IDEAS+ WP3520
Calibration and data quality toolbox

July 2016

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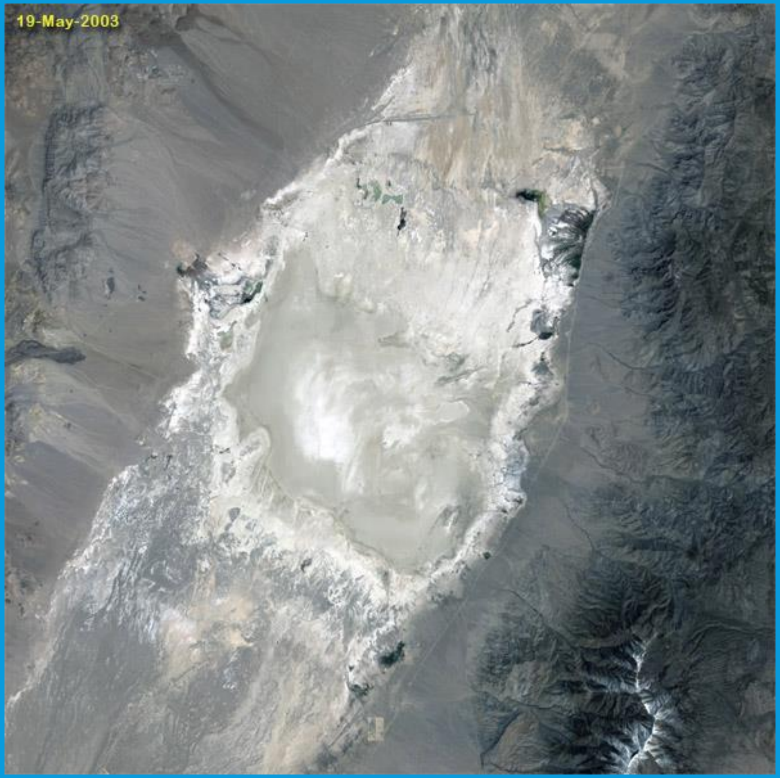
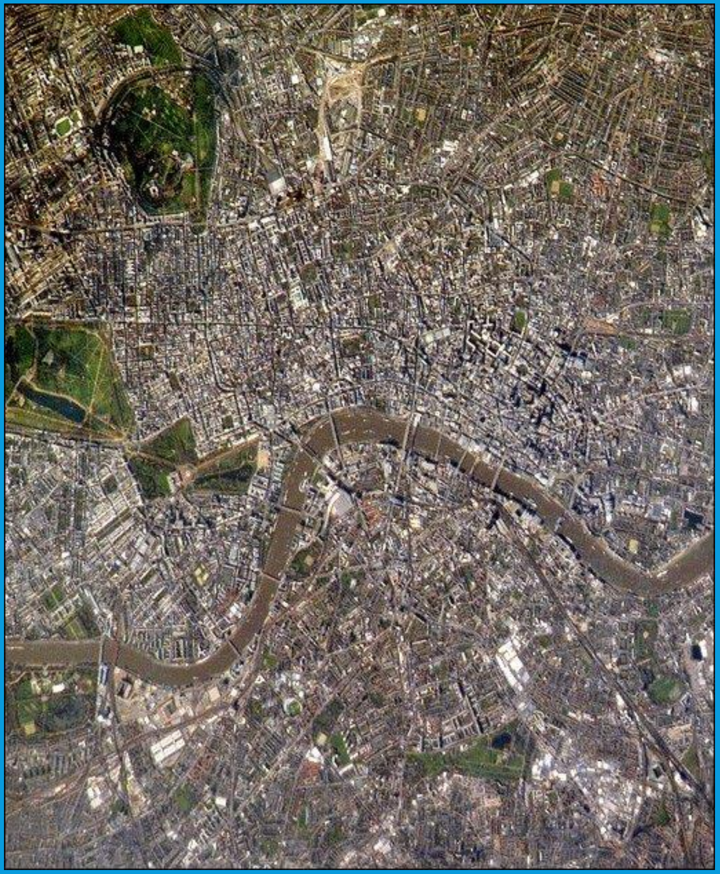
Proposition : Every image contains the same information



Railroad Valley, Nevada



London, UK

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Rationale for the project

- By using normal images, we have a much higher sampling density (every image) and hence can monitor and update our results with a much higher frequency than many on-board devices and vicarious methods which use specific sites that can only be accessed infrequently.
- By using normal images, in theory we can update coefficients automatically as soon as an issue is encountered (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.

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Areas to be explored

The number of areas to be explored has grown with time, given additional knowledge of what can and cannot be extracted from the image data alone. These include (at this time),

- Signal to Noise Ratio (SNR)
- Absolute Calibration Drift
- Relative Gain Correction
- Single Pixel Drift
- Spectral Calibration Drift
- Micro-Vibration and attitude stability
- Instrument focus

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Signal to Noise Ratio (SNR)

Developing automated methods to estimate SNR in heterogeneous scenes

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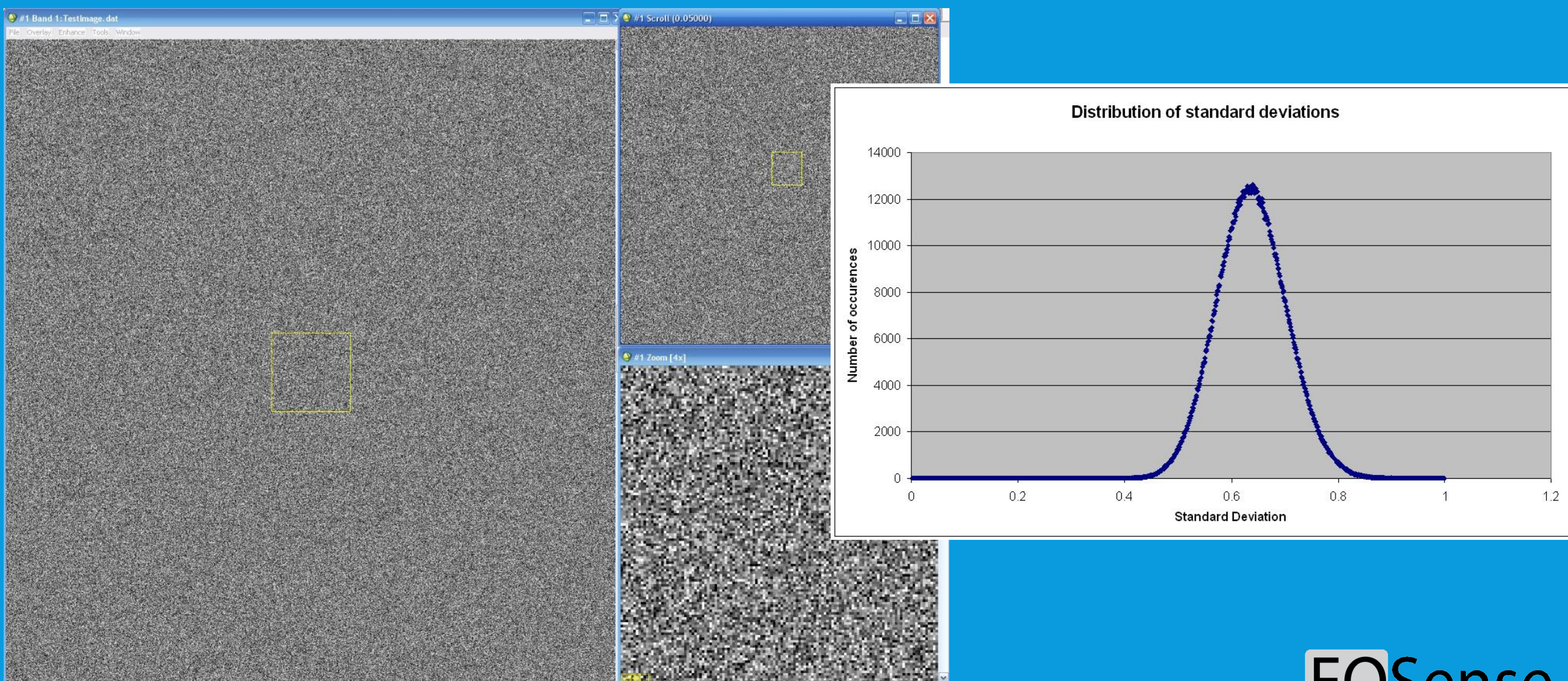
Signal to Noise Ratio (SNR) - Simulation

- Simulated “snow” scene (SD = 0.64)



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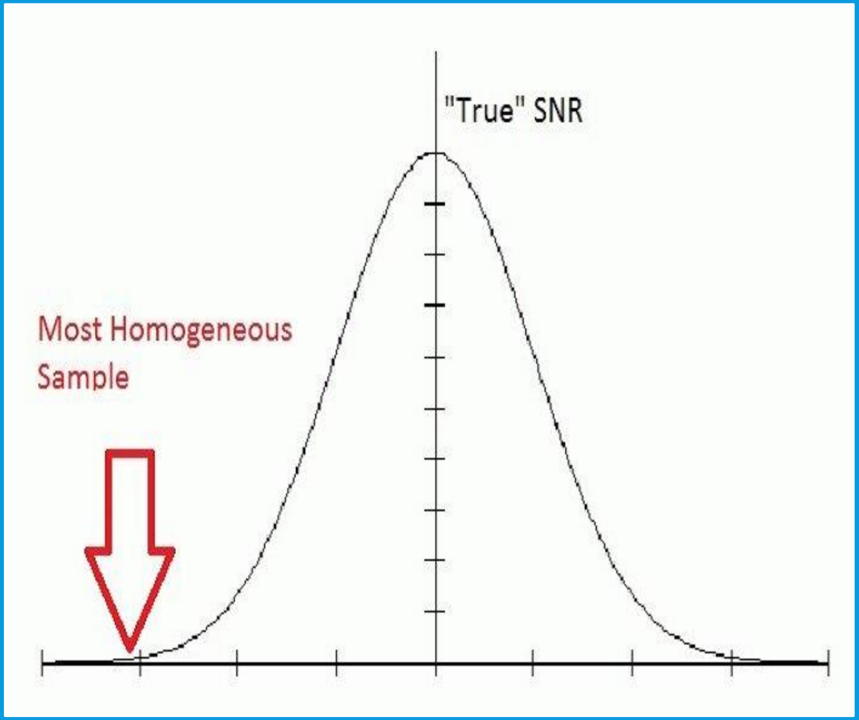
Overestimation and underestimation of SNR using automated methods



- Most automated methods tend to overestimate the SNR for relatively homogeneous surfaces
- Automated methods have been shown to underestimate the SNR over moderately heterogeneous surfaces

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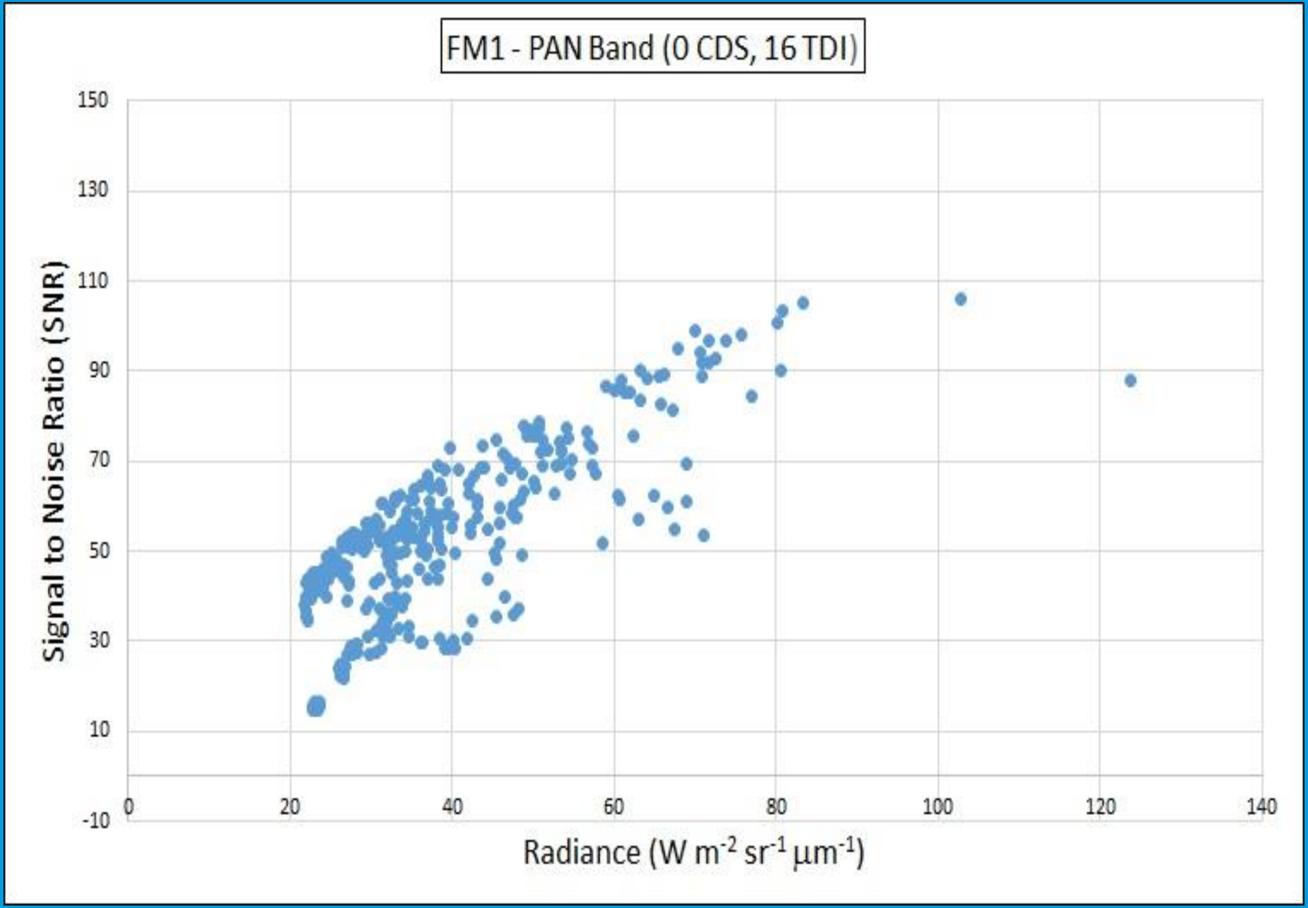
Real surfaces are often mixtures



- Upper line of data cloud shows the "true" SNR.
- Validated using manual methods
- Allows the monitoring of changes in operational procedures or sensor response
- Extension of single detectors under investigation

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Absolute Calibration Drift

The aim is to provide a simple, but effective way of inspecting the calibration of an instrument without complex modelling or processing.

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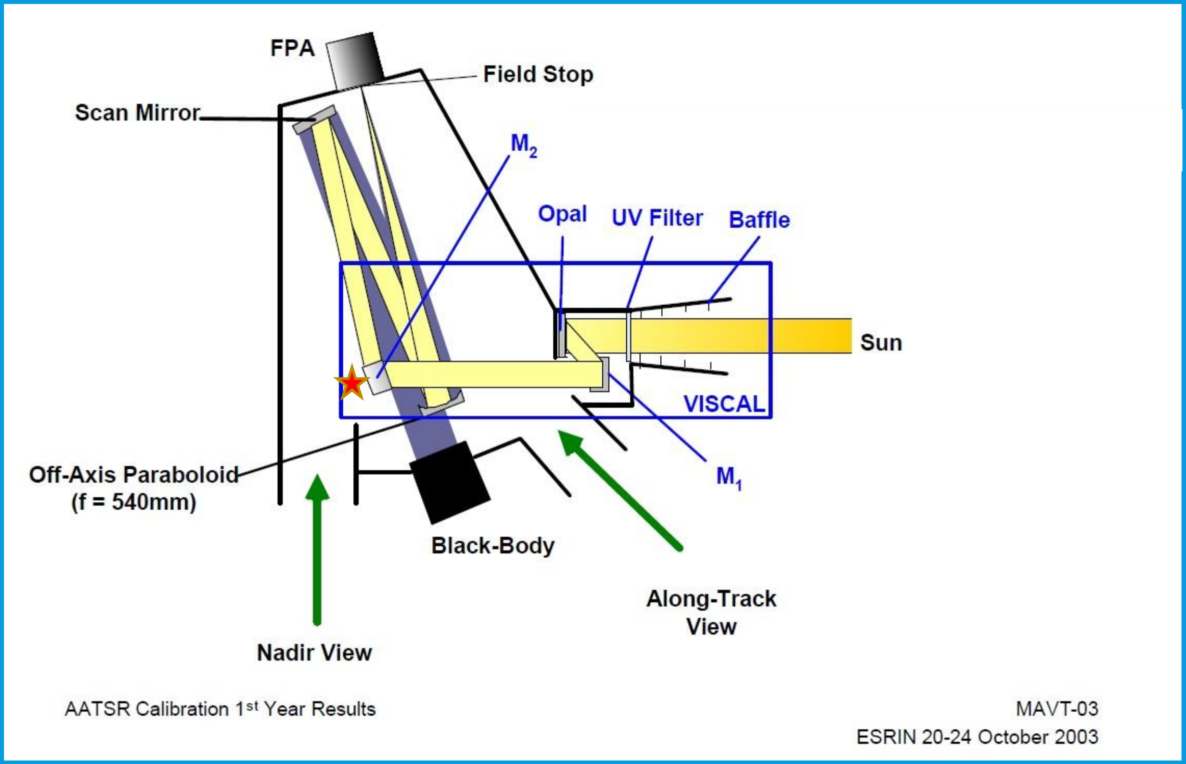
AATSR Instrument - calibration drift



- VISCAL is a calibration device for the VNIR bands and the 1.6 μm band.
- Piece of OPAL characterised by NPL in the lab under 0°/45° conditions.
- Photodiode placed by mirror M2 to monitor the signal, VISCAL data and photodiode information both recorded.

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The major assumptions?

Basic principles are that we have two independent references on the behaviour of the instrument.

- Calibrator (reflectance diffuser)
  - If recorded signal of calibrator drops with time then there is degradation in the optics / detector, ASSUMING that the calibration device does not change (using annual averages to avoid sun-earth difference effects)
- The Earth
  - If recorded signals on average of the earth drop with time then there is degradation in the optics / detector, ASSUMING that the earth does not change (using annual averages to avoid sun-earth distance and seasonal effects).

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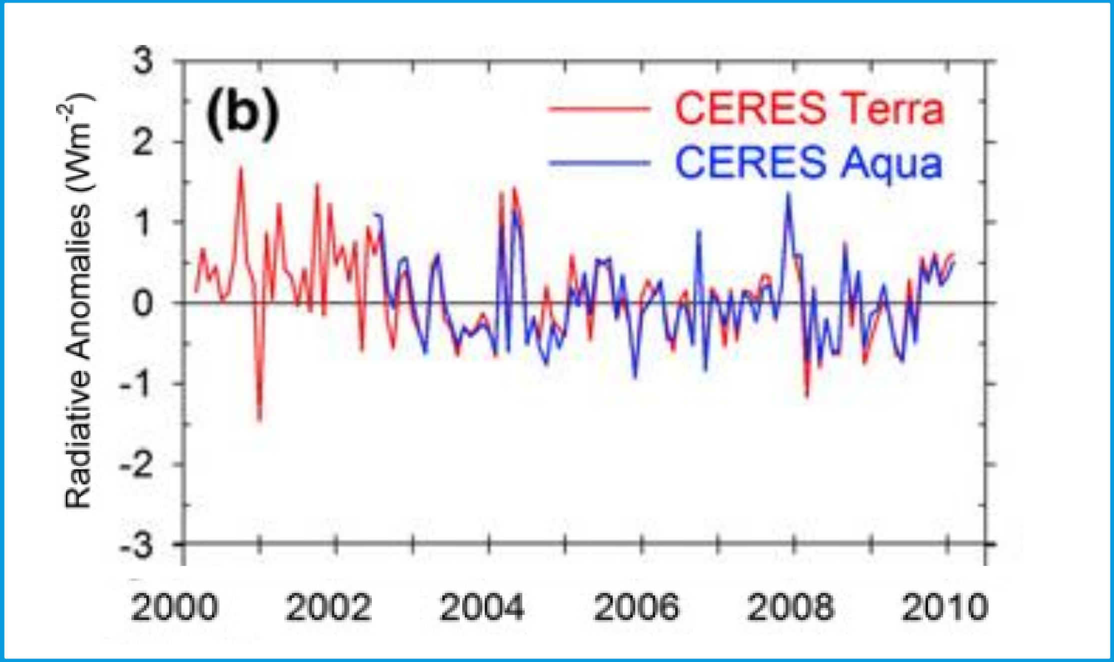
The Earth's albedo is stable?

- The Earth as measured by CERES



TOA irradiance stability is 0.5 Wm^{-2} per decade.

Negligible drift over the lifetime of AATSR

http://lasp.colorado.edu/sorce/news/2011ScienceMeeting/docs/presentations/4e_Kato_SORCE_2011_presentation.pdf

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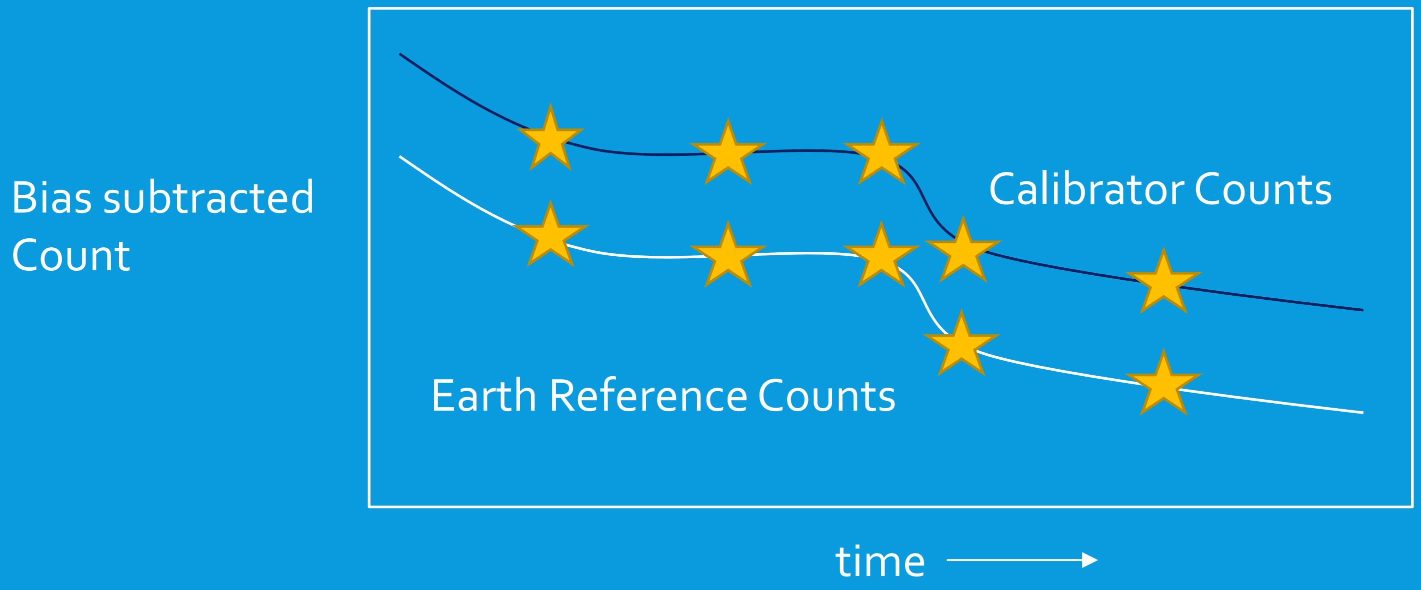
Principles of operation – Level 0 processing

- If we take annual average values of our data (billions of data points) and take annual average values of our on-board calibrator. We will have two data points with a specific relationship at start of life. Over several years we get a profile.



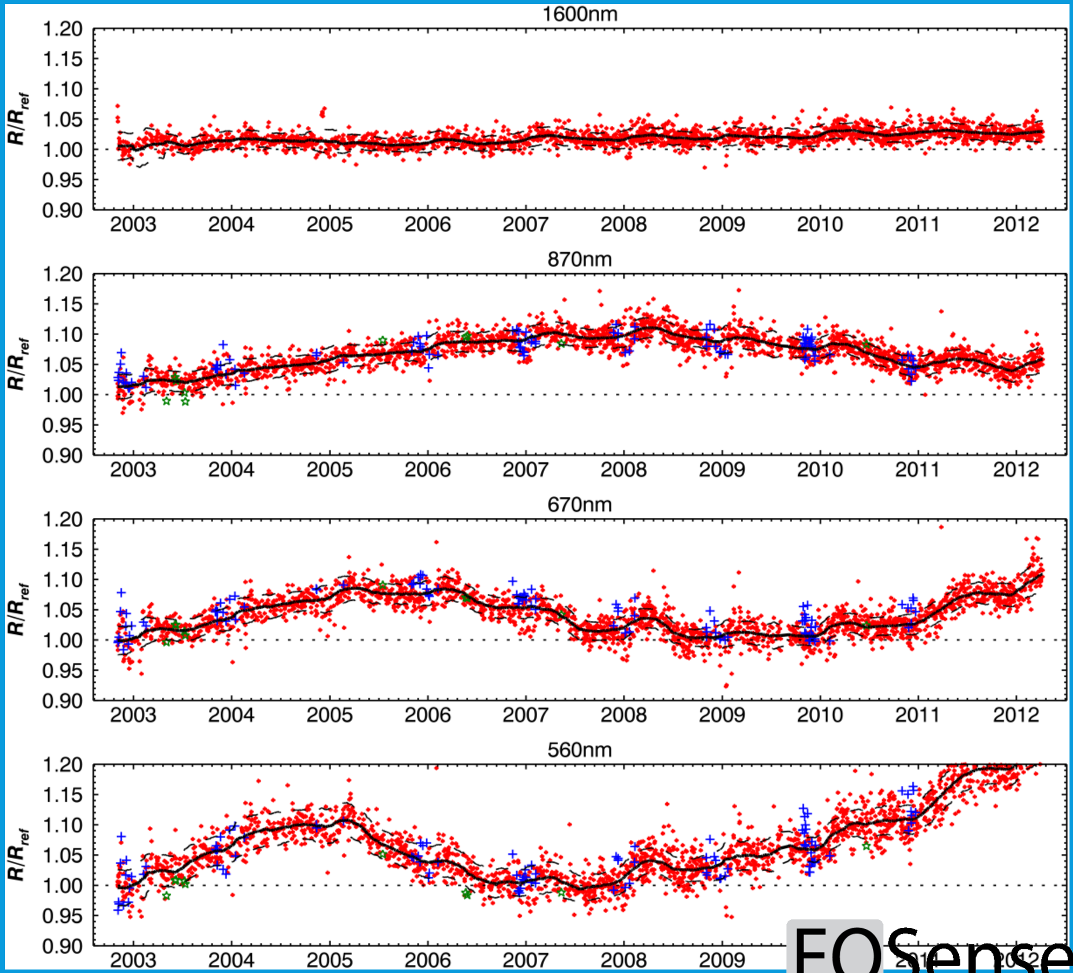
Digital gain changes or common instrument related changes are common to both counts

Validation step - What were RAL's findings? Used a complex processing based on Level 1

To obtain drift RAL compared measured BRF against reference BRF (ATSR-2) for all sites

Trend is obtained by averaging drift for all sites of 120 day window filtering for values <2 sigma from mean (5 iterations usually to get stability)

Results provide input to drift correction look-up-table



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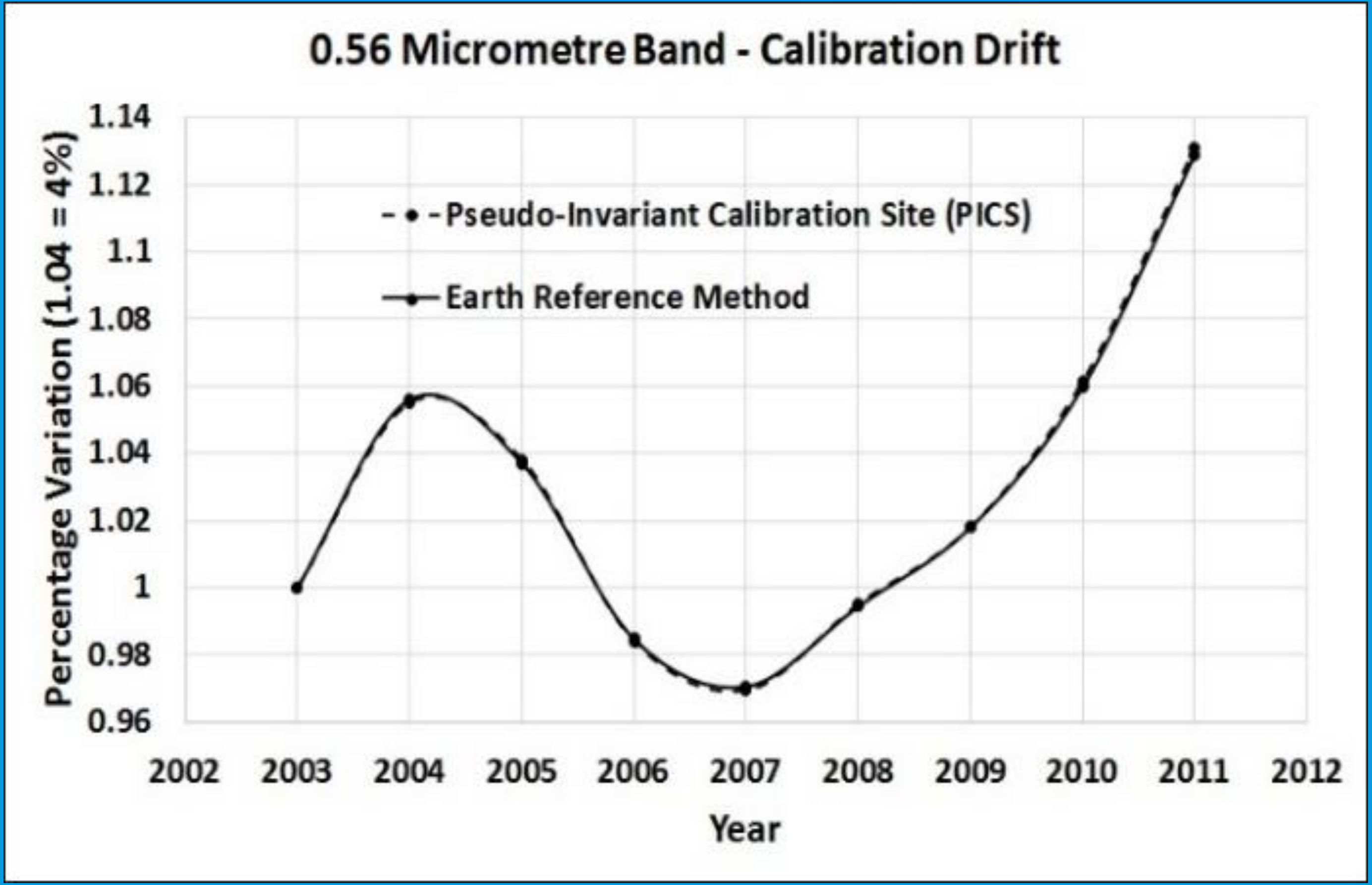
Results - 0.56 micrometre band



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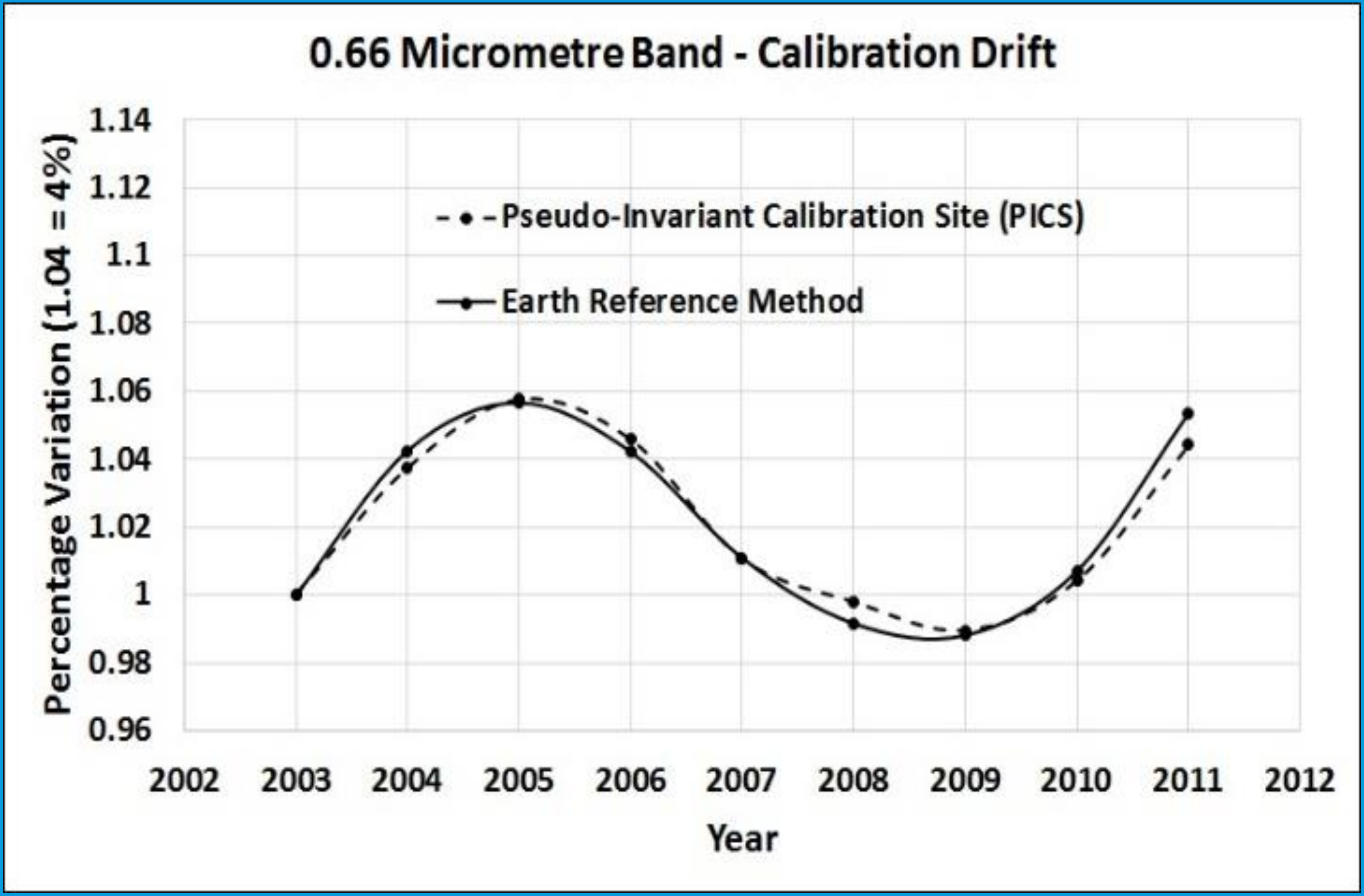
Results - 0.66 micrometre



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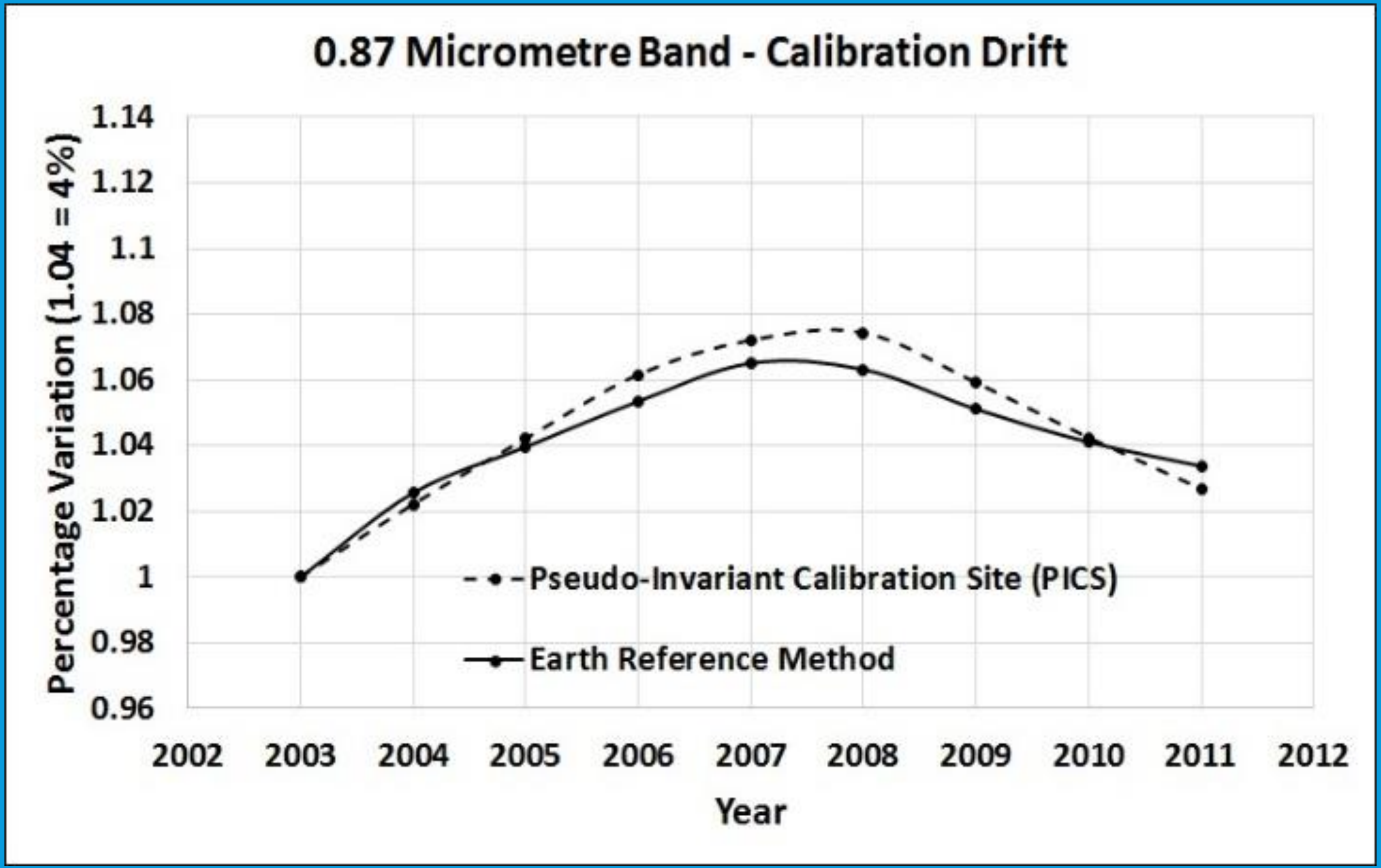
Results – 0.87 micrometre



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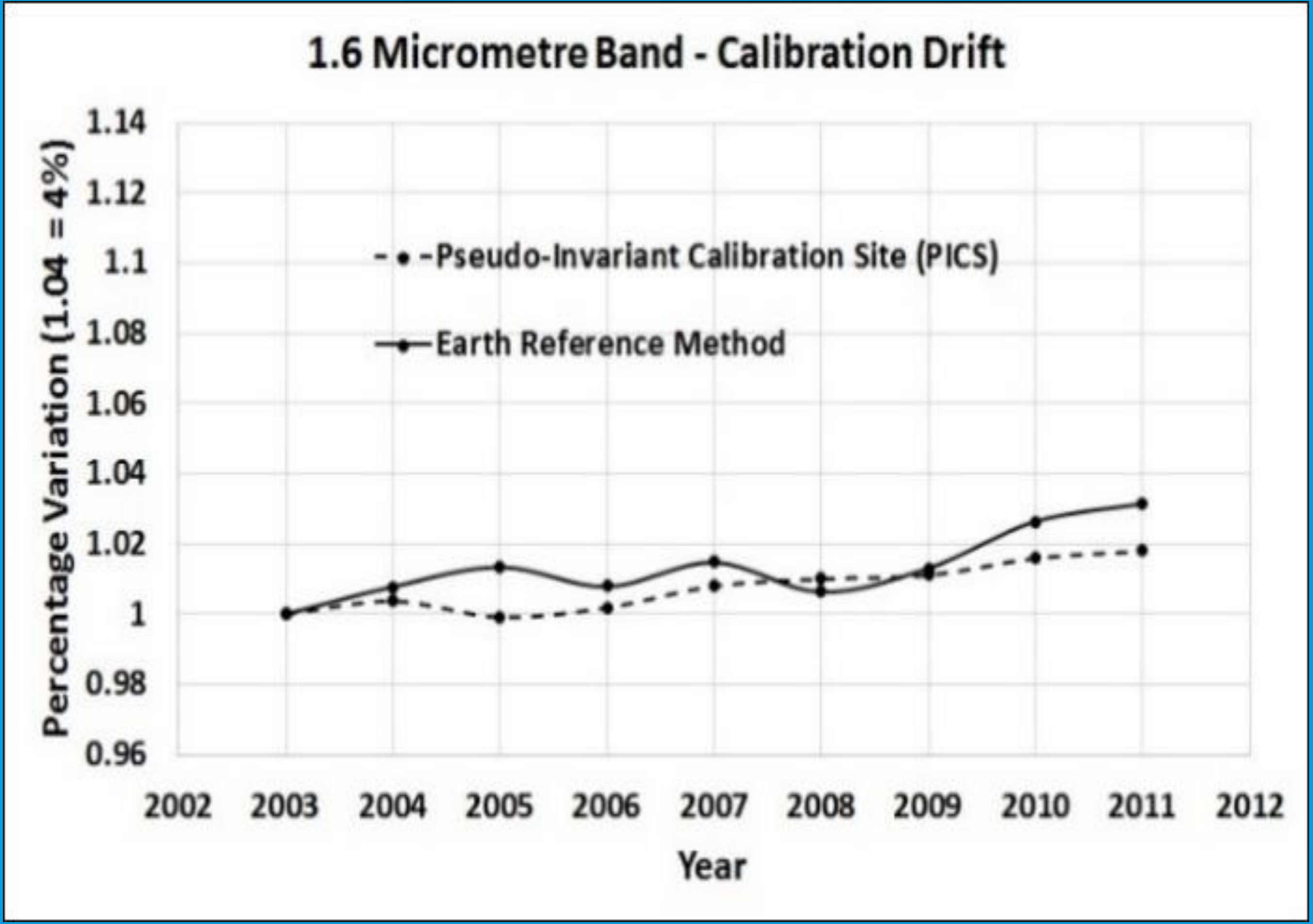
Results – 1.6 micrometre band



A reasonable result at limits of the quoted uncertainties

Is there a reason why the fit is not so good?

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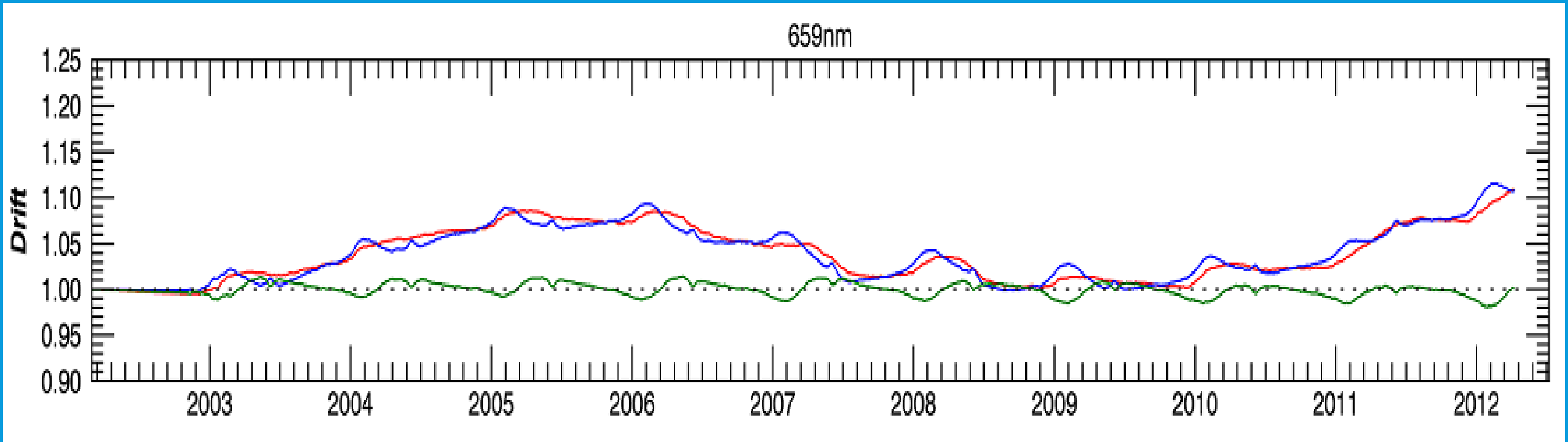
Drift table repeat pattern – BRDF?



Drift data with VISCAL monitor data (blue line), without VISCAL monitor data (red line) and difference (green line)

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Relative Gain Calibration

This is essentially detector equalisation to avoid striping effects in pushbroom sensors, but in our case using single heterogeneous images

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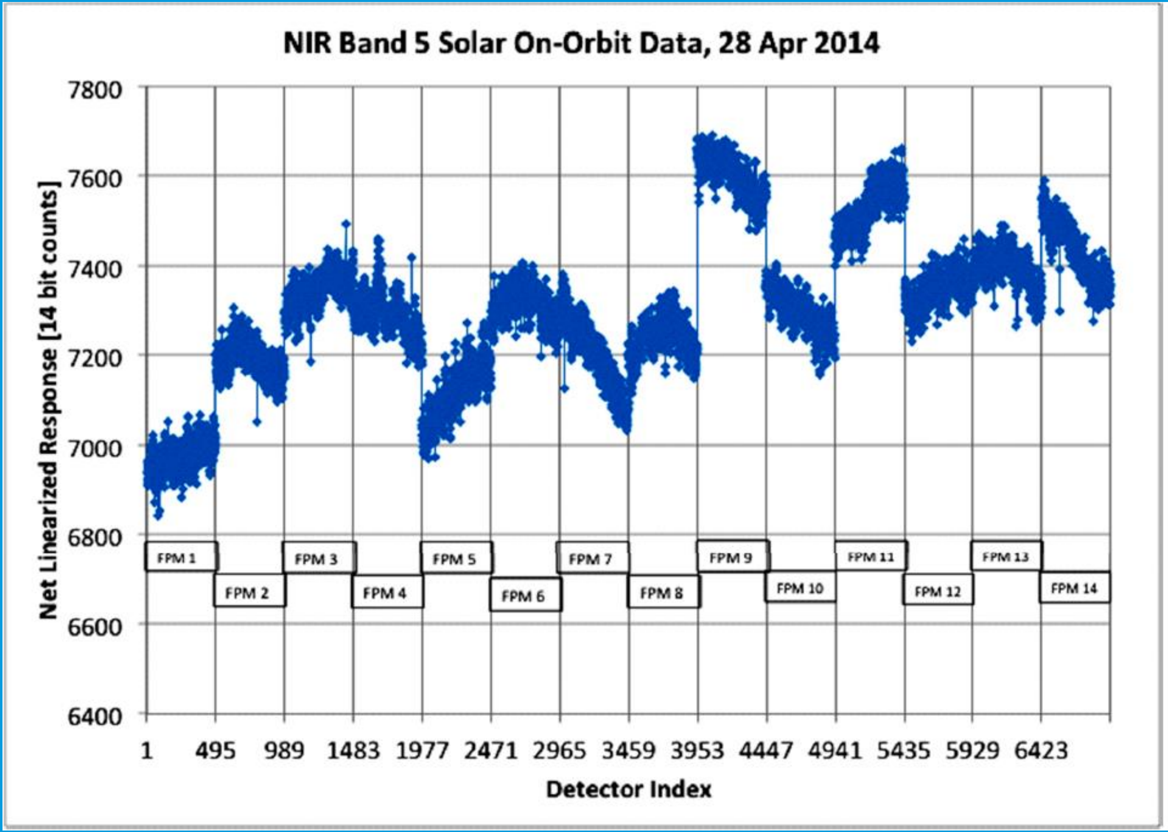
Relative Calibration using the on-board diffuser



As long as the diffuser does not vary spatially it should work.

The sensitivity to changes in the BRDF of the diffuser with time may be difficult to detect

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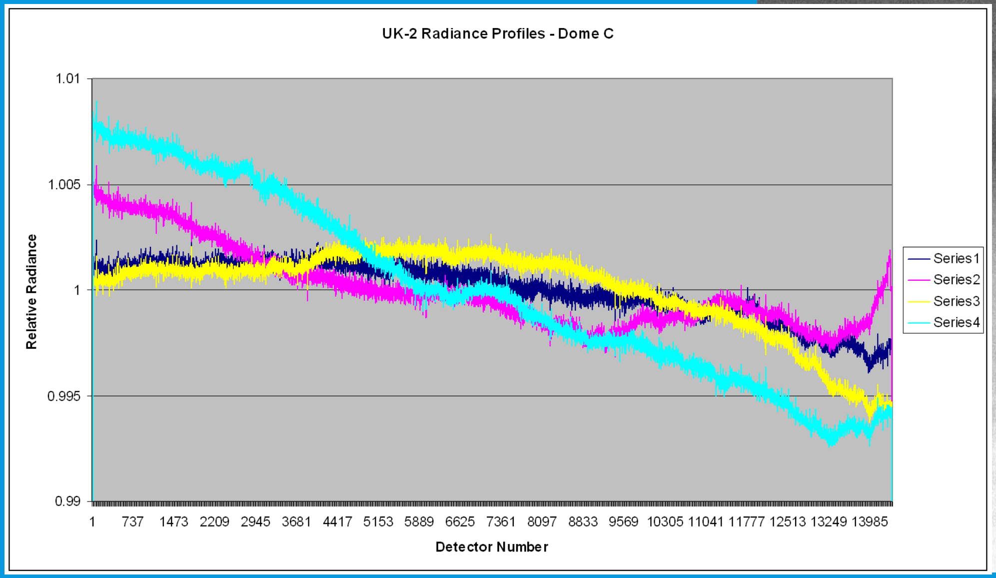
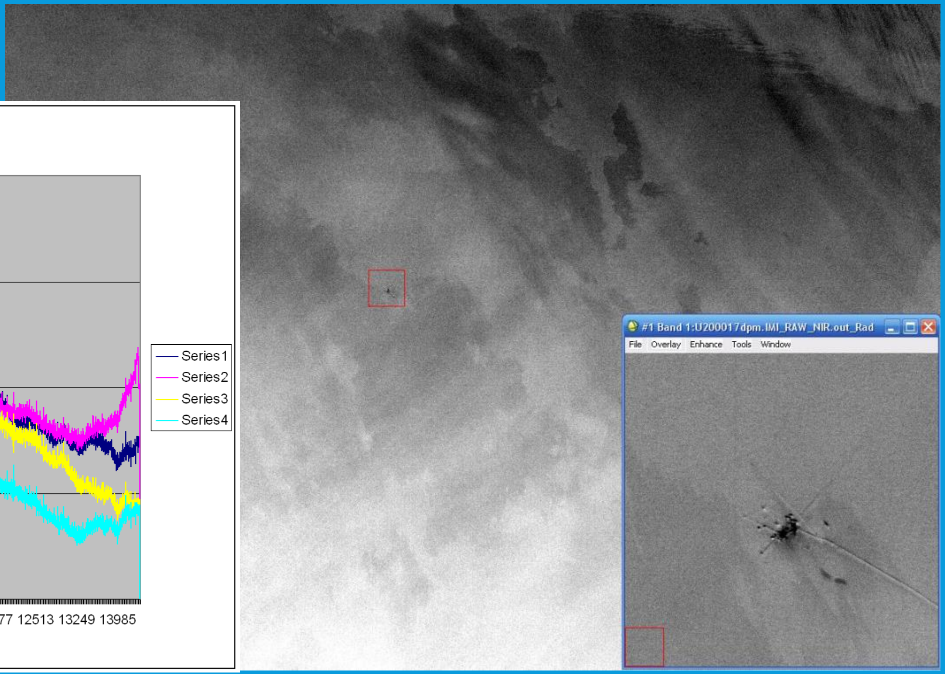
Relative Calibration using “flat-fields”

- Multiple white images over Antarctica or Greenland to derive relative gain terms, yawing the spacecraft, removing scenes with clouds or hoar frost effects.





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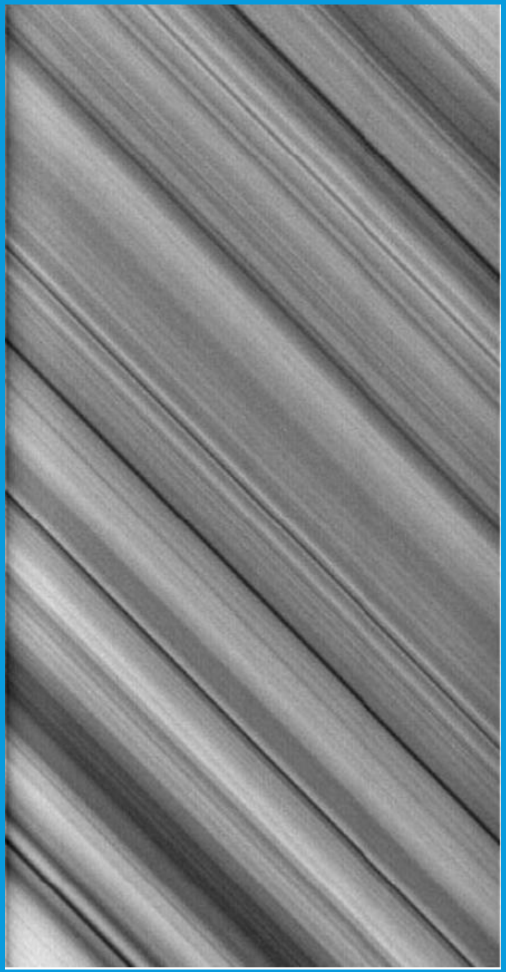
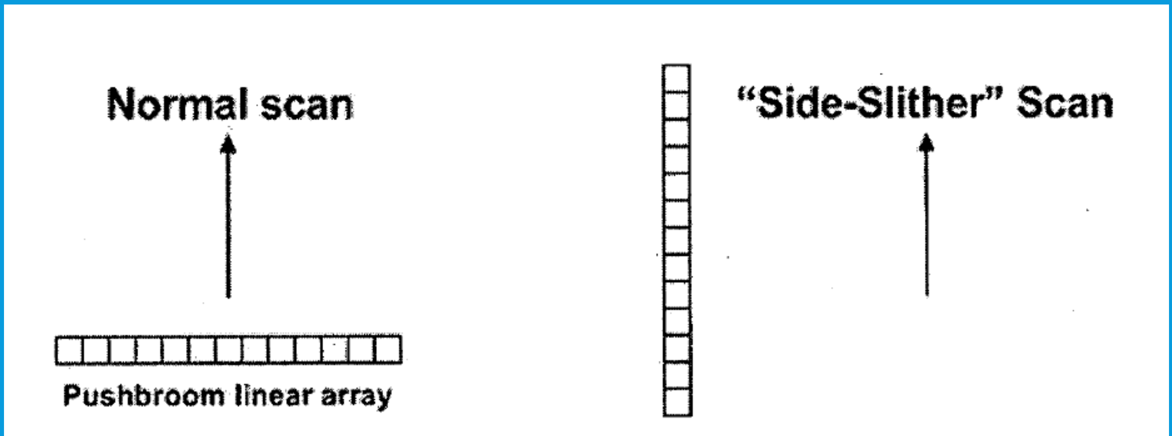
Relative Calibration using "Side Slither"





PROBLEMS :
Landsat 8 has a 15 degree FOV and the CCD relative azimuth to the sun will vary depending on acquisition. Many surfaces will show BRDF effects.

The Landsat 8 FPA has staggered arrays with around 1.5 degrees difference. This means you are looking at two targets and inducing a small BRDF difference.

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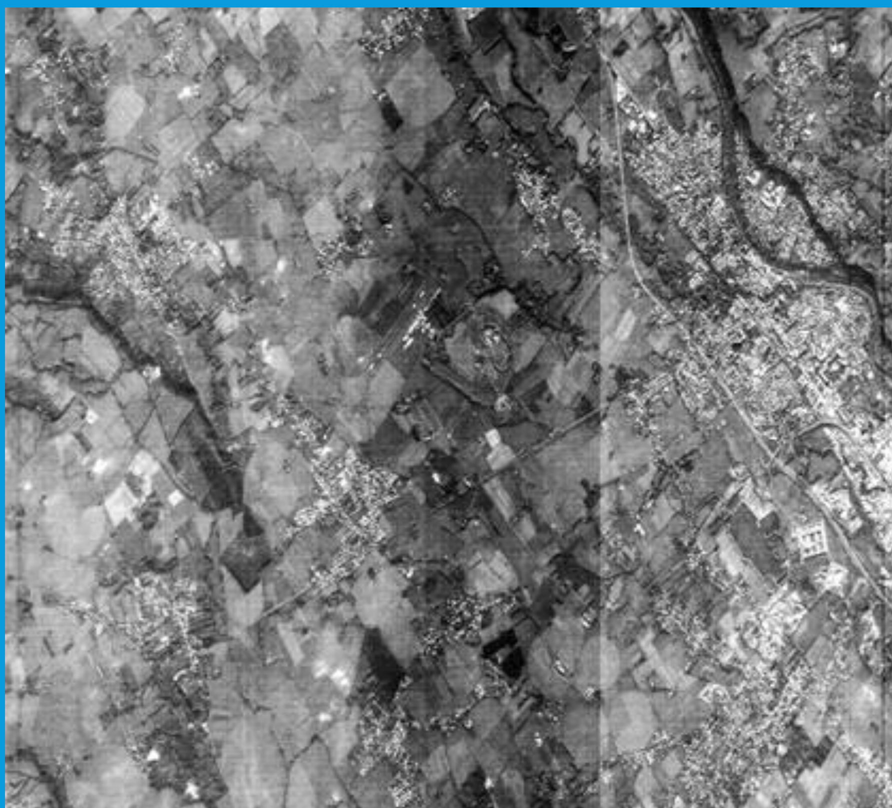
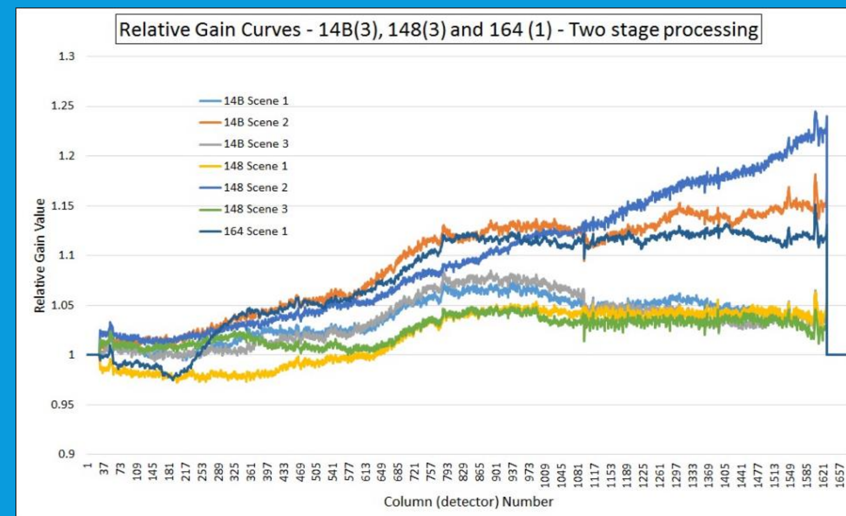
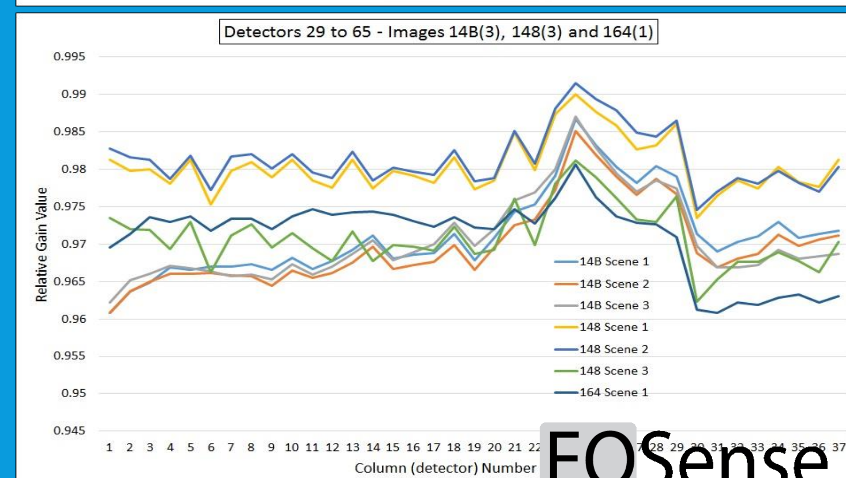
Relative calibration from single heterogeneous images



Bias subtracted “raw” image used to derive the relative gains





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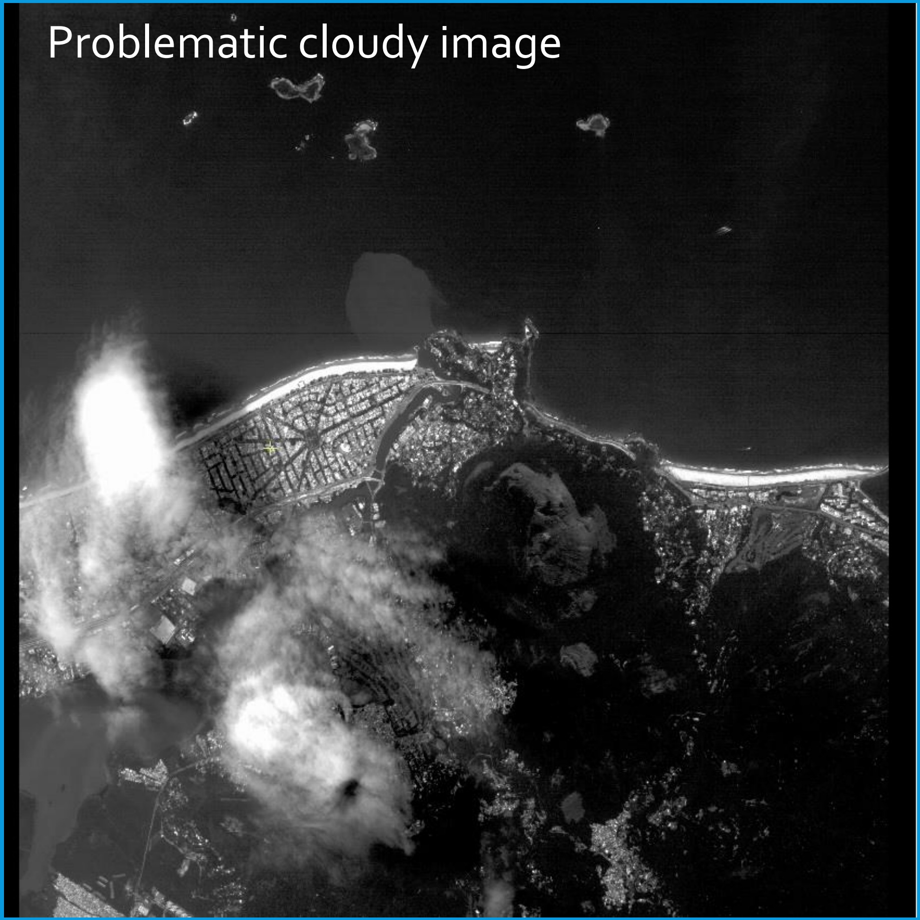
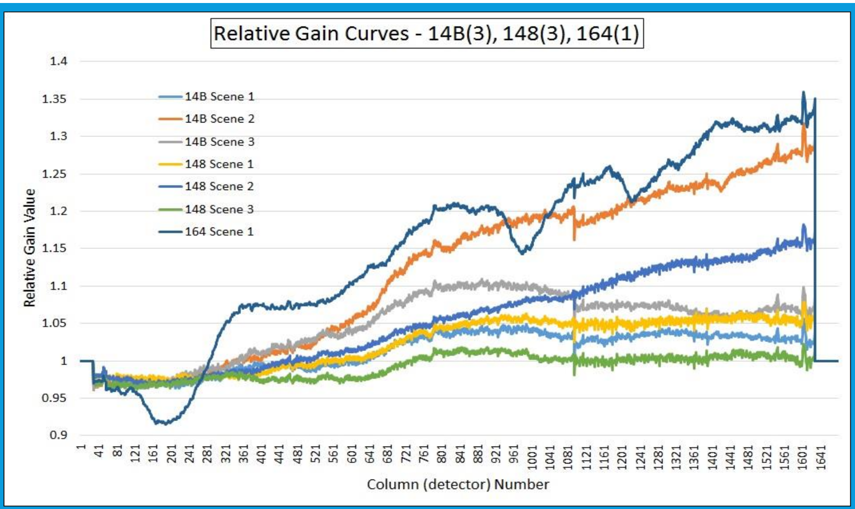
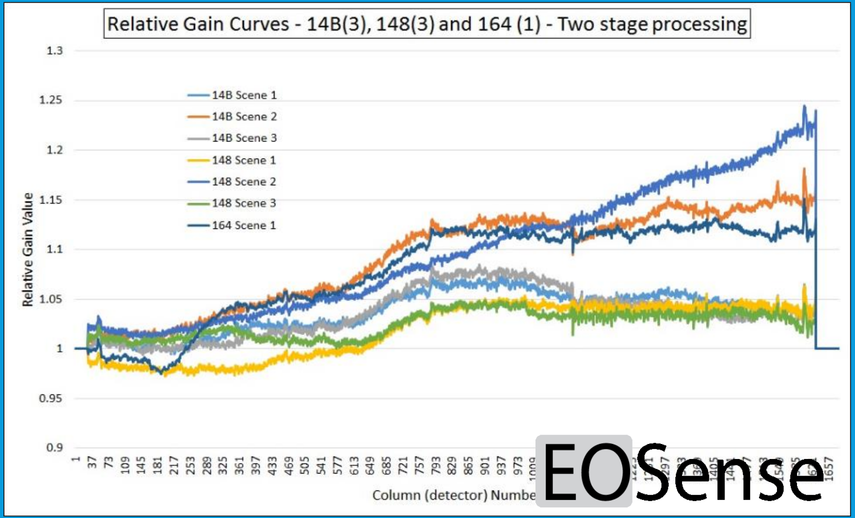
Clouds were an issue originally







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Instrument Focus

The aim in this case is to have a simple metric of the "focus" condition of any image, affected by electronics, optics, atmosphere etc.

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Instrument focus and MTF

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

Which is most in focus?

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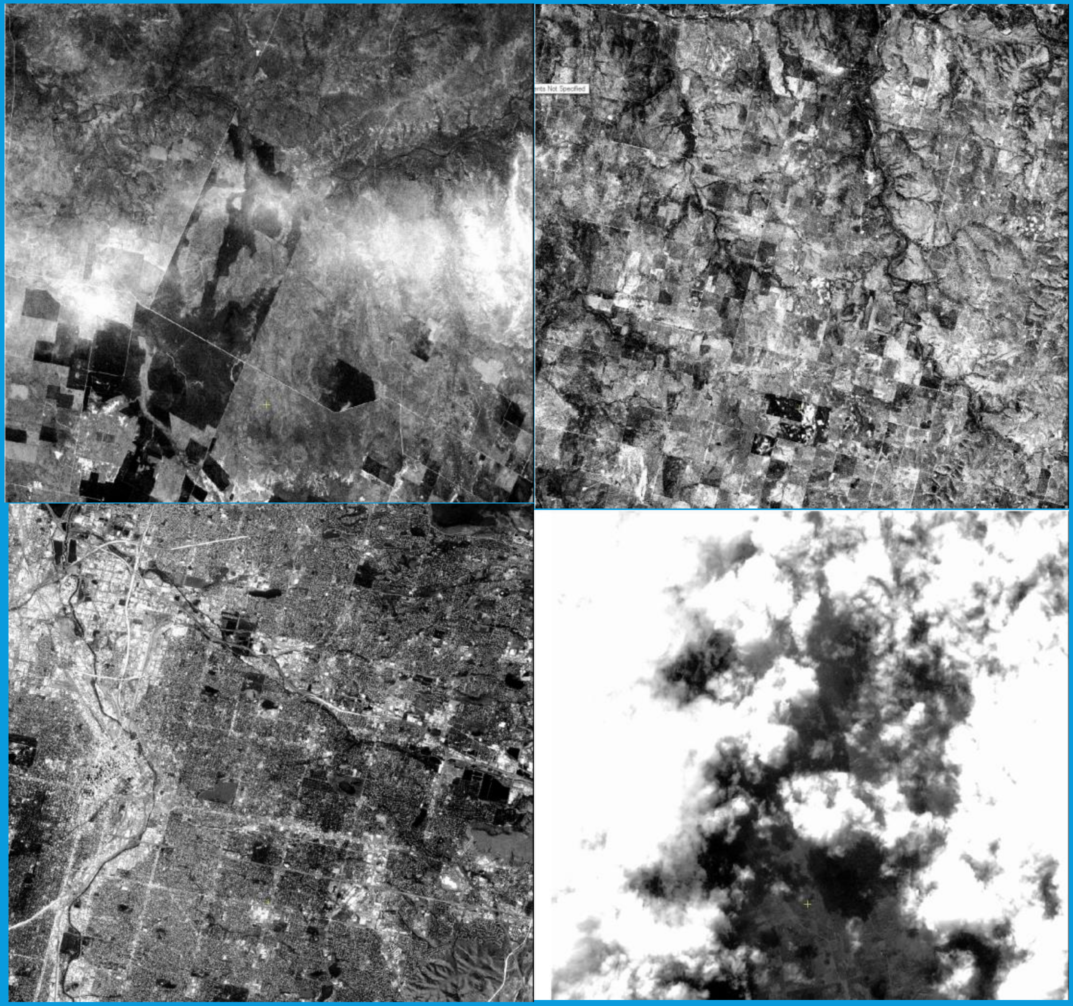
Instrument focus and MTF



These are the images we use, far more difficult.

There is no pre-selection (currently), so all these images have been used in the analysis.

The bottom right image presents particular challenges, as you can imagine the atmospheric conditions do reduce the effective focus.

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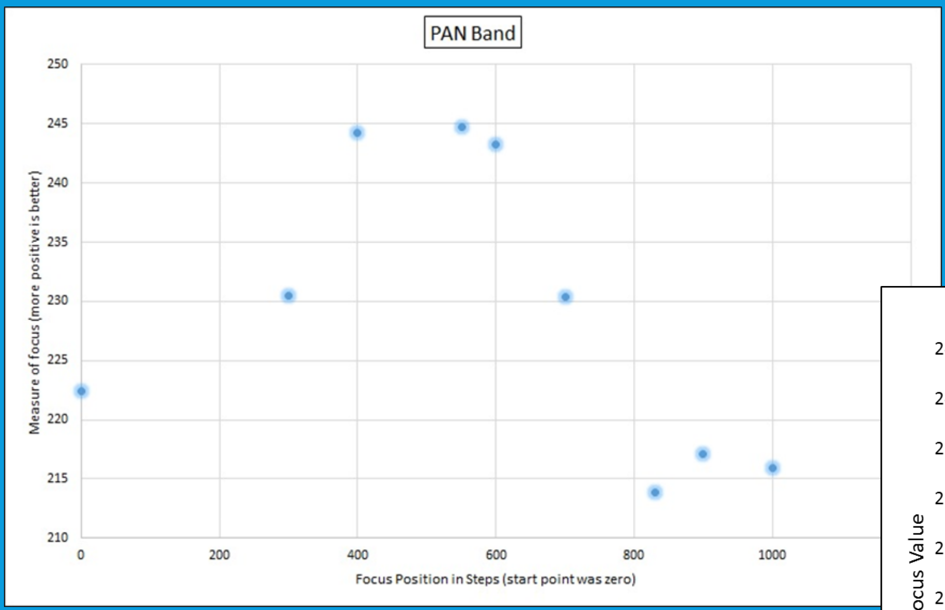
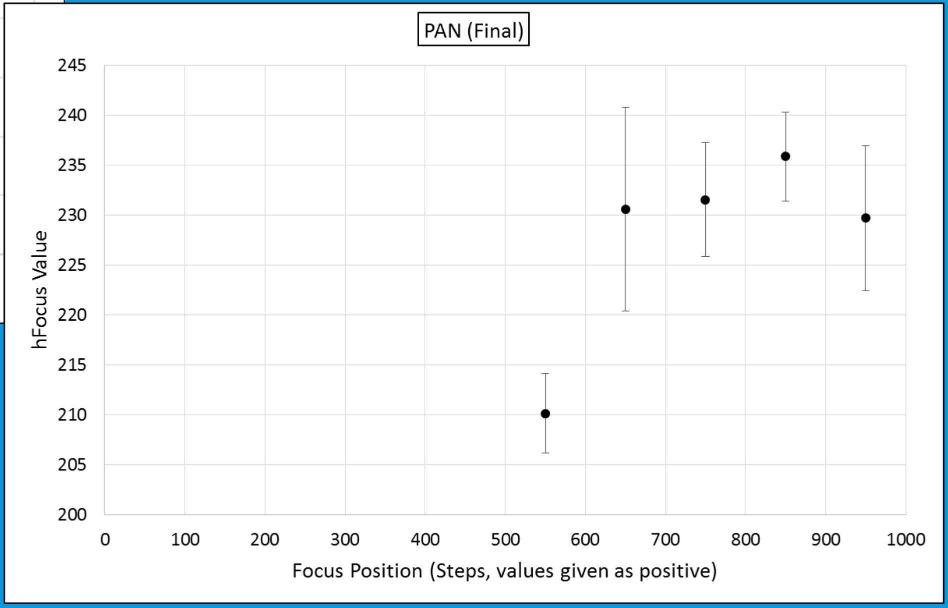
Monitoring changes in focus with time



Launch plus five years. Focus has changed, now peaks at around 830 "steps"



At launch, best focus Focus was changed in "steps" from zero, peaks at 550.

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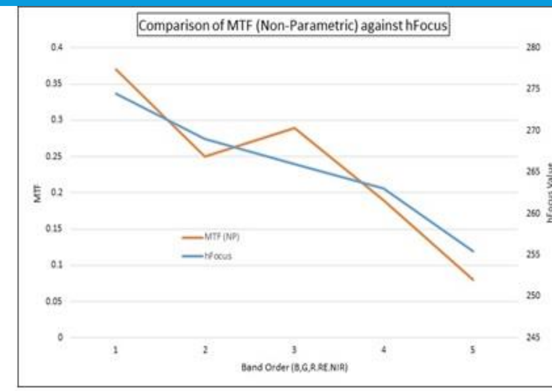
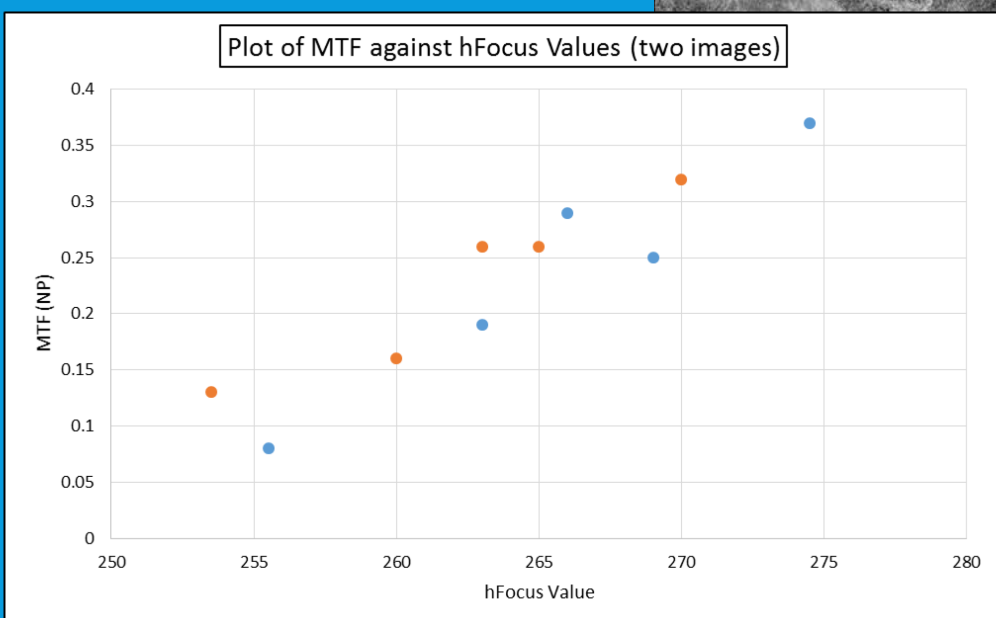
Relationship between the focus measure and MTF at Nyquist



Quantitative relationship modelled



Same image used for MTF and focus assessment. MTF based on small checkerboard target

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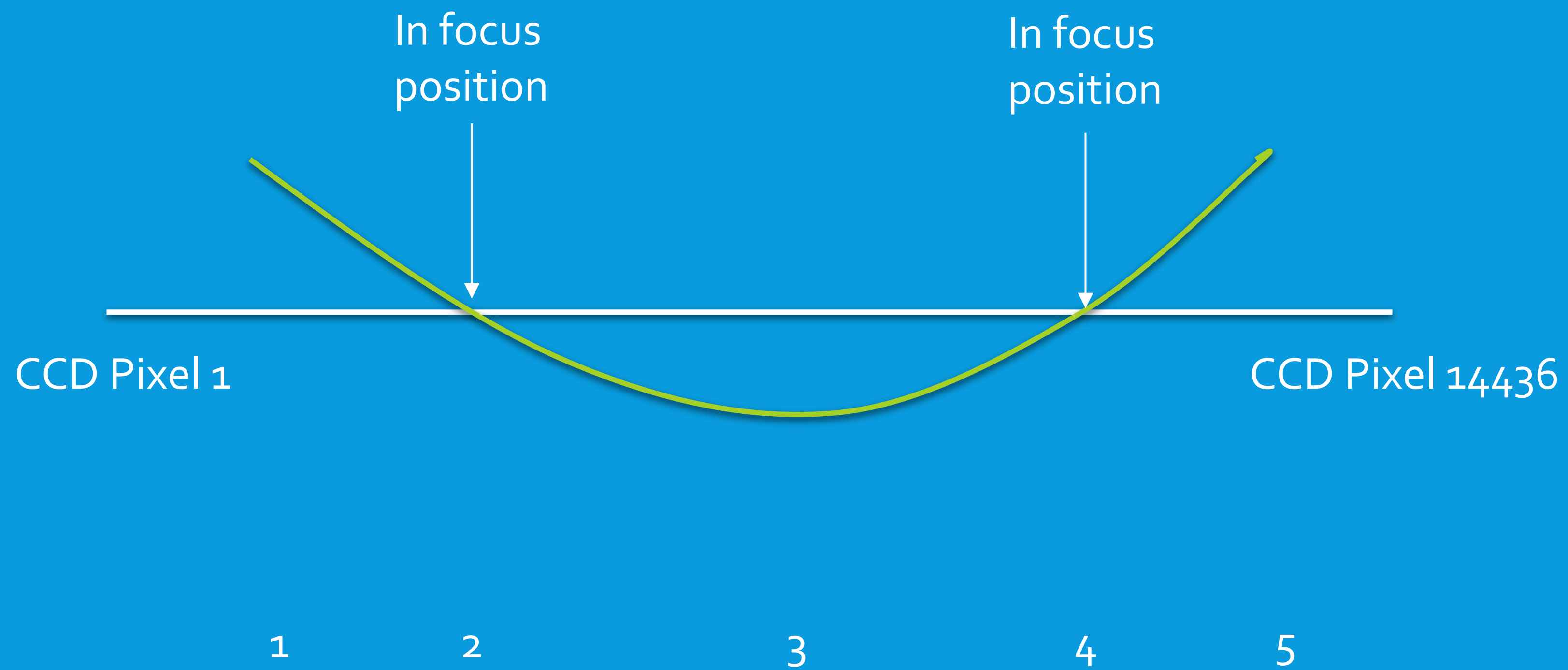
Monitoring instrumental effects

- Cross-track variation in Focus (UK-DMC-2)



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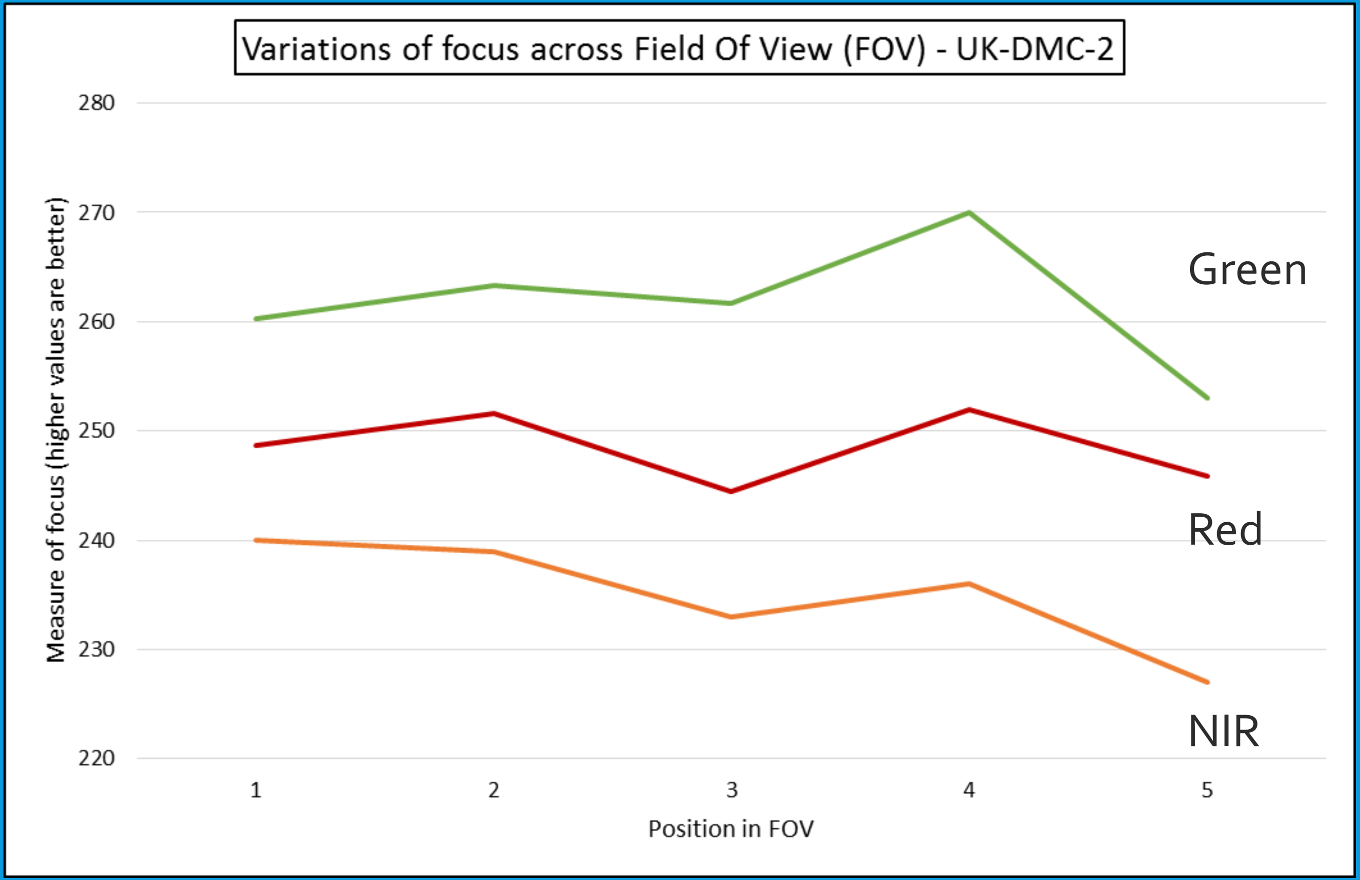
Monitoring instrumental effects



Variation in focus across the FOV is captured

Variation in focus value due to “charge diffusion” effects in the silicon detectors is also captured.

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Conclusions

- Results suggest we can monitor a wide range of parameters on a regular basis with uncertainties similar to those obtained using on-board and other more complex vicarious methods.
- Using the data we can have a much higher sampling density hence we can deal with instabilities and changes on short time scales and embed automated corrections in our processing chains.
- Still under development, but we have reached the prototype implementation stage.

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