Operational use of GRACE and MetOp occultation data for GSM in JMA
Current state of COSMIC experiments

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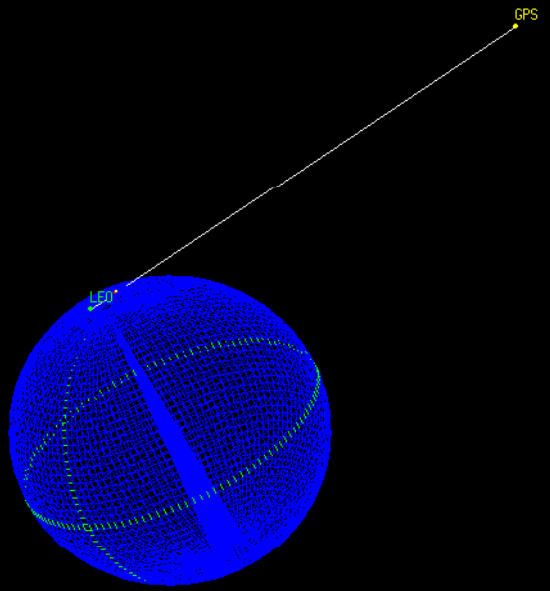
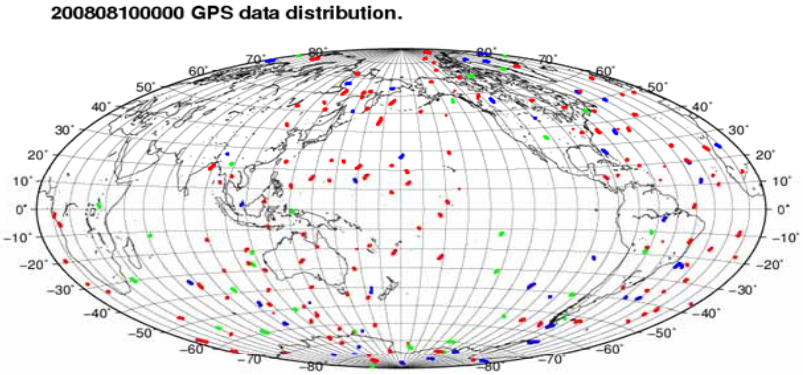
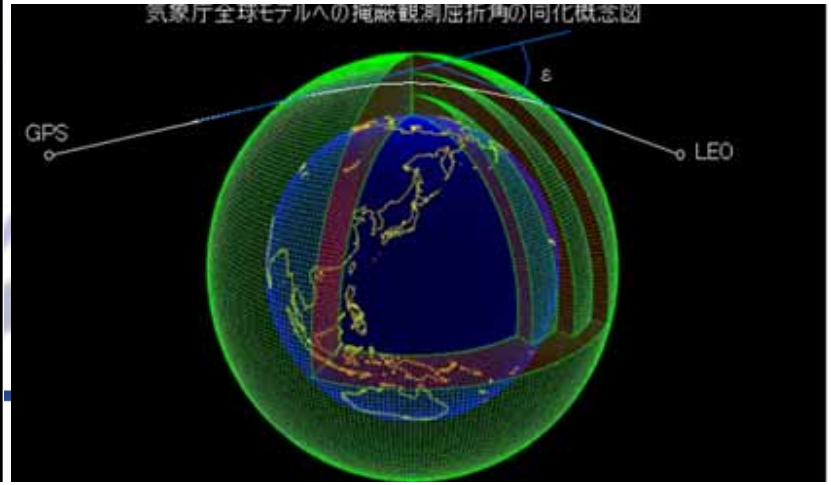
(3) National Institute of Polar Research

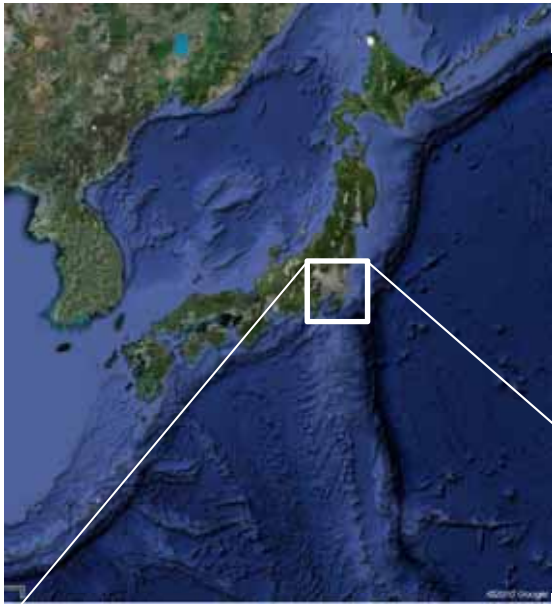


Last revised on February 16,2010

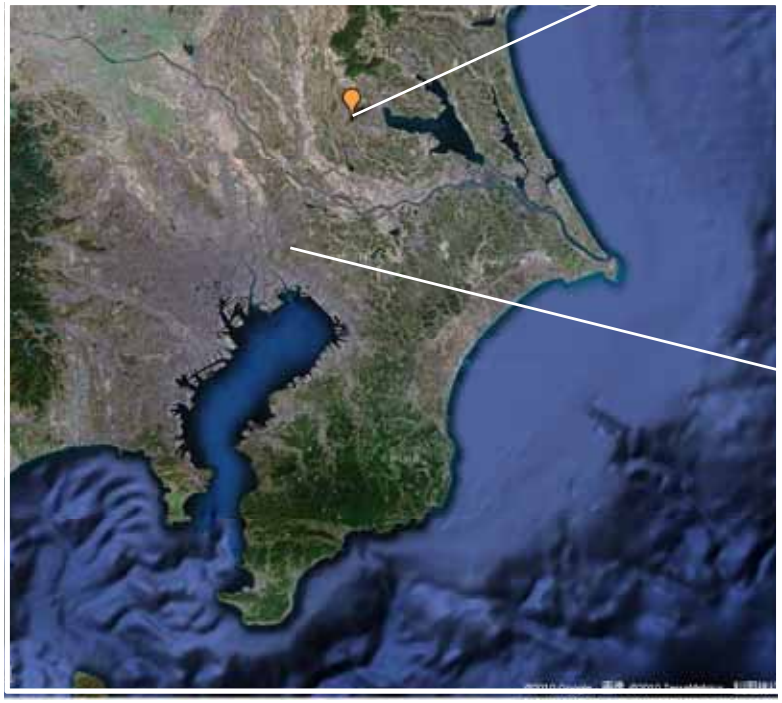




JMA & MRI



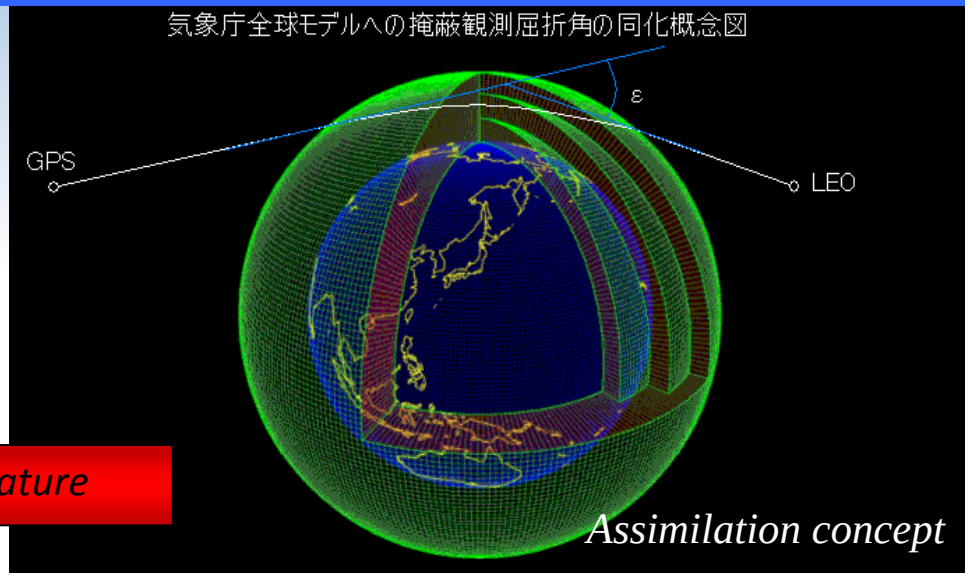
MRI (Meteorological Research Institute)



JMA (Japan Meteorological Agency)

Various methods of GNSS occultation data assimilation

Order of retrieval



Excess phase

bending angle

refractivity

temperature

Forward

Tangent Linear

Adjoint

No operator

First guess

JMA

Analysis

Forecast

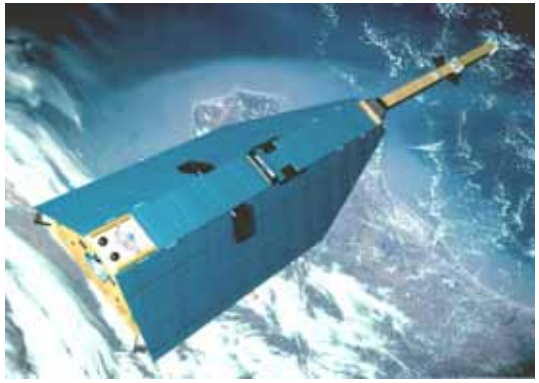
4D-Var

Improvement of Analysis

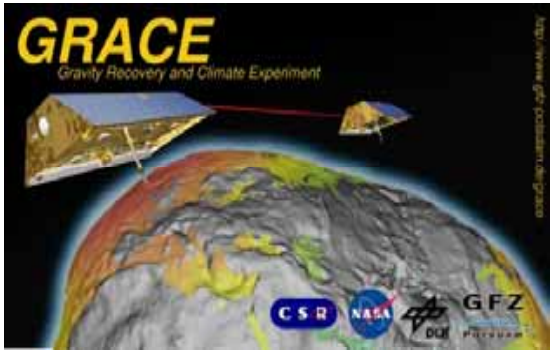
Improvement of Forecast

Among them, we are assimilating refractivity for JMA operational model.

Our Target



CHAMP data were used March 22,2007-November 20,2007



GRACE data were used November 30,2009-December 04,2009

MetOp data have been using since November 30, 2009.

COSMIC Launch - Picture provided by Bill Kuo - April 14th, 2006

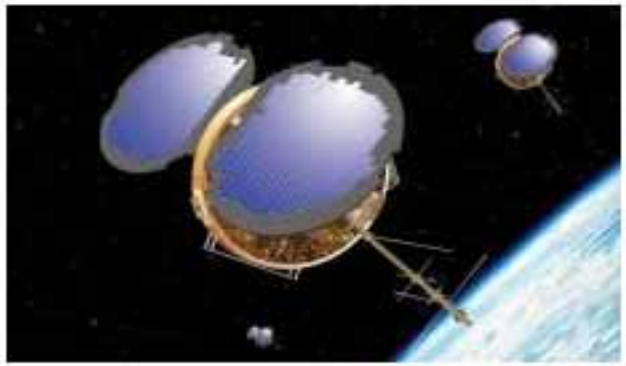


Illustration Courtesy of Orbital

Planning to use COSMIC data from October 2010.

Observation operator

Forward

$$N = (n-1)\times 10^6 = \left(c_1 \frac{p}{T} + c_2 \frac{e}{T^2} \right) \times 10^6$$

p: pressure

T : temperature

e: evaporation pressure

Tangent Linear

$$\delta n = \begin{pmatrix} \left(-\frac{c_1}{T^2} P - 2c_2 \frac{e}{T^3} \right) & c_2 \left(\frac{1}{T^2} \right) \end{pmatrix} \begin{pmatrix} \delta T \\ \delta e \end{pmatrix}$$

Adjoint

$$\begin{pmatrix} \delta \tilde{T} \\ \delta \tilde{e} \end{pmatrix} = \begin{pmatrix} \left(-\frac{c_1}{T^2} P - 2c_2 \frac{e}{T^3} \right) \\ c_2 \left(\frac{1}{T^2} \right) \end{pmatrix} \delta \tilde{n}$$

C_1=77.6x10^{-6} C_2=0.373

--- *Refractivity assimilation* ---

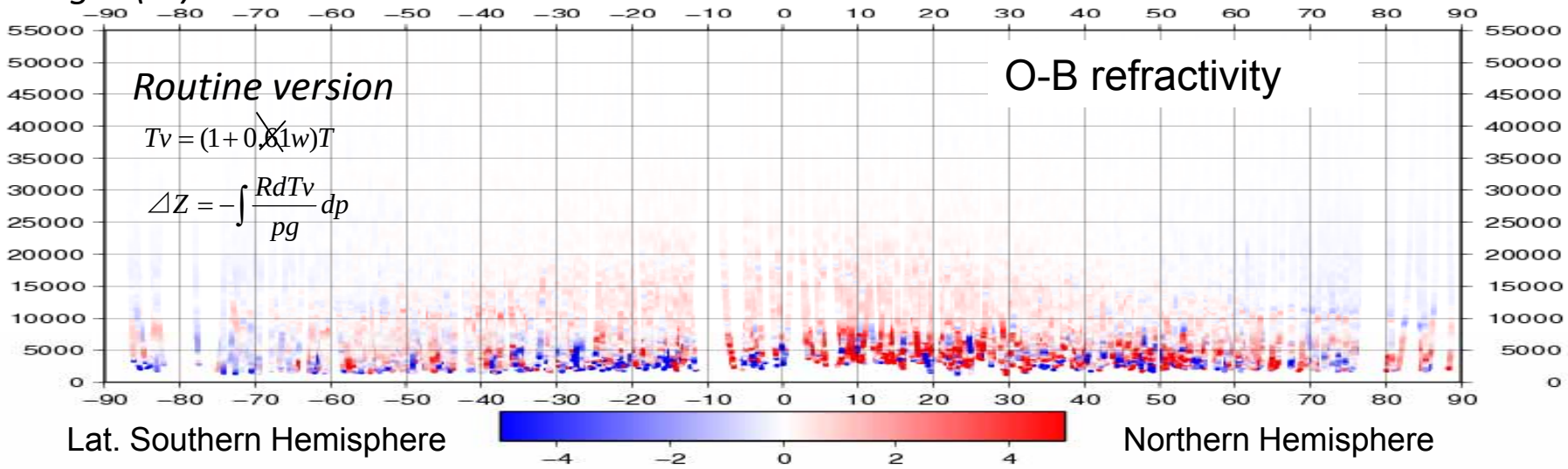
- *Distributional data*
  - ① *Refractivity* $n_{1(observation)}$
  - ② *Tangent point.*
- *Procedure of data assimilation*
  - *(1) Calculate the refractivity (n_2) at the tangent point using forward model by first guess.*
  - *(2) Calculate the analysis field that was minimized the sum of* $n_{2(first\ guess)}$-$n_{1(observation)}$ *and distance from the first guess.*

気象庁 JMA

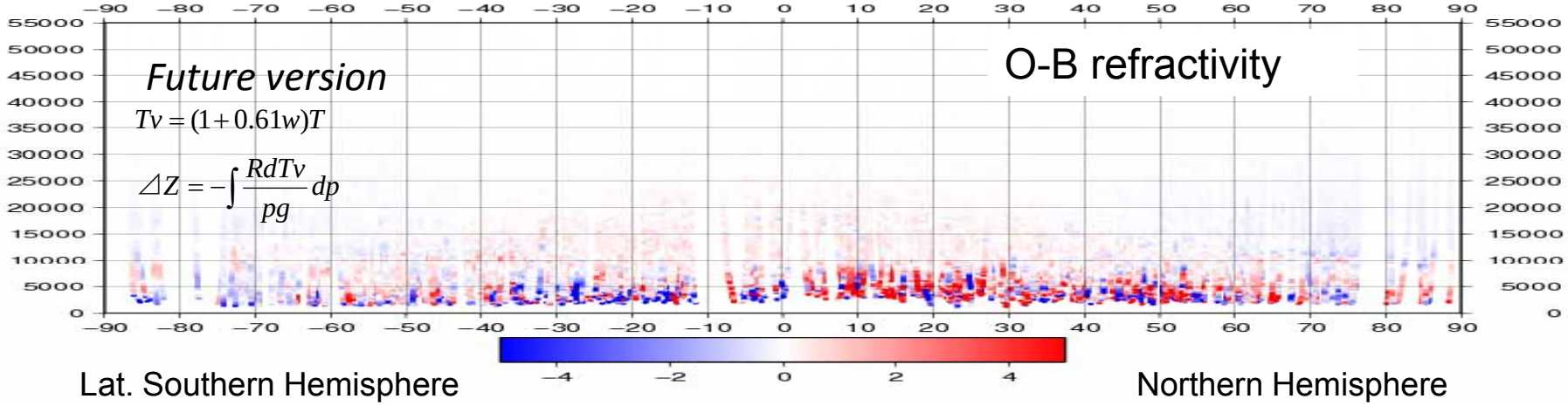
Assimilation of refractivity is very simple and effective method.

Cross section of D(O-B)

Height (m) *Routine Version*



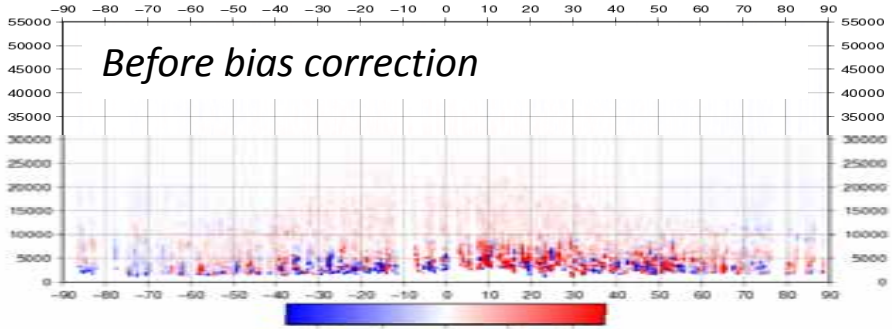
Height (m) *Future Version*

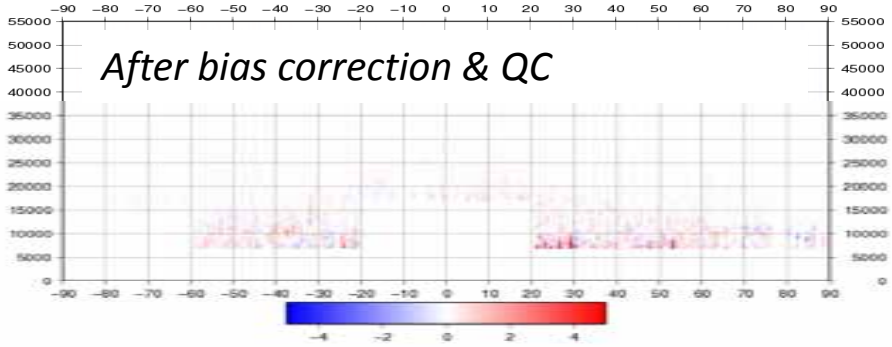


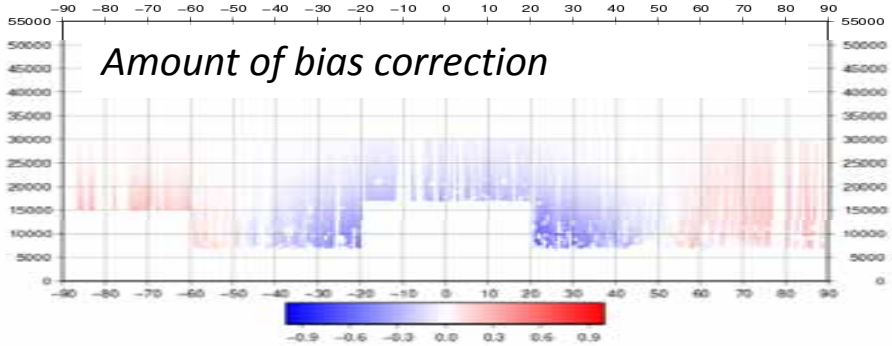
In the routine version, when the calculation of GPS height of the model, w is not considered. The effect is not small. But after this correction, tropical biases are still remained. It may course our model dry bias.

Cross section of D(O-B)

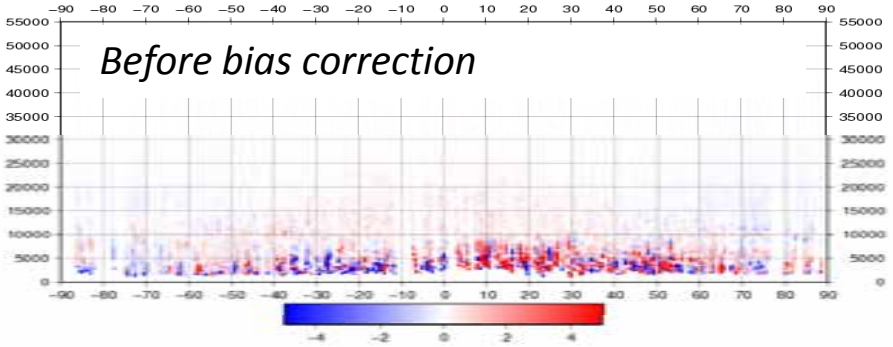
Specification of routine version

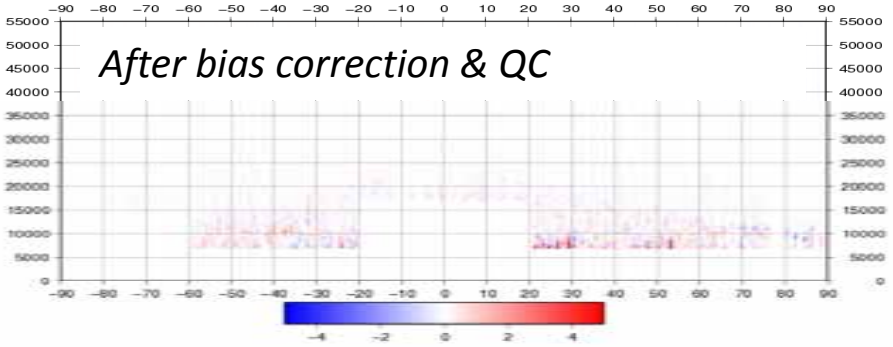


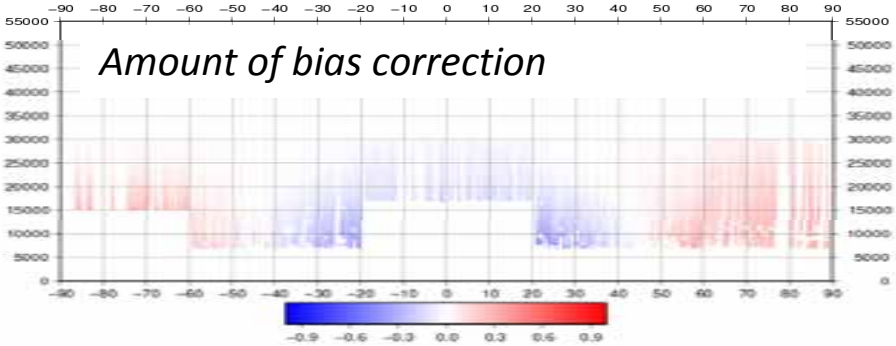




Specification of future version







Thinning and setting of observation errors

Thinning

- *Vertical thinning is 1km interval.*
- *Horizontal thinning is nothing.*

Observation errors

Observation errors are set as another value in summer and winter

From summer to winter MetOp and COSMIC observation errors are interpolated by trigonometric function.

Observation errors were defined as a function of height.

Observation errors are set 1.9 times of RMS.

Vertical correlations of observation error are not considered.

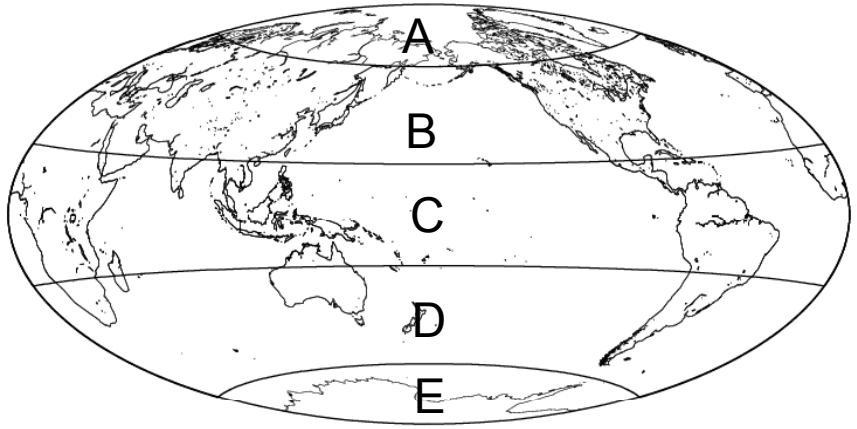
Bias correction

The biases were removed by linear regression equations.

$$N_b = c_1 + c_2 f_2(\text{latitude}) + c_3 f_3(N_{OBS}) + c_4 f_4(\text{altitude})$$

c_1, c_2, c_3, c_4 *are updated by Kalman filter*

- *Areas were divided five latitudinal bands*
  - *Arctic area*
  - *Middle latitude of NH*
  - *Tropics*
  - *Middle latitude of SH*
  - *Antarctic area*

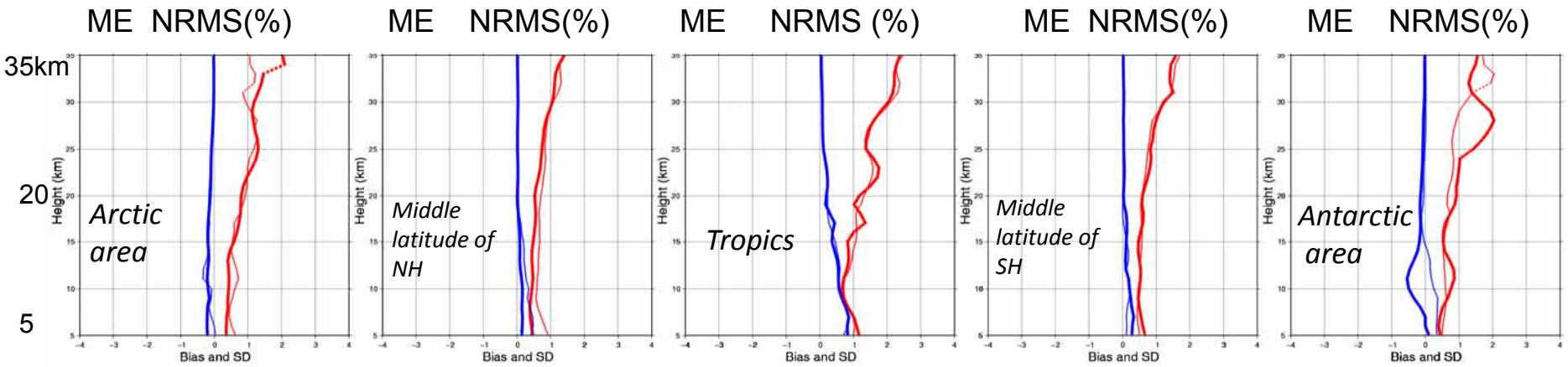


Coefficients exist each 5 domain. (A - E)

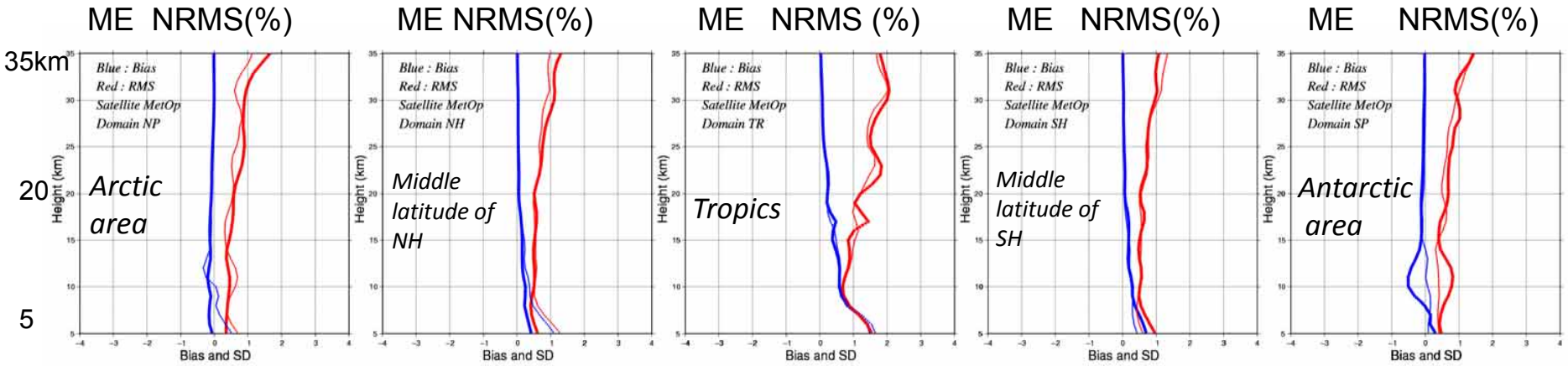
- *Different coefficients are determined*

  GRACE, MetOp, COSMIC 1-3,COSMIC 4-6

Seasonal variation of Departure(O-B) statistics(Bias and NRMS)



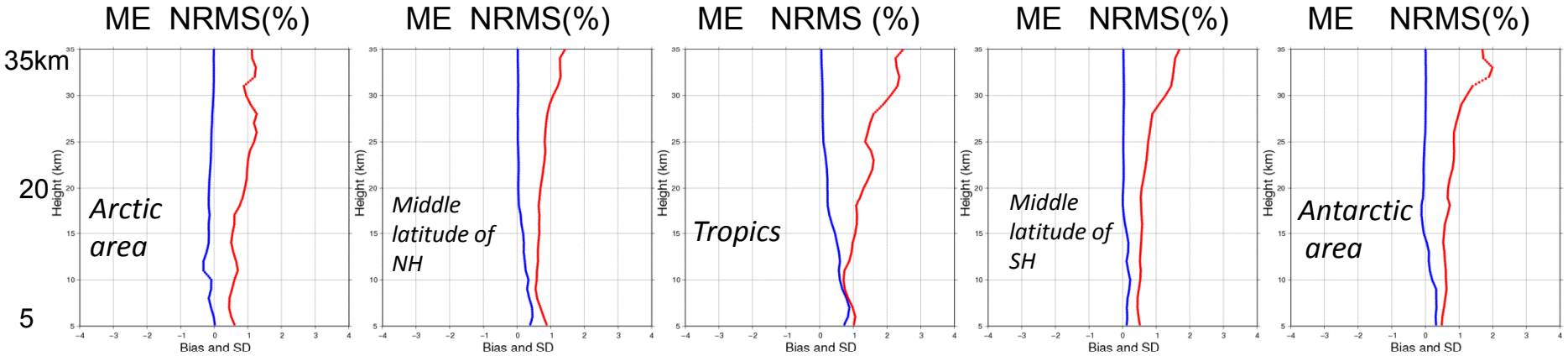
MetOp(Statistics Summer :Aug. 1 - 31 2008 Winter : Jan. 1 – 31 2009)



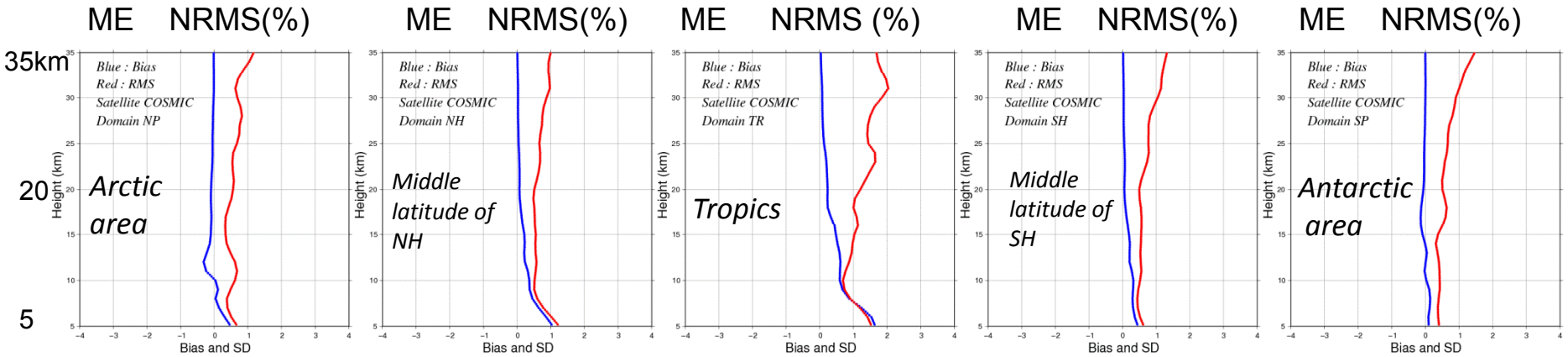
COSMIC(Statistics Summer :Aug. 1 - 31 2009 Winter : Jan. 1 – 31 2009)

Blue :'BIAS Red :'NRMS (%) Thin lines :'Summer Thick lines :'Winter

Seasonal variation of Departure(O-B) statistics(Bias and NRMS)



MetOp(Statistics Summer :Aug. 1 - 31 2008 Winter : Jan. 1 – 31 2009)

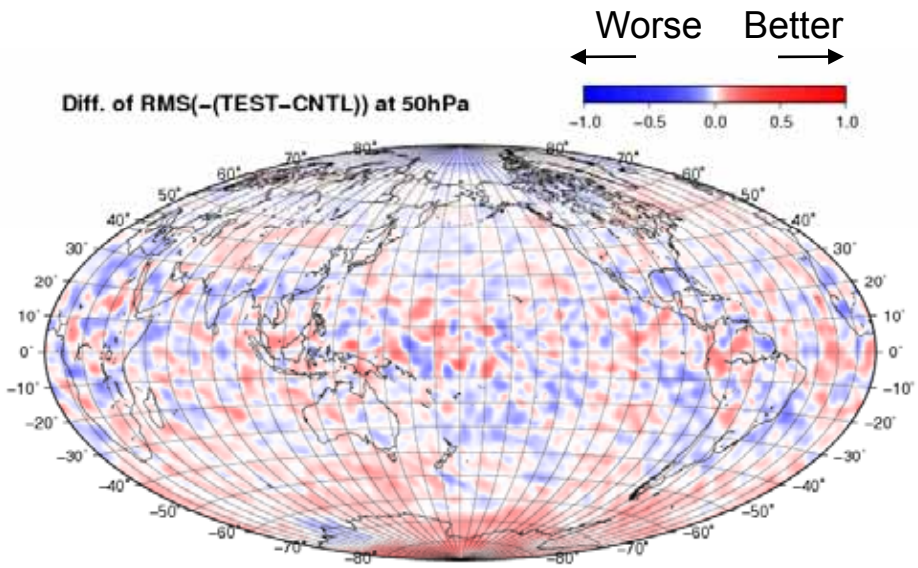


COSMIC(Statistics Summer :Aug. 1 - 31 2009 Winter : Jan. 1 – 31 2009)

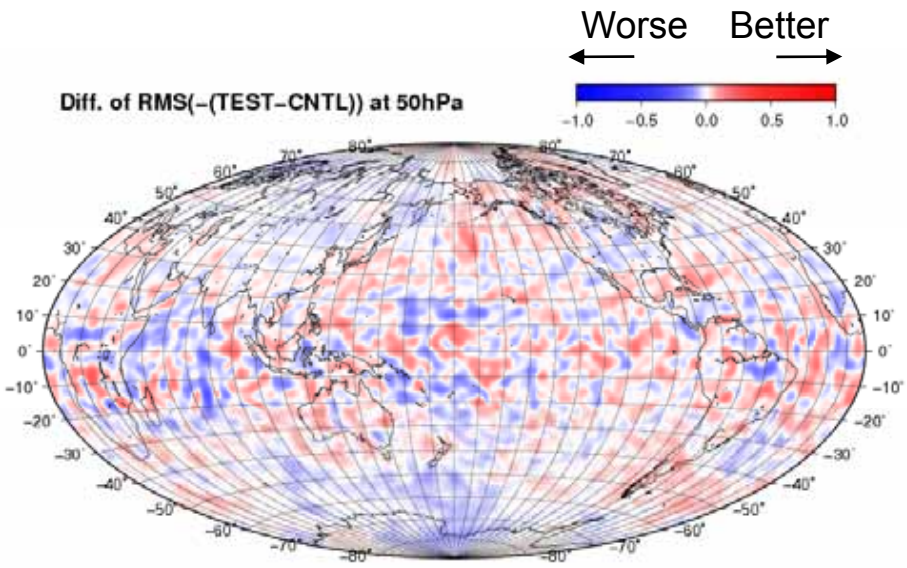
Blue :BIAS Red :NRMS (%)

From summer to winter MetOp and COSMIC observation errors are interpolated by trigonometric function.

RMS(CNTL)-RMS(TEST) map at 50hPa on FT=48



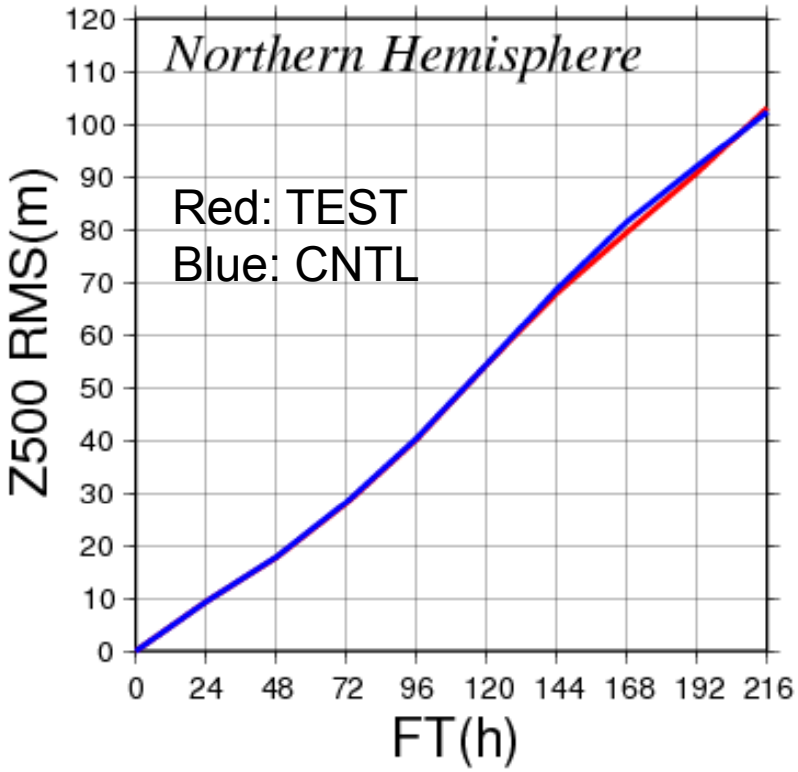
Summer experiment
Statistics in September 1- 30, 2008



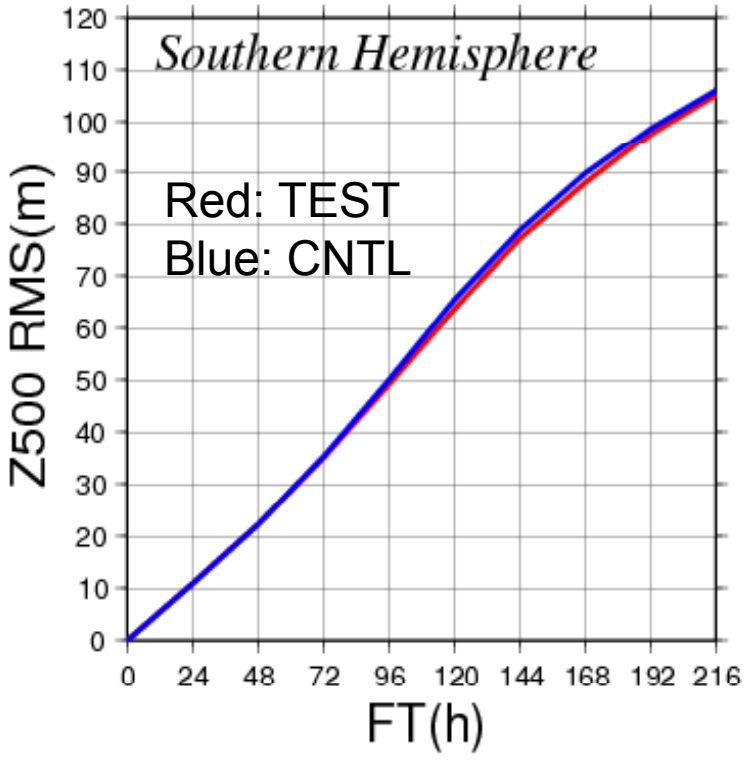
Winter experiment
Statistics in January 1 – 31, 2009

Red arias are dominant compared with blue area.

RMS scores of Z500 by MetOp and GRACE experiments



Winter experiment
With MetOp and GRACE
(g012_v17_win)



Summer experiment
With MeOp and GRACE
(g012_v17_sum)

Scores of the winter hemisphere became good.

GRACE and MetOp data

have been used in operation since November 30, 2009

COSMIC registration completed.
COSMIC experiments have finished.

April 14, 2006 *COSMIC launched*
February 25, 2010 *COSMIC registration completed formally in JMA*

We got cooperation from a lot of people.

Method of the bias correction will be improved

Operation method (2009.9.30-2010.10.XX)

Predictors of bias correction are Latitude, hight, refractivity

$x_1 = 1$ $\quad x_2 = (90 - abs(lat)\,)/c_1$ $\quad c_1 = 10$ $\quad c_2 = 100$ $\quad c_3 = 10000$

$x_3 = N_{obs}/c_2$ $\quad x_4 = (alt_{max} - alt)/c_3$ $\quad alt_{max} = 30km$

$y = N_{bias\_cor}/c_2$

$$y = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 \quad \rightarrow \quad Kalman\ \ Filter$$

New method (2010.10.XX-)

Introduction normalized function.

It is necessary to reduce the altitude dependence of the refractivity variance before handing over Kalman filter.

$$N_{\mathrm{mod}} = \exp(a_0(alt_{\max} - alt) + b_0)$$

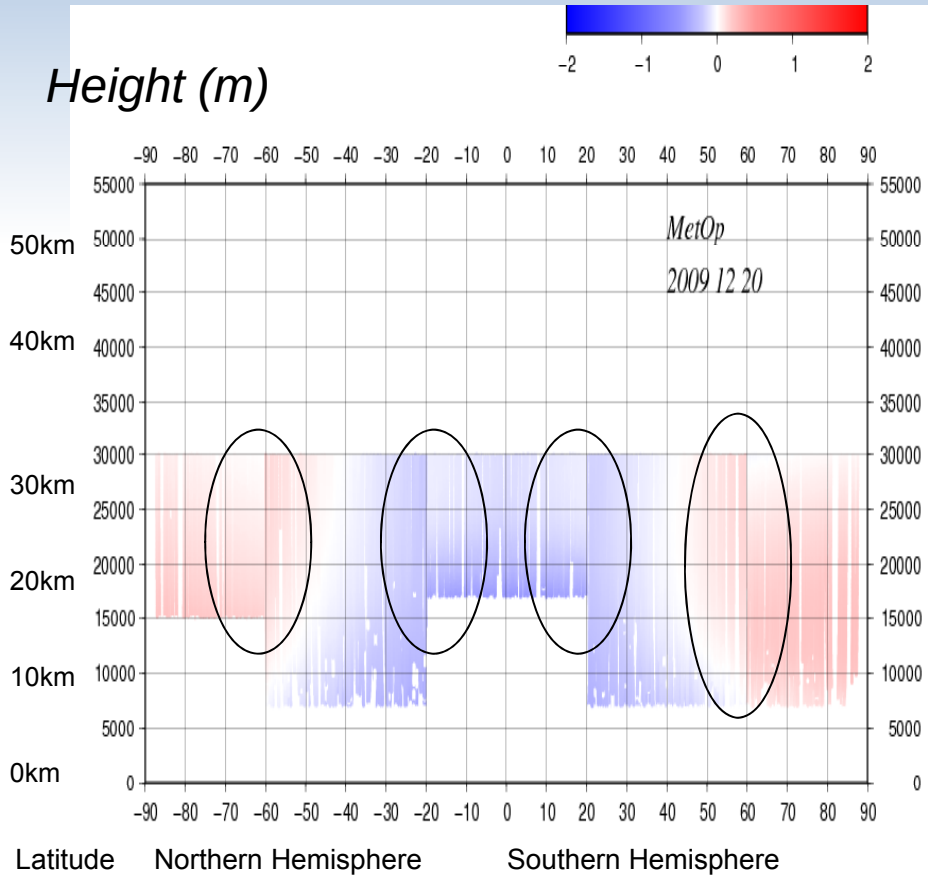
N 300 at alt= 0km Value of typical refractivity

N 80 at alt=10km Value of typical refractivity

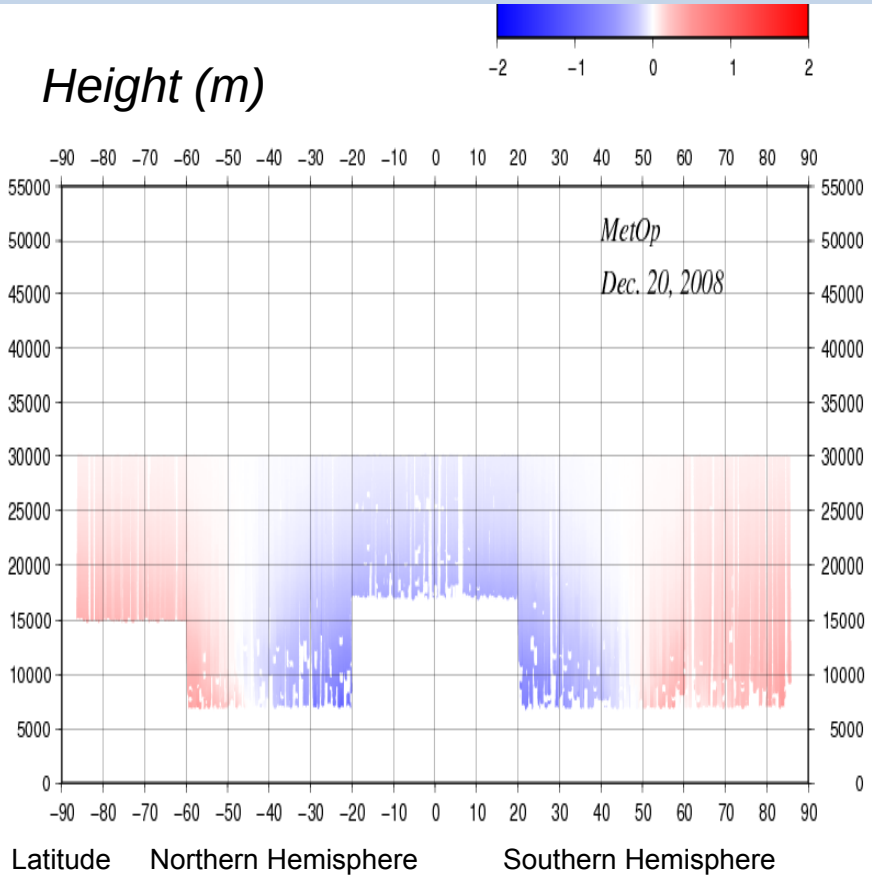
a_0,b_0 were calculated with upper condition.

$$\frac{y}{N_{\mathrm{mod}}} = a_1x_1 + a_2x_2 + \frac{a_3x_3}{N_{\mathrm{mod}}} + a_4x_4 \quad \rightarrow \quad Kalman\ \ Filter$$

Comparison of routine and new method of the bias correction



Routine version



New version

Amount of bias correction.
The gaps of connected area were canceled
by introduction of a new bias correction method.

COSMIC data assimilation

Summer experiment(TL959L60)

TEST ： With COSMIC (H014_CTG_200909)

Assimilation period : August 20, 2009 - October 09, 2009

Forecast period : September 01 – 30 , 2009

CNTL： Without COSMIC (G014_200909_CNTL)

Winter experiment(TL959L60)

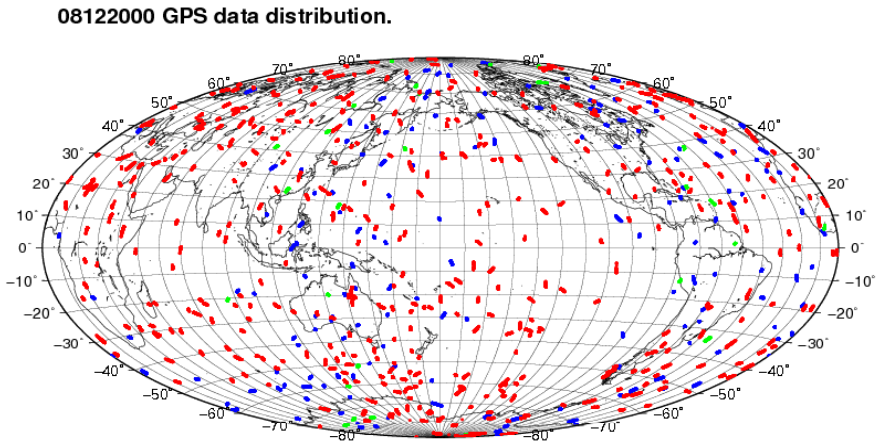
TEST : With COSMIC (H014_CTG_200901)

Assimilation period : December 20 ,2008 - February 09, 2009

Forecast period : January 01 - 31, 2009

CNTL： Without COSMIC (H012_AG2_200901)

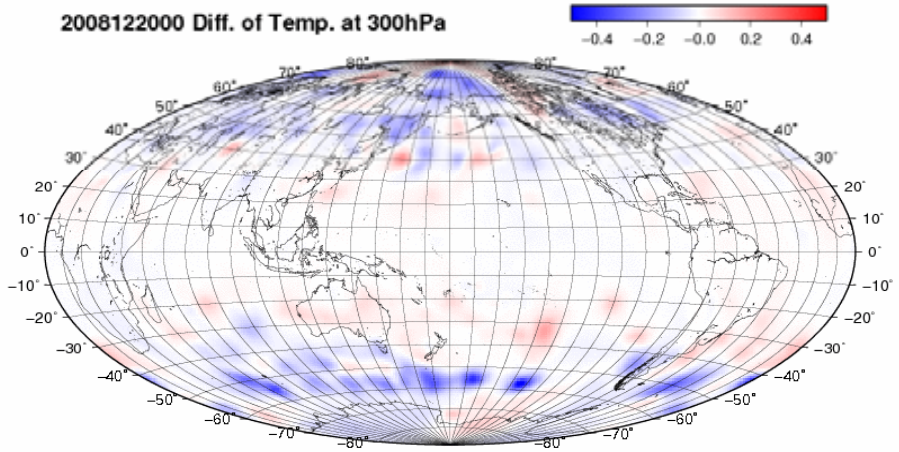
Difference of Analysis fields in winter experiment



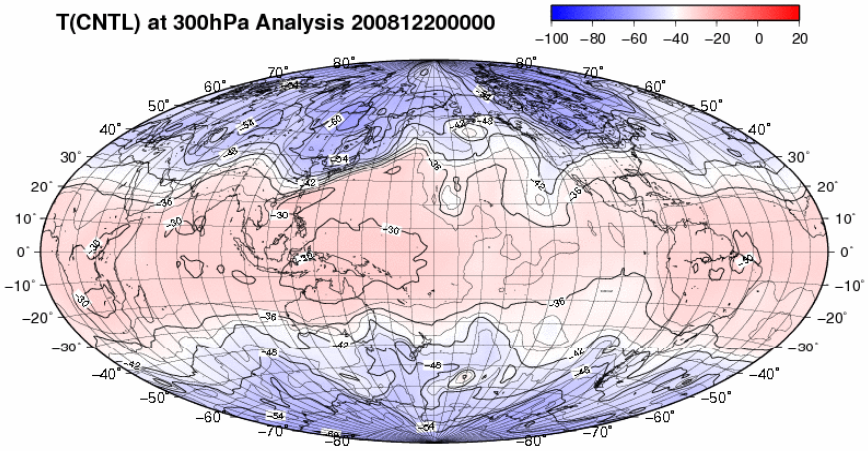
00UCT December 20, 2008 ～

Data distribution

Red：COSMIC Blue：MetOp Green：GRACE

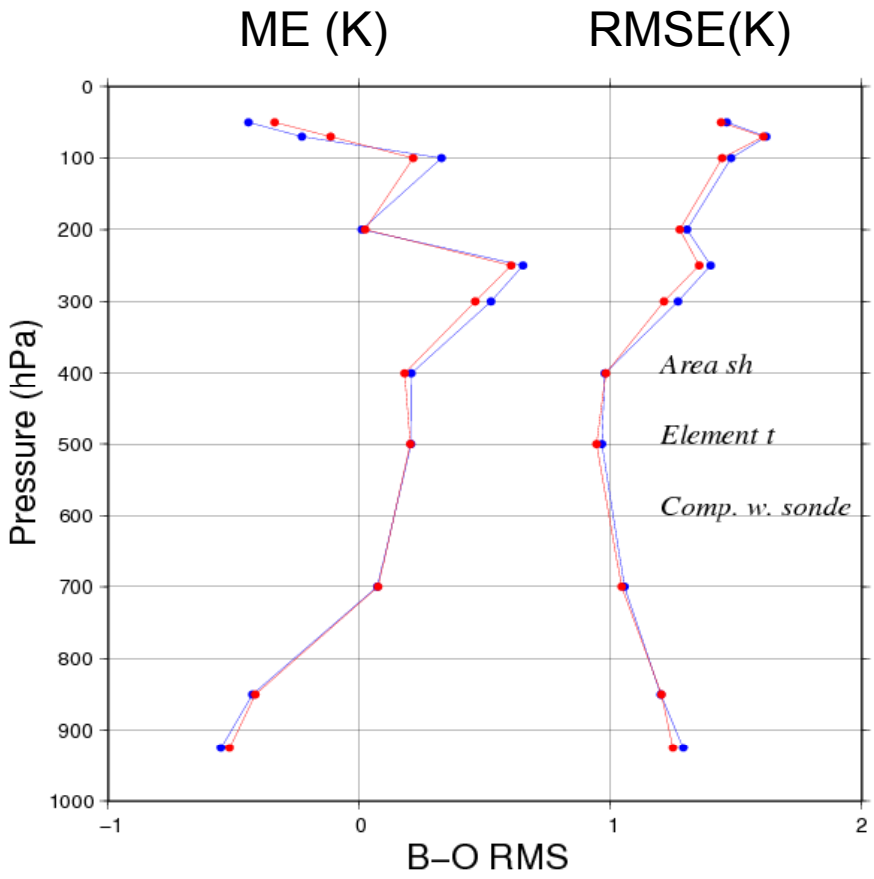


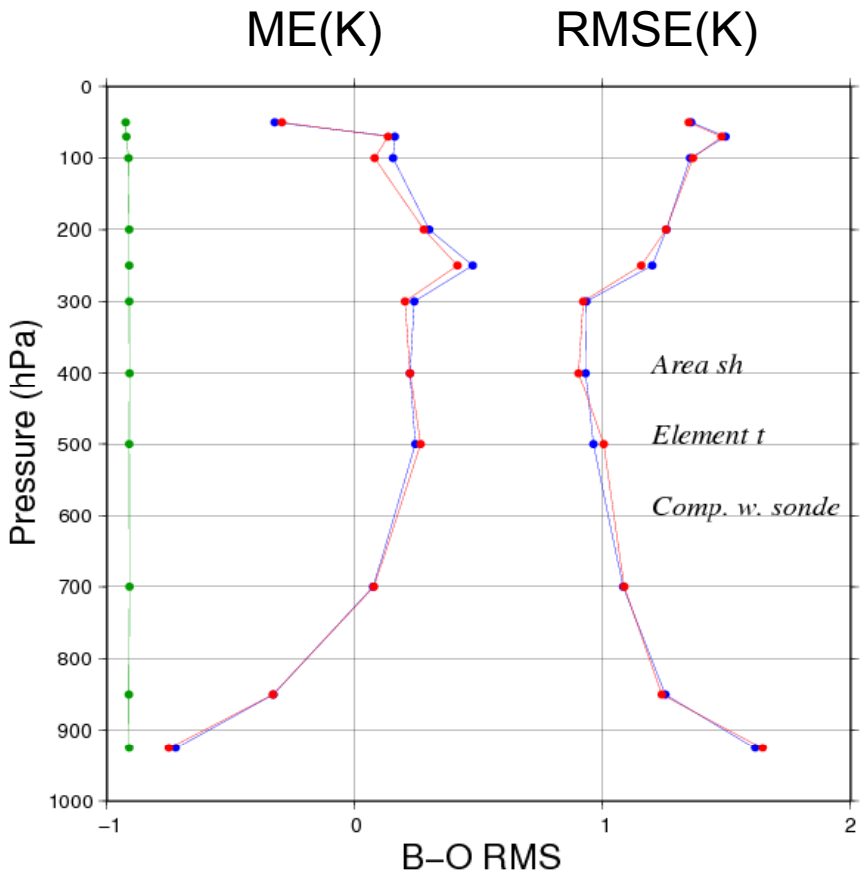
T(TEST)- T(CNTL) at 300hPa



T(CNTL) at 300hPa

Comparison of first guess vs. radio sonde(SH,Temperature)





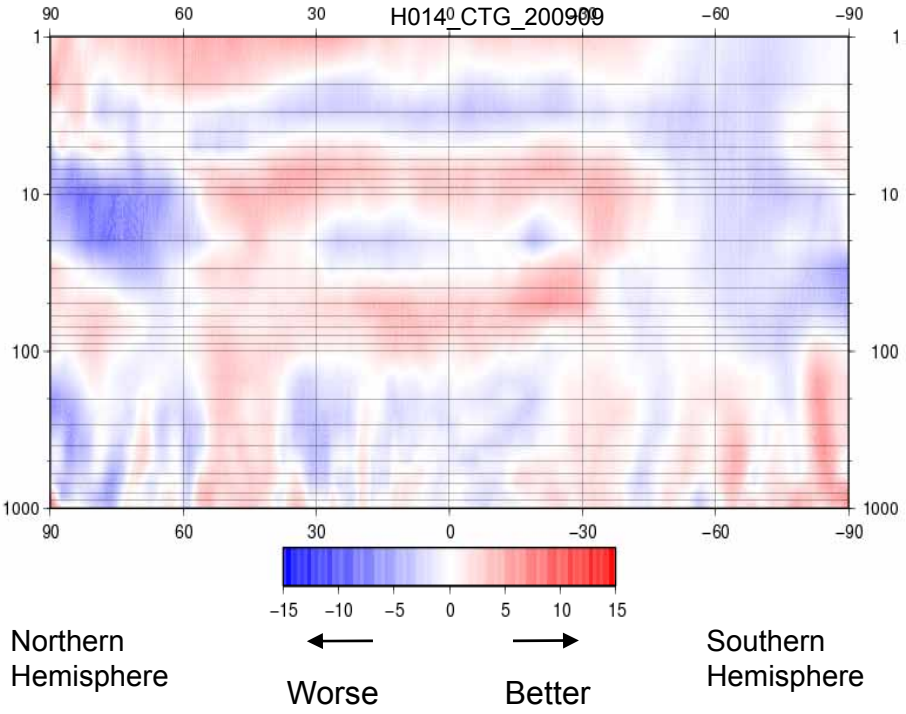
Summer experiment
Red: TEST with GPS
Blue: CNTL without GPS
H014_CTG_200909

Winter experiment
Red :TEST with GPS
Blue: CNTL without GPS
H014_CTG_200901

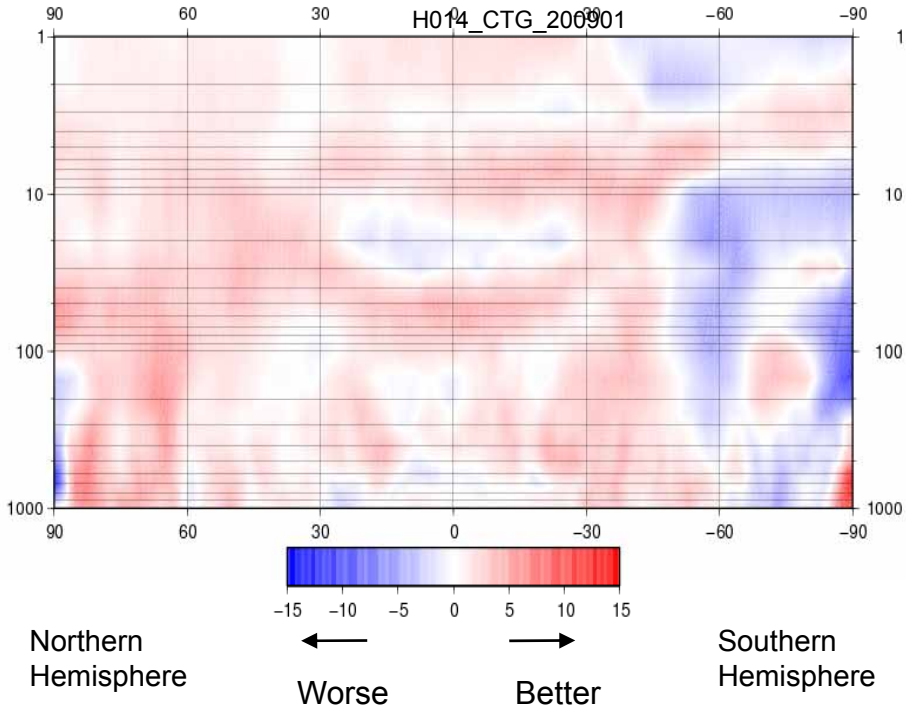
Improvement rate of zonal mean at FT=72

$$i\_rate = \frac{RMS(test) - RMS(cntl)}{RMS(cntl)} \quad \text{X100 (\%)}$$

Pressure [hPa]



Pressure [hPa]



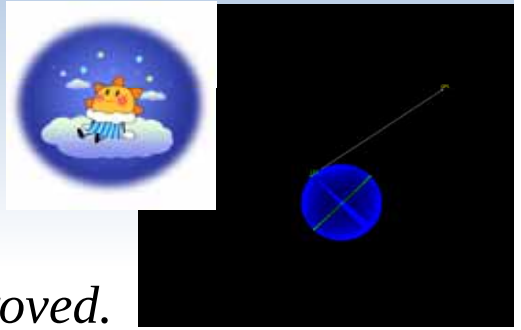
Latitude [deg.]

Summer experiment
TEST : with COSMIC
CNTL: without COSMIC

Winter experiment
TEST:with COSMIC
CNTL:without COSMIC

Red areas are wide compared with Blue areas.

Summary



- *Bias correction procedure is using now in our assimilation system. We will aim to remove this process in near future.*
- *In the GRACE and MetOp experiments, RMS scores of Winter Hemisphere against initial were improved.*
- *GRACE and MetOp data have been using in operation since November 30, 2009. (GRACE data stopped in December, 2009)*
- *In the COSMIC experiments, in the troposphere, forecast scores against the initial field improved in winter experiment, and neutral in summer experiment.*
- *In the COSMIC experiment, Typhoon track positional forecast errors are neutral in statistic from T0912 to T0919.*
- *COSMIC data will be used in operation from October 2010.*

We would like to thank GFZ for providing GRACE-A/BlackJack data, EUMETSAT for providing Metop-A/GRAS data, NSPO and UCAR for providing COSMIC data.