FDR4ATMOS (Task B): FDR Long time series for spectral imagers

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DLR

Outline

Introduction

- The Fundamental Data Record for ATMOSpheric Composition (FDR4ATMOS) project is part of the ESA Long Term Data Preservation (LTDP) programme
- It has two main tasks
  - Task A: Correction of SCIAMACHY degradation and incorporation of lunar data → Poster B4.01, Board 32
  - Task B: Creating a cross instrument time series of Level 1 data for GOME-1 and SCIAMACHY

Goals

- The main objective of the FDR4ATMOS project is to develop a cross-instrument Level 1 product for GOME-1 and SCIAMACHY
- The FDR product will contain *harmonised* irradiances and reflectances for each instrument
- The focus is on the spectral windows in the UV, VIS and NIR used for $O3$, $SO2$, $NO2$ total column retrieval and the determination of cloud properties.
- The FDR4ATMOS products will be based on Level 1, i.e. on irradiances and reflectances.

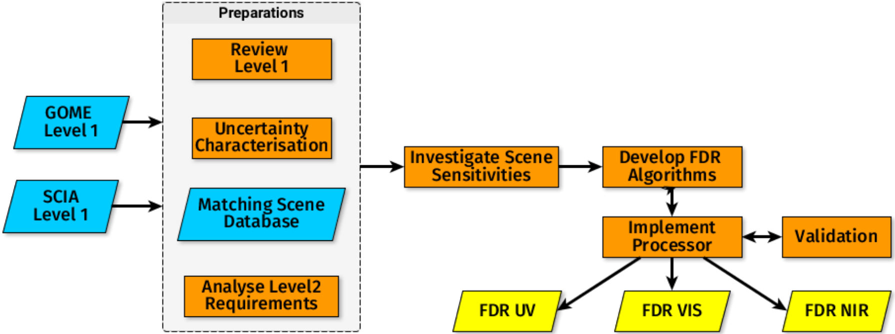
Why Level 1?

- Up to now projects that aim at the harmonisation of atmospheric trace gas data have done this on Level 2
- However, starting at Level 1 offers some advantages:
  - Harmonisation on Level 2 often depend on the specific Level 2 algorithms
  - If data are properly harmonised on reflectance or radiance level, this restriction no longer applies, i.e. the harmonised data could also be used for future, still to be developed Level 2 algorithms

Challenges

- Contrary to previous cross-calibrations (e.g. FIDUCEO project) harmonisation has to be done on a highly resolved spectral grid without changing the spectral structures used for retrieval
- GOME-1 and SCIAMACHY do not have exact co-locations (different orbits)
- To avoid a bias due to instrument effects comparison scenes have to cover
  - different observation geometries
  - different signal intensities
  - different signal polarisations

Study overview



General Method

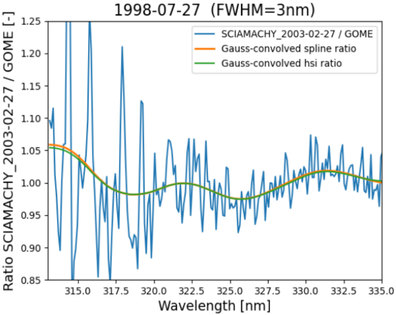
- Generic Formula:

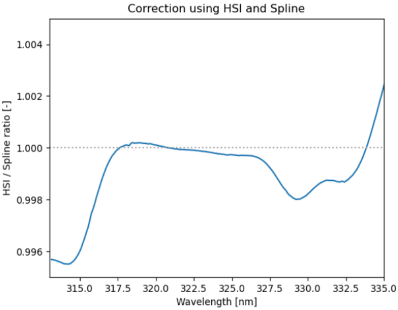
$$S_{inst1} = S_{inst2} \times C_{\Delta inst} \times C_{1,scene}(geometry, S_{inst1.2}, \ldots) + C_{2,scene}$$

- Goal: Harmonise the broadband signal offset while keeping spectral structures
- Steps:
  - Align the spectral grids of both instruments
  - Ratio GOME and SCIAMACHY spectra
  - Smooth Ratio by convolution with Gaussian kernel $\Rightarrow$ Scaling factors
  - For reflectance: Investigate scene dependent effects
  - Apply to fully resolved spectra

Harmonisation Solar Irradiances - Choices

1. Ratio → smooth or vice versa: we first ratio (slightly less noisy result)
2. Spectral alignment: HSM vs Spline interpolation
   No significant difference (see below), we chose the spline method to reduce external dependencies





Harmonisation Solar Irradiances - Choices

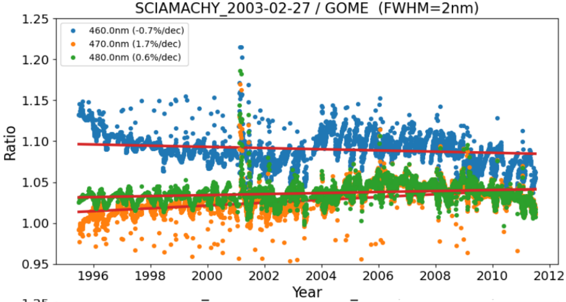
We chose a SCIAMACHY solar spectrum from February 2003 as the reference to harmonise GOME-1 solar measurements

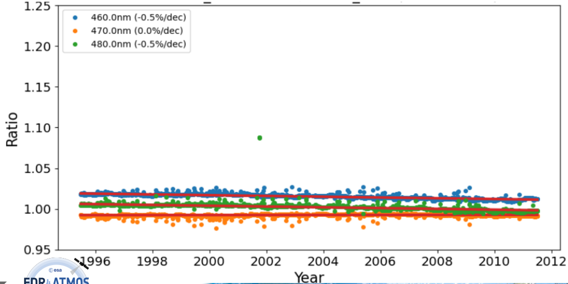
Reasons:

- The SCIAMACHY spectrum is the first one with instrument temperature as in the remainder of the mission
- This SCIA irradiance is validated against other solar reference spectra (Hilbig, 2018).
- It contains an on-ground to in-flight correction
- It is the zero point for the SCIMACHY degradation correction
- GOME-1 shows an unpredictable etalon effect in the spectra that cannot be corrected

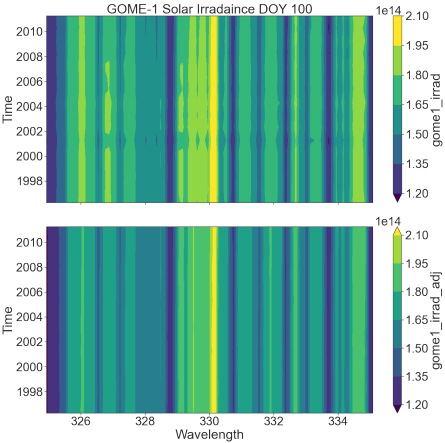
GOME etalon

Harmonisation Solar Irradiances - Results

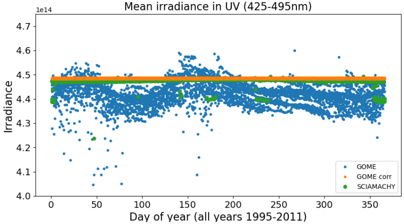




Harmonisation Solar Irradiances - Results



UV irradiance for every day and wavelength before (top) and after harmonisation.

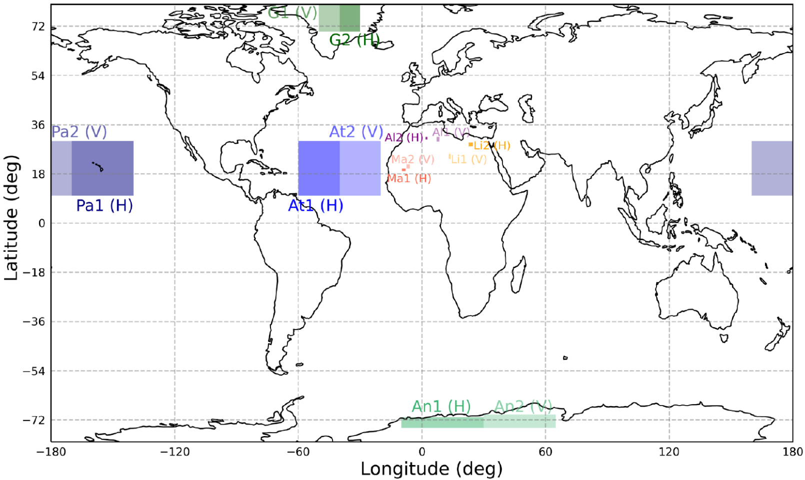


Mean irradiance VIS for every DOY showing BSDF correction related pattern (blue) and harmonised irradiance with patterns removed

Study Set-up Reflectances

- Harmonisation will be done on reflectances (cancels GOME-1 etalon)
- Contrary to solar irradiance, scene dependent effects have to be taken into account
- Therefore, "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
- The data from these scenes will be used to identify scene effects

Matching Scene Areas



Study Set-up Reflectances

- Half of the matching scenes are reserved for validation purposes to avoid circular reasoning
- The year 2003 was chosen as the "golden year" to be used in the investigations
- Additional data before and after 2003 will be used to avoid effects from insufficient degradation corrections
- Tests using Level 2 retrievals will also be performed to check the usefulness of the harmonised data

Summary & Conclusions

- The FDR4ATMOS project aims to deliver FDRs on Level 1 Basis
- Using SCIAMACHY the solar spectra from GOME-1 were harmonised removing artefacts
- Studies for the harmonisation of the reflectances have started
- We will generate and publish products containing a harmonised reflectance and irradiance for the spectral retrieval windows of O3, SO2 (UV), NO2 (VIS) and cloud parameters (NIR) for both SCIAMACHY and GOME-1
- The goal is to develop methodologies and algorithms for the harmonisation of spectrally resolved data that can also be used for current and future instruments
- FDR4ATMOS is a pathfinder project to explore how and how far spectrally resolved data can be harmonised and be used for Level 2 retrievals

FDR4ATMOS Team

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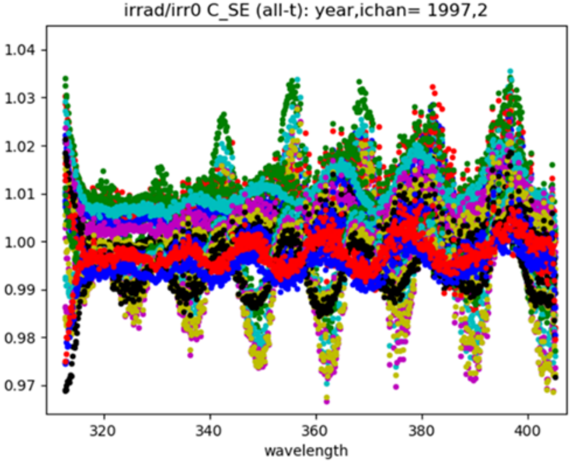
Additional Slides

GOME Residual Etalon

Ratio to first spectrum of the year, every two weeks after degradation correction



Uncertainties in the FDR Product

Metrological best practice will be followed to determine the FDR uncertainties:

1. A measurement function (or series of functions within a process) is defined that converts raw signal to the base sensor output, or FDR product.
2. A diagram is used to document the traceability and sources of uncertainty
3. For each source of uncertainty identified in the diagrams, an 'effects table' will be filled with (as far as they are known)
   - 3.1 the magnitude of the uncertainty
   - 3.2 its sensitivity and pdf
   - 3.3 error correlations

Uncertainty Tree Diagram

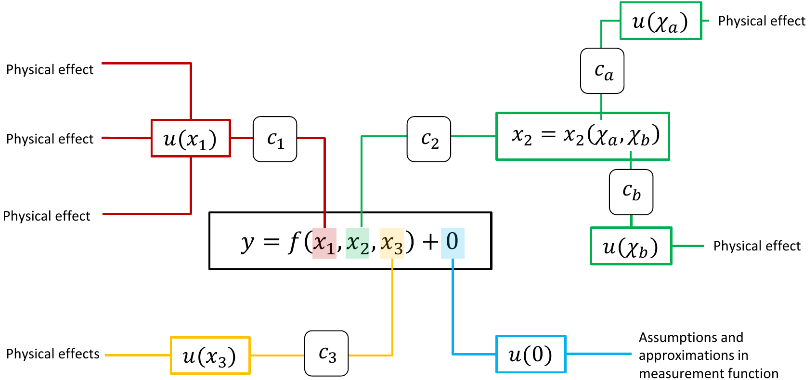


Figure by NPL UK

What is an FDR?

Definition (Original)

An 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.

Definition (Proposed by C. Merchant at CEOS and CGMS WGC Meeting)

An FDR consists of a consistently reprocessed record of uncertainty-quantified sensor observations that are calibrated to physical units and located in time and space, together with all ancillary and lower level instrument data used to calibrate and locate the observations and to estimate uncertainty.

FDR Product Content

Level 1a shall at least contain:

- Radiances & irradiances needed for the reflectances
- Intermediate results needed for Level-1b, e.g. harmonisation conversion factors
- Intermediate uncertainties that are needed for Level 1b

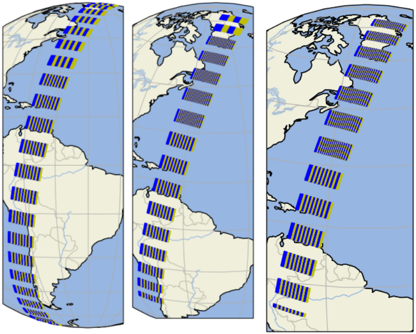
Level 1b shall at least contain:

- Harmonised GOME-1 and SCIAMACHY reflectances & irradiances
- Uncertainties
- SRF (spectral response functions) that may enable a user to obtain fully homogenised reflectances

Data of known bad quality (e.g. SCIAMACHY decontaminations) are *removed from L1b*.

SCIAMACHY clusters

- SCIAMACHY data have different spatial resolutions over orbit and spectral regions
- It is planned to harmonise by conversion to the smallest integration time,
- The impact will be checked
- Scaled data will be flagged



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

Reminder GOME-1 and SCIAMACHY

Both instruments span 17 years of data. The table shows only the relevant channels for FDR4ATMOS

	GOME	SCIAMACHY
Launch	April 21st 1995	March 1st 2002
End of Mission	July 2nd 2011	April 8th 2012
Orbit	sun-synchronous, 790 km	sun-synchronous, 799.8km
Local Time (DNX)	10:30 am	10:00 am +/- 5 Min
Observation Geometries	Nadir	Nadir, Limb, Occultation
Ground Pixel Size	40 x 320 km^2	32 x 233 km^2 to 26 x 30 km^2
Number of channels	4	8
Pixel Per Channel	1024	1024
Total Spectral Range	237 - 793 nm	212 - 2386 nm
UV Channel Range/Resolution	311 - 405 nm/0.17 nm	300 - 412 nm/0.26 nm
VIS Channel Range/Resolution	405 - 611 nm/0.29 nm	383 - 628 nm/0.44 nm
NIR Channel Range/Resolution	595 - 793 nm/0.33 nm	595 - 812 nm/0.48 nm