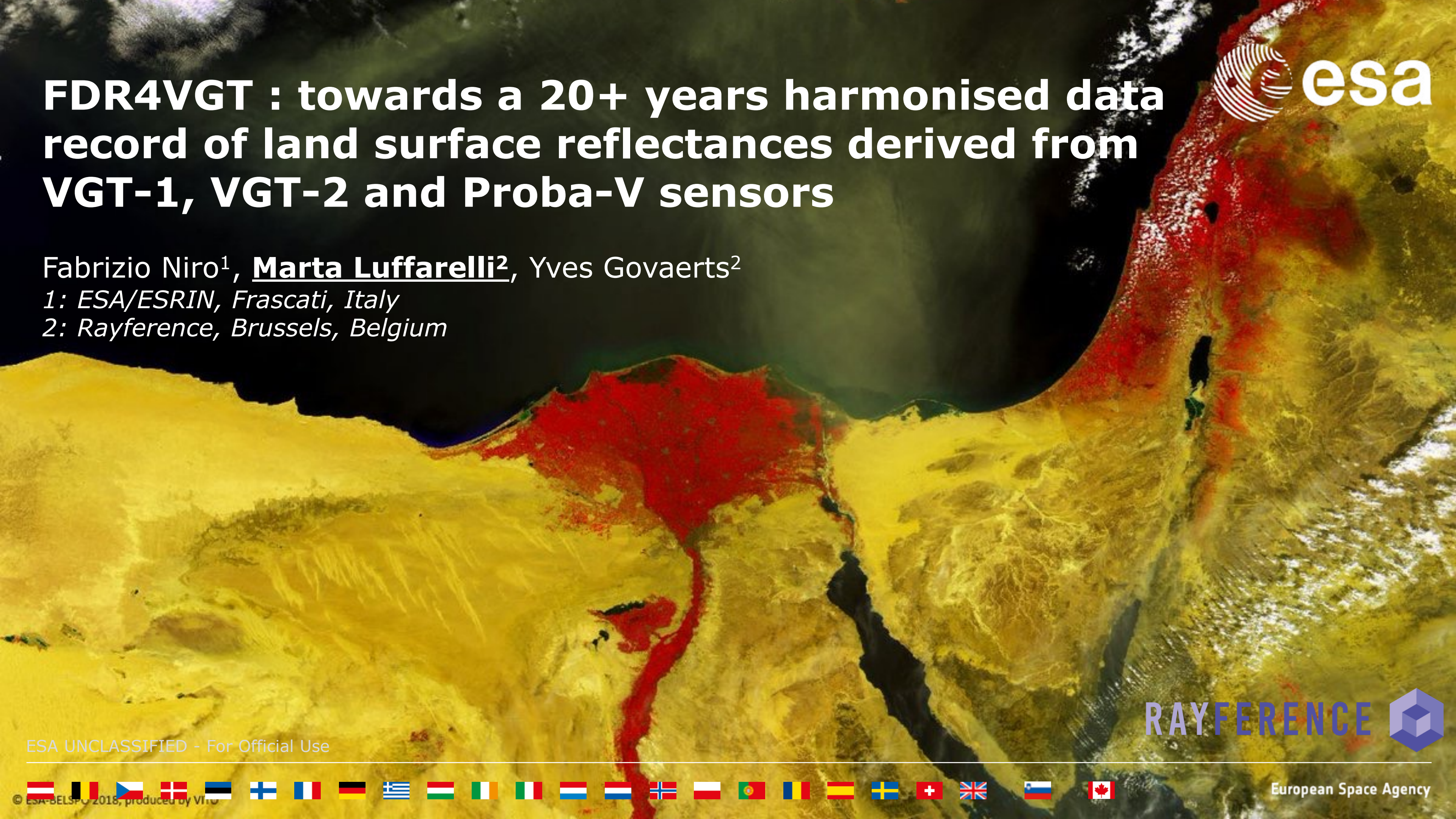


FDR4VGT : towards a 20+ years harmonised data record of land surface reflectances derived from VGT-1, VGT-2 and Proba-V sensors

Fabrizio Niro[1], **Marta Luffarelli[2]**, Yves Govaerts[2]

1: ESA/ESRIN, Frascati, Italy

2: Rayference, Brussels, Belgium

RAYFERENCE

Motivations

- Land global-daily monitoring from the VEGETATION programme (SPOT-VGT-1, SPOT-VGT2, PROBA-V) has led to **20+ years** of uninterrupted observations in the VNIR/SWIR range (1998 – 2020).
- The radiometric, geometric and spectral **consistency** of the three sensors and the temporal stability of the long-term archive remain to be assessed.
- Per-pixel **uncertainties** are not estimated.
- A **metrological approach**, following the guidelines developed in FIDUCEO, is essential for reliably quantifying anthropogenic trends in the derived records of terrestrial ECVs, such as the ones generated in the framework of ESA CCI and Copernicus C3S.

SPOT-VGT1, VGT-2, PROBA-V time series

Bridging the gap to S-3 for Land applications

Sentinel-3B

Sentinel-3A

98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20

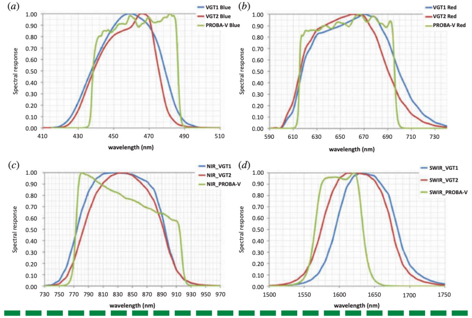
SPOT-VGT1

SPOT-VGT2

Proba-V

Global near-daily coverage

Blue, Red, NIR, SWIR bands



Terminology

*A **Fundamental Data Record** (FDR) is a record, of sufficient duration for its application, of **uncertainty-quantified** sensor observations **calibrated** to physical units and located in time and space, together with all ancillary and lower-level instrument data used to calibrate and locate the observations and to estimate uncertainty.*

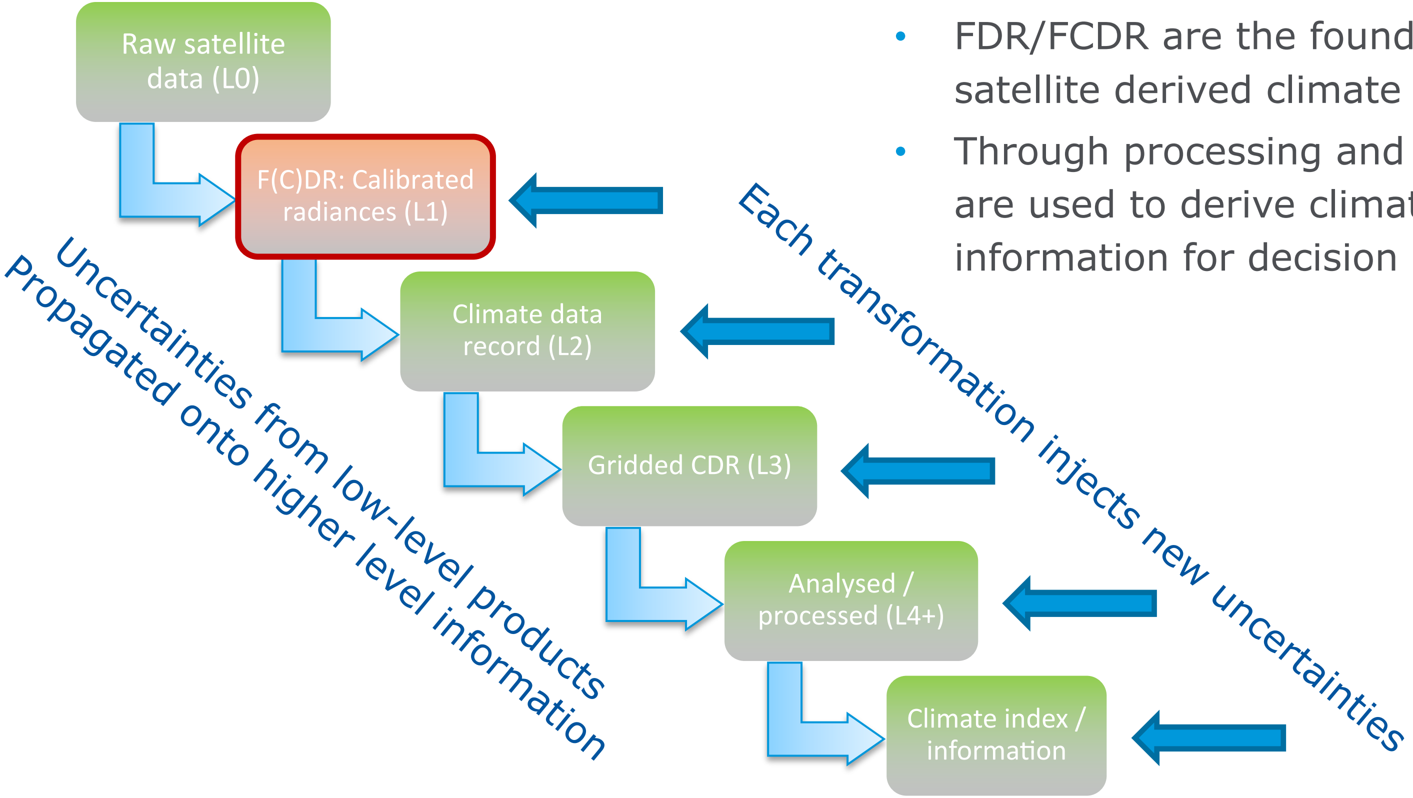
- Long → multidecadal
- Stabilised → combining results from multiple sensors (harmonised)
- Uncertainty quantified → to propagate uncertainties to the next level
- Calibrated to physical units and located in time and space → ready to be used for higher level products generation
- With all instrument and ancillary data used to calibrate and to determine uncertainty → with what is needed for long term data preservation

https://qa4eo.org/

QA4EO A QUALITY ASSURANCE FRAMEWORK FOR EARTH OBSERVATION

- The Quality Assurance framework for Earth Observation (QA4EO)
- Looks to make the GUM accessible to the EO community

Traceability for reliable climate information



- FDR/FCDR are the foundation of all satellite derived climate information.
- Through processing and analysis they are used to derive climate information for decision makers

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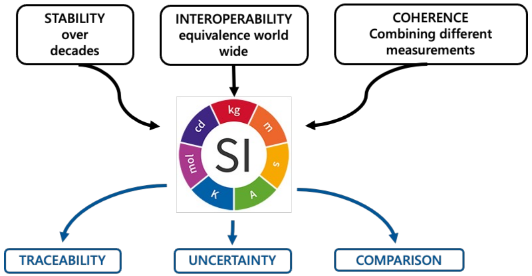
Metrological steps to FDR



MEASURAND 01

Define the measurand and measurement function

TRACEABILITY 02

Establish the traceability with a diagram

UNCERTAINTY 03

Evaluate each source of uncertainty and fill out an effects table

HARMONISE 04

If appropriate recalibrate / harmonise against a reference

CALCULATE 05

Calculate the data product and uncertainties

STORE 06

Store relevant information in a Full FDR for future users

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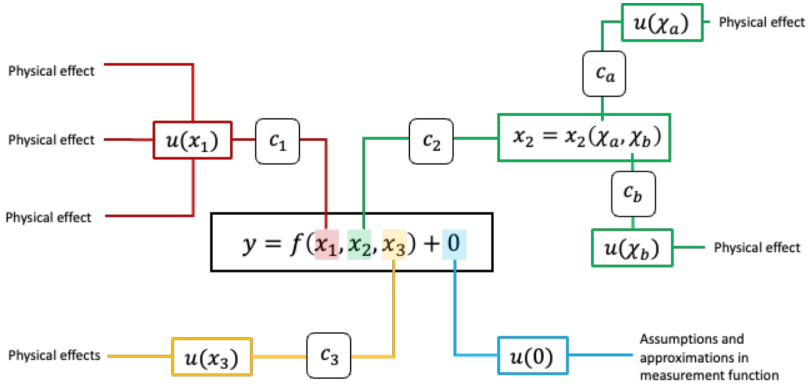
Uncertainty analysis

- Uncertainty analysis starts by identifying the **measurement function** *f*, which links the measurand *y* to the input quantities x_i.
- Given *f*, develop an **uncertainty tree diagram**: breaking each term down to the originating process for uncertainty.
- Once defined the sources of uncertainty, fill out an **effects table** to synthetise uncertainty/error correlation structures.



Mittaz et al. 2019

		Comments
Name of effect		A unique name
Affected term in measurement function		Name and standard symbol
Instruments in the series affected		List names
Correlation type and form	Pixel-to-pixel [pixels]	From a set of defined correlation forms
	from scanline to scanline [scanlines]	
	between images [images]	
	Between orbits [orbit]	
	Over time [time]	
Correlation scale	Pixel-to-pixel [pixels]	As needed to define type
	from scanline to scanline [scanlines]	
	between images [images]	
	Between orbits [orbit]	
	Over time [time]	
Channels/bands	List of channels / bands affected	Channel names
	Error correlation coefficient matrix	A matrix
Uncertainty	PDF shape	Functional form
	units	Units
	magnitude	
Sensitivity coefficient		Value, equation or parameterisation of sensitivity of measurand to term

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Harmonisation

Objective: secure radiometric consistency between VGT-1, VGT-2 and PROBA-V for the generation of higher level thematic data record.

- **Homogenisation –** All radiometers are forced to look the same such that when looking at the same location at the same time they would give the same signal.
- **Harmonisation –** All the calibrations of the sensors have been made consistent with (a) reference dataset(s) which can be traced back to known (SI-traceable) reference sources. Each sensor is calibrated to the reference, maintaining its features such that the calibration radiances represent the unique nature of each sensor.

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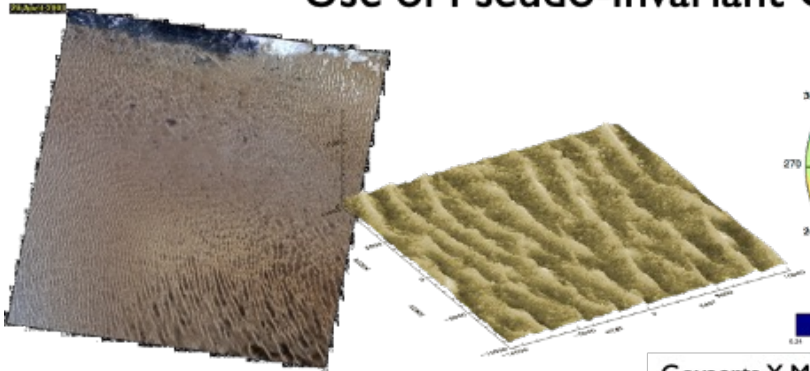
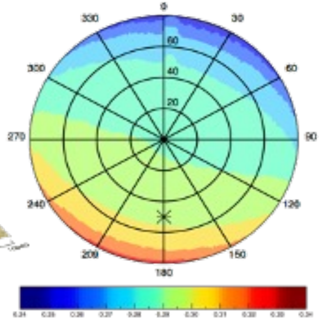
→ Following FIDUCEO, we apply Harmonisation

Harmonisation over Libya-4

esa

Use of Pseudo-Invariant Calibration Site (PICS) (Libya-4);





Govaerts, Y. M. 1999. "Correction of the Meteosat-5 and -6 VIS Band Relative Spectral Response with Meteosat-7 Characteristics." *International Journal of Remote Sensing* 20 (18): 3677–82.

Govaerts, Y. M., and M. Clerici. 2004. "Evaluation of Radiative Transfer Simulations over Bright Desert Calibration Sites." IEEE TGARS, 42 (1).

Govaerts, Yves, et al. 2013. "Use of Simulated Reflectances over Bright Desert Target as an Absolute Calibration Reference." RSE, 523-- 531.

Govaerts, Y. M. 2015. "Sand Dune Ridge Alignment Effects on Surface BRF over the Libya-4 CEOS Calibration Site." Sensors 15 (2): 3453–70;

Govaerts, Y. M., et al. 2018. "Climate Data Records from Meteosat First Generation Part I: Simulation of Accurate Top-of-Atmosphere Spectral Radiance over Pseudo-Invariant Calibration Sites for the Retrieval of the In-Flight Visible Spectral Response." Remote Sensing 10 (12): 1959.

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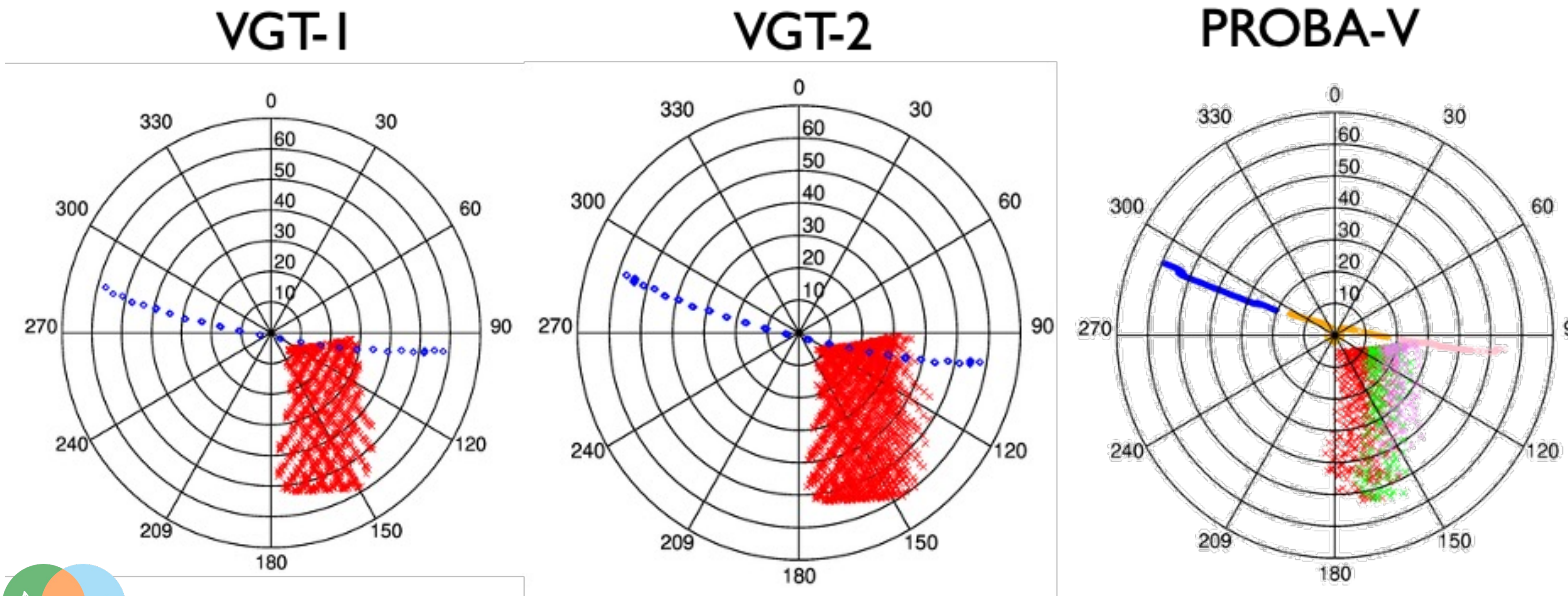
Viewing geometry over Libya-4



SPAR@MEP

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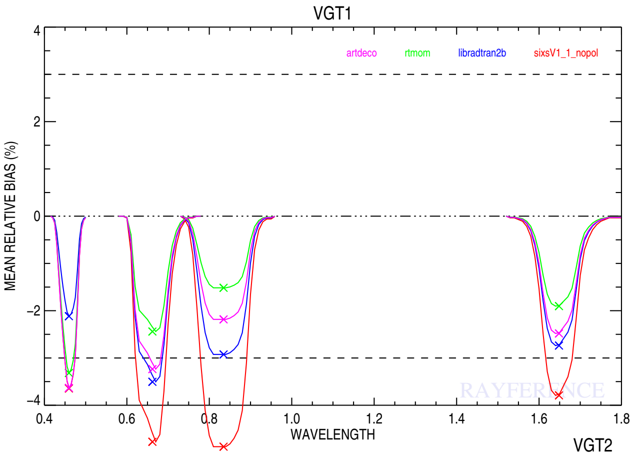
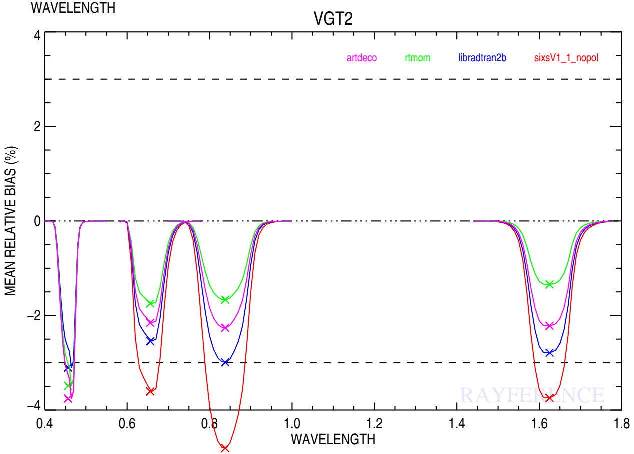
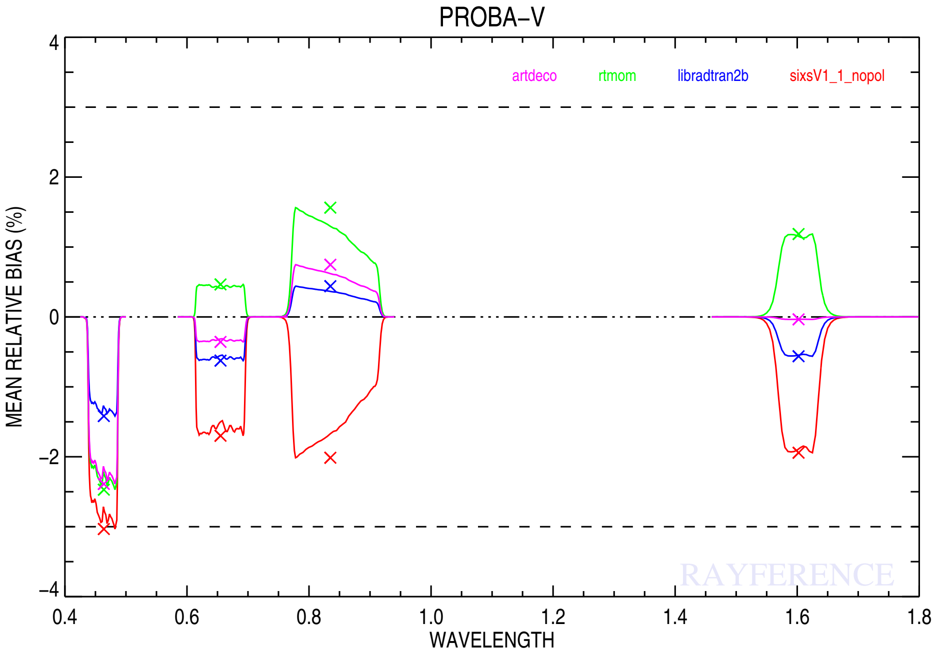
Mean Relative Bias over Libya-4







SPAR@MEP

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Harmonisation factors

	BLUE	RED	NIR	SWIR
SPOT-VGT1				
	1.042	1.028	1.020	1.026
SPOT-VGT2				
	1.036	1.024	1.013	1.019
PROBA-V				
ALL	1.024	1.005	0.997	1.004
LEFT	1.040	1.005	0.997	1.001
CENTRAL	1.011	1.012	1.001	1.003
RIGHT	1.010	0.999	0.993	1.014

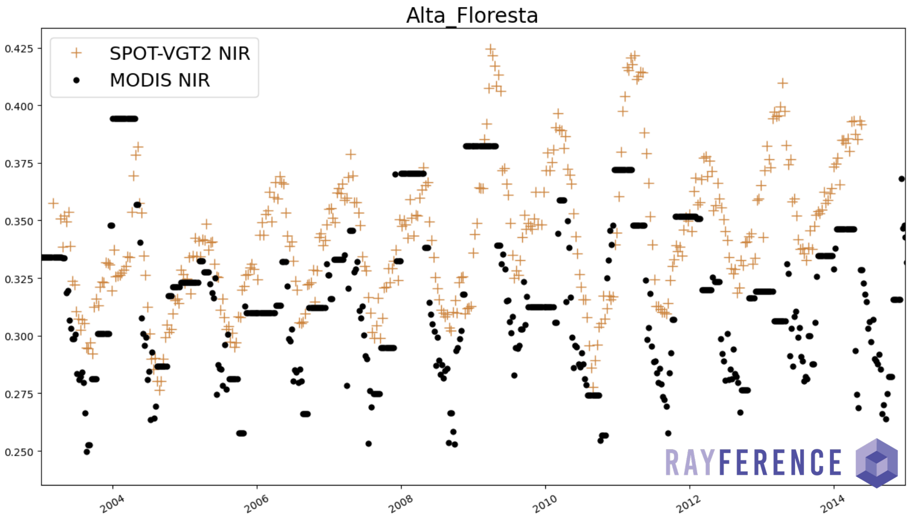
For PROBA-V, it is suggested to apply a correction per camera

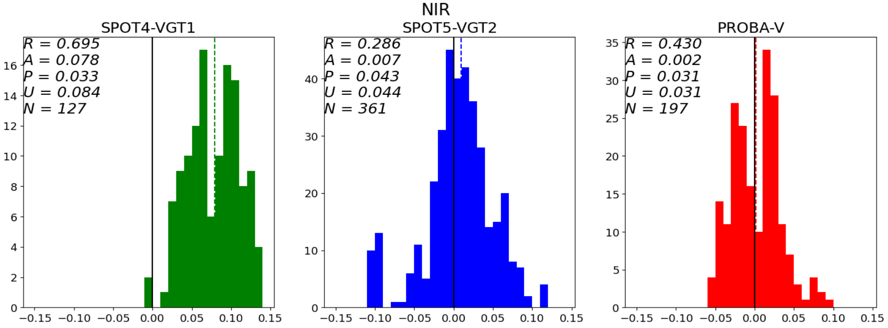
SPAR@MEP

RAYFERENCE

Example of BHR LTDR

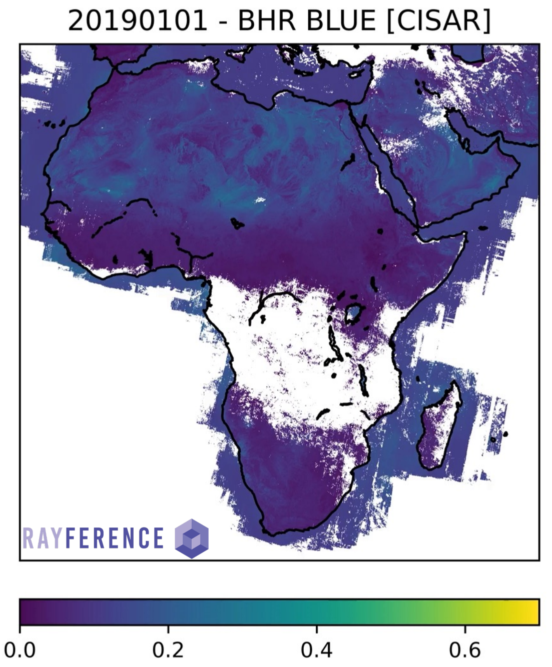
- Verification of **BHR** against **MODIS** MCD19A3 albedo product.
- CISAR tends to systematically **overestimate** the BHR with respect to MAIAC/MODIS, especially at lower wavelengths.
- The systematic overestimation remains in all the processed bands for VGT1.
- At longer wavelengths, the BHR retrieval shows better agreement between CISAR and MAIAC products.

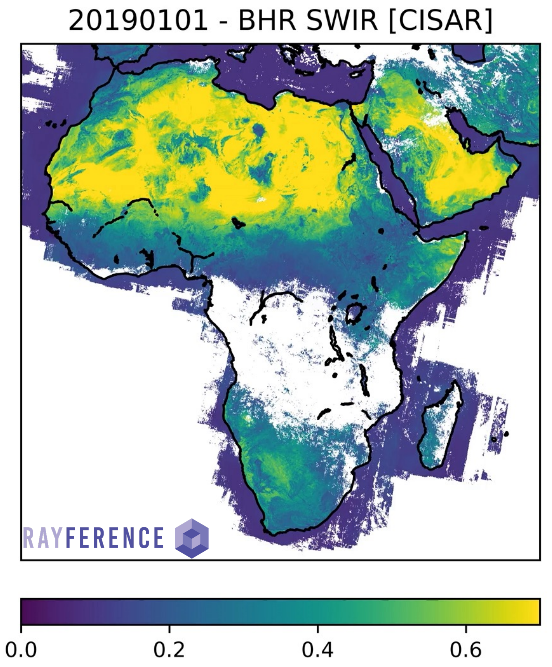




Impact of Radiometric characterization

- The SWIR band shows larger residuals of the relative gain among the detectors, compared to the other bands.
- The BHR product over Sahara region shows higher stability in the BLUE band, where the uncertainty is well defined, compared to the SWIR band where some noise is visible in the retrieval.





Lessons learned from SPAR@MEP

- The SPAR@MEP project demonstrates the interest of the VGT-1/2 PROBA-V time series for the generation of climate-relevant thematic data record of aerosol and surface properties.
- **Two main benefits** of this dataset:
    - Global coverage with **wide swath** sensor (>2000km), dense sampling in the angular domain (after accumulation) good information content;
    - **Long time series** (starting before MODIS era), with similar sensors, allowing to bridge the gap from AVHRR to Sentinel-3.
- Several **limitations** were identified and discrepancies across the sensors, mostly related to the **poor knowledge** about radiometric and geometric characterisation for those sensors.

FDR4VGT Objectives

FDR4VGT project builds on SPAR@MEP lessons learned and on the best practices and methods developed within FIDUCEO, with the following **objectives**:

- Ensuring long-term data **preservation** and **valorisation** of SPOT-VGT1, SPOT-VGT-2 and PROBA-V data archives;
- Improving **consistency**, by fully characterising the radiometric, geometric and spectral differences across sensors;
- Enhancing **harmonisation** and temporal **stability** by quantifying and correcting inter-sensors biases and sensor-induced spurious drifts;
- Providing **uncertainty estimates** at pixel level, ensuring **traceability** along the full processing chain, starting from raw data;
- Generating a temporally stable and **harmonised data record** of reflectances at TOA and BOA level to be used as input for climate studies.

Expected Outcomes and Approach

The expected outcomes are:

- Fundamental Data Record of TOA reflectances with information on calibration harmonization factors and uncertainty estimates at pixel level.
- Thematic Data Record of land Surface Reflectances, compliant to CEOS-CARD4L, generated with a common algorithm, together with all ancillary data and per-pixel uncertainty.

A 2-phased approach is proposed:

- **Phase 1 (2023-25) :** development of the **algorithms** for the data processing and for inter-sensors biases assessment and uncertainties estimation; delivery of SW, ATBD and Validation Report.
- **Phase 2 (2025-27):** integration of the prototype algorithm in the target platform @VITO and reprocessing/validation of the 20+ years archive.

Conclusion and Outlook

- Application of metrological practices to EO (traceability and uncertainty) is key to ensure **trustworthy climate information** for decision making.
- **Uncertainty analysis** starts from the measurement equation by identifying and characterizing any potential source of uncertainties, which are then propagated through the various processing steps.
- **Uncertainty at pixel level** at Level 1 (calibrated radiances/reflectances) is crucial for proper exploitation of these measurements in retrieval algorithms and for assimilation into physical models.
- The **FIDUCEO** project developed best practices and tools to ensure proper application of metrological guidelines in EO; **FDR4VGT** will build on these practices to derive a consistent and harmonised FDR of reflectances at TOA and BOA level for use in climate applications.

Thank you!

Contact: fabrizio.niro@esa.int