LANDSAT 8 / SENTINEL 2 FUSION TECHNICS

L1WG – DAVOS 9th December 2015

Sebastien Saunier

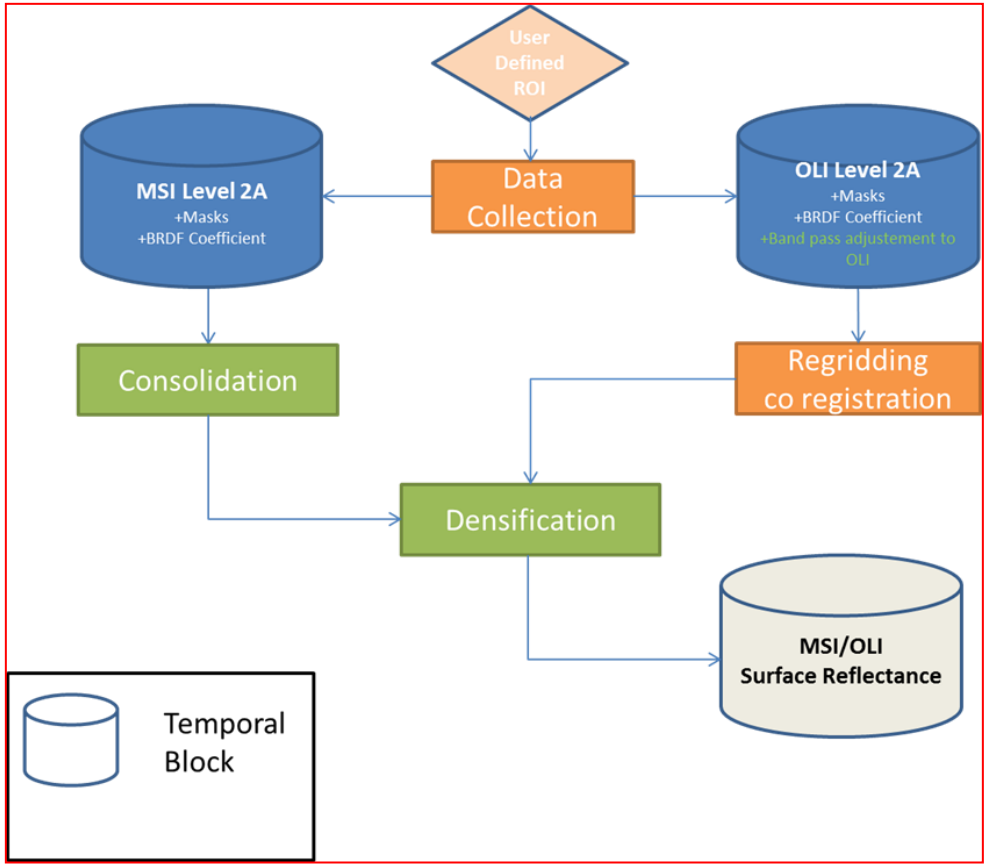
Scope

- On going development of remotely sensed composites that are pixel based rather than scene based
  - Griffiths, “Regionalized and application-specific compositing – a review of requirements, opportunities and challenges”, Sentinel 2 for science workshop. 2014.
- On going development of methods that use multi year pixel based composites as input to modelling in the forest, vegetation domain…
  - Shanley D. and al, “Mapping dominant tree species over large forested areas using Landsat best-available-pixel image composites” CJRS 2015.
- On going efforts of agencies to ensure compatibility between Sentinel 2 / Landsat 8 data
  - Vermote, Woodcock “Enhancing Compatibility of Sentinel-2 and Landsat Products for improved Monitoring of the Earth System”, Sentinel 2 for science workshop. 2014.

Goals

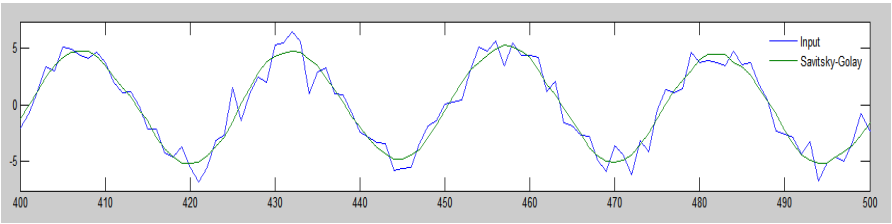
- Producing harmonized Sentinel 2 / Landsat 8 time series starting from L2A products maximizing pixel time revisit , it includes
  - A) Consolidation
  - B) Densification .
  - C) QA&QC process to measure uncertainty

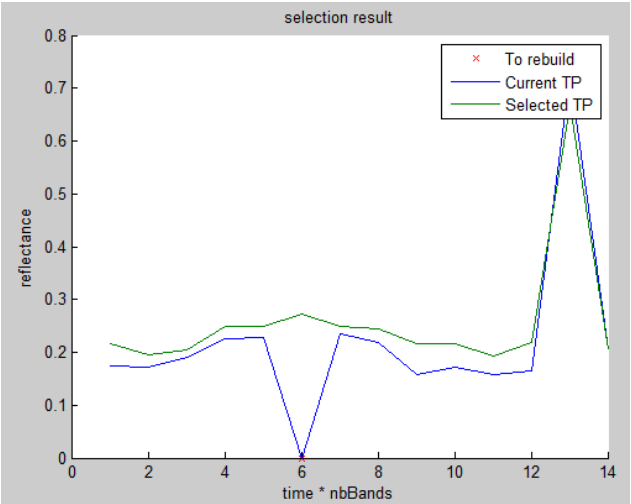
General scheme

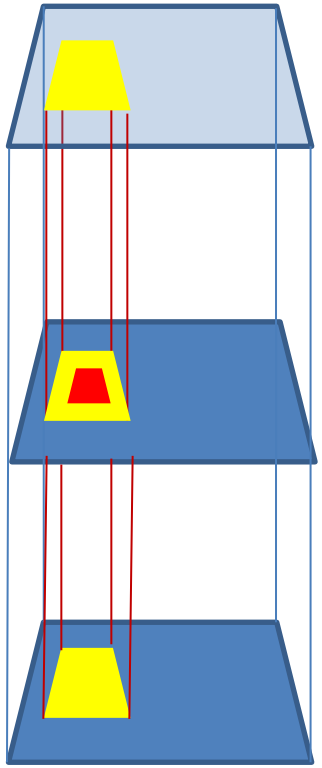


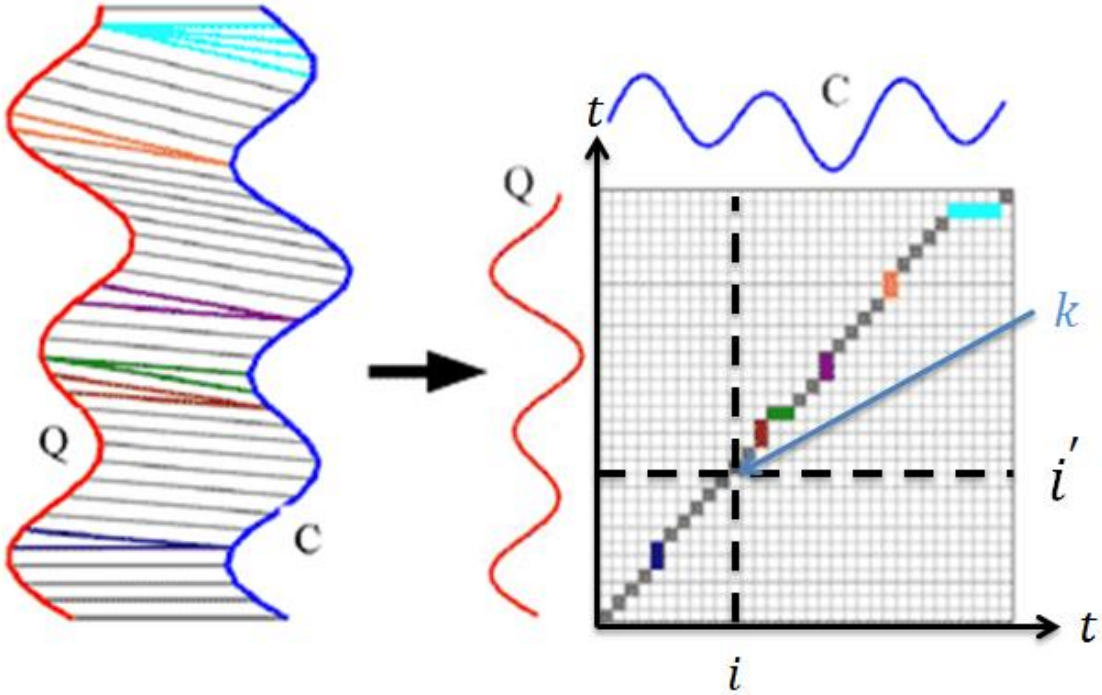
Basis on Interpolation / Interpolation Methods

- The interpolation based methods
- The Distance based methods








Q
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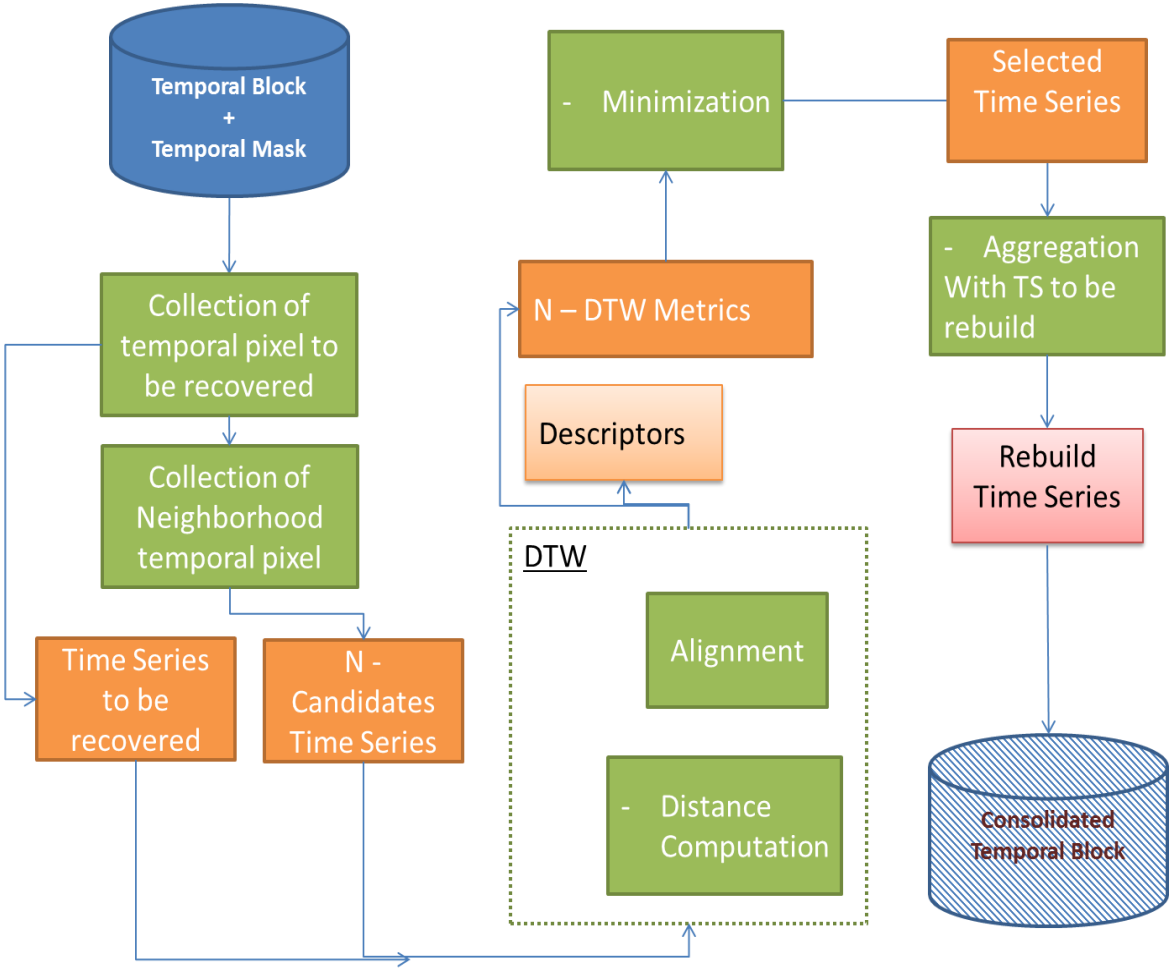
On the DTW


Temporal Block
+
Temporal Mask
Collection of temporal pixel to be recovered
Collection of Neighborhood temporal pixel
Time Series to be recovered
N - Candidates Time Series
DTW
Alignment
- Distance Computation
Descriptors
N – DTW Metrics
- Minimization
Selected Time Series
- Aggregation With TS to be rebuild
Rebuild Time Series
Consolidated Temporal Block

Evaluation of the consolidation process - inputs

- Methods are sensitive to several parameters,
  - The number of observation dates in the TS for which data is occluded; The spectral bands,
  - The atmospheric conditions;
  - The ground feature itself in term of spatial density (example of sparse/dense vegetation) with homogeneity or heterogeneity,
  - The ground feature itself in term of phenological cycle,
  - The phenological state of a given vegetation specie that might be different depending on its geographical location;
  - The location of the feature boundary in the area defining the feature extent; fully included or partially included, interpolation algorithm being forced cop with heterogeneous data;
  - The geometries of observation summarized with the observation angles and sun angles,
  - The definition of the sensor (spatial resolution, spectral band definition, RSRs).

Evaluation of the consolidation process - methods

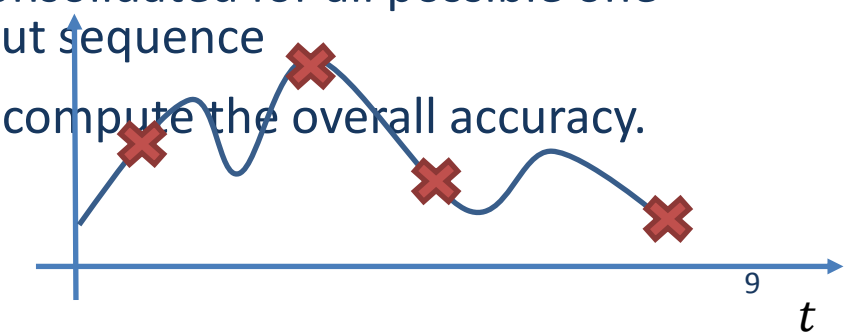
- The baseline concept relies on the following stages:

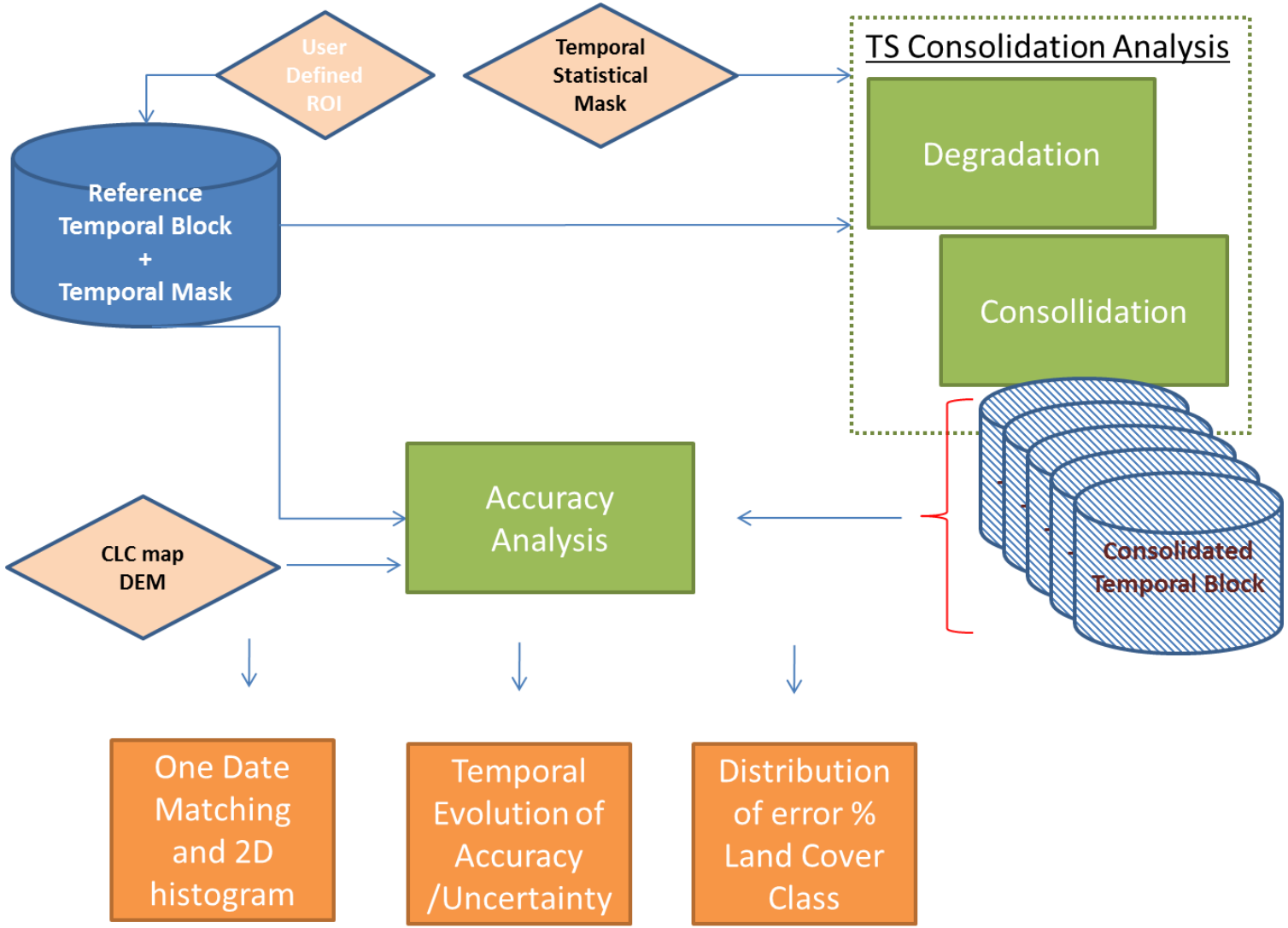
1. to degrade a reference temporal block (qc pass)
2. to consolidate the degraded temporal block
3. to compare degraded and reference temporal blocks.

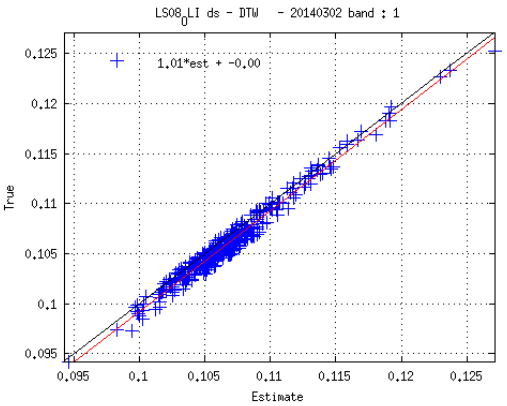
- The statistical comparison is performed based on an iterative approach

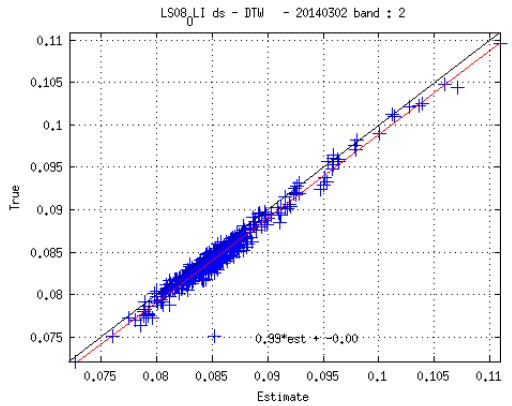
  – The reference block is degraded / consolidated for all possible one date missing permutation in the input sequence

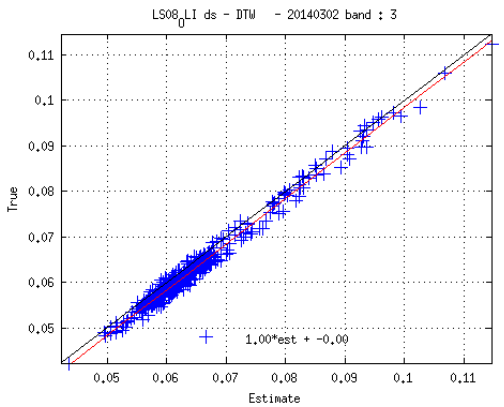
  – Leave one out methods are used to compute the overall accuracy.

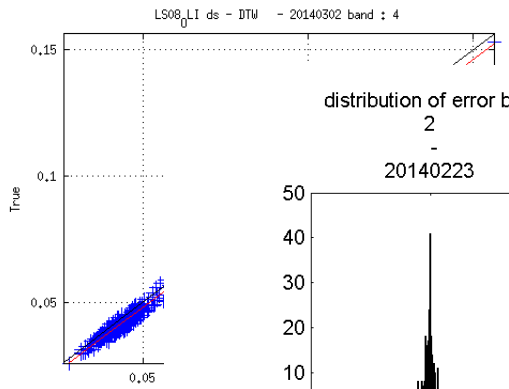


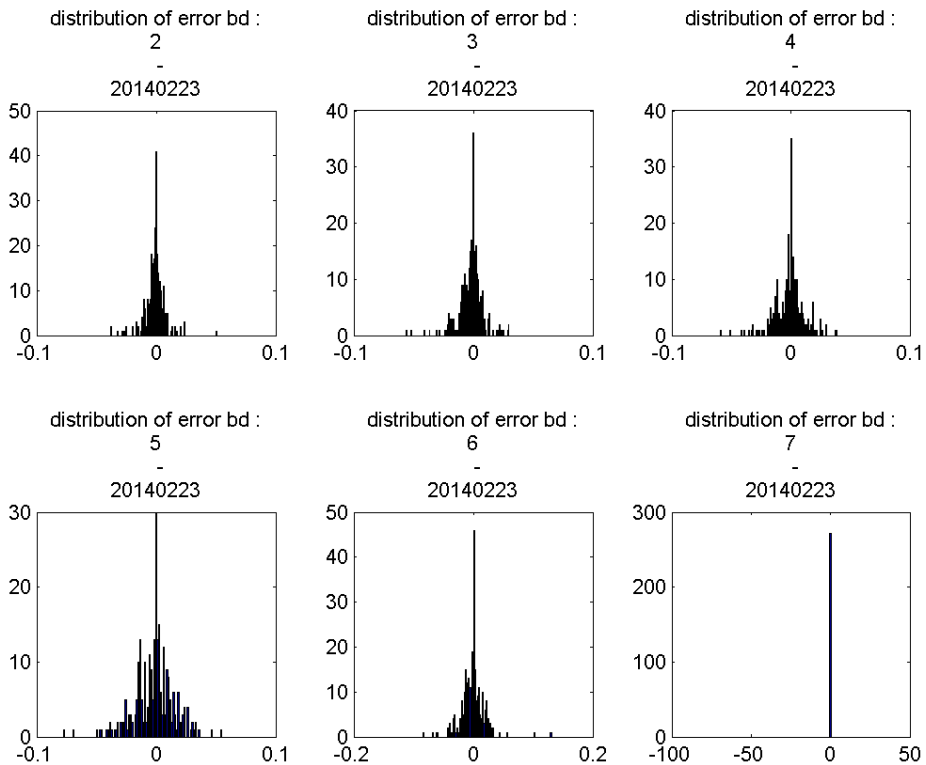

User Defined ROI
Temporal Statistical Mask
TS Consolidation Analysis
Degradation
Consollidation
Reference Temporal Block + Temporal Mask
Accuracy Analysis
CLC map DEM
Consolidated Temporal Block
One Date Matching and 2D histogram
Temporal Evolution of Accuracy /Uncertainty
Distribution of error % Land Cover Class

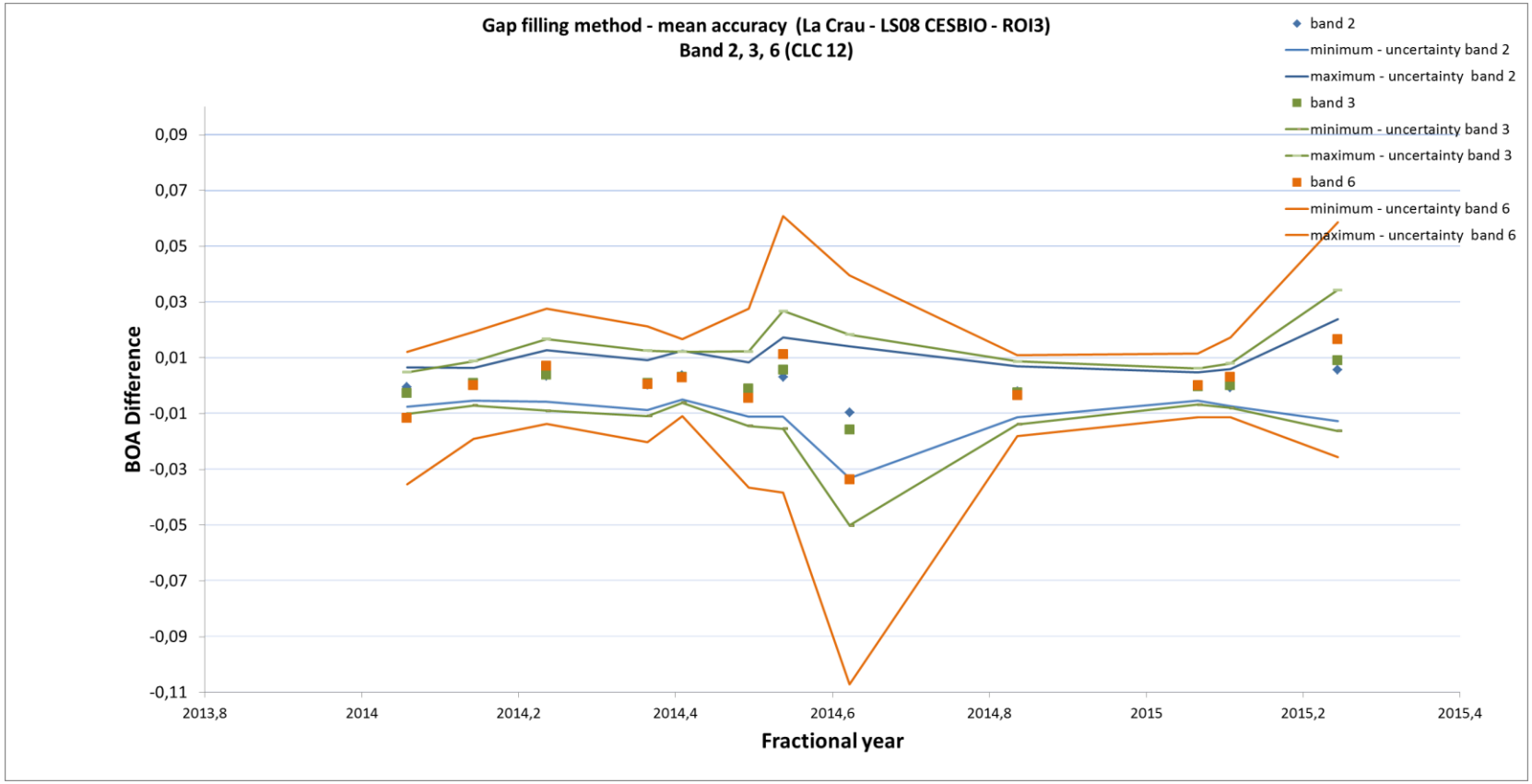

LS08_0LI ds - DTW - 20140302 band : 1
1.01*est + -0.00
True
Estimate

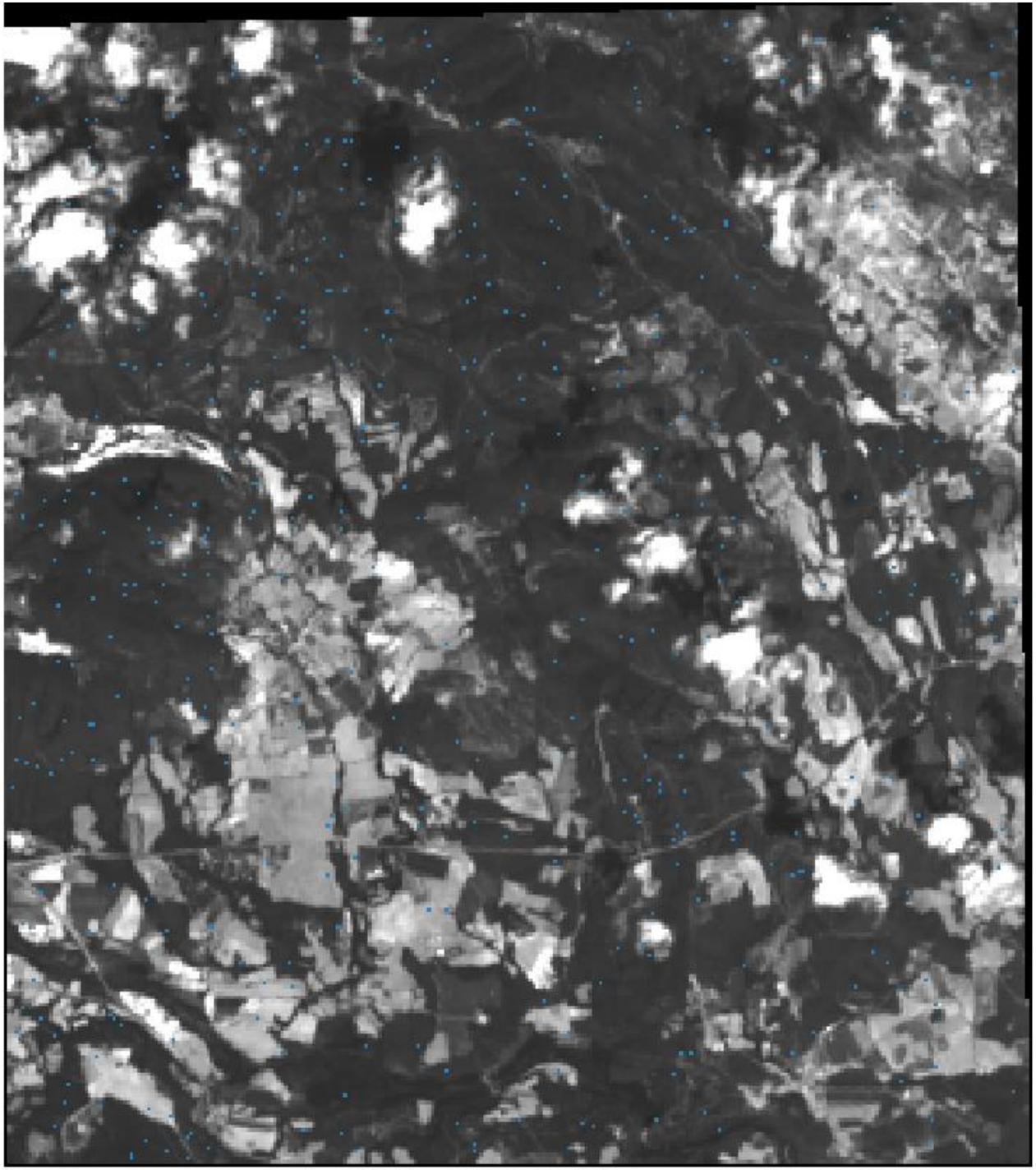

LS08_0LI ds - DTW - 20140302 band : 2
0.99*est + -0.00
True
Estimate


LS08_0LI ds - DTW - 20140302 band : 3
1.00*est + -0.00
True
Estimate


LS08_0LI ds - DTW - 20140302 band : 4
True


distribution of error bd : 2 - 20140223
distribution of error bd : 3 - 20140223
distribution of error bd : 4 - 20140223
distribution of error bd : 5 - 20140223
distribution of error bd : 6 - 20140223
distribution of error bd : 7 - 20140223


Gap filling method - mean accuracy (La Crau - LS08 CESBIO - ROI3)
Band 2, 3, 6 (CLC 12)
band 2
minimum - uncertainty band 2
maximum - uncertainty band 2
band 3
minimum - uncertainty band 3
maximum - uncertainty band 3
band 6
minimum - uncertainty band 6
maximum - uncertainty band 6
BOA Difference
0,09
0,07
0,05
0,03
0,01
-0,01
-0,03
-0,05
-0,07
-0,09
-0,11
2013,8
2014
2014,2
2014,4
2014,6
2014,8
2015
2015,2
2015,4
Fractional year



Functionalities

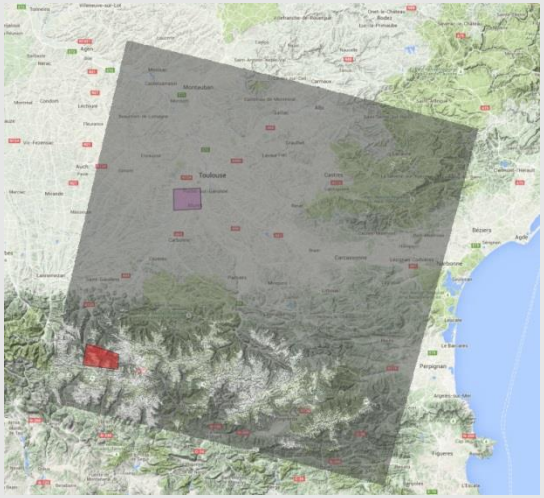
- Today the prototype includes the following processing functions
  - Assimilation of products, to ingest **multi mission** products and also to bring/produce additional information required for subsequent processing
    - Md extraction, TOA convertion, Classification maps selection, digital elevation data selection, MODIS albedo data selection, Creation of ROI, Cloud / shadow computation
  - Times series Preparation,
    - QC / QA information – “Cloud occurrence map”, “statistics on time series”
  - Time series Consolidation,
    - (Module delivered to ESA)
  - Sensitivity analysis
    - Product of degraded time series
    - Statistical analysis

Let ‘s work with data !!!

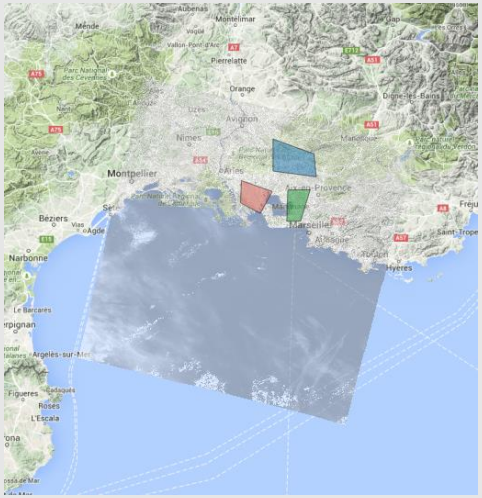
Dataset	Number of Products	Site	ROI Number
LS08_OLI	30 (2014-2015)	Barrax	1
RE00	13 (2015)	Barrax	1
CENPEX	(2) 2009 (June/July)	Barrax	1
LS08_OLI	19 (2014-2015)	Figueres	2
RE00	15 (2015)	Figueres	2
LS08_OLI	19 (2014-2015)	La Crau	3
LS08_OLI (L2 CESBIO)	15 (2014-2015)	La Crau	3
LS05_MSS	17 (1984-1987)	Lybia 4	2
LS05_TM	16 (1984-2011)	Lybia 4	2
LS08_OLI	25 (2013-2015)	Lybia 4	2
RE00	14 2015	Lybia 4	2
LS05_MSS	22 (1984-1987)	Toulouse	3
LS05_TM	18 (1984-1987)	Toulouse	3
LS07_ETM+	22 (2005-2012)	Toulouse	3
LS08_OLI	21 (2014-2015)	Toulouse	3
LS08_OLI (L2 CESBIO)	16 (2014-2015)	Toulouse	3

As, at the time of TDS collection
We did not have Sentinel 2 data.

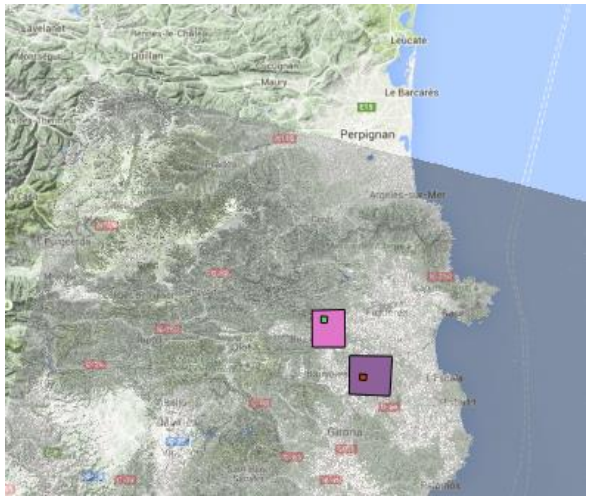
The data fusion processing is applied between RapidEye (RE) and Landsat 08/OLI data.



Toulouse site



La Crau site



Figueres site

Barrax site

Method Comparison – “ROI”

Method	Parameter Identifier	ROI	Number Of Dates	Band Number	Mean Accuracy	Mean Precision	Mean Uncertainty
EXP0	P_1	ROI2	7/11*	2	0,0016	0,0306	0,0334
EXP0	P_1	ROI2	7/11*	3	0,0022	0,0324	0,0335
EXP0	P_1	ROI2	7/11*	4	0,0038	0,0353	0,0370
EXP0	P_1	ROI2	7/11*	5	-0,0059	0,0458	0,0552
EXP0	P_2	ROI3	7/11*	2	0,0006	0,0154	0,0206
EXP0	P_2	ROI3	7/11*	3	0,0000	0,0206	0,0233
EXP0	P_2	ROI3	7/11*	4	-0,0004	0,0275	0,0298
EXP0	P_2	ROI3	7/11*	5	-0,0006	0,0549	0,0572

Method	Parameter Identifier	ROI	Number Of Dates	Band Number	Mean Accuracy	Mean Precision	Mean Uncertainty
EXP 2	P_3	ROI2	10/11	5	-0,0054	0,0443	0,0467
EXP 2	P_4	ROI3	11/11	5	0,0053	0,0379	0,0393

Method Comparison – “Bands”

Method	Parameter Identifier	ROI	Number Of Dates	Band Number	Mean Accuracy	Mean Precision	Mean Uncertainty
EXP 0	P_5	ROI3	12/16*	1	-0,0012	0,0081	0,0206
EXP 0	P_5	ROI3	12/16*	2	-0,0011	0,0091	0,0203
EXP 0	P_5	ROI3	12/16*	3	-0,0009	0,0109	0,0190
EXP 0	P_5	ROI3	12/16*	4	-0,0009	0,0149	0,0213
EXP 0	P_6	ROI4	12/16*	1	-0,0015	0,0142	0,0223
EXP0	P_6	ROI4	12/16*	2	-0,0015	0,0161	0,0235
EXP0	P_6	ROI4	12/16*	3	-0,0014	0,0189	0,0245
EXP0	P_6	ROI4	12/16*	4	-0,0017	0,0270	0,0319

Method	Parameter Identifier	ROI	Number Of Dates	Band Number	Mean Accuracy	Mean Precision	Mean Uncertainty
EXP 2	P_10	ROI3	14/14	2	-0,0006	0,0033	0,0035
EXP 2	P_10	ROI3	14/14	3	-0,0005	0,0046	0,0048
EXP 2	P_10	ROI3	14/14	4	-0,0006	0,0066	0,0068
EXP 2	P_10	ROI3	14/14	5	0,0000	0,0186	0,0191
EXP 2	P_10	ROI3	14/14	6	0,0000	0,0122	0,0125
EXP 2	P_10	ROI3	14/14	7	-0,0004	0,0097	0,0099

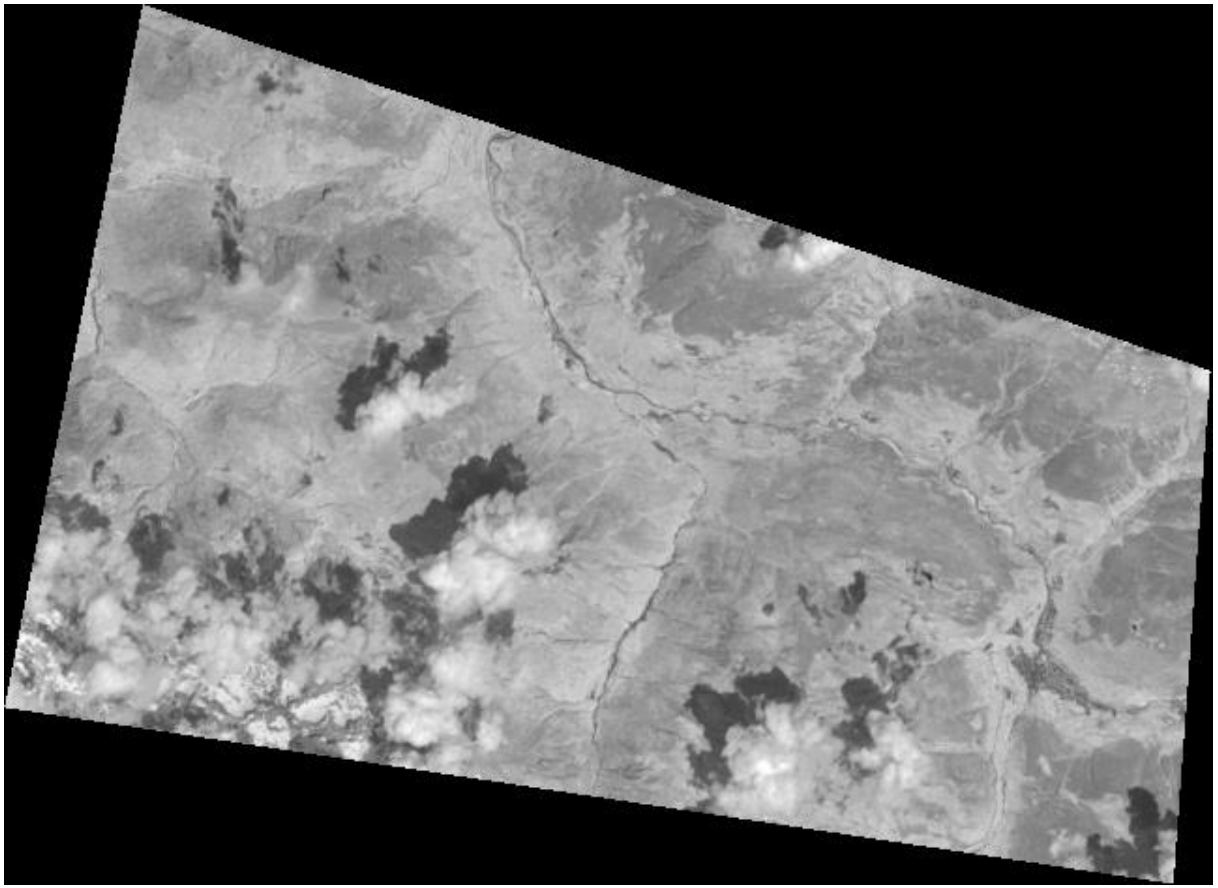
Method Comparison->selection

- The DTW outperforms the other methods, and it is interesting to better understand how is varying the uncertainty.
- Date to date variability is observed, it strongly depends on the quality of mask : cloud , shadow, snow …
- And also the land cover …
- For in depth analysis,
  - The contributions of ATMOSPHERE, TERRAIN, ENVIRONNEMENT should be minimized => Select SR products.
  - The mask should be without errors => validate each mask and produced new one if needed.
  - The uncertainties depending on the land cover will be analyzed by using CLC map.

Reference ?

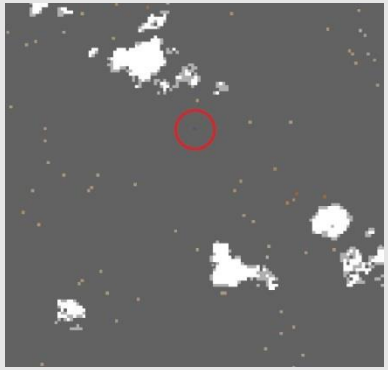
Band	Blue (band 2)	Green (band 3)	Red (band 4)	NIR (band 5)	SWIR1 (band 6)	SWIR2 (band 7)
TOA Mean	0.24143	0.32852	0.44497	0.56941	0.65524	0.60153
TOA Standard deviation	**0.0023729**	**0.0018866**	**0.0039056**	**0.0056626**	**0.012236**	**0.012361**
Temporal Uncertainty (%)	1	0.6	0.9	1	1.9	2.1
Linear interpolation Estimated Slope	-4.5066e-6	-2.8003e-6	-1.3734e-6	-7.7441e-8	1.2727e-5	4.0552e-6
Linear interpolation Estimated Intercept	0.24431	0.33031	0.44585	0.56946	0.64712	0.59894
Norm of Residuals error	0.011907	0.0096709	0.020631	0.029964	0.063761	0.065308

Cloud Mask

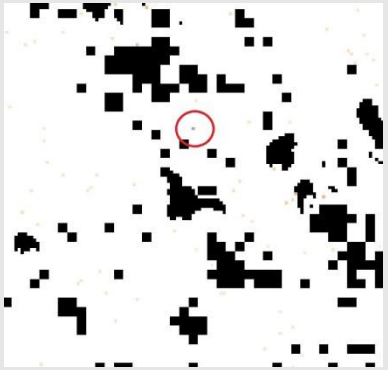


BQA Image.

Zoom on LC81970312015240LGN00 (20150828) product - band 5

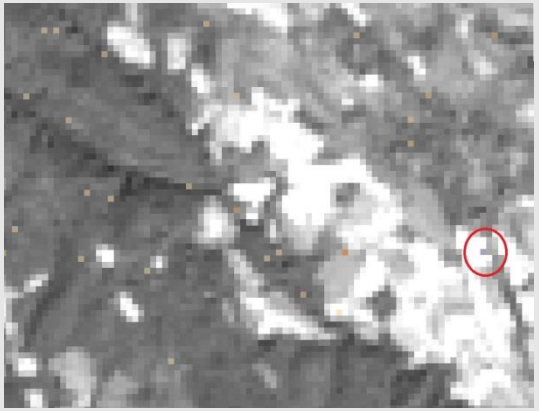


Zoom on LC81970312015240LGN00 (20150828) product - band BQA

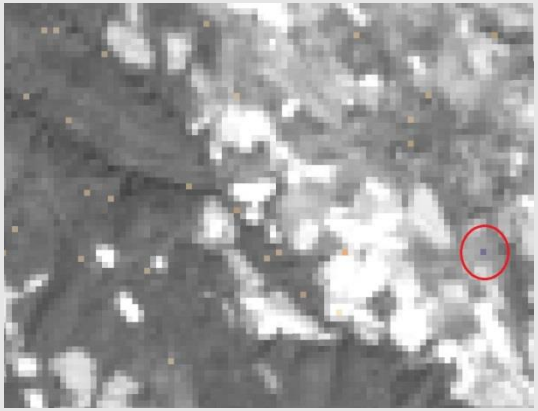


Zoom on LC81970312015240LGN00 (20150828) product – clear sky mask

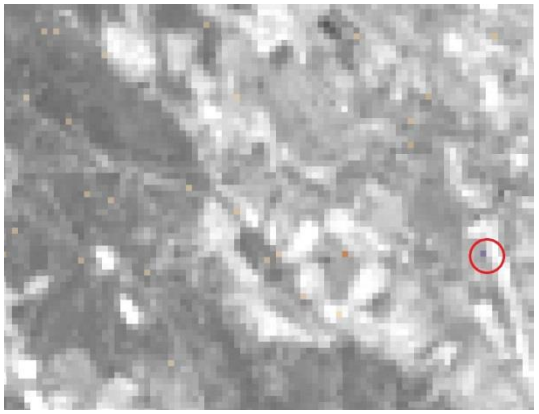
Landscape change



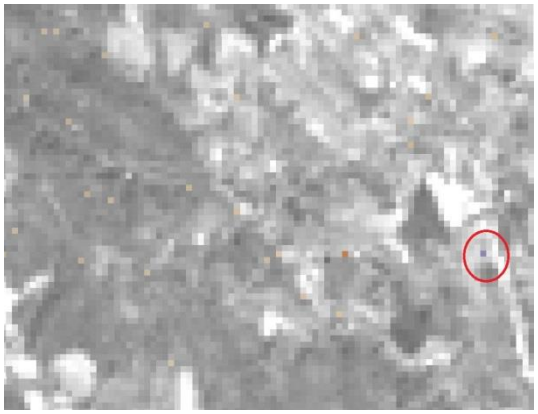
Zoom of 20140302 product (Figueres ROI3)



Zoom of 0140318 product (Figueres ROI3)



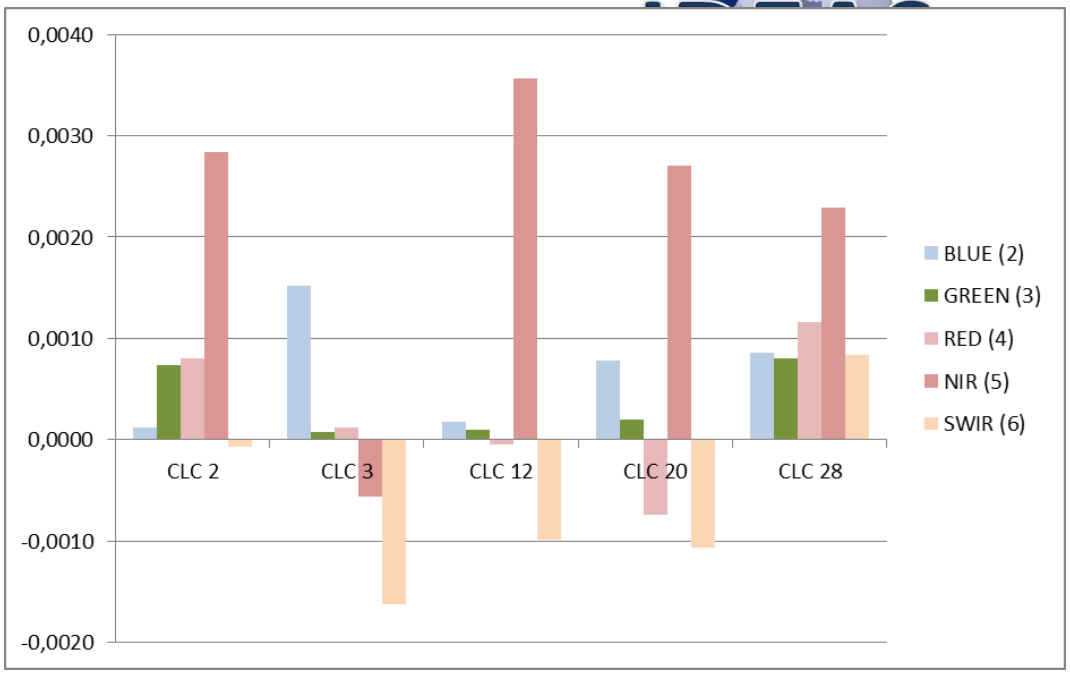
Zoom of 20140505 product (Figueres ROI3)



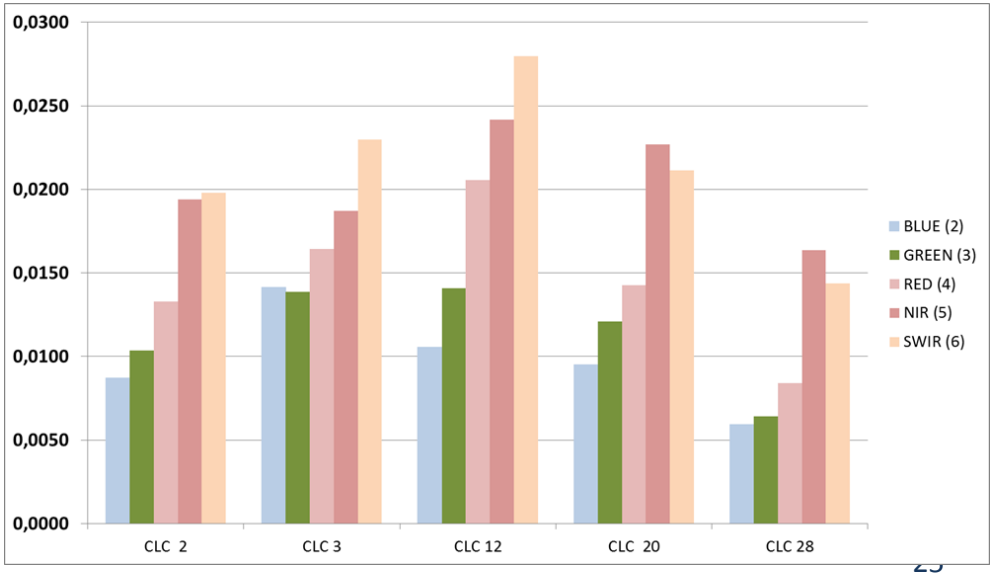
Zoom of 20140910 product (Figueres ROI3)

2	tissu urbain discontinu
3	zones industrielles et commerciales
4	réseaux routiers et ferroviaires
6	aéroports
7	extraction de matériaux
8	décharges
9	chantiers
12	terres arables
20	prairies
25	forêts de feuillus
28	pelouses et pâturages naturels
29	landes et broussailles
33	zones incendiées
42	lagunes littorales

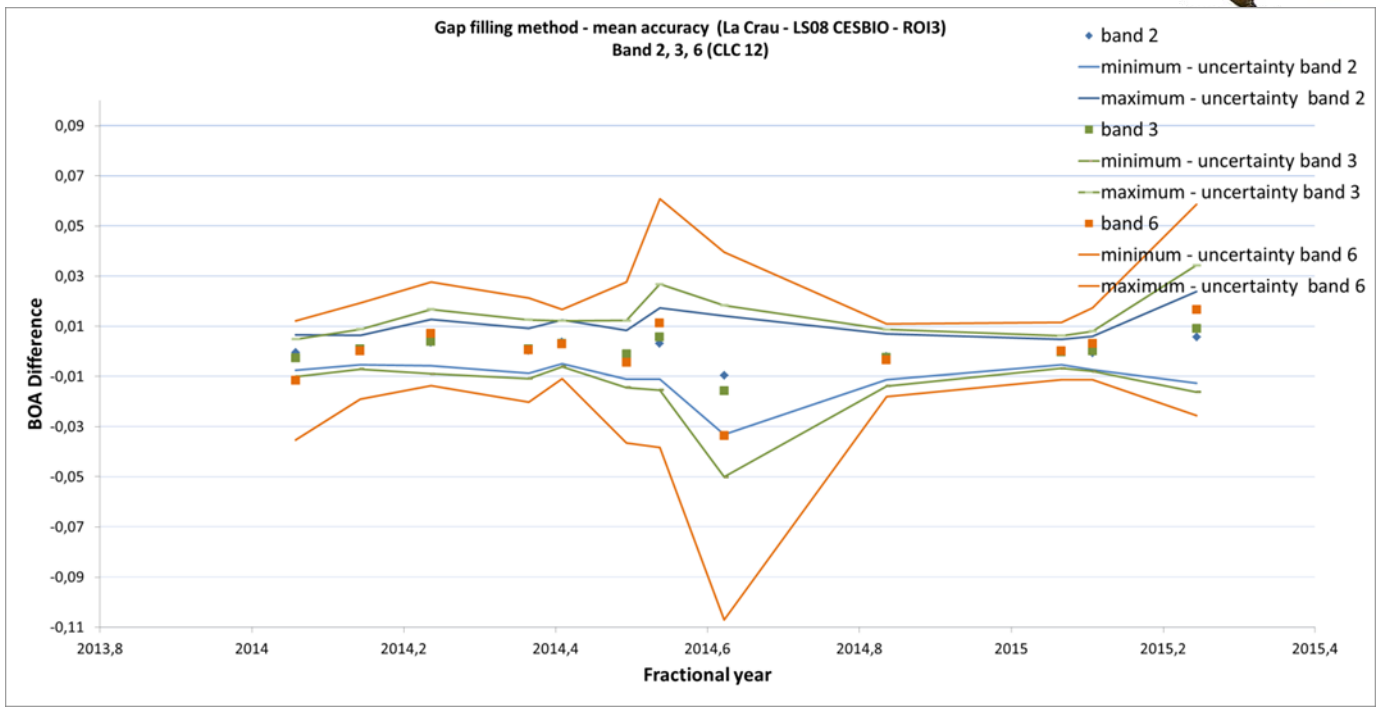
Étiquettes de lignes	CLC 2	CLC 3	CLC 12	CLC 20	CLC 28
BLUE (2)	0,0001	0,0015	0,0002	0,0008	0,0009
GREEN (3)	0,0007	0,0001	0,0001	0,0002	0,0008
RED (4)	0,0008	0,0001	-0,0001	-0,0007	0,0012
NIR (5)	0,0028	-0,0006	0,0036	0,0027	0,0023
SWIR-1 (6)	-0,0001	-0,0016	-0,0010	-0,0011	0,0008
Total général	**0,0009**	**-0,0001**	**0,0006**	**0,0004**	**0,0012**



Étiquettes de lignes	CLC 2	CLC 3	CLC 12	CLC 20	CLC 28
BLUE (2)	0,0087	0,0141	0,0106	0,0095	0,0059
GREEN (3)	0,0104	0,0139	0,0141	0,0121	0,0064
RED (4)	0,0133	0,0164	0,0206	0,0143	0,0084
NIR (5)	0,0194	0,0187	0,0242	0,0227	0,0164
SWIR-1 (6)	0,0198	0,0230	0,0280	0,0211	0,0144
Total général	**0,0143**	**0,0172**	**0,0195**	**0,0159**	**0,0103**



In depth Analysis – BOA – La Crau – Per Class



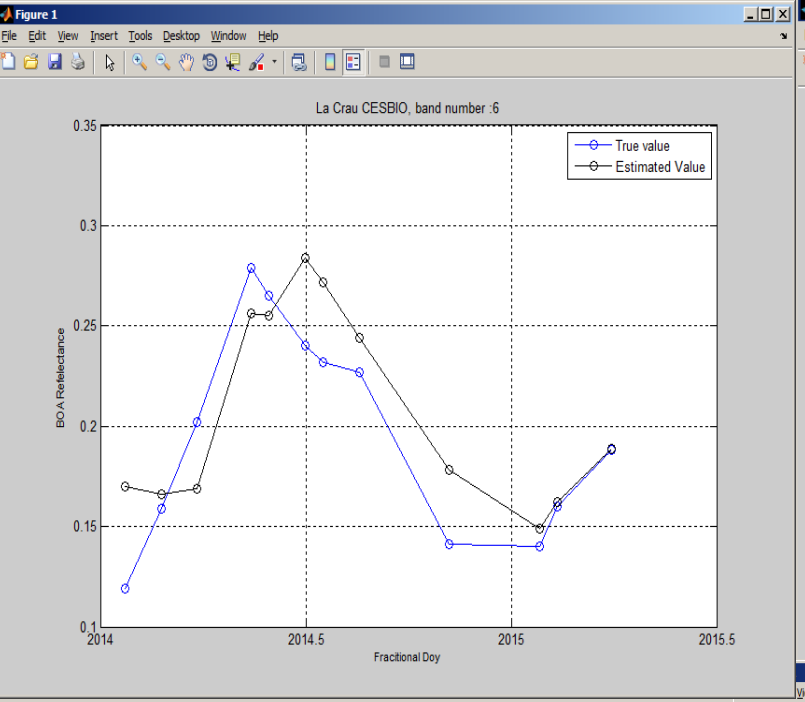


Figure 1
File Edit View Insert Tools Desktop Window Help
La Crau CESBIO, band number :6
True value
Estimated Value
BOA Refelectance
Fracitional Doy
0.35
0.3
0.25
0.2
0.15
0.1
2014
2014.5
2015
2015.5

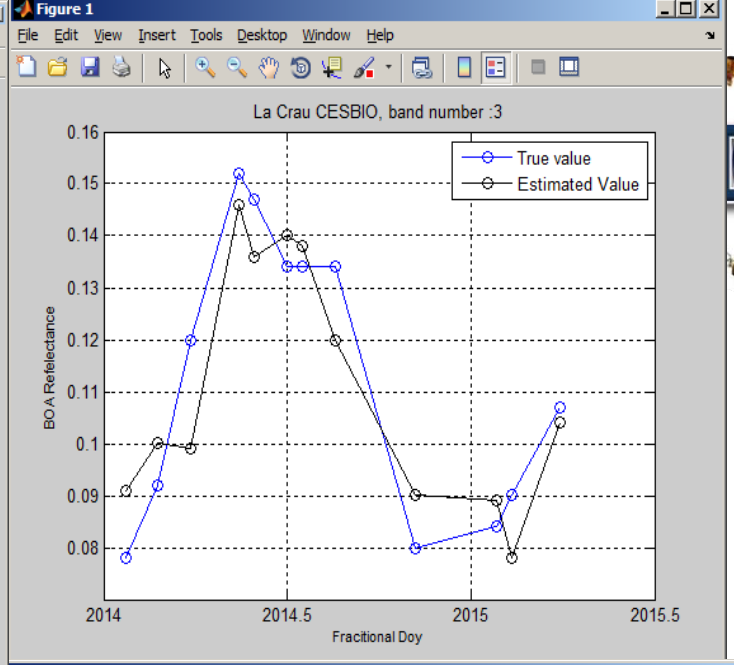
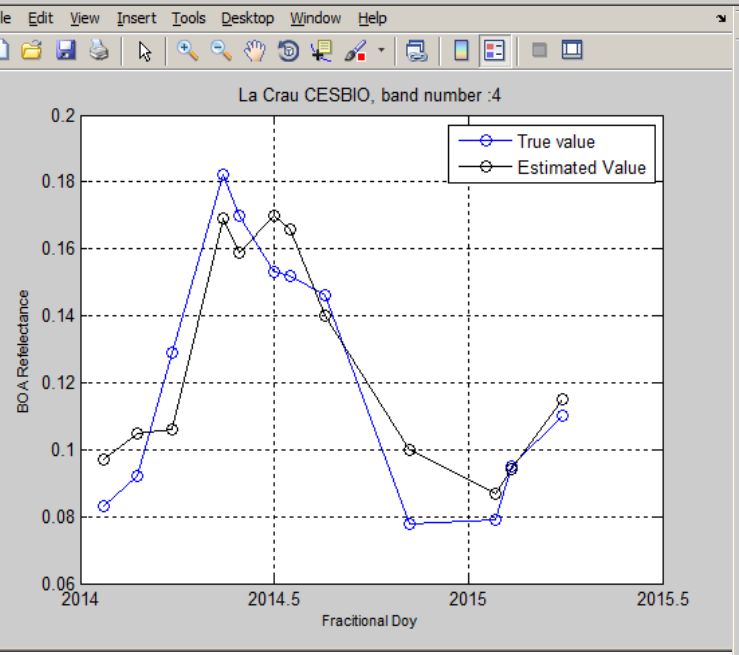
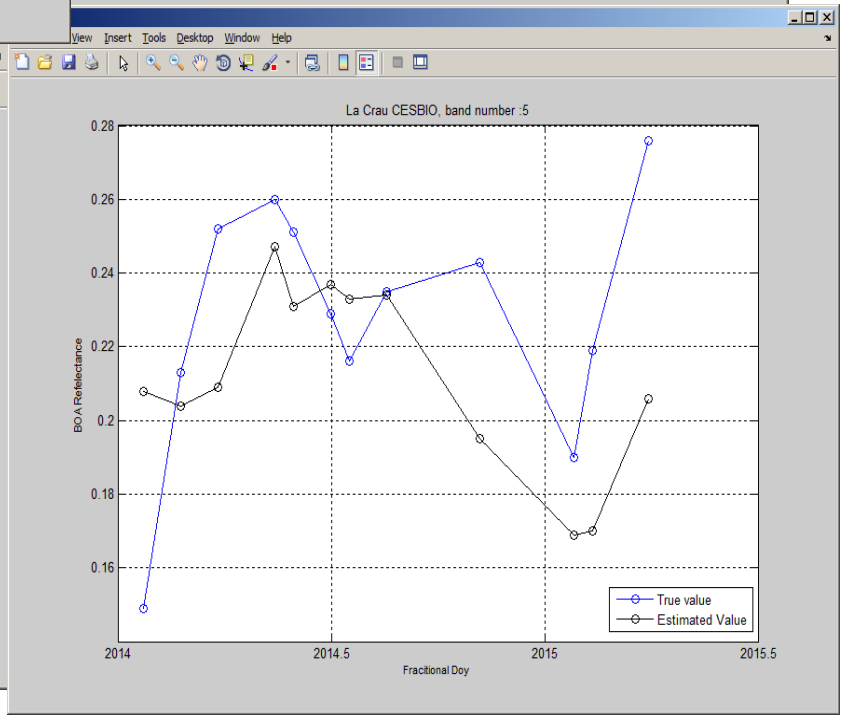


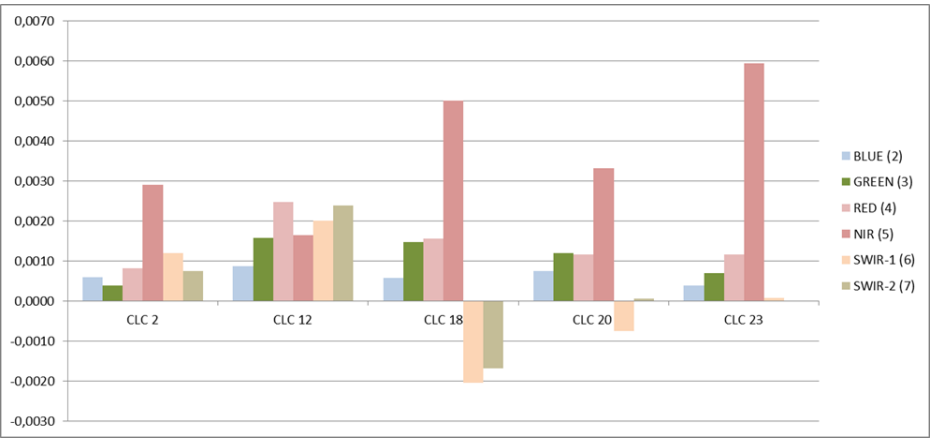
Figure 1
File Edit View Insert Tools Desktop Window Help
La Crau CESBIO, band number :3
True value
Estimated Value
BOA Refelectance
Fracitional Doy
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
2014
2014.5
2015
2015.5


Edit View Insert Tools Desktop Window Help
La Crau CESBIO, band number :4
True value
Estimated Value
BOA Refelectance
Fracitional Doy
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
2014
2014.5
2015
2015.5

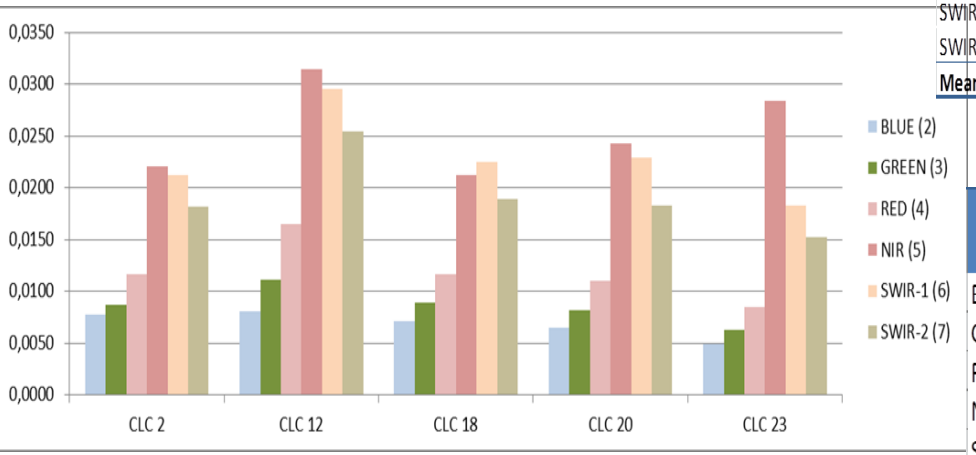

View Insert Tools Desktop Window Help
La Crau CESBIO, band number :5
True value
Estimated Value
BOA Refelectance
Fracitional Doy
0.28
0.26
0.24
0.22
0.2
0.18
0.16
2014
2014.5
2015
2015.5

In depth Analysis – BOA – Toulouse– Per Class

2	tissu urbain discontinu
12	terres arables
18	vergers et petits fruits
20	prairies
23	surfaces essentiellement agricoles interrompues par des espaces naturels importants

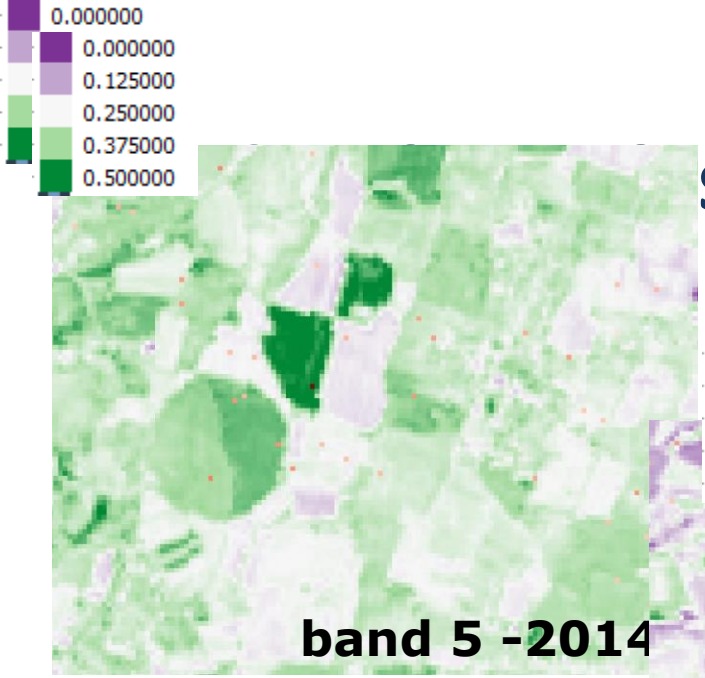


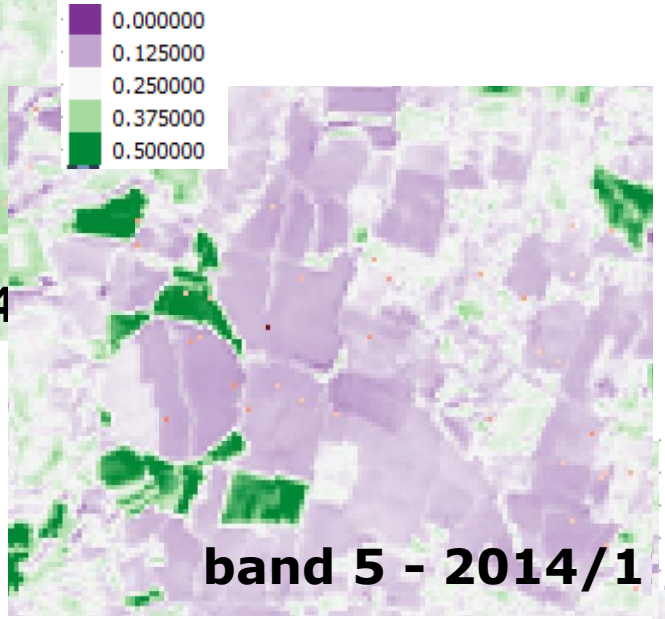
Band Number	CLC 2	CLC 12	CLC 18	CLC 20	CLC 23
BLUE (2)	0,0006	0,0009	0,0006	0,0008	0,0004
GREEN (3)	0,0004	0,0016	0,0015	0,0012	0,0007
RED (4)	0,0008	0,0025	0,0016	0,0012	0,0012
NIR (5)	0,0029	0,0016	0,0050	0,0033	0,0059
SWIR-1 (6)	0,0012	0,0020	-0,0020	-0,0007	0,0001
SWIR-2 (7)	0,0008	0,0024	-0,0017	0,0001	0,0000
Mean Value	**0,0011**	**0,0018**	**0,0008**	**0,0010**	**0,0014**

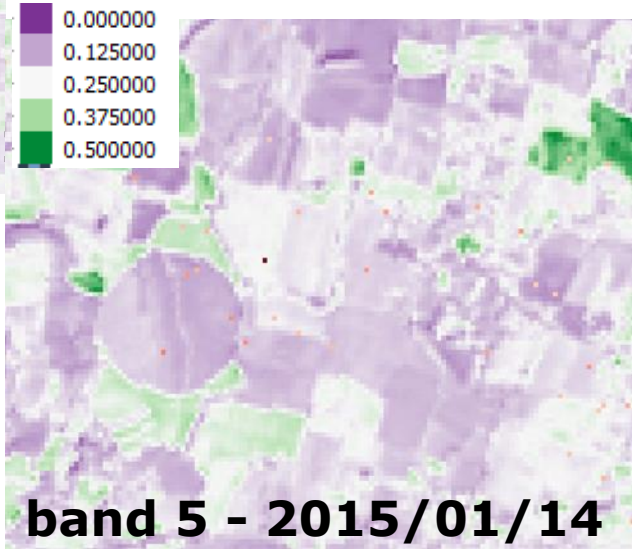


LS08/OLI bands	CLC 2	CLC 12	CLC 18	CLC 20	CLC 23
BLUE (2)	0,0077	0,0081	0,0071	0,0065	0,0049
GREEN (3)	0,0087	0,0111	0,0090	0,0081	0,0063
RED (4)	0,0117	0,0165	0,0117	0,0110	0,0085
NIR (5)	0,0220	0,0314	0,0212	0,0243	0,0284
SWIR-1 (6)	0,0212	0,0296	0,0224	0,0229	0,0183
SWIR-2 (7)	0,0182	0,0255	0,0189	0,0183	0,0152
Mean Value	**0,0149**	**0,0204**	**0,0151**	**0,0152**	**0,0136**

sis – Data fusion



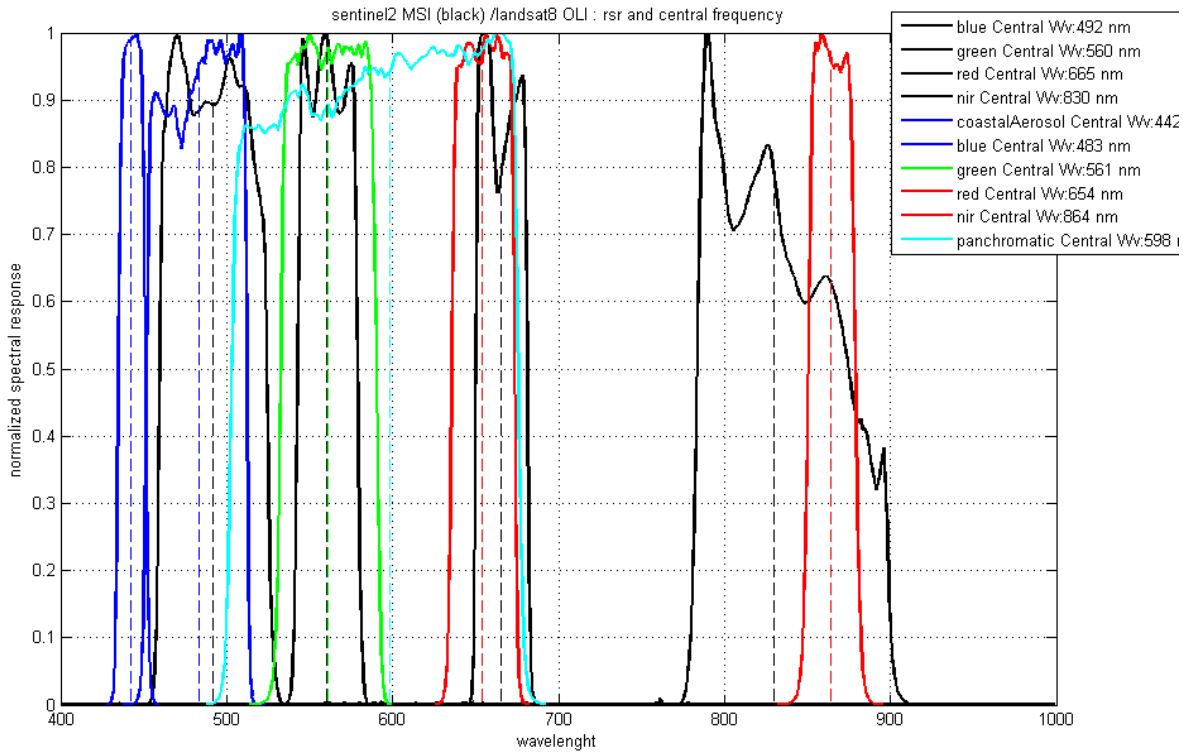




- A new Method for data interpolation in the context of Time Series from EO products has been presented.
- Validation has been performed for a better understanding of the method, underlying limitations mostly linked to pre processing and product definition.
- This method is attractive but processing very time consuming – Way forward
  - To do pre segmentation
  - To use classification map
  - To do a pre classification
-

Thank you

sebastien.saunier@telespazio.com



Common spectral range; LS8 OLI and Sentinel 2 MSI 10 m bands (black).