

# Copernicus Sentinel-2 and Landsat Missions: Cooperation and Coordination Activities in Cal/Val Harmonization

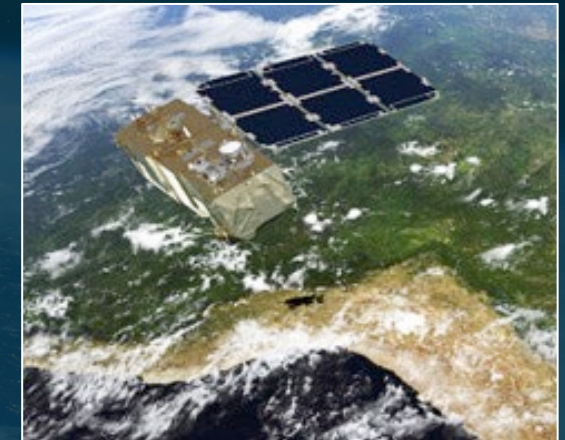
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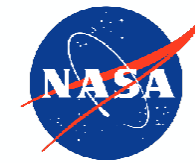
# Sentinel-2 & Landsat



**Coordination on Cal/Val and data quality activities** becomes even more crucial when data from different satellites are **used by users worldwide in a complementary and synergetic manner.**

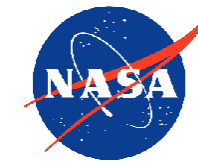
- ❖ Data quality has enormous downstream impacts on the accuracy and reliability of the products;
- ❖ Facilitate cross-calibration and interoperability;
- ❖ Support synergetic use of data coming from different sensors/satellites

# S2 – Landsat : Harmonisation Overview



- ✓ **Geometry :**
  - ✓ S2 GRI (Global Reference Image)
  - ✓ Copernicus DEM (Digital Elevation Model)
  - ✓ DEMIX (DEMs Intercomparison eXercise)
  - ✓ DGG (Discrete Global Grid System)
- ✓ **Level-1 Radiometry :**
  - ✓ Sensor radiometric inter-comparison using an integrating sphere
  - ✓ S2 inspired by Landsat-8 bands
  - ✓ Absolute radiometry inter-comparison
- ✓ **Level-2A Radiometry and Cloud Mask:**
  - ✓ ACIX (Atmospheric Correction Intercomparison eXercise)
  - ✓ CMIX (Cloud Mask Intercomparison eXercise)
  - ✓ CARD4L
- ✓ **Level-2H and Level-2F**
  - ✓ Sen2Like
- ✓ **Other**

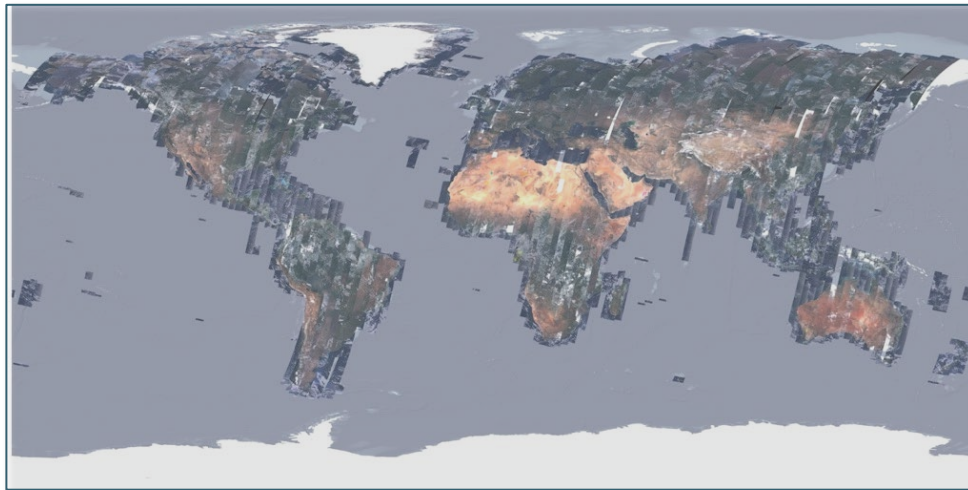
# Geometry / S2 GRI



- ✓ Sentinel-2 EO data processor has been upgraded to improve geolocation and multi-temporal co-registration;
- ✓ Processing is now based on the usage of the **GRI (Global Reference Image)**, as source of Ground Control Points (GCPs);



It is a full repeat cycle dataset of well-localized and as cloud-free as possible mono-spectral (band 4) Sentinel-2 Level-1B products



Open Access Article

### Harmonizing the Landsat Ground Reference with the Sentinel-2 Global Reference Image Using Space-Based Bundle Adjustment

by Rajagopalan Rengarajan <sup>1,\*</sup>, James C. Storey <sup>1</sup> and Michael J. Choate <sup>2</sup>

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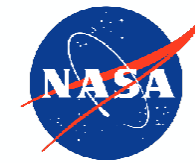
*Remote Sens.* **2020**, *12*(19), 3132; <https://doi.org/10.3390/rs12193132>

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- ✓ Landsat also uses the S2 GRI in Collection-2. This has greatly improved the co-registration between the two missions.



# Geometry / Copernicus DEM

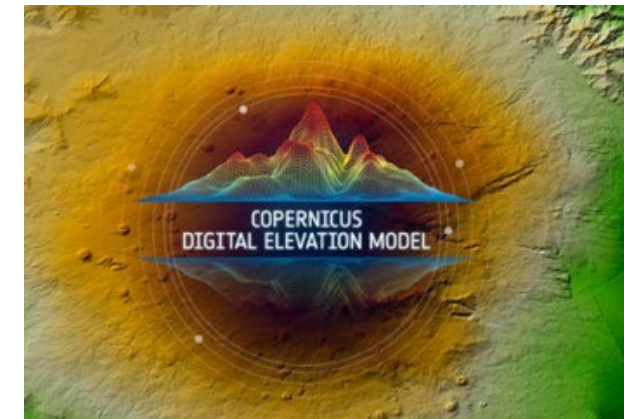


- The Copernicus DEM includes three instances with different resolutions:
  - **90 meter** dataset for global coverage (open and free);
  - **30 meter** dataset for global coverage (open and free);
  - **10 meter** dataset for the EEA-39 area (restricted to eligible users) .

- All Copernicus Program DEM instances are available at: <https://spacedata.copernicus.eu/>

- USGS is evaluating the Copernicus DEM and considering its usage for Landsat Collection-3.

- If it materialises, this would further improve the geometric harmonisation, in terms of:
  - Landat – Sentinel-2 co-registration;
  - Absolute geo-location (for regions where Copernicus DEM is better than currently used Landsat DEM).



# Geometry / DEMIX

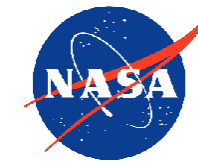
## DEMIX = DEMs Inter-comparison eXercise

- ✓ To identify a consistent and comprehensive DEM definitions and terminology;
- ✓ To define a base and extended set to benchmarking metrics and respective algorithms with open source tool able to provide accuracy at pixel level;
- ✓ To perform detailed comparison results on test areas and aggregated wall to wall benchmarking results;
- ✓ To provide recommendation of a reference DEM and consistently orthoimage;
- ✓ To elaborate a final reports and peer-reviewed publications.

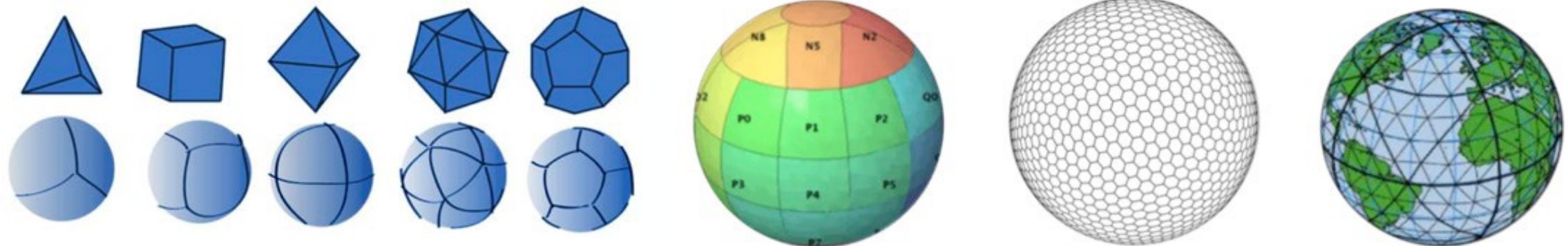


- ✓ It includes comparison of Sentinel-2 DEM (**Copernicus DEM**) and Landsat DEM (**NASA DEM**).
- ✓ Participants: JRC, ESA, USGS, EOEXPLORER UG, Department of Oceanography, US Naval Academy, Yale University, VisioTerra, Imaging Group, LatinGEO, University of Sao Paulo.

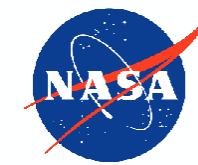
# Geometry / DGGS



- ✓ Need to explore innovative approaches to organise, store, manage and analyse EO imagery.
- ✓ ESA has initiated an activity to assess and prototype the usage of DGGS (Discrete Global Grid System) for Sentinel-2 data;
- ✓ Expectation to have a unified framework for EO data seamless integration, multi-source data fusion and cloud computing on a global scale.
- ✓ The goal is therefore to assess the feasibility of adopting DGGS for Sentinel-2 data and testing them for Analysis Ready Data (ARD) products Level-2A, Level-2H and Level-2F;
- ✓ Exchanges on the subject with USGS.



# TOA Radiometry / Pre-flight

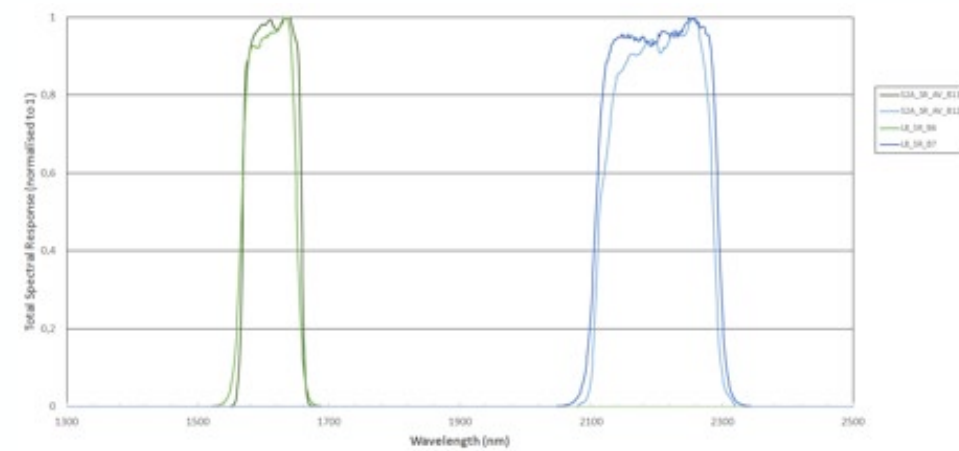
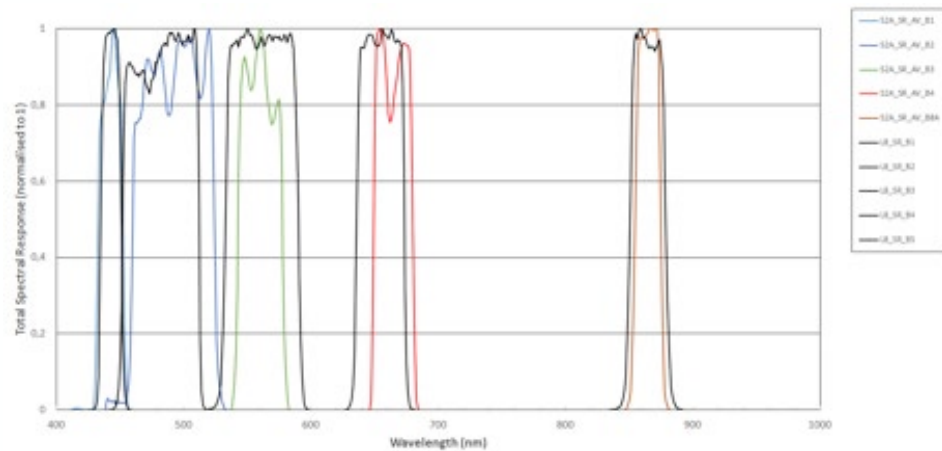


✓ Sensor absolute radiometry inter-comparison using an integrating sphere.

- <https://landsat.gsfc.nasa.gov/article/esa-nasa-collaboration-fosters-comparable-land-imagery>

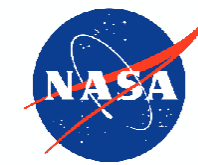


✓ Sentinel-2 “inspired” by Landsat-8 bands.

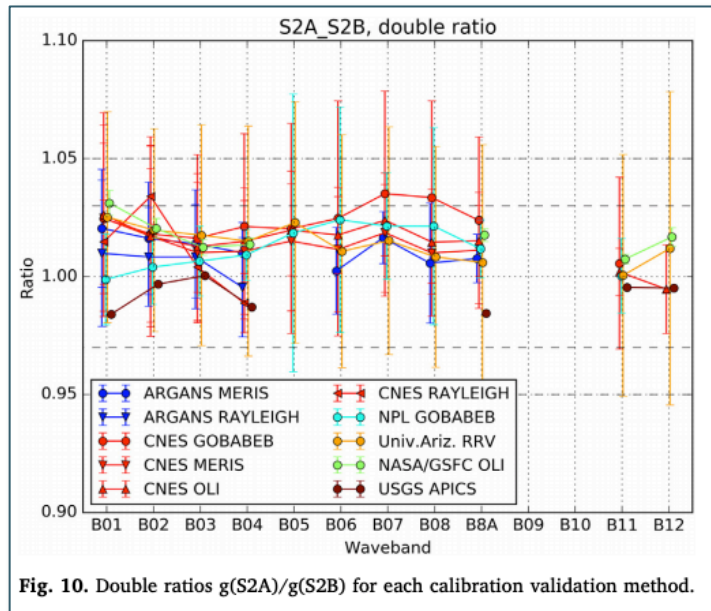




# TOA Radiometry / In-flight



✓ Absolute radiometry inter-comparison with NASA/GSFC and University of Arizona teams involved.



✓ S2B radiometry will be matched with S2A in Sentinel-2 Collection 1, S2A being at the same time the S2 sensor closer to Landsat-8.

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ELSEVIER

An inter-comparison exercise of Sentinel-2 radiometric validations assessed by independent expert groups

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ARTICLE INFO

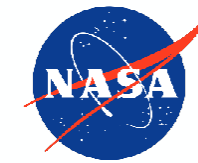
Keywords:  
 Sentinel-2  
 Radiometric validation  
 Vicarious methodologies  
 Inter-comparison  
 Expert groups

ABSTRACT

Copernicus is the European Union's Earth Observation and Monitoring programme, delivering free access to operational and historical environmental data to support applications in a wide range of societal benefit areas. To allow meaningful long-term environmental monitoring and robust decision-making, it is essential to ensure that satellite-retrieved products are of high quality and consistency. This paper describes the outputs of an international workshop on the radiometric calibration validation of the Copernicus Sentinel-2A and Sentinel-2B Multi-Spectral Instrument. A wide range of vicarious methodologies have been applied independently and then compared per type of target. All methods agree on the good radiometric performance of both Sentinel-2A and Sentinel-2B with respect to the mission requirements as well as on evidence of a slight bias between the two instruments. Comparisons of all these results are discussed to highlight the benefits and advantages of the methods as well as to propose potential improvements either for the methods themselves and/or for the comparison exercise.



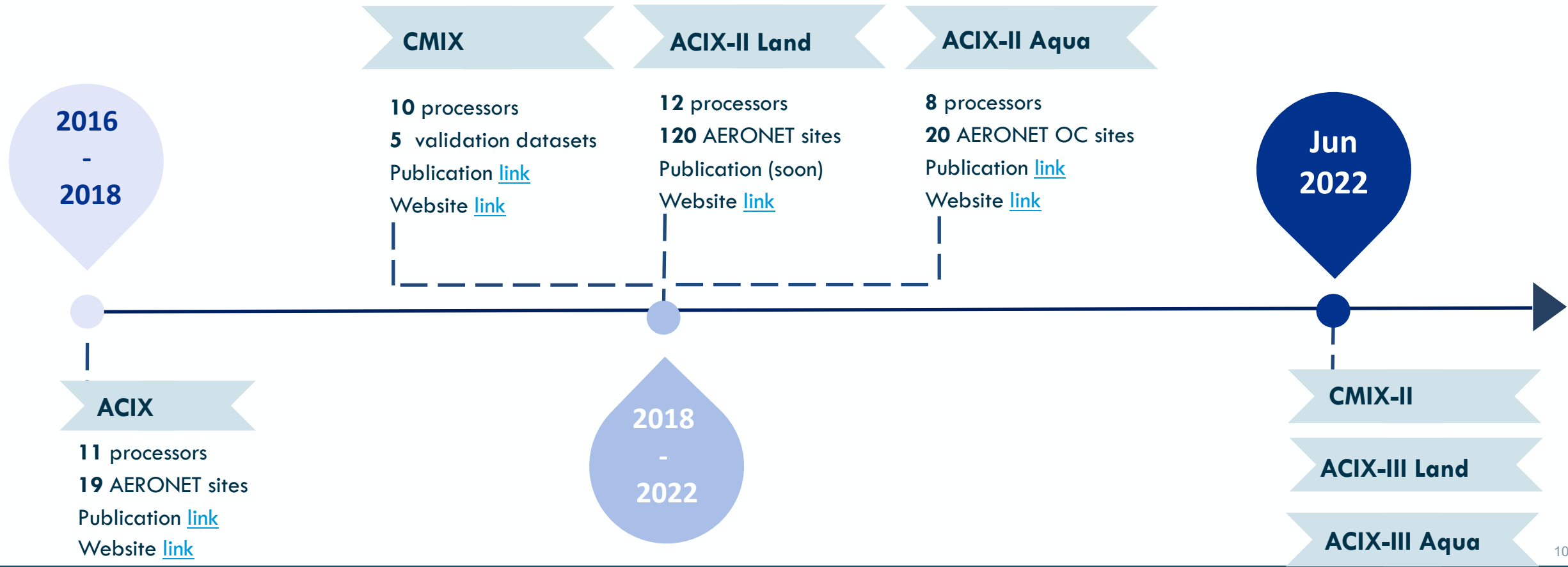
# BOA Radiometry / ACIX and CMIX



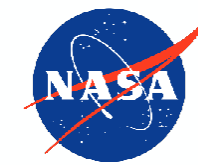
**ACIX:** Atmospheric Correction Inter-comparison Exercise

**CMIX:** Cloud Mask Inter-comparison Exercise

} **CEOS WGCV** (Working Group on Calibration & Validation) initiatives to bring together AC and CM developers for Sentinel-2 and Landsat 8 imagery



# BOA / S2 and CEOS ARD



**CEOS Analysis-Ready Datasets**

The following table summarises all of the satellite EO datasets that have been assessed as CEOS Analysis Ready Data (CEOS ARD). DOI links are provided for access, along with links to further information, sample products, and the completed CEOS ARD self-assessment and peer review outcome documents.

Product	CEOS ARD Type	PFS Version	Agency	Mission(s)	Threshold Specification	Target Specific
Landsat Collection 2	Surface Reflectance	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	81%
Landsat Collection 2	Surface Temperature	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	83%
Sentinel-2 Level-2A	Surface Reflectance	v5.0	ESA	Sentinel-2A, 2B	100%	Not assessed
EnMAP	Surface Reflectance	v5.0	DLR	EnMAP	100%	Not assessed



<http://ceos.org/ard>

**CEOS ANALYSIS READY DATA**

CEOS Analysis Ready Data for Land (CARD4L) are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets.



**Product Family Specifications**

**Surface Reflectance**

Data collected with multispectral sensors operating in the VIS/NIR/SWIR wavelengths. These typically operate with ground sample distance and resolution in the order 10-100m however the Specification is not inherently limited to this resolution.

[Read Product Family Specification >>](#)

**Surface Temperature**

Data collected with multispectral sensors operating in the thermal infra-red (TIR) wavelengths. These typically operate with ground sample distance and resolution in the order 10-100m.

[Read Product Family Specification >>](#)

**Radar Backscatter**

Data collected by Synthetic Aperture Radar (SAR) sensors.

[Read Product Family Specification >>](#)

- ✓ Landsat Collection-2 products compliant to CEOS ARD for SR at threshold level.
- ✓ Since 25<sup>th</sup> January 2022 Sentinel-2 L2A data are **Analysis Ready Data** according to CEOS ARD Specifications at Threshold Level





# Level-2H and Level-2F / Sen2Like Project



## GOAL:

to provide **S2-like surface reflectance** with increased frequency through a harmonisation/fusion process **combining data from different sensors**.

## Current Status:

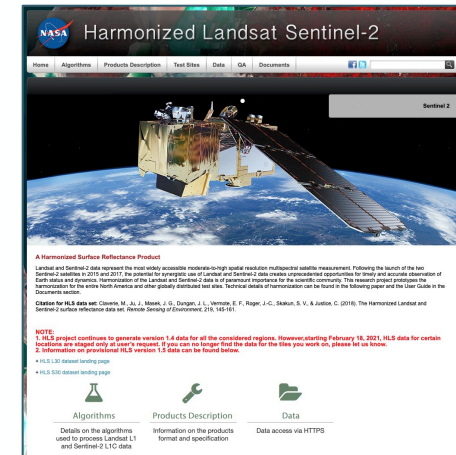
combining **Sentinel-2** and **Landsat-8/9** using SMAC and Sen2Cor.

Pilot production over Belgium available for assessment.

✓ Project similar to NASA HLS [<https://hls.gsfc.nasa.gov/>] but instead of transforming S2 into Landsat, Sen2Like transforms Landsat (and other missions) into S2.

## Sen2Like future steps:

- Integration of ASI **PRISMA** hyperspectral mission.
- Improving the operationalisation aspects as an on-demand processor.
- BRDF validation using specific DRONES campaigns.

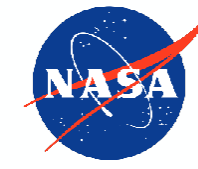


<https://hls.gsfc.nasa.gov>

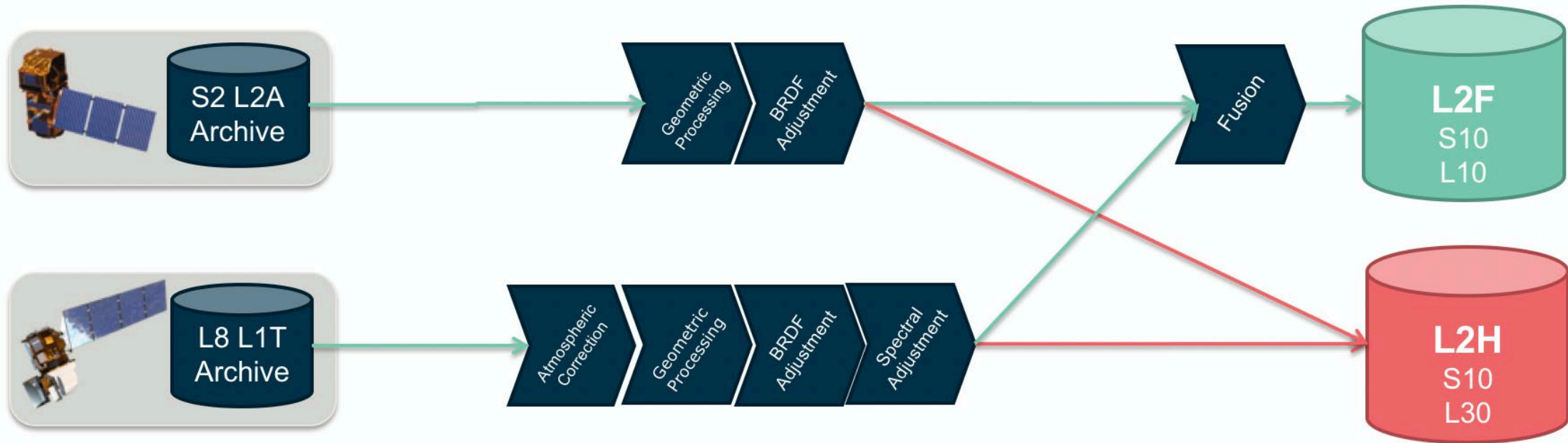
Sen2Like software available in open-source at:  
<https://github.com/senbox-org/sen2like>



# Level-2H and Level-2F / Sen2Like Project



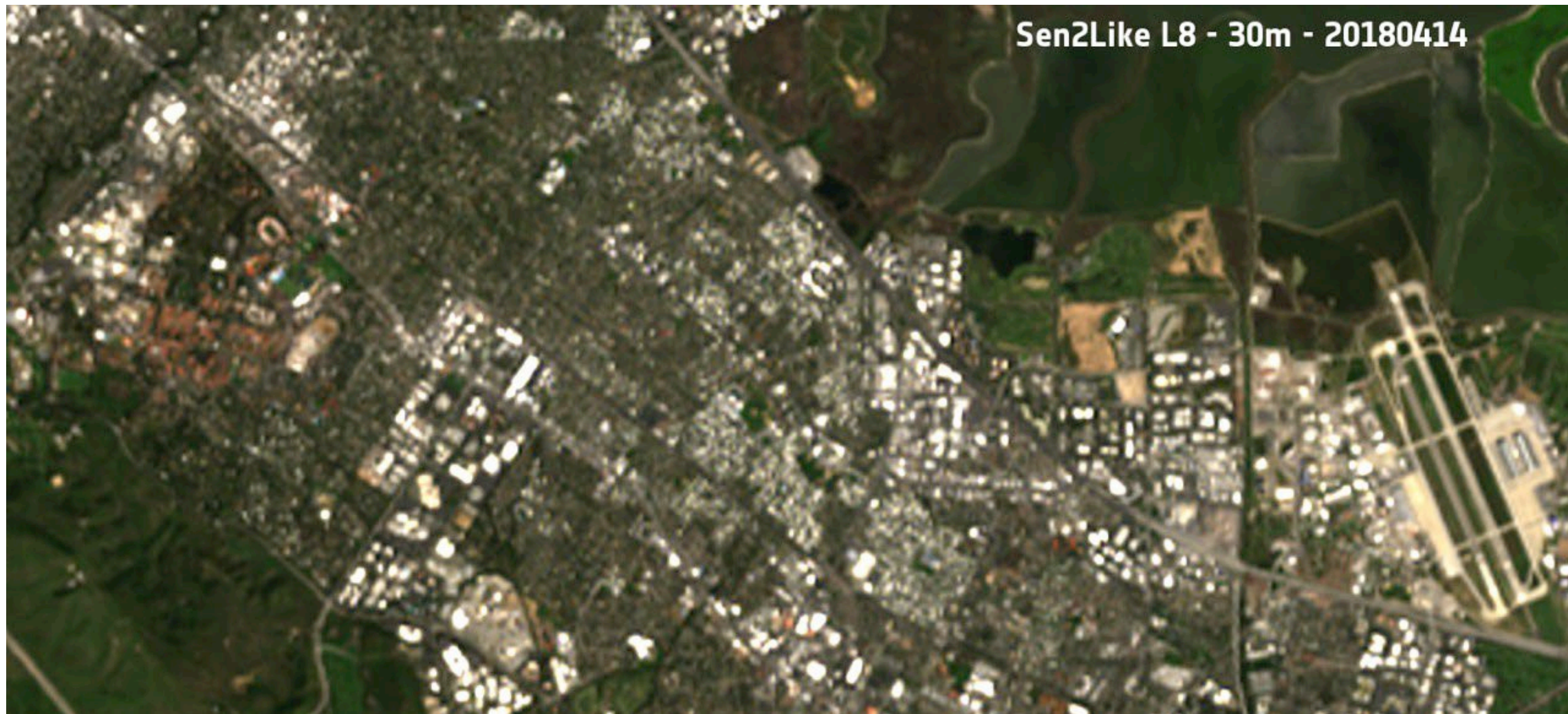
- ✓ **Harmonisation** includes consistent atmospheric corrections, spectral adjustments, BRDF adjustments and re-gridding.
- ✓ **Fusion** goes beyond bringing Landsat-8 to Sentinel-2 spatial resolution.



# Level-2H and Level-2F



## Example of Level-2H from Landsat

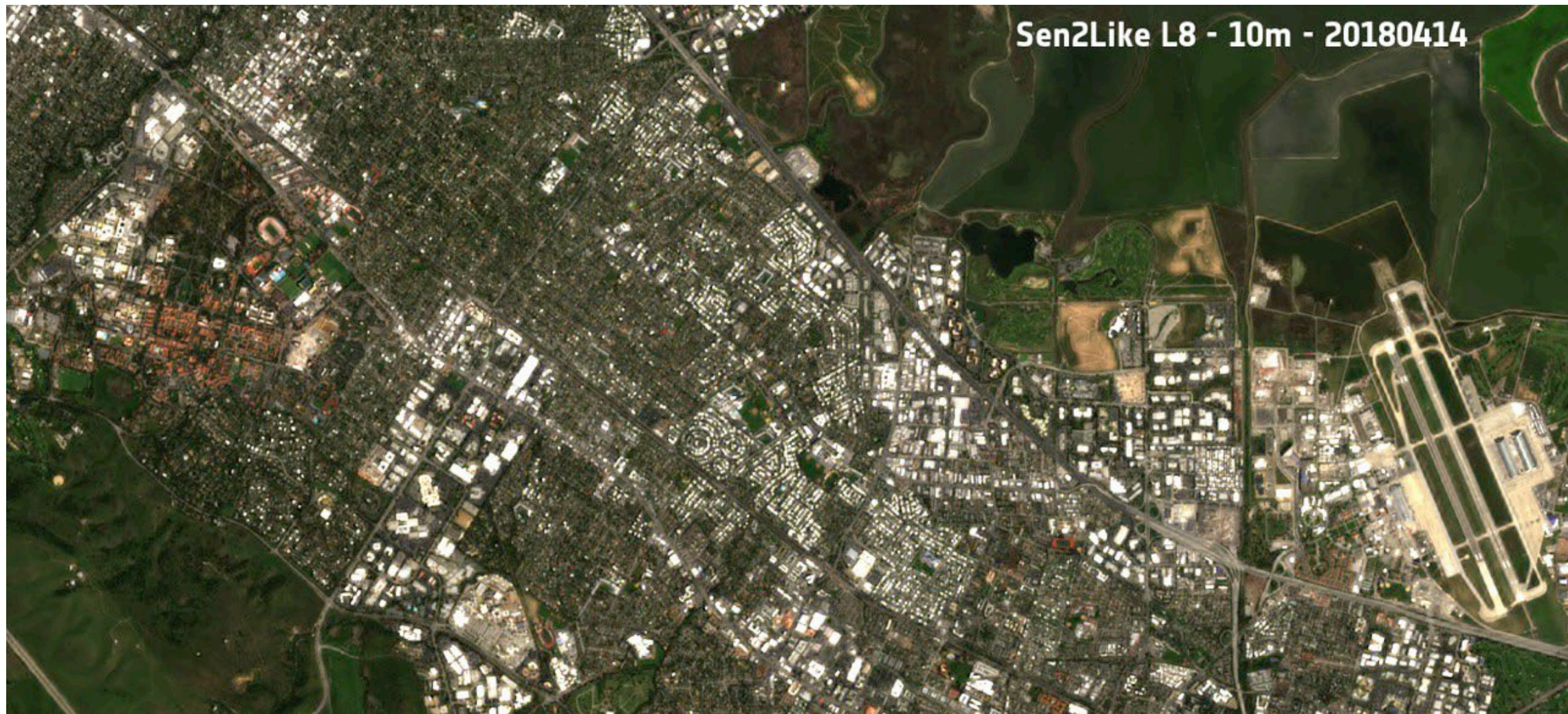




# Level-2H and Level-2F

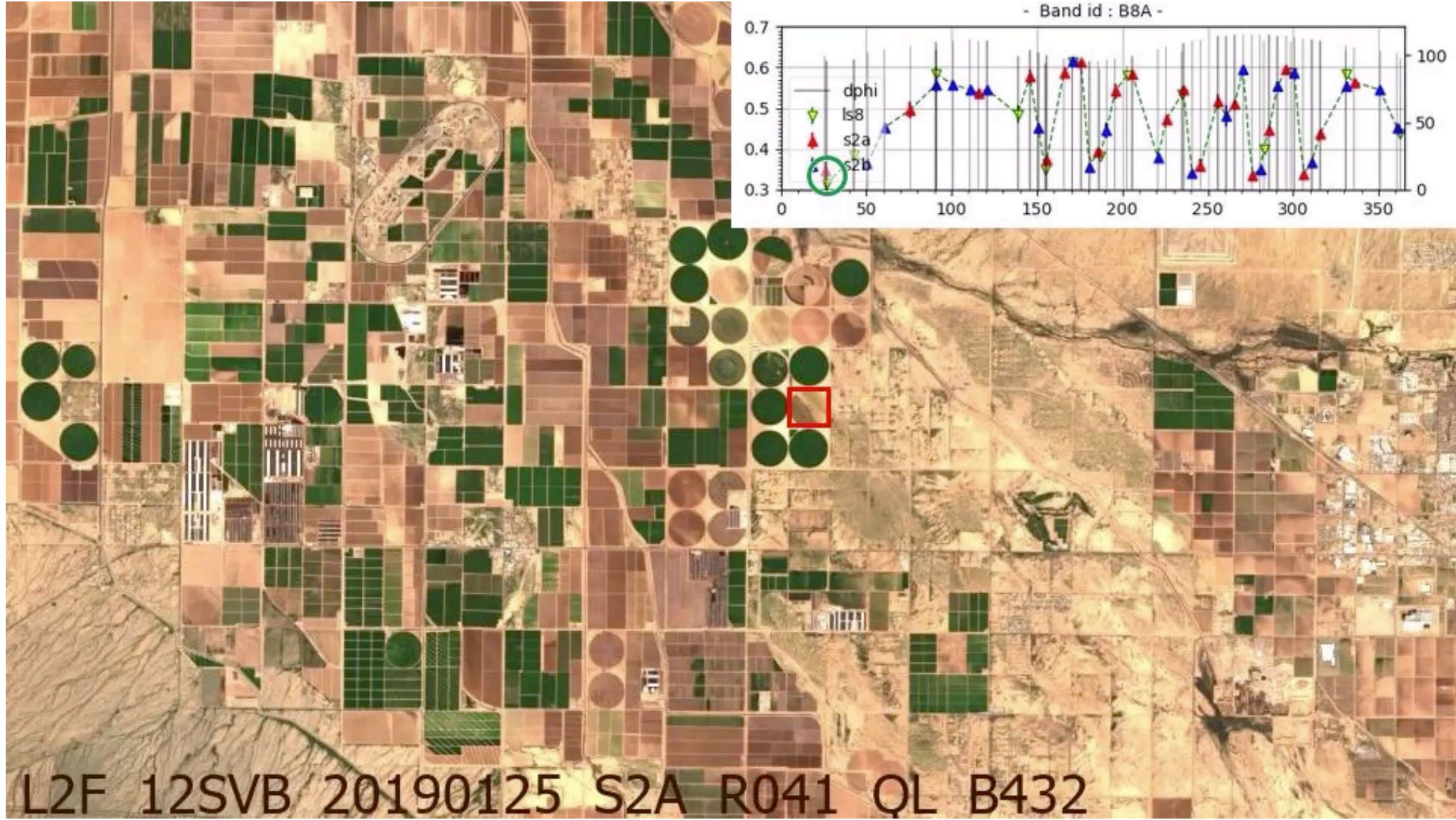
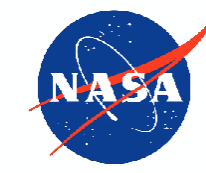


## Example of Level-2F from Landsat





# Level-2H and Level-2F / Sen2Like Overview



# Conclusion



A number of **cooperation and coordination** activities between the Copernicus Sentinel-2 & Landsat missions have been **carried out** and many are **on-going**.

On top of all the already mentioned activities, we are actively involved in international forums and in mission-dedicated forums, with the goal to continue the Sentinel-2 & Landsat cooperation activities **for the benefit of the worldwide EO users community**.

# Next Steps

In the context of the next generation of land imaging satellites (i.e. Sentinel Next Generation & Landsat Next), we are investigating a **collaborative work program** for establishing ongoing **joint EO activities** on sustainable land monitoring for **cost reduction, better complementarity, and increased efficiency**.





**Thank you for your attention!**

