

## GOME Instrument Performance Monitoring

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### Abstract

**The Global Ozone Monitoring Experiment (GOME) was launched on ERS-2 in April 1995 and has been functioning continuously since then. To monitor the GOME instrument performance operational software tools were developed to be operated within the Product Control Service at ESA/ESRIN. An ESA working group on this topic was set up including scientists working with GOME products. The basic functions, reports produced, and interfaces set up to users of these software tools and the major results of the first workshop held on GOME instrument performance monitoring are presented here.**

*Keywords: GOME, Instrument Performance Monitoring*

### Introduction

ESA/ESRIN is responsible for operational exploitation of the ERS mission, this requires on the one hand a close and regular monitoring of the sensor performance, and on the other hand close coordination with the off-line product generation facilities.

It is a mandatory ESA/ESRIN responsibility to ensure that the existing user community is kept fully informed as regards the mission status and performance, the quality of the products available and the service provided by the existing ERS ground segment.

Therefore ESA/ESRIN Product Control Service has been monitoring the quality of data products and the performance of all radar based instruments on the satellite ERS-1 and ERS-2. After the launch of the satellite ERS-2 the existing operational facilities were extended to include the monitoring of GOME (Global Ozone Monitoring Experiment) as well (the only completely new instrument on ERS-2).

### GOME Raw Data Products Dissemination

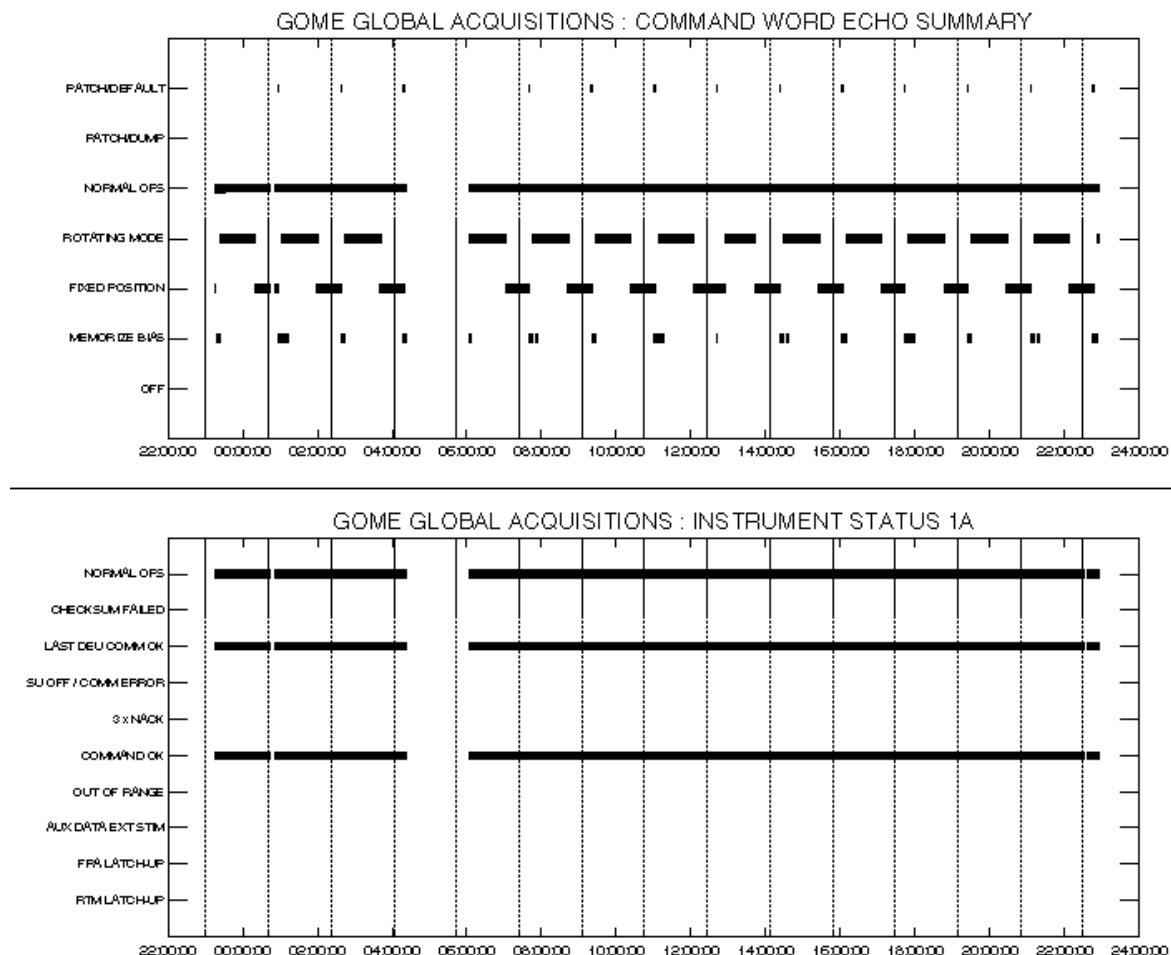
GOME telemetry (low bit rate) is acquired at 4 ESA ERS ground receiving stations (Gatineau - Canada, Kiruna - Sweden, Maspalomas - Canary Islands, Prince Albert - Canada). The full data stream (EGOC - Extracted GOME Calibration Data) is transcribed on Exabytes and arrives within about two weeks (shipment via normal mail) at the processing facility (D-PAF) and ESA/ESRIN. The existing ERS ground segment includes (for the express purpose of ESA near real time instrument performance monitoring) the capability to extract small subsets of raw telemetry data (EGOI - Extracted GOME Instrument Header data) from GOME source packets around entire orbit. This data are disseminated from ESA near real time stations (Gatineau, Kiruna, Maspalomas) to ESA/ESRIN Product Control Service within 3 hours after acquisition.

### Software Tools

Following the strategy already used for other instruments two operational software systems were developed to perform GOME instrument performance monitoring.

The **GOME Daily Reports** software (developed at ESRIN) analyses only EGOI products arriving at ESRIN within one day (exclusion of the data acquired at the Prince Albert ground station). The output of this software system are about 15 hardcopy sheets, which contain plots of instrument health parameters (ancillary data in the GOME source packet) over the time period of 26 hours, a listing of anomalies detected (e.g. data gaps and overlaps, anomalous flags etc.) and images providing quick checks on the acquisition and coverage (plot of ground tracks on the world map) and meaningful detector readouts (from the appearance of the images). All these plots are inspected and analysed daily by an operator and a short summary is sent via e-mail to the people in charge at ESA/ESRIN.

The two graphs below show an example of the plotting of GOME instrument health parameters and the first page of an anomaly log for March 10 1997.



First Product : 09-MAR-1997 23:15:33.855 : ORBIT : 9861.1437

Last Product : 10-MAR-1997 22:54:00.431 : ORBIT : 9875.2437

Total Products Processed : 52690

Day : 69

Page : 12

GAP	: 00:13:32.710 - 00:13:35.710 :	1 packet missing AT GATINEAU
GAP	: 00:42:22.382 - 00:52:28.441 :	403 packets missing AT GATINEAU
GAP	: 00:52:28.441 - 00:52:58.445 :	19 packets missing AT GATINEAU
DUPLICATE	: 00:52:58.445 - 01:01:47.999 :	354 packets twice AT GATINEAU
GAP	: 01:01:47.999 - 01:02:30.003 :	27 packets missing AT GATINEAU
DUPLICATE	: 02:21:42.484 - 02:29:41.035 :	320 packets twice AT GATINEAU
GAP	: 02:29:41.035 - 02:29:44.034 :	1 packet missing AT GATINEAU
DUPLICATE	: 02:29:44.034 - 02:42:29.113 :	511 packets twice AT GATINEAU
GAP + WRAP	: 04:21:22.203 - 06:04:27.333 :	4122 packets missing BETWEEN GATINEAU & KIRUNA
GAP	: 06:23:21.454 - 06:25:42.469 :	93 packets missing AT KIRUNA
GAP	: 06:27:36.481 - 06:27:39.481 :	1 packet missing AT KIRUNA
GAP	: 07:41:35.419 - 07:43:29.430 :	75 packets missing AT KIRUNA
GAP	: 17:55:27.131 - 17:55:30.132 :	1 packet missing AT KIRUNA
GAP	: 19:18:38.132 - 19:18:41.132 :	1 packet missing AT KIRUNA
GAP	: 21:19:38.864 - 21:21:32.876 :	75 packets missing AT KIRUNA
GAP	: 22:31:46.798 - 22:37:21.333 :	222 packets missing AT KIRUNA

Figure 2: First page of the GOME Daily Reports Anomaly Log (date: 10/03/97) - the gap over 4000 missing products indicates the missing orbit from Prince Albert ground station

The **ERGO** (Extended RASCALS for GOME - developed by the companies Dornier and SRON) software system gives the possibility to analyse all GOME raw data products (EGOC and EGOI) arriving at the Product Control Service. Quality assurance parameters and the instrument modes are routinely monitored and stored for each orbit into a database. For calibration measurements (sun and monthly calibration sequences) reports are created in an automated way. Interactive tools enable on the one hand detailed investigations on anomalies found and on the other hand by the inspection of the database content long term trend analysis of instrument performance parameters (e.g. diffuser plate reflectivity, detector noise etc.). A tool to plot selected parameters over three days on the world map lead to the invention of GOME Quick-Look Images which were implemented into the GOME Daily Reports for operational generation.

The two graphs below should demonstrate the main principles of this software tool: to investigate problems down to single product level and to perform trend analysis of specific parameters over the whole instrument life-time.

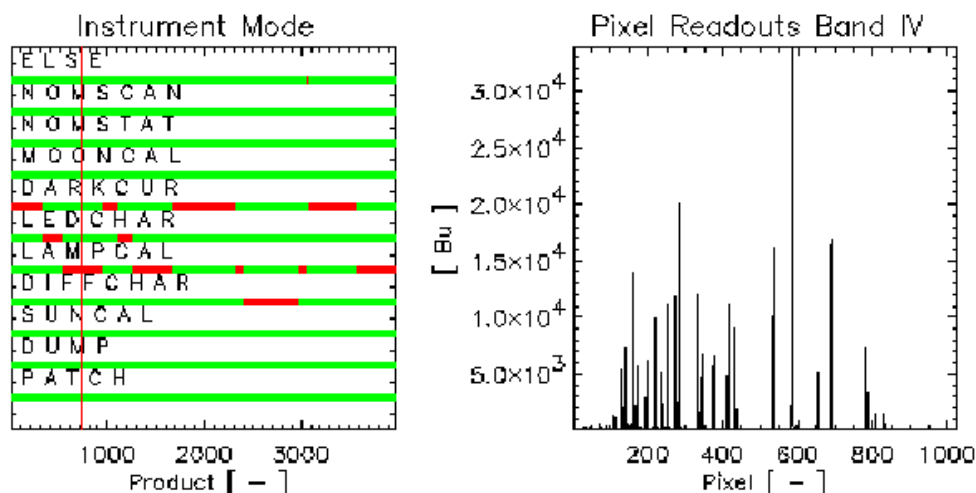


Figure 3: ERGO Interactive Analysis plot - EGOI Analysis: The bar-chart shows the GOME instrument modes during an orbit where monthly calibration is performed - the red colour indicates the actual mode. The second plot shows the readouts of detector 4 for a single product during wavelength calibration mode - the different emission lines of the calibration lamp can be clearly seen (date: 28/06/96).

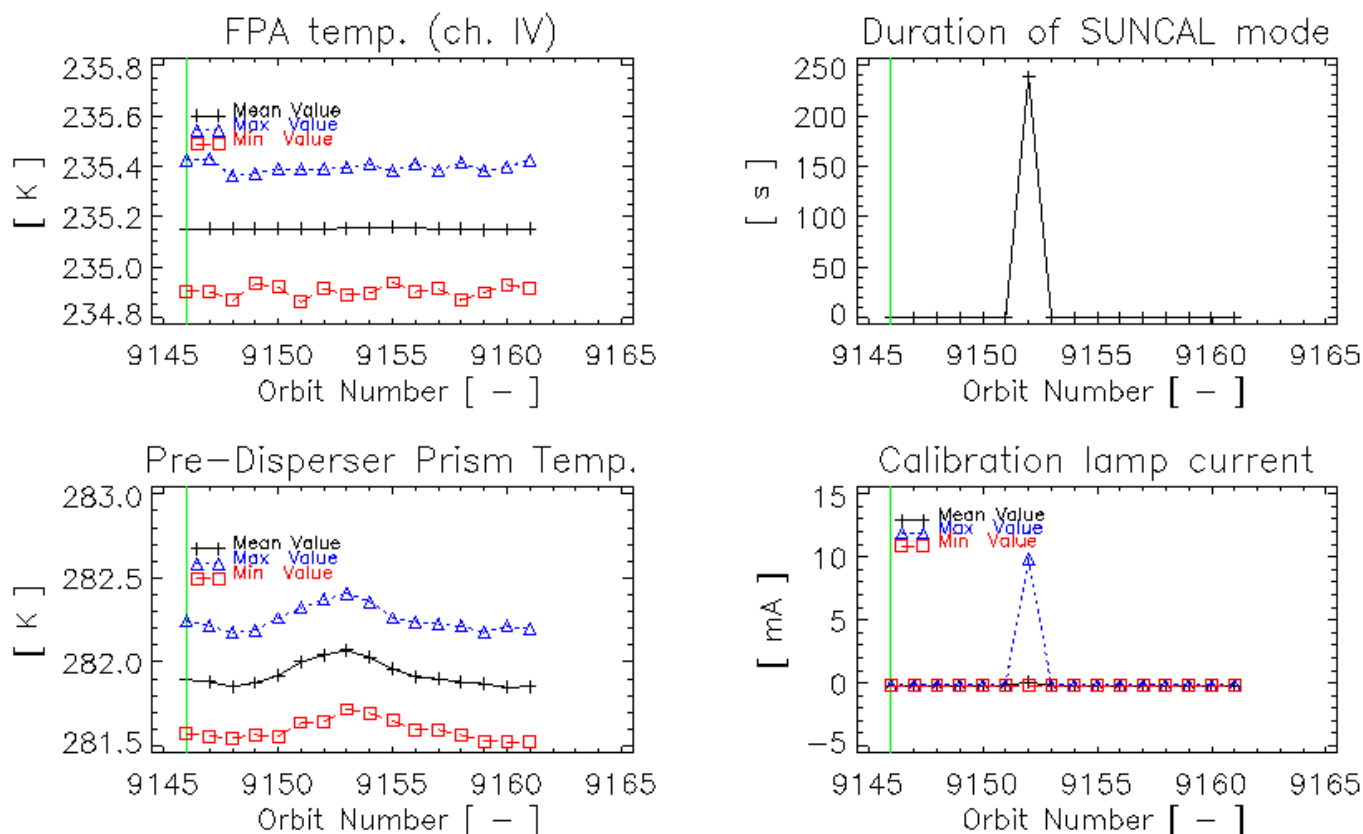


Figure 4: ERGO Interactive Analysis plot - Inspection of the database content: Some parameters are plotted to illustrate nominal GOME instrument performance over one day: a stable detector temperature, the execution of the daily sun calibration, the change of the temperature of the key optical element due to sun illumination and switch on of the calibration lamp (in connection to the sun calibration) can be seen (date: 19/01/97).

Information Operationally Provided to Users <http://earth.esrin.esa.it/eeo4.102>

The analysis of the Daily Reports is combined with the ERGO database content into weekly, monthly, and yearly reports.

Following information on GOME instrument performance is provided to users:

**On a daily basis - GOME Quick-Look Images** (using uncalibrated raw data) provide information about coverage over one day (except the orbit acquired at Prince Albert ground station) and nominal detector performance (by the appearance of the images).

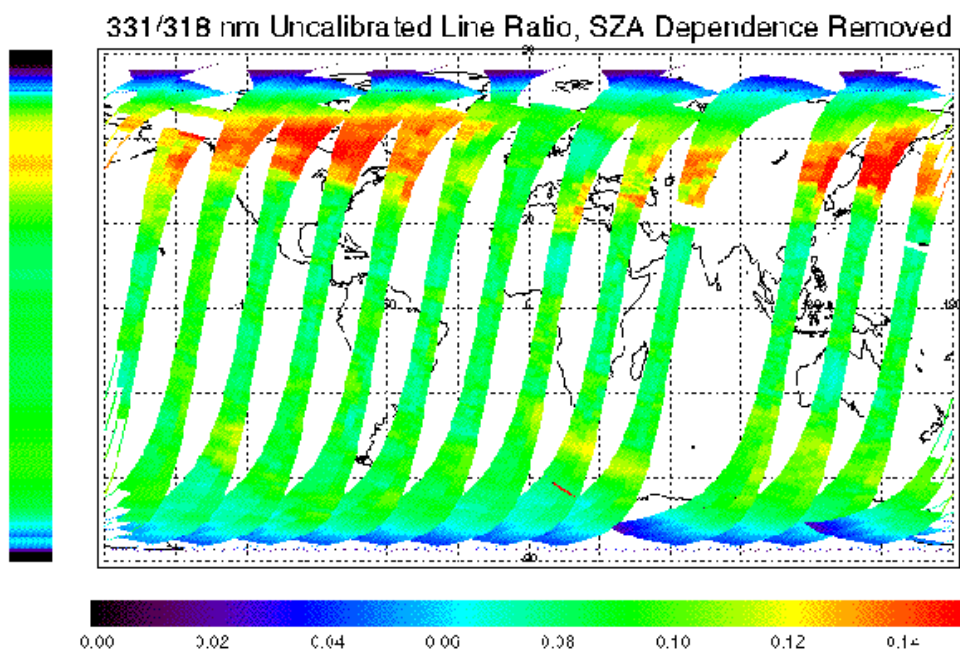


Figure 5: Ozone Line Ratio - gives a relative indication of the global ozone field by ratioing the intensity received in the ozone lines around 331nm and 318nm, and removing dependence on the solar zenith angle (SZA). Normal features which can be seen include the mid-latitude maxima belts around 60 degrees and the Equatorial minimum. Data are omitted whenever the SZA exceeds 75 degrees (date: 10/03/97).

Uncalibrated PMDs as RGB Signal

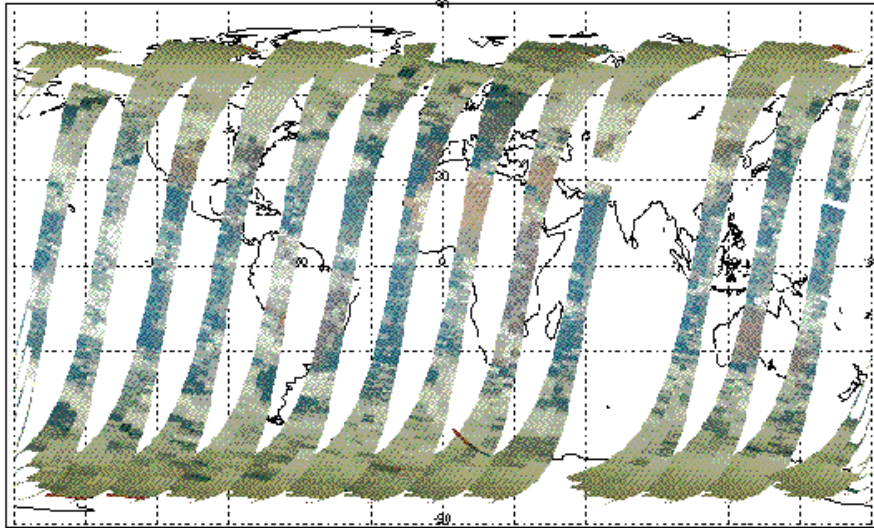


Figure 6: PMD Image - is generated by combining the data from GOME's Polarisation Measurement Devices (PMDs), which give broad band sampling of the Earthshine radiance at wavelengths approximately corresponding to red (PMD3), green (PMD2) and blue (PMD1). On this image the outline of continents can clearly be seen, along with clouds particularly for latitudes less than around 60 degrees. Above this latitude it starts to become very difficult to distinguish cloud features from ice (date: 10/03/97).

780/665 nm Uncalibrated Line Ratio Log 10

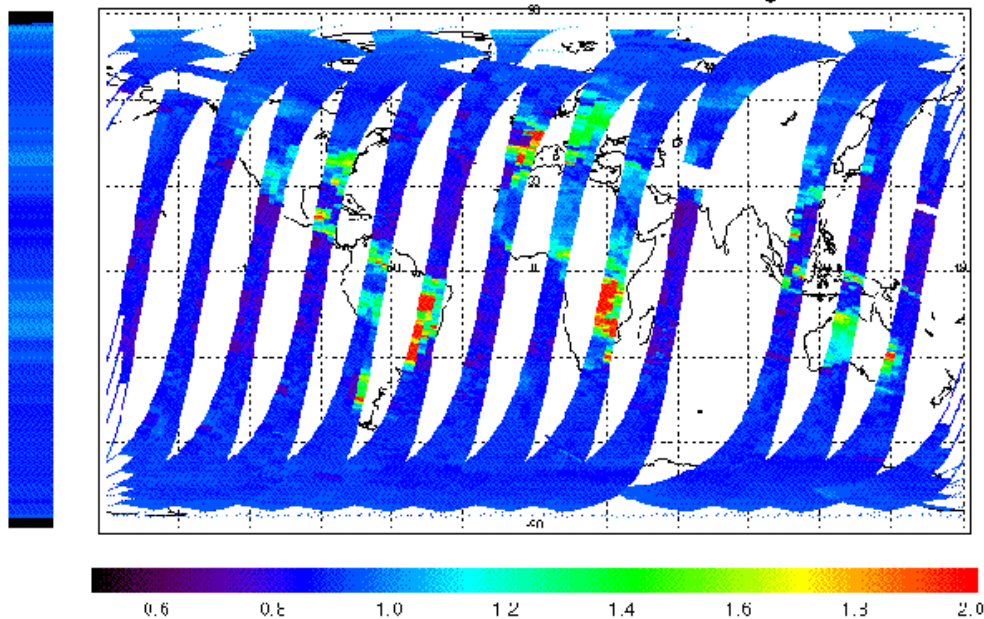


Figure 7: NDVI (Vegetation Index) Image - shows a normalized difference vegetation index, obtained by taking the logarithm after ratioing the data from a chlorophyll line at 665nm with a window at 780nm. On this plot areas of high vegetation stand out clearly, such as the heavily forested regions of South America and Africa (date: 10/03/97).

**On a weekly basis - Weekly Reports** summarize in simple tables the GOME instrument performance over one week. Following daily measurements are performed during nominal operations: dark current, nominal scanning, polar view measurements, and sun calibration (including specific dark current and calibration lamp measurements).

**Draft report based on analysis of EGOI data using the Daily Reports and ERGO software system of the PCS**

**GOME Operations during 23 February – 01 March 1997**

Date	operations	remark
23/02/97	nominal	start of sun calibration : 10:41:40.61
24/02/97	nominal	start of sun calibration : 10:10:01.07
25/02/97	nominal	start of sun calibration : 12:59:28.73
26/02/97	nominal	start of sun calibration : 12:27:43.20
27/02/97	nominal	start of sun calibration : 11:55:57.66
28/02/97	nominal monthly calibration performed	start of calibration sequence: ~ 13:14  end of calibration sequence: ~ 22:58  start of sun calibration : 11:24:12.12
01/03/97	nominal	start of sun calibration : 10:52:32.55

**Anomalies:**

single event upsets (SEU): none

*Figure 8: First table of a GOME Weekly Report specifying instrument performance on a daily basis.*

**On a monthly basis - Monthly Reports** replace the weekly reports and summarize GOME instrument performance over one month.

**On a yearly basis - Yearly Anomaly Reports** list patches of the on-board software and anomalies like single event upsets (changes in the on-board software due to radiation impacts), datagaps, cooler switchings, timeline interruptions, and others over one year.

## ANOMALIES (01.01.96 – 31.12.96)

### [About GOME Performance](#)

single event upsets:

Date	reason
17/04/96	SEU in latch up counter caused an automatic switch off by the ATSR
30/04/96	as above
05/05/96	as above
29/10/96	on-board software problem (cooler switching)
09/12/96	on-board memory problem
28/12/96	SEU in latch up counter caused an automatic switch off by the ATSR
29/12/96	on-board software problem (no setting of specific flags)

patches of the on-board software

uplink date	description
11/03/96	"non critical" patches to convert RAM memory image to version F'5. As uplink was not successful, the patches were not applied to the target RAM.
11/03/96	See above comments
12/03/96	See above comments
12/03/96	"critical" patches for (completing) conversion of RAM memory image to version F'5
15/03/96	See above comments
15/03/96	See above comments
18/03/96	"non critical" patches for conversion of EEPROM memory image to version F'5
18/03/96	"critical" patches for (completing) conversion of EEPROM memory image to version F'5

*Figure 9: First two tables of the GOME Yearly Anomaly Report for the year 1996.*

### [ESA Working Group on GOME Instrument Performance Monitoring](#)

A workshop on GOME instrument performance monitoring was held on Sep. 11-12 1996 at ESRIN. The goal of this workshop was to exchange and discuss results found on this issue and to make recommendations for change requests to the GOME Data Processor at D-PAF.

Following Institutions participated in this workshop:

- ESA/ESTEC on diffuser reflectivity and wavelength calibration
- ESA/ESRIN on diffuser reflectivity, straylight, and Mg II index
- DLR on the improvement of the pre-flight calibration data
- IASB on radiometric instrument stability and Mg II index
- KNMI on investigations on the development of a GOME FD product by using EGOI products
- SRON on the usage of moon measurements to study instrument degradation
- TPD on diffuser reflectivity
- University Bremen on wavelength calibration, Mg II index, and radiometric corrections by using polarisation measurements

The major results of this workshop:

- Instrument degradation takes place in the UV part of the spectrum.
- New/improved algorithms were found for wavelength calibration.
- The diffuser reflectivity was found to be stable for the channel 2-4.
- The GOME Mg II index is sensitive to cooler switchings due to the change of the ice layer on the detectors.
- New results were found on the straylight corrections scheme used in the GOME Data Processor at D-PAF.
- Gaps were identified in the geolocation information provided for GOME higher level products.

In the meantime work was going on and following presentations/demos are given at the 3rd ERS symposium related to GOME instrument performance:  
<http://florence97.ers-symposium.org:80/>



#### **Presentations:**

David Pemberton on GOME diffuser reflectivity analysis

Kelly Chance on GOME wavelength calibration using solar and atmospheric spectra

Philippe Peeters on GOME solar irradiance validation using UARS SOLSTICE data

#### **Posters:**

Ilse Aben on First results on GOME Breadboard measurements on vacuum characteristics and atmospheric radiation (Gobelin project)

Marcel Dobber on GOME Moon measurements (including instrument characterisation and moon albedo)

Rob Koopman on Analysis of GOME Stray light

The next workshop is planned for the end of May 1997 at ESA/ESRIN.

#### **Conclusions**

**Information about GOME instrument performance has to be regularly given to users and the processing facility to ease the use of the products and the processing.**

**Long-term interaction with users and scientists is essential.**

**Findings which effect the data processing have to be included into the processing chain.**

**Useful experience is gained for Quality Assurance and Long Loop Sensor Performance on future missions.**

#### **Acknowledgements**

All activities on GOME instrument performance monitoring were done under the supervision of M. Doherty. I would like to thank him for his helpful advice.

#### **References**

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