EOSense

FINAL PRESENTATION

Statistical Degradation Model Project
Contract EUM/CO/18/4600002181/Abu

Project - 18	Statistical Degradation Model		Doc – 0046
07/06/2020	Eumetsat	Presentation	Rev – 1.0

AGENDA

11:00 – 12:00 CEST: Part 1 – Final Presentation

- Introduction (AB)
- Overview of Results and Study Conclusions (SM)
- Comments/Questions (All)
- Conclusions (AB)

12:00 – 13:00 CEST: Part 2 – Contract Close Out

- Review of Deliverables
- Actions (if any) required before contract completion

CONTENTS

- Aims of the study (five areas)
- Using heterogeneous images
  - Advantages (automation, no models)
  - Based on statistical distributions, from single or multiple images
- Level 0 Results
- Level 1 Results
- Key findings
- Future direction

Note that spectral radiance values given in this document are stated as Watts (W) but refer to ($Wm^{-2}sr^{-1}mm^{-1}$)

AIMS OF THE STUDY

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- Five areas to be examined and at least three developed,

- Level 0 – OLCI and SLSTR
  - Calibrator drift
  - Absolute Calibration drift

- Level 1
  - Signal to Noise Ratio (SNR) - OLCI and SLSTR
  - Relative gain estimation - OLCI
  - Non-linearity estimation - OLCI

USING HETEROGENEOUS IMAGES

Basic principles

- Currently radiometric calibration and data quality relies largely on infrequently acquired on-board data (Sentinel-3 has a calibration cycle every two weeks) or through vicarious calibration using specific sites that may have environmental limitations (Dome-C is seasonal, cloud cover limits Libya 4). So opportunities are limited.

OUR APPROACH

- All images collected contain useful information for assessing changes in radiometry and data quality, this provides very high temporal sampling of parameters of interest.

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Types of images we use, essentially everything

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Advantages of using normal images

- By using normal images, we have <u>a much higher sampling interval</u>, sampling every few minutes in some cases, rather than every two weeks using on-board devices. We can therefore monitor and update our results with a much higher frequency than many on-board devices or vicarious methods which use specific sites, that can only be accessed infrequently.
- By using normal images, in theory we can <u>identify issues as they occur</u> and either flag issues or <u>update coefficients automatically</u> (for example, detector non-uniformity, where a single detector responsivity changes dramatically in a short period of time)
- We also avoid "dead" periods where a specific site cannot be used, such as the polar sites in Antarctica and Greenland that for precision work can only be used effectively for one to two months per year.
- Finally we can sometimes see things that cannot be detected using the on-board devices, as we view normal background radiance values.

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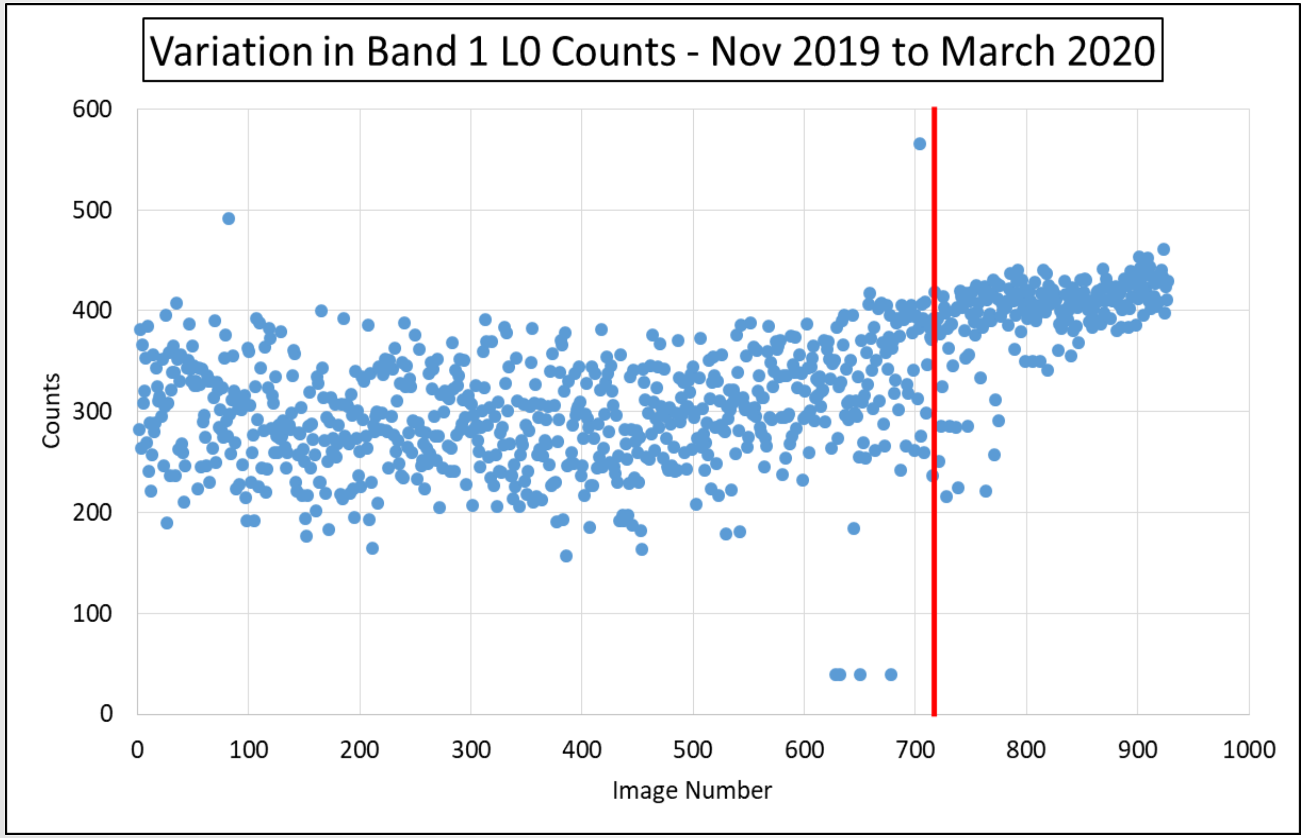
LEVEL 0 RESULTS

LEVEL 0 STUDIES

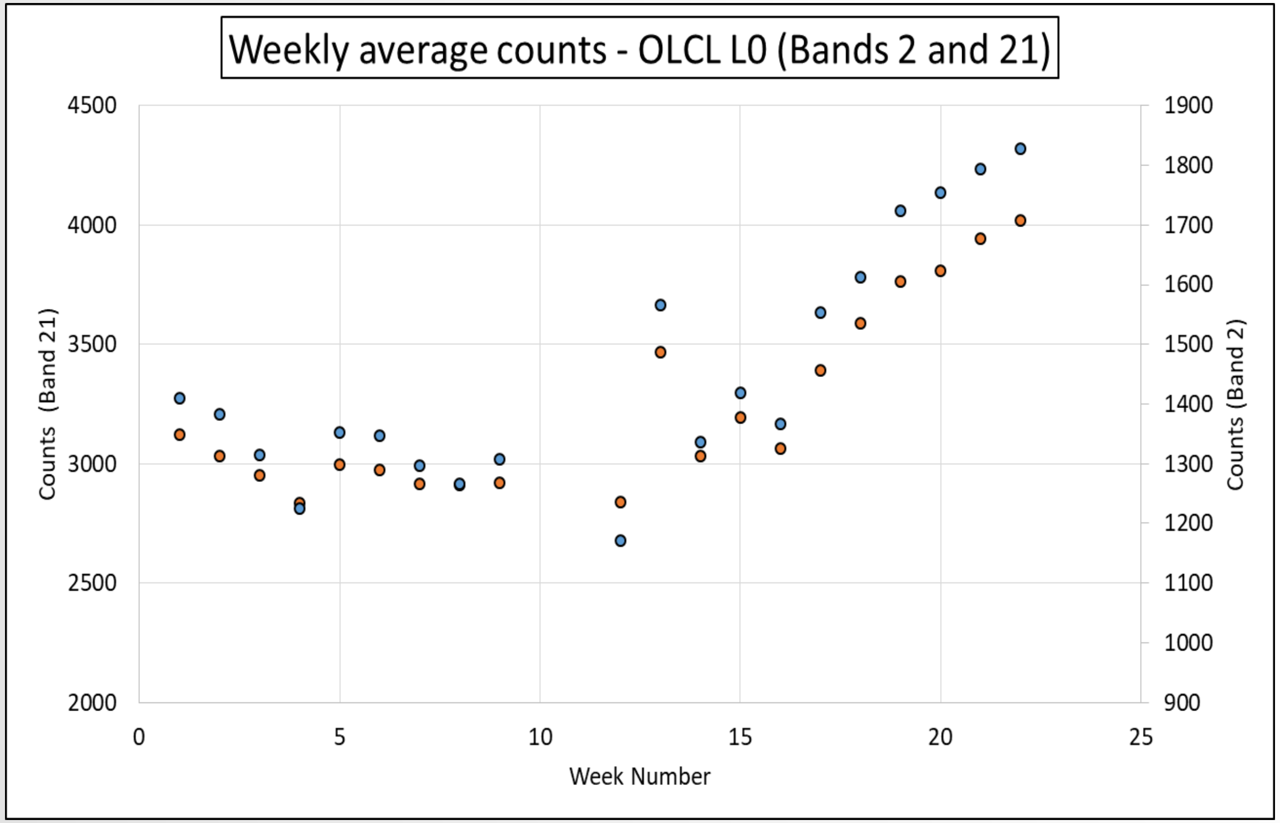
- By using bias subtracted Level 0 data we can simply track how the counts vary from one year to the next.
- Given the number of data points, we average away effects that need to be accounted for in other vicarious methods that use a limited number of images of specific test sites (BRDF for example).
- Essentially we are treating the Earth (over a limited timescale) as a fixed reference.
- We can use this method in one of two modes,
  - Direct use of counts.
  - Ratioing counts from the earth against the on-board diffuser to estimate diffuser drift. The two modes use the same premise. A constant earth.

OLCI LEVEL 0 COUNTS



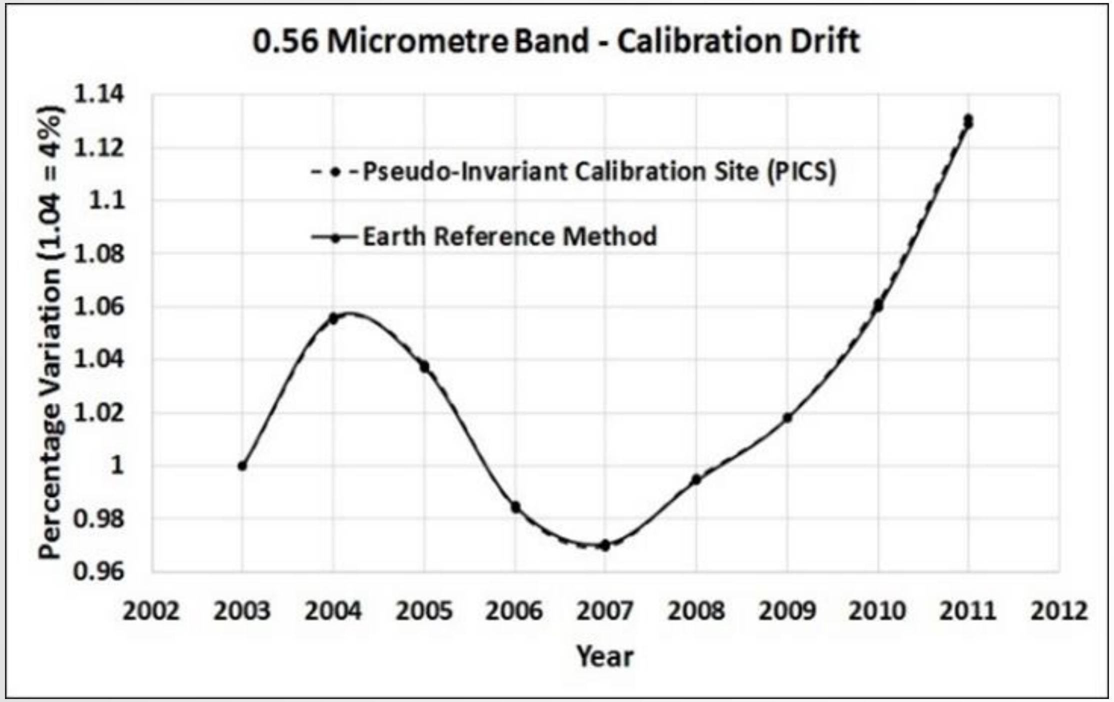
- Each dot is an image average across all detectors for all lines in an image.
- We see a lot of scatter in the counts, but we also see a trend and some differences in behaviour with time.
- Red line is 1st March 2020.

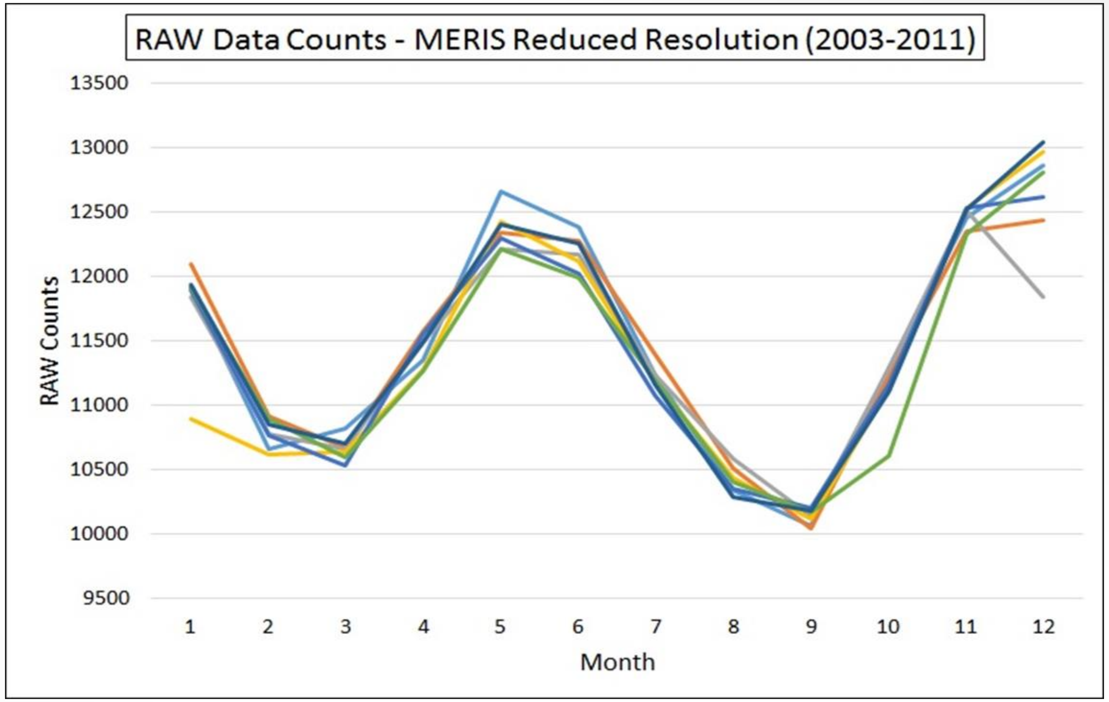
OLCI LEVEL 0 AVERAGE COUNTS



- We can average the values for each band and plot weekly averages.
- Very different bands (412nm and 1020nm) give similar trends. The shape we assume is a function of
  - Average surface brightness effects
  - Earth sun distance

AATSR RESULTS AND MERIS REPEATABILITY



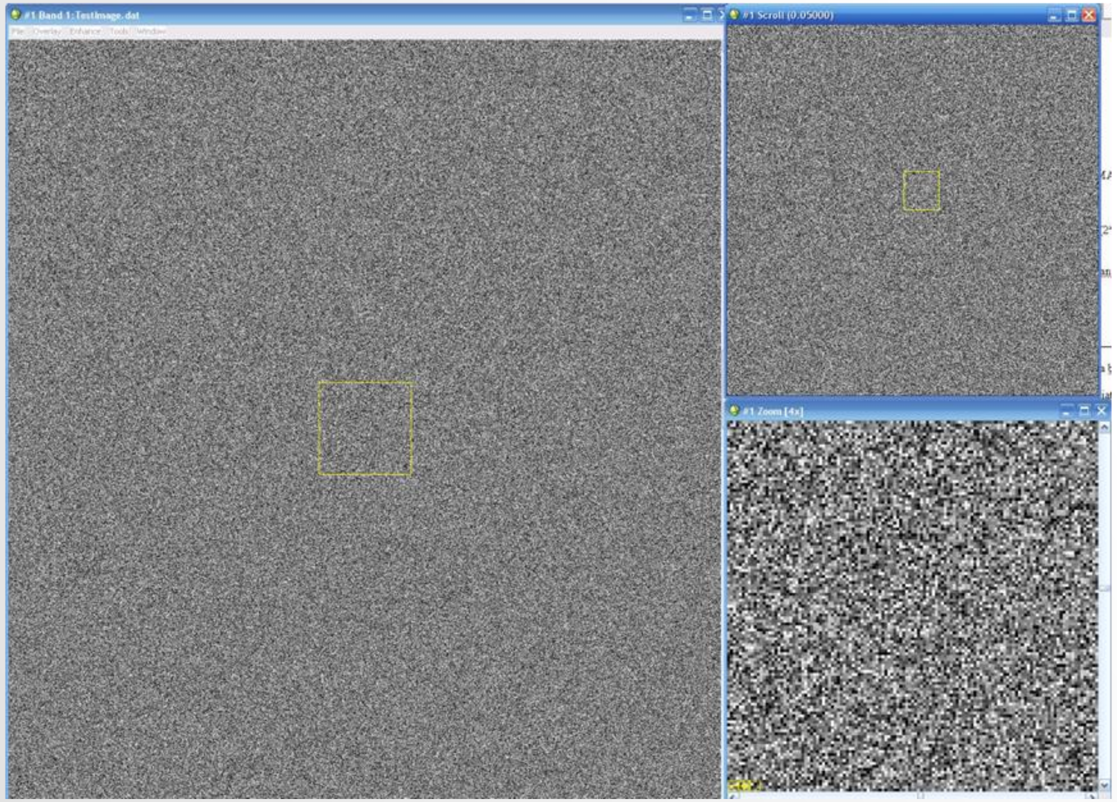


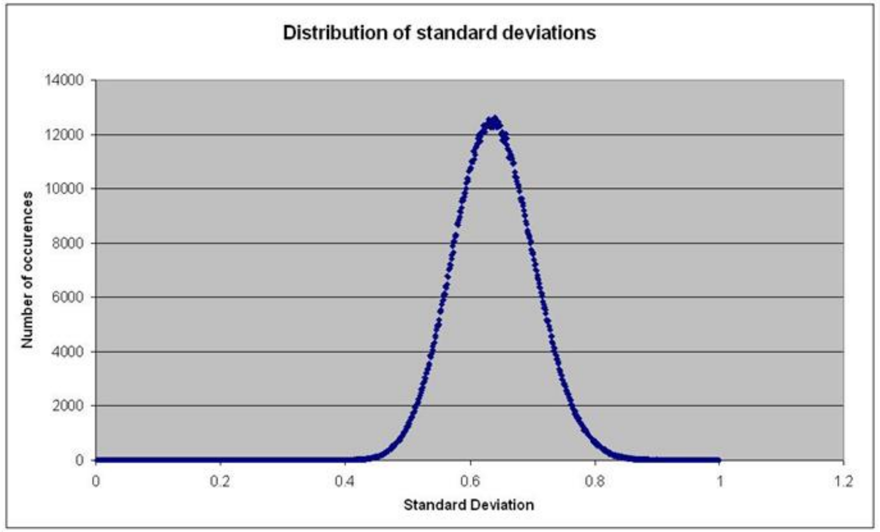
No results as yet as we had only five months of OLCI and hardly any SLSTR data. However, from previous studies we can see that a ratio of data counts against diffuser for AATSR (left) gave a very close correspondence and that MERIS counts repeated very closely in a very brief study of a band in the red region (right).

LEVEL 1 OLCI RESULTS

SNR ALGORITHM OPERATION

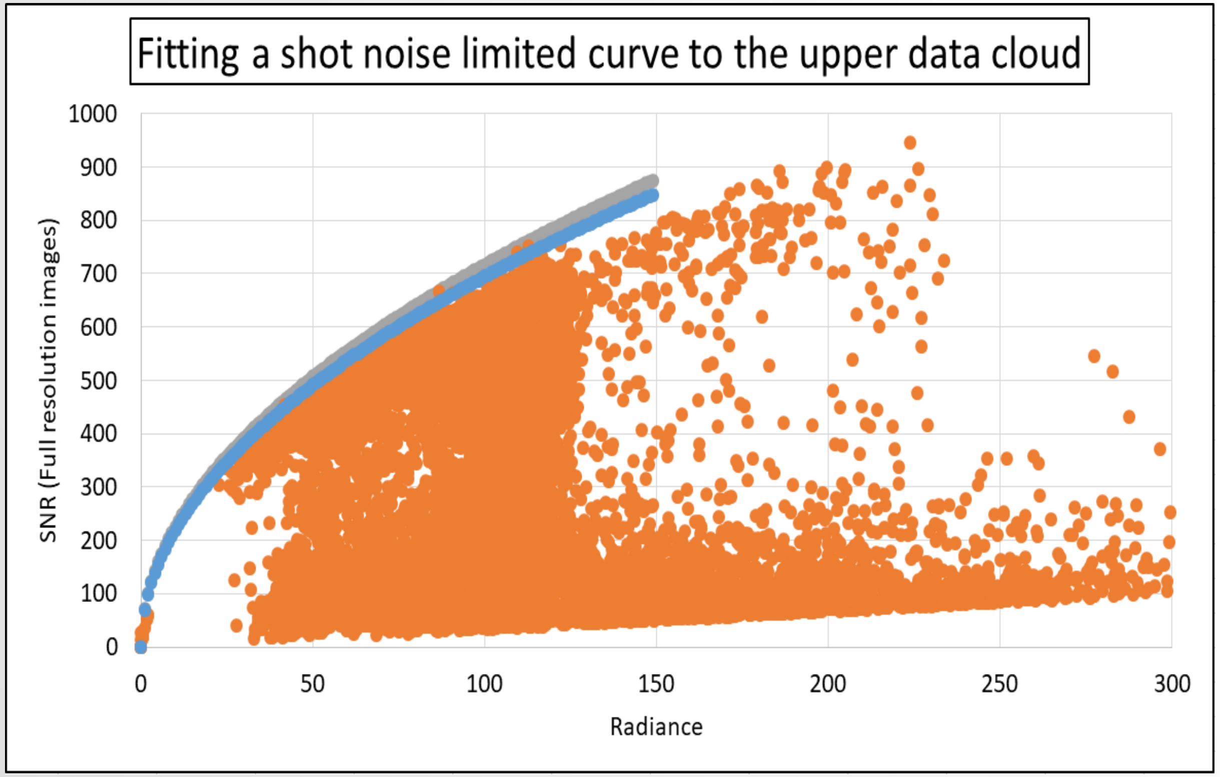
- Simulated “snow” scene (SD = 0.64)





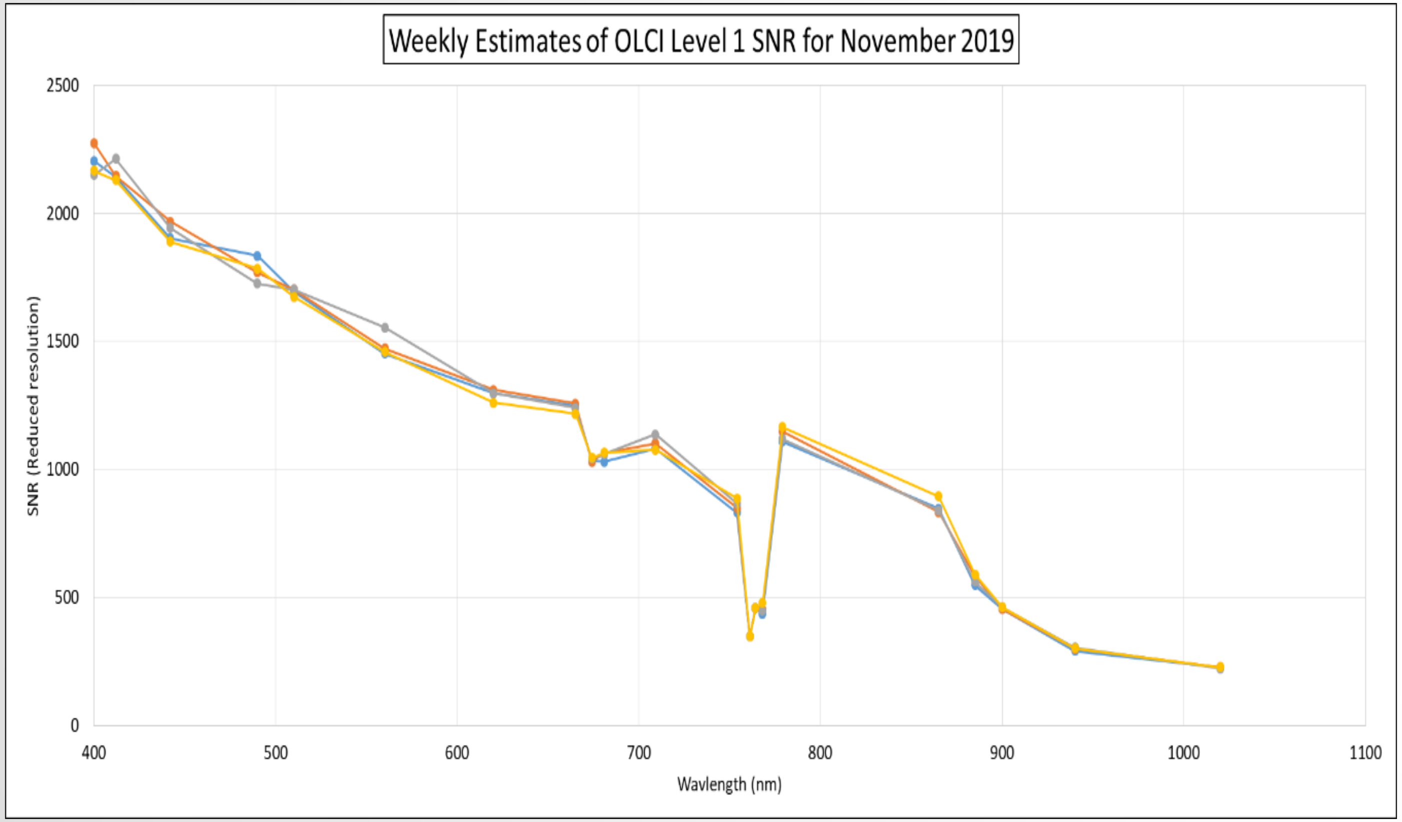
- Simulated homogeneous image and corresponding derived noise related peak in the distribution.
- Real snow scenes gave similar distributions but with a longer tail.

SIGNAL TO NOISE RATIO - OLCI



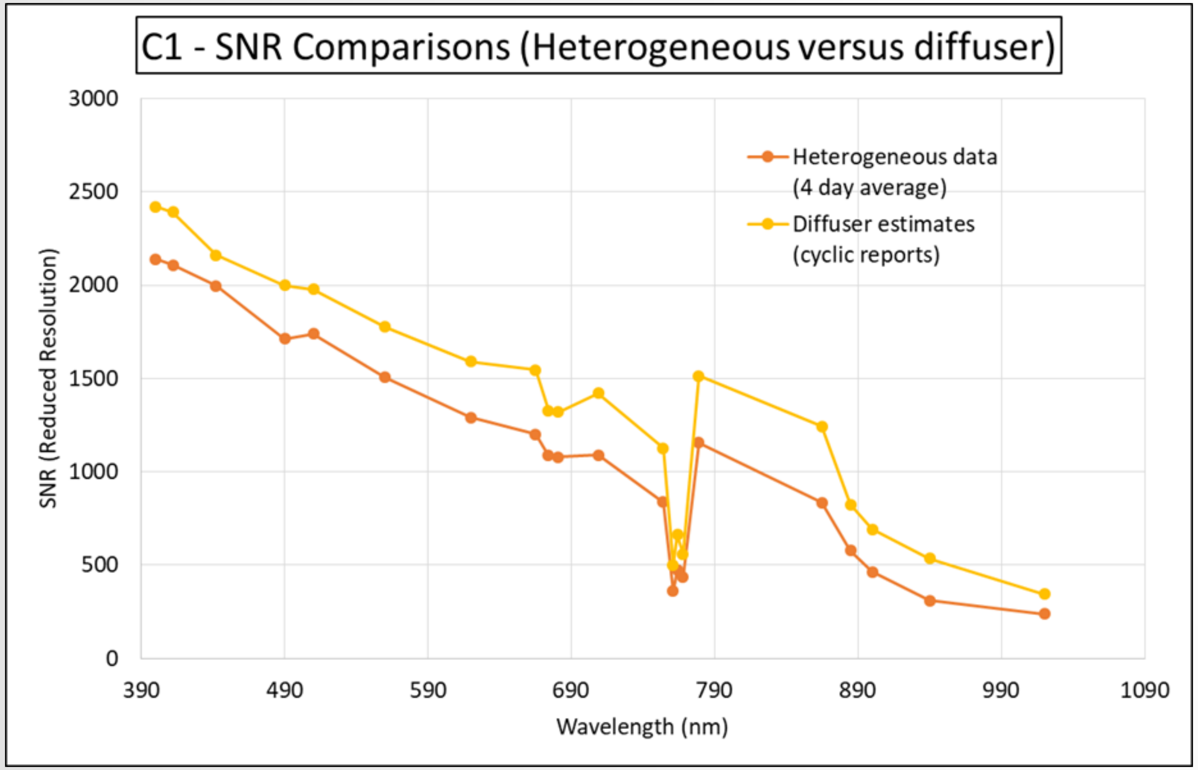
- Each data point is an image. In this SNR plot the upper part of the data cloud defines the "true" SNR.
- The curves are modelled data using a shot-noise limited model (same used in cyclic reports)
- Blue curve is from one week of data, grey curve another week. We have looked at five months of data to find the highest point.

CONSISTENCY OF WEEKLY SNR ESTIMATES



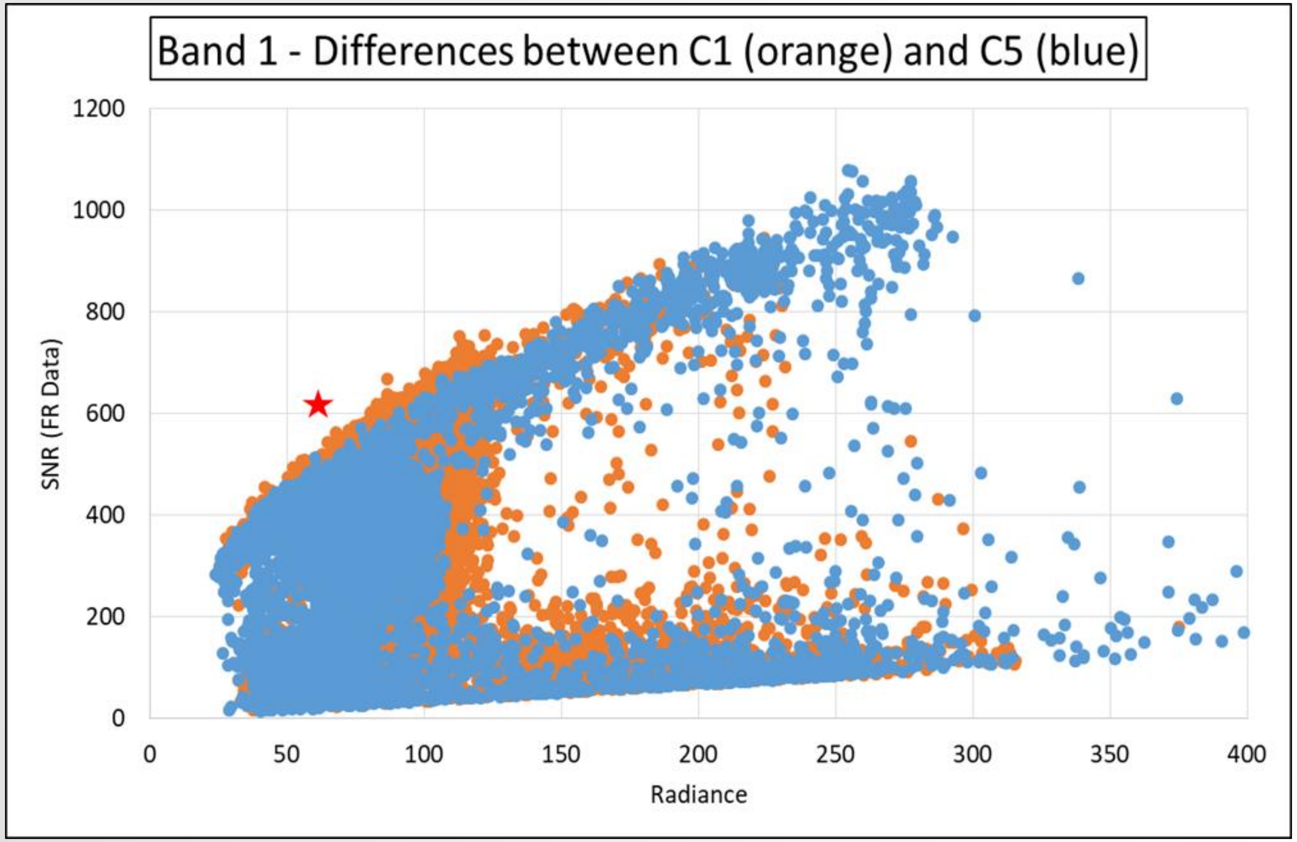
- We estimated the SNR in weekly batches and compared them.
- The results for November show very good consistency across all bands.
- The SNR is calculated at the target radiance for each band using the shot-noise limited model and the data point giving the highest SNR

SNR COMPARISON TO DIFFUSER



- We compared our results against the on-board diffuser results (in the cyclic reports).
- The diffuser data shows a substantially higher SNR than our results.
- The relative differences are however very similar. Even when comparing cameras, relative differences are the same.

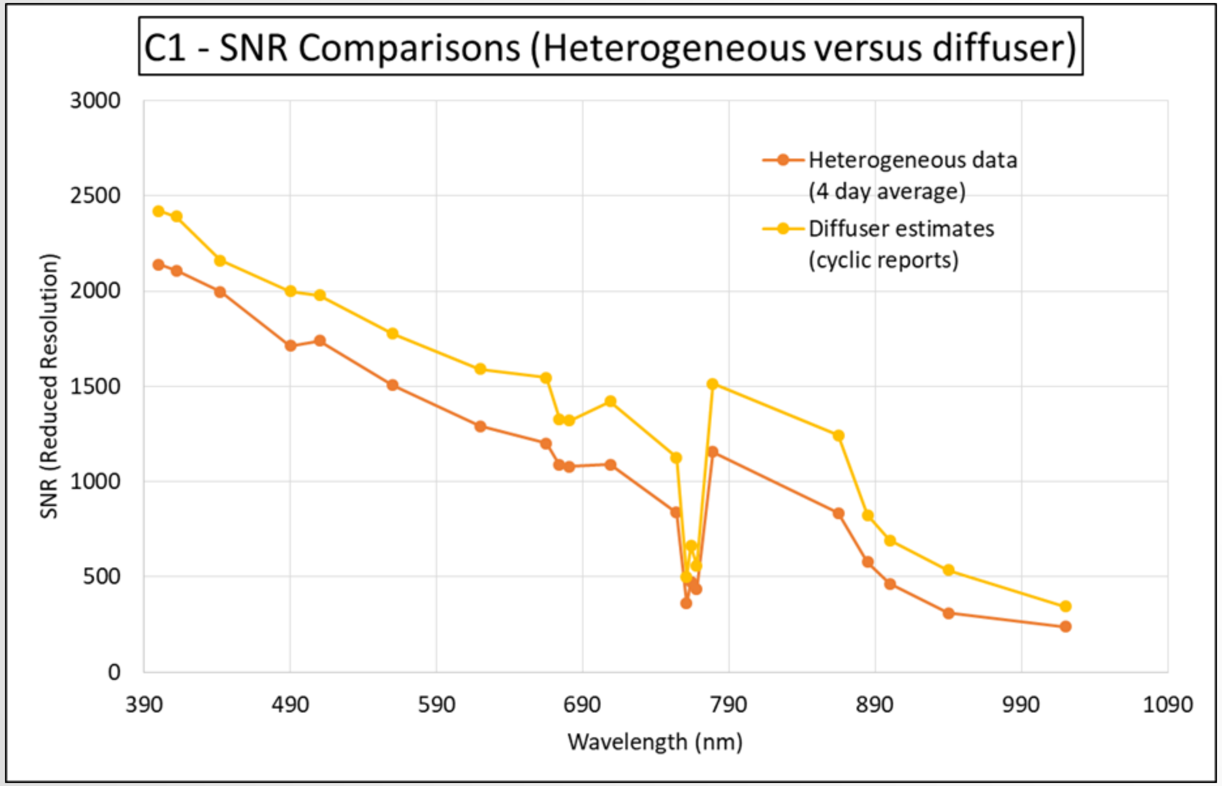
RELATIVE DIFFERENCES

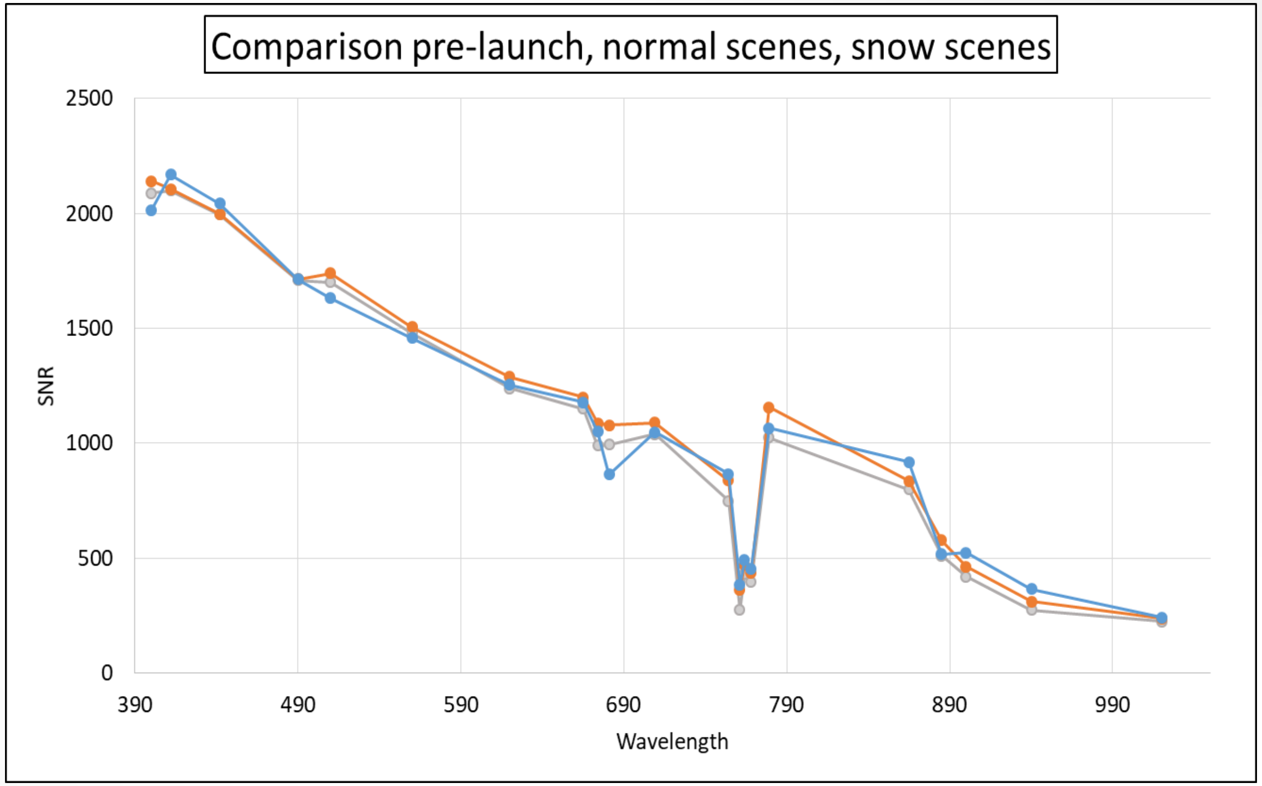


- For example the data cloud of Camera 1 (orange) has higher values than that from Camera 5 (blue).
- The corresponding cyclic report values for band 1 are shown below. Units differences are due to RR to FR conversions (RR values are 4 times higher than FR).
- Red star is the diffuser value for band 1 Camera 1.

	L_{ref}	SNR	C1		C2		C3		C4		C5		All	
nm	LU	RQT	avg	*std*	avg	*std*	avg	*std*	avg	*std*	avg	*std*	avg	*std*
400.000	63.0	2188	2421	6.1	2397	6.5	2327	6.6	2375	11.6	2281	9.4	2360	6.9

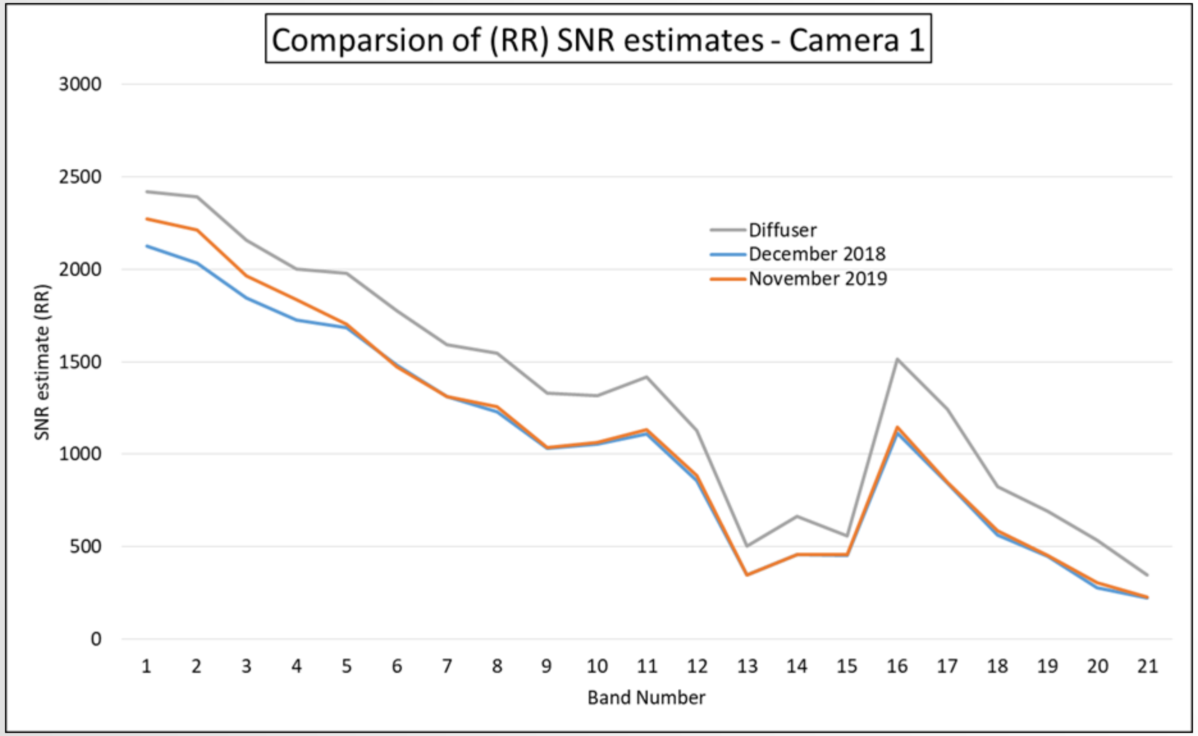
VALIDATION





We had hoped to validate against the diffuser (left) as an alternative (right) we found one reference to a pre-launch curve and we processed homogeneous snow scenes to get SNR estimates. These sources were more in line with the heterogeneous images rather than the diffuser.

WHY THE DIFFERENCE?



- We considered the difference might be related to other methods using spatial averaging across detectors, while the diffuser used single detector estimates (tbc).
- A relative gain model update in April 2019 did give an improvement to the first four spectral bands. However, not enough to align the data.
- This would suggest some other effect may be producing some of the difference we observe.

RELATIVE GAIN INTRODUCTION

- What is relative gain
  - When a detector array is manufactured each detector in the (let us assume) silicon substrate has slightly different behaviour, including
    - Different bias values when there is no signal
    - Some non-linearity in response
    - Different overall response to the same signal level (gain values)

So to get a stripe free image from a group of detectors in a linear array we need to equalise all the detectors, so we get the same response to the same radiant energy on the detector surface.

<u>This is the relative gain correction</u>.

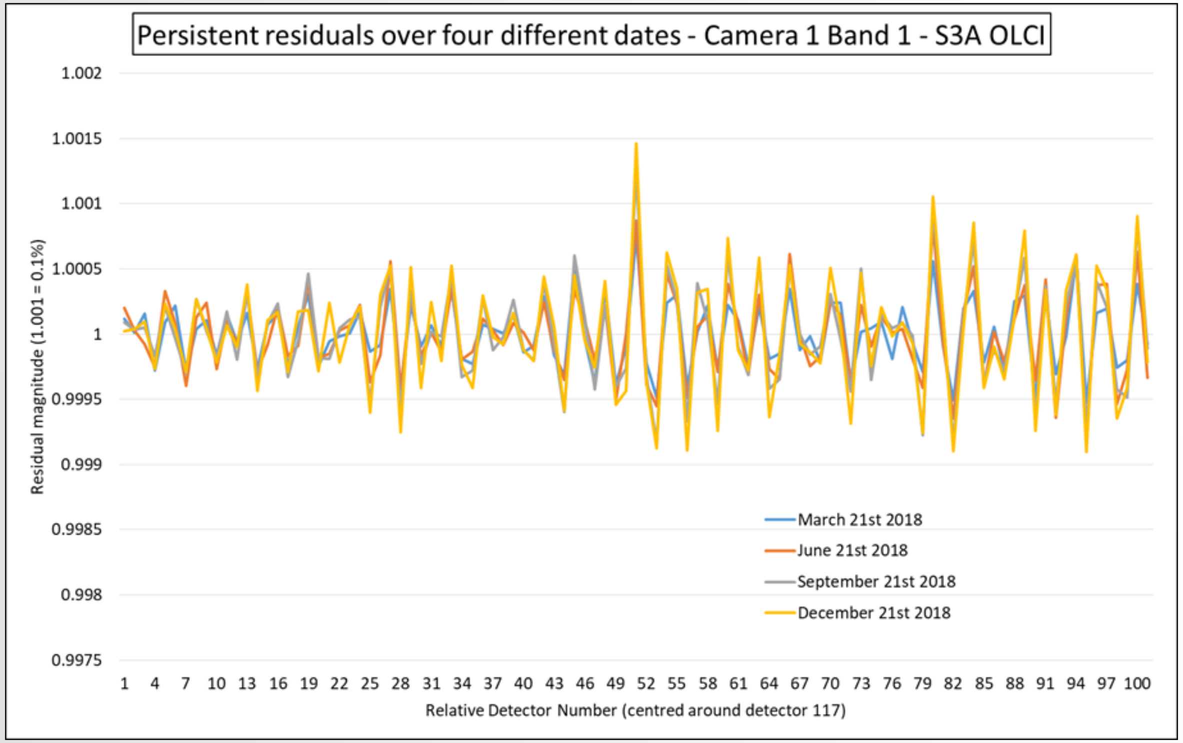
RELATIVE GAIN

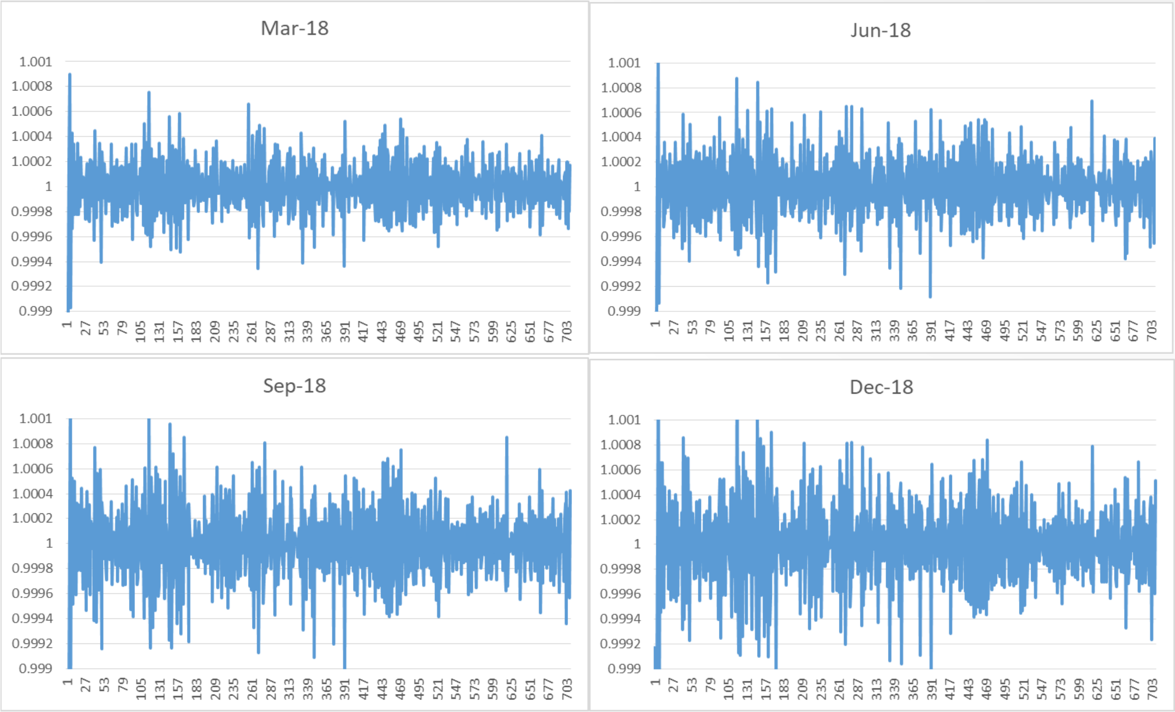
We identified in the Product Validation Plan that we can consider two types of relative gain residual,

- Type 1: When a detector has drifted in response between calibration cycles and is present for several days before the on-board diffuser is used to identify its presence and it is removed.
- Type 2: When the non-linearity correction for the individual detectors is not perfectly correct and thus we see features in normal images, but for the diffuser on-board they are not visible. These can persist for the lifetime of the sensor if not detected and removed.

The focus of the discussion will be on type 2 residuals

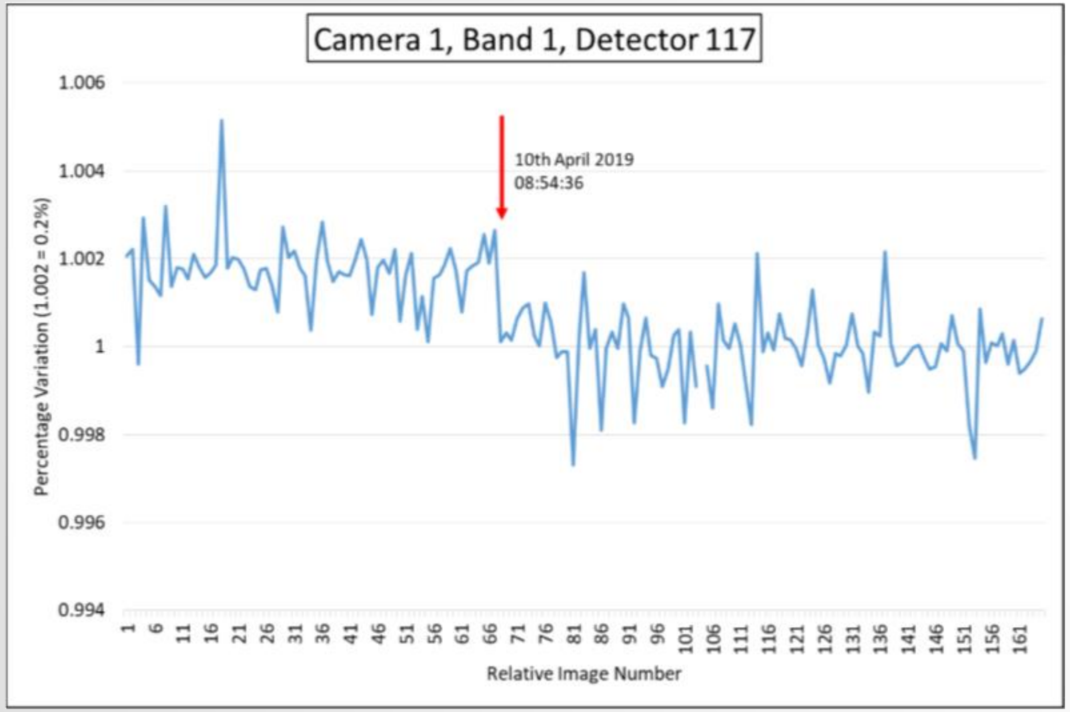
EXAMPLES FROM OLCI

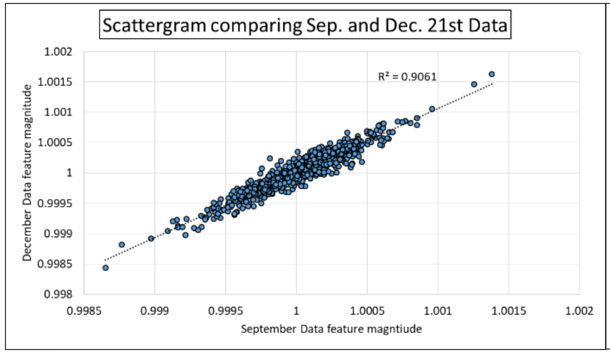


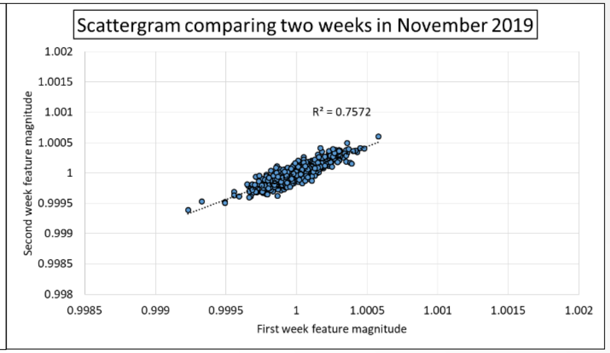


We have plotted a sub-set of residuals from Camera 1, band 1, calculated on four separate daily averages of extracted relative gain data. The correlation between days is very high. Long term persistent residuals (left). These residuals grew in magnitude as the year progressed (right).

EFFECTS OF A NEW RELATIVE GAIN MODEL

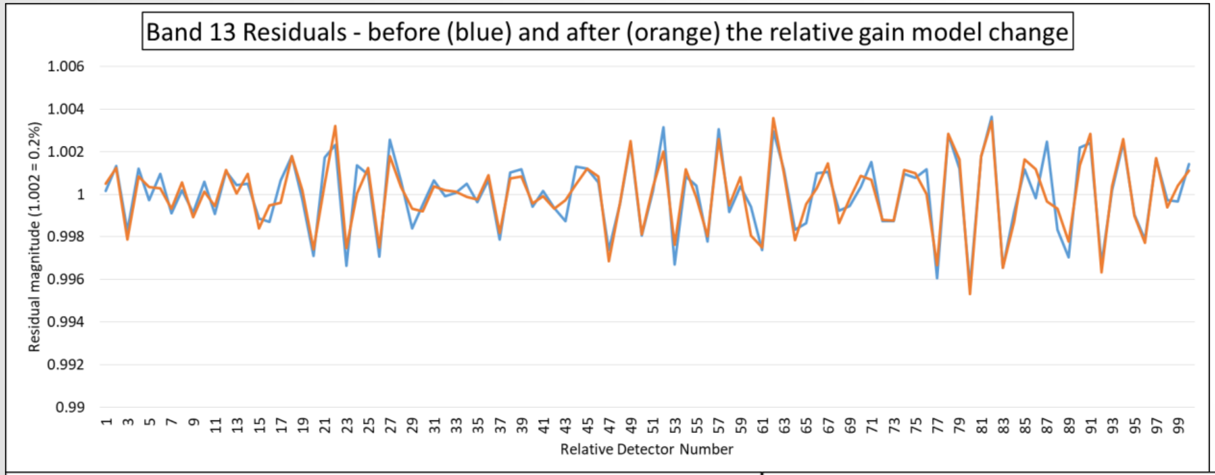


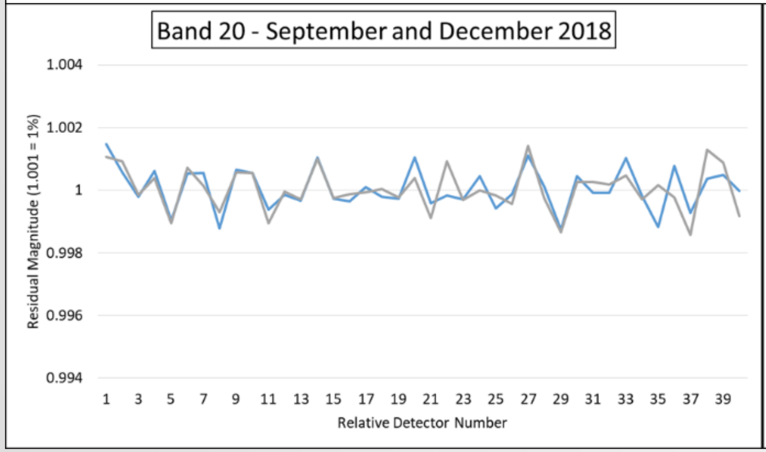


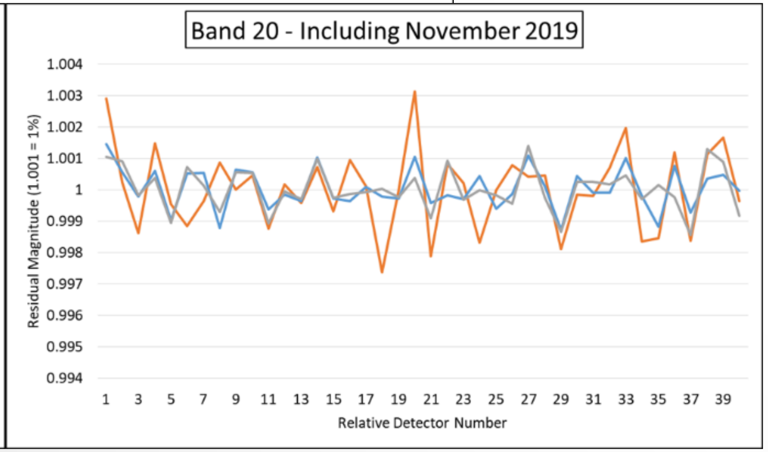


- On the 10th April 2019 we observed that the relative gain values for a distinct detector changed suddenly. In the cyclic reports they say an update of the relative gain model was used from 11th April. The effect was to reduce the overall size of the residuals (see scattergrams above, same scaling) but not remove them. This affected the first four spectral bands.

EFFECTS OF A NEW RELATIVE GAIN MODEL

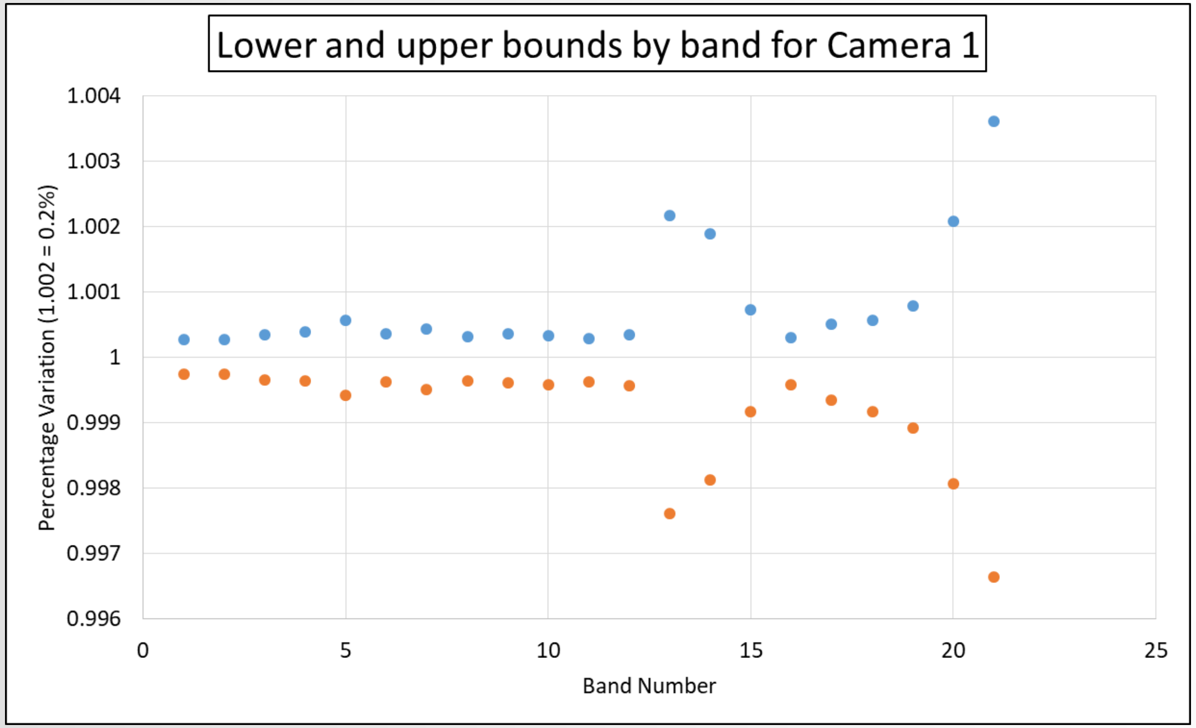


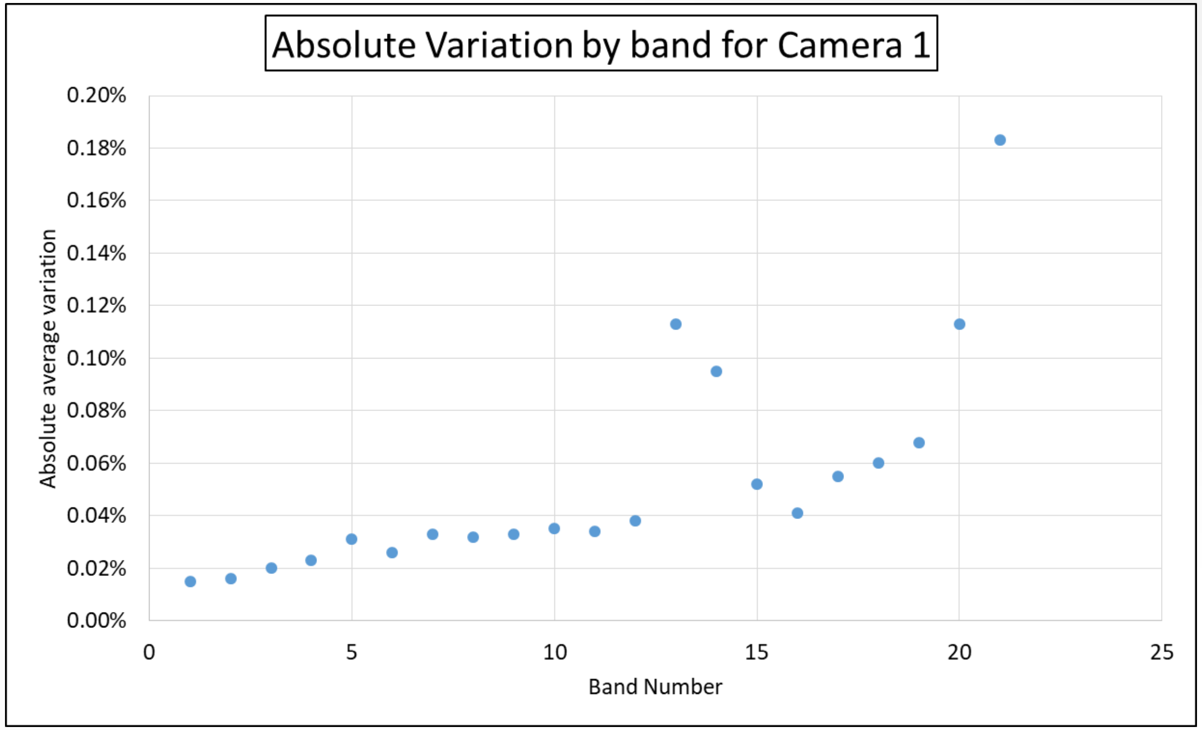




- However, for Band 13, there was no significant change (top)
- For Band 20 the residuals seemed to get larger. Multiple measurements in 2019 and 2020 confirmed that the weekly averages showed that the feature magnitude was greater for Band 20 than in the whole of 2018.

RESIDUAL VARIATION WITH BAND

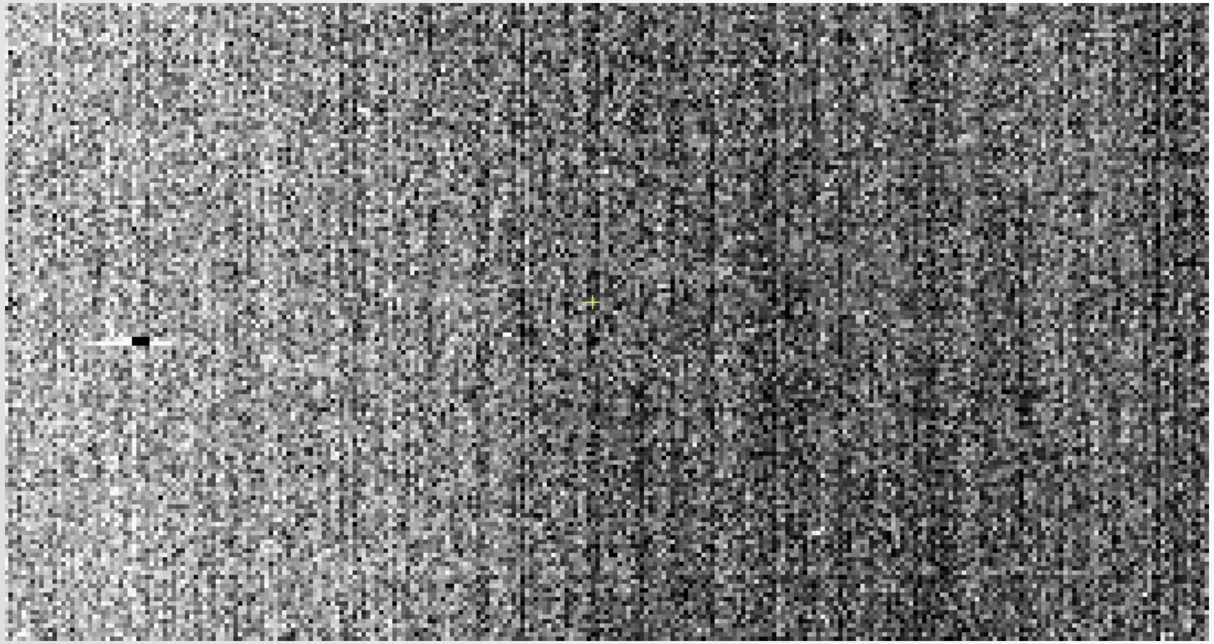




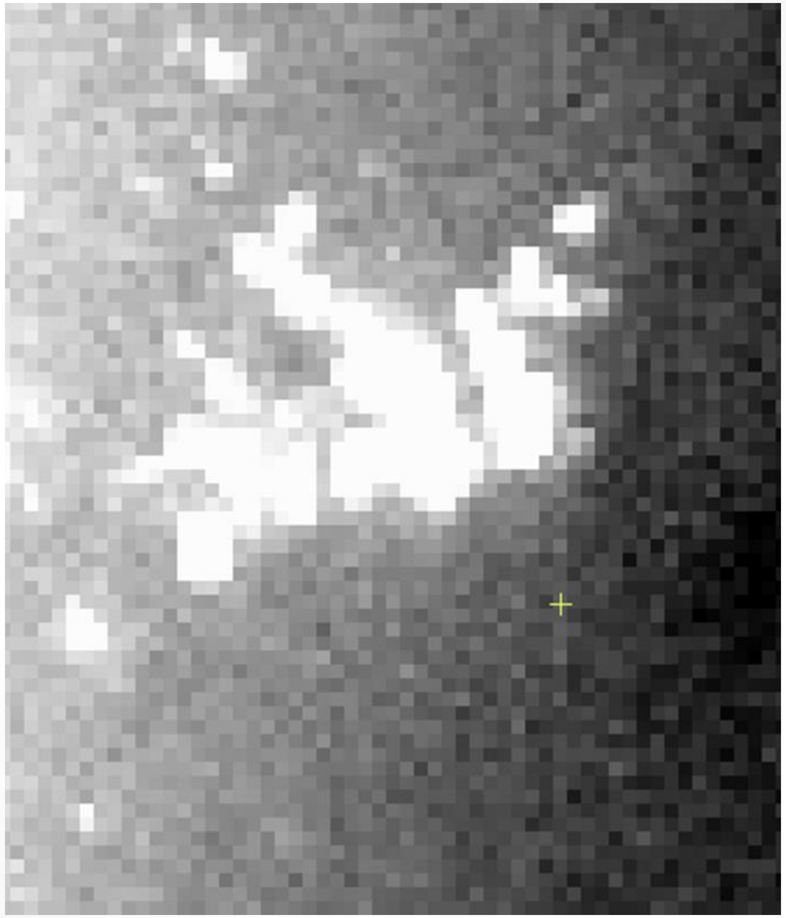
Two different measurements are shown. The boundary variations that include 90% of the data are shown (left) while the absolute average variation of all detectors is shown (right).

VALIDATION – DO RESIDUALS EXIST?

The cyclic reports say these features do not exist. With very low variability between detectors. Over the next few slides we show some examples.

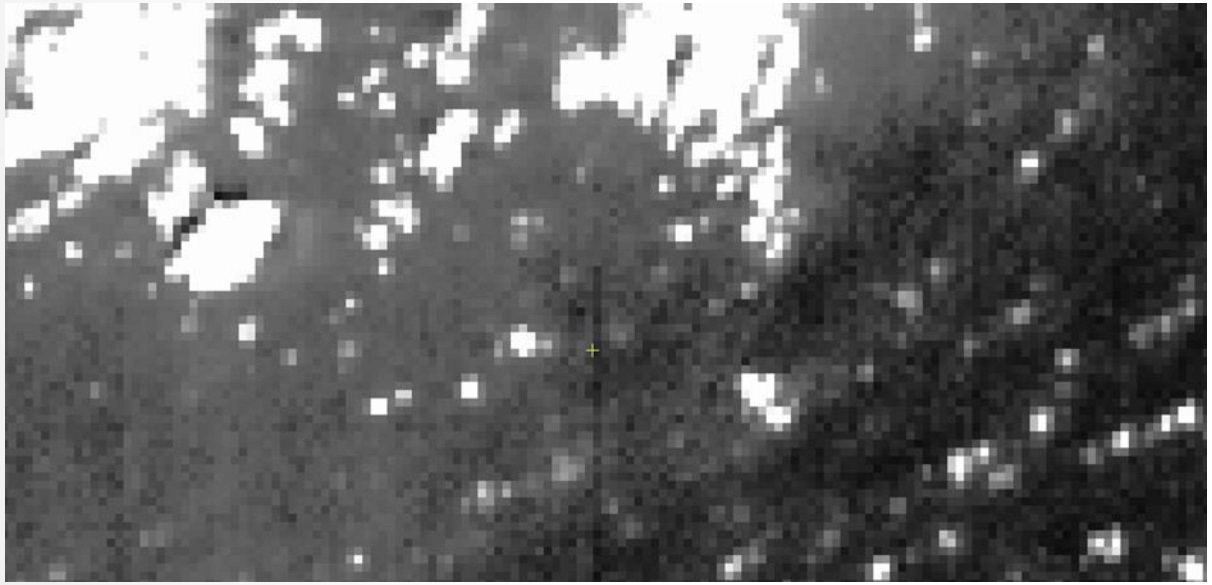


Band 21 over water



Band 1 over land and cloud

VALIDATION DO THEY EXIST.

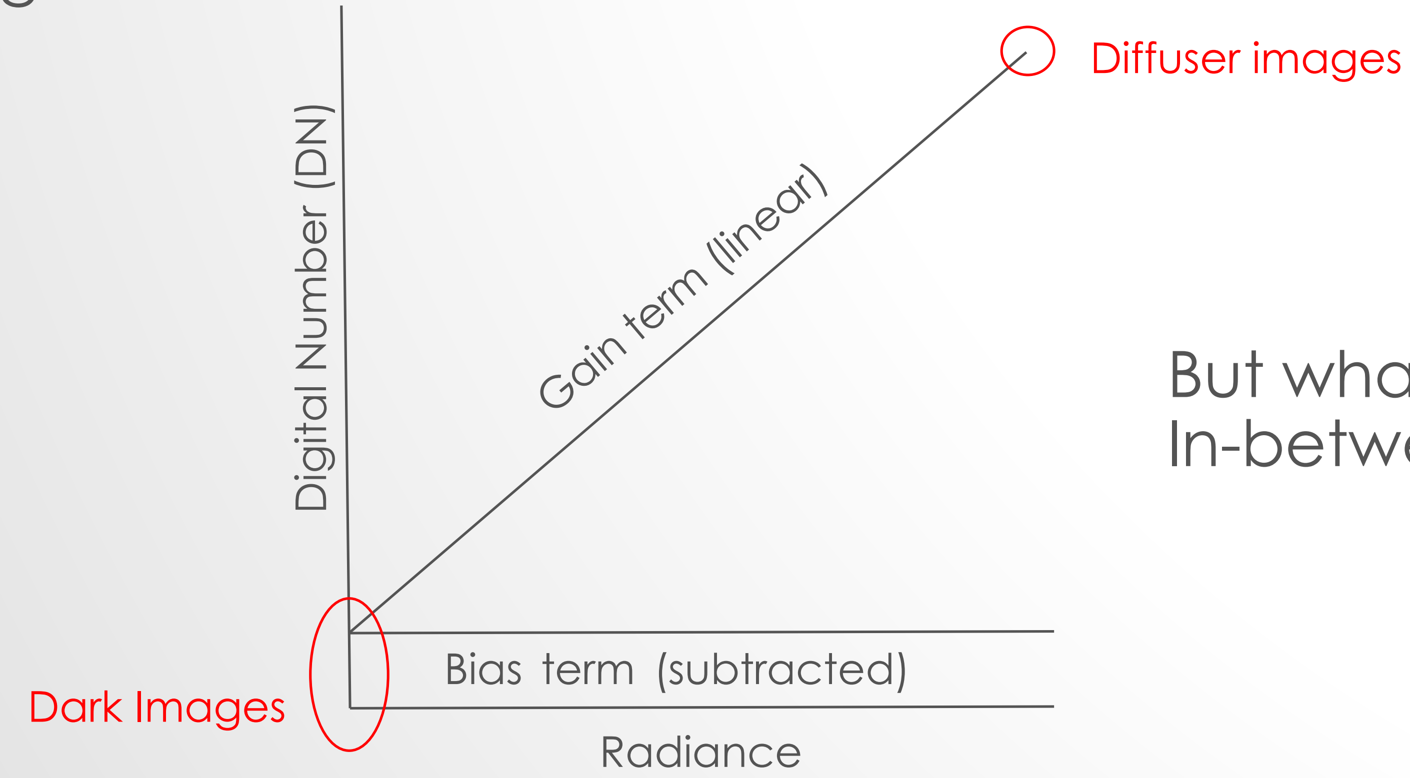


Band 21 Stripes disappearing into cloud.

Band 13, long bright stripe.

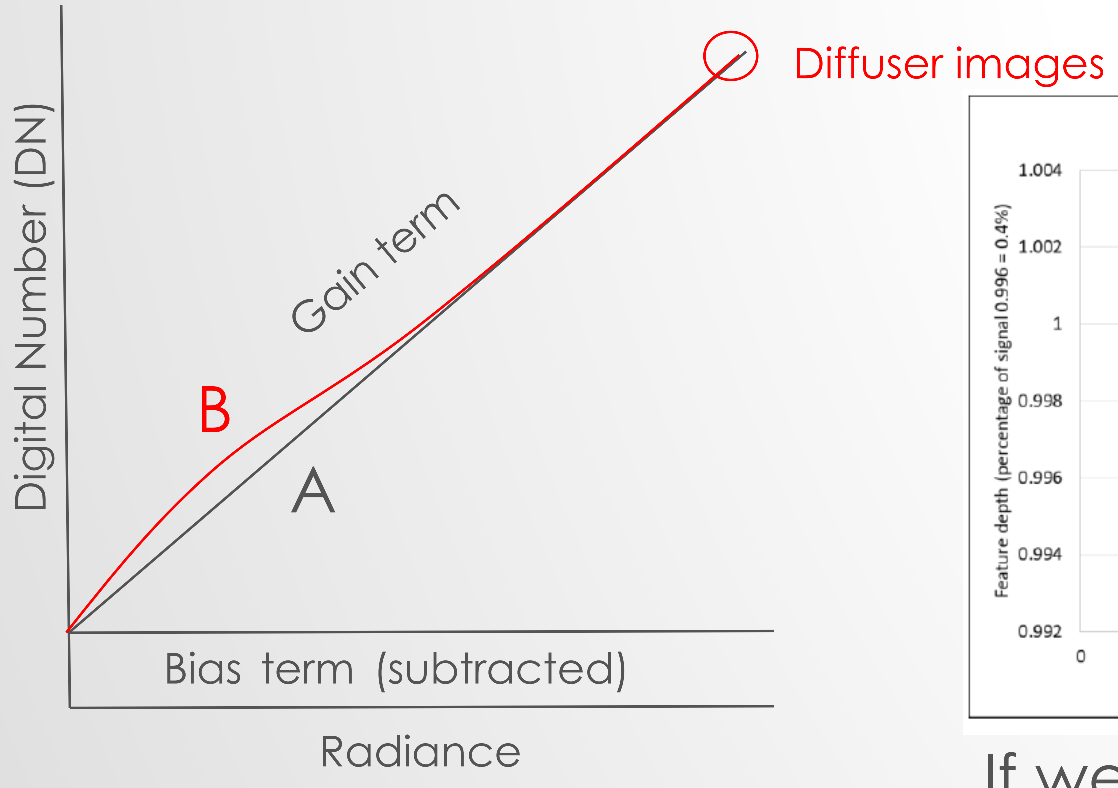
NON-LINEARITY INTRODUCTION

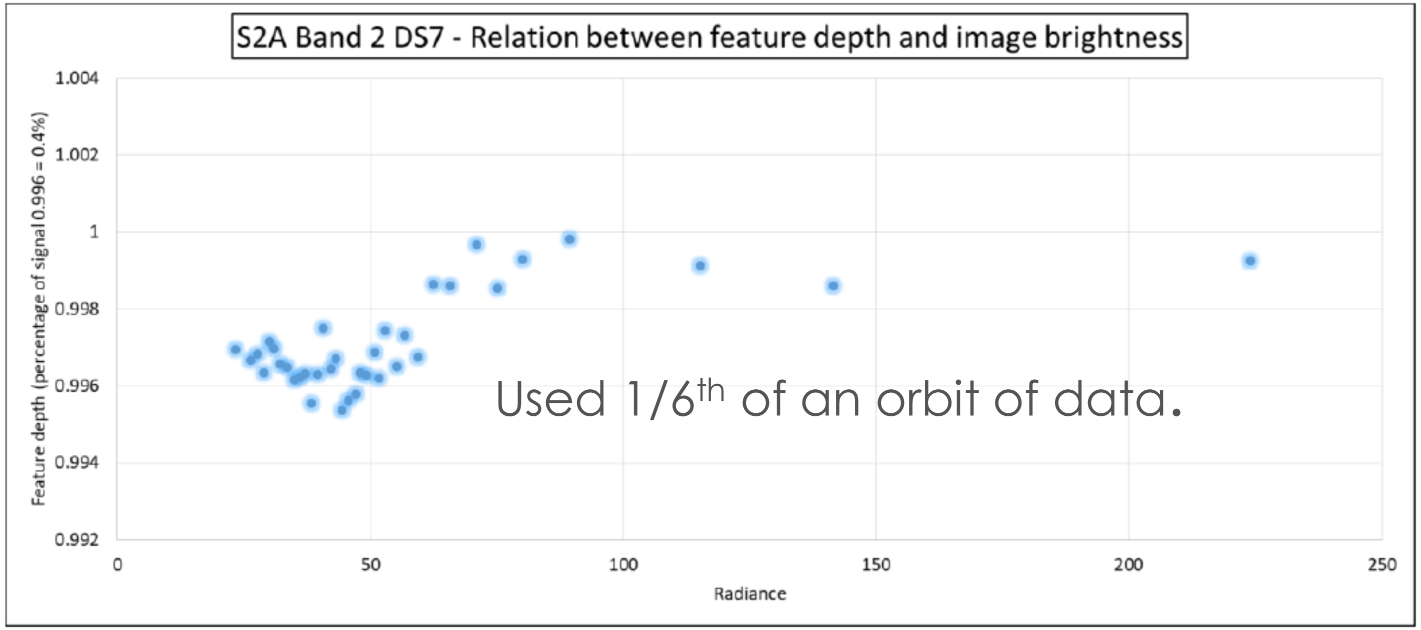
- Not easily validated in space, we can get the bias term from dark images and we can get the upper bound from diffuser images.



But what happens In-between?

NON-LINEARITY INTRODUCTION

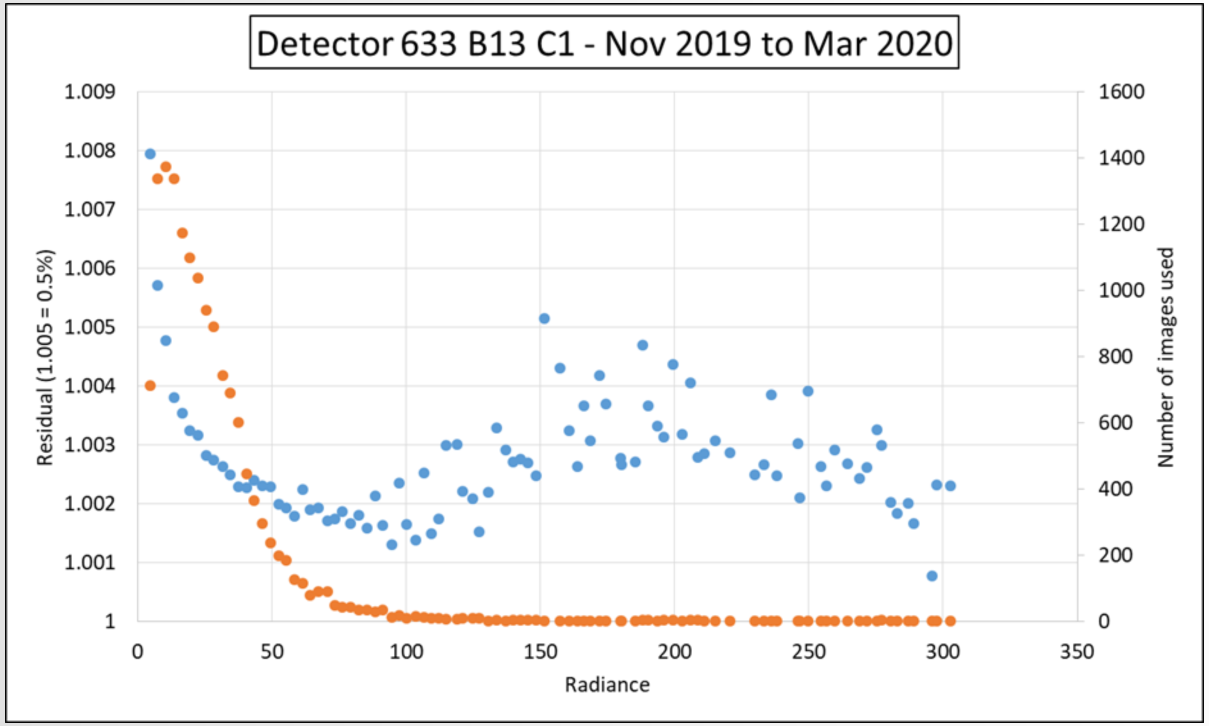




If we ratio the values A/B we get a distinct pattern of behaviour which shows the correction required to remove the persistent residuals

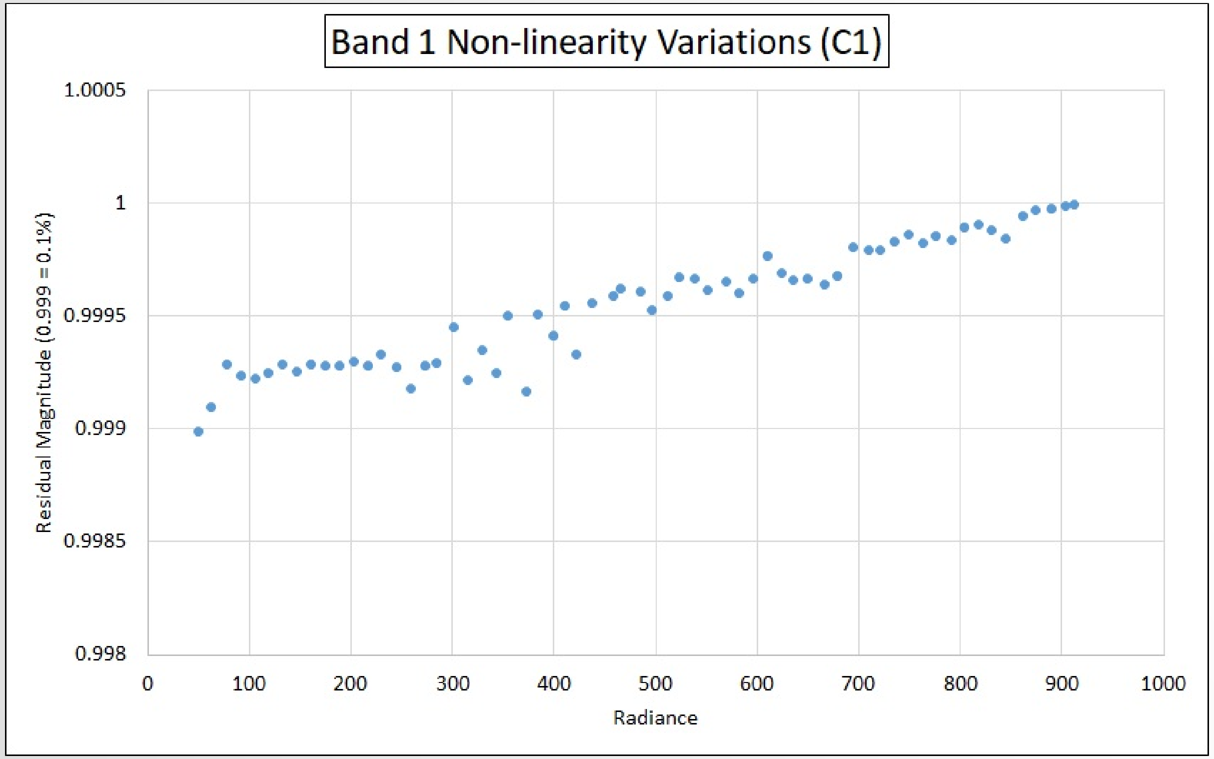
Assuming our non-linearity correction is not perfect (B)

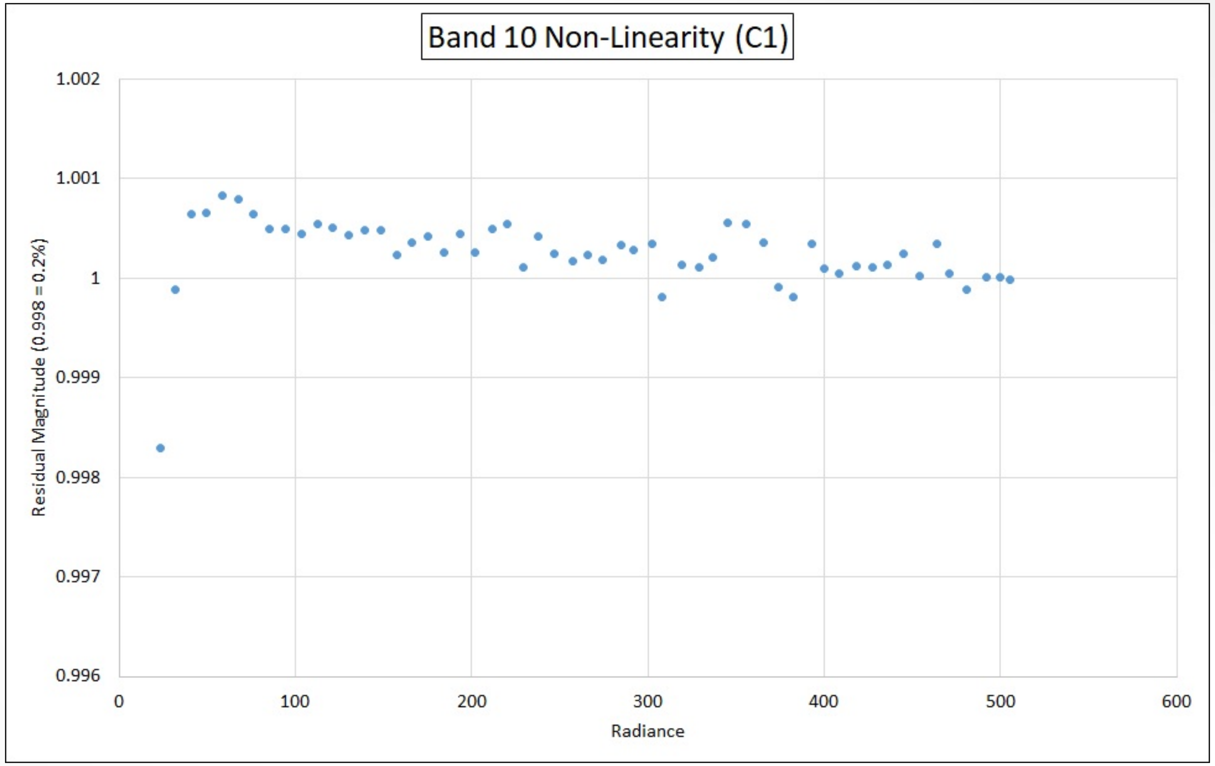
NON-LINEARITY OLCI



- The causes of the variable behaviour with brightness are not entirely clear, but based on the plots we can say something about the source.
- A typical plot has the data points (blue) in this case showing a steep drop and then more variable behaviour.
- The orange dots show the number of images used to generate the average values, almost 1400 at lower radiance values.

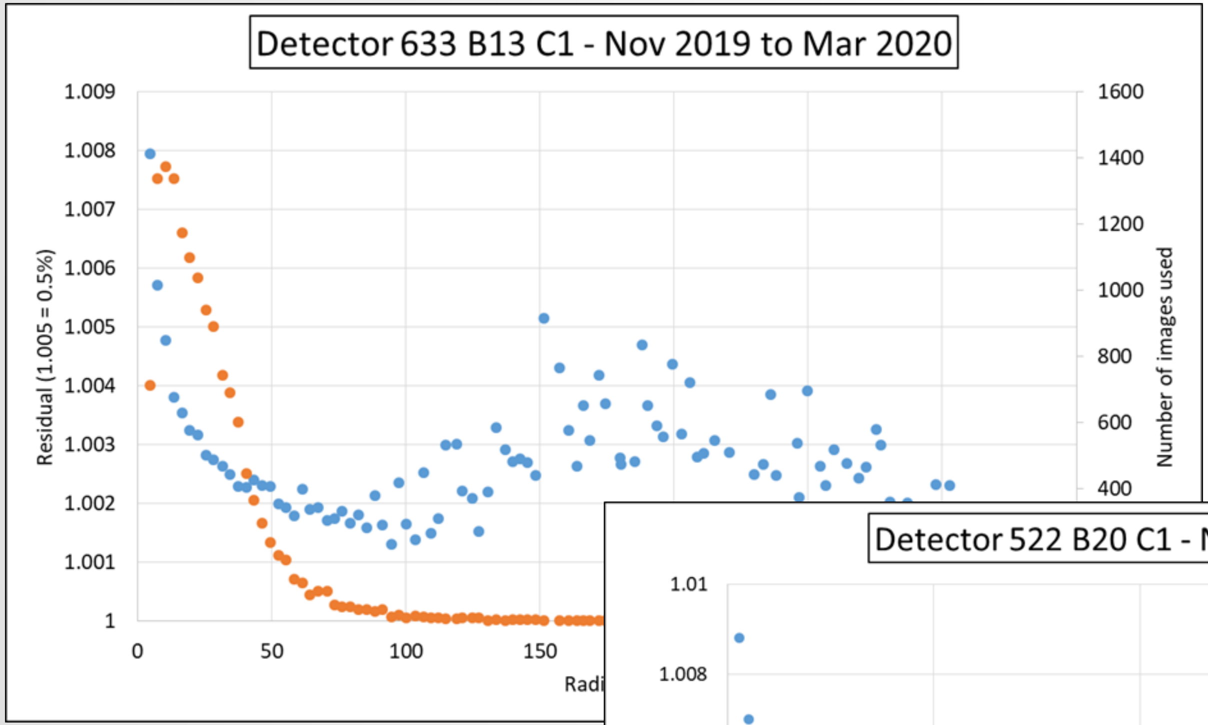
NON-LINEARITY EXAMPLES

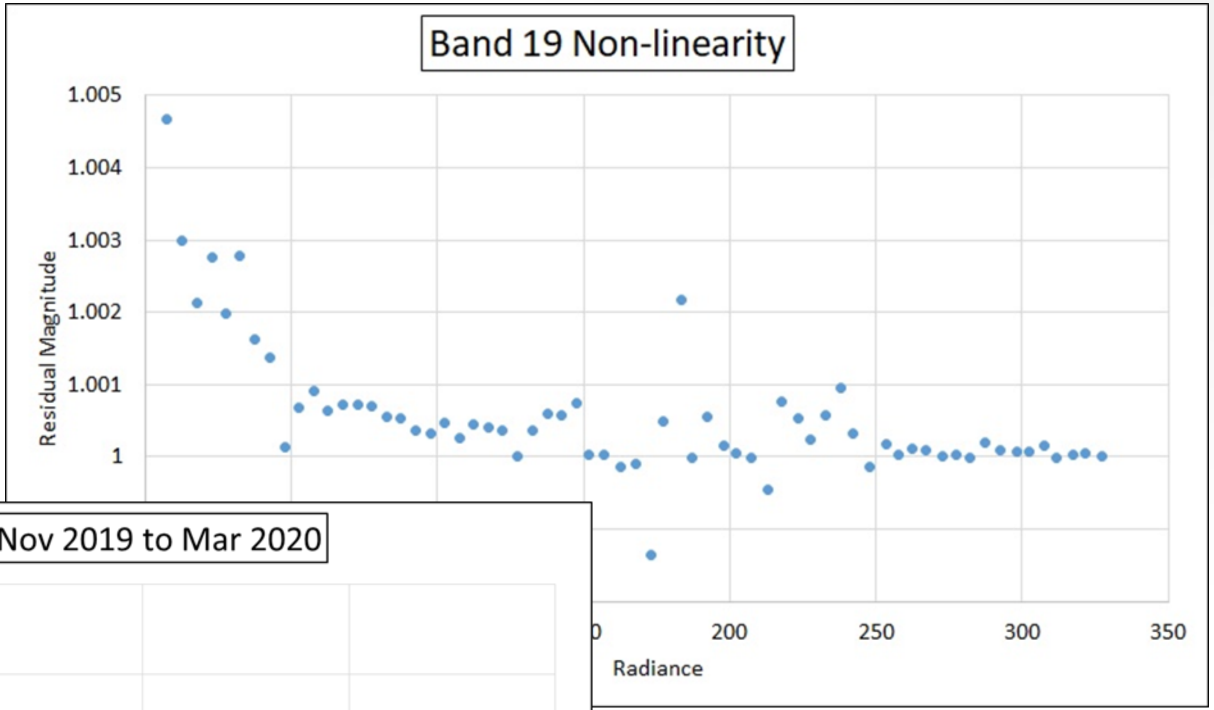


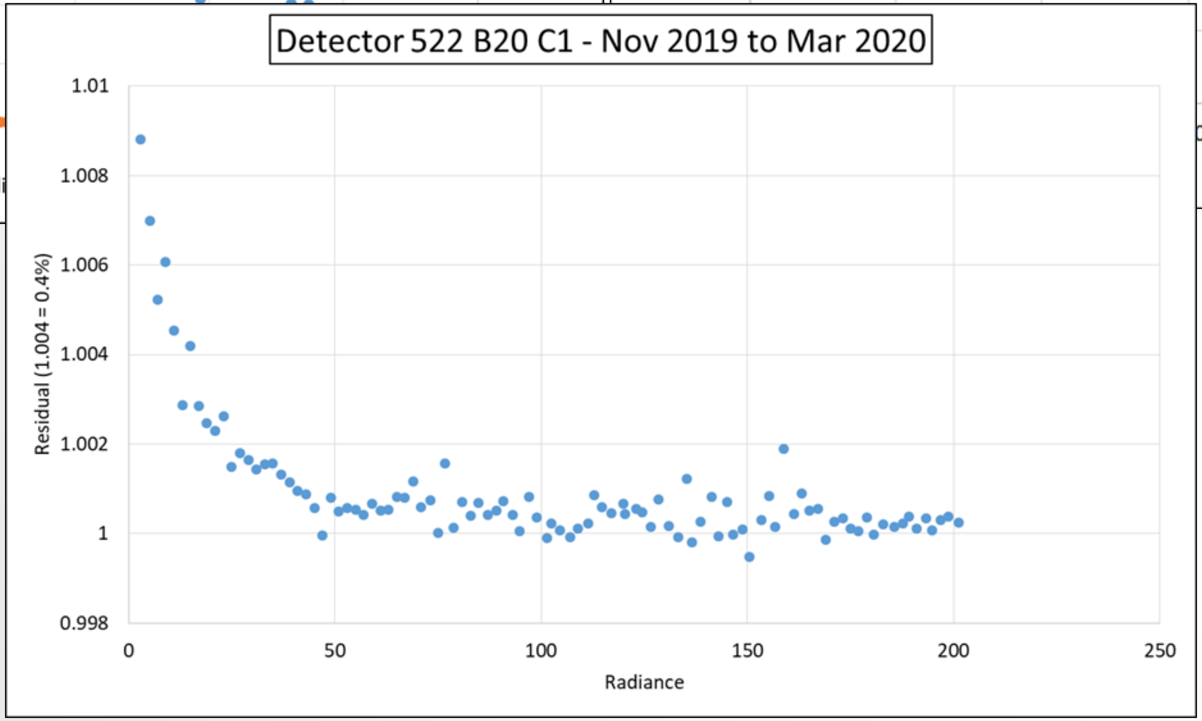


Variability seen with spectral band. Shorter wavelength bands such as band 1 (left) show a distinct almost linear pattern with large residuals at lower radiances and none at higher radiances. For band 10 (right) at longer wavelength we see similar behaviour with the addition of a sharp change at very low radiances, which we believe is an additive term.

NON-LINEARITY EXAMPLES



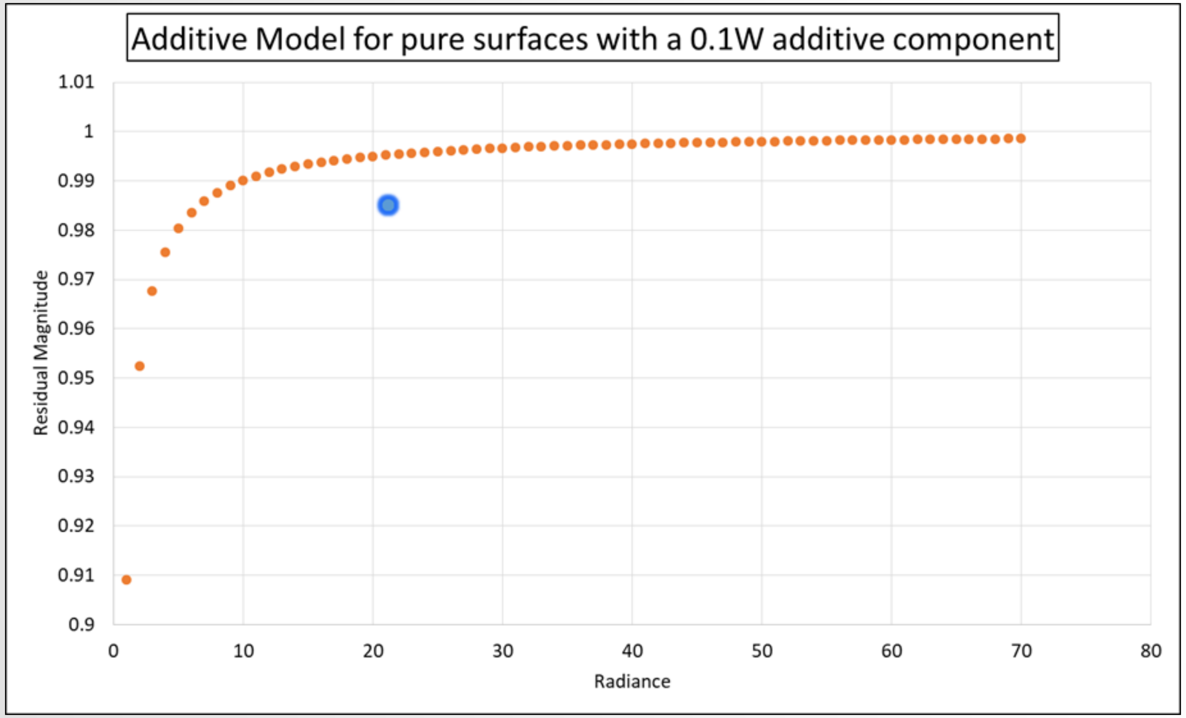


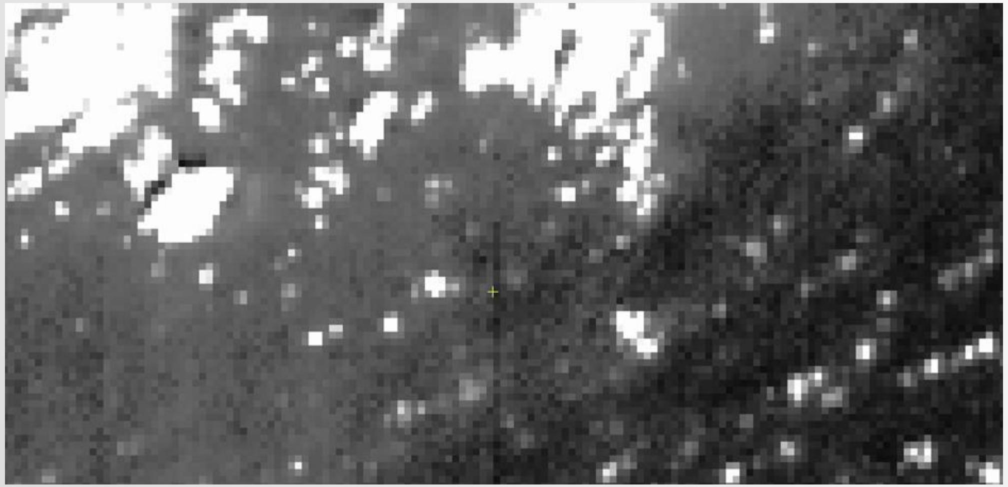


As we moved to longer wavelengths the feature looks more additive

This additive term is a function of the wavelength.

ADDITIVE MODEL AND POTENTIAL PROBLEMS

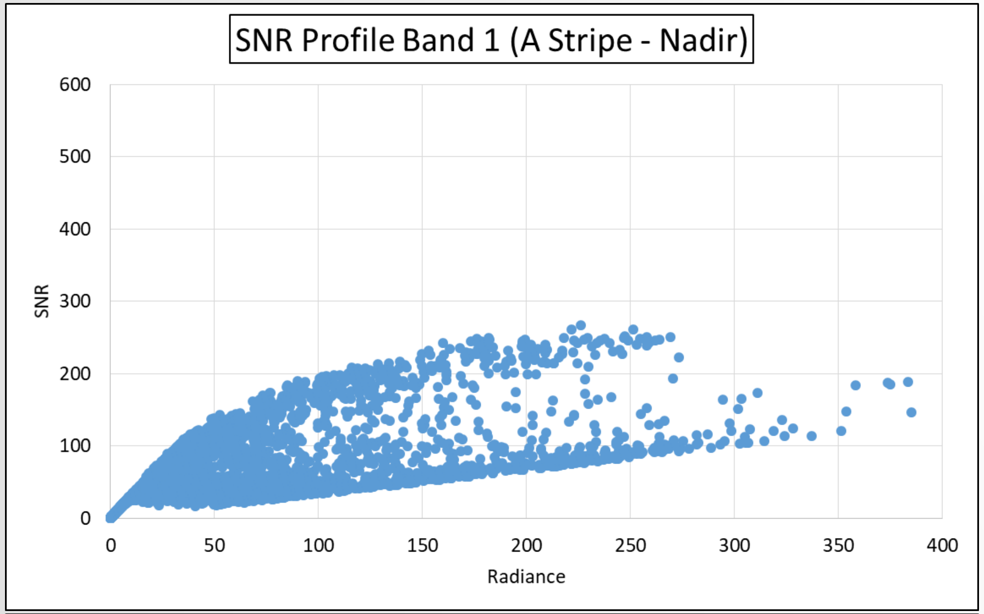


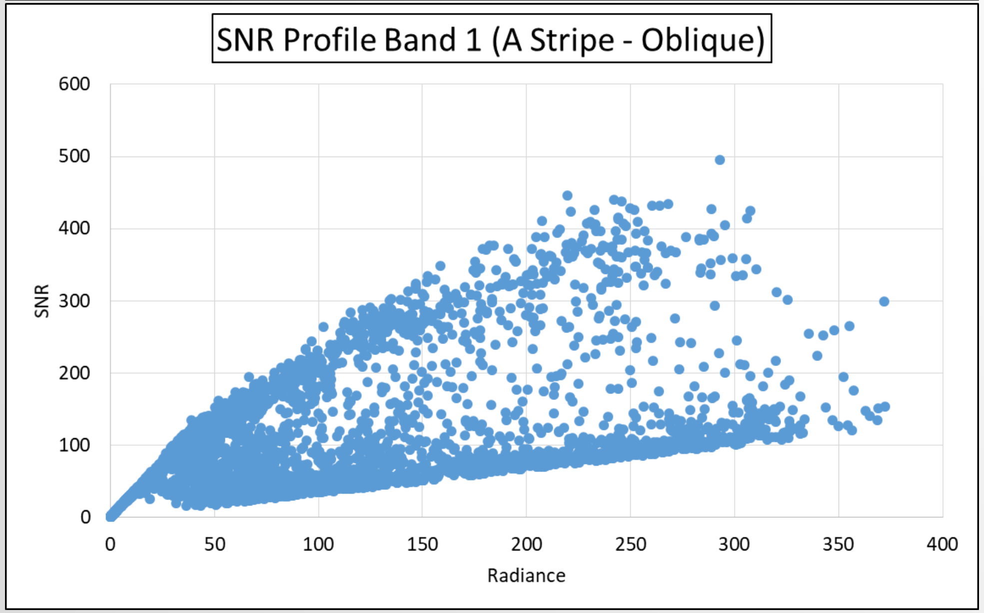


- On the left top (orange dots) we show how an additive change between two columns would look as residuals.
- Using the plot we can see a rapid drop off in the residual magnitude as the radiance increases, similar to that seen in Band 21 imagery (bottom).
- The smaller the additive component the more rapidly the curve would converge. Results suggest a very small amount of contamination is producing a large effect at very low radiances.

LEVEL 1 SLSTR RESULTS

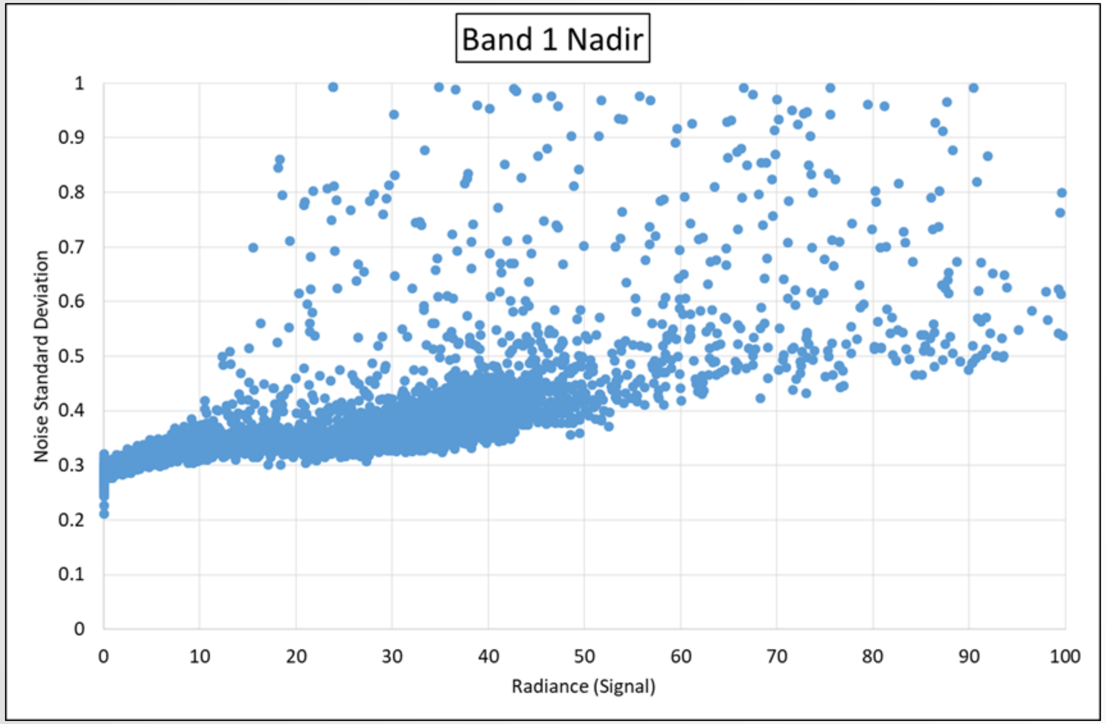
SLSTR SNR

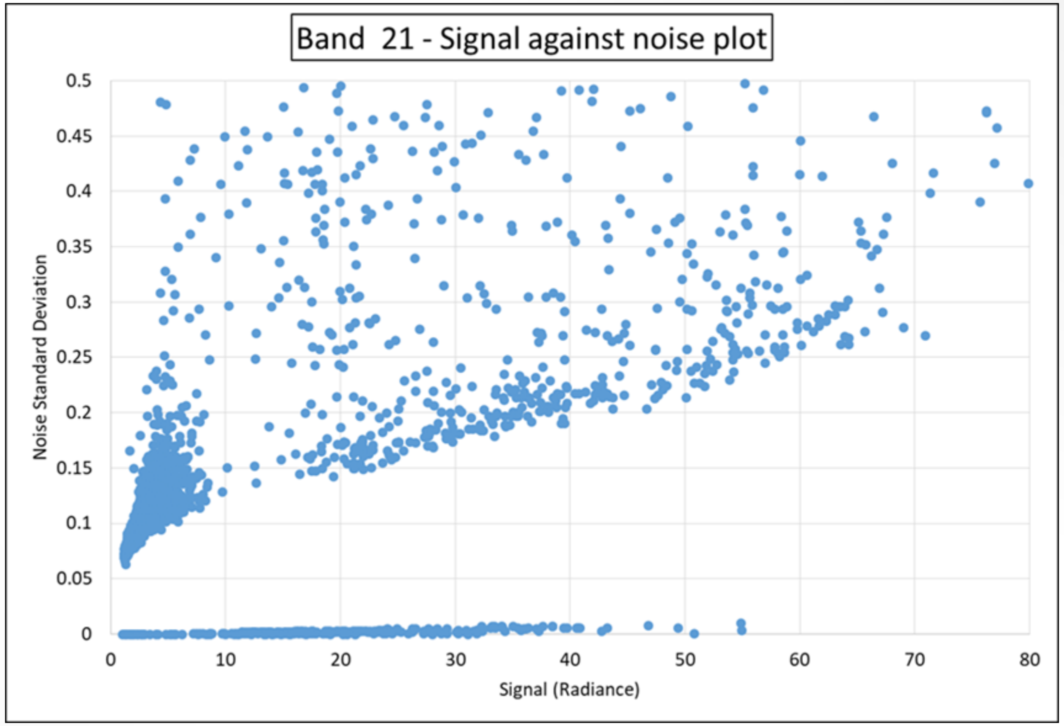




- The SNR results proved very promising. We did see some very strong linear features in the SNR plot which was not expected.
- The data cloud looked very clean with a nicely defined upper boundary, allowing a good estimation of the SNR at various radiance levels.
- In this case the oblique view shows a significantly higher SNR than the nadir view.

SLSTR SIGNAL AGAINST NOISE





- Unusual shape to the SLSTR signal vs. noise profiles (left) with a plateau region on the lower side of the data cloud between 10W and 30W.
- A more typical profile (right) is shown for OLCI data, with a relatively steep rise in the noise and then a more gradual rise.

SLSTR SNR FOR ALL BANDS

Band	View	Stripe	Target Radiance	SNR
1	Nadir	A	100W	200
1	Oblique	A	100W	250
2	Nadir	A	100W	285
2	Oblique	A	100W	325
3	Nadir	A	100W	400
3	Oblique	A	100W	395
4	Nadir	A	4W	40
4	Oblique	A	4W	35
4	Nadir	B	4W	35
4	Oblique	B	4W	30
5	Nadir	A	2.5W	90
5	Oblique	A	2.5W	50
5	Nadir	B	2.5W	100
5	Oblique	B	2.5W	65
6	Nadir	A	2.5W	65
6	Oblique	A	2.5W	85
6	Nadir	B	2.5W	100
6	Oblique	B	2.5W	75

The table (left) shows the estimated SNR values for specific target radiance values.

Differences are seen between bands (Band 3 has higher SNR than Band 1)

Nadir is usually higher than oblique and B-stripe higher than the A stripe.

KEY FINDINGS

Finally we can conclude the following from this study at this time,

- Level 0 – OLCI
- The Level 0 data aggregated at the weekly level does show coherent patterns of behaviour over a five month period, which suggests we may be able to define a reference curve for both the calibrator drift and the absolute calibration drift. The data collection needs to continue to a minimum of the end of November 2020 to at least assess the methodology.
- Multiple sensors may need to be used to remove anomalous values in the weekly aggregates related to periods of unusual cloud cover for example.
- Level 0 – SLSTR
- Due to anomalies in the code provided, no SLSTR database data is available. These anomalies were corrected in February 2020 and we expect that data is or soon will be collected for this sensor. A full year of data is required for this sensor and this should overlap with the OLCI data collection of Level 0 data, so that the OLCI data can be a reference for the SLSTR data analysis.

- Level 1 – OLCI
- Three algorithms were implemented. SNR, relative gain and non-linearity. All three gave very useful results which was part validated by the on-board devices, but also raised some important questions on the results currently obtained by the on-board devices and potential issues with either the methodologies being used or the sensor operation.
- The SNR values mirrored the on-board diffuser measurements, showing similar relative behaviour between bands and between cameras. However, there was a large disparity in the magnitude of the results obtained, with the heterogeneous image analysis giving SNR values that were tens of percent lower in most cases.
- The SNR values obtained were cross-checked against a single pre-launch source and snow scenes of homogeneous nature. These results were consistent and all were lower than the diffuser estimate. Details of the diffuser calculation of the SNR are required to try and identify why there is such a discrepancy.
- Part of the SNR discrepancy can be accounted for by the use of spatial statistics for the heterogeneous image analysis and the snow scene analysis, as if there are relative gain differences, these will tend to give lower SNR values. However, modelling suggests that this will at best only account for half of the difference observed and only for the first four spectral bands.

- The relative gain differences observed consist of two types, simple deviations from normal for single detectors that can be seen by both the heterogeneous imagery and the on-board diffuser. These are the type 1 residuals discussed and can be easily removed. However, we observed persistent residuals which have been present for at least two years which are not detected by the on-board diffuser and cannot be corrected. Validation using simple image analysis shows the observed features for Bands 20 and 21 are clearly visible over homogeneous water bodies.
- Corrections of the relative gain model (such as that in April 2019) tend to reduce the relative gain effects at shorter wavelength bands, have no effect on middle wavelength bands of OLCI and can have a negative effect on the longer wavelength bands.
- There is a pattern in behaviour of the relative gain residuals which suggest small calibration errors at shorter wavelength bands, a mix of additive term and multiplicative terms in the mid wavelength range and almost pure additive in the longer wavelength range. The additive term effects have the biggest effect in defining the presence of large relative gain residuals.

- The non-linearity algorithm can be used to deduce the type of effect seen (multiplicative, mixed or additive) and provide some indication of the magnitude of the effect.
- The non-linearity algorithm in its current form seems to be over estimating the relative gain residual due to the way the algorithm operates. Using average values from a scene, instead of gathering statistics at the pixel level. Improvements to the algorithm would produce a more accurate non-linearity mapping that could be used to correct for these effects.
- Level 1 – SLSTR
- The SNR algorithm produced very good results. There seems no pattern in which view gives the higher SNR. Over all the bands, two thirds are nadir view and one third oblique. Which suggests that the cosmetic infill has little impact on the SNR estimation.
- The data without cosmetic infill should be also examined with the SNR algorithm to determine exactly the difference it makes in the SNR estimation.
- There is no specific difference between the A stripe SNR estimates and B stripe estimates for bands 4 to 6. In some cases the A stripe is better (band 4) and others the B stripe (bands 5 and 6). In terms of the first three bands, band 1 has the lowest SNR and band 3 the highest.
- There is some unusual behaviour observed in the signal against noise plot which at the moment cannot be explained. A plateau of noise is reached between 10W and 30W radiance range in which the noise is essentially constant. This type of effect should not be present in a shot noise limited system and this behaviour has not been observed before with other sensors.

FUTURE DIRECTION

HIGHEST PRIORITY ISSUES

- Understanding exactly how the OLCI SNR is calculated on-board. Also try and get access to pre-launch reports on how the SNR was estimated.
- Using the non-linearity data from longer wavelength bands, try and determine the magnitude of the additive effect and whether it is spatially varying and wavelength dependent, this may require a re-write of the non-linearity element.
- Completion of full year Level 0 data collections for OLCI and SLSTR.
- Fully understand the relative gain model and how it is applied to determine why it affects short wavelength bands positively, mid-wave bands with no effect and long wavelength bands negatively. The assumption is that it is using multiplicative corrections, but it needs to be fully understood.
- Try to find information on why the SLSTR SNR profile is so unusual.

ADMIN

Red – Part 1
Green – Part 2

DELIVERABLE DOCUMENTS

Reporting

G[D-13]	Product Validation and Evolution Report V2

Software*

S[D-3]	Final software Installation Manual/Release Note
G[D-12]	User Technical Note (User Manual) V2

Design and Test Documents/Data

G[D-7/11]	ATBD – (to be updated at end of contract if necessary)
G[D-6/11]	IODD – (includes Product Spec info S[D-5])
S[D-2]	Software Design Technical Note (SDD) V2
G[D-5]	PVP V2
G[D-9]	TDS/DDS – documents and data

Outreach

S[D-4]	Draft Version of a Scientific Publication
S[D-7]	Final Presentation Material
	Updated web template

* Code delivered via GitLab