EOSense

Novel methods for the evaluation of image quality

(Where to next?)

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Contents

- Statistical methods and their applicability
- Measuring focus – hFocus Approach
- Future work
- Conclusions

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Statistical methods and their applicability

Basic principles

- The basic idea is instead of using a limited number of specific examples (MTF targets, Radiometric Calibration sites, flat-field sites), we instead use as many images as possible.
- The algorithms are usually simple (summation and measuring parameters of a distribution) and by the use of a large amount of data we often achieve a very precise and accurate result.
- Methods have been developed to determine relative gain (without flat fields) extracting bias and gain values, to measure SNR and to determine instrument focus (without MTF targets).

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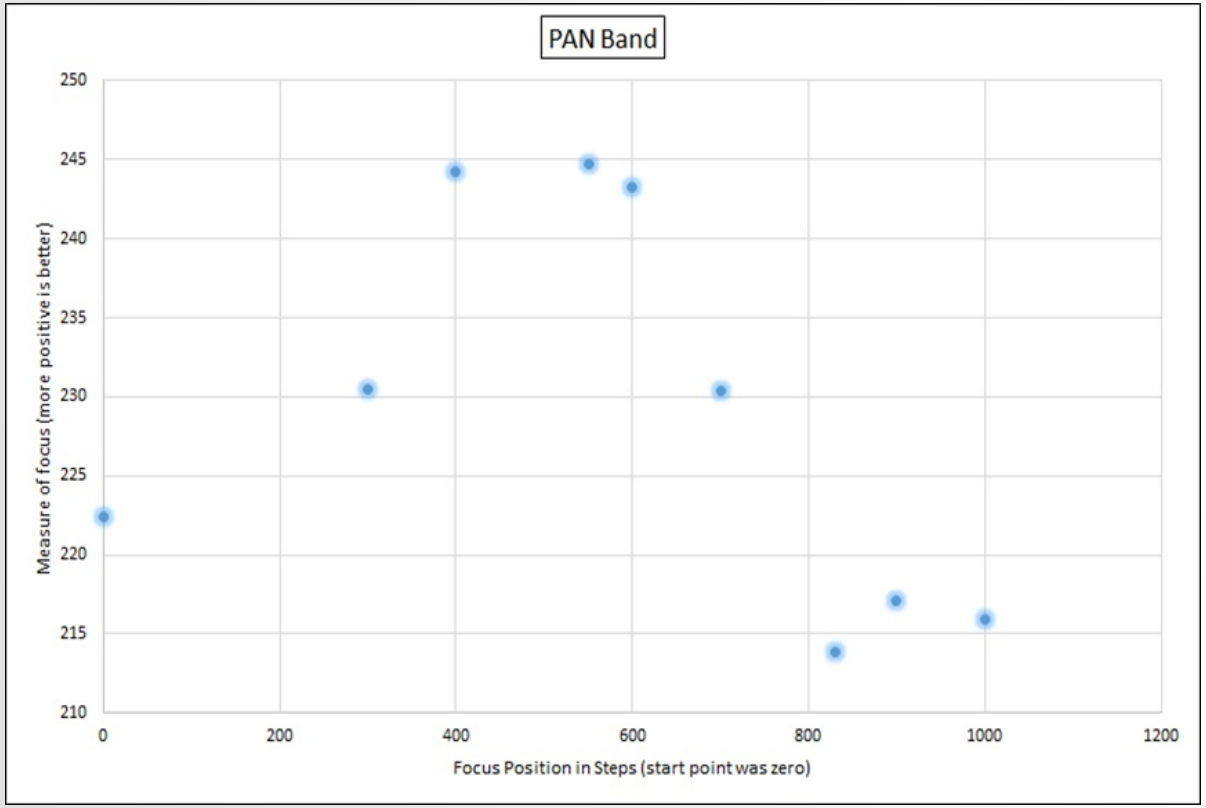
Measuring focus – hFocus Approach

Instrument focus - first test image

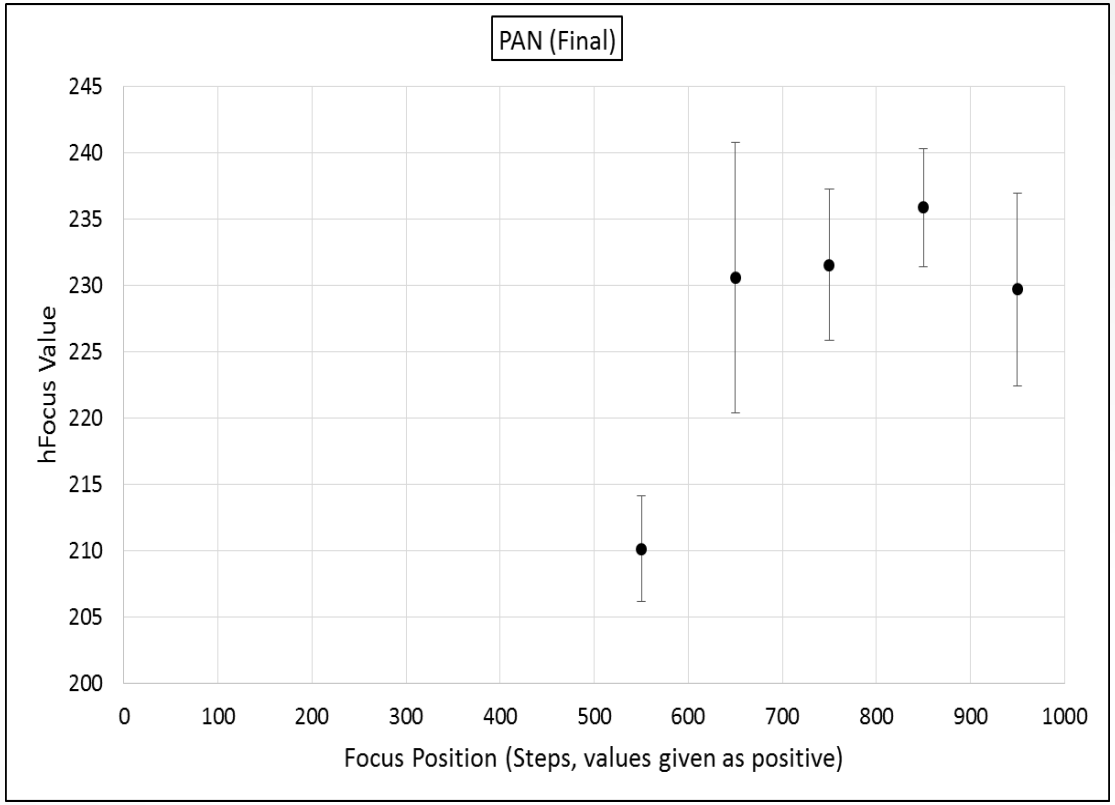
- Algorithm that uses any image to try and determine “best” focus

Which of these two is better focused?

First satellite test – NigeriaSat 2

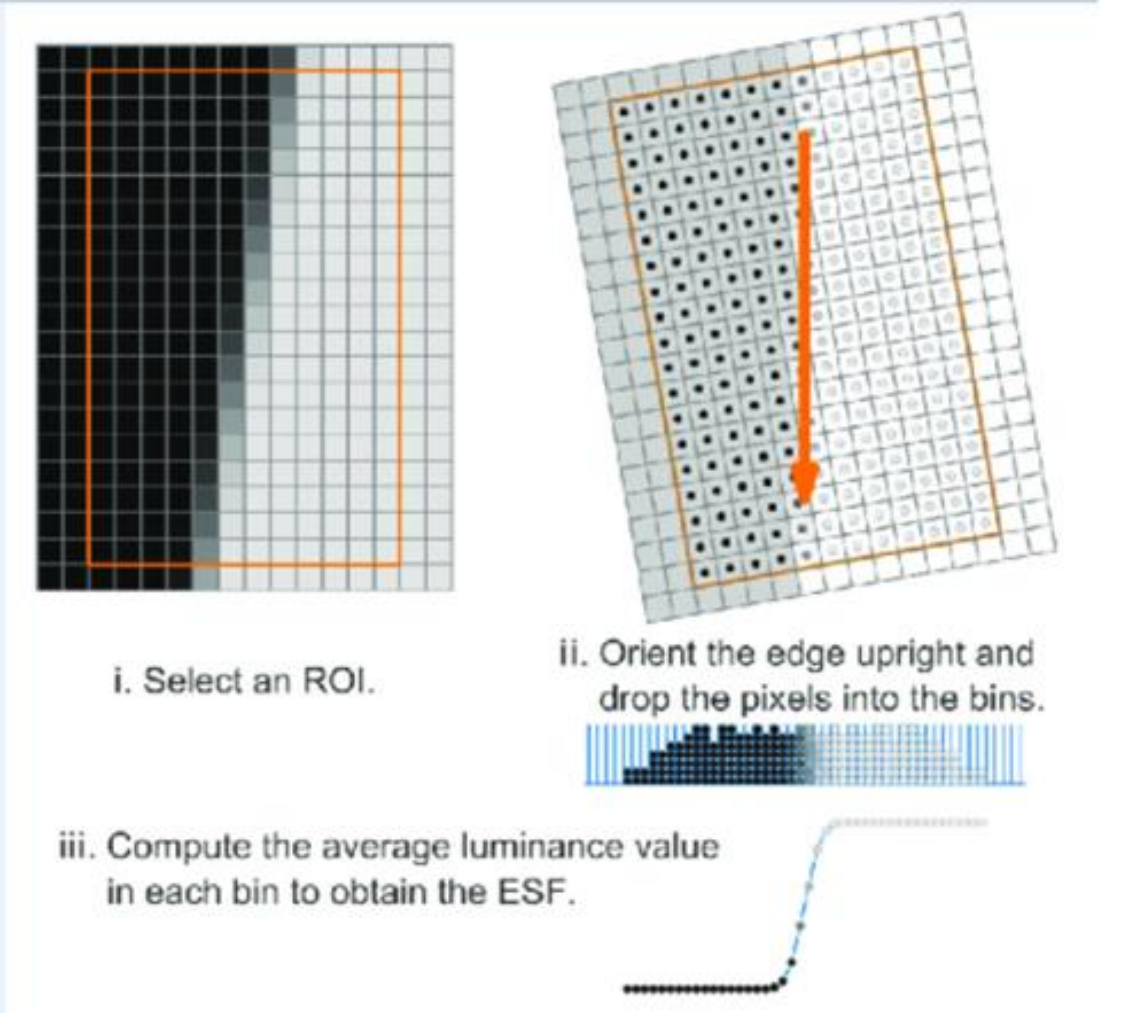


At launch, best focus



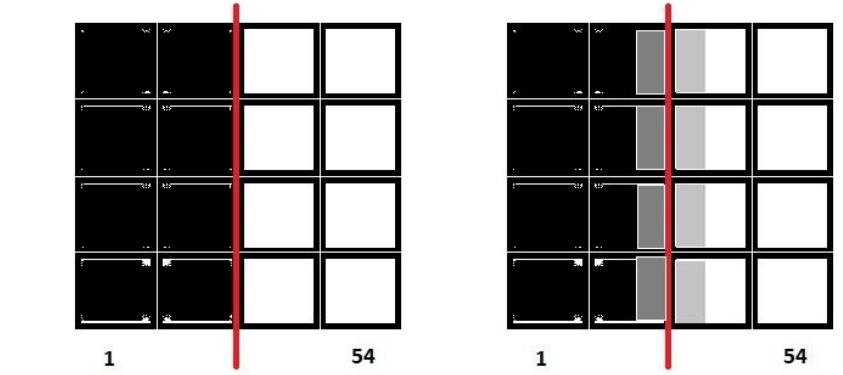
Launch plus five years

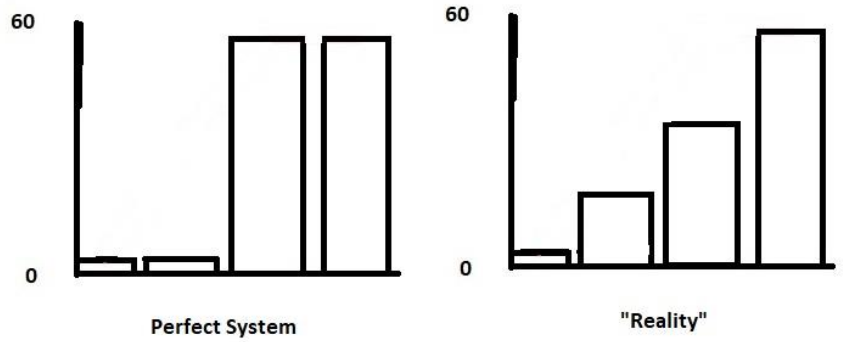
Traditional MTF (focus) calculation



- A sharp inclined edge is oversampled and a profile drawn of this edge (Edge Spread Function – ESF)
- Slope of the edge defines how good the system is, steep is well focused with a good MTF
- QUESTION – How can we do this with
  (a) No knowledge of edges
  (b) Edges of different sharpness
- One thing we do know, the steeper the edge the bigger the step between samples.

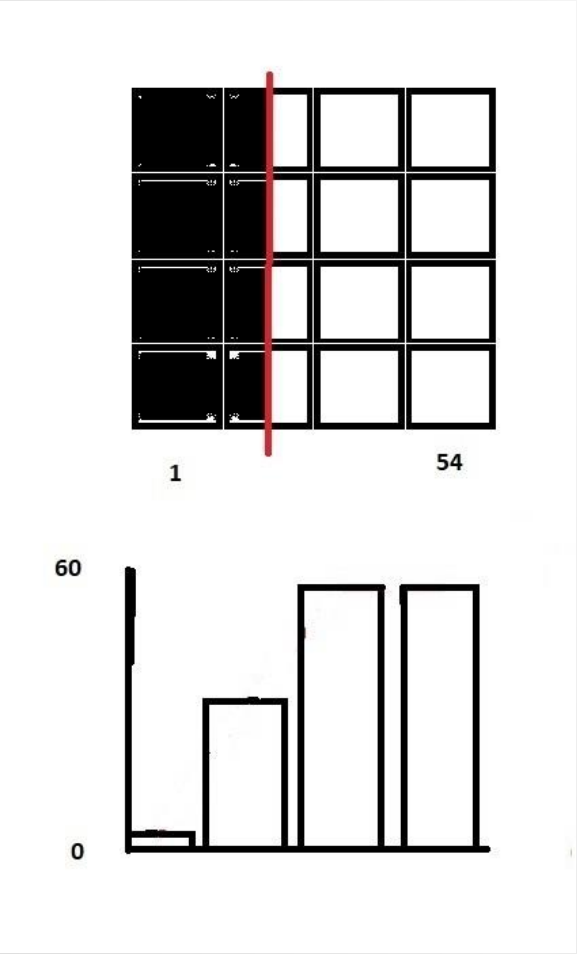
hFocus - Principles





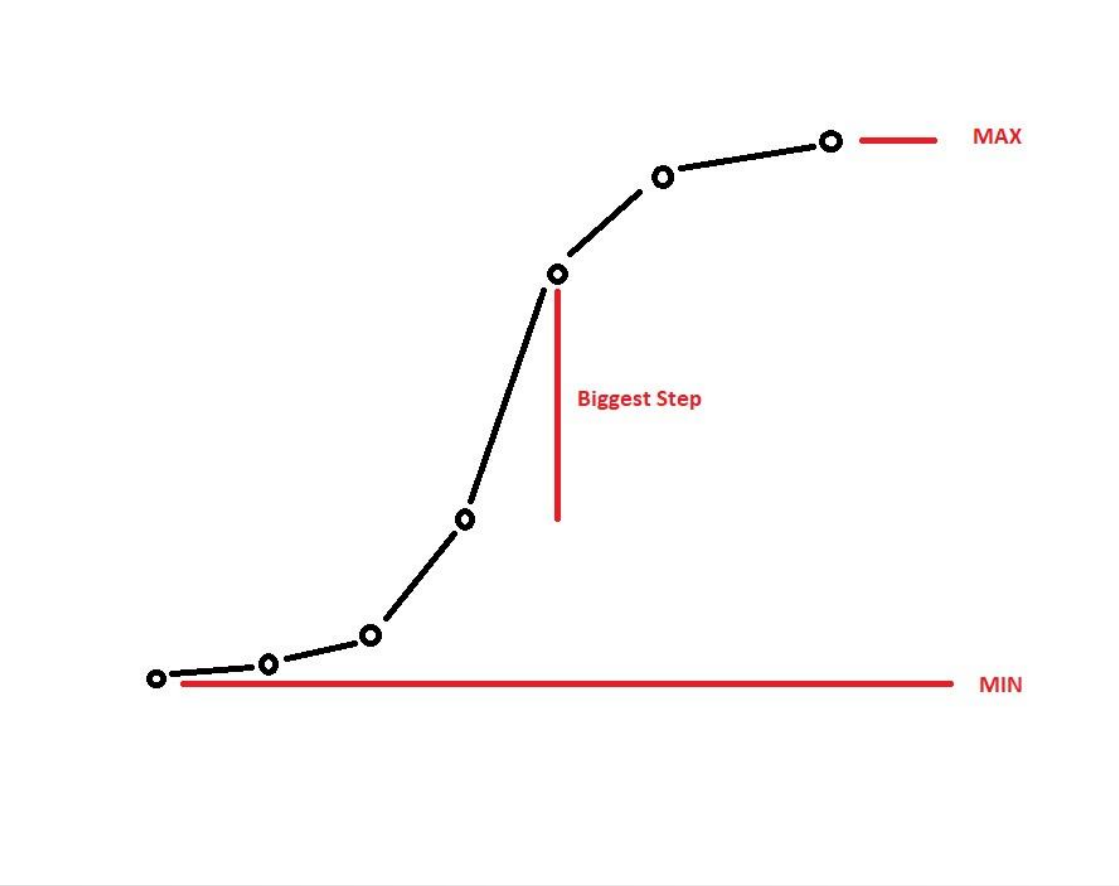
- The left plot (top) shows 16 detectors with a dark surface target on the left and a bright target on the right, a perfect optical system
- The intensity plot (left, bottom) shows that there is a very steep rise in radiance from the second to the third pixel in this perfect system
- The right plot (top) shows the same, except in this case there is some “spreading” of the signal (optics, detector, movement) that makes the boundary less precise.
- The corresponding intensity plot (right, bottom) shows smaller steps. The better the focus the bigger the step between highly contrasting targets.

hFocus - Complexities



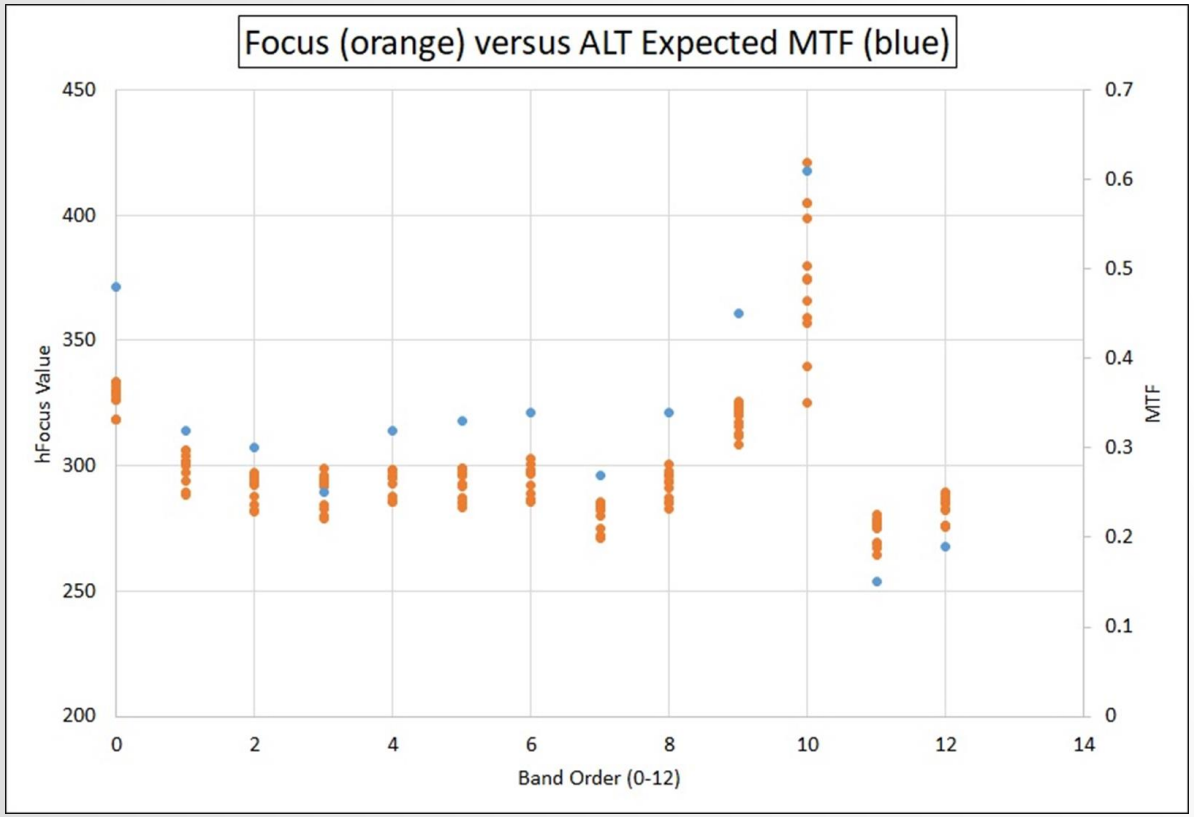
- The boundary may actually not be at detector boundaries, so an average pixel response may produce a step. This information is useful for edge target MTF studies.
  - However, the proportion of edges falling in any position across a detector is equal, so we can in a way ignore this effect.
- The edges may not be sharp (field boundaries, edge of a forest, etc.) Note that the hFocus algorithm is just looking for edges that match simple criteria. This will produce smaller steps.
- Spectrally flat areas (snow and deserts) may not have a large amount of edges to use in analysis.
- Clouds have very good, but diffuse edges, so small steps.

hFocus – So what are we looking for?



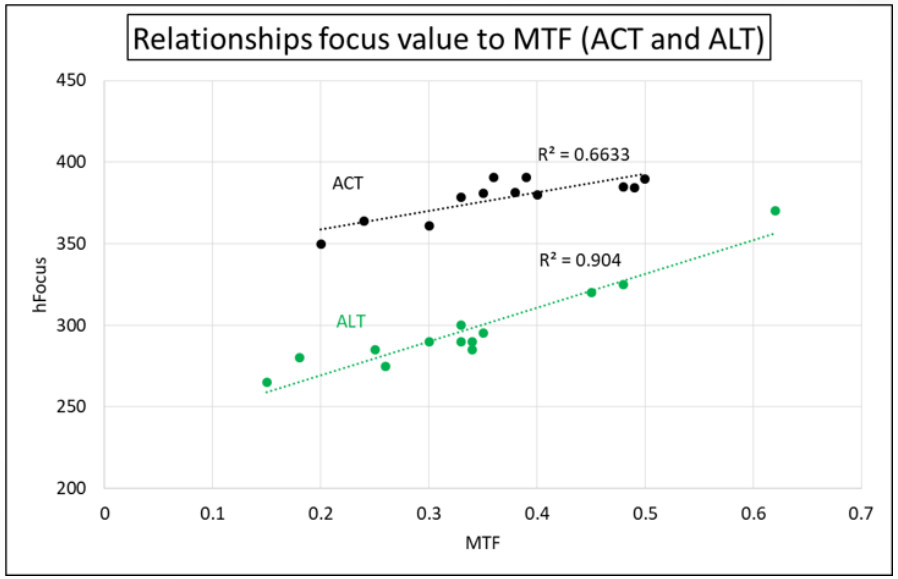
- Simply put, we are looking for how big the biggest step is in a profile, along with the maximum and minimum values.
- We look for positive profiles (increasing or equal values across a profile)
- We have a minimum allowed min-max separation.
- We can ratio our biggest step against our max-min value, which increment into an array (a distribution), so the more often we have a particular ratio the bigger the peak in a distribution.

Does it work? – Yes and No…



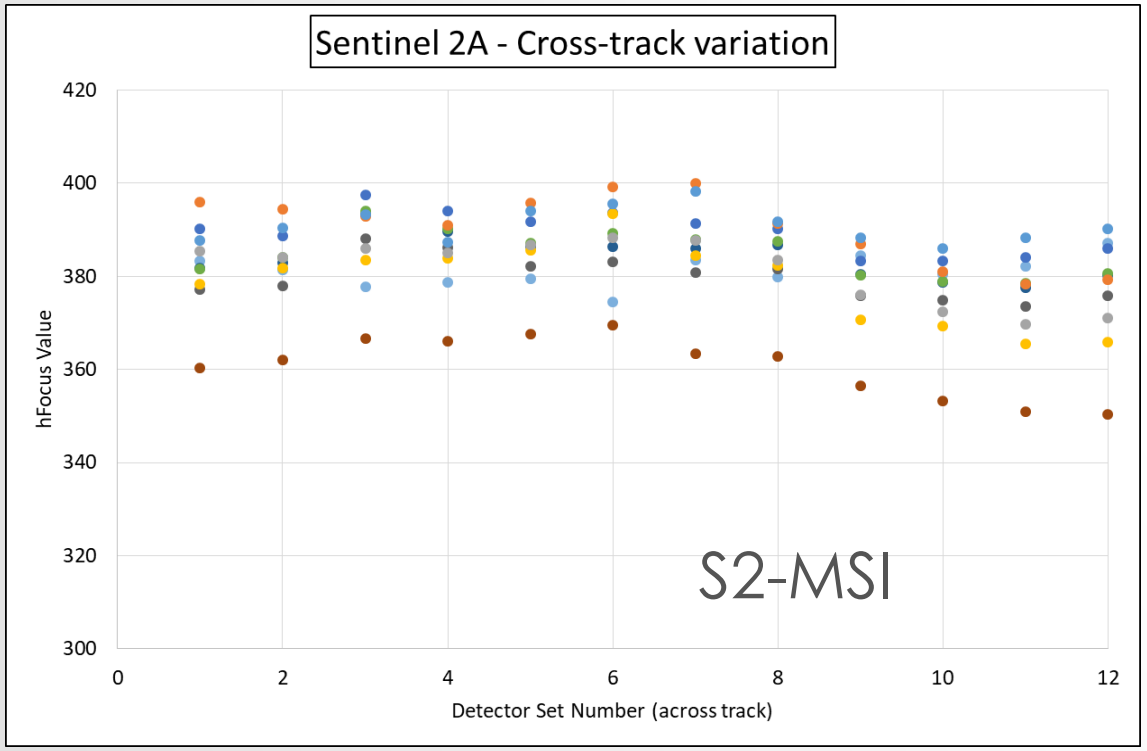
Focus values compared to MTF along track (ALT) for Sentinel 2 MSI

- The result shown uses less than one orbit of S2 data, compared to estimated MTF values.



- We can also extract cross-track variations in sensor focus for a single band

Across swath variations in focus



- The plot shows the average values for each detector set (x-axis) for each spectral band which are the different coloured dots.
- The profile across the swath (x-axis) is consistent across multiple sets of observations.

Sentinel 2A and 2B show an asymmetry across track that causes a variation of the order of 3.5%.

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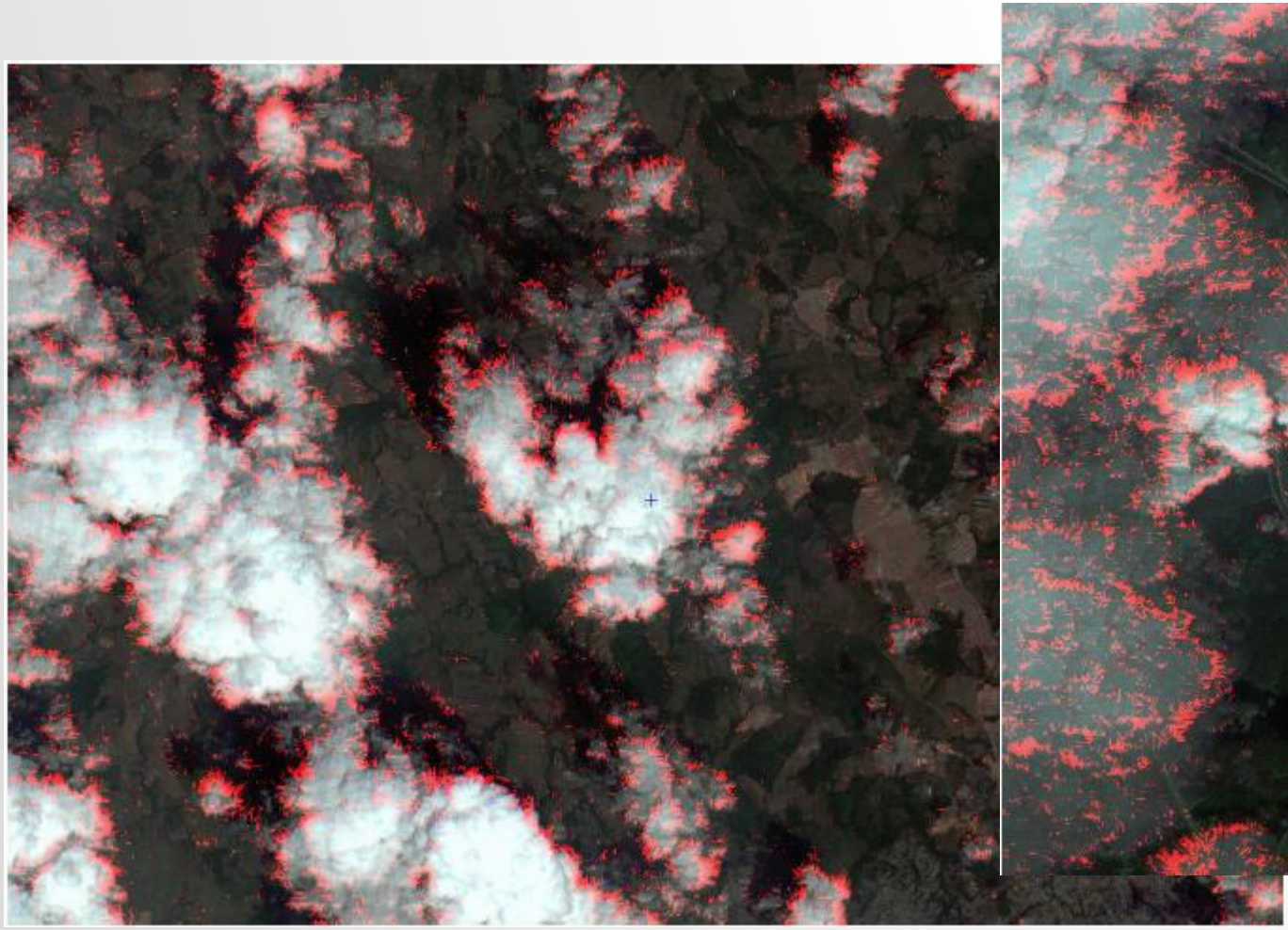
Future Work

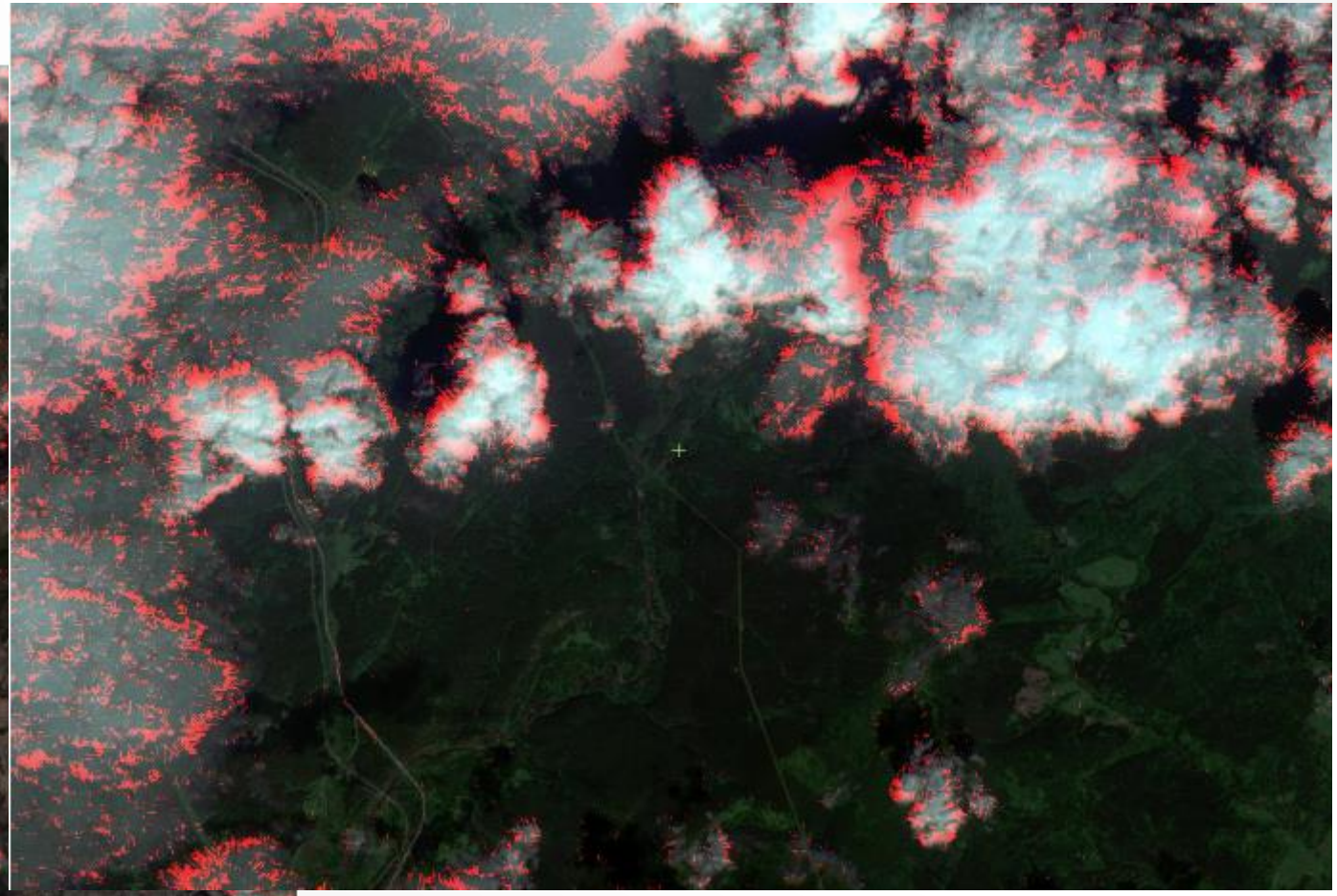
Future work

- Looking more into the underlying theory of its operation with a mathematician (finally ☺) to derive the fundamental math and its limitations.
- Examining the empirical relationship between MTF and hFocus to see if once “calibrated” the hFocus can be used as a regular proxy for MTF measurements.
- Maybe look at other interesting uses of the baseline algorithm!

Interesting uses? – Clouds?

- Did some preliminary work using two algorithms (one being hFocus) for cloud identification and masking.





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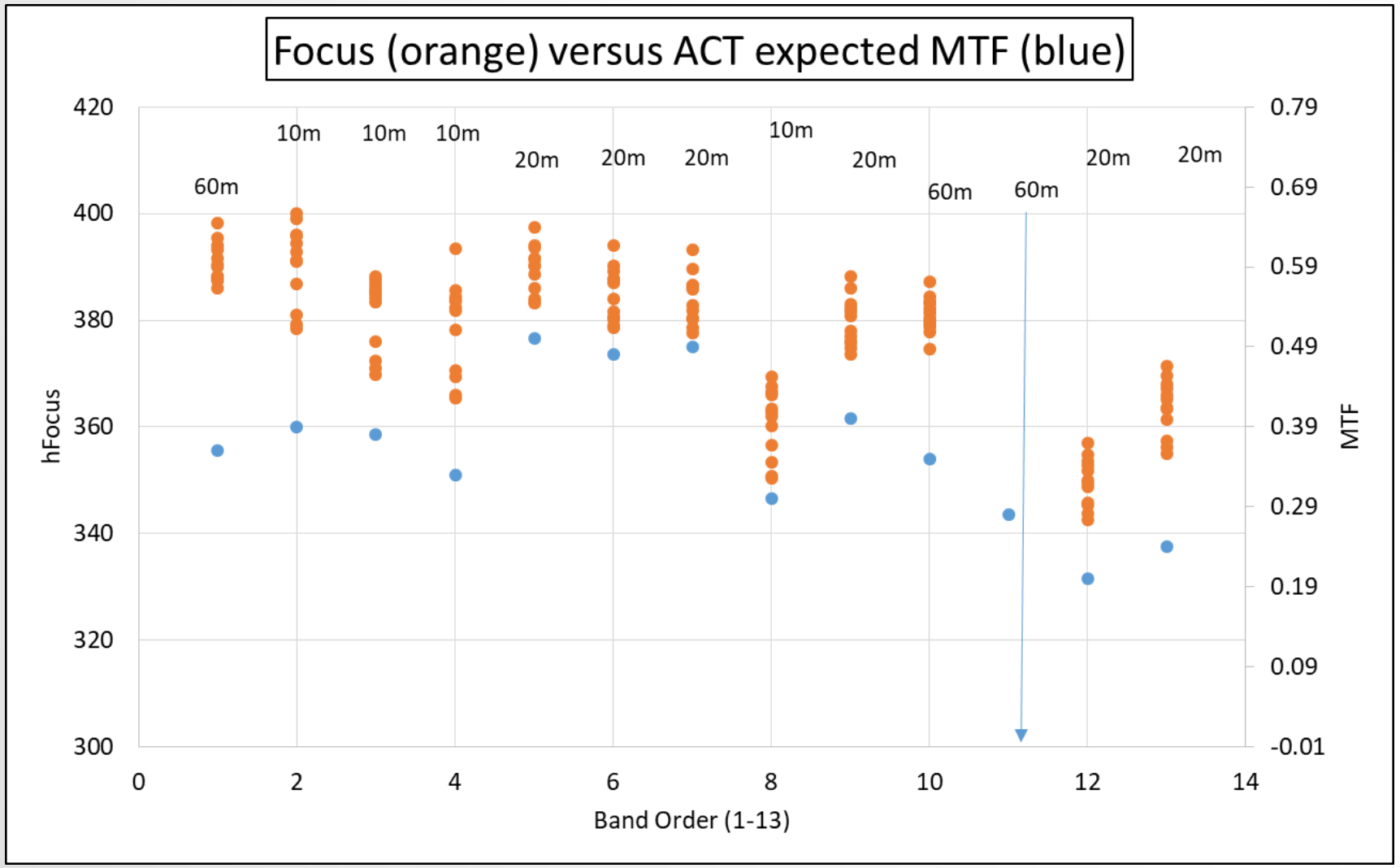
Conclusions

Conclusions

- The focus algorithm has proven useful, but the underlying theory and sources of uncertainty need to be more clearly identified.
- The results can be empirically related to MTF measurements for Sentinel-2 providing the possibility of determining MTF measurements temporally and across track on a daily basis if desired.
- The use of simple slope relationships in imagery profiles is not only a proxy for focus and MTF, but also provides some interesting additional information for identifying the presence of clouds, that is not based on knowledge of the radiance of the scene and is applicable (without modification) to any sensor.


Focus (orange) versus ACT expected MTF (blue)
hFocus
MTF
Band Order (1-13)
420
400
380
360
340
320
300
0.79
0.69
0.59
0.49
0.39
0.29
0.19
0.09
-0.01
0
2
4
6
8
10
12
14
60m
10m
10m
10m
20m
20m
20m
10m
20m
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