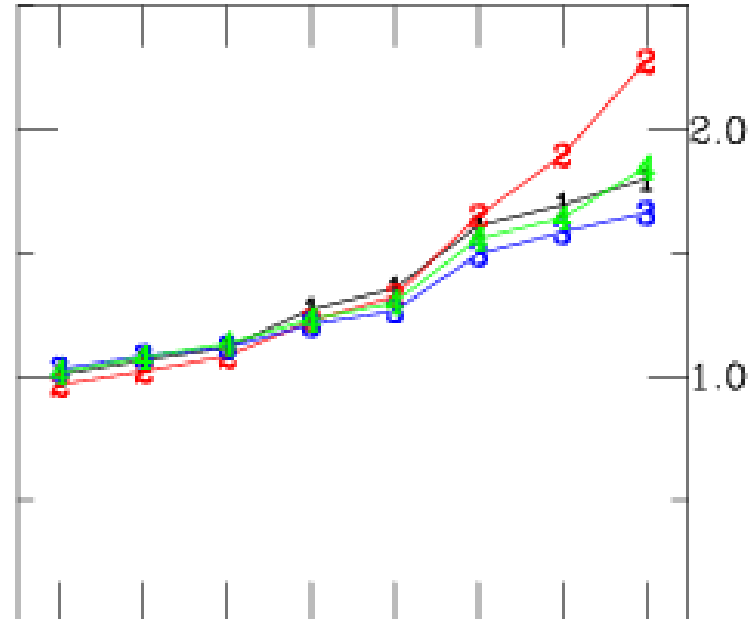
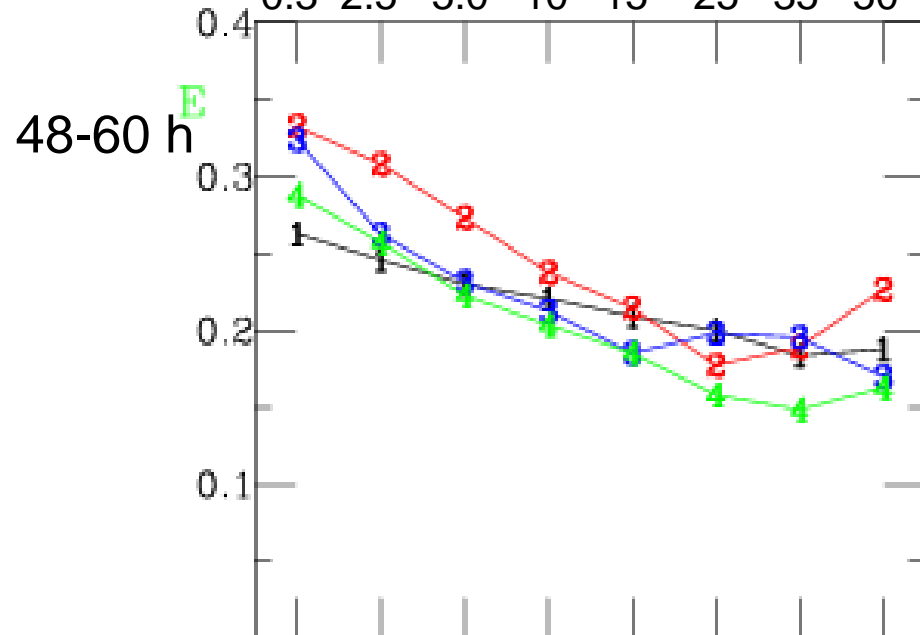


# ETS and bias, verified against rain gauges

12-h accumulated rainfall

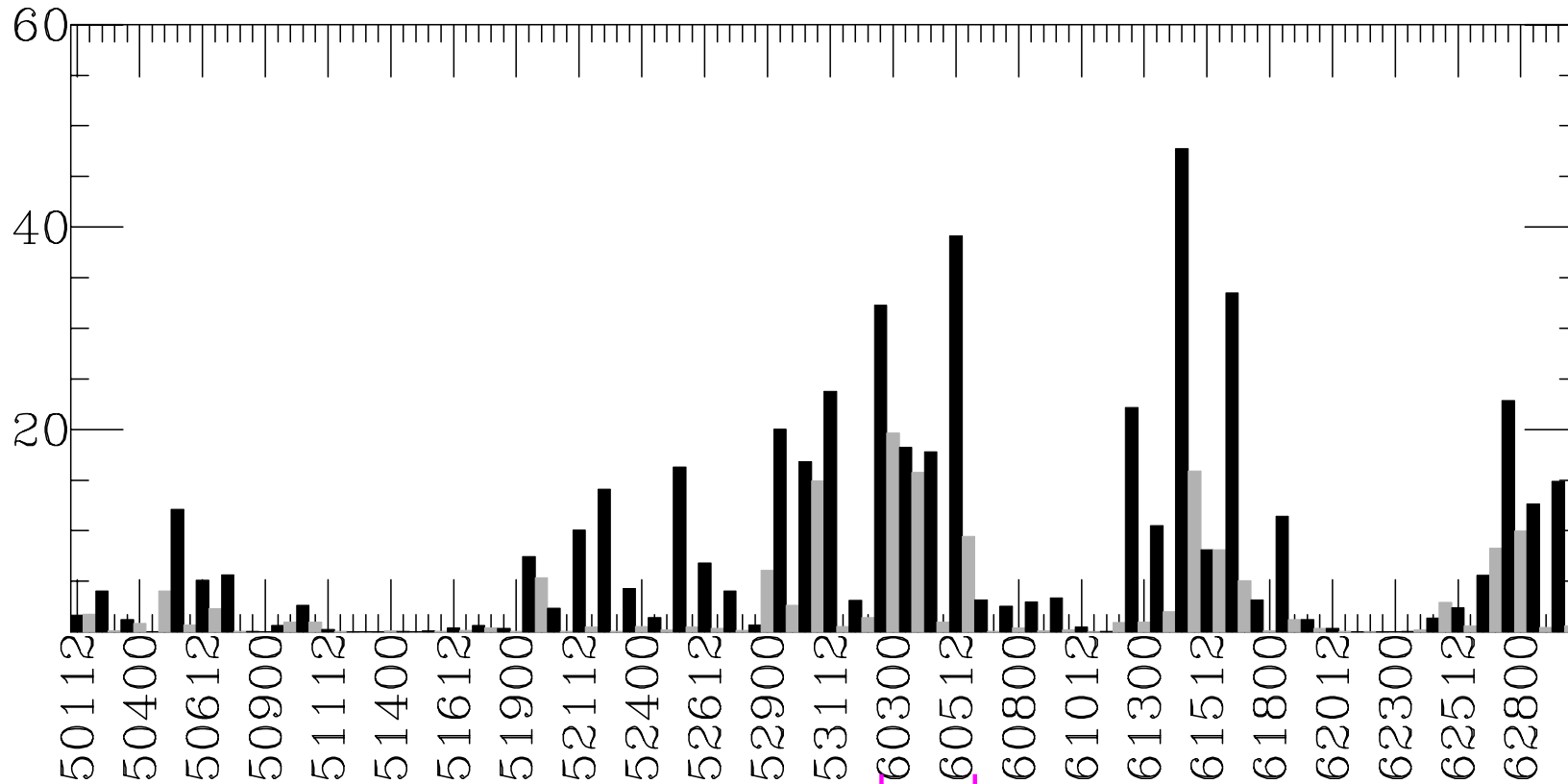


1:CON  
2:GPS  
3:DRP  
4:ALL



# ■ 2008060312 UTC – 2008061400 UTC

The 12-h accumulated rainfall observation in Taiwan(May 1-June 30 2008)



Dropsonde obs  
Simulation period

Black: (0000UTC-1200UTC)

Gray: (1200UTC-0000UTC)

# Data amounts used in WRF Var (6-h)

<b>Init time ( dd/hh )</b>	<b>6/3 12</b>	<b>6/3 18</b>	<b>6/4 00</b>	<b>6/4 06</b>	<b>6/4 12</b>	<b>6/4 18</b>	<b>6/5 00</b>	<b>6/5 06</b>	<b>6/5 12</b>	<b>6/5 18</b>	<b>6/6 00</b>	<b>6/6 06</b>
SYNOP	955	906	954	935	966	911	971	972	967	861	958	961
SOUND	135	3	146	4	134	3	145	4	136	4	149	4
<b>GPS</b>	<b>11</b>	<b>13</b>	<b>9</b>	<b>16</b>	<b>15</b>	<b>24</b>	<b>23</b>	<b>32</b>	<b>12</b>	<b>23</b>	<b>25</b>	<b>28</b>
<b>Dropsonde</b>	<b>12</b>	<b>0</b>	<b>16</b>	<b>8</b>	<b>0</b>	<b>0</b>	<b>15</b>	<b>10</b>	<b>0</b>	<b>0</b>	<b>11</b>	<b>0</b>
<b>Init time ( dd/hh )</b>	<b>6/6 12</b>	<b>6/6 18</b>	<b>6/7 00</b>	<b>6/7 06</b>	<b>6/7 12</b>	<b>6/7 18</b>	<b>6/8 00</b>	<b>6/8 06</b>	<b>6/8 12</b>	<b>6/8 18</b>	<b>6/9 00</b>	<b>6/9 06</b>
SYNOP	964	908	966	968	961	919	965	931	943	884	948	950
SOUND	137	5	146	4	139	4	149	4	135	4	150	4
<b>GPS</b>	<b>16</b>	<b>9</b>	<b>12</b>	<b>24</b>	<b>23</b>	<b>20</b>	<b>12</b>	<b>17</b>	<b>18</b>	<b>29</b>	<b>16</b>	<b>17</b>
<b>Dropsonde</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>

**GPS RO:  $\Phi$ , T, and q**

**Dropsonde:  $\Phi$ , T, q, and wind**

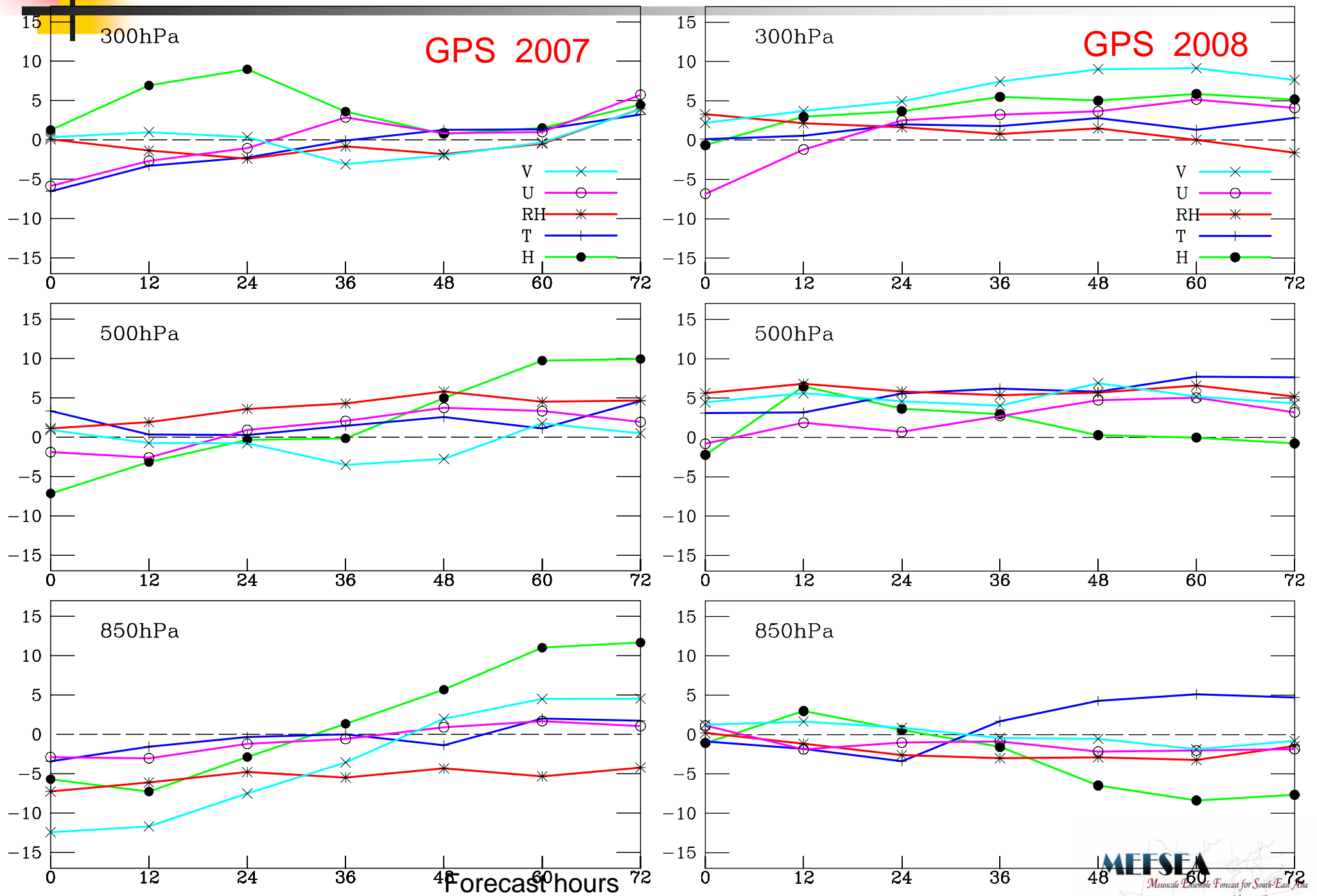
# Data amounts used in WRF Var

Init time (dd/hh)	6/9 12	6/9 18	6/10 00	6/10 06	6/10 12	6/10 18	6/11 00	6/11 06	6/11 12	6/11 18	6/12 00	6/12 06
SYNOP	943	905	968	974	968	911	963	975	968	918	960	957
SOUND	138	4	153	5	140	4	152	3	139	4	151	4
GPS	29	23	10	27	17	23	18	25	26	18	29	21
Dropsonde	0	0	0	0	0	0	0	0	0	0	0	0
Init time (dd/hh)	6/12 12	6/12 18	6/13 00	6/13 06	6/13 12	6/13 18	6/14 00					
SYNOP	973	906	980	970	963	916	953					
SOUND	142	4	155	4	140	4	154					
GPS	24	18	23	12	24	4	15					
Dropsonde	0	0	0	0	0	0	0					

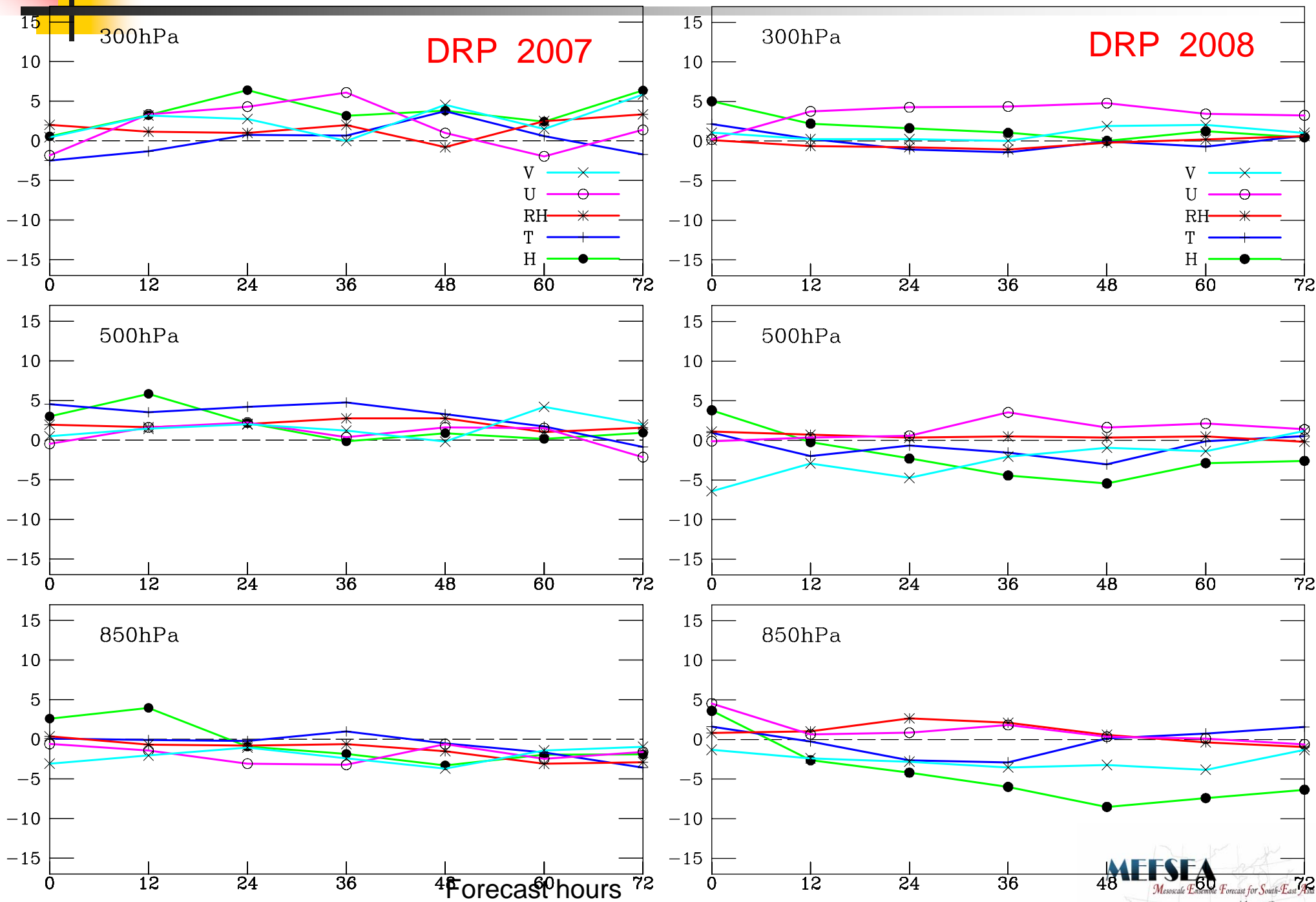
**GPS RO:  $\Phi$ , T, and q**

**Dropsonde:  $\Phi$ , T, q, and wind**

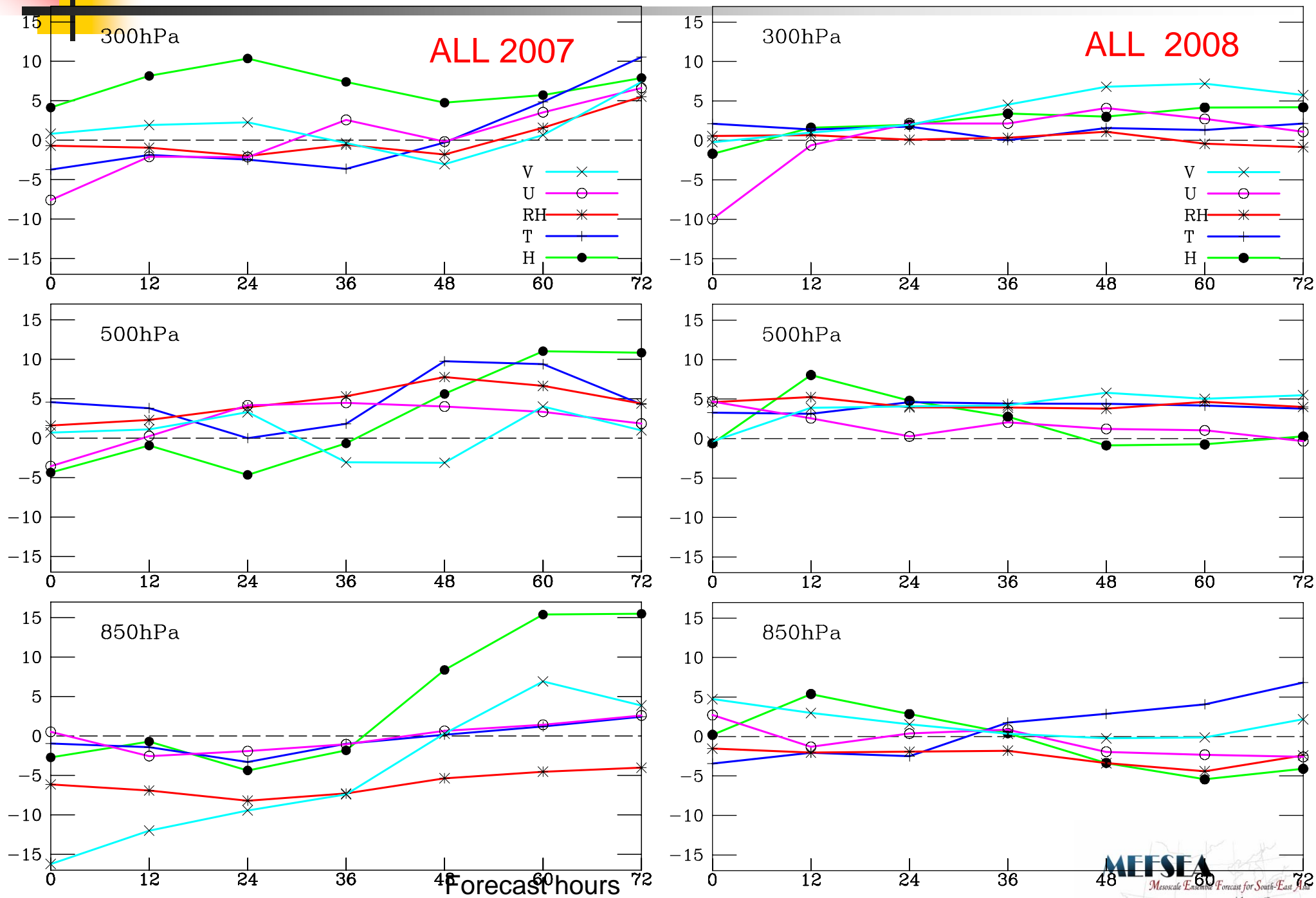
# Skill Score of GPS against CON



# Skill Score of DRP against CON

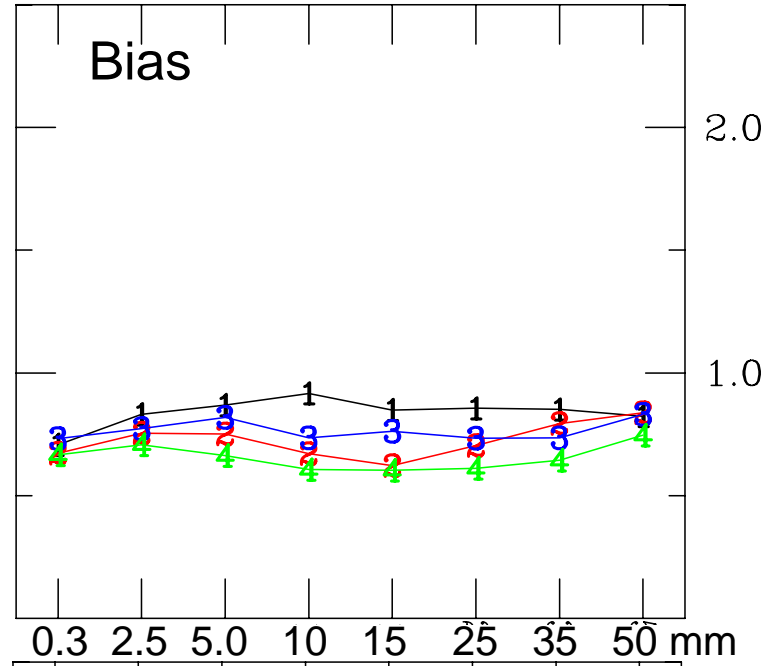
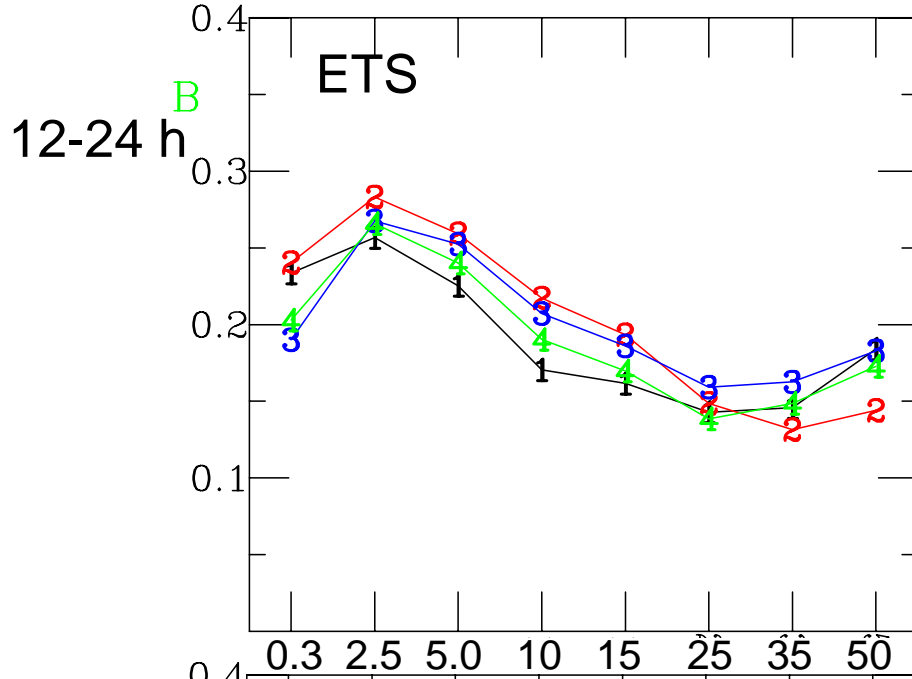


# Skill Score of ALL against CON

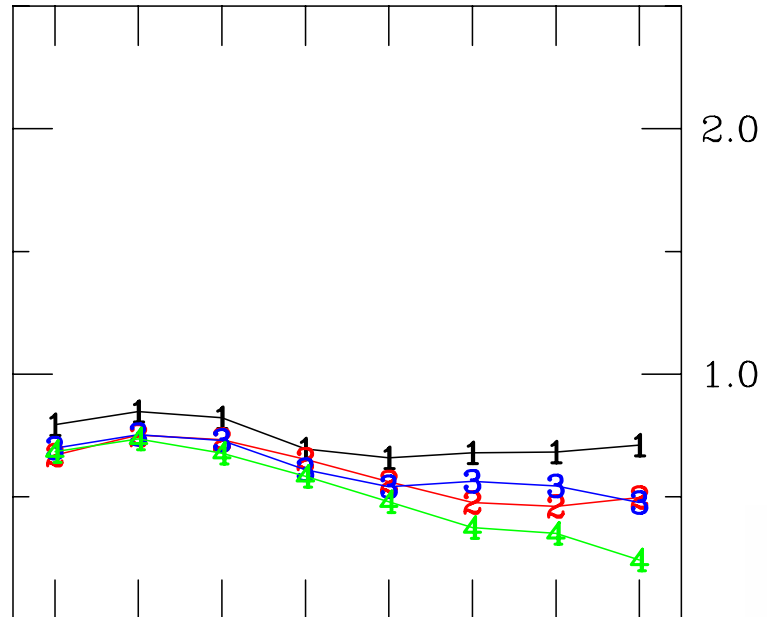
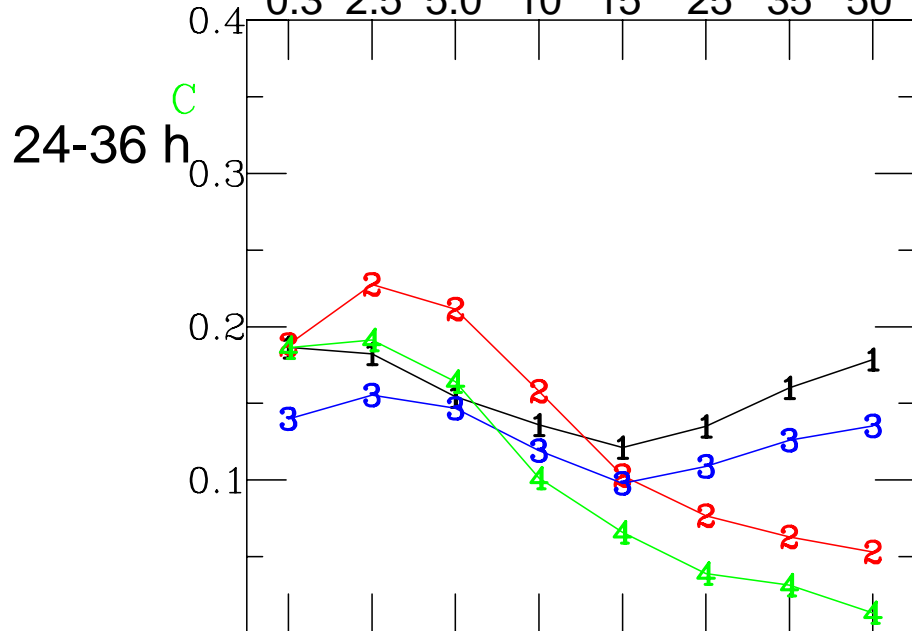


# ETS and bias, verified against rain gauges

12-h accumulated rainfall



- 1: CON
- 2: GPS
- 3: DRP
- 4: ALL





# Conclusions

- 2007 (12-h update cycle):
  - The assimilation of the GPS data can help to improve the simulation for longer integration. The dropsonde data has smaller positive impact than the GPS data, and the impact decreases over time.
  - There are few GPS RO observations in the fine domain. The large-scale simulation is first improved using the GPS RO observations, and the resulting changes can have a positive impact on the mesoscale at the later time. The dropwindsonde observations were taken inside the fine domain such that their impact can be detected early in the simulation.
  - With both the GPS and the dropsonde data assimilated together, the simulation shows even greater improvement.
  - At early time, there is no impact of GPS and dropsonde data on rainfall forecasts. However, when the integration time getting longer, the GPS and dropsonde data start to help the rainfall simulation.
- 2008 (6-h update cycle):
  - A positive impact of GPS and dropsonde data is still found, but the influence of individual variable is slightly different to that of 2007. More investigation is needed.