WP3520 : FURTHER THOUGHTS ON AUTOMATION OF SENSOR QUALITY MONITORING

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Relative Gain

- Can be used with bias subtracted RAW data to derive the original relative gain curve.

OR

- Can be used with radiometrically corrected data to derive corrections to the current relative gain curve.
Relative Gain – What is it?

- Can be viewed as the relative correction to be made to equalise all the detectors across a homogeneous surface. In this case the on-board diffuser on Sentinel-2, viewed every month.

Notice the vertical banding and striping in this Sentinel-2B image extract from the Blue band of the first set of detectors.
Relative Gain – What do we do differently?

- We use the normal images to derive the correction coefficients rather than vicarious flat field targets on the earth or on-board devices. Using every image, every day if required.

Sentinel-2 image corrected with coefficients derived from an average of two along track granules.
S2B Granules used in analysis

(S2B_OPER_MSI_L1B_GR_SGS__20170325T131116_S20170325T110730_D01_N01.00)
S2B Corrections

The granule derived coefficients from both the sea and land granules matched very well to the correction derived from the S2B coefficients provided by ESA in both shape and magnitude.

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Other anomalies?

- We use multiple methods to try and identify residual features, which sometimes highlights features which are very small, that do not seem to be detected using the on-board diffuser.
Summary

• We can derive a very similar correction to that of the diffuser in both shape and magnitude.

• We can derive it every day rather than wait a month and monitor short term instabilities of the instrument response.

• By using targets that are of different brightness we have the possibility to see residuals related to non-linearity.

• During the next year we will explore the non-linearity correction.
Signal to noise ratio (SNR)

• Normally **pre-launch** estimates are made of the signal to noise radiance at target radiances, this is essentially the noise performance of the system.

• Usually measured **post-launch** with on-board diffusers or by using homogeneous ground targets, this gives SNR estimates at specific radiances.

• What we do differently is use ALL images, including heterogeneous images and assess the SNR profile across all radiance levels in a continuous manner.

• We also can now provide it at the detector level, to help monitor detectors that are “mis-behaving”.
Noise Models and Single detector retrieval

An extension has been developed where we fit the low standard deviation range to a theoretical model of noise.

It is designed to infer instrumental noise from histograms formed with fewer pixels in a window, hence it is more applicable to single detector retrievals.

The peak is no longer a good guide to the true value, so we instead fit the whole of the low-sd range to a theoretical model of noise.

Noise sd retrieved varies little with the size of window used, and the fit of data to 'model' is usually good.

The smaller the window size, the more sensitive we are to quantisation of the image signal.
Example retrievals

- Original Histogram based approach
- Modelling approach
Recent improvements I

- Left plot shows noise distribution past the peak.
- Modelling of just the area to the left of the peak (right plot) produces a more accurate estimate, avoiding the effects of surface mixing.
Recent improvements II

- The bottom plot shows our distribution and model fit.

- The top plot shows how the estimate of noise standard deviation varies depending on how much of the original curve we include.

- It shows that as we go past the peak of the distribution, we see an increasing noise standard deviation.

- Not too big an increase as the surface in Libya 4 is reasonably homogeneous.
Recent improvements III

• For a more heterogeneous image we can see the model fit is worse near to and after the peak which we believe is due to the surface mixing of this very heterogeneous scene.
SUMMARY

- We can derive very good estimates of SNR from heterogeneous images.
- We can monitor at the individual detector level and determine changes in behaviour with time.
- Improvements allow us to reconstruct the SNR curve rather than use a few point measurements, with a limited number of images.
Focus what is it?

• Almost everyone talks about MTF of a system, not the focus. It’s the same thing in a way, but MTF is a more detailed assessment of an optical systems behaviour.

• Normally measured using specific targets of which there are very few, or…

• Bridges and other man-made targets can be used for lower resolution sensors
Focus - What Do we do differently?

- We use all images, not specific targets
- We give an overall estimate of system “focus” using a measure that has to be shown to be related to MTF at Nyquist or LSF FWHM.
- So every band of every image, or even sub-areas of a band can give an estimate of the focus.
- So we can watch the focus evolve with time and correct it when it drifts too far from the ideal, without the need for specific sites and processing it can all be automated.
- We can also (we believe) see the effects of the atmosphere (specifically aerosols) on the focus, which helps us correct the scatter we see in our radiometric calibration.
Focus across-track

Sentinel-2B

Small Satellite System

We seem to be seeing consistent variations in relative focus in two different images. However we are at an early stage of analysis for Sentinel-2.
Small satellite Focus

Focus Values all imagers - PAN Band - Libya 4

Commissioning  Start of Service  After Re-focus

Date 26/05/2015 23/10/2015 21/03/2016 18/08/2016 15/01/2017 14/06/2017 11/11/2017

AOD - Libya 4

Data from SDSU database
First steps in trying to understand why our focus estimates vary

Grey dots are the blue-green ratio values, orange are focus values (left scale) and blue dots are the AOD values.

We are not excluding illumination changes affecting the algorithm at this time, nor temperature changes of the satellite systems.

Summary

- We are able to extract consistent focus values from heterogeneous images and therefore monitor and trend focus changes on a daily basis.

- The values we extract can be related directly to MTF measurements during a “calibration” exercise.

- The focus values recorded vary in part with surface condition, but the largest control seems to come from the atmosphere itself.

- An exercise is planned using the RadCalNet sites to try and evaluate the relationship of focus, AOD and MTF.

- Additional tests on thermal behaviour will follow.
ABSOLUTE CALIBRATION DRIFT – WHAT IS IT?

- We are trying to determine absolute changes in the radiometry over the lifetime of the satellite system.
- This is normally performed using on-board diffusers and lamps and on occasion with vicarious targets such as Libya 4.
Absolute calibration drift – What we do differently

• We use ALL images of the earth and do not require an on-board calibrator
• Has proven to work well, it is different from normal calibration methods as it uses RAW counts
• Does not require calibration of the sensor to derive the drift
• Is not confined to a few data points over a limited target set
• It does not require correction for view angle/ solar zenith or BRDF effects
• It requires no models or corrections or iterations to operate it is a simple statistical calculation. Hence it provides an alternative approach to validate methods using models or corrections.
• Can be applied on sensors without diffusers or compared to results using diffusers to detect diffuser drift.
AATSR – Example of diffuser drift

- The PICS curve is based on an intense analysis of Pseudo-Invariant Calibration Sites in North Africa and Dome-C and Greenland snow fields.

- The Earth Reference Method uses all data and no models.
CONCLUSIONS

• Using the data itself to provide information on calibration and data quality seems a very powerful way forward, that possibly opens new ways of evaluating the data and new applications.

• The strength lies in the quantity and frequency of data used, and in many ways the simplicity of its use with a limited use of models and external data sources.

• Calibration sites or on-board calibration devices should still be considered the primary methods using established techniques, however, the methods demonstrated provide an alternative route for validation and perhaps the development of additional in-flight methods (non-linearity?)
FUTURE WORK

• An ideal way forward would be to use these techniques on a well-calibrated and monitored system and determine their reliability compared to traditional approaches.

• The aim is to use these methods on Sentinel-2 data looking at
  • Relative gain residuals and auto-correction
  • Non-linearity and its determination from “normal” imagery
  • Focus variations and the possibility of assessing AOD
  • SNR estimations at the detector level and the variability with time.