Turning the Sentinel-2 Global Reference Image into a Database of Ground Control Points

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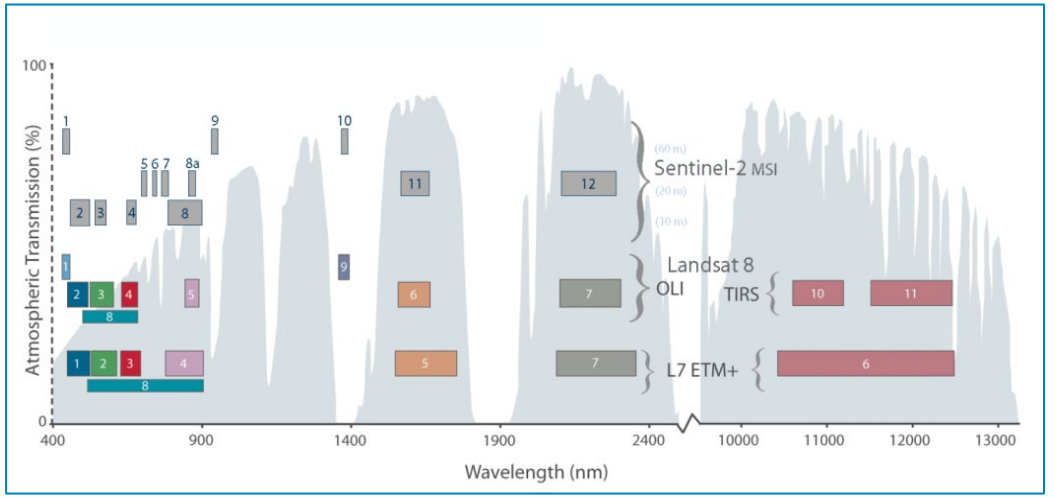
Copernicus Sentinel-2 Constellation

- ✓ Optical multi-spectral mission for the monitoring of land and in-land/coastal waters.
- ✓ Constellation of two satellites (Sentinel-2A and Sentinel-2B).
- ✓ Polar sun-synchronous orbit at an altitude of 786km, with LTDN 10h30.
- ✓ Swath of 294km.



Source ESA

- ✓ Free & open products for feeding a large range of applications.

Sentinel 2 Geometric Accuracy Targets

- **Geometric target justification**
  - › Sentinel 2 is designed to produce high revisit time series at medium resolution
  - › Geometric requirements ensure the repeatability of images and contribute to image quality (multi-spectral registration)

- **Main Sentinel 2 products:**
  - Level 1B: radiances, radiometrically corrected product

in sensor geometry: not publicly disseminated

- Level 1C: TOA reflectances orthorectified product (geometric ortho-correction considering a DEM) (UTM – MGRS)
- Level 2A: BOA reflectances (same projection)

Sentinel 2 Geometric Accuracy Targets

- **Absolute geolocation**
  - Without geometric refinement **< 20 m**
  - With geometric refinement **< 12.5 m**

- **Multi-temporal (relative) geolocation < 5 m**

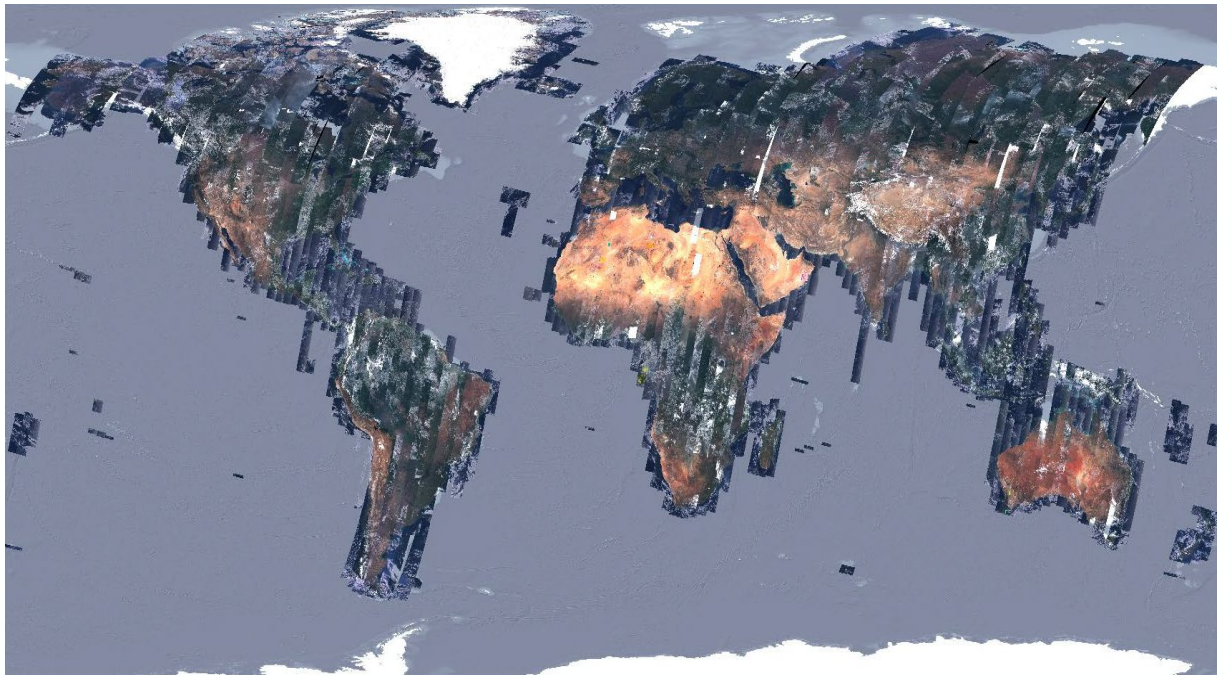
What is the Global Reference Image (GRI)?

GRI is composed of about 1000 Level 1B Sentinel-2A & B mono-spectral (B4, red channel) images

› worldwide coverage including many isolated islands

› stack of images limiting clouds (up to 5 images)

- computed in a refined global block
  - Accuracy: 7m CE95
  - Internal coherence: 0.1p @95%
- designed to reach L1C targets:
  - 12.5m CE95
  - multi-temporal registration 0.5p @95%



Global Reference Image (GRI)

- the 30th of March 2021 over Euro-Africa region followed the 23rd of August 2021 worldwide;
- the geometric refinement algorithm was introduced in order to improve the geometric performance of Copernicus Sentinel-2 products based on the use of the Global Reference Image (GRI).

- ✓ **Absolute geolocation** accuracy
  - from 11 m improved to < 7 m (CE95)
- ✓ **Multi-temporal co-registration** accuracy
  - from 9 m improved to < 5 m (CE95)

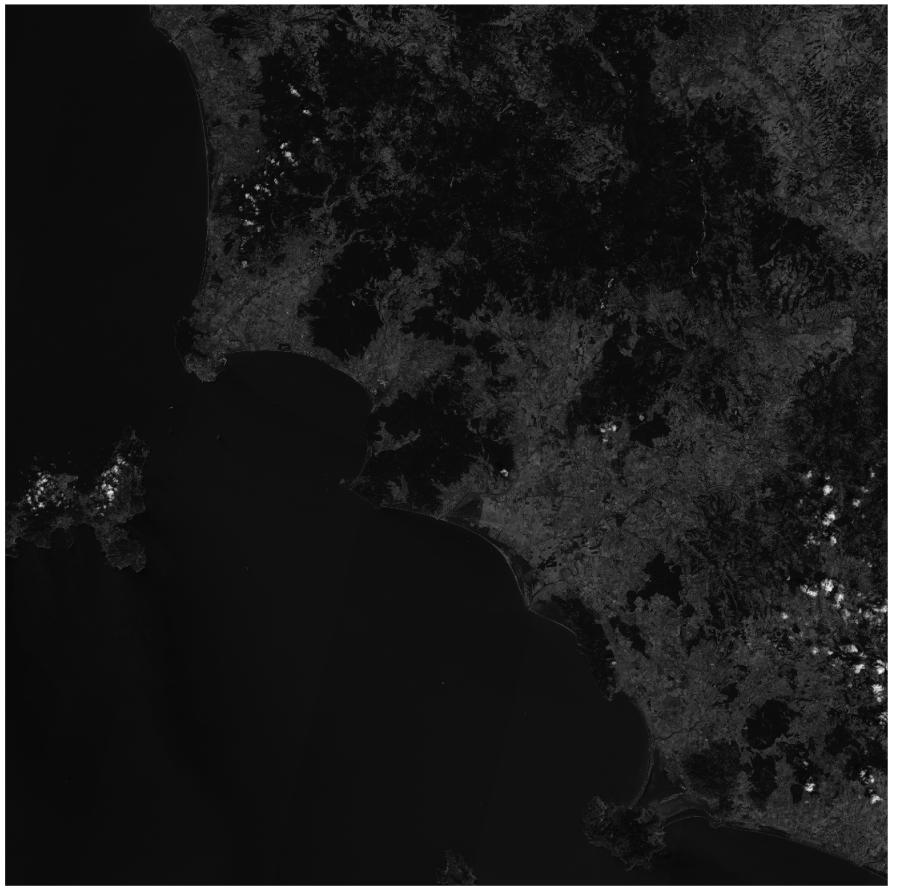
Collection 1:

consistent time series for the Sentinel 2 users' community

- ➢ Strong potential but not really user oriented
- ➢ Making the GRI useful and usable for the international user community requires some evolutions of the current GRI

Multi-layer GRI product in Level 1C

- generated by converting to Level 1C the multi-layer GRI product in Level 1B
- compliant to the last Sentinel 2 Level 1C format evolutions (PSD 14.9, PB 04.00)
- generated with the Copernicus DEM at 30m resolution
- composed by multiple layers



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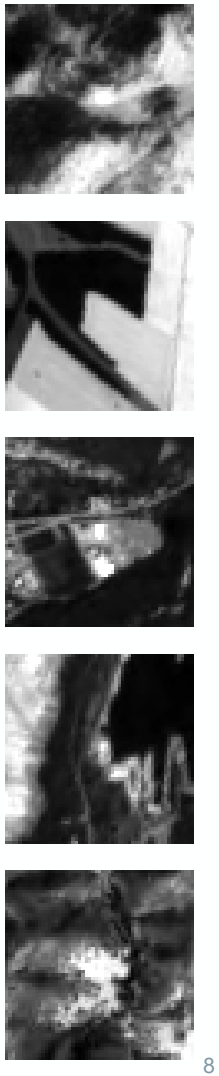
GRI Ground Control Points DB

- What is the GRI GCP DB?
  - A set of textured points of interest extracted from GRI images
    - Subset of GRI coverage
    - Relevant features of the landscape automatically detected
    - Same Geometric Quality as GRI
    - Perennial
    - Qualified

- Use context :
  - In order to be easily usable for S2 refining but also in other contexts than S2 (LSTM, CHIME...), up to 50m resolution.
  - Points have to be considered as cluster (statistical set)



GRI GCP DB main requirements

GCP's in L1B

- sensor geometry as the L1B GRI
- reference to the L1B datastrips
- attached crop image(s): 10m resolution, 57x57p

GCP's in L1C

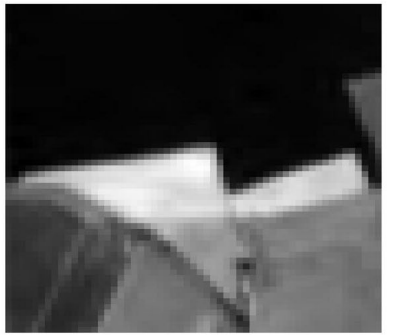
- user oriented
- ground coordinates (with Copernicus DEM 30m)
- attached crop image(s): 10m resolution, 57x57p, rectification on constant Z value, local UTM projection

Generic constraints

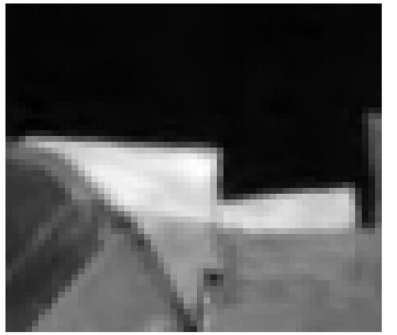
- distributed by square degree
- mean density about 200pt/deg^2
- free open source
- a related documentation for public distribution: Product Handbook and Validation Report

57x57 pixels

L1B chip(s)



L1C chip(s)



GRI GCP DB building process

Generate candidates from the GRI

- Extracting textured points using hessian criteria: radiometric criteria only
- Same coordinates as the GRI
- Associate homologuous points from each GRI overlapping image

Validate and filter points

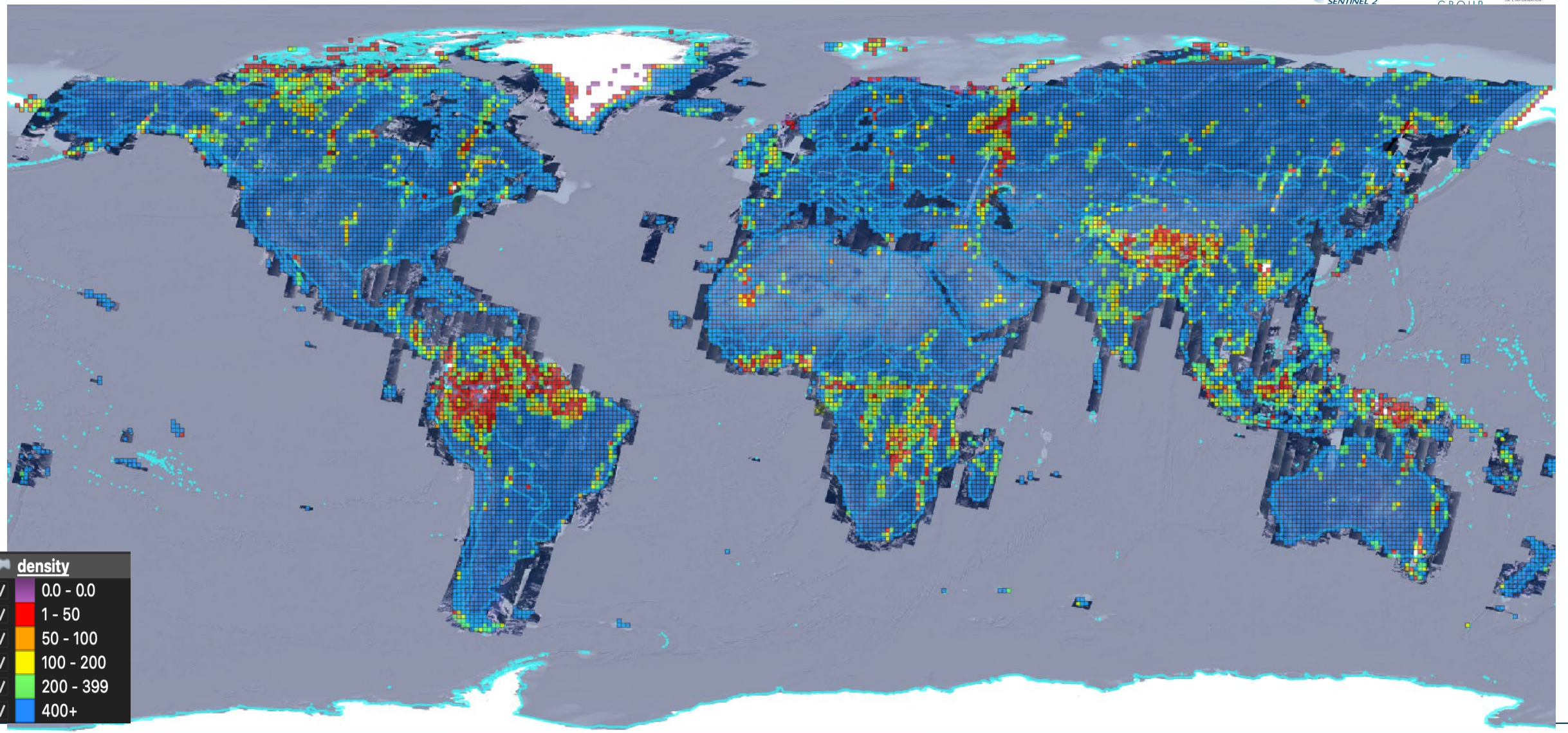
- Validate points on a S2 L1C stack by correlation
- Spatial filtering
- Manual checking

Generate products

- Distribute as square degree DB
- Points description (JSON)
- L1B and L1C (UTM) chips (TIF)

Collect quality indicators: radiometric, geometric, seasonal…

GRI GCP DB expected density



GRI GCP DB final validation

Validation for each GCP

- Includes strong gradients or enough texture to be used by the S2 correlation tool (gradients, entropy & anisotropic ratio)
- Clouds, snow and water bodies assessment using with Fmask
- Has a good potential using the S2 correlation tool: estimation of the winter and summer correlation scores using at least 3 non-cloudy 2020-21 images

Validation of the spatial distribution of the GCPs:

- An adequate density of the GCPs over the 1°x1° grids
- An adequate density in the overlaps between the S2 orbits (for the S2 refining optimisation)

GRI GCP DB: JSON file metadata

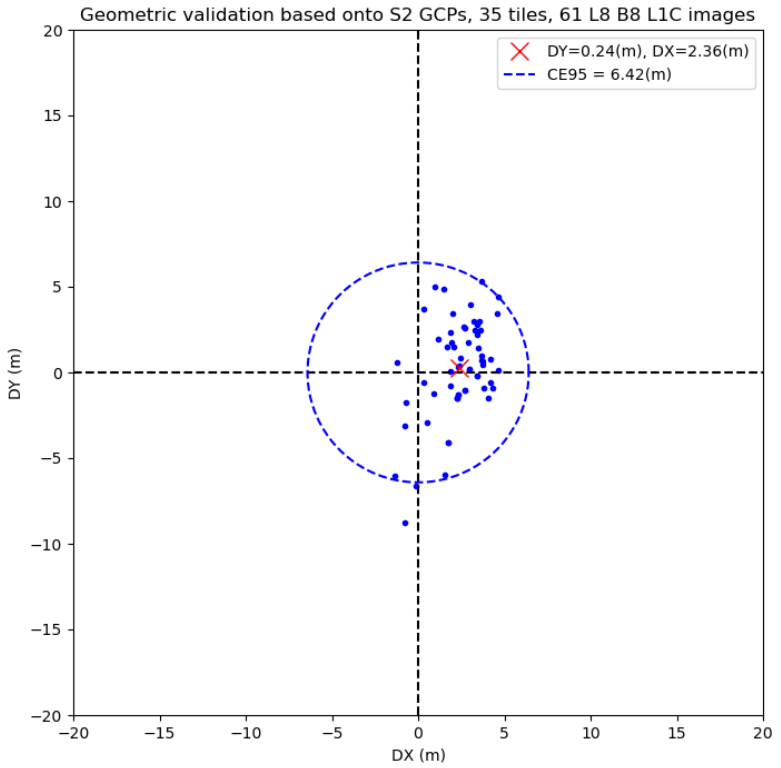
- **Product Info/ Tile Info**
  Version , Z Source, Ellipsoid Name, Geoid Name, Tile Name, Tile Extent
- **GCP Info**
  ID, Longitude & Latitude (°), MGRS Tiles, Altimetry, Planimetric Accuracy
- **Radiometry**
  Y&X gradient sums, Anisotropic ratio, Entropy, Clouds/Cloud shadows/Water/Snow Masks coverages(%)
- **Quality_Indicators**
  Quality Score , Seasonal correlation scores , Seasonal curvature scores
- **GRI List**
  L1B: Product Name, Datastrip Name, S2 Detector, L1B Chip/ Image Coordinates, L1B Chip/Chip File
  L1C: L1C Chip / EPSG ChipFile, L1C Chip / Image Coordinates, L1C Chip/Chip File
- **GCP Validation L1C List**
  List of the L1C S2 products used to validate the GCP (from 2020 to 2021).

GRI GCP DB expected added values

- Optimised performances:
  - easy to handle by the Sentinel 2 Level 1 processor and for users
  - relevant, preselected and validated points
  - multi-temporal registration improvement
- Accessibility:
  - freely distributed to users for their own geometric applications up to 50m resolution
  - easy to support spatial query: distributed in square degrees, include spatial information about points and MGRS tile
  - parameters accessible for query defined on priorities of the end-user: include quality indicators
- Easy to update and improve density locally (by other S2 refined products or external products)

Landsat 8 Collection 2 geometric accuracy results vs the GRI GCP DB

Example of use of the S2 GCP DB with L8 Collection 2 products



Over Europe

- 61 images used for geometric accuracy estimation
- Very good results: DY=0,24m, DX=2,36, CE95=6,42m

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Thank you for your attention