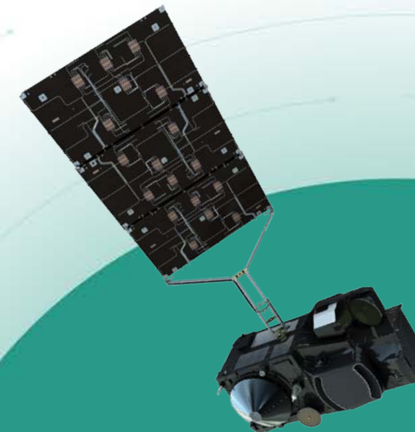
Sentinel-3 yaw manoeuvres for solar diffuser characterization on orbit



International Ocean Colour Science Meeting 2017

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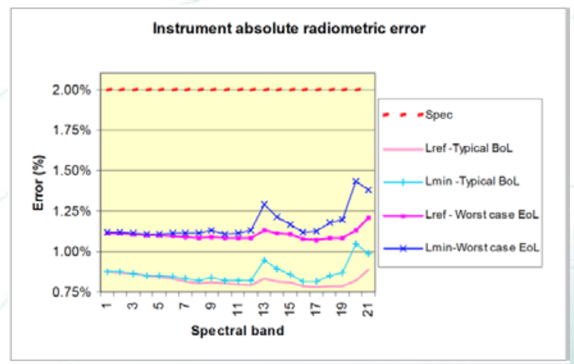
Sentinel-3 OLCI solar diffuser characterization

- **Solar diffusers are OLCI primary radiometric standard**
  - Knowledge of solar diffuser BRDF allows quantitative interpretation ❶ **absolute radiometric response and** ❷ **temporal degradation**, via regular on-orbit radiometric calibrations [ESA/EUM Cal/Val plan, OLCI-L1B-CV-200]
- **Importance of solar diffuser characterization for the quality of ocean colour products**
  - Ocean colour products are particularly sensitive to instrument characterization [IOCCG Report 13]
  - ❶ accuracy and ❷ stability of ocean colour products depend on solar diffuser BRDF uncertainties
- **Pre-launch characterization**
  - Pre-launch BRDF characterization is difficult and can only be made at a limited set of solar illumination and camera view angles, and at a few selected bands
- **Potential of solar diffuser BRDF assessment on-orbit**
  - Assessment of solar diffuser characterization is possible on-orbit with yaw maneuvers
  - Experience from Terra and Aqua MODIS and Suomi NPP VIIRS

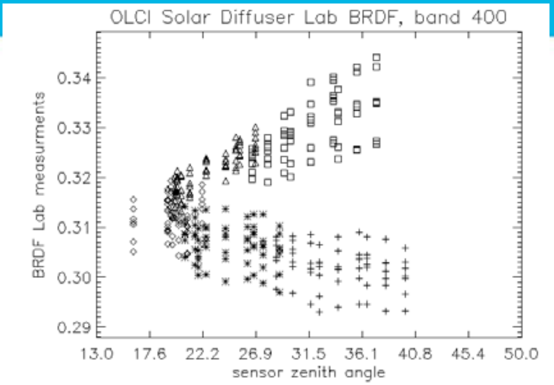
Spectral bands		Oa1	Oa2	Oa3	Oa4	Oa5	Oa6	Oa7	Oa8	Oa9	Oa10	Oa11	Oa12	Oa13	Oa14	Oa15	Oa16	Oa17	Oa18	Oa19	Oa20	Oa21
Central wavelength		400.0	412.5	442.5	490.0	510.0	560.0	620.0	665.0	673.8	681.3	708.8	753.8	761.3	764.4	767.5	778.8	865.0	885.0	900.0	940.0	1020.0
Width		15.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	7.5	7.5	10.0	7.5	2.5	3.8	2.5	15.0	20.0	10.0	10.0	20.0	40.0
Error term	Error type																					
Diffuser characterisation error	NSB	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%	0.29%
Diffuser model error	NSB	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%
Diffuser alignment error	NSB	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%	0.31%
Orbital stability	random	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%
Intrument ageing	SBE	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%
Calibration straylight	NSB	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%
Post-calibration straylight	NSB	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%
Calibration speckle	NSB	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.20%	0.20%	0.20%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%
Diffuser 1 ageing	SBE	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%
Diffuser 2 ageing	SBE	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%	0.24%
Integral NL - Lref	NSB	0.47%	0.47%	0.47%	0.47%	0.47%	0.47%	0.47%	0.47%	0.47%	0.47%	0.47%	0.47%	0.48%	0.47%	0.48%	0.47%	0.48%	0.48%	0.48%	0.50%	0.62%
Integral NL - Lmin	NSB	0.47%	0.47%	0.47%	0.47%	0.47%	0.47%	0.47%	0.47%	0.48%	0.48%	0.47%	0.48%	0.50%	0.48%	0.49%	0.48%	0.48%	0.49%	0.49%	0.54%	0.60%
DNL - Lref	NSB	0.03%	0.03%	0.03%	0.03%	0.04%	0.06%	0.07%	0.09%	0.12%	0.08%	0.10%	0.13%	0.22%	0.18%	0.12%	0.12%	0.13%	0.19%	0.20%	0.31%	0.28%
DNL - Lmin	NSB	0.09%	0.08%	0.08%	0.08%	0.09%	0.15%	0.17%	0.20%	0.27%	0.19%	0.23%	0.28%	0.53%	0.43%	0.28%	0.27%	0.29%	0.41%	0.46%	0.77%	0.56%
Gain ratio error -Lref	NSB	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.08%
Gain ratio error -Lmin	NSB	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.06%
Offset error - Lref	random	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.02%	0.02%	0.02%	0.03%	0.09%	0.05%	0.07%	0.02%	0.03%	0.05%	0.05%	0.07%	0.09%
Offset error - Lmin	random	0.02%	0.02%	0.02%	0.02%	0.02%	0.04%	0.03%	0.04%	0.05%	0.05%	0.04%	0.06%	0.20%	0.12%	0.16%	0.04%	0.07%	0.11%	0.11%	0.17%	0.19%
Dark stability error - Lref	random	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%	0.02%	0.07%	0.19%
Dark stability error - Lmin	random	0.01%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.03%	0.02%	0.02%	0.02%	0.03%	0.03%	0.05%	0.18%	0.38%
Absolute radiometric acc. (% - 1sigma)	**Lref**	**1.12%**	**1.11%**	**1.11%**	**1.10%**	**1.10%**	**1.10%**	**1.09%**	**1.09%**	**1.09%**	**1.08%**	**1.08%**	**1.08%**	**1.13%**	**1.11%**	**1.11%**	**1.08%**	**1.07%**	**1.09%**	**1.08%**	**1.13%**	**1.21%**
	Lmin	**1.12%**	**1.12%**	**1.11%**	**1.11%**	**1.11%**	**1.11%**	**1.11%**	**1.11%**	**1.13%**	**1.11%**	**1.11%**	**1.13%**	**1.29%**	**1.21%**	**1.17%**	**1.12%**	**1.12%**	**1.18%**	**1.20%**	**1.43%**	**1.38%**



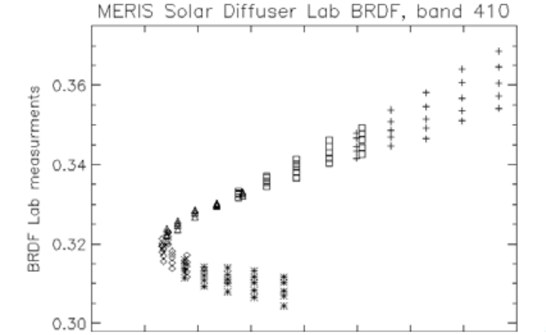
S3A OLCI solar diffuser pre-launch characterization

- **OLCI solar diffuser pre-launch laboratory BRDF characterizations applied lessons learned from MERIS**
  - BRDF measurements **relative and absolute** for OLCI flight modules (FM) FM-A and FM-B were performed at Centre Spatial de Liège (CLS) for
    - all 5 cameras,
    - 7 wavelengths,
    - 7 incidence angles, and
    - 9 observation angles
  - Traceability to the international standard was established by PTB, Germany

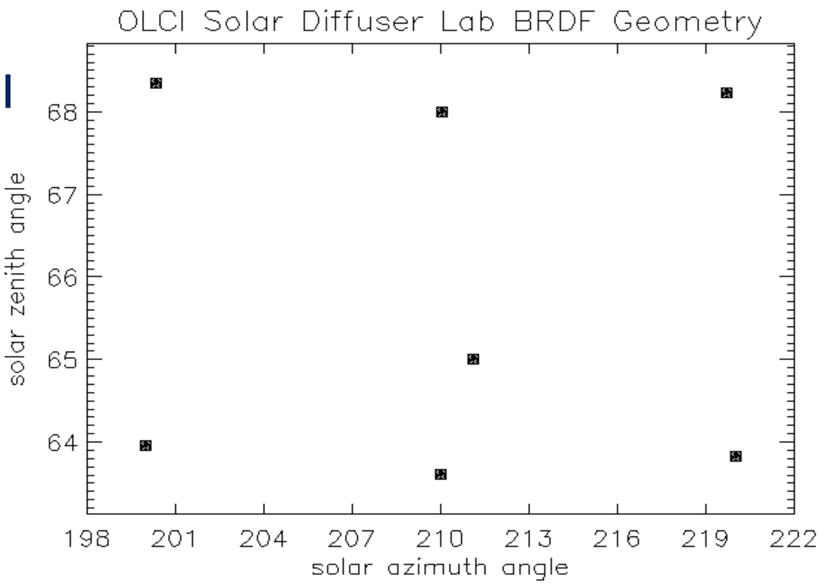
OLCI



MERIS



OLCI



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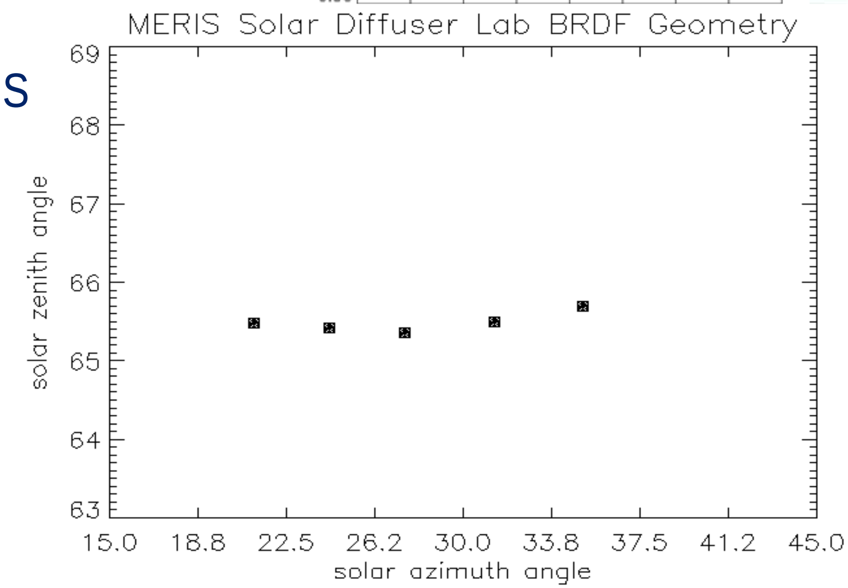
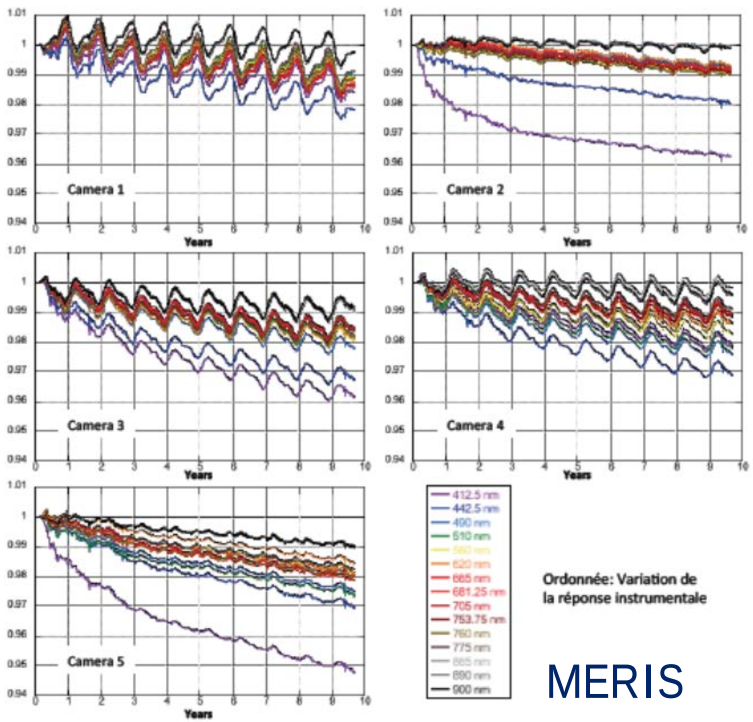


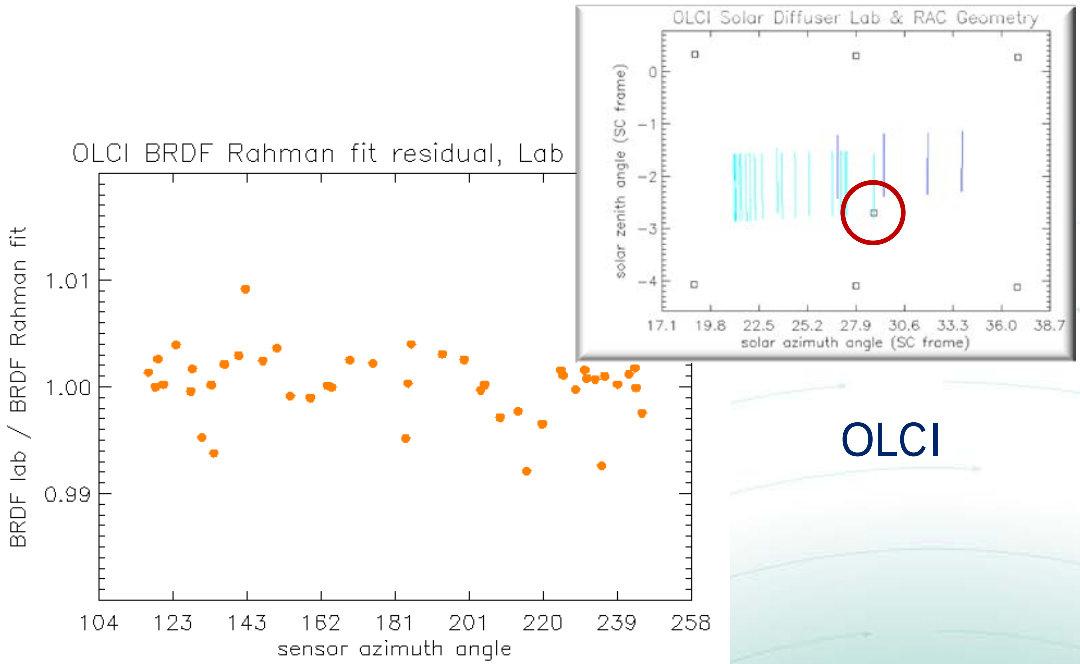
S3A OLCI solar diffuser BRDF modelling

- **OLCI solar diffuser BRDF model**
  - Lab BRDF measurements are fit with a model for the operational calibration processing
  - OLCI BRDF model is a variation of the MERIS BRDF Rahman model, the model was developed and tested to fit the absolute measurements with about 0.3% uncertainty
  - Experience with MERIS: radiometric gains displayed a seasonal pattern correlated with solar azimuth angles on the solar diffuser (BRDF model dependency)
  - Experience with OLCI: BRDF model reproduces the reference geometry within ± 0.9 %
- **Only a single Lab BRDF incidence angle matches the on-orbit geometry of radiometric calibrations**



Ordonnée: Variation de la réponse instrumentale

MERIS



OLCI

S3A OLCI solar diffuser on-orbit activities

❶ Sentinel-3 OLCI operational radiometric calibration cycles

❷ OLCI in-flight solar diffuser assessment with yaw manoeuvres

❶ Selection of a set of solar azimuth angles for OLCI operational radiometric calibration sequences, S01 and S04/05

- The same set of predefined azimuths will be used year-after-year

❷ Yaw manoeuvres to reproduce in a single day the annual range of variations in solar geometry on the diffuser

- Assessment of solar diffuser BRDF on orbit with real on-orbit calibration geometries for
  - continues solar elevations,
  - more azimuth incidence angles,
  - all viewing angles and
  - all operational spectral bands
- Yaw manoeuvres are a low risk routine, they replicate the geometries operationally encountered on orbit
- Yaw manoeuvres only provide information on relative BRDF characterization, not absolute

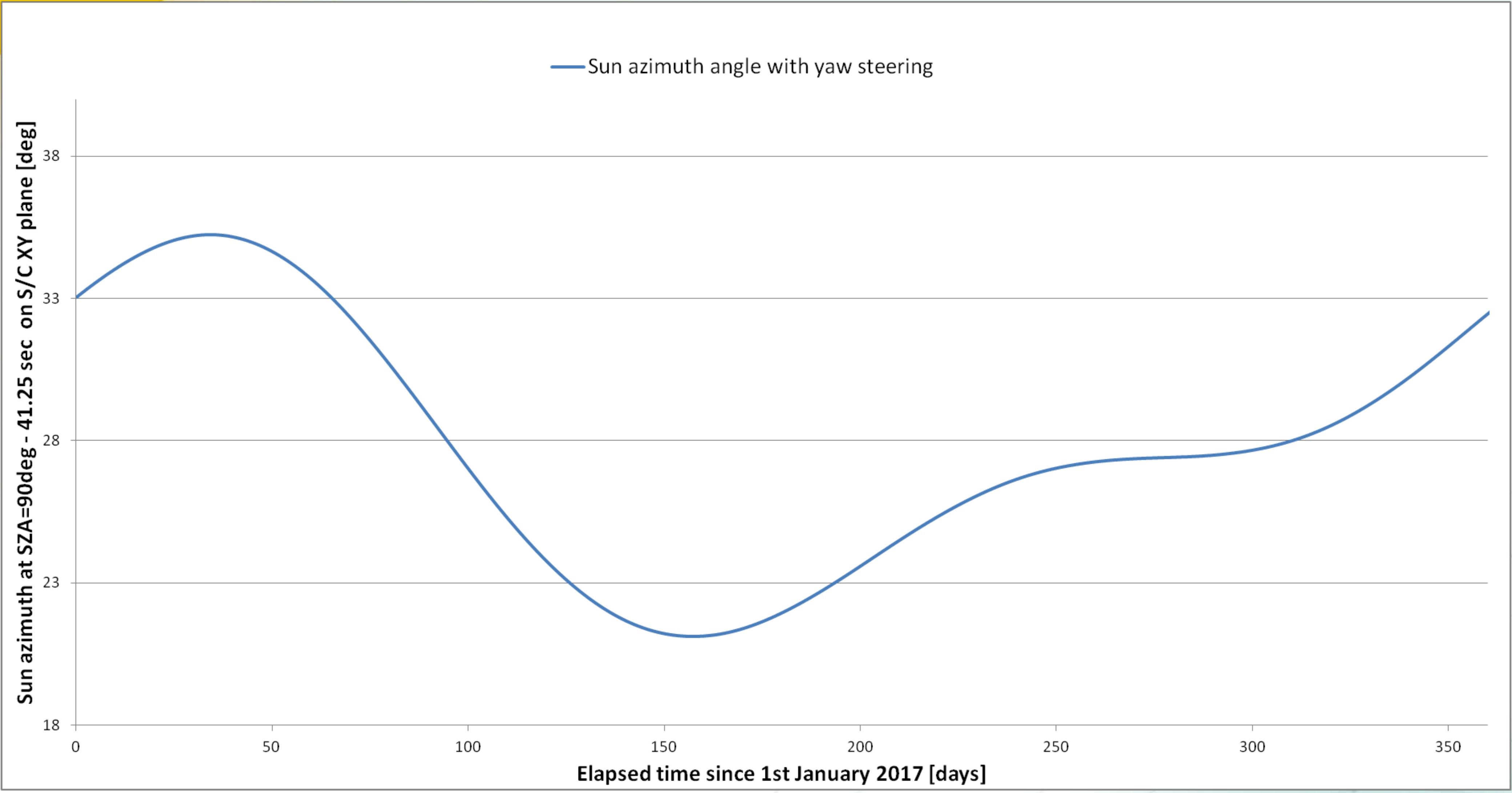
Sentinel-3A yaw manoeuvres

– Sentinel-3A MAG endorsed "the scientifically robust approach to use one-off satellite yaw manoeuvres during the Phase-E2 PDGS Commissioning Ramp-up to perform an in-flight verification of the OLCI and SLSTR solar diffuser calibration measurements for all seasonal geometry changes" (S3MAG–M4–A10)

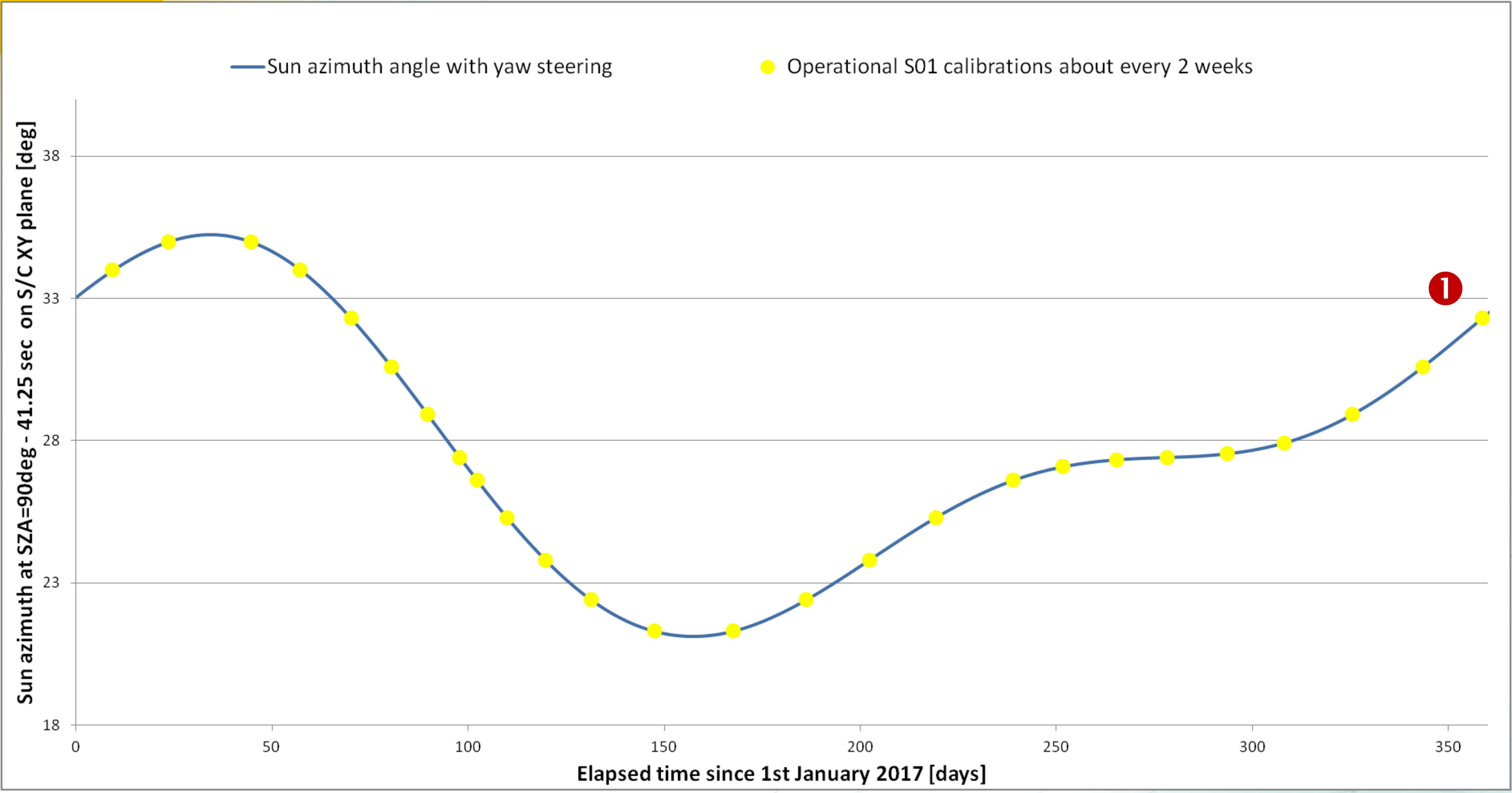
– OLCI Cal/Val task in the S3 Cal/Val Plan, 2014 (OLCI-L1B-CV-280)

– Sentinel-3A IOCR technical meeting recommendation (S3-MN-ESA-OL-752)

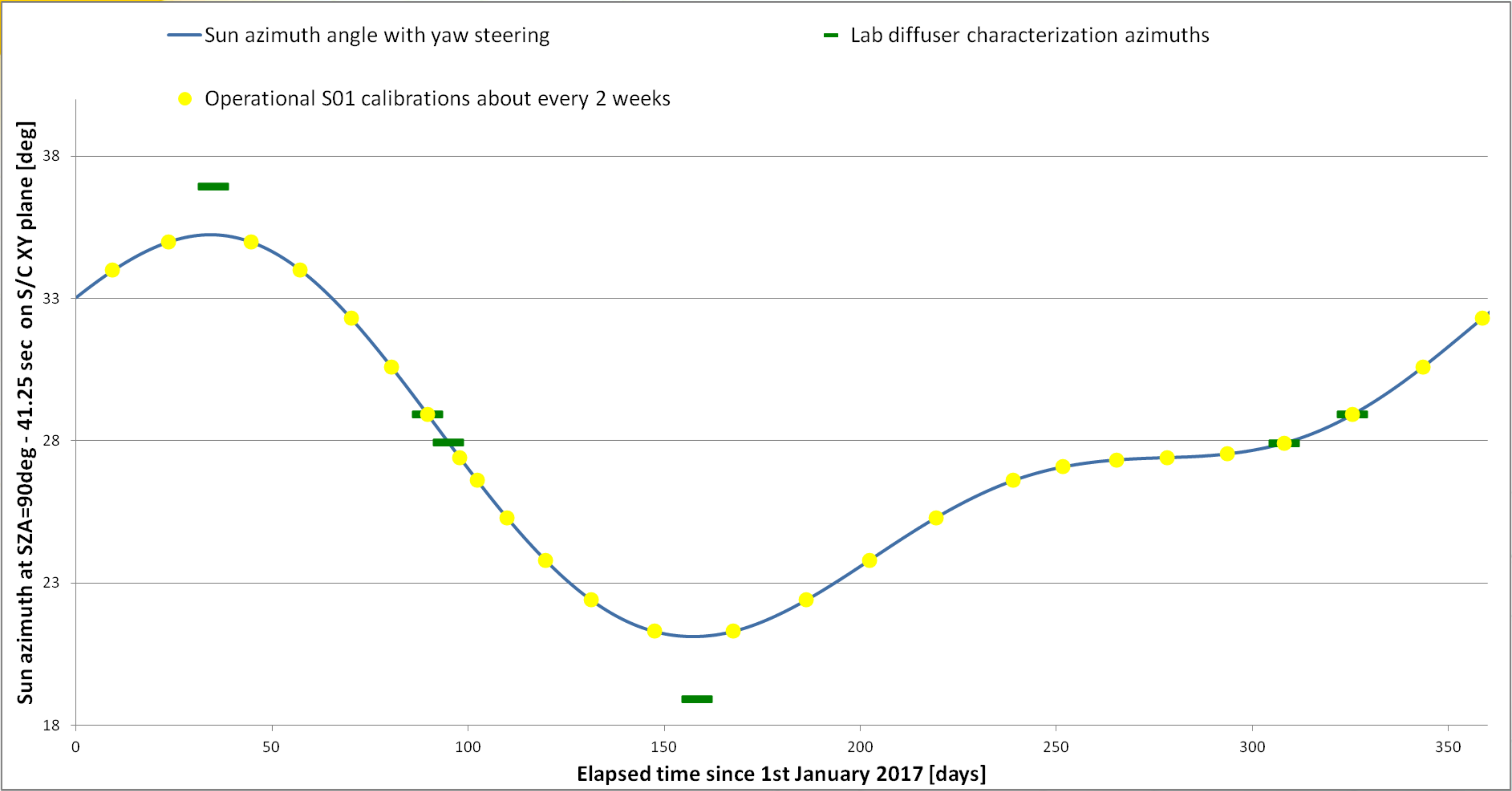
Evolution of solar azimuth angle on the OLCI solar diffuser over a full year on orbit



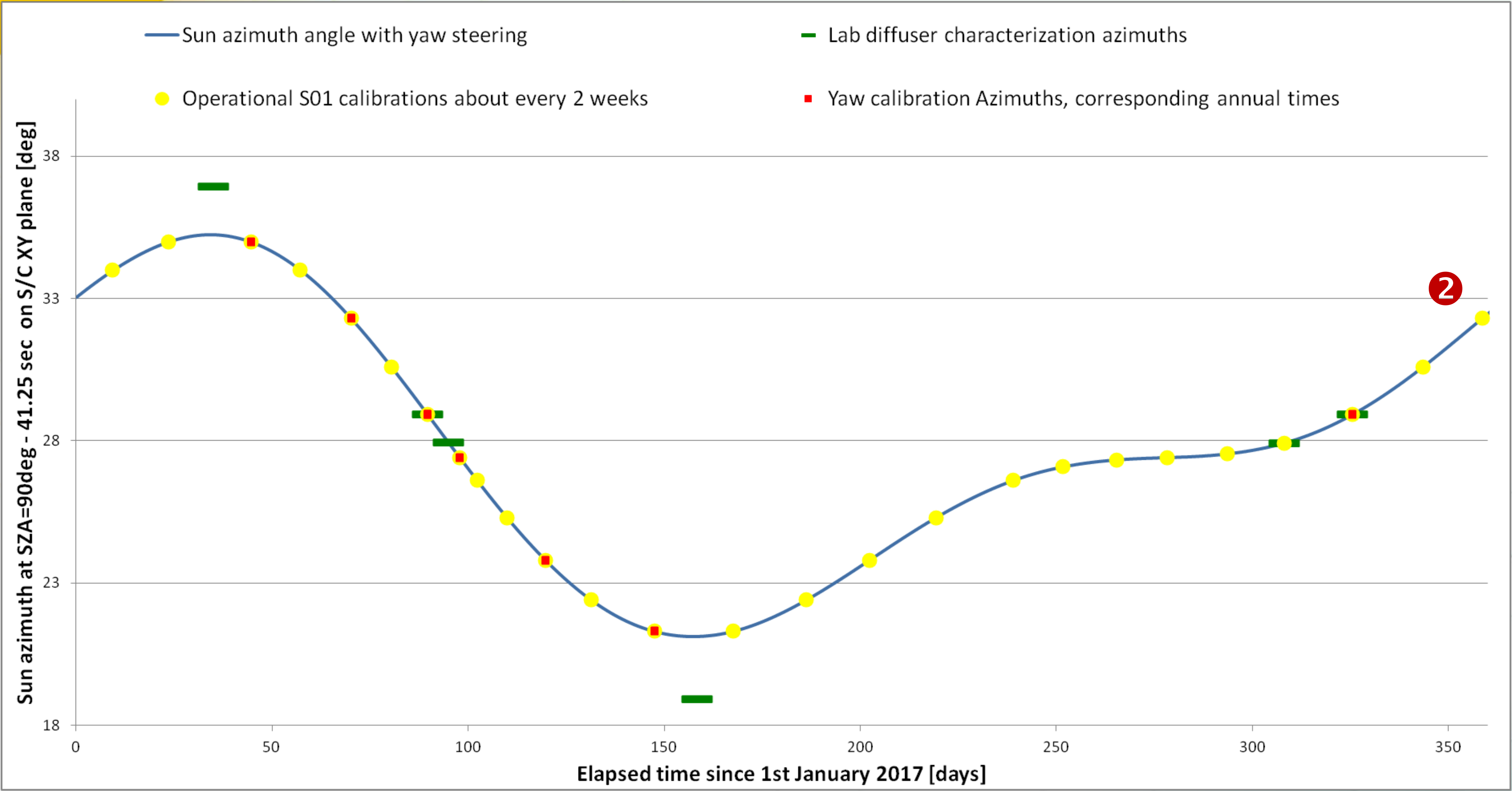
Added azimuth angles of operational radiometric calibrations S01



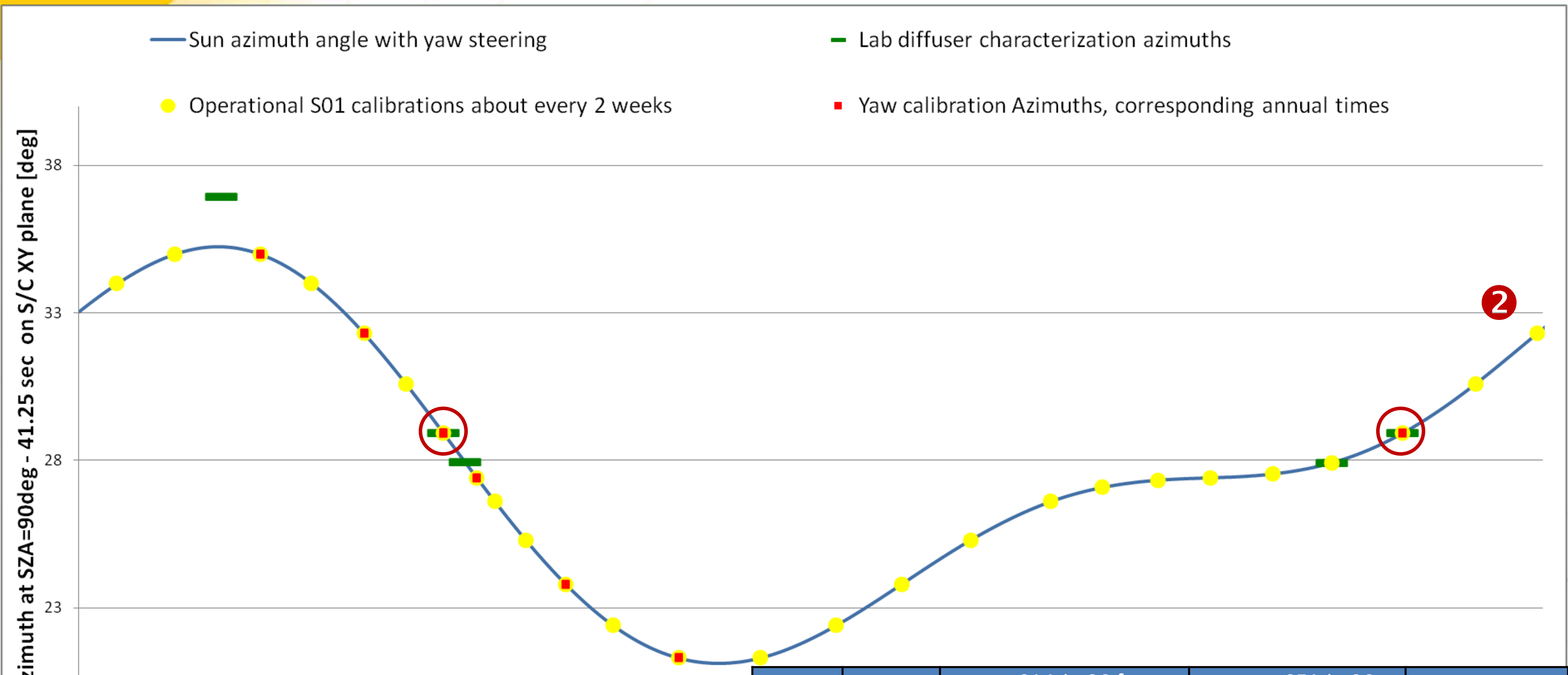
Added azimuth angles of pre-launch characterizations

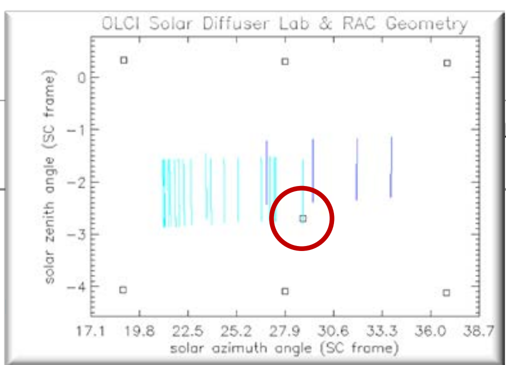


Added angles of yaw manoeuvres



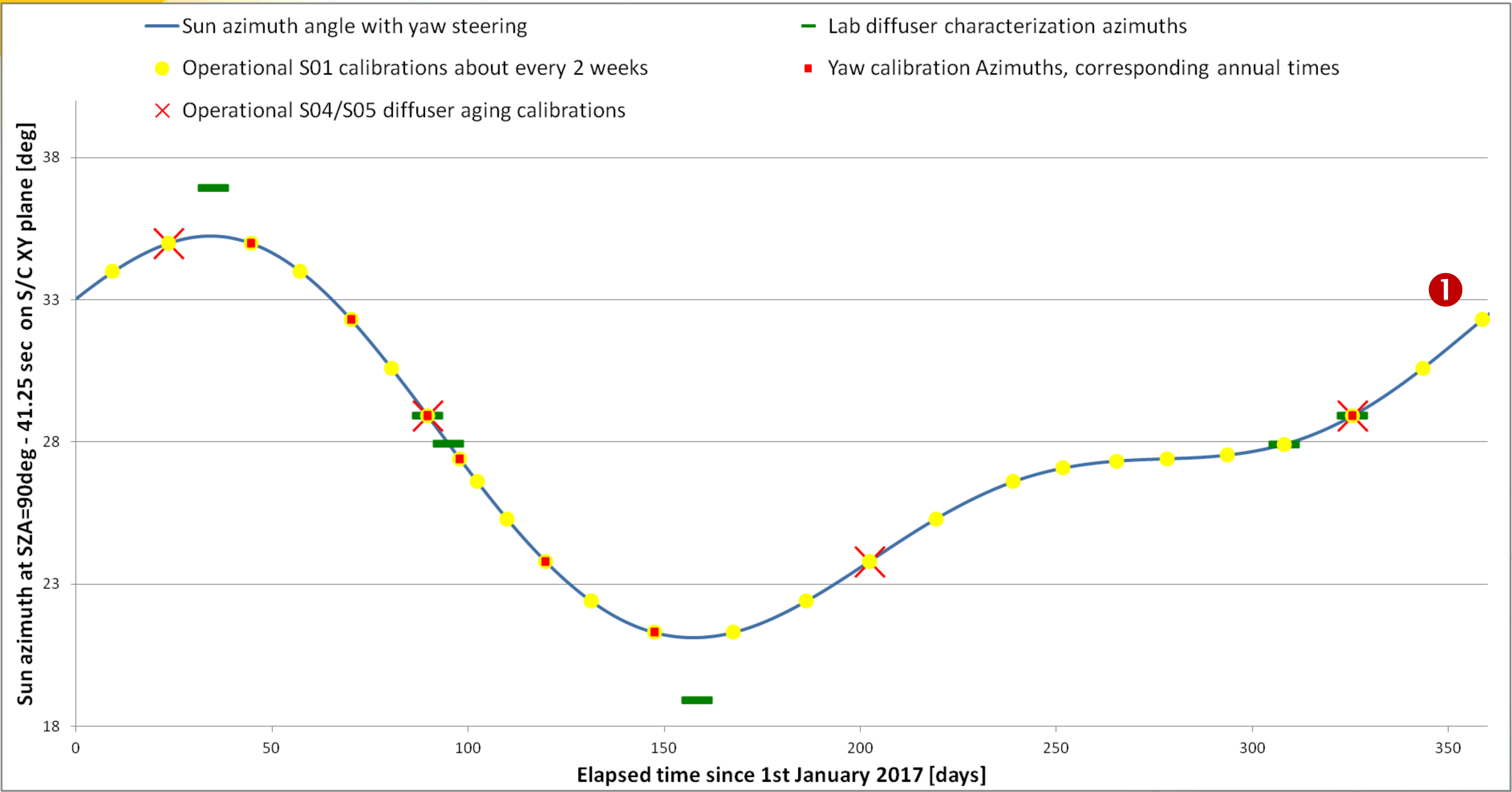
Defined the yaw manoeuvres with a tie to the pre-launch absolute BRDF reference value





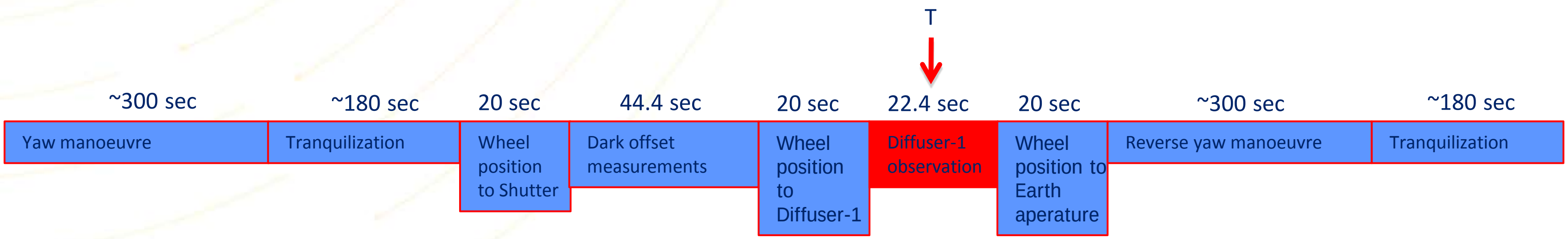
Cal#	Type	target SAA in SC frame [deg]	target SEA in SC frame [deg]	yaw bias [deg]
1	S01	28.919	-2.179	0.117
2	S01	35.0		-5.957
3	S01	32.3		-3.249
4	S01	27.41		1.648
5	S01	23.8		5.265
6	S01	21.3		7.771
7	S01	28.919		0.158
8	S05	28.919		0.166

Added azimuth angles of diffuser ageing calibrations S04/S05

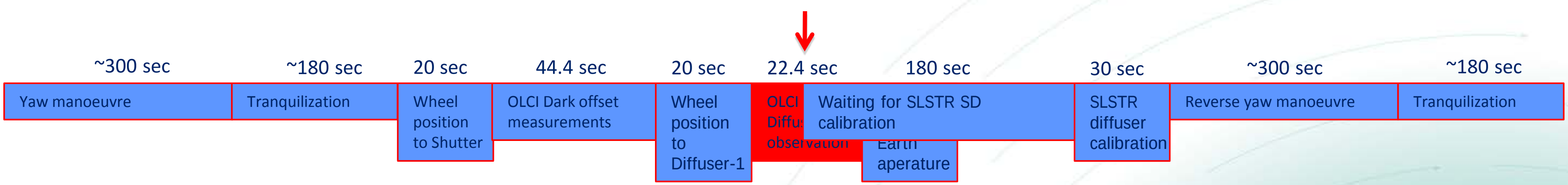


Yaw manoeuvres implementation

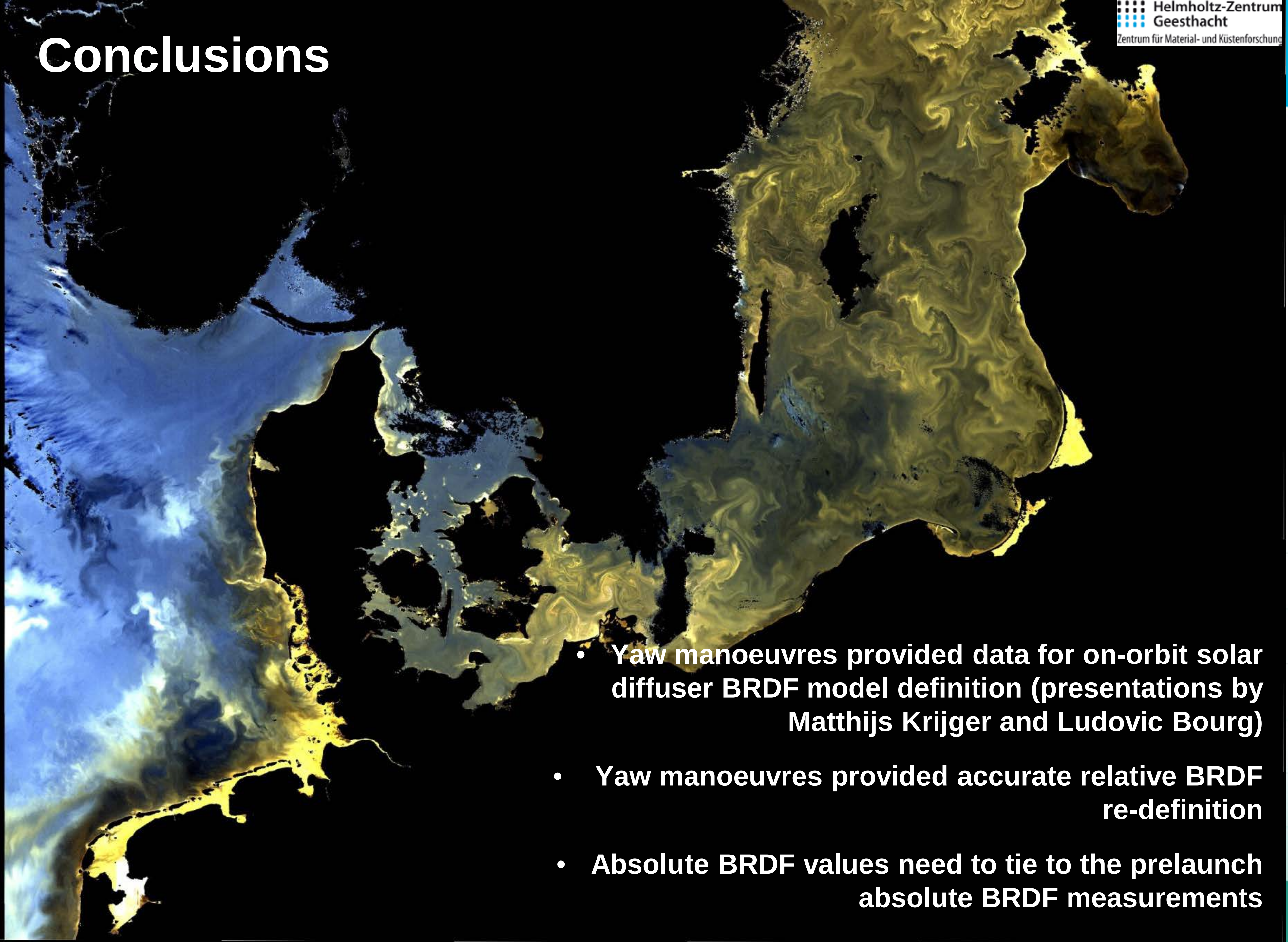
- **Nominal option:**
  - S01 calibration sequences were performed when the satellite was transitioned to predefined yaw steering for the event of the calibrations



- **OLCI and SLSTR solar diffuser yaw activity**
  - Yaw manoeuvres were extended to enable SLSTR SD acquisitions preformed 3 min after OLCI calibrations
  - For SLSTR, the SD BRDF effects are secondary. The yaw data were used to characterize on-orbit the vignetting of the SLSTR SD at both sides of the SD baffle



Conclusions



- Yaw manoeuvres provided data for on-orbit solar diffuser BRDF model definition (presentations by Matthijs Krijger and Ludovic Bourg)
- Yaw manoeuvres provided accurate relative BRDF re-definition
- Absolute BRDF values need to tie to the prelaunch absolute BRDF measurements