

A hint of the revolutionary potential of Sentinel-2 time series using the SPOT4(Take5) data set

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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 : 20 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
- ▶ “Ready to use” products
 - Level 1C : ortho rectified TOA reflectance product
 - Level 2A : surface reflectance with cloud masks (TBC)
- ▶ Constant viewing angles :=> minimized directional effects
 - high quality time series

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 km² : 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

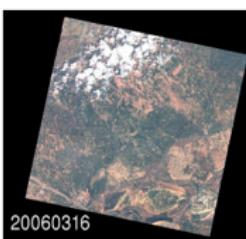
- ▶ Aerial acquisitions
 - High **resolution**, all S-2 **spectral** bands but no **revisit** and small **coverage**
- ▶ Other satellites
 - Formosat-2 : **revisit** and **resolution**
 - Landsat 5,7,8 : **coverage** and **spectral** bands
 - SPOT, R-E, DMC, **resolution** **coverage** and **revisit**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

SPOT4 (Take5)

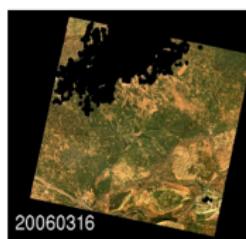
- ▶ SPOT4 orbit was changed to simulate Sentinel-2 time series
 - **revisit** : every 5 days, February to June 2013, 28 acquisitions
 - **resolution** : 20m
 - **coverage** : large sites 60*60 km², 120*120, 300*200
 - **spectral** : Only 4 bands, but with a SWIR band

Products

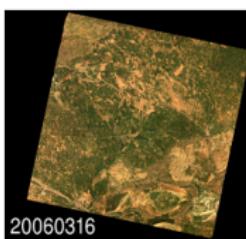
- ▶ Level 1C product :
 - Ortho-rectified images in TOA reflectance
- ▶ Level 2A Product :
 - As Level 1C, but surface reflectance
 - Cloud and Cloud shadows mask
 - Snow and Water masks
- ▶ Level 3A Product :
 - Synthesis of surface reflectance of cloudfree pixels over 1 month
 - Not available yet
- ▶ ESA will produce Level 1C and considers producing level 2A



Level 1C:



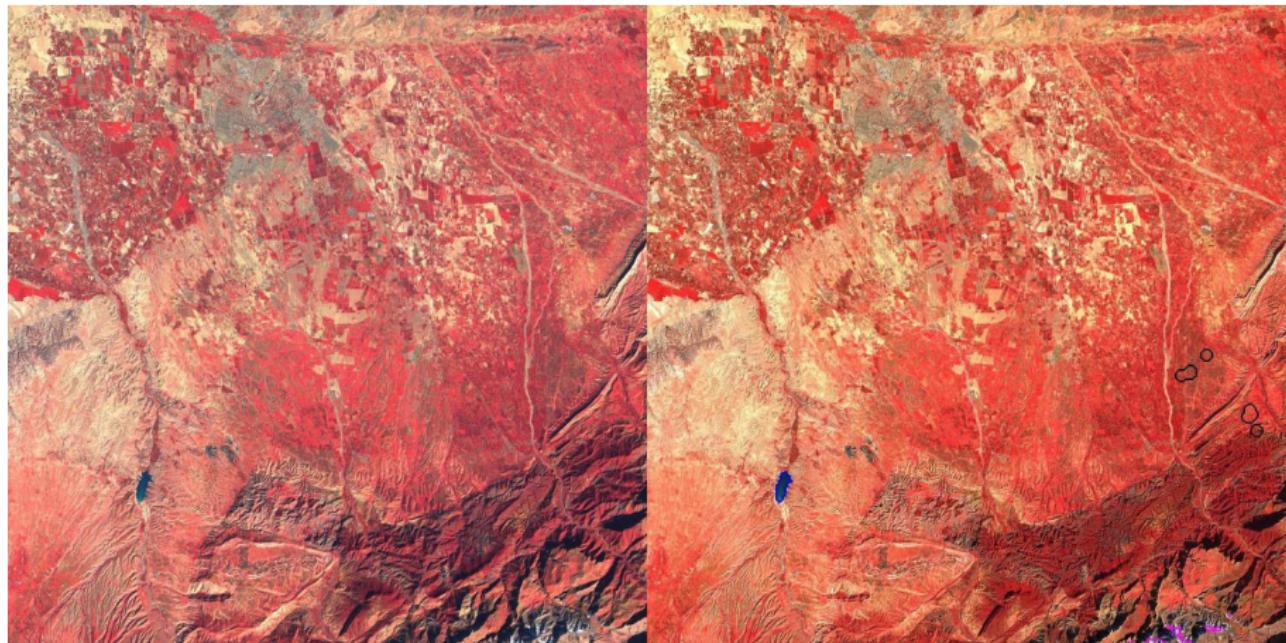
Level 2A:



Level 3A:

Simulated Sentinel-2 time series from Take5 data

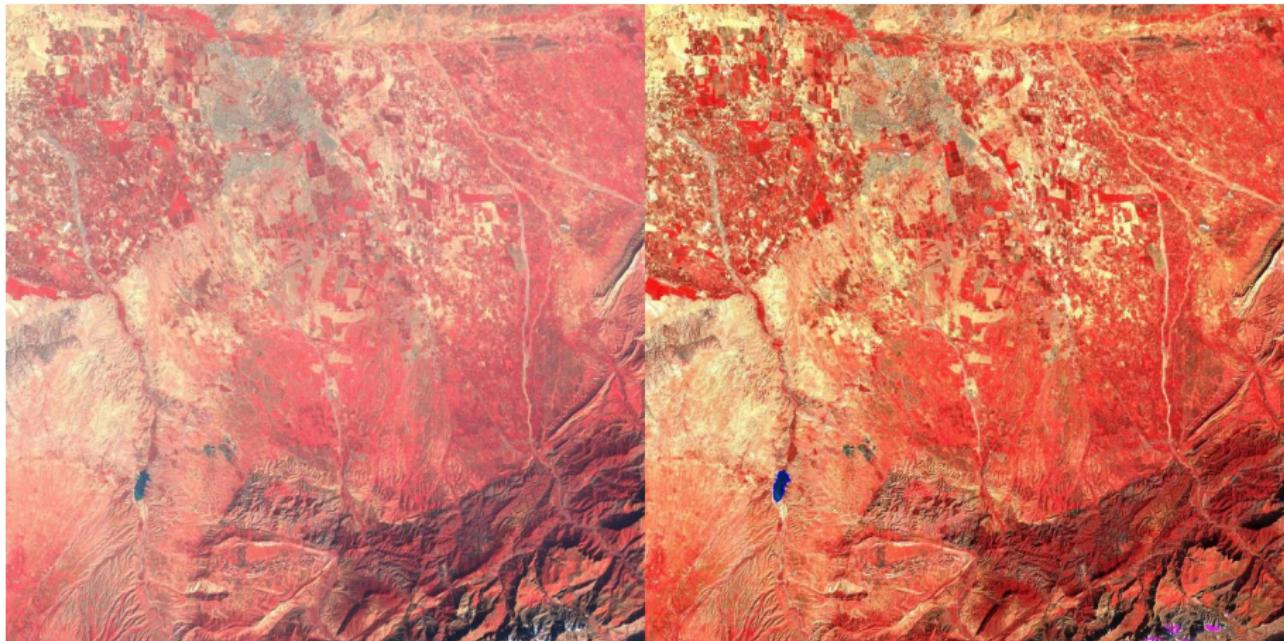
- ▶ Example over Morocco, February and March



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

Simulated Sentinel-2 time series from Take5 data

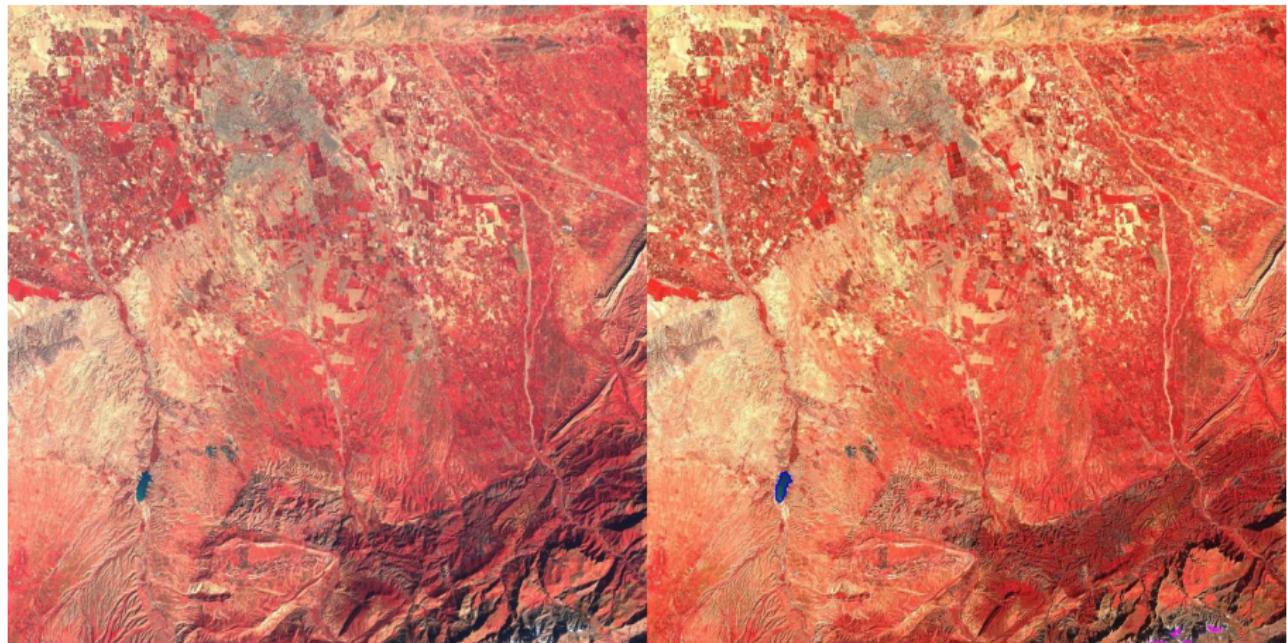
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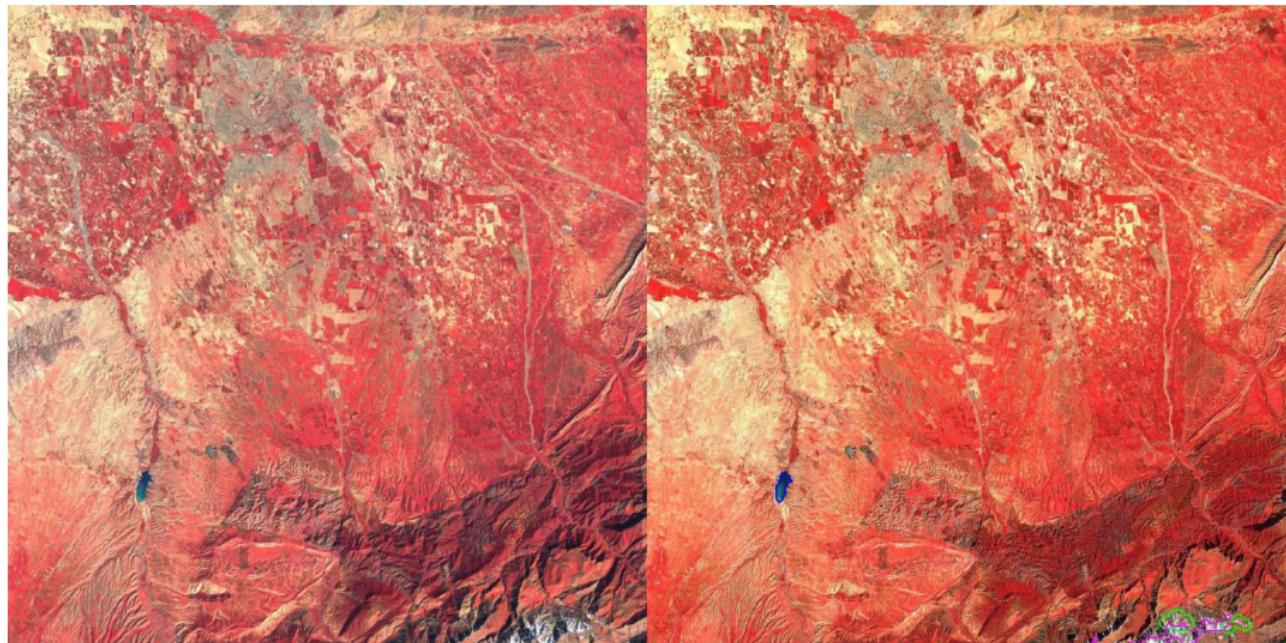
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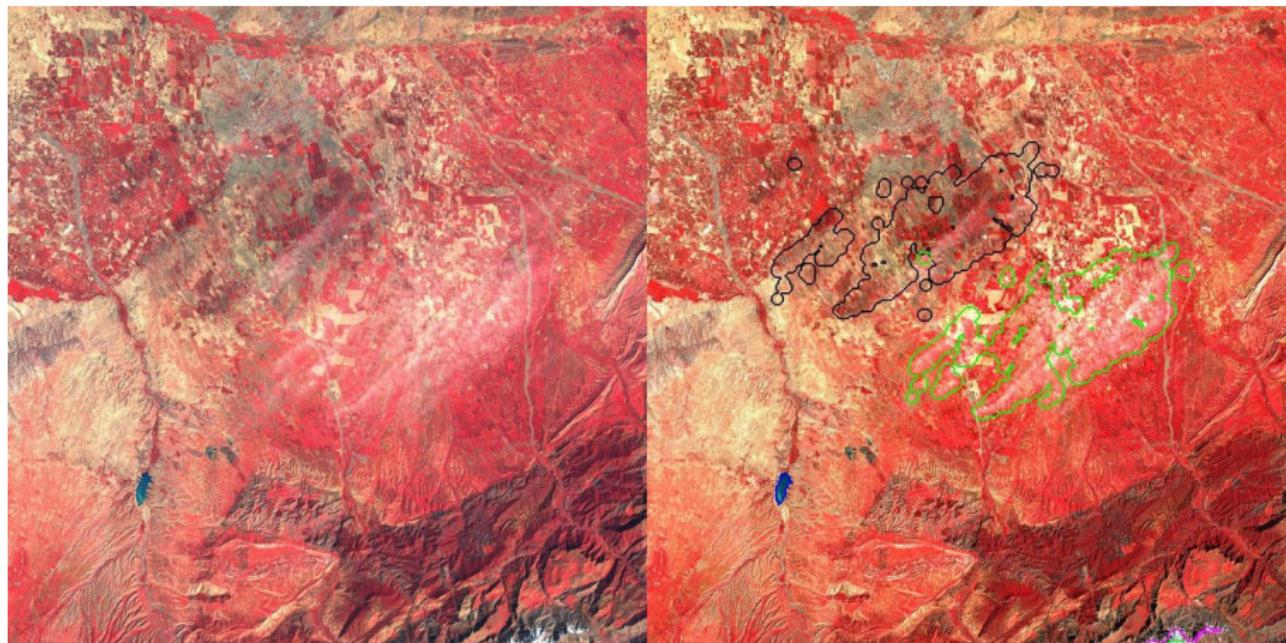
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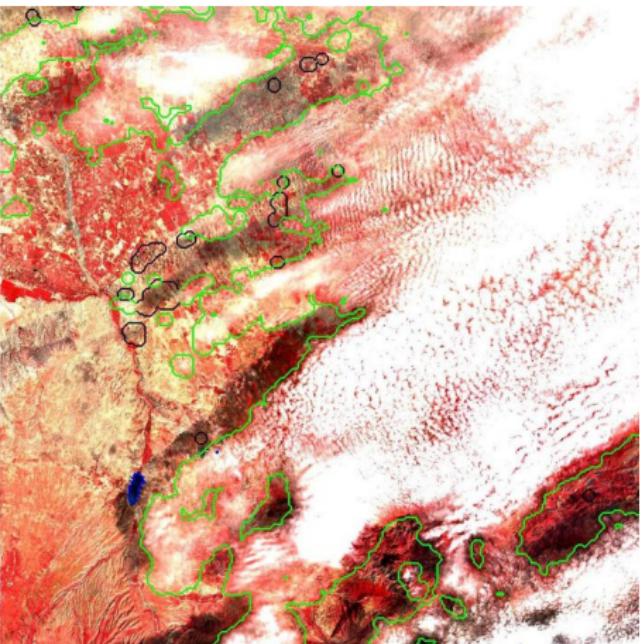
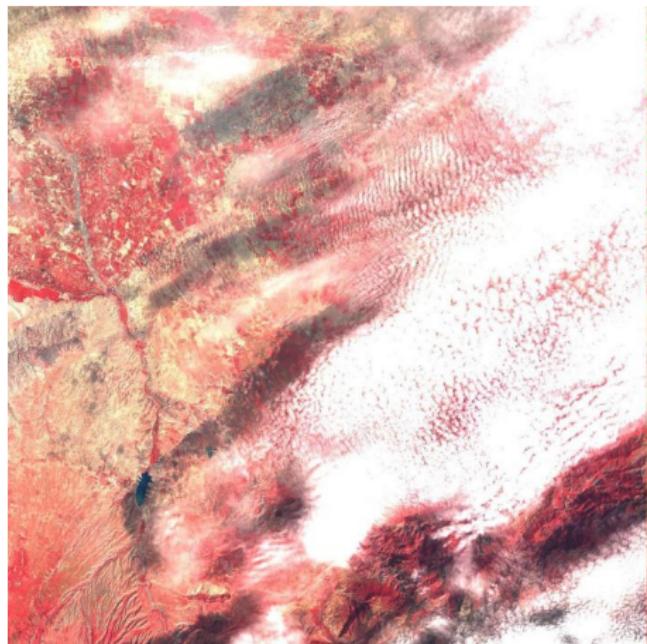
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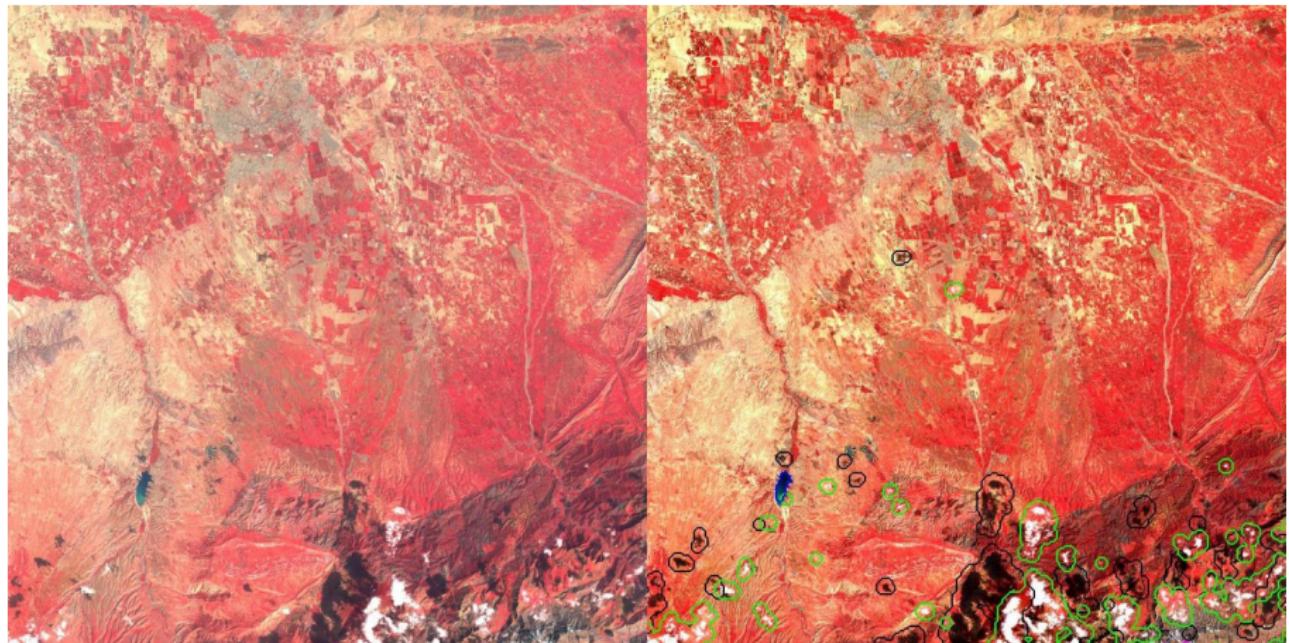
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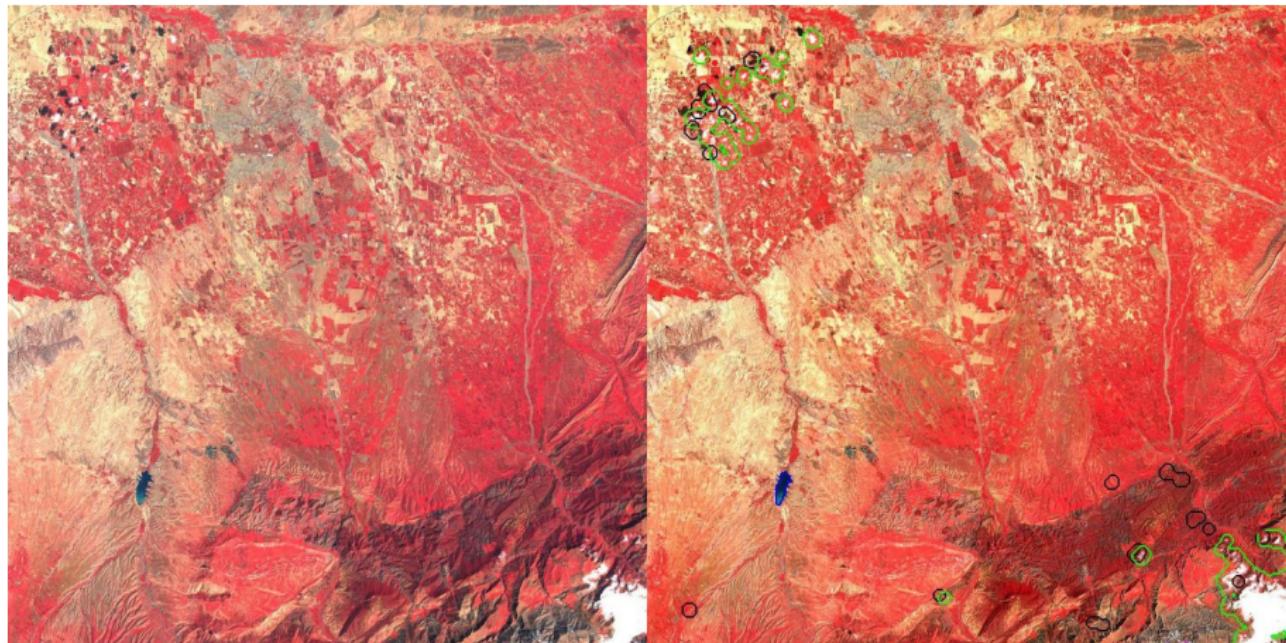
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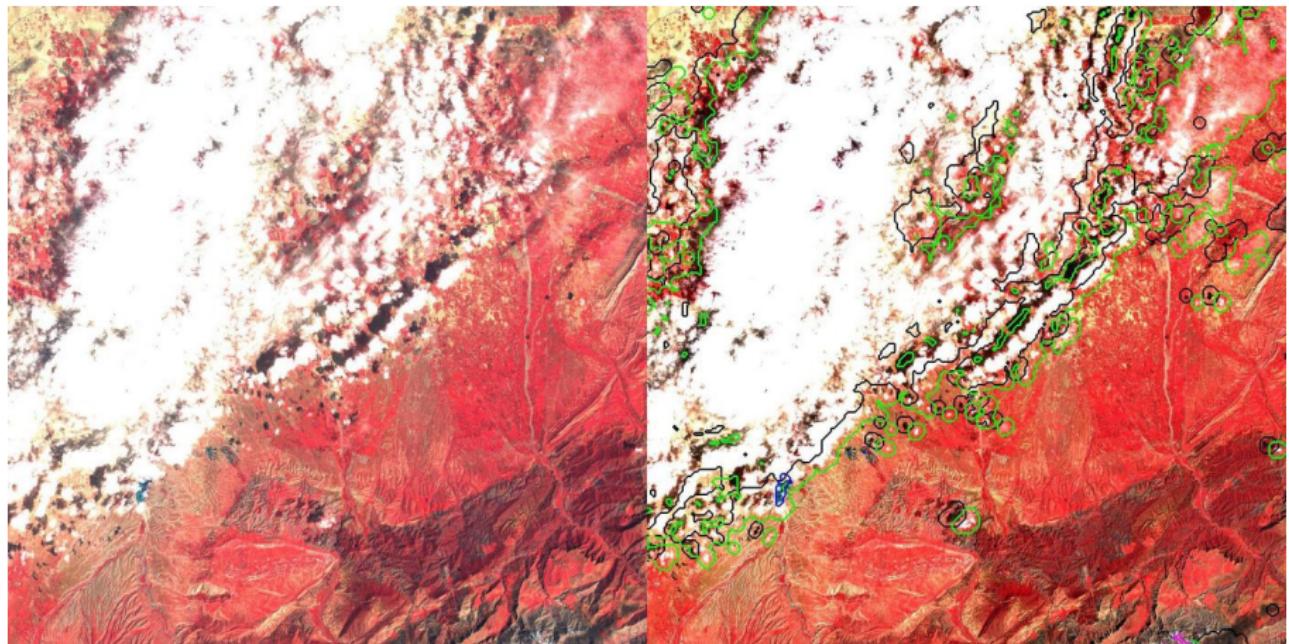
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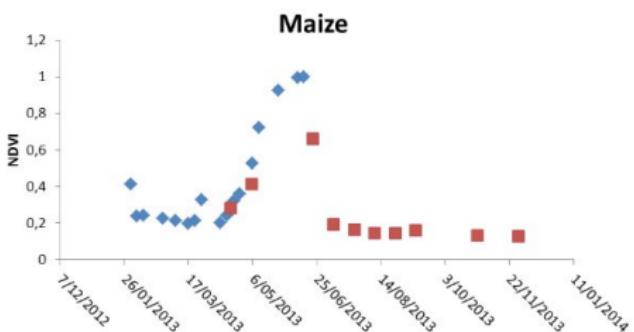
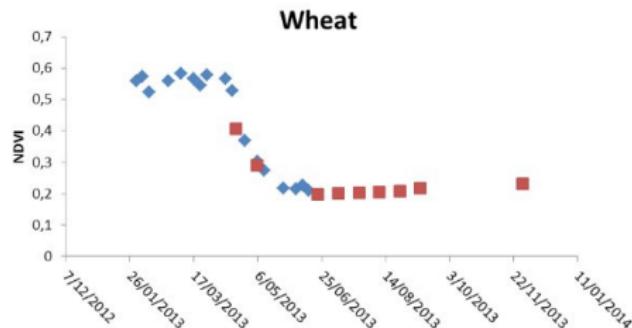
- ▶ Example over Morocco, February and March



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

Simulated Sentinel-2 time series from Take5 data

- Smoothness of reflectance profiles (Morocco)



Blue Take5, Red Landsat8

European SPOT4 (Take5) sites



Processing and Data Access

Data Production

- ▶ L1C and L2A Images produced at the French Land Data Center THEIA (created end of 2012)
- ▶ Production MACCS prototype L2A processor developped at CESBIO
 - MultiSensor Atmospheric Correction and Cloud Screening
 - Applicable to Formosat-2, Take5, LANDSAT (5,7,8), Venus and Sentinel-
- ▶ MACCS operational version (CNES) now implemented at THEIA

Free Data download

- ▶ from THEIA web site : <http://spirit.cnes.fr/take5/>

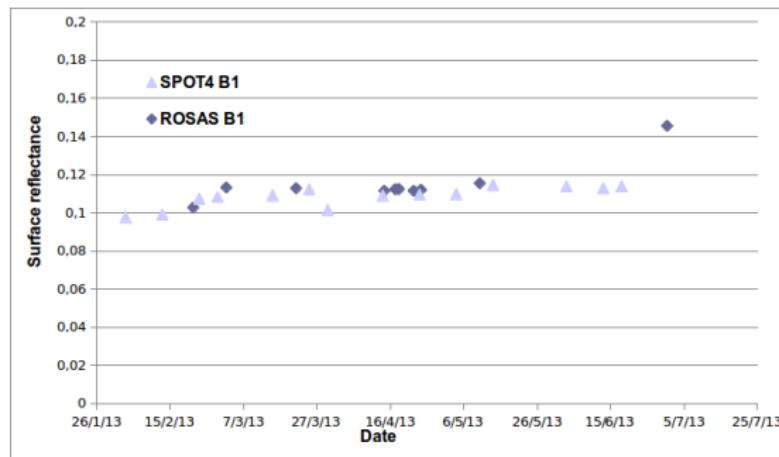
L2A methods

- ▶ MACCS uses the time dimension to better detect clouds and aerosols
- ▶ Some validation results already presented here 4 years ago
- ▶ Many other results shown at Sentinel-2 Symposium in May
- ▶ See also <http://www.cesbio.ups-tlse.fr/multitemp/>



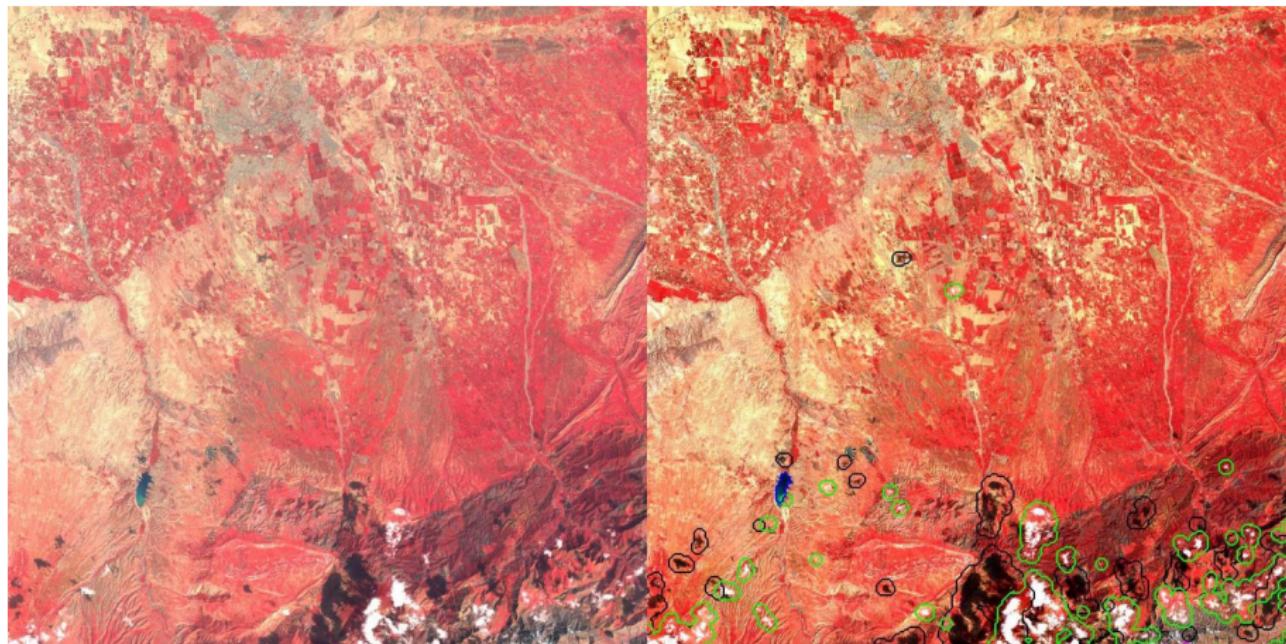
Surface Reflectance validation using La Crau Rosas station

- ▶ CNES owns and operates 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



Multi-temporal detection of clouds and aerosols

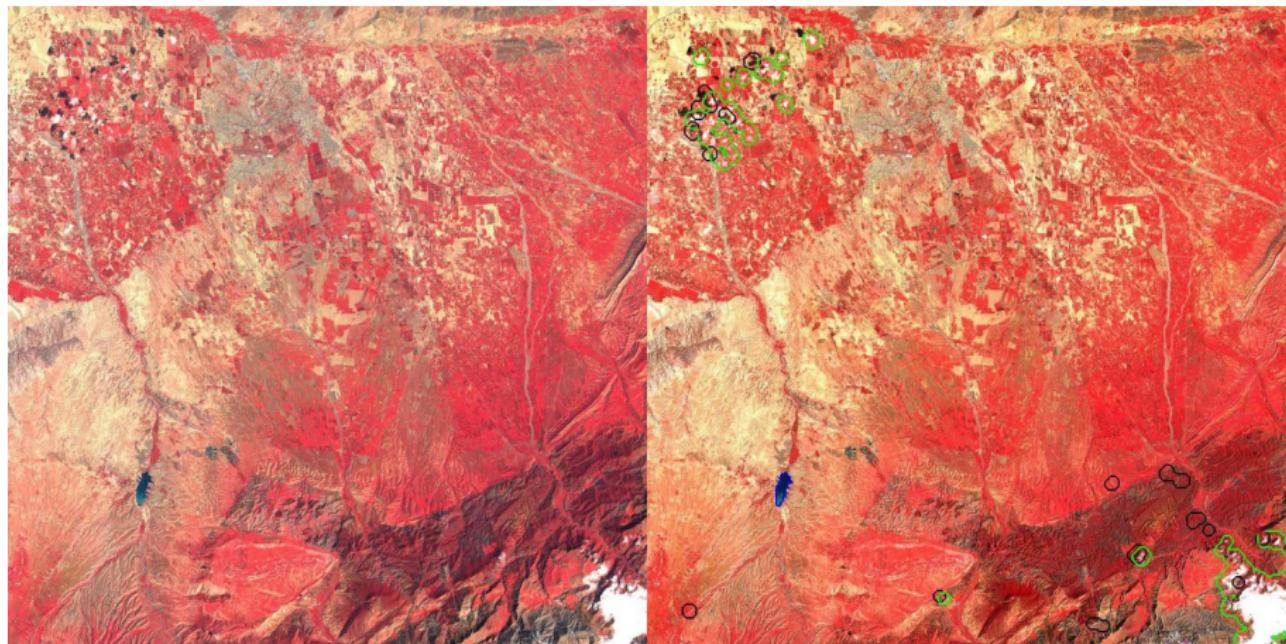
- ▶ Multi-temporal detection of clouds



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

Multi-temporal detection of clouds and aerosols

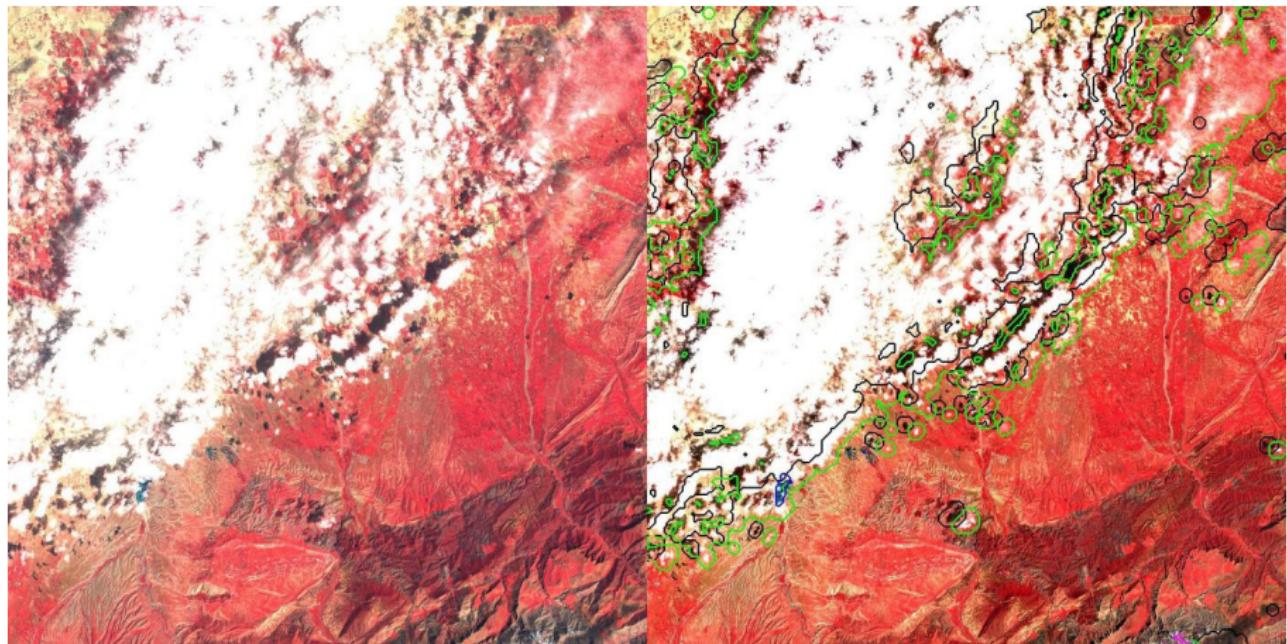
- ▶ Multi-temporal detection of clouds



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

Multi-temporal detection of clouds and aerosols

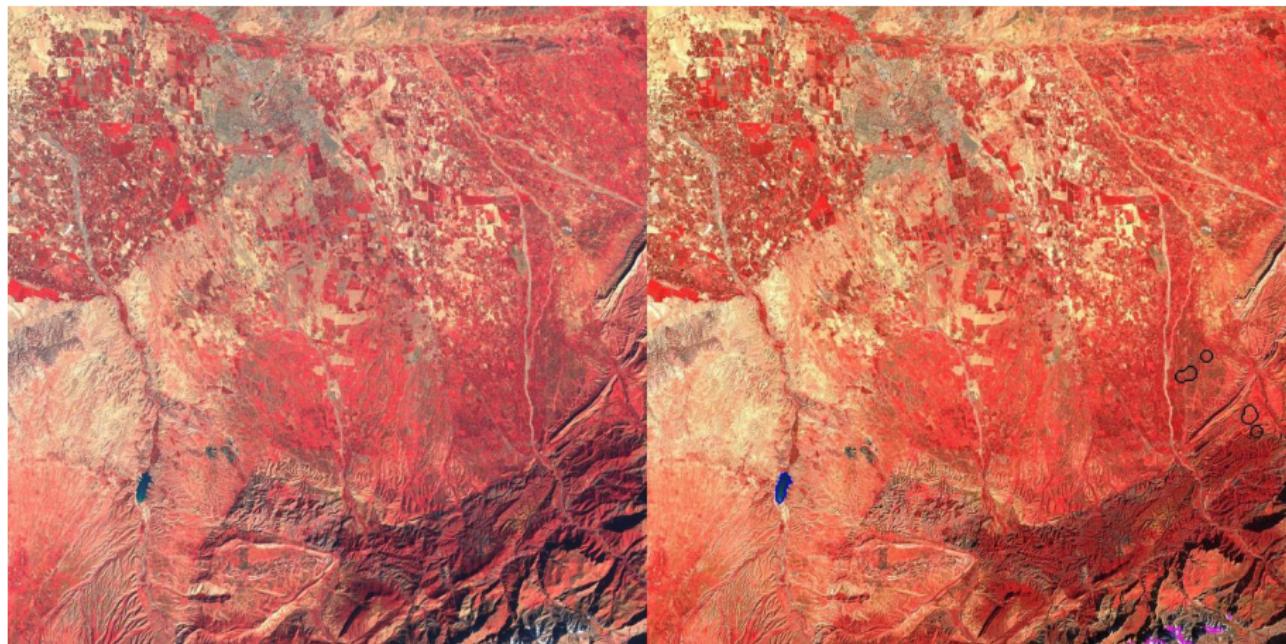
- ▶ Multi-temporal detection of clouds



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

Multi-temporal detection of aerosols

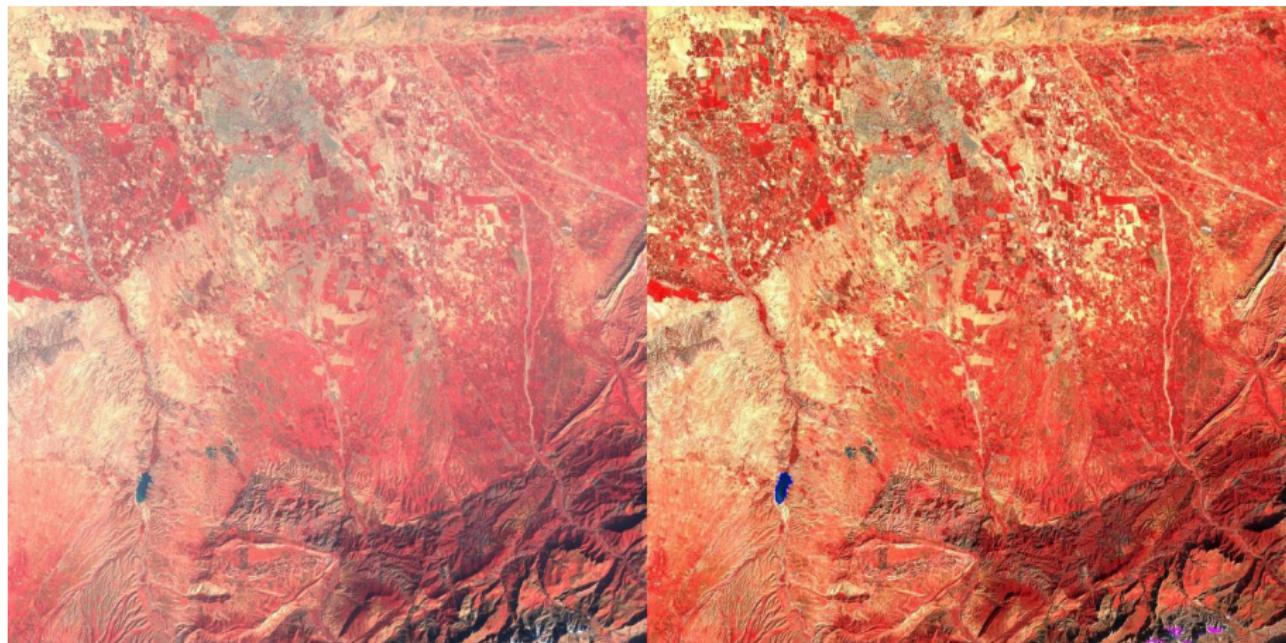
- ▶ Multi-temporal detection of aerosols



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

Multi-temporal detection of aerosols

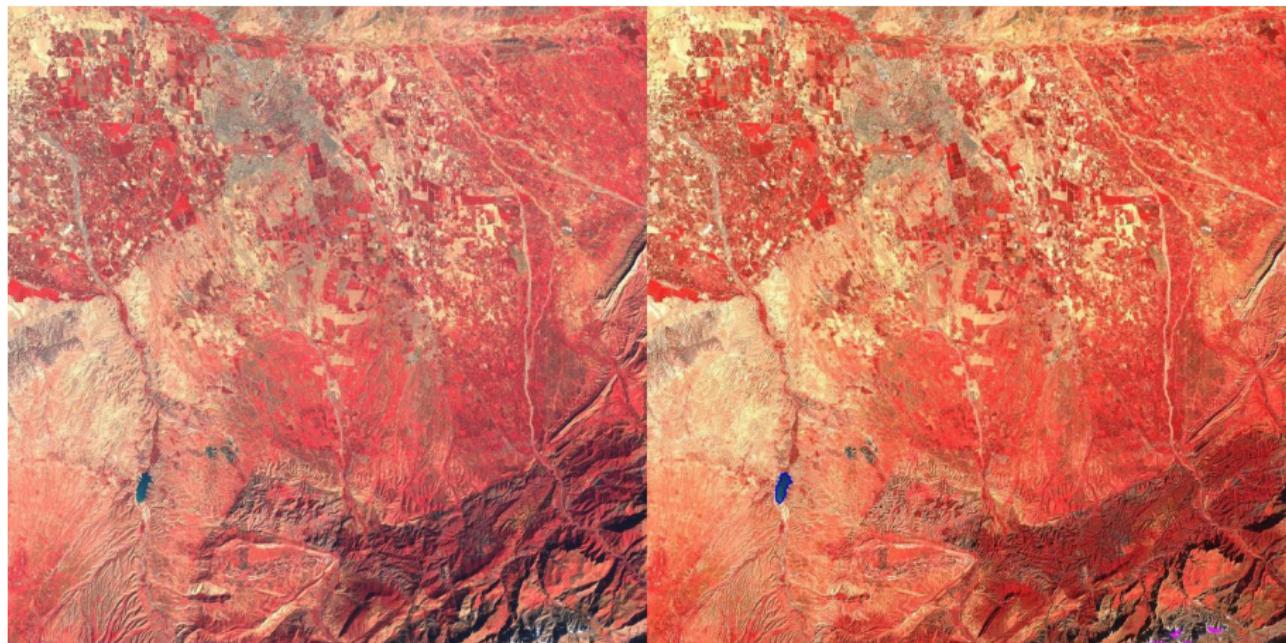
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TOA Reflectance (L1C) => Surface Reflectance (L2A)

Multi-temporal detection of aerosols

- ▶ Multi-temporal detection of aerosols

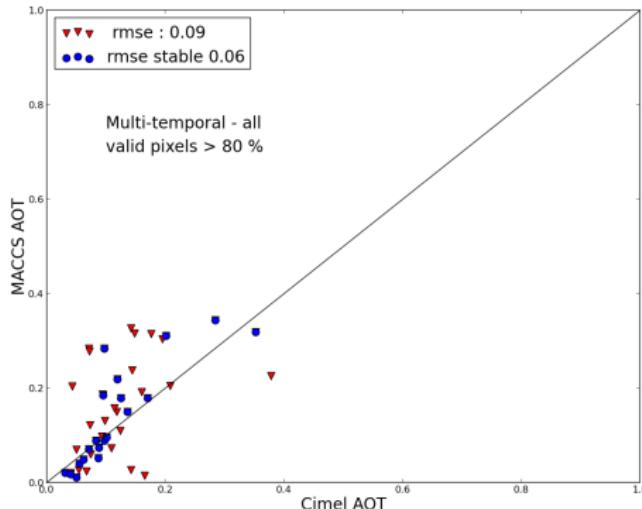


TOA Reflectance (L1C) => Surface Reflectance (L2A)

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 : Gwangju, Korea
- ▶ same aerosol model for all sites



Level 3A product : monthly synthesis

What for ?

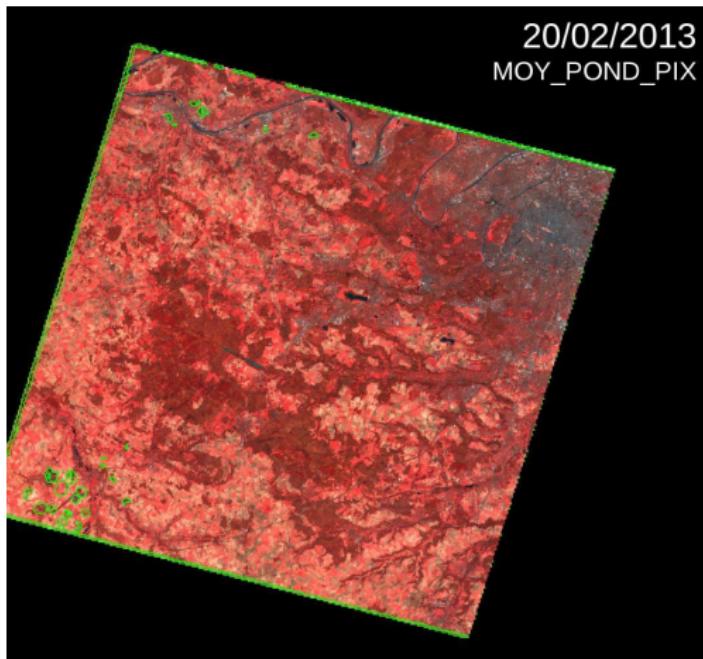
- ▶ Provide monthly cloud free images without gaps
- ▶ Reduce data volume, but information loss, less accuracy in terms of dates
- ▶ Easy to use, advanced users should rely on Level 2A.
- ▶ How would it be used ?
 - As if the image had been acquired at the middle of the month
 - Then average all cloud free reflectances
 - Or only select the best date for each pixel, and provide acquisition date
 - Would users use that date ?

Our composite product

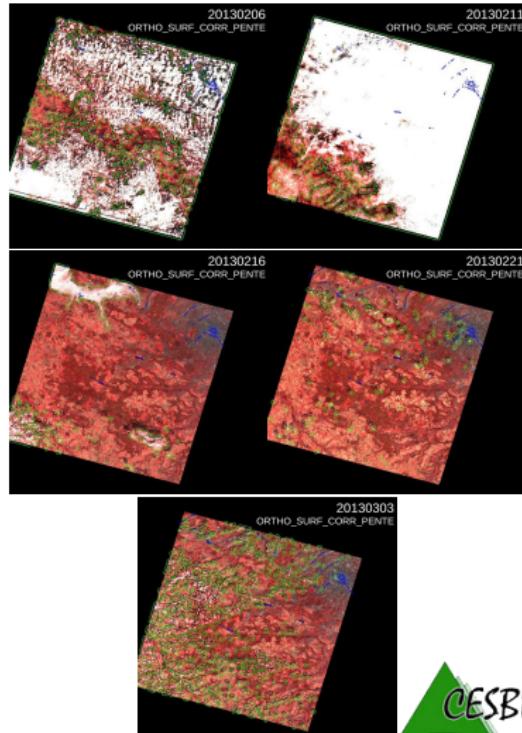
- ▶ Weighted average
 - more weight to images with low cloud amount
 - more weight to pixels far from clouds
 - more weight images with low aerosol content

- ▶ Example of Weighted Average L3A time series from Versailles SPOT4 (Take5) site

L3A February

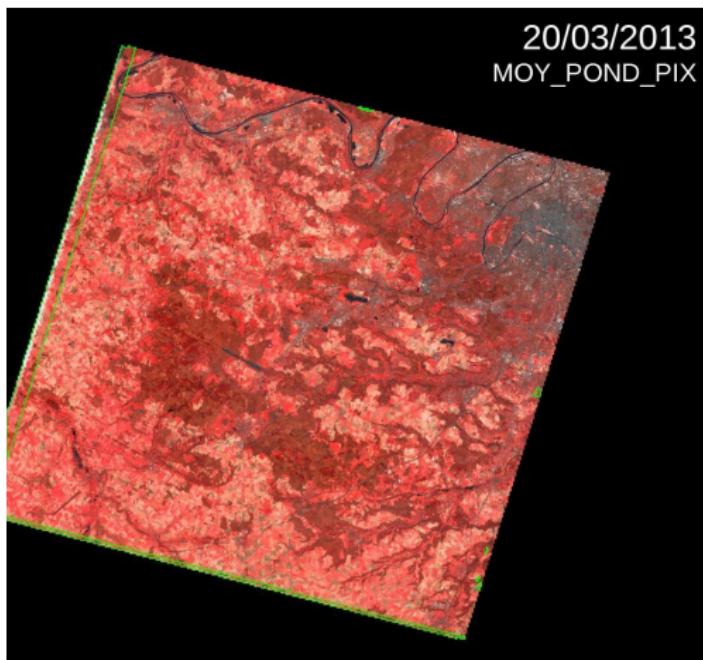


L2A

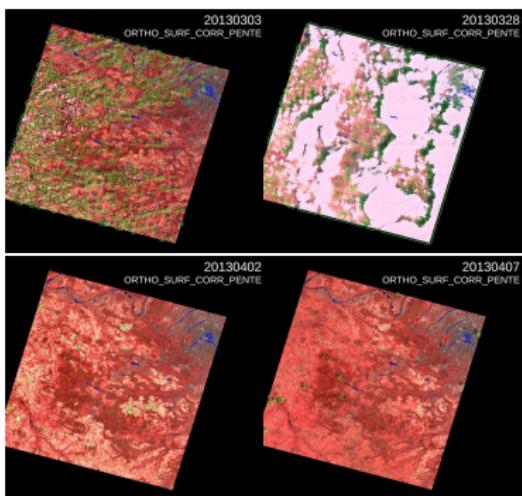


- ▶ Example of Weighted Average L3A time series from Versailles SPOT4 (Take5) site

L3A March

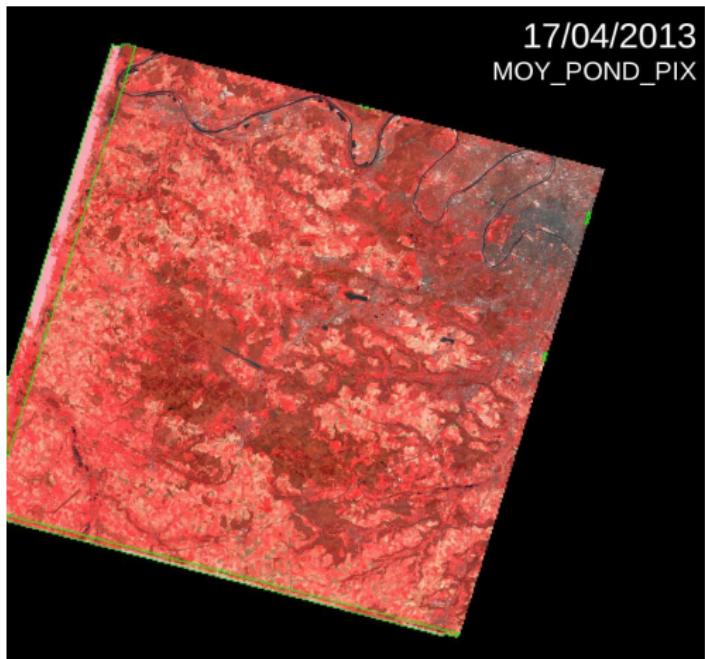


L2A

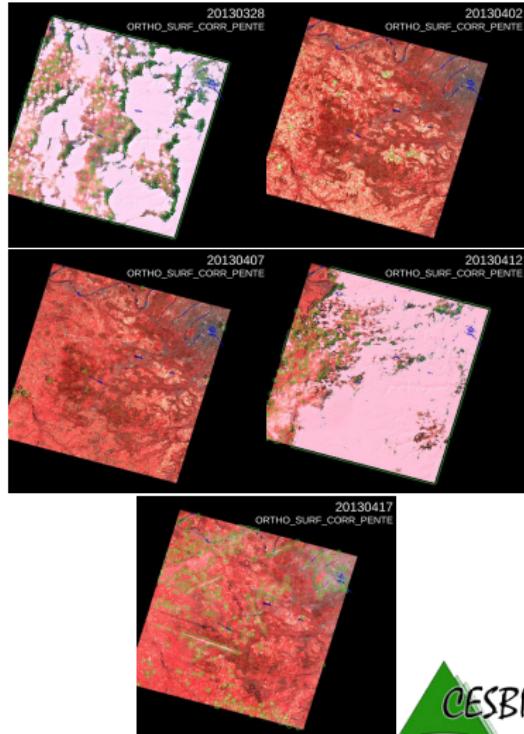


- ▶ Example of Weighted Average L3A time series from Versailles SPOT4 (Take5) site

L3A April

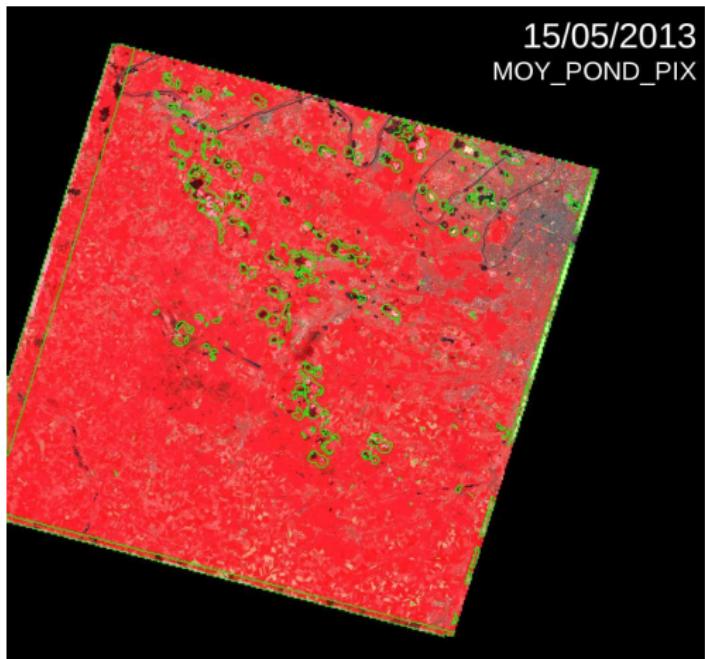


L2A

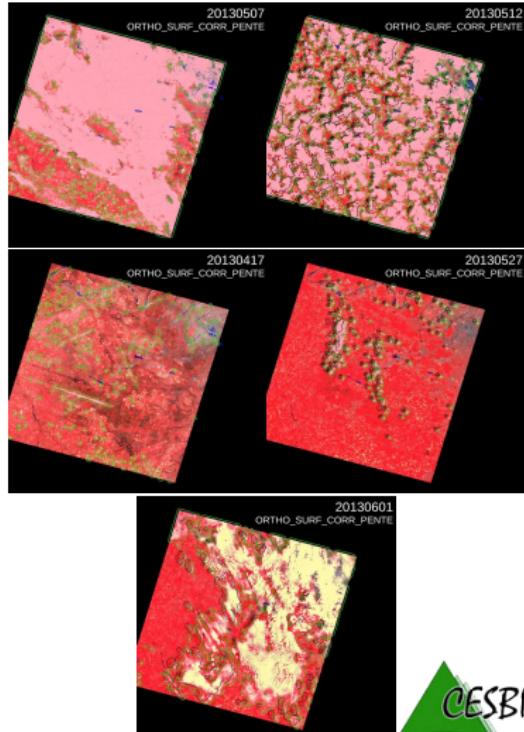


- ▶ Example of Weighted Average L3A time series from Versailles SPOT4 (Take5) site

L3A May

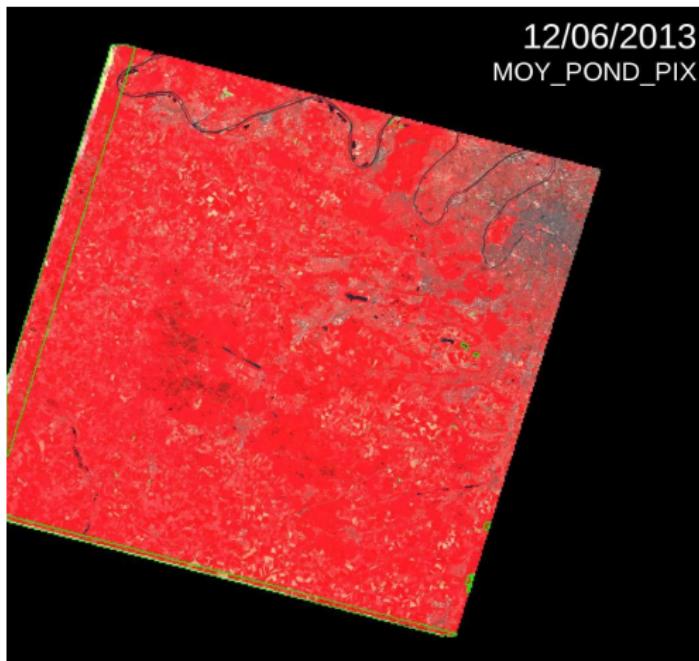


L2A

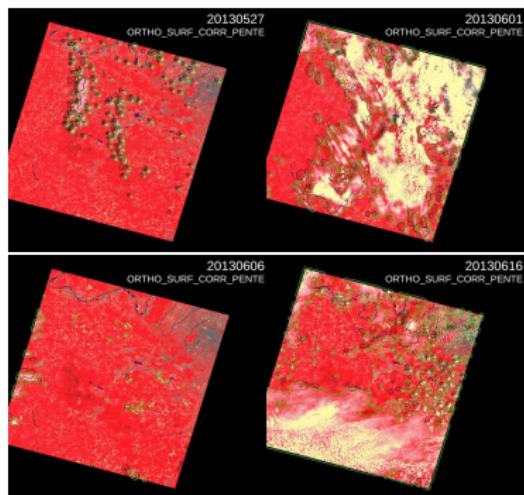


- ▶ Example of Weighted Average L3A time series from Versailles SPOT4 (Take5) site

L3A June

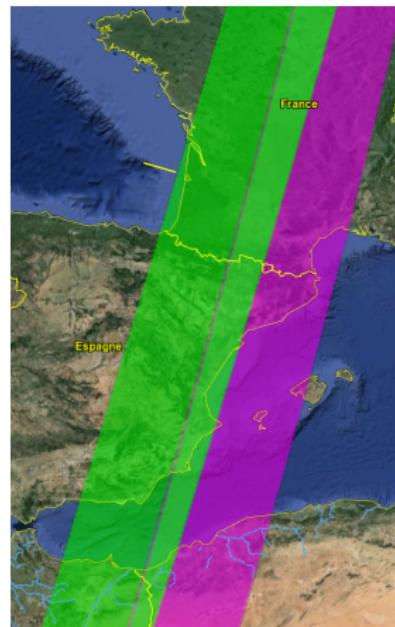


L2A

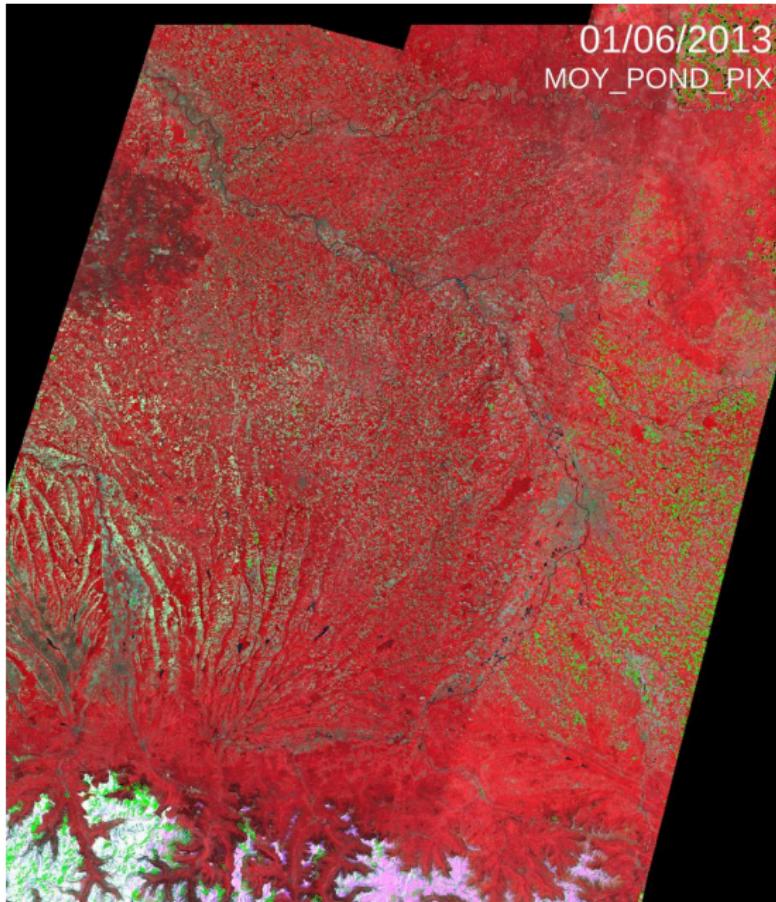


Directional effects correction for composites

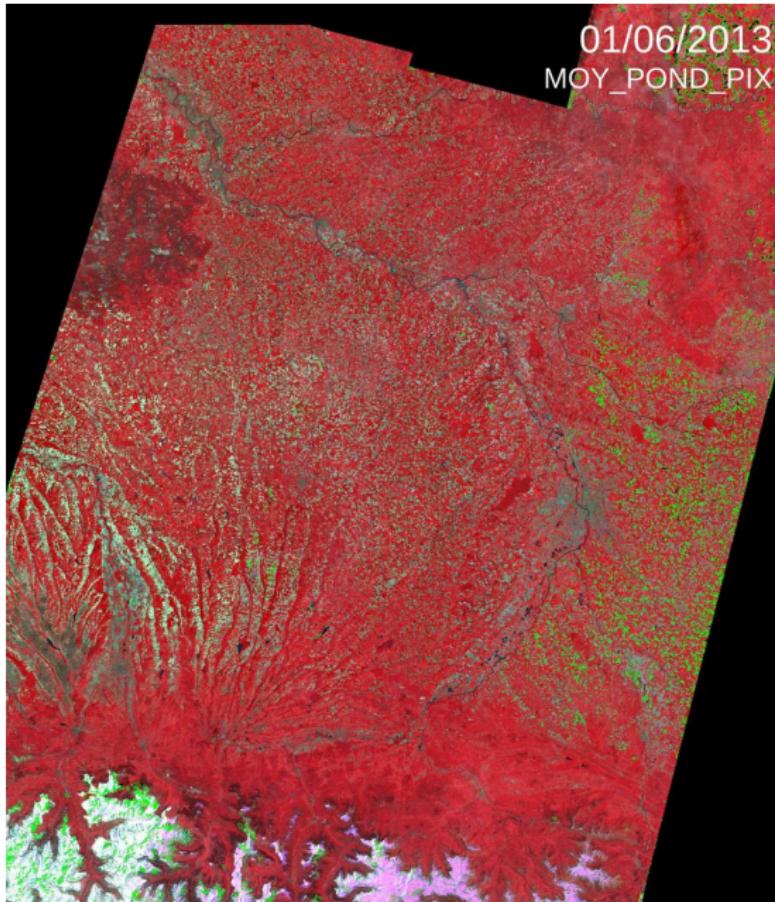
- ▶ Sentinel-2 field of view is +/- 12 degrees
- ▶ Necessity to correct for directional effects to stitch images from different orbits
- ▶ Tested with SPOT4 (Take5) images taken from 2 viewing directions (Maricopa, Sudmipy, Provence, Bretagne)
- ▶ Estimate of directional model coefficients or Ross-Li-Sparse + hotspot model
- ▶ The angle differences being small, we use the same model for all surfaces but water
- ▶ Good results with 4 sites during 5 months
- ▶ To be confirmed with other sites



Directional effects correction for composites



Directional effects correction for composites



Directional effects correction for composites



Without directional correction

Directional effects correction for composites

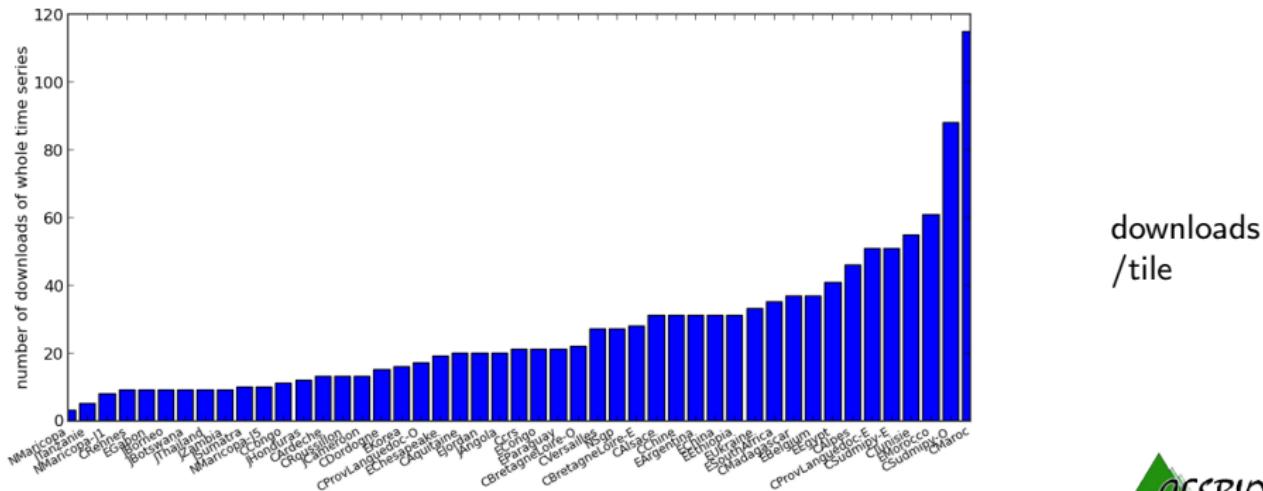


With directional correction

Data usage

Statistics at end of April 2014

- ▶ 3000 downloads among which 1280 full time series (29/site)
- ▶ 75% of downloads are Level 2A.
- ▶ 530 different email addresses, at least 26 countries
 - Fr,It,De,Ma,Usa,Be,Ca,Mg,Tu,Es,Za,Eg,Ru
 - Cn,Br,No,Ar,At,Se,bf,Uk,Pl,Cz,Pt,Cn,Dz

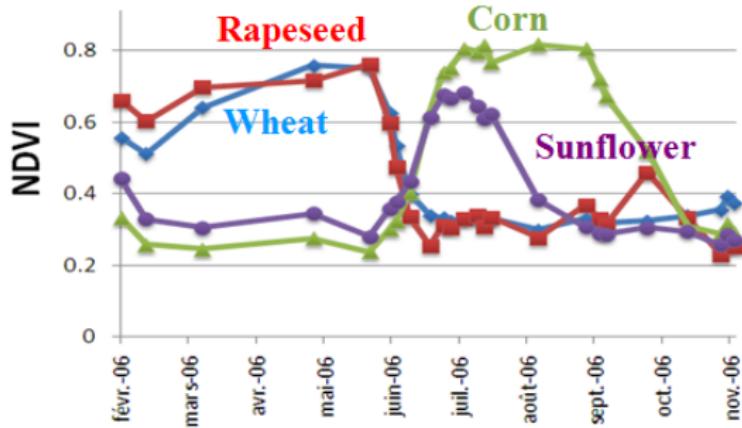


downloads
/tile

Use of time series for land cover

Idea

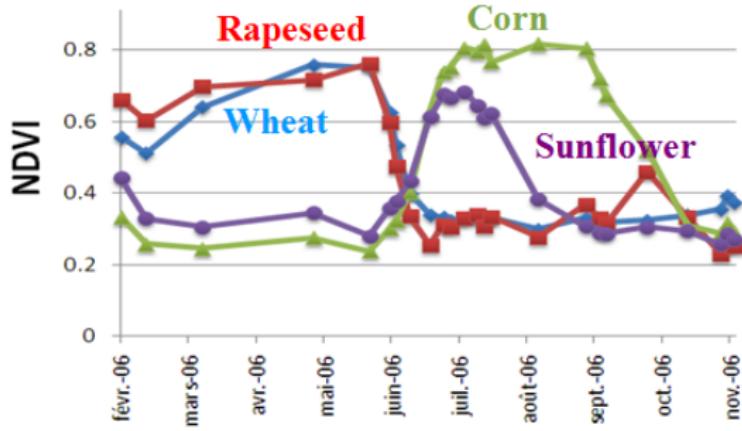
- Vegetation types may be separated thanks to time series



Use of time series for land cover

Idea

- Vegetation types may be separated thanks to time series



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



Data set

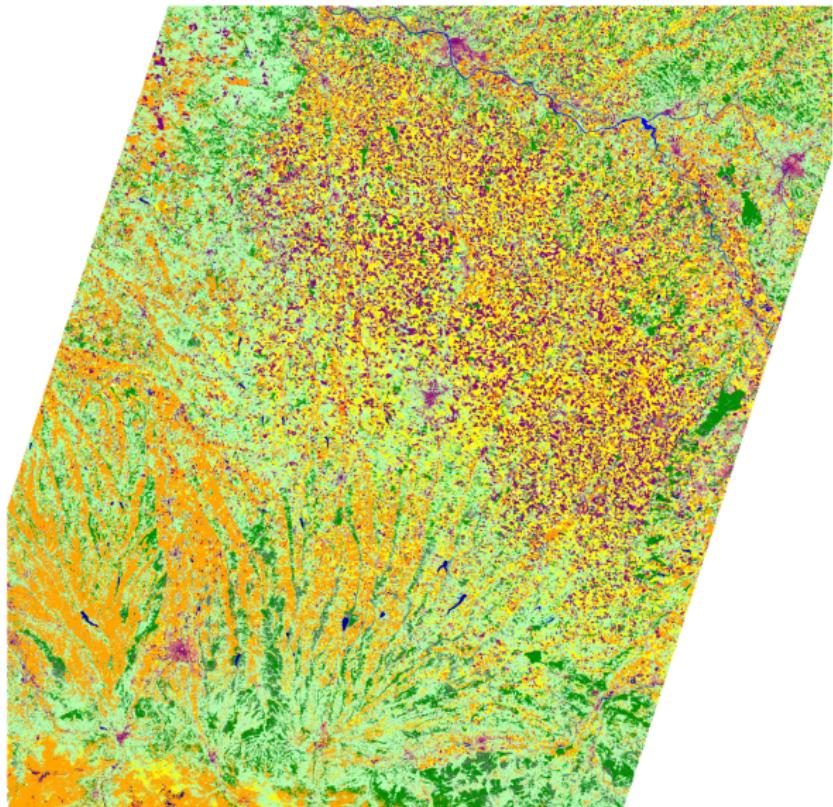
- ▶ First tests with CESBIO's site near Toulouse
- ▶ S4-Take5 : 9 dates, 4 bands, 12500×9500 pixels => 7.7 GO
- ▶ LANDSAT 8 : 8 dates, 4 bands, 12500×9500 pixels => 6.8 GO
- ▶ In situ land cover campaigns (+ Land Cover databases when existing)

Methods

- ▶ Baseline method : Supervised classification with Random Forest from OTB
- ▶ 4 other supervised approaches will be compared (see J.Inglada's poster)



Multi-Temporal classification

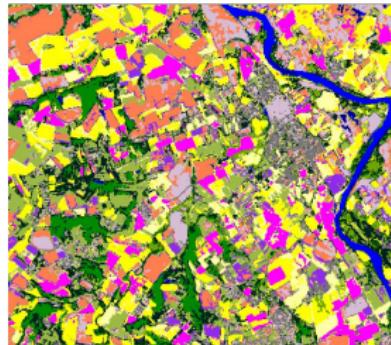


Feuillus	[Dark Green]
Résineux	[Medium Dark Green]
Eucalyptus	[Blue]
Peupliers	[Dark Blue]
Blé	[Yellow]
Colza	[Pink]
Orge	[Light Yellow]
Mais	[Orange]
Tournesol	[Purple]
Sorgho	[Brown]
Soja	[Red]
Pois	[Light Blue]
Jachère	[Grey]
Prairies	[Light Green]
Friche	[Dark Grey]
Eau	[Dark Blue]
Bâti dense	[Light Pink]
Bâti / Industriel	[Red]

Multi-Temporal classification



West Track



East Track

Conclusions

- ▶ Already good performances ($\text{Kappa} = 0.81$)
- ▶ Quick processing (Learning 2mn, Classification 70 mn) thanks to Orfeo ToolBox
- ▶ Sen2-Agri only starts...

RAQRS Talks and Posters using Take5

- ▶ S6.5 Remote Sensing of Water Resources in the semi-arid Mediterranean areas : The Joint International Laboratory TREMA [L. Jarlan](#)
- ▶ S14.2 A follow-up for Sentinel-2 : Sentinel for Global Agriculture Requirements [G. Dedieu](#)
- ▶ P4.42 Algorithm selection for the operational production of crop maps in the frame of the Sentinel-2 Agriculture project : [J.Inglada](#)
- ▶ P3.35 How to think global : Exploring different alternatives for global crop type classification in the framework of Sentinel-2 Agriculture project : [G.Sepulcre](#)
- ▶ P3.37 Exploring the synergies between decametric crop/land cover classification with biophysical variable retrieval and disaggregation of 300 m FAPAR : [F.Waldner](#)
- ▶ P3.12 Estimation of water requirements and biomass of maize crops using high spatial and temporal resolution images and a simple crop model, in the perspective of the Sentinel 2 mission [M.Battude](#)
- ▶ P3.28 Potential summer crop detection using high spatial resolution image time series [C. Marais-Sicre](#)

Conclusions

A successful experiment

- ▶ Everything worked well in a short time frame : satellite, processors
- ▶ Level 2A Multi-temporal methods works well even without a blue band
 - The French Land Data Center (THEIA) will produce Sentinel-2 L2A data over 5M km², using MACCS
 - Already used to produce LANDSAT 8 L2A data
 - Extension to the whole world to be discussed
- ▶ Large number of users shows how Sentinel-2 is awaited.
- ▶ Very large diversity of applications, starting with land cover
- ▶ Two events to see SPOT4 (Take5) results :
 - A Spot4 (Take5) meeting in CNES on November 18th and 19th 2015
 - A special issue is open at MDPI remote sensing : deadline February 2015

SPOT 5 (Take5)

- ▶ SPOT5 (Take5) nearly decided (90% likelihood)
- ▶ With a Large ESA contribution
- ▶ April 2015 - August 2015 (Sentinel 2 should take over for the end of the year)
- ▶ Emphasis on Northern Hemisphere summer crops
- ▶ Call for site proposals to be issued very soon by ESA
- ▶ Will be announced here : <http://www.cesbio.ups-tlse.fr/multitemp/>