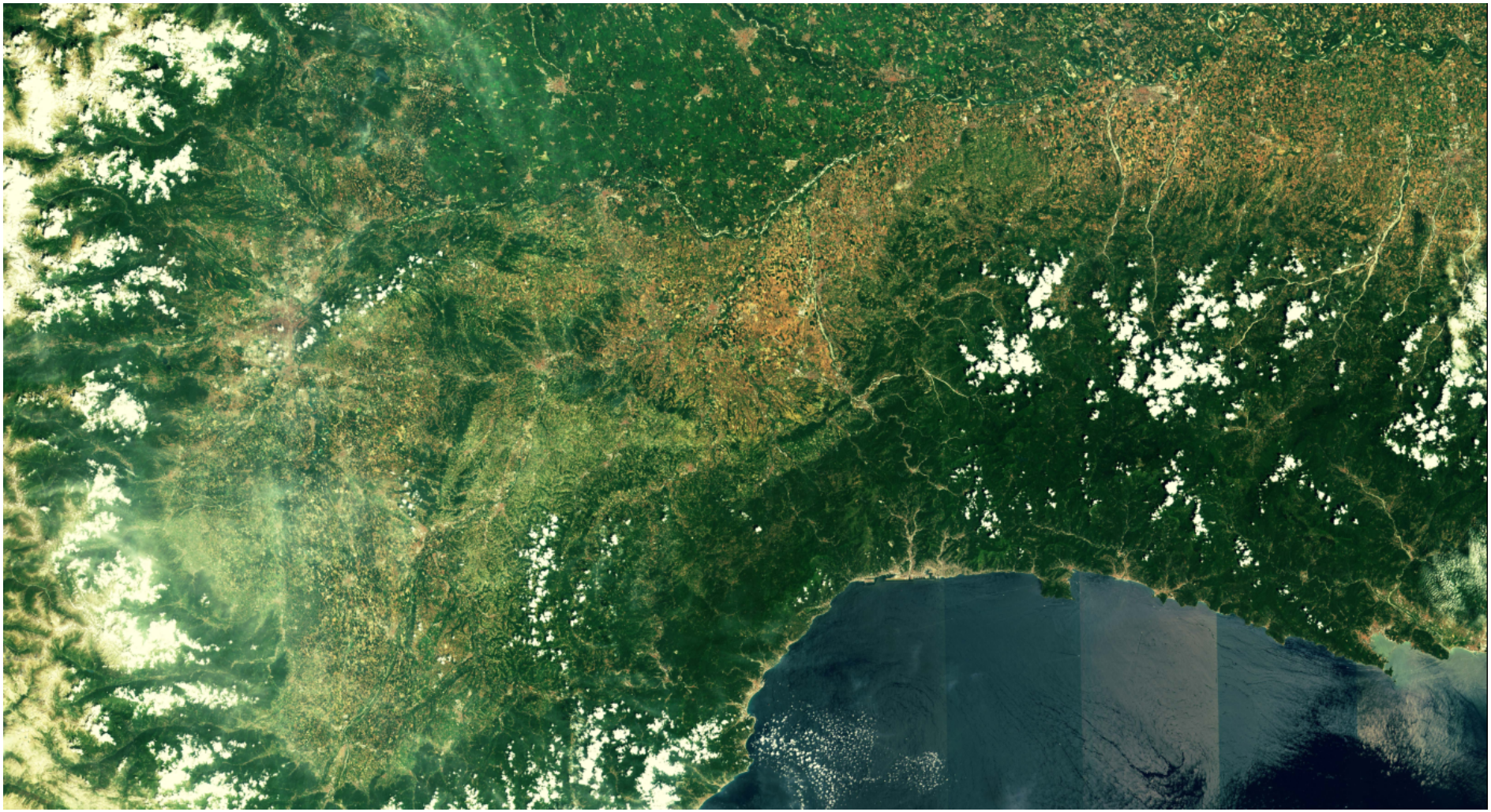
# Simulation of Sentinel-2 time series with SPOT (Take5) experiments

O.Hagolle, G. Dedieu, J.Inglada (CESBIO/CNES), M. Huc (CESBIO/CNRS),
S. Sylvander (CNES), B. Hoersch, B. Koetz, O. Arino (ESA)

Multitemp, Annecy, July 2015

# First Sentinel-2A image



# Sentinel-2 : a revolution for vegetation monitoring by satellite

## Main Sentinel-2 image features

- High resolution :10m-20m
- Large coverage : all lands, 290 km swath
- Frequent revisit with constant view angles: 5 days with 2 satellites
- 13 spectral bands including SWIR

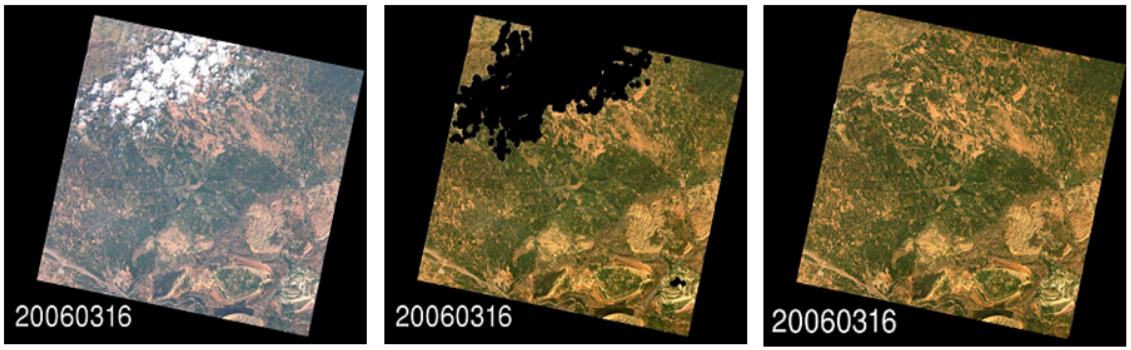
## Other revolutionary aspects

- Mission duration : 15 years (with follow-on satellites)
- Systematic acquisitions with high repetitivity
  - The user can rely on data availability once a month
  - => operational use (ex : Annual Land Cover)
- Free and open data
- Constant viewing angles :=> minimized directional effects
  - high quality time series

cnes CESBIO esa

# "Ready to use" Products

- Level 1C product :
  - Ortho-rectified images in TOA reflectance
- Level 2A Product :
  - As Level 1C, but surface reflectance
  - Cloud and Cloud shadows mask
  - Snow and Water masks
- Level 3A Product :
  - Synthesis of surface reflectance of cloudfree pixels over 1 month
- ESA will produce Level 1C, provide a toolbox for L2A
- An operational production of L2A is being discussed




Level 1C: Level 2A: Level 3A:

# Sentinel-2 : A revolution for methods

## Time

- SPOT, RapidEye : 1 to 4 images per year
- Sentinel-2 : 1 to 2 images per month

## Surface

- SPOT, R-E : 60*60 km. Landscape and climate are homogeneous
- Sentinel-2 : 300*300 $km^2$: Landscape and climate are heterogeneous

## Clouds

- SPOT, R-E : use only almost cloud free images and detect clouds manually
- Sentinel-2 : all images are cloudy

## Use

- SPOT, R-E : Very supervised processing of an image, once in a while
- Sentinel-2: Automatic processing of large regions

# Need for Sentinel-2 simulated data sets

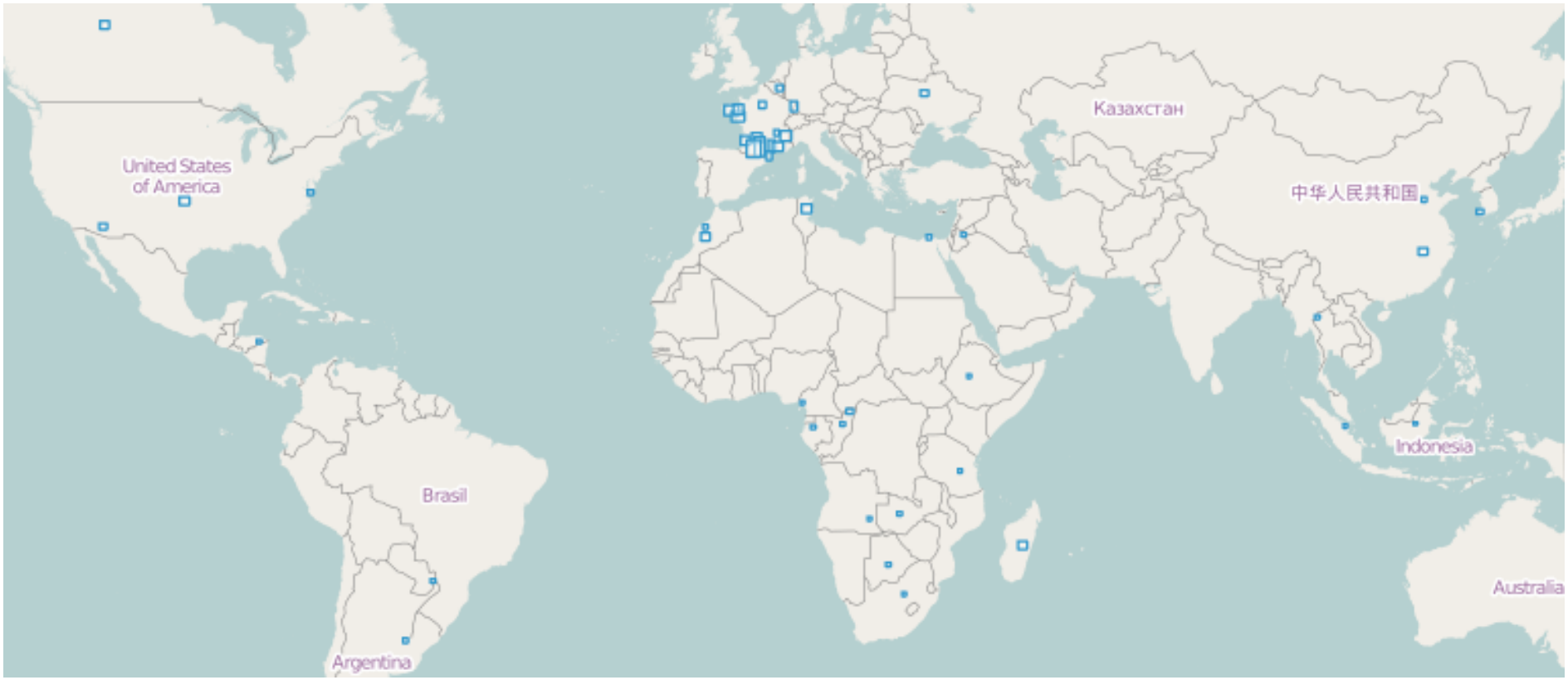
## Available simulation data sets in 2012

- Aerial acquisitions
  - High resolution, all S-2 spectral bands but no revisit and small coverage
- Other satellites
  - Formosat-2 : revisit and resolution
  - Landsat 5,7,8 : coverage and spectral bands
  - SPOT, R-E, DMC, resolution coverage and revisit but with changing angles

## SPOT (Take5) experiments

- Idea : change SPOT (4,5) orbit to simulate Sentinel-2 time series
- SPOT4 : February to June 2013, 45 sites, funded by CNES
- SPOT5 : April to August 2015, 150 sites, co-funded by ESA and CNES
- Features:
  - revisit : every 5 days, 28 acquisitions/site in 5 months
  - resolution : 20m
  - coverage : large sites 60*60 km², 120*120, 300*200
  - spectral : Only 4 bands, but with a SWIR band

# SPOT (Take5) sites, SPOT4 : 45, SPOT5, 150



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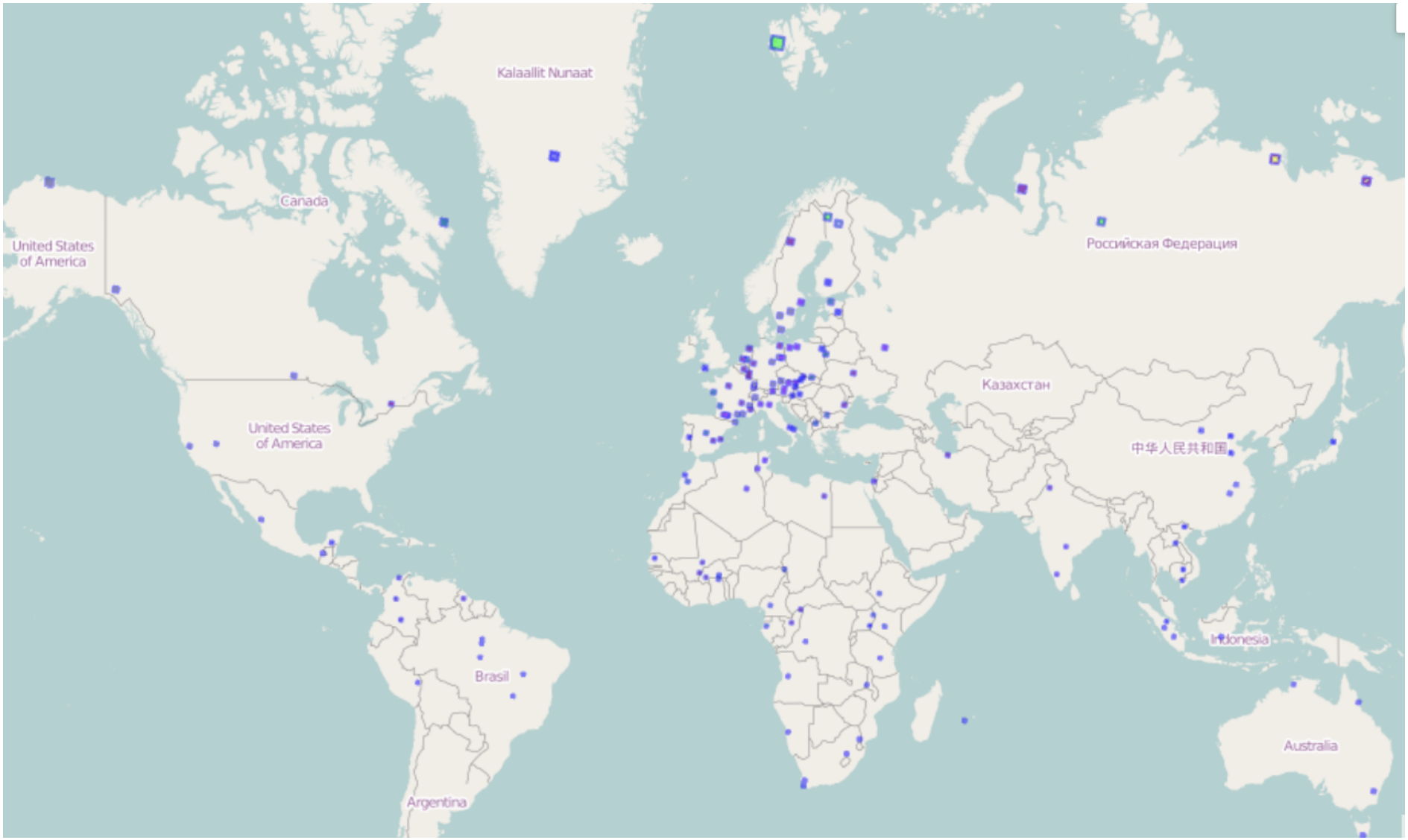
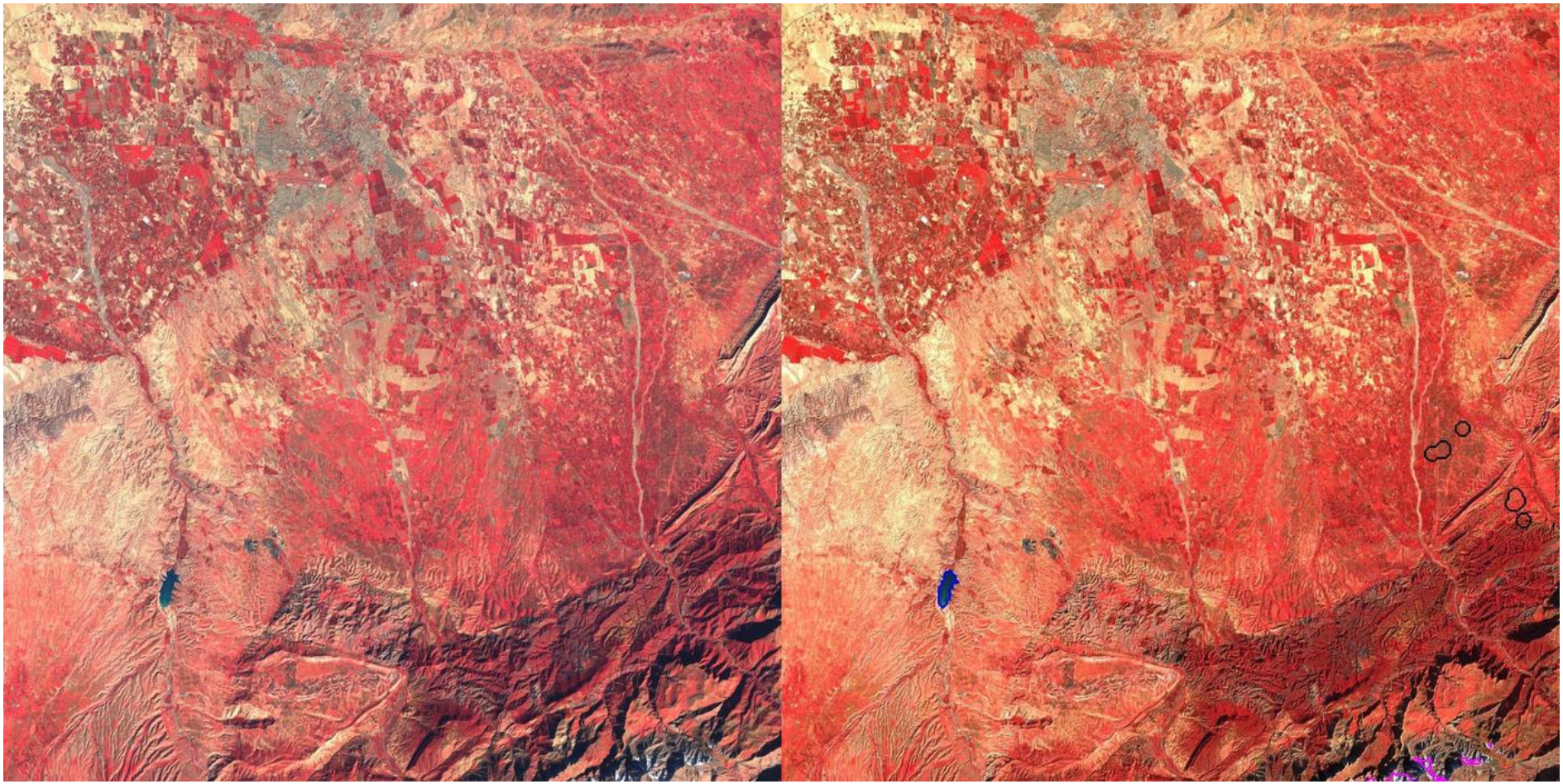


# Simulated Sentinel-2 time series from Take5 data

- Example over Morocco, February and March



TOA Reflectance (L1C) => Surface Reflectance (L2A)

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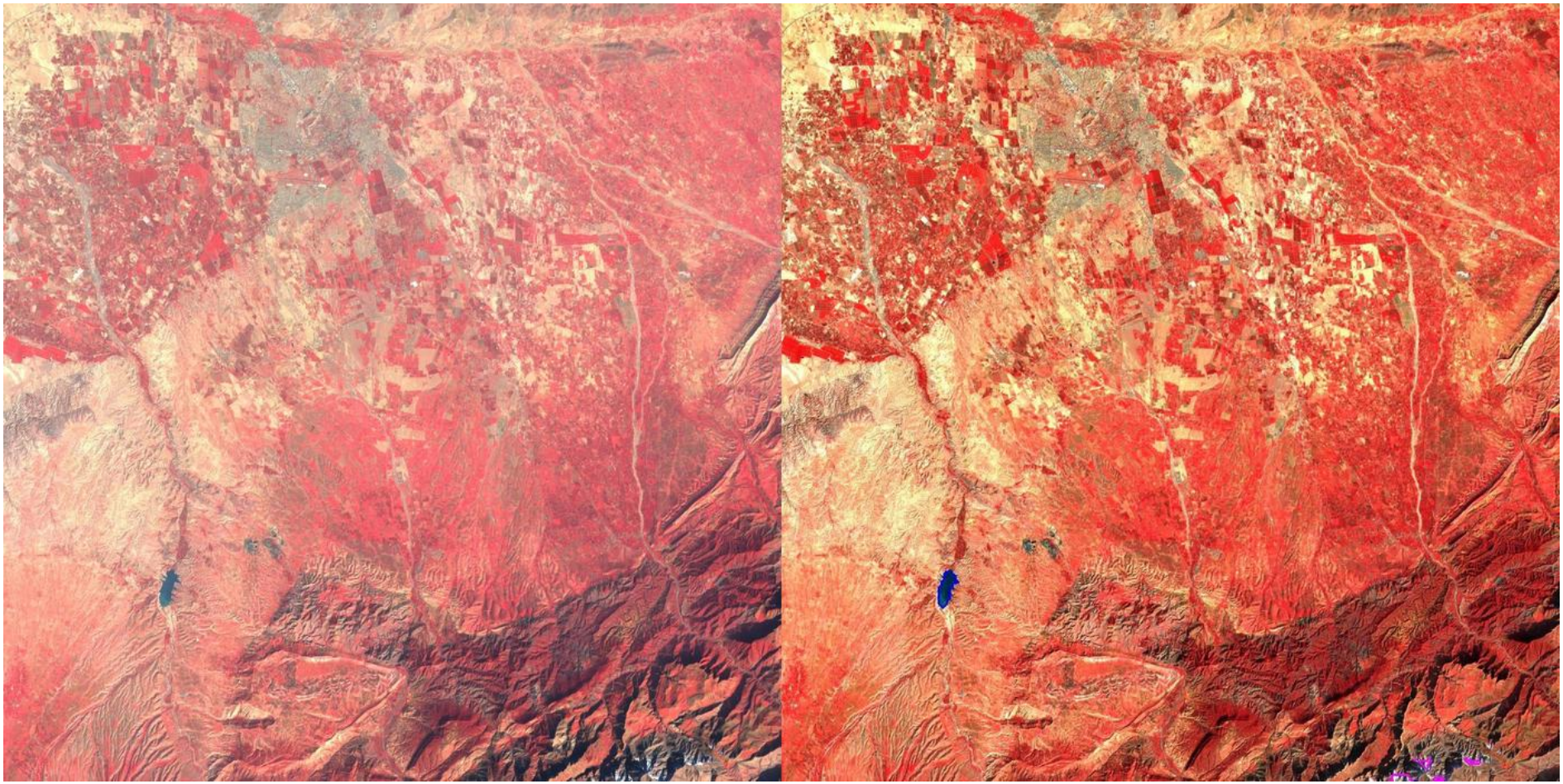

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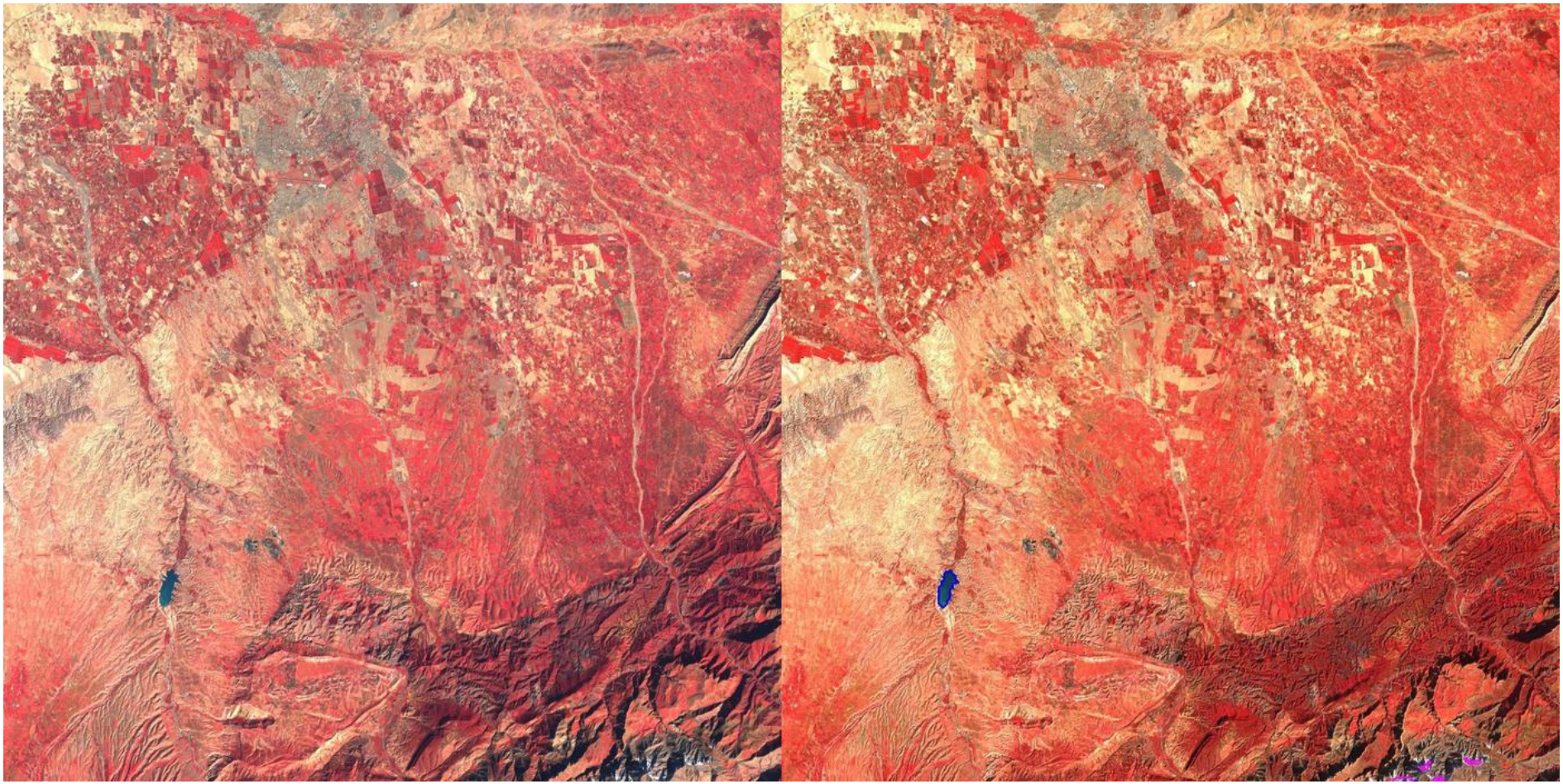

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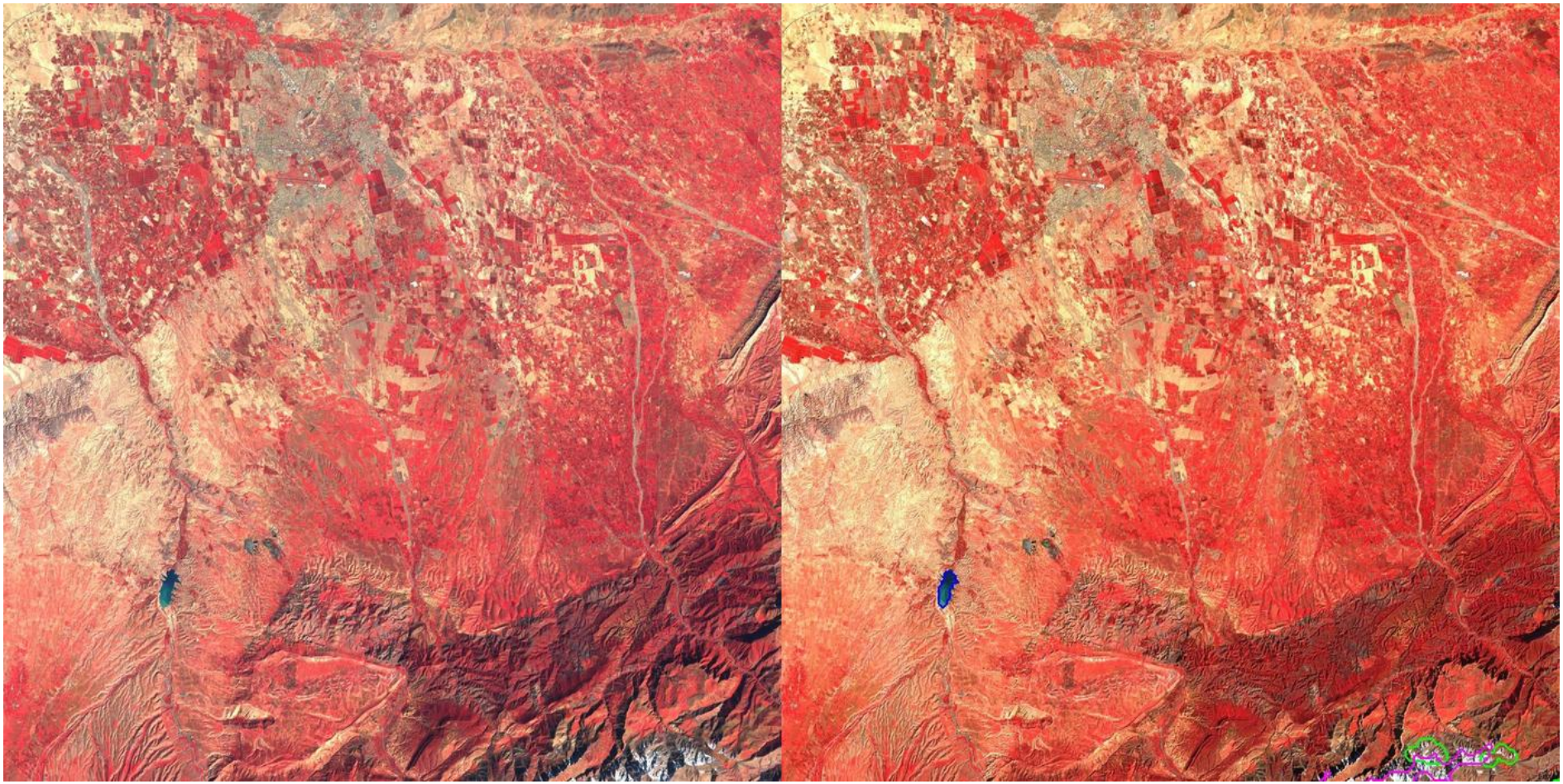

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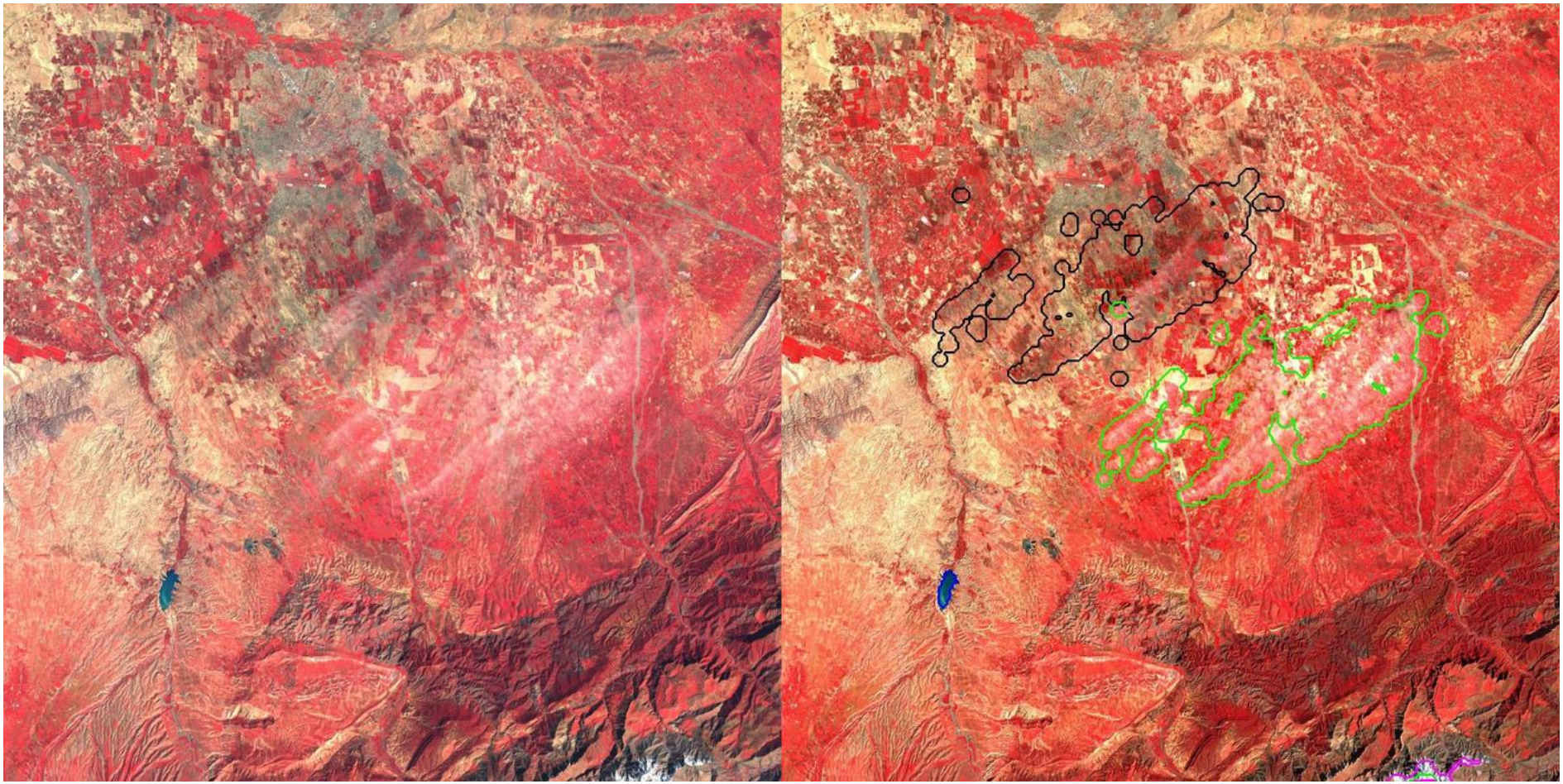

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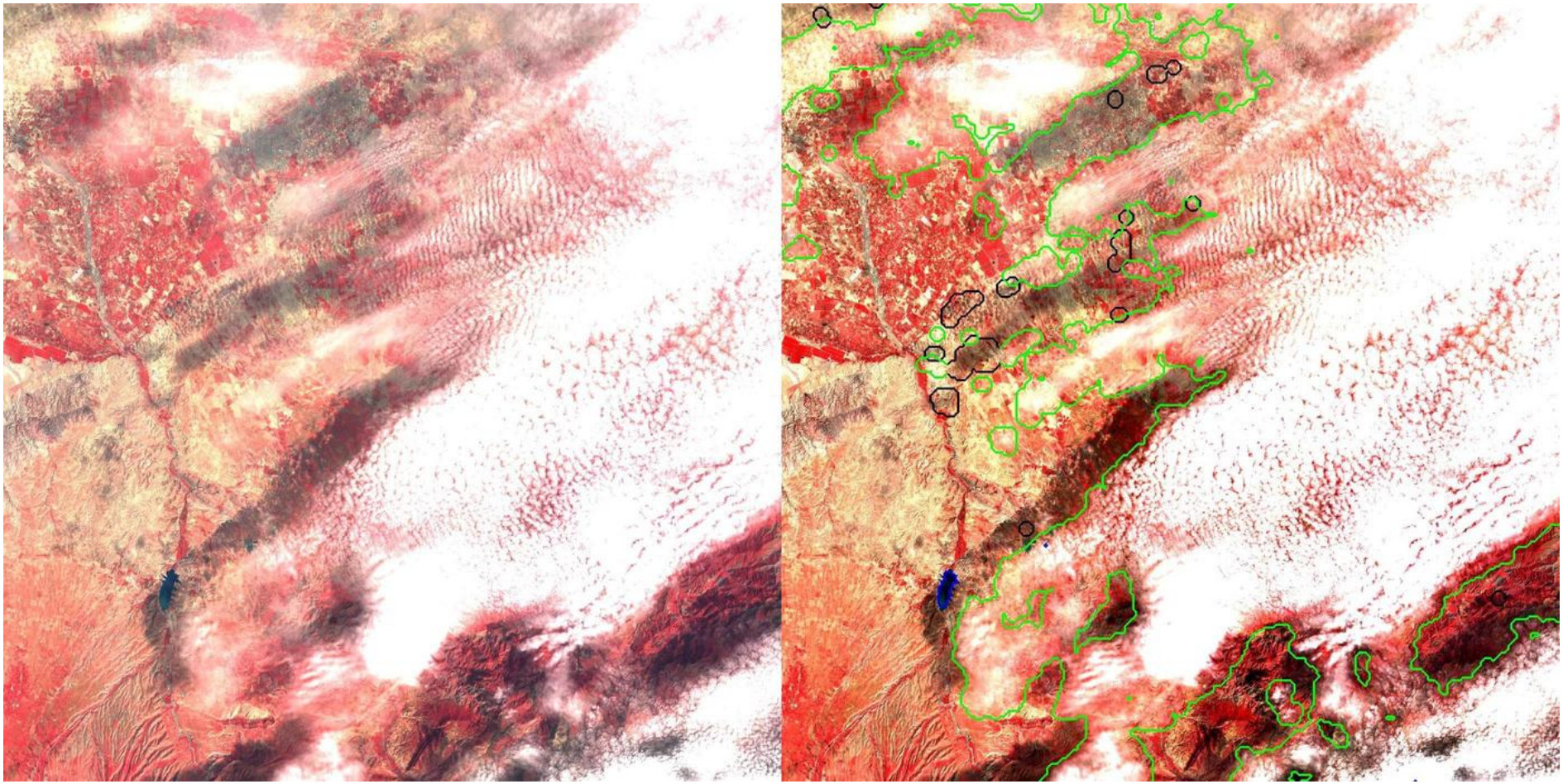

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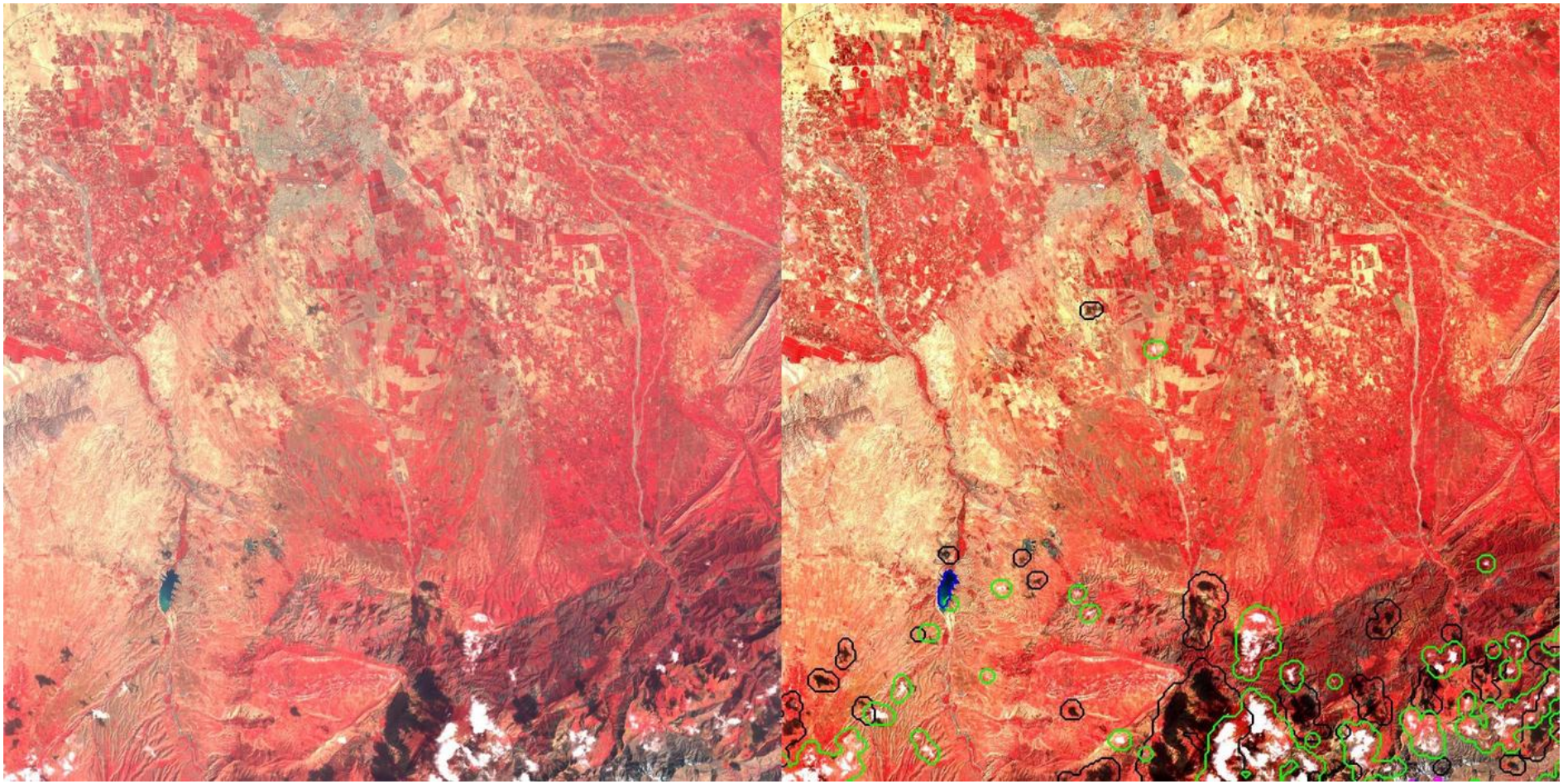

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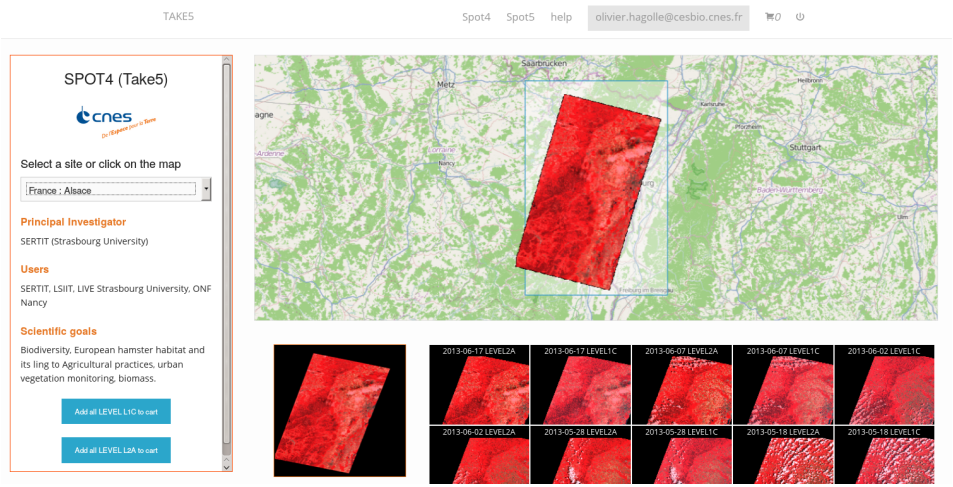
# Processing and Data Access

## Data Production

- L1C and L2A Images are produced at the French Land Data Center THEIA
- L2A are produced with MACCS method developped at CESBIO
  - MACCS : Multisensor Atmospheric Correction and Cloud Screening
  - Applicable to Formosat-2, Take5, LANDSAT (5,7,8), Venµs and Sentinel-
- MACCS operational version (CNES) now implemented at THEIA

## Free Data download

- from THEIA web site : https://spot-take5.org/



# MACCS S2 Cloud Mask method

## Clouds are bright

- Threshold on blue reflectance (rather high)
- Confusion with brights surfaces, bare soils, buildings

## Clouds are high

- Threshold on 1.38 µm spectral band (LANDSAT 8, Sentinel-2A)
- Confusions with mountains for low clouds

## Clouds move : multi-temporal method

- Threshold on variation between successive images in the blue
- Cloud must be whiter than previous cloud free image
- Correlation with previous images

## Clouds are not snow

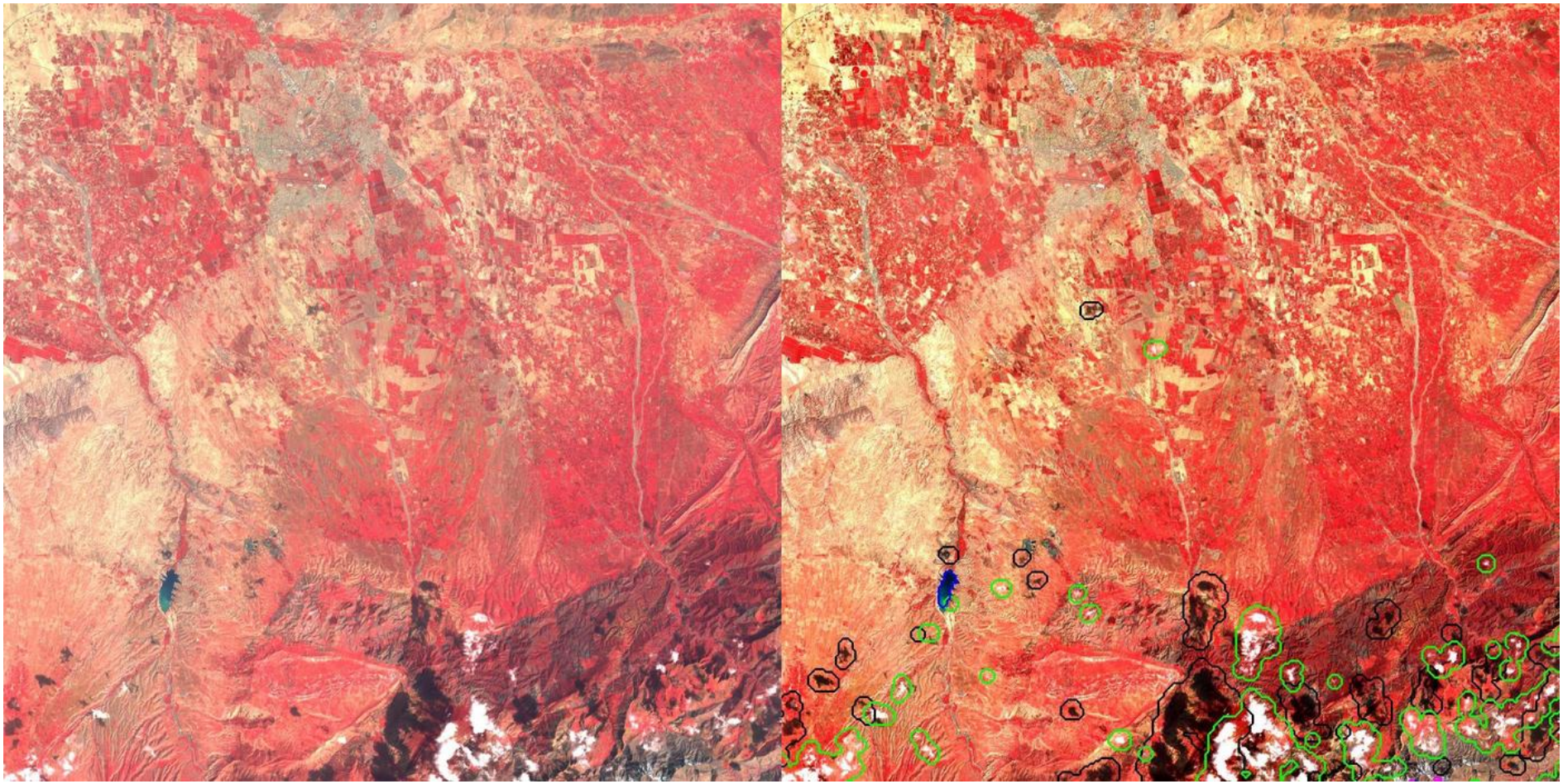
- Threshold on snow index ( green-SWIR bands) and on red band

## Clouds have fuzzy edges

- Dilation of Cloud Mask

# Level2A : surface reflectances + cloud mask

- Multi-temporal detection of clouds



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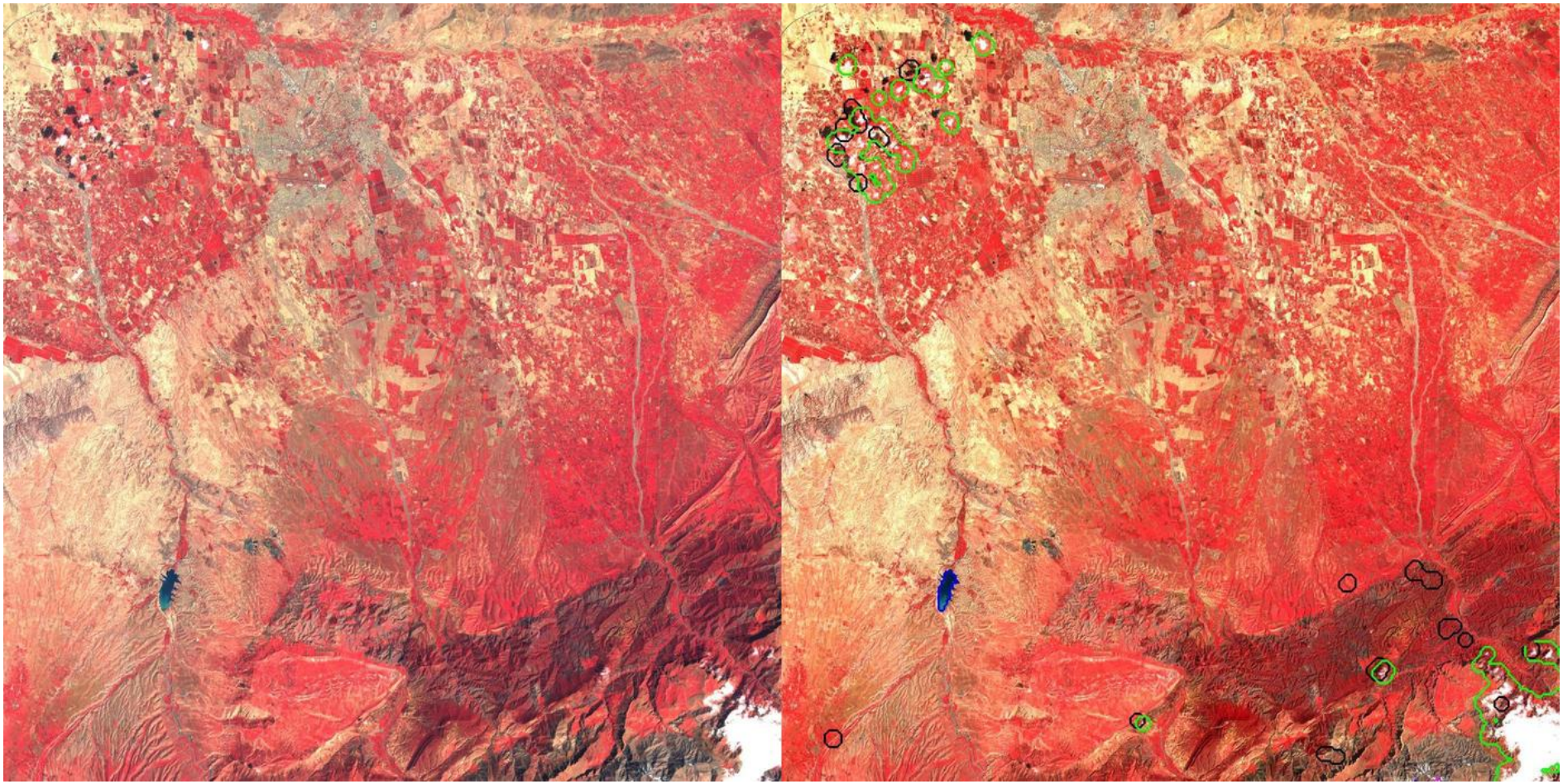

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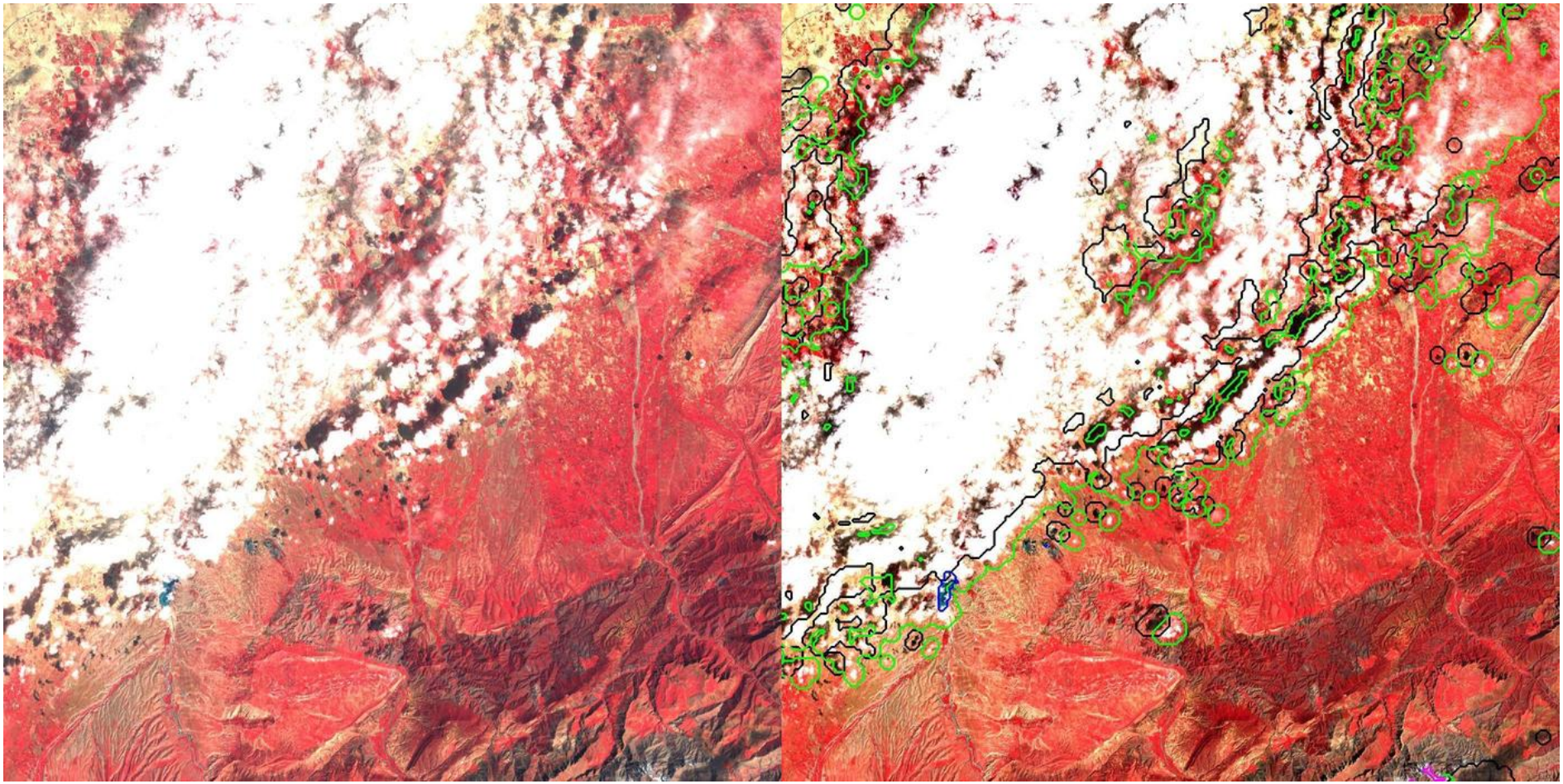

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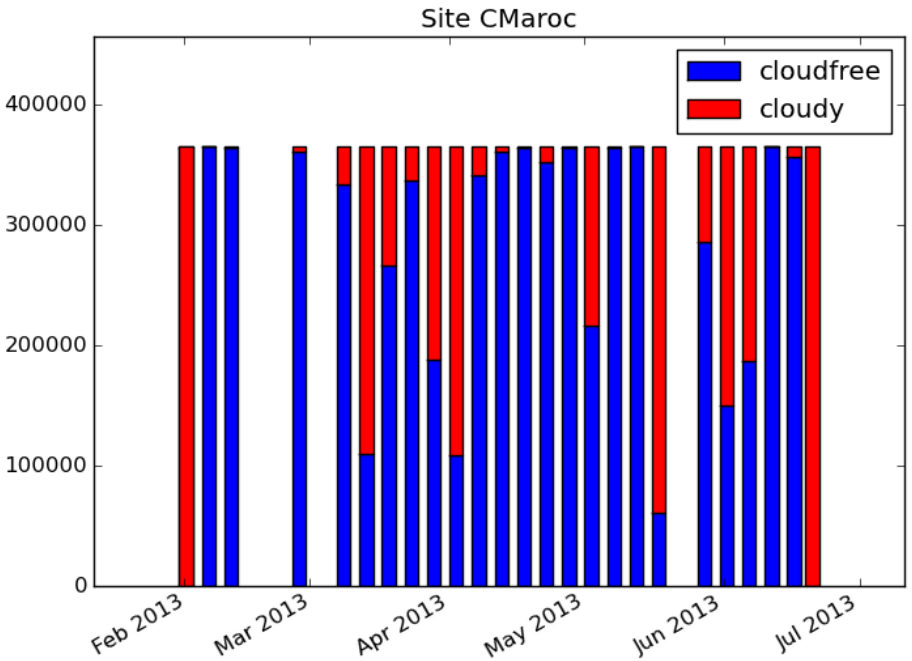
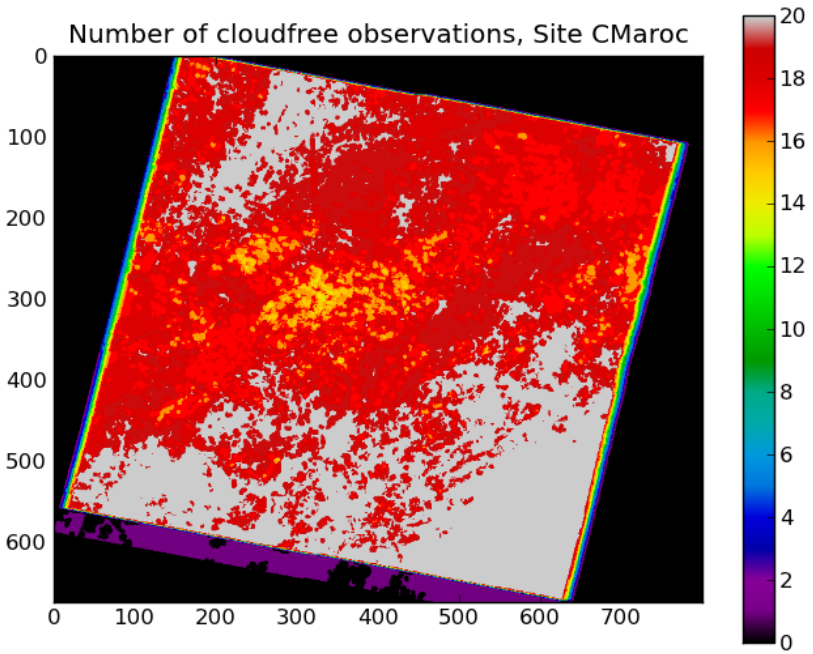
# Cloud Free Observations




Morocco Tensift

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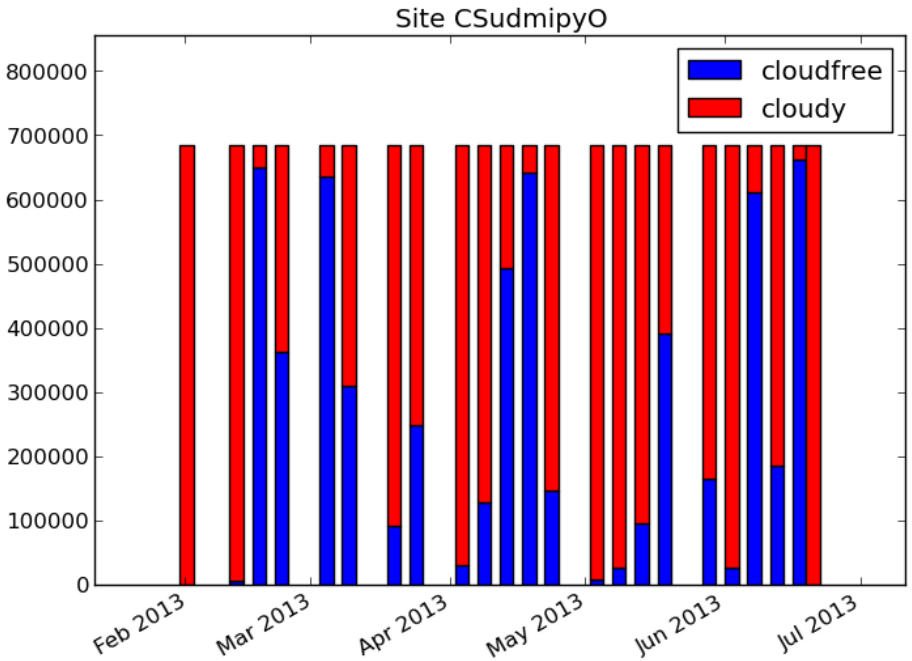


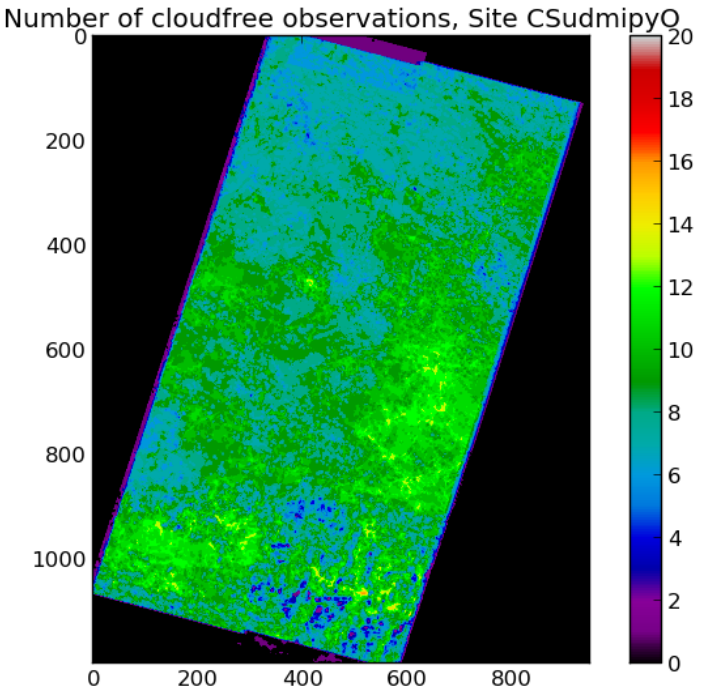


France Midi-Pyrénées

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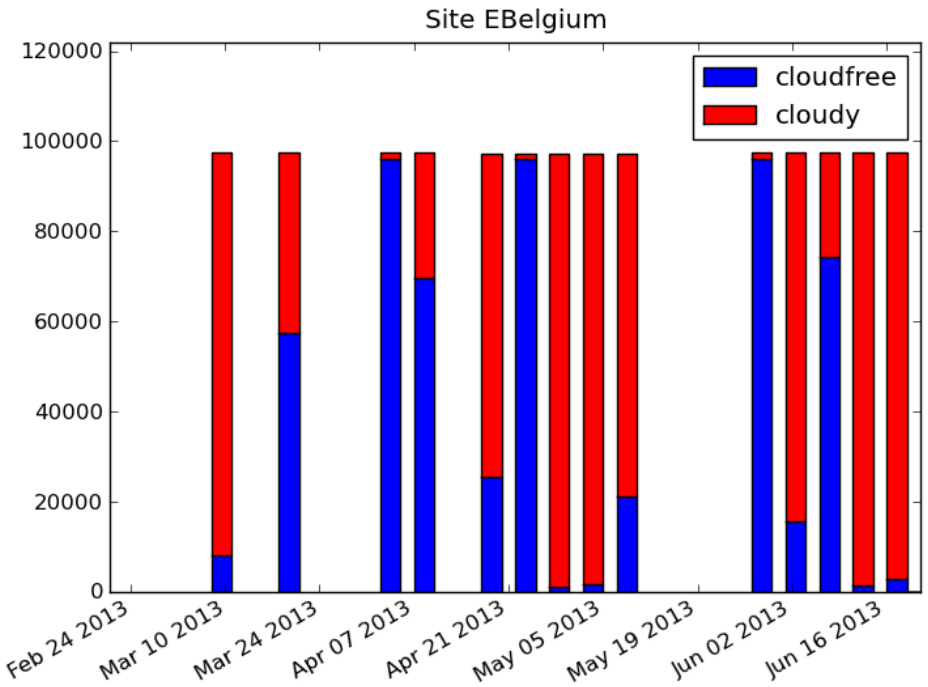
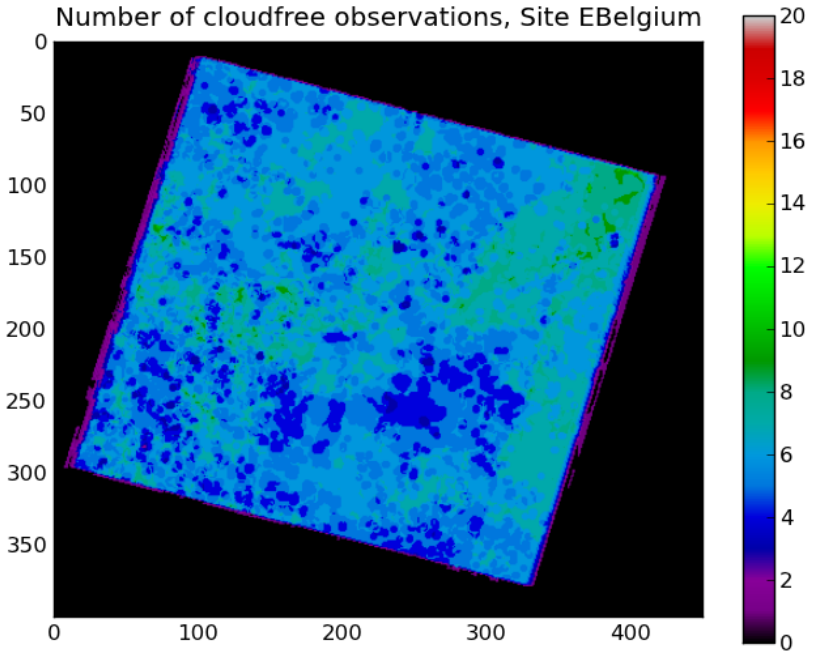



Belgium

# Atmospheric correction

## MACCS atmospheric correction

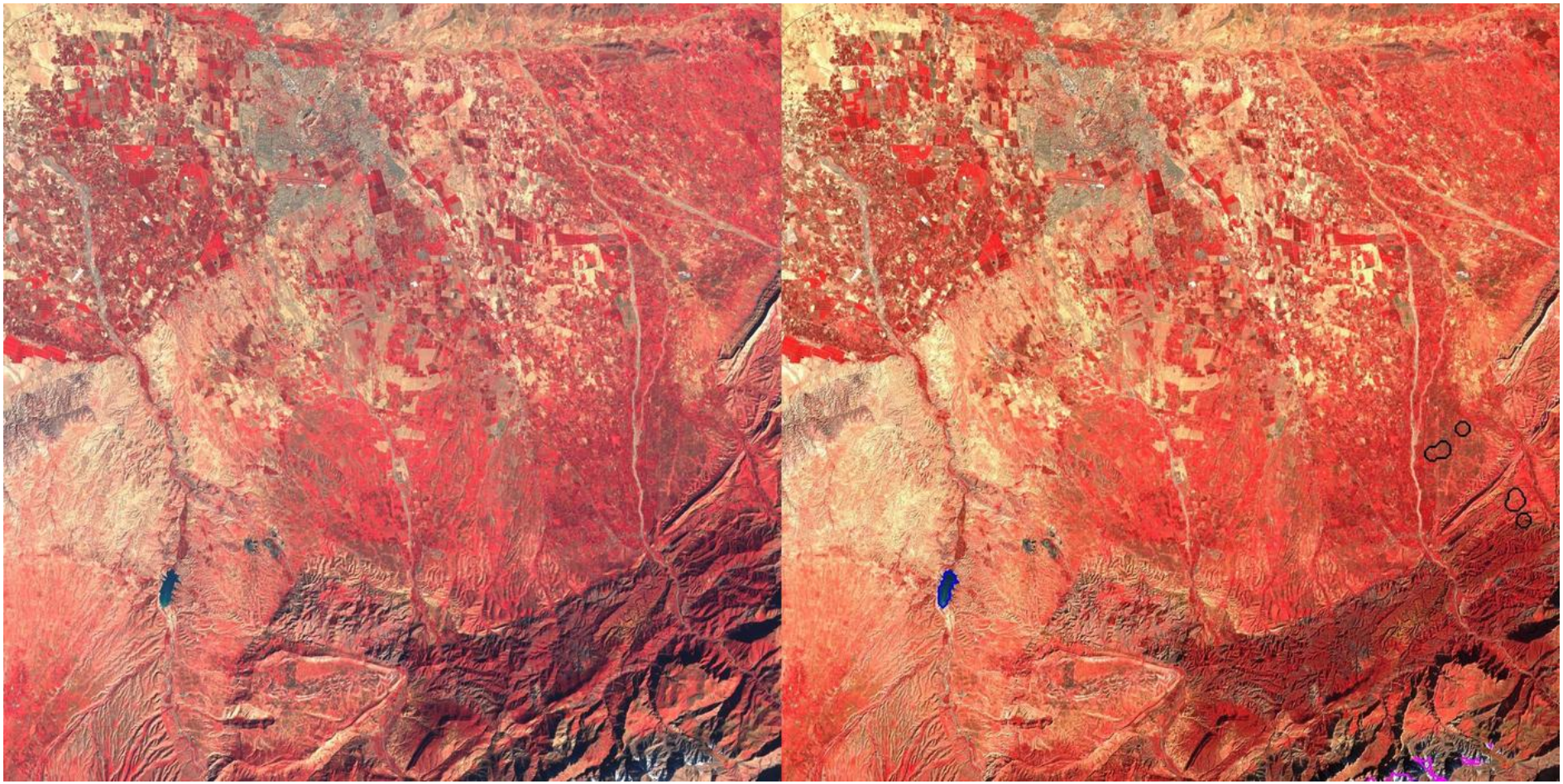
- MACCS takes into account :
  - Absorption
  - Scattering by molecules and aerosols
  - Aerosol parameters are estimated
  - Adjacency effects
  - Illumination effects due to topography

## Aerosol estimation method within MACCS

- Classical methods rely on multi-spectral relations above vegetation
- MACCS also uses a multi-temporal method to estimate aerosol content
  - two successive L2A images should be similar (at 200 m resolution)
  - thanks to constant viewing angles
- No blue band in SPOT satellites => Only multi-temporal in Take5
- the aerosol model is constant per site

# Multi-temporal detection of aerosols

- Multi-temporal detection of aerosols



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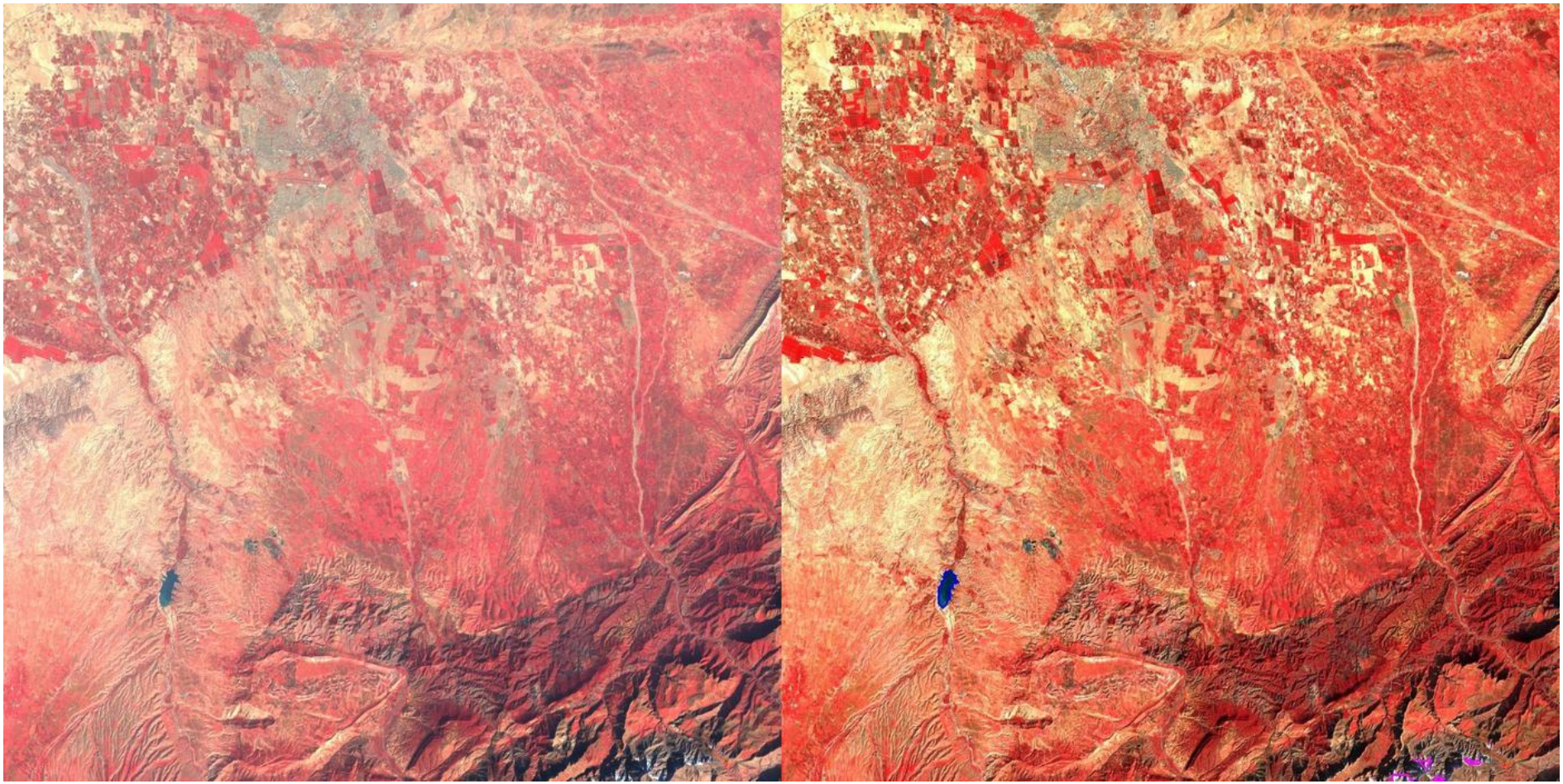

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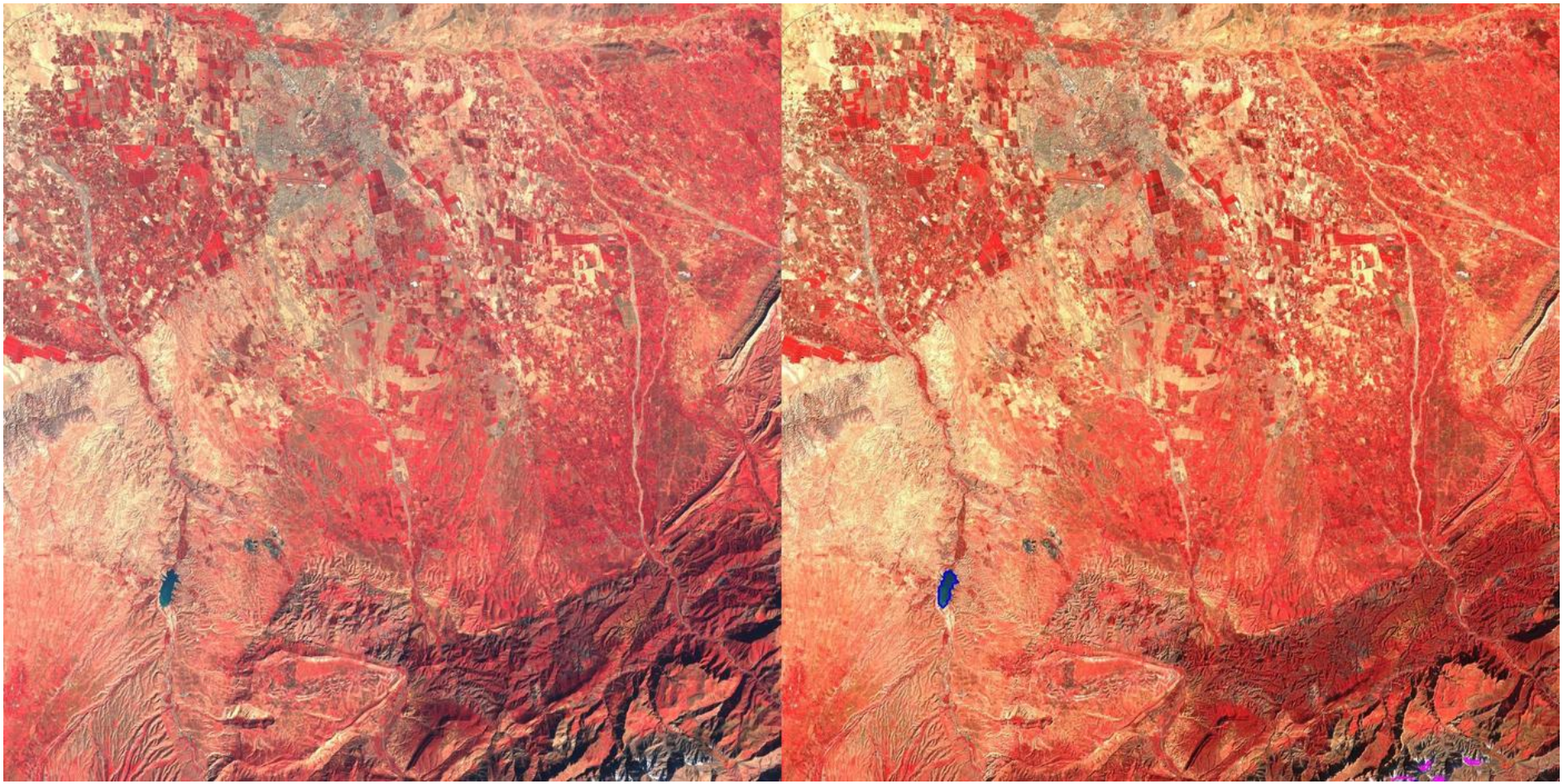

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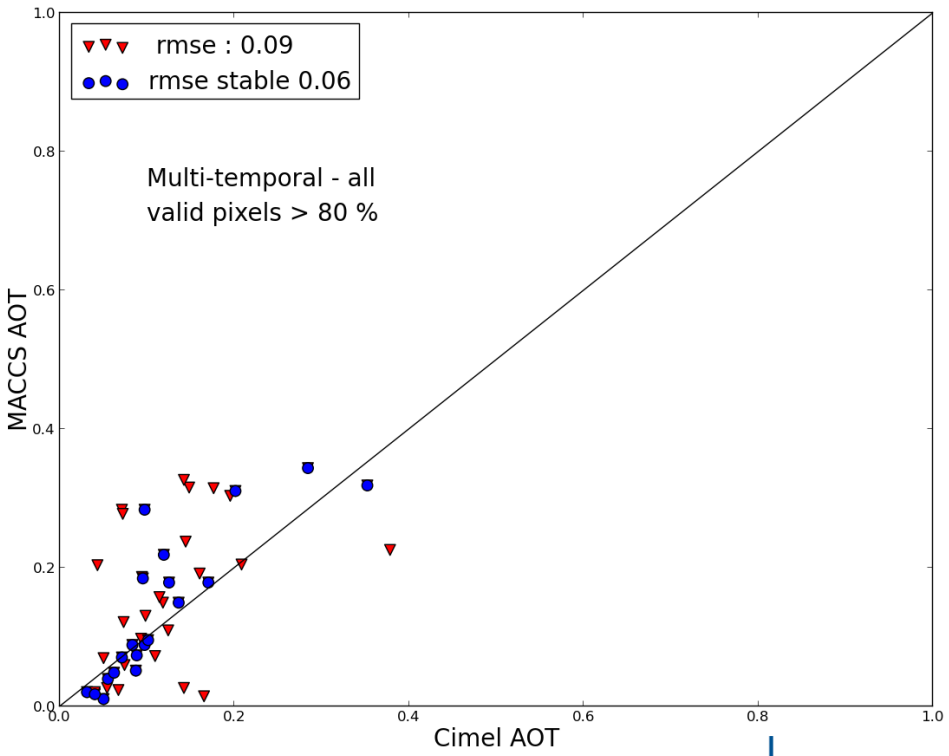
# Performances for SPOT4 (Take5)

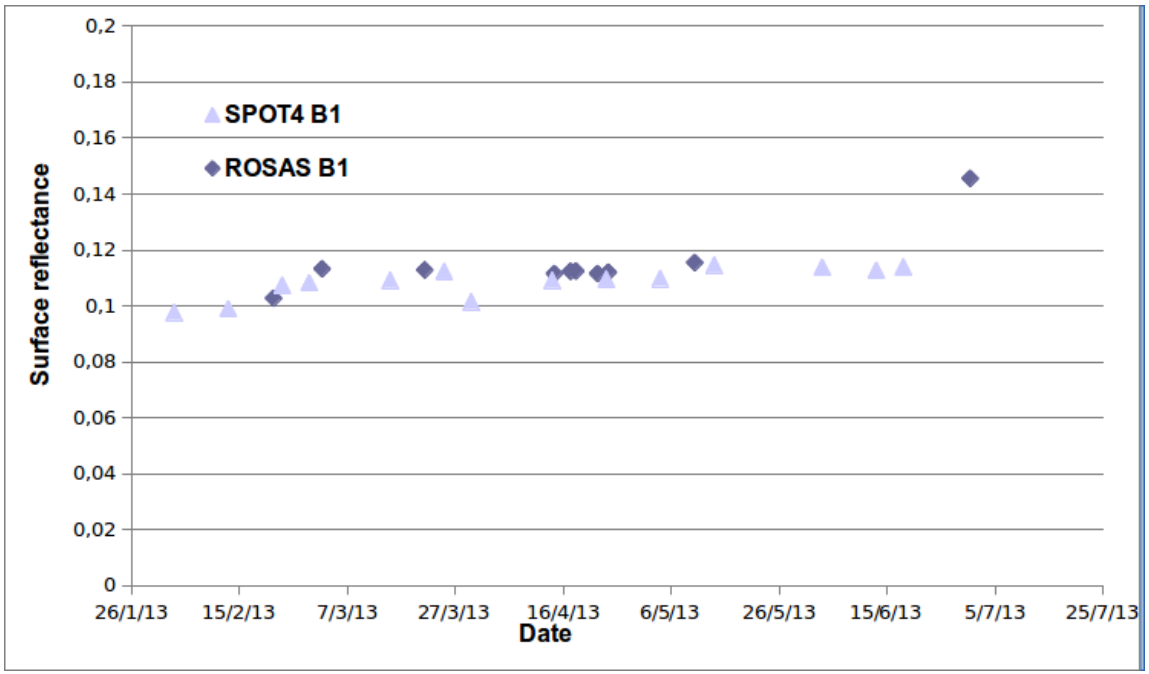
## Aerosol Validation

- Aerosol validation sites with a cimel nearby
  - Europe : Arcachon, Carpentras,Seysses,Le Fauga,Palaiseau,Paris,Kyiv
  - Africa : Saada, Ouarzazate (Morocco), Ben salem(Tunisia)
  - USA : Wallops, Cart Site
  - Asia : Gwangjiu, Korea
- same aerosol model for all sites



# Surface Reflectance validation using La Crau Rosas station

- CNES maintains an operational station for absolute calibration at La Crau, France
  - A CIMEL instrument characterises the surface reflectance and the atmosphere
  - Every 90 minutes
  - Operationally used for satellite "vicarious calibration"
  - May be used for the validation of surface reflectances



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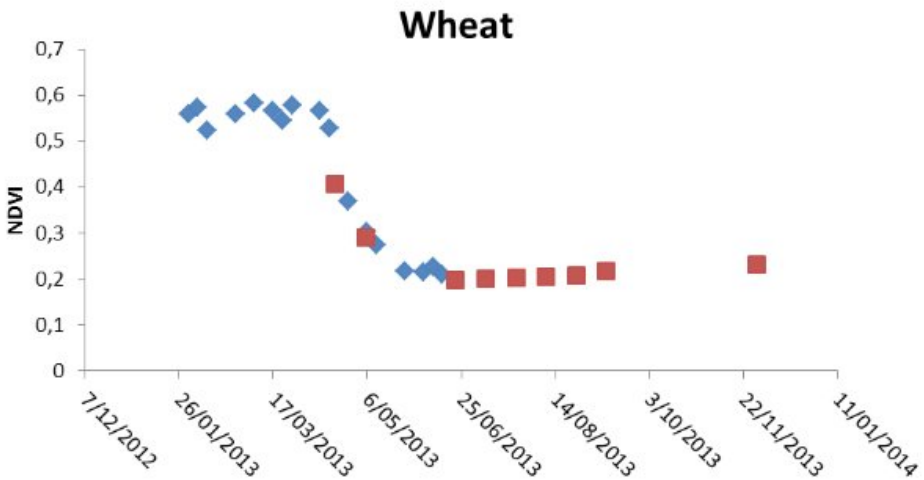
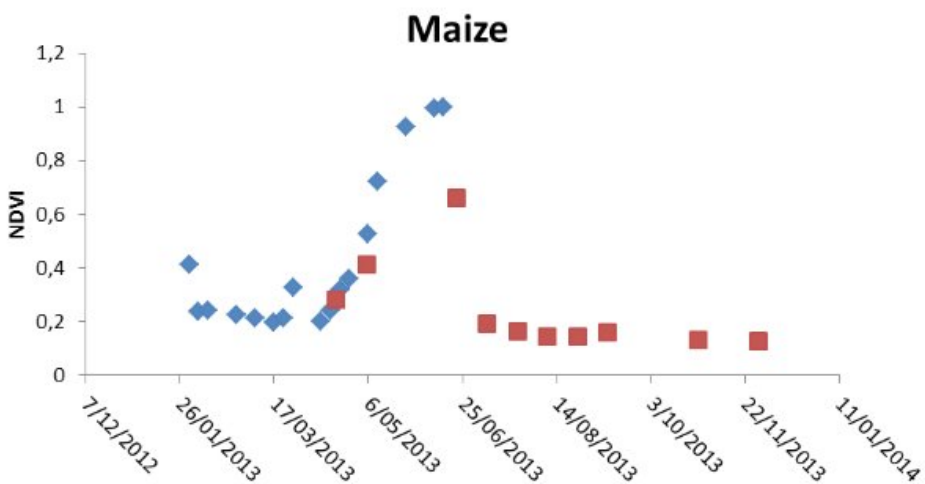
- Smoothness of reflectance profiles (Morocco)




Blue Take5, Red Landsat8

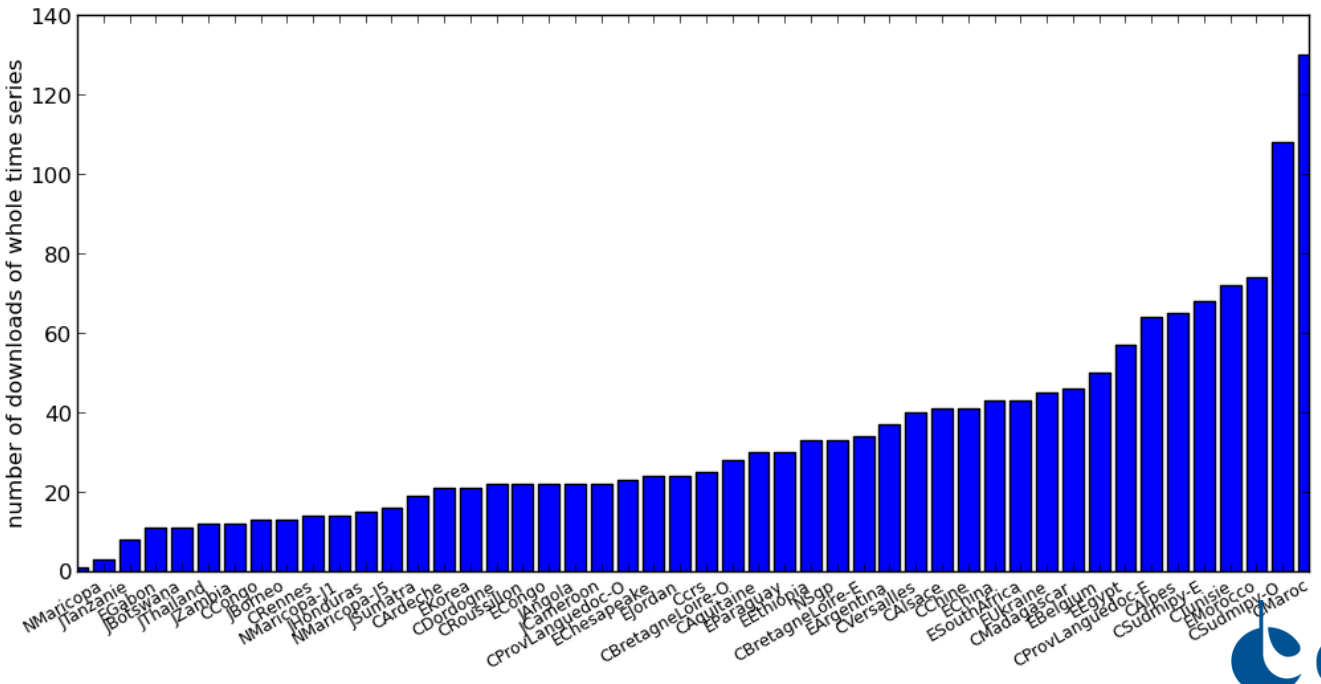
# Data usage

## SPOT4 (Take5) statistics at end of June 2015

- 3960 downloads among which 1680 full time series (37/site)
- 77% of downloads are Level 2A.
- 700 different email addresses, at least 30 countries
  - Fr,It,De,Ma,Usa,Be,Ca,Mg,Tu,Es,Za,Eg,Ru,Dk,Si
  - Cn,Br,No,Ar,At,Se,bf,Uk,Pl,Cz,Pt,Cn,Dz,Ro,Rs

## SPOT5 (Take5) statistics at end of June 2015

- Service opened on July the 2nd, already more than 100 users




downloads /tile

# Application examples

- SPOT5(Take5) series near Valencia, Spain (where paella grows)
  - Bare soil in April
  - Rice watered beginning of May
  - Full development, end of June
- Applications
  - Identify the crop => Land cover
  - Estimate the sowing date => crop modelling
  - Monitor crop growth => yield
  - Works in conjunction with Sentinel-1

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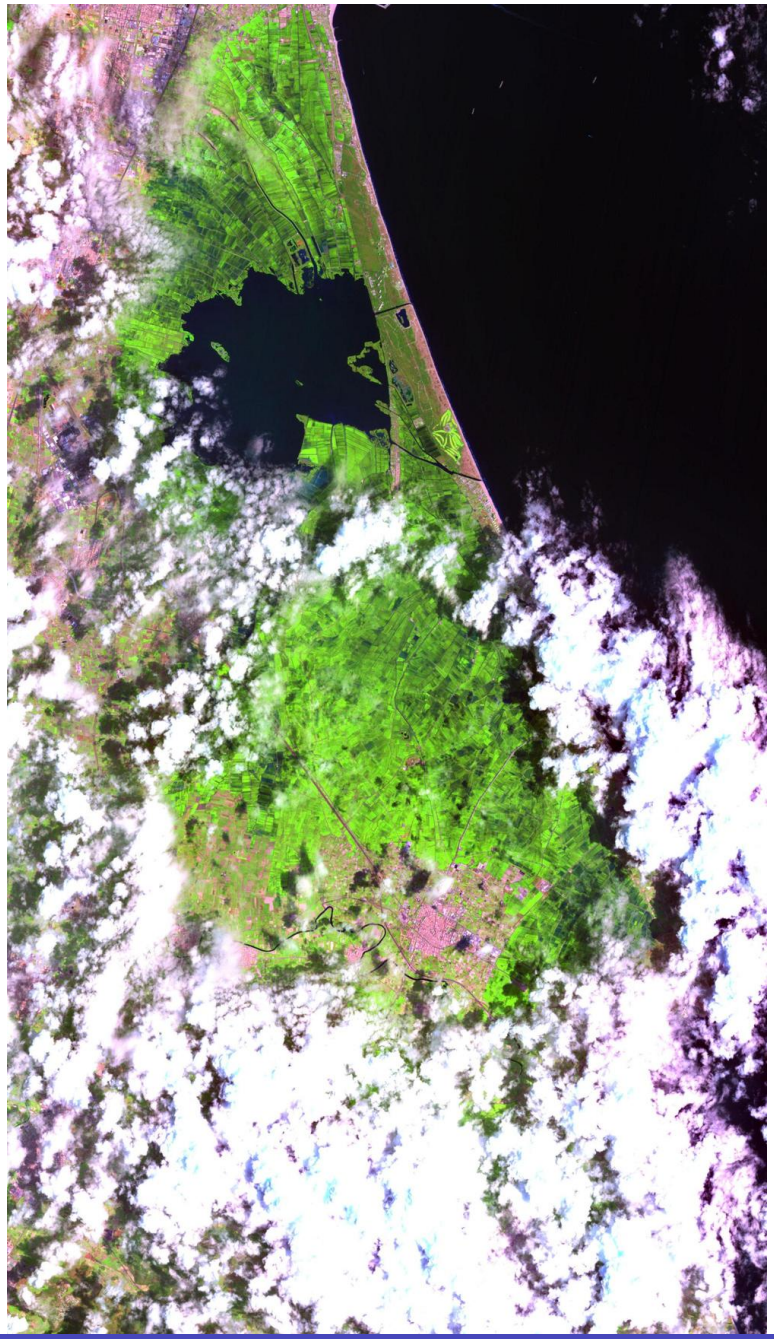

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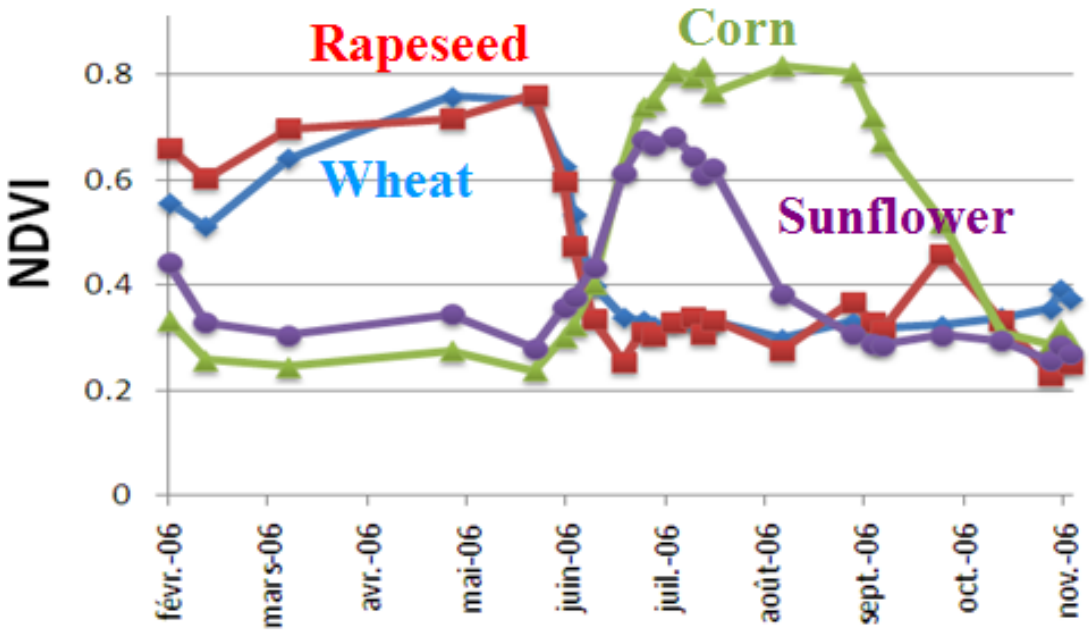
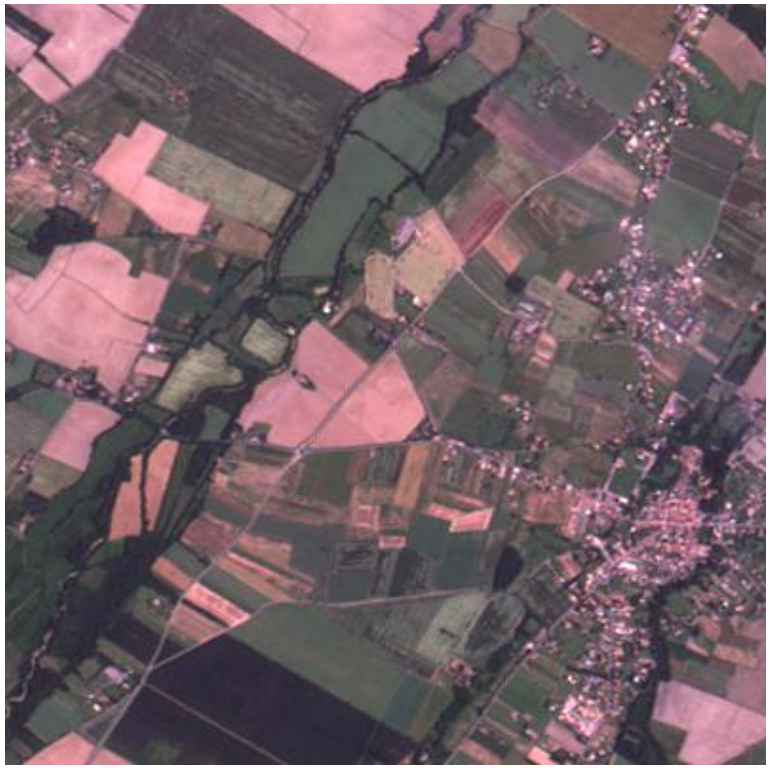
- Vegetation types may be separated thanks to time series



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## Idea

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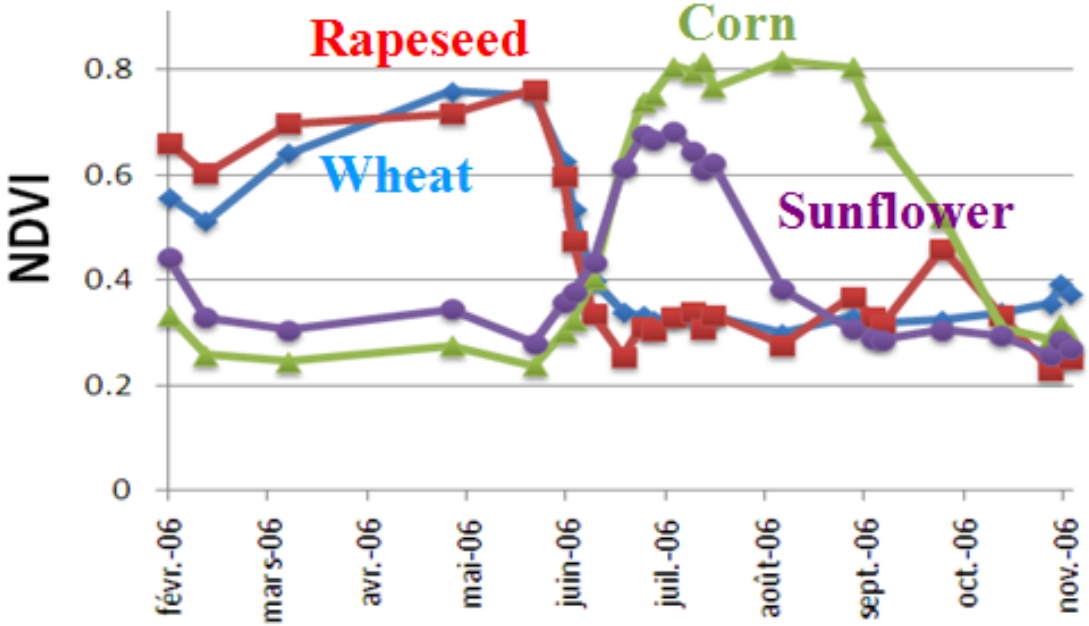
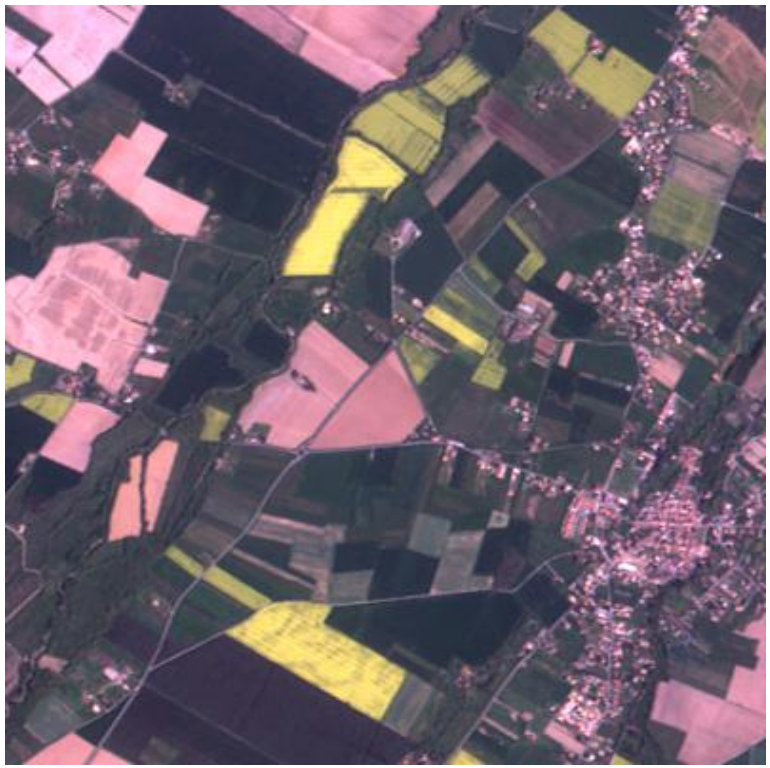
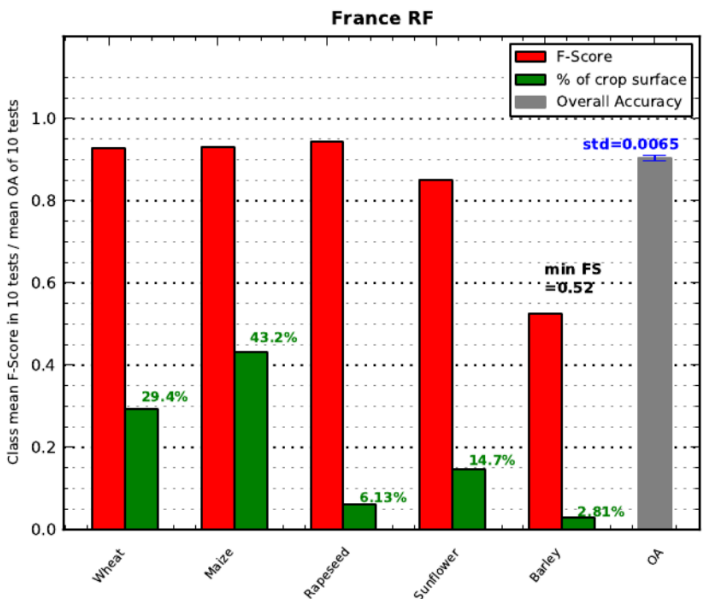


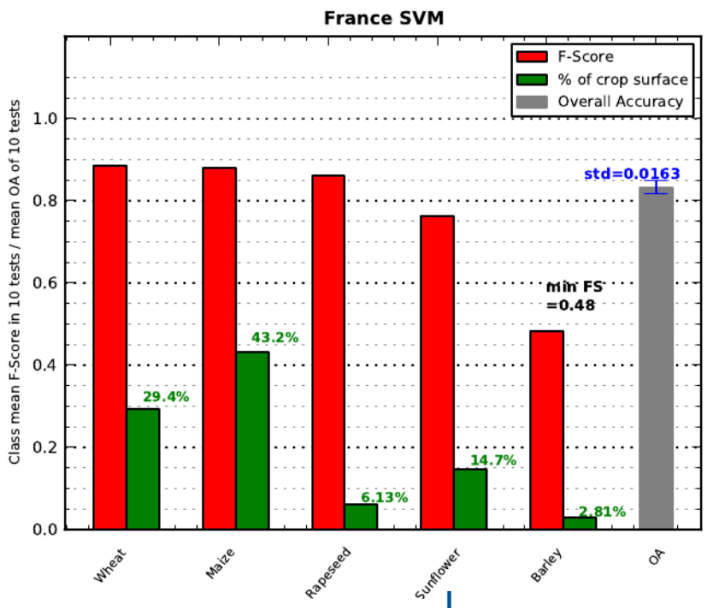



# Use of time series for Land Cover

## ESA's Sentinel-2 Agri project

- Consortium : UC Louvain, CESBIO, CS (France, Romania)
- 4 products : Composites, Crop Mask, Crop Type map, LAI)
  - 9 SPOT4 (Take5) sites processed in the first phase
  - 3 full countries to be processed with Sentinel-2 in 2016
  - Explained in Inglada et al 2015, remote sensing, submitted
- The crop type product is a land cover map specialised for agriculture
- Production system will be open source, based on Orfeo Tool Box

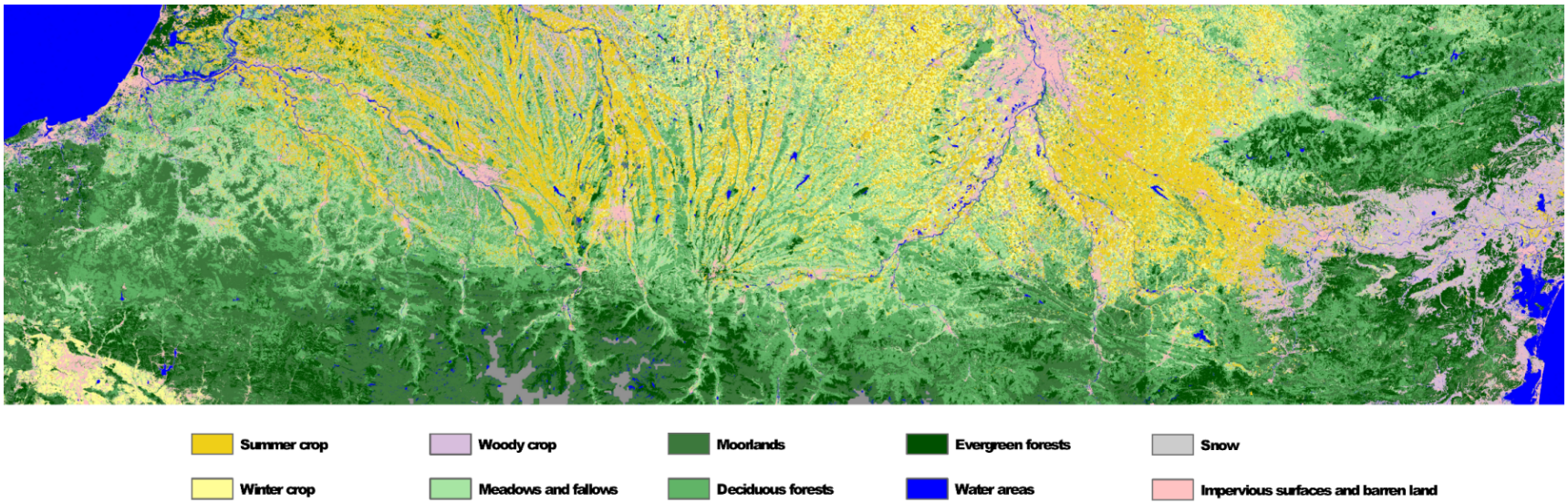


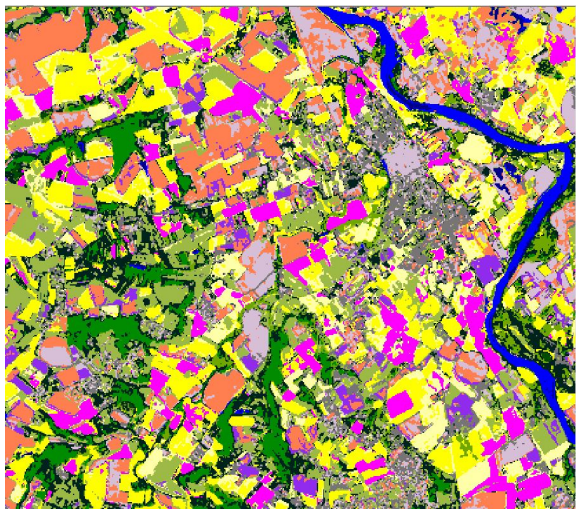
# Use of time series for Land Cover

## THEIA's project for France Annual Land Cover Map

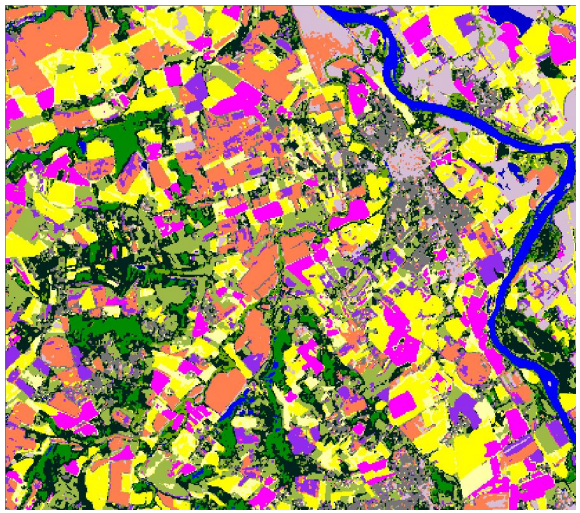
- THEIA land data center will produce annual land cover maps
  - based on Sentinel-2 data
- Based on CESBIO methods also used for Sentinel-2 agri
- 20-25 classes, natural vegetation and agriculture (main crops)
- Issued at end of each year, start end of 2016



# Multi-Temporal classification



West Track



East Track

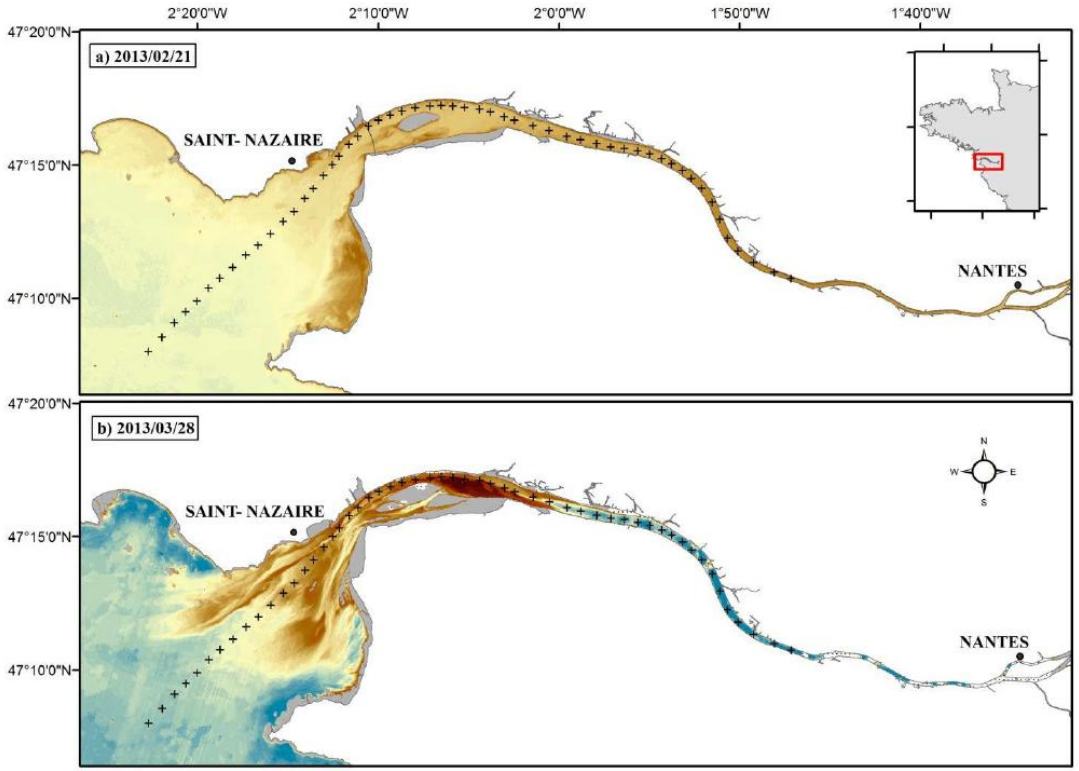
**Comparison of lan cover maps from overlapping SPOT Take5 sites**

- 90% of pixels have the same class in both images

# Coastal water monitoring

## water colour

- Universities of Bordeaux and Nantes (P.Gernez, V.Lafon)
- Monitoring of suspended matter within estuaries (Gironde, Loire)
- High turbidity => Oxygen loss
- Avoid releasing mud from water treatment plants when water is very turbid
- Users happy with Level 2A quality, although optimized for land surfaces
- Gernez et al, 2015 MDPI remote sensing



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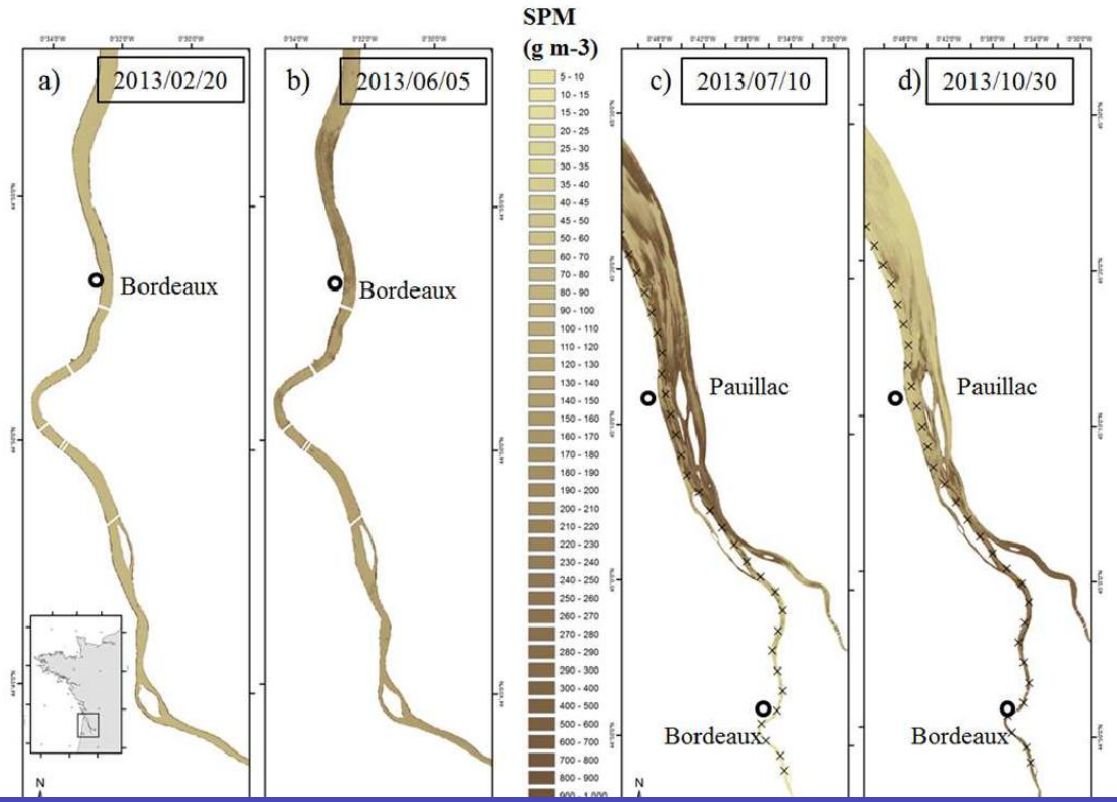

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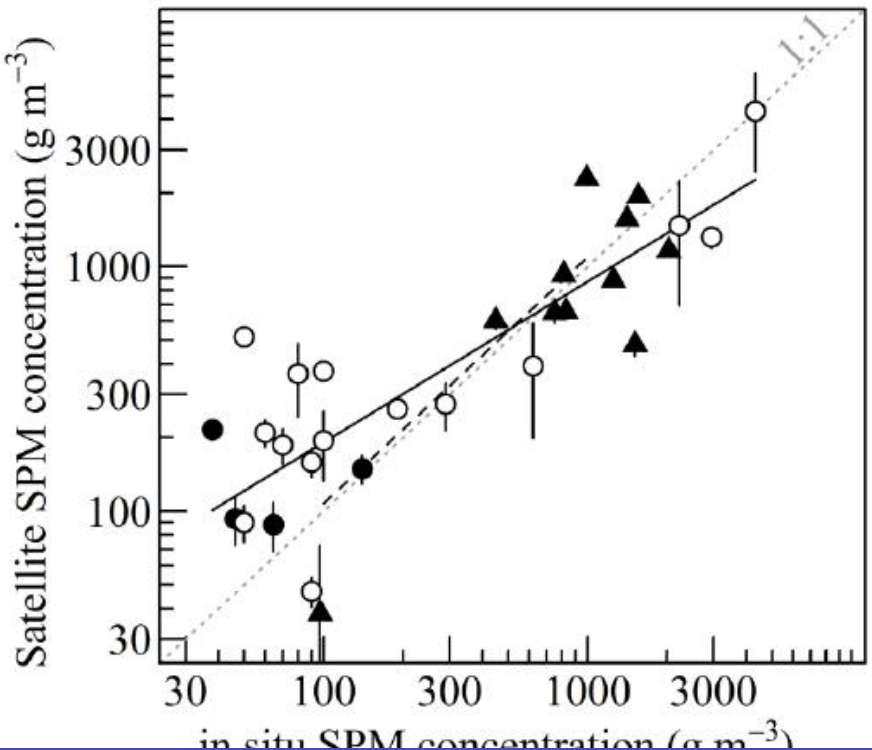
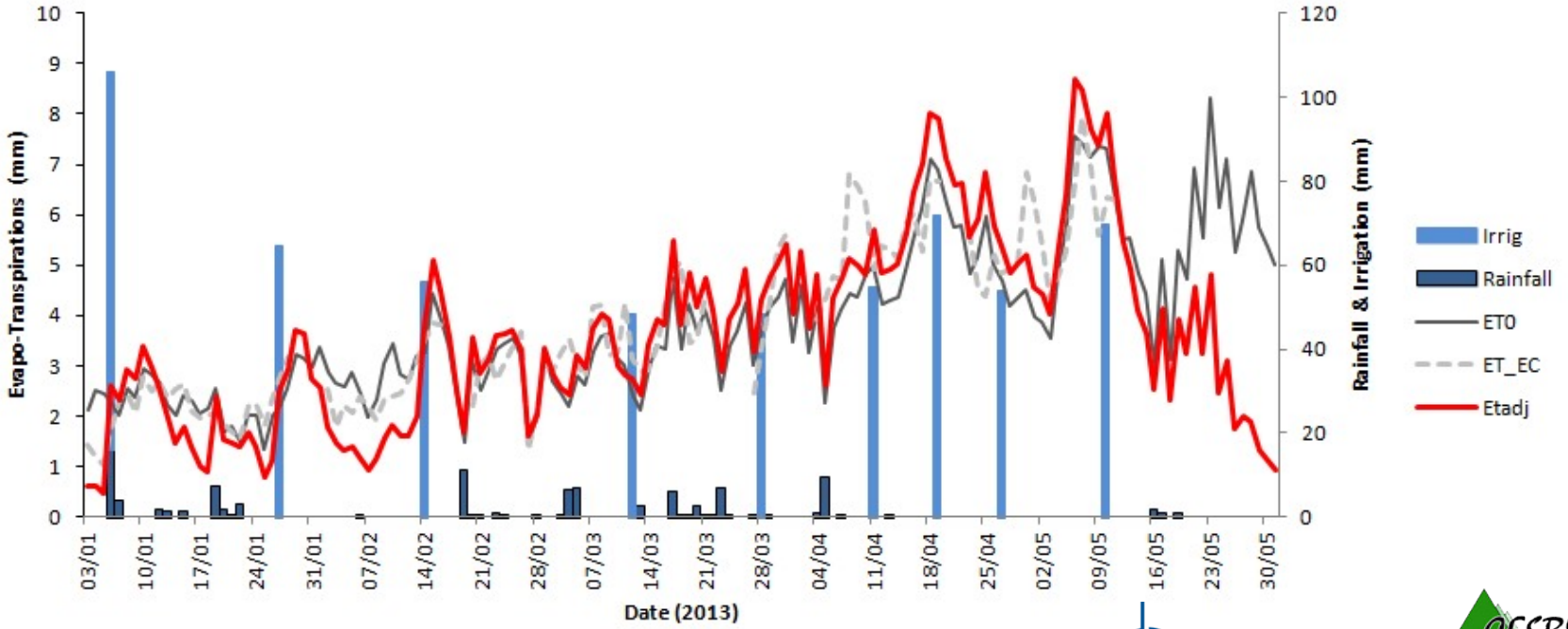


# Irrigation scheduling in real time in Morocco

## Expérimentation

- One wheat plot is watered according to recommandations from SAMIR model,
- One reference plot is watered upon farmers decision
- SAMIR is an evapo transpiration model, uses Wearther data as input
- Vegetation development is also ingested, taken from SPOT (Take5) data



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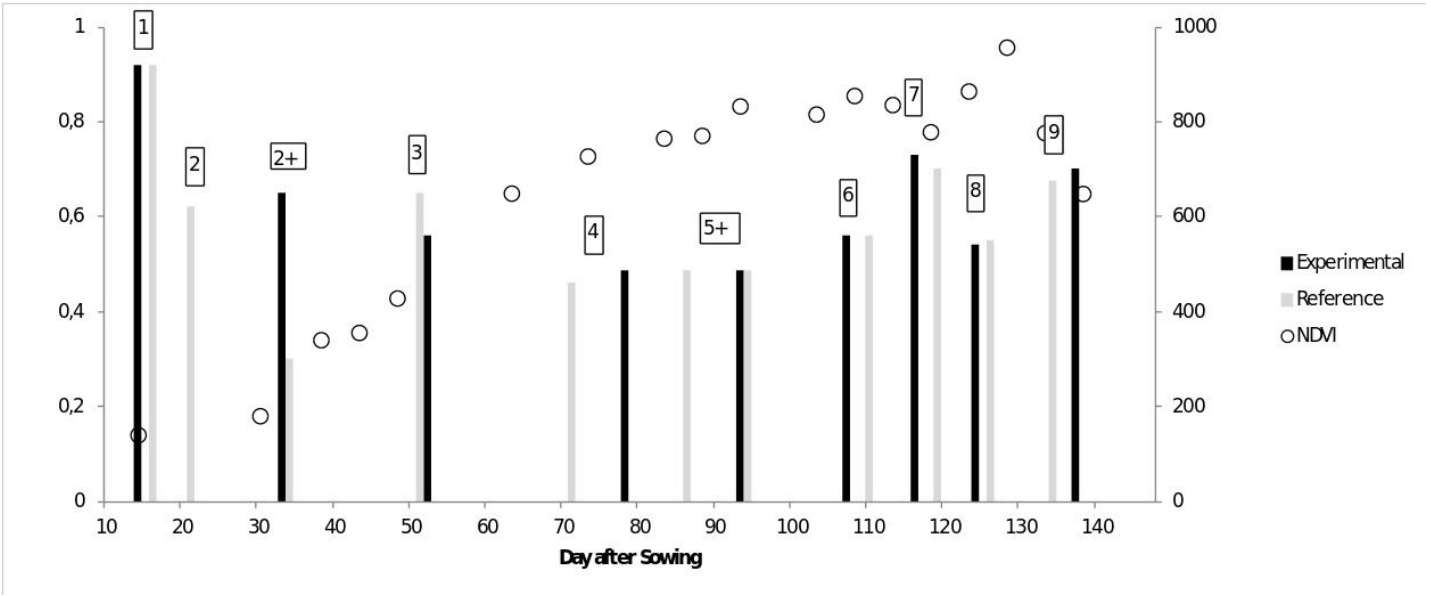

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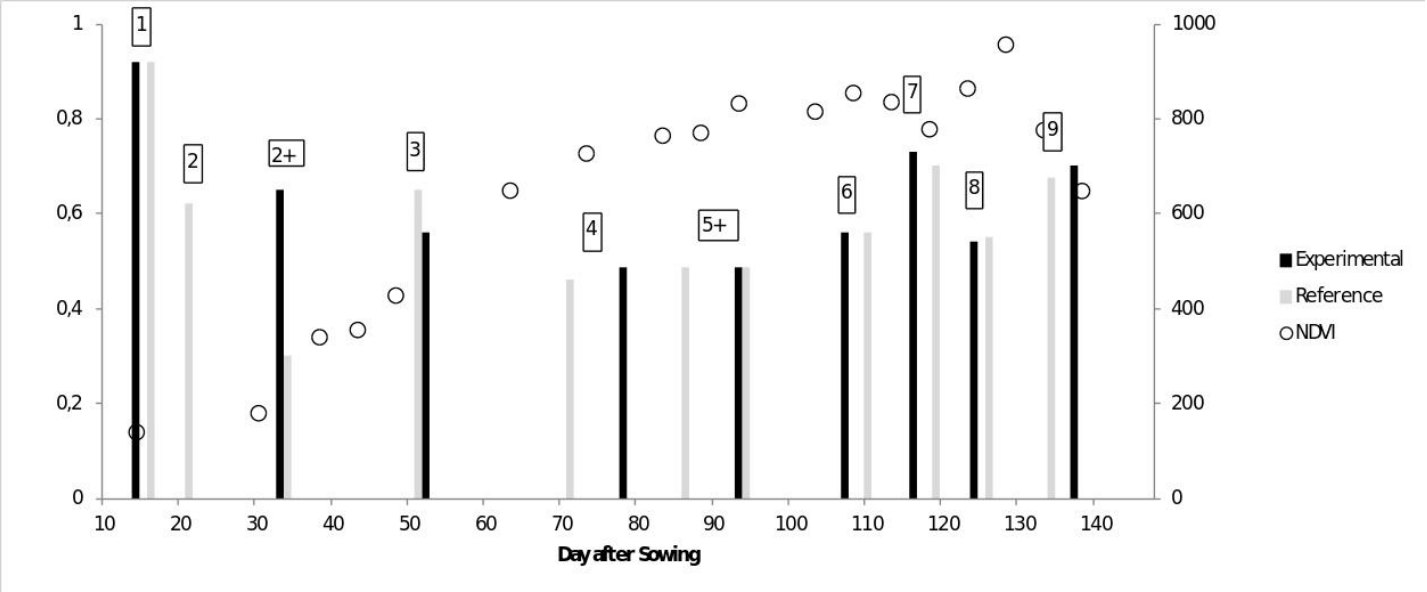


## Résultats

- Scientists did not know it was necessary to water twice to remove a crust
  - Farmer 1 - 0 Satellite

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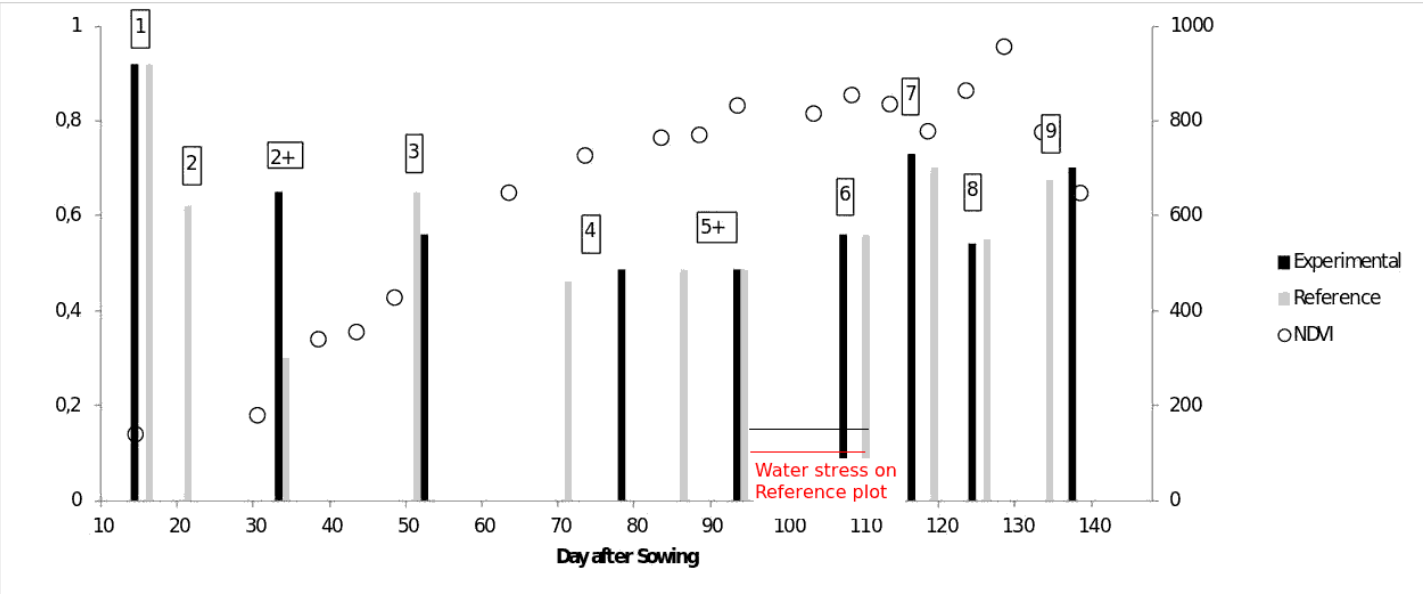


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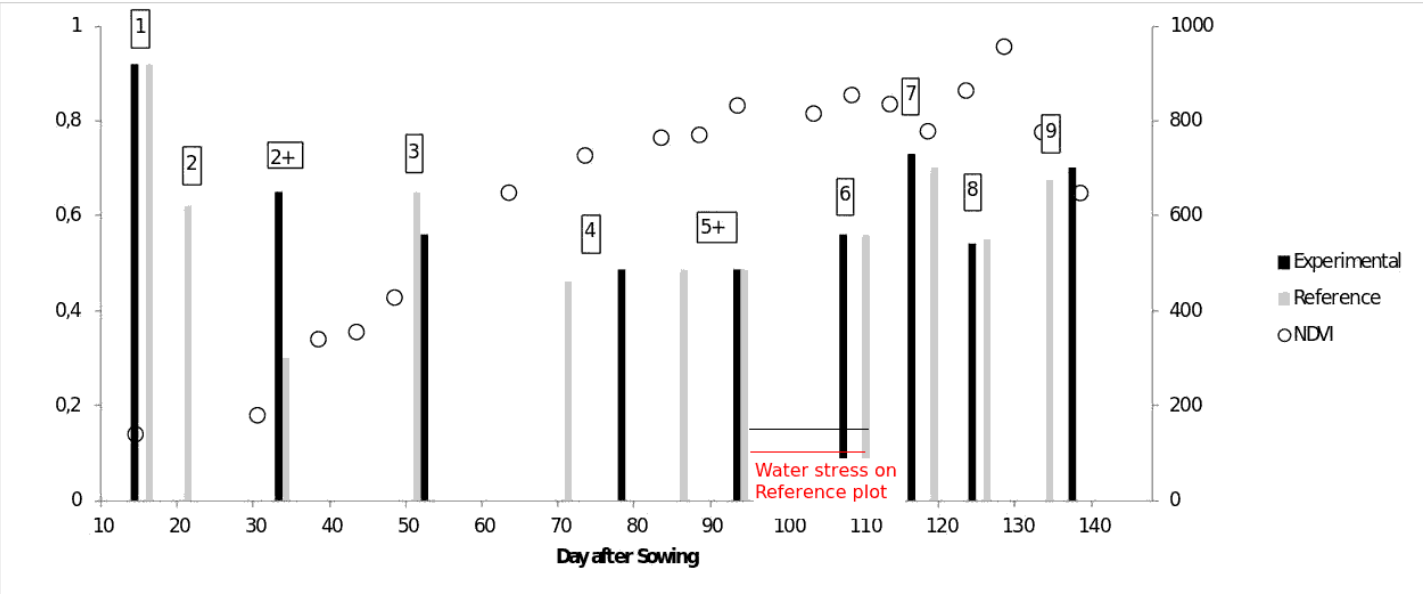


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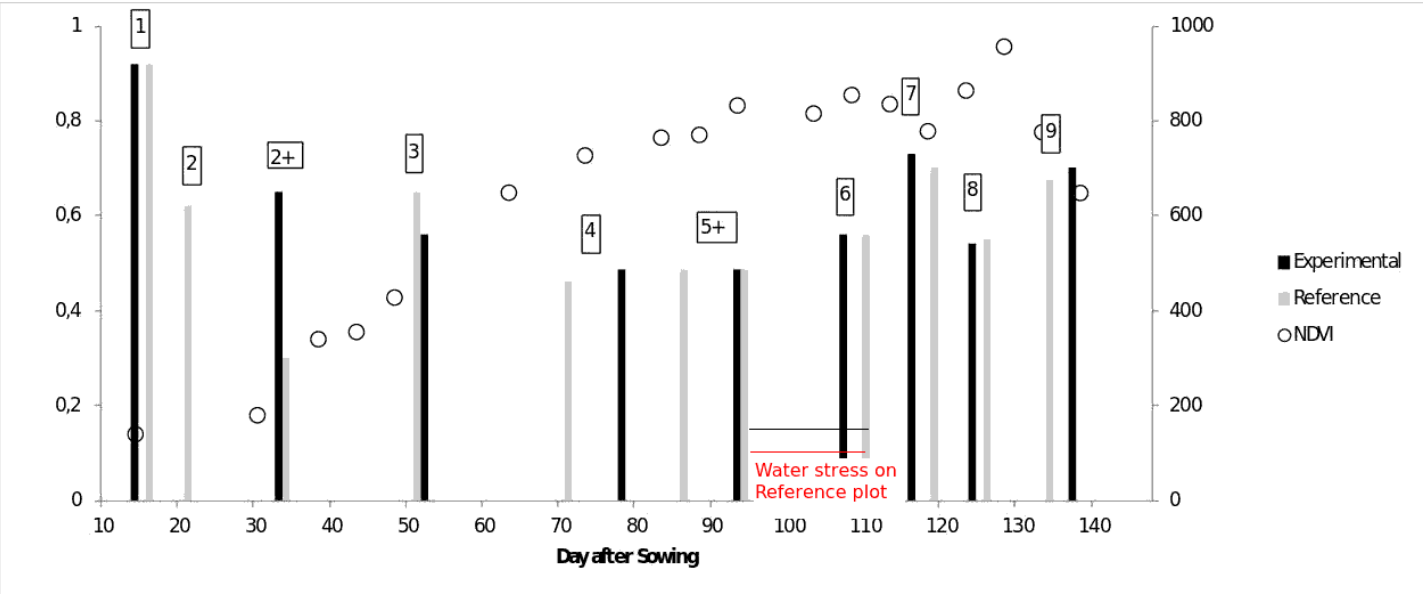


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- The farmer's parcel suffered from water stress = Same yield
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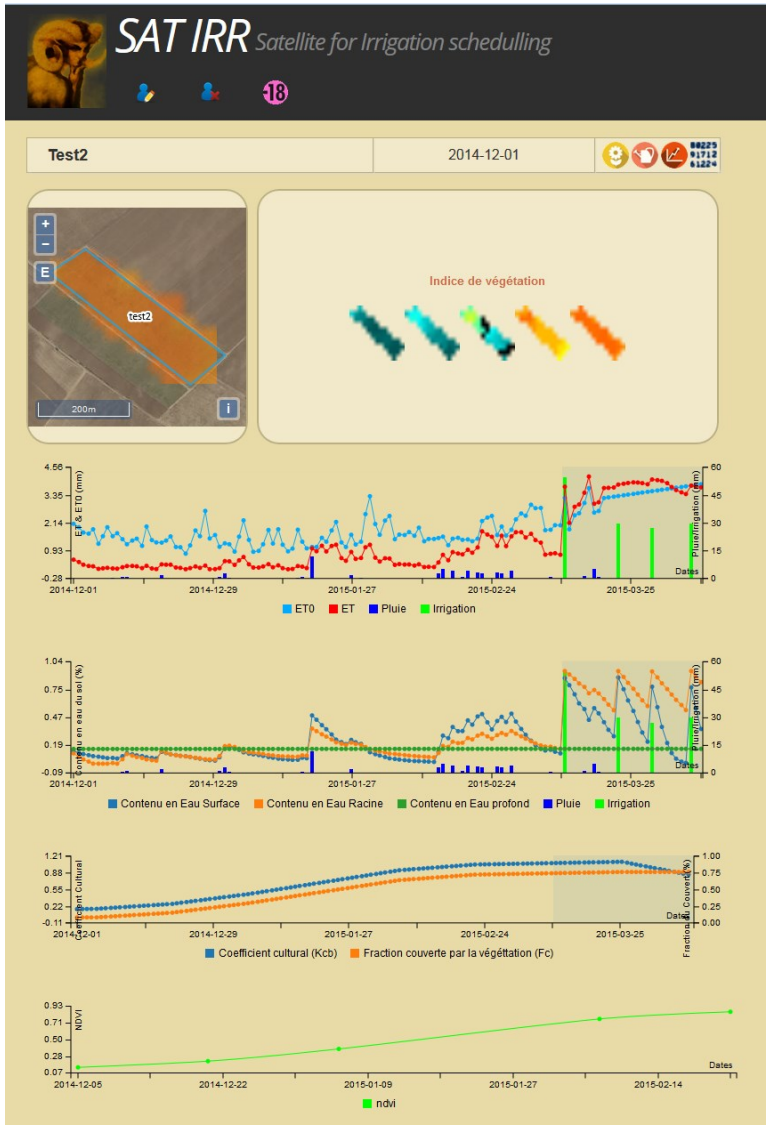
  - Farmer 1 - 2 Satellite
- Operational irrigation scheduling in semi-arid landscape seems possible Sentinel-2
- Le Page et al, A Life-Size and Near Real-Time Test of Irrigation Scheduling with a Sentinel-2 Like Time Series (SPOT4-Take5) in Morocco, MDPI remote sensing,

# Irrigation

- Michel Le Page, CESBIO/IRD, Université Cadi Ayyad Marrakech
- Prototype service for helping farmers decide irrigation: SATIRR
  - http://osr-cesbio.ups-tlse.fr/Satirr
  - Experiment in 2013 with SPOT4 (Take5), Le Page et al 2014, remote sensing
  - Use of LANDSAT L2A (in 2015) to monitor vegetation cover (NDVI)
  - Use of the closest weather station (with rain gauge)
  - Integration of weather forecast (not to water if rain forecasted on the next day)
  - Estimation of the amount of water to provide
- Operational test with Sentinel-2 in 2016



# Conclusions

## Take5 : A successful experiment

- Download data from https://spot-take5.org
- Everything worked well in a short time frame: satellite, processors
- Large number of users shows how Sentinel-2 data are awaited.
- Very large diversity of operational applications expected for Sentinel-2
- Level 2A Multi-temporal methods are operational even without a blue band
  - The French Land Data Center (THEIA) will produce Sentinel-2 L2A data over 5 M km², using MACCS
  - Already used to produce LANDSAT 8 L2A data
  - Extension to the whole world is discussed with ESA

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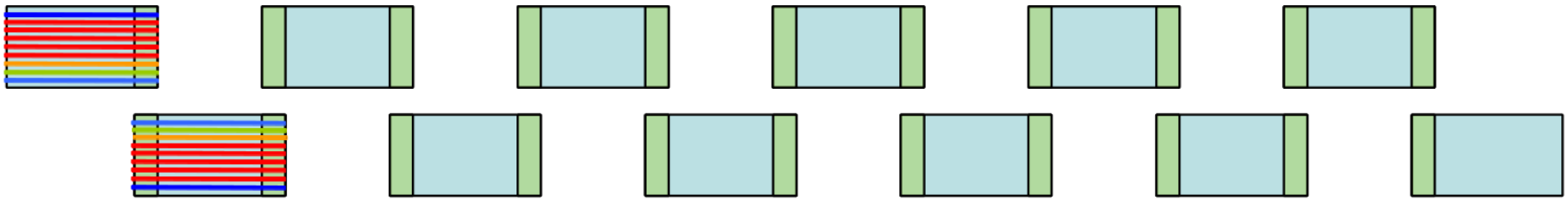
## Where to see more SPOT (Take5) results

- A general audience film, search "Take5 movie CESBIO"
- A special issue at MDPI remote sensing (first papers released soon)
- A special event at Living Planet Symposium, Prague, May 2016
- A “Multitemp” blog http://www.cesbio.ups-tlse.fr/multitemp/