LIVING PLANET SYMPOSIUM 2025

FDR4ATMOS: A data set for harmonised solar irradiance and Earth reflectances and future plans

Motivation

Definition (FDR)

A FDR is a long-term record of selected EO Level 1 parameters, possibly multi-instrument, which provides improvements of performance with respect to the individual mission datasets and provides (metrological) uncertainties

- $\Rightarrow$ Cross-calibration/harmonisation of instrument data is needed
- Is often done for imagers, but was not done before for spectrally resolved imagers
- Challenges:
  - No collocated measurements (e.g. GOME-1 and SCIAMACHY are 30 Minutes apart)
  - Different spatial resolutions
  - Spectral structures must not be changed in the harmonisation
- The FDR4ATMOS projects aims to build a FDR data record spanning different instruments
- Project phases:
  - Phase 1 2019-2024: Harmonisation GOME-1 and SCIAMACHY, data set available at ESA
  - Phase 2 2024-2026: Add GOME-2 to timeseries, in cooperation with EUMETSAT

General Method

- Generic Formula:

$$S_{inst1} = S_{inst2} \times C_{\Delta inst} \times C_{1,scene}(geometry, S_{inst1.2}, \ldots) + C_{2,scene}$$

  - with $C_{\Delta\ inst}$, $C_{1,\ scene}$(geometry, $S_{inst1.2}$,. . .), $C_{2,\ scene}$ as harmonisation factors
- Goal: Harmonise the broadband signal offset while keeping spectral structures
- Steps:
  - Align the spectral grids of both instruments
  - Ratio instrument spectra
  - Smooth ratio by polynomial (avoids Level 2 impact for DOAS like retrievals) ⇒ Scaling factors
  - Investigate scene dependent effects
  - Apply to fully resolved spectra

FDR Data Products Version 1

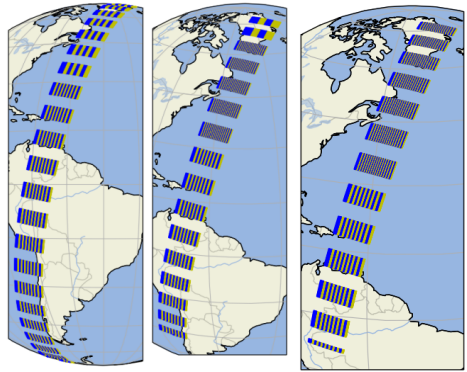
- Spectral bands harmonised Earthshine (GOME-1)

UV (O3, SO2)	VIS (NO2)	NIR (O2A Band)
313-347nm	424-495nm	754-774nm

- Span the combined mission time of GOME-1 to SCIAMACHY 1995-2012
- Reference Instrument: SCIAMACHY
- Each product contains reflectances from one day for GOME-1, SCIAMACHY or both
- Spectral bands solar irradiances: Full channel range of GOME-1 and SCIAMACHY
- SCIAMACHY re-scaled to the minimum integration time in the band
- Version 1 of the dataset was released in Q3 2024
  - Link: DOI:10.5270/ESA-852456e
    - Note: V1 shows an index issue in the lambda variable. This is fixed and a version 1.1 will be released soon. For a V.1 work-around see README on ESA product page

SCIAMACHY Rescaling

- Original SCIAMACHY integration time varies with orbit phase and spectral band

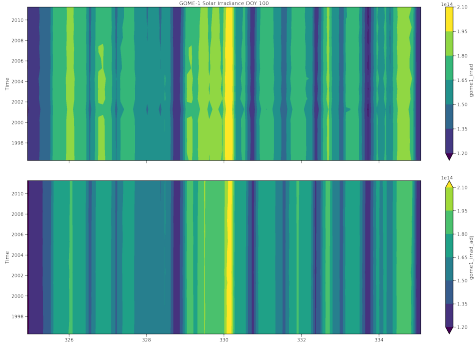


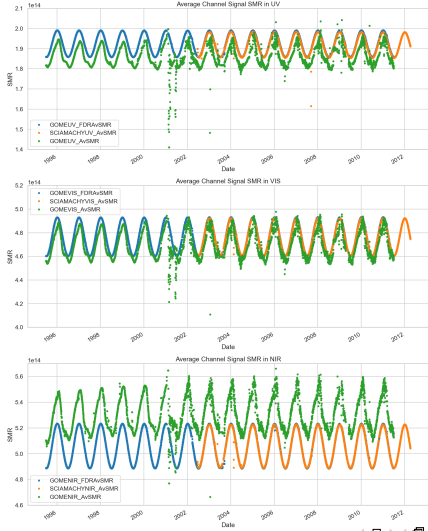
(a) UV (b) VIS (c) NIR

- We rescaled all data to the minimum IT in each band, so the data are uniform over the orbit
- This is done using 32Hz PMD measurements

Harmonisation Solar Irradiances - version 1

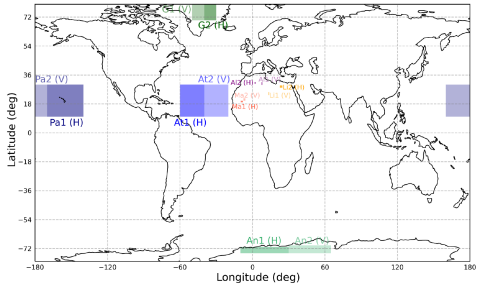
- Etalon GOME-1 removed
- BSDF related pattern removed
- Below: Original and corrected (UV)
- Right: Channel Averages
- V1 data shown here, already available

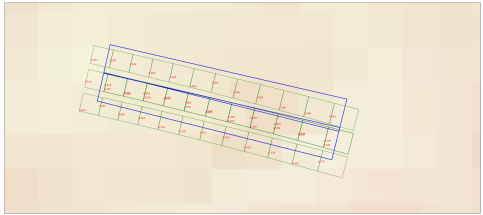




Harmonisation Reflectances - Method

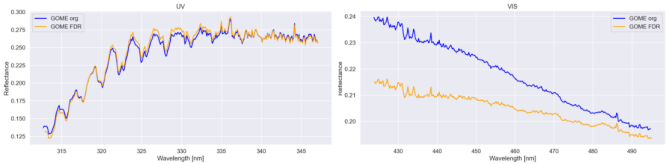
- Harmonisation was done on reflectances (cancels multiplicative instrument effects, e.g.GOME-1 etalon)
- Matching Scenes with homogeneous signal have been defined to
  - cover different signal levels to avoid instrumental biases due to e.g. non-linearity
  - cover different observation geometries
  - Ocean scenes could not be used (high variation)
- Spatially higher resolved SCIAMACHY data were mapped onto GOME-1 footprints
- Harmonisation factors were calculated for all scenes (reference year 2003)

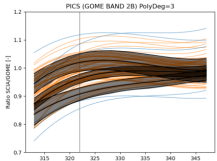


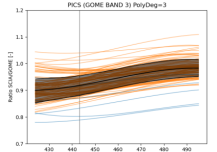


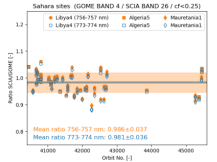
Harmonisation Reflectance - Transfer Factors

- FDR V1 benefits:
  - A consistent data set from 1995-2012
    - Reflectances, radiances and solar irradiances all available in a daily product
  - GOME-1 UV viewing angle dependency mitigated
  - Effect tables, covariance matrix and uncertainty estimate example available
    - uncertainties for individual measurements planned for V.2
  - SCIAMACHY data have a uniform ground-pixel size
  - The FDR data set is fully documented to ESA standards



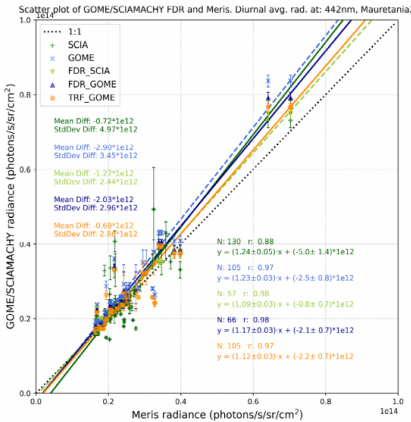


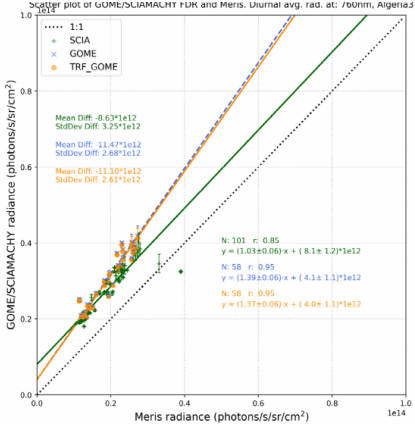




Harmonisation Reflectance - Validation

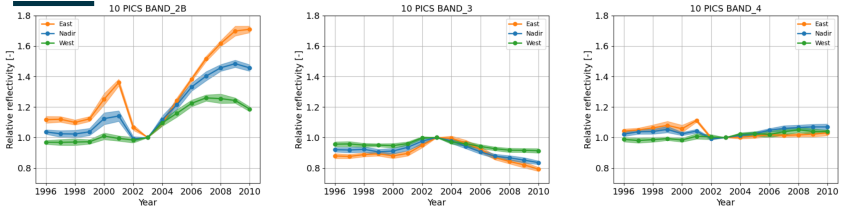
- Daily averages in VIS band agree well with MERIS
- Daily averages in NIR show offset (band mismatch) but show a good correlation



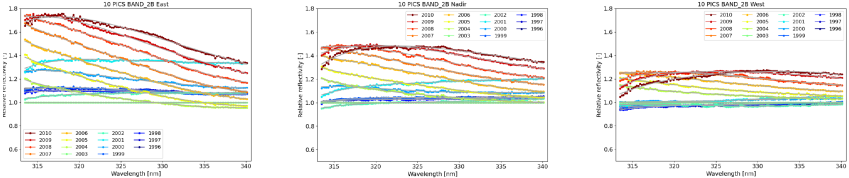


V.2: GOME-1 Degradation Correction

- Variability in time:



- Spectral Variability

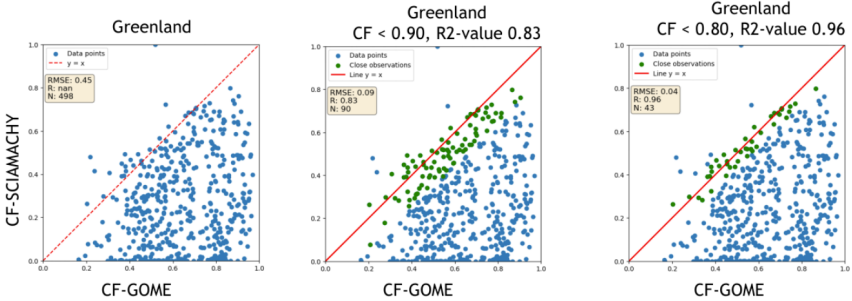


- smooth behaviour in time and wavelength

Details Poster C.02.02 M. Coldewey-Egbers Study on the possible correction of the GOME/ERS-2 reflectance degradation as part of FDR4ATMOS

V.2 Transfer Function

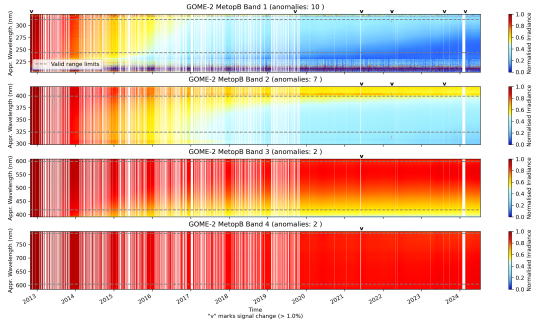
- In phase 1 we saw that non-PIC sites could not be used for harmonisation (too high variance of the individual transfer curves)
- We set up a study to extend the data base (more scenes) and find the reason for the unusable scenes
- Using PMD/cloud fraction data to judge the similarity of the GOME-1 and SCIAMACHY scenes, we can improve the transfer curves and use more scenes (paper is in preparation)



Details Poster C.02.02 A. Owda Scenes investigation for enhancing cross-calibration performance: GOME and SCIAMACHY case study

Assessment of GOME-2 Solar Irradiances

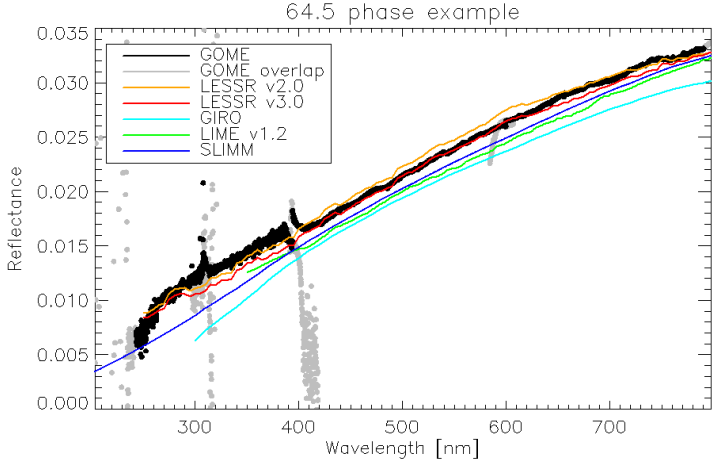
- We analysed GOME-2 to identify gaps or anomalies in the solar irradiance data



- Defining an anomaly as a >1% deviation between to data points (“v” mark above)
- We only found a few anomalies, most had already been filtered out by EUMETSAT QC
- We communicated the additional anomalies to EUMETSAT

GOME-2/SCIAMACHY: Lunar Data

- We analysed lunar data of GOME-2 that were calibrated by EUMETSAT
- From the data the lunar irradiance and reflectance was calculated
- Additionally anomalies of the lunar data were analysed and mitigation measures proposed
- GOME-2 and SCIAMACHY lunar data products will be released this year



Summary

- The FDR4ATMOS project delivers FDRs on Level 1 Basis
- Improvements V2 vs V1.1:
  - GOME-2 data will be added ⇒ FDR spanning 1995 - 2024
  - Adding random uncertainties for all measurements based on metrological principles
  - GOME-1 degradation correction
  - Solar irradiance harmonisation based on GSICS recommended TSIS-HSRS spectrum
  - Planned release V2: end 2026
- Lunar Products:
  - SCIAMACHY stand-alone Lunar Data Product will be released in autumn (DOI 10.57780/en1-9b49745 and 10.57780/en1-d549f05)
  - GOME-2 stand-alone Lunar Data Product
  - Lunar model LESSR update based on SCIAMACHY and GOME-2 data
- Questions or suggestions? Contact me: guenter.lichtenberg@dlr.de

FDR4ATMOS Team

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