OCR using Copernicus Sentinel-2 and status of Sentinel-3

Craig Donlon Sentinel-3 Mission Scientist (ESA/ESTEC)
Bianca Hoerch Sentinel-2 Mission Manager (ESA/ESRIN)
Ferran Gascon Sentinel-2&FLEX data quality (ESA/ESRIN)
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Susanne Mecklenburg Sentinel-3 Mission Manager (ESA/ESRIN)

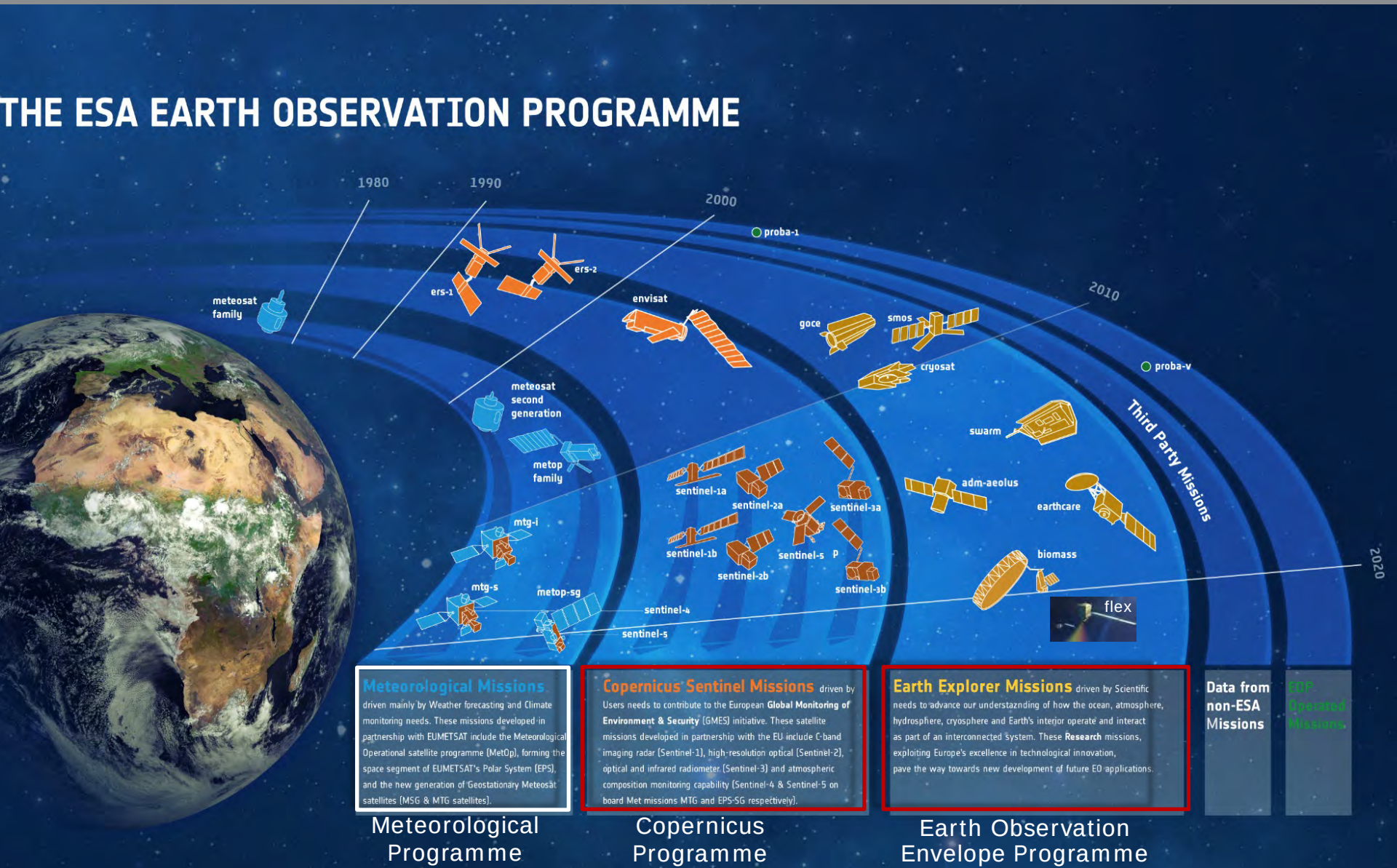
International Ocean Colour Science Meeting 2017

IOCS 2017, Lisbon, Portugal, 15th May 2017

Overview

- The Copernicus Sentinel-2 Mission and OCR
  - Performance
  - Products
  - Example applications
- Fiducial Reference Measurements
  - FRM4SOC developments
  - AMT4Sentinel developments
- Sentinel-3B status
- Summary

Earth Observation in ESA



Lisbon from Sentinel-2A MSI 05/05/2017 & 27/09/16

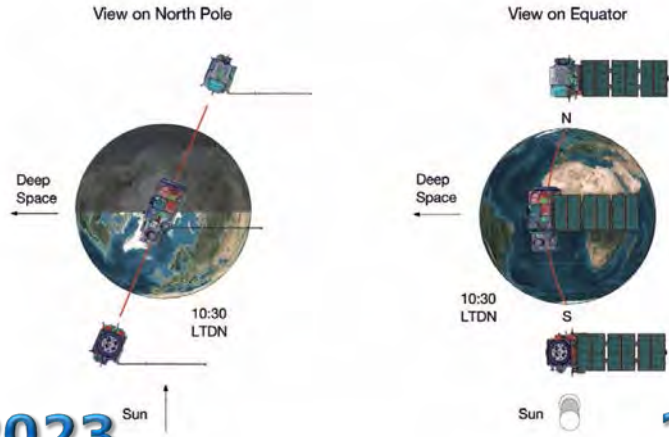
Sentinel-2B Launch 7th March 2017

Sentinel-2B

Netherlands
16 Mar 2017

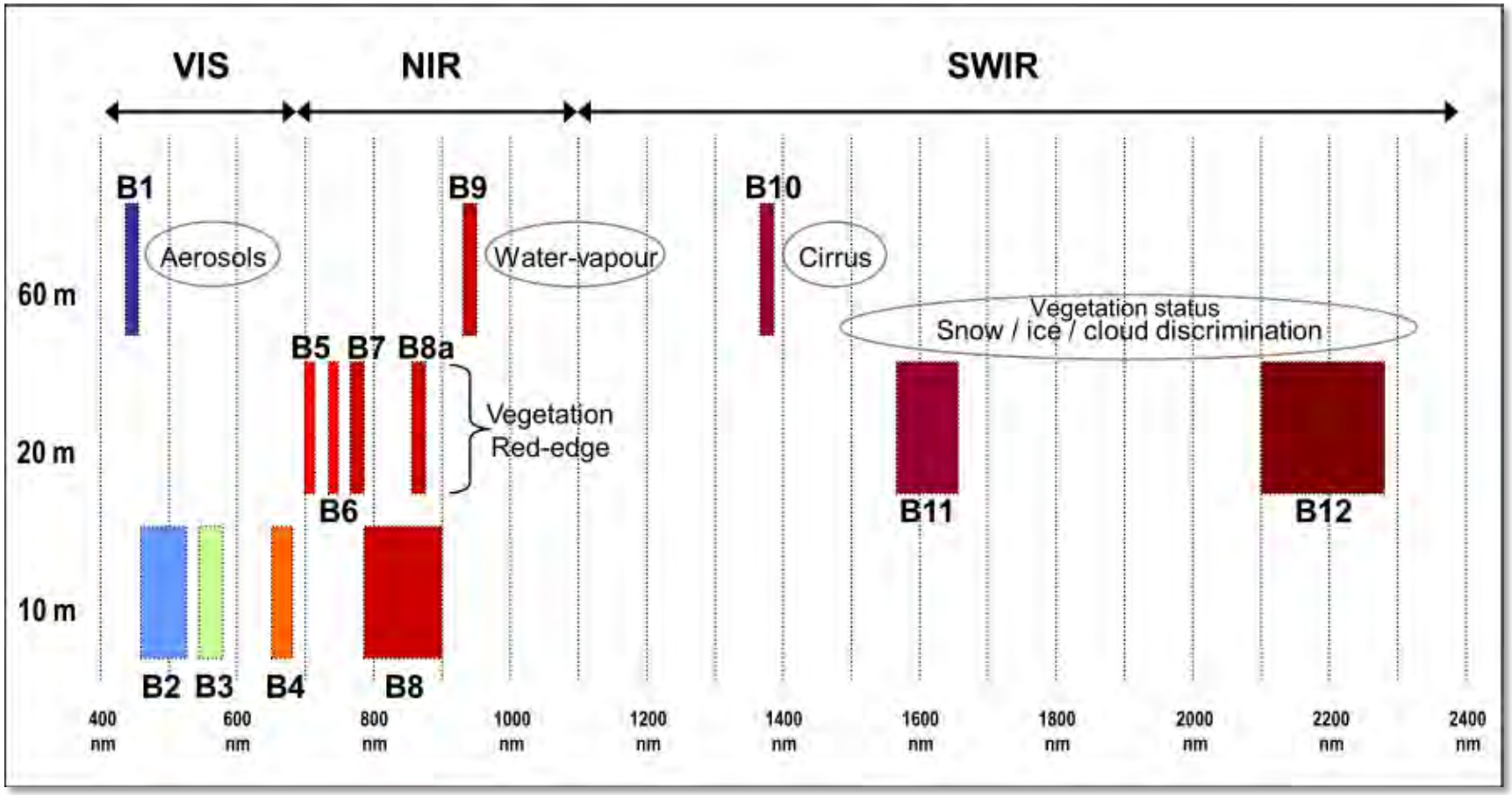
Sentinel-2 Mission Overview

- **Two** Identical Spacecraft operating in twin configuration
- Sun-synchronous orbit **786 km**, **LTDN** 10:30 AM
- **Multi-Spectral Instrument (MSI**) push-broom imager: filter-based, multi-spectral sampling, 295 km swath with **13** spectral bands (**VIS, NIR & SWIR**), at **10**, **20** and **60 m** spatial resolution
- **5 day** revisit at Equator with 2 satellites
- **7 years** design life time for each satellite, consumables for 12 years

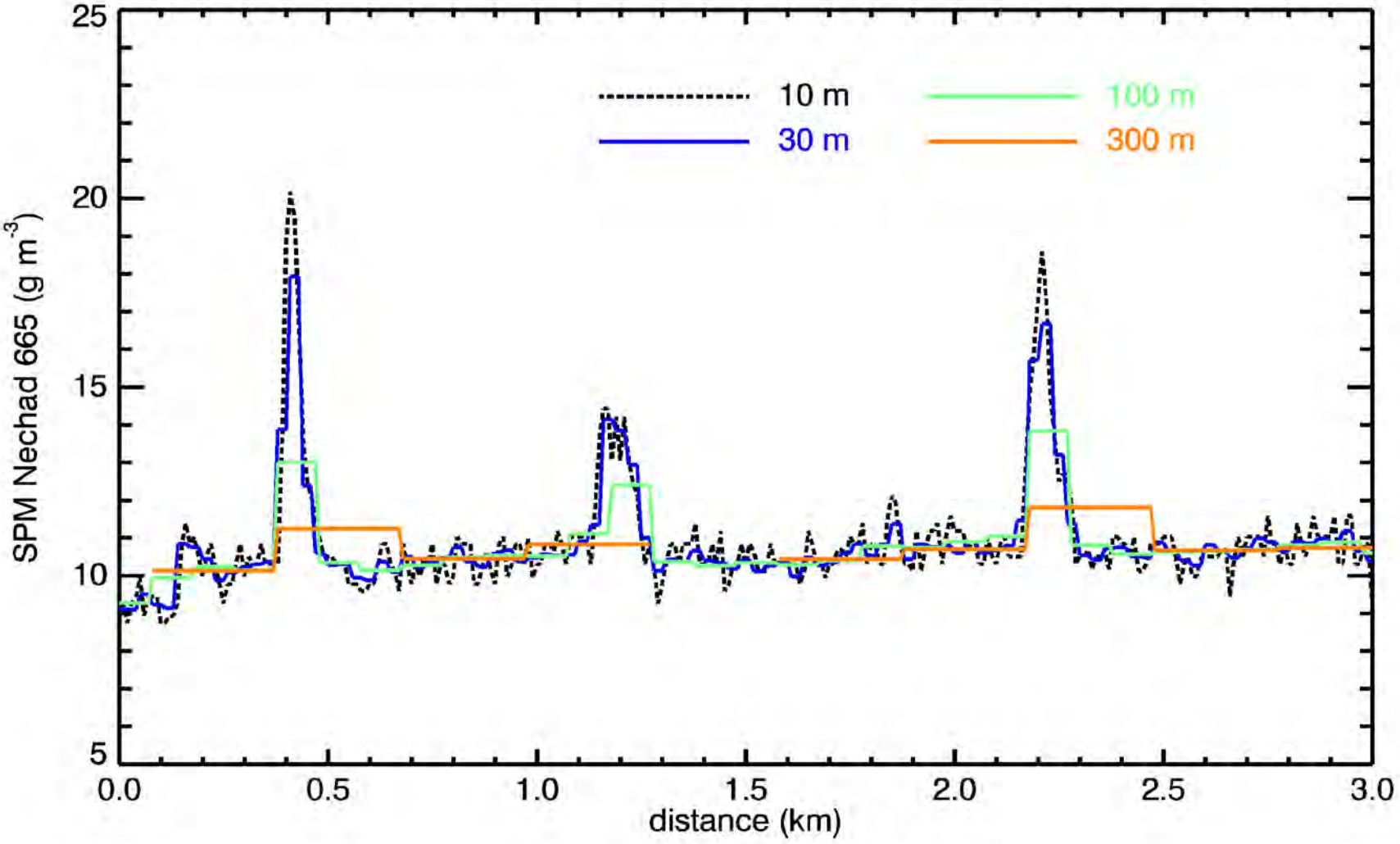


Multi-spectral Imager band settings

- 13 MSI bands are optimized for accurate atmospheric correction and vegetation monitoring
- But clearly have huge potential for marine applications



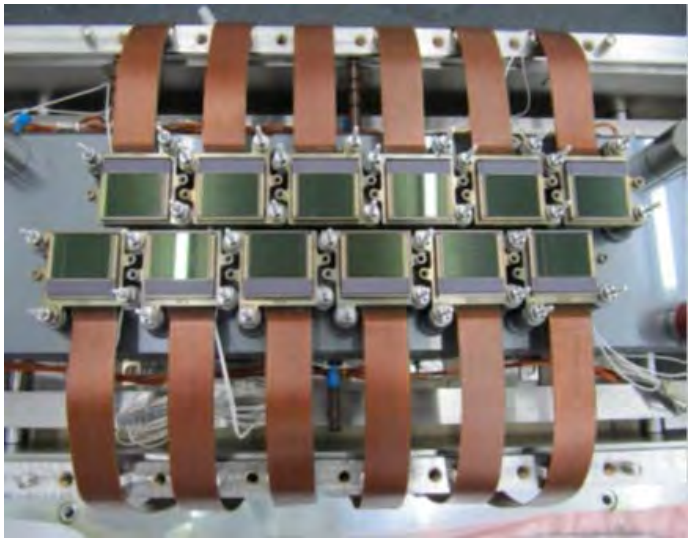
S2A resolution in E. Channel 28/08/15



(Quinten Vanhellemont & Kevin Ruddick)

MSI Calibration

- **Calibration of detectors using a PTFE diffuser once per month and after every decontamination activity (~every 6 months)**



← VNIR Flight Focal Plane
(Astrium SAS (France) and e2v Technologies (UK))

→ MSI Calibration and Shutter Mechanism showing the very large (!) solar calibration diffuser.
(Sener, Spain and CSL, Belgium)

SNR Performance S2A

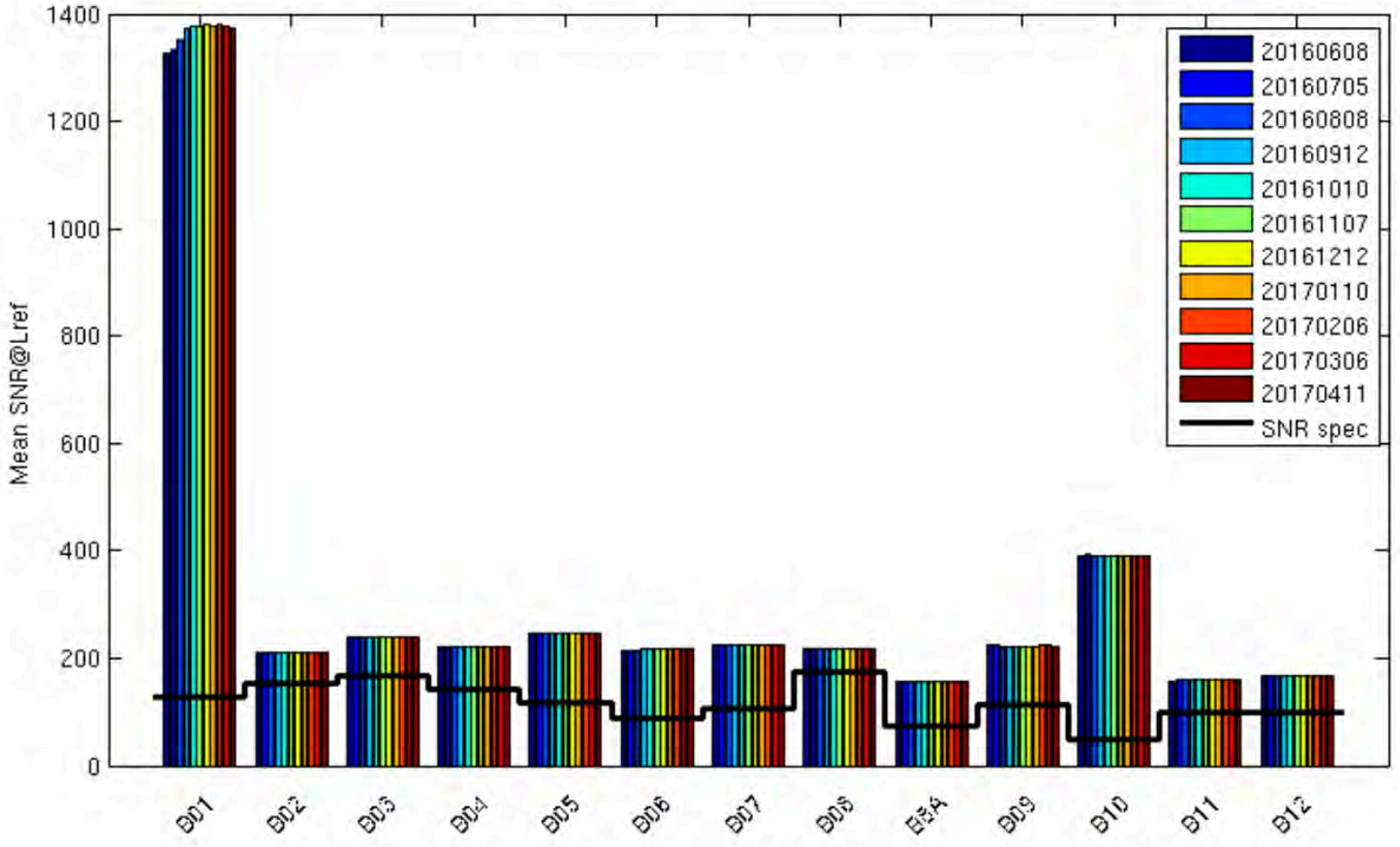
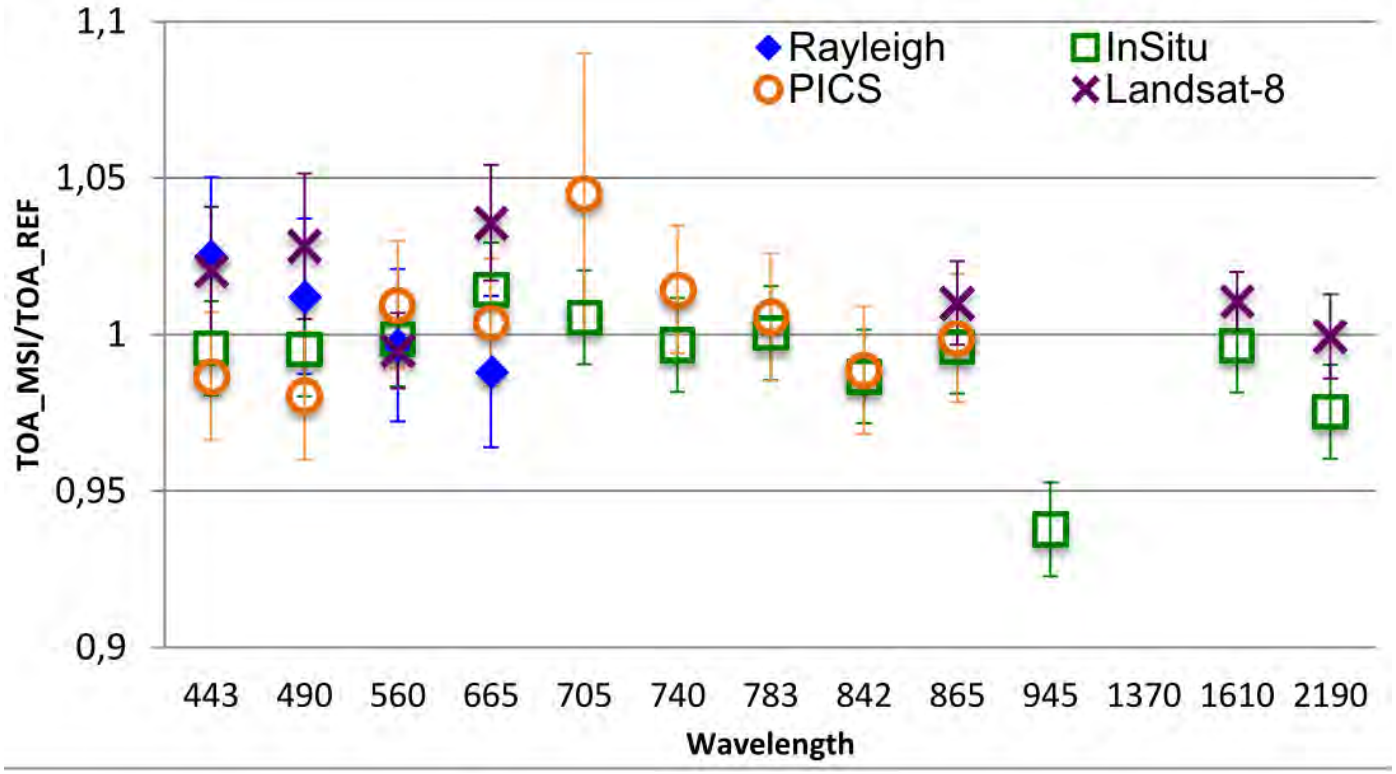


Figure 5: Evolution of the SNR performance since 06/08/2016.

Radiometric accuracy

- Different methods are used to validate the absolute radiometric accuracy, and provide relatively consistent results
- < 5% requirement met for all spectral bands not affected by gaseous absorption
- B09 and B10 performance better addressed by inter-band validation
- **Sentinel-2 Calibration methodology is very effective and reliable**

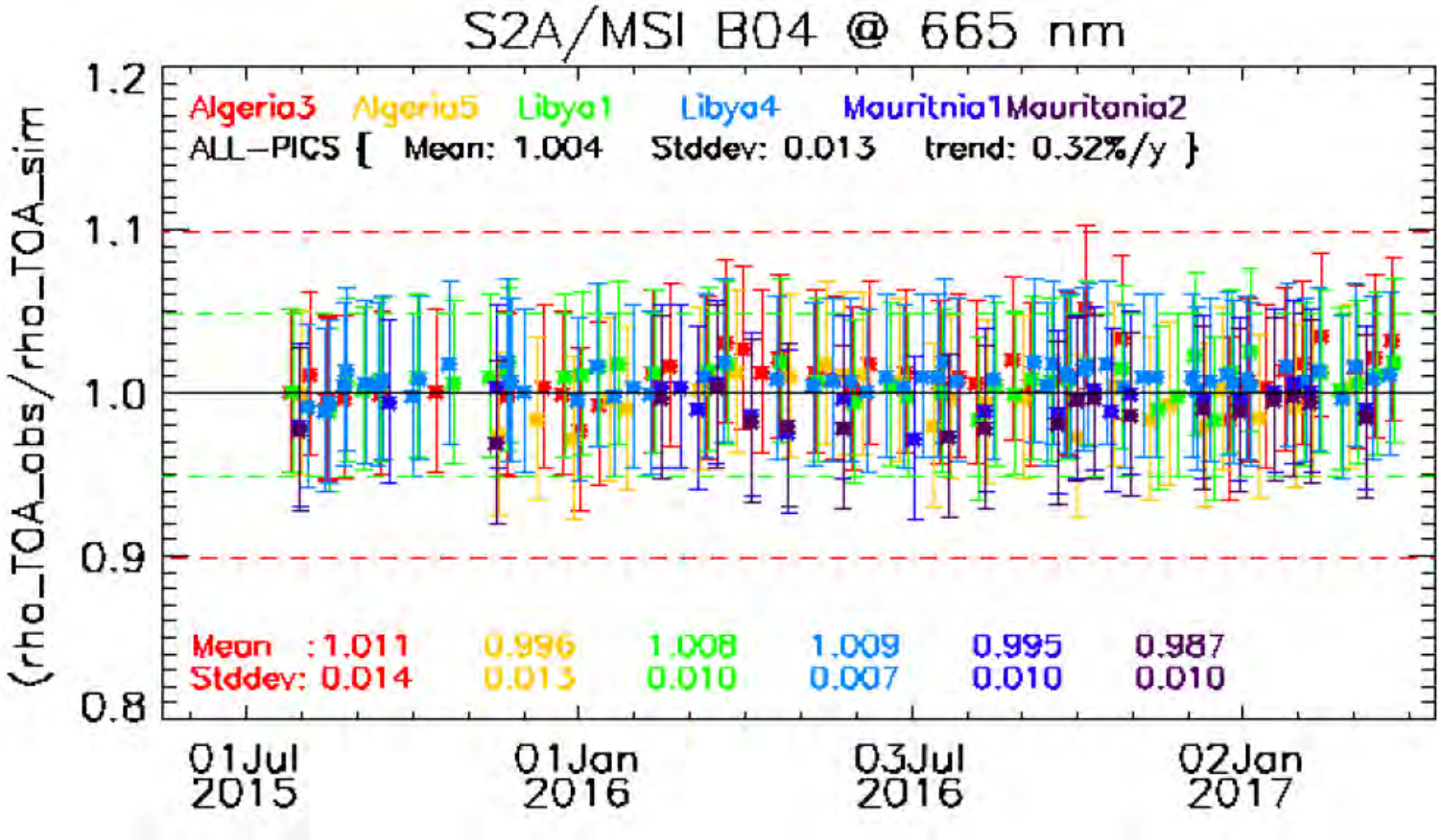


Rayleigh (deep ocean)

(PICS) Pseudo-Invariant Calibration Sites - Desert

Evolution of the radiometric response

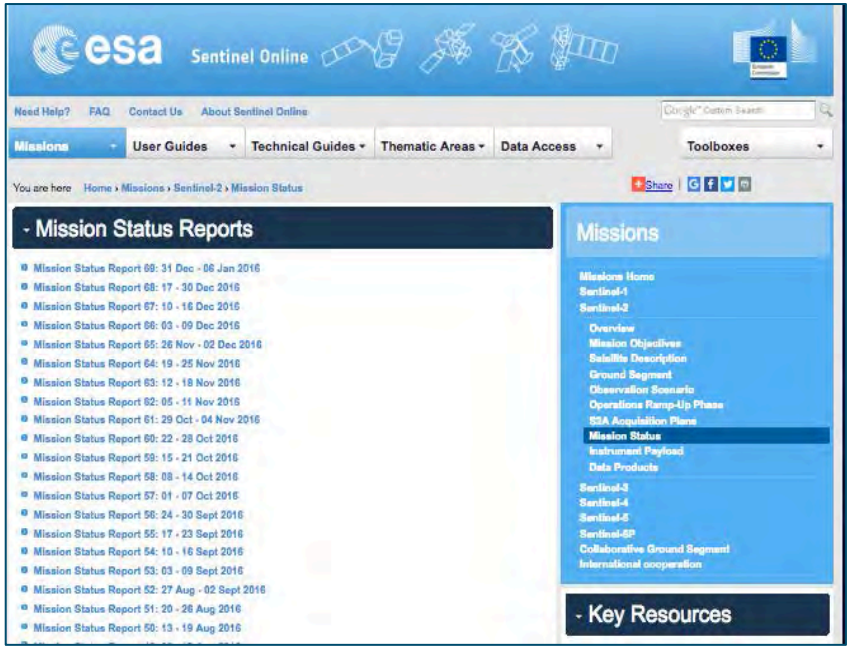
- **S2A: Better than 1% per year in VIS-NIR bands**
- **No obvious evidence of on-board calibration diffuser degradation**

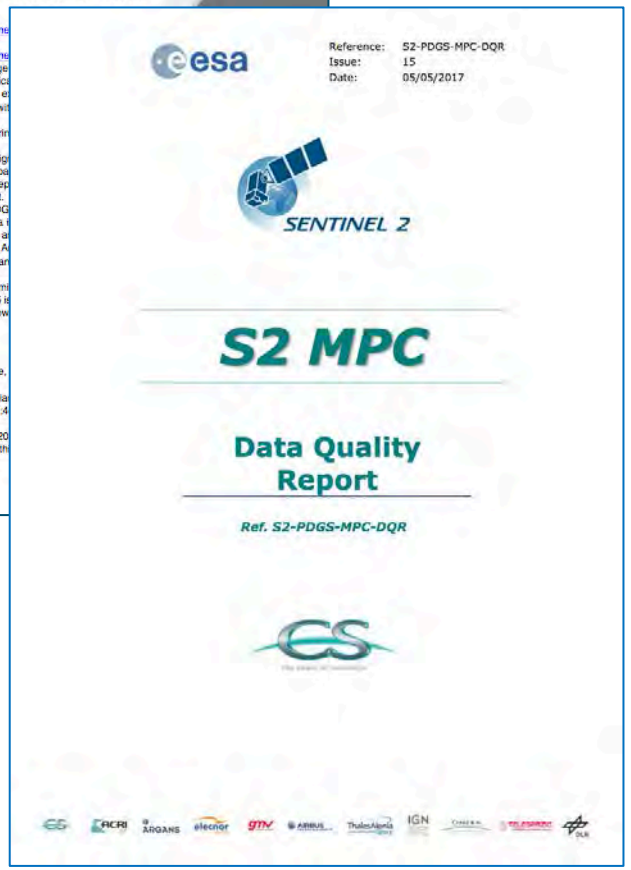


Summary of S2A Performance (05/05/2017)

Requirement	Description	Measured performance
Absolute geolocation (without ground control points)	The geo-location uncertainty shall be better than 20 m at 2σ confidence level (without Ground Control Points).	< 11 m at 95.5% confidence (baseline 02.04)
Multi-spectral registration	The inter-channel spatial co-registration of any two spectral bands shall be better than 0.30 of the coarser achieved spatial sampling distance of these two bands at 3σ confidence level.	< 0.3 pixel at 99.7% confidence
Absolute radiometric uncertainty	The absolute radiometric uncertainty shall be better than 5 % (goal 3%).	B1 to B12, excl. B10: < 5%±2%
SNR	The Signal-to-Noise Ratio (SNR) shall be higher than specified values (see Table 2-4 in this document)	All bands compliant with > 27% margin

S2 Mission status reports





User support Copernicus help desk:
EOSupport@copernicus.esa.int

S2MPC Monthly Data Quality Report:
https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/document-library

Sentinel-2 Products

Name	High-level Description	Production	Preservation Strategy	Volume
Level-1B	*Top-of-atmosphere radiances in sensor geometry*	*Systematic*	*Long-term*	*~27 MB (each 25x23km²)*
Level-1C	Top-of-atmosphere reflectances in cartographic geometry	Systematic	Long-term	~500 MB (each 100x100km²)
Level-2A (New)	Bottom-of-atmosphere reflectances in cartographic geometry	On user side (using Sen2Cor on Sentinel-2 Toolbox**)	N/A	~600 MB (each 100x100km²)

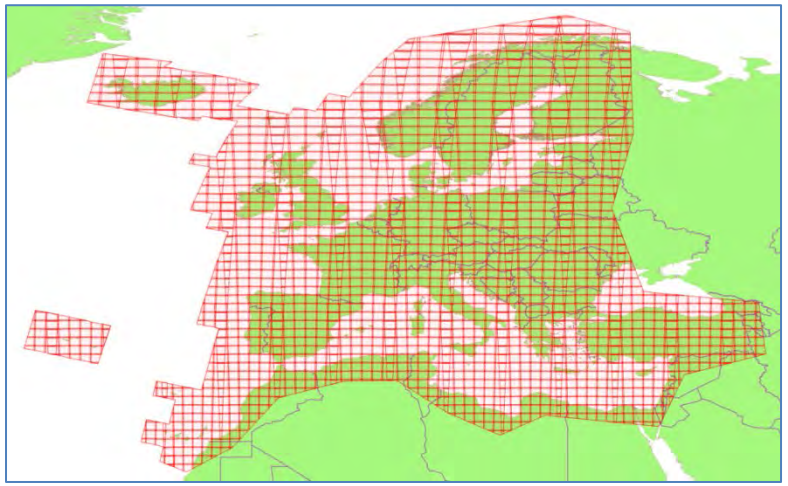
**: https://sentinels.copernicus.eu/web/sentinel/toolboxes/sentinel-2

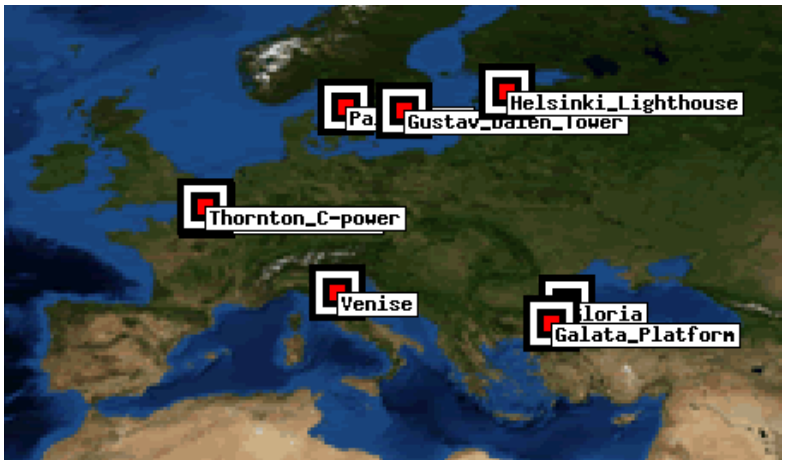
L1C Products

Characteristics	Current status
Definition	Top-of-Atmosphere reflectances
Projection	Cartographic Projection (UTM)
Dissemination unit	Since September 2016: Single MGRS tile 110 x 110 km²
Production	Systematic
Preservation	Long-term
Volume	~ 600 MB
Images format	JPEG 2000 15 bits integer with quantization value = 10000
Metadata	Acquisition conditions Processing parameters Quality checks and masks Cloud / cirrus masks
Auxiliary data	Meteorology (pressure, ozone, water vapour)

L2A Production Pilot Project 'Europe'

- A systematic production of **L2A Bottom of Atmosphere** products over Europe started in September 2016.
- The **Sen2Cor** processor (version 2.3.0) has been integrated in the **ESA-RSS** environment
- It generates daily up to **300GB** of **L2A** products data (~600 Tiles per Day).
- Products granularity of **L2A** will be the same of **L1C** available on OPEN Access data hub.
- **L2A** product format is aligned with the new compact naming convention.





Potential validation test sites

L2A products now available through

http://scihub.copernicus.eu

L2A Products

Characteristics	Current status
Definition	Bottom-of-Atmosphere reflectances
Projection	Same as L1C
Dissemination unit	Same as L1C from May 2nd 2017 via SciHub
Production	User-side production with publicly available software Sen2cor
Preservation	N/A
Volume	~ 700 MB
Images format	JPEG 2000 15 bits integer with quantization value = 10000
Metadata	Same as L1C + Radiometric classification (cloud, cloud shadows, water, snow…)
Auxiliary data	Same as L1C + Retrieved aerosol optical thickness and water vapour

Water Quality Monitoring: Lake Turkana, Maximum Chlorophyll Index

Getintravel

UNEP
United Nations
Environment Programme

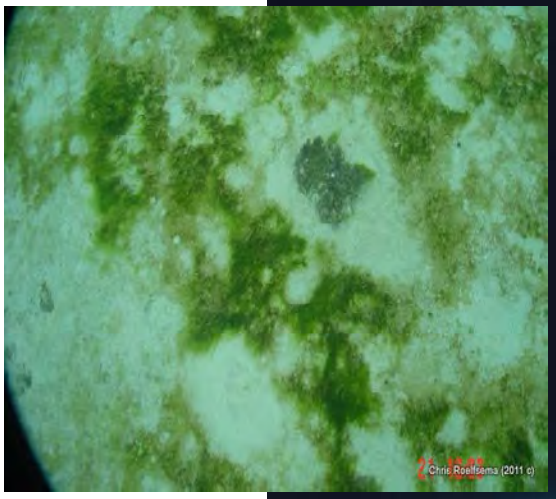
GEMS Water

innovators
sponge

http://www.odermatt-brockmann.ch/sponge/

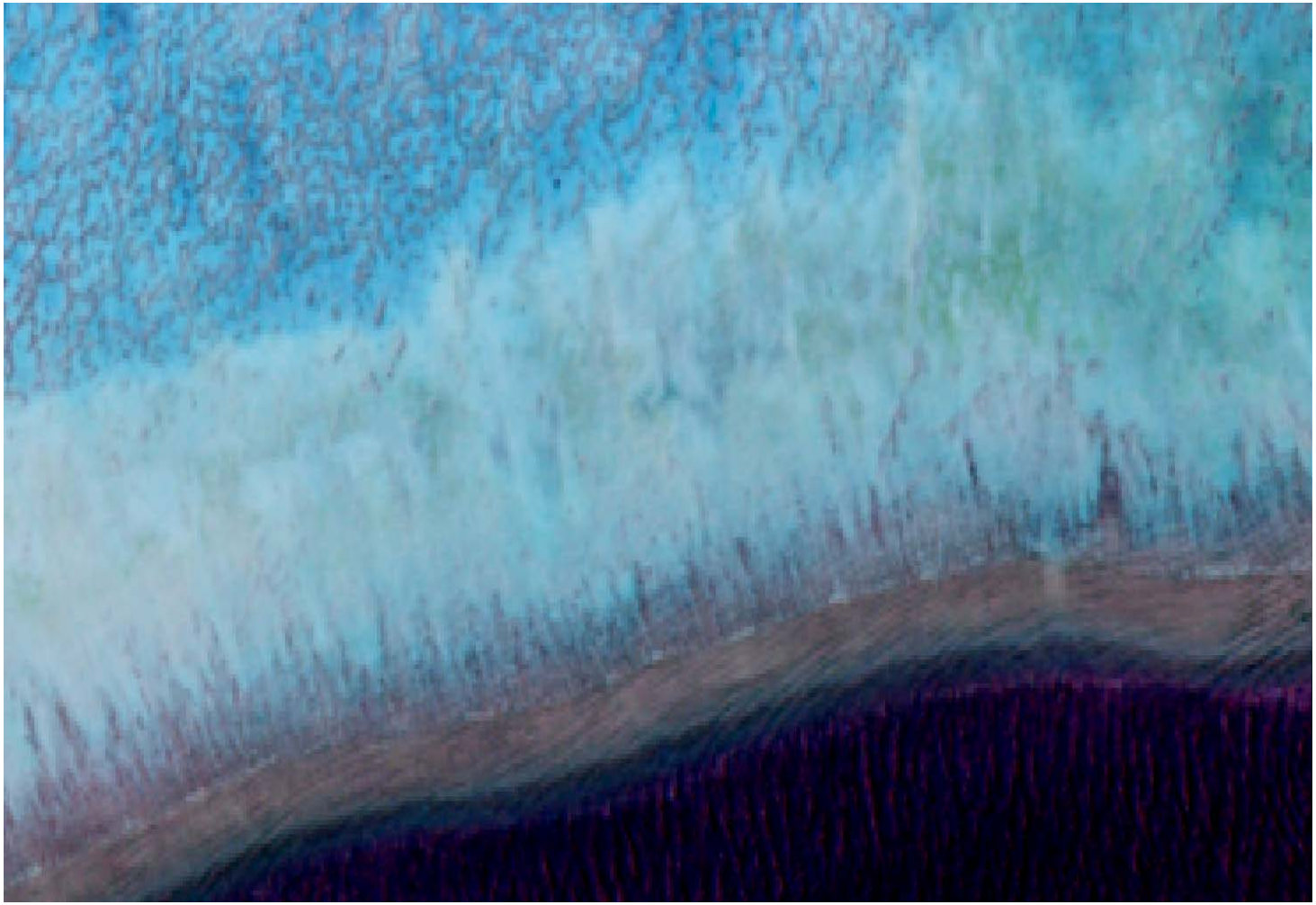
Contains modified Copernicus Sentinel data [2016]

Coral Reefs: Benthic Microalgae Dynamics Wistari Reef, Great Barrier Reef

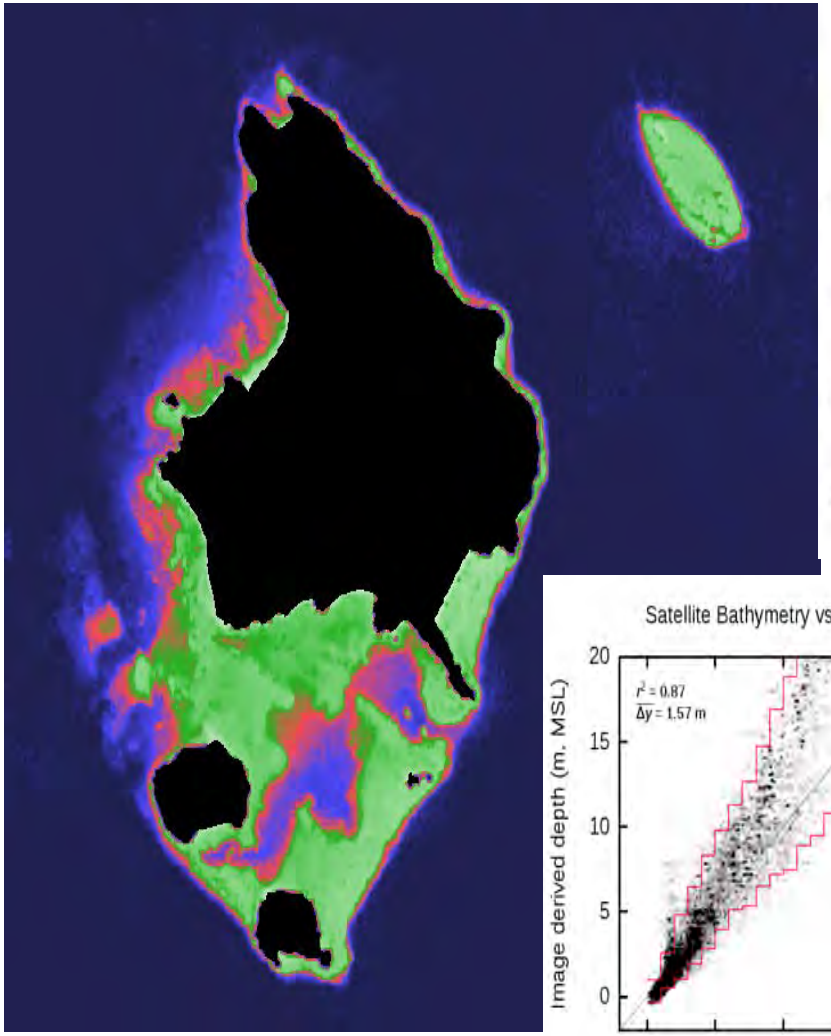


Coral Reefs: Benthic Microalgae Dynamics

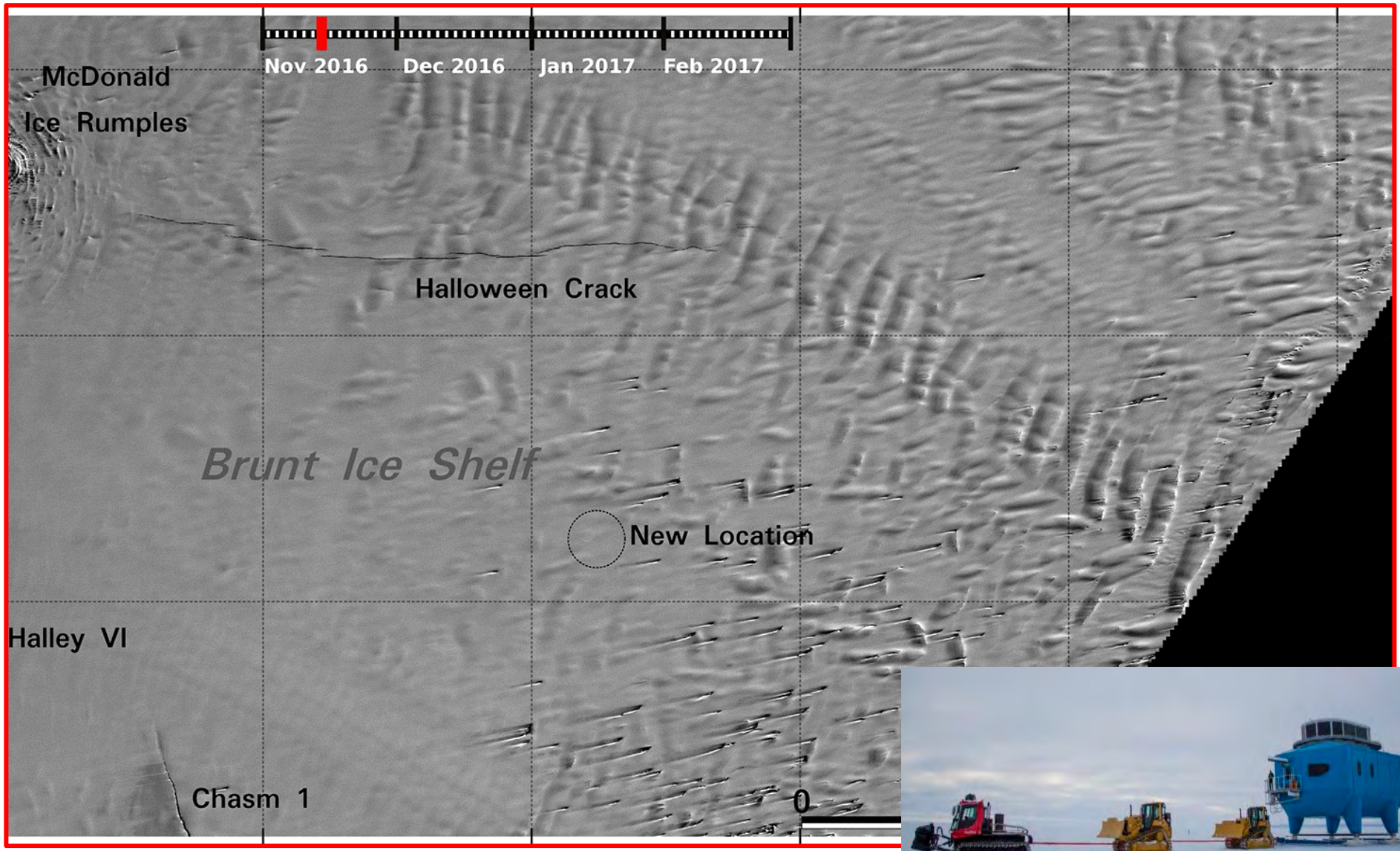
30 October 2016



Coral Reef: Bathymetry
Lizard Island, Great Barrier Reef

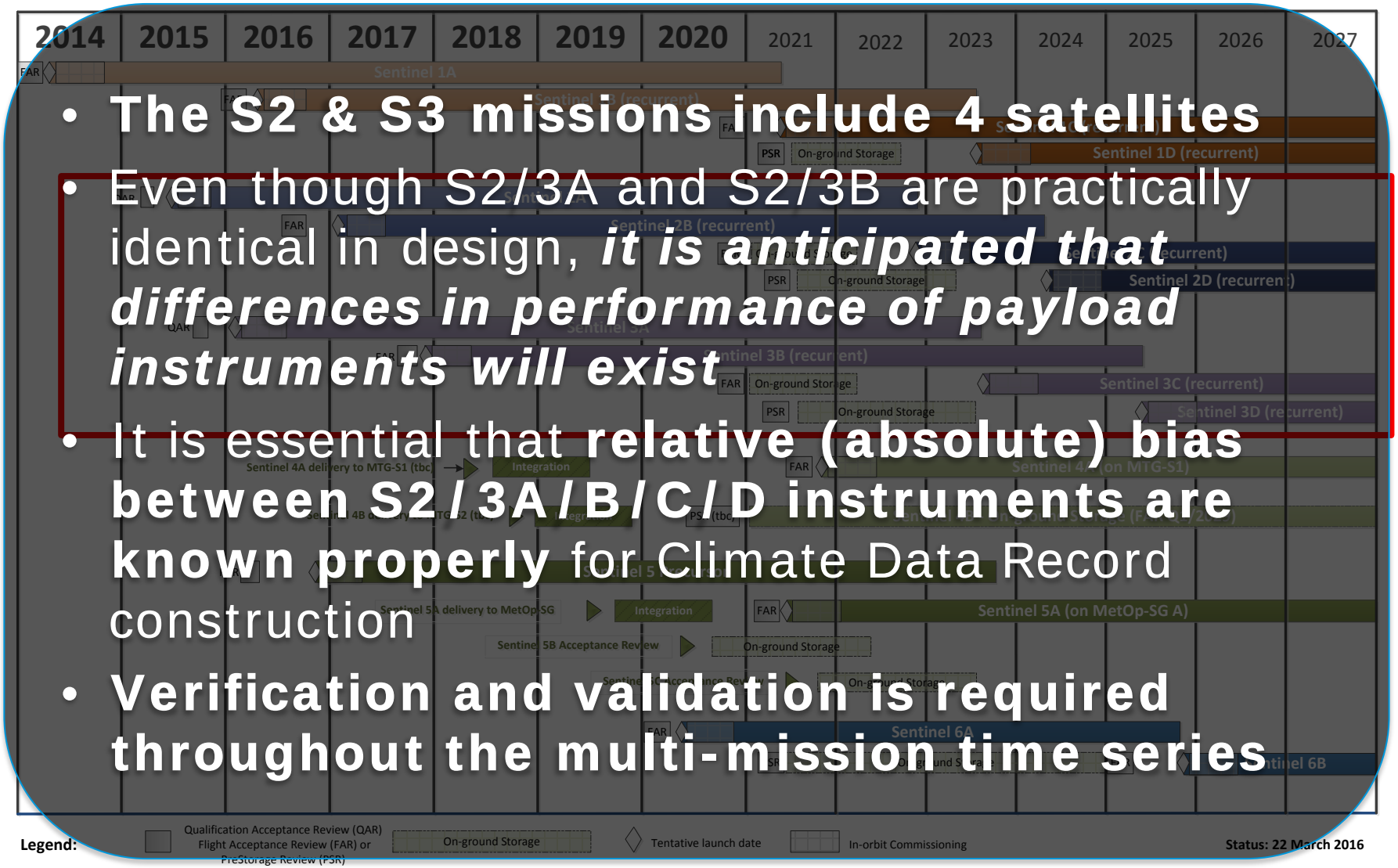


Relocation of British Antarctic Station Brunt Iceshelf Antarctica



Rio Verde Bay, West Falkland on 17/09/16 (image ~10 x 10 km!)

The Copernicus Sentinel Deployment Schedule



- **The S2 & S3 missions include 4 satellites**
- Even though S2/3A and S2/3B are practically identical in design, ***it is anticipated that differences in performance of payload instruments will exist***
- It is essential that **relative (absolute) bias between S2/3A/B/C/D instruments are known properly** for Climate Data Record construction
- **Verification and validation is required throughout the multi-mission time series**

Fiducial Reference Measurements

- **Fiducial Reference Measurements (FRM)** are
- *the suite of **independent ground measurements** that provide the **maximum Scientific Utility and Return On Investment for a satellite mission** by delivering, to users, the required **confidence in data products**, in the form of independent **validation results and satellite measurement uncertainty estimation, over the duration of the mission.***

- **The defining mandatory characteristics of an FRM are:**
  a. Have **documented evidence of SI traceability** via inter-comparison of instruments under operational-like conditions.
  b. Are **independent** from the satellite SST retrieval process.
  c. Include an uncertainty budget for all FRM instruments and derived measurements is available and maintained, traceable where appropriate to SI ideally directly through an NMI
  d. Are **collected using measurement protocols** and community-wide management practices (measurement, processing, archive, documents etc.) are defined and adhered to.
- **FRM are required to determine the on-orbit uncertainty characteristics of satellite measurements via independent validation activities.**

21 – 23 February 2017 at ESRIN, IT Options for future European satellite OCR vicarious adjustment infrastructure for the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments

- 38 attendees
  - USA : 5 from NOAA, Uni. of Miami, NIST Sea-Bird Scientific, NASA GISS
  - Canada : 1 from Dalhousie Uni.
  - Australia : 1 from Uni. Of Western Australia
  - Korea : 1 from KIOST
- EU : 30 from 7 countries
  - ESA, EUMETSAT
  - France : 7 from LOV, ACRI-ST, SOLVO
  - Italy : 7 from JRC, CNR, ISPRA, ESA
  - Estonia : 6 from Tartu Observatory and Estonian Marine Institute
  - UK : 4 from NPL and PML
  - Germany : 2 AWI
  - Belgium : 2 from RBINS, European Environment Agency
  - Ireland : 1 Techworks Marine

TARTU OBSERVATORY space research centre ACRI ST PML Plymouth Marine Laboratory NPL National Physical Laboratory museum

Comparison of Reference Irradiance and Radiance Sources (3 – 6 April 2017 at NPL, UK)

12 organisations from 9 countries

NPL (UK), pilot
TO (EE)
JRC (EU)
LOV (FR)
Satlantic (CA)
Cimel (FR)
In-situ Marine Optics (AU)
CSIRO (AU)
NIVA (NO)
NERC-FSF (UK)
NOAA (US)
DLR-IMF (DE)

Copernicus fiducial reference measurements for satellite ocean colour

CEOS https://frm4soc.org esa

FRM radiometer inter-comparison (8 – 13 May 2017 at TO, Estonia)

13 organisations from 8 countries

- ESA
- TO (EE), pilot
- AWI (DE)
- CIMA (PT)
- Cimel (FR)
- CNR (IT)
- HZG (DE)
- NPL (UK)
- PML (UK)
- RBINS (BE)
- Satlantic (CA)
- UT (EE)
- UVIC (CA)

Indoor / Outdoor

41 Radiometers calibrated!

TARTU OBSERVATORY space research centre

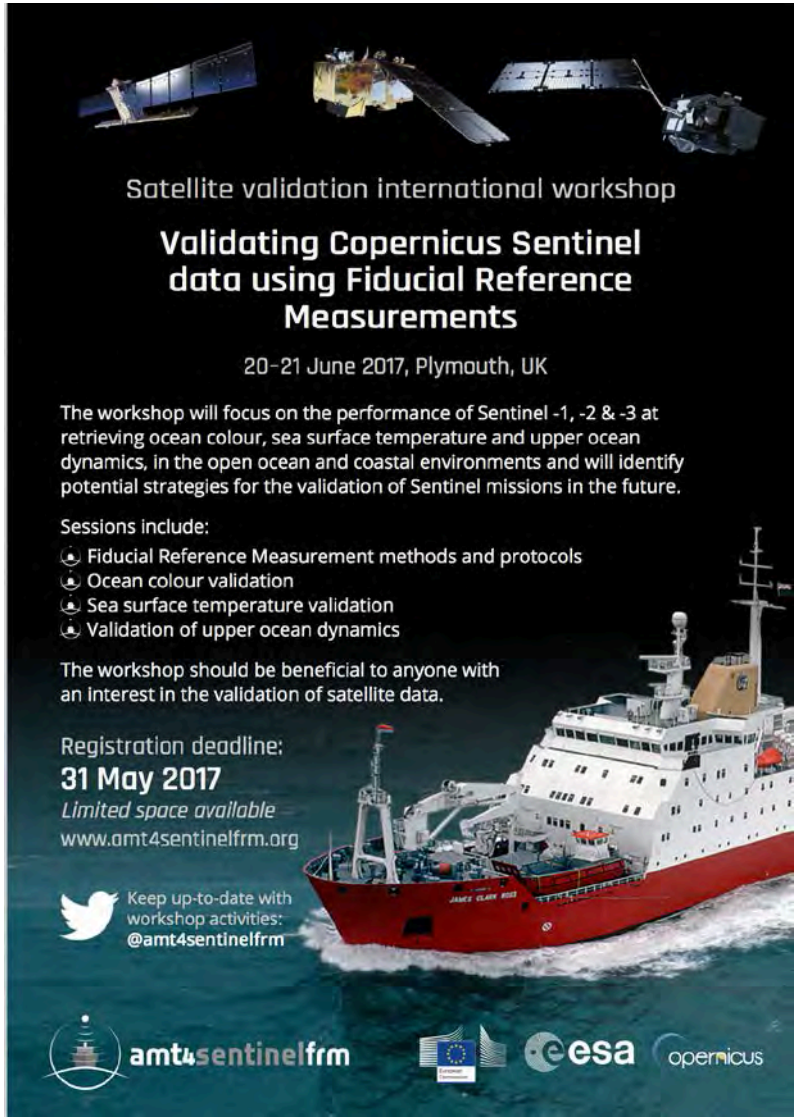
ACRI ST

PML Plymouth Marine Laboratory

NPL National Physical Laboratory

museum

European Space Agency



Workshop programme

Tuesday 20th June

Welcome plenary session
- Craig Donlon, Steve Groom, Susanne Mecklenburg, Andy Rees, Gavin Tilstone

FRM procedures, methodologies and protocol
- Jeremy Werdell (keynote), Andrew Banks, Giorgio Dall'Olmo, Craig Donlon, Hayley Evers-King, Rodney Foster, Tim Smyth, Kenneth Voss

Ocean colour validation: open ocean
- Shubha Sathyendranath (keynote), Robert Brewin, George Graham, Christophe Lerebourg, Constant Mazeran, Emanuele Organelli, Stefan Simis, Menghua Wang

Ocean colour validation: coastal
- David Doxaran, Silvia Pardo, Gavin Tilstone, Hans van der Woerd

Poster session and cocktail reception

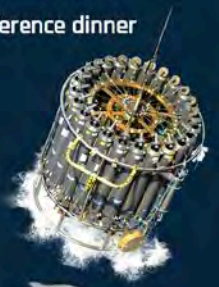
Wednesday 21st June

Ocean colour validation: coastal
- Maycira Costa, Cédric Jamet, Nima Pahlevan

Sea surface temperature validation
- Peter Minnett (keynote), Anne O'Carroll, Prasanjit Dash, Jean-François Piolle, Werenfrid Wimmer

Validation of upper ocean dynamics
- Bertrand Chapron (keynote), Graham Quartly, Louis Marie, Francesco Nencioli

Conference dinner



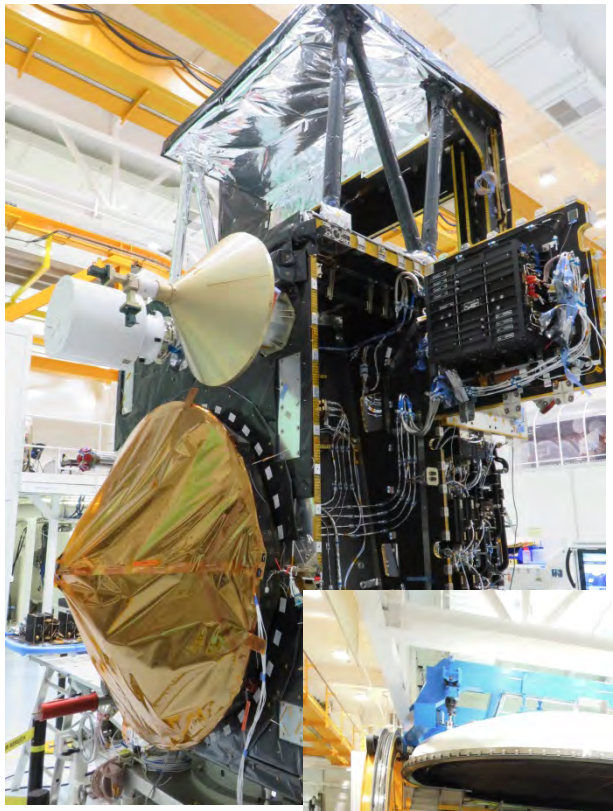
PML Plymouth Marine Laboratory | University of Southampton | Ifremer

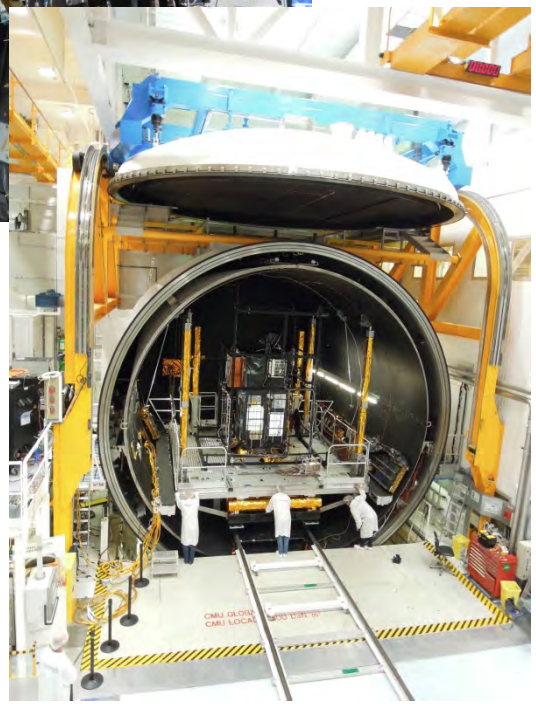
The workshop is hosted by the Atlantic Meridional Transect (AMT) for Fiducial Reference Measurements Campaign (AMT4SentinelFRM) which is led by Plymouth Marine Laboratory and includes two partners as subcontractors: the University of Southampton and the Institut Français de Recherche pour l'Exploitation de la Mer, Plouzane, France (IFREMER).

For further information about the workshop see our website, www.amt4sentinelfrm.org, twitter feed @amt4sentinelfrm or email comms.AMT4SFRM@pml.ac.uk

Satellite images courtesy of ESA, RRS James Clark Ross images by C. Gilbert and P. Bucktrout, British Antartic Survey.

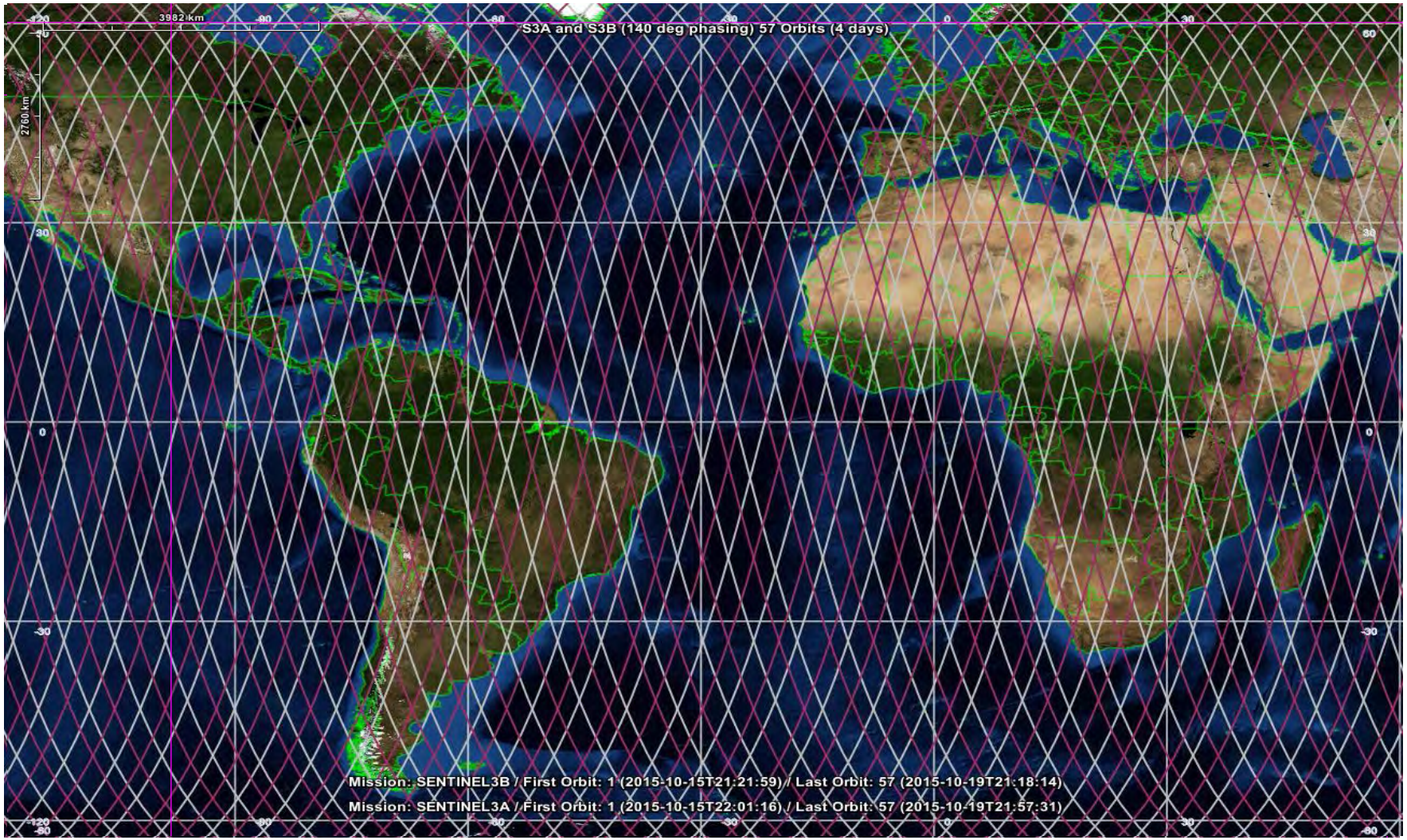
Sentinel-3B: status





- All 5 OLCI-B cameras have been refurbished following anomaly last year.
- Test campaign results show radiometric, spectral and geometric performances similar compared to the previous build.
- OLCI-B instrument integration was completed successfully.
- Satellite now in Thermal Vacuum chamber without OLCI FM (OLCI simulator used)
- Launch planned end 2017
- Procurements for the Sentinel-3C and D models has now started
- New 120Deg Orbit phasing and a Tandem mission (flying S3B 20s in time behind S3A during commissioning approved by EC)
- **More details of the S3 Mission in S. Mecklenburg's Talk**

Optimising the Constellation: Sentinel-3B phasing to 140° (instead of 180°) after 4 days



OLCI 2 day and 3 day coverage after mitigation of sun-glint

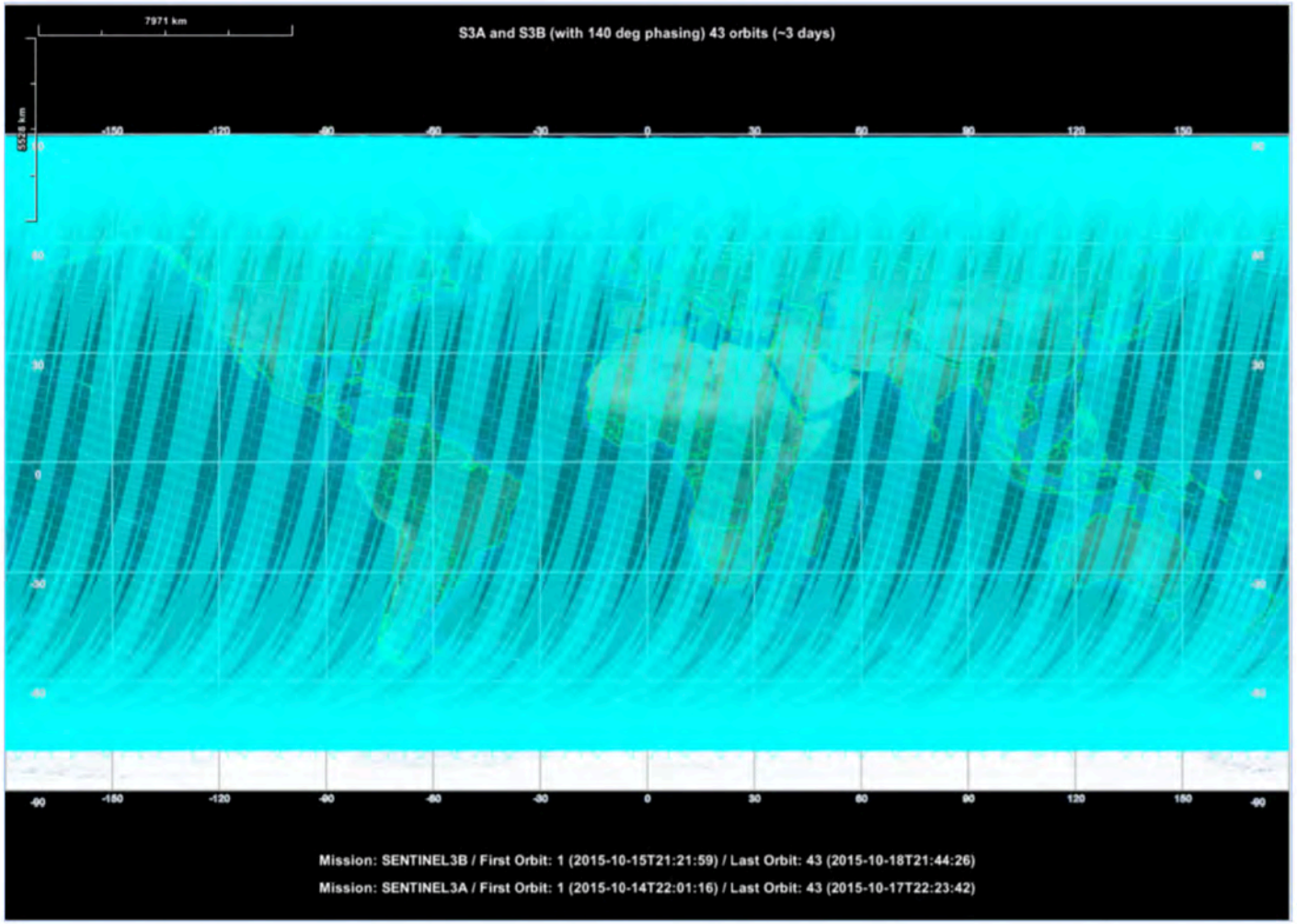
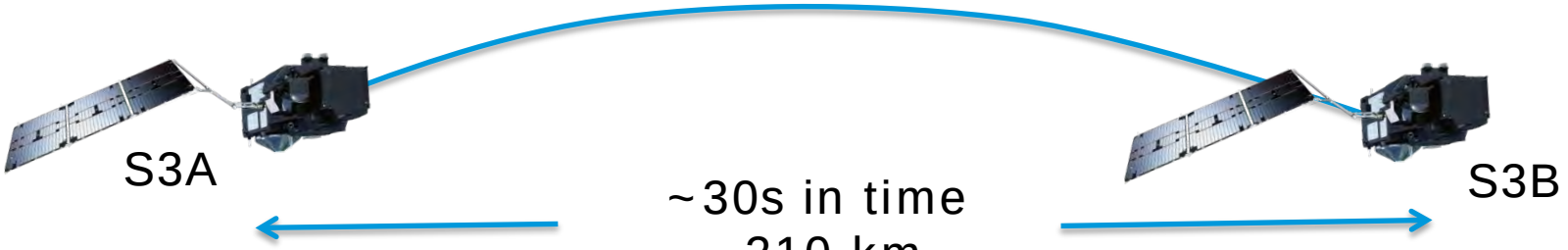


Figure 7. Complete coverage of OLCI after mitigation of sun-glint with S3B set in 140° phasing with S3A is reached after 3 day

Sentinel-3 Tandem phase



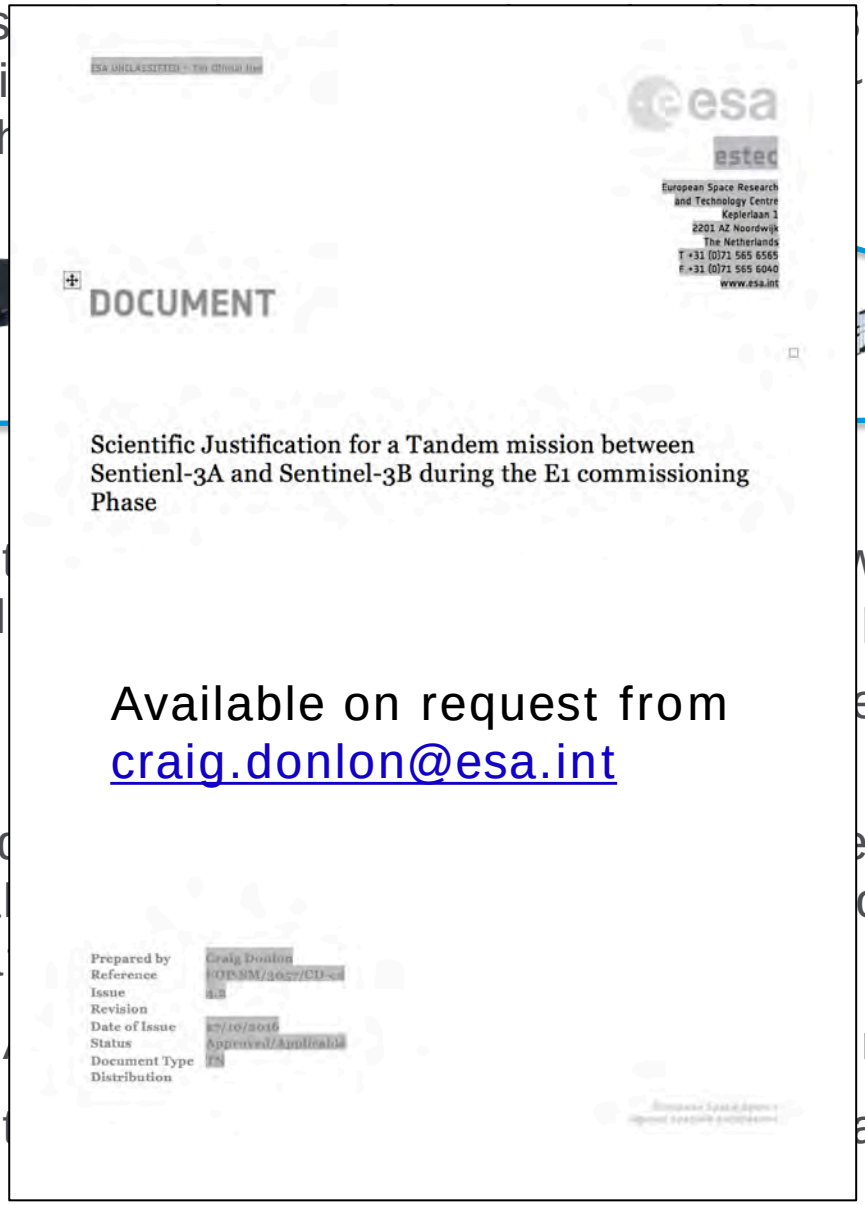
Tandem Rationale

- A tandem phas 0 s separation in time between satelli 4-5 months will be flown during Ph

S3A

S3B

- At ~30s, the at will be reduced to negligible level paring data.
- At ~30s, more e cloud tops and hot deserts can be
- multiple coincid e of atmospheric conditions at al ower to characterise relative calibra
- We can run S3 modes
- We are interest andem phase.



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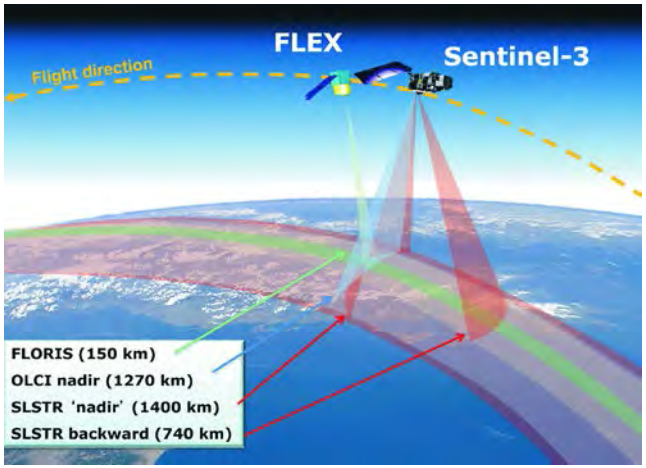
DOCUMENT

Scientific Justification for a Tandem mission between Sentienl-3A and Sentinel-3B during the E1 commissioning Phase

Available on request from craig.donlon@esa.int

Prepared by	Craig Donlon
Reference	
Issue	
Revision	
Date of Issue	
Status	
Document Type	
Distribution	

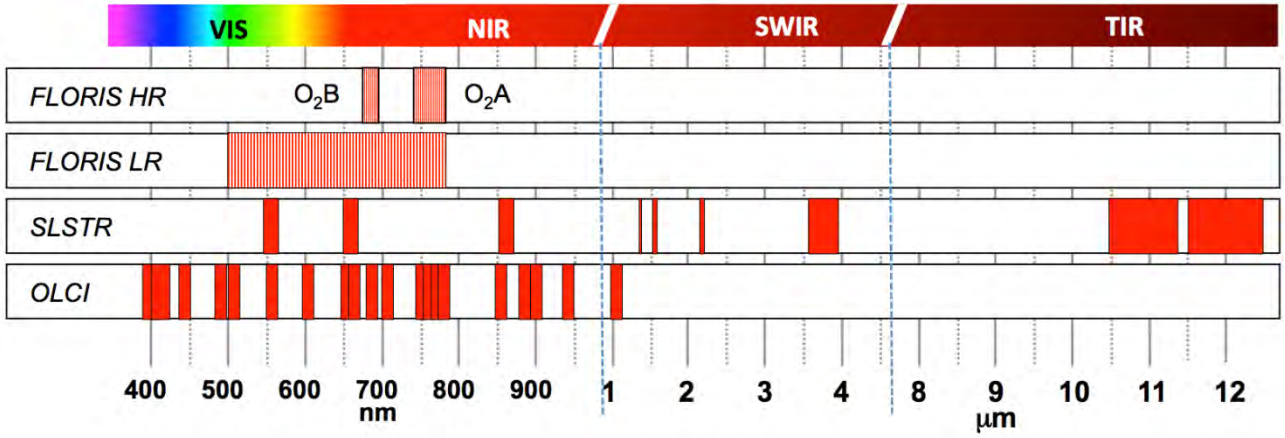
ESA's EARTH EXPLORER 8 - FLEX



Tandem Mission Concept with Sentinel-3:

- 5-30 sec temporal collocation with OLCI
- 300 × 300 m^2 spatial resolution
- 150 km swath width

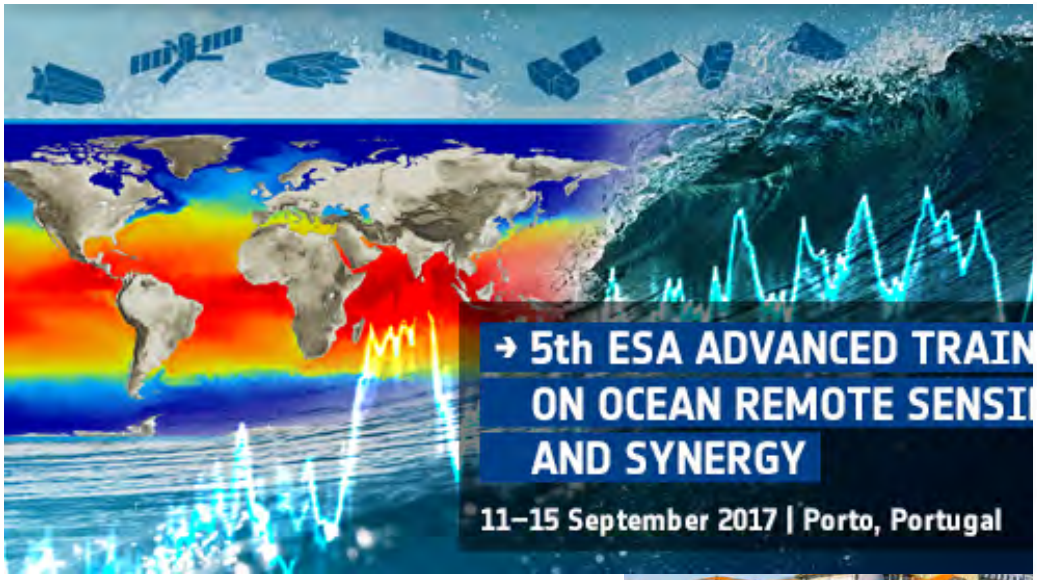
- 500 – 780 nm spectral coverage
- 0.3 – 2 nm spectral sampling intervals



FLEX Poster available in Sessions 1 and 2!

ESA Ocean Training 2017, Porto Portugal
11-15th September 2017

eo science for society



	Monday	Tuesday	Wednesday	Thursday	Friday
Ocean Synergy Challenge [	Mesoscale and sub-mesoscale Structures □	Sea Level and Ocean Surface Transport □	Wind Waves and Wave/current interaction □	Salinity and Marine Inorganic Carbon □	Climate Change and Polar Oceans □
08:30	*Registration*	**Lecture 3:** Sea Level and ocean heat content from space	**Lecture 5:** Wind waves and wave current interaction from space	**Lecture 6:** Measuring ocean surface salinity from space	**Lecture-8:** Polar oceans and Climate change from space
09:00	*Official Welcome*				
09:15	*Course introduction*				
09:30	**Lecture-1:** Measuring the ocean using different satellite instruments in synergy	**Interactive Lecture 4:** What can an ocean altimeter do for me?	**Interactive Lecture 8:** How to measure ocean waves from space [1]	**Interactive Lecture 12:** Investigating sea surface salinity from space [1]	**Interactive Lecture 16:** Understanding the polar oceans from space
09:45					
10:00					
10:15					
10:30	Coffee	Coffee	Coffee	Coffee	Coffee
11:00	**Interactive Lecture 1:** Exploring the ocean mesoscale and sub-mesoscale using thermal and optical imagery	**Interactive Lecture 5:** Investigating sea level and ocean heat content using satellite altimeters	**Interactive Lecture 9:** How to measure ocean waves from space [2]	**Interactive Lecture 13:** Investigating sea surface salinity from space [1]	**Interactive Lecture 17:** Climate impact and the polar oceans
11:15					
11:30					
11:45					
12:00					
12:15	**Lecture-2:** Ocean Biology from Space				
12:30					
12:45					
13:00	Lunch	Lunch	Lunch	Lunch	Lunch

50 places available

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http://oceantrainingcourse2017.esa.int/

Conclusions

- **Successful launch of Sentinel-2B on 7th March 2017 – full constellation in place**
- **All performance of S2A is compliant (or better) than requirements**
- **S2B commissioning is nearly complete: The IOCR is 15th June 2017 so expect products shortly afterwards.**
- **The S2 Mission is responding to user needs and evolving to meet those needs – eg inclusion of L2A products**
- **S2 has great potential for marine applications in the coastal zones and projects at ESA are in place (more to come) to drive user uptake in this domain**
- **Validation activities are well advanced and dedicated projects are in place to develop a culture of FRM validation**
- **Sentinel-3B Satellite integration well advanced.**
- **With the inclusion of the C and D models to the fleet of Sentinel-2 and 3 satellites, mission continuity is ensured for at least 25 years from the launch of the first Satellite**
- **ESA is here to help you deliver the best ocean colour science from space – please take a visit to our booth!**


Thank You –
any Questions
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