

Copernicus Sentinel-2 Mission Overview and Data Quality Performance

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Sentinel-2 Mission Outlook



- ✓ Optical multi-spectral mission for the monitoring of land and coastal waters.
- ✓ Constellation of two satellites (Sentinel-2A and Sentinel-2B).
- ✓ Polar sun-synchronous orbit at an altitude of 786km, with LTDN 10h30.
- ✓ High revisit frequency (5 days with same viewing direction).
- ✓ Swath of 294km.
- ✓ High/moderate spatial resolution (10m / 20m / 60m).
- ✓ Large number of spectral bands (13 in VNIR-SWIR domain).
- ✓ Free & open products for feeding a large range of applications.
- ✓ Long-term mission availability (>2030).

Copernicus Sentinel-2 High-Level Mission Status



- Nominal Sentinel-2 operations with Sentinel-2A and Sentinel-2B.
- Routine provision of Sentinel-2 data to Copernicus operational services.
- Good health of both Sentinel-2A and Sentinel-2B satellites.
- Sentinel-2 is operated beyond the initially required observation scenario.

23/06/2015

07/03/2017

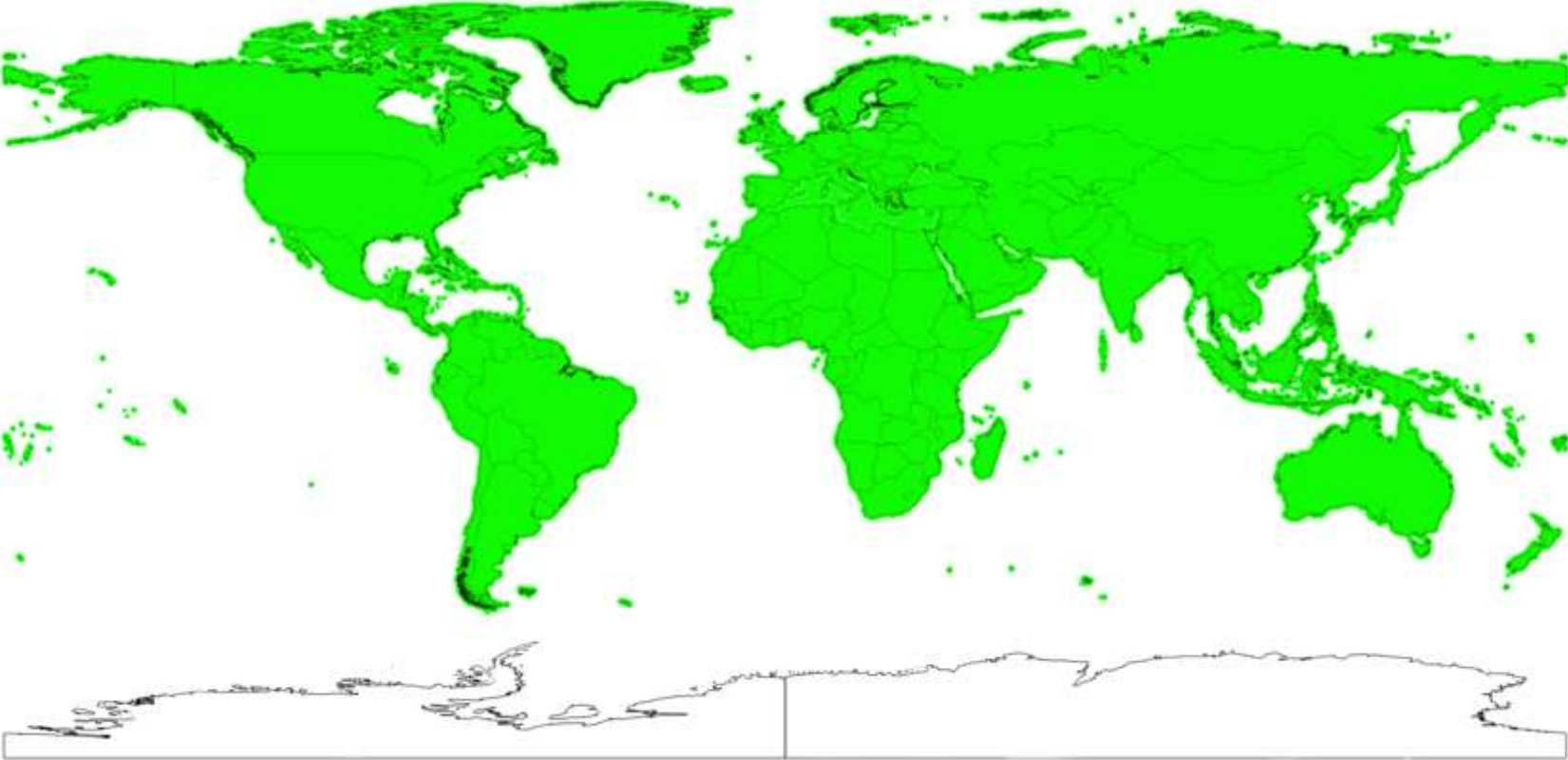
Sentinel-2 A/B/C/D



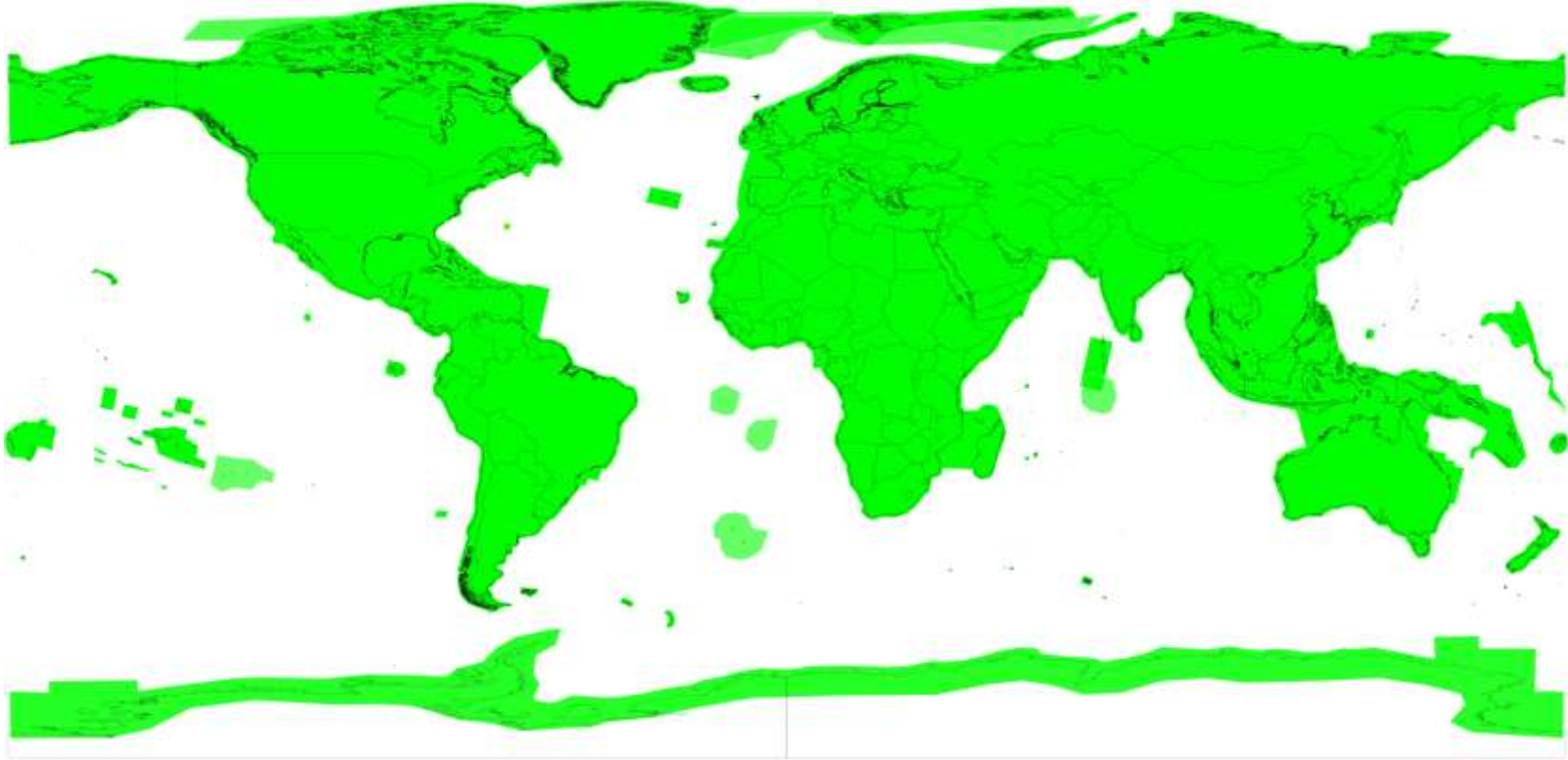
Sentinel-2 Second Generation



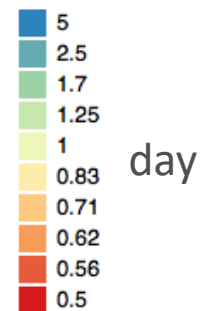
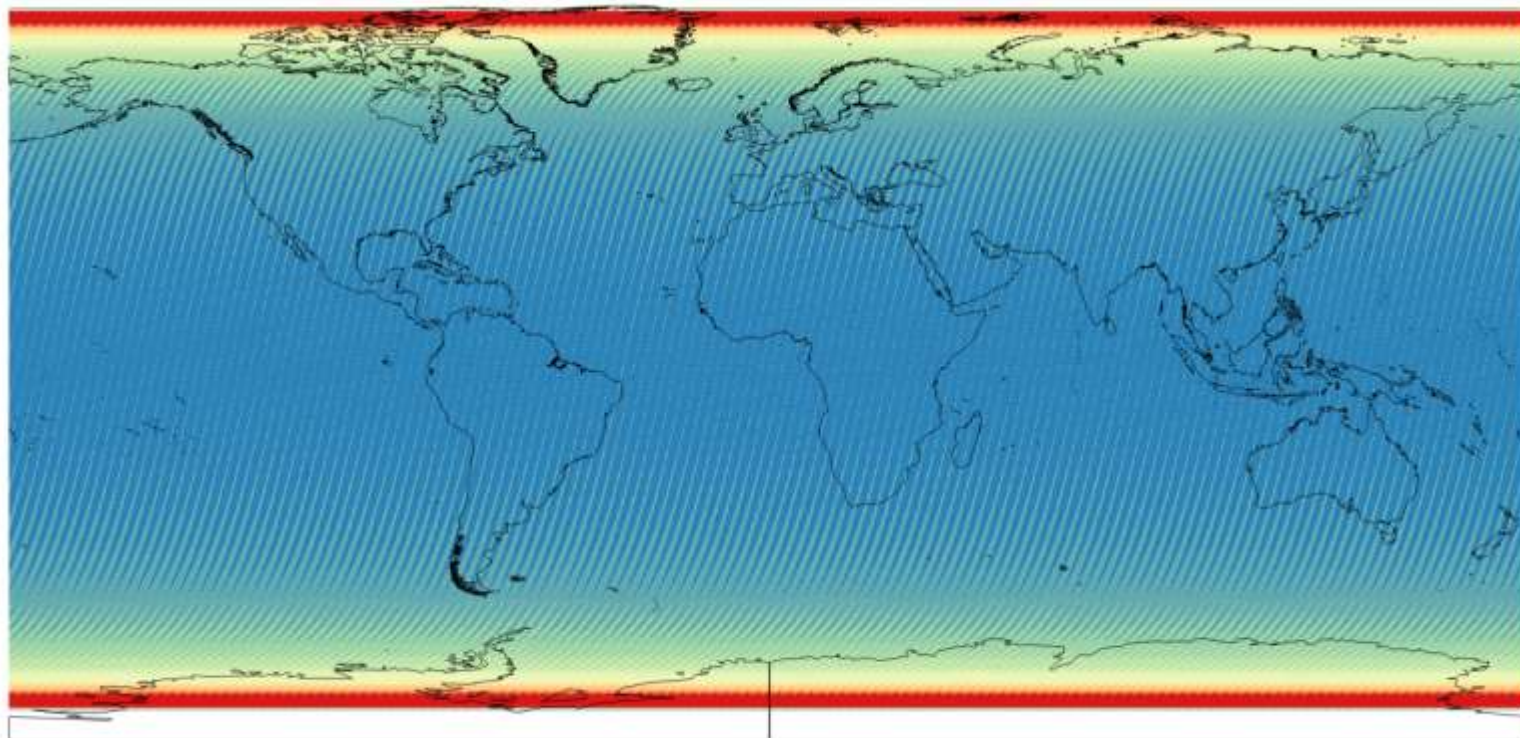
Observation Scenario (Mission Requirements)



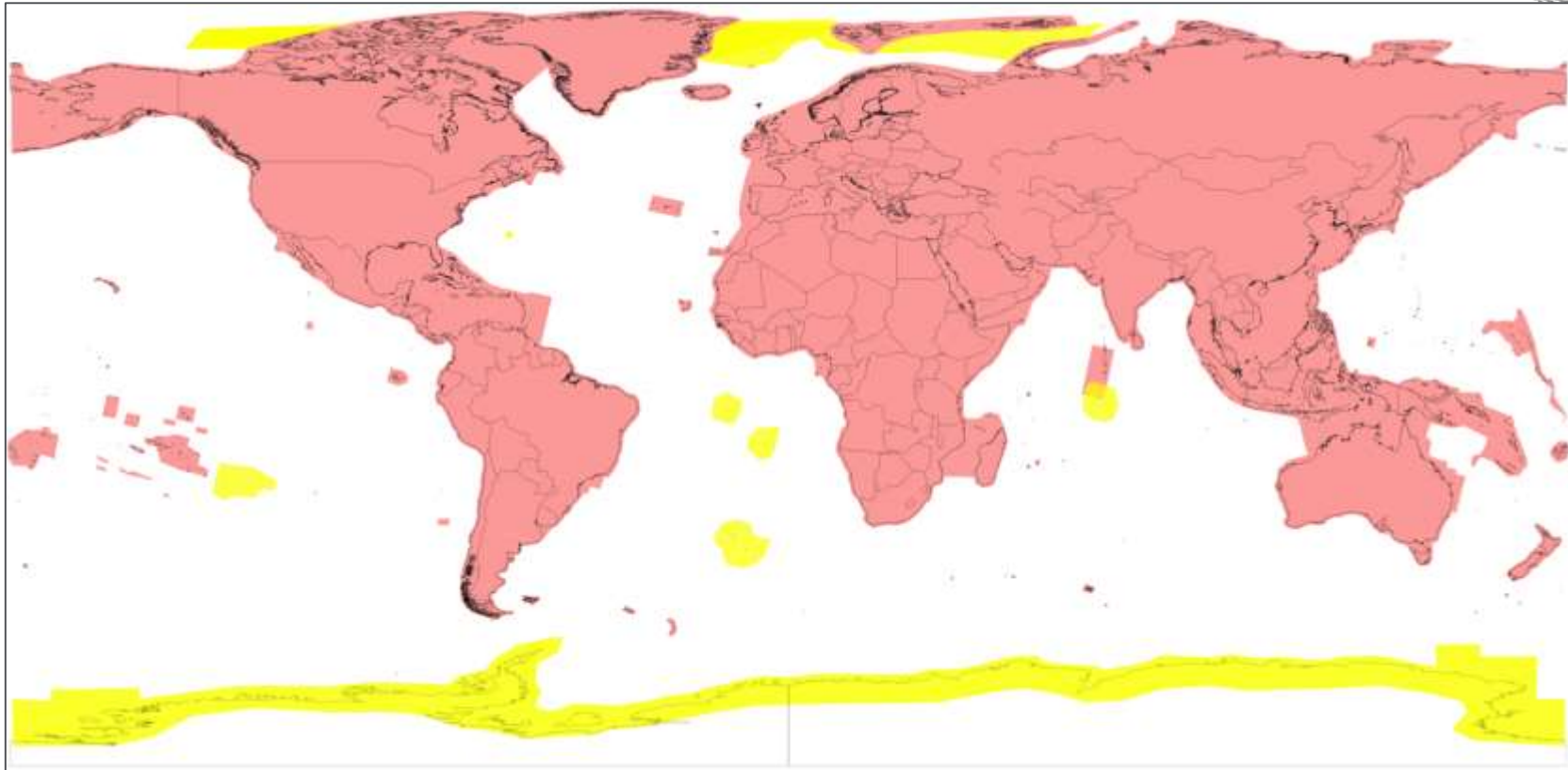
Observation Scenario (Current)



Coverage



Observation Scenario



Sentinel-2 Mission Products Catalogue



Product Name	Measurement Provided	Distribution	Production	Preservation
Level-1B	Top-of-atmosphere radiances in sensor geometry	Expert users	Systematic	Long-term
Level-1C	Top-of-atmosphere reflectances in cartographic geometry	Public	Systematic	Long-term
Level-2A	Surface reflectances and pixel classification in cartographic geometry	Public	Systematic + <u>SNAP</u>	1,5 year rolling archive



Sentinel-2 Mission Products Catalogue



Product Name	Measurement Provided	Distribution
Level-1B	Top-of-atmosphere radiances in sensor geometry	Expected
Level-1C	Top-of-atmosphere reflectances in cartographic geometry	P
Level-2A	Surface reflectances and pixel classification in cartographic geometry	P



Level-2A products are systematically generated worldwide since 13 December 2018.



Sentinel-2 Mission Products Catalogue



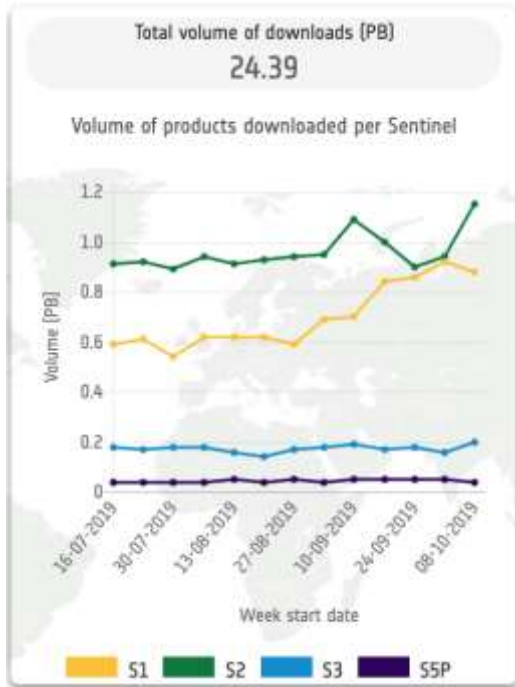
Product Name	Measurement Provided	Distribution	Production	Preservation
Level-1B	Top-of-atmosphere radiances in sensor geometry	Expert users	Systematic	Long-term
Level-1C	Top-of-atmosphere reflectances in cartographic geometry	Public	Systematic	Long-term
Level-2A	Surface reflectances and pixel classification in cartographic geometry	Public	Systematic + <u>SNAP</u>	1,5 year rolling archive

Next Steps:

- ✧ Level-2A on-demand service for Copernicus Services before end 2019, and later to all users.
- ✧ Sentinel-2 Level-1B products will be distributed in a rolling-archive before the end of 2019.



Copernicus Data Hubs



Private companies re-distributing Sentinel products through free and pay-per-use schemes



Collaborative mirror sites



International partners mirror sites disseminating towards own national communities

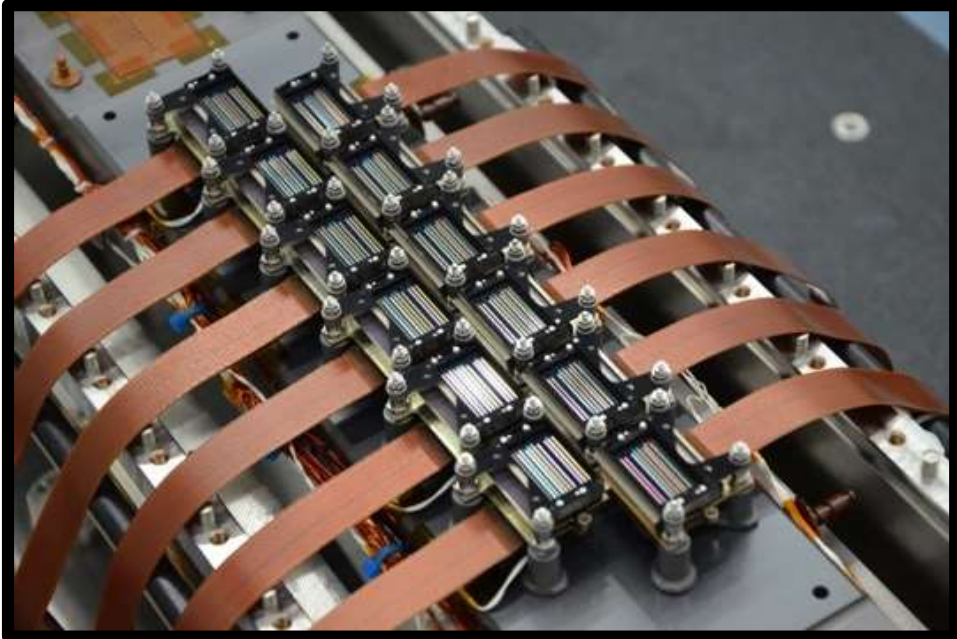


Sentinel-2 Data Quality



Namibia

Sentinel-2 MSI instrument



Sentinel-2 products performance status



<https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi/document-library>



On-line products anomaly database with API



- Data Product Quality Reports

The MPC-CC provides a monthly status of the quality of Sentinel-2 L1C and L2A products via respective Data Quality Reports (DQR). The DQRs provide information on the monitoring and measurement of L1C and L2A product performances against the proposed specification, via:

Geometric Performance

- Geometric Calibration Status
- Absolute Geolocation
- Multi-Spectral Registration
- Multi-Temporal Registration

Radiometric Performance

- Radiometric Calibration Status
- Radiometric Uncertainty
- Noise
- Modulation Transfer Function

It also documents observed anomalies and known issues, the list of defective pixels, and any processing chain improvements resulting in an increment of the Processing Baseline.

Latest Data Quality Reports

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
2018	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
2017	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
2016												
2015												

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
2018	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Sentinel-2 Anomaly Database

The Sentinel-2 on-line anomaly database provides a searchable access to the list of known anomalies on Sentinel-2 products. This database includes both on-board anomalies (usually irrecoverable) and processing anomalies (potentially recoverable), and covers image data as well as metadata and format anomalies. For each anomaly, a short description and illustrations are provided. Affected products are defined and the status of the anomaly is presented.

The search interface allows to list anomalies potentially affecting a given product or a list of products. Queries can be performed using a product name, a sensing orbit number, a sensing date or processing baseline. Anomalies classified as "systematic" are returned if and only if they affect the selected products. On the other hand, anomalies classified as "random" may not affect the selected products.

In addition to the search interface, this website provides a REST API (Application Programming Interface) for machine-to-machine access using scripts. The API provides two services:

- 1) Retrieve all anomalies potentially affecting a product:
https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2/msi/sentinel-2-anomalies/api/product/ESA_MSI_L1C_20190412T321301_NO206_NO20_1219MSI_20190412T03400T
Example of GET Request which returns a list of anomalies or error code 404 if the product does not exist in the OpenHub archive
- 2) Anomaly description
<https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2/msi/sentinel-2-anomalies/api/anomaly/1>
Example of GET Request which returns a description of the anomaly or error code 404 if the anomaly does not exist in the Sentinel 2 anomaly archive

<https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi/sentinel-2-anomalies/>



Sentinel-2 Data Quality Team



The Team in charge of all the aspects related to data quality (algorithms, cal/val, product evolutions and quality control) for the Sentinel-2 in-orbit lifetime period (Phase E2).

S2 MPC (Mission Performance Centre)



Valentina Boccia (ESA)

Rosario Iannone (Rhea / ESA)
Roberto De Bonis (Rhea / ESA)

Laëtitia Pessiot (CSSI)
Sébastien Clerc (ACRI-ST)
Carine Quang (CSSI)
Antoine Bourie (CSSI)
Dimitra Lebreton (ADS)
Bruno Lafrance (CSSI)
Mathieu Jung (ADS)
Stéphane Massera (IGN)
Marion Neveu Van Malle (TAS)
Bahjat Alhammoud (ARGANS)

Jan Jackson (ARGANS)
Alejandro García-Soto (DEIMOS)
Lawrence Dudley (ARGANS)
Françoise Viallefont (ONERA)
Jérôme Louis (Telespazio)
Vincent Debaecker (Telespazio F)
Bringfried Pflug (DLR)
Magdalena Main-Knorn (DLR)
Uwe Müller-Wilm (Telespazio D)

Damien Rodat (CNES)
Florie Languille (CNES)



Sentinel-2 Data Quality Team



Sentinel-2 Quality Working Group (QWG)



- ✓ Review and Assess mission end-to-end performances (flight and ground segment)
- ✓ Provide recommendations for improvements on algorithm and products quality
- ✓ Support Cal/Val and scientific activities



2 times/year



4th Sentinel-2 Validation Team (S2VT) Meeting

esa
Invitation



Objectives

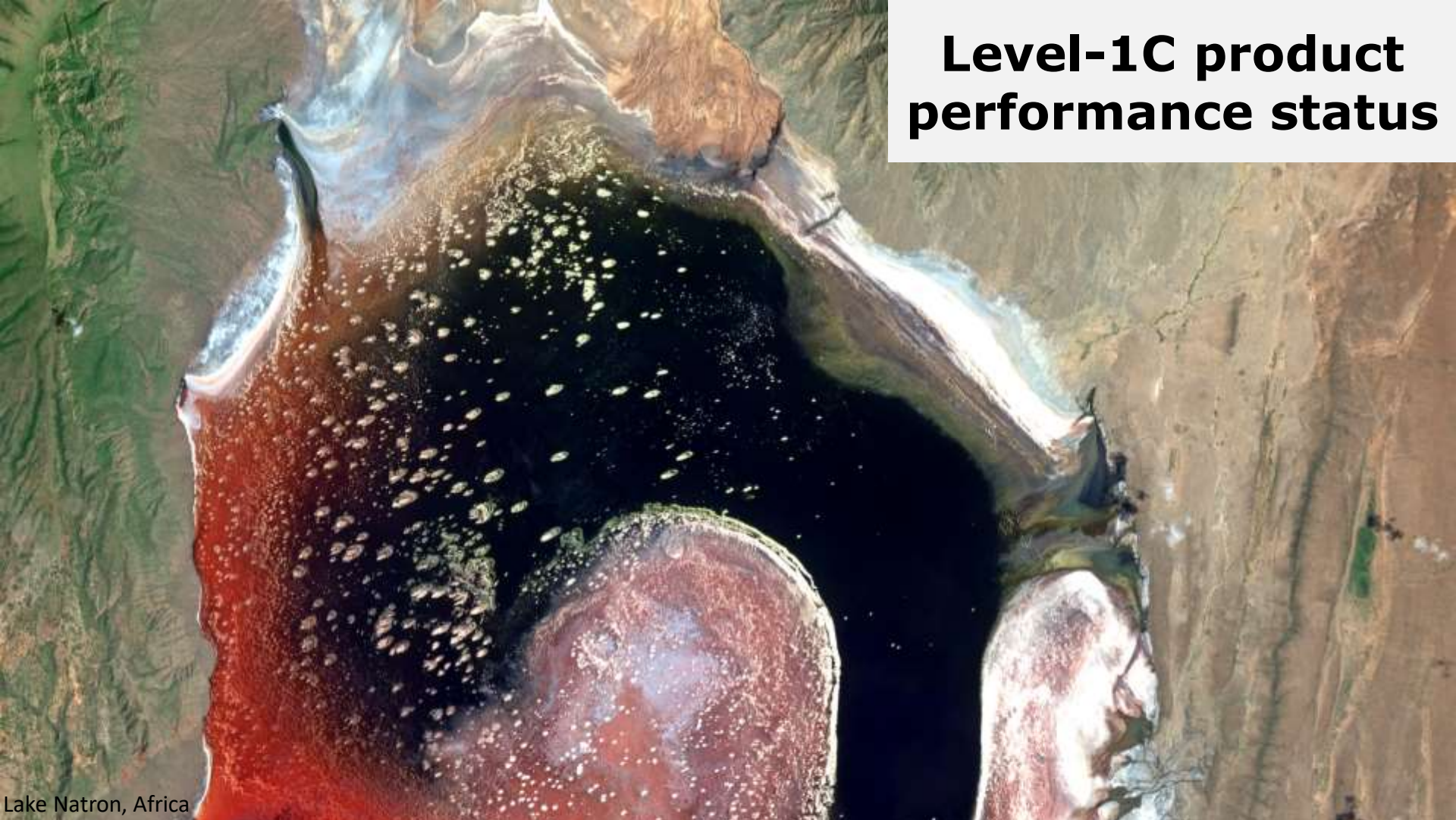
- Collect lessons learnt on **validation procedures** used to contribute to the quality assessment of the Copernicus Sentinel-2 mission Level-1 and Level-2A products for both **radiometry and geometry**.
- Review and consolidate the **cal/val methods** used operationally.
- Provide **recommendations** for ad-hoc Sentinel-2 products validation campaigns (in complement to the permanent network of validation sites).
- Gather the Sentinel-2 scientific and user community and to **foster cooperation and synergies among Cal/Val teams**



<https://nikal.eventsair.com/NikalWebsitePortal/4th-sentinel-2-validation-team-meeting/esa>



**Level-1C product
performance status**



Lake Natron, Africa

Copernicus Sentinel-2 Level-1C (TOA)



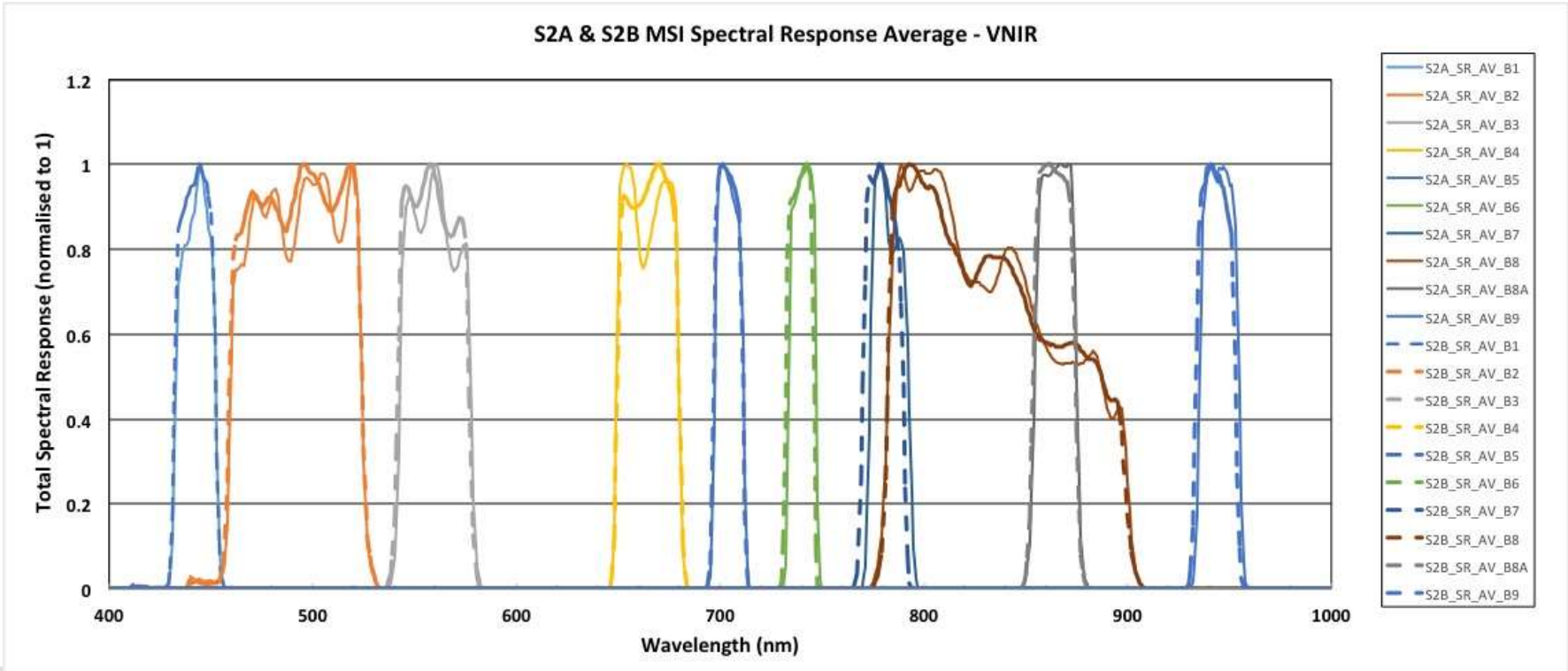
	2015			2016			2017			2018			2019		
Sentinel-2A	[Shaded area]														
Sentinel-2B	[Shaded area]						[Shaded area]								
Processing Baseline (PB)	02.00	02.01	02.02	02.04			02.05	02.06			02.07	02.08			
	02.04														
Product Specification Document (PSD)	11.0	12.0	13.1	13.1	13.2	14.1/14.2	14.3				14.4				
	13.1														



L1C – Spectral band characteristics



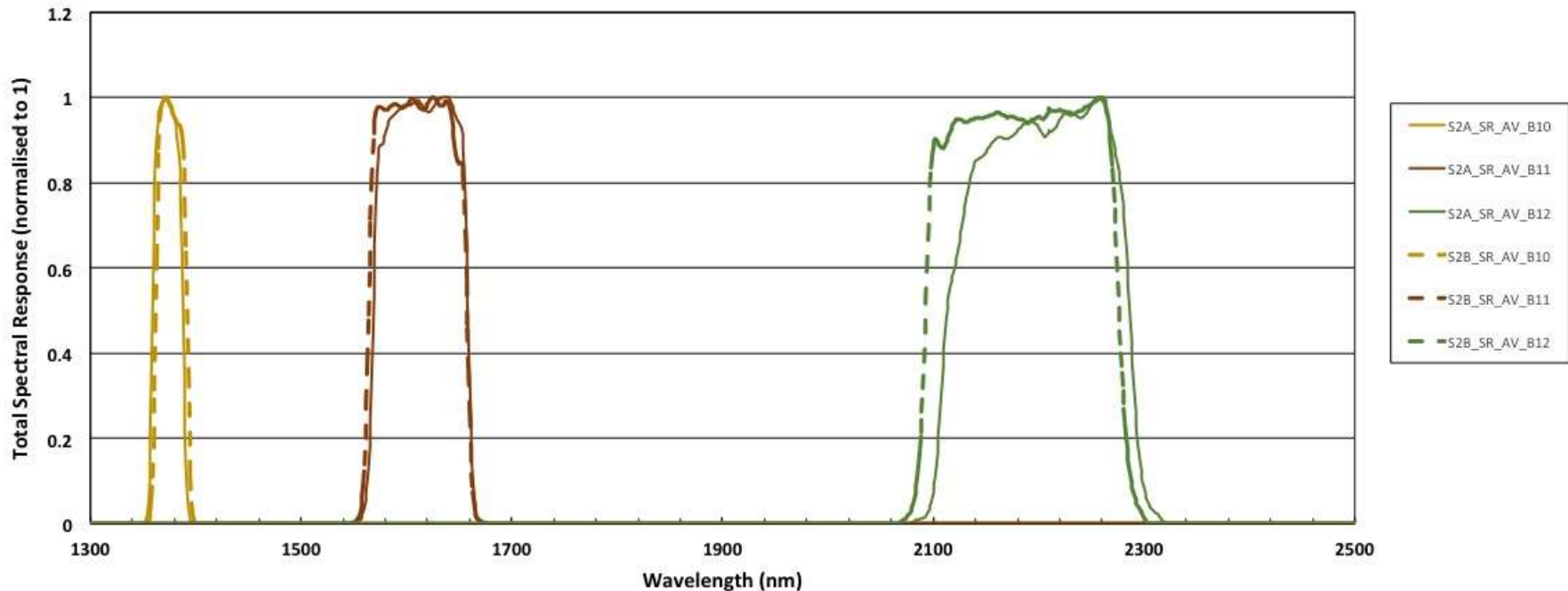
All the Sentinel-2 MSI bands are **compliant with the requirements** set in the Copernicus Sentinel-2 Mission Requirements Document.



L1C – Spectral band characteristics

https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi/document-library/-/asset_publisher/Wk0TKajiISaR/content/sentinel-2a-spectral-responses

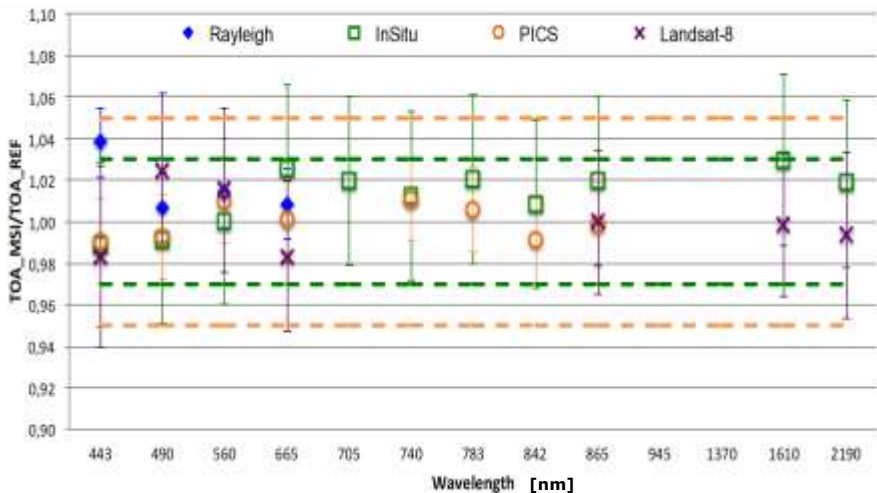
S2A & S2B MSI Spectral Response Average - SWIR



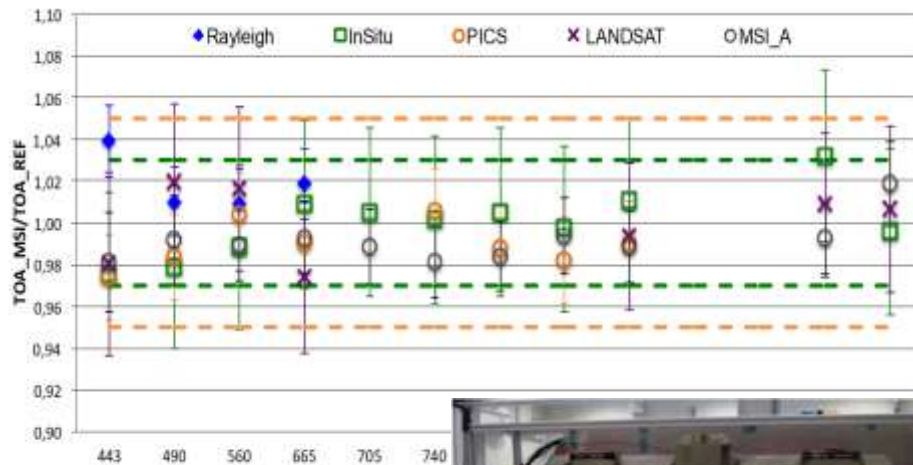
L1C - Absolute Radiometric Accuracy

The Absolute Radiometric Accuracy is **within the goal level (3%)** or **within the threshold level (5%)**. Good consistency over all methods.

S2A



S2B

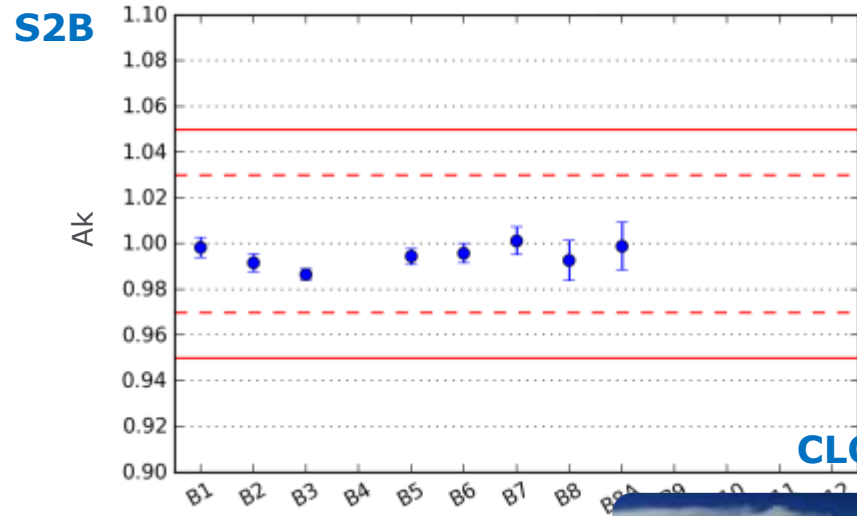
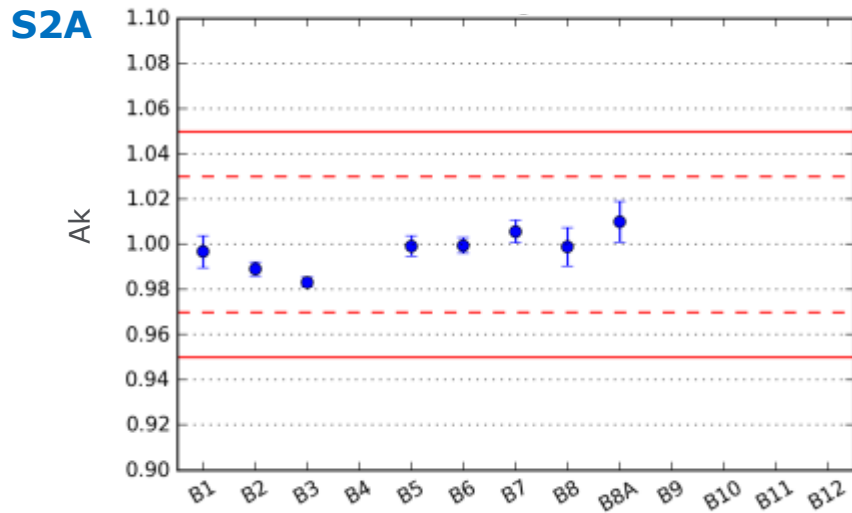


Plots show the ratio of MSI measurements over reference values. Error bars indicate the validation method uncertainty.



L1C - Inter-band calibration

The inter-band radiometric calibration is within $\pm 1.5\%$ (**compliant with MRD requirement**).



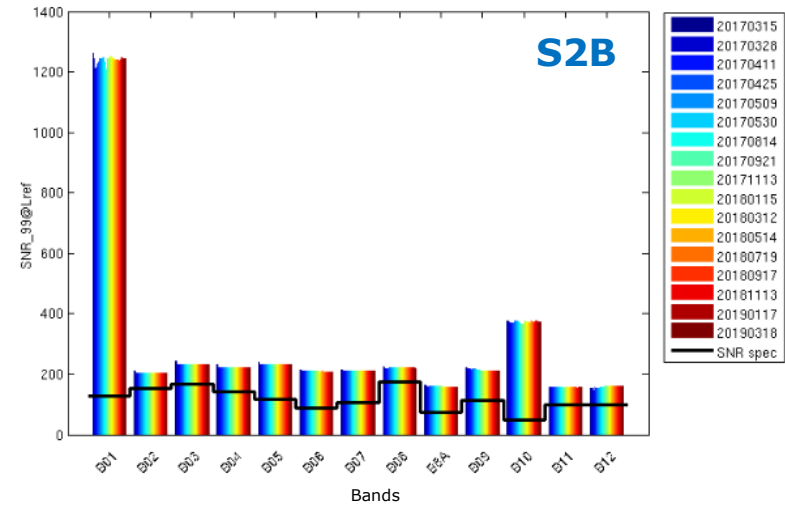
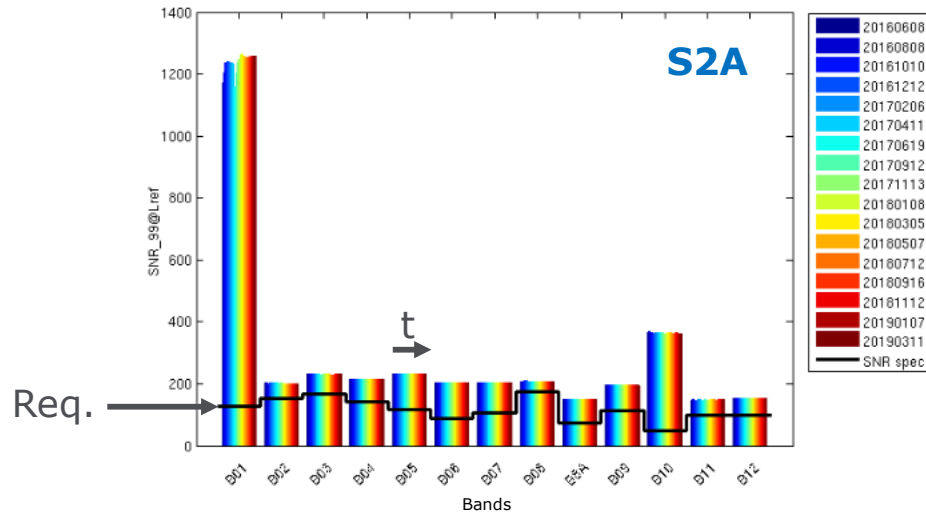
CLOUDS



The plots show the inter-band calibration coefficient (A_k) for the several bands.

L1C - Signal-to-Noise Ratio (SNR)

The SNR for both S2A and S2B is **compliant with the MRD requirement**.



The noise characteristics are very stable over time and within requirements for all bands of both S2A and S2B.

L1C – Polarization: The MSI polarisation sensitivity is less than 0.05 (0.03 goal), **as per requirement** [compliant based on on-ground characterisation]

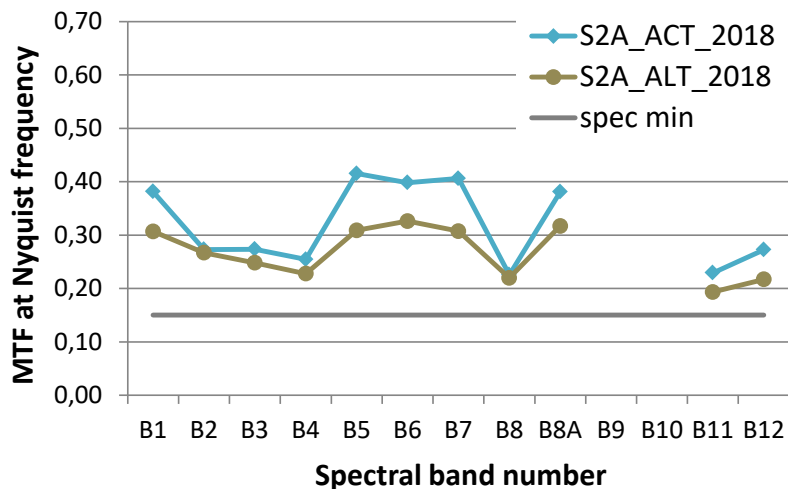
L1C - Spatial Resolution



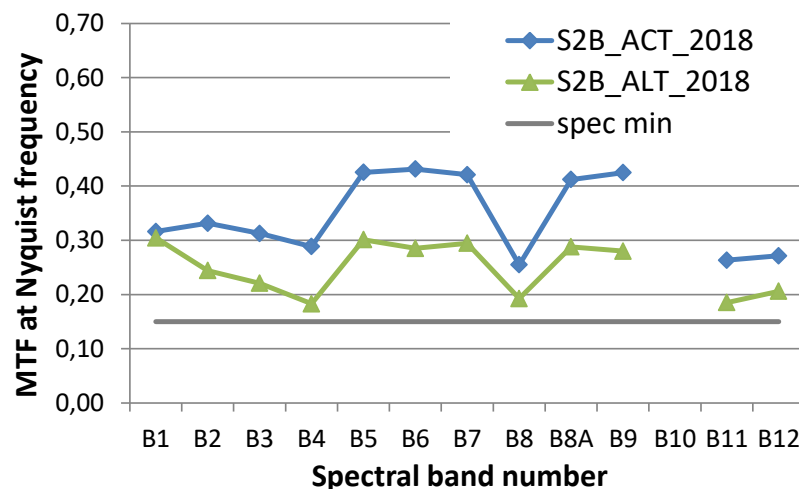
Spatial resolutions of the several MSI bands are **as per requirement** (MR-S2-20):

Band	1	2	3	4	5	6	7	8	8a	9	10	11	12
Spatial Resolution [m]	60	10	10	10	20	20	20	10	20	60	60	20	20

S2A



S2B

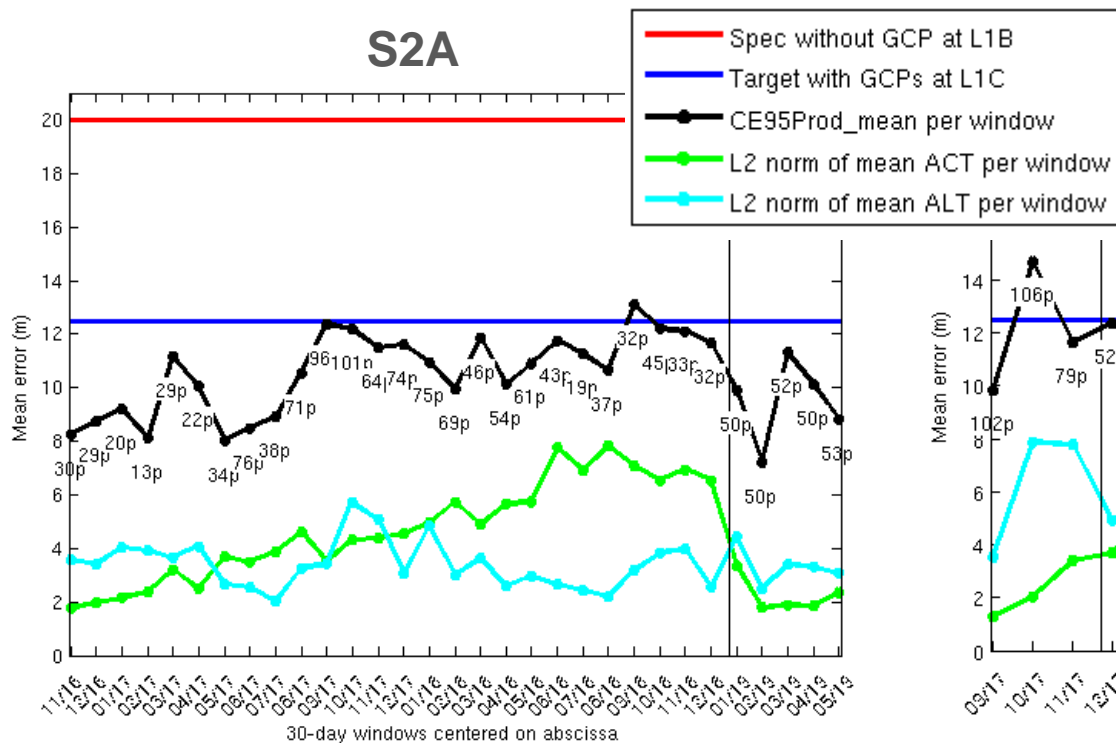


L1C - Geolocation accuracy

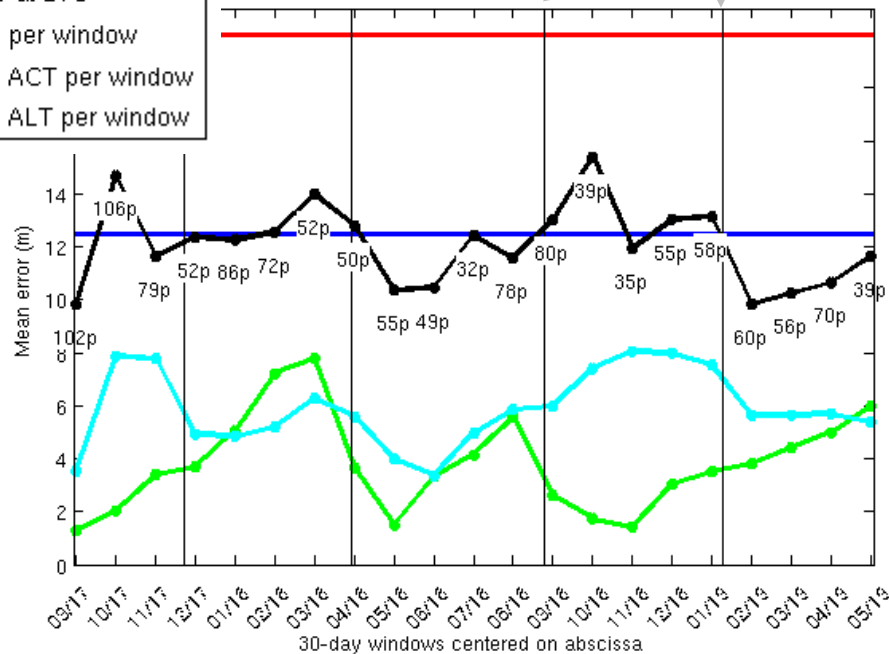


calibrations

S2A

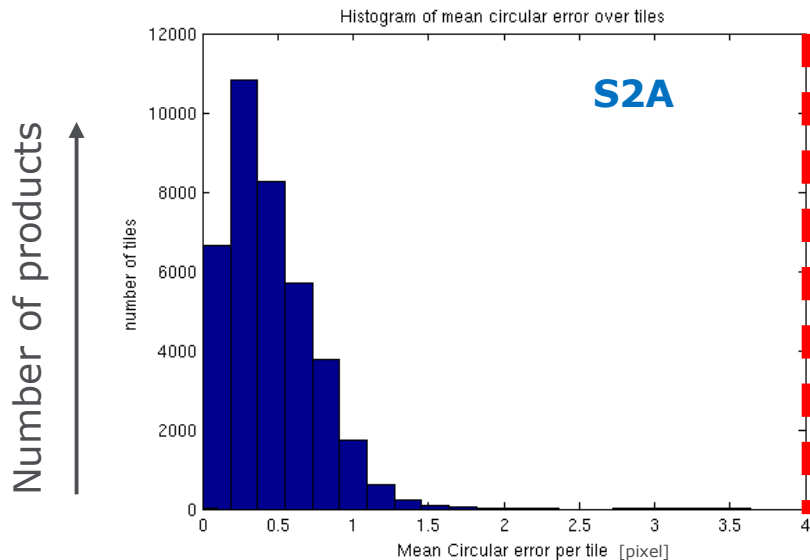


S2B

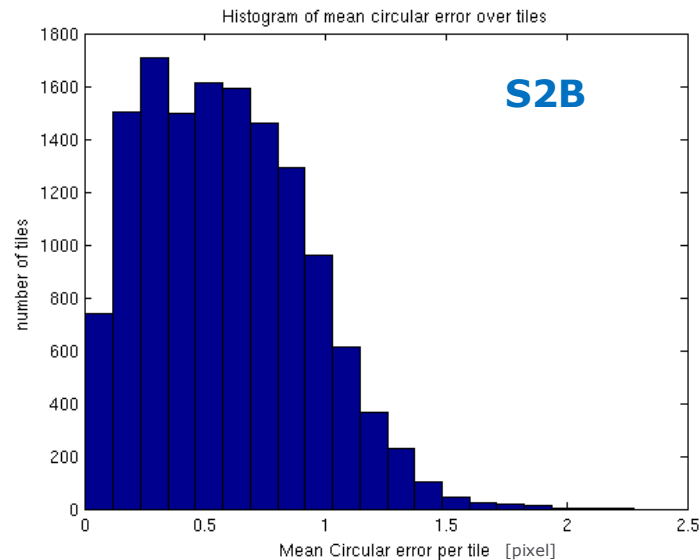


L1C - Multi-temporal co-registration

The multi-temporal co-registration for both S2A and S2B is **compliant with the MRD requirement.**



Mean Circular Error at 2σ : 1 pixel
1430 products (06/2016 - 05/2019)



Mean Circular Error at 2σ : 1.19 pixel
922 products (05/2017 - 05/2019)

L1C - Multi-spectral registration

BAD multi-spectral registration



GOOD multi-spectral registration

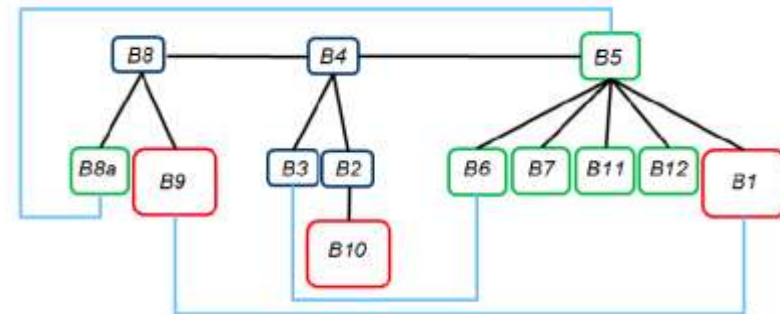


Example

L1C - Multi-spectral registration

CE@99,73%	B01	B04	B05	B11
B02		0,152		
B03		0,122		
B06			0,070	
B07			0,088	
B08		0,121		
B8A			0,096	
B09	0,221			
B11			0,179	
B12			0,166	0,124

S2A



Requirement met for all the tested band couples: <0.3 pixel at 99.7% conf. level

CE@99,73%	B01	B04	B05	B11
B02		0,141		
B03		0,094		
B06			0,068	
B07			0,076	
B08		0,130		
B8A			0,089	
B09	0,167			
B11			0,146	
B12			0,161	0,118

S2B



**Level-2A product
performance status**

Lake Mackay,
western Australia

Copernicus Sentinel-2 Level-2A (BOA)

New Core Product generated and distributed since 26 March 2018.

- ➔ initially over the Euro-Mediterranean region;
- ➔ since December 2018: **Worldwide** Level-2A production!

L2A Processor outputs



L1C

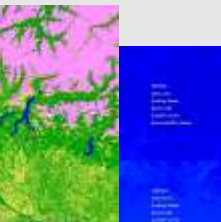


L2A

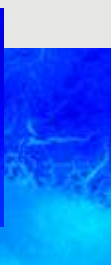
+ Cloud &
Snow Confidence QI



SCL



AOT



WV

Ispra (Italy)



Ganges Delta

Copernicus Sentinel-2 Level-2A (BOA)



New Core Product generated and distributed since 26 March 2018.

- ➔ initially over the Euro-Mediterranean region;
- ➔ since December 2018: **Worldwide** Level-2A production!
- ➔ In October 2018 the last Scene Classification Algorithm using ESA CCI has been activated in S2 PDGS with L2A PB 02.09, with a significant improvement on urban areas (much lower false cloud detection on urban and bright areas);
- ➔ Further improvements for the Scene Classification Algorithm/Cloud detection are currently under development and will be tested by S2-MPC in the frame of the CMIX (Cloud Masking Inter-comparison eXercise).



Copernicus Sentinel-2 Level-2A (BOA)



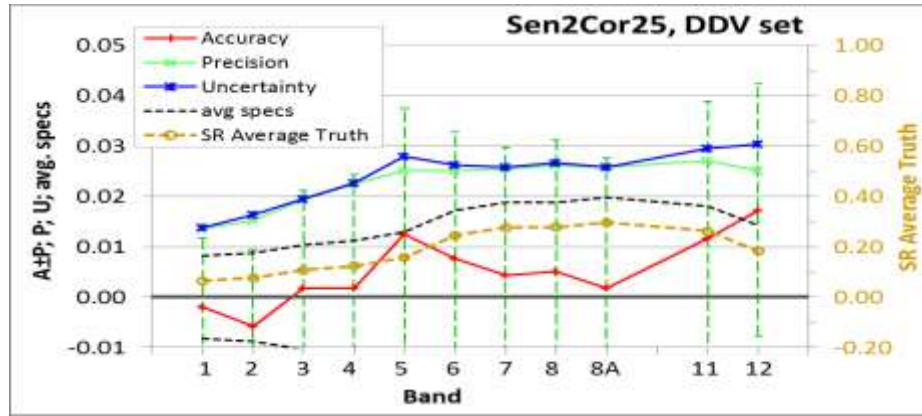
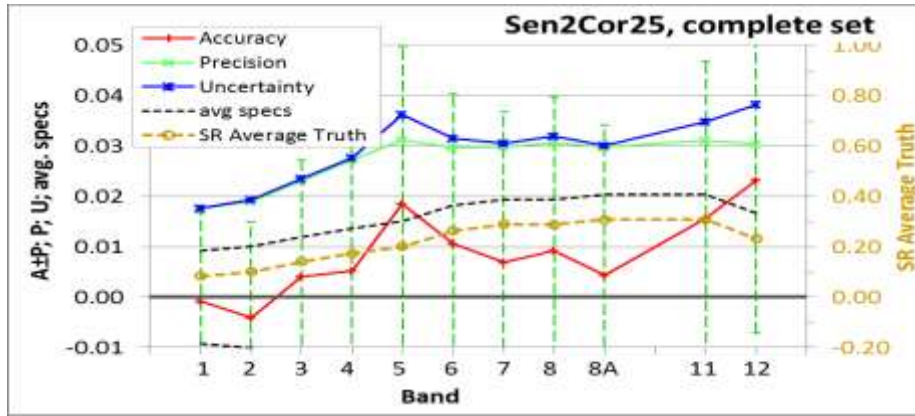
2nd S2VT

3rd S2VT

	2018					2019		
Sentinel-2A								
Sentinel-2B								
Processing Baseline (PB)	02.07	02.08	02.09	02.10	02.11	02.12	02.13	
Product Specification Document (PSD)	14.4							



L2A - Surface Reflectance Radiometric Accuracy



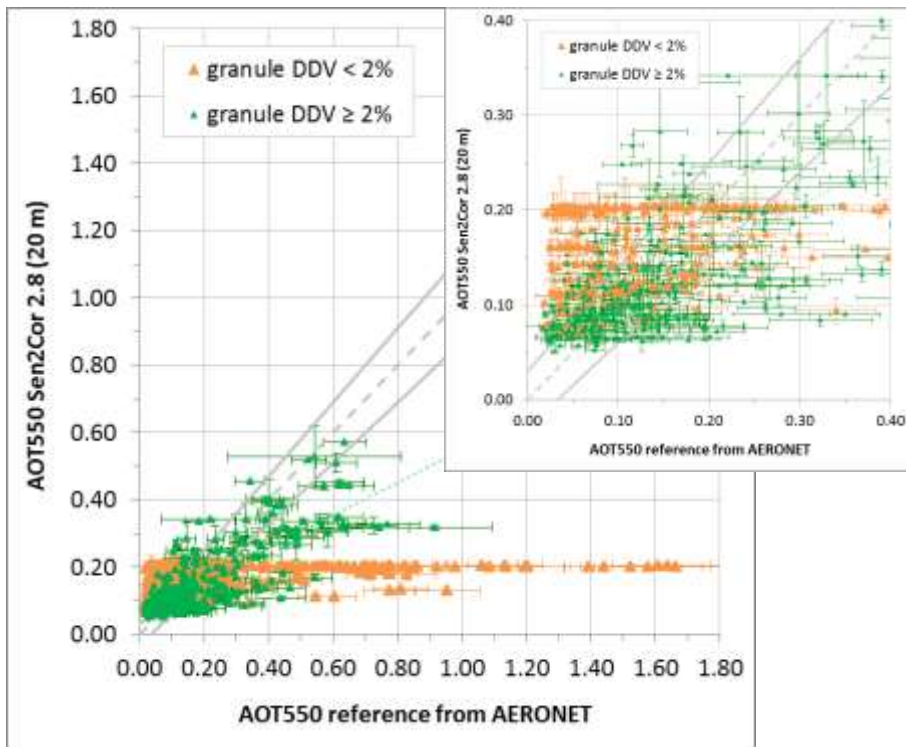
Band average data reported for each band using Sen2Cor 2.5 based on the ACIX-1 dataset.

- ➔ DDV subset performs better than the complete data set
- ➔ Best accuracy for bands 3, 4, 8A, however better uncertainty for bands 1 and 2
- ➔ Accuracy is within specs except band 5_{complete_set} and band 12



L2A – Aerosol Optical Thickness (AOT) Accuracy

Correlation plot of Sen2Cor 2.8 AOT₅₅₀ output at 20 m resolution over AOT₅₅₀ reference from AERONET on basis of the ACIX-1 data set.



Accuracy requirement (solid lines):
 $|\Delta AOT_{550}| \leq 0.1 * AOT_{550_{ref}} + 0.03$

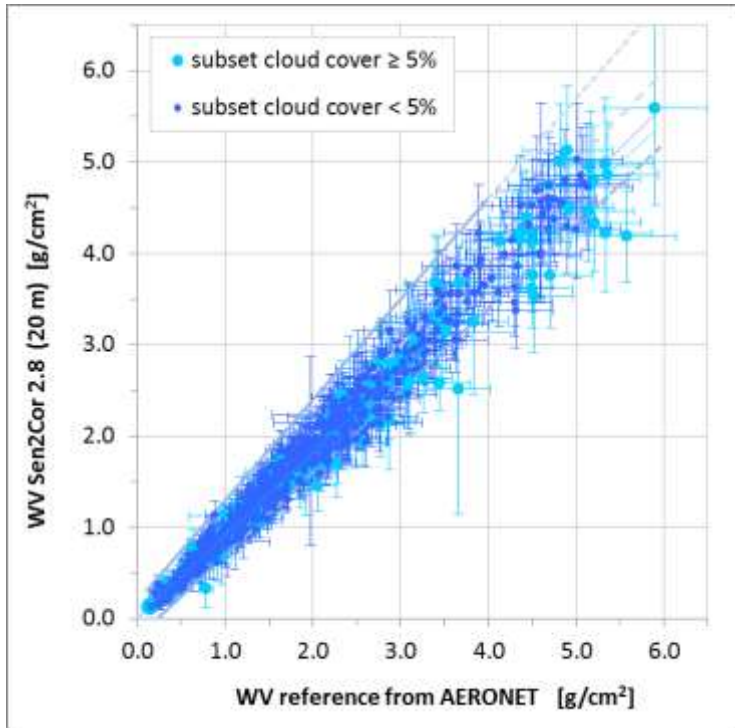
Dashed line:
Sen2Cor-output = Reference

Green triangles:
Results for DDV-algorithm

Orange triangles:
Results for fall-back processing with
configured start VIS=40 km (AOT₅₅₀=0.2)

L2A – Water Vapour (WV) Accuracy

Correlation plot of WV values retrieved with Sen2Cor 2.8 over WV reference from AERONET on the basis of the ACIX-1 data set.



WV accuracy requirement (solid lines):
 $|\Delta WV| \leq 0.1 * WV_ref + 0.2$

No. of products: 559

WV retrieval within the requirement: 92%

Sentinel-2 Mission / Next Steps

✧ Start of the geometry-refined production using the **Global Reference Image (GRI)** in Q1 2020 to improve multi-temporal registration.

GRI is a full repeat cycle dataset of well-localized and as cloud-free as possible mono-spectral (band 4) Level-1B products



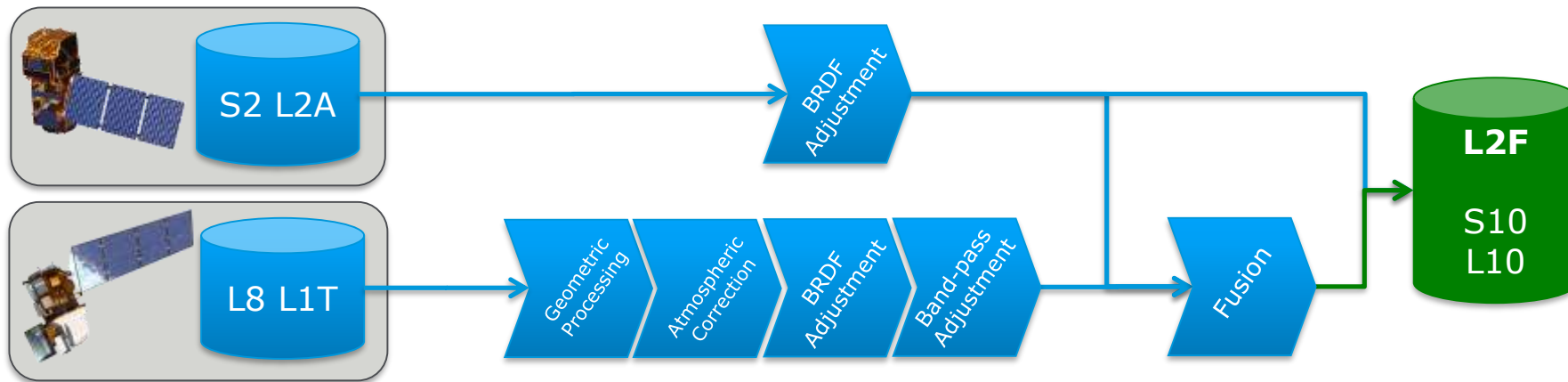
✧ Usage of **Copernicus DEM** for Level-1C and Level-2A productions (Q1 2020 for 90m resolution DEM, and Q4 2020 for 30m resolution DEM).

DEM instance	Geographical coverage	Horizontal sampling	DEM licence
Global (GLO-90-F)	Global	90 m	Full, free and open
Global (GLO-30-R)	Global	30 m	Restricted
Europe (EEA-10-R)	EEA39	10 m	Restricted

Sen2Like project / Level-2F demonstration product



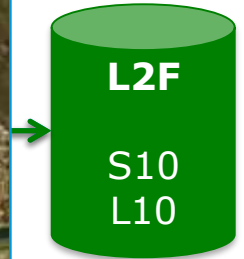
Objective: To combine S2 surface reflectance with the one from other sensors in a single fused data stream with S2 characteristics in terms of spatial resolution and spectral response.



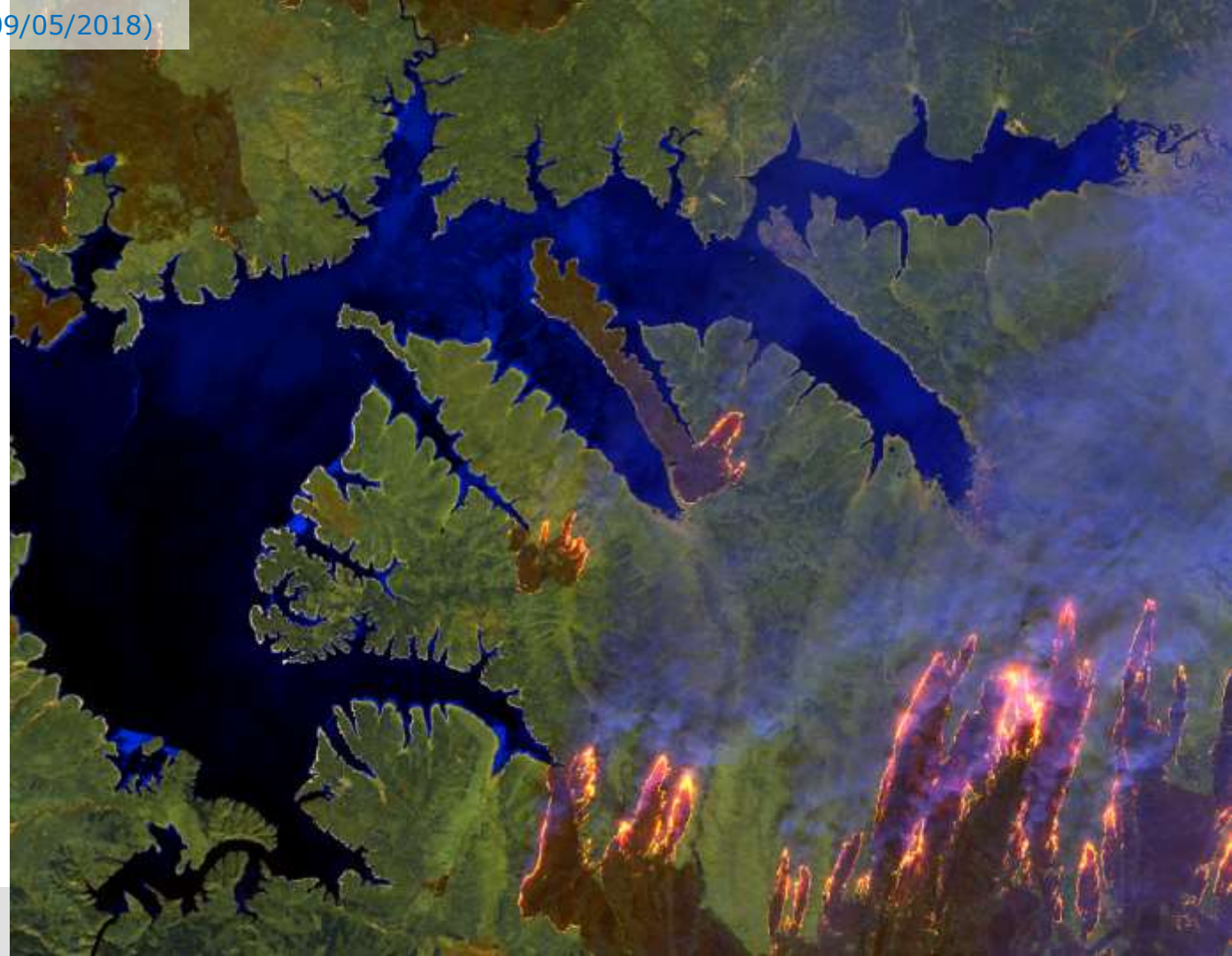
Sen2Like project / Level-2F demonstration product



Objective: To combine S2 with Landsat in a single fused data stream with S2 characteristics in terms of spatial resolution and spectral response.







Thank you
for your kind attention!

