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EVOLUTIONS STUDIES - AUTOMATED OPTICAL SENSOR REGISTRATION MONITORING TOOL

Product Validation Plan

Deliverable D06

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EUMETSAT STUDY CONTRACT REPORT

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ABSTRACT:

This document specifies the Product Validation Plan (PVP) and describes the methods and procedures approach to validate the developed OSMON software tool. Detailed test scenarios on module level are defined to evaluate the accuracy of the implemented algorithms and software tools. We also outline the system end-to-end tests which will be carried out as part of work package WP-4.3. The primary test environment will be set up at ENVEO, but the EUMETSAT offline environment will be also considered.

The work described in this report was done under EUMETSAT Contract. Responsibility for the contents resides in the authors or organization that prepared it.

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DOCUMENT CHANGE LOG

Issue/ Revision	Date	Modification	Modified pages	Observations
1.0	08.03.2019	All new	All	-
1.1	07.05.2019	restructured tests	All	Account for RIDs by EUMETSAT and discussion at PM1.
1.2	27.05.2019	Added TIR test (Section 3.6); several editorial improvements	All	Include EUMETSAT comments
1.3	18.7.2019	EUMETSAT Copyright added		Added © EUMETSAT in Footers of all pages

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APPLICAPLE AND REFERENCE DOCUMENTS

ID	Source
[AD-1]	ECSS-E-ST-40C – Software general requirements (6 March 2009)
[AD-2]	Aksakal, S. *et al.* (2015) 'Geometric Quality Analysis of AVHRR Orthoimages', *Remote Sensing*, 7(3), pp. 3293–3319. doi: 10.3390/rs70303293.

ID	Source
[RD-1]	Sentinel-3 Mission Requirements Traceability Document (MRTD) EOP-SM/2184/CD-cd, 07. 02. 2011, ESA
[RD-2]	Sentinel-3 Product Notice – SLSTR, S3.PN-SLSTR-L1.06, 07.11.2018, S3 Mission Performance Centre and by ESA and EUMETSAT

ACRONYMS

AVHRR ..... *Advanced Very High-Resolution Radiometer*

DW ..... *data window*

GCP ..... *Ground Control Point*

MROI ..... *Medium Resolution Optical Imager*

OLCI ..... *Ocean and Land Colour Instrument*

SLSTR ..... *Sea and Land Surface Temperature Radiometer*

TIR ..... Thermal Infrared

1. INTRODUCTION

The objective of this document is to define the Product Validation Plan (PVP) and to describe the approach of to validate the developed software tool. At the end of the development process ENVEO will assess if the specified requirements (RDB) are met and if the software tool satisfies intended use and user needs. This is done by intercomparing OSMON derived shifts with publicly available assessments, by comparing the matching results with shits derived with EUMETSAT tools and by a set of systematic and methodical test described in this document. The primary test environment will be set up at ENVEO the EUMETSAT offline environment will be also considered.

The technical system end-to-end test is specified as part of the work package WP-4.3 and is not covered by this document.

The product validation is organized as

- Intercomparison of OSMON geolocation accuracy with independent Data sets and with shift estimates retrieved from EUMETSAT tools.
- Validation of method for estimating geolocation by performing a set of tests on OSMON Core-Module. The task is to estimate and or recover geolocation shifts between GCPs and current medium resolution EUMETSAT sensors (such as AVHRR, SLSTR, OLCI) under predefined test conditions.

2. INTERCOMPARISON OF OSMON GEOLOCATION ACCURACY WITH INDEPENDENT DATA SETS

The geolocation estimate retrieved with the OSMON Core-Module will be intercompared with publicly available findings and with accuracy estimates derived with EUMETSAT assessment tools. For scenes acquired during the same season over Europe the following parameters, revered to as statistics in the below stated tests, will be derived for all GCPs covered by the MROI-DW:

- Minimum shift in Easting
- Minimum shift in Northing
- Maximum shift in Easting
- Maximum shift in Northing
- Mean shift in Easting
- Mean shift in Northing
- Standard deviation of shift in Easting
- Standard deviation of in Northing
- RMSE of the difference between GCP and target

These tests were introduced to intercompare and study the consistency or differences, respectively, between different tools used for estimating the geolocation accuracy of medium resolution satellite data. These tests are not providing absolute accuracy values as these data sets used for intercomparison are no "*true*" reference data.

2.1. VV-CI-0010 Intercomparing with Sentinel-3 SLSTR Product Notice

The Sentinel-3 Product Notice – SLSTR Version 1.1 Rev. Date 19/11/2018 summarizes the current state of the Level-1B product. Where the processing baseline for SLSTR-A Level-1B products is v2.37 and for SLSTR-B is v1.08. Both sensors meet the required nadir and oblique view geolocation accuracy of 0.5 pixel (S3 MRTD,2011). A sub-pixel mis-registration of S7 regarding S8 and S9 of ~250 m for SLSTR-A and ~120 m for SLSTR-B has been detected and is being investigated.

Module under Test	Core Module	
Objective	Asses agreement on geolocation shifts with Sentinel-3 Product Notice – SLSTR	
Requirements addressed	-	
Dataset used	GCP	• 10 GCPs Sentinel-2, Band-8a • 10 GCPs Landsat-8, Band-5, Collection Category T1
	MROI	25 different dates, cloud free, snow free, day time • SLSTR, Band-S3

Steps performed	1. Select GCP 2. Import MROI 3. Match GCP with MROI 4. Store estimated 2d-shift and statistics 5. Compute average shift in East/ West and North / South direction
Success Criteria	Not applicable
Fail Criteria	Not applicable

2.2. VV-CI-0020 Intercomparing with shifts stated in Aksakal et al. 2015 (AVHRR)

Aksakal *et al.*, 2015 reported for MetOp-A over Europe a mean shift of -0.1 pixel in x and -0.4 pixel in y. The corresponding standard deviation in x-direction was 0.4 pixel and 1.1 pixel in y-direction. The retrieved geolocation accuracy by the OSMON Core-Module will be intercompared for scenes acquired during the same season.

Module under Test	Core Module	
Objective	Asses agreement on geolocation shifts with Aksakal et al. 2015	
Requirements addressed	-	
Dataset used	GCP	• 10 GCPs Sentinel-2, Band-8a • 10 GCPs Landsat-8, Band-5, Collection Category T1
	MROI	25 different dates, cloud free, snow free, day time • AVHRR, Band-2
Steps performed	1. Select GCP 2. Import MROI 3. Match GCP with MROI 4. Store estimated 2d-shift and statistics 5. Compute average shift in East/ West and North / South direction	
Success Criteria	Not applicable	
Fail Criteria	Not applicable	

2.3. VV-CI-0030 Intercomparing with EUMETSAT Tool GEOCAL (SLSTR)

This quality assessment test compares the shifts derived from independent EUMETSAT Tool GEOCAL with the output of the OSMON Core-Module.

Module under Test	Core Module	
Objective	Asses agreement on geolocation shifts with EUMETSAT Tool GEOCAL	
Requirements addressed	-	
Dataset used	GCP	• 10 GCPs Sentinel-2, Band-8a • 10 GCPs Landsat-8, Band-5, Collection Category T1
	MROI	25 different dates, cloud free, snow free, day time • SLSTR, Band-S3
Steps performed	1. Select GCP 2. Import MROI 3. Match GCP with MROI 4. Store estimated 2d-shift and statistics 5. Compute average shift in East/ West and North / South direction	
Success Criteria	Not applicable	
Fail Criteria	Not applicable	

2.4. VV-CI-0040 Intercomparing with EUMETSAT Tools (AVHRR)

This quality assessment test compares the shifts derived from independent EUMETSAT Tool IDEAL with the output of the OSMON Core-Module.

Module under Test	Core Module	
Objective	Asses agreement on geolocation shifts with EUMETSAT Tool IDEAL	
Requirements addressed	-	
Dataset used	GCP	• 10 GCPs Sentinel-2, Band-8a • 10 GCPs Landsat-8, Band-5, Collection Category T1
	MROI	25 different dates, cloud free, snow free, day time • AVHRR, Band-2
Steps performed	1. Select GCP 2. Import MROI 3. Match GCP with MROI 4. Store estimated 2d-shift and statistics 5. Compute average shift in East/ West and North / South direction	
Success Criteria	Not applicable	
Fail Criteria	Not applicable	

3. VALIDATION OF METHOD FOR ESTIMATING GEOLOCATION SHIFTS

The estimation of the colocation is performed by applying a phase-correlation procedure. It is the core module for estimating the shift between GCPs and medium resolution optical sensors. The algorithm calculates the cross-correlation matrix between the GCP data window, and the corresponding data window of the MROI optical sensors resampled to the resolution of the GCP data. The algorithm provides the shifts in terms of true meters in in latitude and longitude direction as well as in terms of pixels of the medium resolution sensors in along and across track direction.

As a quality measure for the shifts two statistical parameters are used

- Value of the Correlation Peak in the correlation matrix
- Signal to noise ratio (SNR) of the peak of the correlation matrix versus its adjacent pixels

The Normalized Cross Correlation $\gamma(u,v)$ ranging from -1 to 1 is calculated by

$$\gamma(u,v) = \frac{\sum_{x,y}[f(x,y) - \bar{f}u,v][t(x-u,y-v) - \bar{t}]}{\{\sum_{x,y}[f(x,y) - \bar{f}u,v]^2[t(x-u,y-v) - \bar{t}]^2\}^{0.5}}$$

The SNR is given by the ratio of the peak signal value r_{max} over the average of the background $\overline{r_{bg}}$ of the correlation matrix:

$$SNR = \frac{r_{max}}{\overline{r_{bg}}}$$

r_{max} and SNR are used as the quantify the uncertainty of the matching and related shifts. The estimated absolute shifts are expressed in easting and northing in true meters and as well as in image coordinates of the target sensor in terms of pixels.

To the method for estimating geolocation shifts, the matching method will be validated in methodical tests.

3.1. VV-CM-0010 Assess geolocation accuracy with known shifts

Therefore, we select at least 10 GCPs (Landsat, Sentinel-2) and resample them with a predefined shift, (including full pixels but also sub-pixel shifts). The OSMON tool is applied to the original and resampled images and the difference between the applied shift and recovered shifts are intercompared and the unbiased RMSE is estimated.

$$RMSE = \sqrt{\frac{\sum_{n=1}^{N}(\hat{y}_n - y_n)^2}{N}}$$

Module under Test	Core Module	
Objective	Estimate noise floor of shift estimation	
Requirements addressed	SW-HL-0010 SW-COM-0010, SW-COM-0020, SW-COM-0030	
Dataset used	GCP	• 10 GCPs Sentinel-2, Band-8a • 10 GCPs Landsat-8, Band-5, Collection Category T1
	MROI	25 different dates, cloud free, snow free, day time • AVHRR, Band-2 • SLSTR, Band-S3 • OLCI, Band-Oa17
Steps performed	Step A: Estimate shifts between GCP and original data: 1. Select GCP 2. Import MROI 3. Match GCP with MROI 4. Store estimated 2d-shift and statistics Step B: Add additional shift to MROI data 5. Resample MROI with predefined 2d-shift of 1/3 MROI-pixel size (MROI_res) 6. Match GCP with MROI_res 7. Retrieve 2d-shifts pf GCPs Step C: Evaluate of added shifts are retrieved 8. Compute RMSE between resampled GCP shifts and corresponding GCP shifts from Step 1 + additional shift.	
Success Criteria	Predefined 2d-shift recovered (with accuracy < 0.3 pixel)	
Fail Criteria	Predefined 2d-shift not recovered (with accuracy > 0.3 pixel)	

3.2. VV-CM-0020 Evaluate suitability of matching method for differently shaped GCPs

The aim of this test is to investigate the effect of different shapes of matching features (lakes, islands, geological features) on the estimated shifts in East and North direction. Three shapes are classified, (i) circle, (ii) extended in easting or northing direction; (iii) complex shapes.

Module under Test	Core Module
Objective	Evaluate suitability of matching method for differently shaped GCPs
Requirements addressed	SW-HL-0010 SW-COM-0010, SW-COM-0020, SW-COM-0030

Dataset used	GCP	Sentinel-2, Band-8a and Landsat-8, Band-5, Collection Category T1 • 10 GCPs circular shape • 10 GCPs extended in easting or northing direction • 10 GCPs complex shaped
	MROI	25 different dates, cloud free, snow free, day time • AVHRR, Band-2 • SLSTR, Band-S3 • OLCI, Band-Oa17
Steps performed	1. GCPs with different shapes: 2. Import MROI 3. Match GCP with MROI 4. Store estimated 2d-shift and statistics 5. Resample MROI with predefined 2d-shift of 1/3 MROI-pixel size (MROI_res) 6. Match GCP with MROI_res 7. Retrieve introduced 2d-shift and statistics 8. Compute RMSE	
Success Criteria	Predefined 2d-shift recovered	
Fail Criteria	Predefined 2d-shift not recovered	

3.3. VV-CM-0030 Assess effect of cloud and snow cover on retrieving geolocation shifts

The aim of this test is to investigate the use of scenes affected by clouds / snow for retrieving the accuracy. For this purpose, we selected several GCPs and corresponding cloud free MROI data sets and estimate the shifts for the cloud free case as reference. In a second step clouds are randomly introduced in the MROI images and the estimated shifts are intercompared with the cloud free case.

Module under Test	Core Module	
Objective	Assess effect of cloud and snow cover on retrieving geolocation shifts	
Requirements addressed	SW-HL-0010 SW-COM-0040, SW-COM-0050, SW-COM-0060, SW-COM-0070, SW-COM-0080	
Dataset used	GCP	• 10 GCPs Sentinel-2, Band-8a • 10 GCPs Landsat-8, Band-5, Collection Category T1
	MROI	25 different dates, cloud free, snow free, day time • AVHRR, Band-2

		• SLSTR, Band-S3 • OLCI, Band-Oa17
Steps performed	1. Select GCP 2. Import MROI 3. Match GCP with MROI 4. Store estimated 2d-shift and statistics 5. Resample MROI with predefined 2d-shift of 1/3 MROI-pixel size and introduce randomly artificial clouds (MROI_res) 6. Match GCP with MROI_res 7. Retrieve introduced 2d-shift and statistics 8. Compute RMSE	
Success Criteria	Predefined 2d-shift recovered	
Fail Criteria	Predefined 2d-shift not recovered	

3.4. VV-CM-0040 Test multispectral cloud/snow classification algorithm

The aim of this test is to ensure that the quality check performed during MROI-data import works properly and rejects unsuitable MROI data windows before the matching. Cloud/snow covered MROI DW should be marked as processed but unsuitable in the OSMON database.

Module under Test	Core Module	
Objective	Test multispectral cloud/snow classification algorithm	
Requirements addressed	SW-HL-0010 SW-COM-0040, SW-COM-0050, SW-COM-0060, SW-COM-0070, SW-COM-0080	
Dataset used	GCP	• 10 GCPs Sentinel-2, Band-8a • 10 GCPs Landsat-8, Band-5, Collection Category T1
	MROI	25 different dates, cloud covered, snow covered, night time • AVHRR, Band-2 • SLSTR, Band-S3 • OLCI, Band-Oa17
Steps performed	1. Select GCP 2. Import MROI 3. Apply Module with Quality Checks and Matching of GCP with MROI 4. Store estimated 2d-shift and statistics	
Success Criteria	Reject MROI DW, label as Cloud/Snow in OSMON database	
Fail Criteria	Computes shift for MROI DW, store shifts in OSMON database	

3.5. VV-CM-0050 Assess geolocation accuracy of TIR bands with known shifts

In night-time acquisitions of Landsat-8 (ascending orbits) the cloud cover values will always be zero. Therefore, we manually check the cloud coverage and select and 10 suitable GCPs (Landsat-8, band 10). For each GCP AVHRR and SLSTR TIR-scenes covering these GCPS must be selected manually and checked for cloud coverage. First the shift between GCP and MROI data will be estimated. In a second step the MROI will be resampled with a predefined shift, (including full pixels but also sub-pixel shifts). The OSMON tool is applied to the original and resampled images and the difference between the applied shift and recovered shifts are intercompared and the unbiased RMSE is estimated.

Module under Test	Core Module	
Objective	Estimate noise floor of shift estimation	
Requirements addressed	SW-COM-0010, SW-COM-0020, SW-COM-0030 SW-GCP-0070	
Dataset used	GCP	• 10 GCPs Landsat-8, Band-10
	MROI	5 different dates, cloud free, snow free, night-time • AVHRR, Band-4 (TIR) • SLSTR, Band-S8 (TIR Ambient bands)
Steps performed	Step A: Estimate shifts between GCP and original data: 1. Select GCP 2. Import MROI 3. Match GCP with MROI 4. Store estimated 2d-shift and statistics Step B: Add additional shift to MROI data 5. Resample MROI with predefined 2d-shift of 1/3 MROI-pixel size (MROI_res) 6. Match GCP with MROI_res 7. Retrieve 2d-shifts pf GCPs Step C: Evaluate of added shifts are retrieved 8. Compute RMSE between resampled GCP shifts and corresponding GCP shifts from Step 1 + additional shift.	
Success Criteria	Predefined 2d-shift recovered (with accuracy < 0.3 pixel)	
Fail Criteria	Predefined 2d-shift not recovered (with accuracy > 0.3 pixel)	