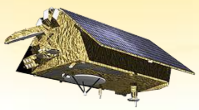
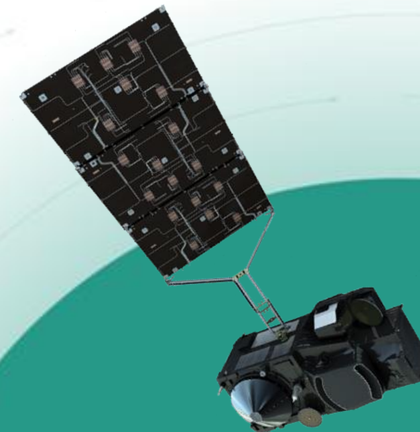
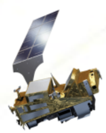
Activities and plans for Cal/Val of Sentinel Ocean Colour Radiometry



International Ocean Colour Science Meeting 2017

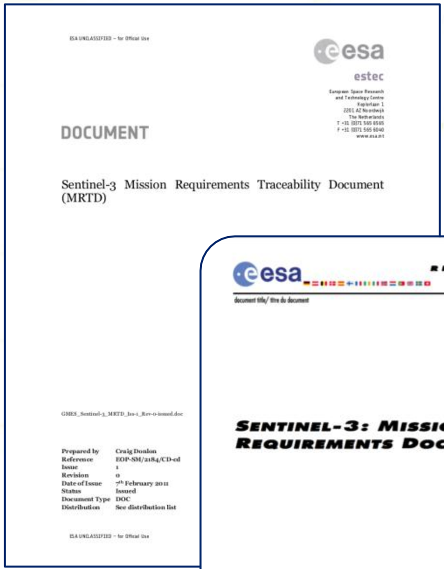


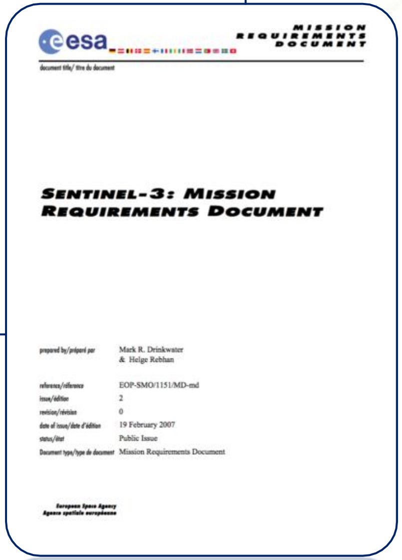


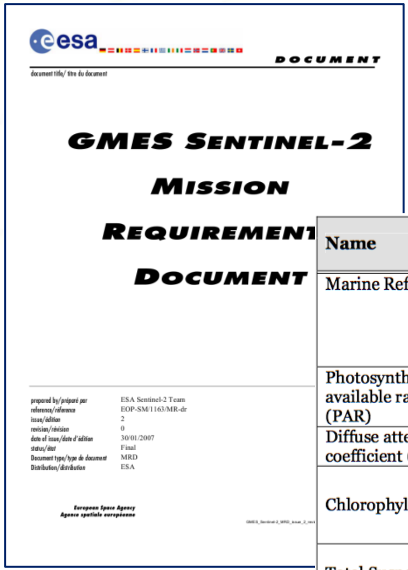
ewa.kwiatkowska@eumetsat.int

Sentinel Ocean Colour Radiometry requirements

- **Cal/val aims to fulfill the mission requirements**
- **Cal/val planning ensures traceability to the mission requirements** [S3 Mission Requirements Traceability Document, 2011; S2 Mission Requirements Document, 2007]





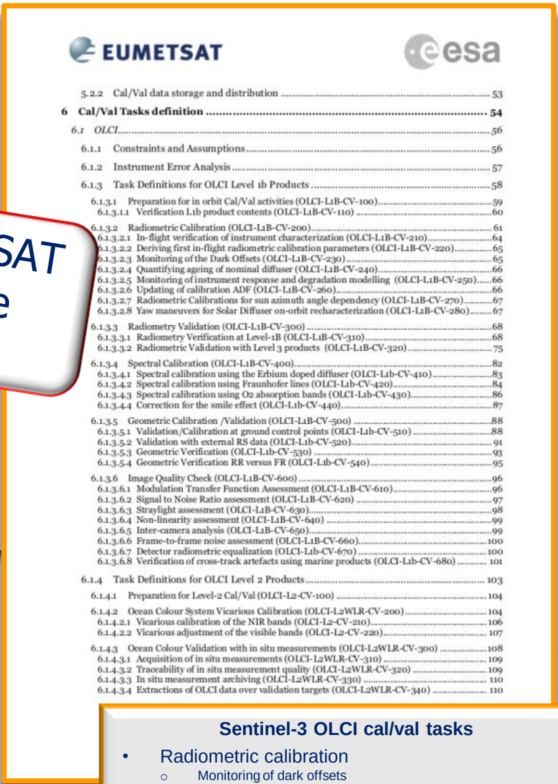


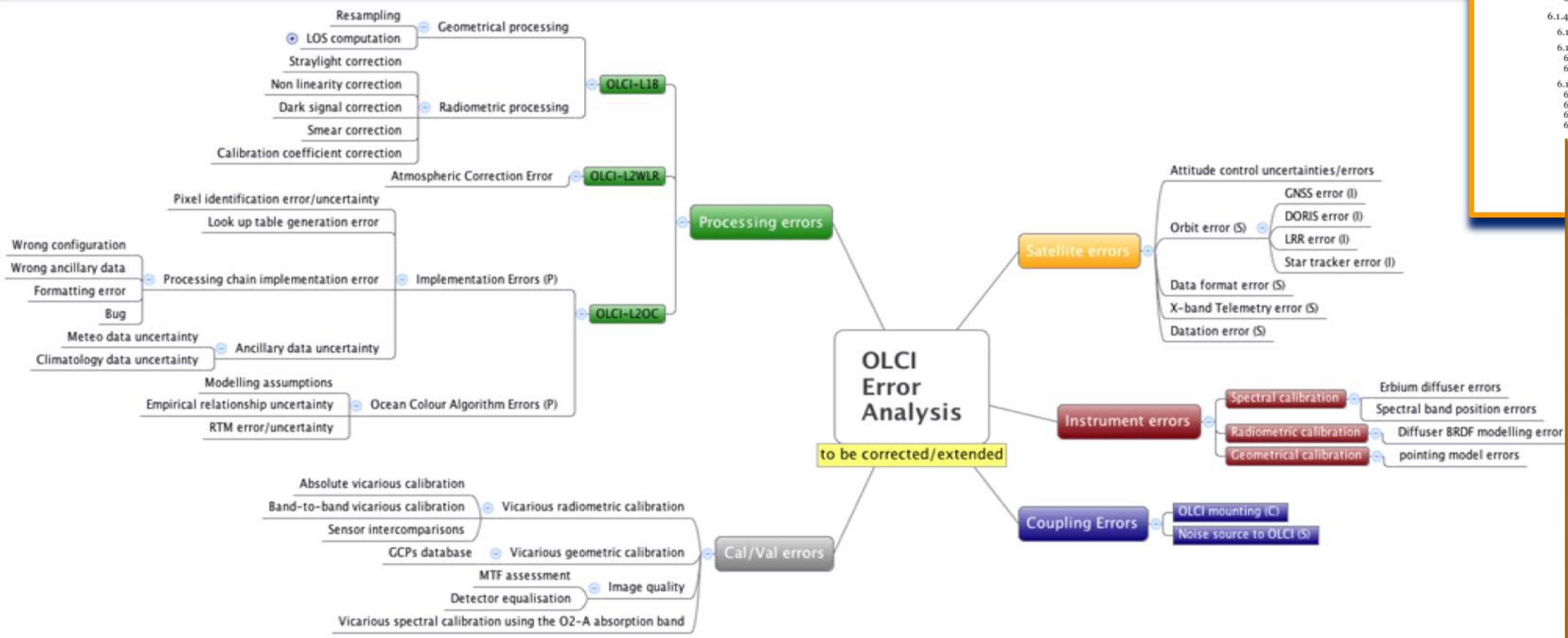
Name	Description	Units	Resolution	Range	Goal Accuracy Case-1:	Goal Accuracy Case-2	Prod. Level	Delivery
Marine Reflectance (R)	Surface directional reflectance, corrected for atmosphere and Sun specular reflection, at all channels except those dedicated to atmosphere absorption measurements, and associated error estimates. (atmospherically corrected)	-	0.3 – 1.2 km	0.001 – 0.04	5 x 10-4	5 x 10-4	L2	NRT
Photosynthetically available radiation (PAR)	Quantum energy flux from the Sun in the spectral range 400-700 nm and associated error estimates.	µmol quanta/ m2/s	0.3 - 1.2 km	0 – 1400	5%	5%	L2	NRT and NTC
Diffuse attenuation coefficient (Kd)	Diffuse attenuation coefficient for downwelling irradiance, and associated error estimates	m^{-1}	0.3 - 1.2 km	0.001 – 0.1	5%	5%	L2	NRT and NTC
Chlorophyll (Chl)	Chlorophyll-a concentration, and associated error estimates in coastal and open ocean waters.	mg/m^3	0.3 - 1.2 km	0.001 – 150	Thresh. 30 % goal 10 %	Thresh. 70 % goal 10 %	L2	NRT and NTC
Total Suspended Matter (TSM)	Total suspended matter concentration, and associated error estimates	g/m^3	0.3 - 1.2 km	0 - 100	Thresh. 30 % goal 10 %	Thresh. 70 % goal 10 %	L2	NRT and NTC
Coloured Dissolved Organic Material (CDOM)	Absorption of Coloured Detrital and Dissolved Material, and associated error estimates, at 443 nm.	m^{-1}	0.3 - 1.2 km	0.01 – 2	Thresh. 50 % goal 10 %	Thresh. 70 % goal 10 %	L2	NRT and NTC
Integrated Water vapour column (IWV)	Global coverage of total amount of water vapour integrated over an atmosphere column, and associated error estimates over land and ocean (global).	$kg.m^{-2}$.	0.3 – 1.2 km	0 - 50			L2	NRT and NTC
Aerosol Optical Depth (AOD (τ)) over water at 865 nm	Global coverage over water of aerosol load, expressed in optical depth at 865 nm, and associated error estimates.	-	0.3 – 1.2 km	0-3	50% [RD-118]	10%	L2	NRT and NTC
Aerosol Angstrom exponent (Å) over water at 865 nm	Global coverage over water of spectral dependency of the Aerosol Optical Depth with associated error estimates.	-	0.3 – 1.2 km	0 - 3			L2	NRT and NTC

Sentinel-3 cal/val and Mission Performance Framework

- **Sentinel-3 OLCI cal/val activities**
  - based on joint ESA and EUMETSAT Cal/Val Plan
- **Sentinel-3 Mission Performance Framework**
  - Quality Working Groups (OLCI-SYN QWG)
  - Mission Performance Centre
  - Sentinel-3 Validation Team
  - Mission Performance activities in-house

Joint ESA and EUMETSAT Mission Performance Framework

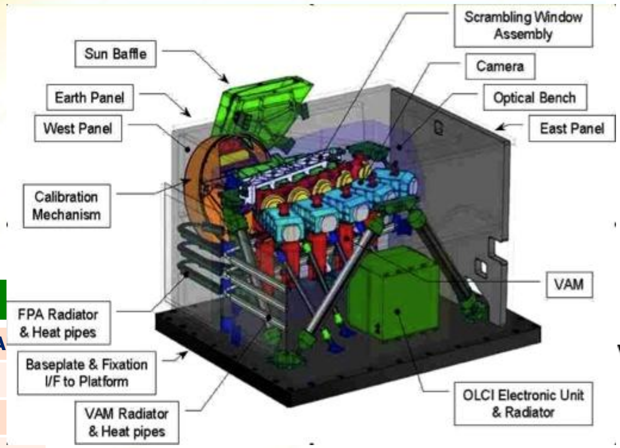

EUMETSAT esa



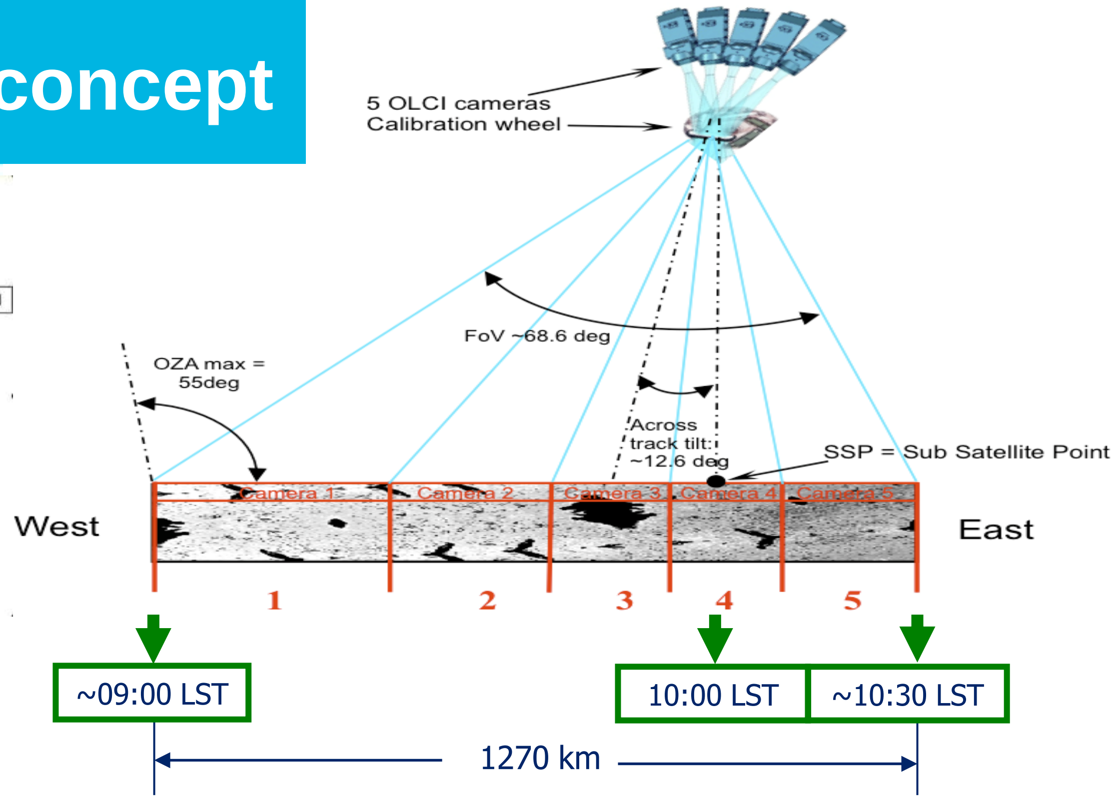
Sentinel-3 OLCI cal/val tasks

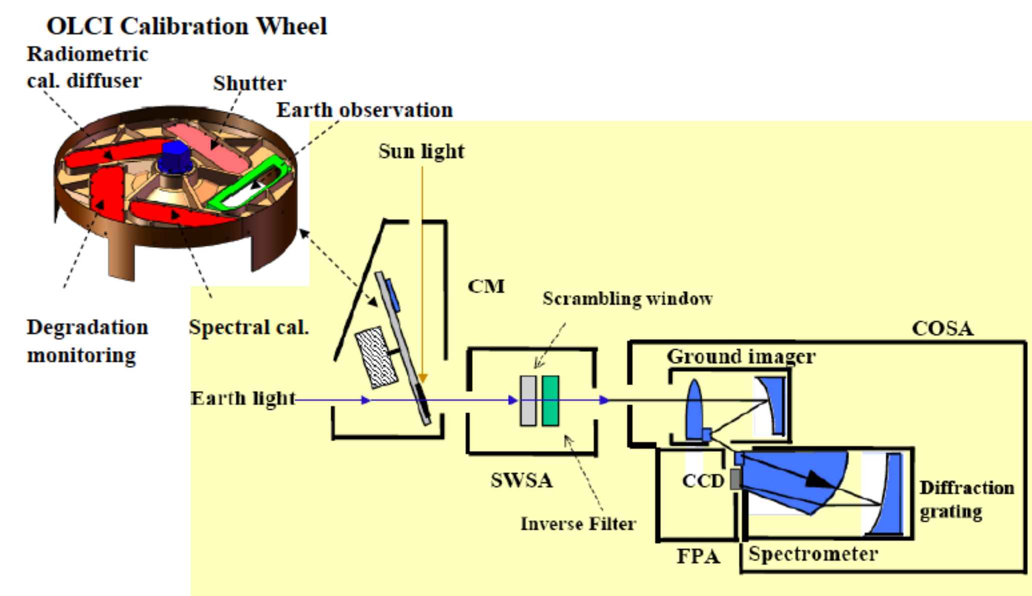
- Radiometric calibration
  - Monitoring of dark offsets
  - Quantifying of aging of solar diffusers
  - Monitoring of instrument response and degradation modelling
- Radiometry validation
  - Verification with Level-1B and Level-3 products
- Spectral calibration
  - Erbium doped diffuser
  - Campaigns: Fraunhofer line and O2 absorption band calibration
  - Correction for the smile effect
- Geometric calibration and validation
- L1 product quality verification
- System vicarious calibration
  - NIR and VIS band system vicarious calibration
- Validation with in situ measurements
  - Acquisition of in situ measurements, measurement archiving
  - Traceability of in situ measurement quality
  - Extraction of OLCI data over validation sites, extract archiving
  - Generation of matchups and trend results
- Validation with Level-3 products
  - Evaluation of algorithm performance over time and space
  - Evaluation of consistency with other missions
  - Monitoring of the processing chain and implementation
- L2 product quality verification

OLCI in-flight calibration concept



#	modules
5	Camera Optical Sub Assemblies (**COSA**)
5	Focal Plane Assemblies (**FPA**)
5	Video Acquisition Modules
1	Scrambling Window Sub-Assembly (**SWSA**)
1	OLCI Electronic Unit (OEU) managing all instrument functions
1	Calibration mechanism (**CM**) allowing radiometric, spectral and dark calibration



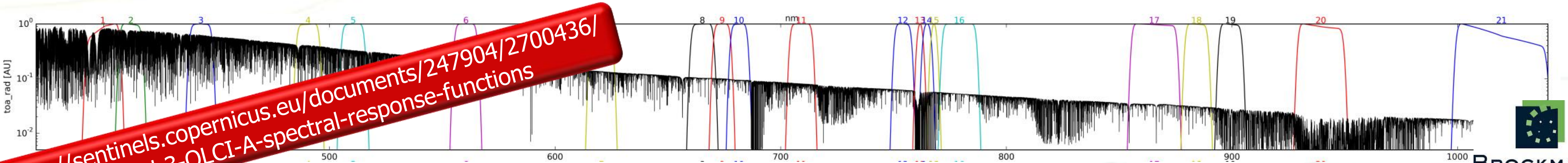


#	calibration type	measurements	frequency	conditions
S01	Radiometric calibration	Dark Shutter calibration Radiometric calibration w Diffuser 1	About every 2 weeks	South Pole Nominal band set
S02	Spectral calibration with diffuser Orbit n	Dark Shutter calibration Radiometric calibration w Diffuser 1	About every 3 months	South Pole Erbium band set
S03	Spectral calibration with diffuser Orbit n+1	Dark Shutter calibration Spectral calibration w Diffuser 3	Same as S02	South Pole Erbium band set
S04	Diffuser 1 ageing Orbit n	Dark Shutter calibration Radiometric calibration w Diffuser 1	About every 3 months	South Pole Nominal band set
S05	Diffuser 1 ageing Orbit n+1	Dark Shutter calibration Radiometric calibration w Diffuser 2	Same as S04	South Pole Nominal band set
S06	Orbital stability	Dark Shutter calibrations operated over an orbit	Specific calibration campaigns	Nominal band set
S07	Spectral calibration using solar Fraunhofer lines	Dark Shutter calibration Spectral calibration w Diffuser 1	Specific calibration campaigns	South Pole Fraunh. band set
S08	Radiometric calibration for observation of atmospheric absorption lines	Dark Shutter calibration Spectral calibration w Diffuser 1	Same as S02	South Pole Atm. absorption band set
S09	Observation of atmospheric absorption lines	Observations, particularly over deserts	Same as S02	Atm. absorption band set

S3A OLCI spectral calibration

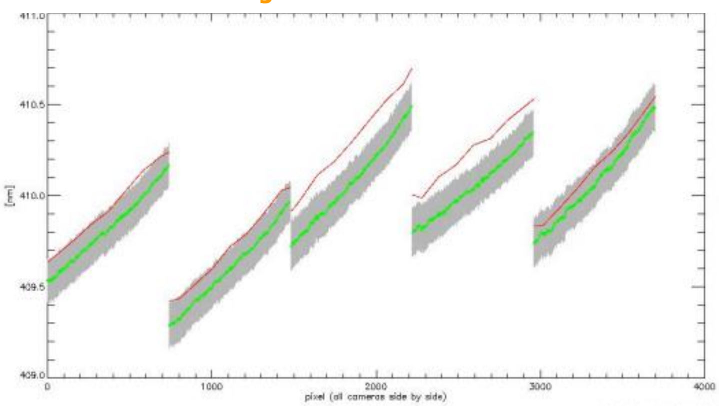
- **OLCI is fully compliant with spectral requirements**
  - spectral misregistration << 1.4nm (OL-DE-020)
  - pre-flight SRF confirmed on-orbit < 0.4nm << 1nm (OL-IQ-100)
- **OLCI spectral calibrations on orbit**
  - OLCI is programmable and can observe up to the highest spectral sampling of 1.25nm
  - Erbium-doped diffuser, Diffuser 3
  - Fraunhofer lines, Diffuser 1
  - atmospheric absorption lines (O_2A), Earth targets

#	OLCI nominal spectral bands	λ center	Width
1	Aerosol, in-water property	400	15
2	Yellow substance/detrital pigments	412.5	10
3	Chlorophyll absorption max	442.5	10
4	Chlorophyll and other pigments	490	10
5	Suspended sediments, red tide	510	10
6	Chlorophyll absorption min	560	10
7	Suspended sediment	620	10
8	Chlorophyll absorption & fluorescence	665	10
9	Fluorescence retrieval	673.75	7.5
10	Chlorophyll fluorescence peak	681.25	7.5
11	Chlorophyll fluorescence ref., atm. corr.	708.75	10
12	Vegetation, clouds	753.75	7.5
13	O_2 R-branch absorption	761.25	2.5
14	Atmospheric parameters	764.375	3.75
15	Cloud top pressure	767.5	2.5
16	O_2 P-branch absorption	778.75	15
17	Atmospheric correction	865	20
18	Vegetation, water vapour reference	885	10
19	Water vapour, land	900	10
20	Atmospheric/aerosol correction	940	20
21	Atmospheric/aerosol correction	1020	40



https://sentinels.copernicus.eu/documents/247904/2700436/Sentinel-3-OLCI-A-spectral-response-functions

Absolute wavelength for CCD row 553 across 5 cameras



BROCKMANN CONSULT

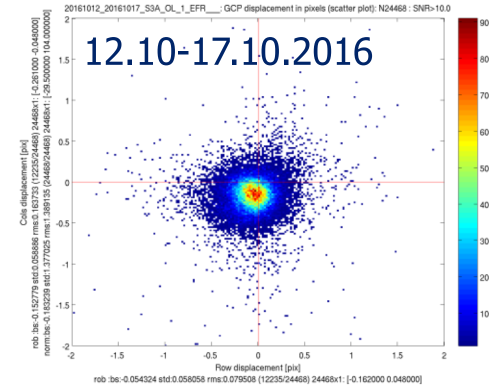
OLCI on-orbit spectral information

- Sentinel-3 OLCI-A spectral response functions (SRF), Sentinel 3 CalVal Team, S3-TN-ESA-OL-660, 2016
- centre wavelength, bandwidth, solar irradiance, RSF x200
- three SRF definitions available (section 7):
  - 21 bands x 5 cameras x 740 CCD columns
  - 21 bands x 5 cameras x 3 CCD columns (start, centre, end)
  - 21 bands average

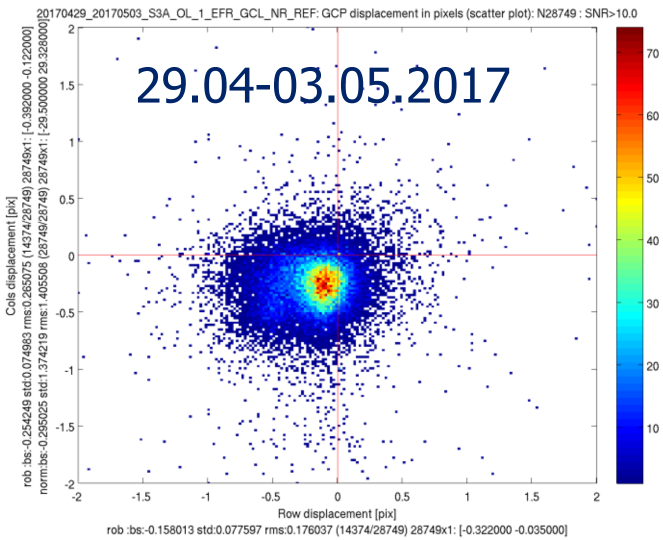
OLCI Smile correction is accomplished at L2 processing

S3A OLCI geometric calibration

- **OLCI is fully compliant with geolocation requirements**
  - Accuracy << 0.5 SSD rms with GCPs (SY-OB-210)
- **Operational performance monitoring: periodic assessment using Ground Control Points from Landsat land cover**
  - Initial analysis 12.10-17.10.2016
    - AC -0.15 ± 0.06 pix; AL: -0.05 ± 0.06 pix
  - Latest analysis 29.04-03.05.2017
    - AC: -0.25 ± 0.07 pix; AL: -0.16 ± 0.08 pix (robust statistics)

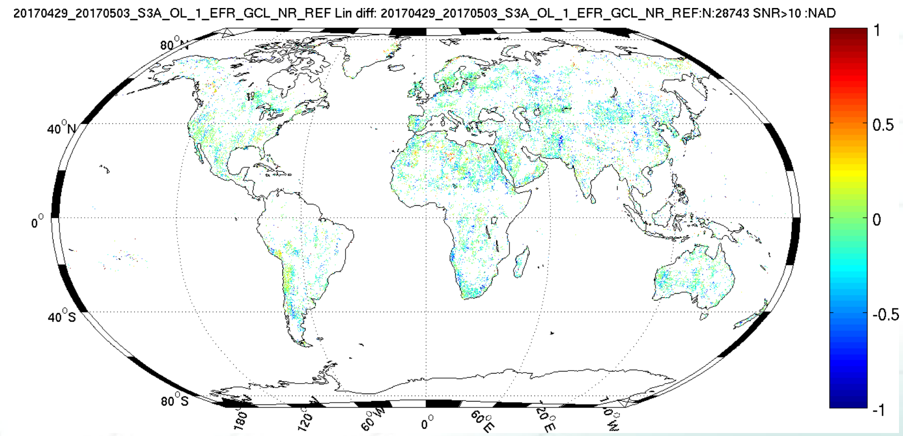


Across track



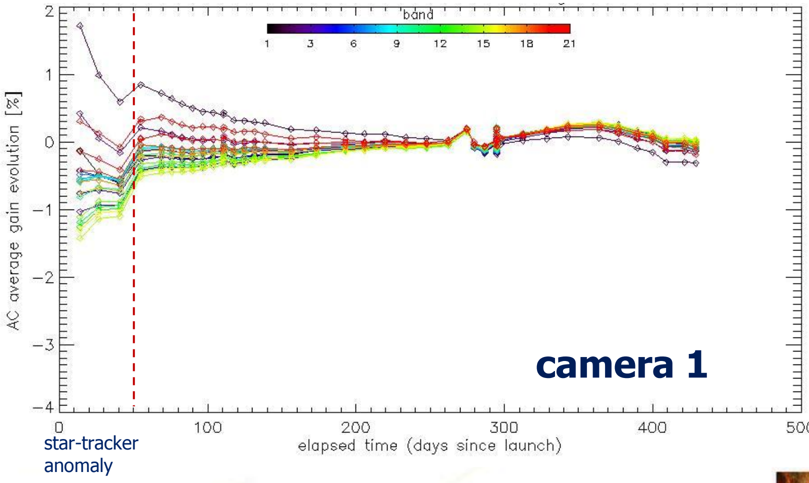
Along track

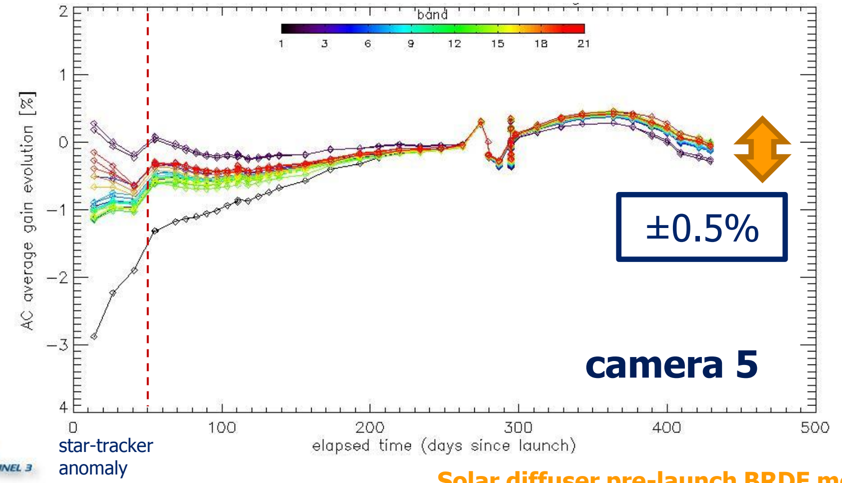
Location of used GCP and associated along track differences



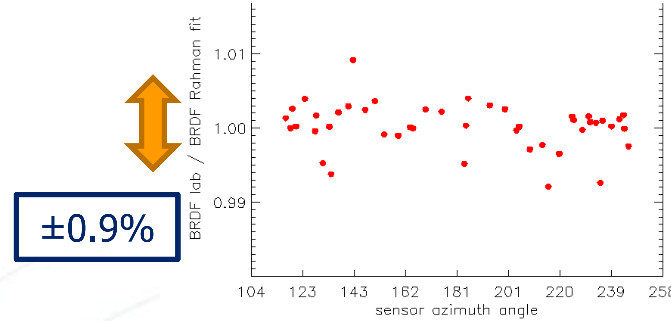
S3A OLCI radiometric response evolution

OLCI relative radiometric evolution since launch

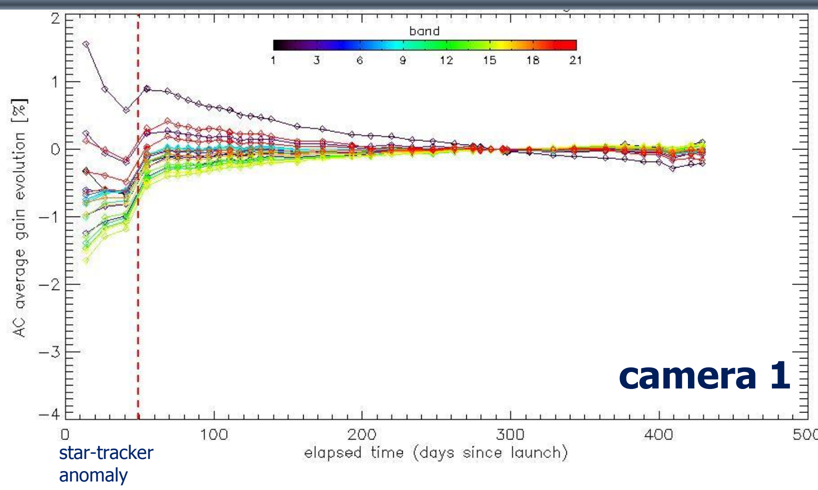




Solar diffuser pre-launch BRDF model residuals



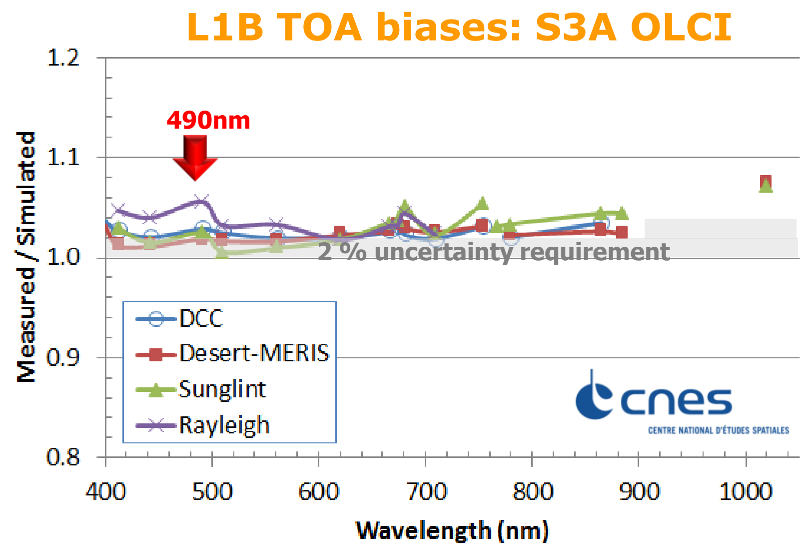
OLCI revised relative radiometric evolution since launch using the new solar diffuser BRDF model derived from yaw manoeuvres

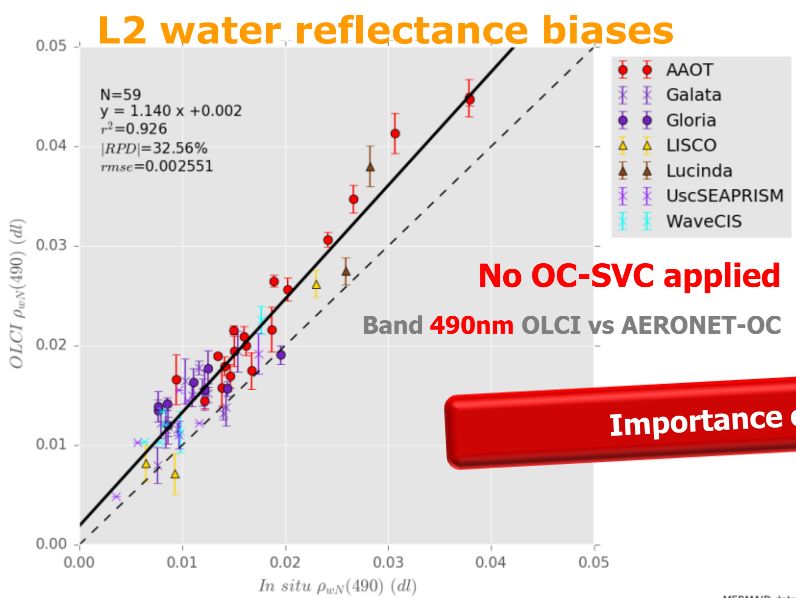


- **OLCI solar diffuser assessment on-orbit performed with a sequence of S3A yaw manoeuvres**
  - To reproduce in a single day the annual range of variations in solar geometry on the diffuser
    - S3A Mission Advisory Group recommendation (S3MAG–M4–A10, 2014)
    - S3 OLCI Cal/Val task (OLCI-L1B-CV-280), S3 Cal/Val Plan (S3-PL-ESA-SY-0265, 2014)
    - S3A IOCR technical meeting recommendation (S3-MN-ESA-OL-752, 2016)
- **Sequence of yaw manoeuvres executed 07 Dec 2016**

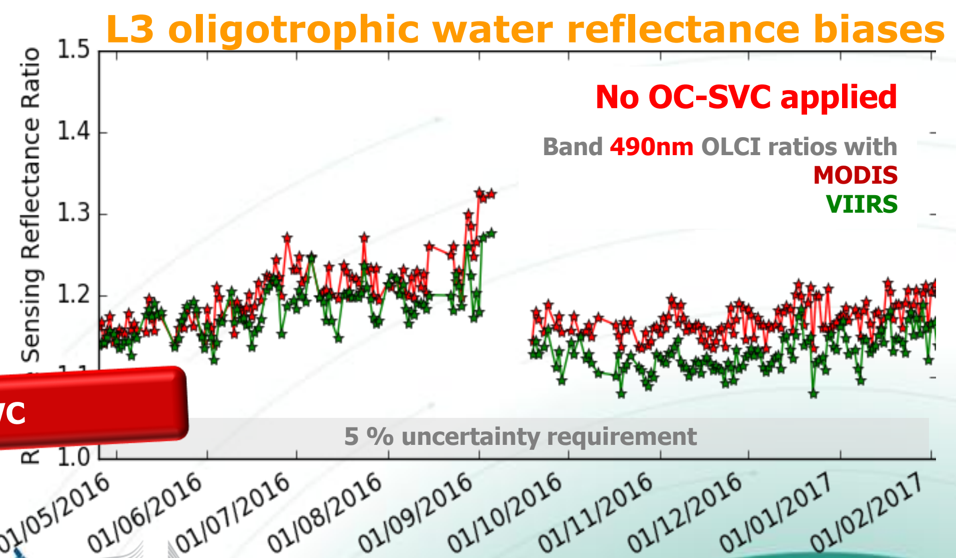
S3A OLCI absolute radiometric calibration

- **OLCI radiometric limitations**
  - Absolute and inter-band radiometric calibration are not fully compliant: 2% absolute and 1% inter-band uncertainty for bands < 900nm (OL-IQ-040, -050)
- **Ocean Colour System Vicarious Calibration OC–SVC**
  - Modified strategy is applied to mitigate low matchup numbers early in the mission
  - NIR – Franz *et al.*, 2007, and unconstrained all-NIR fit
  - VIS – MOBY, BOUSSOLE and oligotrophic sites





Importance of OC–SVC



MERMAID data

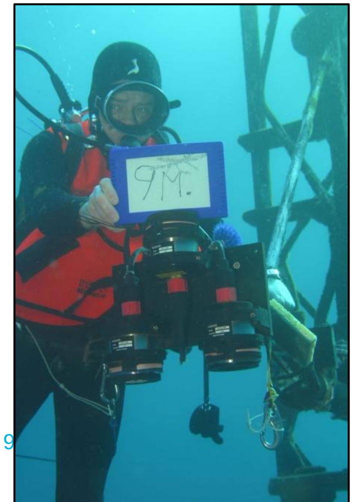
Development of operational Copernicus SVC capabilities

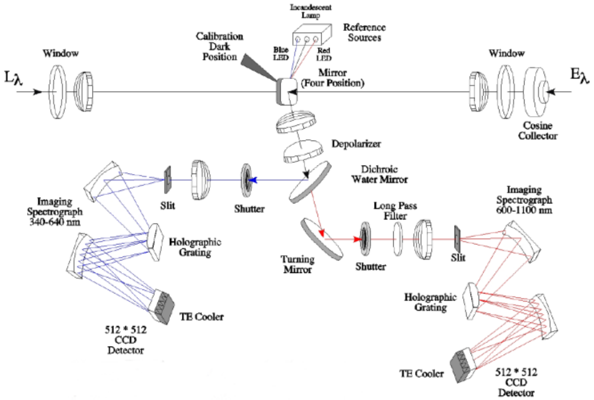
IOCS'17 breakout: Ocean Colour Vicarious Calibration Community Requirements for Future Infrastructures

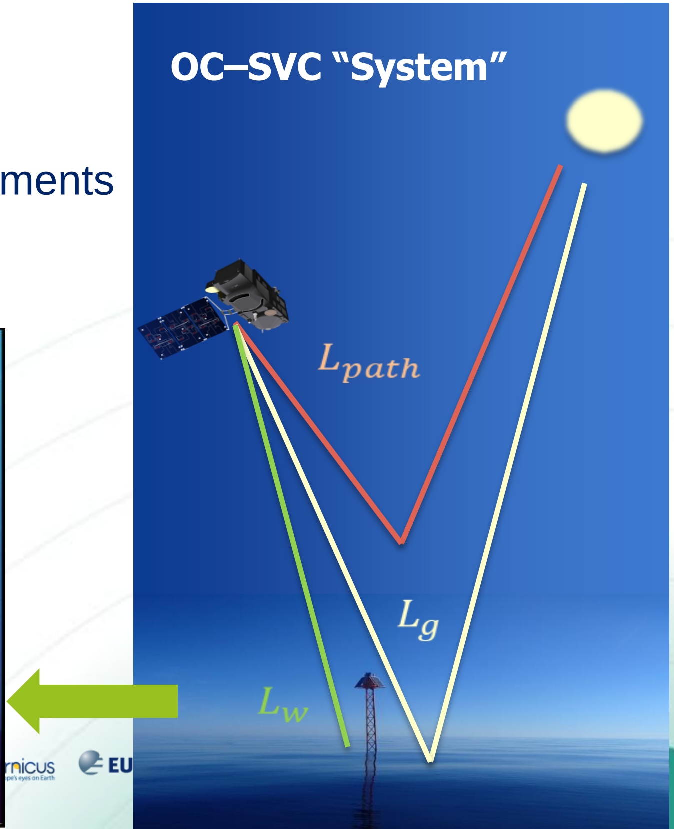
- **Development of Copernicus OC–SVC is required**
  - for Sentinel-3 and Sentinel-2 missions
  - for decades of upcoming ocean colour operations A/B/C/D [S3 MRTD'11; S3 Cal/Val Plan'14]
  - based on international cooperation and harmonization

IOCCG Working Group

- **ESA FRM4SOC OC–SVC workshop, Feb 2017**
  - need for MOBY-like development, while supporting BOUSSOLE
- **EUMETSAT Copernicus OC–SVC studies, Oct 2016 –**
  - Step 1: Scientific, Technical and Operational Requirements (pre-phase A)
  - Step 2: Preliminary Design, Project Plan and Costing (phase-A)
  - Step 3: Technical Definition, Specifications, Detailed Design (phase B)
  - Step 1: OC–SVC Scientific, Technical and Operational Requirements
    - Deliverables: requirements document and review process
    - Development of a complete OC-SVC "System" measurement uncertainty budget
    - OC-SVC uncertainty budget is the justification for the requirements
    - Review process: two review meetings by the international Review Expert Team and the community







Validation: Sentinel-3 Validation Team – Ocean Colour

- Sentinel-3 Validation Team (S3VT) – international group of expert users
- S3VT provides independent validation evidence on the quality of OLCI products
- S3VT is based on a rolling announcement of opportunity, ESA AO call is <u>continuously open</u>

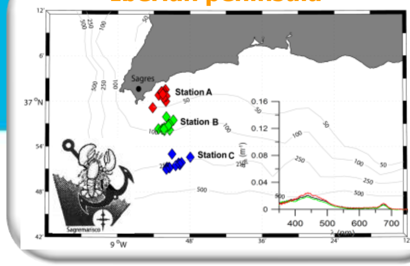
for more information on S3VT-OC
marc.bouvet@esa.int
ewa.kwiatkowska@eumetsat.int

Prj ID	Project Lead	Country	Institution	Project Title
13765	Alikas Krista	ESTONIA	Tartu Observatory	Increasing quality of above water spectral measurements in lakes/turbid waters
13246	Antoine David	FRANCE	Laboratoire d'Océanographie de Villefranche	BOUSSOLE
13653	Babin Marcel	CANADA	Université Laval, UMI Takuvik	OLCI data validation in the Canadian Arctic
13616	Barciela Rosa	UK	Met Office	Validation of Sentinel-3 Sea Ocean Colour data in Met Office global carbon cycle models
13732	Bernard Stewart	SOUTH AFRICA	Council for Scientific and Industrial Research	Validation and Development of OLCI Products for Southern African Eutrophic Waters
28755	Bialek Agnieszka	UK	NPL	QA4OC - Quality Assurance for Ocean Colour in situ
34562	Blix Katalin	NORWAY	UiT the Arctic University of Norway	Validation of Sentinel-3 for Arctic ocean waters in the Marginal Ice Zone
13751	Bracher Astrid	GERMANY	Alfred-Wegener-Institute for Polar and Marine Research	Validation of OLCI ocean colour products with focusing on high latitudes (OCVAWI)
13760	Brockmann Carsten	GERMANY	Brockmann Consult	
13739	Brotas Vanda	PORTUGAL	Centre of Oceanograp	
13743	Bryere Philippe	FRANCE	ACRI-ST	lidation
13583	Chami Malik	FRANCE	LOV, Université Pierre	rious calibration & validation (RADFLOAT)
13625	Costa Maycira	CANADA	Institut Maurice-Lamo	
13552	D'Alimonte Davide	PORTUGAL	Faculty of Science and	lected European basins
13772	Darecki Miroslaw	POLAND	Institute of Oceanolog	Baltic optically complex waters (VABAX)
13741	DiGiacomo Paul	USA	NOAA	Validation Support for S3: Ocean Color
29293	Dogliotti Ana	ARGENTINA	Instituto de Astronomí	
33829	Eleveld Marieke	NETHERLANDS	Deltares	
13716	Fabardines Michèle	FRANCE	Mercator-Ocean	
13758	Fearns Peter	AUSTRALIA	Curtin University	
13744	Fischer Jürgen	GERMANY	Institute for Space Sci	
35342	Hanafin Jenny	[illegible]	[illegible]	lour product validation
13723	[illegible]	[illegible]	[illegible]	nal lakes: GloboLakes-S3VT
[illegible]	[illegible]	[illegible]	[illegible]	
13742	[illegible]	[illegible]	[illegible]	complex worldwide coastal waters
14552	[illegible]	USA	University of California	cosystem
13597	[illegible]	BELGIUM	VITO	and highly turbid waters
13729	Knox Nichole Marie	SOUTH AFRICA	South African National	Land Surface Temperature products
13596	Kratzer Susanne	SWEDEN	Department of System	Sea and Lake Vänern)
13721	Krężel Adam	POLAND	Depart. of Physical Oc	from space
13607	Lavender Samantha	UK	Pixalytics Ltd	
13717	Maritorena Stéphane	USA	Earth Research Institu	lifornia-PnB) in support of OLCI sensor
13656	Meister Gerhard	USA	NASA	
13766	Morris Edward	SPAIN	Instituto de Ciencias M	sediment load Guadalquivir estuary
17234	Moses Wesley J.	USA	Naval Research Labora	
13675	Oliveira Paulo	PORTUGAL	Instituto Português do	
13747	Peters Steef	NETHERLANDS	Water Insight BV	n
13452	Röttgers Rüdiger	GERMANY	Helmholtz-Zentrum Ge	
13623, 13702	Ruddick Kevin	BELGIUM	Royal Belgian Institute	rspectral VIS/NIR radiometers (HYPERNET-OC)
13697	Santoleri Rosalia	ITALY	CNR -Istituto di Scienz	VOLCI)
13658	Schroeder Thomas	AUSTRALIA	CSIRO Land & Water	
13750	Shum C.K.	USA	Ohio State University	ation of Radar Altimeters (LIVE-S3)
13753	Silió-Calzada Ana	SPAIN	Environmental Hydrau	rial Ecosystems
13654	Sørensen Kai	NORWAY	Norwegian Institute fo	
13737	Tilstone Gavin	UK	Plymouth Marine Labo	stal waters of the Western English Channel
13738	Torres Jesus M.	SPAIN	University of Vigo	
13768	Wüest Alfred	SWITZERLAND	École Polytechnique Fé	
13652	Zhu Jianhua	China	National Ocean Techn	
13587	Zibordi Giuseppe	ITALY	Joint Research Centre	

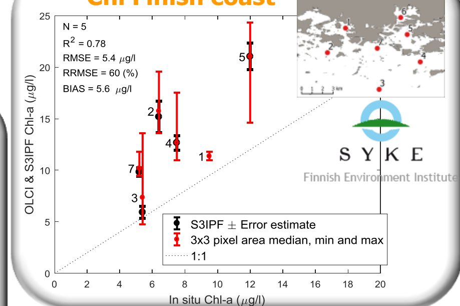
Sentinel-3 Validation Team meeting Feb 2017

- Detailed evaluation of OLCI products
- Recommendations towards product improvements for OLCI L2 public release
- Recommendations towards improved ocean colour user services

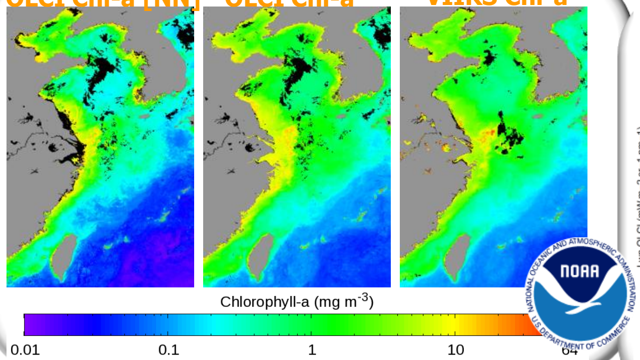
Iberian peninsula



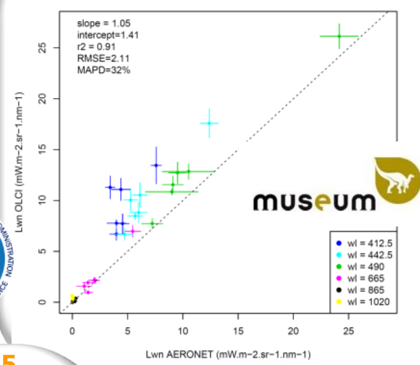
Chl Finish coast



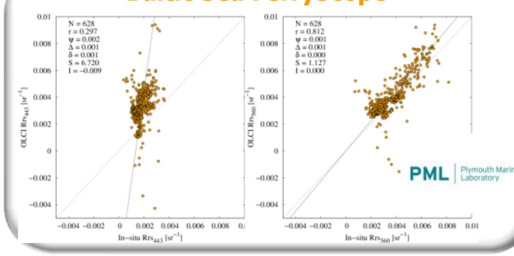
OLCI Chl-a [NN] OLCI Chl-a VIIRS Chl-a



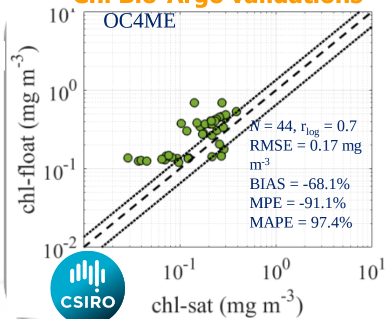
AERONET –OC Thornton C-Power



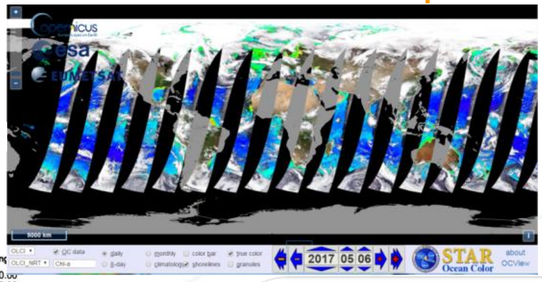
Baltic Sea FerryScope



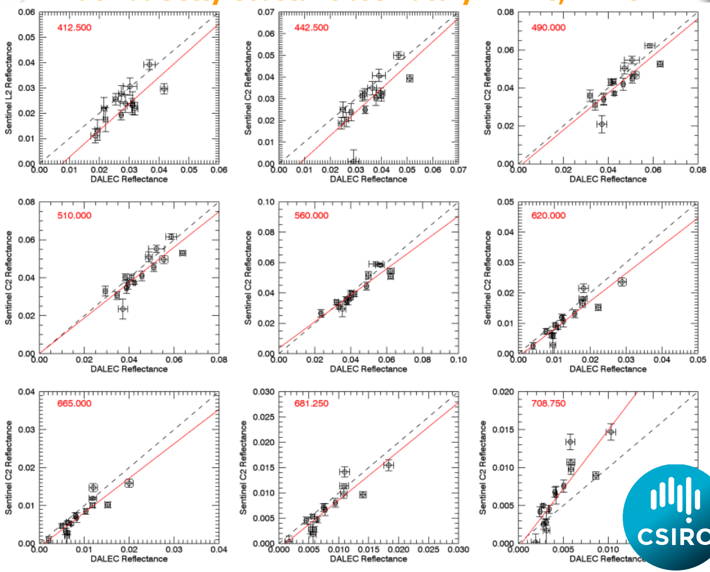
Chl Bio-Argo validations



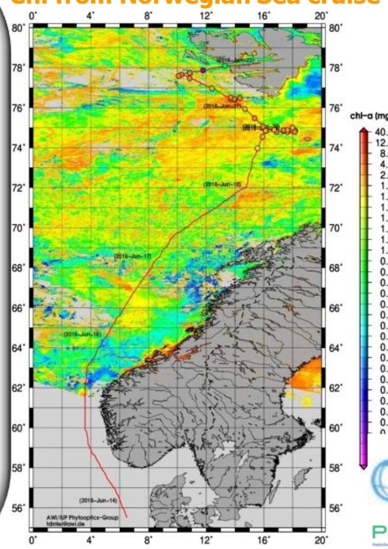
NOAA STAR OCView with OLCI capabilities



Lucinda Jetty Coastal Observatory DALEC, N=15



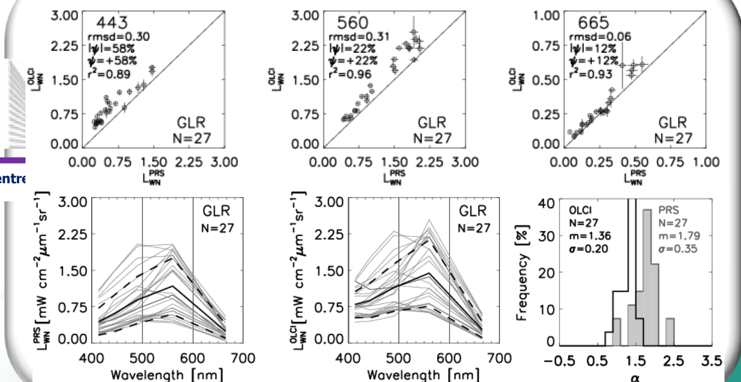
Chl from Norwegian Sea cruise



Joint Research Centre

AWI
PHYTOOPTICS

AERONET-OC Gloria Tower



Fiducial Reference Measurements FRM4SOC

FRM = highest quality *in situ* measurements required to determine whether satellite data products meet the mission requirements

esa

fiducial reference measurements for satellite ocean colour

CEOS

To establish and maintain SI traceability of FRMs for satellite ocean colour

To consolidate and further develop FRM protocols

To federate the community validating satellite ocean colour radiometry

Web: ***https://frm4soc.org***
Contact: riho.vendt@to.ee

▾ Activities

Ref	Event	Dates	Location
WKP-1	Workshop on Vicarious Adjustment	21 – 23 February 2017	ESRIN, Italy
LCE-1	SI-traceable Laboratory inter-comparison experiment for FRM OCR and reference irradiance/radiance calibration targets. Verification of reference irradiance and radiance sources	3 – 7 April 2017	NPL, UK
LCE-2	SI-traceable Laboratory inter-comparison experiment for FRM OCR and reference irradiance/radiance calibration targets. Verification of FRM OCR	08 – 13 May 2017	TO, Estonia
FICE AMT	Field Inter-Comparison Experiment in the Atlantic Meridional Transect (AMT)	August-September 2017	AMT
FICE AAOT	Field Inter-Comparison Experiment in the Acqua Alta Oceanographic Tower (AAOT)	July 2018	AAOT
WKP-2	Final Workshop	August 2018	NPL, UK

TARTU OBSERVATORY space research centre

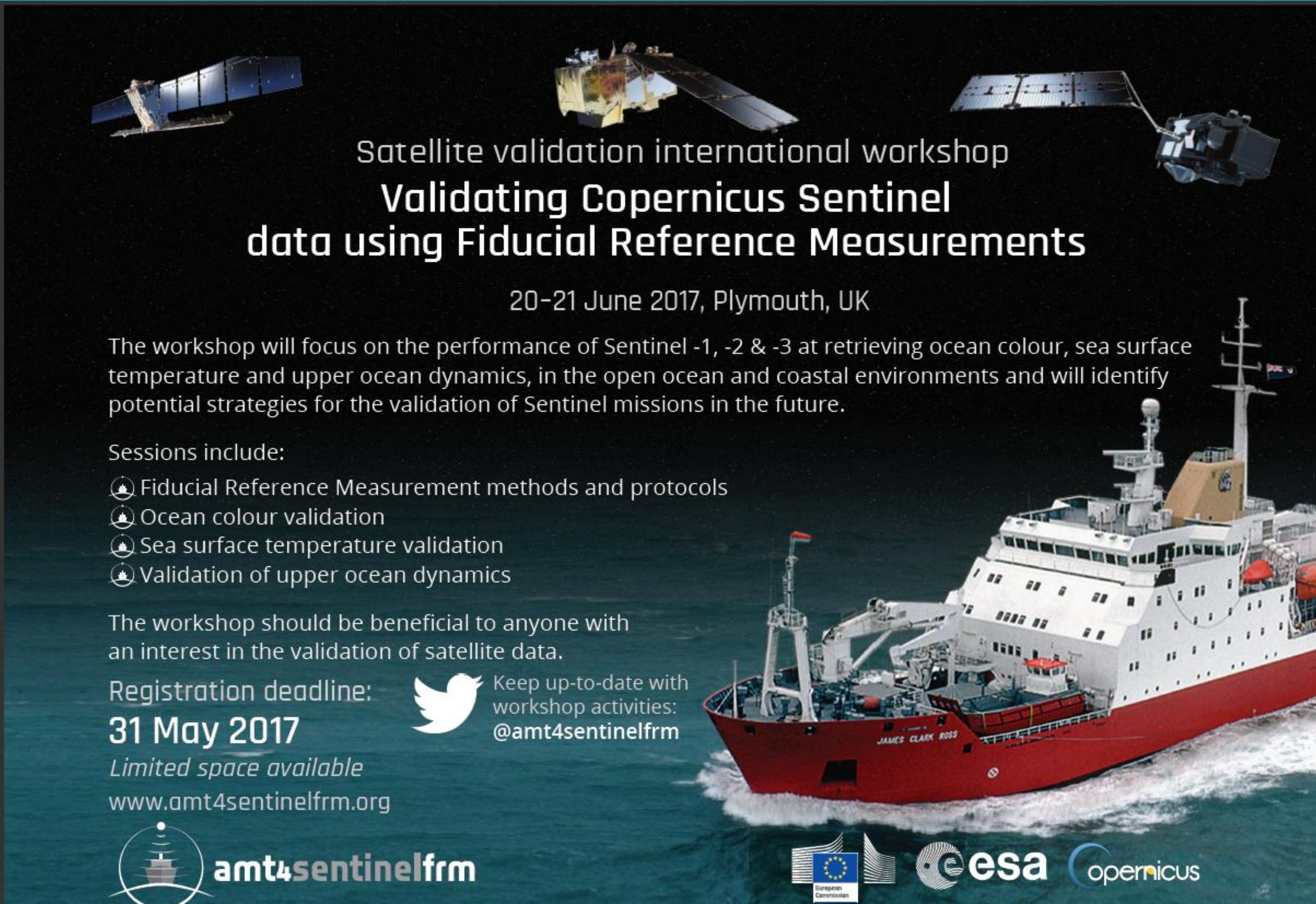
ACRI ST

PML Plymouth Marine Laboratory

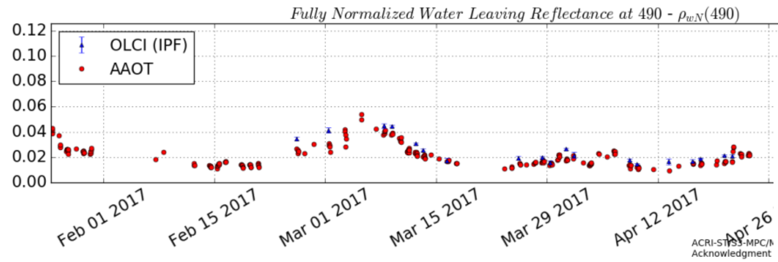
NPL National Physical Laboratory

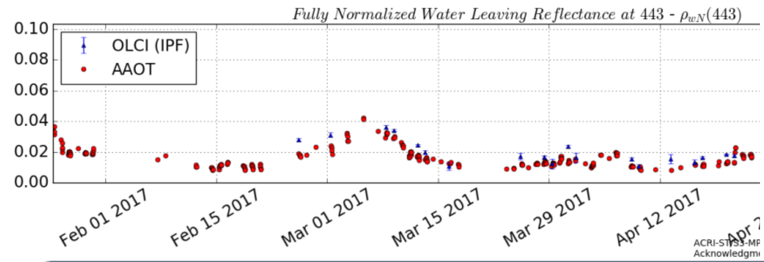
museum

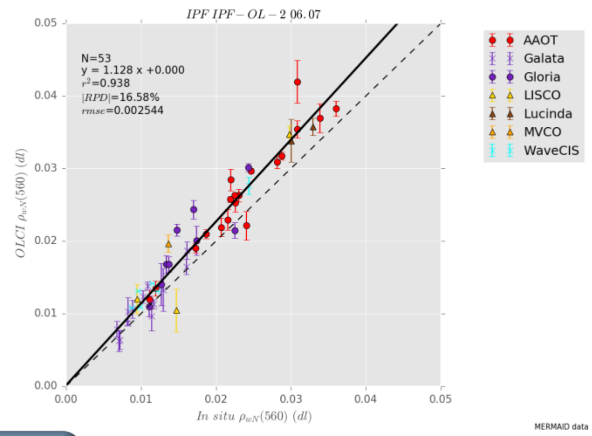
Next FRM4SOC event



Operational validation tools and activities

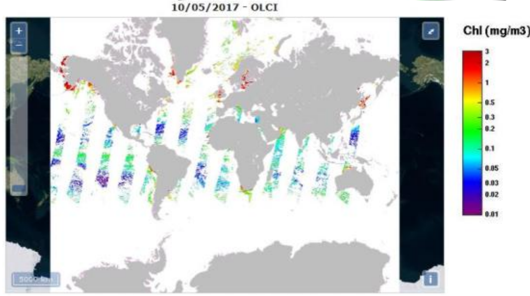


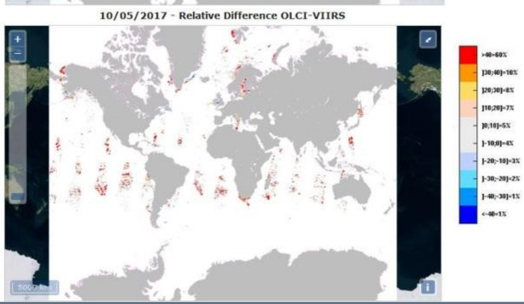




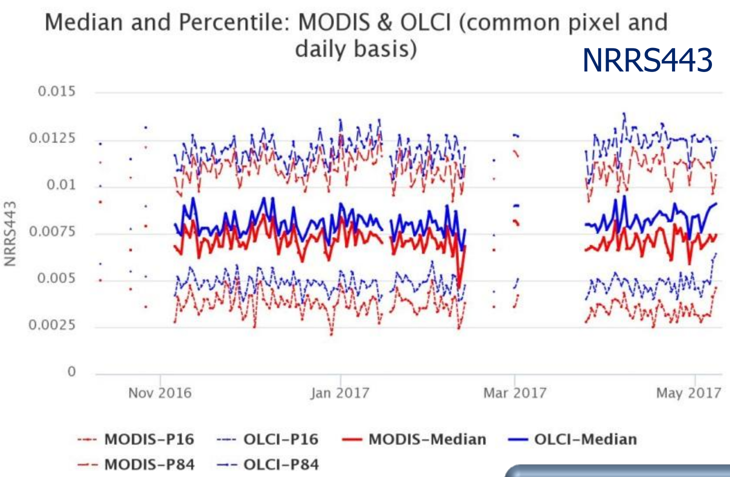
MERMAID Level 2 match-ups:

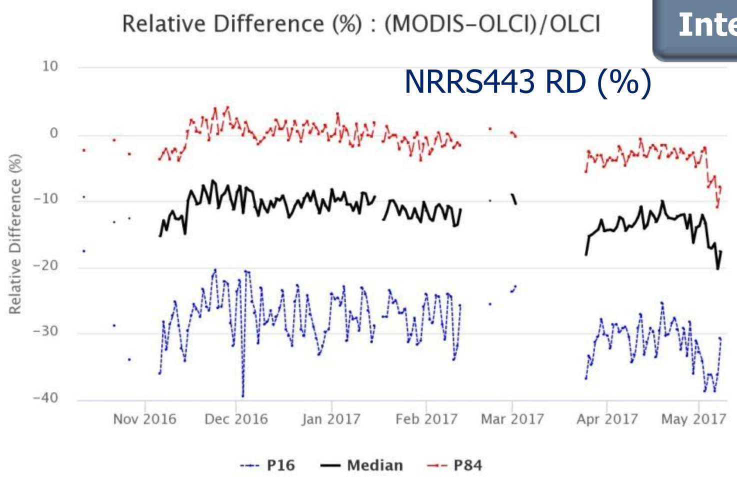
Time series, scatter plots and statistics

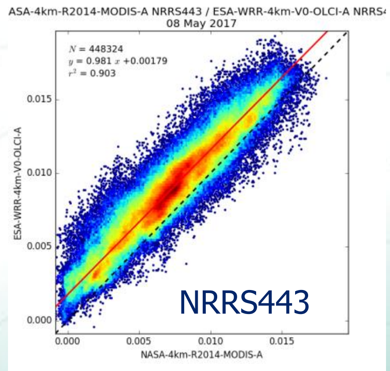




Inter-sensor comparisons at Level 3





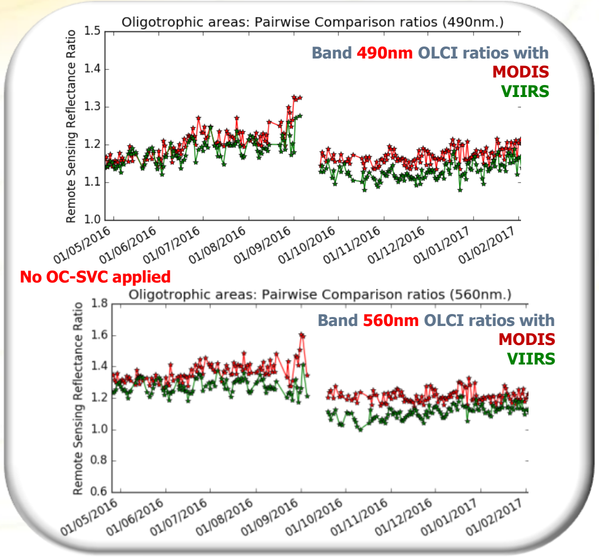


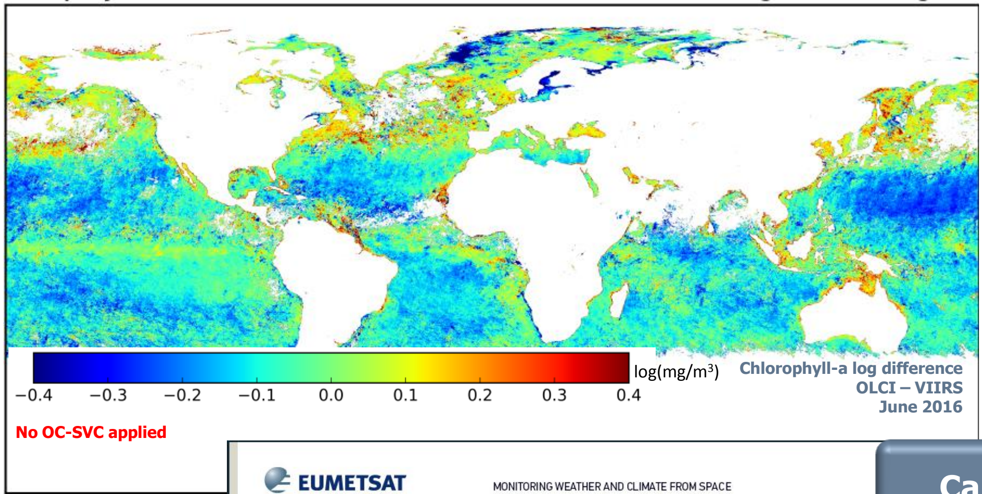
Inter-sensor time series and scatter plots

Operational validation tools and activities

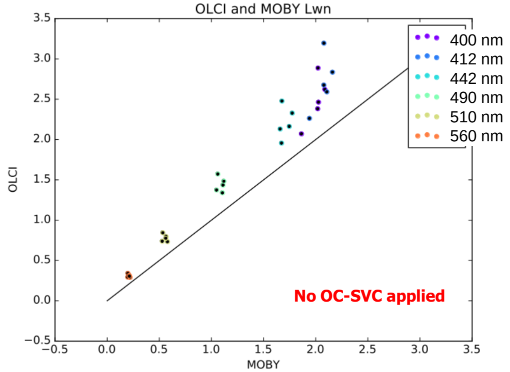
EUMETSAT

Running Level 3 inter-comparisons with contemporaneous global missions and climatologies (L3 binning for validation and monitoring)

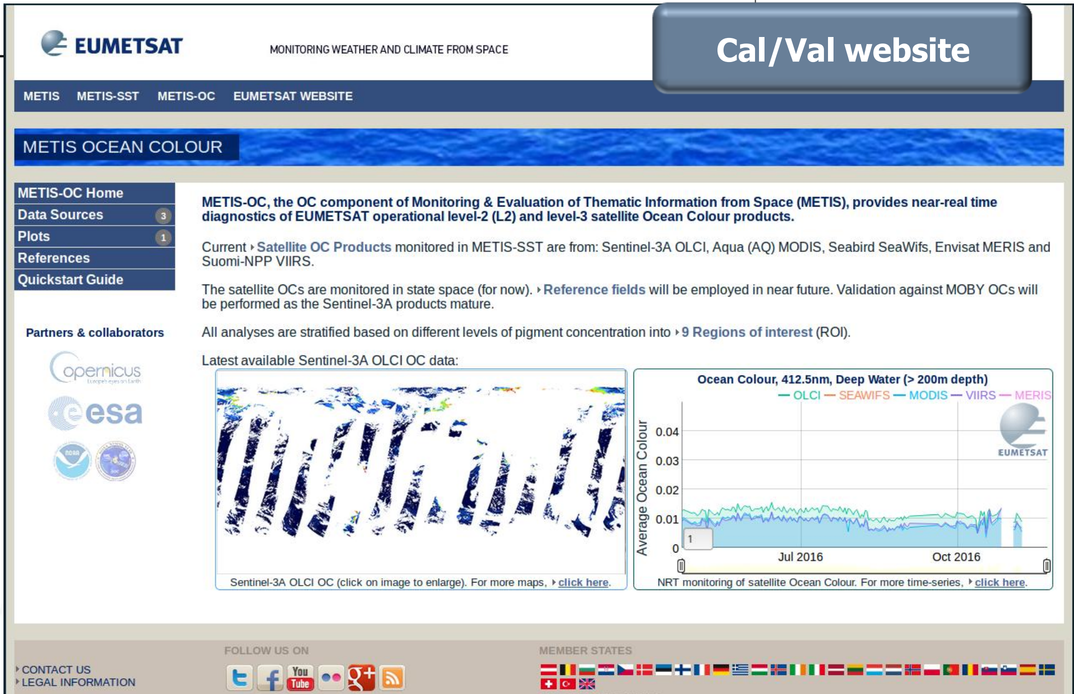




Level 2 in situ matchups with FRMs

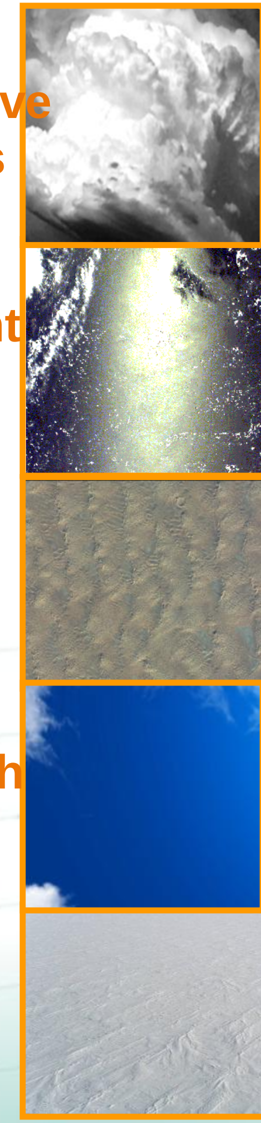


Cal/Val website

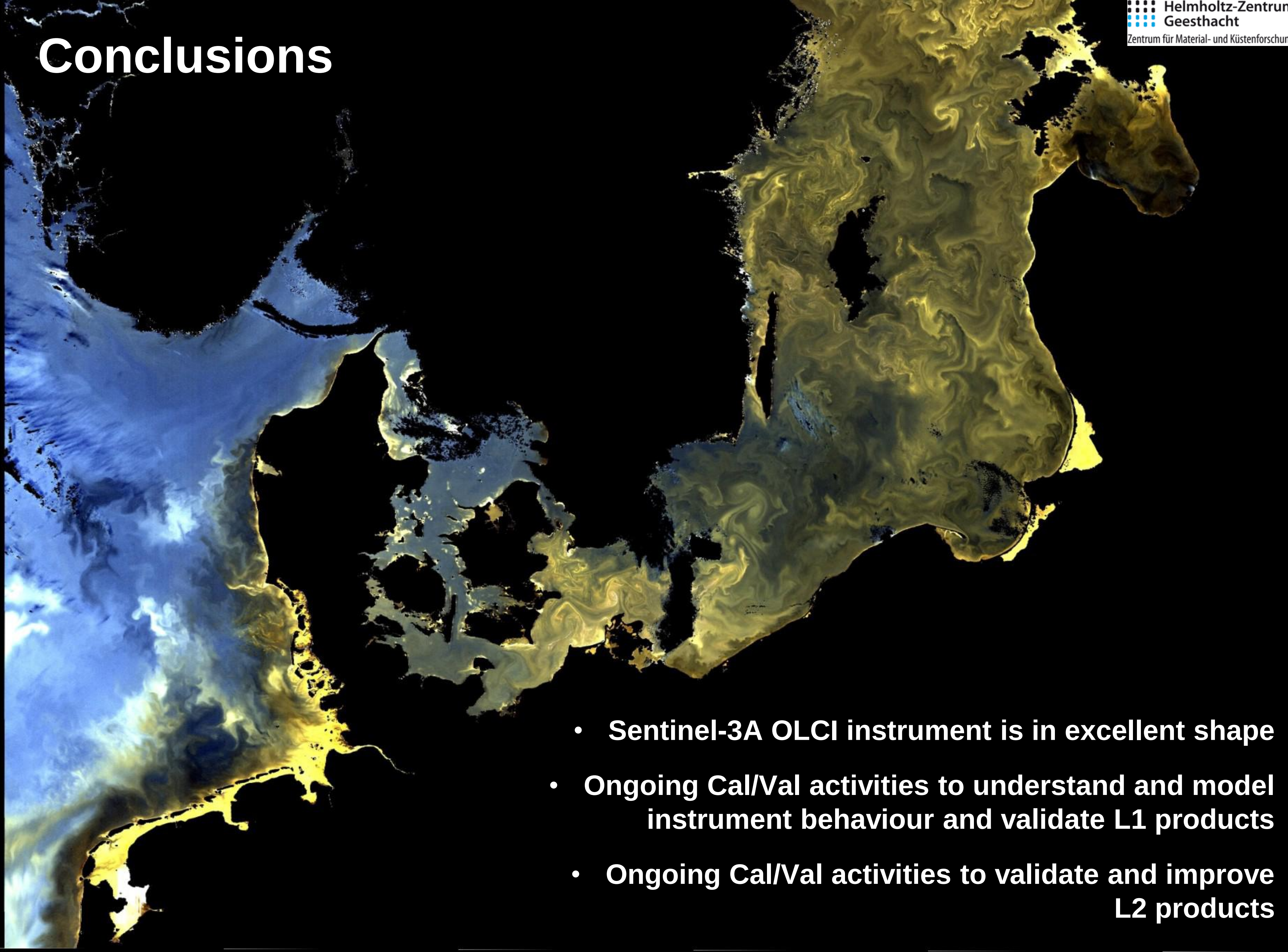


Sentinel-3B commissioning phase in tandem with S3A

- **Ocean colour scientific justification for S3A and S3B Commissioning tandem configuration**
  - Assuring stability, accuracy, and homogeneity of OLCI missions [MRTD, 2011; GCOS 2016]
  - Joint instrument calibration and characterisation
  - Overlapping coverage in support of sensor inter-comparisons and product validations
- **Planned activities**
  - Inter-satellite comparisons over target surfaces using the vicarious methods will benefit of
    - minimized ocean geophysical space and time variability
    - minimized atmospheric space and time variability
    - identical observation and solar geometries
  - Inter-satellite comparisons of calibration and characterization will benefit of
    - direct inter-comparisons of instrument responses, including diffuser and straylight
    - absolute and relative comparisons between the in-flight OLCI-A and the more pristine OLCI-B units



Conclusions



- **Sentinel-3A OLCI instrument is in excellent shape**
- **Ongoing Cal/Val activities to understand and model instrument behaviour and validate L1 products**
- **Ongoing Cal/Val activities to validate and improve L2 products**