Developing a strategy to transfer TRUTHS radiometric accuracy to surface reflectance measurements

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TRUTHS mission

Traceable Radiometry Underpinning Terrestrial- and Helio-Studies

Primary goal: provide highly accurate and trusted SI-traceable climate records.

Secondary goal: provide ‘in-space’ reference calibration to other satellite sensors.

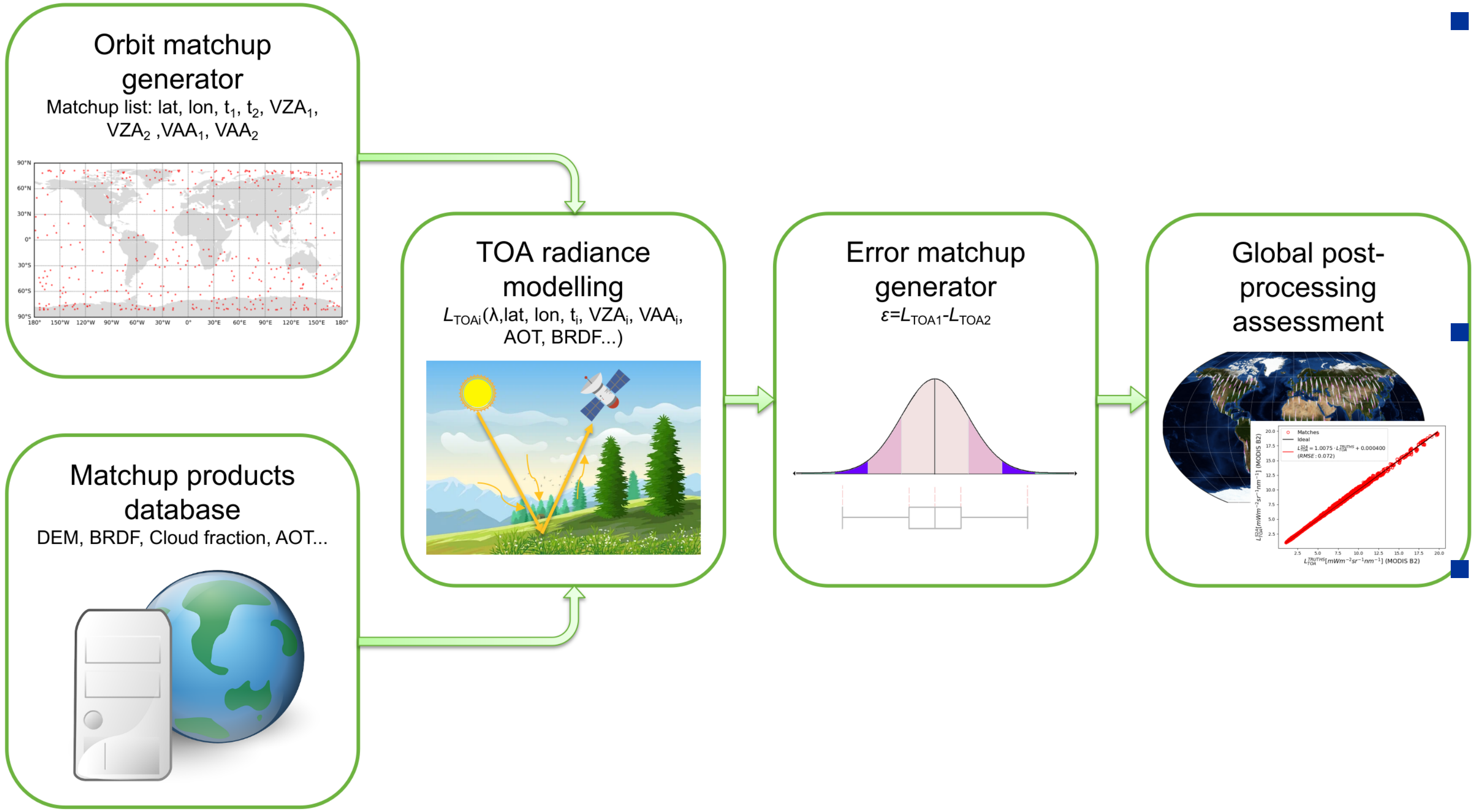
Global and continuous measurement Earth reflected spectral radiance

- 320 to 2400 nm spectral range
- spectral resolution of 4-8 nm
- ground sampling distance of 50 m
- uncertainty goal of 0.3% (k=2).

SI-traceable uncertainty through regular re-calibration of its Hyperspectral Imaging Spectrometer (HIS) linked to a space-borne primary reference standard, a **Cryogenic Solar Absolute Radiometer (CSAR)**.

Introduction

- Goal: Develop an E2E global inter-calibration simulator (or **inter-calibration digital twin**)
- Challenge: generate multiple scenarios and consider the interrelation of different error sources, orbits and scenes.



- Directional reflectance effects can represent one of the most challenging effects for the mission. Main directional effects:
  - **Temporal sun change**: sun angle varies between satellite overpasses.
  - **Matching viewing**: two satellites view the same spot with differing angles.

Orbit simulations

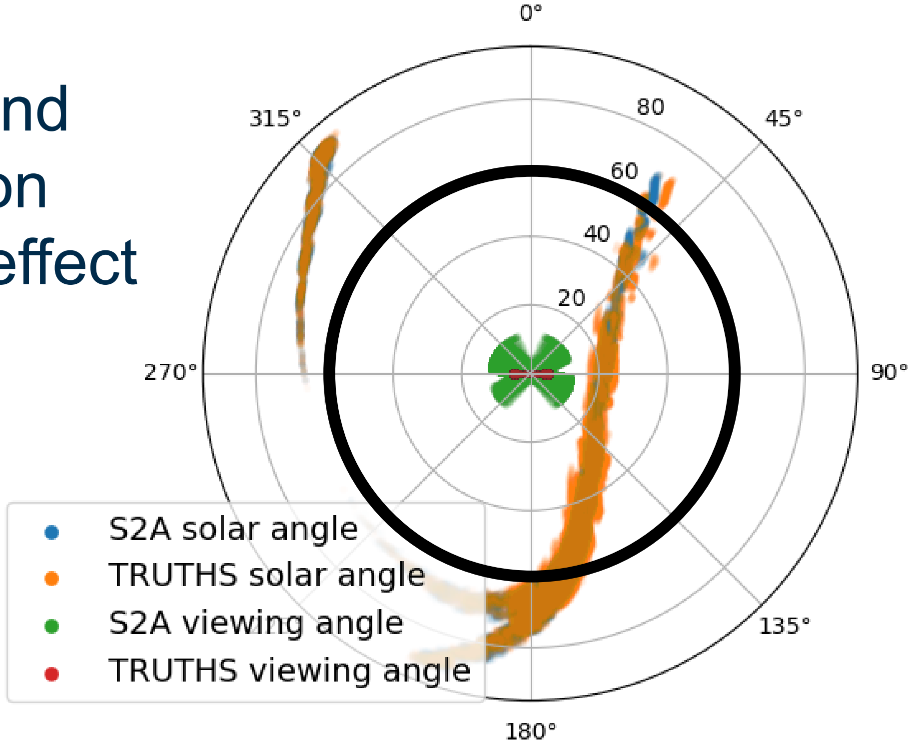
Target satellite: S2A

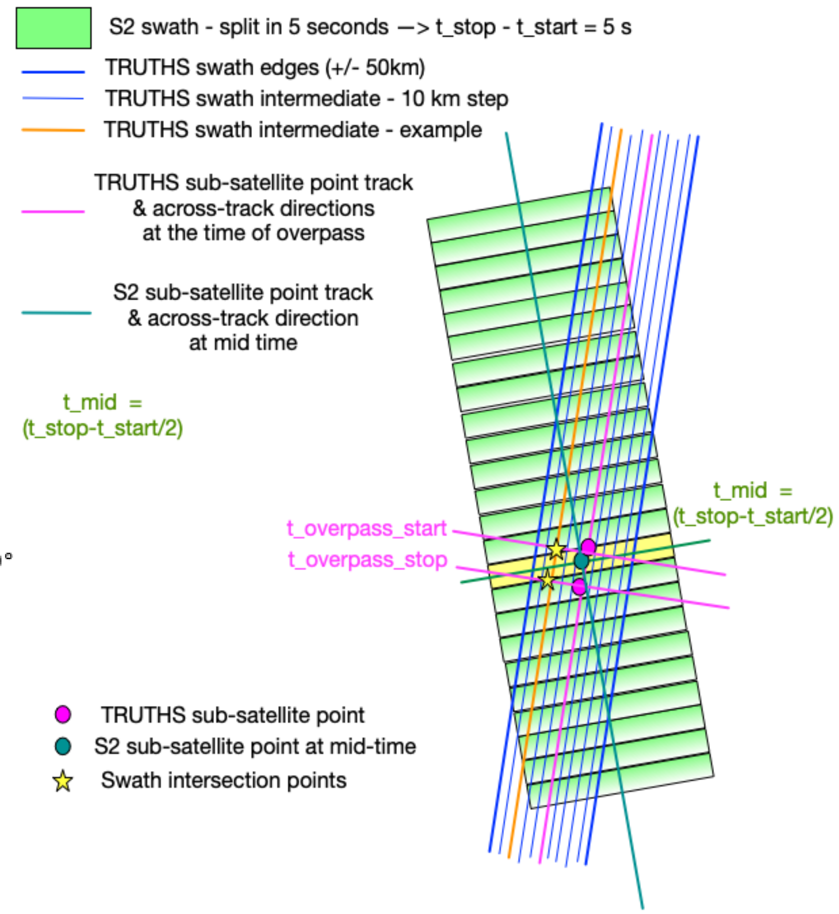
Define sample points for lineswaths at [-50,50] km that scan the TRUTHS FOV in 10km steps.

Timestep=5s --> sampling ~ 0.3° (~30km)

SZA > 60° are discarded. They represent a large fraction of opportunities and can distort intercomparison due to strong directional effect and low radiance.

Specific consideration needed.





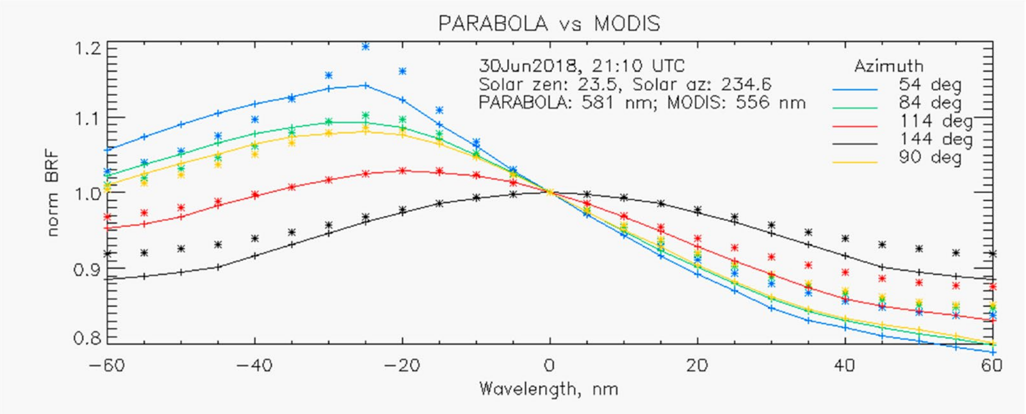
Surface definition

Use of **MODIS MCD43 products**

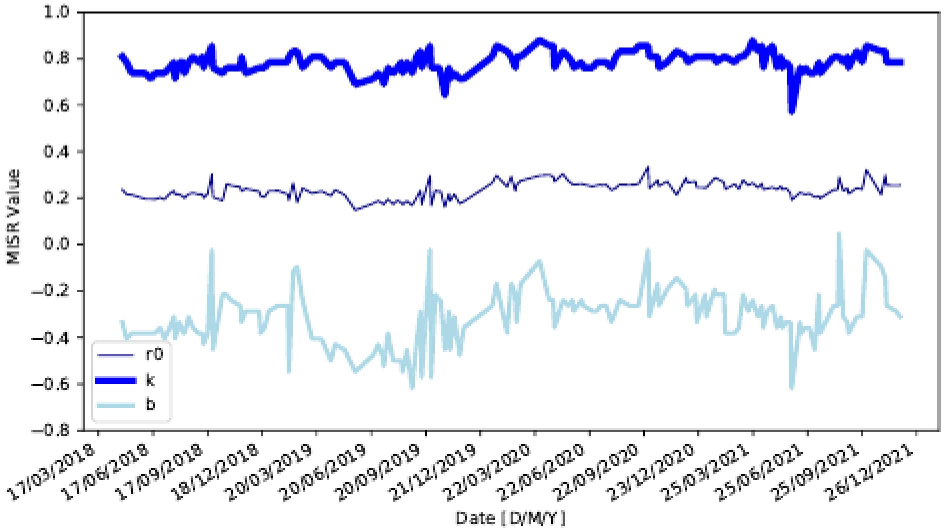
- At a **global level**, they define realistic angular effects over a land area.
- At a **homogeneous pseudo-invariant validation site**, they can approximate a correction up to 15° VZA

Implementation at three levels:

1. Select product with specific day and location of the crossing.
2. If invalid or unavailable, refine for closest days.
3. If still not good quality MODIS BRDF product is available, define a **BRDF based on the landclass** as default in Libradtran.



Extracted fom Bruegge et al., 2019



Extracted fom van Kempen et al. 2023

TOA radiance modelling.

Libradtran setup for each opportunity based on lat/lon and timestamp.

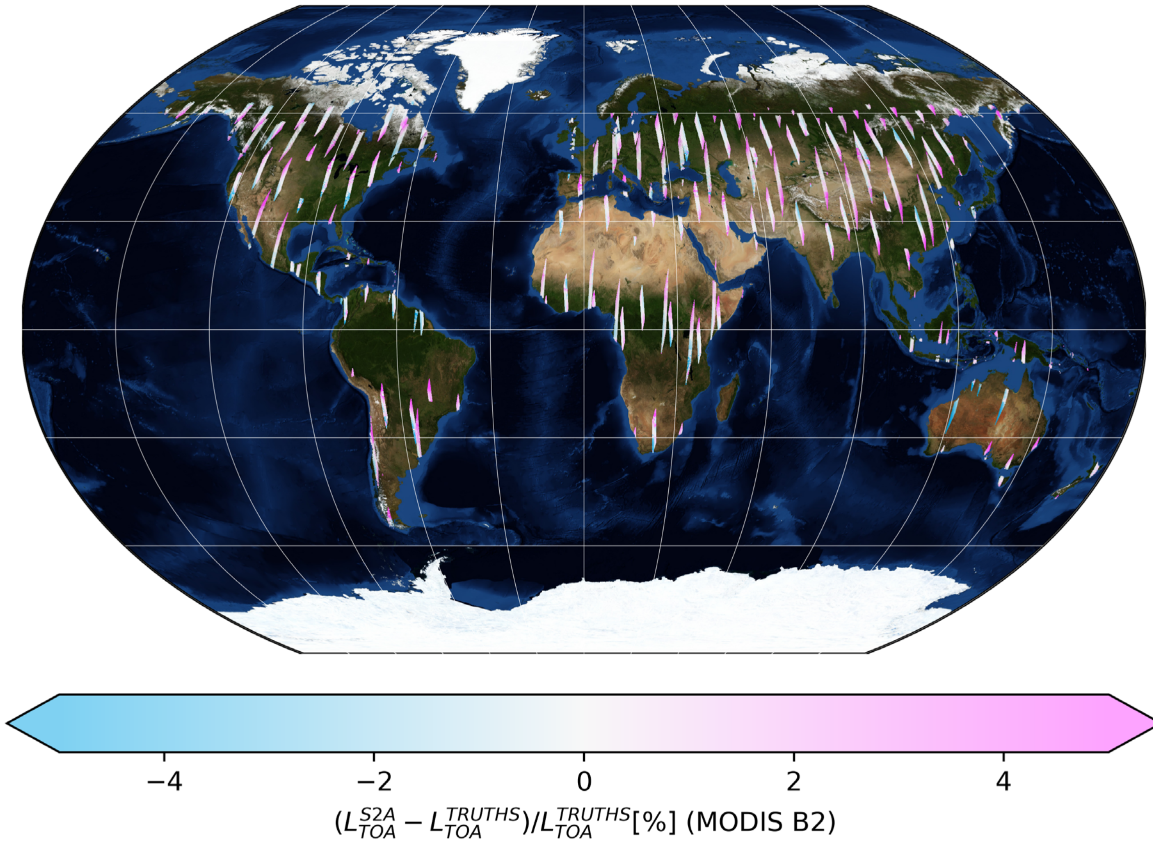
Coupling of BRDF-atmosphere accounted in the radiative transfer.

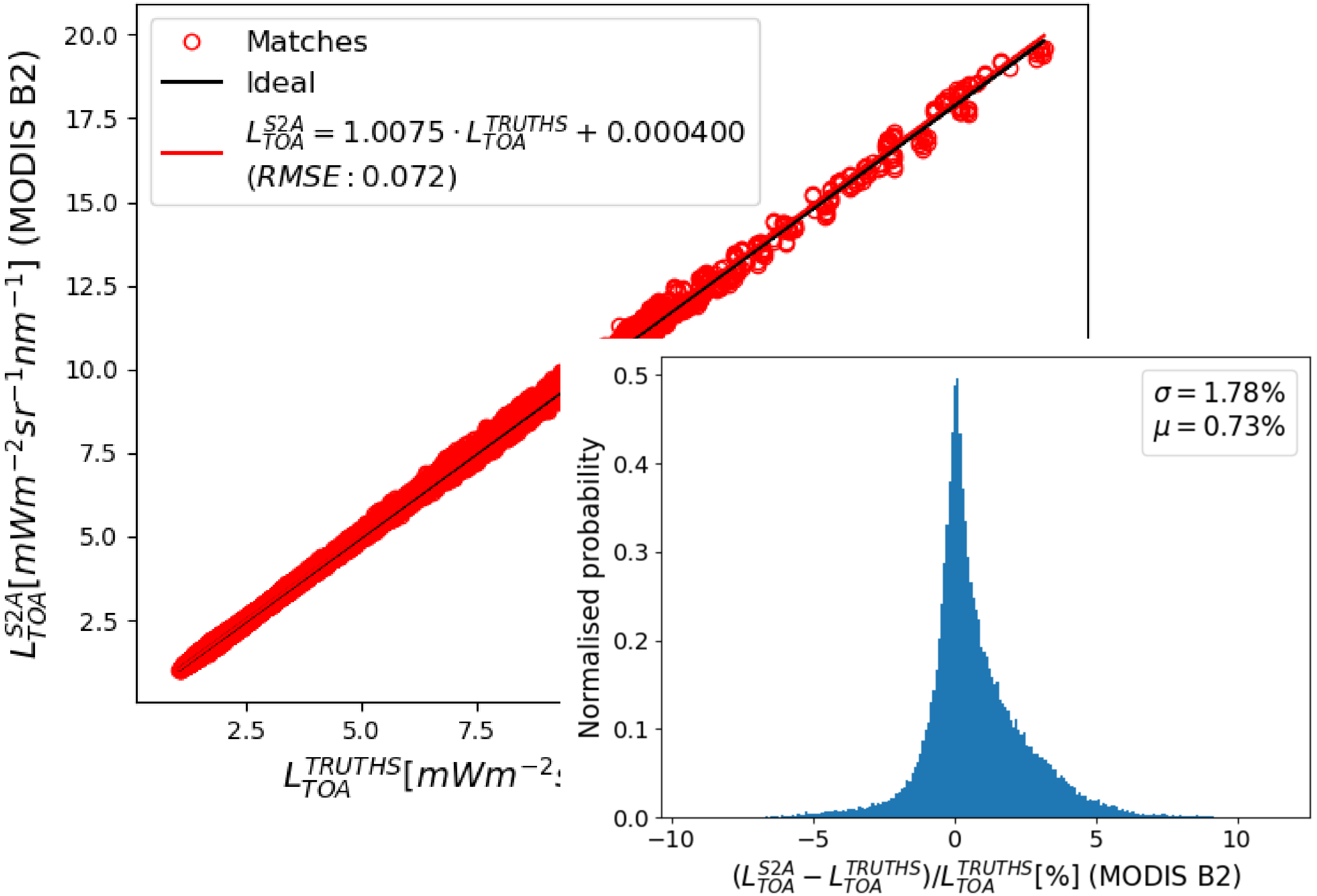
Libradtran parameter	Dataset	Description
AOT	ECMWF CAMS NRT forecast product MODAL2_M_AER_OD_2019-mm	processed from GEE Monthly averaged AOT@550nm at 0.1ºx0.1º resolution
WV	NOAA GFS0P25 forecast product MODAL2_M_SKY_WV_2019-mm	processed from GEE Monthly averaged water vapour [cm] at 0.1ºx0.1º resolution
Elevation	SRTM_RAMP2_TOPO_2000	Altitude [m] for land surfaces at 0.1ºx0.1º resolution
BRDF	MCD43Dxx or Libradtran BRDF default	IGBP landclass based MCD12C products from GEE
angles	Orbit simulations.	SZA, SAA, VZA, VAA for S2 and TRUTHS at each crossing.
Molecular atmosphere	Midlatitude summer atmosphere. Parameterisation based on REPTRAN.	Reptran channel for MODIS bands (consistency BRDF products).
Cloud prob.	NOAA GFS0P25 forecast product	processed from GEE

Results over land. Broad scenario

SZA<60°, Δt<15min, S2VZA all.

- Good spatial sampling and large number of opportunities.
- Radiance curve fit with ~1% bias. Skewed error dist. with positive mean.

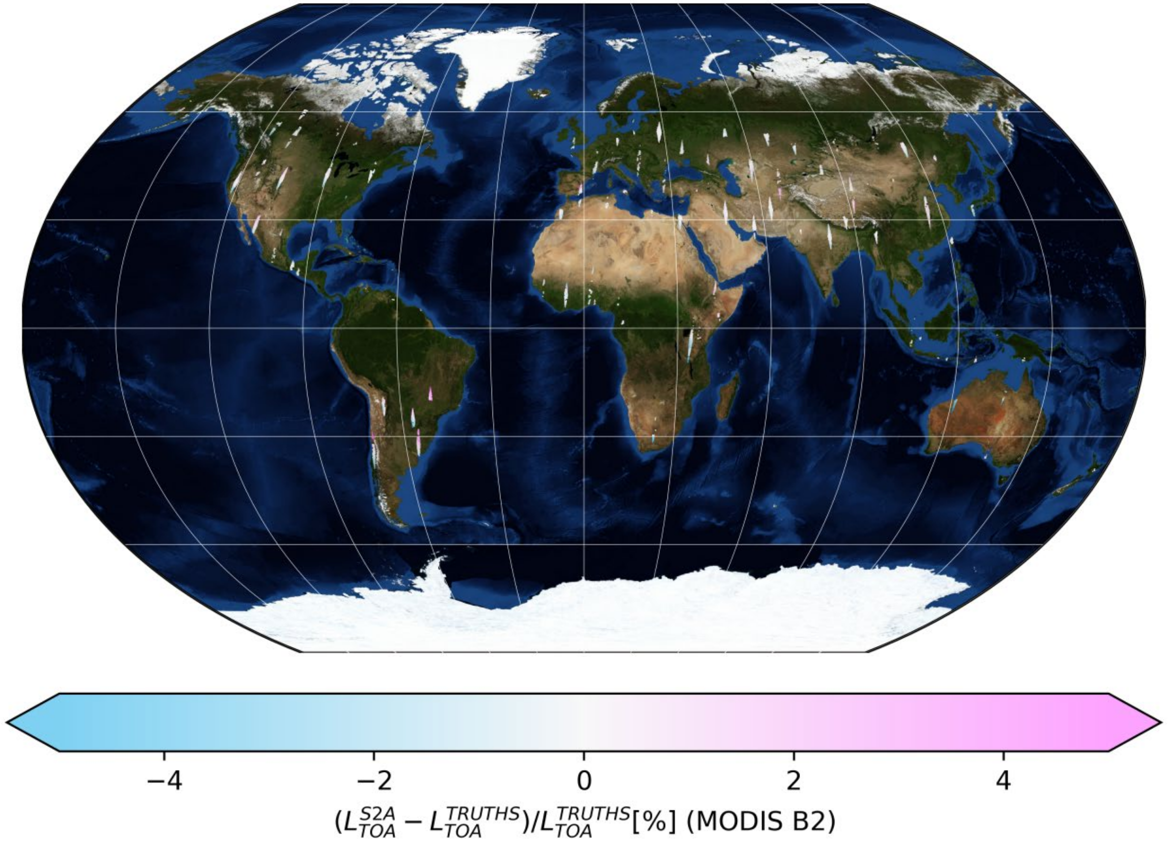


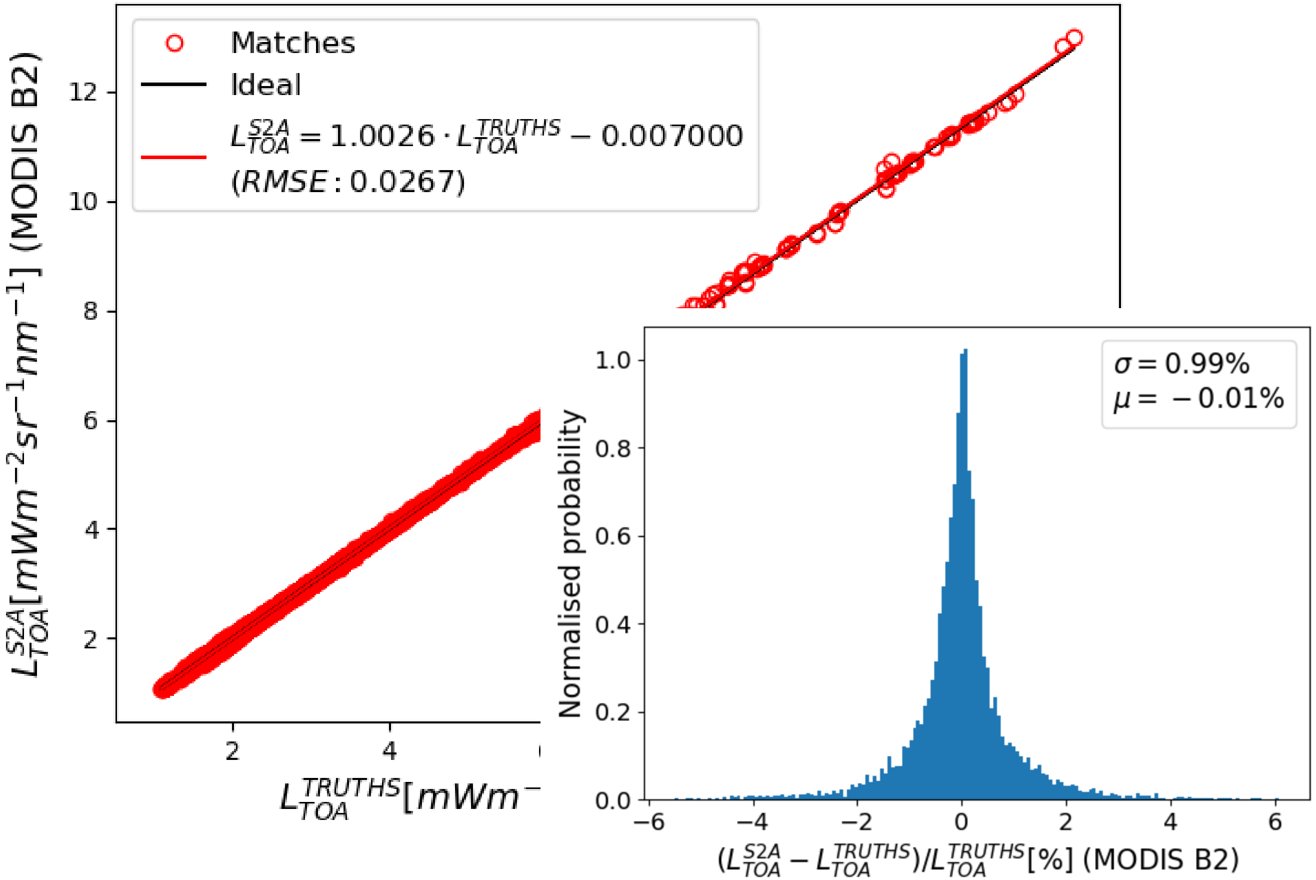


Results over land. Potential scenario

SZA<60°, Δt<15min, S2VZA <5°, cloud prob<20% @ 28×28 Km.

- Reduced number of locations but still good spatial sampling and number of opp.
- **Matching viewing + reciprocity --> unbiased error distribution**

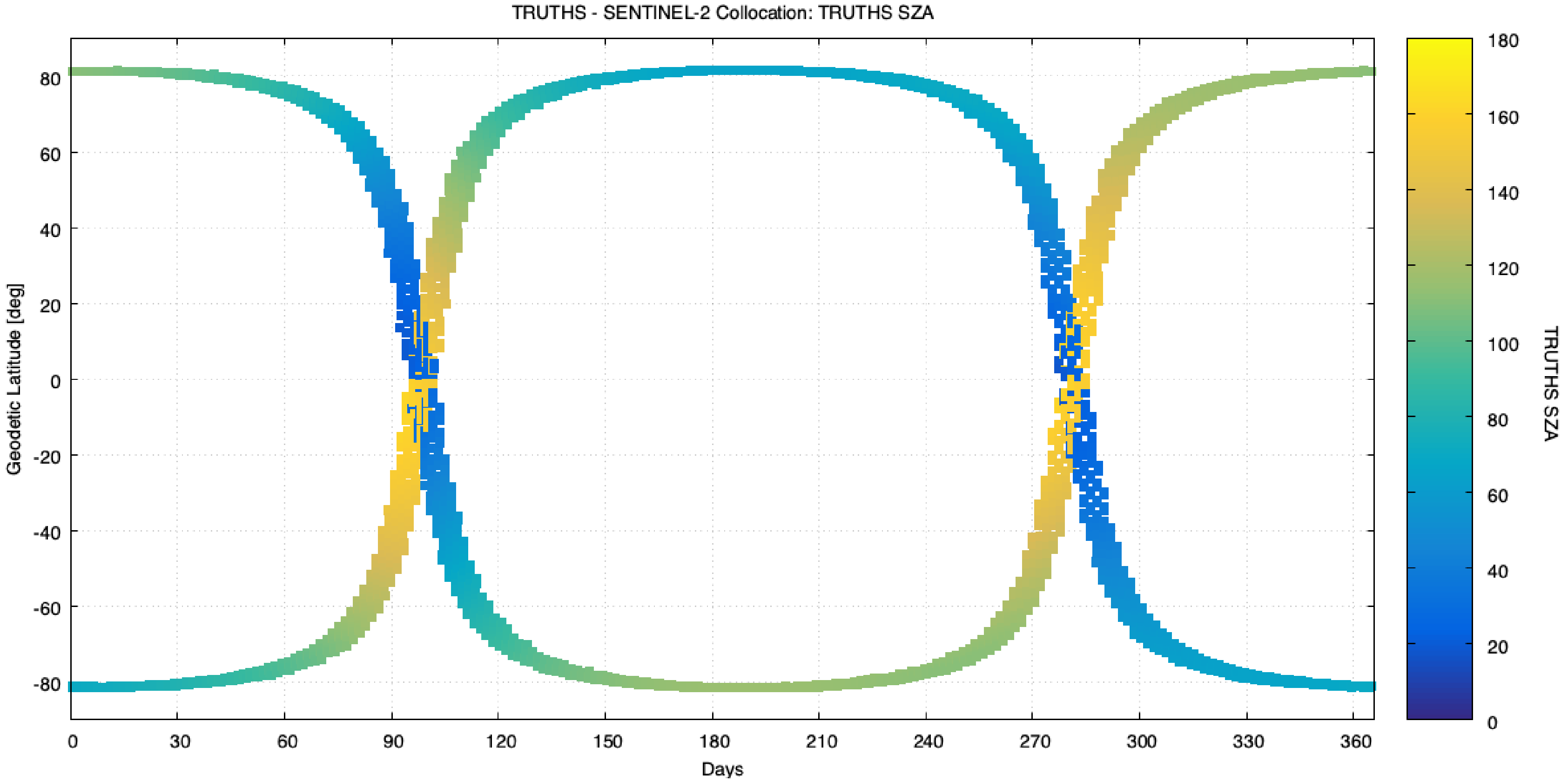




Results over land. Temporal opp.

Distribution of matches throught the year imply:

- SZA<60->6 month cycle of ~ 2month opp + 4month no opp.
- Can be complemented with manouevres during 4 month periods
- Alternative: modelling opp at polar areas with high SZA.



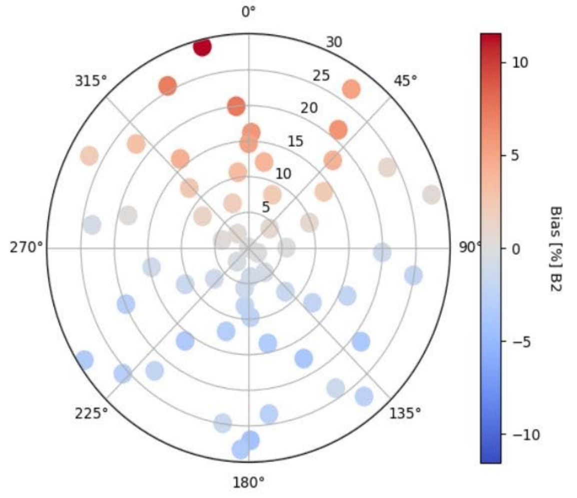
Results over instrumented sites

TRUTHS opportunities over the year at Gobabeb and Railroad Valley.

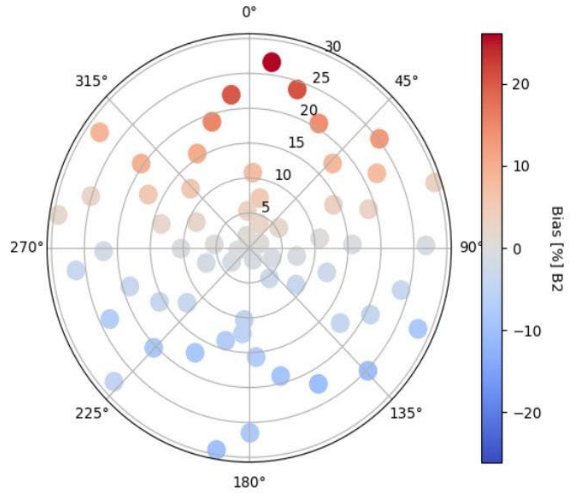
Considering no BRDF correction:

- Mean error <0.3% up to 15° due to low impact of anisotropy
- Number of opp. at nominal FOV 5° very low. Cloud cover will reduce further.
- 20 manoeuvres per year for VZA<15° with up to 29 opp (lower with cloud cover)

RVUS	B2	B3	B6	B2	B3	B6	B2	B3	B6
	VZA < 5°			VZA < 15°			VZA < 30°		
Mean[%]	0.04	0.06	0.03	0.01	0.22	-0.01	0.84	1.71	0.59
Std[%]	1.14	1.14	0.9	3.3	3.33	2.61	7.59	7.61	5.98
Abs. max[%]	2.45	2.48	1.93	7.62	8.21	5.96	26.04	27.45	20.31
Opportunities	9	9	9	29	29	29	65	65	65
GONA	B2	B3	B6	B2	B3	B6	B2	B3	B6
	VZA < 5°			VZA < 15°			VZA < 30°		
Mean[%]	-0.1	-0.18	-0.11	0.13	0.34	0.1	0.32	1.35	0.15
Std[%]	0.57	0.71	0.58	2.09	2.71	2.1	3.31	4.23	3.4
Abs. max[%]	1.04	1.41	1.07	5.23	7.76	5.21	11.53	15.49	11.48
Opportunities	9	9	9	29	29	29	59	59	59



GONA MODIS B2 (860nm)



RVUS MODIS B2 (860nm)

- TRUTHS and some sites able to model the BRDF leading to lower errors

Conclusions and further work

End-to-end full implementation with preliminary results shows the usefulness of the approach to generate on-demand scenarios.

For global inter-calibration strategy

- Matching FoV results in an unbiased distribution of errors
- with large number of match-ups and radiance dynamic range

For in-situ campaigns and instrumented sites

- Limiting to ~ FOV 15° indicates a good trade-off anisotropy vs. #opportunities

Constant development with new features and studies ongoing:

- Include spectral, atmospheric, spatial effects.
- TOA radiance model for the full VNIR-SWIR in high resolution.
- Use alternative datasets. e.g. cloud probability from S2/Landsat cloud masks.
- Potential real example. S2-Landsat or S2-EnMAP.

Preprint under review:

- https://eartharxiv.org/repository/view/7101/