Advances in EO Technologies for Agricultural Monitoring

Waldner F., Defourny P., Bontemps S., Arias M., Bellemans N., Cara C., Dedieu G., Guzzonato E., Hagolle O., Inglada J., Morin D., Rabaute T., Savinaud M., Udroiu C., Valero S., Koetz B. & 12 benchmarking & demonstration site partnerS

Unique momentum for satellite remote sensing in agriculture

Need for better agricultural monitoring capabilities
→ EO observation can help

EO response to operational agricultural applications:

- Emerging collaborative initiatives endorsed by G20 in the context of GEO (AMIS, GEOGLAM)
- JECAM initiative opening the door to move from local experiments to global solutions
- CEOS support to global agriculture users requirements
- US and Chinese efforts on 30-m global croplands mapping
- **Sentinel-2a&b mission to finally reach agric. Application requirements, jointly with Landsat-8 and Sentinel-1a&b**

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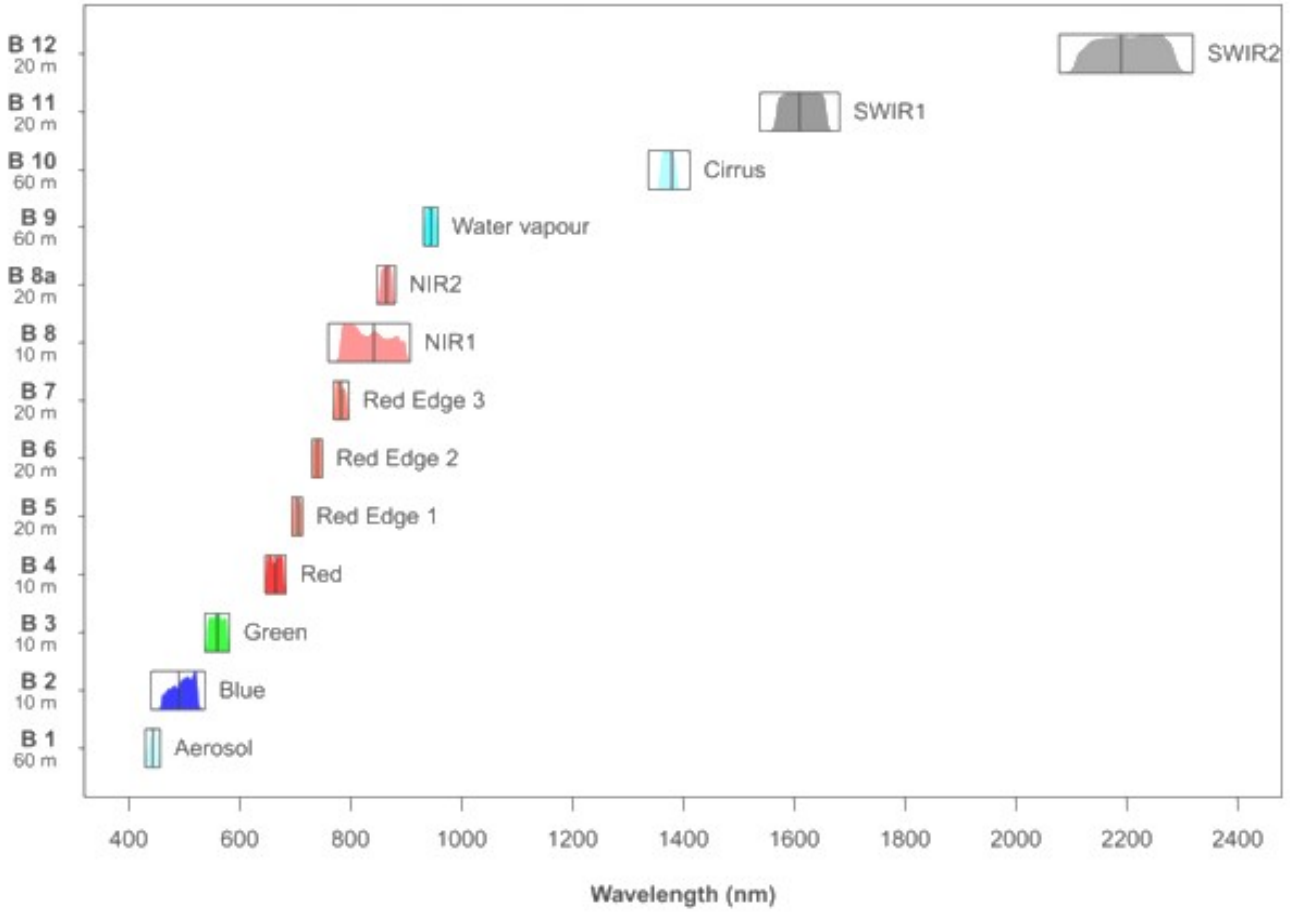
A closer look at Sentinel-2

10-day revisit cycle with Sentinel-2A, 5-day revisit cycle with Sentinel-2A and -B



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Sentinel-2 for Agriculture Objectives

Preparation for national to regional agricultural monitoring based on Sentinel-2

- R&D for full exploitation of temporal & spatial resolution of S2

Consolidate Best Practices for EO agricultural monitoring

- Benchmarking & validation of algorithms for 4 EO products
- Testing products over a wide range of conditions (globally distributed JECAM network)

Strengthening National Capacity for Agricultural Monitoring

- Open source system for **national reporting & food security**
- Transfer to users including local system installation & training
- Demonstration of agricultural EO products at national scale

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Sen2–Agri : a 3-phase approach

User req. and method development 2014

System development and EO products 2015

Demonstration & Validation 2016

JECAM
Joint Experiment for Crop Assessment and Monitoring

- ✓ **User Requirements**
- ✓ **Products specification**
- ✓ **Methods development**

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User-driven approach

onsortium

upport & data provider

esa

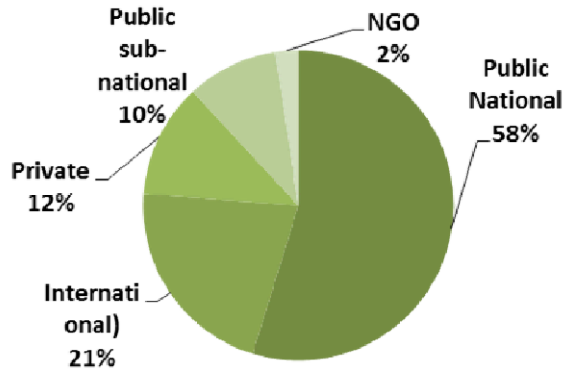
hampion sers

Agriculture and Agri-Food Canada

1st User Consultation organized by ESA in 2012

2nd User Consultation through surveys in 2014

Survey filed up by 42 institutions



1st Sen2-Agri Users Workshop – FAO May 2014

2nd Sen2-Agri Users Workshop – EU Nov.2015

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System to deliver 4 Sen2-Agri products

in line with the GEOGLAM core products

Monthly cloud free surface reflectance composite at 10-20 m

CLOUD FREE SURFACE REFLECTANCE COMPOSITES

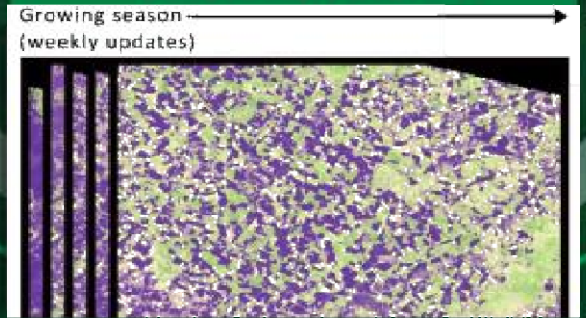
Vegetation status map at 20 m delivered every week (NDVI, LAI, pheno index)

DYNAMIC CROPLAND MASK

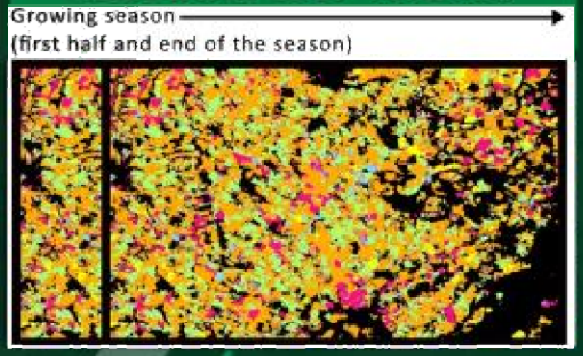
Binary map identifying annually cultivated land at 10m updated every month

Open source toolbox
Capacity building and training

VEGETATION STATUS

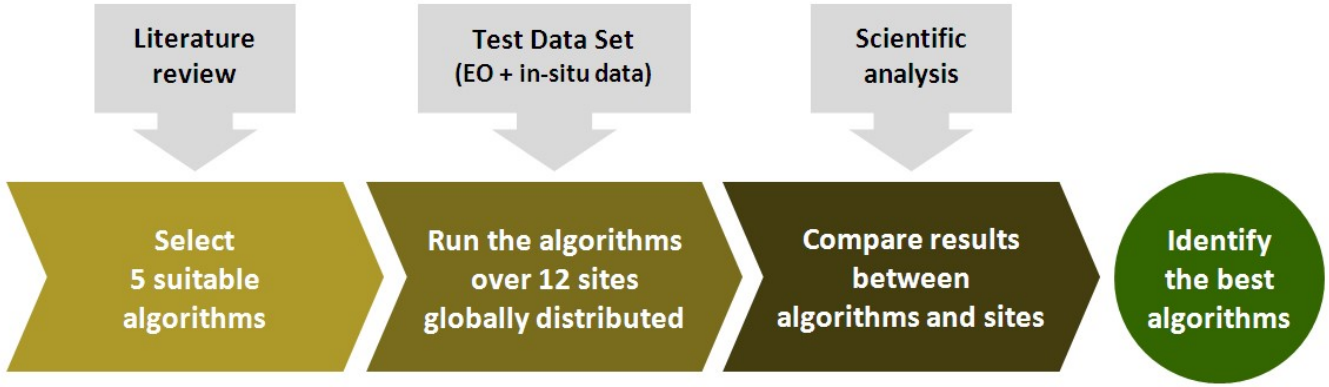


CULTIVATED CROP TYPE MAP



Crop type map at 10 m for the main regional crops including irrigated/rainfed discrimination

Benchmarking for selecting the best algorithms for each product



12 test sites, relying on JECAM network, spread over the world, which represent more than 17 major crop types

JECAM
Joint Experiment for Crop Assessment and Monitoring

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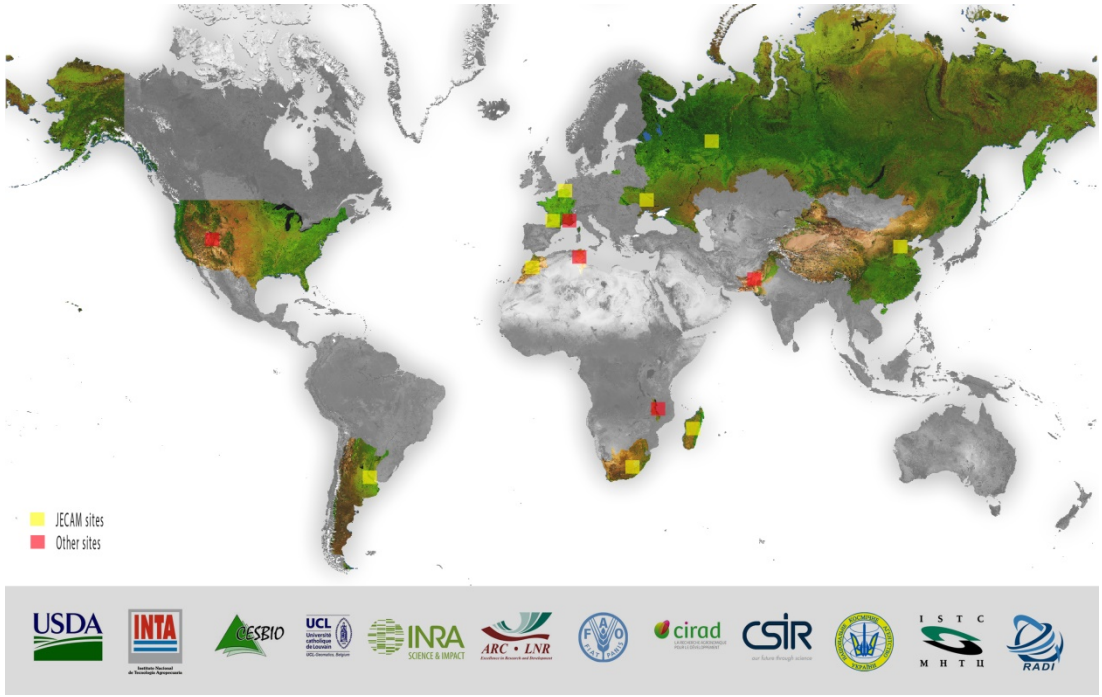
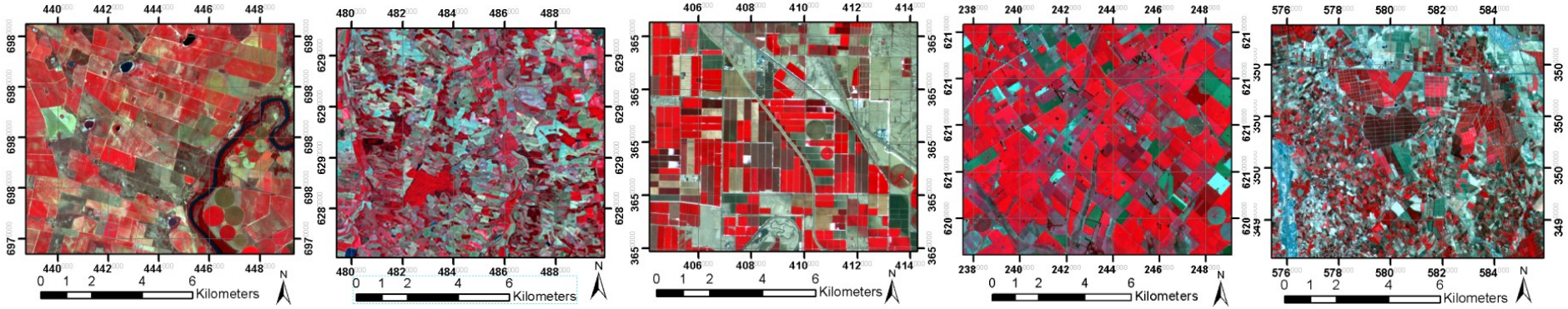
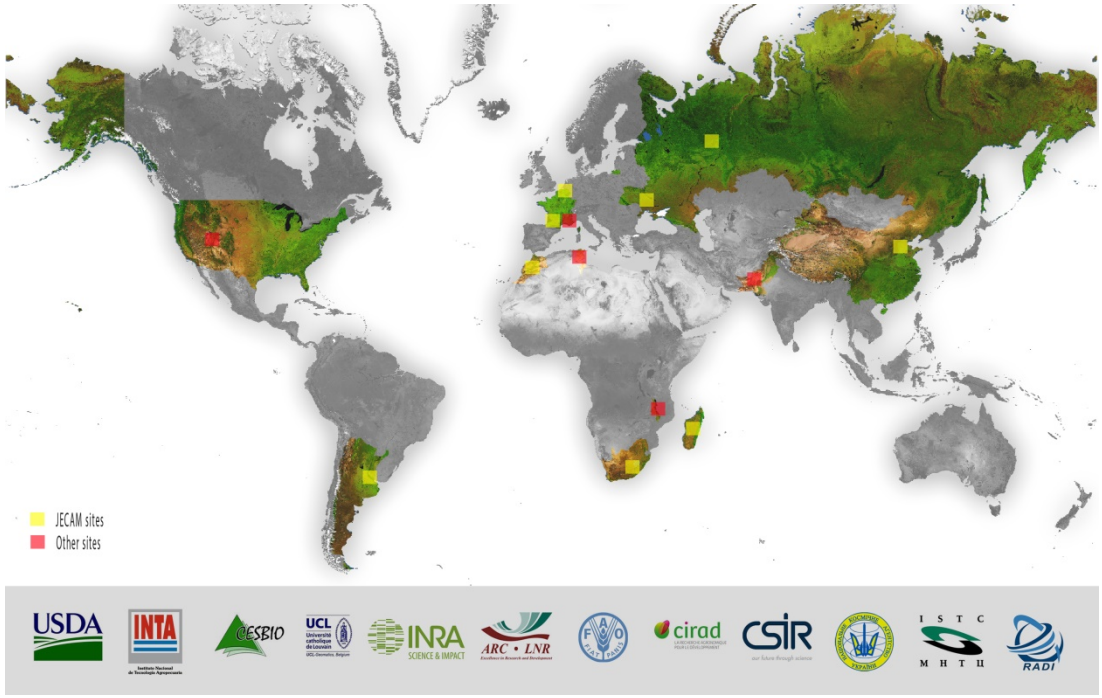


Benchmarking for selecting the best algorithms for each product



4 scientific papers published



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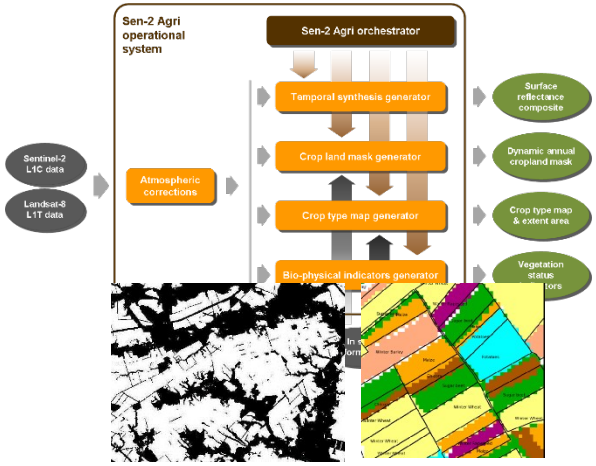
Current Sen2–Agri Achievements

Users req. and methods development 2014

System development and EO products 2015

Demonstration & Validation 2016-2017

JECAM
Joint Experiment for Crop Assessment and Monitoring



- ✓ **User Requirements**
- ✓ **Products specification**
- ✓ **Methods development**

- ✓ **4 agriculture products**
- ✓ **Open source system**

- ➢ **Prototypes & validation based on SPOT 4/5 Take 5 & Landsat-8**

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5 main Sen2-Agri Challenges

- **Portable open-source solution** for operational production
- **Timeliness** of EO products from Sentinel-2 large volume
- Algorithm selection and system development **before S-2**
- **EO products validation** by users and external partners
- Addressing the **large diversity** of agricultural systems

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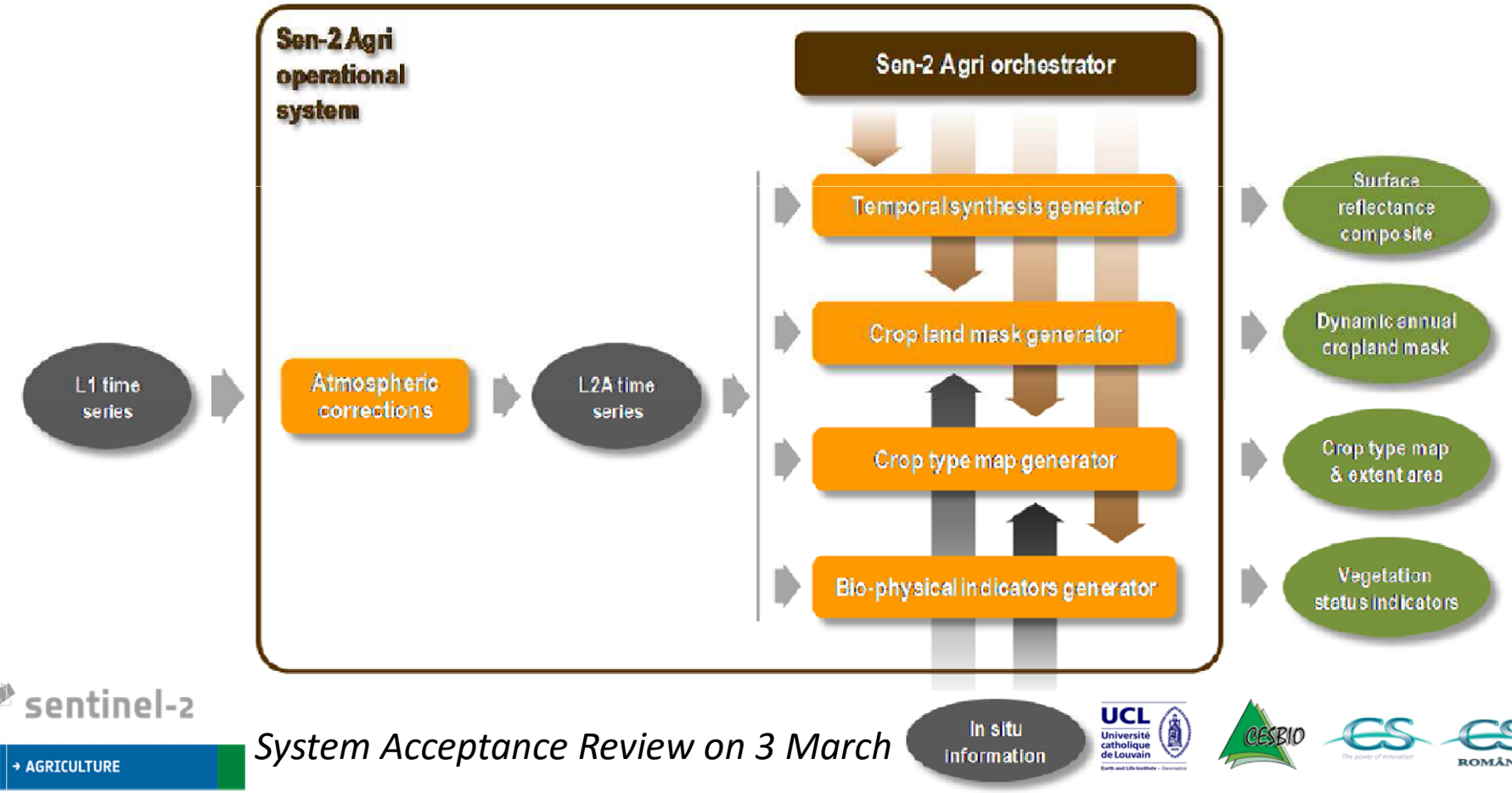
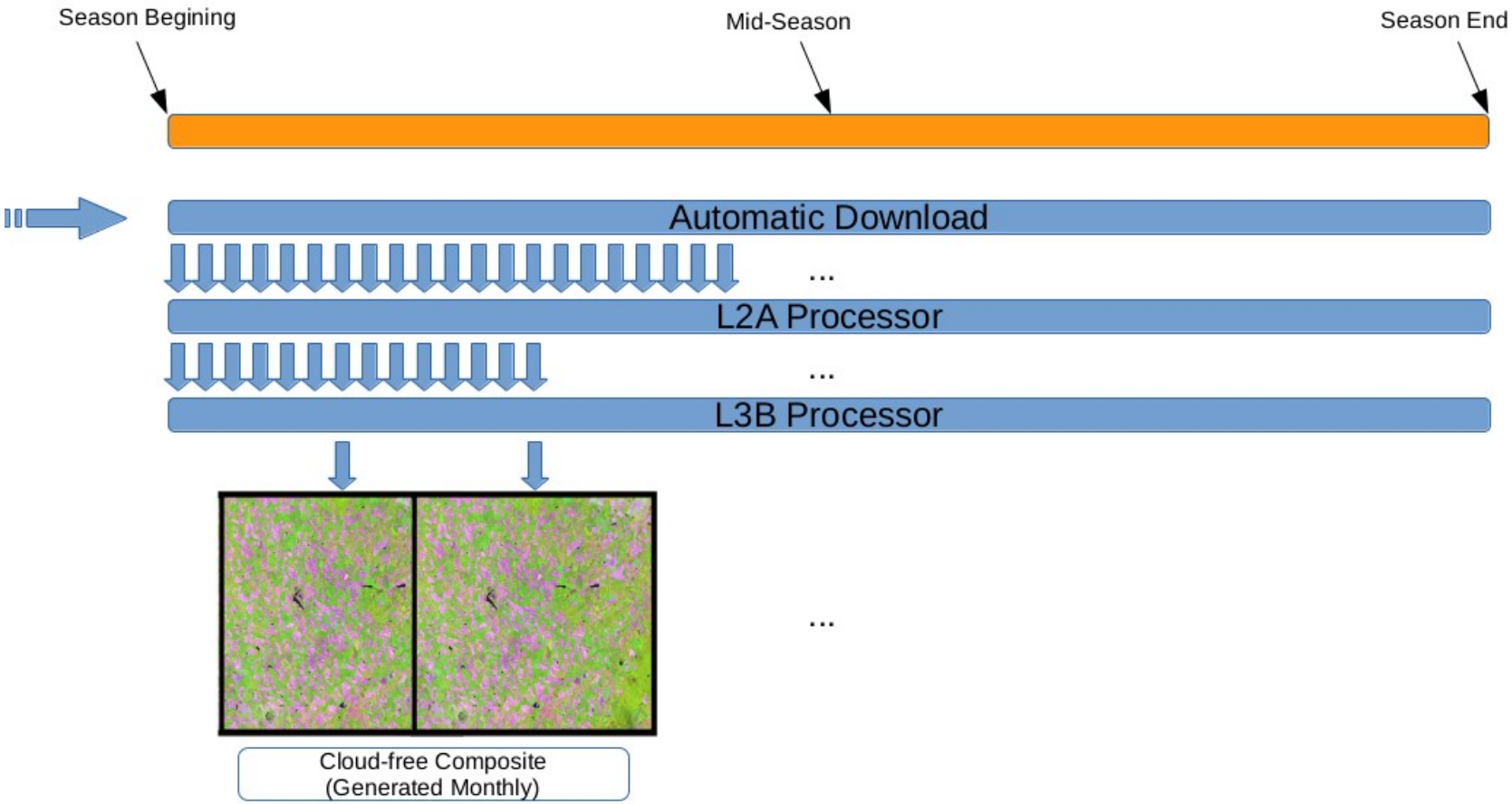
Sen2-Agri system : design and development

A system designed to run in an automated/off line mode and deliver agric. products as the satellite images are ingested

=> **Orchestrator concept**

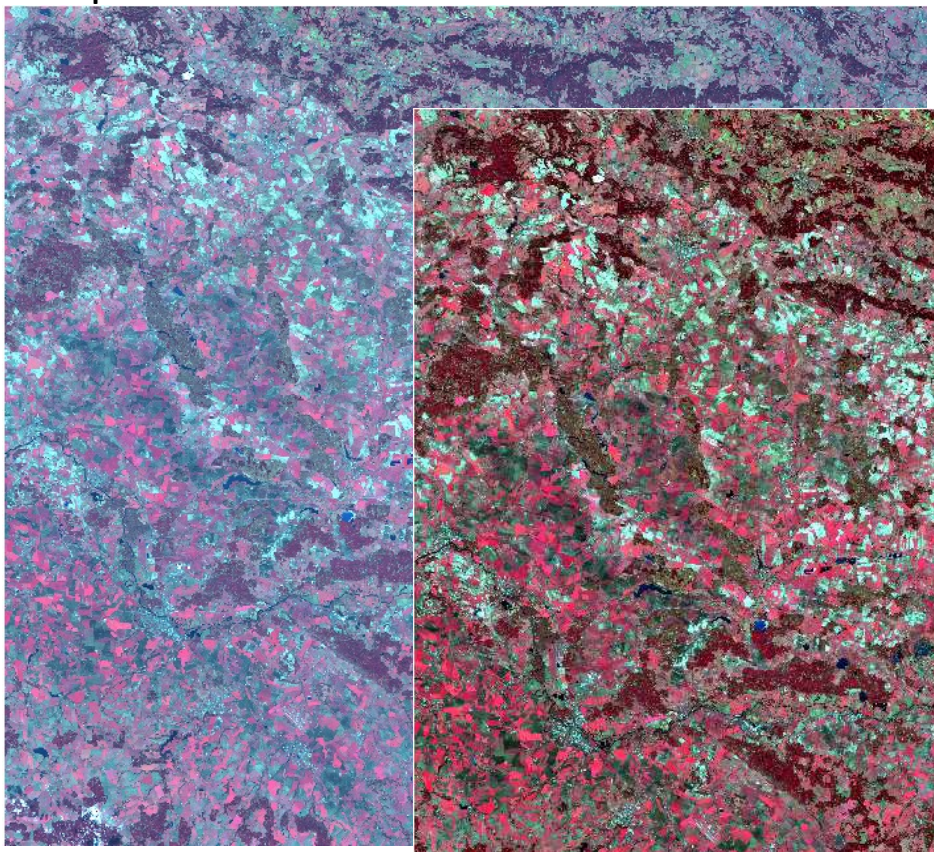


Automatic production of monthly cloud-free composite

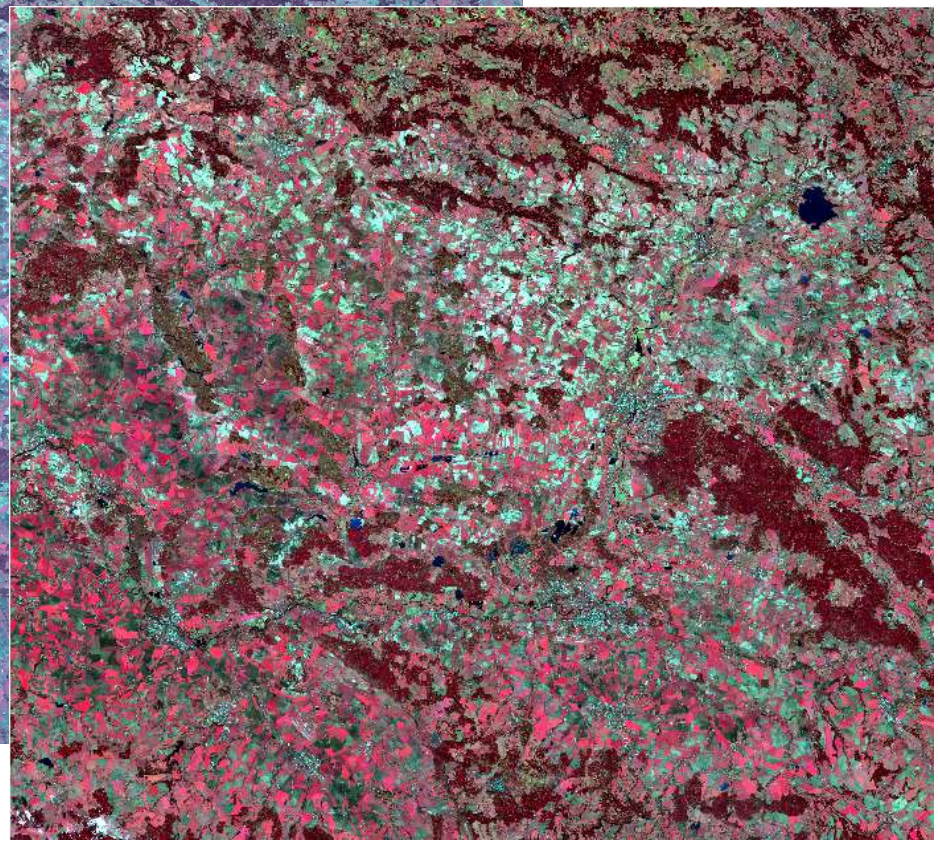


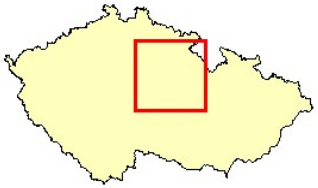
Cloud-free surface reflectance composite

L1C product – as downloaded from ESA hub



L2A / L3A composite product





Sentinel-2 image acquired on 17 March 2016
Czech Republic

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Cloud free surface reflectance composite

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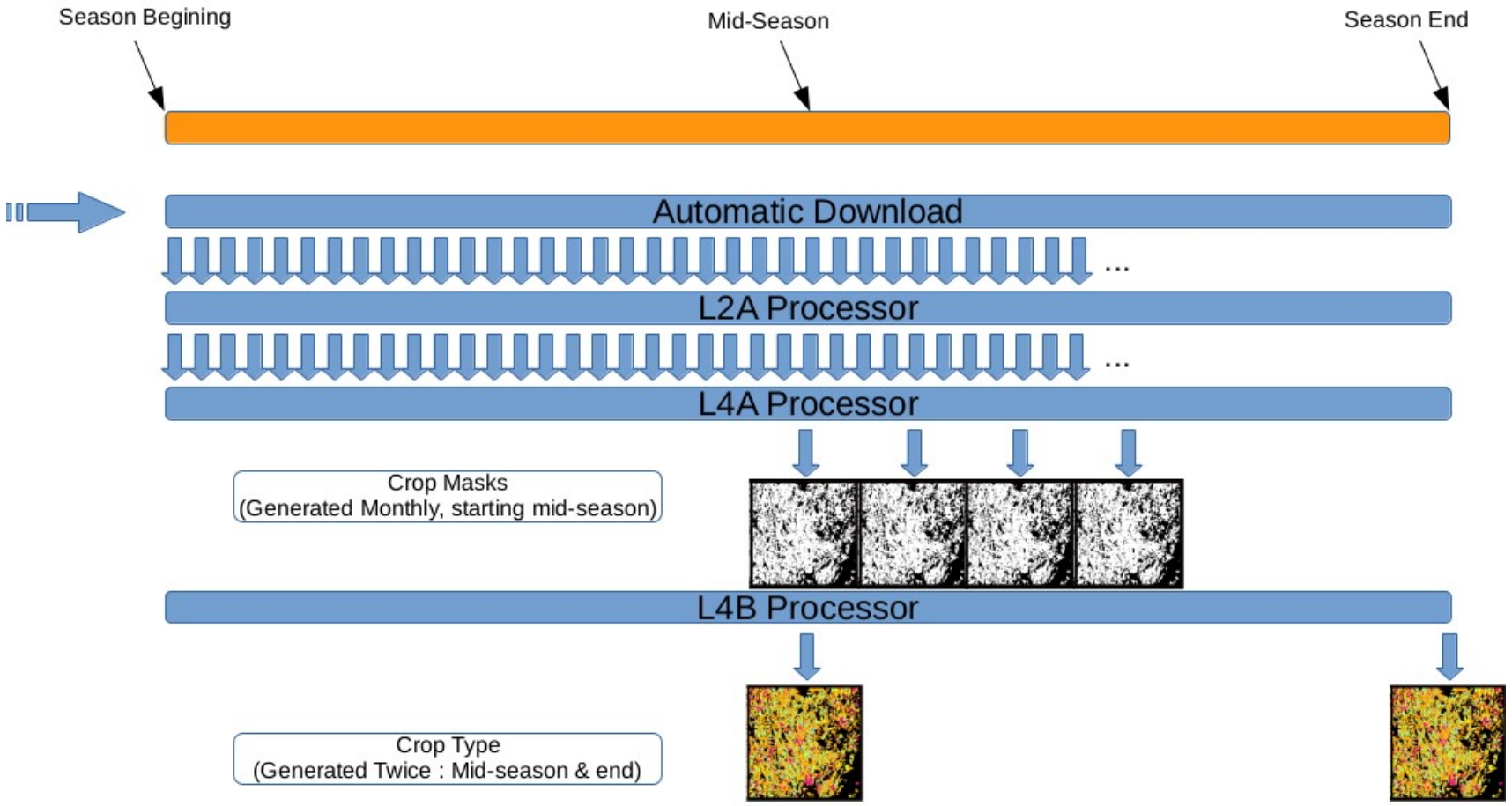
Production of Crop Mask & Crop Type
(machine learning and unsupervised processor)



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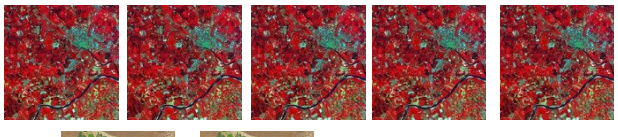
System operation for crop mask

Before the start of the monitoring period

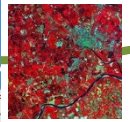
Monitoring period

Automatic EO data download
Manual in situ data upload

System initialization



EO data providers



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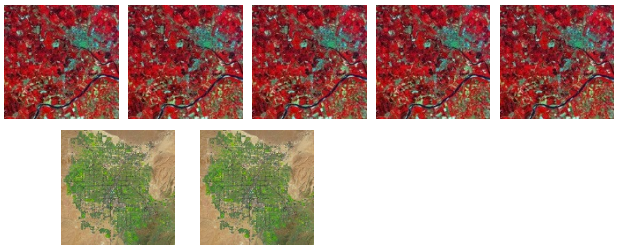

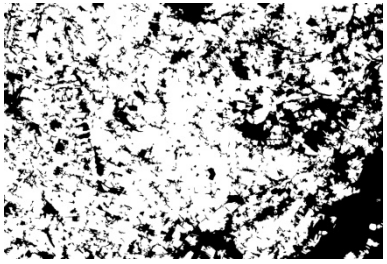

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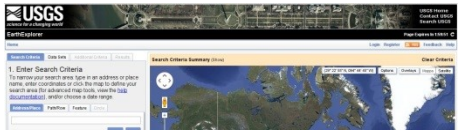

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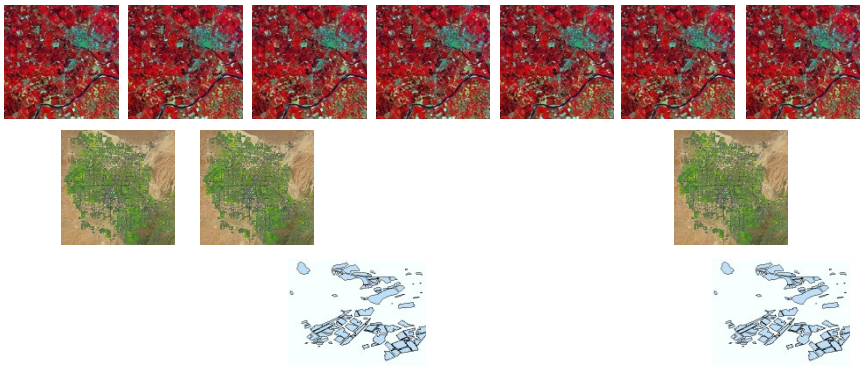

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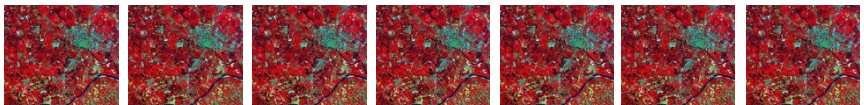

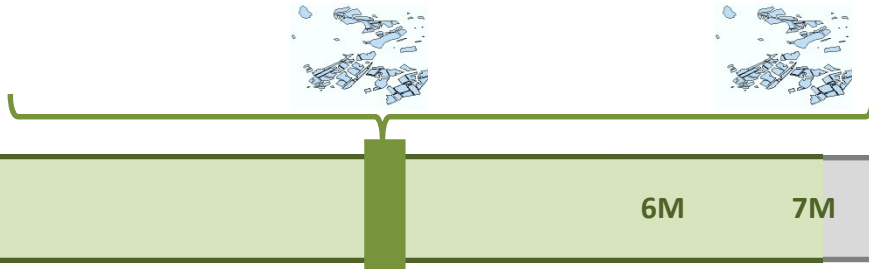

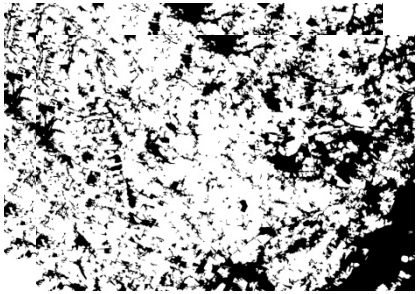

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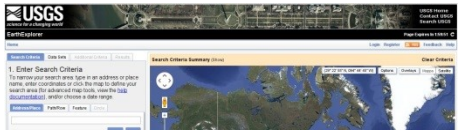

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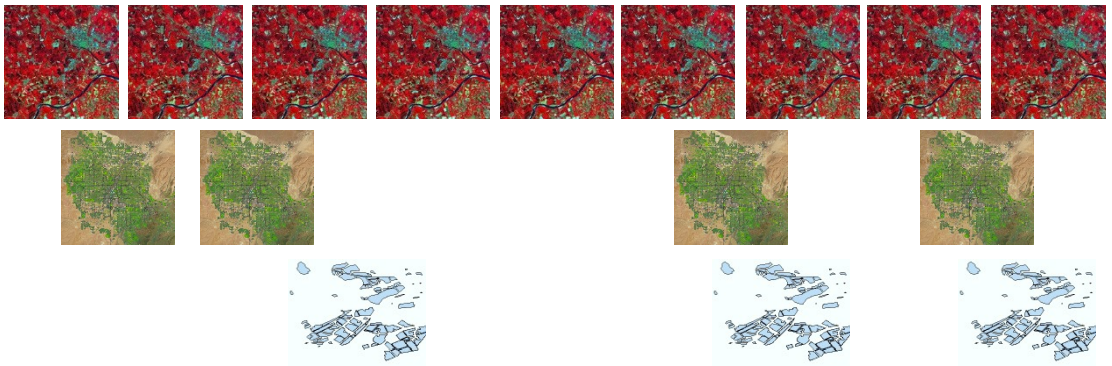

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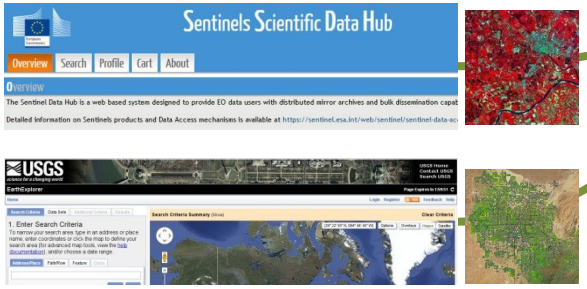

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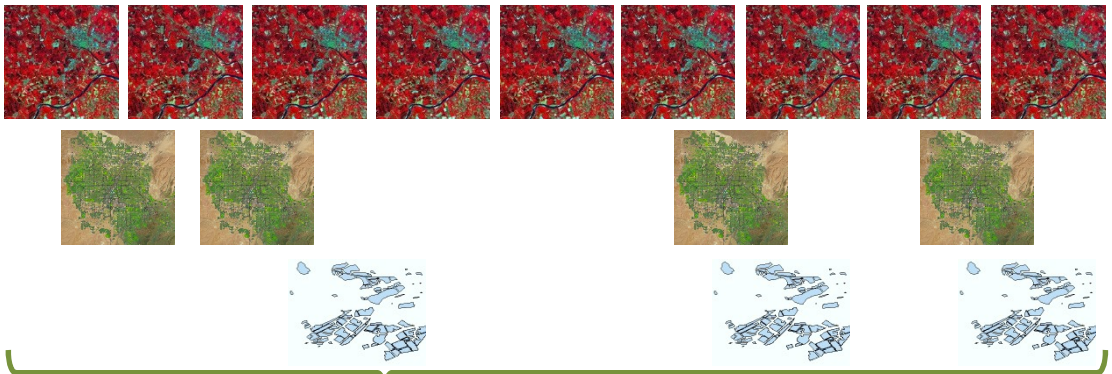

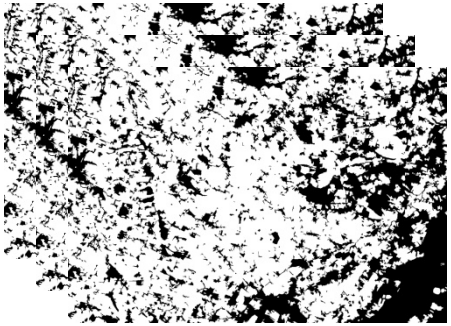

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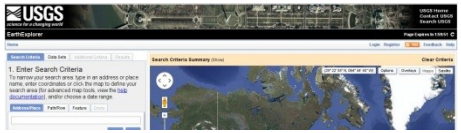

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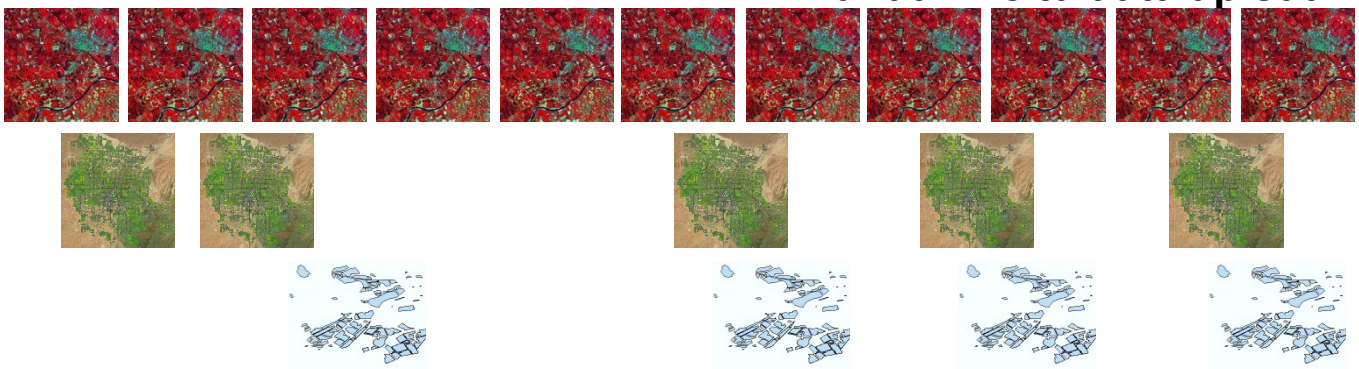

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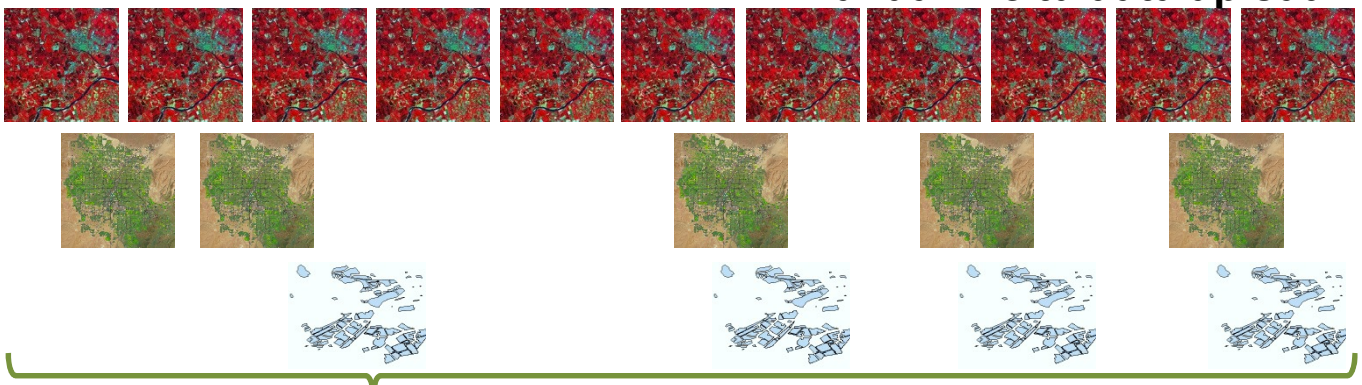

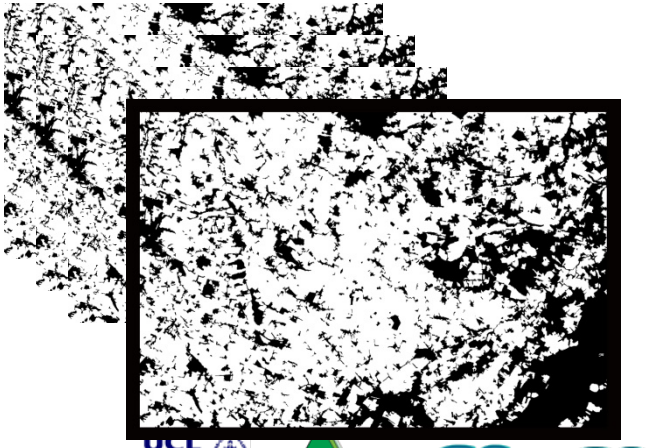

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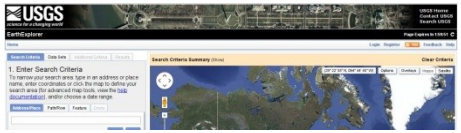

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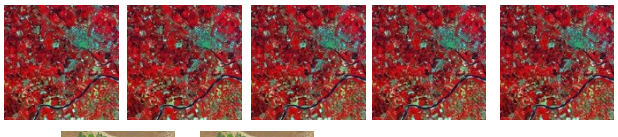

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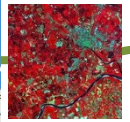

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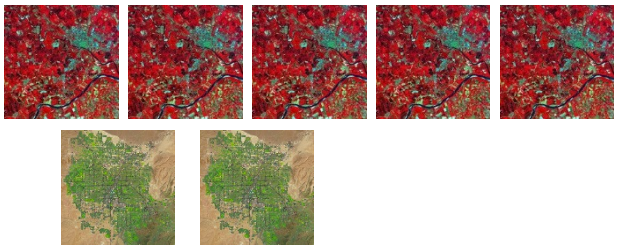

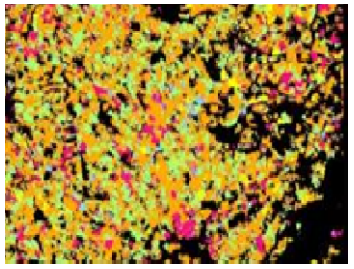

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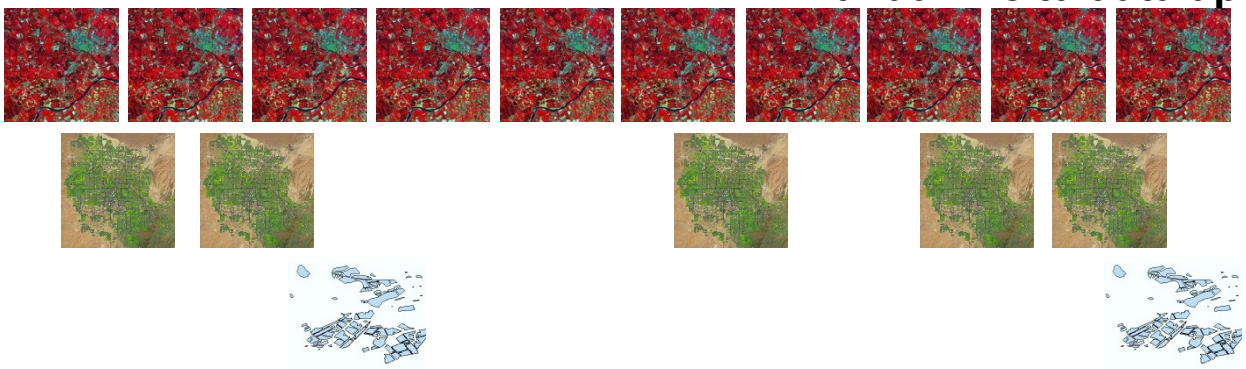

SoS — 6M — EoS

EO data providers

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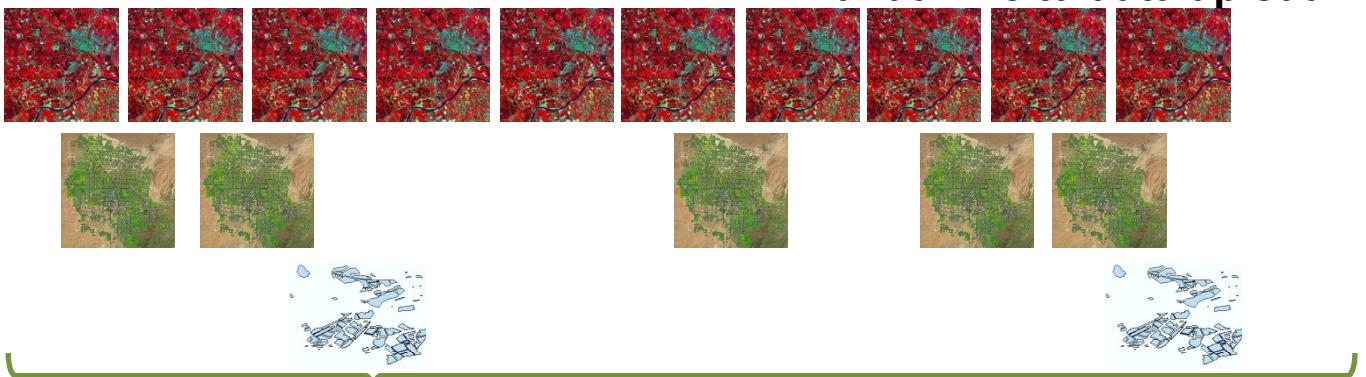

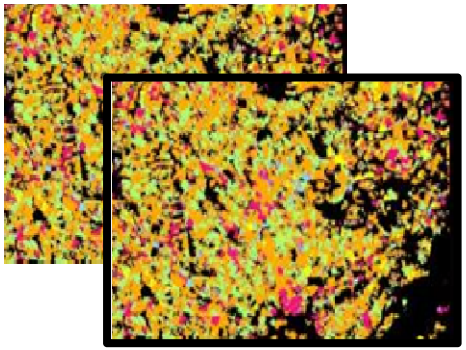

EO data providers

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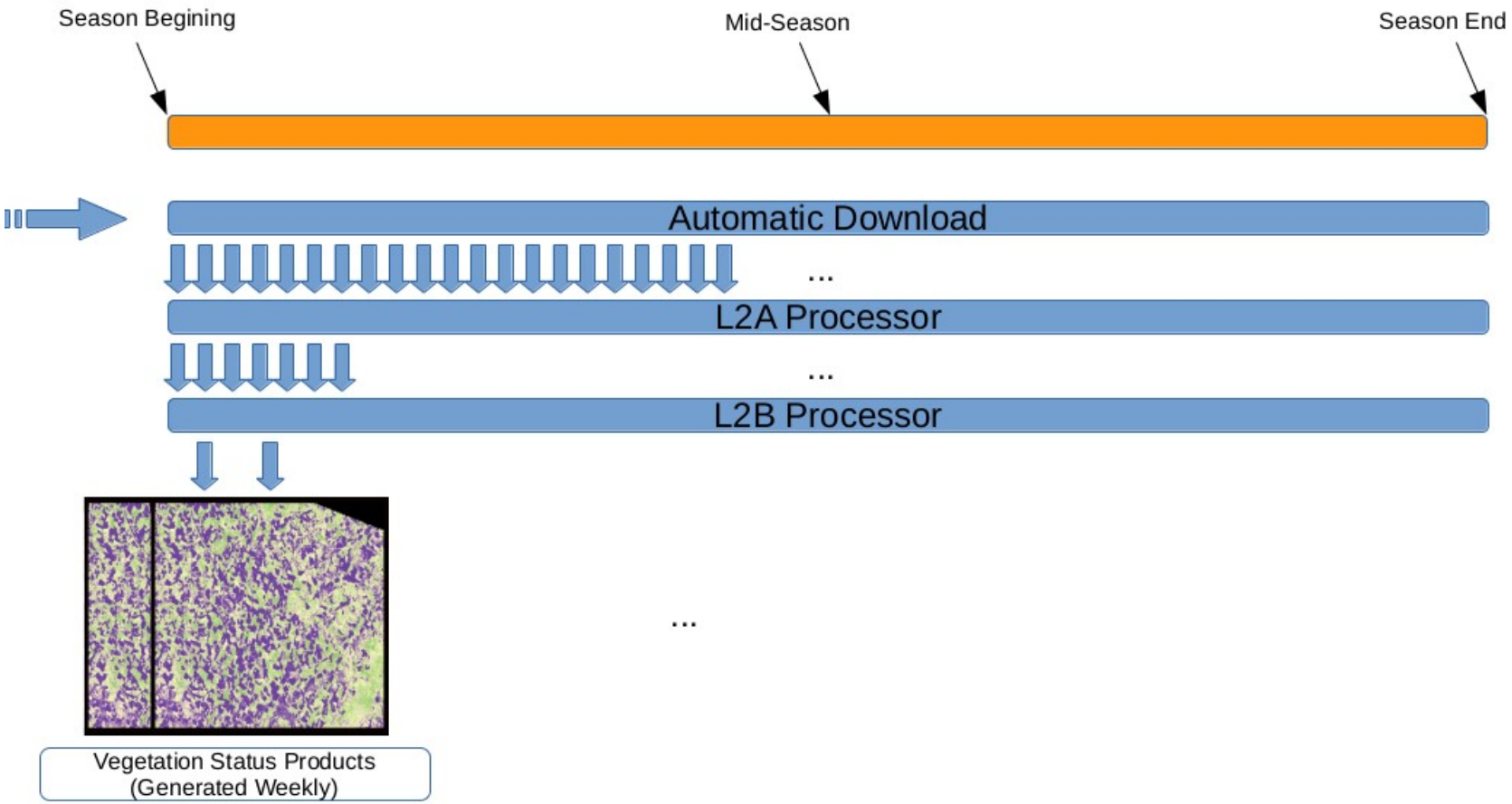
Automatic production of Vegetation Status on weekly basis (LAI, NDVI)



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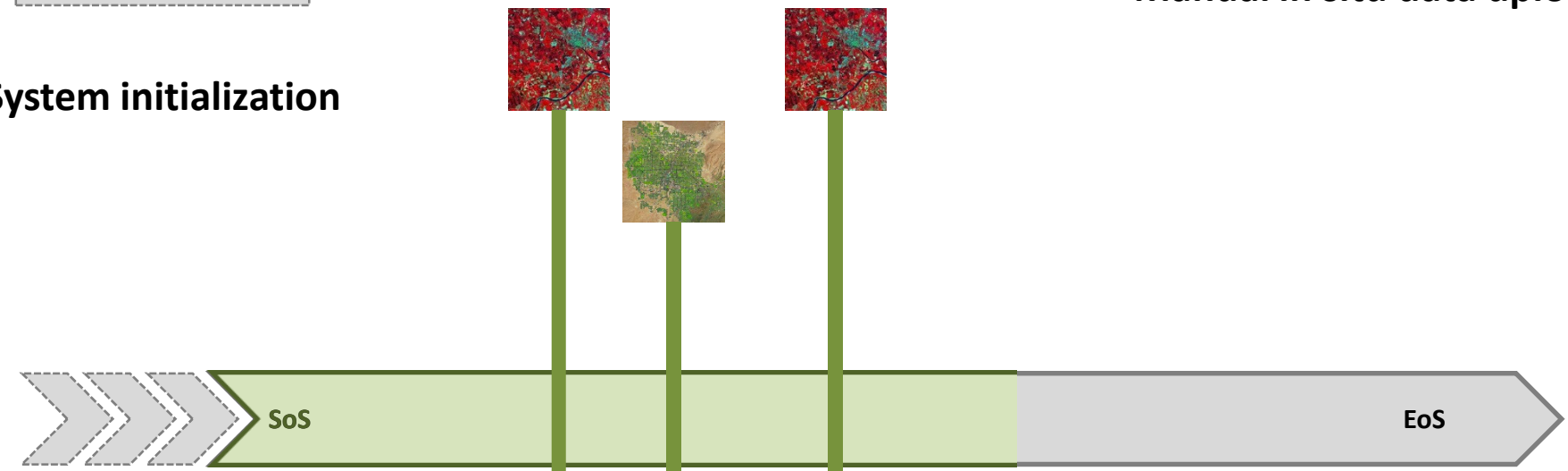
System operation for single-date LAI

Before the start of the monitoring period

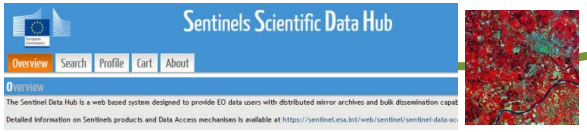
Monitoring period

Automatic EO data download
Manual in situ data upload

System initialization



EO data providers



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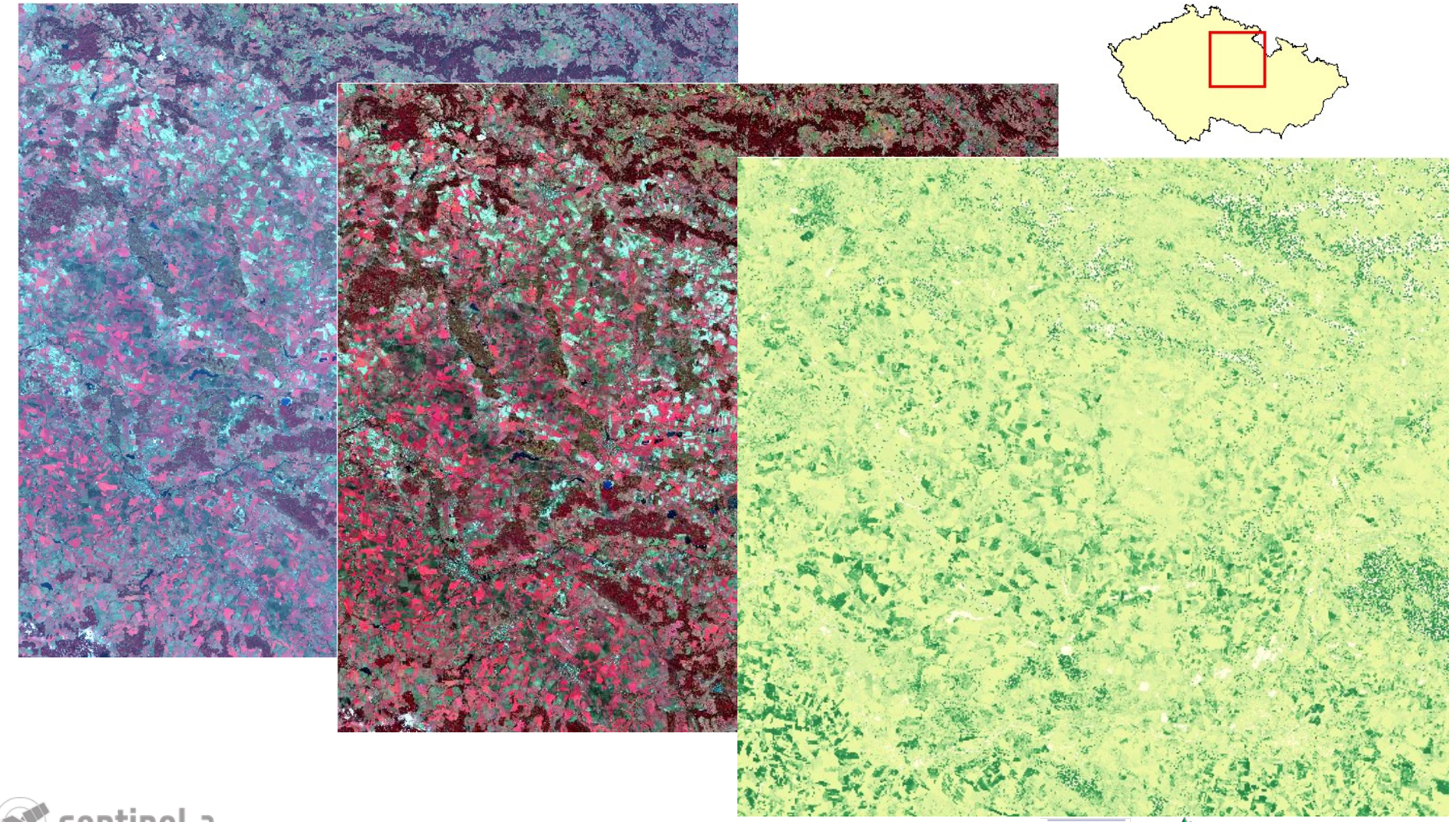
Sen2-Agri single date LAI map



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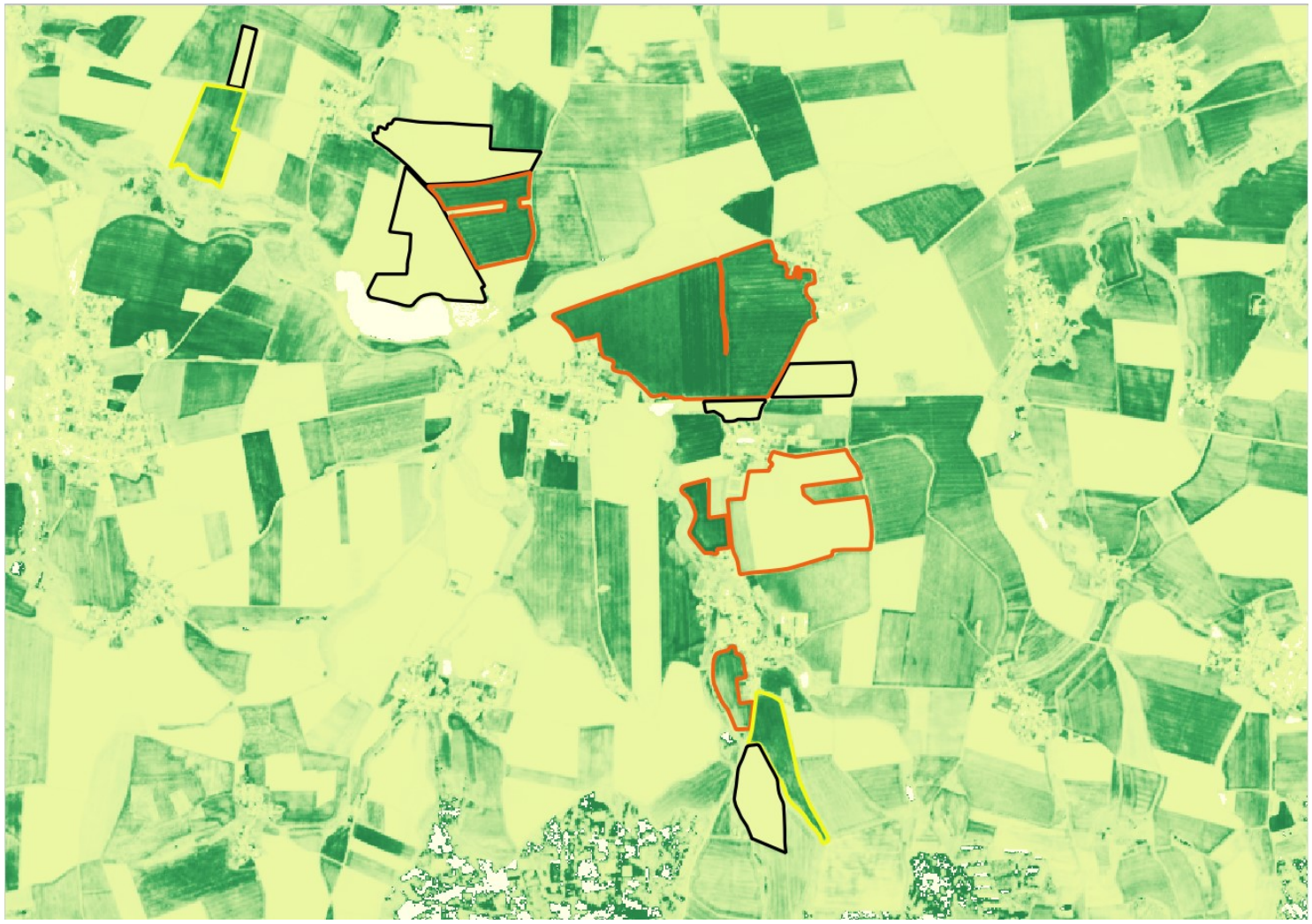
Sen2-Agri single date LAI map from Sentinel-2



Leaf Area Index
17 March 2016

- winter rapeseed
- winter cereals
- fodder crops
- no vegetation

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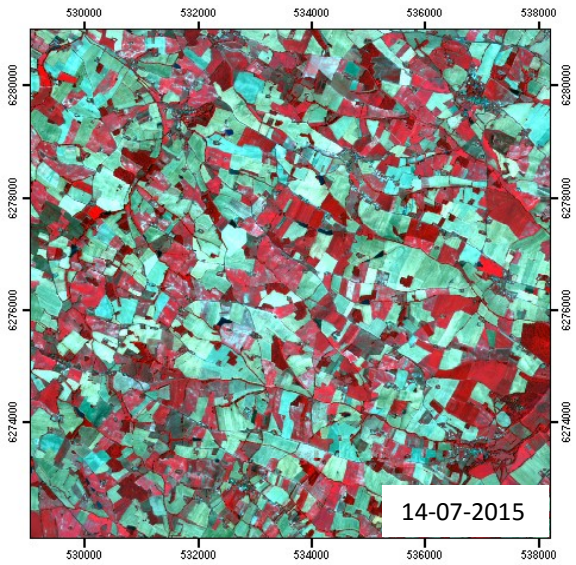
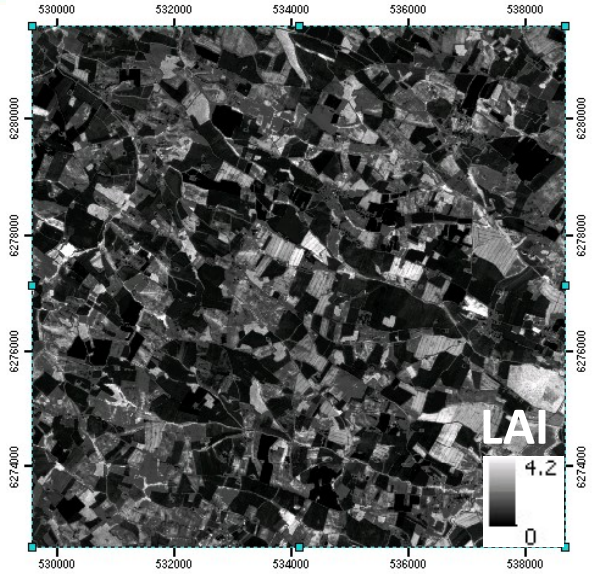
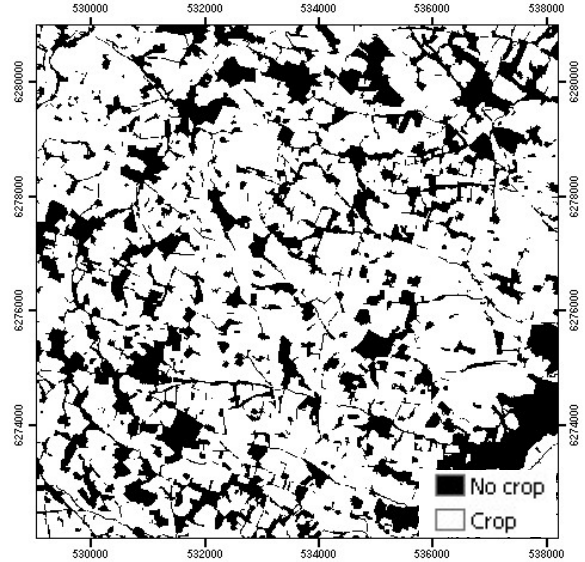
Prototype products on SudMiPy

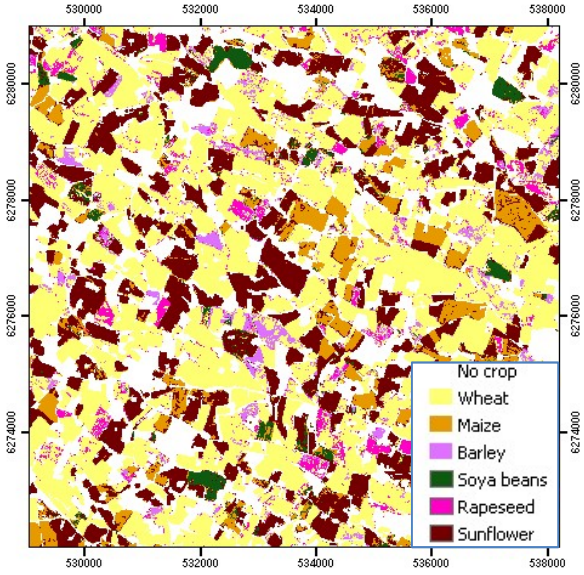
(SPOT 5 Take 5 - 2015)

France









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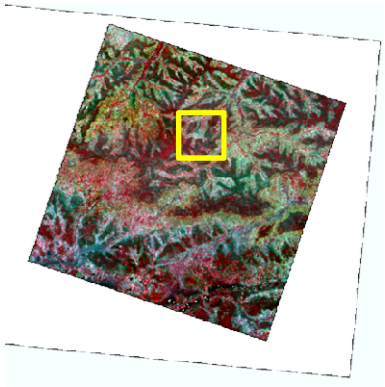
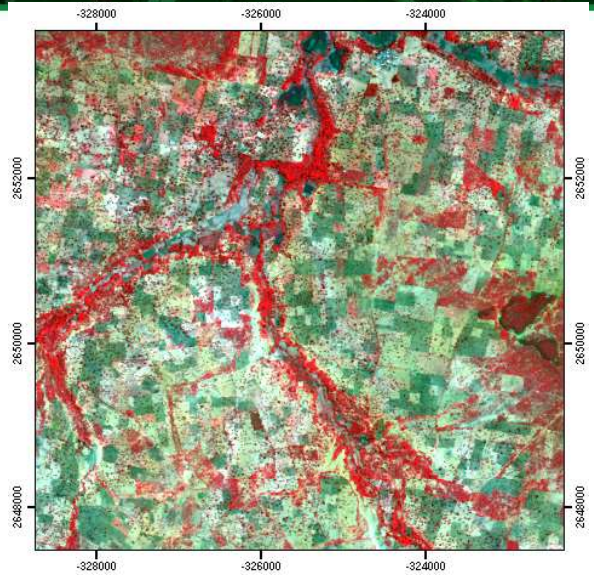
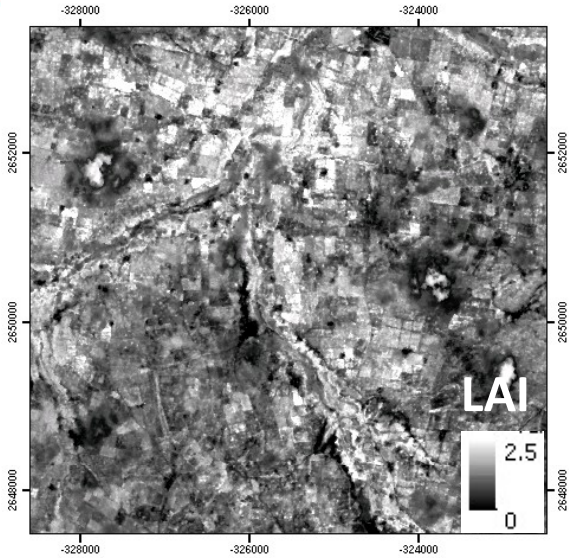
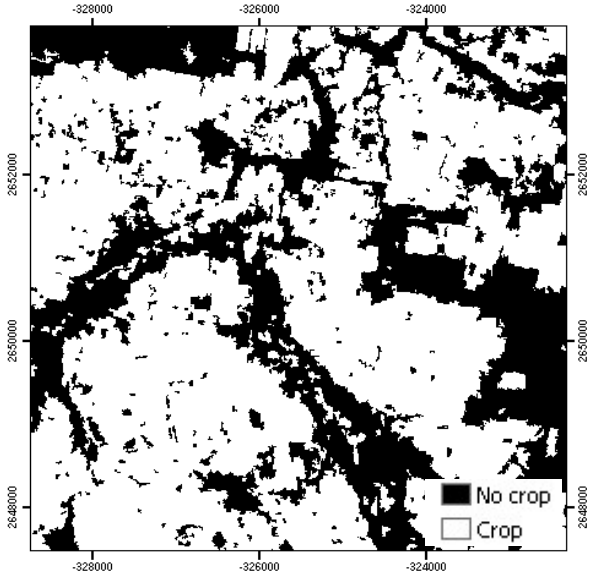
Prototype products in Mali site
(SPOT 5 Take 5 - 2015)

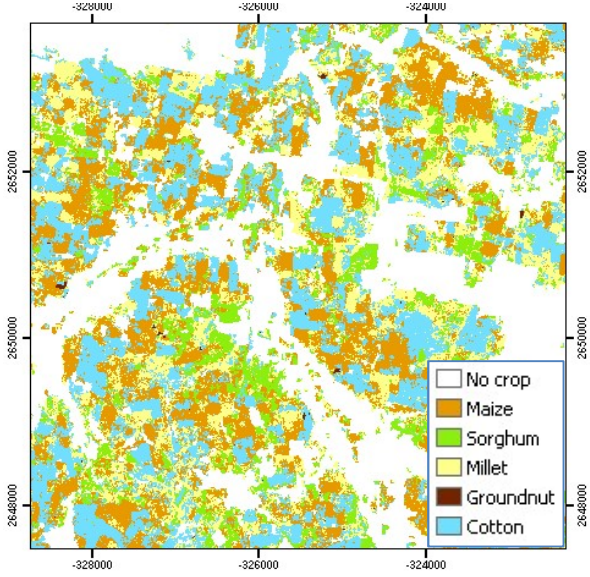
Mali (JECAM)











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Sen2-Agri System ready for demonstration

Algorithm Development 2014

Prototypes of EO products 2015

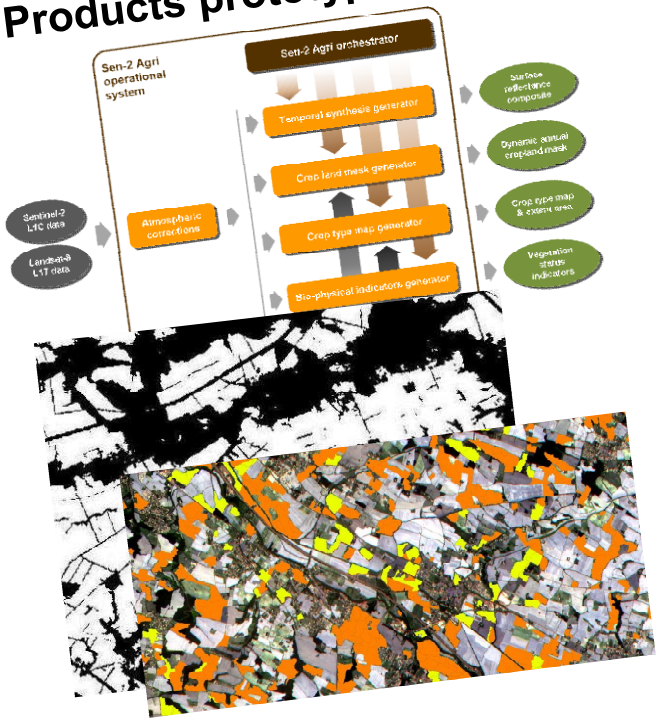
Demonstration & Validation 2016-2017

Users Products specifications

Benchmarked Methods (4 pub.)

System ready in April 2016

Products prototype SPOT5-T5



National use cases

Local use cases

Capacity building

Training activities

Fitness-to-use assessment

System qualification

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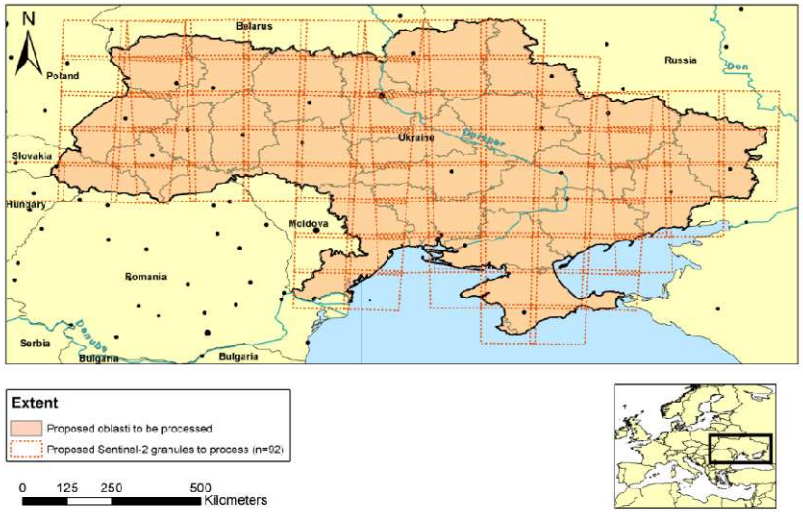
Demonstration phase : 3 national cases

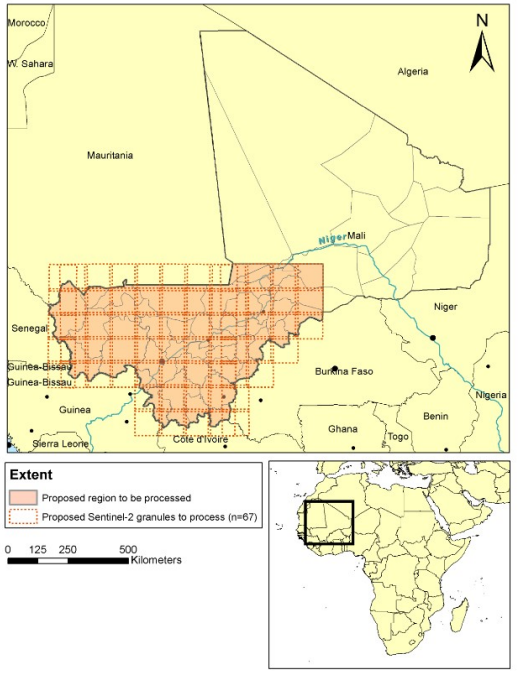
To demonstrate the Sen2-Agri system and NRT products using Sentinel-2a & Landsat 8 *(but without Sentinel-2b)* **at national scale with *in situ* system implementation** :

Ukraine (SRI)



South Africa (ARC)

Mali (ICRISAT & IER)



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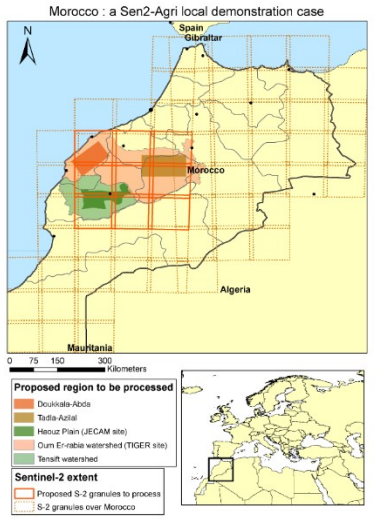
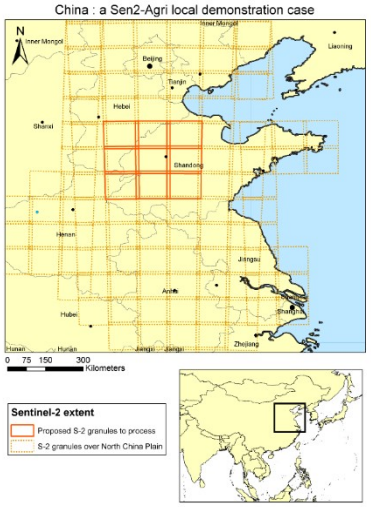
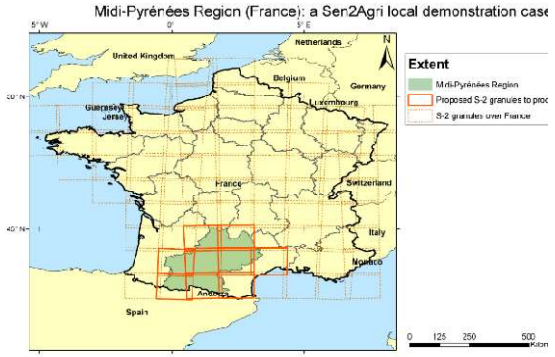
Demonstration phase : 7 local cases

To demonstrate NRT products using Sentinel-2 & Landsat 8 at local scale (~ 300 x 300 km) :

Site ID	Site name and localization
Sen2-Agri supported sites	
1	France, Midi-Pyrénées
2	Morocco, Tensift
3	China, Shandong
4	Madagascar, Antsirabe
5	Sudan, White Nile /South-Sudan
Additional demonstration sites	
6	Czech sites , Czech (CCN2)
7	Belgium, Belgium







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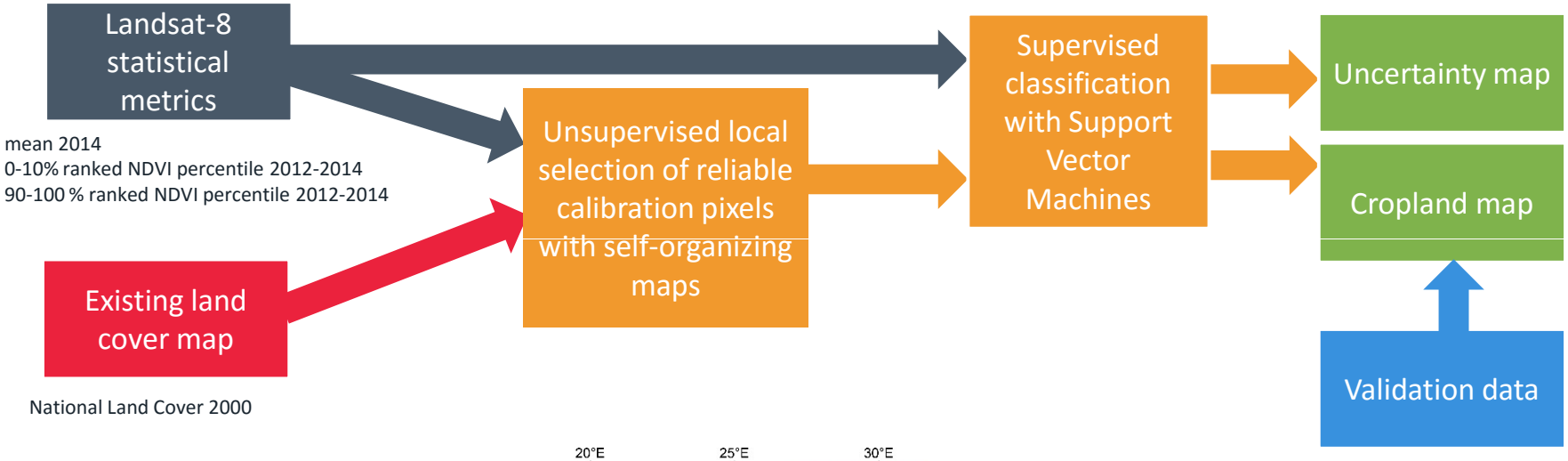
Crop mapping in South Africa with Landsat-8 and Sentinel-2

F. Waldner and Pierre Defourny (UCLouvain, Belgium)

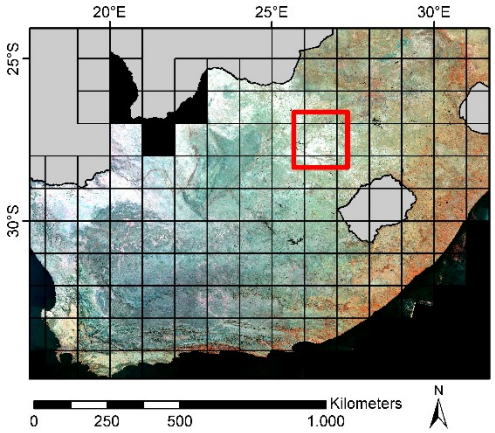
M. Hansen (UMD, USA)

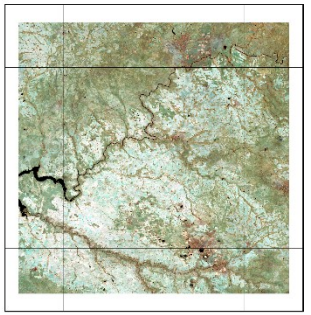
T. Newby (ARC, South Africa)

Fully automated cropland classification based on Landsat-8 metrics and existing land cover information



The method is applied locally on 150x150 km2 spatial windows.



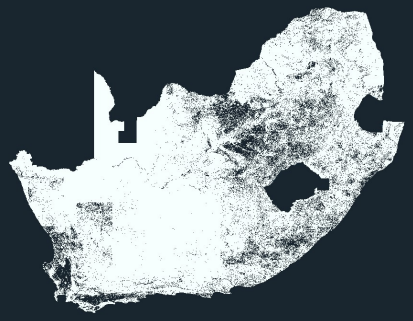


Wall-to-wall classification and validation

Preliminary results: overall accuracy 87.33%

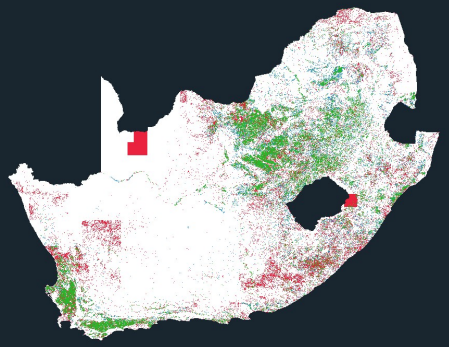
Cropland map

Macroscopic errors remain, tiling effect



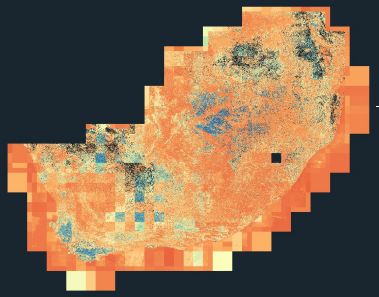
Error map

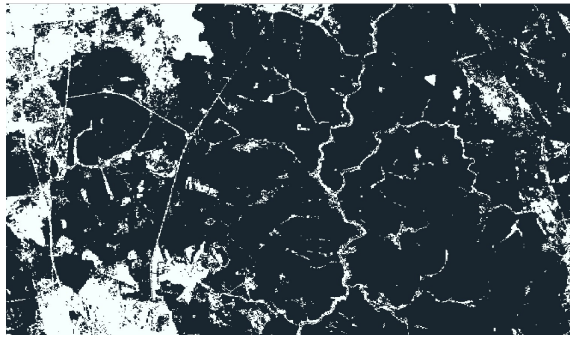
Confusion wetland-irrigated crops

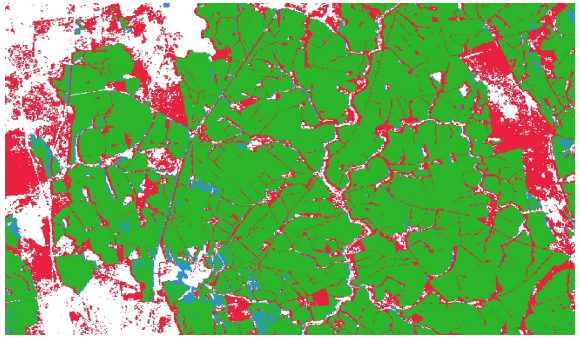


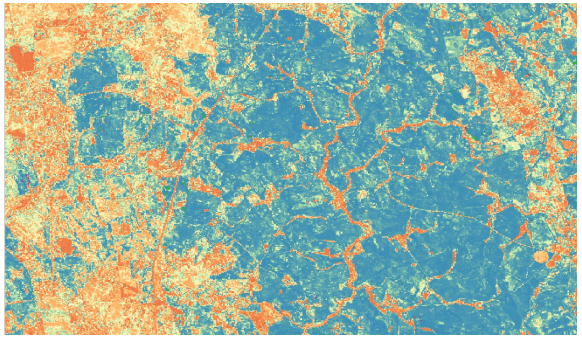
Uncertainty map

Errors mostly associated with high uncertainty









Defining the spatial resolution gain...
... predicting the added value of Sentinel-2

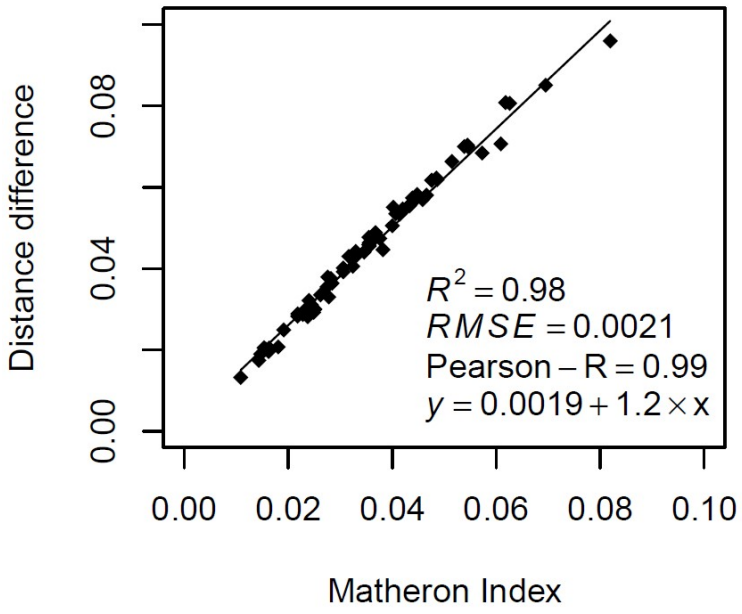
CLASSIFICATION ERROR = SPATIAL RESOLUTION BIAS + CLASSIFIER ERROR (Boschetti et al., 2004)

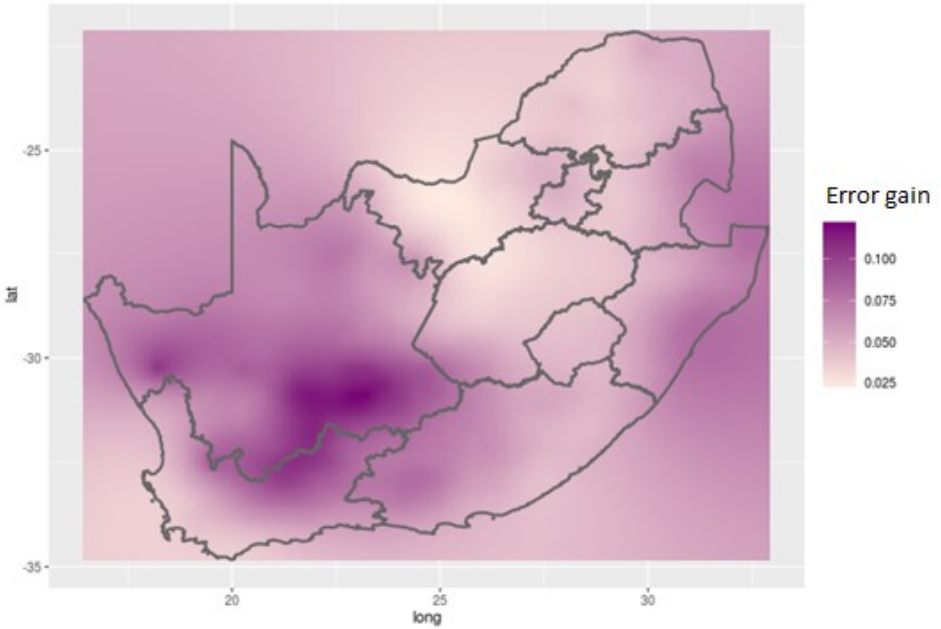
RESOLUTION GAIN = SPATIAL RESOLUTION BIAS at 30m – Spatial RESOLUTION BIAS at 10m

$$MI = \frac{crop\ perimeter}{\sqrt{crop\ area} * \sqrt{total\ area}}$$

Can we predict the resolution bias based on landscape fragmentation metrics?

Calibration of a linear regression with a landscape fragmentation metric and application countrywide





The Matheron index measures the ratio between the total outer perimeter of crop patches and the product between the area of crop and the total area

$$MI = \frac{crop\ perimeter}{\sqrt{crop\ area} * \sqrt{total\ area}}$$

Conclusions

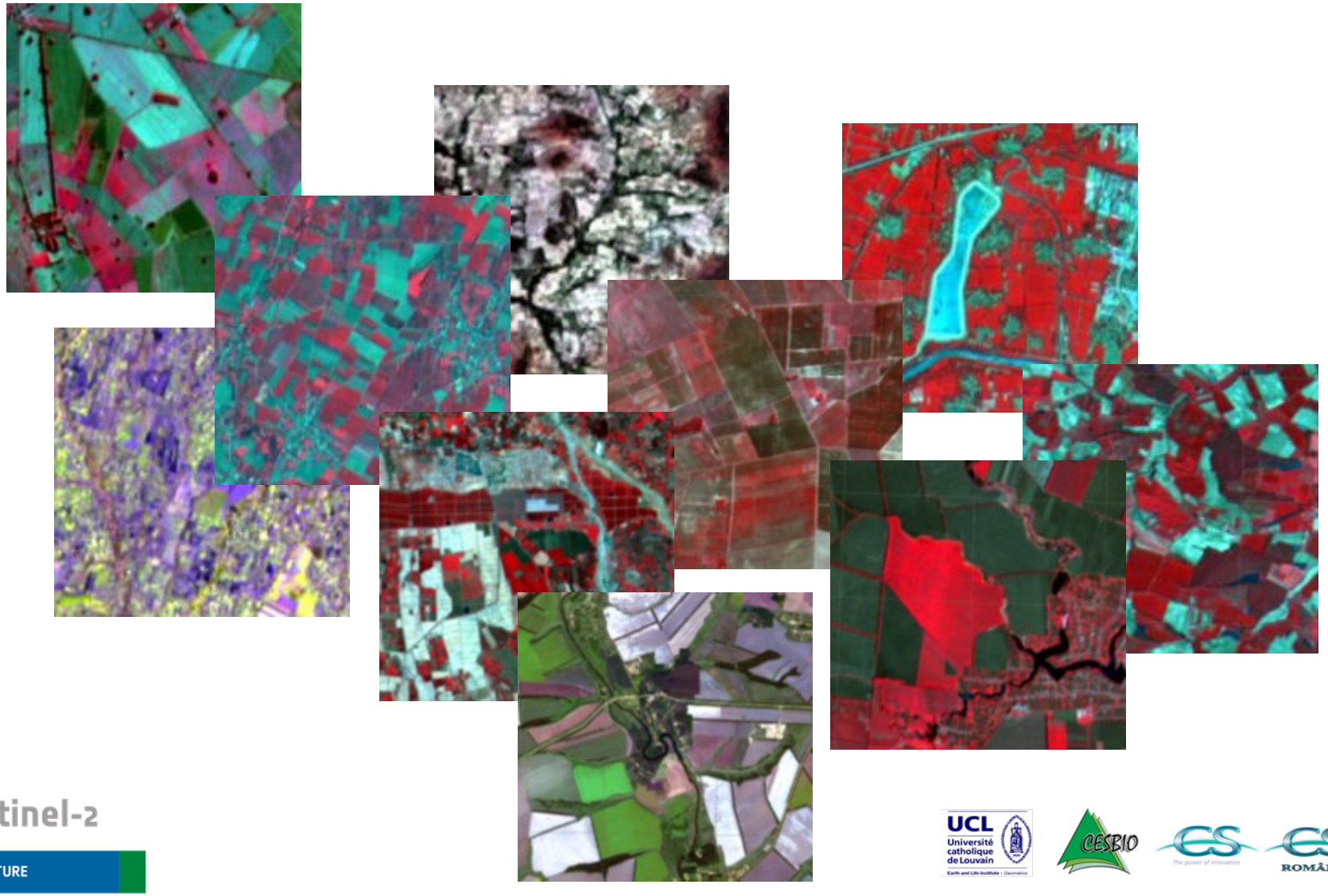
- Unique momentum in ag. Monitoring with satellite remote sensing
- For the first time, the combination of current HR sensors is able to meet the requirements for ag. monitoring.
- Remote sensing methods need to be combined with local knowledge, expertise and field observations to achieve accurate results.

  → open source toolbox can be locally adapted
- Sen2Agri toolbox alleviates the (pre)processing time

  → more time to focus on the interpretation of the RS products

Thank you for your attention

…and let's learn from the diversity of agrosystems



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