EOSense

INNOVATIVE METHODS FOR IN-FLIGHT CALIBRATION

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WEBEX			

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Achievements since project start

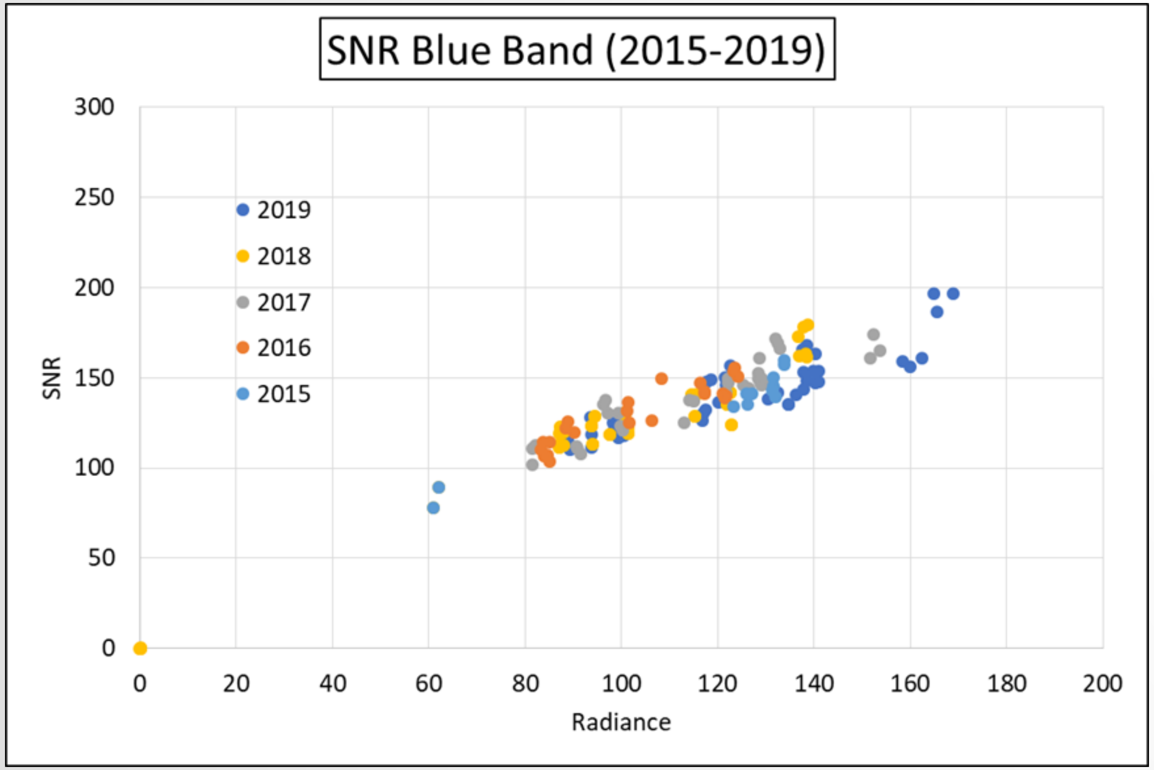
SIGNAL TO NOISE RATIO (SNR)

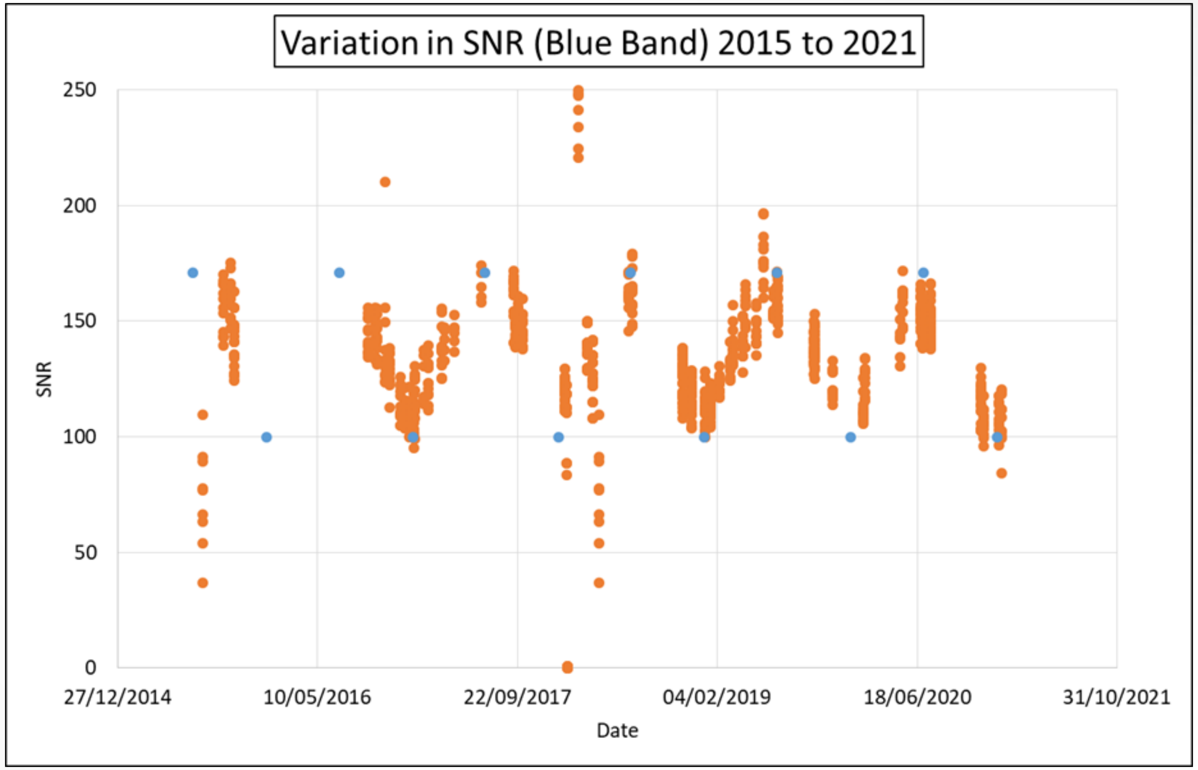
FINDINGS

- The developed methodologies have been tested successfully on multiple sensors with resolutions from 1m to over 300m.
- Results overall have been good and reproducible, but the more interesting findings, relate to the different anomalies we have observed during processing.
- Single detector analyses are more difficult, as would be expected, but open up the possibilities of providing some information on pixel level uncertainty estimation.

EXAMPLE RESULTS

Small satellite results using Libya 4 images only.



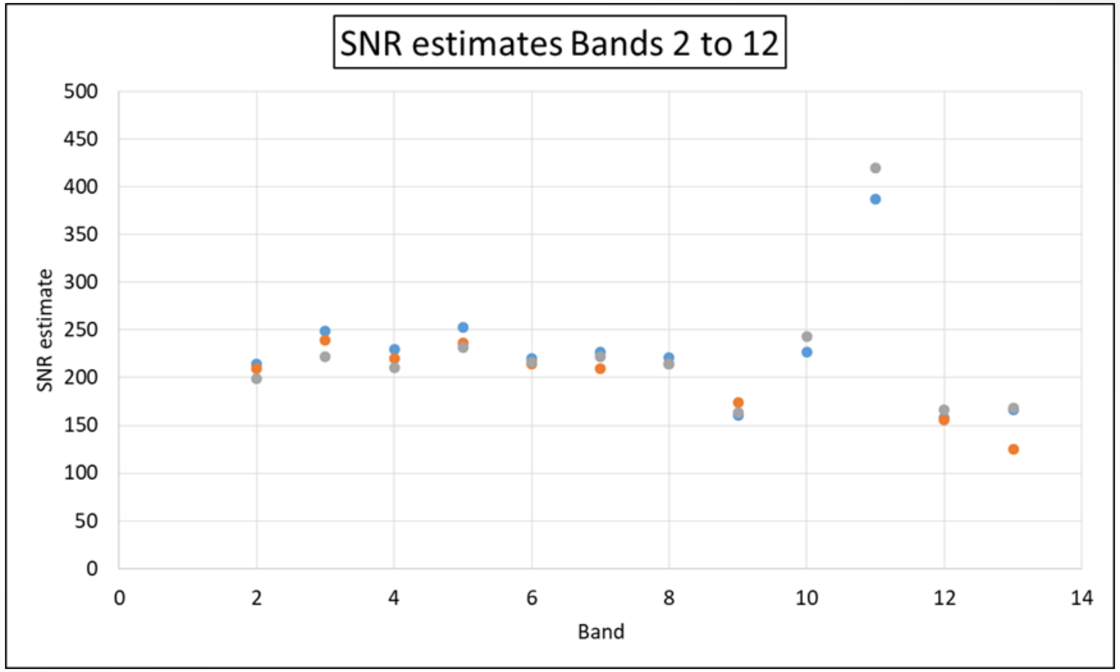


Multiple year estimates of SNR over Libya 4 using less than a dozen images each year.

Seasonal effects in SNR estimates, blue dots are mid-summer and mid-winter positions (Libya 4).

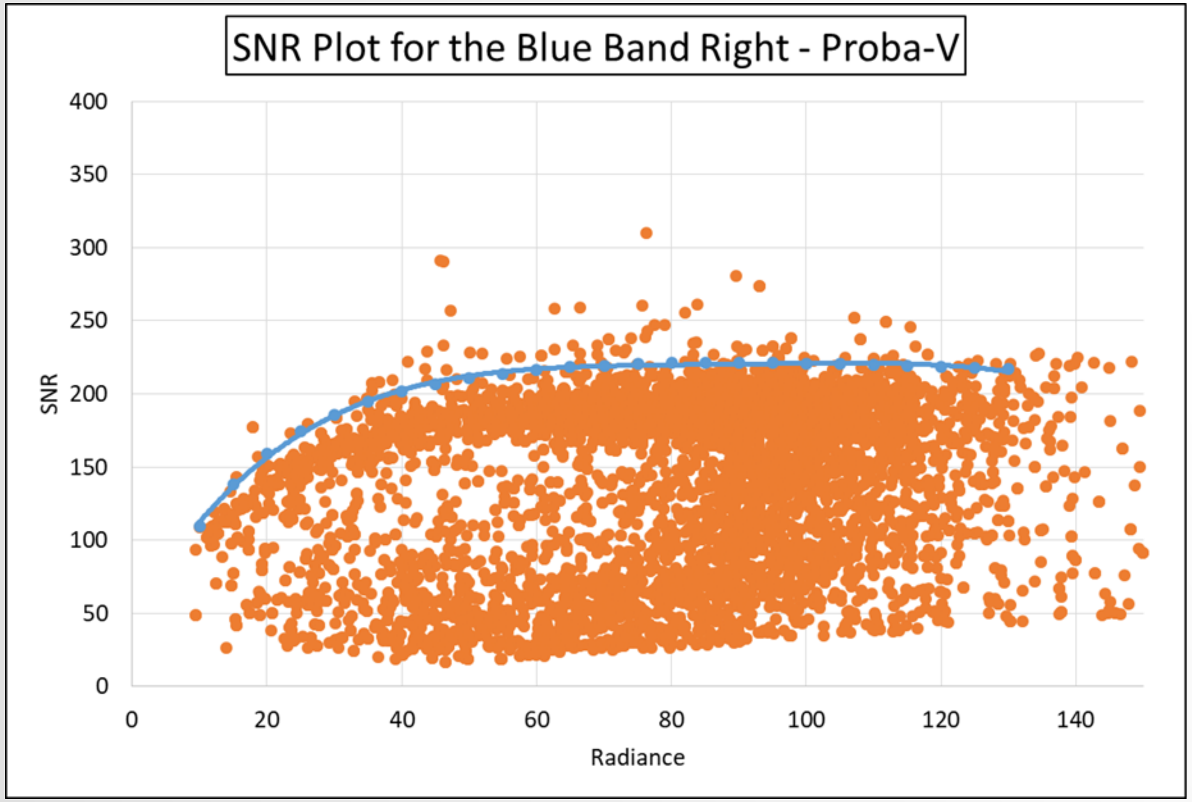
EXAMPLE RESULTS

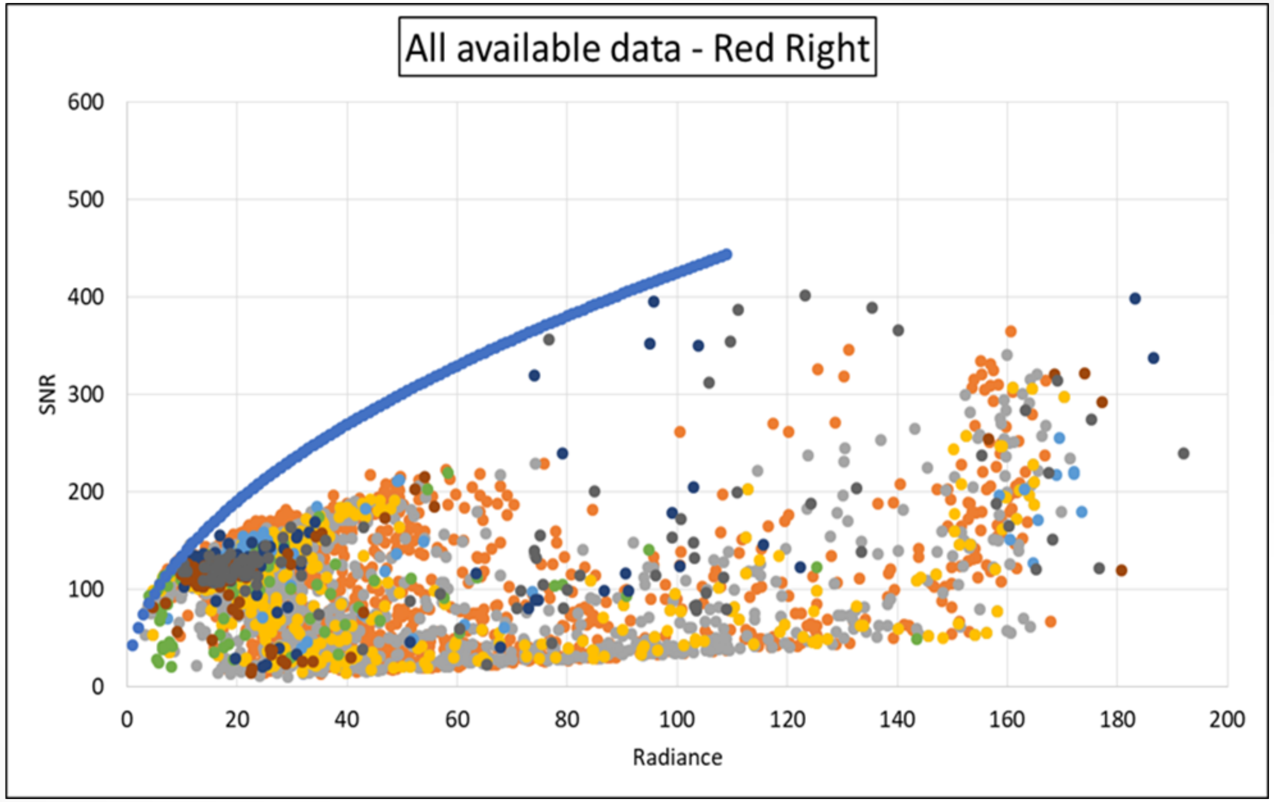
Band	Target Radiance	SNR predicted*	EOSense (Heterogeneous)	Dome-C (Homogeneous)	Comments
1	129	1361	992	1081 quantised	Poor distribution, needs more data.
2	128	214	210	199	Good distribution
3	128	249	239	222	Good distribution
4	108	230	220 (revised)	211	Moderate distribution
5	74.5	253	236	232	Weak distribution, needs more data.
6	68	220	236 (193 lower)	216	Weak distribution, needs more data.
7	67	227	238 (182 lower)	222	Weak distribution, needs more data.
8	103	221	214	214	Weak distribution, needs more data.
8A	52.5	161	174 (revised)	163	Moderate distribution
9	9	227	90 (approximate as data shows severe quantisation)	243 Quantised	Very poor distribution, no valid result
10	6	387	No estimate	420 Quantised	Very poor distribution, no valid result
11	4	158	156	166 Quantised	Limited data points but enough in lower radiance range
12	1.5	166	125	168 Quantised	Very low values, very rough approximation



Sentinel-2 SNR estimates in table form (left) and plot form (top).

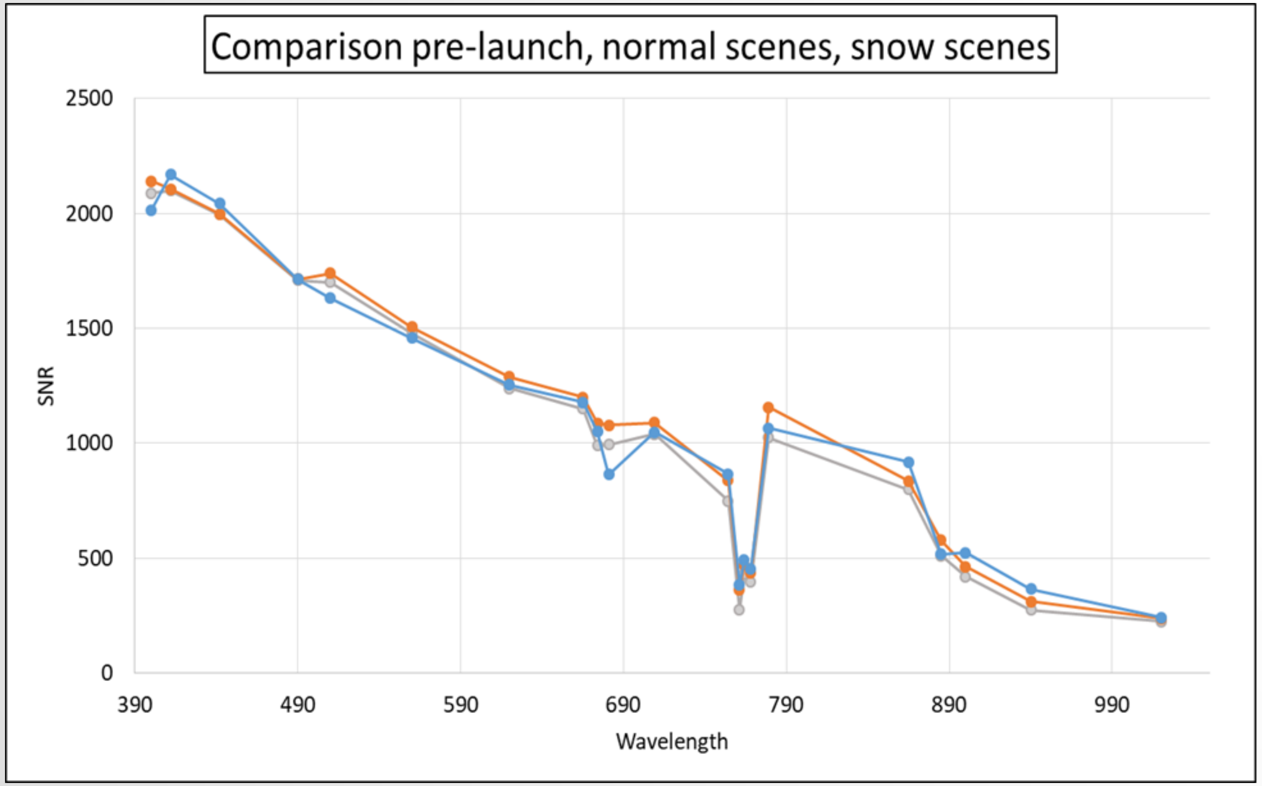
EXAMPLE ANOMALIES – PROBA-V

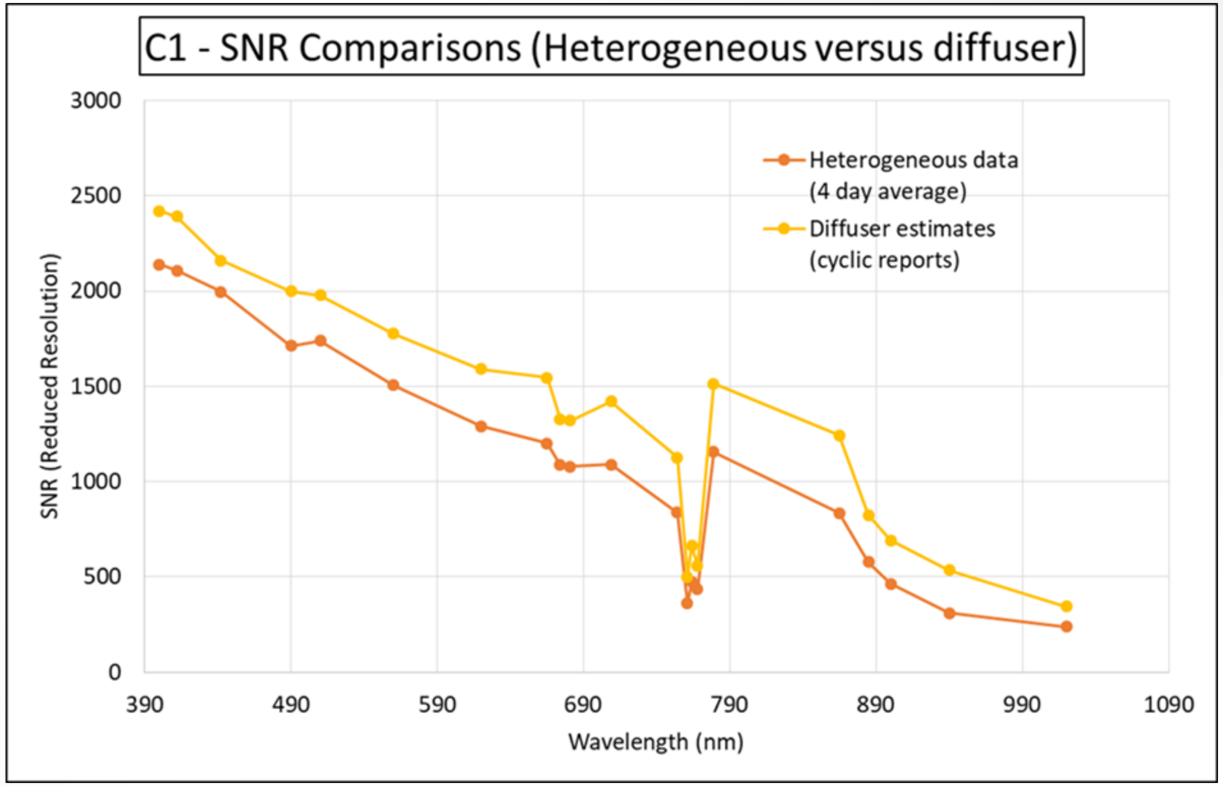




Proba-V bands showing fits (blue dots and blue line) to the SNR data clouds. A shot noise curve does not fit the data cloud. Almost linear increase in noise with signal, discussions in progress with VITO.

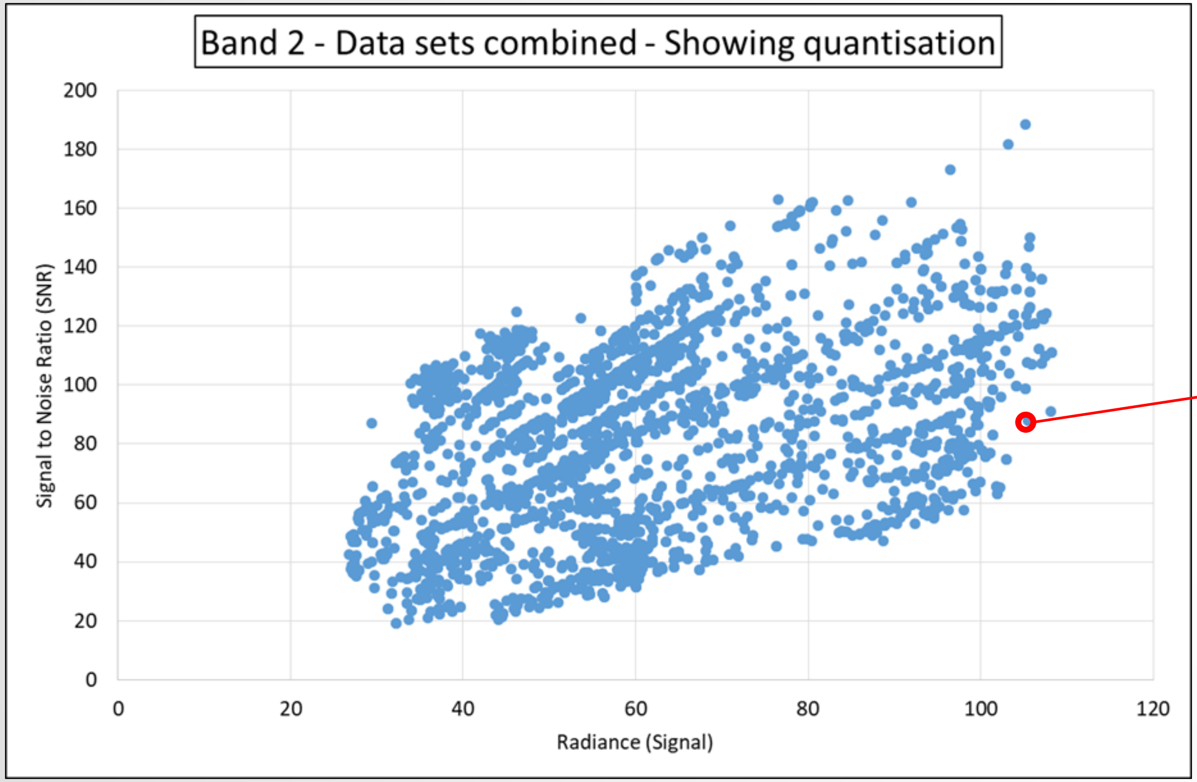
EXAMPLE ANOMALIES – S3 OLCI

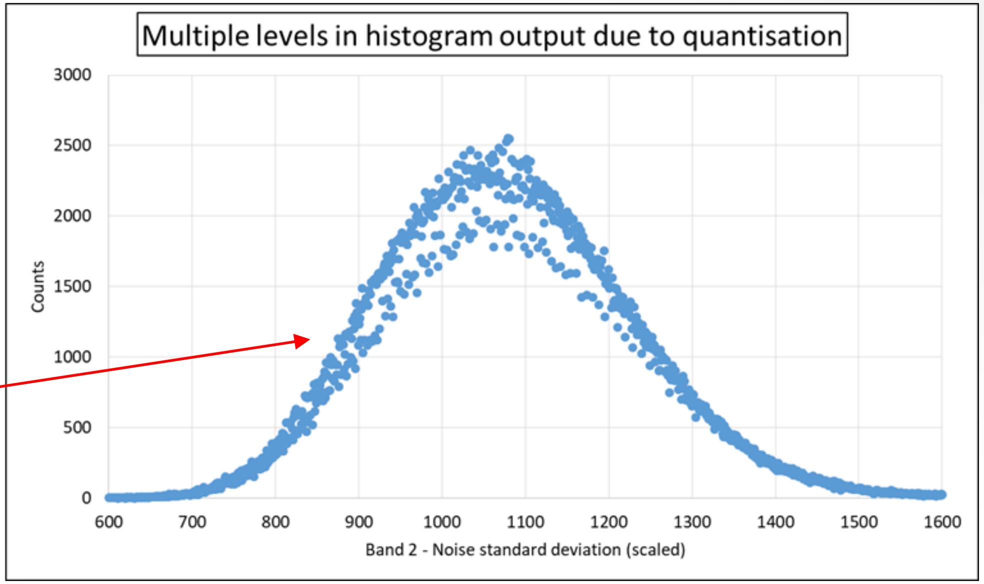




Although pre-launch, our estimates and snow scenes (Dome-C) gave consistent results (left). The diffuser results were tens of percent higher (right). The cause is still unknown.

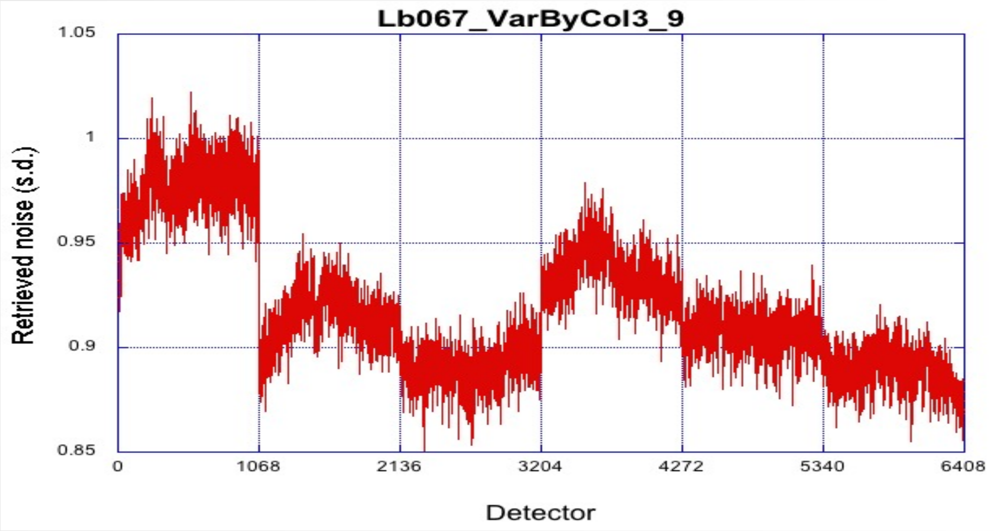
EXAMPLE ANOMALIES – S2 MSI

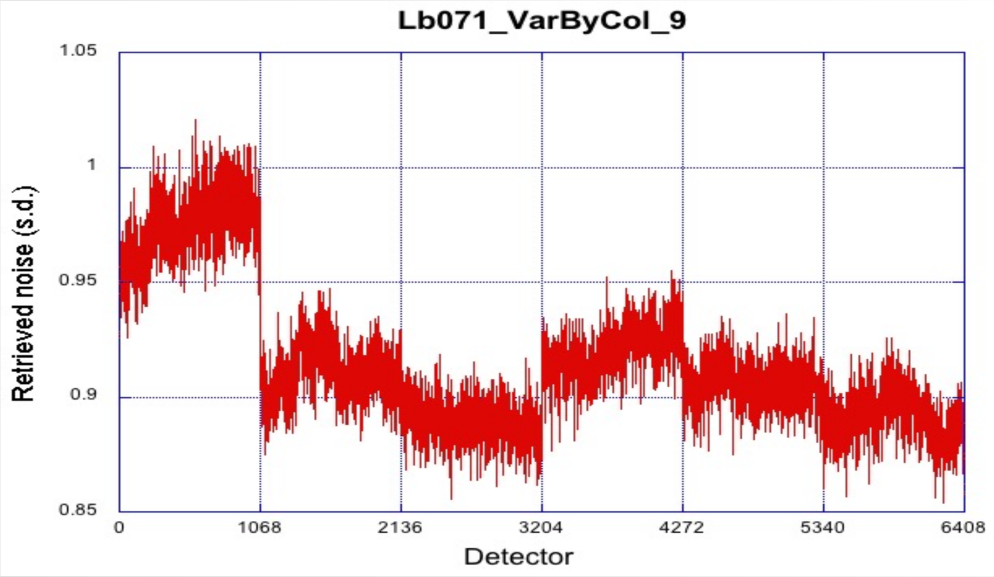




Although we achieved quite consistent results with the ESA estimates for S2-MSI we did clearly see the effects of signal quantisation in both the data clouds and the statistical distributions for single images used.

EXAMPLE SINGLE PIXEL





Each CCD on the FPA has six separate readouts, the boundaries are clearly visible between the CCD segments.

Each individual detector is shown, the noise standard deviation varies because of the electronics and the varying surface radiance across Libya 4 (shot noise component)

The pattern is quite repeatable for multiple images.

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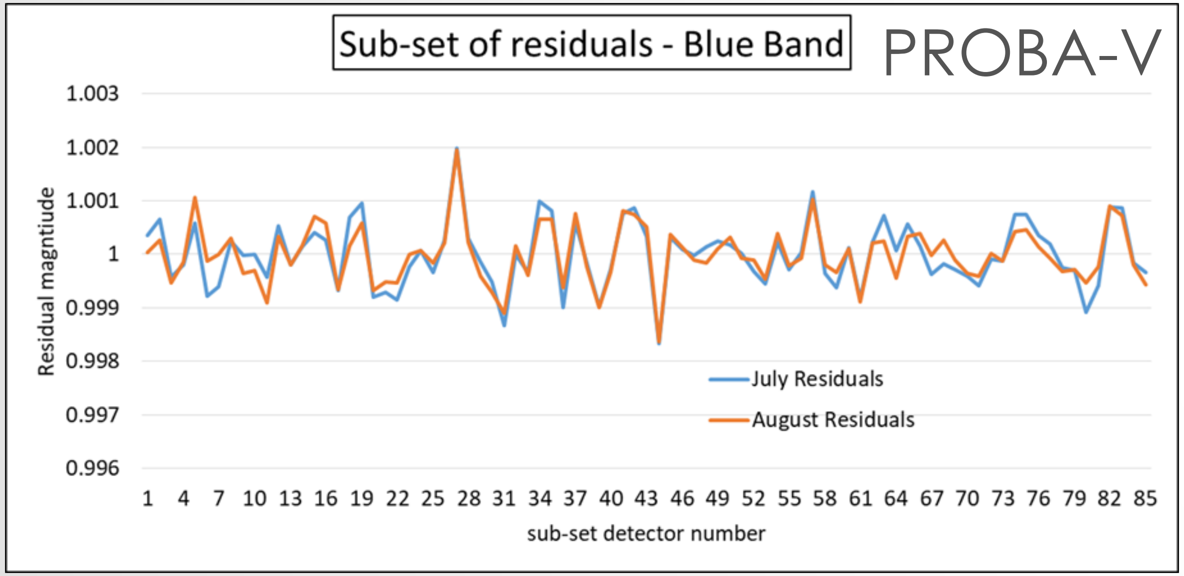
Achievements since project start

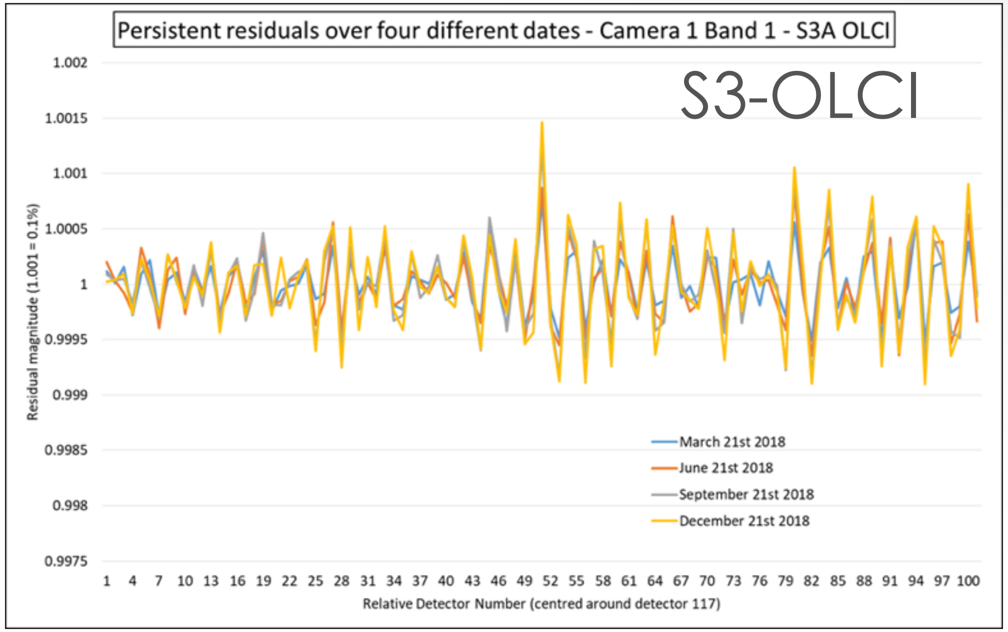
RELATIVE GAIN AND NON-LINEARITY

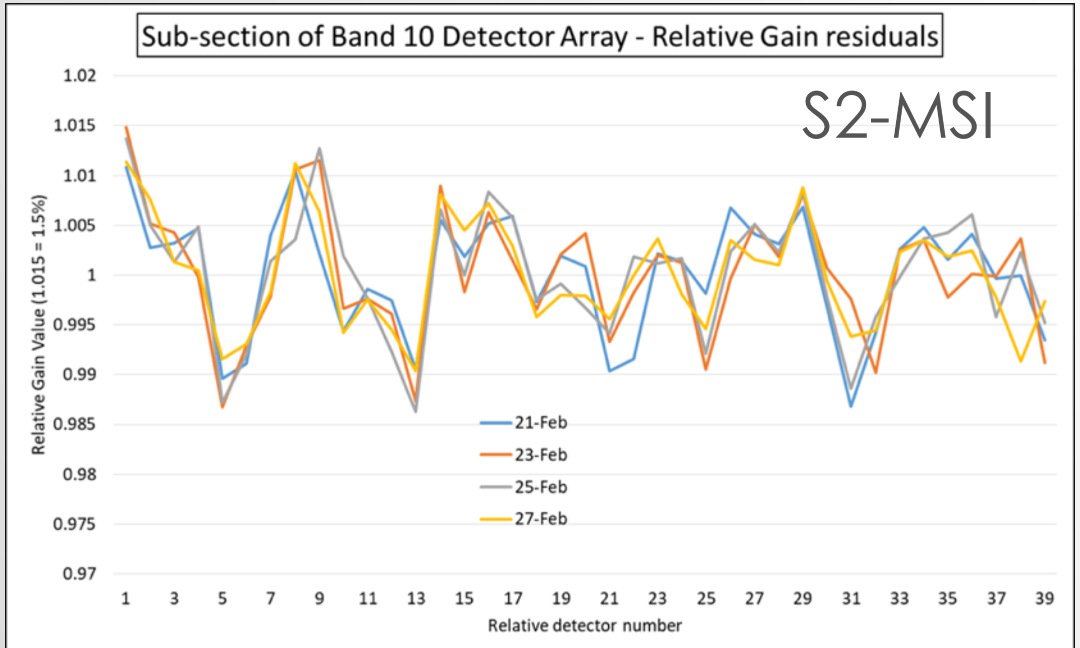
FINDINGS

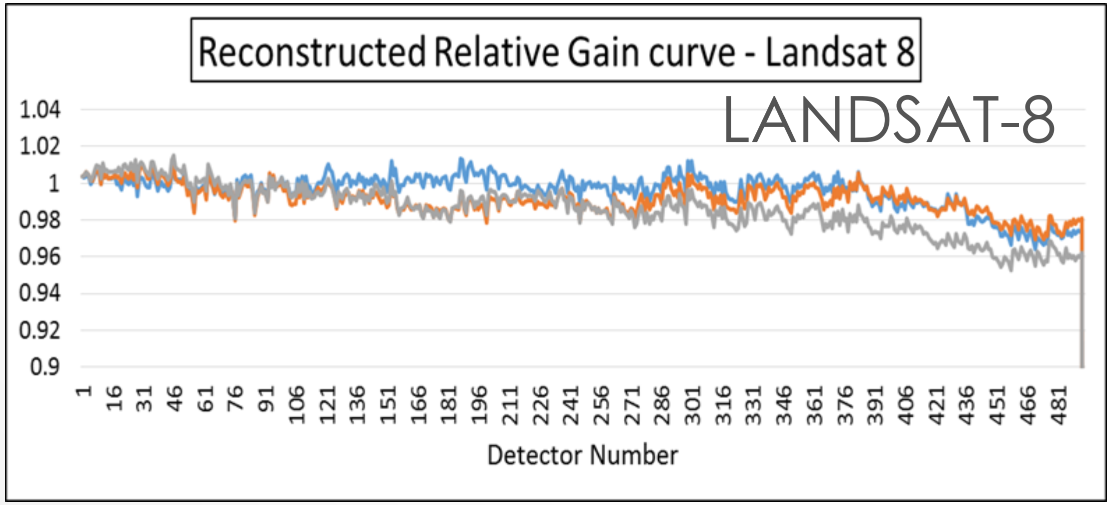
- Effects are present in all sensors, S2-MSI, Landsat 8, S3-OLCI, Proba-V, DMC3. Probably due to the way we calibrate them.
- Three types of non-linear behaviour observed in the residuals, multiplicative, additive and small differences in linearity between detectors.
- Behaviour seems to be wavelength dependent, with small multiplicative and non-linear differences in the VNIR and large additive (bias) effects in the SWIR. Mixed behaviour is possible.
- The magnitudes of the effects can be estimated and corrections determined.

EXAMPLE – DIFFERENT SENSORS









VARIATION WITH TARGET RADIANCE

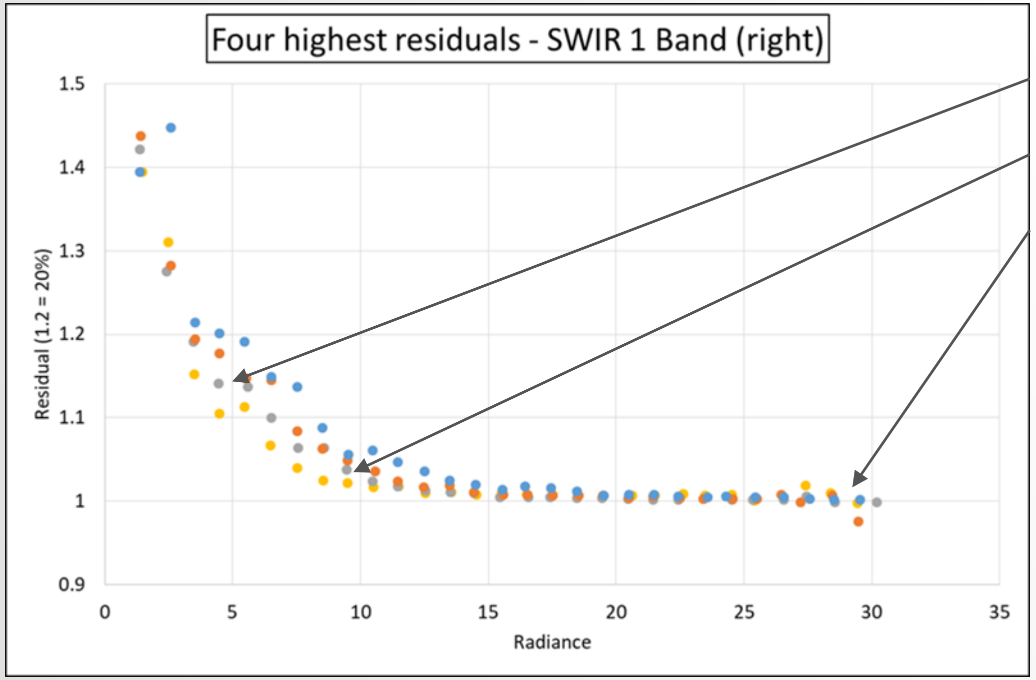
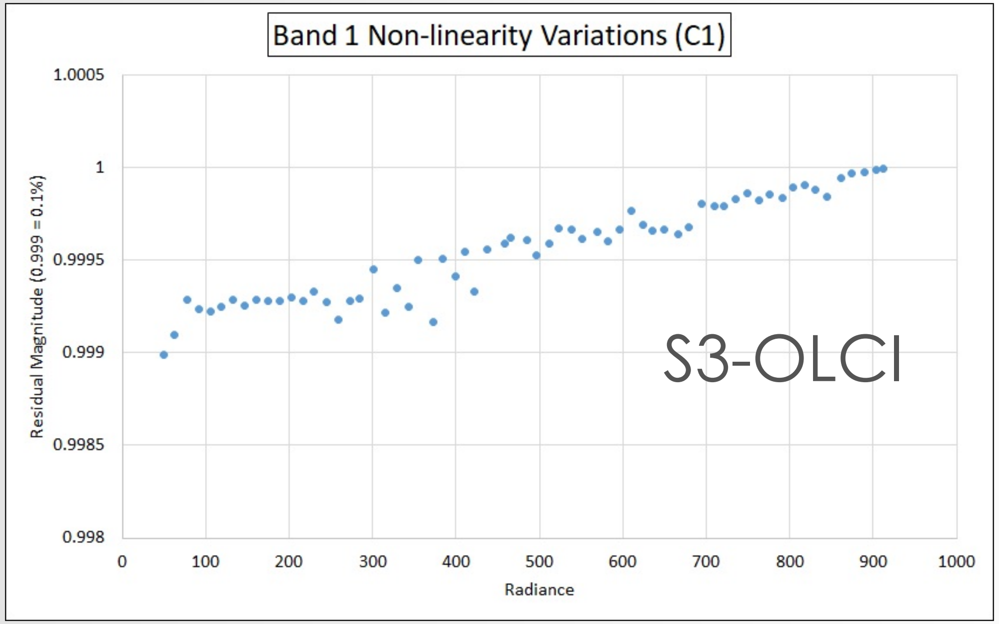
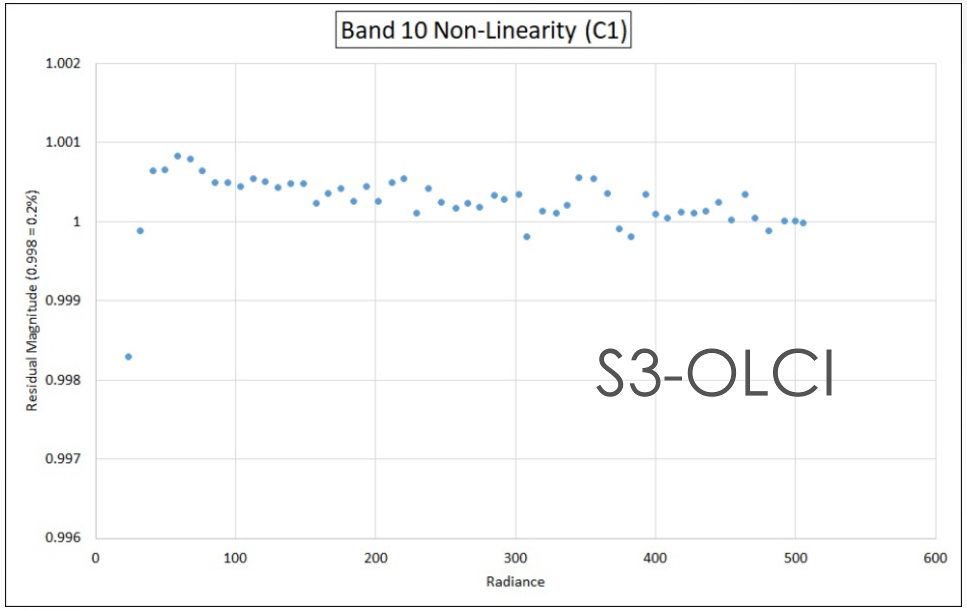


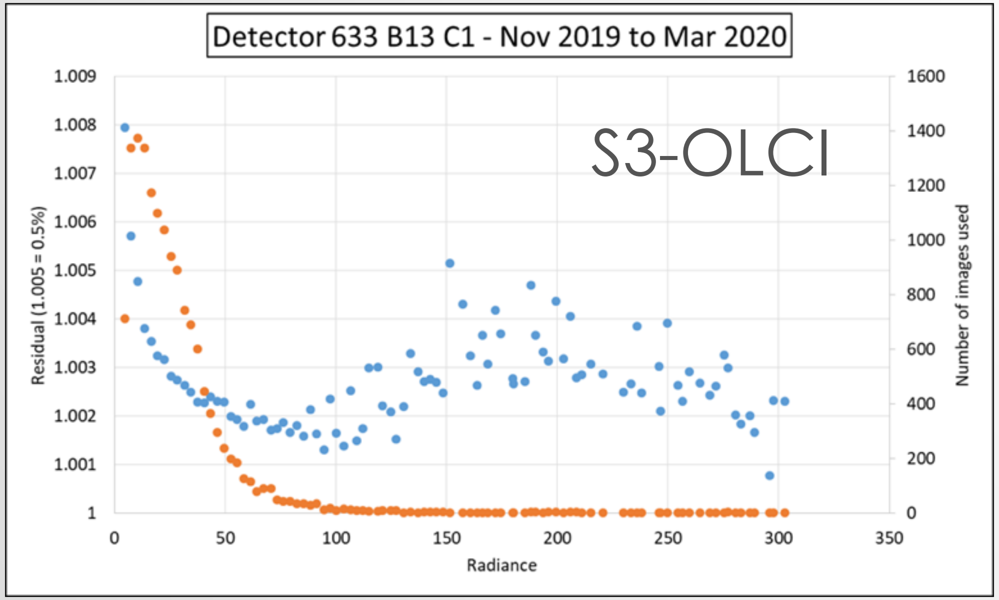
Image 1 – Radiance 5, Residual 0.75 (15%)
Image 2 – Radiance 10, Residual 0.4 (4%)
Reference for calibration (very bright)

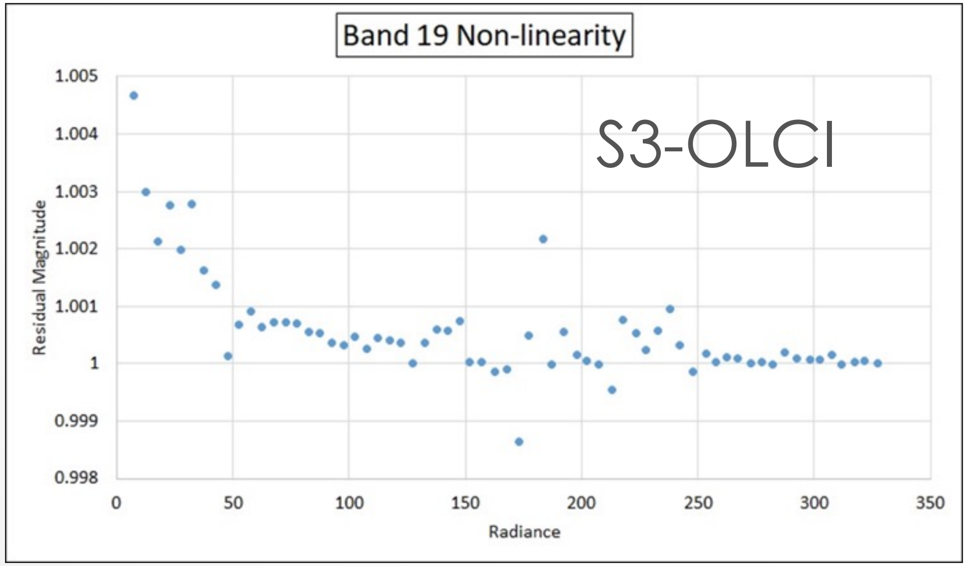
Generally these effects not seen with diffusers or bright targets as worst effects are at low radiances.

EXAMPLE – WAVELENGTH BEHAVIOURS

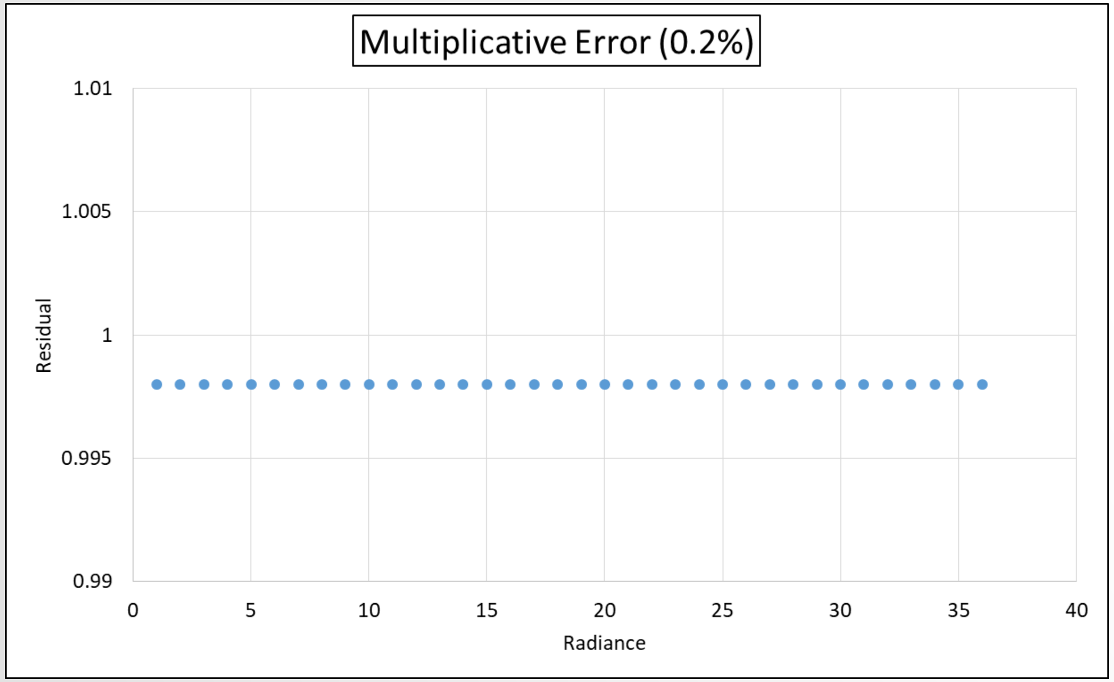


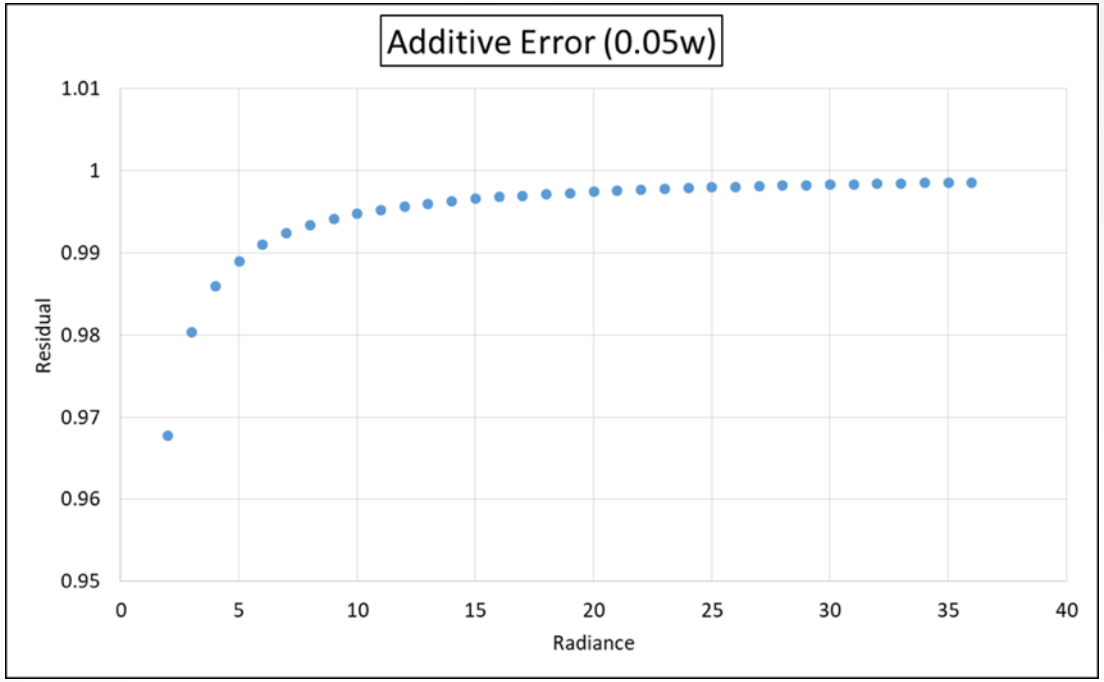






ORIGINS OF FEATURES



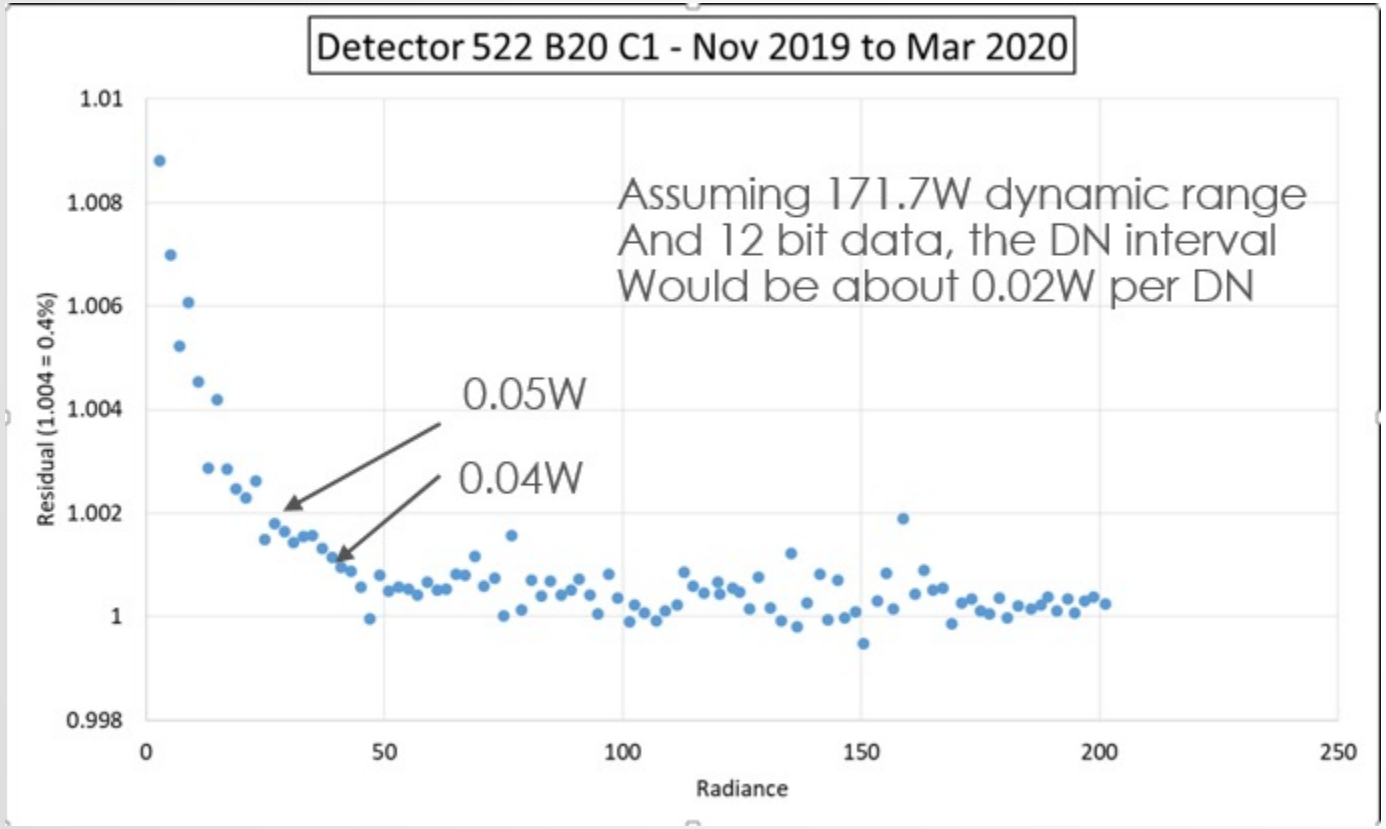


Most common features in Proba-V are multiplicative at shorter wavelengths and additive at longer wavelengths.

In OLCI we see sloping residuals at shorter wavelengths (due to non-linearity differences between detectors) and additive at longer wavelengths.

EXAMPLE – CORRECTIONS

- For multiplicative the correction is relatively simple as has been applied commercially for the several years.
- The additive correction requires some more development.



Using the knowledge of the radiance and residual magnitude we can estimate the error in radiance given the dynamic range of the sensor for any specific band.

In this case points to a 2 DN bias error.

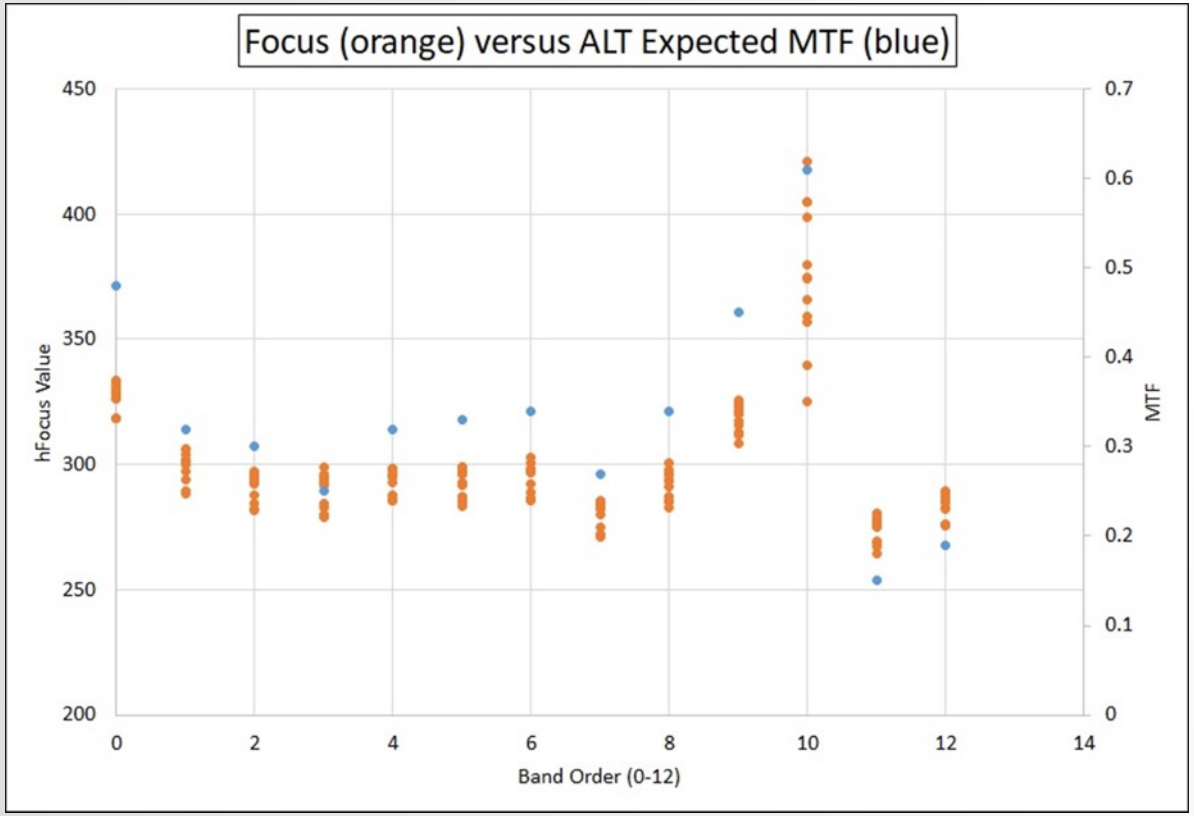
Achievements since project start

FOCUS

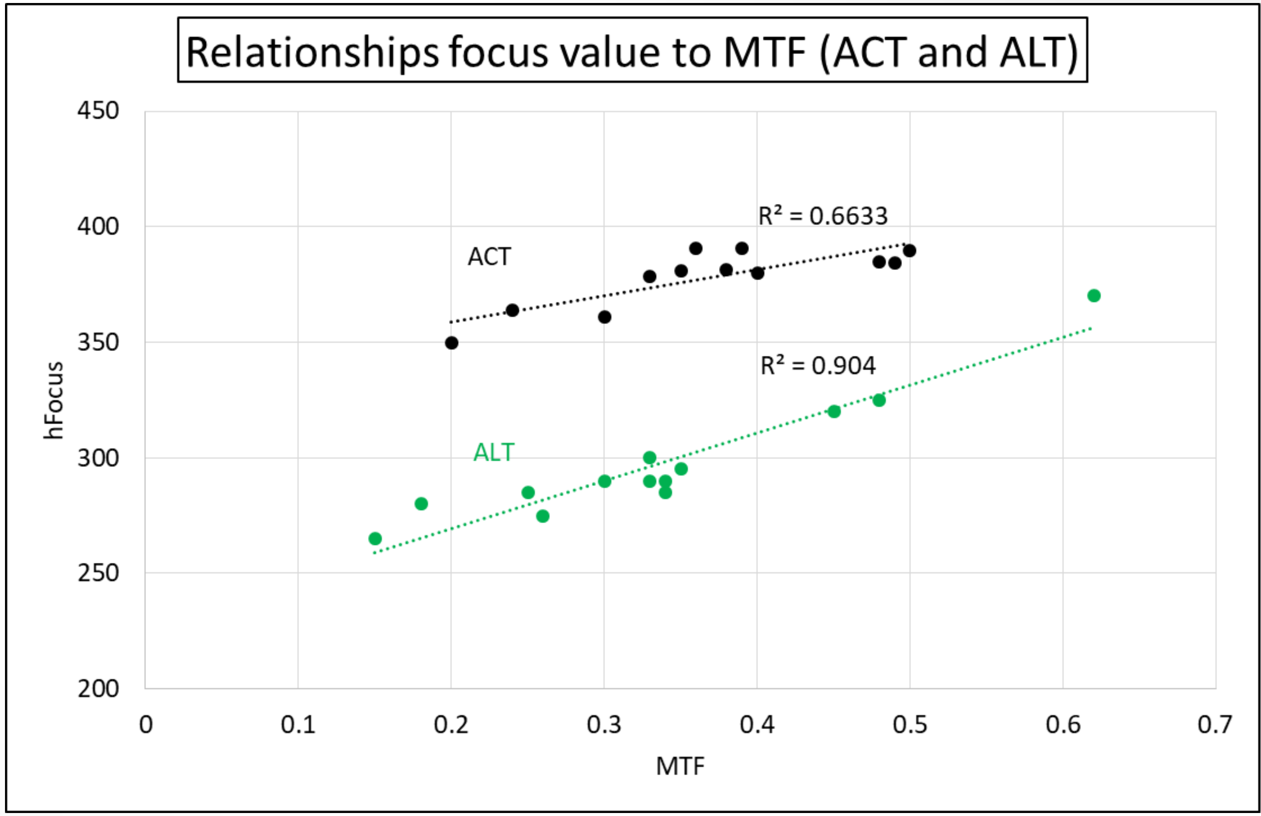
FINDINGS

- Results are consistent from one group of images to another.
- Relationship to MTF can be clearly seen in across and along track comparisons to S2-MSI.
- Relationship to MTF can be determined using an internal calibration between the focus measure and MTF determined using standard approaches.
- Changes with time are observable in high resolution sensors.
- Across-track asymmetry has been observed in several sensors, which means that measured MTF values only give approximate results if using a measurement from a single point in the swath.

RELATIONSHIP MTF AND FOCUS VALUE

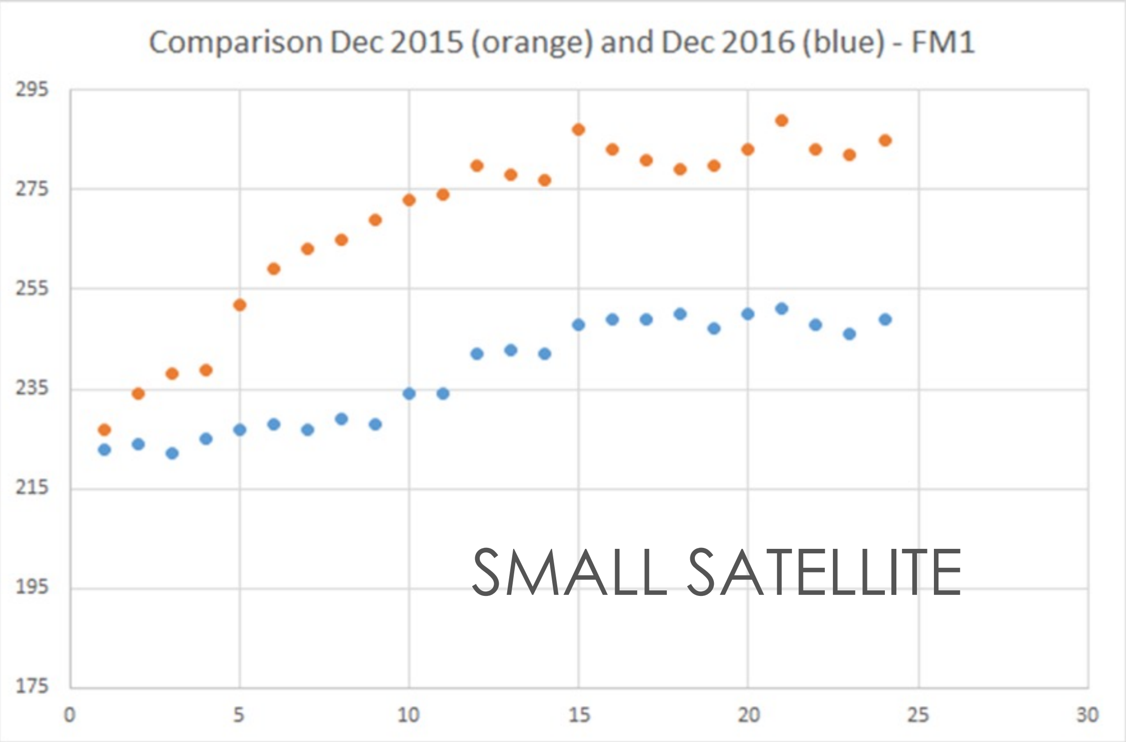


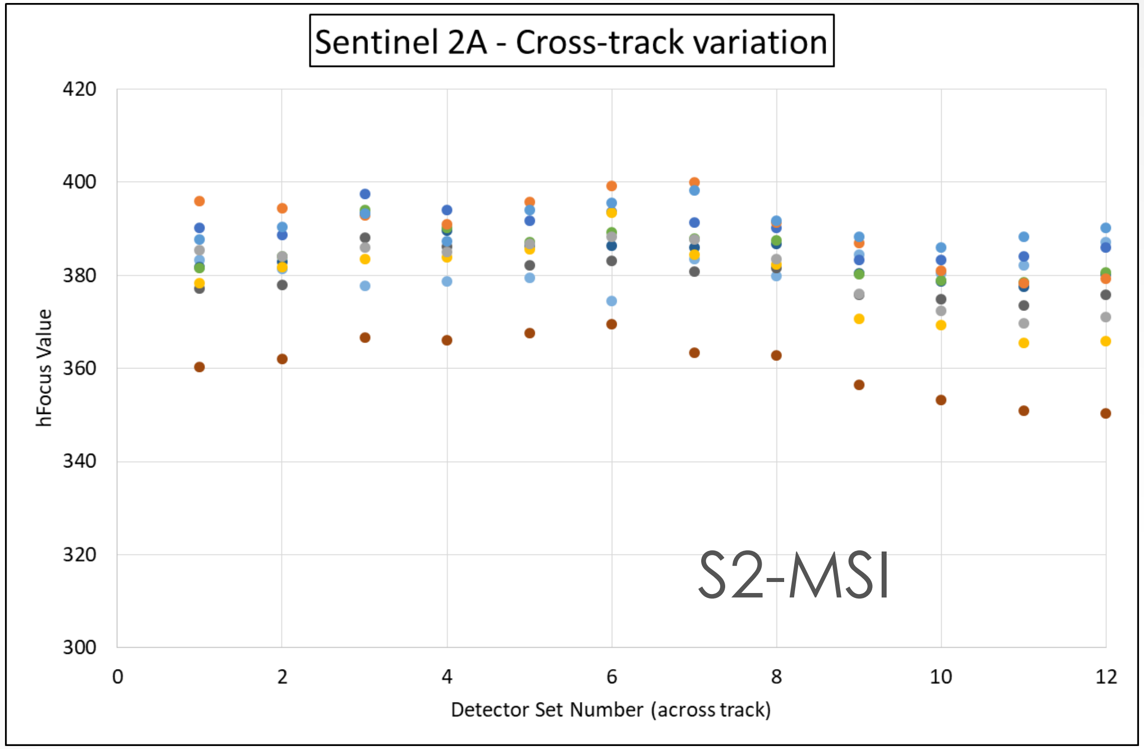
Focus values compared to MTF along track (ALT) S2-MSI



Correlation between MTF and focus values Along Track ALT and Across Track ACT. S2-MSI.

ACROSS TRACK ASYMMETRY





Two images from a small satellite system showing change in the magnitude of the focus value with time.

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

Next Steps

FURTHER RESEARCH

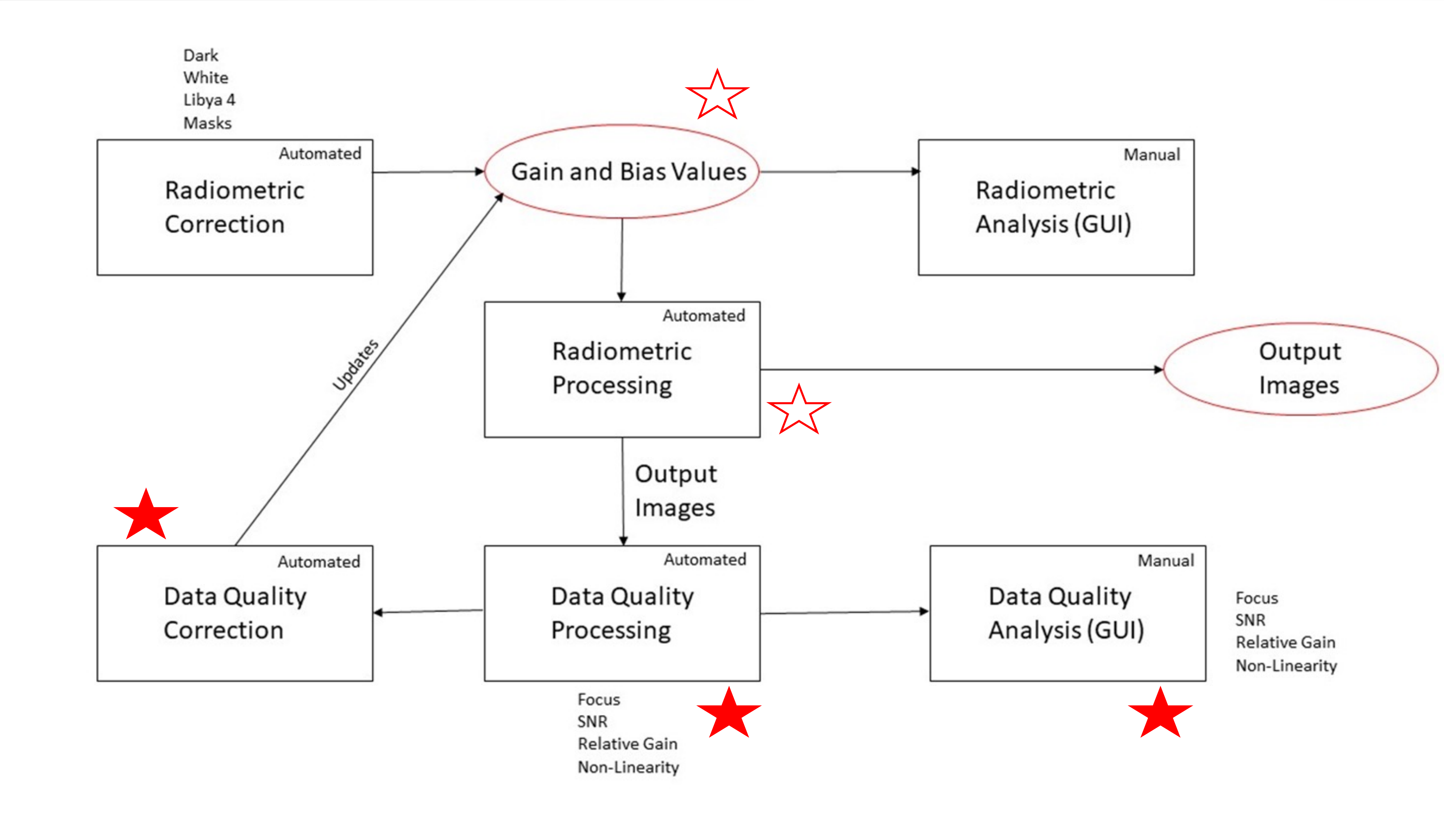
RESEARCH ON ANOMALIES

- Finding the cause of the S2 Data quantisation, why is it present only in Sentinel-2, what is causing it? Consult with MPC.
- S3 differences in the SNR estimate. For other sensors we see consistency between estimates, while for S3-OLCI we see tens of percent differences. Why? Consult with MPC
- Proba-V what is causing the non shot noise limited behaviour. Consult with VITO (already begun).
- Understanding exactly how the standard non-linearity correction is applied to S2 and S3, to explain some of the variability in relative gain with the target brightness.
- Why our S2 across-track focus/MTF so poorly correlated compared to along track estimates? It has to be something to do with going across multiple detectors rather than using single detector estimates. Consult with MPC in part.

Next Steps

PROTOTYPE IMPLEMENTATION

PHASE 2 DEVELOPMENT



Windows based package to be implemented in Phase 2 in co-operation with VITO.

CONCLUSIONS

- We are pleased with the results of all the methods applied and their consistency.
- We need to work more closely with the different groups (ESA, MPC, VITO) to understand the anomalies which could be real or due to our processing (hopefully not our processing).
- The methods to derive the parameter databases are simple to apply and can be fully automated. We hope to implement much of this in Phase 2 for the Proba-V follow on small satellite system.
- One important thing that has come out of this study was the **lack of access to pre-launch information**. One would expect ESA to have this and make it available. Data on SNR and MTF in some cases was difficult to find. Additionally, more details of how the MPC derives some of the results would be useful. More communication is needed. Not so much for me (getting old) but for other younger researchers in future.