CS ROMANIA

Image Processing Tools for Earth Observation

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Presentation to: UNIVERSITATEA DIN CRAIOVA

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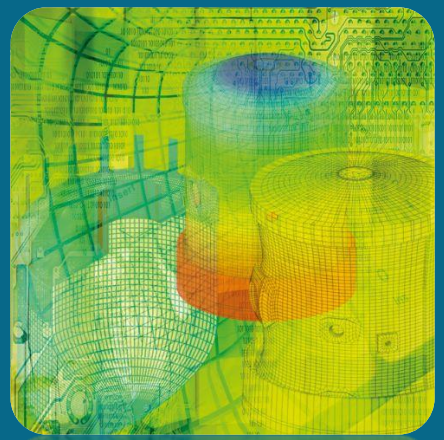


14TH OF DECEMBER, 2018

AGENDA

- What is Earth Observation?
- ESA SNAP Toolboxes
- Operational EO Data Processing for Agriculture
- TAO: Multi-purpose Processing Framework

WHAT IS EARTH OBSERVATION?

1

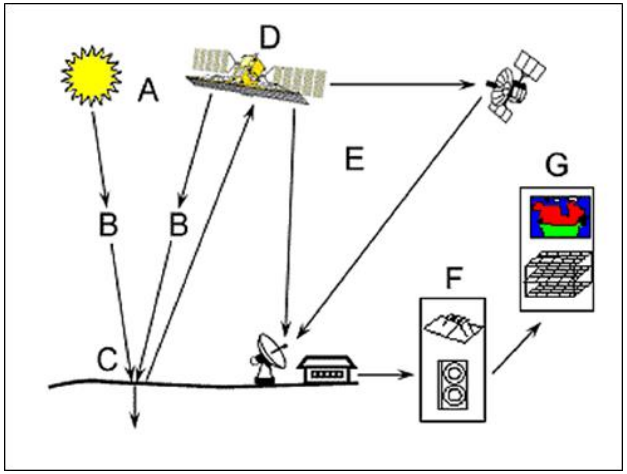
Earth Observation (EO)

What is Earth Observation?

- Gathering information about the planet's physical, chemical and biological systems via remote-sensing technologies
- Used to monitor and assess status changes in natural and built environments

What is EO remote-sensing?

- Analysis and interpretation of measurements of electromagnetic radiation that is reflected from or emitted by objects on Earth's land, ocean or ice surfaces, or within atmosphere
- A 7-steps process:
  - A: Energy source or illumination
  - B: Radiation and the Atmosphere
  - C: Interaction with the target
  - D: Recording of energy by a sensor
  - E: Transmission, reception and processing
  - F: Interpretation and analysis
  - G: Application



Earth Observation (EO)

➔What are EO use cases?

- Weather forecasting
- Tracking biodiversity
- Measuring land-use changes
- Monitoring and responding to natural disasters (fires, floods, earthquakes, landslides,…)
- Managing natural resources (energy, water, agriculture)
- Predicting and mitigating climate change

EO Acquisitions

- Spatial Resolution
  - The size of the pixel of the remote sensing image (or distance between adjacent pixel centers measured on the ground)
    - Low resolution: 300m – 1000m
    - Medium resolution: 30m – 300m
    - High resolution: 5m – 30m
    - Very high resolution: <5m
- Scene Size (Swath)
  - The area imaged on the Earth surface
  - The larger the swath, the lower the resolution
- Spectral Resolution
  - The number of spectral bands in which the sensor can capture radiation
  - The position of the bands in the EM spectrum is also essential
- Radiometric Resolution (Pixel Bit Size)
  - Sensitivity of a detector to variations in the intensity of emitted, reflected or scattered EM energy
    - 8 bits: 256 values (unsigned)
    - 12 bits: 4096 values (unsigned)
    - 16 bits: 65536 values (signed or unsigned)
    - 32 bits (floating point): scientific precision
- Temporal Resolution
  - Satellite revisit frequency to a specific location
    - Low resolution: >16 days
    - Medium resolution: 4 – 16 days
    - High resolution: <1 day – 3 days

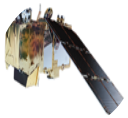
ESA SNAP TOOLBOXES

2

What are the Sentinels?

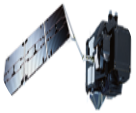
Sentinel-1 (A+B) – *launched 2014 and 2016*

Day and night radar imagery for land and ocean



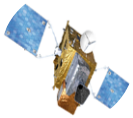
Sentinel-2 (A+B) – *launched 2015 and 2017*

High resolution multi-spectral optical imagery for land



Sentinel-3 (A+B) – *launched 2016 and 2018*

High accuracy optical, radar and altimetry data for marine and land services



Sentinel-4 (2019)

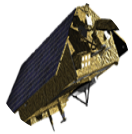
Atmospheric composition monitoring

Sentinel-5 (2021)

Atmospheric composition monitoring

Sentinel-5P – *launched 2017*

Continuity mission before Sentinel-5 (gases and aerosols)



Sentinel 6 (2020)

High accuracy altimetry for measuing sea-surface height

SENTINEL-1

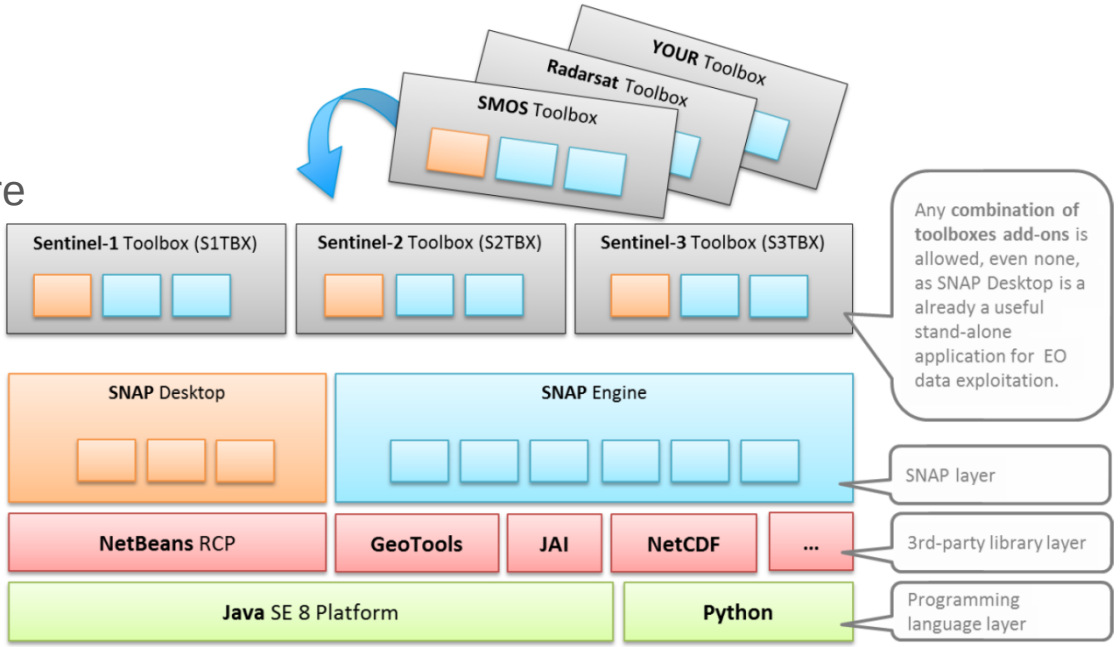
- Instrument: Synthetic Aperture Radar (SAR)
- Applications:
  - Monitoring of sea ice and the Arctic environment
  - Marine surveillance
  - Monitor risks due to ground displacement (earthquakes)
  - Maps to organize humanitarian aid in crisis situations
- Temporal resolution: 6 days at Equator with 2 satellites (decreases with latitude)
- 4 operating modes:
  - Strip map: 80km swath, 5m × 5m resolution (400MB – 8GB / product)
  - Interferometric wide swath: 250km swath, 5m × 20m resolution
    - ~7GB per product, 6 bands, ~21000 × 15000 pixels / band
  - Extra wide swath: 400km swath, 20m × 40m resolution (~400MB / product)
  - Wave: 20 × 20km, 5m × 5m resolution (3GB – 10GB / product)
- Example: Romania coverage for 1 year (2018)
  - 2677 level 1 SLC products => 15 TB disk space

SENTINEL-2

- Instrument: Super-spectrometer with 13 bands (VNIR & SWIR)
- Applications:
  - Land cover maps
  - Vegetation and chlorophyll maps
  - Risk and fast hedge maps in case of emergencies
- Temporal resolution: 5 days at Equator with 2 satellites (decreases with latitude)
- Spatial resolution:
  - Swath: 290 km × 290 km / scene, 110 km × 110 km / granule (10 km overlap)
  - Resolution:
    - Bands 2,3,4 and 8: 10 m / pixel
    - Bands 5,6,7,8A,9,10,11 and 12: 20 m / pixel
    - Band 1: 60 m / pixel
  - ~700MB, 4 bands @ 10980 × 10980, 8 bands @ 5490 × 5490, 1 band @ 1830 × 1830
- Example: Romania coverage for 1 year (2018)
  - 7356 level 1C products => 6 TB disk space

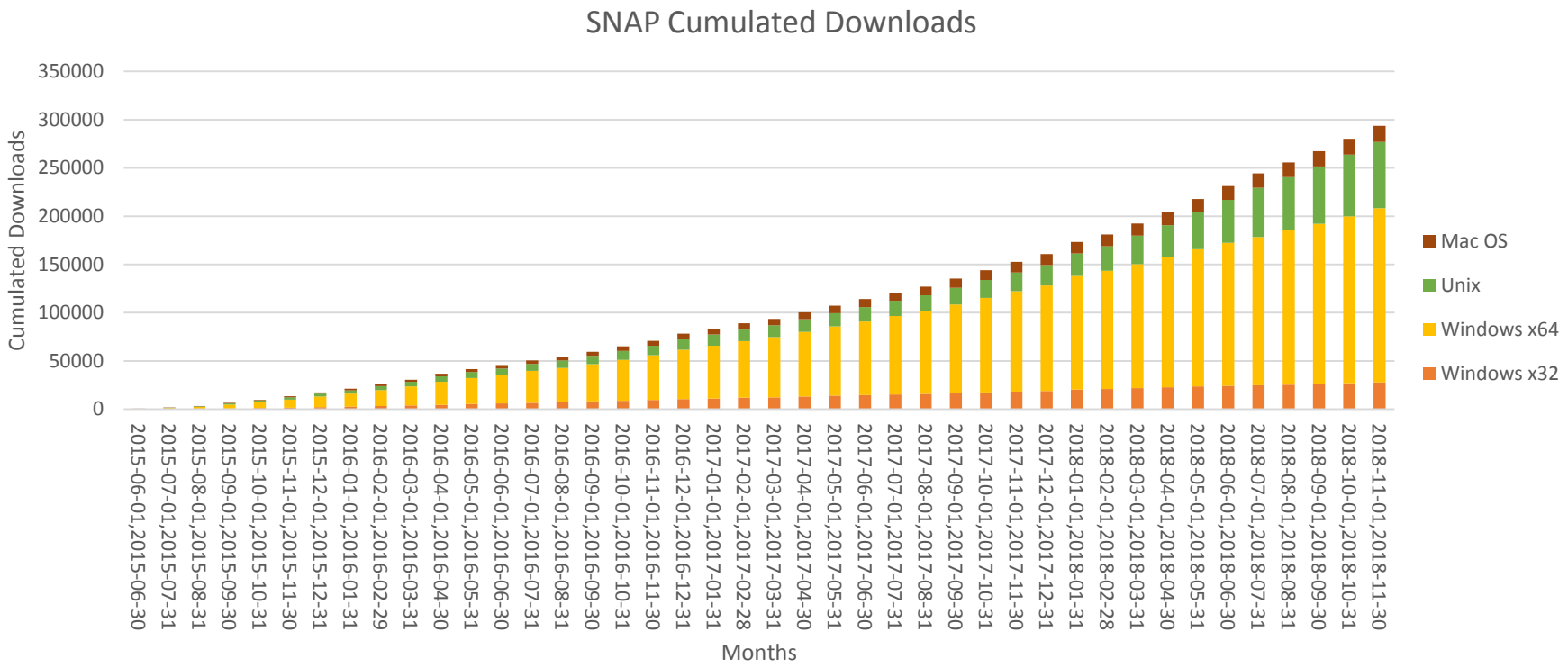
What is SNAP ?

- SNAP (SeNtinel Application Platform)
  - The common architecture for all Sentinel Toolboxes (1,2 and 3) and SMOS Toolbox
  - Ideal for Earth Observation processing and analysis due to:
    - Extensibility
    - Portability
    - Modular Rich Client Platform
    - Generic EO Data Abstraction
    - Tiled Memory Management
    - Graph Processing Framework
  - Developed as open source software
  - Runs on



What is SNAP ?

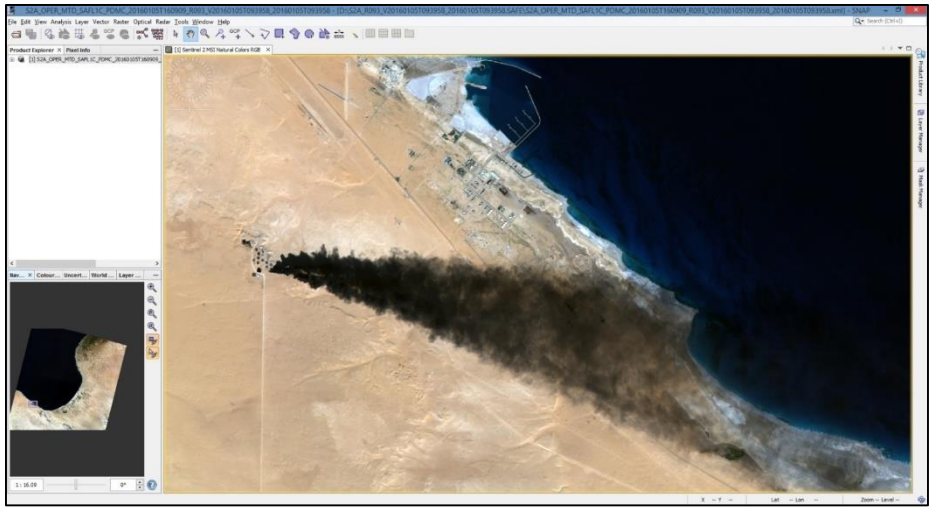
➔ Downloaded more than 250k times since the first version



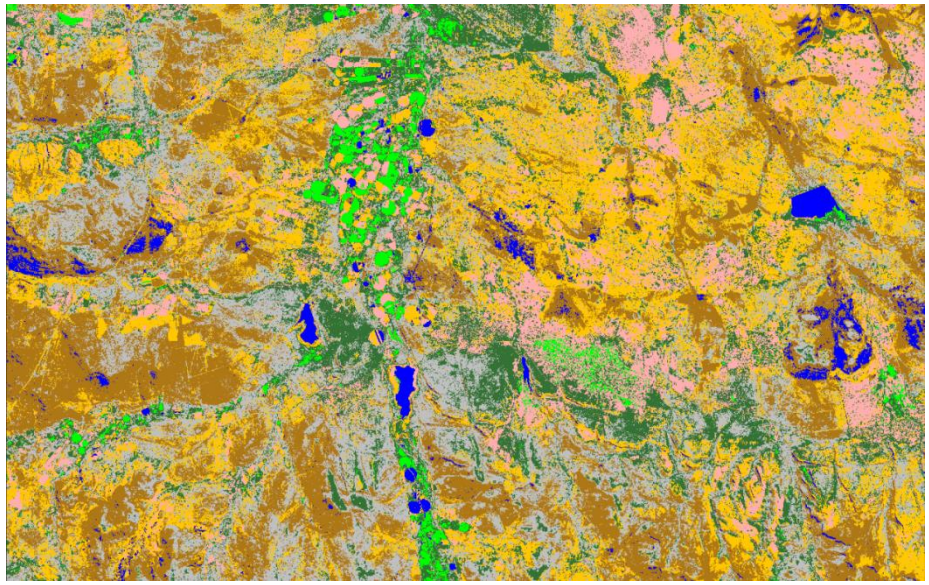
➔ Community of 20+k users: http://step.esa.int (maintained by CS RO)

SNAP Showcases

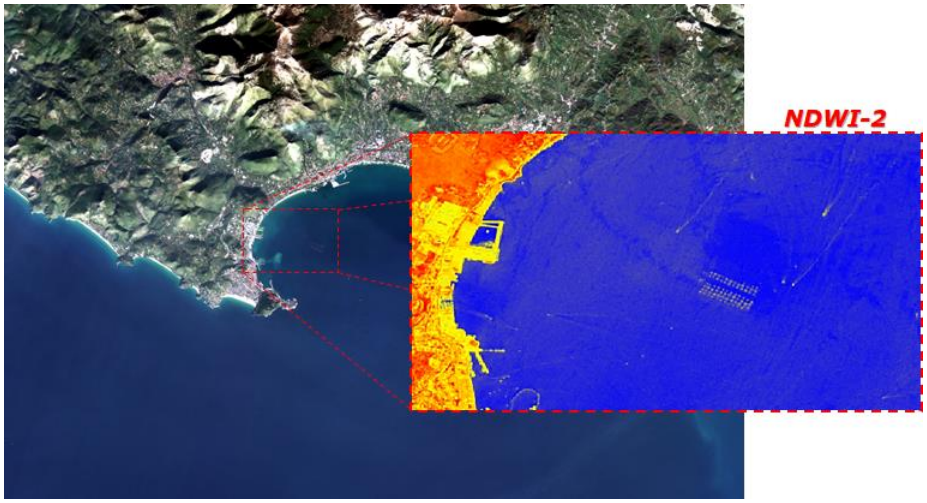
➔ Sentinel-2 Oil well fire (Libya 05.01.2016)



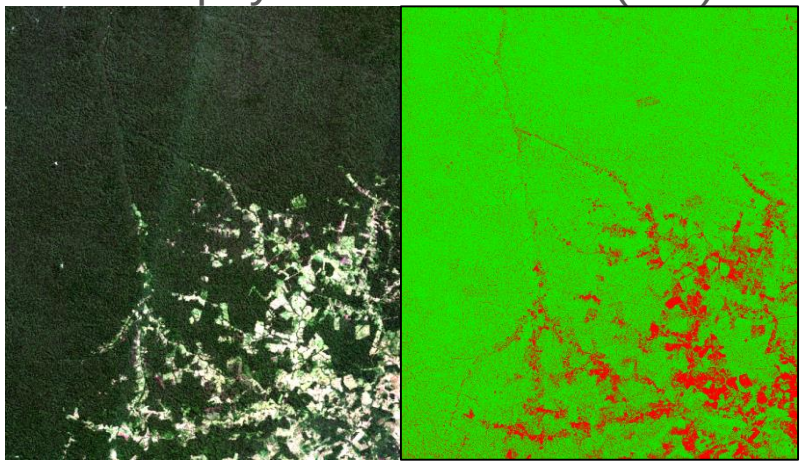
➔ Sentinel-2 Unsupervised Classification



➔ Sentinel-2 Aquaculture (Gaeta Gulf, Italy)



➔ Sentinel-2 Biophysical Processor (LAI)



Sentinel-2 Toolbox and STEP 2.0

- CS ROMANIA involvement:
  - Sentinel-2 Toolbox 

    - Integration of third party mission products (RapidEye, Deimos, SPOT 1-7, Pleiades, WorldView, Kompsat)
    - Integration of third party computing modules as plugins
    - Radiometric indices processors
    - Implementation of supervised classification algorithms
    - Implementation of scientific processor modules (eg. Forrest Cover change)
    - Cloud execution environment
  - STEP 2.0 

    - Responsible of the http://step.esa.int toolboxes portal
    - SNAP forum community animation
    - Video tutorials for SNAP modules
    - Showcase gallery
- Starting with 2017, our team became member of the SNAP Developer Forum (main developers of the SNAP platform)
- Current responsibiliy: SNAP new features for releases 7.0 to 10.0 (2020)

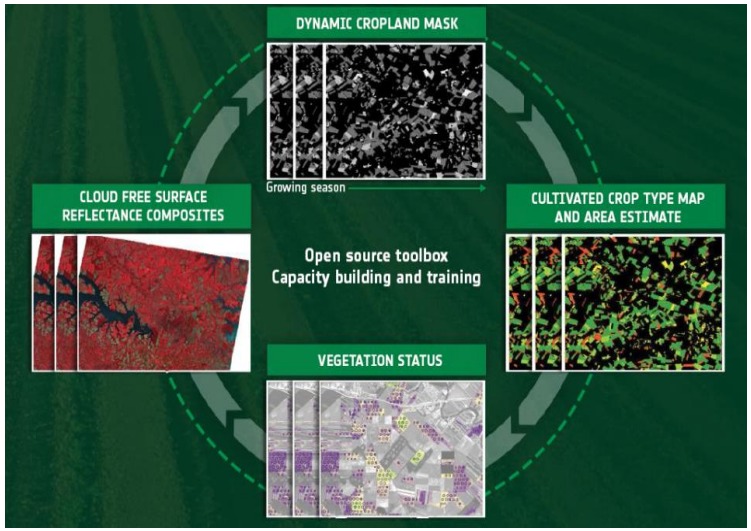
OPERATIONAL EO DATA PROCESSING FOR AGRICULTURE

3

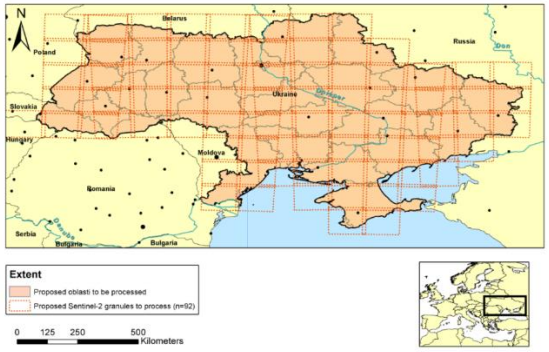
Operational Challenges

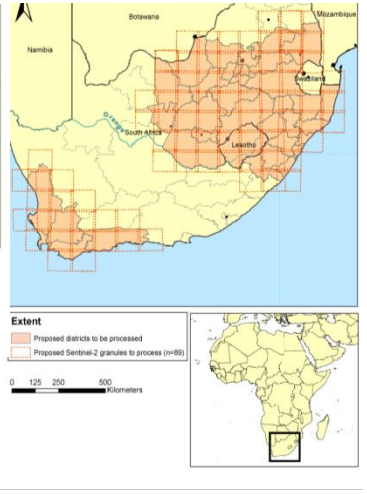
- Large product dimensions:
  - Sentinel-2 (optical)
    - 13 spectral bands
    - mono-tile product has 100km x 100km @ 10m/pixel => 10980 x 10980 pixels / band
  - Landsat-8 (optical)
    - 11 spectral bands
    - Single scene product has 180km x 180km @ 30m/pixel => 6000 x 6000 pixels / band
  - Sentinel-1 (radar)
    - 4 polarization bands
    - Single frame has ~25000 x 18000 pixels / band
- Frequent revisit times:
  - Sentinel-2: 5 days revisit at Equator, more frequent at higher latitudes
  - Sentinel-1: 6 days revisit
  - Landsat-8: 16 days revisit
- Large areas of interest (order of 10^4 - 6×10^5 km^2)

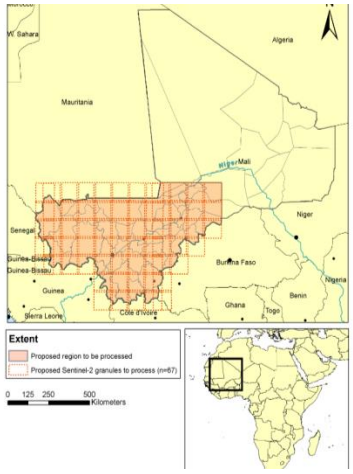
- Launched by ESA in February 2014 as part of the Data User Element Programme
- Innovative algorithms for
  - Cloud-free BOA reflectance composite
  - Vegetation status indicators
  - Dynamic cropland mask
  - Dynamic crop type map

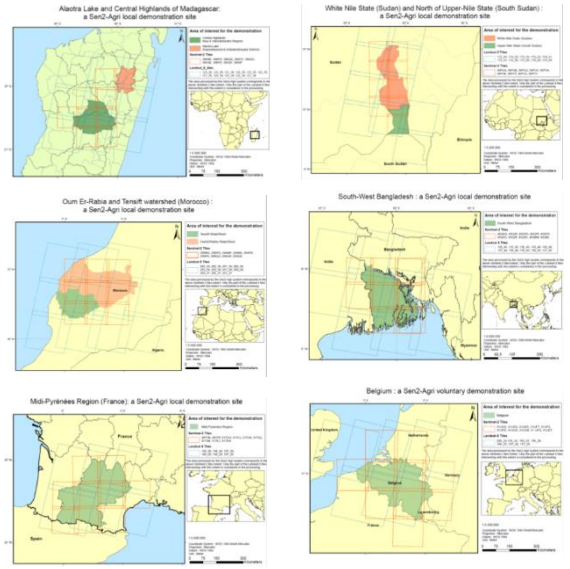


- 3 national sites and 9 local sites (300km x 300km)







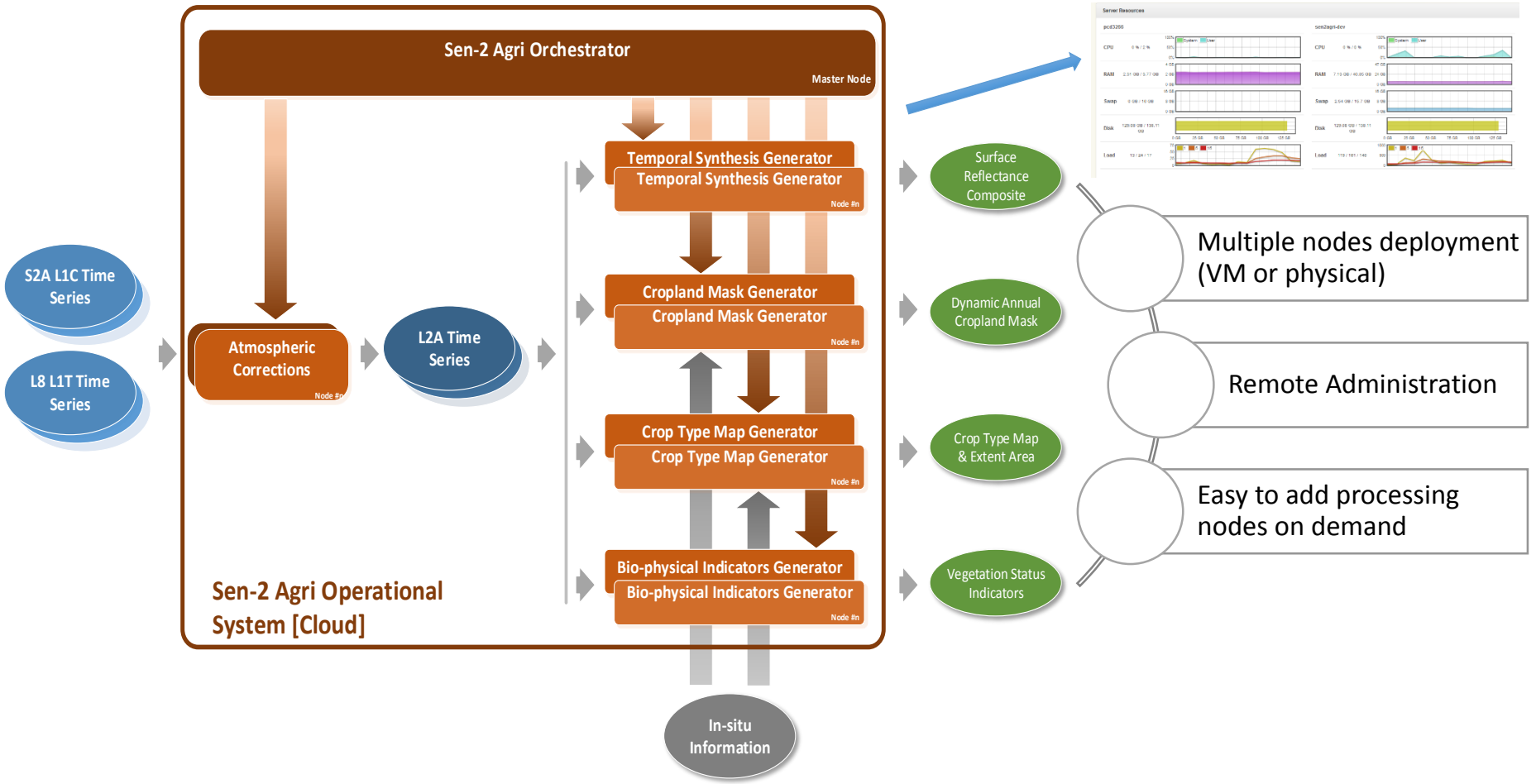


sentinel-2

→ AGRICULTURE

Sentinel-2 for Agriculture

➔ A system designed to run in an automated mode and deliver agricultural products as the satellite images are ingested (near-real time)

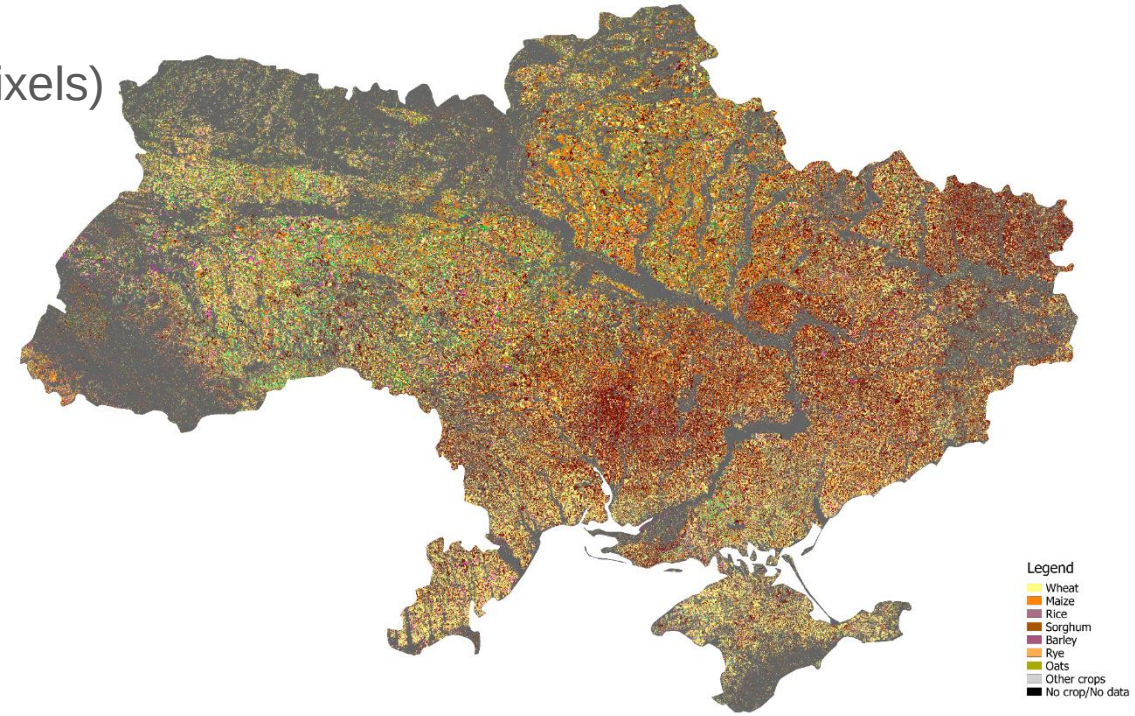


sentinel-2

→ AGRICULTURE

Sentinel-2 for Agriculture

- Open-source fully automated processing system
- Development in C++ and Java
- Cluster-ready architecture (relying on SLURM)
- Currently in use in 50+ locations world-wide
- First national automatically produced crop map @ 10 m resolution (Ukraine in July 2016)
  - ~120000 x 100000 (12 Gigapixels)



sentinel-2

→ AGRICULTURE

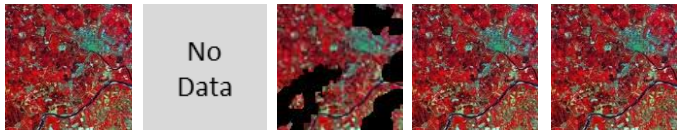
SEN2AGRI OPERATION FOR CROP TYPE MAP

Before the start of the monitoring period

System initialization

Monitoring period

Automatic EO data download
Manual in situ data upload

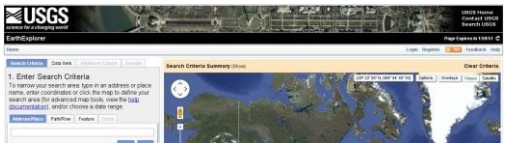


SoS

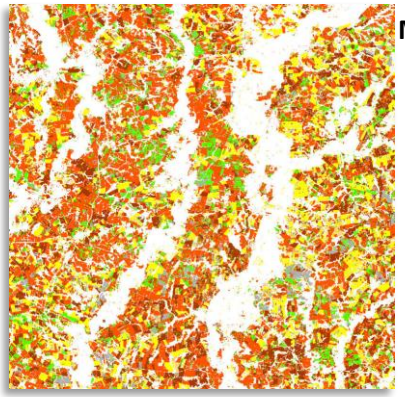
6M

EoS

EO data providers



Operators



Mid-season crop type

SEN2AGRI OPERATION FOR CROP TYPE MAP

Before the start of the monitoring period

System initialization

Monitoring period

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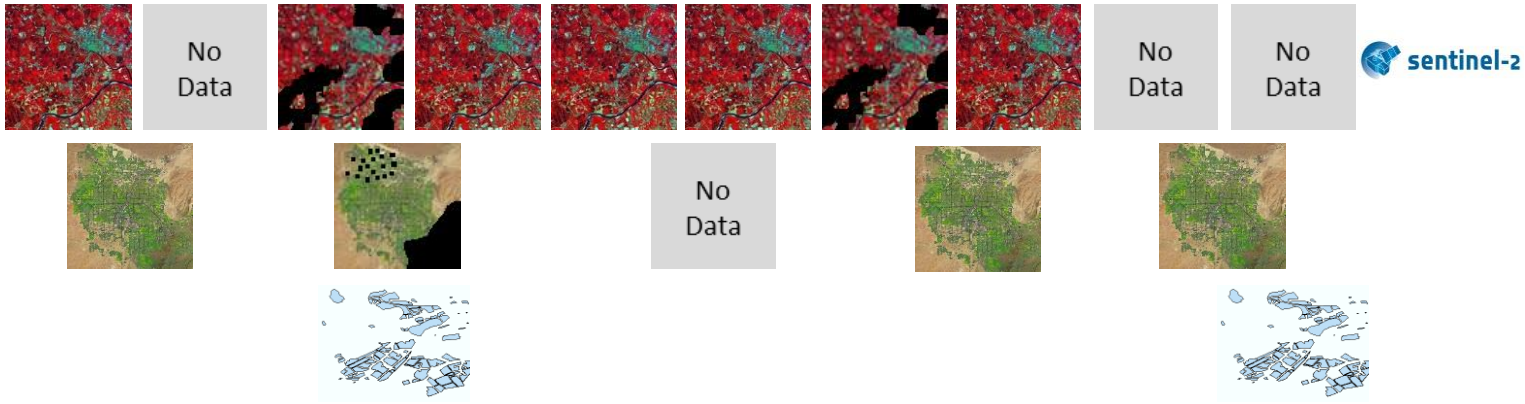
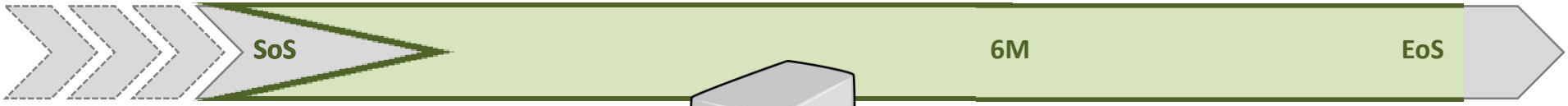
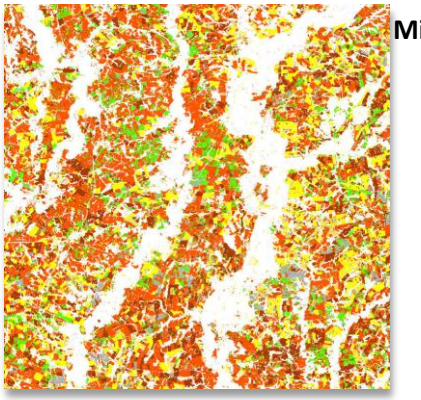
Manual in situ data upload





EO data providers



Mid-season crop type

Operators

SEN2AGRI OPERATION FOR CROP TYPE MAP

Before the start of the monitoring period

System initialization

Monitoring period

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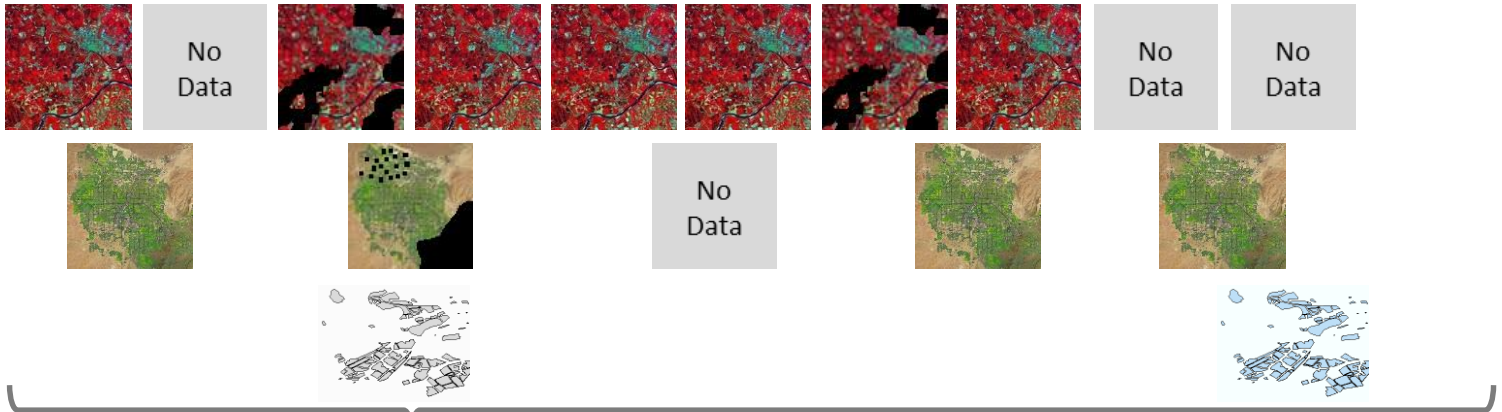
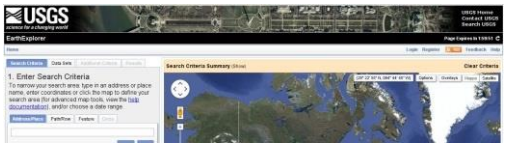


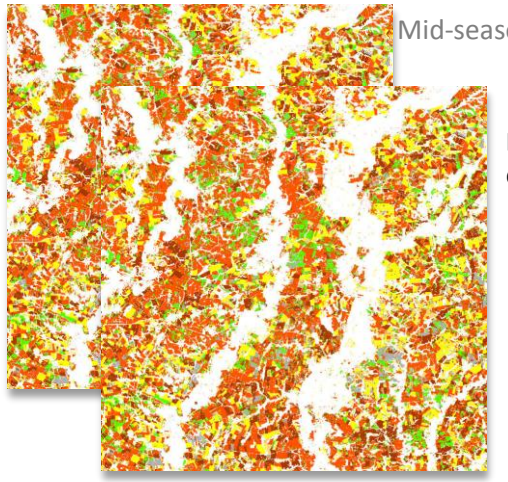
SoS

EoS

EO data providers



Operators



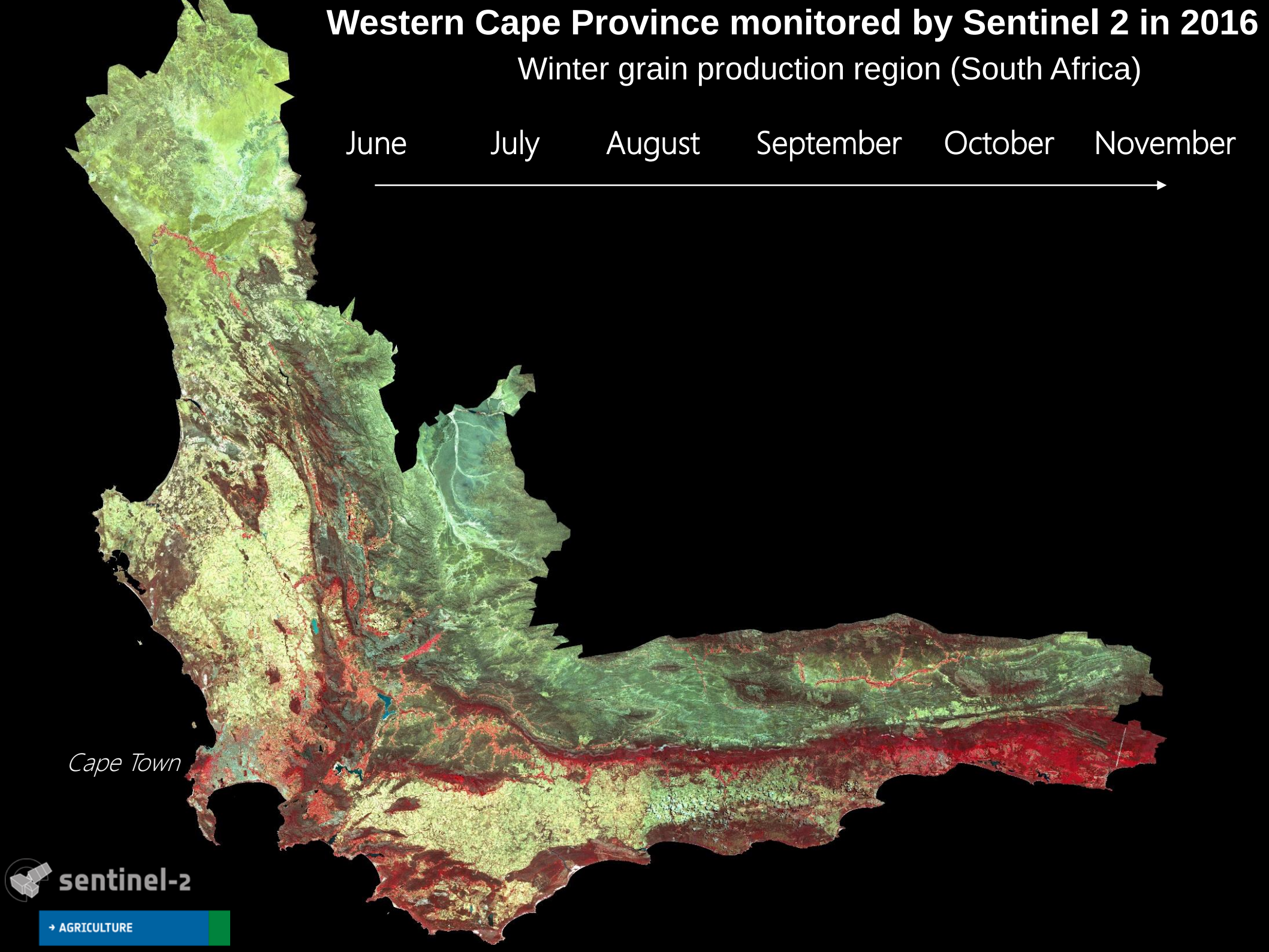
Mid-season crop type

End of season crop type

Western Cape Province monitored by Sentinel 2 in 2016

Winter grain production region (South Africa)

June July August September October November



sentinel-2

→ AGRICULTURE

Sentinels for Common Agricultural Policy

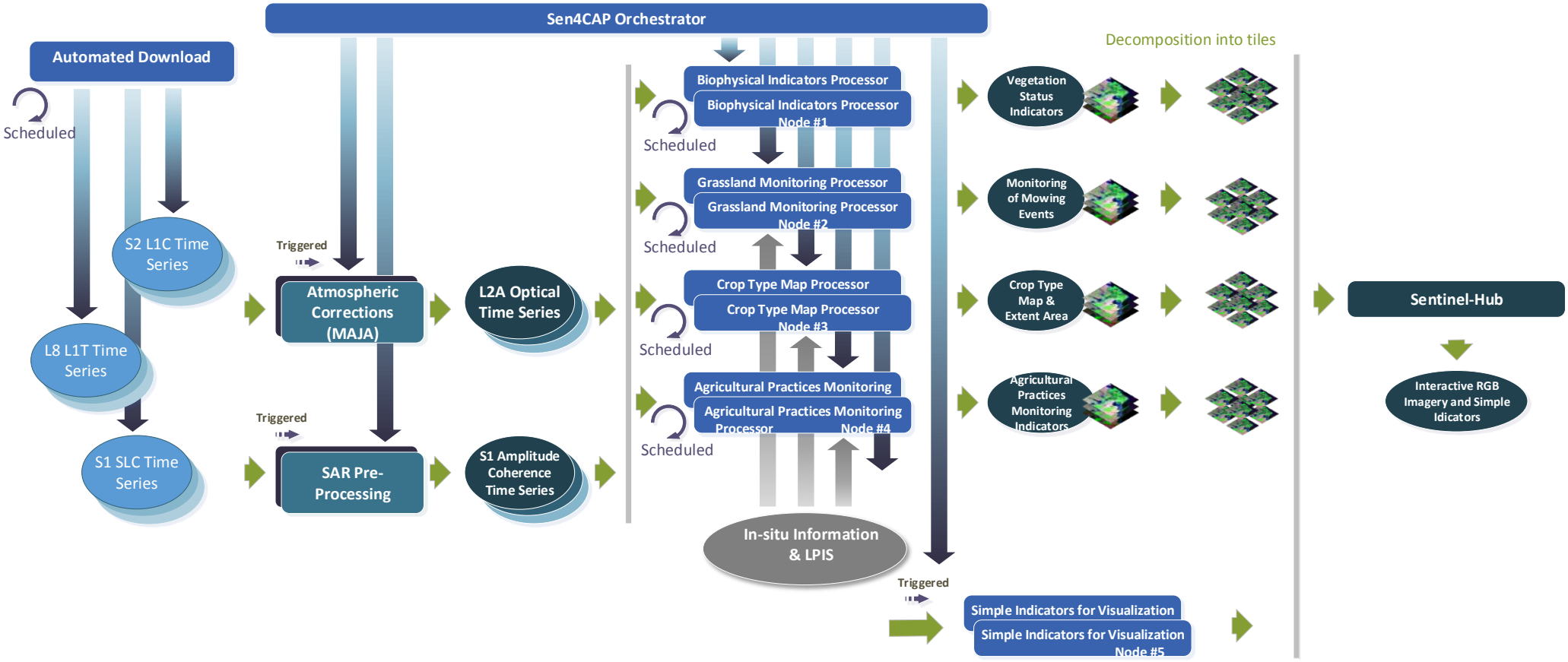
www.esa-sen4cap.org

- Launched by ESA in July 2017
- Pilot for the future EC CAP monitoring plan, producing:
  - more Vegetation Status Indicators
    - To give information about vegetation status and its growing condition
  - Cultivated crop type maps
    - To discriminate crop types or crop type groups
  - Agricultural Practices products
    - Identification of crop harvesting and ploughing of grasslands
    - Comparison of farmer declarations against EO data
  - Grassland Monitoring products
    - Detect mowing events with data ranges at parcel level
    - Assess compliance with several CAP subsidy schemes
- Synergy of exploiting optical (Sentinel-2, Landsat-8) and radar (Sentinel-1) sensors
- Combine EO data with LPIS (cadaster) / GSAA (farmer declarations) national data

➔ Sen4CAP pilot countries

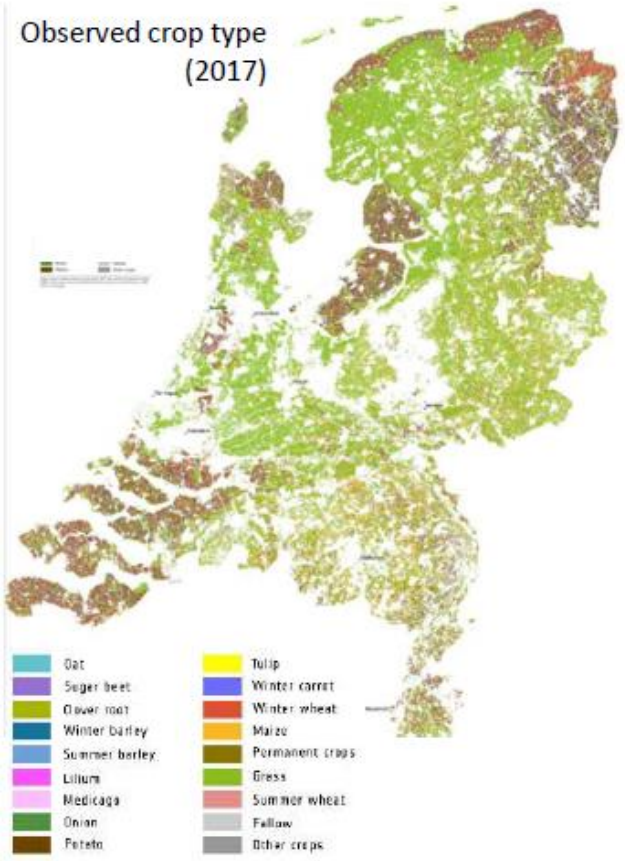
Sentinels for Common Agricultural Policy

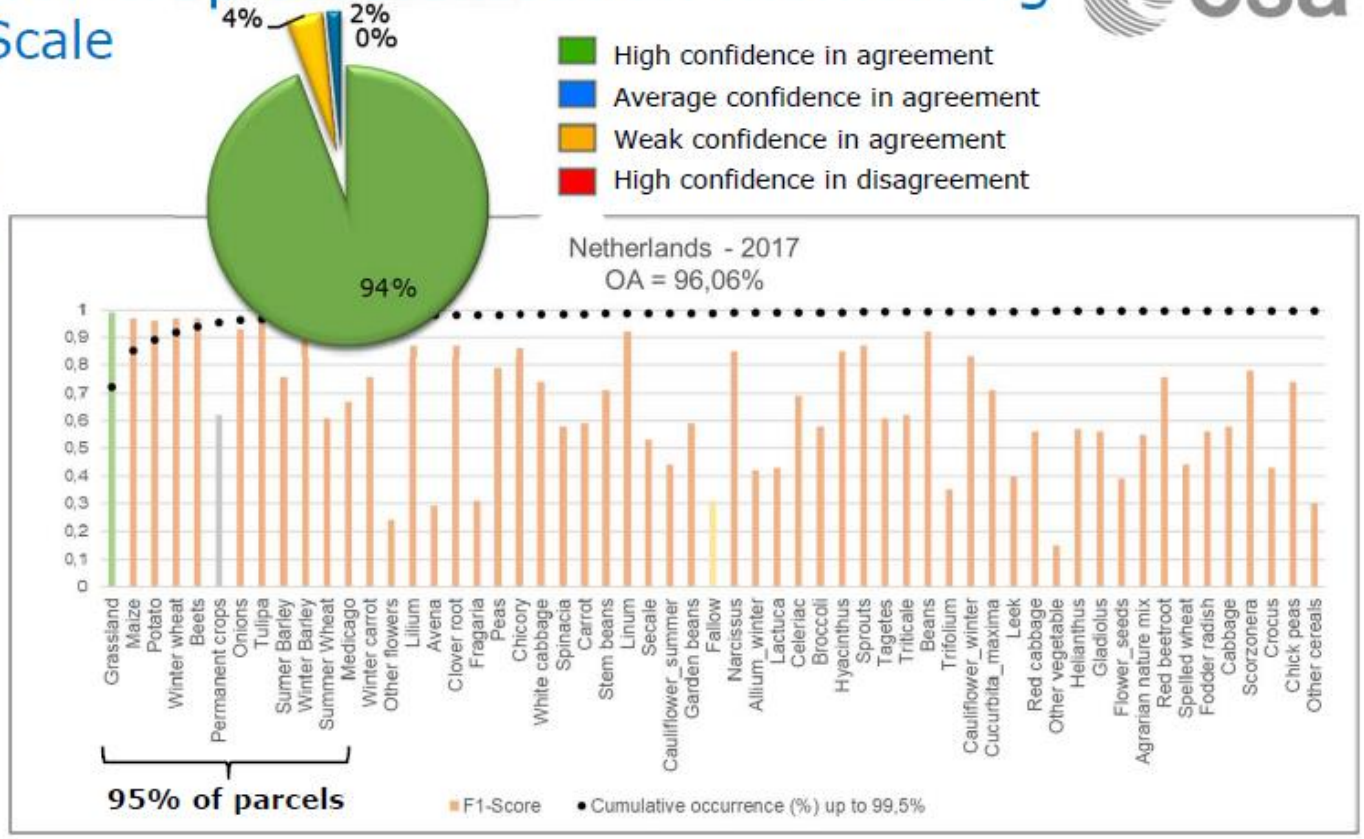
- “Big brother” of the Sen2-Agri system
- Larger EO data volumes (~470 TB for pilot countries only for 2018-2019)



Crop type mapping for crop diversification monitoring

Netherlands - National Scale





Full Resolution Visualization Online:
http://www.esa.int/spaceinimages/Images/2018/05/Crop_map

Preliminary 2018 results
Grassland mowing detection - Lithuannia

From National to European scale

	Czech Republic	Italy	Europe (indicative)
Input EO data (2018-2019)	28 TB	100 TB	2 PB
Output L2 data (2018-2019)	34 TB	123 TB	2 PB
Output L3 data (2018-2019)	14 TB	50 TB	1 PB
Processing & pre-processing resources (ongoing)	16 cores, 128 GB	32 cores,256 GB	500 cores, 4 TB
Distribution resources (ongoing)	8 cores, 64 GB	16 cores, 96 GB	50 cores, 352 TB

TAO: MULTI-PURPOSE PROCESSING FRAMEWORK

4

Beyond Agriculture: TAO

➔What is TAO?

- A framework for **integrating** in an uniform way existing heterogeneous **EO processing toolboxes** (such as OTB, SNAP, GDAL, etc.)
- A framework for **querying and retrieving EO products** from various sources (SciHub, AWS, PEPS, USGS, etc.)
- A framework for building scientific **workflows**
- A framework for **distributing the execution** of processing components across many machines

With as little IT knowledge as possible

… and **Open-Source**!

TAO Concept

Wrappers (software components):

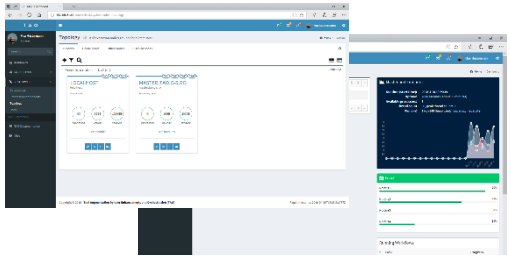
- Define how to invoke an executable

- Docker containers are used for deployment of:
  - System images for toolboxes
  - Support images for user-defined script execution (Python, R, …)

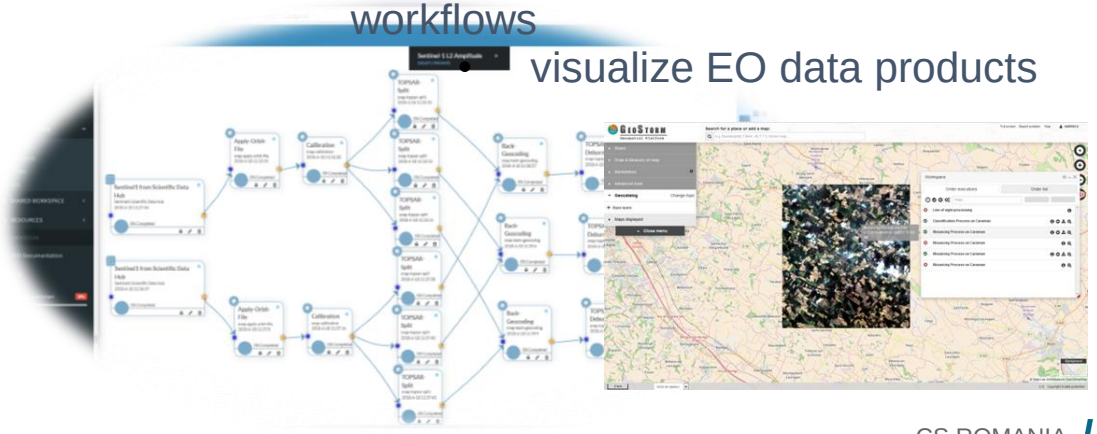
TAO Concept

Two graphical (web) interfaces:

- **Administration interface**
  - management of platform users
  - management of processing components
  - management of execution nodes
  - parametrization of built-in data sources



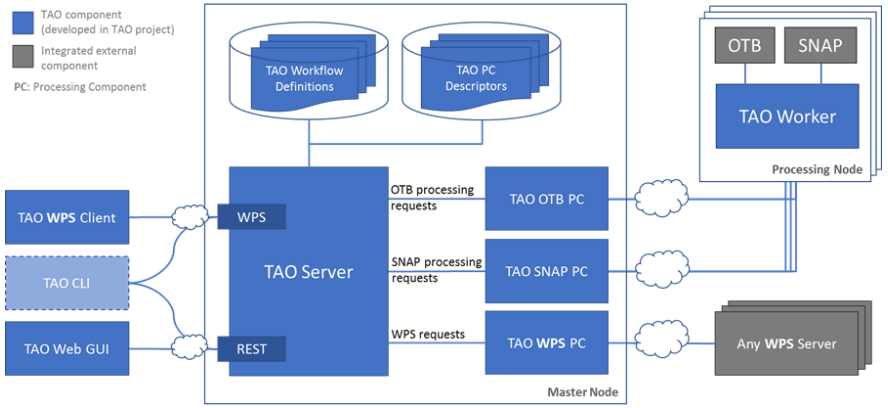
- **User interface**
  - login into platform
  - access owned resources from catalogue and see the dashboard
  - add, execute and follow status of workflows
  - visualize EO data products



TAO Concept

Two-way interfacing:

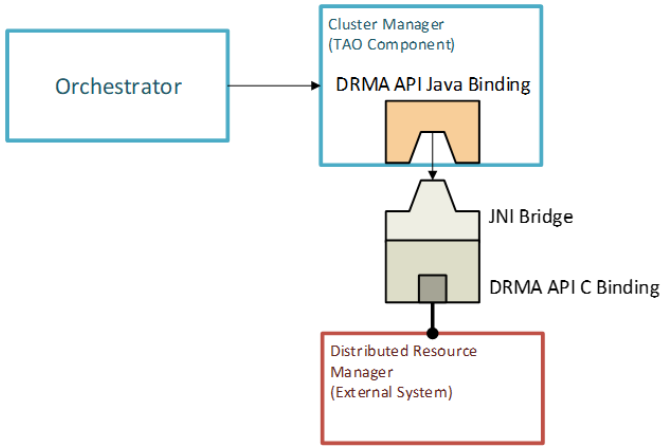
- **TAO WPS Server**
  - Allows incoming requests
  - OGC WPS compliant
- **TAO WPS Processing Component**
  - Performs requests to external WPS interfaces
  - OGC WPS-client compliant



TAO Concept

DRMAA (Distributed Resource Management API) – "standard" in the cluster computing world

- DRMAA-compliant plugins for:
  - Torque
  - SLURM
  - SSH invocation
  - Local process invocation



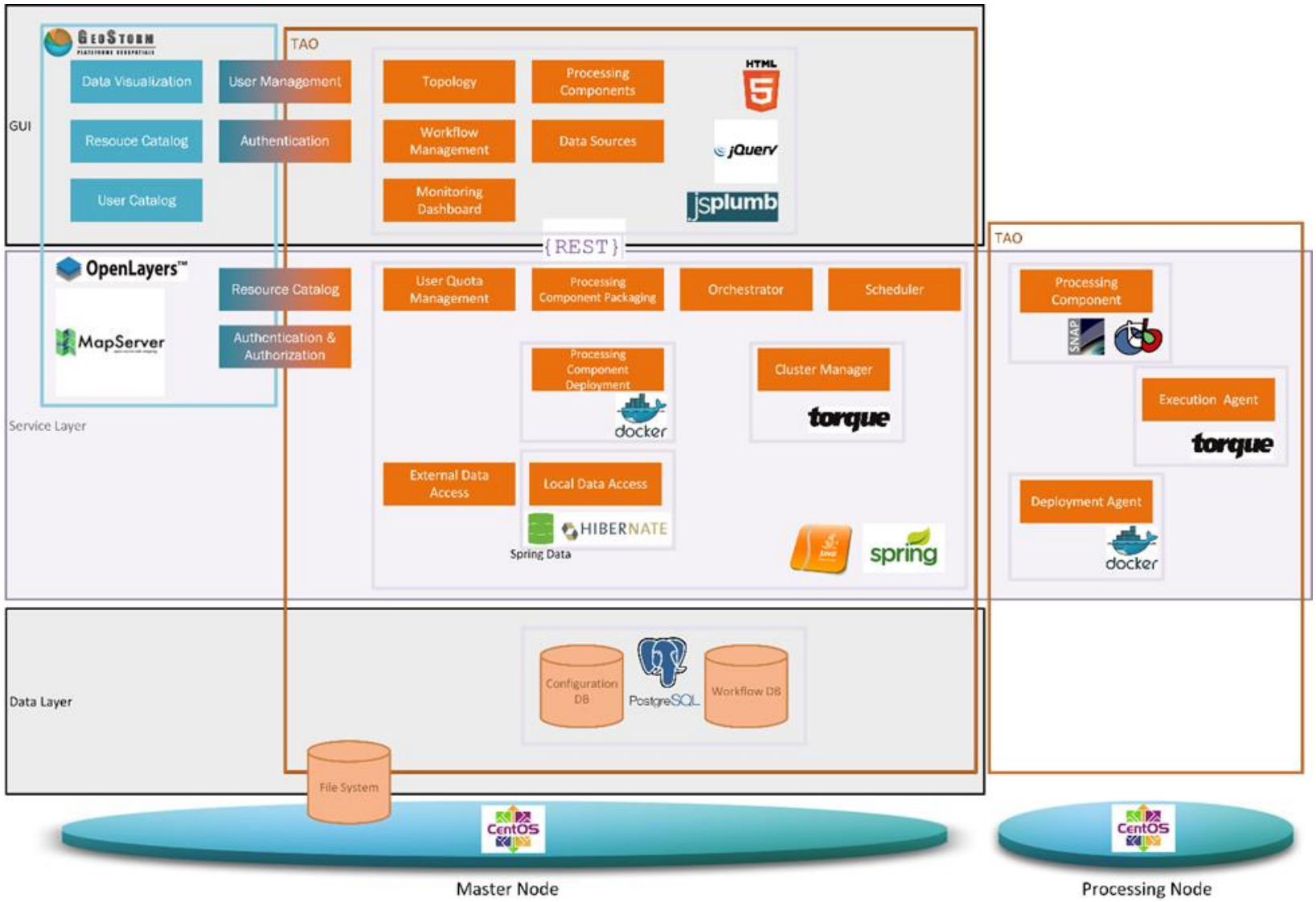
TAO Concept

The TAO framework allows two deployment modes:

- **Standalone mode** where only a set of core components are deployed allowing execution of orchestrated workflows from an external toolbox that does not possess orchestration

- **Platform mode** where the full platform is deployed, allowing users management, resource catalogue and distributed execution on multiple nodes via topology management

➔Technology stack



ROMANIA

THANK YOU!