Lessons learned from the SPOT (Take5) experiments : simulations of Sentinel2 time series on 195 sites

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(1) CESBIO; (2) CNES; (3) ESA/ESRIN; (4) Cap Gemini; (5) Steria

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spot
take 5
CESBIO
cnes
esa

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

Specificity

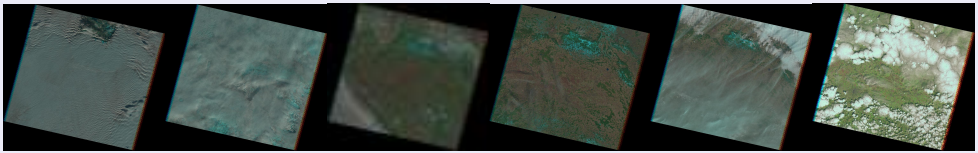
- High resolution images 6 times/month on all surfaces with 2 satellites
- High probability to get cloud free images every month
- Use of time series instead of images => Operational applications instead of case studies
- Simulations time series needed :
  - to help users get a better idea of this kind of imagery
  - to help users implement and test their processors
  - to show the applications

Available Sentinel-2 simulations in 2012

Aerial acquisitions

- Aerial acquisitions provide
  - High resolution and all S-2 spectral bands
- but lack
  - revisit and coverage coverage

Other satellites



Landsat 8 data, January - April 2011 over Prague

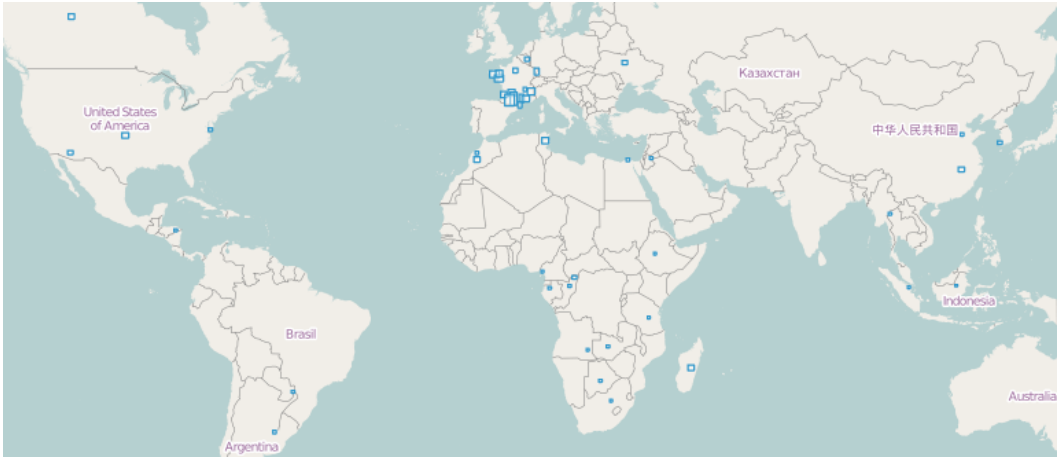
- Landsat data more similar to Sentinel-2 but much reduced repetitivity
- CNES/ISA Venμs mission (2 days repetitivity on 1000 sites) much delayed (launch in 2017)

How to obtain Sentinel2-like time series ?

SPOT (Take5) experiments

- CNES issued calls for experiment proposals at end of routine operations of SPOT 2, 4, 5
  - CESBIO suggested to use this period to simulate Sentinel-2 time series
  - 5 day repeat cycle orbit available 2 km below SPOT orbit
  - Declined for SPOT2 (2009), but accepted for SPOT4 (2013) and SPOT5 (2015)
    - SPOT4 : CNES funding with participation of ESA, JRC, NASA, CCRS
    - SPOT5 : CNES-ESA co-funding
- Change SPOT orbit to simulate Sentinel-2 time series
  - revisit : every 5 days, 30 acquisitions in 5 months
  - resolution : 20m (SPOT4), 10m (SPOT5)
  - coverage : large sites 60*60 km^2, 120*120,
  - spectral : Only 4 bands, but with a SWIR band
- Data available at https://spot-take5.org

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



SPOT4

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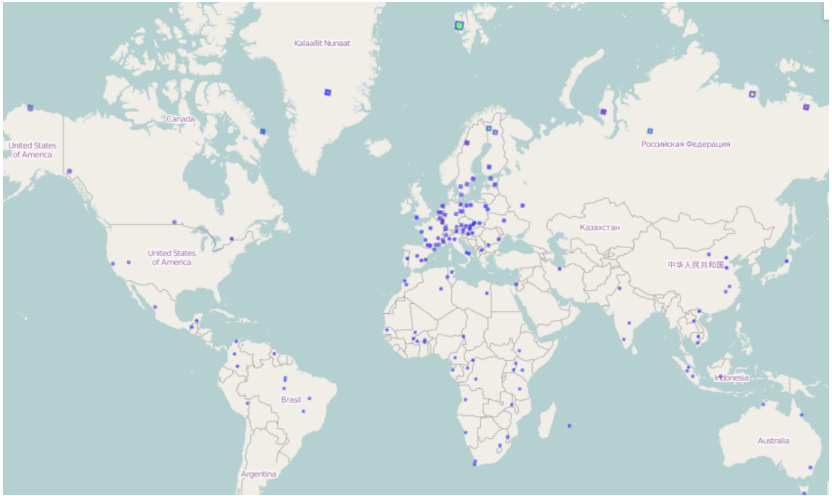
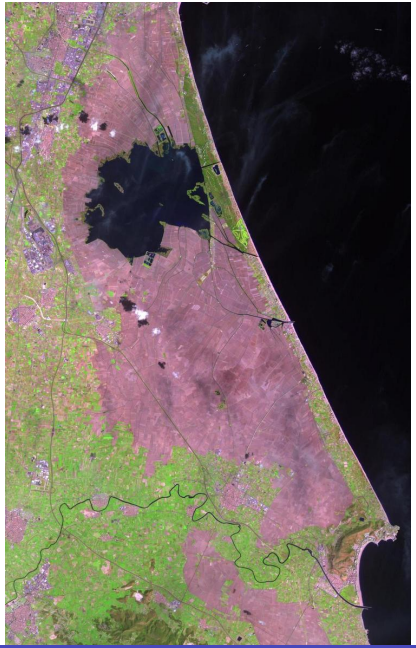


SPOT5



- SPOT5(Take5) time series near Valencia
  - Bare soils in April
  - Start of Irrigation en May
  - Full development in July
  - Start of ripening in September
- Applications
  - Identify the crop => Land Cover
  - Flooded period => Methane emissions
  - Estimate emergence date => Crop modelling
  - Monitor rice growth => Biomass, Yield

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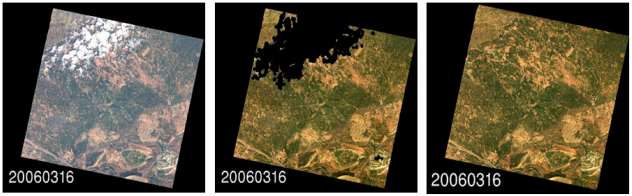
Products

- 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 cloud free pixels over 1 month



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

Products

L1C

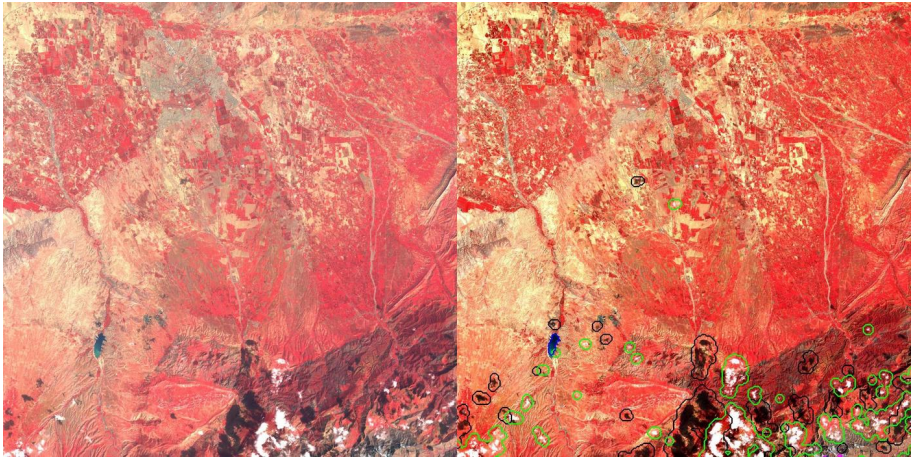
- L1C : ortho rectified TOA reflectances
  - Based on CNES Sigma software
  - Use of LANDSAT 8 as reference for obtaining ground control points
    - Standard deviation of 18m for geolocation accuracy (not as good as S2A !)
    - Very large work to select cloud free images above all the sites
    - Successful for all sites but Greenland (completely uniform), only processed at Level 1A
  - DTM : SRTM under 60°N and Planet Observer above
- 99.75 % of images have a registration error below 0.5 pixel (1 sigma)

L2A Methods

MACCS processor

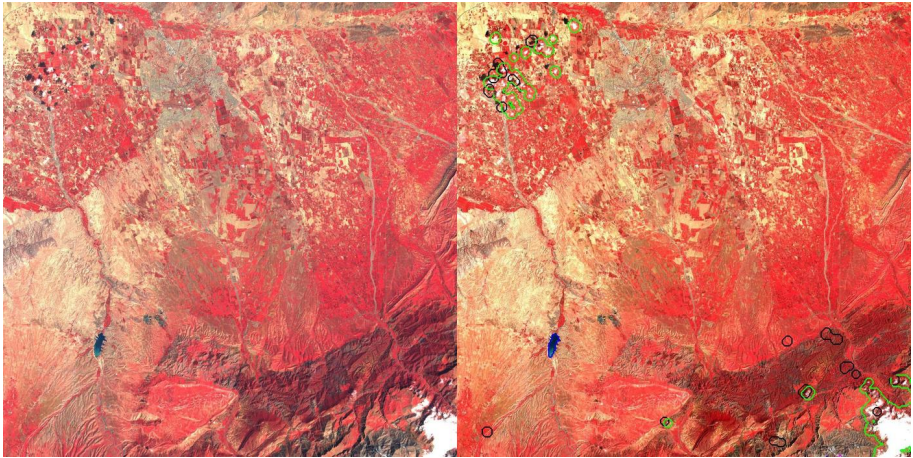
- Multisensor Atmospheric Correction and Cloud screening, developped by CNES and CESBIO
- Classical cloud detection and aerosol estimation methods rely on multi spectral assumptions involving the blue band
  - No blue band on SPOT images
  - Same criteria transposed to the green band are inaccurate for aerosol estimates (OK for clouds)
- MACCS method usually combines multi-temporal and multi-spectral assumptions for aerosols estimates
  - Here, only multi-temporal assumptions were used
- Multi-temporal assumptions are (in short...)
  - surface reflectance in the green changes slowly with time
  - a large increase of reflectance in the green => cloud
  - a large decrease of reflectance in the red => cloud shadow
  - moderate variations of surf reflectance at 1km res. => aerosols

Multi-temporal detection of clouds



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

Multi-temporal detection of clouds



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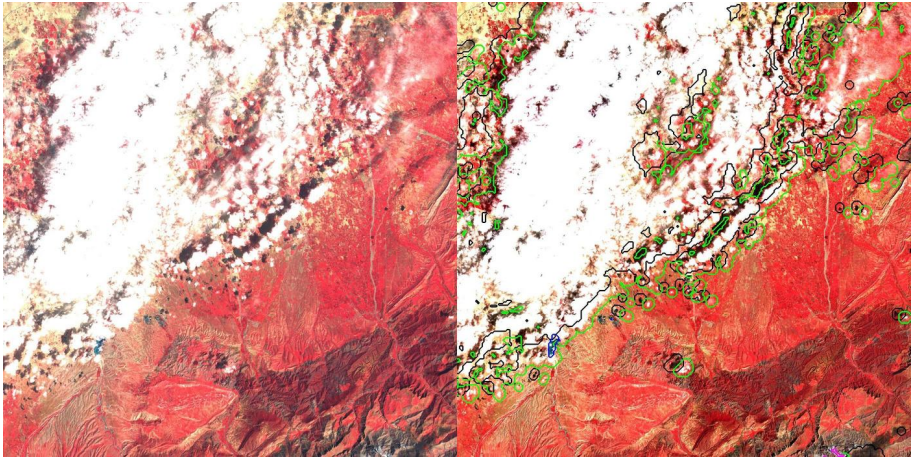

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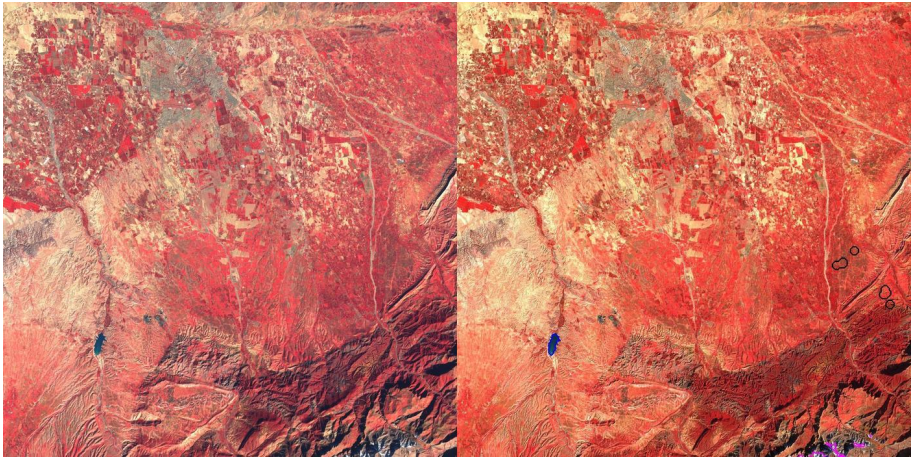

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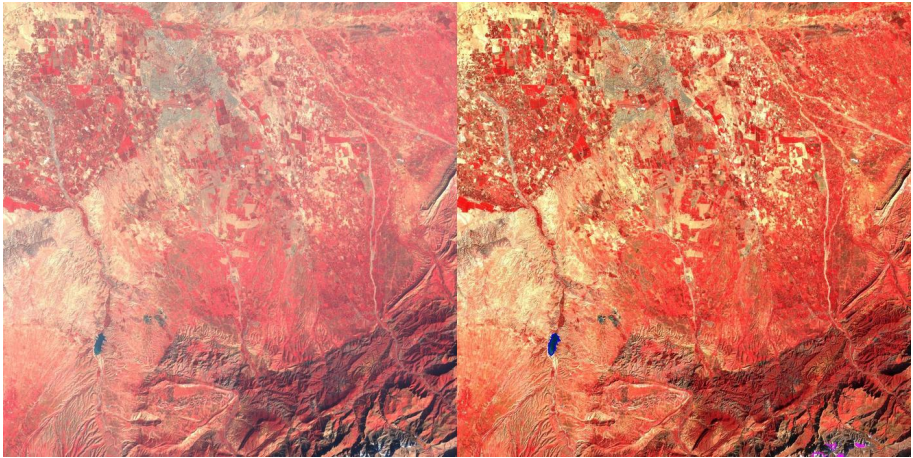

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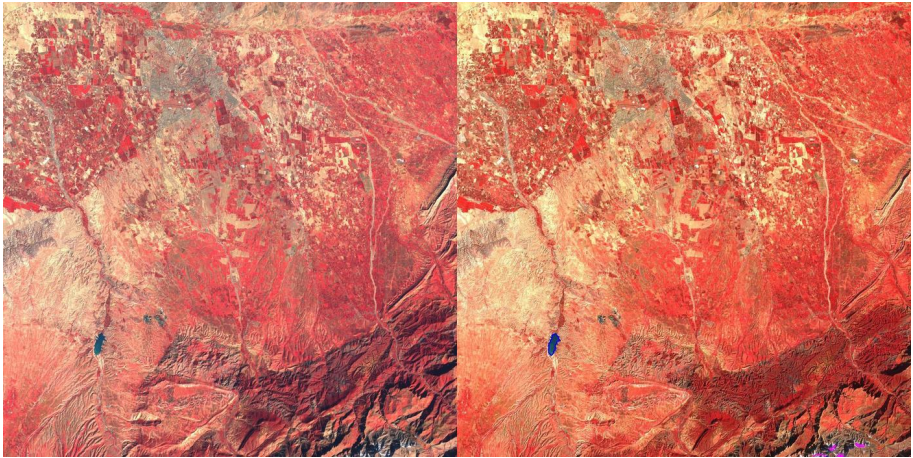
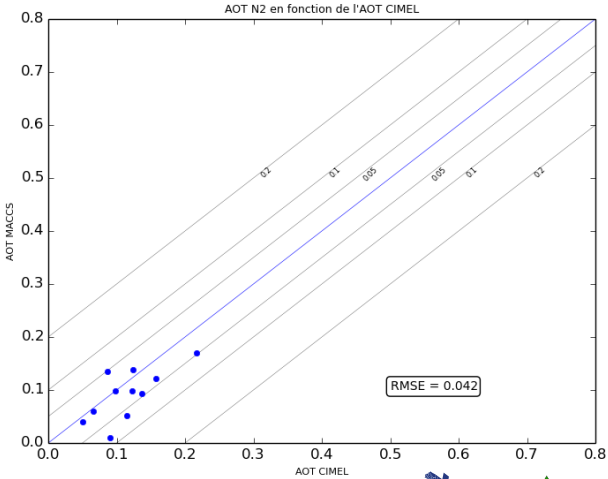


TOA Reflectance (L1C) => Surface Reflectance (L2A)

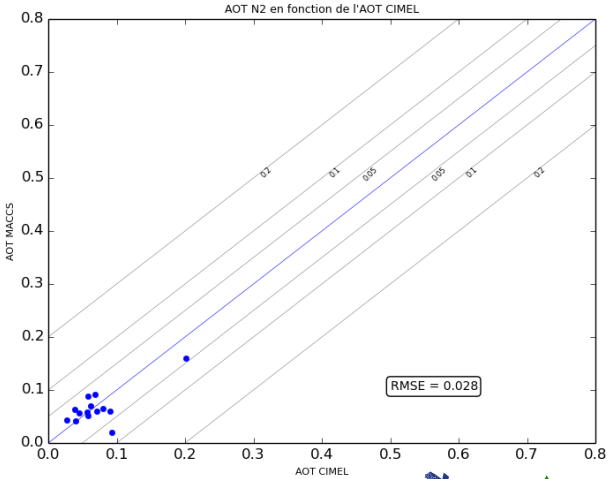
Many good aerosol validation results with Aeronet

Madrid, Spain



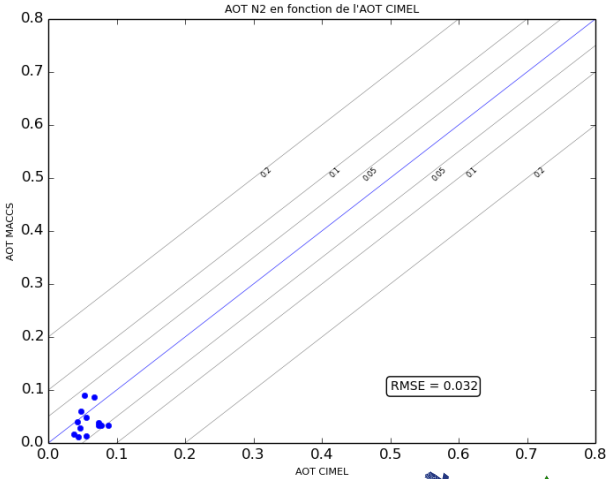
Many good aerosol validation results with Aeronet

Railroad valley, USA



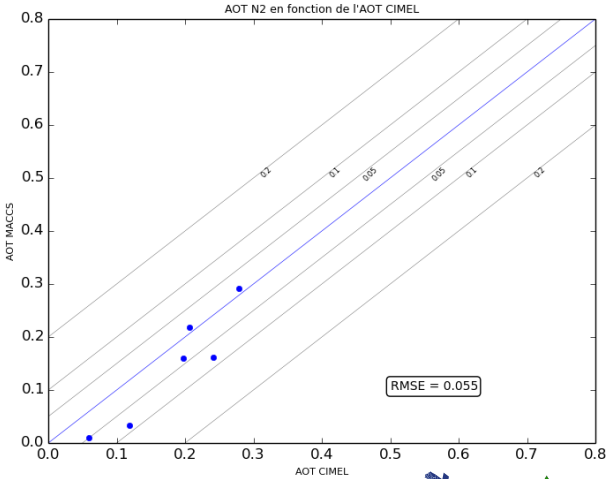
Many good aerosol validation results with Aeronet

La Réunion, France (Indian Ocean)



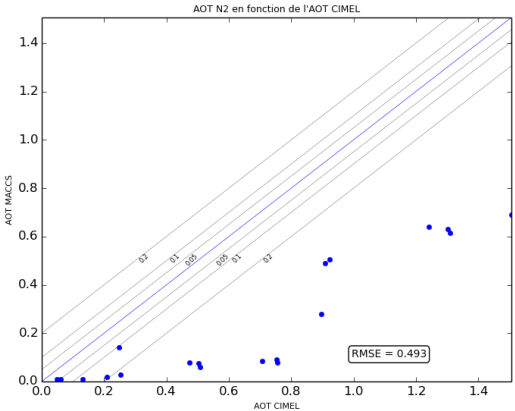
Many good aerosol validation results with Aeronet

Kranzberger, Germany



Some less good aerosol validation results

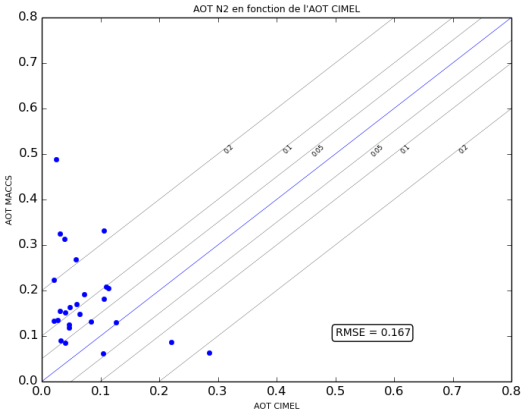
Beijing, China



- Huge aerosol optical thickness with absorbing aerosols
- Blue reflectance increases much less with AOT

Some less good aerosol validation results

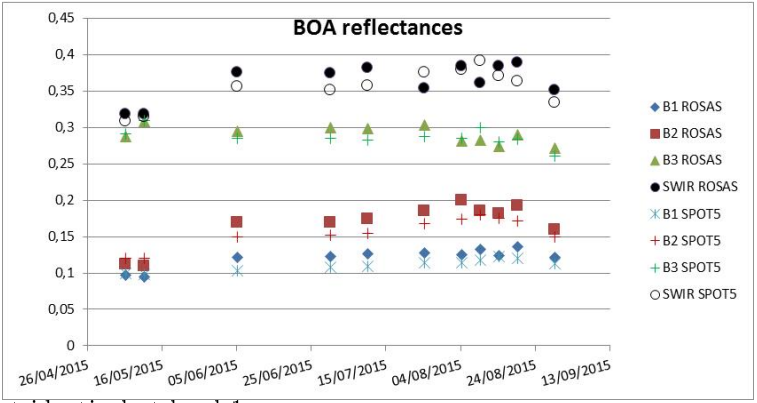
Gobabeb, Namibia



- Very bright desert
- Better results with low reflectances

Surface reflectance validation results

- Using ROSAS station in La Crau, France
- Permanent measurements of surface reflectance on top of a pole



- Bias exits, but identical at level 1.
  - Probably due to ROSAS absolute calibration
- Small noise, SPOT time series smoother than ROSAS

SPOT5 (Take5) Re-Processing in March (V2)

Several small enhancements implemented

- One reference image for ortho-rectification (Devon, UK) caused registration errors up to 1 pixel
- Absolute threshold on green reflectance for cloud detection was too low for 2 desert sites (Tunisia and Libya)
- L2A were not issued for fully snow covered sites
  - we only issue product if cloud cover is less than 90 %
  - but snow was included in cloud cover percentage
- Shadow detection method completely changed (see dedicated presentation by M.Huc)
- An error on DTM file caused no production of site in Romania.
- Aerosol optical images sometimes too noisy => smoothing increases
  - Potential drawback when aerosol content varies sharply
    - Near aerosol source,
    - or in presence of large altitude variations
- New version released Mid April, late for LPS 2016, sorry !

L2A Download statistics

SPOT5 (Take5) after 1 year

Number of downloaded products	24685
Average download per image	11
Number of users	335
Percentage of L1C downloads	48.5%
Percentage of L2A downloads	51.5%

SPOT4 (Take5) after 2 years

Number of downloaded products	34000
Average download per image	37
Number of users	750
Percentage of L1C downloads	24%
Percentage of L2A downloads	76%

- Comments :
  - Number of users similar to that of SPOT4 (Take5) at same period
  - Presence of Sentinel-2 now reduces interest for its simulations
  - More sites for SPOT5 (Take5) and download of zip files per site was easier for SPOT4 (Take5)
  - Apparently less success of L2A products compared to SPOT4
    - L2A percentage is 57% since october
    - L1C delivered before L2A, lots of L1C downloads at the beginning
    - A lot of users downloaded both L1C and L2A (more than for SPOT4 (Take5))

Lessons Learned

Acquisition and Production

- Many thanks to the SPOT teams who did a great work
- Satellite out of its nominal configuration => lots of manual work
- Success rate of acquisitions above 95%
- Very large configuration work given the number of sites
- No big issues with processing despite the use of prototype ground segments

Methods

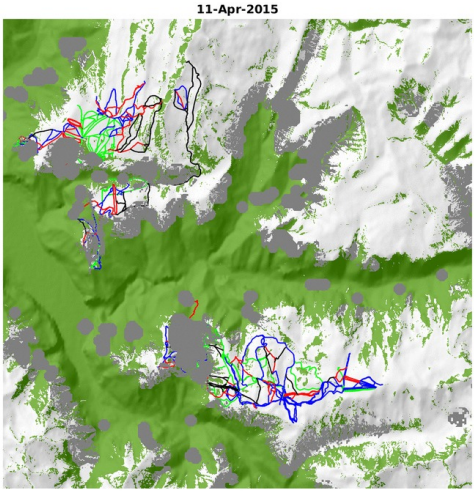
- Large progress in the parametrization of ortho-rectification software with SPOT4 (Take5)
- Many lessons learned for MACCS
  - Better tuning of several parameters
  - Enhancement of shadow detection, already implemented
  - Need to find a method to constrain the aerosol model
  - Direct estimate of aerosol model is quite noisy
  - Current research at CESBIO focuses on the use of Copernicus Atmosphere aerosol forecasts

Lessons Learned

Applications

- Lots of clouds, 5 days repetitivity really needed and not always enough
  - Less than one clear view per pixel in Gabon
  - First clear image in Sodankyla, Finland, obtained after 4 months
  - looking forward Sentinel-2B launch !
- Take 5 has helped almost 1000 users get a better idea of what Sentinel-2 is
- Spot (Take5) are still the only S2-Like data with 5 days repetitivity
  - https://spot-take5.org
- Methods, validation, tests, applications have been developed
- 14 papers published (+1 recently submitted) within SPOT (Take5) special issue (*remote sensing*)
  - a few others here and there
- 20 talks in SPOT (Take5) sessions in LPS + about 15 posters
- Take5 also present in other sessions

Snow cover monitoring with SPOT5 (Take5)



Snow in white, clouds in grey, ski tracks in color
S.Gascoin, CESBIO, "Let It Snow" processor

- North : Alpe d'Huez
  - Winter ski resort
- South : Deux Alpes
  - Winter and Summer ski resort

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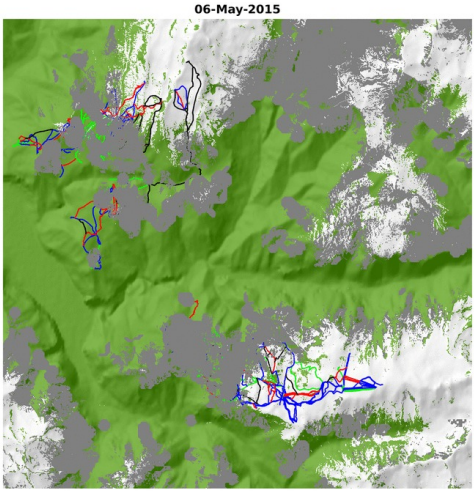

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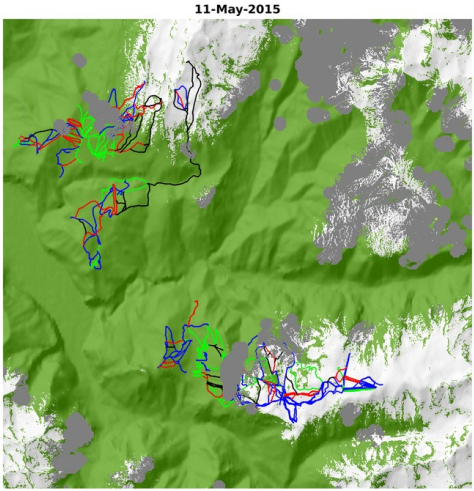

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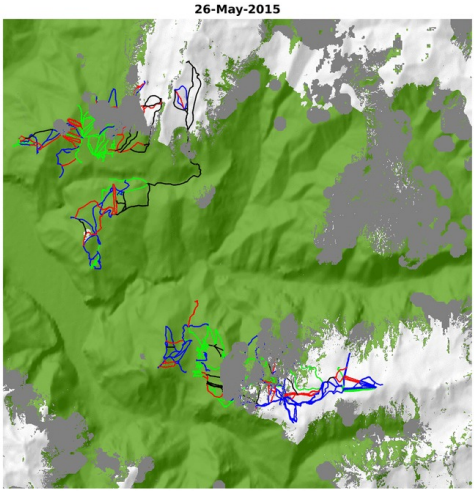

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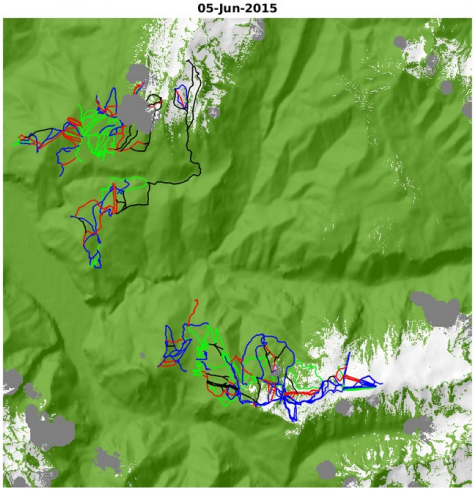

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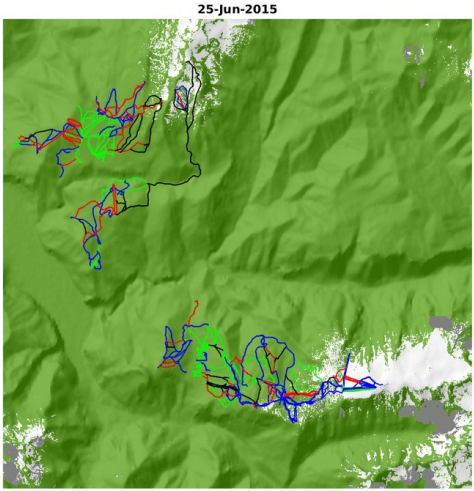

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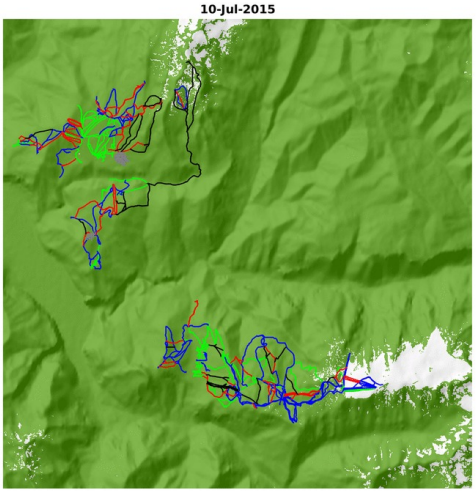

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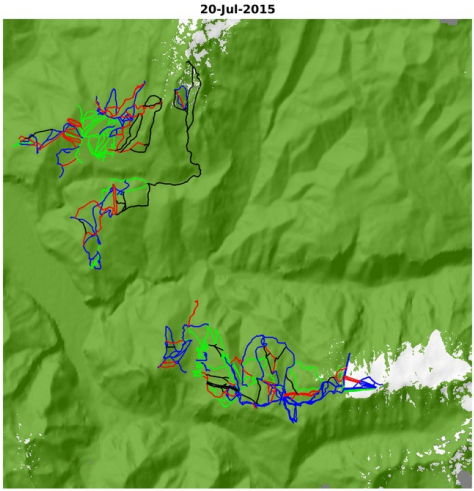

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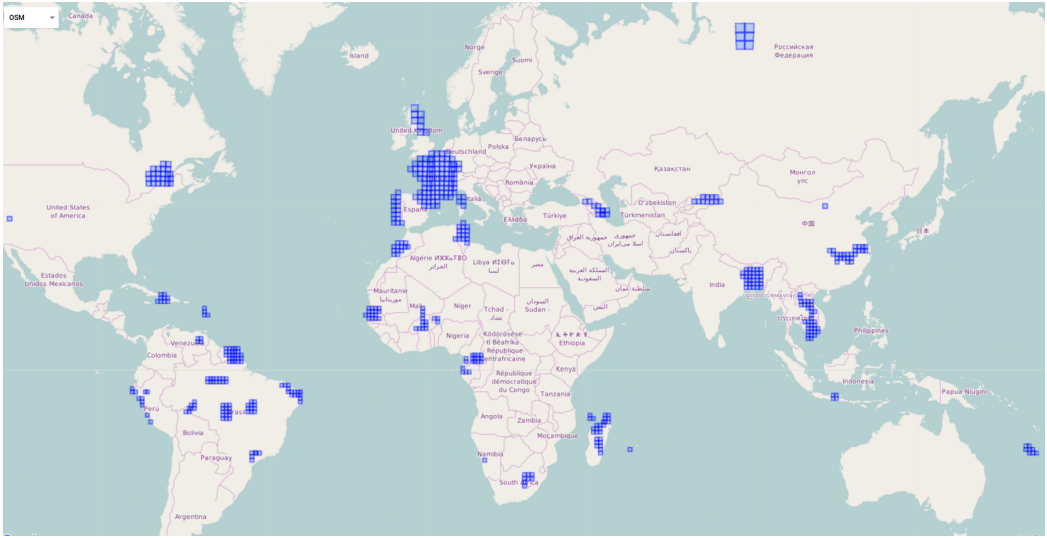
Next Step : Sentinel-2 data

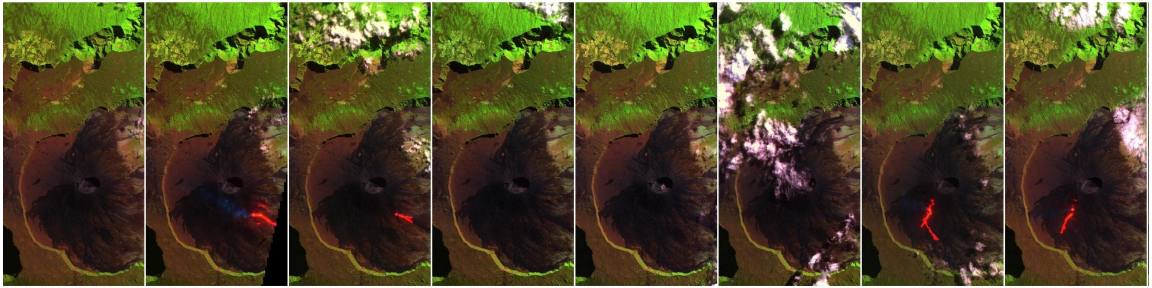
- THEIA French land data center to produce level-2A products with Sentinel-2
- A new ground segment has been set-up : MUSCATE
- Uses MACCS to produce data over 6.4 M km2 (Size of Europe)
- Better results expected than for SPOT (Take5) thanks to Sentinel-2 spectral bands
- Start of production : June or July (Hopefully)
- Other products will be generated automatically based on these data, starting end of 2016
  - Annual land cover over France at least
  - Snow mask over France
  - other products being prepared
- Proposal of a MACCS-ATCOR Joint Algorithm (MAJA), with DLR, for a global production
  - But there are other runners !

Sentinel-2A data to be processed by MACCS within THEIA



https://frama.link/S2THEIA

Thank you !



Eruptions of Piton de La Fournaise, Reunion, France

More news on CESBIO multitemp blog