Assimilation of Ground-based GNSS data in KMA Local area model

Numerical data application division, KMA

Eunhee Lee

KMA
Korea Meteorological Administration

Observation Operator

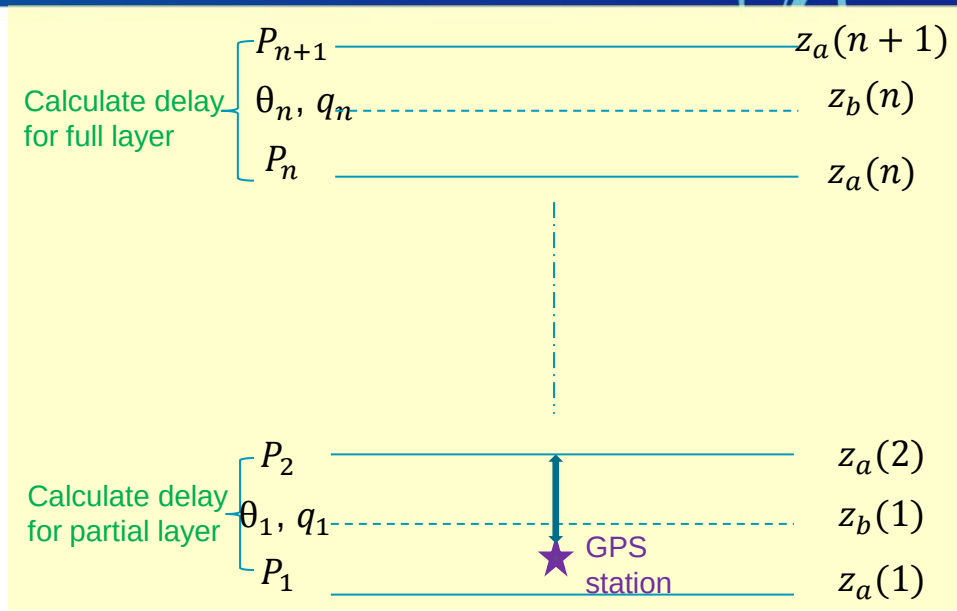
❖ *ZTD(Zenith Total Delay)*

$$ZTD = 10^{-6} \int_{z=0}^{z=\infty} N dz$$

$$= ZHD + ZWD$$

$$N(refractivity) = \frac{ap}{T} + \frac{be}{T^2}$$

(T: temp. e: water vapour press. a,b:constant)



Θ level *i layer* (θ_i): $N_i = \frac{ap_{\theta_i}}{T} + \frac{bp_{\theta_i} q_{\theta_i}}{T^2(\varepsilon+(1-\varepsilon)q_{\theta_i})}$

$ZenithDelay_i = 10^{-6} N_i (z_{a_{i+1}} - z_{a_i})$ *! Refractivity is constant between model layer (old)*

$= 10^{-6} \int_{Z_{b_i}}^{Z_{b_{i+1}}} N_i \exp(-c(z - z_{b_i}))dz$ *! Refractivity exponential decay with height(new)*

$= 10^{-6} \frac{N_i}{c} exp(cz_{b_i})\left(exp(-cz_{b_{i+1}}) - exp(-cz_{b_i})\right)$ *! Full layer*

$= 10^{-6} \frac{N_i}{c} exp(cz_{b_i})\left(exp(-cz_{b_{i+1}}) - exp(-cz_{station})\right)$ *! Partial layer(station)*

Model top : $ZenithDelay_i = 10^{-6} \frac{N_i}{c} exp(cz_{b_i})\left(exp(-cz_{a_{i+1}}) - exp(-cz_{b_i})\right)$

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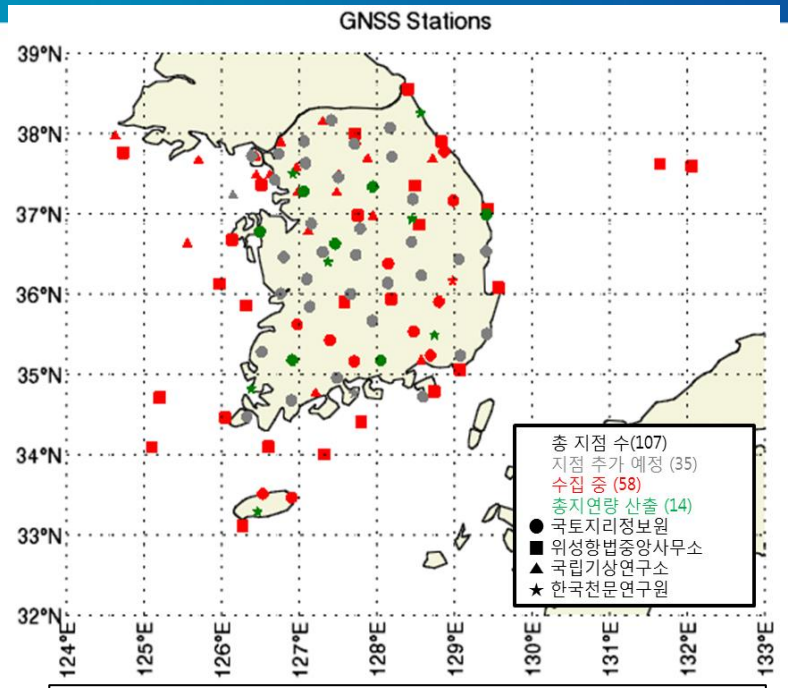
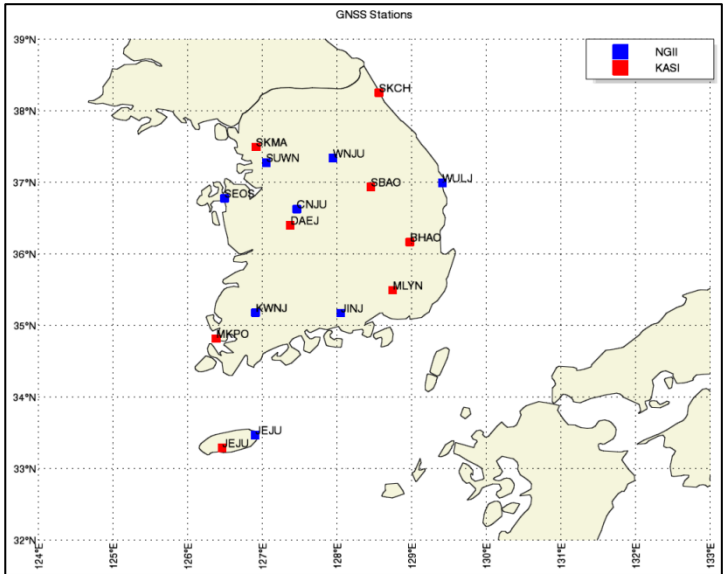
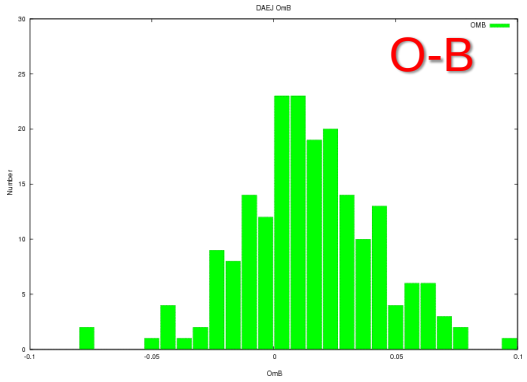
Status in 2015

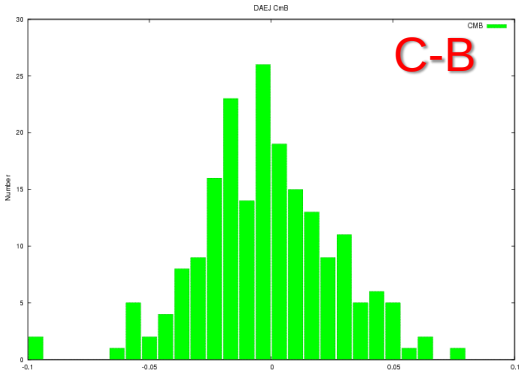


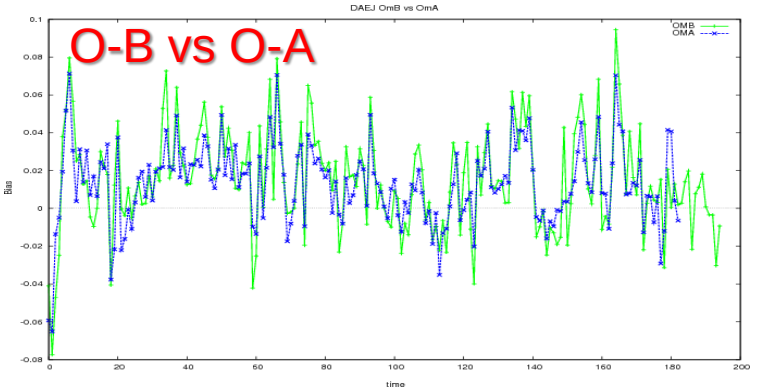


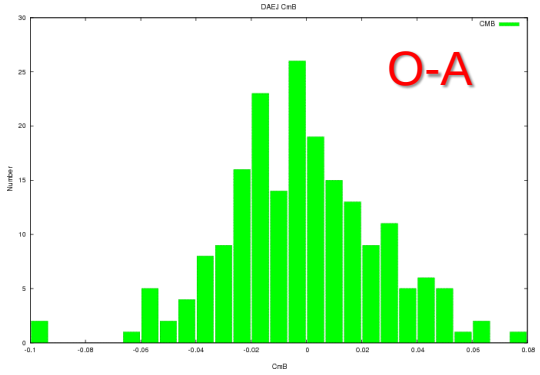
No	Agency	Station	Latitude	Longitude	지점	Country
1	NGII	CNJU	36.62689456	127.4612271	청주	Korea
2	NGII	JEJU	33.46780458	126.9047134	제주	Korea
3	NGII	JINJ	35.17308714	128.0496745	진주	Korea
4	NGII	KWNJ	35.17837539	126.9102368	광주	Korea
5	NGII	SEOS	36.77640911	126.4942027	서산	Korea
6	NGII	WNJU	37.33720708	127.9470885	원주	Korea
7	NGII	WULJ	36.99197653	129.4129955	울진	Korea
8	NGII	SUWN	127.0542	37.2755	수원	Korea
9	KASI	BHAO	36.16374011	128.976325052	보현산 천문대	Korea
10	KASI	DAEJ	36.399429251	127.374477713	대전	Korea
11	KASI	MKPO	34.816851627	126.381407615	목포	Korea
12	KASI	MLYN	35.491372507	128.743968353	밀양	Korea
13	KASI	SBAO	36.934232495	128.456929053	소백산 천문대	Korea
14	KASI	SKCH	38.250963696	128.564749458	속초	Korea
15	KASI	SKMA	37.493528493	126.917998245	서울	Korea
16	IGS	chan	125.4433	43.7905	CHANGCHUN	China
17	IGS	irkm	104.3162	52.219	Irkutsk	Russia
18	IGS	lhaz	91.104	29.6573	Lhasa	China
19	IGS	mizu	141.1328	39.1352	Mizusawa	Japan
20	IGS	usud	138.362	36.1331	Usuda	Japan

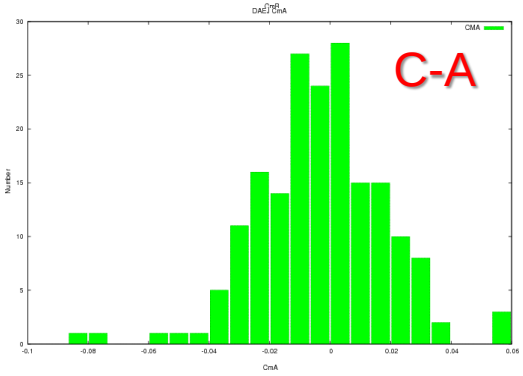
2014.08 DAEJ(Daejeon)

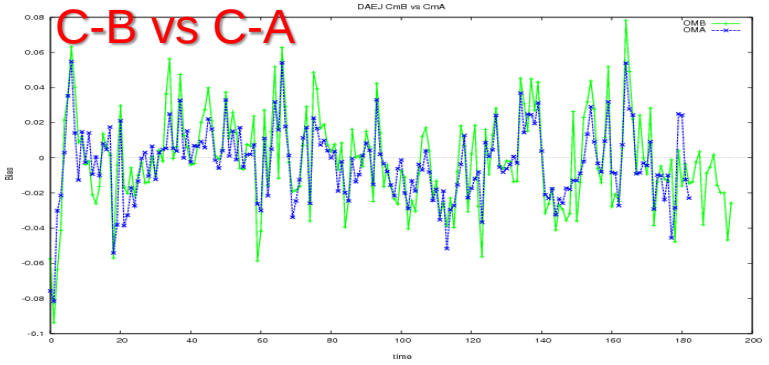










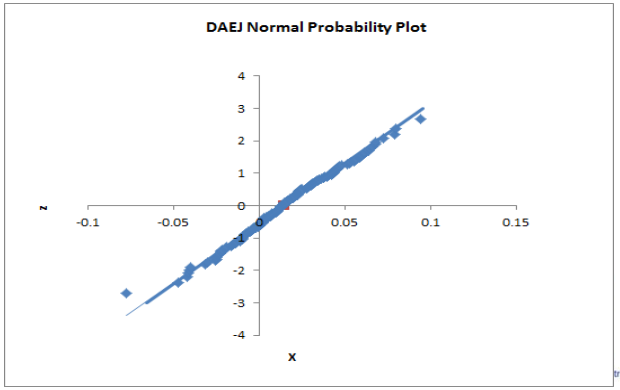


Normality test (Anderson-Darling test):

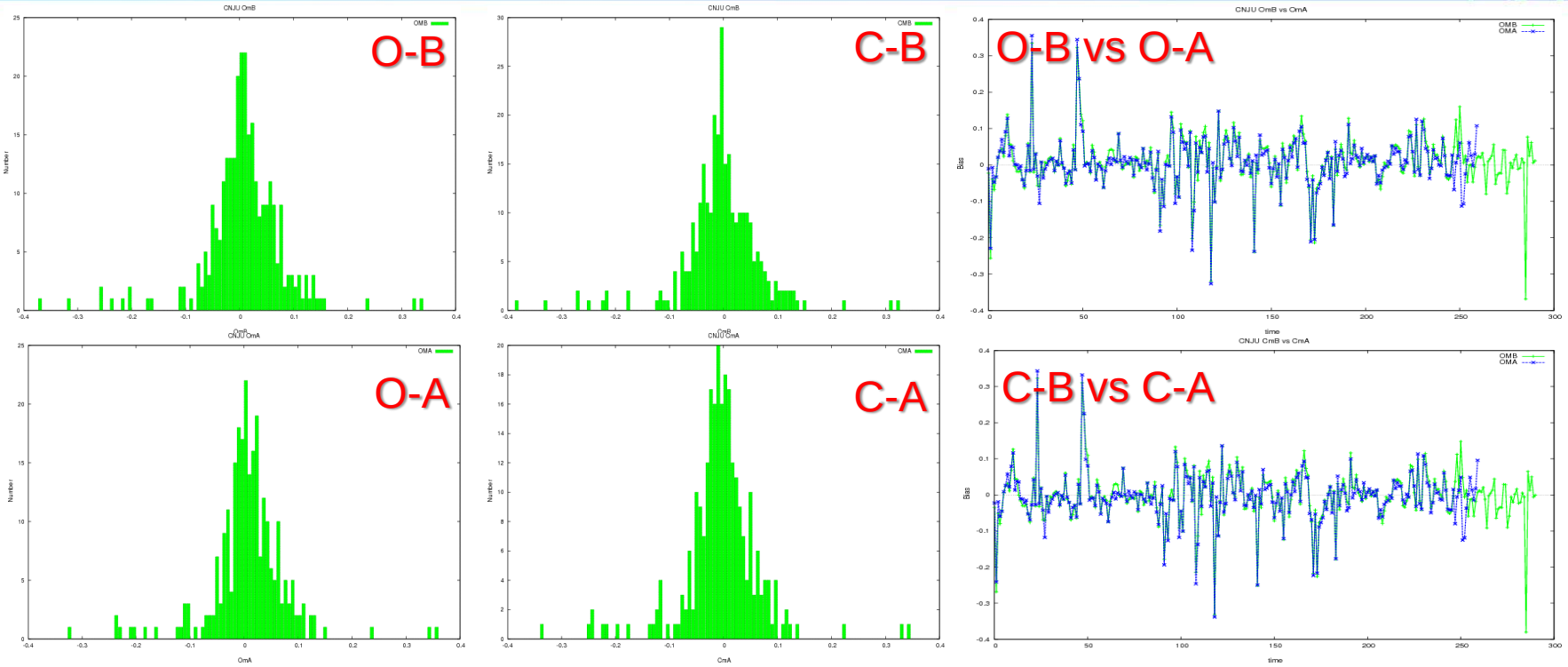
p-value $\geq$ 0.05 ; normal

DAEJ(n=195)

p-value: 0.332297, mean:0.015, sigma: 0.026862



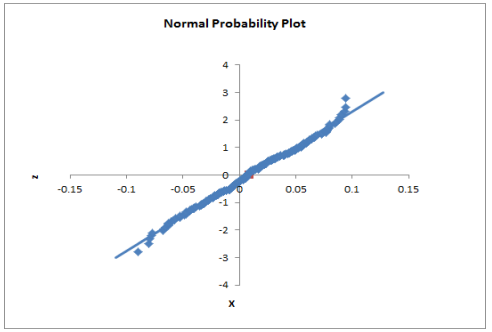
2014.08 CNJU(ChungJu)



Outlier ±0.1 applied,

CNJU(n=254)

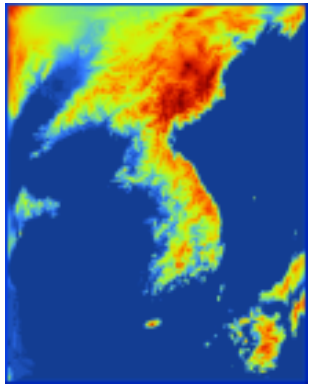
p-value: 0.176117, mean:0.0083, sigma: 0.039523



Experimental description

- **Period**: 2014. 08. 01. ~ 2014. 08. 31.
- **Model**: UM (1.5kmL70)
- **Target Length** : 36hrs
- **Data Assimilation**: 3D-var
- **Time window**: 3hrs(±1.5hr)
- **Control Exp(NWP)**: operation(without GGPS)

  (used obs- radar, sonde, surface, aircraft, scatwind)
- **Exp1(BC_GGPS)**: with GGPS after Bias Correction
- **Exp2(NoBC_GGPS)**: with GGPS no Bias Correction



LOCAL

- Resolution
  1.5kmL70 (UM)
  (744×928 / top =39km)
- Target Length
  36hrs
- Initialization : 3DVAR

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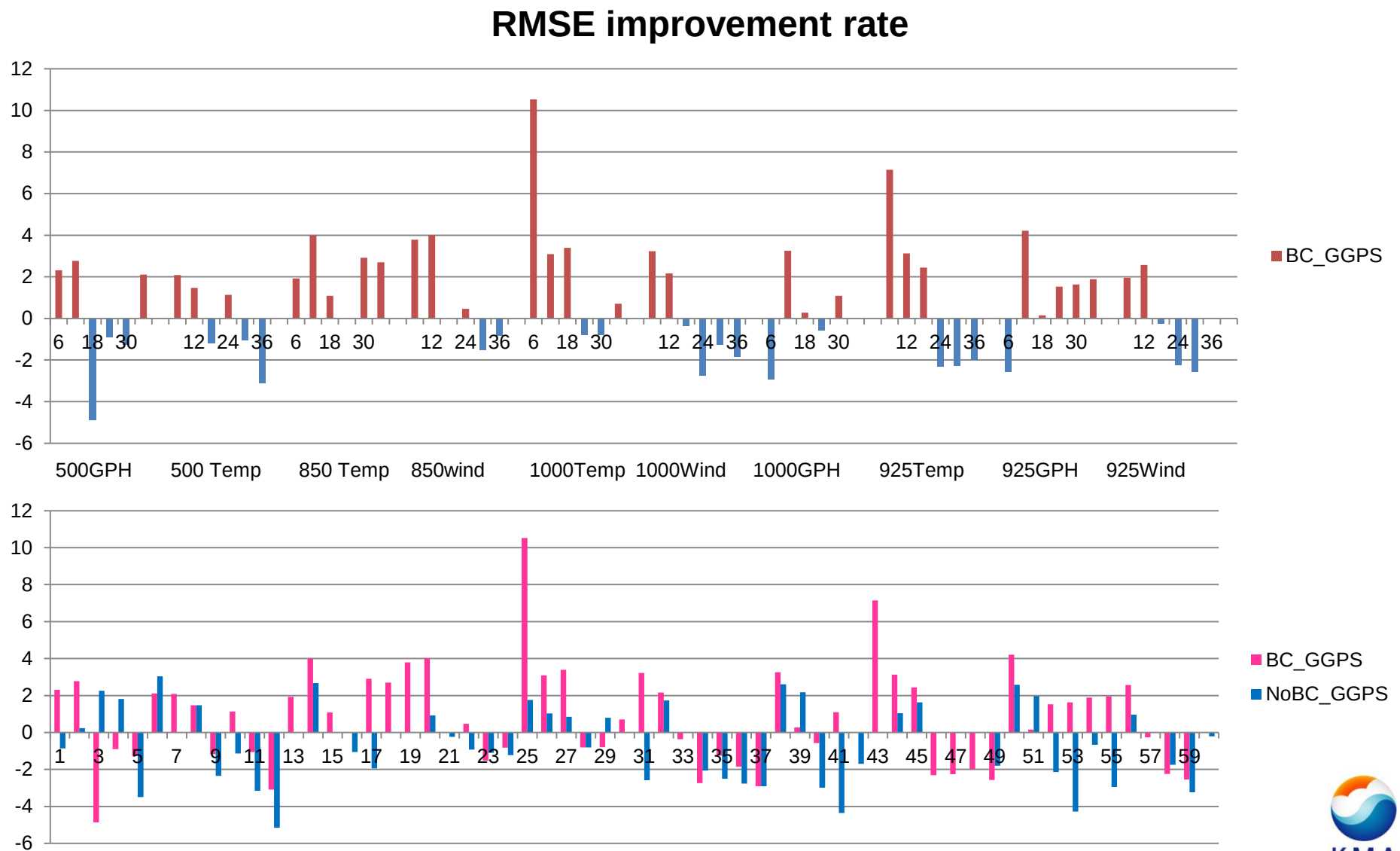
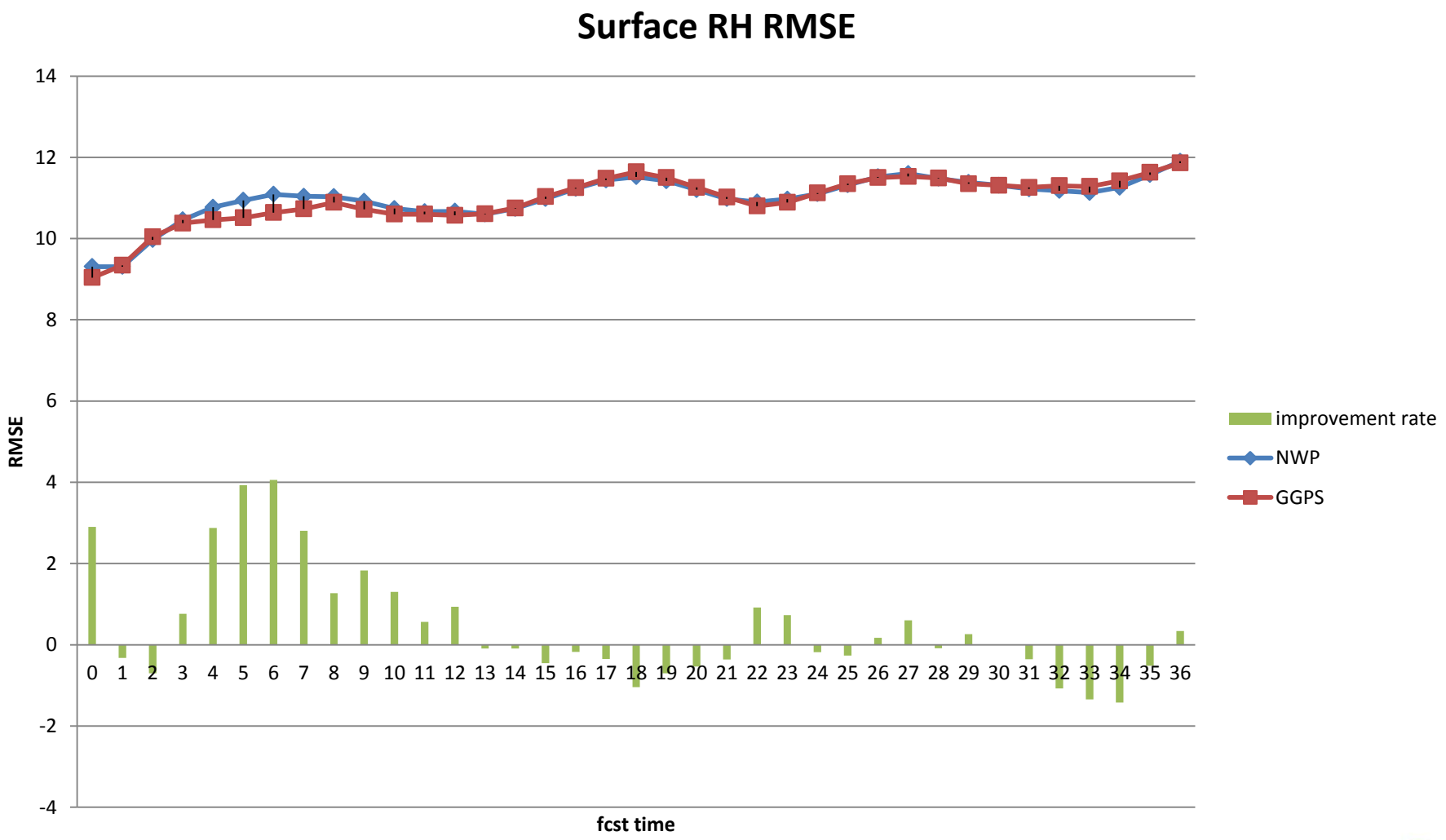
Analysis verification



Verification against Surface obs.(SYNOP,AWS)



Rainfall cases

- **2014. 8. Heavy rainfall cases**

a. 8. 18. Yangsan (southern part of Korea)

maximum *1hour* precipitation : 50mm, *24hour* : 284.5mm

b. 8. 21. Seosan

maximum *24hour* precipitation :126.4 mm

c. 8. 25. Changwon

maximum *1hour* precipitation : 118 mm , *24hour* : 241mm

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2014. 8. 18.

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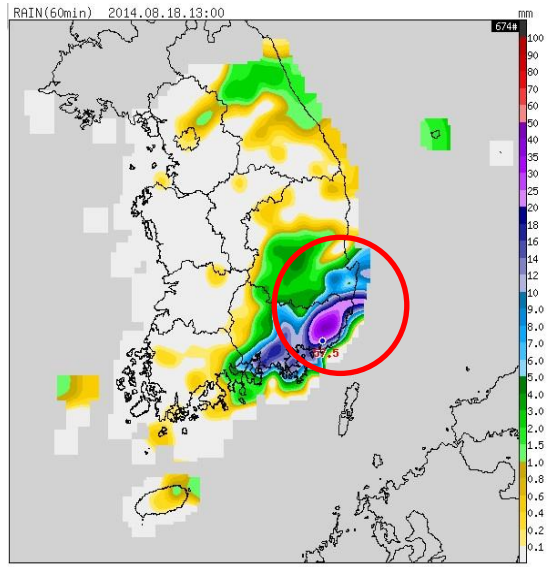
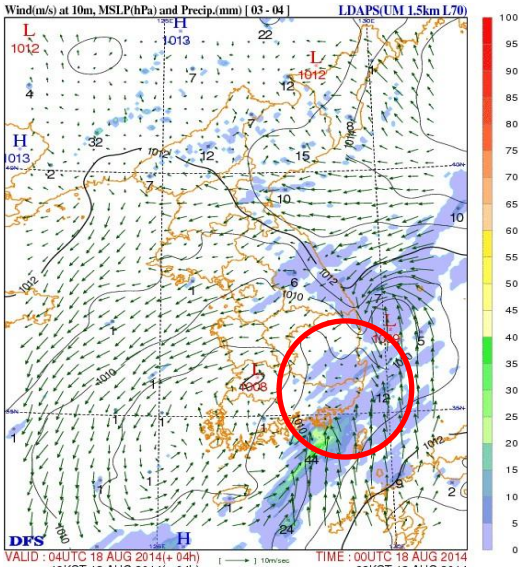
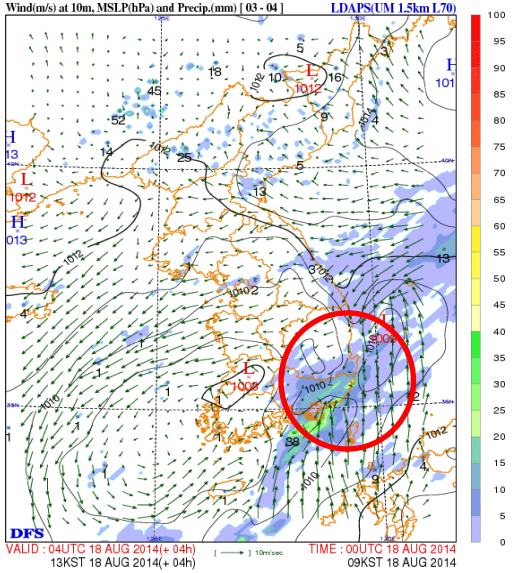
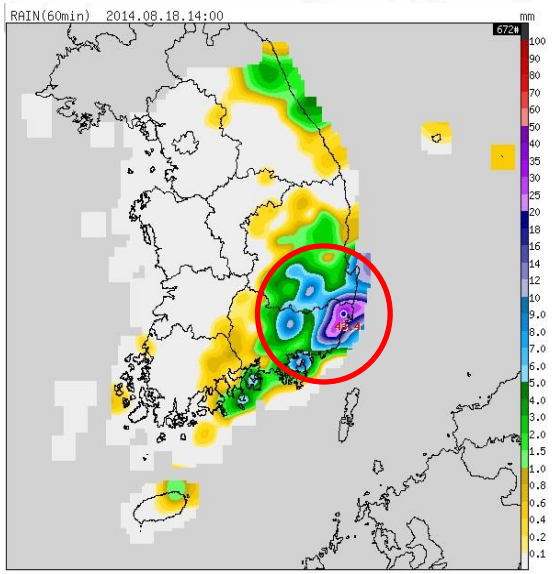
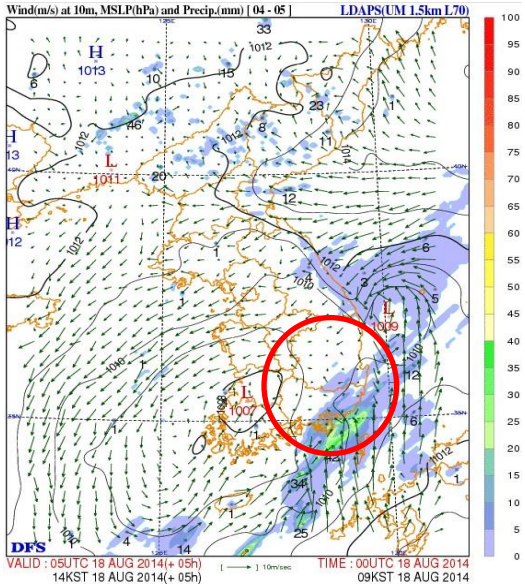
BC_GGPS

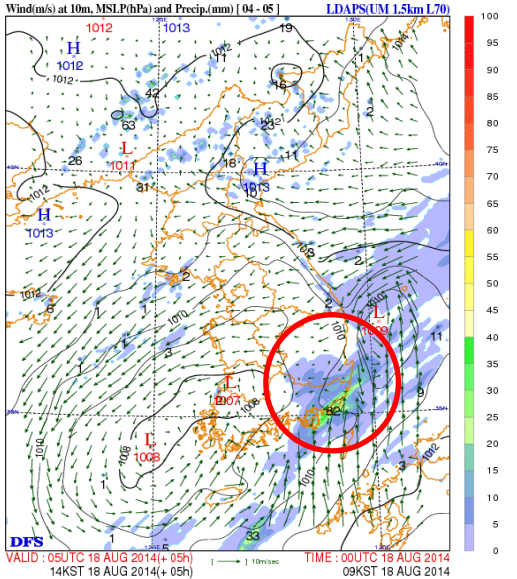












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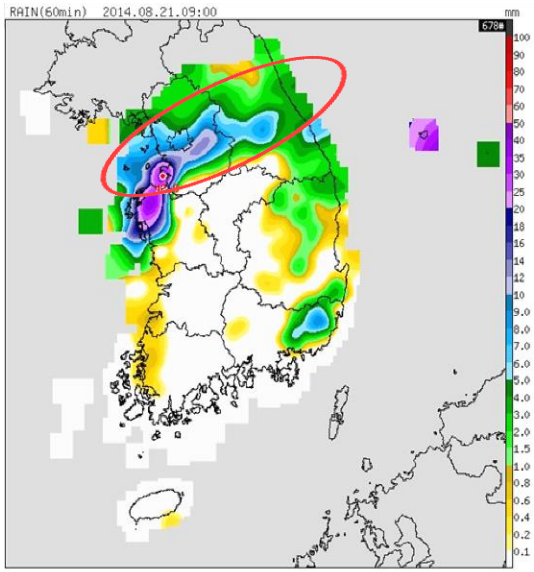
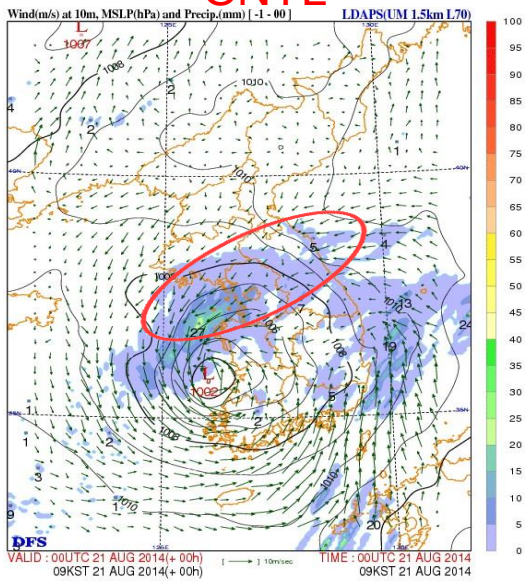
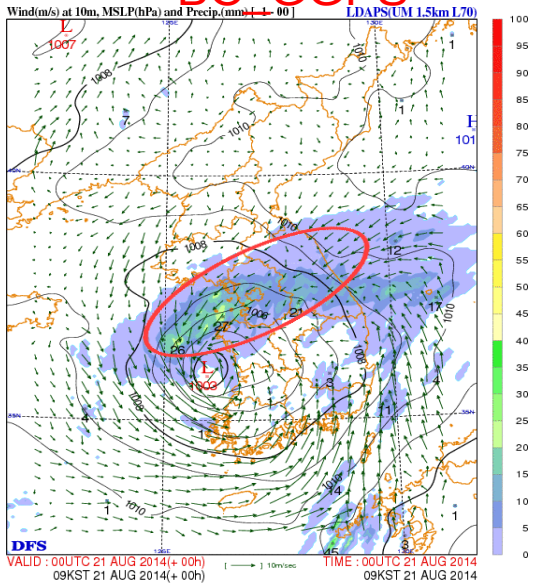
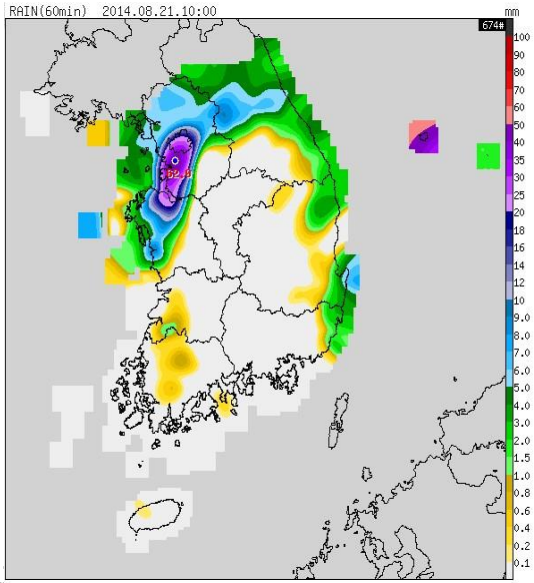
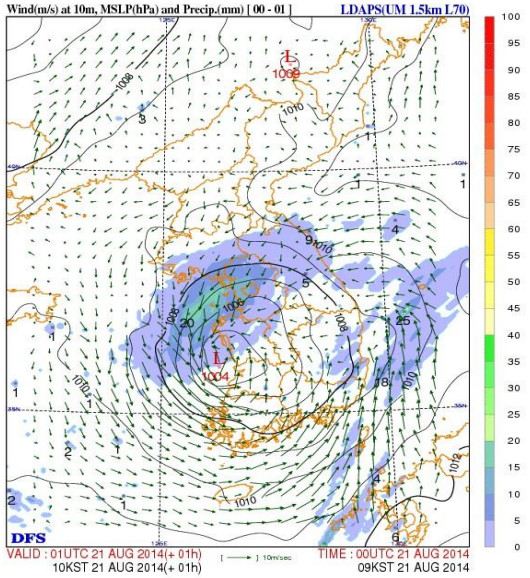
BC_GGPS

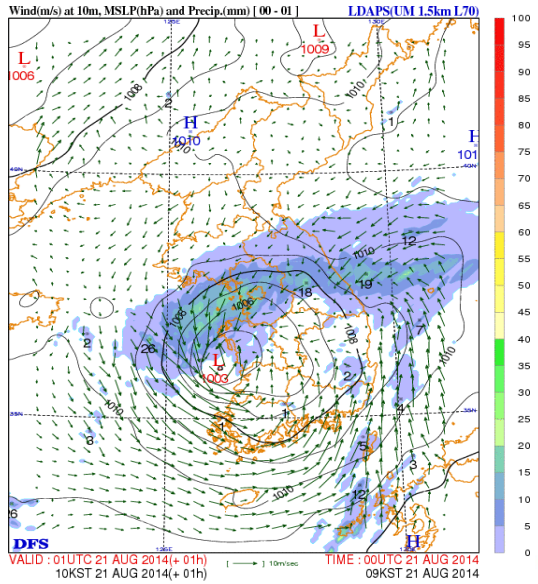












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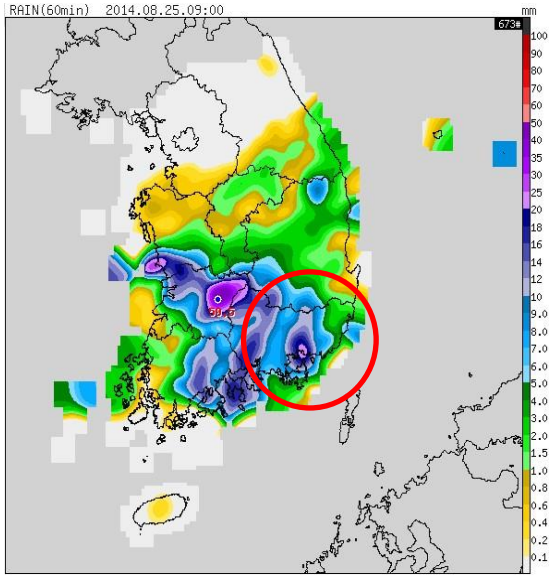
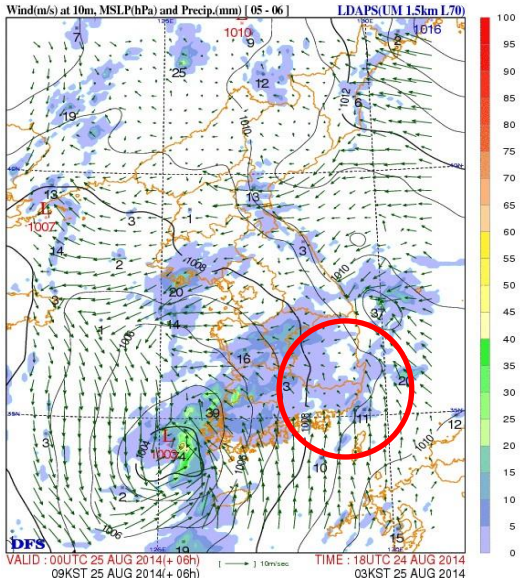
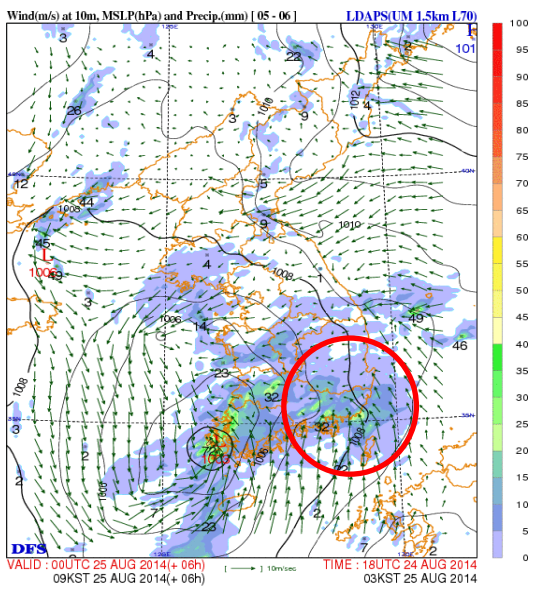
2014. 8. 25.

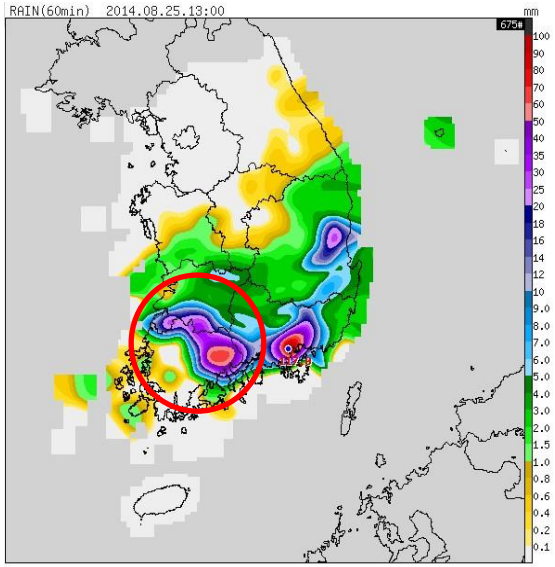
CNTL

GGPS





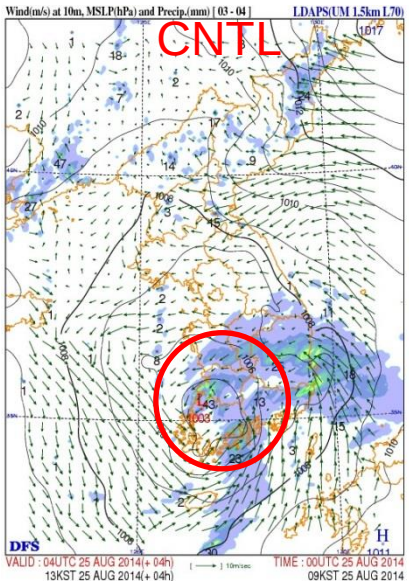


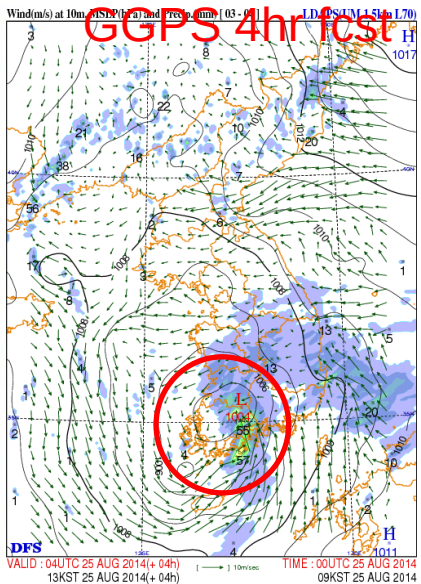


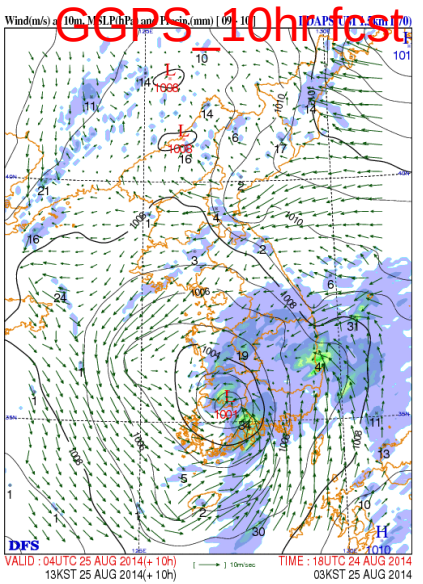
CNTL

GGPS 4hr fcst

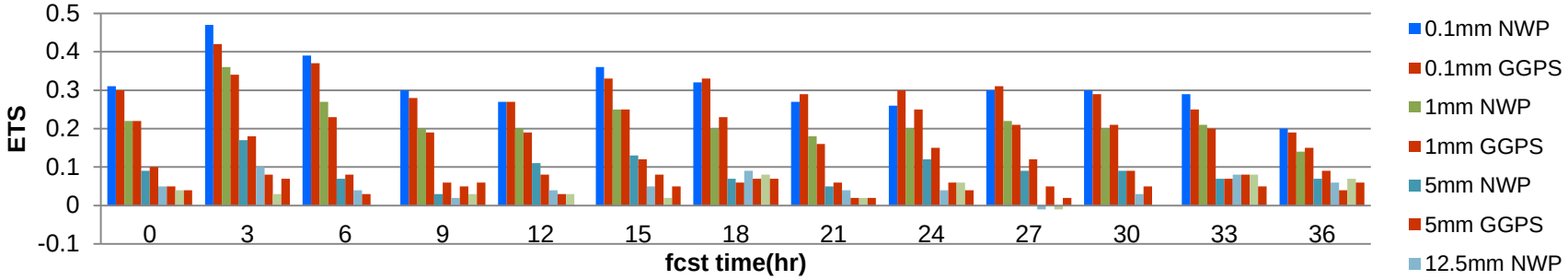
GGPS_10hr fcst

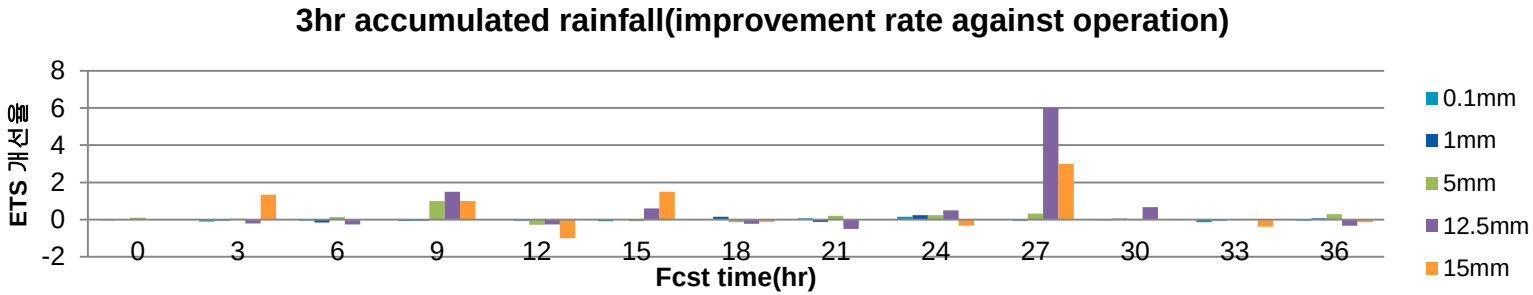


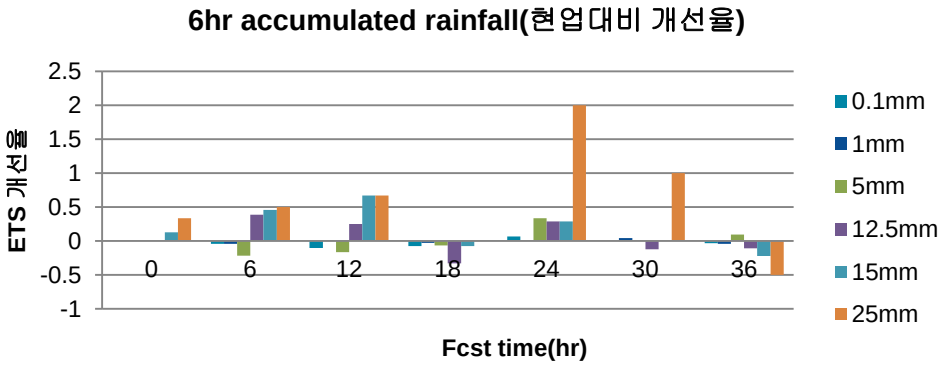


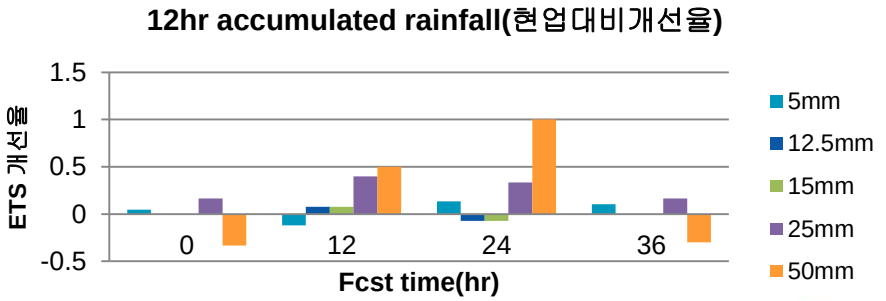


Rainfall verfication









Summary and Future Plan

- Assimilation of ZTD into KMA local area model has shown a promising result. ETS show improvement by up to 60%.
- Simple static bias correction method was applied, more advanced bias correction methods have been studied. (e.g. multi regression eq.)
- Estimation of observation errors
- Additional sites and faster access
- It will be applied operationally at the end of 2015.

- Application GGPS data into Global NWP system

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Quality control

- Bias corrections

- Height check

  - height diff > 300

- (O-B) check

  - (O-B) > 0.055

- Missing value check

- Temporal thinning / Spatial thinning

BIAS

- ZHD: air mass, sfc pressure (variation of pressure)
- ZTD: TPW (variation of water vapor)

Systematic error of Observation Operator

- potential temp. & specific humidity are considered to be constant within each layer
- Difference in height between model sfc and actual sfc of STN

  ; obs lies between model layers : exner P. interpolation

  ; obs lies below model sfc : exner P. extrapolation & θ, q of upper layer
- Delay above the model top

  ; Using the assumption of hydrostatic equlibrium

$$10^{-6}\int_{z=model\ top}^{z=\infty}\frac{aP}{T}dz = 10^{-6}\frac{aRP^{top}}{g}$$

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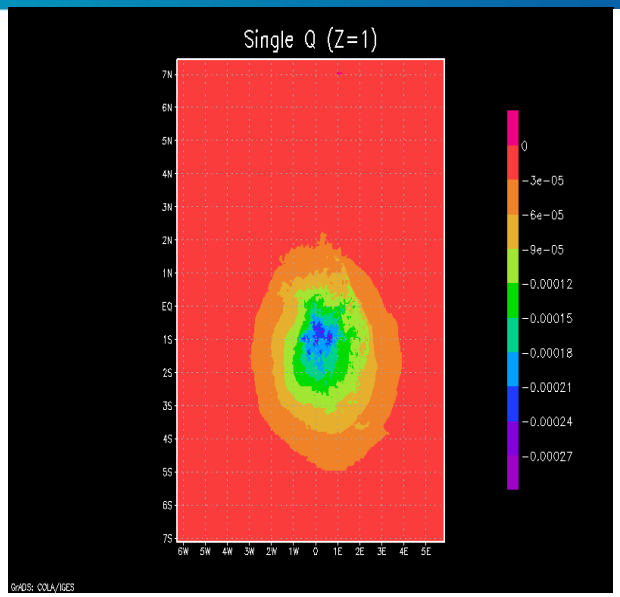
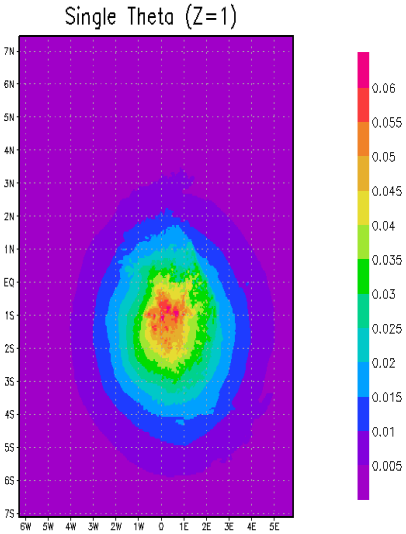
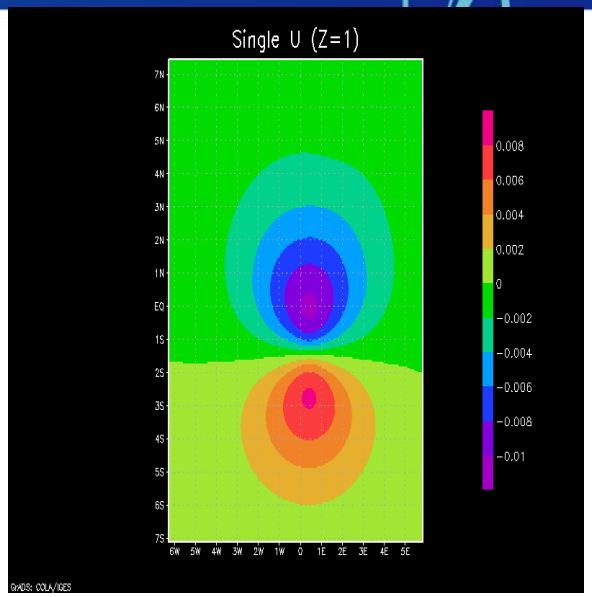
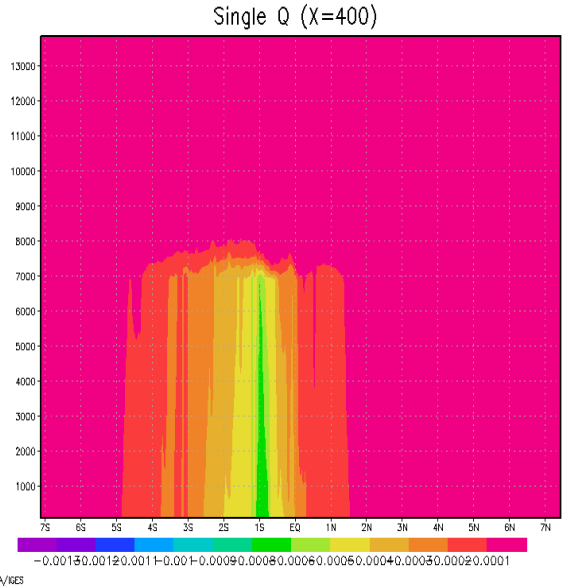
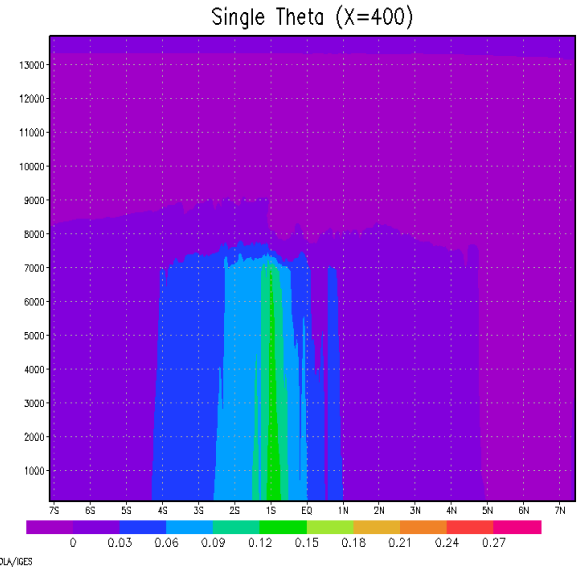
Single Observation test(DAEJ)

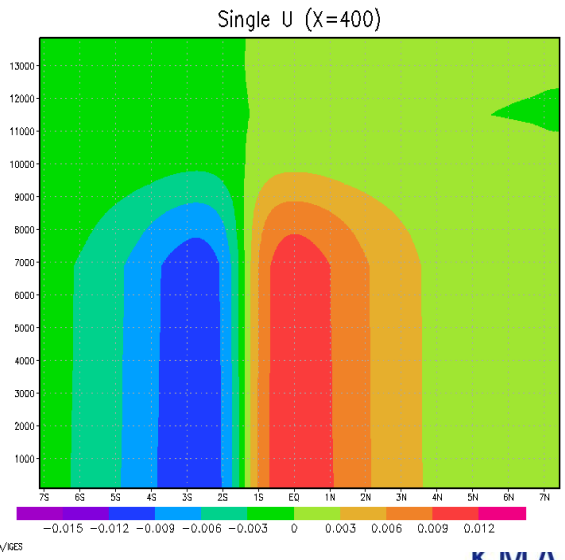


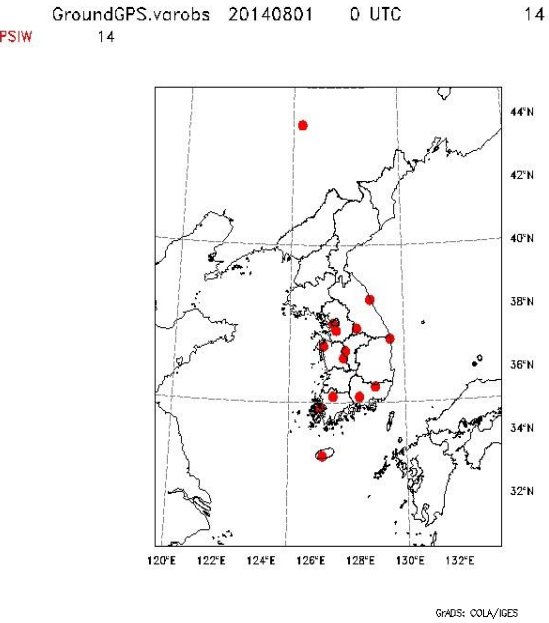


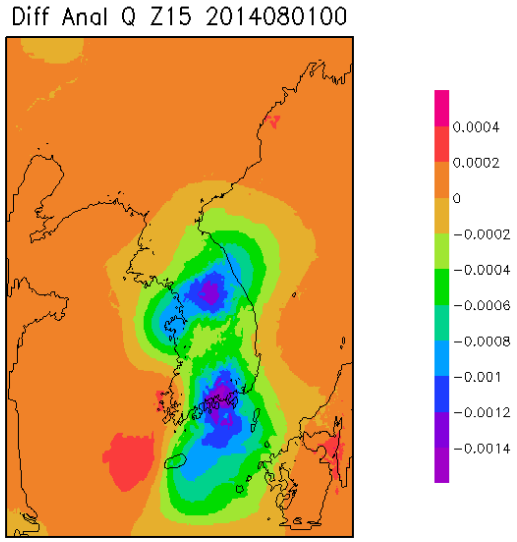




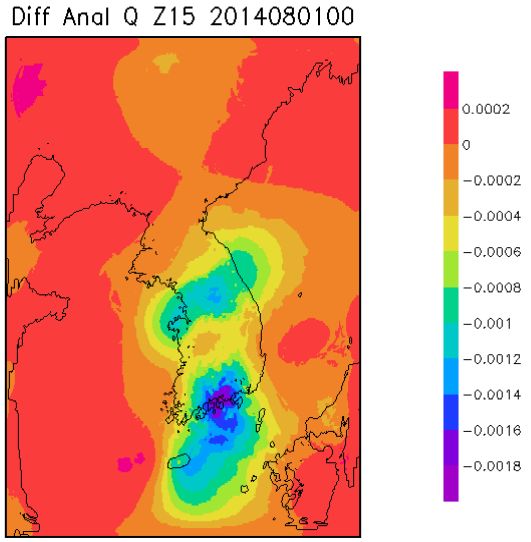




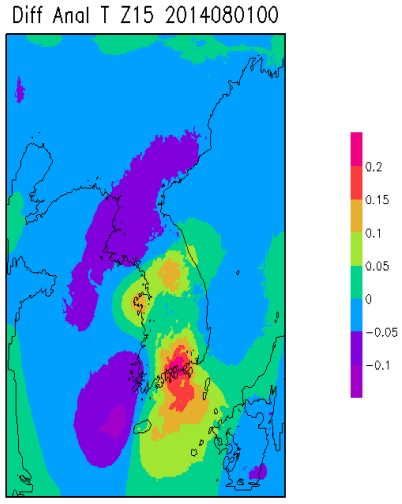




BC



No BC (obs er 0.009)



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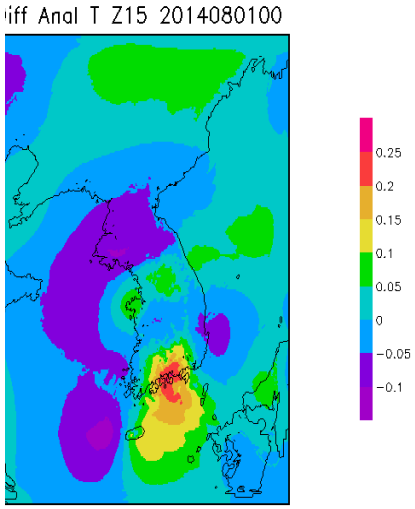

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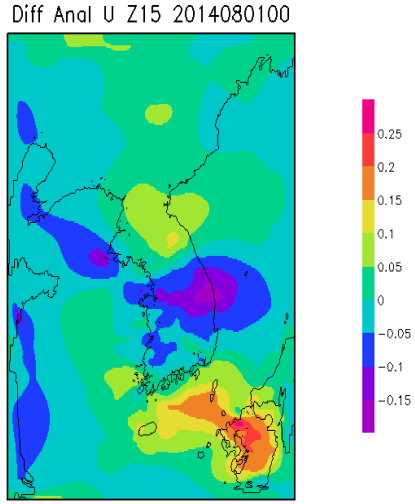

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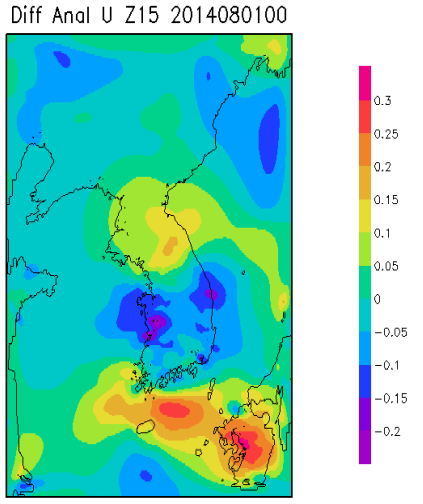
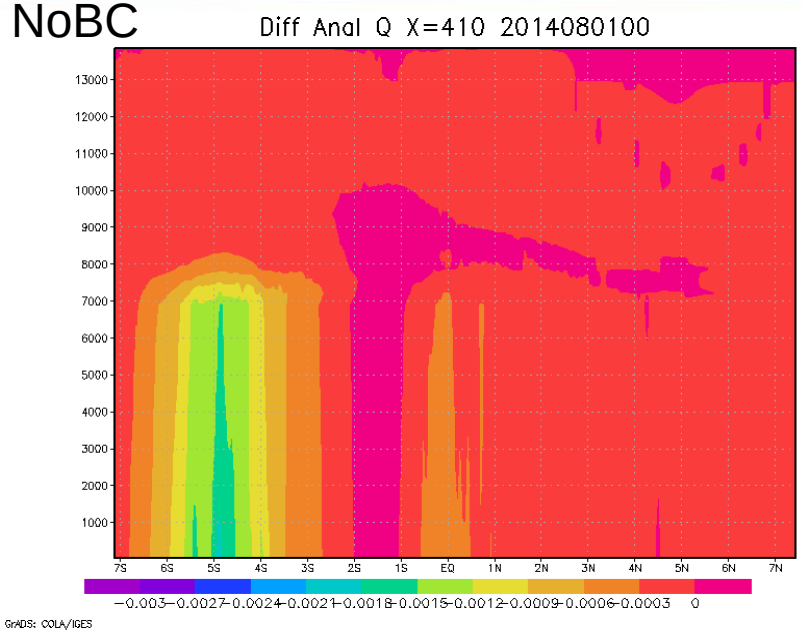
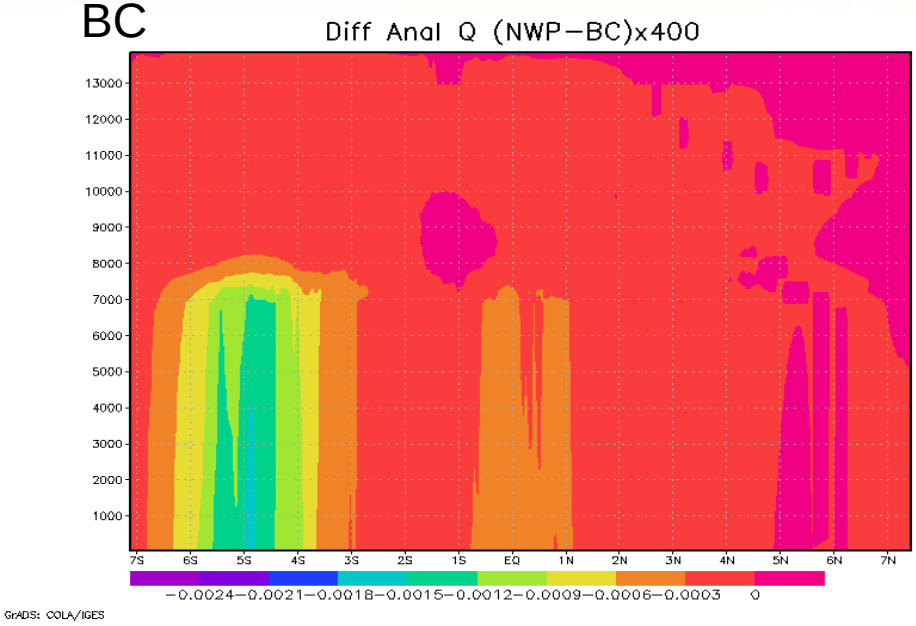


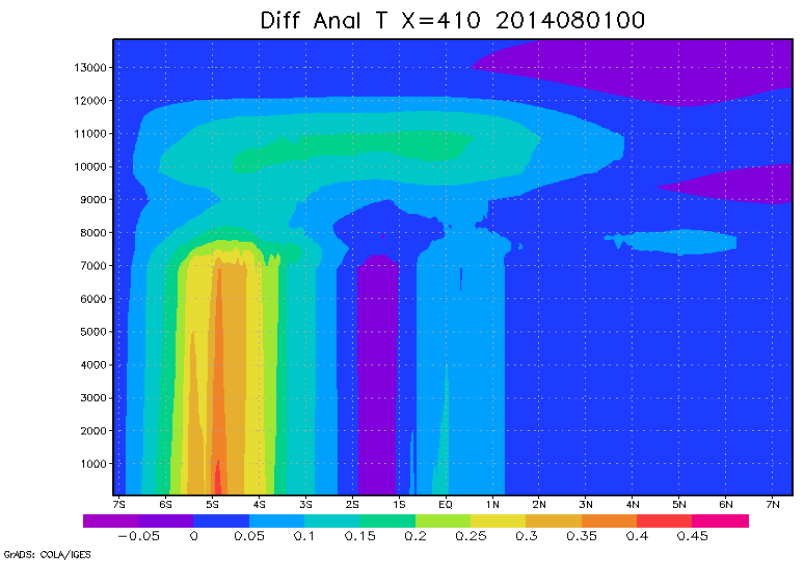
No BC

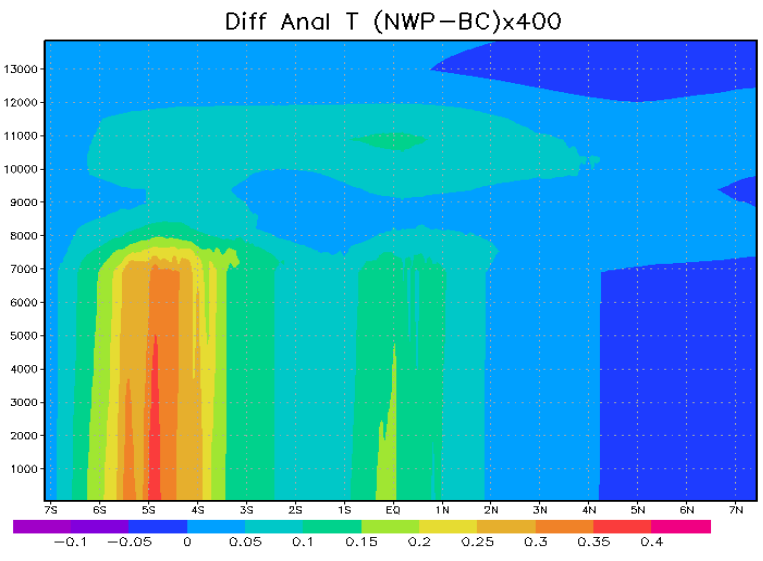
NoBC


Diff Anal Q X=410 2014080100
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
7S 6S 5S 4S 3S 2S 1S EQ 1N 2N 3N 4N 5N 6N 7N
−0.003 −0.0027 −0.0024 −0.0021 −0.0018 −0.0015 −0.0012 −0.0009 −0.0006 −0.0003 0
GrADS: COLA/IGES

BC


Diff Anal Q (NWP−BC)x400
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
7S 6S 5S 4S 3S 2S 1S EQ 1N 2N 3N 4N 5N 6N 7N
−0.0024 −0.0021 −0.0018 −0.0015 −0.0012 −0.0009 −0.0006 −0.0003 0
GrADS: COLA/IGES


Diff Anal T X=410 2014080100
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
7S 6S 5S 4S 3S 2S 1S EQ 1N 2N 3N 4N 5N 6N 7N
−0.05 0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45
GrADS: COLA/IGES


Diff Anal T (NWP−BC)x400
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
7S 6S 5S 4S 3S 2S 1S EQ 1N 2N 3N 4N 5N 6N 7N
−0.1 −0.05 0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4