Eradiate: 3D radiative transfer community model to support metrological applications

Metrology and Traceability

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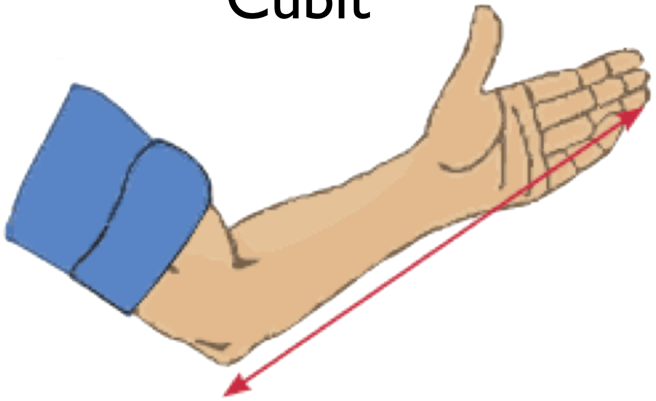
Rayference

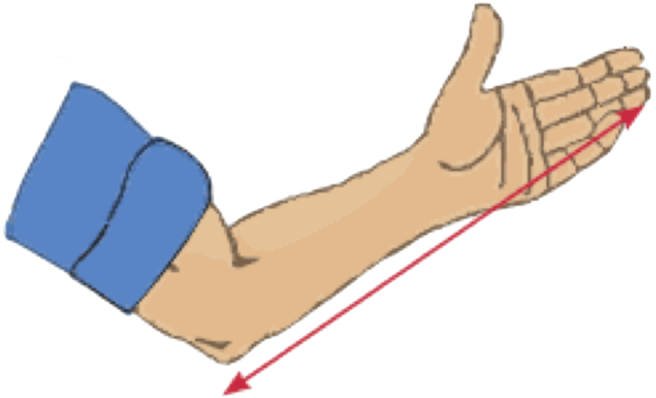
QA4EO/IDEAS Cal/Val Workshop#1, University La Sapienza, Rome (Italy)

19 – 21 February 2020

Cubit



1792 (definition)
1875 acceptance

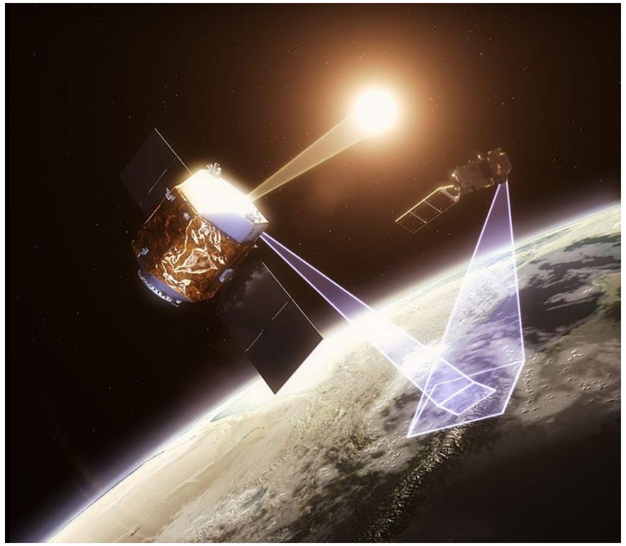


1792 (definition)
1875 acceptance

MODIS ??

MERIS ?? ??

MSI ??



TRUTHS

Typical vicarious calibration targets/methods

METHOD	UV	VIS	NIR	SWIR
Desert	?	A T X	A T X	A T X
DCC	?	A T I X	T	?
Snow/ice	?	T X	T	T
Rayleigh	?	A T I X	T I	-
Sun-glint	I	I	-	-
Moon	?	[A]T	[A]T	

A = Absolute, T = Trending, I = Inter-band, X = cross-calibration (SNO)

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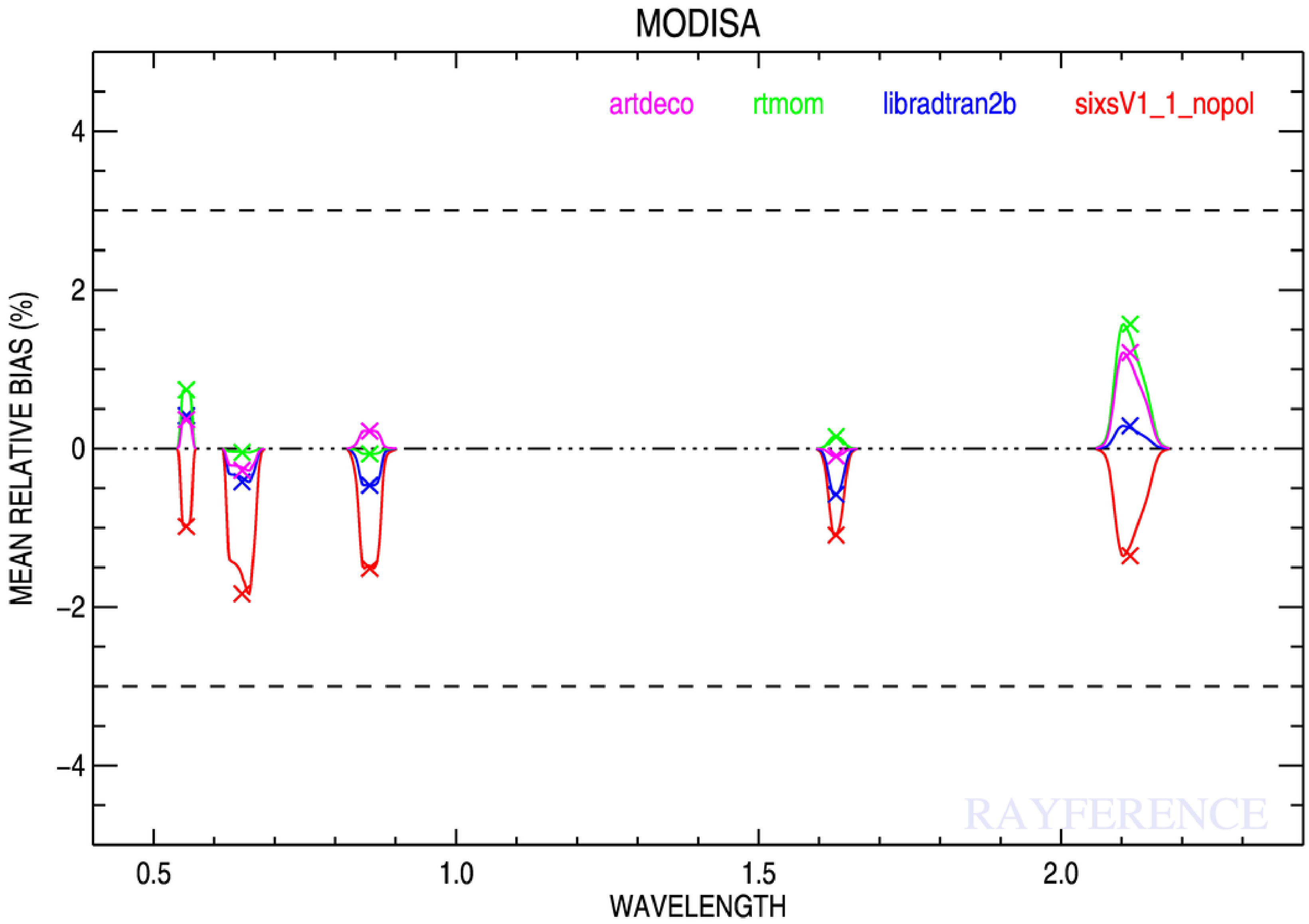
Absolute vicarious calibration methods rely on different references not traceable to a unique SI standard. Homogenisation of radiometers combining different methods is very cumbersome.

Libya-4 Rayference Calibration Reference (LRCR)

- Characterisation of surface BRF from 300nm to 2800nm with a 1nm spectral resolution (assuming a flat surface for an area >100km^2);
- Characterization of the atmospheric vertical profile and gas concentrations (H_2O, O_3, CO_2, CH_4, …);
- Characterization of aerosol type and concentration;
- Simulation of spectral TOA BRF with 4 different models implementing:
  - Different methods to solve the radiative transfer equation;
  - Different assumptions for molecular absorption and its coupling with scattering;
- Can be used from 300nm to 2800nm at about 1 nm spectral resolution for sun and viewing zenith angles up to 65°.
- Estimated MEAN accuracy: 2.5%

Nadir view verification: AQUA/MODIS



120 clear-sky MODIS observations over Libya-4

Nadir view verification: AQUA/MODIS

AQUA/MODIS					
BAND	0.55μm	0.66μm	0.84μm	1.62μm	2.20μm
	B4	B1	B2	B6	B7
6SV	-0.98±1.03%	-1.83±0.75%	-1.51±0.77%	-1.09±0.47%	-1.35±1.22%
LibRadtran	+0.41±1.06%	-0.42±0.78%	-0.46±0.81%	-0.58±0.57%	+0.28±1.34%
RTMOM	+0.74±1.09%	-0.05±0.80%	-0.07±0.78%	+0.15±0.50%	+1.57±1.27%
ARTDECO	+0.36±0.99%	-0.28±0.74%	+0.22±0.66%	-0.09±0.37%	+1.21±1.01%
RTM range	1.72%	1.78%	1.44%	1.24%	2.92%

Mean relative bias (120 obs.) and its standard deviation

The RTMs are a major source of uncertainty

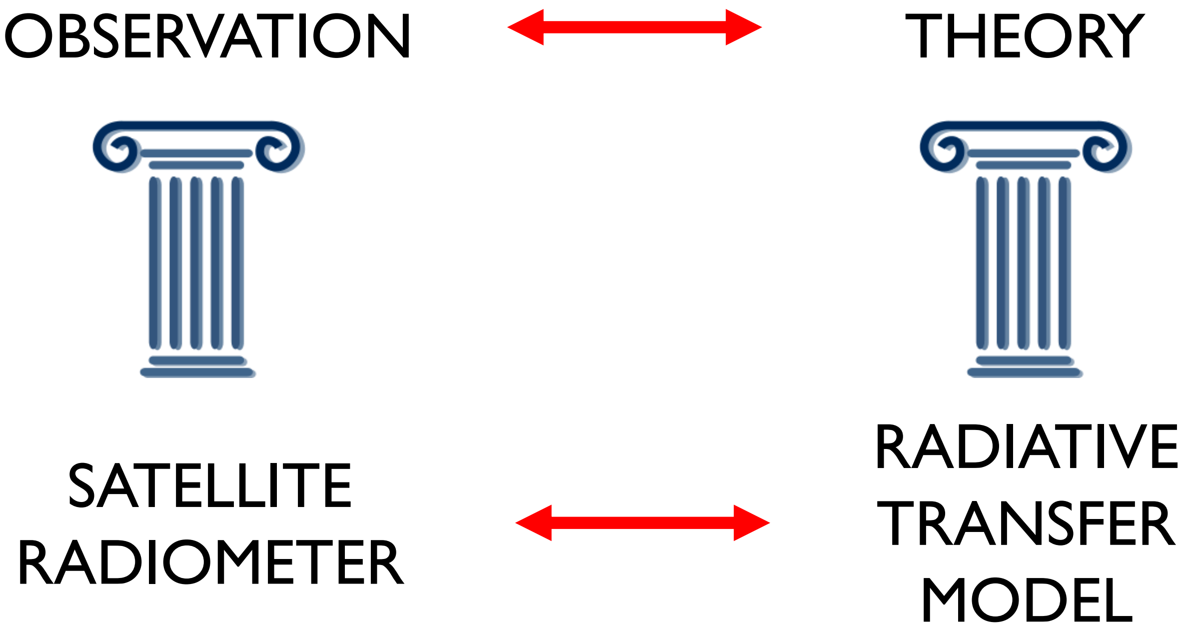
General concept

Physics is based on two fundamental pillars

OBSERVATION ⟷ THEORY

General concept

Physics is based on two fundamental pillars

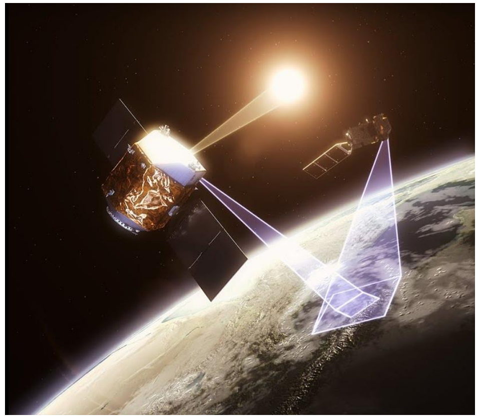


General concept

Physics is based on two fundamental pillars

OBSERVATION ⟷ THEORY

SATELLITE RADIOMETER ⟷ **R**ADIATIVE **T**RANSFER **M**ODEL



TRUTHS
0.3% - 1.0% ⟷ RTM Accuracy
?.?%

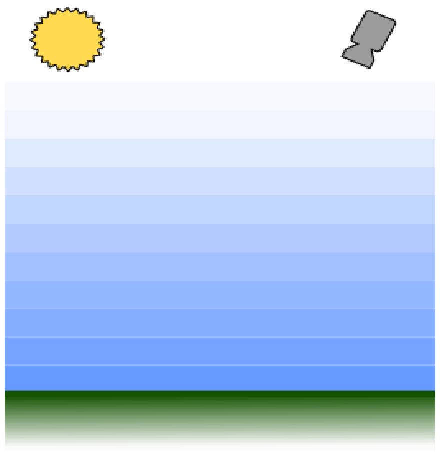
Toward a 1% RTM accuracy

- Surface BRF : accounting for topography (e.g., oriented sand dunes);
- Molecular absorption: account for species like O_4;
- Rigorous calculation of the coupling between:
  - Surface reflectance and atmosphere scattering;
  - Aerosol scattering and molecular absorption;
- Polarization, non flat earth for large zenith angles;

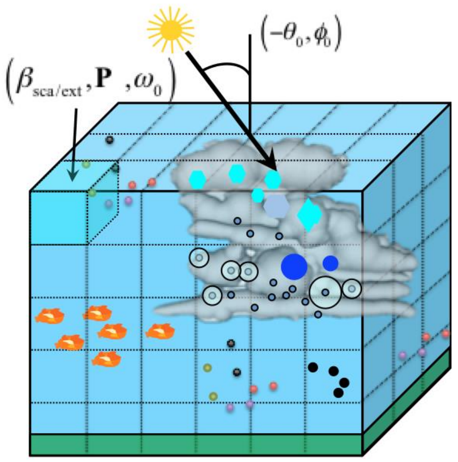
- Improvement of the surface and atmospheric property characterization;

Review of existing models

- 1D plane parallel atmosphere
  - Vertical structure of the atmosphere
  - No 3D cloud effects (e.g. for DCC)
  - Only flat surface
  - Not accurate for large sun and viewing angles because of the plane parallel approximation.

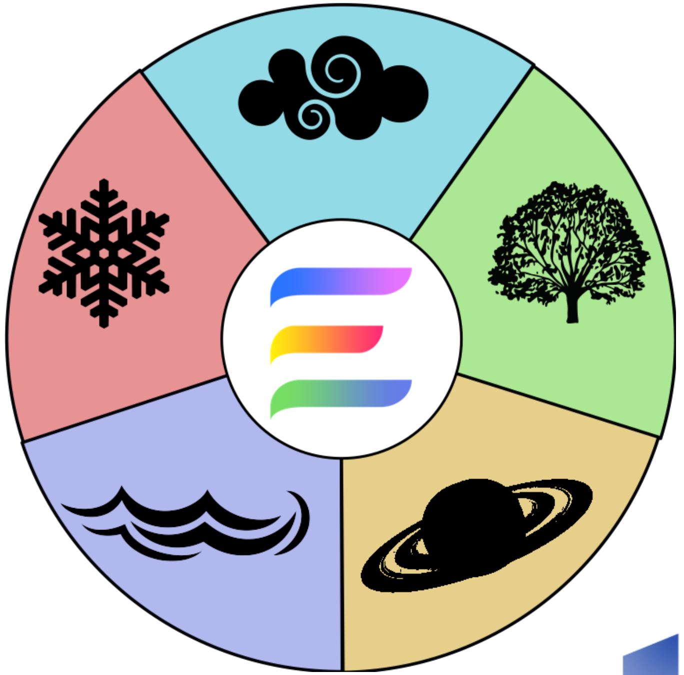


- 3D plane parallel atmosphere
  - The atmosphere is divided into regular voxels
  - Each voxel might have different optical properties
  - RTE solver : discrete ordinate or Monte Carlo



The Eradiate radiative transfer model

- New **open-source** 3D RTM specifically dedicated to support Cal/Val activities;
- Based on most advanced 3D Monte Carlo Ray Tracing rendering techniques;
- Not limited to only one (atmospheric) community;
- Will include 3D representations of land / ocean / atmosphere / cryosphere in a single framework;
- Will allow the simulation of
  - BRF field at the infinity;
  - Satellite images;
  - Ground observations;
  - Laboratory measurements.



Eradiate development phases

2017 2018 2019 2020 2021 2022 2023 2024

Timeline

- Phase 0 General Design
- Phase 1 Core Development
- Phase 2 Community Development

Availability

- rayference Internal
- GPLv3 Free Software Free as in Freedom — Open for Testing
- GPLv3 Free Software Free as in Freedom — Open for Contribution

Funding

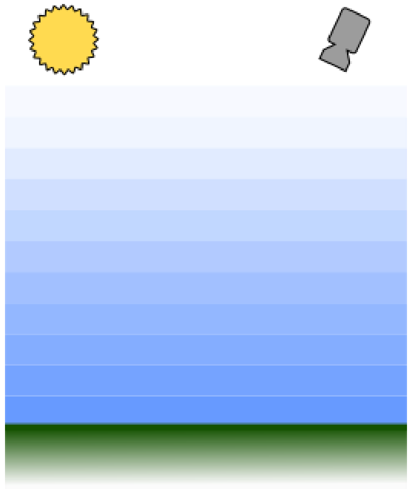
- Metrology for Earth Observation and Climate
- EURAMET
- esa
- Copernicus
- ? To Be Determined

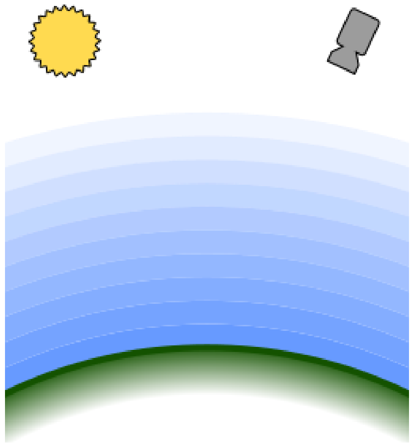
www.eradiate.eu

Register to the Eradiate newsletter (under contact tab) to be updated on latest developments.

Eradiate phase 1 : Planned Scene Elements

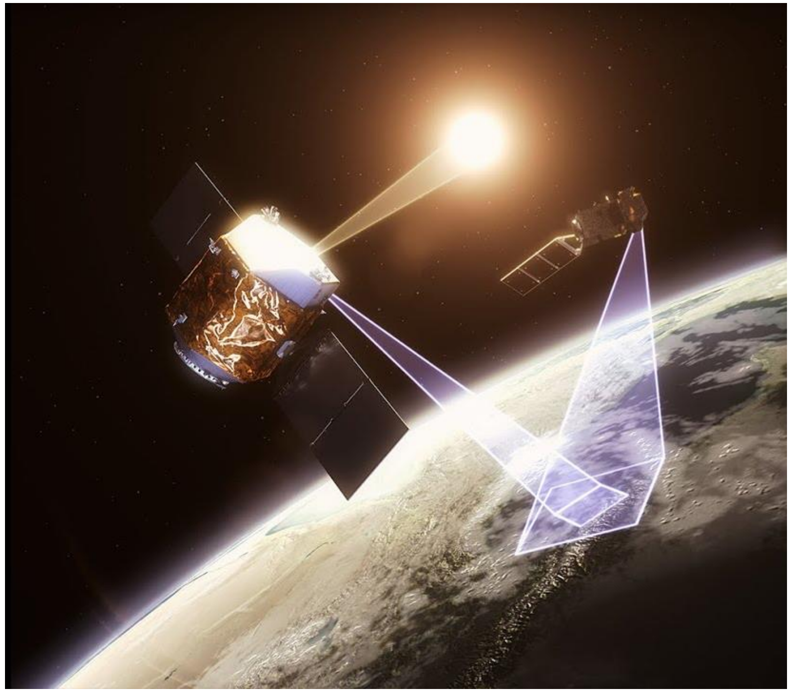
- 1D Atmosphere
  - Plane-parallel (“flat-Earth”)
  - Layered spheroids (“round-Earth”)
- Surface
  - Standard empirical BRF models (e.g. RPV, Ross-Li, Hapke)
  - Microfacet models (e.g. semi-discrete, Oren-Nayar, Torrance-Sparrow, Cox-Munk)
  - Including parameter texturing
  - 3D scenes with detailed typography and objects (e.g. Libya-4, RadCalNet, Dome-C, …)
- Illumination
  - Infinitely distant collimated
  - Finite-size solar disc (uncollimated)
- Sensors
  - Flux & radiance meters (ground observations)
  - Ideal detector (pinhole camera)
  - BRF at finite or infinite distance

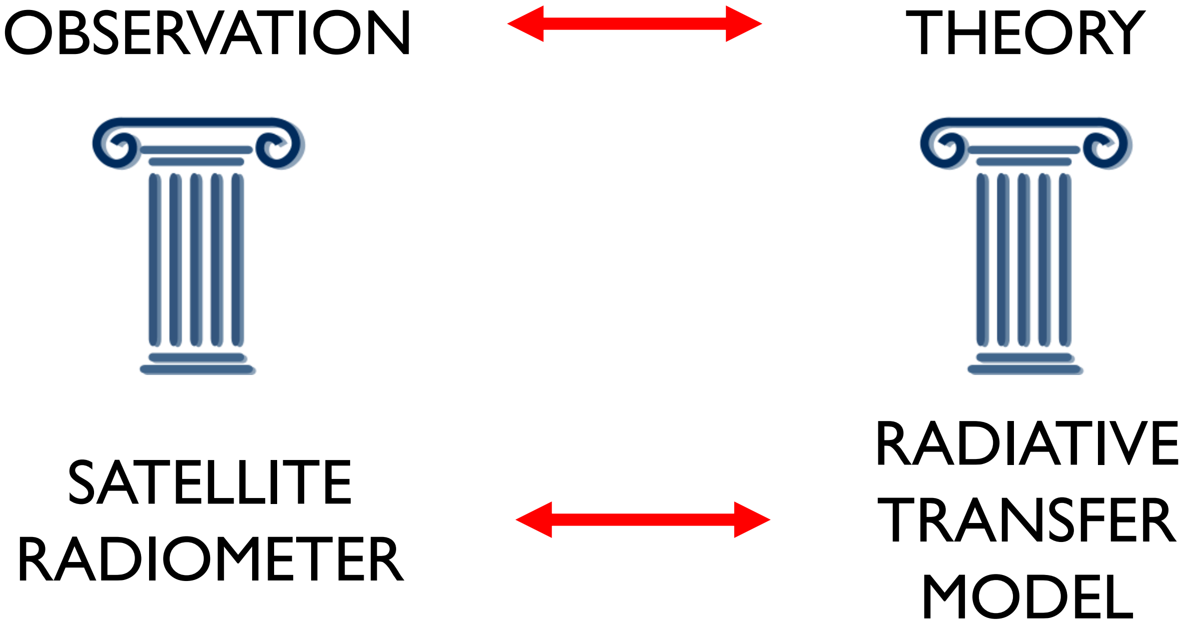




Building blocs for a SI traceable space-based system

1. SI traceable space-based reference measurements (TRUTHS)
   - Highly accurate observations between 350 nm and 2400 nm;
   - Nadir view (angular information only from seasonal changing SZA);
   - Moon and sun view.

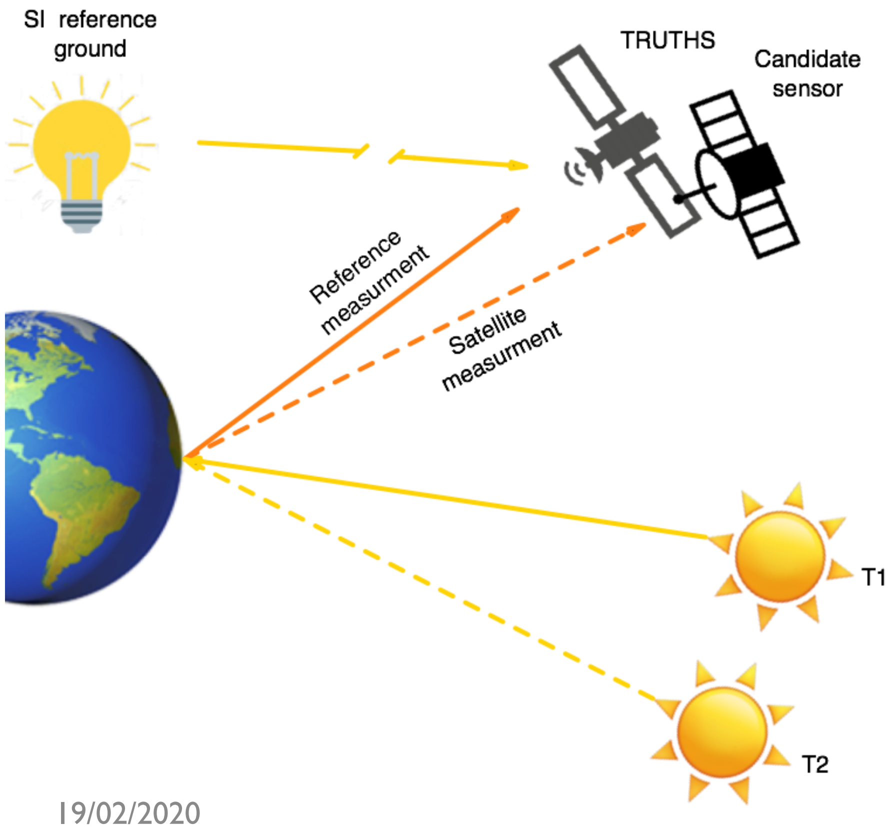




Building blocs for a SI traceable space-based system

2. Methods to account for the sampling differences between the reference measurements and observations to be calibrated/verified

Simultaneous Nadir Overpass (SNO) requires sampling difference corrections



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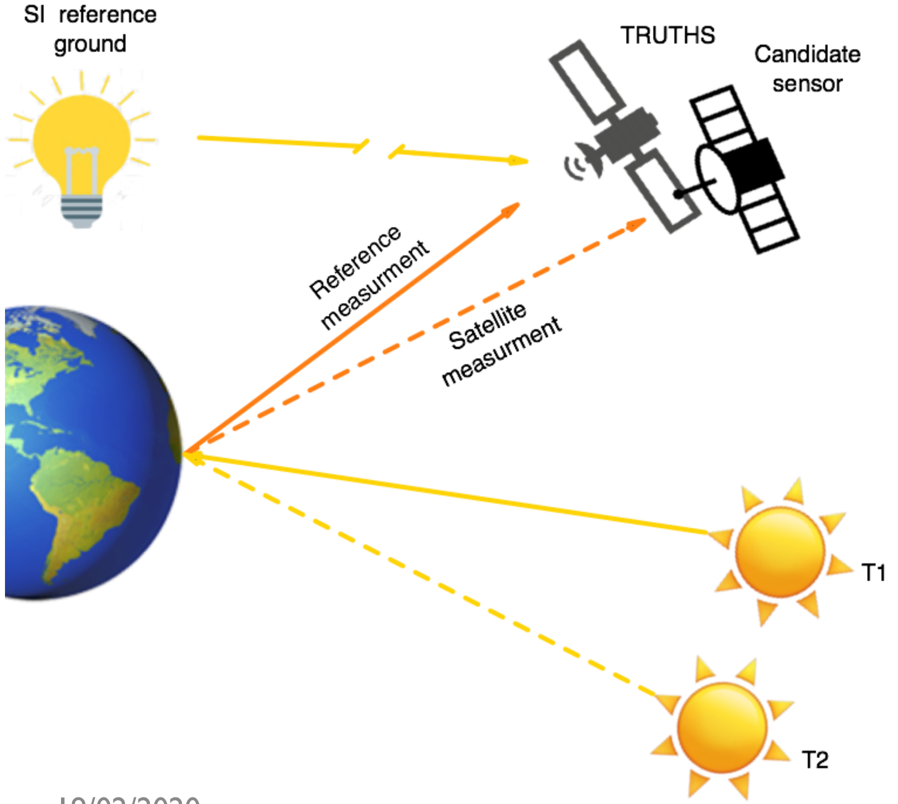
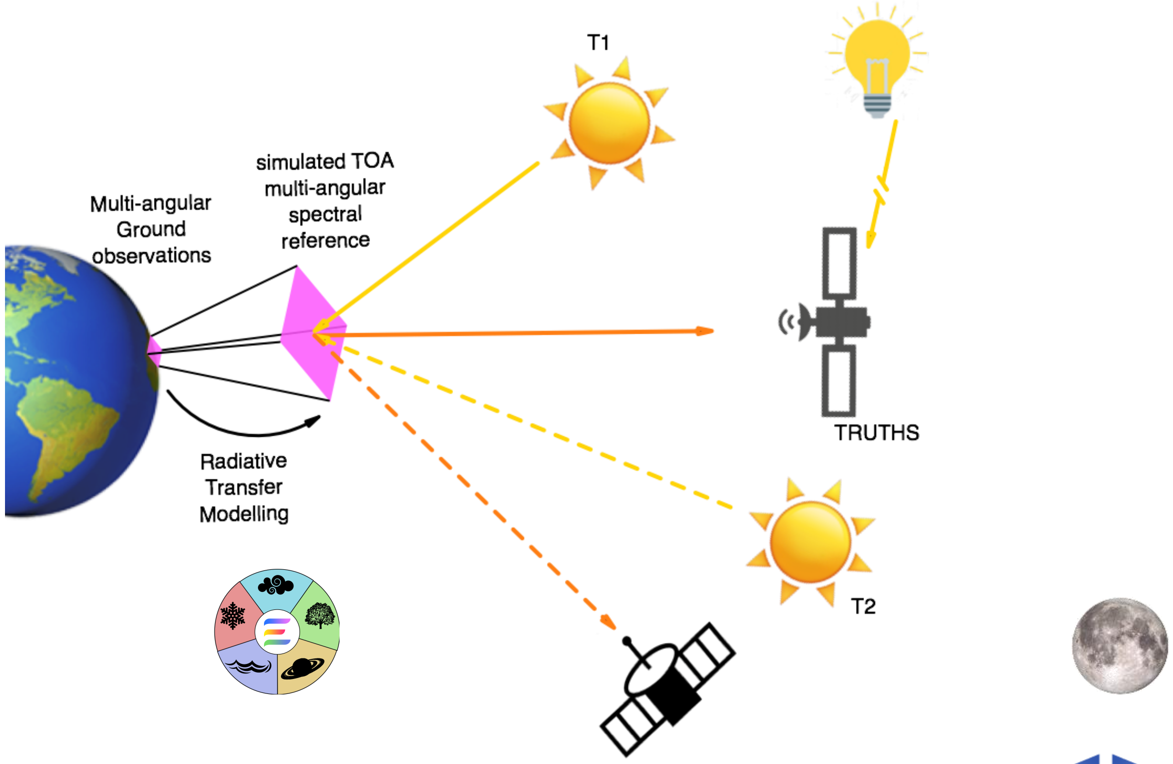
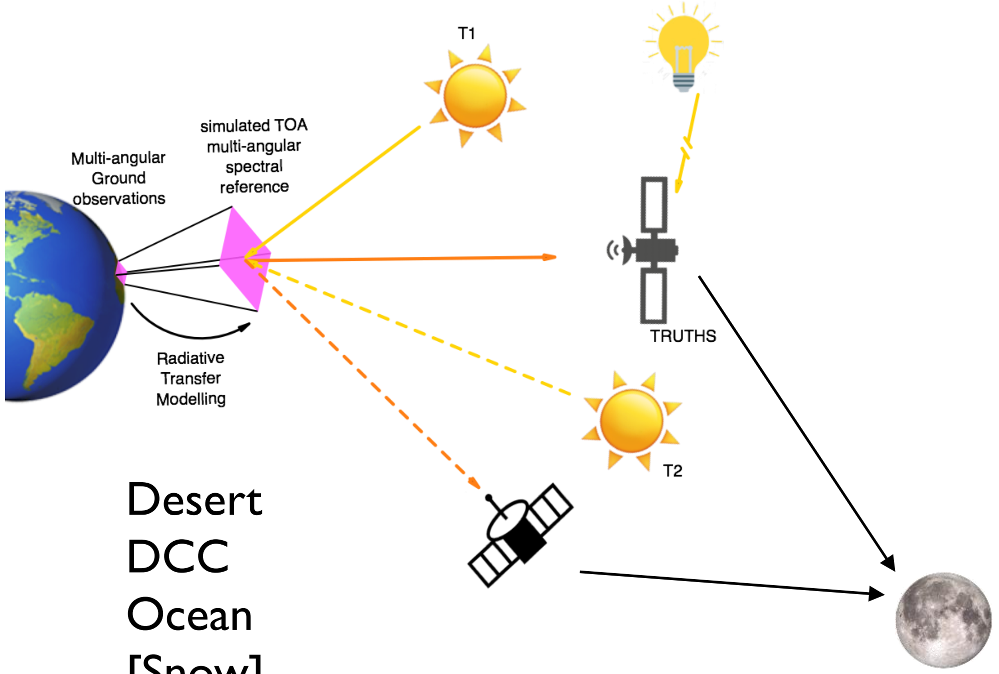


Generation of a TOA simulated calibration reference bound to TRUTHS



Building blocs for a SI traceable space-based system

3. Harmonization methods
   - **Unique radiation transfer model**;
   - Unique uncertainty propagation scheme;
   - Unique reference measurement.



Desert
DCC
Ocean
[Snow]

Moon

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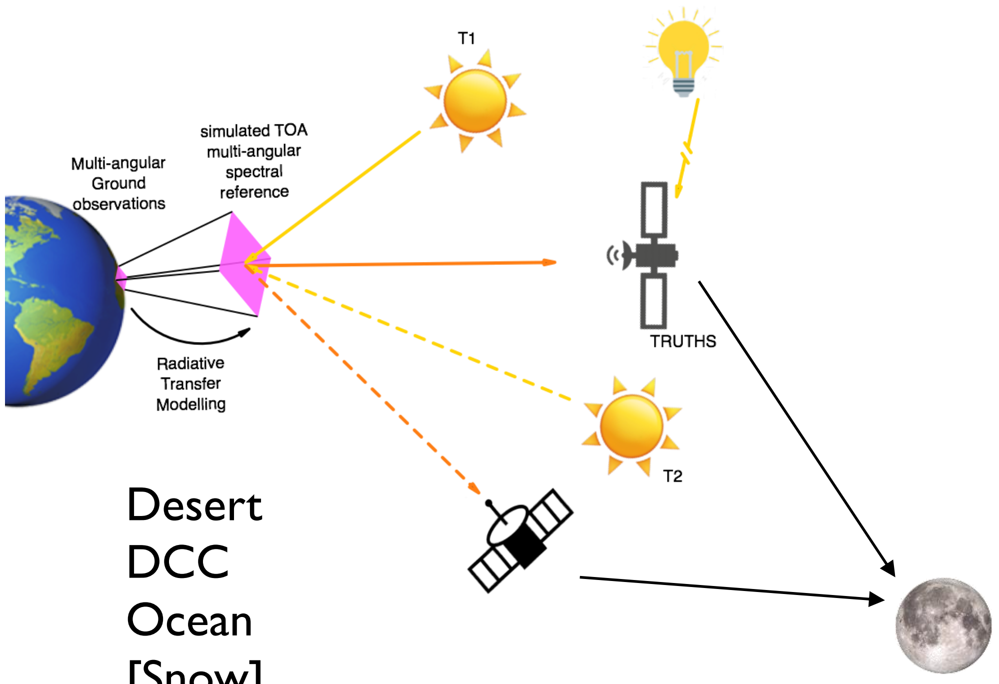
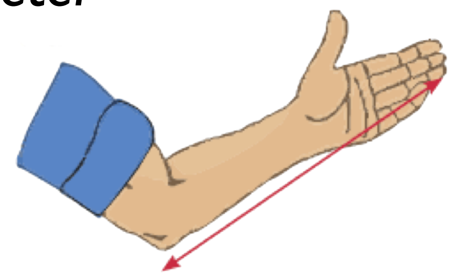


Desert
DCC
Ocean
[Snow]

Moon

All the different absolute calibration targets and associated methods should be traceable to the **same** SI standard … to avoid statement like:

I use the desert PICS methods simulated with this code tied to that radiometer



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