DEVELOPING IMAGE PROCESSING CHAINS FOR THE THEIA LAND DATA CENTRE

PROVIDING NEAR REAL-TIME IMAGERY

PETER KETTIG (CNES)
JOELLE DONADIEU (CNES)

cnes
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Outline

- The Theia land data center
  - Purpose
  - Theia's role in the context of CNES' EO ground segments
- Muscate – Theia's processing module
  - Workflow
  - Current status
- Analysis-ready data and respective improvements
  - Maja
  - LIS (Let it snow)
  - Wasp
  - Water quality
  - Biophysical parameters
- Conclusion and future work

The Theia land data center

What is Theia?

Theia
Pôle Thématique
Surfaces Continentales

theia.cnes.fr

Purpose:

- Multi-agency Organization for the studies of continental surfaces
- Promote the use of satellite data by scientific community and institutional actors.

Addition of Processing center

- **Open data access**
- Analysis-ready data

Theia's role in the context of CNES' EO ground segments

Data is a key element

- Big amount of EO data available at CNES
- Databases are permanently growing

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peps

- Sentinel 1,2,3 mirror of ESA
- On-demand processing

sentinel-1 sentinel-3

sentinel-2

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sentinel-1 sentinel-3 sentinel-2

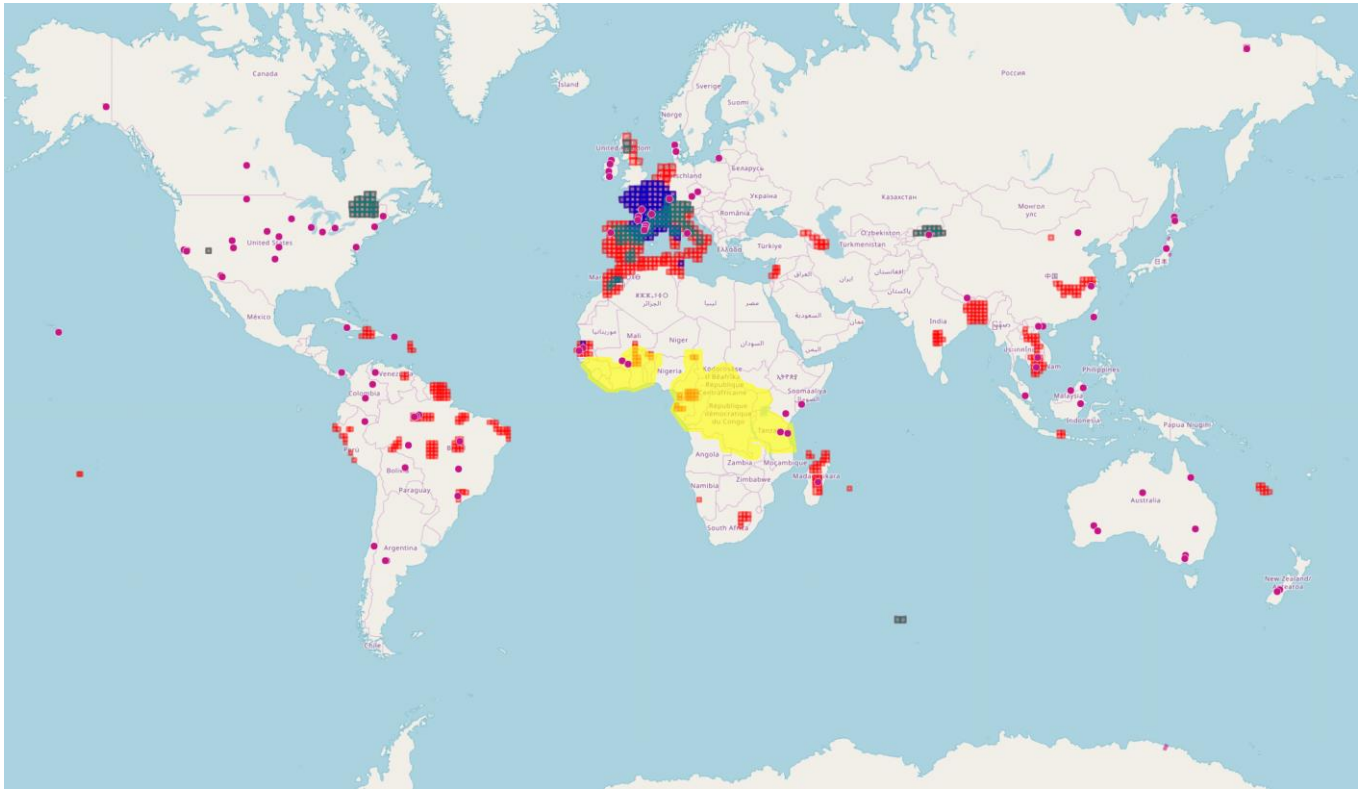
Theia Pôle Thématique Surfaces Continentales

- Pleiades data (limited to scientific usage)
- Spot 1-5 archive (SWH)
- Venus
- Sentinel
- Landsat

Already more than 30 years of data !

Muscate – Theia's processing module

Current status:



Legend:

- L2A
- L3A
- L2B-Snow
- SWH
- Venus

Muscate – Theia's processing module

= Multi-satellite, multi-sensor ground segment for multi-temporal data

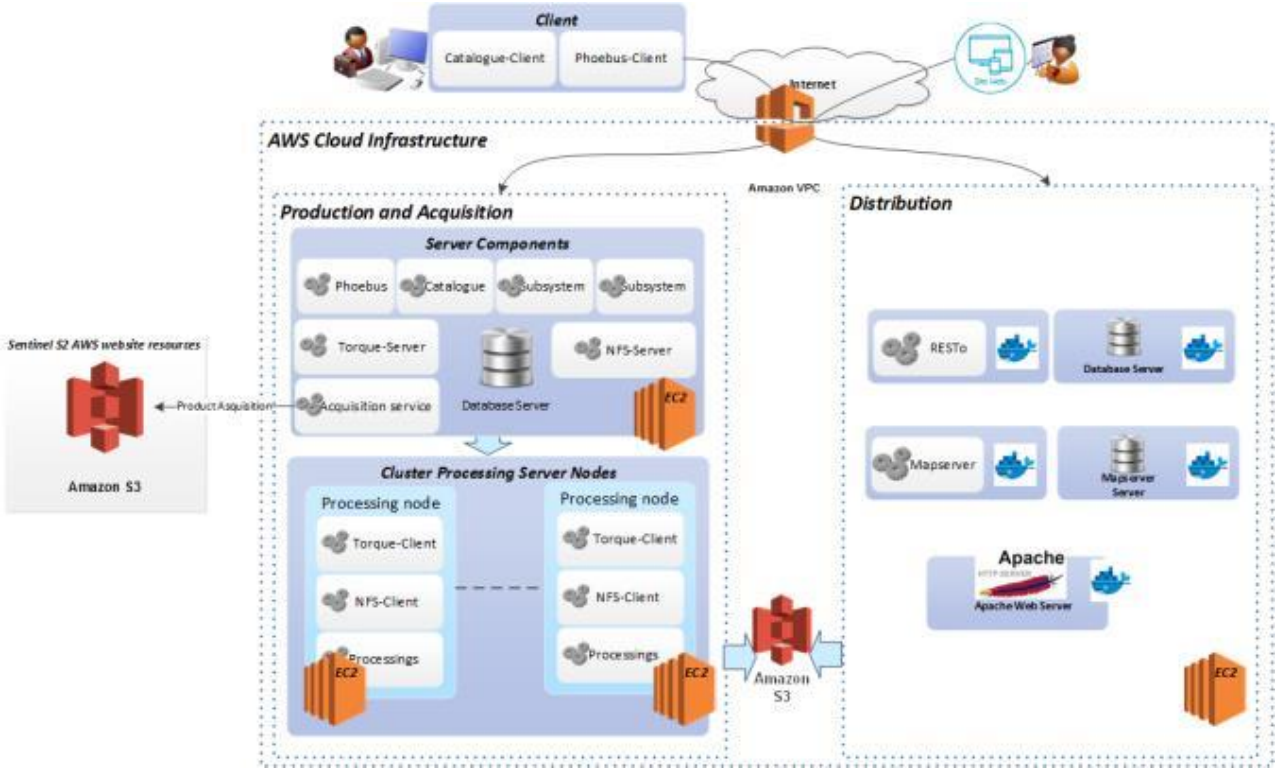
- **Goal**: Offer near real-time images to the user
- **Handling all steps**: From arrival of L1C products to distribution
- Interfaces to:
  - Previous processing centers (PEPS, VIP, etc)
  - Processing chains
  - Computing center
  - Storage systems (Disks, bands…)

→ Abstraction layer to all subsystems

Muscate – Theia's processing module

Cloud instance:

- Deployable for other agencies and institutions
- Highly scalable
- Transparent addition of new processing chains
- To be set up on a DIAS platform



Muscate – Theia's processing module

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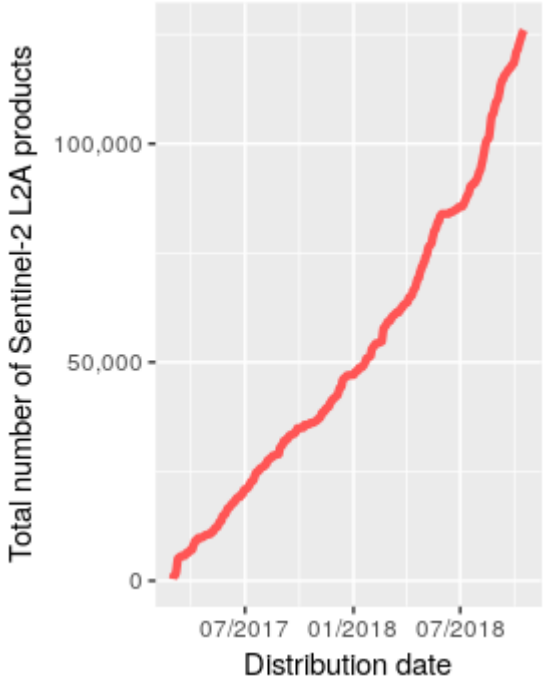

Muscate – Theia's processing module

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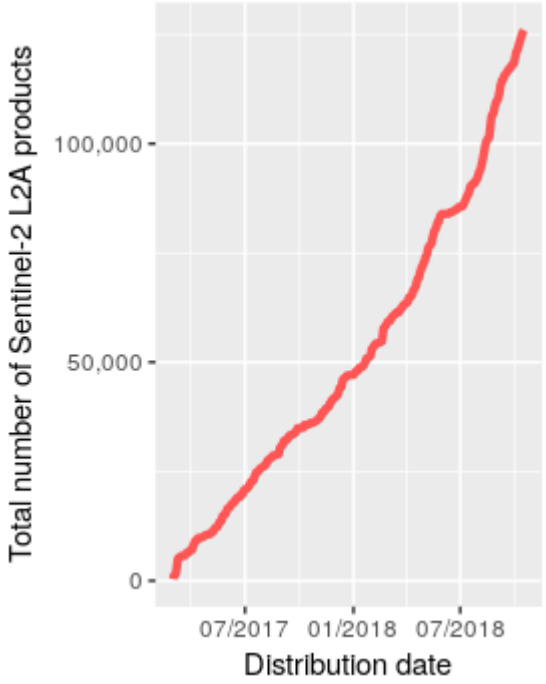
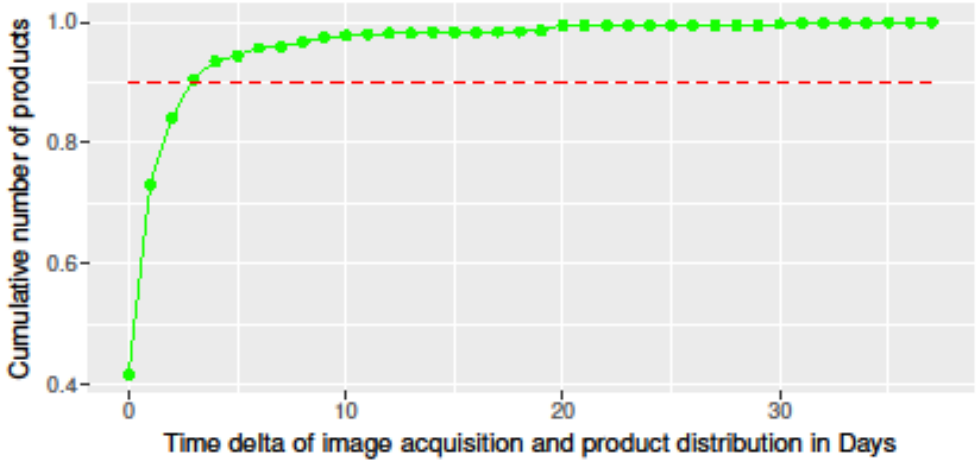




Analysis-ready data

Presentation of the processing chains

- Traditional approaches combined with AI
- Set-up of multiple processing chains to generate value-added products:
    - Maja (Maccs Atcor joint algorithm)
    - Let-it-snow (LIS)
    - Wasp (Weighted average synthesis processor)
    - OSO (Land cover map)
- Improvements of the existing models

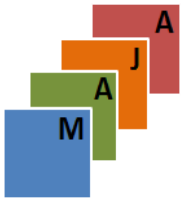
Upcoming:

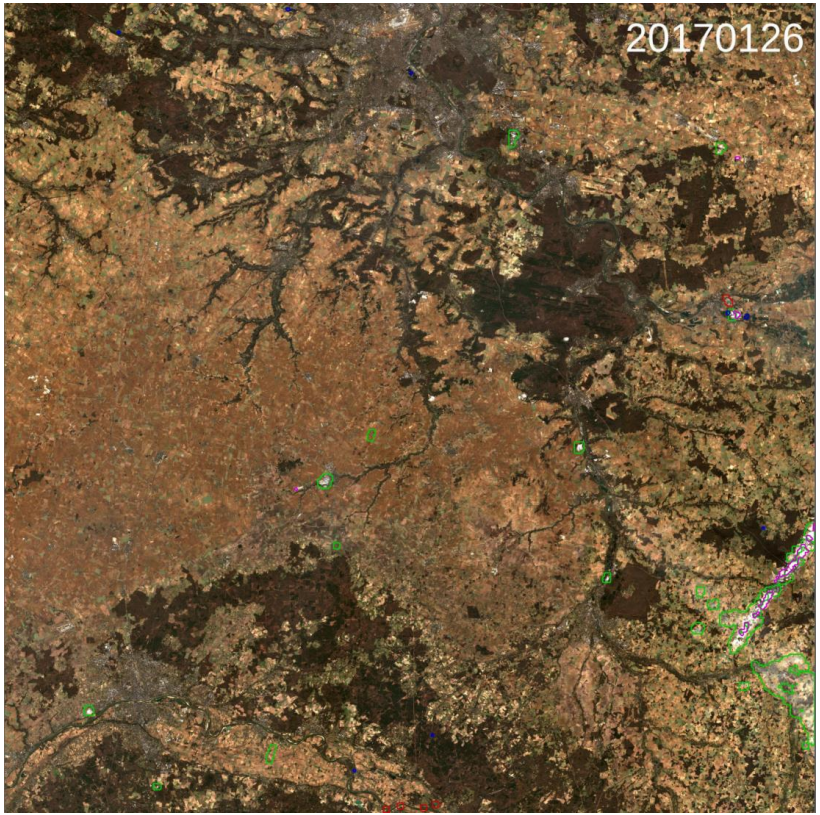
- WaterColor (OBS2CO)
- Biophysical parameters

Analysis-ready data

Maja (Maccs Atcor joint algorithm)

- Atmospheric correction/cloud detection
- Basis for all further pipelines
- Now supports use of CAMS and Meteorological data
- Executable distributed freely





Hagolle et al., CESBIO CNES

Analysis-ready data

Maja (Maccs Atcor joint algorithm)

Deep learning studies ongoing:

- atmospheric correction
- cloud detection

Cloud detection:

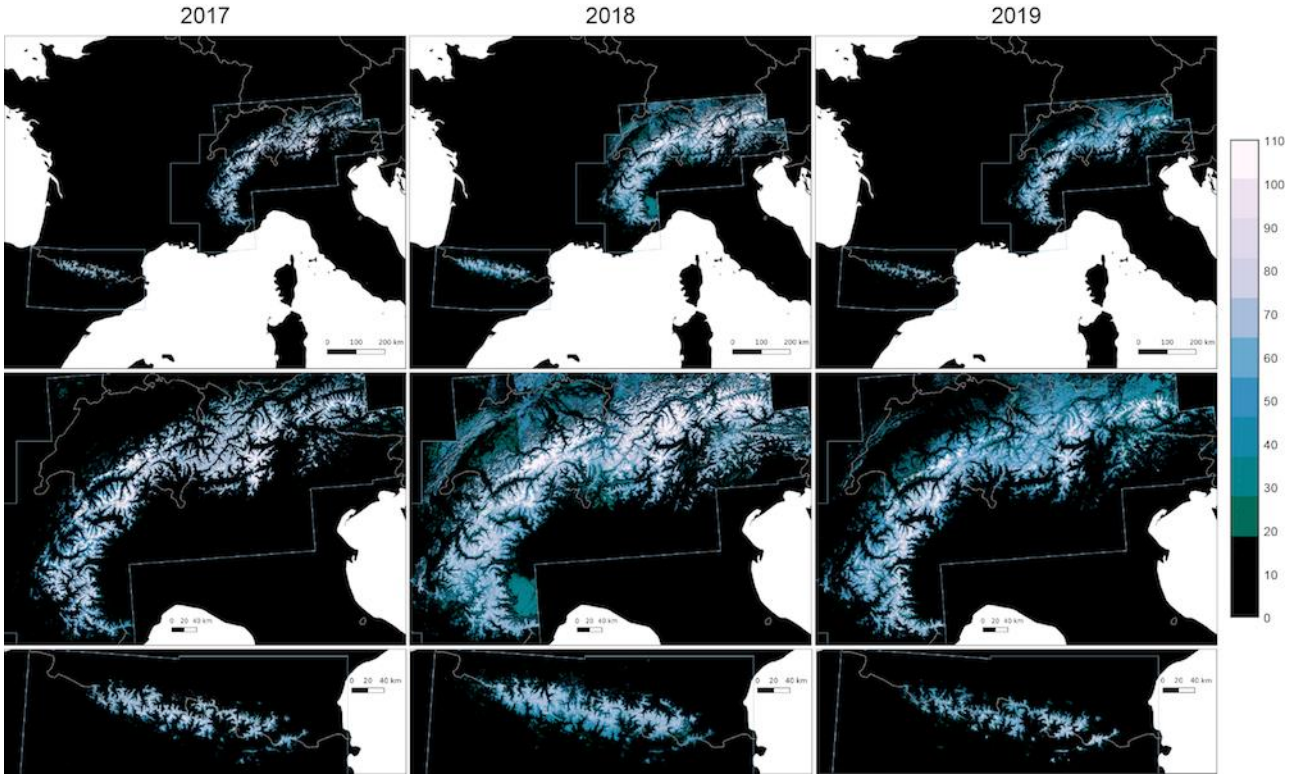
- Combination of multiple source algorithms for the training set
- Validation using multiple hand labeled datasets
- Collaboration with experts of the **physical processes**
  - Separate detection of classes
  - Active learning

Comparison of Maja (left) and Sen2Cor (right) for the same date (Desjardins et al.)

Analysis-ready data

Let-it-snow (LIS)

- Detection of snow surfaces on mayor mountain ranges
- Fusion of Landsat-8 and Sentinel-2 for higher coverage
- New version: Output of yearly snow-cover maps
- Code: Open source



Grizonnet et al., CNES CESBIO

Analysis-ready data

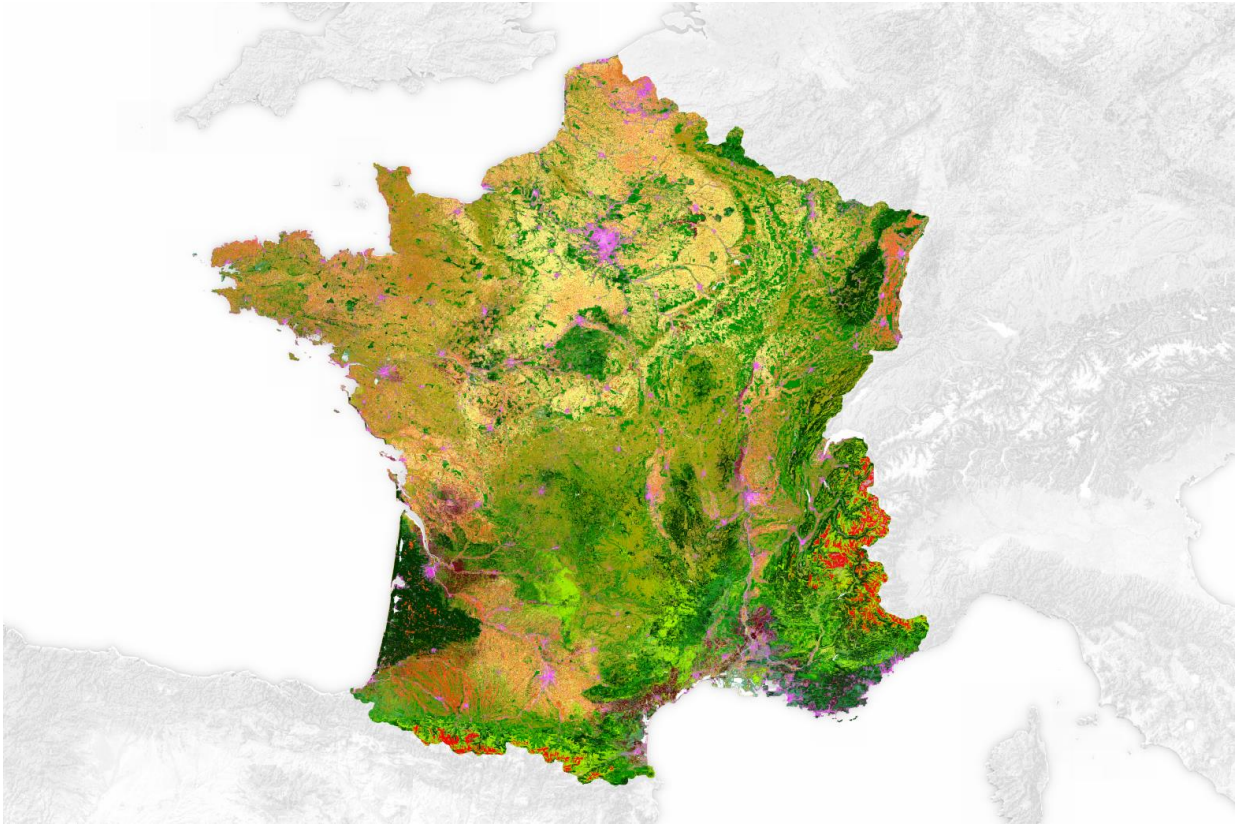
Wasp (Weighted average synthesis processor):

- Weighted average synthesis of a Level-2A time series
- Runs on Venus and Sentinel-2 inputs
- Production of monthly cloud-free composite images
- Soon:
  - To be run on all existing S2-tiles of Theia
  - Code: Open source

Analysis-ready data

OSO (Land cover mapping):

- Uses on Landsat-8 (<2016) and Sentinel-2
- Based on a random-forest classifier
- Creation of a yearly land cover map for France
- Code: Open source



Inglada et al., CESBIO CNES

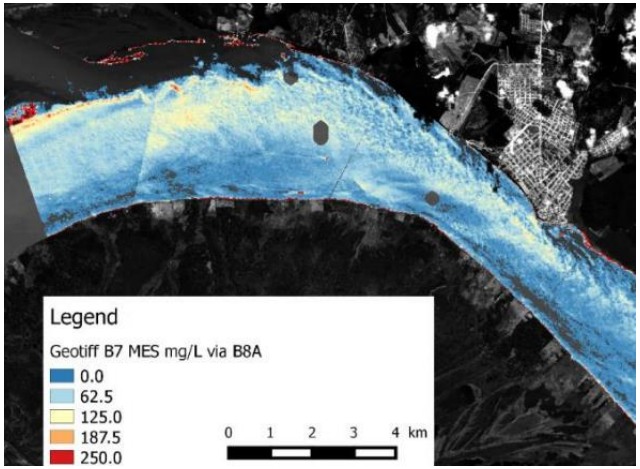
Analysis-ready data tomorrow

Biophysical parameters:

- Collaboration with the INRA laboratory
- Three neural network trained for Sentinel-2, Venus and Landsat-8 to produce:
  - LAI
  - FAPAR
  - Fcover

WaterColor (OBS2CO):

- Calculation of suspended particulate matter (SPM)
- To be run on inland water-bodies



Martinez et al., GET CNES

Conclusions and future work

Continuous researches together with industry, startups and laboratories

- Preparation of future EO missions and applications with innovative technologies

  → Artificial intelligence combined with traditional approaches

Perspectives

- Validation of (AI) implementations for operational services
- Deployment on new platforms (DIAS)

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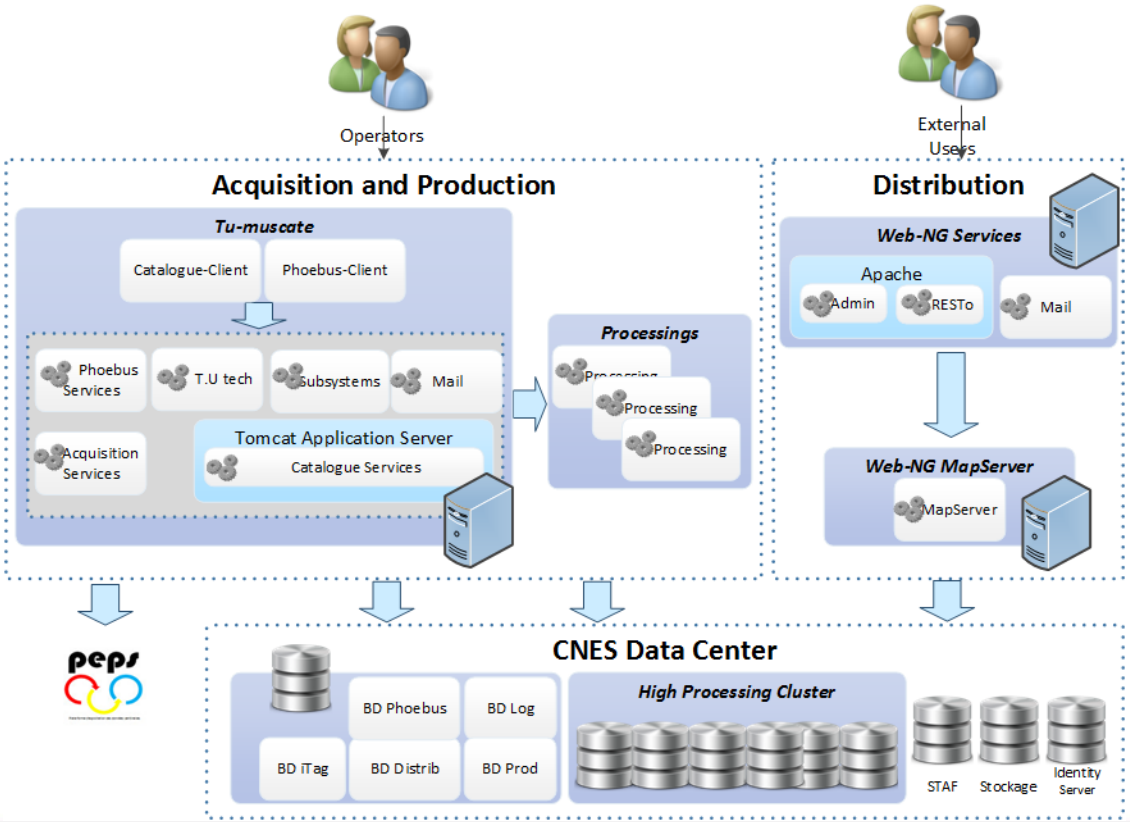
Thank you!

Backups

Muscate – Theia's processing module

Core utility: Phoebus (a.k.a. the orchestrator)



ORFEO ToolBox

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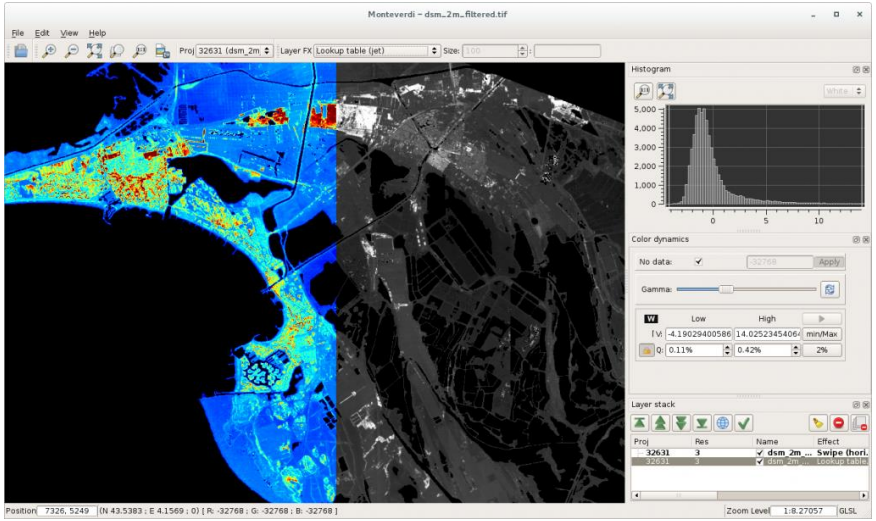
https://www.orfeo-toolbox.org/



- **Open-source** remote sensing image processing library
- Large community and easy to contribute: https://www.orfeo-toolbox.org/community/
- Image algorithms written in C++ and wrapped into OTB applications
- Easy to use and to incorporate into Python scripts: in-memory connection of OTB applications: https://www.orfeo-toolbox.org/CookBook/recipes/python.html

Image processing toolboxes

Important set of optimized and generic image processing libraries inherited from legacy missions

- Image resampling, deconvolution, denoising, etc.
- Sensor modeling (camera model)
- Correlation, image matching, image mosaicking, fusion
- Atmospheric corrections (joint algorithm CNES-DLR)
- Segmentation, Classification, 3D…
- New: **Tensorflow-module**

Sub-set as open source library available on-line :

https://www.orfeo-toolbox.org/

Machine learning for cloud detection and transfer learning

Ongoing internal project

- Development of a new Deep Learning processing chain for cloud/snow/shadow detection in Sentinel-2 images
- Comparison with the output masks of MAJA

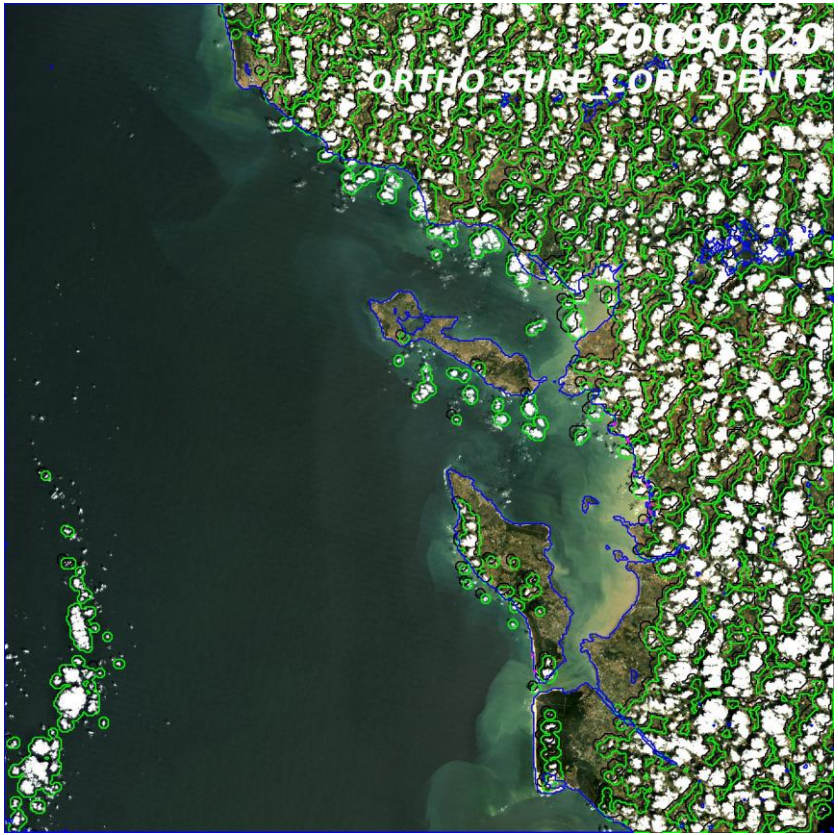


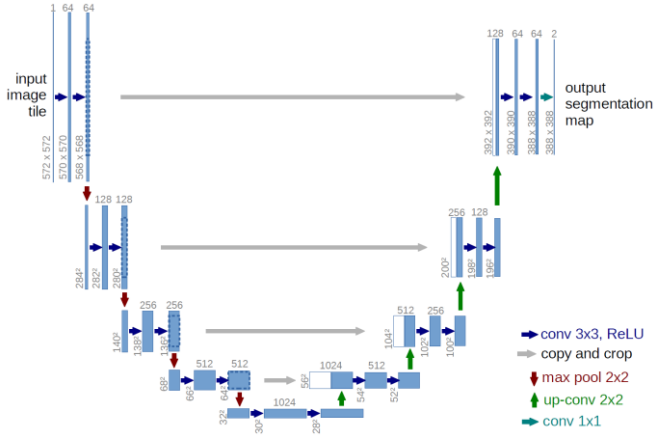
Illustration of cloud detection with MAJA on S2 images
© Cesbio

Cloud detection in detail:

Creating an adaptable model

Different configurations for the output classes:

- Clouds (different types)
- Shadows (with and without)

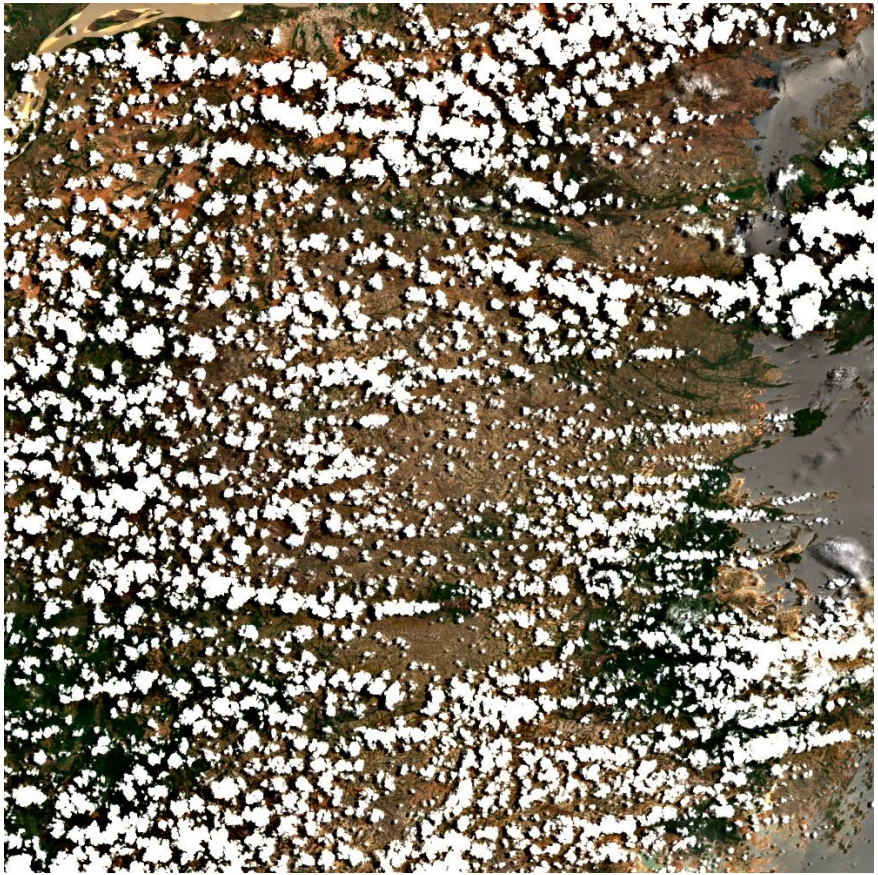


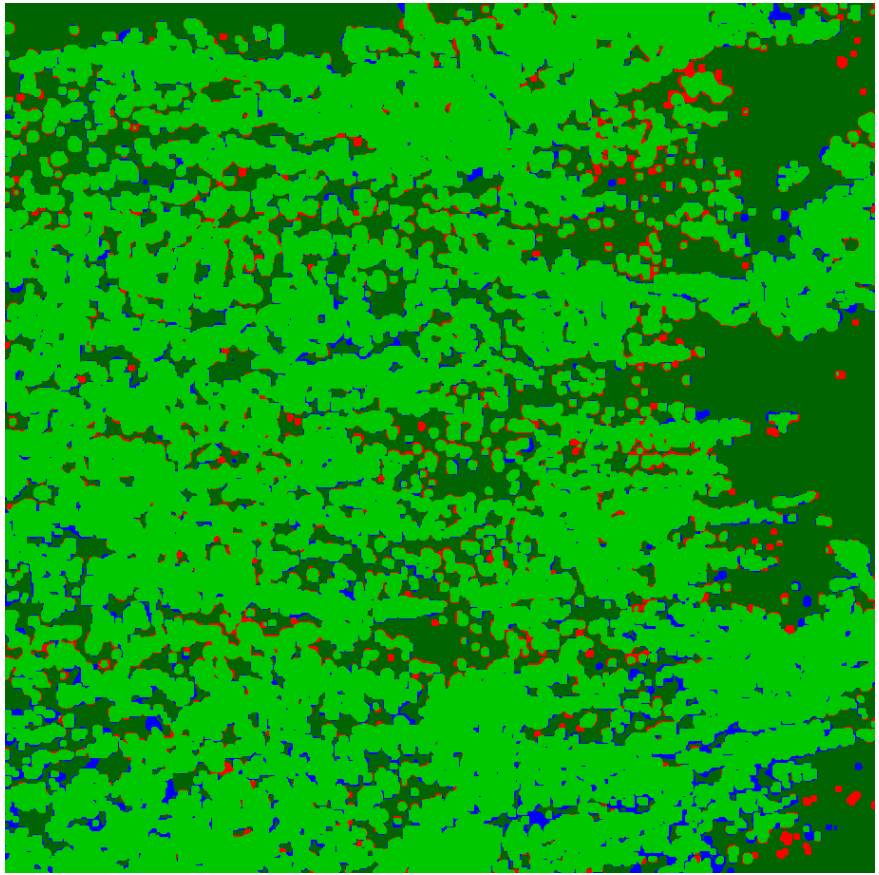
Unet illustration © Uni Freiburg

Transfer learning approach

- Using existing models: Unet, VGG etc. → Variation with regularization techniques
- Adding inputs:
  - Sen2Cor
  - Fmask
- Accuracy (maja trained only): **82% F2-score**
- Accuracy (combined with sen2cor): **85% F2-score**

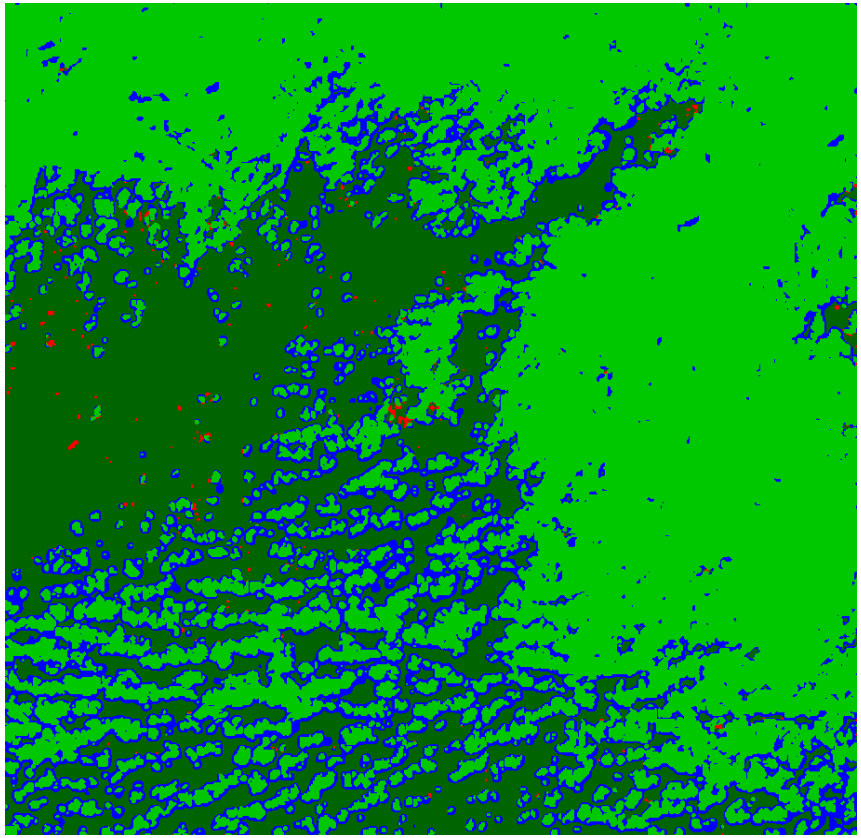
Analysis-ready data





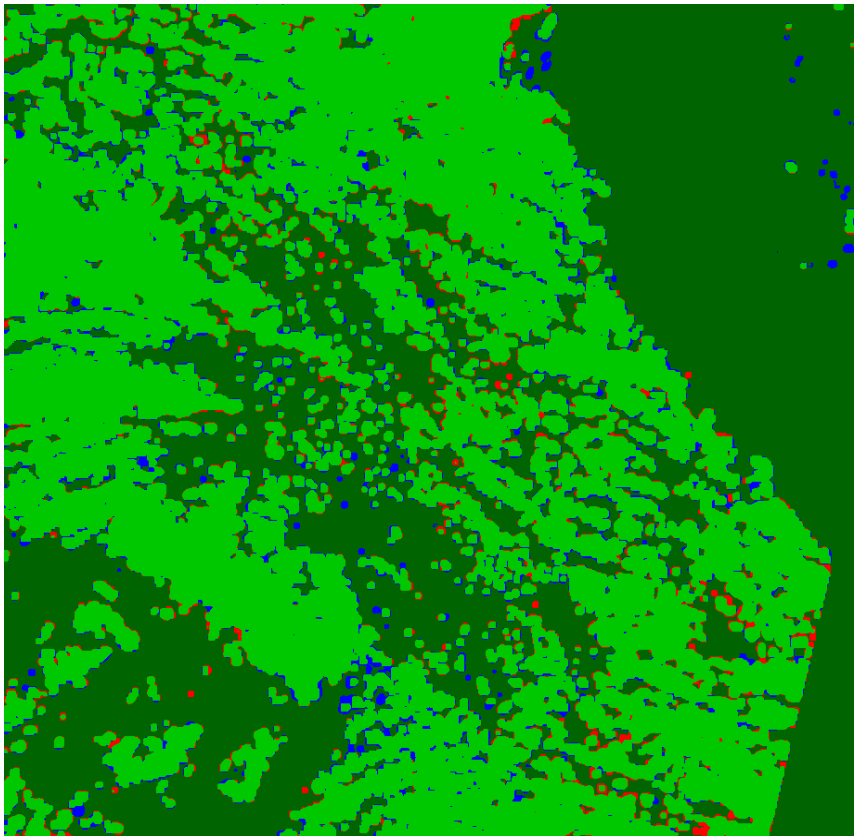
Cloud detection in detail

Cloud Clear Omission Overdetection



Cloud detection in detail

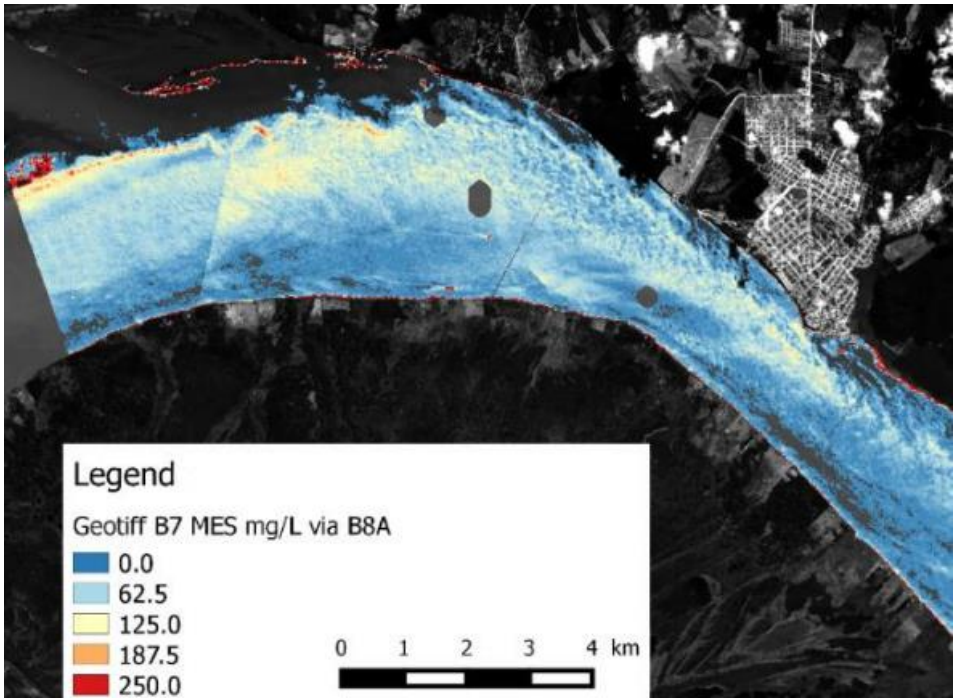
Cloud Clear Omission Overdetection



Analysis-ready data

WaterColor (OBS2CO):

- Calculation of suspended particulate matter (SPM)
- To be run on inland water-bodies
- Selected regions:



Martinez et al., GET CNES