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China Meteorological Administration (CMA)

Dynamic Channel Selection for Microwave Temperature Sounding Channels in Cloudy Condition

AOMSUC-10, Melbourne, Australia
Dec. 4-6, 2019
Satellite data assimilation group in NSMC:

To prepare high quality satellite observations to assimilation
To develop fast radiative transfer model to FY satellite
To develop new pre-quality control to assimilation
To perform OSE & OSSE to new sensor of FY satellite

<table>
<thead>
<tr>
<th>Name</th>
<th>Task</th>
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<tbody>
<tr>
<td>Ma, Gang</td>
<td>fast model &amp; assimilation</td>
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<tr>
<td>Liu, Ruixia</td>
<td>analysis to 3D cloud condition</td>
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<tr>
<td>Bai, Wenguang</td>
<td>fast model (infrared)</td>
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<td>Guo, Yang</td>
<td>QC to microwave data</td>
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<tr>
<td>Liu, Hui</td>
<td>LBL &amp; retrieval profile</td>
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<td>Xi, Shuang</td>
<td>satellite data assimilation to regional model</td>
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<td>Zheng, Jing</td>
<td>assimilation to retrievals</td>
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<td>Xiao, Xianjuan</td>
<td>satellite data assimilation to high spectral infrared radiance</td>
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<td>Yu, Tianlei</td>
<td>assimilation to image radiance of FY satellite</td>
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<tr>
<td>Li, Xiaoqing</td>
<td>precipitation retrieval for MWRI</td>
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Outline

1. Overview
2. Look-up table for Dynamic Channel Selection
3. Impact to Assimilation
4. Impact to Simulation of a Typhoon case
5. Data Service
6. Further Study
7. Summary
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1. Overview

Courtesy: Stephen English, ECMWF
Operational ECMWF system September to December 2008. Averaged over all model layers and entire global atmosphere. % contribution of different observations to reduction in forecast error.

AMSU-A: Adv MW Sounder A on Aqua and NOAA POES (T)
IASI: IR Atmos Interferometer on METOP (T,H)
AIRS: Atmos IR Sounder on Aqua (T,H)
AIREP: Aircraft T, H, and winds
GPSRO: RO bending angles from COSMIC, METOP
TEMP: Radiosonde T, H, and winds
QuikSCAT: sfc winds over oceans
SYNOP: Sfc P over land and oceans, H, and winds over oceans
AMSU-B: Adv MW Sounder B on NOAA POES
GOES winds
METEOSAT winds
Ocean buoys (Sfc P, H and winds)
PILOT: Pilot balloons and wind profilers (winds)
HIRS: High-Resol IR Sounder on NOAA POES (T,H)
MSG: METEOSAT 2nd Generation IR rad (T,H)
MHS: MW humidity sounder on NOAA POES and METOP (H)
AMSRE: MW imager radiances (clouds and precip)
SSMI: Special Sensor MW Imager (H and sfc winds)
GMS: Japanese geostationary satellite winds
MODIS: Moderate Resolution Imaging Spectroradiometer (winds)
GOES IR rad (T,H)
MTSATIMG: Japanese geostationary sat vis and IR imagery
METEOSAT IR Rad (T,H)
O3: Ozone from satellites

Note:
1) Sounders on Polar Satellites reduce forecast error most
2) Results are relevant for other NWP Centers, including NWS/NCEP

Courtesy: Carla Cardinali and Sean Healy, ECMWF
Overview of FY-3 Satellite

FY-3C (SSO, AM)  
Launched on September 23, 2013

FY-3A (SSO, AM)  
Launched on May 27, 2008

FY-3B (SSO, PM)  
Launched on November 5, 2010

FY-3D (SSO, PM)  
Ready to launch (November, 2017)

FY-3E (SSO, Early-morning)  
Being manufactured

Infrared Atmospheric Sounder (IRAS)  
20 channels (~HIRS/3)
HIRAS(1370 channels)

Microwave Temperature Sounder (MWTS)  
4 channel (~MSU)  
13 channels  
17 channels

Microwave Humidity Sounder (MWHS)  
5 channel (~MHS)  
15 channels with channels at 118 GHz

FY-3RM (Inclined orbit)  
Being manufactured

FY-3RM (Inclined orbit)  
Being manufactured

Microwave Radiation Imager  
10 channels (~AMSR-E)
WindRAD C, Ku HH, VV

GNSS Radio-Occultation Sounder (GNOS)  
(~GPS)
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<table>
<thead>
<tr>
<th>MWTSII</th>
<th>AMSU-A</th>
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<tbody>
<tr>
<td>Central Freq.(GHz)</td>
<td>Central Freq(GHz)</td>
</tr>
<tr>
<td>1</td>
<td><strong>23.8</strong></td>
</tr>
<tr>
<td>2</td>
<td><strong>31.4</strong></td>
</tr>
<tr>
<td>3</td>
<td>50.3</td>
</tr>
<tr>
<td>4</td>
<td>51.76</td>
</tr>
<tr>
<td>5</td>
<td>52.8</td>
</tr>
<tr>
<td>6</td>
<td>53.596+/−0.115</td>
</tr>
<tr>
<td>7</td>
<td>54.4</td>
</tr>
<tr>
<td>8</td>
<td>54.94</td>
</tr>
<tr>
<td>9</td>
<td>55.5</td>
</tr>
<tr>
<td>10</td>
<td>$f_0=57.29±0.344$</td>
</tr>
<tr>
<td>11</td>
<td>$f_0±0.217$</td>
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<tr>
<td>12</td>
<td>$f_0±0.3222±0.048$</td>
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<tr>
<td>13</td>
<td>$f_0±0.3222±0.022$</td>
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<tr>
<td>14</td>
<td>$f_0±0.3222±0.010$</td>
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<tr>
<td>15</td>
<td>$f_0±0.3222±0.045$</td>
</tr>
<tr>
<td>16</td>
<td><strong>89.0</strong></td>
</tr>
</tbody>
</table>

Scattering index (SI)

$$ETB_{15} = a + b*TB_1 + c*TB_2 + d*TB_3$$

$$SI = ETB_{15} - TB_{15}$$

Current precipitation detection

$$CLW = \sec \theta \left( D_0 + D_1 \cdot \log(285 - TB_1) + D_2 \cdot \log(285 - TB_2) \right)$$

$$CLW < 0.25g/kg$$
Visible reflection is screened by cloud top,
Microwave radiance is scattered by particles of precipitation

Inference:
1. **Visible cloud cover must be no less than microwave precipitation area**
2. **Visible cloud top height must be no lower than height of microwave precipitation**
Impact to brightness temperature (Jabobian)

Emission by cloud liquid water

- 52.8GHz
- 53.6GHz
- 54.4GHz
- 54.94GHz
- 55.5GHz
- 57.29GHz

Jacobian

Pressure (hPa)

Weighting Function

Pressure (hPa)
\[ N_{\text{max}} = \sum_{j=1}^{k} N_j \]
Cloud top height in MERSI foot-points (left) & unified cloud top height in MWTSII foot-point (right)
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# Experiments Design

### MWTS-Ⅱ QC

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1.</td>
<td>Var BC</td>
</tr>
<tr>
<td>2.</td>
<td>tossed data with mixed surface type</td>
</tr>
<tr>
<td>3.</td>
<td>Tossed 8 pixels at edge of a scan line</td>
</tr>
<tr>
<td>4.</td>
<td>Tossed data containmented by precipitation</td>
</tr>
<tr>
<td>5.</td>
<td>Data were analysed over ocean</td>
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</table>

### Experiments approach – single moment

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>CTRL</td>
<td>Cloud cover &gt;0.76, radiance were tossed to channel 5,6,7 (Li2016)</td>
</tr>
<tr>
<td>DCD_005</td>
<td>Look up table with 0.05K to $L_{i\text{tot.clr}} - L_{i\text{tot}}$</td>
</tr>
<tr>
<td>DCD_010</td>
<td>Look up table with 0.1K to $L_{i\text{tot.clr}} - L_{i\text{tot}}$</td>
</tr>
<tr>
<td>DCD_020</td>
<td>Look up table with 0.1K to</td>
</tr>
</tbody>
</table>

### Experiments approach – analysis with 10 days data

<p>| | |</p>
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<tbody>
<tr>
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</tr>
<tr>
<td>DCD_020</td>
<td>Look up table with 0.1K to</td>
</tr>
</tbody>
</table>
Volumes of MWTSII observations to channels 5, 6, 7 increased 2 times as the dynamic channel selection was used.
MWTSII data used in assimilation in 4 experiments
– single moment

Channel 5

MWTSII data used in assimilation in 4 experiments
– single moment

Channel 5
In clouds area

- More observations in cloud area
- More observations in upper atmosphere
- O-B < 0.8K
- CLW > 1.0g/kg
O-B to single moment experiment

Invisible increments for all channels
O-B to control (right) & to DCD_005 at 2018121006 (left)
Experiments with 10 days’ data

ch5

ch6

ch7
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Experiment approach

- Assimilation in D01 with 3hr window
- 4 assimilation from 080606 per 6 hr

- noDA : no assimilation
- Sound: only sounding assimilated
- CTRL : traditional QC in assimilation
- DCD : dynamic channel selection used

- Smallest track error
- More impact to track error than CTRL
- No obvious impact to MSLP & MWP
Distribution to MWTSII observations in assimilation
Horizontal compare to FNL

-080706

180hPa (MWTSII ch 7)
Vertical compare to FNL - 080706

180hPa (MWTSII ch 7)
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1. Responsible Organizations

Leading organization (if any): China Meteorological Administration (CMA).

Participating organization(s): the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).

2. Requirements and Purposes

The VASS (Vertical Atmospheric Sounding System) is a sounding instrument package loaded on FY-3 (A, B, C) satellite series. CMA is preparing to disseminate VASS products of FY-3 in BUFR on GTS. A proposal of new BUFR entries to represent VASS products was submitted as item 2.4(3) to IPET-CM-1 meeting (Geneva, 24-28 July 2017) and was approved for validation during the meeting.

**TABLE - REFERENCES**

<table>
<thead>
<tr>
<th>TABLE - REFERENCES</th>
<th>ELEMENT NAME</th>
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**BUFR test files encoded by CMA:**

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<tr>
<th>YYMDD</th>
<th>bbbm</th>
<th>File name</th>
<th>Numbers of Scan Line</th>
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</table>

(Hhttp://www.wmo.int/pages/prog/www/WMO306_y12/LatestVERSION/LatestVERSION.html)
Delays to MWHSII FY-3C in GTS

2017

Direct Broadcast

All global data arrive after cut-off time

Latency to long curve MWHSII
Delays to MWHSII FY-3C in GTS

FY-3D data are going to be delivered by GTS
Outline

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7. Summary
• Strong non-linear interaction between visible cloud & microwave precipitation can not be used by a linear regression
• Strong non-linear deep learning could be used in the non-linear interaction
5. Summary

◆ Missing channels in MWTSII taking a new precipitation detection

◆ Visible/infrared cloud features being used as temporary precipitation detection

◆ Dynamic channel selection being carried out by fused visible/infrared cloud top height to MWTSII channels 5, 6, 7

◆ More observation being introduced into assimilation with unchanged O-B

◆ More impact to track error than CTRL but no obvious impact to MSLP & MWP as dynamic channel selection used

◆ Visible/infrared cloud features being integrated into a data set and being delivered to NWP users by GTS

◆ Further study to relationship to visible cloud features and microwave precipitation detection by deep learning
Make the data better and easier to use!