EXPLOITATION OF METOP-A END-OF-LIFE BACKFLIP MANOEUVRE: ESTIMATING MHS MIRROR REFLECTIVITY AND REVEALING SCAN-DEPENDENT BIASES

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Abstract:

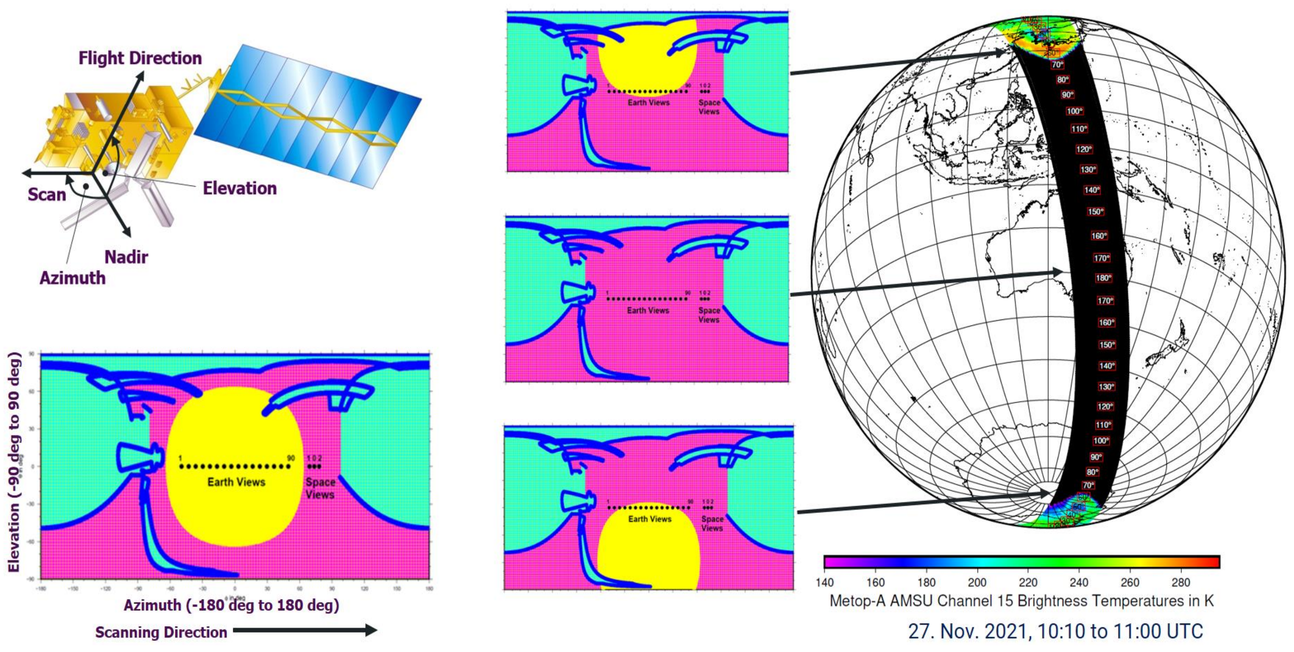
We estimate the mirror reflectivity of MHS in-flight, and as additional result, we discover a scan-dependent instrumental bias that may be attributed to on-board Radio Frequency Interference.

The Metop-A End-Of-Life test campaign in Q3 of 2021 encompassed a backflip manoeuvre of the satellite. During this manoeuvre, the MHS instrument measures deep space in the 90 Earth Views. This offers a unique possibility to observe a constant cold background in the Earth views while the instrument is in orbit, thus providing a valuable means for analysing scan-dependent instrumental effects, whose characterisation is important for (re)calibration.

We apply a known theoretical model for this backflip setting, which allows us to estimate the mirror reflectivity from the MHS backflip manoeuvre measurements. The deviations from that model present further insight on the instrument. They reveal an unobscured view on the scan-dependent bias that we can also detect in inter-satellite biases based on monthly means. In view of previous studies on MHS and AMSU-B instruments showing related results, we suspect the origin of those scan-dependent biases in on-board Radio Frequency Interference.

Backflip manoeuvre

- During the manoeuvre, the pitch angle of the spacecraft changed from nadir direction (0°) to local zenith (180°) and back to nadir.



- MHS scans over homogeneous background at very low temperature (Deep space).
- Opportunity to detect scan dependent biases and retrieve mirror reflectivity

1. Observations and retrieval of mirror reflectivity

Fig 1: Observations of counts during backflip manoeuvre

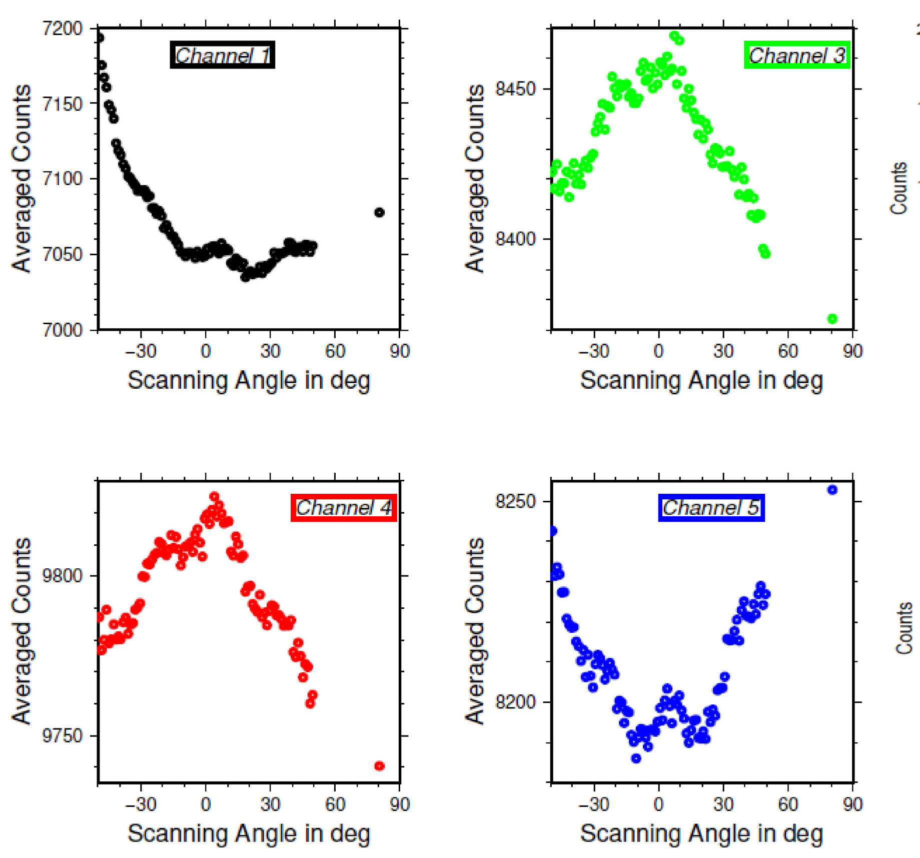


Fig 2: Model fit to data to determine model DSV counts

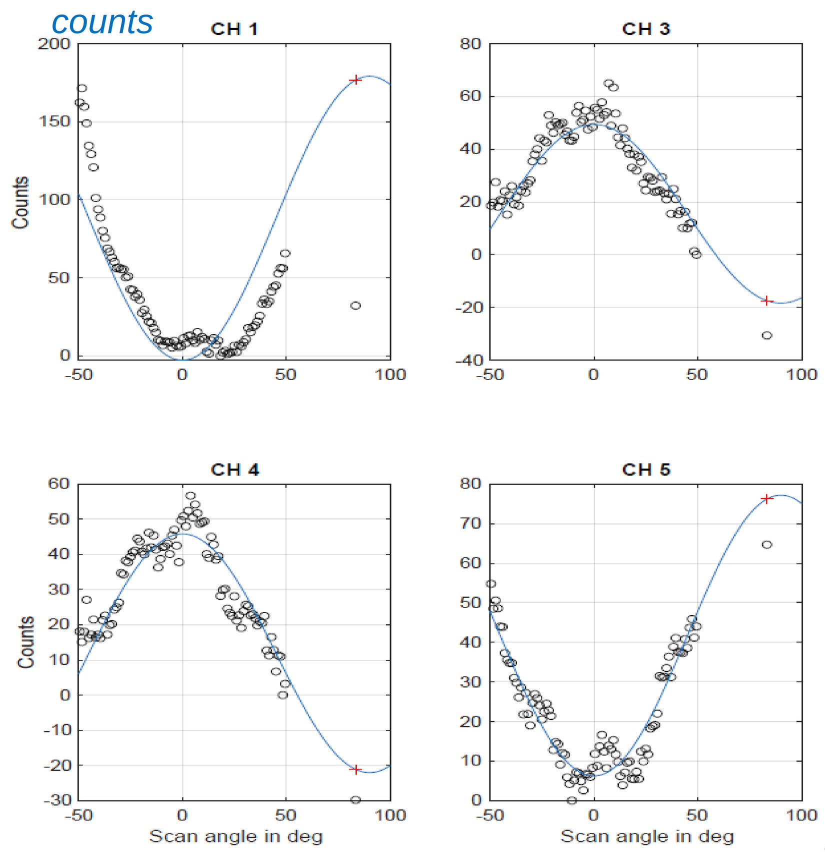
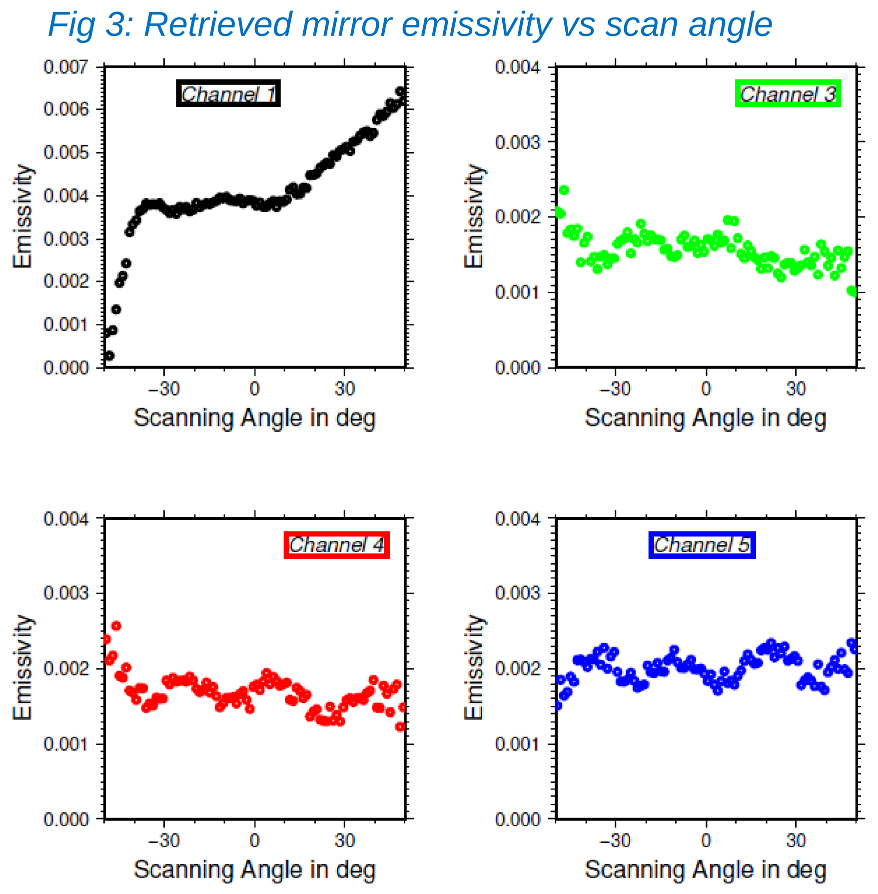
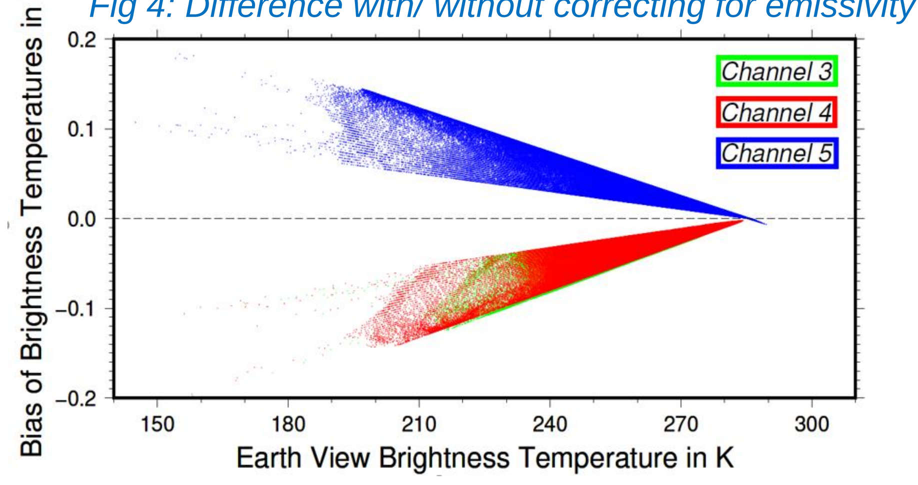


Fig 3: Retrieved mirror emissivity vs scan angle



CH	emissivity	reflectivity
1	(3.27E-03)	(0.99673)
2	-	-
3	1.56E-03	0.998436
4	1.68E-03	0.998321
5	2.00E-03	0.997999

Fig 4: Difference with/ without correcting for emissivity



- Channels show expected behaviour (see [1]): CH3,4 horizontally polarised→ "frown"-shape; CH5 vertically polarised → "smile"-shape
- CH1 suffers from a stronger asymmetric scan bias
- Note the small dip/peak close to 0°, e.g. giving the CH5 a "W" shape. This is a deviation from the theoretically expected shape to be discussed in 2.

- Mirror Reflectivity can be determined by applying a model (see [1])
- 1) Apply antenna pattern correction on count level. In order to also correct the Deep Space View (DSV) count, we apply a fit to the curve to determine model DSV counts (red crosses in Fig. 2).
- 2) per scan angle, apply EQ 13 of [1] to retrieve mirror emissivity ε, or reflectivity r (with $\varepsilon = 1 - r$), based on antenna pattern corrected counts, model DSV counts, radiances from space and warm target and scan angle yields emissivity per scan angle. In theory, the value should be constant (deviations hint at another uncorrected effect, see 2.).
- Mean emissivity and reflectivity displayed in table

- CH1 needs further attention and the emissivity value is not trustworthy as seen from the strong variation across scan.
- Impact of emissivity on calibration (Fig. 4): Applying the mirror emissivity in the calibration of the instrument corrects for biases about 0.1 K, depending on temperature and scan angle.

→ Retrieved mirror emissivity is very useful for reprocessing exercises in climate studies, in order to remove biases.

2. Analysing scan dependent bias

Fig 5: Difference 'Measurement minus model': oscillating pattern (smooth variations plus zig-zag pattern)

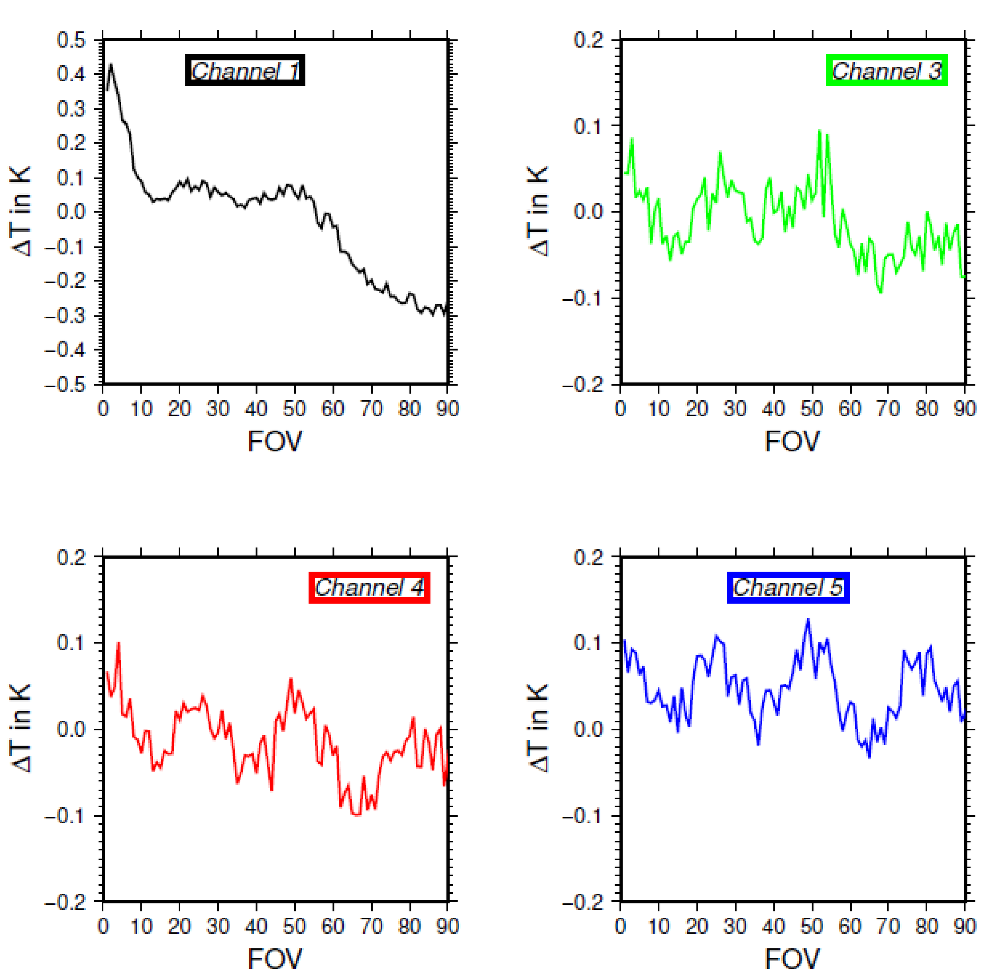


Fig 6: Monthly mean bias MHS Metop-A – Metop-B for 2016

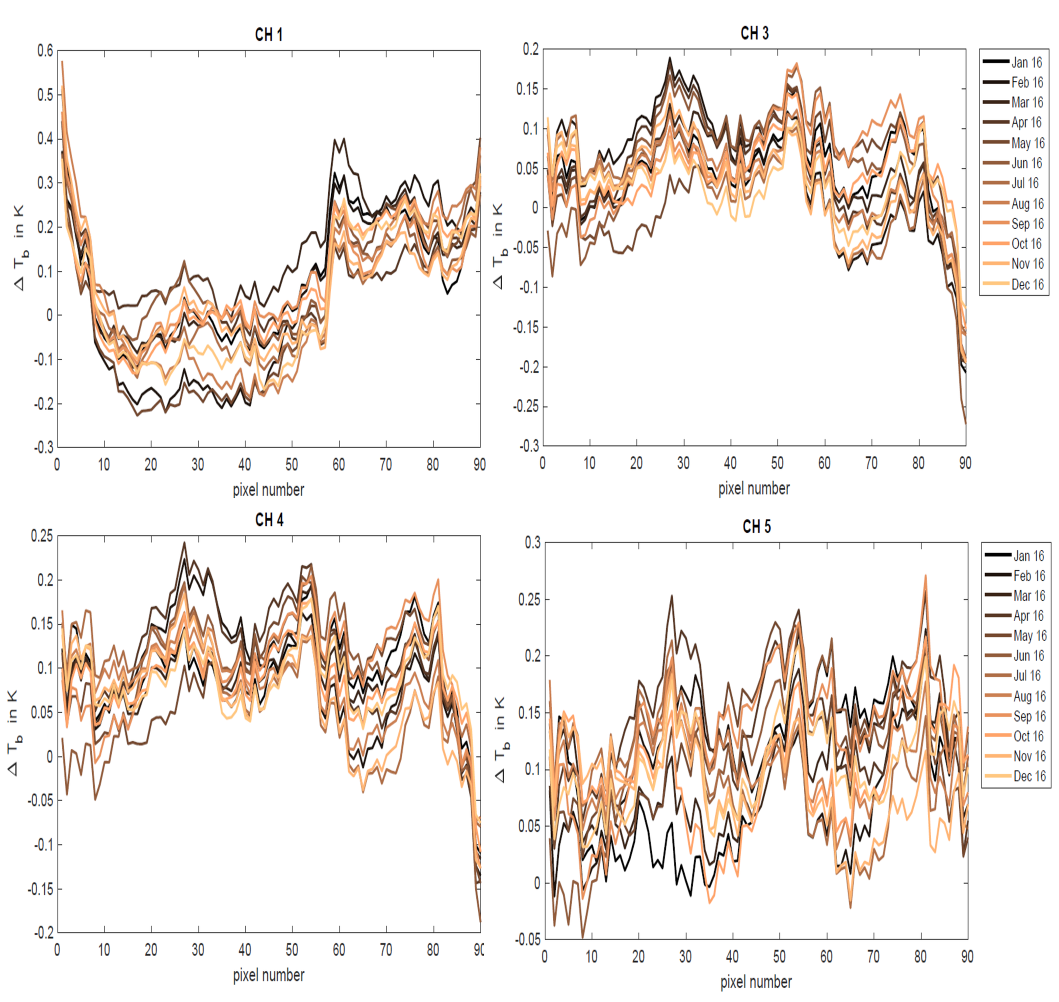


Fig 7: Gain evolution MHS Metop-A. CH2 (black) suffers from strong gain decrease in 2019

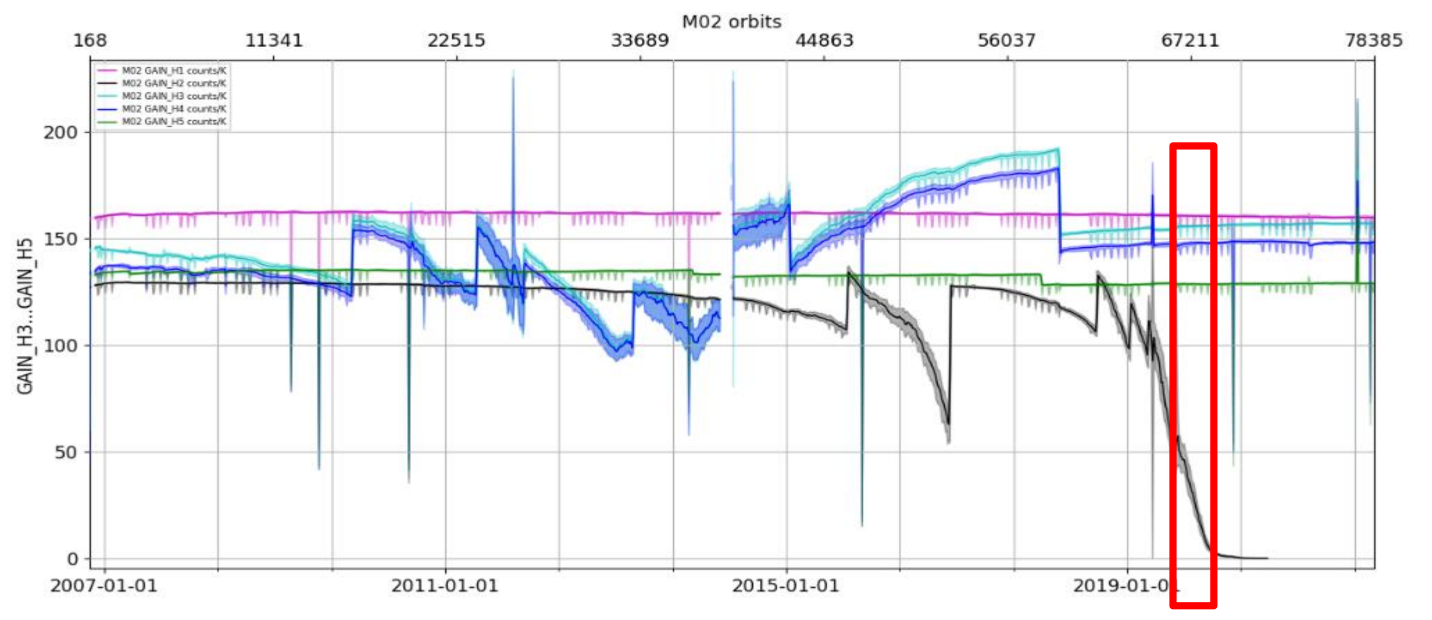
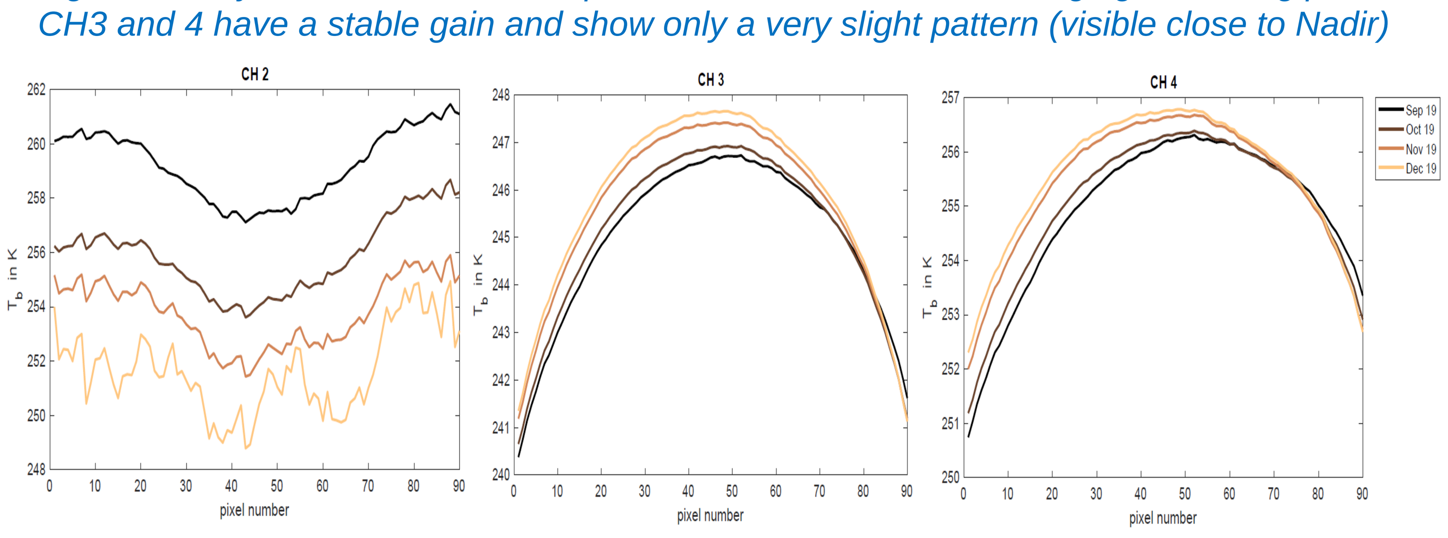
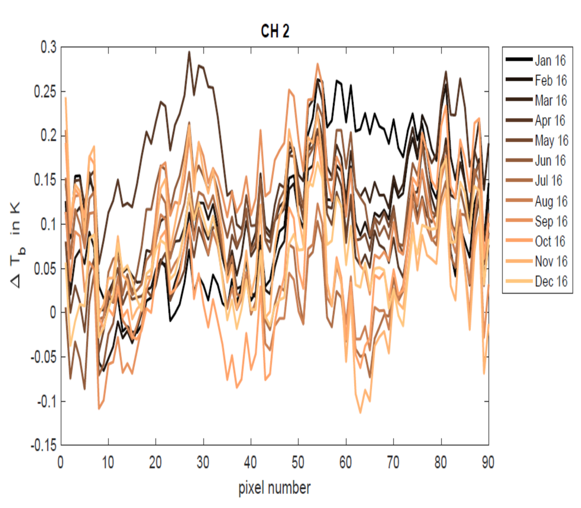


Fig 8: Monthly mean Tb, MHS Metop-A, 2019. CH2 shows an emerging oscillating pattern. CH3 and 4 have a stable gain and show only a very slight pattern (visible close to Nadir)



- Slight deviations from "frown" and "smile"-shape, and oscillating emissivity over scan positions hint at deviations from the theoretical behavior (see Fig. 2 and 3)
- Figure 5 shows the differences *'Measurement minus Model'*, and reveals an oscillating pattern of the scan bias in CH3-5 (CH1 is still dominated by asymmetric scan bias)
- Very similar patterns (shape and amplitude) are observed independently in monthly mean differences of MHS Metop-A – Metop-B, too. See Figure 6 for all months of 2016.
- Oscillating pattern of the bias is rather stable over months and very similar to observations from the backflip (slight differences naturally exist because of the impact of MHS Metop-B effects)



- The amplitude of the oscillating pattern is correlated with the gain evolution: CH2 had a strong decrease in 2019 (Fig. 7, red box). In parallel, an oscillating pattern emerges (on top of the curve shaped by the limb effect, Fig. 8). The pattern reaches an amplitude of about 1K in Dec '19. Later, the channel failed completely. Therefore, it could not be analysed during backflip. However, already in 2016 (Fig. 6), also CH2 showed an oscillating pattern as the other channels did. Hence, we assume that the other channels suffer from the same effect as CH2.
- Previous studies related those biases to Radio Frequency Interference (RFI) from on-board transmitters [2, 3], because of the similarity to the RFI observed for AMSU-B on NOAA-15 [4].

→ Backflip manoeuvre data reveal the scan bias free from impact of second instrument as in inter-comparison efforts

→ Scan bias probably relates to on-board RFI

References

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