Monitoring the Data Quality and Stability of the FY-3 Sounders and Microwave Imager

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NSMC

Outline

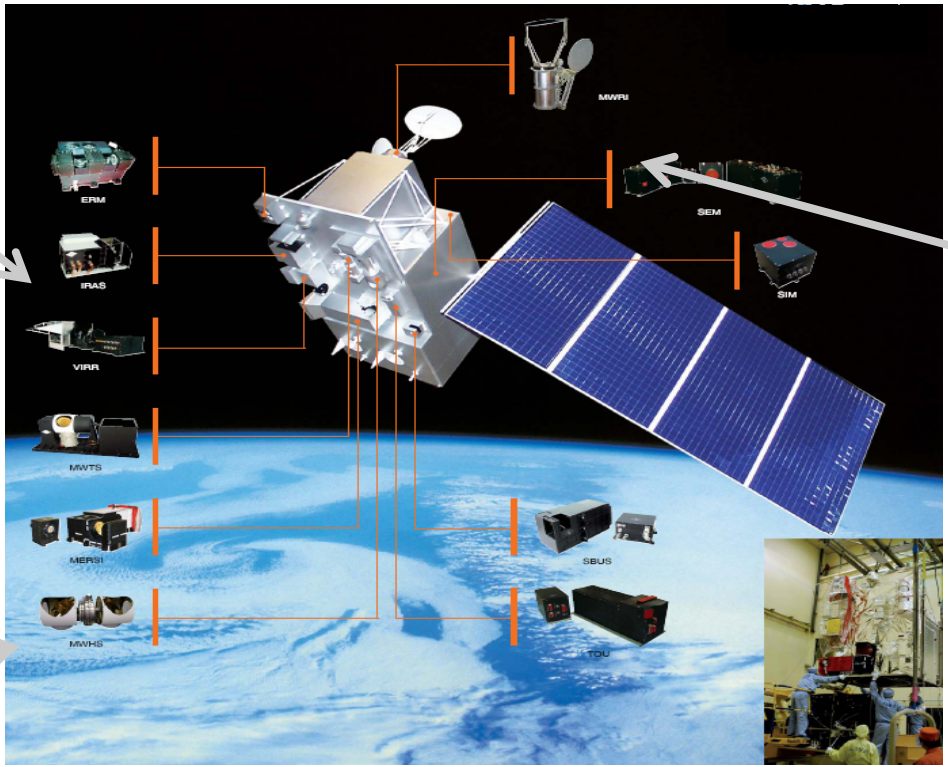
- Initial FY-3A data quality assessment at ECMWF
  - (OBS – Modelled T_B) for FY-3A & comparison with MetOp & Aqua
  - Initial Assimilation Experiments
- Characterising the FY-3A MWTS (Optimizer for Instrumental Parameters On-orbit)
  - Passband Uncertainties & Non-linearity Effects
  - Improved Assimilation of MWTS
  - Improved MSU/AMSUA
- Initial Assessment of FY-3B

The FY-3A/B Instrument Suite

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

Microwave Temperature Sounder (MWTS) 4 channel (~MSU)

Microwave Humidity Sounder (MWHS) 5 channel (~MHS)



Microwave Radiation Imager 10 channels (~AMSR-E)

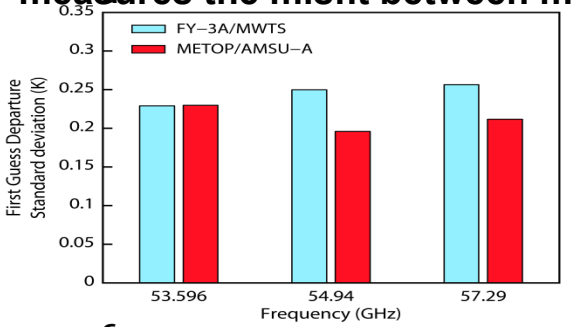
Initial Data Quality Assessment : General Approach

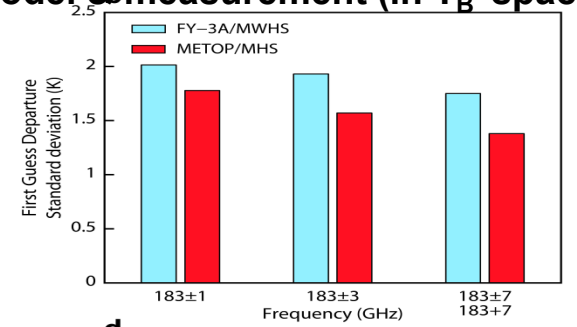
- Approach involves a comparison of observations (OBS) with simulated observations based on short range (up to T+9 hour) forecast fields ('First Guess', FG) and radiative transfer modelling → 'FG departures'
- FG is 'proxy' for truth 'FG departures' (OBS – FG) indicate error in the measurements or RT modelling
- High accuracy of the NWP fields results from the large & diverse range of observations assimilated (MW sounders, Advanced IR sounders, GPSRO, radiosondes … etc)
- Able to detect biases at ~0.1K level for temperature sounders (MWTS and IRAS), sensitivity slightly lower for MW humidity sounders & imagers (~0.5K)
- Similar work ongoing at NOAA/NCEP, UK Met Office, DWD and JMA

Initial Data Quality Assessment at ECMWF: Comparison of FY-3A with MetOp & Aqua

STDEV (first guess departures):
measures the misfit between model & measurement (in T_B space)

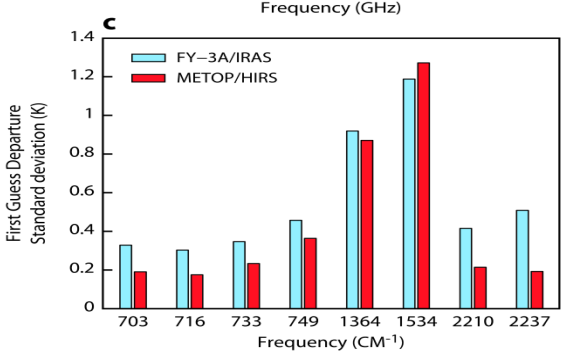
Microwave Temperature Sounder

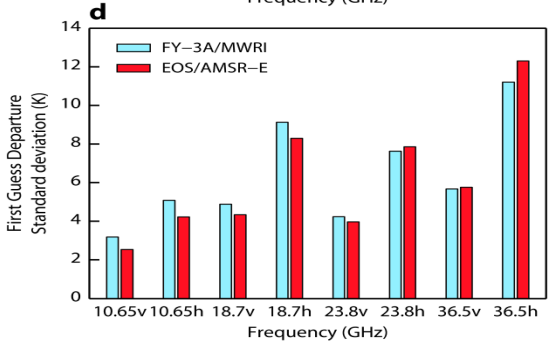




Microwave Humidity Sounder

Infrared Sounder

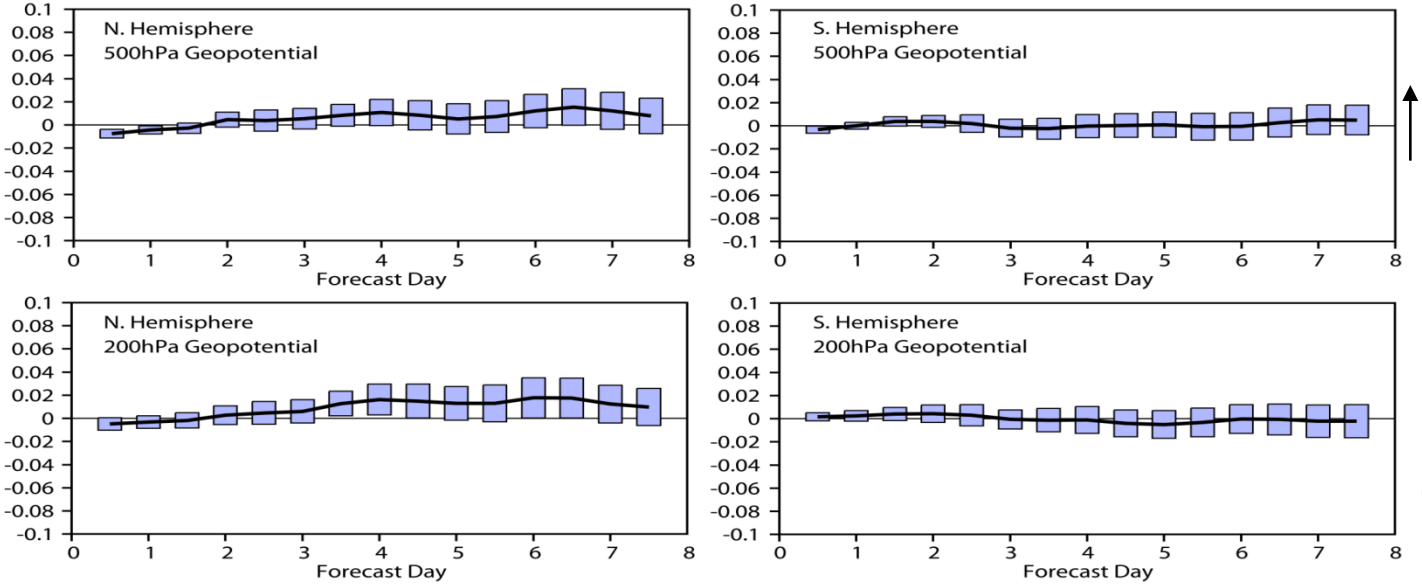




Microwave Imager

FY-3A data quality is comparable with MetOp/Aqua equivalents

Initial Data Quality Assessment at ECMWF: Assimilation Experiments



positive impact from FY-3A

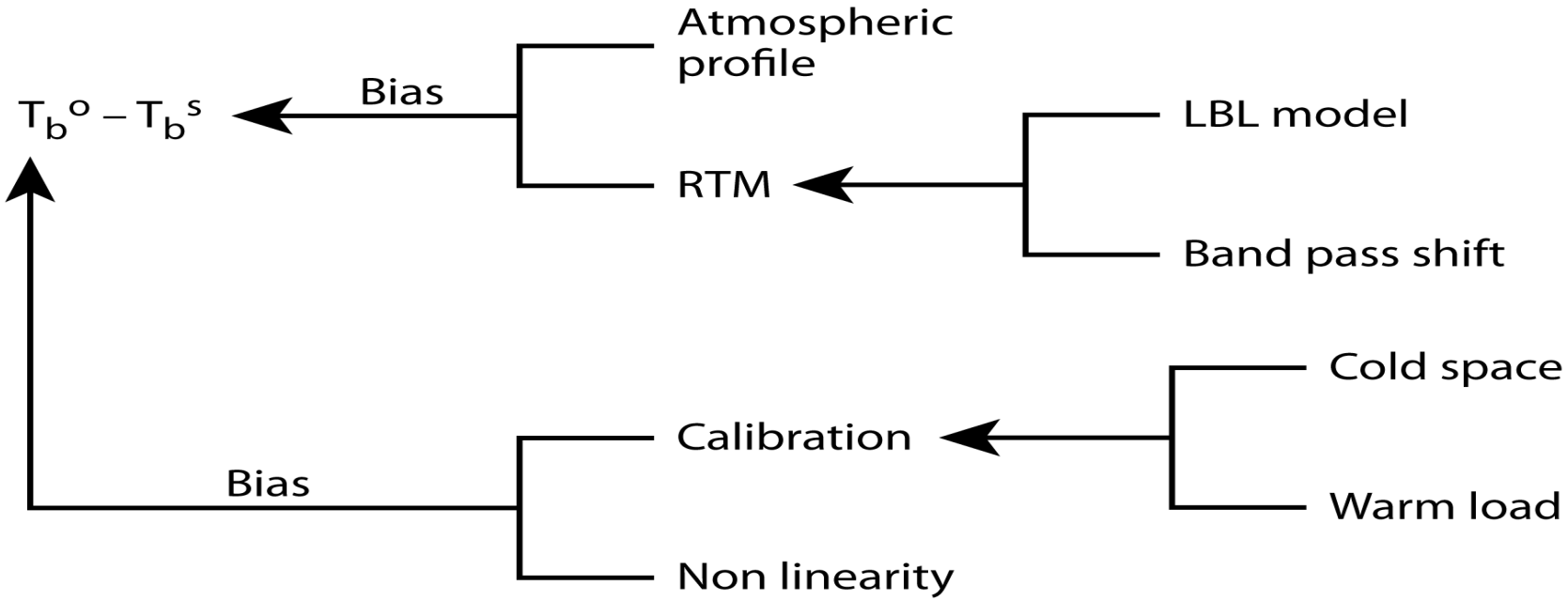
Full System OSEs:
Full System + FY-3A VASS suite (MWTS, MWHS, IRAS)
T511, 3 month experiment

The impact of the FY-3A data is :

- **neutral in SH**
- **slightly positive in the NH**

Characterize the MWTS

Schematic of error terms



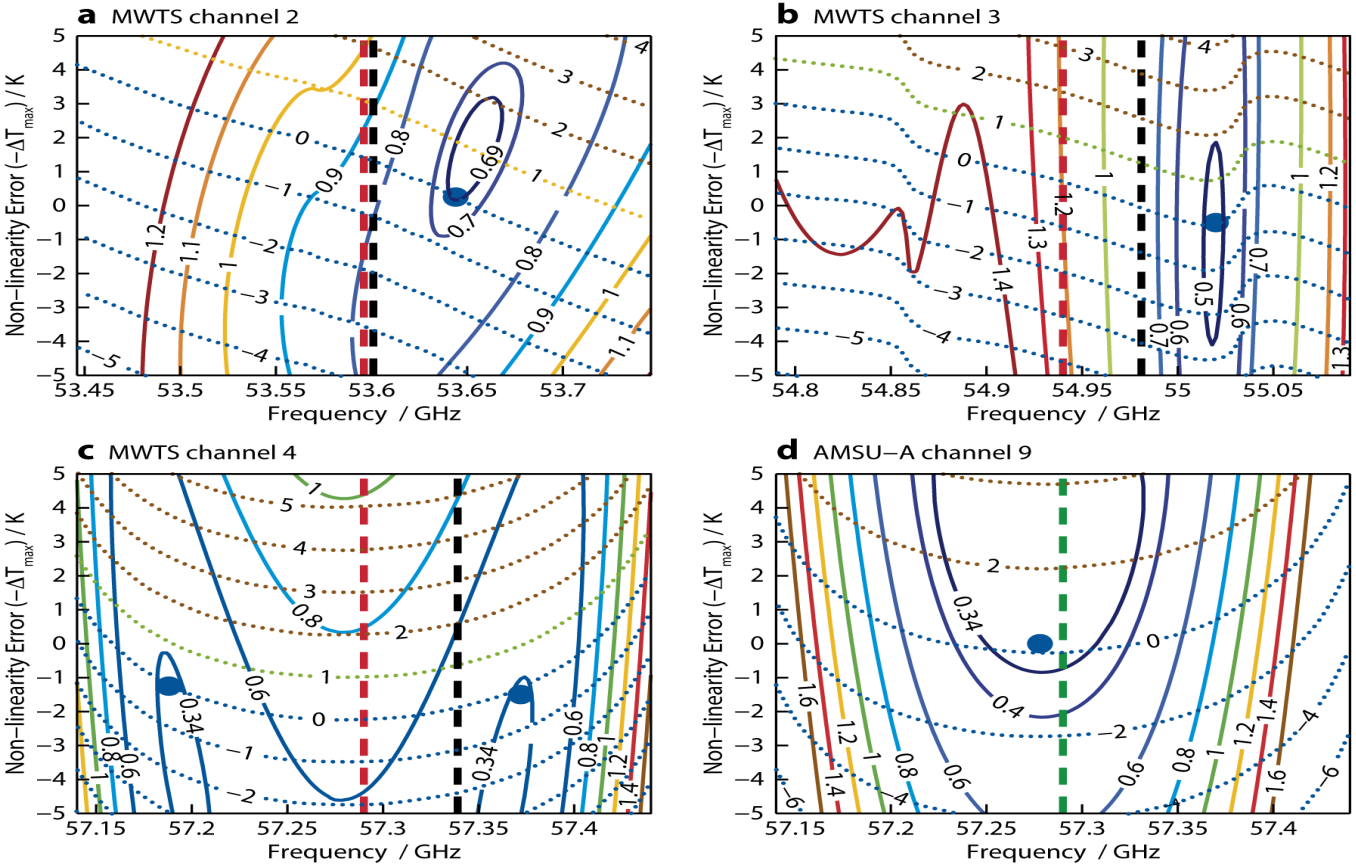
Optimize the instrumental parameters

departures are shown in Fig. 9. Because both factors are important in constraining the optimal estimate of the instrument parameters these were combined in an empirical penalty function $J(\Delta v_0, \Delta T_{\max})$, as

$$J(\Delta v_0, \Delta T_{\max}) = \frac{m(\Delta v_0, \Delta T_{\max})^2}{\sigma_m^2} + \frac{s(\Delta v_0, \Delta T_{\max})^2}{\sigma_s^2}, \quad (6)$$

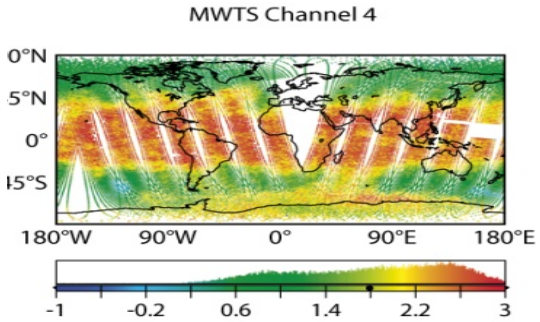
where σ_m and σ_s are chosen to represent our estimate, based on an educated guess, of the uncertainties in the expected residual bias and tolerable increase in standard deviation relative to the absolute minimum obtained

Results of the Optimizations for MWTS and the Equivalent AMSU-A

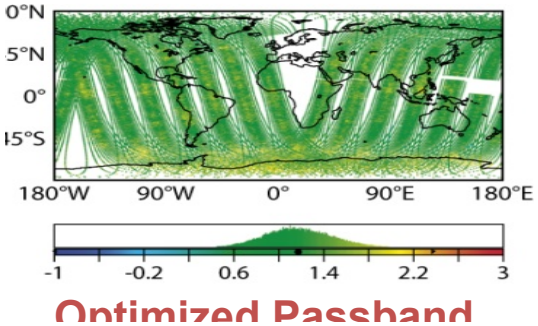


Characterize the MWTS

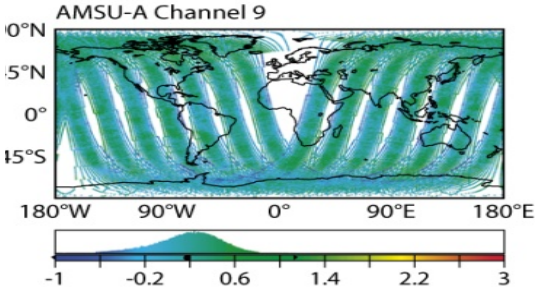
The OMB comparison between FY-3A/MWT and MetOp/ AMSU-A



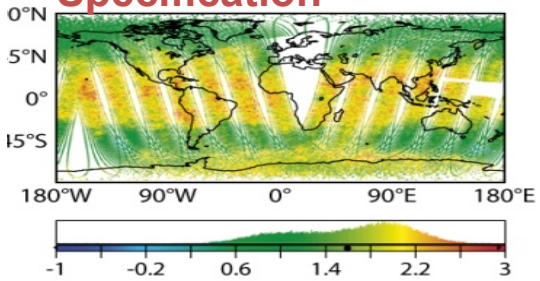
Specification



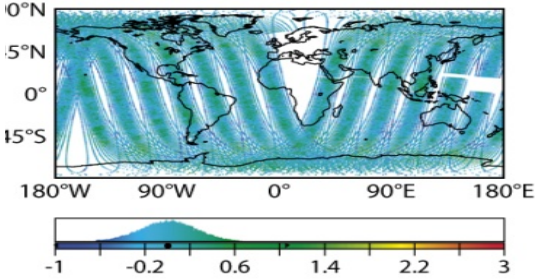
Optimized Passband



MetOp AMSU-A



PreLaunch Measurement



Optimization+NonLinearity Correction

MWTS OSEs Forecast Verification: Z at 200, 500 and 700 hPa

Normalised differences in RMS Errors in Z, verified against own analysis
90% confidence intervals shown

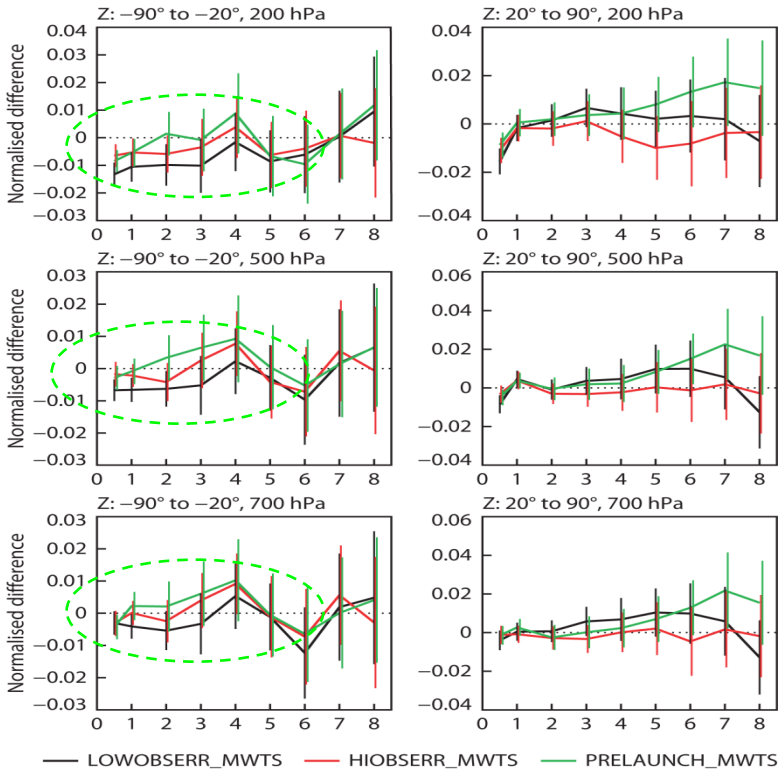
Small improvements in SH in going from:

original data

→ recalibrated (low weight)

→ recalibrated (high weight)

NH close to neutral with some benefit in recalibrated data



Improvement due to MWTS data

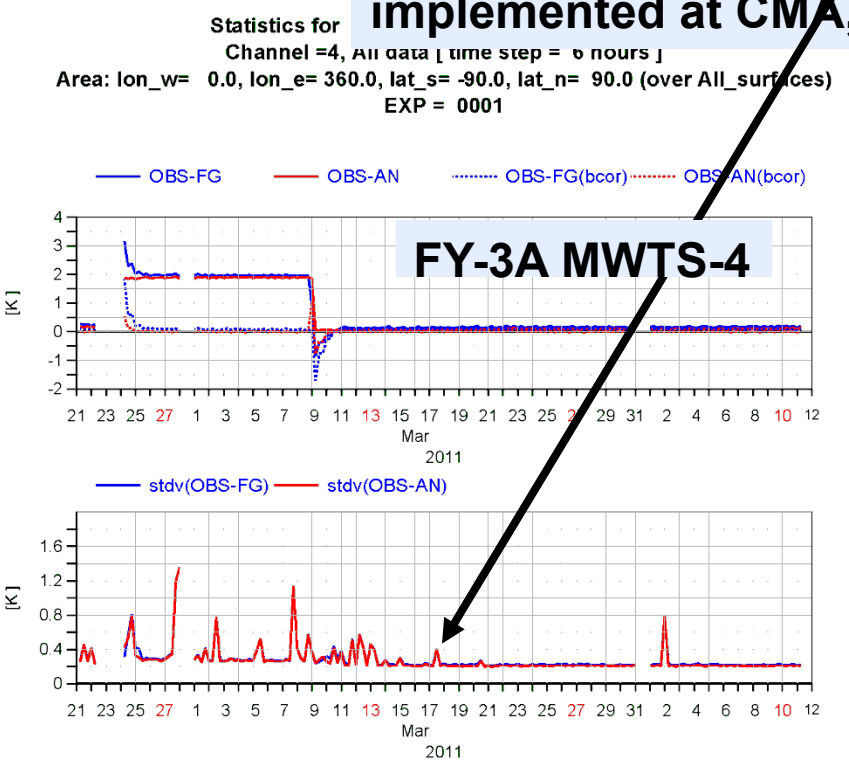
PRELAUNCH_MWTS
(full system + original MWTS data)

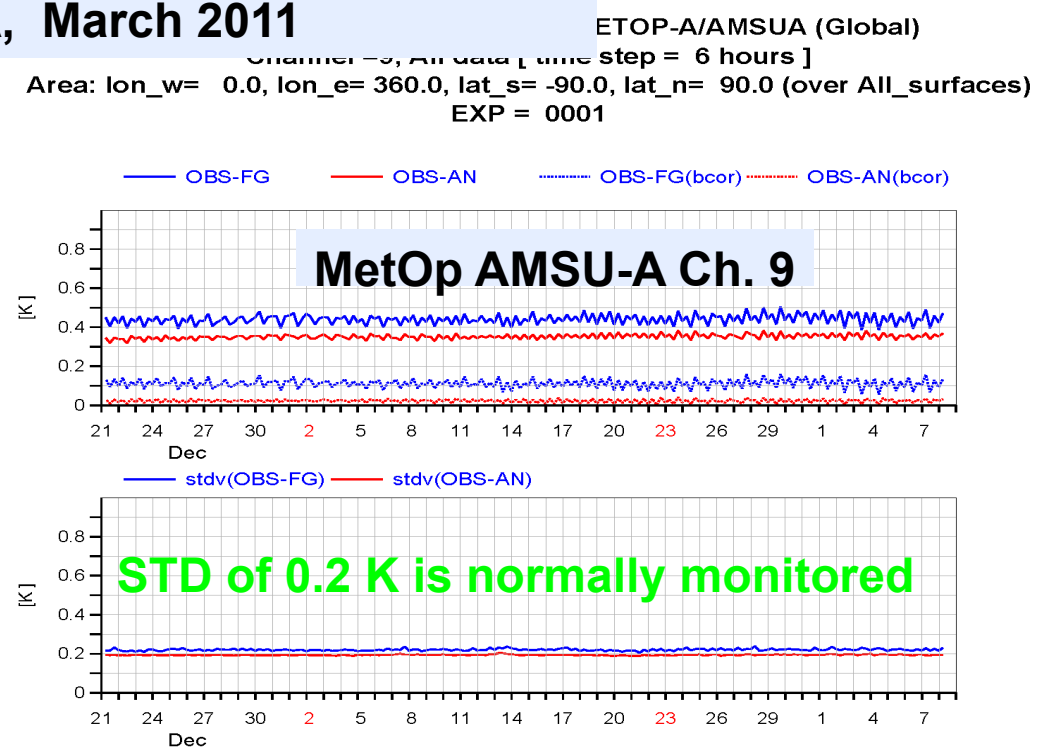
HIOBSERR_MWTS
(Full system + optimised MWTS with low weight)

LOWOBSERR_MWTS
(Full system + optimised MWTS with high weight)

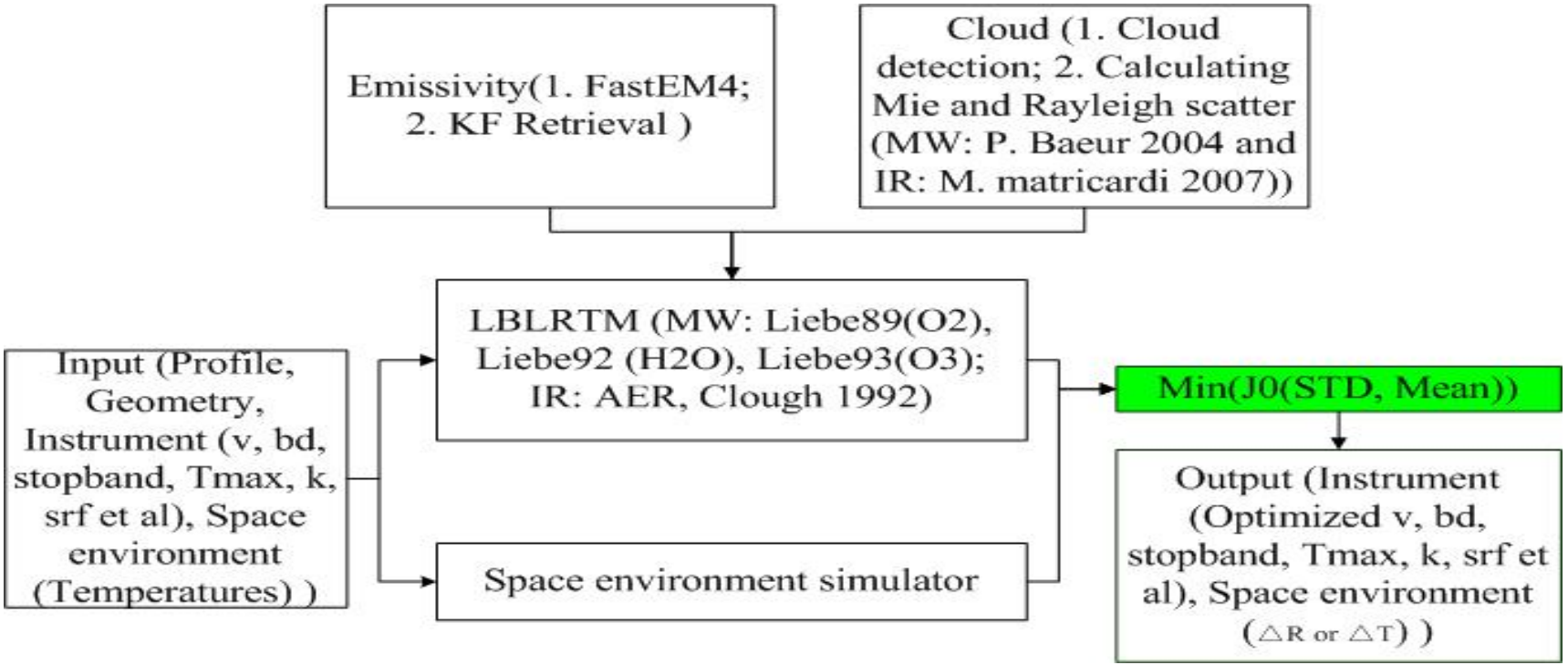
MWTS: current status

Ground system changes implemented at CMA, March 2011



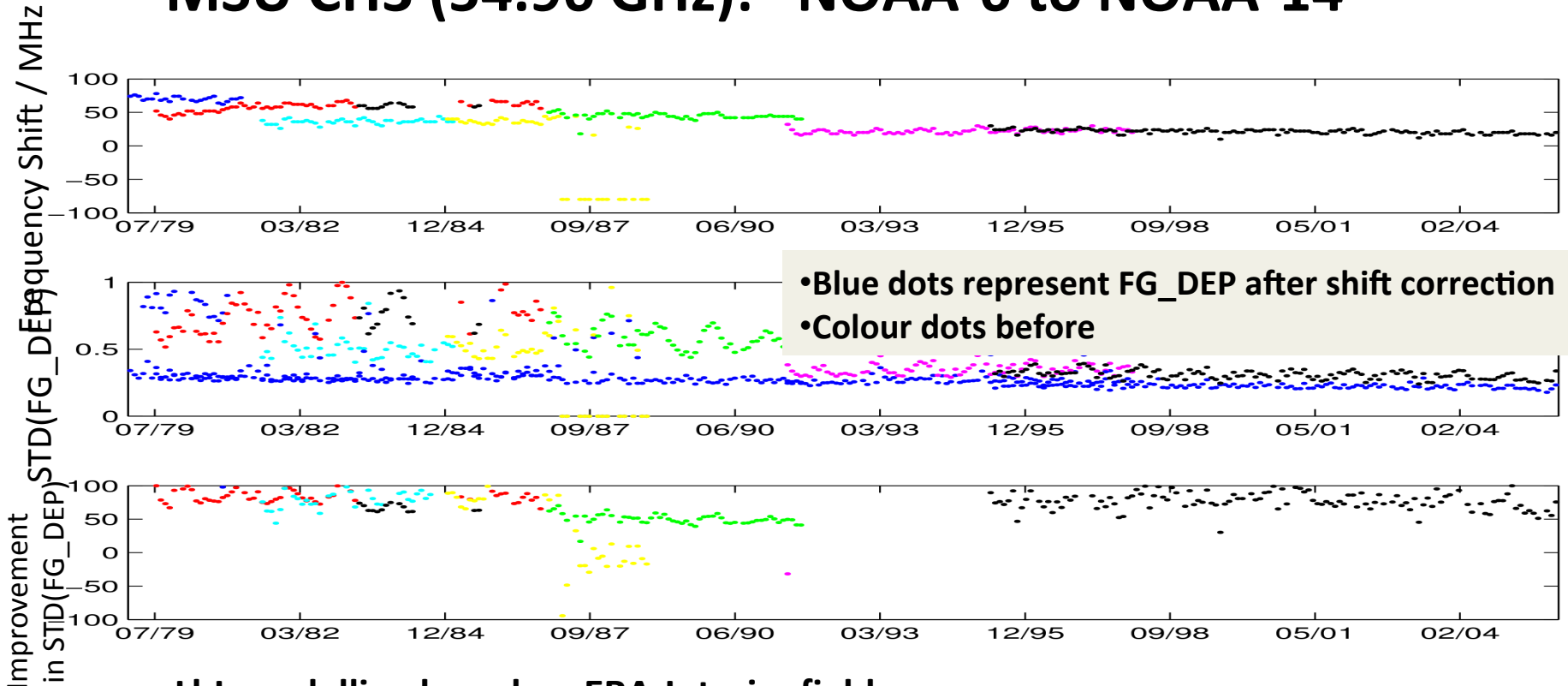


Optimizer of Satellite Instrumental Parameters On-orbit (OSIPOn)



Initial results from an evaluation of MSU and AMSUA from 1978

MSU CH3 (54.96 GHz): NOAA-6 to NOAA-14



- Blue dots represent FG_DEP after shift correction
- Colour dots before

- LbL modelling based on ERA-Interim fields
- 1 cycle per month: 1979 -2011

Initial FY-3B Evaluation

FY-3B MWTS FG Departure Channel 3: 54.072 GHz

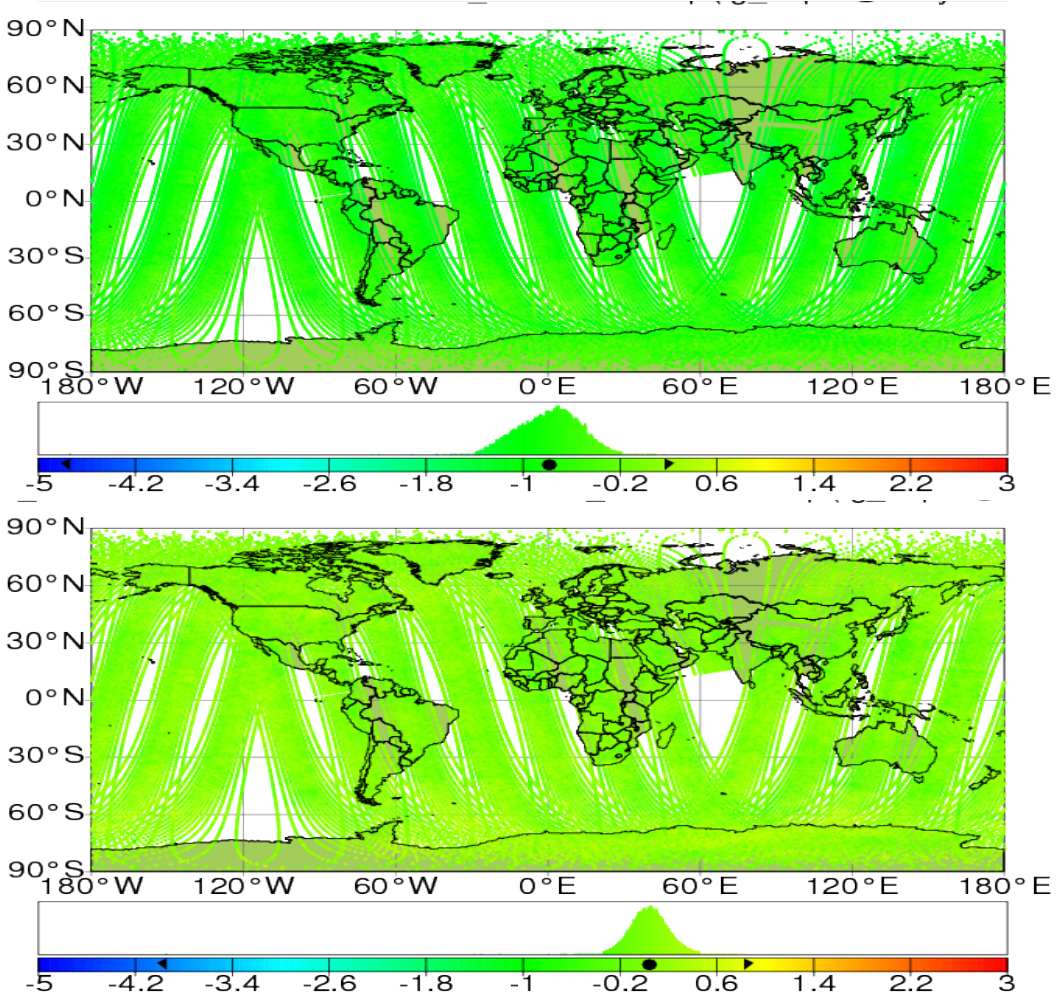
- Correction of passband measurement bias and radiometer non-linearity has been implemented in pre-processing at NSMC/CMA

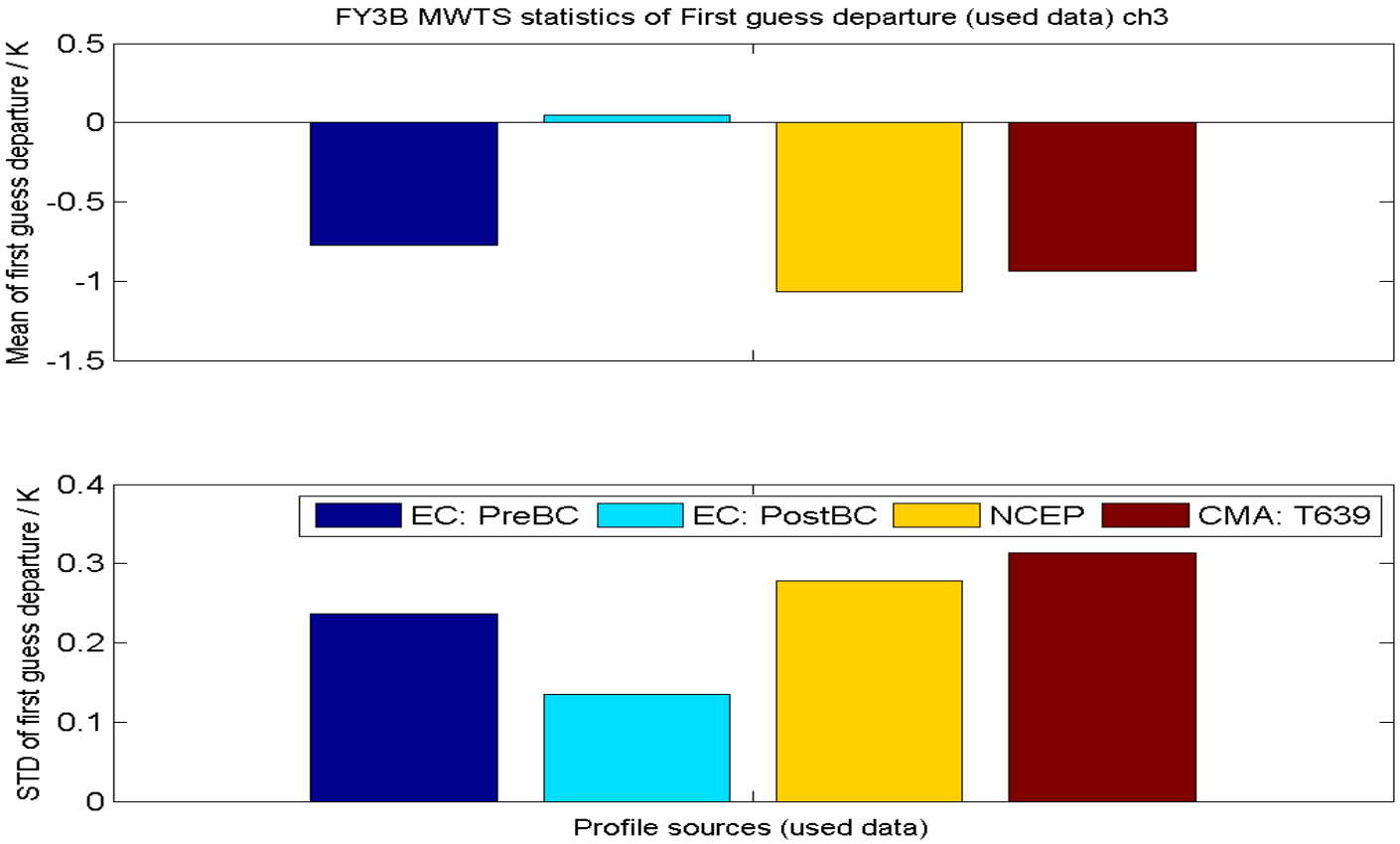
- No significant problems with the MWTS-2 and -3 observations

- Cross scan bias is dominant & accounts for non-gaussian FG departures (corrected by variational bias correction scheme):

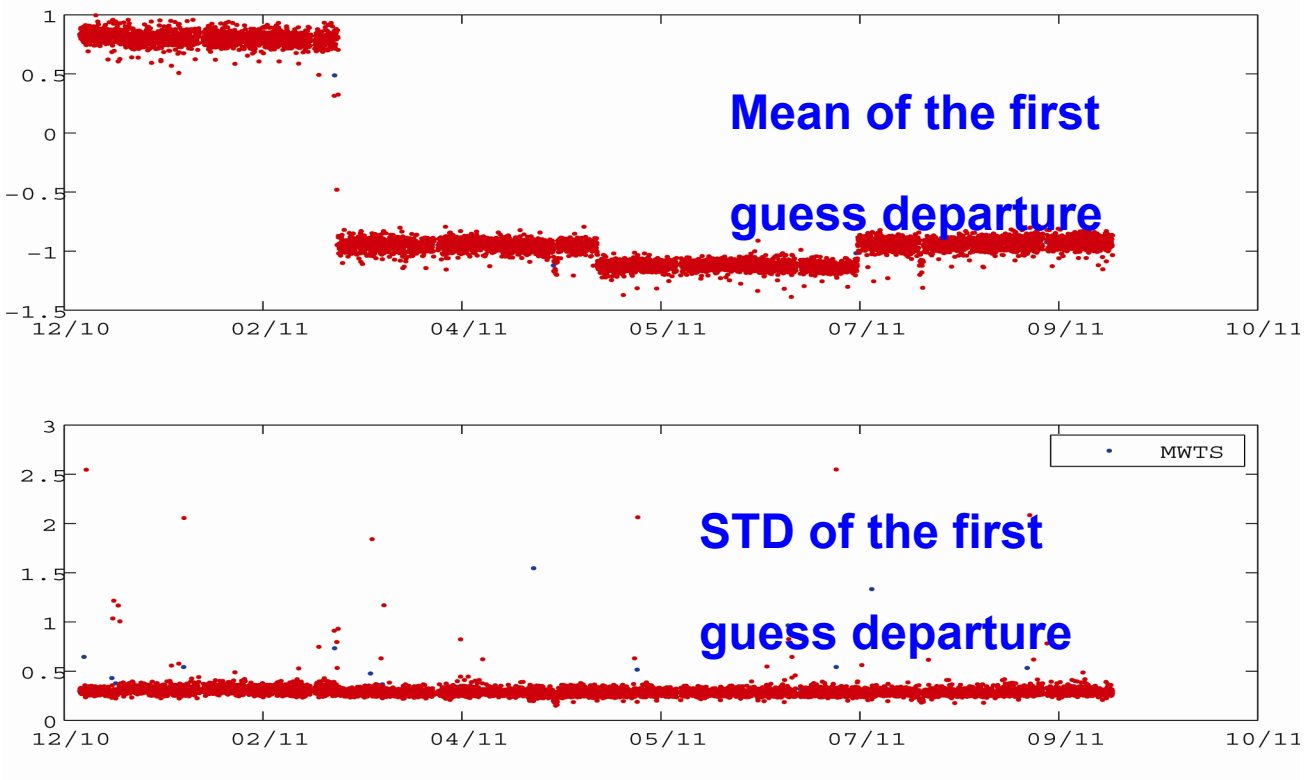
  After VarBC

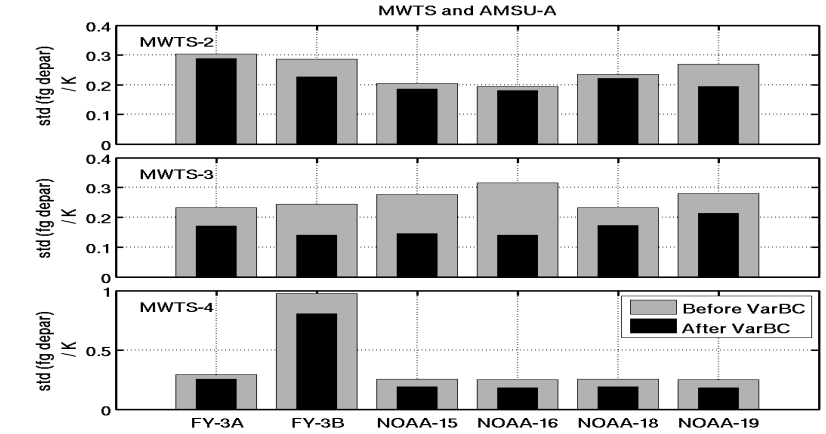
  STDEV(O-FG) = 0.17 K

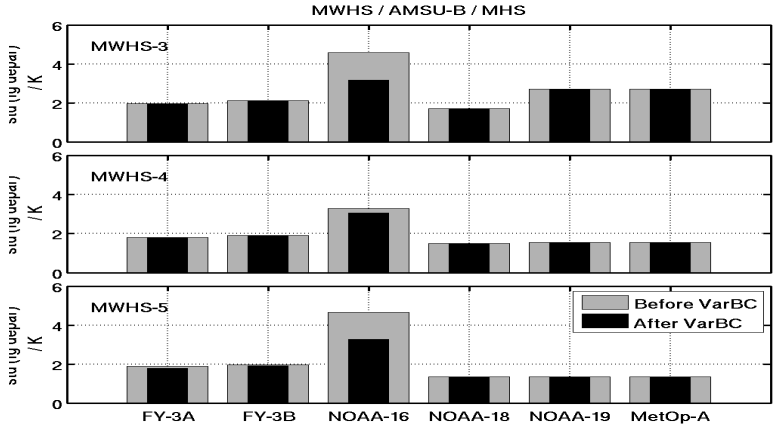


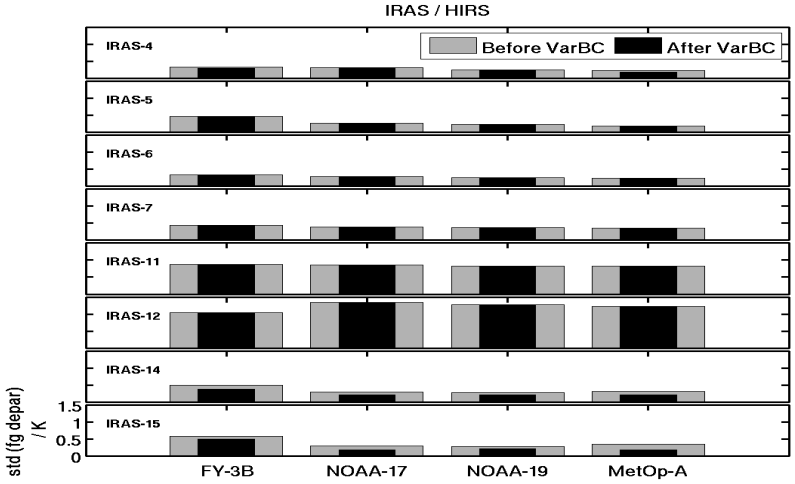

FY3B MWTS statistics of First guess departure (used data) ch3
Mean of first guess departure / K
0.5
0
-0.5
-1
-1.5
STD of first guess departure / K
0.4
0.3
0.2
0.1
0
EC: PreBC
EC: PostBC
NCEP
CMA: T639
Profile sources (used data)

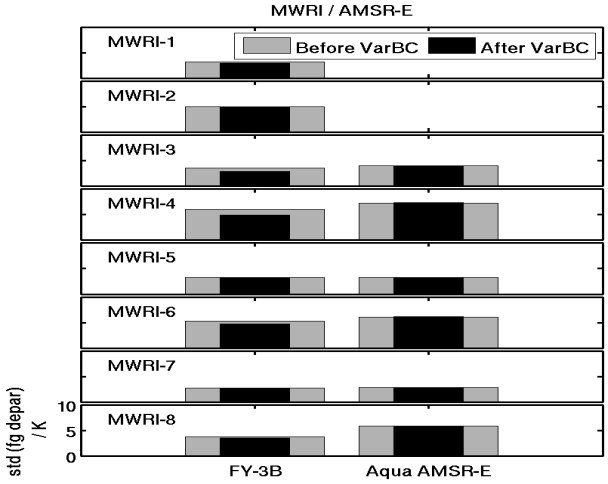
Statistics time series of first guess departure from FY-3B MWTS-CH3

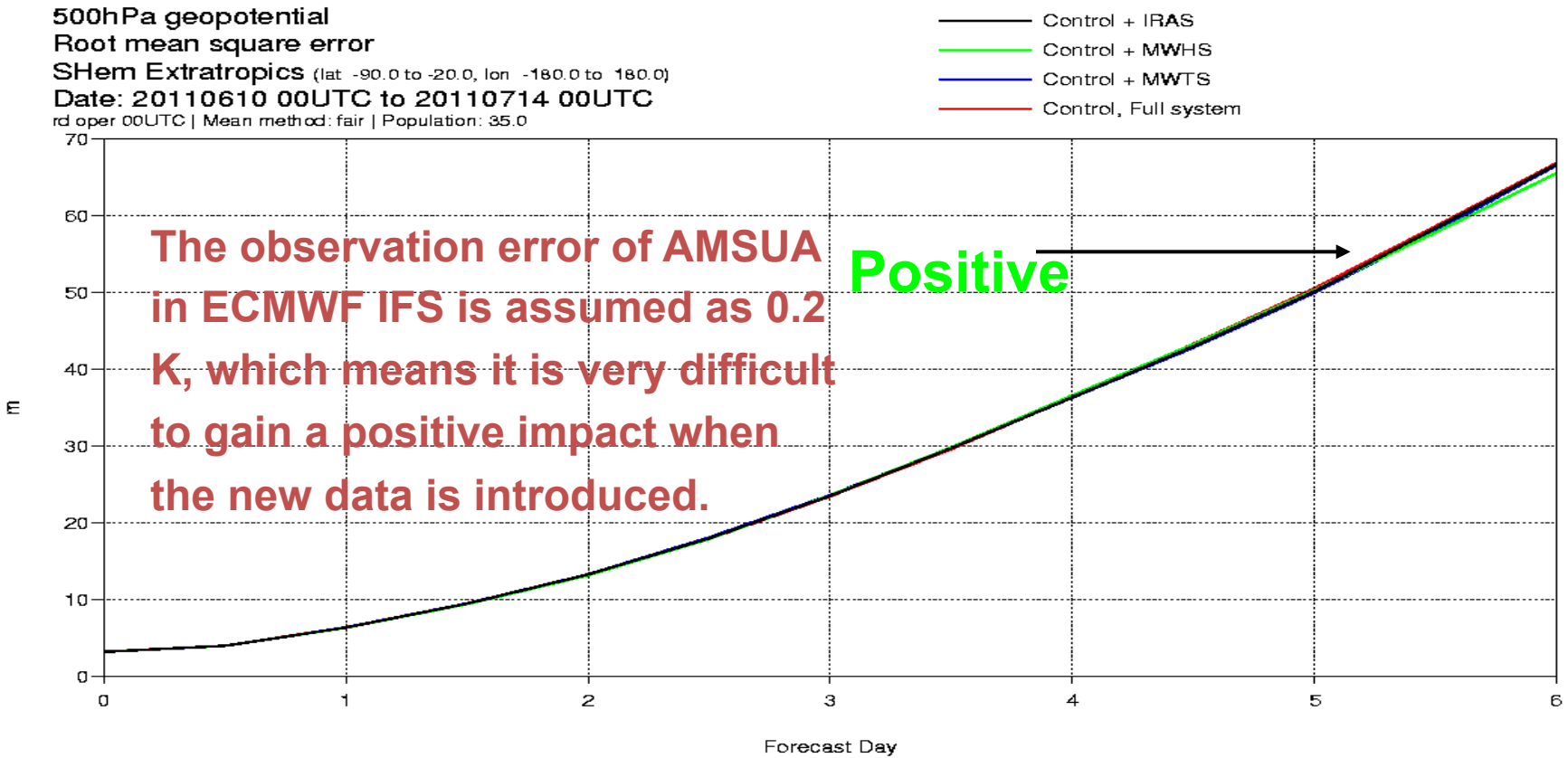



MWTS and AMSU-A
MWTS-2
MWTS-3
MWTS-4
std (fg depar) / K
Before VarBC
After VarBC
FY-3A
FY-3B
NOAA-15
NOAA-16
NOAA-18
NOAA-19


MWHS / AMSU-B / MHS
MWHS-3
MWHS-4
MWHS-5
std (fg depar) / K
Before VarBC
After VarBC
FY-3A
FY-3B
NOAA-16
NOAA-18
NOAA-19
MetOp-A


IRAS / HIRS
IRAS-4
IRAS-5
IRAS-6
IRAS-7
IRAS-11
IRAS-12
IRAS-14
IRAS-15
Before VarBC
After VarBC
std (fg depar) / K
FY-3B
NOAA-17
NOAA-19
MetOp-A


MWRI / AMSR-E
MWRI-1
MWRI-2
MWRI-3
MWRI-4
MWRI-5
MWRI-6
MWRI-7
MWRI-8
Before VarBC
After VarBC
std (fg depar) / K
FY-3B
Aqua AMSR-E


500hPa geopotential
Root mean square error
SHem Extratropics (lat -90.0 to -20.0, lon -180.0 to 180.0)
Date: 20110610 00UTC to 20110714 00UTC
rd oper 00UTC | Mean method: fair | Population: 35.0
Control + IRAS
Control + MWHS
Control + MWTS
Control, Full system
The observation error of AMSUA in ECMWF IFS is assumed as 0.2 K, which means it is very difficult to gain a positive impact when the new data is introduced.
Positive
m
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
Forecast Day

Update for MWTS and MWHS from FY-3C

- **MWTS is extended from 4 to 13 channels with 90 scanned points;**
- **MWHS is extended form 5 to 15 channels with 8 channels near 118 GHz and another 2 channels near 183 Ghz**

We are still improving the tool, OSIPOn, to characterize the instrumental performance, hopefully the Fengyun satellite would be even better.

Publications for reference

1. Lu et al, 2011, **An Evaluation of FY-3A Satellite Data for Numerical Weather Prediction**, Quarterly Journal of the Royal Meteorological Society,137(658).
2. Lu et al, 2011, **Characterizing the FY-3A Microwave Temperature Sounder Using the ECMWF Model**, Journal of Atmospheric and Oceanic Technology, 28.
3. Lu et al, 2012**, Improved assimilation of data from China’s FY-3A Microwave Temperature Sounder**, Royal Meteorological Society, Atmospheric Science Letters， 13(1).
4. Lu et al, 2013**, Characterising channel center frequencies in AMSU-A and MSU microwave sounding instruments**, ECMWF Technical Memorandum 700.

Summary

- FY-3A data has been evaluated at ECMWF through a comparison with simulated radiances & full assimilation experiments in which FY-3A data is introduced in the ECMWF system.
- A detailed study of the FY-3A revealed, and corrected, biases in MWTS related to :
  - Uncertainties in the passband centre frequencies
  - Radiometer non-linearities
- These corrections bring the MWTS data close to the quality of equivalent AMSU-A data & in assimilation experiments this MWTS data delivers improvements in forecast accuracy.
- Initial assessment of FY-3B suggests the data is comparable with its counterpart.
- The high values of OSIPOn in Cal/Val of new satellite sensors has been clearly demonstrated – the improved FY-3 data would be expecting to contribute more to the NWP community.