Assimilation of GNSS RO Data for The JMA Global Model

Hiromi Owada, Japan Meteorological Agency
howada@met.kishou.go.jp
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

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

**GNSS RO data are assimilated.**

As of March 2012
## History on the use of GNSS RO data in the JMA global analysis

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Period of operational use (Available for experimental use)</th>
<th>Current status of provided data</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAMP</td>
<td>22 Mar. 2007 - 20 Nov. 2007</td>
<td>No dissemination</td>
</tr>
<tr>
<td>GRACE</td>
<td>30 Nov. 2009 - 04 Dec. 2009</td>
<td>Disseminated, but experimental use only</td>
</tr>
<tr>
<td></td>
<td>(20 Dec. 2010 - )</td>
<td></td>
</tr>
<tr>
<td>Metop-A</td>
<td>30 Nov. 2009 -</td>
<td>Operational use (refractivity)</td>
</tr>
<tr>
<td>COSMIC</td>
<td>01 Nov. 2010 -</td>
<td></td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>(20 Dec. 2010 - )</td>
<td>Disseminated, but experimental use only</td>
</tr>
</tbody>
</table>

*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.

<table>
<thead>
<tr>
<th>Data availability (number of profiles provided per one cycle analysis)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metop-A</strong></td>
</tr>
<tr>
<td><strong>COSMIC</strong></td>
</tr>
</tbody>
</table>

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

\[
N = 77.6 \left( \frac{P}{T} \right) + 3.73 \times 10^5 \left( \frac{P_w}{T^2} \right)
\]

where

- $N$ : 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

35km
20
5
Arctic region
Middle latitude of NH
Tropics
Middle latitude of SH
Antarctic region

bias

35km
20
5
Arctic region
Middle latitude of NH
Tropics
Middle latitude of SH
Antarctic region


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)

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRACE</td>
<td>about 20</td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>about 50</td>
</tr>
<tr>
<td>C/NOFS</td>
<td>about 30</td>
</tr>
</tbody>
</table>

As of Mar. 2012

**RO refractivity data assimilated in one cycle analysis**
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

<table>
<thead>
<tr>
<th>Height (hPa)</th>
<th>2-day Forecast</th>
<th>Improvement rate (%) of the forecast RMSE from one month experiment without bias correction at 48 hour forecasts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GL</td>
<td>NH</td>
</tr>
<tr>
<td>1</td>
<td>-0.85</td>
<td>-1.50</td>
</tr>
<tr>
<td>2</td>
<td>-0.72</td>
<td>-0.80</td>
</tr>
<tr>
<td>3</td>
<td>-1.08</td>
<td>-0.66</td>
</tr>
<tr>
<td>5</td>
<td>-1.02</td>
<td>-1.09</td>
</tr>
<tr>
<td>7</td>
<td>-0.30</td>
<td>-1.36</td>
</tr>
<tr>
<td>10</td>
<td>0.43</td>
<td>-0.35</td>
</tr>
<tr>
<td>20</td>
<td>-2.24</td>
<td>0.66</td>
</tr>
<tr>
<td>50</td>
<td>0.77</td>
<td>0.92</td>
</tr>
<tr>
<td>100</td>
<td>0.66</td>
<td>0.90</td>
</tr>
<tr>
<td>200</td>
<td>-0.22</td>
<td>0.01</td>
</tr>
<tr>
<td>300</td>
<td>-0.31</td>
<td>0.27</td>
</tr>
<tr>
<td>500</td>
<td>0.20</td>
<td>0.60</td>
</tr>
<tr>
<td>850</td>
<td>0.07</td>
<td>0.44</td>
</tr>
<tr>
<td>1000</td>
<td>-0.28</td>
<td>0.24</td>
</tr>
</tbody>
</table>

- **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
