Spectral Band Adjustment Factor (SBAF), Methods and Processing

IDEAS-QA4EO Cal/Val WS #3
March 31 - April 1st ,2022

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

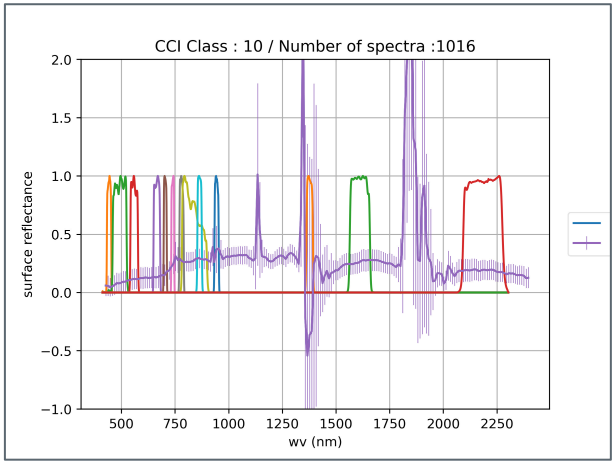
- Technical Note / Code / Database

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.

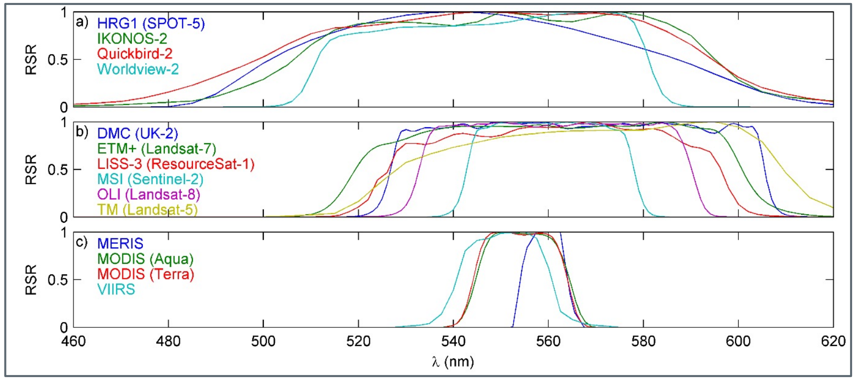
RSR and Spectrum Convolutions

- 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;
  - $c(\lambda), o(\lambda)$ 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]

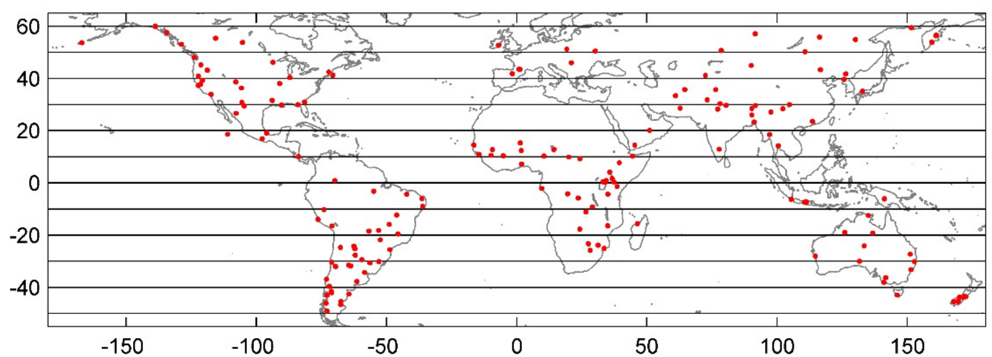
[RD 4] J. Barsi, B. Alhammoud, J .Czapla-Myers, Ferran-Gascon, Md. Obaidul Haque and al (2018). Sentinel-2A MSI and Landsat-8 OLI radiometric cross comparison over desert sites. https://doi.org/10.1080/22797254.2018.1507613

[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 .

Assets

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.

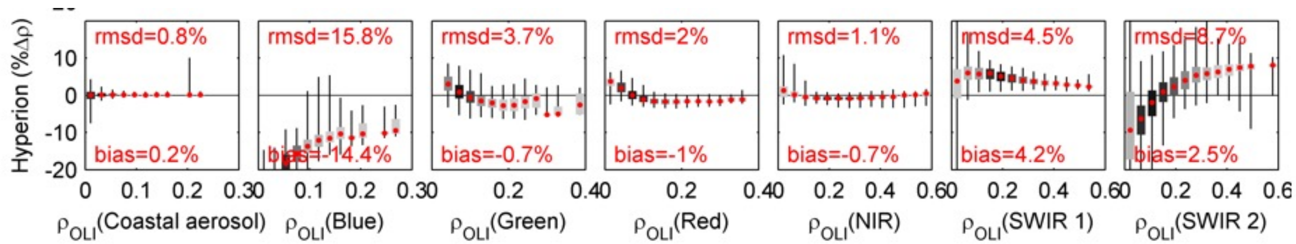


Map of the 161 Hyperion scenes used in this study.

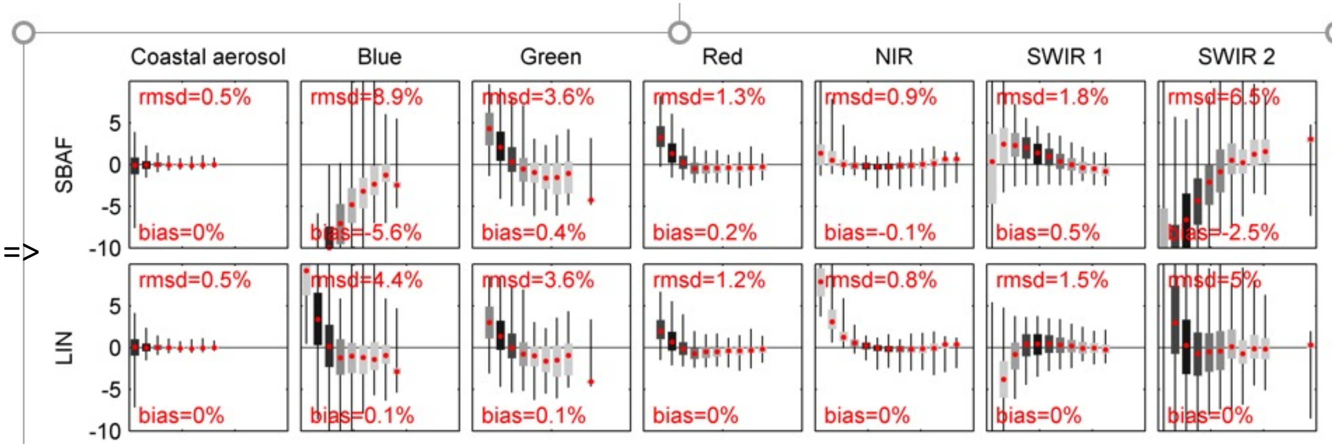
Application of the database (Modis / OLI)

- SBAF Computation with different methodologies (Linear, Adaptive, Machine Learning)
-

Original Data =>



SBAF Corrected Data =>



The distribution of the differences between simulated OLI reflectance and simulated **MODIS reflectance adjusted to OLI bandpass** using the Hyperion data set

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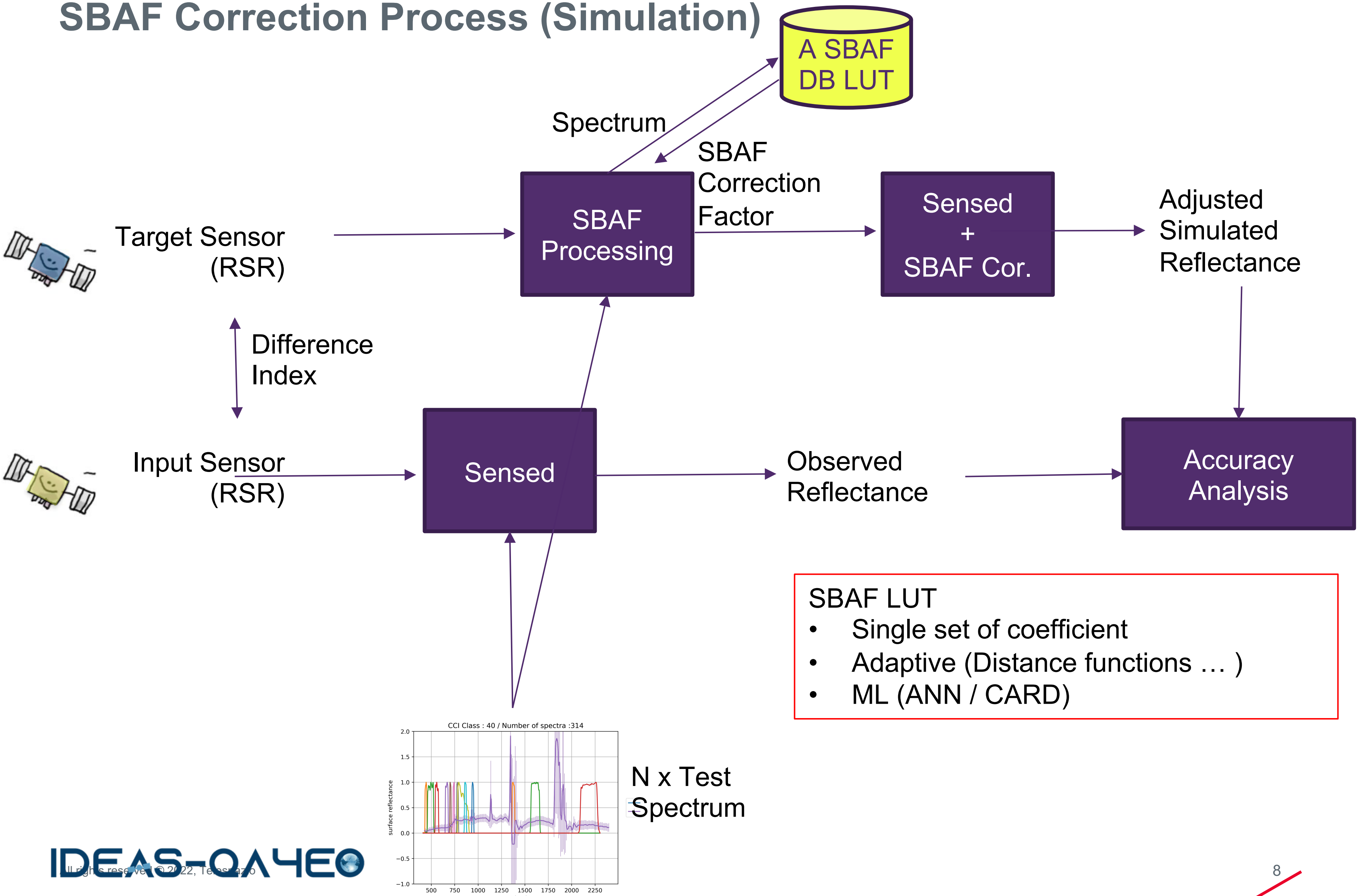
SBAF Correction Process (Simulation)



SBAF LUT
- Single set of coefficient
- Adaptive (Distance functions …)
- ML (ANN / CARD)

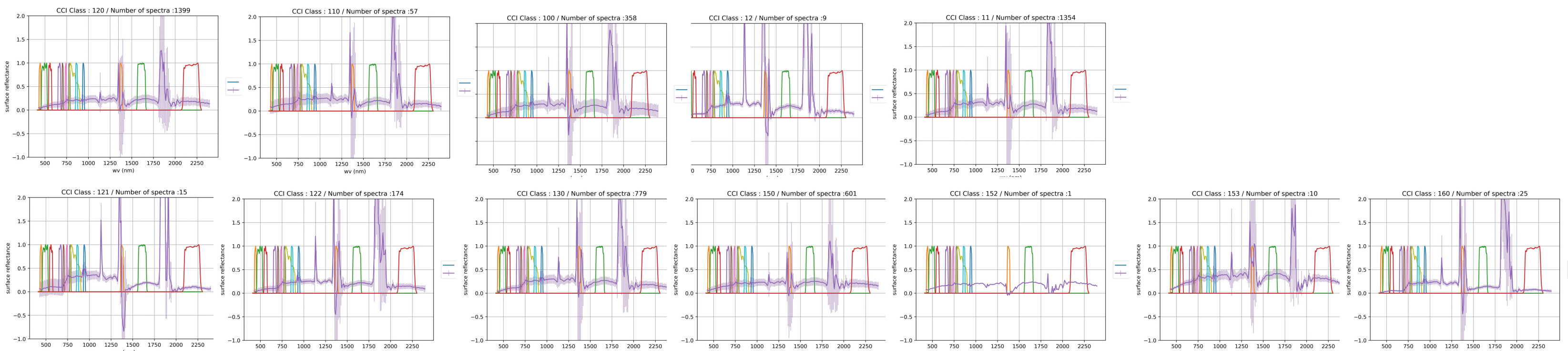
WP Work

- Select 5 / 8 sensors (with customer), collect RSRs and related specifications,
- Set up processing code for adaptive SBAF (including three distance functions),
- For all mission twins, analyze variability of SBAF (ANOVA) depending on :
  - 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
- Share database & code
- Prepare application oriented documentation & input for a user tool

WP Work

- First analysis with CCI (Level 1 (or global) and regional legends of the CCI-LC maps)
- Add CCI info / metadata to hyperion spectra

Hyperion_image_name	EO1H0010742010153110K0
x	1143
y	585
latitude	-4.06525
longitude	-42.2476
band_wavelength	[426.82, 436.99, 447.17, 457.34, 467.52, 477.6...
Spectrum	[0.011, 0.026, 0.0175, 0.0177, 0.0246, 0.0379,...
CCI_Class	120
CCI_Class_qaf_1	1
CCI_Class_qaf_2	1
CCI_Class_qaf_3	132
CCI_Class_qaf_4	0



THANK **YOU**
FOR YOUR ATTENTION

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