Spectral Band Adjustment Factor (SBAF), Methods and Processing

IDEAS-QA4EO Cal/Val WS #4
February 28 - March 2st ,2023

S. Saunier
E. De Grandis (Serco)

Project Description

Scope of the study

- The scope of this QA4EO R&D study is the analysis of Spectral Band Difference Effects (SBDE).

Final objective

- To develop a tool dedicated to SBDE analysis and shared with community (https://earthconsole.eu/discover)

Interests

- Data calibration / validation domain: improved cross calibration analysis
- Data application domain: anticipate error when comparing NDVI from different sources
- Data processing domain: Validation of Spectral band adjustment approach

Schedule

- May 1st 2022 – April 30 2023

Projects deliverables

- Technical Note / Code / Database

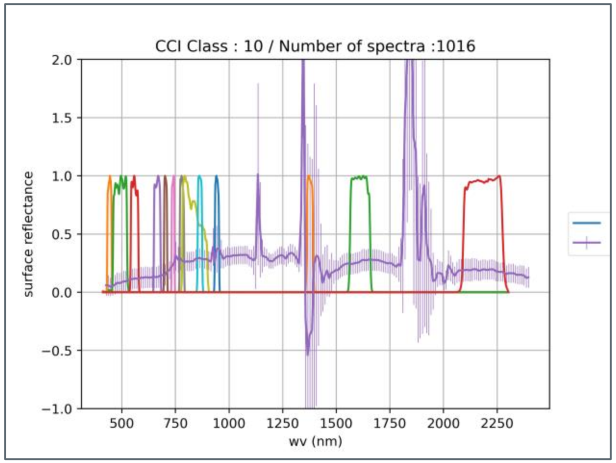
RD 1) Teillet, P.M.; Fedosejevs, G.; Thome, K.J.; Barker, J.L. Impacts of spectral band difference effects on radiometric cross-calibration between satellite sensors in the solar-reflective spectral domain. Remote Sensing of Environment 2007, 110, 393-409.

RD 2) Kruse, F.A.; Lefkoff, A.B.; Boardman, J.W.; Heidebrecht, K.B.; Shapiro, A.T.; Barloon, P.J.; Goetz, A.F.H. The spectral image-processing system (sips) - interactive visualization and analysis of imaging spectrometer data. Remote Sensing of Environment 1993, 44, 145-163.

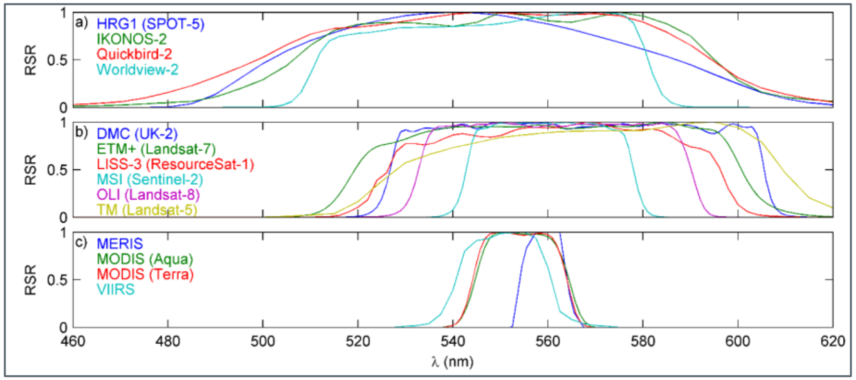
RSR and Spectrum Convolutions

- The simulated surface reflectance of a satellite sensor is obtained by weighting the **hyperspectral surface reflectance** with the relative spectral responses (RSR) and integrating over the satellite sensor bandpass .

$$\overline{\rho_\lambda} = \frac{\int \rho_\lambda \times RSR_\lambda \, d\lambda}{\int RSR_\lambda d\lambda}$$



Example of green spectral band Relative Spectral Responses (RSRs) for 14 sensors, categorized in three groups: (a) wide bandwidth, (b) medium bandwidth, (c) narrow bandwidth.



- Considering two sensors: Band pass adjustment technic is used to estimate **Spectral Band Adjustment Factors …**

Band Pass Adj technics (Linear): Chander, G.; Mishra, N.; Helder, D.L.; Aaron, D.B.; Angal, A.; Choi, T.; Xiong, X.; Doelling, D.R. Applications of spectral band adjustment factors (sbaf) for cross-calibration. IEEE Transactions on Geoscience and Remote Sensing 2013, 51, 1267-1281.

SBAF Correction – Sen2Like

- For a given Sentinel-2 (S2B-MSI) / Landsat 8/9 satellites (OLI) Image, select slop and intercept parameter values, Apply rescaling as follows:
- $\rho_{MSI,\lambda}^{Adj} = c(\lambda) \times \rho_{MSI,\lambda}^{Brdf} + o(\lambda)$
- Where:
  - $\rho_{MSI,\lambda}^{Adj}$ is the adjusted MSI reflectance (to OLI);
  - $c(\lambda), o(\lambda)$ are the linear transformation parameter, slope, intercept (SBAF Coefficient);
  - $\rho_{MSI,\lambda}^{Brdf}$ is the BRDF Adjusted reflectance;

			Sentinel-2A		Sentinel-2B	
HLS Band name	OLI band number	MSI band number	Slope (a)	Intercept (b)	Slope (a)	Intercept (b)
CA	1	1	0.9959	-0.0002	0.9959	-0.0002
BLUE	2	2	0.9778	-0.004	0.9778	-0.004
GREEN	3	3	1.0053	-0.0009	1.0075	-0.0008
RED	4	4	0.9765	0.0009	0.9761	0.001
NIR1	5	8A	0.9983	-0.0001	0.9966	0.000
SWIR1	6	11	0.9987	-0.0011	1.000	-0.0003
SWIR2	7	12	1.003	-0.0012	0.9867	0.0004

S. Skakun, J. Ju, M. Claverie, J.C Roger, E. Vermote, B. Franch, J.L Dungan and J. Masek. Harmonized Landsat Sentinel-2 (HLS) Product User's Guide. Version 1.4, October 2018. https://hls.gsfc.nasa.gov/wp-content/uploads/2018/10/HLS.v1.4.UserGuide_draft_ver3.0_clean.pdf

SBAF Correction & absolute calibration (LS8 / S2)

- PICSCAR CEOS initiative
- Considering the Libya 4 site, cross calibration has been done.
- The table below (Rho_OLI / Rho_MSI) shows a comparison between gain from HLS and gain from cross calibration. Results are consistent, main differences exist for the blue band (above 1 %).

With BRDF Correction - Threshold 1 degree (3 / 54 products)

Band	(L1 TOA)	(L1 TOA) MODIS BRDF	Slope given in NASA / HLS guide v 1,4, [RD 3]	Slope given in , (Clavery 2018) [RD 5]	Barsi SBAF (2018) L4, [RD 4]
BLUE	1,0310	0,96734	0,9778	0,9770	0,9640
GREEN	0,9943	1,003	1,0060	1,0050	1,0030
RED	1,0279	0,96879	0,9765	0,9820	0,9660
NIR20	1,0030	0,99131	0,9983	1,0010	0,9960
SWIR1	1,0003	0,9929	0,9987	1,0010	0,9990
SWIR2	0,9925	1,0025	1,0030	0,9960	0,9980

[RD 3] S. Skakun, J. Ju, M. Claverie, J.C Roger, E. Vermote, B. Franch, J.L Dungan and J. Masek. Harmonized Landsat Sentinel-2 (HLS) Product User's Guide. Version 1.4, October 2018.[1]

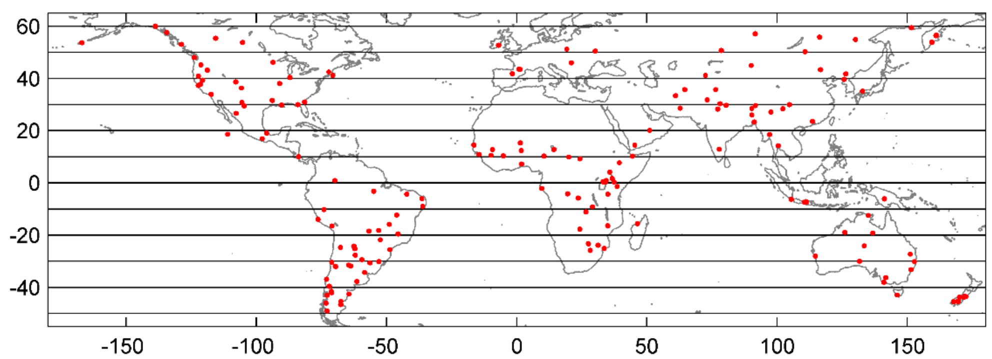
[RD 4] J. Barsi, B. Alhammoud, J .Czapla-Myers, Ferran-Gascon, Md. Obaidul Haque and al (2018). Sentinel-2A MSI and Landsat-8 OLI radiometric cross comparison over desert sites. https://doi.org/10.1080/22797254.2018.1507613

[RD 5] M. Claverie, Junchang Ju, Jeffrey G. Masek, Jennifer L. Dungan, Eric F. Vermote, Jean-Claude Roger, Sergii V. Skakun, Christopher Justice, The Harmonized Landsat and Sentinel-2 surface reflectance data set, Remote Sensing of Environment, Volume 219, 2018, Pages 145-161, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2018.09.002 .

Hyperion Database 1/2

Database

- Hyperion scenes were selected for each band of latitude (10° width, from -50° to +60°) by choosing one scene per latitude band with a "0 to 9% Cloud Cover" assigned in the metadata for each of the 17 biome types as defined in the IGBP (International Geosphere Biosphere Program) land cover map
- Atmospheric correction of Hyperion scenes (6s & MODIS CMG)
- For each scene, a Principal Components Analysis (PCA) performed on the SR data.
- An unsupervised k-means classifier run on each scene using the PCA coefficients accounting for 99% of the variance.
- The centroid spectra of each class identified
- The Hyperion spectra data set thus includes 10,000 spectra corresponding to 10,000 georeferenced pixels.

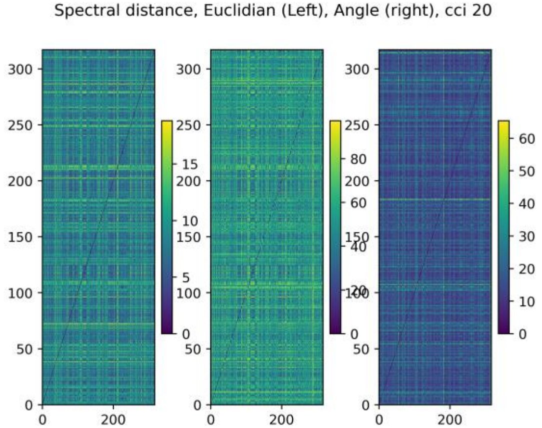


Map of the 161 Hyperion scenes used in this study.

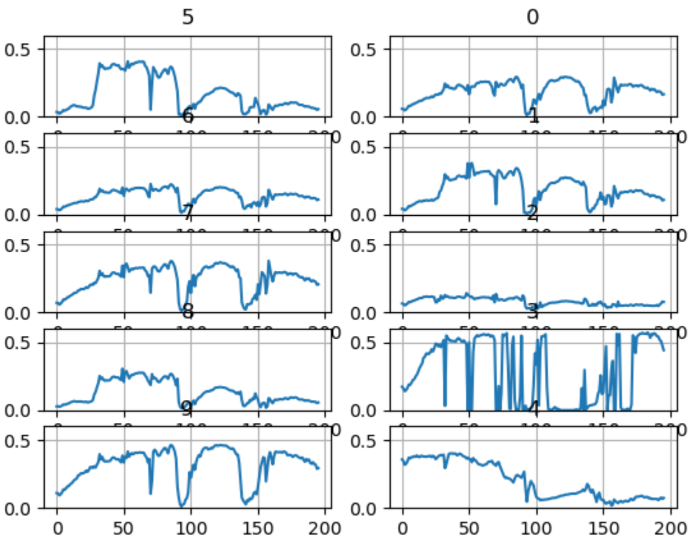
Hyperion Database 2/2

Work

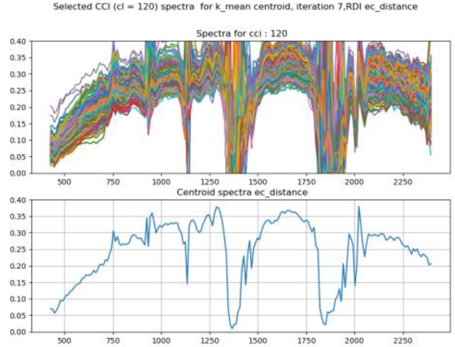
- Ingest / Clean Hyperion Database to obtain vegetation representative spectra and if possible homogeneous within CCI Class)
- Check Hyperion Database and centroid (Kmean) in view of LUT
- Analyze variability of SBAF depending on :
  - The input spectrum class (CCI Class)
  - RSR difference index (Euclidean distance, Spectral Angle)
- Results : Some Hyperion spectra broken into CCI class and season



Removing outlier using RDI



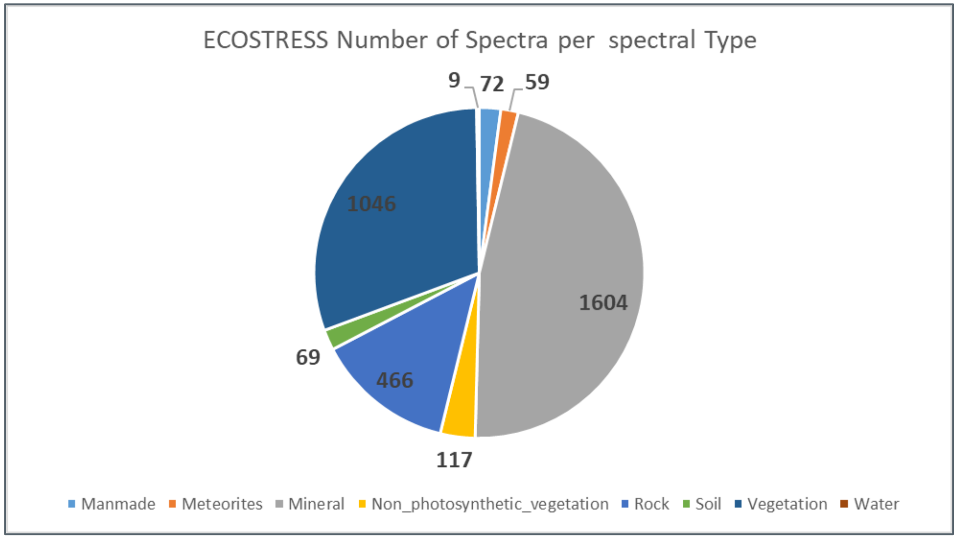
Centroid results (Kmean clustering)



Centroid (bottom), all Hyp spec(cl 120) - Shrubland

ECOSTRESS

- https://speclib.jpl.nasa.gov/
- Version 1.0 of the ECOSTRESS spectral library was released on February 2, 2018. This release added over 1100 new vegetation and non-photosynthetic vegetation spectra.
- The ECOSTRESS spectral library is a compilation of over 3400 spectra (2nm sampling interval) of natural and man made materials.



These libraries were developed
as part of the ASTER and ECOSTRESS

RadCalNet

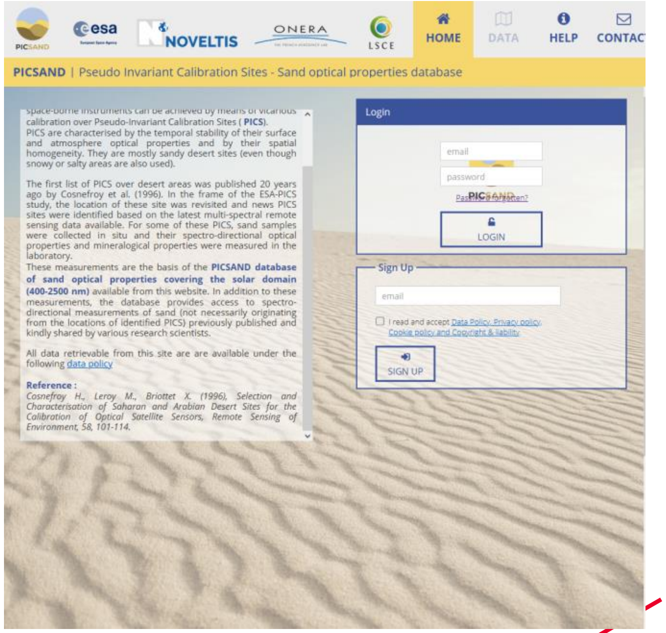
- https://www.radcalnet.org/#!/
- RadCalNet is an initiative of the Working Group on Calibration and Validation of the Committee on Earth Observation Satellites.
- The RadCalNet service provides satellite operators with SI-traceable Top-of-Atmosphere (TOA) spectrally-resolved reflectances to aid in the post-launch radiometric calibration and validation of optical imaging sensor data.
- BOA / TOA* Data over several years from the Baotou (B{S,T}CN, Gobabeb (GONA), La Crau (LCFR) , Railroad Valley Playa (RVUS).
- 10 nm Sampling interval for VNIR/SWIR (except Baotou)

Site	# Spectra (BOA/TOA)	Start Date	End Date
BSCN	2852 / 4056	26/06/2017	19/10/2022
BTCN	4970 / 6643	05/04/2016	06/11/2022
GONA	15444 / 15444	19/07/2017	30/12/2022
LCFR	11908 / 11908	06/01/2015	17/12/2022
RVUS	22219 / 31694	01/04/2013	30/12/2022

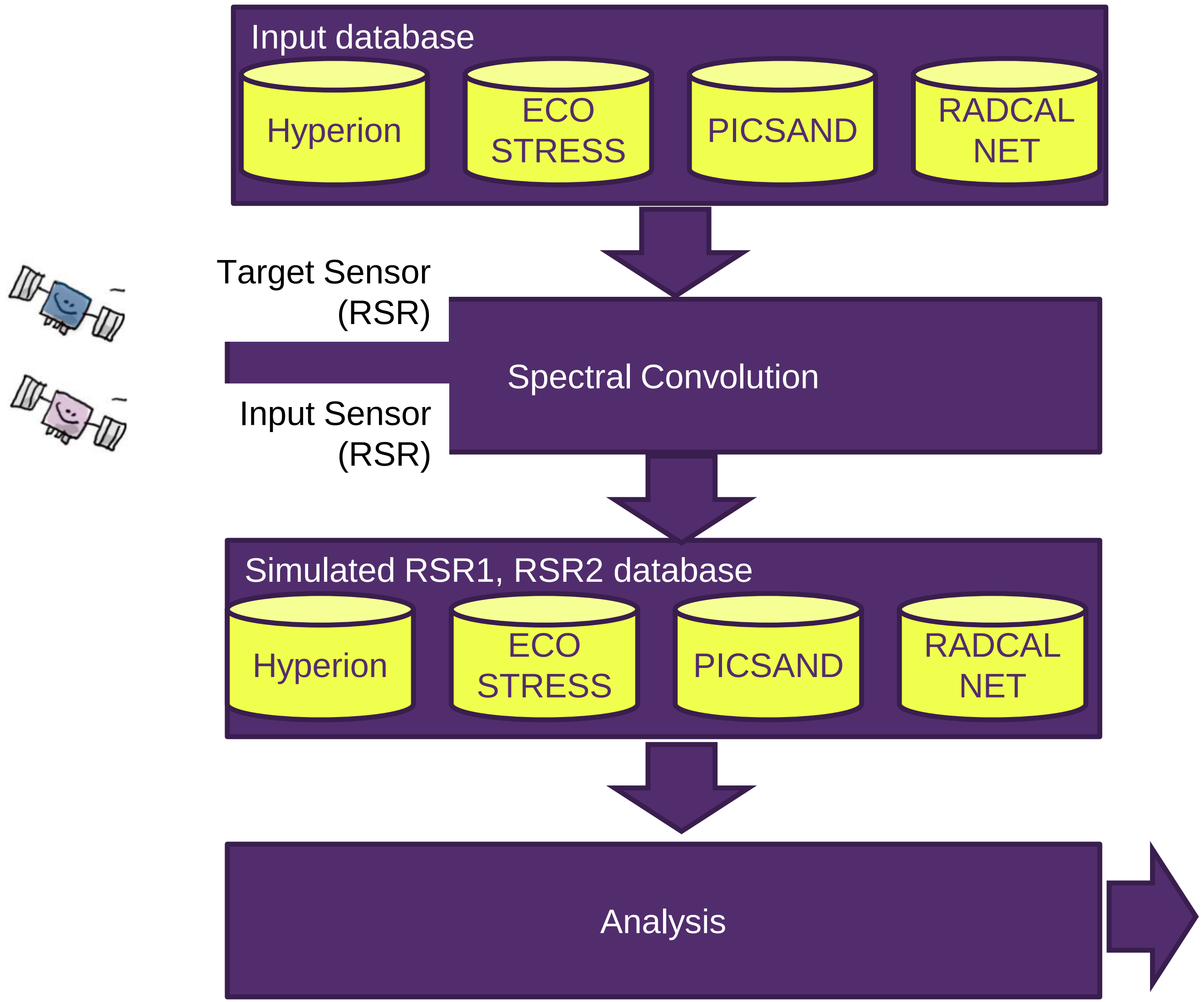
Bouvet, M.; Thome, K.; Berthelot, B.; Bialek, A.; Czapla-Myers, J.; Fox, N.P.; Goryl, P.; Henry, P.; Ma, L.; Marcq, S.; Meygret, A.; Wenny, B.N.; Woolliams, E.R. RadCalNet: A Radiometric Calibration Network for Earth Observing Imagers Operating in the Visible to Shortwave Infrared Spectral Range. *Remote Sens.* **2019**, *11*, 2401. https://doi.org/10.3390/rs11202401

PICSAND

- https://picsand.noveltis.fr/
- PICSAND | Pseudo Invariant Calibration Sites - Sand Properties
- These measurements are the basis of the PICSAND database of sand optical properties covering the solar domain (400-2500 nm)
- Number of Spectra (1 nm sampling interval, VNIR/SWIR) per institute (spectral / biconical reflectance factor) :
  - 30 : NPL
  - 16 : ONERA
  - 4 : USGS
  - 77 : University of Reading
- Note: spectro directional measurements (BRF) not ingested (included PICS)

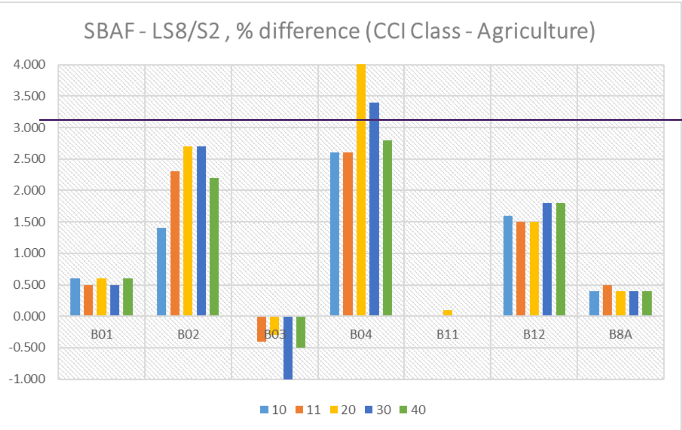


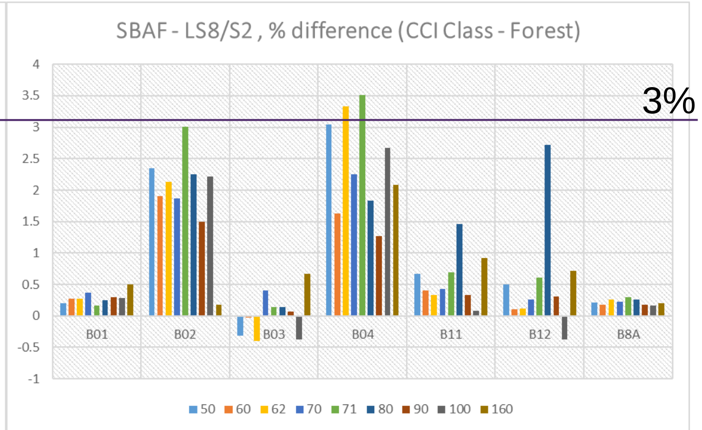
Protocol

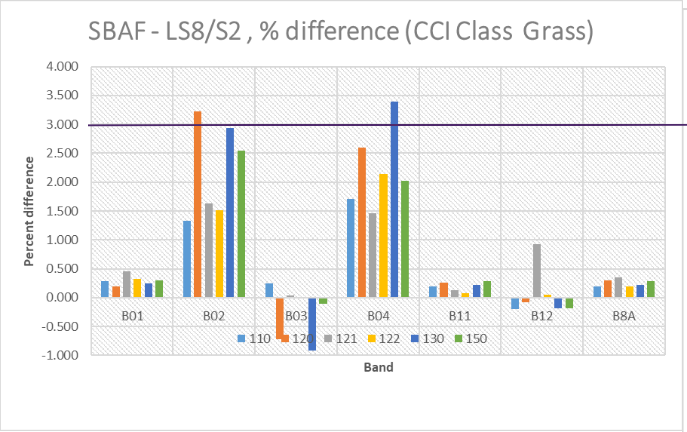


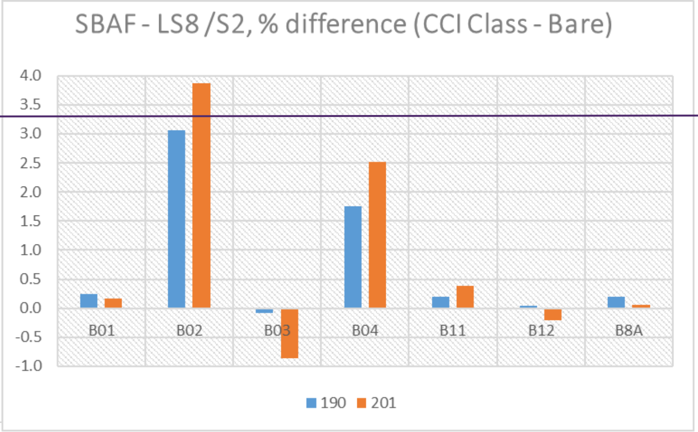
SBAF Results depending on Database / Spectra / site …

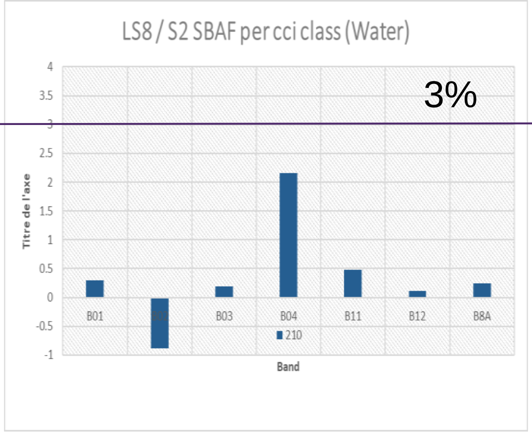
Hyperion (cci), (MSI => OLI)



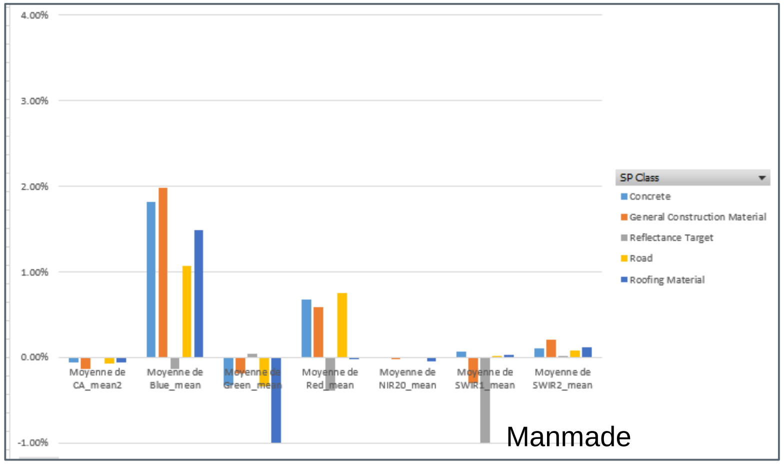


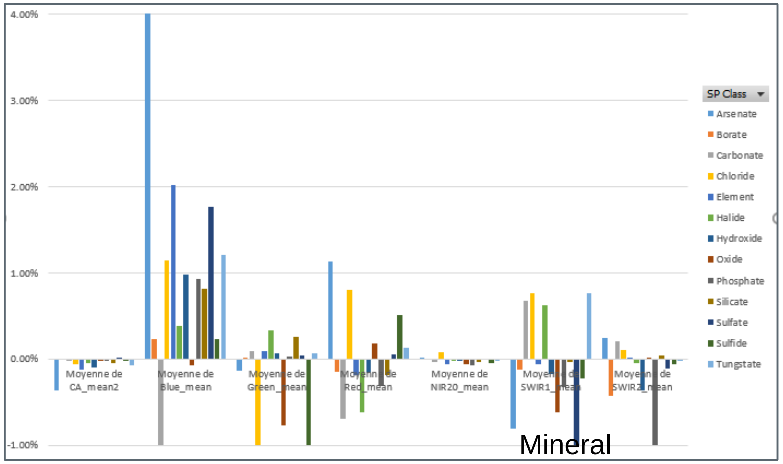


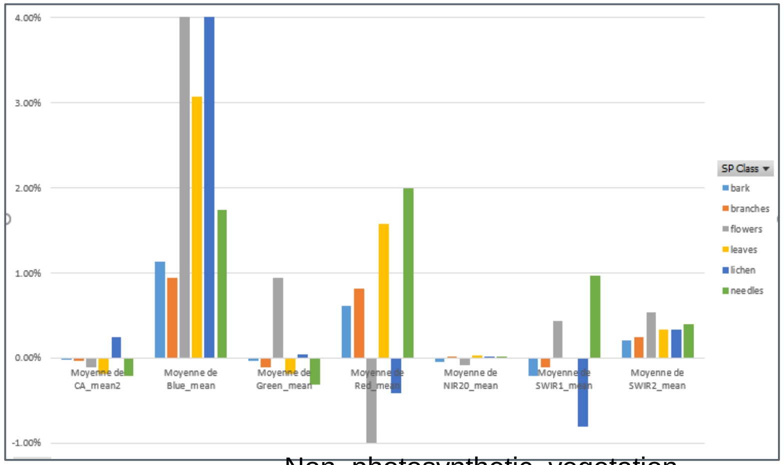




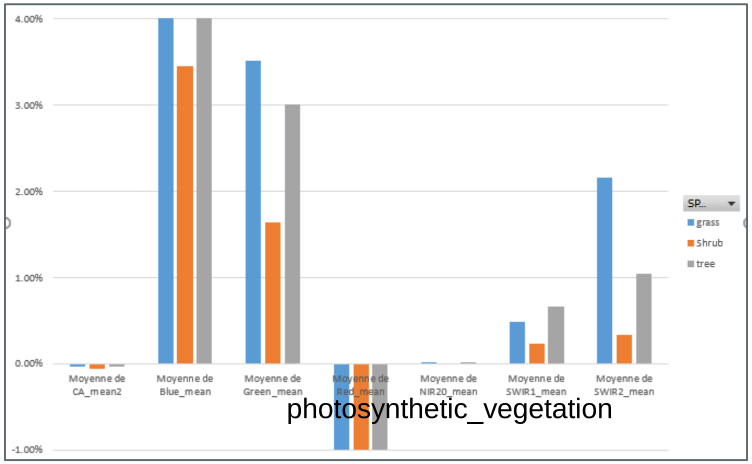
ECOSTRESS: Results (MSI => OLI)



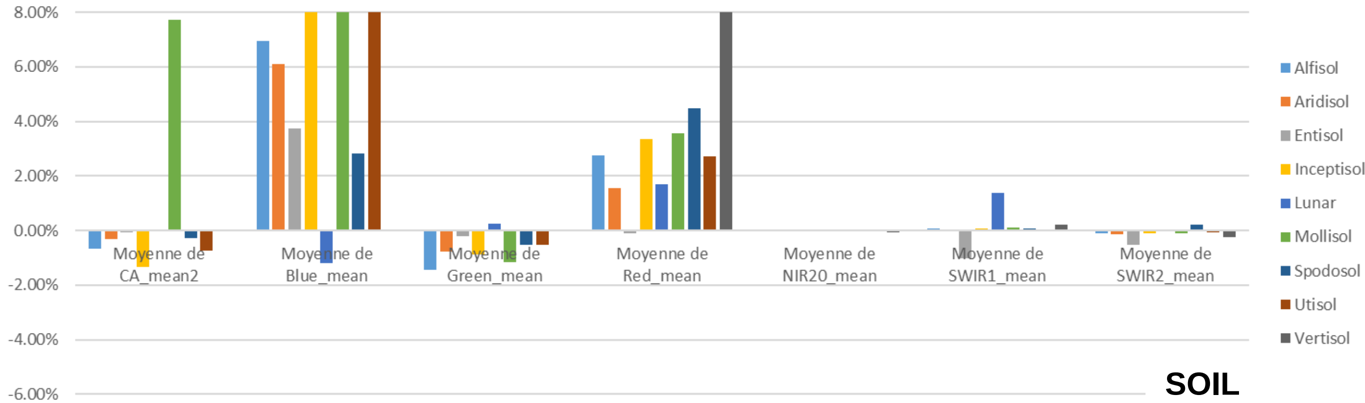




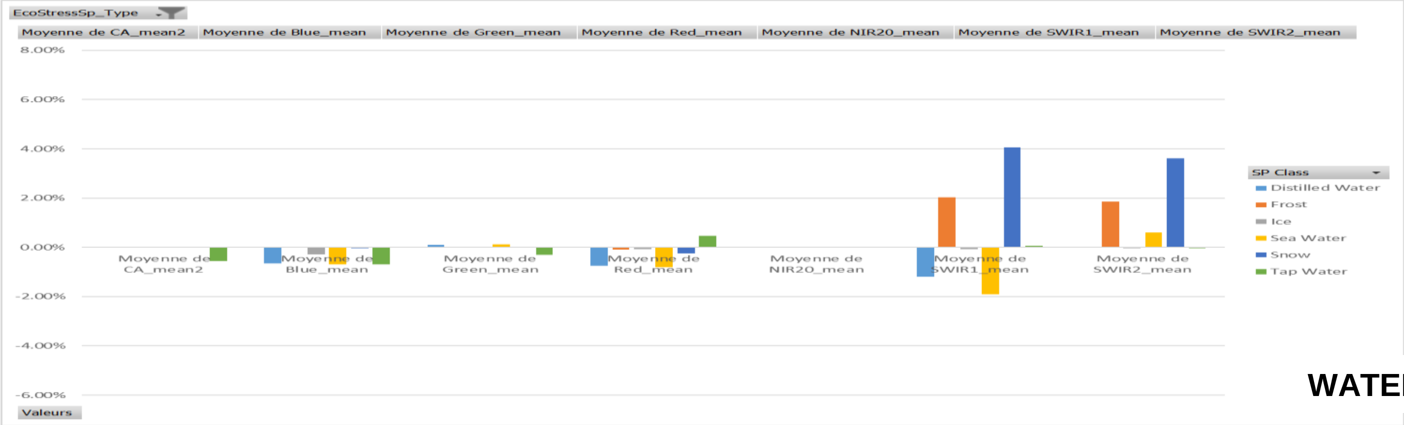
Non_photosynthetic_vegetation



ECOSTRESS: (MSI => OLI)

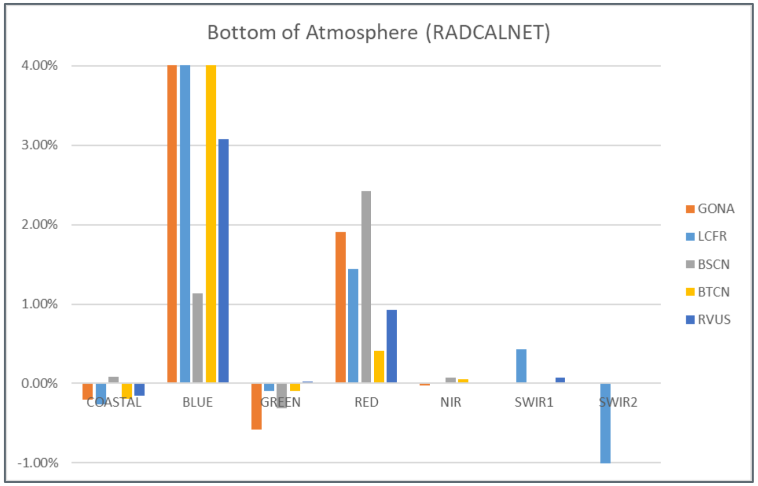


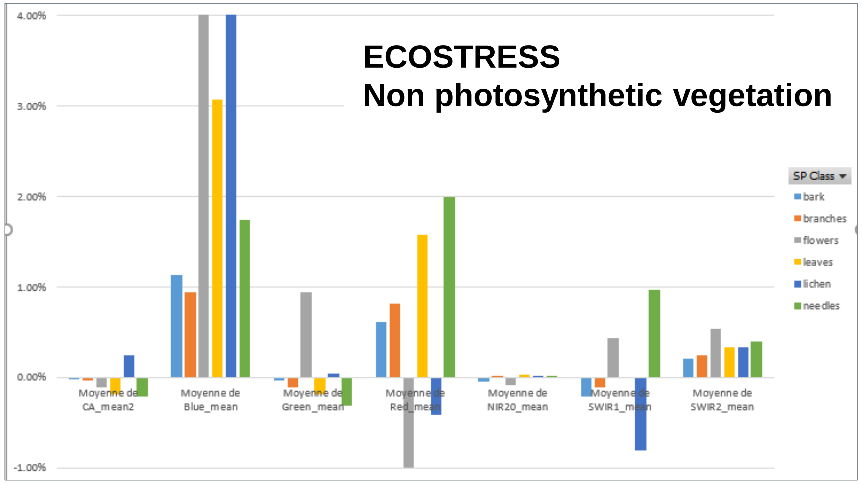
SOIL



WATER

RadCalNet vs Ecostress (MSI => OLI)



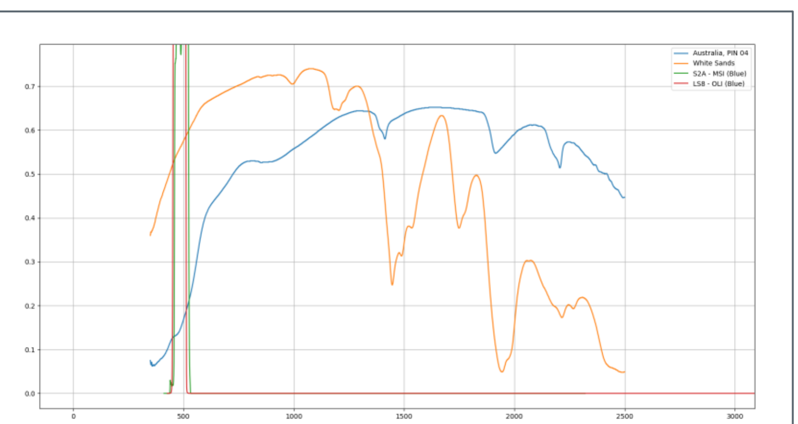


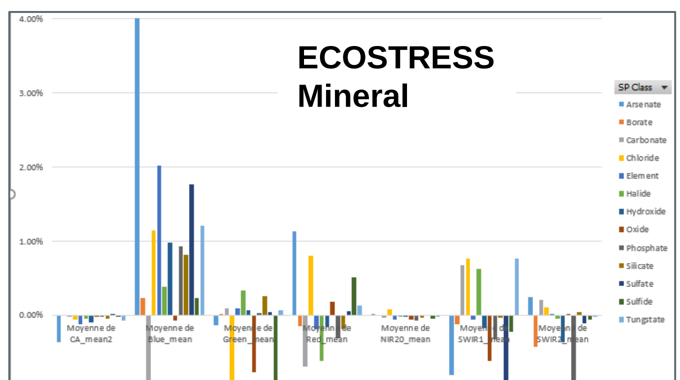
PICSAND: Global Results

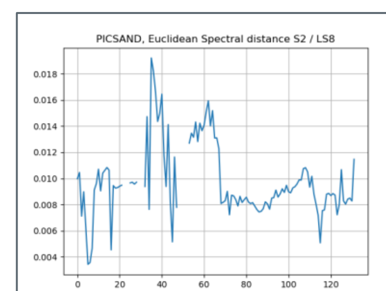
- Strong diversity of spectra in PICSAND
- SBAF Percent Difference
- Overall agreement with MSI/OLI NASA SBAF / Cross Calibration Results in particular Barsi 2018 (Calibration over PICS) except SWIR2
- Overall agreement with ECOSTRESS

PICSAND Results							
SBAF OLI / MSI (S2A)	CA	BLUE	GREEN	RED	NIR20	SWIR1	SWIR2
Min	-0.48%	0.94%	-4.57%	0.00%	-0.05%	-0.08%	-1.64%
Max	0.22%	7.35%	0.13%	3.15%	0.03%	1.57%	0.64%
Moyenne	*-0.19%*	*5.21%*	*-1.66%*	*1.94%*	*-0.01%*	*0.08%*	*-0.16%*
Ecart Type	0.08%	1.21%	1.07%	0.76%	0.02%	0.14%	0.21%
Delta Min/Max	0.70%	6.41%	4.69%	3.15%	0.08%	1.65%	2.28%

Cross Calibration / SBAF Results							
NASA / HLS guide		2.22%	-0.60%	2.35%	0.17%	0.13%	-0.30%
, (Clavery 2018)		2.30%	-0.50%	1.80%	-0.10%	-0.10%	0.40%
BARSI 2018		3.60%	-0.30%	3.40%	0.40%	0.10%	0.20%







WP Initial Work Plan / Deviations

- Select 5 / 8 sensors (with customer), collect RSRs and related specifications, (ok)
- Set up processing code for adaptive SBAF (including three distance functions), (partial)
- For all mission twins, analyze variability of SBAF (ANOVA) depending on :(partial)
  - The input spectrum class (CCI Class)
  - RSR difference index
- Compare with results from NASA SatCORPS SBAF Tool, NASA-LaRC CERES (GSICS): https://www-pm.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=SBAF (nok)
- Share database & code (ok)
- Prepare application oriented documentation & input for a user tool (ok)

- Cleaning and data analysis of Hyperion database for opening to user
- Broad Coverage of Land spectra achieved with Add Ecostress, Radacalnet, PICSAND database (spectro)
- Panda Database (all spectra) ready to be shared and shared

IDEAS-QA4EO

WP Conclusion / Proposed Future work

- Results slightly different depending on database even if same feature/class and Hyperion should again be consolidated
- Infrastructure (RSR, Db, code, processing flow) set up to propose representative spectra and output relevant SBAF values.
- First investigation on processing method for Adaptive SBAF (Distance to Centroid and look up table)
- Interesting tool for new space
- Interesting tool to better understand cross calibration results

- Define interface for users: SBAF given according to class of spectra, database, site, missions => organized input data
- Continue Analysis of SBAF results
- Select spectra depending on sensor geometry (RADCALNET)
- Add uncertainty, in particular for Hyperion
- Propose different statistical model to compute SBAF
- Pre Compute LUT (Missions, Centroid, SBAF)

IDEAS-QA4EO

THANK **YOU**
FOR YOUR ATTENTION

telespazio.co.uk