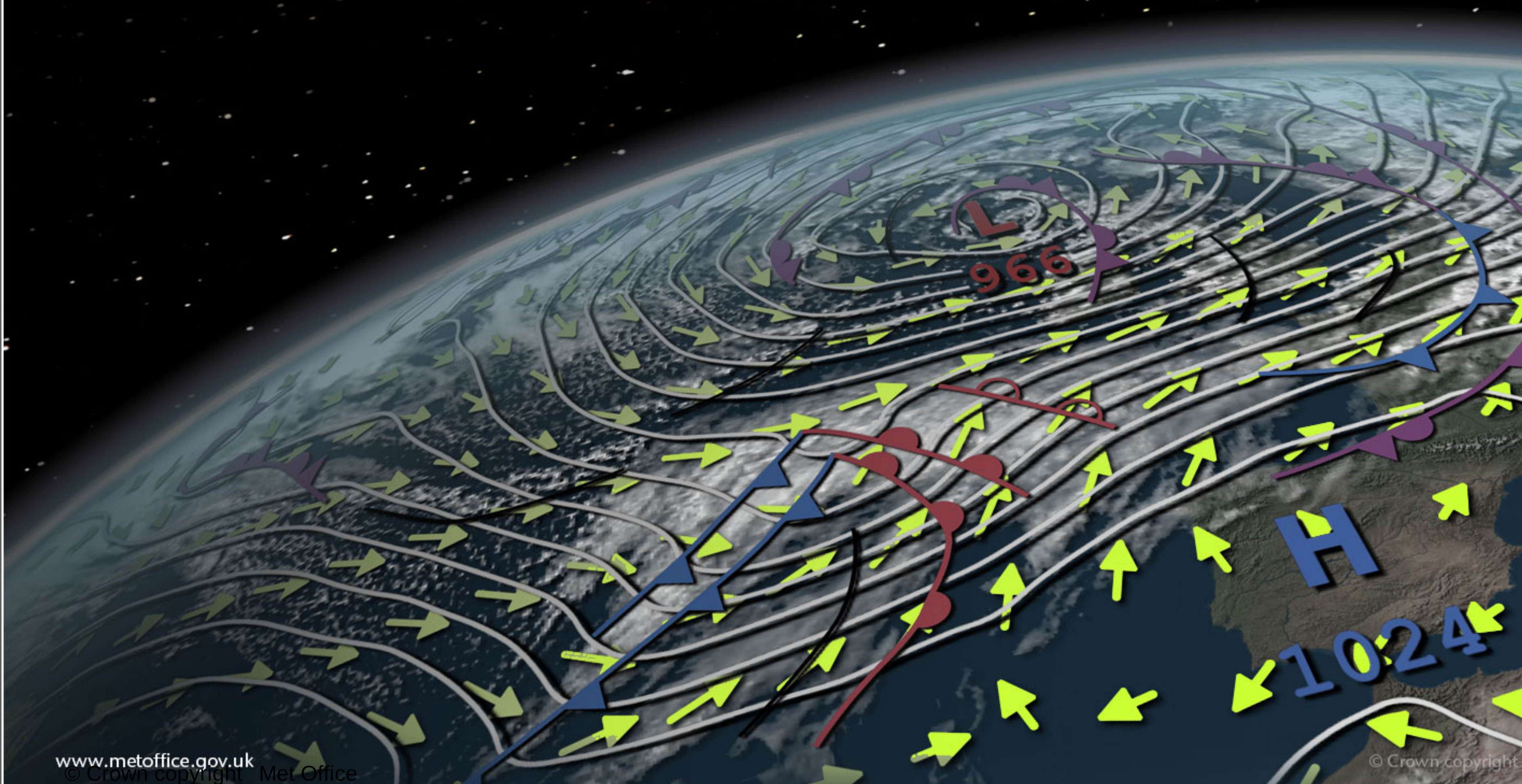
An improved bias correction for SSMIS: Assimilation Assessment

Anna Booton, Bill Bell, Ed Pavelin



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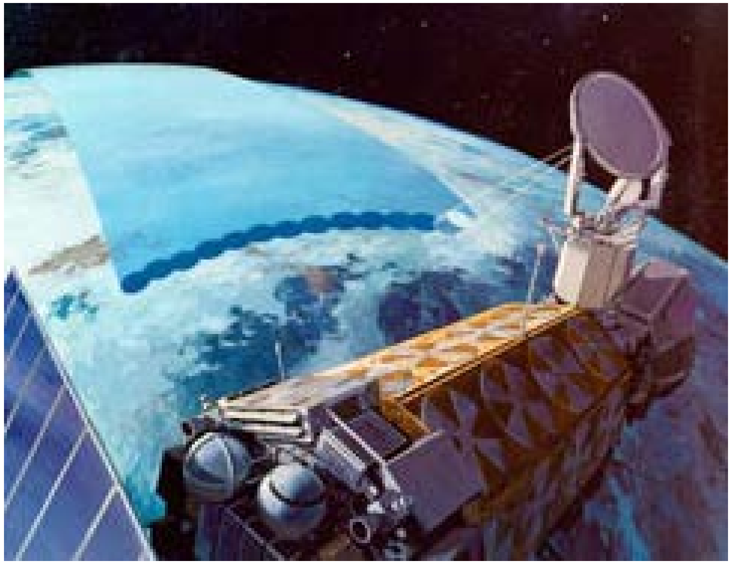
Special Sensor Microwave Imager Sounder (SSMIS) Instruments

The SSMIS instruments flying onboard the US Defense satellites provide

- Temperature (50- 63 GHz) } soundings
- Humidity (183 GHz) } soundings
- Imager dater (90 – 150 GHz)

measuring radiances from the surface to the mesosphere



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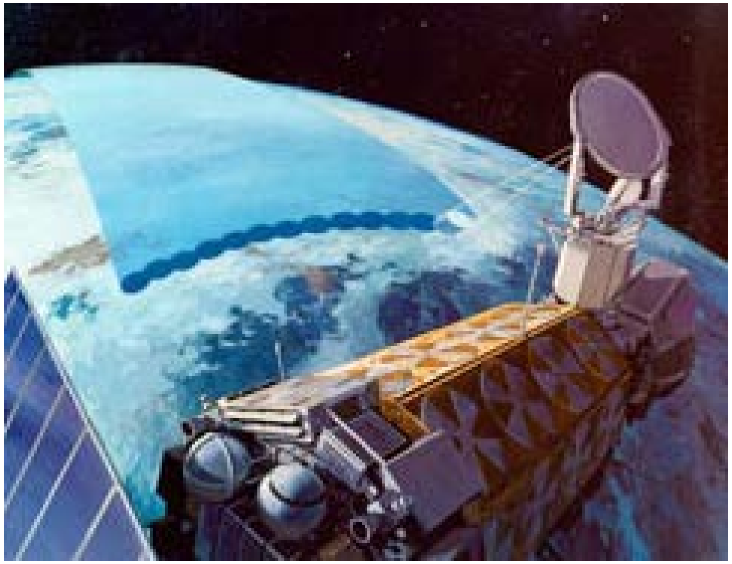
Unfortunately...

- The instruments' suffer from calibration anomalies making the data difficult to utilize...



Calibration anomalies:
Orbital biases

- The anomalies manifest as complex, residual, systematic biases
- Are apparent when comparing the observed brightness temperature (O) with those from NWP model backgrounds (B)

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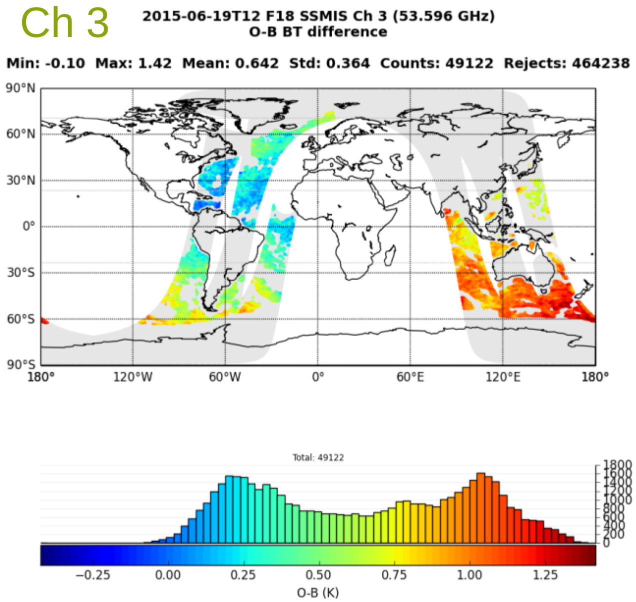
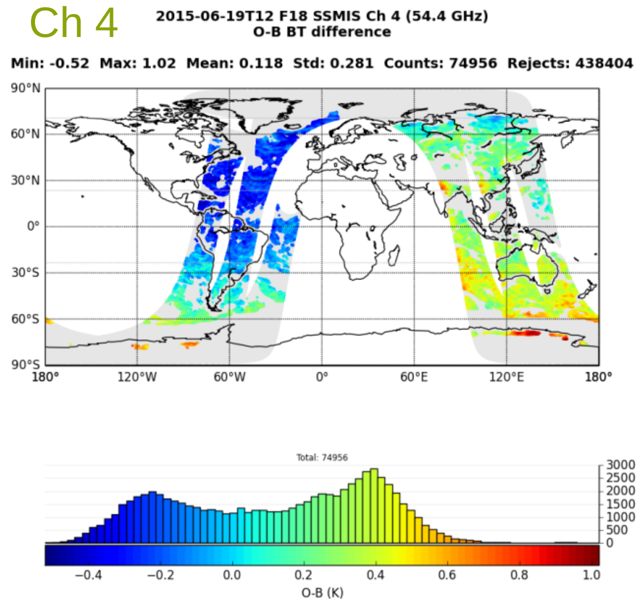
F18:

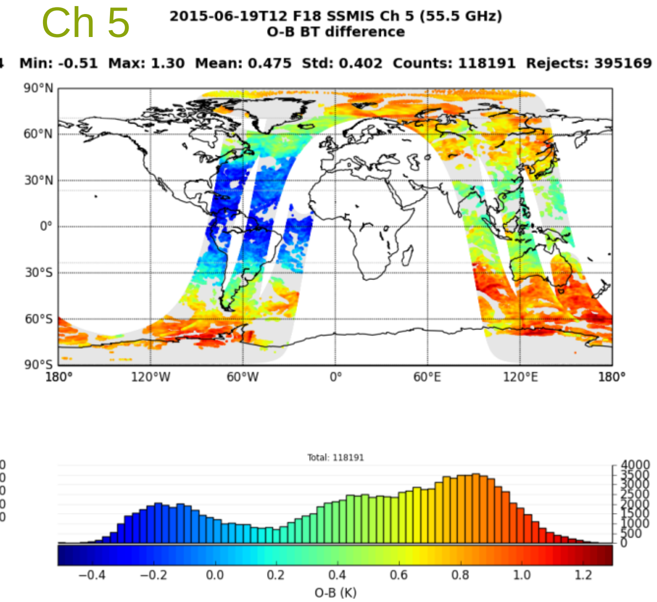
Ch 3



Ch 4



Ch 5



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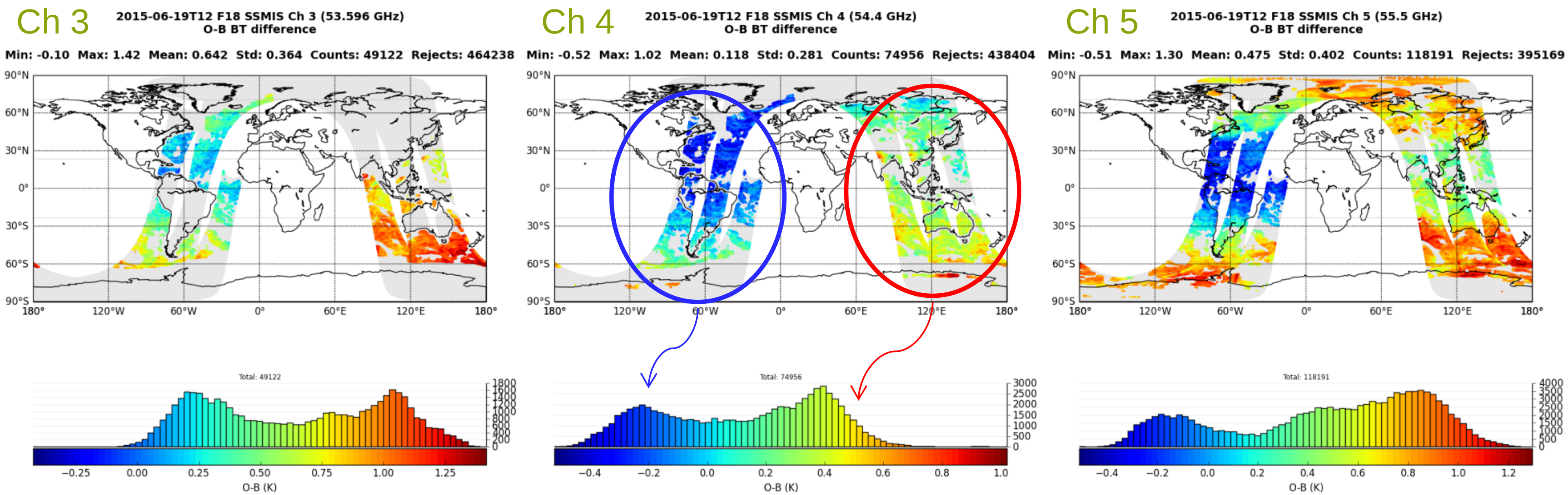

Cooler descending pass | **Warmer ascending pass**

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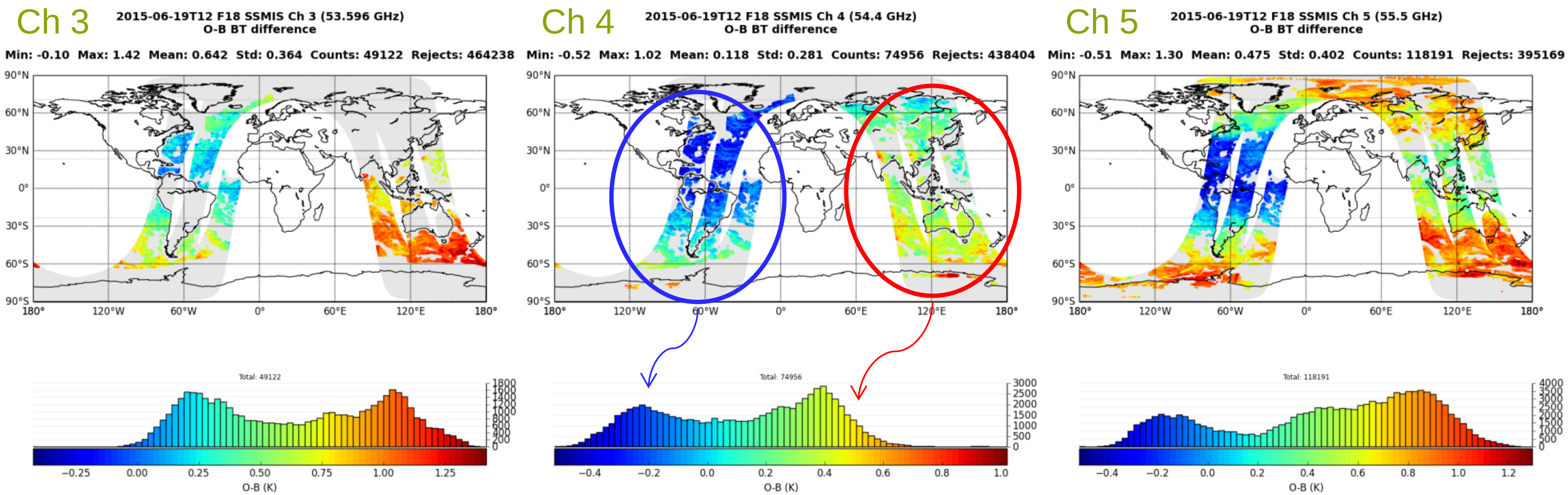

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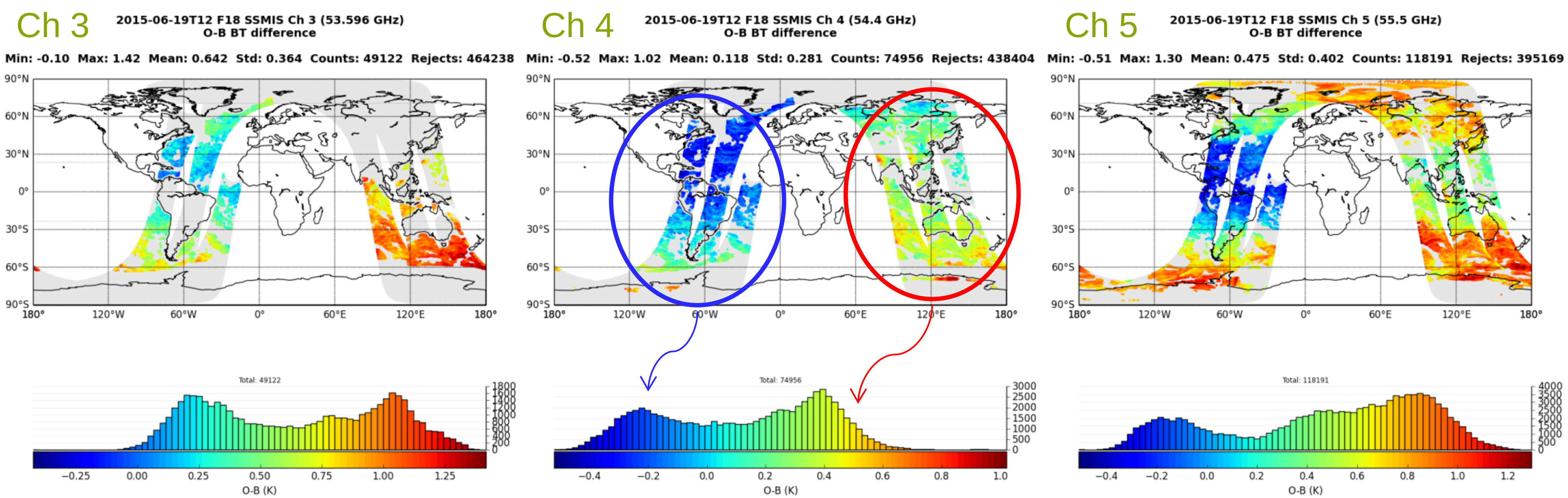


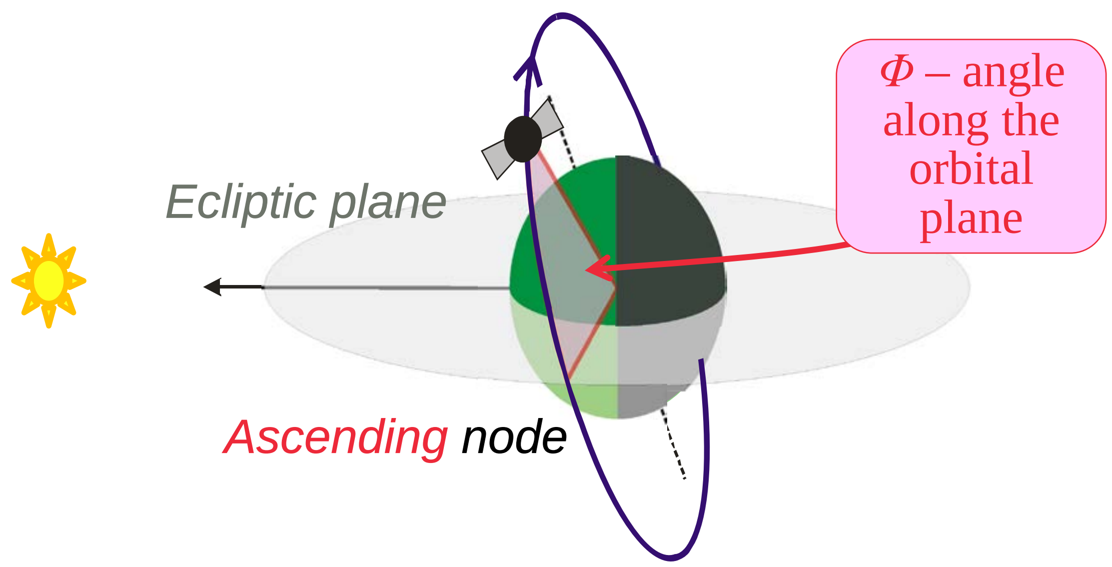
Orbital bias

If we assess the (O-B) biases with respect to the satellite's orbital angle...

The Satellite Orbital Angle

..where the orbital angle is the angle along the orbital plane

- Referenced from the intersection of the satellite's ascending node and the ecliptic plane

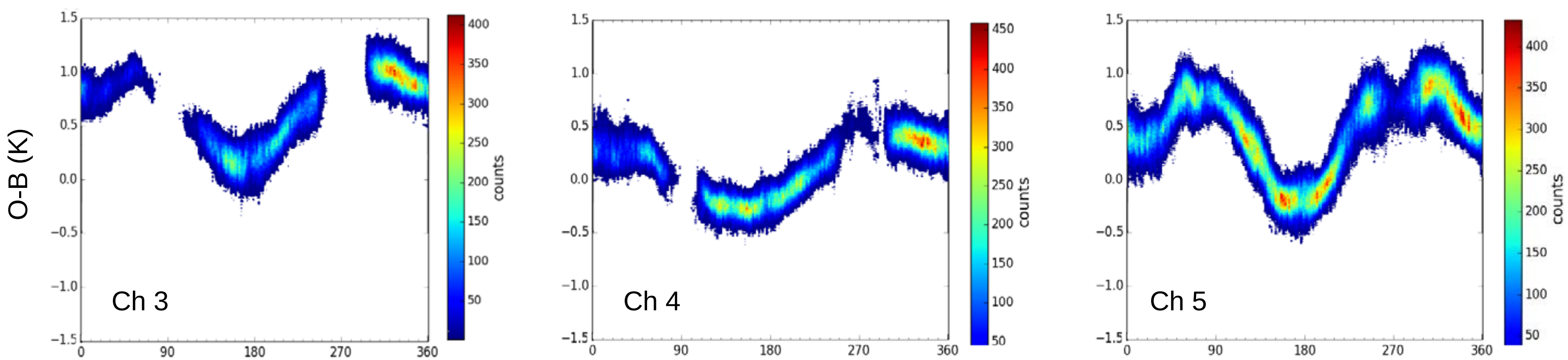


Calibration anomalies: Orbital biases

... the structure of the residual biases is apparent

F18

Cumulative counts for (O-B) for 28 cycles from 17th June – 24th June 2015



Aggregated O-B's wrt satellite's orbital angle for 7 days

Calibration anomalies: Orbital biases

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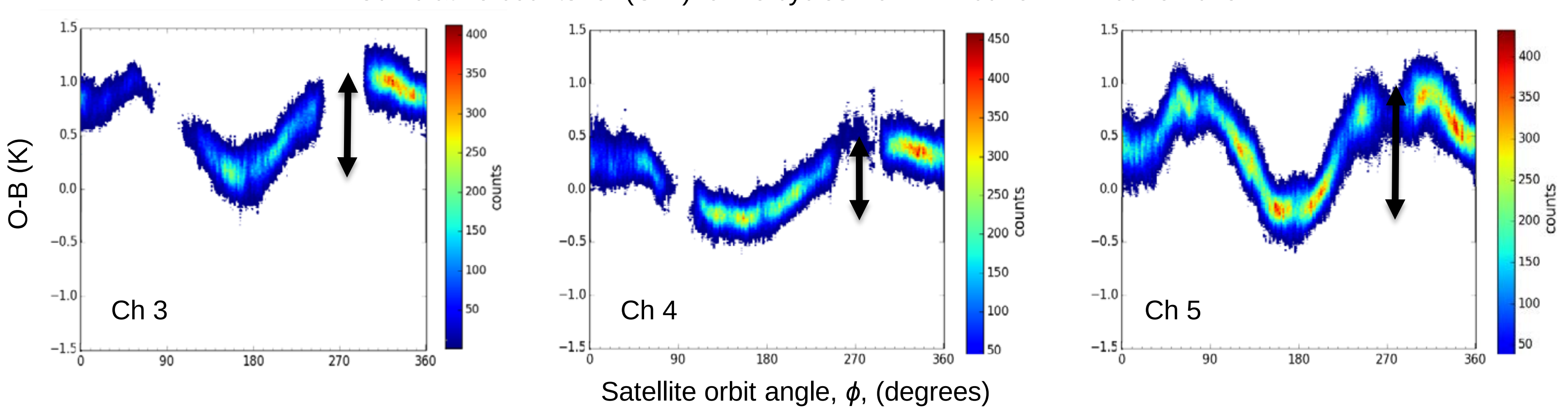


Pk-Pk Residual bias **~ 1K** **~ 0.7K** **~ 1.2K**

- The biases are stable over several days

The Orbital Bias Correction

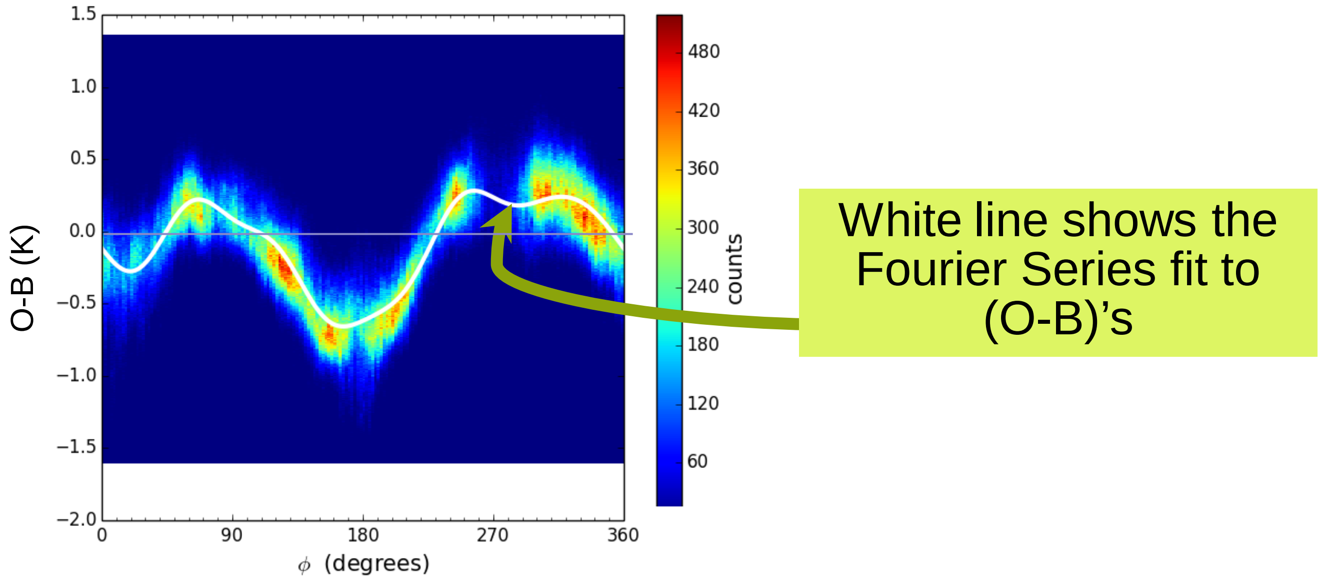
A Fourier Series Approach

The orbital bias correction technique

- We have developed a new orbital bias correction technique

- Uses a Fourier Series 'fit' for characterising the form of the orbital bias.

F18: Ch 6



- This 'correcting fit' is then subtracted from the raw brightness temperatures to obtain the corrected (C) values....

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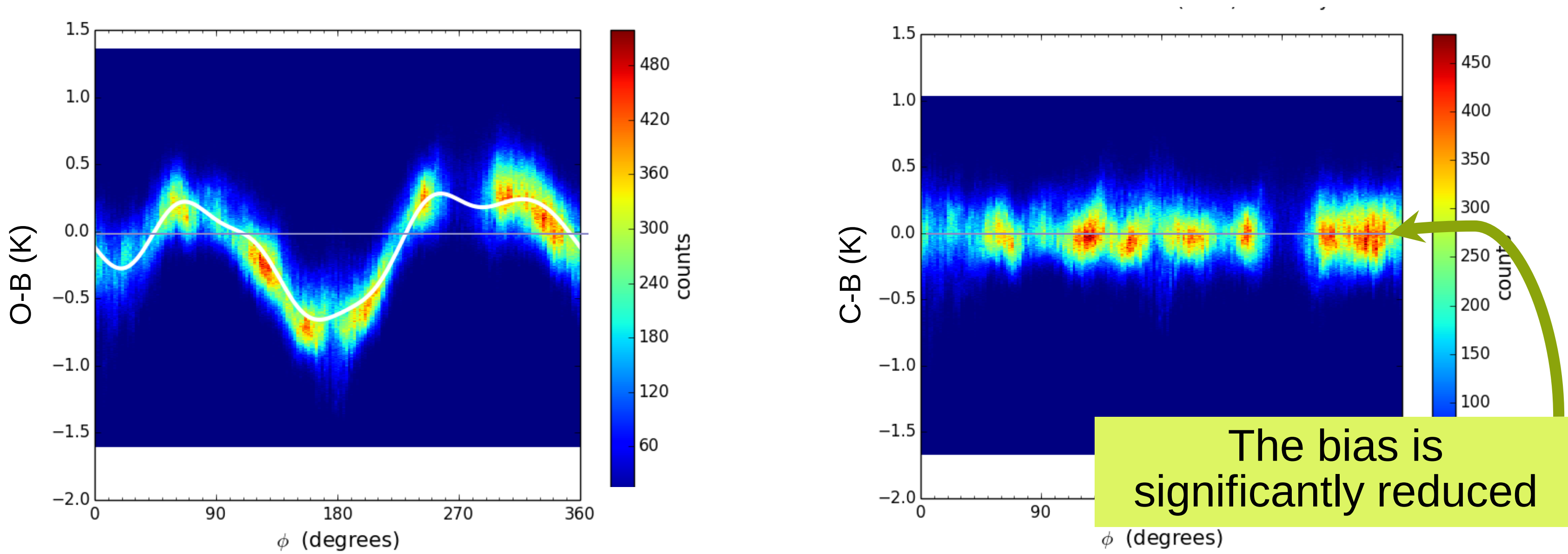

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The orbital bias correction technique

• The cyclic nature of the bias is well modelled by Fourier Series

• Increasing the number of Fourier components enables the more complex structures to be fitted...

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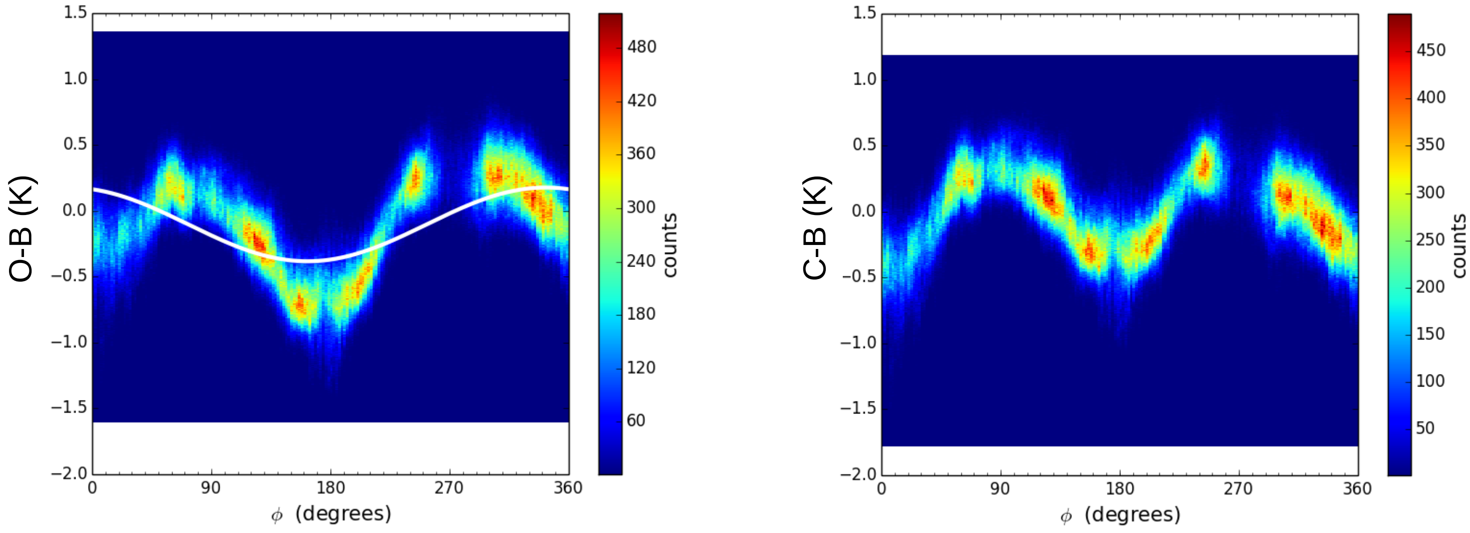

No. Fourier components: N=1, constant + $a_1\cos(\phi) + b_1\sin(\phi)$

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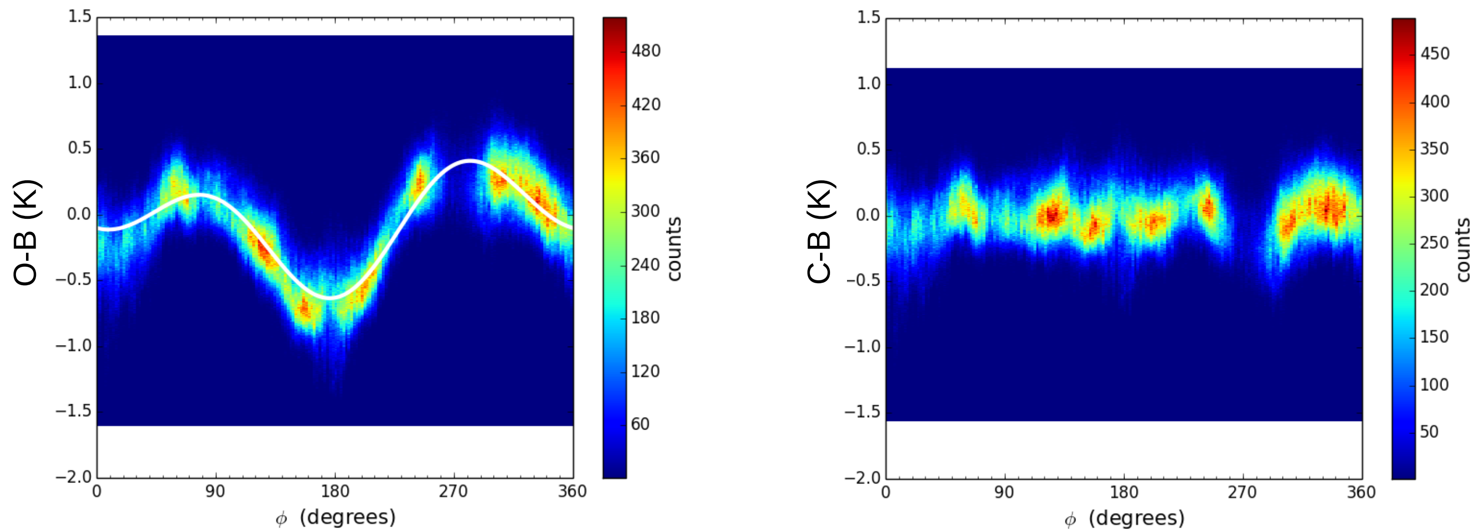

No. Fourier components: N=2, constant + $a_1\cos(\phi) + b_1\sin(\phi) + a_2\cos(2\phi) + b_2\sin(2\phi)$

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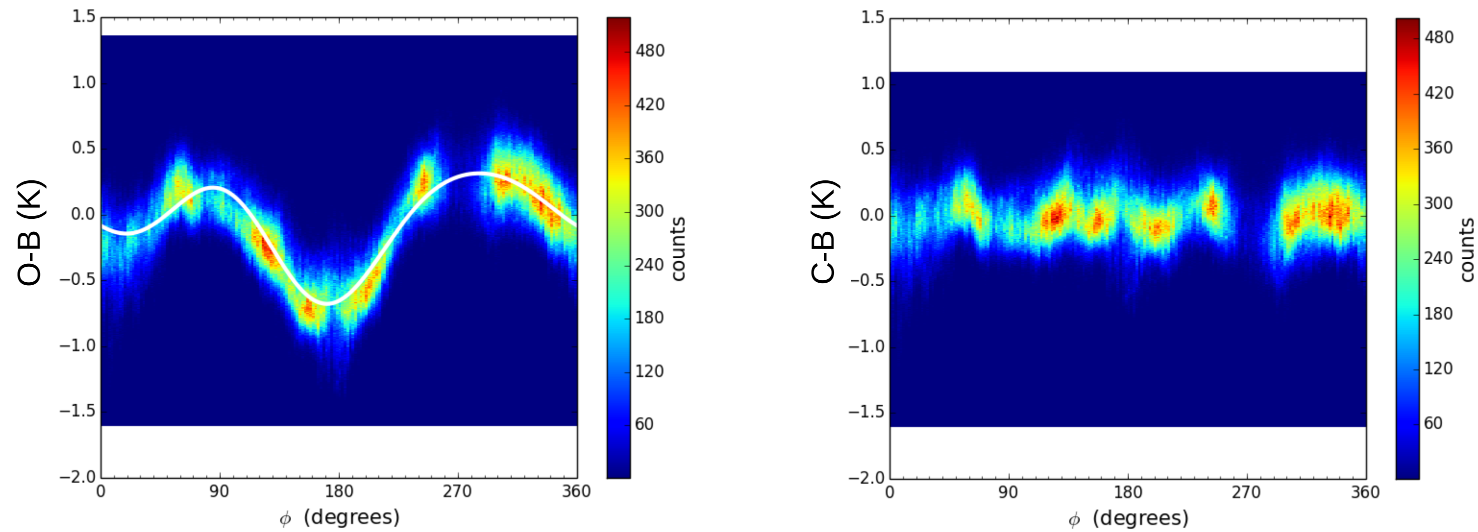

No. Fourier components: N=3,

$$\text{constant} + a_1\cos(\phi) + b_1\sin(\phi) + a_2\cos(2\phi) + b_2\sin(2\phi) + a_3\cos(3\phi) + b_3\sin(3\phi)$$

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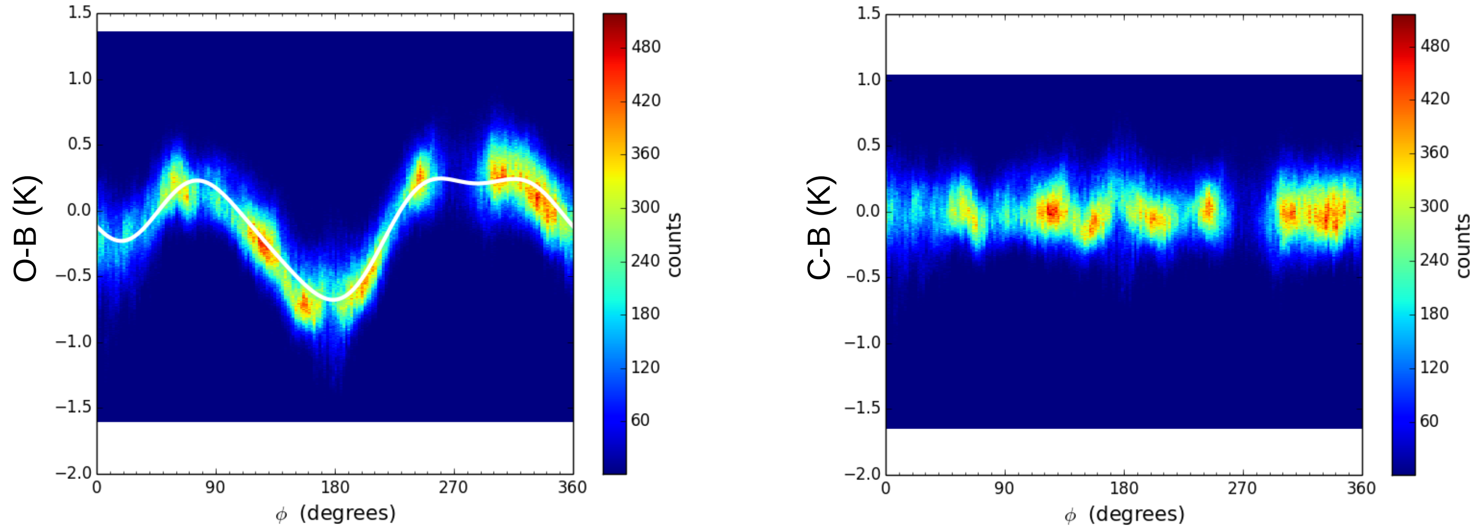

No. Fourier components: N=4, constant + $a_1\cos(\phi) + b_1\sin(\phi)$ + ... + $a_4\cos(4\phi) + b_4\sin(4\phi)$

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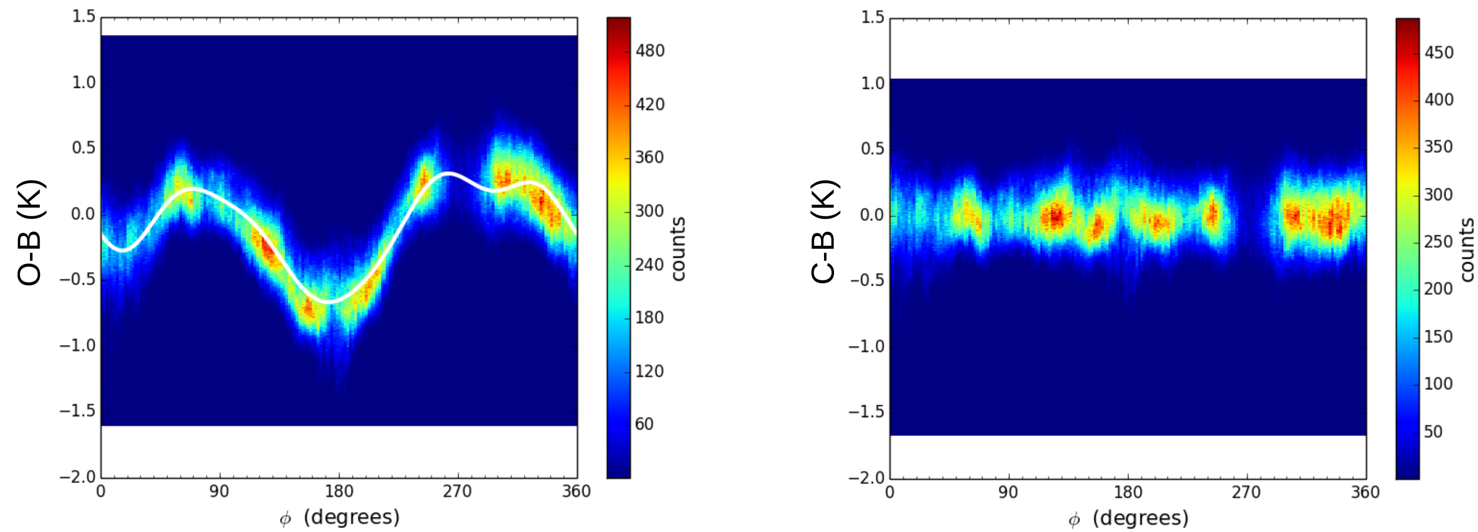

No. Fourier components: N=5, $\text{constant} + a_1\cos(\phi) + b_1\sin(\phi) + \ldots + a_5\cos(5\phi) + b_5\sin(5\phi)$

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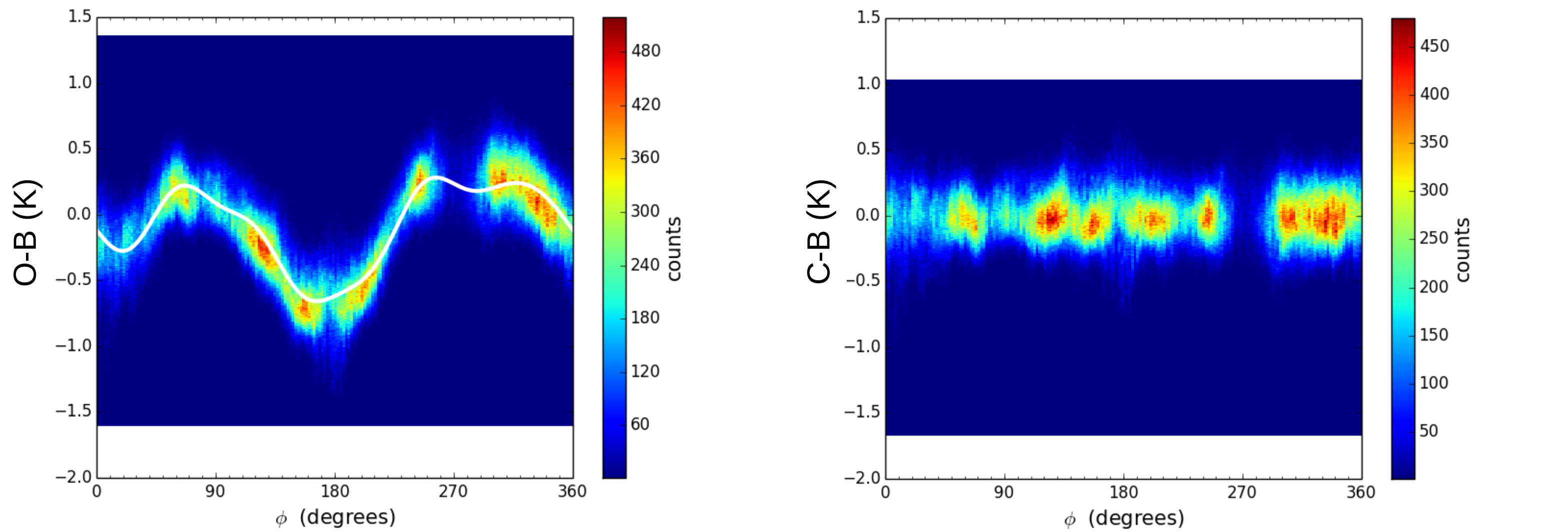

No. Fourier components: N=6, $\text{constant} + a_1\cos(\phi) + b_1\sin(\phi) + \ldots + a_6\cos(6\phi) + b_6\sin(6\phi)$

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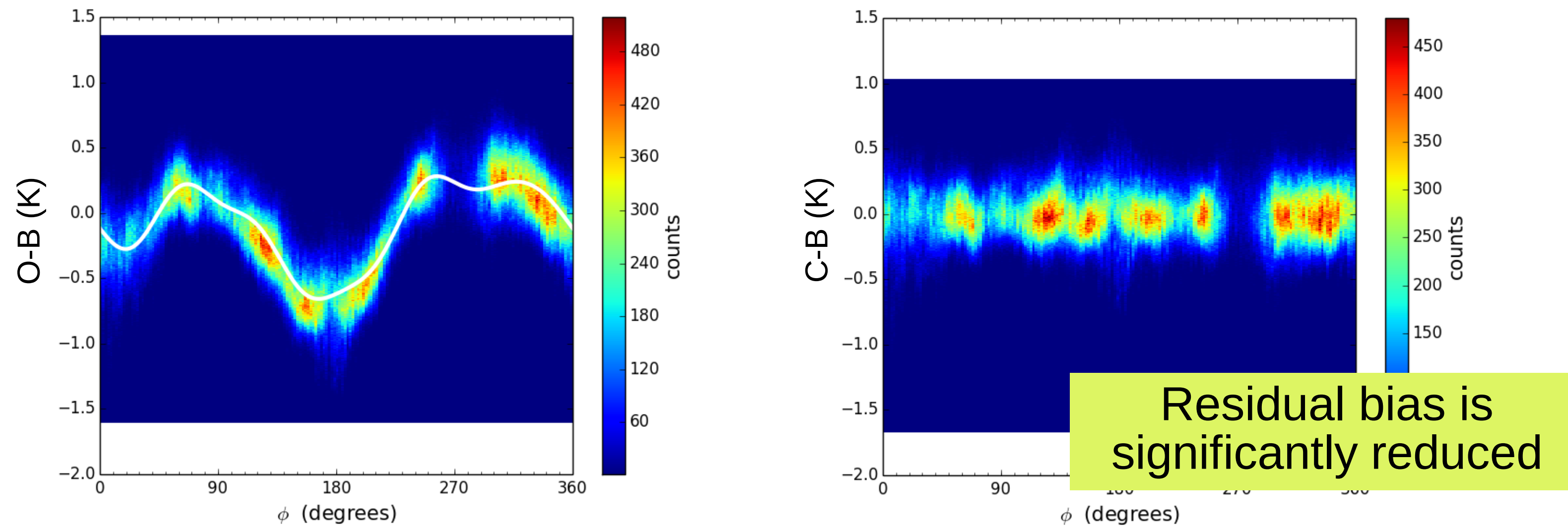


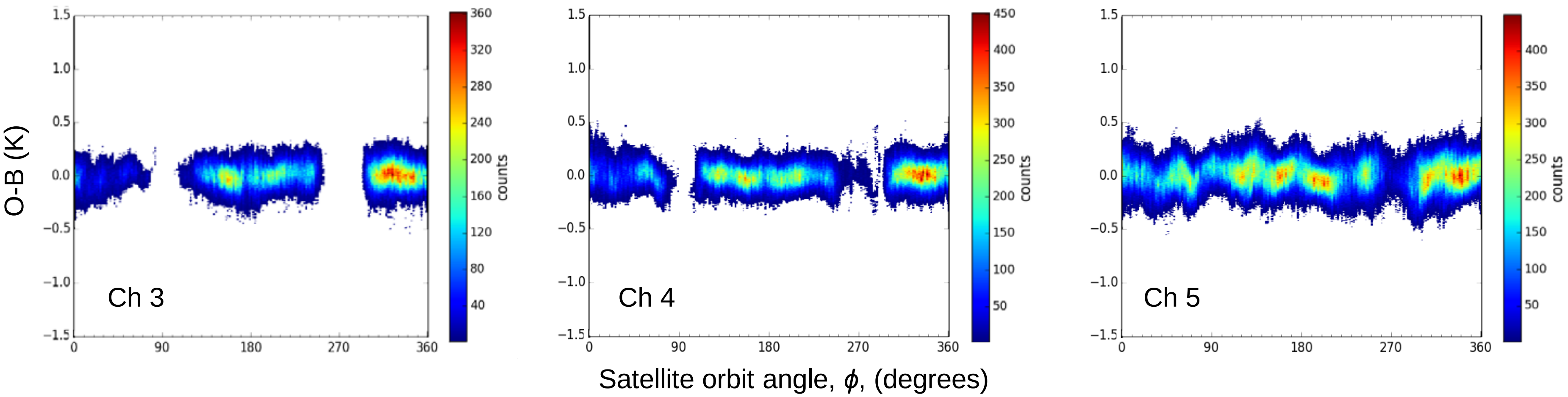
No. Fourier components: N=6, $\text{constant} + a_1\cos(\phi) + b_1\sin(\phi) + \ldots + a_6\cos(6\phi) + b_6\sin(6\phi)$

Applying the correction...

Combining it with cross-scan bias correction proved successful at mitigating these biases

F18

Cumulative counts for (C-B) for 28 cycles from 17th June – 24th June 2015



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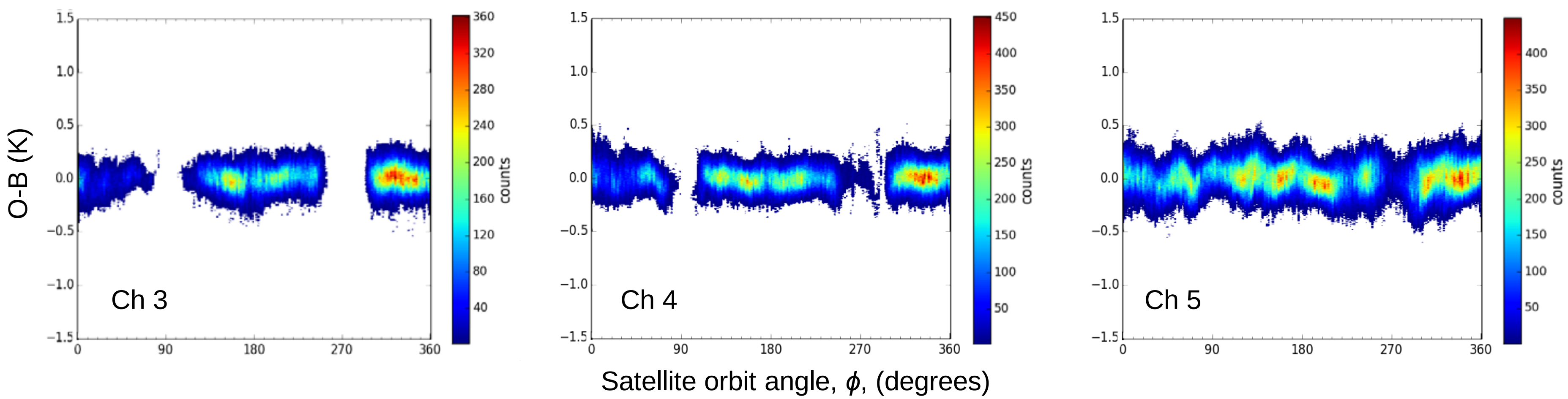

The correction is working well for all channels

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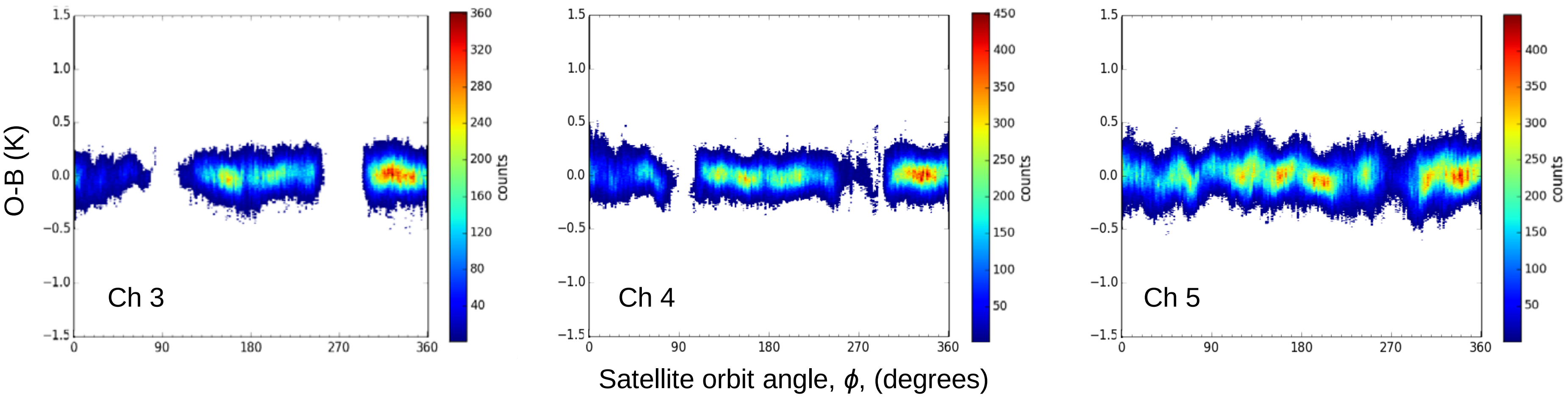

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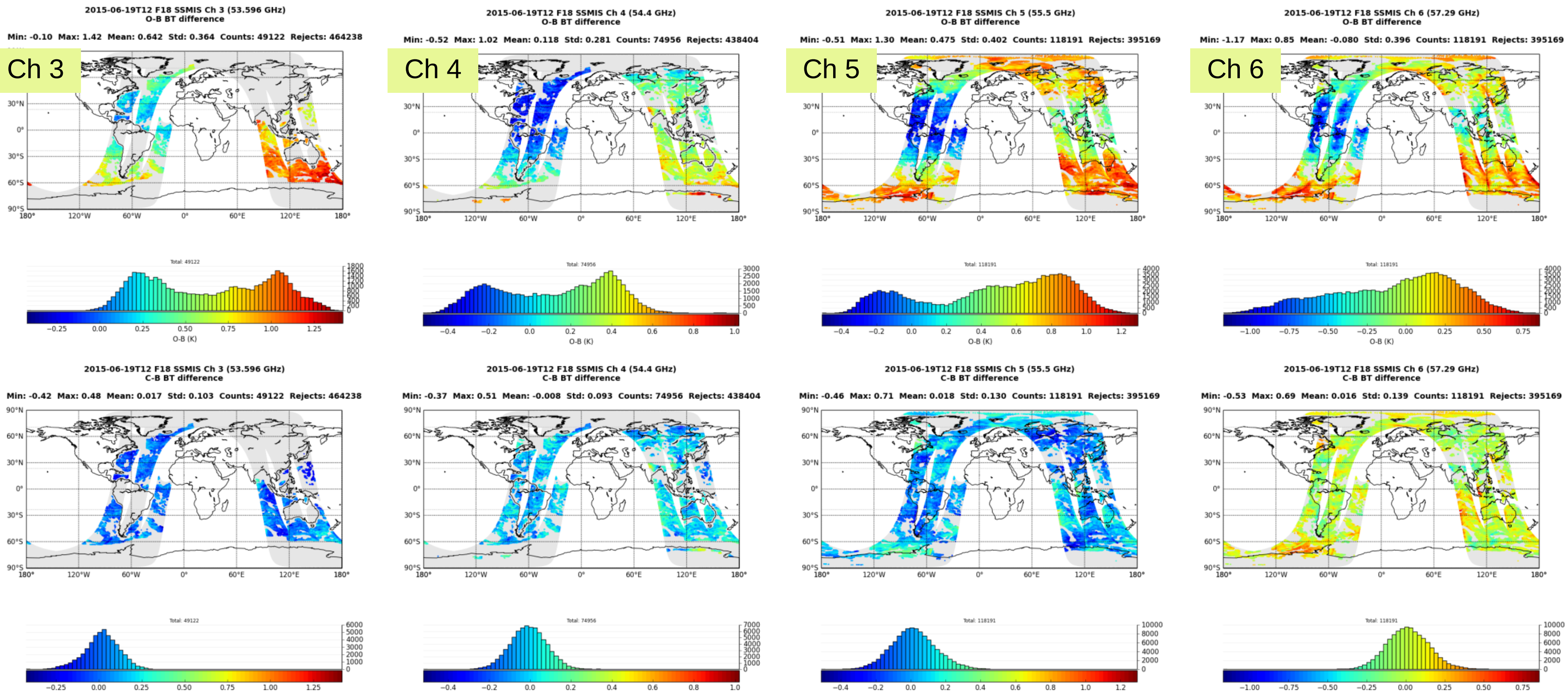
Looking in more detail...

First-guess departure maps:
Temperature Sounding channels

F-18

Pre-bias correction



Post-bias correction

First-guess departure maps:
Temperature Sounding channels

F-18

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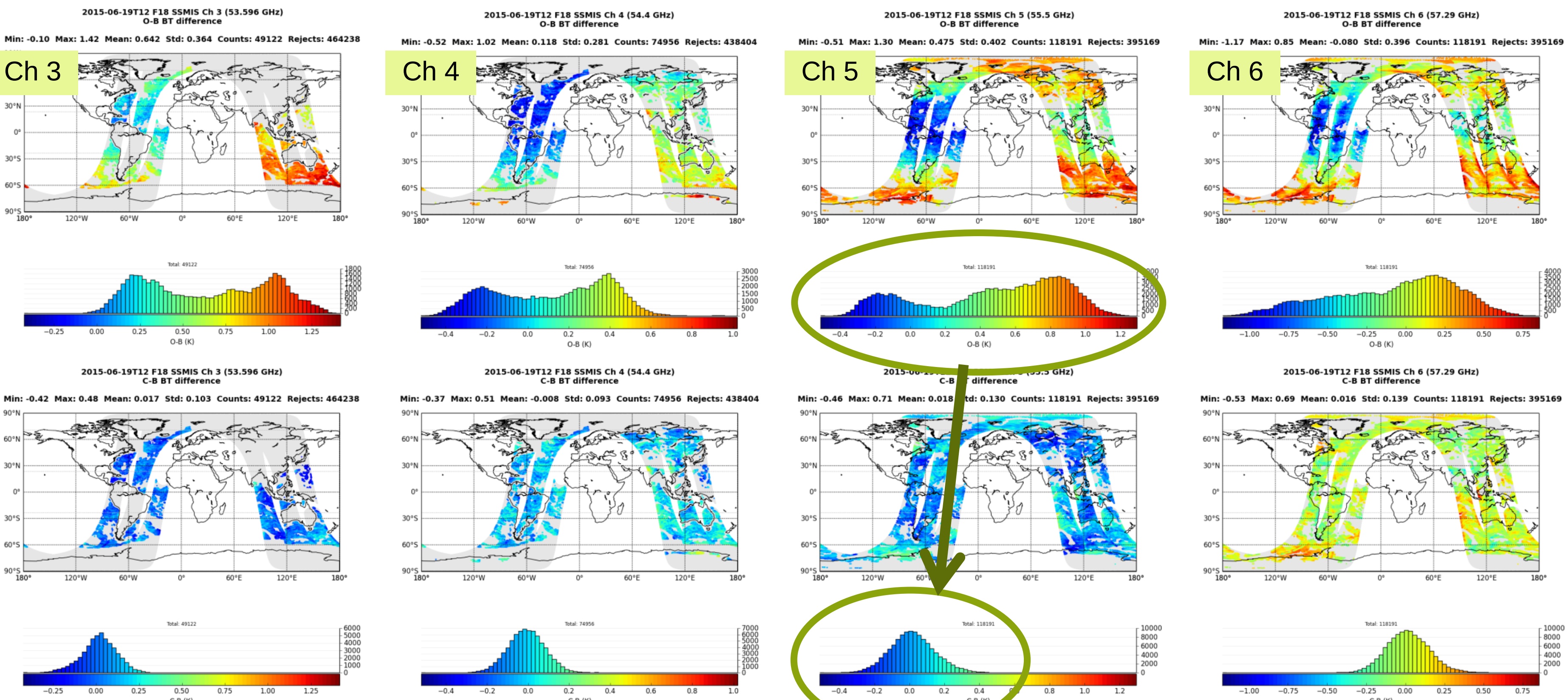


Post-bias correction

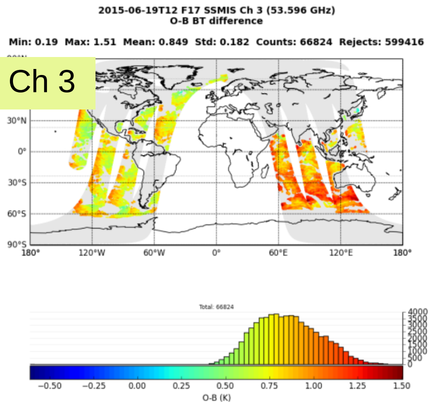
The complex structure is well modelled

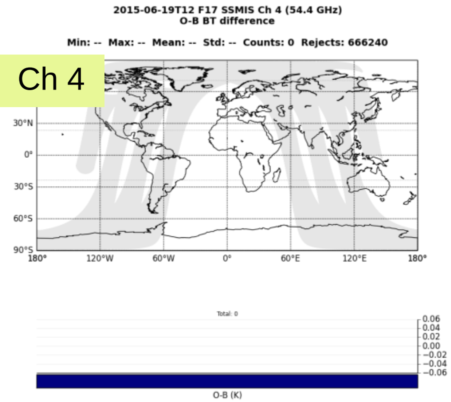
First-guess departure maps:
Temperature Sounding channels

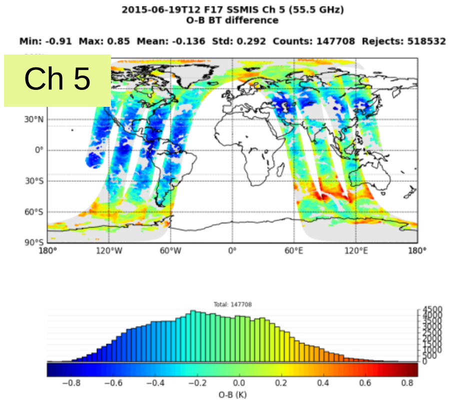
Met Office

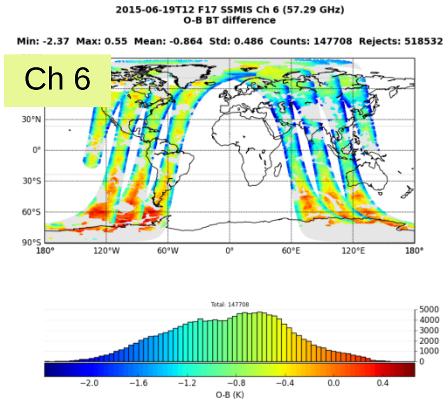
F-17

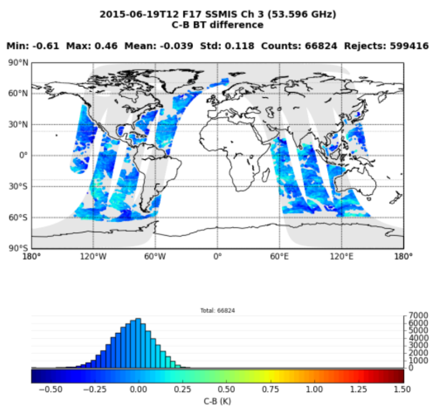
Pre-bias correction

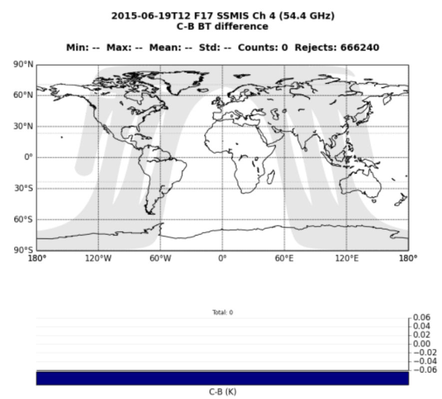


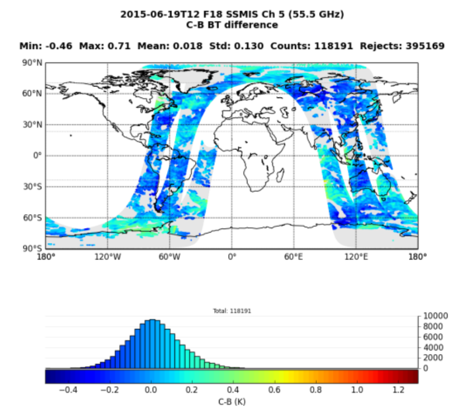


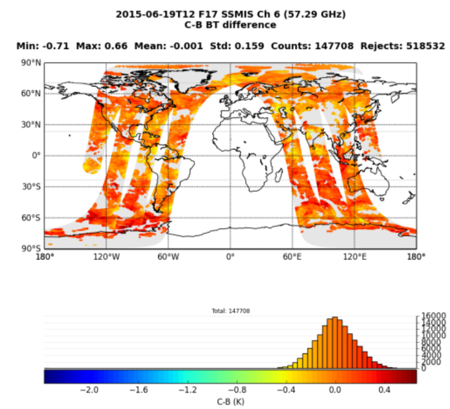










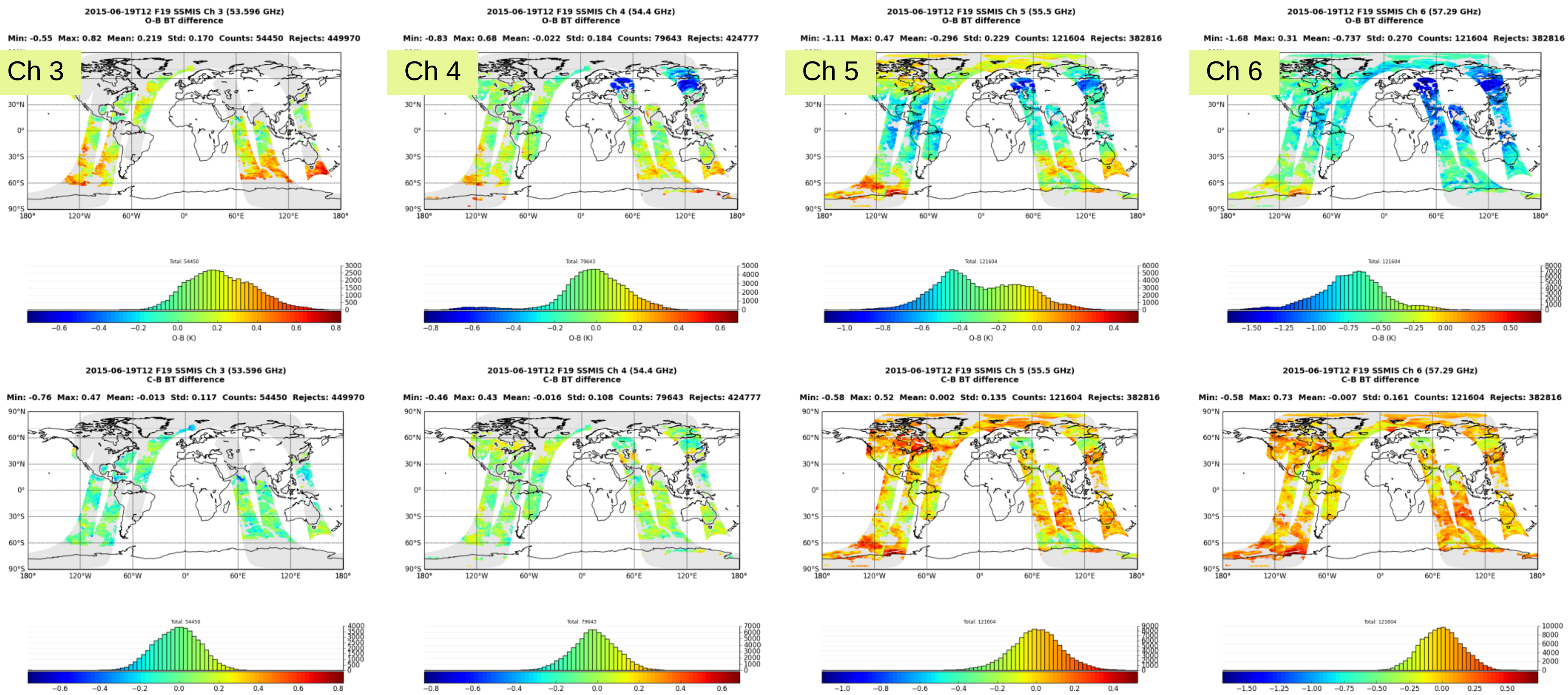


Post-bias correction

First-guess departure maps:
Temperature Sounding channels

F-19

Pre-bias correction



Post-bias correction

Met Office

First-guess departure maps:
Temperature Sounding channels

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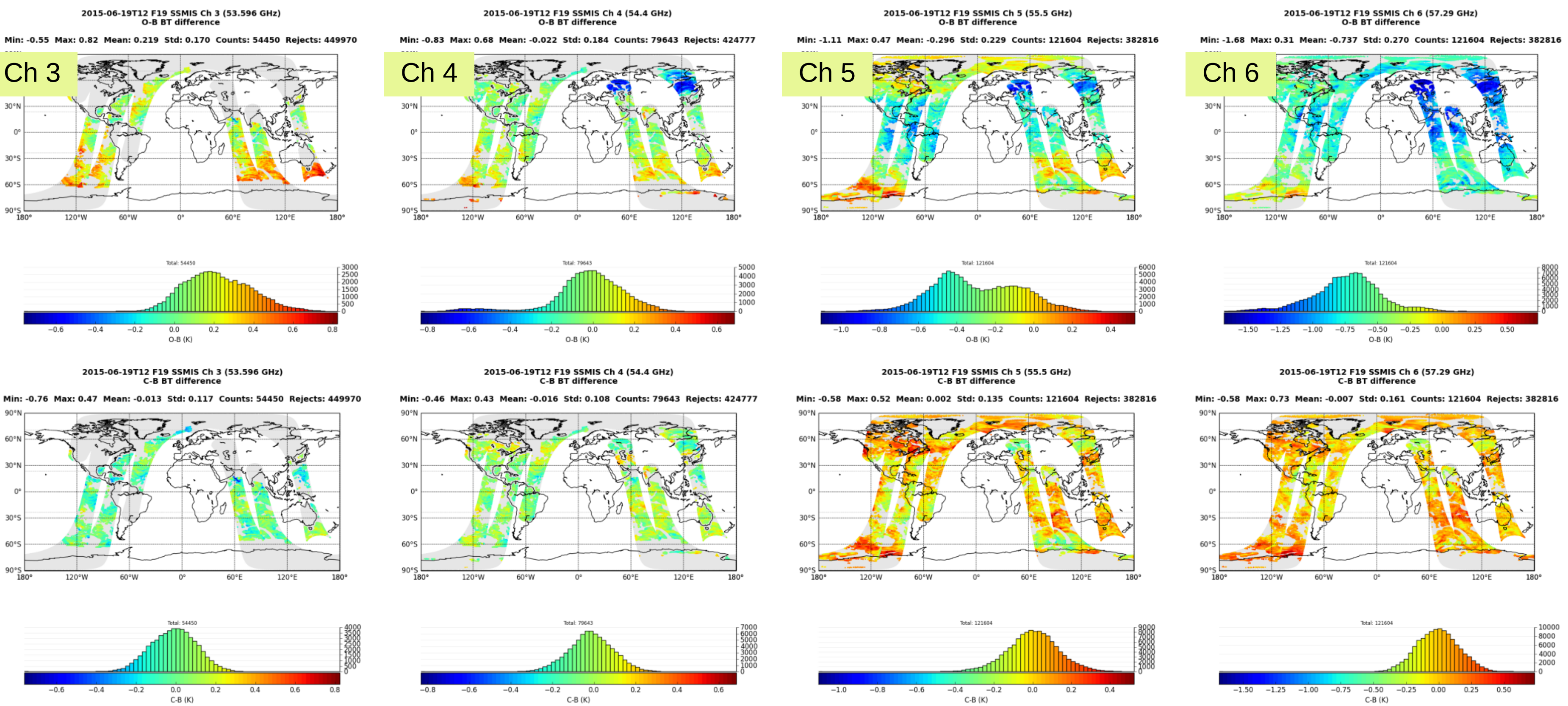
Pre-bias correction



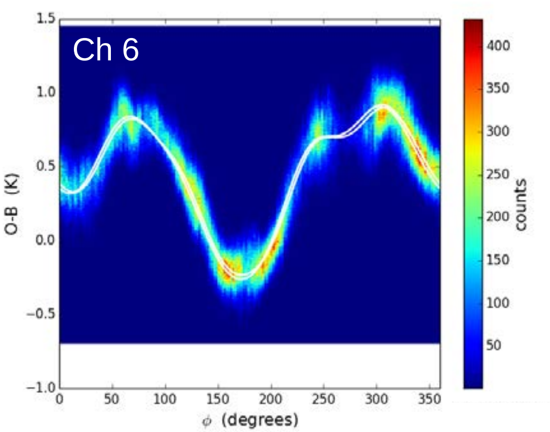
Post-bias correction

And performs equally well for the humidity and imager channels.
Although less Fourier bias predictors were used....

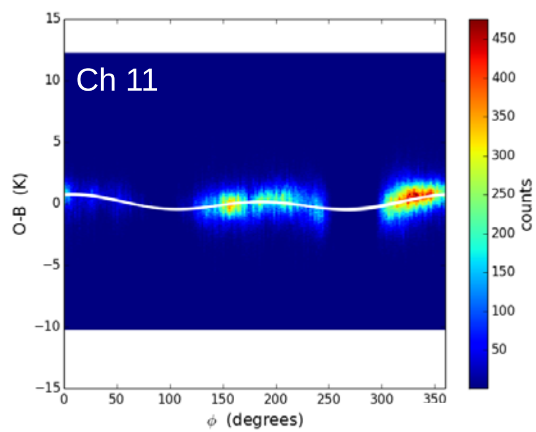
The number of predictors used...

- **12** Fourier predictors + constant (N=6) for correcting the **temperature** sounding channels
- **4** Fourier predictors + constant (N=2) for the **humidity** and **imager** channels
  - To constrain the fit where surface observations are rejected

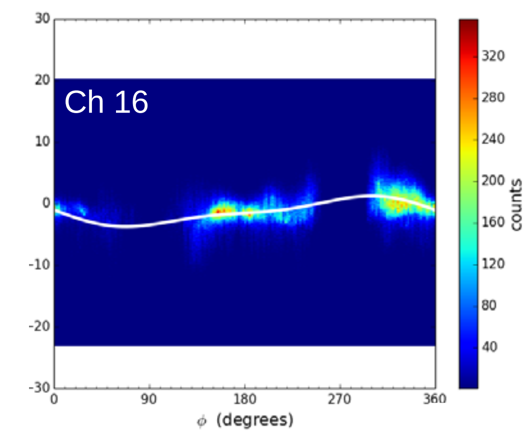
F18



Temperature,
N=6 (Ch 2-7, 23-24)



Humidity,
N=2 (Ch 9-11)



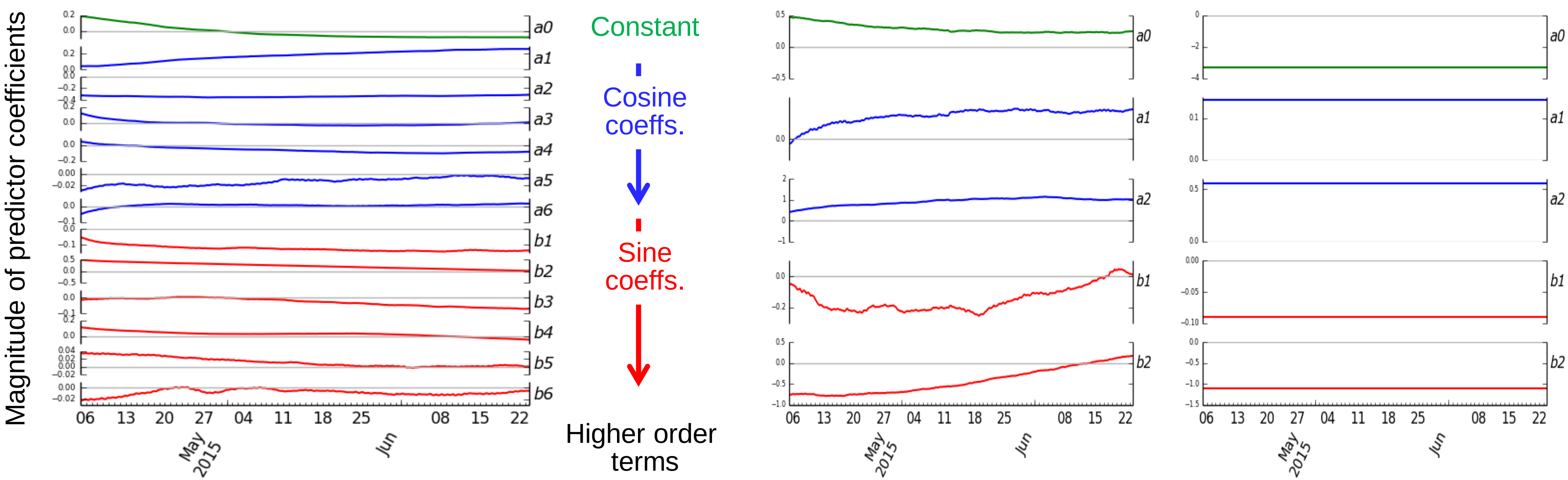
Imager,
N=2 (Ch 12-16)

Evolution of the predictor coefficients

- Orbital predictors have been implemented within our variational bias correction system

- We monitored the magnitude of the coefficients over a three month time period.

Evolution of Orbital Bias Predictor Coefficients



Temperature: F18 Ch 6

Humidity: F18 Ch 11

Imager: F18 Ch 16

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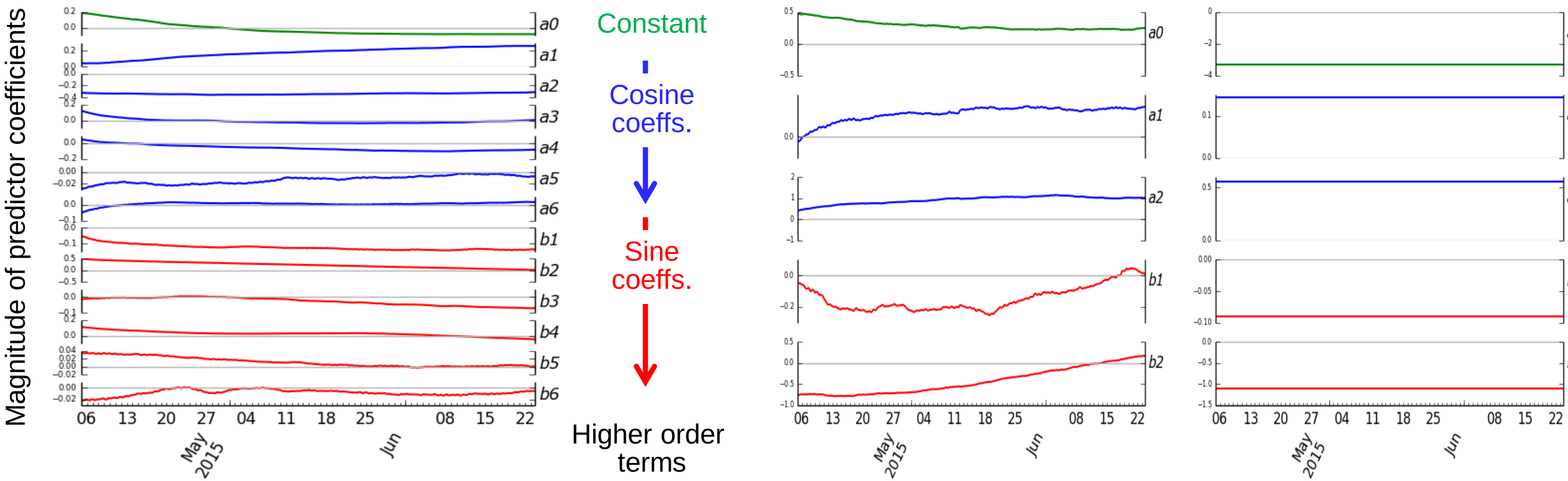


Temperature: F18 Ch 6

Humidity: F18 Ch 11

Imager: F18 Ch 16

The slow evolution indicates the bias correction is stable

The Assimilation Experiments

Assimilation Experiments

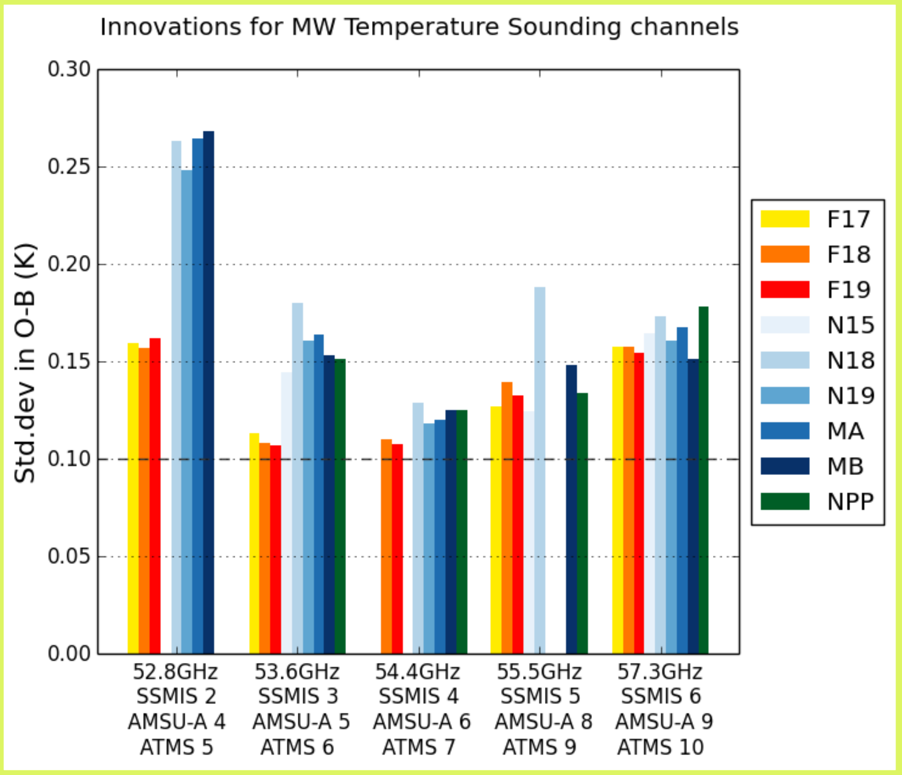
- NWP trials assimilating SSMIS data from F17 & F18 instruments, to separately assess the impact of:
  - Temperature sounding (Ch: 2-7,23,24)
  - Humidity sounding (Ch: 9-11)
  - Imager (Ch: 12-16)

as well as a

- ‘Unified’ – temperature & humidity & imager trial

were run for a summer period, June 2014.

SSMIS innovations for key channels:



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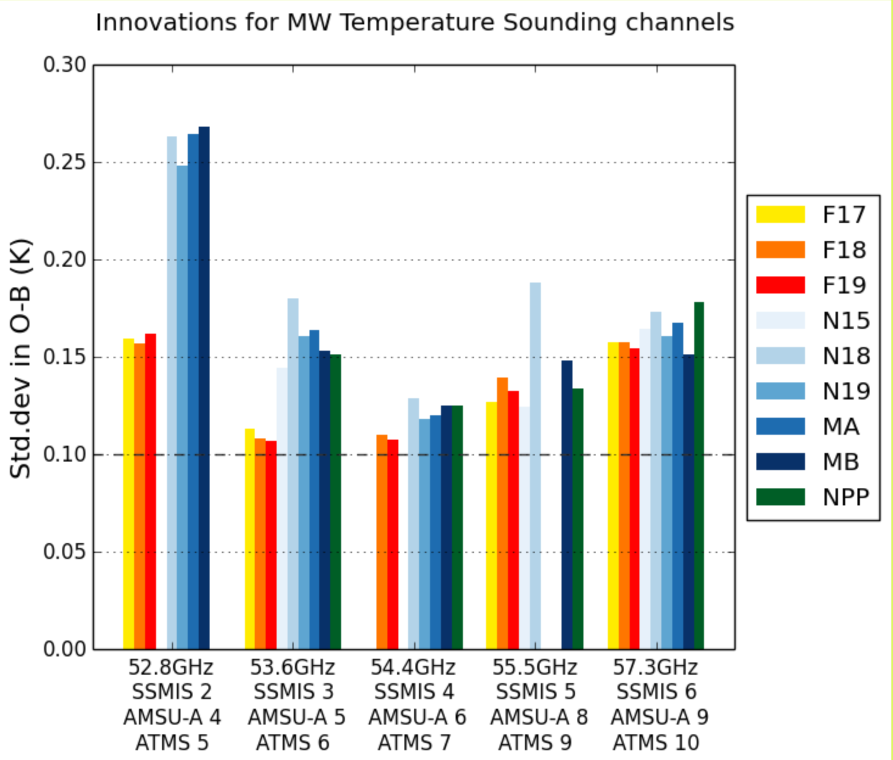
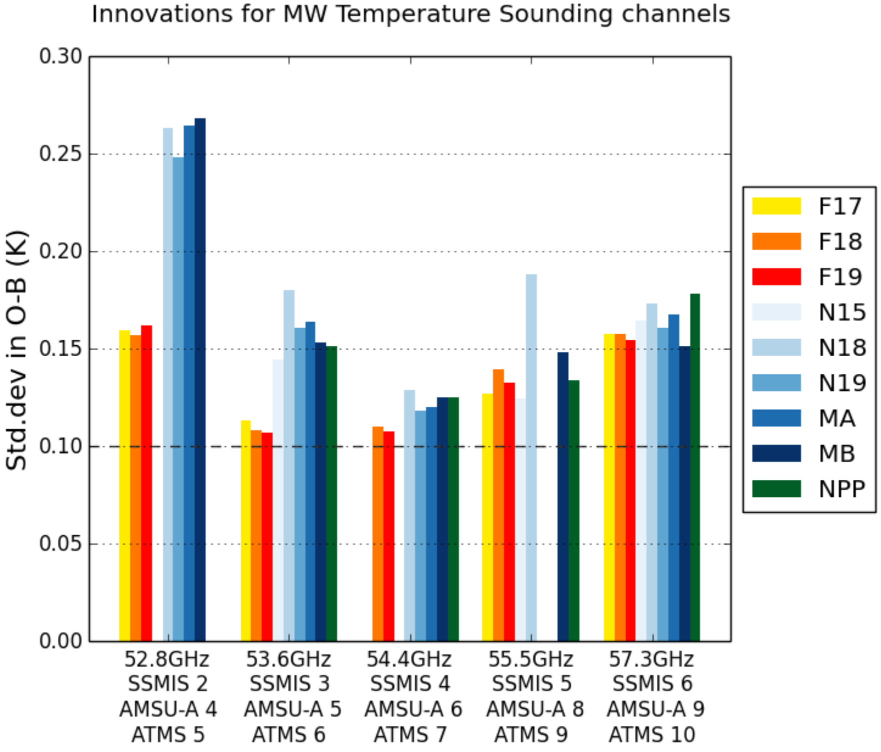
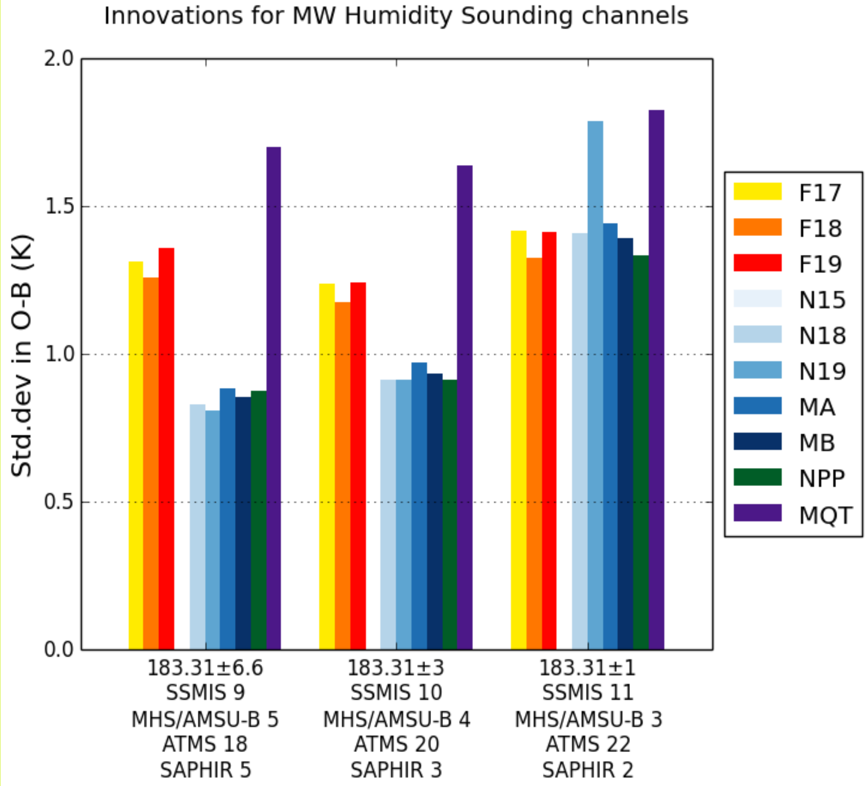


SSMIS departure statistics are: comparable to or better than the equivalent AMSU-A and ATMS channels

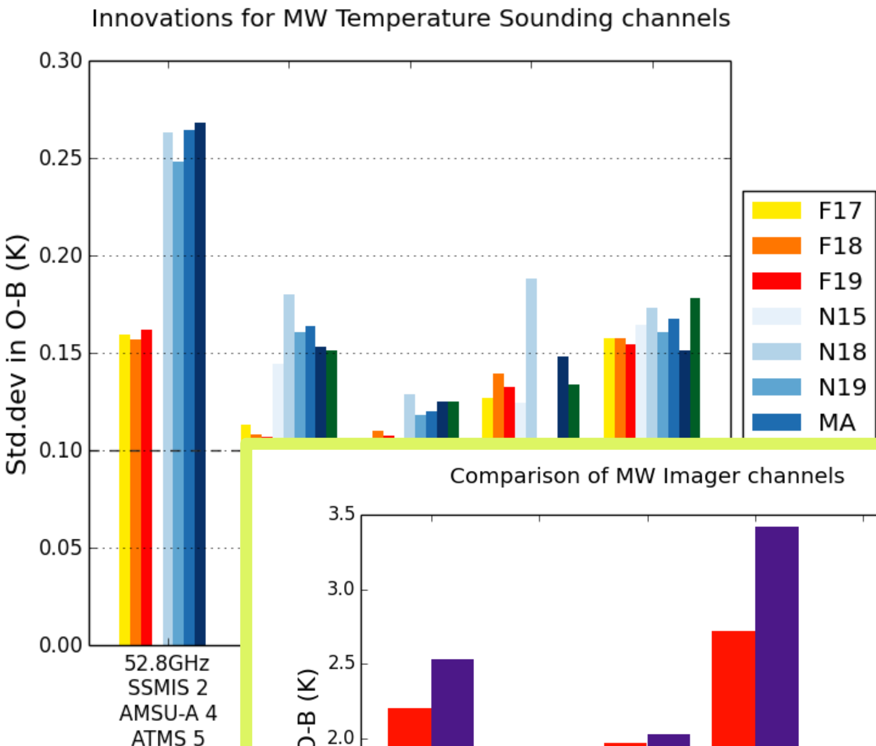
SSMIS innovations for key channels:

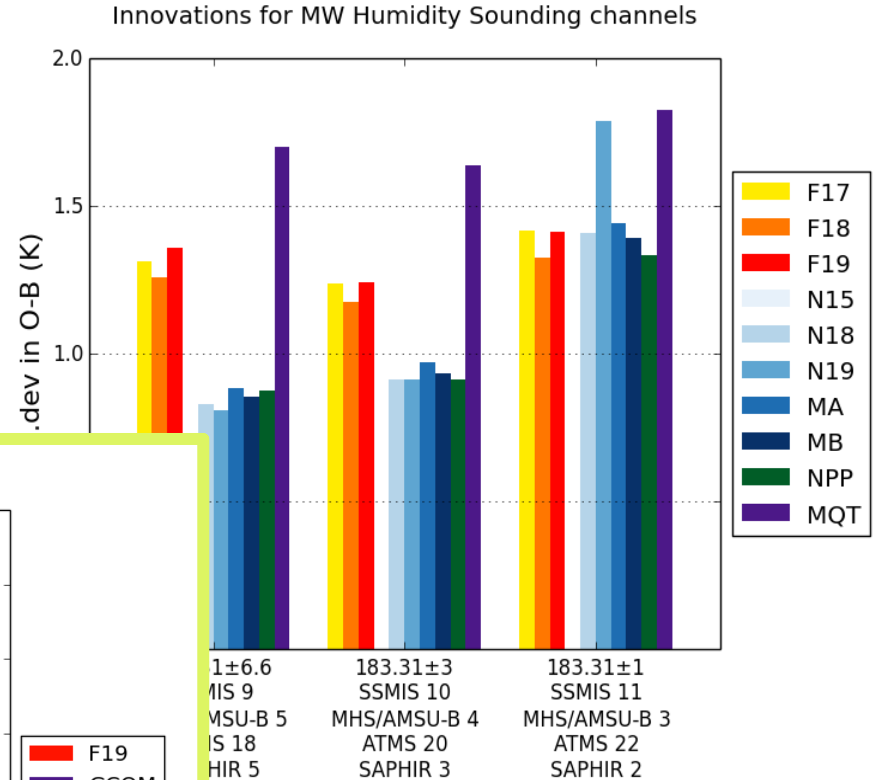


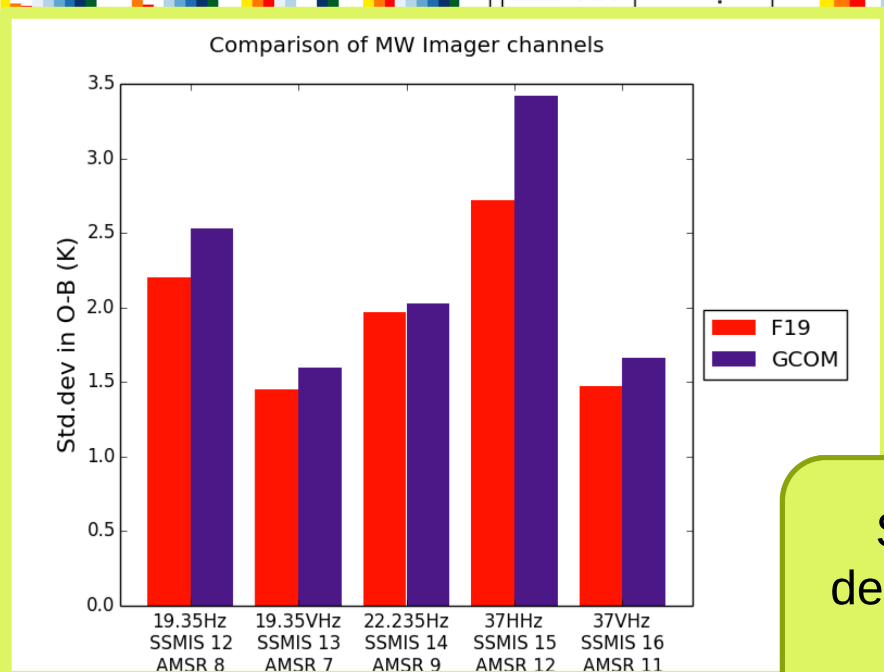


SSMIS departures are slightly larger than MHS/AMSU-B but less than SAPHIR

SSMIS innovations for key channels:





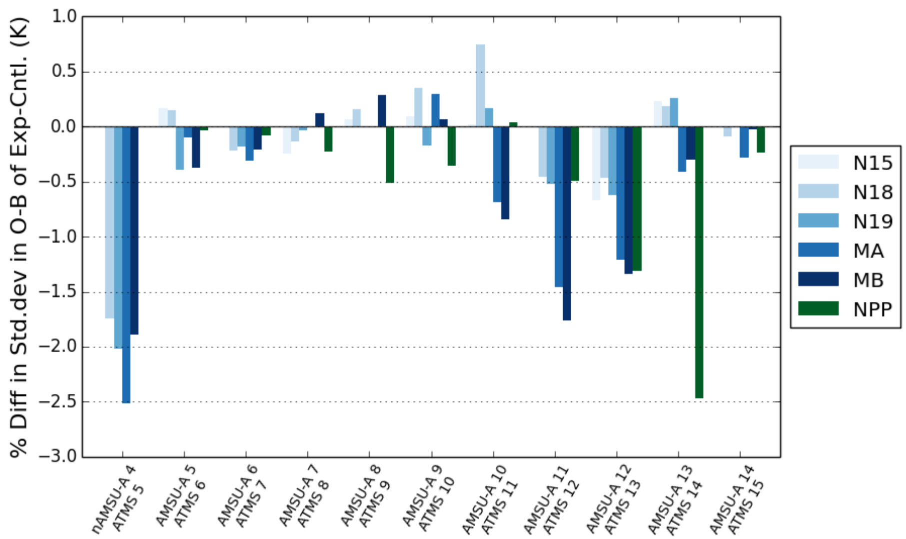


SSMIS Imager channel departure statistics are less than AMSR

Background fits to other observations:

Sounding channels of AMSU and ATMS

Temperature Sounding Channels



The background fits are generally improved –

- Particularly in the lowest and highest peaking channels
- More mixed around the tropopause

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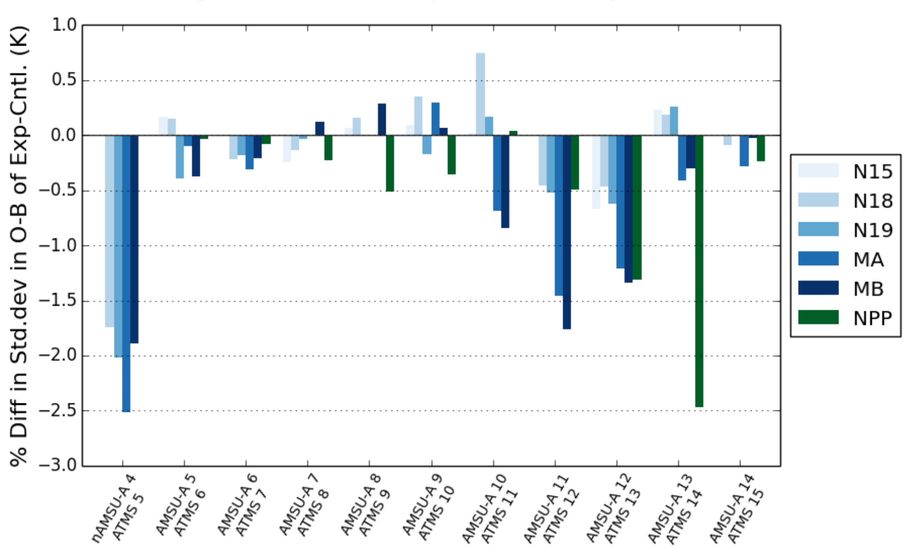
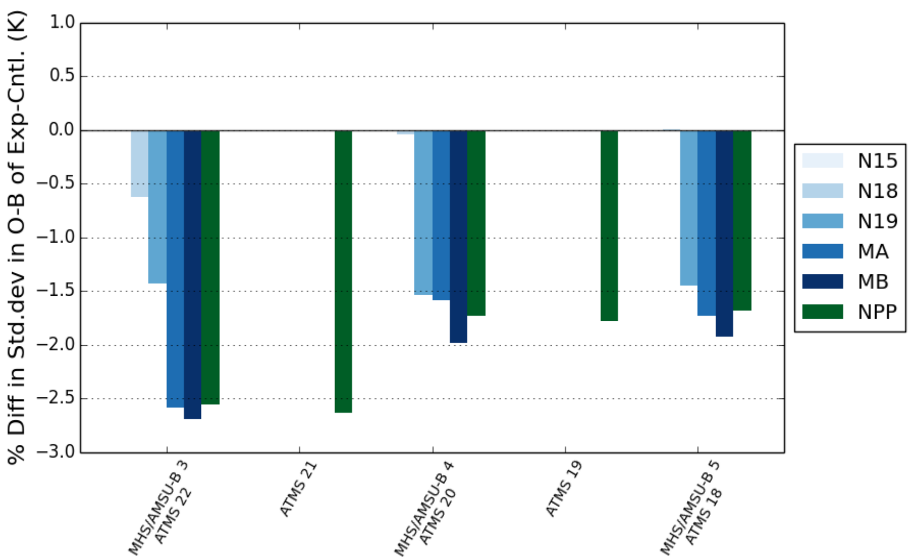


Humidity Sounding Channels



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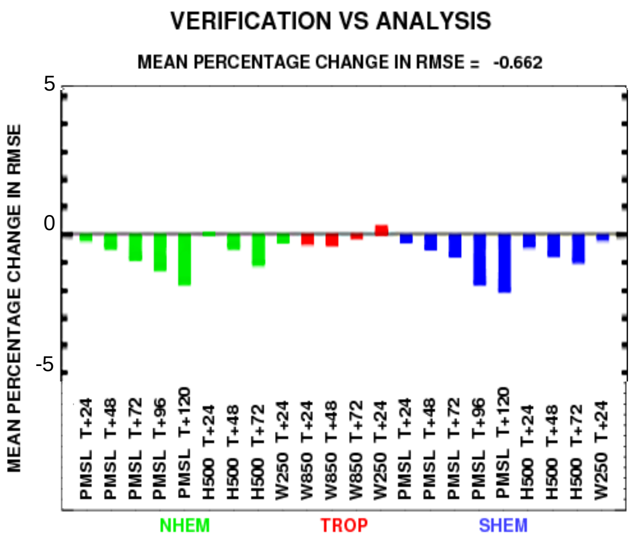
Improved background fits for other humidity observations

Verification

vs own analysis for month July 2014

Temperature



- Assessing the change in RMS errors of (forecast - analysis) wrt control (no SSMIS)

Improvements

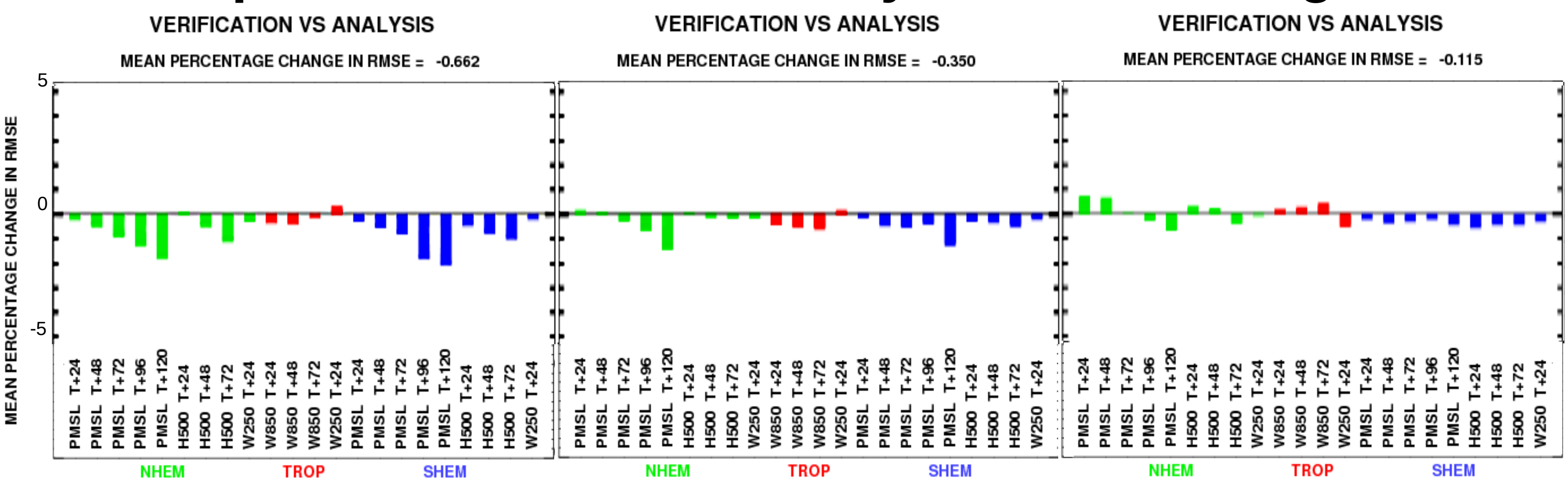
- Mean sea level pressure (PMSL)
- Geopotential height at 500 hPa
- Winds

- For the N.Hem, Tropics, and S.Hem.

Verification

vs own analysis for month July 2014

Temperature | Humidity | Imager



- Consistent small improvements in most verification metrics
- Particularly in the SH
- Slightly mixed for the imager

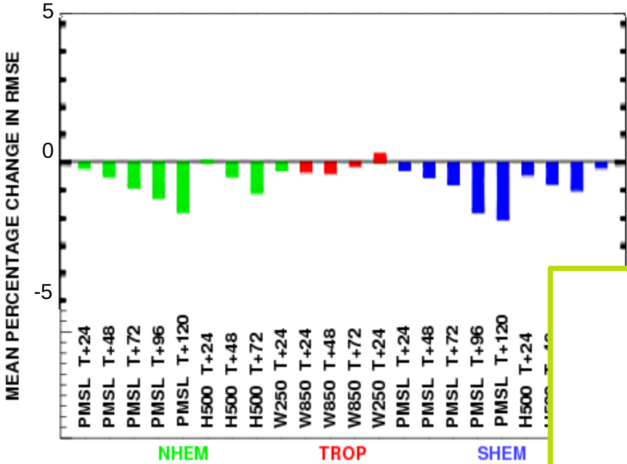
Verification

vs own analysis for month July 2014

Temperature

VERIFICATION VS ANALYSIS

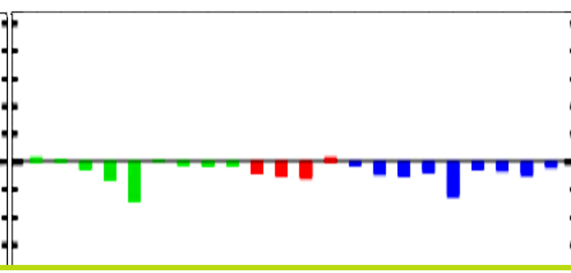
MEAN PERCENTAGE CHANGE IN RMSE = -0.662



Humidity

VERIFICATION VS ANALYSIS

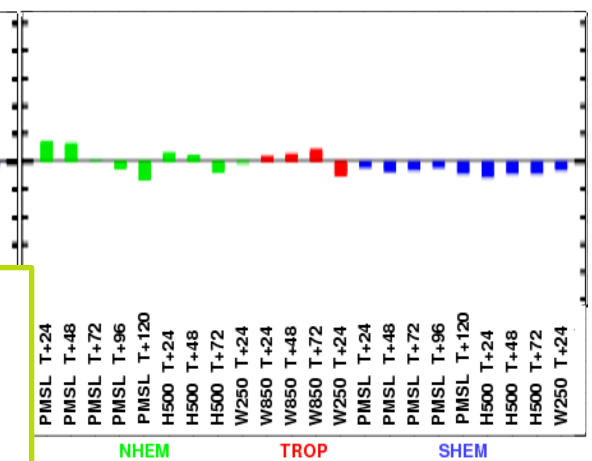
MEAN PERCENTAGE CHANGE IN RMSE = -0.350



Imager

VERIFICATION VS ANALYSIS

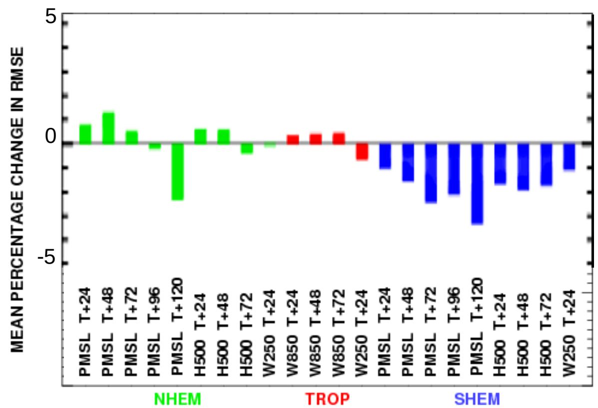
MEAN PERCENTAGE CHANGE IN RMSE = -0.115



Unified (T+H+I)

VERIFICATION VS ANALYSIS

MEAN PERCENTAGE CHANGE IN RMSE = -0.715



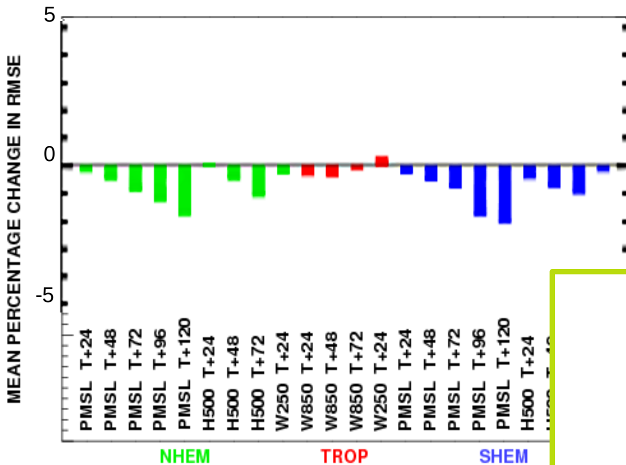
Verification

vs own analysis for month July 2014

Temperature

VERIFICATION VS ANALYSIS

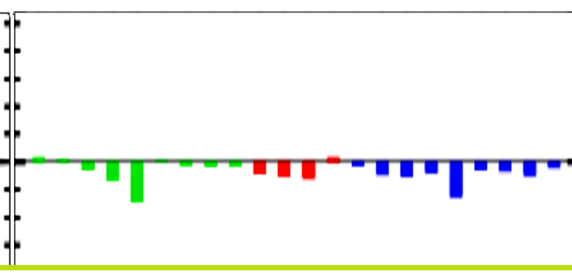
MEAN PERCENTAGE CHANGE IN RMSE = -0.662



Humidity

VERIFICATION VS ANALYSIS

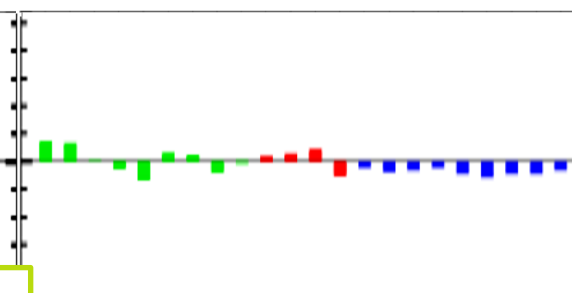
MEAN PERCENTAGE CHANGE IN RMSE = -0.350



Imager

VERIFICATION VS ANALYSIS

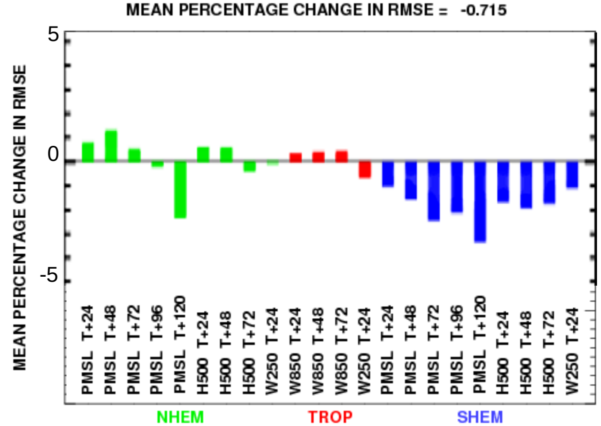
MEAN PERCENTAGE CHANGE IN RMSE = -0.115



Unified (T+H+I)

VERIFICATION VS ANALYSIS

MEAN PERCENTAGE CHANGE IN RMSE = -0.715



Benefits appear to combine.

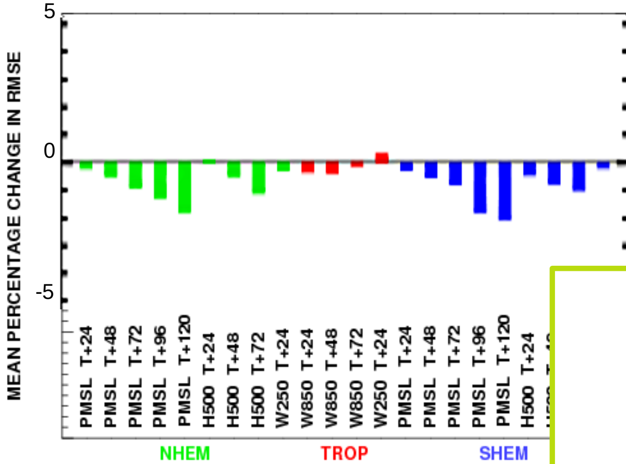
Verification

vs own analysis for month July 2014

Temperature

VERIFICATION VS ANALYSIS

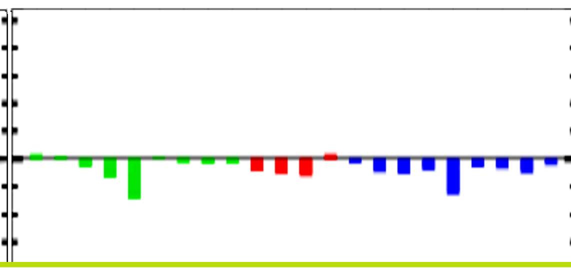
MEAN PERCENTAGE CHANGE IN RMSE = -0.662



Humidity

VERIFICATION VS ANALYSIS

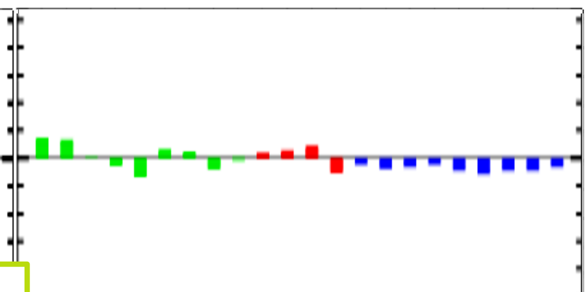
MEAN PERCENTAGE CHANGE IN RMSE = -0.350



Imager

VERIFICATION VS ANALYSIS

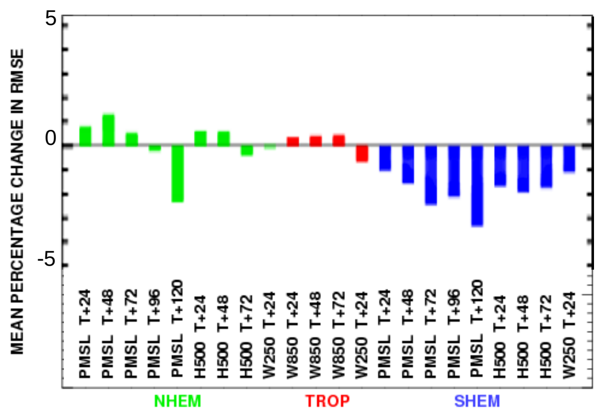
MEAN PERCENTAGE CHANGE IN RMSE = -0.115



Unified (T+H+I)

VERIFICATION VS ANALYSIS

MEAN PERCENTAGE CHANGE IN RMSE = -0.715



Benefits appear to combine.

Stronger positive impact in SH, as seen in individual components

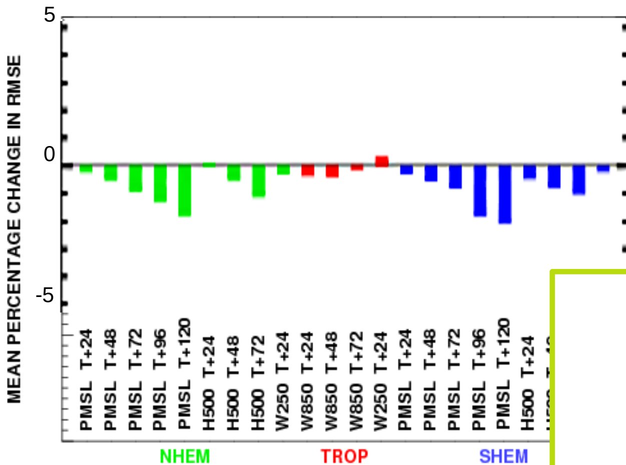
Verification

vs own analysis for month July 2014

Temperature

VERIFICATION VS ANALYSIS

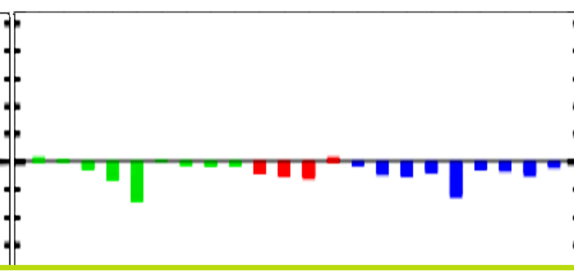
MEAN PERCENTAGE CHANGE IN RMSE = -0.662



Humidity

VERIFICATION VS ANALYSIS

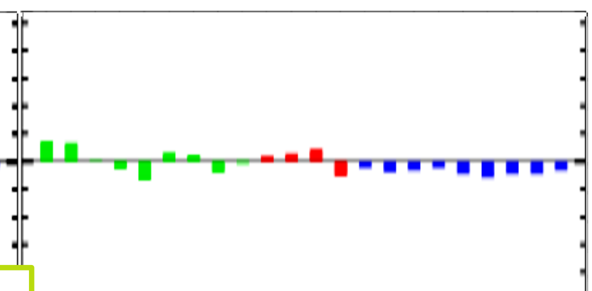
MEAN PERCENTAGE CHANGE IN RMSE = -0.350



Imager

VERIFICATION VS ANALYSIS

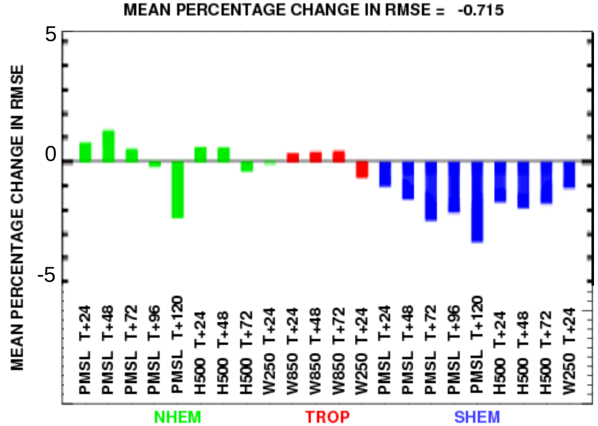
MEAN PERCENTAGE CHANGE IN RMSE = -0.115



Unified (T+H+I)

VERIFICATION VS ANALYSIS

MEAN PERCENTAGE CHANGE IN RMSE = -0.715



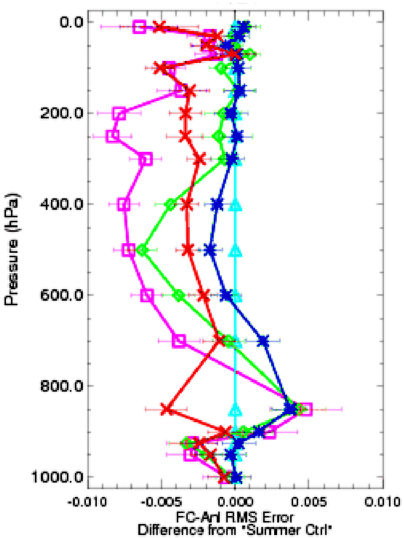
Benefits appear to combine.

Stronger positive impact in SH, as seen in individual components

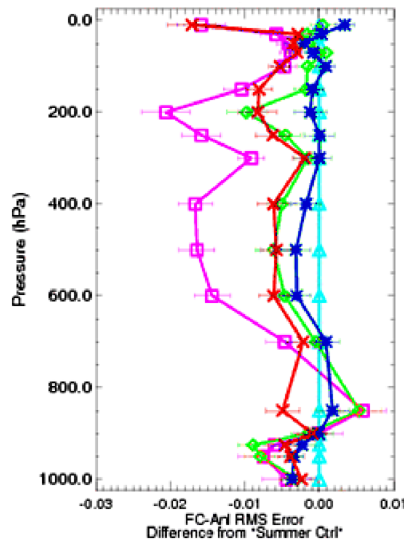
Looking in more detail...

SH Profiles: Temperature

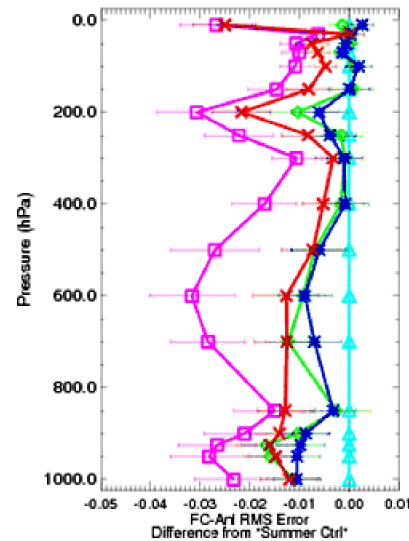
T+24



T+48



T+72

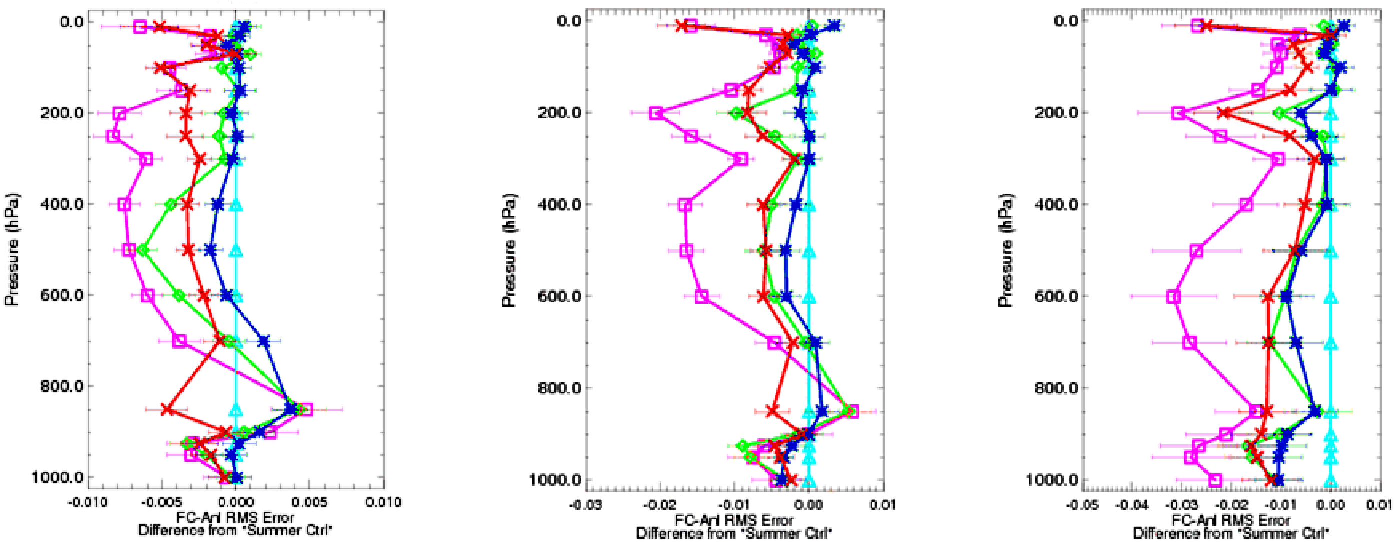


Improvement

Trials: Temperature, Humidity, Imager, Unified

SH Profiles: Temperature

T+24 T+48 T+72

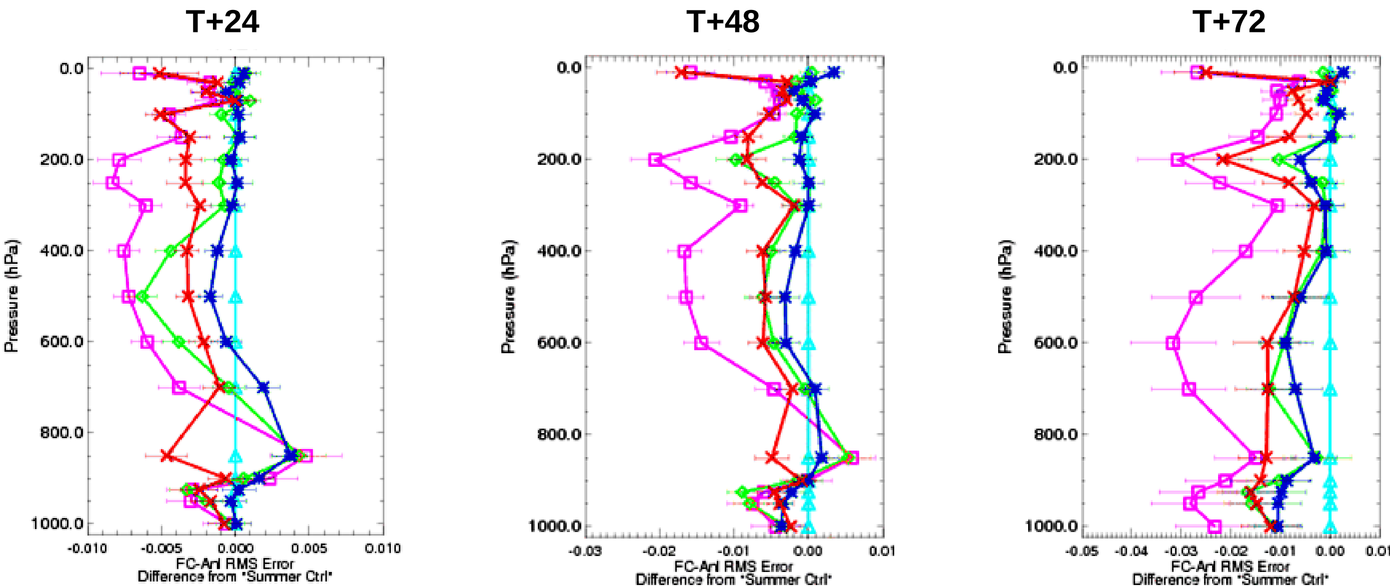


Temperature channels provide consistent benefit.

Trials: Temperature, Humidity, Imager, Unified

SH Profiles: Temperature

Met Office

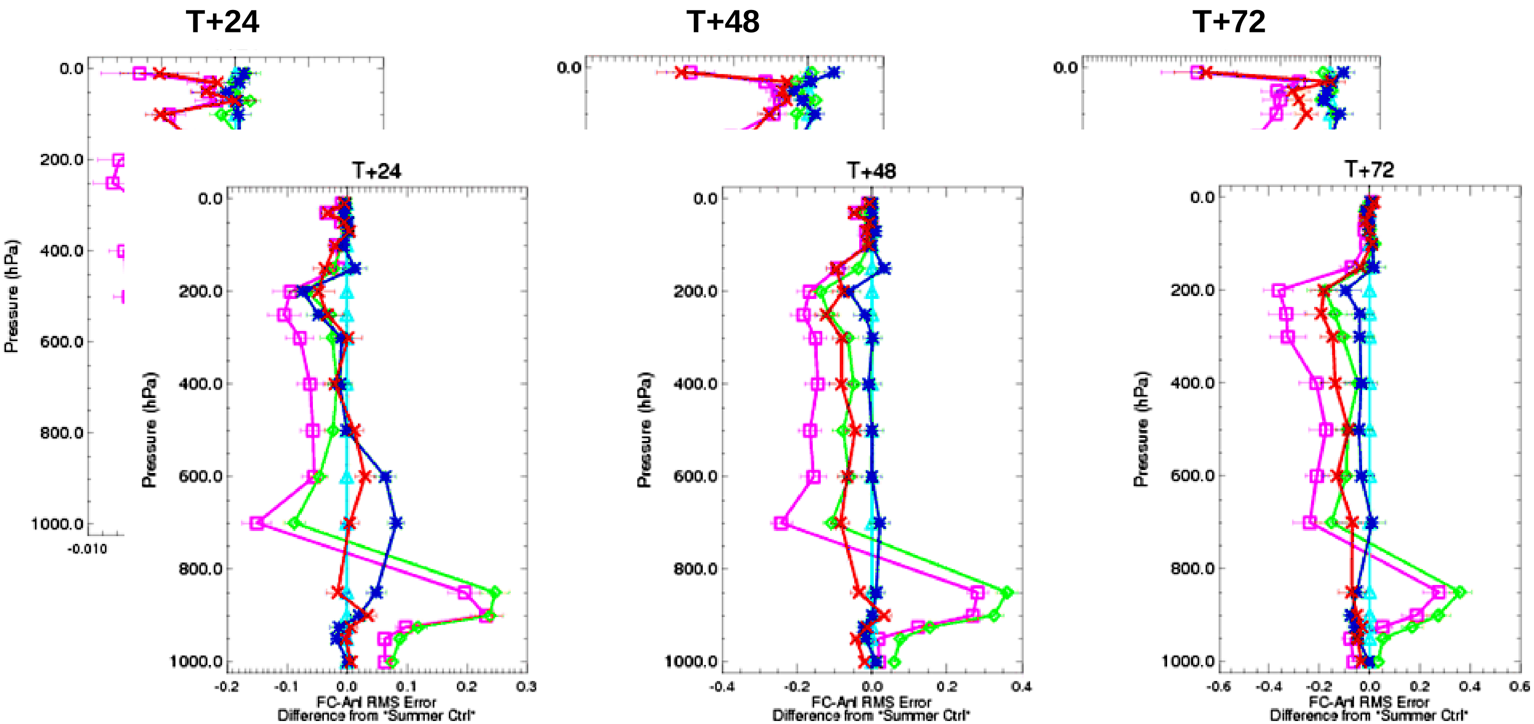


Temperature channels provide consistent benefit.

Combination of T, H, and I channels provides best impact, particularly in the mid-troposphere

Trials: Temperature, Humidity, Imager, Unified

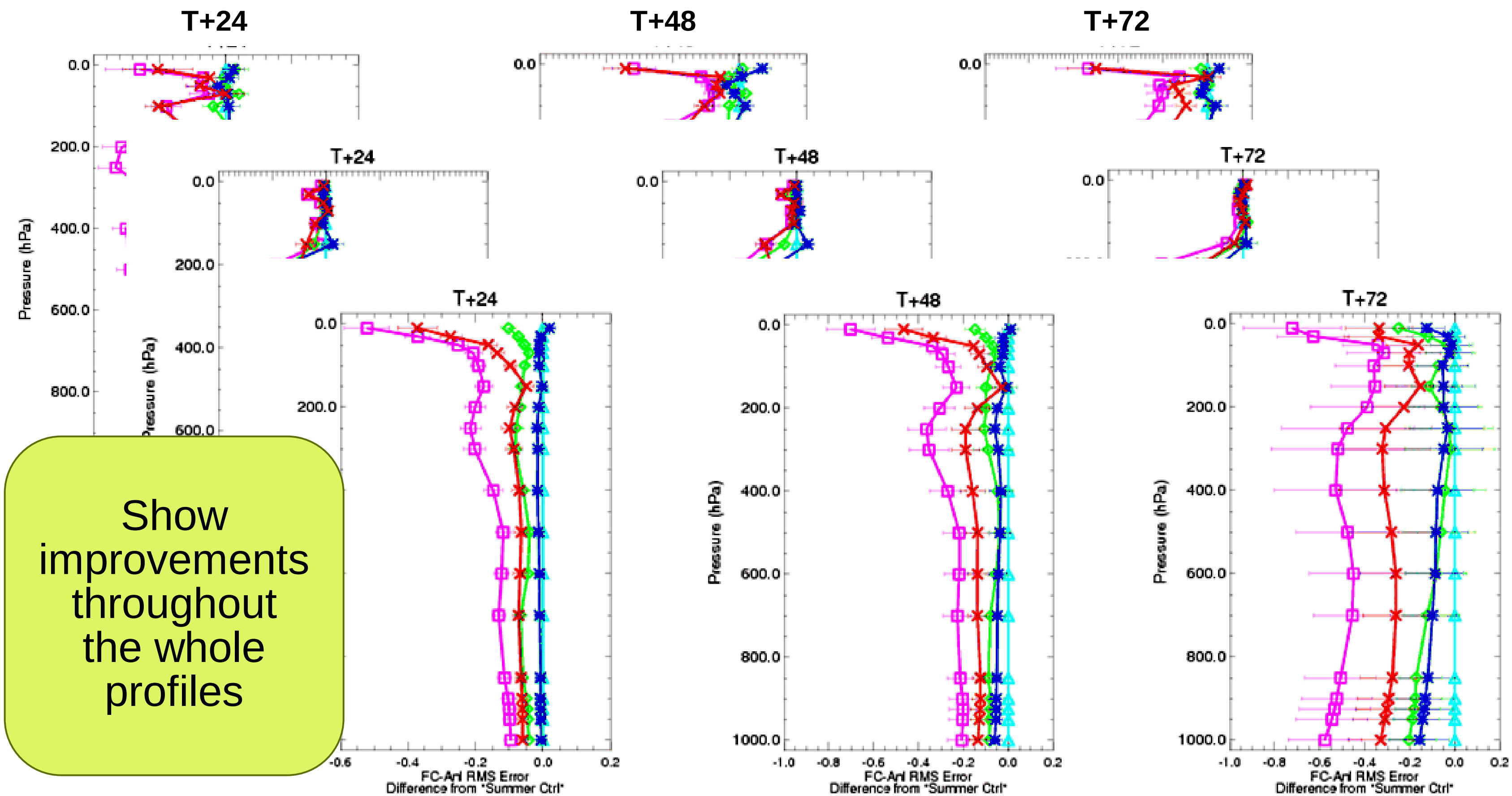
SH Profiles:
Relative humidity



Generally improved –
they show apparent degradation at 850hPa.

Trials: Temperature, Humidity, Imager, Unified

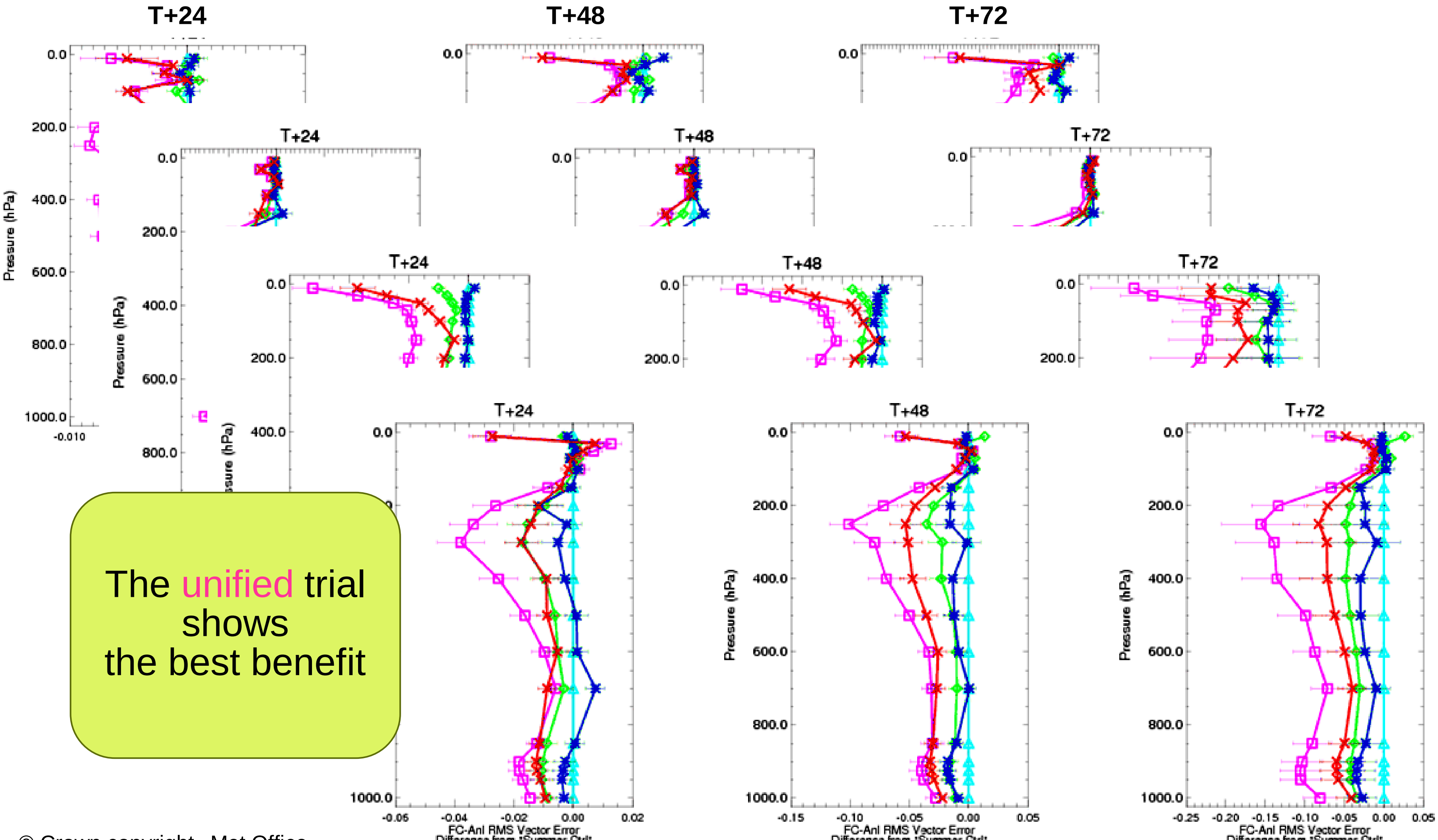
SH Profiles:
Height analysis



Show improvements throughout the whole profiles

Trials: Temperature, Humidity, Imager, Unified

SH Profiles: Winds



The unified trial shows the best benefit

Conclusions

Met Office

- New orbital correction in VarBC works well for all SSMIS instruments
- Data quality for bias corrected observations is better than the equivalent AMSU/ATMS and AMSR-3, worse for MHS/AMSU-B
- Assimilation experiments carried out using two SSMIS instruments
- Showed benefit to temperature, geopotential heights and winds
- F17 & F19 included in latest operational upgrade (starts November due to go operational March 2016)

Thank you for listening!