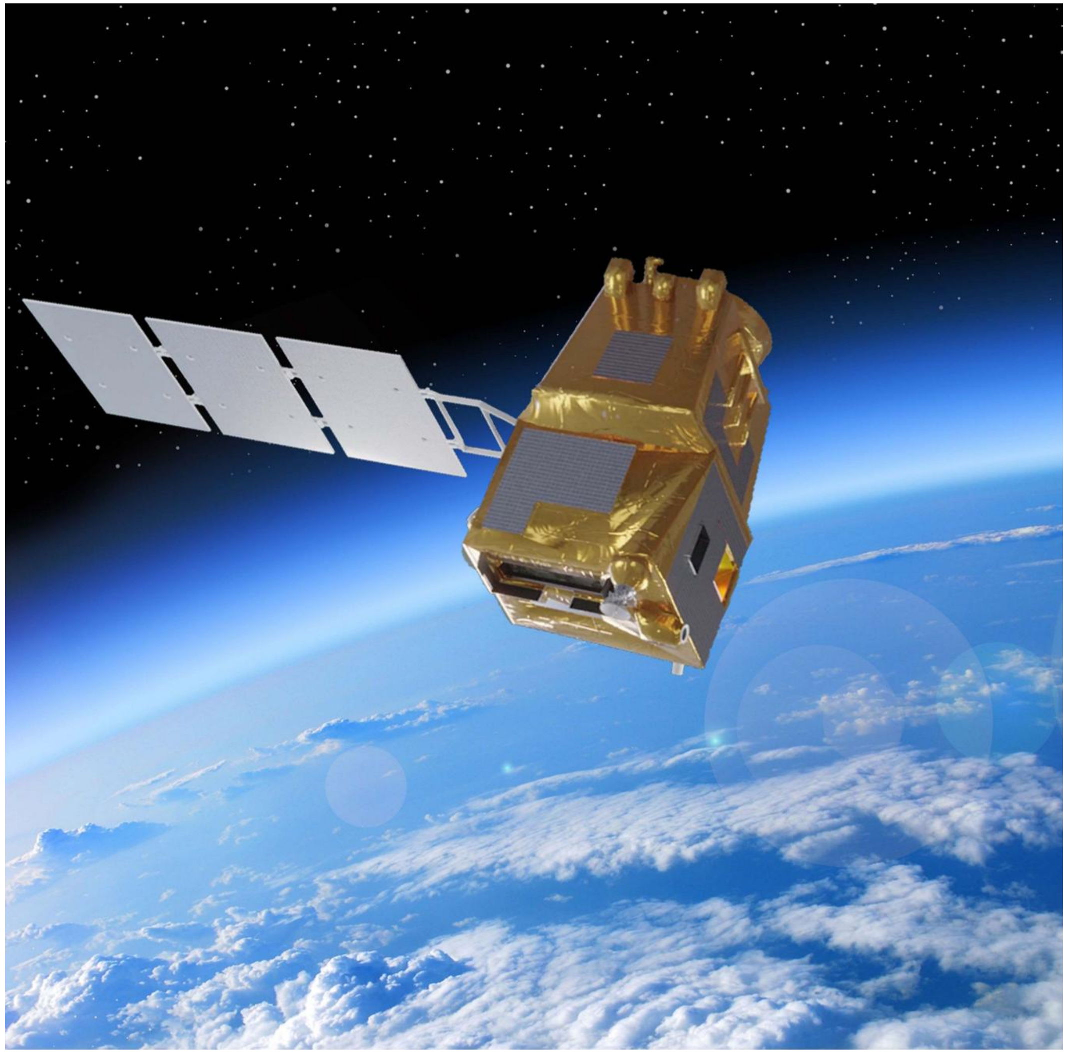
MASTER X

M4.8 PAYLOAD MISSION AND APPLICATIONS

PROFESOR: LUCIA SOTO SANTIAGO
ASIGNATURA: PAYLOADS AND MISSIONS APPLICATIONS (PLMA)



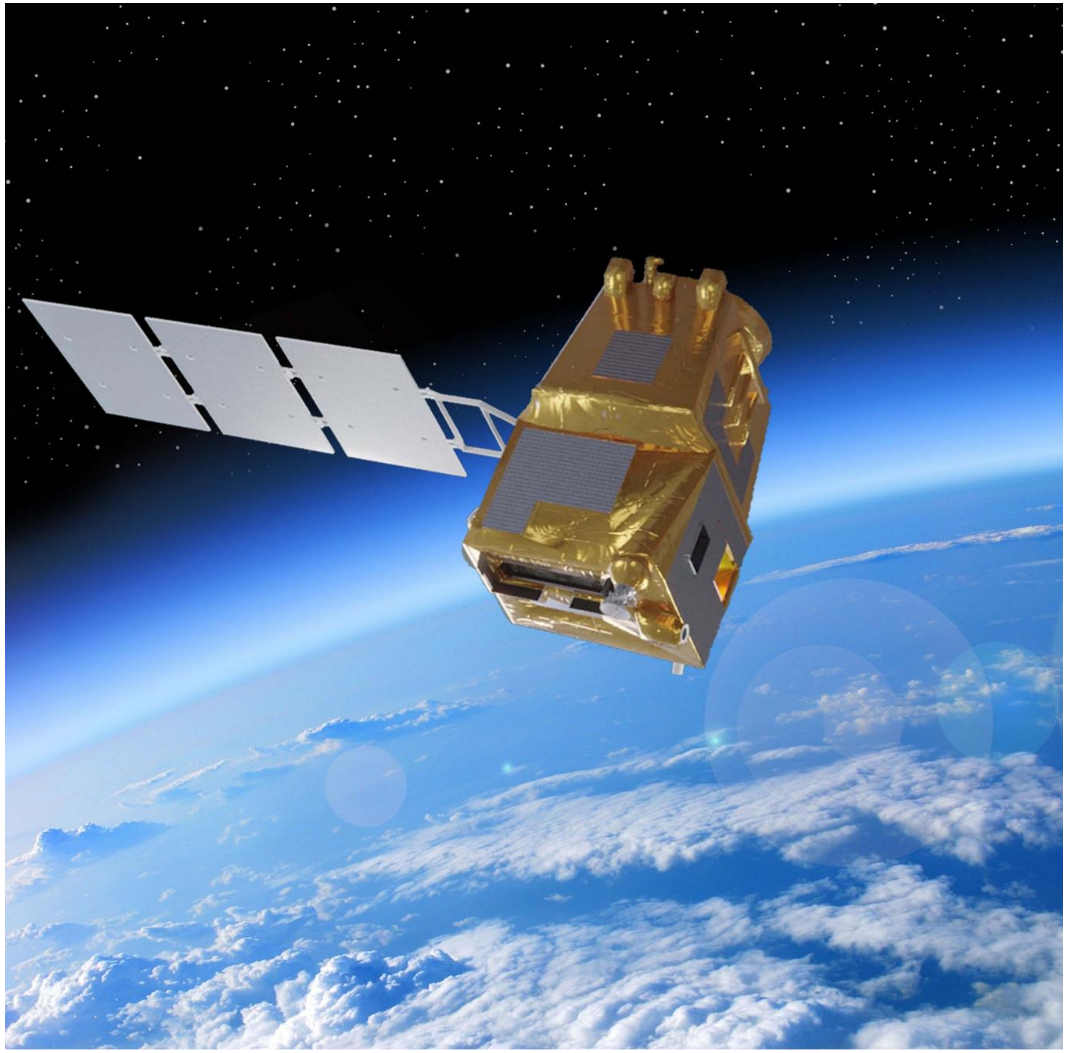
MASTER X ®

ON-GROUND DATA PRODUCTS

- Data extraction
- Levels of data processing
- Description of the Payload Data Ground Segment (PDGS)
- End-to-End Simulators (E2ES)
  - Instrument Data Simulators (IDS)
  - Ground Processor Prototypes (GPP)
- Operational processors

*In this topic we will introduce **Earth Observation Data Processing**, a fundamental activity in the Space domain.*

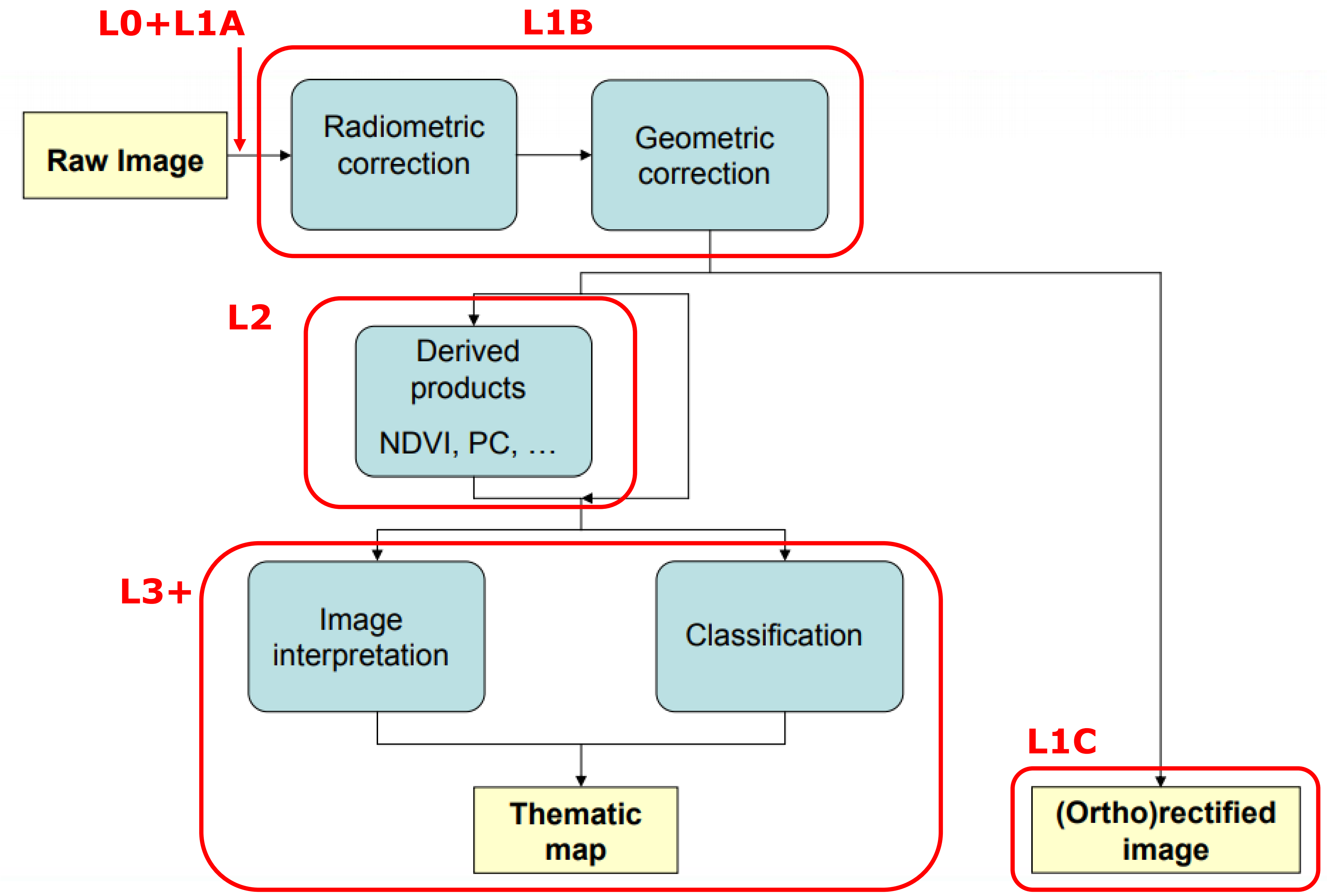
DATA EXTRACTION



MASTER X®

Data processing steps

- The satellite sends to Earth a stream of data.
- That data, which is formatted and compressed, needs to be processed to retrieve the information we are looking for (e.g., the weather forecast).
- Essentially, the steps that we need to do are:
  - **Uncompress the data and check** that it is not corrupted, has gaps, etc. → **L0.**
  - Translate the digital numbers to **physical units** (e.g., radiances) → **L1A**
  - **Calibrate** the data (geometrical, radiometrical, spectrally) → **Appended in L1A and applied in L1B** processing. Obtain the „best possible data" as measured by the sensor.
  - **Regrid**. Interpolate to a common orthorectified grid → **L1C**
  - Process to obtain the desired derived **variables** (e.g., Land Surface Temperature, soil moisture) → **L2**
  - Process to obtain **maps**, evolution of parameters, statistics, trends → **L3+**



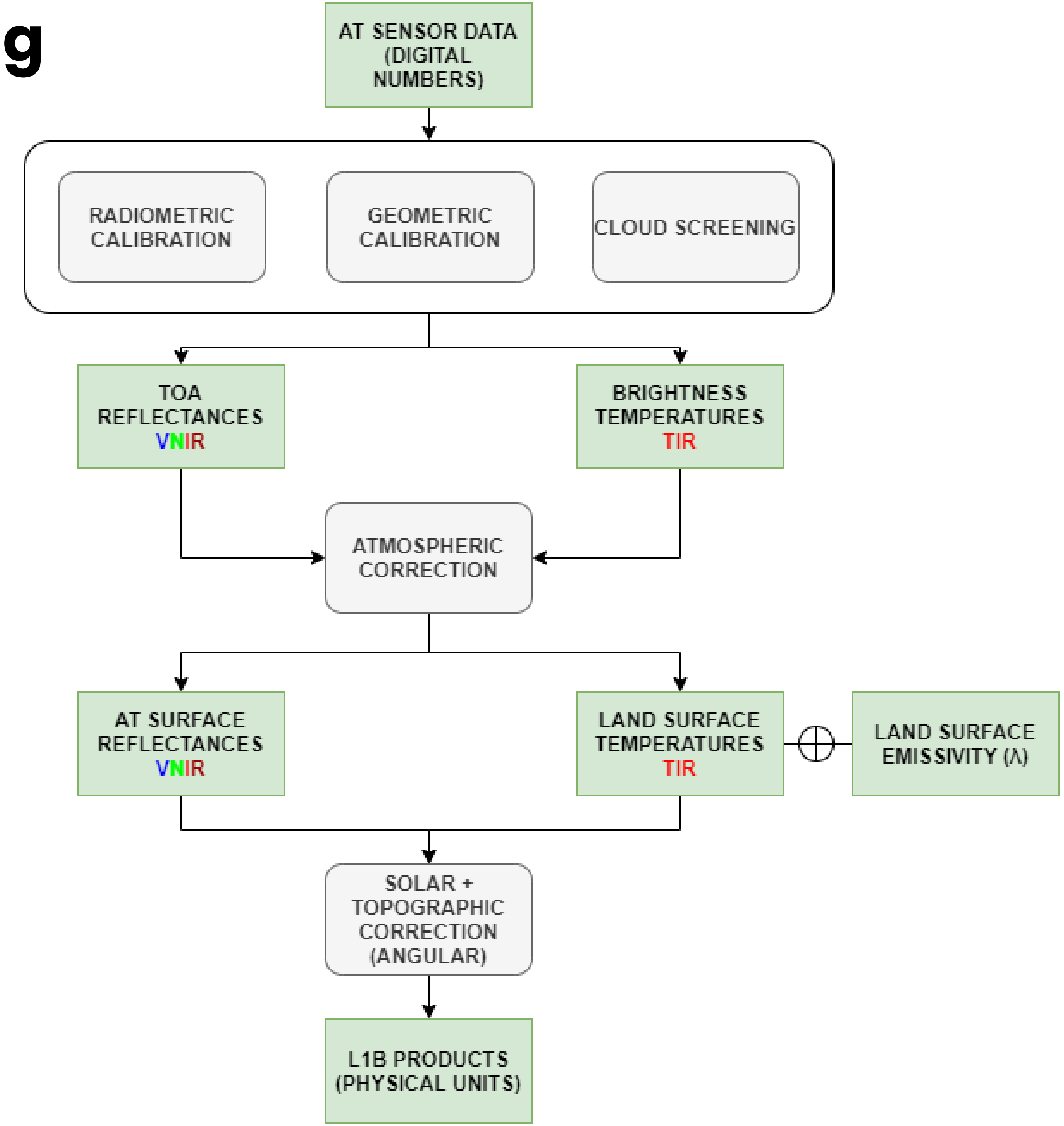
Source: http://earth.esa.int/landtraining09/D1Lb2_PotuckovaOpticalBasics.pdf

Terminology

- **Processing** → The satellite stores the data in the on-board memory (in „digital numbers”). Processing is all of the stes applied to this digital number in order to retrieve what we actually want to measure (for example „the salinity of the ocean”).

- **Calibration** → Any instrument, and each of its detector elements, responds in a not-ideal way due to a number of effects. This response is measured against a standard in the laboratory on-ground (before launch) and during the satellite’s operation. This reponse is used to remove the errors introduced by the response of the instrument, to try to achieve the best possible knowledge of the physical variable being measured.

L1B processing steps



Radiometric & Spectral Calibration

- The instrument is *not* ideal in the following ways:
  - **Imperfect optics** (telescope, spectrometer, lenses, any optical element) → straylight, smile/keystone effects
  - **Imperfect detection**:
    - Each detector element responds differently to the same input radiance → Photo Response Non-Uniformity.
    - Electronic noise → Dark-noise, dark signal.
    - Readout errors → Cross-talk

→ Radiometric & spectral calibration

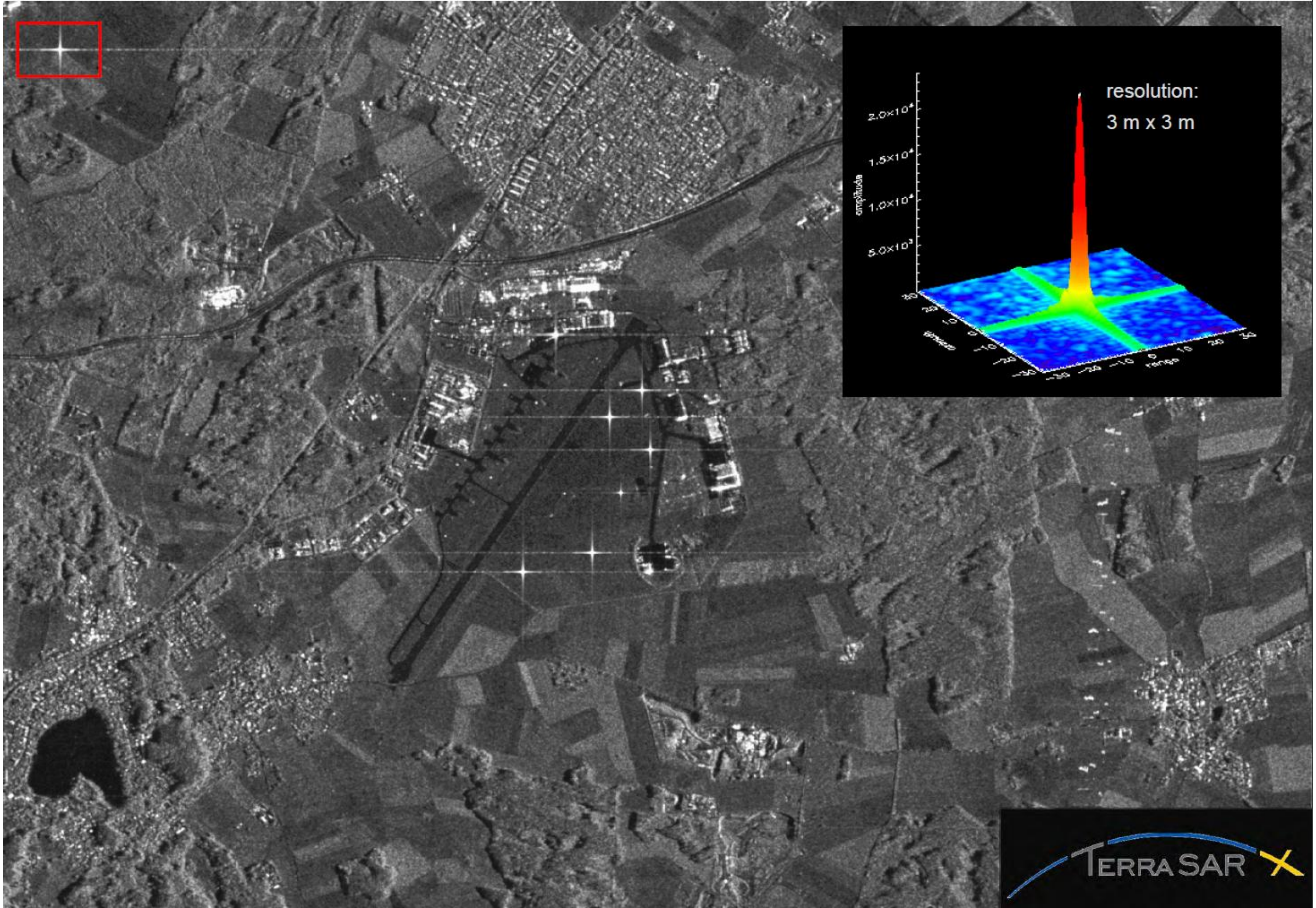
ⓘ Photon Response Non-Uniformity

(a) Input Y (b) r_a (values increased by $\times 10^4$)

ⓘ Calibration Devices

- Examples of calibration targets with well-known reflectivity (Radar Cross Section) for external calibration of the SAR system

Source: http://seom.esa.int/landtraining2015/files/Day_1/D1T2a_LTC2015_Younis.pdf



Source: http://seom.esa.int/landtraining2015/files/Day_1/D1T2a_LTC2015_Younis.pdf

Correction to obtain Surface properties (T, ρ)

- After correcting the radiances for the instrument effects (calibration), we are interested in retrieving the surface properties:
  - **VNIR:** Surface reflectances — ρ
  - **TIR:** Surface temperatures — T
- For this we need to:
  - Correct for the **Atmospheric** propagation we use the Radiative Trasnfer Models to estimate the atmospheric effects of absorption and scattering (see #3 Passive Optical instruments).
  - **TIR:** Correct for the **Emissivity**
  - **Cloud** screening.
  - Correct for the **topography** (angular corrections) and **Solar** conditions

Geometrical Calibration

- The satellite records its own ephemeris:
  - **Position**: with **GNSS** sensors (Galileo, GPS)
  - **Attitude**: with **accelerometers/star-trackers**.
- The instruments that record the position/attitude have associated knowledge errors, which we try to compensate.
- This is quite an elaborate processing and can be done in several ways:
  - With ground control points.
  - Feature matching

→Geometrical calibration

1. In your image, you are calculating the geolocation for all the pixels based on your knowledge of the satellite position, attitude and line-of-sight.
2. Additionally, you know the location on ground (lat,lon,alt) of certain features (a building, or any feature with enough contrast) – the **ground control points**.
3. You compare the position of your geolocation with the real position of the GCPs. You use this to correct the location of all your pixels.

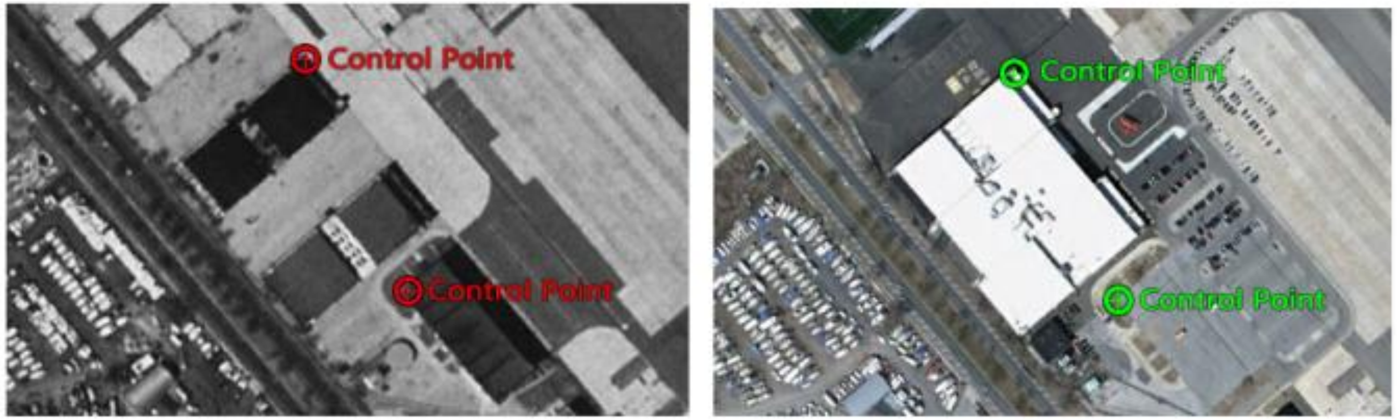
Example of calibration: Ground Control Points

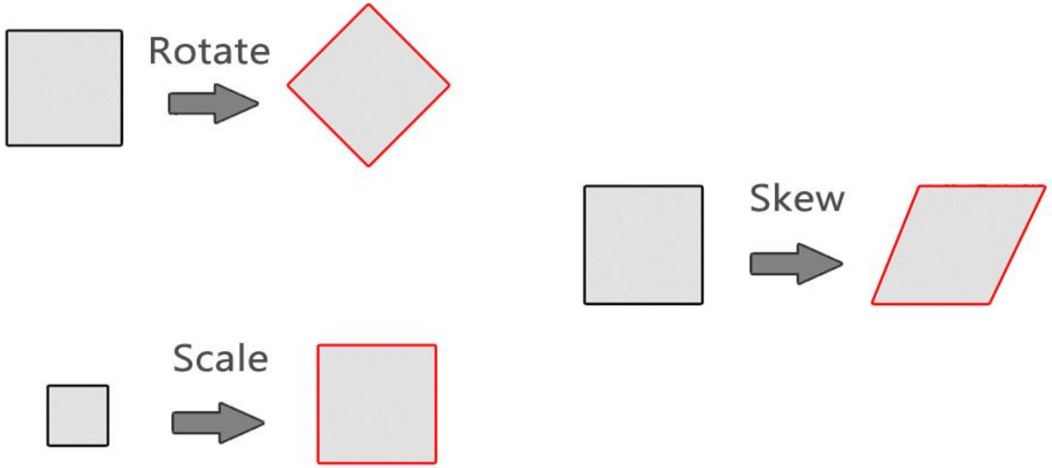
Source: https://www.researchgate.net/figure/GCP-locations-on-Landslide-1-debris_fig4_305031016

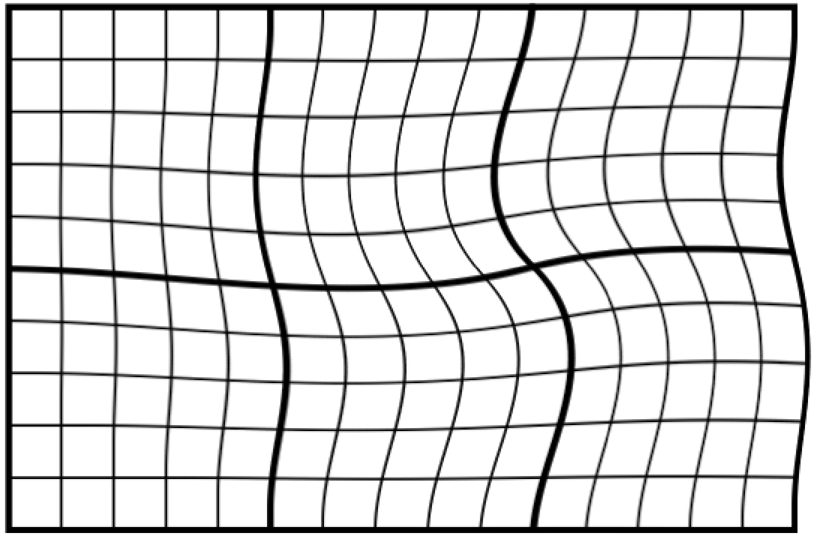
Example of Calibration
Ground Control Points on Reference Image

Source: https://gisgeography.com/georeferencing/

Example of Calibration
Ground Control Points on Reference Image



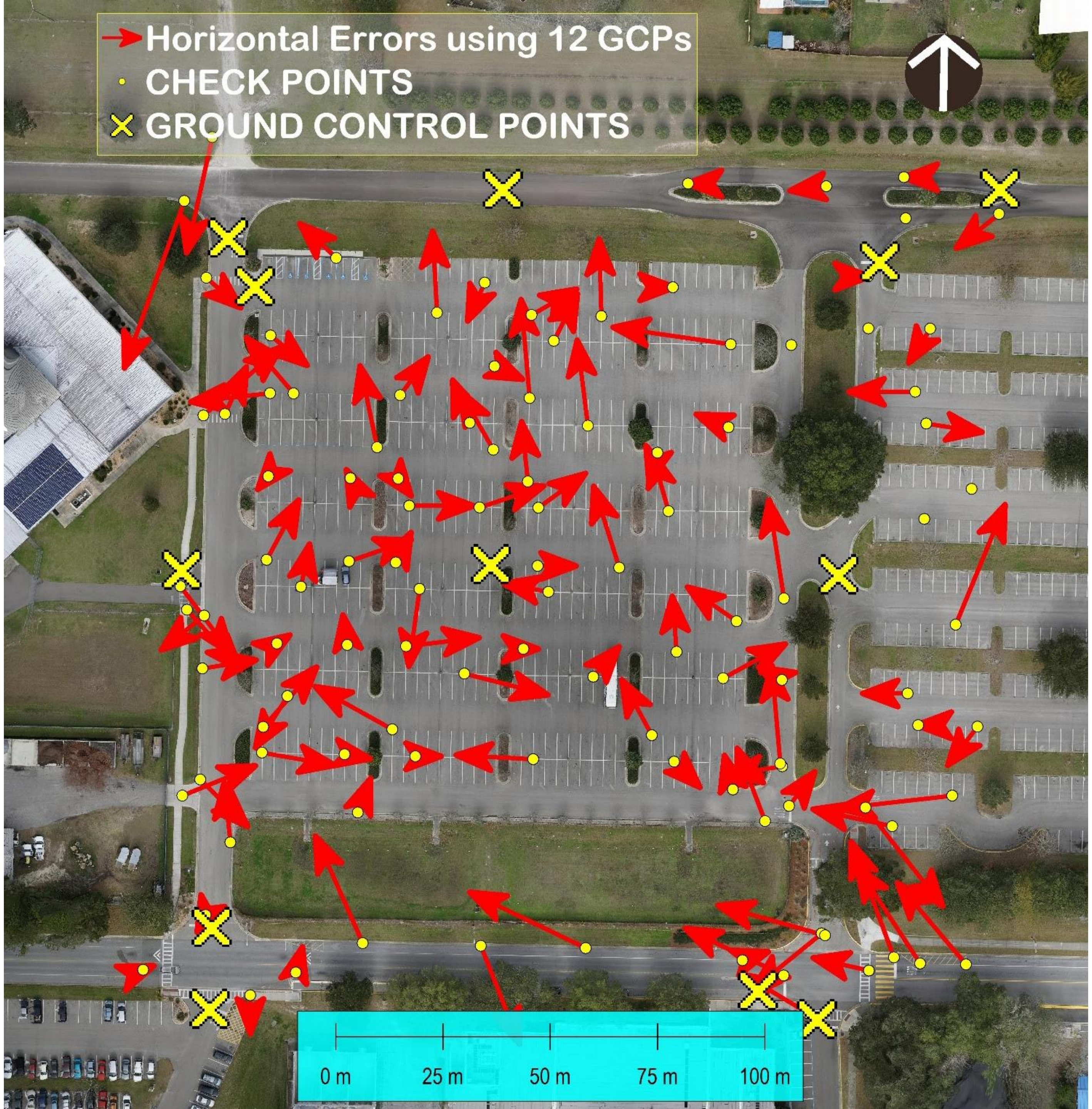




Often enough with affine transformations

In other cases, it may need rubbersheeting

Source: https://gisgeography.com/georeferencing/



Source: http://v-map.net/wp-content/uploads/2015/09/HorizontalErrors12GCPs1.jpg

ⓘ FLEX L0+L1B processing steps →

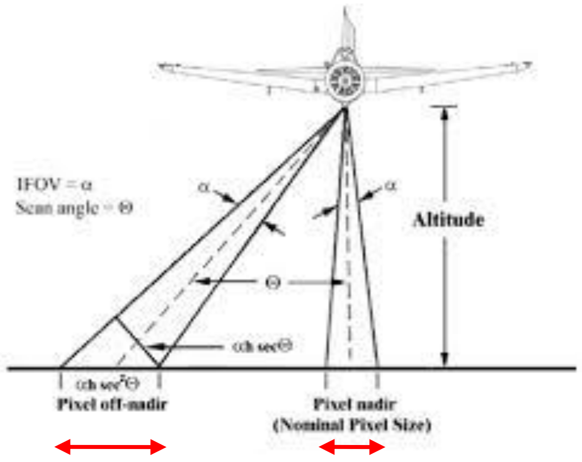
ⓘ Sentinel-3 MWR (radiometer) L1B processing steps →

Table of content

Source: https://sentinel.esa.ir ts/247904/351187/Se Level-1b-MWR-Algorit Theoretical-Baseline-Definition.pdf

Orthorectification and co-regristration (L1C)

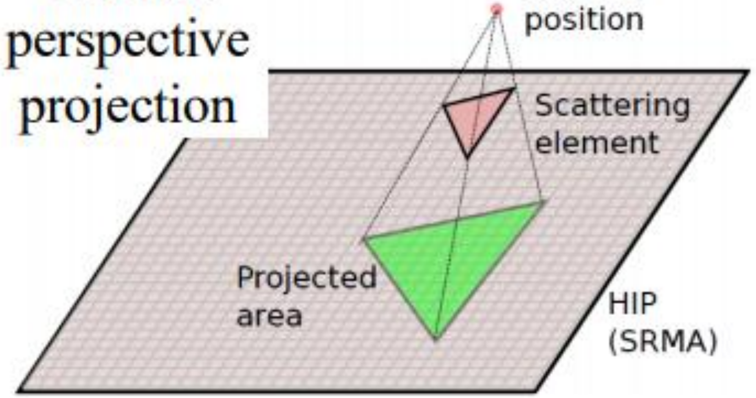
- The L1B product is in sensor geometry. The satellite is in an SSO orbit (probably, or any other orbit), looking with a certai angle ⍰ the position on ground of the detectors is **not** regula
- **Orthorectification is projecting the L1B product to a regular grid**.
- **Co-registration** is an ample term to describe the processing of ≥ two images into a final product. These images can come from different passes of the satellite over a given area, or from different detector lines fron an instrument.

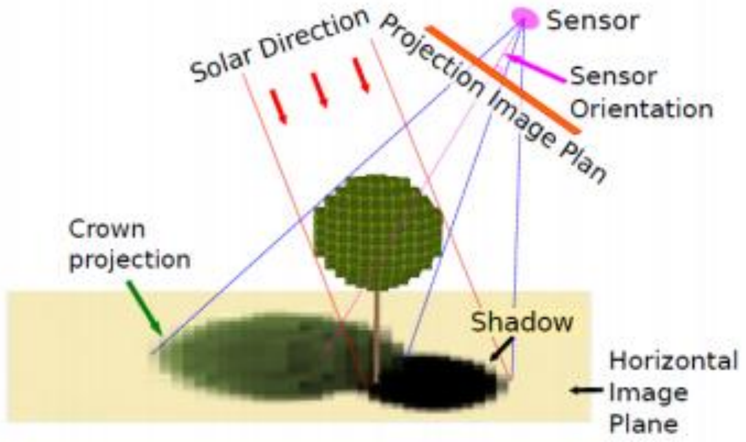


The ground sampling distance off-nadir is larger than in nadir (& lower spatial resolution, higher distortions).

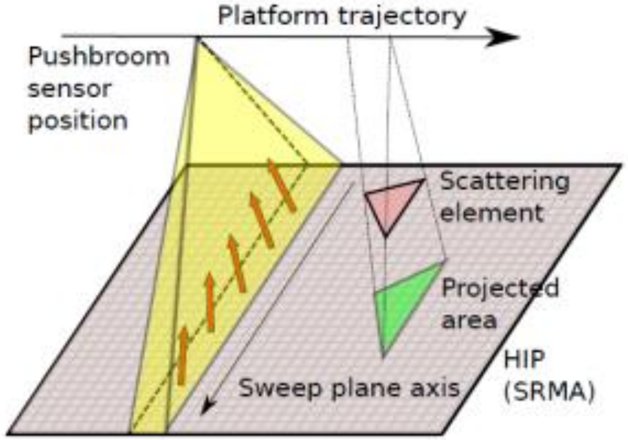
Source: https://link.springer.com/chapter/10.1007%2F978-1-4020-3100-7_3

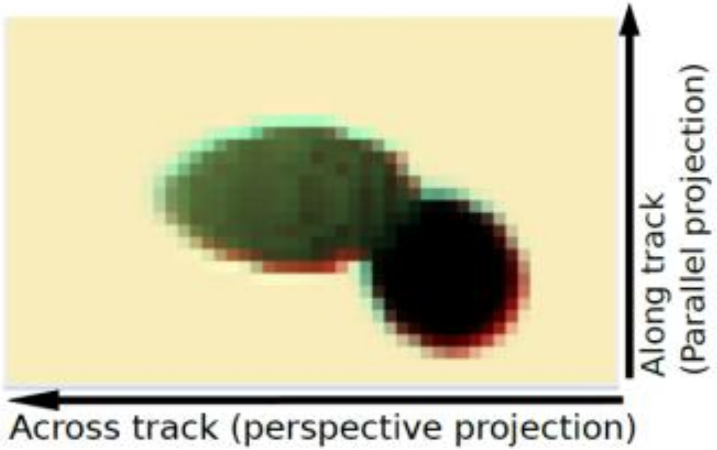
Camera: perspective projection





Pushbroom: parallel-perspective projection

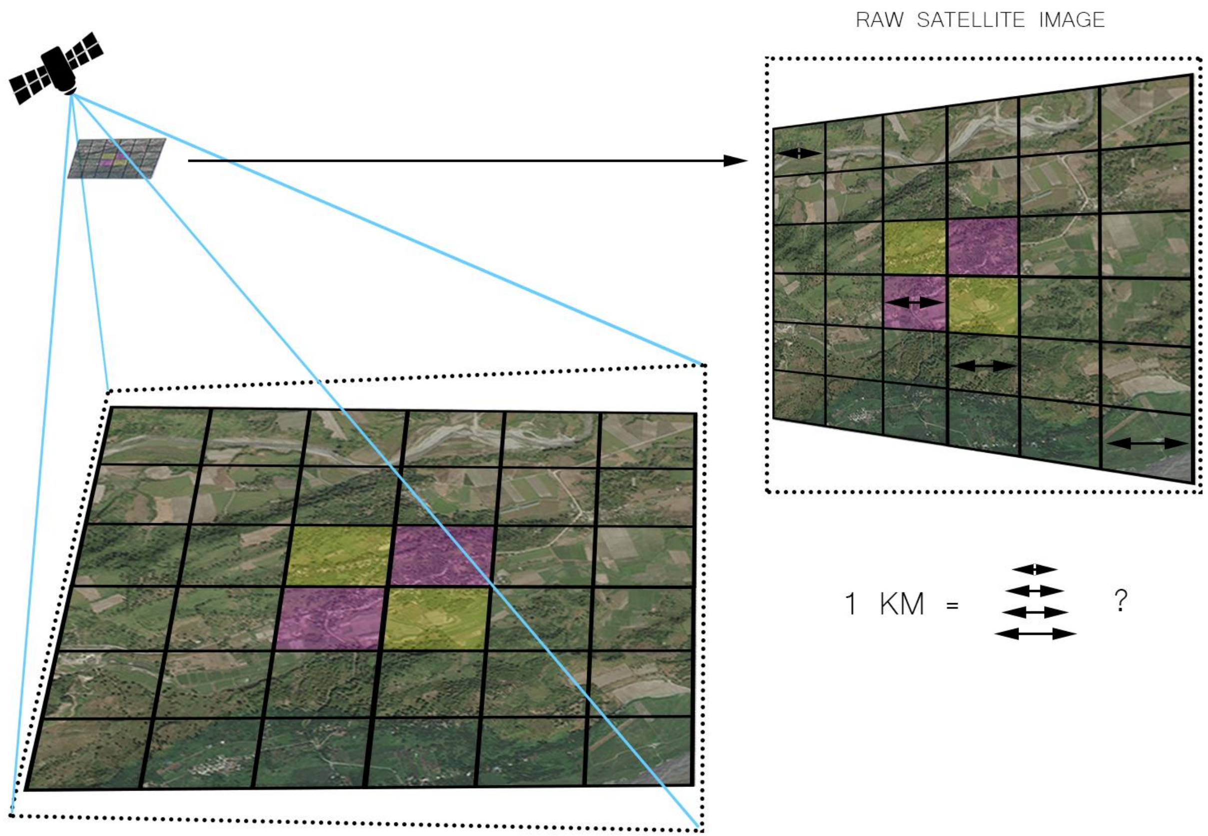


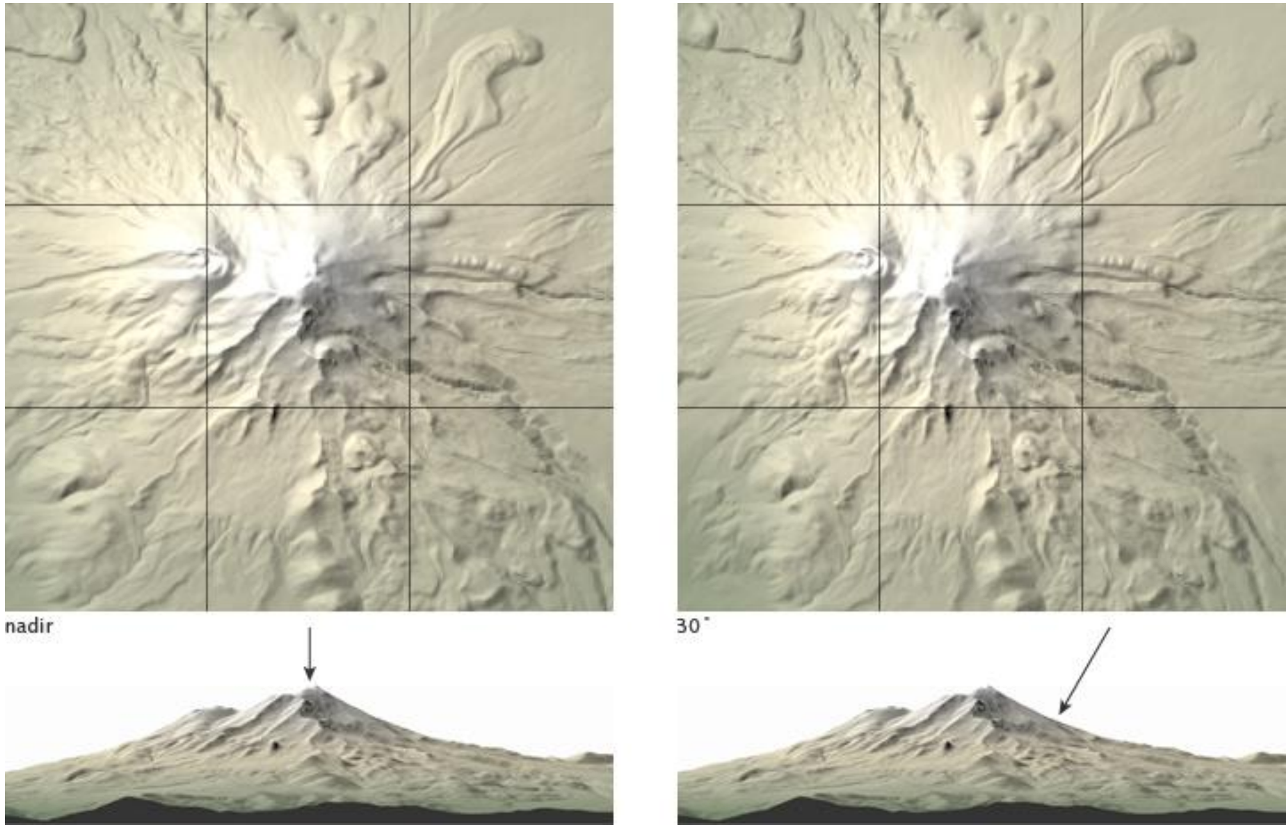


Non-zero FOV impacts RS data: **geometric distortion + view direction difference**

Source: http://seom.esa.int/landtraining2015/files/Day_1/D1T1a_LTC2015_Chuvieco.pdf

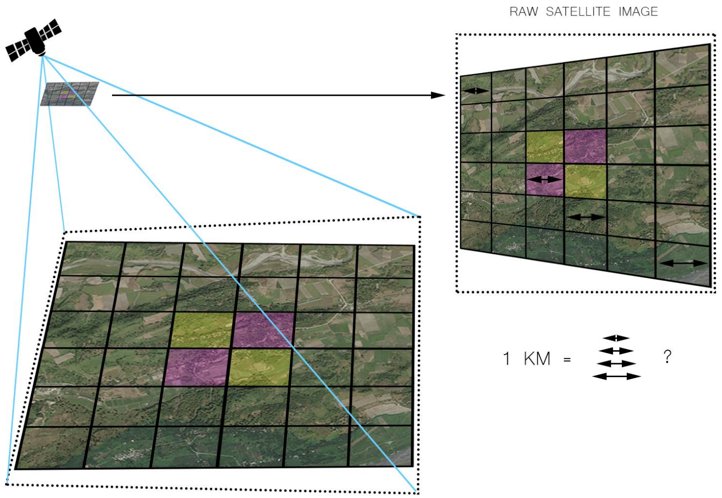
PERSPECTIVE DISTORTION

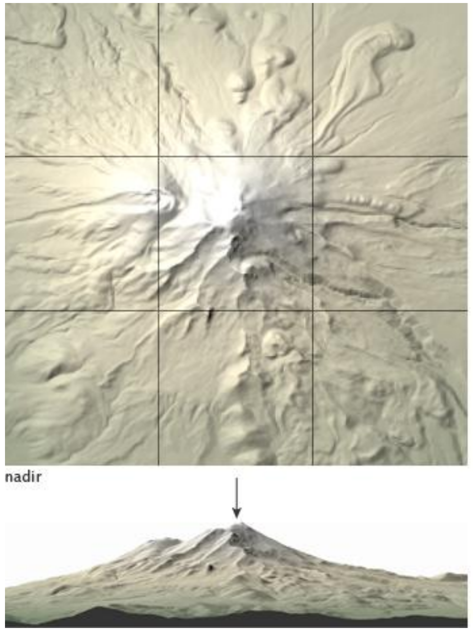


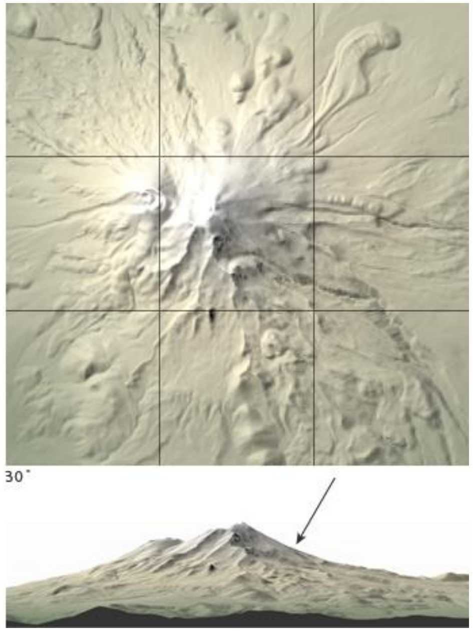


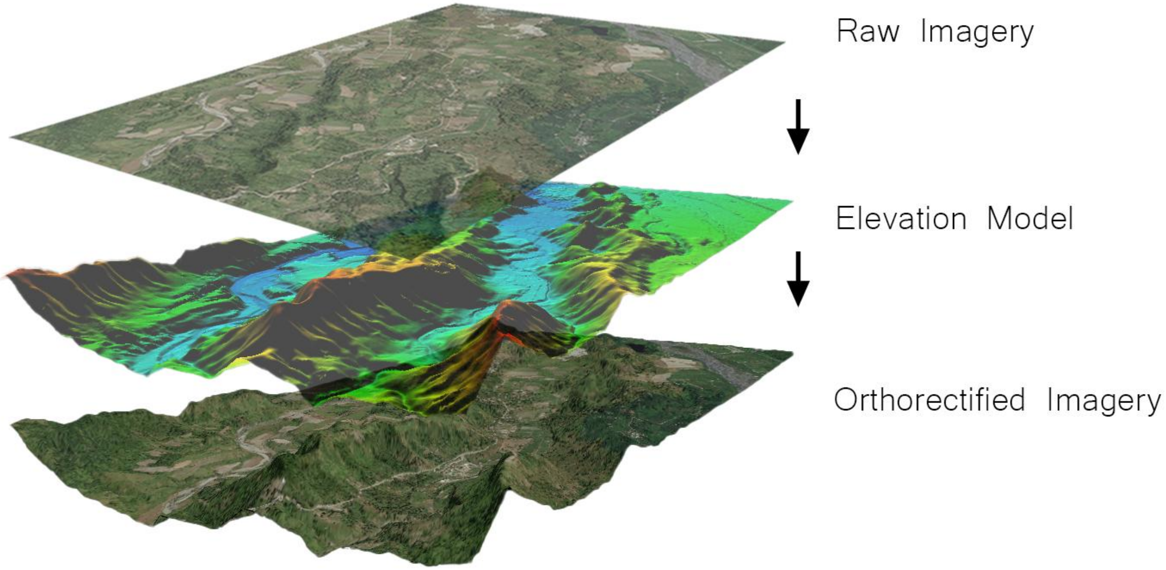
Source: http://seom.esa.int/landtraining2015/files/Day_1/D1T1a_LTC2015_Chuvieco.pdf

PERSPECTIVE DISTORTION

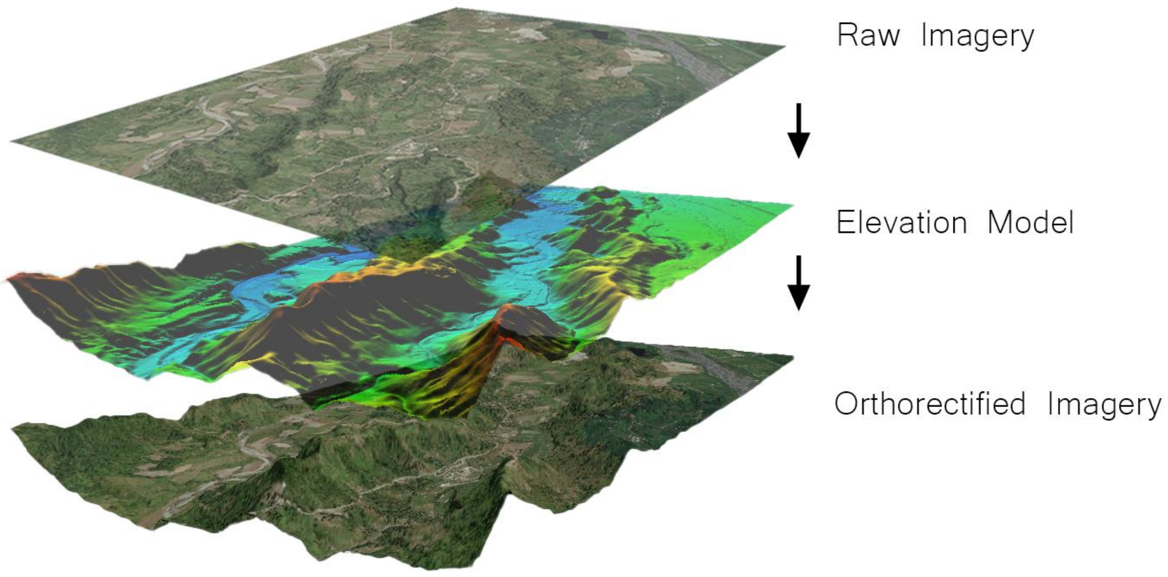


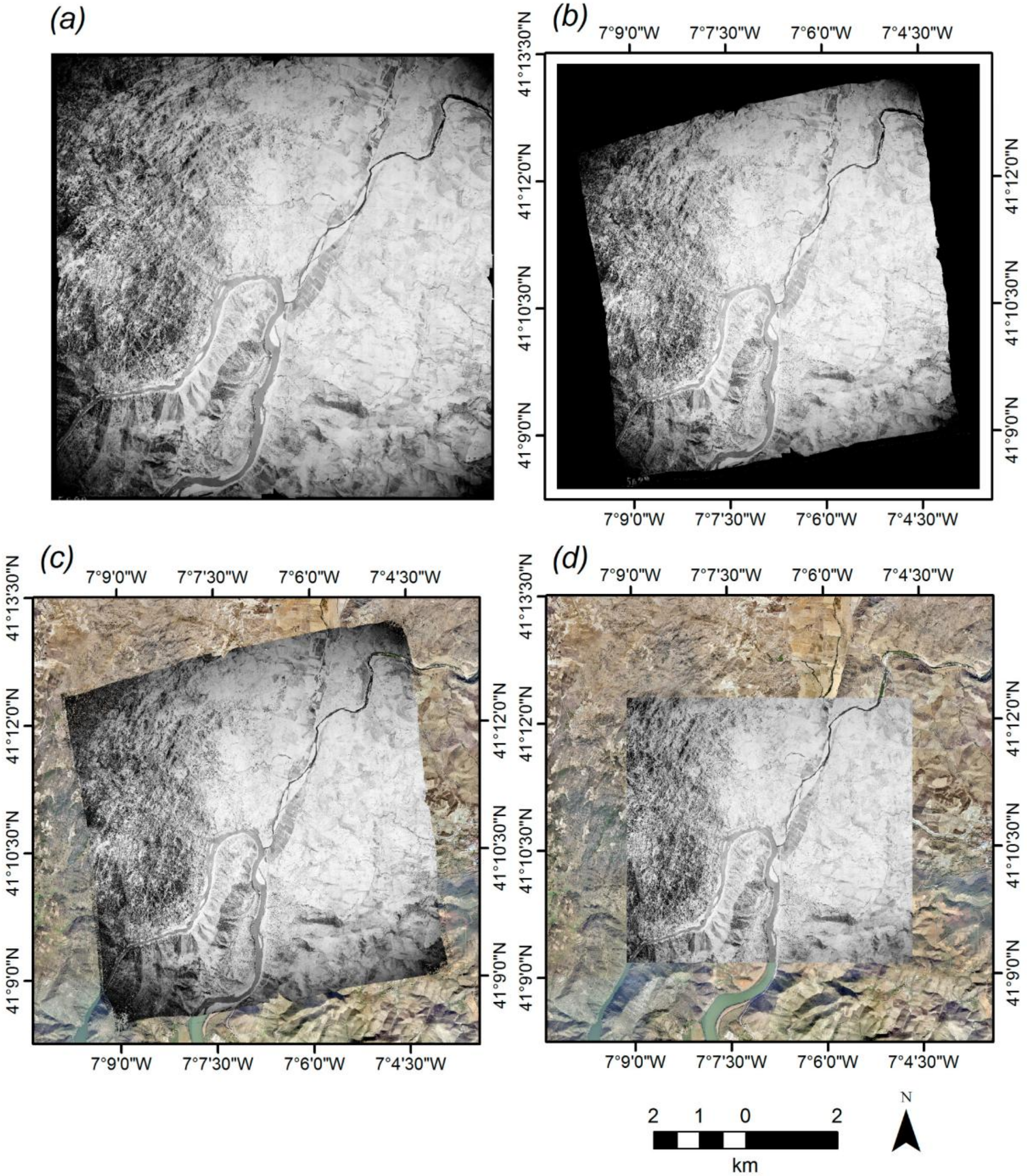






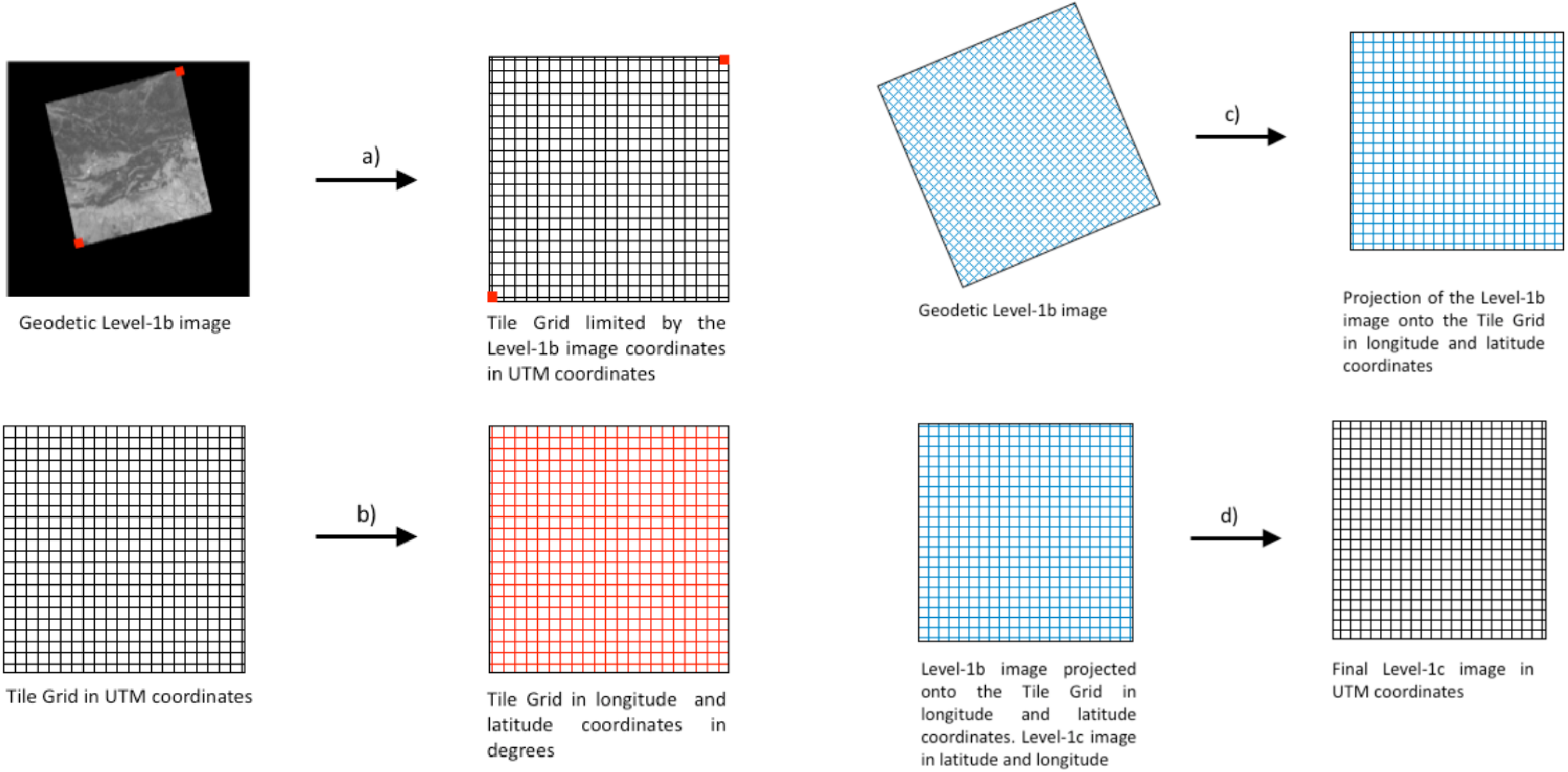
Source: http://seom.esa.int/landtraining2015/files/Day_1/D1T1a_LTC2015_Chuvieco.pdf





Source: http://seom.esa.int/landtraining2015/files/Day_1/D1T1a_LTC2015_Chuvieco.pdf

L1B → L1C. Orthorectification



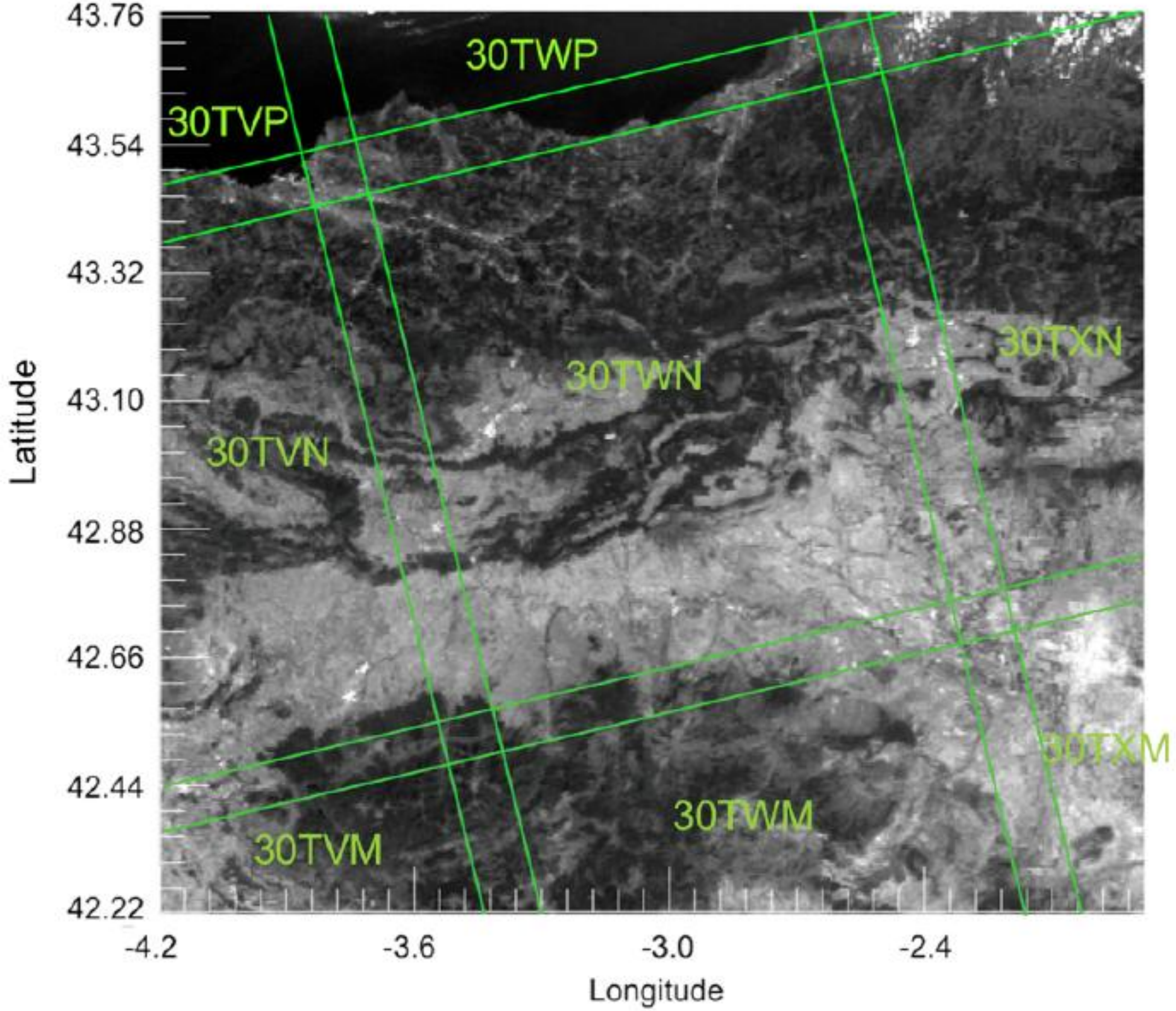
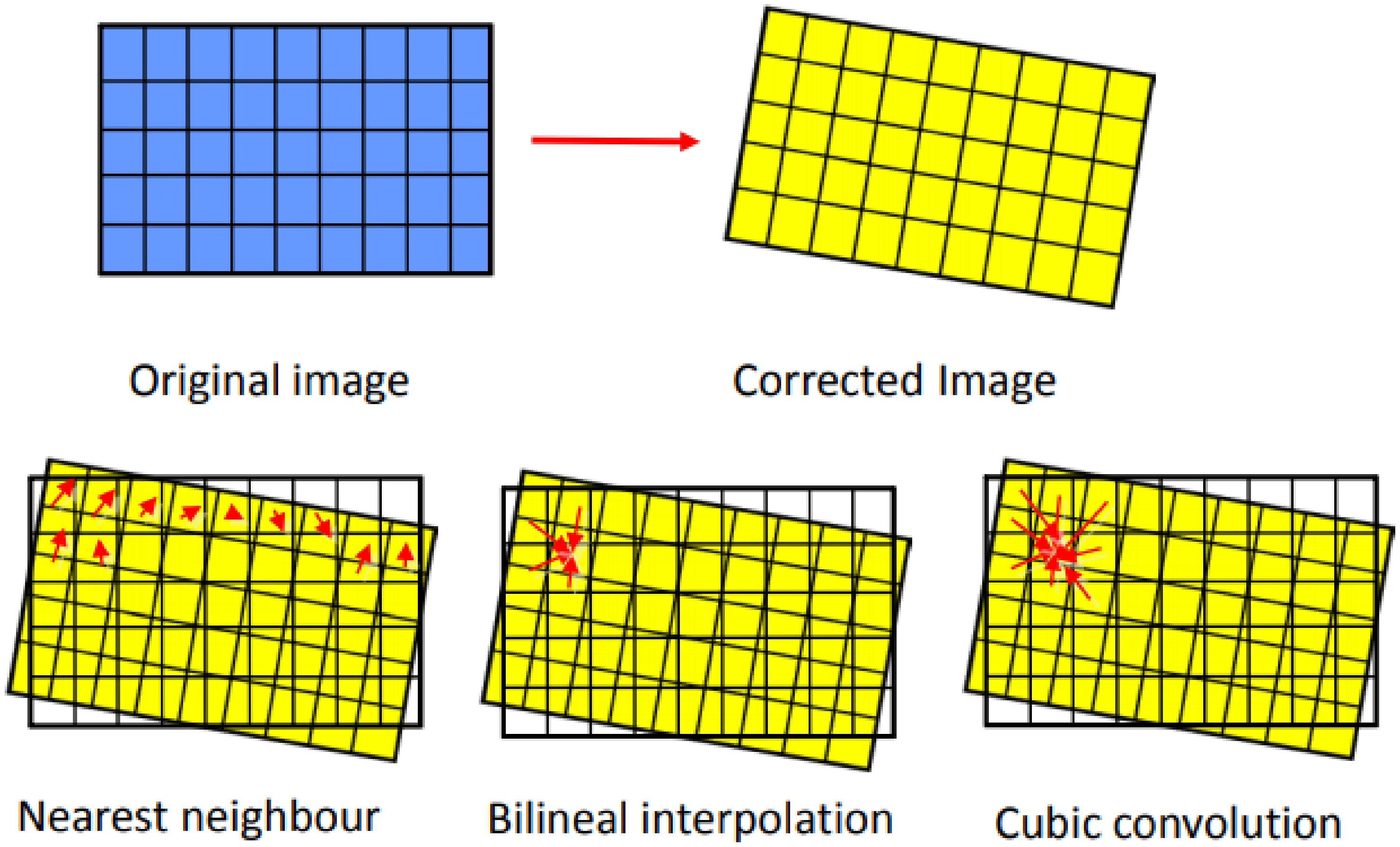


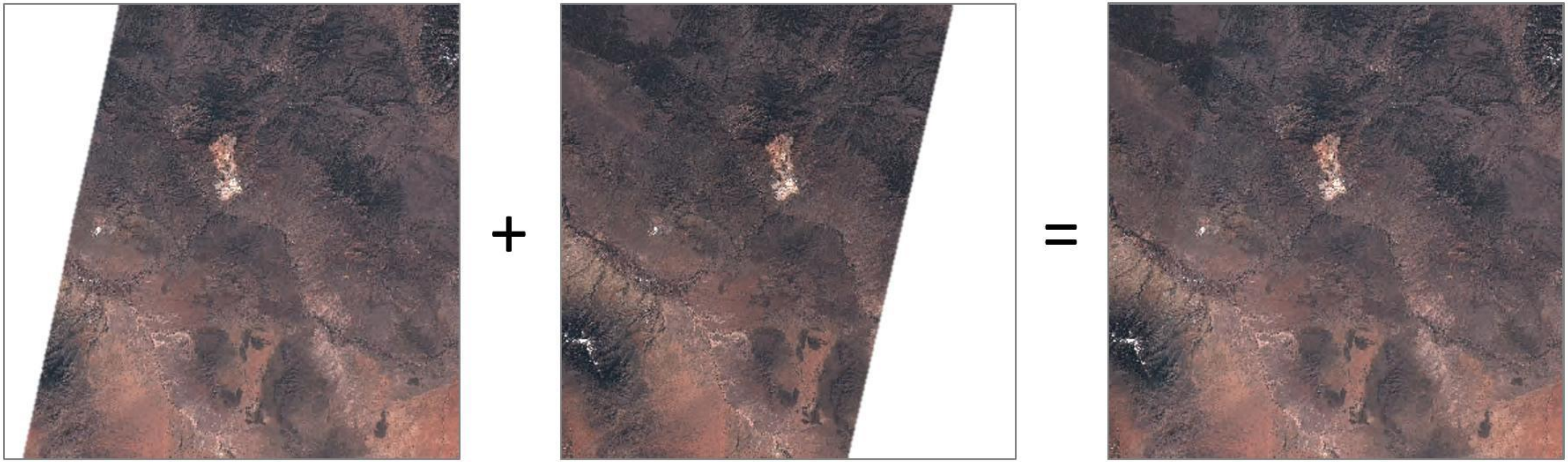
Figure 7: Sentinel-3a SLSTR image with the MGRS tiles over plotted.



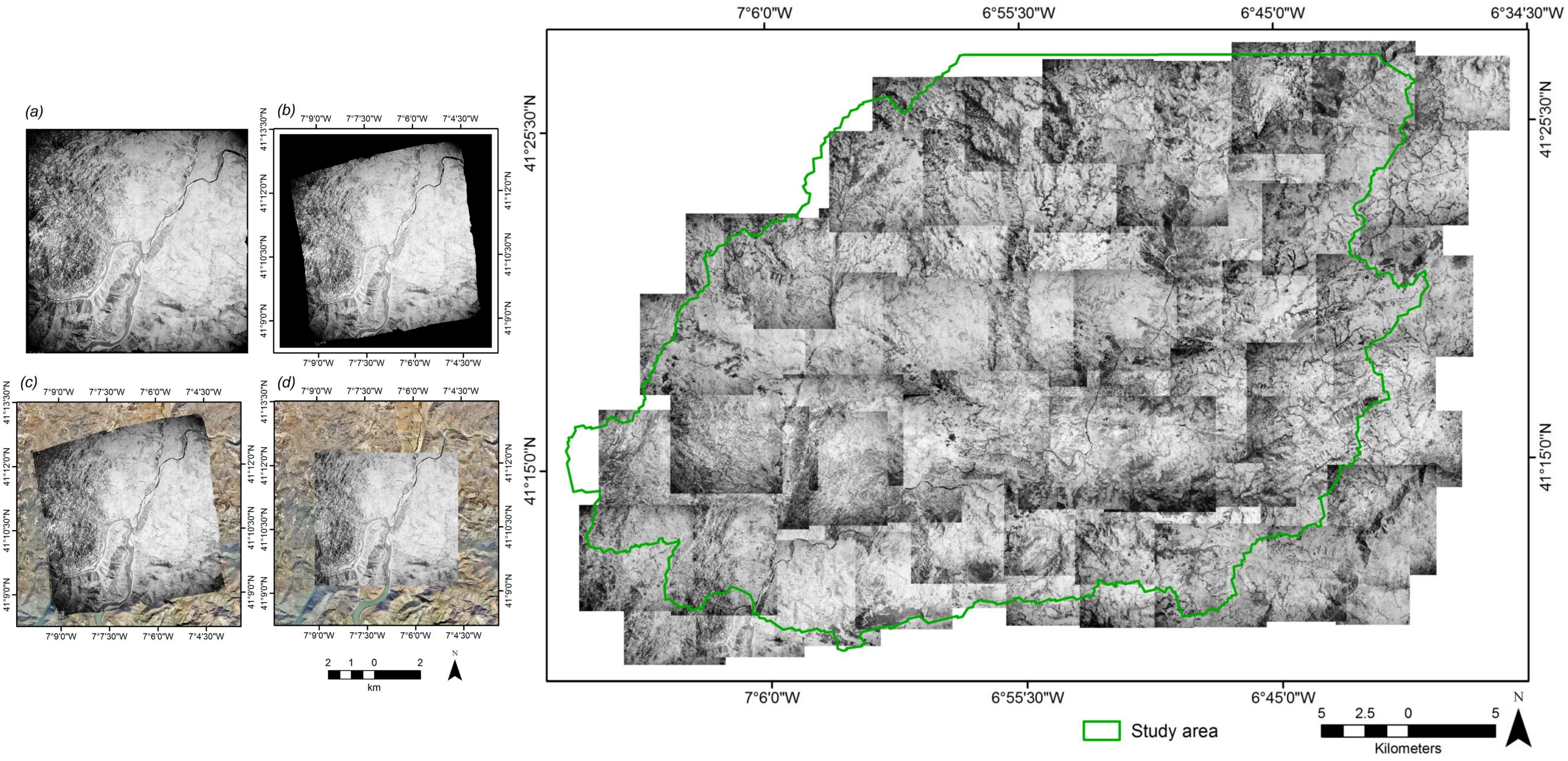
Source: http://seom.esa.int/landtraining2015/files/Day_1/D1T1a_LTC2015_Chuvieco.pdf

Co-registration

This example shows the composition of two Sentinel-2 images from different satellite passes (different temporal acquisitions).



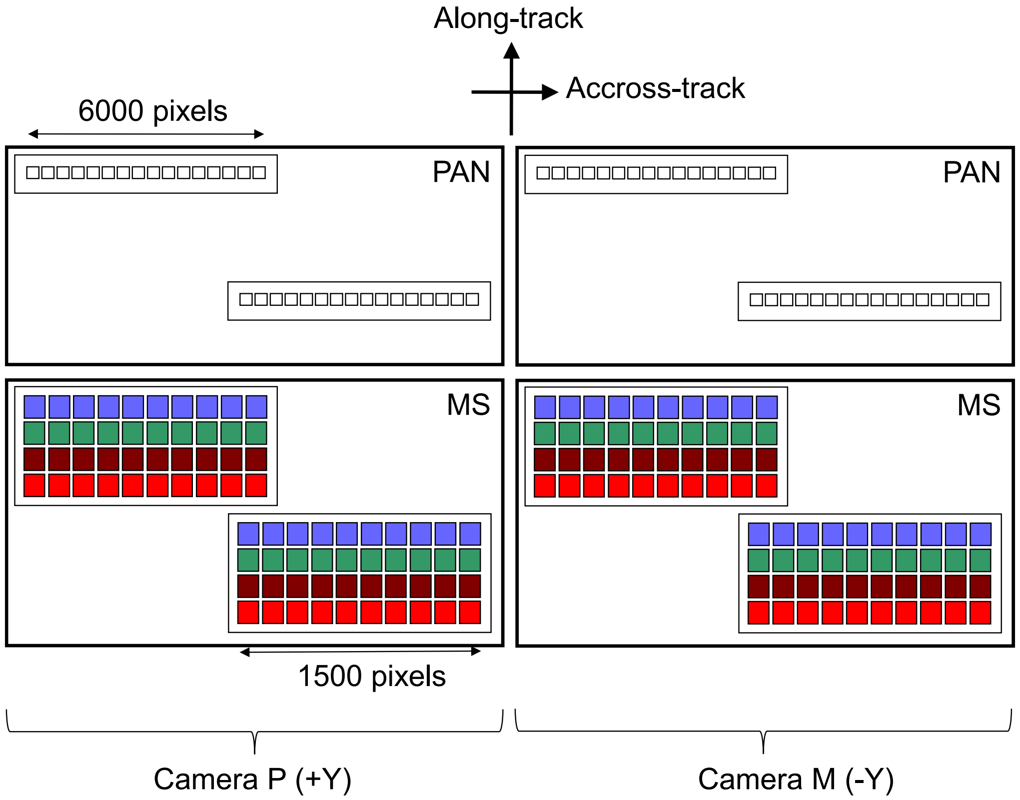
Source: https://gis.stackexchange.com/questions/252592/completing-satellite-imagery-tiles-when-data-coverage-is-less-than-100

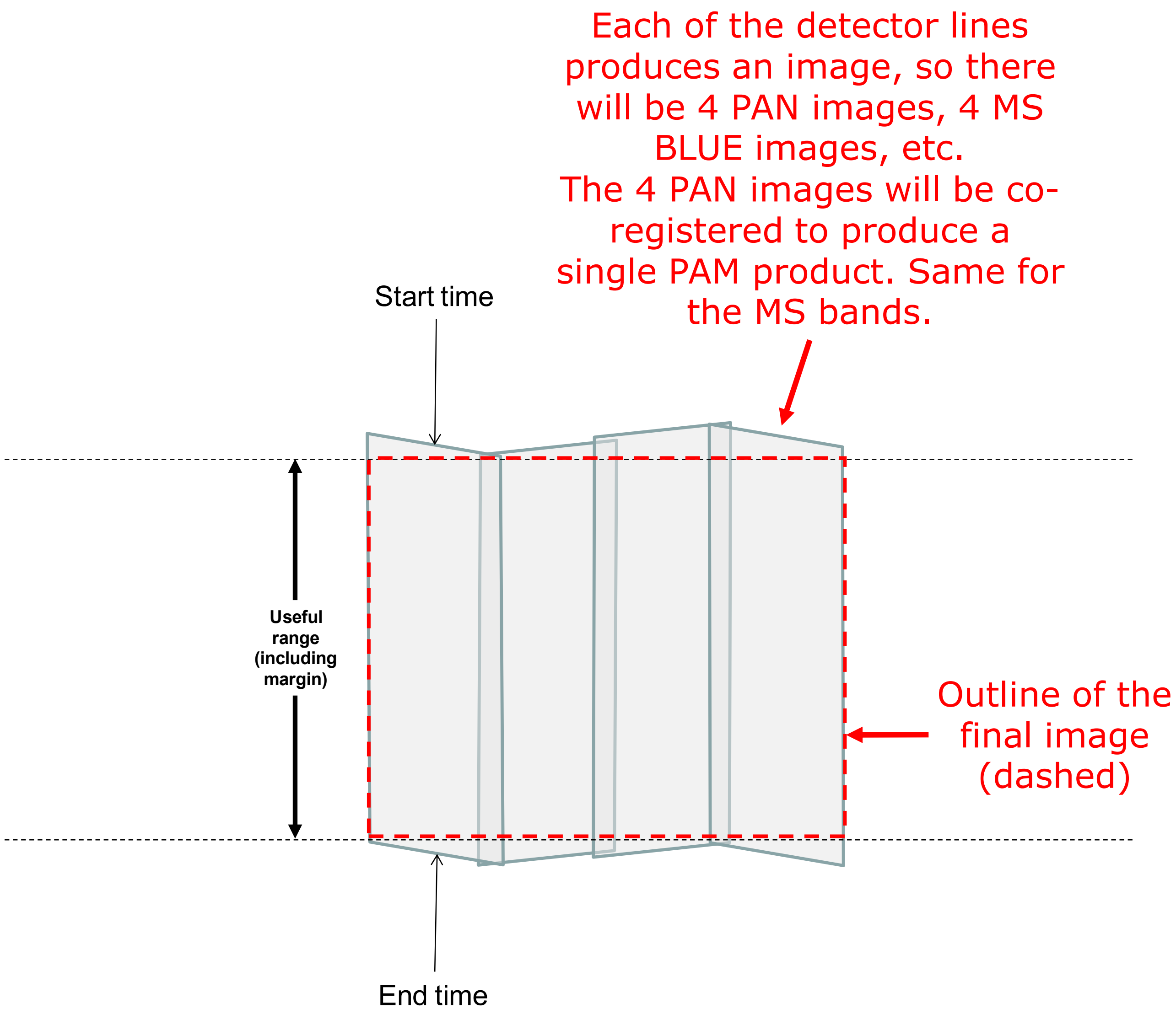


Source: http://seom.esa.int/landtraining2015/files/Day_1/D1T1a_LTC2015_Chuvieco.pdf

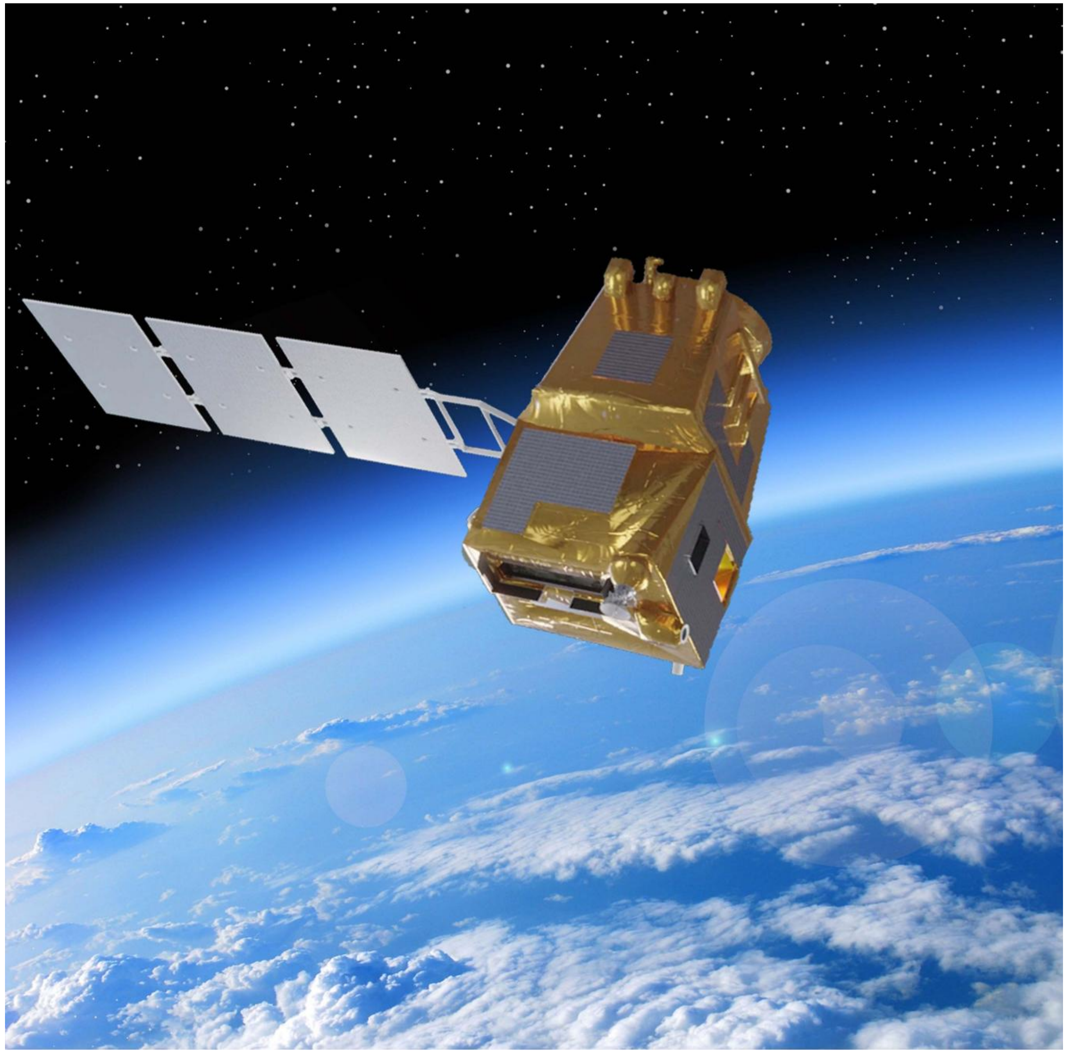
Inter channel co-registration

Diagram showing the coregistration for SEOSAT, which has four detector lines each for the PAN and MS blue, green, red and NIR.





LEVELS OF DATA PROCESSING



Levels of data processing

There is only a loose convention of the data processing levels, so each mission & instrument tweaks and defines its own levels. However, the conventions follows approximately the following data levels for **ESA** projects.

- **Level-0**

Uncompressed, time sorted and annotated data from Instrument Source Packet (ISP).

Missing and duplicate packets removed. Some quality checks are performed.

- **Level-1A**

The **digital values** are transformed into **physical units** (for example radiances).

Calculation of the geolocation for each pixel appended to the product. Ortho-rectification (geometrical calibration) can be calculated at this stage or in Level-1B.

Radiometric calibration calculated and appended (not applied). Some calibration steps can also be performed at L1B.

Levels of data processing

- **Level-1B**

The **calibration** coefficients are applied. This is generally the highest level of „true” physical variables that can be obtained.

This is usually the level of data the scientists want because it has not been interpolated or further processed. This is also the lowest level of data commericially available (Landsat, Sentinel, etc.)

- **Level-1C**

Resampling to a reference equally-spaced grid.

Co-registration of the bands (if there are several sensors, compose the whole image).

Levels of data processing

- **Level-2**

Geophysical variables, the goal of the mission (for example „evapotranspiration”).

- **Level-3+**

Level-3 and higher products are derivatives, for example, time series, global maps, etc.

Example L0 to L1C of the LSTM

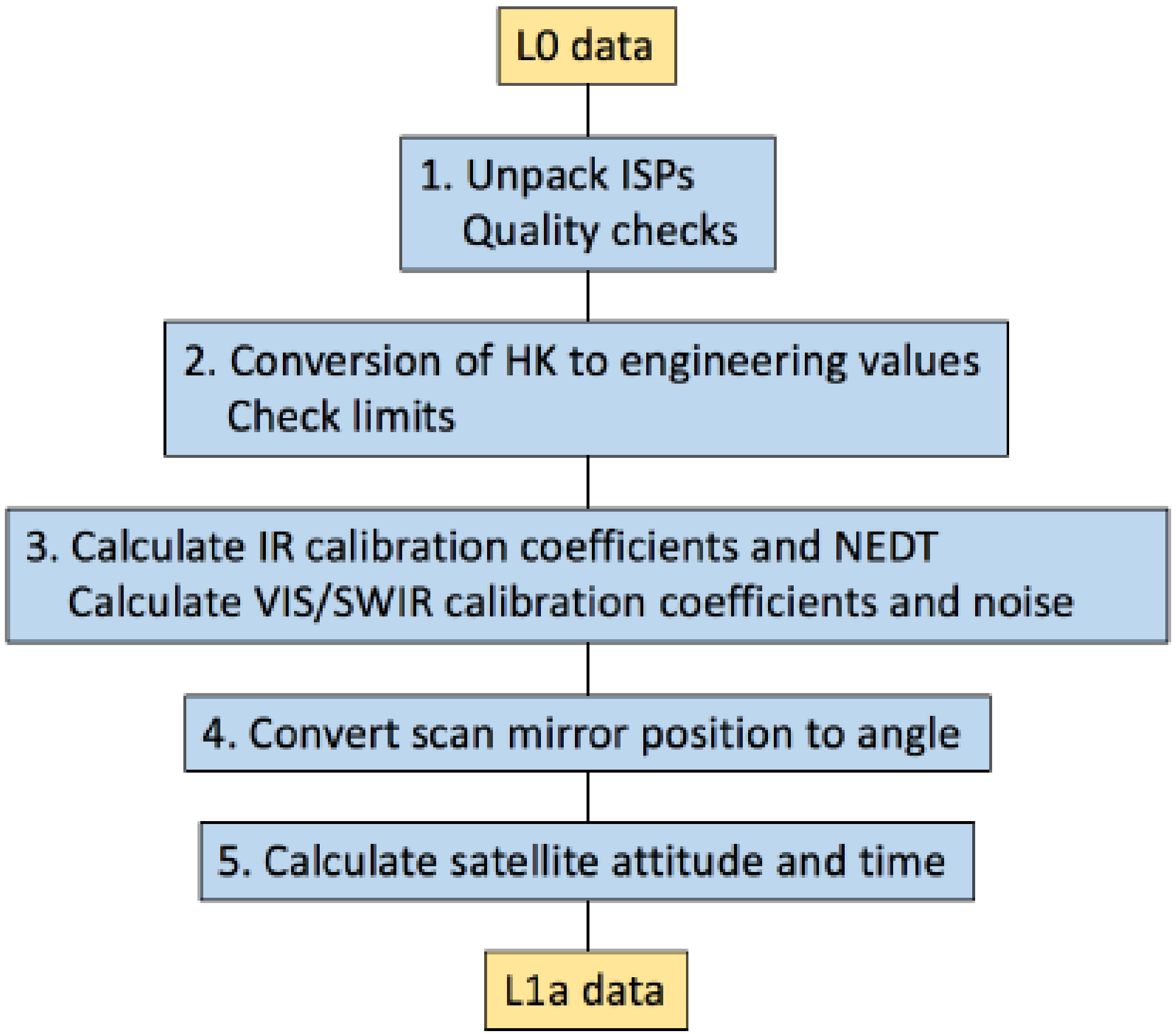


Figure 1: Level-0 to Level-1a processing steps.

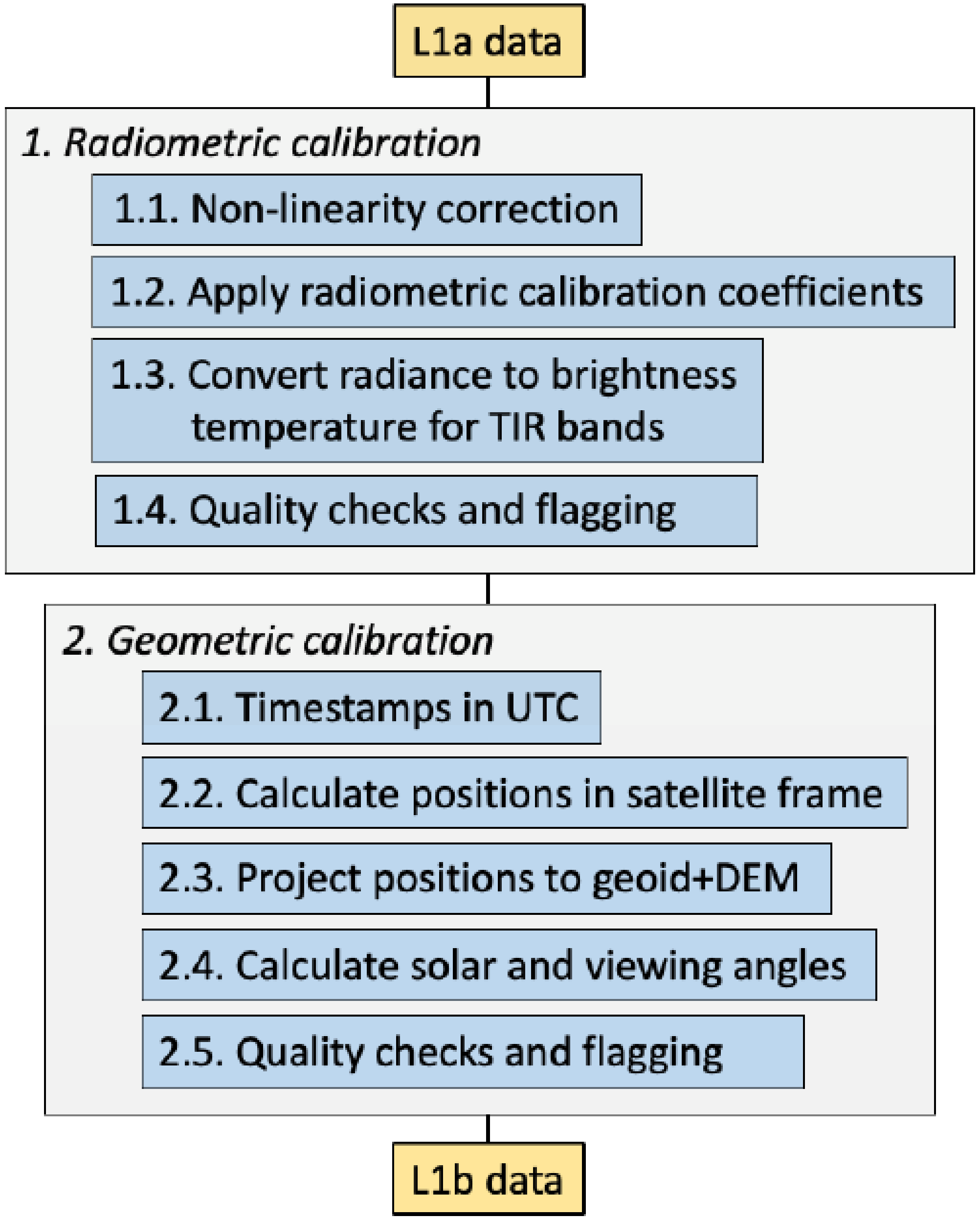


Figure 2: Level-1a to Level-1b processing steps.

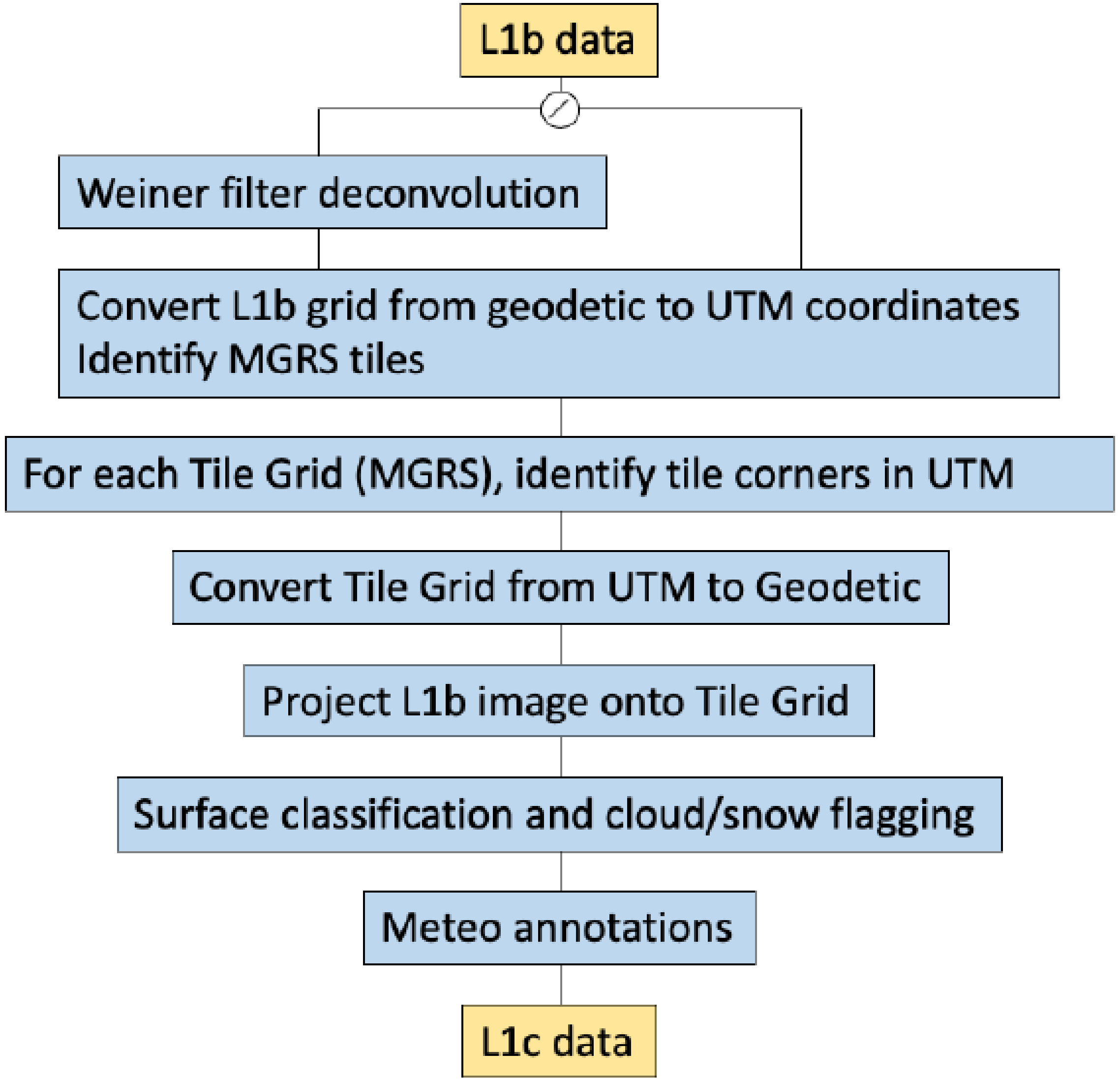


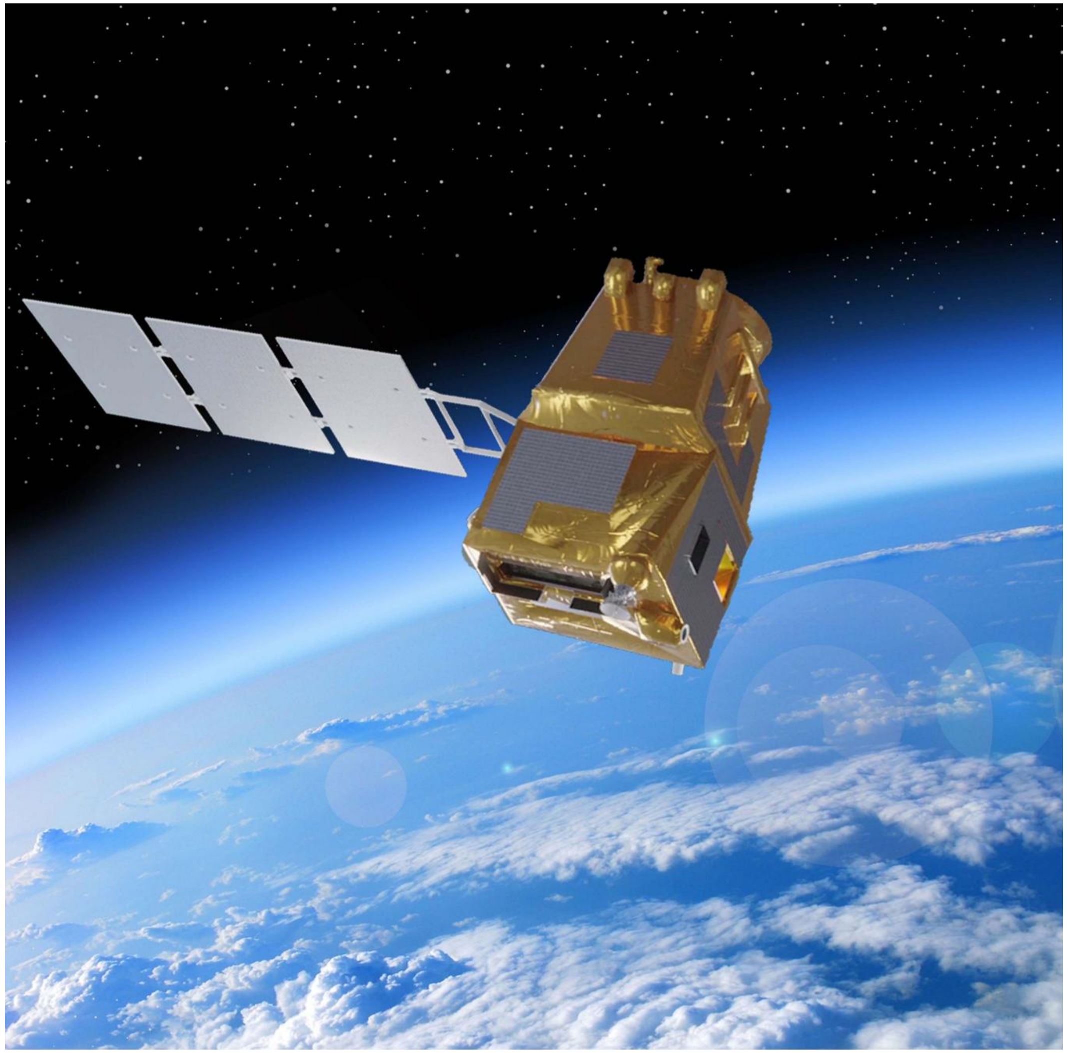
Figure 3: Level-1b to Level-1c processing steps.

ⓘ NASA's data levels

Data Level	Description
Level 0	Reconstructed, unprocessed instrument and payload data at full resolution, with any and all communications artifacts (e.g., synchronization frames, communications headers, duplicate data) removed. (In most cases, NASA's EOS Data and Operations System [EDOS] provides these data to the Distributed Active Archive Centers [DAACs] as production data sets for processing by the Science Data Processing Segment [SDPS] or by one of the Science Investigator-led Processing System [SIPS] to produce higher-level products.)
Level 1A	Reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters (e.g., platform ephemeris) computed and appended but not applied to Level 0 data.
Level 1B	Level 1A data that have been processed to sensor units (not all instruments have Level 1B source data).
Level 2	Derived geophysical variables at the same resolution and location as Level 1 source data.
Level 3	Variables mapped on uniform space-time grid scales, usually with some completeness and consistency.
Level 4	Model output or results from analyses of lower-level data (e.g., variables derived from multiple measurements).

Source: https://earthdata.nasa.gov/collaborate/open-data-services-and-software/data-information-policy/data-levels

PAYLOAD DATA GROUND SEGMENT



Ground Segment

The ground segment includes:

- **The Flight Operations Segment (FOS)** – Responsible for all flight operations of the spacecraft including monitoring and control, execution of all platform activities and commanding of the payload schedules.
- **The Payload Data Ground Segment (PDGS)** – The PDGS is responsible for payload and downlink planning, data acquisition, processing, archiving and downstream distribution of the satellite data, while contributing to the overall monitoring of the payload and platform in coordination with the FOS.
- In ESA, the FOS is located in ESOC (Germany) and the PDGS in ESRIN (Italy).

Source: https://www.esa.int/Enabling_Support/Operations/Sentinel-2_operations

Payload Data Ground Segment (PDGS)

The PDGS is constituted by:

- The **Ground Stations** that receive the source packets from the satellite. The data is sent to ground to two type of stations:
  1. Telemetry, Tracking and Control (TT&C) ground stations HKTM data. Uses the S-band.
  2. Mission Data Acquisition (MDA) ground stations payload data. Uses the X-band to download the data.
- **Mission Operations Facility** in charge of the satellite and mission operations and flight dynamics.
- **Instrument Processing Facilities** (IPF) Performs the Level-1 processing. The IPF is called the „operational”. There is an IPF per instrument on board of the Satellite. The PDGS manages the data from the several payloads and the processing in the different IPFs.
- **Level-2 Processing Facility** (L2PF).

Payload Data Ground Segment (PDGS)

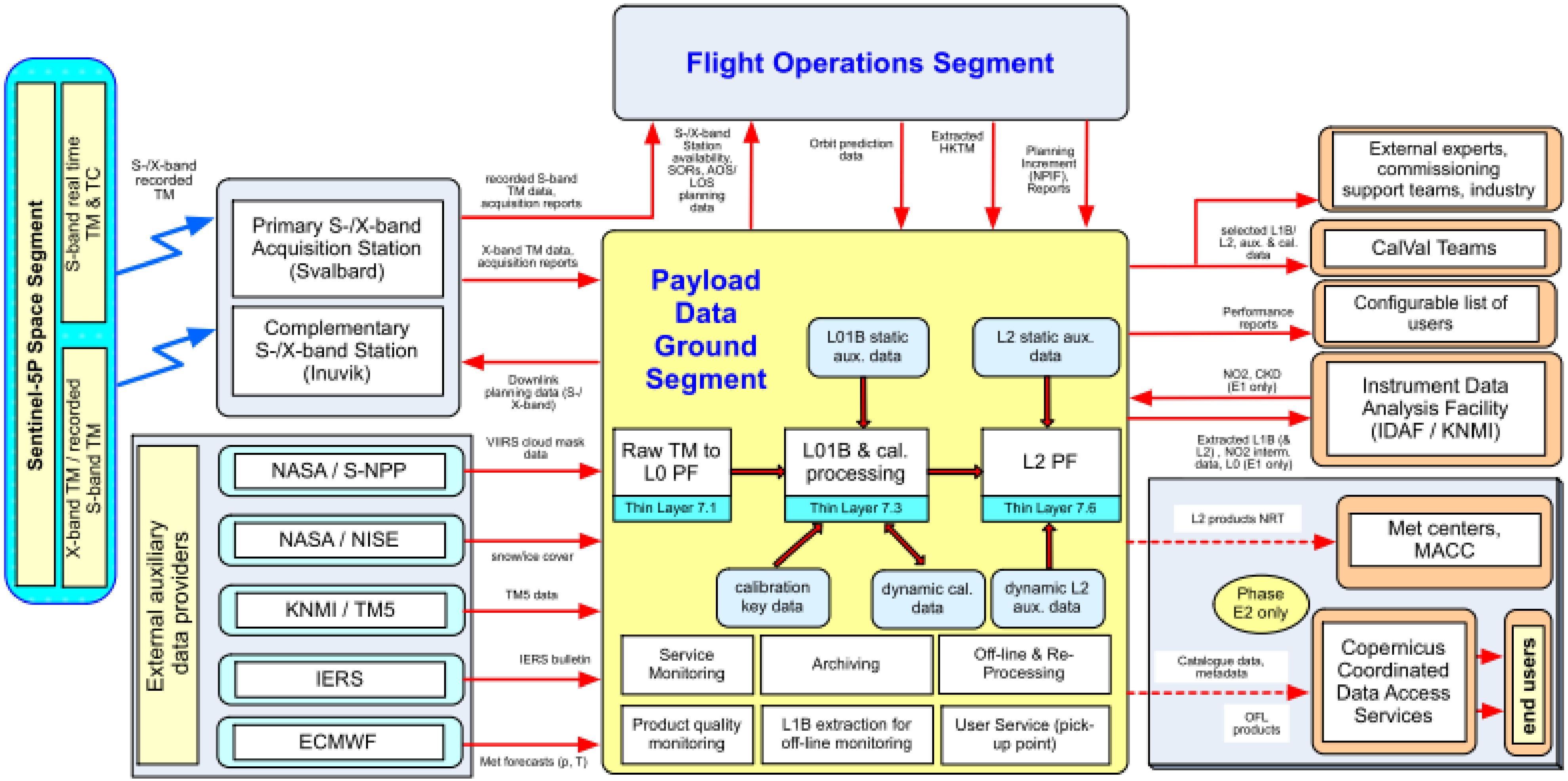
The Payload Data Ground Segment (PDGS) is responsible for exploitation of instrument data: generation, archiving and dissemination of Level-1B and Level-2 products to the user community. The PDGS is operated from DLR, the German Aerospace Center, in Oberpfaffenhofen, Germany.

The main tasks performed by the PDGS are:

- The reception of the S/X-band acquisition timeline from the FOS and planning of the S/X-band downlink.
- The acquisition of the instrument measurement data and the recorded satellite housekeeping telemetry data from the S/X-band ground station and the ingestion of the data into the processing chain.
- The systematic and data driven provision of received S-band telemetry to the FOS.
- The systematic and data driven generation of Level-0, Level-1 and Level-2 science products in NRT and offline (see Data Products section).
- The on-request re-processing of science data if needed.
- The archiving of all products and associated auxiliary data.
- The provision of access to SENTINEL-5P products from the PDGS archive to SENTINEL-5P end users.
- The interface to external auxiliary data providers for the reception of data required to generate the SENTINEL-5P products.
- Interfacing to the multi mission Copernicus facilities to ensure coherency of user services between the Sentinel missions.

SENTINEL-5P/TROPOMI products are provided to the user through online access.

Figure 1 shows a schematic of the PDGS functionalities and its interfaces with the other facilities of the core ground segment.

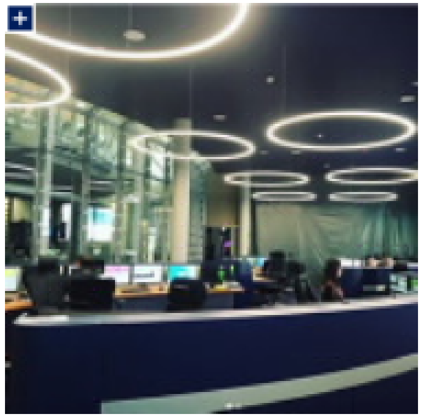


Source: https://sentinels.copernicus.eu/documents/247904/1624461/S5P_MISSION_PDGS_in_coreGS.png/6f2554b9-c2a7-49bd-beea-fd0fa9dad28c?t=1423829224183

MTG GROUND SEGMENT

SATELLITES
CURRENT SATELLITES
FUTURE SATELLITES
METEOSAT THIRD GENERATION
MTG IMAGING SERVICE
MTG SOUNDING SERVICE
MTG DESIGN
MTG DATA
EVOLUTIONS TO EUMETCAST SERVICES FOR THE MTG ERA
MTG IN OPERATIONS
MTG GROUND SEGMENT
MTG RESOURCES
EUMETSAT POLAR SYSTEM -

The Meteosat Third Generation Ground Segment will acquire data from all the MTG satellites, and generate, archive and distribute the products.



It will also provide the capabilities to command and control the satellites and the ground segment itself.

The ground segment consists of:

- The Telemetry, Tracking and Control (TT&C) ground stations — the TT&C interface between the Space Segment and the **Mission Control Centre** (Figure 1).
- The Mission Data Acquisition (MDA) ground stations — the payload data interface between the Space Segment and the Mission Control Centre.
- The Mission Operations Facility (MOF) — provides functions for the preparation, planning and operation of the system, including satellite and mission operations and flight dynamics.
- The Instrument Level 1 Data Processing facilities (IDPF-I and IDPF-S) — these extract the measurements from the sensors. They also perform a series of functions for the generation of level 1b data and the processing of level 1c data.
- Level 2 Processing Facility (L2PF), for the extraction of centrally generated products.

On-board Data Processing

On-board payload data processing includes the **data acquisition, selection, compression or reduction** (depending on the specific scenario), as well as their **storage**.

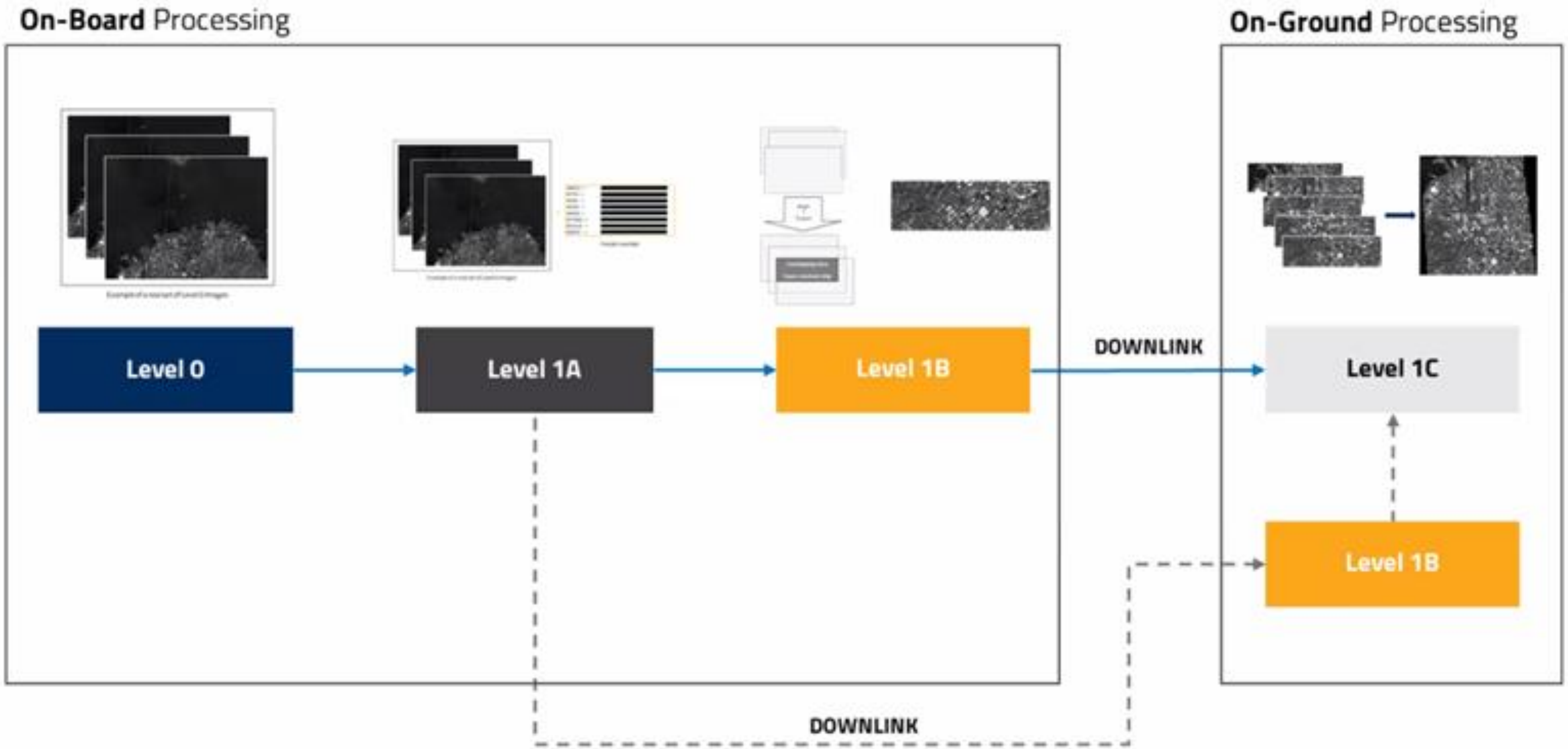
Data acquisition and selection involves gathering pertinent information and analysing it (for instance, removing cloudy images).

Data compression involves changing the method of recording information to minimize redundancy and, effectively, the volume of the data set.

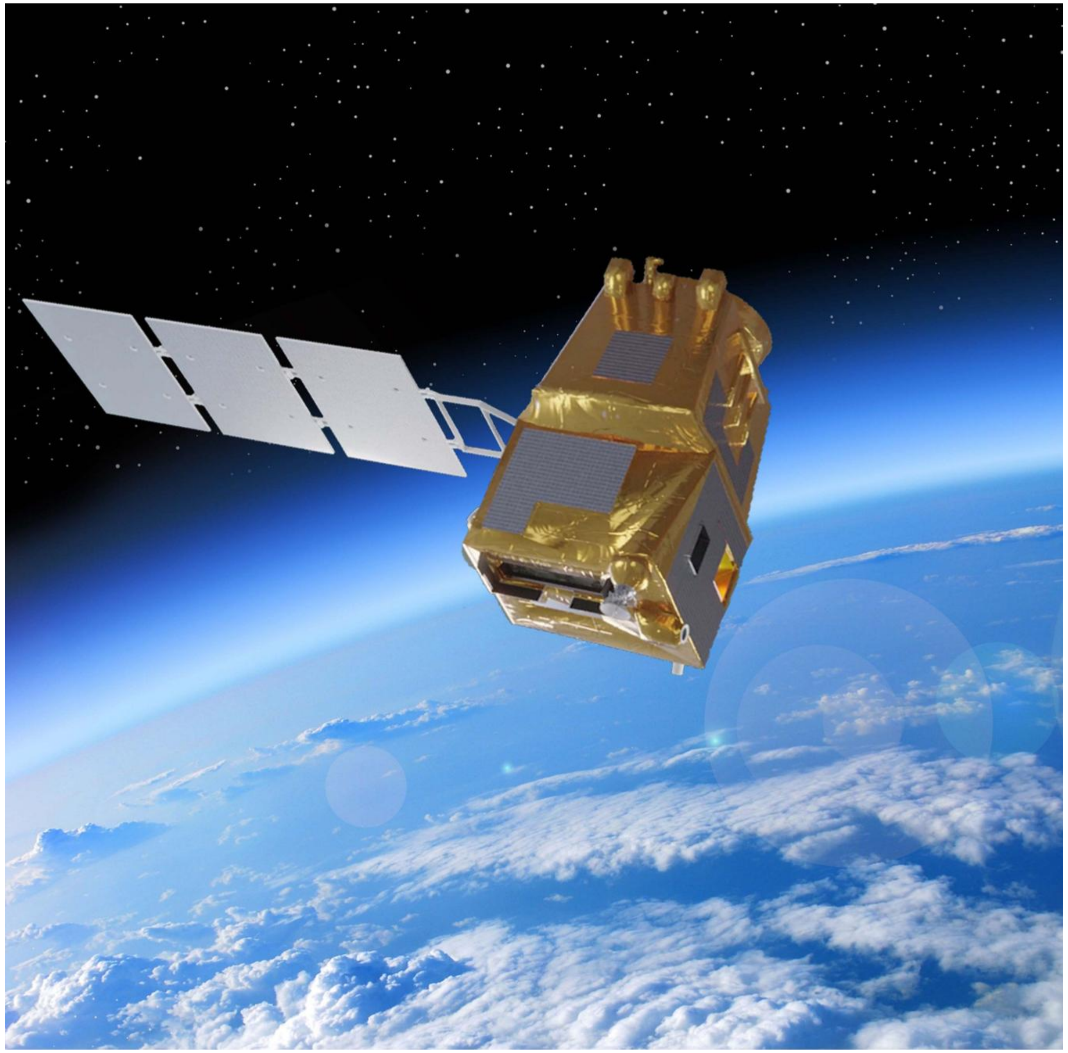
When it comes to **data storing**, currently, the biggest problem is posed by huge amounts of the generated raw data unable to reach Earth quickly due to their size. Consequently, they need to be stored for a long time on board of the satellite, which has limited storage capabilities.

It is crucial to speed up the data analysis if you want to use the downlink throughput most efficiently. One of the most effective solutions are currently **field-programmable gate arrays (FPGAs)**, which, combined with **artificial intelligence**, work much more efficiently, resulting in faster data analysis than before.

On-board Data Processing



END-TO-END SIMULATORS



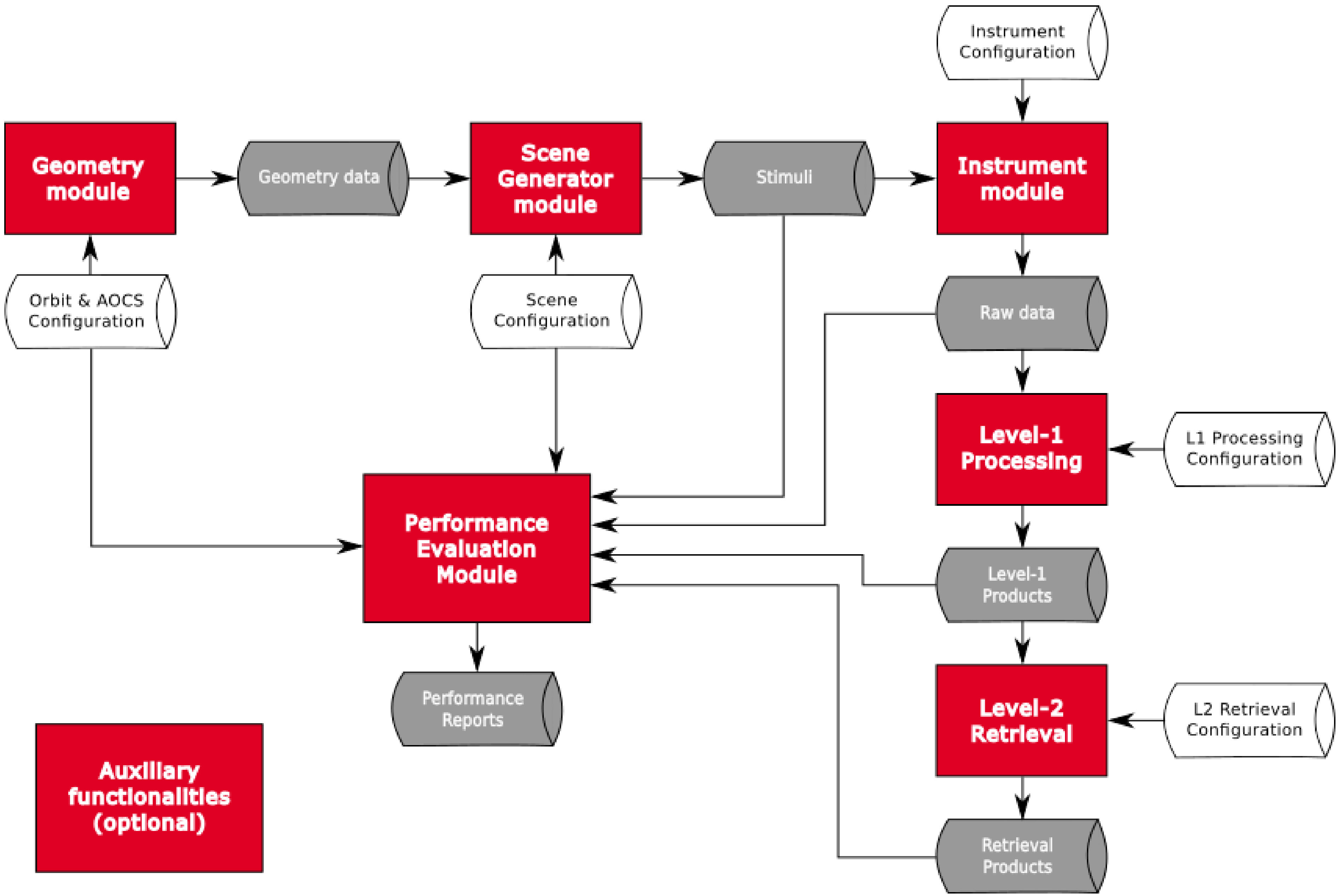
End-to-End Simulators (E2ES)

- Before we spend several hundred million euros on building a satellite & payload, we want to make sure that a) it works & b) we can process the data to obtain whatever we are looking for This is why we develop E2ES starting in phase A.
- An End-to-End Simulator is a tool for the engineering and scientific team.
- The **engineering team**, responsible of the instrument, needs the E2ES to:
  - Validate the **instrument performances** – if the instrument responds in the expected way to the input stimuli.
  - Validate the **calibration** strategy. The calibration strategy is essential for the processing. There is typically a calibration programme which includes on-ground calibration campaigns, airborne campains and sometimes a proto-flight model of the satellite (e.g. GIOVE-A for the Galileo constellation).
  - **Support** the development of the **operational** processor by providing datasets and for cross-validation.

End-to-End Simulators (E2ES)

- The **scientific team**, responsible of the mission outputs, needs the E2ES to:
  - Validate the retrieval algorithms.
  - Works with the instrument team for the compromise between accuracy and processing time. Right now, that's the core problem in most missions – scientists want maximum accuracy, but the processing times makes it unfeasible, so a certain degradation or simplification of the L1 and L2 algorithms need to be done. An example is the straylight correction in FLEX (on-going...).

- It is composed of the **Instrument Data Simulator (IDS)** and the **Ground Processor Prototype (GPP).**



Source: https://gmv-biblos.gmv.com/the-biblos-projects/the-archeo-e2e-projects/the-reference-architecture/

Instrument Data Simulator (IDS)

The IDS is in charge of simulating the **space** segment. It simulates the scene, the payload acquisition, and the on-board processing and packetisation. The main three modules are:

1. **Geometry Module** – in charge of simulating the SC orbit and attitude, as well as the generation of the observation geometry of each instrument.
2. **Scene Generator Module** – in charge of simulating the scene to be observed (terrain, ocean or atmosphere) and all environmental effects (radiative transfer models, atmosphere simulation, illumination conditions…) to be considered for the correct generation of the stimuli to be entered to the instrument model.
3. **Instrument Module** – in charge of simulating the sensor behaviour, having different outputs depending on the type of instrument.
4. There can be a 4th module called the **On-board Data Generation Module**, in charge of simulating the on-board processing and packetisation.

Ground Processor Prototype (GPP)

The GPP is in charge of simulating the **ground** segment. It simulates the L0, L1 processing and L2 retrieval. The main two modules are:

1. **Level-1 Processing Module** – in charge of the generation of level-1 products, from level-1a to level-1c.
2. **Level-2 Retrieval Module** – in charge of performing the retrieval of the geophysical parameters that are objective of the mission/instrument. Depending on the mission and on its definition of the products, this module would generate level-2 data or products at higher level of processing.
3. Level-3 processing and above are not usually part of the E2ES, as they obtain derivative products.

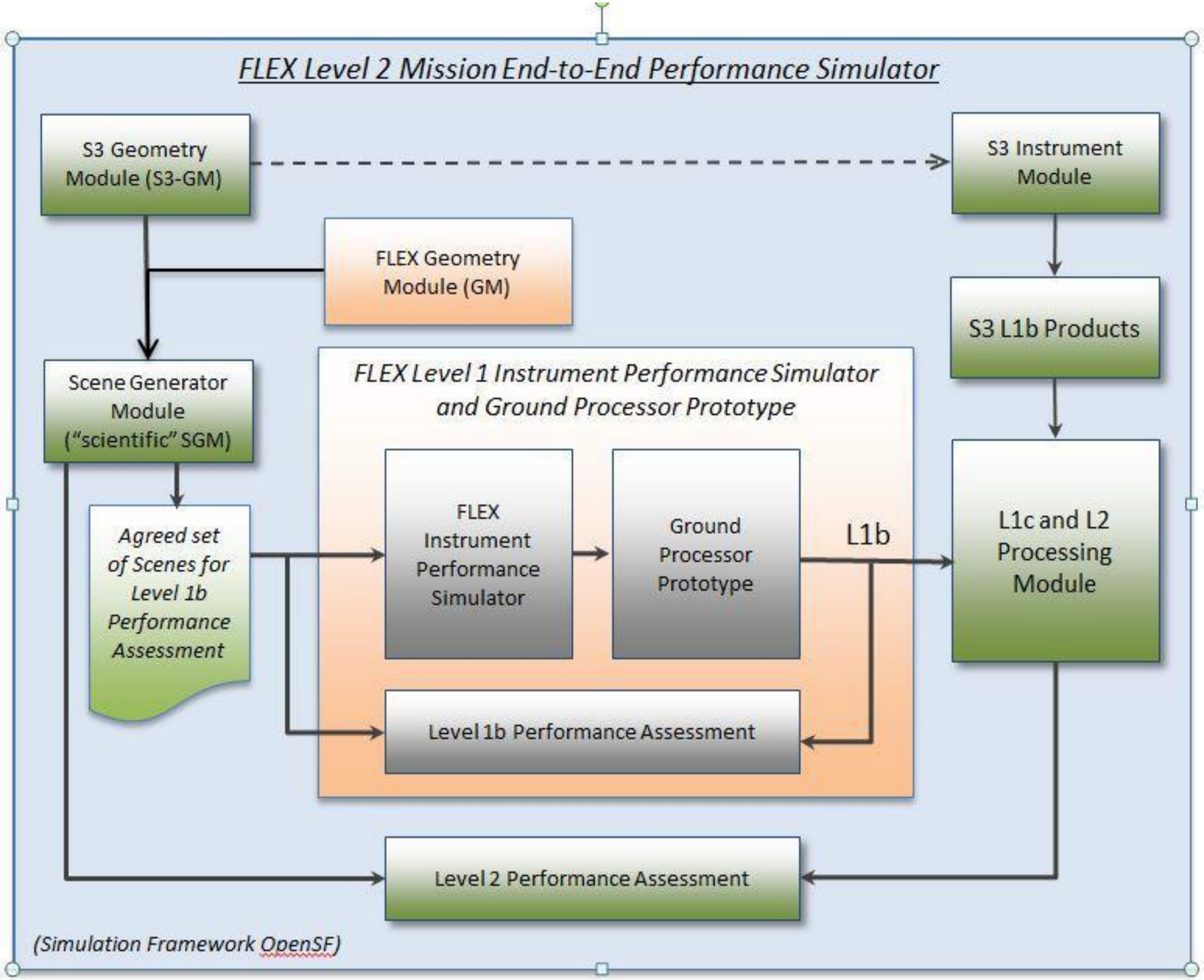
Performance Assessment Module (PAM)

- The PAM is used to verify and validate the instrument and mission requirements.
- Instrument requirements → These requirements are on the payload performance. They specify how well the instrument shall function.
- **Instrument performances** are obtained by comparing :
  - the input of the instrument modulel, the physical truth. For example, the input radiance that reaches the camera, which is „the truth”;
  - and the outputs of the Level-1 processing, the physical variable retrieved after calibration.

Performance Assessment Module (PAM)

- Mission requirements → These requirements are on the final output of the Level-2 retrieval algorithms, the „science”. They specify what accuracy the outputs shall have.
- **Mission performances** are obtained by comparing:
  - The scene from the Scene Generation Module (the input geophysical variables that feed the forward model).
  - The output of the Level-2 retrieval algorithms.

① FLEX E2ES



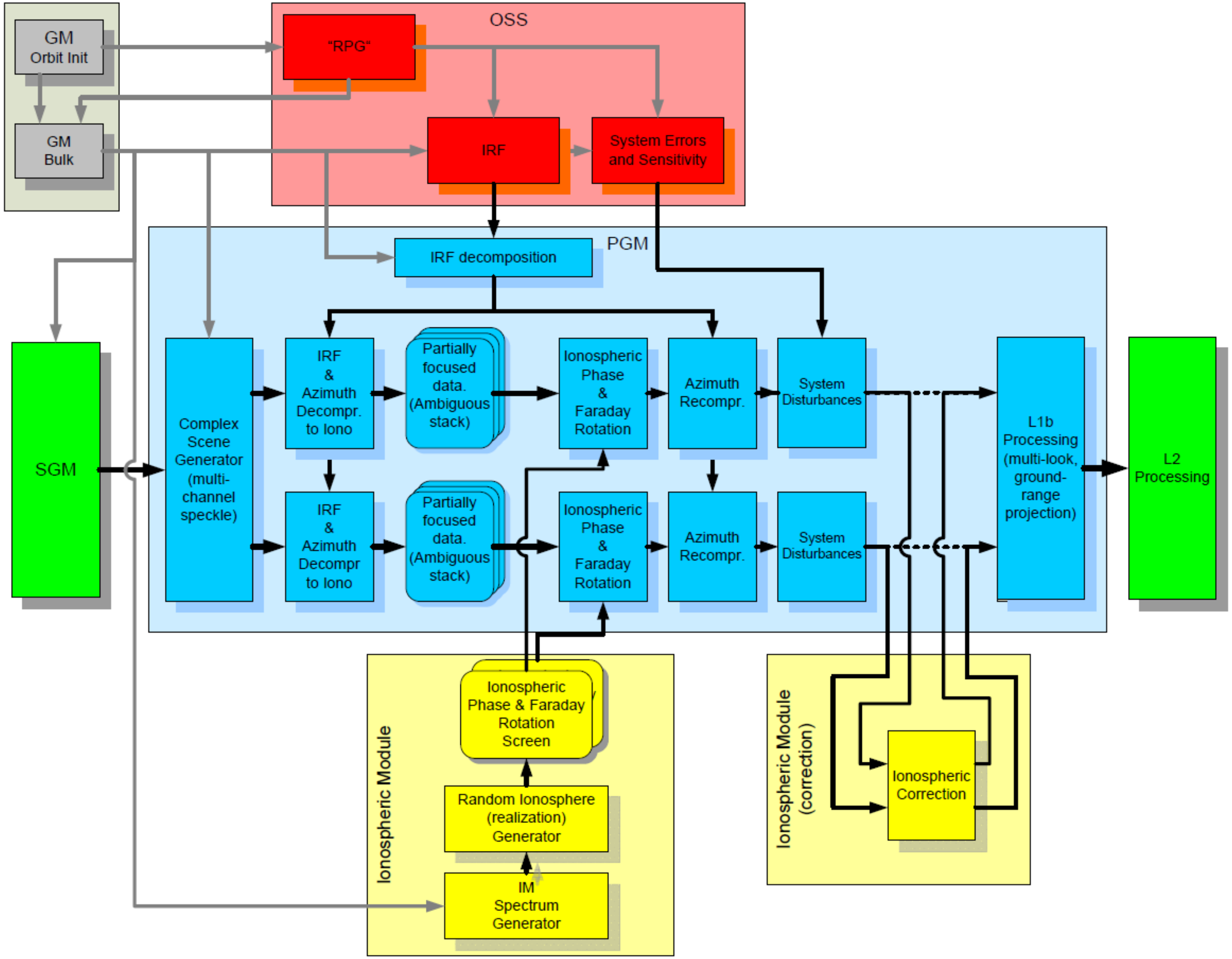
FLEX Level 2 Mission End-to-End Performance Simulator
S3 Geometry Module (S3-GM)
S3 Instrument Module
FLEX Geometry Module (GM)
S3 L1b Products
Scene Generator Module ("scientific" SGM)
FLEX Level 1 Instrument Performance Simulator and Ground Processor Prototype
Agreed set of Scenes for Level 1b Performance Assessment
FLEX Instrument Performance Simulator
Ground Processor Prototype
L1b
L1c and L2 Processing Module
Level 1b Performance Assessment
Level 2 Performance Assessment
(Simulation Framework OpenSF)

ⓘ BIOMASS E2ES

OSS = Observing System Simulator

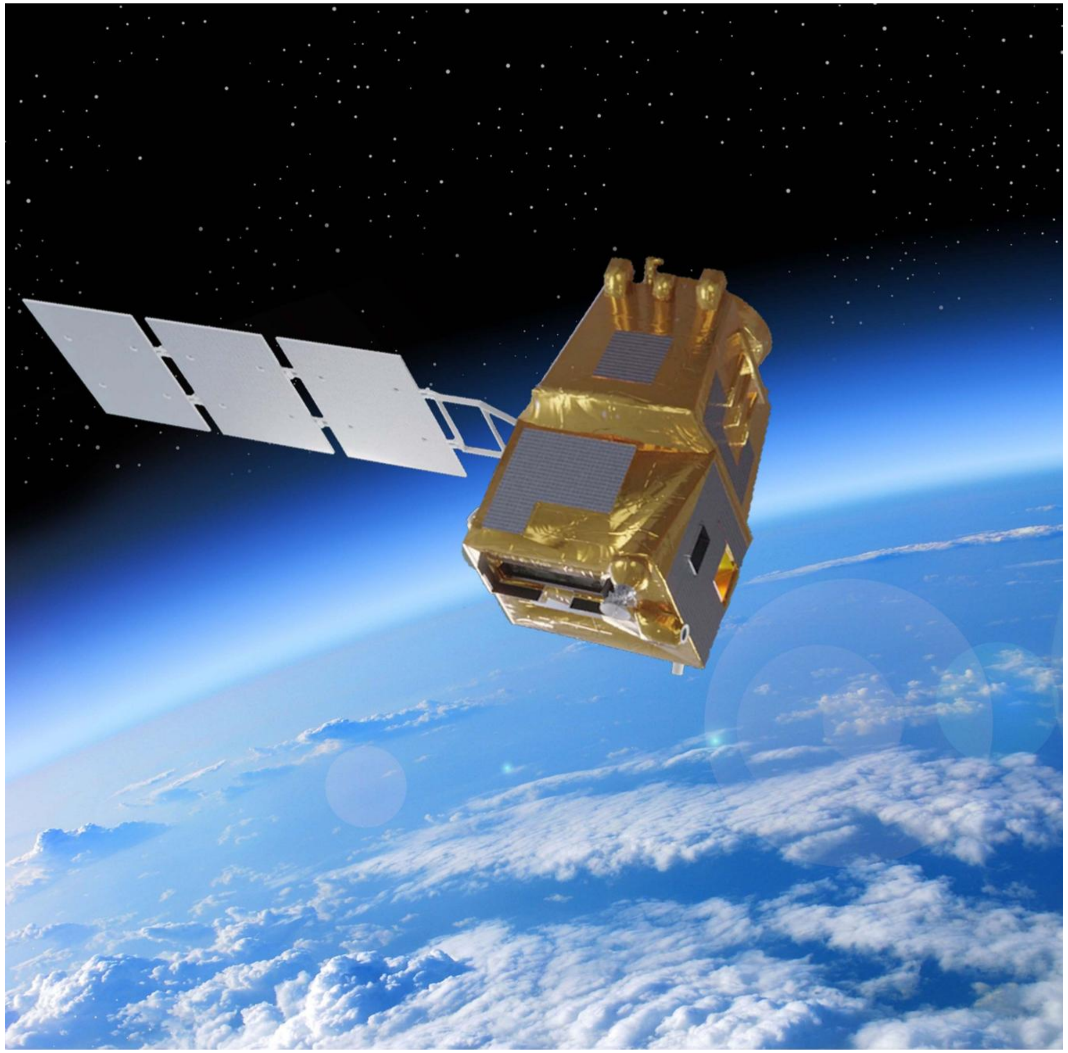
PGM = Product Generation Module

IRF = Impulse Response Function (chirp)



Source: https://www.researchgate.net/publication/220819286_BIOMASS_end-to-end_mission_performance_simulator

OPERATIONAL PROCESSORS



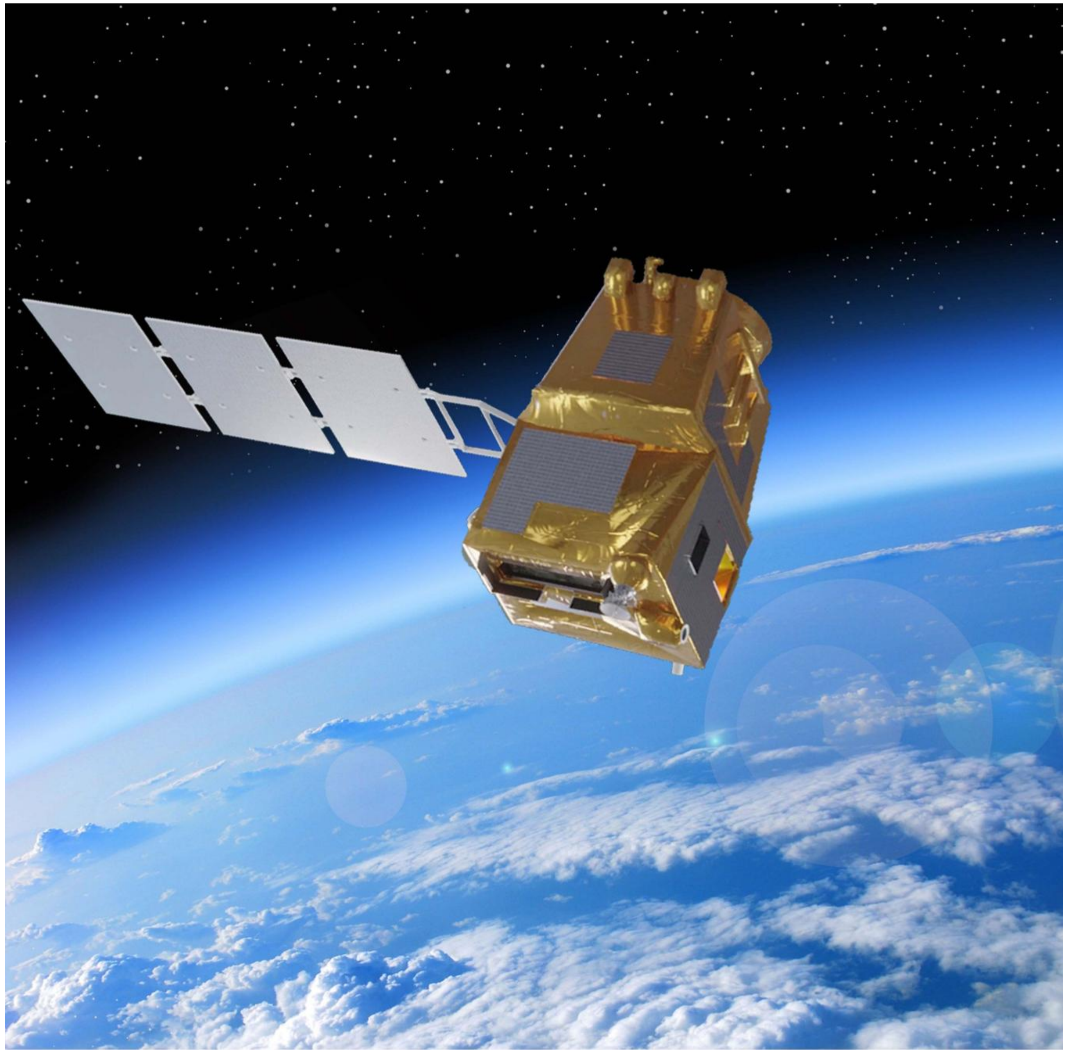
Operational Processors

- The «operational processors» are the actual processors used in the exploitation of the payload data.
- The processing time requirements are very stringent (for near-real time data requests). They also have to manage a continuous data flow of input packets (RAW or L0 packets) provided by the PDGS that come from the Satellite.
- The «operational processors» is basically the chain of elements and tasks used to generate a products.
- The task of operational software processors within the ground segment of an earth observation mission is to generate **fast and continuously predefined products** from the incoming raw data, and work largely without interactive intervention.

Operational Processors

- Operational processors are used to generate data in near-real-time (NRT) and in an off-line mode to produce the highest possible precision.
- For test and development purposes prototype versions evolve at each development level, supporting interactive control and —if required— detailed investigation of single processing steps.
- In the course of a mission, processors and baseline algorithms are continuously updated because of subsequent improvements in instrument calibration and ability to extract predefined and new geophysical parameters from the data. It is not unusual to reprocess the entire data volume of a mission from time to time, using updated state-of-the-art algorithms.

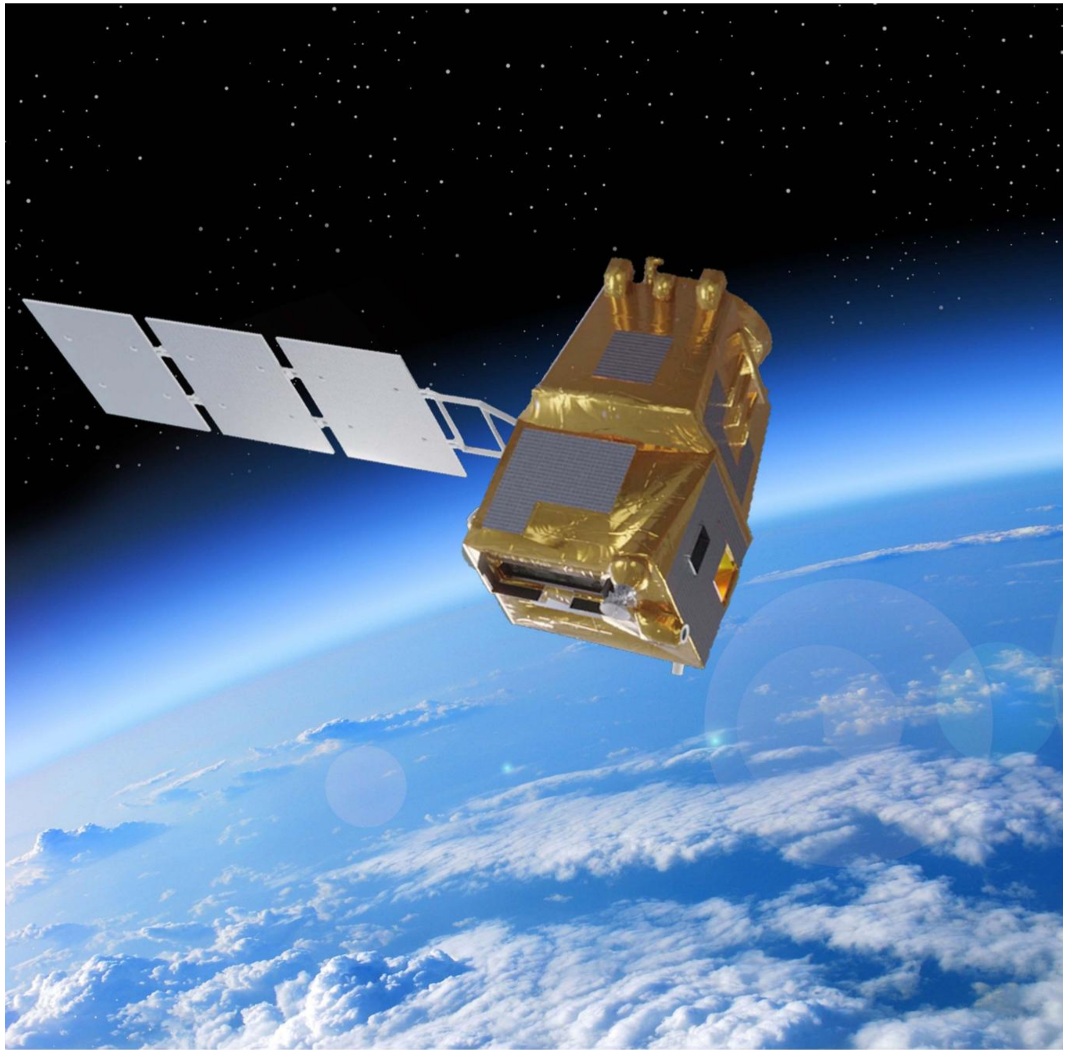
SUMMARY



Take-away points of this topic

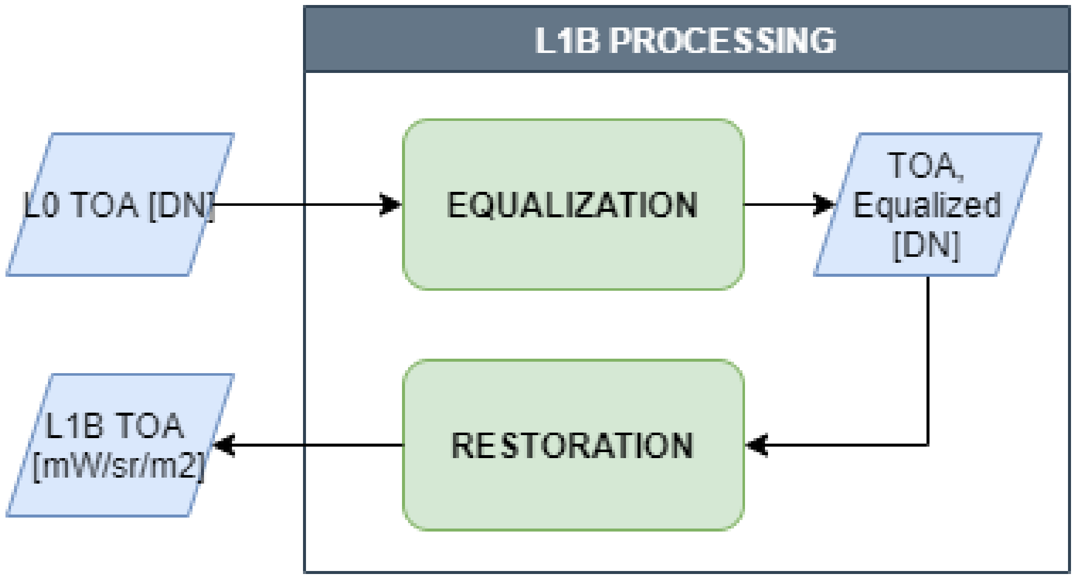
- What is calibration, processing, geolocation, a DEM and ISPs.
- Data extraction.
  - Conversion from Digital numbers, to physical units.
  - Correction for the sensor imperfections (radiometric & spectral calibration); geometrical calibration, cloud screening, atmospheric correction, topographic & solar correction → L1B products;
  - Orthorectification, co-registration → L1C products
  - Retrieval → L2 products;
  - Interpretation, classification, analysis → L3 products.
- Levels of Earth Observation data processing: L0, L1A, L1B, L1C, L2, L3.
- Components of the Ground Segment. Components of the PDGS.
- End-to-end simulators. What they are, what are the used for. What is the IDS, GPP and PAM.
- What is an operational processor. What is the difference with the GPP.

WS1: APPLY CORRECTION ON L1 DATA



L1B calibration

- The goal of this excercise is to apply a basic first-order calibration (gain, offset)
- And compare with the ideal, and the uncalibrated data.



L1B calibration

8.1. EODP-ALG-L1B-1000: Radiometric Correction.

The Level-1B processing chain is quite simple conceptually. The input to the Level-1 processing chain are the Level-0 packets, which are the time-ordered (with several quality checks) satellite RAW packets. This is reconstructed to form an image in Digital Numbers. The EODP simulator starts at this point, with an input image in DN. In the Level-1 processing the input Digital Numbers need to be converted to radiances by multiplying by the Gain [mW/m2/nm/sr/DN]. This is the "absolute radiometric gain application", § 8.1.3. In the previous section, the Instrument Model, the physics of the system was presented as well as the non-ideal response. In the Level-1B processing, this non-ideal response is partially reverted through the application of the calibration coefficients. The geometric and radiometric calibration is presented in § 8.2 and § 8.3. The application of the coefficients is the "radiometric correction" or equalization, § 8.1.1.

Other activities in the Level-1 processing are the compensation of bad/dead pixels ("cosmetic filling"), the straylight correction and denoising & deconvolution. Both the straylight correction and the deconvolution require the deconvolution of the image with kernels which are the inverse of the effect, so the inverse of the straylight pollution, and the inverse of the Point Spread Function.

8.1.1. EODP-ALG-L1B-1010: Radiometric Correction (equalization)

The radiometric corrections can be reduced to an equalization of the response of the pixels that are responsible for capturing the image such that, overall, a flat response is obtained when observing a homogenous landscape.
The correction is based on a bilinear model which allows correction for offset (Dark Signal), gain (PRNU) and non-linearity, with 2 parameters per pixel, an offset and a gain.
From § 7, there are two effects that affect the readout value (not taking into account defective pixels):

L1B calibration

- The Dark Signal. This is an additive factor which varies from pixel to pixel, and is constant in time. When the satellite acquires a black image (no input illumination), the read-out value shall be the Dark Signal (this is the philosophy used for its calibration).
- The PRNU, which is the modulation of the response inherent to each pixel. For an input "flat", homogeneous scene (e.g. a desert), the response of each pixel will vary slightly. This response is a function of the radiance. The simplest model is to assume it is linear, so TOA_measured = TOA_real*(1+k*PRNU).

The following plot shows the measured signal with respect the real signal.

$$TOA_{measured} = TOA_{real} \cdot (1 + k \cdot PRNU) + DS$$

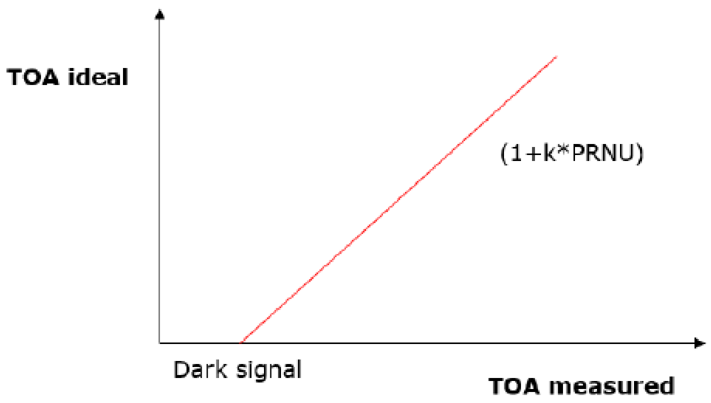


Figure 8-2: Equalization model

The goal of the equalization is to retrieve the "real" input signal. This is done this way:

$$TOA_{real} = (TOA_{measured} - DS)/(1 + k \cdot PRNU)$$

The DS and (1+PRNU) is measured and stored in the Instrument Characterisation Database and are applied to the measured signal.

$$TOA_{real} = (TOA_{measured} - eq_{add})/eq_{mult}$$

Where eq_add and eq_mult are two factors provided by the Instrument manufacturer, per pixel.

L1B calibration

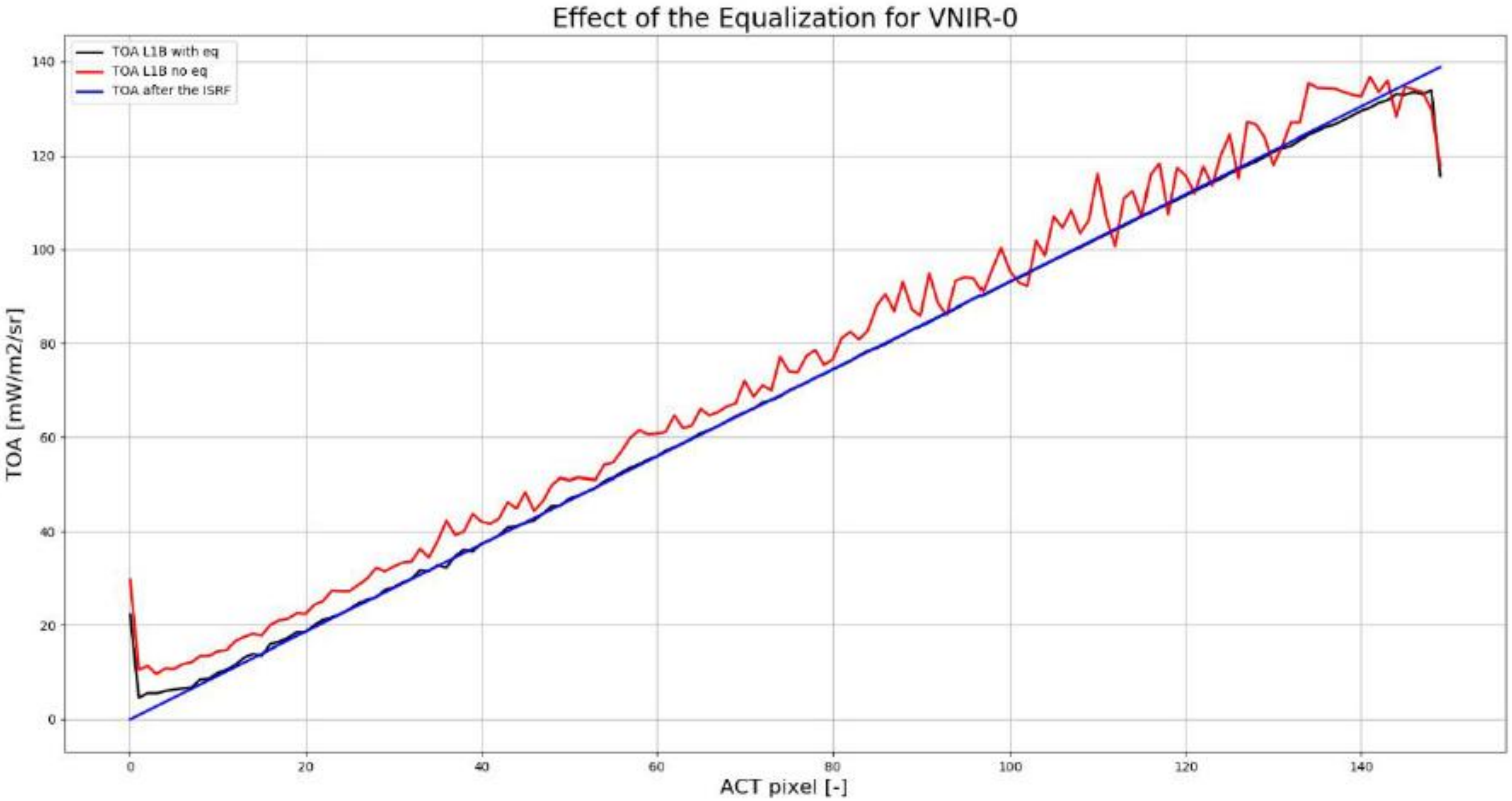
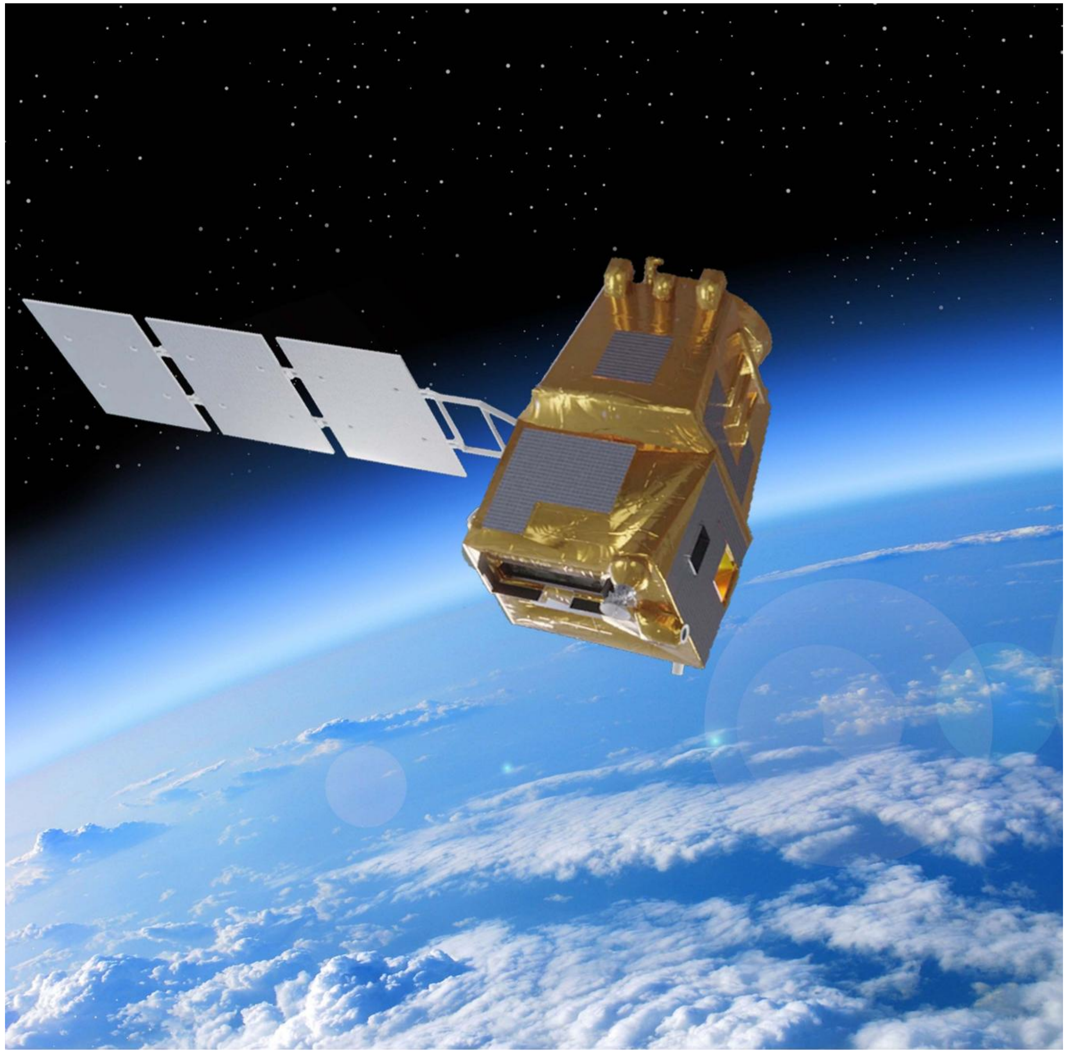


Figure 8-3: Equalization model

WS2: BROWSE LANDSAT DATA



MASTER X®

Exploiting information from different bands

Workshop goals:

1. Choose your favourite disaster disaster e.g. 15-20 June 2022 in Zamora (Sierra de la Culebra).

https://www.lavanguardia.com/natural/20220620/8352286/incendio-forestal-zamora-entra-lista-peores-fuegos-siglo-espana.html

2. Download data from USGS Landsat 8&9 in Thermal Infrared and Visual bands

3. Open data in QGIS and compare before and after the disaster, in visual and thermal imagery.

4. Analysis: What differences do you see?

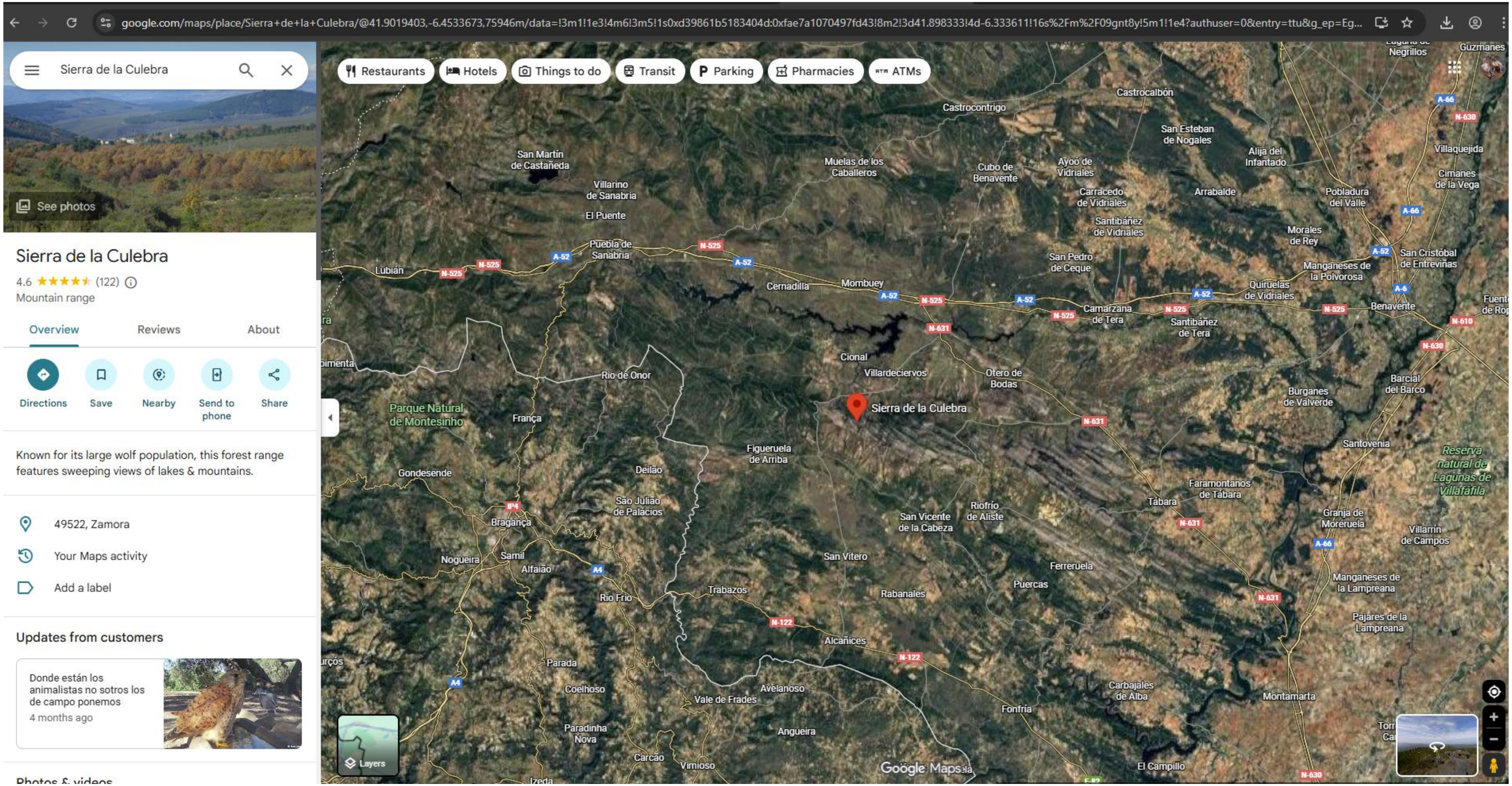
LANDSAT 8 & 9 Bands

https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites

Landsat 8 and Landsat 9 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images consist of nine spectral bands, and two thermal bands. The approximate scene size is 170 km north-south by 183 km east-west (106 mi by 114 mi).

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Coastal aerosol	0.43-0.45	30
Band 2 - Blue	0.45-0.51	30
Band 3 - Green	0.53-0.59	30
Band 4 - Red	0.64-0.67	30
Band 5 - Near Infrared (NIR)	0.85-0.88	30
Band 6 - Shortwave Infrared (SWIR) 1	1.57-1.65	30
Band 7 - Shortwave Infrared (SWIR) 2	2.11-2.29	30
Band 8 - Panchromatic	0.50-0.68	15
Band 9 - Cirrus	1.36-1.38	30
Band 10 - Thermal Infrared (TIRS) 1	10.6-11.19	100 (resampled to 30)*
Band 11 - Thermal Infrared (TIRS) 2	11.50-12.51	100 (resampled to 30)*

Sierra de la Culebra (Zamora)



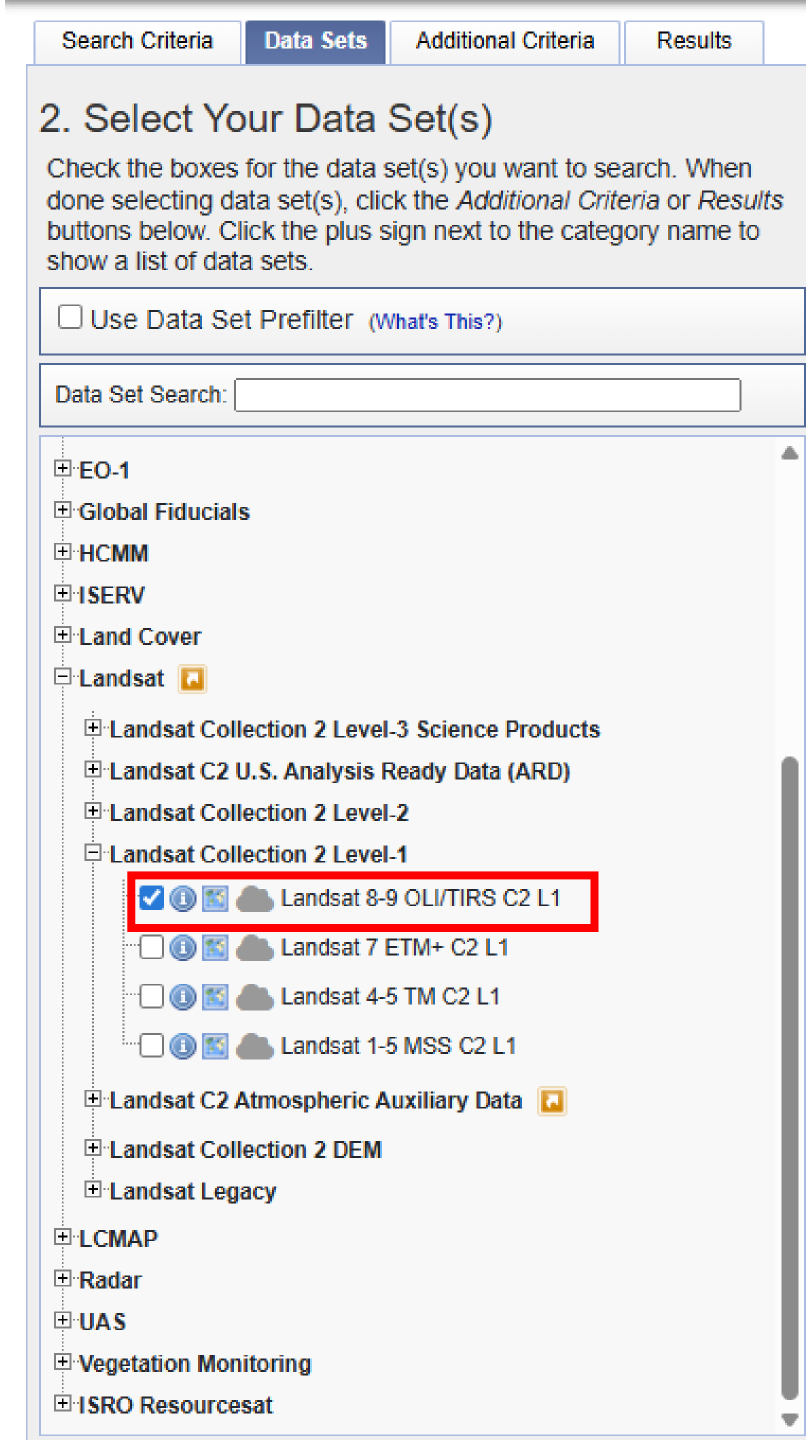
Download data from USGS

https://earthexplorer.usgs.gov/

1. **Select only Landsat 8 & 9**

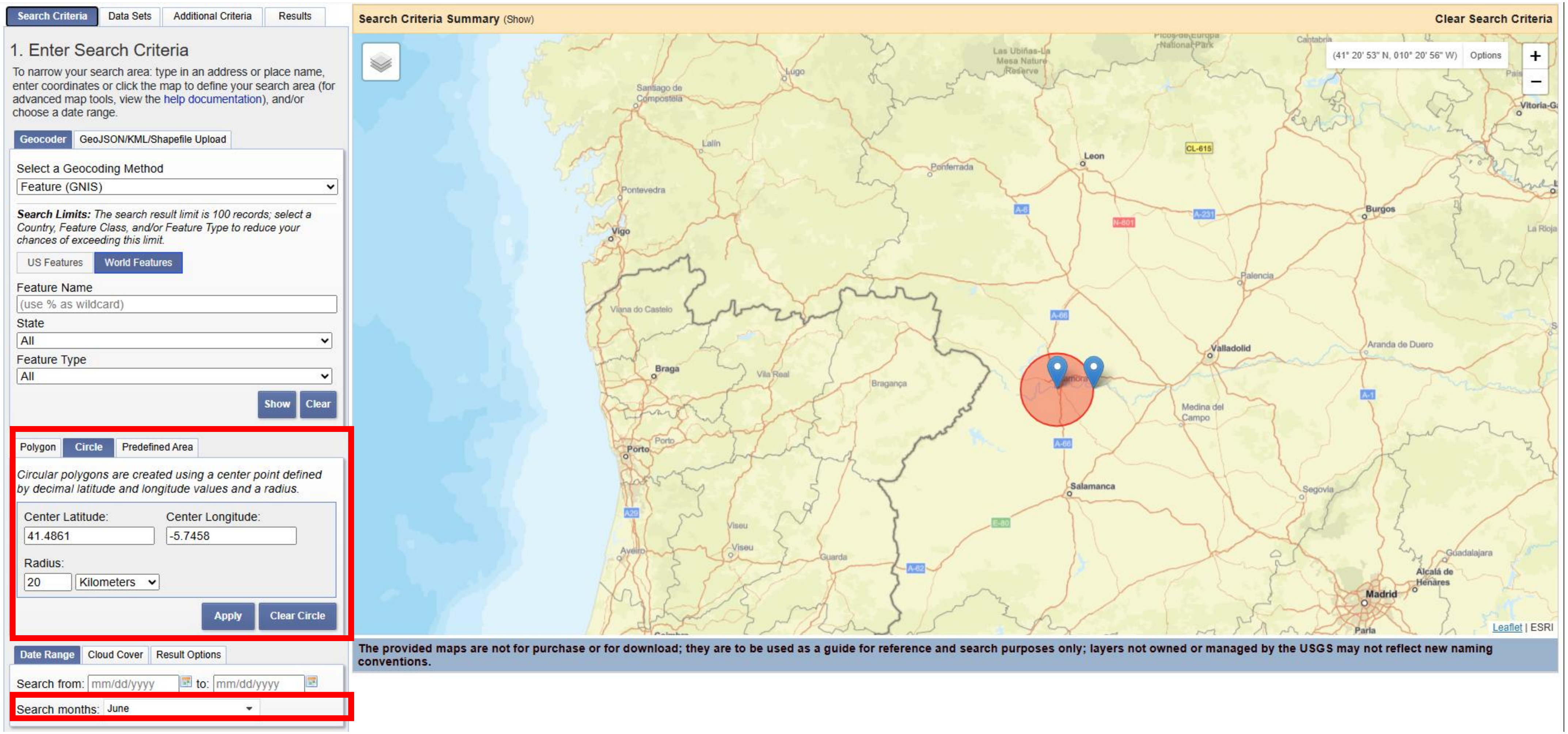
2. **Define a small circle around the area of interest.** It will return any image intersecting this circle so don't make it too big.

3. Select the **Month** of the disaster to filter out other acquisitions



Download data from USGS

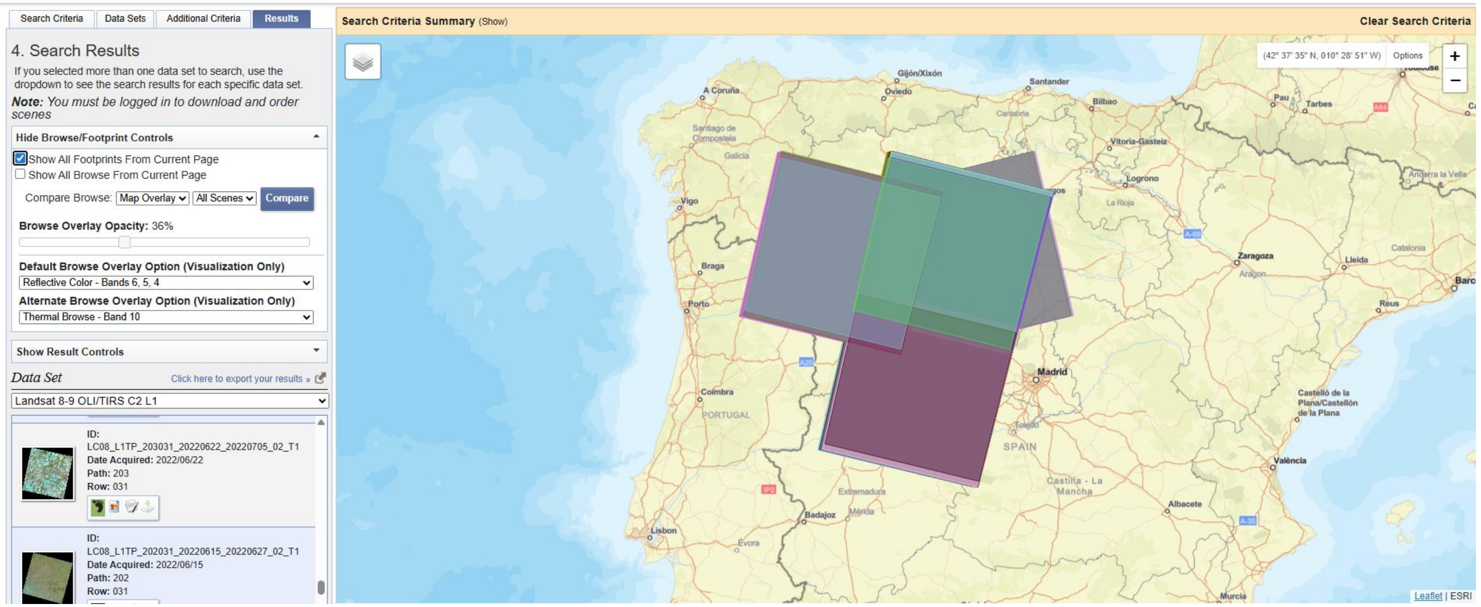
https://earthexplorer.usgs.gov/

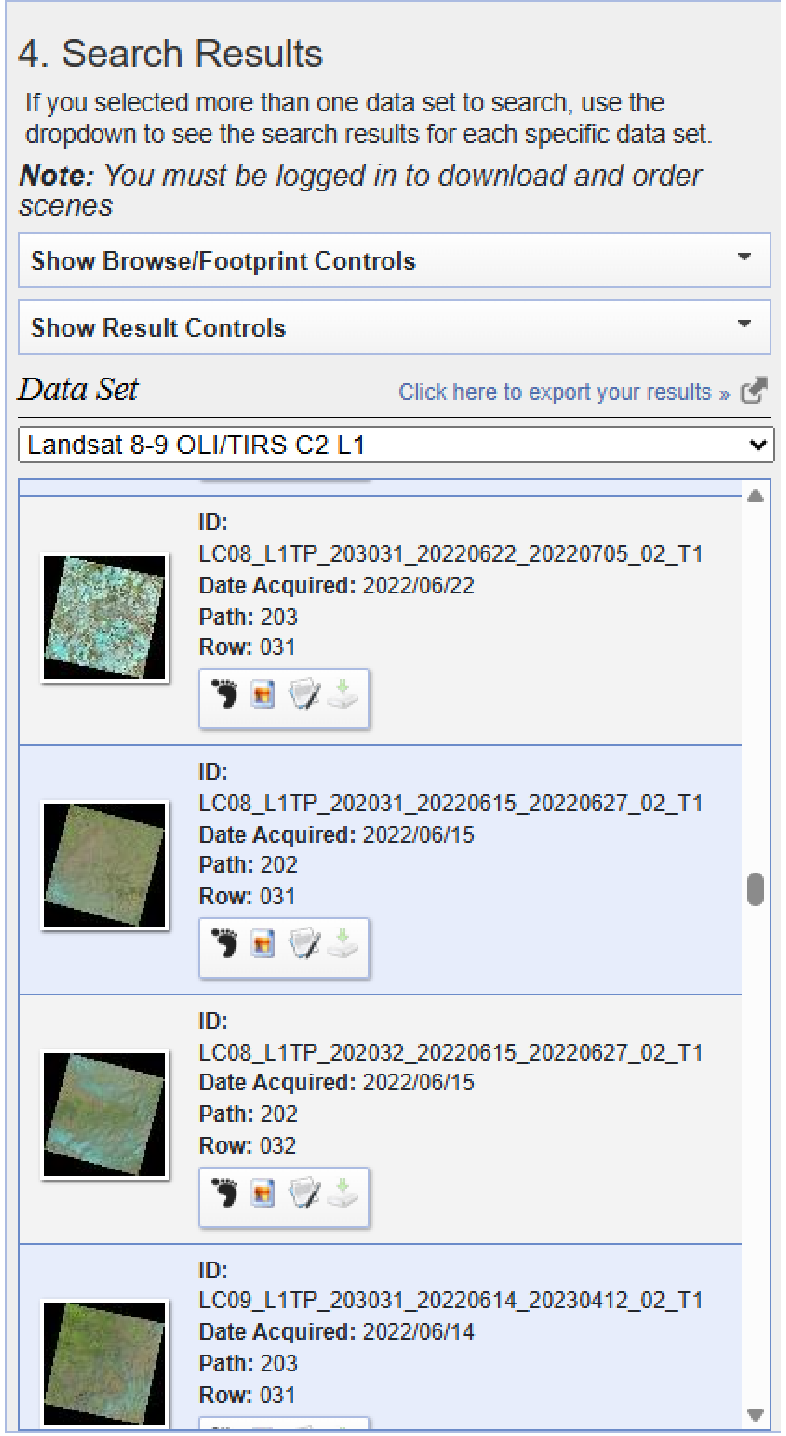


Download data from USGS

https://earthexplorer.usgs.gov/

The query will result in many acquisitions from the descending pass (daylight) and some ascending (nighttime).

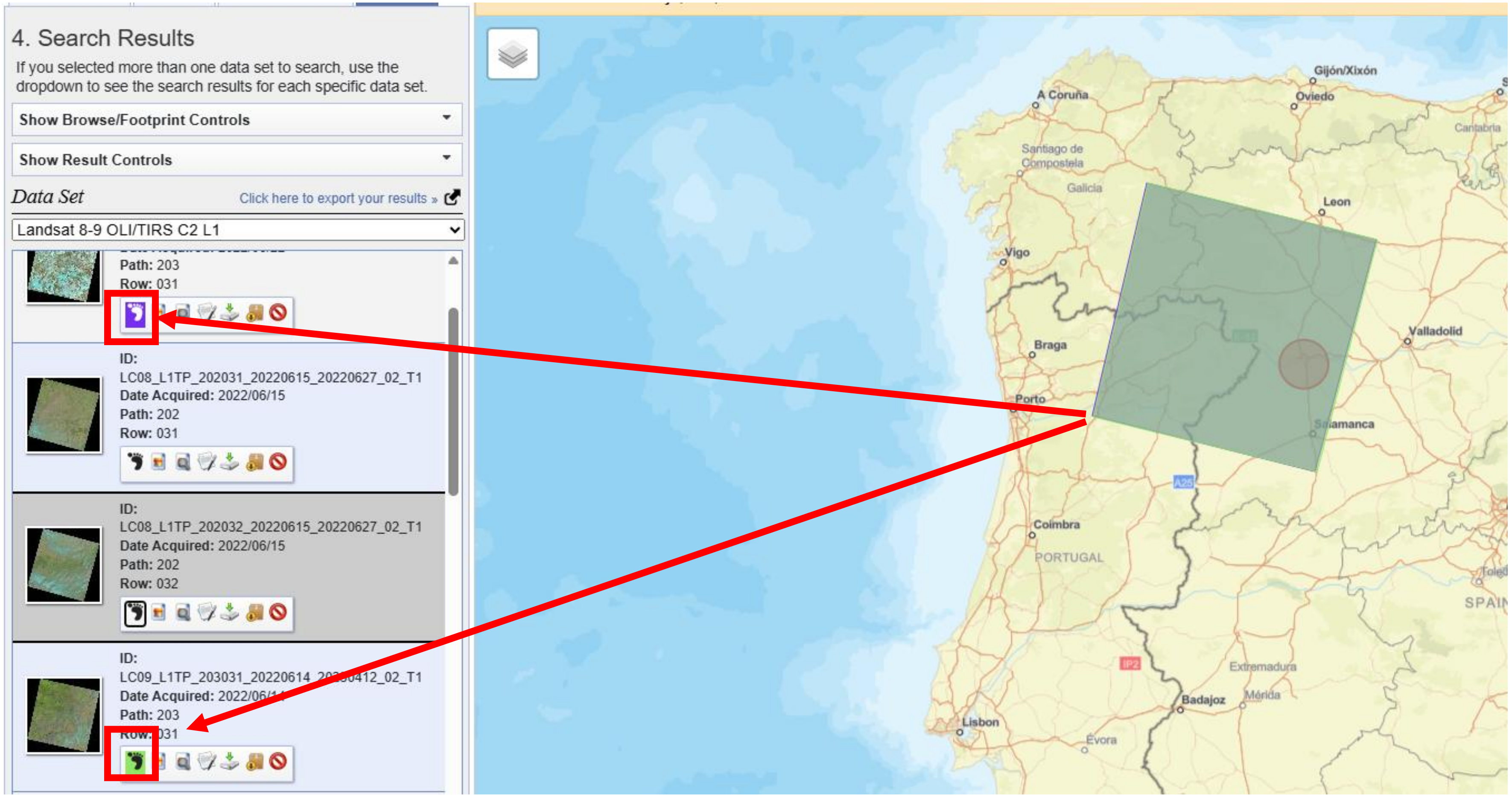




Download data from USGS

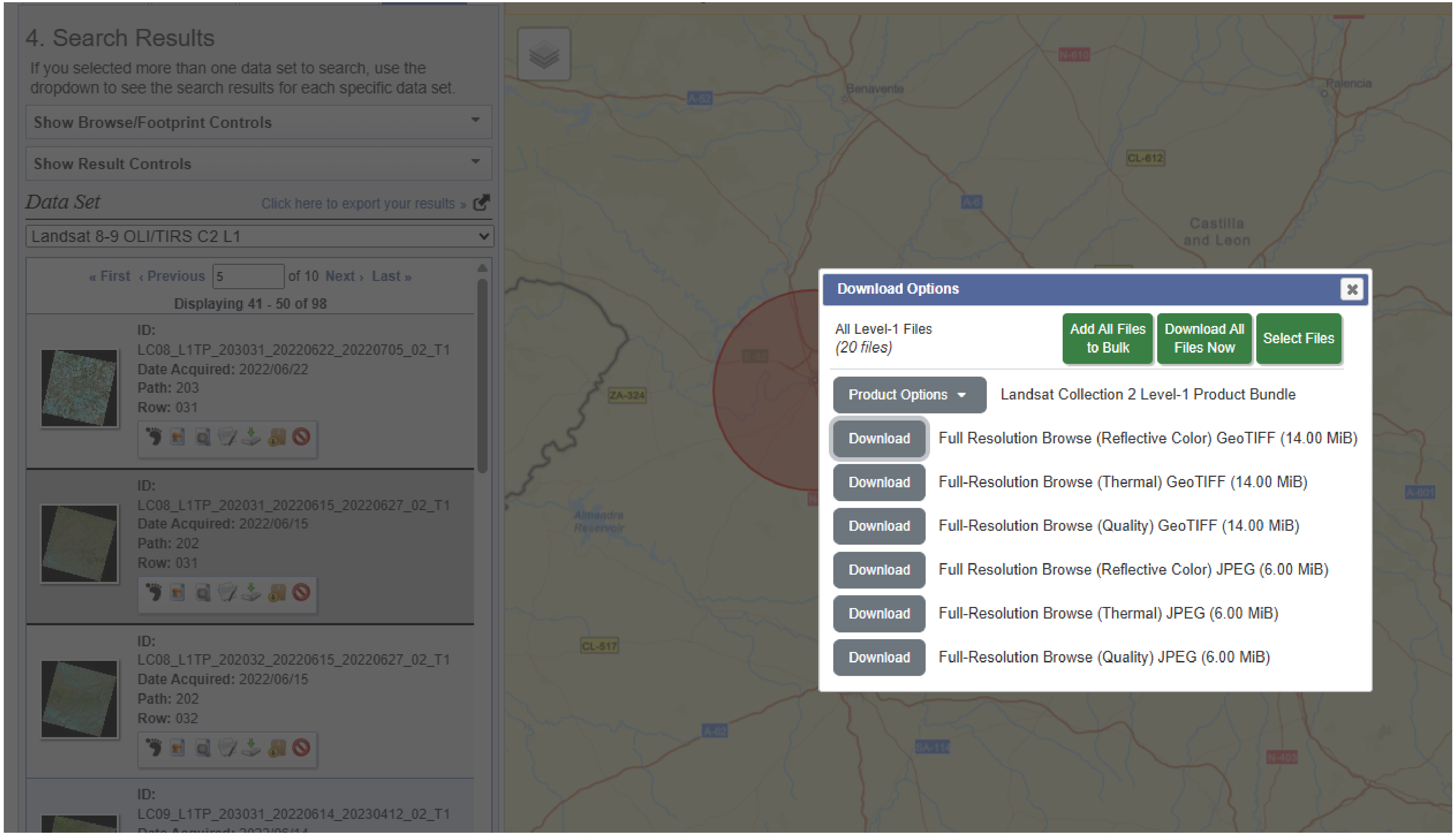
4. Select images before and after the disaster, for example here on the 14th and 22 of June.

With the footpring icon, check the map overlay and check they cover the same area and your area of interest.



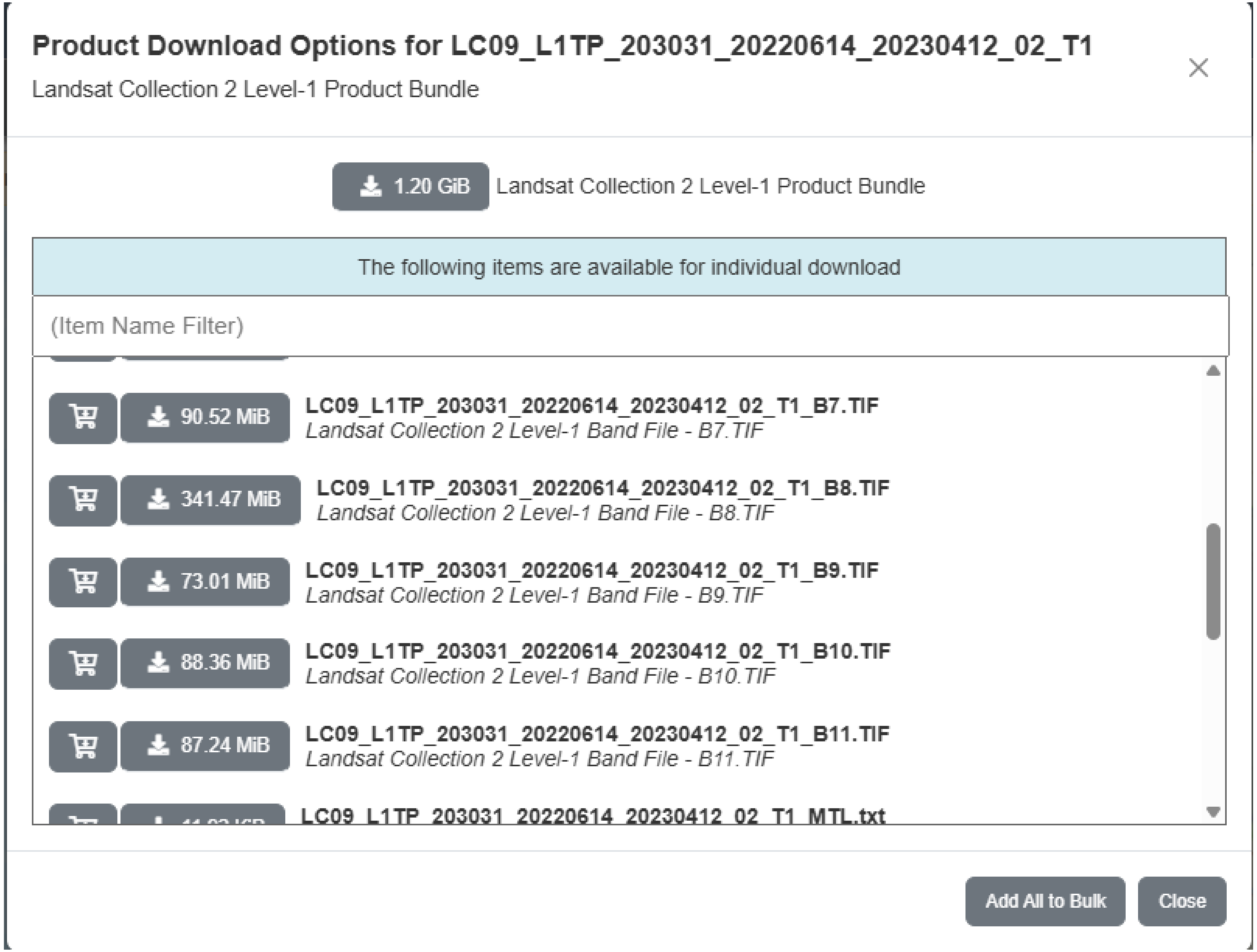
Download data from USGS

5. Download color and thermal data



Download data from USGS

5. Download B2, B3, B4 (RGB data), B10, B11 (thermal), and quality data.



Analysis

What to do. Individual assignment. Send slides with the following:

1. **Choose disaster, area and date.**

Send description of the disaster (e.g. Newspaper summary). Screenshot in google maps of area.

In QGIS:

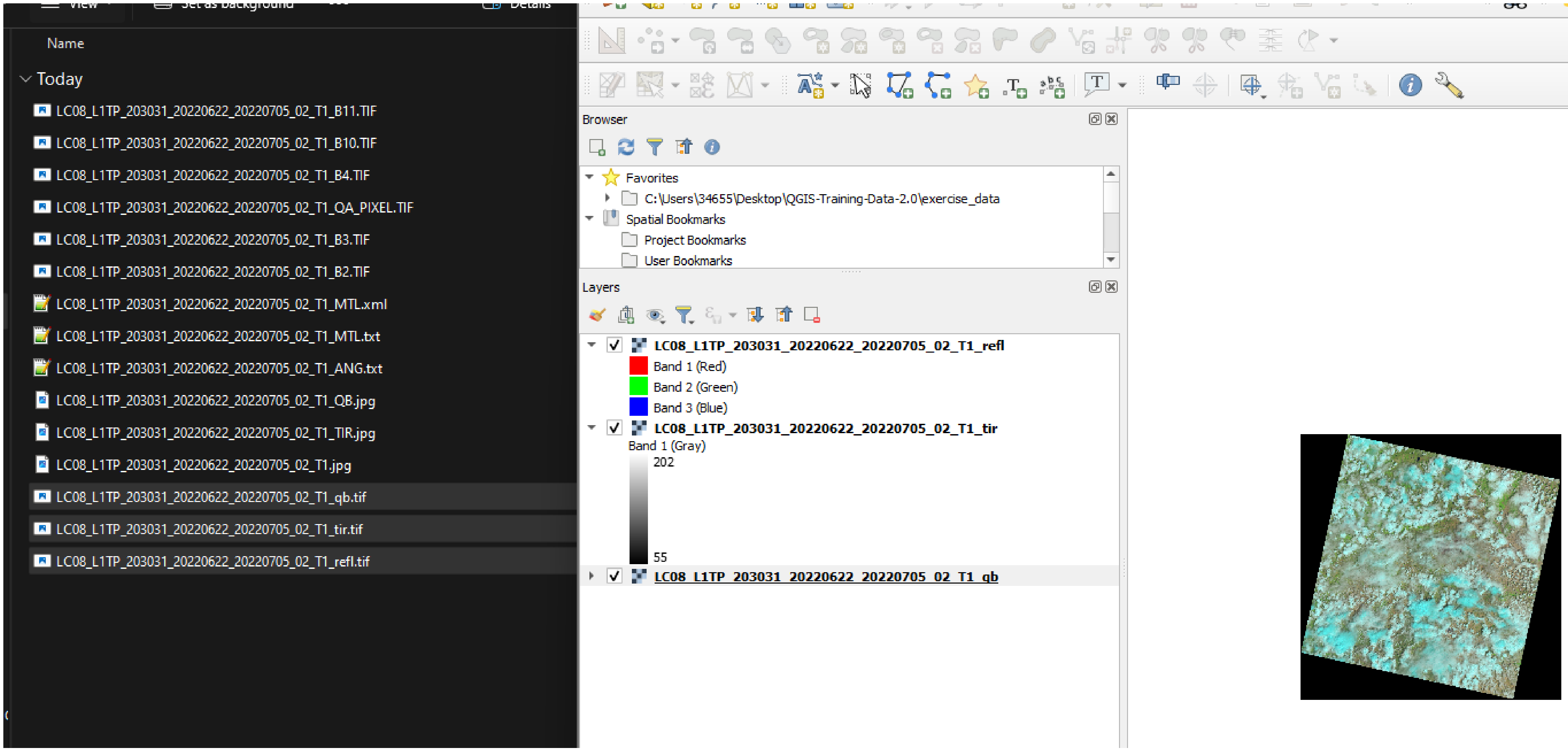
2. **For the prior and then the after-disaster dates: compare the RGB data versus thermal.**

Screenshot data and describe what you see.

3. **Compare the RGB data for both dates, what has changed?**

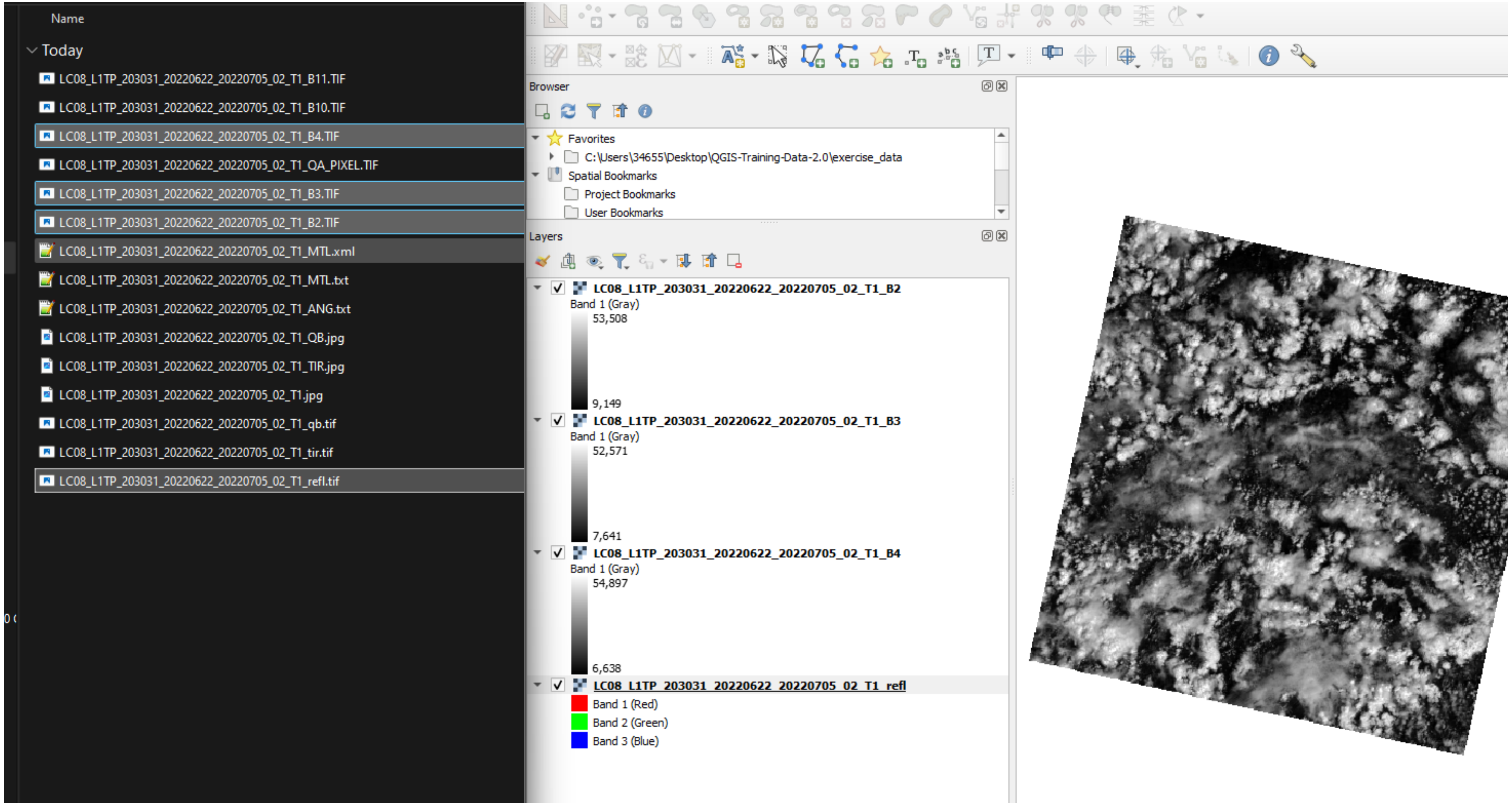
4. **Compare the thermal data for both dates, what do we see, and what are the differences w.r.t. RGB data**

Example 22-06-2022



Compare RGB bands

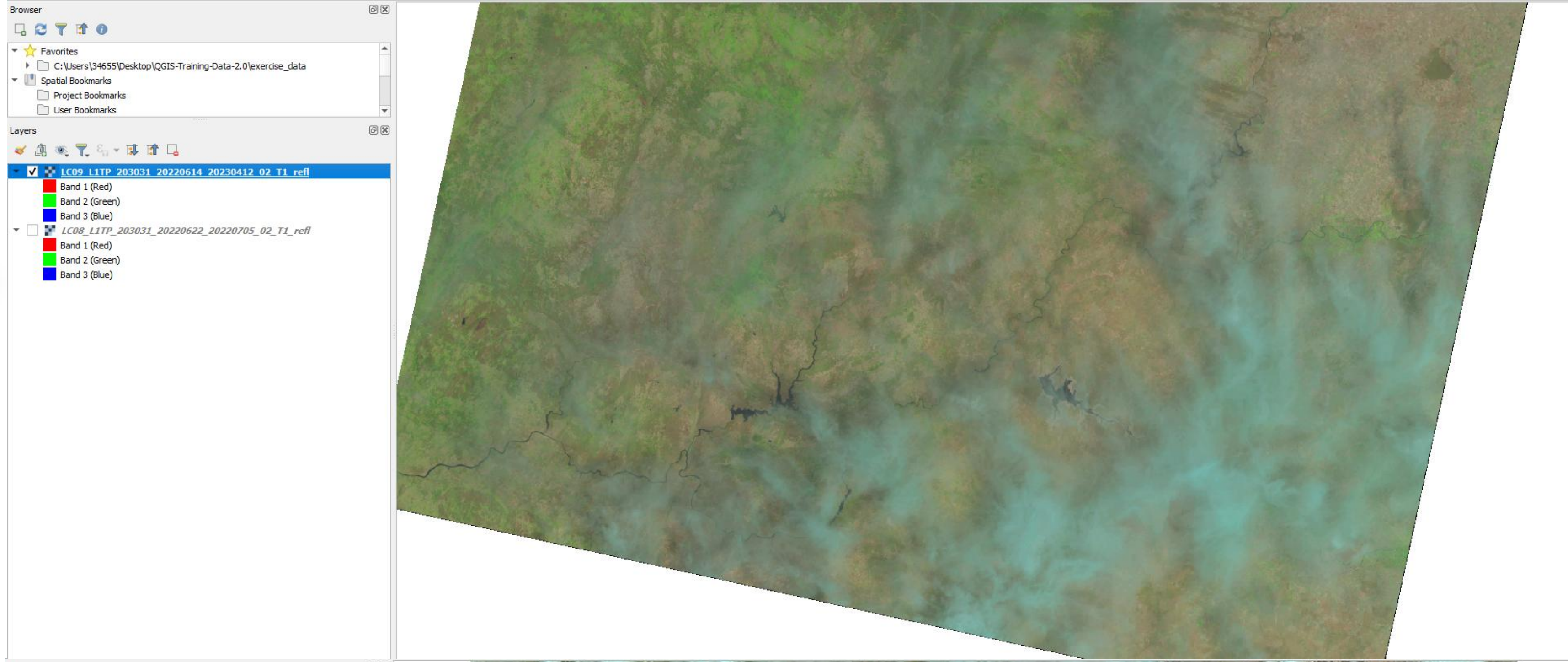
The refl product has RGB data, compare with the B2, B3 and B4 date.

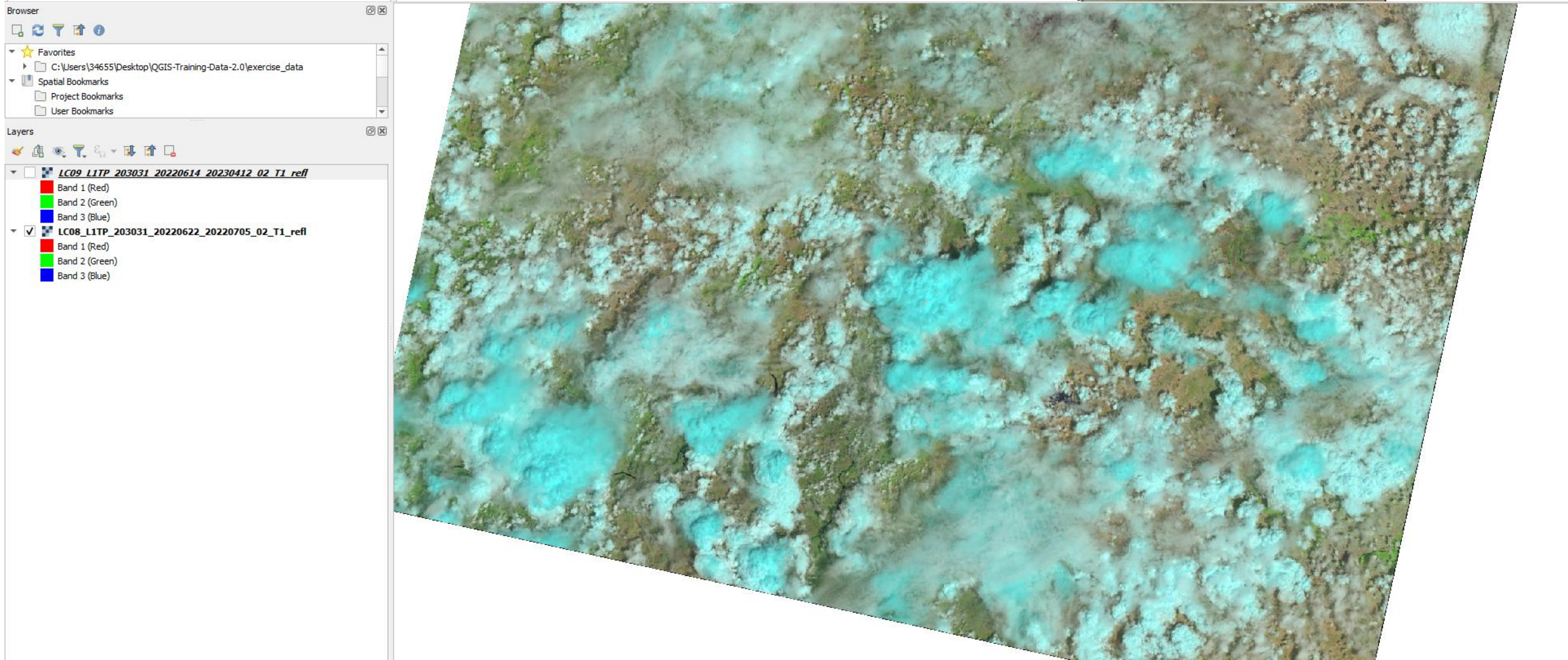


Compare visual data before and after the disaster

Open the refl product for both dates. Notice that you will only see the top layer. You need to toggle/untoggle.

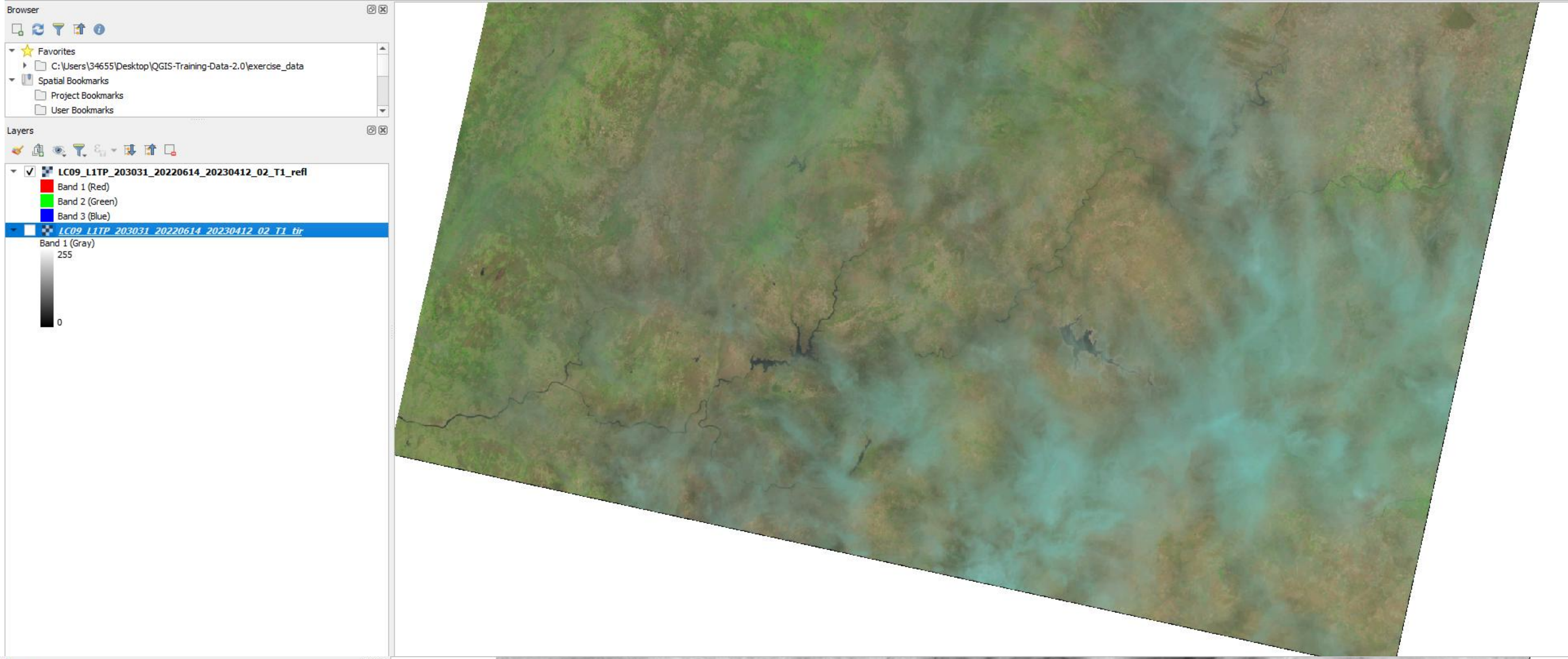
Notice the clouds of smoke

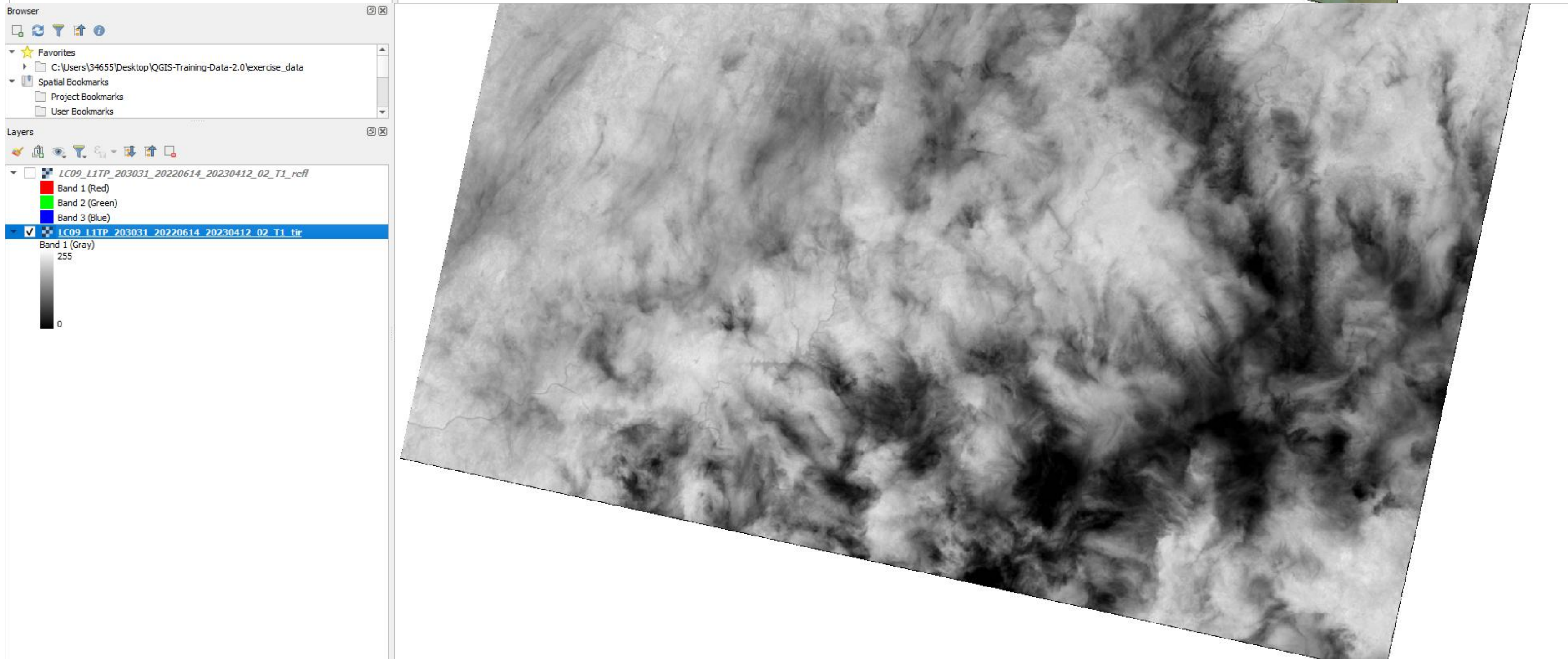




Compare visual with thermal data

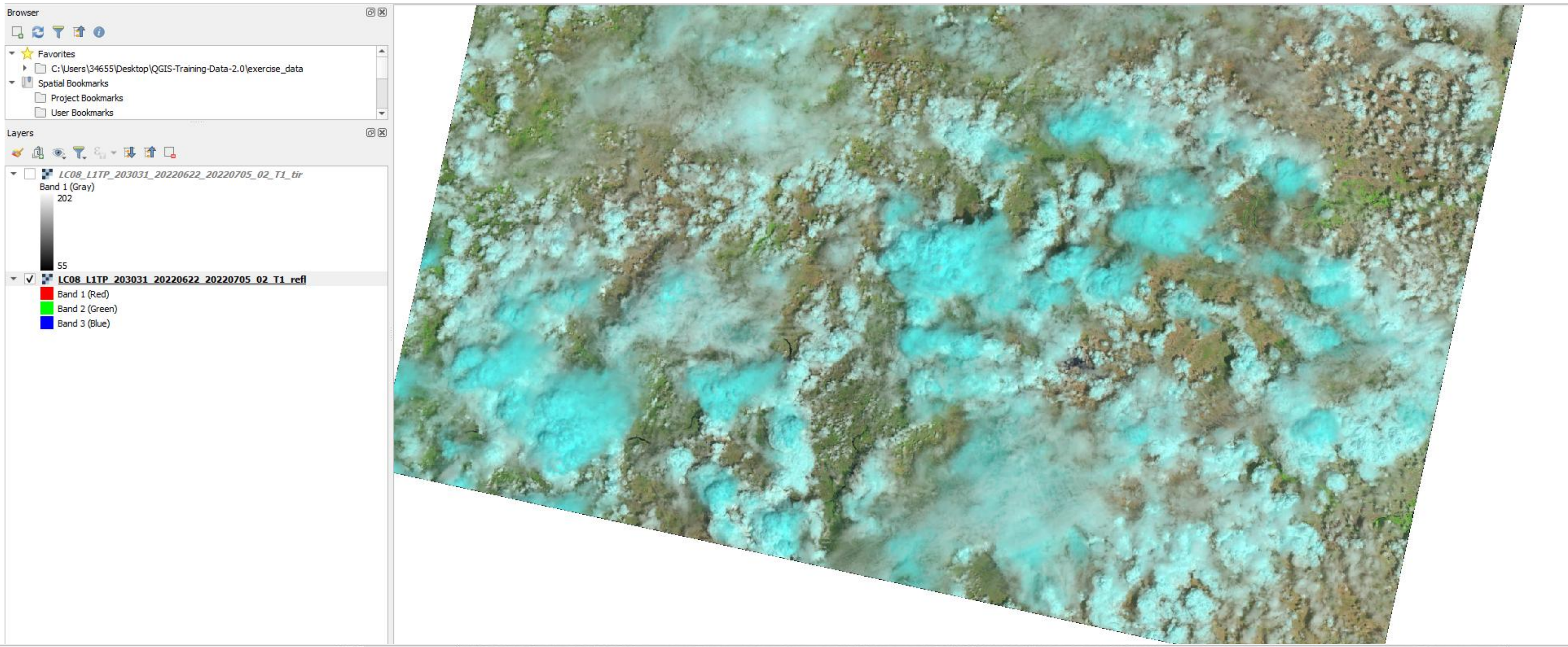
BEFORE the fire

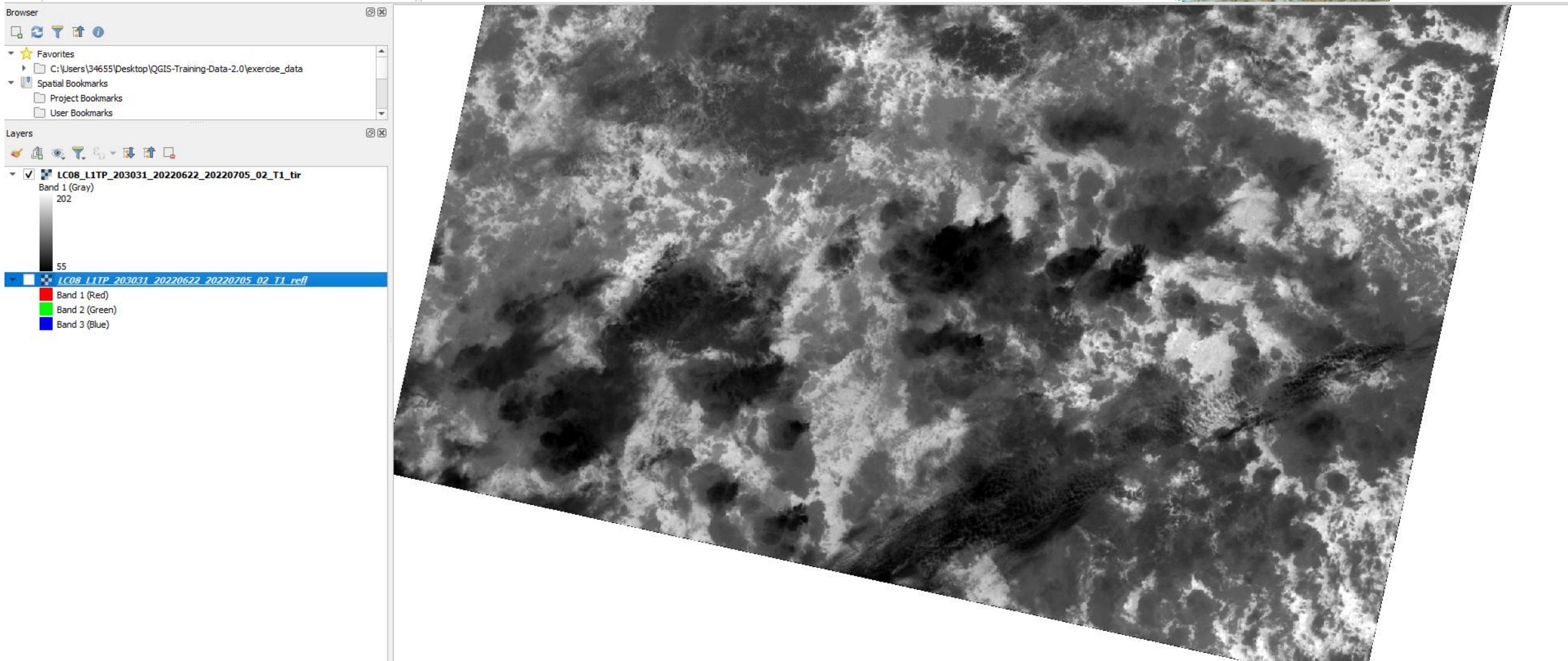




Compare visual with thermal data

AFTER the fire





MASTER X