1. Harmonisation of PICS
2. FRM protocol for SR validation based on artificial targets

IDEAS-QA4EO Cal/Val Workshop#3

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Rayference

ESRIN, 31/03 – 01/04 2022

rayference

Part 1
PICS harmonisation

Harmonisation

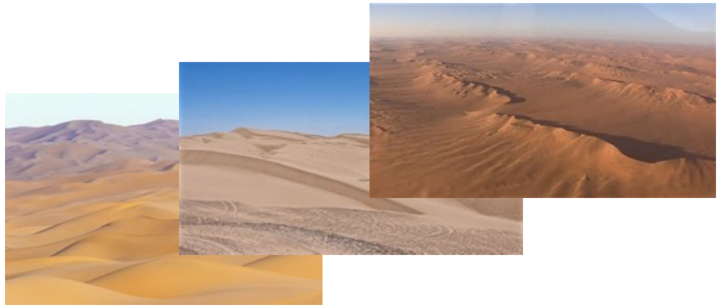
FIDUCEO project

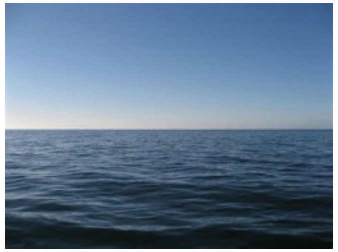
Harmonised(1) satellite series is one where all the calibrations of the sensors have been done *consistently* relative to **reference datasets** which can be traced back to known reference sources, in an ideal case back to SI.

How to build **reference datasets** for satellite series harmonisation?

(1) Unlike harmonisation, homogenisation is where all satellites are forced to look the same such that when looking at the same location at the same time they would (in theory) give the same signal

Vicarious radiometric calibration





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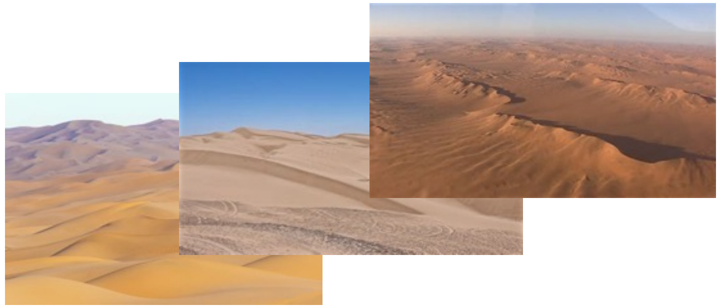

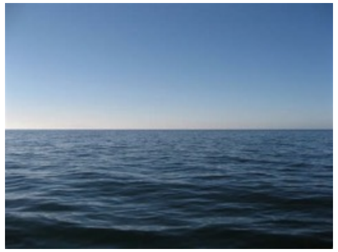

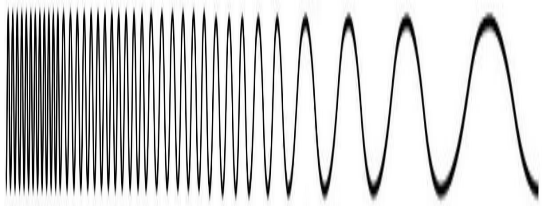

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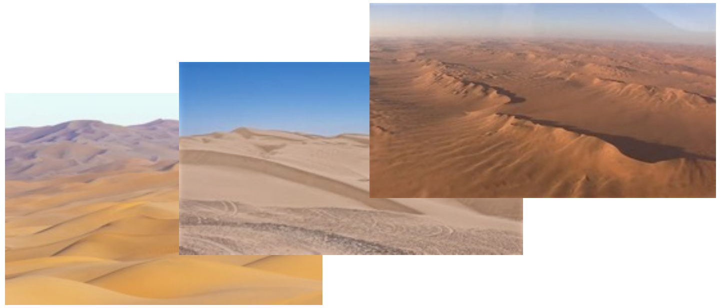
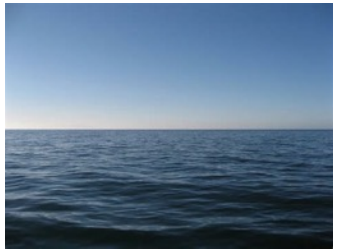
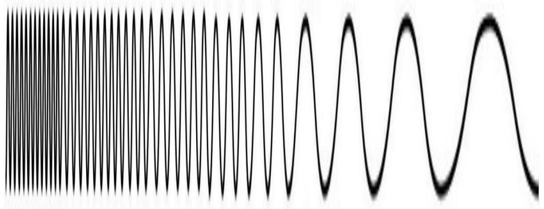
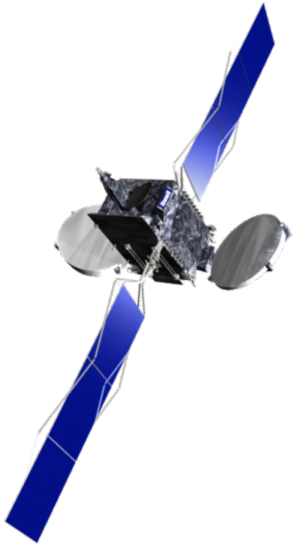






How to harmonise different calibration targets in a consistent and traceable **vicarious calibration reference**?



Approach

Issues

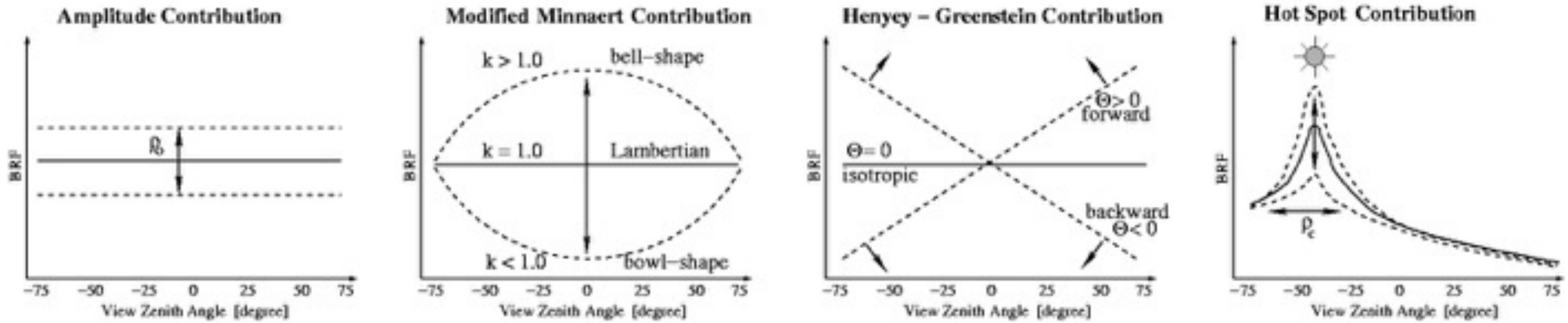
- How to combine (harmonise) desert targets as a single calibration reference (surface and atmospheric spatial correlation)?
- How to combine different observations (temporal/spatial correlation)?
- Are there spectral correlations?

Proposed approach

- Define **correlated uncertainties** between state variables;
- **Propagade** uncertainties accounting for these correlations.

Bright desert calibration reference

- Surface
  - Surface reflectance simulated with the RPV model
    $\rho_0(p,\lambda), k(p,\lambda), \Omega(p,\lambda), \rho_c(p,\lambda)$



- Atmosphere
  - US standard vertical profile
  - Rescaling of the water vapour and ozone concentration (U_{H2O} (p,t), $U_{O3}(p,t)$)
  - Sahara desert aerosol type (non spherical particles)
  - Aerosol optical thickness (τ_{550} (p,t))

Propagation of uncertainties

Following the GUM and the formalism adopted by Mittaz et al. (2019), two methods can be used for the propagation of uncertainties.

- The first one is referred to as the ‘Law of Propagation of Uncertainty’ (**LPU**)
- The second uncertainty propagation approach relies on Monte Carlo Methods (**MCM**).

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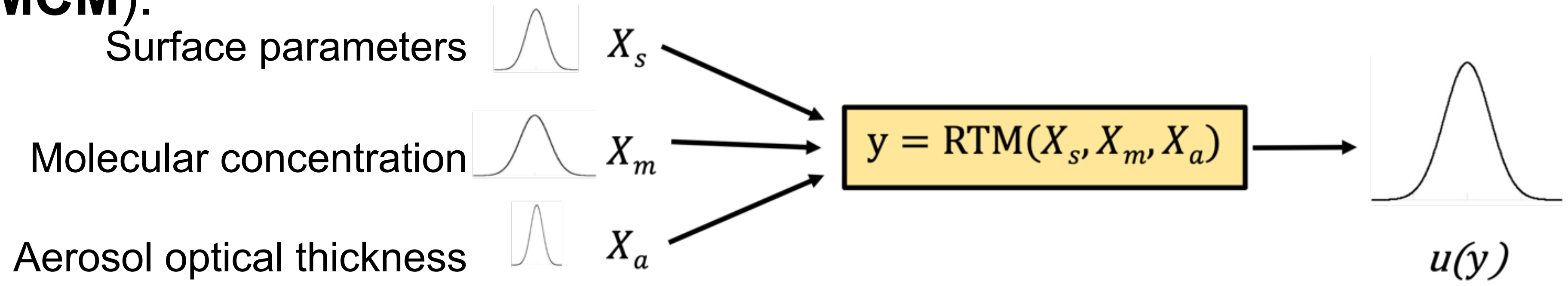

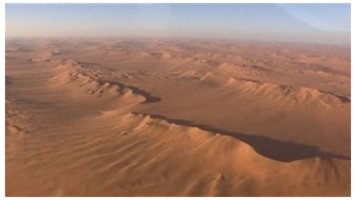

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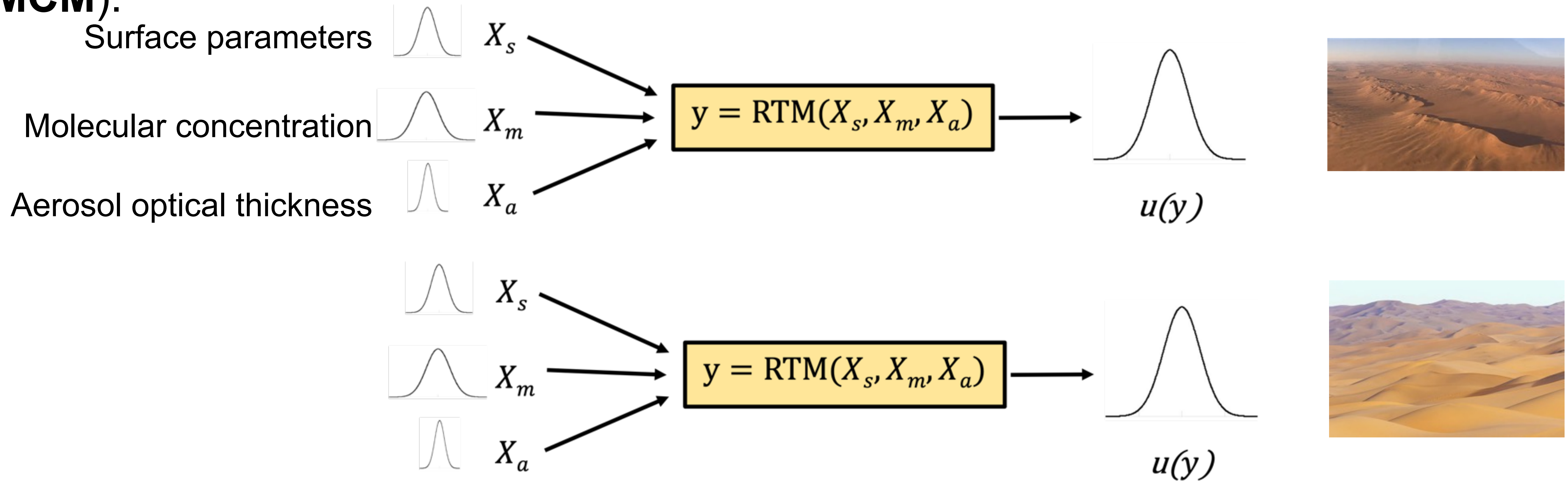

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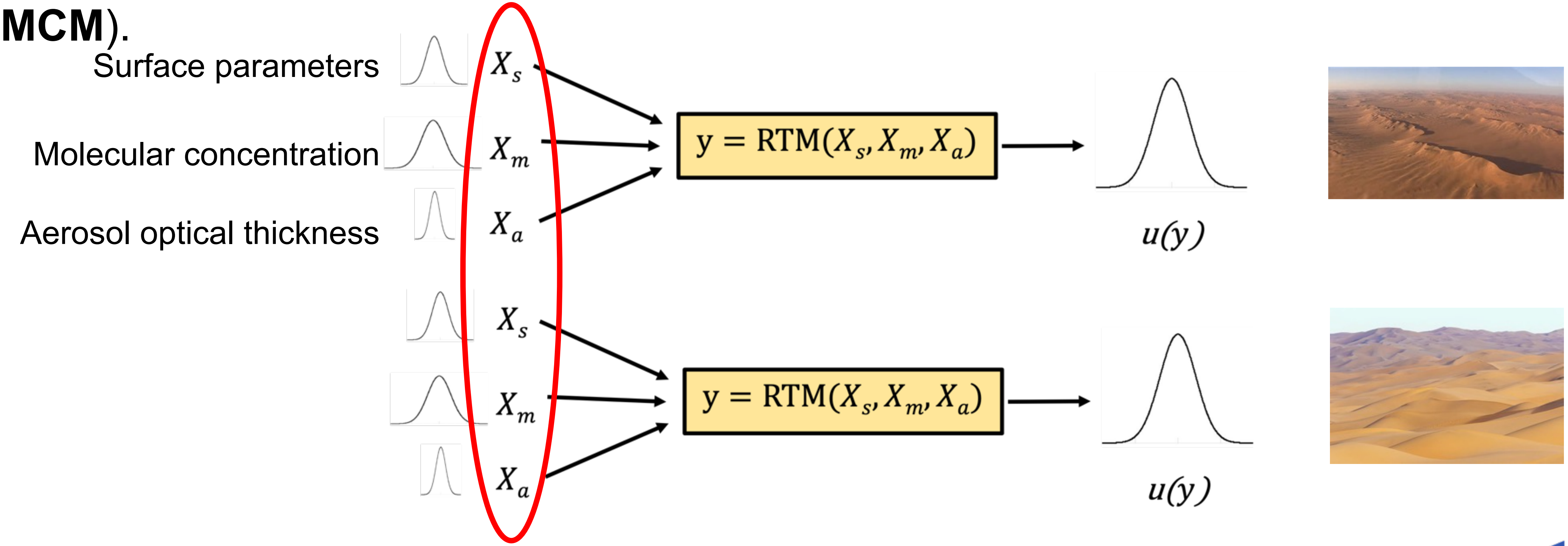


Define the correlations between the uncertainties

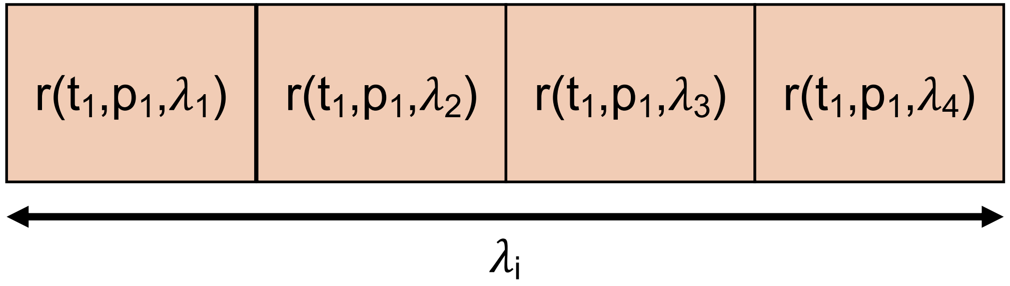
Calibration reference harmonisation

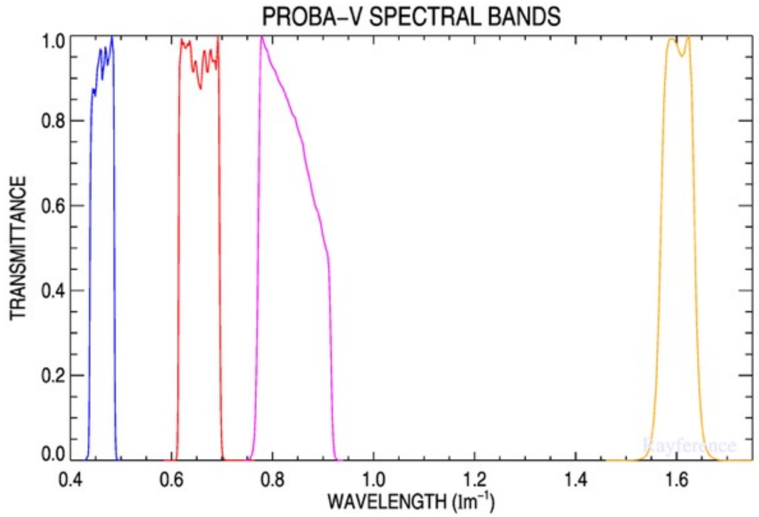
$r(t_1, p_1, \lambda_1)$

One observation over one target in one spectral band:

- Correlation between $\rho_0(t_1, p_1, \lambda_1), \Omega(t_1, p_1, \lambda_1), k(t_1, p_1, \lambda_1), \rho_c(t_1, p_1, \lambda_1)$
- Correlation between $U_{H2O}(p_1, t_1)$, $U_{O3}(p_1, t_1)$, $\tau_{550}(p_1, t_1)$

Calibration reference harmonisation





One observation over one target in **all spectral bands**:

- Spectral correlation between $\rho_0(t_1,p_1,\lambda_i), \Omega(t_1,p_1,\lambda_i), k(t_1,p_1,\lambda_i), \rho_c(t_1,p_1,\lambda_i)$
- Correlation between U_{H2O} (p_1,t_1), $U_{O3}(p_1,t_1)$ (molecular absorption)
- Aerosol optical thickness τ_{550} (p_1,t_1) : spectral correlation imposed by the aerosol model

Calibration reference harmonisation

$r(t_1,p_1,\lambda_1)$	$r(t_1,p_1,\lambda_2)$	$r(t_1,p_1,\lambda_3)$	$r(t_1,p_1,\lambda_4)$
$r(t_2,p_1,\lambda_1)$	$r(t_2,p_1,\lambda_2)$	$r(t_2,p_1,\lambda_3)$	$r(t_2,p_1,\lambda_4)$
$r(t_3,p_1,\lambda_1)$	$r(t_3,p_1,\lambda_2)$	$r(t_3,p_1,\lambda_3)$	$r(t_1,p_1,\lambda_4)$
$r(t_4,p_1,\lambda_1)$	$r(t_4,p_1,\lambda_2)$	$r(t_4,p_1,\lambda_3)$	$r(t_4,p_1,\lambda_4)$

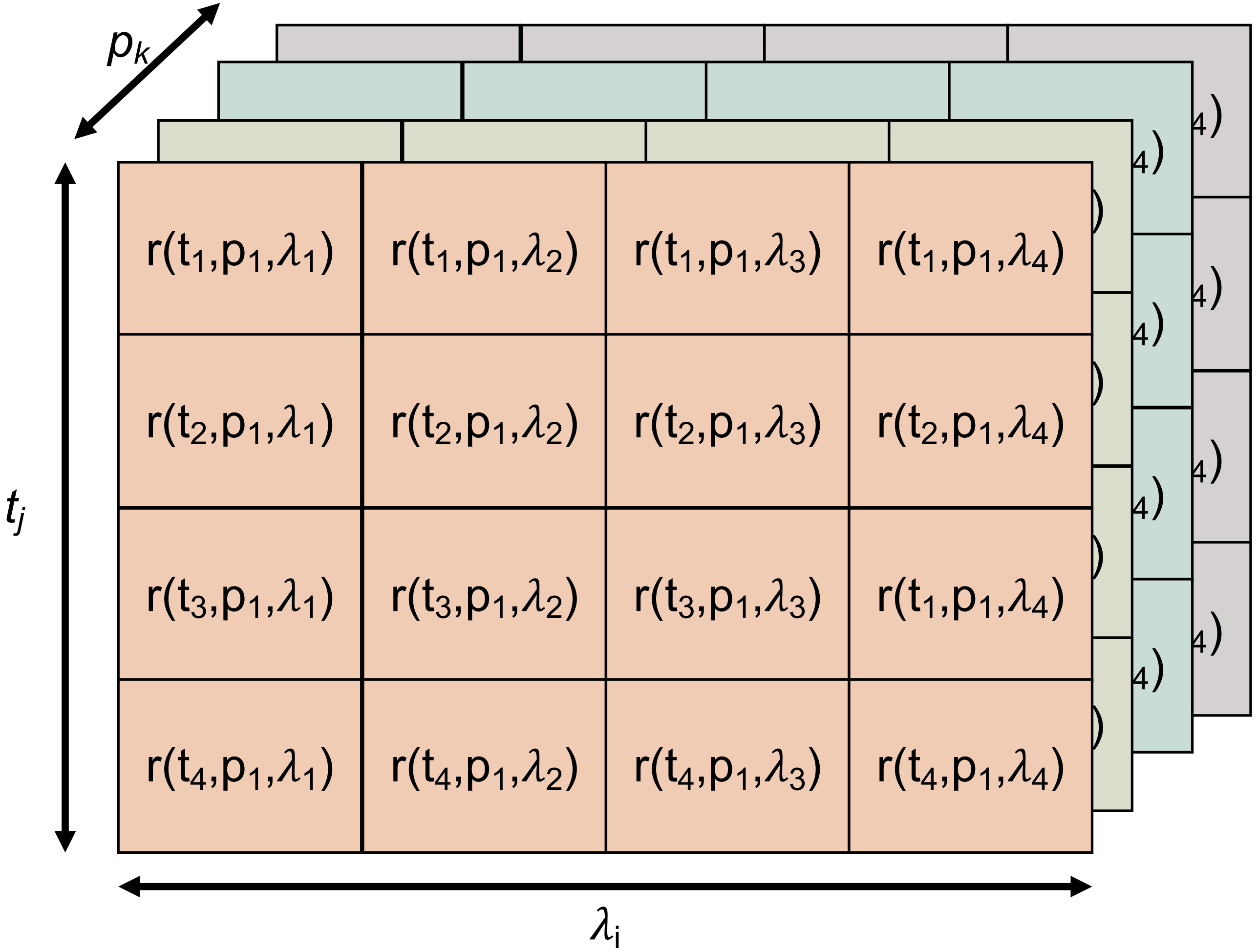
t_j

λ_i

Time series of observations over one target in all spectral bands:

- temporal correlation between $\rho_0(t_j,p_1,\lambda_i), \Omega(t_j,p_1,\lambda_i), k(t_j,p_1,\lambda_i), \rho_c(t_j,p_1,\lambda_i)$
- Temporal correlation between $U_{H2O}(t_j, p_1)$, $U_{O3}(t_j, p_1)$ (molecular absorption)
- Temporal aerosol optical thickness $\tau_{550}(t_j, p_1)$ correlation

Calibration reference harmonisation

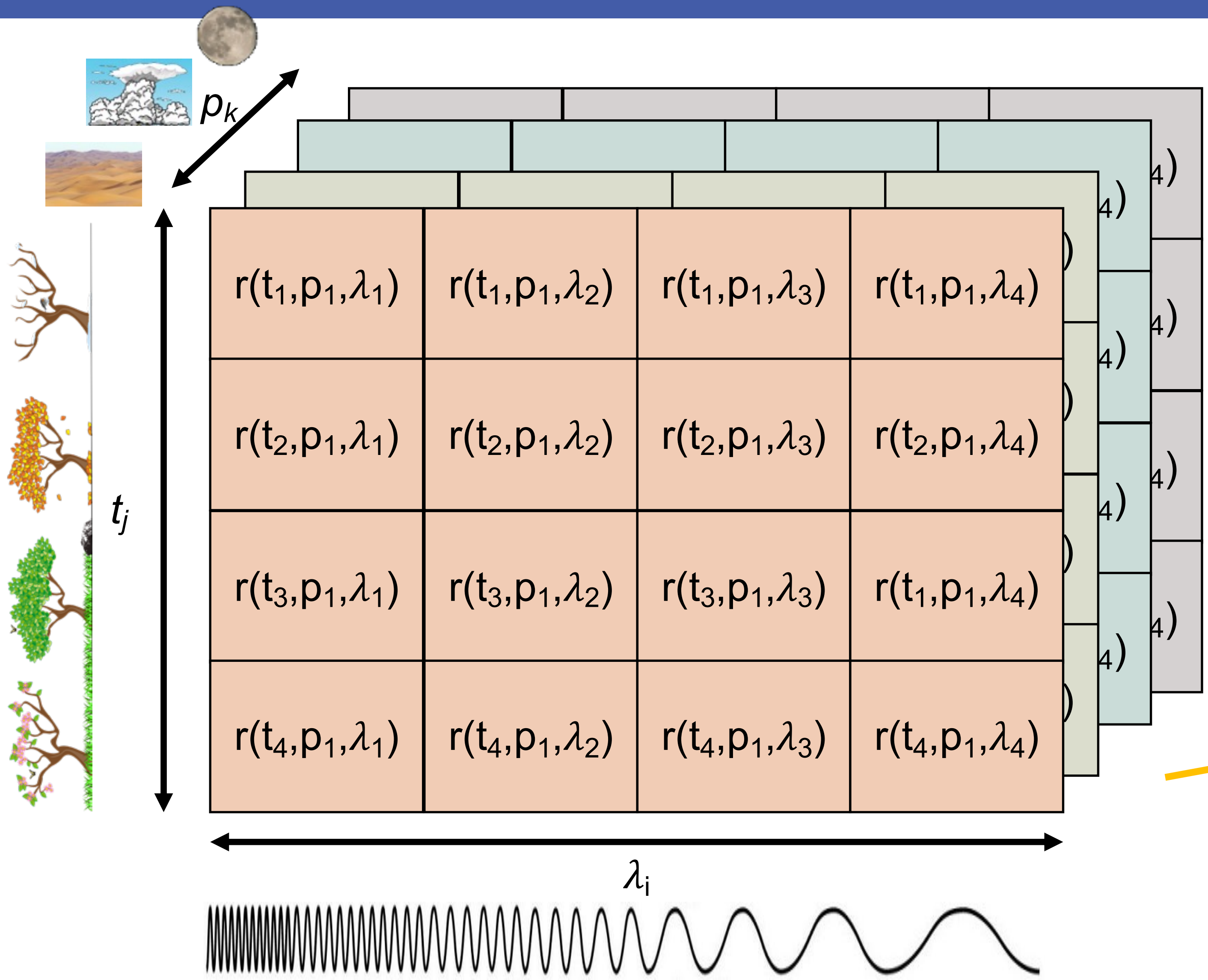


Vicarious calibration reference

Time series of observations over **several targets** in all spectral bands:

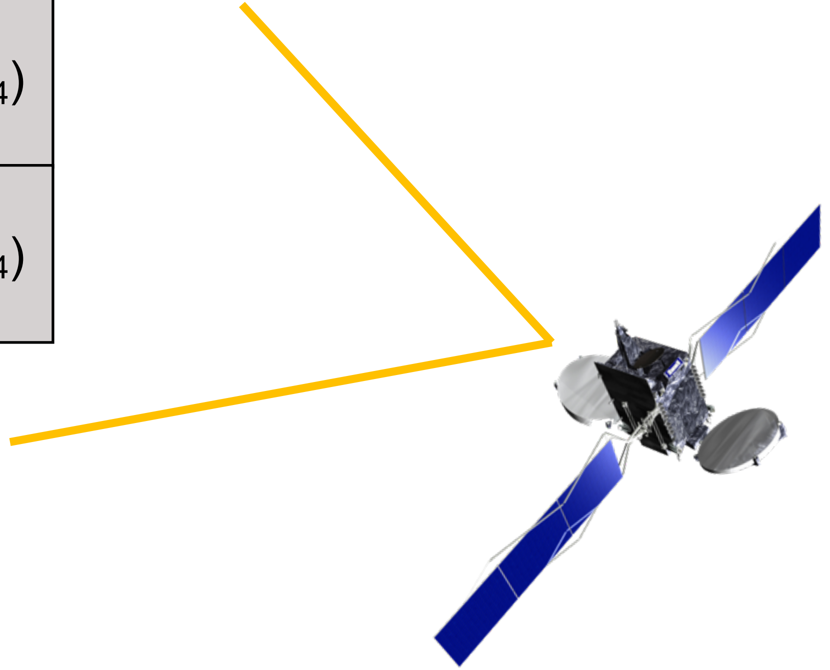
- spatial correlation between $\rho_0(t_j, pk, \lambda_i), \Omega(t_j, pk, \lambda_i), k(t_j, pk, \lambda_i), \rho_c(t_j, pk, \lambda$
- Spatial correlation between U_{H2O} (t_j, p_k), $U_{O3}(t_j, p_k)$ (molecular absorption)
- Spatial aerosol optical thickness τ_{550} (t_j, p_k) correlation

Calibration reference harmonisation

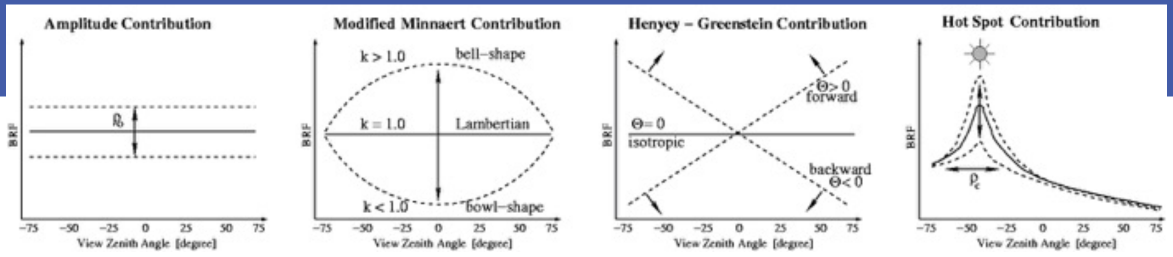


Vicarious calibration reference

Definition of a harmonised calibration reference with traceable uncertainty propagation



Practical example



Let’s consider the surface parameters

Param./ Symbol	Unit	Description	Correlation			Remark
			Spectral	Spatial	Tempor.	
$\rho_0(\lambda)$	-	Intensity	Yes	(1)	Yes	The parameters are weakly correlated between themselves. This correlation can be neglected for spectral bands distant of more than 500nm.
$k(\lambda)$	-	Shape	Yes	(1)	Yes	
$\Omega(\lambda)$	-	Forward/backward	Yes	(1)	Yes	
$\rho_c(\lambda)$	-	Hot spot	Yes	(1)	Yes	

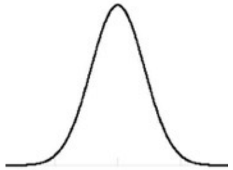

$u(\rho_0(\lambda))$


$u(k(\lambda))$


$u(\Omega(\lambda))$


$u(\rho_c(\lambda))$

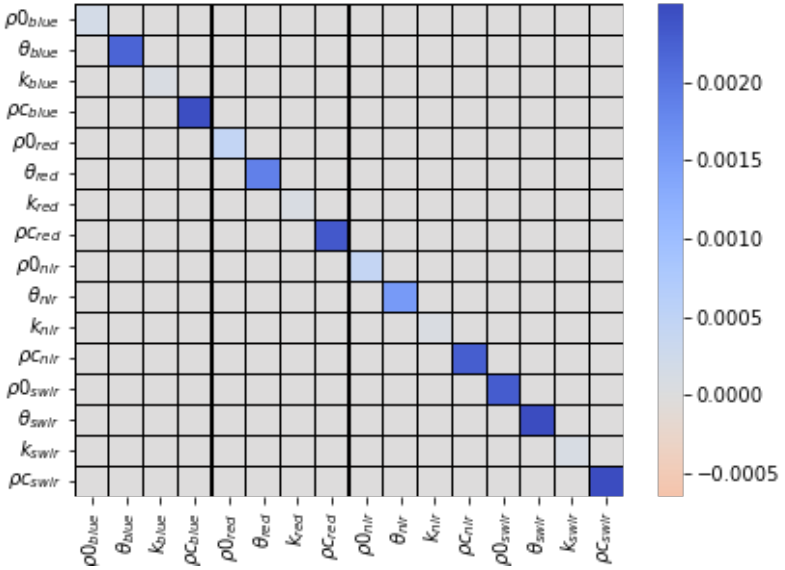
$$y = \mathrm{RPV}(\rho_0(\lambda), k(\lambda), \Omega(\lambda), \rho_c(\lambda))$$


$u(y)$

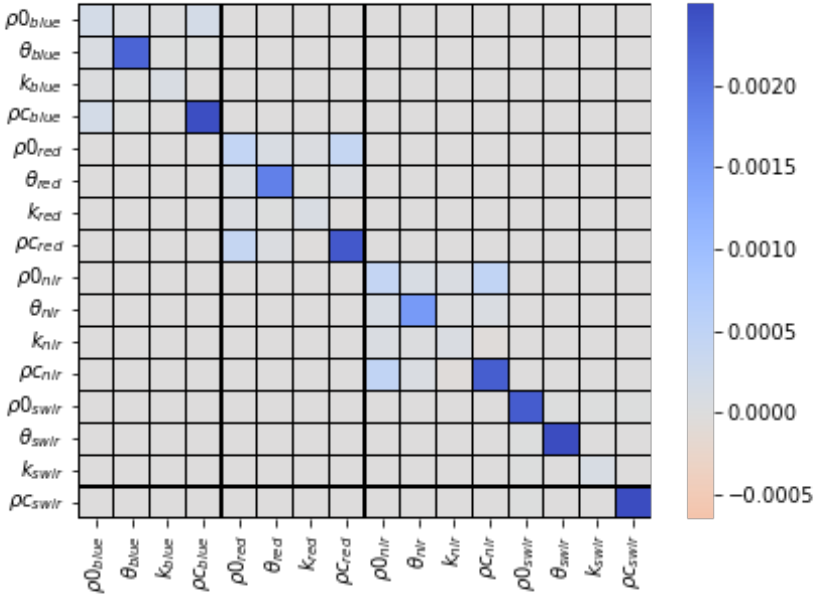
Covariance matrix

PROBA-V observation on 08/10/2014 over Libya-4

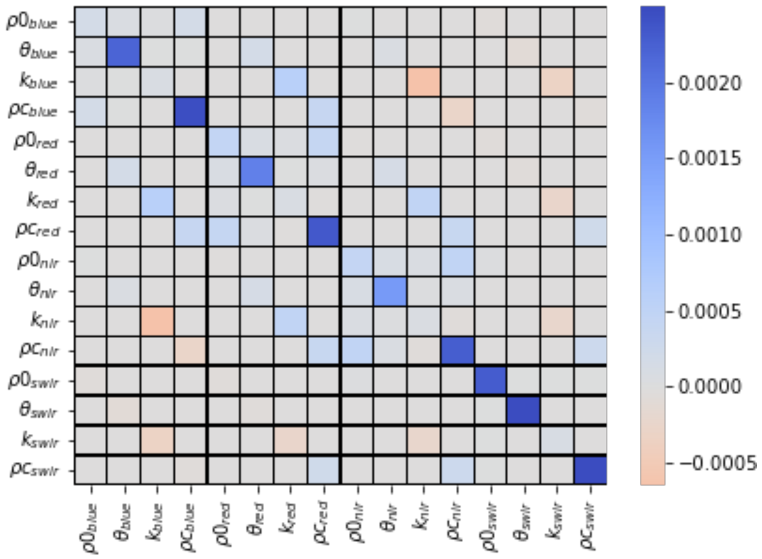
No correlation



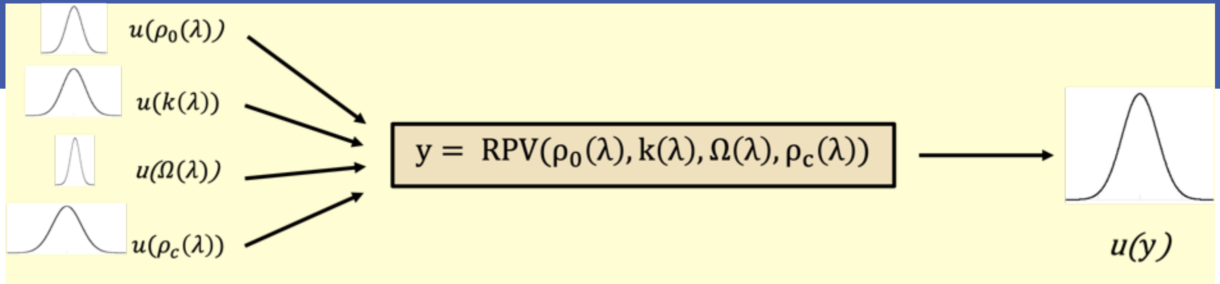
Correlation between RPV
No spectral correlation



Full correlation

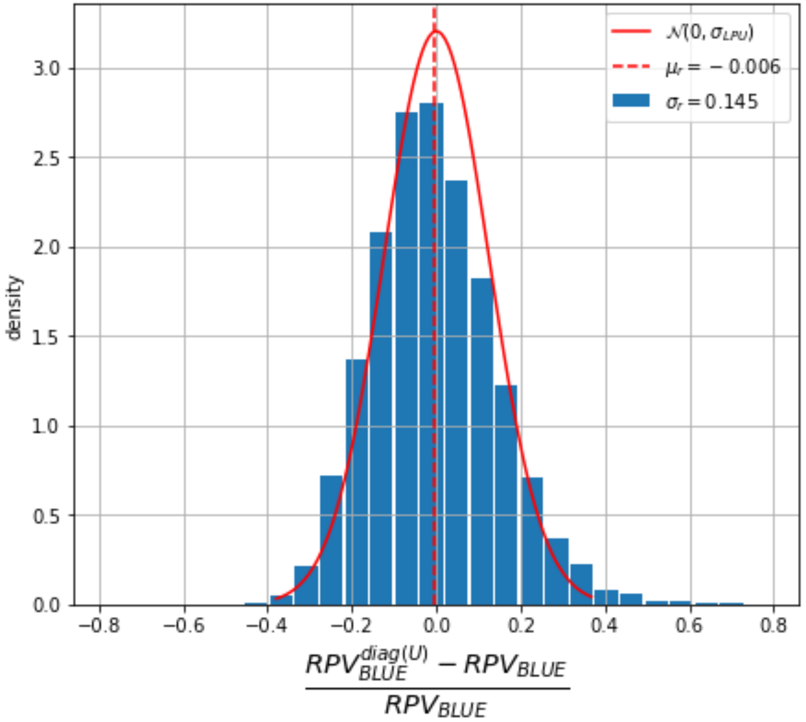


Error distribution

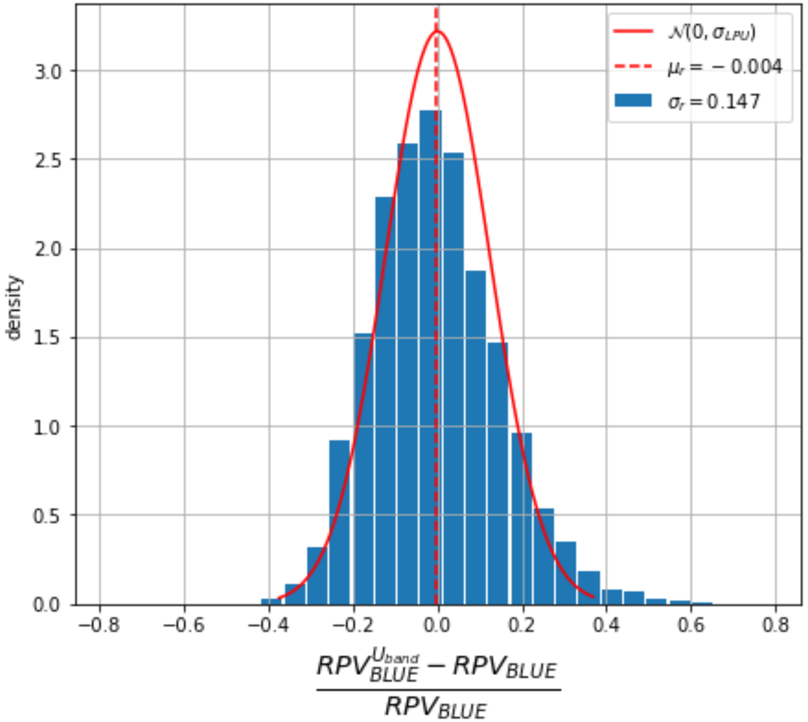


LPU (solid line)
MCM (histogram)

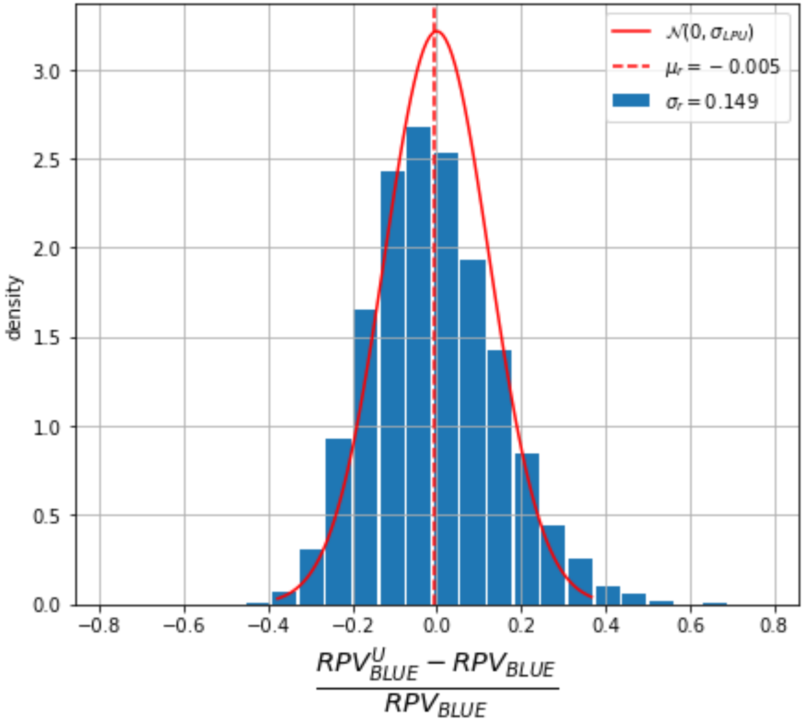
PROBA-V blue band, simulation of one observation over Libya-4



No correlation



Correlation between RPV
No spectral correlation



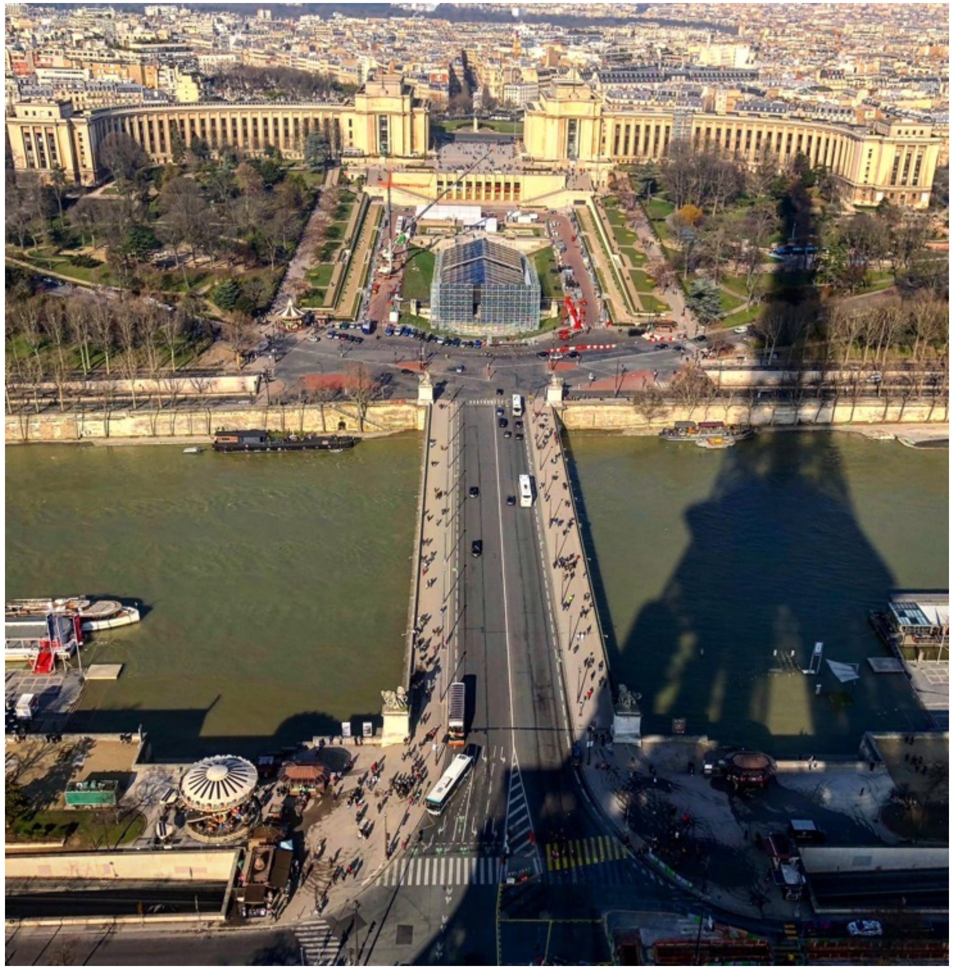
Full correlation

Part 2
FRM protocol for SR validation based on artificial targets

Top-of-atmosphere reflectance

Bottom-of-Atmosphere reflectance

Clear-sky



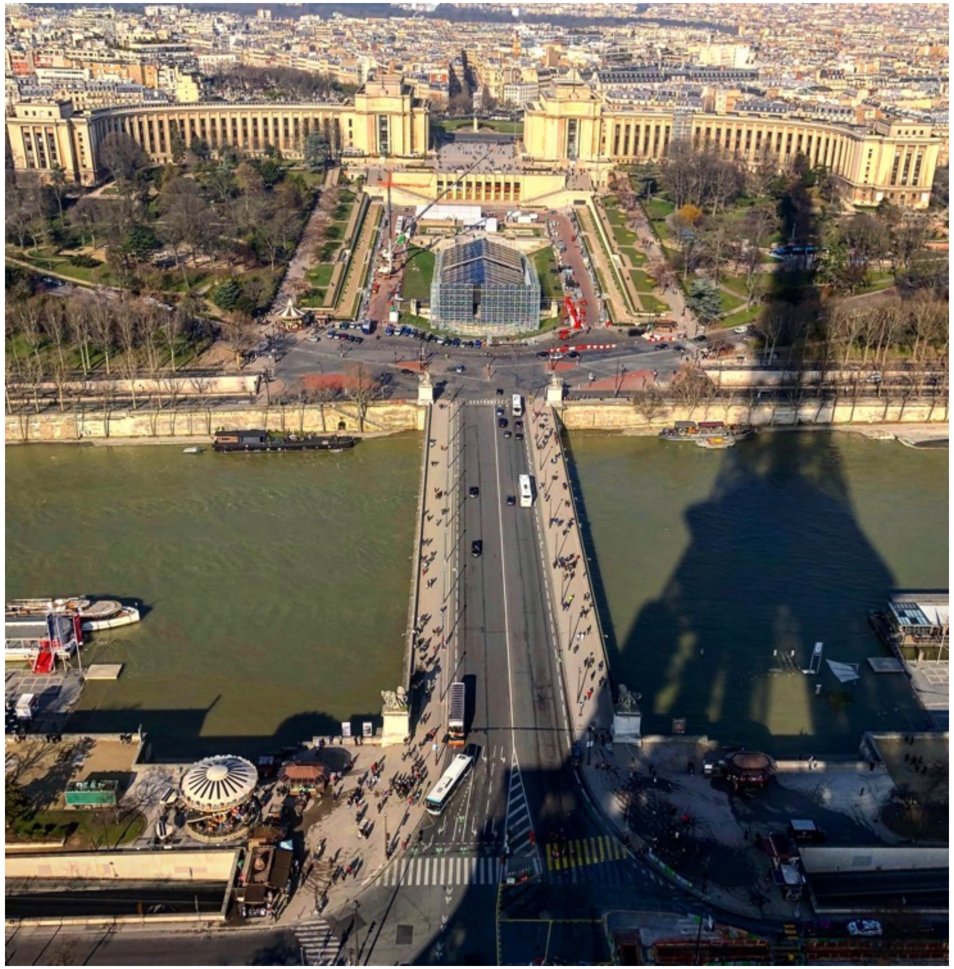
Overcast

Top-of-Canopy

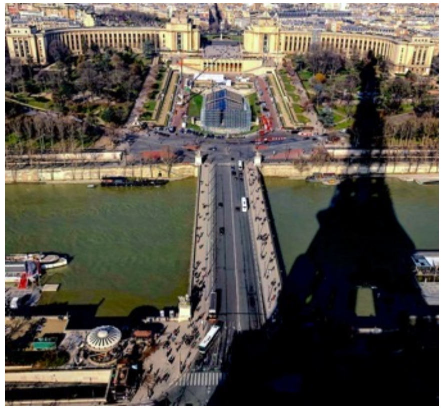
No atmosphere

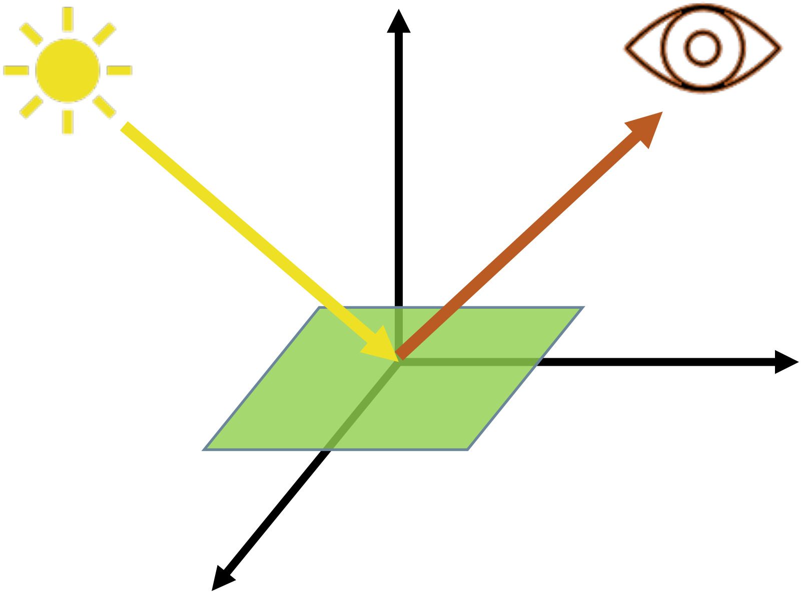
Bottom-of-Atmosphere

Atmosphere



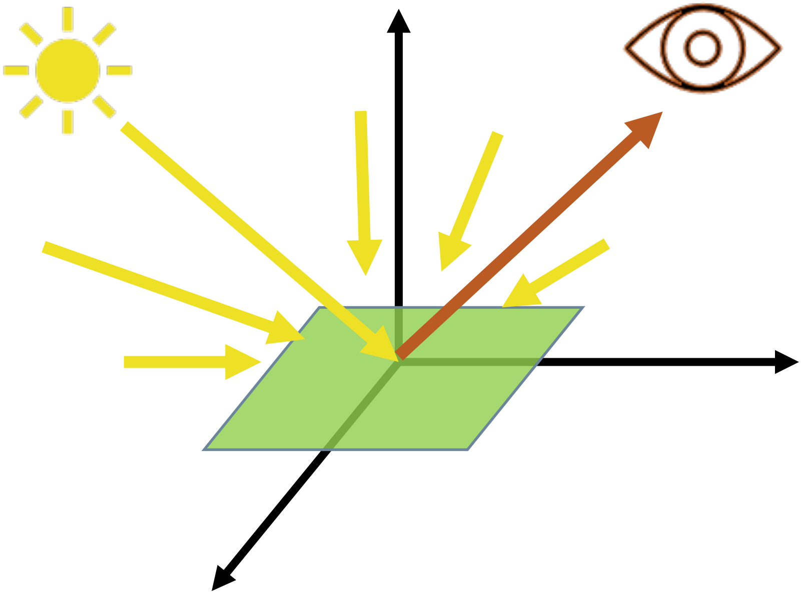
Definition of FRM surface reflectance





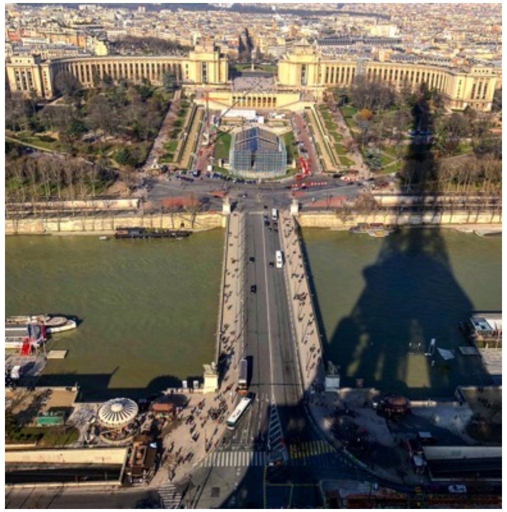
- Surface reflectance depends only on the illumination Ω_s and viewing Ω_v directions
- It will be referred to as the Bidirectional Reflectance Factor (Nicodemus, 1977) at the Top-of-Canopy (TOC BRF)
- Does not depend on the illumination (sky radiation) conditions

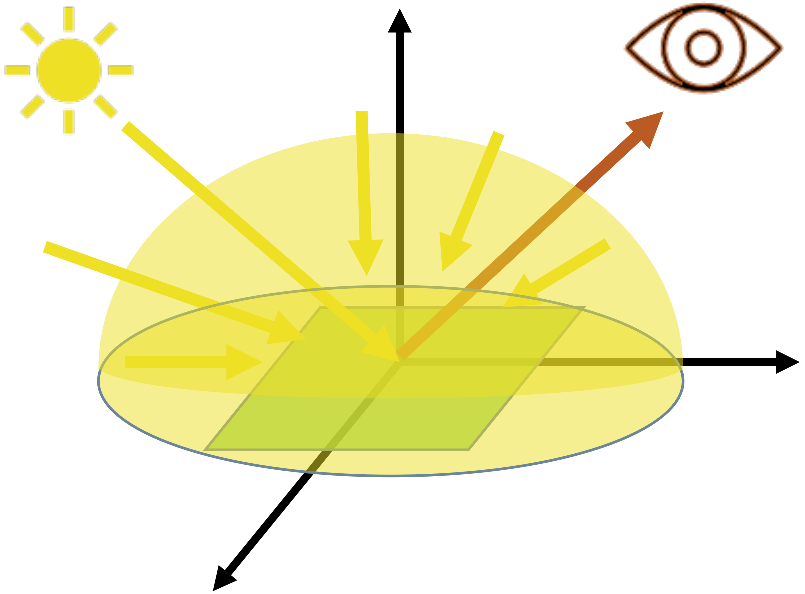
Definition of FRM surface reflectance

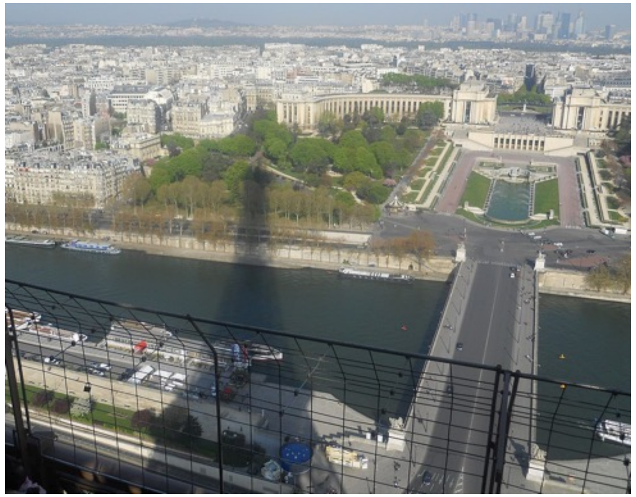


The Bidirectional Reflectance Factor at the Top-of-Canopy (TOC BRF) **cannot be** directly observed in the field because of the unavoidable contribution of the sky radiation

Definition of FRM surface reflectance

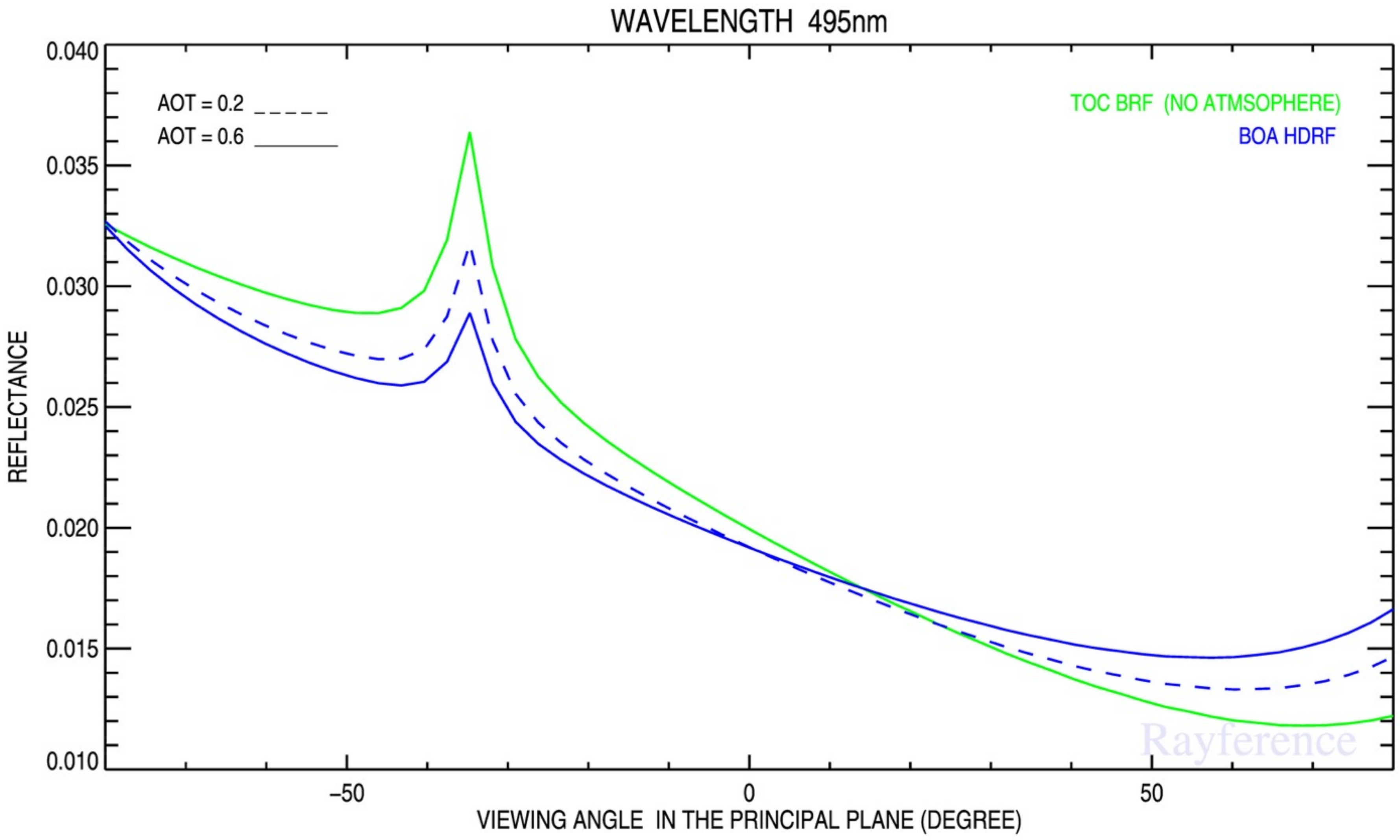






- Only the so-called **H**emispherical **D**irectional **R**eflectance **F**actor at the Bottom-of-Atmosphere (BOA HDRF) can be observed directly in the field;
- HDRF depends on the state of the atmosphere (illumination conditions).

Atmospheric effects on TOC BRF and BOA HDRF



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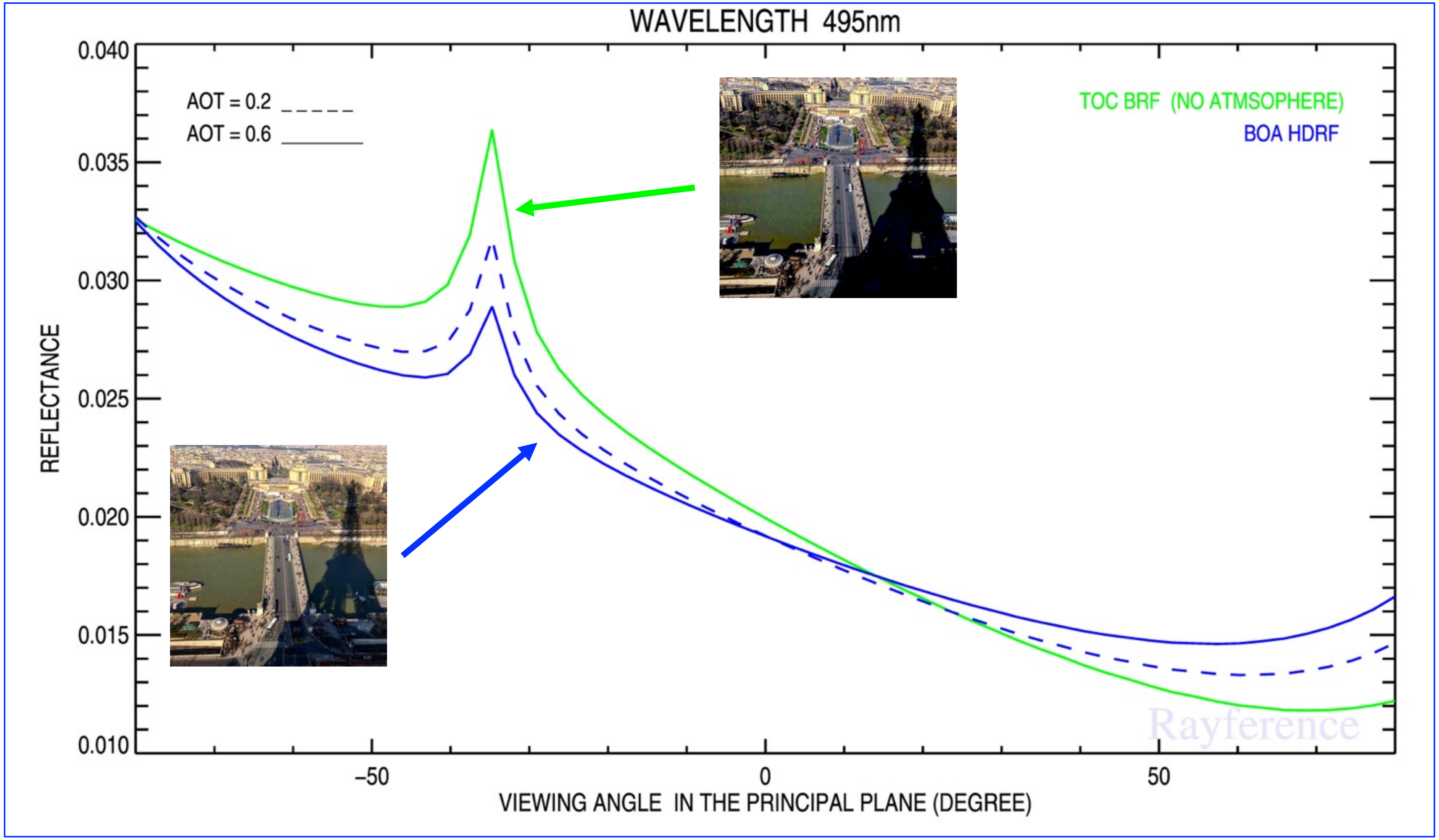

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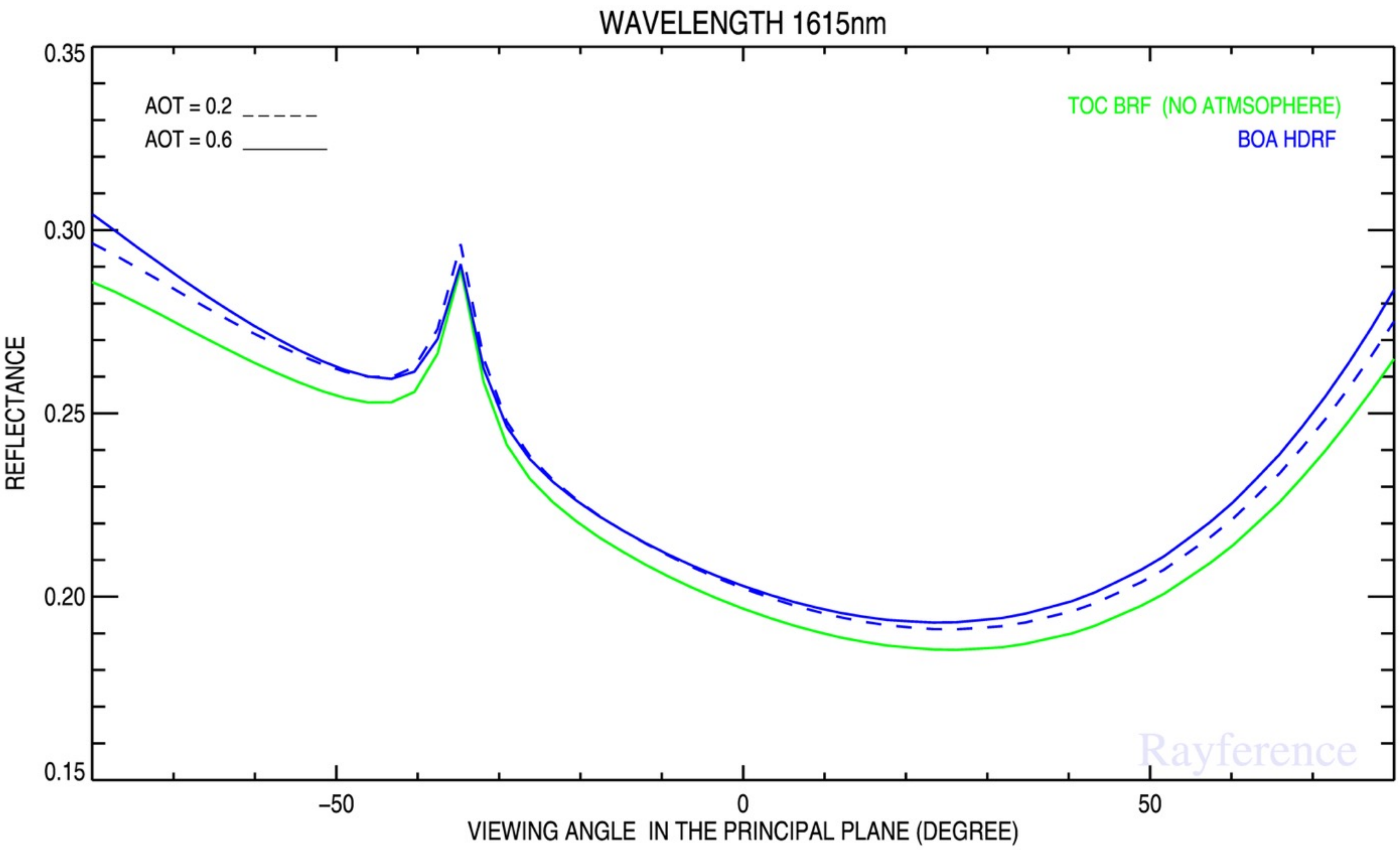
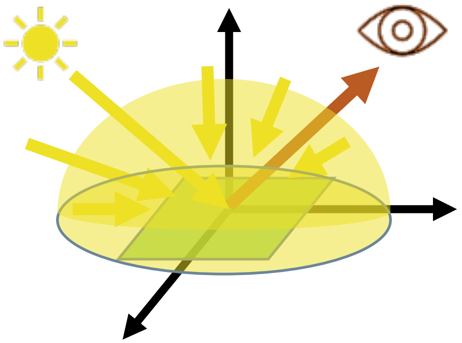


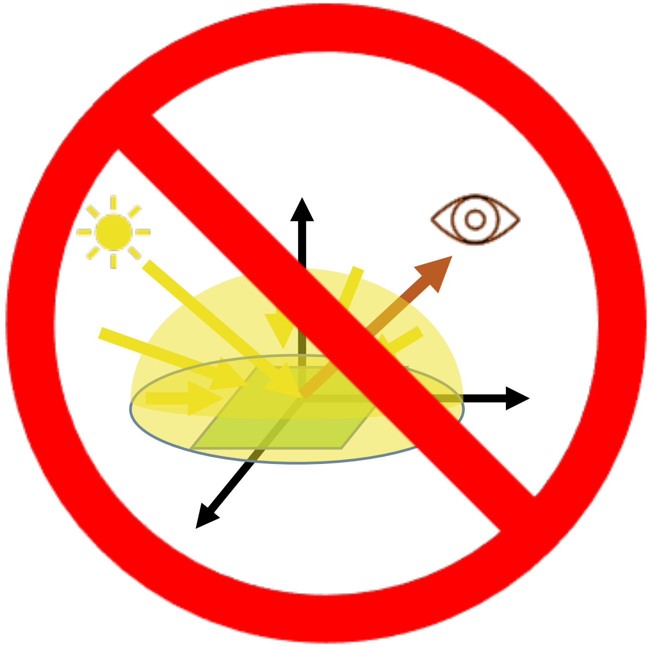
Atmospheric effects on TOC BRF and BOA HDRF

- At a given wavelength and viewing direction, the magnitude of the BoA HDRF is influenced by the atmospheric scattering;



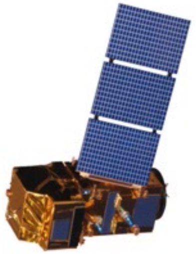
- The magnitude of this influence depends on the wavelength;

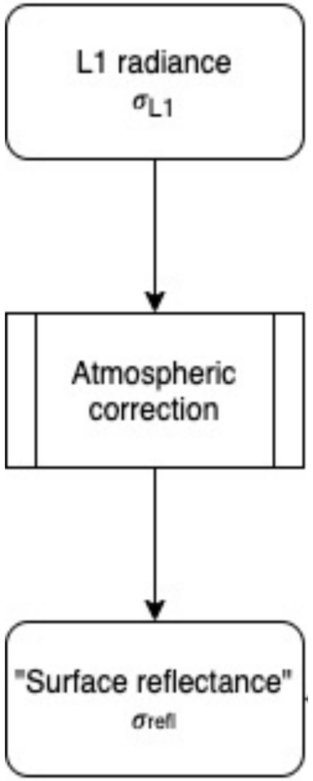
- ToC BRF ≈ BoA HDRF when sky scattering is low (SWIR).



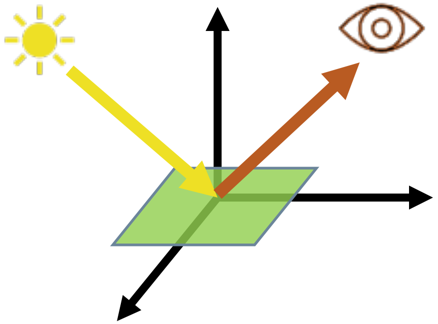
BoA HDRF is not a good surface reflectance FRM as it depends on the atmospheric conditions

Proposed protocol





TOC BRF



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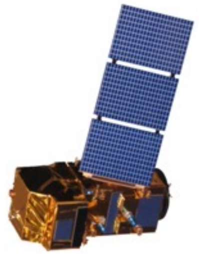
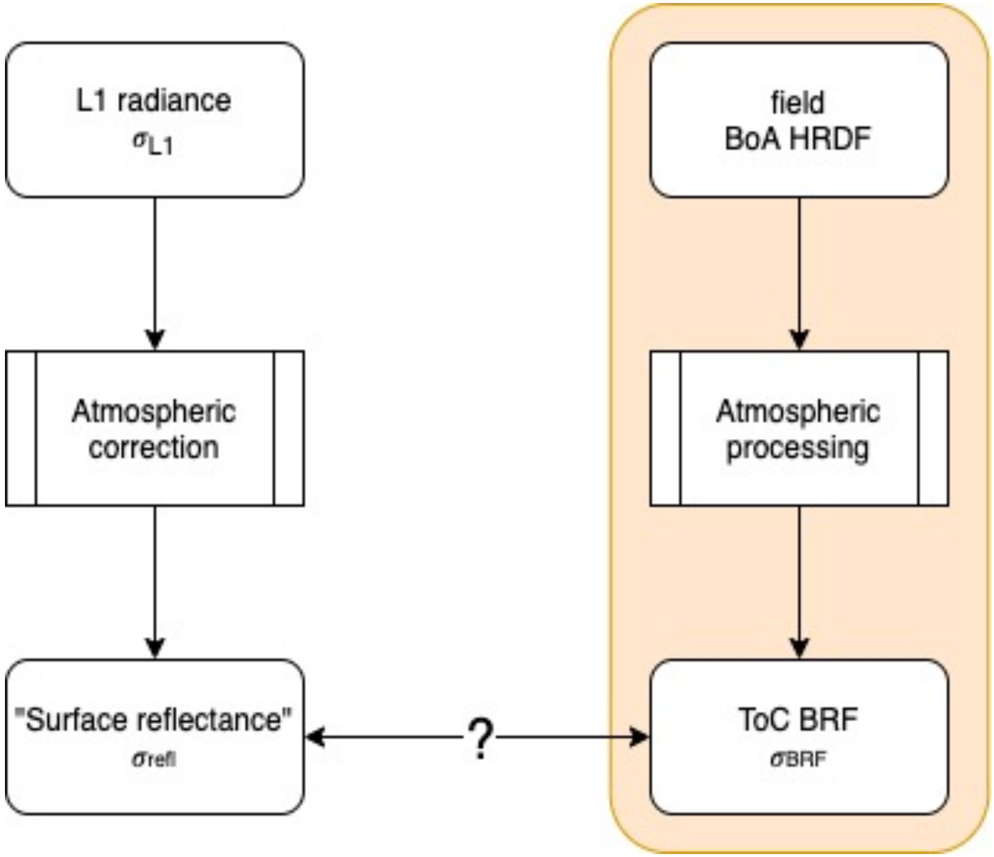
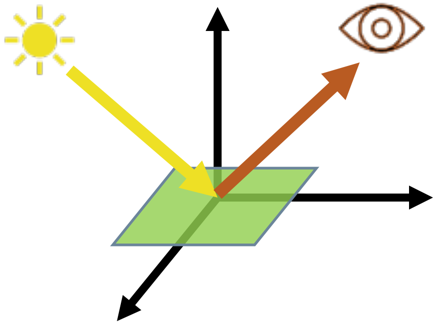


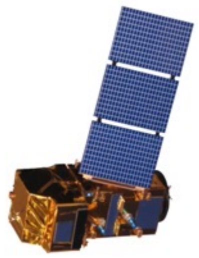


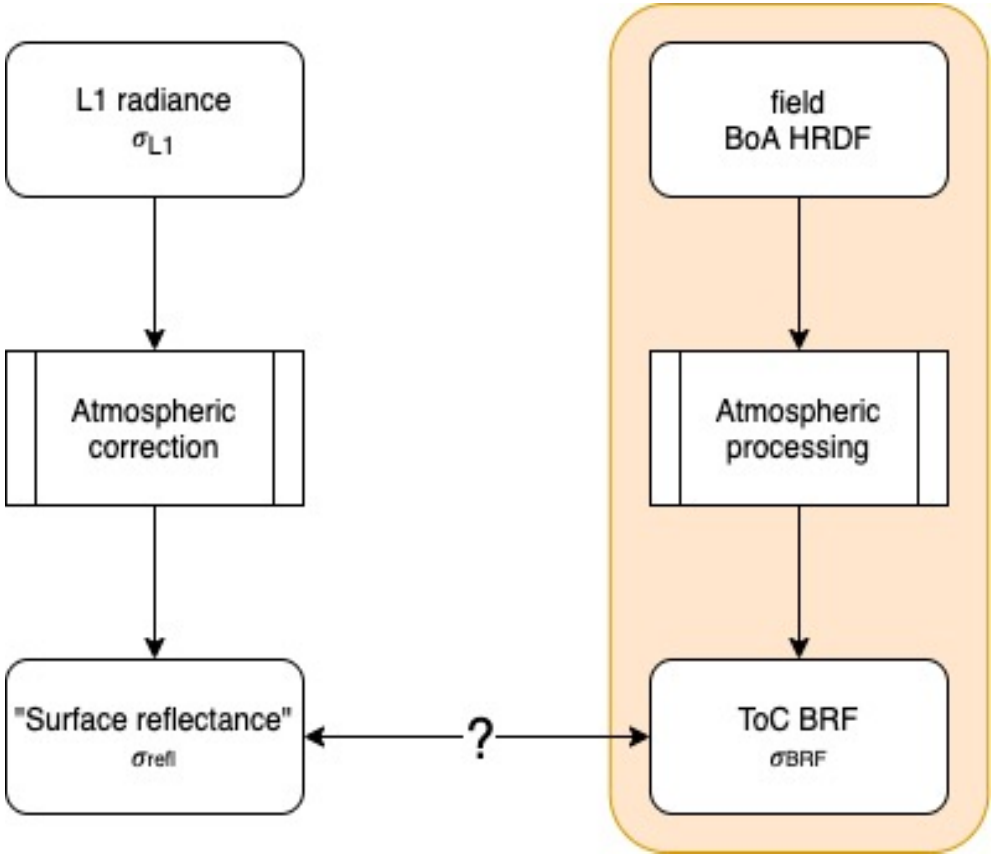
HDRF
Hemispherical Directional Reflectance Factor

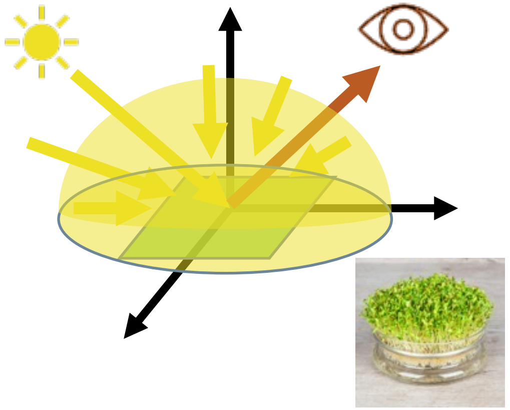
TOC BRF



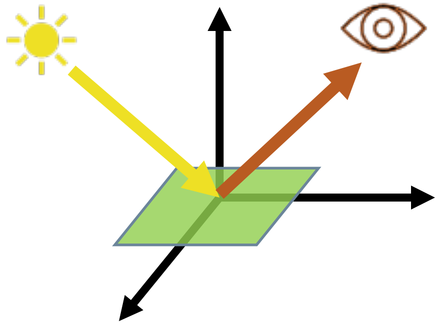
Proposed protocol







TOC BRF



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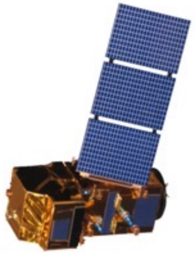
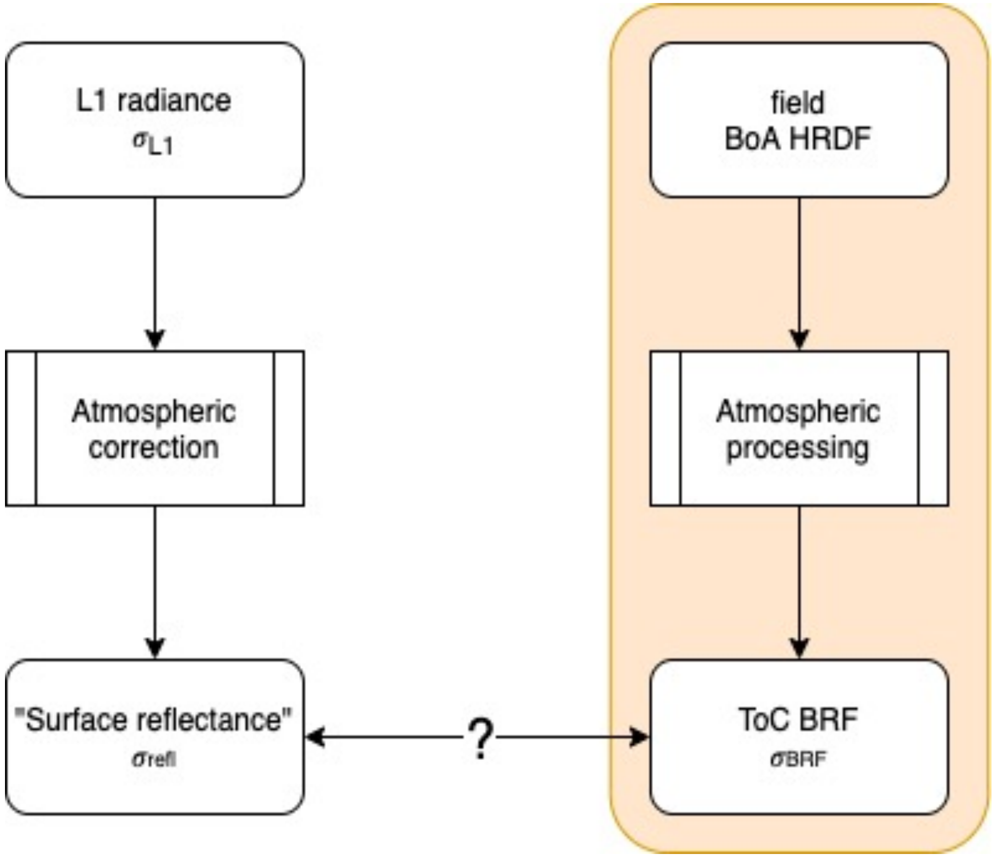
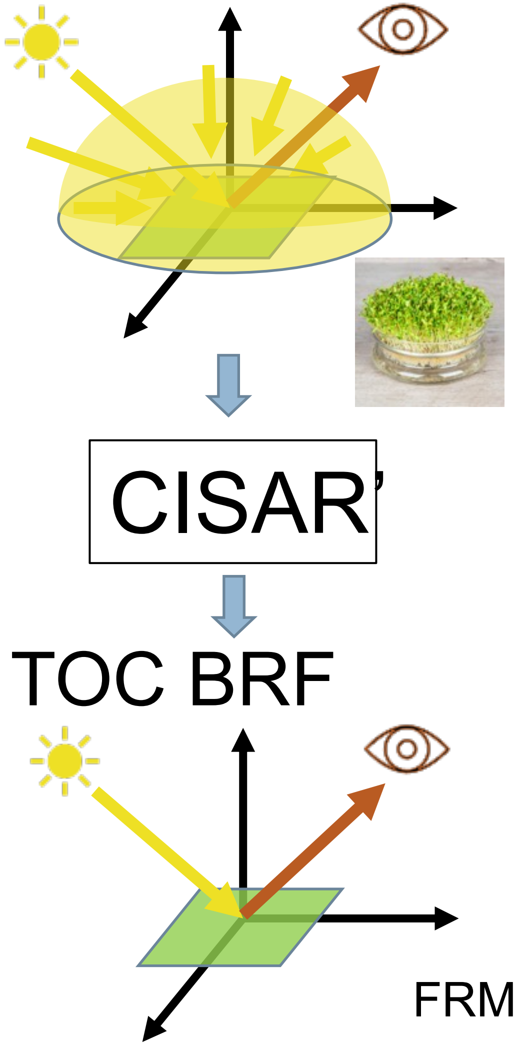
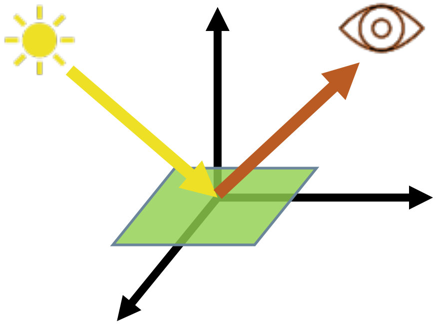


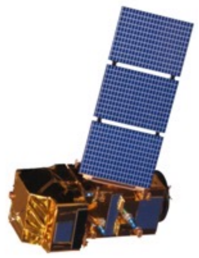


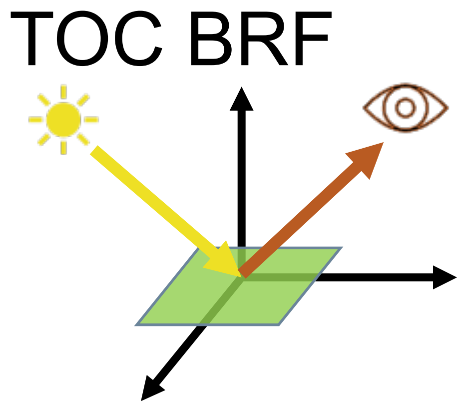


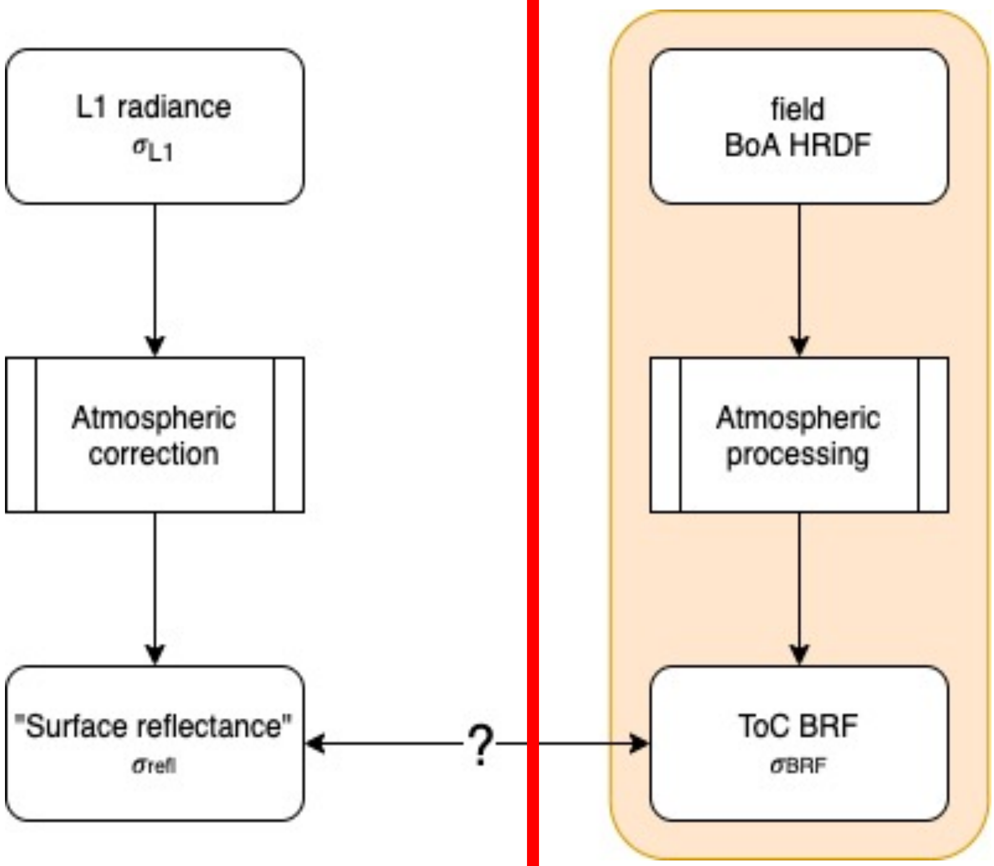
TOC BRF

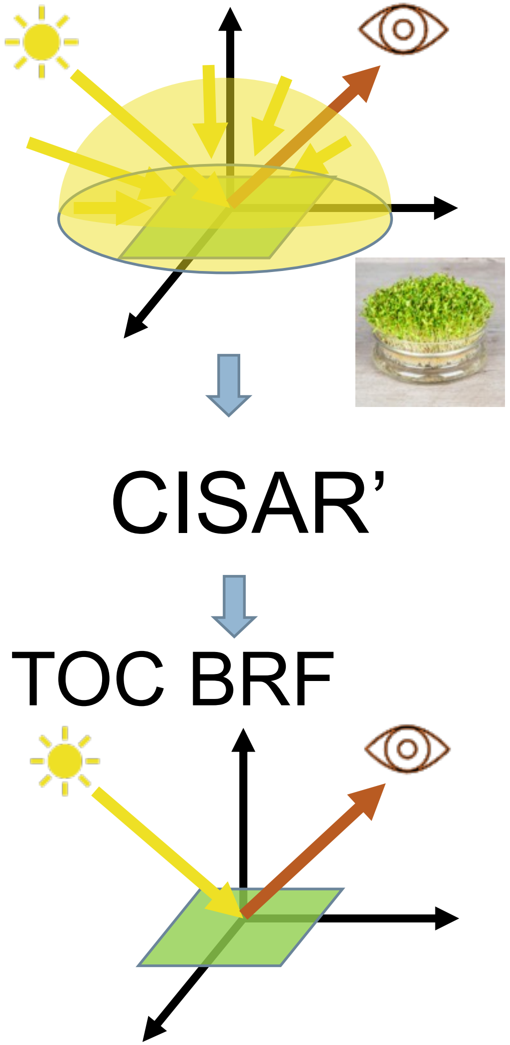


Proposed protocol





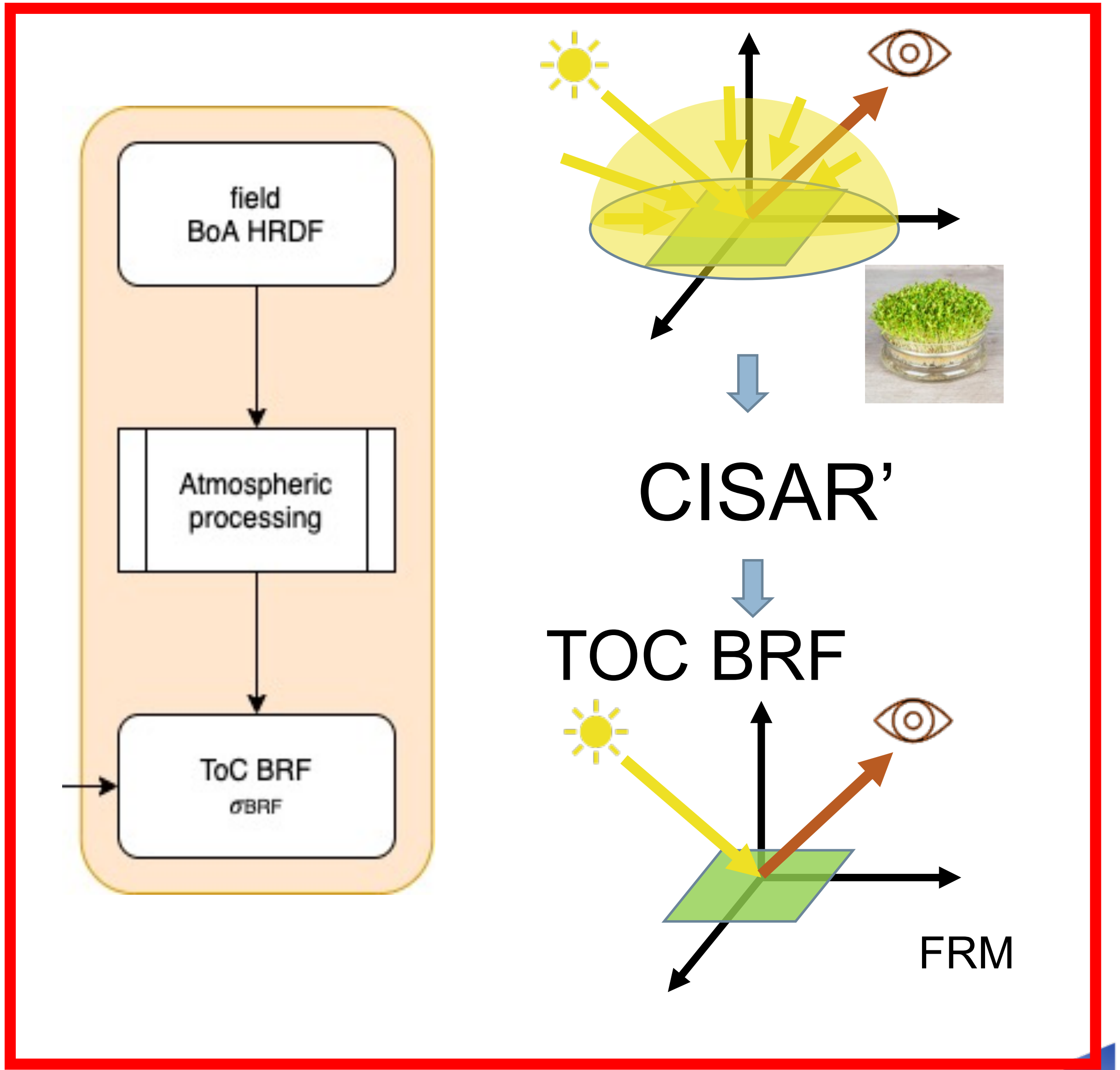




How to validate this branch?

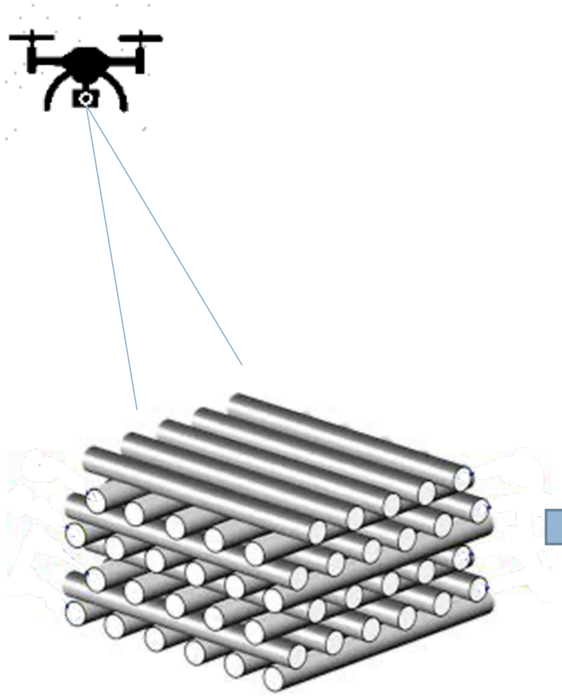
Proposed new protocol

As ToC BRF cannot be directly measured in the field, it is not possible to verify the ToC BRF FRM and associated uncertainties

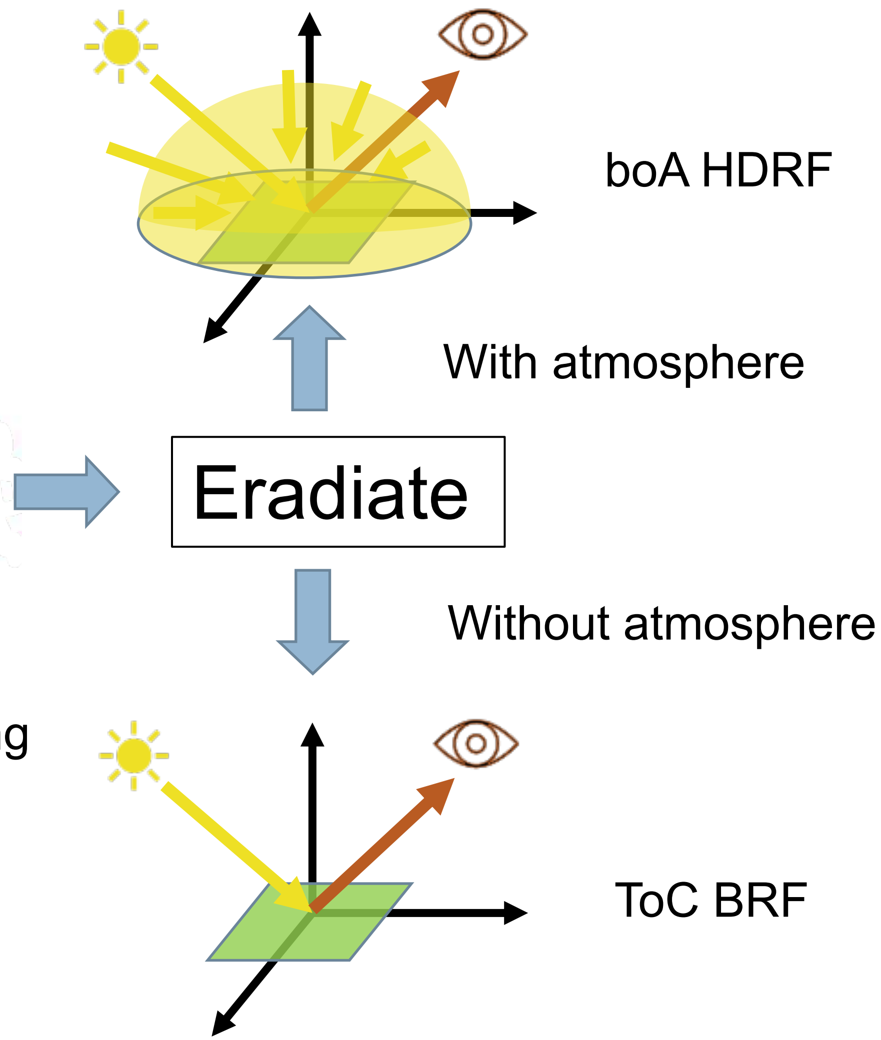


How to validate this branch?

Proposed protocol

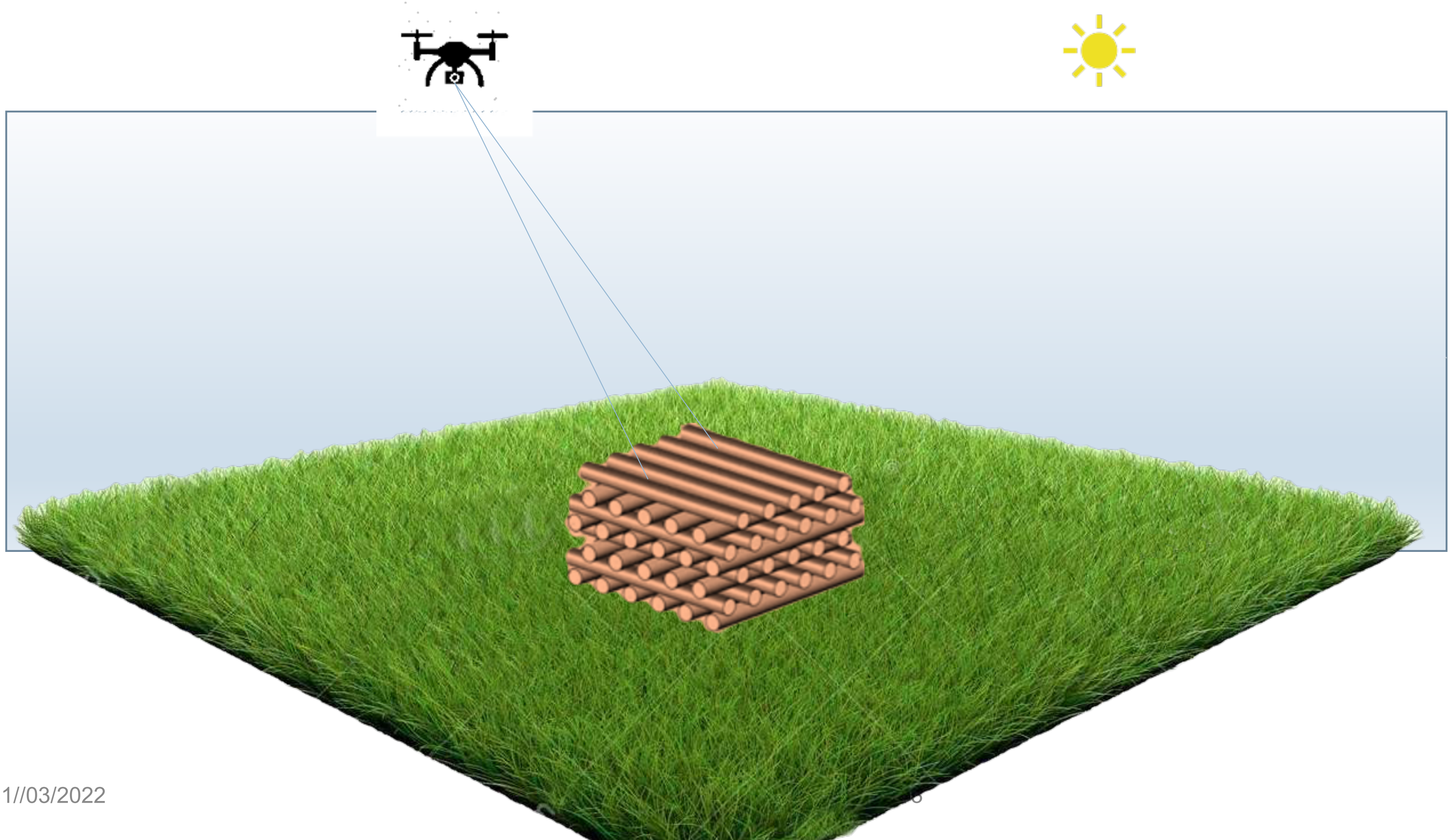


Artificial target covering the entire ground observations FOV

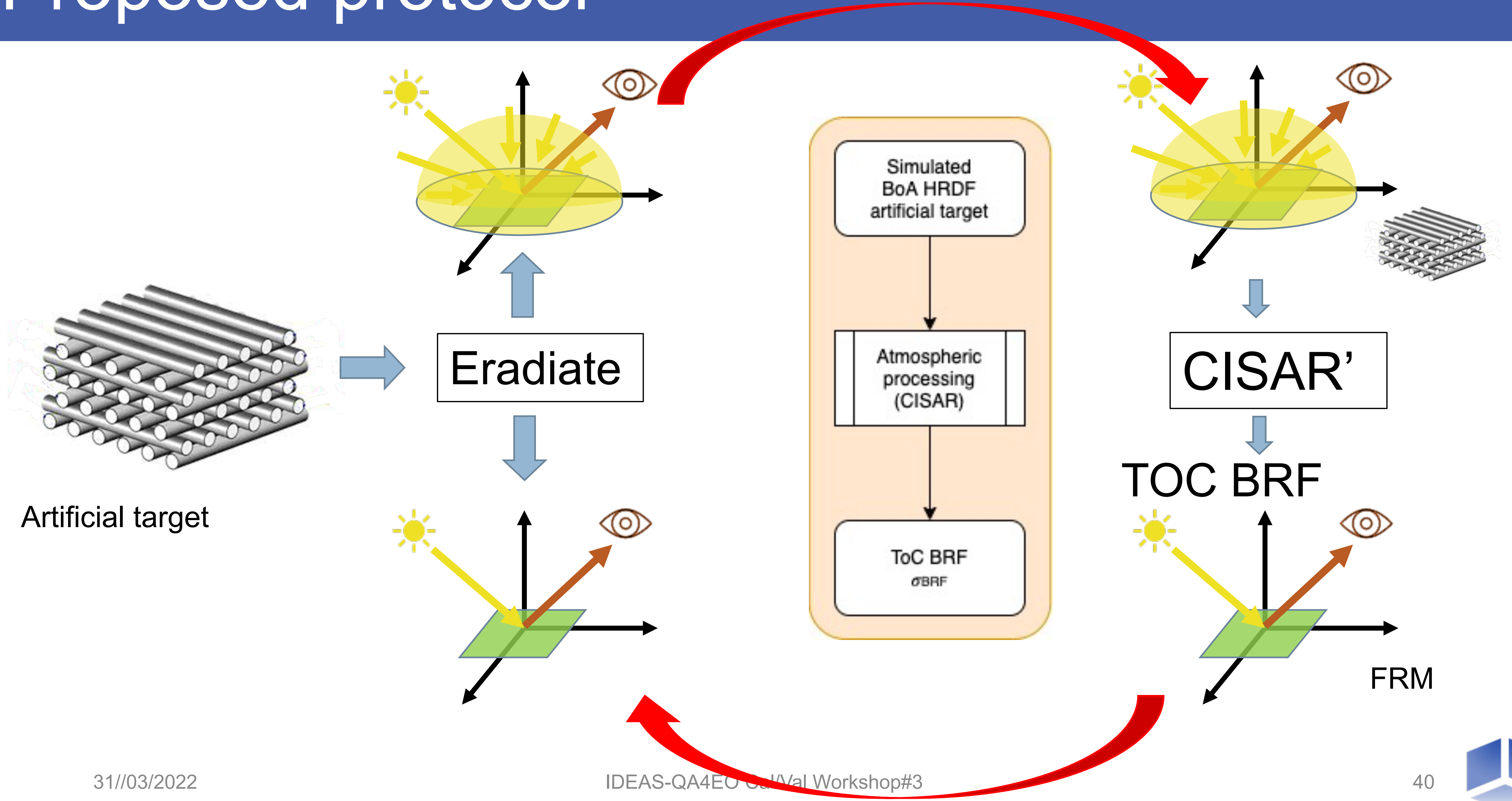


FRM

Eradiate



Proposed protocol



Study output

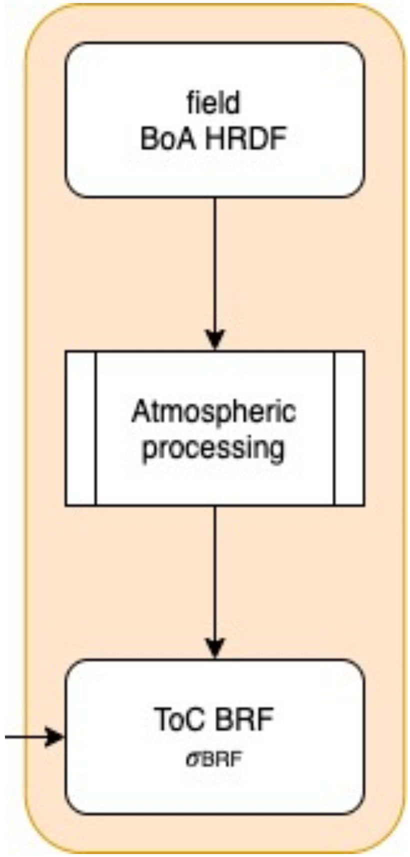
- The design of an artificial target of known BRF that can be brought where FRM field experiment take place;

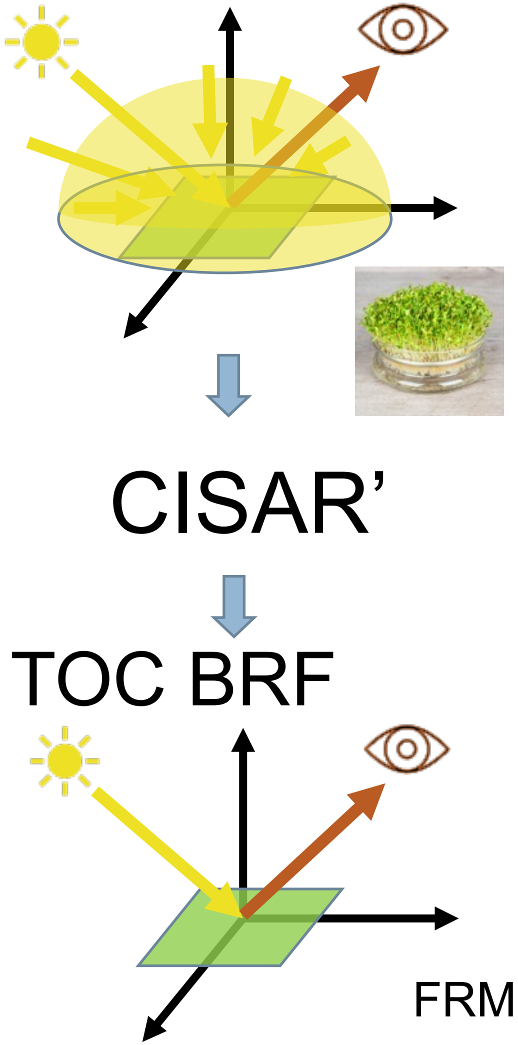
- The ATBD to rigorously convert BoA HDRF field measurement into ToC BRF FRM according to the available information and to provide the associated uncertainty;

- A protocol for the validation of ToC BRF FRM;

Any questions?

Next step: how to exploit these results?

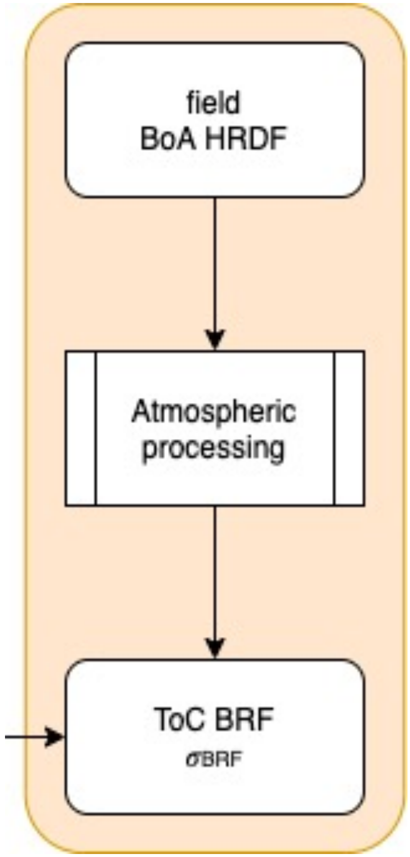


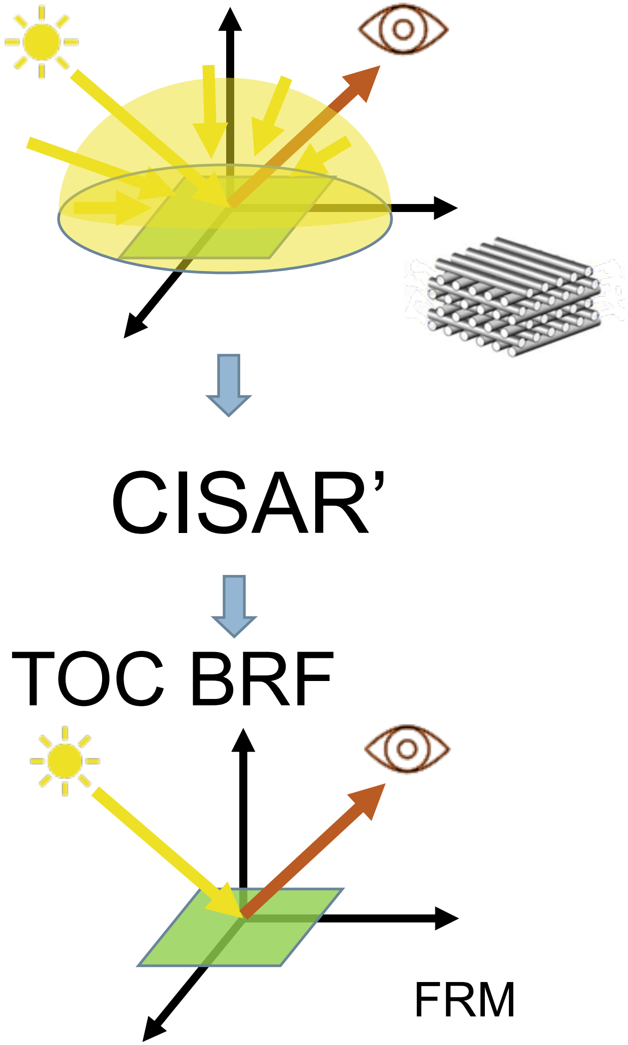


How to validate this branch?

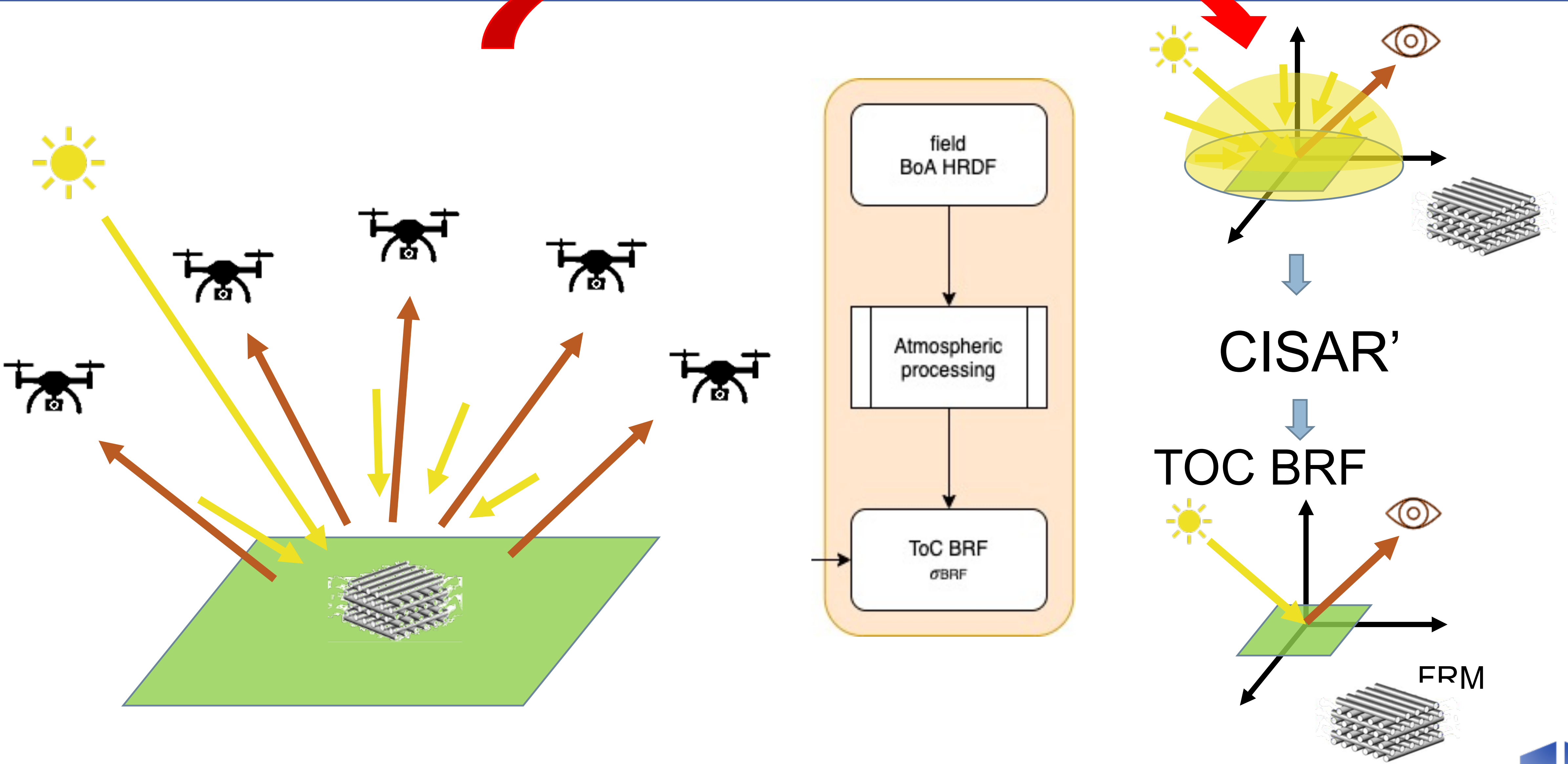
Next step: how to exploit these results?

1. Manufacture the artifical target and characterise its optical properties
2. Bring the target to the field
3. Perform field observations over the artificial target

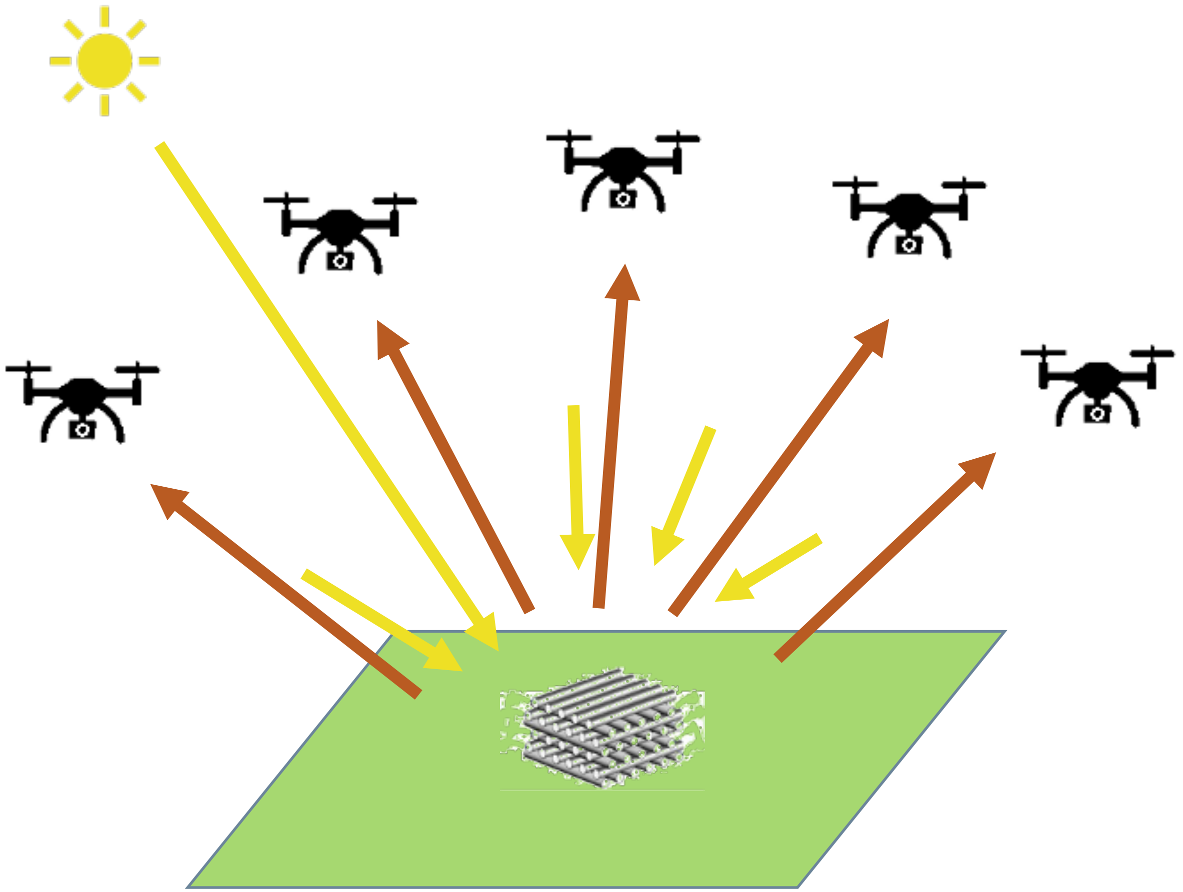


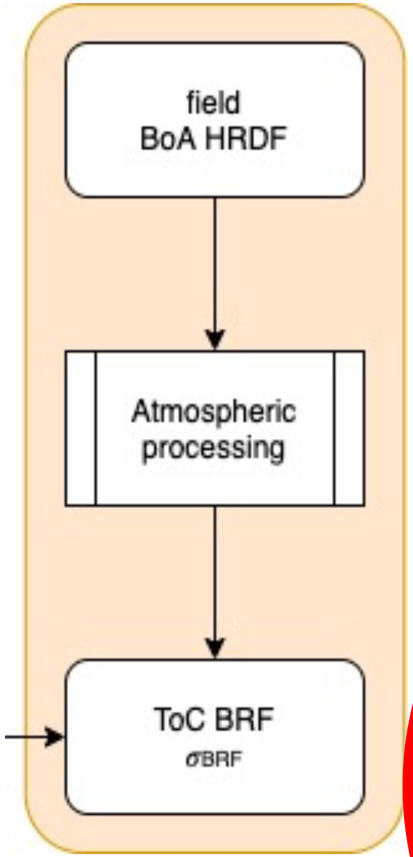


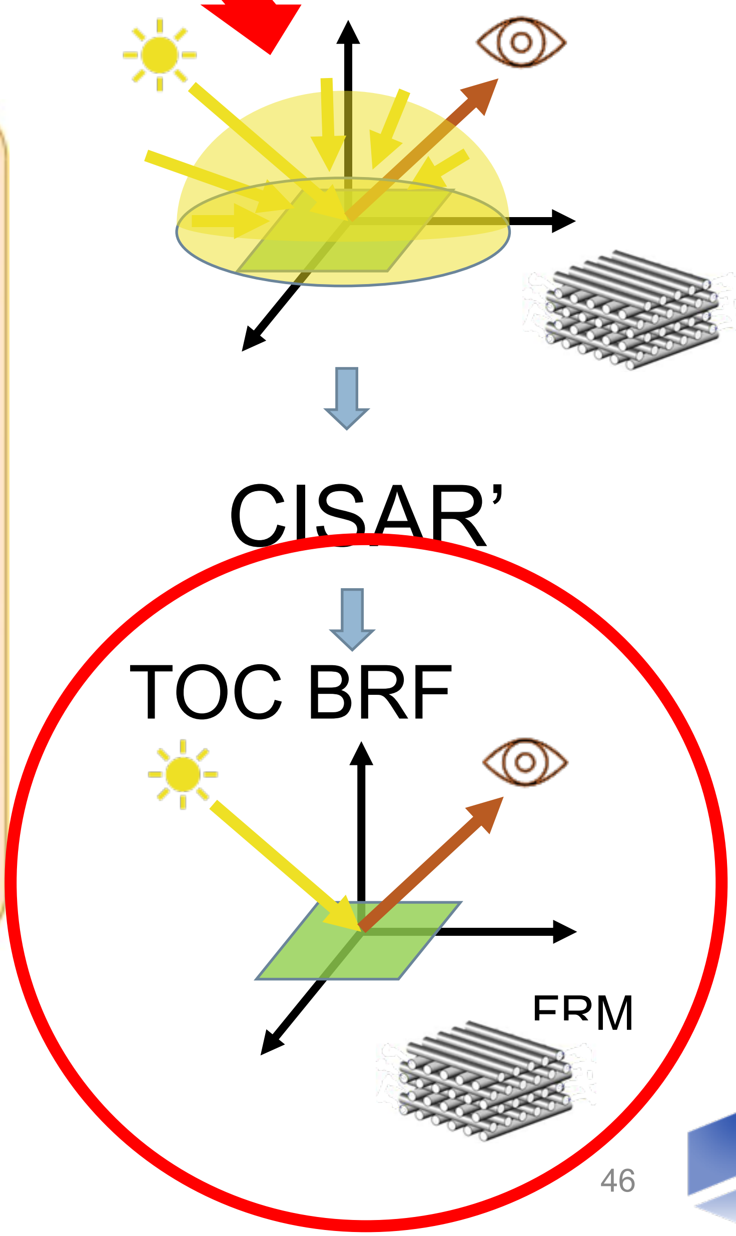
Next step : how to exploit these results?



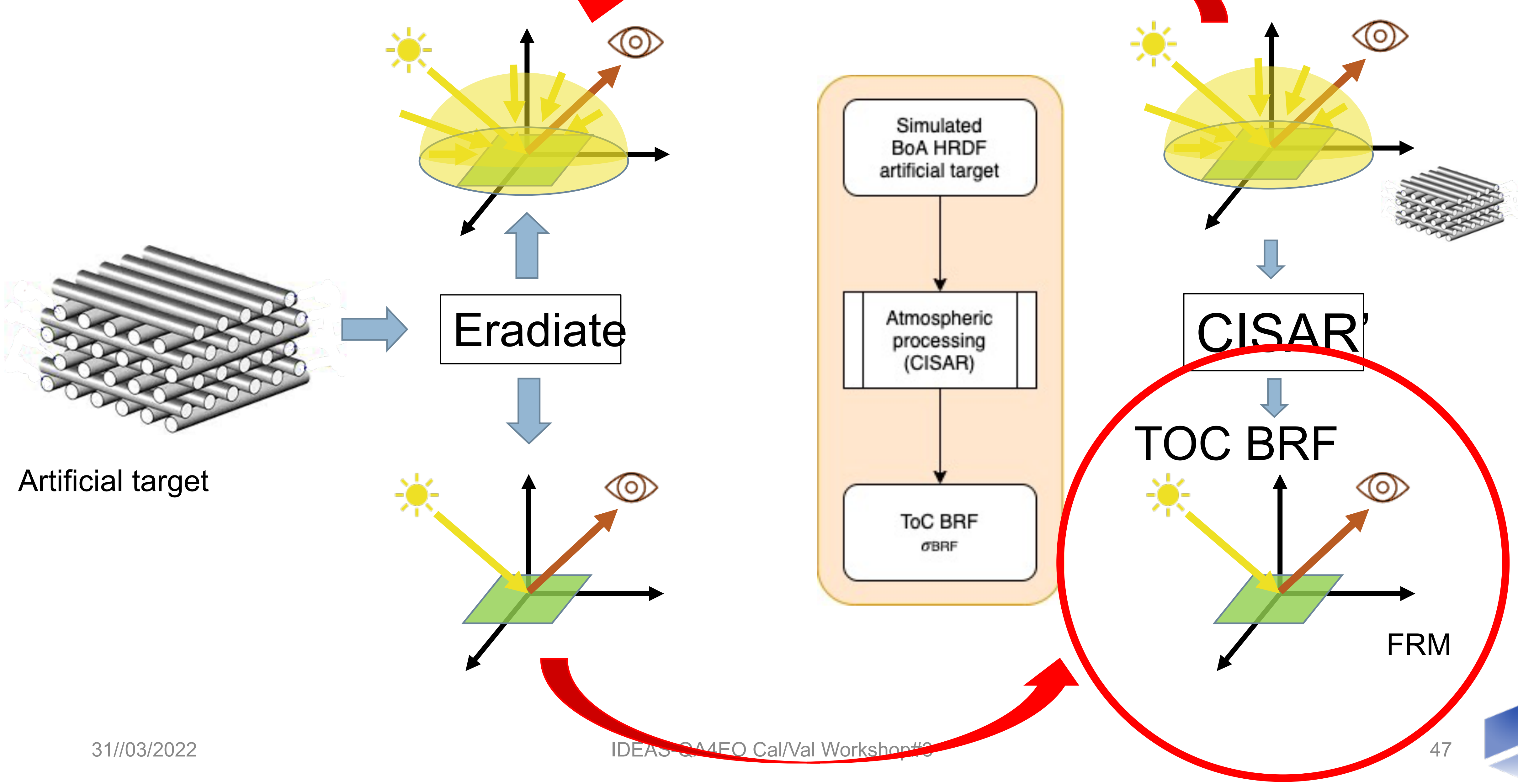
Next step : how to exploit these results?



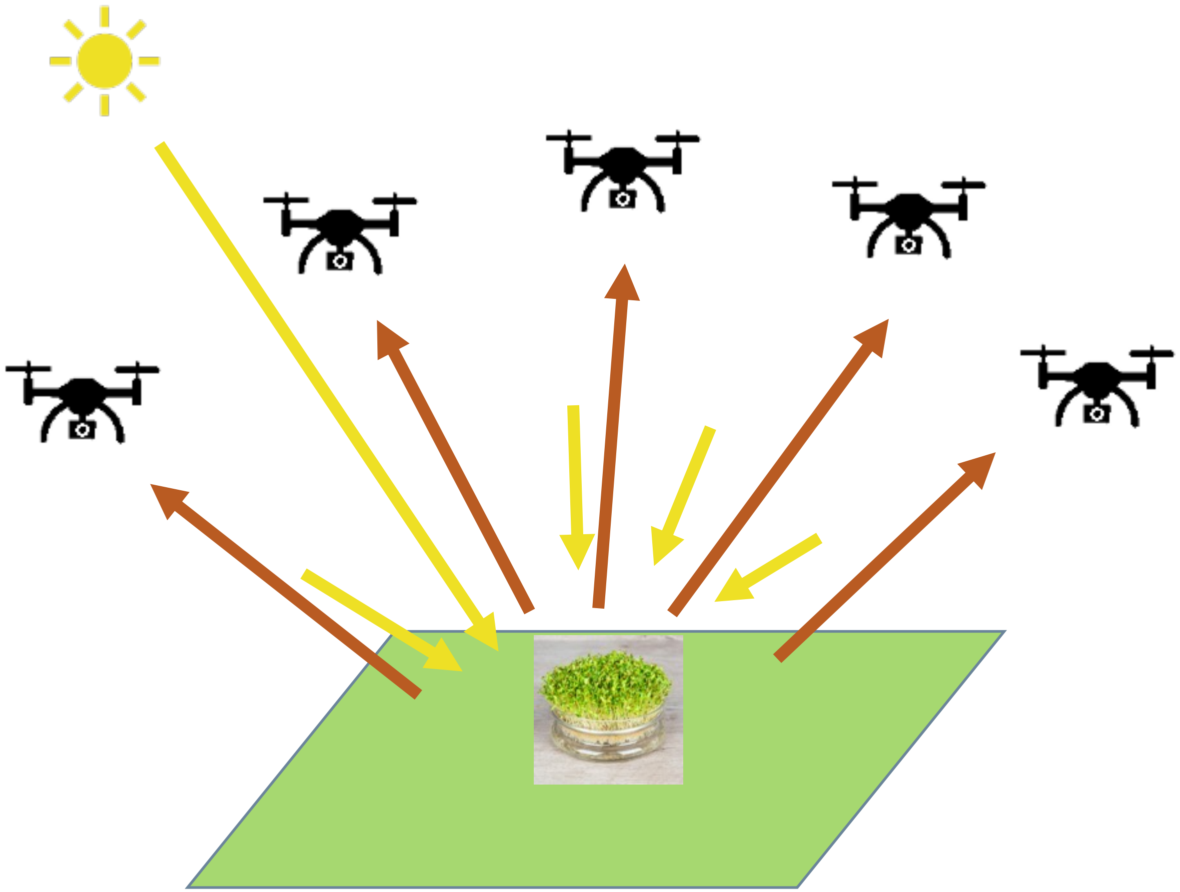


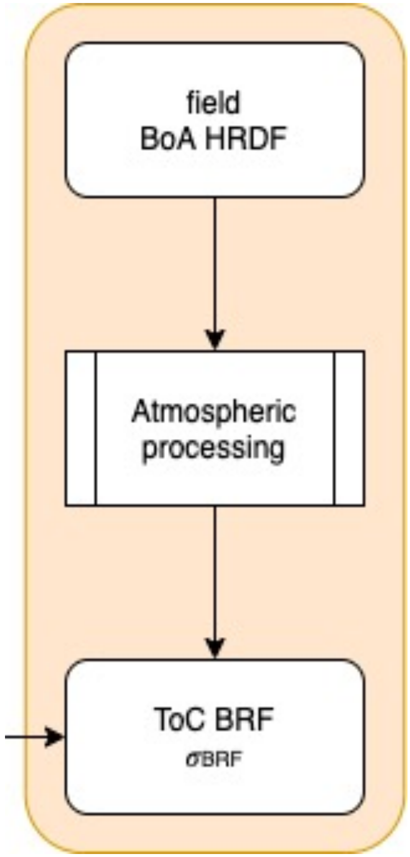


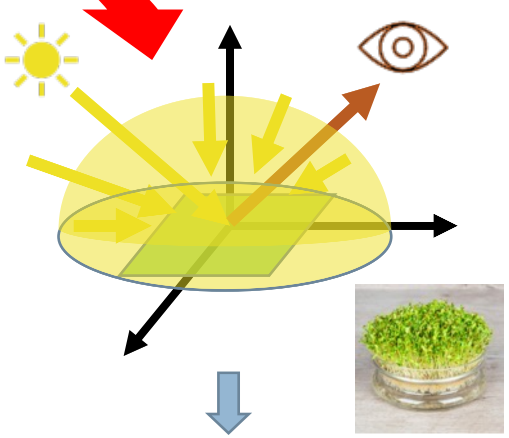
Next step : how to exploit these results?



Next step : how to exploit these results?

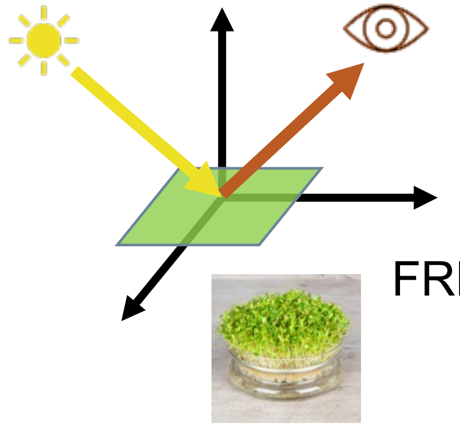






CISAR’

TOC BRF



FRM