



# The Sentinel-3(A) Mission:

## *Mission status*



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*ESA and EUMETSAT Sentinel-3 development and operations teams*



# SENTINEL-3 MISSION OVERVIEW

- Operational mission in high-inclination, low Earth orbit
- Full performance achieved with 2 satellites in orbit (S-3A,-3B)

## Optical Mission Payload providing

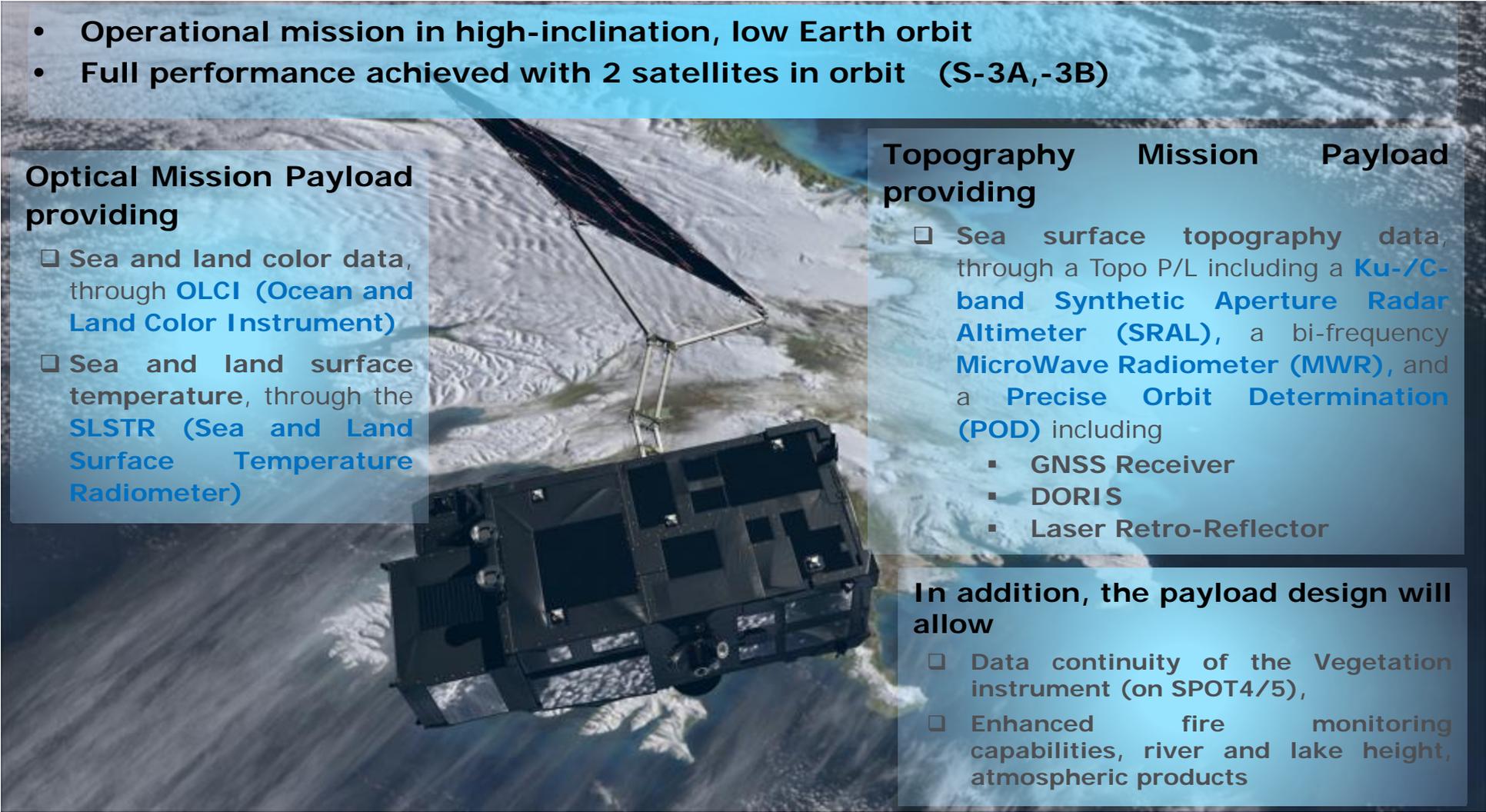
- ❑ Sea and land color data, through **OLCI (Ocean and Land Color Instrument)**
- ❑ Sea and land surface temperature, through the **SLSTR (Sea and Land Surface Temperature Radiometer)**

## Topography Mission Payload providing

- ❑ Sea surface topography data, through a Topo P/L including a **Ku-/C-band Synthetic Aperture Radar Altimeter (SRAL)**, a bi-frequency **MicroWave Radiometer (MWR)**, and a **Precise Orbit Determination (POD)** including
  - **GNSS Receiver**
  - **DORIS**
  - **Laser Retro-Reflector**

## In addition, the payload design will allow

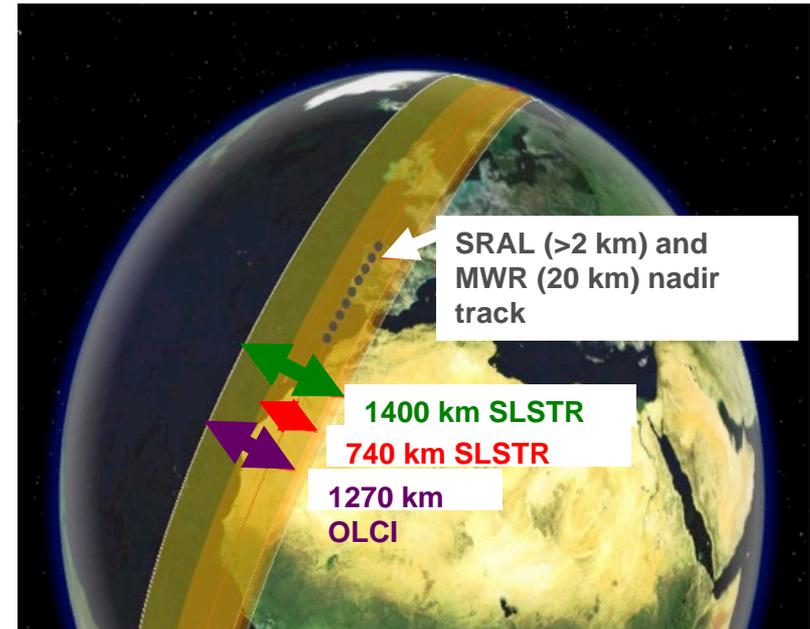
- ❑ Data continuity of the Vegetation instrument (on SPOT4/5),
- ❑ Enhanced fire monitoring capabilities, river and lake height, atmospheric products



# NEW FEATURES - optical payload

- ❑ **100% overlap** between SLSTR and OLCI
- ❑ **Increased number of bands** compared to both AATSR and MERIS allowing
  - ❑ Synergy between OLCI and SLSTR measurements
  - ❑ Enhanced fire monitoring capabilities
- ❑ **Broader swath**
  - ❑ OLCI: from 1150 km to 1270 km
  - ❑ SLSTR: Nadir view 500km → 1400km, Oblique view: 500km → 740km
- ❑ Optical payload **< 2 days global coverage** (with 2 Satellites) in view of the substantially increased swath
- ❑ **Increased spatial resolution:**
  - ❑ OLCI: 300m for land and ocean
  - ❑ SLSTR: 500m for VIS-SWIR, 1km for IR-Fire
- ❑ **Mitigation of sun glint** by tilting cameras 12.5 deg in westerly direction
- ❑ **Near-Real Time** (< 3 hr) availability of L2 core products

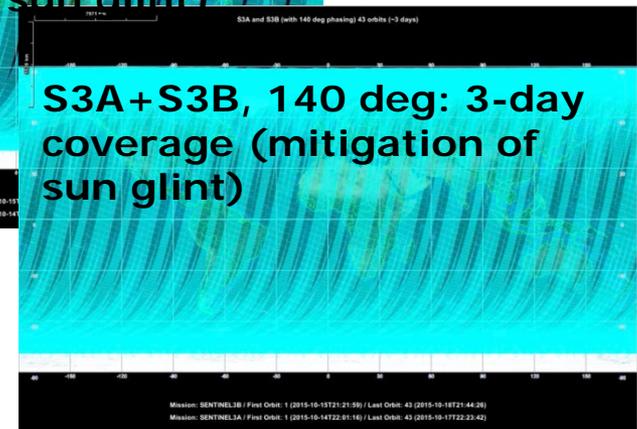
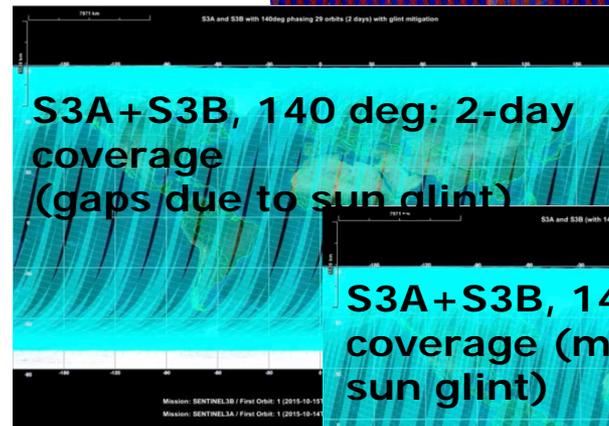
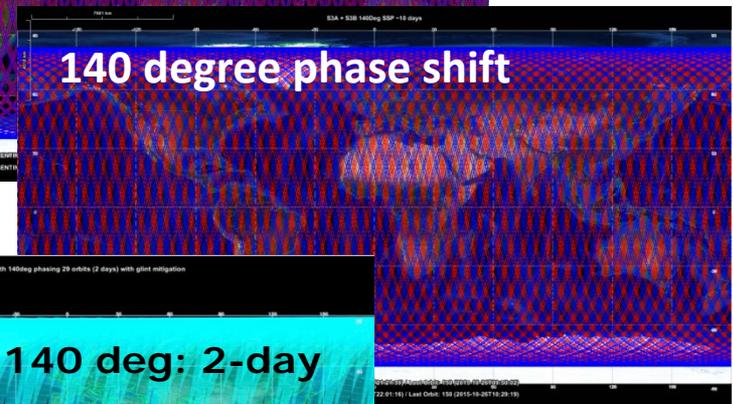
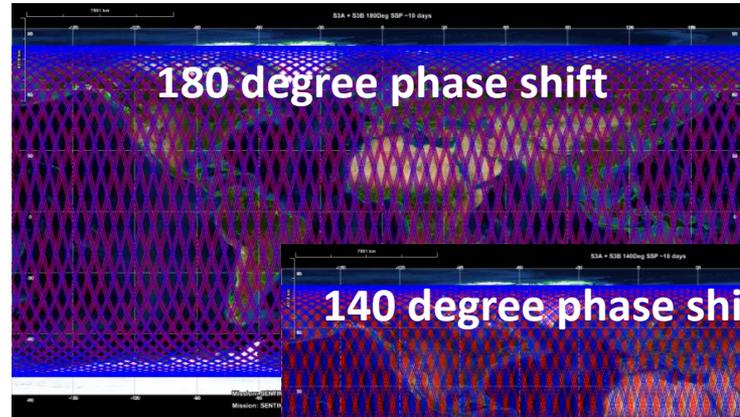
## Instrument Swath Patterns



Orbit type	Repeating frozen SSO
Repeat cycle	27 days (14 + 7/27 orbits/day)
LTDN	10:00
Average altitude	815 km
Inclination	98.65 deg

# OPTIMISED ORBIT PHASING OF S3A/B AND C/D

- ❑ Copernicus Marine Environment Monitoring Service (CMEMS) asked for optimising orbit phase shift to **improve interleave between S3A and S3B for improved SRAL meso-scale sampling at 4-7 days**
- ❑ Solution of **140°** separation recommended by ESA, and confirmed by EUMETSAT assessment.
- ❑ EC has confirmed implementation for S3B
- ❑ **Minimal impact on optical mission**
  - ❑ **Over ocean**
    - ❑ OLCI: global coverage <2 days but parts of the swath will be impacted by sun-glint. Sun-glint free coverage by OLCI will be attained in ~3 days over the ocean.
    - ❑ SLSTR: coverage and revisit of the SLSTR remains compliant with requirements.
  - ❑ **Over land** (sun glint unproblematic, unless inland water) OLCI and SLSTR coverage is expected to remain compliant with requirements.



# What happened since launch ...

## Sentinel-3A successfully launched from Plesetsk Cosmodrome (Russia) on 16 February 2016

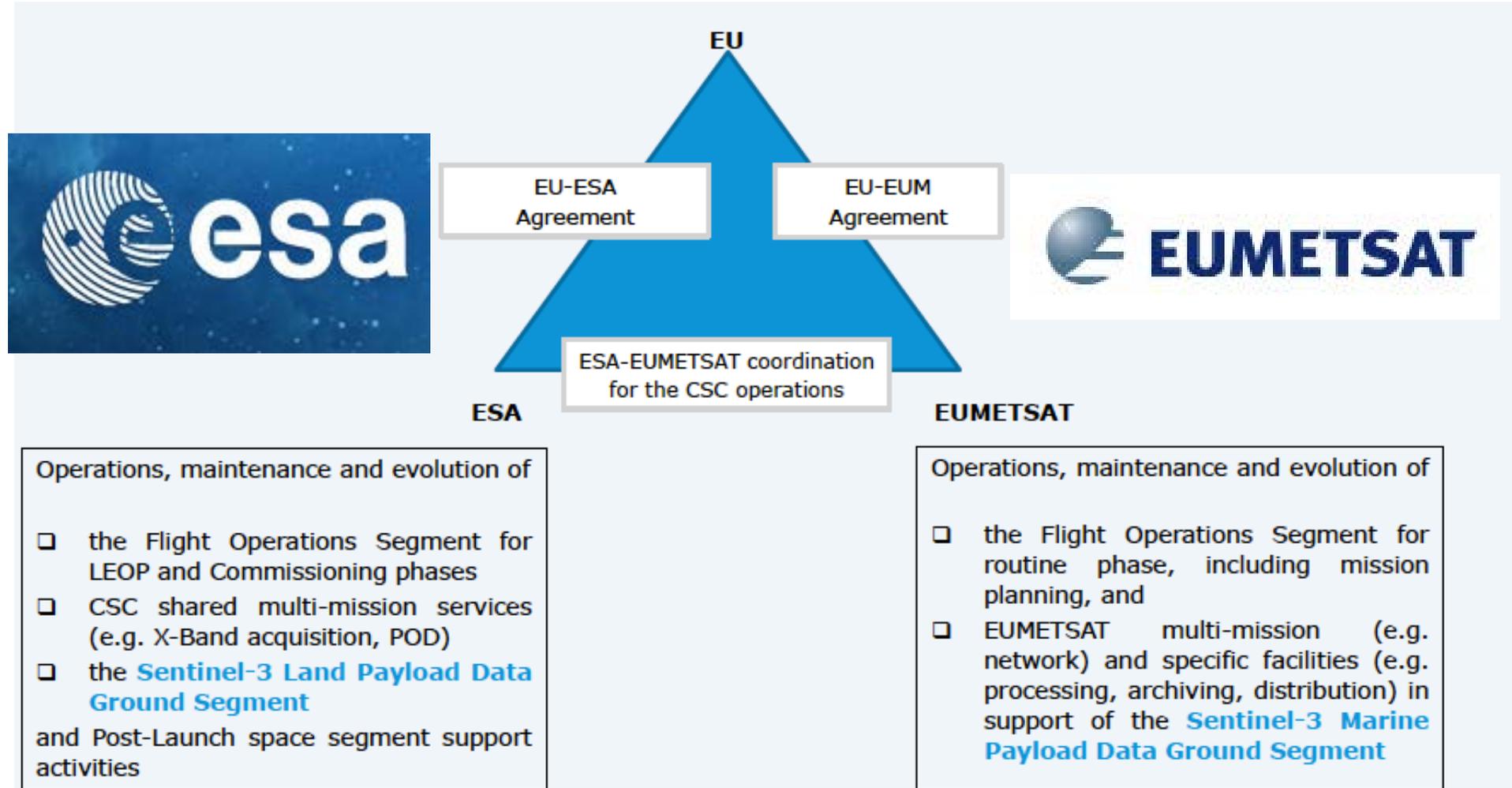


Spacecraft and all instruments in nominal operational mode and functioning well.

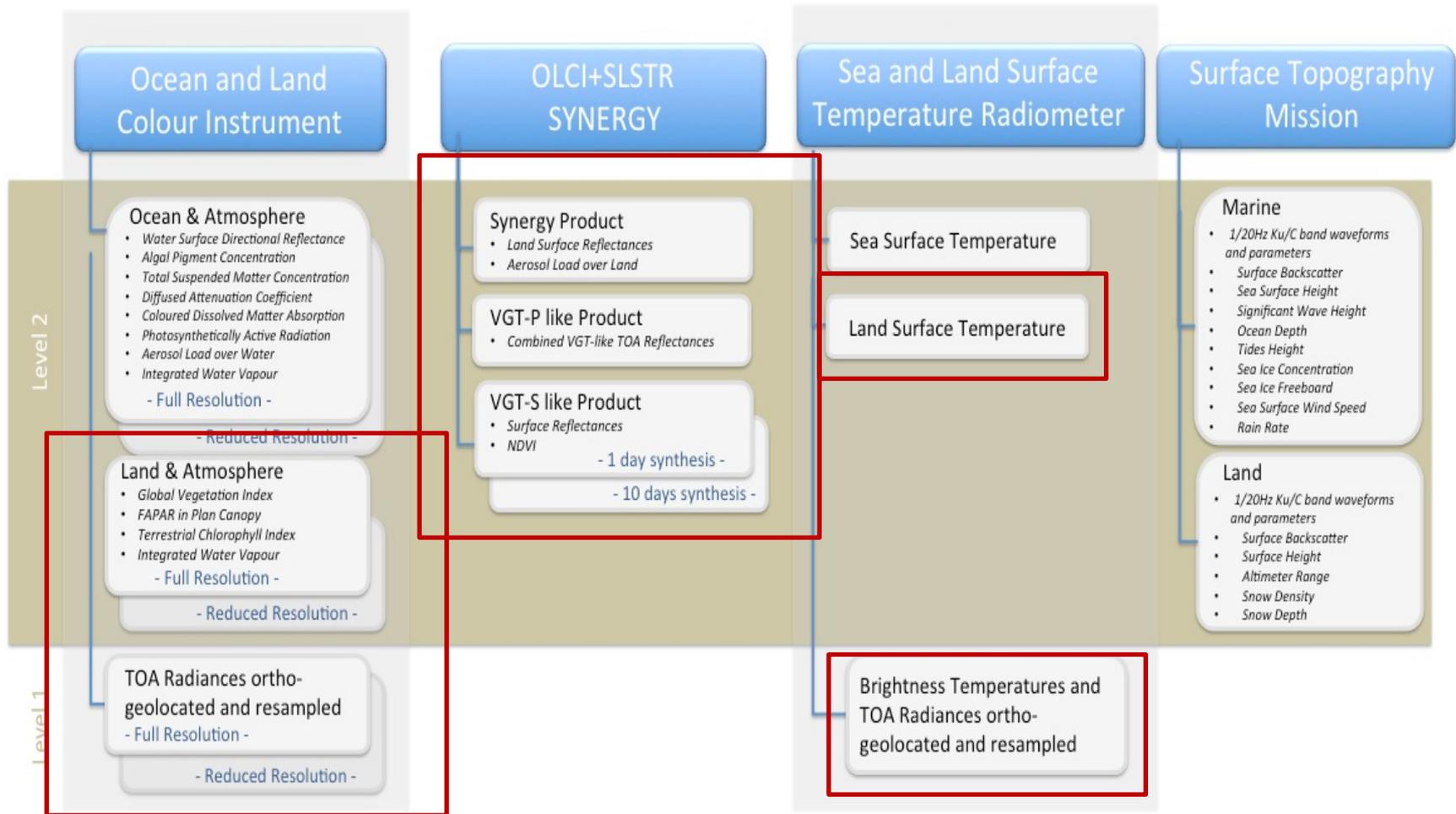
16 Feb	Successful Launch
18 Feb	LEOP phase concluded successfully <ul style="list-style-type: none"> <li>✓ Perfect orbit injection from the launcher</li> <li>✓ Rapid and smooth Solar Array deployment</li> <li>✓ Only one minor anomaly encountered (Star Tracker depointing due to incorrect quaternion data), rapidly identified and corrected</li> </ul>
26 Feb	Platform In-Orbit Verification completed
4 March	Payload In-Orbit Verification completed <ul style="list-style-type: none"> <li>✓ All instrument ON and operating (except SLSTR in decontamination mode, as planned)</li> <li>✓ Level-0 products being generated</li> </ul>
7 March	Cal/Val Phase of S3 commences
April/May	Mid-Term-Reviews for OLCI, SLSTR and SRAL
mid- May	<b>Release of sample products to all users for familiarisation</b>
28-30 June	Expert users meeting – first feedback from S3 validation teams
11/12-July	In-Orbit Commissioning Review (IOCR)– <b>successful completion of commissioning phase, start of ramp-up phase (initial operations)</b>
13 July	ESA internal handover from development to operations team; Handover of flight operations from ESA to EUMETSAT
10 October	Handover of Marine PDGS from ESA to EUMETSAT
Q3 2016	<b>Progressive release of Level 1 data</b>
Till RORR	<b>Progressive release of Level 2 data</b>
Dec 2016	Mid-term review check point for ramp-up phase
June/July 2017	<b>Start of routine operations phase – Routine Operations Readiness Review (RORR)</b>

# ESA & EUMETSAT SHARE OPERATIONS

- ❑ **EU Copernicus Regulation:** full, open and free data policy, defining responsibilities for ESA and EUMETSAT and overall financial envelope
- ❑ **Dedicated EU-ESA and EU-EUMETSAT Copernicus agreements**

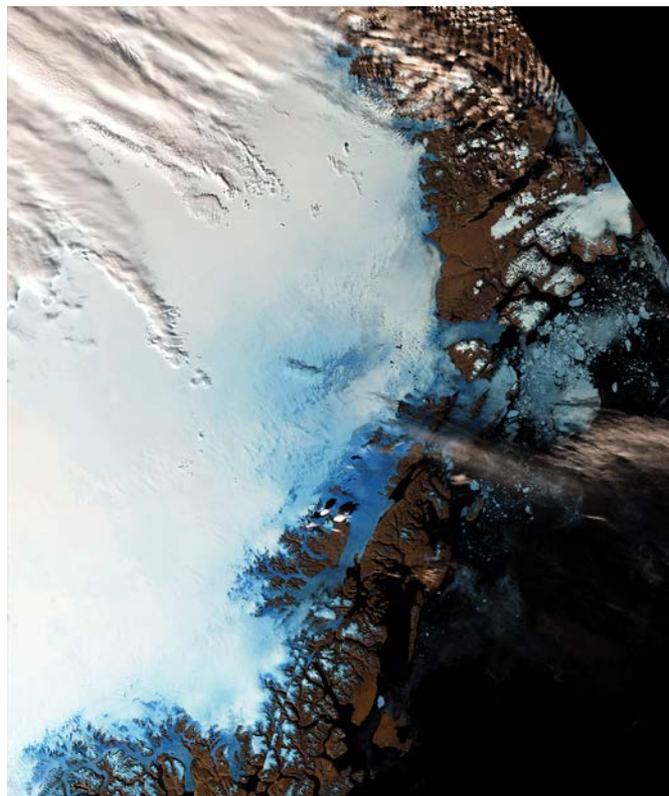


# Sentinel-3: core data products



# STATUS OF CORE OPTICAL DATA PRODUCTS

# OLCI: Status Level 1 (TOA radiances)



Switch on 29 Feb 2016

Sample L1/L2 data available May/June 2016

L1 data release 20 Oct 2016

L2 data release Spring 2017

- ❑ Ocean and Land Colour Instrument (OLCI) designed for observation with high absolute (relative) accuracy of 2 (1) % in reflectance, providing continuity for MERIS (Envisat)
- ❑ **Level 1 performance**
  - ❑ Radiometry: on-board radiometric calibration based; SNR is compliant with specification; calibration gains show some time variability but stability seems to improve with time; vicarious calibration shows spectrally/spatially/dynamically/X-track consistent results, however a  $\sim +3\%$  bias (yaw steering maneuvers for diffuser BRDF characterization)
  - ❑ Spectrally: fully compliant; pre-flight characterisation confirmed for all cameras in-flight ( $<0.15\text{nm}$ ); small temporal trends since beginning of the mission (comparable to MERIS)
  - ❑ Geometry: fully compliant (60m @ Nadir); bi-monthly check that thermo-elastic model is accounting for seasonal variations.

# OLCI: Status Level 2 LAND (FAPAR/OGVI, OTCI)

## Level 2 product status

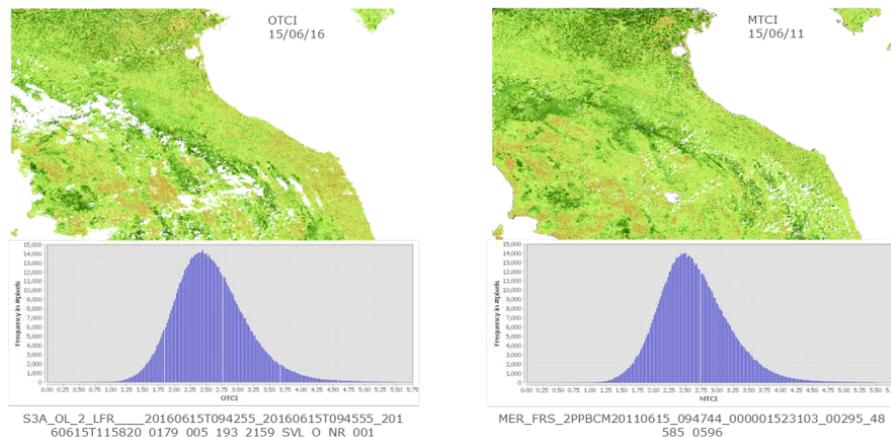
- ❑ Cloud flag needs improvement
- ❑ L2 products unavailable for inland waters
- ❑ Improving standard product flags

## Level 2 product validation on-going, comparisons between

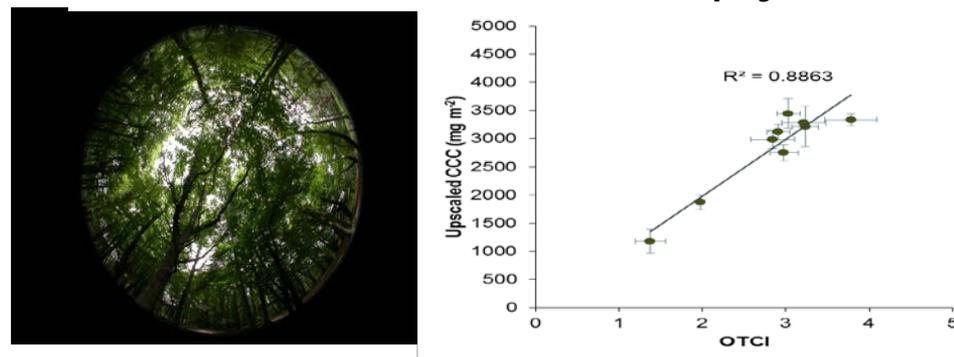
- ❑ OLCI and MERIS Terrestrial Chlorophyll Index shows good consistency
- ❑ OLCI and MODIS FAPAR (at 250m) over selected sites show good agreement
- ❑ OLCI and in-situ Terrestrial Chlorophyll Index shows good agreement

ESA VAL4VEG project planned for vegetation relevant data products from S2 and S3 (2017)

## OLCI and MERIS Terrestrial Chlorophyll Index



## OLCI and in-situ Terrestrial Chlorophyll Index

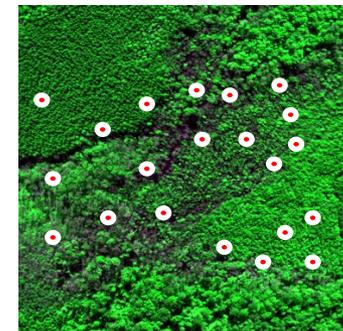
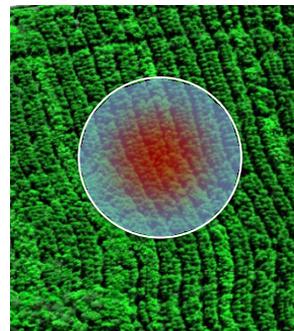


Credit: J.Dash, University of Southampton

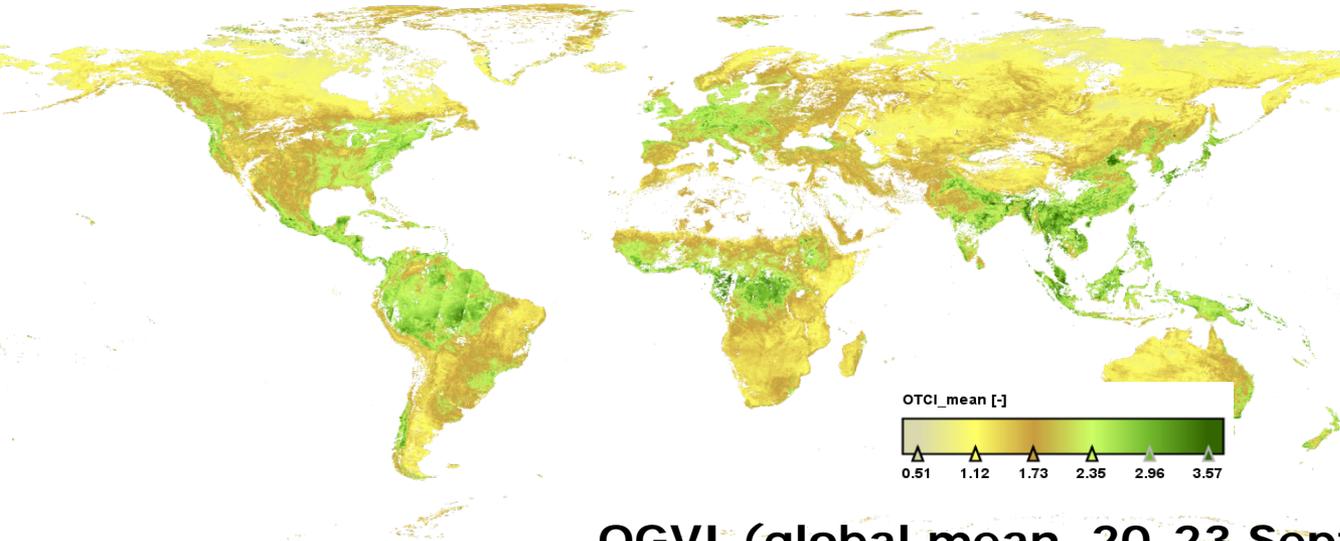
# Fiducial Reference Measurements for Vegetation Products (VAL4VEG)

Aim *To establish and maintain SI traceability of Fiducial Reference Measurements (FRM) for land vegetation products (Cab, FAPAR and Surface Reflectance).*

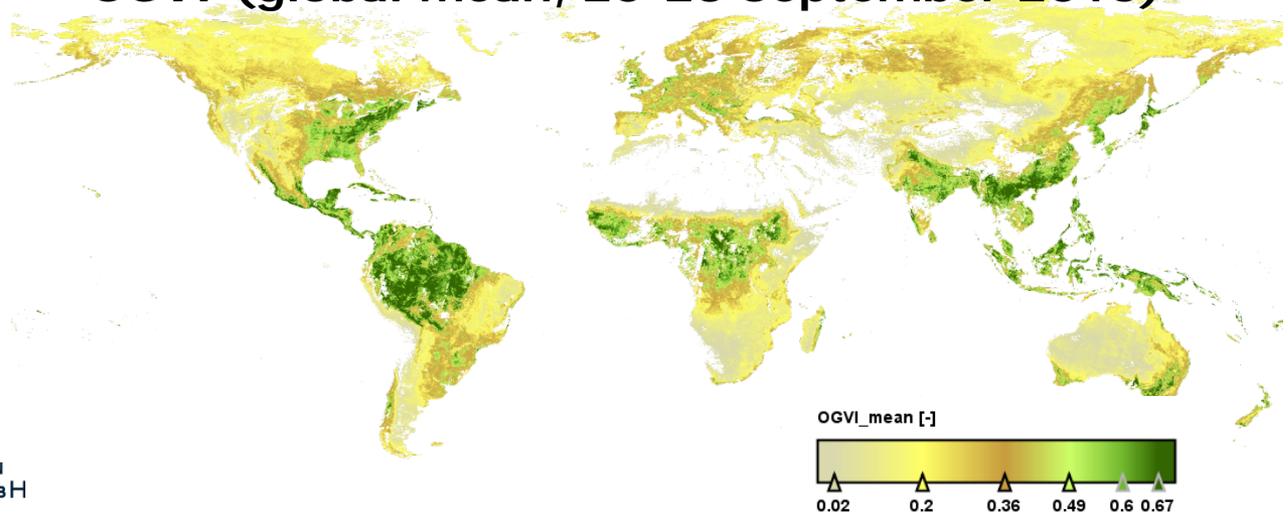
- Laboratory and field individual measurement characterization experiments
- Round-robin performance assessment of Cab, FAPAR and Surface Reflectance measurement methods at OLCI pixel scale
- Kick-Off Q2 2017



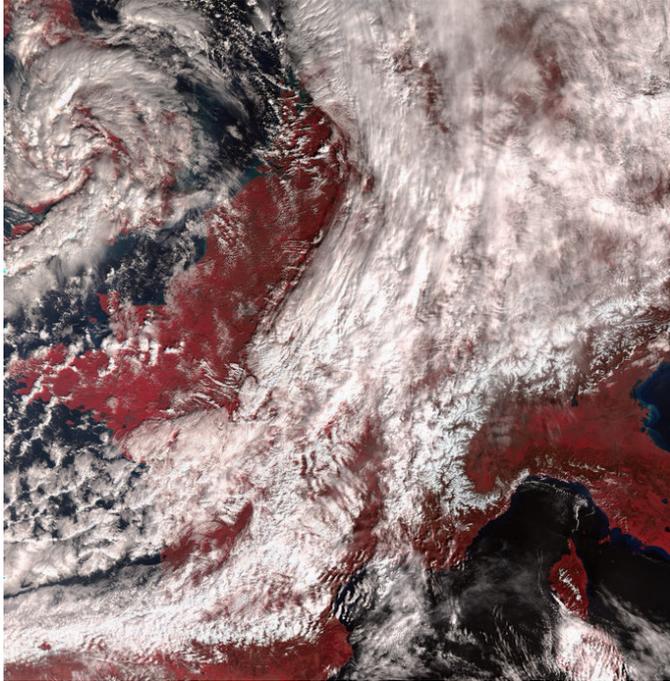
## OTCI (global mean, 20-23 September 2016)



## OGVI (global mean, 20-23 September 2016)



# SLSTR: Status Level 1 (TOA radiances)



- ❑ Sea and Land Surface Temperature Radiometer (SLSTR) designed for observations with high radiometric accuracy <2% (BOL)/<5% (EOL); < 0.2K (0.1K goal), providing continuity for(A)ATSR (Envisat); 100% overlap with OLCI
- ❑ Nighttime acquisitions for S1-S4 (“day channels”) over Siberia and Gulf of Guinea in Jan 2017 to be characterize gas flares (9 collocation with VIIRS)
- ❑ **Level 1 performance**
  - ❑ Corrections to Basic Cloud Screening - improved
  - ❑ SWIR calibration – improved, residual of 10%
  - ❑ Geometric calibration corrections in Nadir and Oblique – May 2017
  - ❑ Saturation thresholds – improved
  - ❑ Co-registration of fire channels and their nominal channels (F1/S7 and F2/S8)– end 2017
  - ❑ Co-registration of VIS and SWIR – March 2017

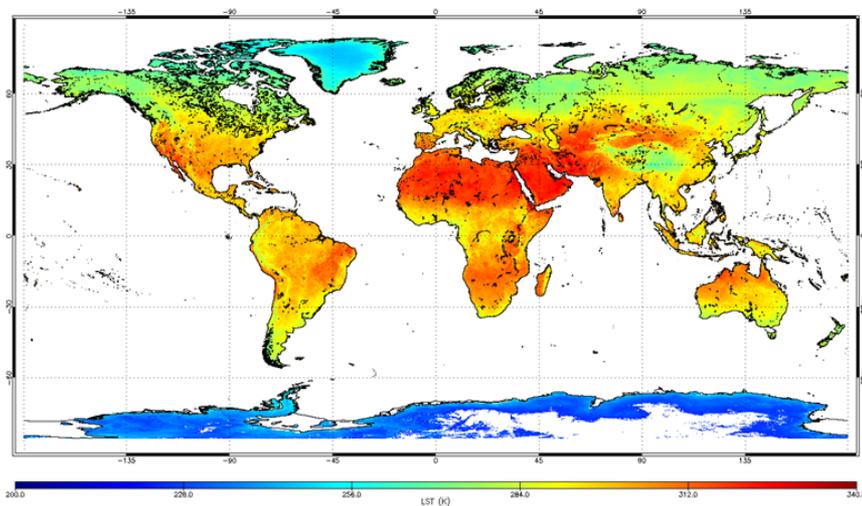
**Switch on**                    **2 March 2016**

**Sample L1/L2 data available**                    **May/June 2016**

**L1 data release**                    **17 Nov 2016**

**L2 data release**                    **Spring 2017**

# SLSTR: Status Level 2 (Land Surface Temperature)



Land Surface Temperature monthly composite for September 2016 (D. Ghent, University of Leicester)

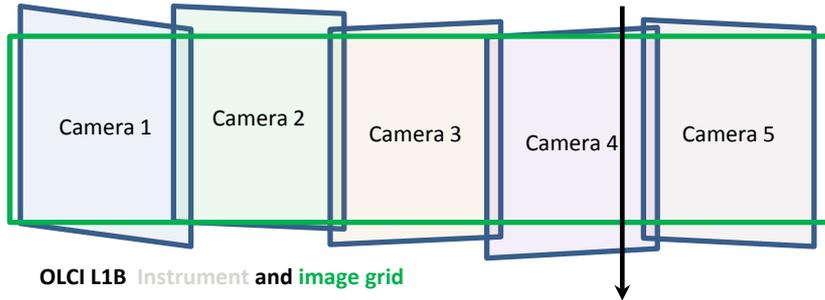
## Level 2 product status

- ❑ Improvements for Level 1
- ❑ LST coefficients continuously fine-tuned
- ❑ Uncertainty estimates to be improved (future work: use GlobTemperature approach)
- ❑ Optimisation of visible cloud test for daytime images – May 2017
- ❑ Improvements to LST retrieval algorithm: correct assignment of biome and fractional vegetation cover – May 2017

## Level 2 validation on-going

- ❑ Initial validation using SURFRAD sites shows LST product is near to the mission requirement. The retrieval accuracy varies from 0.6 to 1.6 (MRD requirement < 1K)
- ❑ Intercomparison with respect to GlobTemperature MODIS indicates product has very small overall differences
  - ❑ Differences correlated with orography and biome
  - ❑ Larger differences in bare soil regions where solar insolation is high
- ❑ Next validation steps in S3 MPC/ESL will be further comparisons with MODIS and SEVIRI

# Combining OLCI and SLSTR radiances = SYNERGY/VGT products



OLCI L1B Instrument and image grid

Band	$\lambda$ centre (nm)	Width (nm)
Oa1	400	15
Oa2	412.5	10
Oa3	442.5	10
Oa4	490	10
Oa5	510	10
Oa6	560	10
Oa7	620	10
Oa8	665	10
Oa9	675	7.5
Oa10	687.5	7.5
Oa11	697.5	7.5
Oa12	712.5	10
Oa13	727.5	7.5
Oa14	742.5	2.5
Oa15	757.5	15
Oa16	772.5	20
Oa17	787.5	10
Oa18	802.5	10
Oa19	900	10
Oa20	940	10
Oa21	1 020	40

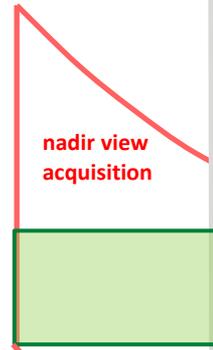
Band	$\lambda$ centre ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )
S1	0.555	0.02
S2	0.659	0.02

S3	0.865	0.02
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S4	1.375	0.015
S5	1.61	0.06
S6	2.25	0.05

- ❑ Combining all OLCI (but O<sub>2</sub>/H<sub>2</sub>O absorption) channels and SLSTR S1, 2, 4-6
- ❑ Rational for combination: Covering larger spectral range and collocate different info from 2 complementary instruments

**co-registration channel**



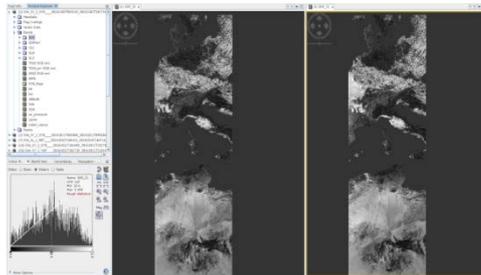
SLSTR L1B Instrument nadir view and oblique view and image grid

# S3 SYN-VGT algorithm overview

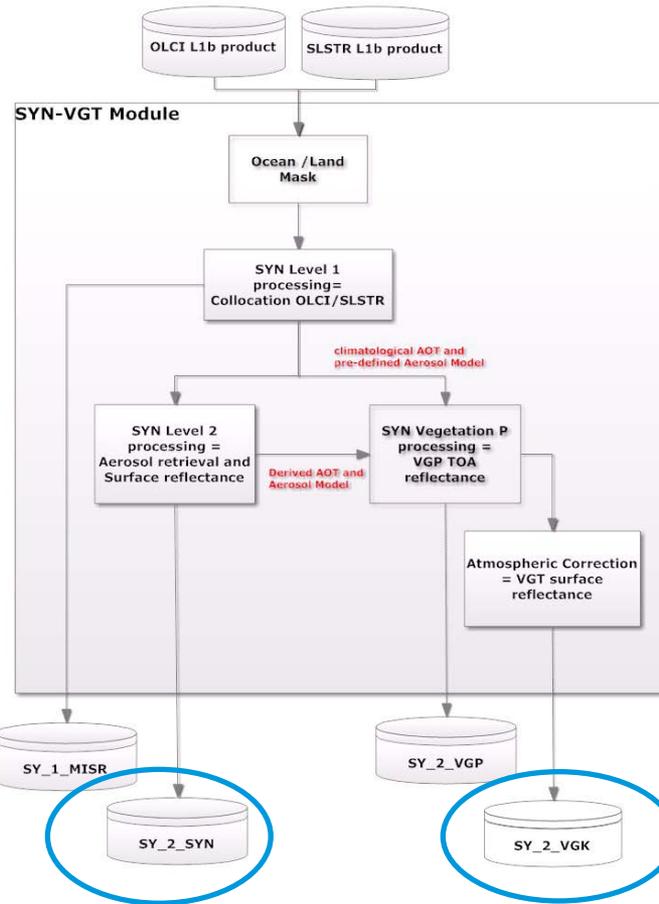
**SYNERGY (SY\_2\_SYN)**  
 Atmospherically corrected land surface reflectance at all OLCI and SLSTR wavebands (both nadir and oblique views), other than within gaseous absorption bands (O<sub>2</sub>, H<sub>2</sub>O)

Resolution 300 m, contains:

- ❑ Surface Reflectance (per channel on OLCI grid)
- ❑ Aerosol Optical Thickness + associated error
- ❑ Aerosol Angstrom Exponent
- ❑ Aerosol Model File
- ❑ Contextual parameters = Lat, long, time, quality flags
- ❑ Sub-sampled Contextual parameters = Lat, long, solar and viewing angles, meteo



Sample SYN L2 product; Surface reflectance at 865 nm derived from OLCI channel and SLSTR nadir channel Credit: C.Henocq/ACRI/MPC

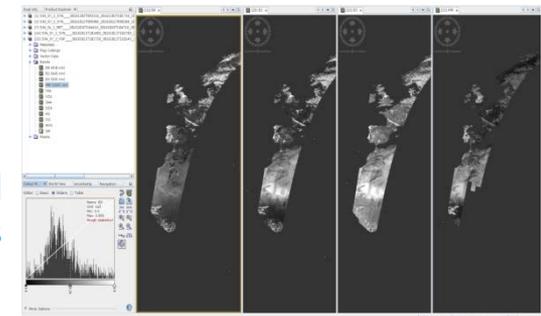


**VEGETATION (VGT SY\_2\_VGP (P/S1/S10)):** Top of Atmosphere Reflectance product provided for the continuity of the SPOT VGT-P product. Generated from OLCI and SLSTR channels interpolated to VGT bands.

Resolution 1 km Plate Carrée grid (for continuity with Spot-5/ Proba-V continuity, but 300m option)

Based on OLCI/SLSTR data interpolated on to 4 channels from Spot-5/Proba-V (= Real heritage product) Both OLCI and SLSTR, contains:

- ❑ VGT TOA Reflectance
- ❑ NDVI
- ❑ 1km Sub-sampled Contextual parameters : VZA; VAA, SAA, SZA, AOT, O<sub>3</sub>, TCWV

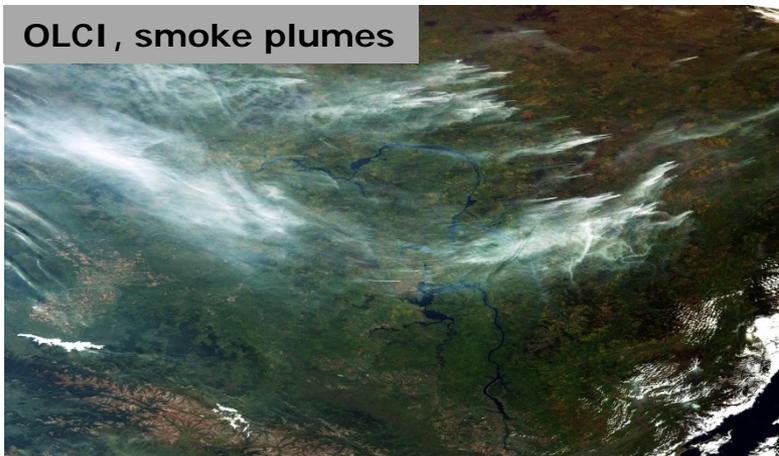


Credit: C.Henocq/ACRI/MPC

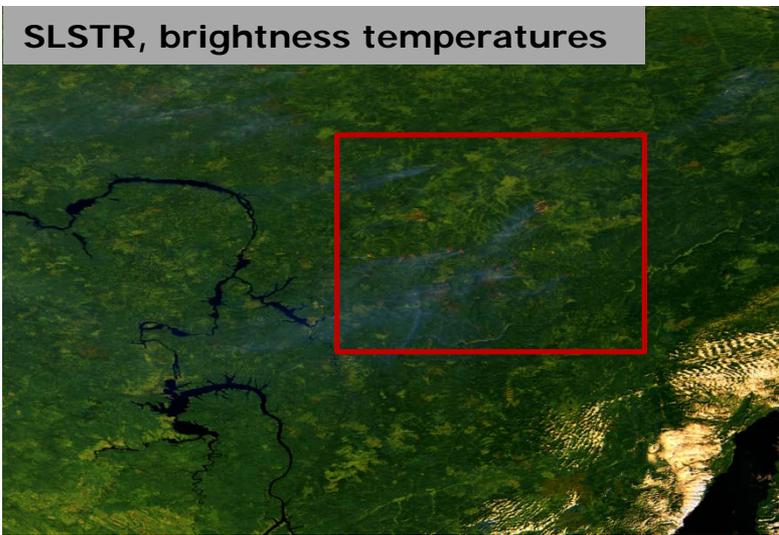
**USER PRODUCTS: SYNERGY and VEGETATION** Sample products expected May 2017, official release summer 2017

## Fires in Siberia, September 2016

OLCI, smoke plumes



SLSTR, brightness temperatures



## Aerosol Optical Depth (AOD)

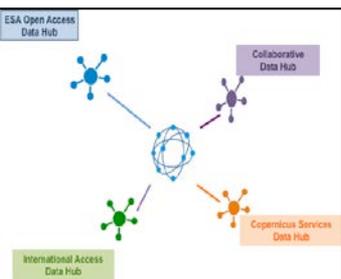
- ❑ AOD **NRT**: Based on P.North (2002): " Estimation of aerosol opacity and land surface bi-directional reflectance from ATSR-2 dual-angle imagery: operational method and validation"; Validated with AATSR data within ESA's CCI: provides best results when compared with AERONET and over bright surface.
- ❑ AOD **NTC**: Based on above algorithm adapted for SYNERGY products including spectral capacities of OLCI (North et al., 2010); Validated using MERIS and AATSR.
- ❑ The above algorithms will need to be extended to cover the retrieval of aerosol properties over ocean.
- ❑ **Implementation on-going, available in [mid-2017](#) in NRT from EUMETSAT and NTC from ESA**

## Fire Radiative Power (FRP)

- ❑ Current algorithm based on Wooster et al. (2005) JGR D21111:doi: 10.1029/2005JD006318 ; SLSTR algorithm : Wooster et al. (2012) Remote Sens. Environ, 120, 236-254.
- ❑ Needs to be extended to include detection of fire over sea surface in coastal areas and in known oil-gas producing areas.
- ❑ Database of land and ocean gas flare and volcano masks will be included in the data product to provide a hotspot classification/type to users.
- ❑ **Implementation on-going, available in [end-2017](#) in NRT from EUMETSAT and NTC from ESA**

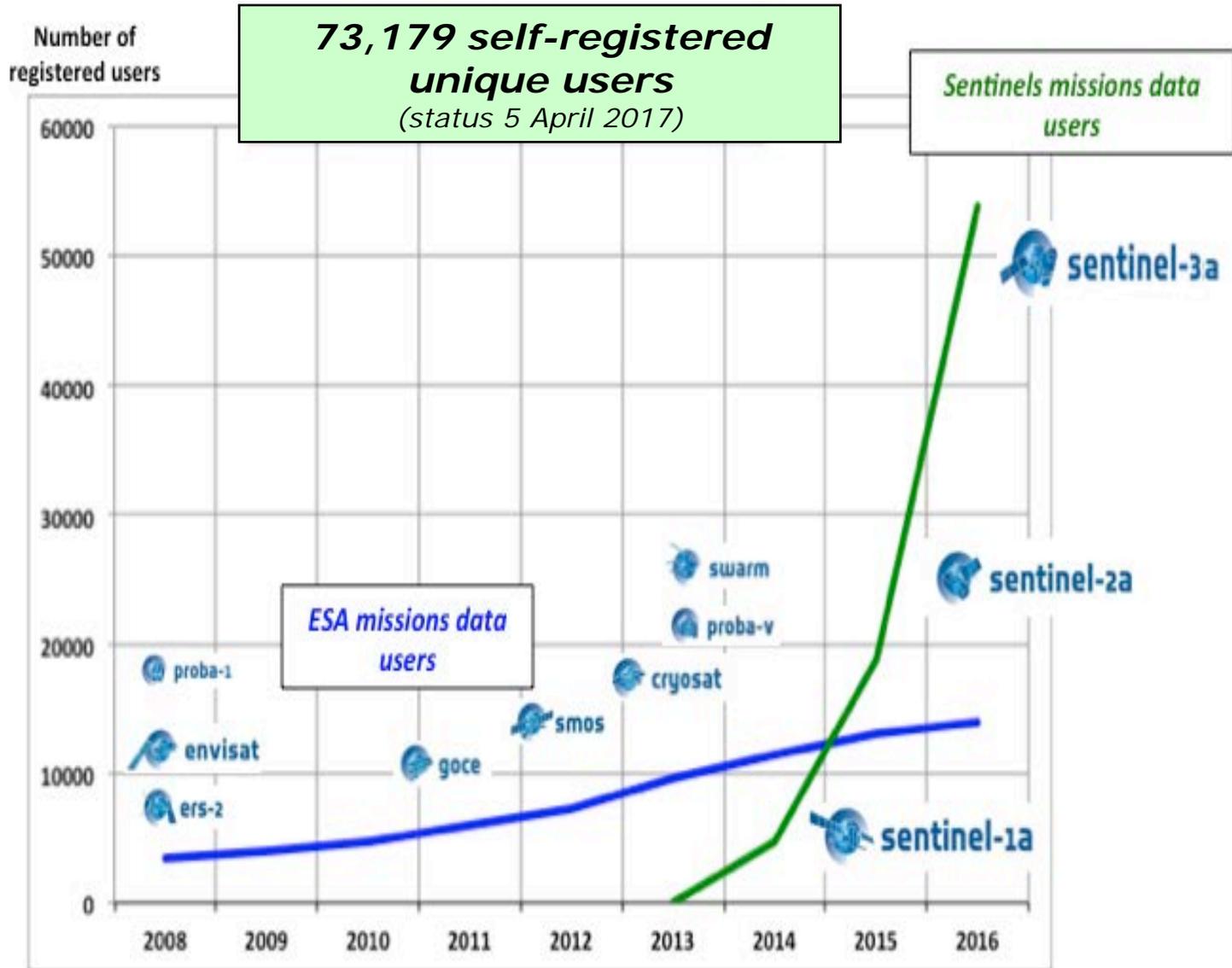
# DATA ACCESS & DISSEMINATION

# Sentinel Data Distribution - Configuration



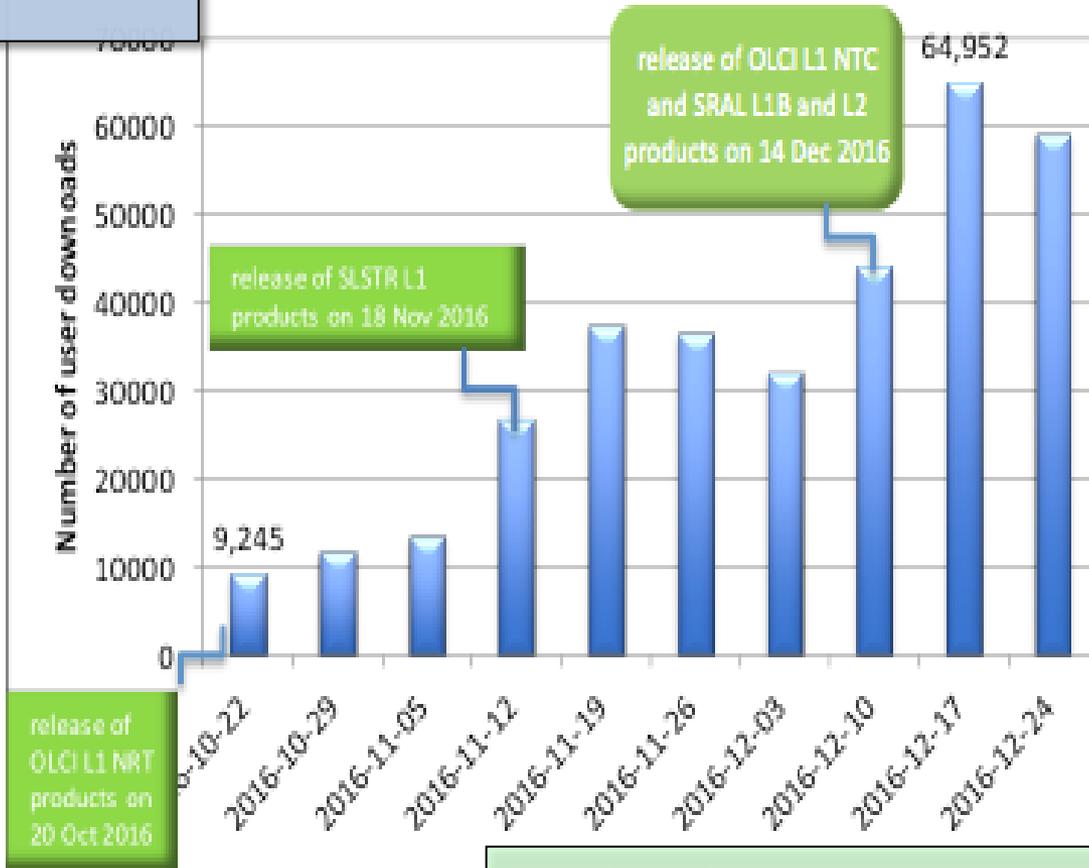
Statistics: 5 April 2017

# Sentinel Data Distribution – User Registration



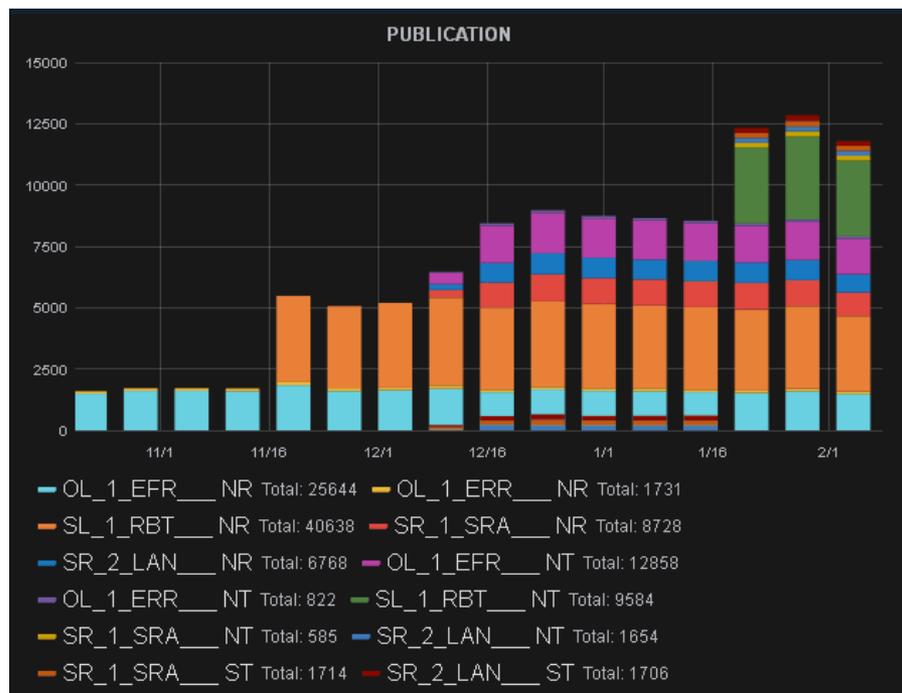
*Approx. 344,000 products were downloaded during Q4-2016 (175 TB of data)*

## Number of Sentinel-3 user downloads

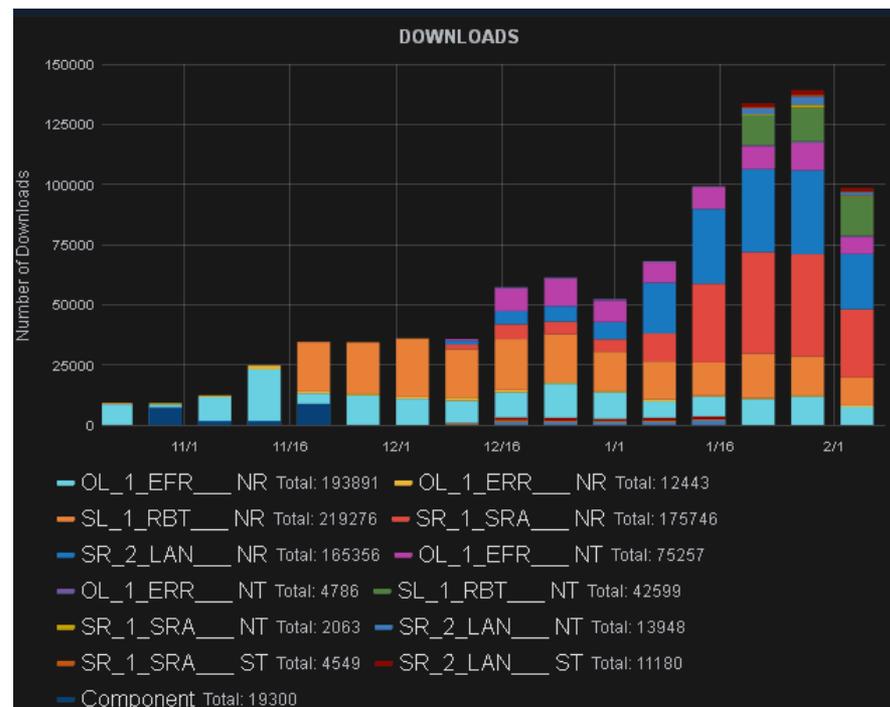


**Exploitation ratio - 1:6**  
*on average each product published has been downloaded 6 times*

## Publication of products (#) 20 Oct 2016 – 8 Feb 2017

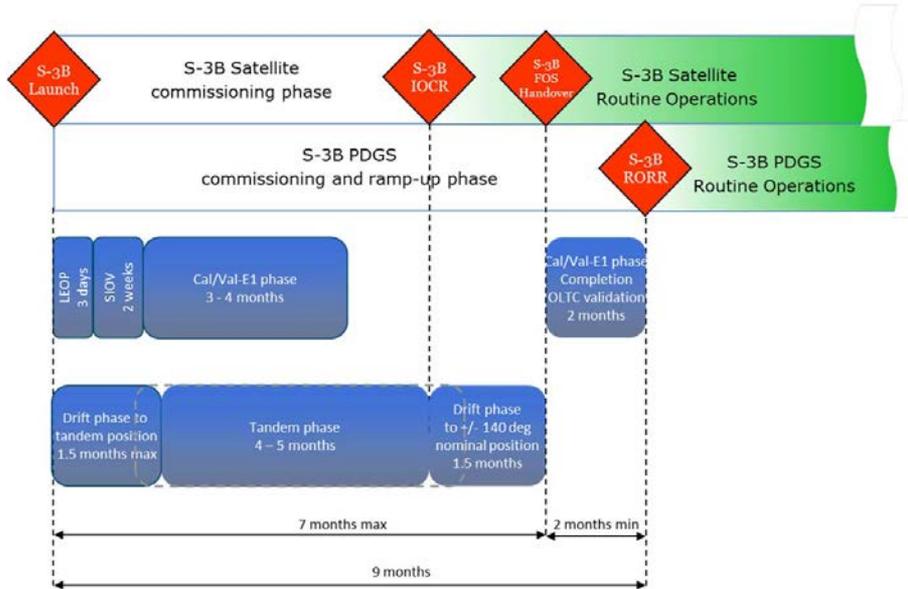


## Download of products (#) 20 Oct 2016 – 8 Feb 2017



# Update on Sentinel-3B

- ❑ **Sentinel-3B activities restarted in Q2 2016** after Sentinel-3A launch in Feb 2016
- ❑ Implementation of Return of Experience (REX) from S3A on-going
- ❑ Instrument status
  - ❑ **Topography** payload fully available and integrated, no open issues
  - ❑ **SLSTR** Proto-Flight Model assembly and testing progressing according to plan: Instrument calibration tests successfully completed in Feb in RAL and instrument currently at TAS-F for integration. before delivery to Prime planned mid-Feb 2017
  - ❑ **OLCI-B** model experienced major anomaly (same as for A instrument) during instrument TVAC in July 2016; decision to refurbish all 5 cameras, which are now available and tested with good performance results; delivery of OLCI-B for S/L integration by mid June 2017 confirmed
- ❑ In view of late delivery of OLCI, Sentinel-3B S/L Integration and test activities reorganised to fit launch schedule
- ❑ Sentinel-3B Flight Acceptance Review planned for October 2017, launch date foreseen for end of 2017 (TBC)



## TECHNICAL PLANNING

- ❑ Operate S3A and S3B in Tandem for ~4-5 months at start of mission
- ❑ One satellite follows the other with 30 sec separation: minimum oceanographic and atmospheric variability reducing uncertainty in comparing measurements from both satellites
- ❑ Tandem and drift phase into final orbit separation of 140 degree between S3A/B separation completed by launch + 7 months
- ❑ Full operational capacity reached by launch + 9 months

## MOTIVATION

**GCOS Climate Monitoring Principles (GCMP): need to fully understand biases between satellite missions**

- ❑ *“Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system”*
- ❑ *“A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations”*

**Improved data quality for climate (CDR) and operational applications alike**

# MAIN MESSAGES

- ❑ S-3A now in ramp-up phase, following successful launch and commissioning phase
- ❑ All instruments are switched on and working well.
- ❑ Sample data products for expert users available since May/June.

## ❑ Official data release

- OLCI Level 1 NRT: 20 October 2016
- SLSTR Level 1 NRT: 17 November 2016
- SRAL L1B and L2 NRT and STC: 13 December 2016
- OLCI Level 1 NTC: 14 December 2016
- SLSTR Level 1 NTC: 19 January 2017
- SRAL L1B NTC: Jan 2017
- SRAL L1A and L1BS STC: April 2017
- OLCI L2 and SLSTR L2: May/June 2017.
- SYN/VGP: Q2/ 2017
- AOD and FRP: Q3/4 2017.

## ❑ Data access in operations

- ❑ ESA through the Sentinel Data Hub, Copernicus Services Hub, Collab Hub etc
- ❑ EUMETSAT's Earth Observation Portal (EUMETSAT's ODA, Data Centre, EUMETCast)
- ❑ Sentinel-3B launch planned for end 2017



### OVERALL MISSION

- The overall status of the spacecraft is nominal, with all subsystem performing nominally.
- All instruments, including OLCI, SRAL, SLSTR and MWR, are switched on and perform nominally.
- The Flight Operations Segment (FOS) is operating nominally.
- The Payload Data Ground Segment (PDGS) is operating broadly as expected in the mission ramp-up phase, gradually moving towards full operational capacity. Some outages and data delays occurred due to recent upgrading of the PDGS systems in preparation of full operations and the on-going core data release.

### MISSION MANAGEMENT

- The Sentinel-3A commissioning phase ended on 12th July with the successful passing of the In-Orbit Commissioning Review (IOCR). The mission is now in the ramp-up phase, moving towards full operational capacity at approximately IOCR + 9 months.
- Following the handover of the responsibility for the routine operations of the spacecraft and the Marine PDGS from ESA to EUMETSAT, the joint ESA-EUMETSAT mission management has started.

### DATA AVAILABILITY AND ACCESS

- Following the IOCR, some remaining issues affecting the released sample data products needed to be addressed. The following core data products have been released:
  - OLCI Level 1 NRT: 20 October 2016
  - SLSTR Level 1 NRT: 17 November 2016
  - SRAL L1B and L2 NRT and STC: 13 December 2016
  - OLCI Level 1 NTC: 14 December 2016
- The current plan for further core data product releases is: (TBC):
  - SLSTR Level 1 NTC: 12 January 2017
  - SRAL Level 1A NRT, L1B NTC and L1B5 STC: 19 January 2017
  - OLCI L2: early 2017.
  - SLSTR L2: early 2017
  - SYN: early 2017
  - Aerosol Optical Depth (AOD) and Fire Radiative Power (FRP): mid-2017.
- In the meantime, the following sample data products continue to be available to Sentinel-3A expert users:

Data product (*)	Released on	Available data
OLCI L2 over land (ESA)	20 June	20 June - today
OLCI L2 over ocean (EUMETSAT)	22 June	22 June - today
SLSTR L1	13 June	8 June - today
SLSTR L2 - LST (ESA)	20 June	9 June - today
SLSTR L2 - SST (EUMETSAT)	21 June	21 June - today
SRAL L1B (**)	15 June	Reprocessed data: • 6 April – 6 May (SAR, 9-12 April in LRM), • 5 June – 13 Oct (SAR), Current data: 18 June - today
SRAL L2 over land (ESA)	15 June	Reprocessed data: • 6 April – 6 May (SAR, 9-12 April in LRM), • 5 June – 13 Oct (SAR), Current data: 06 July - today
SRAL L2 over ocean (EUMETSAT)	15 June	Reprocessed data: • 6 April – 6 May (SAR, 9-12 April in LRM), • 15 June – 13 Oct (SAR), Current data: 12 July - today

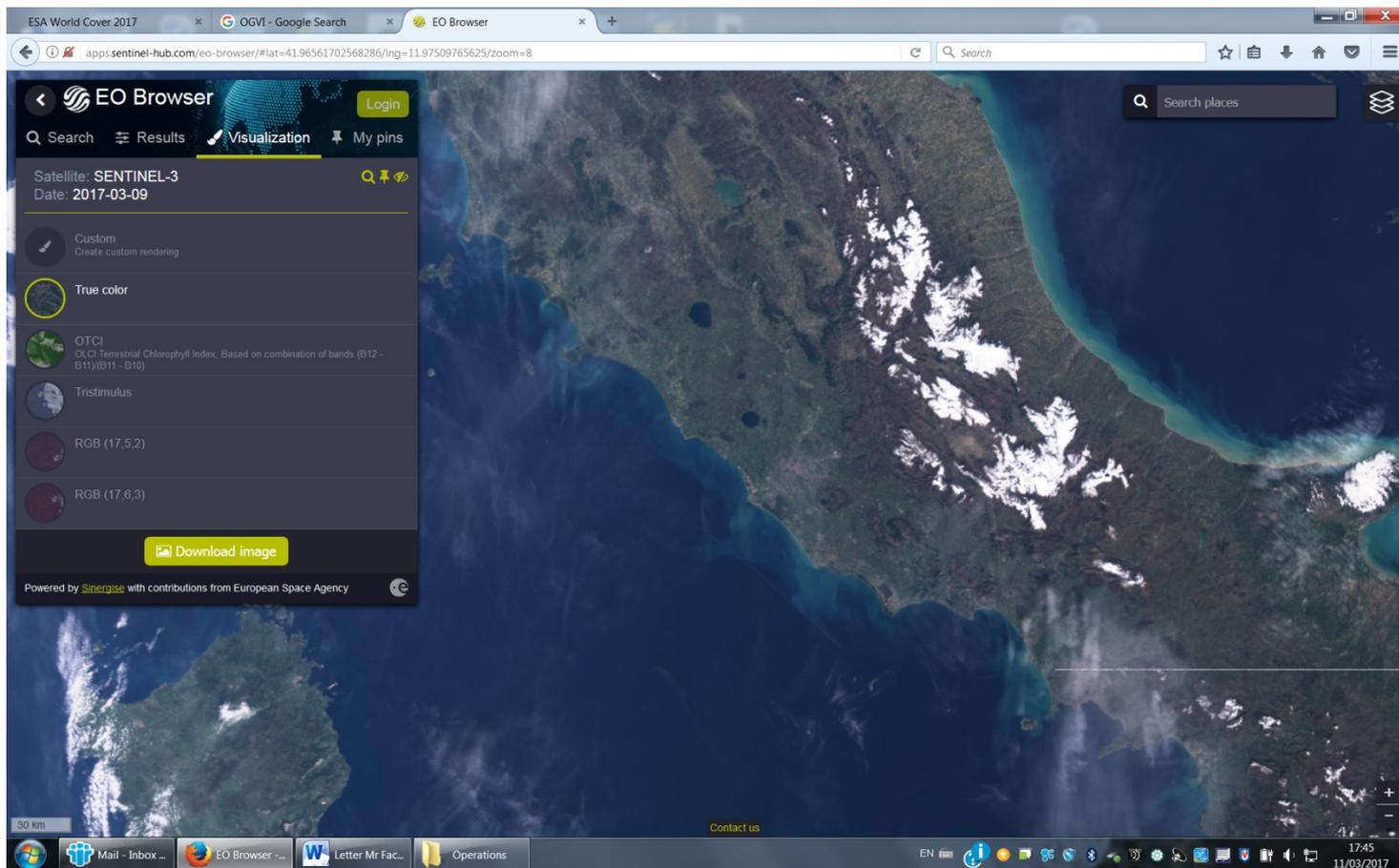
### USER INTERACTION

- The Sentinel-3 Quality Working Groups will meet for the 2<sup>nd</sup> time in the December 2016/January 2017 time frame.
- **Please note change of date:** A Sentinel-3 Validation Team (SV3T) meeting is planned for 15-17 February 2017 at ESA-ESRIN, Frascati, Italy.

### OUTLOOK

- Release of operationally qualified core data products - see above for schedule.
- Report prepared by the ESA and EUMETSAT Sentinel-3 Operations Team

Weekly mission status on <https://sentinel.esa.int/web/sentinel/missions/sentinel-3/mission-status>



**New tool for Sentinel-2, Sentinel-3, Landsat, data visualisation: <http://apps.sentinel-hub.com/eo-browser/> (Sinergise, Slovenia)**

**THANK YOU**

**Susanne Mecklenburg**

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