





## TRUTHS, SI-intercalibration reference from space

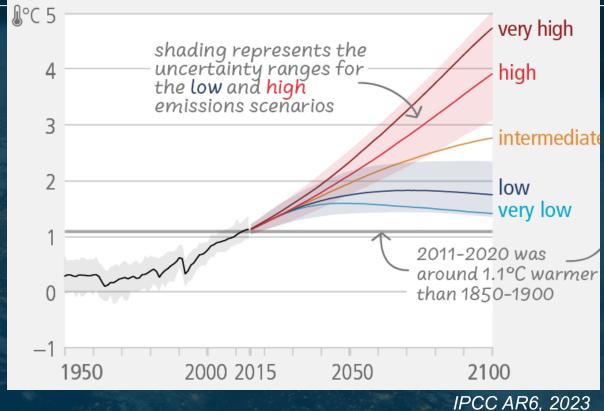
GSICS annual meeting 2024, 14/03/2024

Thomas August, ESA/ESTEC + TRUTHS Project and Science teams

## Climate emergency: Apprehend, Anticipate, Adapt, Act







Models uncertainties

- physical processes
- input observations

#### The Earth Observation calibration challenge





Satellite optical sensors generally suffer from drifts and biases relative to their pre-launch calibration

- caused by launch
- → aging in the space environment



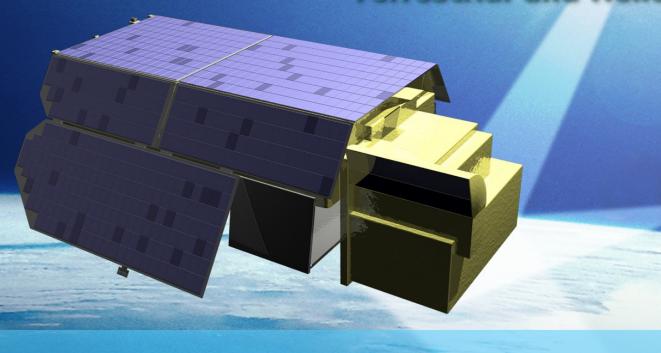
Severe limitation on the fundamental reliability and accuracy that can be assigned to satellite derived information

- → for long time base studies for climate change
- for interoperability and Analysis Ready Data.

# TRUTHS

Traceable Radiometry Underpinning Terrestrial and Helio-Studies





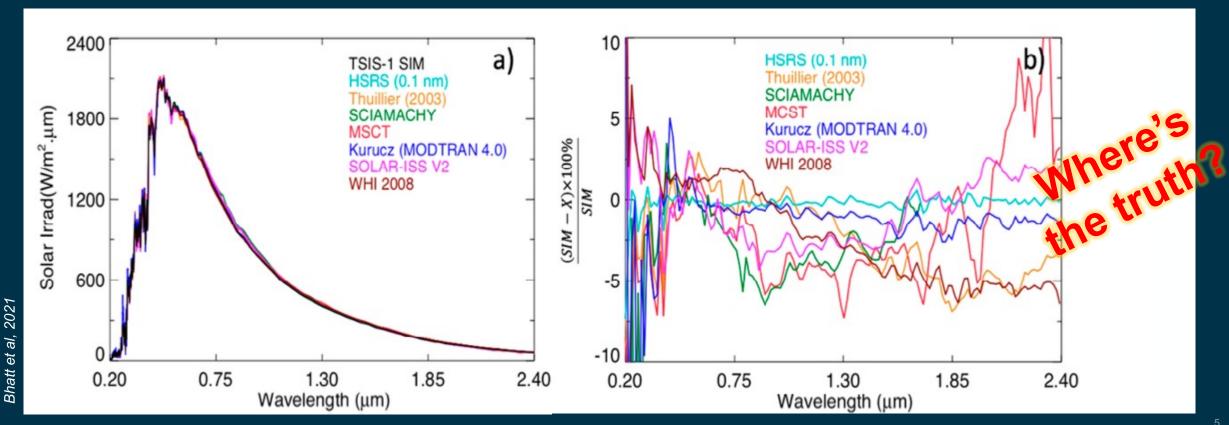
TRUTHS is explicitly designed to:

- ✓ re-calibrate itself in-orbit directly to a primary standard of the <u>international system of units</u> (SI) in-orbit.
- ✓ Extend this SI-traceability to other sensors through in-flight crosscalibration: simultaneous observations and CEOS calibration sites.

## Solar forcing & EO sensor calibration

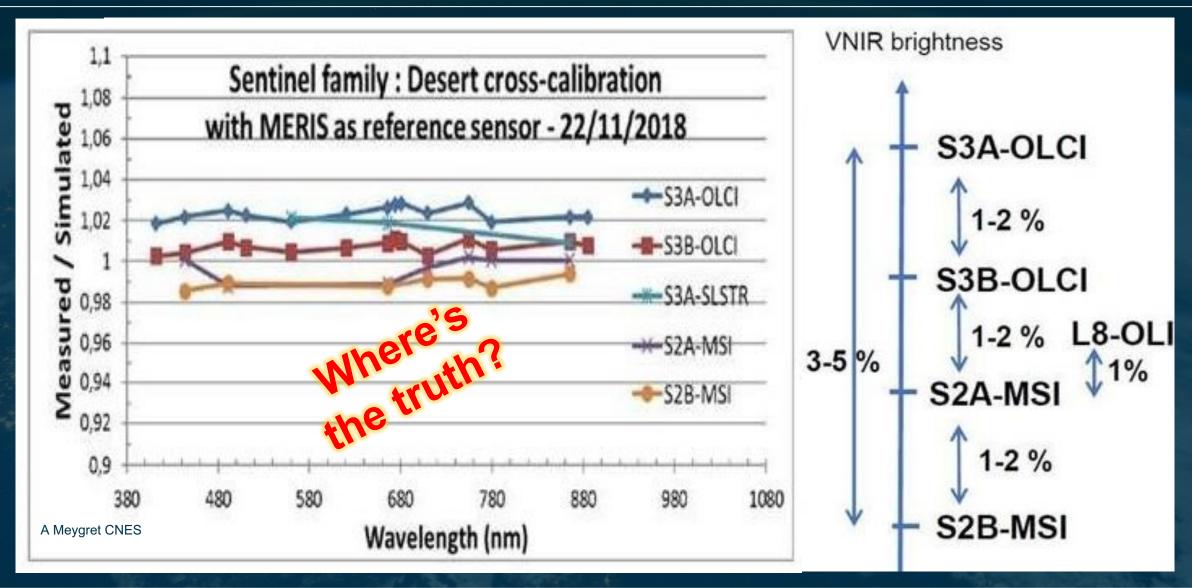


- Sun ≈ all (99.96%) the energy powering Earth's climate system
- 11-year cycle + long-term variations
- Solar forcing is spectrally dependent
- Solar Spectral Irradiance (SSI) also measured for EO sensor calibration



#### The Earth Observation calibration challenge





## The Earth Observation calibration challenge



#### **OLCI-A and OLCI-B** vs 3 different Lunar models

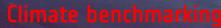


# TRUTHS Mission Objectives

SI-traceable measurements of the solar spectrum

addressing direct science questions.





enhance by an order-ofmagnitude our ability to estimate the spectrally resolved Earth Reflected Solar Radiation Budget through direct measurements of incoming & outgoing energy

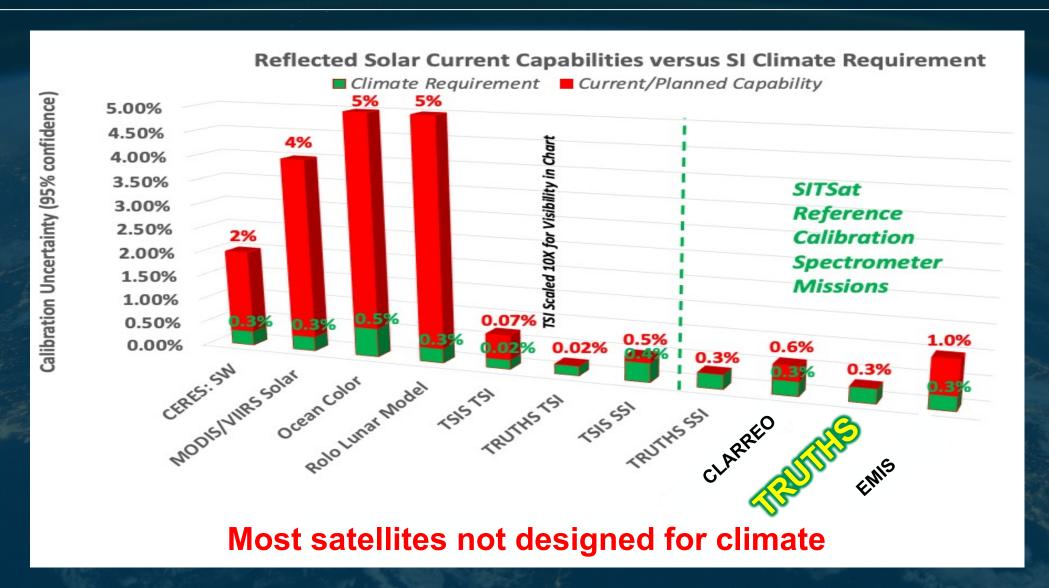
Objective: 0.3% (k=2) absolute radiometric accuracy

#### Satellites cross-calibration

Establish a 'metrology laboratory in space' to create a fiducial reference data set to cross-calibrate other sensors and improve the quality of their data

# The Earth Observation calibration challenge TRUTHS for Climate

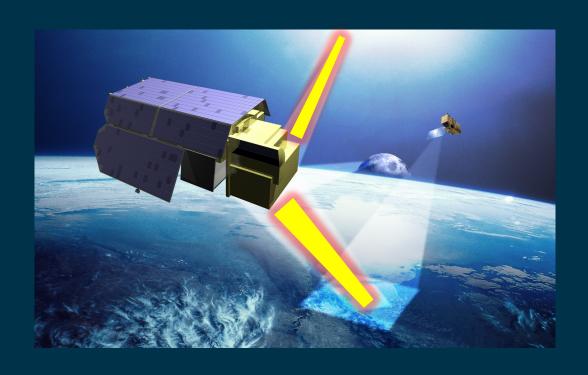


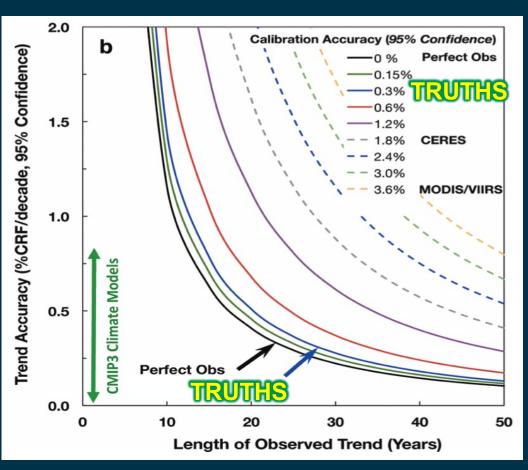


## **Earth Radiation Budget**



- Balance of incoming and reflected solar energy
- Distinguish trends from natural variablity





- TRUTHS direct measurements of radiation budget at unprecedented accuracy!
- Shorten time-to-detect trends -> accurate timely inputs to policy-makers

#### A golden reference for Climate and cross-calibration

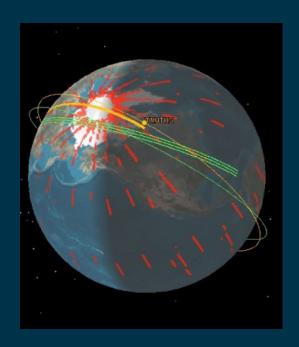


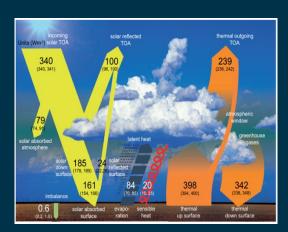


- TRUTHS will provide SI-traceable anchor calibration measurements
- TRUTHS will bring Lunar irradiance knowledge and modelling to new levels

## TRUTHS orbit – Global coverage and diurnal sampling







Nadir push-broom, 100km swath

√ 90° pole to pole orbit, non-Sun-synchronous

Travelling standard through diurnal cycle

61-day repeat cycle

5 to 8 year lifetime

0.3% absolute radiometric calibration (k=2)

Earth radiation balance series

Ray-match Polar sun-synchronous sensors

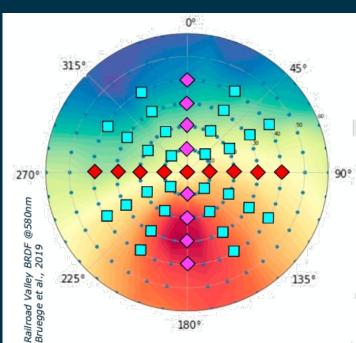
Ray-match GEO-ring at sub-sat. point



## TRUTHS, an agile pointing hyperspectral benchmark



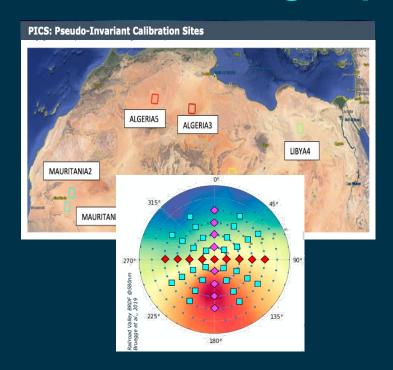




- Nadir push-broom, 100km swath
  - 50m max resolution (100m land, 200m ocean)
- 320-2400nm range, 4-8nm sampling
- ✓ Slew pitch/roll, nominal ±20°, up to ±40°
  - vicarious calibration targets, PICS BRDF
    - PICS → BRDF: sampling guidance?
    - RadCalNet, HyperNets...
    - Maritime sites (Moby, Boussole...)
    - Aeronet-OC
    - Polar ice/snow
    - DCC
    - Mid-lat vegetated, crops...

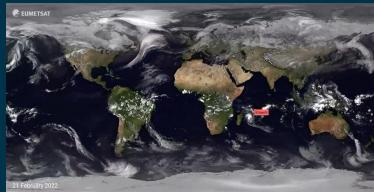
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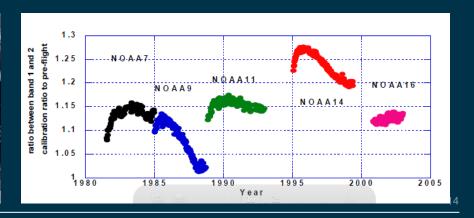




- Nadir push-broom, 100km swath
- 50m max resolution (100m land, 200m ocean)
- 320-2400nm range, 4-8nm sampling
- ✓ Slew pitch/roll, nominal ±20°, up to ±40°.
- 👉 vicarious calibration targets, PICS BRDF
- slanted ray-matching with GEO
  - intercalibrate GEO-ring
  - historical FCDRs...





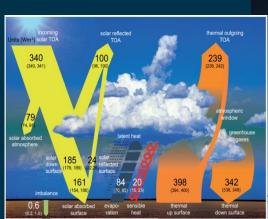


#### Calibration anchor for Essential Climate Variables



#### **TRUTHS: operational calibration segment**

- Sentinel-2/MSI -NG
- Sentinel-3/OLCI -NGO
- Sentinel-4/-5
- CERES
- VIIRS
- CHIME
- CO2M
- LSTM
- Landsat-NG
- EPS-SG
  - METimage
  - 3MI
- GEO-ring
  - FCI, ABI, AHI...
  - S-4, TEMPO, GEMS





**OCEANIC** 

**ATMOSPHERIC** 

TERRESTRIAL

About 2/3 of the ECVs require space observations TRUTHS can support half of these!

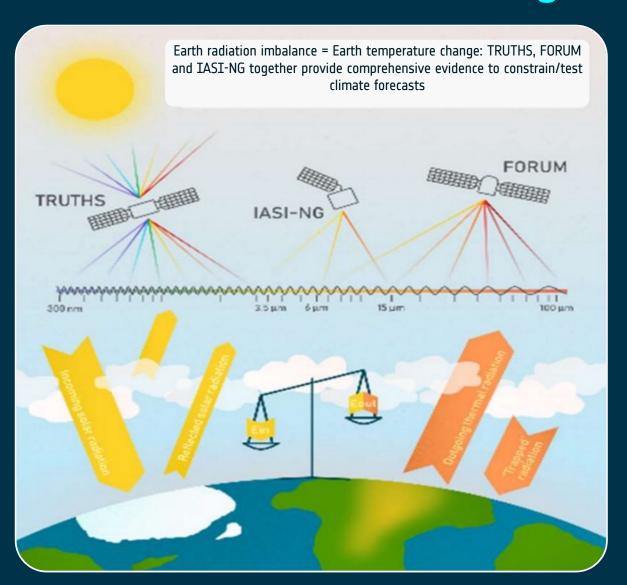
#### TRUTHS products... active dialog with users



- **ESA** open data policy latency 5-7 days
- **L1B TOA radiances (0.32-2.40µm, 0.3%) + full uncertainties, on demand** 
  - land 100m ← bandwidth constraints, User requests for 50m?
  - ocean 200m
  - ⇒ special calibration events 50m ← 1 min/day bandwidth constraints
- **L1C TOA radiances, regridded spatially (UTM/WGS84) and spectrally (TBC)**
- Fig. L1B Total (0.3-30μm, 0.02%) and Spectral (0.3%) Solar Irradiance, < daily
- **€** L1B Lunar Spectral Irradiance (0.3%), < weekly
- L2 BOA spectral reflectance land/ocean (0.38-2.40μm, 1%)
- L3 BRDF/HDRF for PICS
- Simultaneous overpass catalogue for identified target missions

  Intercalibration tools → match-ups and calibration coefficients

### TRUTHS cousins and siblings



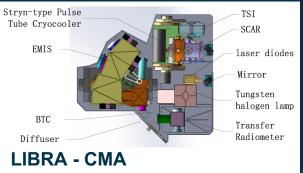




CLARREO PATHFINDER -NASA







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#### TRUTHS Program context and current status



- TRUTHS was proposed by UKSA in May 2019 as a new Earth Watch (EW) Element.
- TRUTHS Phase A/B1 has been fully subscribed at CM-19 by 5 Participating Countries: UK, GR, CH, CZ and RO
- Industrial Phase A/B1 system studies and technology predevelopments completed in ~ 18 months.
  - Phase-A kicked-off at end Oct-20 and completed at end-July 2021. Phase B1 completed in Jun-22 with successful ISRR
- Science study (TMAC) held in parallel to A/B1 to support mission consolidation, S2SC, science scenes, L2.
- MAG formed with 14 scientists from ESA MS and observers from NASA, C3S and Eumetsat.
- Independent Science review held in Jun-22- successful, SRL-5 achieved
- Programmatic "Gate Review": go/no-go decision, passed in July-22, to submit program to CM-22



**Geo-return** 

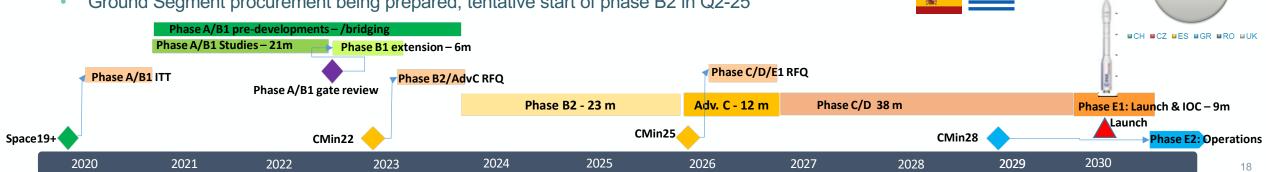
TRUTHS B2/Adv.C

→ THE EUROPEAN SPACE AGENCY

Phase B2/C/D/E1 for funding at CM-22/-25: CM-22 UK+ CH, CZ,ES, GR, RO subscribed TRUTHS Implementation

#### Phase 1 (B2/Adv.C)

- Phase B2/Adv.C Space Segment Kicked-off in Nov-23. Phase B2 to be completed by Sep-25
- Support science studies (TMAC-2) being procured, tentative start Jul-24.
- Ground Segment procurement being prepared, tentative start of phase B2 in Q2-25



# Earth's Spectrally Resolved Reflected Radiation: Climate applications with TRUTHS benchmark satellite measurements





## **TRUTHS**

#### Traceable Radiometry Underpinning Terrestrial- and Helio-Studies



#### Optical climate mission

- . measuring incoming solar and outgoing reflected radiation
- . unprecedented accuracy, 0.3% (k=2)
  - → reduce time-to-detect climate trends

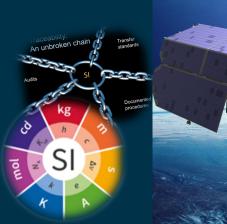
#### A Metrology lab in orbit — SI-Traceable

- . flying a primary calibration standard
- . 10x more accurate than current EO
- . SIT-Sat family

#### Unequivocal reference - anchor and traveling standard

- . to calibrate individual EO missions
- . to intercalibrate satellite systems and long-term data records

**Key Climate link**, to improve climate modeling and inform policy- and decision- makers Serving also operational applications: weather, air quality, oceano, land... Calibration reference for the New Space





## Thank you!





Requirements?
Opportunities?
Suggestions?
Questions?





