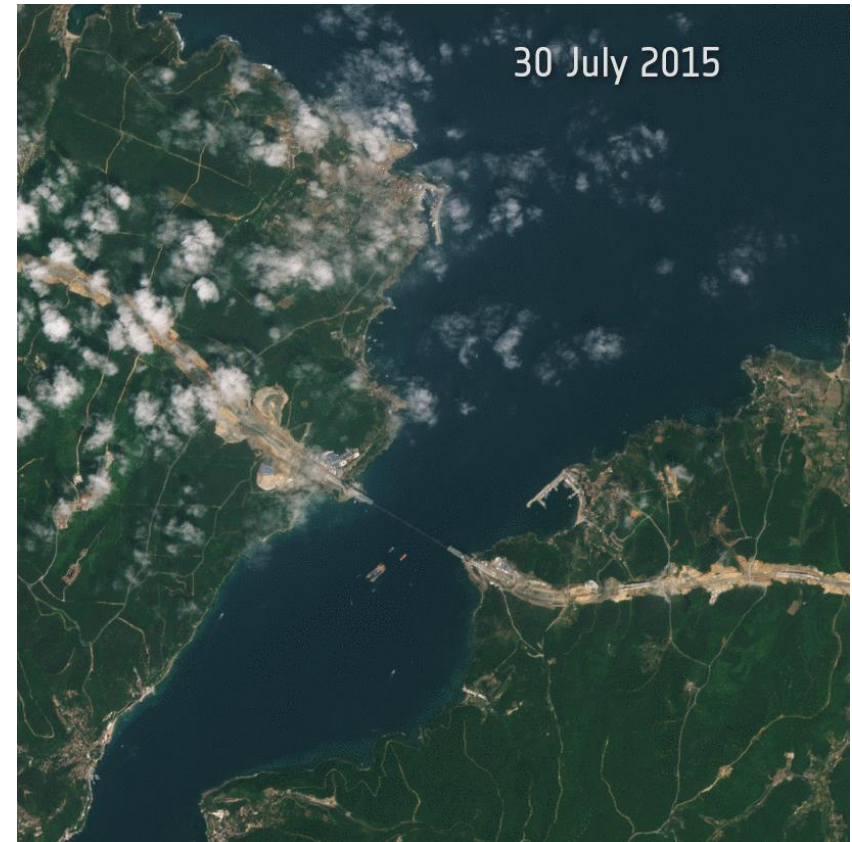


Sentinel-2: Products Data Quality and Evolutions

Ferran Gascon

11 October 2016

NSC, Oslo



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 25x23km ²)
Level-1C	Top-of-atmosphere reflectances in cartographic geometry	Systematic	Long-term	~500 MB (each 100x100km ²)
Level-2A	Bottom-of-atmosphere reflectances in cartographic geometry	On user side* (using Sen2Cor on Sentinel-2 Toolbox**)	N/A	~600 MB (each 100x100km ²)

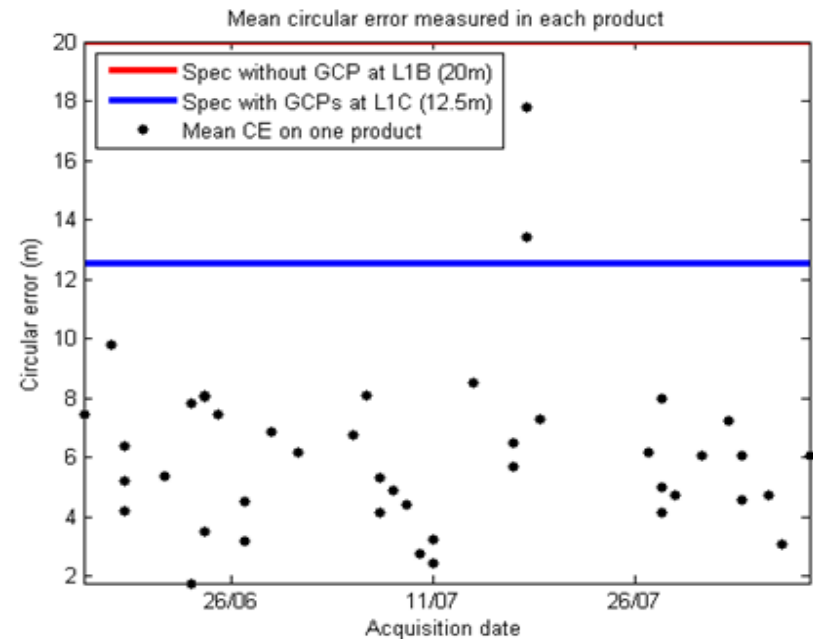
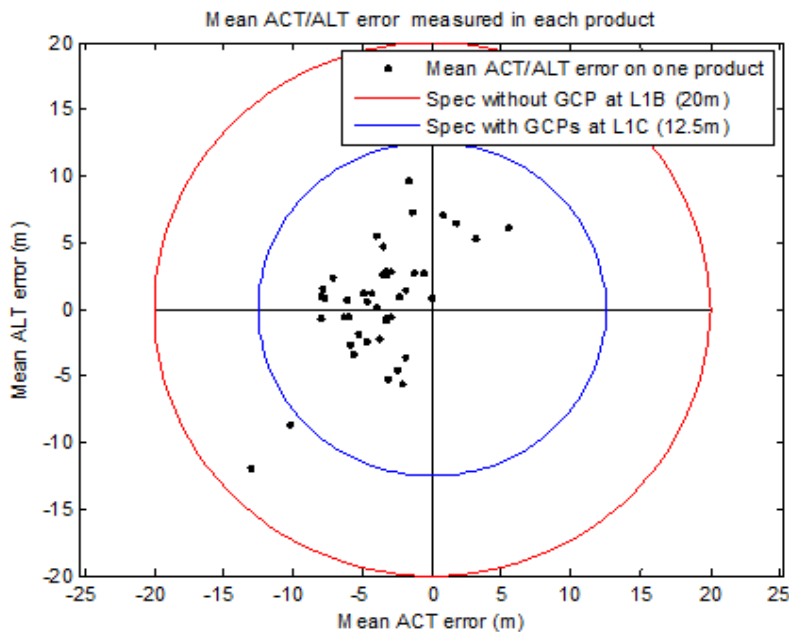
*: Systematic global production of L2A is currently being prepared.

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

Geolocation

- **Method:** Matching L1 images with perfectly geolocalized reference images (GCPs).
- **Results:** Performance analysed on 43 products including 430 GCPs.

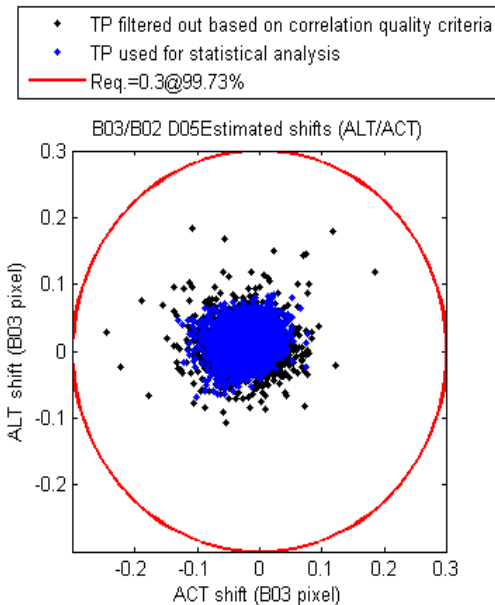
Parameter	Value
Circular error @95.4% over all GCPs	9.2 m



Multi-spectral Registration

- **Method:** Correlation of a large number of tie points between spectral bands couples.
- **Results:**

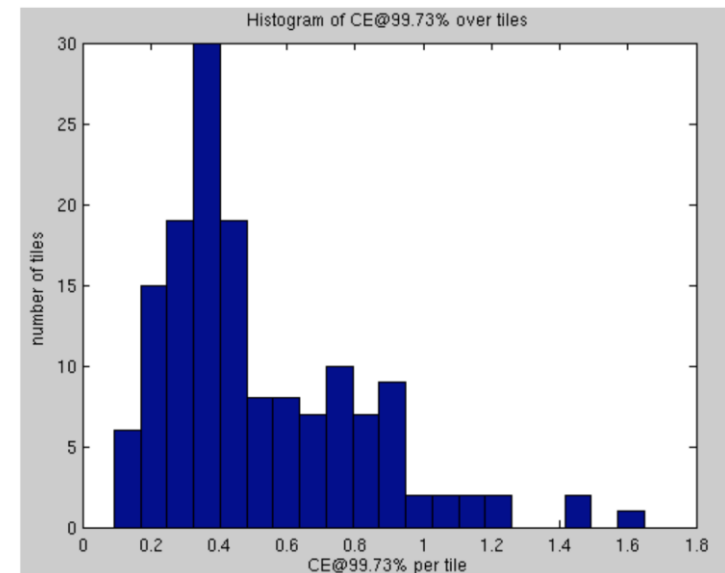
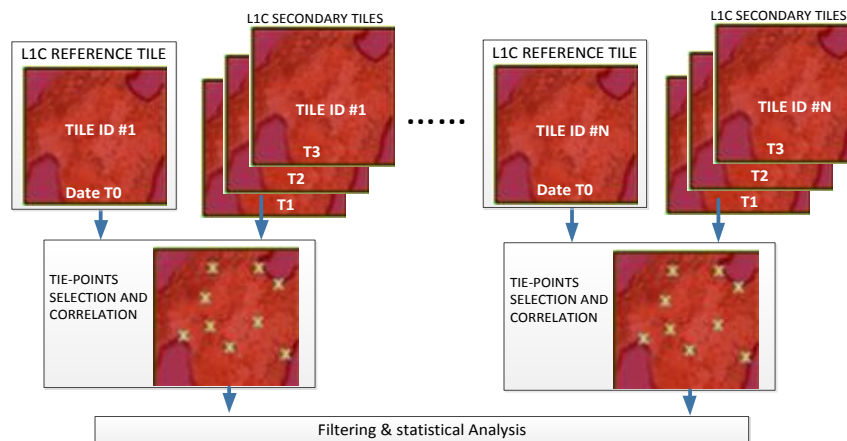
Bref/Bsec - Det	CE@99.73%	Bref/Bsec - Det	CE@99.73%
B04/B03-D01	0.237	B05/B11-D01	0.189
B04/B03-D02	0.214	B05/B11-D02	0.222
B04/B03-D03	0.202	B05/B11-D03	0.181
B04/B03-D04	0.165	B05/B11-D04	0.15
B04/B03-D05	0.182	B05/B11-D05	0.16
B04/B03-D06	0.168	B05/B11-D06	0.147
B04/B03-D07	0.203	B05/B11-D07	0.151
B04/B03-D08	0.162	B05/B11-D08	0.143
B04/B03-D09	0.146	B05/B11-D09	0.127
B04/B03-D10	0.145	B05/B11-D10	0.111
B04/B03-D11	0.135	B05/B11-D11	0.125
B04/B03-D12	0.122	B05/B11-D12	0.113
B11/B12-D01	0.259	B05/B12-D01	0.212
B11/B12-D02	0.292	B05/B12-D02	0.221
B11/B12-D03	0.218	B05/B12-D03	0.178
B11/B12-D04	0.155	B05/B12-D04	0.151
B11/B12-D05	0.182	B05/B12-D05	0.141
B11/B12-D06	0.133	B05/B12-D06	0.121
B11/B12-D07	0.109	B05/B12-D07	0.115
B11/B12-D08	0.121	B05/B12-D08	0.117
B11/B12-D09	0.107	B05/B12-D09	0.113
B11/B12-D10	0.084	B05/B12-D10	0.107
B11/B12-D11	0.114	B05/B12-D11	0.114
B11/B12-D12	0.091	B05/B12-D12	0.096



- ✓ Spatial Registration error is lower than the requirement (0.3 pixel CE @ 99.73% conf. Level) for all measured band couples

Multi-temporal Registration

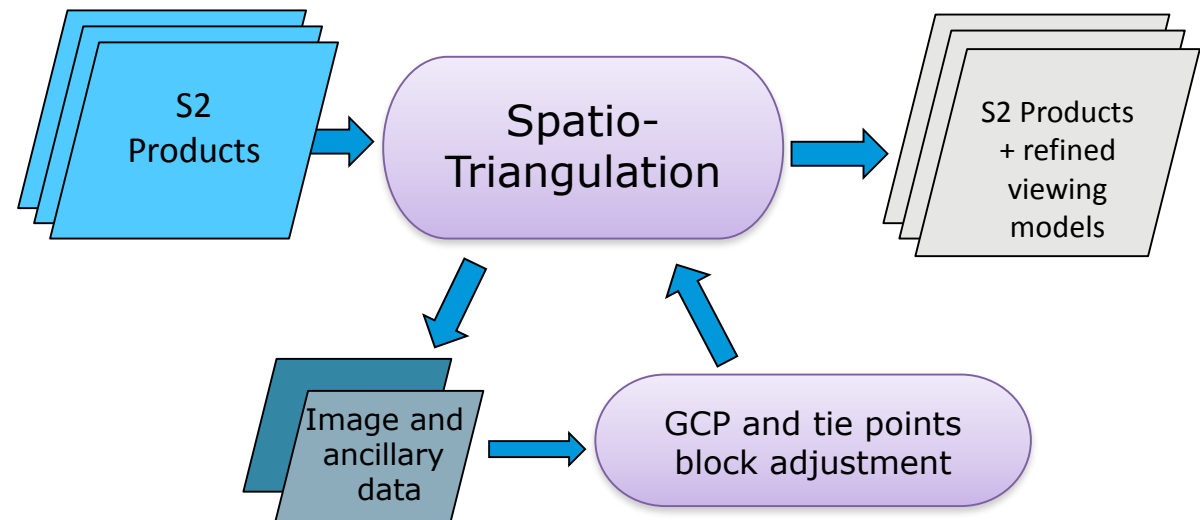
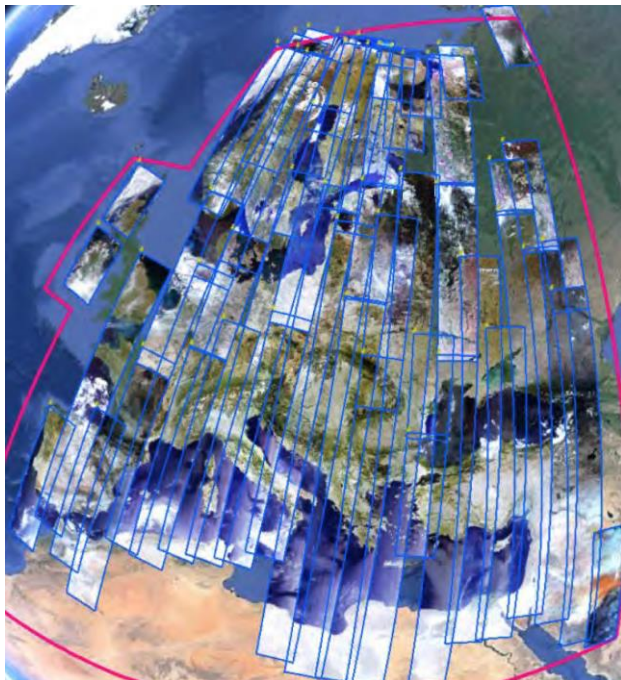
- **Method:** Correlation of L1C tiles acquired with same relative orbits at various dates.
- **Results:** 105 L1C tiles (covering 53 geographic tiles) analyzed over the world without geometric refinement.



- ✓ CE at 95.45% is 1.12 pixel
- ✓ Not yet compliant with requirement (0.3 pixel)
- ✓ Expected to become compliant with the geometric refinement using a Global Reference Image (GRI).

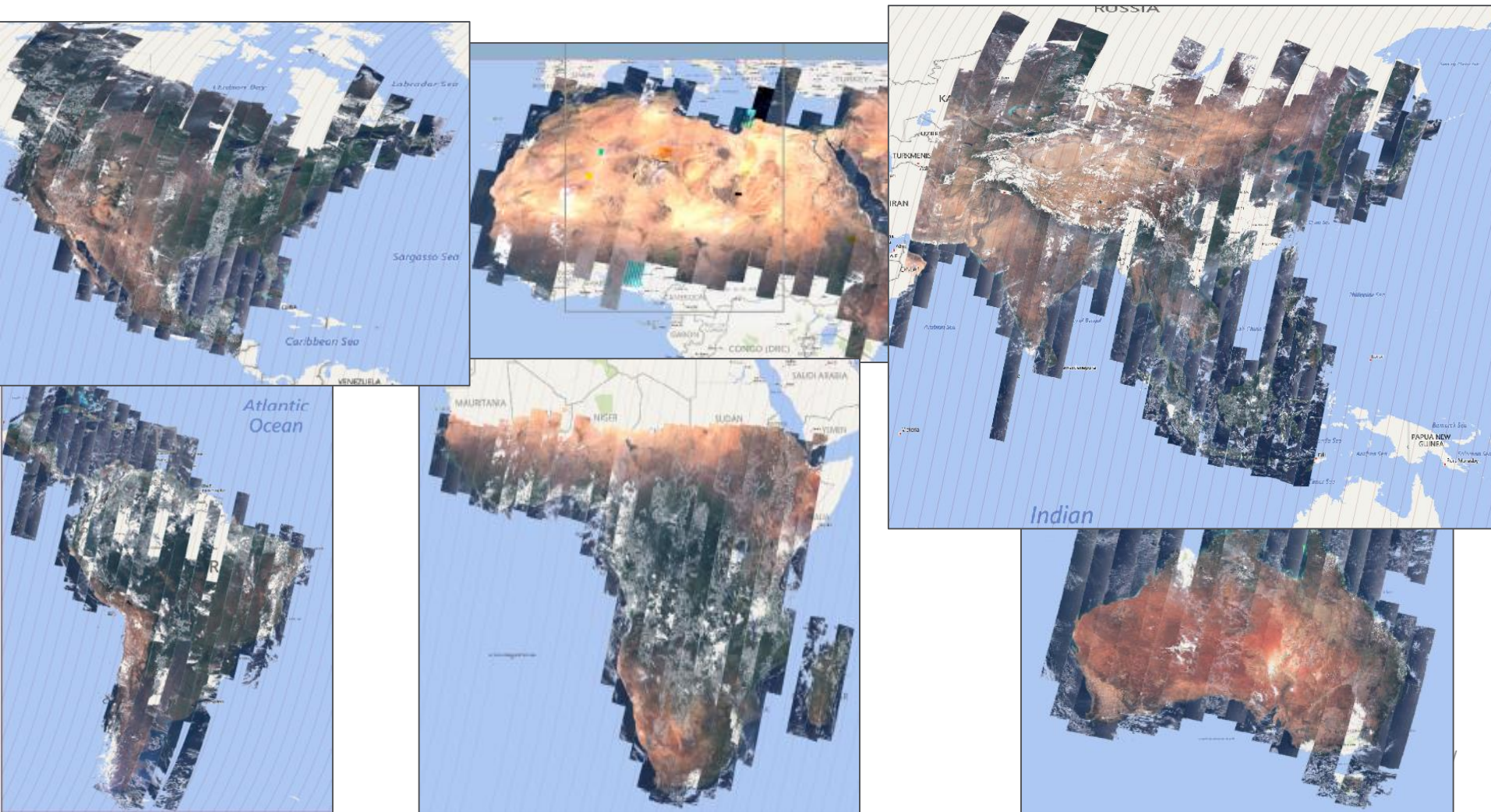
GRI (Global Reference Image)

- **Objective:** To obtain a full repeat cycle dataset of well-localized mono-spectral Level-1B images (band 4) which will be used as reference images in the processing to improve geolocation and multi-temporal registration.
- **Methodology:** Massive spatio-triangulation on large blocks.



GRI Construction Status

- ✓ Worldwide GRI will be completed (including validation) by Q4 2017.



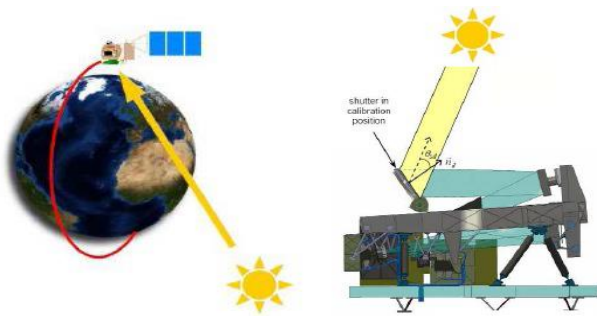
First GRI validation results



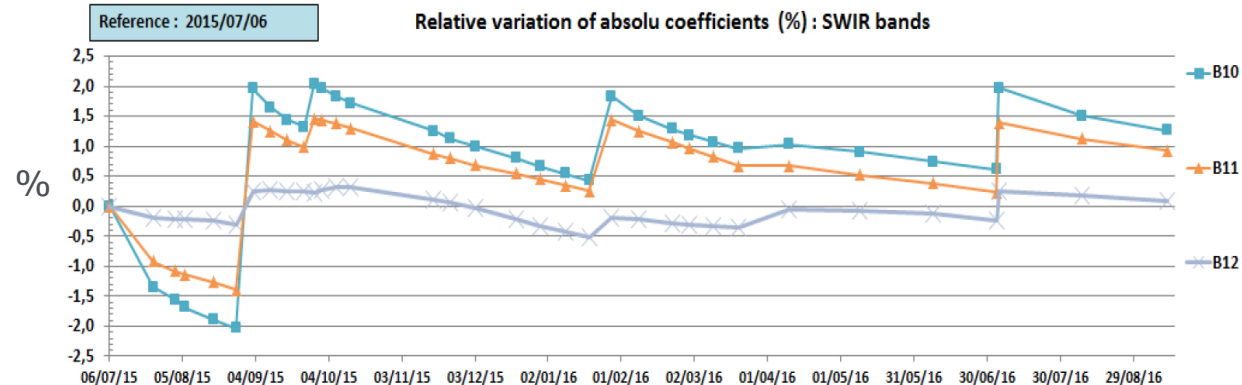
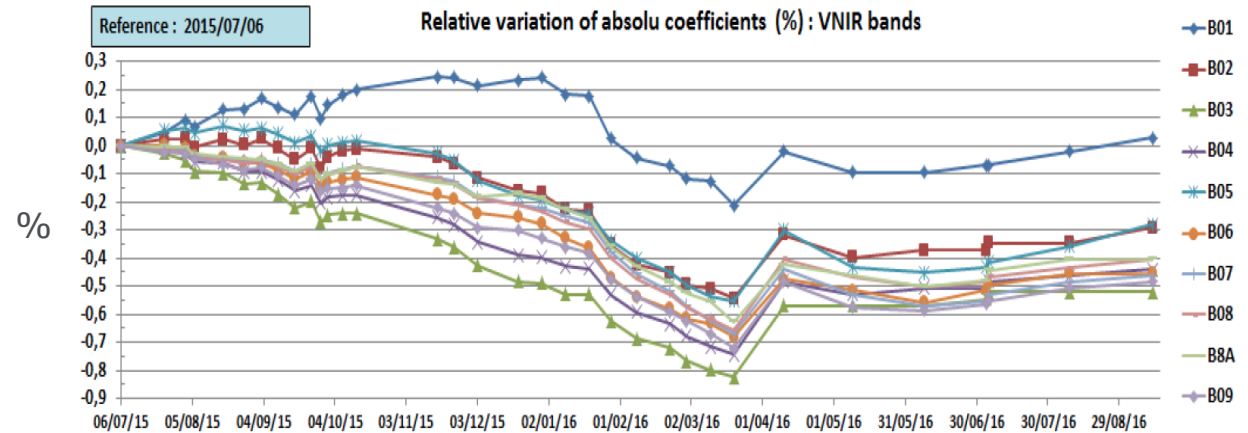
Green <7m **Orange** <10m **Red** >10m

Pre-validation made internally.
Geolocation estimated to 9m CE95

Absolute Radiometry / Calibration Approach

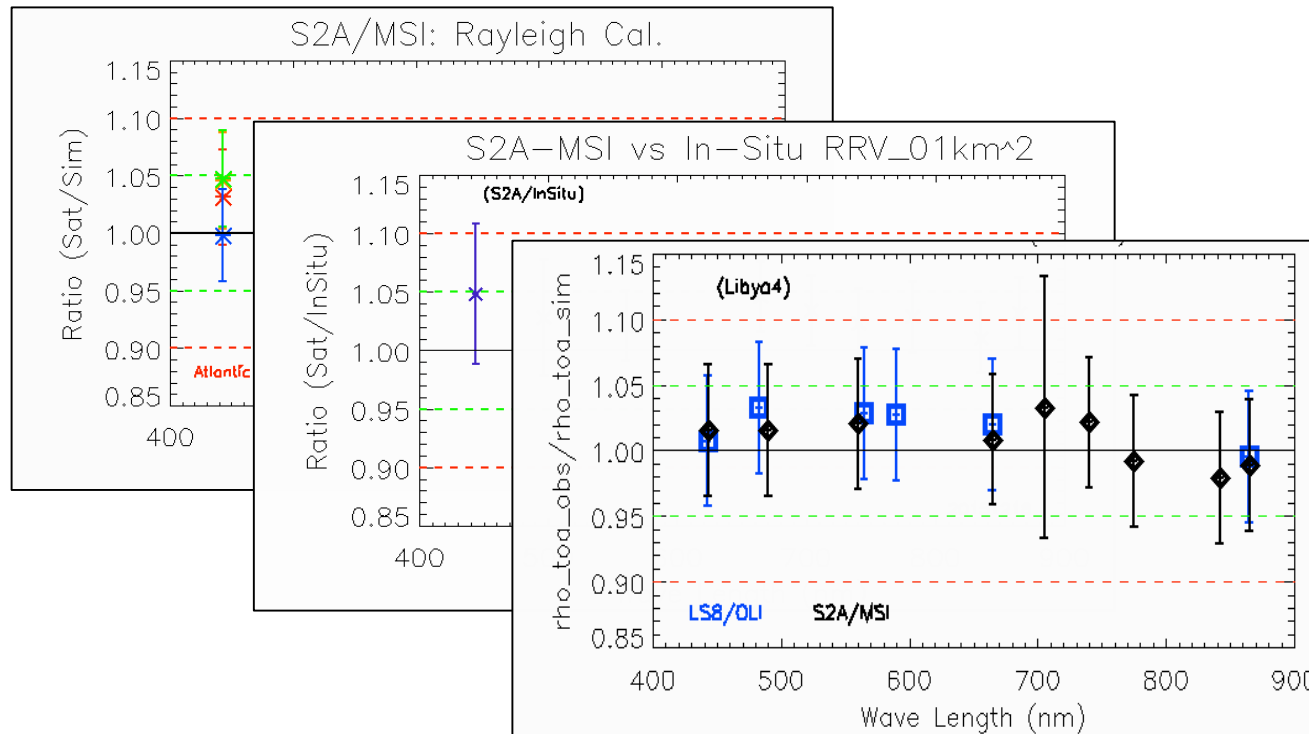


On-board sun diffuser



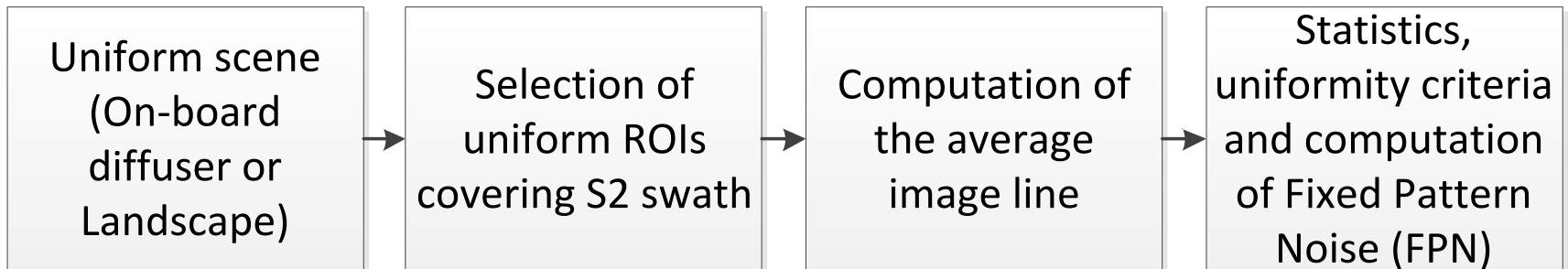
Absolute Radiometry

- **Method:** Rayleigh scattering using ocean targets, using ground measurements over RadCalNet sites, and inter-comparison with Landsat-8.
- **Results:**



Equalisation

- **Method:** With on-board diffuser after calibration, and vicarious on uniform scenes.

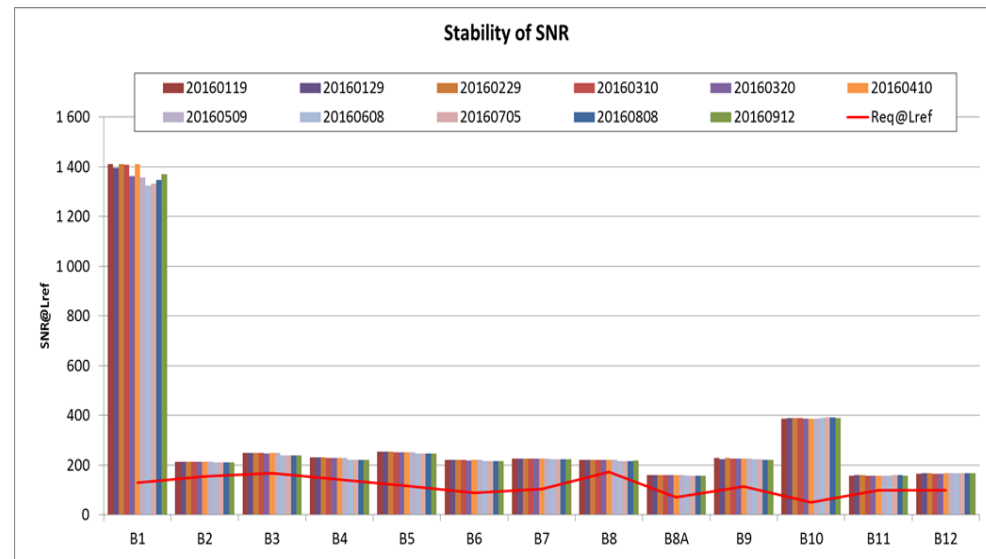


- **Results:** FPN < 0.2 %

SNR (Signal-to-Noise Ratio)

- Method:** Calculation from on-board diffuser, and vicarious approach based on a re-estimation of noise model from a dark image and absolute calibration coefficient measured by vicarious validation activity.
- Results:** SNR performance is well better than requirements for all bands and very stable in time.

Spectral Band	Lref	SNR SPEC @Lref	SNR@Lref	SNR/spec relative diff
B1	129	129	1410.3	993.2%
B2	128	154	214.3	39.2%
B3	128	168	249.0	48.2%
B4	108	142	230.2	62.1%
B5	74.5	117	253.3	116.5%
B6	68	89	220.6	147.9%
B7	67	105	227.1	116.3%
B8	103	174	220.8	26.9%
B8A	52.5	72	160.8	123.3%
B9	9	114	228.9	100.8%
B10	6	50	389.9	679.8%
B11	4	100	159.2	59.2%
B12	1.5	100	217.4	117.4%

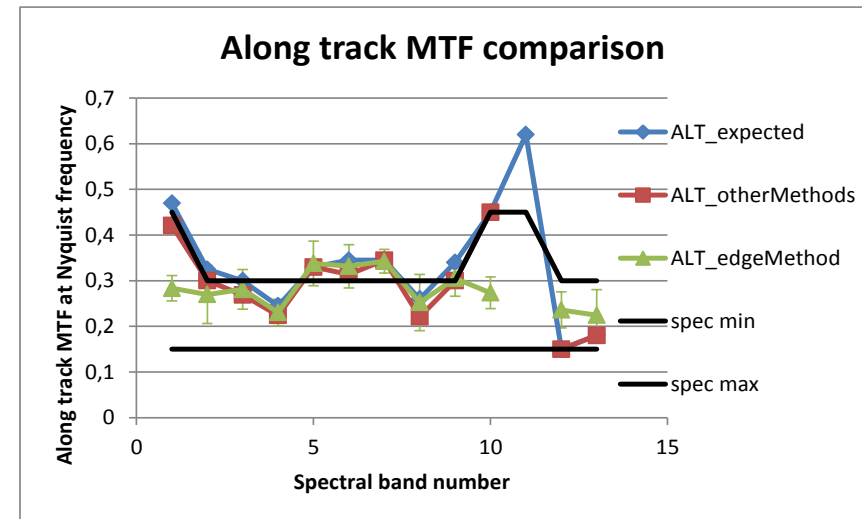
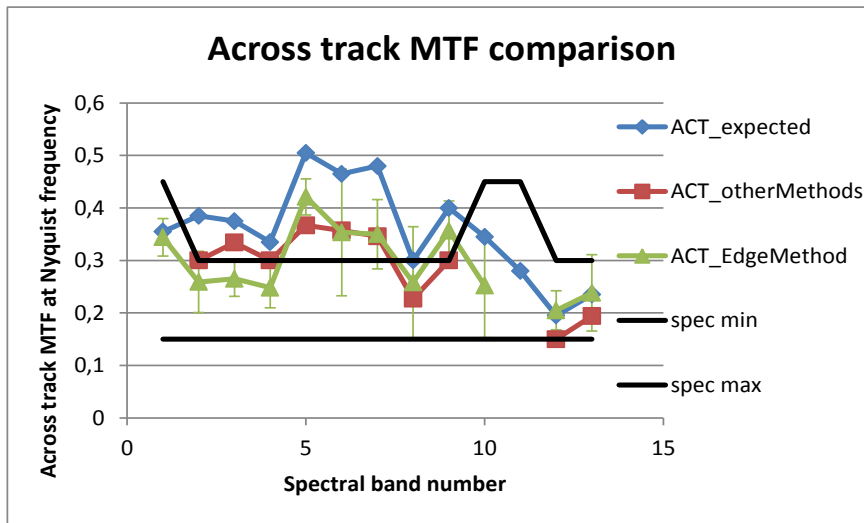


MTF (Modulation Transfer Function)

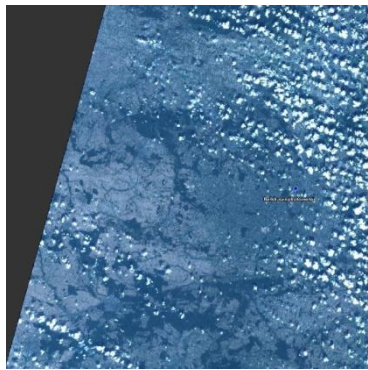
- Method:** Slanted edge (on fields and bridges) and reference image methods.



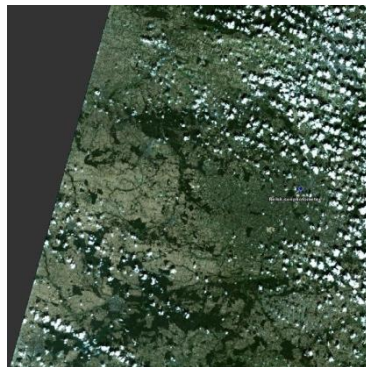
- Results:**



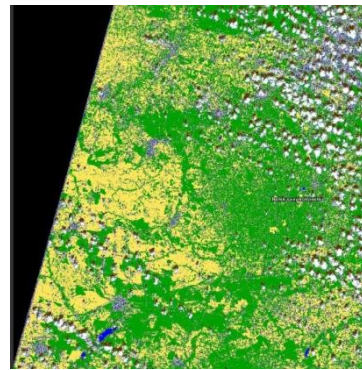
Surface Reflectance



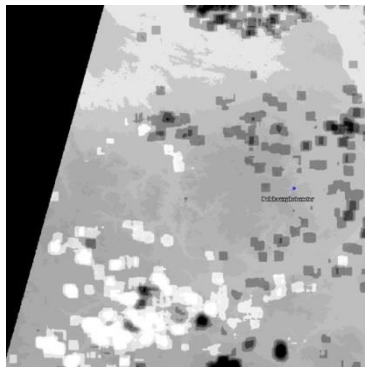
TOA-RGB (L1C-input)



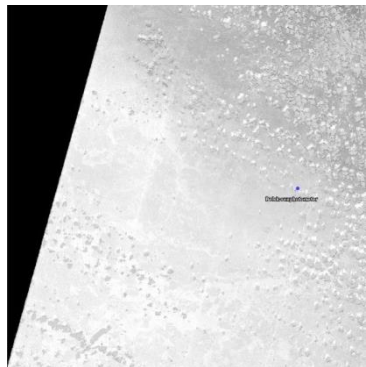
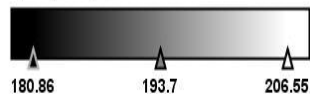
BOA-RGB (L2A-output)



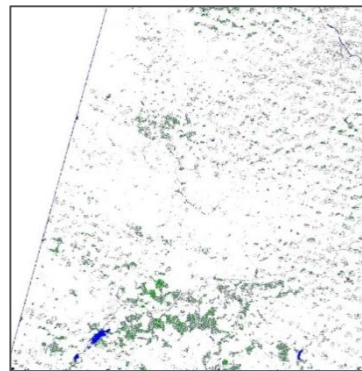
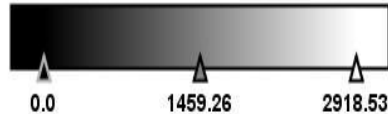
Scene classification



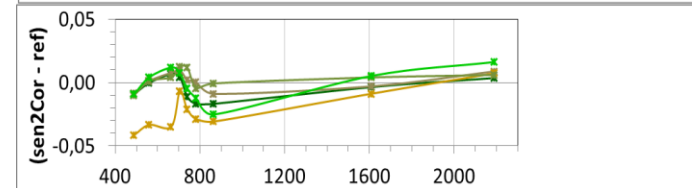
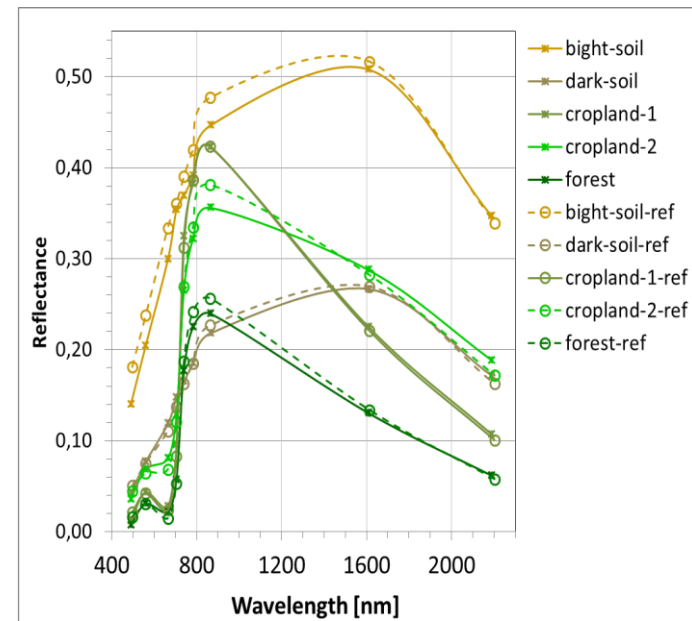
quality_aot [dl]



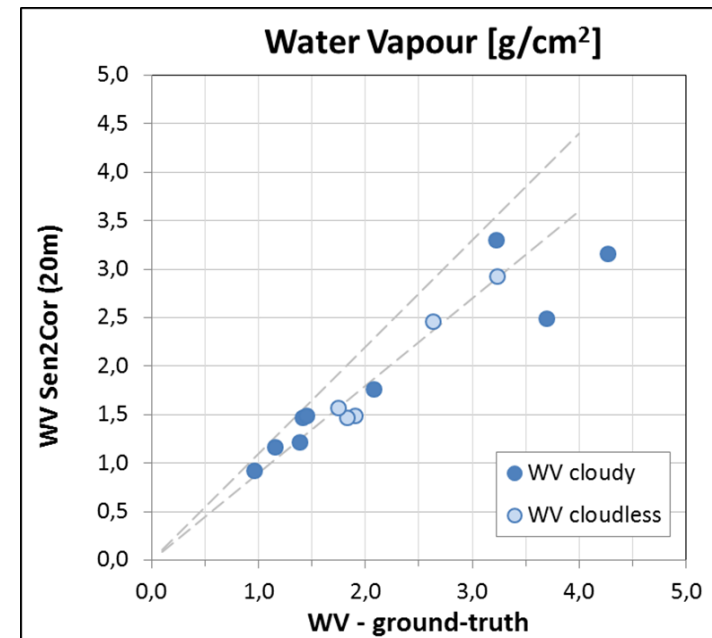
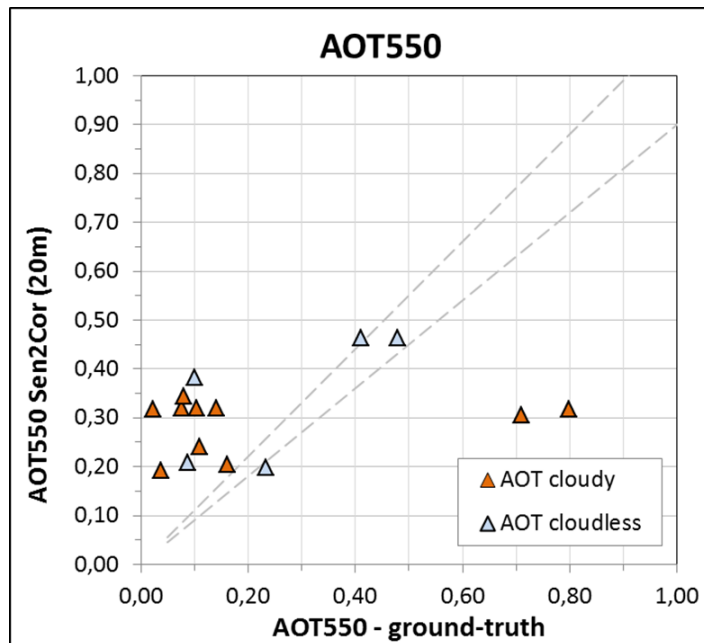
quality_wvp [dl]



DDV (Dense Dark Vegetation)



Surface Reflectance



Processing Baselines and Anomalies



✓ <https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/data-quality-report>

Anomaly ID	Baseline number	02.01		02.02	02.03	02.04		
	Deployment date	27/01/2016	31/03/2016	03/05/2016	09/06/2016	15/06/2016	03/08/2016	
	Anomaly title							
4	Instrument Measurement Time MTD		yes					
5	Minimum Reflectance "0"	yes						
6	Detector Footprint at Equator	yes						
7	Missing Physical Gains MTD	yes						
11	Missing Viewing Angles MTD	yes, not systematic						
12	Anomalous Pixels	yes, few products impacted						
15	Strong Misregistration				yes			
16	Stretched 60 m bands	A few orbits impacted						

Processing Baselines and Anomalies



✓ <https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/data-quality-report>

Anomaly ID	Anomaly title	Classification	Affected products	Product status
9	Striping of SWIR bands	Minor	A few orbits, not systematic	Not released
10	Striping of Visible bands	Major	A few orbits, not systematic	Removed from archive
13	B10 noise	Minor	Products with high reflectances	Available
14	Geolocation error	Major	Orbits 3218, 4080 and 4081	Removed from archive
17	Misaligned detectors on band 1	Minor	A few orbits impacted (beginning of the datastrip)	Available
18	Geolocation Error	Minor	Orbits 6003 to 6011	Available

Not an anomaly!



Data Quality Summary and Next Steps



✓ Excellent product data quality:

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).	< 9.2 m at $2s$
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.	< 0.26 pixel at $3s$
Absolute radiometric uncertainty	The absolute radiometric uncertainty shall be better than 5 % (goal 3%).	B1 to B9: < $5\% \pm 2\%$
SNR	The Signal-to-Noise Ratio (SNR) shall be higher than specified values (see Table 2.2 in this document)	All bands compliant with > 20% margin

✓ Next main steps:

- ✧ GRI generation and validation on-going.
- ✧ To complete on-going reprocessing campaign.
- ✧ Commissioning of Sentinel-2B in Q1/Q2 2017.

Data Quality Team Organisation



- Mission Performance Centre (MPC)
 - ✓ Calibration of the MSI sensor and L1/L2A processors
 - ✓ Validation of L1/L2A products
 - ✓ L1 Production Quality Control
 - ✓ L1/L2A processors prototyping/maintenance
- Centre National d'Études Spatiales (CNES)
 - ✓ L1 products validation
 - ✓ GRI validation
- Quality Working Group (QWG)
- Sentinel-2 Validation Team (S2VT)



Data Quality Entities



Val Support

ESL L2A

ESL L1 Val

ESL L1 Cal

Operators

MPC Prime



- ✓ QWG is a forum providing recommendations to ESA on products data quality aspects.

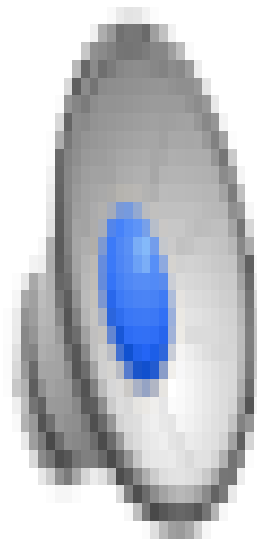
- ✓ Participants include Copernicus Services, EC and ESA representatives:
 - ✧ **Land Monitoring:** Dufourmont (EEA), Wijesingha (EEA), Strobl (JRC), Soille (JRC), Cherlet (JRC), Szantoi (JRC), Lacaze (Hygeos)
 - ✧ **Emergency Management:** Kucera (JRC), Wania (JRC), Spruyt (JRC), Broglia (JRC)
 - ✧ **Marine Environment Monitoring:** Bahurel (Mercator Ocean)
 - ✧ **Security:** Joyanes (Satcen)
 - ✧ **EC DG Grow:** Bamps, Bydekerke

- ✓ S2VT is an open forum to gather feed-back on S2 products, algorithms and cal/val activities.

- ✓ First S2VT (Sentinel-2 Validation Team) on 28-29 Nov 2016
 - ✓ <http://esaconferencebureau.com/2016-events/16c20/home>

- ✓ L1C Production over Norway with Higher-Resolution DEM
- ✓ L2A Pilot Pre-Operational Production
- ✓ L2A Feasibility Study for Operational Production

- L1C products geolocation is less accurate over mountainous areas due to the 90m resolution DEM used in the production.

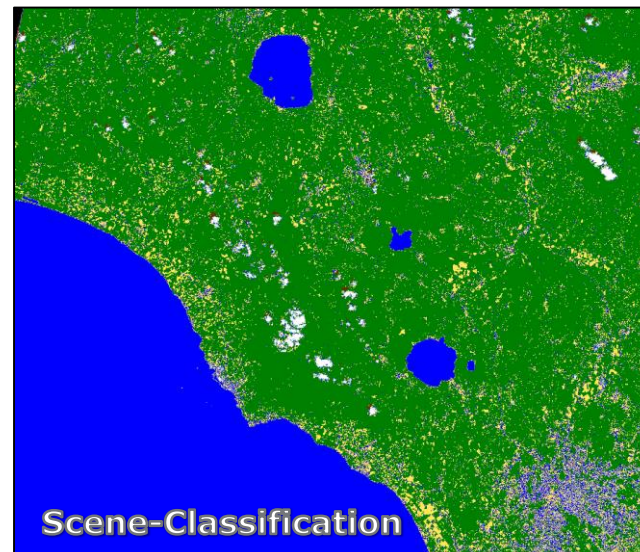


- Pilot project over Norway to generate L1C products using a national 10m DEM.
- Test period during Norwegian vegetation period 2016 (as per DWH definition 01 July 2016 to 15 August 2016).
- All S2A products acquired over Norway will be processed and made available for evaluation.
- Ortho-rectification quality will be assessed by Norwegian users and QWG, and feedback provided to ESA.

L2A Pilot Pre-Operational Production



- A systematic production of L2A over Europe will start in October 2016.
- The Sen2Cor processor (version 2.2.3) will be used for generating the surface reflectance products.
- It will daily generate up to 250GB of L2A products data (~600 Tiles/Day).
- L2A output products will be made available, after a validation period, through <http://scihub.esa.int>
- Products granularity of resulting L2A in tiles.



Label	Classification
0	NO_DATA
1	SATURATED_OR_DEFECTIVE
2	DARK_AREA_PIXELS
3	CLOUD_SHADOWS
4	VEGETATION
5	BARE_SOILS
6	WATER
7	CLOUD_LOW_PROBABILITY
8	CLOUD_MEDIUM_PROBABILITY
9	CLOUD_HIGH_PROBABILITY
10	THIN_CIRRUS
11	SNOW

L2A Feasibility Study for Operational Production

- The following algorithms are being assessed by a group of experts:
 - ✓ BC by Brockmann Consult
 - ✓ MAJA (MACCS ATCOR Joint Algorithm) by CNES/DLR
 - ✓ SCAPE-M by GFZ Potsdam
 - ✓ Sen2Cor by DLR/TPZ
- First meeting on the evaluation of the processors took place on 07 July.



L2A Feasibility Study for Operational Production - Links with ACIX

- In the framework of CEOS, ESA and NASA are co-organizing an inter-comparison of atmospheric correction algorithms for high-resolution optical missions, in particular S2 and Landsat-8:

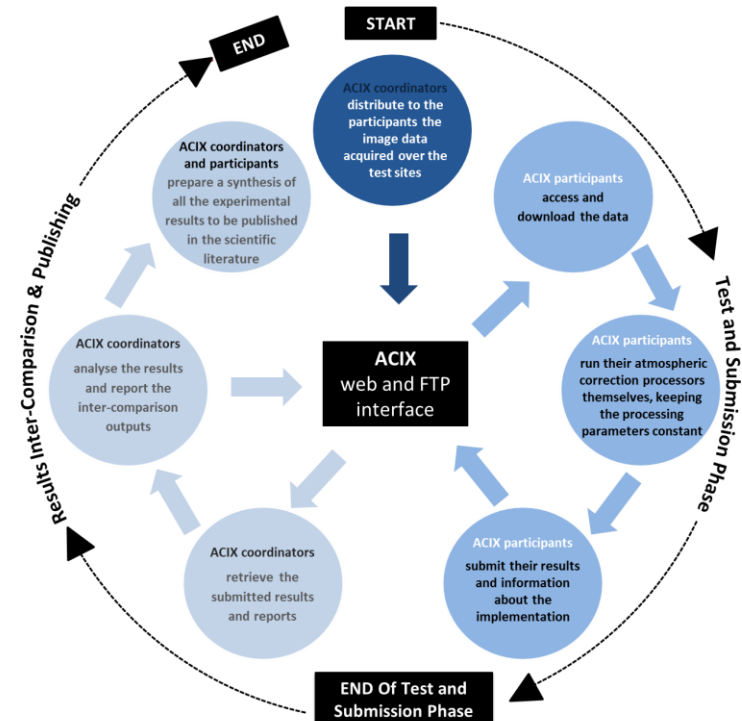
- ✓ **ACIX** (Atmospheric Correction Intercomparison eXercise)
- ✓ <https://earth.esa.int/web/sppa/meetings-workshops/acix>

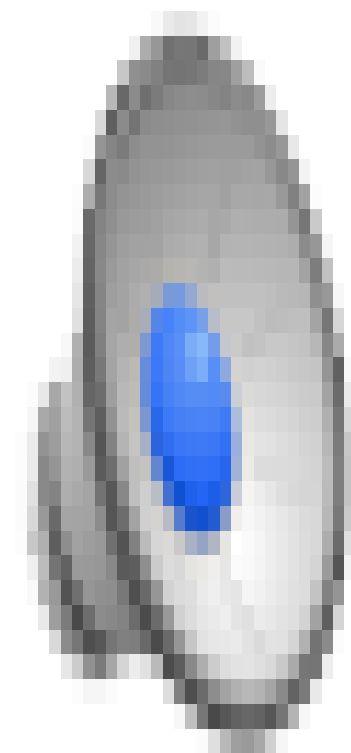


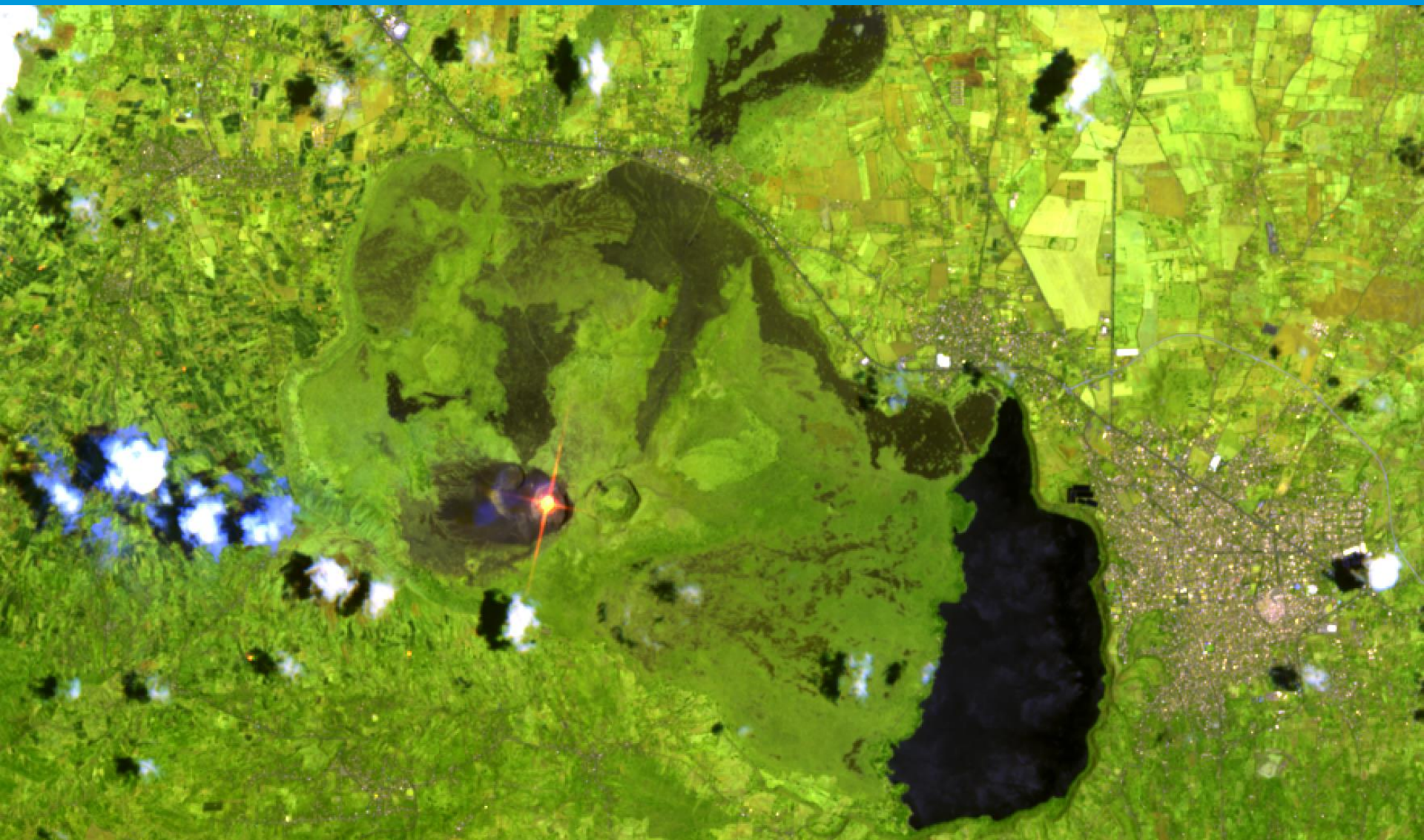
- ACIX will bring to the L2A Feasibility Study metrics on how different algorithms compare.
- ACIX organized in three phases:
 - ✓ Definition of the inter-comparison protocol.
 - ✓ Run of the AC processors.
 - ✓ Analysis of the results.

- 14 algorithms participating:

FLAASH (Spectral Sciences), **SMACAA** (South Dakota State University), **Sen2Cor** (DLR/TPZ), **L8SR** (NASA), **GA-PABT** (Geoscience Australia), **ACOLITE** (Royal Belgian Institute for Natural Sciences), **GRASP** (LOA), **OPERA** (VITO), **BC** (BC), **LAC** (ACRI), **MACCS** (CNES), **ATCOR** (DLR), **Ind-prepro** (Trier University), **SCAPE-M** (GFZ).







More information at: <http://sentinels.copernicus.eu>