Calibration and In-Flight Performance of the Sentinel-3 Sea and Land Surface Temperature Radiometer

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The Remote Sensing Problem
A very indirect measurement

RAL Space

Noise
Responsivity
Spectral Response
Resolution
Coverage
Stability…

Atmosphere (absorption, scattering, emission), surface state, geometry, illumination...

'Real world'
e.g. SST, cloud...

Instrument Calibration Parameters

Uncertainties are introduced at ALL levels and will affect the final physical quantity of interest

Validation
x_v and S_v

Instrument measurements (y_m) and uncertainty (S_y)

Accurate Physics and Environment

Retrieval
Forward model y(x)

Retrieved parameters and uncertainty
x and S_x

A priori information (x_a)
And uncertainty (S_a)

$$J(\mathbf{x}) = (y(\mathbf{x}) - y_m)\mathbf{S}_y^{-1}(y(\mathbf{x}) - y_m)^T + (\mathbf{x} - \mathbf{x}_a)\mathbf{S}_a^{-1}(\mathbf{x} - \mathbf{x}_a)^T$$

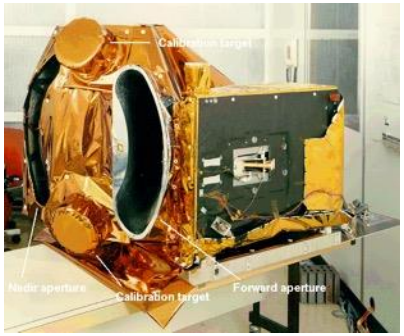
Cost function

Understanding of what was missed

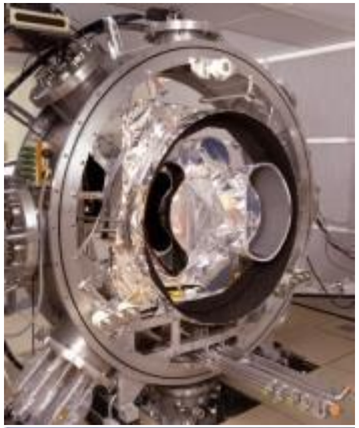
Knowledge of environment

ATSR Series

1991-2000 ATSR-1



1995-2008 ATSR-2

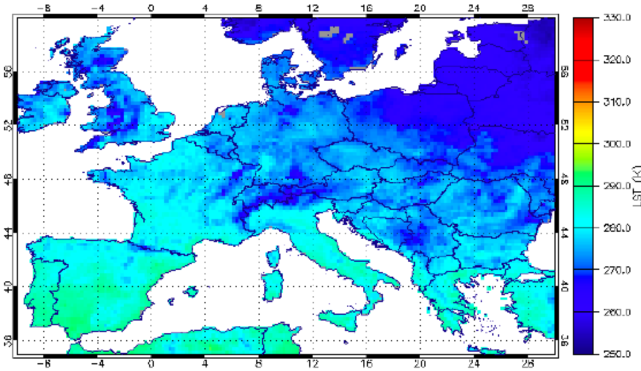


2002-2012- AATSR

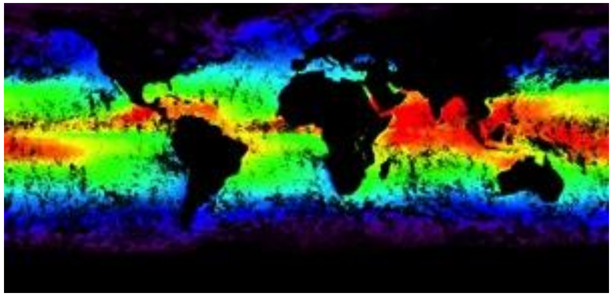
SLSTR Key Requrements

- Continuity of Sea and Land Surface Temperature datasets derived from (A)ATSR
- Additional bands for fire radiative power measurements and improved cloud detection
- Dual-View Capability
- On-board calibration sources
- Daily global coverage (with 2 satellites)

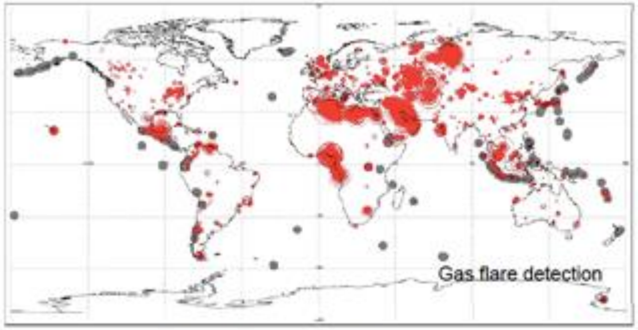
AATSR Level-3 product at user-defined spatial resolution Europe daytime Feb 2011 at 0.25°



Global SST ENVISAT AATSR monthly composite



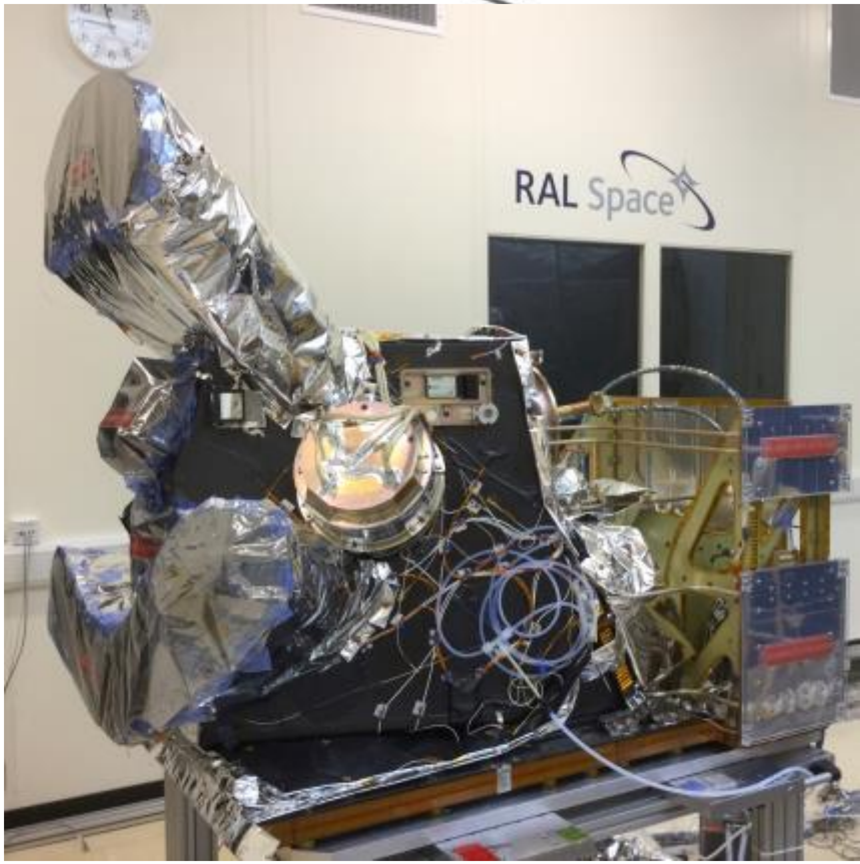
ENVISAT AATSR hot spot fires and world fire atlas



Casadio et al; ALGO3 persistent hot spot sites (1991–2009) RSE 2012

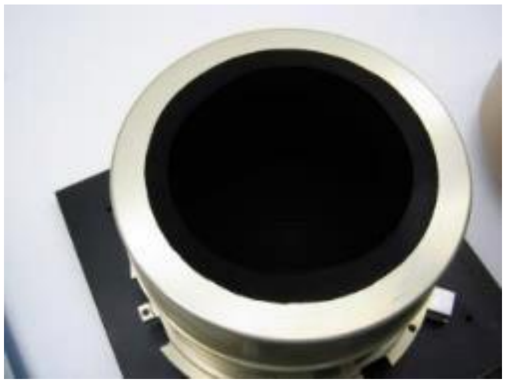
SLSTR instrument

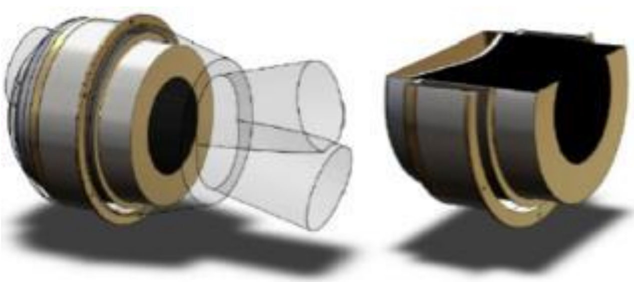
Nadir swath	>74°	(1400km swath)
Dual view swath	49°	(750 km)
Two telescopes	Φ110 mm / 800mm focal length	
Spectral bands	TIR : 3.74µm, 10.85µm, 12µm SWIR : 1.38µm, 1.61µm, 2.25 µm VIS: 555nm, 659nm, 859nm	
Spatial Resolution	1km at nadir for TIR, 0.5km for VIS/SWIR	
Radiometric quality	NEΔT 30 mK (LWIR) – 50mK (MWIR) SNR 20 for VIS - SWIR	
Radiometric accuracy	0.2K for IR channels 2% for Solar channels relative to Sun	
On-Board Calibration	Blackbody Sources for TIR VISCAL for solar channels	



On-Board Calibration systems

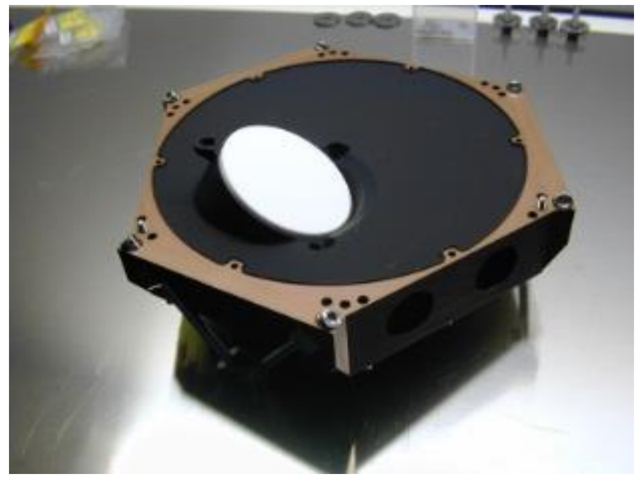
Thermal InfraRed Blackbodies





Effective e >0.998
T non-uniformity < 0.02 K
T Abs. Accuracy 0.07 K
T stability < 0.3 mK/s
8 PRT sensors + 32 Thermistors

VIS-SWIR Channels VISCAL



Zenith diffuser + relay mirrors
Uncertainty <2%

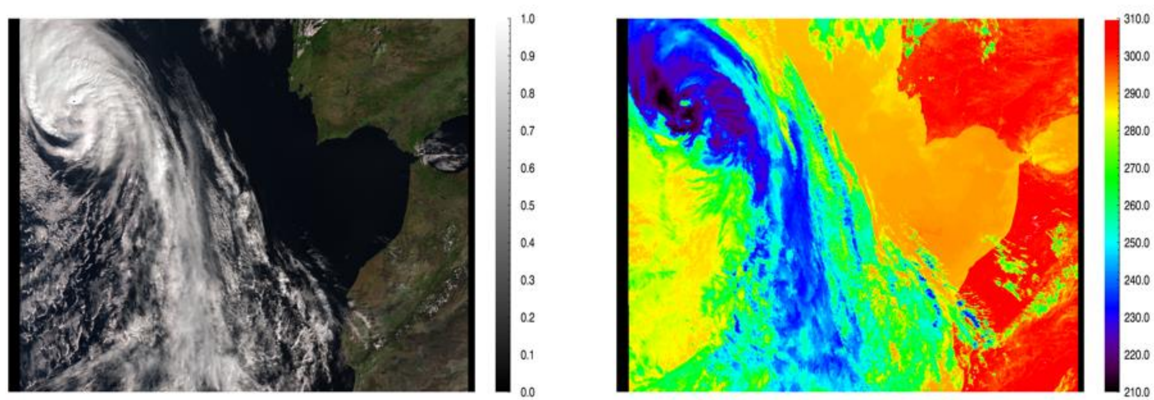
SLSTR-A

Calibration at RAL - Jan-June 2015

Sentinel-3A launch - Feb 2016

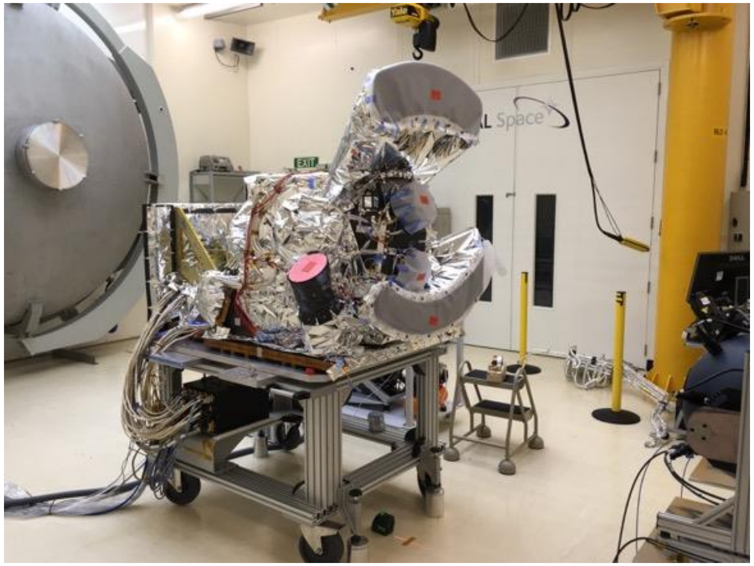
First Image - March 2016

In-Orbit Commissioning Review – July 2016



Hurricane Ophelia 15/10/2017

SLSTR-B



Arrived at RAL for calibration – Oct 2016

In-Air Tests – October – Nov 2016

In-Vacuum Tests – Nov 2016 – Feb 2017

S3B Launch – Spring 2018

SLSTR-B = Refurbished Proto-Flight Model (PFMr)

Refurb includes:

- Rebuilt BB1
- New flight BB2
- Recoated telescope aperture stop to reduce internal strays

The Goal

To ensure the interoperability of satellite datasets it is a requirement for their measurements to be calibrated against standards that are traceable to SI units

For temperature this is the International Temperature Scale of 1990

For IR instruments such as SLSTR the traceability is achieved via internal BB sources


Instrument

←


Blackbody Source

←

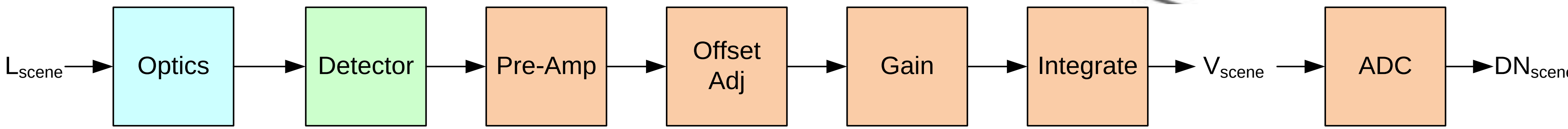

S-PRT

←


Fixed Point Cells

Calibration Model

RAL Space



Typically DN will be some function of scene radiance

$$DN_{scene} = F_{ADC}.(V\{A\Omega(\tau_{opt}L_{scene} + (1-\tau_{opt})L_{inst})\} + V_{off})$$

which reduces to

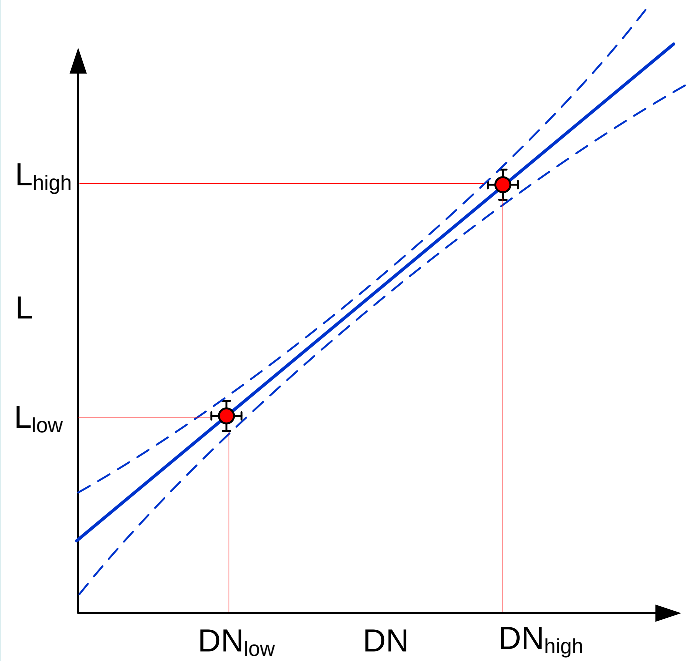
$$DN_{scene} = g(L_{scene}) + offset$$

We invert this to get scene radiance as a function of DN

$$L_{scene} = g^{-1}(DN_{scene} - DN_{offset})$$

$$\approx a_0 + a_1 DN_{scene} \text{ (assuming linear function)}$$

$$(uL_{scene})^2 = \sum_{i=0}^{n}(uL_i)^2$$



We obtain calibration coefficients via reference to known calibration sources

SLSTR L1 Processing

Processing specification defined by

ATBD -> DPM

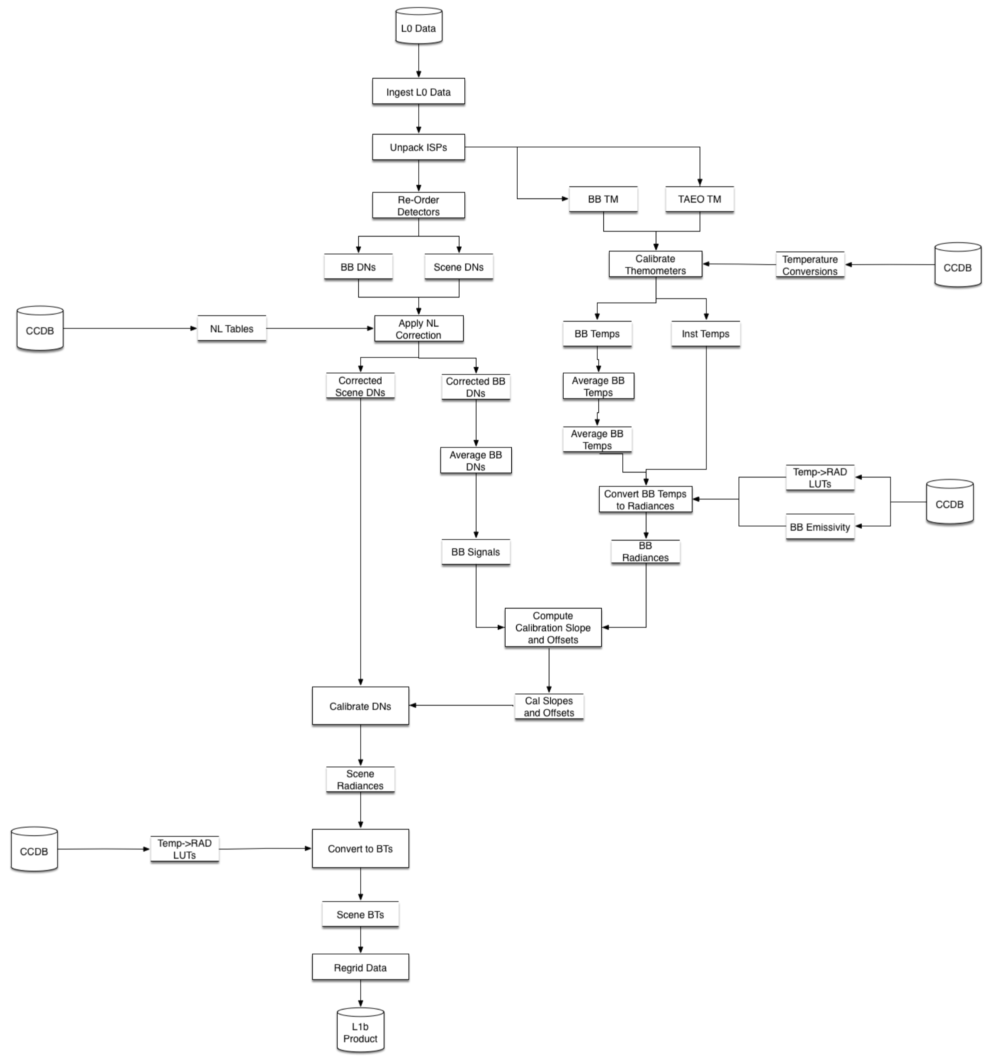
L0 and L1 Product Specifications

Each spectral band (5 thermal bands) and detector element (2x2) for each for each earth view (separate for nadir and oblique) has unique set of calibration calibration coefficients

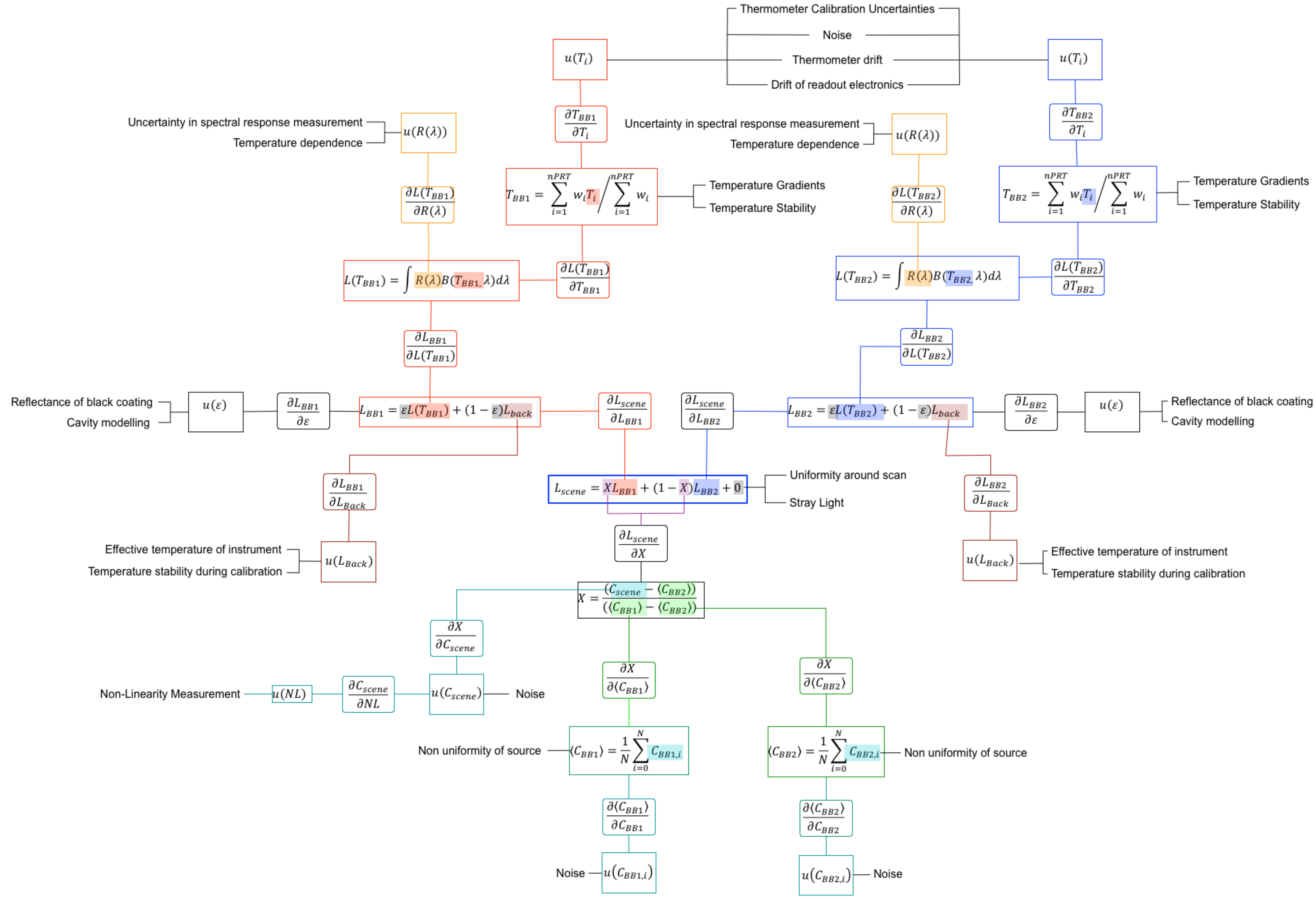
= 40 for IR channels alone

Contained in Satellite Characterisation and Calibration Database Document (S-CCDB)

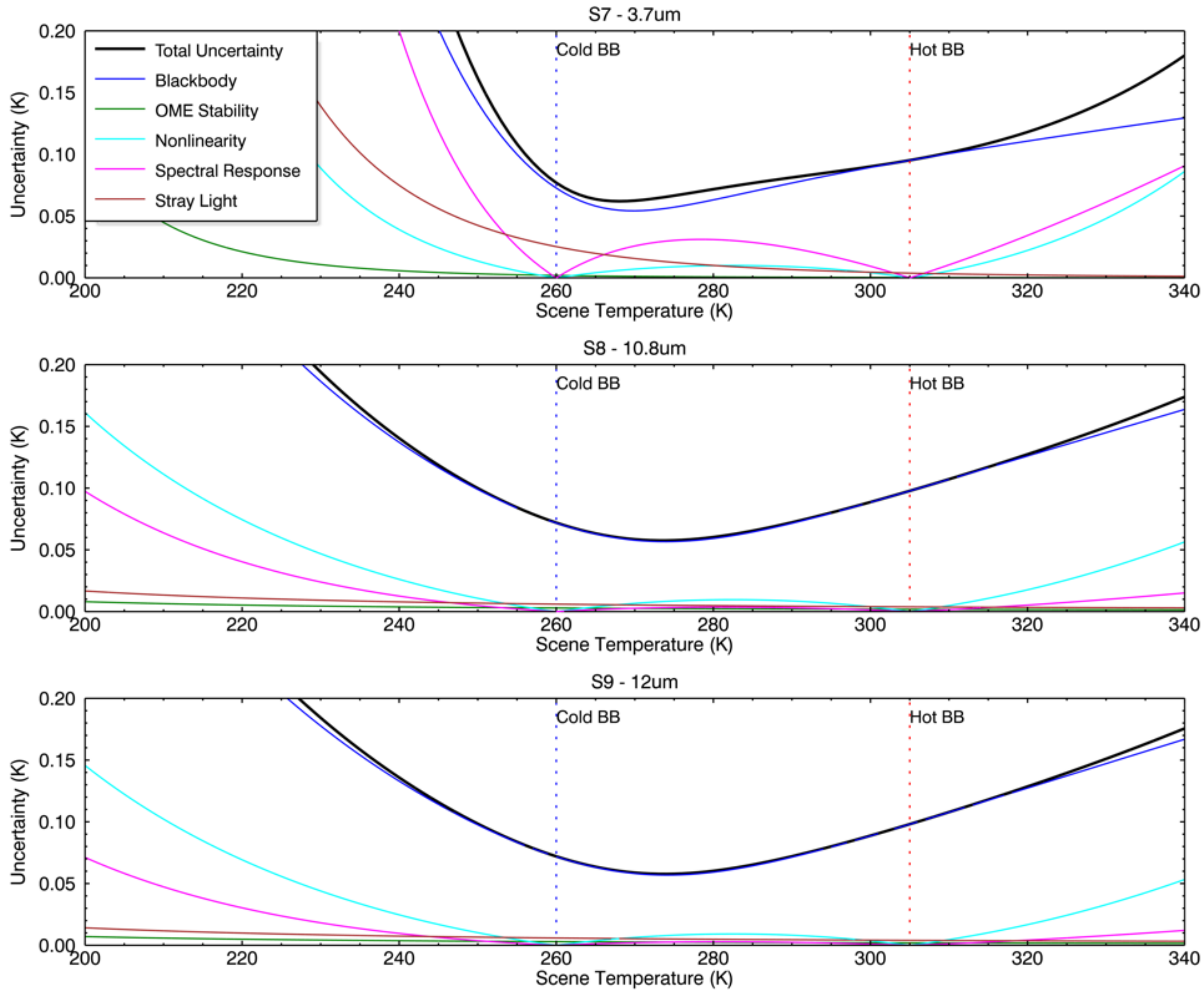
Configuration controlled by MPC



SLSTR IR Traceability Tree



SLSTR IR Channel Calibration Budget



This is the flight calibration budget

Instrument Calibration – Objectives

- **Provision of calibration data needed for data processing chain**

- **Does the end-to-end flight instrument calibration scheme work?**
  - New optical design – 2 telescopes not 1, multiple detectors per channel
  - OME thermal design – not based on AATSR heritage

- **Does the instrument calibration work over the full field of view and dynamic range?**
  - Wider instrument swath compared to AATSR
  - Nonlinearity, Noise performance, Dynamic range

- **Does calibration work in flight representative environment?**
  - Nominal BOL
  - EOL (Hot)
  - Orbital temperature variations

Calibration Topics

IR Radiometry

- Blackbody calibration
- Radiometric accuracy over dynamic range
- Linearity
- Radiometric noise performance
- Orbital Stability

Solar Channel Radiometry

- Calibration of VISCAL system
- Radiometric response over dynamic range
- Linearity
- Radiometric noise performance

Spectral Response Calibration

- In-band response
- Out of band response
- Temperature dependency of response

Geometric Calibration

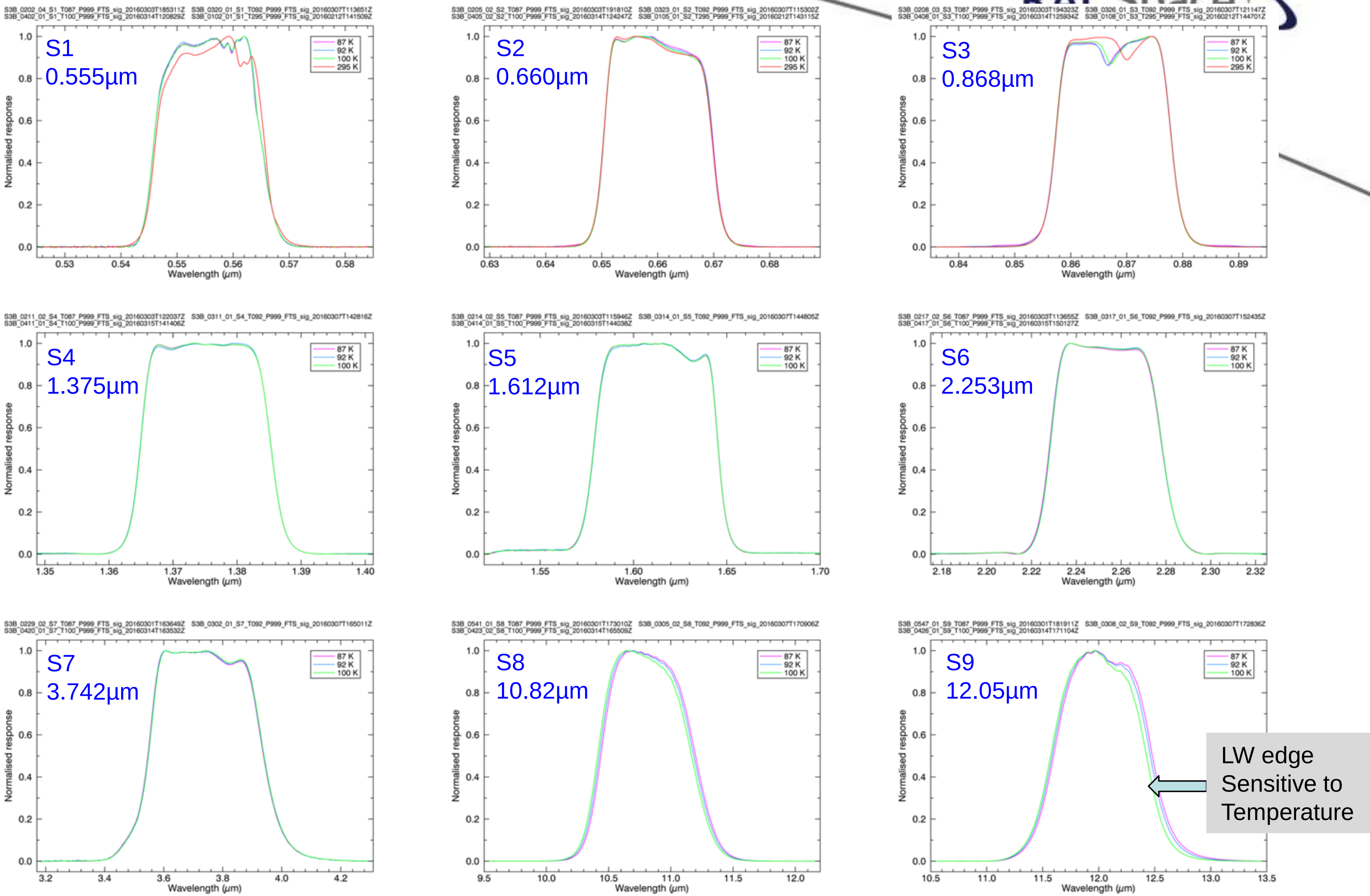
- Pointing Direction (LoS)
- Spatial Sampling
- Co-Registration
- Image Quality (MTF)

Spectral Response Calibration

- Measurement technique:
  - Operated the SLSTR focal plane array as the detector in a Michelson Fourier transform spectrometer
  - Derived spectral responses from time-resolved interferograms collected by the FPA detectors

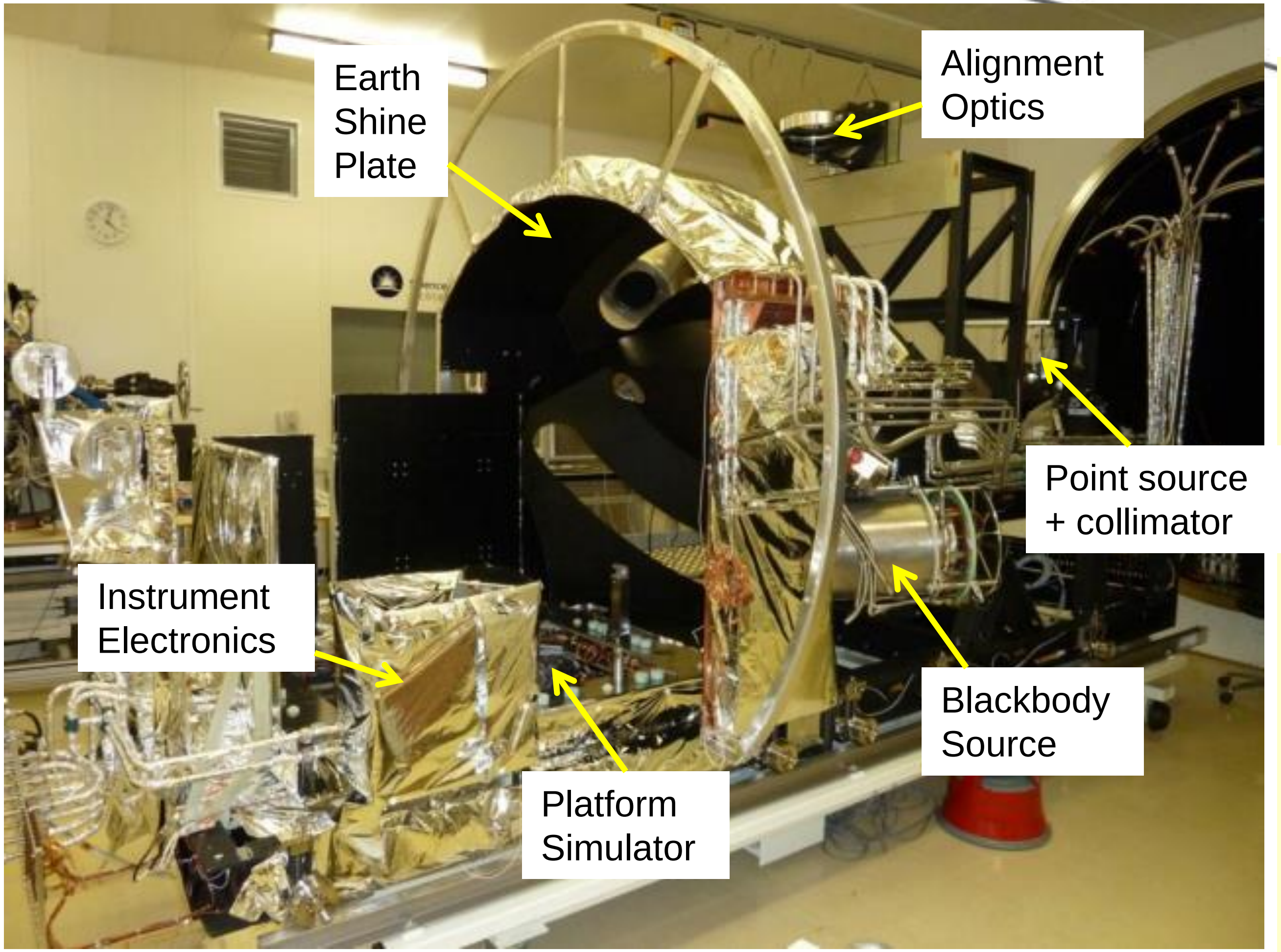
- Characterised:
  - Spectral responses of all standard channels (S1 – S9) at FPA temperatures of 87K, 92K, 100K
  - Spectral polarisation (depth, plane and unpolarised response) of longwave channels (S7 – S9) at an FPA temperature of 87K

Spectral Response Profiles



All channels within requirements ☺

Thermal IR Calibration Facility



Initial Trials with STM completed April 2012

TV and calibration of S3A instrument March-May 2015

S3B Calibration Oct 2016 – Feb 2017

S3C 2019

S3D 2020…

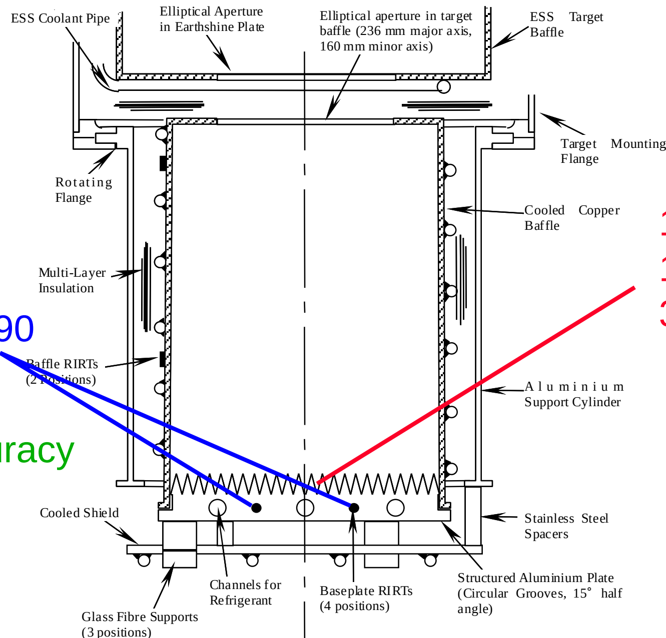
- ESA requirement to perform calibration tests under flight representative conditions.
  - *Thermal balance*
  - *Steady State*
  - *Instrument fully operational*

TIR calibration- Blackbody Source

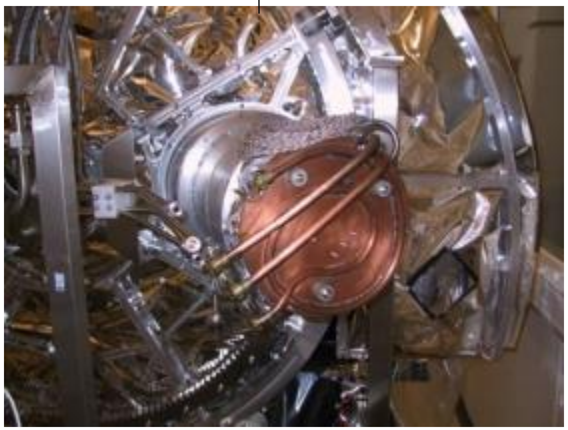
RAL Space

Precision RIRTs
Calibrated to ITS90
< 0.01K

Radiometric Accuracy
< 0.05K



Emissivity
12µm = 0.99871
11µm = 0.99870
3.7µm = 0.99911



Sources previously used for all ATSR instruments

Standards
↓
ATSR
↓
ATSR-2
↓
AATSR
↓
S3 SLSTR

IR Calibration Test Summary

- Calibration at ‘Nominal’ BOL conditions
  - Centre of Nadir/Oblique views
  - On-Board BBs at nominal settings (250K, 300K)
  - Test over full dynamic range (5K intervals)
  - Test over full swath (reduced number of scene temperatures)

- Calibration at ‘Hot’ EOL conditions
  - Centre of Nadir/Oblique views
  - On-Board BBs at nominal settings (250K, 300K)
  - Test over part dynamic range (10K intervals)

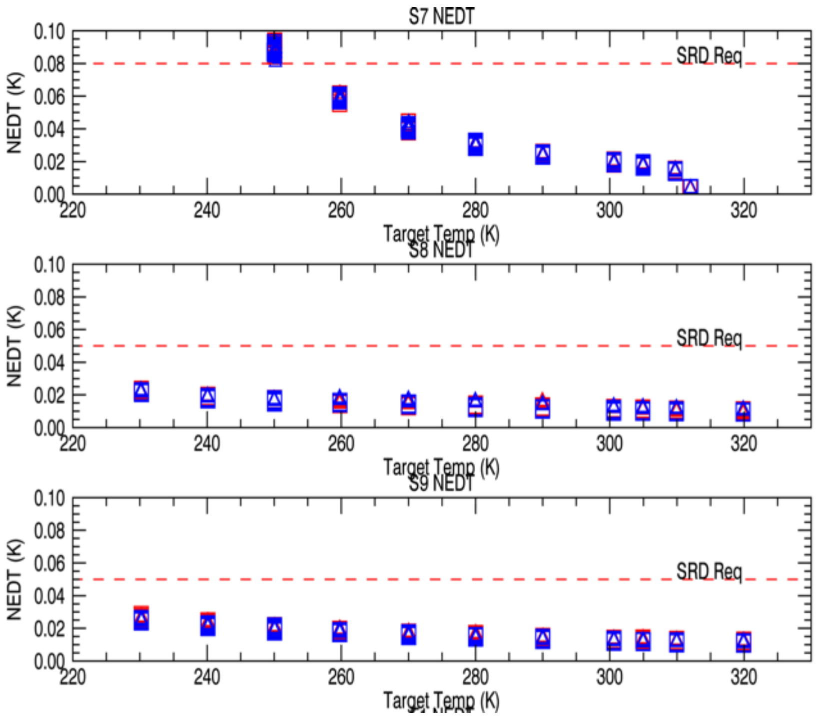
- Tests with different on-board BB temperatures
  - Test performed at ‘Nominal’ BOL conditions
  - Currently at ‘low’, ’medium’, ’high’ power settings
  - +Y and –Y BBs will be switched
  - Test over part dynamic range (10K intervals)

- Orbital simulation tests

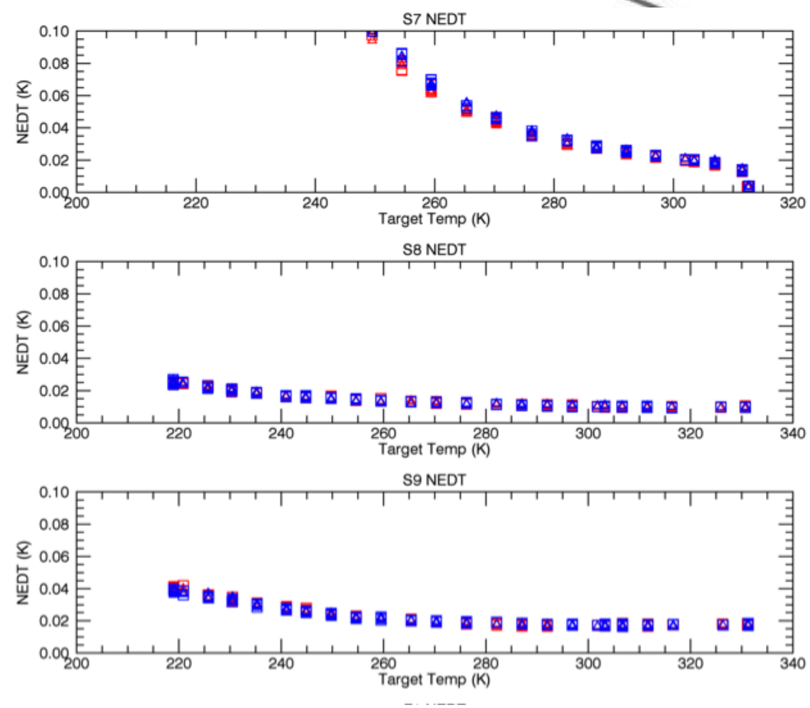
Radiometric Noise

RAL Space

SLSTR-B

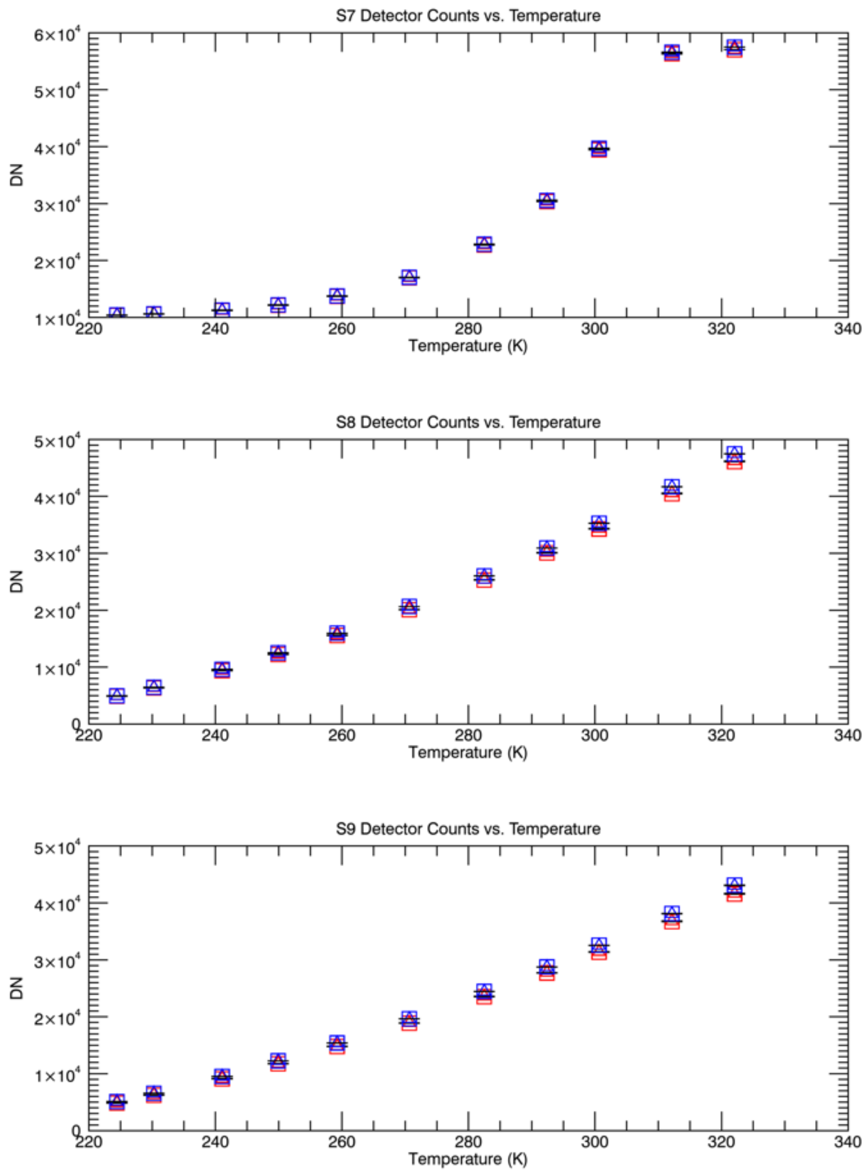


SLSTR-A



Both instruments have comparable NEDT performance and well inside mission requirements

IR Calibration - Counts Vs. Temps



70us integration time shown only

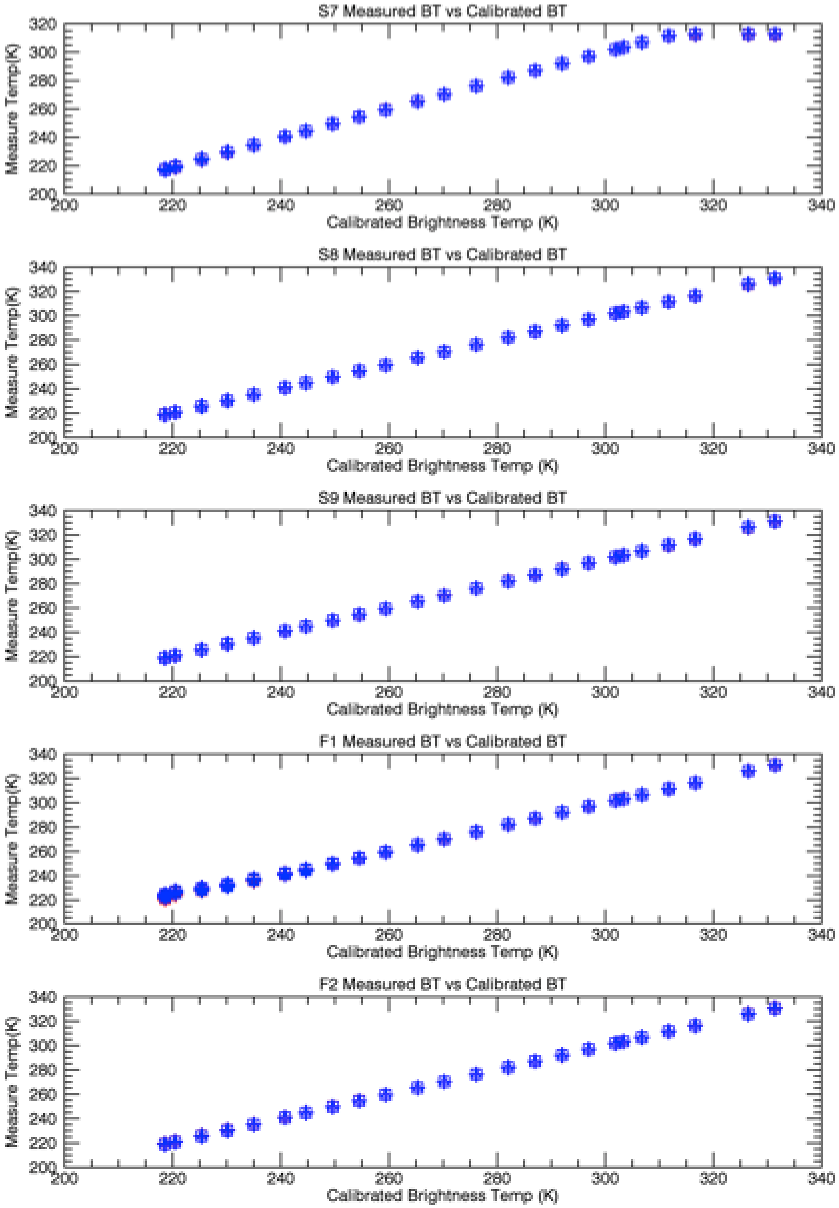
Min temperature achieved is 224K

Saturation of S7 > 300K (additional step at 305K to confirm)

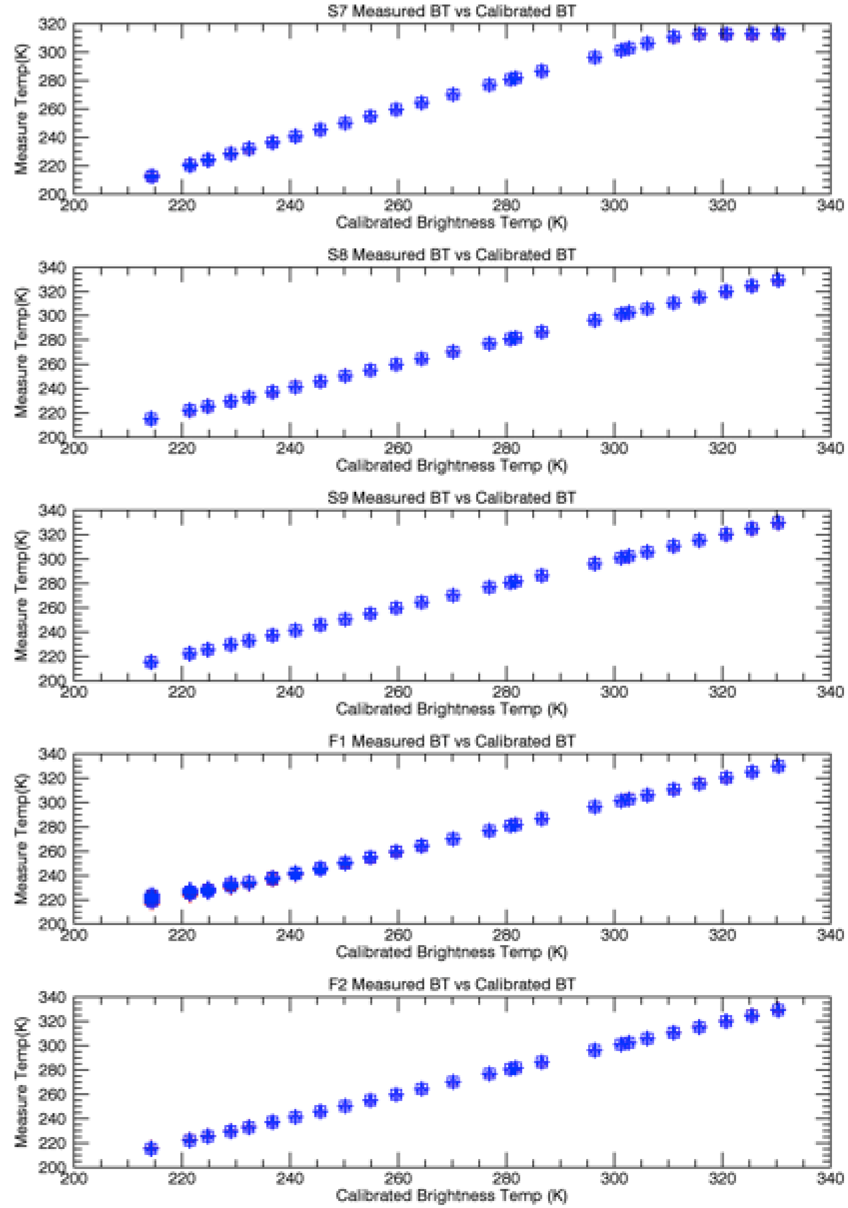
TIR Calibration - Measured vs Actual BT

RAL Space

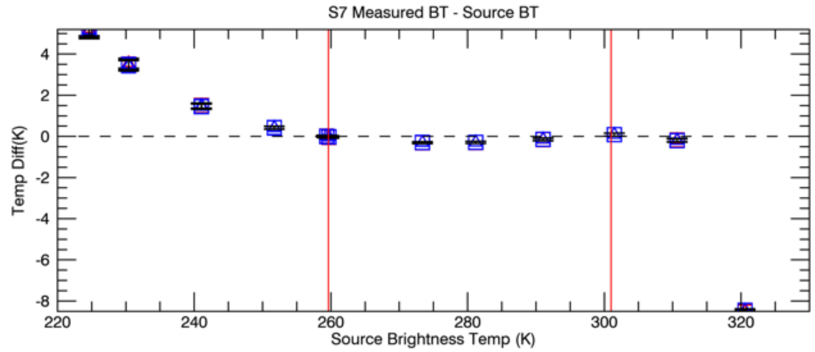
Nadir

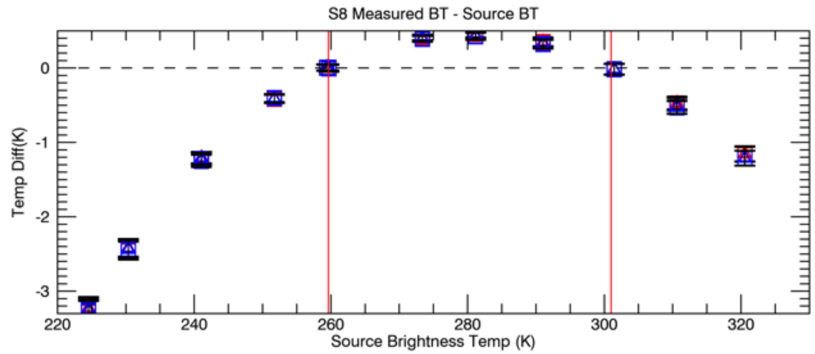


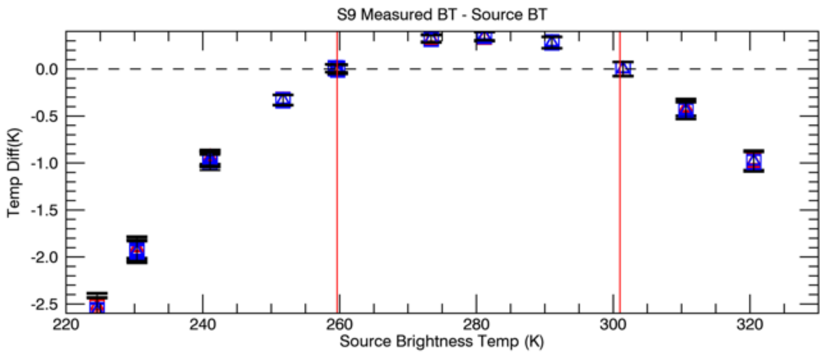
Oblique



IR Calibration Initial Results







Non-Linearity of S8 and S9 consistent with expected behaviour of PC MCT detectors.

S3A and S3B show very similar behaviour.

Creation of NL Table

Measured Counts and BB Radiances normalised to signal corresponding to 65535 counts

$$y = \frac{L_{actual}(DN) - L(0)}{L(DN_{ref}) - L(0)}$$ - from thermometers

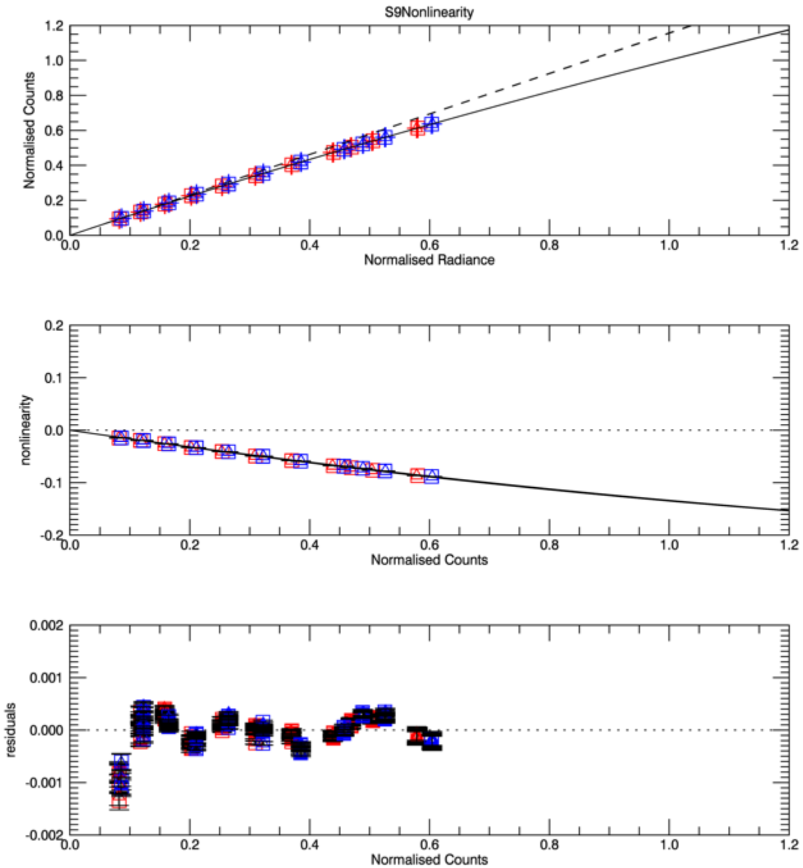
$$x = \frac{DN_{meas}}{DN_{ref}}$$ - from SLSTR

Polynomial function fitted to data to generate coefficients for NL function

$$NL = \sum_{i=2}^{n} \frac{a_i}{a_1} x^{i-1}$$

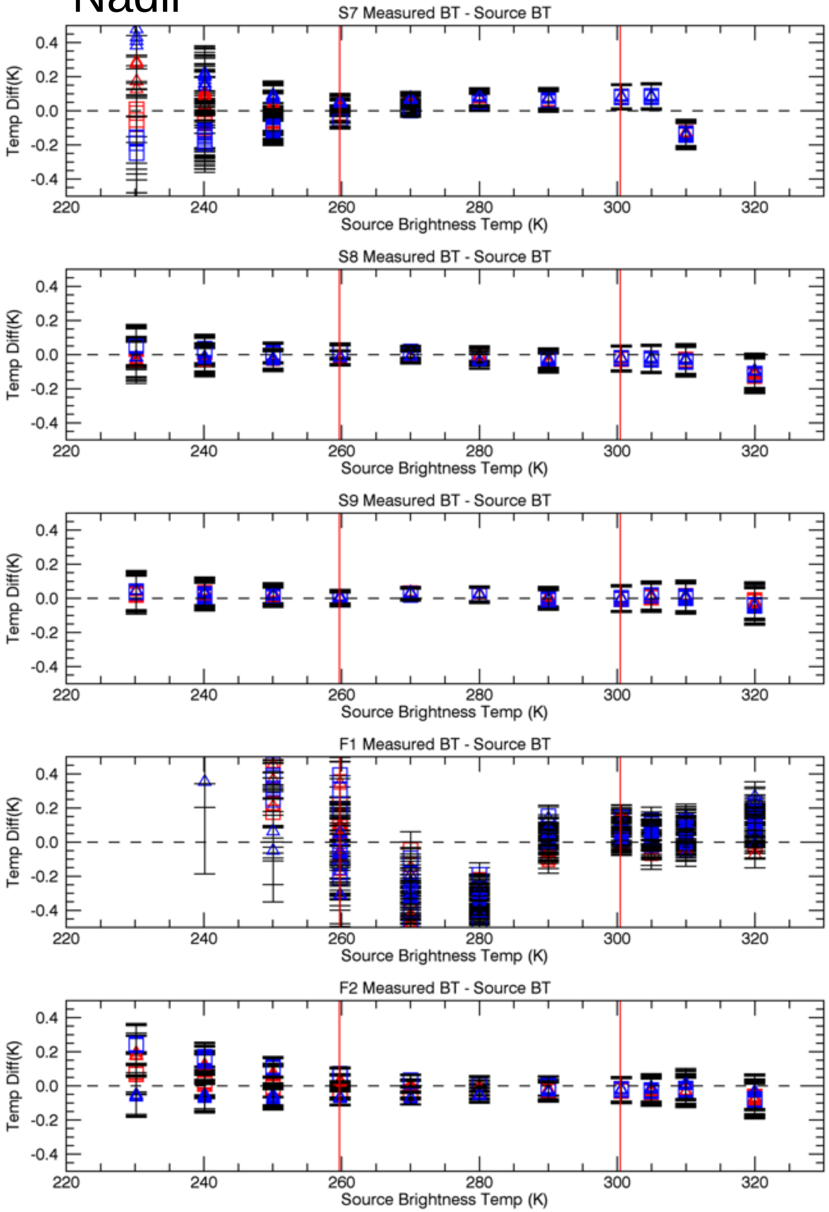
Digital counts are linearized using

$$D\acute{N} = DN/(1.0 + NL(x))$$

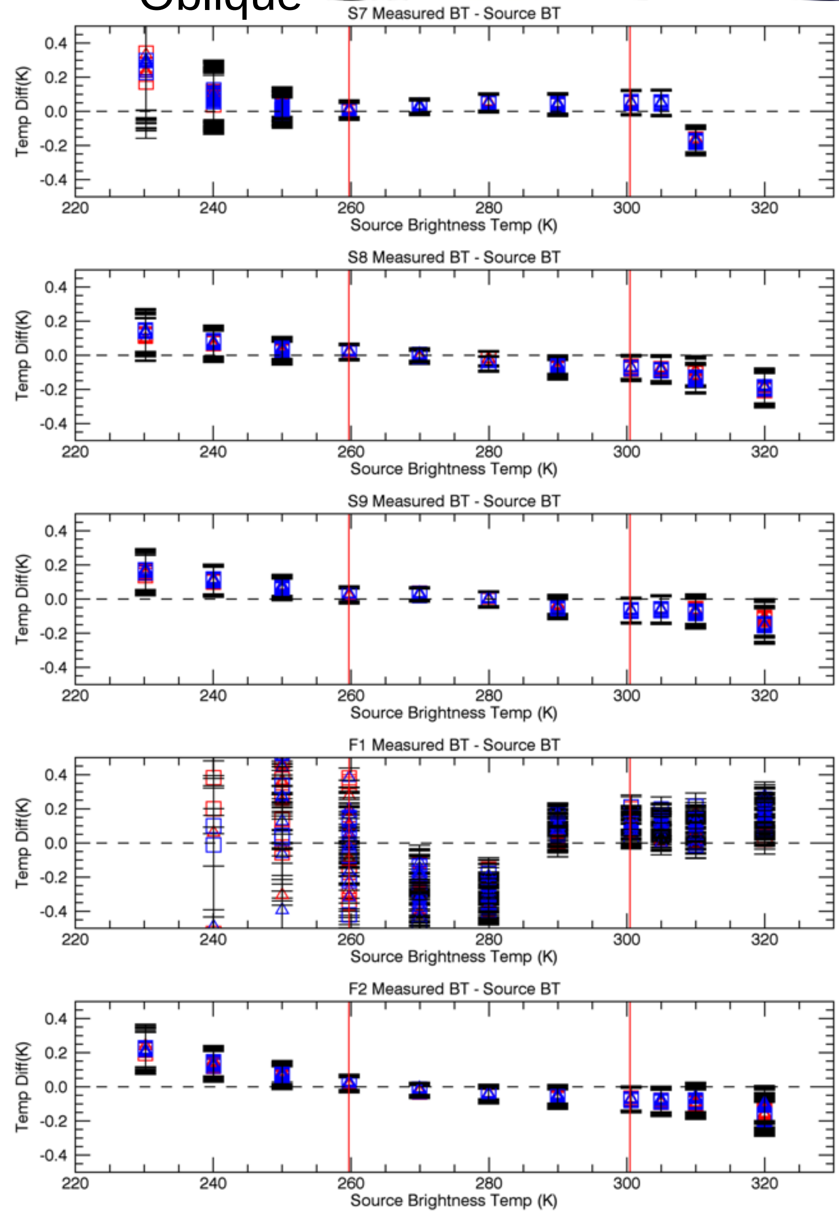


Measured - Actual BT SLSTR-B

Nadir

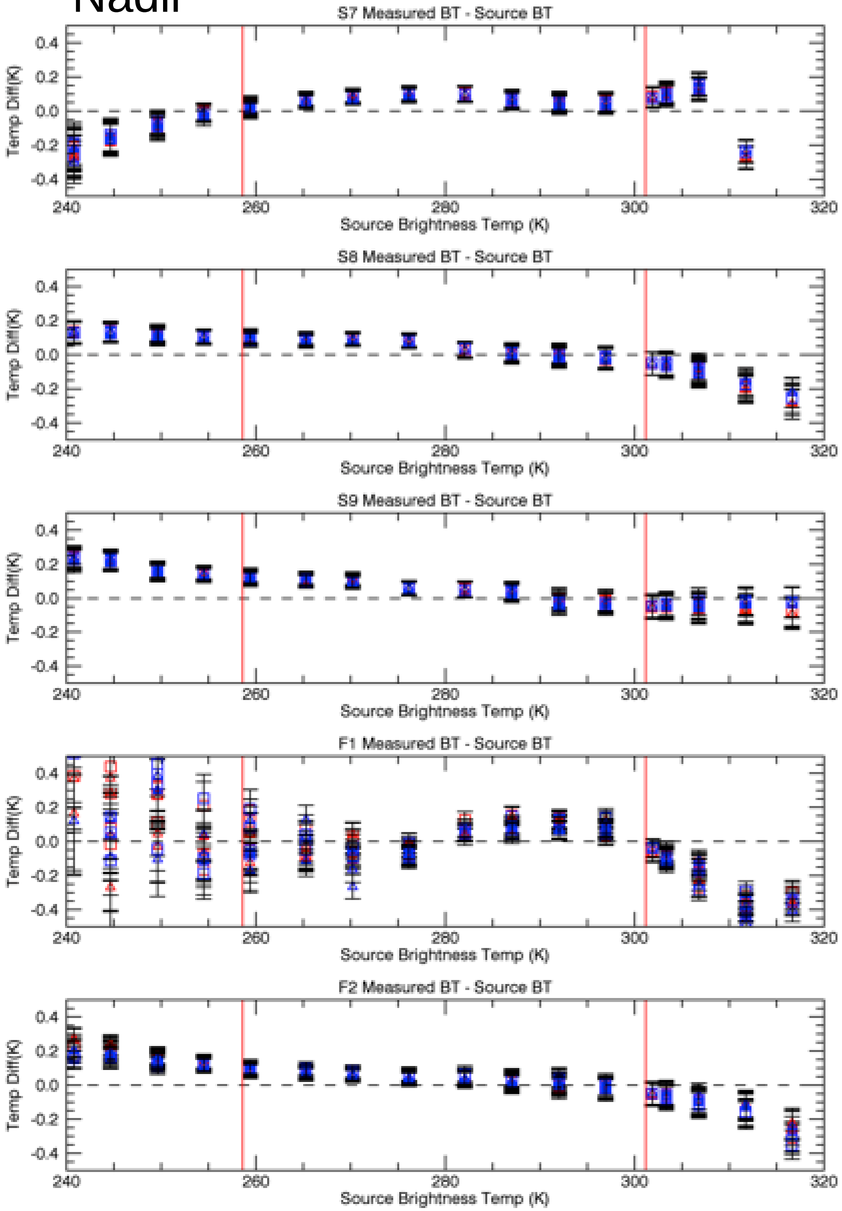


Oblique

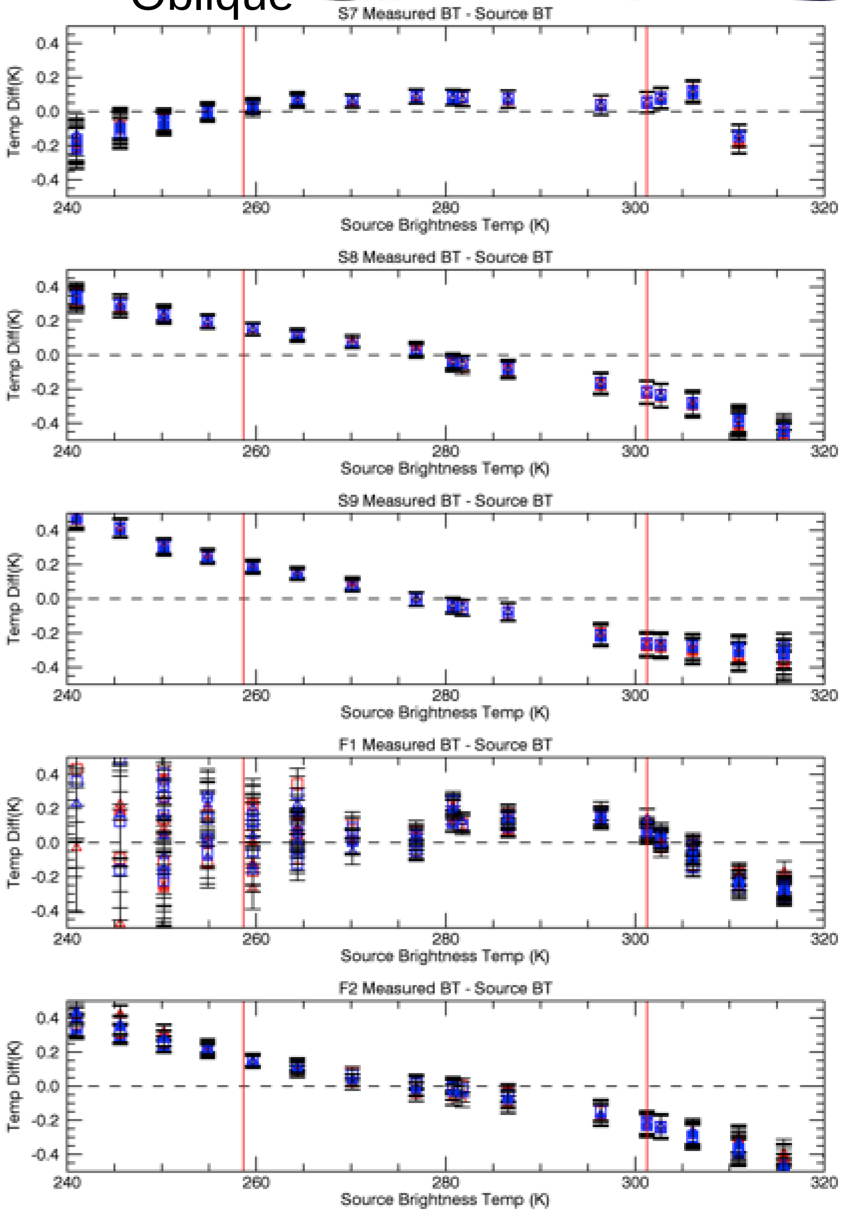


Measured - Actual BT SLSTR-A

Nadir

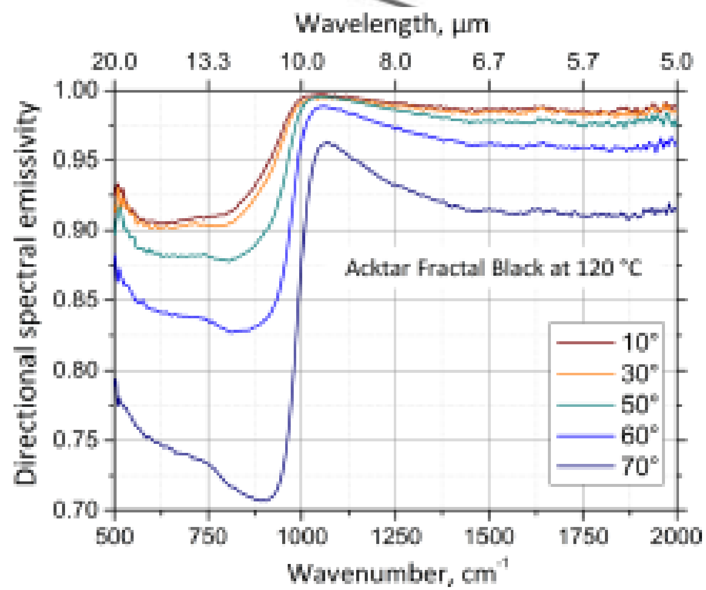


Oblique



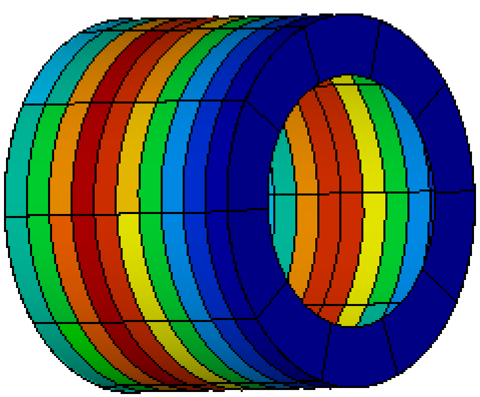
Why the differences?

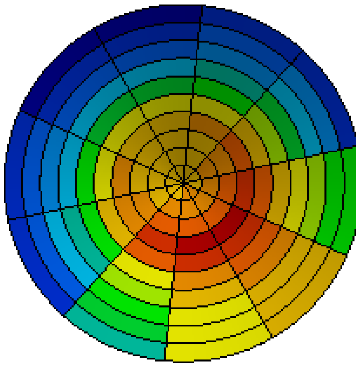
Non-Blackness of optical stops (i.e. ε < 0.9) causing non-uniform thermal background



Measurements by PTB confirm 2015 investigation

Hence modification to stop coatings





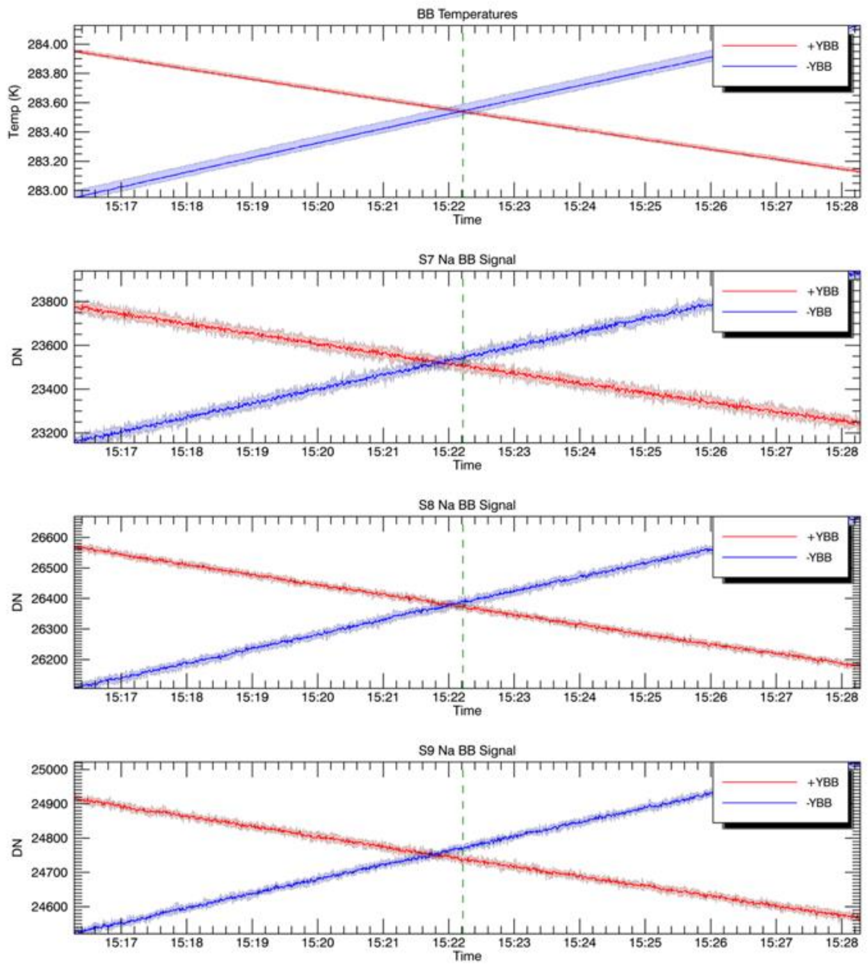
Temperature gradients in flight BBs

Thermal modelling shows asymmetry of baseplate temperatures

Analysis of BB radiances in progress

Black-Body Cross-Over Test

Nadir Scanner

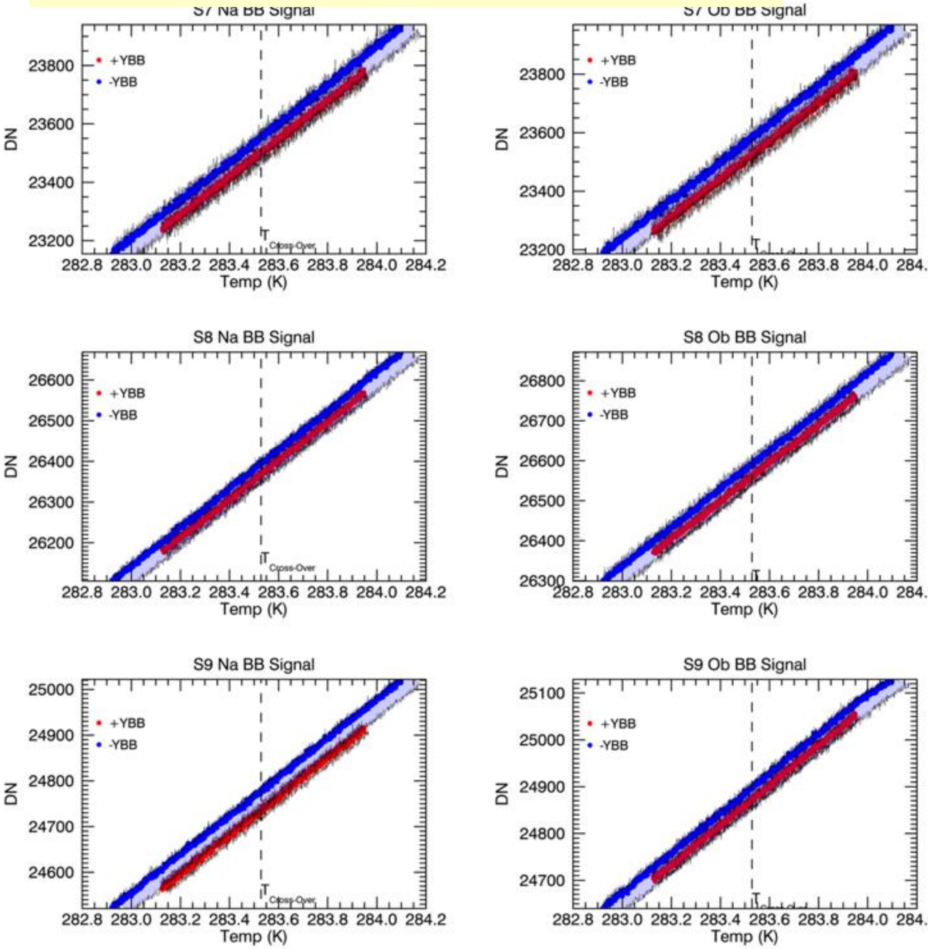


Post launch – we can ‘check’ BB signals by comparing the signals when the BBs are at the same temperatures. This is achieved by switching the heated BB and allowing their temperatures to cross-over.

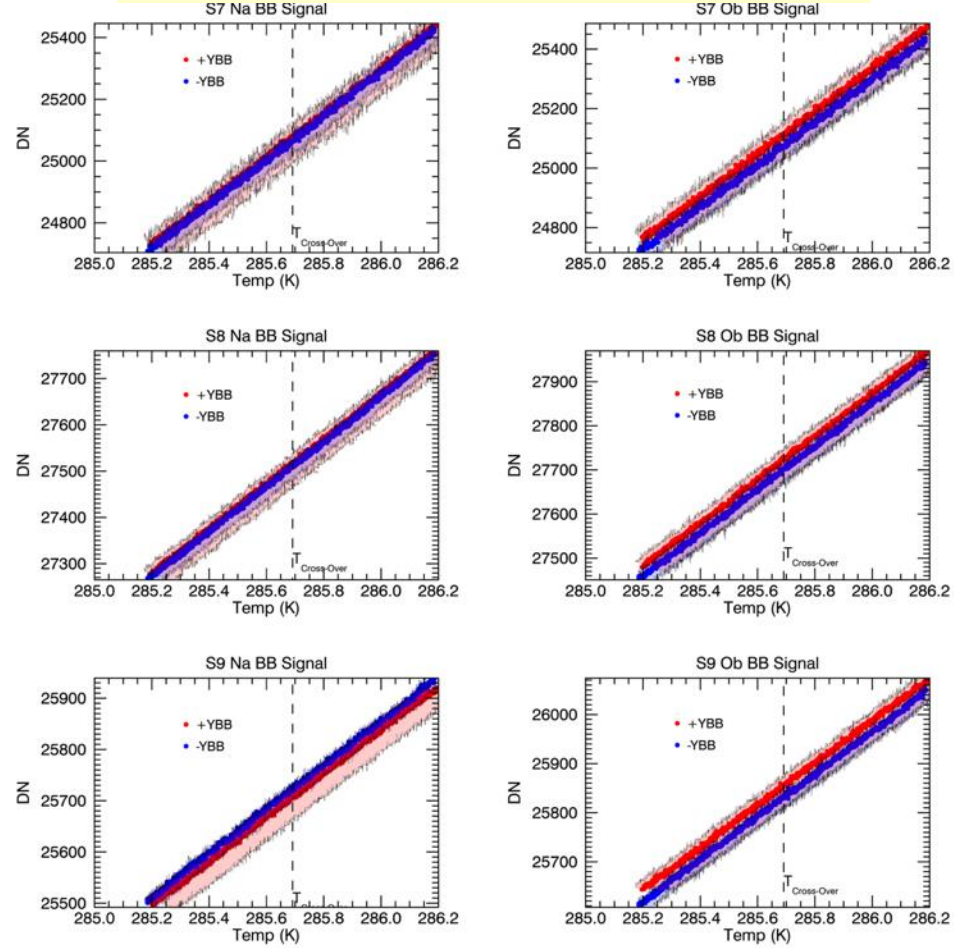
Test is performed during ground calibration as a baseline

Comparison DN vs BB Temps

1st Cross Over (RAD06)



2nd Cross Over (RAD08)



S3B BB Counts at Cross-Over

BB X-Over 1 - Temp = 283.529K

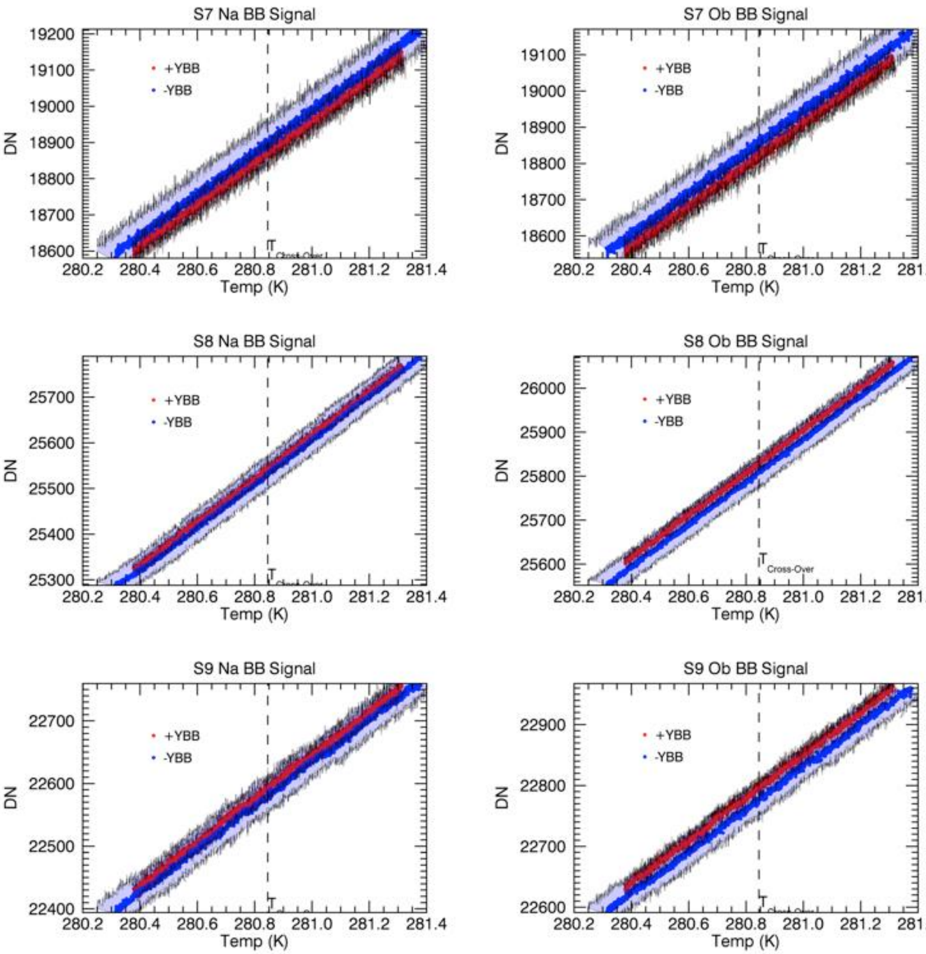
	+YBB	-YBB	ΔDN	ΔT
S7 Nadir	23501	23554	53	**0.082**
S8 Nadir	26397	26394	-3	**0.055**
S9 Nadir	24735	24778	43	**0.101**
S7 Oblique	23524	23584	60	**0.002**
S8 Oblique	26560	26591	31	**0.002**
S9 Oblique	24872	24896	24	**0.002**

BB X-Over 2 Temp = 285.690K

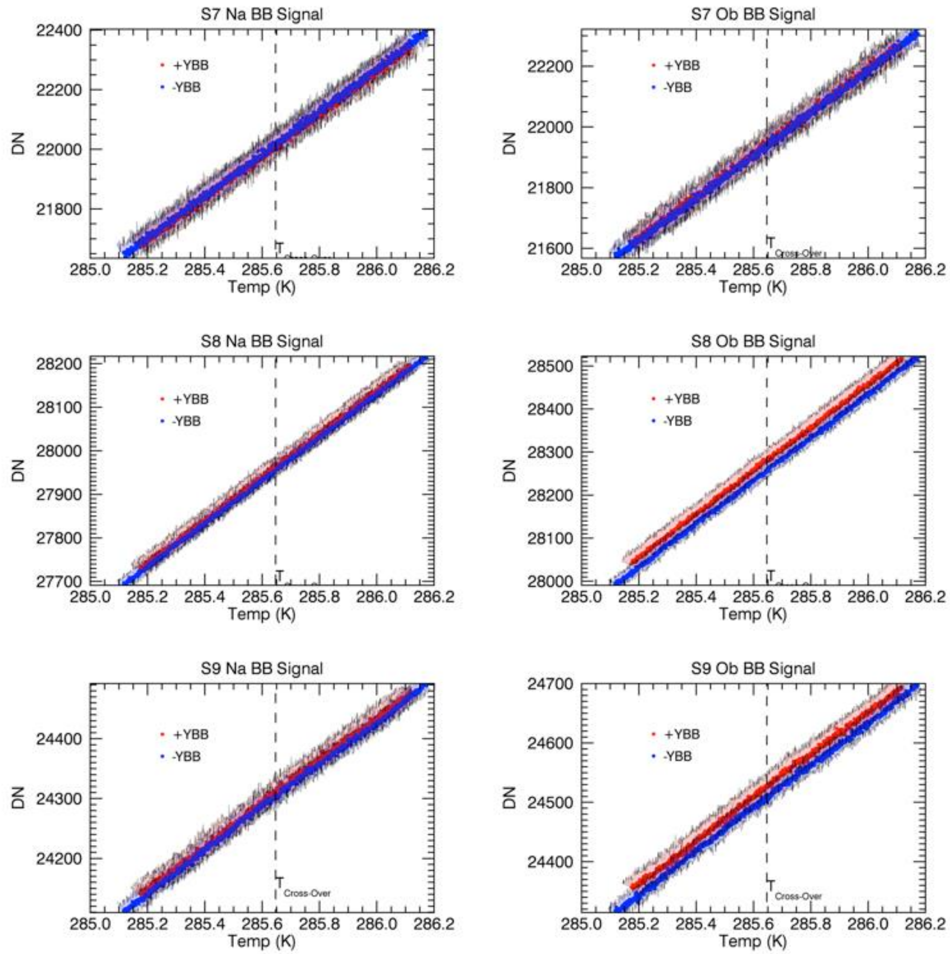
	+YBB	-YBB	ΔDN	ΔT
S7 Nadir	25077	25070	-7	**-0.010**
S8 Nadir	27516	27511	-5	**-0.011**
S9 Nadir	25706	25723	17	**0.038**
S7 Oblique	25114	25079	-35	**-0.050**
S8 Oblique	27722	27700	-22	**-0.046**
S9 Oblique	25854	25831	-23	**-0.054**

SLSTR-A Pre-Launch

Part 1



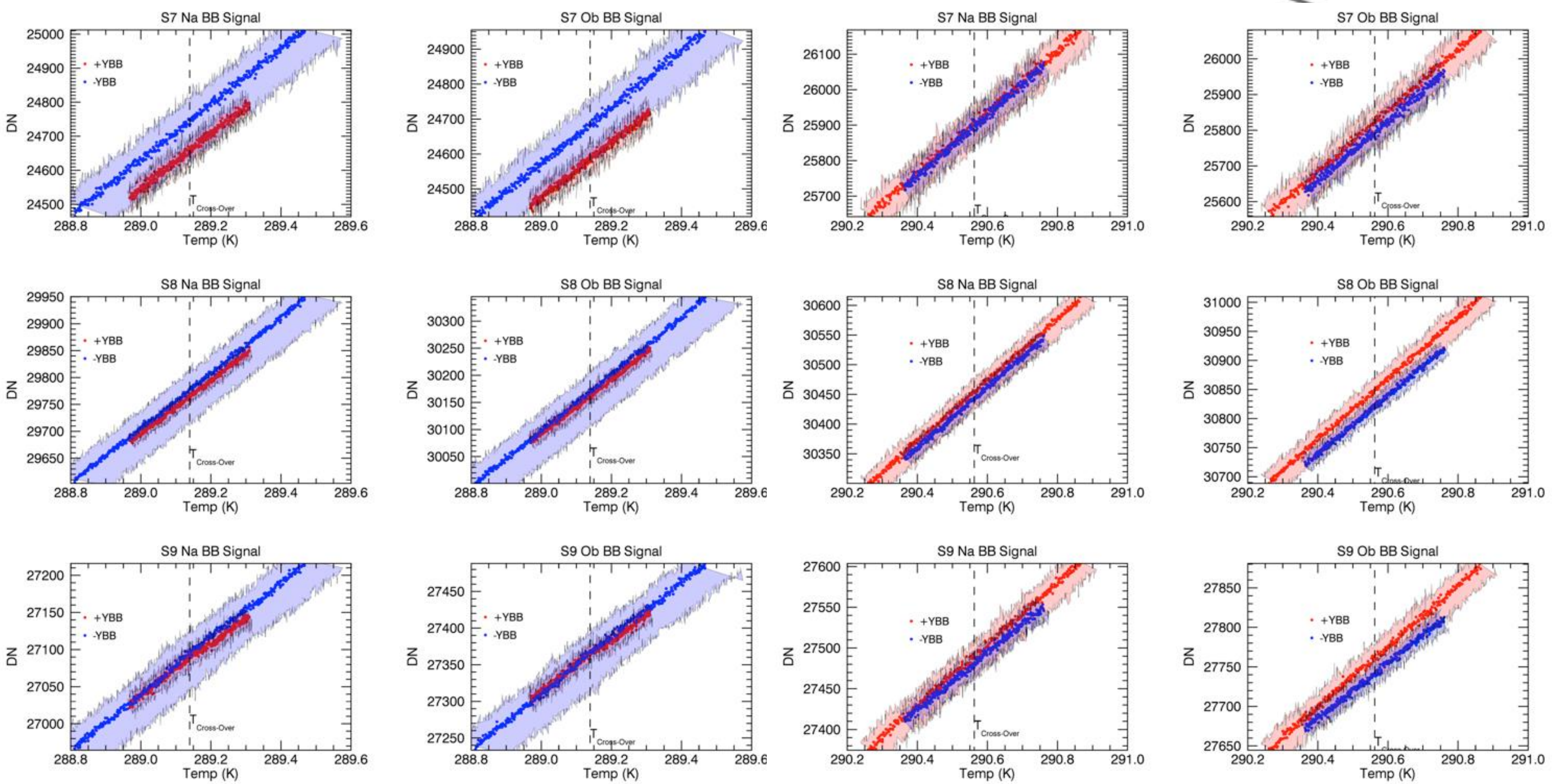
Part 2



SLSTR-A – Post Launch

RAL Space

Part 1 | Part 2



S3A BB Counts Comparison at X-Over

Post Launch – 29 Mar-2016

BB X-Over 1 - Temp = 289.1392K

	+YBB	-YBB	ΔDN	ΔT
S7 Nadir	24658	24745	87	**0.108**
S8 Nadir	29764	29777	13	**0.026**
S9 Nadir	27087	27093	6	**0.017**
S7 Oblique	24585	24685	100	**0.128**
S8 Oblique	30162	30171	8	**0.017**
S9 Oblique	27363	27364	1	**0.004**

BB X-Over 2 Temp = 290.5619K

	+YBB	-YBB	ΔDN	ΔT
S7 Nadir	25904	25896	-8	**-0.010**
S8 Nadir	30454	30443	-11	**-0.022**
S9 Nadir	27490	27481	-9	**-0.024**
S7 Oblique	25821	25794	-27	**-0.031**
S8 Oblique	30849	30821	-28	**-0.054**
S9 Oblique	27762	27742	-20	**-0.052**

Pre Launch – 29 Mar-2016

BB X-Over 1 - Temp = 280.85K

	+YBB	-YBB	ΔDN	ΔT
S7 Nadir	18868	18898	31	**0.053**
S8 Nadir	25543	25531	-12	**-0.025**
S9 Nadir	22593	22581	-12	**-0.036**
S7 Oblique	18819	18857	37	**0.065**
S8 Oblique	25830	25809	-21	**-0.043**
S9 Oblique	22797	22777	-20	**-0.059**

BB X-Over 2 Temp = 285.65K

	+YBB	-YBB	ΔDN	ΔT
S7 Nadir	22010	22016	6	**0.009**
S8 Nadir	27963	27955	-8	**-0.017**
S9 Nadir	24311	24304	-7	**-0.019**
S7 Oblique	21942	21937	-5	**-0.007**
S8 Oblique	28280	28257	-24	**-0.047**
S9 Oblique	24527	24509	-18	**-0.049**

On-Orbit Monitoring

- Routine monitoring of SLSTR performance is performed by Sentinel-3 Mission Performance Centre
  - Analysis of parameters critical for on-orbit calibration

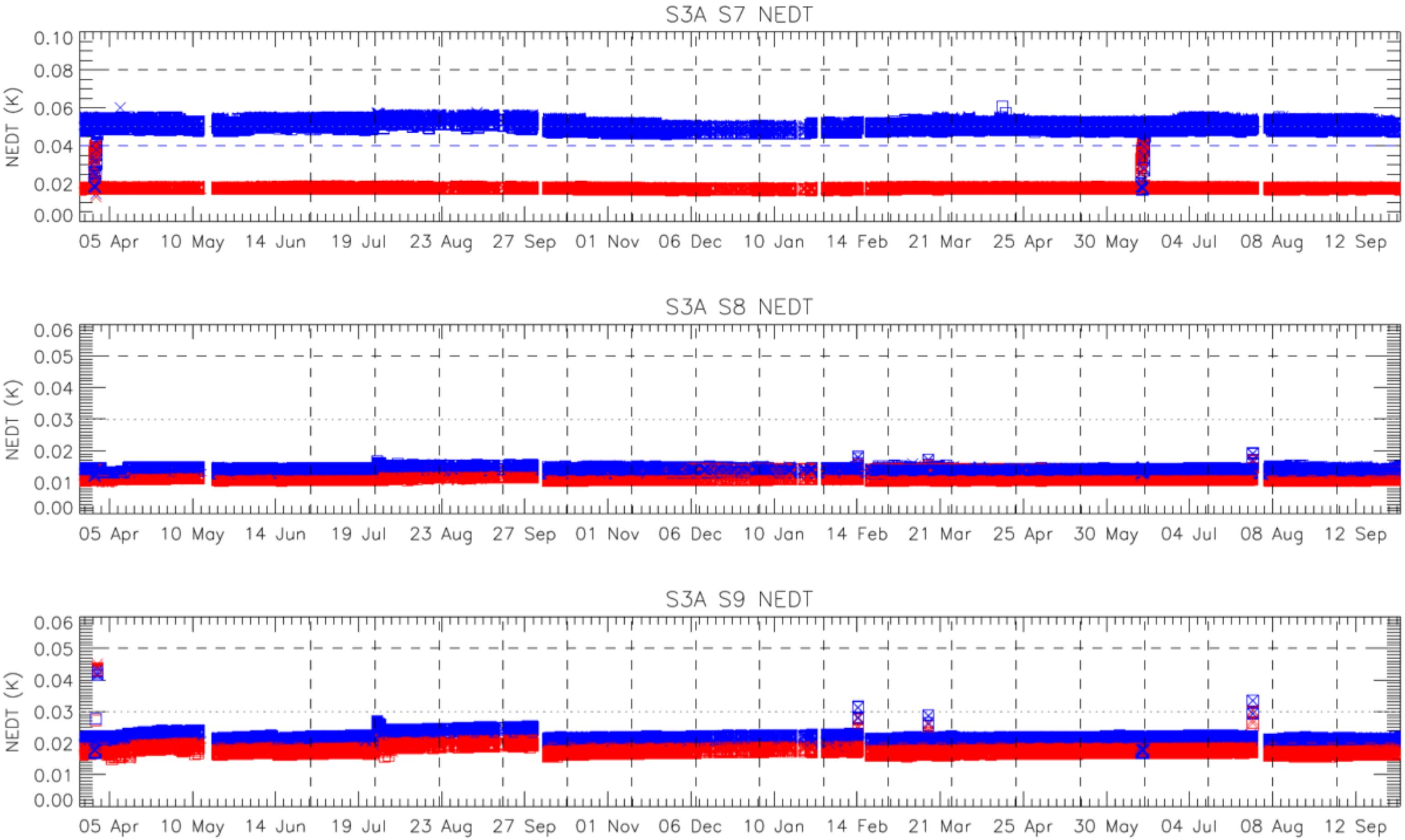
- Analysis of SLSTR data are performed using.
  - Level-0 data are provided via the MPC FTP server.
  - Level-1 assessment is made via IPF products made available on the MPC server.

- Routine monitoring plots for L0 data are available at:

http://gws-access.ceda.ac.uk/public/slstr_cpa/phase_E1/SLSTR_Calibration.html

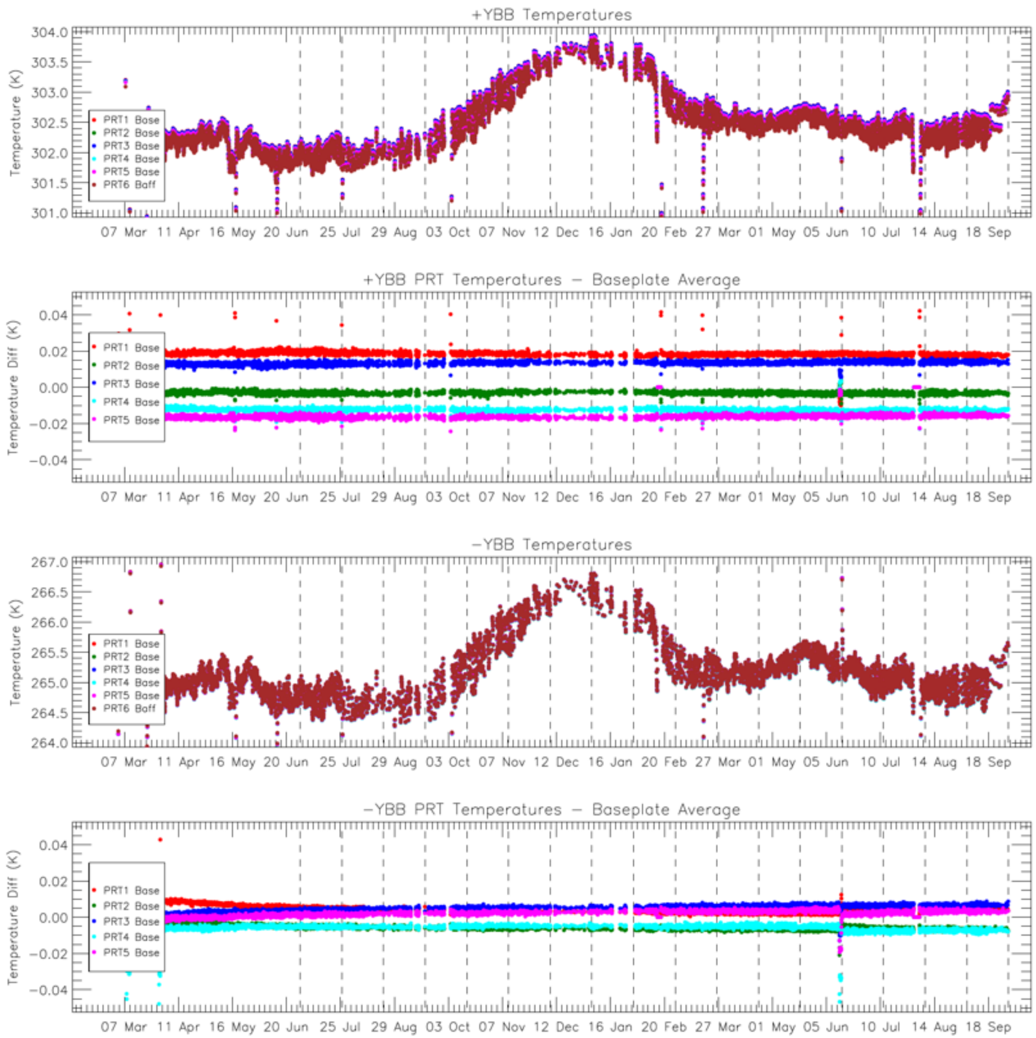
with username RAL_monitoring and password Sentinel3_RAL.

TIR Radiometric Noise Performance



All channels within specification

BB Temperatures

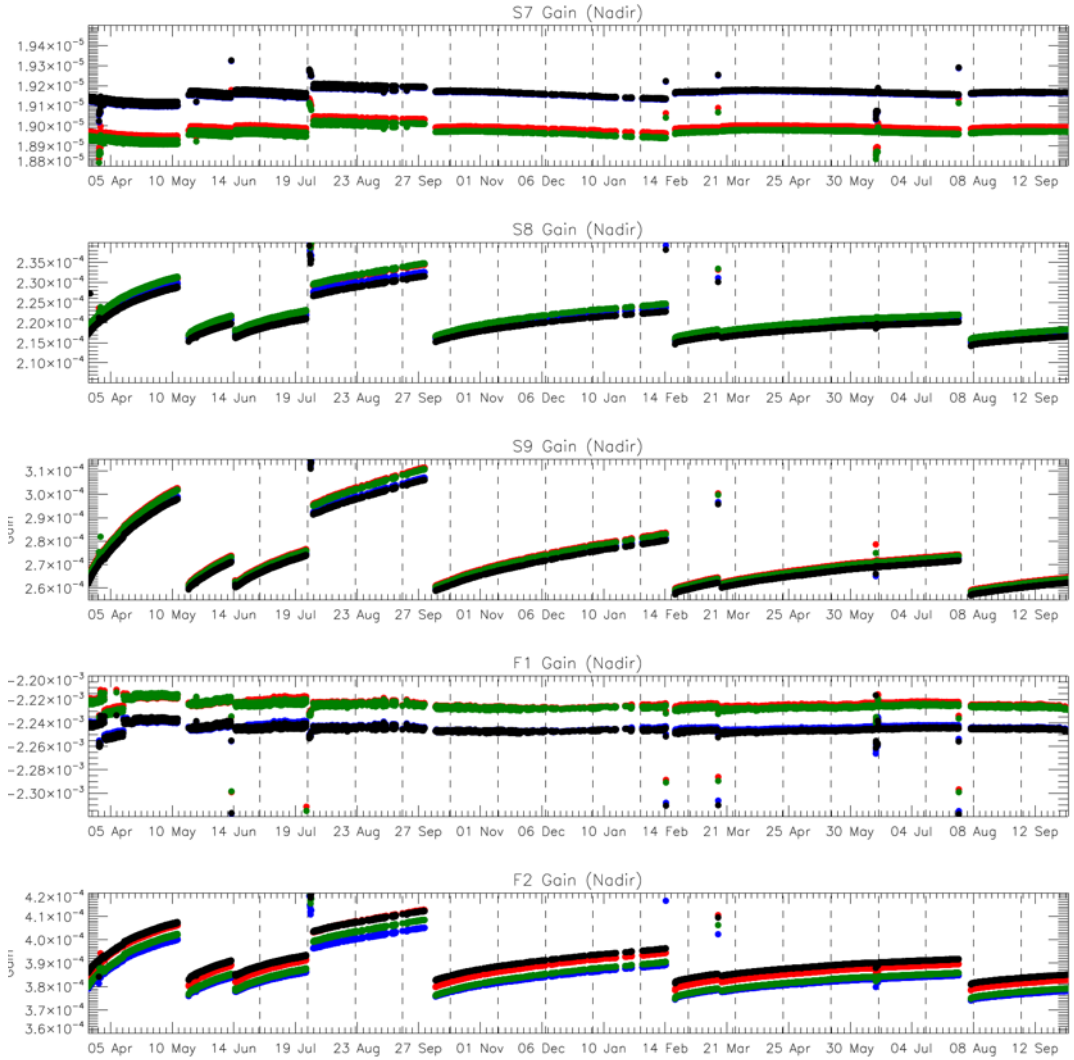


Heated BB temperature showed increase towards perihelion – Tbb ~ 304K – just below S7 saturation threshold (305K).

May need to reduce heater power to avoid Tbb = 305K

Small drift of PRT#1 (centre of BB) observed

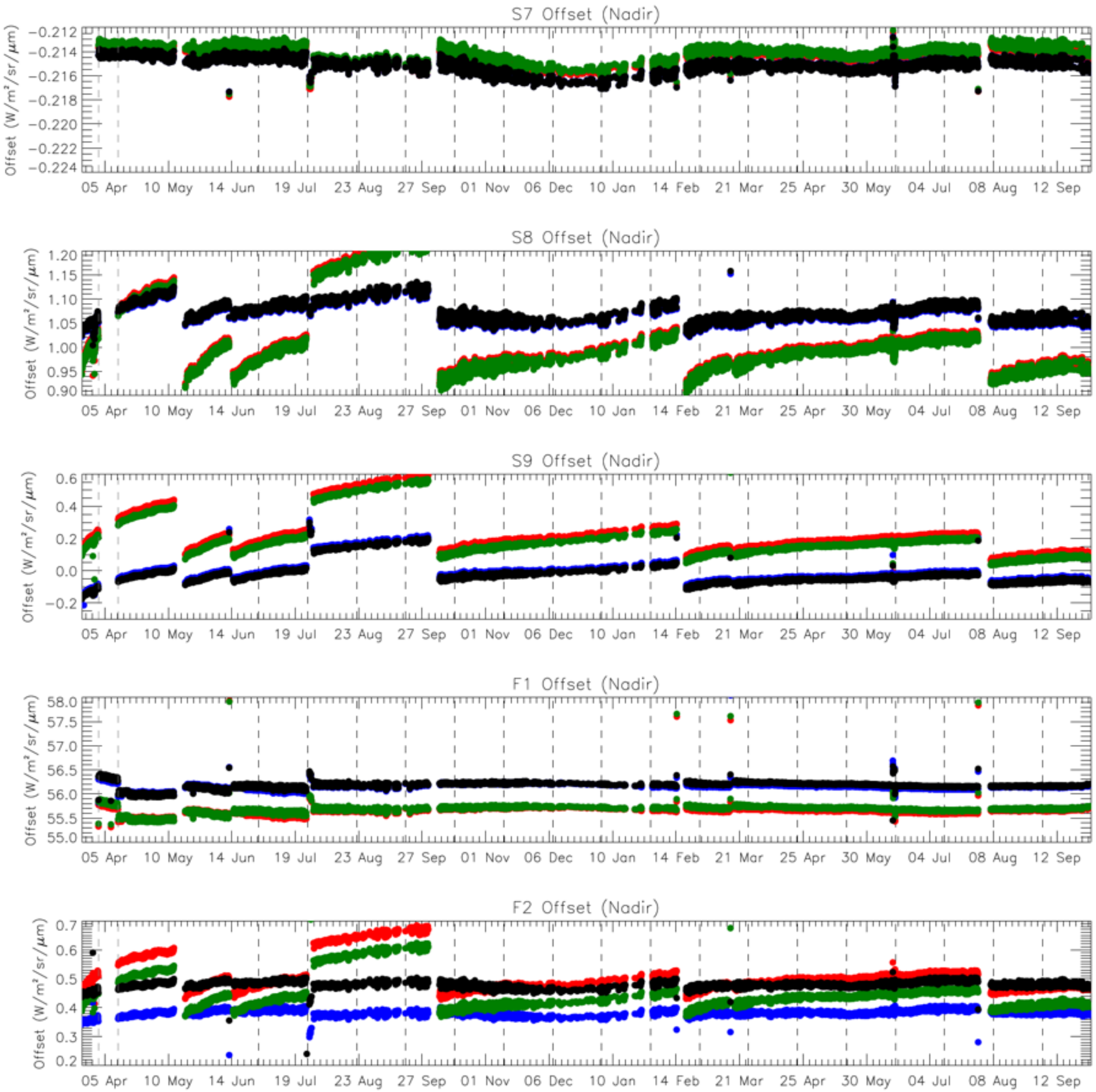
IR Gains



IR gains show increase as detector temperatures warm-up between outgassing cycles.

Calibration should compensate but may see variations in calibration at extremes of scene temperature range due to non-linearity errors.

IR Channel Offsets

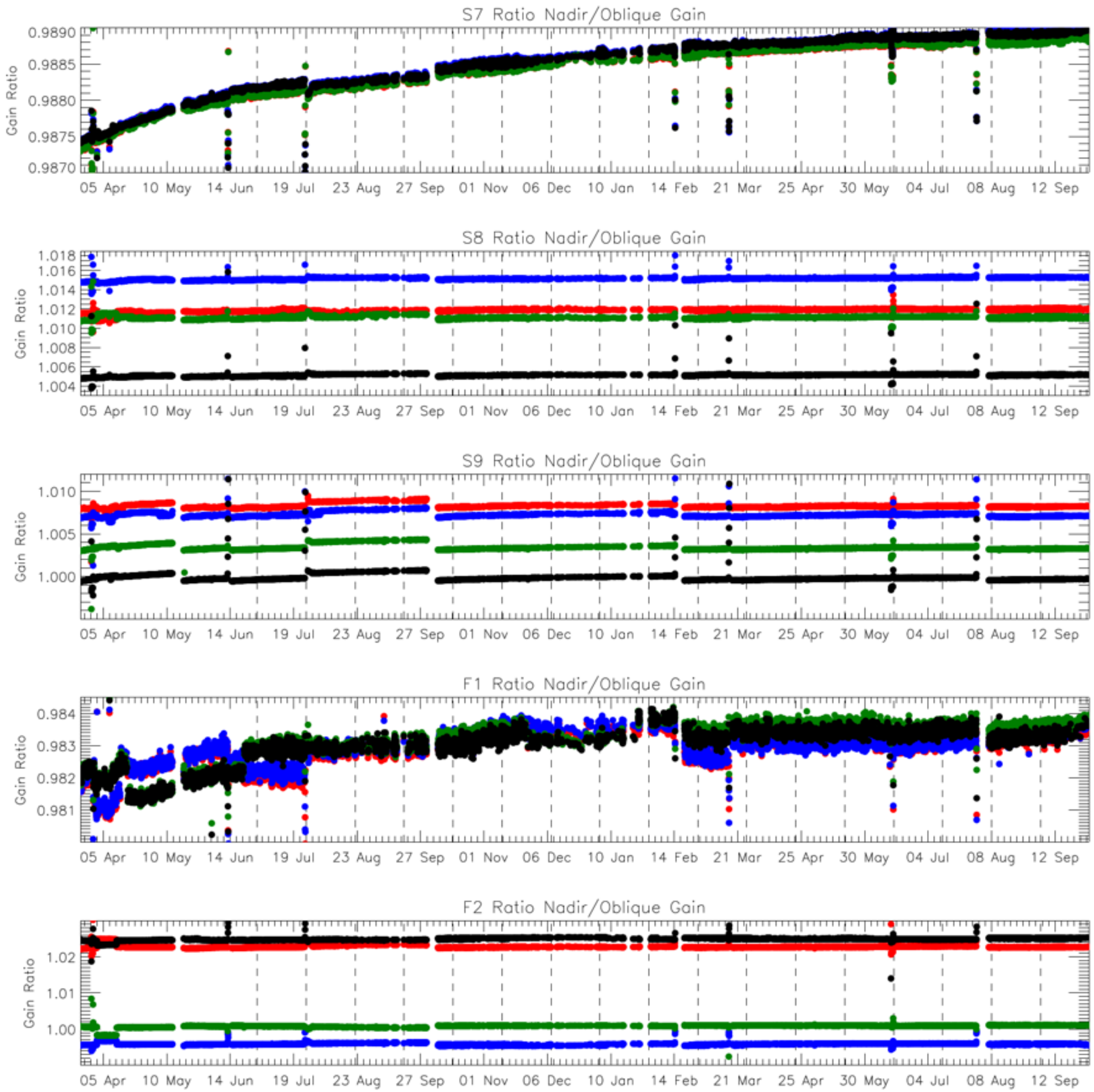


IR offsets show small variation due to detector and optics temperature variations.

Offset variations will determine minimum BTs (see later slides on S8 minimum temperature)

Note each detector and odd/even pixels have different offset values

Nadir/Oblique View Comparisons



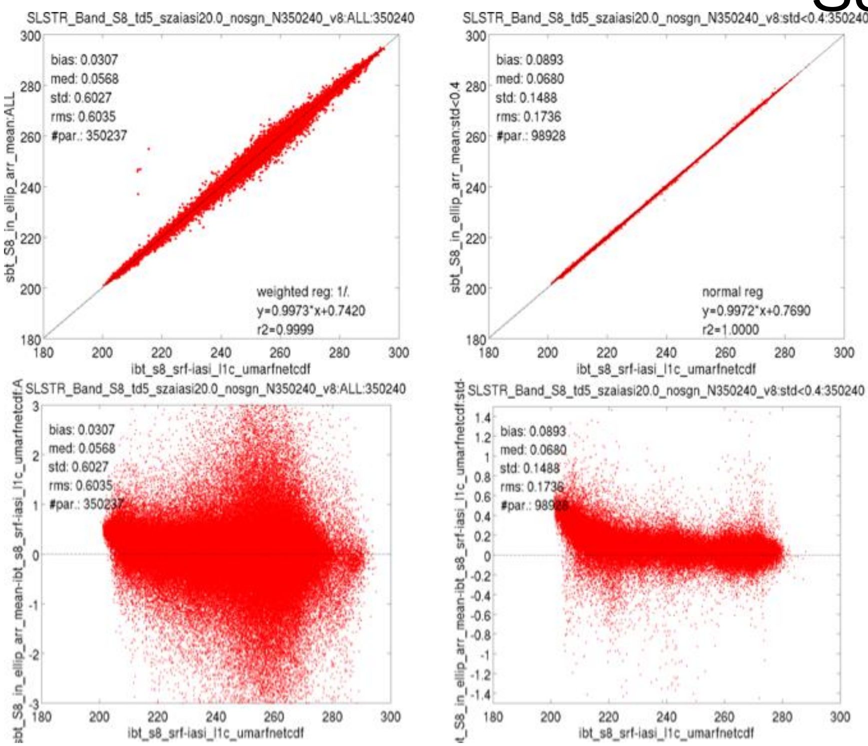
S7 shows change between gains of Nadir and Oblique views ~ 0.1%

S8/S9 show small differences <0.01%

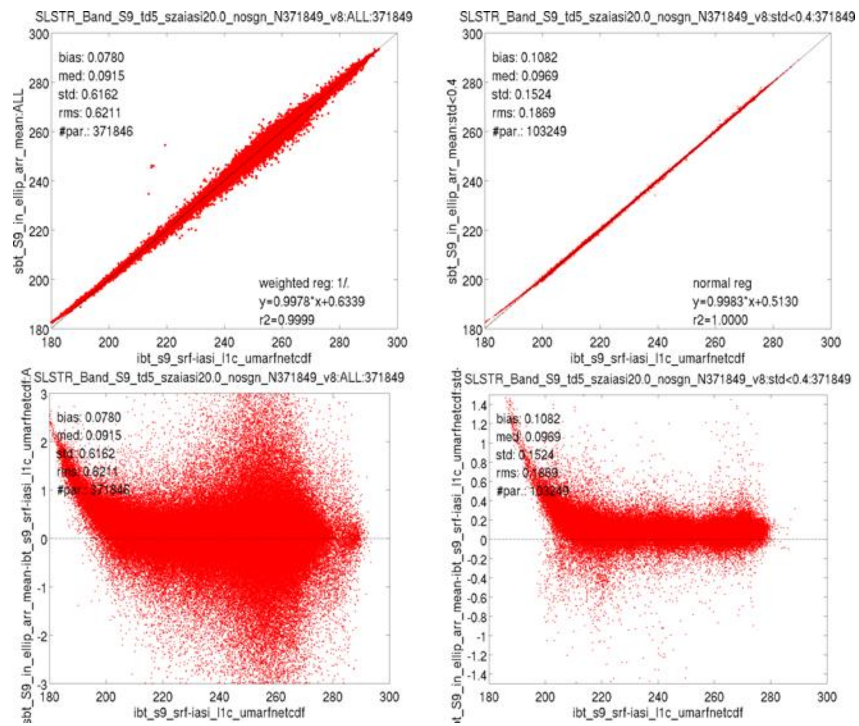
SLSTR-A – IASI-A Comparisons

Time Difference 5 min
|IASI sza|<20deg:no_signal filtered

S8



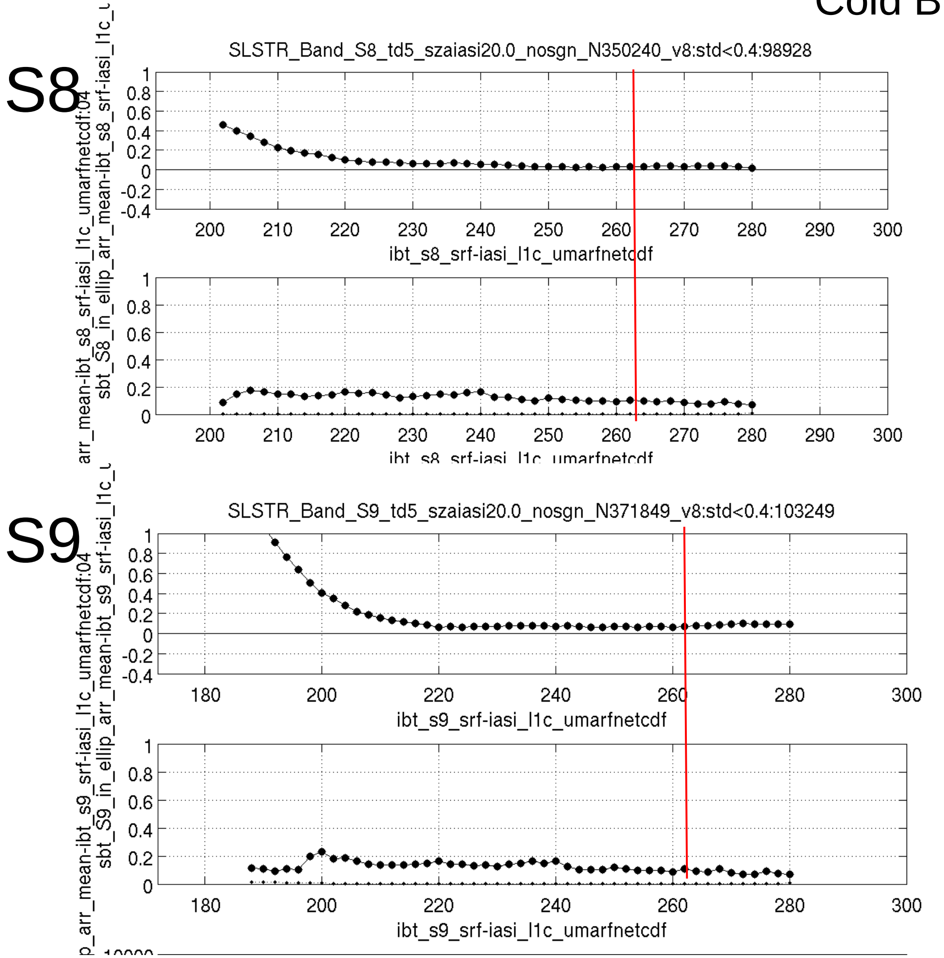
S9



Tomazic et al Eumetsat Conference 2016

SLSTR-A - IASI-A Comparisons
2K Binned averages

Cold BB at 262K



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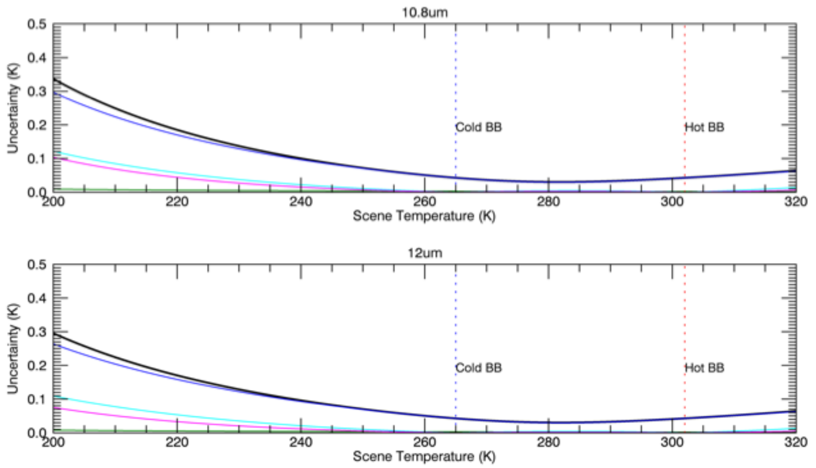
Note calibration Budget



Where is the 'stray light'?

Conclusions

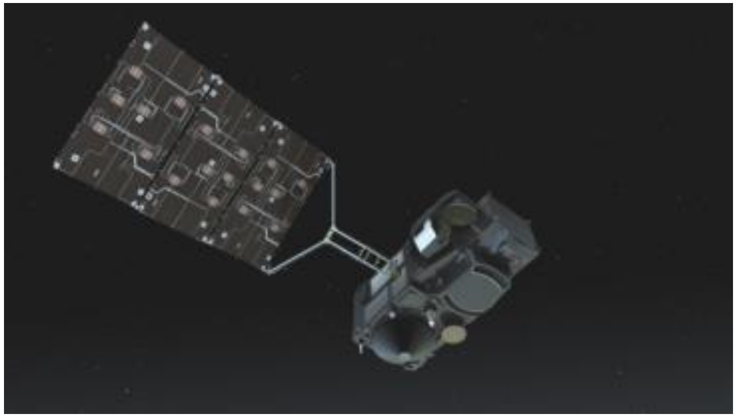
- Pre-Launch Calibration allows us to validate the end-to-end instrument flight calibration systems against known reference targets.
  - Not possible after launch
  - Provides a reference dataset against which the processing algorithms can be verified.

- Papers on calibration results are being prepared

- L1 products contain basic uncertainty estimates
  - Noise derived from BB sources
  - Estimates of calibration uncertainties from pre-launch characterisation
  - Improvements are foreseen…

- Traceability chain needs to be documented in-order for SLSTR to become a reference sensor.

Credits: SLSTR Core team



- Leonardo (formerly Selex ES), Instrument prime contractor, supply of Detector Assembly (the Focal Plane Assembly (FPA), the Front End electronics (FEE) and the Cryocooler (CCS)).
- JOP, supplier of opto-mechanical enclosure.
- RAL, responsible for calibration and systems design consultancy under ThalesAlenia as Sentinel 3A prime contactor.

Additional Slides

References

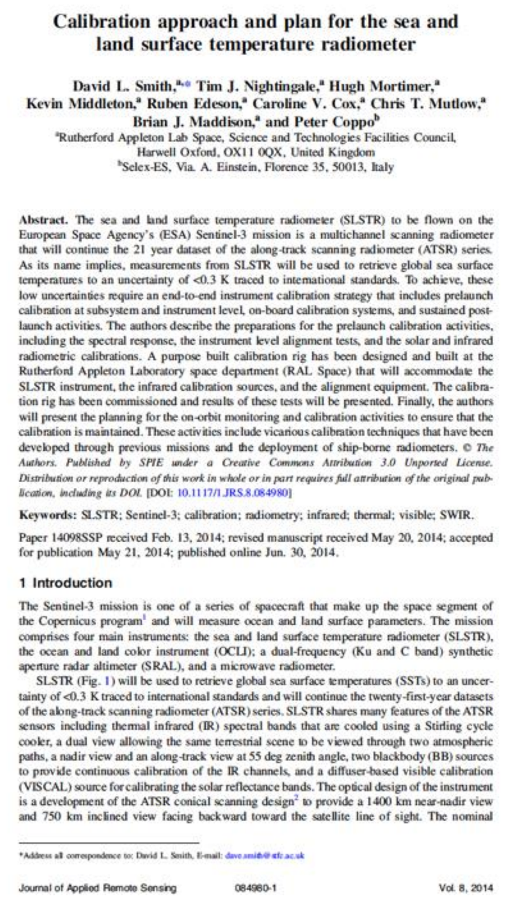
Calibration Plan

David L. Smith, Tim J. Nightingale, Hugh Mortimer, Kevin Middleton, Ruben Edeson, Caroline V. Cox, Chris T. Mutlow, Brian J. Maddison, Peter Coppo "Calibration approach and plan for the Sea and Land Surface Temperature Radiometer" *J. Appl. Remote Sens*. 8(1), 084980 (Jun 30, 2014).

[doi:10.1117/1.JRS.8.084980]

Description of SLSTR design

Coppo, B. Ricciarelli, F. Brandani, J. Delderfield, M. Ferlet, C. Mutlow, G. Munro, T. Nightingale, D. Smith, S. Bianchi, P. Nicol, S. Kirschstein, T. Hennig, W. Engel, J. Frerick, J. Nieke, "SLSTR: A High Accuracy Dual Scan Temperature Radiometer For Sea And Land Surface Monitoring From Space", Journal of Modern Optics, 57(18), 1815-1830 (2010) [doi:10.1080/09500340.2010.503010].



Calibration approach and plan for the sea and land surface temperature radiometer

David L. Smith,[a,*] Tim J. Nightingale,[a] Hugh Mortimer,[a] Kevin Middleton,[a] Ruben Edeson,[a] Caroline V. Cox,[a] Chris T. Mutlow,[a] Brian J. Maddison,[a] and Peter Coppo[b]
[a]Rutherford Appleton Lab Space, Science and Technologies Facilities Council, Harwell Oxford, OX11 0QX, United Kingdom
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Abstract. The sea and land surface temperature radiometer (SLSTR) to be flown on the European Space Agency's (ESA) Sentinel-3 mission is a multichannel scanning radiometer that will continue the 21 year dataset of the along-track scanning radiometer (ATSR) series. As its name implies, measurements from SLSTR will be used to retrieve global sea surface temperatures to an uncertainty of <0.3 K traced to international standards. To achieve, these low uncertainties require an end-to-end instrument calibration strategy that includes prelaunch calibration at subsystem and instrument level, on-board calibration systems, and sustained post-launch activities. The authors describe the preparations for the prelaunch calibration activities, including the spectral response, the instrument level alignment tests, and the solar and infrared radiometric calibrations. A purpose built calibration rig has been designed and built at the Rutherford Appleton Laboratory space department (RAL Space) that will accommodate the SLSTR instrument, the infrared calibration sources, and the alignment equipment. The calibration rig has been commissioned and results of these tests will be presented. Finally, the authors will present the planning for the on-orbit monitoring and calibration activities to ensure that the calibration is maintained. These activities include vicarious calibration techniques that have been developed through previous missions and the deployment of ship-borne radiometers. [DOI: 10.1117/1.JRS.8.084980]

Keywords: SLSTR; Sentinel-3; calibration; radiometry; infrared; thermal; visible; SWIR.

Paper 14098SSP received Feb. 13, 2014; revised manuscript received May 20, 2014; accepted for publication May 21, 2014; published online Jun. 30, 2014.

1 Introduction

The Sentinel-3 mission is one of a series of spacecraft that make up the space segment of the Copernicus program[1] and will measure ocean and land surface parameters. The mission comprises four main instruments: the sea and land surface temperature radiometer (SLSTR), the ocean and land color instrument (OCLI); a dual-frequency (Ku and C band) synthetic aperture radar altimeter (SRAL), and a microwave radiometer.

SLSTR (Fig. 1) will be used to retrieve global sea surface temperatures (SSTs) to an uncertainty of <0.3 K traced to international standards and will continue the twenty-first-year datasets of the along-track scanning radiometer (ATSR) series. SLSTR shares many features of the ATSR sensors including thermal infrared (IR) spectral bands that are cooled using a Stirling cycle cooler, a dual view allowing the same terrestrial scene to be viewed through two atmospheric paths, a nadir view and an along-track view at 55 deg zenith angle, two blackbody (BB) sources to provide continuous calibration of the IR channels, and a diffuser-based visible calibration (VISCAL) source for calibrating the solar reflectance bands. The optical design of the instrument is a development of the ATSR conical scanning design[2] to provide a 1400 km near-nadir view and 750 km inclined view facing backward toward the satellite line of sight. The nominal

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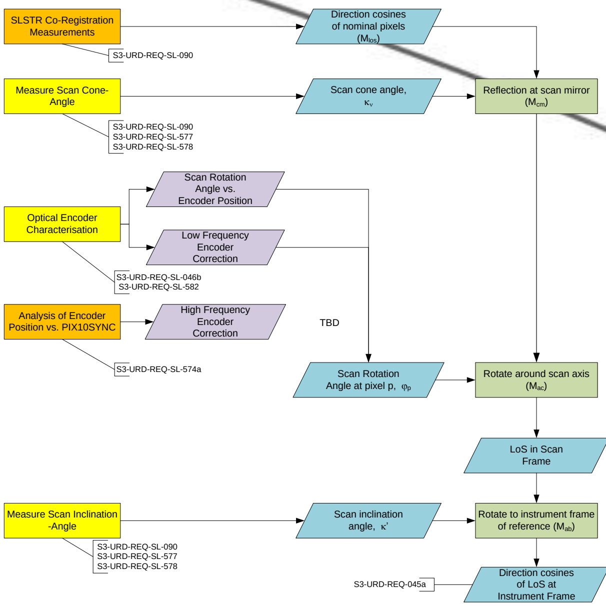
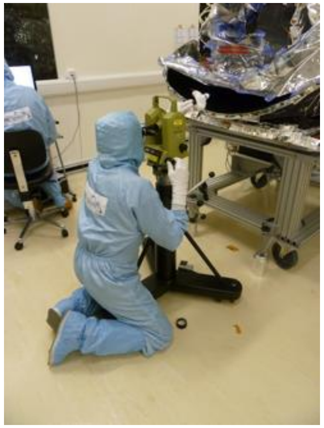
Line-Of-Sight Model and Verification

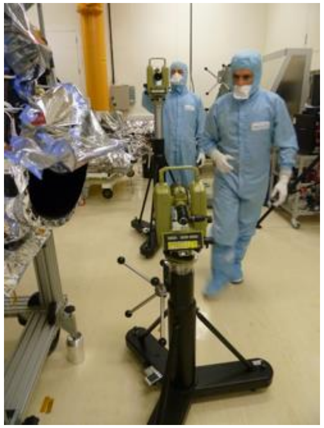
- Inputs to LoS Model
  - Direction cosines of detectors relative to nominal beam
  - Scan cone angles
  - Scan rotation angles
    - Encoder characterisation
  - Scan inclination angles



- Required Uncertainty
  - Total uncertainty wrt optical cube, < 0.05° (180”)
  - Period <30s, Precision <7”
  - Period < 1 orbit, Precision <15”

- Line-Of-Sight model in L1 processor is being modified to account for alignment differences in the two scanners compared to ideal pointing



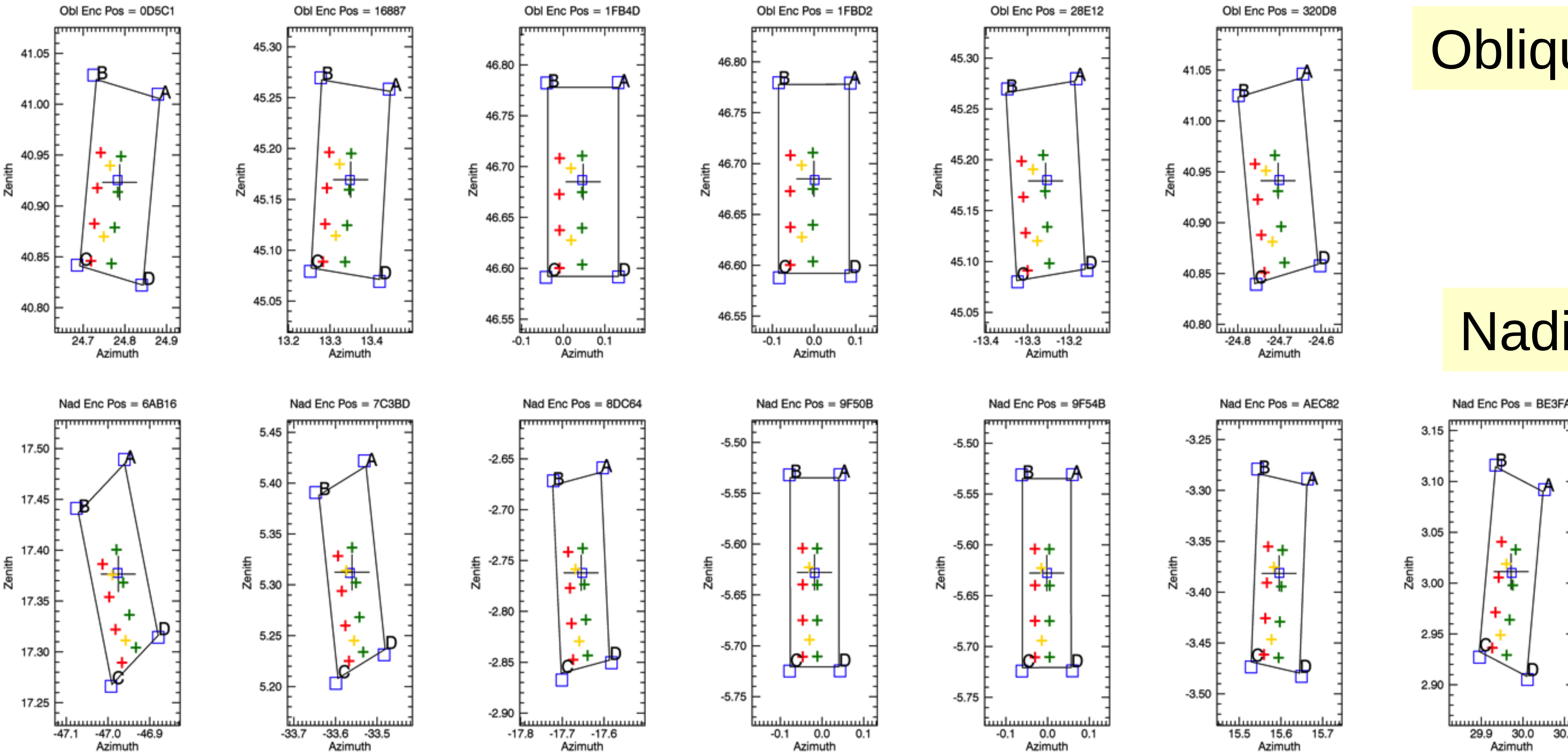


S3B - Geometric calibration: LoS Measurements vs Model

RAL Space

Oblique

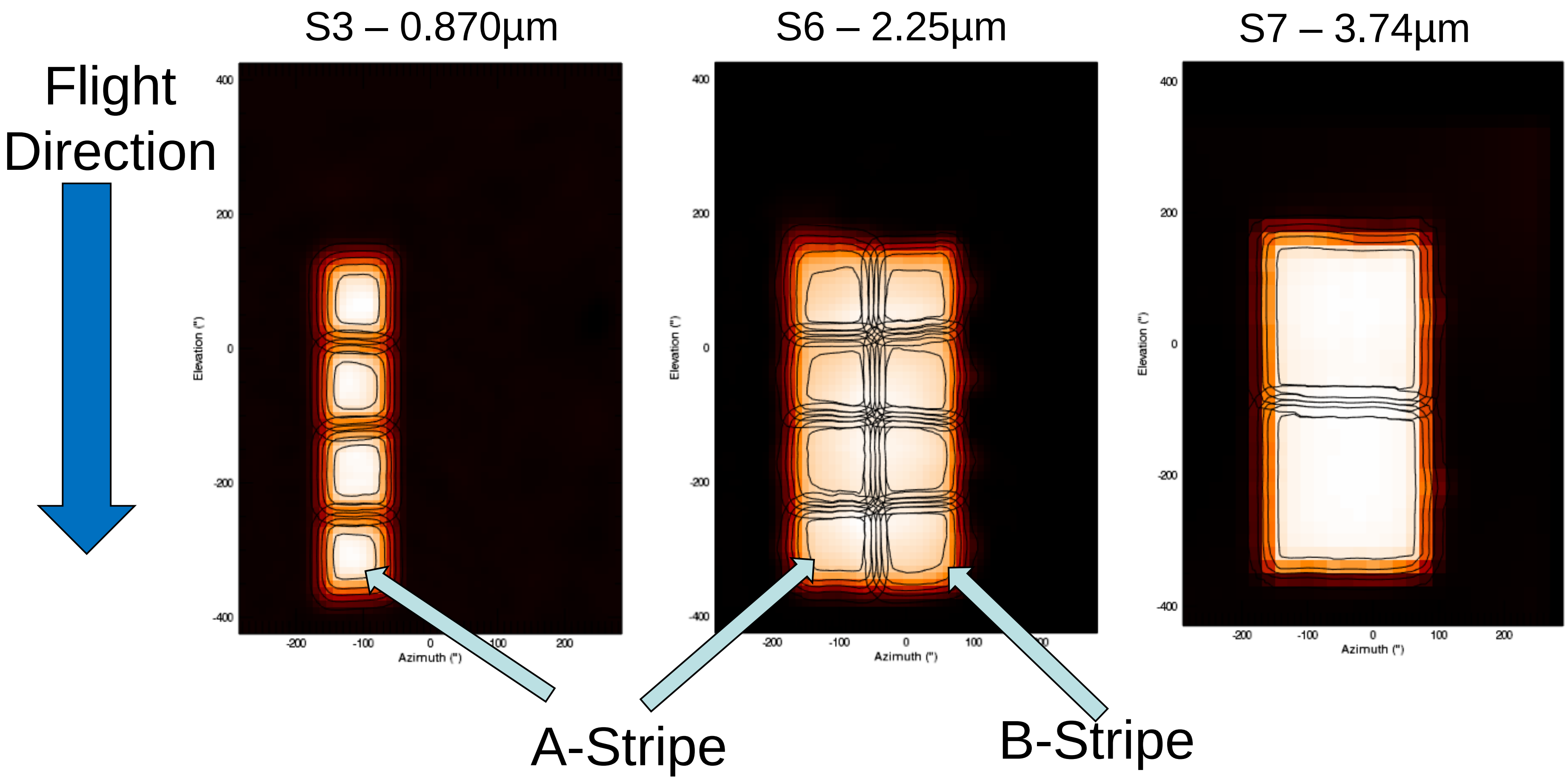
Nadir



Solid = model, squares = measurements, x = JOP cone model

Updated processor model gives excellent agreement with measurements ☺

IFOV Measurements

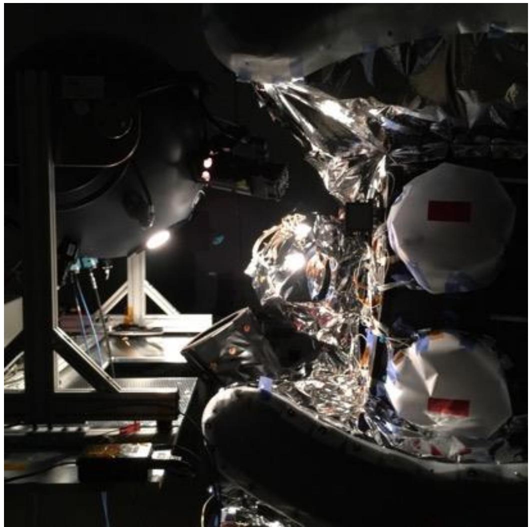


All corresponding channels are optically co-registered

VIS/SWIR Calibration

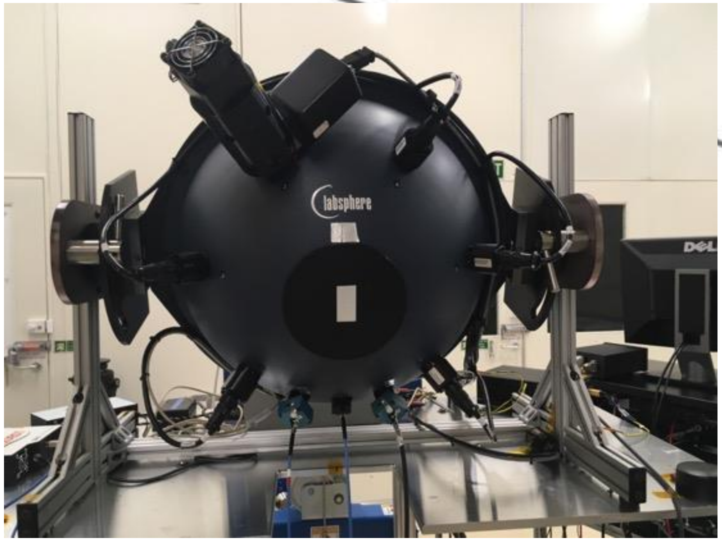
- SLSTR VIS/SWIR channels are calibrated via a diffuser based calibration VISCAL system – based on (A)ATSR concept
  - VISCAL is illuminated once per-orbit by the Sun

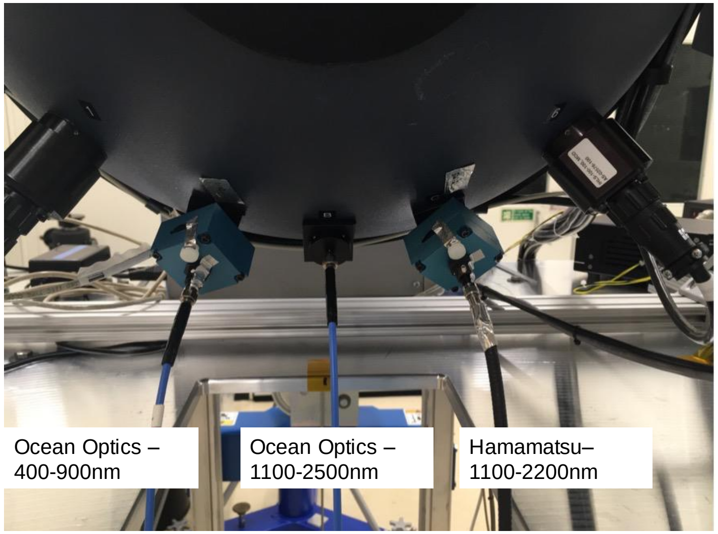
- Pre-Launch Calibration is to characterise key instrument performance
  - Radiometric response of each detector
  - Signal-to-Noise performance of each detector
  - Reflectance factor of VISCAL system
  - Polarisation sensitivity



Source Setup

- Integrating sphere used for calibration of SLSTR
- 6 lamps, one (lamp 3) has a variable aperture. 0%=open, 100%=closed. Percentage is not proportional to open area.
- Lamp settings controlled and data recorded using labview interface on a PC
- Three spectrometers mounted on the sphere to monitor source output and traceability to NPL calibration
  - 2 SWIR
  - 1 for VIS-NIR





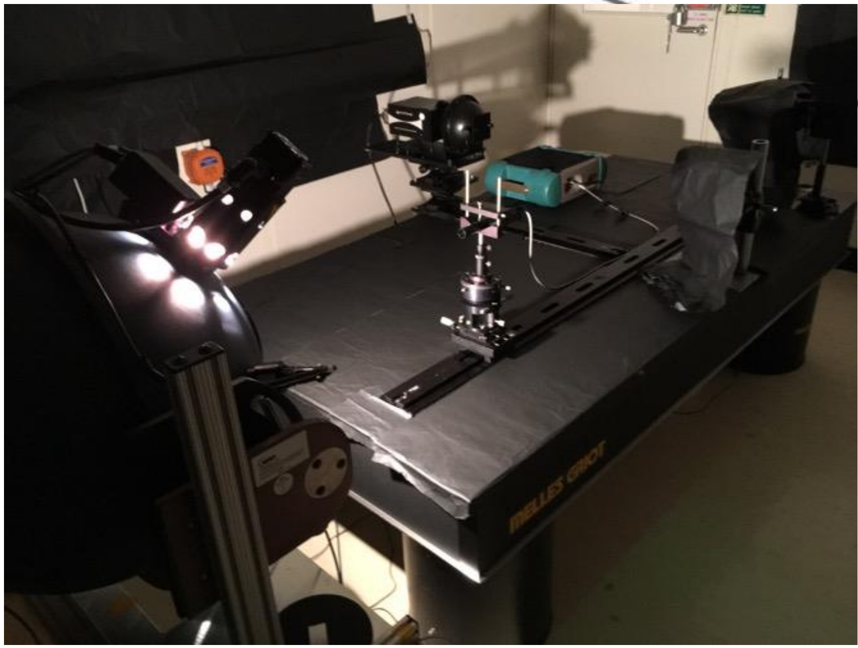
NPL-RAL-TAS Sphere Intercomparisons

An exercise was initiated to compare spectral radiances of integrating sphere sources used for SLSTR (RAL Space) and OLCI (Thales Alenia Space, France) calibrations.

NPL have performed measurements using spectroradiometers and reference source at host institution.

Measurements performed at RAL in December during SLSTR calibration campaign. Data being processed.

Measurements for OLCI performed in April



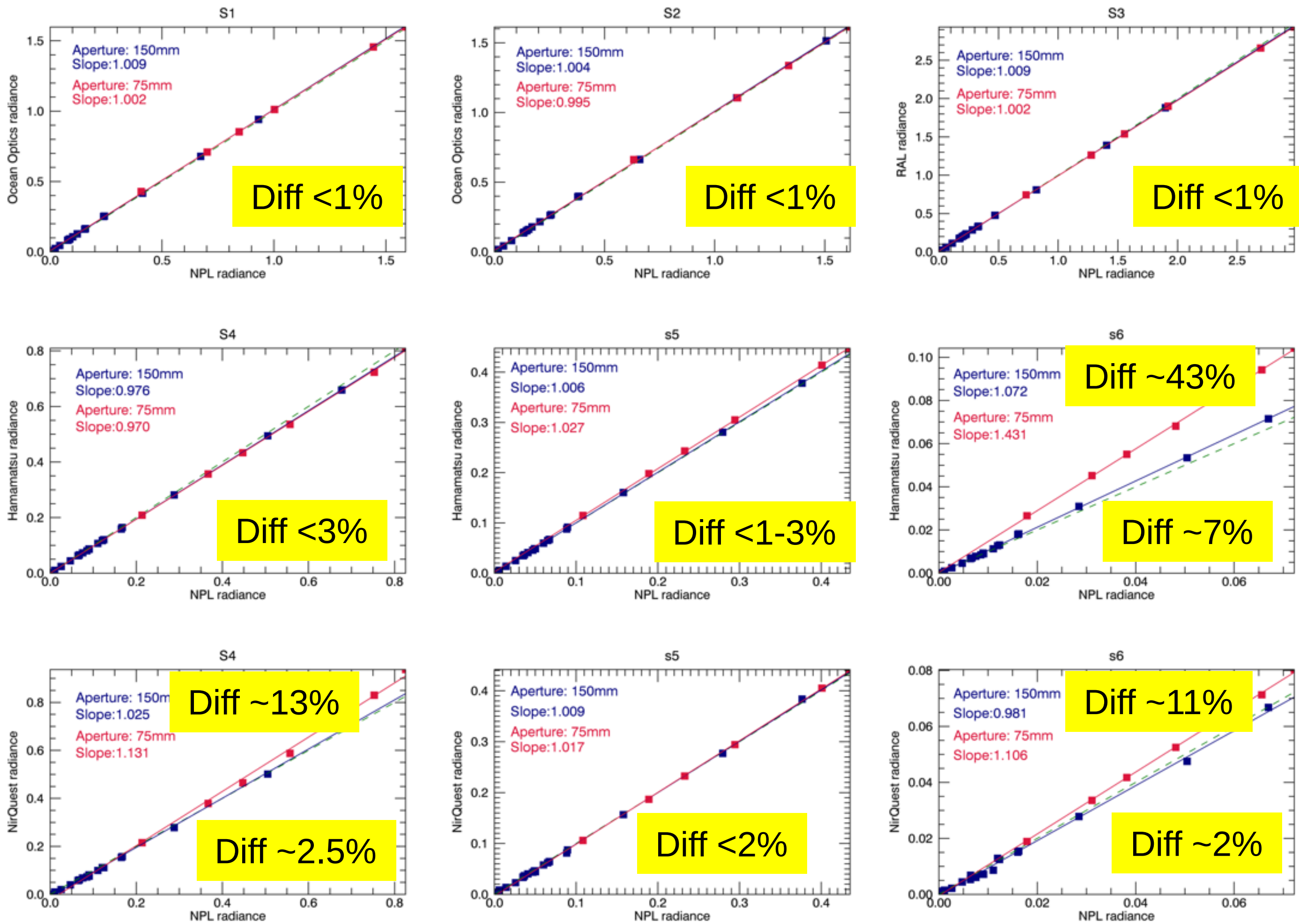
NPL's ASL spectrometer and source viewing RAL integrating sphere source.

Comparisons – RAL vs NPL measurements

VIS-NIR (S1-S3)
Ocean Optics

SWIR (S4-S5)
Hamamatsu

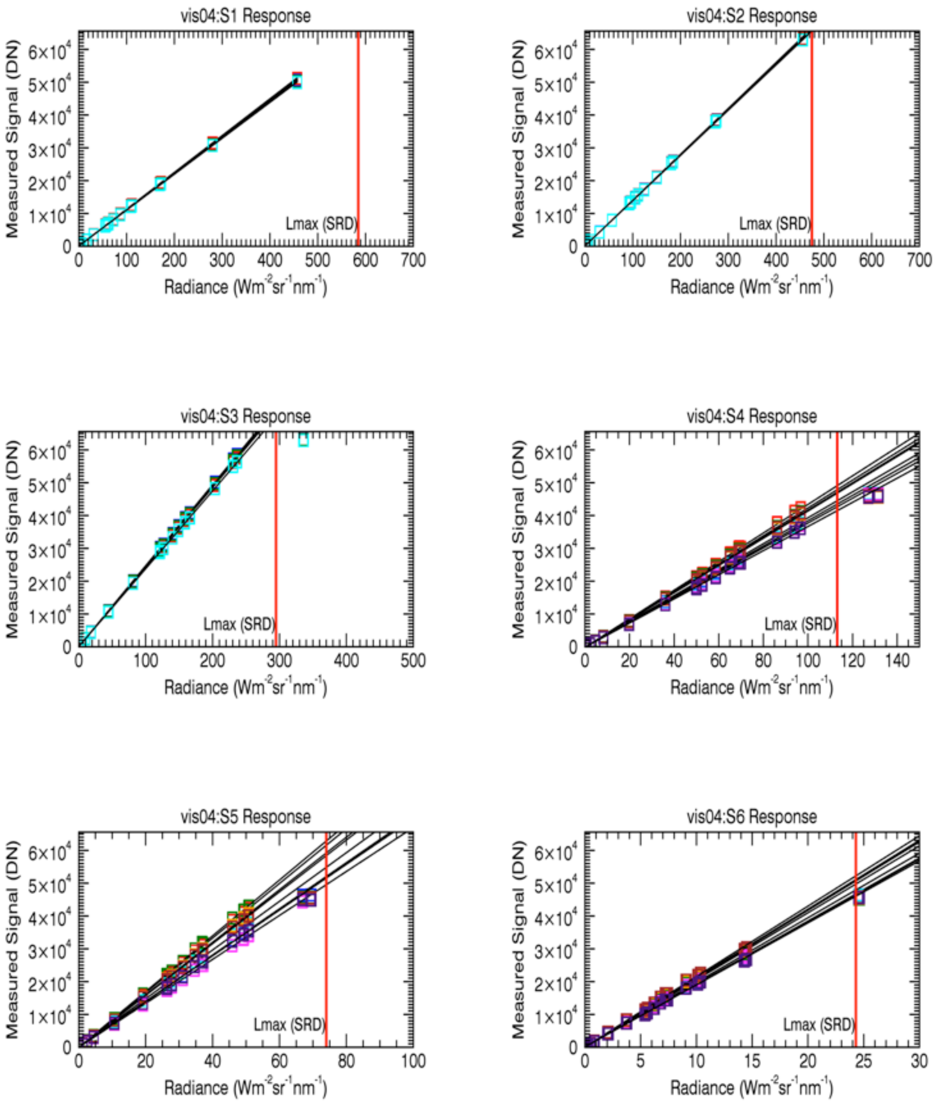
SWIR (S4-S5)
Ocean Optics



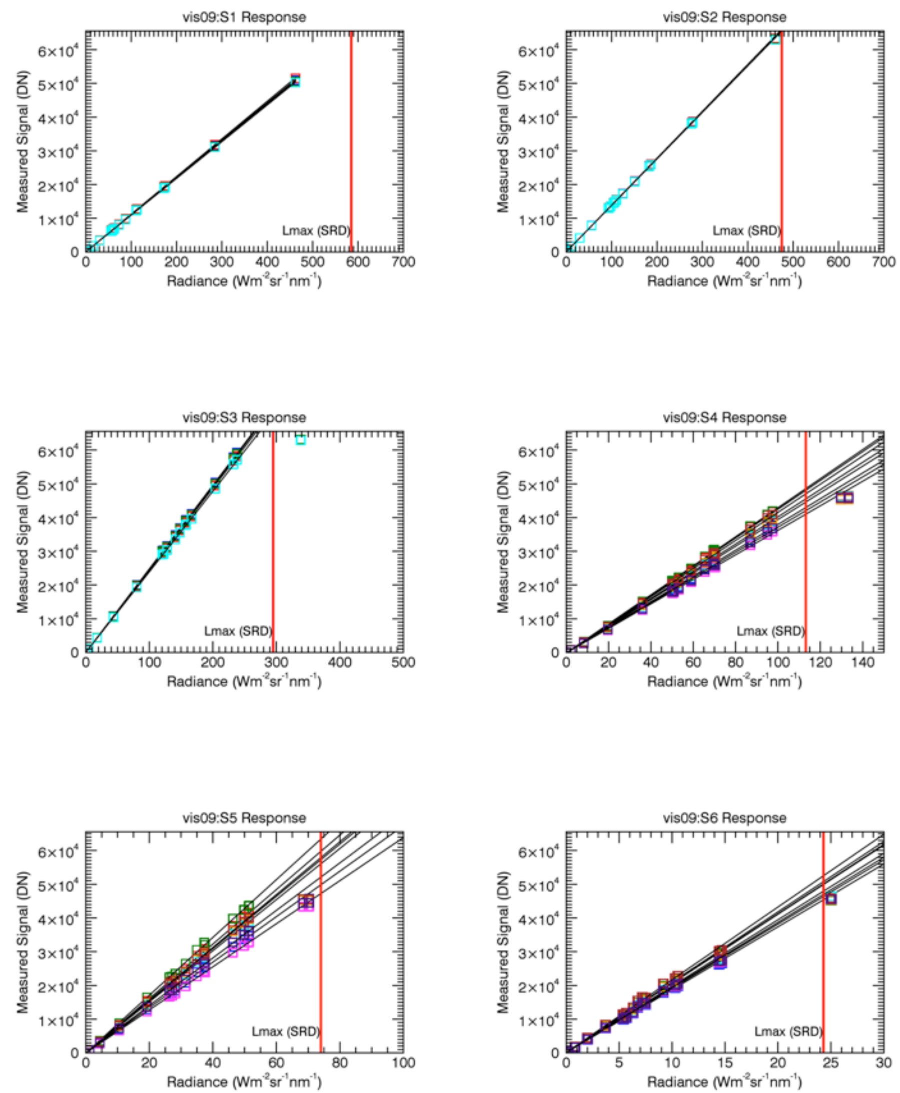
Good agreement at S1-S3, S5. Discrepancies at S4, S6

Radiometric Response in Earth View

Response Nadir View



Response Oblique View



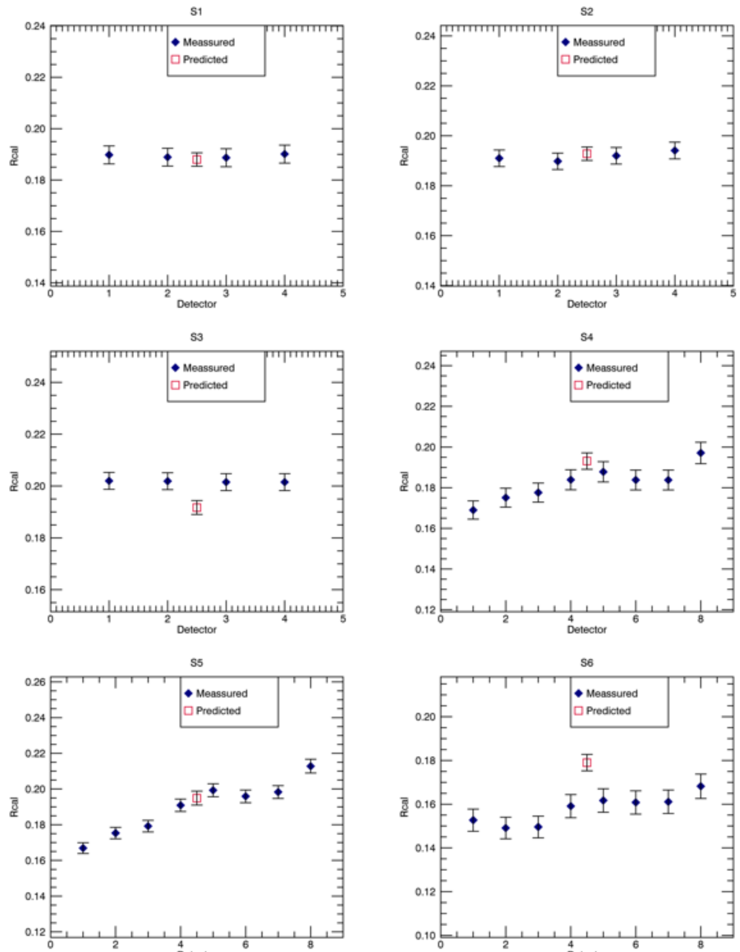
SLSTR-B VISCAL Reflectance Factors

RAL Space

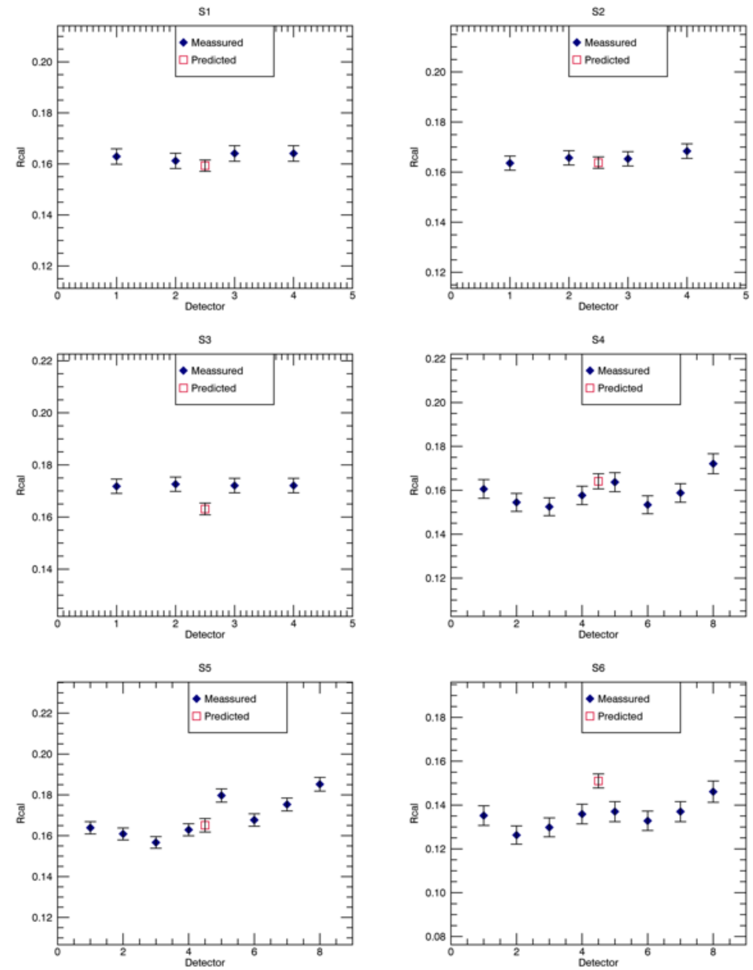
Predicted

Measured

Nadir



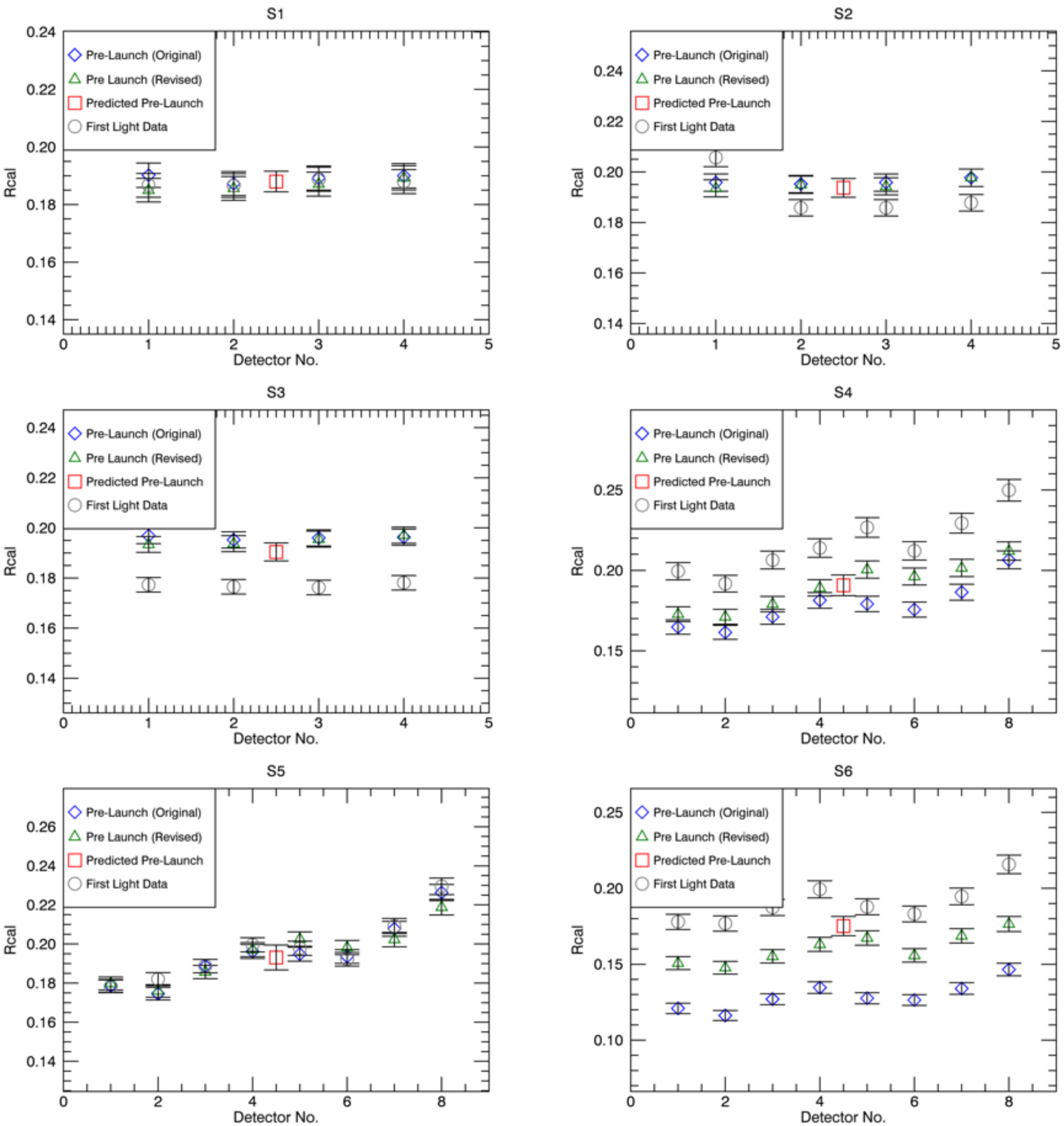
Oblique



Note – Separate values for each detector + view

SLSTR-A Viscal Reflectance Factors (Nadir)

RAL Space



Differences have been observed between different methods of evaluating VISCAL reflectance factors in SWIR channels.

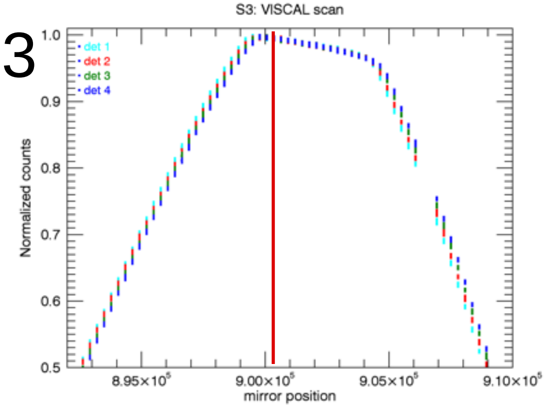
- Detector-Detector differences
- - Image stripes
- Differences in absolute factors
- – Especially S6

BOL on-orbit measurement of VISCAL signals appear to be more in-line with vicarious calibration + destriping correction.

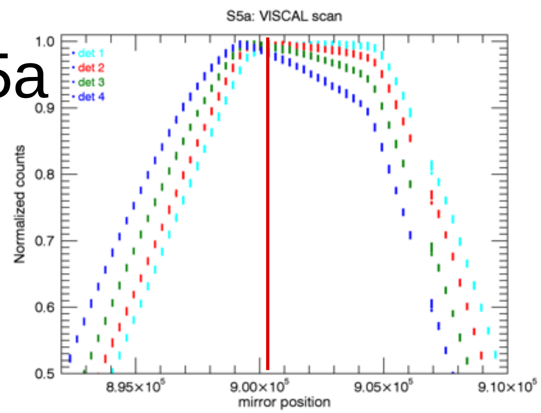
S1 and S5 Results show good consistency with different methods!

VISCAL Pixel Range and Uniformity

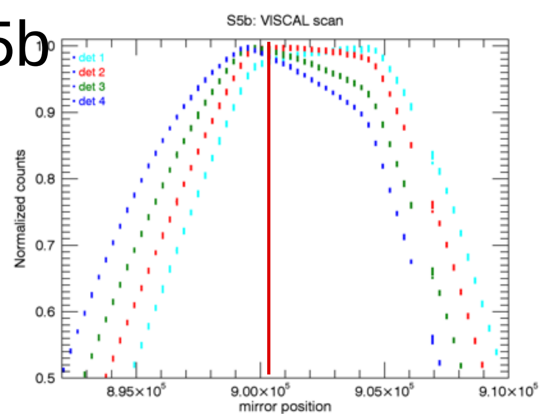
S3



S5a



S5b



We performed a set of measurements where the source illuminated the diffused and measured the signal response for different scanner positions.

Results determined the range of pixels to use on-orbit.

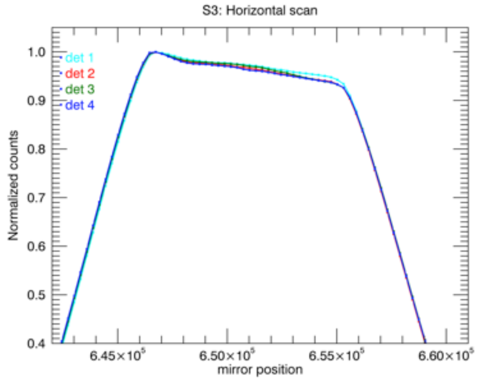
Showed a significant non-uniformity in the measured responses.

- For SWIR channels different for each detector
- Greater than expected variation in diffuser BRDF

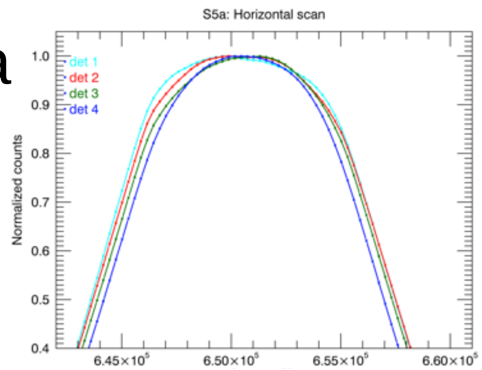
Why?

Pupil Uniformity – Along Scan

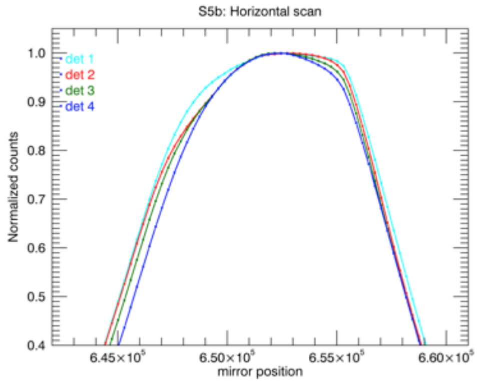
S3



S5a



S5b



To investigate cause of non uniformity we performed some additional measurements at centre of earth view.

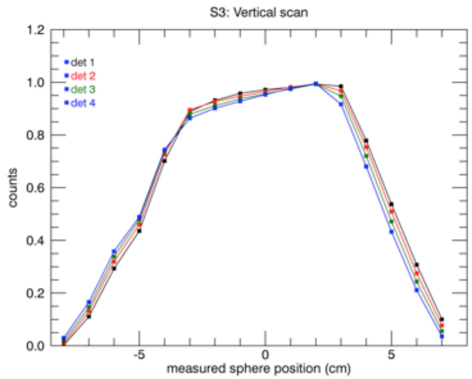
We illuminate the earth view with a 50mm diameter source (i.e. underfilling the pupil) and measure the instrument response as a function of scanner position (along scan direction)

Results show all VIS channels appear to fill main aperture uniformly.

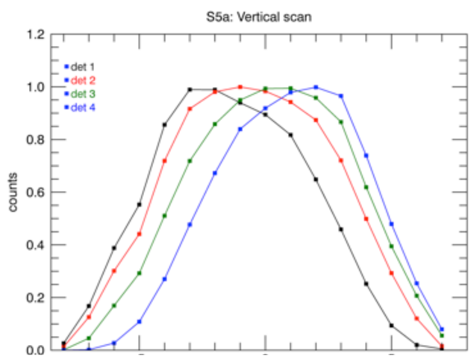
Differences seen in SWIR channel A and B stripes. Less uniform response

Pupil Uniformity – Along Track

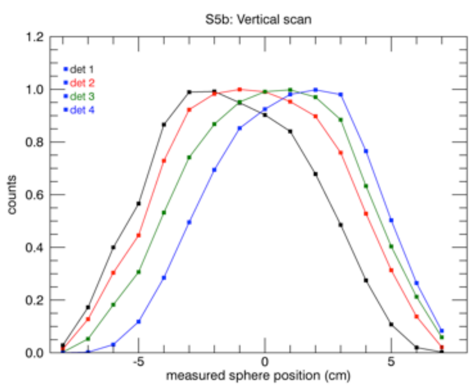
S3



S5a



S5b



We then repeated the measurements, this time moving source in vertical direction (along track direction)

Results show all VIS channels appear to fill main aperture uniformly.

Noticeable differences seen in each SWIR detector.

Conclusion:
Main telescope aperture is not the primary pupil for the SWIR channels

Provides root cause for variations in measured instrument response and Rcal