Rosemary Munro¹, Craig Anderson¹, Jörg Callies², Enrico Corpaccioli², Michael Eisinger², Rūdiger Lang¹, Alain Lefebvre², Yakov Livschitz¹, Abelardo Pérez Albiñana¹

(1) EUMETSAT (2) ESTEC

ESA Atmospheric Science Conference, ESA-ESRIN, Frascati, 8–12 May 2006
Overview

- Mission context
- Instrument
- Calibration
- Commissioning
- Data processing, products, dissemination

Important changes GOME-2 wrt GOME-1 highlighted in yellow.
**EPS/MetOp mission**

- Series of three polar-orbiting satellites for operational meteorology and climate monitoring

- European element of EUM/NOAA Initial Joint Polar System
  US: NOAA N/N’

- Orbit: sun-synchronous, **09:30h** (descending node), repeat cycle 412 orbits / 29 days

- ESA: Development of MetOp-1
  EUMETSAT: Metop-2/3, launch, ground segment, operations

- Main instruments: IASI, ASCAT, GOME-2, GRAS, AVHRR, ATOVS = HIRS + AMSU-A + MHS
MetOp during final assembly
# EPS/MetOp calendar

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tr>
<td>1992</td>
<td>POEM mission separated into Envisat and MetOp</td>
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<tr>
<td>1998</td>
<td>MetOp phase C/D kickoff</td>
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<td>March 2006</td>
<td>Last MetOp-A system test</td>
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<td></td>
<td>Baikonur Cosmodrome Readiness Review</td>
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<td>Launch &amp; Operations Readiness Review</td>
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<td>April 2006</td>
<td>MetOp-A shipment to Baikonur</td>
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<td>17 July 2006</td>
<td><strong>MetOp-A launch!</strong></td>
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<tr>
<td>December 2010</td>
<td>MetOp-B launch</td>
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<tr>
<td>June 2015</td>
<td>MetOp-C launch</td>
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</table>
Soyuz - the MetOp launcher is ready
## GOME-2 instrument overview

<table>
<thead>
<tr>
<th><strong>Principle</strong></th>
<th>nadir-scanning UV/VIS grating spectrometer</th>
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<tbody>
<tr>
<td><strong>Wavelength range</strong></td>
<td>240–790 nm in 4 main channels</td>
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<tr>
<td></td>
<td>300–800 nm in 2 polarisation channels (s/p)</td>
</tr>
<tr>
<td><strong>Detectors</strong></td>
<td>1024-element Reticon linear diode arrays</td>
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<tr>
<td><strong>Readout time</strong></td>
<td>46.875 ms (complete array)</td>
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<td></td>
<td>(1/2)</td>
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<tr>
<td><strong>Spectral sampling</strong></td>
<td>0.12–0.21 nm (main channels)</td>
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<td><strong>Spectral resolution</strong></td>
<td>FWHM 0.26–0.51 nm (main channels)</td>
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<tr>
<td><strong>Swath width</strong></td>
<td>Default 1920 km</td>
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<tr>
<td><strong>Swath type</strong></td>
<td>Earth-curvature compensating</td>
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<tr>
<td><strong>Min effective IT</strong></td>
<td>187.5 ms</td>
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<td>(1/8)</td>
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<tr>
<td><strong>Spatial resolution</strong></td>
<td>Default 80 x 40 km²</td>
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<td>(1/4)</td>
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<tr>
<td><strong>Internal calibration</strong></td>
<td>LED, Spectral lamp (PtCrNeAr), White lamp</td>
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<tr>
<td><strong>Sun diffuser</strong></td>
<td>Quartz quasi-volume (DOAS!)</td>
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<tr>
<td><strong>Data rate</strong></td>
<td>400 kbit/s or 300 MB/orbit</td>
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<td></td>
<td>(*10)</td>
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</table>
GOME-2 zenith sky spectrum

GOME-2 FM3 zenith sky spectrum

TNO-TPD Delft (NL)
5 Sep 2003
Main channels
Dark signal corrected

Signal [BU/s]

Wavelength [nm]
GOME-2 instrument: other improvements

- Polarisation measured in 15 programmable spectral bands per channel, default IT 23.4 ms (16 per main channel readout)

- Reduced polarisation sensitivity $\eta$

- Reduced straylight levels

- Dichroic filter in channels 3/4: $\eta$ spectral structures reduced, coating hardened for improved stability

- Analog to Digital conversion close to detectors: cross-talk gone

- Reduced sensitivity to Single Event Upsets (automatic memory refresh)
Mostly flight-representative conditions:
thermal vacuum, optical bench temperatures -5, +5, +15°C.
Exception: angular dependencies in ambient

Key parameters:

- Absolute (ir)radiance response
- Polarisation sensitivity
- Straylight characteristics
- Ozone/NO₂ absorption cross sections (U Bremen CATGAS)
- Instrument slit function (evaluated by RAL)
GOME-2 in-orbit verification

In-orbit verification (ESA) – first 8 weeks after launch

- Verify compliance to requirements (functional/performance)

- Compare pre-flight/in-flight performance

- IOV specific operations
GOME-2 in-flight calibration

• **Daily** calibration
  - sun calibration
  - spectral calibration
  - dark signal characterisation
  - white light source characterisation

• **Monthly** calibration
  - spectral calibration
  - diffuser monitoring
  - engineering parameters

• **Moon** calibration
GOME-2 routine operations

- On-board timelines controlling sequence of instrument modes
- One timeline per orbit
- <10 different timelines needed for routine operations
- Similar to GOME-1 operations, including polar and narrow swaths, and lunar “calibrations”
- Timelines synchronised with orbit repeat cycle
### GOME-2 timeline planning per 412/29 repeat cycle. Version 1.0, 1 March 2005

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- **D** Daily calibration (incl. Sun mode)
- **M** Monthly calibration (incl. LED, WLS, SLS, SLS over diffuser modes)
- **N** Narrow swath (320 km)
- **P** Polar (north/south, overrides nominal swath if used)
- **S** Nadir static
- **X** Nominal swath (1920 km)
GOME-2 data processing

Data acquisition

MetOp
EPS CGS EUMETSAT
Ozone Monitoring SAF
& Scientific data users

NRT level 0-1 processing

Level 1b data

NRT level 1-2 processing

Ozone Monitoring SAF

Offline processing

Other products

Level 1b data

Raw data

0 135 min 180 min
time

NRT products
(ozone, UV, aerosols...)

Level 1b data

Other products
## GOME-2 operational processing overview

<table>
<thead>
<tr>
<th>Data reception</th>
<th>EPS ground station in Longyearbyen, Svalbard</th>
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<tbody>
<tr>
<td><strong>Level 0 to 1</strong></td>
<td>Near-real time (NRT) processing, dissemination, archiving at EPS Core Ground Segment at EUM</td>
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<tr>
<td><strong>Level 1 to 2</strong></td>
<td>NRT and offline processing at Ozone SAF institutes. Dissemination and archiving at EUM</td>
</tr>
<tr>
<td><strong>Timeliness</strong></td>
<td>2h 15min from sensing for level 1 products</td>
</tr>
<tr>
<td></td>
<td>3h from sensing for level 2 products</td>
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<tr>
<td><strong>Data formats</strong></td>
<td>Generic EPS binary format for level 1 products</td>
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<td>(converter to HDF5 available)</td>
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<tr>
<td></td>
<td>HDF5 for level 2 products</td>
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GOME-2 level 0/1 processing & products

- **Products**
  - Level 0 (300 MB/orbit)
    - orbit state vectors
    - time correlation
    - raw instrument data
  - Level 1a (250 MB/orbit)
    - Müller matrix
    - in-flight cal data
    - geolocation
    - polarisation
    - raw instrument data
  - Level 1b (1 GB/orbit)
    - solar irradiance
    - geolocation
    - polarisation
    - earth radiance
    - cloud parameters

- **Processing**
  - Level 0 to 1a
    - determine mode
    - Müller matrix
    - in-flight cal data
    - geolocation
    - polarisation
  - Level 1a to 1b
    - calibrate radiance
    - determine cloud parameters

- **Auxiliary data**
  - pre-flight calibration data
  - in-flight calibration data
  - processor configuration
  - databases for cloud algorithm
  - topography: land/sea elevation
  - solar irradiance

- **Processing steps**
  - to level 1 to 2 processing
GOME-2 level 2 SAF operational products

- Ozone profiles (KNMI) (NRT & offline)

- Ozone and trace gas total columns (DLR) (NRT & offline)
  Continuity with GOME-1 time series

- Aerosol optical depth and Absorbing aerosol index (KNMI) (NRT)

- Clear-sky UV (DMI) (NRT)

- UV with clouds (FMI) (offline)
GOME-2 calibration & validation

- Ensure products satisfy EPS end user requirements and continuously improve their quality
- Instrument & data product long-term monitoring
- Level 1 verification, confidence checking & validation
- Feedback from level 2 required for full level 1 validation
- O3MSAF responsible for validation of operational level 2 products
- Nominal operations
GOME-2 calibration & validation milestones

- **Launch** 17th July 2006
- **Release from GOME-2 IOV** mid-September 2006
- **Verified** level 1b product mid-November 2006
- **Commissioning hand-over** review mid-January 2007
- **Validation continues** for the lifetime
GOME-2 instrument monitoring

- **House-keeping data**
  - usage statistics, thermal performance, electrical performance, scanner performance

- **Internal calibration sources**
  - internal light sources, diffuser reflectivity

- **In-flight calibration parameters**
  - dark signals, PPG, spectral stability, etalon, throughput (solar)

- **Radiance & polarisation**
  - throughput (earthshine)
    - stokes fractions (solar, special earth viewing)
    - earthshine scanning, FPA and PMD consistency
GOME-2 product quality monitoring

- Basic quality information
- Quality flags related to geolocation
  - SAA, sun-glint, rainbow
- Counts of non-nominal temperatures
  - detector, pre-disperser, radiator
- In-flight calibration data quality
  - missing data, threshold checks, back-up algorithms
    fitting checks, missing/bad Stokes fractions
- Quick-look parameters
  - PMD false colour images, ozone line ratios etc
GOME-2 level 1 verification, confidence checking & validation

- **Geolocation**
  - simple checks, PMD false colour images

- **Wavelength calibration**
  - alternative algorithm using Fraunhofer lines

- **Stokes fractions**
  - vector RTM

- **Cloud parameters**
  - ISCCP and AVHRR data

- **Sun Mean Reference Spectrum**
  - other reference spectra, other satellite measurements

- **Earthshine spectra & albedo**
  - confidence checking, other satellite measurements, RTM simulations
GOME-2 data availability

EPS global near-real time (NRT) products (level 1b, level 2) distributed via EUMETCAST (telecom satellite link)

Required: PC + Digital Video Broadcast (DVB) card connected to a satellite antenna + client software obtainable from EUMETSAT user services.

Archived products from the EUMETSAT Unified Meteorological Archive and Retrieval Facility (UMARF) available on request (various delivery media).

NRT and archived data free of charge for PIs of EPS/MetOp Research Announcement of Opportunity.

Check EUMETSAT web page for useful tools and libraries.
Further reading

EUMETSAT homepage: www.eumetsat.int


- GOME-2 Products Guide (high-level introduction)
- GOME-2 Level 1 Product Generation Specification
- GOME-2 Level 1 Product Format Specification

Ozone/Atmospheric Chemistry SAF documentation