Chapter 3

Global Ozone Monitoring Experiment (GOME)

3.1 The European research satellite ERS-2

On April, 21, 1995 the second European research satellite (ERS-2) was launched as the successor of ERS-1. Besides the GOME instrument ERS-2 is equipped with several further instruments for the investigation of the earth's environment. The payload for ERS-2 consists of the following instruments (see Figure 3.1)

A) The Active Microwave Instrument (AMI) measures the microwave reflection on the earth's surface for the detection of wind and wave fields at the surface of the oceans.

B) The Radar Altimeter (RA) is a nadir pointing pulse-RADAR measuring the echoes from ocean and ice surfaces for the determination of the earth's topography.

C) The Along-Track Scanning Radiometer (ATSR) consists of an InfraRed Radiometer (IRR) and a MicroWave Sounder (MWS). They measure the sea surface temperature and the total water content of the atmosphere.

D) The Precise Range and Range Rate Equipment (PRARE) is an all-weather microwave ranging system for orbit determination and geodetic applications.

During 1988, when the ESA started the preparatory work for ERS-2, it was felt necessary to complement this equipment with an instrumentation which could contribute to issues such as global warming or ozone depletion.

Among the proposals reached was one of John Burrows and P. Crutzen for a minor version of the passive UV/vis spectrometer 'SCIAMACHY' (SCanning Imaging Absorption Spectrometer for Atmospheric CHartographY) which is now part of the ENVISAT project [Burrows et al., 1988; Bovensmann and Burrows, 1997]. This instrument was added to the scheduled payload of ERS-2. It was called the 'Global Ozone Monitoring Experiment', GOME.

The ERS-2 satellite operates at an altitude of about 780 km. It flies at a sun-synchronous polar orbit with an equator crossing time around local noon.

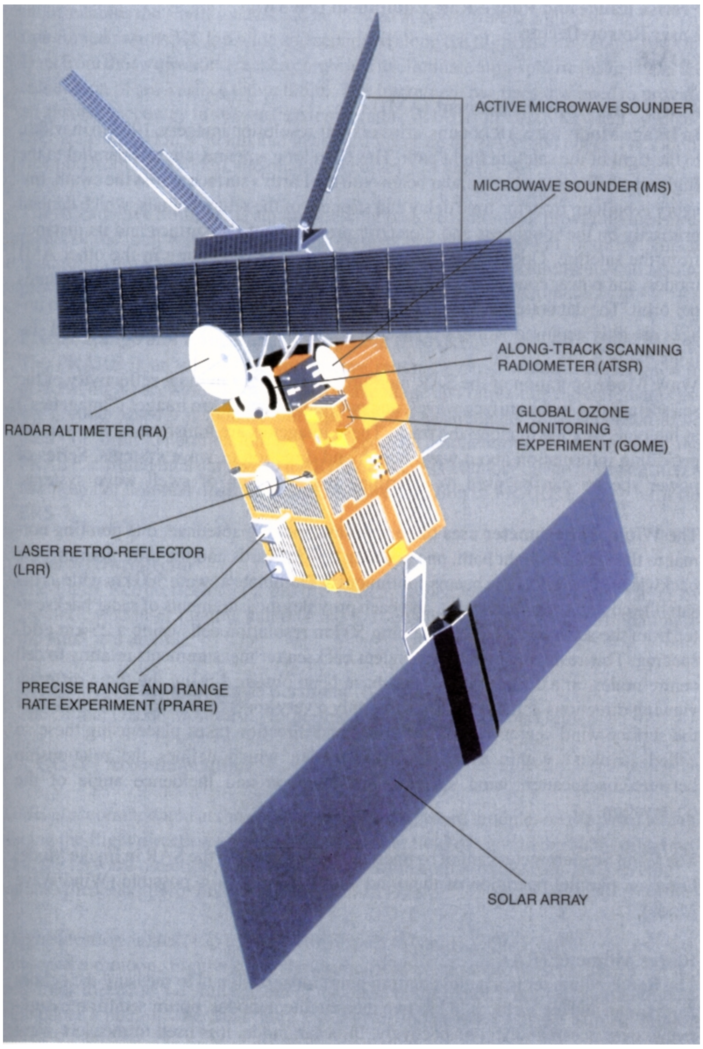

Figure 3.1 ERS-2 satellite (adapted from [ESA, 1995]).

3.2 The GOME instrument

GOME is a passive UV/vis spectrometer which measures the light reflected from the Earth's surface or scattered from the atmosphere. The size of the instrument is about 60 x 30 x 20 cm^3, its weight about 30 kg and it consumes an electrical power of about 30 W (see also [ESA, 1995]).

GOME consists of four separate channels (see Figure 3.2) covering the spectral range from 240 to 790 nm with a moderate spectral resolution of 0.17 to 0.33 nm (FWHM) (see Table 3.1).

Channel	Spectral range [nm]	Spectral resolution (FWHM) [nm]
1	240 - 316	0.2
2	311 - 405	0.17
3	405 - 611	0.29
4	595 - 793	0.33

Table 3.1 Spectral properties of the different channels of GOME

Figure 3.2 shows a scheme of GOME as well as a photograph of the open instrument. The light enters the GOME instrument via a scanning mirror and two telescope mirrors, then it is separated into the wavelength intervals of the different channels by prisms and beam splitters (see Figure 3.2). For the final dispersion of the light four gratings are used. The spectra are sampled by photodiode arrays of 1024 photodiodes each.

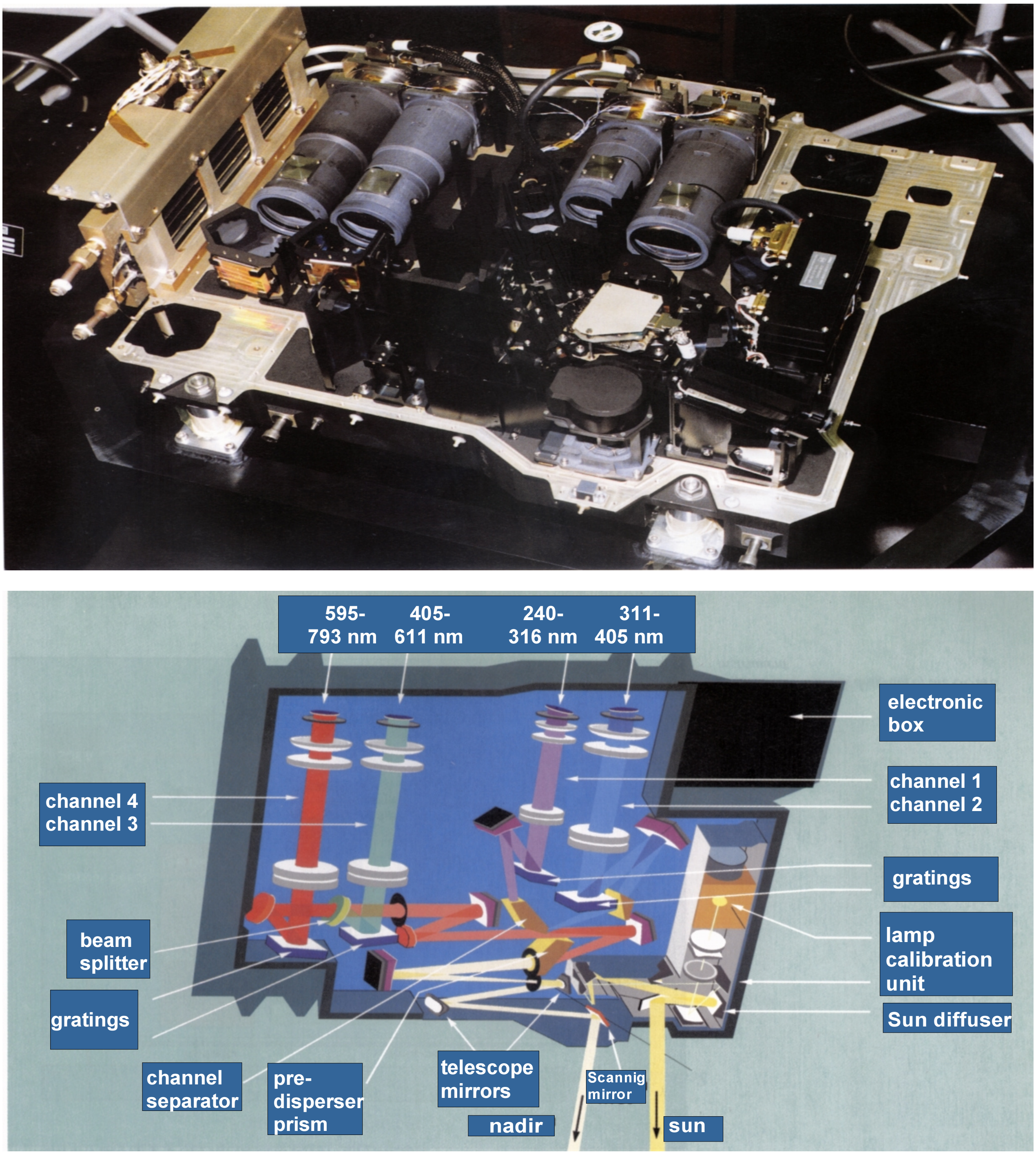

Figure 3.2 Top: Photograph of the open instrument. Bottom: Scheme of the GOME spectrometer (adapted from [ESA, 1995]).

Besides the measurement of the light reflected from the Earth GOME also performs observations of direct sun and moon light. The moon light is measured via the canning mirror, for the sun measurements the light is measured via a diffuser plate.
Also included in the instrument is a calibration unit consisting of a Pt-Cr-Ne-lamp. The emission lines of these elements are distributed over the whole wavelength range of the GOME instrument.

3.3 Viewing geometry and coverage of the Earth's surface

GOME is designed as a nadir viewing instrument. The light enters the spectrometer via a scanning mirror which moves perpendicularly (mainly from east to west) to the flight direction (see Figure 3.3). During the 'pre-scan' of the scanning mirror GOME measures three individual spectra with an integration time of 1.5 s each. The east-west extension of the observed area for the single measurements is about 320 km (the total east-west extension for the whole pre-scan of the mirror is about 960 km). The scanning mirror moves back within 1.5 s covering an east-west extension at the Earth's surface of about 960 km with a single spectrum. The speed of the satellite along its orbit is about 6.7 km/s.
This leads to an area of about 320 x 40 km² for the pre scan ground pixel and of about 960 x 40 km² for the back-scan pixel (see Figure 3.3).
Due to the reduced intensities during sunset and sunrise the integration time of GOME is set to 6 s instead of 4 x 1.5 s for solar zenith angles[1] (SZA) larger than 85° resulting in a ground pixel size of 960 x 40 km².
Although the repeat cycle of the satellite is 35 days a global coverage is already achieved after 3 days. Towards higher latitudes the overlap of the area observed by GOME for following satellite orbits increases. For example polewards of about 75° the earth's surface is totally covered by GOME within one day.

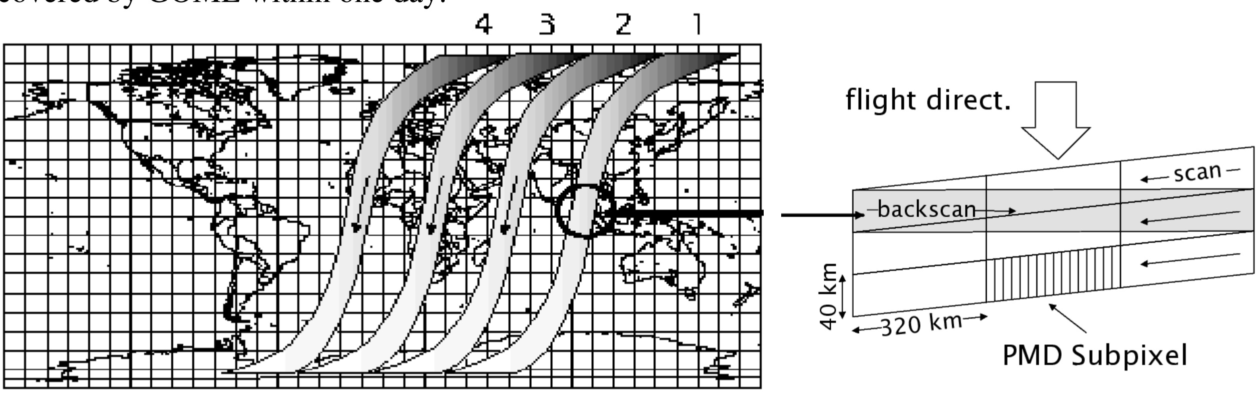

Figure 3.3 Left: Area at the Earth's surface covered by GOME measurements for following satellite orbits. Right: While GOME flies in north-south direction the scanning mirror of the instrument (see Figure 3.2) moves in east-west direction. During the pre-scan of the mirror 3 individual measurements are performed, during the back-scan, one measurement. Each of the pre-scan measurements covers an area of 320 x 40 km², the back-scan measurement, an area of about 960 x 40 km².

[1] The solar zenith angle is defined as the angle between the direction of the sun and the zenith (see Figure 5.16).

3.4 GOME products and data formats

The spectra measured by GOME are temporarily stored aboard the satellite and transmitted to the receiving stations several times a day.
These spectra contain the raw signal of the photodiode arrays (level 0 data). In order to derive radiometrically calibrated spectra (level 1 data) several corrections have to be applied to the level 1 data. These include a spectral calibration, a radiometric calibration, and a correction of the polarisation sensitivity of the instrument [ESA, 1995; ESA, 1996]. The resulting spectra are used as input data for the spectral analysis of the absorptions of the atmospheric trace gases (see section 4).
The operational GOME products also include higher level data such as vertical column densities of O_3 and NO_2 (level 2 data) [ESA, 1995].
Besides the four channels of the GOME spectrometer the instrument is additionally equipped with three so-called 'Polarisation Measurement Devices' (PMD, silicium photodiodes) which are sensitive to light over broad spectral ranges similar to the spectral ranges covered by the spectrometer channels (see Table 3.2). The PMDs are used to determine the degree of polarisation of the observed light [Aben et al., 1996; Stammes et al., 1997; Tanzi et al., 1998]. Since GOME is sensitive to the polarisation of the measured light this information is necessary for the radiometric calibration of the spectra.
Because of the broad spectral sensitivity of the PMDs they receive more light compared to an individual photodiode of the diode array detector. Thus the integration time of the PMDs is about 16 times shorter resulting in a much higher spatial resolution compared to the size of the ground pixels of the GOME spectrometer (see Figure 3.3). Thus the PMD measurements can be used in particular to detect the cloud coverage across one GOME ground pixel [Kurosu et al., 1997; Wenig, 1998]. In addition, from PMD data the albedo of the Earth's surface can be determined (with low spectral resolution) [Leue, 1999].

PMD	spectral range [nm]
1 (UV)	295 -397
2 (blue, green)	397 - 580
3 (red)	580 - 745

Table 3.2 Spectral ranges of the PMDs.