Microwave Radiance Assimilation in JMA/NWP and Expectations for GPM Mission

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Update on JMA/NWP models and DA systems

Major Forecast Models in JMA

<table>
<thead>
<tr>
<th>Year</th>
<th>GSM(T213)</th>
<th>GSM(TL319)</th>
<th>GSM(TL959)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY2002</td>
<td>60km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY2003</td>
<td></td>
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<td></td>
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<tr>
<td>FY2004</td>
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<tr>
<td>FY2005</td>
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<tr>
<td>FY2006</td>
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<tr>
<td>FY2007</td>
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<td></td>
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<tr>
<td>FY2008</td>
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<td></td>
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<tr>
<td>FY2009</td>
<td></td>
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<td></td>
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<tr>
<td>FY2010</td>
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</tbody>
</table>

Data Assimilation Systems

Objective Analysis for

- GSM
  - 3DVAR(T106)
  - (T63)
- RSM
  - OI
  - 4DVAR(40km)
- MSM
  - 4DVAR(20km)

Current Stage

HPC System Upgrade
Update on JMA/NWP models and DA systems

Global Model (GSM) and Mesoscale Model (MSM)

<table>
<thead>
<tr>
<th>Model</th>
<th>Global Model (GSM)</th>
<th>Meso-scale Model (MSM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal res.</td>
<td>20km</td>
<td>5km</td>
</tr>
<tr>
<td>Vertical res. (model top)</td>
<td>60 (0.1hPa)</td>
<td>50 (21.8km)</td>
</tr>
<tr>
<td>Forecast range (Initial time)</td>
<td>84h (00,06,18UTC)</td>
<td>15h (00,06,12,18UTC)</td>
</tr>
<tr>
<td></td>
<td>216h (12UTC)</td>
<td>33h (03,09,15,21UTC)</td>
</tr>
<tr>
<td>frequency</td>
<td>4/day</td>
<td>8/day</td>
</tr>
<tr>
<td>Target</td>
<td>• One-week forecast • Short-range forecast • Aeronautical forecast</td>
<td>• Disaster prevention information</td>
</tr>
<tr>
<td>Data Assimilation</td>
<td>4D-Var</td>
<td>4D-Var</td>
</tr>
</tbody>
</table>
Update on JMA/NWP models and DA systems

4D-Var data assimilation system for both GSM (since 2005) and MSM (since 2002) in JMA

Minimization of Cost Function $J$

$$J(x_0) = \frac{1}{2} (x_0 - x_0^b)^T B^{-1} (x_0 - x_0^b)$$
$$+ \sum_{k=0}^{N} \frac{1}{2} (H_k x_k - y_k^o)^T R_k^{-1} (H_k x_k - y_k^o)$$
$$+ J_c(x_0, \ldots, x_N)$$

$H_k$: Observation Operator (RTM for Microwave radiance data)
$B$: background error covariance matrix
$R_k$: observation error covariance matrix
$x_0^b$: Background
$y_k^o$: Observation (ex. Brightness Temperature)

Constrain from numerical model

$$x_{k+1} = M_k x_k \quad (k = 0, \ldots, N - 1)$$

$x_k$: Analysis variables
$M_k$: Forecast model
$N$: Number of time step

4D-Var data assimilation finds an optimized analysis field by using observations in the assimilation time window and numerical model constrain.

The analyzed field is used as initial field for the following numerical forecast.

An example of 4D-Var analysis of a one-dimensional field.
Current microwave radiance assimilation in JMA/NWP

- Microwave radiance data (radiances or/and retrievals) are essential for NWP system.
  Improvement the forecast of TC, rain distribution, geopotential height etc…

**Used data in GSM**
- AMSU-A/B radiance: Temperature & Moisture sounding information
- SSMI, TMI, AMSR-E radiance: Moisture (Column water vapor) information

An example of Microwave Imager data coverage

**Used data in MSM**
- Temperature profiles from AMSU-A
- TPW, rain rate from AMSR-E, TMI, SSMI
Microwave Imager data in GSM

- Assimilation of radiances from DMSP/SSMI, TRMM/TMI and Aqua/AMSR-E
  - Less cloud-affected radiances over the ocean with SST > 5 deg.C
  - Only vertical polarized channels at 19 – 89 GHz (to obtain moisture information)
  - VarBC corrects biases against analysis

- Impacts on analyses/forecasts
  - Better TCWV analysis verified against TRMM retrieved TCWV
  - Better precipitation forecasts: larger correlation between 1-day-forecast and GPCP (0.881 => 0.891 for Aug 2004)
  - Better typhoon track forecasts

Time sequence of TCWV RMSE and bias between analysis and TRMM retrieval

Start MWR radiance assimilation
Update on Radiative Transfer Model (RTM)
Fast RTM : RTTOV developed by EUMETSAT for satellite radiance data assimilation
Update from RTTOV-7 to RTTOV-8 in JMA global DA system
New Ocean Emissivity model (FASTEM-3) is available in RTTOV-8

Use of ocean surface wind speed information from MW radiances
Use of Wind speed Jacobian from RTM in the 4D-Var analysis

New microwave radiance data : DMSP-F16 SSMIS data
Extension of data coverage and additional temperature sounding information
Preliminary assimilation experiment results

- Single analysis study in JMA global 4D-Var system (AMSR-E radiance data + conventional data (including SeaWinds data)) using wind speed Jacobian from RTM
- Used AMSR-E channels: 6.9GHz(V,H), 10GHz(V,H), 19GHz(V,H), 23GHz(V), 37GHz(V,H), 89GHz(V)

Assimilation of AMSR-E radiance data adds some wind speed increments in data sparse area over the ocean

Data coverage of AMSR-E/Aqua (green) and SeaWinds/QuikSCAT (blue) in 6-hour assimilation time window in 00UTC 1 August, 2007
DMSP-F16 SSMIS data

DMSP-F16/SSMIS launched in Oct. 2003, and also F17 was launched in Nov. 2006. Recalibrated F-16 SSMIS data by UKMO and NESDIS are investigated for operational use in JMA.

QC passed Microwave Imager data coverage in 6 hour assimilation time window.

SSMIS/DMSP-F16 can fill the gap in the data coverage and additional temperature & moisture sounding channels are available.
Microwave Imager data coverage in MSM

SSMI-F13, SSMI-F14, TMI, AMSR-E (TPW, RAIN) and Rader AMeDaS (RAIN)

8 times/day for MSM 4D-Var data assimilation in JMA/NWP

Example: Nov. 23, 2007

No Microwave Imager data in the 21UTC analysis time window
Data Distribution Sample for MSM

In MSM 4D-Var analysis, the observations are divided in 6 time slots:

Example: 00UTC Nov. 30, 2007 MSM analysis

<table>
<thead>
<tr>
<th>Time (UTC)</th>
<th>Slot number in 6-hour time window</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>21</td>
<td>3</td>
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<td>23</td>
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</tr>
<tr>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>27</td>
<td>6</td>
</tr>
</tbody>
</table>

Actual data distribution in MSM model domain

SSMI/DMSP-F13,14

TMI/TRMM

SSMIS/DMSP-F16

The data distribution in 4D-Var time slot

JMA 4D-Var DA systems are ready for frequent satellite measurements
The operational time schedule imposes operational data assimilation system on rigid data cut-off

**Cutoff Time for Data Assimilation**

- **MSM:** Analysis Time +0:50
- **GSM – Early Analysis:** Analysis Time +2:25
- **GSM – Cycle Analysis:** Analysis Time +5:15 (06,18UTC) +11:15 (00,12UTC)

**Early delivery of the satellite measurement is important for the operational data utilization**
Expectations for GPM mission

- JMA/NWP requires more Microwave Radiance data in 4D-Var data assimilation system for GSM and MSM. GPM Microwave Imager (GMI) will be essential data to obtain moisture and sea surface wind speed information for JMA/NWP.

- Well calibrated radiance data and high quality retrievals (total column water and rain) are necessary to improve analysis and forecast accuracy in JMA/NWP.

- Data latency is important factor for the operational data use in NWP. Frequent measurements and timely data delivery are highly expected.