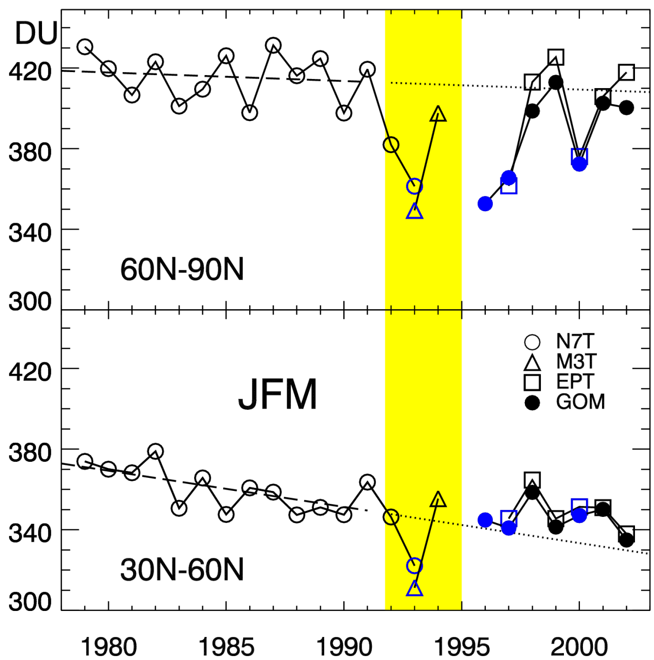
Technical Proposal in Response to ESA ITT AO4235

# GOTOCORD

## GOME Total Ozone Column Retrieval Development

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# Cover Page

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**Compliance Statement**
The requirements of the specification and/or work statement will be met by the tenderer. The tenderer explicitly states that the contract conditions are read, understood and accepted and that any sales conditions of his own do not apply.

Place/Date    Dr. Mark Weber

# Contents

***Figure caption for title graphics**. 1979–2002 Winter time series of total ozone zonal mean in northern hemispheric mid-latitudes (30°N-60°N) and polar region (60°N-90°N). In this graph all TOMS data from Nimbus-7 (N7T), Meteor-3 (M3T) and Earthprobe (EPT) have been combined with GOME data in 1996–2002 (GOM). Shaded region indicates the post Pinatubo period with enhanced stratospheric aerosol loading following the volcanic eruption in the Phillipines. Blue symbols indicate values for so-called cold arctic winter where extensive areas of polar stratospheric clouds existed. The linear regression lines are the fit to the pre-Pinatubo data (before 1991). A major issue of future ozone reasearch is the study on the dynamical and chemical contribution to decadal change within the next decades and its possible link with climate change issue. A prerequisite of future trend studies are high quality ozone data from various platforms in particular from satellites (from EU Commission Report Scientific Assessment on European Research in the Stratosphere 1996–2000, ISBN 92-894-1398-0, 2001).*

# Abstract

A novel total ozone retrieval algorithm is proposed to replace the standard DOAS (differential optical absorption spectroscopy) approach in current operational GOME retrieval. Using the weighting function approach the separation between slant column spectral fitting and airmass factor (AMF) calculation can be avoided. This weighting function method, called WF-DOAS, has been demonstrated to be applicable to near-infrared tracegas column retrieval for SCIAMACHY and has been adapted for total ozone retrieval in the near UV region. First results using this promising approach show significant improvement as compared against V2.7 GOME level 2 data. The processing of the GOME data will be achieved using look-up-tables of reference intensities, weighting functions, and Ring spectra using state-of-the-art radiative transfer models CDI (spherical) and SCIATRAN (pseudo-spherical). Particular attention will be placed on the most appropriate use of modeled Ring spectra, which show strong dependence on the ozone profile shape at large solar zenith angles. The inclusion of molecular Ring will be explicitly accounted for in the retrieval. In addition to the prototype development of the algorithm extensive validation using GOME reference orbits and the WOUDC Dobson/Brewer data will be carried out.

# 1 Introduction and Relevant Background

The GOME is the first European satellite experiment dedicated to global ozone measurements (Burrows *et al.*, 1999b) and after seven years of operation (1995–2002) provides a unique long-term dataset. Combined with the TOMS dataset the satellite data record now extends to 24 years starting in 1978. GOME covers part of the data gap between 1994 and 1996, where no TOMS was available. Uncertainties in the continuation of the long-term trend in the late nineties are partially caused by this data gap due to a possible bias between EP-TOMS (1996-present) and the earlier TOMS data record (before 1994) (WMO Report, 1999).

In 2005 the first of a series of new GOME instruments (GOME2 generation) will be launched on the METOP series continuing ozone long-term monitoring in the next two decades. With the recent failure of QuikTOMS, GOME along with EP-TOMS are currently the only global ozone measurements from space available at the moment. Both instruments show some sign of aging since early 2000 (Bramstedt *et al.*, 2002a). The current and future total ozone algorithms in use with GOME are applicable to SCIAMACHY (Bovensmann *et al.*, 1999) and OMI, so that the latter might be added to fill part of the data gap up to GOME2 if the data record of GOME and EP-TOMS cannot be extended to 2005.

The current GOME aboard ERS-2 plays a vital role in bridging the early satellite era (TOMS era) to the series of new platforms such as GOME2 and OMI. However, from various validation exercises there remain shortcomings in the current total ozone retrieval from GOME. In the standard DOAS approach the slant column density is first derived from a spectral fit to the logarithm of the sun-normalized radiance and conversion to vertical column densities are derived in a second step using airmass factors (AMF) calculated with radiative transfer models.

The seasonal variation observed in the differences to groundbased data (Lambert *et al.*, 1999; Lambert, 1995; Bramstedt *et al.*, 2002a) indicate problems with the airmass factor calculation in the GOME Data Processor (GDP) V2.7. In the most recent version 3.0 (not operational yet) an iterative AMF scheme with improved a-priori ozone profile climatology did not remove completely this seasonal variation [see ESA Users Consultation Meeting on Total Ozone, January 2002, J.C. Lambert, private communication]. There is still a need for further improvement.

In this study we propose a new total ozone algorithm, WF-DOAS (weighting function DOAS), which has been first demonstrated to be applicable to tracegas column retrieval in the near-infrared region of SCIAMACHY (Buchwitz *et al.*, 2000a). This algorithm has been adapted to UV retrieval of total ozone and first results seem to indicate its promising potential. In this study the WF-DOAS will be developed into a prototype quasi-operational data processor using look–up tables for most RTM quantities such as reference intensities, weighting functions, and Ring spectra. Particular emphasis is put on the use of the most appropriate Ring spectra by including the effect of molecular Ring. A cloud correction based either on the operational GOME Data Processor (GDP) ICFA algorithm (initial cloud fitting algorithm) or the FRESCO algorithm (Koelemeijer *et al.*, 2001) will be used. The ghost vertical column up to the cloud-top-pressure will be estimated from an updated ozone climatology, either TOMS V7 (Wellemeyer *et al.*, 1997) or TOMS V8 climatology [G. Labow, private communication].

The new algorithm will be validated using the GOME reference orbits and by comparing with Dobson/Brewer data from the WOUDC database (Hare and Fioletov, 1998) as described in Bramstedt *et al.* (2002a). The goal of this study is to provide a novel algorithm which maintains a 1% relative consistency in the GOME data over the lifespan of GOME.

# 2 Technical Proposal

## 2.1 Standard DOAS

Differential Optical Absorption Spectroscopy (DOAS) was developed for ground-based zenith-sky and long path measurements of atmospheric trace constituents Platt and Perner (1980). The GOME instrument launched in 1995 permits for the first time the DOAS method to be applied to space-borne observations (Burrows *et al.*, 1993, 1999b; GOME LVL2, 2000)

For space application of the DOAS algorithm to back-scattered measurements of upwelling radiances comprises of three steps. First the slant column density is obtained by fitting a superposition of molecular absorption cross-section spectrum and a polynomial to the measured intensity, i.e.

$$-\ln I^{mea}(\lambda) = \sum_{i}^{M} SCD_i \cdot \sigma_i(\lambda) + SCD_{Ring} \cdot \sigma_{Ring}(\lambda) + \sum_{k=0}^{n} a_k \lambda^k. \quad (1)$$

$I^{mea}(\lambda)$ is the measured sun-normalised radiance, $M$ denotes the number of different molecules that have to be considered in the selected wavelength range, $SCD_i$ are the molecular slant columns (fit parameters) and $\sigma_i$ are the altitude independent absorption cross-sections. The polynomial function serves as a high pass filter and accounts for all broadband effects, e.g., scattering by molecules, aerosols and clouds. The Ring effect which arises from Raman scattering is treated as an effective absorber.

In the second step the airmass factor (AMF) is used to convert the slant columns into vertical columns. The AMF has to be determined by radiative transfer calculations and it depends on several atmospheric parameters, such as sun-satellite geometry, surface albedo and ozone profile. As there is only one slant column per molecule for the entire fit window, there is only one AMF for this window. For optically thin atmospheres, the AMF is nearly wavelength independent. However, atmospheric ozone absorption between 325 - 335 nm is too strong and the AMF shows significant wavelength dependence, particularly, for large solar zenith angles.

The third step is a correction for cloud effects. Part of the ozone column below the cloud cannot be observed. In this case the obscured ghost vertical column is estimated using climatological values and has to be added to the retrieved column amount. In the current GDP (GOME Data Processor) Version 2.7, the oxygen-A-band transmittances are used to estimate the fractional cloud cover and cloud-top-height is derived from a cloud climatology (GOME LVL2, 2000).

## 2.2 Weighting Function DOAS (WF-DOAS)

### 2.2.1 Theory

The weighting function modified DOAS algorithm (WF-DOAS) has been developed for trace gas retrieval in the near-infrared spectral range measured by SCIAMACHY (Buchwitz *et al.*, 2000a). It explicitly accounts for both weak and strong absorption. Total column precisions have been estimated to be better than 1% for $H_2O$, $CO_2$, and $CH_4$, and better than 10% for $N_2O$ and CO for SCIAMACHY. However, the algorithm is not limited to a particular wavelength range and molecular line absorbers. It is directly transferable to ozone retrieval in the ultraviolet spectral range requiring only minor modifications.

The measured atmospheric optical depth is approximated by a Taylor expansion around the reference intensity plus a low-order polynomial. The total column information is obtained only from differential trace gas absorption structures as in case of standard DOAS. The polynomial $P_i$ accounts for all broadband contributions.

$$
\begin{aligned}
\ln I_i^{mea}\left(V^t, \vec{b}^t\right) \approx\; & \ln I_i^{mod}\left(\bar{V}, \bar{\vec{b}}\right) \\
& + \frac{\partial \ln I_i^{mod}}{\partial V}\Big|_{\bar{V}} \times (\hat{V} - \bar{V}) \\
& + \sum_{j=1}^{F} \frac{\partial \ln I_i^{mod}}{\partial b_j}\Big|_{\bar{b}_j} \times (\hat{b}_j - \bar{b}_j) \\
& + SCD_{Ring} \cdot \sigma_{i,Ring} \\
& + SCD_{usamp} \cdot \sigma_{i,usamp} \\
& + P_i
\end{aligned}
\qquad (2)
$$

$I^{mea}$ is the measured intensity and $I^{mod}$ the reference intensity, as provided by the radiative transfer model. Index $t$ denotes the true atmospheric state. The entire right-hand side of the equation has to be adjusted to the measured intensity (left-hand side) at all spectral points (index $i$) simultaneously. $\bar{V}$ is the reference ozone column matched to the reference intensity, and $\hat{V}$ the retrieved vertical column. $\vec{b}$ contains all other atmospheric and surface parameters, such as interfering trace gases, temperature or albedo. All model parameters are denoted by overbars ($\bar{\ }$), and all fit parameters are denoted by hats ($\hat{\ }$). The Ring effect ($\sigma_{i,Ring}$) and the under-sampling spectrum ($\sigma_{i,usamp}$) are treated as effective absorbers similar to the approach used in standard DOAS.

The main difference between the WF-DOAS algorithm and the standard DOAS algorithm is the use of wavelength dependent trace gas weighting functions instead of absorption cross-sections and air mass factors. Weighting functions (WF) describes the relative radiance change due to a vertical profile change assuming an altitude independent scaling factor $(WF = \frac{\partial I}{I} / \frac{\partial V}{V})$.

The need for an airmass factor conversion is eliminated in the new algorithm as the fit parameters are the vertical columns. By introducing additional terms in vector $\vec{b}$, the algorithm compensates atmospheric effects such as pressure and temperature. The unknown fit parameters are derived using a linear least-squares minimization:

$$||\vec{y} - \tilde{A}\vec{x}||^2 \rightarrow \text{min} \qquad \Longrightarrow \qquad \hat{\vec{x}} = \tilde{C}_x \tilde{A}^T \vec{y}.$$

Vector $\vec{x}$ contains the fit parameters $\bar{V}$, $\bar{b_j}$ and the polynomial coefficients. The weighting functions and the polynomial basis functions are contained in matrix $\tilde{A}$. $\vec{y}$ contains the difference between the logarithm of measured intensity and the reference intensity.

### 2.2.2 WF-DOAS algorithm

For the planned global total ozone retrieval from GOME data, a large set of reference spectra has to be built up, which must include nearly all possible atmospheric states. The radiance spectra and weighting functions are computed as a function of total ozone (profile shape), zonal band, solar zenith angle (SZA), line-of-sight (LOS), surface albedo $\alpha_s$, and altitude. The SCIATRAN code, an extension of the GOMETRAN++ radiative transfer model (Rozanov *et al.*, 1997), was used which enables altitude-resolved weighting functions to be determined quasi-analytically with only a negligible amount of additional computer effort (Rozanov *et al.*, 1998).

Table 1 gives an overview on the parameter space. Investigations have to be performed to show, whether the step-size of the various parameters in the LUT is sufficiently small. Each reference spectrum contains sun-normalized radiances, and weighting functions for $O_3$, $NO_2$, BrO, temperature, albedo, and pressure scaling in the spectral region 323 - 337 nm. Ozone and temperature profiles are taken from TOMS Version 7 climatology

Table 1: *Parameter space of the look-up-tables*

| Atmospheric Parameter | Min | Max | $\Delta$ | N |
|---|---|---|---|---|
| Total Ozone (high latitudes) | 125 DU | 575 DU | 50 DU | 10 |
| Total Ozone (mid latitudes) | 125 DU | 575 DU | 50 DU | 10 |
| Total Ozone (low latitudes) | 225 DU | 475 DU | 50 DU | 6 |
| Solar Zenith Angle | 15° | 90° | 5° if SZA $\leq$ 70°<br>1° if SZA $>$ 70° | 30 |
| Line-Of-Sight | -20° | 20° | 20° | 3 |
| Surface Albedo | 0.05 | 0.9 | 0.1 | 10 |
| Ground Altitude | 0 km | 3 km | 1 km | 4 |

which contains different profile shapes for three latitude belts (low, middle, and high) as a function of the total ozone column (Wellemeyer *et al.*, 1997).

In order to avoid time consuming online radiative transfer calculations, the WF-DOAS algorithm uses look-up-tables (LUTs) of all pre-calculated reference spectra.

For the present, the same spectral window (325–335 nm) as in GDP V2.70 is selected. Within this study several tests will be performed to optimize the spectral range.

Latitude, solar zenith angle $\theta$ and LOS are taken from the GOME level1 data header. Surface albedo is assumed to be the Lambertian Effective Reflectivity (LER) around 380 nm, which also accounts for the higher albedo due to clouds. In the iterative scheme, the first step is to find the nearest neighbor reference scenario. As a first guess the scenario which most closely matches the vertical ozone column derived from GDP V2.7 or V3.0 or alternatively from the TOMS V8 zonal mean climatology is selected. Linear interpolation between solar zenith angles and effective albedo is performed to obtain the closest reference.

After the spectral fitting the retrieved total ozone column is compared with that of the reference scenario and the fit is repeated if a reference vertical column is found which is closer to the retrieved value. A schematics of the algorithm is shown in Fig. 1.

In addition to ozone vertical column, $NO_2$ and BrO weighting functions, scalar temperature offset, and the effective albedo are fitted. An under-sampling correction spectrum as described by (Slijkhuis *et al.*, 1999) is also fitted. A *shift-and-squeeze* of individual spectra can be carried out to improve wavelength misregistration.

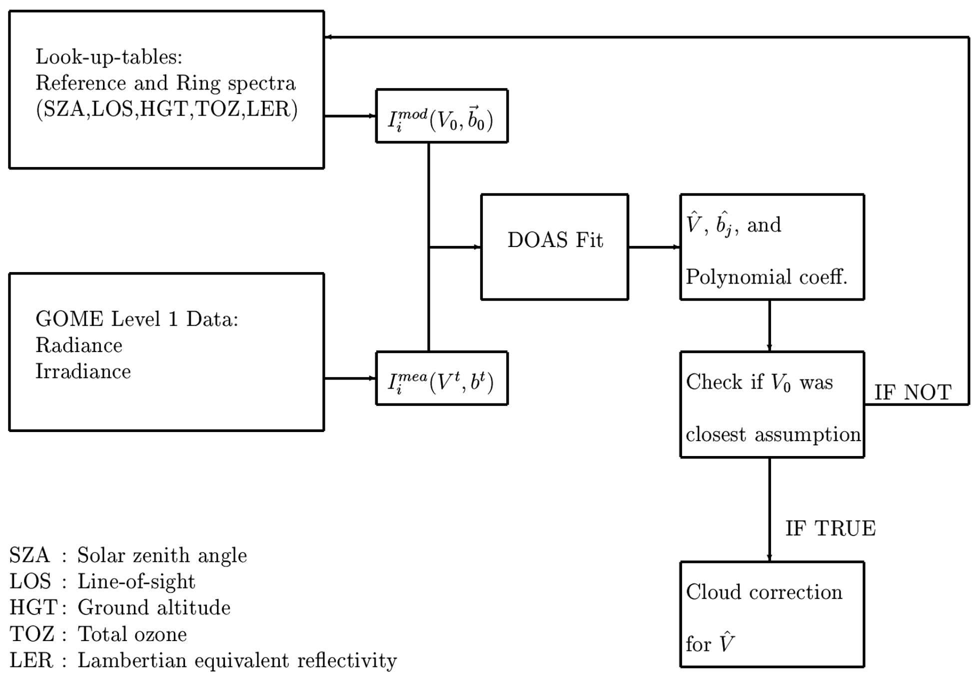


Figure 1: *Schematics of the iterative WF-DOAS scheme for total ozone*

## 2.3 Ring Effect

The depth of solar Fraunhofer lines in scattered light is less than those observed in direct sunlight. This fact, known as the Ring effect, has been discovered by Shefov (1959) and Grainger and Ring (1962). Several publication studied this effect and proposed that rotational Raman scattering provides the dominant contribution to the Ring effect (Burrows *et al.*, 1996; Kattawar *et al.*, 1981; Fish and Jones, 1995; Joiner *et al.*, 1995). Chance and Spurr (1997) calculated a Ring spectrum directly from a Fraunhofer spectrum. Sioris and Evans (1999) used model radiances to derive Ring spectra. Detailed investigations of the effect of trace gas absorption and particle and cloud scattering requires a radiative transfer model which includes rotational Raman scattering. Vountas *et al.* (1998) introduced a new method to derive Ring spectra from multiple scattering radiative transfer calculations in pseudo spherical mode, using the radiative transfer model GOMETRAN (Rozanov *et al.*, 1997). By taking rotational Raman scattering (RRS) into account within the radiative transfer processing, including trace

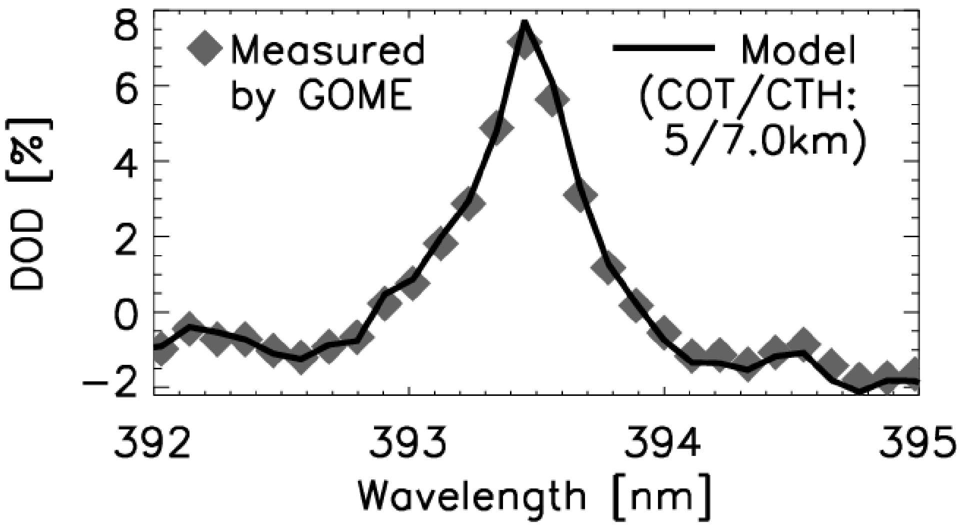


Figure 2: *Differential optical depths (DOD) derived for the spectral range from 390 nm to 400 nm from a GOME observation on the 15th October 1996 at 43.23 N, 27.44 W, 12.52 h UTC, solar zenith angle 52.9°, identified to be totally cloud covered. The random measurement error is negligible ($\approx 0.1\%$). Solid line is a model calculation using a standard nimbostratus cloud reaching from 6 to 7 km height with optical thickness 5 (de Beek* et al.*, 2001).*

gas absorption and aerosol and Rayleigh scattering, it was shown that the filling-in of Fraunhofer and gas absorption features, explains to high accuracy the Ring effect (Vountas *et al.*, 1998).

The Ring Effect has a significant impact on the retrieval of atmospheric trace constituents from satellite observations. As clouds can also have strong impacts on radiative transfer in the UV/visible spectral range, possible changes of the Ring Effect due to clouds have to be considered (de Beek *et al.*, 2001).

Ring structures can be clearly observed in the differential optical depths (DOD) which is defined as

$$DOD = -\ln(I/I_0) - P \quad , \tag{3}$$

where $I$ specifies the atmospheric radiance, $I_0$ is the solar irradiance, and $P$ is a fitted polynomial.

Fig. 2 shows a DOD spectrum of GOME measurements made under cloudy condi-

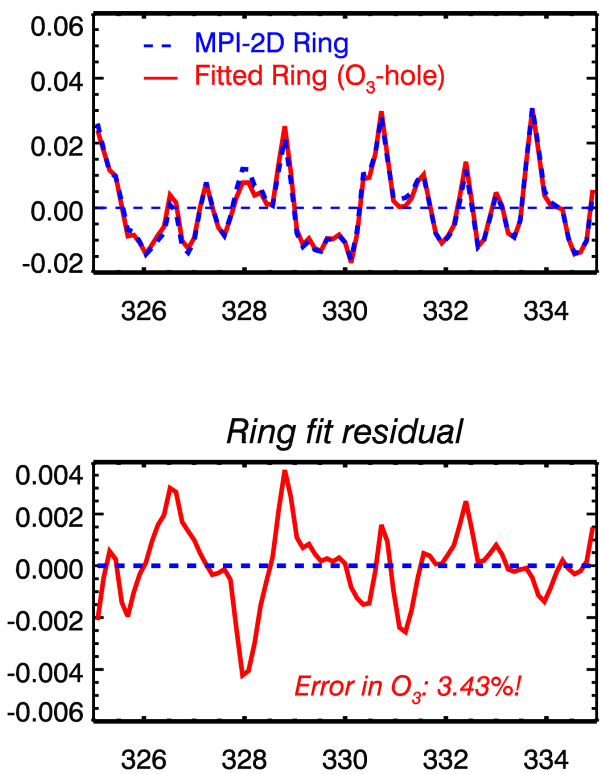


Figure 3: *Top: Ring spectra calculated for October 75S for normal and ozonehole conditions. The latter is fitted onto the normal spectrum (fit factor 1.07). Bottom: Residual of the fit.*

tions over the northern Atlantic. The Ring structure due to the filling-in of the CaII line around 393.37 nm perfectly fits a SCIATRAN calculation using appropriate cloud and atmospheric parameters (de Beek *et al.*, 2001).

For total ozone retrieval the Ring effect, e.g. a model Ring spectrum $R$, has to be fitted to the measurement spectrum. $R$ is defined as (Vountas *et al.*, 1998)

$$R = \ln\left(I^{+}/I^{-}\right) \quad , \tag{4}$$

where for the calculation of the radiance $I^{+}$ rotational Raman scattering is included and for $I^{-}$ it is not.

Fitting one *representative* Ring spectrum to the measured spectra, which is the current

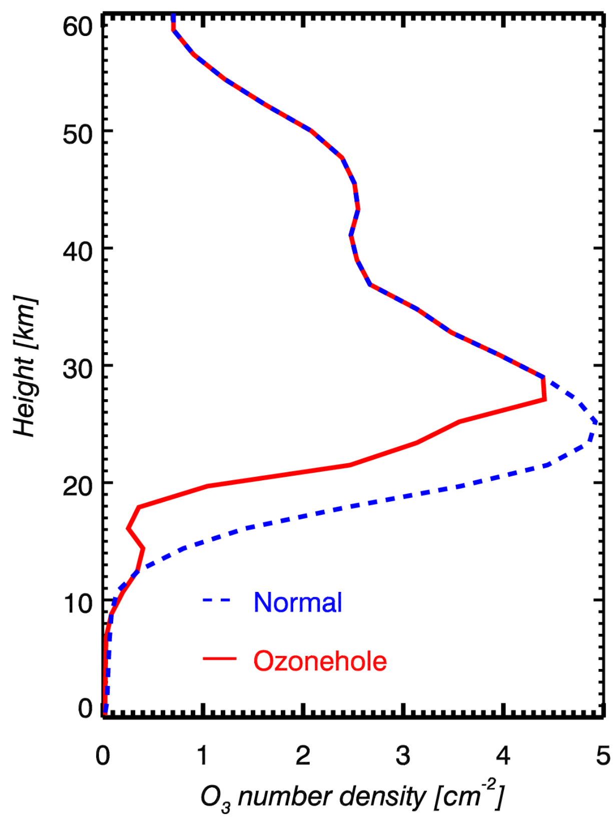


Figure 4: *Ozone profiles as used for the Ring simulation.*

baseline for operational GOME data processing, is not sufficient. As absorption structures also contribute to the Ring spectral signature (*molecular filling-in*) their variations have to be taken into account. Otherwise the strong correlation of these structures with trace gas cross-sections lead to errors in the retrieval.

This is demonstrated in Fig. 3, where two Ring spectra are shown one for October 75°S for background (MPI-2D climatology as used in GDP 2.7) and a realistic ozonehole profile (see Fig. 4). The top figure in Fig. 3 illustrates the ozonehole Ring spectrum (red) when fitted onto the Ring spectrum for background conditions. The residual is shown in the bottom of Fig. 3. This provides the spectral error pattern obtained when using the wrong Ring spectrum in the ozone fitting. The percentage error in vertical column arising due to this residual can be determined by fitting ozone absorption cross-sections onto the residual, which gives a slant column of 5.665E+17 cm$^{-2}$. Compared to the slant column of the ozonehole scenario used this results in a 3.43% error. calculations were done here for SZA of 60°. Larger errors should be expected at larger solar zenith angles.

To account for such spectral variability of the Ring effect it is proposed to generate a Ring data base containing spectra which are calculated using SCIATRAN and the WF-DOAS climatology, which also includes the ozone profile shape dependency. The optimal extent of such a database in order to achieve the required accuracy of ozone retrieval has to be investigated in this study.

## 2.4 Cloud Correction

In case of cloud contaminated GOME ground pixels, the part of the ozone column which is below the top of the clouds cannot be seen by the satellite. This ghost vertical column (GVC) has to be estimated from climatological vertical ozone profiles and then added to the vertical column retrieved from the spectral fit. The GVC is computed by integrating the ozone profile from the surface to the cloud top pressure.

Partial cloudiness can be taken into account by weighting the GVC with fractional cloud cover, $f$, derived from the Initial Cloud Fitting Algorithm ICFA (Kuze and Chance, 1994; GOME LVL2, 2000; Burrows *et al.*, 1999b):

$$GVC = f \cdot \int_{p(z_0)}^{p(cth)} O_3(p)\, dp, \tag{5}$$

where $p(z_0)$ is surface pressure, $p(cth)$ is cloud top pressure and $O_3(p)$ is the profile number density at pressure level $p$. Fractional cloud cover from ICFA algorithm is an effective cloud cover, assuming an optically thick cloud with $\tau = 20$(GOME LVL2, 2000). Cloud top height is taken from the ISCCP climatology (Rossow and Garder, 1993, International Satellite Cloud Climatology Project).

The new TOMS V8 ozone climatology can be alternatively used to obtain the appropriate ghost vertical column. This new climatology has particularly improved by adding more sonde data from the tropics [G. Labow, private communication]. In this study we propose the use of the FRESCO algorithm from Koelemeijer *et al.* (2001). This algorithm also uses oxygen A-band transmittances from GOME to derive, in addition to effective cloud cover, cloud-top-height as the second parameter.

## 2.5 First results using synthetic spectra

The ozone absorption and airmass factor shows a significant wavelength dependence in the near UV. These structures increase with larger solar zenith angles. The standard DOAS approach a single airmass factor for the entire fit window to convert slant columns into vertical columns. We performed a first case study which will show the deficit of a single airmass factor.

These investigations have been performed using RTM simulated spectra. For simplicity, the reference spectra were identical to the synthetic spectra and the representative airmass factor at 325 nm were used in all cases to avoid additional errors due to other atmospheric parameters. Ground altitude is 0 km, surface albedo is 0.05 and an ozone column of 260 DU is assumed for the radiative transfer simulations. Fig. 5 shows the relative errors of the DOAS retrieval. Below $80^\circ$ SZA the relative error of the standard DOAS column is small but for larger angles it may reach a few percents. For all solar zenith angles, the WF-DOAS algorithm reproduces the correct column.

## 2.6 First GOME results

First investigations using GOME satellite data have been performed under ozone hole conditions at high southern polar latitude. From September to December 1997 25 satellite overpasses were evaluated and compared with ozone sonde ascents from Neumayer-Station (8°W, 70°S) (König-Langlo and Marx, 1997). Figure 6 shows the ratio of ozone column derived from satellite data to ozone column derived from the sondes as a function of time. One can see that the known bias in the operational GDP V2.70 products is significantly reduced using WF-DOAS (Lambert *et al.*, 1999).

## 2.7 Proposed Research and Approaches

Main goal for this study is to provide a novel scientific prototype total ozone algorithm for GOME based upon the WF-DOAS method. Many of the important details to the application of WF-DOAS have been provided in the previous sections. Indications for some further work as part of this study have been already discussed and shall be detailed in this section.

A first version of WF-DOAS algorithm for total ozone is available and some initial testing

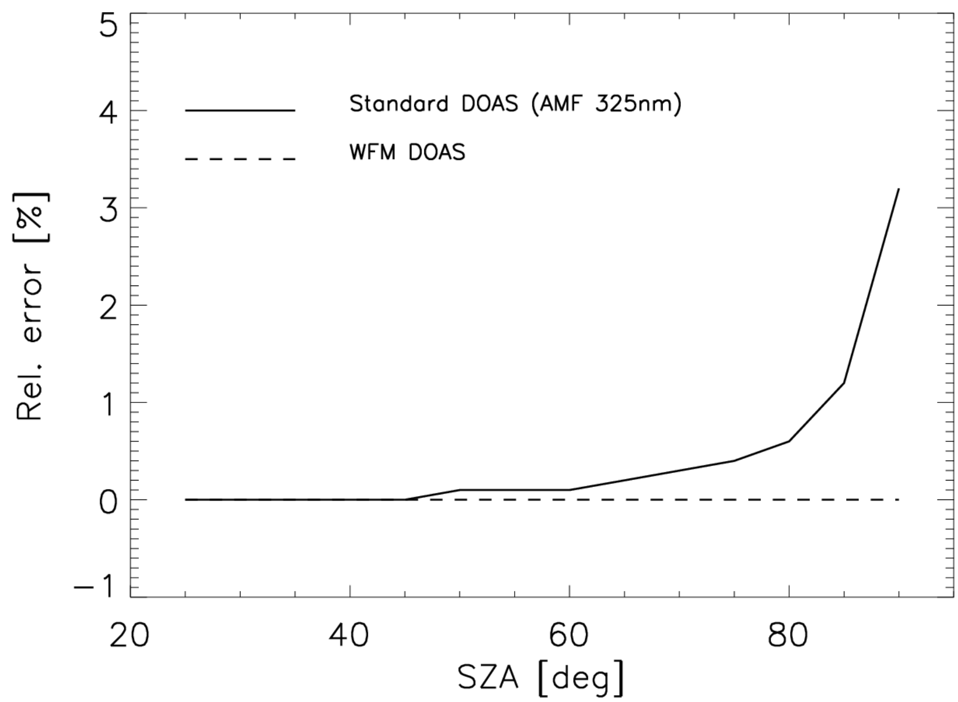


Figure 5: *Relative error between DOAS retrieval and true vertical column for different solar zenith angles. Solid line: standard DOAS and dashed line: WF-DOAS approach.*

have been done. The software is written in Fortran90, our standard software language. For use in operational retrieval further fine-tuning and modifications may be necessary and shall be investigated in this study.

### 2.7.1 Phase 1: Sensitivity Study and Optimisation

In the first phase the WF-DOAS method is reviewed and possible error sources identified. We believe that this phase is very critical since it sets the stage for the successful completion of Phase 2. We suggest that this phase is extended to 4 months. This makes also sense since the Statement of Work was optimized for the standard DOAS approach and did not account for direct fitting of vertical columns.

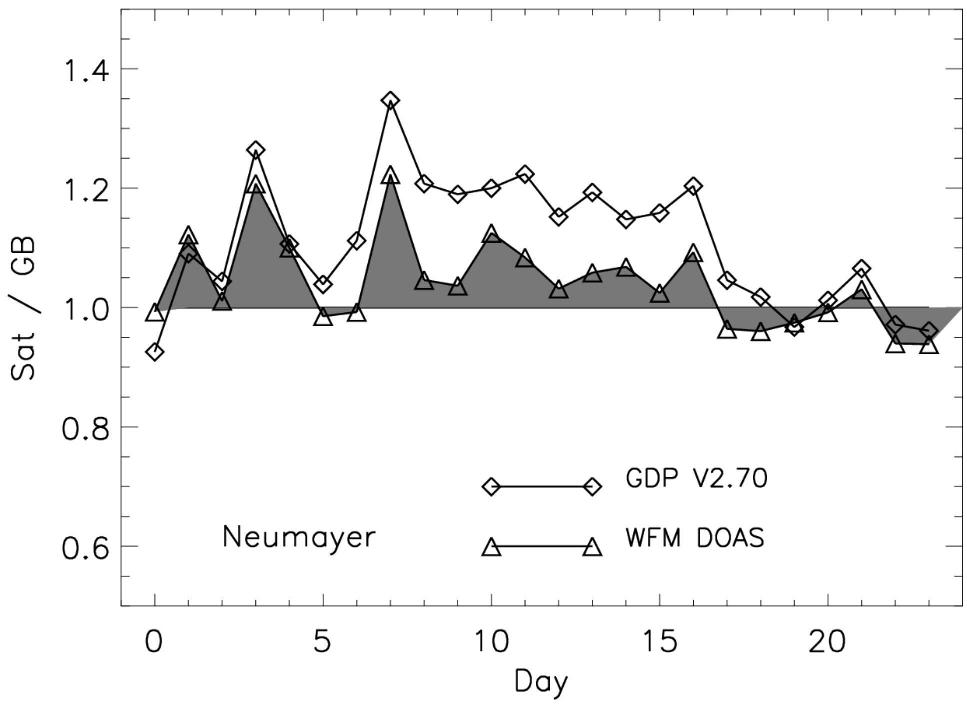


Figure 6: *Ratio of ozone column from GOME to ozone column from ground-based measurements at Neumayer-Station for several days from September to December 1997 (ozone hole conditions). Diamonds denote the GDP V2.70 values and the grey shaded curve with triangles denotes the new WF-DOAS retrieval.*

During Phase 1 following investigations must be carried out:

- The optimum parameter space for the LUT have to be defined. In the current algorithm the settings are specified as given in Table 1. The optimum spacing for each of the parameter has to be found. This is particularly important for high solar zenith and/or high line-of-sight angles, where the spacing needs to be reduced further.
- To which complexity the Ring effect has to be treated in WF-DOAS has to be studied in further details. Particularly the molecular Ring effect indicates a de-

pendency on the ozone profile. de Beek *et al.* (2001) showed that the Ring effect is also strongly modified by clouds. A sensible approximation for the cloud dependence has to be found. Calculations of Ring spectra are computationally expensive and may require down-sizing of the parameter space as used for the reference and weighting function spectra. An investigation of which of the parameters as given in Table 1 are important to Ring needs to be undertaken.

- An optimum selection of weighting functions to be included in the fitting procedure have to be defined. For instance, minor trace gas weighting functions are most likely not needed and cross-section fitting can be done for NO2 and BrO instead, thereby keeping the LUT table size small. Some weighting functions such as for albedo may show large correlation with others and may require some modification in their use.

- Selection of the optimum spectral range for WF-DOAS fitting of total ozone will be carried out. A trade-off between number of wavelengths(low value is good for LUT generation and computing speed) and retrieval accuracy needs to be achieved. The current setup is optimized for the GOME spectral window of 325-335 nm.

- Including *Shift-and-squeeze* procedure for aligning wavelength axes of the various spectra shall be avoided. From standard DOAS of the minor trace gases it has been shown that from a large number of orbit analyzed a representative shift for all terms can be found and kept fixed for all later retrievals. A similar approach is proposed for WF-DOAS of ozone. This will considerably enhance computational speed.

- The use of GOME FM98 cross-sections (Burrows *et al.*, 1998a, 1999a) in WF-DOAS and standard DOAS means that no slit function convolution is needed in the reference spectra. This is only strictly true in the weak-absorber case. Ozone in the near UV at 330 nm absorbs quite strongly so that the slit-function convolution of cross- section does not completely account for the slit function convolution of intensities, but this error is rather small. An error estimate will be provided during this study.

- Processing of geolocation information needs to be optimised. For instance, a decision needs to be made for which altitude (top-of-atmosphere, ground) the representative viewing geometry is selected for use in pseudo–spherical RTM. At large line-of-sights beyond 20° this may lead to differences in the few percent range if TOA angles are used (Kerridge *et al.*, 2002). A decision has to be made if SCIATRAN or CDI will be the preferred choice for generation of LUTs. CDI is a full spherical RTM which can be used for large line-of-sights in non-limb geometry (Rozanov *et al.*, 2000, 2001).

During Phase 1 first the ATBD and a first draft of a Software Requirement Document will be prepared.

### 2.7.2 Phase 2: Algorithm Implementation

During Phase 2 complete look-up-tables are generated using the optimum selection of parameters and grid spacing as outlined during phase 1. Particular emphasis will be put on optimizing the read-out of the various databases with regard to computational speed. Auxiliary information such as ghost vertical column and FRESCO cloud data will be pre-calculated and summarised in a separate database. Interfaces to GDP Level 1 (spectral radiance and irradiance) and Level 2 (ICFA cloud information) are created. Some preliminary validation will be carried out for testing purposes and further optimisation. Ring reference spectral database will be created from SCIATRAN RTM. This procedure is quite computationally expansive and needs great care.

This phase shall last 6 months. As deliverables, the software requirement documents will be updated and verification processes specified and documented.

### 2.7.3 Phase 3: Validation

An extensive validation will be carried out using the analysis of 2000 reference orbits. These orbits are used to assess the errors as a function of solar zenith angle, season, and total ozone (profile shape) by comparison with collocated groundbased data.

In addition to these orbits a comparison with an extensive WOUDC Dobson and Brewer data (about 50,000 coincidences will be carried out as described in (Bramstedt *et al.*, 2002b). Time series of differences between GOME-Dobson will be carried out for almost 90 stations covering the southern and northern hemisphere for the entire period 1996-2002. Fig. 7 shows as an example the weekly mean difference between GOME GDP V2.7 and EPTOMS V7 with respect to Dobson/Brewer between 1996 and 2000. The strong seasonal cycle in GDP V2.7 is clearly recognisable. Even though, EPTOMS differences show virtually no seasonal cycle a strong hemispheric bias is seen, with differences in SH mid–latitudes reaching several percent.

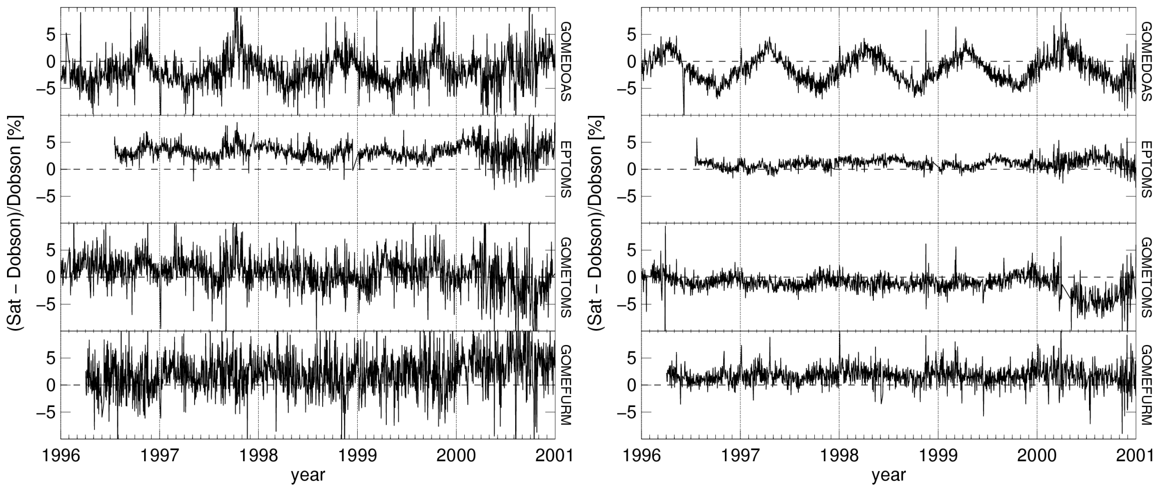


Figure 7: *Comparison of different satellite data sets and algorithms. Weekly percentage bias of GOME and EPTOMS with respect to Dobson/Brewer data averaged over the southern (left) and northern hemisphere (right) during the period 1996-2000 (Bramstedt* et al.*, 2002b). Top Panel: GDP V2.7 applied to GOME (GOMEDOAS); Second panel: TOMS V7 applied to EPTOMS (EPTOMS); Third panel: TOMS V7 applied to GOME (GOMETOMS); Fourth panel: University of Bremen $O_3$ profile algorithm applied to GOME (GOMEFURM). After 2000, the GOMEDOAS results appear to be less sensitive to degradation effects than the TOMS V7 algorithm. However, decreasing signal-to-noise ratio has increased and leads to enhanced scatter of the satellite–Dobson differences.*

This work will partially overlap with Phase 2 and covers mainly the last two months. As deliverables, a validation report is generated. Final reporting will consist of a Software User Document and preparing a data CD with prototype software, test data, and LUTs.

# 3 Work Breakdown Structure

In this section the activities associated with each Work Package are listed in detail with start and end dates or events. An overview of all work packages and the corresponding time allocations are given in Table 4. The study schedule is depicted in Table 3.3.

## 3.1 Work Packages

| | | |
|---|---|---|
| **Project Title:** GOTOCORD | | **WP 100** |
| **WP Title:** Technical Management | | |
| **WP Manager:** M. Weber | | |
| **Start Event:**<br>Start of contract | **End Event:**<br>End of contract | **Sheet 1 of 1** |
| Objectives:<br>> Direct technical work in Bremen<br>> Technical interface to ESRIN | | |
| Inputs:<br>> ESA/ESRIN Contract<br>> Discussions with ESA/ESRIN technical representative | | |
| Outputs:<br>> Recommendation on direction of study | | |

| | | |
|---|---|---|
| **Project Title:** GOTOCORD | | **WP 200** |
| **WP Title:** Administration | | |
| **WP Manager:** M. Weber | | |
| **Start Event:**<br>Start of Contract | **End Event:**<br>End of Contract | **Sheet 1 of 1** |

Objectives:

- > Exercise effective management control of study
- > Administer ESA/ESRIN Contract
- > Produce milestone reports
- > communication with ESA/ESRIN technical representative
- > Deliver documents and drafts to ESA/ESRIN in timely manner as per contractual agreement
- > Administer travel budget
- > Arrange milestone meetings
- > Arrange dates of meetings
- > Send out invitations to meetings
- > Produce and distribute Minutes of meetings

Inputs:

- > Project contract
- > Correspondence with ESA/ESRIN

Outputs:

- > Status and progress reports
- > Documents
- > Minutes of milestone meetings

| | | |
|---|---|---|
| **Project Title:** GOTOCORD | | **WP 300** |
| **WP Title:** Sensitivity Study and Optimisation | | |
| **WP Manager:** R. De Beek | | |
| **Start Event:**<br>Kick-off meeting | **End Event:**<br>Kick-Off Meeting + 4 months | **Sheet 1 of 1** |

Objectives:

- > Survey of relevant literature
- > Review of existing algorithm
- > Identification of error sources
- > Optimisation of parameter settings and grid spacing:
  - −− > Weighting function LUT spacing
  - −− > Consolidation of database, optional cross-section fitting
  - −− > Spacing of Ring database
  - −− > Selection of optimal fitting windows and number of spectral points
  - −− > Fixed-shift approach instead of shift&squeeze
  - −− > Errors due to cross-section selection for WF calculations
  - −− > Selection of appropriate RTM (pseudo-spherical/full-spherical)
  - −− > Selection of geometrical parameter settings for RTM

Inputs:

- > WF-DOAS prototype algorithm
- > GDP database
- > GDP level-1 and level-2 data
- > O3 profile climatologies

Outputs:

- > ATBD
- > Software Requirements Document

| | | |
|---|---|---|
| **Project Title:** GOTOCORD | | **WP 400** |
| **WP Title:** Algorithm Implementation | | |
| **WP Manager:** M. Coldewey-Egbers | | |
| **Start Event:**<br>Kick-off Meeting + 3 months | **End Event:**<br>Kick-off Meeting + 10 months | **Sheet 1 of 1** |

Objectives:

> Generation of WF LUT
> Generation of Ring reference database
> Optimisation of database read-out
> Preparation of database ghost vertical columns
> Preparation of FRESCO cloud database
> Interfaces to GOME level 1 and level 2 data
> Preliminary validation

Inputs:

> WF-DOAS prototype algorithm
> GDP database
> GDP level-1 and level-2 data
> O3 profile climatologies
> Optimum selections of parameters and grid spacing from Phase 1
> FRESCO cloud retrieval algorithm
> Comparative data for first validation

Outputs:

> Update of software requirements document
> Verification specification and documentation

<table>
<tr><td colspan="2">Project Title: GOTOCORD</td><td rowspan="3">WP 500</td></tr>
<tr><td colspan="2">WP Title: Validation</td></tr>
<tr><td colspan="2">WP Manager: M. Weber</td></tr>
<tr><td>Start Event:<br>Kick-off Meeting + 8 months</td><td>End Event:<br>End of contract</td><td>Sheet 1 of 1</td></tr>
<tr><td colspan="3">Objectives:<br>> Analysis of 2000 reference orbits<br>> Error determination as functions of SZA, season, total ozone, ozone profile shape, using collocated ground-based data<br>> Comparison with extensive WOUDC Dobson and Brewer data</td></tr>
<tr><td colspan="3">Inputs:<br>> GDP level-1 and level-2 data<br>> Ground-based data</td></tr>
<tr><td colspan="3">Outputs:<br>> Validation report<br>> Software user document<br>> WF-DOAS CD:<br>−− > Software<br>−− > Test data<br>−− > LUTs<br>−− > Documentation</td></tr>
</table>

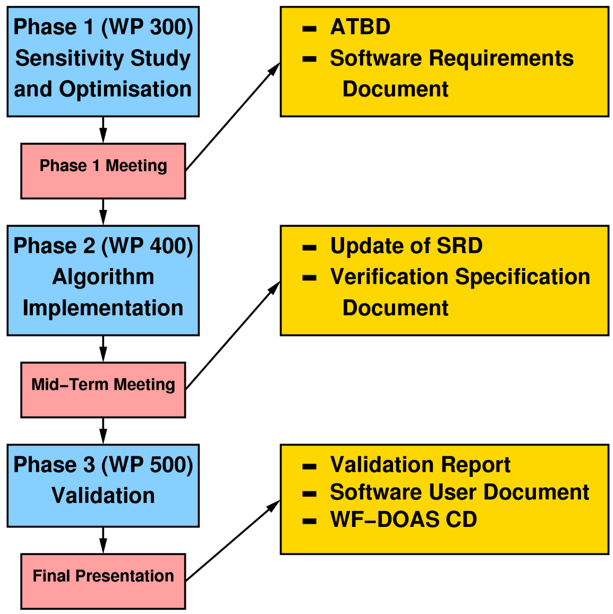


Figure 8: *Deliverables and Milestones in GOTOCORD*

## 3.2 Deliverables

An overview of the proposed deliverables as indicated in Sections 2.7.1,2.7.2, and 2.7.3 and in the Work Package description are given in Fig.8.

## 3.3 Study Schedule

Table 3.3 sets out the study schedule of the proposed project.

Table 2: *Study Schedule. K: Kick-off Meeting, P: Phase-1 Meeting, M: Mid-Term Review, F: Final Workshop, S: Monthly Status and Progress Report*

# Study Schedule

| | Year ⟶ | 2002 | | | 2003 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Month ⟶ | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| Work Packages | | | | | | | | | | | | | |
| | Phase 1 | | | | | | | | | | | | |
| WP 300 | Sensitivity Study and Optimisation | x | x | X | $\frac{1}{2}$ | $\frac{1}{2}$ | | | | | | | |
| | Phase 2 | | | | | | | | | | | | |
| WP 400 | Algorithm Implementation | | | | $\frac{1}{2}$ | $\frac{1}{2}$ | x | x | x | x | $\frac{1}{2}$ | $\frac{1}{2}$ | |
| | Phase 3 | | | | | | | | | | | | |
| WP 500 | Algorithm Validation | | | | | | | | | | $\frac{1}{2}$ | $\frac{1}{2}$ | x |
| Milestones | | | | | | | | | | | | | |
| | Meetings | K | | | | P | | M | | | | | F |
| | Minutes | K | | | | P | | M | | | | | F |
| | Reports | S | S | S | S | S | S | S | S | S | S | S | |
| | Month ⟶ | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| | Year ⟶ | 2002 | | | 2003 | | | | | | | | |

# 4 Management Proposal

## 4.1 Study Team

The study team consists of four scientists with long standing experience in satellite remote sensing of atmospheric constituents from space. Detailed curriculum vitae of the key personnel can be found in Section 6.

Project manager and principal investigator (PI) of this proposal is **Dr. Mark Weber** who as a senior researcher is currently leading the Ozone and UV Satellite Application Group in the Institute of Environmental Physics (IUP), University of Bremen. Within the last six years he has been instrumental in introducing new algorithms for retrieval of ozone profiles and total column from nadir UV space observations of GOME. Recently he was managing the IUP contribution to the GOME2 Error Study. Further emphasis in his work was the use of ozone satellite data for case studies in atmospheric chemistry and dynamics. He was a co-author on the scientific assessment to European research in the stratosphere published by the EU. Other field of research are solar-terrestrial interaction and UV surface flux modeling from space. He is currently speaker of the satellite-to-satellite validation group (national validation group and SCIAVALIG) of SCIAMACHY. Apart from administrative and management duty he will guide and assist in the implementation of the WF-DOAS algorithm for total ozone retrieval.

The IUP is headed by **Prof. John Burrows**. He is the lead scientist of the GOME project and PI of the successor instrument SCIAMACHY aboard ENVISAT. Within the last ten years and under his leadership IUP has gained vast experience in UV/vis satellite remote sensing ranging from scientific support in technical matters to industry and space agencies, calibration characterization of space instruments, to development of scientific algorithms for UV/vis trace gas, cloud, and aerosol retrieval from space. Prof. John Burrows is participating in this project as advisor and expert to GOME matters.

**Dr. Rüdiger de Beek** will assist the PI in project management. His expertise in ozone profiling and DOAS retrieval from nadir space observation and in Ring effect will be valuable to this project. He has been participating in several ESA studies on SCIAMACHY calibration and algorithm verification studies. He is one of the co-authors of the GOME2 Error Study. His main contribution will be his participation in the Ring sensitivity study and its optimum implementation for the WF DOAS algorithm.

The major work of implementing the WF-DOAS algorithm will be carried out by **Dipl.-**

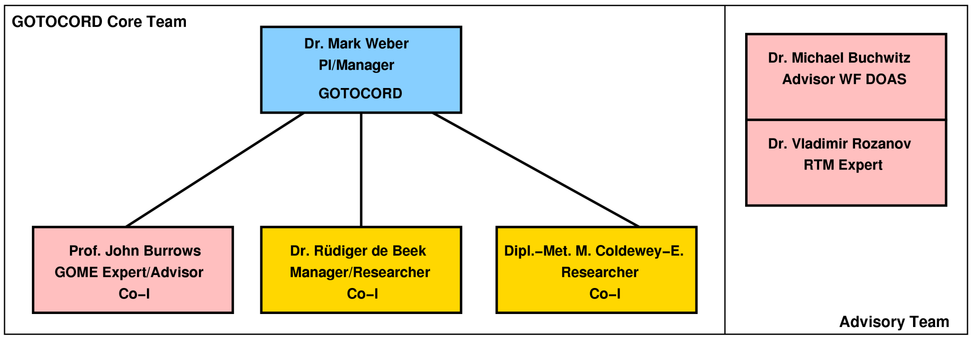


Figure 9: *Organisation of the GOTOCORD Study Team*

Table 3: *Time allocation for GOTOCORD*

| | | Time Contribution |
|---|---|---|
| PI/Manager | Dr. M. Weber | 15 % |
| Researcher/Manager | Dr. R. de Beek | 30 % |
| Researcher | Dipl. Met. M. Coldewey-Egbers | 50 % |
| Advisor | Prof. J. Burrows | 5% |

**Met. Melanie Coldewey-Egbers**. She is currently a doctoral student at IUP and is part of the UV surface modeling group using GOME data.

**Dr. Michael Buchwitz** and **Dr. Vladimir Rozanov** act as advisors to the core group. The WF-DOAS algorithm was originally developed by Dr. Buchwitz for SCIAMACHY near-ir trace gas retrieval. His expertise will be valuable to the adaptation of this algorithm into the UV. In atmospheric radiative transfer matters the support of Dr. Rozanov's vast expertise is instrumental to this project. During this project preparation and implementation of SCIAMACHY retrieval algorithms (trace gas, cloud, and aerosol retrieval) will be an ongoing activity. Any important results from these activities which have possible bearings on WF-DOAS will be regarded as options to this project. However, one has to keep in mind that resources to this project are tight and no contractual obligation can be given here with respect to these options.

In Fig. 9 the organisation of the study team is graphically presented. Table 3 shows the time allocation of each member of the core group

Table 4: *Overview of work Packages (Mmth: Man-month)*

| Work Package | Title | Time Resources |
|---|---|---|
| WP 100 | Technical Management | 0.5 Mmth |
| WP 200 | Administration | 0.5 Mmth |
| WP 300 | Sensitivity Study and Optimisation | 4.0 Mmth |
| WP 400 | Algorithm implementation | 6.0 Mmth |
| WP 500 | Validation | 2.0 Mmth |
| Total Time Resources of Project | | 13.0 Mmth |

In Fig. 9 a diagram on the organisation of personnel is summarised. Table 4 summarises the man months divided into the various work packages.

## 4.2 Relevant Experiences

During the last decade the Institute of Environmental Physics (IUP) in Bremen had a leading role in the scientific-technical development of the ESA project GOME and the Dutch-German-Belgian SCIAMACHY mission (Burrows *et al.*, 1993, 1995, 1999b; Bovensmann *et al.*, 1999). John Burrows is the lead scientist of the GOME project and the principal investigator of the German part of the SCIAMACHY mission. This required longstanding collaborations with a large international group of scientists and various national and international space agencies (ESA, DLR, EUMETSAT, and NASA) and industry.

Major focus of IUP research has been the development of various scientific algorithms for the retrieval of high level data products from the spectral measurements provided by GOME and SCIAMACHY (Burrows *et al.*, 1993, 1994, 1995, 1996, 1999b; Diebel *et al.*, 1995; Guzzi *et al.*, 1995, 1998; Bovensmann *et al.*, 1999). The radiation transfer code GOMETRAN and the DOAS trace gas column retrieval software which were developed at IUP are now part of the routine and operational retrieval at the German Remote Sensing Data Center (DFD) at DLR.

The highlights of scientific research related to GOME and SCIAMACHY is summarized as follows.

- Development of a scientific algorithms for satellite retrieval of trace gas columns from UV/VIS spectra of GOME, SCIAMACHY, and GOME2 (Rozanov *et al.*, 1993; Burrows *et al.*, 1994; Diebel *et al.*, 1995; Eisinger *et al.*, 1996a,b, 1997b; Eisinger and Burrows, 1998; Hegels *et al.*, 1997, 1998; Richter *et al.*, 1998a,b; Buchwitz *et al.*, 2000a,b; Müller *et al.*, 2002; Kerridge *et al.*, 2002).

- Development of the inversion algorithm FURM (Full Retrieval Method) for the retrieval of vertical ozone profiles (Chance and Spurr, 1997; de Beek *et al.*, 1997; Hoogen *et al.*, 1998b,c,a,d, 1999b,a; Eichmann *et al.*, 1998; Bramstedt *et al.*, 1998, 2002b,a).

- Scientific investigation of Arctic Ozone loss using GOME ozone profiles and trace gas data from GOME (Bramstedt *et al.*, 1998; Eichmann *et al.*, 1999, 2002; Sinnhuber *et al.*, 2000; Bremer *et al.*, 2002; Weber *et al.*, 2002).

- Routine groundbased zenith sky DOAS measurements in Bremen and Ny-Alesund (Spitsbergen), validation of operational GOME ozone and $NO_2$ vertical columns by comparison with groundbased data (Eisinger *et al.*, 1997a; Richter *et al.*, 1998c; Ladstätter-Weissenmayer *et al.*, 1996).

- Development and Optimization of a pseudo-spherical multiple scattering radiative transfer model (RTM GOMETRAN) (Rozanov *et al.*, 1997, 1998), extension into the near UV (inclusion of O2 Schumann-Runge bands) for derivation of photolysis rates based on actinic flux estimations (Blindauer *et al.*, 1996) and into the near–ir for SCIAMACHY application (SCIATRAN).

- Development of a full spherical multiple scattering RTM for limb radiances (Rozanov *et al.*, 2000, 2001).

- RTM simulation of rotational inelastic Raman scattering (Ring effect) (Vountas *et al.*, 1998) and scientific case studies on the Ring effect (de Beek *et al.*, 2001).

- RTM modeling of homogenous clouds with arbitrary vertical extent and cloud top heights according to various cloud classification (Kurosu *et al.*, 1997; Guzzi *et al.*, 1995), introduction of new cloud detection algorithms for GOME (Guzzi *et al.*, 1998).

- Global UV surface radiation modeling using GOME satellite data (Köpke *et al.*, 1998; Menkhaus *et al.*, 1999; DeBacker *et al.*, 2001).

- Algorithm development for deriving proxy indicators for long term natural variability of solar radiation from daily solar observations by GOME, study of UV degradation of GOME using solar and lunar measurements (Weber *et al.*, 1998; Weber, 1999; Burrows *et al.*, 1998b; Dobber *et al.*, 1998; Viereck *et al.*, 2001)

- laboratory spectroscopic measurements and analysis of UV/vis molecular cross-section for atmospheric applications, participation in GOME and SCIAMACHY flight model measurements of reference cross-section (Burrows *et al.*, 1998a, 1999a; Orphal *et al.*, 2002)

The IUP is part of the SCIAMACHY Operations Support Team (SOST) which provides operational support to the SCIAMACHY project. Especially, the SOST is involved in the on-ground and in-flight calibration and monitoring activities.

## 4.3 Facilities

The IUP is well equipped with several SUN (Ultra I, Ultra II, Sunblade 1000) and Alpha (XP 1000, DS 20) workstations. Mass storage devices (RAID Systems) are available which hold the entire GOME level-1 data set. In addition the Department of Physics has two Cray J90 super computer with 32 processors which can be accessed for extensive numerical calculations. They will be replaced by a more powerful IBM Regatta system in about half a year. Most computations will be carried out on the workstation cluster. Within this study current resources and the associated administration cost (technical support) will be provided at no extra cost.

# 5 Financial Proposal

| | |
|---|---|
| **Labour & Administration** | |
| 13 Man Months (2080 hours total × 35.40€) | 73,632€ |
| **Consumable Items** | |
| telephone, fax, computer accessories, stationaries | 1,000€ |
| **Travel** | |
| Kickoff Meeting (3×705€) | 2,115€ |
| Phase-1 Final Meeting (3×705€) | 2,115€ |
| Midterm Meeting (3×705€) | 2,115€ |
| Final Workshop (3×810€) | 2,430€ |
| **Total** | 83,407€ |
| **Overhead (20% of Total)** | 16,681€ |
| **Grand Total** | 100,088€ |

Major cost are man hours to be invested in for completion of this project. In addition requests for travel money to the four planned meetings (Kick-off, Phase 1, Midterm, and final wokshop) are made. Some consumables have to be financed in order to organise and administrate this study. Within the framework of this study a total of 13 man months (160 hours per month) for a scientist paid at the German university research scientist scale BAT 2A is estimated as necessary to fulfil the objectives. The hourly rate is fixed at 35.40€.

For a 1-day meeting (kick-off, Phase 1, Midterm) the travel cost (presumably to ESRIN) is estimated at 705€ per person (600€ flight, 75€ for one over-night stay at hotel, and 35€ daily allowance in Italy sums to 705€), For a two-day final workshop, an additional night and daily allowance totalling 105€ has to be added to get at 810€ per person. Each meeting will be attended by three persons from our institute.

Consumables are estimated at 1,000€ during the entire project year.

## 5.1 Payment Plan

| | | |
|---|---|---|
| Advance payment | 1st October 2002 | 30,000€ |
| Payment at midterm | 1st April 2002 | 40,000€ |
| Final payment upon final acceptance | 30th September 2002 | 30,088€ |

# 6 Key Personnel

Full curricula vitæ for all the key personnel listed below are contained in the following sections: Dr. M. Weber, , Dr. R. de Beek, Prof. John Burrows, Dipl. Met. M. Coldewey–Egbers. A short vita is given for the advisory group members Drs. M. Buchwitz and V. Rozanov.

## 6.1 CV Dr. Mark Weber

Mark Weber studied at the University of Bonn, Germany, and received his Ph.D. degree in physics from the University of Tennessee, Knoxville, USA, in 1992. From 1992 until 1995 he was a National Academy of Sciences/ National Research Council Resident Research Associate at the Laboratory for Extraterrestrial Physics at NASA Goddard Space Flight Center. In 1993 he and his co-authors received the Sir Harold Thompson Memorial Award (UK) for outstanding contributions in the field of molecular spectroscopy published in Spectrochimica Acta. In November 1995 he joined the Institute of Remote Sensing at the University of Bremen, Germany. Currently he is the leader of the Ozone and UV Satellite Application Group at IUP.

**Name:** Mark Weber

**Address:**

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Fachbereich 1
Universität Bremen
Postfach 330440
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*Parcel delivery*
University of Bremen FB1
Otto-Hahn-Allee
D–28359 Bremen

Tel: 49-421-2184584
Fax: 49-421-2182362

e-mail: weber@uni-bremen.de

**Personal:**

Born 4th April 1961, Trier, Germany

German Citizen

**Qualifications:**

Ph.D., University of Tennessee, Knoxville, USA, 1992.

Sir Harold Thomson Memorial Award (UK) for outstanding contributions on the field of molecular spectroscopy (with co-authors), 1993

Leader of the Ozone and UV Satellite Application Group at the Institute of Environmental Physics

Co-I of GEOTROPE (Geostationary Tropospheric Explorer

**Employment:**

Institute of Remote Sensing, University of Bremen,
Senior Researcher

1995 to present.

Laboratory for Extraterrestrial Physics
NASA Goddard Space Flight Center Research Associate With National Academy of Sciences,
National Research Council, USA

1992 to 1995.

**Selected Publications:**

MW-1 Weber, M., W.E. Blass, S. Nadler, G.W. Halsey, W.C. Maguire and J.J. Hillman, l-Resonance Effects in C2H2 near 13.7mm, Part II: The Two Quantum Hotbands, Spectrochim. Acta 49A, 1659, 1993 **(The Sir Harold Thompson Memorial Award 1993)**.

MW-2 Weber, M., J.P. Burrows and R.P. Cebula, GOME Solar UV/VIS Irradiance Measurements between 1995 and 1997 : First Results on Proxy Solar Activity Studies, Solar Physics 177, 63-77, 1998.

MW-3 Burrows, J.P., M. Weber, M. Buchwitz, V.V. Rozanov, A. Ladstdter-Weissenmayer, A. Richter, R. de Beek, R. Hoogen, K. Bramstedt, K.-U. Eichmann, M. Eisinger und D. Perner, The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results, J. Atm. Sci., 56, 151-175, 1999.

MW-4 Eichmann, K. -U., K. Bramstedt, M. Weber, V.V. Rozanov, R. Hoogen and J.P. Burrows, O3 profiles from GOME satellite data - II: Observations in the Arctic spring 1997 and 1998, Physics and Chemistry of the Earth 24, 453-457, 1999.

MW-5 Hoogen, R., V.V. Rozanov, K. Bramstedt, K.-U. Eichmann, M. Weber, and J.P. Burrows, Ozone profiles from GOME satellite data-I: Comparison with ozonesonde measurements, Physics and Chemistry of the Earth 24, 447-452, 1999.

MW-6 Sinnhuber, B.M., M.P. Chipperfield, M.S. Davies, J.P. Burrows, K.-U. Eichmann, M. Weber, P. van der Gathen, M. Guirlet, G. Cahill, A. Lee, J. Pyle, Large loss of total ozone during the Arctic winter 1999/2000, Geophys. Res. Lett. 27, 3473-3476, 2000.

MW-7 Hauchecorne, A., T. Peter, D. Balis, A. Bregman, M.P. Chipperfield, N.R.P. Harris, W.A. Norton, J. Staehelin, and M. Weber, Mid-latitude and tropical ozone, Chapter 4 in: Scientific Assessment, European Research in the Stratosphere 1996-2000, Advances in our understanding of the ozone layer during THESEO, EUR 19867, European Commission, Directorate-General for Research Information and Communication Unit, ISBN 92-894-1398-0, Brussels, 2001.

MW-8 Weber M., K.-U. Eichmann, F. Wittrock, K. Bramstedt, L. Hild, A. Richter and J.P. Burrows and R. Müller, 2002: The cold Arctic winter 1995/96 as observed by the Global Ozone Monitoring Experiment GOME and HALOE: Tropospheric wave activity and chemical ozone loss, *Quarterly Journal of Royal Meteorological Society*, **128**, 1293–1320.

**Languages:**

German mother tongue
English fluent
French working knowledge

**Main Research Interest:**

Retrieval of trace gas constituents and other atmospheric parameters (clouds, aerosol, and surface radiation) from space

Solar variability observation from space, solar–terrestrial interaction

Atmospheric dynamics and chemistry

## 6.2 CV Dr. Rüdiger de Beek

**Name:** Rüdiger de Beek

**Address:**

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Fachbereich 1
Universität Bremen
Postfach 330440
D–28334 Bremen

Tel: 49-421-2184584
Fax: 49-421-2184555
e-mail: debeek@iup.physik.uni-bremen.de

**Personal:**

Born 17th August 1963, Bremen, Germany

German Citizen

Married, two Childs

**Education:**

Ph.D., Institute of Remote Sensing, University of Bremen, Germany 1998.
Ph.D. thesis title: "Bestimmung von Ozonvertikalprofilen aus Messungen des Satelliteninstruments GOME im ultravioletten und sichtbaren Spektralbereich".
Research Supervisor, Professor J. P. Burrows

M. A. (Diplom), Institute of Environmental Physics, University of Bremen, Germany 1993.
Masterthesis title: "Vergleich von Totalozondaten verschiedener Messmethoden".

Research Supervisor, Prof. K. Künzi

**Employment:**

Review of the SCIAMACHY operational processor documentation (Level 0-to-1 and Level 1-to-2)
Investigation of the Ring Effect especially in the presents of clouds
Analysis of potential instrumental and methodical errors of operational trace gas column retrieval algorithms for GOME-2
Verification and development support of the SCIAMACHY Level 0-to-1 processor (ESA project SCALD/SUPPRO, ESA/ESTEC Contract 13594/99/NL/PR, member of SCIAMACHY Algorithm Calibration and Verification Team, ESA, SCIAMACHY CAL-DP Tiger Team, SSAG, support of SCIAMACHY commissioning phase activities)

April 1999 to present.

Institute of Remote Sensing, University of Bremen,
Retrieval of ozone concentration profiles and other trace gas constituents from GOME UV nadir measurements
Development and Error analysis of the IUP FURM (Full Retrieval Method) ozone profile algorithm
Error analysis of the IUP DOAS (Differential Optical Absorption Spectroscopy) algorithm, as applied for GOME operational processing
Validation of IUP DOAS ground-based measurements

January 1994 to June 1997.

**Selected Publications:**

RdB-1 R. de Beek, V.V. Rozanov, and J.P. Burrows, Ozone Total Columns and Vertical Profiles from the Global Ozone Monitoring Experiment (GOME): Theory, Polar Stratospheric Ozone - Proceedings of the 3rd European Workshop, 18.–22. September 1995, Schliersee, Germany, Air Pollution Research Report 56, pages 833–838, 1996.

RdB-2 R. de Beek, R. Hoogen, V.V. Rozanov, and J.P. Burrows, Ozone Profile Retrieval from GOME Satellite Data I: Algorithm Description, 3rd ERS Scientific Symposium, 17-21 March 1997, Florence, Italy, Space at the Service of our Environment II, pages 749–754, 1997.

RdB-3 R. Hoogen, V. V. Rozanov, K. Bramstedt, K.-U. Eichmann, M. Weber, R. de Beek, M. Buchwitz, and J. P. Burrows, Height-Resolved Ozone Information from GOME Data, Earth Observation Quarterly, 58, pages 9–10, 1998.

RdB-4 Burrows, J.P., M. Weber, M. Buchwitz, V.V. Rozanov, A. Ladstdter-Weissenmayer, A. Richter, R. de Beek, R. Hoogen, K. Bramstedt, K.-U. Eichmann, M. Eisinger und D. Perner, The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results, J. Atmos. Sci., 56, 151-175, 1999.

RdB-5 R. de Beek, M. Vountas, V. V. Rozanov, A. Richter and J. P. Burrows, The Ring Effect in the cloudy atmosphere, Geophys. Res. Lett. 28, 721–724, 2001.

**Languages:**

German mother tongue
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**Main Research Interest:**

Retrieval of trace gas constituents and other atmospheric parameters (clouds and aerosol) from UV, vis., and NIR measurements, including improvement of atmospheric radiative transport modeling.

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M. A. (Diplom), Institute of Marine Science, Department of Marine Meteorology, University of Kiel, Germany 2000.
Masterthesis title: "Vorhersagemöglichkeiten mit neuronalen Netzen".
Research Supervisor, Prof. E. Ruprecht

**Employment:**

Institute of Environmental Physics, University of Bremen,
Surface UV flux estimation from GOME measurements,

Retrieval of total ozone from GOME UV-nadir-measurements

2000 to present.

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## 6.4 CV Prof. John P. Burrows

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**Qualifications:**

Ph.D. (Cantab) in Physical Chemistry, Trinity College, Cambridge 1979.
Study of free radical reactions by laser magnetic resonance
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M. A. (Cantab) in Natural Sciences, Trinity College, Cambridge University 1979.

B. A. (Hons) in Natural Sciences, Trinity College, Cambridge University 1975.

Gassiot Student of the Royal Society, 1975 to 1987

Proposer and PI of the SCIAMACHY, Chairman of the SCIAMACHY science advisory committee

Vice Chairman of the GOME science advisory committee, Member of CEOS Ozone Committee

Member of the IGBP-IGAC-GLONET committee, Member of the IGBP-IGAC-GTOP committee

Member of the American Geophysical Society, Member of the American Chemical Society, Member of SPIE

**Employment:**

Institute of Environmental Physics and Remote Sensing, University of Bremen,
Professor of Atmospheric Physics
Research focused on spectroscopy, kinetics and spectroscopy of atmospherically related species, development of atmospheric in situ and remote sensing techniques, atmospheric physics and chemistry

1992 to present.

Honorary Positions Held
NASA-GSFC Consultant Scientist,
Consultant Scientist to ESA

1992 to present

Department of Atmospheric Chemistry, Max-Planck-Institut für Chemie, Mainz, Germany, Photochemistry, Atmospheric Kinetics, in-situ and remote sensing measurements

1982 to 1992

Atomic Energy Research Establishment,
Environmental and Medical Sciences Division Higher Scientific Officer,
Simultaneously Member of the Physical Chemistry Laboratory Kinetics Group (Professor R.P. Wayne).

1979 to 1982

**Selected Publications:**

JPB-1 A. Richter, M. Eisinger, F. Wittrock and J. P. Burrows, BrO Observed from GOME in the Northern Hemisphere in 1997, Geophys. Res. Lett. 25 2683-2686.

JPB-2 M. Eisinger and J. P. Burrows 1998, Tropospheric Sulfur Dioxide observed by the ERS-2 GOME Instrument, Geophys. res. Lett. 25 4177-4180.

JPB-3 J. P. Burrows, M. Weber, M. Buchwitz, V. V. Rozanov, A. Ladstätter, Weissenmayer, A. Richter, R. DeBeek, R. Hoogen, K. Bramstedt and K.U. Eichmann 1999, The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results, J. Atmos. Sci. 56 151-175.

JPB-4 H. Bovensmann, J. P. Burrows, M. Buchwitz, J. Frerick, S. Noël, V. V. Rozanov, K. V. Chance, A. P. H. Goede 1999, SCIAMACHY- Mission Objectives and Measurement Modes, J. Atmos. Sci. 56 126-150.

JPB-5 J. P. Burrows 1999, Current and future passive remote sensing techniques used to determine atmospheric constituents, in Developments in Atmospheric Sciences 24: Approaches to Scaling Trace Gas Fluxes in Ecosystems, Ed A. F. Bouwman Elsevier Amsterdam pp 315-347. ISBN: 0-444-82934-2.

JPB-6 Wittrock, F.; Müller, R. ; Richter, A. ; Bovensmann, H. ; Burrows, J. P. 2000, Measurements of Iodine monoxide (IO) above Spitsbergen Geophys. Res. Lett. 27, 1471-1475.

**Languages:**

English mother tongue
German fluent

**Main Research Interest:**

Spectroscopy, kinetics and spectroscopy of atmospherically related species, development of atmospheric in-situ and remote sensing techniques, atmospheric chemistry and physics

## 6.5 Scientific Advisors

Drs. Michael Buchwitz and Vladimir Rozanov will be advisor to the key personnel in matters of WF-DOAS and radiative transfer modeling.

**Dr. Michael Buchwitz** is working in the area of remote sensing of the Earth's atmosphere at the IUP University of Bremen, Germany, since 1993 (with a one year break where he was working as project manager and software developer in a German Internet e-commerce company). He is a specialist in radiative transfer and satellite remote sensing in the UV-Visible-NIR spectral region. He has been working mainly in the GOME/ERS-2 and SCIAMACHY/ENVISAT satellite projects. In the GOME project he was responsible for the radiative transfer program GOMETRAN++, which has been used, e.g., for ozone and NO2 airmass factor calculations for the operational processing of GOME data and was working on GOME retrieval algorithm improvements. He has also been working for several years as scientific secretary of the GOME Science Advisory Committee (GSAC). In the SCIAMACHY project he was working on instrument specification, mission planning, near-infrared (NIR) detector selection, etc. During his Ph.D. he has extended the radiative transfer model GOMETRAN++ to cover the NIR spectral region by developing and implementing a correlated-k distribution and a line-by-line scheme for the modeling of H2O, O2, CH4, CO, CO2, and N2O line-absorption. The corresponding version of the radiative transfer model was called SCIATRAN. He also extended the standard UV-Visible DOAS algorithm for application in the NIR spectral region and also for H2O and O2 cloud retrieval in the visible. The new algorithm was called *Weighting Function Modified (WFM) DOAS*, which is termed in this proposal as WF-DOAS.

**Dr. Vladimir Rozanov** studied at the University of St Petersburg, Russia, and received his Ph.D. degree in physics and mathematics from the University of St Petersburg, Russia, in 1977. From 1973 until 1991 he was Research scientist at the Department of Atmospheric Physics of the University of St. Petersburg. In 1990-1991 he was a research scientist at Max-Planck Institute of Chemistry on secondment from the Department of Atmospheric Physics of the University of St. Petersburg. In July 1992 he joined the Institute of Remote Sensing at the University of Bremen, Germany. He is author and co-author of about 90 papers and other publications. His expertise is in atmospheric radiative transfer modeling and inversion methods. recently, he developed the first full spherical multiple scattering radiative transfer model, which is not based upon Monte Carlo simulation. This state-of-the-art RTM forms the base for the limb retrieval for SCIAMACHY.

# 7 Acronyms

| ACRONYM | MEANING |
|---|---|
| AMF | AIRMASS FACTOR |
| ATBD | ALGORITHM THEORETICAL BASIS DOCUMENT |
| CDI | COMBINED DIFFERENTIAL INTEGRAL |
| DFD | GERMAN REMOTE SENSING DATA CENTRE |
| DLR | GERMAN AEROSPACE CENTER |
| DOAS | DIFFERENTIAL OPTICAL ABSORPTION SPECTROSCOPY |
| DOD | DIFFERENTIAL OPTICAL DEPTH |
| EP-TOMS | EARTH PROBE - TOTAL OZONE MAPPING EXPERIMENT |
| ERS-2 | SECOND EUROPEAN REMOTE SENSING SATELLITE |
| ESA | EUROPEAN SPACE AGENCY |
| EUMETSAT | EUROPEAN ORGANISATION FOR THE EXPLOITATION OF METEOROLOGICAL SATELLITES |
| FRESCO | FAST RETRIEVAL SCHEME FOR CLOUDS FROM THE OXYGEN A-BAND |
| FURM | FULL RETRIEVAL METHOD |
| GDP | GOME DATA PROCESSOR |
| GOME | GLOBAL OZONE MONITORING EXPERIMENT |
| GOTOCORD | GOME TOTAL COLUMN RETRIEVAL DEVELOPMENT |
| GSAC | GOME SCIENCE ADVISORY COMMITTEE |
| GVC | GHOST VERTICAL COLUMN |
| ICFA | INITIAL CLOUD FITTING ALGORITHM |
| ISCCP | INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT |
| IUP | INSTITUTE OF ENVIRONMENTAL PHYSICS |
| LER | LAMBERTIAN EQUIVALENT REFLECTIVITY |
| LOS | LINE-OF-SIGHT |
| LUT | LOOK-UP-TABLE |
| OMI | OZONE MONITORING INSTRUMENT |
| RRS | ROTATIONAL RAMAN SCATTERING |
| RTM | RADIATIVE TRANSFER MODEL |
| SCD | SLANT COLUMN DENSITY |

| ACRONYM | MEANING |
|---|---|
| SCIAMACHY | SCANNING IMAGING ABSORPTION SPECTROMETER FOR ATMOSPHERIC CHARTOGRAPHY |
| SOST | SCIAMACHY OPERATIONS SUPPORT TEAM |
| SRD | SOFTWARE REQUIREMENTS DOCUMENT |
| SZA | SOLAR ZENITH ANGLE |
| TOA | TOP OF ATMOSPHERE |
| TOMS | TOTAL OZONE MAPPING SPECTROMETER |
| UV | ULTRAVIOLET |
| UTC | UNIVERSAL TIME CONSTANT (GREENWICH MERIDIAN TIME |
| VCD | VERTICAL COLUMN DENSITY |
| WF-DOAS | WEIGHTING FUNCTION DOAS |
| WMO | WORLD METEOROLOGICAL ORGANIZATION |
| WOUDC | WORLD OZONE AND ULTRAVIOLET RADIATION DATA CENTRE |

# References

BLINDAUER, C., ROZANOV, V.V., AND BURROWS, J.P. 1996. Actinic flux and photolysis frequency comparison computations using the model PHOTOGT. *Journal of atmospheric chemistry*, **24**, 1–21.

BOVENSMANN, H., BURROWS, J. P., BUCHWITZ, M., FRERICK, J., NOEL, S., ROZANOV, V.V., CHANCE, K. V., AND GOEDE, A. H. P. 1999. SCIAMACHY - Mission objectives and measurement modes. *Journal of the atmospheric sciences*, **56**, 125–150.

BRAMSTEDT, K., EICHMANN, K.-U., WEBER, M., ROZANOV, V.V., HOOGEN, R., DE BEEK, R., BUCHWITZ, M., KUROSU, T., AND BURROWS, J.P. 1998. Ozone profiles from GOME satellite data - Part II: First results from the Arctic winter campaign. *Pages 189–192 of:* HARRIS, N.R.P., KILBANE-DAWE, I., AND AMANATIDIS, G.T. (eds), *Polar stratospheric ozone 1997 - proc. fourth european symposium on stratospheric ozone research*. Air Pollution Research Report, vol. 66. Luxembourg: European Commission, for BMBF. 22.–26. September 1997, Schliersee, Germany.

BRAMSTEDT, K., GLEASON, J., LOYOLA, D., THOMAS, W., BRACHER, A., WEBER, M., AND BURROWS, J.P. 2002a. Comparison of total ozone from the satellite instruments GOME and TOMS with measurements from the Dobson network 1996–2000. submitted to Atmos. Chem. Phys. (Discuss.).

BRAMSTEDT, K., EICHMANN, K.-U., WEBER, M., ROZANOV, V., AND BURROWS, J. P. 2002b. GOME ozone profiles: A global validation with HALOE measurements. *Advances in space research*. accepted for publication.

BREMER, H., VON KÖNIG, M., KLEINBÖHL, A., KÜLLMANN, H., KÜNZI, K., BRAMSTEDT, K., BURROWS, J. P., EICHMANN, K.-U., WEBER, M., AND GOEDE, A. P. H. 2002. Ozone depletion observed by ASUR during the arctic winter 1999/2000. *Journal of geophysical research*. in press.

BUCHWITZ, M., ROZANOV, V.V., AND BURROWS, J.P. 2000a. A near-infrared optimized DOAS method for the fast global retrieval of atmospheric $CH_4$, CO, $CO_2$, $H_2O$, and $N_2O$ total column amounts from SCIAMACHY Envisat-1 nadir radiances. *Journal of geophysical research*, **105**, 15,231–15,245.

BUCHWITZ, M., ROZANOV, V.V., AND BURROWS, J.P. 2000b. A correlated-k distribution scheme for overlapping gases suitable for retrieval of atmospheric constituents from moderate resolution radiance measurements in the visible/near-infrared spectral region. *Journal of geophysical research*, **105**, 15,247–15,261.

BURROWS, J. P., DEHN, A., DETERS, B., HIMMELMANN, S., RICHTER, A., VOIGT, S., AND ORPHAL, J. 1998a. Atmospheric remote-sensing reference data from GOME: Part 1. Temperature-dependent absorption cross sections of $NO_2$ in the 231-794 nm range. *Journal of quantitative spectroscopy and radiative transfer*, **60**, 1025–1031.

BURROWS, J. P., RICHTER, A., DEHN, A., DETERS, B., HIMMELMANN, S., VOIGT, S., AND ORPHAL, J. 1999a. Atmospheric remote-sensing reference data from GOME: Part 2. Temperature-Dependent absorption cross sections of $O_3$ in the 231-794 nm range. *Journal of quantitative spectroscopy and radiative transfer*, **61**, 509–517.

BURROWS, J.P., CHANCE, K.V., GOEDE, A.P.H., GUZZI, R., KERRIDGE, B.J., MULLER, C., PERNER, D., PLATT, U., POMMEREAU, J.-P., SCHNEIDER, W., SPURR, R.J.D., AND VAN DER WOERD, H. 1993. *Global Ozone Monitoring Experiment: Interim Science Report*. Tech. rept. ESA, ESTEC, Publication Divisions, Noordwijk, The Netherlands. ESA Special Publication 1151.

BURROWS, J.P., DIEBEL, D., KERRIDGE, B., MUNRO, R., PEMBERTON, D., PLATT, U., AND FRANK, H. 1994. *A Study of Methods for Retrieval of Atmospheric Constituents*. Final Report ESA Contract 9687/91/NL/BI. European Space Agency, ESA/ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands.

BURROWS, J.P., HÖLZLE, E., GOEDE, A.P.H., VISSER, H., AND FRICKE, W. 1995. SCIAMACHY - Scanning Imaging Absorption Spectrometer for Atmospheric Chartography. *Acta astronautica*, **35**, 445–451.

BURROWS, J.P., ROZANOV, V.V., VOUNTAS, M., RICHTER, A., PLATT, U., HAUG, H., MARQUARD, L., AND CHANCE, K. 1996. *Study of the Ring Effect (Final Report)*. European Space Agency/ESTEC, ESA Contract 10996/94/NL/CN.

BURROWS, J.P., WEBER, M., HILSENRATH, E., GLEASON, J., JANZ, S., , CEBULA, R.P., GU, X.-Y., AND CHANCE, K. 1998b. Global Ozone Monitoring Experiment (GOME): Comparison of backscattered measurements and $O_3$ DOAS/BUV retrievals. *Pages 657–660 of:* BOJKOV, R.D., AND VISCONTI, G. (eds), *Atmospheric ozone - proc. 18th quadrennial ozone symposium l'aquila, italy*. PSTd'A.

BURROWS, J.P., WEBER, M., BUCHWITZ, M., ROZANOV, V.V., LADSTÄDTER-WEISSENMAYER, A., RICHTER, A., DE BEEK, R., HOOGEN, R., BRAMSTEDT, K., EICHMANN, K.-U., EISINGER, M., AND PERNER, D. 1999b. The Global Ozone Monitoring Experiment (GOME): Mission concept and first scientific results. *Journal of the atmospheric sciences*, **56**, 151–175.

CHANCE, K., AND SPURR, R. J. D. 1997. Ring effect studies: Rayleigh scattering, including molecular parameters for rotational Raman scattering and the Fraunhofer spectrum. *Applied optics*, **36**, 5224 – 5230.

DE BEEK, R., HOOGEN, R., ROZANOV, V.V., AND BURROWS, J.P. 1997. Ozone profile retrieval from GOME satellite data I: Algorithm description. *Pages 749–754 of:* GUYENNE, T.-D., AND DANESY, D. (eds), *Space at the service of our environment*. ESA SP-414, vol. II. ESTEC, Noordwijk, The Netherlands: ESA Publications Division, for European Space Agency. 3rd ERS Scientific Symposium, 17-21 March 1997, Florence, Italy.

DE BEEK, R., VOUNTAS, M., ROZANOV, V. V., RICHTER, A., AND BURROWS, J. P. 2001. The Ring effect in the cloudy atmosphere. *Geophysical research letters*, **28**, 721–724.

DEBACKER, H., KOEPKE, P., BAIS, A., DE CABO, X., FREI, T., GILLOTAY, D., HAITE, C., HEIKKILÄ, A., KAZANTZIDIS, A., KOSKELA, T., KYRÖ, E., LAPETA, B., LORENTE, J., MAYER, B., PLETS, H., REDONDAS, A., RENAUD, A., SCHMALWIESER, A., AND VANICEK, K. 2001. Comparison of measured and modelled uv indices. *Journal of meteorological applications*, **8**, 267–277.

DIEBEL, D., BURROWS, J.P., DEBEEK, R., KERRIDGE, B., MARQUARD, L., MUIRHEAD, K., MUNRO, R., AND PLATT, U. 1995. *Tracegas Study–Detailed Analysis of the Retrieval Algorithms Selected for the Level 1–2 Processing of GOME Data (Final Report)*. European Space Agency/ESTEC, ESA Contract 10728/94/NL/CN.

DOBBER, M.R., GOEDE, A.P.H., AND BURROWS, J.P. 1998. Observations of the moon by GOME: Radiometric calibration and lunar albedo. *Applied optics*, **37**, 7832–7841.

EICHMANN, K.-U., WEBER, M., BRAMSTEDT, K., HOOGEN, R., ROZANOV, V.V., AND BURROWS, J.P. 1998. Ozone Profile Distributions in the Arctic from GOME satellite observations during spring 1997 and 1998. *Pages 357–366 of:* RUSSELL, JAQUELINE E. (ed), *Satellite remote sensing of clouds and the atmosphere iii*. Proceedings of SPIE, vol. 3495.

EICHMANN, K.-U., BRAMSTEDT, K., WEBER, M., ROZANOV, V.V., HOOGEN, R., AND BURROWS, J.P. 1999. $O_3$ profiles from GOME satellite data - II: Observations in the Arctic spring 1997 and 1998. *Physics and chemistry of the earth*, **24**, 453–457.

EICHMANN, K.-U., WEBER, M., BRAMSTEDT, K., AND BURROWS, J.P. 2002. Ozone depletion in the NH winter/spring 1999/2000 as measured by GOME on ERS-2. *Journal of geophysical research*. in press.

EISINGER, M., AND BURROWS, J.P. 1998. Tropospheric sulfur dioxide observed by the ERS-2 GOME instrument. *Geophysical research letters*, **25**, 4177–4180.

EISINGER, M., RICHTER, A., BURROWS, J.P., AND PITERS, A. 1996a. Studies on DOAS ozone column retrieval from the UV and visible measurements of GOME. *Pages 161–174 of: Gome geophysical validation campaign proceedings- final results (24–26 january, frascati, 1996)*. ESA-WPP 108. European Space Agency.

EISINGER, M., BURROWS, J.P., AND RICHTER, A. 1996b. Studies on the precision of GOME irradiance and radiance products and GOME measurements of OClO and BrO over Antarctica. *Pages 93–105 of: Gome geophysical validation campaign proceedings - final results*. ESA-WPP 108. European Space Agency. 24–26 January 1996, Frascati, Italy.

EISINGER, M., RICHTER, A., LADSTÄDTER-WEISSENMAYER, A., AND BURROWS, J.P. 1997a. DOAS zenith sky observations: 1. BrO measurements over Bremen $53°N$ 1993–1994. *Journal of atmospheric chemistry*, **26**, 93–108.

EISINGER, M., BURROWS, J.P., RICHTER, A., AND LADSTÄTTER-WEIŠENMAYER, A. 1997b. $SO_2$, OClO, BrO, and other minor trace gases from the Global Ozone Monitoring Experiment (GOME). *Pages 675–680 of:* GUYENNE, T.-D., AND DANESY, D. (eds), *Space at the service of our environment*. ESA SP-414, vol. II. ESTEC, Noordwijk, The Netherlands: ESA Publications Division, for European Space Agency. 3rd ERS Scientific Symposium, 17-21 March 1997, Florence, Italy.

FISH, D.J., AND JONES, R.L. 1995. Rotational Raman scattering and the Ring effect in zenith-sky spectra. *Geophysical research letters*, **22**, 712–716.

GOME LVL2. 2000. GOME level 1 to 2 algorithms descriptions. *Tech. Rep. ER-TN-DLR-GO-0025, Issue 2B*. prepared by R. Spurr and W. Thomas, http://atmos.af.op.dlr.de/cgi-bin/home.cgi?page=projdocs.

GRAINGER, J.F., AND RING, J. 1962. Anomalous Fraunhofer line profiles. *Nature*, **193**, 762.

GUZZI, R., BURROWS, J., KUROSU, T., ROZANOV, V.V., CHANCE, K., WATTS, P., AND MUIRHEAD, K. 1995. *A Study of Cloud Detection*. Tech. rept. ESA Contract 10997/94/NL/CN. European Space Agency, ESA/ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands.

GUZZI, R., BURROWS, J.P., CATTANI, E., CERVINO, M., KUROSU, T., LEVONI, C., AND TORRICELLA, F. 1998. *GOME Cloud and Aerosol Data Products Algorithms Development*. Tech. rept. ESA Contract 11572/95/NL/CN. European Space Agency, ESA/ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands.

HARE, E., AND FIOLETOV, V. 1998. An examination of the total ozone data in the World Ozone and Ultraviolet Radiation Data Center. *Pages 45–48 of:* BOJKOV, R., AND VISCONTI, G. (eds), *Atmospheric ozone - proc. 18th quadrennial ozone symposium, l'aquila, italy*.

HEGELS, E., CRUTZEN, P.J., KLÜPFEL, T., PERNER, D., BURROWS, J.P., SEN MAYER, A. LADSTÄTTER-WEIS EISINGER, M., CALLIES, J., HAHNE, A., CHANCE, K., PLATT, U., AND BALZER, W. 1997. Satellite measurements of halogen oxides by the Global Ozone Monitoring Experiment GOME on ERS-2: Distribution of BrO and comparison with groundbased observations. *Pages 681–686 of:* GUYENNE, T.-D., AND DANESY, D. (eds), *Space at the service of our environment*. ESA SP-414, vol. II. ESTEC, Noordwijk, The Netherlands: ESA Publications Division, for European Space Agency. 3rd ERS Scientific Symposium, 17-21 March 1997, Florence, Italy.

HEGELS, E., CRUTZEN, P.J., KLÖPFEL, T., PERNER, D., AND BURROWS, J.P. 1998. Global distribution of atmospheric bromine monoxide from GOME on earth-observing satellite ERS-2. *Geophysical research letters*, **25**, 3127–3130.

HOOGEN, R., ROZANOV, V. V., BRAMSTEDT, K., EICHMANN, K.-U., WEBER, M., DE BEEK, R., BUCHWITZ, M., AND BURROWS, J. P. 1998a. Height-resolved ozone information from GOME data. *Earth observation quarterly*, **58**, 9–10.

HOOGEN, R., ROZANOV, V. V., AND DE BEEK, R. 1998b. $O_3$ profile retrieval from GOME satellite data. *Pages 253–254 of:* CHAUMERLIAC, N., MÉGIE, G., PAPINEAU, N., AND ANGELETTI, G. (eds), *Proc. advanced study course on tropospheric chemistry and space observation*. Air Pollution Research Report, vol. 65. Luxembourg: European Commission. 21-31 July 1997, Riom, France.

HOOGEN, R., ROZANOV, V. V., DE BEEK, R., BRAMSTEDT, K., EICHMANN, K.-U., WEBER, M., BUCHWITZ, M., KUROSU, T., AND BURROWS, J. P. 1998c. Ozone profiles from GOME satellite data - Part i: Advances in retrieval algorithm development. *Pages 677–680 of:* HARRIS, N.R.P., KILBANE-DAWE, I., AND AMANATIDIS, G.T. (eds), *Polar stratospheric ozone 1997 - proc. fourth european symposium on stratospheric ozone research*. Air Pollution Research Report, vol. 66. Luxembourg: European Commission. 22.–26. September 1997, Schliersee, Germany.

HOOGEN, R., ROZANOV, V. V., BRAMSTEDT, K., EICHMANN, K.-U., WEBER, M., AND BURROWS, J. P. 1998d. Validation of ozone profiles from GOME satellite data. *Pages 367–378 of:* RUSSELL, JAQUELINE E. (ed), *Satellite remote sensing of clouds and the atmosphere iii*. Proceedings of SPIE, vol. 3495.

HOOGEN, R., ROZANOV, V. V., BRAMSTEDT, K., EICHMANN, K.-U., WEBER, M., AND BURROWS, J. P. 1999a. $O_3$ profiles from GOME satellite data - I: Comparison with ozonesonde measurements. *Physics and chemistry of the earth*, **24**, 447–452.

HOOGEN, R., ROZANOV, V. V., AND BURROWS, J. P. 1999b. Ozone profiles from GOME satellite data: Algorithm description and first validation. *Journal of geophysical research*, **104**, 8263–8280.

JOINER, J., BARTHIA, P.K., CEBULA, R.P., HILSENRATH, E., MCPETERS, R.D., AND PARK, H. 1995. Rotational Raman scattering (Ring effect) in satellite backscatter ultraviolet measurements. *Applied optics*, **34**, 4513–4525.

KATTAWAR, G.W., YOUNG, A.T., AND HUMPHREYS, T.J. 1981. Inelastic scattering in planetary atmospheres, I, the Ring effect, without aerosols. *The astrophysical journal*, **243**, 1049–1057.

KERRIDGE, B., SIDDANS, R., LATTER, B., BURROWS, J.P., , WEBER, M., DE BEEK, R., ROZANOV, V., RICHTER, A., ABEN, I., TANZI, C., AND HARTMANN, W. 2002. *GOME-2 Error Assessment*. EUMETSAT, Darmstadt, Contract EUM/CO/01901/DK. Final Report Draft.

KOELEMEIJER, R.B.A., STAMMES, P., HOVENIER, J.W., AND DE HAAN, J.F. 2001. A fast method for retrieval of cloud parameters using oxygen A-band measurements from the Global Ozone Monitoring Experiment. *Journal of geophysical research*, **106**, 3475–3496.

König-Langlo, G., and Marx, B. 1997. The Meteorological Information System at the Alfred-Wegener-Institute. *In:* Lautenschlager, M., and Reinke, M. (eds), *Climate and Environmental Database Systems*. Kluwer Academic Publisher.

Köpke, P., Bais, A., Balis, D., Buchwitz, M., Backer, H. De, de Cabo, X., Eckert, P., Eriksen, P., Gillotay, D., Koskela, T., Lapeta, B., Litynska, Z., Lorente, J., Mayer, B., Renaud, A., Schauberger, G., Seckmeyer, G., Seifert, P., Schmalwieser, A.W., Schwander, H., Vanicek, K., and Weber, M. 1998. Comparison of models used for UV index calculations. *Photochemistry and photobiology*, **67**, 657–662.

Kurosu, T., Rozanov, V.V., and Burrows, J.P. 1997. Parameterization schemes for terrestrial water clouds in the radiative transfer model GOMETRAN. *Journal of geophysical research*, **102**, 21809–21823.

Kuze, A., and Chance, K. 1994. Analysis of Cloud Top Height and Cloud Coverage from Satellites using the $O_2$ A and B bands. *Journal of geophysical research*, **99**, 14481–14491.

Ladstätter-Weissenmayer, A., Burrows, J.P., Richter, A., Wittrock, F., Buchwitz, M., Weber, M., Eisinger, M., and Neuber, R. 1996. Validation of GOME $O_3$ and $NO_2$ measurements in Bremen, Ny Alesund, and Neumayer. *Pages 153–160 of: Gome geophysical validation campaign proceedings- final results*. ESA-WPP 108. European Space Agency. 24–26 January 1996, Frascati, Italy.

Lambert, J.C., van Roozendael, M., de Maziere, M., Simon, P.C., Pommerau, J.-P., Goutail, F., Sarkissian, A., and Gleason, J.F. 1999. Investigation of pole-to-pole performances of space-borne atmospheric sensors with ground-based networks. *Journal of the atmospheric sciences*, **56**, 176–XXX.

Lambert, J.C. *,et al.* 1995. Combined characterisation of GOME and TOMS total ozone measurements from space using ground-based observations from NDSC. *Advances in space research*, **35**, 445–451.

Menkhaus, A., Weber, M., Haite, C., and Burrows, J.P. 1999. Surface uv modelling using GOME data. *Pages 325–332 of: European symposium on atmospheric measurements from space, proc. esams'99*, vol. ESA-WPP-161.

Müller, M.D., Kaifel, A., Weber, M., and Burrows, J.P. 2002. A new method for retrieving total ozone from GOME data. *Applied optics*. in press.

ORPHAL, J., BOGUMIL, K., DEHN, A., DETERS, B., DREHER, S., FLEISCHMANN, O.C., HARTMANN, M., HIMMELMANM, S., KROMMINGA, T. HOMANNAND H., SPIETZ, P., TÜRK, A., VOGEL, A., VOIGT, S., AND BURROWS, J.P. 2002. Laboratory Spectroscopy in Support of UV-Visible Remote-Sensing of the Atmosphere. *In:* PANDALAI, S. G. (ed), *Recent Research Developments in Physical Chemistry*. Transworld Research. in press.

PLATT, U., AND PERNER, D. 1980. Direct measurements of atmospheric hcho, hono, $o_3$, $no_2$, and $so_2$ by differential optical absorption in the near UV. *Journal of geophysical research*, **85**, 7453–XXXX.

RICHTER, A., WITTROCK, F., EISINGER, M., AND BURROWS, J.P. 1998a. Gome observations of tropospheric BrO in northern hemispheric spring and summer 1997. *Geophysical research letters*, **25**, 2683–2686.

RICHTER, A., EISINGER, M., WITTROCK, F., AND BURROWS, J.P. 1998b. Measurements of halogen oxides by GOME. *Earth observation quarterly*, **58**, 19–20.

RICHTER, A., EISINGER, M., WITTROCK, F., SCHLIETER, S., LADSTÄTTER-WEISSENMAYER, A., AND BURROWS, J.P. 1998c. Zenith sky measurements and GOME DOAS measurements of atmospheric trace gases above Bremen, 53°N, 1994–1997. *Pages 482–485 of:* HARRIS, N.R.P., KILBANE-DAWE, I., AND AMANATIDIS, G.T. (eds), *Polar stratospheric ozone 1997 - proc. fourth european symposium on stratospheric ozone research*. Air Pollution Research Report, vol. 66. Luxembourg: European Commission, for BMBF. 22.–26. September 1997, Schliersee, Germany.

ROSSOW, W.B., AND GARDER, L.C. 1993. Cloud detection using satellite measurements of infrared and visible radiances for ISCCP. *J. climate*, **6**, 2341–2369.

ROZANOV, A., ROZANOV, V., AND BURROWS, J. P. 2000. Combined differential-integral approach for the radiation field computation in a spherical shell atmosphere: non-limb geometry. *Journal of geophysical research*, **105**, 22,937–22,942.

ROZANOV, A., ROZANOV, V., AND BURROWS, J. P. 2001. A numerical radiative transfer model for a spherical planetary atmosphere: Combined differential–integral approach involving the Picard iterative approximation. *Journal of quantitative spectroscopy and radiative transfer*, **69**, 491–512.

ROZANOV, V.V., TIMOFEYEV, Y.M., BIRYULINA, M.S., BURROWS, J.P., SPURR, R.J.D., AND DIEBEL, D. 1993. Accuracy of atmospheric constituent retrieval from multichannel remote sensing instruments. *Pages 394–397 of:* KEEVALLIK, S., AND KÄRNER, O. (eds), *Irs '92: Current problems in atmospheric radiation*. Ganotibm VAm USA: Deepak Publishing.

ROZANOV, V.V., D.DIEBEL, SPURR, R.J.D., AND BURROWS, J.P. 1997. GOMETRAN: A radiative transfer model for the satellite project GOME, The plane-parallel version. *Journal of geophysical research*, **102**(D14), 16683–16695.

ROZANOV, V.V., KUROSU, T., AND BURROWS, J.P. 1998. Retrieval of atmospheric constituents in the UV/visible: A new analytical approach to calculating weighting functions. *Journal of quantitative spectroscopy and radiative transfer*, **60**, 277–299.

SHEFOV, N. N. 1959. Spectroscopic, photoelectric, and radar investigations of aurorae and the nightglow. *Izd. akad. nauk*, **1**(25). in Russian.

SINNHUBER, B.M., CHIPPERFIELD, M.P., DAVIES, M.S., BURROWS, J.P., EICHMANN, K.-U., WEBER, M., VAN DER GATHEN, P., GUIRLET, M., CAHILL, G., LEE, A., AND PYLE, J. 2000. Large loss of total ozone during the arctic winter 1999/2000. *Geophysical research letters*, **27**, 3473–3476.

SIORIS, C. E., AND EVANS, W. F. J. 1999. Filling in of Fraunhofer and gas-absorption lines in sky spectra as caused by rotational Raman scattering. *Applied optics*, **38**, 2706 – 2713.

SLIJKHUIS, S., V. BARGEN, A., THOMAS, W., AND K.V.CHANCE. 1999. Calculation of Undersampling correction spectra for DOAS spectral fitting. *Pages 563–569 of:* ESA (ed), *Esams'99 - european symposium on atmospheric measurements from space*. ESA, Noordwijk, The Netherlands.

VIERECK, R., PUGA, L., MCMULLIN, D., JUDGE, D., WEBER, M., AND TOBISKA, W.K. 2001. The Mg II index: A proxy for solar EUV. *Geophysical research letters*, **28**, 1343–1346.

VOUNTAS, M., ROZANOV, V.V., AND BURROWS, J.P. 1998. Ring effect: Impact of rotational raman scattering on radiative transfer in earth's atmosphere. *J. Quant. Spectrosc. Radiat. Transfer*, **60**(6), 943–961.

WEBER, M. 1999. Solar activity during solar cycle 23 monitored by gome. *Pages 611–616 of: European symposium on atmospheric measurements from space, proc. esams'99*, vol. ESA-WPP-161. Noordwijk: European Space Agency Publication Division.

WEBER, M., BURROWS, J.P., AND CEBULA, R.P. 1998. GOME solar UV/VIS irradiance measurements between 1995 and 1997 – First results on proxy solar activity studies. *Solar physics*, **177**, 63–77.

WEBER, M., EICHMANN, K.-U., WITTROCK, F., BRAMSTEDT, K., HILD, L., RICHTER, A., BURROWS, J.P., , AND MÜLLER, R. 2002. The cold arctic winter 1995/96 as observed by the Global Ozone Monitoring Experiment GOME and HALOE: Tropospheric wave activity and chemical ozone loss. *Quarterly journal of the royal meteorological society*, **128**, 1293–1320.

WELLEMEYER, C., TAYLOR, S., SEFTOR, C., MCPETERS, R., AND BARTHIA, P. 1997. A correction for Total Ozone Mapping Spectrometer profile shape errors at high latitude. *Journal of geophysical research*, **102**, 9029–9038.

WMO REPORT. 1999. *Scientific Assessment of Ozone Depletion: 1998*. World Meteorological Organization, Gobal Ozone Research and Monitoring Project, Report No. 44.

# 8 Appendix: PSSA Forms

| | | |
|---|---|---|
| **COMPANY COST ELEMENT DATA SHEET** | **FORM No. PSS A1 Issue 2** | Page no. 1 of 1 |
| RFQ/ITT no.: ESA ITT AO/1-4235/02/I-LG | | COMPANY NAME: IUP University of Bremen |
| PROPOSAL no.: GOTOCORD-V1A | | Name and title: Dr. Mark Weber |
| NATIONAL CURRENCY *: Euro (€) | | Signature: |
| Period for which agreed rates and overheads are valid : From 1st July. 2002 To 31st Oct. 2003 | | |
| ECONOMIC CONDITIONS: | | |

| 1. LABOUR | Labour hourly Rate (€) | Labour OH% | Gross hourly rate (€) | Total hours | Gross Total (€) |
|---|---|---|---|---|---|
| WP 100: Management BATIIa Research Scale | 35.40 | 20 | 42.48 | 80 | 3,398.40 |
| WP 200: Administration BATIIa Research Scale | 35.40 | 20 | 42.48 | 80 | 3,398.40 |
| WP 300: Sensitivity Study and Optimisation | 35.40 | 20 | 42.48 | 640 | 27,187.20 |
| WP 400: Algorithm Implementation | 35.40 | 20 | 42.48 | 960 | 40,780.80 |
| WP 500: Validation | 35.40 | 20 | 42.48 | 320 | 13,593.60 |
| | | | | **A Gross Total Labour** | **88,358.40** |

| 2. INTERNAL SPECIAL FACILITIES | Type of Unit | UNIT RATE (NC) | Gross Total (€) |
|---|---|---|---|
| | | **B Gross Total Internal Special Facilities** | **0.00** |

| 3. OTHER COST ELEMENTS | | | | | |
|---|---|---|---|---|---|
| According to ESA type | | Cost (€) | Overhead (%) | Overhead (€) | Gross Total (€) |
| 3.1 | Raw materials | | | | |
| 3.2 | Mechanical parts | | | | |
| 3.3 | Semi-finished products | | | | |
| 3.4 | Electric & electron components | | | | |
| 3.5 | Hired parts | | | | |
| | a) procured by company | | | | |
| | b) procured by 3rd party | | | | |
| 3.6 | External major products | | | | |
| 3.7 | External services | | | | |
| 3.8 | Transport, insurance | | | | |
| 3.9 | Travels | 8,775.00 | 20 | 1,755.00 | 10,530.00 |
| 3.10 | Consumables | 1,000,00 | 20 | 200.00 | 1,200.00 |
| 3.11 | Subcontracts | | | | |
| | | | | **C Gross Total Other Expenses** | **11,730.00** |

| GENERAL EXPENSES | | | | |
|---|---|---|---|---|
| According to ESA type | According to normal company type | Applicable on cost element no. | | |
| 5. General & Admin. expenses | | | | |
| 6. Research & Developm. expenses | | | | |
| 7. Other (specify) | | | | |
| | | | **D Gross Total Other Expenses** | **0.00** |

| | |
|---|---|
| 12. **Cost without additional charge (A+B+C+D)** | **100,088.00** |

| | | |
|---|---|---|
| **COMPANY PRICE BREAKDOWN FORM** | Form No. PSS A2 | Issue 3 __________<br>Page No. 1 No. of Pages 1 . |
| RFQ/ITT No. ESA ITT AO/1-4235/02/I-LG | | **COMPANY NAME:** IUP University of Bremen |
| Proposal/Tender No. GOTOCORD-V1A | | Name and Title: Dr. Mark Weber |
| Economic Condition | Type of Price: fixed | Signature: |

**SUPPLIES AND/OR SERVICES TO BE FURNISHED**
GOME Total Ozone Retrieval Development

| **LABOUR**<br>Direct Labour cost centres or categories | Manpower effort in Manhours | Gross Hourly Rates in € | NC=€ | |
|---|---|---|---|---|
| WP 100 | 80 | 42.48 | 3,398.40 | |
| WP 200 | 80 | 42.48 | 3,398.40 | |
| WP 300 | 640 | 42.48 | 27,187.20 | |
| WP 400 | 960 | 42.48 | 40,780.80 | |
| WP 500 | 320 | 42.48 | 13,593.60 | |
| | | | | |
| | | | | |
| 1 Total Direct Labour Hours and Cost | | | A 88,358.40 | |

| **INTERNAL SPECIAL FACILITIES** | Type of unit | No. of units | Unit rates in NC | | |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| 2 Total Internal Special Facilities Cost | | | | B 0.00 | |

| **OTHER COST ELEMENTS** | Amounts in NC | OH% | x Amounts = | | |
|---|---|---|---|---|---|
| 3.1 Raw materials | | | | | |
| 3.2 Mechanical parts | | | | | |
| 3.3 Semi-finished products | | | | | |
| 3.4 Electrical & electronic components | | | | | |
| 3.5 Hirel parts | | | | | |
| a) procured by company | | | | | |
| b) procured by third party | ( ) p.m. | | | | |
| 3.6 External Major Products | | | | | |
| 3.7 External Services | | | | | |
| 3.8 Transport/Insurance | | | | | |
| 3.9 Travels | 8,775.00 | 20 | 1,755.00 | 10,530.00 | |
| 3.10 Miscellaneous | 1,000.00 | 20 | 200.00 | 1,200.00 | |
| 3 Total Other Direct Cost | C 9,775.00 | | D 1,955.00 | E 11,730.00 | |
| 4. SUB TOTAL COST | | | (A+B+E) | F 100,088.00 | |

| **GENERAL EXPENSES** | Cost items to which % applies | Base in NC to which % applies | % | | |
|---|---|---|---|---|---|
| 5. General & Admin. Expenses | | | | G | |
| 6. Research & Develop. Exp. | | | | H | |
| 7. Other___________________ (to be specified) | | | | J | |
| 8. Total Cost of All Work Packages | | | (F+G+H+J) | K 100,088.00 | |
| 9. Overheads on Subcontractors (Base in NC on which % applies: ) | | | % | L 0.00 | |
| 10. Sub-total | | | (K+L) | M | |
| 11. Profit ( % on item(s)) | | | | N | |
| 12. Cost without additional charge (to be itemised on Exhibit A) | | | | P | |
| 13. Financial Provision for escalation, if applicable | ( justification and details to be stated on Exhibit A) | | | Q | |
| 14. Total | | | (M+N+P+Q) | R 100,088.00 | |
| 15. Reduction for company contribution (if applicable) | | | | S | |
| 16. TOTAL PRICE FOR ESA | | | (R-S) | T 100.088.00 | |

**Manpower and Price Summary** **PSSA8 Issue 3**

Subject: GOTOCORD-V1A Proposal ITT/RFQ: . ESA ITT AO/1-4235/02/I-LG

National Currency (NC) : €

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Company IUP | | | | | | | |
| WP Title | | | | | | | |
| WP Number | | WP 100 | WP 200 | WP 300 | WP 400 | WP500 | Total WBS-Level |
| Labour hours as per PSS A2 (*) | | 80h | 80h | 640h | 960h | 320h | 2080h |
| 1. Total Direct Labour Cost | | 3,398.40 | 3,398.40 | 27,187.20 | 40,780.80 | 13,593.60 | 88,358.40 |
| 2. Internal Special Facilities | | | | | | | |
| 3.1-3.4 Material Costs | | | | | | | |
| 3.5 High Rel Parts Costs | | | | | | | |
| 3.6 External major products Cost | | | | | | | |
| 3.7 External Services Cost | | | | | | | |
| 3.8 Transport/Insurance Cost | | | | | | | |
| 3.9 Travel and Subsistance Cost | | | | 5,076.00 | 2,538.00 | 2,916.00 | 10,530.00 |
| 3.10 Miscellaneous Cost | | 600.00 | 600.00 | | | | 1,200.00 |
| 3. Total Other Costs | | | | | | | |
| 4. Subtotal Cost | | | | | | | |
| 5.- 7. General expenses | | | | | | | |
| 8. Total Cost of WPs | | 3,898.40 | 3,898,40 | 31,417.20 | 42,895.80 | 16,023.60 | 100,088.40 |
| 9. Overhead on Subcontractors | | | | | | | |
| 10. Subtotal (8+9) | | | | | | | |
| 11. Profit | | | | | | | |
| 12. Cost without additional charge | | | | | | | |
| 13. Financial Provision for escalation | NC | | | | | | |
| 14. Total | NC | | | | | | |
| | EUROs | 3,898.40 | 3,898,40 | 31,417.20 | 42,895.80 | 16,023.60 | 100,088.40 |
| 15. Reduction for company contribution | NC | | | | | | |
| (if applicable) | EUROs | | | | | | |
| 16. Total Price | NC | | | | | | |

**Work Breakdown Structure Level 1**



Price Projection by Contractor in KEURO

Subject: GOTOCORD-V1A Proposal

EURO Conversion Rate: as per form PSS A2 :

ITT/RFQ ref: . ESA ITT AO/1-4235/02/I-LG

Currency: €

Economic Conditions:

Time periods expressed in: months (total 12 months)

| Company | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Labor Cost WP 100/WP 200 | 552.24 | 552.24 | 594.72 | 552.24 | 552.24 | 594.72 | 552.24 | 552.24 | 594.72 | 552.24 | 552.24 | 594.72 |
| Labor Cost WP 300/WP 400/ WP 500 | 6796.80 | 6796.80 | 6796.80 | 6796.80 | 6796.80 | 6796.80 | 6796.80 | 6796.80 | 6796.80 | 6796.80 | 6796.80 | 6796.80 |
| Comsumables | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Travel | 2538.00 | | | 2538.00 | | | 2538.00 | | | | | 2916.00 |
| Amount in KEURO * | 9987,04 | 7449.04 | 7491.52 | 9987.04 | 7449.04 | 7491.52 | 9987.04 | 7449.04 | 7491.52 | 7449.04 | 7449.04 | 10407,52 |
| Cumulative Amount in KEURO * | 9987.04 | 17436.08 | 24927.60 | 34914.64 | 42363.68 | 49855.20 | 59842.24 | 67291.28 | 74782.80 | 82231.84 | 89680.88 | 100088.40 |

* To be understood as the "Total Price for ESA " as per box 16 of for

**WORK BREAKDOWN STRUCTURE LEVEL 1** FORM NO PSS A15.1 ISSUE 3
**PRICE PROJECTION BY CONTRACTOR VS. PAYMENT PLAN IN KEURO**

| | |
|---|---|
| SUBJECT: GOTOCORD-V1A Proposal | ITT/RFQ REF. ESA ITT AO/1-4235/02/I-LG |
| CONTRACTOR IUP University of Bremen | TIME PERIODS EXPRESSED IN months |
| CURRENCY (if NOT EURO ): | |

| Periods | | 1-4 | 5-6 | 6-10 | 10-12 |
|---|---|---|---|---|---|
| 1. MAJOR MILESTONES | | Phase 1 | Phase 2 Part A | Phase 2 Part B | Phase 3 |
| 2. | EXPENDITURES PER PERIOD | 34914.64 | 14950.56 | 32376.64 | 17856.56 |
| | CUMULATIVE EXPENDITURES | 34914.64 | 49855.20 | 82231.84 | 100088.40 |
| 3. | PAYMENT PLAN PER PERIOD * | 30000.00 | 40000.00 | 0.00 | 30088.00 |
| | CUMULATIVE PAYMENTS * | 30000.00 | 70000.00 | 70000.00 | 100088.00 |