Evaluation of Direct Broadcast and Global Microwave Sounder Data from FY-3C

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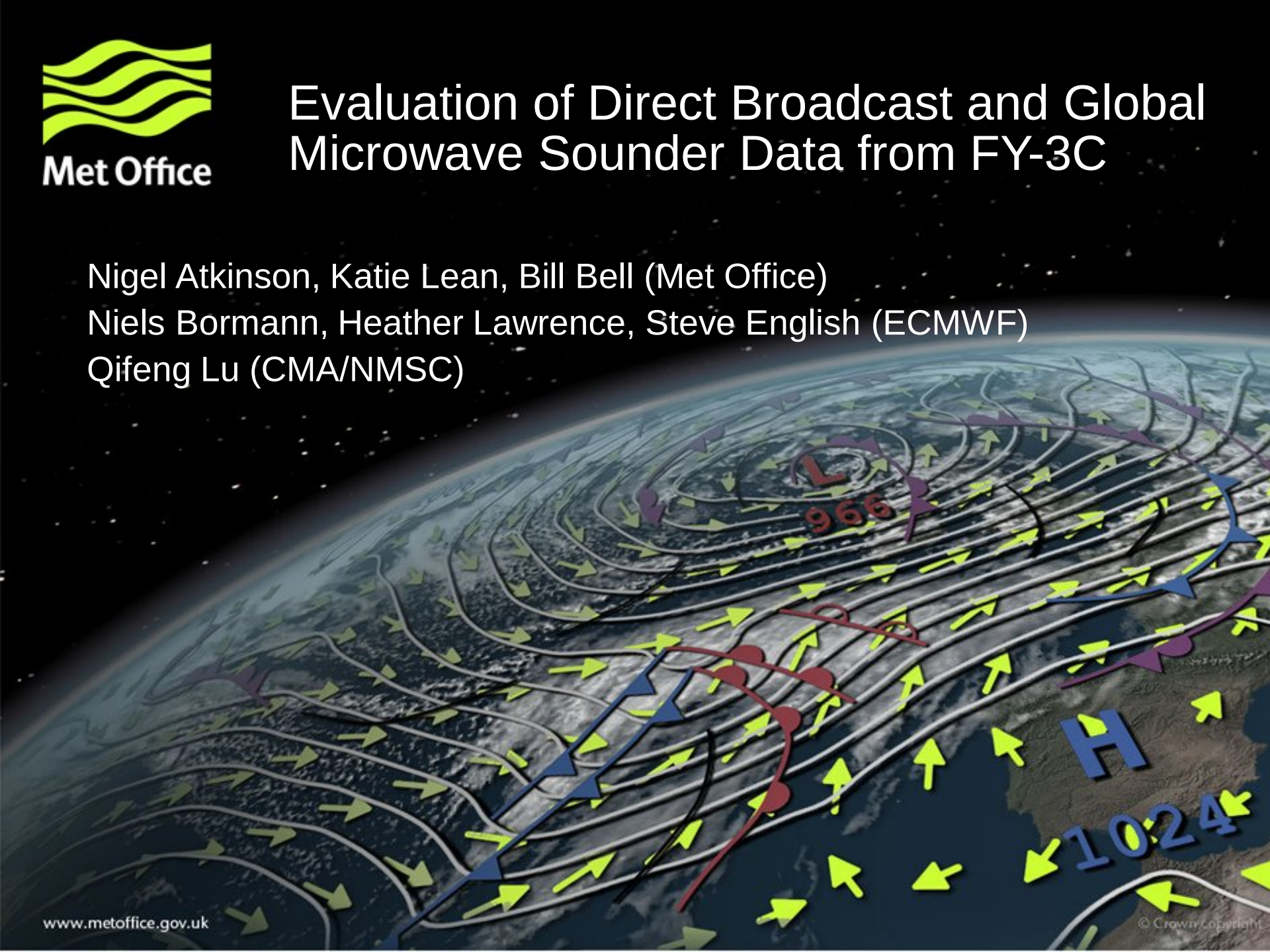
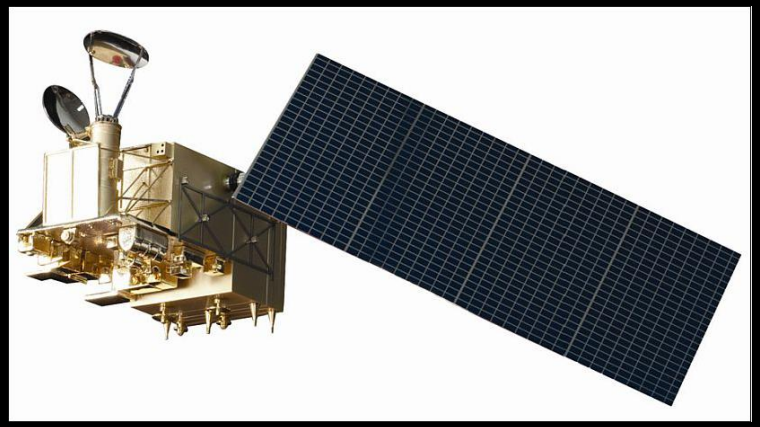


FY-3C launch 23 Sep 2013



Aims of project:

- To evaluate the sounders on FY-3C for use in NWP
- To strengthen international partnerships

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 occultaion]

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

The DB Packages

- CMA processing packages:
  - fy3cl0db (raw to level 0)
  - fy3cl1db (level 0 to level 1)
  - Available on request, see http://satellite.cma.gov.cn/portalsite/default.aspx Tools > Softwares
- Level 1 processing available for MWTS-2, MWHS-2, IRAS, VIRR, MERSI (currently not MWRI or GNOS)
- Distributed as binaries
- Reasonably straightforward to run
- Output files can be BUFR encoded using *AAPP*

The microwave sounders

- MWHS-2
  - 15 channels at 89, 118 (8 chans), 150, 183 (5 chans) GHz
  - The 118GHz is a new band – not previously used for NWP
  - Information on temperature, humidity and cloud
  - 98 spots per scan, resolution around 17km for high frequencies
- MWTS-2
  - 13 channels from 50.3 to 57.3 GHz – similar to ATMS temperature sounding channels
  - 90 spots per scan, resolution around 33km
  - *MWTS-2 failed on 17th Feb 2015 – it stopped scanning. But has recently come back (20th March). We shall see.*
- *We used NWP comparison to evaluate them*
- *We also examined internal consistency of the calibration*

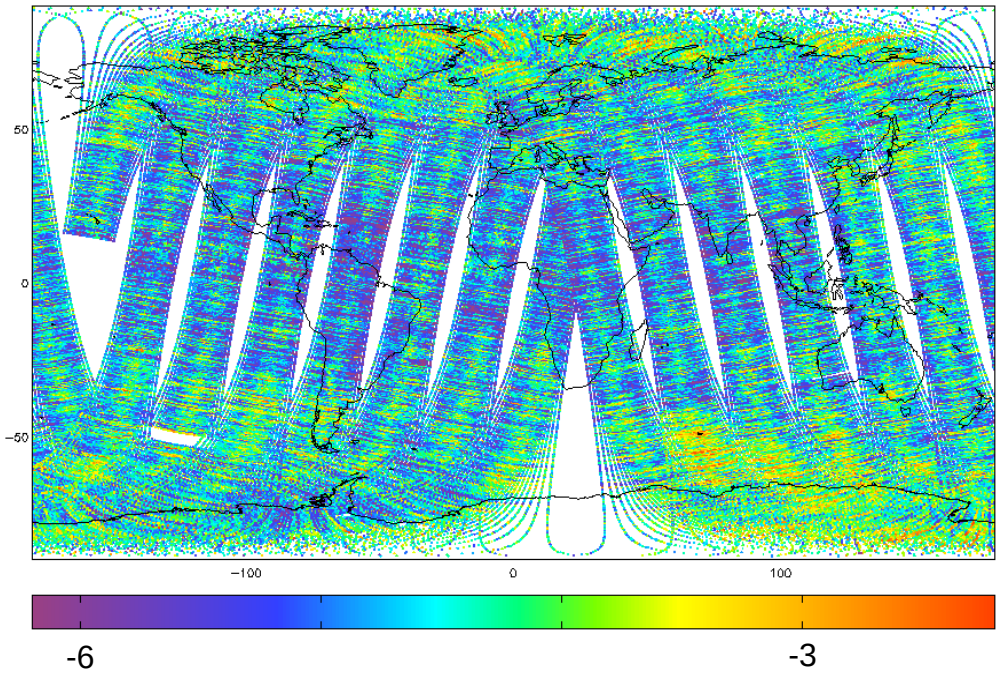
Issues with MWTS-2

I'll talk about these:

- Striping
- Unexpected land/sea sensitivity
- Large negative BT biases
- Nonlinearity correction
- Ascending-descending differences

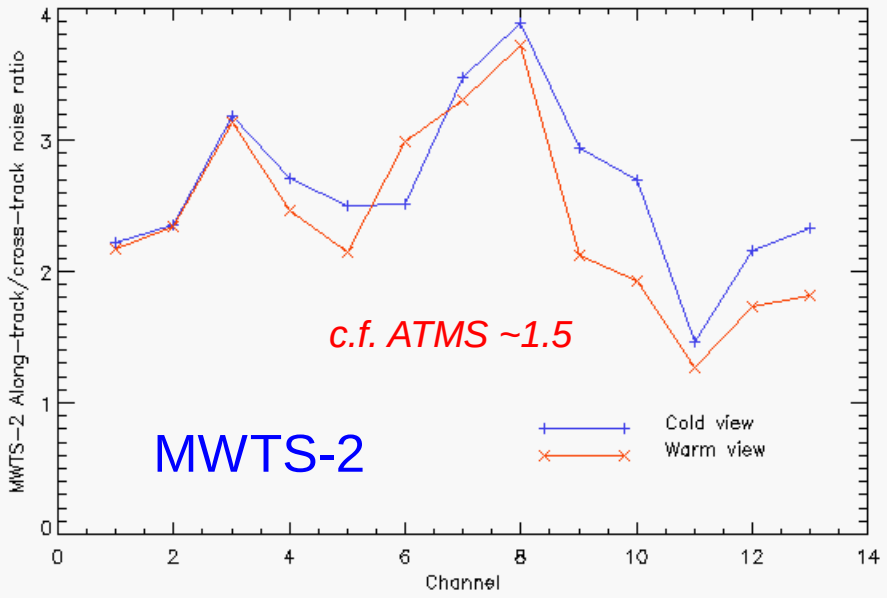
Striping

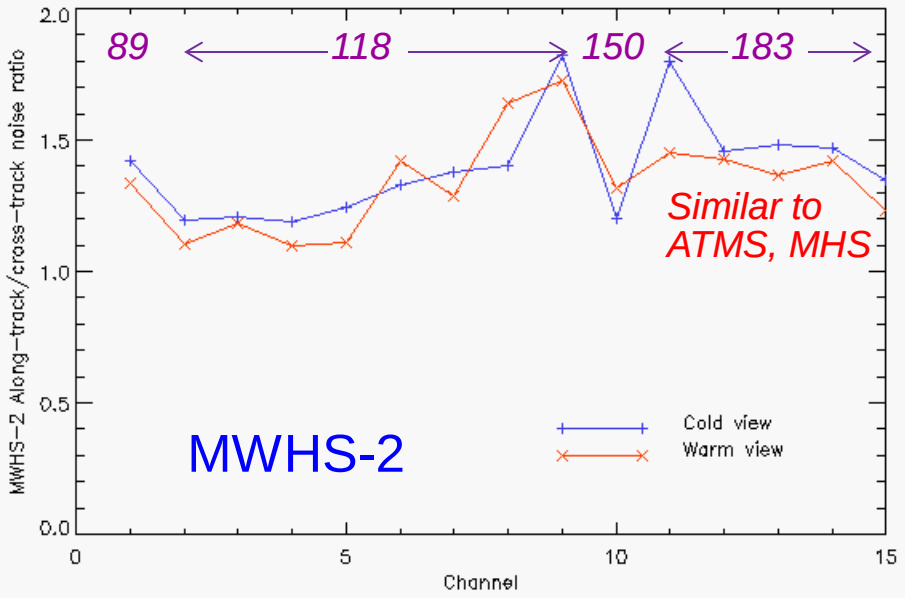
O-B BT for MWTS-2 8 (57.29 GHz, ~85hPa)



- Probably 1/f noise in the front-end low noise amplifier (LNA). Also affects MWHS-2
- Also seen in ATMS and MHS, but larger in MWTS-2
- Can be quantified using the variability of the warm target and space view counts

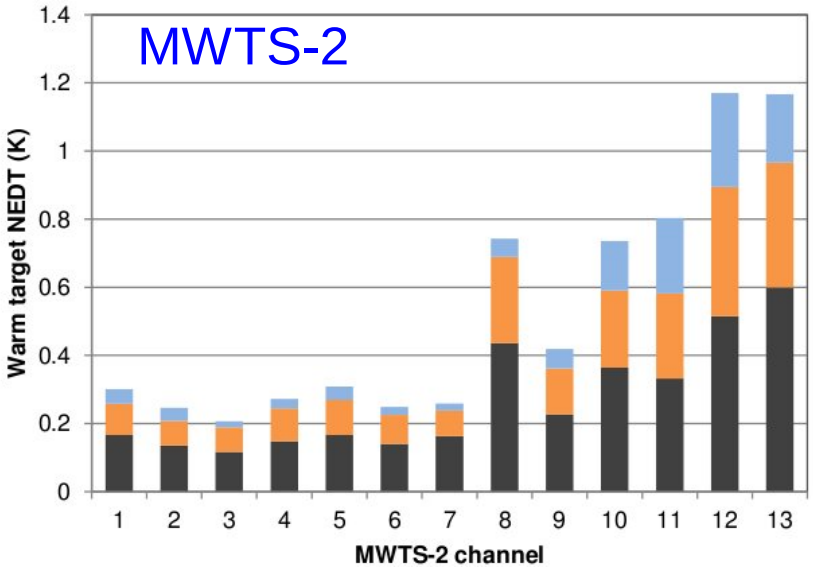
Striping ratio for MWTS-2 and MWHS-2

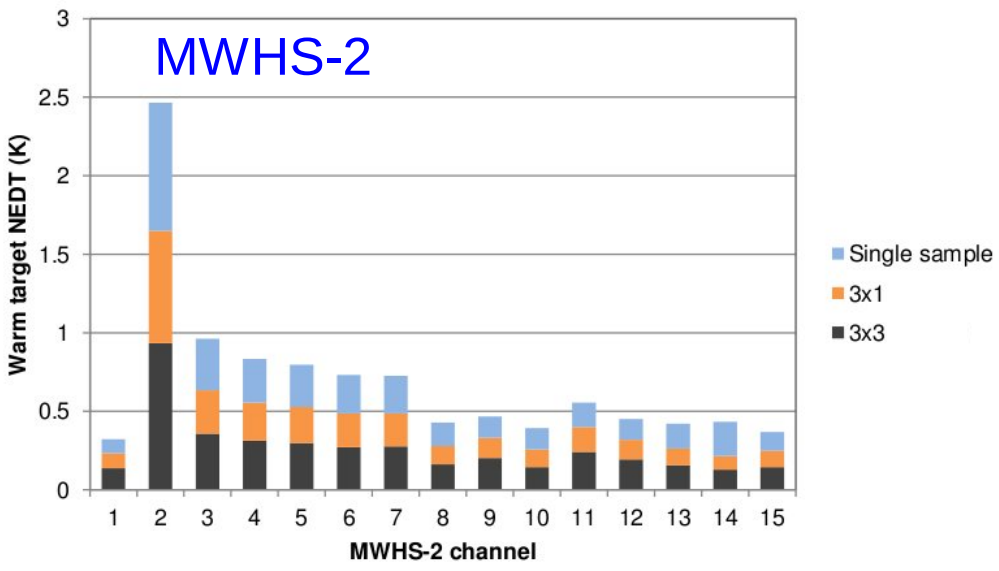




- Striping ratio is the square root of the along-track variance / cross-track variance for 3x3 boxes, for cal view counts
- Very large for tropospheric sounding channels of MWTS-2 – but need to consider NEΔT also
- May be able to alleviate striping using the scheme of Qin et al. (2013)

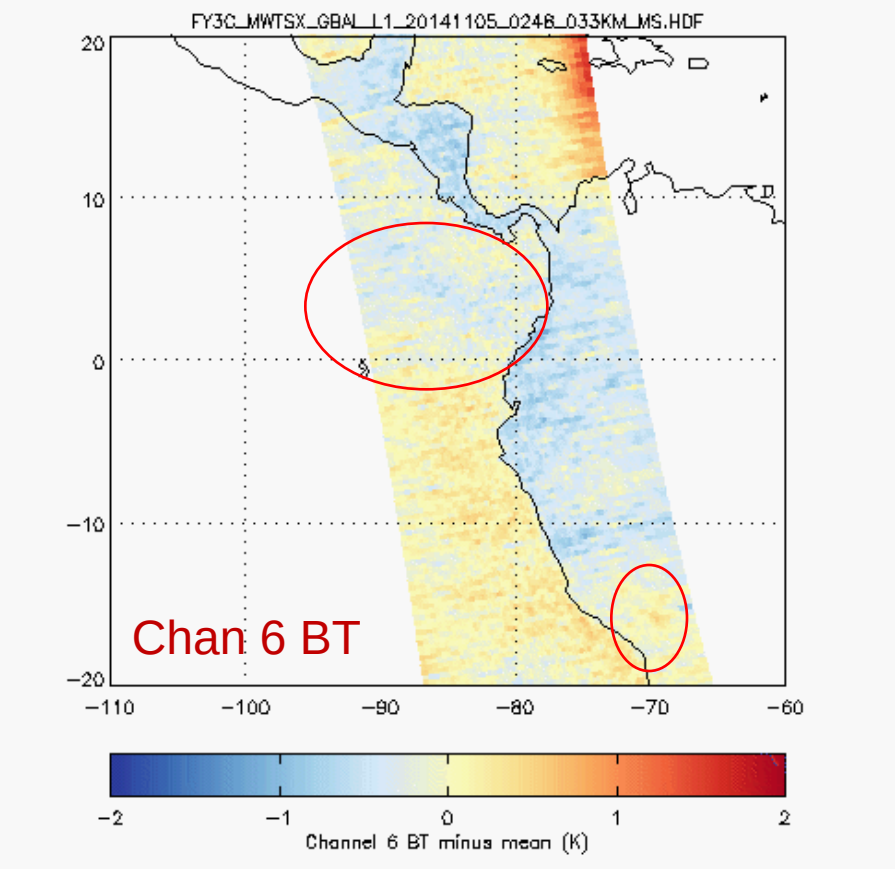
NEΔT values – with and without spatial averaging

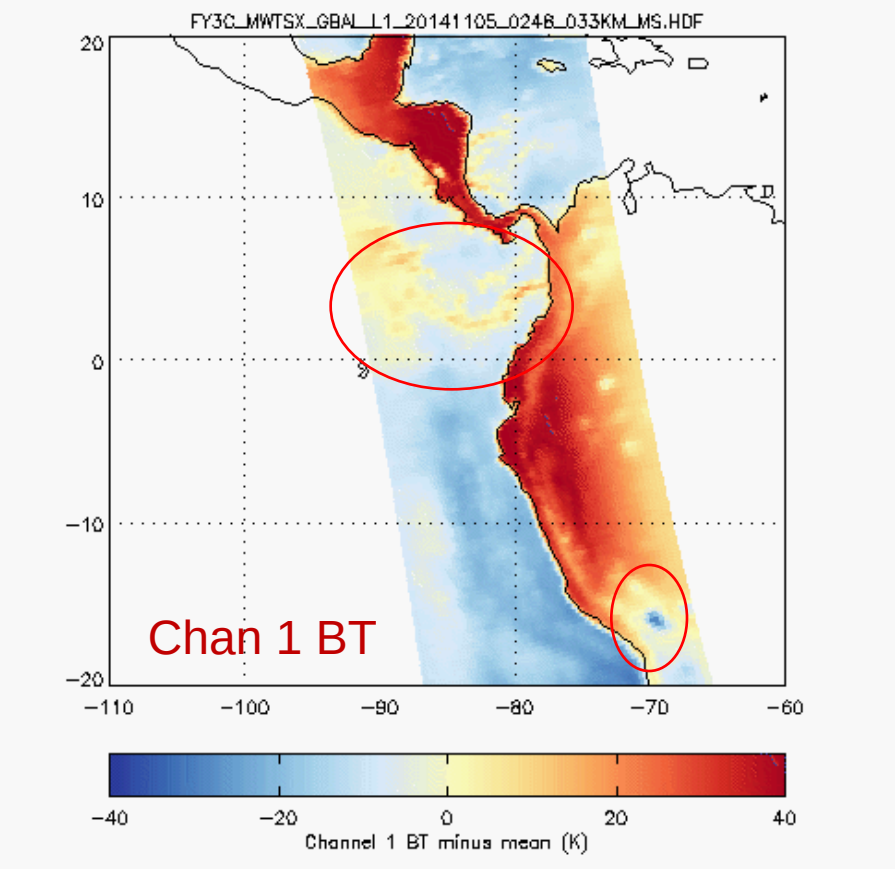




- These NEDT plots include the striping noise
- MWTS-2 channel 8 is particularly noisy, but 1-7 are looking good
- They are based on cal counts – not NWP

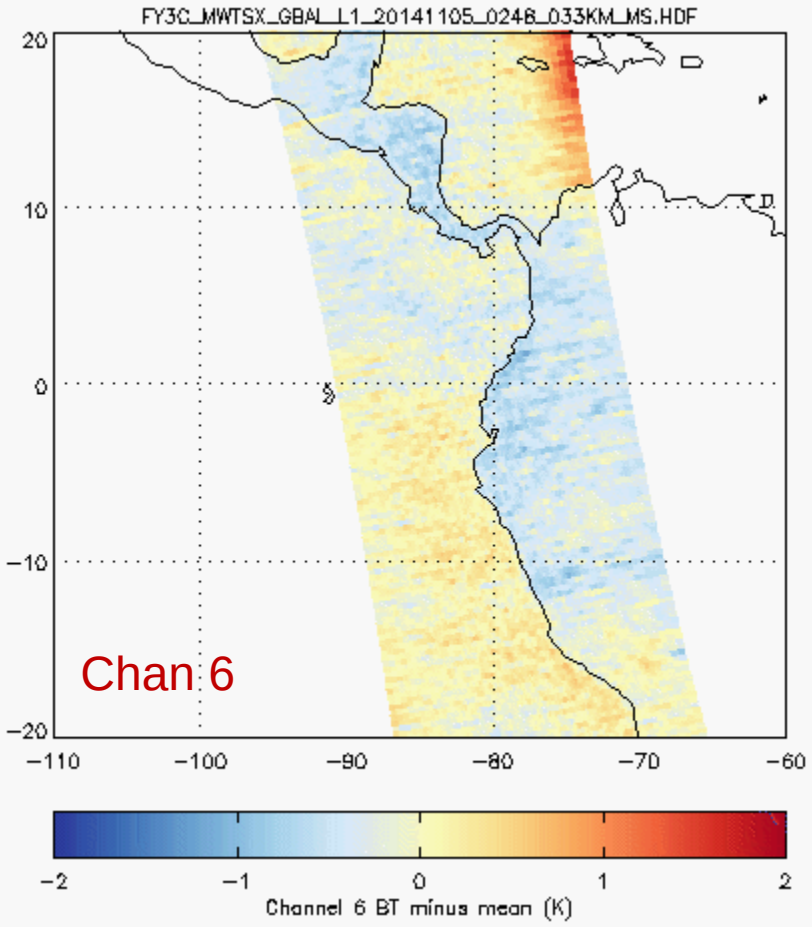
MWTS-2 Land/sea bias

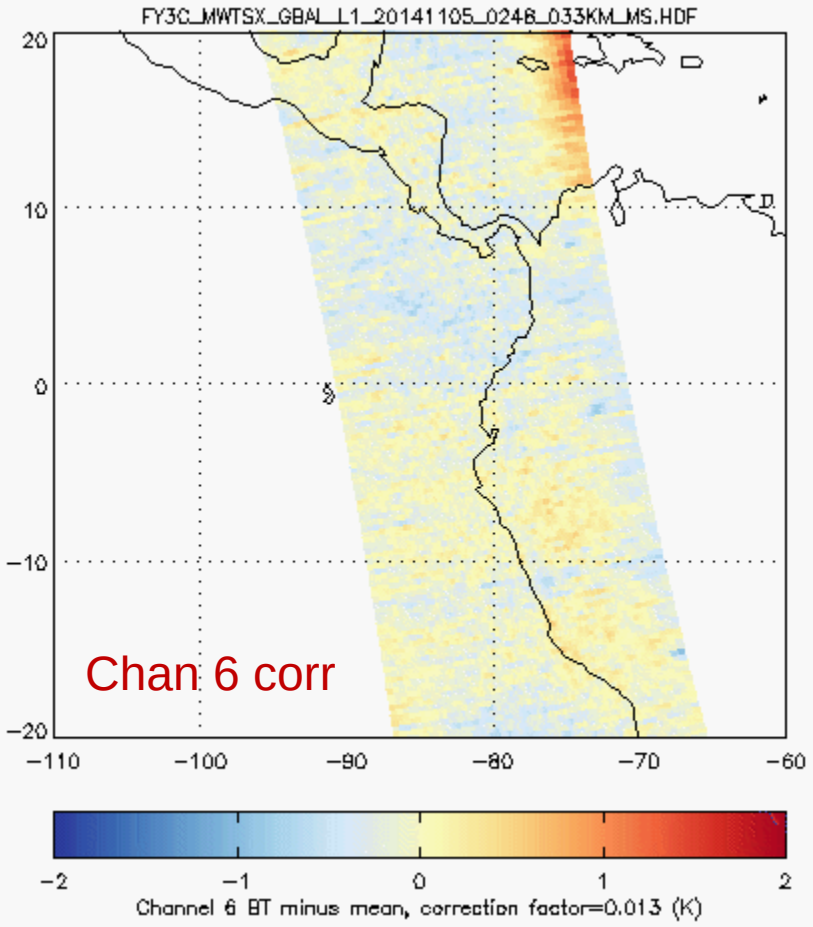




- Ch 5, 6, 7 and 8 display unphysical temp depressions over land
- These channels are not supposed to be surface sensitive
- Direct broadcast and global data affected
- *anti-correlation* with ch 1
- We formulated en empirical fix – subsequently adopted by CMA in their global processor

Empirical correction





$BT_j(corr) = BT_j + k(BT_1 - BT_j)$ k = 0.013 for channel 6

Window channel Sounding channel

Other channels

- Values of k derived by Niels Bormann by comparing O-B over land and over sea:

Channel	k
5	0.0169
6	0.0128
7	0.0052
8	0.0034

Possible causes:

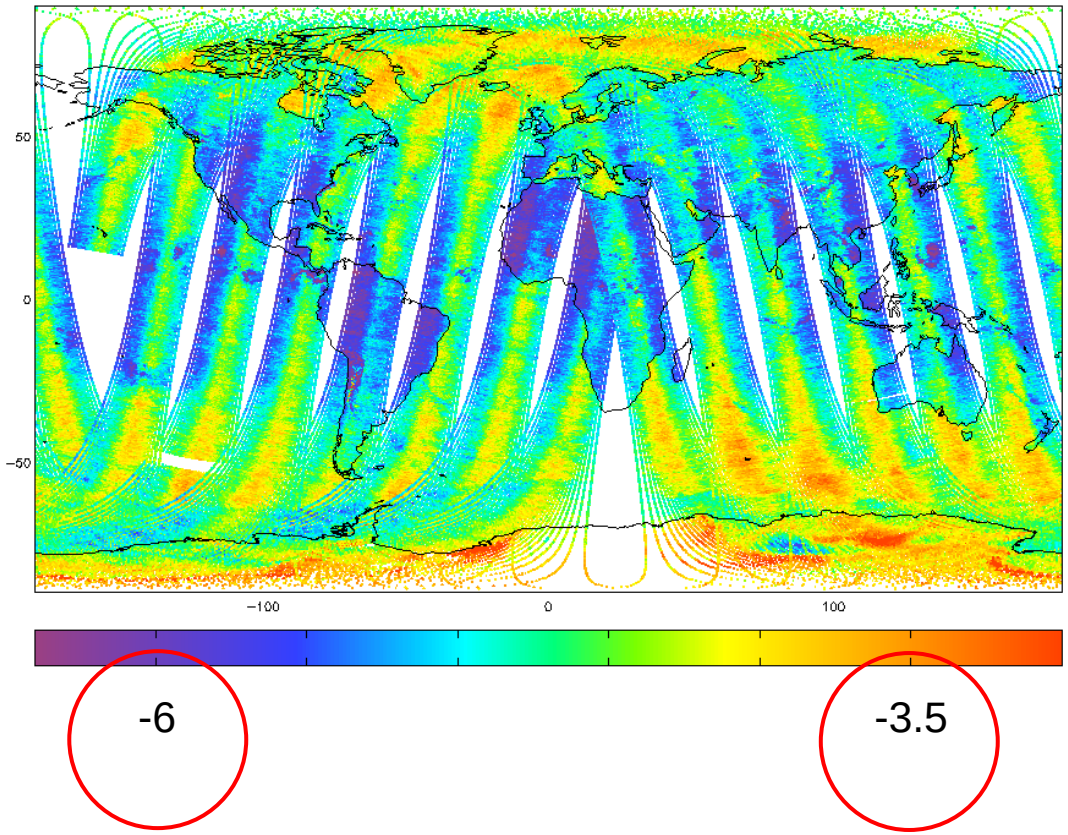
- Cross-talk in the receiver?
- Unlikely to be passband leakage because that would give warm bias over land

Raises the interesting question

- ***How to detect an effect like this before launch?*** *Implications for other missions*.

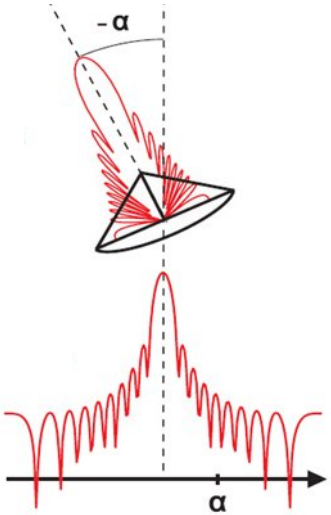
Large negative BT bias

O-B BT for MWTS-2 5 (54.4Ghz, ~400hPa)



Oct 2014

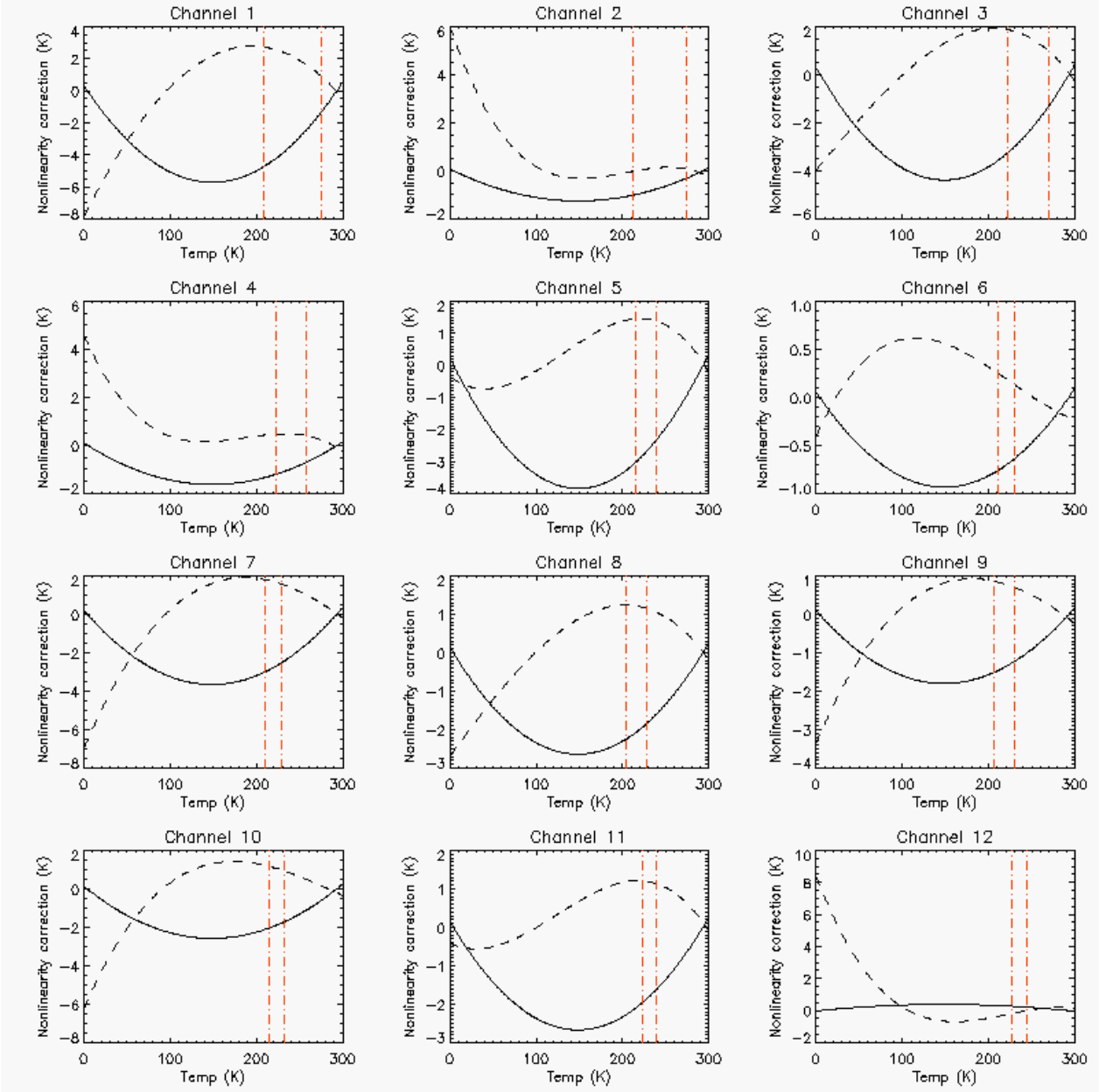
Several things could cause a cold bias



- Cold space antenna correction too small
  - Sidelobes view earth when antenna is in space view
  - Unlikely to be sufficient – would need an increase >10K)
- Warm target PRT readings too cold (unlikely)
- Incorrect nonlinearity correction (possible)
- Earth-view antenna correction too small
  - Sidelobes view cold space and therefore depress the BTs (quite likely)
  - Qifeng has devised a new antenna correction, but not yet implemented
- *Perhaps a combination of the last two?*

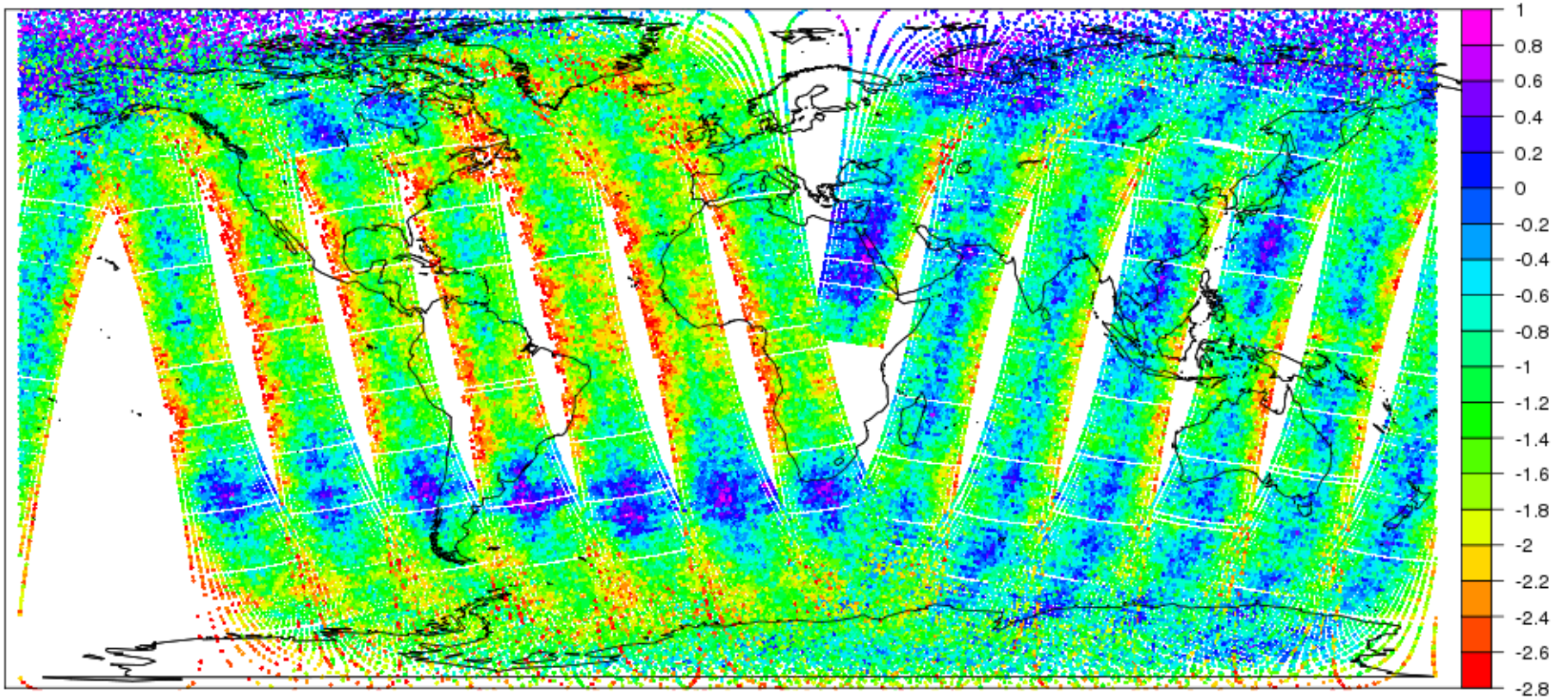
CMA operational change 6th Jan 2015

- CMA have reversed the sign of the nonlinearity correction and made it a 3rd order polynomial
- These corrections are very large
- Are they justified by pre-launch data?
- *Open issue*



MWTS-2 processing change: O-B

07/01/2015



- Some of the bias has been fixed, but now have an ascending/descending difference
- Thought to be an error in the calibration view averaging
- *Still not resolved*

Finally for MWTS-2 ...

- In the 15th Jan software patch for fy3cl1db, certain files were hard-coded

  /home/fy3c/fy3cl1db/SysData/MWTS_chazhaobiaoA3.txt

  /home/fy3c/fy3cl1db/SysData/MWTS_chazhaobiaoA2.txt

  /home/fy3c/fy3cl1db/SysData/MWTS_chazhaobiaoA1.txt

  /home/fy3c/fy3cl1db/SysData/MWTS_chazhaobiaoA0.txt

- The MWTS-2 calibration software crashes if the files are not there
- Not good practice – users will in general want to install the software in a location of their choosing
- We modified our copy of the mtpc_F3C executable to change the path for these files

Issues with MWHS-2

- 118GHz airmass-dependent biases
- Striping (as for MWTS-2 – already discussed)
- Software errors – wrong nonlinearity constants
- Global-local consistency issues

MWHS-2: O-B bias as a function of orbit angle

- Definition of orbit angle, Φ:
- Angle about orbital track, relative to the intersection of the satellite's ascending node with the ecliptic plane

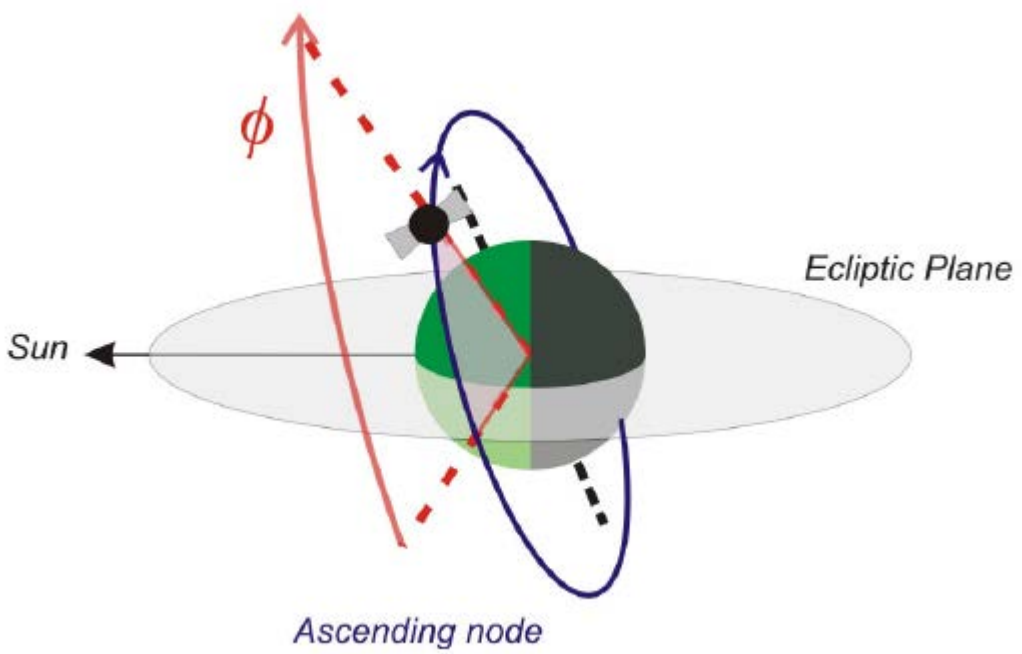
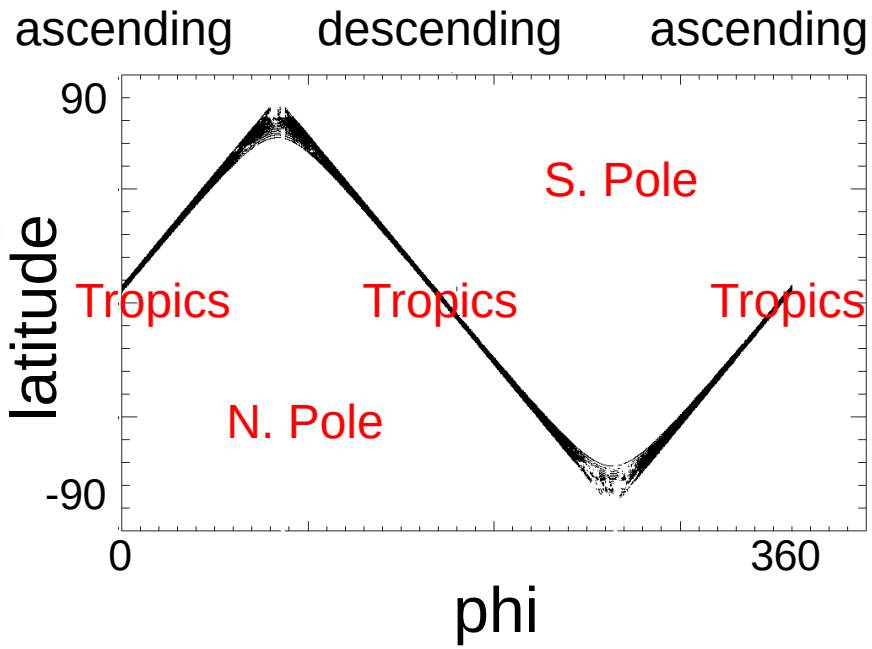
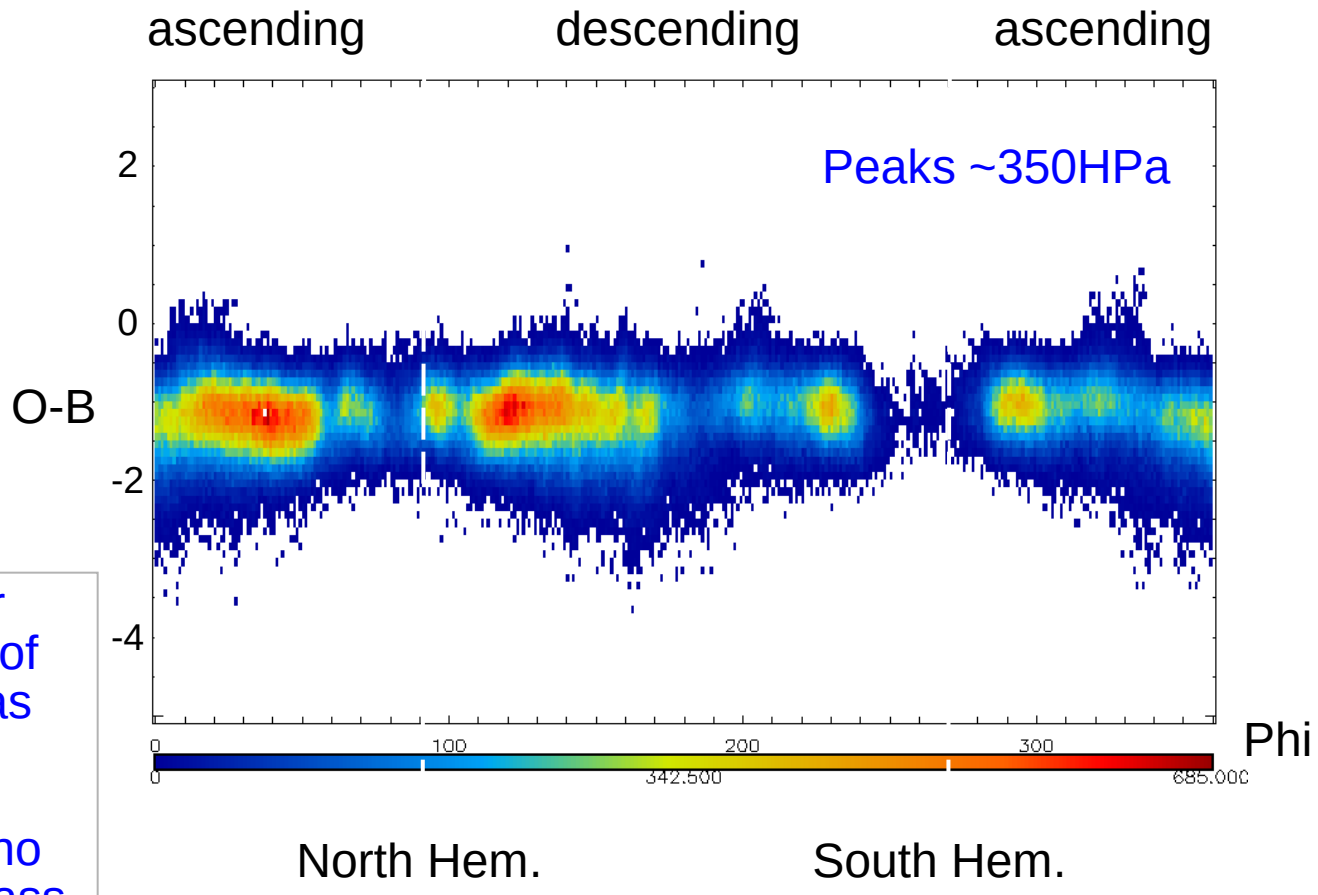


Diagram courtesy of A. Booton



MWHS-2 channel 6, 118±1.1GHz



No clear evidence of orbital bias

Showing no clear air mass bias

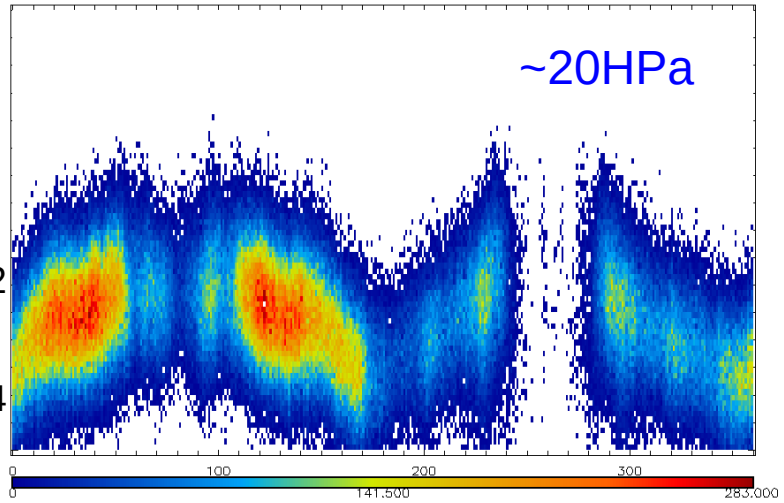
Higher peaking channels show air mass bias

Lower peaking channels are better

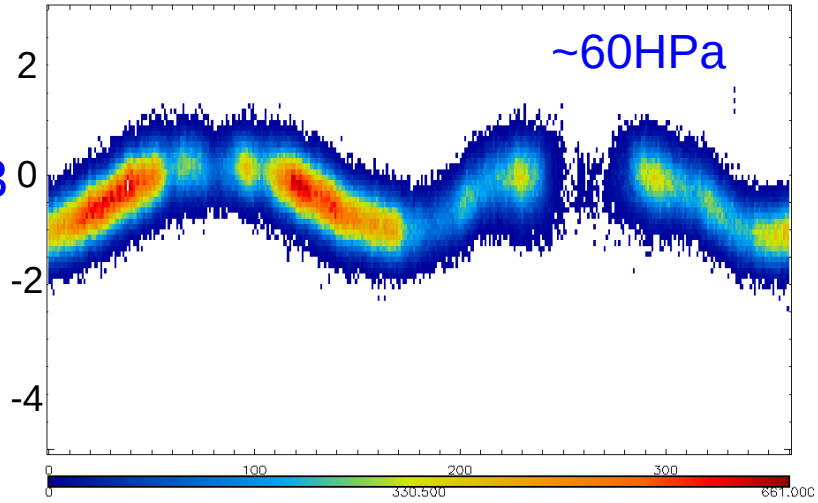
Possibly effect due to errors in spectroscopy?

Needs further study

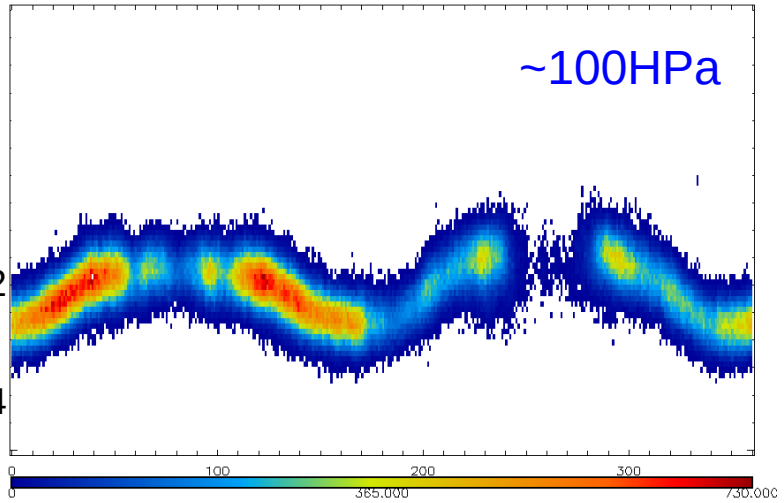
Ch 2



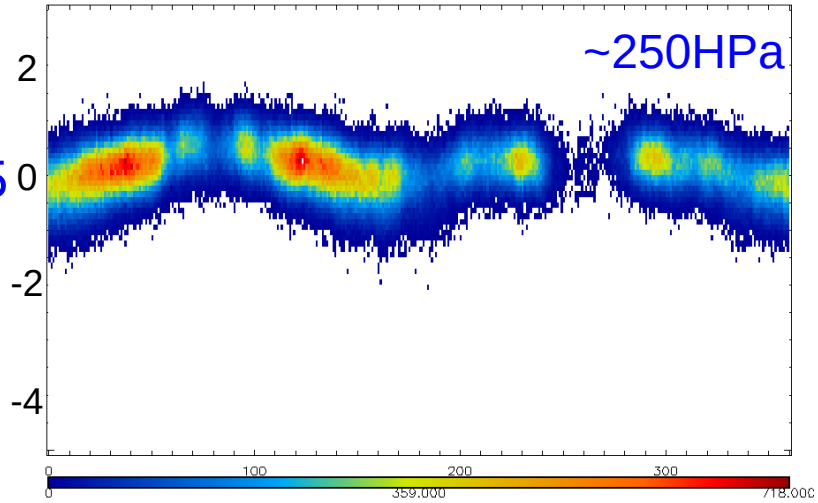
Ch 3



Ch 4



Ch 5



Software errors

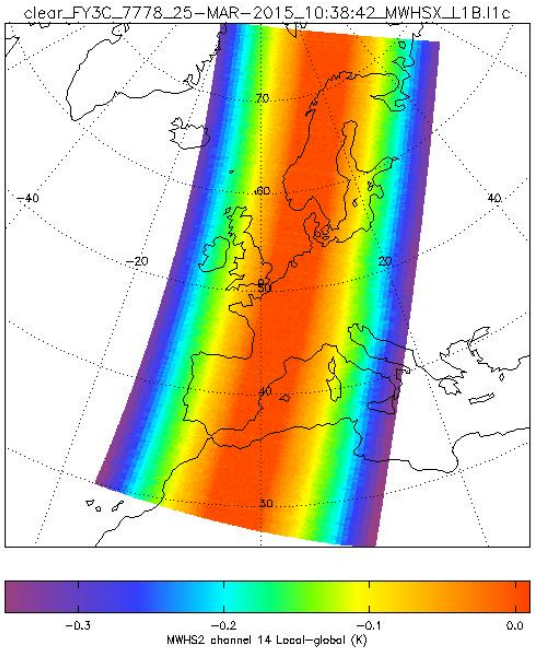
- We were able to diagnose calibration software errors using the “OBC” files from DB package (giving access to raw counts), plus data files
  - FY3C_MWHS_CAL.XCONF (MWHS-2)
  - FY3C_MWTS_CAL.XCONF (MWTS-2)
- For MWHS-2, there are 3 sets of nonlinearity corrections, corresponding to 3 reference instrument temps. Call them u1, u2, u3
- Found that the software was using [u1(5:14),u2(0:4)], i.e. The channels were jumbled – throwback to the old MWHS-1 with 5 channels
- Also found that the wrong cal target was used for some channels
- These were fixed in the fy3cl1db patch of 6th Feb 2015
- *Lesson: if you are getting a contractor to modify software (as CMA had done), be sure to test it independently!*

Global-local consistency

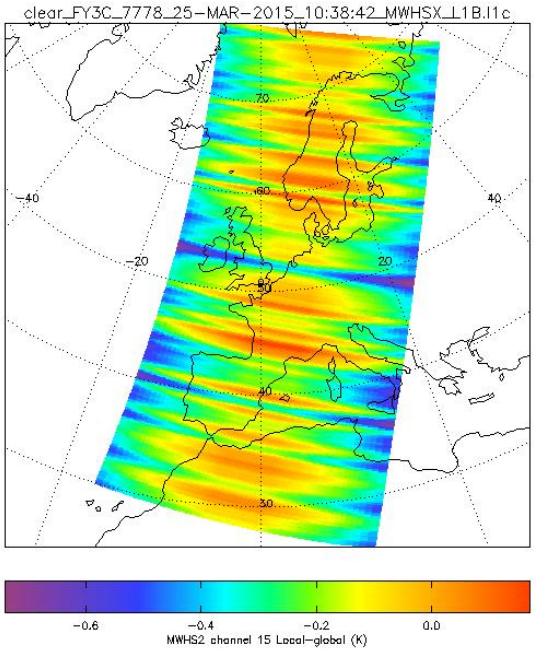
- We monitor global-local consistency routinely
- Local software is under our control, but for the global data we rely on CMA's processing
- Not always synchronised (see image)
- There's also an issue for MWHS-2 channel 15 related to which warm calibration sample is used. This has been reported to CMA

25/03/2015

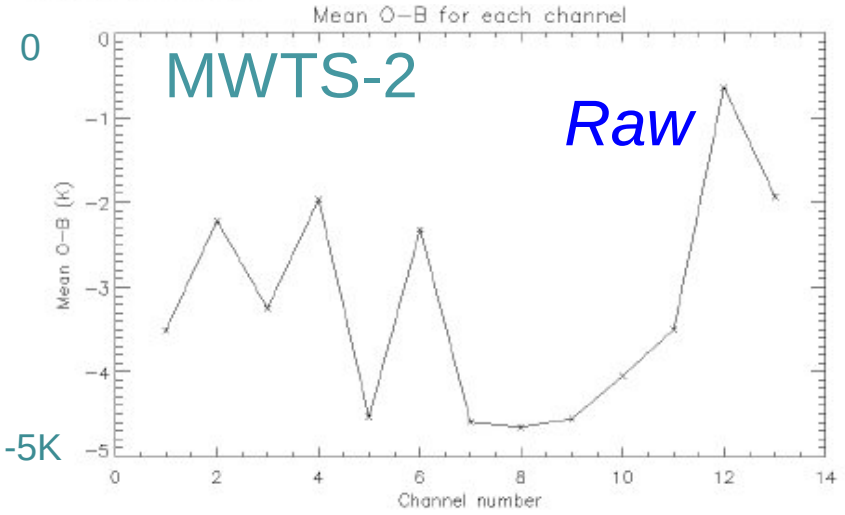
Ch 14: Change to antenna correction on 16th March

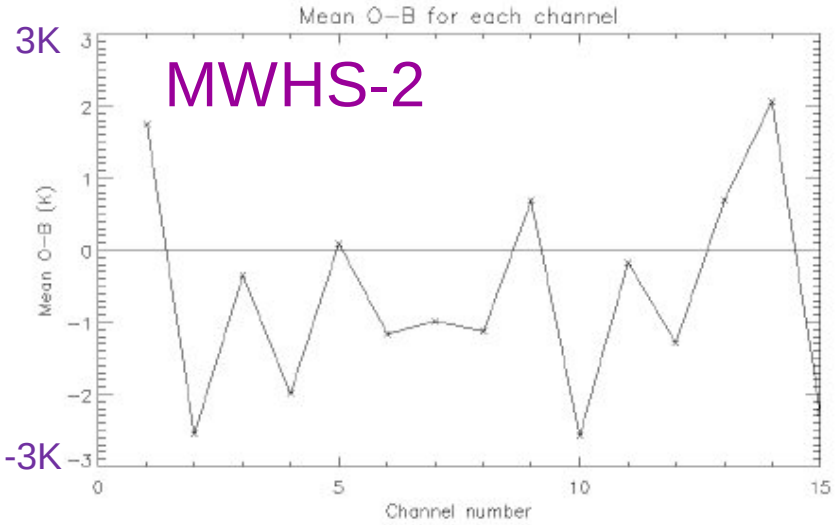


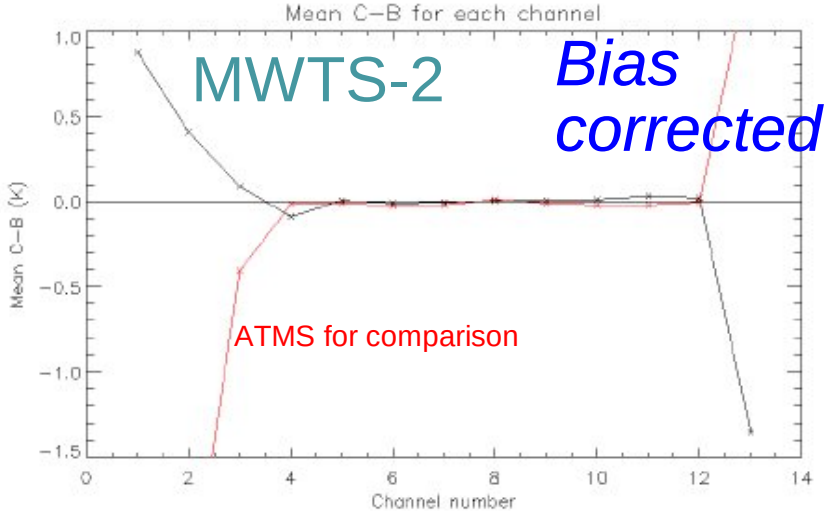
Ch 15: Warm target sample issue

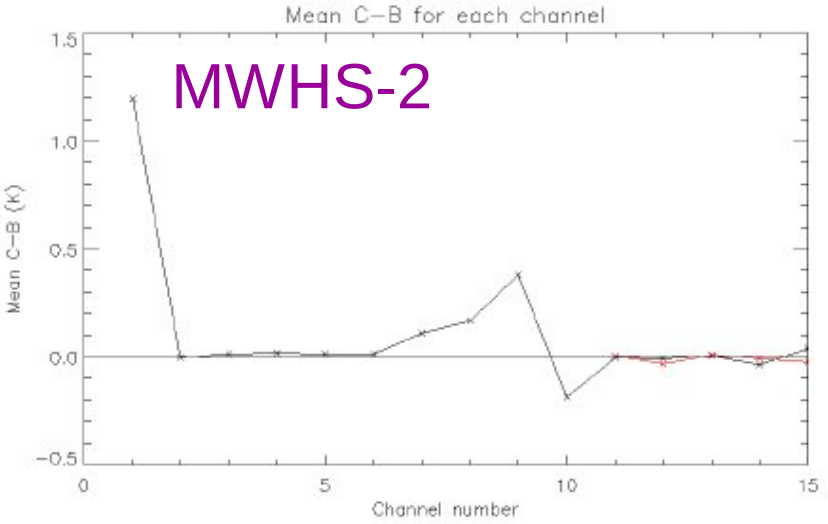


Effectiveness of NWP bias correction

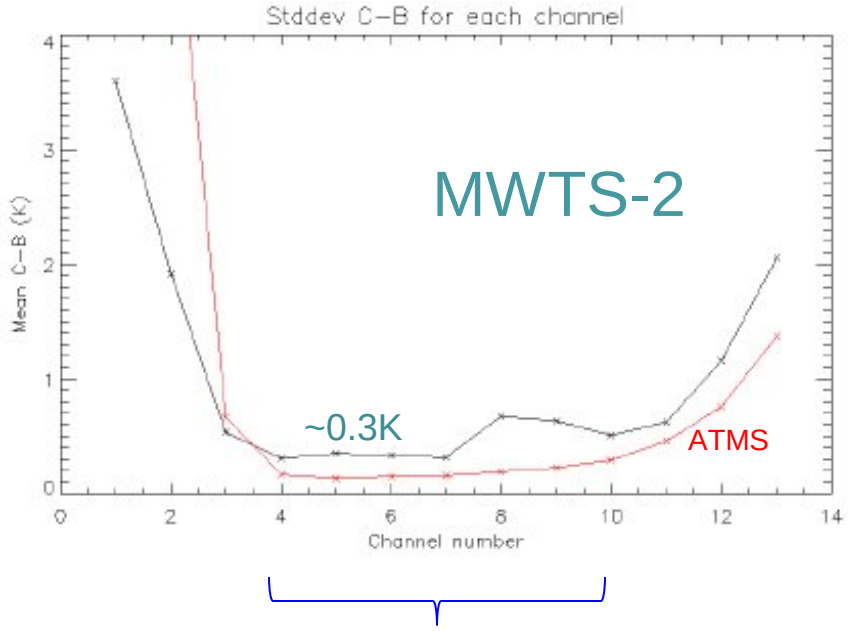


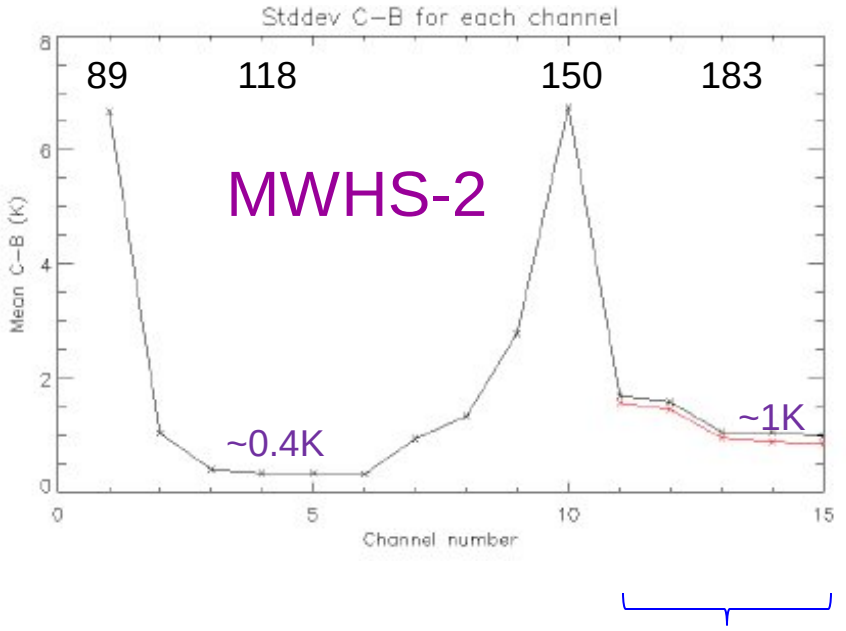






Std deviation of C-B





ATMS is a factor ~2 better than MWTS-2
(but ATMS has more spatial smoothing in our system)

Similar performance for humidity channels

Assimilation experiment for MWHS-2 humidity channels promising

- Improved background fit to other sounders
- Not got time to go into details!

Conclusions on FY-3C

- MWHS-2 has potential. We plan assimilation trials using the humidity channels, and to investigate the usefulness of the 118GHz channels
- MWTS-2 has some problems:
  - Reliability of scan mechanism.
  - Root cause of land-sea anomaly?
  - Some remaining calibration issues.
- Not looked at MWRI or IRAS. MWRI potentially of interest but not currently part of the DB package.
- The DB package works well, and could form part of DBNet (the evolution of RARS).
- Better communication is needed when there are changes to central processing

Prospects for FY-3D and beyond

- Look out for the new IR spectrometer on FY-3D (late 2015 launch)
  - Atmospheric Sounding Interferometer ASI also known as HIRAS
- FY-3E (2017) will have an exciting new early morning orbit
  - 0600(Desc) / 1800(Asc) equator crossing
  - Probably close to the ageing NOAA-18
- Direct broadcast moving to X-band (7820 MHz) for all instruments.
  - Polarisation issue (LHCP) has been raised at CGMS. Details to be confirmed.

Thank you for listening!

Questions?

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Direct broadcast characteristics

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

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

- 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