KARIOS : A fast & efficient open source tool for geometric deformation analysis.

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The Earthnet Data Assessment Project (EDAP+) continues the work of its predecessor (EDAP 2018 – 2021) and is responsible for assessing the quality and suitability of **candidate missions** being considered for ESA's Earthnet Programme as Third Party Missions (TPM). Early data assessments are publicly disclosed to the community ([RD-1]). Based on its own infrastructure ([RD-2]), Telespazio is responsible for the analysis of Very High Resolution optical data, including assessment on geometry, radiometry and image quality ([RD-3]).
In most cases, inherited from design tradeoffs in the **new space domain**, the geometry remains a critical aspect. Main outcomes from various workshops ([RD-4]) point out the needs regarding openly available reference data and **openly available data assessment processing tools.** In this context, a new tool dedicated to geometric assessment has been created:
Kanade Lucas Tomassi (KLT) based **A**lgorithm for **R**egistration of **I**mages from **O**bserving **S**ystem' (**KARIOS**)

Functionalities

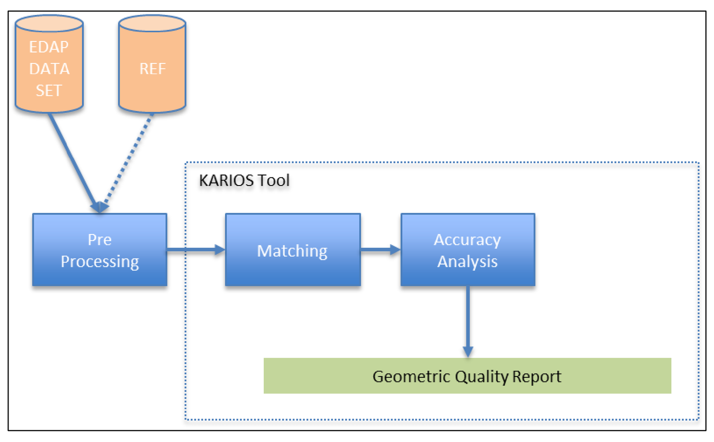
The main driver of KARIOS initiative is to support operator for following quality control assessments

- Multi temporal geolocation to evaluate the geolocation stability of the mission,
- Absolute geolocation to evaluate the geolocation accuracy of an input image grid against a well-controlled absolute reference image,.
- Band-to band registration to evaluate co-registration between image band grids, all within a same product.

The KARIOS tool has been designed to **compare** two image grids (matching) and output consistent mapping **accuracy analysis** statistics,

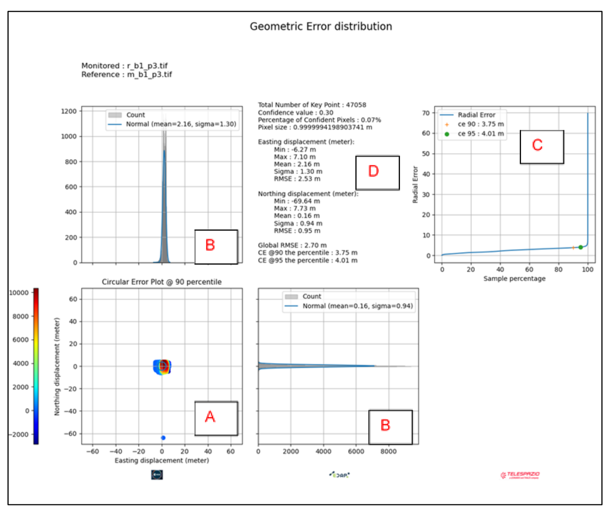
Key features of KARIOS are:

- Free and Open-Source licensing policy (Apache-2)
- Multi Missions capabilities; Optical / Radar, Medium Resolution / High Resolution image data
- Python Code (3.10)
- Increased processing performance
- Reduced Uncertainties

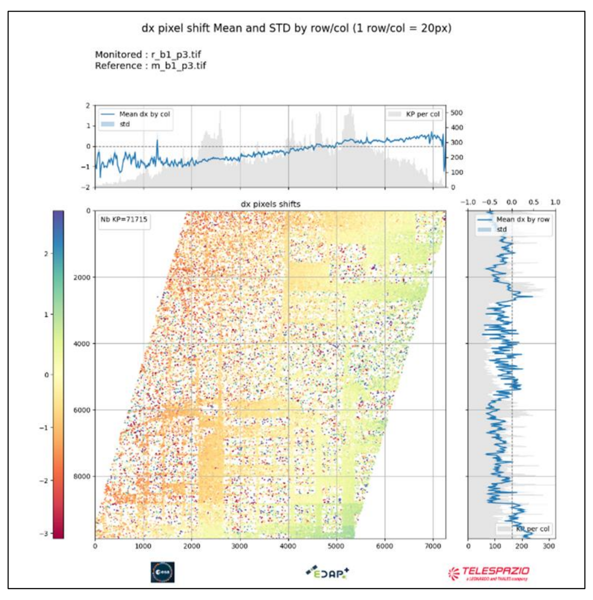


Scope of KARIOS Tool

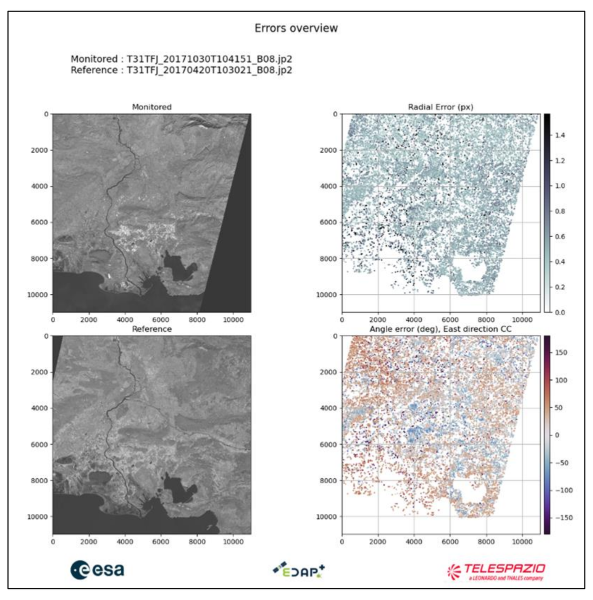
Unlike commonly shared approach in the domain, the matching process relies on tracking algorithm initially used for motion analysis: the KLT (Kanade-Lucas-Tomasi Tracking) algorithm.
The displacement measurement sample is large and so that, in most cases, representative of image geometry deformation, it enables full characterization of image geometry. Through accuracy analysis module, the KARIOS tool process matching results and provide systematically key accuracy information items.



Geometric error distribution figure; Circular Error (A), Histogram for each direction (B), 2D Error Cumulative functions (C) and statistics (D)



Disparity map (in one direction) and mean error in along / across the image



Error overview images: Input images (right) and radial / angle error (left), South of France area (Salon de Provence)

Algorithms

- A similar method has been previously used for the matching of MSG SEVIRI and AVHRR image series ([RD 5]).
- Mathematical formulation of algorithm is given in ([RD 6], ([RD 7])) and their implementation is part of OpenCV libraries. There are basically two steps; candidate point selection and matching with optical flow.
- Dedicated filtering is used to enhance image textural information.
- Statistical outlier detection for eliminating false matches from the results is performed
- A statistical confidence value is attached to every pixel
- Beside disparity maps and mean displacement along with image line, image column, different statistics are provided to appreciate to check product compliance compliance with respect to the **National Map Accuracy Standard (NMAS)** horizontal accuracy standards,

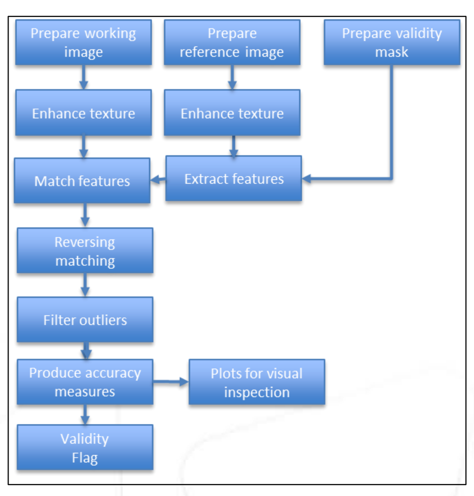


Image matching algorithm

Comparison with existing tools

- Based on same dataset, KARIOS results have been compared with those from other tools as MEDICIS (M. Cournet 2016) or AROSICS.
- Results agree together (refer to Fig A)
- Differences exist regarding the number of Key Points (KP) and spatial distribution (refer to Fig B)
- MEDICIS raised more KPs than KARIOS, with all KPs localized into specific image area
- KARIOS KPs cover a larger geographical area.

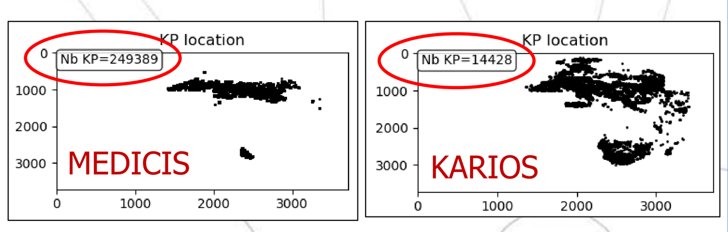


Fig B) Number of KPs and Geographic distribution, MSG HRV Image (Full disk)

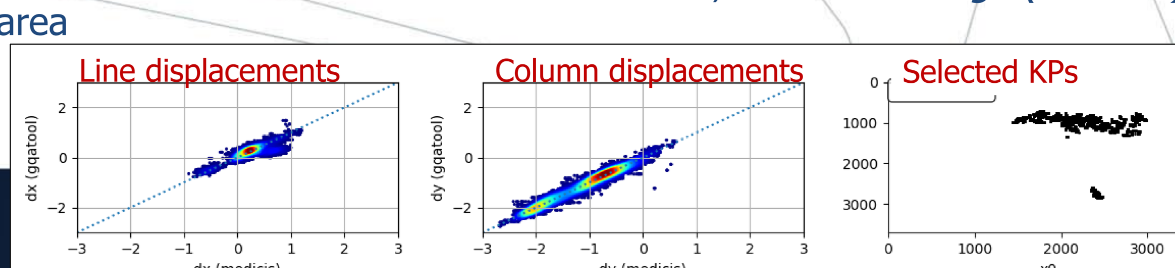
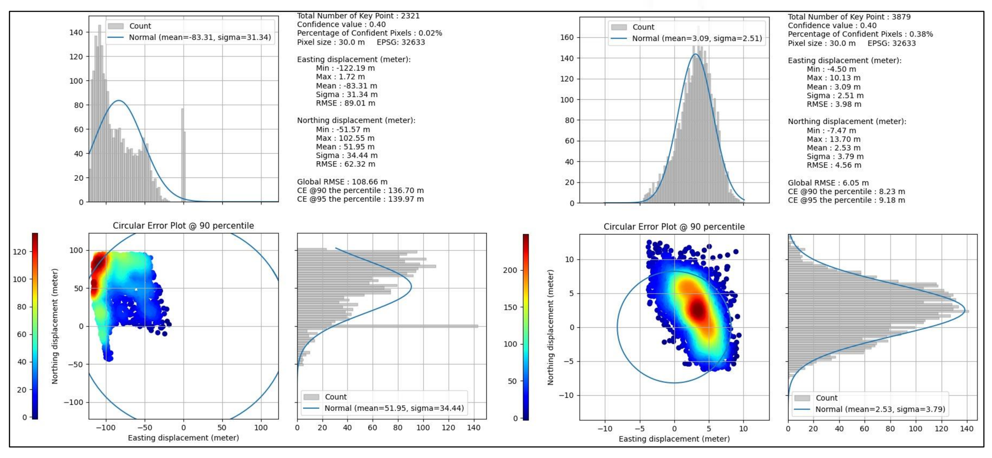


Fig A) MEDICIS / KARIOS Results comparison ,MSG HRV Image (Full disk).

Results

Product Geometric Quality Control

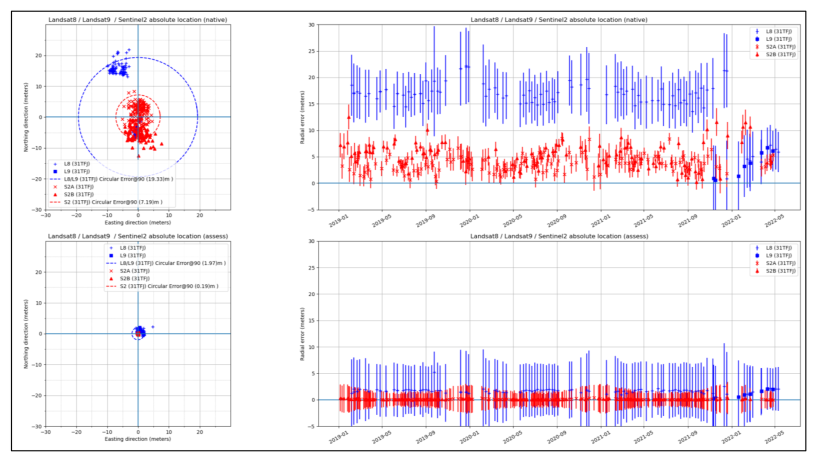
- KARIOS is used to validate geometric processing of Sen2Like ([RD 8]) in particular **PRISMA L1C georeferencing**.



Validation L1C processing (before Sen2Like (left / after (left) registration

Multi temporal analysis

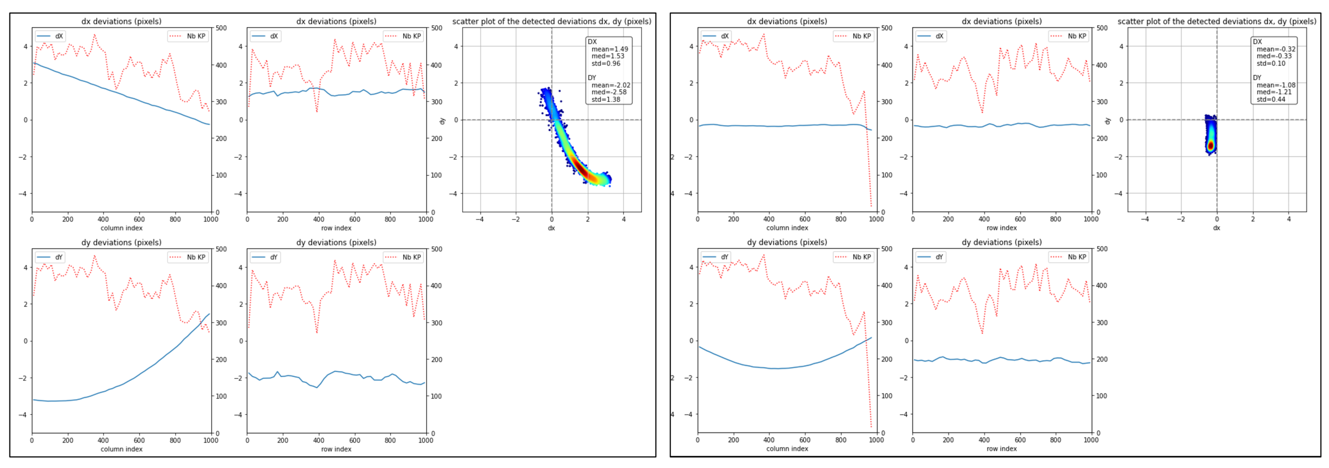
- KARIOS can be orchestrated to perform multi temporal analysis over large dataset.
- Small changes in Processing Baseline can be easily detected, notably systematic shifts between Landsat and Sentinel 2 products and improvements (end of the period) as show in right figure (upper graphics).
- KARIOS is also used to validate Sen2Like processing results (right figure (lower graphics)).



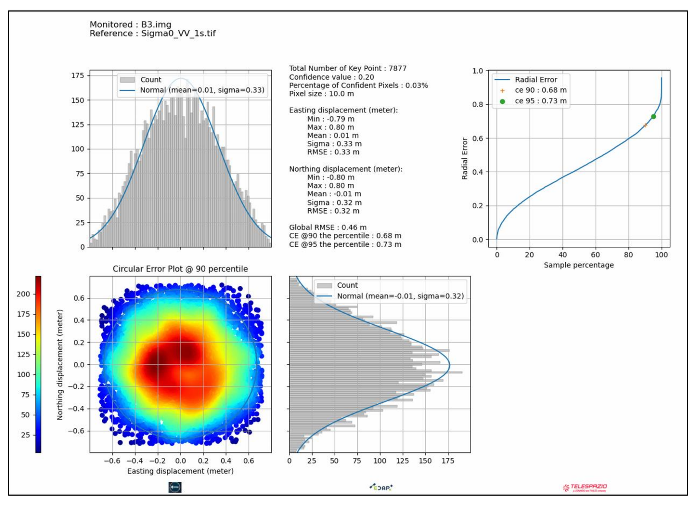
Validation L1C processing (before Sen2Like (left / after (left) refinement)

PRISMA Geometric Model Calibration

- Image warping into instrument grid and matching are used to estimate Line of Sight parameters.



Geometric Model calibration in instrument grid; before (left figure), after (right figure)



S1 / S2 Image grid comparison

Different types of sensor / mission

KARIOS can be used to compare image grids from

- Optical / Radar Instrument
- LR, MR, VHR Image sensors
- Visible / Thermal infrared channels

Conclusions and Future Plans

An additional tool enabling geometric assessment is now available for the community. The use of this tool is straightforward and processing fast / efficient. The algorithm accommodate with various configurations, The reports are self explaining and support accuracy analysis.
In the context of EDAP+ / Copernicus, shared with data provider, it will be used for cross validation; based on the same dataset & the same tool.

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