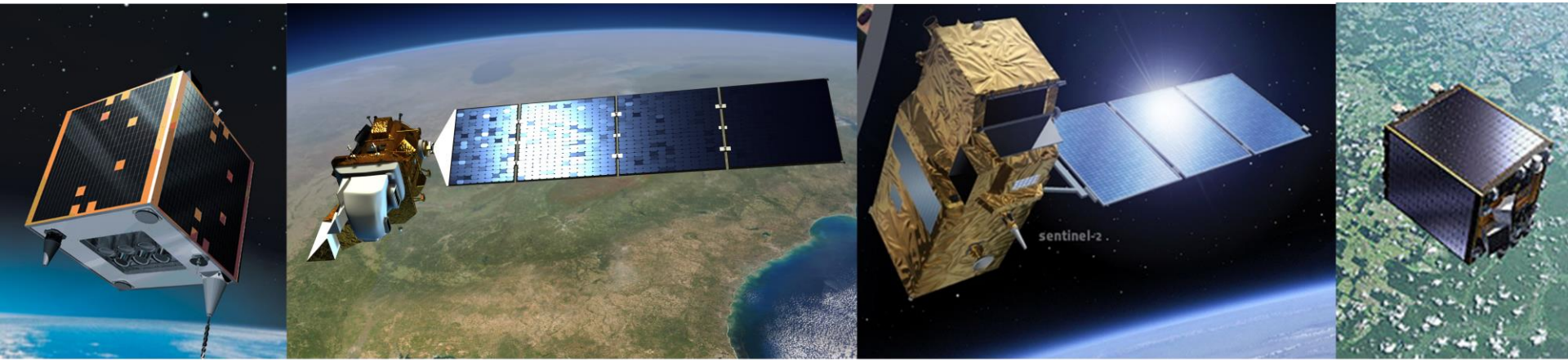

TOWARDS HARMONIZATION OF MULTI-SENSOR TIME SERIES: THE BELHARMONY APPROACH

Sindy Sterckx[1,*], Else Swinnen[1] ,Erwin Wolters[1] , Jonathan Leon Tavares[1] , Isabelle Piccard[1] , Charlotte Wirion[2],Boud Verbeiren[2], Cristiana Bassani[3]

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*

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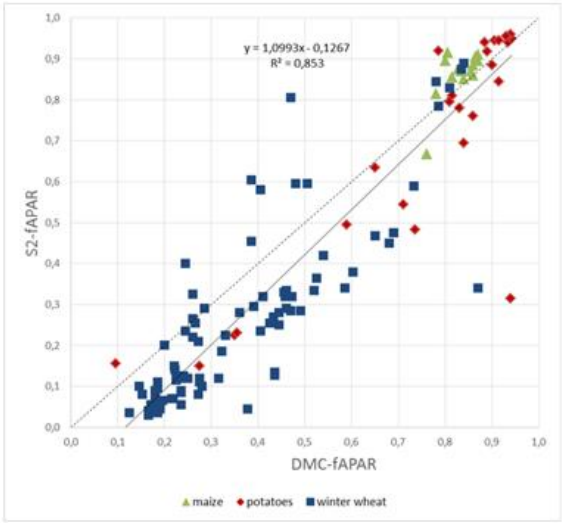
BELHARMONY OVERALL OBJECTIVE

- To assess and improve the consistency of multi-sensor high resolution time series. (HARMONY)
- Landsat-8, Sentinel-2, PROBA-V (central camera) and Deimos-1/DMC
- How ?

  Bottom-up approach

  (from L1 to L2 to L3)



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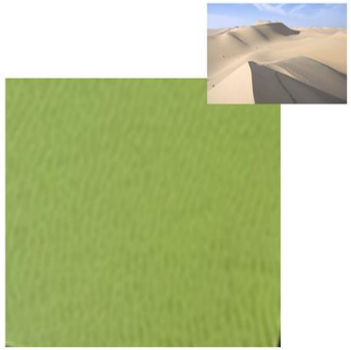
BELHARMONY SCIENTIFIC QUESTIONS

1. Are the the L1 TOA data consistent ?

Medium to high radiances

Inter-comparison over the Libya-4 PICS desert site following the OSCAR* desert approach



Bias Assessment over instrument RadCalNet sites (Land Equipped Sites (LIS))

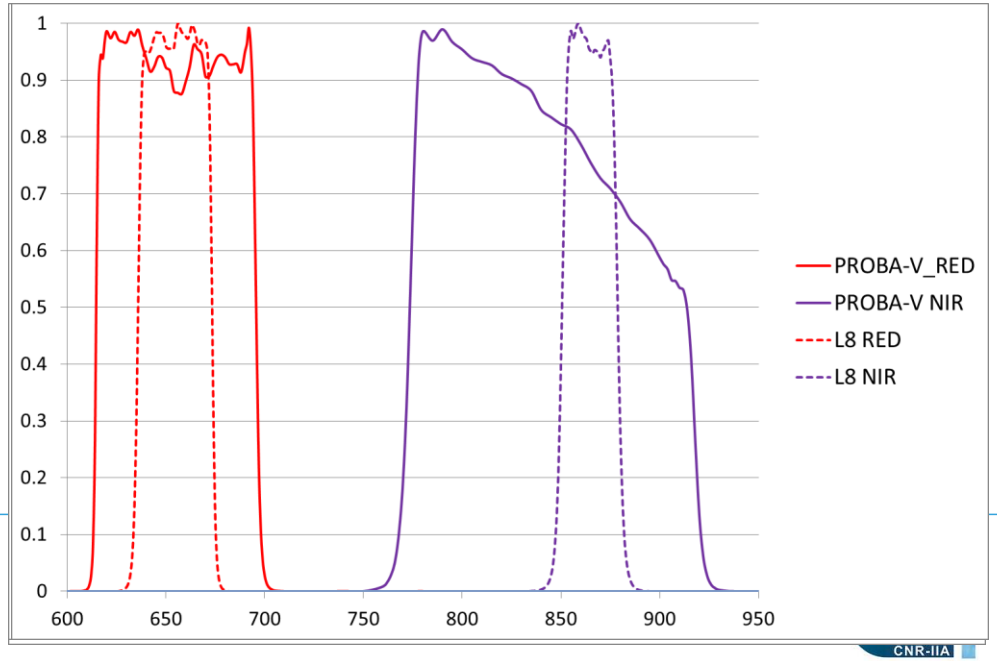
Low radiances

**OSCAR (Optical Sensor Calibration with simulated Radiances). Govaerts, Y., S. Sterckx, and S. Adriaensen (2013). Use of simulated reflectances over bright desert target as an absolute calibration reference. Remote Sensing Letters, , Vol. 4: 6, 523-531.*

BELHARMONY SCIENTIFIC QUESTIONS

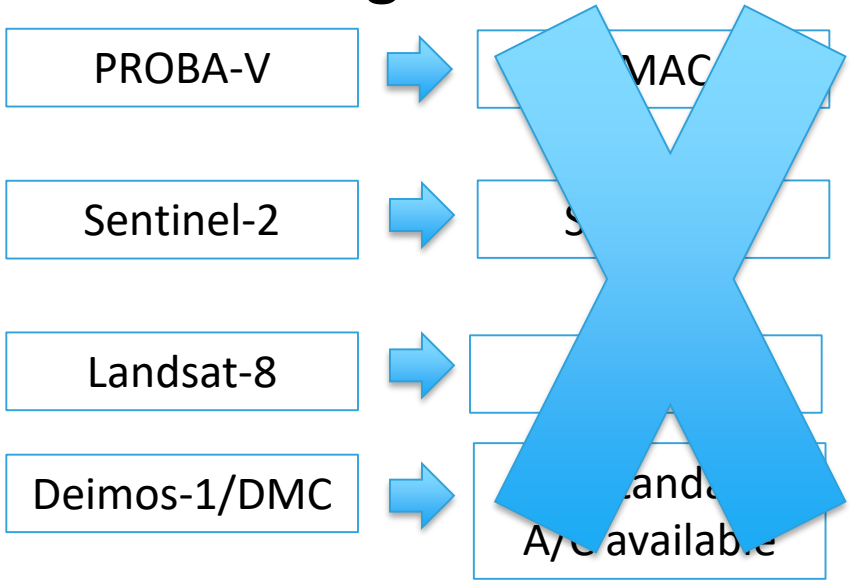
1. Are the the L1 data consistent ?
2. What is the impact of intrinsic differences in the RSRF of the different sensors ?

- Can BELHARMONY through the introduction of band or index dependent spectral adjustment functions correct for this ?



BELHARMONY SCIENTIFIC QUESTIONS

1. Does there exist a bias in the L1 data ?
2. What is the impact of intrinsic differences in the RSRF of the different sensors ?
3. Can differences in L2 and L3 data be reduced through the use of a common processing chain ?



De Keukelaere et al. (2018)

BELHARMONY SCIENTIFIC QUESTIONS

1. Does there exist a bias in the L1 data ?
2. What is the impact of intrinsic differences in the RSRF of the different sensors ?
3. Can differences in L2 and L3 data be reduced through the use of a common processing chain ?
4. What is impact of all these harmonization measures on the consistency of the multi-sensor L2/L3 time series?

=> BELHARMONY APPROACH:

BELAIR CASE STUDIES

BELHARMONY RESULTS

Does there exist a bias in the L1 data ?

S2	S2	S2A	% dif S2B	LS8	LS8	% dif LS8	Deimos1	Deimos-1	% dif D-1	PV	PV	% dif PV
band	cwv	ratio	vs S2A	band	cwv	vs S2A	band	cwv	vs S2A	band	cwv	vs S2A
1	443	1.008	−1.05%	CA	443	−1.05%				Blue	460	−1.30%
2	490	0.985	−0.03%	Blue	492	0.94%					460	0.97%
3	560	0.999	−0.16%	Green	561	0.82%	Green	549	−3.5%			
4	665	1.005	−0.76%	Red	654	0.08%	Red	679	0.2%	Red	658	−1.55%
5	705	1.016	−1.32%									
6	740	1.023	−1.49%									
7	783	1.034	−1.35%									
8	842	0.999	−0.40%				NIR	803	0.8%	NIR	834	0.78%
8A	865	1.027	−0.84%	NR	865	−0.28%						
9	945	NA	NA									
10	1375	NA	NA	Cirrus	1373	NA						
11	1610	0.998	−0.40%	SWIR1	1610	−0.30%				SWIR	1610	−0.21%
12	2190	0.973	−0.12%	SWIR2	2200	0.28%						

Open Access Article

Radiometric Top-of-Atmosphere Reflectance Consistency Assessment for Landsat 8/OLI, Sentinel-2/MSI, PROBA-V, and DEIMOS-1 over Libya-4 and RadCalNet Calibration Sites

by Sindy Sterckx * and Erwin Wolters

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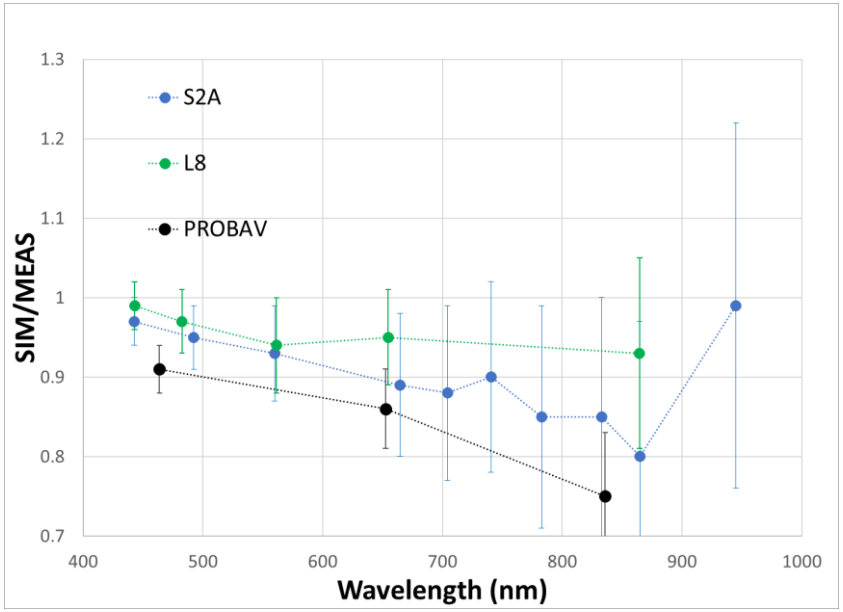
- Relative differences between sensors small Lybia 4 (< ±1.5%) and Gobabeb (< ±2.5%)
- Deimos 1 green band larger differences 3.5%
- Differences between S2A and S2B of the same magnitude as differences observed between Sentinel-2A and the other sensors.
- S2A possibly slightly brighter than S2B, but within uncertainty range of reference methods

CNR-IIA VUB vito

BELHARMONY RESULTS

Does there exist a bias in the L1 data ?



1. AERONET-OC products Lev 2.0
2. Configuration of sensor acquisition

↓ 6SV

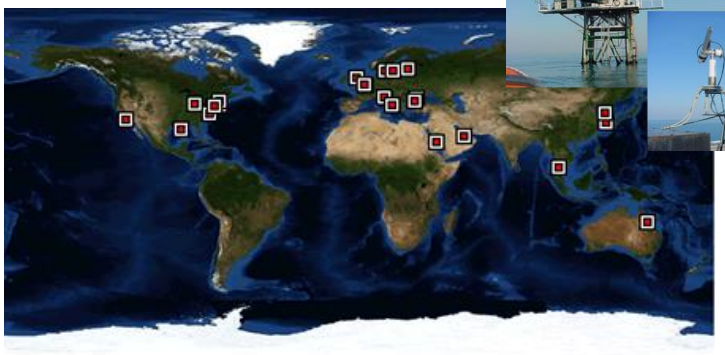
Hyperspectral TOA simulated reflectance

↓ Convolution to RSR

REF == Simulated TOA signal

↓ Screenings

GAINS=REF/MEAS



BELHARMONY RESULTS

Spectral correction functions derivation

1. **Generate simulations of vegetation and mixtures with different background**
   → Coupled Soil-Leaf-Canopy (SLC) RTM

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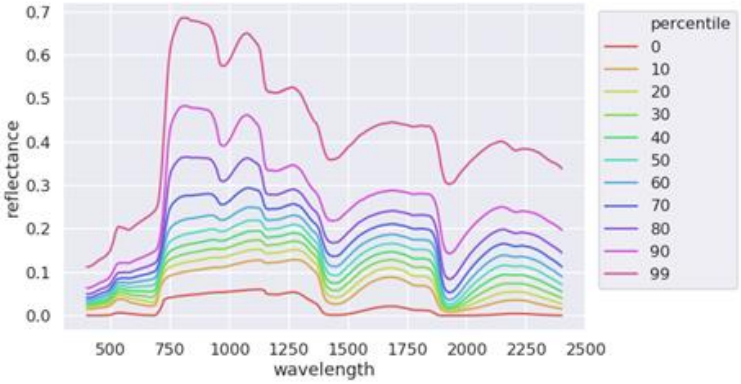
2. **Add man-made and water spectra**
   → Spectral library + ASD measurements



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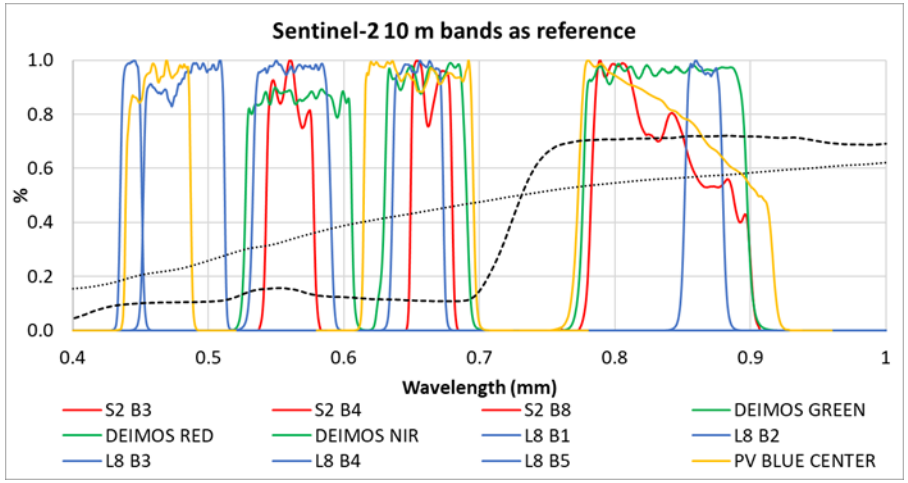

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4. **Estimate correction functions per band**

Different models were explored for each band

- Linear model
  - $\bar{\rho}_{\lambda,ref} = a + b \cdot \bar{\rho}_{\lambda,tar}$
- Multi-linear regression models
  - $\bar{\rho}_{\lambda,(red,nir),ref} = \beta_1 \bar{\rho}_{red,tar} + \beta_2 \bar{\rho}_{nir,tar} + \beta_3 NDVI + \beta_3 NDVI^2 + \epsilon$
  - $\bar{\rho}_{\lambda,(g,red,nir),ref} = \beta_1 \bar{\rho}_{(g,red),tar} + \beta_2 \bar{\rho}_{nir,tar} + \beta_3 \left(\bar{\rho}_{(g,red),tar} \cdot \bar{\rho}_{nir,tar}\right) + \beta_4 \left(\bar{\rho}_{(g,red),tar}\right)^2 + \beta_5 \left(\bar{\rho}_{(nir),tar}\right)^2 + \epsilon$
- Quadratic model of the relative difference in function of the NDVI
  - $SBAF = \frac{\bar{\rho}_{\lambda,ref}}{\bar{\rho}_{\lambda,tar}} = a + b \cdot NDVI + c \cdot NDVI^2$
  - $abs.diff = a + b \cdot NDVI + c \cdot NDVI^2$
  - $rel.diff = a + b \cdot NDVI + c \cdot NDVI^2$
- Exponential function of the SBAF, AD, RD in function of the NDVI
  - $SBAF = a \cdot e^{b \cdot NDVI} + c \cdot e^{d \cdot NDVI}$
  - $AD = a \cdot e^{b \cdot NDVI} + c \cdot e^{d \cdot NDVI}$
  - $RD = a \cdot e^{b \cdot NDVI} + c \cdot e^{d \cdot NDVI}$

BELHARMONY RESULTS

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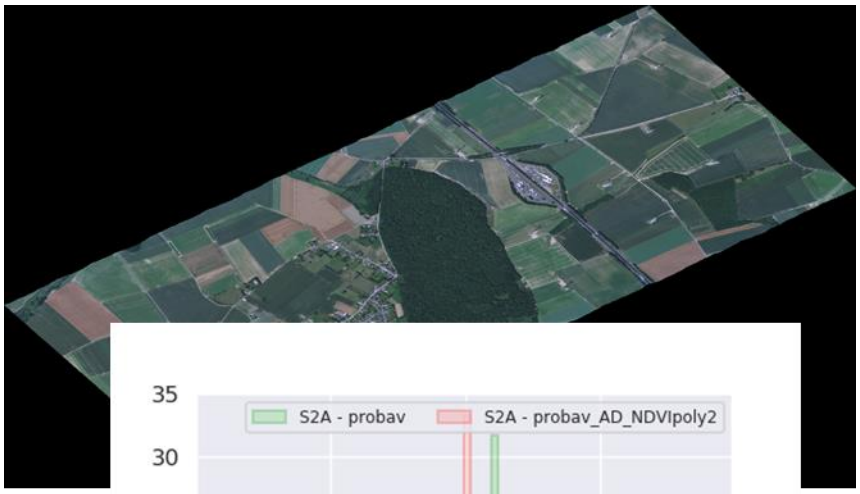
4. **Estimate correction functions per band**

5. **Validate the correction functions**



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Final spectral correction functions

S2A – Landat8

Corresponding Band	Input	Function	Order	Remark
B3	SBAF	NDVIpoly	2	
B4	SBAF	NDVIpoly	3	
B8	-	-	-	No correction possible
B8A	-	-	-	Original bands sufficiently similar
B11	AD	NDVI2exp	-	
B12	refl	Qmultilin	-	

S2A – Deimos1

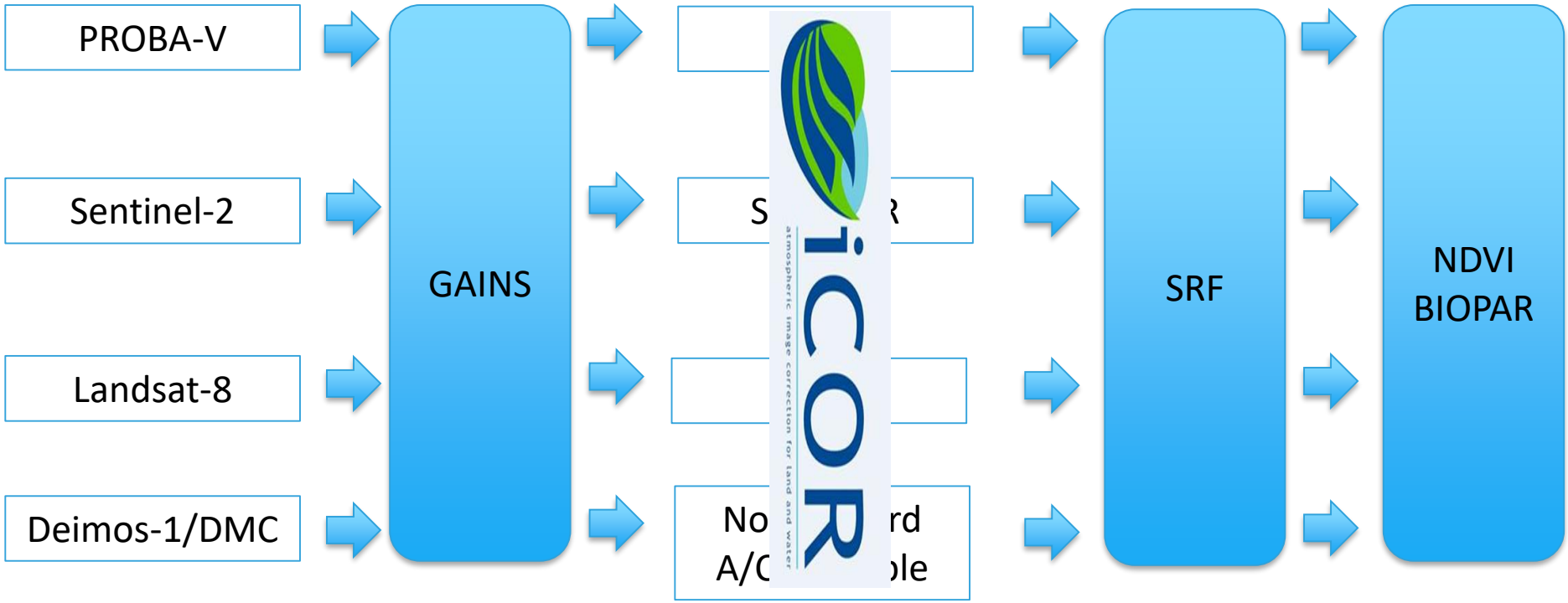
Corresponding Band	Input	Function	Order	Remark
B3	SBAF	NDVIpoly	2	
B4	SBAF	NDVIpoly	3	
B8	-	-	-	Original bands sufficiently similar
B8A	SBAF	NDVI2exp	-	Correction not very effective: optional

S2A – Proba-V

Corresponding Band	Input	Function	Order	Remark
B4	SBAF	NDVIpoly	2	
B8	SBAF	NDVI2exp	-	Small improvement
B8A	-	-	-	No correction possible
B11	AD	NDVIpoly	2	

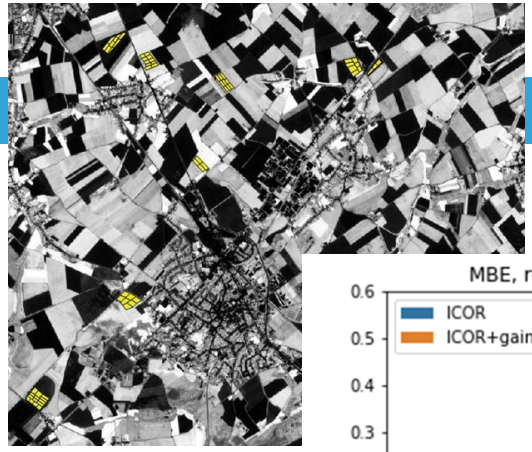
BELHARMONY RESULTS

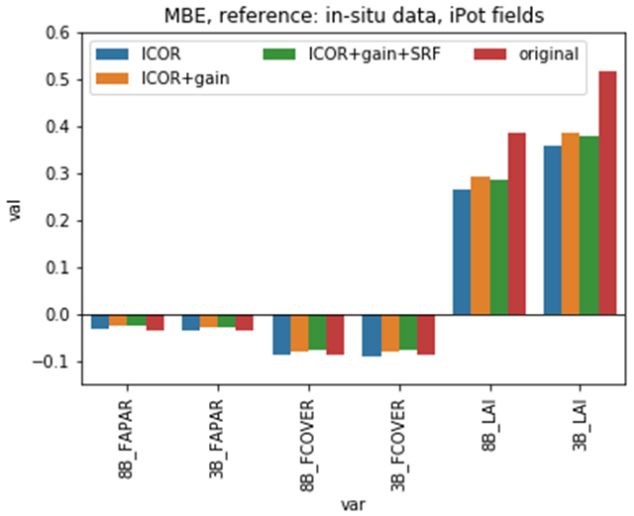
What's the impact of all the harmonisation measures ?

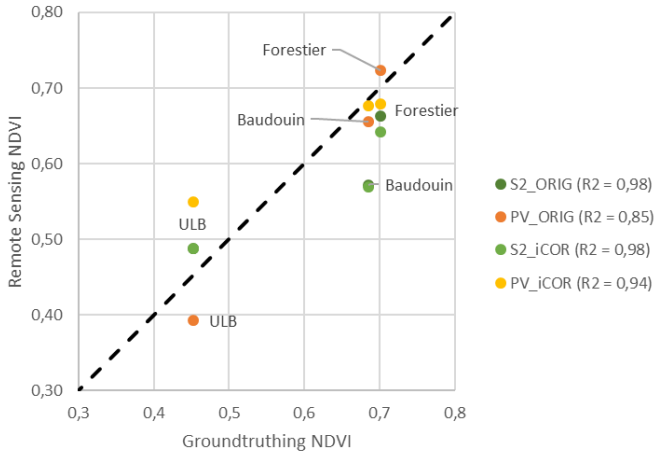


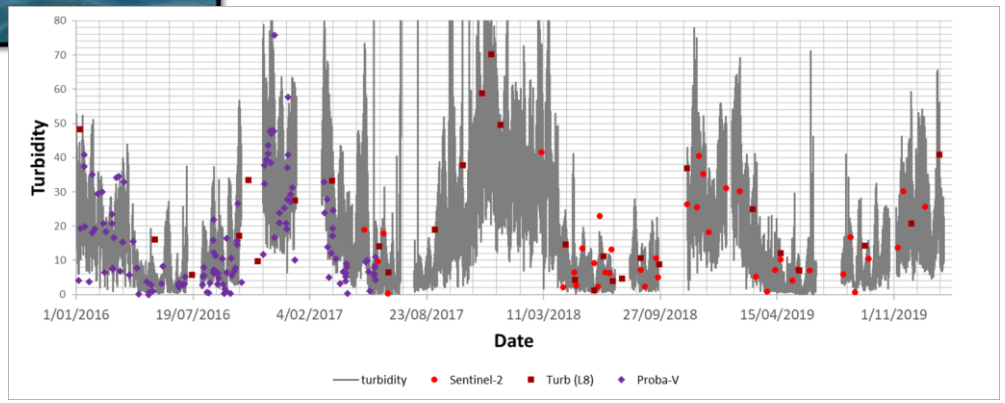
VALIDATION OVER BELAIR SITES

1. Validation with in-situ data





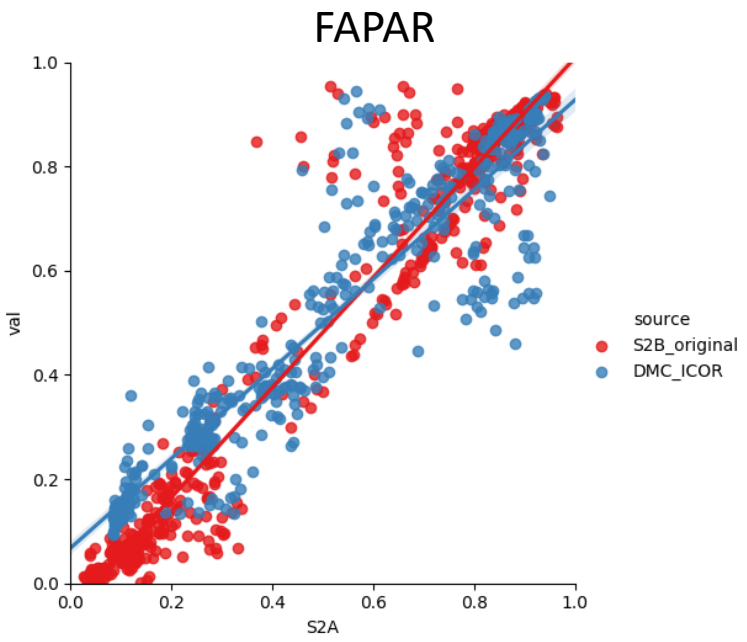


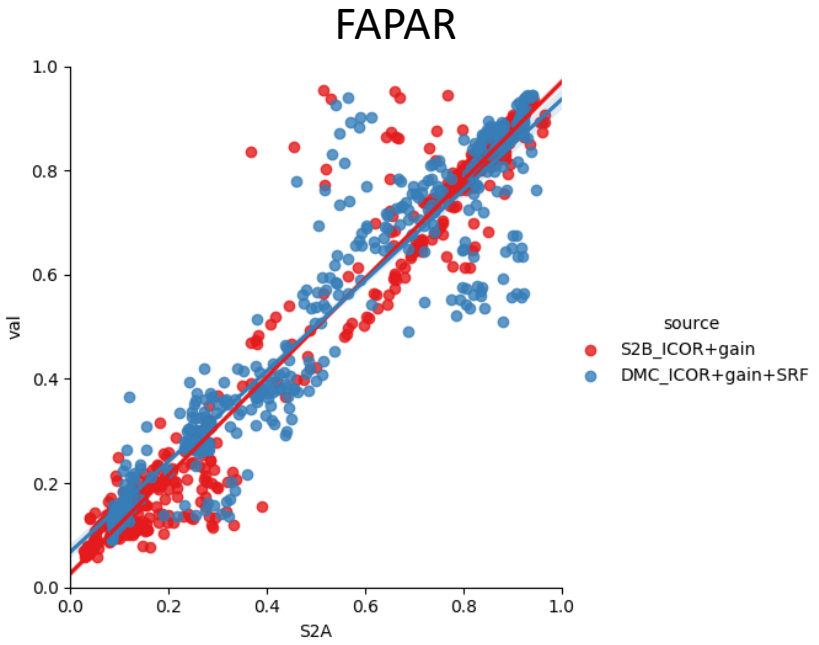


VALIDATION OVER BELAIR SITES

1. **Validation with in-situ data**

2. **Matchups between sensors**

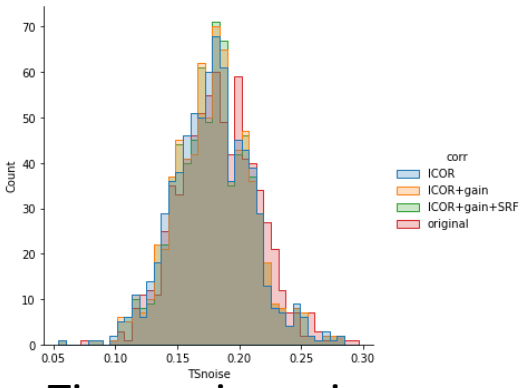




VALIDATION OVER BELAIR SITES

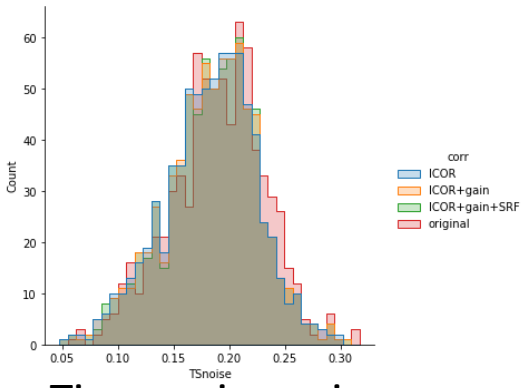
1. **Validation with in-situ data**
2. **Matchups between sensors**
3. **Time series analyses**

FAPAR



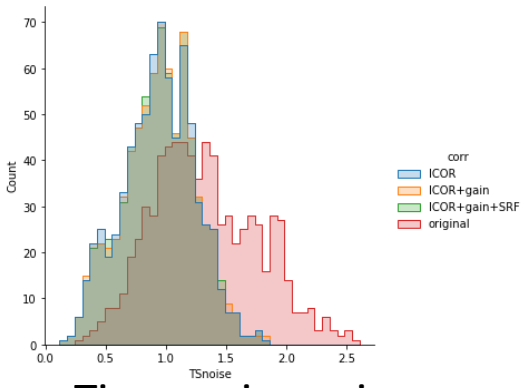
Time series noise

FCOVER



Time series noise

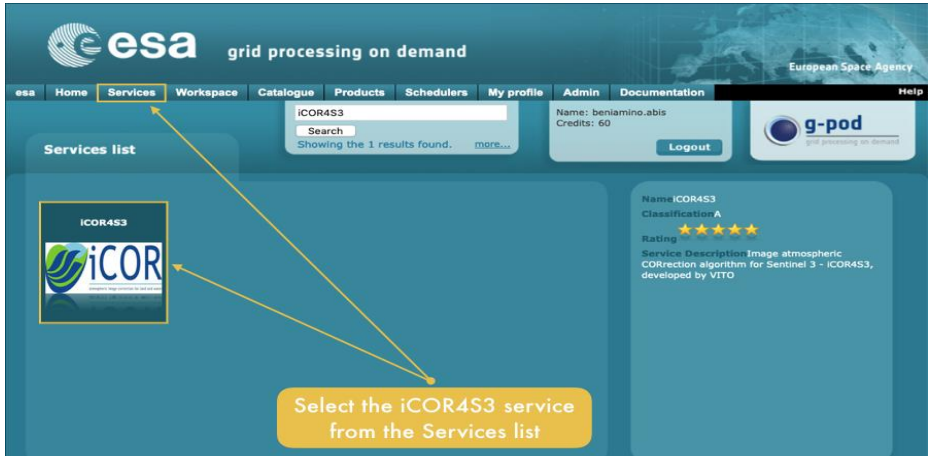
LAI

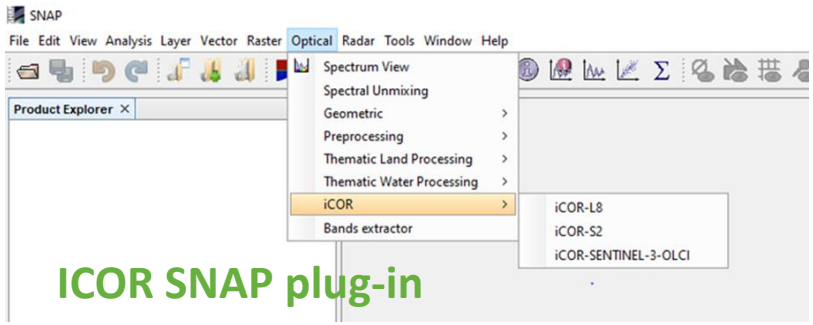


Time series noise

CONCLUSIONS

- Largest gain of improvement in consistency by applying the same atmospheric correction.
  - ➢ Strength of iCOR: can be applied on various sensors !





- Inter-calibration and SRFs are also important aspects of inter-sensor consistency, but for the considered sensors in Belharmony, only a minor improvement could be seen. Reason for this are that the absolute radiometric calibration of the sensors are close to each other and the spectral bands are defined very similarly.
- BRDF, geometric co-registration not considered in Belharmony

Thank you!