SPOT4 (Take 5) validation, user feedback and lessons learned

O. Hagolle, M.Huc, CESBIO, C. Dechoz, S. Sylvander, V. Lonjou , CNES
V. Poulain, THALES, D. Clesse, CAP GEMINI, M.Claverie, U.Maryland

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Outline

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- Ortho-rectification
- Cloud masks
  - Lessons learned about observed nebulosity
- Aerosols and Atmospheric correction
- Surface reflectance
- User feedback and lessons learned

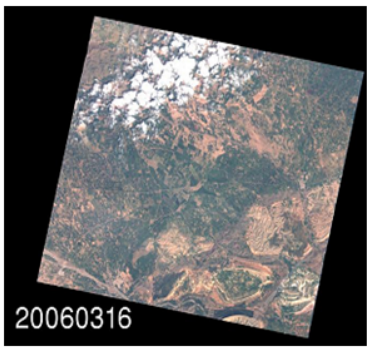
Products

Production

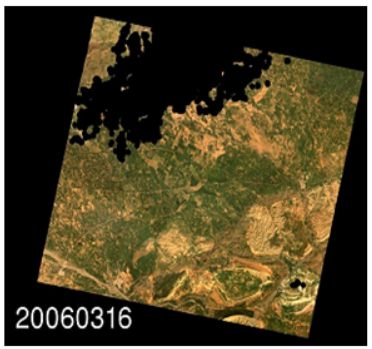
- THEIA Data Center produced and distributed SPOT4 (Take5) products
  - It was the first production of THEIA MUSCATE Center at CNES
  - Using a prototype ground segment developped at CNES by CAP GEMINI
  - Using a L1C processor from CNES, and a L2A processor from CESBIO
  - V1.0 : July 2013, V2.0 : Jan 2014.
  - A very nice distribution tool : http://spirit.cnes.fr/Take5

Products

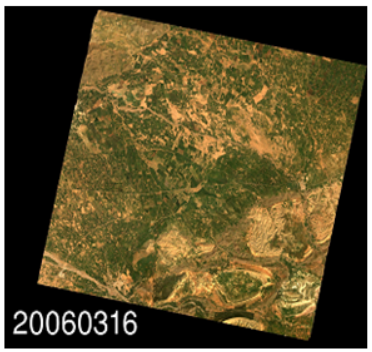
- Level 1C product : orthorectified images in TOA reflectance
- Level 2A Product : orthorectified images in Surf. reflectance with cloud masks
- Level 3A Product : Monthly synthesis of L2A (not distributed, but available)



Level 1C:



Level 2A:



Level 3A:

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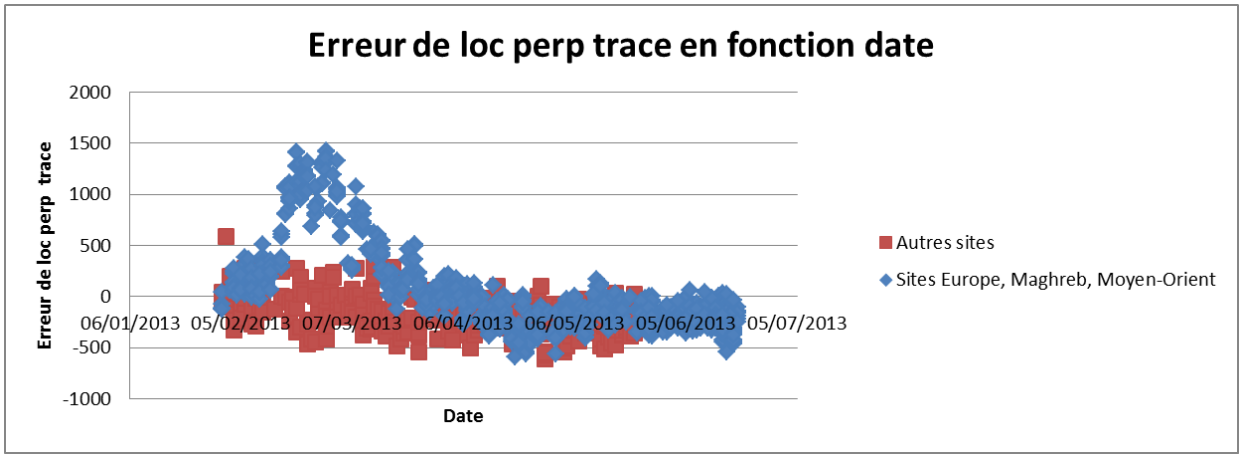
L1C Ortho-rectification

Method

- Old SPOT4 satellite had poor location performances (errors up to 1500m)
- Ground control points (GCP) to ortho-rectify images accurately
- Reference images are used to obtain accurate GCP via automatic matching
- Use of CNES SIGMA Tool
- First operational use of SIGMA with very cloudy images
  - Above France : Geo-Sud RapidEye cover of France, processed by IGN
  - LANDSAT 8 elsewhere



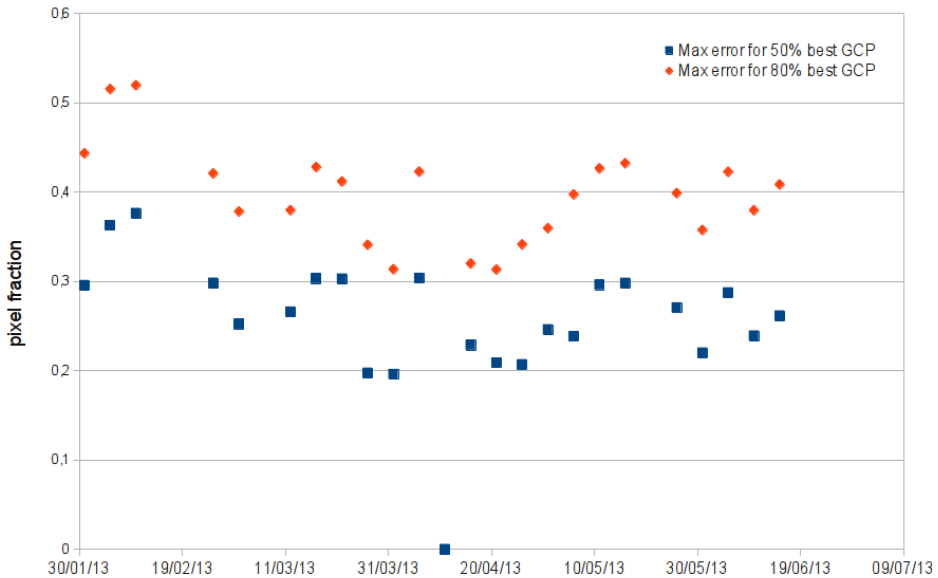
SPOT4 Take5 localisation

L1C Ortho-rectification

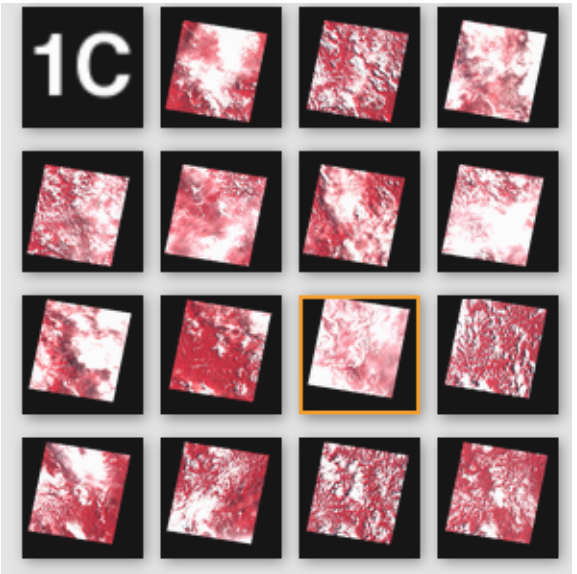
Results

- Good overall registration performances : 80% of measures within 0.5 pixel
- A few images with geolocation errors (at least 2) due to large cloud coverage
- 1 site with poor performances, : Borneo
  - Not a single image with less than 50% clouds in the whole LANDSAT archive
  - Errors up to 10 pixels

Morocco



Borneo



L1C Ortho-rectification

lessons learned

- Difficulty related to SPOT4 bad location performance
  - Necessity to search GCP within a very large window
  - Higher probability of finding incorrect GCP
  - => Need to add a stricter filtering of GCP quality
- Difficulties related to the large presence of clouds, including broken clouds
  - SIGMA GCP extraction was hierarchical to optimize computation time
    - First iteration at coarse resolution with large research window
    - Then iterations at finer resolution
  - Problems with broken clouds at a lower resolution
  - => all iterations at full resolution

impact

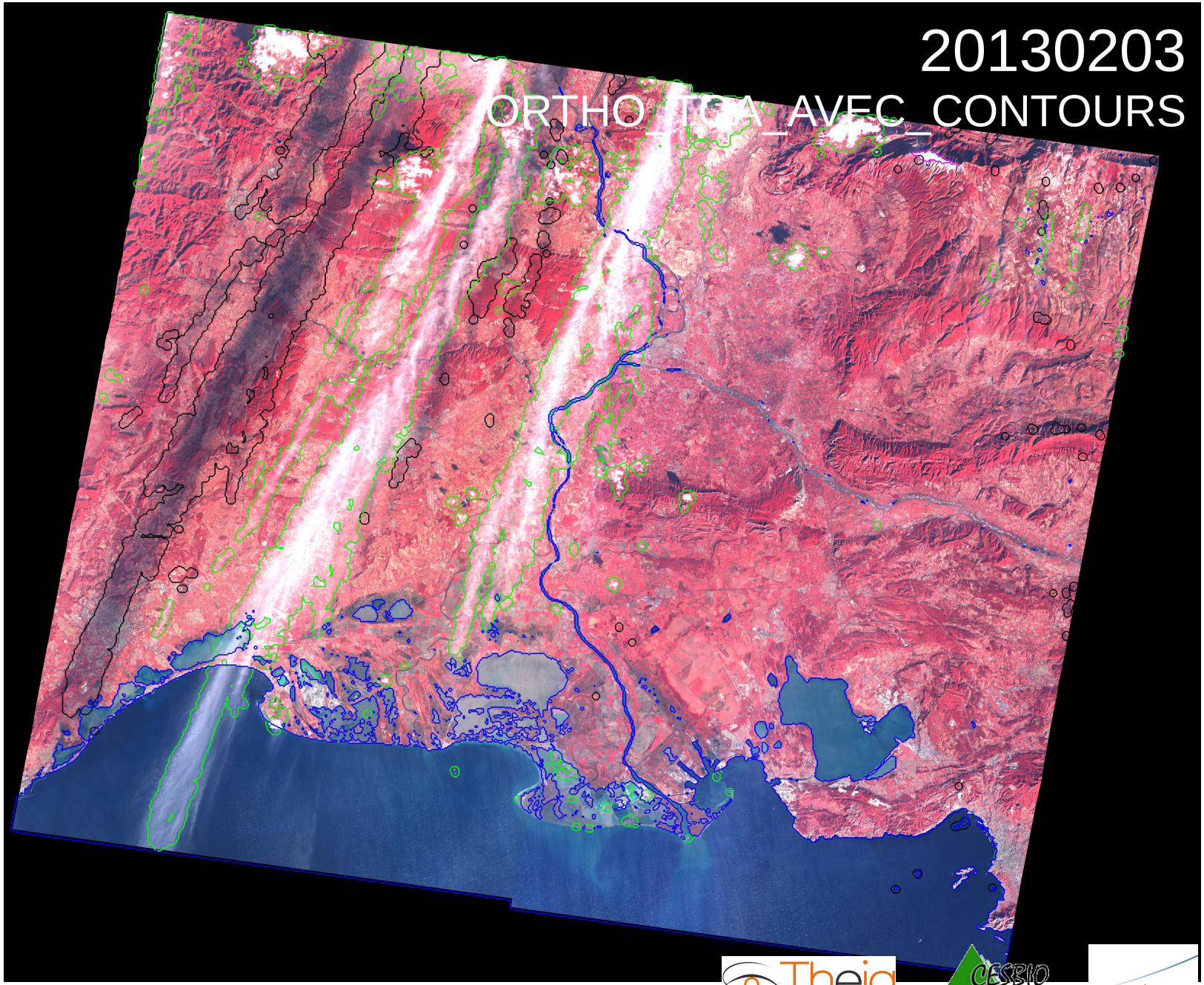
- Reused for THEIA production of Spot World Heritage and LANDSAT 5

Level 2A

Level 2A processing

- THEIA used CESBIO's prototype for Level 2A production (Thanks M. Huc)
- MACCS method uses :
  - A multitemporal cloud/cloud shadow mask
  - A multitemporal water mask
  - Multi-temporal estimates of Aerosol Optical Thickness (AOT)
    - Usually helped by a muti-spectral method for AOT, but requires a blue band
  - Atmospheric correction based on Look-up tables
  - Correction for adjacency effect
  - Correction for illumination variations due to terrain
- An operational version of MACCS was developped by CNES, now integrated into MUSCATE

L2A Masks : Clouds, Shadows, Water, Snow



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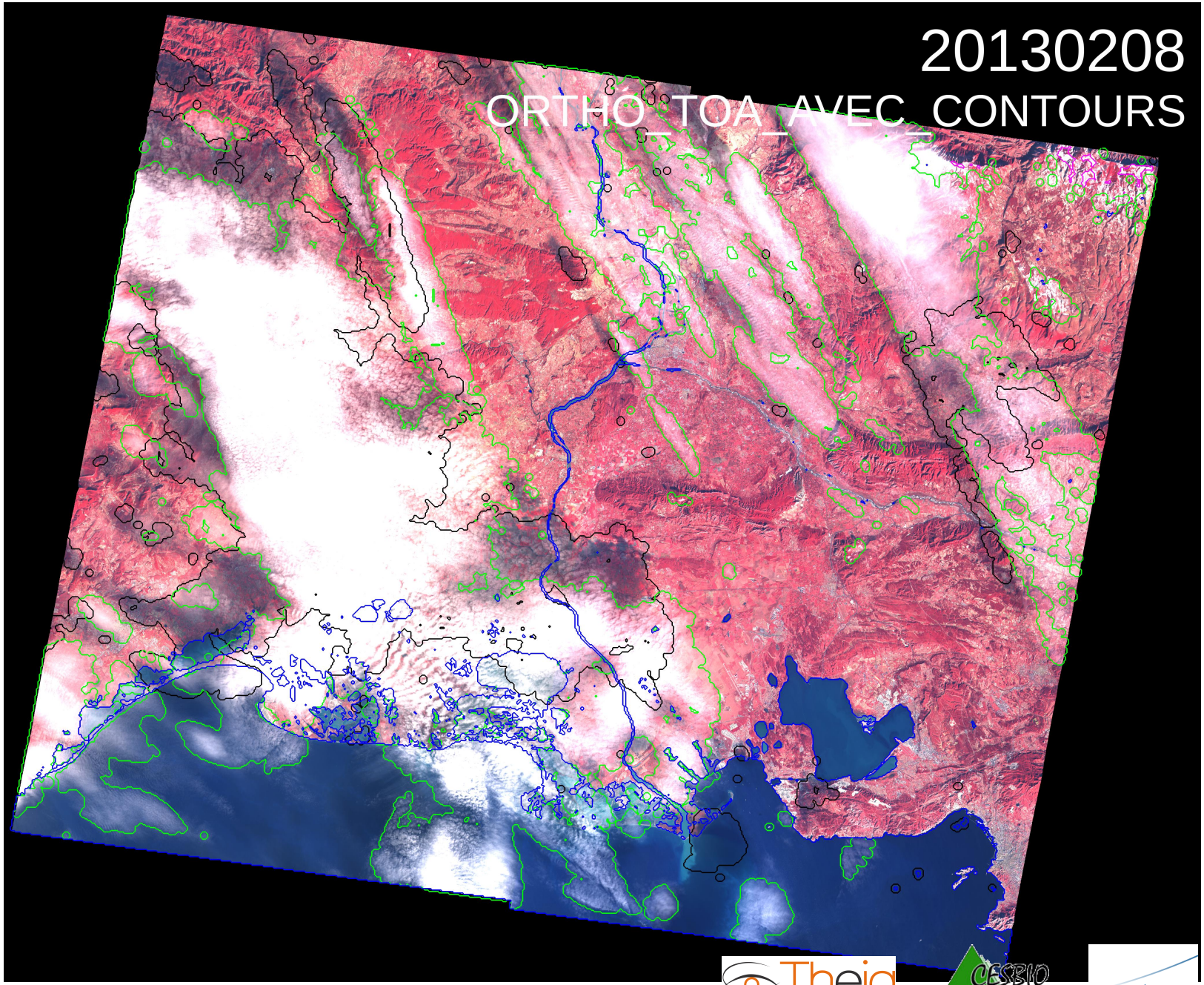

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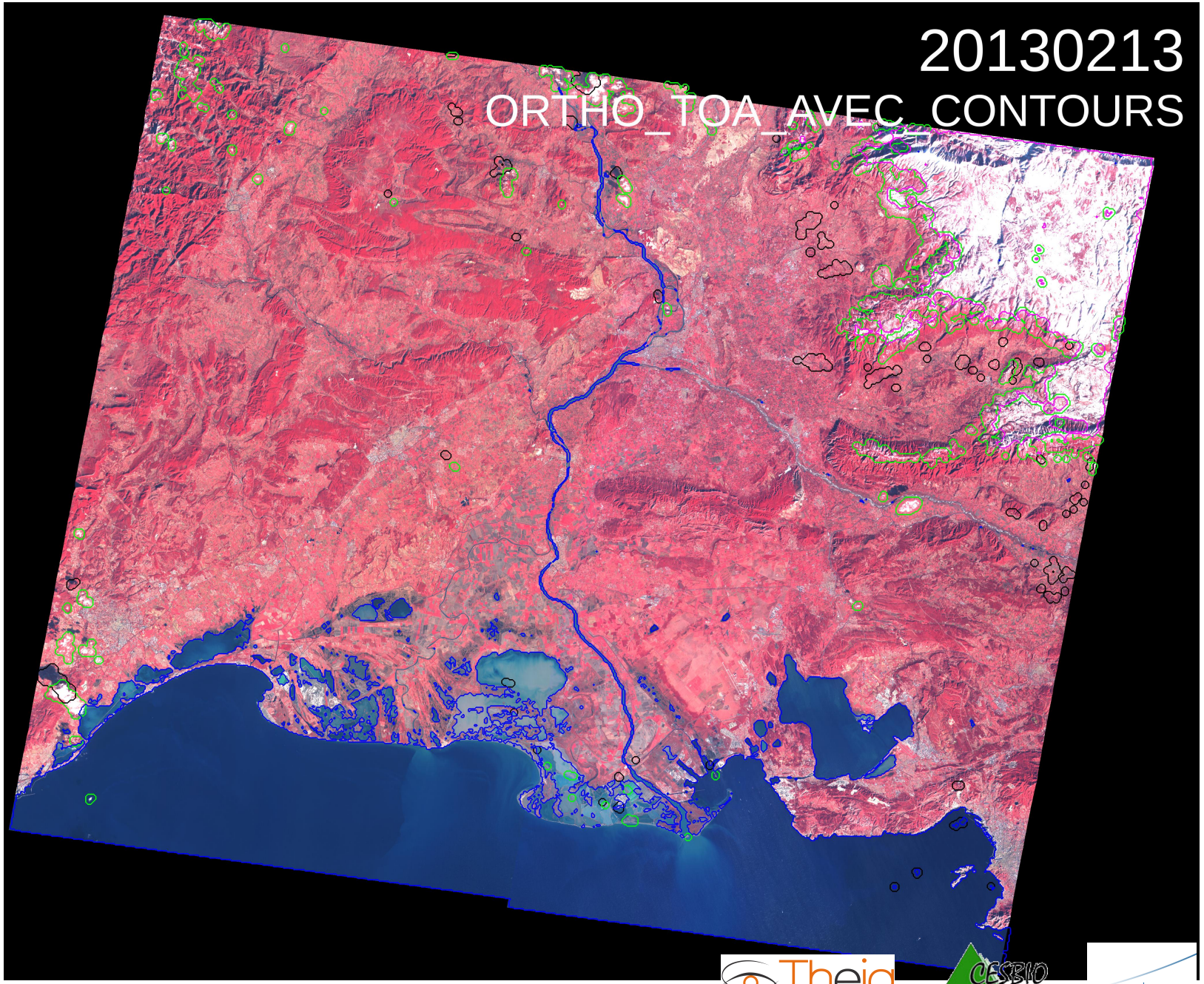
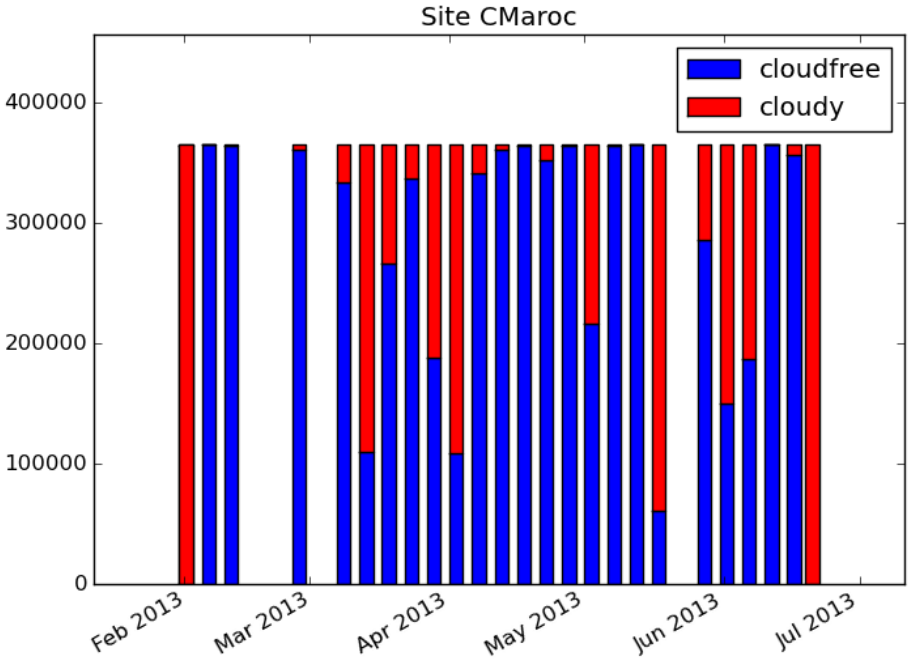


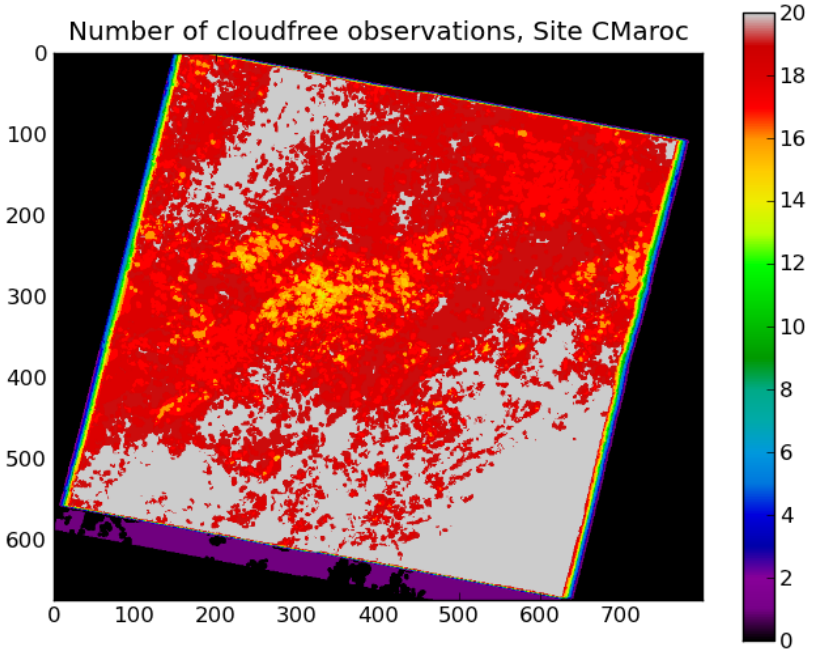
L2A Masks : Clouds, Shadows, Water, Snow

lessons learned and user feedback, so far

- Good overall quality, despite absence of a blue band
- Users that process large sites happy to have access to a cloud mask
- Users interested by a small region select manually the dates to process
- Cloud mask computed at 200 m resolution
  - Bad identification of small broken clouds, problematic in tropical regions
  - Dilation of cloud mask can discard large regions of cloud free pixels
  - => test at 100 m resolution for SPOT5 (Take5)
  - => impact on processing time
- Missed shadow detection for large clouds that overlap most of the shadow
  - Solution probably found but not yet tested and implemented

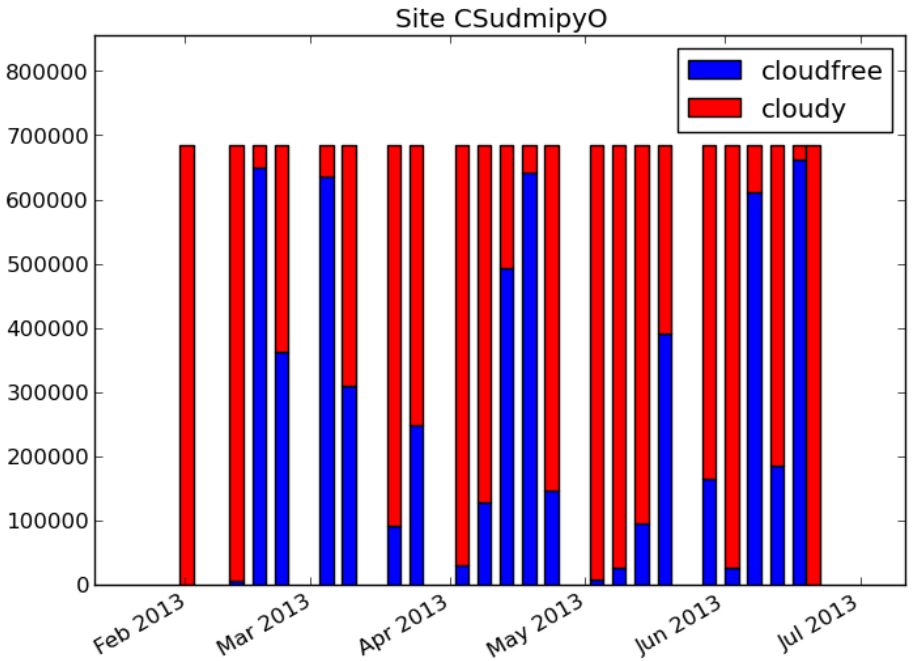
Cloud Free Observations

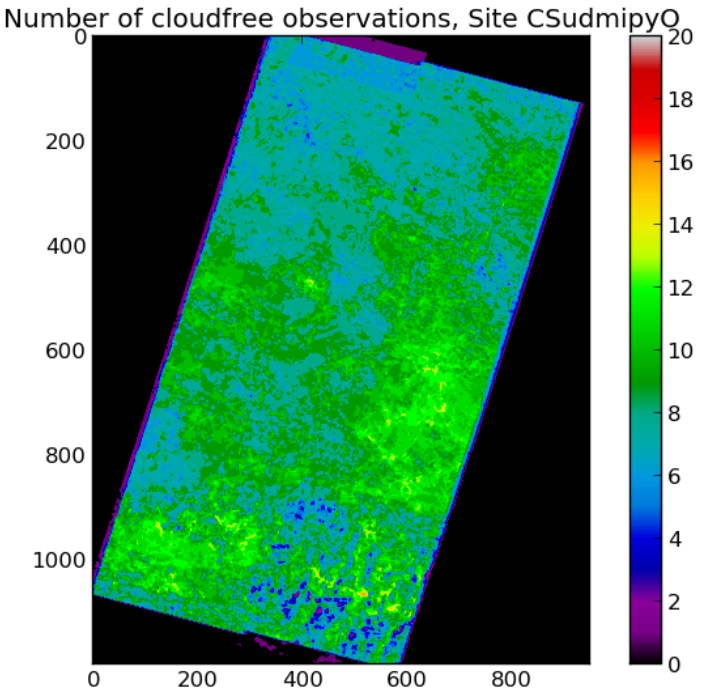




Morocco Tensift

Cloud Free Observations





France Midi-Pyrénées

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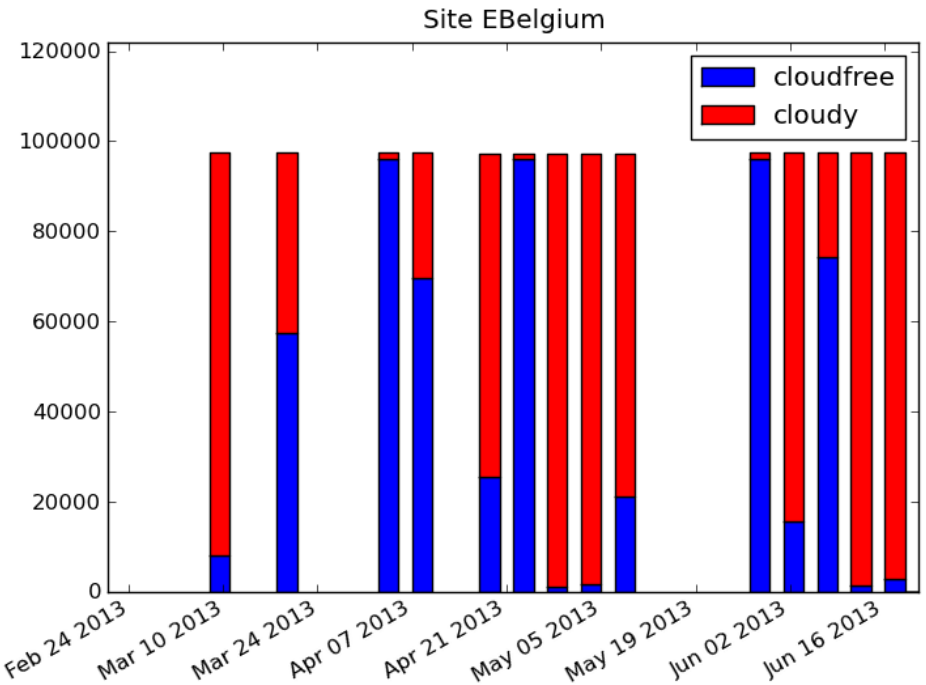
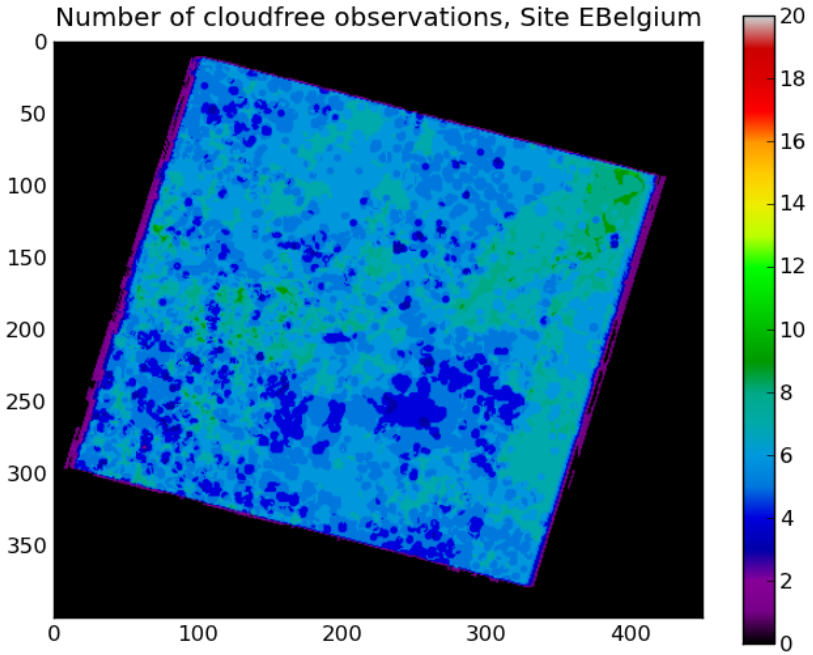
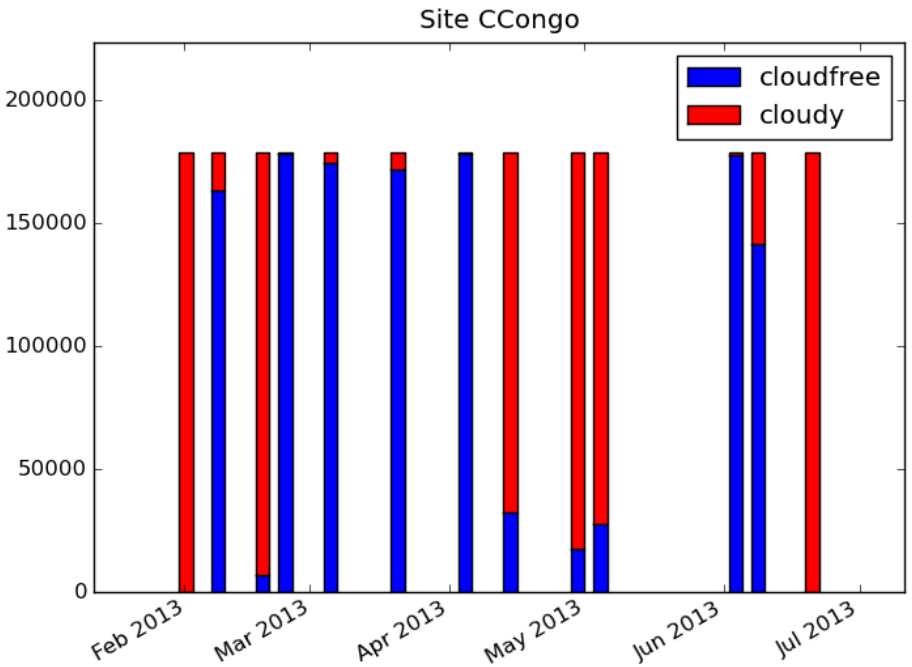
Cloud Free Observations

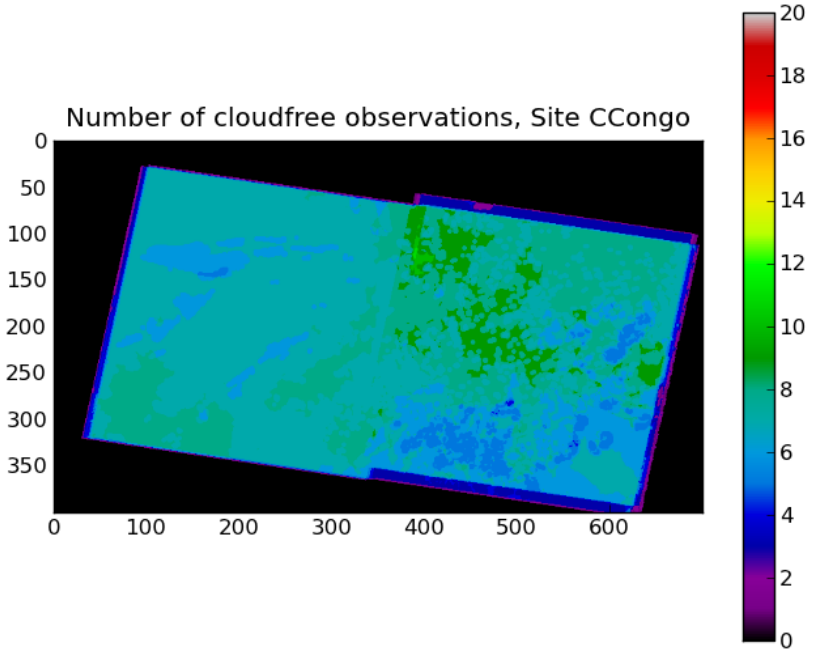




Belgium

Cloud Free Observations





Congo (1)

Lessons learned

Cloud Free Observations

- Very nice time series over a lot of sites :
  - Morocco, Provence, Paraguay, Angola, Maricopa, Congo...
- Not far from 1 clear observation/month for most sites
  - Despite bad weather in Europe
    - Except in Belgium, Alsace, Aquitaine, or even Tunisia
  - And with exceptions in Equatorial regions
- Big sites always have clouds
  - Necessity to develop methods which are robust to data gaps
  - Composite products should be useful (Level 3A)

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Message

- With 10 days repetitivity, SPOT4(Take5) would have failed in Western Europe
- Necessity to launch S2-B shortly after S2-A
- Next S2 generation should consider increased repetitivity

Atmospheric correction

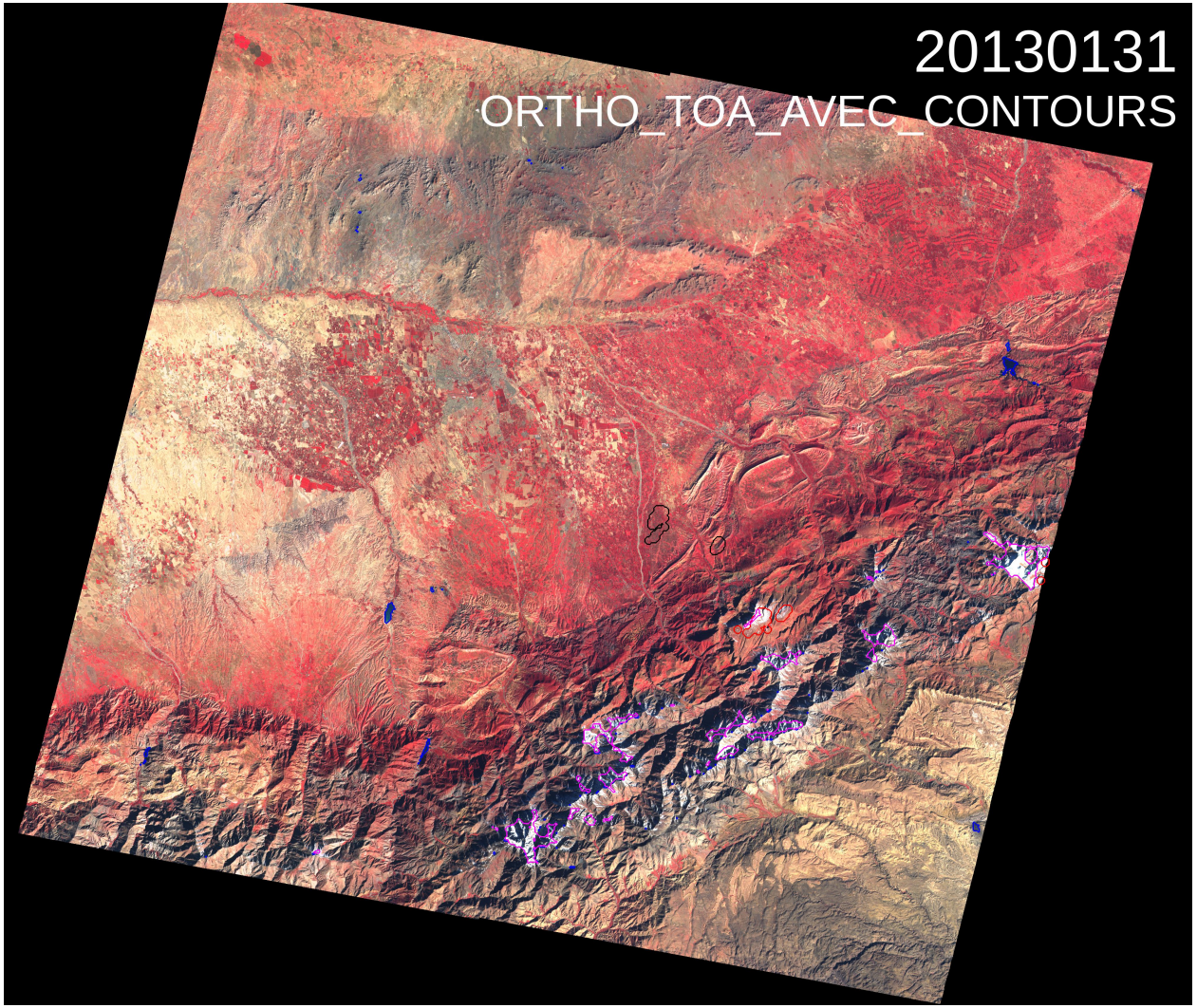
Atmospheric correction

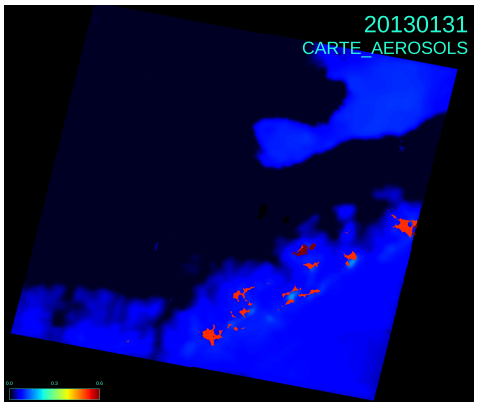
- takes into account :
  - Absorption
  - Scattering by molecules and aerosols
  - Aerosol parameters are estimated
  - Adjacency effects
  - Illumination effects due to topography

Aerosol estimation method (MACCS)

- No blue band in SPOT satellites
- Use of a multi-temporal method to estimate aerosol content
  - two successive L2A images should be similar (at 200 m resolution)
- Aerosol model is constant per site

Aerosol maps with SPOT4(Take5)





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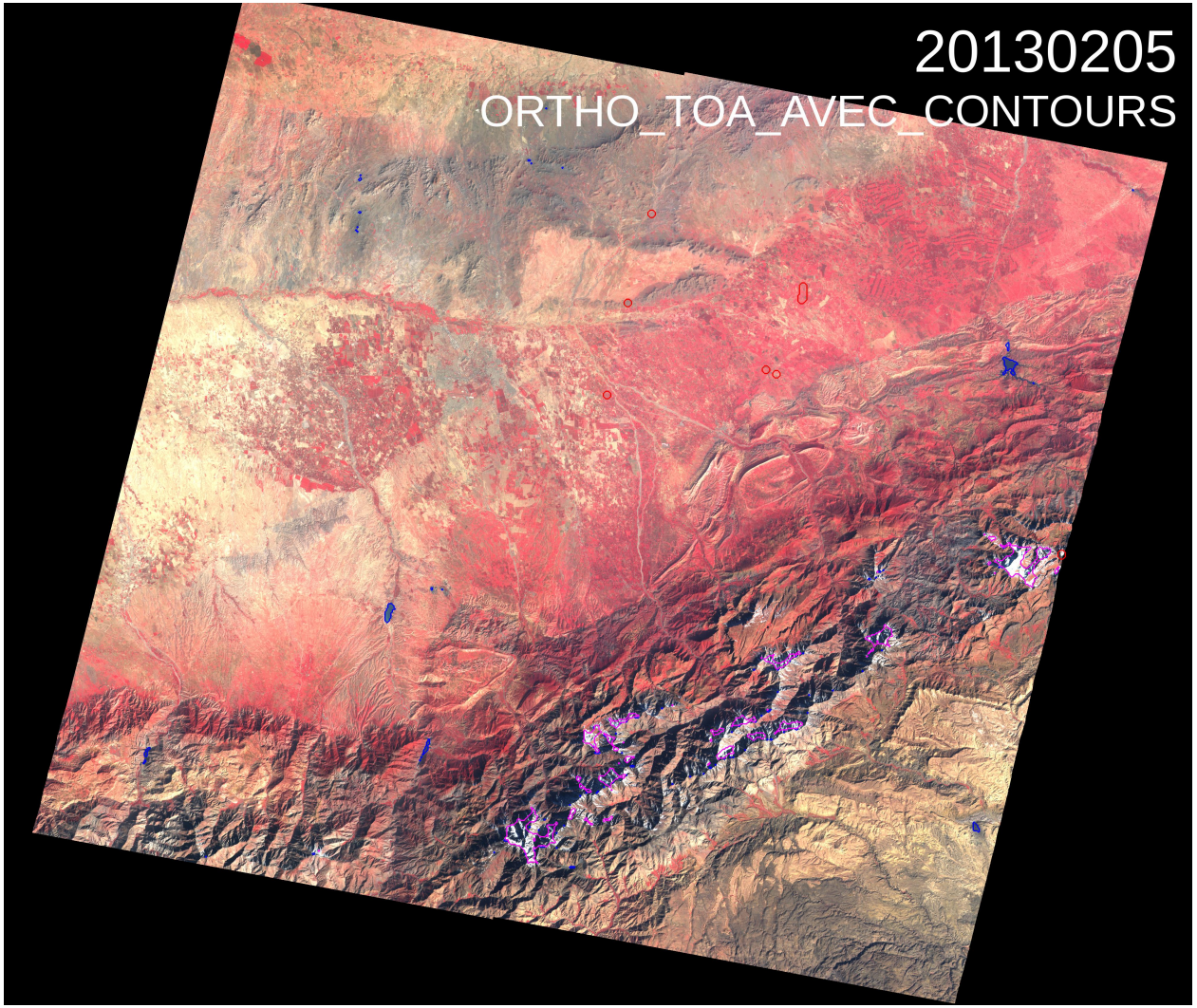

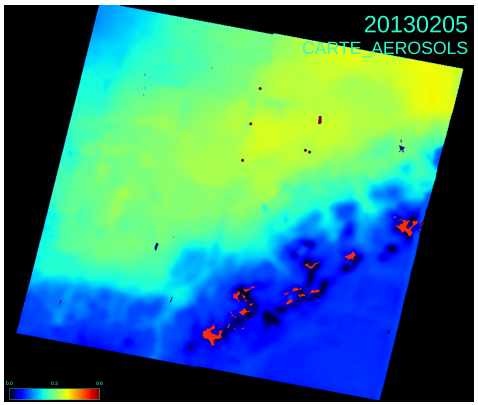

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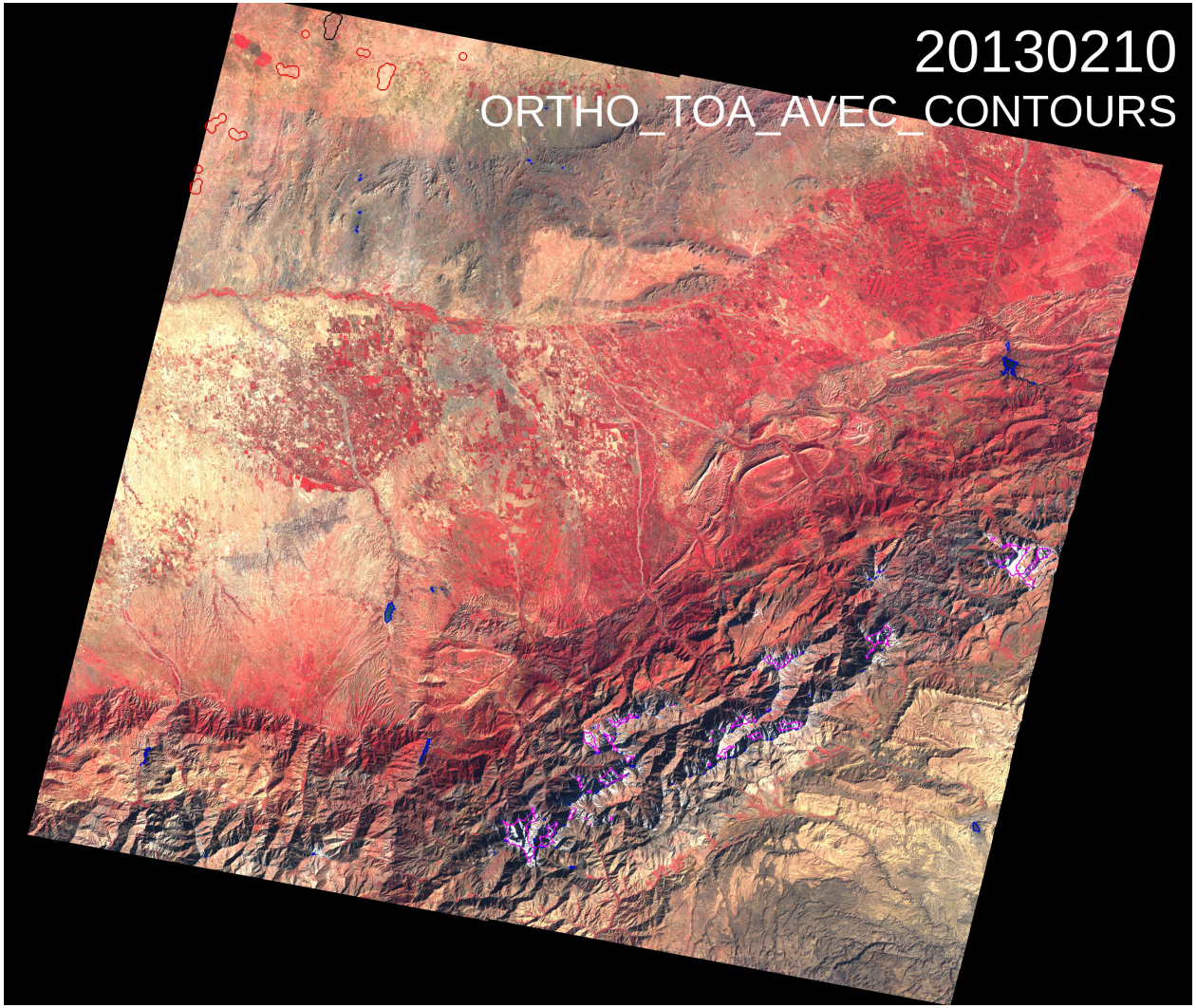

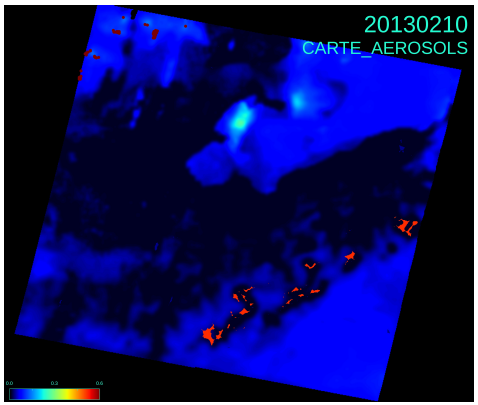

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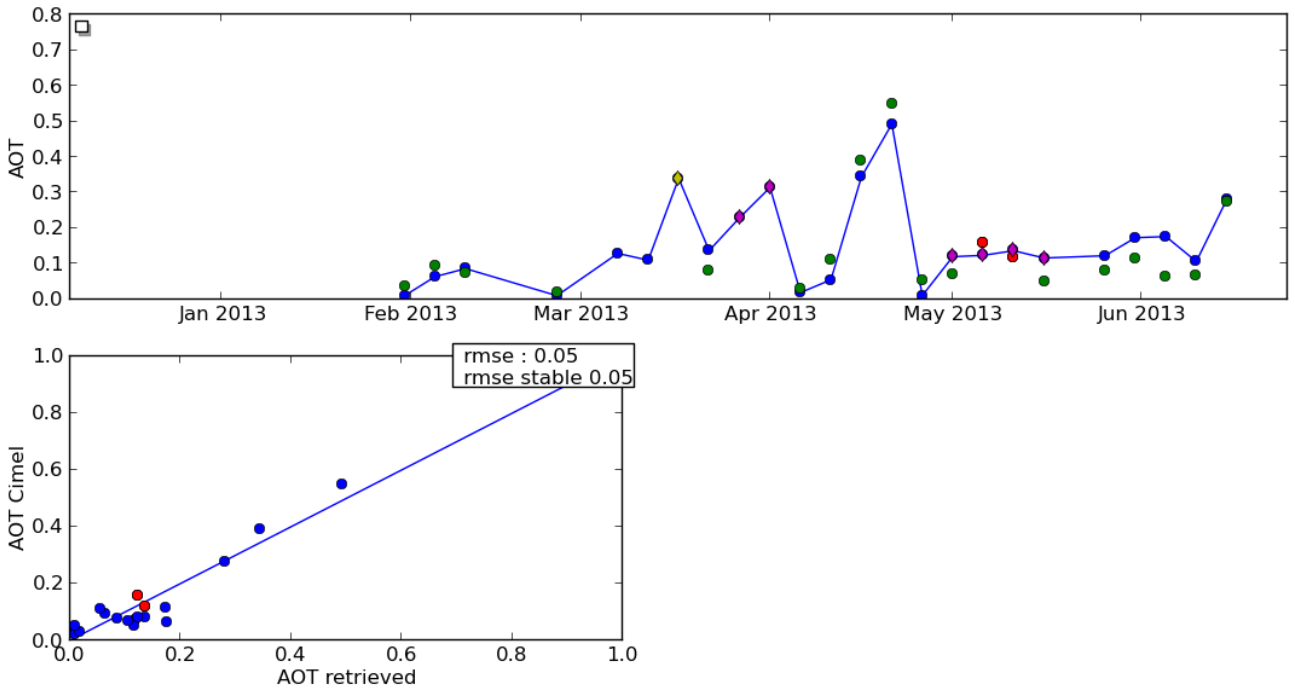
Atmospheric correction

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



Ouarzazate

Performances for SPOT4 (Take5)

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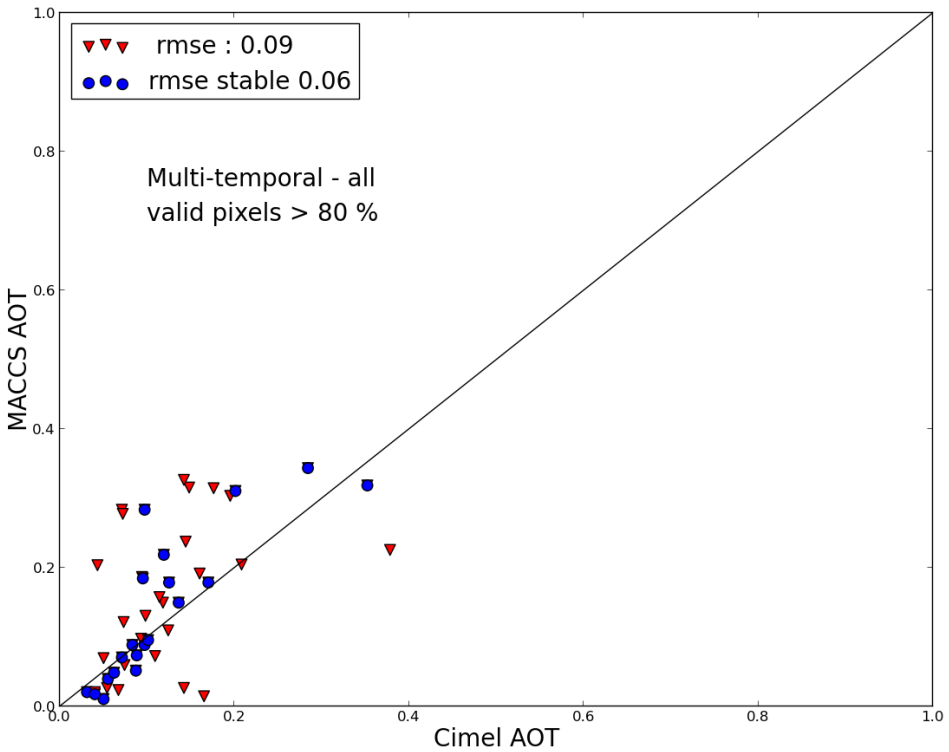
  - Africa : Saada, Ouarzazate (Morocco), Ben salem(Tunisia)
  - USA : Wallops, Cart Site
  - Asia : Gwangjiu, Korea
- same aerosol model for all sites (could be enhanced !)



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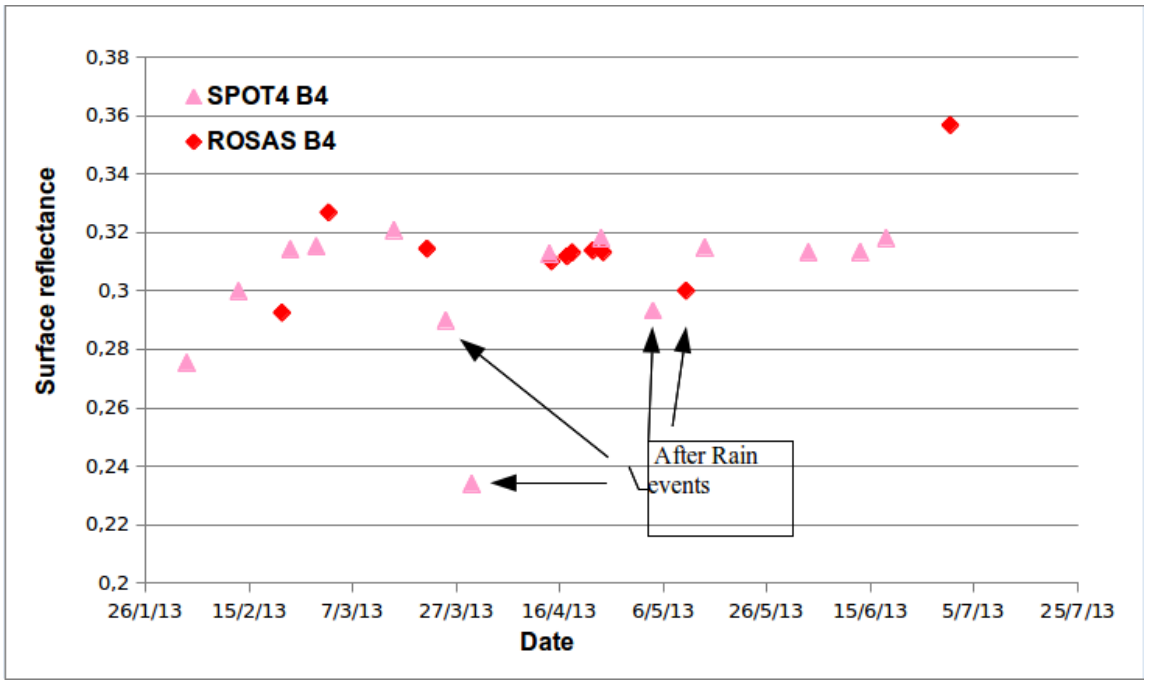
Surface Reflectance validation

Surface reflectance in-situ validation

- CNES operates an absolute calibration station 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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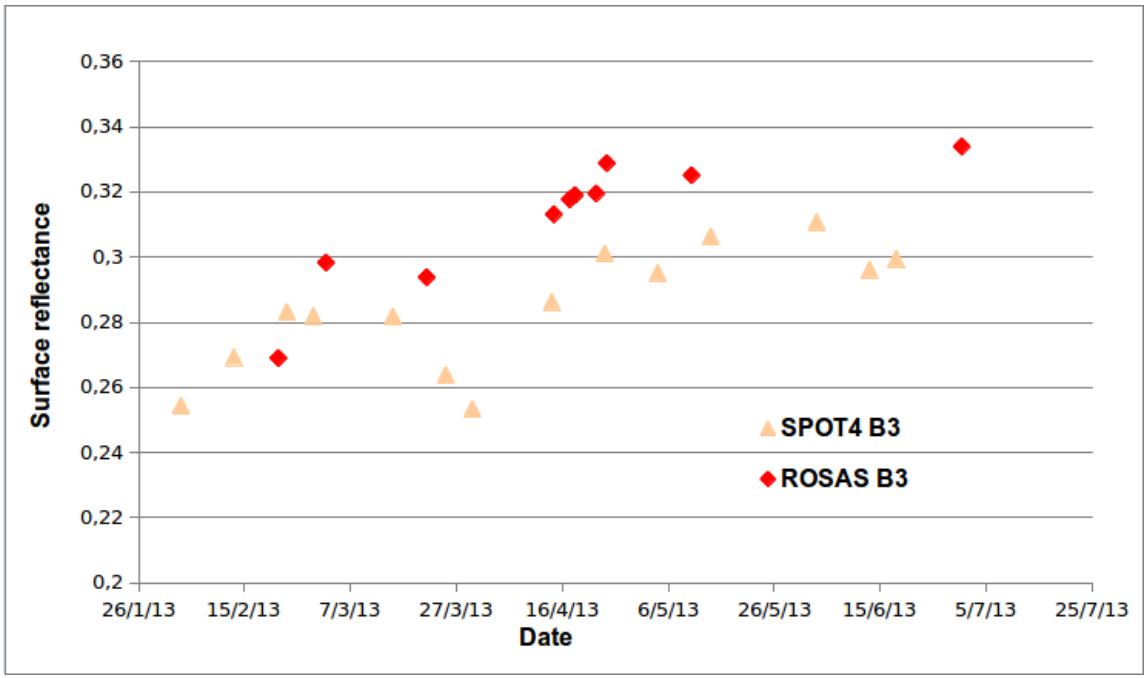

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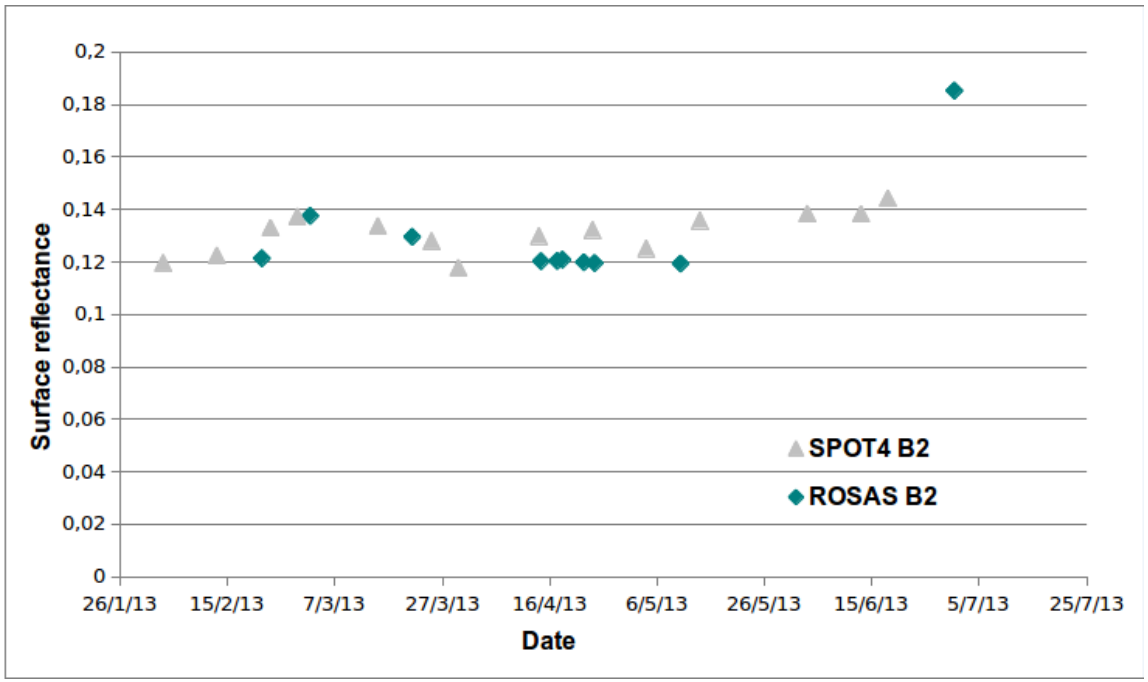

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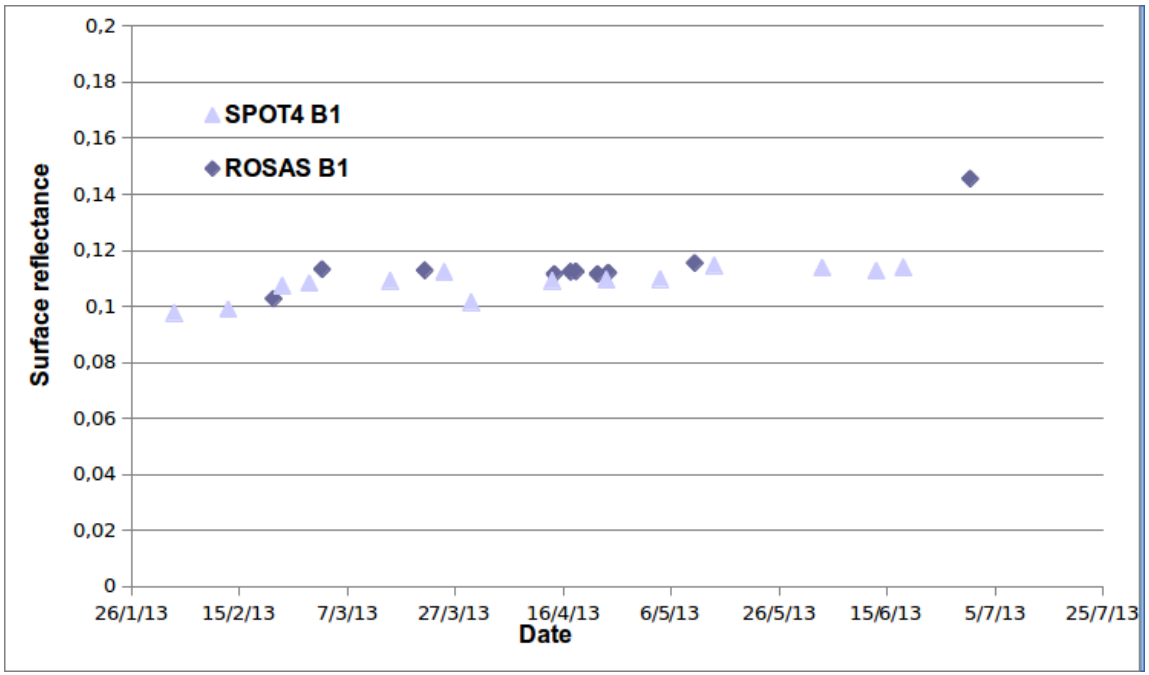
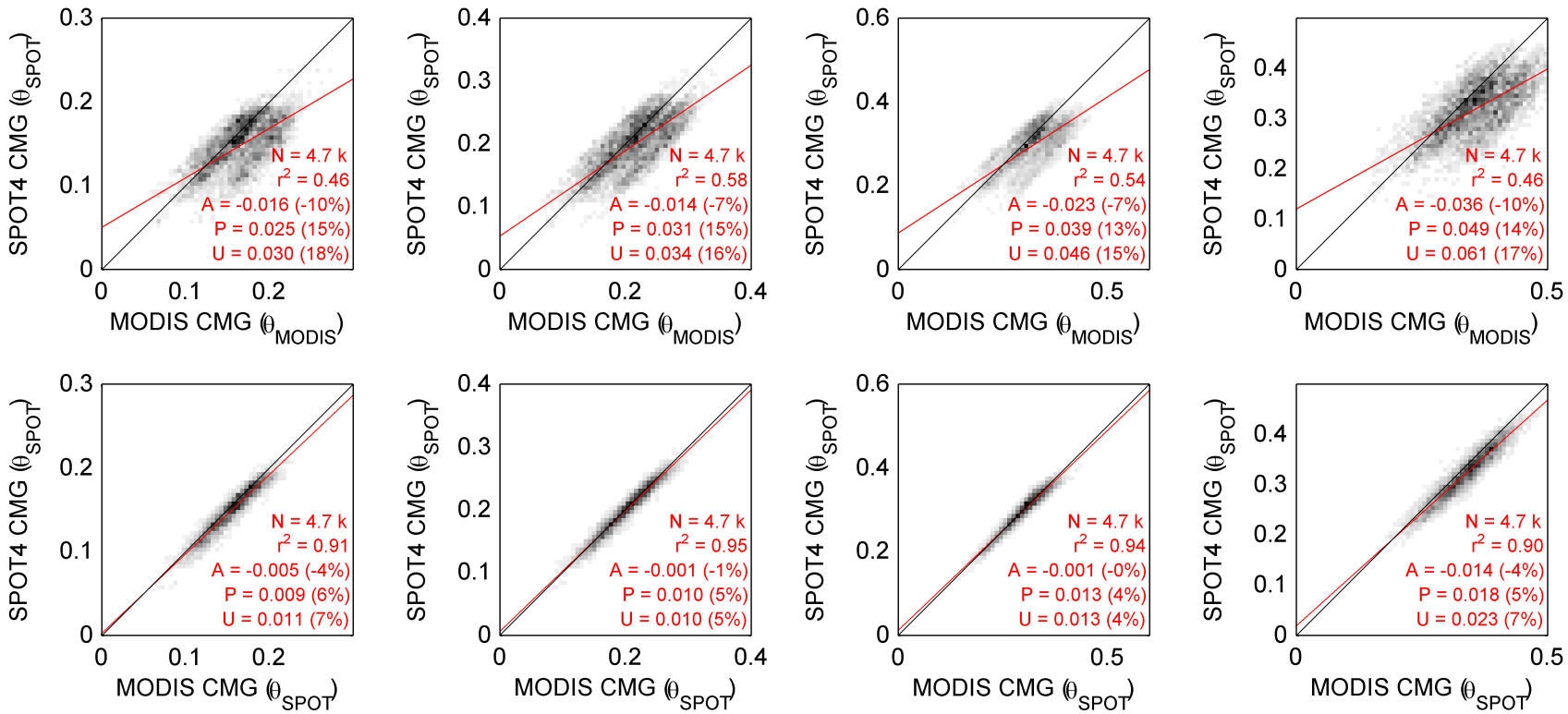


Surface Reflectance validation

- NASA compared MODIS and Take5 Surface reflectances for cloud free pixels
  - On Maricopa site, at 5 km resolution, using 25 dates
  - A directional effect correction is necessary (Vermote 2009)
  - Excellent agreement that validates Cloud Masks and atmospheric corrections
  - (M.Claverie,E.Vermote J.Masek)



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Atmospheric correction

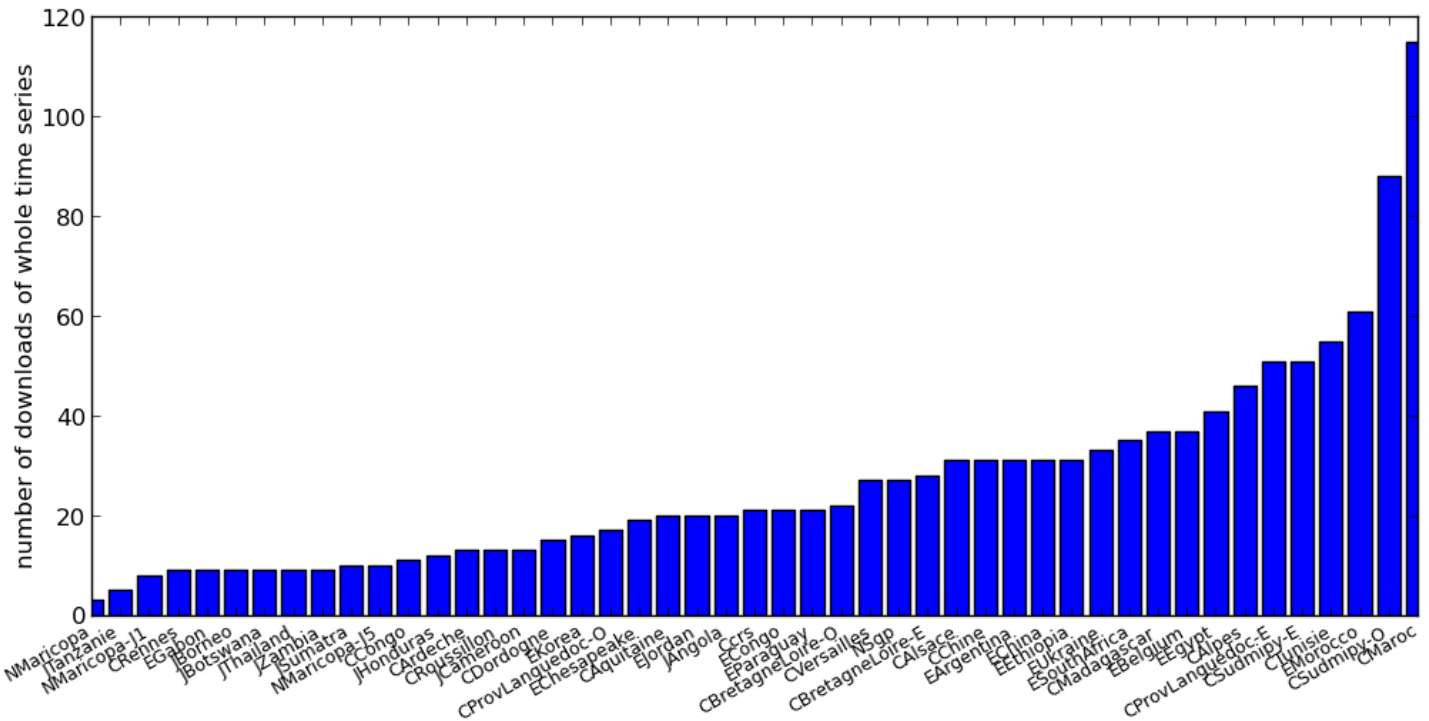
Validation

- Good validation results for Level 1C and Level 2A
  - Good performances for aerosol detection, despite absence of a blue band
  - Performances not far from those obtained by MODIS teams
  - Good performances for surface reflectances at La Crau
  - Some difficulties with very high aerosol content (China for instance)
    - Probably due to the use of a wrong aerosol model

Data usage

Statistics at Mid September 2014

- 3150 downloads among which 1330 full time series (29/site)
- 160 downloads since 1st of September 2014
- 76% of downloads are Level 2A.
- 550 different email addresses, at least 27 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,Dz,Il,In



downloads /tile

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Summary

Validation

- Validation of THEIA prototype ground segment in operational conditions
- Validation and tuning of SIGMA L1C software with cloudy time series
- Validation of MACCS L2A, incl. the way of operating a multi-temporal processor
- => feedback reused for THEIA reprocessing of Spot Archive, and for LANDSAT Processing

Users

- Unexpected success in terms of number of users
- Users happy with Level 2A => Pushed ESA to reconsider including L2A within S2 standard products
- Helped users have a better idea of the type of data provided by Sentinel-2
- Showed the potential of dense time series
  - Showed also that 5 days revisit might be sometimes insufficient
  - Already taken into account for current studies about new generations
- Already 3 published papers

Summary

Next events

- SPOT5 (Take5) call for site proposals
- SPOT4 (Take5) Special issue : MDPI remote sensing => Feb. 28th, 2015
- SPOT5 (Take5) April - August 2015
- Sentinel-2A Launch in less than 6 months

Acknowledgements

- Many thanks to :
  - CNES for allowing and perfectly conducting the experiment
  - Airbus DS for L1A products and contracts
  - THEIA CNES teams, for GS segment, data processing and distribution
  - CNES Image Quality teams for their technical support
  - ESA, JRC, NASA, CCRS for supporting and co-funding the access to data
  - Users for their mobilization and participation
  - My CESBIO colleagues, especially Mireille Huc
  - Sylvia Sylvander and Danielle Barrère for organizing this workshop