



Institut für Chemie und Dynamik der Geosphäre
Institut I: Stratosphäre

***Description of the
Anisotropic Radiation Transfer Model ART
to Determine Photodissociation Coefficients***

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Introduction

All natural chemistry is driven directly or indirectly by the sunlight. Therefore, the fate of the photons coming from the sun on their way through the earth's atmosphere is essential to know if chemical processes of the biosphere or the atmosphere shall be understood. Especially in the atmosphere the processes, both physical and chemical in nature, are primarily driven by the sunlight. That is why it is so important for atmospheric models to include algorithms which simulate the photon flux through the earth's atmosphere as exactly as possible.

While the dynamics of the atmosphere depend on the energy flux covering the whole wavelength regime from the vacuum ultraviolet to the far infrared, atmospheric chemistry reactions are only influenced by light of wavelengths reaching from 180 nm to 700 nm, approximately. And, moreover, the chemistry deals with the actinic flux, i. e. the number of photons passing through a volume of given size independent on the direction, as for photodissociation processes the encounter between photons and molecules is not subject to the angle of the collision.

Whereas the physics of the direct beam from the sun through the atmosphere is well understood since long, the multiple scattering of photons by molecules (Rayleigh scattering) was included in the nineteen hundred seventies in photochemical models (e.g.: Isaksen et al., 1976, Luther and Gelinas, 1976, Bahe et al., 1979). And in the eighties the scattering by aerosols and water droplets (Mie scattering) was added to the determination of photolysis coefficients, examples can be found in Stamnes et al. (1988), Lary and Pyle (1991), Kylling et al. (1993), Ruggaber et al. (1994), Minschwaner et al. (1995), Trautmann and Box (1995), Kylling et al. (1995), Blindauer et al. (1996).

In photochemical models of the atmosphere (e.g. Röth, 1980, McKenna et al., 2001) three-stream approximations of the photonflux are applied to determine photodissociation rates. These models are based on the assumption that the diffuse radiation is isotropic. To improve the three-stream models they have to be compared to more sophisticated calculations which include the anisotropy of the photonflux. Such a model is the Anisotropic Radiation Transfer Model ART, which will be described here.

The purpose of the model ART is to determine the photodissociation coefficients for the interpretation of measurements of radicals. Likewise, radiometer signals

measuring a hemispheric actinic photon flux can be simulated by means of this model. Such radiometer measurements were carried out since 1980 at the Institute for Atmospheric Chemistry of the Research Centre at Jülich, both at ground level and on balloons. Especially, the data from the balloon borne radiometers were of interest for the development of this model, as they measure the light coming from above as well as the radiation being scattered upwards. By comparison of the simulated upward and downward fluxes to the radiometer signals the model was validated (see section "Validations"). For these purposes we rather emphasised the accuracy of the model than the speed of the calculation. A fast but less accurate algorithm for use in global photochemical models is enclosed in the source deck, but is described elsewhere (Röth, 1992).

After this introduction the physical background entering the simulations is described. To determine photodissociation coefficients it is not necessary to follow single rays. On the contrary, in this model each 'ray' represents a whole bunch of light covering a large portion of the earth surface area. This model philosophy has some implications for the use of the model. Especially those applications which need an exact determination of the incident radiation in respect to both, zenith and azimuth angle, are not possible with ART.

Next, the algorithms used to solve the differential equations for the flux and to integrate the scattering functions to determine the phase function are described. A detailed description of the frame program and the subroutines FLUXES and PHOTO follows. The frame program governs the input and output of the model and calls the subprograms. FLUXES is the routine which actually calculates the photon fluxes and then the routine PHOTO is used to determine the rate coefficients or the radiometer signals.

In the chapter which follows next the handling of the model is explained. Here, especially the meaning of the different steering parameters and the different possibilities for running the model are described.

Typical results of the simulations for different purposes are shown in chapter "Results". Within this chapter the model's results are compared to measurements and to other more sophisticated models. Additionally, results of diverse specific tests are shown.

In the last section “Validations“ the model outcome is compared to published spectral radiometer measurements (Herman and Mentall,1982) at 40 km altitude and to actinometer observations of the photolysis frequency of NO₂ (Shetter et al., 1992). An especially crucial test for the accuracy of the model is the simulation of filter radiometer signals during ascent and descent while the UV-B edge is moving through the sensitivity range of the device. An example of the simulation of such a measurement (Schiller et al., 1994) is also included.

The Physical Background

The model follows a ray coming from the sun and reaching the earth's atmosphere at 100 km altitude. The wavelength dependent solar flux used in this model is that given by the WMO, (1985). Actually, each model ray represents a whole bunch of light which covers a large surface area compared to the model's layer thickness of 1 km. Therefore, all processes the photons undergo within the layer may be treated as if they take place in a plane parallel atmosphere. This implicates, that we cannot follow a single ray or a small bundle of rays as it is essential for interpreting e.g. the results of a spectrometer experiment where only the light out of a small angle of view enters the spectrograph.

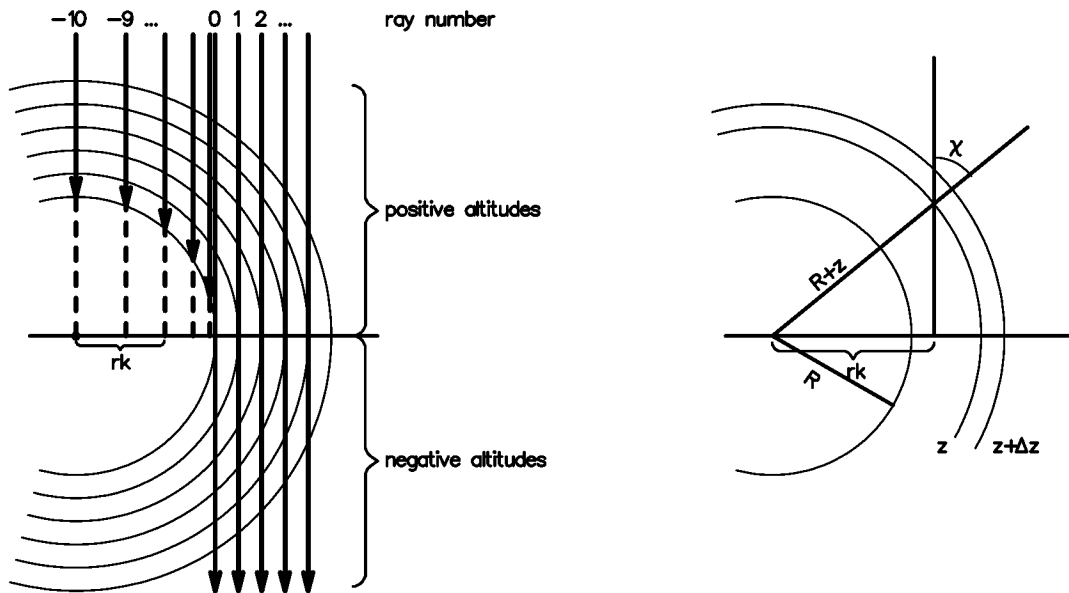


Figure 1: Sketch of the geometry for the different rays. Each ray is represented by its distance rk from the earth's centre. R is the radius of the solid earth. Because of the earth's spherical geometry the solar zenith χ angle is altitude dependent.

The rays can be distinguished by the distance rk at which they pass the centre of the earth (see Fig. 1). We did not choose the solar zenith angle as a discriminator

for the rays as due to the spherical geometry, the zenith angle is altitude dependent for a specific ray. Moreover, for those rays passing the earth's surface at a certain distance solar zenith angles are not defined at all heights.

From the distance rk the solar zenith angle χ at an altitude z can be calculated

$$\sin \chi = \frac{rk}{R+z} \quad (1)$$

and the path length Δs through a spherical shell of thickness Δz is given by

$$\Delta s = \sqrt{(R+z+\Delta z)^2 - rk^2} - \sqrt{(R+z)^2 - rk^2} \quad (2)$$

with R the radius of the earth. This formula is then modified to account for the refraction within the atmosphere. Actually, the refraction does not change the path length considerably, but influences mainly the observed solar zenith angle.

Beside the collimated rays coming directly from the sun there is diffusive light resulting from scattering events at molecules and aerosols and from the reflection at the earth's surface. This diffuse light is represented in the model by n beams, with typically $n = 20$ as a default value. These beams are distinguished by their angles φ_i against the vertical to the layer's surface. Each beam stands for all light within a cone shell with an discrete opening angle $\Delta\varphi$ (see Fig. 2).

On its way through the atmosphere a photon may undergo different processes. First, it may be absorbed by a constituent of the air. If there is sufficient energy of the photon to break down the chemical bonds of the absorbing species, molecule fragments are formed. These fragments then start a chain of chemical reactions. This process, the photodissociation, is the starting point of all chemical transformations going on in the atmosphere.

If the energy of the photon is not high enough to break down the particle, the excited molecule will be quenched and by this process the energy is gradually transformed into heat, a process which is not considered in purely photochemical models. Beside being quenched the excited molecule may release its energy by radiation of the same wavelength as that of the incident photon. This process, known as scattering, does not change the amount of photons but the direction of the photon flux. Photons can be scattered by molecules (Rayleigh scattering) and/or by aerosols and water droplets (Mie scattering). Raman scattering with the

frequency of the emitted radiation different from the incoming one is rather scarce in the earth's atmosphere and need not to be considered.

Additionally, a part of the photons which reach the earth's surface, is not absorbed by the soil or the biosphere, but is reflected upwards. The reflected fraction of the incoming flux is called 'albedo'. Here, albedo always stands for the surface albedo. The reflectance of the clouds, 'cloud albedo', is taken into account by the scattering algorithm for optically dense media. Due to the model philosophy that each ray represents always a broad bundle of light the surface albedo is an average over a large area rather than the local albedo of the site of the experiment.

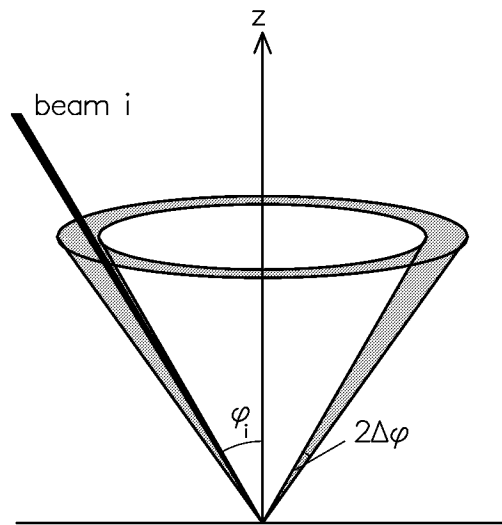


Figure 2: Sketch showing how a beam i represents all diffusive light within a cone of an angle interval $[\varphi_{i-1}, \varphi_i]$. The axis of the cone shell is vertical in respect to the earth's surface.

The direct beam

Due to the different processes which may occur, one distinguishes between the direct, collimated beam and the scattered, diffuse photon flux. First, the direct beam shall be followed. In a layer of thickness Δz in the altitude interval $[z+\Delta z, z]$ the photons experience absorption as well as scattering. In respect to the direct beam both processes mean a loss of photons, governed by the Beer-Lambert law.

$$dF = -F \cdot \tau ds - F \sigma ds \quad (3)$$

Here, F stands for the photon flux per unit area, and τ and σ are the total optical depths due to absorption (τ) and scattering (σ). In the ultraviolet (UV) and visible (VIS) region of the spectrum the only relevant absorption processes are those of molecular oxygen (O_2), ozone (O_3) and nitric dioxide (NO_2) :

$$\tau = \tau_{O_2}[O_2] + \tau_{O_3}[O_3] + \tau_{NO_2}[NO_2] \quad (4)$$

The τ_i are the absorption cross sections of the respective species, and $[X]$ stands for the concentration of the component X .

Likewise, the scattering can be split into three different processes : molecular (Rayleigh)-, aerosol-, and droplet-scattering :

$$\sigma = \sigma_R[M] + \sigma_{Ae}[Ae] + \sigma_{Dr}[Dr] \quad (5)$$

M stands for the medium (i.e. the sum of all constituents of the air), Ae for the dry aerosol, and $[Dr]$ is the number density of the water droplets. In the program scattering on water droplets is calculated by a separate algorithm, as clouds represent an optically thick medium which needs a special treatment. The way how optical thick media are handled in the program is described in the last section of this chapter.

It is assumed that the concentrations of all species shall be constant within a given layer $[z+\Delta z, z]$. With this, Equation 3 can be integrated :

$$F_z = F_{z+\Delta z} e^{-(\tau+\sigma)\Delta z} \quad (6)$$

Next, the photon flux F per unit area perpendicular to the vertical (or the irradiance) shall be connected to the actinic flux I . For these definitions we follow the papers by Madronich (1987,1993). Figure 3a displays the geometry of the relationship

between F and I . By definition the irradiance presents the photon flux through a flat plane, declined against the direction of the photon flux by the zenith angle θ . Due to geometrical reasons the irradiance is related to the radiance L (per unit area perpendicular to the light's direction) by

$$F(\theta, \phi) = L(\theta, \phi) \cos \theta \quad (7)$$

The radiance $L(\theta, \phi)$ represents the incoming photonflux from a specified direction (θ, ϕ) .

The actinic flux I stands for the photon flux through a given area, independent of the direction of the incoming light :

$$I(\theta, \phi) = L(\theta, \phi) \quad (8)$$

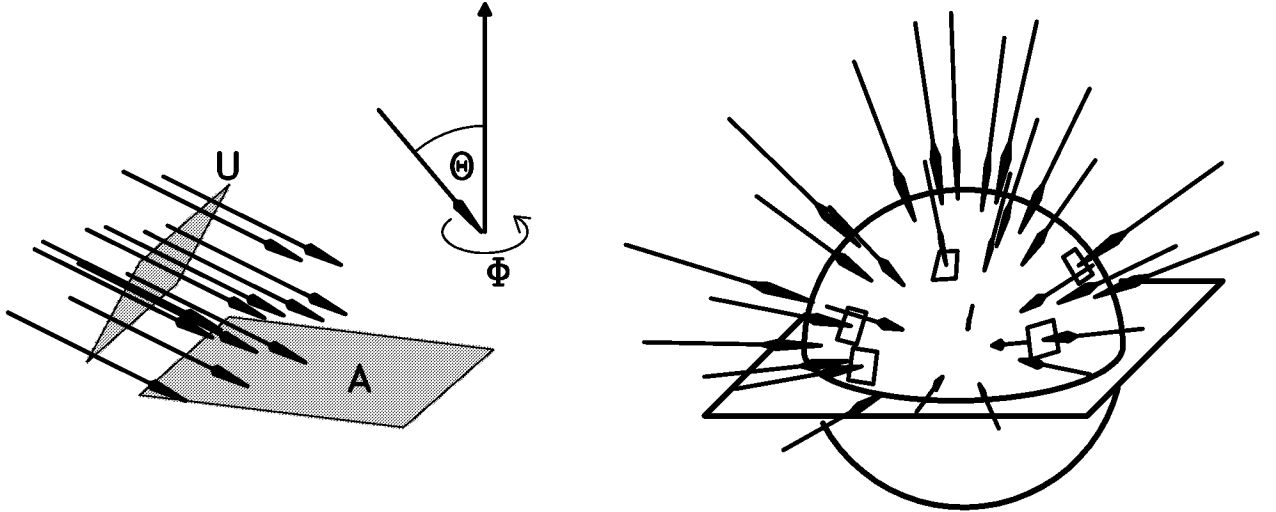


Figure 3: Relationship between the irradiance and the actinic flux for a) a parallel radiance and b) a totally isotropic photonflux.

In other words, if a flat area is considered, the irradiance F represents the vector component perpendicular to the plane, whereas the actinic flux stands for the number density of photons passing through the plane.

The total irradiance and the total actinic flux are the integrals of the specific quantities over all directions :

$$\begin{aligned}
 F &= \int_0^{2\pi} \int_{-1}^{+1} F(\theta, \phi) d \cos \theta d\phi = \\
 &= \int_0^{2\pi} \int_{-1}^{+1} L(\theta, \phi) \cos \theta d \cos \theta d\phi
 \end{aligned} \tag{9}$$

and

$$\begin{aligned}
 I &= \int_0^{2\pi} \int_{-1}^{+1} I(\theta, \phi) d \cos \theta d\phi = \\
 &= \int_0^{2\pi} \int_{-1}^{+1} L(\theta, \phi) d \cos \theta d\phi
 \end{aligned} \tag{10}$$

Figure 3b displays the case of a totally isotropic photon flux where the radiance L is independent of the direction. For this example the irradiance and the actinic flux are given by

$$\begin{aligned}
 F &= \pi L \\
 I &= 2\pi L
 \end{aligned} \tag{11}$$

if only one hemisphere is considered. For an isotropic spherical geometry I doubles and F equals 0, as the actinic flux is independent on the directions, whereas for the irradiance the upwards and downwards directed fluxes cancel each other.

In the model only a limited number of directions is considered where each flux represents the integration over a cone shell :

$$F = \int_{\theta-\Delta/2}^{\theta+\Delta/2} \left[\int_0^{2\pi} I(\theta, \phi) d\phi \right] \cos \theta d \cos \theta \tag{12}$$

If it is assumed that within the single cone shell the radiance L is independent of θ , the relation between the total actinic flux and the irradiance is given by

$$I = \sum_{i=1}^n F_i(\theta_i) / \cos \theta_i \quad (13)$$

This assumption represents the reality if the number of directions is sufficiently large. According to tests n should not be much smaller than 20, if all angular intervals are equal. This number can become smaller, if the spacing of the intervals is selected according to the angular distribution of the diffuse light.

The diffuse light

For the diffuse light, a beam is defined by its direction

$$\mu_i = \cos \chi_i \quad (14)$$

The respective photon flux F_i will undergo absorption as well as scattering, just as it is with the direct beam. But, contrary to the collimated light, for a diffuse beam scattering is no longer a mere loss. Each beam i will gain photons from scattering processes from all other beams j :

$$dF_i = \left\{ -F_i(\tau + \sigma) + \sum_j F_j \left[\sigma P_{ij} \right] \frac{\mu_i}{\mu_j} \right\} ds_i \quad (15)$$

with $\left[\sigma P_{ij} \right] = \sigma_R P_{ijR} [M] + \sigma_{Ae} P_{ijM} [Ar] + \sigma_{Dr} P_{ijM} [Dr]$

P_{ij} , the appropriate phase function of the Rayleigh and Mie scattering, determines which portion of the photons from direction j are scattered into direction i . The factor μ_i/μ_j pays regard to the differences in the path lengths, and, henceforth, in the encounter probability.

The Differential Equation 15 cannot be solved directly as the source function Q_i

$$Q_i = \sum_j F_j [\sigma P_{ij}] \mu_i / \mu_j \quad (16)$$

links the equations for the different directions. The algorithm used to solve this coupled differential equation system will be described in the next chapter.

In the program the irradiance F is followed through the atmosphere. The actinic flux I is afterwards calculated according to Equation 13. This has the advantage that both quantities are always available in the model.

The Rayleigh scattering and the albedo

The probability of a photon to be scattered into the direction Θ , the scattering angle, i. e. the angle between the incident and the outgoing beam, is given by the scattering function. The Rayleigh scattering function is (Paltridge and Platt, 1976)

$$f_R(\Theta) = 3/8 \cdot \sin \Theta \cdot (1 + \cos^2 \Theta) \quad (17)$$

The scattering angle is related to the directions φ_0 of the incident beam, φ of the outgoing beam and η , the rotational angle around the z-axis (see Fig. 4).

$$\cos \Theta = \sin \varphi_0 \cdot \cos \eta \cdot \sin \varphi + \cos \varphi_0 \cdot \cos \varphi \quad (18)$$

As a plane parallel geometry is assumed within each layer and the φ_i represent cone shells of opening angle $\Delta\varphi$ and cone angle φ_i (see Fig. 2), the probability of a photon incoming from beam i and being scattered into any new direction represented by φ_j , is given by the phase function

$$P_{ij} = \int_{\varphi_i + \Delta\varphi/2}^{\varphi_i + \Delta\varphi/2} \int_0^{2\pi} f(\Theta) \sin \varphi \, d\eta \, d\varphi \quad (19)$$

The phase function is normalized to 1. In the model the normalization of the different cone shells is combined with the normalization of P_{ij} .

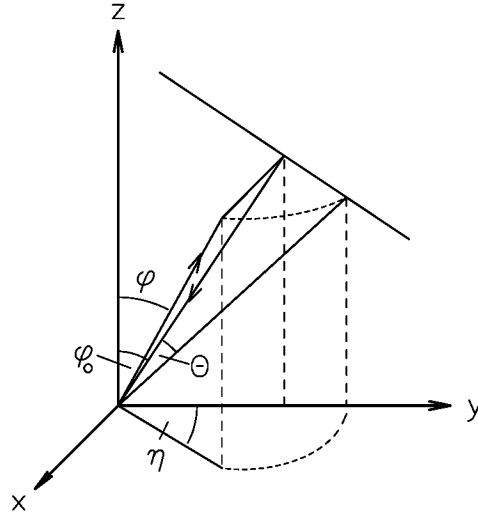


Figure 4: The relation between an incoming ray φ_0 and the ray φ after a scattering event. θ is the scattering angle defined by the scattering function. The incoming ray lies in the yz -plane.

Finally, the reflectance of the earth's surface has to be defined. Some part of the incoming light is not absorbed by the soil or the plants but scattered backwards. The amount of the photons being reflected (albedo) and the angular distribution after the reflection are strongly dependent on the conditions at ground level. On an average the ground albedo is about 12% over land and 10% over oceans. These values were determined from comparisons of measured photonfluxes with model calculations (Bahe et al. (1979), Schiller et al. (1987), Volz-Thomas et al. (1996)). And for the angular distribution isotropic scattering, i.e. a Lambertian surface, is assumed. With this the probability for a photon to be reflected into the new direction φ is given by

$$f(\varphi) = \sin \varphi \quad (20)$$

or for the cone shell represented by φ_i and $\Delta\varphi$:

$$f(\varphi_i) = \int_{\varphi_i - \Delta\varphi/2}^{\varphi_i + \Delta\varphi/2} \sin 2\varphi \, d\varphi = \cos\left(\varphi_i - \frac{\Delta\varphi}{2}\right) - \cos\left(\varphi_i + \frac{\Delta\varphi}{2}\right) \quad (21)$$

This formula can be applied for all zenith angle but the one at 90° . For a Lambertian surface all directions are equal, in the true atmosphere, however, the rough-

ness of the surface prevent the light to be radiated into directions just below 90 degrees. We, therefore, allow only radiation into the cone shell

$$\left[\varphi_n - \frac{\Delta\varphi}{2}, \varphi_n \right],$$

keeping the shell $\left[\varphi_n, \varphi_n + \frac{\Delta\varphi}{2} \left(= \frac{\pi}{2} \right) \right]$ empty.

Scattering by aerosols

For the encounter of photons with aerosols or water droplets the scattering function $f_M(\Theta)$ is no longer symmetrical in respect to the forward and backward directions. According to Hansen and Travis (1974) the scattering is strongly forward directed. If we assume a broad size distribution for the aerosols which is correct under average atmospheric conditions, the scattering function can be expressed by

$$f_{Ae}(\Theta) = \left[19 \exp(-3.6\Theta) + 67 \exp(-42\Theta^2) + 0.4 \exp(1.42(\Pi - \Theta)) \right] \sin \Theta \quad (22)$$

and the phase function is defined by Equation 14. Figure 5a shows how the aerosol scattering function fits the exact data given by Hansen and Travis (1974).

For the scattering cross section again Hansen and Travis (1974) is referred to. Under the assumption of a broad and unspecific distribution of the aerosols the curve given by these authors in their Figure 8 can be replaced by an analytical function, as depicted in Fig. 5b :

$$Q = 0.22 + 5.17 x^{1.6} e^{-0.905 x^2} + 1.75 \left(1 - e^{-0.11 x^4} \right) \quad (23)$$

Here, x stands for the logarithm of the effective mean aerosol radius r in relation to wavelength λ .

$$x = \lg \frac{2\pi r}{\lambda}$$

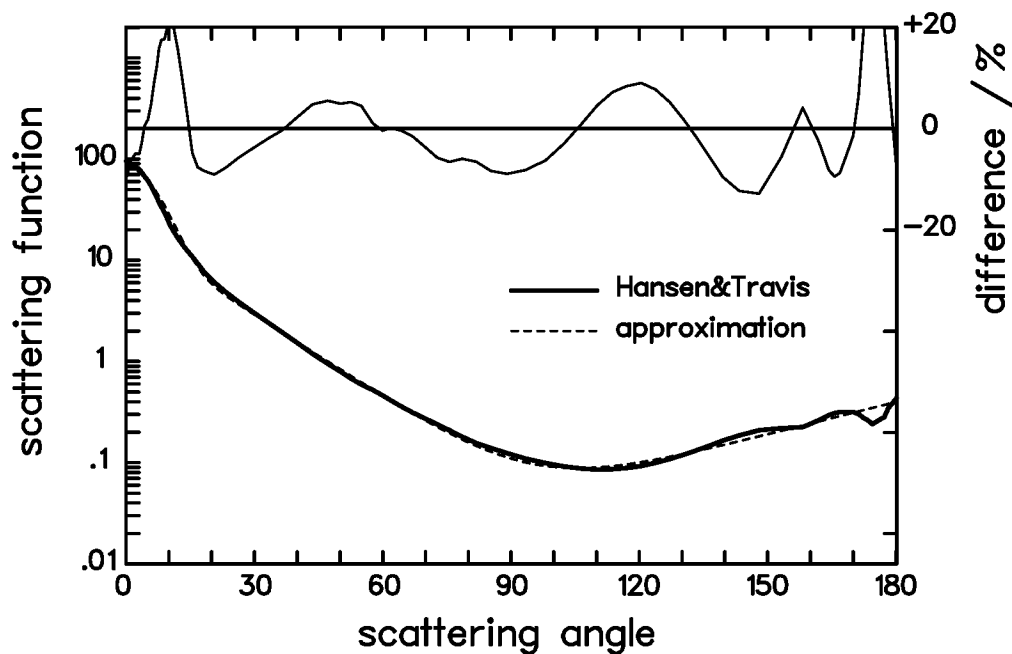


Figure 5a: Comparison of the aerosol scattering function given by Hansen and Travis (1974) with the analytical function used in the model.

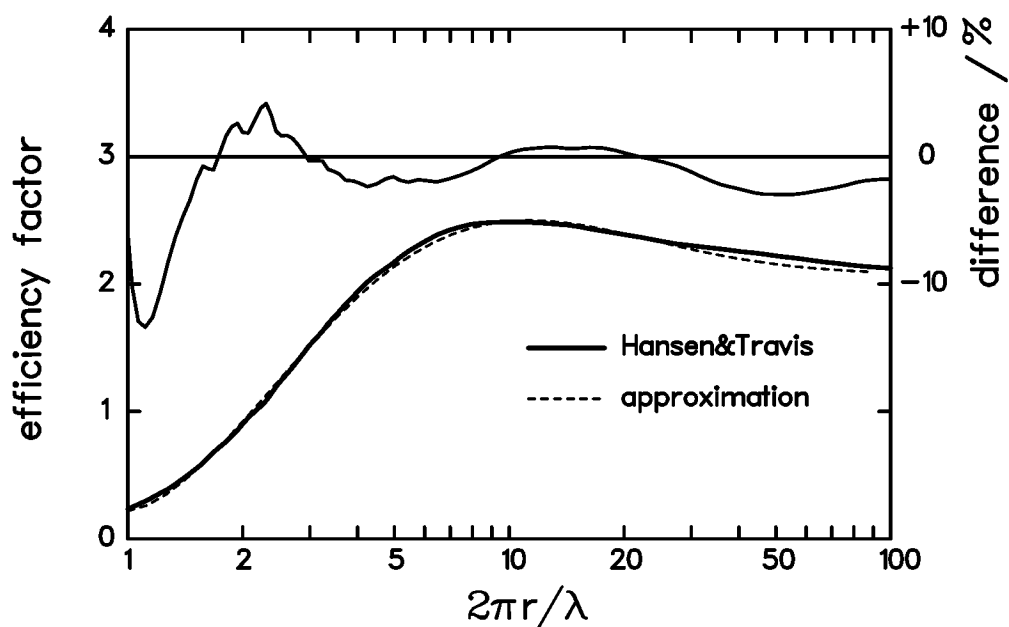


Figure 5b: Fit for the wavelength dependency of the efficiency factor given by Hansen and Travis (1974) of a broad size distribution

As Q is the quotient of the scattering cross section divided by the geometrical aerosol cross section the wavelength dependent scattering cross section σ_M is given by

$$\sigma_M = Q \cdot (\pi \cdot r^2) \quad (24)$$

With these equations the scattering cross sections for two types of aerosols and two types of clouds, each with different mean radii and different absorption can be inserted into the model. Actually, as only the optical densities at a fixed wavelength (typically 550 nm) are listed in the WMO Report 24 (1986), we use Equations 23 and 24 to derive the wavelength dependent absorption spectra of the aerosols, assuming that in the atmosphere only broad size distributions of the particles are present.

For simplification the absorption cross sections of the specific aerosol are connected to the scattering cross sections. This is a sufficient approximation for dry aerosols, but it might create difficulties for droplets as in this case the dissolved species are responsible for the UV/VIS absorption and, therefore, the absorption is only weakly dependent on the droplet radius. This has to be taken into account, if clouds of different effective radii but with the same composition shall be calculated.

The treatment of optical dense media

Optically dense media in the atmosphere, such as clouds, need a special treatment as the integrated form of the Beer-Lambert law is no longer valid, due to the nonlinear absorption and scattering processes. For the layers with clouds of an optical density larger than 1 the method described by Röth (1992) is applied following this procedure: For an infinitesimal thin layer the differential form of the Beer-Lambert law is given by

$$d\bar{b} / -dz = -(\tau_b + \sigma_b) \bar{b}$$

$$d\bar{i} / -dz = -(\tau_d + \sigma_d) \bar{i} + a \sigma_d \bar{i} + (1-a) \sigma_d \bar{j} + a \sigma_b \bar{b} \quad (25)$$

$$d\bar{j} / +dz = -(\tau_d + \sigma_d) \bar{j} + a \sigma_d \bar{j} + (1-a) \sigma_d \bar{i} + (1-a) \sigma_b \bar{b}$$

where τ and σ stand for the optical depth of absorption and scattering. a is the percentage of the forward scattering, normally a is set to 50 % for Rayleigh scattering and 1 % for Mie processes. The suffixes b and d distinguish the optical depths of the direct beam $\bar{b}$, the diffusive light down $\bar{i}$, and the diffuse light up $\bar{j}$. The altitudinal differential dz is negative for $\bar{b}$ and $\bar{i}$, since these beams are directed downwards and the height's positive direction is upward.

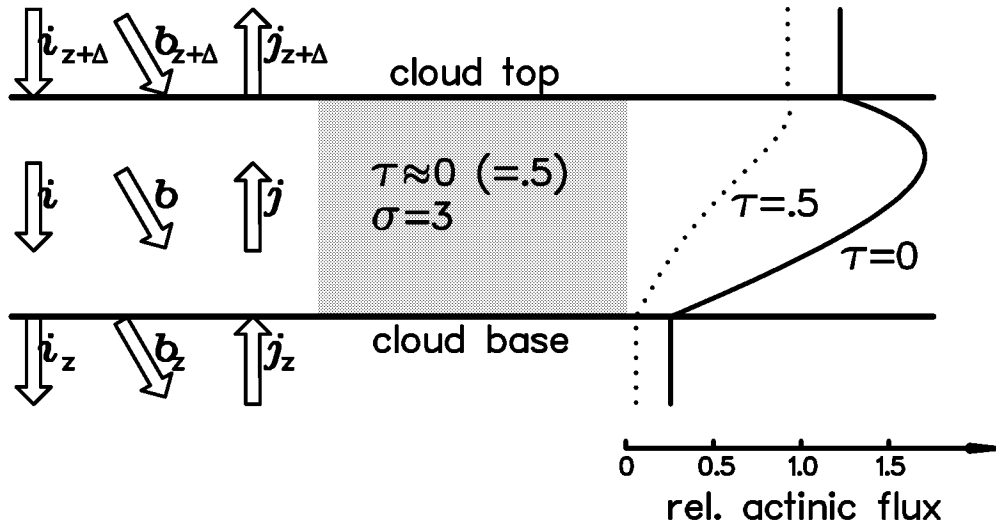


Figure 6 : Sketch of the actinic flux within a cloud with no absorption ($\tau=0$) and an optical absorption density of 0.5.

As was demonstrated by Kubelka and Munk (1936) and Röth (1992) this differential equation can be solved analytically. For an optically thick layer $[z, z+\Delta]$ within

the atmosphere the resulting formulas for the actinic fluxes at the top and bottom of the layer are :

$$b_z = b_{z+\Delta} R(\Delta)$$

$$\dot{i}_z = S(0) \dot{i}_{z+\Delta} + T(\Delta) \dot{j}_z - [\omega R(\Delta) T(\Delta) + \xi S(0) - \xi R(\Delta)] b_{z+\Delta}$$

$$\dot{j}_{z+\Delta} = S(\Delta) \dot{j}_z + T(0) \dot{i}_{z+\Delta} - [\omega R(\Delta) S(\Delta) + \xi T(0) - \xi R(\Delta)] b_{z+\Delta}$$

with (26)

$$R(x) = \exp(-\chi x)$$

$$S(x) = 1/N [(\alpha-\rho) \exp(-x) - (\alpha+\rho) \exp(+x)]$$

$$T(x) = \beta/N [\exp(-\rho x) - \exp(+\rho x)]$$

$$N = (\alpha-\rho) \exp(-\Delta\rho) - (\alpha+\rho) \exp(+\Delta\rho)$$

$\omega, \xi, \alpha, \beta, \rho$, and χ are coefficients described in the paper by Röth (1992).

For in-cloud photodissociation processes the equations can be applied at any intermediate altitude as they represent the actinic flux at any location within a homogeneous medium. The function includes e.g. the enhanced photon flux just below the cloud top as displayed in Figure 6. In the figure the actinic fluxes with scattering only and with additional absorption are compared.

For the model described here the fluxes are only of interest at discrete altitudes. As the procedure depends on a two-stream approximation plus a separate treatment of the direct beam, the incoming downward and upward directed diffusive light is summed up and then used as input parameters for the special algorithm. The outgoing diffusive light, on the other hand, is assumed to be totally isotropic and, hence, distributed into the different directions according to Formula 21. This is no restriction to the generality as the photons within an optically thick medium undergo so many scattering processes that a cloud represents a Lambertian surface both at top and bottom.

The Algorithms

The differential equation system

To solve the differential equation system for all diffuse beams at each altitude, we start with Equation 15 for one beam at altitude z , which can be rewritten as

$$dF_i = -(\tau + \sigma)F_i ds + Q_i ds \quad (27)$$

As for the direct beam we assume a homogeneous distribution of the absorbing material and the scattering species for the diffuse light, too. Additionally, the source function Q_i should be constant within the layer $[z+\Delta z, z]$. This is a rather realistic postulation as Q represents contributions from all fluxes. While the downward fluxes decrease with altitude, the upward fluxes become more intense, so overall, the source function changes only slowly with height. This assumed, the differential equation becomes solvable :

$$\begin{aligned} F_{-i}(z) &= \frac{Q_i}{\tau + \sigma} + \left(F_{-i}(z + \Delta z) - \frac{Q_i}{\tau + \sigma} \right) \exp \left(-(\tau + \sigma) \frac{\Delta z}{\mu_i} \right) \\ F_{+i}(z + \Delta z) &= \frac{Q_i}{\tau + \sigma} + \left(F_{+i}(z) - \frac{Q_i}{\tau + \sigma} \right) \exp \left(-(\tau + \sigma) \frac{\Delta z}{\mu_i} \right) \end{aligned} \quad (28)$$

The plus and minus signs with the index i mean the upward and downward directions, respectively.

In the model ART an iteration method is applied to determine the fluxes of the various beams at different altitudes. As the calculation of the direct beam is straight forward, it can be used to derive a first guess of the diffuse, upward, or downward directed fluxes. Within a layer the amount of scattered photons is approximated by

$$X_{sc} = F_{col}(z + \Delta z) \left(1 - e^{-\frac{-(\tau + \sigma)\Delta z}{\cos \mu}} \right) \quad (29)$$

where F_{col} stands for the direct, collimated beam.

Half of these photons are scattered upwards, half downwards, if Rayleigh scattering is assumed. For Mie processes we assume a backward scattering of 10%. As a first guess we presume a spherical distribution and so the initial values for the F_i can be defined :

$$\begin{aligned} F_{-i}(z) &= \frac{X_{sc}}{2} + F_{-i}(z + \Delta z) \\ F_{+i}(z) &= \frac{X_{sc}}{2} + F_{+i}(z - \Delta z) \end{aligned} \quad (30)$$

These formulas are already pretty close to reality.

For rays hitting the earth's surface, first the actual downward fluxes are calculated, starting at 99 km altitude. At ground level all fluxes are summed up, multiplied by the ground albedo, and the resulting total upward flux is then distributed among the beams (with positive indices) according to a Lambertian surface

$$F_{+i}(0) = Alb \cdot 0.5 (\cos 2\varphi_{i-1} - \cos 2\varphi_i) \sum F_{-j}(0) \quad (31)$$

After that, the upward directed beams can be determined, using the downward fluxes of the previous approximation. This calculation is repeated ten times to minimize the errors due to the initial assumption.

For the rays passing the earth's surface, the same procedure is applied. Instead of the boundary conditions at ground level, i.e. the ground albedo, we now assume that there is no light coming from space opposite to the position of the sun. That gives the boundary conditions at -99 km, where the ray leaves the earth's atmosphere :

$$f_{+i}(-99) = f_{-i}(-99) \left[1 - \exp\left(-(\tau + \sigma) \frac{\Delta z}{\mu_i}\right) \right] \cdot 0.5 \quad (32)$$

Negative altitudes are those after passing the nearest point to the earth (see Fig. 1).

The phase function

The phase function, i. e. the probability that a photon coming from direction φ_i is scattered into the direction φ_j (see Fig.4) is defined as

$$P_{ij} = \int_{\varphi_i - \Delta\varphi/2}^{\varphi_i + \Delta\varphi/2} \int_0^{2\pi} f(\theta) \sin \eta \, d\eta \, d\varphi \quad (33)$$

In the model ART the beams are not represented by the mean direction but by the largest angle of a cone shell for simplicity. The angles are equally spaced between 0 and $\pi/2$. The scattering angle θ must therefore be expressed by angles in the interval $[\varphi_{i-1}, \varphi_i] = \Delta\varphi$ and $0 \leq \eta \leq 2\pi$. To integrate Equation 33 a simple trapezoid formula is used with a resolution of 1 degree for both integrations. To ensure that $\int P \, d\theta$ equals unity finally all P_{ij} were summed up and then divided by this sum. Because of this procedure it is not necessary to include normalisation factors in the scattering functions f_R and f_M .

The photolysis rate function

To determine actual photolysis frequencies there are three ways possible in the program :

- 1 : The wavelength spectra of the actinic fluxes are calculated for the actual time and location and then the photolysis coefficients are determined by integration from these data for a single point.
- 2: The actinic fluxes are calculated for at least 20 fixed solar zenith angles and after the determination of the respective photolysis frequencies, the actual values are derived by linear interpolation between the fixpoints.
- 3 : For a given solar zenith angle at ground level the actinic fluxes along the corresponding ray are calculated and, afterwards, the photodissociation rates are determined by integration.

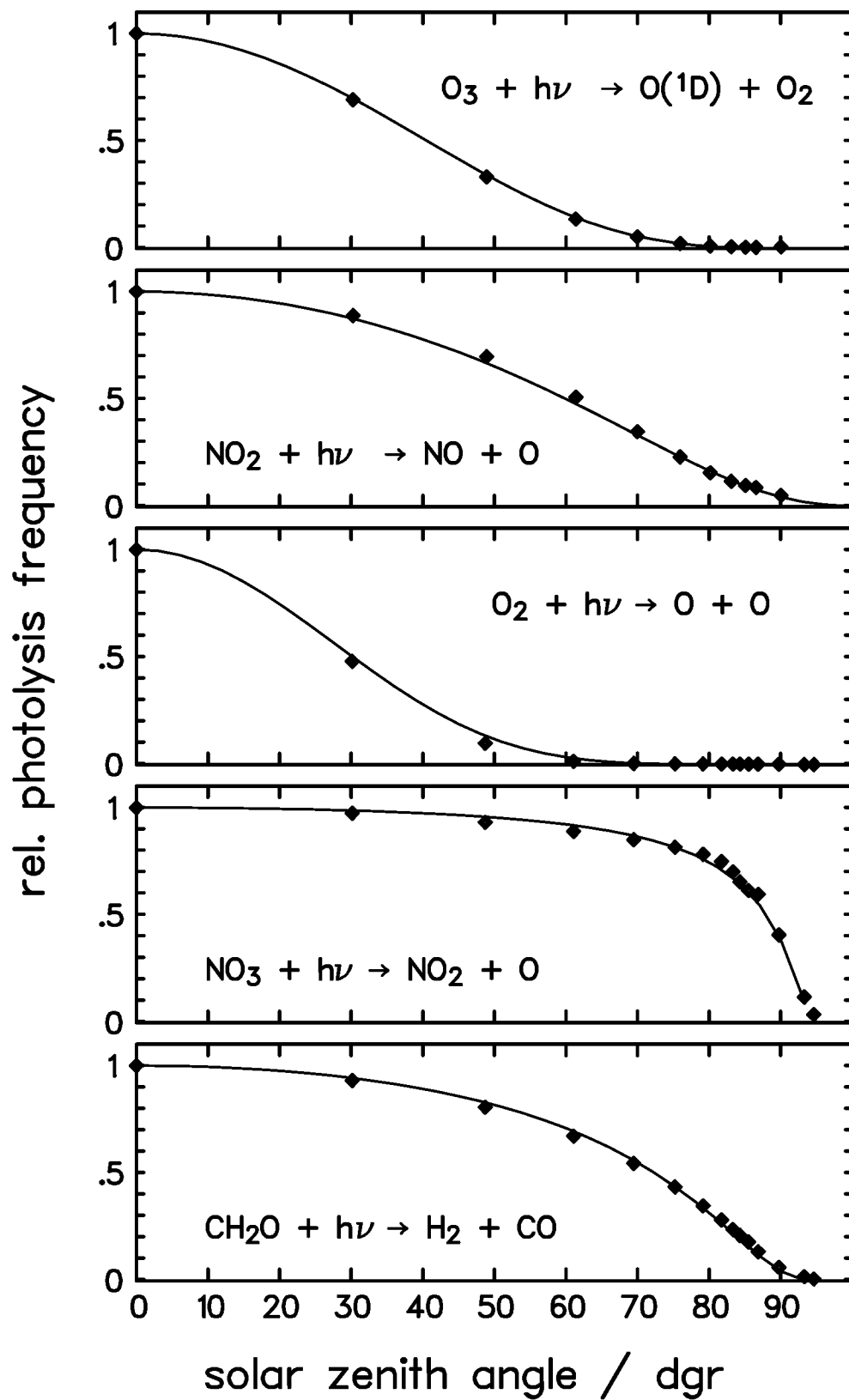


Figure 7 : The dependence of the relative photolysis frequencies on the solar zenith angle.

To minimize the computing time and the storage space, we applied the third method in our atmospheric chemistry model (Röth, 1980) and, therefore, the photolysis rate is also given by a three-coefficient-formula for its solar zenith angle dependence.

According to the laws of spherical geometry, the photon flux at a single wavelength should be dependent by a two-coefficient-formula from the solar zenith angle χ (e.g. H. Levy II, 1974) :

$$f = f_0 \exp [b \{1 - \sec\chi\}] \quad (34)$$

This equation is only valid for a completely transparent atmosphere. For a real absorbing and scattering atmosphere the formula for the single line photon flux and, hence, that for the photolysis rate must have more than two coefficients. By a close inspection of the solar zenith angle dependence of a number of photolysis frequencies at different heights, we found that only a third coefficient is required to represent the photolysis rates with sufficient accuracy.

Obviously the photolysis rates do not vanish at $\chi = \pi/2$ as implied by Equation 34. Actually, there is still light after the geometrical sunset. To account for this fact, the zenith angle axis has to be compressed by a third coefficient :

$$f = f_0 \exp [b \{1 - \sec(c\chi)\}] \quad (35)$$

In Figure 7 the zenith angle dependence of the photolysis rates of several atmospheric components are shown. The displayed curves represent the variety of possible zenith angle dependencies. The accuracy of the formula is sufficient for model calculations of atmospheric chemistry as the deviations from the separately calculated values are less than 5% up to zenith angles of 95°. For simulations of photon flux measurements this accuracy is not good enough and we prefer in that case a direct determination by separate calculations.

Description of the Model

The photon flux model ART consists of a frame program, the subroutines FLUXES and PHOTO, and some other subroutines for the various graphic outputs. A detailed flux diagram is given in Figure 8 for the main program and in Figure 9 for the subroutine FLUXES. The diagram for subprogram PHOTO is displayed in Figure 10. The source code contains a second subroutine FLUX3B for calculating the actinic fluxes according to a three-stream model. This subroutine is much faster but less accurate than FLUXES. It can be used for fast estimations of the photodissociation coefficients and is actually designed for use in global chemistry models.

The frame program

The frame program first defines the data types and sizes, the COMMON-blocks, and the FORMAT-statements, and then initialises the parameters and data fields. All sizes of data fields are defined by constants which are set by a PARAMETER-statement at the beginning of each subroutine. By this way of handling the constants it is rather simple to change them, if necessary.

Most of the steering parameters specifying the type of the calculation and of the input and output can be defined by an auxiliary interactive program FLUXSTRT described in the next chapter. Otherwise the input file can be changed by any commercial editor as all inputs are ordinary ASCII-files. Those steering parameters which are only used for testing purposes, are fixed by assign statements within the program and cannot be altered via the input.

The headers for the printed outputs are written before the input data are read in. This is necessary as the head lines of the input data identify the run. Beside the concentrations of the absorbing constituents of the air (O_2 , O_3 , NO_2) and those for the scattering (air density, aerosols and water droplets) their respective absorption spectra and scattering parameters are read in. These data sets can be selected by a preceding run of FLUXSTRT according to the date and location for which the calculations should be carried out.

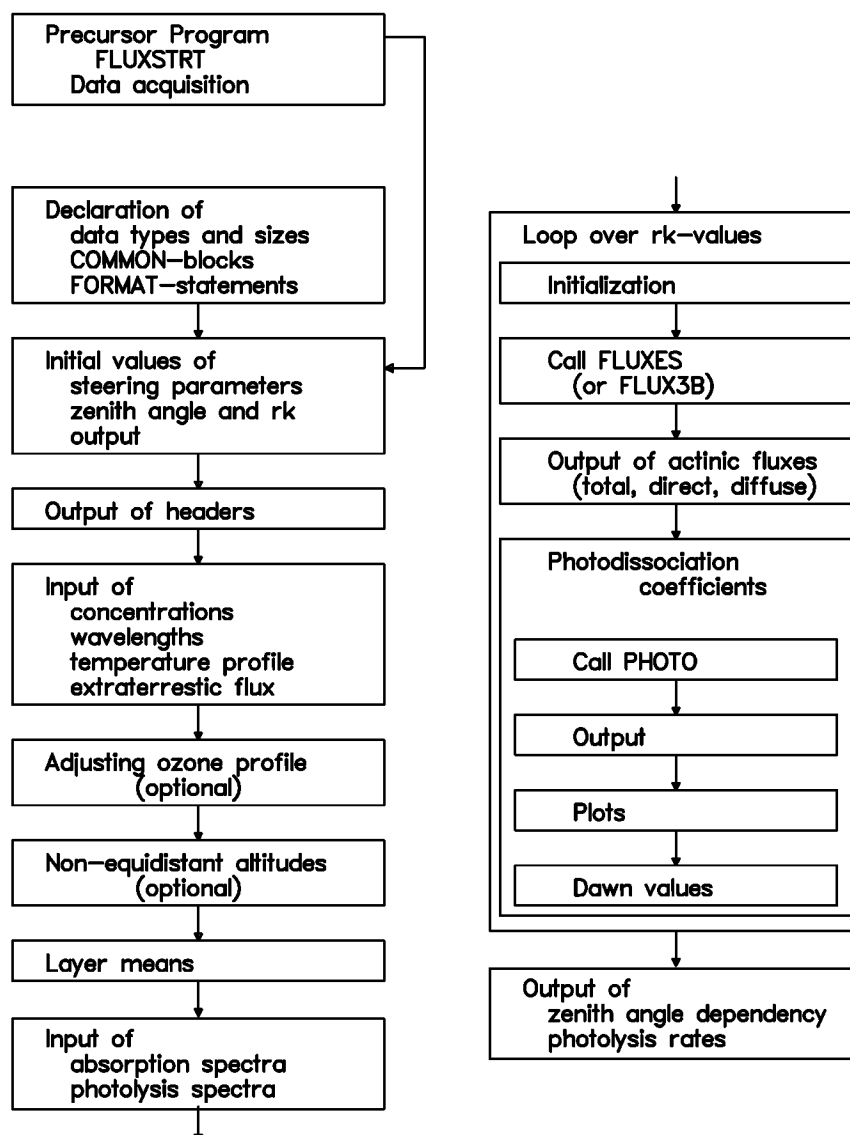


Figure 8 : Diagram of the main program of model ART which mainly regulates the input and output of the data and calls the subprograms.

Other data sets like the wavelengths, the extraterrestrial flux and the temperature profile are less variable and cannot be selected via the precursor program FLUXSTRT. To determine the photolysis coefficients up to 120 spectra of different species and reactions can be read in. The formats of these data sets are described in the following chapters. The selection of these photodissociation reactions is again carried out by FLUXSTRT.

Sometimes it is required to adjust an ozone profile to a predefined column density. This will be done if the parameter DOBSON does not equal 0. In this case, the whole profile is multiplied by a constant factor to ensure that the shape of the profile remains unchanged.

For some purposes it is essential to use non-equidistant altitudinal steps. These steps are defined by a DATA-statement. The adjustment is carried out by a logarithmic interpolation for all concentrations and linearly for the temperature. By the same procedure the concentration profiles of the absorbing and scattering species are converted into layer means. The profiles are read in as concentrations at discrete, equidistant heights.

As the algorithms for the flux determination assume homogeneity within a layer, all concentrations are averaged geometrically to give mean values for each layer. The highest layers from 80 to 99 km are extrapolated into space to account for the atmosphere above 99 km. Layer 99 consists of the integral column density above 99 km for all species under consideration.

Normally, the fluxes are calculated for 130 wavelength intervals between 185 nm and 730 nm, but for some tests it may become necessary to select a smaller wavelength regime or single lines. This is made possible by setting the appropriate parameters.

The actual calculations of the actinic flux and the photodissociation frequencies are placed within a loop over several rays. These rays are defined by their closest distance r_k to the earth's centre (see Fig. 1). If the loop over r_k is active, it provides a zenith angle dependency for both, the fluxes and the photolysis coefficients.

For calculations of Type 1 or 2 the loop parameters are all set to 1 and the ray chosen either by the definition of time and location (Type 1) or by ground solar zenith angle (Type 2) is the one for which the calculations are carried out. For an active loop (Type 3) the r_k are defined by

$$r_k = R(1 - \exp(-0.7n - 7)) \quad \text{for } -10 \leq n \leq -1$$

(36)

and $r_k = R + n \cdot 10 \quad \text{for } 0 \leq n \leq 9$

After the initialisation of the matrices DA and DO2 for the photodissociation frequencies, the matrix MAT for the printer plot is set to blanks. This done, the program calls the subroutine FLUXES to determine the actinic fluxes for a given ray and for all wavelengths.

As the solar zenith angle and the path length for the different layers is altitudinal dependent due to the earth's spherical geometry, these values are calculated for use in the output of the fluxes. The actinic fluxes are separated into the total flux, the flux of the collimated beam, and the downward and upward diffuse fluxes. For rays hitting the earth's surface the fluxes are printed every 5 km starting at ground level, and those passing the earth are given every 10 km from -50 to +50 km altitude. Negative altitudes indicate where the ray passes the same sphere shell a second time (see Fig. 1).

For test purposes the distributions of the total flux into the different directions can be printed. There are two possibilities for this :

- 1) for one wavelength at 10 different altitudes and
- 2) the spectral dependency at ground level for the incoming light (colour of the sky, seen from ground) and at 99 km for the outgoing beams (colour of the earth, seen from space).

Another optional output is the plot of the spectral dependency of the actinic fluxes at 0, 10, 20, and 40 km height. For comparison with the data given by Luther and Gelinas (1976), or by Isaaksen et al. (1976) the ratio of the total flux divided by the flux FABS through a purely absorbing atmosphere is plotted. For this the flux FABS is calculated the same way as the collimated flux, only the diminution by scattering is omitted. To this plot data calculated by a Monte-Carlo program can be added. These data are read in from a separate file.

After the various outputs of the actinic flux are done, the photolysis rates will be determined. To do so, the program calls the subroutine PHOTO. Beside a printer output of the photodissociation coefficients, they may also be plotted. For a single ray the altitudinal profiles are plotted and for an active loop the wavelength dependency can be displayed.

To estimate the flux and the photodissociation rates during dawn, the backward scattered flux at negative altitudes of ray # 0, i. e. the ray with a solar zenith angle of 90° at ground level, is transferred to ray # -1. For the negative altitudes of ray # -1 the photodissociation coefficients are then calculated and added to the matrix containing the photolysis data for the different rays.

The subroutine FLUXES

The subroutine FLUXES calculates the actinic flux for one ray simultaneously for 130 spectral lines in the wavelength regime from 185 nm to 730 nm. For the Schumann-Runge bands (185 to 195 nm) the approximation given by Kockarts (1971) is used to determine both the photon flux and the O_2 photodissociation coefficient in this spectral region. As this flux equals 0 below 20 km where most of the scattering occurs, neither Rayleigh nor Mie scattering is included for the SR-bands.

The subprogram starts with the declarations of the types and sizes of the variables, the COMMON-blocks, and the FORMAT-statements. Included are the definitions of the scattering functions RFKT for Rayleigh and AFKT for aerosol scattering. The initialisation block which follows, defines the parameters for the Schumann-Runge bands and output parameters.

The phase functions for the Rayleigh and the Mie scattering are then integrated according to the algorithms described in the previous chapter. If necessary, the matrices can be printed by setting the parameter IPRALL to 1 within the source code.

The calculation of the actinic fluxes is carried out by two blocks, one for the rays hitting the earth's surface, the other for those passing it. As these blocks are nearly identical, only one will be described here, referring to the second if differences occur.

All calculations are carried out separately for each spectral line starting with the Schumann-Runge (SR) bands after the determination of the path lengths in the various sphere shells. The determination of the photon flux and the photolysis rates in the SR-bands is described in detail by Kockarts (1971).

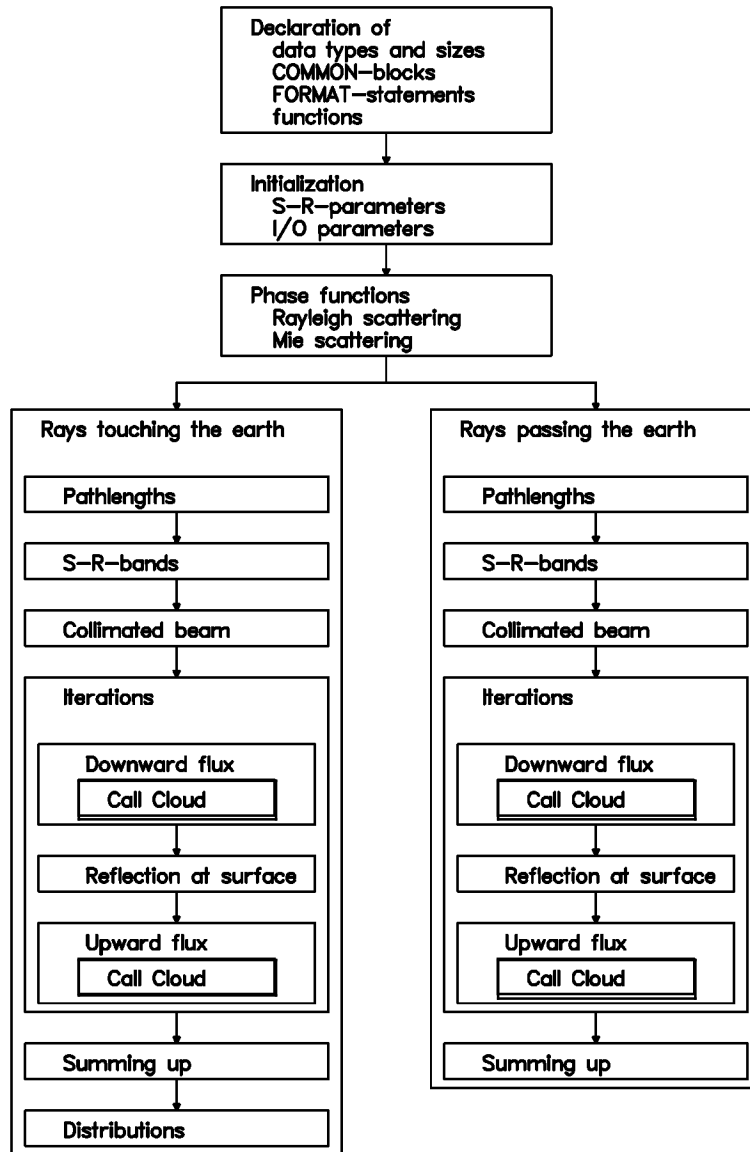


Figure 9 : Flux diagram of the subroutine FLUXES which calculates the photon flux through the atmosphere.

The direct, collimated beam is determined straight forward together with the total optical densities τ_{AUT} for the absorption and σ_{IGT} for the scattering. In this part of the program the different beams are initialised, too.

The diffuse light is calculated by 10 iterations, starting with the downward flux. Within each layer first the source strength is defined, and then the integrations are carried out simultaneously for all beams directed downwards. The same procedure

is applied for the upward fluxes after their boundary values are set, either for reflection at ground level, or by setting them equal to one half of the scattered light from the downward flux at -99 km altitude.

When the loop over the iterations is through, the fluxes of the downward directed beams are summed up, weighted by the factor $\cos \chi / \cos \theta_i$ with χ the solar zenith angle at 99 km height and θ_i the angle of the individual beam. The cosine of θ_i enters the sun due to Equation 13, and the solar zenith angle pays regard to the fact that the extraterrestrial flux is given for an area perpendicular to the direction of the sum. For the upward fluxes the same procedure is applied, and then both are added to the flux of the collimated beam to give the total actinic flux FTOT.

For test purposes the distributions of the fluxes are stored in the matrices DISTRI and FARBE. The first gives the distribution at different altitudes for one wavelength defined by the parameter LDISTRI. The latter defines the wavelength dependency of the incoming light at ground level and the outgoing light at 99 km altitude.

The subroutine PHOTO

The subroutine PHOTO integrates Equation 37 to determine j , the photodissociation coefficient, by means of the absorption cross section σ of the reacting species, and the actinic flux F . The quantum yield ϕ defines the probability that a certain photodissociation reaction can take place.

$$j = \int_0^{\infty} \phi \cdot \sigma \cdot F_{tot} d\lambda \quad (37)$$

The integration starts with the Lyman- α region of the spectrum after the normal declarations (data types and sizes, COMMON-blocks, etc.). The Lyman- α regime is presented by a single line, whereas the wavelength region between 185 nm and 730 nm is divided into 130 intervals of different widths. The interval widths, which can be changed via the input data, are printed alongside with the output of the fluxes.

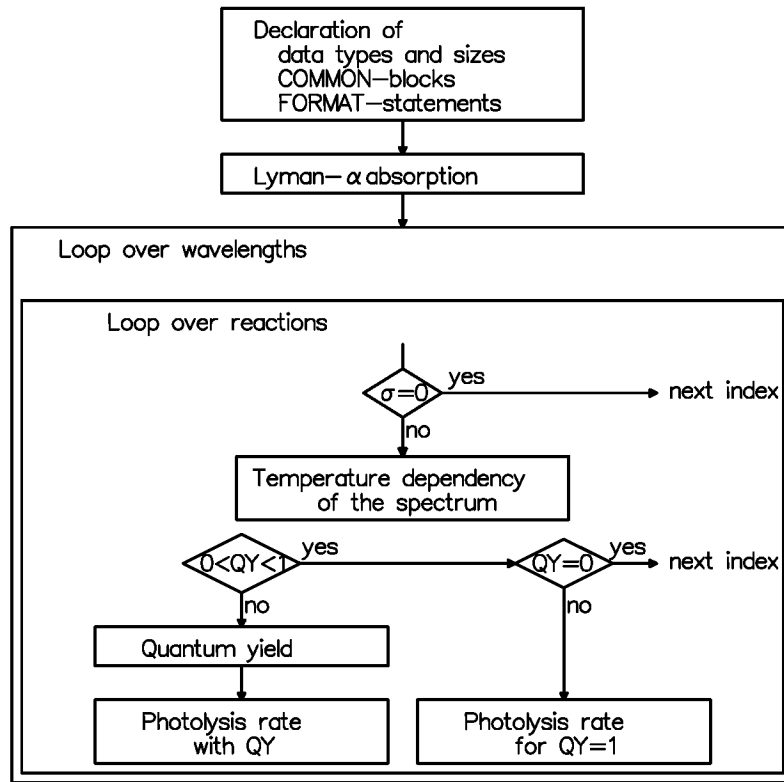


Figure 10 : Flux diagram of the subroutine PHOTO which integrates the product of the actinic flux, the absorption spectrum and the quantum yield to form the photo-dissociation coefficient.

For each wavelength and reaction first the temperature factor for the spectrum is calculated. This factor defines the deviation of the cross section at the local temperature T from that at a specified temperature T_0 . Up to now the equations listed in Table 2 can be used to define the temperature factor. These formula were found by a trial-and-error procedure to be sufficiently accurate. Figure 11a shows for a number of spectra the agreement between the approximation and the measured values.

The parameters of the temperature factor T_0 , a to f , λ_1 , and λ_2 are read in after the header of each set of data for a photodissociation reaction.

Likewise, seven different functions for the quantum yield ϕ are included in subroutine PHOTO (see Table 3). Here A, B, C, D, E, F are the parameters of the function and λ , T and M are the wavelength, the temperature and the air density, respectively (Röth et al., 1997). In Figure 11b examples of these functions for the

quantum yield are displayed. The number of functions for both, the temperature factor and the quantum yield can easily be expanded, if necessary.

Table 2 : The analytical functions used in the model for the temperature dependence of the spectra

	TFAK	A ₀
0	1	
1	$A_0 + \frac{1 - A_0}{\exp[(c + d \cdot T)(\lambda - (e + f \cdot T))] + 1}$	$1 + a(T_0 - T) + b(T_0 - T)^2$
2	$1 - A_0 \exp[(c + d \cdot T)(\lambda - (e + f \cdot T))^2]$	$a(T_0 - T) + b(T_0 - T)^2$
3	$1 - a(T_0 - T) \exp(c(\lambda - \lambda_1)^2) - b(T_0 - T) \exp(c(\lambda - \lambda_2)^2)$	
4	$\exp[(a + b(T_{\max} - T))(\lambda - (e + f(T_{\max} - T)))]$	
5	$\frac{A_0}{\exp[(c + d(T_{\max} - T))(\lambda - (e + f(T_{\max} - T)))] + 1}$	$a + b(T_{\max} - T)$
6	$A_0 \exp[b(\lambda - \lambda_0)] + c(1 - \exp(d(T_{\max} - T))) \exp[e(\lambda - (\lambda_0 + f(T_{\max} - T)))]$	$1 + a(T_{\max} - T)$

Additionally, these quantum yields can be combined with those of the preceding reaction. This ensures that for two possible reaction channels, one with ϕ , the other with $1 - \phi$, the sum of both channels does not exceed 1. The combinations made possible by the subprogram are the following

$$1: \quad \phi = 1 - \phi_{old}$$

$$2: \quad \phi = \phi_{new} - \phi_{old}$$

$$3: \quad \phi = \phi_{new} \cdot \phi_{old}$$

The index 'old' stands for the preceding reaction, 'new' is the quantum yield calculated with the equation and coefficients specified in the actual photolysis. The later will be replaced by the total rate ϕ .

After all terms and the product $\phi(\lambda) \cdot \sigma(\lambda)$ are defined, the factor $\text{TFAK} \cdot F_{\text{tot}}$ can be added to the photodissociation coefficient for integration.

If the absorption cross section equals 0, the program skips the calculation and goes straight to the next reaction. And, in case the quantum yield is unity, the calculation of the quantum yield is passed by and the product $\sigma(\lambda) \cdot \text{TFAK} \cdot F_{\text{tot}}$ is added to the dissociation coefficient in a separate program block to speed up the calculation.

Table 3 : The different Fermi functions for the approximation of the measured quantum yields. For some quantum yields it is necessary to use a combination of these functions.

	ϕ
1	A
2	$\frac{A}{\exp[B(\lambda - C)] + 1}$
3	$\frac{A}{\exp[(B + C \cdot T)(\lambda - (D + E \cdot T))] + 1}$
4	$\frac{A}{1 + \left(B - C \cdot \frac{T}{300}\right) \exp\left[\left(D - E \cdot \frac{T}{300}\right)(\lambda - F)\right] \frac{M}{10^{19}}}$
5	$\frac{A}{\exp[B(\lambda - C)] + 1} \cdot \left\{ 1 - \frac{D}{\exp[E(\lambda - F)] + 1} \right\}$
6	$\frac{A}{1 + B \cdot \exp[C(\lambda - D \cdot T)] \frac{M}{10^{38}}}$
7	$\frac{A}{\exp[B(\lambda - C)] + 1} + \frac{D}{\exp[E(\lambda - F)] + 1}$

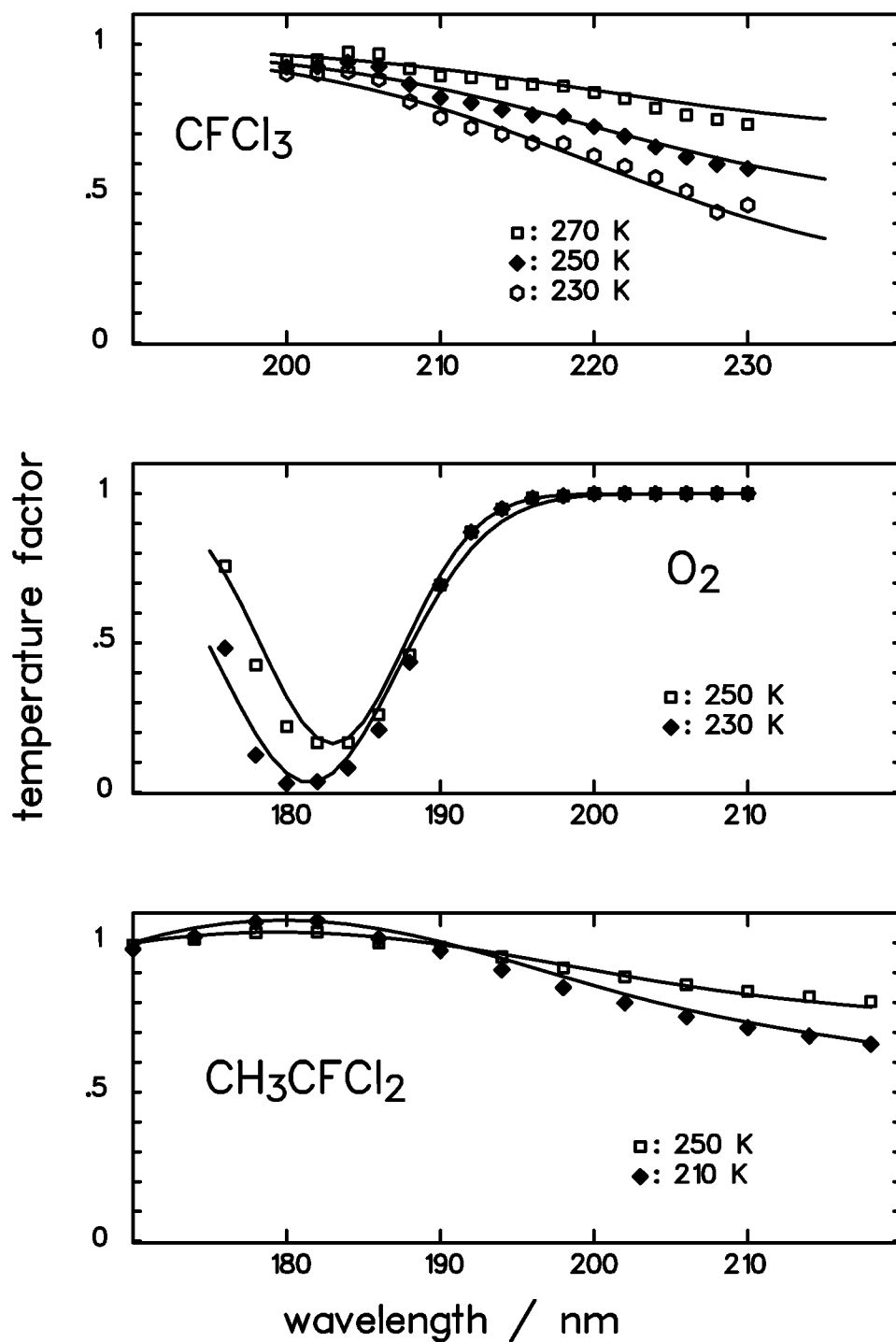


Figure 11a : Examples of the approximation of the temperature factors by the functions listed in Table 2 (CFCl₃:#1, O₂:#2, CH₃CFC1₂:#6). The symbols stand for the measured values and the solid lines give the approximations.

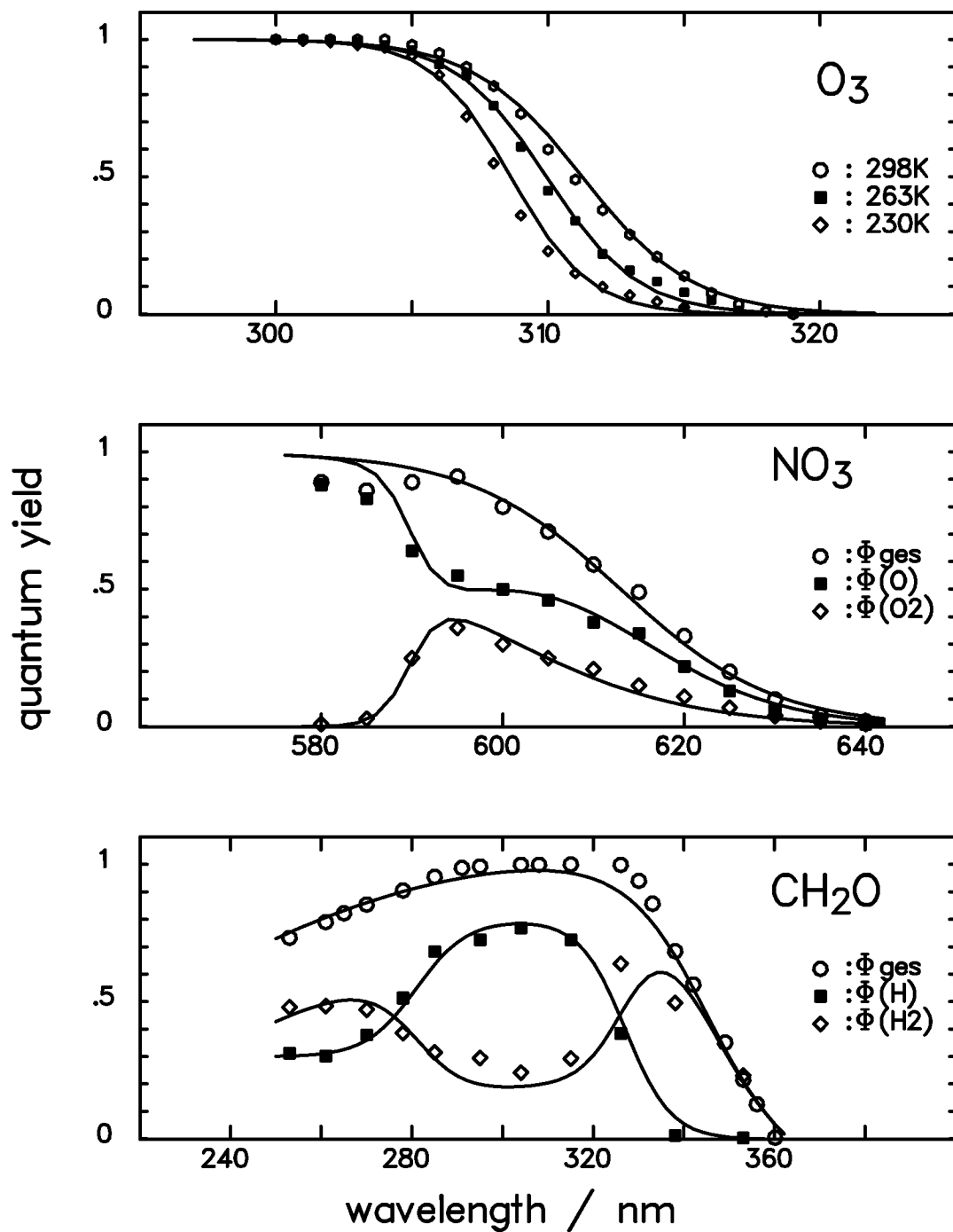


Figure 11b : Approximations of measured quantum yields by a combination of the Fermi functions given in Table 3. O_3 represents function #7, NO_3 a combination of #2 and #5, and the quantum yields for CH_2O are combinations of #6 and #7. The symbols stand for the measured values and the solid lines give the approximations.

The subroutine CLOUD

Optically thick media like clouds are not fulfilling the assumptions which lead to the integrated form of Lambert-Beer's law as applied so far. Especially multiple scattering processes cannot be covered by the algorithm applied to solve Equation 3. On the other hand, the algorithm of a three-beam radiation model given in Equation 25 takes into account the non-exponential altitudinal dependency of the photon flux. An explicit integration of Equation 25 is possible as only 3 beams are considered, the direct light from the sun and the upwards and downwards directed diffusive radiation. Therefore, in altitudinal regions where clouds are present, this algorithm is applied.

The algorithm results for a layer of thickness Δz in the following formula :

$$\begin{aligned}
 b &= b_0 \cdot e^{-(\tau+\sigma)\Delta z} \\
 i &= f \cdot i_0 + g \cdot j_0 - \left(w \cdot g \cdot e^{-(\tau+\sigma)\Delta z} + h \cdot f - h \cdot e^{-(\tau+\sigma)\Delta z} \right) b_0 \\
 j &= f \cdot j_0 + g \cdot i_0 - \left(w \cdot f \cdot e^{-(\tau+\sigma)\Delta z} + h \cdot g - w \right) b_0
 \end{aligned} \tag{38}$$

with f , g , w , and h functions of the absorption (τ) and scattering (σ) density of the layer. For details see R  th (1992). An example of the photon flux through a cloud is given in Figure 6.

The meaning of the fluxes b , i , and j becomes apparent by the left side of Figure 6. The direct beam b is treated according to Equation 6, i.e. in the same way as everywhere. The boundary fluxes i_0 and j_0 are the sums of the downwards and upwards directed fluxes F_i from subroutine FLUXES.

The resulting diffuse fluxes i and j have to be distributed into the different directions φ_i at the end of subroutine CLOUD. For this it is assumed that the partitioning after leaving an optically dense medium with strong multiple scattering is

close to a Lambertian distribution. So, the beams i and j are divided up and the values are then returned to the calling subroutine FLUXES.

$$F_{-i} = i \cdot (\cos \varphi_{i-1} - \cos \varphi_i)$$

$$F_{+i} = j \cdot (\cos \varphi_{i-1} - \cos \varphi_i)$$
(39)

How to Use the Model

In this chapter the standard handling of the program will be described. "standard" means the way how an ordinary user who wants to calculate actinic fluxes or photodissociation rates, will run the model. For this purpose a precursor program FLUXSTRT was developed, too. This interactive program will be described in detail first. The program defines all those parameters which are essential for getting results for the interpretation of radiometer data or for decisive photodissociation coefficients to be included in photochemical models.

Beside the description of the program FLUXSTRT the formats of the input data of the model will be given. It is, of course, also possible to alter the existing files or to create new ones by commercial editors. For this application the following sections will give the meaning of the steering parameters and the formats of the input files.

For test runs one has to go into the program where several other parameters can be set to get results for testing e.g. the algorithms but which are not necessary for ordinary runs. The choice of these parameters will be presented in the next chapter along with the output of such runs.

The precursor program FLUXSTRT and the steering parameters

The program FLUXSTRT covers two fields : in the first part (SPECW) it builds up a file WERTE FORTRAN which is later included in the source code of the model ART. This file contains all parameters necessary for the definition of a run, together with comments which will appear in the program's listing. All parameters which can be selected by the user will be printed out on any of the output files, so that each output file contains all information about the specific run. If the parameters influence the choice of data, these data will be printed in place of the parameters themselves.

The second part (SPEC D) of the program FLUXSTRT selects the input files and builds up a file called "DATASET DATEN". This file includes all data to be read in and it is merged to the batch job via the job control language.

Figure 12 presents the flux diagram of the program FLUXSTRT. It opens with a short description of the program. If the section for WERTE FORTRAN is active, the type of the run will be selected. There are three possibilities : First, the run can be carried out for a given location, date and time. If this type is selected the program will ask for the latitude, given in degree. This done the altitude has to be put in.

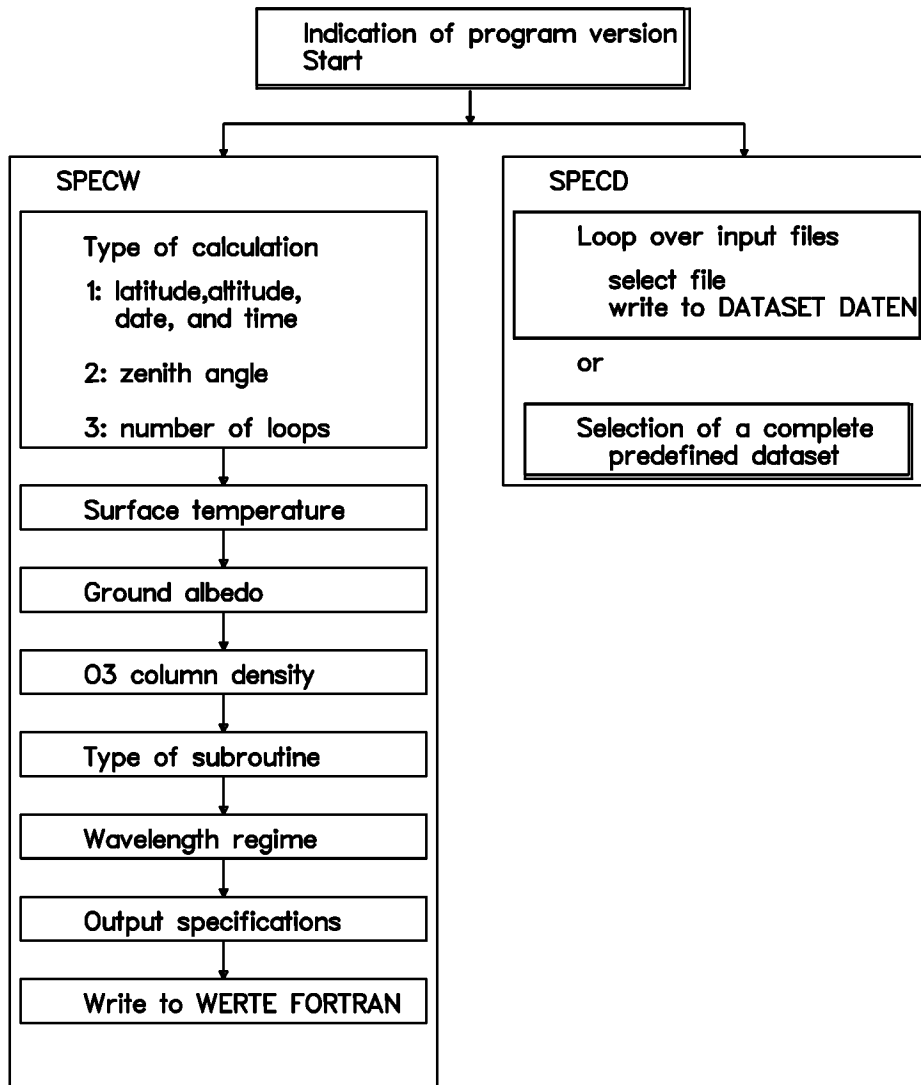


Figure 12 : Flux diagram of the precursor program FLUXSTRT which helps to build up the input data files of the model ART as well as providing the program with the steering parameters.

In a Type 1 run only the photodissociation frequencies at this altitude will be given on the output file. Then the date has to be specified by giving the day and the month in the format "dd.mm". After that, the local time is read in by typing the hour and the minute in the format "hh.mm". This information is sufficient to specify the ray which will be followed in the calculations. This type of run is normally selected if measurements are to be simulated. From latitude and date the sun's elevation at noon is calculated. Together with the time and the altitude this value defines the actual solar zenith angle at the point of the measurements.

The solar zenith angle χ is related to the ray's distance from the centre of the earth via

$$\sin \chi = \frac{r_k}{R_{\text{Erd}} + \text{altitude}} \quad (40)$$

Else the ray can be defined by a fixed solar zenith angle (Type 2). The angle has to be given in degree. This type of run is chosen if more general information shall be obtained, e.g. for the estimation of the magnitude of the actinic flux to be expected in a field measurement, or which photodissociation rates may occur.

And last, several rays can be followed, from overhead sun to the ray passing the earth atmosphere at 90 km altitude (Type 3). In this case the rays are defined by the loop parameter n according to

$$\begin{aligned} r_k &= R(1 - \exp(-0.7n - 7)) & \text{for } -10 \leq n \leq -1 \\ \text{and} \quad r_k &= R + n \cdot 10 & \text{for } 0 \leq n \leq 9 \end{aligned} \quad (41)$$

with R the earth's radius and r_k the shortest distance of a ray to the earth's centre. $n = -10$ represents overhead sun condition, $n = 0$ gives the ray just passing the earth's surface, and $n = +9$ stands for the ray passing at 90 km altitude.

The range of the loop may be specified by selecting the start and the end index. The default values are -10 and +9, respectively. This type of run produces a zenith angle dependence of the actinic flux and the photodissociation coefficients. If a plot of this dependency is required, the height has to be specified, for which the photolysis rates should be plotted. In this case, the rays should not exceed the height of this plot. Therefore, the loop's end shall be set to heights ≤ 9 .

Another purpose for such a run may be the production of a condensed matrix of the photodissociation coefficients. This matrix is printed on a file named PHOTMAT. This file contains n sets of photodissociation rates, starting at ground level. The altitudinal step for these data ranges from 1 km to 5 km and can be specified in FLUXSTRT as well as the number n of the steps.

Sometimes it is necessary to use another surface temperature than defined in the data set TEMP DATA. For this purpose the surface temperature can be defined in °C and the program then overwrites the value from the input data set. It should be pointed out, however, that no further adjustment of the temperature profile is made.

A typical value for the surface albedo is 12 % as a global average. The surface albedo has to be specified by giving the absolute fraction of the incoming flux which shall be reflected at the earth's surface. There is no default value for this parameter. If no value is typed, the program will return to the question.

The ozone column density will be derived from the input O₃ profile. To adjust the number to any other one required by the observation or elsewhere, the answer to the question concerning the column density must be "1". Then the program asks for the new ozone column density expressed in Dobson units. The model will multiply the ozone profile by a factor to achieve the correct column density without changing the shape of the profile. By this procedure e.g. a typical seasonal ozone profile may be used which is then shifted to give the measured column density. This has been proven to be sufficient even for the interpretation of radiometer data.

There are two subroutines available for calculating the actinic fluxes. By default the subprogram FLUXES, described in this paper, is selected. This program gives exact fluxes, but requires some computer time. If there is no necessity for very exact data, it is suggested to choose FLUX3B instead by pressing "2" when questioned.

For the simulation of photometer signals, for example, it is not necessary to run the model for all 130 spectral lines. The wavelength regime can be narrowed by setting the lower and upper boundaries. The program then will correspond by setting the wavelength indices closest to the chosen data.

It has to be stressed at this point, that the user is responsible for getting meaningful results out of the model by choosing the correct parameters. It does not make sense, e.g., to calculate photodissociation rates with a wavelength regime smaller than the default range. **There are no tests in the model to ensure meaningful results !**

The next part of the program defines the kind of output. A large variety of outputs is possible : prints, plots, and outputs on separate files. The default values for the output are set as required by the most common use of our models (Röth, 1986, and Ruhnke and Röth, 1995), i.e. the determination of photodissociation rates without paying any attention to the actinic flux itself. Therefore, the printout of the fluxes requires to type "1" as an answer to the respective question.

If the calculation is carried out for only one spectral line, the altitude dependence of the flux, separated into total flux, collimated flux, and diffuse flux from above and from below, can be exposed on a printer. This printer plot has no high resolution, but it is sufficient to get an idea about the relationship between the different fluxes.

For further investigations, e.g. for plots of the photon flux, the output files can be transferred to another computer and there the user has to write his own program for the data handling. The model described here, only serves to produce outputs for further use.

If only the actinic fluxes are of interest, the determination of the photodissociation coefficients can be skipped. Otherwise, if the photolysis rates are calculated, they will be printed in any case.

For Type 2 runs, the altitude profiles of the photolysis coefficients may be plotted. Again, the model only provides the output files for the plot. If a Type 3 run was selected, the program offers a plot of the solar zenith angle dependence. As the model provides the data for all altitudes, the height for which the data are to be plotted, has to be specified. Another possibility for the output of photodissociation coefficients is on a separate file in a condensed form. In this case the altitudinal step and the number of altitudes has to be specified. The lowest level is always 0 km.

For the input of data the program offers standard data sets. If they are chosen, only the [return]-key must be hit. Otherwise, the data files which shall replace the

default sets, have to be specified by the filename, the file type (or extension), and the path where the file is stored. The program tries to find the specified data file. In case of success it will turn to the next question, else the question is repeated until a valid information is given. **But only the file head is examined, not its contents !**

Data sets which are not subject to a selection, like the files with the solar fluxes or the wavelengths are merged automatically.

The program closes with a few remarks concerning the further handling of the output data. It explains where the output can be found, i. e. it gives the names of the output files with a short comment on their contents.

As meanwhile a standard application of the model ART has evolved without using the precursor program FLUXSTRT the steering parameters are set in the source code starting at statement 162 : '\$Include WERTE'

The formats of the input data

Next the input files will be described in some detail. Beside the sequence of the different data sets, their formats will be given, too. Also, those data sets which are not subject to selection by the precursor program FLUXSTRT, will be included here. The different files are combined into one input file DATASET.DATEN by FLUXSTRT or by the operating System in case that the precursor program is not used.

First the concentration profiles of the different absorbing and scattering species (air, NO₂, O₃, aerosols, and cloud droplets) have to be specified. Molecular oxygen is calculated from the concentration of the air by a factor which is 0.20946 for nearly all altitudes beside the highest ones where the factor decreases according to the photodissociation of O₂. Oxygen was handled like this to ensure that it is consistent with the data set "Air". The concentrations (in particles per ccm) at the altitudes from 0 to 99 km are written consecutively, always 7 values in a line. The format is 7E10.3 by which the concentrations can be expressed with 4 digits plus

the exponent to the base of 10 . This format is applied in most of the other input profiles, too. Table 5 gives an example for these input data.

Each data set must have a headline with information on the data set. This header is read in as a whole and transferred to the output file. The headline of the absorbers first has three blanks (used for other purposes), then the filename, the range for which the data are valid, e.g. "global spring/fall", and the reference, e.g. "US Standard Atmosphere 1976", are given.

To calculate the optical depth for the scattering by aerosols and cloud droplets two sets of concentration profiles for both types can be read in. This has two advantages as either a bimodal distribution with different mean particle diameters can be applied or by combining e.g. a stratospheric profile with different tropospheric aerosol concentrations it is made easy to change the conditions for a set of runs. The data sets for aerosols and clouds are identical. They have three additional lines. After the header the effective particle radius is given. The next line consists seven values to determine the absorption by the particle. These data are factors by which the scattering cross sections has to be multiplied to get the absorption cross sections. The factors are given for seven wavelengths : 300, 350, 400, 450, 500, 600, and 700 nm. Between this points the factors are interpolated linearly. A line with information on the absorption coefficients of the aerosol particles separates the header from the concentration values.

The format for the temperature profile is the same as that for the absorbers. Again, the headline informs on the filename, the validity range, and on the reference. An example of such an input file is given in Table 6.

All data which are normally kept fix are combined into the file DATASET.WAVE, given in Table 7. The data sets WAVE and WAVEINT specify the centres and the widths of the spectral intervals for which the calculations are carried out. The headlines of the files are skipped by the program. They only inform on the contents of the data files and give the date of the last revision. The data format for both sets is 8F8.2. In the input file the wavelengths are given in [nm] the way they are used in the program. On the output files both, the interval midths and ranges, are printed alongside with the output of the fluxes.

Table 5 : Example of the input files defining the altitude profiles of the absorbing substances, here concentrations of air and the background aerosol.

000	AIR.044 45 GRD / Juni			Cole+Kantor, Air Force Ref.1978		
2.54E+19	2.28E+19	2.05E+19	1.85E+19	1.67E+19	1.51E+19	1.35E+19
1.21E+19	1.08E+19	9.65E+18	8.59E+18	7.56E+18	6.71E+18	5.78E+18
5.00E+18	4.26E+18	3.62E+18	3.09E+18	2.64E+18	2.25E+18	1.92E+18
1.64E+18	1.39E+18	1.19E+18	1.02E+18	8.69E+17	7.47E+17	6.35E+17
5.47E+17	4.65E+17	3.99E+17	3.42E+17	2.93E+17	2.52E+17	2.17E+17
1.87E+17	1.62E+17	1.40E+17	1.21E+17	1.05E+17	9.14E+16	7.93E+16
6.92E+16	6.05E+16	5.28E+16	4.65E+16	4.09E+16	3.59E+16	3.16E+16
2.82E+16	2.48E+16	2.20E+16	1.97E+16	1.75E+16	1.56E+16	1.39E+16
1.23E+16	1.10E+16	9.73E+15	8.58E+15	7.62E+15	6.75E+15	5.97E+15
5.27E+15	4.66E+15	4.07E+15	3.61E+15	3.15E+15	2.77E+15	2.41E+15
2.10E+15	1.83E+15	1.59E+15	1.38E+15	1.19E+15	1.03E+15	8.86E+14
7.54E+14	6.48E+14	5.48E+14	4.67E+14	3.95E+14	3.35E+14	2.81E+14
2.37E+14	1.99E+14	1.67E+14	1.37E+14	1.13E+14	9.27E+13	7.59E+13
6.34E+13	5.31E+13	4.43E+13	3.65E+13	3.02E+13	2.48E+13	2.05E+13
1.71E+13	1.42E+13	1.19E+13				
...						
...						
...						
	Aerosol Global Standard			WMO/TD-NO.24 (1986)		
	2.00E-05					
6.169E-02	3.834E-02	3.703E-02	3.625E-02	3.599E-02	4.226E-02	4.965E-02
					average continental dry	
2.959E+02	2.959E+02	2.959E+02	1.783E+01	1.783E+01	1.783E+01	1.783E+01
1.783E+01	1.783E+01	1.783E+01	1.783E+01	1.783E+01	1.783E+01	1.314E+01
9.688E+00	7.141E+00	5.264E+00	3.881E+00	2.861E+00	2.109E+00	1.555E+00
1.288E+00	1.067E+00	8.839E-01	7.323E-01	6.067E-01	5.026E-01	4.164E-01
3.449E-01	2.858E-01	2.367E-01	2.053E-01	1.781E-01	1.545E-01	1.340E-01
1.162E-01	1.008E-01	8.743E-02	7.583E-02	6.577E-02	5.705E-02	4.991E-02
4.366E-02	3.819E-02	3.341E-02	2.923E-02	2.557E-02	2.237E-02	1.957E-02
1.712E-02	1.497E-02	1.317E-02	1.158E-02	1.018E-02	8.948E-03	7.868E-03
6.917E-03	6.082E-03	5.347E-03	4.701E-03	4.133E-03	3.634E-03	3.195E-03
2.809E-03	2.470E-03	2.172E-03	1.909E-03	1.679E-03	1.476E-03	1.298E-03
1.141E-03	9.634E-04	8.134E-04	6.868E-04	5.799E-04	4.897E-04	4.135E-04
3.491E-04	2.948E-04	2.489E-04	2.102E-04	1.775E-04	1.498E-04	1.265E-04
1.068E-04	9.020E-05	7.616E-05	6.431E-05	5.430E-05	4.585E-05	3.871E-05
3.269E-05	2.760E-05	2.330E-05	1.968E-05	1.661E-05	1.403E-05	1.185E-05
1.000E-05	8.445E-06	7.131E-06				
...						
...						

Table 6 : Example of the input file with the temperature profile.

000	TEMP.044 45 GRD / Juni						Cole+Kantor, Air Force Ref.1978	
	2.88E+02	2.85E+02	2.81E+02	2.75E+02	2.70E+02	2.63E+02	2.57E+02	
	2.51E+02	2.45E+02	2.38E+02	2.32E+02	2.26E+02	2.19E+02	2.18E+02	
	2.16E+02	2.16E+02	2.16E+02	2.17E+02	2.17E+02	2.18E+02	2.19E+02	
	2.20E+02	2.22E+02	2.23E+02	2.24E+02	2.25E+02	2.26E+02	2.28E+02	
	2.29E+02	2.32E+02	2.34E+02	2.37E+02	2.39E+02	2.42E+02	2.44E+02	
	2.47E+02	2.49E+02	2.52E+02	2.55E+02	2.58E+02	2.60E+02	2.63E+02	
	2.66E+02	2.68E+02	2.70E+02	2.71E+02	2.73E+02	2.74E+02	2.75E+02	
	2.75E+02	2.75E+02	2.74E+02	2.72E+02	2.70E+02	2.67E+02	2.64E+02	
	2.62E+02	2.59E+02	2.56E+02	2.54E+02	2.51E+02	2.48E+02	2.45E+02	
	2.42E+02	2.38E+02	2.35E+02	2.31E+02	2.28E+02	2.24E+02	2.21E+02	
	2.18E+02	2.14E+02	2.11E+02	2.07E+02	2.04E+02	2.00E+02	1.97E+02	
	1.94E+02	1.91E+02	1.89E+02	1.86E+02	1.83E+02	1.80E+02	1.78E+02	
	1.75E+02	1.72E+02	1.69E+02	1.69E+02	1.68E+02	1.68E+02	1.68E+02	
	1.68E+02	1.69E+02	1.70E+02	1.74E+02	1.78E+02	1.84E+02	1.88E+02	
	1.91E+02	1.93E+02	1.95E+02					

The extraterrestrial photon flux is not subject to arbitrary changes. It is connected to specific cross sections of the absorbers and, therefore, the program distinguishes between the cross sections of the absorbing species and those used for calculating the photodissociation frequencies. At the moment the data used are those from the WMO Report 16 (1985). These data are also listed in Table 7. The format is again 7E10.3.

The absorption cross sections of the absorbers O₂, O₃, and NO₂, are read in next. These data sets use the same format 7F10.3 as most of the files, but the headlines are different. The first 8 columns (214) refer to the wavelength index start and end, to specify the spectral region for which the cross sections are given. The columns 9 to 30 give the heading of the set and the rest of the line is for the reference from which the data are taken. After the header a line specifying the temperature dependence is given. The format of this line is the same as the equivalent

Table 7: The input file DATASET.WAVE defining the wavelength dependent data for the calculation of the optical depth for scattering and absorption.

```

***** WELLENLAENGE IN (nm) 13.3.77 *****
184.650 186.400 188.250 190.250 192.400 194.700 197.200 199.800
202.200 203.700 205.150 207.250 209.400 211.650 213.900 216.200
218.600 221.000 223.450 226.000 228.600 231.250 233.950 236.700
239.550 242.450 245.400 248.450 251.600 254.800 258.050 261.450
264.950 268.500 272.150 275.900 279.750 283.700 287.800 292.000
296.300 300.500 303.000 304.000 305.000 306.000 307.000 308.000
309.000 310.000 311.000 312.000 313.000 314.000 316.000 320.000
325.000 330.000 335.000 340.000 345.000 350.000 355.000 360.000
365.000 370.000 375.000 380.000 385.000 390.000 395.000 400.000
405.000 410.000 415.000 420.000 425.000 430.000 435.000 440.000
445.000 450.000 455.000 460.000 465.000 470.000 475.000 480.000
485.000 490.000 495.000 500.000 505.000 510.000 515.000 520.000
525.000 530.000 535.000 540.000 545.000 550.000 555.000 560.000
565.000 570.000 575.000 580.000 585.000 590.000 595.000 600.000
605.000 610.000 615.000 620.000 625.000 630.000 635.000 640.000
644.750 651.000 660.000 670.000 680.000 690.000 700.000 710.000
720.000 730.000
***** WELLENLAENGENINTERVALLE 13.3.77 *****
1.700 1.800 1.900 2.100 2.200 2.400 2.600 2.600
2.200 0.800 2.100 2.100 2.200 2.300 2.200 2.400
2.400 2.400 2.500 2.600 2.600 2.700 2.700 2.800
2.900 2.900 3.000 3.100 3.200 3.200 3.300 3.500
3.500 3.600 3.700 3.800 3.900 4.000 4.200 4.200
4.400 4.000 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 3.000 5.000
5.000 5.000 5.000 5.000 5.000 5.000 5.000 5.000
5.000 5.000 5.000 5.000 5.000 5.000 5.000 5.000
5.000 5.000 5.000 5.000 5.000 5.000 5.000 5.000
5.000 5.000 5.000 5.000 5.000 5.000 5.000 5.000
5.000 5.000 5.000 5.000 5.000 5.000 5.000 5.000
4.500 8.000 10.000 10.000 10.000 10.000 10.000 10.000
10.000 10.000
***** Photonflux WMO Report 16 (1985)
1.819E+11 2.220E+11 2.788E+11 3.307E+11 3.671E+11 4.693E+11 5.905E+11
6.868E+11 8.176E+11 9.203E+11 1.050E+12 1.324E+12 2.092E+12 3.101E+12
3.585E+12 3.712E+12 4.444E+12 4.985E+12 6.063E+12 5.415E+12 5.440E+12
5.708E+12 5.228E+12 5.546E+12 5.448E+12 7.082E+12 6.692E+12 6.382E+12
6.524E+12 9.344E+12 1.390E+13 1.564E+13 2.877E+13 3.251E+13 2.985E+13
2.683E+13 2.393E+13 3.740E+13 5.391E+13 7.745E+13 7.724E+13 7.369E+13
8.068E+13 8.494E+13 8.918E+13 9.239E+13 9.498E+13 9.756E+13 1.002E+14
1.026E+14 1.041E+14 1.052E+14 1.064E+14 1.076E+14 1.108E+14 1.199E+14
1.394E+14 1.591E+14 1.584E+14 1.651E+14 1.643E+14 1.712E+14 1.798E+14
1.746E+14 2.045E+14 2.155E+14 2.026E+14 2.162E+14 1.901E+14 2.162E+14
2.083E+14 3.189E+14 3.432E+14 3.652E+14 3.753E+14 3.845E+14 3.620E+14
3.453E+14 3.893E+14 4.070E+14 4.365E+14 4.663E+14 4.653E+14 4.757E+14
4.765E+14 4.790E+14 4.885E+14 4.950E+14 4.675E+14 4.780E+14 4.918E+14

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4.835E+14	4.913E+14	4.930E+14	4.700E+14	4.770E+14	4.865E+14	5.058E+14
5.025E+14	5.000E+14	5.080E+14	5.067E+14	5.067E+14	5.027E+14	5.125E+14
5.180E+14	5.317E+14	5.348E+14	5.373E+14	5.278E+14	5.348E+14	5.288E+14
5.343E+14	5.307E+14	5.222E+14	5.335E+14	5.242E+14	5.237E+14	5.242E+14
5.250E+14	5.199E+14	5.071E+14	5.124E+14	5.225E+14	5.215E+14	5.105E+14
5.140E+14	5.010E+14	4.930E+14	4.910E+14			
1 28***** O2-Absorption WMO Report 16, 1985						
2. 300.	.02375-	.000141	.017	-.00016	175.5	.03 TD
6.744E-24	7.102E-24	7.429E-24	7.724E-24	7.962E-24	8.113E-24	8.158E-24
8.081E-24	7.911E-24	7.774E-24	7.617E-24	7.327E-24	6.972E-24	6.438E-24
5.822E-24	5.244E-24	4.718E-24	4.260E-24	3.806E-24	3.351E-24	2.898E-24
2.453E-24	2.053E-24	1.686E-24	1.301E-24	9.175E-25	4.719E-25	6.054E-26
1 130***** O3-Absorption WMO Report 16, 1985						
2. 298.	.0116	0.	-.0005	0.	436.	-.27 TD
6.790E-19	6.295E-19	5.734E-19	5.123E-19	4.572E-19	4.162E-19	3.665E-19
3.293E-19	3.262E-19	3.338E-19	3.556E-19	4.121E-19	4.909E-19	6.370E-19
8.650E-19	1.171E-18	1.533E-18	1.984E-18	2.557E-18	3.247E-18	4.013E-18
4.853E-18	5.809E-18	6.865E-18	7.965E-18	9.000E-18	9.970E-18	1.076E-17
1.126E-17	1.144E-17	1.117E-17	1.056E-17	9.596E-18	8.319E-18	6.904E-18
5.429E-18	4.037E-18	2.807E-18	1.825E-18	1.119E-18	6.495E-19	3.707E-19
2.662E-19	2.318E-19	1.975E-19	1.733E-19	1.549E-19	1.365E-19	1.182E-19
1.005E-19	8.920E-20	7.943E-20	6.965E-20	5.988E-20	4.526E-20	2.644E-20
1.288E-20	6.470E-21	2.972E-21	1.294E-21	6.205E-22	2.866E-22	1.219E-22
5.480E-23	6.862E-24	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
0.000E+00	0.000E+00	3.637E-24	2.575E-23	3.217E-23	4.202E-23	6.258E-23
7.022E-23	8.911E-23	1.232E-22	1.487E-22	1.734E-22	2.250E-22	3.402E-22
3.714E-22	4.116E-22	5.064E-22	6.997E-22	8.246E-22	8.400E-22	9.377E-22
1.231E-21	1.565E-21	1.587E-21	1.620E-21	1.794E-21	2.094E-21	2.514E-21
2.734E-21	2.886E-21	3.059E-21	3.181E-21	3.401E-21	3.869E-21	4.301E-21
4.635E-21	4.715E-21	4.550E-21	4.384E-21	4.435E-21	4.621E-21	4.849E-21
4.809E-21	4.540E-21	4.235E-21	3.905E-21	3.616E-21	3.419E-21	3.149E-21
2.778E-21	2.611E-21	2.373E-21	2.023E-21	1.682E-21	1.408E-21	1.127E-21
9.250E-22	7.675E-22	6.300E-22	5.238E-22			
8 127***** NO2-Absorption Schneider etal, J.Photochem.40,195(87)						
3.298.	.0023	.004	-.005	-.0003	272.	600. TD
2.298E-19	4.222E-19	4.317E-19	4.438E-19	4.472E-19	4.640E-19	4.838E-19
4.841E-19	5.942E-19	4.488E-19	4.651E-19	3.811E-19	3.861E-19	2.829E-19
2.726E-19	1.743E-19	1.540E-19	9.073E-20	7.490E-20	3.991E-20	2.721E-20
2.106E-20	1.953E-20	2.116E-20	2.358E-20	2.714E-20	3.241E-20	3.805E-20
4.556E-20	5.592E-20	6.520E-20	7.775E-20	9.521E-20	1.126E-19	1.276E-19
1.481E-19	1.523E-19	1.557E-19	1.553E-19	1.628E-19	1.644E-19	1.770E-19
1.838E-19	1.891E-19	1.959E-19	1.991E-19	2.000E-19	2.178E-19	2.454E-19
2.733E-19	3.015E-19	3.337E-19	3.738E-19	3.903E-19	4.227E-19	4.564E-19
4.617E-19	4.959E-19	5.047E-19	5.260E-19	5.337E-19	5.410E-19	5.629E-19
5.393E-19	5.766E-19	5.293E-19	5.631E-19	5.304E-19	5.377E-19	5.481E-19
5.261E-19	5.469E-19	4.890E-19	4.857E-19	4.905E-19	4.199E-19	4.366E-19
4.065E-19	3.494E-19	3.750E-19	3.442E-19	2.722E-19	2.986E-19	3.032E-19
1.914E-19	2.486E-19	2.345E-19	1.718E-19	1.692E-19	1.797E-19	1.543E-19
1.040E-19	1.026E-19	1.227E-19	1.033E-19	7.334E-20	5.591E-20	8.065E-20
7.729E-20	4.362E-20	3.948E-20	4.142E-20	4.861E-20	3.623E-20	3.504E-20
1.658E-20	2.280E-20	3.193E-20	2.363E-20	1.620E-20	1.055E-20	1.153E-20
1.333E-20	1.610E-20	1.125E-20	5.051E-21	8.081E-21	5.656E-21	2.738E-21
1.104E-21						

Table 7 cont.

one of the photolysis spectra described in the next section. As the scattering cross sections are calculated according to Equation 23, the necessary input data are given alongside with the altitude profiles.

For the refraction index of the air from which the Rayleigh scattering cross sections are derived we use the formula of B. Edlen (1966) :

$$n = 1 + 8.34213 \cdot 10^{-5} + \frac{2.40603 \cdot 10^{-10}}{(1.3 \cdot 10^{-6} - \lambda^{-2})} + \frac{1.5997 \cdot 10^{-12}}{(3.89 \cdot 10^{-7} - \lambda^{-2})} \quad (42)$$

The spectra from which the photodissociation coefficients are derived are also combined into one file, e.g. PHOTOLYS.STD. The headline of this file is skipped. The file may contain up to 70 different photodissociation processes, followed by a line with only blanks to terminate the data set. With this file the data input ends.

The data for each photodissociation reaction consist of a headline, followed by 2 lines with the parameters for the quantum yield calculation and the coefficients for the temperature factor. After that, the absorption spectrum is given. It is possible to add several spectra from different authors. In this case the values read in last will overwrite the earlier ones. A line with blanks or zeros terminates the input for one reaction. An example of the first data for the photolysis input is given in Table 8. A compilation of spectra and quantum yields ready for use in the model ART can be found in Röth et al. (1997)

The main headline first has 3 blanks and then the name of the species being photolyzed follows within 8 columns. A field of 20 characters may be used for further specifications. Then comes the definition of the reaction, first given in a numeric manner, then explicitly. The explicit description of the process is transferred to the output file.

The line with the quantum yield parameters first has 2 words of length 3 in which the indices for the function and a subsequent combination are given. The next two words with format 2F5.0 specify the start and the end of the wavelength regime for which the calculation of the quantum yield will be carried out. Outside this range the quantum yield is set either to 1 or to 0. There are two reasons for the narrowing of the spectral range : Primarily it reduces the computer time considerably. And, on the other hand some compiler will produce error messages if the expo

Table 8 : The first out of 70 absorption spectra which are used to calculate the photo-dissociation frequencies.

PHOTODISSOZIATIONEN									
102	-PHOTOLYSE				O2	+ HV ---> O + O			
1.0.	1.					QY			
2. 300.	.02375-	.000141	.017	-.00016	175.5	.03	TD		
6	26Cheung etal, Planet.SpaceSci.34, 1007(1986)								
6.280E-24	6.466E-24	6.587E-24	6.600E-24	6.559E-24	6.486E-24	6.318E-24			
6.013E-24	5.589E-24	5.247E-24	4.731E-24	4.210E-24	3.727E-24	3.298E-24			
2.812E-24	2.321E-24	1.911E-24	1.530E-24	1.223E-24	9.776E-25	4.250E-25			
11	25Yoshino etal, Planet.SpaceSci.36, 1469(1988)								
7.276E-24	6.986E-24	6.607E-24	6.125E-24	5.746E-24	5.309E-24	4.745E-24			
4.269E-24	3.788E-24	3.213E-24	2.683E-24	2.219E-24	1.791E-24	1.387E-24			
1.070E-24	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00			
203	-PHOTOLYSE				O3	+ HV ---> O(1D) + O2			
7.0. 40. 58.	.86	.865	307.68	.0051	-.46	.00245	1.	320.	QY
2. 298.	.0116	0.	-.0005	0.	436.	-.27	TD		
1	30Yoshino etal, J.Geophys.Res.98, 5205(1993)								
6.249E-19	5.938E-19	5.492E-19	4.920E-19	4.360E-19	3.826E-19	3.378E-19			
3.100E-19	3.077E-19	3.274E-19	3.519E-19	4.268E-19	5.296E-19	6.755E-19			
8.736E-19	1.141E-18	1.488E-18	1.914E-18	2.476E-18	3.140E-18	3.856E-18			
4.669E-18	5.627E-18	6.616E-18	7.676E-18	8.770E-18	9.706E-18	1.044E-17			
1.102E-17	6.240E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00			
6	61Daumont etal, J.Atmos.Chem.15, 145(1992)								
3.815E-19	3.450E-19	3.181E-19	3.183E-19	3.333E-19	3.629E-19	4.311E-19			
5.379E-19	6.951E-19	9.063E-19	1.178E-18	1.539E-18	1.985E-18	2.538E-18			
3.168E-18	3.913E-18	4.789E-18	5.757E-18	6.766E-18	7.838E-18	8.923E-18			
9.809E-18	1.056E-17	1.103E-17	1.128E-17	1.102E-17	1.056E-17	9.618E-18			
8.358E-18	6.925E-18	5.412E-18	4.034E-18	2.813E-18	1.834E-18	1.126E-18			
6.526E-19	3.724E-19	2.617E-19	2.331E-19	1.991E-19	1.776E-19	1.541E-19			
1.344E-19	1.214E-19	1.020E-19	9.238E-20	7.954E-20	6.910E-20	6.245E-20			
4.658E-20	2.769E-20	1.356E-20	6.975E-21	3.208E-21	1.462E-21	5.614E-22			
74	130Burkholder+Talukdar, Geophys.Res.Lett.21, 581(1994)								
1.000E-28	1.000E-28	4.884E-24	3.980E-23	4.778E-23	5.797E-23	1.056E-22			
1.275E-22	1.601E-22	1.797E-22	3.247E-22	3.400E-22	3.758E-22	4.853E-22			
7.031E-22	7.188E-22	8.244E-22	9.208E-22	1.244E-21	1.577E-21	1.557E-21			
1.657E-21	1.828E-21	2.134E-21	2.586E-21	2.833E-21	2.935E-21	3.154E-21			
3.340E-21	3.513E-21	3.879E-21	4.299E-21	4.576E-21	4.713E-21	4.588E-21			
4.419E-21	4.403E-21	4.623E-21	4.995E-21	5.036E-21	4.729E-21	4.311E-21			
3.976E-21	3.774E-21	3.513E-21	3.226E-21	2.941E-21	2.666E-21	2.427E-21			
2.057E-21	1.720E-21	1.378E-21	1.119E-21	9.245E-22	7.568E-22	6.309E-22			
5.188E-22	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00			
303	-PHOTOLYSE				O3	+ HV ---> O + O2			

nential function becomes too small or too big. These 4 steering parameters are followed by up to 6 coefficients for the quantum yield function. The format for these parameters is 6F7.0. Finally the absorption cross section for the Lyman α line is read in with the format E10.2.

The next line contains the parameters of the factor which adjusts the absorption spectrum at T_0 to that at a given temperature. These coefficients use the format 10E8.2. The first number specifies the type of the function applied. Next comes the reference temperature T_0 and after that follows the function's parameters. The characters QY and TF at the end of the lines only ensure that both lines are present.

Finally one or more absorption spectra are listed. These spectra are given in the same format (7E10.3) as the spectra of the absorbing species. The headline first defines the spectral region covered by the data and then the text follows. The text first gives the reference and then from column 52 to 59 the name of the photolized species is repeated. The total format for the headline is 2I5, A42, A8.

If photometer signals shall be simulated by the model, the overall spectral sensitivity of the photometer replaces the absorption cross sections. The quantum yield field may contain a normalisation factor, for example. The formats are the same as for the determination of the photolysis rates, of course. An example for the input of radiometer parameters is displayed in Table 9.

All data sets are written in such a format that they can be read in and changed easily by means of an editor program.

The table of the ratios $F(\text{scatt})/F(\text{abs})$ is only for comparison with results from a previous Monte-Carlo calculation of the photon flux. It has two headlines which are skipped by the program. They merely serve to make the data set readable. The matrix contains of the ratios for 4 altitudes (0, 10, 20 and 40 km), for 4 ground albedos (0, 0.25, 0.5 and 1), for 3 solar zenith angles at ground level (0, 60 and 80°) and for 5 wavelengths (300.5, 335, 425, 500, and 700 nm). The respective data format is 12X, 4F8.2. As these data are normally not used in a standard run, they are read in from a separate file called CARLO DATEN. An example of this file is printed on Table 10. For a standard run it is of absolutely no importance what this file contains.

Table 9 : For the simulation of the radiometer signals the absorption spectra are replaced by the spectral sensitivity of the devices.

NO209	-Photometer	NO2#09	
1. 0.	1.		QY
			TD
35	72C.Schiller Mai 1992		NO209
6.859E-18	3.727E-17	6.955E-17	1.010E-16
1.317E-16	1.610E-16	1.889E-16	
2.138E-16	2.277E-16	2.330E-16	2.381E-16
2.431E-16	2.480E-16	2.528E-16	
2.574E-16	2.619E-16	2.662E-16	2.705E-16
2.745E-16	2.785E-16	2.859E-16	
2.991E-16	3.126E-16	3.226E-16	3.291E-16
3.319E-16	3.312E-16	3.269E-16	
3.190E-16	3.076E-16	2.865E-16	2.375E-16
1.690E-16	9.403E-17	3.626E-17	
9.120E-18	1.744E-18	2.737E-19	0.000E+00
0.000E+00	0.000E+00	0.000E+00	0.000E+00
NO209	-Photometer	NO2#09	
1. 0.	1.		QY
			TD
35	72C.Schiller Mai 1992		NO209
6.859E-18	3.727E-17	6.955E-17	1.010E-16
1.317E-16	1.610E-16	1.889E-16	
2.138E-16	2.277E-16	2.330E-16	2.381E-16
2.431E-16	2.480E-16	2.528E-16	
2.574E-16	2.619E-16	2.662E-16	2.705E-16
2.745E-16	2.785E-16	2.859E-16	
2.991E-16	3.126E-16	3.226E-16	3.291E-16
3.319E-16	3.312E-16	3.269E-16	
3.190E-16	3.076E-16	2.865E-16	2.375E-16
1.690E-16	9.403E-17	3.626E-17	
9.120E-18	1.744E-18	2.737E-19	0.000E+00
0.000E+00	0.000E+00	0.000E+00	0.000E+00
NO2	-PHOTOLYSE	10.HV. 01.09. NO2+ HV ---> O + NO	
2. 0.	70. 75. 1. .025 4040.		QY
			TD
1	73BASS ET AL /1976/	NO2	5
2.800D-19	2.860D-19	3.110D-19	3.120D-19
2.820D-19	2.610D-19	2.590D-19	
2.740D-19	3.080D-19	3.360D-19	3.820D-19
4.000D-19	4.380D-19	4.670D-19	
4.740D-19	4.980D-19	4.490D-19	4.880D-19
3.990D-19	4.130D-19	2.990D-19	
2.960D-19	1.860D-19	1.560D-19	8.180D-20
5.890D-20	3.930D-20	1.630D-20	
1.740D-20	1.730D-20	1.760D-20	2.080D-20
2.360D-20	2.870D-20	3.600D-20	
4.390D-20	5.670D-20	6.630D-20	8.200D-20
1.010D-19	1.140D-19	1.320D-19	
1.610D-19	1.730D-19	1.760D-19	1.720D-19
1.750D-19	1.770D-19	1.940D-19	
1.920D-19	2.020D-19	2.110D-19	2.170D-19
2.210D-19	2.450D-19	2.730D-19	
3.020D-19	3.270D-19	3.660D-19	4.150D-19
4.380D-19	4.810D-19	5.230D-19	
5.290D-19	5.670D-19	5.820D-19	6.040D-19
6.010D-19	6.120D-19	6.400D-19	
6.210D-19	6.640D-19	5.990D-19	
NO209	-Photometer	NO2#09	
1. 0.	1.		QY
			TD
35	72C.Schiller Mai 1992		NO209
6.859E-18	3.727E-17	6.955E-17	1.010E-16
1.317E-16	1.610E-16	1.889E-16	
2.138E-16	2.277E-16	2.330E-16	2.381E-16
2.431E-16	2.480E-16	2.528E-16	
2.574E-16	2.619E-16	2.662E-16	2.705E-16
2.745E-16	2.785E-16	2.859E-16	
2.991E-16	3.126E-16	3.226E-16	3.291E-16
3.319E-16	3.312E-16	3.269E-16	
3.190E-16	3.076E-16	2.865E-16	2.375E-16
1.690E-16	9.403E-17	3.626E-17	
9.120E-18	1.744E-18	2.737E-19	0.000E+00
0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 10 : The first lines of the files CARLO DATEN with data gained from a separate model which uses a Monte Carlo method to desire the fluxes.

TABELLE DER VERHAELTNISSE F (SCATT.) / F (ABS.)						
LAM.	X	B.ALB	0 KM	10 KM	20 KM	40 KM
3005	0	0.00	0.68	1.42	1.03	1.01
		0.25	1.05	1.51	1.04	1.01
		0.50	1.49	1.57	1.05	1.01
		1.00	2.67	1.84	1.07	1.01
	60	0.00	0.38	1.12	0.97	1.00
		0.25	0.54	1.16	0.98	1.00
		0.50	0.73	1.21	0.98	1.00
		1.00	1.27	1.28	0.98	1.00
	80	0.00	10.00	10.00	10.00	0.99
		0.25	10.00	10.00	10.00	0.99
		0.50	10.00	10.00	10.00	0.99
		1.00	10.00	10.00	10.00	0.99
3350	0	0.00	0.96	1.76	1.67	1.56
		0.25	1.54	2.04	1.89	1.73
		0.50	2.26	2.40	2.15	1.95
		1.00	4.45	3.55	2.98	2.62
	60	0.00	0.55	1.39	1.52	1.44
		0.25	0.78	1.51	1.61	1.51
		0.50	1.04	1.66	1.72	1.59
		1.00	1.91	2.08	2.01	1.84
	80	0.00	0.13	0.63	1.09	1.21
		0.25	0.18	0.65	1.11	1.22
		0.50	0.25	0.68	1.14	1.24
		1.00	0.45	0.80	1.22	1.29
4250	0	0.00	1.04	1.34	1.33	1.32
		0.25	1.64	1.75	1.68	1.65
		0.50	2.29	2.18	2.07	2.00
		1.00	3.90	3.27	3.01	2.87
...						

The operating system

As the model ART is written in a standard FORTRAN programming language, it can be compiled and run under most operating systems. At the moment we operate the model under UNIX. The respective operating commands are listed in Table 11.

The job will be prepared on a workstation, but it runs on a CRAY computer. Therefore, after the job is put together on the workstation, one has to switch to the CRAY by help of the UNIX script command 'cray'. On the CRAY then, the program can be started by typing 'flux.j'.

After the calculations are done, the output files are automatically transferred back to the workstation. There the output files are available for further use by means of their names, e.g. 'PHOTMAT' or 'FLUXOUT'.

Table 11 : The UNIX commands used to merge the job 'flux.j' together.

```
# QSUB -r FLUX
# QSUB -lT 1500
# QSUB -lM 8Mw
# QSUB -q high
# QSUB
#
rm -f errors listing
cat > flux.f << 'EOFPROG'
C
C
PROGRAM          FLUX

...              SOURCE CODE

END
EOFPROG
#
cat $MOUNT/ich227.home3/ich301/Flux/Data/Air.044 > daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/NO2.Std >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/O3.028 >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Aer.Glo >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Aer.Nul >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Cloud.Nul >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Cloud.Nul >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Temp.044 >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Dataset.Wave >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Photolys.Std >> daten
#
touch $MOUNT/ich227.home3/ich301/Flux/fluxplt
touch $MOUNT/ich227.home3/ich301/Flux/fluxout
touch $MOUNT/ich227.home3/ich301/Flux/photmat
f90 -ef -l grgts,kfalib -o fluxrun flux.f
env FILENV=fluxenv assign -a $MOUNT/ich227.home3/ich301/Flux/fluxplt fort.8
env FILENV=fluxenv assign -a $MOUNT/ich227.home3/ich301/Flux/fluxout fort.9
env FILENV=fluxenv assign -a $MOUNT/ich227.home3/ich301/Flux/photmat fort.11
#
env FILENV=fluxenv fluxrun < daten 1>>listing 2>>errors
#if [ $? -ne 0 ]
#then
#  debug -d 9,9,2,2,1 -B -s fluxrun
#fi
#ls -lisa

flowview -Luc > cpuvievw

if [ -f fluxrun ]
then
  rm -f fluxrun
fi
if [ -f core ]
then
  rm -f core
fi
```

site of the experiment is given together with the location and time. The ozone column density gives the actual value for the calculation (either the defined value or the integration of the read-in profile). The header ends with the references for the O₂, O₃, and NO₂ absorption spectra and for the refraction index.

On the next page after the header the output FLUXOUT registers the optical densities for the scattering and absorption processes at discrete wavelengths. The phase function values for Rayleigh and Mie scattering follow (these data are not shown here).

The output of the fluxes is presented in Table 13. First the parameters for the specific beam (the nearest distance to the earth centre r_k , the albedo at 400 nm, and the number of scattering directions) are printed.

As it is always indispensable to calculate the photon fluxes at all altitudes of the atmosphere. Even if in a Type 1 run only one location is selected, the whole altitude profile of the specified beam is given on the output. The headlines of that part show the altitudes and the zenith angles at these heights. The photon fluxes are given in [photons / cm² sec], separated for the direct flux (2nd row), and the diffuse downwards (3rd row) and upwards (4th row) directed light. The total actinic flux is given in the 1st row of each column. The first column indicates the wavelength interval, given by its centre and width. The arrangement of the values is repeated first for the altitudes from 0 to 50 km and then from 40 to 90 km. The solar flux in the last column is the input value of the extraterrestrial flux, i.e. the radiance at 100 km. The fluxes are printed for all calculated lines.

Figure 13 exhibits the data of Table 13. The altitude profiles of the direct photon flux, the upwards and downwards directed diffuse light and the total actinic fluxes are depicted for the wavelengths 303 nm and 550 nm. The interval at 303 nm is 1 nm broad, and at 550 nm wavelength the width is 5 nm.

The wavelength dependence of the actinic flux is shown in Figure 14 for the chosen altitude of 0 km. The contributions of the different parts of the actinic flux (collimated, diffuse up and diffuse down) to the overall photon flux are brought to light by this figure. For comparison the extraterrestrial flux is displayed, too. Contrary to the data given in Table 13 where the fluxes are given for the respective wavelength interval, now the values are normalized to 1 nm interval width.

site of the experiment is given together with the location and time. The ozone column density gives the actual value for the calculation (either the defined value or the integration of the read-in profile). The header ends with the references for the O₂, O₃, and NO₂ absorption spectra and for the refraction index.

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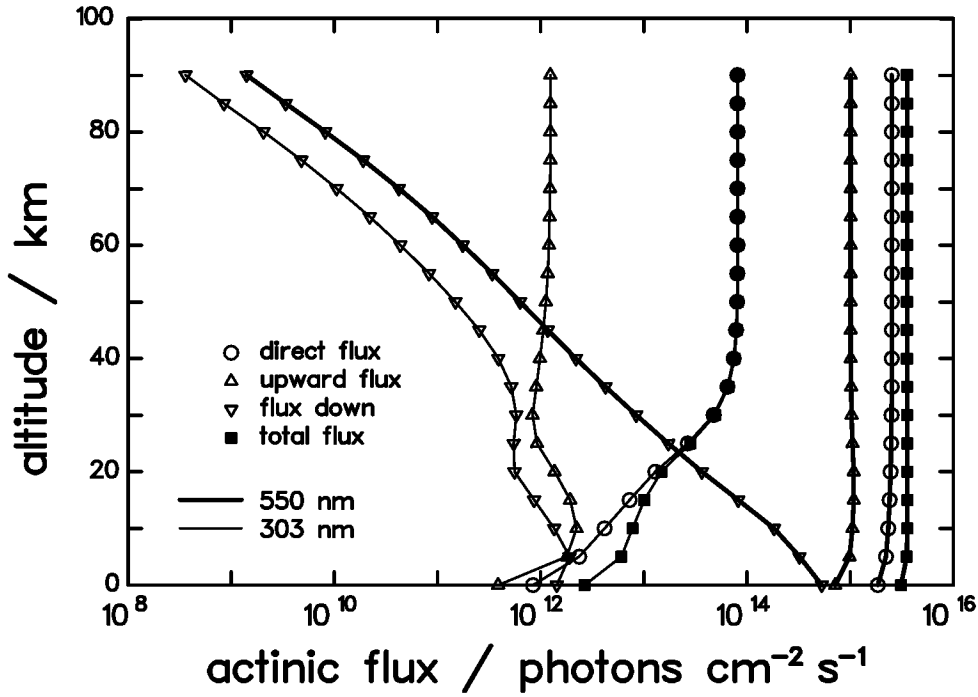


Figure 13 : The altitudinal profiles of the actinic fluxes at 303 and 550 nm, separated into the direct, collimated flux, the diffuse light directed upward and downward, and the total flux. The calculation was done for June 20th at 50°N.

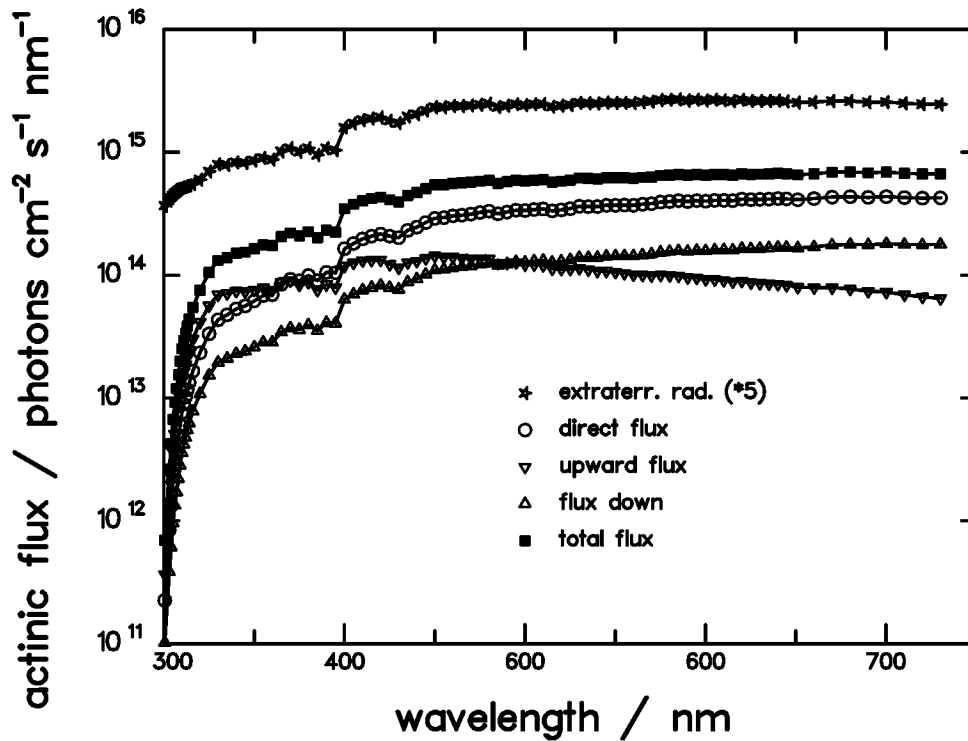


Figure 14 : The wavelength dependence of the actinic flux at ground level.

The output of a Type 2 run is nearly identical to the just described one. Therefore, it is not necessary to give special examples for these files. In a Type 3 run up to 20 beams are followed on their way through the atmosphere and, hence, the output FLUXOUT repeats the pattern given above in Table 13 for every beam.

Table 14 gives an example of the way the photodissociation coefficients are presented. It shows the output file PHOTMAT for a Type 3 run. After the header (according to Table 12, not shown) the first page explains for which reactions the calculation is carried out. For each photodissociation reaction the references for the absorption spectra are listed. If more than one spectrum is cited the complete absorption spectrum is built up by superposing several parts of it from different authors. Each part overwrites the preceding one. Altogether, 118 photolysis frequencies are calculated at the moment, the last ones for aqueous phase reactions.

A condensed output for further use of the coefficients is given on the second page of Table 14. The data are given for the different beams followed by the program. As the beams are identified by their nearest distance r_k to the earth's centre, the r_k -values are listed at the top of the output. Then follows the formula for the determination of the solar zenith angle which depends on the geometrical height due to the spherical geometry of the earth's atmosphere. The next line describes for how many altitudes the data are presented. Here an altitudinal step of 5 km is chosen, starting at ground level.

Then follow the photolysis rates written in a condensed form. The first number in each line gives the coefficient for overhead sun conditions, the following represent the fractions relative to the first data. The fractions are given by integer numbers which had to be multiplied by a factor of 10^{-5} to get the actual values.

The photolysis rates are always given for one altitude at the time which is indicated at the top of the data. The altitudes for which the rates should be printed can be chosen within the source program by selecting the height interval and the number of altitudes. The output always starts with altitude 0 km. The altitudinal dependence of some selected photolysis rates are presented in Figure 14. These plots are obtained directly from the program by answering "yes" to the appropriate question in the precursor program FLUXSTRT or by setting the key number IPLOTP to 1.

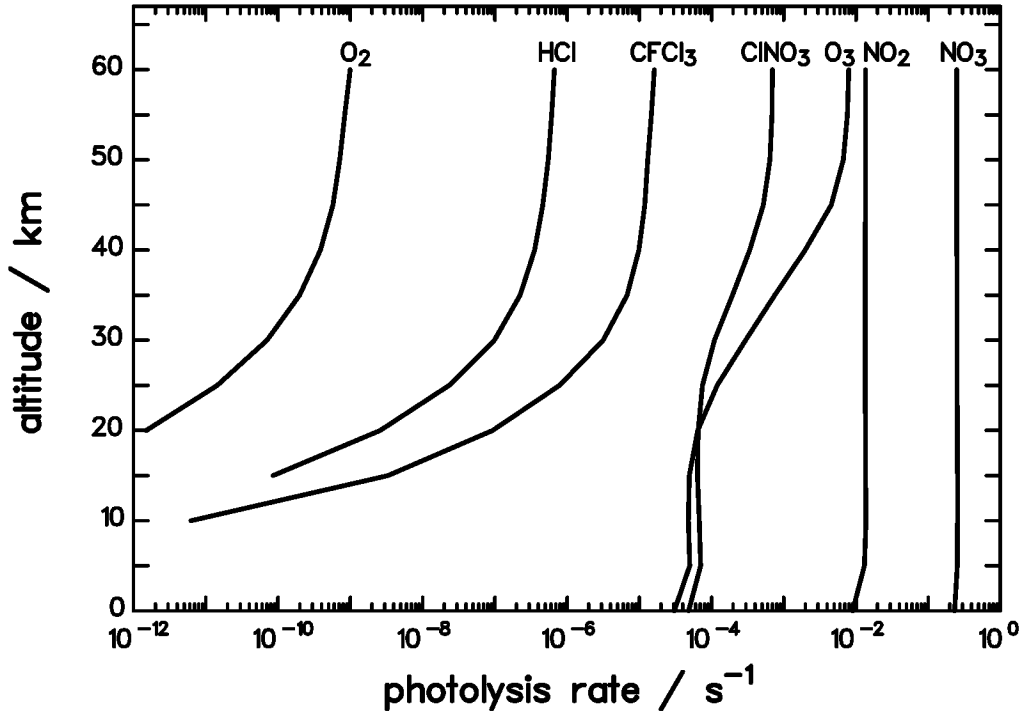


Figure 15 : The altitude profiles of some selected photolysis frequencies for overhead sun.

Along with the exact data points derived from the 10 or more beams an approximate formula is given, too, for each photodissociation rate j . The equation

$$j = j_0 \cdot e^{a(1-\cos b\chi)} \quad (43)$$

presents quite well the dependence of j on the solar zenith angle χ , the coefficients j_0 , a , and b are determined from the data at a solar zenith angle of 0° , 60° and 90° , respectively (see section “The photolysis rate function” on page 19 for details). Figure 7 gives some examples for different shapes of the zenith angle dependence of j . In most cases this equation is sufficiently accurate for calculation of a specific photolysis rate, keeping in mind that there are uncertainties in modelling much bigger than those made by using the above formula.

For a Type 1 run only the data at the chosen altitude are presented. In case the height is not an integer number of km, a linear interpolation between the neighbouring levels is applied. For a Type 2 run, i.e. a run for a given solar zenith angle, the output is identical to the one for a run of Type 1. But, due to the spherical geometry of the earth's atmosphere the calculation is somewhat different. For Type 1 only a single beam which hits the chosen altitude at the specified solar

zenith angle, is followed by the program. Here it is unimportant that the zenith angle varies with height. In case of a Type 2 run two beams are calculated, one with a value of r_k corresponding to the given solar zenith angle at ground level, the other one for the same zenith angle at 100 km altitude. The respective photodissociation matrices are collected in the subprogram INTERPOL and afterwards the interpolation is carried out by this subroutine. Because of this procedure two sets of fluxes are printed, but only one set of photolysis coefficients. As even for very high solar zenith angles the difference between the r_k of the two beams is rather small, a linear interpolation with respect to the zenith angle is applied.

Special test runs

The first test shown here, compares the results of the two possible ways to calculate the photon flux, i.e. by the models ART and FLUX3B. In Figure 16 the wavelength dependence of the two fluxes is exhibited. The curves are obtained in the same manner as those of the Figures 13 and 14. The differences in the fluxes are always smaller than 10% at all altitudes. Above 15 km height the three-beam model FLUX3B overestimates the actinic flux for wavelengths larger than 500 nm. And it underestimates the flux at ground level below 400 nm. These differences can be avoided if a more sophisticated formula for the mean path length within a layer with more terms is applied.

The vertical profiles for the respective photodissociation coefficients are displayed in Table 15. In the stratosphere the deviations between the two methods do not exceed 5%, as the algorithm FLUX3B is adjusted to this atmospheric region. Only in cases where the photolysis frequencies are smaller than 10^{-10} sec the differences might become larger. But this has no effect to model calculations of atmospheric chemistry as in these cases the photolytic lifetime exceeds 3000 years. Due to possible numerical errors all photodissociation rates less than 10^{-13} sec are set to 0 in the model FLUX3B.

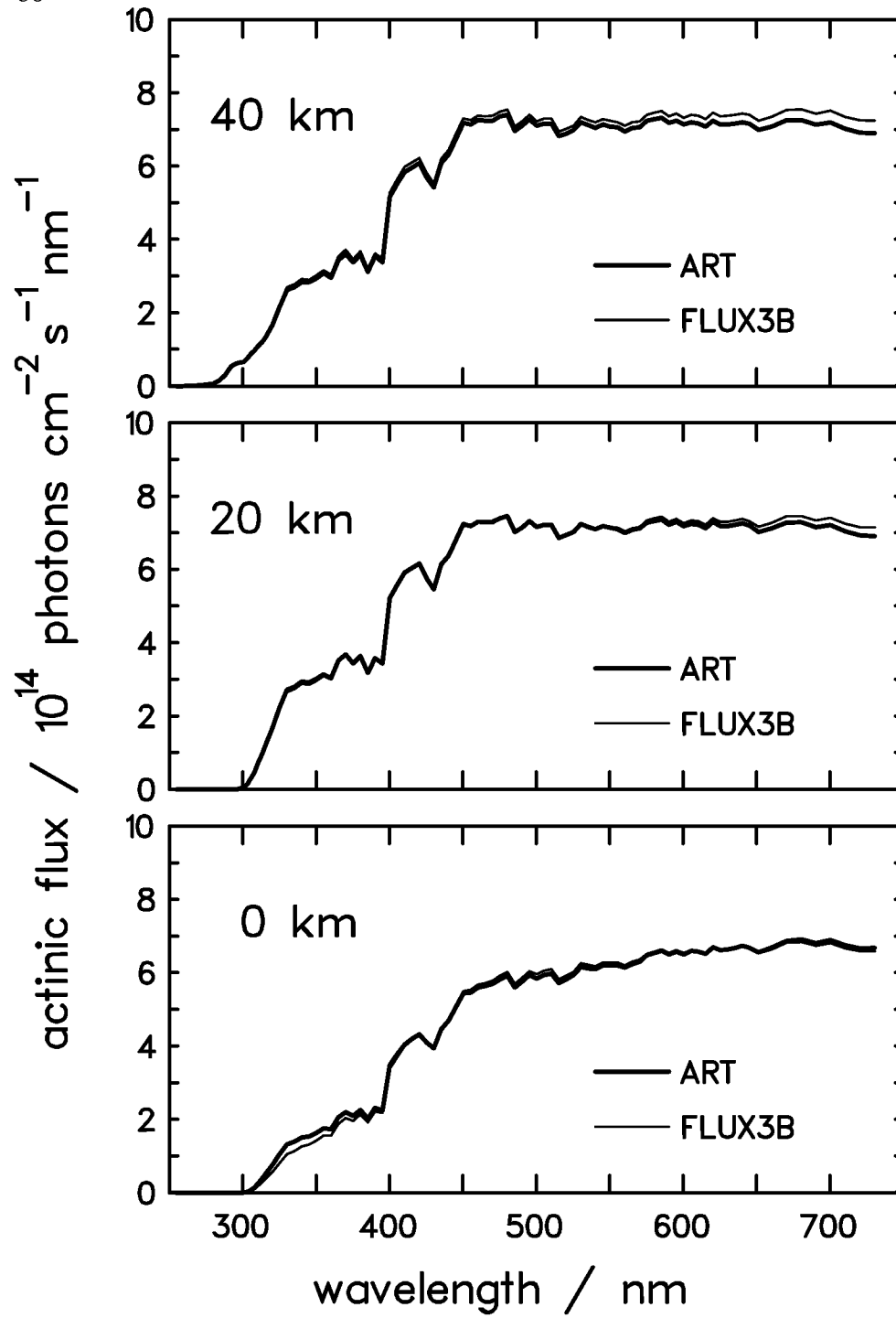


Figure 16 : The wavelength dependence of the actinic flux at three altitudes calculated for 50° N at 10.00 h on June 20th with the models ART and FLUX3B.

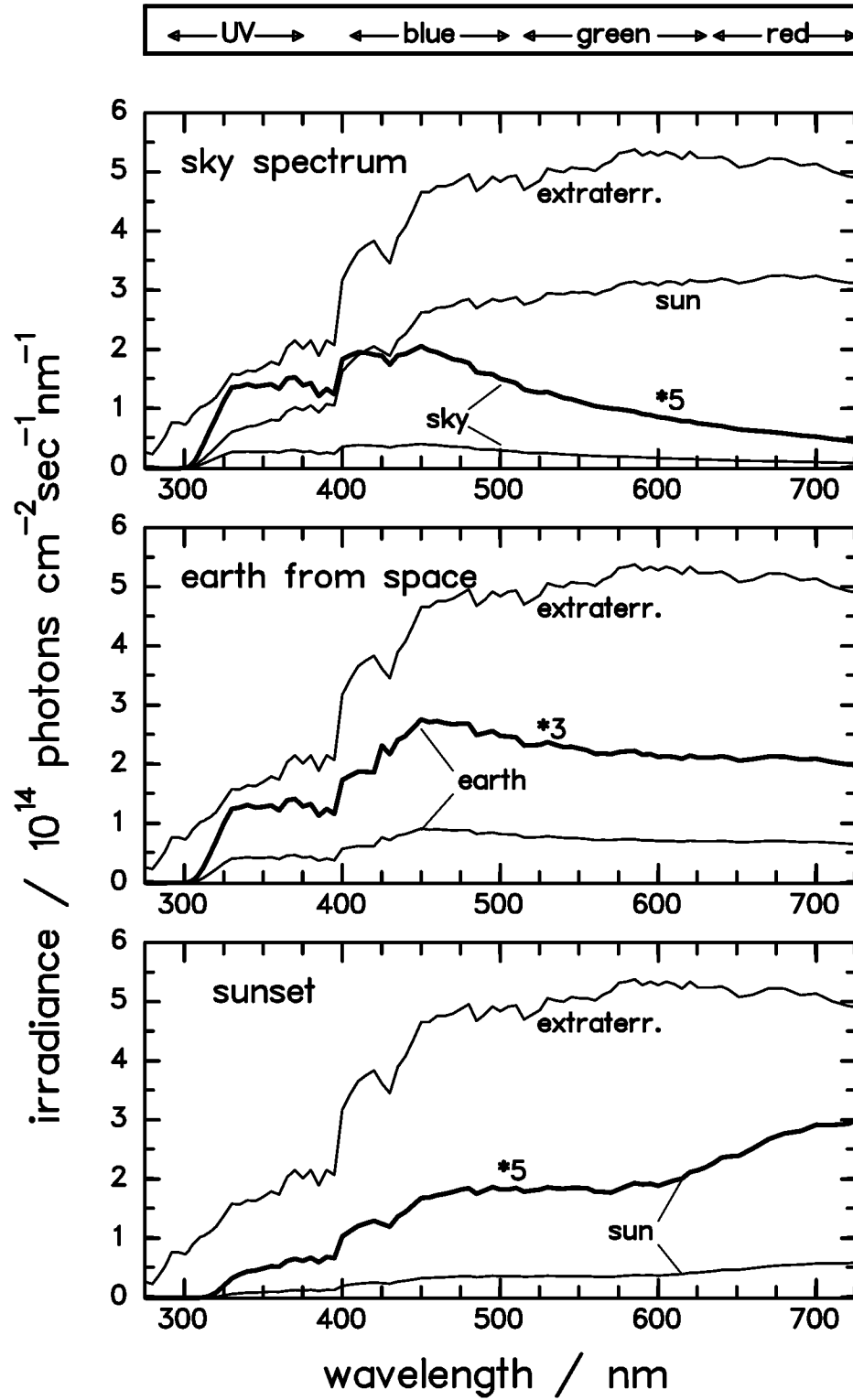


Figure 17 : Simulated spectra of the sky seen from ground level, of the earth seen from space, and of the sky and the earth at sunset. The calculations were carried out for clear sky conditions at 50° N on June 20th.

To examine the angular distribution of the fluxes, the steering parameter IFARB must be set to 1 within the source code. Then a spectral dependence of the distribution of the incoming light at the earth's surface, and that of the outgoing light at 99 km altitude will be obtained. Figure 17 shows results for overhead sun and for a solar zenith angle of 80° , i. e. close to sunset. Here, like in all other calculations, clear sky conditions were assumed. The plots were obtained by using the model's output (see Table 16) in a separate graphics routine. The model correctly enhances the blue region of the sky and the red light coming directly from the sun at sunset. It is also shown that the earth reflects especially the blue light back into space.

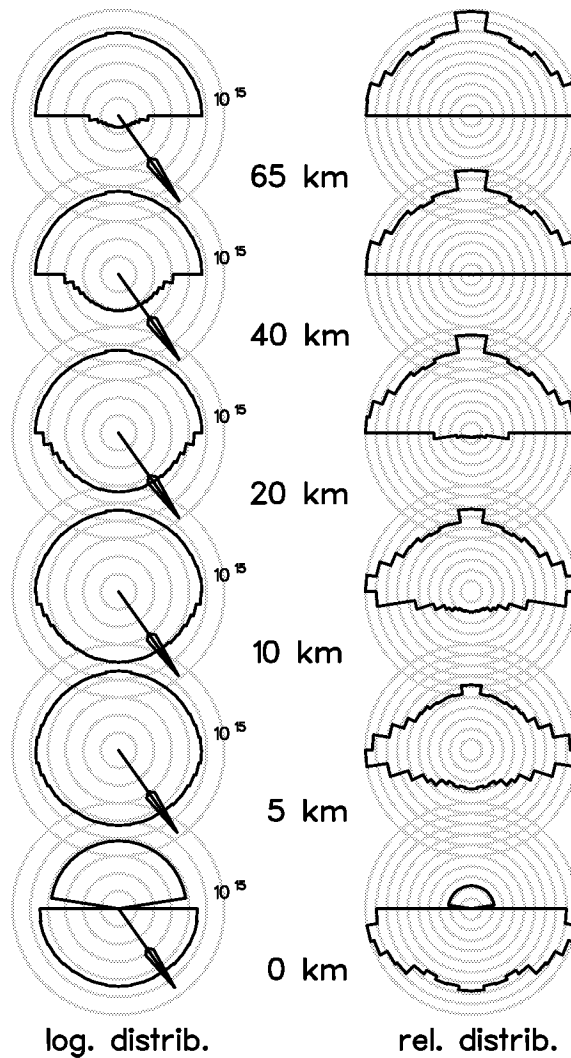


Figure 18 : The angular distribution of the diffuse light at several altitudes. The arrow indicates the direct beam.

For testing the total angular dependence of the diffuse light, the wavelength regime has to be set to a single line. If the parameter IDISTR equals 1, the angular dependence of the flux is printed for 11 different height, from ground level to 65 km (see Table 17). These angular distributions are shown in Figure 18 for a spectral line at 350 nm. The boundary conditions were again 50° N, 10.00 h on June 20th. On the left side of the plot the absolute actinic fluxes are depicted in a logarithmic scale together with an arrow indicating the direction and the amount of the direct, collimated beam. The right side shows the distributions relative to the direction with the largest value. The results are equivalent to the distribution given by Ruggaber et al. (1994).

There are other tests allowed by the program. Here only the most common ones could be explained. E.g., the calculations can be done not only for the total actinic flux but also for the flux from above and from below. This is important if radiometer measurements are to be simulated. As well the photodissociation rates can be separated into the parts from the direct light and the diffuse radiation upwards and downwards. But for these runs, one has to go into the source code in more detail.

*** F L U X S *** Version Mar.95 ***

Type 1 Run

	AIR_044	H5 GRD / Juni	Cole+Kantor,	Air Fo
[AIR]	profile : 000			I column : 2.148580715527103E+25
[O3]	profile : 03.028	Heissenbguni	Monatmittel	I column : 4.01955870054720.
[NO2]	profile : 046	NO2.001 Global/am.average	Roeth Modell 1988	I column : 9.381571791757585E+18
Aerosol1	profile :	Aerosol Global Standard	WMO/TD-NO.24 (1986)	I column : 88674510.47502327
Aerosol2	profile :	AEROSOL NULL		I column : 9.89999999999932E-34
Clouds 1	profile :	CLOUD NULL		I column : 9.89999999999932E-34
Clouds 2	profile :	CLOUD NULL		I column : 9.89999999999932E-34
				I = 2.00E-05
				I = 1.00E-10
				I = 1.00E-10
				I = 1.00E-10
				I = 1.00E-10

Wavelength range from 184.65 to 730.00 nm

O3 column density is 352. Dobsons

Latitude : 50.00 Date : 20.06 Time : 10.00

aerosol radius less than 4E-6 cm: No Scattering !

Table 14 : Example of an output file PHOTMAT from a Type 3 run of model ART

000	AIR.044 45 GRD / Juni	Cole+Kantor, Air Fo	2.148580715527103E+25	
	03.028 HPeissenbgJuni	Monatsmittel	4101955870054720.	
046	NO2.001 global/ann.average	Roeth Modell 1988	9.381571791725985E+18	
	Aerosol Globa l Standard	WMO/TD-NO.24 (1986)	88674510.47502327	r= 2.00E-05
	CLOUD NULL9.		899999999999932E-34	r= 1.00E-10
-01	TEMP.044 45 GRD / Juni			
Reactions:				
1	O2	+ HV ----> O + O	Cheung etal, Planet.SpaceSci.34, 1007(1986)	
			Yoshino etal, Planet.SpaceSci.36, 1469(1988)	
2	O3	+ HV ----> O(1D) + O2	Yoshino etal, J.Geophys.Res.98, 5205(1993)	
			Daumont etal, J.Atmos.Chem.15, 145(1992)	
3	O3	+ HV ----> O + O2	Burkholder+Talukdar, Geophys.Res.Lett.21, 581(1994)	
			Yoshino etal, J.Geophys.Res.98, 5205(1993)	
			Daumont etal, J.Atmos.Chem.15, 145(1992)	
			Burkholder+Talukdar, Geophys.Res.Lett.21, 581(1994)	
4	HO2	+ HV ----> O + OH	Crowley etal, J.Photochem.Photobiol.60, 1(1991)	
5	H2O	+ HV ----> H + OH	Hochanadel etal, J.Chem.Phys.56, 4426(1972)	
6	H2O2	+ HV ----> OH + OH	Vaghjiani+Ravinsankara, J.Geophys.Res.94, 3487(1989)	
7	NO	+ HV ----> O + N	Thompson etal, J.Geophys.Res.68, 6431(1963)	
8	NO2	+ HV ----> O + NO	Bass etal, J.Res.NBS80a, 143(1976)	
			Schneider etal, J.Photochem.Photobiol.40, 195(1987)	
9	NO3	+ HV ----> O2 + NO	Sander, J.Phys.Chem.90, 4135(1986)	
10	NO3	+ HV ----> O + NO2	Sander, J.Phys.Chem.90, 4135(1986)	
11	N2O	+ HV ----> O(1D) + N2	Johnston+Selwyn, Geophys.Res.Lett.2, 549(1975)	
			Hubrich+Stuhl, J.Photochem.12, 93(1980)	
12	N2O4	+ HV ----> NO2 + NO2	Bass etal, J.Res.NBS80a, 143(1976)	
13	N2O5	+ HV ----> O + 2 NO2	Johnston+Graham, Can.J.Chem.52, 1415(1974) (mod.)	
14	NH3	+ HV ----> products	Thompson etal, J.Geophys.Res.68, 6431(1963)	
15	HNO2	+ HV ----> NO + OH	Bongartz etal, J.Phys.Chem.95, 1076(1991)	
116	H2O2	+ HV --> products	Zellner&Herrmann,AbschluuberichtFK07EU780A,1996	
117	Fe(Ox)2	+ HV --> products	Ervens, priv.Mitteilung, 1999	
118	Fe(Ox)3	+ HV --> products	Ervens, priv.Mitteilung, 1999	
Distance rk from Ray to the Center of the Earth :				
			0. 3205. 4796. 5586. 5979. 6174. 6271. 6319. 6342. 6354. 6366. 6376. 6386. 6396. 6406. 6416. 6426. 6436. 6406. 6396.	

Header.Bottom : 1.00

Table 15 : Comparison of photolysis frequencies from the models ART and FLUX3B at selected altitudes

Alt.	O ₂	O ₃	NO ₂	NO ₃	HCl	CINO ₃	CFCI ₃	Model
0 km	1.09E-26	2.10E-05	7.97E-03	2.15E-01	6.00E-23	4.13E-05	7.20E-22	ART
	0.000	1.52E-05	7.42E-03	2.19E-01	0.000	3.57E-05	0.000	FLUX3B
		-27.8%	-6.9%	2.1%		-13.5%		Δ
5 km	6.93E-22	3.66E-05	1.23E-02	2.42E-01	8.43E-19	6.42E-05	2.73E-17	ART
	0.000	3.16E-05	1.15E-02	2.41E-01	0.000	5.77E-05	0.000	FLUX3B
		-13.6%	-6.8%	-0.1%		-10.0%		Δ
10 km	1.70E-17	3.59E-05	1.31E-02	2.45E-01	2.26E-14	6.27E-05	8.98E-13	ART
	0.000	3.40E-05	1.27E-02	2.47E-01	0.000	5.78E-05	0.000	FLUX3B
		-5.4%	-3.0%	0.7%		-7.9%		Δ
15 km	1.58E-14	3.81E-05	1.31E-02	2.47E-01	2.63E-11	6.03E-05	1.02E-09	ART
	0.000	3.75E-05	1.30E-02	2.48E-01	0.000	5.57E-05	6.83E-10	FLUX3B
		-1.6%	-1.0%	0.5%		-7.6%	-33.0	Δ
20 km	7.20E-13	5.10E-05	1.31E-02	2.45E-01	1.28E-09	6.18E-05	4.59E-08	ART
	2.73E-13	5.12E-05	1.31E-02	2.49E-01	5.38E-10	5.97E-05	3.97E-08	FLUX3B
	-62.1%	0.3%	-0.3%	1.6%	-58.0%	-3.4%	-13.5%	Δ
25 km	9.34E-12	9.84E-05	1.30E-02	2.45E-01	1.56E-08	6.97E-05	5.29E-07	ART
	7.40E-12	9.91E-05	1.32E-02	2.50E-01	1.03E-08	6.99E-05	4.97E-07	FLUX3B
	-20.7%	0.8%	1.9%	2.0%	-34.0%	0.3%	-6.0%	Δ
30 km	5.51E-11	2.51E-04	1.30E-02	2.44E-01	7.93E-08	9.94E-05	2.55E-06	ART
	5.70E-11	2.51E-04	1.33E-02	2.50E-01	6.98E-08	1.01E-04	2.27E-06	FLUX3B
	3.4%	0.0%	2.7%	2.4%	-12.0%	1.8%	-10.9%	Δ
40 km	3.53E-10	1.71E-03	1.31E-02	2.44E-01	3.31E-07	3.10E-04	9.34E-06	ART
	3.60E-10	1.71E-03	1.35E-02	2.51E-01	3.34E-07	3.13E-04	9.31E-06	FLUX3B
	2.1%	-0.1%	3.3%	3.2%	1.0%	0.8%	-0.3%	Δ
50 km	6.90E-10	6.49E-03	1.32E-02	2.44E-01	5.31E-07	6.30E-04	1.29E-05	ART
	7.05E-10	6.49E-03	1.36E-02	2.51E-01	5.34E-07	6.30E-04	1.28E-05	FLUX3B
	2.2%	0.0%	3.3%	3.2%	0.5%	0.1%	-0.2%	Δ
60 km	9.52E-10	7.88E-03	1.32E-02	2.44E-01	6.60E-07	6.95E-04	1.61E-05	ART
	9.87E-10	7.88E-03	1.35E-02	2.51E-01	6.55E-07	6.95E-04	1.59E-05	FLUX3B
	3.7%	0.0%	2.6%	3.2%	-0.7%	0.0%	-1.1%	Δ

Table 16 : The output on file FLUXOUT for IFARB=1

Colour of the Sky seen from Earth											
[nm]	85.5	76.5	67.5	58.5	49.5	40.5	31.5	22.5	13.5	4.5	sun 35.4 [dgr]
199.80	3.55E-07	9.71E-07	1.54E-06	1.96E-06	2.26E-06	2.17E-06	2.05E-06	1.73E-06	1.26E-06	5.15E-07	7.79E-26
202.20	4.26E-07	1.17E-06	1.85E-06	2.35E-06	2.71E-06	2.61E-06	2.48E-06	2.10E-06	1.53E-06	6.25E-07	3.29E-25
203.70	1.99E-07	5.44E-07	8.62E-07	1.10E-06	1.27E-06	1.22E-06	1.16E-06	9.85E-07	7.20E-07	2.95E-07	8.66E-25
205.15	6.35E-07	1.74E-06	2.75E-06	3.49E-06	4.04E-06	3.90E-06	3.72E-06	3.17E-06	2.32E-06	9.52E-07	2.13E-24
207.25	8.37E-07	2.29E-06	3.62E-06	4.60E-06	5.34E-06	5.17E-06	4.96E-06	4.25E-06	3.13E-06	1.29E-06	8.19E-24
209.40	1.45E-06	3.97E-06	6.29E-06	7.99E-06	9.30E-06	9.06E-06	8.75E-06	7.56E-06	5.60E-06	2.32E-06	3.44E-23
670.00	3.31E+13	4.73E+13	4.37E+13	3.95E+13	3.64E+13	2.82E+13	2.11E+13	1.73E+13	1.02E+13	3.52E+12	8.27E-01
680.00	3.27E+13	4.60E+13	4.22E+13	3.81E+13	3.50E+13	2.71E+13	2.02E+13	1.66E+13	9.71E+12	3.36E+12	8.35E-01
690.00	3.17E+13	4.39E+13	4.01E+13	3.60E+13	3.30E+13	2.55E+13	1.90E+13	1.56E+13	9.11E+12	3.14E+12	8.42E-01
700.00	3.16E+13	4.31E+13	3.91E+13	3.50E+13	3.21E+13	2.47E+13	1.84E+13	1.50E+13	8.79E+12	3.03E+12	8.49E-01
710.00	3.03E+13	4.08E+13	3.69E+13	3.30E+13	3.01E+13	2.31E+13	1.71E+13	1.40E+13	8.20E+12	2.82E+12	8.54E-01
720.00	2.94E+13	3.91E+13	3.51E+13	3.13E+13	2.86E+13	2.19E+13	1.62E+13	1.33E+13	7.74E+12	2.66E+12	8.60E-01
730.00	2.89E+13	3.80E+13	3.39E+13	3.02E+13	2.74E+13	2.10E+13	1.55E+13	1.27E+13	7.40E+12	2.54E+12	8.65E-01
Colour of the Earth seen from space											
[nm]	85.5	76.5	67.5	58.5	49.5	40.5	31.5	22.5	13.5	4.5 [dgr]	
199.80	1.22E+09	2.99E+09	3.78E+09	4.28E+09	4.83E+09	4.64E+09	3.93E+09	3.73E+09	2.24E+09	1.11E+09	
202.20	1.17E+09	2.88E+09	3.64E+09	4.12E+09	4.66E+09	4.47E+09	3.79E+09	3.60E+09	2.16E+09	1.08E+09	
203.70	4.64E+08	1.14E+09	1.44E+09	1.62E+09	1.83E+09	1.76E+09	1.49E+09	1.42E+09	8.52E+08	4.24E+08	
205.15	1.33E+09	3.24E+09	4.08E+09	4.61E+09	5.20E+09	4.99E+09	4.22E+09	4.01E+09	2.41E+09	1.20E+09	
207.25	1.56E+09	3.72E+09	4.65E+09	5.23E+09	5.89E+09	5.65E+09	4.77E+09	4.53E+09	2.72E+09	1.36E+09	
209.40	2.37E+09	5.53E+09	6.85E+09	7.66E+09	8.60E+09	8.24E+09	6.96E+09	6.60E+09	3.96E+09	1.98E+09	
670.00	4.45E+13	8.85E+13	1.24E+14	1.45E+14	1.68E+14	1.74E+14	1.57E+14	1.23E+14	7.67E+13	3.07E+13	
680.00	4.64E+13	8.85E+13	1.24E+14	1.45E+14	1.67E+14	1.74E+14	1.57E+14	1.23E+14	7.64E+13	3.05E+13	
690.00	4.75E+13	8.69E+13	1.21E+14	1.42E+14	1.64E+14	1.70E+14	1.53E+14	1.20E+14	7.47E+13	2.98E+13	
700.00	4.96E+13	8.74E+13	1.22E+14	1.43E+14	1.65E+14	1.70E+14	1.54E+14	1.20E+14	7.50E+13	2.98E+13	
710.00	4.97E+13	8.48E+13	1.18E+14	1.39E+14	1.60E+14	1.65E+14	1.49E+14	1.17E+14	7.28E+13	2.89E+13	
720.00	5.04E+13	8.32E+13	1.16E+14	1.36E+14	1.57E+14	1.62E+14	1.46E+14	1.15E+14	7.14E+13	2.82E+13	
730.00	5.16E+13	8.26E+13	1.15E+14	1.35E+14	1.56E+14	1.61E+14	1.45E+14	1.14E+14	7.09E+13	2.79E+13	

Validations

The validation of a model has to be done as far as possible by comparing its outcome to typical measurements. Normally, such a comparison is handicapped by the fact that models give data averaged in space and time, whereas measurements represent values for a specific date and location. In the case of radiation transfer models however, the comparison should be more reliable as the most influential parameters of the computation, solar zenith angle and ozone concentration profile can be well defined for the specific situation of the observation.

To validate our model it was applied to three different experiments. First, balloon-borne data given by Herman and Mentall (1982) for the radiation at 40 km altitude were compared to the appropriate model results. Then, the actinometer experiments by Shetter et al. (1992) on the Mauna Loa volcano were simulated to verify the model's determination of photolysis rates. A rather crucial test of the radiation transfer calculations is the simulation of the balloon-borne radiometer signals carried out by Schiller et al. (1994) as during the ascent and descent of the balloon the UV-B edge of the solar spectrum is shifted through the sensitivity range of the device.

The optical depth for all these cases is always computed from the altitude concentration profiles of the absorbing and/or scattering species measured close to the site and time of the observation. If this is not possible, the air and oxygen profiles as well as the temperature profile are taken from Cole and Kantor (1978) for the respective region. As NO_2 is only a weak absorber a globally averaged concentration profile is inserted. For the aerosols the atmospheric profiles given in the WMO Report TD-24 (1986) were applied to the model.

Contrary to NO_2 , ozone regulates the photon flux in the UV-B regime of the solar spectrum. For a reasonable agreement between measured and simulated quantities it has been proven necessary to use the actual O_3 profile observed at the same day and location. If there is no appropriate ozone measurement available, the error can be minimized by taking any profile typical for the season and the latitude and adjust it to the correct column densities. As the temperature is often measured along with the ozone profile, the actual profile is normally available. The influence of the temperature on radiometer measurements is not very strong, but it

may become important for photolysis rates, as especially the quantum yields are strongly dependant on the temperature.

For consistency the absorption cross sections for oxygen and ozone are those given by the WMO-Report 16 (1985) from which the extraterrestrial flux was taken. For σ_{NO_2} the data measured by Schneider et al. (1987) were used and the absorption by aerosols is handled by taking the ratio of absorption to scattering optical density from d'Almeida et al. (1991). The refraction index of the air was calculated according to the formula given by B. Edlen (1966).

The data of Herman and Mentall

In their publication Herman and Mentall (1982) gave the results of ultraviolet solar flux measurements carried out on a balloon-borne gondola by double monochromators at a float altitude of 40 km. The monochromators pointed into 7 different directions, from which we chose 3 for the comparison: The position towards the sun, the direction 90° to the sun (No. 6 in the authors' notation) and the nadir position (No. 3).

For the simulation we used the following conditions: The temperature profile and the ozone concentrations were taken from Herman and Mentall (1983). For the atmospheric pressure we applied the data of the US Air Force Standard Atmosphere (Cole and Kantor, 1978) for October and 30° N.. Contrary to the calculations carried out by Herman and Mentall, the extraterrestrial solar flux was taken from the WMO Report 16 (1985). For the aerosol burden of the atmosphere the data from the WMO Report TD No. 24 (1986) were adjusted to the ultraviolet region by shifting the optical depth of the scattering at 550 nm to the UV regime. The calculations were carried out for clear sky conditions. The surface albedo was

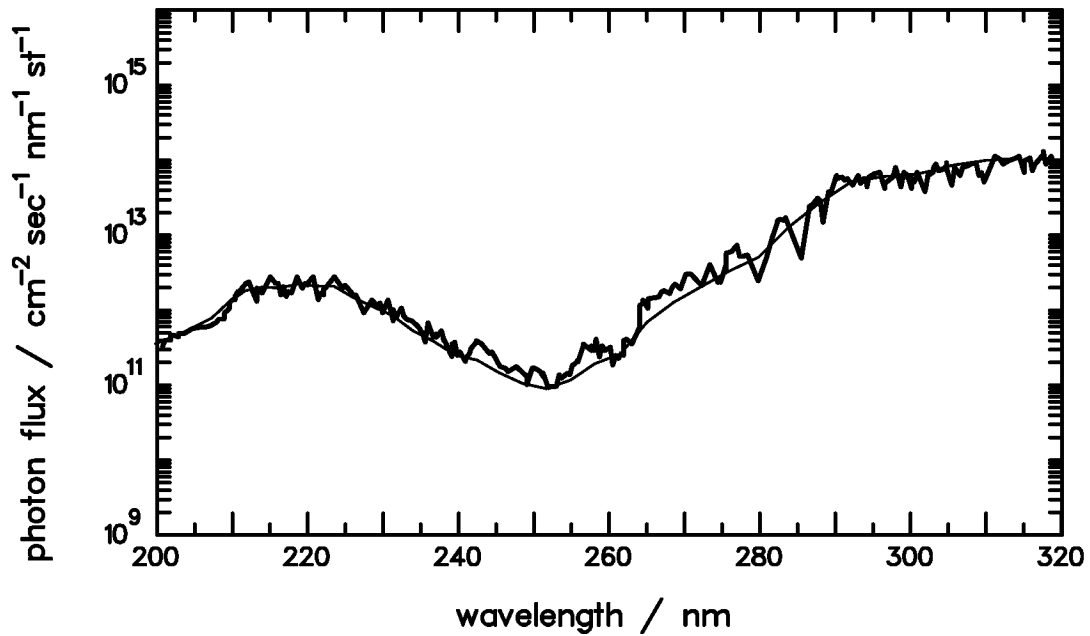


Figure 19a : Comparison of the modeled flux (thin line) and the observation (full line) by Herman and Mentall (1983) for the direct solar radiation.

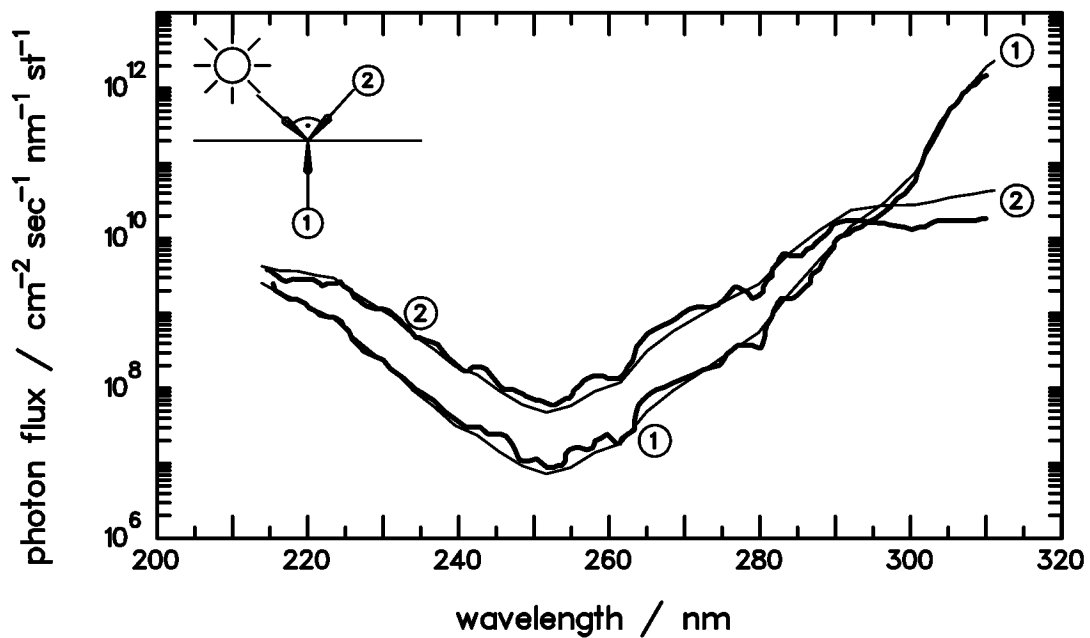


Figure 19b : Comparison of the modeled flux (thin lines) and the measurements (full lines) of Herman and Mentall (1983) for two different viewing angles, the nadir position (1) and the observation perpendicular to the sunlight (2).

set to 10%, a value appropriate for globally averaged reflection if no other indications are given. Test runs showed that the influence of the surface albedo on the data at 40 km given by Herman and Mentall is minimal.

The results of our simulations are presented in Figure 19a for the direct solar flux and in Figure 19b for the diffuse light. As the spectral resolution of the model was lower than that of the experimental devices the fine structure of the measurements is not represented, but the agreement between the model calculation and the experiment is satisfactory for the direct solar flux and for the light observed in the nadir position. For the direction perpendicular to the sun there is a discrepancy between the calculated and the measured downwards directed light at wavelengths above 300 nm. The model overestimates the radiation increasingly with the wavelength. An explanation for this discrepancy may lie in the fact that the model averages over all azimuth angles whereas the radiometer pointed into the direction with the lowest irradiance at a given zenith angle.

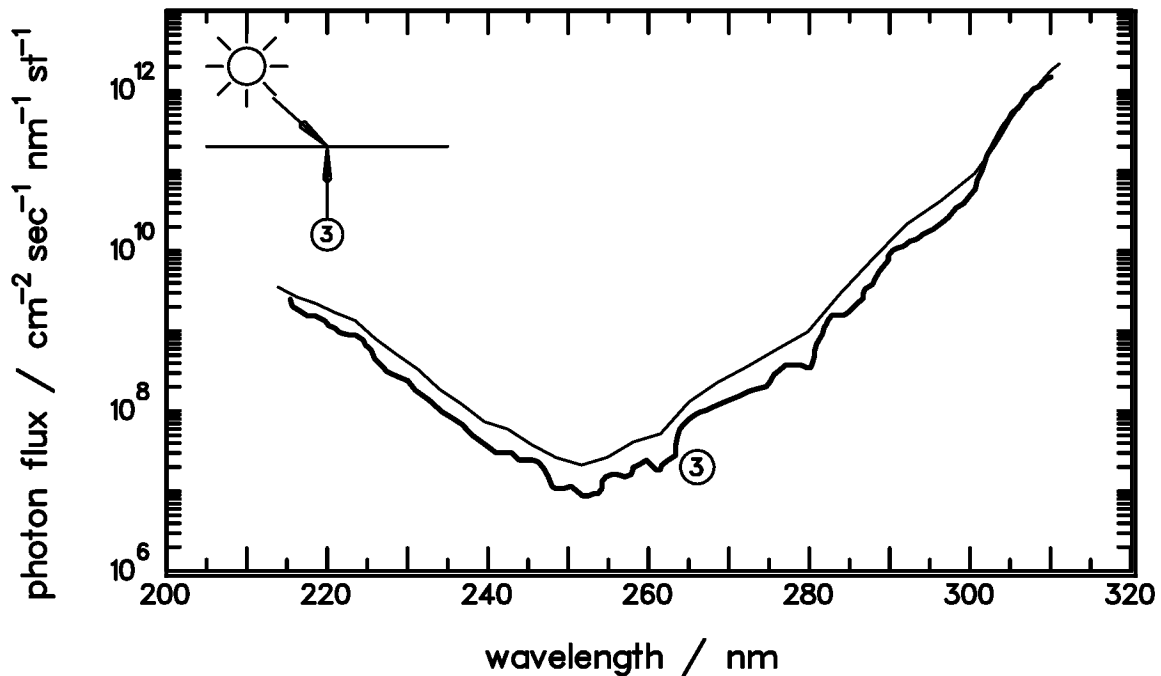


Figure 19c : Comparison of the modeled flux (thin line) and the observations (full line) by Herman and Mentall (1983) for the nadir position. In contrast to Figure 19b the measured ozone concentration profile was replaced by a globally averaged profile with the same ozone column density.

For a correct simulation of the radiative transfer through the atmosphere it is absolutely necessary that the shape of the ozone concentration profile is known. This is demonstrated in Figure 19c. In this figure the result of a calculation for the nadir positioned device is depicted in which the globally averaged ozone concentration of the US Standard Atmosphere 1976 was used instead of the observed ones. Despite the fact that the total ozone column density was the same in both calculations (the Standard Atmosphere profile was multiplied by a constant factor to achieve this) the solar flux at 250 nm is now off by a factor of 2 compared to the measurements.

In the whole it could be shown by these simulations that the model is well able to determine the photon fluxes in the stratosphere above the ozone layer for the direct solar flux as well as for the upwards and downwards directed diffuse light. The comparison of the model results to the data of Herman and Mentall was especially valuable for testing the angular distribution of the actinic flux calculated with our model ART. Beside the cases discussed here, the model was equally able to simulate the data for the observations at other viewing angles.

Comparison to actinometer measurements

Whereas the cloud cover plays only an insignificant role for the photon flux between 200 and 300 nm at 40 km altitude, the density of the clouds above and below the location of an experiment is essential for the simulation of photolysis rates in the troposphere. Clouds below the experiments site increase the amount of photons available and, thereby, the photolysis rate, while higher clouds in most cases diminish the photon flux. These conditions can be studied by a comparison of our model with the observations of Shetter et al. (1992) during the Mauna Loa Observatory Photochemistry Experiment.

For the simulations of these measurements the following conditions were applied: The extraterrestrial solar flux and the O₂- and O₃- absorption spectra were taken

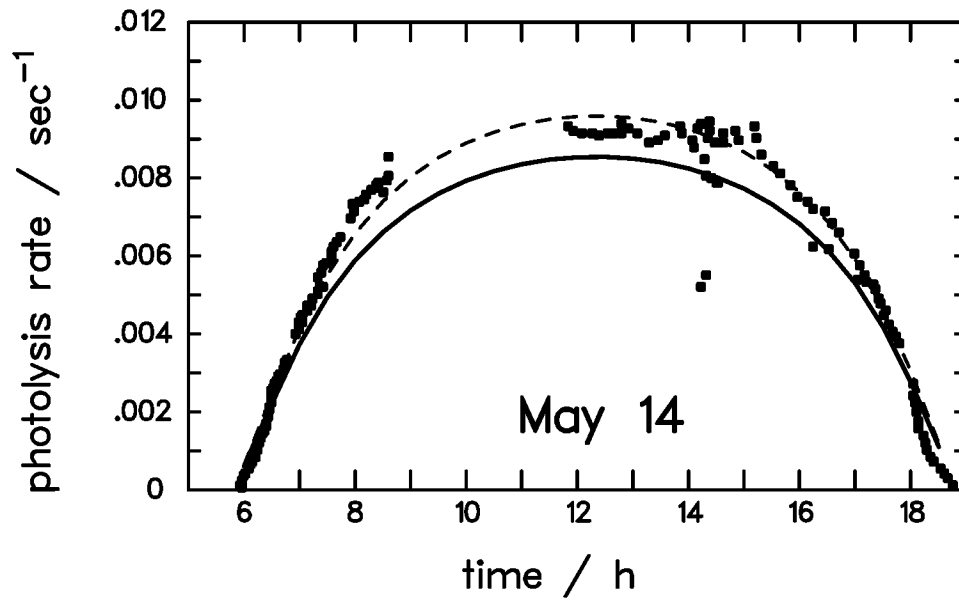


Figure 20a : Simulation of the photolysis rate of NO_2 for a translucent cloud below the observation site (thin line) and for clear sky conditions (bold). The full dots are the measured photolysis frequency by Shetter et al. (1992).

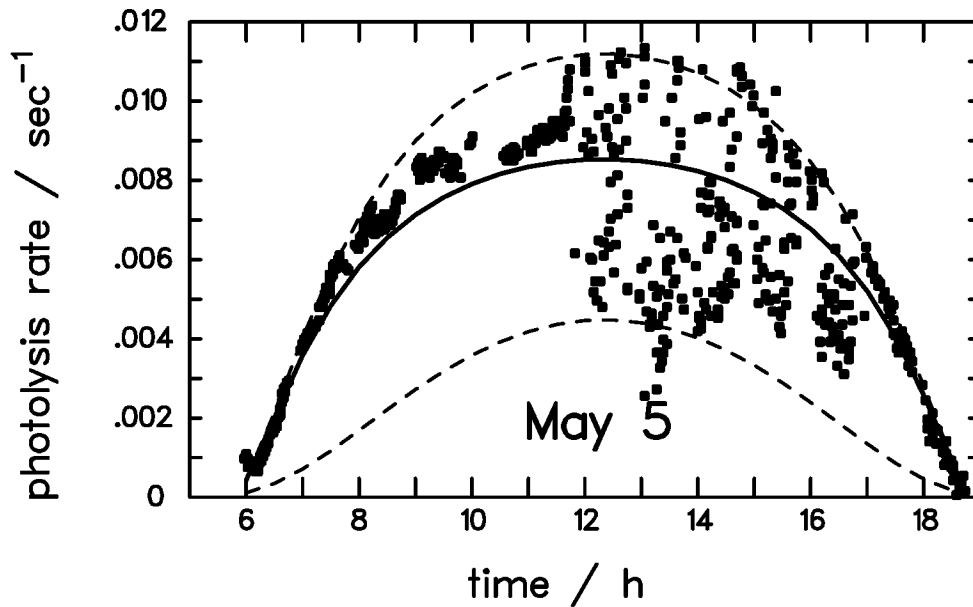


Figure 20b : Simulation of the measured photolysis frequency of NO_2 for a) a dense cloud above the location of the experiment, and b) a dense cloud below the observation site. The full line represents the model result for clear sky conditions and the dots the measurements by Shetter et al. (1992).

from the WMO Report 16 (1985). The atmospheric pressure and temperature profiles were those from the US Air Force Standard Atmosphere (Cole and Kantor, 1978) for 15° N and May. The data for a marine air aerosol from the WMO Report 24 (1986) were used to create an aerosol profile typical for Moana Loa. For the ozone profile the data given by Dütsch (1971) for 20° and spring were multiplied by a constant factor and, thereby, shifted to the appropriate ozone column density of the day under consideration, given by Shetter et al. (1992). The albedo of 2% measured by the authors is obviously the albedo of the surroundings of the experimental set up. As the diffuse radiation from above is mainly governed by light reflected far away from this location, we chose an albedo of 8% which is typical for the reflection on ocean surfaces (Volz-Thomas et al., 1996). The local albedo had only a minimal influence on the measurements as the actinometers were exposed only to the light coming from the upper hemisphere.

With these data the clear sky observations of the NO₂-photolysis rate could be simulated quite well. As an example the simulations for May 14th and May 5th in 1988 are presented in the Figures 20 a and b, respectively. For the zenith angle dependence of the photolysis rate the Equation 35 was applied.

The scatter of the measurements during early morning and in the afternoon on May 14th can be explained by very translucent clouds. The bold lower curve in Figure 20a was calculated for clear sky conditions. The upper curve represents an extended cloud between 1 and 2 km, i.e. below the site of the experiment, with an effective droplet radius of .05 µm and 50 droplets/cm³. It should be pointed out, however, that the calculations including clouds are rather sensitivity studies than simulations of the actual situation, as the cloud parameters for an exact calculation, e.g. cloud height, number density and absorption cross section of the droplets, etc., were not given in the publication.

For the simulations for May 5th the best agreement was achieved if a much more dense cloud cover was taken into account. The curve for the diminished photon flux in Figure 20b was calculated for a homogeneously distributed cloud between 4 and 5 km altitude. The upper curve in Figure 20b represents calculations with a cloud cover between 2 and 3 km. For both lines the effective droplet radius was 2 µm and the average density of the droplets was set to 100 particles/cm³.

Despite the fact that the simulated values seem to represent the observations sufficiently well, it should be mentioned that the calculations could only stand for a totally covered sky. A broken coverage with clouds approximately at the height of the experiment might increase the photolysis rate by reflections of the sunlight at the sides of the clouds. This might be another explanation for the increase of the radiation after the appearance of clouds on May 5th, but such simulations are beyond the possibilities of the model presented. Nevertheless, it can be stated that the model is a powerful tool for the calculation of the radiative transfer and the determination of photolysis frequencies.

Filter radiometer measurements aboard a balloon

During the EASOE campaign (European Arctic Stratospheric Ozone Experiment) in the winter 1991/92 altogether 43 research balloons were launched at the Swedish research base Esrange close to Kiruna in Northern Sweden. Several of the payloads carried filter radiometer operated by the Institute for Stratospheric Research of the Research Center Jülich. These radiometer are described in detail by Junkermann et al. (1989) and Müller (1994). They collect the light from a 2π sr geometry in order to represent photolysis rates rather than energy fluxes.

For the validation of the model ART we chose the flight of March 20, 1992, where a set of 4 radiometers were launched piggy back onto grab samplers for stable atmospheric compounds. Two of the devices pointed downwards, two others upwards. Out of each pair one instrument was sensitive to the UV-A and the other to the UV-B regime of the solar spectrum. The spectral sensitivity of the radiometers as well as the absolute one were calibrated before and after the experiment. These sensitivity curves were inserted in Equation 37 instead of the absorption cross section to simulate the radiometer signals.

The flight altitude is depicted in Figure 21a together with the solar zenith angle for the payload. The balloon was launched at 10.24 h Universal Time at 67.9°N and 21.0°E, i.e. at 11.48 h local time. Therefore, the solar zenith angle increases constantly during the flight time.

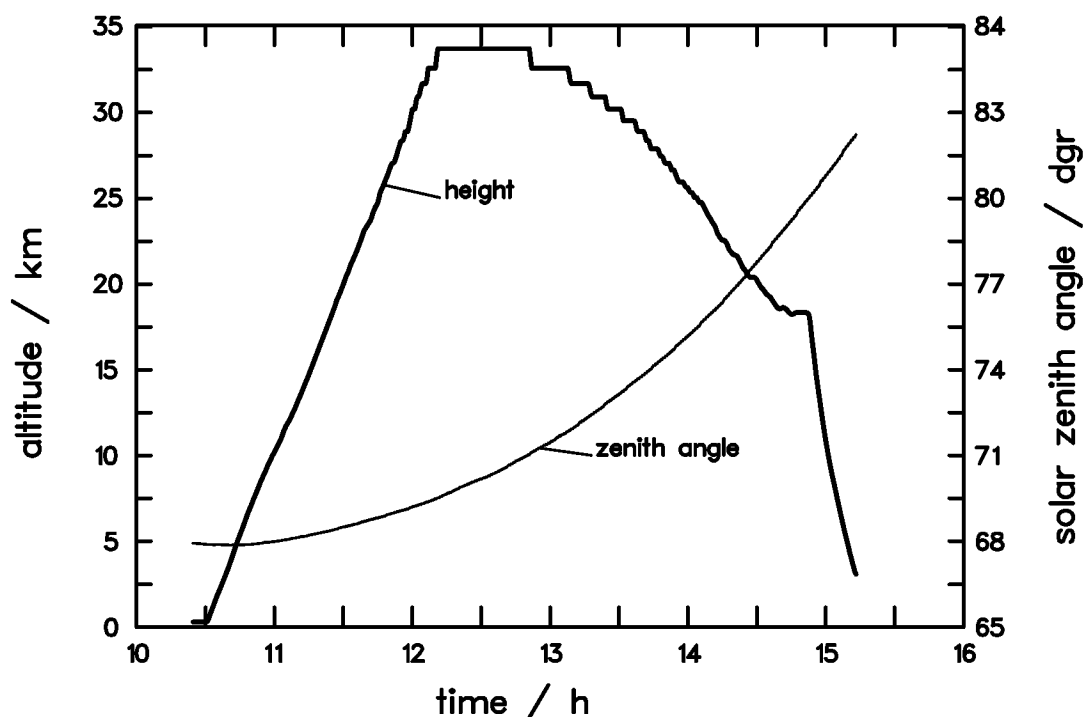


Figure 21a : Flight altitude and solar zenith angle of the balloon flight on March 20, 1992, versus Universal Time. The balloon was launched at Esrang in Northern Sweden.

The calculation of the actinic fluxes were done for clear sky conditions with an ozone profile measured on the same day at Esrang. The temperature had to be taken from a radiosonde launched at Ny-Aalesund in Norway on March 20, 1992, too. For the aerosol profile the stratosphere data from the WMO Report No. 24 (1986) were applied alongside with a clear troposphere. The surface albedo was set to an estimated value of 35% as the country side was covered with snow, but in the forests the snow was blown from the trees and the rocky mountains were only partly snow covered. Beside these data no other adjustments were used to simulate the radiometer measurements.

The simulations of the radiometer signals in the UV-A region are presented in Figure 21b. Just after the launch the diffuse light was brighter than calculated due to the higher local albedo. But otherwise the agreement between measured and modeled radiometer signals is excellent. The fact that the model ART overestimates the upwards directed photon flux can be explained by a lower albedo above the forests of Northern Scandinavia.

In the UV-B region the agreement is equally good (see Figure 21c). The UV-B radiometers were sensitive around 300 nm, with a interval width at half maximum

of 20 nm. Therefore, within the troposphere the signal is very low. But when the ozone maximum is reached, the UV-B edge moves through the sensitivity range of the radiometers, causing a steep increase of the signal. This crucial experiment could be simulated quite well.

The upwards directed light is very weak in the UV-B regime, but nevertheless also in this case the model represents the measurements accurately. The large deviations to higher signals in the lower curve in Figure 21c are caused by direct light from the sun. Due to the high solar zenith angles and the swinging of the payload, the downwards pointing instrument sometimes received radiation directly from the sun. Hence, only the lower envelope of the measurements represents the diffuse light and is simulated by the calculations.

Altogether, it can be stated that the model ART is well able to determine photolysis rates and radiometer measurements for solar zenith angles below 85° within the stratosphere and the troposphere. This was verified in all simulations of photon flux measurements up to now. We might have to make the restriction to solar zenith angles below 85° , as the agreement between measurements above 90° zenith angle and the respective simulations become poor. But the discrepancies might be equally explained by errors in the model and of the measurements, as the signals are then close to the detection limit of the devices.

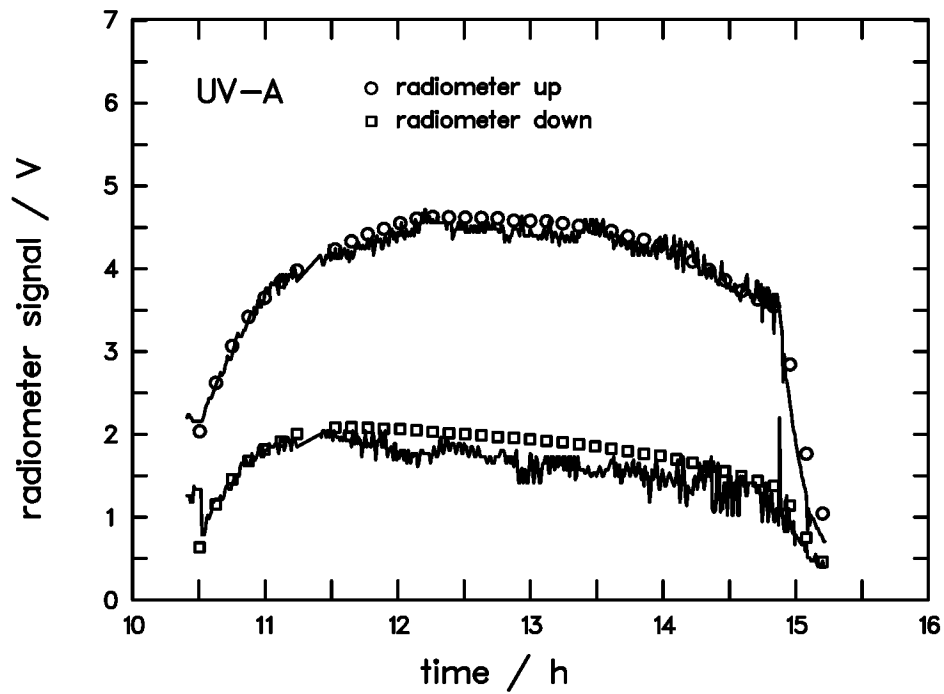


Figure 21b : Measured (lines) and simulated (symbols) radiometer measurements in the UV-A region of the solar spectrum during the flight of Figure 21a.

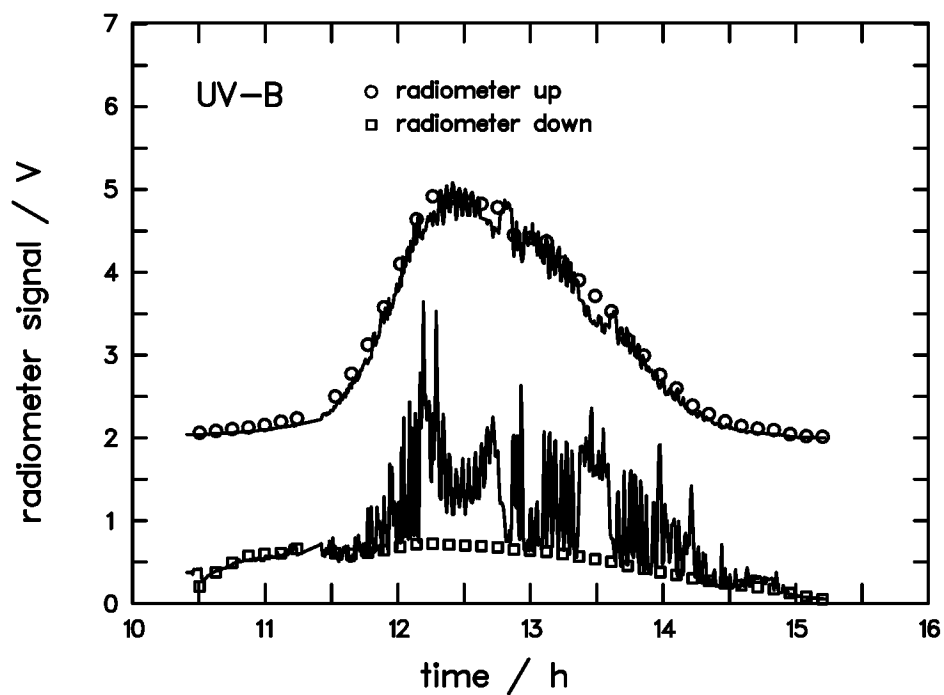


Figure 21c : Same as in Figure 21b, but for the UV-B regime. The curve for the upwards pointing radiometer has an offset of 2 V.

Concluding Remarks

For the interpretation of the measurements of atmospheric constituents, especially of radical concentrations, knowledge about photodissociation rates is required. In most cases measuring photolysis frequencies directly is either difficult or not possible at all. Therefore, a combination of radiometer measurements and radiation transfer modeling might be a reasonable substitute for the direct observation of these quantities. The agreement between the results of the ART model and the observations provides confidence that the photolysis rate coefficients determined with the model are sufficiently accurate for use in photochemical models of the troposphere and stratosphere. The ART model not only gives the observed total flux but also accounts correctly for the different components of the overall flux separately.

For most cases the simulations are consistent within a 10% limit with the measurements. This agreement holds for various conditions, e.g. different ozone column abundance, for solar zenith angles from 70° to 85° or even larger, for stratospheric altitudes up to 40 km and for both, the direct and the diffuse radiation. Most of the discrepancies can be explained by features not included in the present work, e.g. the influence of a broken cloud coverage. Partial cloudiness will result in a non-linear relationship between coverage and actinic flux, due to the reflections at the sides of the clouds. As partial cloudiness is the most common case during the measurements, a parametrization scheme will be developed in the near future to allow for the correct determination of the photodissociation frequencies for these cases, too.

Acknowledgment

The development of the model was sponsored in part by the German “Minister für Forschung und Technologie” under contract No. 01LO 9105/5. The development of the different photon flux models started in 1985 when I was a visiting scientist to the National Center for Atmospheric Research in Boulder, USA. The hospitality of the Atmospheric Chemistry Division of NCAR during later several stays in Boulder is gratefully acknowledged. Likewise, valuable discussions with many colleagues, especially R. Chatfield and S. Madronich from NCAR, Boulder, and C. Schiller and A. Hofzumahaus from FZ - Jülich are appreciated. My former coworkers H. London, St. Huber-Thives, S. Johanning, and M. Wegmann helped to build up the source code of the model and I am very thankful for their engagement.

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Appendix A

Documentation of the Program **FLUXSTRT**

S.Johänning

1996

The program FLUXSTRT was developed only for use within the Institute for Atmospheric Chemistry. It is implemented especially on the computers of the Research Center Jülich. Therefore, this documentation is not translated. The main features of this program are described in the chapter on the use of the model.

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Einleitung

FLUX ist ein Programmpaket zur Berechnung von Photonenflüssen. Es läuft auf der CRAY Y-MP M94/4 256 im Batchbetrieb. Damit der Benutzer möglichst bequem den Ablauf von FLUX steuern kann, wurde ein interaktives Rahmenprogramm FLUXSTRT entwickelt. Das Programm FLUXSTRT ist auf dem Foreground-Rechner IBM ES/9000 Modell 620 zur Cray implementiert. Um dieses Rahmenprogramm zu starten, wurde zusätzlich eine Batchdatei FLUX EXEC geschrieben.

FLUXSTRT gliedert sich in zwei Abschnitte:

(1) Das Einbinden von Parametern zur Ablaufsteuerung in FLUX :

Durch interaktive Fragen wird eine Datei WERTE FORTRAN A angelegt. Diese enthält die für den Ablauf von FLUX notwendigen Steuerparameter in FORTRAN-Notation. WERTE FORTRAN A wird in den FORTRAN-Quelltext von FLUX eingebunden und gemeinsam mit dem übrigen Quelltext compiliert.

2) Das Zusammenstellen der Eingabedaten :

In FLUXSTRT wird eine Datei DATASET DATEN A erstellt, die alle benötigten Eingabedaten enthält. Dem Benutzer stehen dabei drei Möglichkeiten zur Verfügung, DATASET DATEN A aus einzelnen Datensätzen zusammenzustellen :

- (a) Die Datei DATASET DATEN A wird aus Einzeldatensätzen zusammengesetzt. Hierbei wird dem Benutzer jeweils eine Defaultdatei angeboten.
- (b) Die Datei DATASET DATEN A wird aus einem Satz beliebiger Dateien zusammengesetzt.
- (c) Die Datei DATASET DATEN A wird von einer Standarddatei übernommen. Die Standarddatei kann aus einer vorgegebenen Liste ausgewählt werden.

Voraussetzungen an Hard- und Software

Rechnerumgebung: FLUXSTRT wurde auf einer IBM ES/9000 Modell 620 unter dem Betriebssystem VM/ESA mit CMS und dem Compiler VS FORTRAN V2 entwickelt und implementiert. Der Batchjob FLUX läuft zur Zeit auf einer CRAY Y-MP M94/4 256 unter dem Betriebssystem UNICOS und dem Compilersystem FORTRAN CF77.

Zugehörige Programme: FLUX EXEC
FLUXSTRT FORTRAN
FLUX CRAY (mit Unterprogrammen)

Aufruf des Programms

FLUX ist für den allgemeinen Gebrauch nur unter der UserID ICH305 verfügbar. Um zu gewährleisten, daß jeweils nur die neueste Version verwendet wird, sollten die Programme nicht auf andere UserIDs übertragen werden !

Bitte wenden Sie sich vor der ersten Benutzung an Herrn Röth.

Das Programmpaket wird gestartet durch Aufruf von :

FLUX

Danach läuft ein Batchjob FLUX ab, der das Rahmenprogramm FLUXSTRT aufruft. Dieses wiederum ruft das eigentliche, auf der CRAY laufende, Rechenprogramm FLUX auf.

Einbinden der Parameter zur Ablaufsteuerung

Die Steuerungsparameter werden mittels interaktiver Abfragen gesetzt und in FORTRAN-Syntax in der Datei WERTE FORTRAN A gespeichert. Diese Datei wird mittels der INCLUDE-Anweisung in den Quelltext des FORTRAN-Programms eingebunden und kompiliert.

Ein Beispiel für die Datei WERTE FORTRAN A finden Sie im Kapitel Beispieldurchlauf.

Das folgende Struktogramm verdeutlicht die Erstellung von der Datei WERTE FORTRAN A:

PROCEDURE specw

Choose type of calculation: 1: For a given location, date and time, 2: For a given solar zenith angle at 0 km, 3: A loop over several rays to get a zenith angle dependency			
			calculation type
1	2	3	sonst
Input of latitude	Input of ground zenith angle in degree	Loop starts at -10	
Input of date DD.MM		Input of loop—ende	
Input of time HH.SS			
Input of surface temerature if wanted			
Specification of the ground albedo			
Change of column density if wanted			
Choose method of calculation: 1: by FLUXES (exact but timeconsuming), 2: by FLUX3B (fast, but only reasonable)			
Decrease of wavelength regime if wanted			
Create a list of the actinic flux on the printer (Y/N)?			
ja			single line calculation
			nein
Create a plot for the altitudinal dependencies on the printer (Y/N)?			
Calculate the photodissociation rates (Y/N)?			
ja			calculation of photodissociation rates
			nein
ja		calculation type 1 or 2	
		nein	
Plot of altitudinal dependencies (Y/N)?		Plot of the zenith angle dependencies (Y/N)?	
		plot of zenith angle dependencies	
		ja	
		nein	
		Input of altitude for plot	
		Condensed output of photodissociation coefficients (Y/N)?	
		Input of altitudinal step for photodissociation output	

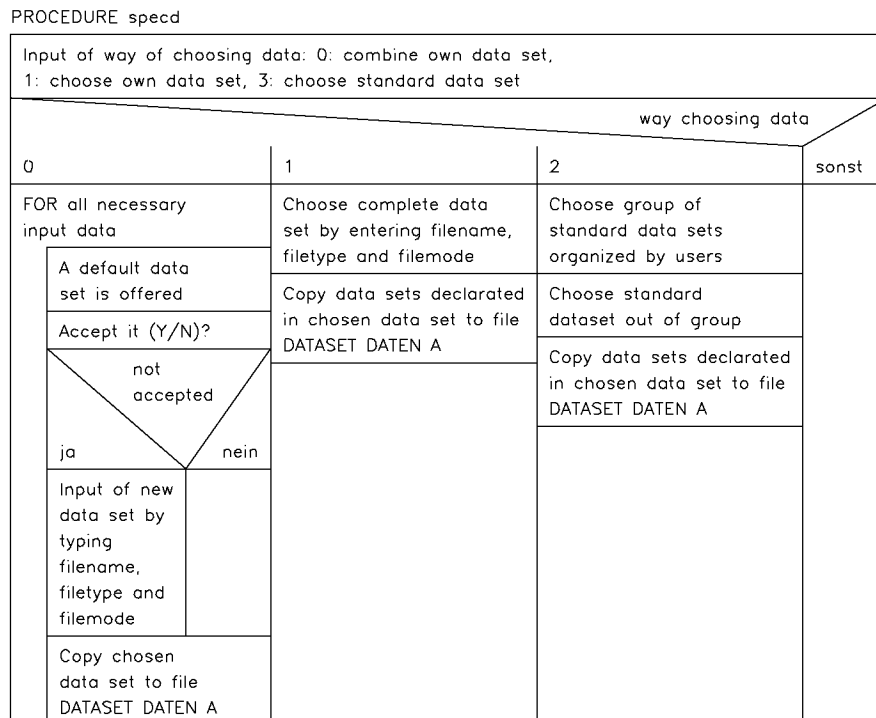
Zusammenstellen der Eingabedaten

Die Eingabedaten werden interaktiv zusammengestellt und in einer Datei DATASET DATEN A gespeichert. Diese wird mit Hilfe der INCLUDE-Anweisung in die Batchdatei eingebunden, von wo aus sie dem Programm FLUX zur Verfügung steht.

Es gibt mehrere Möglichkeiten DATASET DATEN A zusammenzustellen :

- (a) Die Datei DATASET DATEN A wird aus Einzeldatensätzen zusammengesetzt. Hierbei wird dem Benutzer jeweils eine Defaultdatei angeboten.
- (b) Die Datei DATASET DATEN A wird gemäß einer beliebigen Datei zusammengesetzt. Diese Datei wird durch Angabe von
Filename Filetyp Filemode
ausgewählt.
- (c) Die Datei DATASET DATEN A wird gemäß einer Standarddatei zusammengesetzt. Diese Datei wird durch Angabe der ihr zugeordneten Nummer aus einer vorgegebenen Liste ausgewählt.

Das folgende Struktogramm verdeutlicht die Zusammenstellung von DATASET DATEN A :



Unter der UserID ICH305 stehen dem Benutzer Datensätze zum Erstellen von DATASET DATEN A auf der E-Platte zur Verfügung. Eine Übersicht über die vorhandenen Daten erhalten Sie bei Herrn Röth.

Ein Beispiel für die Datei DATASET DATEN A finden Sie in der Beschreibung des Hauptprogramms FLUX.

Beispiel für eine Datei mit Eingabedaten. In ihr werden die Namen der Einzeldateien angegeben, die nach DATASET DATEN A kopiert werden sollen. :

```
* Dies ist ein Beispiel fuer einen Standard-Datensatz zum Job FLUX.
* Ein * in der 1. Spalte kennzeichnet einen Kommentar.
* Die einzelnen Datensatze werden durch Filename, -typ und -mode
* angegeben.
* Ab der 22. Spalte koennen weitere Kommentare angefuegt werden.
* Diese benoetigen kein *.
AIR STANDARD E      Air concentration profile
NO2 STANDARD E      NO2 concentration profile
O3 STANDARD E       O3 concentration profile
AEROSOL STANDARD E
AEROSOL STANDARD E
CLOUD STANDARD E
CLOUD STANDARD E
WAVE DATA E
TEMP STANDARD E     Temperature profile
FLUX DATEN E
ABSORPT SPECTRA E   Absorption spectra
* Photolyses spectra
O2      ROETH      E
O3-1D   ROETH      E
O3-3P   ROETH      E
NO       ROETH      E
NO2      ROETH      E
NO3-NO2  ROETH      E
NO3-NO   ROETH      E
N2O      ROETH      E
N2O5     ROETH      E
NH3      ROETH      E
H2O      ROETH      E
H2O2     ROETH      E
COS       ROETH      E
HNO3     ROETH      E
SO2       ROETH      E
CLO       ROETH      E
HCL       ROETH      E
CO2       ROETH      E
CH2O-H    ROETH      E
CH2O-H2   ROETH      E
CF2CL2    ROETH      E
CFCL3     ROETH      E
CCL4      ROETH      E
CH3CL     ROETH      E
CLNO3     ROETH      E
HO2       ROETH      E
HOCL-OH   ROETH      E
HOCL-HCL  ROETH      E
CL2       ROETH      E
CH3O2     ROETH      E
HNO2-NO2  ROETH      E
HNO2-NO   ROETH      E
HO2NO2    ROETH      E
CS2       ROETH      E
CH2CCL3   ROETH      E
F113      ROETH      E
CH3OOH    ROETH      E
```

Beispiel für ein Protokoll zum Programm FLUXSTRT :

Ready: ... flux
Program FLUX Version:18.09.1991, by S.Johaenning This program calculates the actinic flux of photons through the earth atmosphere, starting at 100km altitude. If desired, it also calculates the photodissociation rates of up to 70 species. To continue hit the ENTER-key, otherwise press 'q'
F L U X S T R T Version 2.2 vom 20.04.1994 WERTE FORTRAN A does not exist DATASET DATEN A does not exist Please choose one of the following points: W: (Re)Specify steering parameters (WERTE FORTRAN) D: (Re)Specify input data set S: Start CRAY-Job FLUX or quit w

Erläuterungen zum Protokoll vom Programm FLUXSTRT :

Das Programm FLUXSTRT wird durch den Aufruf FLUX gestartet.
Zunächst erscheint ein Programmkopf auf dem Bildschirm, der kurz erklärt, was das Photonenflußprogramm berechnet. An dieser Stelle besteht die Möglichkeit FLUXSTRT zu beenden.
Nach Drücken der <ENTER>-Taste gelangt man in das Hauptmenü. Hier wird angezeigt, ob die beiden Dateien WERTE FORTRAN A und DATASET DATEN A existieren. Das ist normalerweise der Fall, da die beiden Dateien nach dem Durchlauf von FLUX nicht gelöscht werden. Dem Benutzer stehen drei Menüpunkte zur Auswahl: Gibt er ein 'W' ein, so kann er interaktiv die Parameter zur Ablaufsteuerung von FLUX bestimmen. Durch die Eingabe von 'D' kann er die Eingabedaten zusammenstellen. Mit Eingabe von 'S' wird FLUXSTRT beendet und, wenn gewünscht, der Job FLUX auf der CRAY gestartet. Zunächst sollen die Ablaufparameter in WERTE FORTRAN A zusammengestellt werden, d.h. es ist ein 'W' einzugeben.

Beispiel für ein Protokoll zum Programm FLUXSTRT :

Now you have to specify the steering parameters for the Cray-job FLUX

Choose type of calculation:

1: For a given location, date and time

2: For a given solar zenith angle (default)

3: A loop over several rays to get a zenith angle dependence

Now give a number of your choice:

?

3

Specify the following data:

Loop-start is always -10

Loop-end (default= 9):

?

Do you want to specify the surface temperature?

1: yes, else: no

?

The ground albedo has to be specified.

A typical global average is 0.16.

Which (absolute) value do you want? (NO DEFAULT)

?

0.16

The O3 column density will be calculated from the input profile.

If you want a different density, press 1.

Then the profile will be shifted by a constant factor to match your choice.

?

Erläuterungen zum Protokoll vom Programm FLUXSTRT :

In diesem Beispiel soll FLUX mit Rechnungstyp 3 laufen, um eine Zenitwinkelabhängigkeit zu erhalten.

Dafür läuft eine Schleife über mehrere Strahlen. Der Beginn ist bei Strahl -10 festgelegt, das Ende kann der Benutzer festsetzen. Als Default wird Strahl 9 angegeben. Näheres zur Nummerierung der Strahlen erfahren Sie aus der Dokumentation zu FLUX.

An dieser Stelle kann man die Temperatur an der Erdoberfläche bestimmen. Will man das nicht, so wird der in der Datei TEMPERATUR festgesetzte Wert angenommen.

Anschließend muß die gewünschte Bodenalbedo eingegeben werden. Hier existiert kein Defaultwert. Wie auch an den anderen Stellen, wo kein Defaultwert existiert, fragt das Programm den Benutzer so lange nach dem Wert, bis er eingegeben wurde.

Die O₃-Säulendichte wird standardmäßig aus dem Eingabeprofil berechnet. Will man einen anderen Wert annehmen, so kann er an dieser Stelle eingegeben werden.

Beispiel für ein Protokoll zum Programm FLUXSTRT :

You can choose between 2 methodes to calculate the photon flux: 1) by subroutine FLUXES (exact, but timeconsuming) 2) by subroutine FLUX3B (fast, but only reasonable) Give your choice now (FLUXES is the default): ? The wavelength regime is form 185nm to 730nm. Do you want to decrease the wavelength regime? Answer: 1: yes, else: no ? Wavelength in nm for the starting point? ? 300 Wavelength in nm for the endpoint? ? 350	
Now select the kind of output: The following outputs are provided: A list of actinic flux on the printer (1: yes, else: no) ? 1	
Now you may choose whether or not you want to calculate the photodissociation rates: Answer: 0:no, else: yes ? The photodissociation rates will be printed in any case. Do you want a plot of the zenith angle dependences, too? Answer: 1: yes, else: no ? 1 For which altitude do you want the zenith angle dependences? (Give the altitude in km, default is 0 km) ?	

Erläuterungen zum Protokoll vom Programm FLUXSTRT :

Es existieren zwei Unterprogramme zur Berechnung der Photonenflüsse. Das eine berechnet genau, ist daher auch zeitaufwendig, das zweite rechnet schneller, aber mit ungenaueren Ergebnissen. Als Default wird das genauere Unterprogramm vorgeschlagen. Der Wellenlängenbereich reicht von 185nm bis 730nm. Man kann ihn jedoch einschränken. In diesem Beispiel wurde ein Wellenlängenbereich von 300nm bis 350nm gewählt.	
Im folgenden soll die Art der Ausgabe bestimmt werden. Zunächst wird gefragt, ob man eine Liste der aktinischen Flüsse haben möchte.	
Die nächsten Abfragen betreffen die Photodissoziationsraten. Sollen sie berechnet werden und wenn ja, möchte man einen Plot der Zenitwinkelabhängigkeiten haben? In diesem Fall ist zusätzlich die Höhe in km einzugeben, für die der Plot erstellt werden soll. Default ist 0km.	

Beispiel für ein Protokoll zum Programm FLUXSTRT :

Do you want a seperate output of the photodissociation coefficients in a condensed form? 1: Yes, Else: no ? 1 Now you shall select the altitudinal step for the photodissociation output. The start is always at ground level. (default is 1km) ?	
F L U X S T R T Version 2.2 vom 20.04.1994 WERTE FORTRAN A exists DATASET DATEN A does not exist Please choose one of the following points: W: (Re)Specify steering parameters (WERTE FORTRAN) D: (Re)Specify input data set S: Start CRAY-Job FLUX or quit d	

Erläuterungen zum Protokoll vom Programm FLUXSTRT :

Es besteht die Möglichkeit, eine komprimierte Ausgabe der Photodissoziationskoeffizienten mit einer bestimmten Höhenschrittweite zu erhalten. Diese Art der Ausgabe dient i.a. der weiteren Verarbeitung durch andere Programme. An dieser Stelle sei auch auf das Programm FLUXZCHN verwiesen, welches diese Ausgabedatei in das ZEICHN-Format umsetzt.	
Nun sind alle Parameter für den Lauf von FLUX festgelegt und man kommt zurück in das Hauptmenü. Als nächstes sollen die Eingabedaten zusammengestellt werden. Deshalb wird ein 'D' angegeben.	

Beispiel für ein Protokoll zum Programm FLUXSTRT :

Now you have to specify the input data sets. We offer you some standard data sets, but you can also combine your own. Please choose one of the following numbers: 0 : Combine your own data set (Default) 1 : Choose your own data set: name type disk 2 : Choose a standard data set ? 0	
You now have to combine your own data set We offer you a standard version, which you may alter. If you want another data set than offered press 1, else return. Specify your dataset as follows: name type disk Air concentration profile: AIR STANDARD E Do you want another data set? ? Data set does not exist: Specify another data set (FN FM FT) : air 001 e NO2 concentration profile: NO2 STANDARD E Do you want another data set? ? O3 concentration profile : O3 STANDARD E Do you want another data set? ?	

Erläuterungen zum Protokoll vom Programm FLUXSTRT :

Nun wird gefragt, auf welche Art man die Eingabedaten zusammenstellen will. Wie schon oben gesagt, gibt es drei Möglichkeiten: (a) Die Datei DATASET DATEN A wird aus Einzeldateien zusammengesetzt. Hierbei wird dem Benutzer jeweils eine Defaultdatei angeboten. (b) Die Datei DATASET DATEN A wird gemäß einer beliebigen Datei zusammengesetzt. (c) Die Datei DATASET DATEN A wird gemäß einer Standarddatei zusammengesetzt. Die Standarddatei kann aus einer vorgegebenen Liste ausgewählt werden. In diesem Beispiel wurde 0 eingegeben um sich den Datensatz interaktiv zusammenzustellen.	
Im folgenden werden der Reihe nach die einzelnen benötigten Daten abgefragt und jeweils den Default-Datensatz angeboten.	

Beispiel für ein Protokoll zum Programm FLUXSTRT :

Aerosol concentration 1 : AEROSOL STANDARD E Do you want another data set? ? Aerosol concentration 2 : AEROSOL NULL E Do you want another data set? ? Cloud concentration 1 : CLOUD STANDARD E Do you want another data set? ? Data set does not exist: Specify another data set (FN FM FT) : cloud null e Cloud concentration 2 : CLOUD NULL E Do you want another data set? ?	
Temperature profile : TEMP STANDARD E Do you want another data set? ? 1 Specify your data set (fn ft fm) temp 001 e Extraterristic photonflux : FLUX DATEN E Do you want another data set? ? 1 Specify your data set (fn ft fm) flux wmo e Absorption spectra : ABSORPT SPECTRA E Do you want another data set? ? 1 Specify your data set (fn ft fm) absorp datanew e Photolyses spectra : PHOTODIS STANDARD E Do you want another data set? ? 1 Specify your data set (fn ft fm) photo diss e	

Erläuterungen zum Protokoll vom Programm FLUXSTRT :

Beispiel für ein Protokoll zum Programm FLUXSTRT :

F L U X S T R T Version 2.2 vom 20.04.1994 WERTE FORTRAN A exists DATASET DATEN A exists Please choose one of the following points: W: (Re)Specify steering parameters (WERTE FORTRAN) D: (Re)Specify input data set S: Start CRAY-Job FLUX or quit s Now all input data are specified and you may start the program by pressing the ENTER-key, otherwise type 'q'. The output files will be sent to your reader list: The printer output is on file FLUXOUT OUTPUT. The plotter output is on file FLUXPLT CARDS. The file PHOTWAT OUTPUT is a compressed list of the altitudinal and zenith angle dependencies of the photodissociation rates. The listing of the program itself will be found on file FLUX LISTING The protocol of the run will be found on file FLUX_Sxx OUTPUT For further handling of these datafiles see the ZAM-manuals Press ENTER to continue. Starting ... Job staged to the Cray Ready; ...	
--	--

Erläuterungen zum Protokoll vom Programm FLUXSTRT :

Nachdem alle Daten gewählt sind, gelangt man wieder in das Hauptmenü. Nun kann FLUX gestartet werden. Dazu wird 'S' ausgewählt.	
An dieser Stelle hat man die Gelegenheit FLUXSTRT zu beenden. Durch Eingabe von 'O' verläßt man FLUXSTRT ohne FLUX zu starten, andernfalls drückt man nur die <ENTER>-Taste. Bevor FLUX gestartet wird, erhält man noch eine Übersicht über die Ausgabedateien.	

Appendix B

Source Codes of Model ART and FLUXSTART

Source Code ART

```

# QSUB -r FLUX
# QSUB -lT 1500
# QSUB -lM 8Mw
# QSUB -q high
# QSUB
#
rm -f errors listing
cat > flux.f << 'EOFPROG'
C
C
C      PROGRAM          FLUX
C      =====
C                               last changes : 23.12.93
C
C +-----+
C I
C I PURPOSE: CALCULATION OF PHOTON FLUXES THROUGH THE ATMOSPHERE
C I INCLUDING RAYLEIGH, AEROSOL, AND CLOUD SCATTERING.
C I THE WAVELENGTH REGION IS 185 TO 750 NM.
C I
C I INPUT:  M: AIR DENSITY
C I          O2: OXYGEN CONCENTRATION
C I          O3: OZONE CONCENTRATION
C I          NO2: NO2 CONCENTRATION
C I          AER1,AER2: AEROSOLE DENSITY
C I          CLW1,CLW2: DENSITY OF CLOUD DROPLETS
C I          ABSS: ABSORPTION SPECTRA FOR 1: O2
C I                                         2: O3
C I                                         3: NO2
C I                                         4: RAYLEIGH SCATTERING
C I                                         5: AEROSOL 1  "
C I                                         6: AEROSOL 2  "
C I                                         7: CLOUD 1   "
C I                                         8: CLOUD 2   "
C I          WAVE: WAVELENGTH IN nm
C I          FLUSS: SOLAR FLUX
C I          ZENIT: SOLAR ZENITH ANGLE
C I          BALB: GROUND ALBEDO
C +-----+
C
C DECLARATIONS
C =====
C
C PARAMETER (IUN=9,INC=15,NP=150)
C
C REAL SIGT (0:99),  TAUT (0:99),  Z (0:99),  TEQ (0:99),
.  AER1 (0:99),  AER2 (0:99),  CLW1 (0:99),  CLW2 (0:99),
.  AEEQ1 (0:99),  CLEQ1 (0:99),  AEEQ2 (0:99),  CLEQ2 (0:99),
.  M (0:99),  O2 (0:99),  O3 (0:99),  NO2 (0:99),
.  MEQ (0:99),  O2EQ (0:99),  O3EQ (0:99),  NO2EQ (0:99),
.  AEREQ1(0:99),  CLWEQ1(0:99),  AEREQ2(0:99),  CLWEQ2(0:99),
.  S(NP,130),  ABSS(3,130,0:99),  WAVE(130),  FLUSS (130),
.  SCTS(0:8,130),  STEP(99),  PRAT(NP,30),  DS(-99:99),
.  TEMP (0:99),  RAER(5:8),  FARBE(-12:12,130),
.  FTOT(-99:99,130),  FTOTU(-99:99,130),  FTOTD(-99:99,130),
.  FCD(-99:99,130),  DISTRI(-99:99,-12:12),  FABS(0:100),
.  FAKTOR(4,130),  ZENRAD(30),  ZENANG(30),
.  PHOTM(NP,30,0:99),ZENGRAD(0:99), WAVEINT(130), RKVEKT(30),
.  Absfac (0:3,7)
C Real Mnorm
C INTEGER DOBSON, KM(4), MONTH(12), FAKEXP(-20:20), MANT(-20:20),
1  ZAELTXT(NP)
C CHARACTER*1 MAT(66,132),BLC,VERT,HORZ,DLIN,IPNT,ZEICHN(10)
C CHARACTER*8 UTX(4), SUBSTZ(NP), TEXT, TEXT1, SUBST, DATUM,
1  CLCK, BLANC
C Character*19 RunTyp(3)
C Character*29 REAKTEX(NP)
C Character*33 RTXT
C CHARACTER*60 O3TEXT, AIRTEXT, TEMPTX, ABSTEXT, PHOTTEX(NP,5),
1  NO2TEXT, Flusstxt
C Character*60 AER1TEXT, AER2TEXT, CLW1TEXT, CLW2TEXT

```

108Source Code ART

C

```

COMMON / MET / EDD(0:99),TEMP,DZ,ZENIT
COMMON /SPECT / WAVE,FLUSS,S,ABSS,SCTS,R(8,9)
COMMON /CHARS / SUBSTZ
COMMON /YIELD / QYP(12,NP),SLYM(NP),TFK(10,NP)
COMMON /CONC / O2,O3,NO2,M,AER1,AER2,CLW1,CLW2
COMMON /FLOUT / FTOTU,FTOTD,FCD,DISTRI,FARBE
COMMON /DISSO / DA(NP,-99:99),DO2(-99:99)
COMMON /TEST / NBEAM,NIT,LANF,LEND,LDISTR,BALB(2),RK

```

C

```

1 FORMAT ((7E10.3))
2 FORMAT ((8F8.2))
3 FORMAT (10I4)
4 FORMAT (7E10.3)
5 FORMAT (12F10.3)
6 FORMAT (/' RK = ',F6.0,10X,' Ground Albedo = ',
/      F5.2,10X,' Number of Scattering Directions = ',I3//
/      1X,'1st row: total      2nd row: direct  ',
/      '3rd row: downward      4th row: upward'//
/      3X,'Alt>',11(F8.0,'km' ),2X,'Sol.Flux')
7 FORMAT (F8.2,1X,1P,12D10.2)
8 FORMAT (8X,F6.2,10X,F6.2,12X,F6.2)
9 FORMAT (' Latitude : ',F6.2,5X,'Date : ',F6.2,5X,'Time : ',F6.2)
10 FORMAT (F9.2,11F10.2)
11 FORMAT ('0')
12 FORMAT (I5,1P,12E10.2)
13 FORMAT ('1 Absorption and Scattering Cross-Sections :'/
*      5X,'Wave',5X,'O2',8X,'O3',7X,'NO2',5X,'Rayleigh',3X,
*      'Aerosol',5X,'Cloud',5X,'Fluss')
14 FORMAT (I3,A8,20X,I2,2(1X,A2),2(I2,1X),I2,4A8)
15 FORMAT (/(7X,5F8.2))
16 FORMAT (2F2.0,2F4.0,8F7.0,E10.2)
17 FORMAT (39X,'Photodissociation-Coefficient in sec^-1 ',A8/,
*      /' RK:',F6.0,' Ground Albedo:',F5.2/,
*      /4X,'Alt.',4X,'Zenith',4X,10(I3, 7X))
18 FORMAT (2I5,A40)
19 FORMAT (F2.0,F5.0,8F8.0)
20 FORMAT ('0 Concentrations'/6X,'Alt',6X,'Air',8X,'O2',8X,
.      'O3',7X,'NO2',4X,'Aerosol',5X,'Cloud'/)
21 FORMAT ('1')
27 FORMAT (22X,10(A8,2X)/)
700 FORMAT (3X,A8,20X,I2,14X,A33)
703 FORMAT (2X,'Latitude: ',F6.3,10X,'Date: ',F5.2,10X,'Time: ',F5.2,
.      10X,'Altitude: ',F5.2)
705 FORMAT (1X,A,1X,11(F8.2,' '))
706 FORMAT (9X,1P,12D10.2)
707 FORMAT (2X,A,F4.2,1X,1P,12D10.2)

```

C

C

INITIAL VALUES

C

=====

C

DATA UTXT/'(total) ', '(direct)', '(down) ', '(upward) '/

DATA KM /0,10,20,40/

C

DATA STEP /4*.15,3*.025,10*.01,3*.005,4*.0025,1*.2,25*.4,29*1.,

C

. 19*3.,0./

DATA STEP /99*1./

DATA MONTH/0,31,59,90,120,151,181,212,243,273,304,334/

C

Data RunType /'T y p e 1 R u n','T y p e 2 R u n',

. 'T y p e 3 R u n'/'

DATA BLC/' /',VERT/'| '/,HORZ/'- '/,DLIN/'=' /,IPNT/'I' /

DATA ZEICHN /'*,', '#', '@', '+', '&', '%', '\$', 'X', 'O', 'H' /

DATA BLANC /' /

C

iscatt=0

x=SECOND()

PI=3.1415927

RERD=6366.

DZ=1.E5

C

Source Code ART

```

C      Initial Set of Parameters
C      -----
C      IFile =0           ! Output in condensed form
C      IRat  =0           ! Printer Output of the ratio FTOT/FABS
C      IFARB =1           ! Calculation of the Colors of Sky and Earth
C      IDISTR=1           ! Calculation of the Angular Distribution of Fluxes
C      LDISTR=62          ! Line Number for IDISTR and IPLOTD
C      NIT=10             ! Number of Iterations
C      IHS=3              ! Altitudinal Step for PHOTMAT
C      NHS=12             ! Number of Altitudes for PHOTMAT
C      IANF=0
C      IPLOTD=0           ! Output of Printer Plot
C      IPLOTP=0           ! Output of Plotter Plot
C      IOA=0              !
C      IOS=5              ! for Flux-Output
C      IOE=IOA+10*IOS      !
C      IHIGH=10           ! Altitude for Plot of Photolysis Rates
C      KPHOT=1            ! =1:FTOT  =2:FCD  =3:FTOTD  =4:FTOTU

C
C      INSERT OF STEERING PARAMETERS
C      =====
ccc $INCLUDE WERTE3 Test A
C      TYPE OF CALCULATION
C      1: FOR A GIVEN LOCATION AND DATE
C      2: FOR A ZENITH-ANGLE (DEFAULT)
C      3: LOOP OVER SEVERAL RAYS
C      ITYP= 3
C      LOOP-START IS ALWAYS -10
C      LOOPA= -10
C      LOOP-END (DEFAULT= 9):
C      LOOPE= 9
C      CHANGE SURFACE TEMPERATURE 1: YES, ELSE: NO
C      NOTDEF= 0
C      INPUT OF SURFACE TEMPERATURE IN C:
C      BODTEMP= 0.0
C      INPUT OF ALBEDO (NO DEFAULT):
C      BALB(1)= 0.10           ! bei 300 nm
C      BALB(2)= 0.12           ! bei 550 nm
C      OZONE COLUMN DENSITY (DEFAULT:0)
C      DOBSON=0.
C      CALCULATION OF PHOTON FLUXES WITH 1: FLUXES (DEFAULT)
C      OR 2: FLUX3B
C      IUP= 1
C      NUMBER OF BEAMS
C      NBEAM=10
C      DECREASE OF WAVELENGTH REGIME: 1: YES, ELSE: NO
C      IWAVOC= 0
C      STARTING WITH WAVELENGTH (DUMMY VALUE)
C      WAVEA=000.
C      ENDING AT WAVELENGTH (DUMMY VALUE)
C      WAVEE=000.
C      PRINT OF FLUXES: 1: YES, ELSE NO
C      IFLUX= 1
C      CALCULATION OF PHOTODISS. RATES: 0: NO, ELSE: YES
C      IPHOT= 1
C      OUTPUT OF RELATIVE PHOTOLYSIS RATES VS. ZENITH ANGLE: 1: YES, ELSE: NO
C      IZNPLT= 0
C      PHOTODISSOCIATION COEFFICIENTS IN A CONDENSED FORM (DEFAULT = 0)
C      IFILE= 1
C      ALTITUDINAL STEP FOR PHOTODISS. OUTPUT (DEFAULT = 1)
C      IHS= 5
C      Number of altitudes for Photodiss. Output (Default = 12)
C      NHS=12

C      =====
C      If (ityp.eq.3) LoopE=MAX(LoopE, (NHS*IHS)/10+1)
C
C      DO 1001 I=1,20
C      ZENANG(I)=0.
C      ZENRAD(I)=0.

```

110Source Code ART

```

DO 1001 J=1,NP
  PRAT(J,I)=0.
1001 CONTINUE
  Do k=1,4
    Do i=1,130
      FAKTOR(K,I)=0.
    Enddo
  Enddo

C
C  INITIAL VALUES ACCORDING TO TYP OF CALCULATION
C  =====
C
  IF (ITYP.EQ.1) THEN
    Phi=50.
    Datm=20.06
    Zeit=10.00
    PHI=PHI*PI/180.
    IDAT=(DATM-INT(DATM)+.005)*100.
    DECL=-23.44*COS((MONTH(IDAT)+INT(DATM)+10.)*2.*PI/365.)
    DECL=DECL*PI/180.
    ITIM=(ZEIT-INT(ZEIT)+.005)*100.
    TIME=INT(ZEIT)+ITIM/60.-12.
    TIME=TIME*PI/12.
    ZENIT=ACOS(SIN(DECL)*SIN(PHI)+COS(DECL)*COS(PHI)*COS(TIME))
    ZENGRD=ZENIT*180./PI
    RK=(RERD+ALTI)*SIN(ZENIT)
    IRK=0
    LOOPA=1
    LOOPE=1
    LOOPS=1
    LANF=1
    LEND=130
    IZNPLT=0

C
  ELSE IF (ITYP.EQ.2) THEN
    IF (zengrd.GE.0) THEN
      ZENIT=ZENGRD/180*PI
      RK=RERD*SIN(ZENIT)
    ELSE
      rk=rerd-zengrd
      zenit=ASIN(rk/(rerd+100))
      zengrd=zenit*180./pi
    ENDIF
    IRK=0
    LOOPA=1
    LOOPE=2
    LOOPS=1
    LANF=1
    LEND=130
    IZNPLT=0

C
  ELSE IF (ITYP.EQ.3) THEN
    LOOPS= 1
    LANF=1
    LEND=130

C
  ELSE IF (ITYP.EQ.4) THEN
    IPLOT=1
    IZNPLT=0
  ENDIF

C
C  OUTPUT OF HEADINGS AND ERROR CONDITIONS
C  =====
C
  CALL DATE (DATUM)
  CALL CLOCK (CLCK)

C
  WRITE (IUN,'(A,100X,A,A,A,A)') '1','Date= ',DATUM,',    Time= ',
    .      CLCK
  WRITE (11,'(A,100X,A,A,A,A)') ' ','Date= ',DATUM,',    Time= ',

```

```

      .      CLCK
C
      IF (IUP.EQ.1) THEN
        WRITE (IUN,'(45X,A)') '*** F L U X E S *** Version Mar.95 ***'
        WRITE (11,'(45X,A)') '*** F L U X E S *** Version Mar.95 ***'
      Endif
      IF (IUP.EQ.2) THEN
        WRITE (IUN,'(45X,A)') '*** F L U X 3 B *** Version Apr.93 ***'
        WRITE (11,'(45X,A)') '*** F L U X 3 B *** Version Apr.93 ***'
      Endif
C
      IF (KPHOT.EQ.1) Then
        WRITE (IUN,'(/A/)') ' Photodissociation rates from FTOT'
        WRITE (11,'(/A/)') ' Photodissociation rates from FTOT'
      Endif
      IF (KPHOT.EQ.2) Then
        WRITE (IUN,'(/A/)') ' Photometer signals from FCD '
        WRITE (11,'(/A/)') ' Photometer signals from FCD '
      Endif
      IF (KPHOT.EQ.3) Then
        WRITE (IUN,'(/A/)') ' Photometer signals from FTOTD'
        WRITE (11,'(/A/)') ' Photometer signals from FTOTD'
      Endif
      IF (KPHOT.EQ.4) Then
        WRITE (IUN,'(/A/)') ' Photometer signals from FTOTU'
        WRITE (11,'(/A/)') ' Photometer signals from FTOTU'
      Endif
      Write (iun,'(/10x,A19/)') RunTyp(ityp)
      WRITE (IUN,'(/A/)') ' Calculated with the following input data : '
C
      IF (NBEAM .GT. 10) THEN
        WRITE (IUN,*) ' ILLEGAL NUMBER OF BEAMS ',NBEAM
        STOP
      ENDIF
      IF (IZNPLT.NE.0)
        .      WRITE (IUN,'(/A,I3/)') ' Hight for ZENPLT Output: ',IHIGH
C
C      INPUT OF CONCENTRATIONS
C      =====
      READ (5,'(A60)') AIRTEXT
      READ (5,'(7E10.3)') MEQ
      Do iz=0,99
        O2EQ(iz)=MEQ(iz)*.20946/(Exp(.0797*(iz-125))+1.)
      Enddo
      READ (5,'(A60)') NO2TEXT
      READ (5,'(7E10.3)') NO2EQ
      READ (5,'(A60)') O3TEXT
      READ (5,'(7E10.3)') O3EQ
      READ (5,'(A60)') AER1TEXT
        READ (5,'(13X,E10.2)') RAER(5)
        Read (5,4) (AbsFac(0,1),l=1,7)
        Read (5,*)
        READ (5,'(7E10.3)') AEREQ1
      READ (5,'(A60)') AER2TEXT
        READ (5,'(13X,E10.2)') RAER(6)
        Read (5,4) (AbsFac(1,1),l=1,7)
        Read (5,*)
        READ (5,'(7E10.3)') AEREQ2
      READ (5,'(A60)') CLW1TEXT
        READ (5,'(13X,E10.2)') RAER(7)
        Read (5,4) (AbsFac(2,1),l=1,7)
        Read (5,*)
        READ (5,'(7E10.3)') CLWEQ1
      READ (5,'(A60)') CLW2TEXT
        READ (5,'(13X,E10.2)') RAER(8)
        Read (5,4) (AbsFac(3,1),l=1,7)
        Read (5,*)
        READ (5,'(7E10.3)') CLWEQ2
      S1=0.
      S2=0.

```

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```

S3=0.
S4=0.
S5=0.
S6=0.
S7=0.
Do iz=1,99
  S1=S1+Sqrt(Meq (iz)*Meq (iz-1))*1E5
  S2=S2+Sqrt(NO2eq (iz)*NO2eq (iz-1))*1E5
  S3=S3+Sqrt(O3eq (iz)*O3eq (iz-1))*1E5
  S4=S4+Sqrt(Aereq1(iz)*Aereq1(iz-1))*1E5
  S5=S5+Sqrt(Aereq2(iz)*Aereq2(iz-1))*1E5
  S6=S6+Sqrt(Clweq1(iz)*Clweq1(iz-1))*1E5
  S7=S7+Sqrt(Clweq2(iz)*Clweq2(iz-1))*1E5
Enddo
WRITE (IUN,*) ' [AIR] profile :',AIRTEXT, ' I column :',S1
WRITE (IUN,*)
WRITE (IUN,*) ' [O3] profile :',O3TEXT, ' I column :',S2
WRITE (IUN,*)
WRITE (IUN,*) ' [NO2] profile :',NO2TEXT, ' I column :',S3
WRITE (IUN,*)
WRITE (IUN,*) ' Aerosol1 profile :',AER1TEXT, ' I column :',S4
  WRITE (IUN, '(21X,A,1p,E12.2)') ' r=',RAER(5)
  WRITE (IUN,*)
WRITE (IUN,*) ' Aerosol2 profile :',AER2TEXT, ' I column :',S5
  WRITE (IUN, '(21X,A,1p,E12.2)') ' r=',RAER(6)
  WRITE (IUN,*)
WRITE (IUN,*) ' Clouds 1 profile :',CLW1TEXT, ' I column :',S6
  WRITE (IUN, '(21X,A,1p,E12.2)') ' r=',RAER(7)
  WRITE (IUN,*)
WRITE (IUN,*) ' Clouds 2 profile :',CLW2TEXT, ' I column :',S7
  WRITE (IUN, '(21X,A,1p,E12.2)') ' r=',RAER(8)
  WRITE (IUN,*)
IF (IFILE.EQ.1) THEN
  WRITE (11,*) 'Input data and column densities :'
  WRITE (11,*) AIRTEXT, ' ',S1
  WRITE (11,*) O3TEXT, ' ',S2
  WRITE (11,*) NO2TEXT, ' ',S3
  WRITE (11,*) AER1TEXT, ' ',S4
  WRITE (11, '(21X,A,1p,E12.2)') ' r=',RAER(5)
  WRITE (11,*) AER2TEXT, ' ',S5
  WRITE (11, '(21X,A,1p,E12.2)') ' r=',RAER(6)
  WRITE (11,*) CLW1TEXT, ' ',S6
  WRITE (11, '(21X,A,1p,E12.2)') ' r=',RAER(7)
  WRITE (11,*) CLW2TEXT, ' ',S7
  WRITE (11, '(21X,A,1p,E12.2)') ' r=',RAER(8)
ENDIF
C
C INPUT OF TEMPERATURE
C =====
READ (5, '(A40)') TEMPTEX
READ (5, '(7E10.3)') TEQ
WRITE (IUN,*) ' Temperature profile :',TEMPTEX
WRITE (IUN,*)
C
C INPUT OF WAVELENGTH AND EXTRATERRISTIC FLUX
C =====
READ (5,2) WAVE
IF (IWAVOC.EQ. 0) THEN
  WAVEA = WAVE(1)
  WAVEE = WAVE(130)
ENDIF
READ (5,2) WAVEINT
READ (5, '(A40)') Flusstxt
READ (5, '(7E10.3)') Fluss
Do l=1,130
  Fluss(l)=Fluss(1)*Waveint(1)
Enddo
Write (iun,*) ' extraterr. flux :',Flusstxt
WRITE (IUN,*)
WRITE (IUN,*)

```

```

      IF (IFILE.EQ.1) THEN
        WRITE (11,*) TEMPTEX
        write (11,*) Flusstxt
        WRITE (11,*)
      ENDIF

      IF (WAVEA .EQ. WAVEE) THEN
        WRITE (IUN,'(/A,F6.2,A)') ' Single line calculation at ' //
> 'wavelength ',WAVEA,' nm'
        IF (IFILE.EQ.1) WRITE (11,*) 'WAVELENGTH: ',WAVEA
      ELSE
        WRITE (IUN,'(/A,F6.2,A,F6.2,A)') ' Wavelength range from ',
> WAVEA,' to ',WAVEE,' nm'
        IF (IFILE.EQ.1) WRITE (11,'(A,F6.2,A,F6.2,A)')
> ' Wavelength range from ', WAVEA,' to ',WAVEE,' nm'
      ENDIF
      IF (ITYP .NE. 3)
> WRITE (IUN,'(/A,F5.2)') ' Solar zenith angle ',ZENGRD
C
C   ADJUSTING THE O3-PROFILE TO NEW DOBSON VALUE
C   =====
      DOB=0.
      DO 1011 I=0,99
1011   DOB=DOB+O3EQ(I)*DZ
      DOB=DOB/2.687E16
      IF (DOBSON.NE.0) THEN
        FACT=DOBSON/DOB
        DO 1012 I=0,99
1012   O3EQ(I)=O3EQ(I)*FACT
        DOB=DOBSON
      ENDIF
      WRITE (IUN,'(/A,F5.0,A)') ' O3 column density is ',DOB,' Dobsons'
      WRITE (IUN,'( /A,F5.2,A/23x,F5.2,A//)') ' The surface albedo is ',
.      BALB(1),' at 300 nm',
.      BALB(2),' at 550 nm'
      WRITE (11,'( /A,F5.2,A/23x,F5.2,A//)') ' The surface albedo is ',
.      BALB(1),' at 300 nm',
.      BALB(2),' at 550 nm'
      IF (ITYP .EQ. 1) WRITE (IUN,9) PHI/Pi*180.,DATM,ZEIT
      IF (IFILE.EQ.1) THEN
        WRITE (11 , '(A,F6.2)') ' Dobson Units :',DOB
        WRITE (11,*)
      ENDIF
C
C   CONVERSION TO NON-EQUIDISTANT ALTITUDES
C   =====
C   WRITE (IUN,20)
      Z(0)=0.
      DO IZ=1,98
        Z(IZ)=Z(IZ-1)+STEP(IZ)
      Enddo
      Z(99)=99
C
      DO IZ=0,98
        I=Z(IZ)+1.E-9
        M(IZ)=MEQ(I)*EXP(LOG(MEQ(I+1)/MEQ(I))*(Z(IZ)-I))
        O2(IZ)=O2EQ(I)*EXP(LOG(O2EQ(I+1)/O2EQ(I))*(Z(IZ)-I))
        O3(IZ)=O3EQ(I)*EXP(LOG(O3EQ(I+1)/O3EQ(I))*(Z(IZ)-I))
        NO2(IZ)=NO2EQ(I)*EXP(LOG(NO2EQ(I+1)/NO2EQ(I))*(Z(IZ)-I))
        TEMP(IZ)=TEQ(I)+(TEQ(I+1)-TEQ(I))*(Z(IZ)-I)
        AER1(IZ)=AEREQ1(I)*EXP(LOG(AEREQ1(I+1)/AEREQ1(I))*(Z(IZ)-I))
        AER2(IZ)=AEREQ2(I)*EXP(LOG(AEREQ2(I+1)/AEREQ2(I))*(Z(IZ)-I))
        CLW1(IZ)=CLWEQ1(I)*EXP(LOG(CLWEQ1(I+1)/CLWEQ1(I))*(Z(IZ)-I))
        CLW2(IZ)=CLWEQ2(I)*EXP(LOG(CLWEQ2(I+1)/CLWEQ2(I))*(Z(IZ)-I))
C      WRITE (IUN,7) Z(IZ),M(IZ),O2(IZ),O3(IZ),NO2(IZ),
C      .      AER1(IZ),AER2(IZ),CLW1(IZ),CLW2(IZ)
      END DO
      M(99)=MEQ(99)
      O2(99)=O2EQ(99)

```

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```

O3(99)=O3EQ(99)
NO2(99)=NO2EQ(99)
TEMP(99)=TEQ(99)
AER1(99)=0.
AER2(99)=0.
CLW1(99)=0.
CLW2(99)=0.

```

C
C
C

```

CONVERSION TO LAYER MEANS
=====

```

```

S1=0.
S2=0.
S3=0.
S4M=0.
S4O2=0.
S4O3=0.
S4NO2=0.
S5M=0.
S5O2=0.
S5O3=0.
S5NO2=0.
DO 23 IZ=80,99
  Z99=99-Z(IZ)
  S1=S1+1
  S2=S2+Z99
  S3=S3+Z99*Z99
  S4M=S4M+ALOG(M(IZ))
  S4O2=S4O2+ALOG(O2(IZ))
  S4O3=S4O3+ALOG(O3(IZ))
  S4NO2=S4NO2+ALOG(NO2(IZ))
  S5M=S5M+ALOG(M(IZ))*Z99
  S5O2=S5O2+ALOG(O2(IZ))*Z99
  S5O3=S5O3+ALOG(O3(IZ))*Z99
  S5NO2=S5NO2+ALOG(NO2(IZ))*Z99

```

23 CONTINUE

```

DO IZ=0,98
  M(IZ)=SQRT(M(IZ)*M(IZ+1))
  O2(IZ)=SQRT(O2(IZ)*O2(IZ+1))
  O3(IZ)=SQRT(O3(IZ)*O3(IZ+1))
  NO2(IZ)=SQRT(NO2(IZ)*NO2(IZ+1))
  AER1(IZ)=SQRT(AER1(IZ)*AER1(IZ+1))
  AER2(IZ)=SQRT(AER2(IZ)*AER2(IZ+1))
  CLW1(IZ)=SQRT(CLW1(IZ)*CLW1(IZ+1))
  CLW2(IZ)=SQRT(CLW2(IZ)*CLW2(IZ+1))

```

END DO

```

RNEN=S1*S3-S2*S2
GA=(S3*S4M-S2*S5M)/RNEN
GB=(S1*S5M-S2*S4M)/RNEN
M(99)=EXP(GA)/GB
GA=(S3*S4O2-S2*S5O2)/RNEN
GB=(S1*S5O2-S2*S4O2)/RNEN
O2(99)=EXP(GA)/GB
GA=(S3*S4O3-S2*S5O3)/RNEN
GB=(S1*S5O3-S2*S4O3)/RNEN
If (GB.gt.1.E-4) O3(99)=EXP(GA)/GB
GA=(S3*S4NO2-S2*S5NO2)/RNEN
GB=(S1*S5NO2-S2*S4NO2)/RNEN
If (GB.gt.1.E-4) NO2(99)=EXP(GA)/GB

```

C
C
C

Input of Absorption-Spectra

=====

```

WRITE(IUN,*) ' Cross Sections from : '
IF (IFILE.EQ.1) WRITE(11,*) ' Cross Sections from : '
DO J=1,3
  DO L=1,130
    Do iz=99,0,-1
      ABSS(J,L,iz)=0.
    Enddo
  END DO
  READ(5,'(2I4,5X,A36)') LA,LE,ABSTEXT

```

```

Read (5,19) (TFK(i,j),i=1,10)
WRITE (IUN,'(21X,A)') ABSTEXT
IF (IFILE.EQ.1) WRITE (11,*) ABSTEXT
READ (5,4) (ABSS(J,L,0),L=LA,LE)
Ifkt=TFK(1,j)
Tmax=TFK(2,j)
Do l=la,le
  wavenm=wave(l)
  Do iz=99,0,-1
    TFac=0.

C
    If (Ifkt .eq. 2) then
      A0=TFK(3,j)*(Tmax-Temp(iz))+TFK(4,j)*(Tmax-Temp(iz))**2
      B0=TFK(5,j) + TFK(6,j)*Temp(iz)
      Wav0=TFK(7,j) + TFK(8,j)*Temp(iz)
      TFac=1.-A0*Exp(B0*(Wavenm-Wav0)**2)
      If (Temp(i).gt.Tmax) TFac=1.
      TFac=MAX(TFac,0.)
    Endif
    If (Ifkt .eq. 3) then
      A0=TFK(3,j)*(Tmax-Temp(iz))
      A1=TFK(4,j)*(Tmax-Temp(iz))
      B0=TFK(5,j)
      B1=TFK(6,j)
      Wav0=TFK(7,j)
      Wav1=TFK(8,j)
      TFac=1.-A0*Exp(B0*(Wavenm-Wav0)**2)-
-      A1*Exp(B1*(Wavenm-Wav1)**2)
      If (Temp(i).gt.Tmax) TFac=1.
      TFac=MAX(TFac,0.)
    Endif
    ABSS(j,l,iz)=ABSS(j,l,0)*TFac
  Enddo
Enddo
END DO

C
C Calculation of Absorption- and Scattering-Spectra for Aerosols
C =====
AbsText=' Refraction Index : B.Edlen (1966)'
Write (IUN,'(21X,A)') AbsText
If (IFILE.EQ.1) then
  Write (11,*) AbsText
  Write (11,*)
Endif
DO J=5,8
  DO L=1,130
    SCTS(J,L)=0.
  END DO
END DO

C
lvergl=30
Mnorm=2.56E+19
DO L=1,130
  W=WAVE(L)*1.E-7
  W1=1./Wave(l)**2 /100.
  Refrac=1.+8.34213E-5+2.40603E-10/(1.3E-6-W1)+
+ 1.5997E-12/(3.89E-7-W1)
  SCTS(4,L)=8.*PI**3*(Refrac**2-1.)**2/(3.*W**4*Mnorm**2)*
* (6.+3.*.028)/(6.-7.*.028)
  DO J=5,8
    IF (raer(j).LT.4E-6) THEN
      scts(j,l)=0.
      IF (iscatt.EQ.0) THEN
        WRITE (iun,*)
        WRITE (iun,*) 'aerosol radius less then 4E-6 cm: ',
. 'No Scattering !'
        WRITE (iun,*)
        WRITE (11,*)
        WRITE (11,*) 'aerosol radius less then 4E-6 cm: ',
. 'No Scattering !'

```

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```

        WRITE (11,*)
        END IF
        iscatt=1
    ELSE
        If (2.*PI*RAER(J)/W .gt. 1.) then
            X=Log10(2.*PI*RAER(J)/W)
            QFAC=0.22+5.17*X**1.6*EXP(-0.905*X*X)+
                1.75*(1.-EXP(-0.11*X**4))
            SctS(J,L)=PI*RAER(J)*RAER(J)*QFAC
        Else
            X=Log10(2.*PI*RAER(J)/W)
            QFAC=0.22*EXP(4.75*X)
            SctS(J,L)=PI*RAER(J)*RAER(J)*QFAC
        Endif
    END IF
    If (Wave(1).le.300.) SctS(j-5,1)=SctS(j,1)*AbsFac(j-5,1)
    If (Wave(1).le.350. .and. Wave(1).gt.300.) then
        FacAbs=AbsFac(j-5,1)+(AbsFac(j-5,2)-AbsFac(j-5,1))/50.
        *(Wave(1)-350.)
        SctS(j-5,1)=SctS(j,1)*FacAbs
    Endif
    If (Wave(1).le.400. .and. Wave(1).gt.350.) then
        FacAbs=AbsFac(j-5,2)+(AbsFac(j-5,3)-AbsFac(j-5,2))/50.
        *(Wave(1)-400.)
        SctS(j-5,1)=SctS(j,1)*FacAbs
    Endif
    If (Wave(1).le.450. .and. Wave(1).gt.400.) then
        FacAbs=AbsFac(j-5,3)+(AbsFac(j-5,4)-AbsFac(j-5,3))/50.
        *(Wave(1)-450.)
        SctS(j-5,1)=SctS(j,1)*FacAbs
    Endif
    If (Wave(1).le.500. .and. Wave(1).gt.450.) then
        FacAbs=AbsFac(j-5,4)+(AbsFac(j-5,5)-AbsFac(j-5,4))/50.
        *(Wave(1)-500.)
        SctS(j-5,1)=SctS(j,1)*FacAbs
    Endif
    If (Wave(1).le.600. .and. Wave(1).gt.500.) then
        FacAbs=AbsFac(j-5,5)+(AbsFac(j-5,6)-AbsFac(j-5,5))/100.
        *(Wave(1)-600.)
        SctS(j-5,1)=SctS(j,1)*FacAbs
    Endif
    If (Wave(1).le.700. .and. Wave(1).gt.600.) then
        FacAbs=AbsFac(j-5,6)+(AbsFac(j-5,7)-AbsFac(j-5,6))/100.
        *(Wave(1)-700.)
        SctS(j-5,1)=SctS(j,1)*FacAbs
    Endif
    If (Wave(1).gt.700.) SctS(j-5,1)=SctS(j,1)*AbsFac(j-5,7)
END DO
c   Output of the total optical density
    If (1.eq.lvergl) then
        Tau1=0.
        Tau2=0.
        Tau3=0.
        Tau4=0.
        Tau5=0.
        Tau6=0.
        Tau7=0.
        Tau8=0.
        Tau9=0.
        Tau10=0.
        Tau11=0.
        Tau12=0.
        Do i=0,99
            Tau1=Tau1+Abss(1,1,i)*O2(i)           ! Abs
            Tau2=Tau2+Abss(2,1,i)*O3(i)           ! Abs
            Tau3=Tau3+Abss(3,1,i)*NO2(i)          ! Abs
            Tau4=Tau4+Scts(4,1)*M(i)              ! Sct
            Tau5=Tau5+Scts(0,1)*Aer1(i)           ! Abs
            Tau6=Tau6+Scts(5,1)*Aer1(i)           ! Sct
            Tau7=Tau7+Scts(1,1)*Aer2(i)           ! Abs

```

```

      Tau8=Tau8+Scts(6,1)*Aer2(i)           ! Sct
      Tau9=Tau9+Scts(2,1)*Clw1(i)           ! Abs
      Tau10=Tau10+Scts(7,1)*Clw1(i)          ! Sct
      Tau11=Tau11+Scts(3,1)*Clw2(i)          ! Abs
      Tau12=Tau12+Scts(8,1)*Clw2(i)          ! Sct
    Enddo
    If (lvergl.eq.30) then
      Write (iun,21)
      Write (iun,*) ' Total optical densities : '
      Write(iun,*) ' Wave           O2           O3           NO2           Air'
>      , '           Aer1           Aer2           Clw1           Clw2'
      Write (11,*)
      Write (11,*)
      Write (11,*)
      Write (11,*) ' Total optical densities : '
      Write(11,*) ' Wave           O2           O3           NO2           Air'
>      , '           Aer1           Aer2           Clw1           Clw2'
    Endif
    Write (iun,'(F7.1,A,1p,12E10.2)') wave(1) , ' Scat : ',
>      0.,0.,0.,Tau4,Tau6,Tau8,Tau10,Tau12
    Write (iun,'(A,1p,12E10.2)') ' Abs : ',
>      Tau1,Tau2,Tau3,0.,Tau5,Tau7,Tau9,Tau11
    Write (11,'(F7.1,A,1p,12E10.2)') wave(1) , ' Scat : ',
>      0.,0.,0.,Tau4,Tau6,Tau8,Tau10,Tau12
    Write (11,'(A,1p,12E10.2)') ' Abs : ',
>      Tau1,Tau2,Tau3,0.,Tau5,Tau7,Tau9,Tau11
    lvergl=lvergl*1.4
  Endif
END DO

C
C INPUT OF PHOTOLYSIS-SPECTRA
C =====
NR=0
READ (5,4)
30 CONTINUE
  READ (5,700) SUBST,NEPP,RTXT
ccc  write (*,'(1x,I3,A33)') nr,Rtxt
  IF (SUBST.EQ.BLANC) GOTO 37
  NR=NR+1
  J=1
  REAKTEX(NR)=RTXT
ccc  Write (iun,*) nr
  READ (5,16) (QYP(I,NR),I=1,12),SLYM(NR)
ccc  Write (iun,'(1p,13E10.2)') (QYP(I,NR),I=1,12),SLYM(NR)
  READ (5,19) (TFK(I,NR),i=1,10)
ccc  Write (iun,'(1p,13E10.2)') (TFK(I,NR),i=1,10)
  SUBSTZ(NR)=SUBST
  DO 33 L=1,130
    S(NR,L)=0.
  33 CONTINUE
  35 CONTINUE
  READ (5,'(2I5,A)') IA,IE,PHOTTEX(NR,J)
ccc  write (*,'(A60)') phottex(nr,j)
  IF (IA.EQ.0) THEN
    ZAELTXT(NR)=J-1
    GOTO 30
  ENDIF
  READ (5,4) (S(NR,I),I=IA,IE)
  J=J+1
  GOTO 35
37 CONTINUE
NRE=NR

C
C START OF CALCULATIONS
C =====
C
  IF (IWAVOC .EQ. 1) THEN
    DO 26 L=1,129
      IF (WAVEA.LT.WAVE(L+1) .AND. WAVEA.GE.WAVE(L)) LANF=L
      IF (WAVEE.GT.WAVE(L) .AND. WAVEE.LE.WAVE(L+1)) LEND=L+1

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26      CONTINUE
      ENDIF
      IF (NOTDEF .EQ. 1) THEN
        TEMP(0) = BODTEMP+273.
        WRITE (IUN,*) 'Surface Temperature is ',Temp(0)-273.,'Degr C'
        IF (IFILE.EQ.1)
>        WRITE (11,*) 'Surface Temperature: ',Temp(0)-273.,'Degr C'
      ENDIF

C
      ICNT=0
      IZMX=NHS*IHS

C
      IF (IFILE.EQ.1) THEN
        WRITE (11,*)
        WRITE (11,*) 'Reactions:'
        DO 708 k=1,NRE
          WRITE (11,'(1X,I3,2X,A,2X,A)') k,REAKTEX(k),PHOTTEX(k,1)
          DO 709 J=2,ZAELTXT(k)
            WRITE (11,'(37X,A)') PHOTTEX(k,J)
709      CONTINUE
708      CONTINUE
      ENDIF

C
      If (Temp(0).lt.100.) stop
      DO 799 LOOP=LOOPA,LOOPE,LOOPS
        ICNT=ICNT+1

C
C      Calculation of rk for TYP=2
C      -----
C      If (Ityp.eq.2) then
C        If (Loop.eq.1) then
C          rk=Rerd * SIN(Zenit)
C        Else
C          rk=(Rerd+100.)*SIN(Zenit)
C        Endif
C        If (rk.gt.Rerd) then
C          rk=Rerd
C          zmx=Rerd*(1./SIN(Zenit)-1.)
C          Write (iun,'(//A,F5.1,A//)') ' WARNING !!! Above',zmx,
C          ' km the flux is extrapolated !'
C        Endif
C      Endif

C
C      CALCULATION OF RK FOR TYP=3
C      -----
C      IF (ITYP.EQ.3) THEN
C        IF (LOOP.LT.0) THEN
C          RK=RERD*(1.-EXP(-.7*LOOP-7.))
C          IRK=0
C          IANF=0
C        ELSE
C          RK=RERD+LOOP*10.
C          IRK=LOOP*10
C          IANF=-99
C        ENDIF
C        ZENIT=ASIN(RK/(RERD+100.))
C        ZENGRD=ZENIT*180./PI
C      ENDIF

C
C      INITIALIZATION
C      -----
C      DO 109 IZ=-99,99
C        DO 107 NR=1,NP
C          DA(NR,IZ)=0.
107      CONTINUE
C        DO2(IZ)=0.
C        DO 108 L=1,130
C          FCD (IZ,L)=0.
C          FTOT(IZ,L)=0.
C          FTOTU(IZ,L)=0.

```

```

      FTOTD(IZ,L)=0.
108      CONTINUE
109      CONTINUE
C
      IF (IPLOTD.EQ.1) THEN
        DO 119 IX=1,66
          MAT(IX,1)=BLC
          MAT(IX,2)=BLC
          MAT(IX,3)=BLC
          MAT(IX,4)=BLC
          DO 118 IY=5,132
            MAT(IX,IY)=BLC
            IF (IX.EQ.((IX/5)*5)) MAT(IX,IY)=HORZ
            IF (IY.EQ.((IY/5)*5)) MAT(IX,IY)=VERT
            IF (IX.EQ.35) MAT(IX,IY)=DLIN
            IF (IY-5.EQ.((IY-5)/50)*50) MAT(IX,IY)=IPNT
118          CONTINUE
119        CONTINUE
      ENDIF
C
C      *****
C
      IF (IUP.EQ.1) CALL FLUXES (Z,FTOT)
      IF (IUP.EQ.2) CALL FLUX3B (Z,FTOT)
C
C      *****
C
      OUTPUT OF FLUXES
      =====
C
      DO 104 I = 0, 99
        IF (RK.LE. (RERD + ABS(Z(I))) .AND. Z(I) .GE. 0) THEN
          ZENGRAD(I) = ASIN(RK/(RERD+Z(I))) * 180. / PI
        ELSEIF (RK.LE. (RERD + ABS(Z(I))) .AND. Z(I) .LT. 0) THEN
          ZENGRAD(I) = 180. - ASIN(RK/(RERD+ABS(Z(I)))) * 180. / PI
        ELSE
          ZENGRAD(I) = -999.
        ENDIF
104      CONTINUE
C
      IF (RK.LT.RERD) THEN
        IF (IFLUX.EQ.1) THEN
          WRITE (IUN,'(A,99X,A,A,A,A//30X,A)') '1',
>          'Date= ',DATUM,' ', Time= ',CLCK,
>          'Actinic Flux per Wavelength-Interval [Photons / cm^2*sec]'
          Alb=Balb(1)+(Balb(2)-Balb(1))/250.*(400.-300.)
          WRITE (IUN,6) RK,Alb,NBEAM*2,(Z(IZ),IZ=IOA,IOE,IOS)
          WRITE (IUN,6) RK,Alb,NBEAM*2,(Z(IZ),IZ=IOA+40,IOE+40,IOS)
          WRITE (IUN,705) 'Zenith>',(ZENGRAD(IZ),IZ=IOA,IOE,IOS)
          WRITE (IUN,705) 'Zenith>',(ZENGRAD(IZ),IZ=IOA+40,IOE+40,IOS)
          WRITE (IUN,*) 'Wave [nm]'
          DO 305 L=LANF,LEND
            WL=WAVE(L)
            WLI=WAVEINT(L)/2.
            WRITE (IUN,7) WL,(FTOT(IZ,L),IZ=IOA,IOE,IOS),FLUSS(L)
            WRITE (IUN,707) '+-',WLI,(FCD (IZ,L),IZ=IOA,IOE,IOS)
            WRITE (IUN,706) (FTOTD(IZ,L),IZ=IOA,IOE,IOS)
            WRITE (IUN,706) (FTOTU(IZ,L),IZ=IOA,IOE,IOS)
            WRITE (IUN,7) WL,(FTOT(IZ,L),IZ=IOA+40,IOE+40,IOS),FLUSS(L)
            WRITE (IUN,707) '+-',WLI,(FCD (IZ,L),IZ=IOA+40,IOE+40,IOS)
            WRITE (IUN,706) (FTOTD(IZ,L),IZ=IOA+40,IOE+40,IOS)
            WRITE (IUN,706) (FTOTU(IZ,L),IZ=IOA+40,IOE+40,IOS)
            WRITE (IUN,7)
305          CONTINUE
        ENDIF
        IZST=IOA
      ELSE
        IOSS=2*IOS
        IOAS=-IOE
        IF (IFLUX.EQ.1) THEN

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        WRITE (IUN, ' (A,99X,A,A,A,A/30X,A) ' ) '1',
>      'Date= ', DATUM, ', Time= ', CLCK,
>      'Actinic Flux per Wavelength-Interval [Photons / cm^2*sec]'
      Alb=Balb(1)+(Balb(2)-Balb(1))/250.*(400.-300.)
      WRITE (IUN,6) RK,Alb,NBEAM*2, (-Z(IZ), IZ=IOE, IOSS, -IOSS),
      (Z(IZ), IZ=IOA, IOE, IOSS)
    ,
      WRITE (IUN,6) RK,Alb,NBEAM*2, (-Z(IZ), IZ=IOE+40, IOSS+40, -IOSS),
    ,
      (Z(IZ), IZ=IOA+40, IOE+40, IOSS)
      WRITE (IUN,705) 'Zenith>', ((180.-ZENGRAD(IZ)),
    ,
      IZ=IOE, IOSS, -IOSS), (ZENGRAD(IZ), IZ=IOA, IOE, IOSS)
      WRITE (IUN,705) 'Zenith>', ((180.-ZENGRAD(IZ)),
    ,
      IZ=IOE+40, IOSS+40, -IOSS), (ZENGRAD(IZ), IZ=IOA+40, IOE+40, IOSS)
      WRITE (IUN,*) 'Wave[nm]'
      DO 306 L=LANF,LEND
        WL=WAVE(L)
        WLI=WAVEINT(L)/2.
        WRITE (IUN,7) WL, (FTOT(IZ,L), IZ=IOAS, IOE, IOSS), FLUSS(L)
        WRITE (IUN,707) '+-', WLI, (FCD (IZ,L), IZ=IOAS, IOE, IOSS)
        WRITE (IUN,706) (FTOTD(IZ,L), IZ=IOAS, IOE, IOSS)
        WRITE (IUN,706) (FTOTU(IZ,L), IZ=IOAS, IOE, IOSS)
        WRITE (IUN,7) WL, (FTOT(IZ,L), IZ=IOAS+40, IOE+40, IOSS), FLUSS(L)
        WRITE (IUN,707) '+-', WLI, (FCD (IZ,L), IZ=IOAS+40, IOE+40, IOSS)
        WRITE (IUN,706) (FTOTD(IZ,L), IZ=IOAS+40, IOE+40, IOSS)
        WRITE (IUN,706) (FTOTU(IZ,L), IZ=IOAS+40, IOE+40, IOSS)
        WRITE (IUN,7)
306      CONTINUE
      ENDIF
      IZST=-60
    ENDIF

C
C
C  OUPUT OF PRINTER-DIAGRAM OF FLUXES (Ldistr)
C  -----
      IF (IPLOTD.EQ.1) THEN
        DO 313 IZ=IZST,68,2
          IX=65-(IZ+60)/2
          IY=5.5+FTOTD(IZ,Ldistr)/FLUSS(Ldistr)*100.
          IY=MIN(IY,132)
          IF (IY.NE.5) MAT(IX,IY)=ZEICHN(4)
          IY=5.5+FTOTU(IZ,Ldistr)/FLUSS(Ldistr)*100.
          IY=MIN(IY,132)
          IF (IY.NE.5) MAT(IX,IY)=ZEICHN(3)
          IY=5.5+FCD(IZ,Ldistr)/FLUSS(Ldistr)*100.
          IY=MIN(IY,132)
          IF (IY.NE.5) MAT(IX,IY)=ZEICHN(2)
          IY=5.5+FTOT(IZ,Ldistr)/FLUSS(Ldistr)*100.
          IY=MIN(IY,132)
          IF (IY.NE.5) MAT(IX,IY)=ZEICHN(1)
313      CONTINUE
      WRITE (IUN, ' (''1'') ' )
      Do ix=1,65
        Write (iun, '(132A1)') (MAT(ix,iy), iy=1,132)
      Enddo
      WRITE(IUN, ' (/A,F8.2,A) ' ) ' Wavelength = ', WAVE(Ldistr), ' nm'
      ENDIF

C
C
C  OUTPUT OF THE COLOURS OF SKY AND EARTH
C  =====
      If (iFarb.eq.1 .and. Loop.eq.1) then
        facfarb=90./nbeam
        WRITE (IUN,21)
        WRITE (IUN,*) '          Colour of the Sky  seen from Earth'
        Write (iun, '(114x,A)') 'sun'
        Write (iun, '(A,11F10.1,A)') ' [nm]', ((i-.5)*facfarb,
    ,
        i=nbeam,1,-1), zengrd, ' [dgr]'
      Do L=LANF,LEND
        WRITE (IUN,7) WAVE(L), (FARBE(I,L), I=-NBEAM,0)
      Enddo
      WRITE (IUN,21)
      WRITE (IUN,*) '          Colour of the Earth  seen from space'
      Write (iun,11)

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Source Code ART

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      Write (iun,'(A,10F10.1,A)') '      [nm]',((i-.5)*facfarb,
      .      i=nbeam,1,-1),' [dgr]'
      Do L=LANF,LEND
      WRITE (IUN,7) WAVE(L), (FARBE(I,L),I=NBEAM,1,-1)
      Enddo
    ENDIF

C
C  OUTPUT OF THE DISTRIBUTION OF FLUXES
C  =====
    If (iDistr.eq.1 .and. loop.eq.1) then
      WRITE (IUN,21)
      WRITE (IUN,'(A,A,F8.2,A)') ' Radiation-distribution for',
      .      ' wavelength',wave(ldistr),' nm'
      WRITE (IUN,11)
      Write (iun,*) ' # < 0 : flux down      ',
      .      ' # > 0 : flux up      # = 0 : direct flux'
      WRITE (IUN,11)
      ioex=ioe-ios
      Write (iun,'(A,11F10.2,A)') ' # ',(Z(iz),iz=ioa,ioex,ios),
      .      Z(65),' [km]'
      Do i=-nBeam,nBeam
      Write (IUN,12) i,(Distri(iz,i),iz=ioa,ioex,ios),Distri(65,i)
      Enddo
      Write (iun,11)
      Write (iun,'(A,1p,E10.2)') ' extraterr. flux :',Fluss(ldistr)
    ENDIF

C
C  RATIO FTOT/FABS FOR COMPARISON WITH LUTHER OR ISAAKSEN
C  =====
    If (iRat.eq.1 .and. loop.eq.1) then
      WRITE (IUN,21)
      Alb=Balb(1)+(Balb(2)-Balb(1))/250.*(400.-300.)
      Write (iun,'(A,F5.2,A,F4.0,A)')
      .      ' Ratio Ftot/Fabs for zenith angle ',Zengrd,
      .      ' [dgr] and ground albedo ',Alb*100.,' % at 400 nm'
      Write (iun,'(50x,I3,A)') nBeam*2,' scattering directions'
      Write (iun,*)
      DO 319 L=LANF,LEND
      Call WEG (Wave(1),Zenit,M,ds)
      FABS(100)=FLUSS(L)
      TAUT(99)=ABSS(1,L,99)*O2(99)+ABSS(2,L,99)*O3(99)
      +      +ABSS(3,L,99)*NO2(99)
      FABS(99)=FABS(100)*EXP(-TAUT(99)*DS(99))
      DO 315 IZ=98,0,-1
      TAUT(IZ)=ABSS(1,L,iz)*O2(IZ)+ABSS(2,L,iz)*O3(IZ)
      +      +ABSS(3,L,iz)*NO2(IZ)
      FABS(IZ)=FABS(IZ+1)*EXP(-TAUT(IZ)*DS(IZ))
      IZZ=Z(IZ)+.99999
      IF(IZZ.EQ.40) FAKTOR(4,L)=FTOT(IZ,L)/FABS(IZ)
      IF(IZZ.EQ.20) FAKTOR(3,L)=FTOT(IZ,L)/FABS(IZ)
      IF(IZZ.EQ.10) FAKTOR(2,L)=FTOT(IZ,L)/FABS(IZ)
      IF(IZZ.EQ. 0) FAKTOR(1,L)=FTOT(IZ,L)/FABS(IZ)
315    CONTINUE
319    CONTINUE
      Write (iun,'(6x,A,I3,A,I6,A,I6,AI6,A)')
      .      'Alt.->',KM(1),' [km]',KM(2),' [km]',KM(3),' [km]',KM(4),' [km]'
      Write (iun,*) '      [nm]'
      Do l=lanf,lend
      Do iz=1,4
      If (Faktor(iz,l).ge.100.) Faktor(iz,l)=-99.99
      Enddo
      Write (iun,10) WAVE(1),(FAKTOR(iz,l),iz=1,4)
      Enddo
    ENDIF

C
C  CALCULATION OF PHOTODISSOCIATION RATES
C  =====
C
400  CONTINUE
C

```

122Source Code ART

```

      IF (IPHOT.EQ.1) THEN
        DO 401 IZ=-99,99
          DA(1,IZ)=DO2(IZ)
401      CONTINUE
        DO 403 N=2,NP
          DO 402 IZ=-99,99
            DA(N,IZ)=0.
402      CONTINUE
403      CONTINUE
      IF (KPHOT.EQ.1) CALL PHOTO (NRE,FTOT,M,DA,IANF)
      IF (KPHOT.EQ.2) CALL PHOTO (NRE,FCD ,M,DA,IANF)
      IF (KPHOT.EQ.3) CALL PHOTO (NRE,FTOTD,M,DA,IANF)
      IF (KPHOT.EQ.4) CALL PHOTO (NRE,FTOTU,M,DA,IANF)

C
      If (Ityp.eq.2) Call INTERPOL (Loop,DA,rk,Zenit)

C
      OUTPUT OF PHOTOLYSIS-RATES
C
      -----
      If (Ityp.eq.2 .and. Loop.eq.1) Goto 416
      N1=1
      N=MIN(NR,10)
      WRITE (IUN,11)
      WRITE (IUN,'(A,10X,A,61X,A,A,A,A)') '1',
        .      'List of Photolysis Reactions',
        .      'Date= ',DATUM,', Time= ',CLK
      WRITE (IUN,*)
      IF (ITYP .EQ. 1) THEN
        WRITE (IUN,703) PHI*180./PI, DATM, ZEIT
      ELSEIF (ITYP .EQ. 2) THEN
        WRITE (IUN,'(2X,A,F5.1)') 'Ground Zenith Angle: ',ZENGRD
      ENDIF
      Alb=Balb(1)+(Balb(2)-Balb(1))/250.*(400.-300.)
      WRITE (IUN,'(/2X,A,F5.2,A)') ' Ground Albedo =',Alb,
        .      ' at 400 nm.'
      WRITE (IUN,'(/2X,A,10X,A,15X,A/)')
        .      'Nr','Reaction','Reference'
      DO 701 L=1,NRE
        WRITE (IUN,'(1X,I3,2X,A,2X,A)') L,REAKTEX(L),PHOTTEX(L,1)
        DO 702 J=2,ZAELTXT(L)
          WRITE (IUN,'(33X,A)') PHOTTEX(L,J)
702      CONTINUE
701      LAST=(NRE-1)/10+1
      IF (ityp.EQ.1) THEN
        IF (zenit.LT.pi/2.) THEN
          iz=alti
        ELSE IF (zenit.GT.pi/2.) THEN
          iz=-alti-1
        END IF
        DO j=1,nre
          da(j,iz)=da(j,iz)+(da(j,iz+1)-da(j,iz))*(alti-iz)
        END DO
      END IF
      DO 415 L=1,LAST
        WRITE (IUN,'(A,99X,A,A,A,A)') '1','Date= ',DATUM,
        .      ', Time= ',CLK
        Alb=Balb(1)+(Balb(2)-Balb(1))/250.*(400.-300.)
        WRITE (IUN,17) UTX(T(KPHOT),RK,Alb,((J),J=N1,N)
        WRITE (IUN,27) (SUBSTZ(J),J=N1,N)
        IF (ityp.EQ.1) THEN
          WRITE (IUN,'(F9.2,F8.2,1P,11E10.2)')
        .      alti, zenit*180./pi, (da(j,iz),j=n1,n)
        ELSE
          IE=-50
          IF (RK .LT. RERD .AND. LOOP.NE.-1) IE=0
          DO I=50,IE,-1
            If (Ityp.eq.2) then
              Zengr=Zengrd
            Else
              Zengr=Zengrad(Abs(i))
            Endif
          
```

```

        WRITE (IUN, '(F9.2,F8.2,1P,11E10.2)')
            Z (ABS(I)), Zengr, (DA(J,I), J=N1,N)
        END DO
    END IF

C
C      PLOT OF PHOTOLYSIS RATE
C      -----
        IF (IPLOTP.EQ.1 .AND. L.EQ.1) THEN
            CALL GRSTRT (35,8)
            CALL GRFONT (-2)
            CALL GRSPTS (30)
            CALL GRCHRC (0.4,0.,30)
            CALL GSTXAL (2,4)
            CALL GRSCLC (2.8,6.0,39.0,24.0)
            XMIN=-10.
ccc        CALL GRSCLV (XMIN,0.0,0.0,50.0)
        ENDIF
        IF (IPLOTP.EQ.1) CALL PLTRAT (N,NRE,XMIN,ZENGRD)
        N1=N+1
        N=MIN(NRE,N+10)
415      CONTINUE
        IF (IPLOTP.EQ.1) CALL GRENDE
416      Continue

C
C      PREPARATION OF ZENITH ANGLE DEPENDENCY
C      -----
        IF ((IZNPLT.EQ.1) .OR. (IFILE.EQ.1)) THEN
            HIV=RK/(RERD+IHIGH)
            HZV=RK/(RERD+IZMX)
            IF (HIV.LE.1.) THEN
                ZENRAD(ICNT)=ASIN( HIV )
                ZENANG(ICNT)=ZENRAD(ICNT)/PI*180.
                DO 404 J=1,NRE
                    PRAT(J,ICNT)=DA(J,IHIGH)
404              CONTINUE
            ENDIF
            IF (HZV.LE.1.00001) THEN
                RKVEKT(ICNT) = RK
                DO 406 IZ=0,NHS*IHS,IHS
                    IH=IZ/IHS
                    DO 405 J=1,NRE
                        PHOTM(J,ICNT,IH)=DA(J,IZ)
405              CONTINUE
406              CONTINUE
            ENDIF
            ICNTM=2*(IHIGH/10+1)-LOOPA
            IZNTM=2*(IZMX/10+1)-LOOPA
            IF (LOOP.GE.0) THEN
                IF (HIV.LE.1.) THEN
                    ZENRAD(ICNTM-LOOP)=PI-ZENRAD(ICNT)
                    ZENANG(ICNTM-LOOP)=180.-ZENANG(ICNT)
                    DO 407 J=1,NRE
                        PRAT(J,ICNTM-LOOP)=DA(J,-IHIGH)
407              CONTINUE
                ENDIF
                IF (HZV.LE.1.00001) THEN
                    RKVEKT(IZNTM-LOOP) = RK
                    DO 409 IZ=0,NHS*IHS,IHS
                        IH=IZ/IHS
                        DO 408 J=1,NRE
                            PHOTM(J,IZNTM-LOOP,IH)=DA(J,-IZ)
408              CONTINUE
409              CONTINUE
                ENDIF
            ENDIF
        ENDIF

C
C      DETERMINATION OF DAWN VALUES
C      =====

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124Source Code ART

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      IF (LOOP.EQ.0 .AND. LOOPA.LT.0) THEN
        DO 425 IZ=0,99
          DO 424 L=1,130
            FTOT(-IZ,L)=FTOTU(-IZ,L)
            FTOT(+IZ,L)=0.
424      CONTINUE
425      CONTINUE
        DO 429 N=1,NP
          DO 428 IZ=-99,99
            DA(N,IZ)=0.
428      CONTINUE
429      CONTINUE
        IF (IPHOT.EQ.1) CALL PHOTO (NRE,FTOT,M,DA,IANF)
        IF (IZNPLT.EQ.1) THEN
          ZENRAD(ICNTM+1)=PI-ZENRAD(-LOOPA)
          ZENANG(ICNTM+1)=180.-ZENANG(-LOOPA)
          DO 439 J=1,NRE
            PRAT(J,ICNTM+1)=DA(J,-IHIGH)
            DO 438 IZ=0,NHS*IHS,IHS
              IH=IZ/IHS
              PHOTM(J,IZNTM+1,IH)=DA(J,-IZ)
438      CONTINUE
439      CONTINUE
          ENDIF
        ENDIF
C
799 CONTINUE
C
C      OUTPUT OF ZENITH ANGLE DEPENDENCY OF PHOTOLYSIS RATES
C      =====
      IF (IZNPLT.EQ.1) THEN
        ICNTM=ICNTM+1
        Do j=ICNTM,1,-1
          Do i=1,NRE
            IF (PRAT(i,1).NE.0.) THEN
              PRAT(i,j)=PRAT(i,j)/PRAT(i,1)
            ELSE
              PRAT(i,j)=0.
            ENDIF
          Enddo
        Enddo
        CALL ZENPLT (ZENANG, PRAT, ICNTM, NRE, IHIGH)
      ENDIF
C
      IF (IFILE.EQ.1) THEN
        WRITE (11,*)
        WRITE (11,*) 'Distance rk from Ray to the Center of the Earth : '
        WRITE (11,*(6X,21F6.0/(12X,20F6.0))) (RKVEKT(I), I= 1, IZNTM)
        WRITE (11,*)
        WRITE (11,*) 'Solar Zenith Angle: Sin(Chi) = rk / (R(Earth)+z)'
        WRITE (11,*)
        Write (11,*(A,I4,A,I2,A,I3,A))
        > ' Output for',NHS+1,' Altitudes      0 :',IHS,' :',NHS*IHS,'km'
        WRITE (11,*)
        WRITE (11,*) 'Condensed Photolysis Rates:'
        WRITE (11,*) 'No. of Reaction | Overhead Sun | ' //
        > 'Rates for rk(2,...,20)'
        WRITE (11,*) ' | Absolute Rate | ' //
        > 'Relative Rates * 1E5'
        WRITE (11,*) '#####'
        Page=01.00
        Write (11,*(A,I5,A,I5,A,I5,30x,A,F5.2))
        > ' Reactions :',NRE,' rk-Values :',IZNTM,
        > ' Altitudes :',NHS+1,'Header.Bottom :',Page
        DO 829 IH=0,NHS
          IZ=IH*IHS
          WRITE (11,*(/A,I3,A)) ' Photolysis Rates at ',IZ,
          > ' km Altitude'
          DO 827 J=1,NRE
            XPHT=PHOTM(J,1,IH)

```

```

DO 825 I=2, IZNTM
  IF (XPHT.NE.0.) THEN
    PHOTM(J, I, IH) = PHOTM(J, I, IH) / XPHT
  ELSE
    PHOTM(J, I, IH) = 0.
  ENDIF
825 CONTINUE
WRITE (11, ' (I3, 1P, E9.2, 0P, 20I6 / (12X, 20I6)) ')
  J, XPHT, (INT(MIN(PHOTM(J, I, IH) * 100000. + 0.5, 999999.))
  , I=2, IZNTM)

  NHM = 11 + IZ / 10
  PHOTM6 = MAX(PHOTM(J, 6, IH), 1E-40)
  PHOTMM = MIN(MAX(PHOTM(J, NHM, IH), 1E-40), .9999 * PHOTM6)
  RKX = RERD * (1. - EXP(-.7 * 6 + .7))
  ZEN = ASIN(RKX / (RERD + IZ))
  A = -LOG(PHOTM6) / (1. / COS(ZEN) - 1.)
  RKX = RERD + (NHM - 11) * 10
  ZEN = ASIN(RKX / (RERD + IZ))
  B = ACOS(A / (A - LOG(PHOTMM))) / ZEN
  RKX = RERD * (1. - EXP(-.7 * 6 + .7))
  ZEN = ASIN(RKX / (RERD + IZ))
  A = -LOG(PHOTM6) / (1. / COS(B * ZEN) - 1.)
  RKX = RERD + (NHM - 11) * 10
  ZEN = ASIN(RKX / (RERD + IZ))
  B = ACOS(A / (A - LOG(PHOTMM))) / ZEN
  RKX = RERD * (1. - EXP(-.7 * 6 + .7))
  ZEN = ASIN(RKX / (RERD + IZ))
  A = -LOG(PHOTM6) / (1. / COS(B * ZEN) - 1.)
  IF (A.LT.9.99) THEN
    WRITE (11, ' (4X, A, 1p, E10.2, A, 0p, F8.5, A, F8.5, A) ')
    'Gamma=', XPHT, ' exp[' , A, ' (1-sec(' , B, '*X)) ] '
  ELSE
    WRITE (11, ' (4X, A, 1p, E10.2, A, 0p, F8.3, A, F8.5, A) ')
    'Gamma=', XPHT, ' exp[' , A, ' (1-sec(' , B, '*X)) ] '
  ENDIF
C
827 CONTINUE
829 CONTINUE
ENDIF
C
C
999 STOP
END

```

126Source Code ART

```

C=====
C
C
C          Subroutine WEG                      R>th, 1.5.96
C
C      This subroutine calculates the path of the direct solar
C      light through the atmosphere in the case of refraction.
C
C      Input : Wave : wavelength in [nm]
C              winkl: zenith angle in [rad] at 100 km
C              Air  : density of the air
C      Output : Path: pathlength in [km]
C=====
C
C      Subroutine WEG (Wave,winkl,Air,Path)
C
C      Real n0,n1,n2, Air(0:99), Path(-99:99)
C
C      Declarations
C      RErd=6366.
C      w1=1./Wave**2 /100.
C      n0=8.34213E-5+2.40603E-10/(1.3E-6-w1)+1.5997E-12/(3.89E-7-w1)
C      rk=(RErd+99.)*SIN(winkl)
C      iend=-99
C      If (rk.lt.RErd) iend=0
C      AirNorm=Air(0)
C
C      Calculation of pathlength
C      sina=SIN(winkl)
C      Path(99)=COS(winkl)*1E5
C      fac=+1.
C      Airobn=Air(99)
C      Do iz=98,iend,-1
C          z=Abs(iz)
C          is=Abs(iz)
C          n1=1.+n0/AirNorm*Airobn
C          n2=1.+n0/AirNorm*Air(is)
C          sinb=sina*n1/n2
C          r=RErd+z
C          If (rk.lt.r) then
C              Path(iz)=(SQRT((r+1.)**2-rk**2)-SQRT(r**2-rk**2))*1E5
C              If (rk/(r-fac).lt.1.) sina=rk/(r-fac)
C              rk=r*sinb
C              Airobn=Air(is)
C          Else
C              Path(iz)=-9999.
C              fac=-1.
C          Endif
C      Enddo
C
C      End

```


128Source Code ART

```

2 FORMAT (' BEAMS AT:',11X,10F8.2/)
3 FORMAT (10I4)
4 FORMAT (I5,1P,12E10.2)
5 FORMAT (12F10.3)
8 FORMAT (///' RAYLEIGH PHASE FUNCTION : '/')
9 FORMAT (///' AEROSOL PHASE FUNCTION : '/')

```

```

C
C      INITIALIZATION
C      =====
C      Data izard /0/
DATA FLFAK /-24.3090, .4970, -23.4269, .4848, -24.0370, .5015,
1          -24.0797, .4845, -24.7619, .5012, -24.3381, .4959,
2          -28.8897, .5697, -25.3433, .5042, -24.9085, .4989,
3          -31.0862, .6078, -30.5188, .6000, -26.9407, .5346,
4          -34.4926, .6683, -33.6523, .6549, -33.1046, .6474,
5          -41.5449, .7963, -40.7366, .7827, -39.1489, .7546,
6          -49.2427, .9377, -48.8488, .9304, -46.8581, .8944/
DATA FAKO2/-23.8493, .5043, -25.3106, .5374, -25.9939, .5521,
1          -24.4365, .5118, -25.6943, .5381, -27.0531, .5668,
2          -24.6454, .5129, -24.8725, .5169, -25.5236, .5294,
3          -27.7670, .5724, -27.1231, .5570, -27.5593, .5642,
4          -36.0202, .7350, -34.5348, .7014, -34.0160, .6876,
5          -37.4590, .7631, -34.1537, .6929, -32.3149, .6509,
6          -34.3023, .6997, -30.5893, .6222, -27.2204, .5493/
DATA FAKSP/4.57E-23, 252.74, 8.27E-23, 141.00, 1.24E-22, 95.643,
1          2.29E-23, 261.24, 3.12E-23, 194.02, 4.24E-23, 145.80,
2          1.50E-23, 188.19, 1.82E-23, 156.84, 2.26E-23, 128.98,
3          1.34E-23, 84.975, 1.51E-23, 76.922, 1.83E-23, 65.271,
4          1.34E-23, 29.663, 1.42E-23, 28.497, 1.56E-23, 26.764,
5          1.30E-23, 9.7606, 1.31E-23, 9.8410, 1.33E-23, 10.051,
6          1.25E-23, 3.0576, 1.25E-23, 3.1069, 1.25E-23, 3.2300/

C
PI=3.1415927
RERD=6366.
izard=izard+1
C      IPRALL=1: OUTPUT OF ALL INFORMATION
C      IPRALL=1
C
ZENIT=ASIN(RK/(RERD+100.))
COSZEN=COS(ZENIT)
C
C
C      PHASE FUNCTION :
C      =====
C      If (izard.ne.1) Goto 99
FAC=1./FLOAT(NBEAM)
PHI(NBEAM)=PI/2.001
DELTA=PI/2.*FAC
DO 41 I=NBEAM-1,0,-1
    PHI(I)=I*DELTA
    MY(I+1)=Cos(Phi(i)+Delta/2.)
41 CONTINUE
C
C      PHASEFUNCTION P(I,J) : FROM BEAM J INTO BEAM I
C      P : Rayleigh scattering
C      Q : Cloud scattering
C      O : Aerosol scattering
C      -----
C
isw=1
Call Phase (isw,nbeam,zenit,Phi,P)
isw=2
Call Phase (isw,nbeam,zenit,Phi,Q)
isw=2
Call Phase (isw,nbeam,zenit,Phi,O)
IF (IPRALL.NE.0) THEN
    WRITE (IUN,1) NBEAM, (PHI(I)*180./PI, I=0, NBEAM)
    WRITE (IUN,2) (ACOS(MY(I))*180./PI, I=1, NBEAM)
    WRITE (IUN,8)

```

130Source Code ART

```

DO2 (IZ)=DA (1, IZ)
FTOTU (IZ, L)=0.
FTOTD (IZ, L)=0.
FTOT (IZ, L)=FCD (IZ, L)+FTOTU (IZ, L)+FTOTD (IZ, L)
118 CONTINUE
SO2A=SO2N
119 CONTINUE
IF (LEND.LT.8) RETURN
C
C The Collimated Beam
C -----
200 Continue
LAN=MAX (8, LANF)
DO 299 L=LAN, LEND
C
Call WEG (Wave (1), Zenit, M, ds)
F (100, -1)=0.
FCOL (100)=FLUSS (L)
Do IZ=99, 0, -1
    TAUT (IZ)=ABSS (1, L, iz)*O2 (IZ)+ABSS (2, L, iz)*O3 (IZ)
    +ABSS (3, L, iz)*NO2 (IZ)
    + Scts (0, L)*AER1 (IZ) + Scts (1, L)*AER2 (IZ)
    + Scts (2, L)*CLW1 (IZ) + Scts (3, L)*CLW2 (IZ)
    SIGT (IZ)=Scts (4, L)*M (IZ)
    + Scts (5, L)*AER1 (IZ) + Scts (6, L)*AER2 (IZ)
    + Scts (7, L)*CLW1 (IZ) + Scts (8, L)*CLW2 (IZ)
    CHI=TAUT (IZ)+SIGT (IZ)
    FCOL (IZ)=FCOL (IZ+1)*EXP (-CHI*DS (IZ))
    F (IZ, +1)=FCOL (IZ+1)*(1.-EXP (-SIGT (IZ)*DS (IZ)))*.5
    F (IZ, +1)=F (IZ, +1)*EXP (-CHI*DS (IZ))
    F (IZ, -1)=F (IZ+1, -1)*EXP (-CHI*DS (IZ))+F (IZ, +1)
    F (IZ, +1)=F (IZ, +1)*.003
    F (IZ, -1)=F (IZ, -1)*.003
Enddo
C
Upwards scattered flux :
Alb=Balb (1)+(Balb (2)-Balb (1))/250.*(Wave (1)-300.)
F (0, +1)=Alb*(FCOL (0)+F (0, -1))
Do IZ=1, 99
    F (IZ, 1)=F (IZ-1, 1)*EXP (- (TAUT (IZ)+SIGT (IZ))*DS (IZ))+F (IZ, 1)
Enddo
C
C Distribution into different directions :
Do I=NBEAM, 1, -1
    COS1=COS (PHI (I-1))
    COS2=COS (PHI (I))
    DELTFC=ABS (COS1-COS2)
    Do IZ=0, 99
        F (IZ, +I)=F (IZ, +1)*DELTFC
        F (IZ, -I)=F (IZ, -1)*DELTFC
    Enddo
Enddo
C
C Iterations
C -----
DO 249 ITERA=1, NIT
C
C The Downward Fluxes
C -----
Do I=1, NBEAM
    F (99, -I)=F (98, -I)
Enddo
Do IZ=98, 0, -1
    DZZ=DZ*(Z (IZ+1)-Z (IZ))
    WEGCOL=DS (IZ)/DZZ
    SIGR=Scts (4, L)*M (IZ)
    SIGA=Scts (5, L)*AER1 (IZ) + Scts (6, L)*AER2 (IZ)
    SIGC=Scts (7, L)*CLW1 (IZ) + Scts (8, L)*CLW2 (IZ)
    CHI=TAUT (IZ)+SIGT (IZ)
    IF (SIGC .GT. 1.E-5) THEN
        Tau=TAUT (iz)

```

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```

DO2 (IZ)=DA (1, IZ)
FTOTU (IZ, L)=0.
FTOTD (IZ, L)=0.
FTOT (IZ, L)=FCD (IZ, L)+FTOTU (IZ, L)+FTOTD (IZ, L)
118 CONTINUE
SO2A=SO2N
119 CONTINUE
IF (LEND.LT.8) RETURN
C
C The Collimated Beam
C -----
200 Continue
LAN=MAX (8, LANF)
DO 299 L=LAN, LEND
C
Call WEG (Wave (1), Zenit, M, ds)
F (100, -1)=0.
FCOL (100)=FLUSS (L)
Do IZ=99, 0, -1
    TAUT (IZ)=ABSS (1, L, iz)*O2 (IZ)+ABSS (2, L, iz)*O3 (IZ)
    .      +ABSS (3, L, iz)*NO2 (IZ)
    .      + Scts (0, L)*AER1 (IZ) + Scts (1, L)*AER2 (IZ)
    .      + Scts (2, L)*CLW1 (IZ) + Scts (3, L)*CLW2 (IZ)
    SIGT (IZ)=Scts (4, L)*M (IZ)
    .      + Scts (5, L)*AER1 (IZ) + Scts (6, L)*AER2 (IZ)
    .      + Scts (7, L)*CLW1 (IZ) + Scts (8, L)*CLW2 (IZ)
    CHI=TAUT (IZ)+SIGT (IZ)
    FCOL (IZ)=FCOL (IZ+1)*EXP (-CHI*DS (IZ))
    F (IZ, +1)=FCOL (IZ+1)*(1.-EXP (-SIGT (IZ)*DS (IZ)))*.5
    F (IZ, +1)=F (IZ, +1)*EXP (-CHI*DS (IZ))
    F (IZ, -1)=F (IZ+1, -1)*EXP (-CHI*DS (IZ))+F (IZ, +1)
    F (IZ, +1)=F (IZ, +1)*.003
    F (IZ, -1)=F (IZ, -1)*.003
Enddo
C
Upwards scattered flux :
Alb=Balb (1)+(Balb (2)-Balb (1))/250.*(Wave (1)-300.)
F (0, +1)=Alb*(FCOL (0)+F (0, -1))
Do IZ=1, 99
    F (IZ, 1)=F (IZ-1, 1)*EXP (- (TAUT (IZ)+SIGT (IZ))*DS (IZ))+F (IZ, 1)
Enddo
C
C Distribution into different directions :
Do I=NBEAM, 1, -1
    COS1=COS (PHI (I-1))
    COS2=COS (PHI (I))
    DELTFC=ABS (COS1-COS2)
    Do IZ=0, 99
        F (IZ, +I)=F (IZ, +1)*DELTFC
        F (IZ, -I)=F (IZ, -1)*DELTFC
    Enddo
Enddo
C
C Iterations
C -----
DO 249 ITERA=1, NIT
C
C The Downward Fluxes
C -----
Do I=1, NBEAM
    F (99, -I)=F (98, -I)
Enddo
Do IZ=98, 0, -1
    DZZ=DZ*(Z (IZ+1)-Z (IZ))
    WEGCOL=DS (IZ)/DZZ
    SIGR=Scts (4, L)*M (IZ)
    SIGA=Scts (5, L)*AER1 (IZ) + Scts (6, L)*AER2 (IZ)
    SIGC=Scts (7, L)*CLW1 (IZ) + Scts (8, L)*CLW2 (IZ)
    CHI=TAUT (IZ)+SIGT (IZ)
    IF (SIGC .GT. 1.E-5) THEN
        Tau=TAUT (iz)

```

```

      nb=NBEAM
      Call CLOUD (FCOL,F,SIGR,SIGA,SIGC,Tau,PHI,IZ,nb)
Else
C      Startvalues :
      Do I=1,NBEAM
        FZU(I)=SQRT(F(IZ+1,I)*F(IZ,I))
        FZD(I)=F(IZ+1,-I)
        FCFAC(I)=WEGCOL*(P(-I,0)*SIGR+Q(-I,0)*SIGC
          +O(-I,0)*SIGA)
      Enddo
      Do J=1,NBEAM
        Do I=1,NBEAM
          PS(I,J)=(P(-I,J)*SIGR+Q(-I,J)*SIGC
            +O(-I,J)*SIGA)/MY(J)
          PS(I,-J)=(P(-I,-J)*SIGR+Q(-I,-J)*SIGC+O(-I,-J)*SIGA)/
            MY(J)
        Enddo
      Enddo
C      Integration :
      Do I=1,NBEAM
        SF(I)=FCOL(IZ+1)*EXP(-CHI*DS(IZ))*FCFAC(I)
      Enddo
      Do J=1,NBEAM
        Do I=1,NBEAM
          SF(I)=SF(I)+PS(I,J)*FZU(J)+PS(I,-J)*FZD(J)
        Enddo
      Enddo
      Do I=1,NBEAM
        A=CHI/MY(I)
        F0=SF(I)/A
        F(IZ,-I)=F0+(F(IZ+1,-I)-F0)*EXP(-A*DZZ)
      Enddo
    Endif
  Enddo

C      Reflection at Groundlevel ( Albedo )
C      -----
C      FSUM0=FCOL(0)
      Do I=1,NBEAM
        FSUM0=FSUM0+F(0,-I)
      Enddo
      FacLam=Abs(Cos(Phi(nbeam-1))**2-Cos(Phi(0))**2)
      Do I=1,nbeam-1
        COS1=COS(PHI(I-1))**2
        COS2=COS(PHI(I))**2
        Alb=Balb(1)+(Balb(2)-Balb(1))/250.*(Wave(1)-300.)
        F(0,+I)=Alb*FSUM0*ABS(COS1-COS2)/FacLam
      Enddo
      F(0,nbeam)=0.

C
C      The Upward Fluxes
C      -----
C      Do IZ=1,99
        DZZ=DZ*(Z(IZ)-Z(IZ-1))
        WEGCOL=DS(IZ-1)/DZZ
        SIGR=Scts(4,L)*M(IZ-1)
        SIGA=Scts(5,L)*AER1(IZ-1) + Scts(6,L)*AER2(IZ-1)
        SIGC=Scts(7,L)*CLW1(IZ-1) + Scts(8,L)*CLW2(IZ-1)
        CHI=TAUT(IZ-1)+SIGT(IZ-1)
        IF (SIGC.GT. 1.E-5) THEN
          Tau=TAUT(iz)
          nb=NBEAM
          Call CLOUD (FCOL,F,SIGR,SIGA,SIGC,Tau,PHI,IZ,nb)
        Else
C          Startvalues :
          Do I=1,NBEAM
            FZD(I)=SQRT(F(IZ-1,-I)*F(IZ,-I))
            FZU(I)=F(IZ-1,I)
            FCFAC(I)=WEGCOL*(P(I,0)*SIGR+Q(I,0)*SIGC
              +O(I,0)*SIGA)
          Enddo
        Endif
      Enddo

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```

      Enddo
      Do J=1,NBEAM
        Do I=1,NBEAM
          PS(I,J)=(P(I,J)*SIGR+Q(I,J)*SIGC
                  +O(I,J)*SIGA)/MY(J)
          PS(I,-J)=(P(I,-J)*SIGR+Q(I,-J)*SIGC+O(I,-J)*SIGA)/
                  MY(J)
        Enddo
      Enddo
C      Integration :
      Do I=1,NBEAM
        SF(I)=FCOL(IZ-1)*EXP(+CHI*DS(IZ-1))*FCFAC(I)
      Enddo
      Do J=1,NBEAM
        Do I=1,NBEAM
          SF(I)=SF(I)+PS(I,J)*FZU(J)+PS(I,-J)*FZD(J)
        Enddo
      Enddo
      Do I=1,NBEAM
        A=CHI/MY(I)
        F0=SF(I)/A
        F(IZ,+I)=F0+(F(IZ-1,+I)-F0)*EXP(-A*DZZ)
      Enddo
      Endif
      Enddo
C
C 249      CONTINUE
C
C      SUMMING UP
C      -----
C      Do IZ=0,99
        FTOTU(IZ,L)=0.
        FTOTD(IZ,L)=0.
        FCD(IZ,L)=FCOL(IZ)
        Do I=1,NBEAM
          FIS=COSZEN/MY(I)
          FTOTU(IZ,L)=FTOTU(IZ,L)+F(IZ,+I)*FIS
          FTOTD(IZ,L)=FTOTD(IZ,L)+F(IZ,-I)*FIS
        Enddo
        FTOT(IZ,L)=FTOTU(IZ,L)+FTOTD(IZ,L)+FCD(IZ,L)
      Enddo
C
C      DISTRIBUTIONS and COLOURS
C      -----
C      IF (L.EQ.LDISTR) THEN
        Do iz=0,99
          Do i=1,nbeam
            Phix=(i-.5)*90./nbeam*Pi/180.
            Distri(iz,i)=F(iz,i)*Coszen/Sin(2.*Phix)
            Distri(iz,-i)=F(iz,-i)*Coszen/Sin(2.*Phix)
          Enddo
          Distri(iz,0)=FCOL(iz)
        Enddo
      ENDIF
      DO 269 I=1,NBEAM
        FARBE(-I,L)=F(0,-I)
        FARBE(+I,L)=F(90,I)
C 269      CONTINUE
        FARBE(0,L)=FCOL(0)/FLUSS(L)
C 270      CONTINUE
C
C      IF (LDISTR.NE.0) THEN
        DO 273 IZ=0,99
          F(-IZ,0)=0.
          F(IZ,0)=FCOL(IZ)
          DO 272 I=1,NBEAM
            AREA=2.*PI*(COS(PHI(I-1))-COS(PHI(I)))
            IF (IZ.NE.0) THEN
              F(-IZ,+I)=0.
              F(-IZ,-I)=0.

```

```

ENDIF
F(IZ,+I)=F(IZ,+I)/AREA
F(IZ,-I)=F(IZ,-I)/AREA
272 CONTINUE
273 CONTINUE
DO 279 IZ=-99,99
    I=-1
    FAKEXP(IZ)=0.
    MANT(IZ)=0.
    IF (F(IZ,I).NE.0.) THEN
        FAKEXP(IZ)=ALOG10(F(IZ,I))-2
        MANT(IZ)=F(IZ,I)*10.**(-FAKEXP(IZ))+.5
    ENDIF
279 CONTINUE
    Alb=Balb(1)+(Balb(2)-Balb(1))/250.*(Wave(1)-300.)
    WRITE (IUW,*) ' RK=',RK,' ALB=',Alb,' LAMDA=',WAVE(L)
    WRITE (IUW,'(11(I4,I3))') (MANT(IZ),FAKEXP(IZ),IZ=-98,99)
ENDIF
C
299 CONTINUE
C
RETURN
C
C
C RAYS PASSING THE EARTH'S SURFACE
C =====
C
400 CONTINUE
C PATHLENGTH
C -----
C IRK=RK-RERD+.001
C
C FLUX AND O2-PHOTODISSOCIATION FOR THE S-R-BANDS
C -----
C IF (LANF.GT.7) GOTO 500
C
    LEN=MIN(7,LEND)
    SO2A=O2(99)*6466.*COS(Zenit)
    TSUM=TEMP(99)
    SUMT=1.
    I1=3-2*INT(230./TEMP(99))
    XA=LOG(SO2A)
    FAKT=(TEMP(99)-230.)/(40.*(I1-2))
    DO 415 L=LANF,LEN
        Call WEG (Wave(1),Zenit,M,ds)
        D0A=FLFAK(1,2,L)+FLFAK(2,2,L)*XA
        D1A=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XA
        DALT=D0A+(D1A-D0A)*FAKT
        FCD(99,L)=FLUSS(L)*EXP(-EXP(DALT)-O3(99)*ABSS(2,L,99)*DS(99))
        FTOTU(99,L)=0.
        FTOTD(99,L)=0.
        FTOT(99,L)=FCD(99,L)+FTOTU(99,L)+FTOTD(99,L)
415 CONTINUE
    DO 419 IZ=98,IRK,-1
        SO2N=SO2A+O2(IZ)*DS(IZ)
        SUMT=SUMT+1.
        TSUM=TSUM+TEMP(IZ)
        TMEAN=TSUM/SUMT
        I1=3-2*INT(230./TMEAN)
        XA=LOG(SO2A)
        XN=LOG(SO2N)
        FAKT=(TMEAN-230.)/(40.*(I1-2))
        DO 418 L=LANF,LEN
            D0A=FLFAK(1,2,L)+FLFAK(2,2,L)*XA
            DON=FLFAK(1,2,L)+FLFAK(2,2,L)*XN
            D1A=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XA
            D1N=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XN
            DALT=D0A+(D1A-D0A)*FAKT
            DNEU=DON+(D1N-DON)*FAKT
            DTAUO2=EXP(DNEU)-EXP(DALT)

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```

      FCD (IZ, L) = FCD (IZ+1, L)
*      *EXP (-DTAUO2-O3 (IZ) *ABSS (2, L, iz) *DS (IZ) )
      P0=FAKO2 (1, 2, L) +FAKO2 (2, 2, L) *XN
      P1=FAKO2 (1, I1, L) +FAKO2 (2, I1, L) *XN
      S0=FAKSP (1, 2, L) *FAKSP (2, 2, L) ** (1. / (1.+EXP (P0) ) )
      S1=FAKSP (1, I1, L) *FAKSP (2, I1, L) ** (1. / (1.+EXP (P1) ) )
      SIGO2=S0+ (S1-S0) *FAKT
      DA (1, IZ) =DA (1, IZ) +SIGO2*FCD (IZ, L)
      DO2 (IZ) =DA (1, IZ)
      FTOTU (IZ, L) =0.
      FTOTD (IZ, L) =0.
      FTOT (IZ, L) =FCD (IZ, L) +FTOTU (IZ, L) +FTOTD (IZ, L)
418      CONTINUE
      SO2A=SO2N
419      CONTINUE
C
      DO 425 IZ=-IRK+1, IRK-1
      DO 424 L=LANF, LEN
      FTOT (IZ, L) =0.
      FTOTU (IZ, L) =0.
      FTOTD (IZ, L) =0.
      FCD (IZ, L) =0.
424      CONTINUE
425      CONTINUE
C
      DO 427 L=LANF, LEN
      FTOT (-IRK, L) =FTOT (+IRK, L)
      FTOTU (-IRK, L) =0.
      FTOTD (-IRK, L) =FTOT (-IRK, L)
      FCD (-IRK, L) =FCD (IRK, L)
427      CONTINUE
C
      DO 429 IZ=IRK+1, 99
      SO2N=SO2A+O2 (IZ) *DS (IZ-1)
      SUMT=SUMT+1.
      TSUM=TSUM+TEMP (IZ-1)
      TMEAN=TSUM/SUMT
      I1=3-2*INT (230. /TMEAN)
      XA=LOG (SO2A)
      XN=LOG (SO2N)
      FAKT= (TMEAN-230.) / (40. * (I1-2) )
      DO 428 L=LANF, LEN
      D0A=FLFAK (1, 2, L) +FLFAK (2, 2, L) *XA
      D0N=FLFAK (1, 2, L) +FLFAK (2, 2, L) *XN
      D1A=FLFAK (1, I1, L) +FLFAK (2, I1, L) *XA
      D1N=FLFAK (1, I1, L) +FLFAK (2, I1, L) *XN
      DALT=D0A+ (D1A-D0A) *FAKT
      DNEU=D0N+ (D1N-D0N) *FAKT
      DTAUO2=EXP (DNEU) -EXP (DALT)
      FCD (-IZ, L) =FCD (-IZ+1, L)
*      *EXP (-DTAUO2-O3 (IZ-1) *ABSS (2, L, iz-1) *DS (IZ-1) )
      P0=FAKO2 (1, 2, L) +FAKO2 (2, 2, L) *XN
      P1=FAKO2 (1, I1, L) +FAKO2 (2, I1, L) *XN
      S0=FAKSP (1, 2, L) *FAKSP (2, 2, L) ** (1. / (1.+EXP (P0) ) )
      S1=FAKSP (1, I1, L) *FAKSP (2, I1, L) ** (1. / (1.+EXP (P1) ) )
      SIGO2=S0+ (S1-S0) *FAKT
      DA (1, -IZ) =DA (1, -IZ) +SIGO2*FCD (-IZ, L)
      DO2 (-IZ) =DA (1, -IZ)
      FTOTU (-IZ, L) =0.
      FTOTD (-IZ, L) =0.
      FTOT (-IZ, L) =FCD (-IZ, L) +FTOTU (-IZ, L) +FTOTD (-IZ, L)
428      CONTINUE
      SO2A=SO2N
429      CONTINUE
      IF (LEND.LT.8) RETURN
C
C      The Collimated Beam
C      -----
500      CONTINUE
      LAN=MAX (8, LANF)

```

```

DO 599 L=LAN,LEND
C
  Call WEG (Wave(1),Zenit,M,ds)
  F(100,-1)=0.
  FCOL(100)=FLUSS(L)
  Do IZ=99,IRK,-1
    TAUT(IZ)=ABSS(1,L,IZ)*O2(IZ)+ABSS(2,L,IZ)*O3(IZ)
+      +ABSS(3,L,IZ)*NO2(IZ)
.      + SctS(0,L)*AER1(IZ) + SctS(1,L)*AER2(IZ)
.      + SctS(2,L)*CLW1(IZ) + SctS(3,L)*CLW2(IZ)
    SIGT(IZ)=SctS(4,L)*M(IZ)
.      + SctS(5,L)*AER1(IZ) + SctS(6,L)*AER2(IZ)
.      + SctS(7,L)*CLW1(IZ) + SctS(8,L)*CLW2(IZ)
    CHI=TAUT(IZ)+SIGT(IZ)
    FCOL(IZ)=FCOL(IZ+1)*EXP(-CHI*DS(IZ))
    F(IZ,+1)=FCOL(IZ+1)*(1.-EXP(-SIGT(IZ)*DS(IZ)))*.5
    F(IZ,+1)=F(IZ,+1)*EXP(-CHI*DS(IZ))
    F(IZ,-1)=F(IZ+1,-1)*EXP(-CHI*DS(IZ))+F(IZ,+1)
    F(IZ,+1)=F(IZ,+1)*.003
    F(IZ,-1)=F(IZ+1,-1)*.003
  Enddo
C
  FCOL(-IRK)=FCOL(+IRK)
  Do IZ=-IRK,IRK-1
    F(IZ,+1)=0.
    F(IZ,-1)=0.
  Enddo
C
  Do IZ=-IRK-1,-99,-1
    IZA=ABS(IZ)
    CHI=TAUT(IZA-1)+SIGT(IZA-1)
    FCOL(IZ)=FCOL(IZ+1)*EXP(-CHI*DS(IZA-1))
    F(IZ,+1)=FCOL(IZ+1)*(1.-EXP(-SIGT(IZA-1)*DS(IZA-1)))*.5
    F(IZ,-1)=F(IZ+1,-1)*EXP(-CHI*DS(IZA-1))+F(IZ,+1)
  Enddo
  Do IZ=-98,99
    IZA=ABS(IZ)
    IF (IZA .LT. IRK) THEN
      F(IZ,1)= 0.
    ELSEIF (IZ .EQ. +IRK) THEN
      F(IZ,1) = F(-IZ,1)
    ELSE
      F(IZ,1)=F(IZ-1,1)*EXP(-(TAUT(IZA)+SIGT(IZA))*DS(IZA))+F(IZ,1)
    ENDIF
  Enddo
C
C
  Distribution into different directions :
  Do I=NBEAM,1,-1
    COS1=COS(PHI(I-1))
    COS2=COS(PHI(I))
    DELTFC=ABS(COS1-COS2)
    Do IZ=-99,99
      F(IZ,+I)=F(IZ,+1)*DELTFC
      F(IZ,-I)=F(IZ,-1)*DELTFC
    Enddo
  Enddo
C
C
  Iterations
  -----
  Do 549 ITERA=1,NIT
C
C
  The Downward Fluxes
  -----
C
  Do I=1,NBEAM
    F(99,-I)=F(98,-I)
  Enddo
  Do 519 IZ=98,-99,-1
    IZA=ABS(IZ)
    IF (IZ.LT.IRK .AND. IZ.GT.-IRK-1) GOTO 518

```

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```

IX=.5*SIGN(1,IZ)-.5
DZZ=DZ*(Z(IZA+1+IX)-Z(IZA+IX))
WEGCOL=DS(IZA+IX)/DZZ
SIGR=SctS(4,L)*M(IZA+IX)
SIGA=SctS(5,L)*AER1(IZA+IX) + SctS(6,L)*AER2(IZA+IX)
SIGC=SctS(7,L)*CLW1(IZA+IX) + SctS(8,L)*CLW2(IZA+IX)
CHI=TAUT(IZA+IX)+SIGT(IZA+IX)
IF (SIGC .GT. 1.E-5) THEN
    Tau=TAUT(iza+ix)
    nb=NBEAM
    Call CLOUD (FCOL,F,SIGR,SIGA,SIGC,Tau,PHI,IZ,nb)
Else
C Startvalues :
Do I=1,NBEAM
    FZU(I)=SQRT(F(IZ+1,I)*F(IZ,I))
    FZD(I)=F(IZ+1,-I)
    IF (IZ.GE.0) THEN
        FCFAC(I)=WEGCOL*(P(-I,0)*SIGR+Q(-I,0)*SIGC
        +O(-I,0)*SIGA)
    ELSE
        FCFAC(I)=WEGCOL*(P(+I,0)*SIGR+Q(+I,0)*SIGC
        +O(+I,0)*SIGA)
    ENDIF
Enddo
Do J=1,NBEAM
    Do I=1,NBEAM
        PS(I,J)=(P(-I,J)*SIGR+Q(-I,J)*SIGC
        +O(-I,J)*SIGA)/MY(J)
        PS(I,-J)=(P(-I,-J)*SIGR+Q(-I,-J)*SIGC
        +O(-I,-J)*SIGA)/MY(J)
    Enddo
Enddo
C Integration :
Do I=1,NBEAM
    SF(I)=FCOL(IZ+1)*EXP(-CHI*DS(IZA+IX))*FCFAC(I)
Enddo
Do J=1,NBEAM
    Do I=1,NBEAM
        SF(I)=SF(I)+PS(I,J)*FZU(J)+PS(I,-J)*FZD(J)
    Enddo
Enddo
Do I=1,NBEAM
    A=CHI/MY(I)
    F0=SF(I)/A
    F(IZ,-I)=F0+(F(IZ+1,-I)-F0)*EXP(-A*DZZ)
Enddo
IF (IZA.EQ.IRK) THEN
    Do I=1,NBEAM
        F(-IZ,-I)=F(+IZ,-I)
    Enddo
ENDIF
Endif
518 Continue
519 Continue
C
C Boundary Conditions at -99 km
C -----
Do I=1,NBEAM
    A=CHI/MY(I)
    F(-99,+I)=F(-99,-I)*(1.-EXP(-A*DZZ))*0.5
Enddo
C
C The Upward Fluxes
C -----
DO 539 IZ=-98,99
    IZA=ABS(IZ)
    IF (IZ.GT.-IRK .AND. IZ.LT.IRK+1) GOTO 538
    IX=.5*SIGN(1,IZ-1)+.5
    DZZ=DZ*(Z(IZA+1-IX)-Z(IZA-IX))
    WEGCOL=DS(IZA-IX)/DZZ

```

```

Sigr=Scts(4,L)*M(IZA-IX)
SIGA=Scts(5,L)*AER1(IZA-IX) + Scts(6,L)*AER2(IZA-IX)
SIGC=Scts(7,L)*CLW1(IZA-IX) + Scts(8,L)*CLW2(IZA-IX)
CHI=TAUT(IZA-IX)+SIGT(IZA-IX)
IF (SIGC .GT. 1.E-5) THEN
  Tau=TAUT(iza-ix)
  nb=NBEAM
  Call CLOUD (FCOL,F,SIGR,SIGA,SIGC,Tau,PHI,IZ,nb)
Else
C   STARTVALUES
  Do I=1,NBEAM
    FZD(I)=SQRT(F(IZ-1,-I)*F(IZ,-I))
    FZU(I)=F(IZ-1,I)
    IF (IZ.GT.0) THEN
      FCFAC(I)=WEGCOL*(P(+I,0)*SIGR+Q(+I,0)*SIGC
        +O(+I,0)*SIGA)
    ELSE
      FCFAC(I)=WEGCOL*(P(-I,0)*SIGR+Q(-I,0)*SIGC
        +O(-I,0)*SIGA)
    ENDIF
  Enddo
  Do J=1,NBEAM
    Do I=1,NBEAM
      PS(I,J)=(P(I,J)*SIGR+Q(I,J)*SIGC
        +O(I,J)*SIGA)/MY(J)
      PS(I,-J)=(P(I,-J)*SIGR+Q(I,-J)*SIGC
        +O(I,-J)*SIGA)/MY(J)
    Enddo
  Enddo
C   Integration :
  Do I=1,NBEAM
    SF(I)=FCOL(IZ-1)*EXP(+CHI*DS(IZA-IX))*FCFAC(I)
  Enddo
  Do J=1,NBEAM
    Do I=1,NBEAM
      SF(I)=SF(I)+PS(I,J)*FZU(J)+PS(I,-J)*FZD(J)
    Enddo
  Enddo
  Do I=1,NBEAM
    A=CHI/MY(I)
    F0=SF(I)/A
    F(IZ,+I)=F0+(F(IZ-1,+I)-F0)*EXP(-A*DZZ)
  Enddo
  IF (IZA.EQ.IRK) THEN
    Do I=1,NBEAM
      F(-IZ,+I)=F(+IZ,+I)
    Enddo
  ENDIF
  Endif
538   Continue
539   CONTINUE
C   549   Continue
C
C   SUMMING UP
C   -----
C   Do IZ=-99,99
    IZA=ABS(IZ)
    FCD(IZ,L)=0.
    FTOTU(IZ,L)=0.
    FTOTD(IZ,L)=0.
    If (IZA.ge.IRK) Then
      FCD(IZ,L)=FCOL(IZ)
      Do I=1,NBEAM
        FIS=COSZEN/MY(I)
        FTOTU(IZ,L)=FTOTU(IZ,L)+F(IZ,+I)*FIS
        FTOTD(IZ,L)=FTOTD(IZ,L)+F(IZ,-I)*FIS
      Enddo
    Endif
    IF (IRK.EQ.0 .AND. IZ.LT.0) THEN

```

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```

      FTOT (IZ, L) = FTOTD (IZ, L) + FCD (IZ, L)
    ELSE
      FTOT (IZ, L) = FTOTU (IZ, L) + FTOTD (IZ, L) + FCD (IZ, L)
    ENDIF
  Enddo
C
C  DISTRIBUTION
C  -----
  IF (LDISTR.NE.0) THEN
    DO 569 IZ=-99,99
      F (IZ, 0) = FCOL (IZ)
      DO 562 I=1, NBEAM
        AREA=2.*PI*(COS (PHI (I-1)) -COS (PHI (I)))
        F (IZ, +I) = F (IZ, +I) / AREA
        F (IZ, -I) = F (IZ, -I) / AREA
562    CONTINUE
        I=-1
        FAKEXP (IZ) = 0.
        MANT (IZ) = 0.
        IF (F (IZ, I) .NE.0.) THEN
          FAKEXP (IZ) = ALOG10 (F (IZ, I)) - 2
          MANT (IZ) = F (IZ, I) * 10. ** (-FAKEXP (IZ)) + .5
        ENDIF
569    CONTINUE
        Alb=Balb (1) + (Balb (2) -Balb (1)) / 250. * (Wave (1) - 300.)
        WRITE (IUW, *) ' RK=', RK, '  ALB=', Alb, '  LAMDA=', WAVE (L)
        WRITE (IUW, ' (11 (I4, I3)) ') (MANT (IZ), FAKEXP (IZ), IZ=-98, 99)
      ENDIF
C
C 599 CONTINUE
C
      RETURN
      END

```

```

=====
C
C                               P H A S E . F O R                               R¶th, 7.3.95
C
C       Berechnung der Phasenfunktion
C
C       gegeben ist der Kegelmantel Phi0(+dPhi)
C       gesucht ist die Anzahl der Streuungen in den
C       Kegelmantel Phi(+dPhi) bei gegebener Streufunktion FKT
C
C   Input :
C       isw = 1 : Rayleigh-Streuung
C           2 : Mie-Streuung
C       nbeam : Anzahl der Strahlen
C       Phi00 : Richtung des direkten Strahls
C       Phi0  : Richtungen der diffusen Strahlen
C
C   Output :
C       P      : Phasenfunktion (normiert)
C
=====
C
C       Subroutine PHASE (isw,nbeam,Phi00,Phi0,P)
C
C       Real Phi0(0:10), P(-12:12,-12:12)
C       Save
C
C Funktionen
C       RFkt(x)=(1.+Cos(x)**2)*Abs(Sin(x))
C       AFkt(x)=(19.*Exp(-3.6*x)+67.*Exp(-42.*x*x)+.4*Exp(1.42*(Pi-x)))*
C       * Abs(Sin(x))
C
C       Pi=3.141592654
C       dPhi=Pi/2. /nbeam
C
C Initialisierung
C       Do i=-12,12
C         Do j=-12,12
C           P(i,j)=0.
C         Enddo
C       Enddo
C
C Addition der Streuvorgänge
C       delta=Pi/15.
C       Do j=1,nbeam
C         phi=(Phi0(j-1)+Phi0(j))/2.
C         cpx=Cos(phi)
C         spx=Sin(phi)
C         cpy=Cos(-phi)
C         spy=Sin(-phi)
C         Do tet=0.,Pi,delta/2.
C           ct=Cos(tet)
C           st=Sin(tet)
C           If (isw.eq.1) then
C             f=RFkt(tet)
C           Else
C             f=AFkt(tet)
C           Endif
C           Do bet=0.,2.*Pi,delta
C             phix=Acos(ct*cpx+st*spx*Cos(bet))
C             phiy=Acos(ct*cpy+st*spy*Cos(bet))
C             i=1+phix/dPhi
C             if (i.gt.10) i=i-21
C             P(i,j)=P(i,j)+f
C             i=1+phiy/dPhi
C             if (i.gt.10) i=i-21
C             P(i,-j)=P(i,-j)+f
C           Enddo
C         Enddo
C       Enddo

```

140Source Code ART

```

      Enddo
c
c direkter Strahl
      phi=Phi00
      cp=Cos(phi)
      sp=Sin(phi)
      Do tet=0.,Pi,delta/2.
        ct=Cos(tet)
        st=Sin(tet)
        If (isw.eq.1) then
          f=RFkt(tet)
        Else
          f=AFkt(tet)
        Endif
        Do bet=0.,2.*Pi,delta
          phix=Acos(ct*cp+st*sp*Cos(bet))
          i=1+phix/dPhi
          if (i.gt.10) i=i-21
          P(i,0)=P(i,0)+f
        Enddo
      Enddo
c
c Normierung
      Do j=-nbeam,nbeam
        sum=0
        Do i=-nbeam,nbeam
          sum=sum+P(i,j)
        Enddo
        If (sum.ne.0.) then
          Do i=-nbeam,nbeam
            P(i,j)=P(i,j)/sum
          Enddo
        Endif
      Enddo
c
      End

```

```

C
C*****
C
C          Subroutine  C L O U D                      Roeth, 29.3.93
C                                                    gedaendert: 1.3.95
C
C  Purpose      : Calculation of the Photonfluxes through
C                  an optically thick medium of 1 km height.
C
C  Input via CALL : FCOL : flux of the collimated beam
C                  F      : fluxes of the diffuse light
C                  IZ      : hight of cloud base
C                  SIGR, SIGA, SIGC : scattering densities
C                  TAU      : optical absorption density
C                  PHI      : angles of the diffusive beams
C                  NB       : number of beams
C
C  Output via CALL : F      : modified diffuse fluxes
C*****
C
C          Subroutine CLOUD (FCOL,F,SIGR,SIGA,SIGC,TAU,PHI,IZ,NB)
C
C          Parameter (IUN=9)
C
C          Real FCOL(-99:100), F(-99:100,-12:12), PHI(0:10)
C          Real i0,j0,i,j
C          Save
C
C          Data izacl /0/
C          izacl=izacl+1
C
C          If (izacl.eq.1) then
C              Write (IUN,*) ' subroutine CLOUD active'
C              Write (11,*) ' subroutine CLOUD active'
ccc          Write (*,'(A,1p,3E12.2,A,1E12.2)')
ccc          .          ' sigma : ',sigr,siga,sigc,' tau : ',tau
C          Endif
C
C          Startvalues
C          -----
C          b0=FCOL(iz+1)
C          i0=0.
C          j0=0.
C          fac=2.
C          dz=1E5
C          i=0.
C          j=0.
C          Do n=1,nb
C              i0=i0+F(iz+1,-n)
C              j0=j0+F(iz,+n)
C              i=i+F(iz,-n)
C              j=j+F(iz+1,+n)
C          Enddo
ccc          if (izacl.lt.100) Write (*,'(A,I5,1p,5E12.2)')
ccc          .          ' iz,b0,i0,i,j,j0:',iz,b0,i0,i,j,j0
C
C          Calculation (3-Beam)
C          -----
C          Bet=fac*((1.-.5)*SigR+(1.-.05)*SigA+(1.-.05)*SigC)
C          Alp=fac*Tau+Bet
C          Gam=.5*SigR+.05*SigA+.05*SigC
C          Del=(1.-.5)*SigR+(1.-.05)*SigA+(1.-.05)*SigC
C          Chi=Tau+SigR+SigA+SigC
C          Rho=SQRT(Alp*Alp-Bet*Bet)
ccc          if (izacl.lt.100) write(*,*) ' Bet etc:',Bet,Alp,Gam,del,chi,rho
C
C          h=(Alp*Gam+Bet*Del+Gam*Chi)/(Rho*Rho-Chi*Chi)
C          w=(Alp*Del+Bet*Gam-Del*Chi)/(Rho*Rho-Chi*Chi)

```

142Source Code ART

```

      x=EXP(-Rho*dz)
      f0=-2.*Rho/((Alp-Rho)*x-(Alp+Rho)/x)
      g=Bet*(x-1./x)/((Alp-Rho)*x-(Alp+Rho)/x)
ccc   if (izael.lt.100) write (*,*) ' h,w,x,f0,g:',h,w,x,f0,g
c
      x=EXP(-Chi*dz)
      i=f0*i0 + g*j0 - (w*g*x +h*f0-h*x)*b0
      j=f0*j0 + g*i0 - (w*f0*x+h*g -w    )*b0
ccc   If (izael.lt.100)
ccc   .      Write (*,'(A,1p,5E12.2)') ' i,j:',i,j
c
c      Distribution into different directions
c      -----
      Fac=Abs(Cos(Phi(nb))**2-Cos(Phi(0))**2)
      Do n=1,nb
        COS1=Cos(Phi(n-1))**2
        COS2=Cos(Phi(n))**2
        Dstr=Abs(COS1-COS2)/Fac
        F(iz,-n)=i*Dstr
        F(iz+1,+n)=j*Dstr
      Enddo
c
      Return
      End

```

C

```
REAL FUNCTION FOD(w,h)
FOD=-249.8211+.090495*w+.493010*Sqrt(h)-11.35164*Sqrt(w)
.      -.035297*h+150.4245*w**(.18)
END
```


Source Code ART

```

DATA FLFAK /-24.3090,.4970,-23.4269,.4848,-24.0370,.5015,
1      -24.0797,.4845,-24.7619,.5012,-24.3381,.4959,
2      -28.8897,.5697,-25.3433,.5042,-24.9085,.4989,
3      -31.0862,.6078,-30.5188,.6000,-26.9407,.5346,
4      -34.4926,.6683,-33.6523,.6549,-33.1046,.6474,
5      -41.5449,.7963,-40.7366,.7827,-39.1489,.7546,
6      -49.2427,.9377,-48.8488,.9304,-46.8581,.8944/
DATA FAKO2/-23.8493,.5043,-25.3106,.5374,-25.9939,.5521,
1      -24.4365,.5118,-25.6943,.5381,-27.0531,.5668,
2      -24.6454,.5129,-24.8725,.5169,-25.5236,.5294,
3      -27.7670,.5724,-27.1231,.5570,-27.5593,.5642,
4      -36.0202,.7350,-34.5348,.7014,-34.0160,.6876,
5      -37.4590,.7631,-34.1537,.6929,-32.3149,.6509,
6      -34.3023,.6997,-30.5893,.6222,-27.2204,.5493/
DATA FAKSP/4.57E-23,252.74,8.27E-23,141.00,1.24E-22,95.643,
1      2.29E-23,261.24,3.12E-23,194.02,4.24E-23,145.80,
2      1.50E-23,188.19,1.82E-23,156.84,2.26E-23,128.98,
3      1.34E-23,84.975,1.51E-23,76.922,1.83E-23,65.271,
4      1.34E-23,29.663,1.42E-23,28.497,1.56E-23,26.764,
5      1.30E-23,9.7606,1.31E-23,9.8410,1.33E-23,10.051,
6      1.25E-23,3.0576,1.25E-23,3.1069,1.25E-23,3.2300/

C
PI=3.1415927
RERD=6366.
ZENIT=ASIN(RK/(RERD+100.))
COSZEN=COS(ZENIT)
FBR=.5
FBA=.01
FBC=0.
ccc      FOD(w,h)=-249.8211+.090495*w+.493010*Sqrt(h)-11.35164*Sqrt(w)
ccc      .      -.035297*h+150.4245*w**.18
C
IF (RK.GE.RERD*.9999) GOTO 400
C
C
C      RAYS TOUCHING THE EARTH'S SURFACE
C      =====
C
C      PATHLENGTH
C      -----
C
C      FLUX AND O2-PHOTODISSOCIATION FOR THE S-R-BANDS
C      -----
C
IF (LANF.GT.7) GOTO 200
C
LEN=MIN(7,LEND)
SO2A=O2(99)*6466.*COS(Zenit)
TSUM=TEMP(99)
SUMT=1.
I1=3-2*INT(230./TEMP(99))
XA=LOG(SO2A)
FAKT=(TEMP(99)-230.)/(40.*(I1-2))
DO 115 L=LANF,LEN
  D0A=FLFAK(1,2,L)+FLFAK(2,2,L)*XA
  D1A=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XA
  DALT=D0A+(D1A-D0A)*FAKT
  FCD(99,L)=FLUSS(L)*EXP(-EXP(DALT)-O3(99)*ABSS(2,L,99)*DS(99))
  FIU(99,L)=0.
  FID(99,L)=0.
  FTOT(99,L)=FCD(99,L)+FIU(99,L)+FID(99,L)
115 CONTINUE
DO 119 IZ=98,0,-1
  SO2N=SO2A+O2(IZ)*DS(IZ)
  SUMT=SUMT+1.
  TSUM=TSUM+TEMP(IZ)
  TMEAN=TSUM/SUMT
  I1=3-2*INT(230./TMEAN)
  XA=LOG(SO2A)
  XN=LOG(SO2N)
  FAKT=(TMEAN-230.)/(40.*(I1-2))

```

146Source Code ART

```

DO 118 L=LANF,LEN
  DOA=FLFAK(1,2,L) +FLFAK(2,2,L) *XA
  DON=FLFAK(1,2,L) +FLFAK(2,2,L) *XN
  DIA=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XA
  DIN=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XN
  DALT=D0A+(D1A-D0A)*FAKT
  DNEU=D0N+(D1N-D0N)*FAKT
  DTAUO2=EXP(DNEU)-EXP(DALT)
  FCD(IZ,L)=FCD(IZ+1,L)
*      *EXP(-DTAUO2-O3(IZ)*ABSS(2,L,iz)*DS(IZ))
  P0=FAKO2(1,2,L) +FAKO2(2,2,L) *XN
  P1=FAKO2(1,I1,L)+FAKO2(2,I1,L)*XN
  S0=FAKSP(1,2,L) *FAKSP(2,2,L) ** (1./(1.+EXP(P0)))
  S1=FAKSP(1,I1,L)*FAKSP(2,I1,L)** (1./(1.+EXP(P1)))
  SIGO2=S0+(S1-S0)*FAKT
  DA(1,IZ)=DA(1,IZ)+SIGO2*FCD(IZ,L)
  DO2(IZ)=DA(1,IZ)
  FIU(IZ,L)=0.
  FID(IZ,L)=0.
  FTOT(IZ,L)=FCD(IZ,L)+FIU(IZ,L)+FID(IZ,L)
118  CONTINUE
     SO2A=SO2N
119  CONTINUE
     IF (LEND.LT.8) RETURN
C
C      COLLIMATED BEAM
C      -----
200  CONTINUE
     LAN=MAX(8,LANF)
C
DO 203 L=LAN,LEND
  FL(100,L)=FLUSS(L)
203  CONTINUE
DO 209 IZ=99,0,-1
  FODC=DS(IZ)/DZ
DO 208 L=LAN,LEND
  Call WEG (Wave(1),Zenit,M,ds)
  xl=MAX(0.,wave(1)-300.) *10.
  xz=1./coszen-1.
c..  fod=1.81+5.336E-4*xl+2.076E-2*xz+1.873E-5*xl*xz-1.161E-7*
c..  *      xl*xl-1.3143e-3*xz*xz
c..  effa=1.21-2.925E-4*xl+2.105E-2*xz+2.685E-5*xl*xz+6.404E-8*
c..  *      xl*xl-6.0673e-3*xz*xz
C
      zz=iz
      FODx=FOD(Wave(1),zz)
      Effa=1.
      TAU=ABSS(1,L,iz)*O2(IZ)+ABSS(2,L,iz)*O3(IZ)+
+      ABSS(3,L,iz)*NO2(iz)
+      +SctS(0,L)*AER1(IZ) + SctS(1,L)*AER2(IZ)
+      +SctS(2,L)*CLW1(IZ) + SctS(3,L)*CLW2(IZ)
      SIGR=SctS(4,L)*M(IZ)
      SIGA=SctS(5,L)*AER1(IZ) + SctS(6,L)*AER2(IZ)
      SIGC=SctS(7,L)*CLW1(IZ) + SctS(8,L)*CLW2(IZ)
      CHI=(TAU+SIGR+SIGA+SIGC)*FODC
      EXPCHI=EXP(-CHI*DZ)
      ALP=(TAU+FBR*SIGR+FBA*SIGA*effa+FBC*SIGC)*FODx
      BET=(FBR*SIGR+FBA*SIGA*effa+FBC*SIGC)*FODx
      If (Alp .eq. Bet) then
        write (iun,*) 1,iz,tau
        write (iun,*) abss(1,1,iz),abss(2,1,iz),abss(3,1,iz)
        write (iun,*) O2(iz), O3(iz), NO2(iz)
        write (iun,*) ' Rays touching the earth'
        Stop
      Endif
      GAM=((1.-FBR)*SIGR+(1.-FBA)*SIGA*effa+(1.-FBC)*SIGC)*FODC
      DEL=(FBR*SIGR+FBA*SIGA*effa+FBC*SIGC)*FODC
      RHO=SQRT(ALP*ALP-BET*BET)
      EXPRHO=EXP(RHO*DZ)
      X=CHI*CHI-RHO*RHO

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Source Code ART

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      PSI = ( - (CHI+ALP) *GAM-DEL*BET) /X
      CSI = ( (CHI-ALP) *DEL-BET*GAM) /X
      X = (RHO+ALP) *EXPRHO+ (RHO-ALP) /EXPRHO
      U = (BET*CSI*EXPCHI-PSI* (RHO+ALP) *EXPRHO) /X
      V = (BET*PSI-CSI* (RHO+ALP) *EXPCHI*EXPRHO) /X
      F (IZ,L) = 2.*RHO/X
      Y = EXPRHO-1./EXPRHO
      If (Y .eq. 0.) Y=2.*Rho
      G (IZ,L) = BET*Y/X
      H (IZ,L) = -U*Y+PSI* (EXPCHI-EXPRHO)
      HS (IZ,L) = -V*Y+CSI* (1.-EXPCHI*EXPRHO)
      FL (IZ,L) = FL (IZ+1,L) *EXPCHI
      FCD (IZ,L) = FL (IZ,L)
C****  WRITE (IUN,1) IZ,F (IZ,L),G (IZ,L),H (IZ,L),HS (IZ,L),FCD (IZ,L)
C****  WRITE (IUN,1) IZ,TAU,SIGR,CHI,FCD (IZ,L),FODC
      208  CONTINUE
      209  CONTINUE
C
C      CALCULATION OF THE ISOTROPIC FLUXES BY MATRIX INVERSION
C      -----
      DO 213 L=LAN,LEND
        Alb=Balb(1)+(Balb(2)-Balb(1))/250.*(Wave(1)-300.)
        C(1,L)=-1./(Alb+.001)
        D(1,L)=-FCD(0,L)
      213  CONTINUE
      DO 217 IZ=1,99
        K=2*IZ
        DO 216 L=LAN,LEND
          X=-G (IZ-1,L) -C (K-1,L)
          C (K,L)=-F (IZ-1,L) /X
          D (K,L)=(H (IZ-1,L) *FCD (IZ,L) -D (K-1,L) ) /X
          X=-G (IZ-1,L) -F (IZ-1,L) **2/X
          C (K+1,L)=1./X
          D (K+1,L)=(HS (IZ-1,L) *FCD (IZ,L) +F (IZ-1,L) *D (K,L) ) /X
        216  CONTINUE
      217  CONTINUE
      DO 219 L=LAN,LEND
        X=-G (99,L) -C (199,L)
        C (200,L)=-F (99,L) /X
        D (200,L)=(H (99,L) *FLUSS (L) -D (199,L) ) /X
      219  CONTINUE
C
      DO 223 L=LAN,LEND
        FL (201,L)=0.
      223  CONTINUE
      DO 229 K=200,1,-1
        DO 228 L=LAN,LEND
          FL (K,L)=D (K,L) -C (K,L) *FL (K+1,L)
        228  CONTINUE
      229  CONTINUE
C
C      CALCULATION OF PHOTON-DENSITY
C      -----
      X=RK/RERD
      DO 309 IZ=0,99
        DO 308 L=LAN,LEND
          xl=MAX(0.,wave(1)-300.) *10.
          xz=1./coszen-1.
          fod=1.81+5.336E-4*xl+2.076E-2*xz+1.873E-5*xl*xz-1.161E-7*
c      *      xl*xl-1.3143e-3*xz*xz
c      *      xfis=1.14+3.508E-4*xl+1.734E-2*xz-1.286E-5*xl*xz-5.455E-8*
c      *      xl*xl-2.5205e-3*xz*xz
          zz=iz
          FODx=FOD (Wave(1),zz)
          XFIS=1.
          fis=FODx*coszen
          FID (IZ,L)=FL (IZ*2+1,L) *FIS*XFIS
          FIU (IZ,L)=FL (IZ*2+2,L) *FIS
          FTOT (IZ,L)=FCD (IZ,L) +FID (IZ,L) +FIU (IZ,L)
      308  CONTINUE

```

148Source Code ART

```

309 CONTINUE
C
      RETURN
C
C
C      RAYS PASSING THE EARTH'S SURFACE
C      =====
C
400 CONTINUE
C      PATHLENGTH
C      -----
      IRK=RK-RERD+.001
C
C      FLUX AND O2-PHOTODISSOCIATION FOR THE S-R-BANDS
C      -----
      IF (LANF.GT.7) GOTO 500
C
      LEN=MIN(7,LEND)
      SO2A=O2(99)*6466.*COS(Zenit)
      TSUM=TEMP(99)
      SUMT=1.
      I1=3-2*INT(230./TEMP(99))
      XA=LOG(SO2A)
      FAKT=(TEMP(99)-230.)/(40.*(I1-2))
      DO 415 L=LANF,LEN
        Call WEG (Wave(1),Zenit,M,ds)
        D0A=FLFAK(1,2,L)+FLFAK(2,2,L)*XA
        D1A=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XA
        DALT=D0A+(D1A-D0A)*FAKT
        FCD(99,L)=FLUSS(L)*EXP(-EXP(DALT)-O3(99)*ABSS(2,L,99)*DS(99))
        FIU(99,L)=0.
        FID(99,L)=0.
        FTOT(99,L)=FCD(99,L)+FIU(99,L)+FID(99,L)
415 CONTINUE
      DO 419 IZ=98,IRK,-1
        SO2N=SO2A+O2(IZ)*DS(IZ)
        SUMT=SUMT+1.
        TSUM=TSUM+TEMP(IZ)
        TMEAN=TSUM/SUMT
        I1=3-2*INT(230./TMEAN)
        XA=LOG(SO2A)
        XN=LOG(SO2N)
        FAKT=(TMEAN-230.)/(40.*(I1-2))
        DO 418 L=LANF,LEN
          D0A=FLFAK(1,2,L)+FLFAK(2,2,L)*XA
          D0N=FLFAK(1,2,L)+FLFAK(2,2,L)*XN
          D1A=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XA
          D1N=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XN
          DALT=D0A+(D1A-D0A)*FAKT
          DNEU=D0N+(D1N-D0N)*FAKT
          DTAUO2=EXP(DNEU)-EXP(DALT)
          FCD(IZ,L)=FCD(IZ+1,L)
          *      *EXP(-DTAUO2-O3(IZ)*ABSS(2,L,iz)*DS(IZ))
          P0=FAKO2(1,2,L)+FAKO2(2,2,L)*XN
          P1=FAKO2(1,I1,L)+FAKO2(2,I1,L)*XN
          S0=FAKSP(1,2,L)*FAKSP(2,2,L)**(1./(1.+EXP(P0)))
          S1=FAKSP(1,I1,L)*FAKSP(2,I1,L)**(1./(1.+EXP(P1)))
          SIGO2=S0+(S1-S0)*FAKT
          DA(1,IZ)=DA(1,IZ)+SIGO2*FCD(IZ,L)
          DO2(IZ)=DA(1,IZ)
          FIU(IZ,L)=0.
          FID(IZ,L)=0.
          FTOT(IZ,L)=FCD(IZ,L)+FIU(IZ,L)+FID(IZ,L)
418 CONTINUE
        SO2A=SO2N
419 CONTINUE
C
      DO 425 IZ=-IRK+1,IRK-1
        DO 424 L=LANF,LEN
          FTOT(IZ,L)=0.

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Source Code ART

```

        FIU(IZ,L)=0.
        FID(IZ,L)=0.
        FCD(IZ,L)=0.
424  CONTINUE
425  CONTINUE
C
    DO 427 L=LANF,LEN
        FTOT(-IRK,L)=FTOT(+IRK,L)
        FIU(-IRK,L)=FIU(IRK,L)
        FID(-IRK,L)=FID(IRK,L)
        FCD(-IRK,L)=FCD(IRK,L)
427  CONTINUE
C
    DO 429 IZ=IRK+1,99
        SO2N=SO2A+O2(IZ)*DS(IZ-1)
        SUMT=SUMT+1.
        TSUM=TSUM+TEMP(IZ-1)
        TMEAN=TSUM/SUMT
        I1=3-2*INT(230./TMEAN)
        XA=LOG(SO2A)
        XN=LOG(SO2N)
        FAKT=(TMEAN-230.)/(40.*(I1-2))
        DO 428 L=LANF,LEN
            D0A=FLFAK(1,2,L)+FLFAK(2,2,L)*XA
            D0N=FLFAK(1,2,L)+FLFAK(2,2,L)*XN
            D1A=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XA
            D1N=FLFAK(1,I1,L)+FLFAK(2,I1,L)*XN
            DALT=D0A+(D1A-D0A)*FAKT
            DNEU=D0N+(D1N-D0N)*FAKT
            DTAUO2=EXP(DNEU)-EXP(DALT)
            FCD(-IZ,L)=FCD(-IZ+1,L)
            *      *EXP(-DTAUO2-O3(IZ-1)*ABSS(2,L,IZ-1)*DS(IZ-1))
            P0=FAKO2(1,2,L)+FAKO2(2,2,L)*XN
            P1=FAKO2(1,I1,L)+FAKO2(2,I1,L)*XN
            S0=FAKSP(1,2,L)*FAKSP(2,2,L)**(1./(1.+EXP(P0)))
            S1=FAKSP(1,I1,L)*FAKSP(2,I1,L)**(1./(1.+EXP(P1)))
            SIGO2=S0+(S1-S0)*FAKT
            DA(1,-IZ)=DA(1,-IZ)+SIGO2*FCD(-IZ,L)
            DO2(-IZ)=DA(1,-IZ)
            FIU(-IZ,L)=0.
            FID(-IZ,L)=0.
            FTOT(-IZ,L)=FCD(-IZ,L)+FIU(-IZ,L)+FID(-IZ,L)
428  CONTINUE
        SO2A=SO2N
429  CONTINUE
    IF (LEND.LT.8) RETURN
C
C
C  COLLIMATED BEAM
C  -----
500  CONTINUE
    LAN=MAX(8,LANF)
C
    DO 503 L=LAN,LEND
        FL(300,L)=FLUSS(L)
503  CONTINUE
    DO 509 IZ=99,-99,-1
        IZA=ABS(IZ)
        IF (IZA.LT.IRK .OR. (IZ.EQ.-IRK .AND. IZ.NE.0)) THEN
            DO 506 L=LAN,LEND
                F(IZ,L)=F(IRK,L)
                G(IZ,L)=G(IRK,L)
                H(IZ,L)=H(IRK,L)
                HS(IZ,L)=HS(IRK,L)
                FL(IZ+200,L)=FL(IRK+200,L)
                FCD(IZ,L)=FCD(IRK,L)
506  CONTINUE
            GOTO 508
        ENDIF
        IX=.5*SIGN(1,IZ)-.5

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```

      IZX=IZA+IX
      FODC=DS (IZX) /DZ
      XR=RK-RERD
      DO 507 L=LAN,LEND
        Call WEG (Wave(1),Zenit,M,ds)
        XL=MAX(0.,WAVE(L)-300.)      *10.
        fodx=3.5
        effa=1.
        TAU=ABSS(1,L,izx)*O2(IZX)+ABSS(2,L,izx)*O3(IZX)+
+         ABSS(3,L,izx)*NO2(izx)
+         +Scts(0,L)*AER1(IZX) + Scts(1,L)*AER2(IZX)
+         +Scts(2,L)*CLW1(IZX) + Scts(3,L)*CLW2(IZX)
        SIGR=Scts(4,L)*M(IZX)
        SIGA=Scts(5,L)*AER1(IZX) + Scts(6,L)*AER2(IZX)
        SIGC=Scts(7,L)*CLW1(IZX) + Scts(8,L)*CLW2(IZX)
        CHI=(TAU+SIGR+SIGA+SIGC)*FODC
        EXPCHI=EXP(-CHI*DZ)
        ALP=(TAU+FBR*SIGR+FBA*SIG*effa+FBC*SIGC)*FODx
        BET=(FBR*SIGR+FBA*SIG*effa+FBC*SIGC)*FODx
        GAM=((1.-FBR)*SIGR+(1.-FBA)*SIG*effa+(1.-FBC)*SIGC)*FODC
        DEL=(FBR*SIGR+FBA*SIG*effa+FBC*SIGC)*FODC
        RHO=SQRT(ALP*ALP-BET*BET)
        EXPRHO=EXP(RHO*DZ)
        X=CHI*CHI-RHO*RHO
        PSI=(-(CHI+ALP)*GAM-DEL*BET)/X
        CSI=((CHI-ALP)*DEL-BET*GAM)/X
        X=(RHO+ALP)*EXPRHO+(RHO-ALP)/EXPRHO
        U=(BET*CSI*EXPCHI-PSI*(RHO+ALP)*EXPRHO)/X
        V=(BET*PSI-CSI*(RHO+ALP)*EXPCHI*EXPRHO)/X
        F(IZ,L)=2.*RHO/X
        Y=EXPRHO-1./EXPRHO
        G(IZ,L)=BET*Y/X
        H(IZ,L)=-U*Y+PSI*(EXPCHI-EXPRHO)
        HS(IZ,L)=-V*Y+CSI*(1.-EXPCHI*EXPRHO)
        FL(IZ+200,L)=FL(IZ+200+1,L)*EXPCHI
        FCD(IZ,L)=FL(IZ+200,L)
507    CONTINUE
C****  WRITE (IUN,1) IZ,F(IZ,L),G(IZ,L),H(IZ,L),HS(IZ,L),FCD(IZ,L)
508    CONTINUE
C****  IF (IZA.LT.25) WRITE (IUN,1) IZ,TAU,SIGR,CHI,FCD(IZ,LAN),FODC
509  CONTINUE
C
C    CALCULATION OF THE ISOTROPIC FLUXES BY MATRIX-INVERSION
C    -----
      DO 513 L=LAN,LEND
        C(1,L)=0.
        D(1,L)=FLUSS(L)*0E-5
513  CONTINUE
      K=0
      DO 517 IZ=-98,98
        IF (IZ.GT.-IRK-1 .AND. IZ.LT.IRK) GOTO 517
        K=K+2
        DO 516 L=LAN,LEND
          X=-G(IZ-1,L)+C(K-1,L)*F(IZ-1,L)
          C(K,L)=1./X
          D(K,L)=(HS(IZ-1,L)*FCD(IZ,L)+D(K-1,L)*F(IZ-1,L))/X
          X=-G(IZ,L)-C(K,L)
          C(K+1,L)=-F(IZ,L)/X
          D(K+1,L)=(H(IZ,L)*FCD(IZ+1,L)-D(K,L))/X
516    CONTINUE
517  CONTINUE
      K=K+2
      DO 519 L=LAN,LEND
        X=-G(98,L)+C(K-1,L)*F(98,L)
        C(K,L)=1./X
        D(K,L)=(HS(98,L)*FCD(99,L)+D(K-1,L)*F(98,L))/X
        X=-G(99,L)-C(K,L)
        C(K+1,L)=-F(99,L)/X
        D(K+1,L)=(H(99,L)*FLUSS(L)-D(K,L))/X
519  CONTINUE

```

```

C      K=K+1
C      DO 523 L=LAN,LEND
C          FL(K+1,L)=0.
523  CONTINUE
C      DO 529 J=K,1,-1
C          DO 528 L=LAN,LEND
C              FL(J,L)=D(J,L)-C(J,L)*FL(J+1,L)
528  CONTINUE
529  CONTINUE
C
C      CALCULATION OF PHOTON-DENSITY
C      -----
C      K=-2
C      DO 539 IZ=-99,99
C          IF (IZ.GT.-IRK-1 .AND. IZ.LT.IRK) THEN
C              DO 533 L=LAN,LEND
C                  FID(IZ,L)=0.
C                  FIU(IZ,L)=0.
C                  FTOT(IZ,L)=0.
533  CONTINUE
C              ELSE
C                  K=K+2
C                  XR=RK-RERD
C                  DO 535 L=LAN,LEND
C                      XL=MAX(0.,WAVE(L)-300.) *10.
C                      XR=RK-RERD
C                      FODx=3.5
C                      FIS=FODx*COSZEN
C                      XFIS=1.
C                      FID(IZ,L)=FL(K+2,L)*FIS*XFIS
C                      FIU(IZ,L)=FL(K+1,L)*FIS
C                      IF (IRK.EQ.0 .AND. IZ.LT.0) THEN
C                          FTOT(IZ,L)=FCD(IZ,L)+FID(IZ,L)
C                      ELSE
C                          FTOT(IZ,L)=FCD(IZ,L)+FID(IZ,L)+FIU(IZ,L)
C                      ENDIF
535  CONTINUE
C                  ENDIF
C                  DO 537 L=LAN,LEND
C                      FID(-IRK,L)=FID(IRK,L)
C                      FIU(-IRK,L)=FIU(IRK,L)
C                      FTOT(-IRK,L)=FTOT(IRK,L)
537  CONTINUE
539  CONTINUE
C
C      RETURN
C      END

```

152Source Code ART

```

C
C *****
C *
C *      I      I
C *      I      I      I      I      I
C *      I      I      I      I      I
C *      I      I      I      I      I
C *
C *
C * PURPOSE          : CALCULATION OF THE PHOTODISSOCIATION
C *                   : FREQUENCIES AT A GIVEN WAVELENGTH INTERVALL
C * INPUT VIA CALL   : NRE : NUMBER OF PHOTODISSOCIATIONS CALCULATED
C *                   : FTOT : PHOTON FLUX
C *                   : AM : DENSITY OF AIR
C * INPUT VIA COMMON : WAVE : WAVELENGTH
C *                   : S : ABSORPTION CROSS-SECTION
C *                   : QYP : COEFFICIENTS OF THE PRESSURE OR TEMPERATURE
C *                   : DEPENDENCE OF THE QUANTUM YIELD
C *                   : SLYM : CROSS-SECTION AT LYMAN ALPHA LINE
C *                   : TFK : COEFFICIENTS FOR THE TEMPERATURE DEPENDENCE
C *                   : OF THE ABSORPTION CROSS-SECTION
C *                   : VO2 : COLUMN DENSITY OF OXYGEN
C *                   : T : TEMPERATURE
C * OUTPUT VIA CALL  : DA : PHOTODISSOCIATION FREQUENCIES INTEGRATED
C *                   : UPTO WAVELENGTH L
C * REMARKS          : IF A COMBINATION SHALL BE CALCULATED, THE FIRST
C *                   : AND SECOND PHOTOLYSIS REACTION MUST FOLLOW EACH
C *                   : OTHER IMMEDIATELY.
C *****
C
C      SUBROUTINE PHOTO (NRE,FTOT,AM,DA,IANF)
C      =====
C
C      PARAMETER (IUN=6,NP=150)
C
C      COMMON
C      -----
C      COMMON / MET / EDD(0:99),T(0:99),DZ,ZENIT
C      COMMON / SL / VO2(0:99), VO3(0:99), VNO2(0:99), VM(0:99),
C *      DVO2(0:99),DVO3(0:99),DVNO2(0:99),DVM(0:99)
C      COMMON /SPECT / WAVE(130),FLUX(130),S(NP,130),ABSS(3,130,0:99),
C *      SCTS(0:8,130),R(8,9)
C      COMMON /CHARS / SUBSTZ
C      COMMON /YIELD / QYP(12,NP),SLYM(NP),TFK(10,NP)
C
C      DIMENSION
C      -----
C      Integer ierr(nre,-99:99), Vz
C      REAL FTOT(-99:99,130),DA(NP,-99:99),AM (0:99),QY2(-99:99),
C *      VO2(0:99),TFK(0:99),QY(-99:99)
C      Real Lam, Lam0, Lam1
C      CHARACTER*8 SUBSTZ(NP)
C
C      Save
C
C      IEND=99
C      Do nr=1,nre
C      Do i=0,iend
C      ierr(nr,i)=0
C      Enddo
C      Enddo
C
C      LYMAN ALPHA ABSORPTION
C      -----
C      DO 1117 I=0,99
C      VO2(I)=0.
1117 CONTINUE
C      DO 9 I=IANF,IEND
C      IF (I.GE.0) VO2I=VO2(I)

```

```

      IF (I.LT.0) VO2I=2.*VO2(0)-VO2(-I)
      VO2I=VO2I/COS(ZENIT)
      DO 8 NR=1,NRE
        DA(NR,I)=1.5D+13*EXP(-1.D-20*VO2I)*SLYM(NR)+DA(NR,I)
8      CONTINUE
9      CONTINUE

C
      Do 299 l=1,130
        Lam=Wave(l)
      Do 298 nr=1,NRE
        If (S(nr,l).eq.0.) Goto 297

C
C      Temperature Dependence of Spectra
C      -----
      Ifkt=TFK(1,NR)
      Tmax=TFK(2,NR)
      a   =TFK(3,NR)
      b   =TFK(4,NR)
      c   =TFK(5,NR)
      d   =TFK(6,NR)
      e   =TFK(7,NR)
      f   =TFK(8,NR)
      g   =TFK(9,NR)
      h   =TFK(10,NR)

C
      Do i=0,iend
        TFAK(i)=0.
      Enddo

C
      If (Ifkt .eq. 0) then
        Do i=0,iend
          TFAK(i)=1.
        Enddo
      Endif

C
      If (Ifkt .eq. 1) then
        Do i=0,iend
          A0=1. + a*(Tmax-T(i)) + b*(Tmax-T(i))**2
          B0=c + d*T(i)
          Lam0=e + f*T(i)
          TFAK(i)=A0+(1.-A0)/(Exp(B0*(Lam-Lam0))+1.)
          If (T(i).gt.Tmax) TFAK(i)=1
          TFAK(i)=MAX(TFAK(i),0.)
        Enddo
      Endif

C
      If (Ifkt .eq. 2) then
        Do i=0,iend
          A0=a*(Tmax-T(i)) + b*(Tmax-T(i))**2
          B0=c + d*T(i)
          Lam0=e + f*T(i)
          TFAK(i)=1.-A0*Exp(B0*(Lam-Lam0)**2)
          If (T(i).gt.Tmax) TFAK(i)=1
          TFAK(i)=MAX(TFAK(i),0.)
        Enddo
      Endif

C
      If (Ifkt .eq. 3) then
        Do i=0,iend
          A0=a*(Tmax-T(i))
          A1=b*(Tmax-T(i))
          B0=c
          B1=d
          Lam0=e
          Lam1=f
          TFAK(i)=1.-A0*Exp(B0*(Lam-Lam0)**2)-
-          A1*Exp(B1*(Lam-Lam1)**2)
          If (T(i).gt.Tmax) TFAK(i)=1
          TFAK(i)=MAX(TFAK(i),0.)
        Enddo

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      Endif
C
      If (Ifkt .eq. 4) then
        Do i=0,iend
          A0=a+b*(Tmax-T(i))
          Lam0=c+d*T(i)
          TFAK(i)=Exp(A0*(Lam-Lam0))
          If (T(i).gt.Tmax) TFAK(i)=1
          TFAK(i)=MAX(TFAK(i),0.)
        Enddo
      Endif
C
      If (Ifkt .eq. 5) then
        Do i=0,iend
          A0=a+b*(Tmax-T(i))
          B0=c+d*(Tmax-T(i))
          Lam0=e+f*T(i)
          TFAK(i)=A0/(Exp(B0*(Lam-Lam0))+1.)
          If (T(i).gt.Tmax) TFAK(i)=1
          TFAK(i)=MAX(TFAK(i),0.)
        Enddo
      Endif
C
      If (Ifkt .eq. 6) then
        Do i=0,iend
          A0=1+a*(Tmax-T(i))
          B0=-LOG(A0)/(b-c)**2
          Lam0=c
          D0=d*(1.-EXP(e*(Tmax-T(i))))
          F0=f
          Lam1=g+h*(Tmax-T(i))
          TFAK(i)=A0*EXP(B0*(Lam-Lam0)**2)+
+          D0*EXP(F0*(Lam-Lam1)**2)
          If (T(i).gt.Tmax) TFAK(i)=1
          TFAK(i)=MAX(TFAK(i),0.)
        Enddo
      Endif
C
C
C
      QUANTUM YIELD PARAMETERS
      -----
      iFkt=QYP(1,nr)
      Komb=ABS(QYP(2,nr))
      Vz =SIGN(1.,QYP(2,nr))
      If (QYP(2,nr).eq.0.) Vz=0.
      lA  =QYP(3,nr)
      lE  =QYP(4,nr)
      a   =QYP(5,nr)
      b   =QYP(6,nr)
      c   =QYP(7,nr)
      d   =QYP(8,nr)
      e   =QYP(9,nr)
      f   =QYP(10,nr)
      g   =QYP(11,nr)
      h   =QYP(12,nr)
C
C
C
      Branching
      -----
      If (iFkt.eq.1 .and. a.eq.1) Goto 210
      If (Komb.eq.3 .AND. (1.lt.lA .or. 1.gt.lE)) Goto 297
      If ((1.lt.lA .and. Vz.gt.0) .or.
+      (1.gt.lE .and. Vz.lt.0)) Goto 210
      If ((1.gt.lE .and. Vz.gt.0) .or.
+      (1.lt.lA .and. Vz.lt.0)) Goto 297
C
C
C
      Quantum Yield Functions
      -----
      If (iFkt.eq.0) Goto 100
C
      If (iFkt.eq.1) then
        Do i=iAnf,iEnd

```

```

        QY(i)=a
        Enddo
    Endif
c
    If (iFkt.eq.2) then
        Do i=iAnf,iEnd
            QY(i)=a/(EXP(b*(Lam-c))+1.)
        Enddo
    Endif
c
    If (iFkt.eq.3) then
        Do i=iAnf,iEnd
            ia=ABS(i)
            QY(i)=a/(EXP((b+c*T(ia))*(Lam-(d+e*T(ia))))+1.)
        Enddo
    Endif
c
    If (iFkt.eq.4) then
        Do i=iAnf,iEnd
            ia=ABS(i)
            QY(i)=a/(1.+(b-c*T(ia)/300.)*EXP((d-e*T(ia)/300.)*
*           (Lam-f))*(AM(ia)/1E19))
        Enddo
    Endif
c
    If (iFkt.eq.5) then
        Do i=iAnf,iEnd
            QY(i)=a/(EXP(b*(Lam-c))+1.)*(1.-d/(EXP(e*(LAM-f))+1.))
        Enddo
    Endif
c
    If (iFkt.eq.6) then
        Do i=iAnf,iEnd
            ia=ABS(i)
            QY(i)=a/(1.+b*EXP(c*(Lam+d*T(ia)))*(AM(ia)/1E38))
        Enddo
    Endif
c
    If (iFkt.eq.7) then
        Do i=iAnf,iEnd
            ia=ABS(i)
            QY(i)=a/(EXP(b*(Lam-(c+d*T(ia))))+1.) +
+           (e+f*T(ia))/(EXP(g*(Lam-h))+1.)
        Enddo
    Endif
c
    Do i=iAnf,iEnd
        If (QY(i).lt.-0.1 .or. QY(i).gt.1.05) then
            If (ierr(nr,i).eq.0) then
ccc          Write (*,*) ' Error : QY=',QY(i),' at nr=',nr,' i=',i,
ccc          '          ' QY is set to 1.'
                ierr(nr,i)=1
            Endif
        Endif
        QY(i)=Min(Max(QY(i),0.),1.)
    Enddo
c
c
c
100  COMBINATIONS
-----
    CONTINUE
    IF (KOMB.EQ.0) GOTO 200
    IF (KOMB.EQ.1) THEN
        DO I=IANF,IEND
            QY(I)=1.-QY2(I)
        ENDDO
    ENDIF
    IF (KOMB.EQ.2) THEN
        DO I=IANF,IEND
            QY(I)=QY(I)-QY2(I)
        ENDDO
    
```

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```

      ENDIF
      IF (KOMB.EQ.3) THEN
        DO I=IANF,IEND
          QY(I)=QY(I)*QY2(I)
        ENDDO
      ENDIF
C
C      PHOTOLYSIS RATES WITH QUANTUM YIELD
C      -----
200  CONTINUE
      DO I=IANF,IEND
        IA=ABS(I)
        DA(NR,I)=DA(NR,I)+QY(I)*S(NR,L)*FTOT(I,L)*TFAK(IA)
        QY2(I)=QY(I)
      ENDDO
      GOTO 297
C
C      PHOTOLYSIS RATES FOR QUANTUM YIELD = 1
C      -----
210  CONTINUE
      DO I=IANF,IEND
        IA=ABS(I)
        DA(NR,I)=DA(NR,I)+S(NR,L)*FTOT(I,L)*TFAK(IA)
      ENDDO
C
297  CONTINUE
298  CONTINUE          ! Loop nr
299  CONTINUE          ! Loop l
C
1000 FORMAT (1P,12E10.2)
2000 FORMAT (20I6)
      RETURN
      END

```


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```

C=====
C
C          Subroutine I N T E R P O L
C
C      Purpose : Collecting and interpolating the photolysis rates
C                between rk1 and rk2 for a type 2 run
C
C      Input   : Isw : Switch = 1 : Collecting of data
C                2 : Interpolating
C                DA  : Photodissociation frequencies
C                rk  : Corresponding rk-value
C                Zenit : Solar zenith angle of the run
C      Output  : DA  : Interpolated photodissociation frequencies
C
C
C                Roeth, 21.9.93
C=====
C
C      Subroutine INTERPOL (Isw,DA,rk,Zenit)
C
C      Parameter (NA=99, NPR=150, IUN=9)
C      Real DA(NPR,-NA:NA), D(2,NPR,-NA:NA), rkz(2)
C      Save
C
C      Data izen /1/
C      Rerd=6366.
C
C      Collecting Data
C      -----
C      Do j=1,NPR
C        Do i=-NA,NA
C          D(izen,j,i)=DA(j,i)
C        Enddo
C      Enddo
C      rkz(izen)=rk
C      izen=2
C
C      Interpolation
C      -----
C      If (Isw.eq.2) then
C        Do i=-NA,NA
C          z=ABS(i)
C          Chi1=ASIN( rkz(1)/(Rerd+z) )
C          Chi2=ASIN( rkz(2)/(Rerd+z) )
C          If (zenit.lt.Chi1*.999999) then
C            Write (IUN,*) ' Subroutine INTERPOL :'
C            Write (IUN,*) ' zenith angle outside of intervall ',
C            .          chil, zenit, chi2
C          .
C            Stop
C          Endif
C          If (Chi1.eq.Chi2) Return
C          Do j=1,NPR
C            If (DA(j,i).ne.0.)
C            .      DA(j,i)=D(1,j,i)+(D(2,j,i)-D(1,j,i))/(Chi2-Chi1)*(zenit-Chi1)
C            Enddo
C          Enddo
C        Endif
C
C      Return
C      End

```

```

C
C +-----+
C I
C I          *****
C I          *
C I          *   SUBPROGRAM : PLOT PHOTOLYSIS RATES   *
C I          *
C I          *****
C I
C I PURPOSE: PLOTTER-OUTPUT  OF PHOTON FLUXES RATES
C I
C I INPUT VIA CALL:
C I          N: INDEX OF MATRIX DA TO START PLOTS WITH
C I          NEND: NUMBER OF SPECIES READ IN
C I          XMIN: MINIMUM OF PLOT SCALE
C I          ZENGRD: ZENITH ANGLE IN DEGREES
C I INPUT VIA COMMON:
C I          DA   : PHOTODISSOCIATION FREQUENCIES
C I          SUBSTZ: NAME OF SPECIES TO BE PLOTTED
C +-----+
C
C
C          SUBROUTINE PLTRAT (N,NEND,XMIN,ZENGRD)
C
C          Parameter (NP=150)
C
C          CHARACTER*8 SUBSTZ(NP)
C          CHARACTER*22 DEGREE
C          INTEGER ISYM(5)
C
C          COMMON /DISO/ DA(NP,-99:99), DO2(-99:99)
C          COMMON /CHARS / SUBSTZ
C
C          DATA ISYM/2,3,4,5,7/,DEGREE/'ZENITH ANGLE   DEGREE'/
C
C          WRITE (DEGREE(14:15),'(I2)') INT(ZENGRD)
C          WRITE (*,*) DEGREE
C          NANZ=50
C          NANF1=N-9
C          NANF2=N-4
C          XS=-XMIN/20.
C          XF=- (XMIN+XMIN/12.)/5.
C
C          1. Diagramm
C          -----
C          CALL GRSCLV (XMIN,0.0,0.0,50.0)
C
C          ACHSEN
C          -----
C          CALL GRAXS ( 7,'Y=1,M=3',1,' ',8,'ALTITUDE')
C          CALL GRAXS (11,'Y=2,M=3,F=0',1,' ',1,' ')
C          CALL GRAXS (11,'X=1,U=3,M=3',1,' ',1,' ')
C          CALL GRAXS (11,'X=2,U=1,F=0',1,' ',1,' ')
C          CALL GRTXT (XMIN*.5,-8.0,40,
C          .          'LG (PHOTODISSOCIATION-COEFFICIENT / S-1)')
C          CALL GRTXT (XMIN*.5,60.,22,DEGREE)
C
C          DO IL=NANF1,MIN(NANF1+4,NEND)
C             ISYMB=ISYM(MOD(IL,10))
C
C          LEGENDE
C          -----
C          XP=XMIN+XMIN/15.+MOD(IL-1,10)*XF
C          CALL GRJMPS (XP,56.,ISYMB)
C          DO P=XP,XP+XS,-XMIN/60.
C             CALL GRDRWS (P,56.,ISYMB)
C          END DO
C          CALL GRTXT (P+XS,55.5,8,SUBSTZ(IL))
C

```

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```

C      KURVEN
C      -----
      XV=MAX(DA(IL,0),10.**XMIN)
      XV=MIN(XV,1.E+0)
      CALL GRJMPS (ALOG10(XV), 0., ISYMB)
      DO IP=1,NANZ
        XV=MAX(DA(IL,IP),10.**XMIN)
        XV=MIN(XV,1.E+0)
        CALL GRDRWS (ALOG10(XV), FLOAT(IP), ISYMB)
      END DO
      END DO
      CALL GRNXTF

C
C      2. Diagramm
C      -----
      CALL GRSCLV (XMIN,0.0,0.0,50.0)

C
C      ACHSEN
C      -----
      CALL GRAXS ( 7,'Y=1,M=3',1,' ',8,'ALTITUDE')
      CALL GRAXS (11,'Y=2,M=3,F=0',1,' ',1,' ')
      CALL GRAXS (11,'X=1,U=3,M=3',1,' ',1,' ')
      CALL GRAXS (11,'X=2,U=1,F=0',1,' ',1,' ')
      CALL GRTXT (XMIN*.5,-8.0,40,
      . 'LG (PHOTODISSOCIATION-COEFFICIENT / S-1)')
      CALL GRTXT (XMIN*.5,60.,22,DEGREE)
      DO IL=NANF2,MIN(NANF2+4,NEND)
        ISYMB=ISYM(MOD(IL-5,10))

C
C      LEGENDE
C      -----
      XP=XMIN+XMIN/15.+MOD(IL-6,10)*XF
      CALL GRJMPS (XP,56.,ISYMB)
      DO P=XP,XP+XS,-XMIN/60.
        CALL GRDRWS (P,56.,ISYMB)
      END DO
      CALL GRTXT (P+XS,55.5,8,SUBSTZ(IL))

C
C      KURVEN
C      -----
      XV=MAX(DA(IL,0),10.**XMIN)
      XV=MIN(XV,1.E+0)
      CALL GRJMPS (ALOG10(XV), 0., ISYMB)
      DO IP=1,NANZ
        XV=MAX(DA(IL,IP),10.**XMIN)
        XV=MIN(XV,1.E+0)
        CALL GRDRWS (ALOG10(XV), FLOAT(IP), ISYMB)
      END DO
      END DO
      CALL GRNXTF

C
      RETURN
      END

```

```

C
C +-----+
C I
C I          *****
C I          *
C I          *   SUBPROGRAM : PLOT PHOTOLYSIS RATES   *
C I          *           VS. ZENITH ANGLES           *
C I          *
C I          *****
C I
C I PURPOSE: PLOTTER-OUTPUT OF PHOTON FLUXES RATES AT ONE ALTITUDE
C I           VS. ZENITH ANGLE
C I
C I INPUT VIA CALL:
C I     ZENANG: ZENITH ANGLE IN DEGREES
C I     PRAT: PHOTOLYSIS RATES
C I     IANG: NUMBER OF ZENITH ANGLES
C I     NREND: NUMBER OF SPECIES READ IN
C I     IHIGH: ALTITUDE OF CALCULATIONS
C I INPUT VIA COMMON:
C I     SUBSTZ: NAME OF SPECIES TO BE PLOTTED
C +-----+
C
C     SUBROUTINE ZENPLT (ZENANG, PRAT, IANG, NREND, IHIGH)
C
C     Parameter (NP=150)
C
C     REAL          ZENANG(25), PRAT(NP,25)
C     CHARACTER*7   NR
C     CHARACTER*8   CSUBST(NP)
C     CHARACTER*11  HIGHT
C
C     COMMON /CHARS / CSUBST
C
C     DATA NR/'Nr.  : '/
C
C     HIGHT='    KM HIGHT'
C     WRITE (HIGHT(1:2),'(I2)') IHIGH
C     CALL GRSTRT (35,8)
C     CALL GR90DG
C     CALL GRFONT (2)
C
C     DO 1000 IOUT=1,NREND,8
C
C     OBERES BILD
C     -----
C         CALL GRSCLC (4.,24.75,21.,36.5)
C         CALL GRSCLV (0.,0.,100.,1.2)
C
C     ACHSEN
C     -----
C         CALL GRCHRC (0.5,0.,16)
C         CALL GRAXS (13,'X=1,F=(4,0),I',12,'ZENITH ANGLE',1,' ')
C         CALL GRAXS ( 9,'X=2,F=0,I',11,HIGHT,1,' ')
C         CALL GRAXS (13,'Y=1,F=(3,1),I',1,' ',24,
C             'RELATIVE PHOTOLYSIS RATE')
C         CALL GRAXS ( 9,'Y=2,F=0,I',1,' ',1,' ')
C         CALL GRCHRC (0.4,0.,16)
C
C     KURVEN
C     -----
C         DO 130 I=IOUT,MIN(NREND,IOUT+3)
C             IL=MOD(I-1,4)+1
C             CALL GRJMPS (ZENANG(1),PRAT(I,1),IL+1)
C             DO 110 J=1, IANG
C                 CALL GRDRWS (ZENANG(J),PRAT(I,J),IL+1)
110         CONTINUE
C
C     LEGENDE

```

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```

C      -----
      CALL GRJMPS (103.,1.2-IL*.15,IL+1)
      DO 120 X=103.,111.,4.0
      CALL GRDRWS (X,1.2-IL*.15,IL+1)
120    CONTINUE
      WRITE (NR(4:5),'(I2)') I
      CALL GRTXT (114.,1.2-IL*.15,7,NR)
      CALL GRTXTC (8,CSUBST(I))
130    CONTINUE
C
C      UNTERES BILD
C      -----
      CALL GRSCLC (4.,3.,21.,14.75)
      CALL GRSCLV (0.,0.,100.,1.2)
C
C      ACHSEN
C      -----
      CALL GRCHRC (0.5,0.,16)
      CALL GRAXS (13,'X=1,F=(4,0),I',12,'ZENITH ANGLE',1,' ')
      CALL GRAXS ( 9,'X=2,F=0,I',11,HIGHT,1,' ')
      CALL GRAXS (13,'Y=1,F=(3,1),I',1,' ',24,
      'RELATIVE PHOTOLYSIS RATE')
      CALL GRAXS ( 9,'Y=2,F=0,I',1,' ',1,' ')
      CALL GRCHRC (0.4,0.,16)
C
C      KURVEN
C      -----
      DO 230 I=IOUT+4,MIN(NREND,IOUT+7)
      IL=MOD(I-1,4)+1
      CALL GRJMPS (ZENANG(1),PRAT(I,1),IL+1)
      DO 210 J=1,IANG
      CALL GRDRWS (ZENANG(J),PRAT(I,J),IL+1)
210    CONTINUE
      WRITE (*,*)
C
C      LEGENDE
C      -----
      CALL GRJMPS (103.,1.2-IL*.15,IL+1)
      DO 220 X=103.,111.,4.0
      CALL GRDRWS (X,1.2-IL*.15,IL+1)
220    CONTINUE
      WRITE (NR(4:5),'(I2)') I
      CALL GRTXT (114.,1.2-IL*.15,7,NR)
      CALL GRTXTC (8,CSUBST(I))
230    CONTINUE
C
      CALL GRNXTF
1000 CONTINUE
      CALL GRENDE
C
      RETURN
      END
EOFPROG
#
cat $MOUNT/ich227.home3/ich301/Flux/Data/Air.069 > daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/NO2.Std >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/O3.017 >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Aer.Glo >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Aer.Nul >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Cloud.Nul >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Cloud.Nul >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Temp.069 >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Dataset.Wave >> daten
cat $MOUNT/ich227.home3/ich301/Flux/Data/Photolys.Std >> daten
#
touch $MOUNT/ich227.home3/ich301/Flux/fluxplt
touch $MOUNT/ich227.home3/ich301/Flux/fluxout
touch $MOUNT/ich227.home3/ich301/Flux/photmat
f90 -ef -l grgts,kfalib -o fluxrun flux.f
env FILENV=fluxenv assign -a $MOUNT/ich227.home3/ich301/Flux/fluxplt fort.8

```

```
env FILENV=fluxenv assign -a $MOUNT/ich227.home3/ich301/Flux/fluxout fort.9
env FILENV=fluxenv assign -a $MOUNT/ich227.home3/ich301/Flux/photmat fort.11
#
env FILENV=fluxenv fluxrun < daten 1>>listing 2>>errors
#if [ $? -ne 0 ]
#then
#   debug -d 9,9,2,2,1 -B -s fluxrun
#fi
#ls -lisa

flowview -Luc > cpuview

if [ -f fluxrun ]
then
    rm -f fluxrun
fi
if [ -f core ]
then
    rm -f core
fi
```


FLUX EXEC A

```

/*****
/*
/* Programm: FLUX EXEC
/*
/* Aufgabe : Wahlweiser Aufruf von FLUXSTRT und FLUX CRAY
/*
/* Version : 18.09.1991
/*
/* Autor   : Susanne Joehaenning
/*
*****/

'LIB ADD INST'
vmfclear
say "Program FLUX  Version: 18.09.1991, by S.Johaenning"
say
say "This program calculates the actinic flux of photons through the"
say "earth's atmosphere, starting at 100km altitude."
say "If desired, it also calculates the photodissociation rates of"
say "up to 70 species."

say "To continue hit the ENTER-key, otherwise press 'q'"
pull ant

if ant<>'Q' then do
  'CALL FLUXSTRT'
  vmfclear

  ant = 'A'
  'set emsg off'
  state 'WERTE FORTRAN A'
  if rc <> 0 then do
    say "File WERTE FORTRAN A does not exist !"
    say "Job FLUX cannot be started."
    say
    ant = 'Q'
  end
  state 'DATASET DATEN A'
  if rc <> 0 then do
    say "File DATASET DATEN A does not exist !"
    say "Job FLUX cannot be started."
    say
    ant = 'Q'
  end
  'set emsg on'
  if ant <> 'Q' then do
    say "Now all input data are specified and you may start the"
    say "program by pressing the ENTER-key, otherwise type 'q'."
    pull ant
  end

  if ant <> 'Q' then do
    say "The output files will be sent to your reader list:"
    say "  The printer output is on file FLUXOUT OUTPUT."
    say "  The plotter output is on file FLUXPLT CARDS."
    say "  The file PHOTMAT OUTPUT is a compressed list of the"
    say "  altitudinal and zenith angle dependencies of the"
    say "  photodissociation rates."
    say "  The listing of the program itself will be found on file"
    say "  FLUX LISTING."
    say "  The protocol of the run will be found on file FLUX_Sxx "
    say "  FLUX_Sxx OUTPUT"
    say "For further handling of these datafiles see the ZAM-manuals."
    say
    say "Press ENTER to continue."
    pull ant
    say "Starting ..."
    'CRAY FLUX'
    say "Job staged to the Cray"
  end
end
end

```

FLUXSTRT FORTRAN A

```

C*****
C**
C** Programmpaket: FLUXSTRT
C**
C** Aufgabe: Erstellen der INCLUDE-Dateien WERTE FORTRAN und
C**          DATASET DATEN fuer den CRAY-Job FLUX.
C**
C** Aufruf : CALL FLUXSTRT
C**
C** Autor  : Susanne Johaenning   ICH318      19.08.1991   (1.0)
C**
C** geaendert: 09.06.93   (S. Huber-Thives)   (2.0)
C**          15.10.93   (E-P. Roeth)         (2.1)
C**          20.04.94   (S. Huber-Thives)     (2.2)
C**
C*****

C*****
C**
C** Bemerkung: Das Unterprogramm GETMAST stammt aus der Instituts-
C**            bibliothek, es ruft die Execs MASTLIST und EXDEL
C**            auf, die auf ICH308 191 stehen.
C**
C*****

C*****
C**
C** Hauptprogramm: FLUXSTRT
C**
C** Aufgabe: Hauptmenue und Ablaufsteuerung
C**
C*****

PROGRAM FLUXSTRT

IMPLICIT NONE

LOGICAL wexist, dexist, ende
CHARACTER ant

ende=.FALSE.

C***** solange nicht QUIT *****
C***** zeige Menue, lese Menuepunkt und fuehre aus *****

DO WHILE (.NOT.ende)
  CALL CLS
  INQUIRE (FILE='/WERTE FORTRAN A', EXIST=wexist)
  INQUIRE (FILE='/DATASET DATEN A', EXIST=dexist)
  WRITE (*,*)
  WRITE (*,*) 'F L U X S T R T   Version 2.2 vom 20.04.1994'
  WRITE (*,*)
  IF (wexist) THEN
    WRITE (*,*) 'WERTE   FORTRAN A exists'
  ELSE
    WRITE (*,*) 'WERTE   FORTRAN A does not exist'
  END IF
  IF (dexist) THEN
    WRITE (*,*) 'DATASET DATEN   A exists'
  ELSE
    WRITE (*,*) 'DATASET DATEN   A does not exist'
  END IF
  WRITE (*,*)
  WRITE (*,*) 'Please choose one of the following points:'
  WRITE (*,*)
  WRITE (*,*) 'W: (Re)Specify steering parameters '//
  .      '(WERTE FORTRAN)'
  WRITE (*,*) 'D: (Re)Specify input data set'

```

```

WRITE (*,*)
WRITE (*,*) 'S: Start CRAY-Job FLUX or quit'
CALL ILCHAR ('S', ant, 0)
IF (ant.EQ.'W') THEN
  CALL SPECW
ELSE IF (ant.EQ.'D') THEN
  CALL SPECW
ELSE IF (ant.EQ.'S') THEN
  ende=.TRUE.
ELSE
  WRITE (*,*) 'The choice ', ant, ' does not exist !'
  WRITE (*,*) 'Please try again'
  CALL PRESS
END IF
END DO
END

C*****
C**
C** Subroutine: SPECW
C**
C** Aufgabe: Zusammenstellen der Steuerdaten in WERTE FORTRAN
C**
C** Aufruf : CALL SPECW
C**
C** geaendert : 28.05.1993 (S. Huber-Thives)
C**
C*****

SUBROUTINE SPECW

IMPLICIT NONE

REAL      dalti
PARAMETER (dalti=0.)
INTEGER   diup, diphot, diflux, diplotd, diplotp, diwavoc,
.         diznplt, dihigh, dihs, dityp, dloopa, dloope, dnotdef,
.         didobs, difile
PARAMETER (diup=1, diphot=1, diflux=0, diplotd=0, diplotp=0,
.         diznplt=0, dihigh=0, dihs=1, dityp=2, dloopa=-10,
.         dloope=9, diwavoc=0, dnotdef=0, didobs=0, difile=0)

REAL      phi, alti, datm, zeit, zengrd, wavea, wavee, bodtemp,
.         balb, dobson
INTEGER   iup, iphot, iflux, iplotd, iplotp, iznplt,
.         ihigh, ihs, ityp, loopa, loope, iwavoc, notdef,
.         idobs, ifile, ios

1 FORMAT (A)
2 FORMAT (A,A)
3 FORMAT (A,F5.2)

C***** Oeffnen der Datei *****

OPEN (UNIT=1, IOSTAT=ios, FILE='/WERTE FORTRAN A')

C***** Rechnungstyp *****

CALL CLS
WRITE (*,*) 'Now you have to specify the steering parameters for',
.         ' the Cray-job FLUX'
WRITE (*,*)
WRITE (*,*) 'Choose type of calculation:'
WRITE (*,*) '1: For a given location, date and time'
WRITE (*,*) '2: For a given solar zenith angle (default)'
WRITE (*,*) '3: A loop over several rays to get a zenith angle',
.         ' dependence'
WRITE (*,*) 'Now give the number of your choice:'
ityp=dityp
CALL ILESE (ityp)
WRITE (1,1) 'C      TYPE OF CALCULATION'

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        WRITE (1,1) 'C      1: FOR A GIVEN LOCATION AND DATE'
WRITE (1,1) 'C      2: FOR A ZENITH-ANGLE (DEFAULT)'
WRITE (1,1) 'C      3: LOOP OVER SEVERAL RAYS'
WRITE (1,*) '      ITYP=', ityp
IF (ityp.NE.1 .AND. ityp.NE.2 .AND. ityp.NE.3) ityp=dityp

C***** Berechnungsdaten *****

WRITE (*,*) 'Specify the following data:'

IF (ityp.EQ.1) THEN
  WRITE (*,*) 'Latitude: (NO DEFAULT)'
  CALL RLESE (phi)
  WRITE (1,*) '      PHI=', phi
  WRITE (*,*) 'Altitude (km): (DEFAULT=0)'
  alti=dalti
  CALL RDLESE (alti)
  WRITE (1,*) '      ALTI=', alti
  WRITE (*,*) 'Date (DD.MM): (NO DEFAULT)'
  CALL RLESE (datm)
  WRITE (1,3) '      DATM=', datm
  WRITE (*,*) 'Time (hh.ss): (NO DEFAULT)'
  CALL RLESE (zeit)
  WRITE (1,3) '      ZEIT=', zeit
ELSE IF (ityp.EQ.2) THEN
  WRITE (*,*) 'Which zenith angle do you want?'
  WRITE (*,*) 'Give the value in degree! (NO DEFAULT)'
  CALL RLESE (zengrd)
  WRITE (1,*) '      ZENGRD=', zengrd
ELSE IF (ityp.EQ.3) THEN
  WRITE (*,*) 'Loop-start is always -10'
  loopa=dloopa
  WRITE (1,1) 'C      LOOP-START IS ALWAYS -10'
  WRITE (1,*) '      LOOPA=', loopa
  WRITE (*,*) 'Loop-end (default= 9):'
  loope=dloope
  CALL ILESE (loope)
  WRITE (1,1) 'C      LOOP-END (DEFAULT= 9):'
  WRITE (1,*) '      LOOPE=', loope
END IF

C***** Bodentemperatur *****

CALL CLS
WRITE (*,*) 'Do you want to specify the surface temperature?'
WRITE (*,*) '1: yes, else: no'
notdef=dnotdef
CALL ILESE (notdef)
WRITE (1,1) 'C      CHANGE SURFACE TEMPERATURE 1: YES, ELSE: NO'
WRITE (1,*) '      NOTDEF=', notdef
IF (notdef.EQ.1) THEN
  WRITE (*,*) 'Which surface temperature do you want (in C)?',
    ' (NO DEFAULT)'
  CALL RLESE (bodtemp)
  WRITE (1,1) 'C      INPUT OF SURFACE TEMPERATURE IN C:'
  WRITE (1,*) '      BODTEMP=', 273+bodtemp
ELSE
  WRITE (1,1) 'C      INPUT OF SURFACE TEMPERATURE IN C:'
  WRITE (1,1) 'C      DUMMY VALUE'
  WRITE (1,1) '      BODTEMP=0'
END IF

C***** Bodenalbedo *****

WRITE (*,*) 'The ground albedo has to be specified.'
WRITE (*,*) 'A typical global average is 0.16.'
WRITE (*,*) 'Which (absolute) value do you want? (NO DEFAULT)'
CALL RLESE (balb)
WRITE (1,1) 'C      INPUT OF ALBEDO (NO DEFAULT):'
WRITE (1,*) '      BALB=', balb
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C***** Saeulendichte *****

WRITE (*,*) 'The O3 column density will be calculated from the'
WRITE (*,*) 'input profile.'
WRITE (*,*) 'If you want a different density, press 1.'
WRITE (*,*) 'Then the profile will be shifted by a constant'
WRITE (*,*) 'factor to match your choice.'
idobs=didobs
CALL ILESE (idobs)
WRITE (1,1) 'C      OZONE COLUMN DENSITY (DEFAULT:0)'
IF (idobs.EQ.1) THEN
  WRITE (*,*) 'Now enter the column density in Dobson units:'
  CALL RLESE (dobson)
  WRITE (1,*) '      DOBSON=', INT(dobson)
ELSE
  WRITE (1,1) '      DOBSON=0'
END IF

C***** Unterprogrammwahl *****

CALL CLS
WRITE (*,*) 'You can choose between 2 methodes to calculate the',
.         ' photon flux:'
WRITE (*,*) ' 1) by subroutine FLUXES (exact, but timeconsuming)'
WRITE (*,*) ' 2) by subroutine FLUX3B (fast, but only reasonable)'
WRITE (*,*) 'Give your choice now (FLUXES is the default):'
iup=diup
CALL ILESE (iup)
IF (iup.NE.1 .AND. iup.NE.2) iup=diup
WRITE (1,2) 'C      CALCULATION OF PHOTON FLUXES WITH 1: FLUXES',
.         ' (DEFAULT)'
WRITE (1,1) 'C                                     OR 2: FLUX3B'
WRITE (1,*) '      IUP=', iup
WRITE (1,1) 'C      NUMBER OF BEAMS'
IF (iup.EQ.1) THEN
  WRITE (1,1) '      NBEAM=10'
ELSE IF (iup.EQ.2) THEN
  WRITE (1,1) '      NBEAM= 1'
END IF

C***** Wellenlaengenbereich *****

WRITE (*,*) 'The wavelength regime is from 185nm to 730nm.'
WRITE (*,*) 'Do you want to decrease the wavelength regime?'
WRITE (*,*) 'Answer: 1: yes, else: no'
iwavoc=diwavoc
CALL ILESE (iwavoc)
WRITE (1,2) 'C      DECREASE OF WAVELENGTH REGIME: 1: YES, ELSE: NO'
WRITE (1,*) '      IWAVOC=', iwavoc
IF (iwavoc.EQ.1) THEN
  WRITE (*,*) 'Wavelength in nm for the starting point?'
  CALL RLESE (wavea)
  wavea=10*wavea
  WRITE (1,1) 'C      STARTING WITH WAVELENGTH'
  WRITE (1,*) '      WAVEA=', wavea
  WRITE (*,*) 'Wavelength in nm for the endpoint?'
  CALL RLESE (wavee)
  wavee=10*wavee
  WRITE (1,1) 'C      ENDING AT WAVELENGTH'
  WRITE (1,*) '      WAVEE=', wavee
ELSE
  WRITE (1,1) 'C      STARTING WITH WAVELENGTH (DUMMY VALUE)'
  WRITE (1,1) '      WAVEA=0'
  WRITE (1,1) 'C      ENDING AT WAVELENGTH (DUMMY VALUE)'
  WRITE (1,1) '      WAVEE=0'
END IF

C***** Ausgaben *****

C***** Aktinischer Fluss *****

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      CALL CLS
      WRITE (*,*) 'Now select the kind of output:'
      WRITE (*,*) 'The following outputs are provided:'
      WRITE (*,*)
      WRITE (*,*) 'A list of the actinic flux on the printer (1: yes,',
      .      ' else: no)'
      iflux=diflux
      CALL ILESE (iflux)
      WRITE (1,2) 'C      PRINT OF FLUXES: 1: YES, ELSE NO'
      WRITE (1,*) '      IFLUX=', iflux

C***** Hoehenabhaengigkeiten (PRINTER) *****

      IF ((wavea.EQ.wavee) .AND. (wavea.NE.0)) THEN
      WRITE (*,*) 'A plot on the printer for the altitudinal ',
      .      'dependencies'
      WRITE (*,*) 'of the total, upward, downward and direct beam.'
      WRITE (*,*) 'Answer: 1: yes, else: no'
      iplotd=diplotd
      CALL ILESE (iplotd)
      WRITE (1,2) 'C      PRINTER-PLOT OUTPUT OF FLUXES: 1: YES,',
      .      ' ELSE: NO'
      WRITE (1,*) '      IPLOTD=', iplotd
      END IF

C***** Photodissoziationsraten *****

      CALL CLS
      WRITE (*,*) 'Now you may choose whether or not you want to'
      WRITE (*,*) 'calculate the photodissociation rates:'
      WRITE (*,*) 'Answer: 0: no, else: yes'
      iphot=diphot
      CALL ILESE (iphot)
      WRITE (1,2) 'C      CALCULATION OF PHOTODISS. RATES: 0: NO,',
      .      ' ELSE: YES'
      WRITE (1,*) '      IPHOT=', iphot

      IF (iphot.NE.0) THEN

C***** Hoehenabhaengigkeiten *****

      IF ((ityp.EQ.1) .OR. (ityp.EQ.2)) THEN
      WRITE (*,*) 'The photodissociation rates will be printed ',
      .      'in any case.'
      WRITE (*,*) 'Do you want a plot of the altitudinal ',
      .      'dependences, too?'
      WRITE (*,*) 'Answer: 1: yes, else: no'
      iplotp=diplotp
      CALL ILESE (iplotp)
      WRITE (1,2) 'C      PLOTTER OUTPUT OF PHOTOLYSIS RATES: ',
      .      '1: YES, ELSE: NO'
      WRITE (1,*) '      IPLOTP=', iplotp

C***** Zenitwinkelabhaengigkeiten *****

      ELSE
      WRITE (*,*) 'The photodissociation rates will be printed ',
      .      'in any case.'
      WRITE (*,*) 'Do you want a plot of the zenith angle ',
      .      'dependences, too?'
      WRITE (*,*) 'Answer: 1: yes, else: no'
      iznplt=diznplt
      CALL ILESE (iznplt)
      WRITE (1,2) 'C      OUTPUT OF RELATIVE PHOTOLYSIS RATES VS.',
      .      'ZENITH ANGLE: 1: YES, ELSE: NO'
      WRITE (1,*) '      IZNPLT=', iznplt

C***** Hoehenangabe fuer Zenitwinkelabhaengigkeit *****

      IF (iznplt.EQ.1) THEN
      WRITE (*,*) 'For which altitude do you want the zenith ',
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.      'angle dependences?'
      WRITE (*,*) '(Give the altitude in km, default is 0 km)'
      ihigh=dihigh
      CALL ILESE (ihigh)
      WRITE (1,2) 'C      ALTITUDE FOR ZENITH ANGLE DEPENDENCY',
.      ' (PLOT) (DEFAULT = 0)'
      WRITE (1,*) '      IHIGH=', ihigh
      END IF

C***** PHOTMAT OUTPUT *****

      CALL CLS
      WRITE (*,*) 'Do you want a separate output of the'
      WRITE (*,*) 'photodissociation coefficients in a ',
.      'condensed form?'
      WRITE (*,*) '1: Yes, Else: no'
      ifile=difile
      CALL ILESE (ifile)
      WRITE (1,2) 'C      PHOTODISSOCIATION COEFFICIENTS IN A',
.      ' CONDENSED FORM (DEFAULT = 0)'
      WRITE (1,*) '      IFILE=', ifile

C***** Hoehensschrittweite *****

      WRITE (*,*) 'Now you shall select the altitudinal step for'
      WRITE (*,*) 'the photodissociation output.'
      WRITE (*,*) 'The start is always at ground level,',
.      ' (default is 1km).'
      ihs=dihs
      CALL ILESE (ihs)
      WRITE (1,2) 'C      ALTITUDINAL STEP FOR PHOTODISS. OUTPUT',
.      ' (DEFAULT = 1)'
      WRITE (1,*) '      IHS=', ihs
      END IF

      END IF
      CLOSE (1)
      END

C*****
C**
C** Subroutine: SPECD
C**
C** Aufgabe: Zusammenstellen der Daten in DATASET DATEN A.
C**
C** Aufruf : CALL SPECD
C**
C** geaendert : 20.04.1994 (S. Huber-Thives)
C**
C*****

      SUBROUTINE SPECD

      IMPLICIT NONE

      INTEGER maxstd, maxusr, maxds
      PARAMETER (maxstd=99, maxusr=9, maxds=12)

      INTEGER std, lauf, change, ios, usr
      LOGICAL da, show
      CHARACTER dataset(maxds)*20, datatex(maxds)*25,
.      stdusr(maxusr)*(40), stdset(0:maxstd)*40,
.      filen*21, datei*20, zeile*80

C***** Initialisieren der Datensatzfelder *****

      DATA datatex /'Air concentration profile',
2      'NO2 concentration profile',
3      'O3 concentration profile',
4      'Aerosol concentration 1',
5      'Aerosol concentration 2',

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6          'Cloud concentration 1',
7          'Cloud concentration 2',
8          'Wavelengths',
9          'Temperature profile',
A          'Extraterristic photonflux',
B          'Absorption spectra',
C          'Photolyses spectra'/

DATA stdusr / 'Roeth',
2          'Poppe',
3          'Mueller',
4          ' ',
5          ' ',
6          ' ',
7          ' ',
8          ' ',
9          ' '/

dataset( 1)='AIR STANDARD E'
dataset( 2)='NO2 STANDARD E'
dataset( 3)='O3 STANDARD E'
dataset( 4)='AEROSOL STANDARD E'
dataset( 5)='AEROSOL NULL E'
dataset( 6)='CLOUD STANDARD E'
dataset( 7)='CLOUD NULL E'
dataset( 8)='WAVE DATA E'
dataset( 9)='TEMP STANDARD E'
dataset(10)='FLUX DATEN E'
dataset(11)='ABSORPT SPECTRA E'
dataset(12)='PHOTODIS STANDARD E'

DO lauf=0,maxstd
  stdset(lauf)=' '
END DO
stdset( 0)='Combine your own data set (Default)'
stdset( 1)='Choose your own data set: name type disk'
stdset( 2)='Choose a standard data set'
cccc stdset(10)='ROETH TEST A'
cc   stdset(10)='ROETH MODEL A'
cc   stdset(11)='ROETH USSTAND A'
cc   stdset(12)='ROETH KIRUNA-W A'
cc   stdset(13)='ROETH AIRE-F A'
cc   stdset(14)='ROETH GAP-S A'
cc   stdset(15)='ROETH AIRE-H A'
cc   stdset(20)='POPPE JUEL90 A'
cc   stdset(30)='MUELLER JST_JO1D A'
cc   stdset(31)='MUELLER RST_JO1D A'
cc   stdset(32)='MUELLER JST_TABH A'
cc   stdset(33)='MUELLER RST_TABH A'
cc   stdset(34)='MUELLER JST_JNO2 A'
cc   stdset(35)='MUELLER RST_JNO2 A'

C***** Oeffnen von DATASET DATEN A *****

OPEN (UNIT=2, FILE='/ DATASET DATEN A')

C***** Angabe der Art der Datensatzzusammenstellung *****

30 CONTINUE
CALL CLS
WRITE (*,*) 'Now you have to specify the input data sets.'
WRITE (*,*) 'We offer you some standard data sets, but you can',
.      ' also combine your own.'
WRITE (*,*) 'Please choose one of the following numbers:'
WRITE (*,*)
lauf=0
DO WHILE ((lauf.LE.9) .AND. (stdset(lauf).NE.' '))
  WRITE (*,*) lauf, ': ', stdset(lauf)
  lauf=lauf+1
END DO
std=0

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CALL ILESE (std)

C***** Zusammenstellen der Datensaeetze *****

CALL CLS

C***** Kombinieren von einzelnen Daten *****

IF (std.EQ.0) THEN
  WRITE (*,*) 'You now have to combine your own data set'
  WRITE (*,*) 'We offer you a standard version, which you may',
  .
  . ' alter.'
  WRITE (*,*) 'If you want another data set than offered ',
  . 'press 1, else return.'
  WRITE (*,*) 'Specify your data set as follows: name type disk'
  WRITE (*,*)
  DO lauf=1,maxds,1

C***** Auswahl der Datensaeetze *****

  change=0
  IF (lauf.NE.8) THEN
    IF (lauf.EQ.4) CALL CLS
    IF (lauf.EQ.9) CALL CLS
    WRITE (*,*) datatex(lauf), ': ', dataset(lauf)
    WRITE (*,*) 'Do you want another data set?'
    CALL ILESE (change)
  END IF

  IF (change.NE.0) THEN
    WRITE (*,*) 'Specify your data set (fn fm ft):'
    CALL ILCHAR (dataset(lauf), dataset(lauf), 0)
  END IF

C***** KOPIEREN DER DATEN DES SATZES NACH DATASET DATEN *****

50  CONTINUE
    filen='/' // dataset(lauf)
    INQUIRE (FILE=filen, EXIST=da)
    IF (da) THEN
      OPEN (UNIT=3,FILE=filen,STATUS='OLD')
      READ (3,'(A)',IOSTAT=ios) zeile
      DO WHILE (ios.EQ.0)
        WRITE (2,'(A)') zeile
        READ (3,'(A)',IOSTAT=ios) zeile
      END DO
      CLOSE (UNIT=3)
    ELSE
      WRITE (*,*) 'Data set does not exist:'
      WRITE (*,*) 'Specify another data set (FN FM FT):'
      CALL ILCHAR (dataset(lauf), dataset(lauf), 0)
      GOTO 50
    END IF
  END DO

C***** Datensatz steht auf einer Datei *****

  ELSE IF ((std.EQ.1) .OR. (std.EQ.2)) THEN

C***** Auswahl einer nicht-STANDARD Datei *****

  IF (std.EQ.1) THEN
80  CONTINUE
    CALL CLS
    WRITE (*,*) 'Please give the name of the data set file:'
    WRITE (*,*) '          NAME TYPE DISK'
    WRITE (*,*) '* gives you a list of all files'
    WRITE (*,*) 'See CMS wildcard notation'
    READ (*,'(A)') datei
90  CONTINUE
    show=.TRUE.

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ios=0
CALL CLS
CALL GETMAST (datei, show, ios) ! Achtung: ICH3 MACLIB
IF (ios.NE.0) THEN
  IF (ios.EQ.1) THEN
    WRITE (*,*) 'Now choose your data set:'
    READ (*, '(A)') datei
    GOTO 90
  ELSE
    WRITE (*,*) 'Data set does not exist.'
    WRITE (*,*) 'Please try again !'
    CALL PRESS
    GOTO 80
  END IF
END IF
```

C***** Auswahl einer STANDARD Datei *****

ELSE

C***** Bestimmen des USERS *****

```
110  CONTINUE
      CALL CLS
      WRITE (*,*) 'The following users have standard data sets:'
      WRITE (*,*)
      lauf=1
      DO WHILE ((lauf.LE.9) .AND. (stdusr(lauf).NE.' '))
        WRITE (*,*) lauf, ': ', stdusr(lauf)
        lauf=lauf+1
      END DO
      WRITE (*,*)
      WRITE (*,*) 'Please make your choice now. '
      WRITE (*,*) 'Enter the number corresponding to the user.'
      WRITE (*,*) 'You can go back to the previous menu by'
      WRITE (*,*) 'entering -1. (Default)'
      usr=-1
      CALL ILESE (usr)
      IF (usr.EQ.-1) THEN
        GOTO 30
      ELSE IF ((usr.GE.lauf) .OR. (usr.LT.1)) THEN
        WRITE (*,*) 'There is no user corresponding to your number!'
        WRITE (*,*) 'Please try again !'
        CALL PRESS
        GOTO 110
      ELSE
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C***** Bestimmen des STANDARDS *****

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130  CONTINUE
      CALL CLS
      WRITE (*,*) 'The user ', stdusr(usr),
      WRITE (*,*) ' has the following standards:'
      WRITE (*,*)
      DO lauf=0,9
        IF (stdset(usr*10+lauf).NE.' ') THEN
          WRITE (*,*) lauf, ': ', stdset(usr*10+lauf)
        ELSE
          WRITE (*,*) lauf, ': Free space'
        END IF
      END DO
      WRITE (*,*)
      WRITE (*,*) 'Please make your choice now. '
      WRITE (*,*) 'Enter the number of your standard.'
      WRITE (*,*) 'You can go back to the previous menu'
      WRITE (*,*) 'by entering -1 (Default).'
      std=-1
      CALL ILESE (std)
      IF (std.EQ.-1) THEN
        GOTO 110
      ELSE IF ((std.GT.9) .OR. (stdset(usr*10+std).EQ.' ')) THEN
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        WRITE (*,*) 'There is no such standard data set !'
        WRITE (*,*) 'Please try again.'
        CALL PRESS
        GOTO 130
    ELSE
        std=usr*10+std
        datei=stdset(std) (1:20)
    END IF
END IF
END IF

C***** Oeffnen der Datei *****

        filen='/ '//datei
        OPEN (UNIT=3, FILE=filen, STATUS='OLD')

C***** Kopieren der Datei nach DATASET DATEN *****

C***** Einlesen des aktuellen Datensatzes *****
C***** * in 1. Spalte ==> Kommentar *****

        lauf=0
        READ (3,'(A20)',IOSTAT=ios) zeile
        DO WHILE (ios.EQ.0)
            IF (zeile(1:1).NE.'*') THEN
                INQUIRE (FILE='/ '//zeile(1:20), EXIST=da)

C***** Datensatz existiert ==> kopieren *****
C***** Datensatz existiert nicht ==> Abbruch *****

                IF (da) THEN
                    lauf=lauf+1
                    IF (lauf.EQ.14) WRITE (2,'(A)') 'PHOTODISSOZIATIONEN'
                    WRITE (*,*) 'Copying data from ', zeile(1:20)
                    OPEN (UNIT=4, FILE='/ '//zeile(1:20), STATUS='OLD')
                    READ (4,'(A)',IOSTAT=ios) zeile
                    DO WHILE (ios.EQ.0)
                        WRITE (2,'(A)') zeile
                        READ (4,'(A)',IOSTAT=ios) zeile
                    END DO
                    CLOSE (UNIT=4)
                    READ (3,'(A20)',IOSTAT=ios) zeile
                ELSE
                    WRITE (*,*) 'Dataset ', zeile(1:20), 'does not exist !'
                    WRITE (*,*) 'Combination of DATASET DATEN terminated!'
                    WRITE (*,*) 'Please correct data set ', datei
                    CALL PRESS
                    ios=1
                END IF
            ELSE
                READ (3,'(A20)',IOSTAT=ios) zeile
            END IF
        END DO

        CLOSE (UNIT=3)

C***** Auswahl eines STANDARD-Datensatzes *****

C***** ungueltiger Menuepunkt *****

        ELSE
            WRITE (*,*) 'Your choice does not exist !'
            WRITE (*,*) 'Please try again !'
            CALL PRESS
            GOTO 30
        END IF

C***** Schliessen der erstellten Datei *****

        WRITE (2,*)

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        WRITE (2,*)
        CLOSE (UNIT=2)
        END

C*****
C**
C** Subroutine: CLS
C**
C** Aufgabe: Loeschen des Bildschirms.
C**
C** Aufruf : CALL CLS
C**
C*****

        SUBROUTINE CLS
        CALL OBEY ('CLRSCRN')
        END

C*****
C**
C** Subroutine: PRESS
C**
C** Aufgabe: Unterbrechen des Programmablaufs, bis die ENTER-Taste
C**          gedrueckt wird.
C**
C** Aufruf : CALL PRESS
C**
C*****

        SUBROUTINE PRESS

        IMPLICIT NONE

        CHARACTER ant

        WRITE (*,*)
        WRITE (*,*) 'Press <ENTER>-key to continue ...'
        CALL ILCHAR (' ', ant, 0)
        END

C*****
C**
C** Subroutine: ILCHAR
C**
C** Aufgabe: Einlesen einer Zeichenkette von der Tastatur. Wird nur
C**          die ENTER-Taste gedrueckt, so wird ein Defaultwert ange-
C**          nommen. Ferner kann gewaehlt werden, ob Kleinbuchstaben
C**          in Grossbuchstaben konvertiert werden sollen.
C**
C** Aufruf : CALL ILCHAR (dflt, ant, icode)
C**          mit:
C**          dflt : CHARACTER*(*), Defaultwert
C**          ant  : CHARACTER*(*), gelesener String
C**          icode: INTEGER, 0 : Konvertierung in Grossbuchstaben
C**                  sonst: keine Konvertierung
C**
C*****

        SUBROUTINE ILCHAR (dflt, ant, icode)

        IMPLICIT NONE

        INTEGER  icode
        CHARACTER dflt*(*), ant*(*)

        INTEGER  ios

        READ (5, '(A)', IOSTAT=ios) ant

        IF (ios.NE.0) THEN
            CLOSE (UNIT=5)
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OPEN (UNIT=5)
ant=dflt
END IF

IF (icase.EQ.0) CALL IGROSS (ant)
END

C*****
C**
C** Subroutine: IGROSS
C**
C** Aufgabe: Konvertieren einer Zeichenkette in Grossbuchstaben.
C**
C** Aufruf : CALL IGROSS (string)
C** mit:
C** string: CHARACTER*(*), String, der konvertiert werden
C** soll
C**
C*****

SUBROUTINE IGROSS (string)

IMPLICIT NONE

CHARACTER string* (*)

INTEGER laenge, i, j
CHARACTER kabc*26, gabc*26

DATA kabc /'abcdefghijklmnopqrstuvwxyz'/
DATA gabc /'ABCDEFGHIJKLMNOPQRSTUVWXYZ'/

laenge=LEN(string)

DO i=1,laenge
j=INDEX(kabc, string(i:i))
IF (j.GT.0) string(i:i)=gabc(i:i)
END DO
END

C*****
C**
C** Subroutine: ILESE
C**
C** Aufgabe: Einlesen einer INTEGER-Zahl mit Defaultwert.
C** Wird statt Eingabe eines Wertes nur die ENTER-Taste ge-
C** drueckt, so bleibt der Wert der Variablen erhalten.
C**
C** Aufruf : CALL ILESE (intzahl)
C** mit:
C** intzahl: INTEGER, eingelesene Zahl
C**
C*****

SUBROUTINE ILESE (intzahl)

IMPLICIT NONE

INTEGER intzahl

INTEGER ios

READ (5,*,IOSTAT=ios) intzahl

IF (ios.NE.0) THEN
CLOSE (UNIT=5)
OPEN (UNIT=5)
END IF
END

C*****

```

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```

C**                                     **
C** Subroutine: RLESE                                     **
C**                                     **
C** Aufgabe: Einlesen einer REAL-Zahl. Tritt hier ein Fehler auf, **
C**          z.B. es wird nur die ENTER-Taste gedrueckt, so wird der **
C**          Wert erneut abgefragt.                                     **
C**                                     **
C** Aufruf : CALL RLESE (rzahl)                                     **
C**          mit:                                     **
C**          rzahl: REAL, eingelesene Zahl                         **
C**                                     **
C*****
      SUBROUTINE RLESE (rzahl)

      IMPLICIT NONE

      REAL    rzahl

      INTEGER ios

      READ (5,*,IOSTAT=ios) rzahl

      DO WHILE (ios.NE.0)
        CLOSE (UNIT=5)
        OPEN (UNIT=5)
        WRITE (*,*) 'Please specify a value. There is NO DEFAULT !'
        READ (5,*,IOSTAT=ios) rzahl
      END DO
      END

C*****
C**                                     **
C** Subroutine: RDLESE                                     **
C**                                     **
C** Aufgabe: Einlesen einer REAL-Zahl mit Defaultwert.         **
C**          Wirt statt Eingabe eines Wertes nur die ENTER-Taste ge- **
C**          drueckt, so bleibt der Wert der Variablen erhalten.     **
C**                                     **
C** Aufruf : CALL RDLESE (rzahl)                                     **
C**          mit:                                     **
C**          rzahl: REAL, eingelesene Zahl                         **
C**                                     **
C** geaendert : 28.05.1993 (S. Huber-Thives)                     **
C**                                     **
C*****
      SUBROUTINE RDLESE (rzahl)

      IMPLICIT NONE

      REAL    rzahl

      INTEGER ios

      READ (5,*,IOSTAT=ios) rzahl

      IF (ios.NE.0) THEN
        CLOSE (UNIT=5)
        OPEN (UNIT=5)
      END IF
      END

C*****
C**                                     **
C** Unterprogramm aus der Institutsbibliothek                     **
C**                                     **
C** Aufgerufen werden ausserdem die Execs MASTLIST und EXDEL,     **
C** diese stehen auf ICH308 191.                                     **
C**                                     **
C*****
      SUBROUTINE getmast (datei, show, irc)

```

```

IMPLICIT none

C-----
C Das Unterprogramm ueberprueft, ob DATEI existiert.
C Enthaeft DATEI die Wildcart '*', so kann eine Liste aller entspre-
C chenden Dateien ausgegeben werden.
C Waehrend des Programmlaufs wird die Unit 18 fuer I/O gebraucht
C-----
C
C Parameter:
C   CHARACTER      datei*20          ! Input
C   Name der Datei
C
C   LOGICAL        show              ! Input
C   SHOW = .TRUE.  ==> Meldungen werden auf den Bildschirm
C                       ausgegeben
C   SHOW = .FALSE. ==> Meldungen werden nicht ausgegeben
C
C   INTEGER        irc              ! Output
C   IRC = 0 ==> DATEI existiert
C   1 ==> DATEI enthaelt Wildcart und es gibt Dateien, die
C       DATEI entsprechen
C   2 ==> Es gibt keine Datei, die DATEI entspricht.
C-----

C
C   INTEGER        ios, i, j
C   CHARACTER      ant, cmd*80, dat(5)*20
C   LOGICAL        quit

C
C Erstellen der Datei MASTER DATEIEN A mit dem Exec MASTLIST
C
C   cmd='mastlist '//datei
C   CALL obey (cmd, 0, ios)

C
C Wenn IOS ungleich 0 ist, so wurde keine Datei gefunden, der DATEI
C entspricht.
C
C   IF (ios .NE. 0) THEN
C     IF (show) THEN
C       WRITE (*,*) 'Die Datei existiert nicht! Neue Eingabe!'
C     ENDIF
C     irc = 2
C
C
C DATEI ist eine Wildcard. Es wird eine Liste der entsprechenden
C Dateien ausgegeben
C
C   ELSEIF (index(datei, '*') .GT. 0) THEN
C     irc = 1
C     IF (show) THEN
C       cmd='filedef 18 disk master dateien a' ! Eroeffnen der
C       CALL obey (cmd)                        ! Masterdatei
C       OPEN(18)                               !
C
C       WRITE (*,*) 'Folgende Dateien entsprechen der Wildcard:'
C
C
C   Ausgeben der Liste der Dateien
C
C     i = 1
C     READ (18, '(a)', iostat = ios) dat(i)
C     DO WHILE (ios .EQ. 0)
C       IF (i .EQ. 3) THEN
C         WRITE (*, '(1x,3(a20,9x))') (dat(i), i = 1,3)
C         i = 0
C       ENDIF
C     ENDIF

```

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```
        i = i + 1
        READ (18,'(a)', iostat = ios) dat(i)
    ENDDO
    i = i - 1
    CLOSE(18)
    IF (i.GT.0) WRITE (*,'(1x,3(a20,9x))') (dat(j), j = 1,i)
    WRITE (*,*)

    ENDIF
ELSE
    irc = 0
ENDIF

CALL obey('exdel master dateien a')

END
```


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