Assimilation of GNSS RO Data for The JMA Global Model

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Outline

- Operational NWP systems at JMA
- History on the use of GNSS RO data
- Current status of GNSS RO data assimilation
- Underway developments
  - Additional use of GRACE, TerraSAR-X and C/NOFS
  - Update of the quality control procedures
- Summary

Operational NWP systems at JMA

Model	Global Model & Analysis (GSM & GA)	Meso-scale Model & Analysis (MSM & MA)
Horizontal/vertical resolutions	TL959/60 (0.1hPa)	5km/50 (21.8km)
Forecast range (initial time)	84h (00,06,18UTC) 216h (12UTC)	15h (00,06,12,18UTC) 33h (03,09,15,21UTC)
Data assimilation (inner loop resolution)	4D-VAR (TL319)	4D-VAR (15km)
Assimilation window	6h (-3 to +3 hours)	3h (-3 to 0 hours)
Data cut off time	Early Analysis : 2h25m Cycle Analysis : 11h15m(00,12UTC), 5h15m(06,18UTC)	50m

GNSS RO data are assimilated.

As of March 2012

History on the use of GNSS RO data
in the JMA global analysis

Satellite	Period of operational use (Available for experimental use)	Current status of provided data
CHAMP	22 Mar. 2007 - 20 Nov. 2007	No dissemination
GRACE	30 Nov. 2009 - 04 Dec. 2009 (20 Dec. 2010 -)	Disseminated, but experimental use only
Metop-A	30 Nov. 2009 -	Operational use (refractivity)
COSMIC	01 Nov. 2010 -	
TerraSAR-X	(20 Dec. 2010 -)	Disseminated, but experimental use only
C/NOFS		
SAC-C	(20 Dec. 2010 – 2 Aug. 2011)	

As of March 2012

Current status of GNSS RO data assimilation

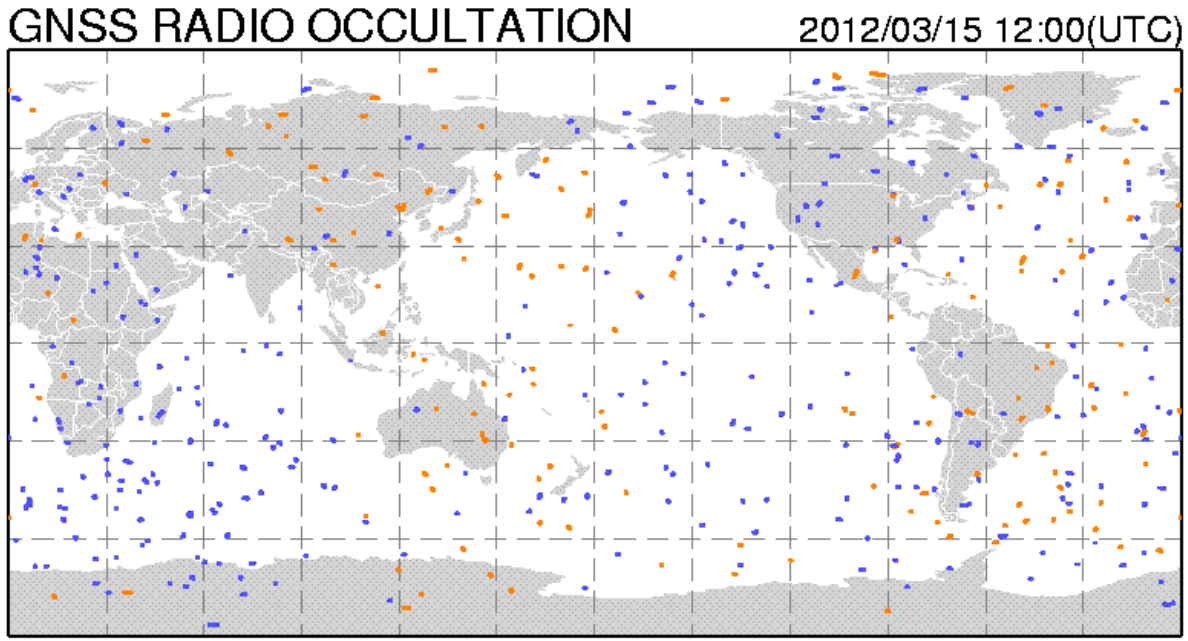
- Use of Metop-A and COSMIC data
- Assimilation of refractivity
- Implementation of bias correction procedure
- Data thinning and observation errors

Data coverage

- Metop-A and COSMIC refractivity data are assimilated in the JMA global analysis

Data availability (number of profiles provided per one cycle analysis)	
Metop-A	about **170** profiles
COSMIC	about **300** profiles

As of Mar. 2012



RO refractivity data assimilated in one cycle analysis

Assimilation of refractivity

- The JMA has been assimilating refractivity (*N*) from Metop-A and COSMIC
- A two-term expression (Smith and Weintraub, 1953) is used as the forward operator

where

$$N = 77.6\left(\frac{p}{T}\right) + 3.73\times10^{5}\left(\frac{p_w}{T^2}\right)$$

N : refractivity T : absolute temperature (K)

P : total pressure (dry and water vapor) (hPa)

P_w : pressure of water vapor (hPa)

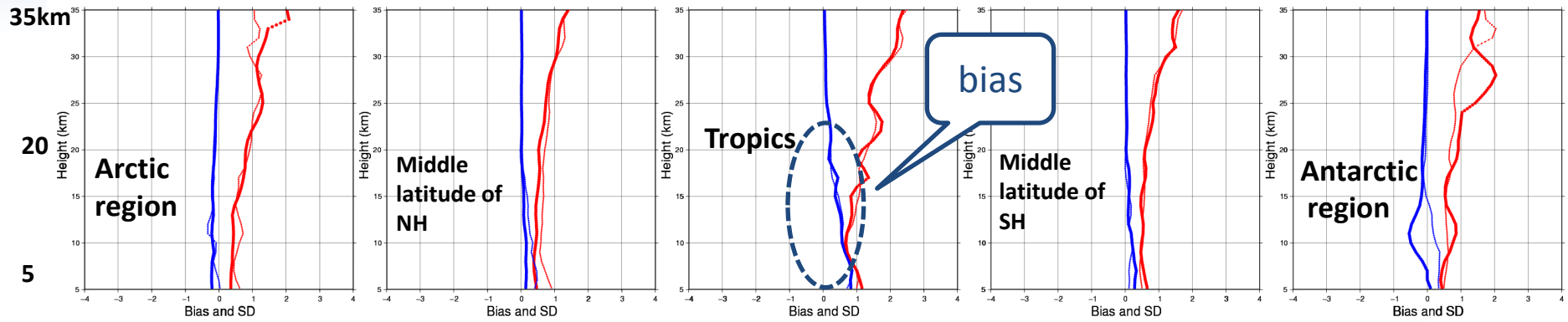
Implementation of bias correction

- The JMA has implemented the bias correction step as one of the quality control procedures because the results of experiments in which the bias correction was introduced showed the better improvements in forecast field than ones of no bias correction
- Kalman filter is used for the bias correction
  - The coefficients are set for each region and each satellite

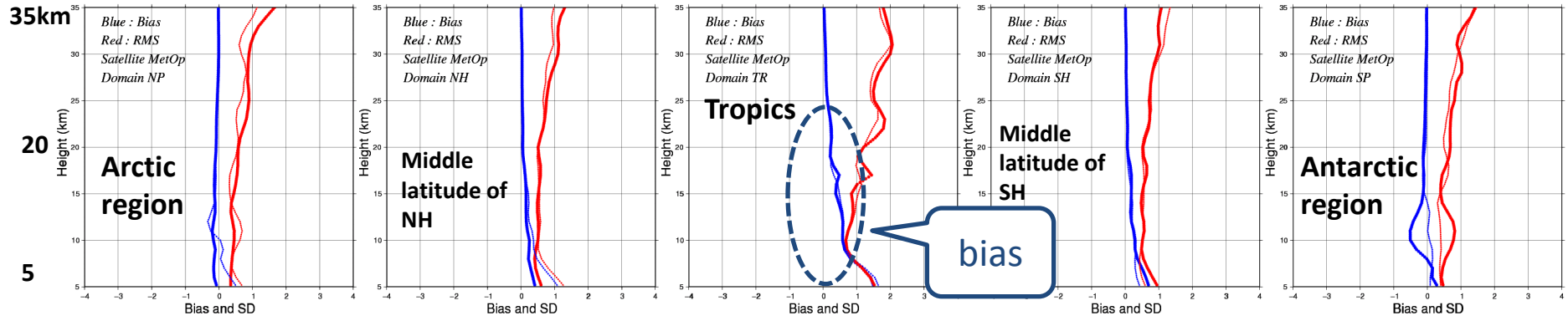
Regions for bias correction
1. Arctic region (90N-60N)
2. Northern Hemisphere (60N-20N)
3. Tropical region (20N-20S)
4. Southern Hemisphere (20S-60S)
5. Antarctic region (60S-90S)

Departures (O-Bs) at no bias correction

Blue : BIAS Red : Normalized RMSE(%) **Thin lines : Summer**, Thick lines : Winter



Metop-A (Statistics **Summer : Aug. 1-31 2008** , Winter : Jan. 1-31 2009)



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

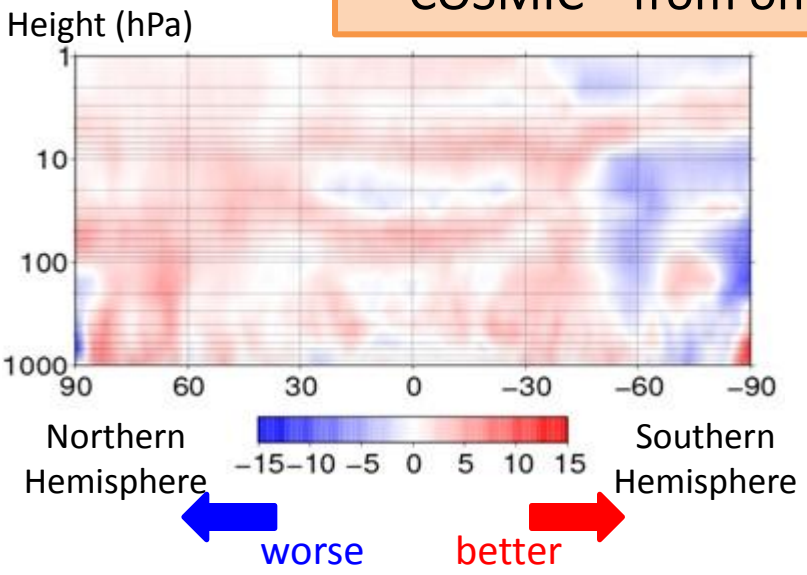
Data thinning and observation errors

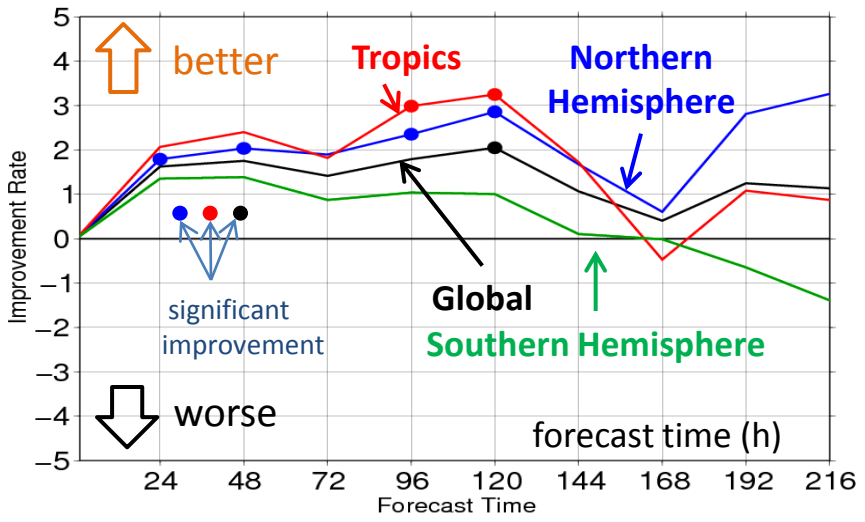
- Data thinning
  - Thinning is not considered for horizontal
  - Interval of vertical thinning is about 1000m for every profile
- Observation errors
  - The original settings are prepared for the specific periods, areas and heights for each satellite
  - Value of the observation error is calculated by interpolation from the original settings
  - Finally, the value is adjusted by multiplying it by 1.9

Impact of COSMIC data

- Results of the experiments performed for the operation showed that COSMIC data improved forecast fields especially in the tropical region

Improvement rate (%) of the forecast RMSE against "without COSMIC" from one month experiment for January 2009





Zonal averaged at 72 hour forecast
Target : geopotential height

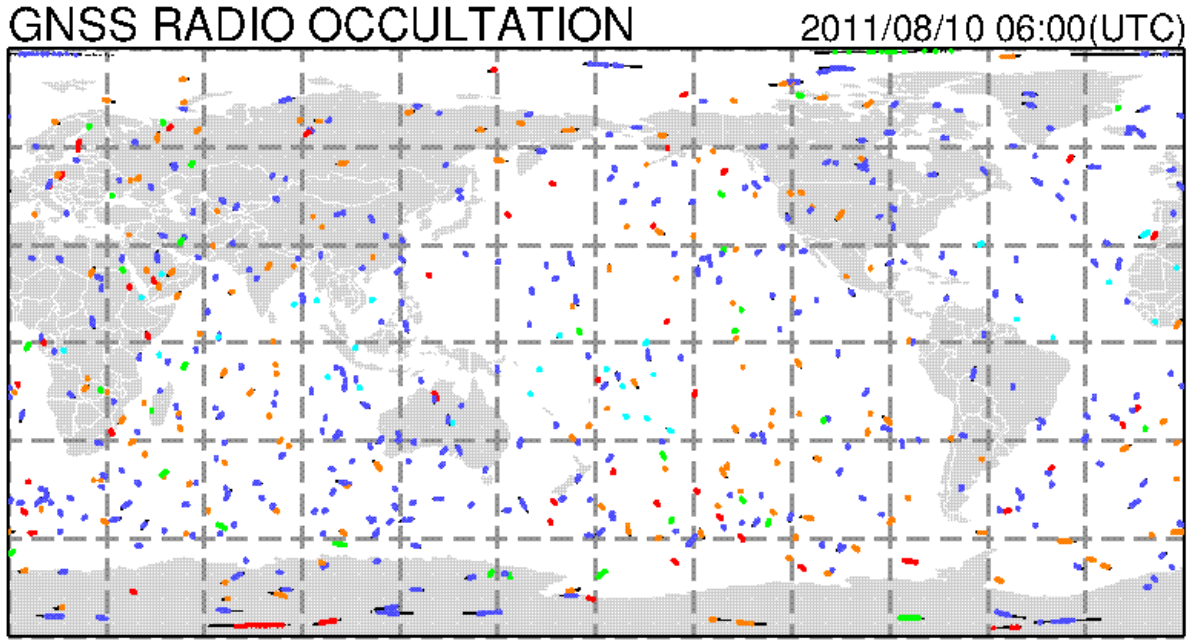
In each region and forecast time
Target : 500hPa geopotential height

Additional use of other satellites

Data coverage

- GRACE, TerraSAR-X and C/NOFS refractivity data are provided and available for additional use

Data availability (number of profiles provided per one cycle analysis)	
GRACE	about **20** profiles
TerraSAR-X	about **50** profiles
C/NOFS	about **30** profiles



RO refractivity data assimilated in one cycle analysis

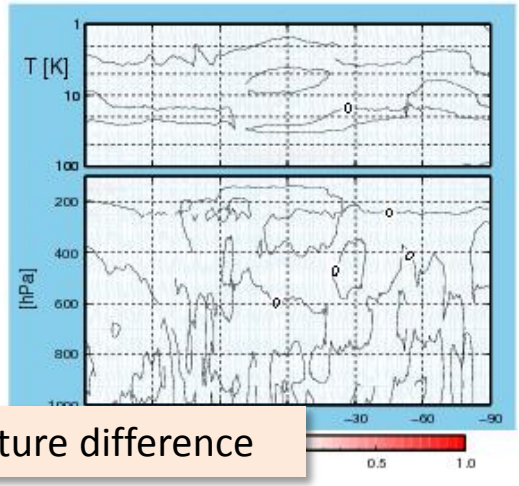
As of Mar. 2012

Additional use of other satellites

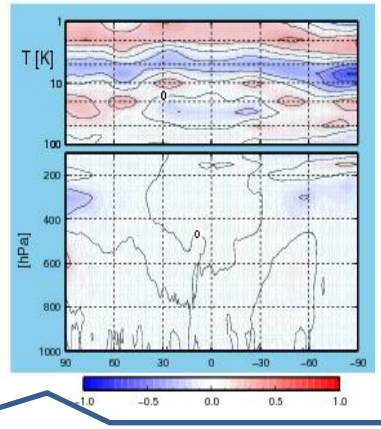
Results of experiments

- Some experiments were performed to see the effect of additional use of other satellites into the current operation
- The results of the experimental use showed a very few impacts in analysis fields

Impact into analysis field by additional use of other satellites from one month experiment for August 2011.



Zonal average of temperature difference



A same image at the experiment for introducing COSMIC data assimilation (for September 2009)

Additional use of other satellites

Current status

- It maybe acceptable to start the additional use of other satellites in operation because the results of the experiments were not worse
- But we have already found some problems in the current quality control procedures
- It will be more effective to start the additional use of other satellites after updating the quality control procedures

→ Additional use of other satellites are **not yet implemented** into the operation as of March 2012

Items to be updated in the current quality control procedures (1)

- Complicated observation error setting
  - Simple observation errors are prepared tentatively
  - They have been calculated based on the recent statistics of O-Bs. The validation is ongoing
- Easy gross error check
  - The current gross error check is simply to check the value of O-B itself. It doesn't work well and most of observations pass through it
  - To check normalized value (O-B)/O seems to be feasible for gross error check

Items to be updated in the current quality control procedures (2)

- Disregarding pressure's perturbation in tangent linear and adjoint operators
  - In the current operation, temperature and water vapor's perturbations are considered
  - The validation of new operators taking account of pressure's perturbation is ongoing
- Traditional forward operator
  - The validation of a three-term expression is ongoing. At first, the indices are from Bevis et al.(1994)

Items to be updated in the current quality control procedures (3)

- Bias correction
  - Results of a recent experiment for without bias correction showed some possibilities to eliminate bias correction
  - The results were not worse

Improvement rate (%) of the forecast RMSE from one month experiment ***without bias correction*** at 48 hour forecasts

Height (hPa)	2–day Forecast				2–day Forecast			
	GL	NH	TR	SH	GL	NH	TR	SH
1	–0.85	–1.50	–0.87	1.17	–0.66	–1.02	–0.03	–0.21
2	–0.72	–0.80	–0.14	–0.86	–0.06	–0.32	0.81	–0.85
3	–1.08	–0.68	–1.13	–3.05	–0.07	–0.39	0.78	–0.81
5	–1.02	–1.09	–0.45	–1.62	–0.30	–0.28	–0.29	–0.49
7	–0.30	–1.36	–0.04	2.68	–0.47	–0.12	–0.69	–0.83
10	0.43	–0.35	0.88	2.00	–0.53	–0.24	–0.43	–1.34
20	–2.24	0.66	0.74	–11.1	0.23	0.79	0.14	–0.83
	–1.55	0.14	0.58	–7.16	0.24	0.48	0.32	–0.42
50	0.77	0.92	0.18	1.85	0.27	0.23	0.58	–0.51
	0.66	0.90	0.58	0.37	0.44	0.34	0.68	0.05
100	–0.22	0.01	0.79	–1.99	0.36	0.46	0.54	–0.25
	–0.31	0.27	0.79	–1.80	0.34	0.36	0.68	–0.55
200	0.20	0.60	0.08	–0.23	0.31	0.46	0.49	–0.06
	0.07	0.44	0.26	–0.41	0.18	0.55	0.22	–0.16
300	–0.28	0.24	0.04	–0.92	0.16	0.46	0.28	–0.24
	–0.07	0.33	–0.23	–0.34	–0.09	0.14	0.07	–0.53
500	–0.09	0.27	0.22	–0.56	0.15	0.29	0.33	–0.20
	0.08	0.24	0.29	–0.25	0.20	0.29	0.23	–0.01
	0.26	0.35	0.48	–0.02	0.10	0.24	–0.12	0.08
850	0.12	0.24	–0.05	–0.03	0.29	0.36	0.32	0.15
	–0.02	0.15	–0.20	–0.29	0.37	0.32	0.53	0.30
1000	–0.11	0.03	–0.08	–0.44	0.27	0.33	0.27	0.16
	Temperature				Wind speed			

Summary

- Metop-A and COSMIC refractivity data are assimilated in JMA global analysis operationally
- GRACE, TerraSAR-X and C/NOFS observations have been available at the JMA since Dec. 2010
- The validations of some changes for improving the current quality control procedures are ongoing

We would like to thank GFZ for providing GRACE and TerraSAR-X data, EUMETSAT for Metop-A data, UCAR for C/NOFS data and NSPO and UCAR for COSMIC data.


BACKUP

References on refractive indices

- Smith, E. K. and S. Weintraub, 1953: The constants in the equation for atmospheric refractive index at radio frequencies. Proceedings of the I.R.E, 41, 1035-1037.
- Bevis, M., S. Businger, S. Criswell, T. Herring, R. Anthes, C. Rocken and R. Ware, 1994: GPS Meteorology: Mapping Zenith Wet Delays onto precipitable water. J. Appl. Meteor., 33, 379-386.