MSI Level 1 Product validation needs

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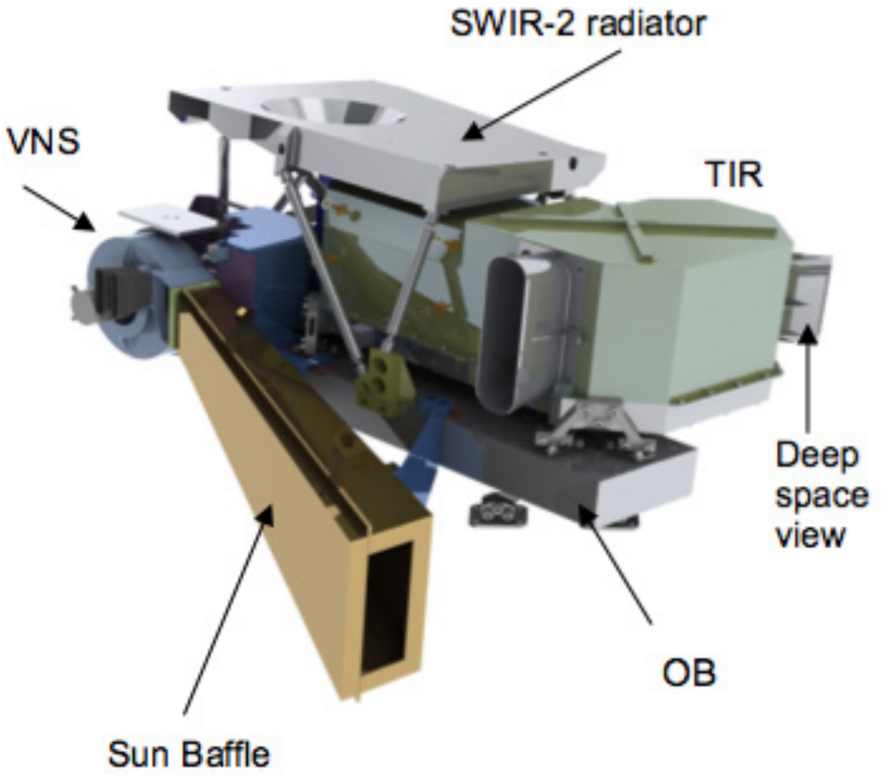
EarthCARE Status – May 2021

2nd ESA EarthCARE Validation Workshop

25-28 May 2021 (online)

MSI – Optical Bench



	λ (μm)	Δλ (μm)
Visible channel	0.67	0.02
NIR channel	0.865	0.02
SWIR1 channel	1.65	0.05
SWIR2 channel	2.21	0.10
TIR1 channel	8.8	0.9
TIR2 channel	10.8	0.9
TIR3 channel	12.0	0.9
Swath width	150 km	
Spatial sampling distance	500 m	
Spatial co-registration	0.15 SSD	
Radiometric accuracy	10 % or 1 K	
Inter channel accuracy	1 % or 0.25 K	
Radiometric stability	1 % or 0.3 K/year	

MSI - SNR and NEDT

Band			Min Signal[(1)]	Reference Signal[(1)]		Max Signal[(1)]	SNR @ Reference Signal	
				Low	High		Low	High
							Goal	Threshold
			W.m^{-2}.sr^{-1}.µm^{-1}					
B	1	VIS	3.85	30	444.6	489.1	75	500
B	2	NIR	0.95	17	282.7	311.0	65	500
B	3	SWIR 1	0.016	1.5	67.9	69.3	18	250
B	4	SWIR 2	0.0015	0.5	24.6	24.6	21	250

(1) TOA spectral radiance

Absolute radiometric accuracy

2% goal
10% threshold

Band			Min Signal[(1)]	Reference Signal[(1)]		Max Signal[(1)]	NEDT @ Reference Signal			
				Low	High		Low		High	
							Threshold	Goal	Threshold	Goal
			K	K	K	K	K	K	K	K
B	7	TIR 1	170	220	293	350	0.80	0.60	0.25	0.10
B	8	TIR 2	170	220	293	350	0.80	0.70	0.25	0.15
B	9	TIR 3	170	220	293	350	0.80	0.80	0.25	0.15

(1) TOA brightness temperature

MSI – VNS (visible/nearIR/shortwaveIR) Calibration

- **Two** radiance reference points for the VNS:
  1) observation of a **diffuser** that can be rotated into the field of view and
  2) instrument response with the aperture closed.
- Two pairs of **diffusers** (QVD) = 4 diffuser = (VNS+SWIR2) x (perDay+perMonth) to monitor degradation (tbc)

➔ VNS is calibrated against **reflectance** standard (not **radiance**)!

- **South Polar Region (**@terminator = shadowed earth, Sun in the line of sight)
- **Dark calibration @ night side of orbit**. (validity to be tested during commissioning!)

MSI – TIR Calibration (in short)

- Warm blackbody +reference body + Cold deep space

- **once per day (orbit?)**
- **Blackbody has been calibrated** pre-flight against an NIST traceable source from NPL.

What needs to be validated (inflight) in order to make L1 fit for purpose?

1. absolute radiometric and relative radiometric, linearity

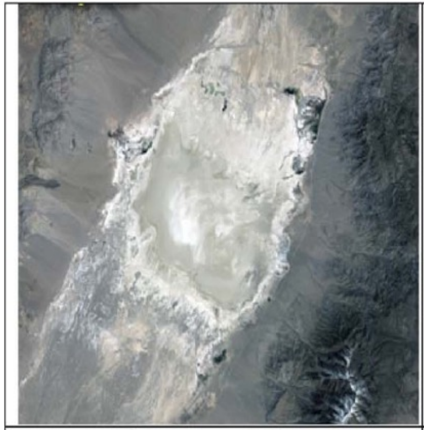
2. straylight (spectral, spatial)

3. spectral position (idealy the *rsr*)

4. FoV and Orbital dependencies of 1-3.

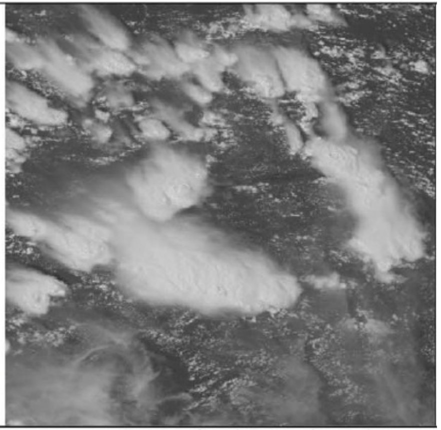
5. (Not discussed here: Pointing / georeferencing / co-registration)

Inflight absolute and relative radiometric using invariant targets



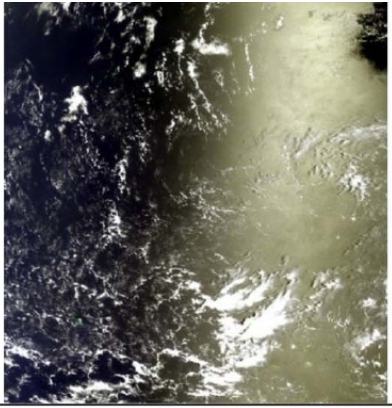
Instrumented Site

Pseudo-Invariant Calibration Sites (PICS)



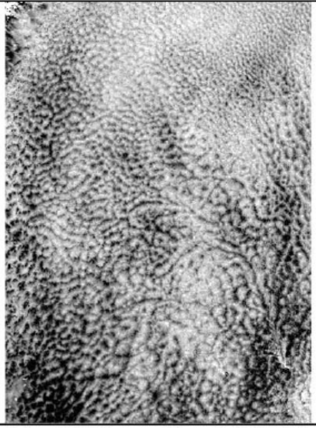
Deep Convective Clouds (DCC)

Rayleigh Scattering



Sunglint

The Moon



Liquid Water Cloud (LWC)

Chander et al 2013

Inflight absolute and relative radiometric

Actually, there is no clear cut between the **validation** of a calibration a calibration (vicarious) **itself** and absolute calibration **monitoring**

1. **Invariant Calibration Targets**: Precise **RTM** simulations, ideally accompanied with ground based atmosphere characterisation. **Use of established sites allows inter-satellite comparisons.** If done correctly, it is very complex! Can not be made without **parallel precise spectral** characterisation
   - **Rayleigh Calibration** oceanic sites, offglint geometry, no clouds, only background aerosol. Applicable only for wavelengths/geometry with significant Rayleigh signal : **VIS 1**.
   - **DCC** (Deep Convective Clouds): nearly perfect solar diffusers (adequate for inter-band: relative radiometric calibration). Worldwide distributed, mainly +- 10°.
   - **LWC** (liquid water clouds, trade wind zones): good for intermediate intensities, non-linearities vs bright
   - **Sun Glint** Reflectance follows refractive index: Good for inter-band, but MSI is slightly tilted to off-glint:-(
   - **Moon** In Orbit manoeuvre to view the moon. ROLO or LIME (ESA) as reference. Only few times a year, only few pixel (moon is small!) . Can be used for straylight too! Good for stability/degradation monitoring!
   - **SST:** relatively stable, monitored by many ground based and satellite missions. Needs good RTM (water vapour)
   - **(Pseudo) Invariant Calibration Sites** (PICS): mostly deserts, DOME-C…
2. **SNO** (Simultaneous Nadir Observations): Inter-satellite. Geos and HR sensors can be used as transfer (but they may have only one nadir!). RSR must be as similar as possible (or RTM based transfer). Spatial variability should be low. Eventually, radiometric consistency (closures) between instruments on one platform (BBR ←→MSI) should be used

- Statistical Intercomparisons (look also on higher moments of pdf's), **Double-Differences** with an intermediate reference

Rayleigh

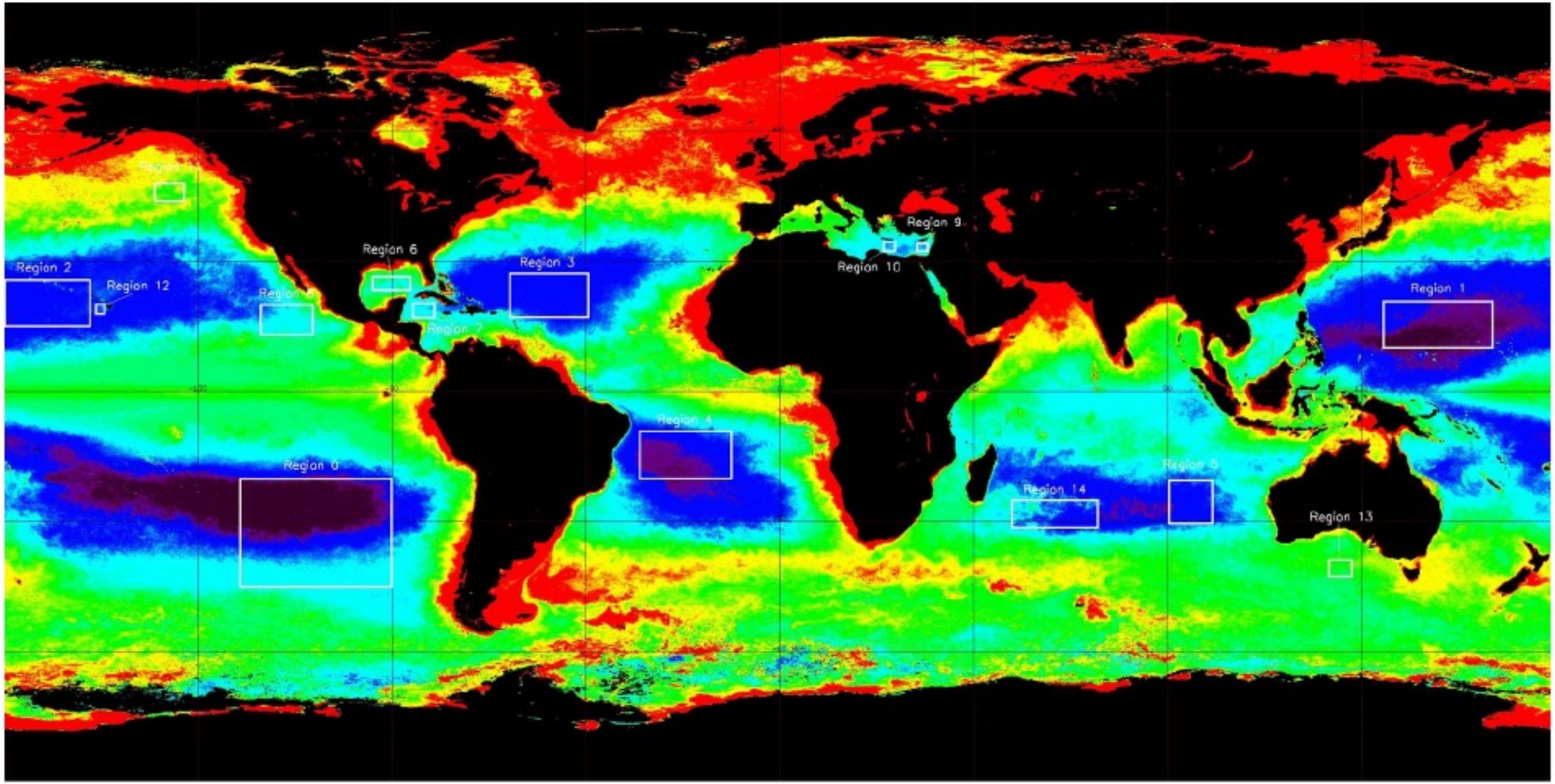
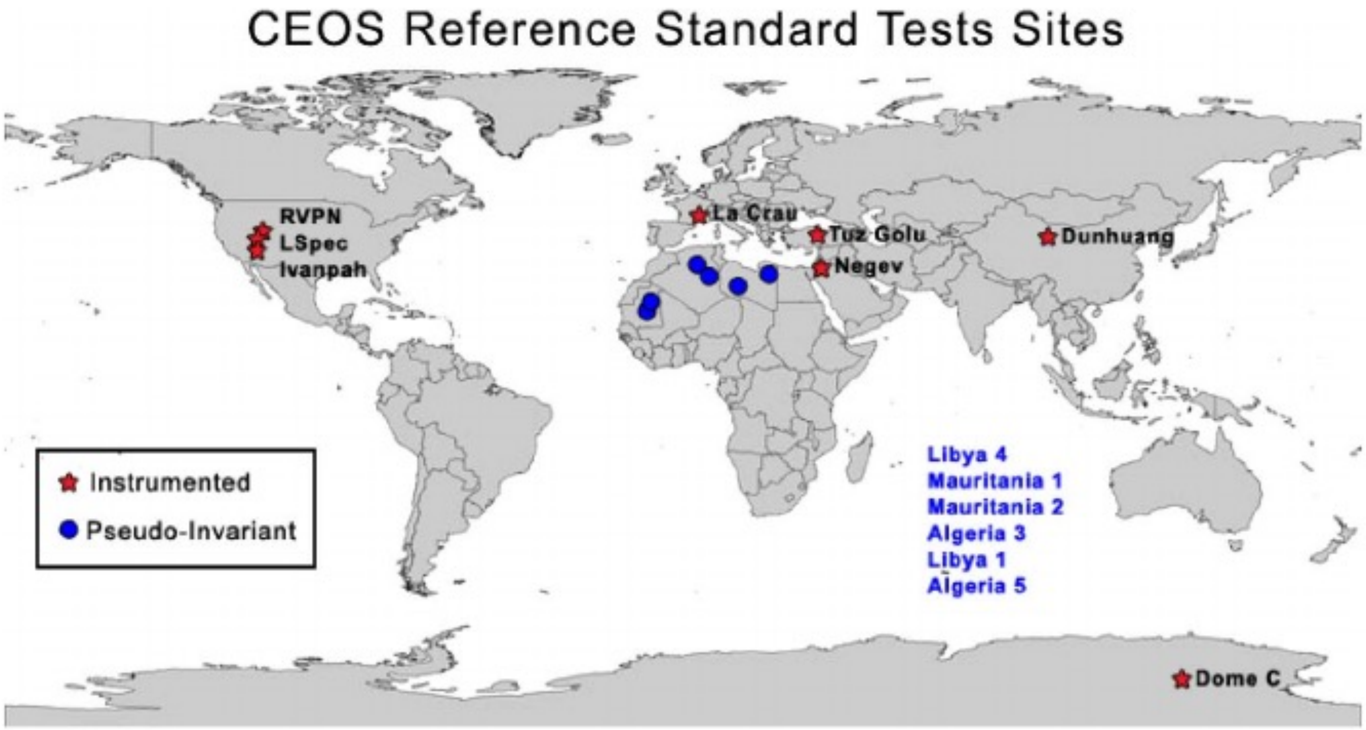


Fig. 5. Distribution of the recommended Raleigh scattering calibration test sites [211] (courtesy: Bertrand Fougnie, CNES). Based on the measurements from the SeaWiFs ocean color data, six spatially homogeneous ocean sites were recommended in the Pacific, Atlantic, and Indian Ocean.

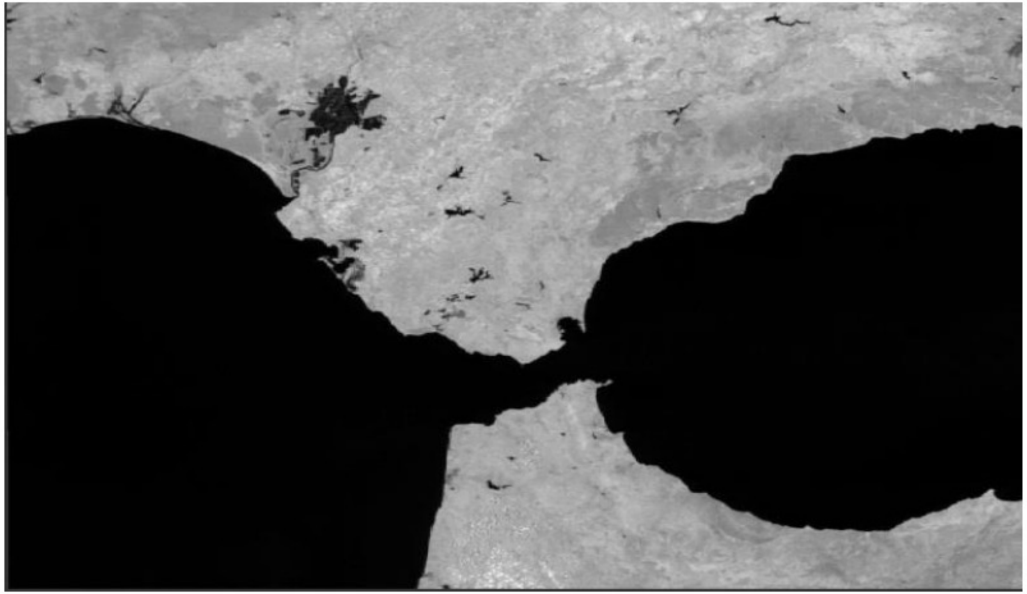
Chander et al 2013



Chander et al 2013

Straylight using steep gradients (OLCI example)

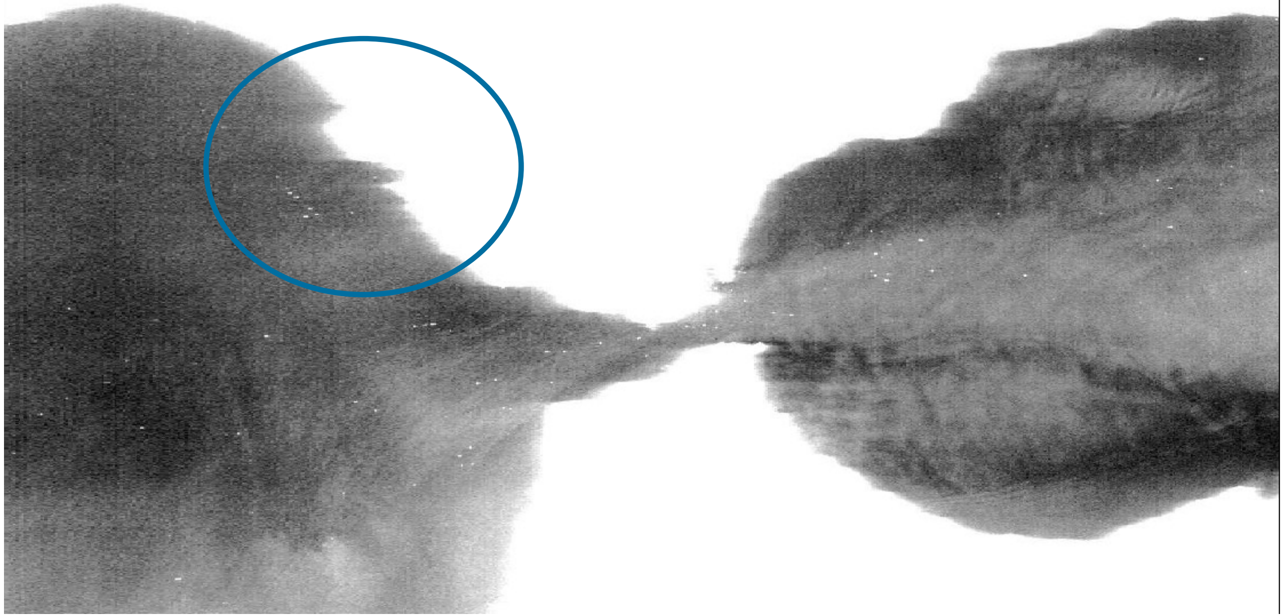
- Tests on highly contrasted image of the straight of Gibraltar
- L1 TOA radiance B21 (1020 nm), worst case



N. Lamquin, L. Bourg, L. Blanot, S. Clerc
ACRI-ST, Sophia Antipolis

Straylight, using steep gradients (OLCI example)

No straylight correction (contrast on small radiances):
most effect across-track (spectro mainly impacts)



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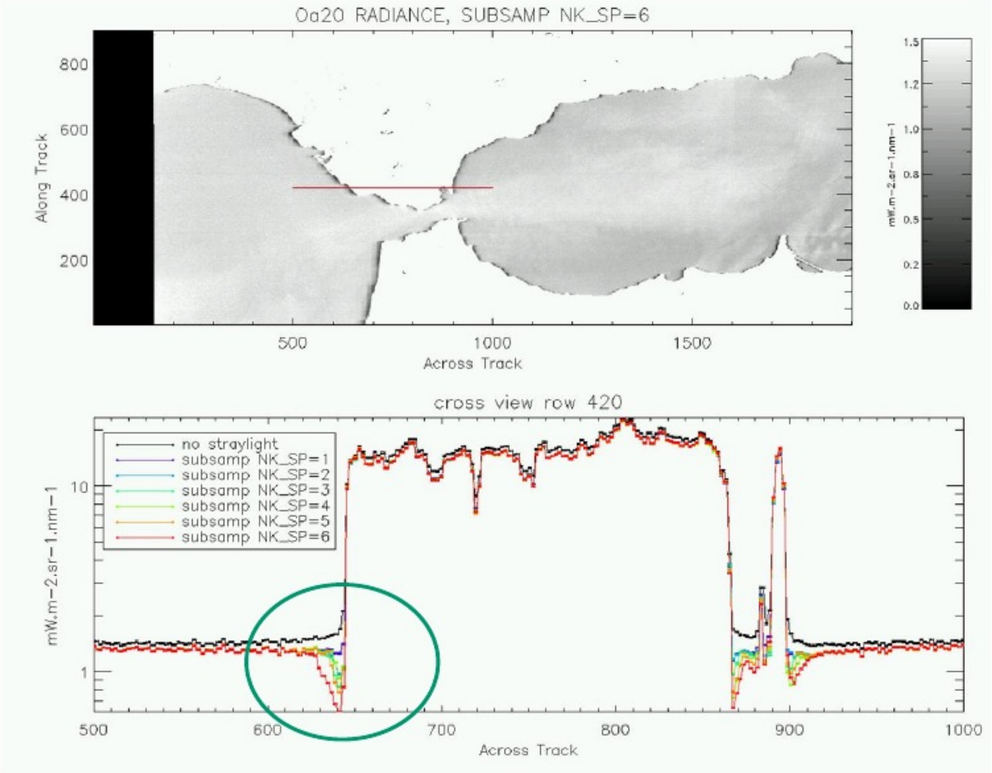

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Straylight using Moon

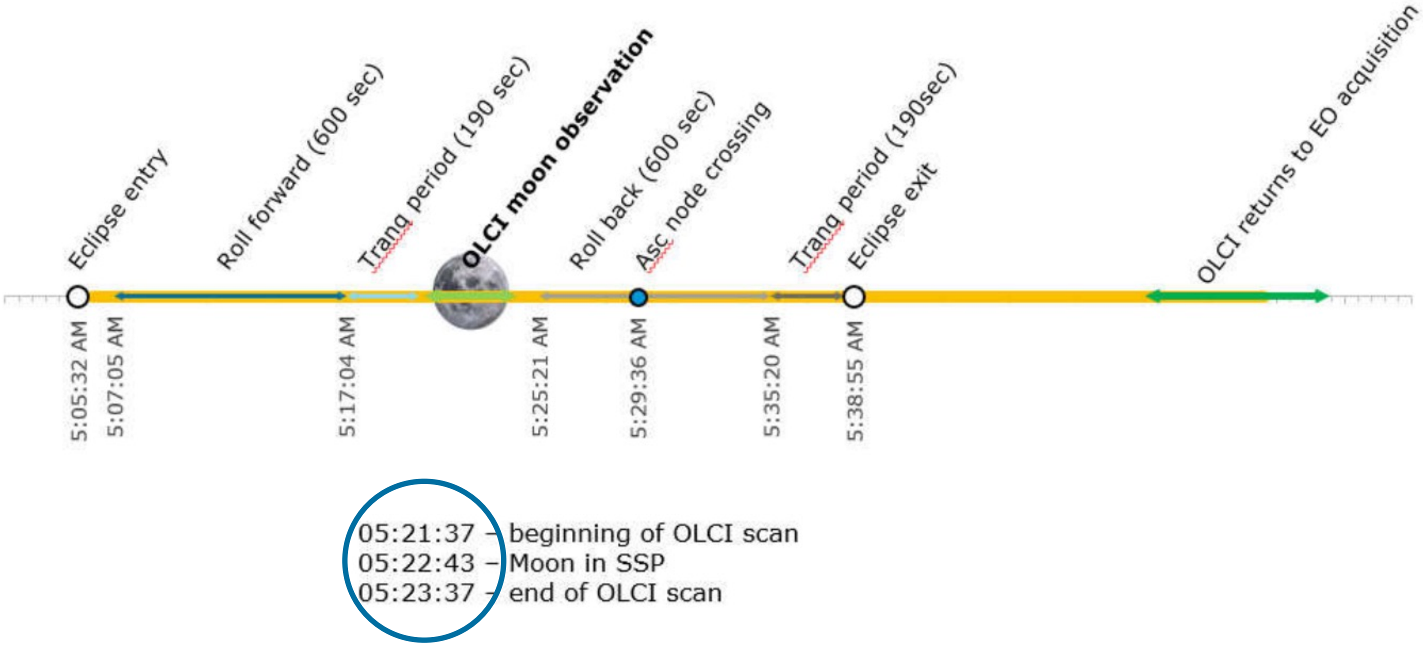
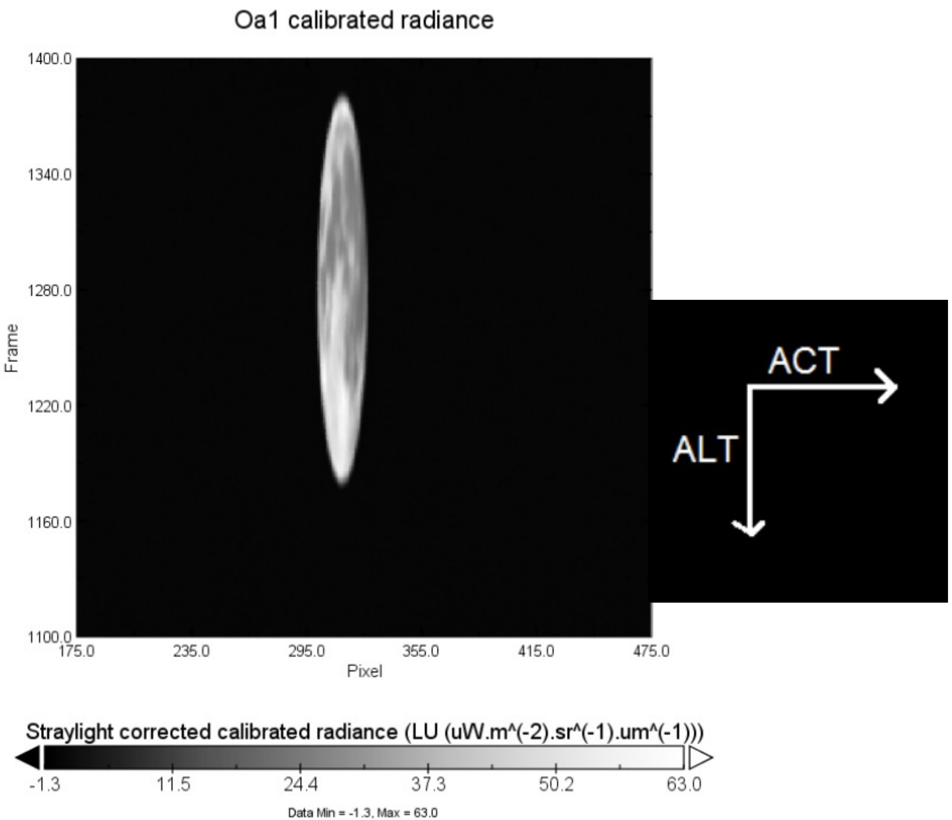


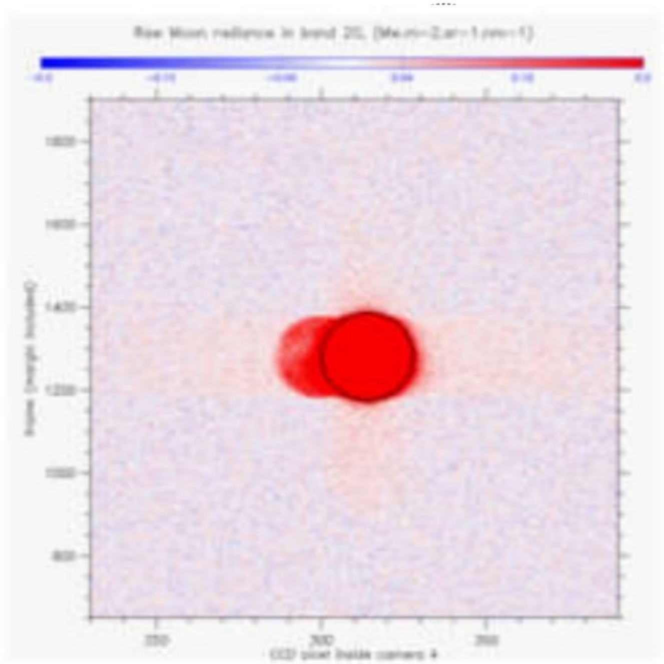
Figure 2. Timeline of OLCI-B Moon Observation.

Use of Moon Observations for Characterization of Sentinel-3B Ocean and Land Color Instrument

Maciej Neneman [1,*], Sébastien Wagner [2], Ludovic Bourg [3], Laurent Blanot [3], Marc Bouvet [1], Stefan Adriaensen [4] and Jens Nieke [1]

Straylight using Moon





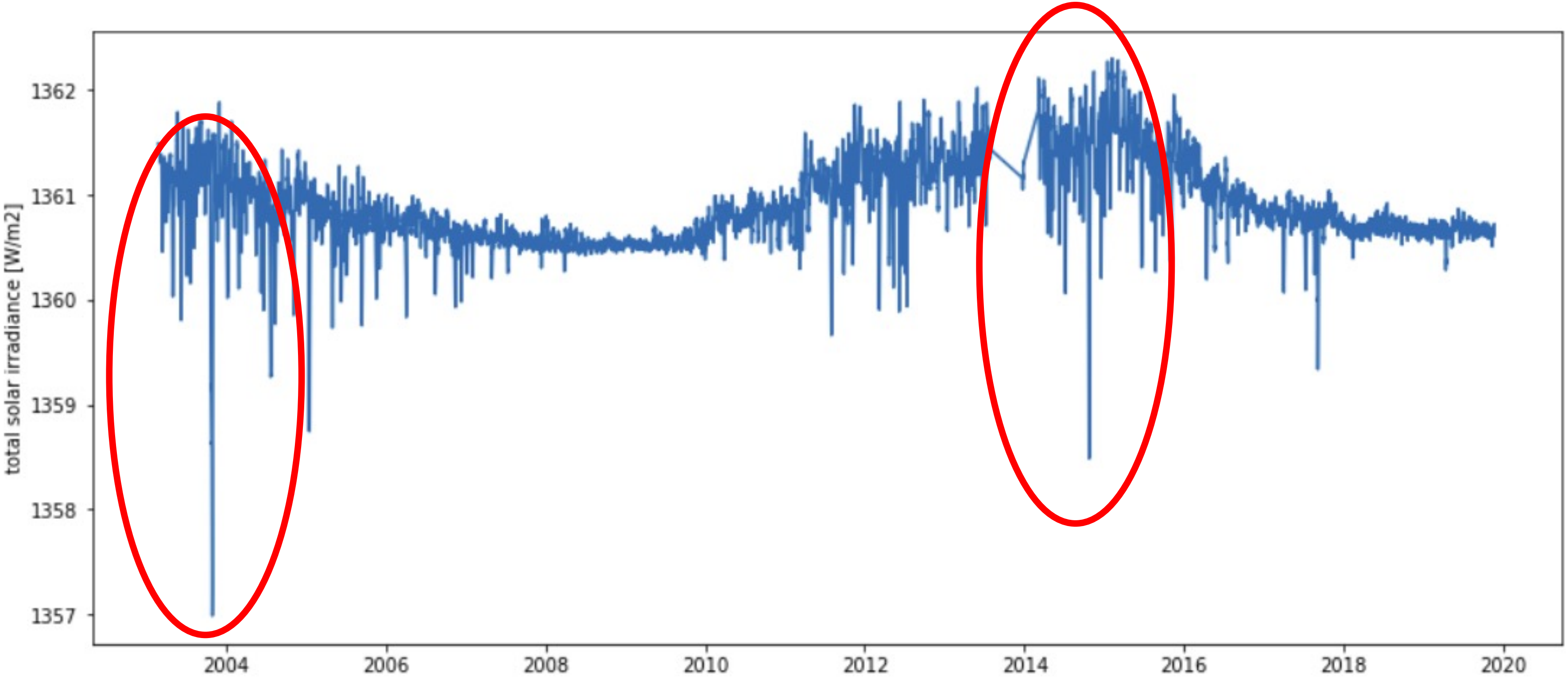
Color scale is linear, centered on zero (deep space value) and limited to stray-light radiance levels

Diffusor BRDF

Manoeuvres can/shall be used to characterize the BRDF of diffuser too! Diffusor is **the** source for VNS calibration. If BRDF is not characterized, annual modifications will be introduced!

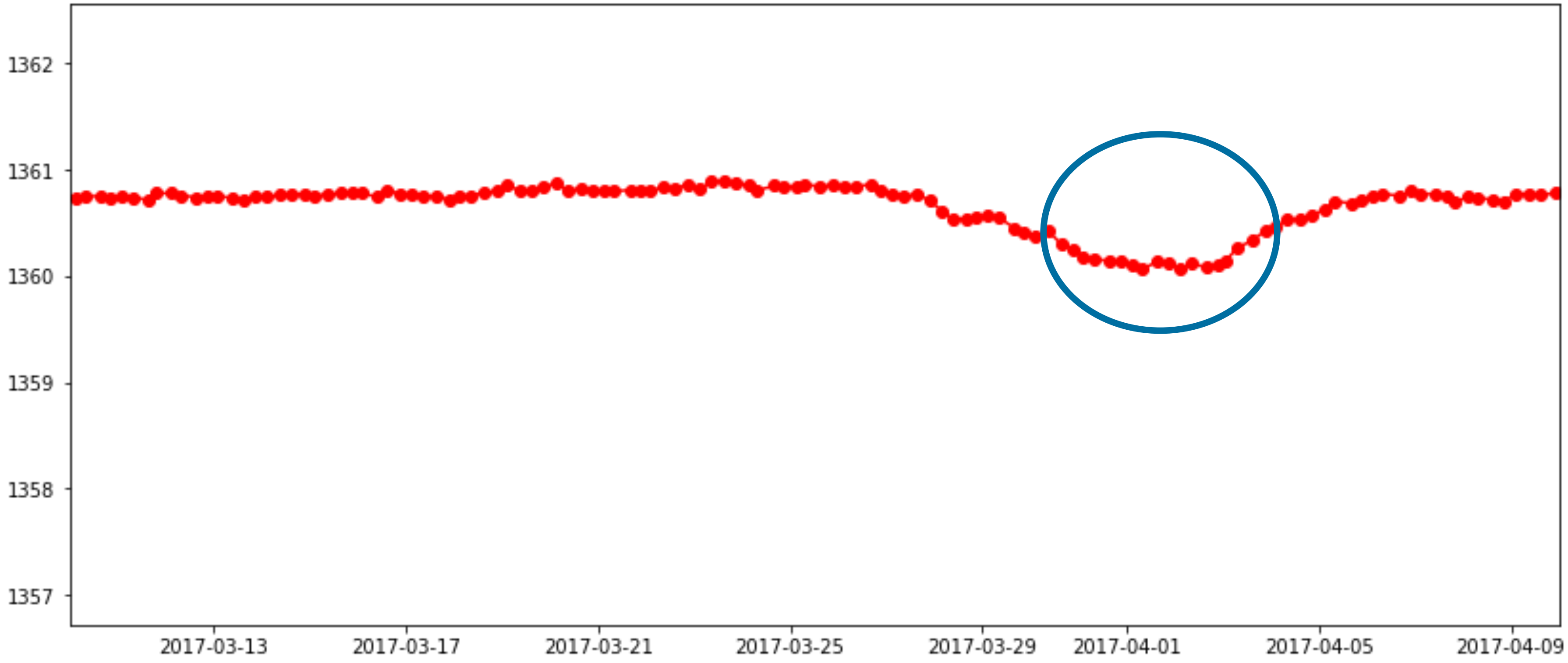
Solar constant constant?

12 years

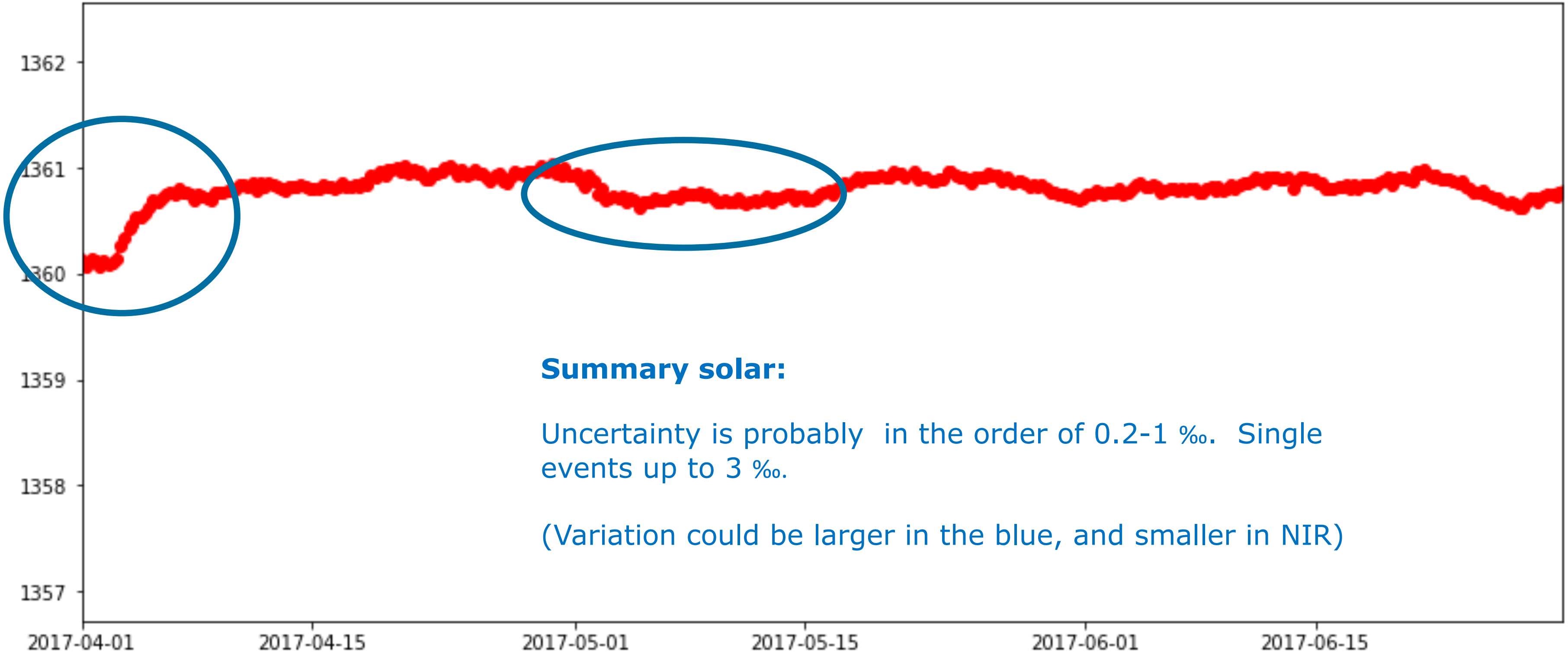


total solar irradiance [W/m2]
1362
1361
1360
1359
1358
1357
2004
2006
2008
2010
2012
2014
2016
2018
2020

1 month: 03/2017



An other month: 05/2017



Summary solar:

Uncertainty is probably in the order of 0.2-1 ‰. Single events up to 3 ‰.

(Variation could be larger in the blue, and smaller in NIR)

Validation of spectral position / rsr

As for radiometric, there is no clear cut between inflight characterisation, monitoring and validation. Precise spectral characterisation is pre-requisite for vicarious radiometric characterisation.

Standard procedure: Convolution of a high resolution **reference** spectra with assumed RSR. The reference spectral must **belong to strong spectral gradients, otherwise there is no spectral sensitivity, and variations cannot be disentangled from radiometric variations**! Also, emphasis on different spatial resolution, if different instruments are used!

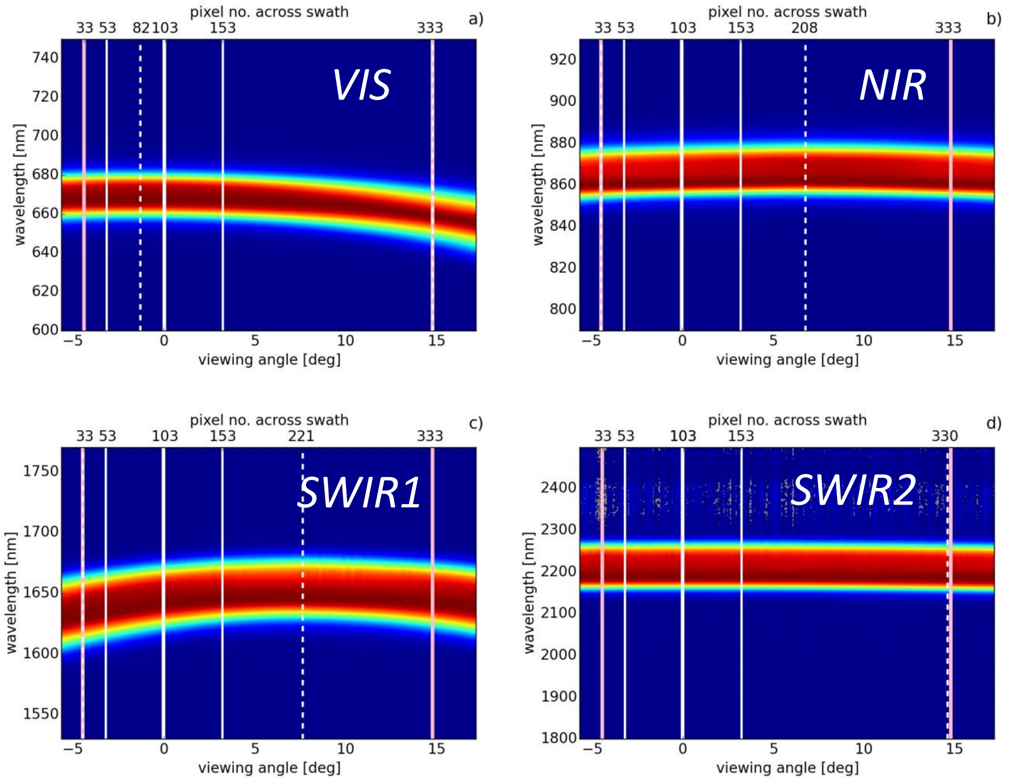
Reference spectra:

- **SNO's** with HR data like FLEX (VIS), Sciamachy, IASI(2) TIR, ...
- Strong spectral atmospheric, surface or solar features (**hardly applicable for MSI**)

FoV and Orbital dependencies

This is the cherry on the cake. Actually everything must be stratified with respect to viewing geometry and orbit! MSI is particularly difficult, since we already know, that MSI has huge spectral variations over small FoV. Further there may be an dependence of **thermal stray-light**, dark current, thermal elastic modifications on orbit (illumination/heating/cooling…)

MSI – Spectral Response Functions



MSI VNS spectral response functions for a) VIS, b) NIR, c) SWIR1 and d) SWIR2 channel. Grey areas indicate responses lower than -0.01, thick white lines indicate nadir view, thin white lines indicate nadir view +/- 50 pixel (~approx. +/-25 km) and dashed white lines indicate viewing angles/across track pixel that exhibit the minimum and maximum of central wavelength within -70 pixel (~approx. -35 km; pink line) and +230 pixel (~approx. 115 km; pink line) around nadir.

Lessons learned from previous missions

1. Effort and budget should be allocated to instrument **pre-launch characterization** and knowledge transfer. *Some instrument features observed during operations are extremely difficult to be characterized and to be disentangled from each-other in-flight!!* House-keeping data can support instrument characterisation (we will never use 99.5 % of the HK data, but we don't want to miss any!)

2. "… **the calibration is a never-ending process and a dedicated effort should be allocated throughout the full mission lifetime (and beyond), this entails the need for regular reprocessing campaigns for the continuous improvements of the level 1 dataset"**

3. Multi-sensor radiometric inter-comparison over *Pseudo-Invariant Calibration Sites* (PICS) is an invaluable source, however, the uncertainty of the methods requires **meticulous work** to incorporate, BRDF, atmospheric, spatial averaging and spectral effects. (RadCalNet, spectral HR sensors to establish transfer functions, community agreed RTM, protocols, …) It is always a **cooperative approach**: (**CEOS, GSICS**)

4. **Orbital maneuverer** provide view on **moon** (ROLO, LIME) for stability monitoring and diffusor BRDF investigations

5. "… **the calibration is a never-ending process and a dedicated effort should be allocated throughout the full mission lifetime (and beyond), …**

TABLE I
SOME OF THE PUBLISHED WORKS ON THE USE OF INTERCALIBRATION TECHNIQUES

Number	Intercalibration Method	References
1	Simultaneous Nadir Overpasses (SNO)	[97], [24], [21], [22], [98], [99], [100], [101], [102], [103], [104], [105]
2	Spectral Band Adjustment	[106], [42], [
3	Statistical Inter-Calibration	[53], [
4	Examples of GEO-LEO Intercalibration	[78], [
5	Examples of LEO-LEO Intercalibration	[98], [[131], [143],
6	Geostationary satellites	[6], [5
7	Series of observations from multiple satellites	[28], [
8	Aircraft observations	[56], [128], [154], [155], [156], [157]
9	Numerical Weather Prediction + Radiative Transfer Models	[57], [58], [124]
10	Vicarious Ground Based Calibration	[43], [88], [107], [109], [110], [137], [140], [142], [158], [159], [160], [161], [162], [163], [164], [165], [166], [167], [168], [169], [170], [171], [172], [173], [174], [175]
11	Pseudo-Invariant Calibration Sites (PICS)	[19], [22], [37], [60], [138], [139], [176], [177], [178], [179], [180], [181], [182], [183], [184], [185], [186], [187]
12	Deep Convective Clouds (DCC)	[44], [67], [68], [70], [132], [188], [189], [190], [191], [192], [193], [194], [195], [196], [197], [198], [199], [200], [201], [202], [203], [204], [205]
13	Rayleigh Scattering	[69], [70], [206], [207], [208], [209], [210], [211], [212], [213]
14	Liquid Water Cloud (LWC)	[191], [214], [215], [195], [196], [198], [200], [201], [202], [216]
15	Sun Glint	[71], [72], [217], [218], [219], [220], [221], [222], [223], [224], [194]
16	The Moon	[8], [73], [74], [75], [76], [143], [146], [225], [226], [227], [228], [229], [230], [231], [232], [233], [234], [235]
17	The Stars	[77], [236], [237], [238],[78], [79], [239]
18	Ray-Tracing	[44], [121], [132], [189]

1056 IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 51, NO. 3, MARCH 2013

Overview of Intercalibration of Satellite Instruments

Gyanesh Chander, *Member, IEEE*, Tim J. Hewison, *Senior Member, IEEE*, Nigel Fox, Xiangqian Wu, *Member, IEEE*, Xiaoxiong Xiong, *Member, IEEE*, and William J. Blackwell, *Senior Member, IEEE*