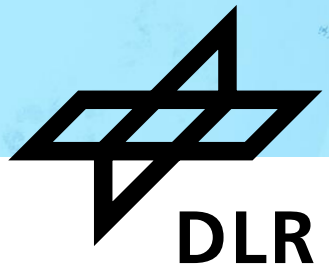
GSICS 2024

FDR4ATMOS Phase 1 Results and outlook to Phase 2



G. Lichtenberg & FDR4ATMOS Team, DLR, IUP, BIRA, NPL ESS, March 13th 2024

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Introduction (I)

- The Fundamental Data Record for ATMOSpheric Composition (FDR4ATMOS) project is part of the ESA Long Term Data Preservation (LTDP) programme
- The main objective of the FDR4ATMOS project is to develop a cross-instrument Level 1 product for GOME-1 and SCIAMACHY (phase 1) and to add GOME-2 data (phase 2)
- The FDR product contains *harmonised* irradiances and reflectances
- 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 are based on Level 1, i.e. on irradiances and reflectances.

Introduction (II)

- Phase 1 had two main tasks
  - Task A: Correction of SCIAMACHY degradation and incorporation of lunar data
    - Level 1 and 2 products were newly generated for the whole mission
  - Task B: Creating a cross instrument time series of Level 1 data for GOME-1 and SCIAMACHY
- Data are currently checked and will become available Q3/2024
- Phase 2 started last December and
  - Will incorporate GOME-2 data into the time series (supported by EUMETSAT)
  - Release a lunar GOME-2 product and develop a lunar model (EUMETSAT/ESA cooperation)

→ Reminder GOME-1, SCIAMACHY

General Method

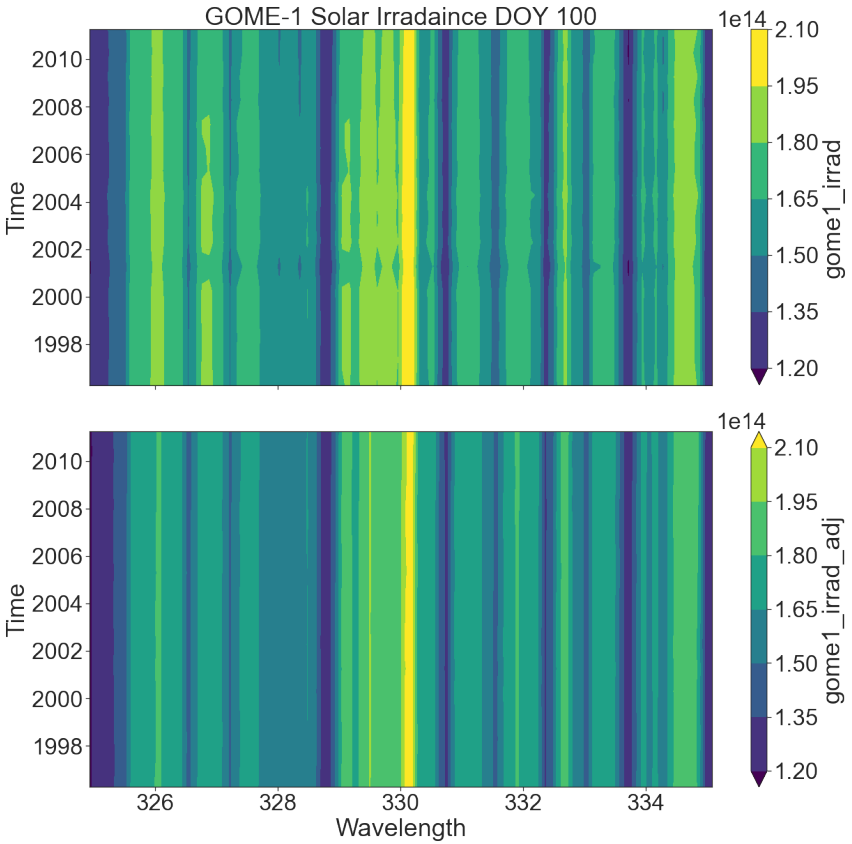
- Generic Formula:

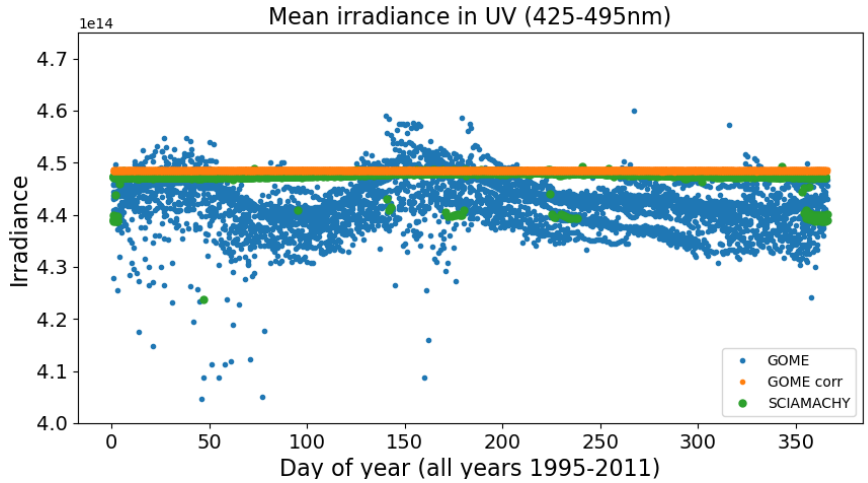
$$S_{inst1} = S_{inst2} \times C_{\Delta inst} \times C_{1,scene}(geometry, S_{inst1.2}, \ldots) + C_{2,scene}$$

- Goal: Harmonise the broadband signal offset while keeping spectral structures
- Steps:
  - Align the spectral grids of both instruments
  - Ratio instrument spectra
  - Smooth ratio by polynomial (avoids Level 2 impact for DOAS like retrievals) $\Rightarrow$ Scaling factors
  - Investigate scene dependent effects
  - Apply to fully resolved spectra

Harmonisation Solar Irradiances

The whole channel was harmonised with a validated SCIAMACHY SMR (27.02.03)



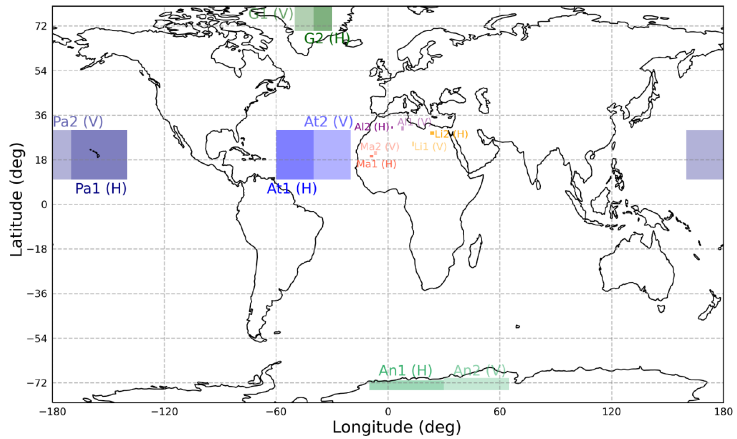


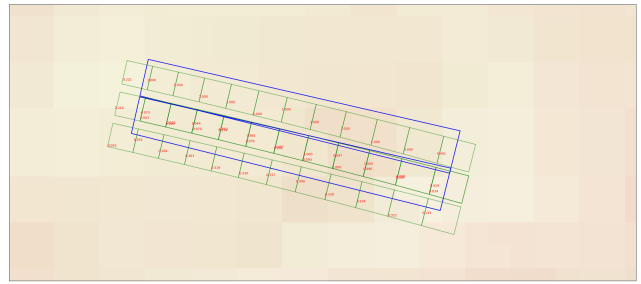
Mean irradiance VIS for every DOY showing BSDF correction related pattern (blue) and harmonised irradiance with patterns removed

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

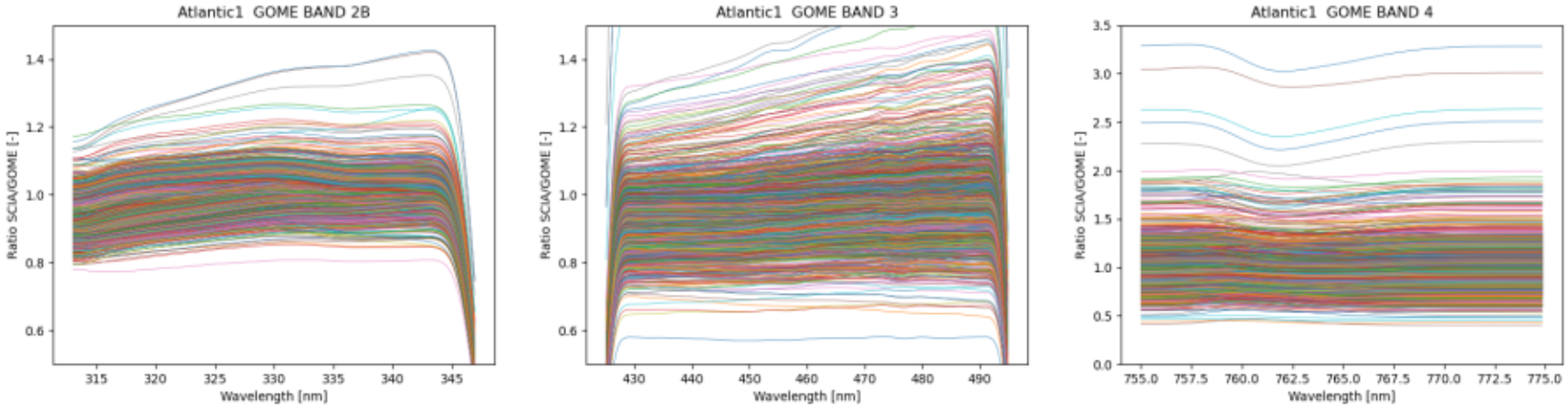
Harmonisation Reflectances

- 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
- Spatially higher resolved SCIAMACHY data were mapped onto GOME-1 footprints
- Harmonisation factors were calculated for all scenes (reference year 2003)



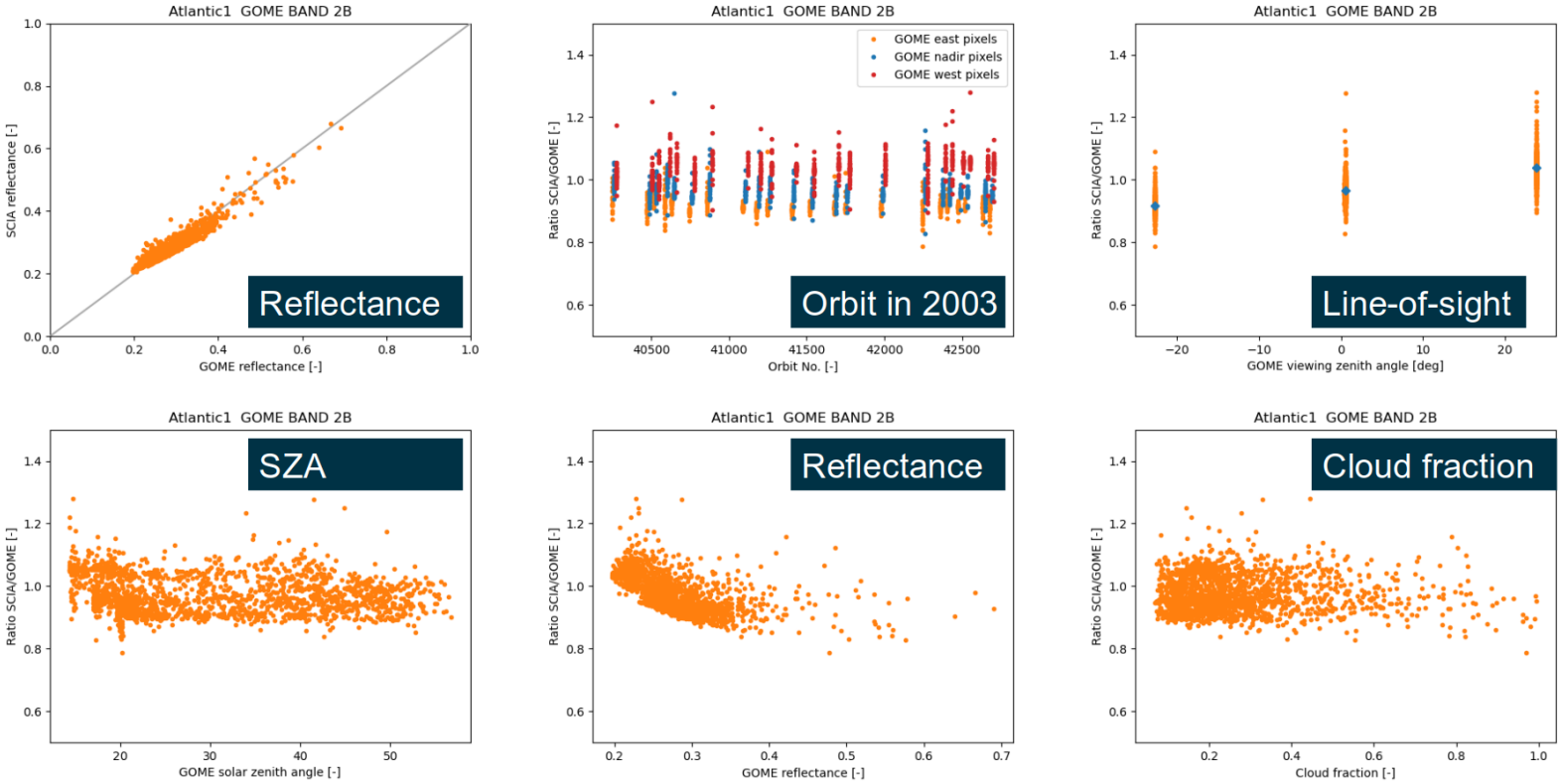


Results for Ocean Scenes



- Pictures above show all transfer factors for 2003 for Atlantic area for UV, VIS, NIR
  - All ocean scenes show a similar high spread of data
  - Investigation of possible scene dependent factors (clouds, viewing angles) showed no correlation
  - $\Rightarrow$ Ocean scenes were excluded from transfer function calculation, only PICS data were used
  - $\Rightarrow$ Further investigations planned for phase 2

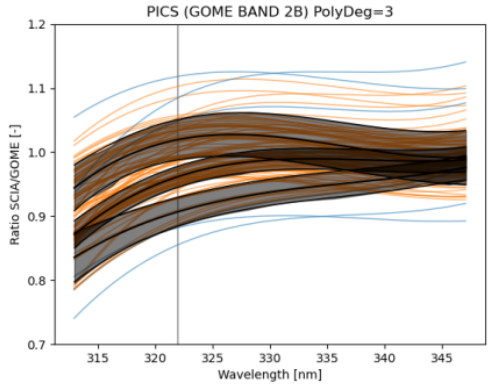
Scene Dependencies Example UV

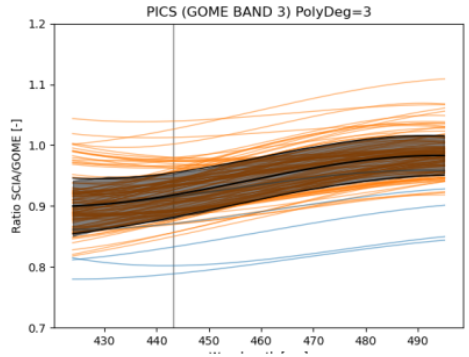


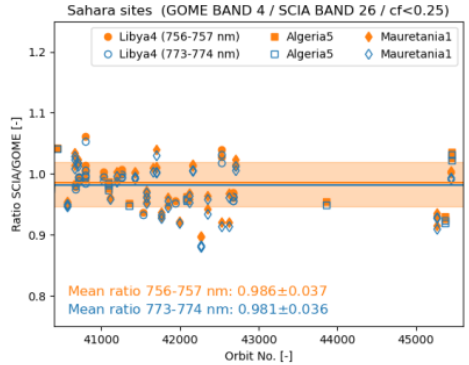
- UV shows known dependence from East/West viewing angles
- VIS, NIR show no correlation with any of the parameters

Transfer Factors

- Transfer curves for all PIC Sites
  - Blue thin line: Excluded curves
  - Black line: Average of all 2003 observations
  - Shaded Area: Standard deviation of Average
- Top: UV
  - 3 curves, one for each viewing angle (East - Nadir - West)
  - Polynomial 3rd degree
- Middle: VIS Polynomial 3rd Degree
- Bottom NIR:
  - Excluded O2A band Absorption
  - One factor for whole channel





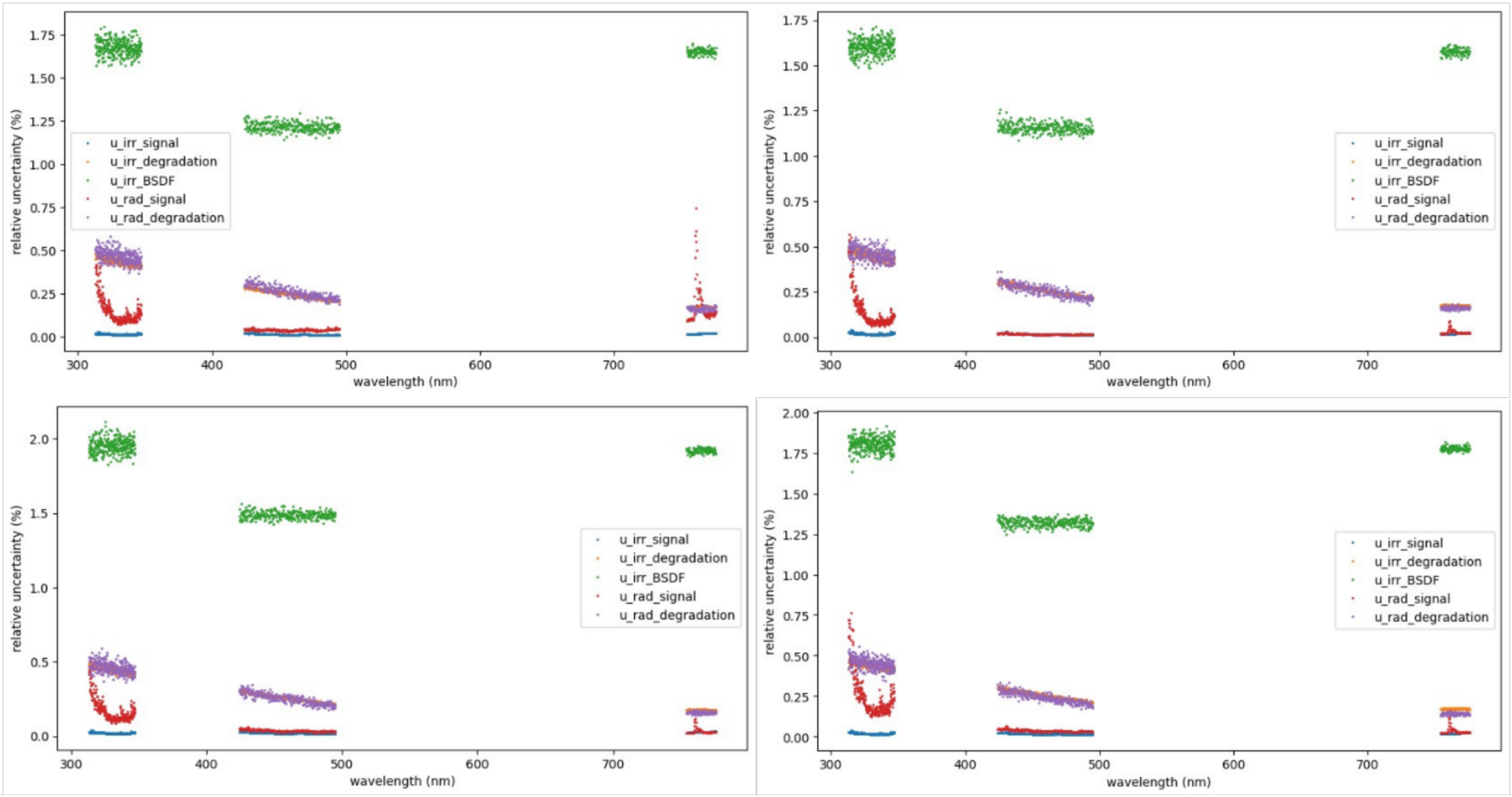


Uncertainties Approach

- Level 1 uncertainties for both instruments were reviewed using metrological principles:
  - For all calibration steps a measurement function was established
  - Effect tables for all error contributions were generated
- From this information, for typical measurements
  - An error propagation model was set up and used to separate different types of uncertainties
  - Error correlations were calculated
- The documentation will be available to the user
- The analysis is currently limited by availability of calibration information and number of scenes analysed
- Further improvement and analysis is planned for the next phase

Decomposition of Reflectance Errors

Top: Atlantic, Bottom: Mauretania Left: 04/2003, Right:04/2010



Summary

- FDR added value
  - GOME-1 SMR harmonised to independently validated SCIAMACHY SMR
  - SCIAMACHY data scaled to minimum integration time in band
  - Reflectances directly available in FDR
  - GOME-1 UV viewing angle dependency mitigated
  - Level 1 errors were thoroughly analysed an decomposed into systematic/random components
- Open:
  - Time dependency GOME-1 is the same as in original data (reflectance degradation)
  - Reason for unusable ocean scenes
- Open points will be addressed in Phase 2 together with the incorporation of GOME-2 data

Conclusions

- The FDR4ATMOS project delivers FDRs on Level 1 Basis
- Using SCIAMACHY the solar spectra from GOME-1 were harmonised removing artefacts
- Products containing a harmonised reflectance and irradiance will be published Q3/2024
- 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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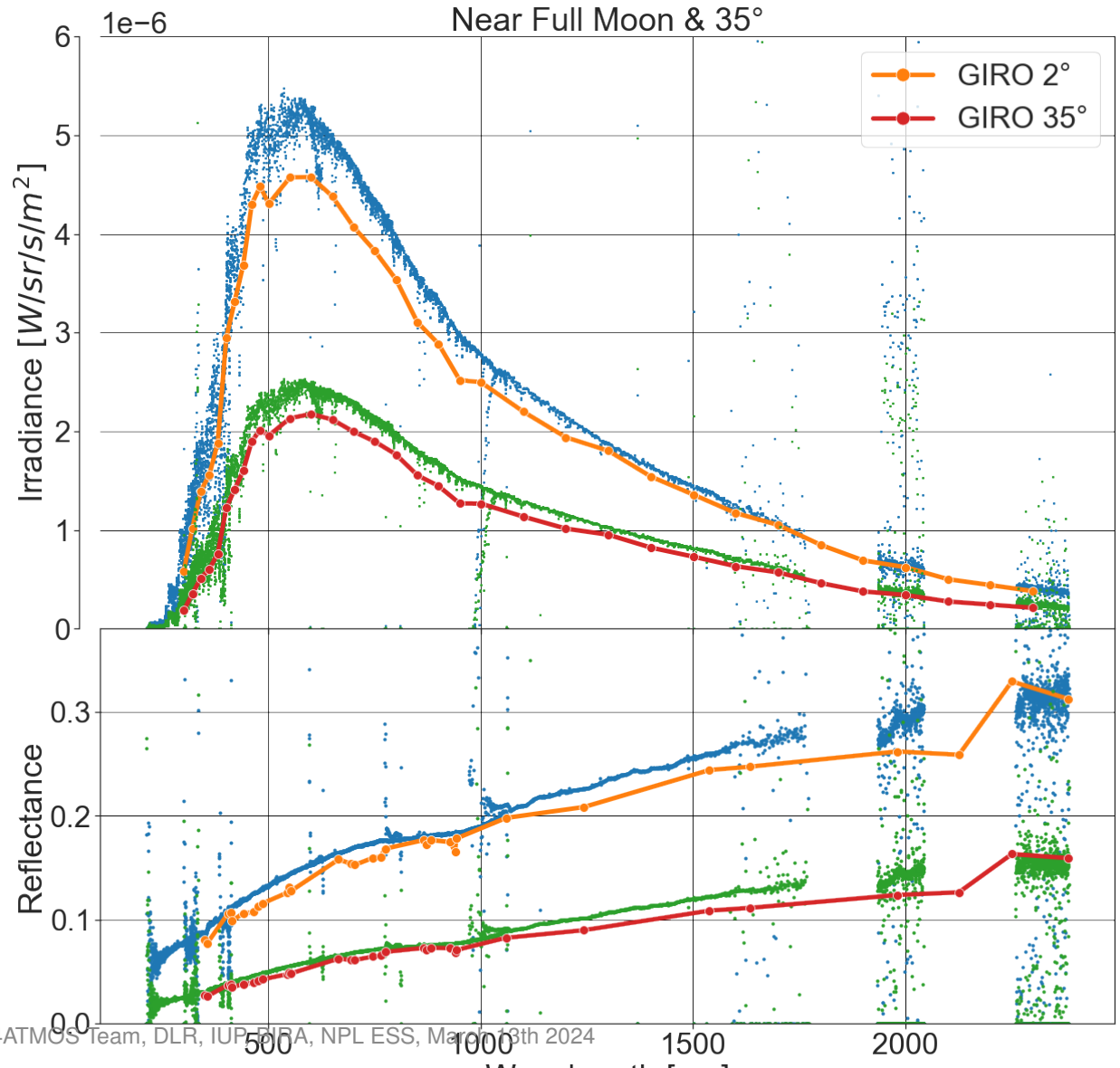
Additional Slides

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
  - Direct assimilation of radiometric data into models is possible independent of the instrument

Task A Lunar Data Validation



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

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.

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 × 320 km^2	32 × 233 km^2 to 26 × 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

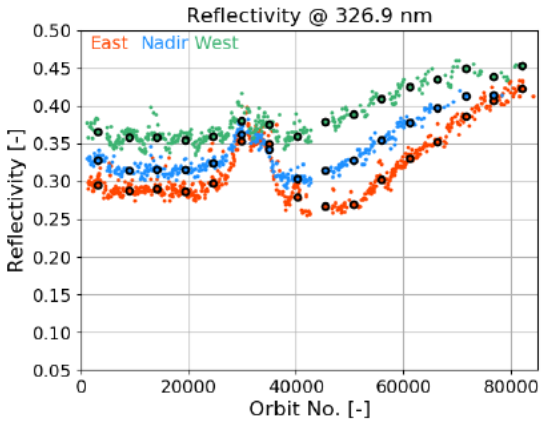
GOME reflectance at PICS Libya-4 (Sahara desert)

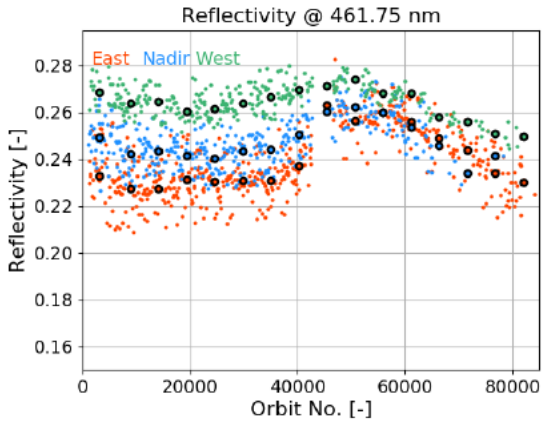
UV (326.9nm)

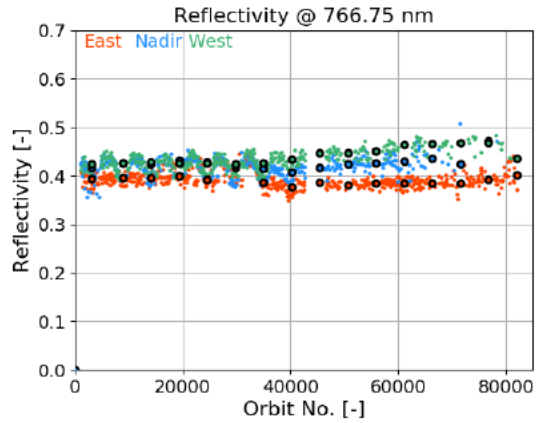
VIS (461.75nm)

NIR (766.75nm)

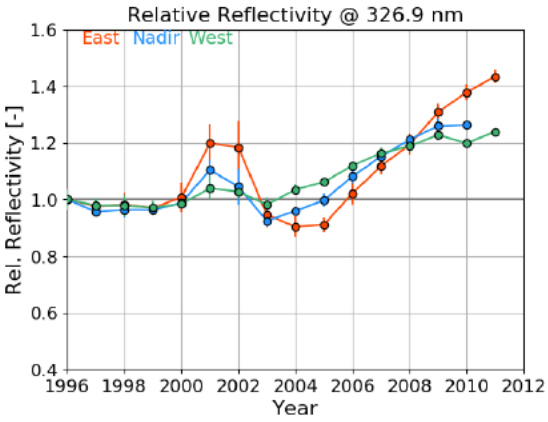
Reflectivity

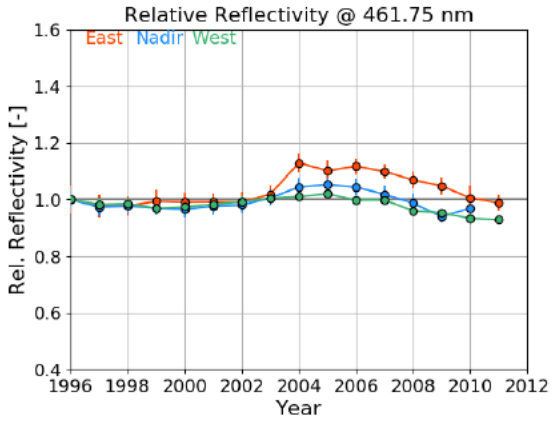


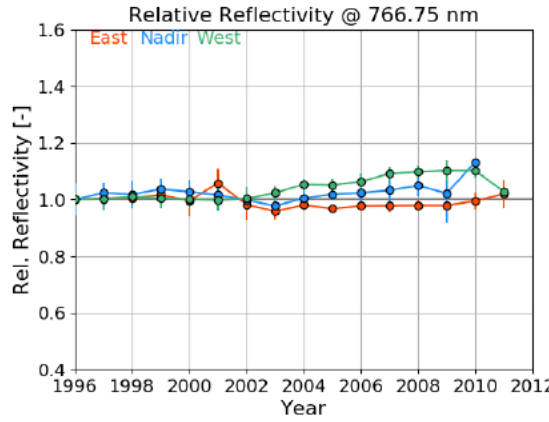
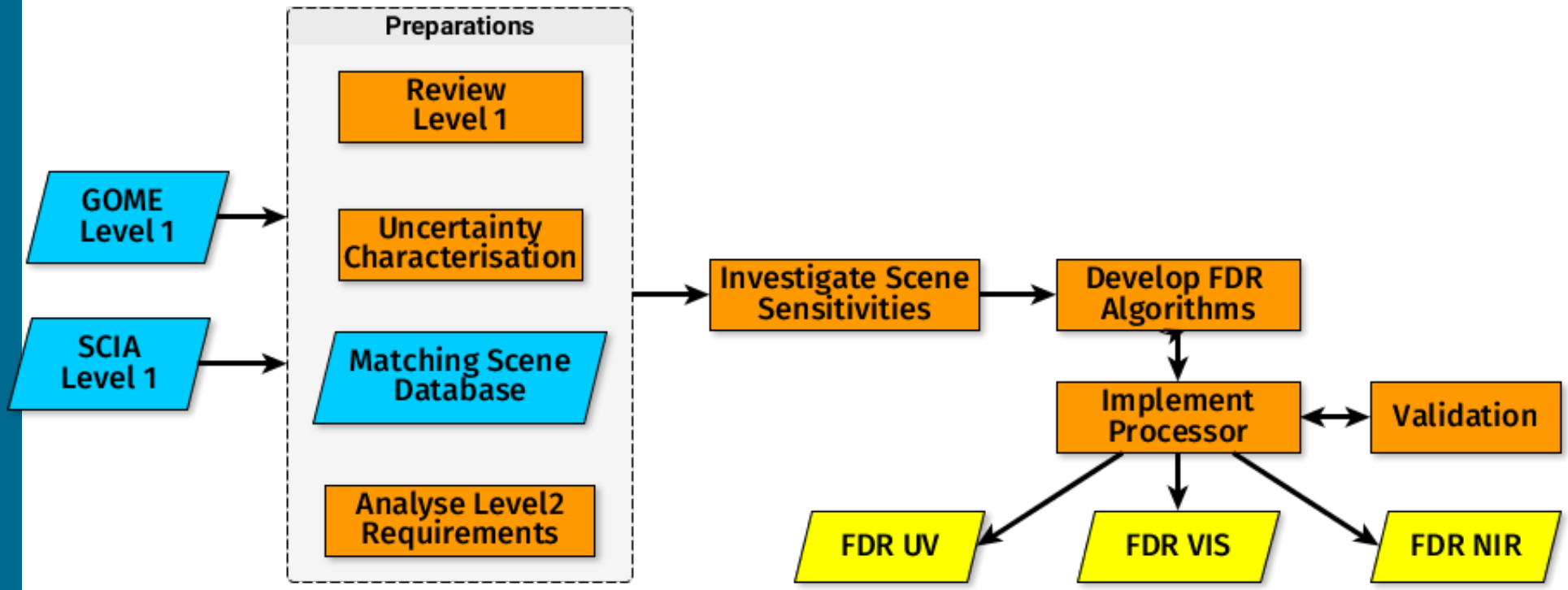




Relative reflectivity w.r.t 1995







Simplified Flow