The FY-3C evaluation project: microwave sounder calibration and direct broadcast experiences

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Qifeng Lu (CMA/NSMC)
Contents:

- Direct broadcast – experiences since ITSC-19
- Current status of FY-3C
- Evaluation of the microwave sounders
Approach to the FY-3C evaluation

• The post-launch evaluation of the FY-3C sounders was a collaborative effort:
  - CMA/NSMC (Qifeng Lu and colleagues)
  - ECMWF (Niels Bormann, Heather Lawrence, Steve English)
  - Met Office (Bill Bell, Katie Lean, Nigel Atkinson, Fabien Carminati)

• Two main strands:
  - Global data in NWP (covered by other talks)
  - Detailed assessment of the calibration – including use of DB data (this talk)

• Emphasis initially on the microwave sounders
  - Making use of previous experience with AMSU, MHS, etc.
Status at ITSC-19 (March 2014)

• First release of the DB package for FY-3C was during the conference

• Action PSWG-1: Test the FY-3C software and report back to the PSWG members

(Nigel Atkinson and Liam Gumley)

http://satellite.cma.gov.cn/portalsite/default.aspx
Initial findings

- L-band data rate has changed for FY-3C: 4.2 → 3.9 Mbps
- X-band (for MERSI) polarisation changed RHCP → LHCP
  - These were a surprise (not announced by CMA in advance) and resulted in some delay to acquisition of data. (June 2014 at MetO)
  - The polarisation is still an issue at some stations (WMO are trying to find out which DBNet stations are affected)
- Installing and running the DB package
  - Distributed as binaries
  - Easy to install on Linux
  - Needs 64-bit platform (issue for some applications e.g. MEOS polar)
  - Processing implemented for MWTS-2, MWHS-2, IRAS, VIRR, MERSI
  - Runs OK, and quickly (~15 seconds)
  - Sometimes there is a lack of diagnostic information – e.g. initial problem with MWTS processing giving segmentation fault – eventually discovered that this was because the scan rate had been changed 2.667 → 5.23 seconds
<table>
<thead>
<tr>
<th>Date</th>
<th>Version</th>
<th>Main Reason</th>
<th>Any problems?</th>
</tr>
</thead>
<tbody>
<tr>
<td>31/3/2014</td>
<td>FY3CL0pp.1.0.0</td>
<td>Initial</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>FY3CL1pp.1.0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>02/7/2014</td>
<td>FY3CL1pp.1.1.0</td>
<td>Update MWTS-2 scan rate</td>
<td>FY3C_MWHS_QC.XCONF needed modifying – to make the file bigger (weird)</td>
</tr>
<tr>
<td>15/1/2015</td>
<td>FY3CL1pp.1.1.2 with patch 1</td>
<td>Modified MWTS-2 calibration method (nonlinearity; treatment of calibration samples; land/sea sensitivity correction)</td>
<td>Path for new MWTS-2 data files had been hard-coded. Solution at MetO was to modify the binary.</td>
</tr>
<tr>
<td>06/2/2015</td>
<td>Patch 2</td>
<td>MWHS-2 bug fixes (wrong cal target, wrong nonlinearity coefs for some channels)</td>
<td>-</td>
</tr>
<tr>
<td>27/8/2015</td>
<td>Patch 3</td>
<td>MWHS-2 antenna correction implemented</td>
<td>Long wait – this change was implemented for global data on 16th March.</td>
</tr>
</tbody>
</table>
Timeline of significant events

FY-3C launch 23 Sept 2013

First release of DB package, with test data: end March 2014

MWTS-2 antenna rotation rate halved May 2014, following scan problems

Data available on CMA Portal: mid June 2014

Data distributed on EUMETCast in near real time: September 2014

MWTS-2 processing changes in Jan 2015

MWHS-2 processing changes in early Feb 2015

MWHS-2 antenna correction implemented in global data March 2015

MWTS-2 scan anomalies starting 17th Feb 2015 – no global data after that

FY-3C loss of all data from 31st May 2015 – power supply anomaly

FY-3C services resumed 30th July 2015, for MWHS-2, IRAS, MWRI, VIRR, GNOS, including partial L-band DB – not MWTS-2 or MERSI (no X-band DB)

FY-3D launch – late 2016?
## Summary of current FY-3C status
(start with the conclusions ... more detail later)

<table>
<thead>
<tr>
<th>Instrument or system</th>
<th>Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>MWHS-2</td>
<td>✓</td>
<td>Included in new EARS-VASS service. Variable bias – needs VarBC.</td>
</tr>
<tr>
<td>MWTS-2</td>
<td>✗</td>
<td>Scan mechanism problems; calibration uncertainties; inter-channel interference</td>
</tr>
<tr>
<td>IRAS</td>
<td>✓</td>
<td>Included in new EARS-VASS. Last instrument of its type.</td>
</tr>
<tr>
<td>MWRI</td>
<td>✓</td>
<td>MetO plans to evaluate in 2016. Not currently in DB package – <em>would benefit regional NWP?</em> Larger instrument planned for FY-3D</td>
</tr>
<tr>
<td>VIRR</td>
<td>✓</td>
<td>Last instrument of its type (AVHRR-like)</td>
</tr>
<tr>
<td>MERSEI</td>
<td>✗</td>
<td>Was working prior to power problems</td>
</tr>
<tr>
<td>GNOS</td>
<td>✓</td>
<td>Under evaluation. NRT data distribution not clear.</td>
</tr>
<tr>
<td>L-band DB</td>
<td>partial</td>
<td>Some passes over Europe (to support Kiruna ground station)</td>
</tr>
<tr>
<td>X-band DB</td>
<td>✗</td>
<td>Not operating (to save power)</td>
</tr>
</tbody>
</table>
EARS-VASS service
MWHS and IRAS: 5 core EARS stations

Ascending (night)  Descending (day)

L-band Transmission stops
Approach to the calibration assessment for microwave sounders

- The **OBC files** (available from direct broadcast) contain all the raw counts.
- The DB package includes **text files** giving external parameters.
- Try to replicate the CMA calibration using external software (which we understand well).
- Also compared results with those of CMA scientists.
  - During Visiting Scientist mission by NCA June 2015.
Calibration for MWHS-2 and MWTS-2

Based on the widely-used formulation used for AMSU-A and MHS

\[ R = R_{BB} + \frac{(X - X_{BB})}{G} + Q \]

Linear calibration plus quadratic correction

\[ G = \frac{(X_{BB} - X_{SP})}{(R_{BB} - R_{SP})} \]

Gain computed from cold/warm views

\[ Q = \mu \frac{(X - X_{BB})(X - X_{SP})}{G^2} \]

Quadratic coefficient, \( \mu \) determined pre-launch

Nonlinearity exaggerated in the diagram!

Shows \( \mu < 0 \)
Calibration parameters determined pre-launch

- Nonlinearity correction, $\mu$
- Warm target bias (PRT measurement error), $\Delta T_W$
- Cold space bias (antenna sidelobes viewing earth/satellite), $\Delta T_C$
- Contamination of earth view by cold space (antenna pattern correction), $\Delta T_i (i = 1, 98)$

These rely on measurements – and modelling – made by the manufacturer

- Requires close dialogue between manufacturer and instrument evaluation team
- Not always achieved in practice!
Example: MWTS-2 nonlinearity

- The plots show the original nonlinearity correction (solid) and a later Jan 2015 update (dotted, cubic form)
- Clearly very different, and both are much larger than expected
- How to determine which is “right”?

Red lines show normal range of BTs for each channel
O-B investigation for MWTS-2

- Looked at the tradeoff between nonlinearity and antenna correction

Original (2014) nonlinearity coef: Negative bias of 3.5K

Try to adjust $\mu$ and $\Delta T_i$ to remove bias
1. CMA’s “new” nonlinearity (cubic): has corrected the bias but introduced a slope.

2. Nonlinearity set to zero, and antenna correction increased: has also corrected the bias; slope reduced.

A 0.8% contribution from cold space is not unreasonable (c.f. AMSU-A)
• In principle we could estimate antenna corrections for all channels in this way
  ➢ Which is effectively what NWP bias correction does

• But better to use pre-launch measured antenna pattern, if these measurements are available – and reliable

• Due to failure of MWTS-2 instrument on FY-3C we haven’t pursued this study – but need to get it right for FY-3D

• There were also some problems with the software implementation – again, parked for now
Ch 5, 6, 7 and 8 display unphysical temp depressions over land
These channels are not supposed to be surface sensitive
anti-correlation with ch 1 – interference?
We formulated an empirical fix – subsequently adopted by CMA in their global processor
Empirical correction

\[ \text{BT}_{j} \text{ (corr)} = \text{BT}_{j} + k(\text{BT}_1 - \text{BT}_j) \]

\[ k = 0.013 \text{ for channel 6} \]

Window channel  
Sounding channel
Cause?

- We discussed this phenomenon with the MWTS-2 manufacturer, but no convincing explanation has been found – yet

- Looked at things like RF leakage

- Not easy to detect during pre-launch testing – because all channels view the same calibration target

  Lesson for other missions
What about MWHS-2?

- A similar exercise was carried out for MWHS-2 – checking the calibration against independent software
- This looked good (a few bugs were fixed in the Jan 2015 update)
- Also, the global and DB package brightness temperatures are now consistent (since 27 Aug 2015)

**BT Chan 11**

(183±1)  

Local minus global  
Consistent to <0.01K
Bias changes

- ECMWF monitoring: channel 13 (183±3 GHz)

What happened here? (This was a processing change – OK)

Also in September
Bias changes (cont.)

- Bias is sensitive to instrument (platform) temperature – especially humidity channels

After sudden 2K drop in instrument temperature when MWTS-2 was powered off.

After prolonged outage due to power problems. Instrument temp is ~3.5K colder than before the outage.

After sudden 2K drop in instrument temperature when MWTS-2 was powered off.
Bias changes: cal counts check

Channels 13 & 14:

- Slight increase in warm & cold counts when cal target temp (and instr temp) dropped by 2K
- Implies gain increase (5%)
- But why does that introduce a ~1K bias shift?
- Unexplained!
- Note the rather large orbital variations (larger than AMSU/MHS)
Conclusions on FY-3C

- MWHS-2 has potential, but needs VarBC to handle unexplained bias changes.

- MWTS-2 had some problems (when it was operating):
  - Reliability of scan mechanism.
  - Root cause of land-sea anomaly?
  - Some calibration parameters are unclear (e.g. nonlinearity; antenna correction)

- Met Office plans to look at MWRI in 2016. Not currently part of the DB package, but we understand that CMA might be willing to add it.
  - Would a request from ITWG help? Could be considered in WGs.

- The DB package works well, and will form part of DBNet (more in the Technical Subgroup).

- Communication of changes to central processing is important

- Close dialogue with instrument manufacturers is essential, including pre-launch
Thank you for listening!

Questions?

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FY-3C introduction

Instruments relevant to NWP:

- MWHS-2 – microwave humidity sounder (also known as MWHTS and AMAS)
- MWTS-2 – microwave temperature sounder
- IRAS – infrared atmospheric sounder (FY-3C has the last one)
- MWRI – microwave radiation imager
- GNOS – GNSS radio occultation

Plus the imagers:

- VIRR and MERSI

Data available by direct broadcast (L-band for sounders and VIRR; X-band for MERSI)

Global sounder data distributed in NRT by EUMETSAT via EUMETCast
Direct broadcast characteristics

- From FY-3A/B Satellites to Ground Interface Control Document (updated for FY-3C, June 2014)

<table>
<thead>
<tr>
<th></th>
<th>FY-3A/3B</th>
<th>FY-3C</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-band data rate</td>
<td>4.2Mbps</td>
<td>3.9Mbps</td>
</tr>
<tr>
<td>L-band carrier freq</td>
<td>1704.50 MHz ± 34 kHz</td>
<td>1701.3 MHz</td>
</tr>
<tr>
<td>L-band polarisation</td>
<td>RHCP</td>
<td>RHCP</td>
</tr>
<tr>
<td>L-band width (zero)</td>
<td>5.6 MHz</td>
<td>5.2 MHz</td>
</tr>
<tr>
<td>X-band data rate</td>
<td>18.7 Mbps</td>
<td>18.7 Mbps</td>
</tr>
<tr>
<td>X-band carrier freq</td>
<td>7775.00 MHz ± 156 kHz</td>
<td>7780 MHz</td>
</tr>
<tr>
<td>X-band polarisation</td>
<td>RHCP</td>
<td>LHCP</td>
</tr>
<tr>
<td>X-band width (zero)</td>
<td>37.4 MHz</td>
<td>37.4 MHz</td>
</tr>
</tbody>
</table>

- We understand that FY-3D X-band will be RHCP and FY-3E likely to be LHCP, but to be confirmed

- For FY-3D, all instruments will be available on X-band. Likely increase in data rate. Not clear what the L-band will have.

- Only X-band for FY-3E