MUSCATE : Operational Production Atmospheric Corrections and Monthly Composites Sentinel-2

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INTRODUCTION (1/3)

- MUSCATE is a multi-satellite, multi-sensor processing centre for multi-temporal data.

- Set up by CNES and CESBIO, in the framework of the THEIA Land Data Centre (www.theia-land.fr)

- THEIA is a partnership between national French institutions dedicated to land surface monitoring.

- The THEIA Land Data Centre includes a joint Space Data Infrastructure and a network of Science Expertise Centres at national scale.

INTRODUCTION (2/3)

- MUSCATE : ready to use products coming from time series of images acquired over large territories, includes atmospheric corrections and time compositing

- What we have now is a prototype version of MUSCATE
  - Based on the atmospheric corrections software called **MACCS**
  - It has already produced data from Landsat 8 and from the SPOT 4 (Take5) experiment .
  - available on the THEIA portal (www.theia-land.fr)
  - It will produce soon Spot data from the **Spot World Heritage** Program.

- A fully automatized, operational version of MUSCATE is under way

- It is designed to process systematically Sentinel-2 and Landsat data when Sentinel-2 is operational

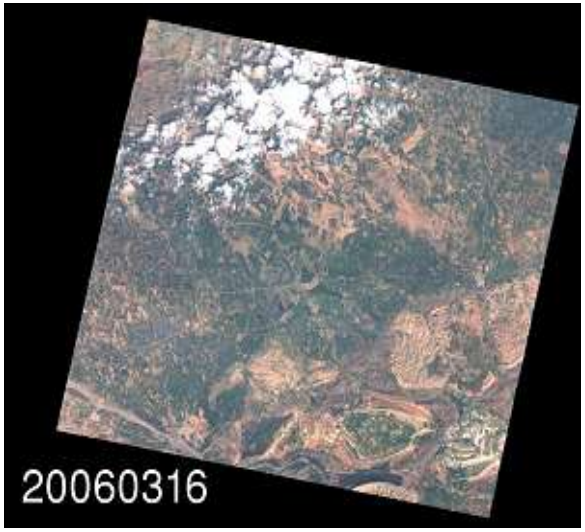
INTRODUCTION (3/3)

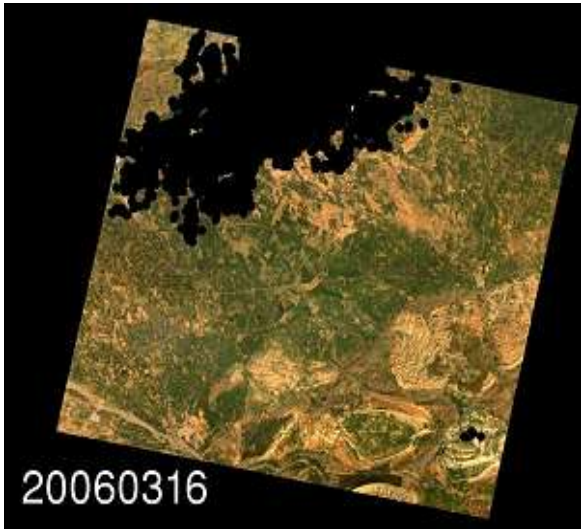
Spot World Heritage Programme

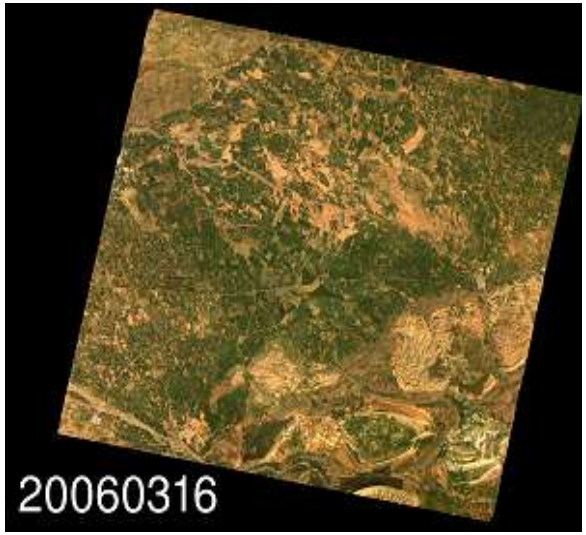
- Objective : free availability for non-commercial use of orthorectified multispectral Spot 1 – 5 images of more than 5 years old
  - Partnership agreement between CNES and Airbus Defence and Space
- Raw images are first processed to the orthorectified level before they are made available to users.
- Start by CNES of the processing of a first batch of 100,000 images with MUSCATE
- CNES is meanwhile inviting the international institutional community to contribute to order large image batches while covering the processing costs
- Access to the SWH database through the THEIA portal (www.theia-land.fr)

PROCESSING

- MUSCATE produces
  - Level 1C : **geometric corrections** (**Spot Take 5**, **Spot World Heritage**)
  - Level 2A : **cloud screening** + **atmospheric corr.** (**Spot Take 5**, **Landsat**, **Sentinel-2**)
  - Level 3A : **time compositing** (**Spot Take 5**, **Sentinel-2**)







Level 1C:

Top of Atmosphere reflectances calibrated & orthorectified

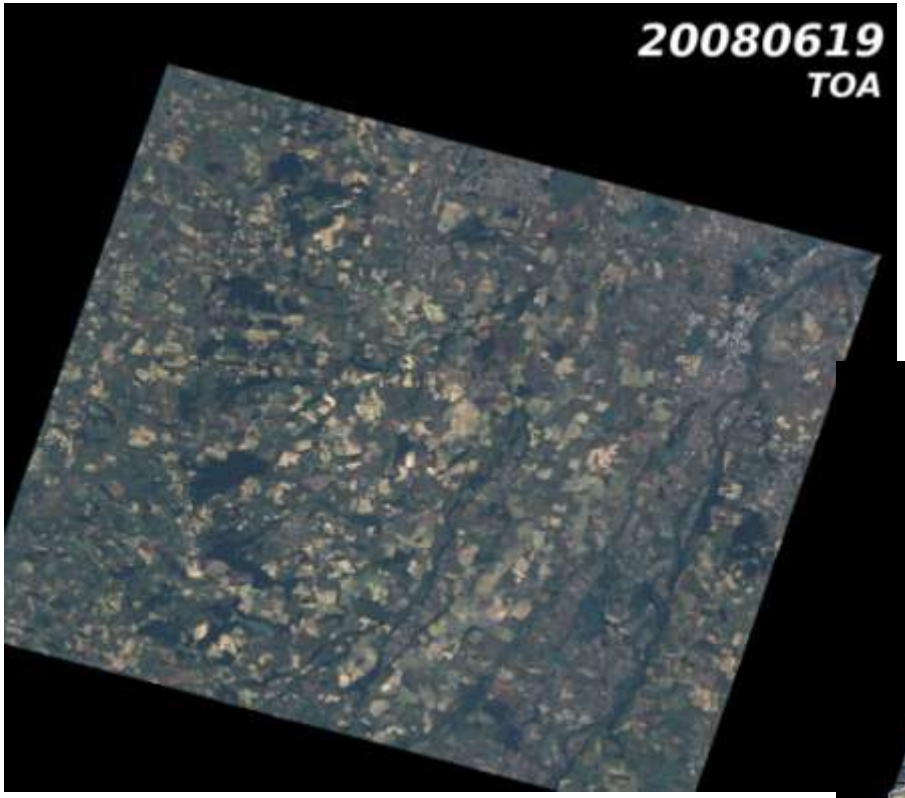
Level 2A:

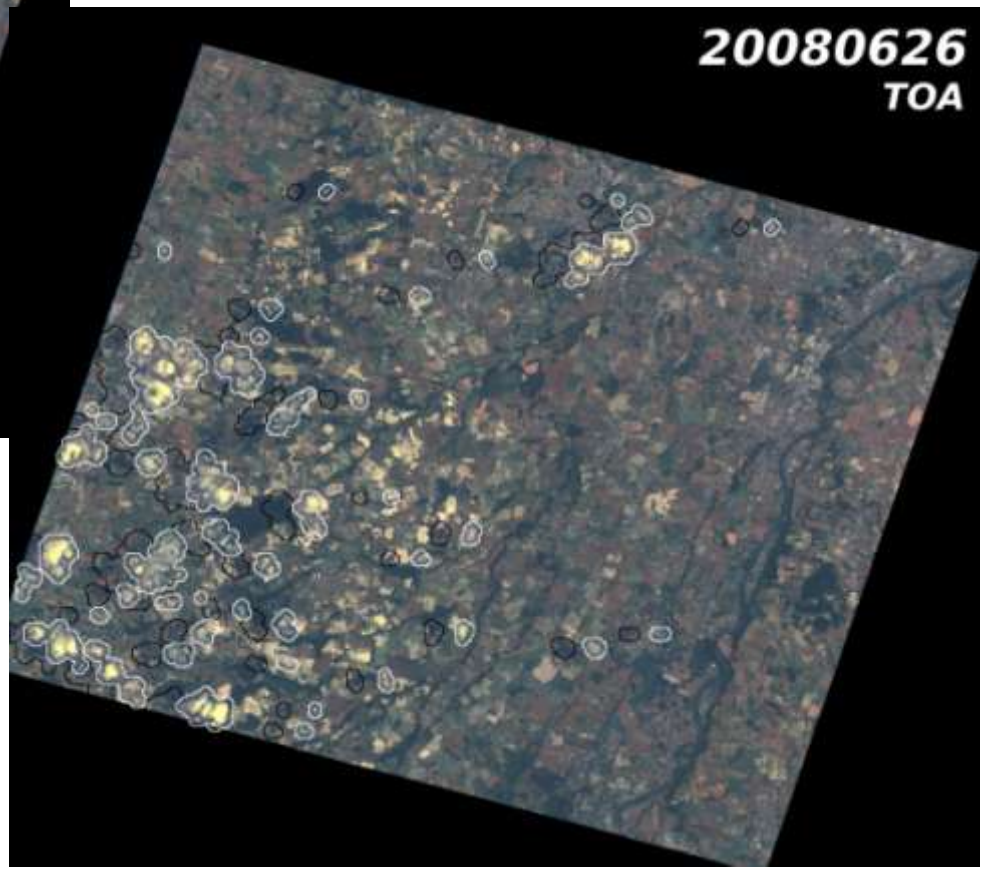
Single date surface reflectances after cloud screening and atmospheric correction

Level 3A:

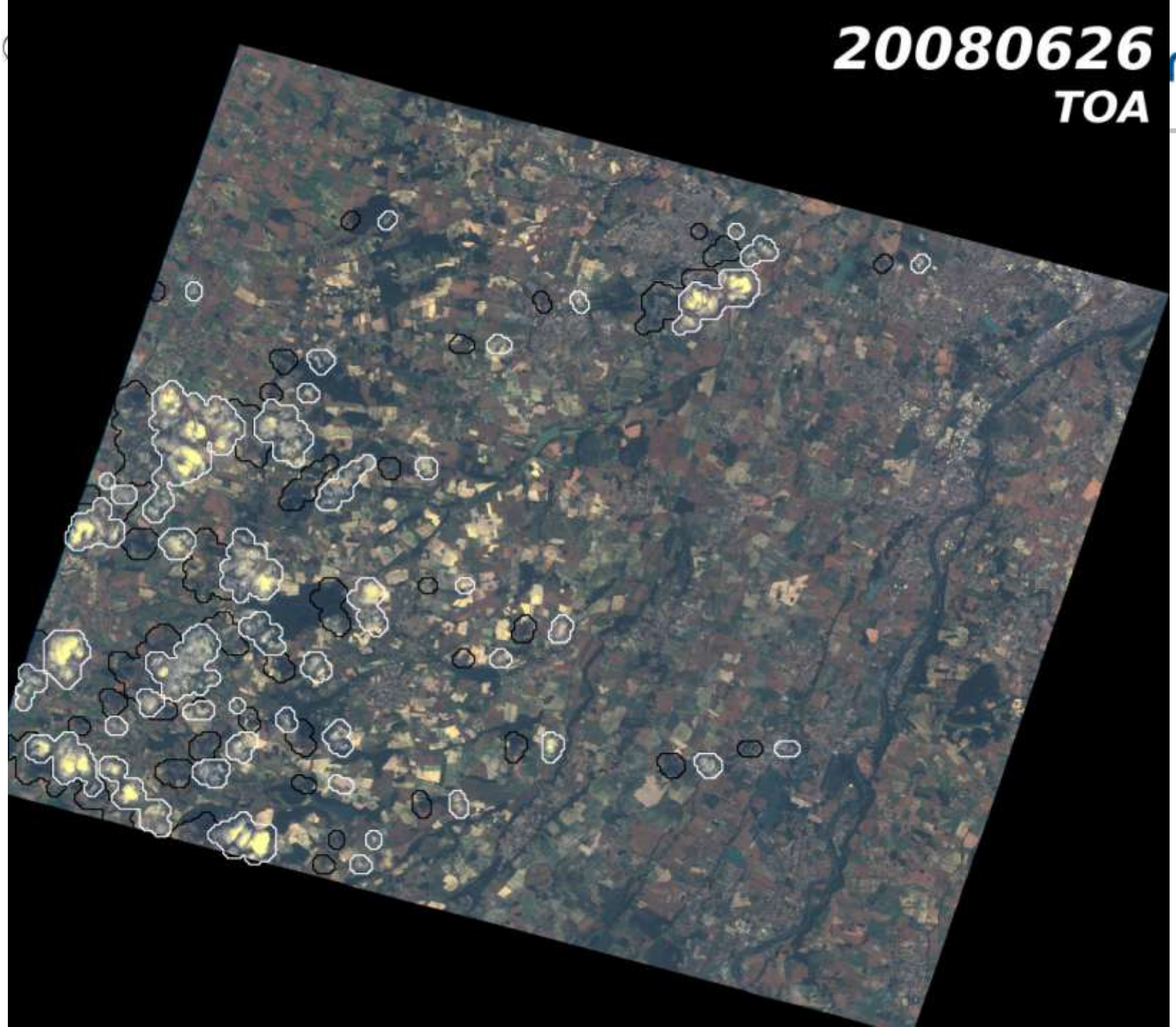
N days time composite of surface reflectances,

CLOUD SCREENING





Cloud screening use multispectral and multitemporal methods
See *Hagolle et al., RSE, 2010*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TOA

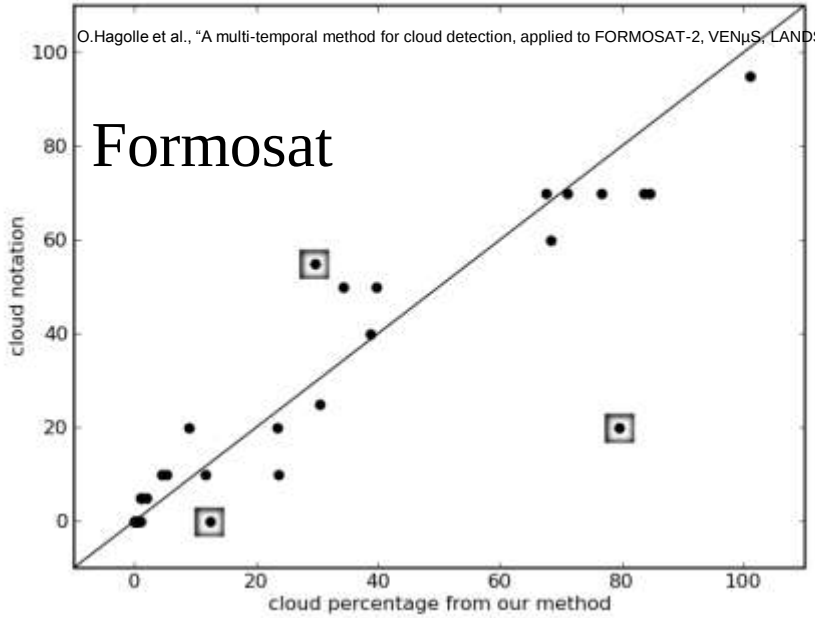
CLOUD MASK VALIDATION

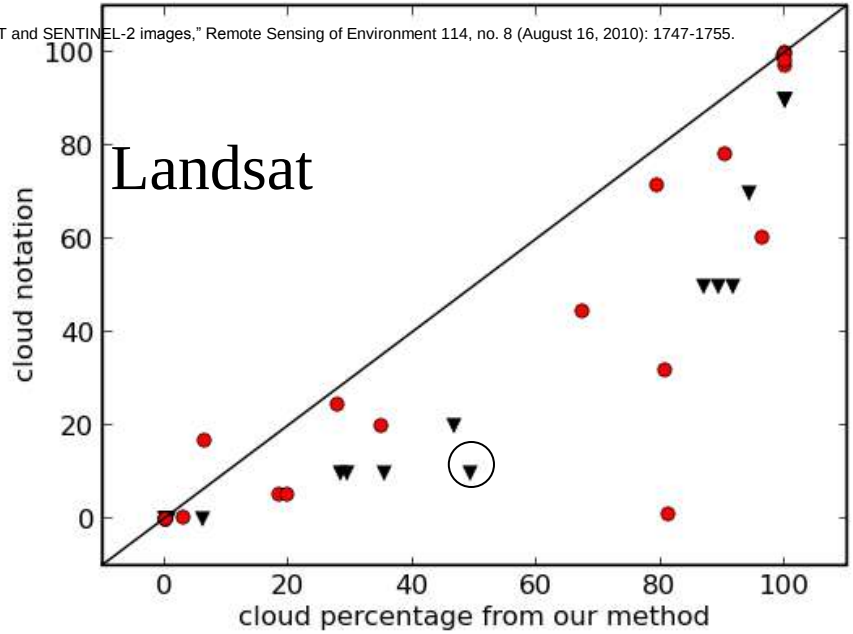
Comparison with Formosat and Landsat notation from catalog :

Formosat : visual notation by NSPO operators

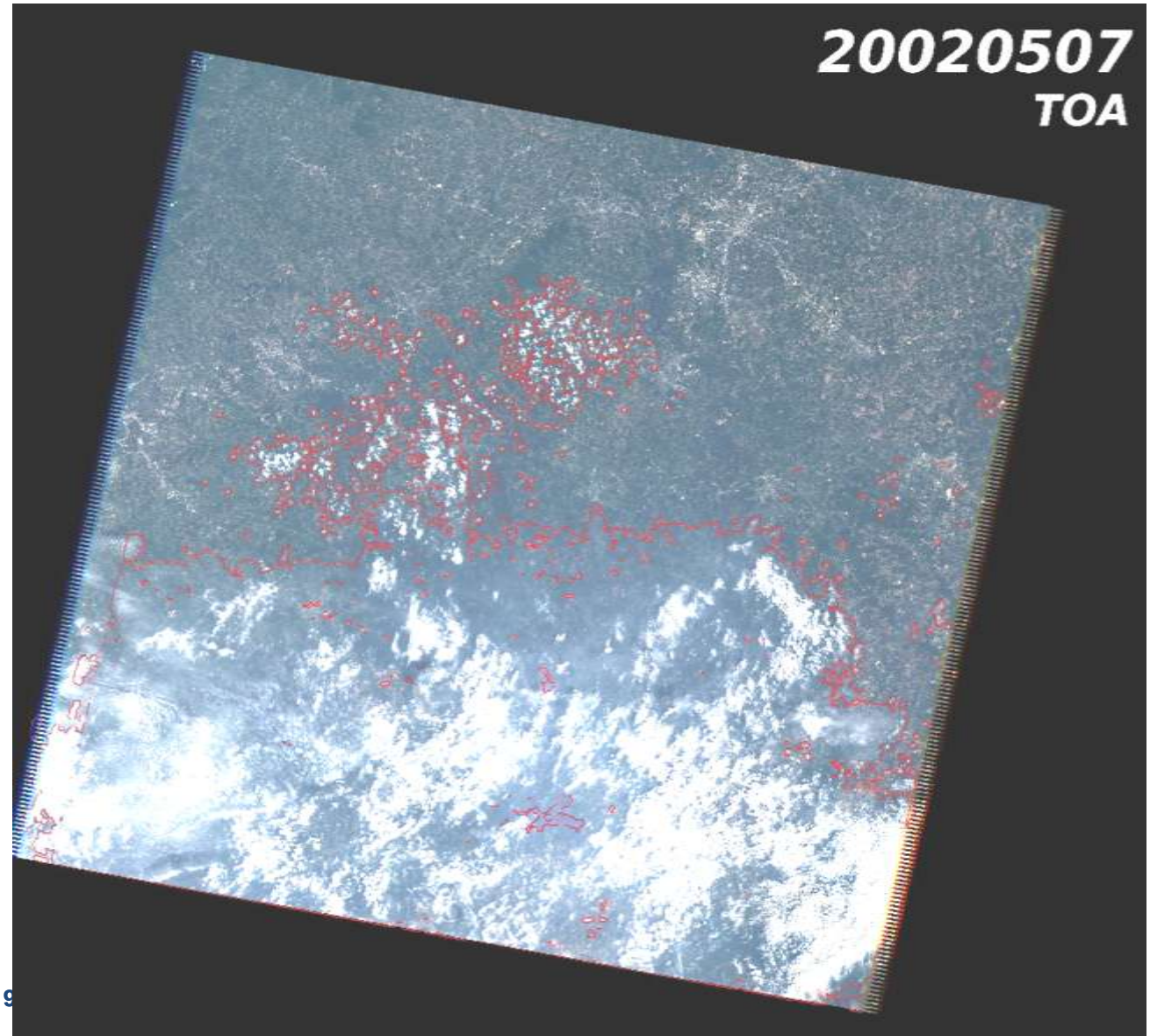
Landsat : automatic notation

O.Hagolle et al., “A multi-temporal method for cloud detection, applied to FORMOSAT-2, VENµS, LANDSAT and SENTINEL-2 images,” Remote Sensing of Environment 114, no. 8 (August 16, 2010): 1747-1755.





CLOUD MASK VALIDATION



LANDSAT

Automatic

Notation : 10%

MACCS: 49%

COMPARISON WITH LEDAPS

LEDAPS project (Masek, Vermote) distributes a software to produce Level 2A data

Performs cloud screening and atmospheric correction

Up to now, only cloud screening was compared

Method comparison

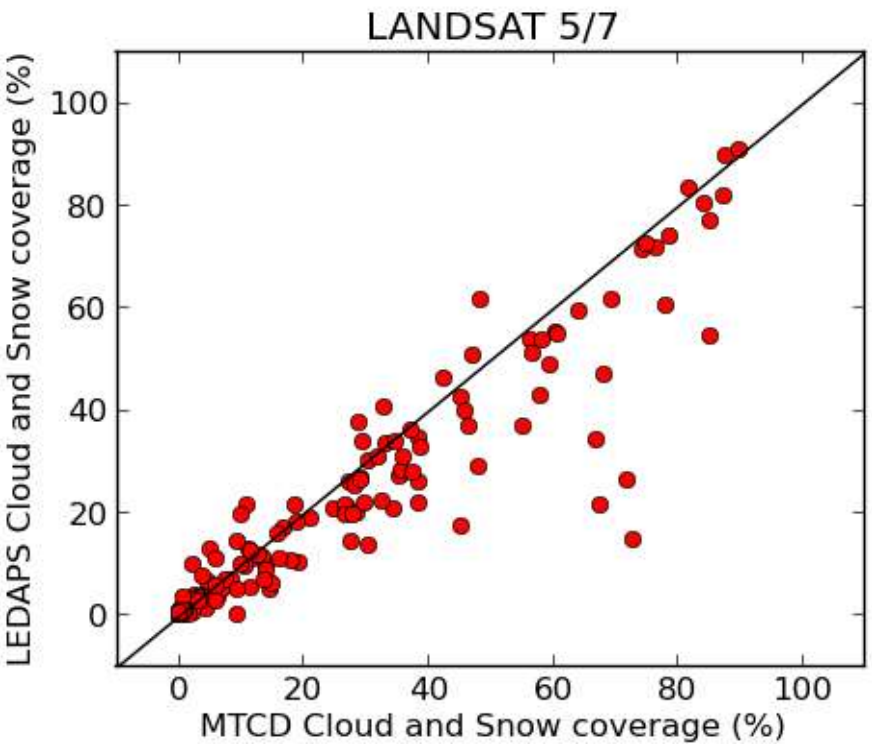
- LEDAPS uses many criteria
  - Brightness
  - Whiteness
  - Thermal Infrared (TIR)
- MACCS
  - does not use TIR
  - Cloud mask is dilated

Results

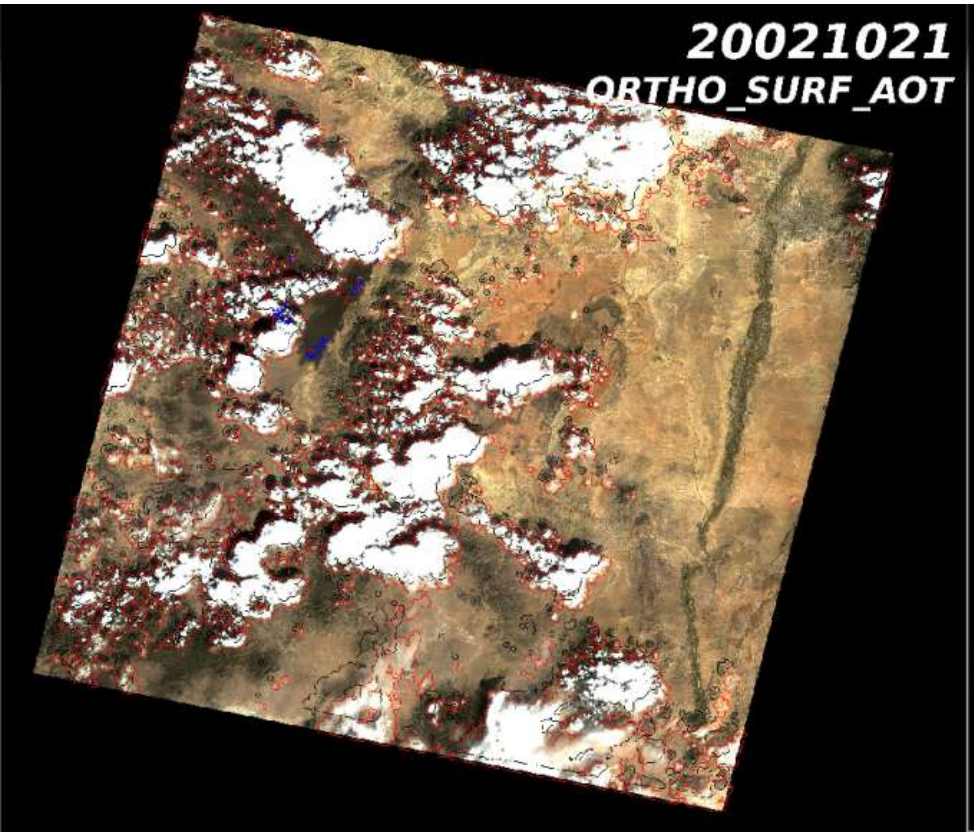
Very good agreement

Some discrepancies

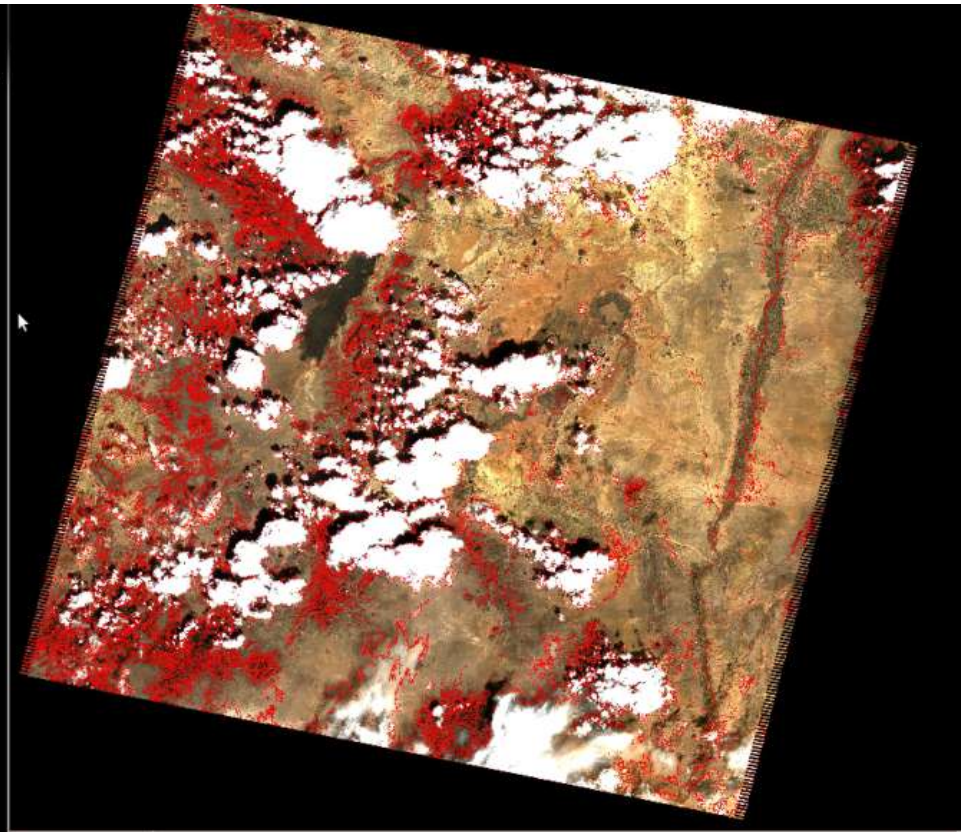
- LEDAPS has more false clouds
- LEDAPS misses some thin clouds
- MACCS dilatation increases cloud cover



CLOUD MASK VALIDATION



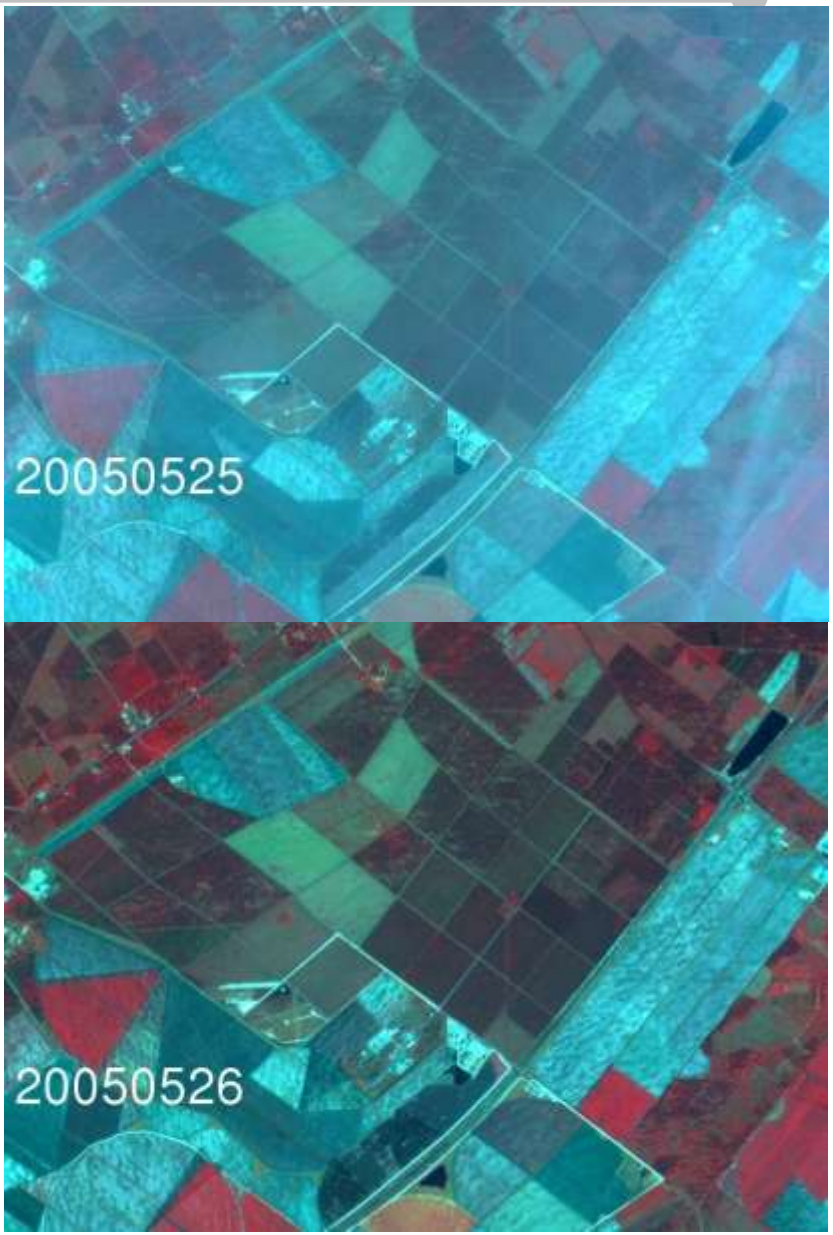
MACCS



LEDAPS

ATMOSPHERIC CORRECTIONS

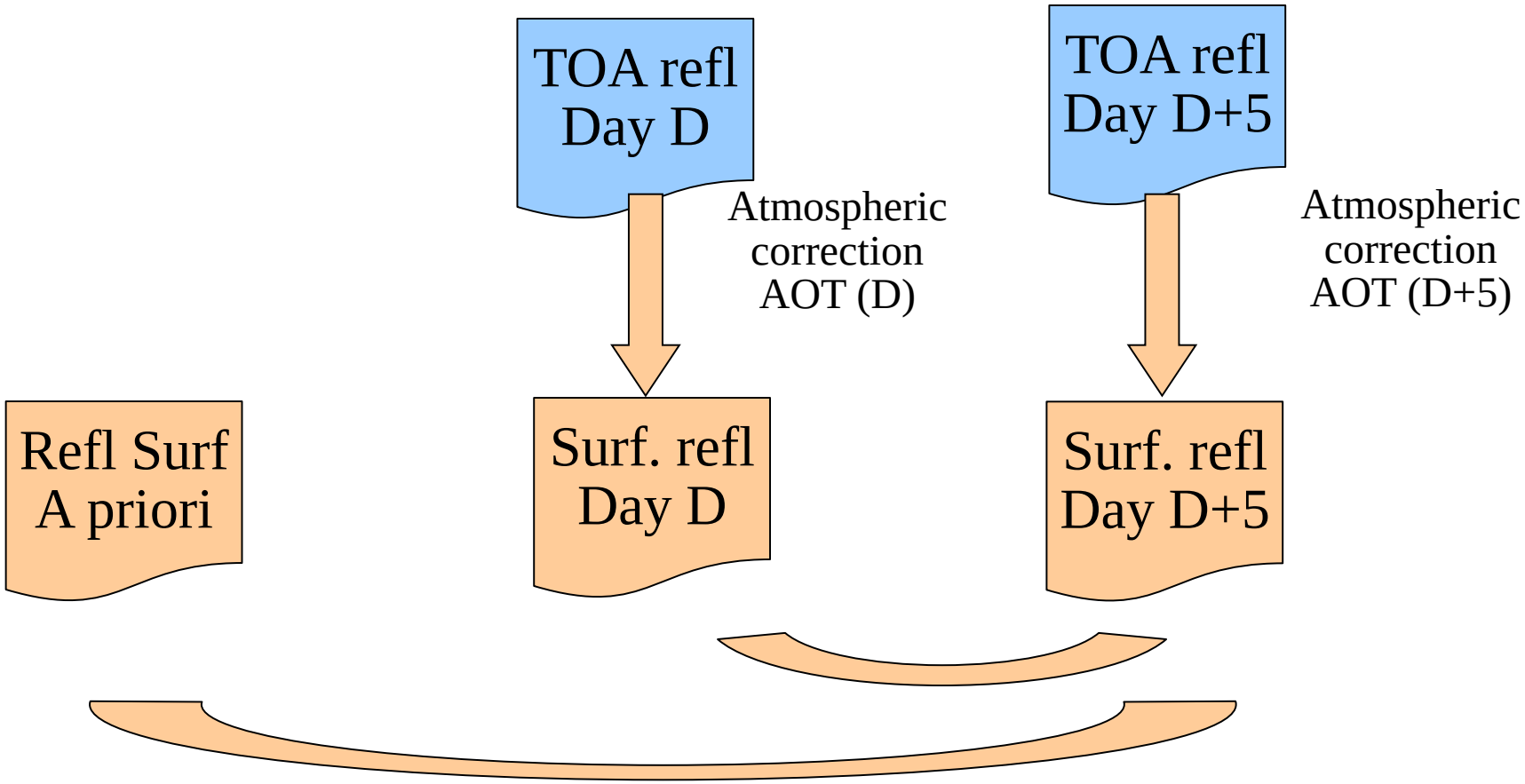
- Scattering correction
  - Performed using Look-Up Tables based on SOS radiative transfer code
  - AOT estimates combine 2 criteria
    - Multi-temporal criterion based on the relative stability of surface reflectance vs time
    - Multi spectral criterion (DDV method)
  - AOT estimates performed at 200m resolution
- Adjacency effect accounted
- Slope illumination correction



Details in *Hagolle et al, RSE, 2008*

Multi temporal Criterion to estimate AOT

- COST FUNCTION



The algorithm searches AOT(D) and AOT(D+5) that minimise differences between the 3 surface reflectances (a priori, D, D+5)

See (Hagolle et al, RSE, 2008)

Multi spectral criterion to estimate AOT

Inspired by the « Dark Dense vegetation » method

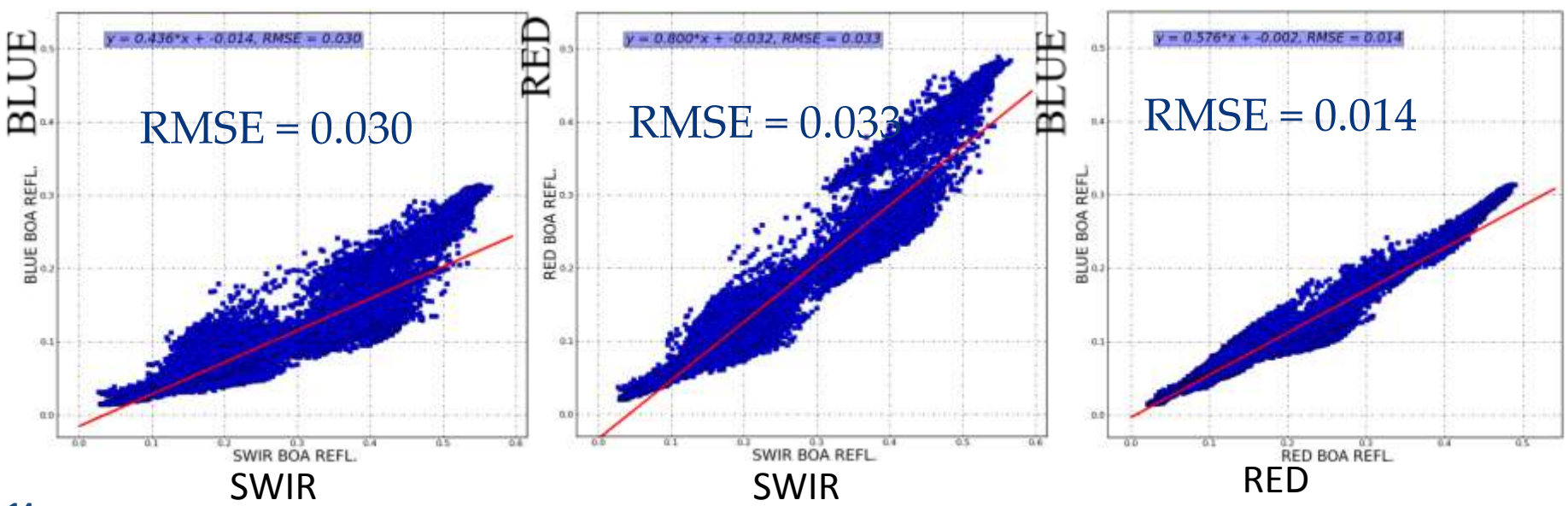
empirical relations between surface reflectances

first papers (Kaufman) used relations between blue, red and swir bands

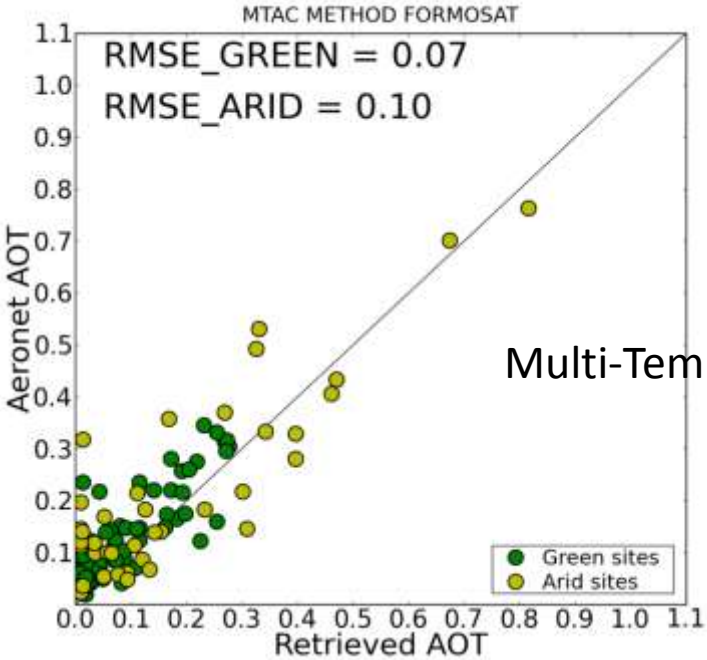
but a better agreement obtained with Blue and Red bands

- Roughly :

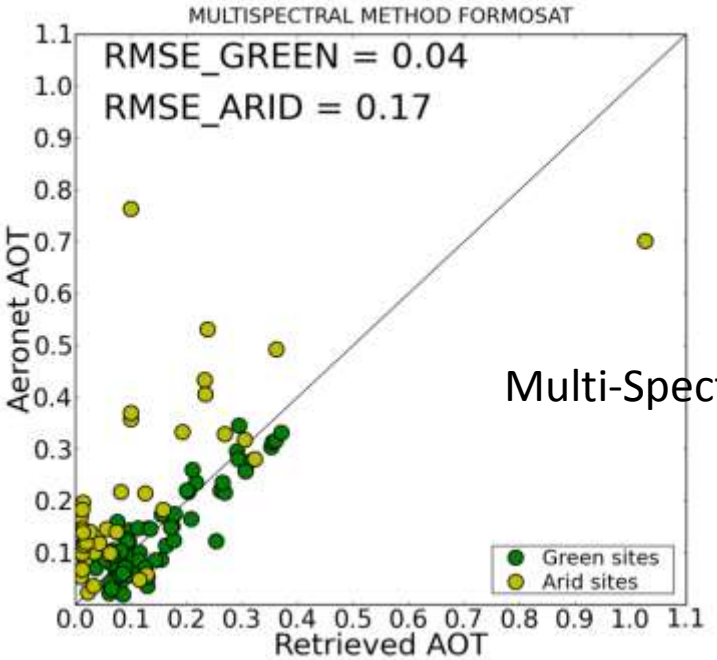
$$\rho_{surf}^{blue} = 0.5\rho_{surf}^{red}$$



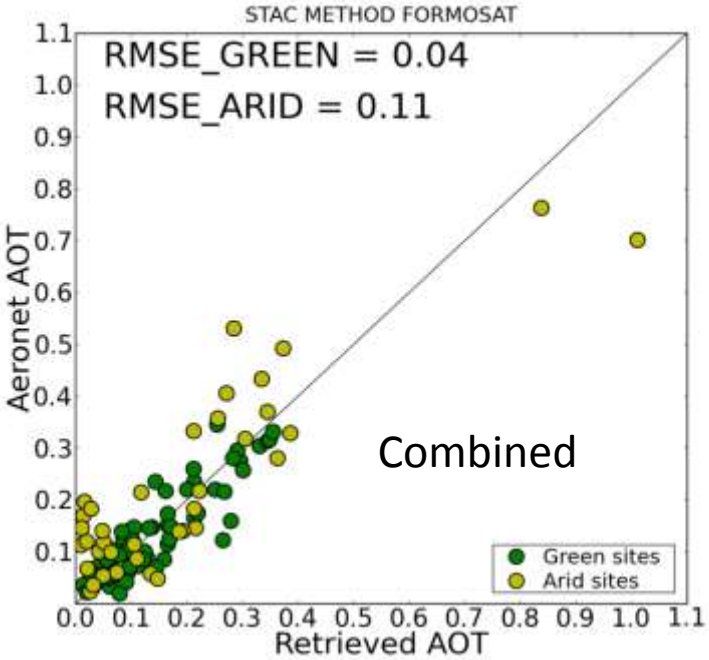
PERFORMANCES FOR FORMOSAT



Multi-Temporal

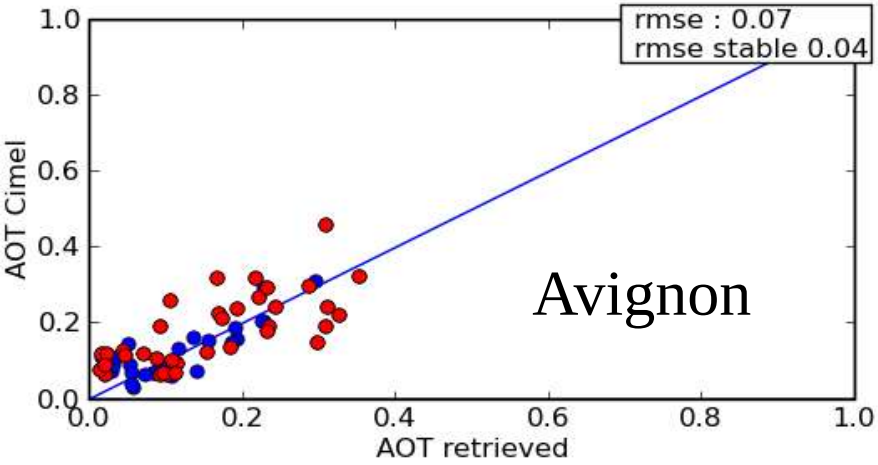


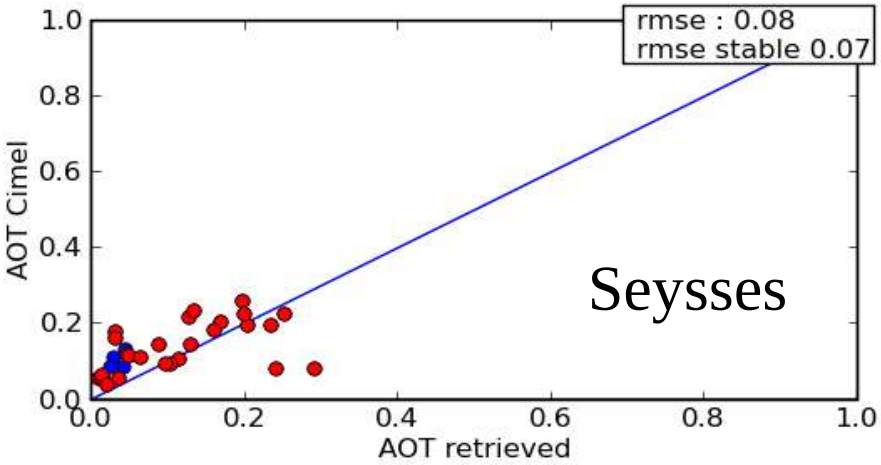
Multi-Spectral



Combined

AEROSOL DETECTION APPLIED TO LANDSAT



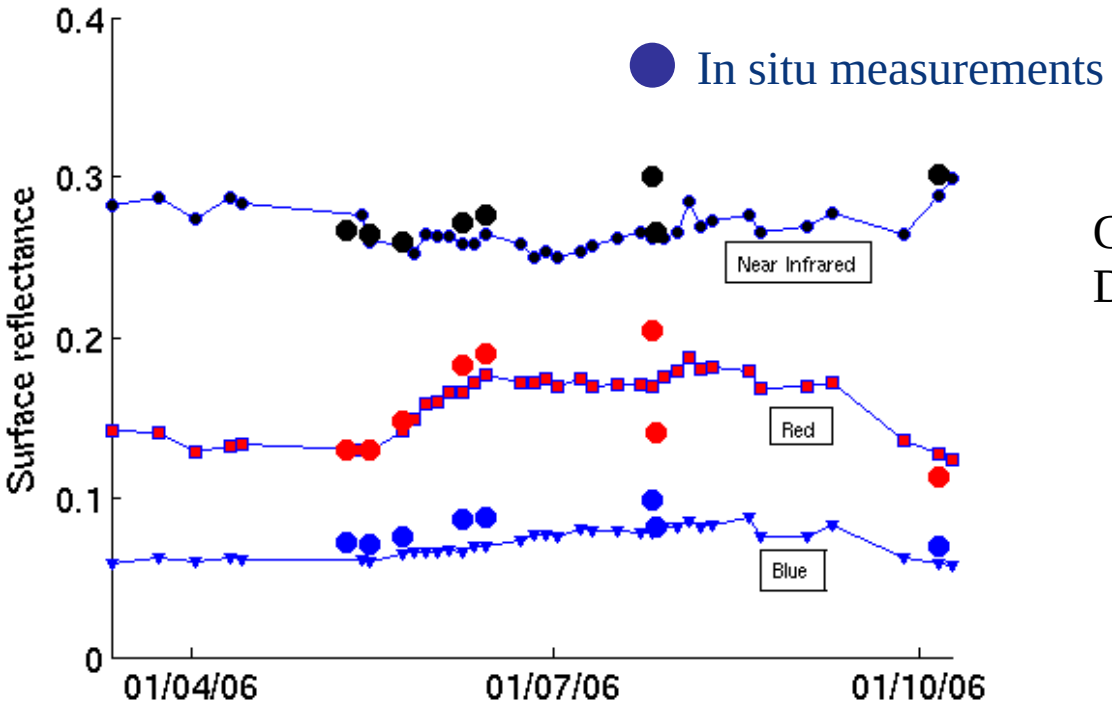


The method still works with a revisit frequency of 16 days.

Using CNES automated station for measuring surface reflectance

Instrument built by CIMEL

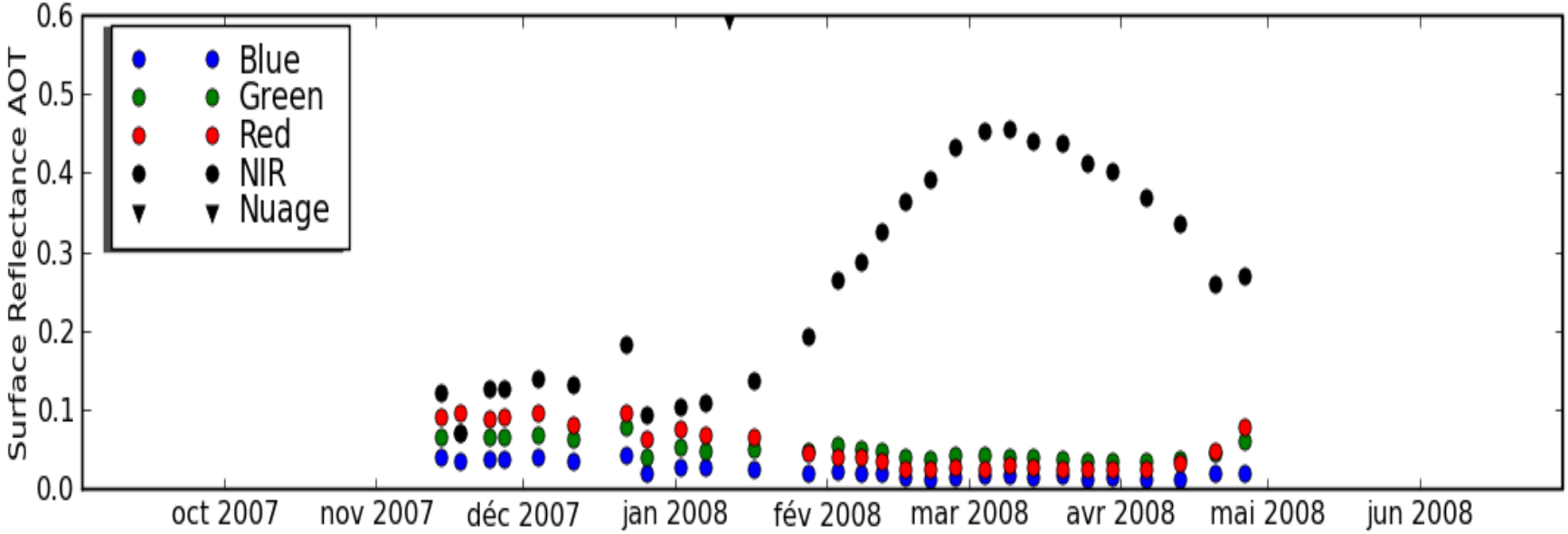
At La Crau, France



Circles : La crau station
Dots : Formosat 2

HIGH QUALITY TIME SERIES

Wheat field –Yaqui Mexico
3*3 pixels, 8m resolution



Level 3A : time compositing

Objective :

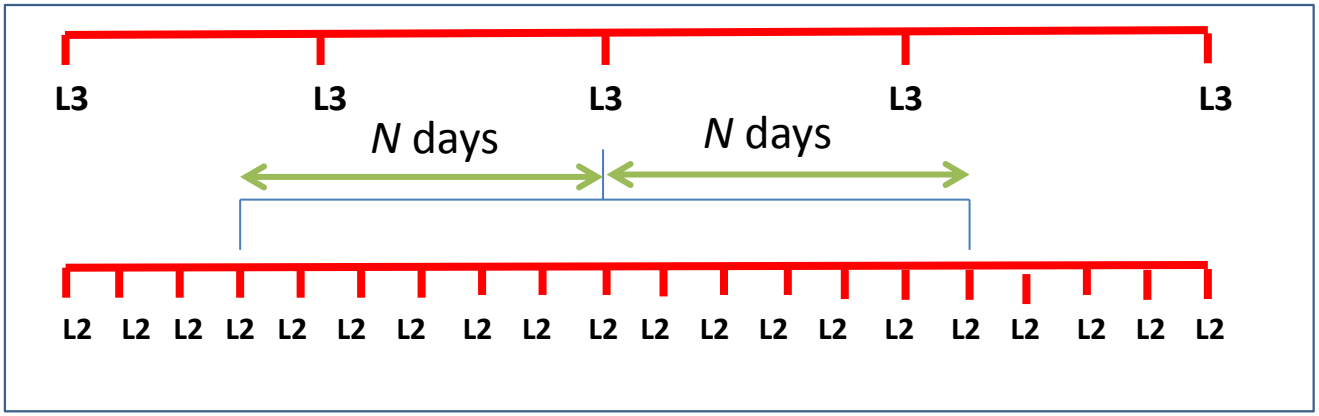
Produce one nearly cloud free image per month, from Level 2A data.

Utility :

- Data volume
- Regular time sampling
- Reduction of data gaps

Level 3A algorithm

Compute, for each pixel, **a weighted average** of the surface reflectance of the cloud free observations, obtained within a ***N* day distance** from the central date of the level 3A product.

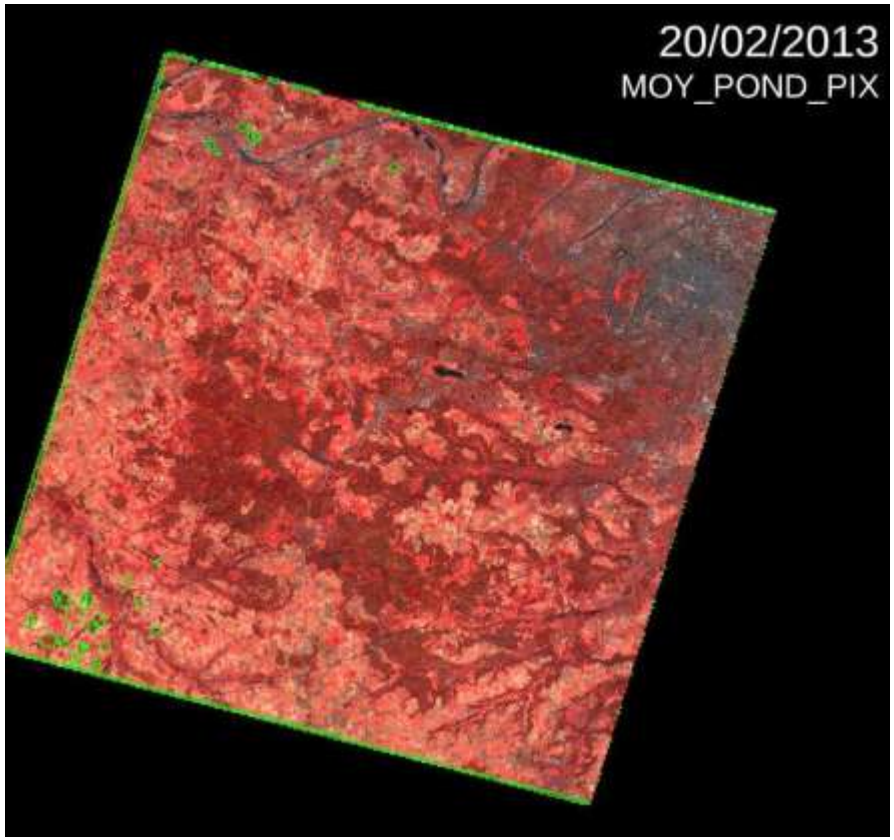


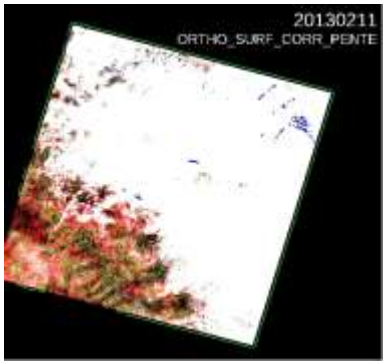
The weighted average gives more weight to :

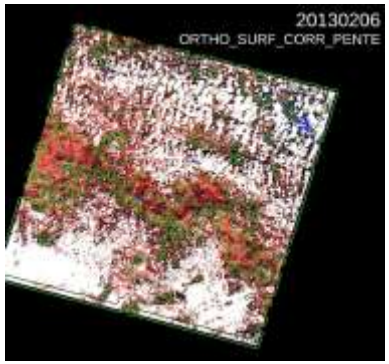
- cloud free images
- pixels far from clouds
- images with a low aerosol content
- images acquired near the level 3A product date

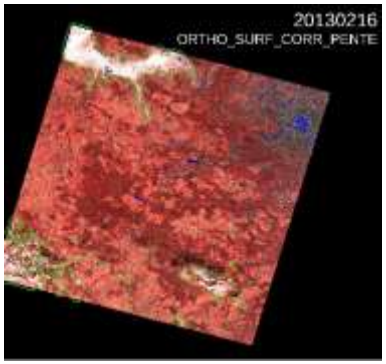
Level 3A results

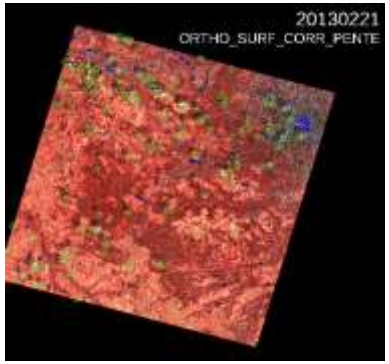
Level 3A products for 45 Take 5 sites around the world

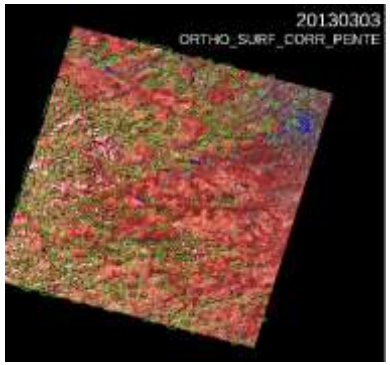








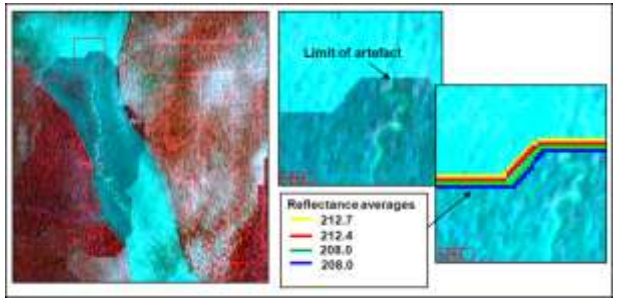


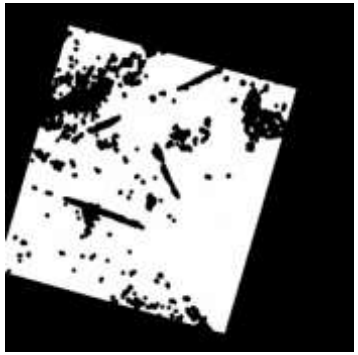


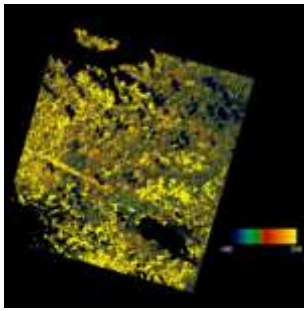
LEVEL 3A QUALITY

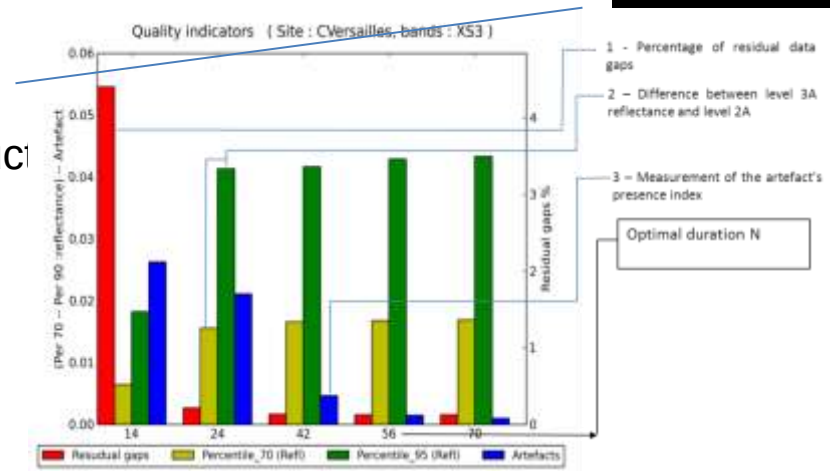
- Quality of level 3A products depends of the weight and the duration ***N***

- Three quality criterias :
  - Measurement of the artefacts presence index
  - Percentage of residual cloudy pixels
  - Difference between level 3A reflectance and level 2A product acquired near the central date
  - Results : histograms









PROTOTYPE PRODUCTION

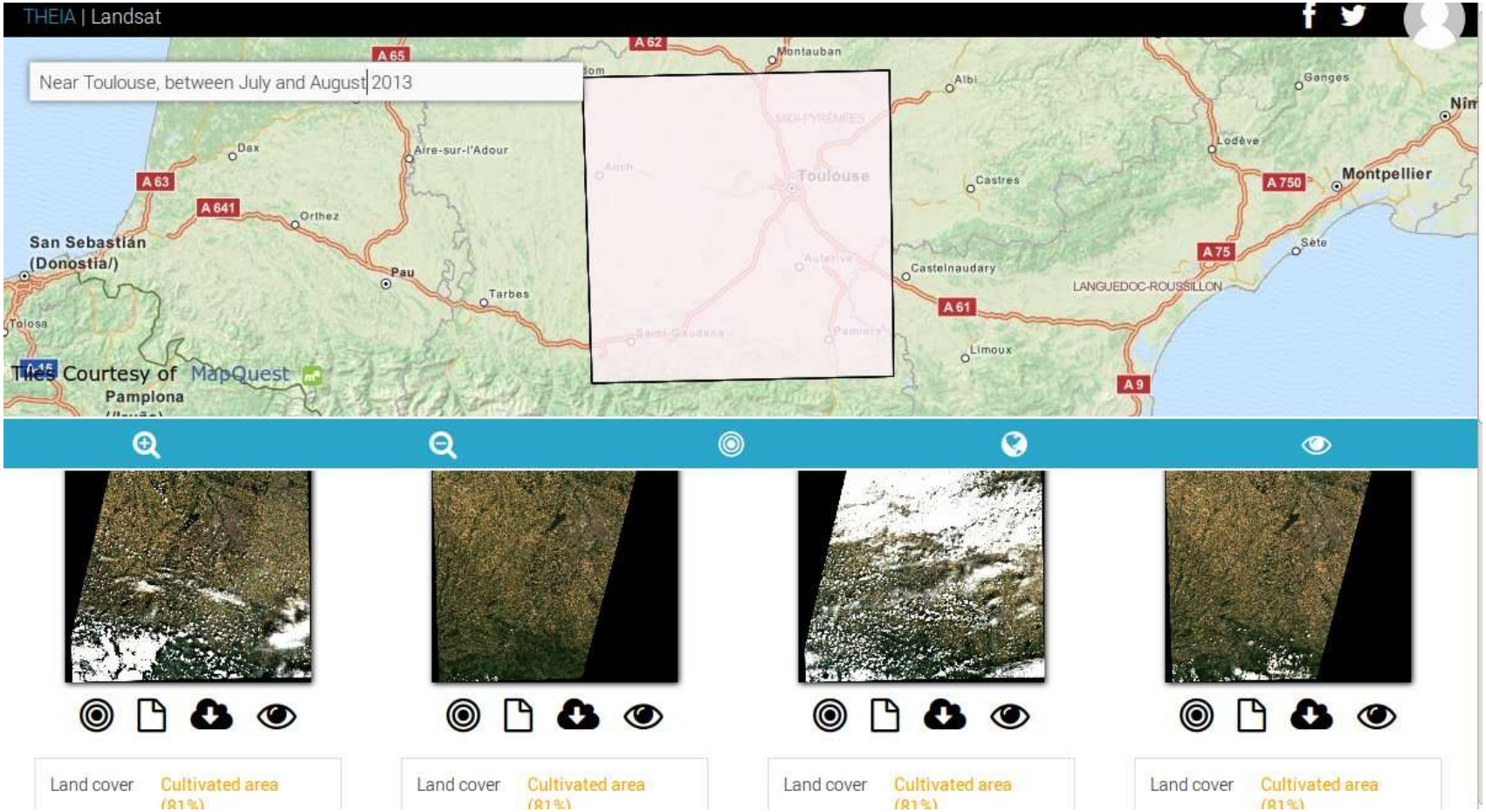
Prototype production so far

- Spot Take 5
  - L1C, L2A, L3A, 45 sites, 4 months, 3000 images
  - processing took one week
- Landsat 8
  - L2A, France, April – Decembre 2013, 900 images
  - processing took 3 days
- Data available on www.theia-land.fr (except L3A Spot Take 5, which will be available soon there)

Prototype production to come

- Landsat 8, Landsat 5-7, Spot World Heritage

LANDSAT-8
LEVEL 2A AVAILABILITY



OPERATIONAL MUSCATE

An operational version of MUSCATE is under way

MUSCATE is built as a flexible and adjustable center to facilitate integration of new treatments.

Timeline

- Call for Tender : January 2014
- Company selection : March 2014
- Kick-off : 14 May 2014
- End of development (target) : 15 November 2015

PRODUCTION REQUIREMENTS

Sentinel-2 :

- Surface area : that of Europe (6 M km2)
- Exact areas processed still TBD
- Timeliness for Level 2A products
  - <= 2,5 calendar days for 90% of products
- Reprocessing
  - 5 months of data reprocessed in one month

Landsat 8 :

- Surface area : France & ROM-COM
- Delivery every day of Level-2 product from Level 1C :
- Reprocessing
  - 5 months of data reprocessed in one month

Also, Landsat 5 & 7 and Spot World Heritage capabilities

Distribution on www.theia-land.fr

FUTURE DEVELOPMENTS

- It is likely that Copernicus Core Services will include some day the production of Level 2A and Level 3 for S2 **globally** .

- CNES, in the framework of THEIA, would like to participate to this venture with others in Europe

- CNES – DLR meeting (Oberpfaffenhofen, July 2014)
  - decision to intercompare MACCS and ATCOR
  - willingness to develop a joint algorithm able to produce consensus in Europe