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Calculation Of Biologically Effective UV-B Radiation In Aquatic Systems

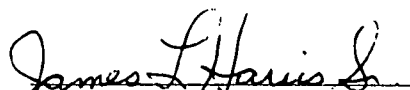
KAREN S. BAKER

SIO Ref. 79-1

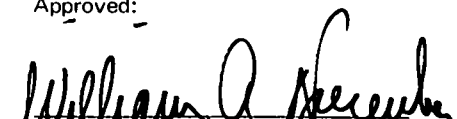
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I. Introduction

A computer program has been developed to aid in the investigation of the effects of solar middle-ultra violet (280-340nm) radiation upon aquatic ecosystems. This program permits a quantitative evaluation of radiation effects throughout the water column. It provides a basis not only for estimating the penetration of present levels of UV-B into various water types but also for estimating the penetration of increased UV-B which may result from changes in the ozone concentration of the stratosphere. Since aquatic organisms are more responsive to some wavelengths than to others, the biologically effective dose rate as a function of depth is calculated. The program performs these calculations in the following manner.

The computer program of A.E.S. Green (Green, *et al.* 1974; 1974a) calculates the middle-ultra violet (280-340nm) spectral radiation levels incident upon natural waters. The extraterrestrial solar irradiance is calculated using an analytic formula. This irradiance is propagated through the atmosphere using input variables such as ozone layer thickness.

The biologically effective irradiance is found using a weighting function $\epsilon(\lambda)$ that takes account of the wavelength dependency of biological action. Three different response functions are available (Green, *et al.* 1975) as shown in figure 1:

- 1) erythema (Komhyr and Machta, 1973)
- 2) plant (Caldwell, 1968)
- 3) DNA (Setlow, 1974)

The choice of a biological weighting function depends upon the organism being studied. We have worked with Setlow's DNA action spectra as representative of a basic action spectra for small ocean organisms. It should be noted that the choice of normalizing wavelength for $\epsilon(\lambda)$ is arbitrary.

The irradiance and the response weighted irradiance are taken through the water surface (Austin, 1974). Propagation through the water column is accomplished using

$$E(Z) = E(0) \cdot e^{-KZ} ,$$

where K is the diffuse attenuation coefficient for irradiance. Four possible sets of spectral K values are available (Smith and Baker, 1978c) as shown in figure 2:

- 1) for chl < .025 mg chl $\alpha \cdot m^{-3}$
- 2) for chl = .05 mg chl $\alpha \cdot m^{-3}$
- 3) for chl = 0.5 mg chl $\alpha \cdot m^{-3}$ (and high DOM)
- 4) for chl = 0.5 mg chl $\alpha \cdot m^{-3}$

The first case is derived from various clear water data (i.e. Sargasso Sea). The second and third cases were obtained using extrapolations of data from a cruise in the Gulf of Mexico. The third case was found to have an abnormally high amount of dissolved organic material (DOM) present. Case four is based on a model developed by Smith and Baker (1978b). As more complete K data are obtained, this program can be added to.

The dose defined by

$$\int E \cdot \epsilon \cdot e^{-KZ} d\lambda$$

and the total daily dose integrated over all sun angles defined by

$$\iint E \cdot \epsilon \cdot e^{-KZ} d\lambda d\theta ,$$

are calculated for each depth. For dosage calculations, times are input. These times must cover the day (i.e. 0600 to 1800) in order to get the total daily dose. Within the program, these times are changed to sun angles by subroutine EPHEM or THETA.

As an example of our use of this program (Smith and Baker, 1978c), figures 3 through 7 are given. Figure 3 shows how the biologically (DNA) weighted spectral irradiance ($E \cdot \epsilon$) changes with ozone concentration. This shape results from the sharp spectral drop in DNA response with increasing wavelength which is mirrored by an equally sharp drop in the spectral irradiance with decreasing wavelengths (figure 1). The standard atmosphere ($W_0 = 0.32\text{cm}$) example is taken to various depths in figure 4 using the clear water diffuse attenuation coefficients (case 1, figure 2). Using the diffuse attenuation coefficients from more productive waters (case 3, figure 2) gives the result in figure 5. It can be seen that the effective biological dose lies below 310nm in all these cases. Figures 6 and 7 then show the total dose as a function of the time of day for various ozone concentrations and various depths, respectively. The total daily dose for different ozone thicknesses and four water types is plotted as a function of depth in figure 8. Thus this figure shows the penetration of biologically effective radiation into various ocean waters. It can be seen that the rate of attenuation is strongly dependent upon water type.

This program is written in FORTRAN IV language. It has been run on an IBM 360 computer. The program uses about 114K bytes in its present form. Its name in the Visibility Laboratory files is UVT.

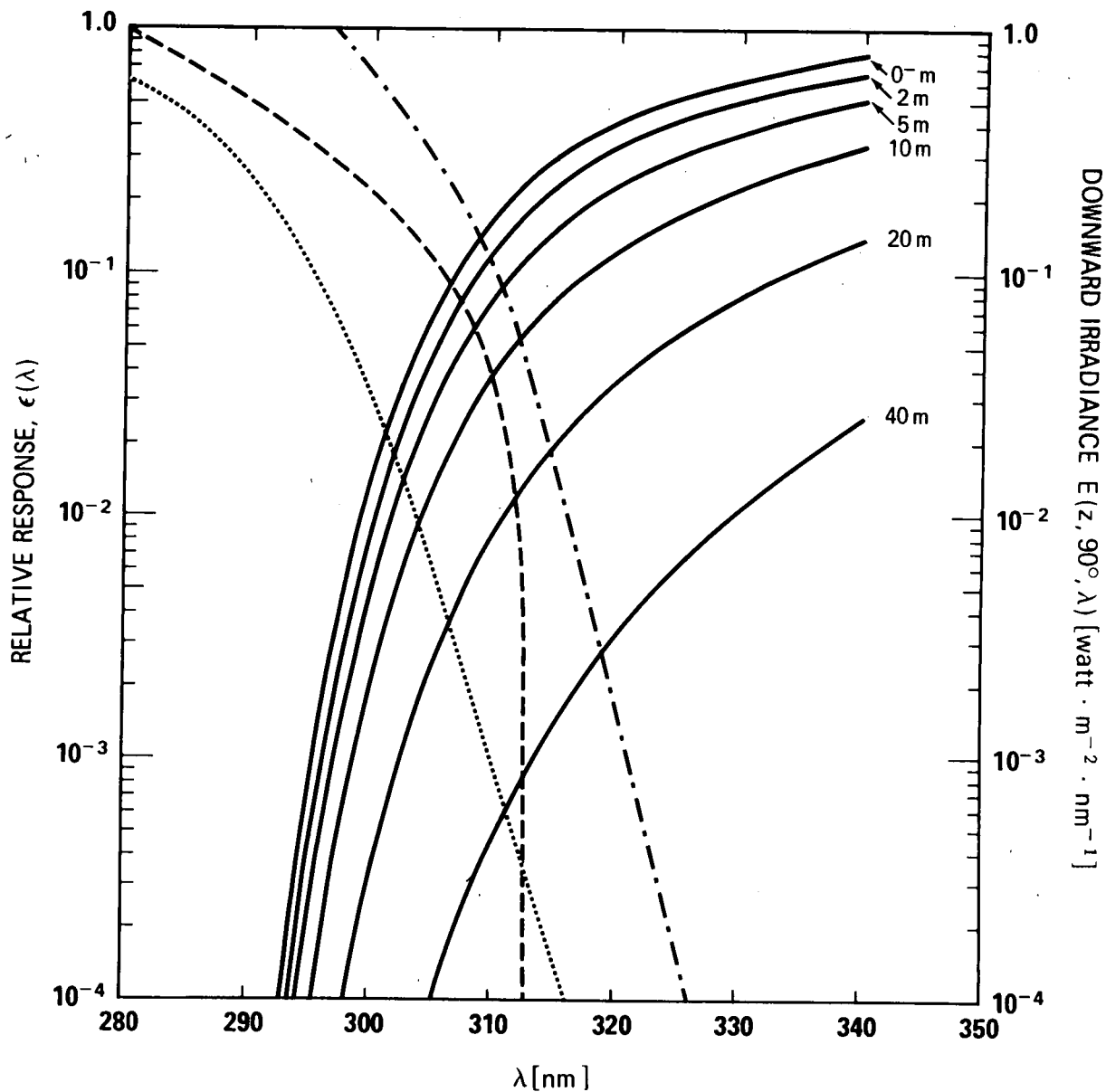


Fig. 1. Relative biological efficiencies $\epsilon(\lambda)$ for Setlow's (1974) average action spectrum for biological effects involving DNA (dotted curve), for Caldwell's (1971) generalized plant response action spectrum (dashed curve) and for erythema (Komhyr and Machta, 1973) response action spectrum (dot-dashed curve) versus wavelength. The relative response (left hand scale) is normalized to 1.0 at the wavelength of maximum response (see Green, et al., 1975 for analytical representation).

The solid curves (corresponding to the right hand scale) give the downward (noon) spectral irradiance, $E(z, 90, \lambda)$ [watt · m⁻² · nm⁻¹], at various depths, as a function of wavelength.

The product of $\epsilon_{DNA}(\lambda)$ and $E(z, 90, \lambda)$ gives the curves shown in Fig. 3.

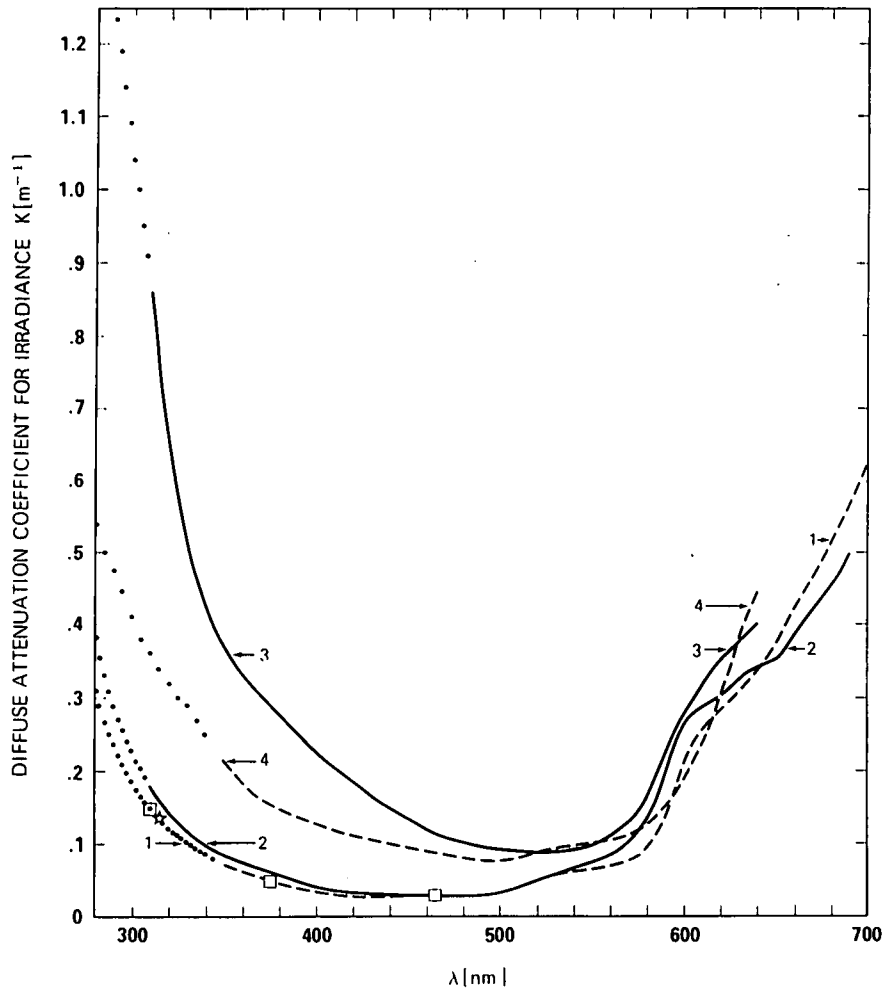


Fig. 2. Diffuse attenuation coefficient for downward irradiance, for various water types, as a function of wavelength.

Curve (1) for clearest open ocean waters where productivity is very low ($0.025 \text{ mg chl } \underline{a} \cdot \text{m}^{-3}$). The dashed curve is data from the Sargasso Sea ($25^{\circ}43'N$ $65^{\circ}41'W$) (Tyler, Smith, Morel, 1974 as given by Smith and Tyler, 1976, Table 4). The individual clear ocean water data points are: \square , Jerlov (1950, 1976) Eastern Mediterranean Sea; *, Calkins (1975) clear ocean water near Puerto Rico. The dotted portion of all curves are extrapolations from the actual data.

Curve (2) for clear ocean waters of low productivity ($0.05 \text{ mg chl } \underline{a} \cdot \text{m}^{-3}$) from the middle of the Gulf of Mexico ($26^{\circ}00'N$, $89^{\circ}00'W$) 22 October 1977. The solid line is data obtained using the underwater UV-Spectroradiometer and the Scripps Spectroradiometer. The dotted portion of the curve is an extrapolation of this data.

Curve (3) for moderately productive waters ($0.5 \text{ mg chl } \underline{a} \cdot \text{m}^{-3}$) and a relatively high concentration of dissolved organic material from coastal waters northwest of Tampa, Florida ($28^{\circ}38.5'N$, $83^{\circ}06.0'W$) 15 October 1977. The solid line is data obtained using the underwater UV-Spectroradiometer and the Scripps Spectroradiometer.

Curve (4) from the model of Smith and Baker (1977b) for moderately productive ocean waters ($0.5 \text{ mg chl } \underline{a} \cdot \text{m}^{-3}$).

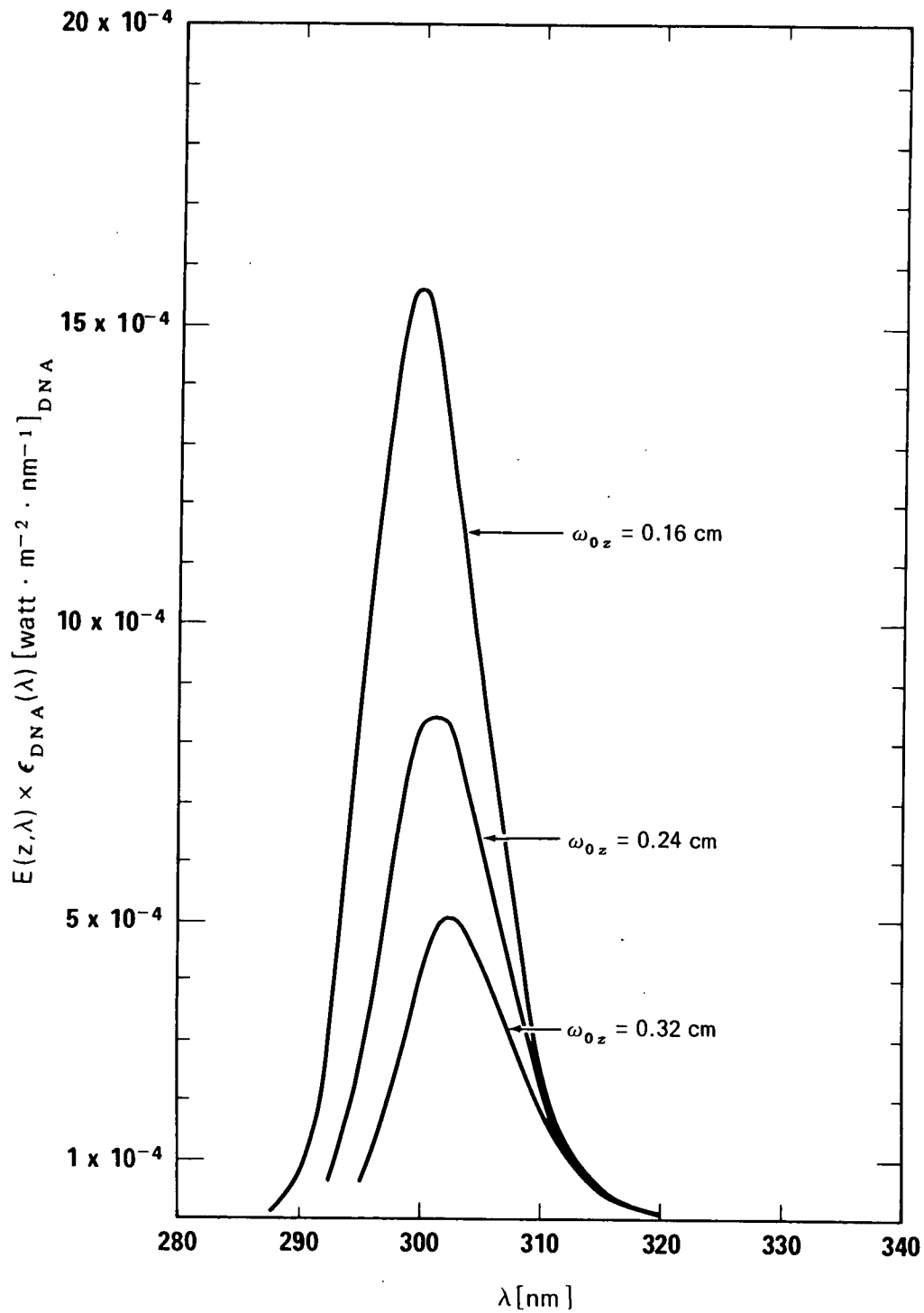


Fig. 3. Downward irradiance, $E_d(0^-, \theta, \lambda)$, times the Setlow DNA action spectrum (Setlow, 1974), $\epsilon_{DNA}(\lambda)$, for ozone thicknesses of $\omega_{oz} = 0.16, 0.24$ and 0.32 cm for noon at San Diego, California ($30^\circ\text{N } 120^\circ\text{W}$) on 15 June 1977.

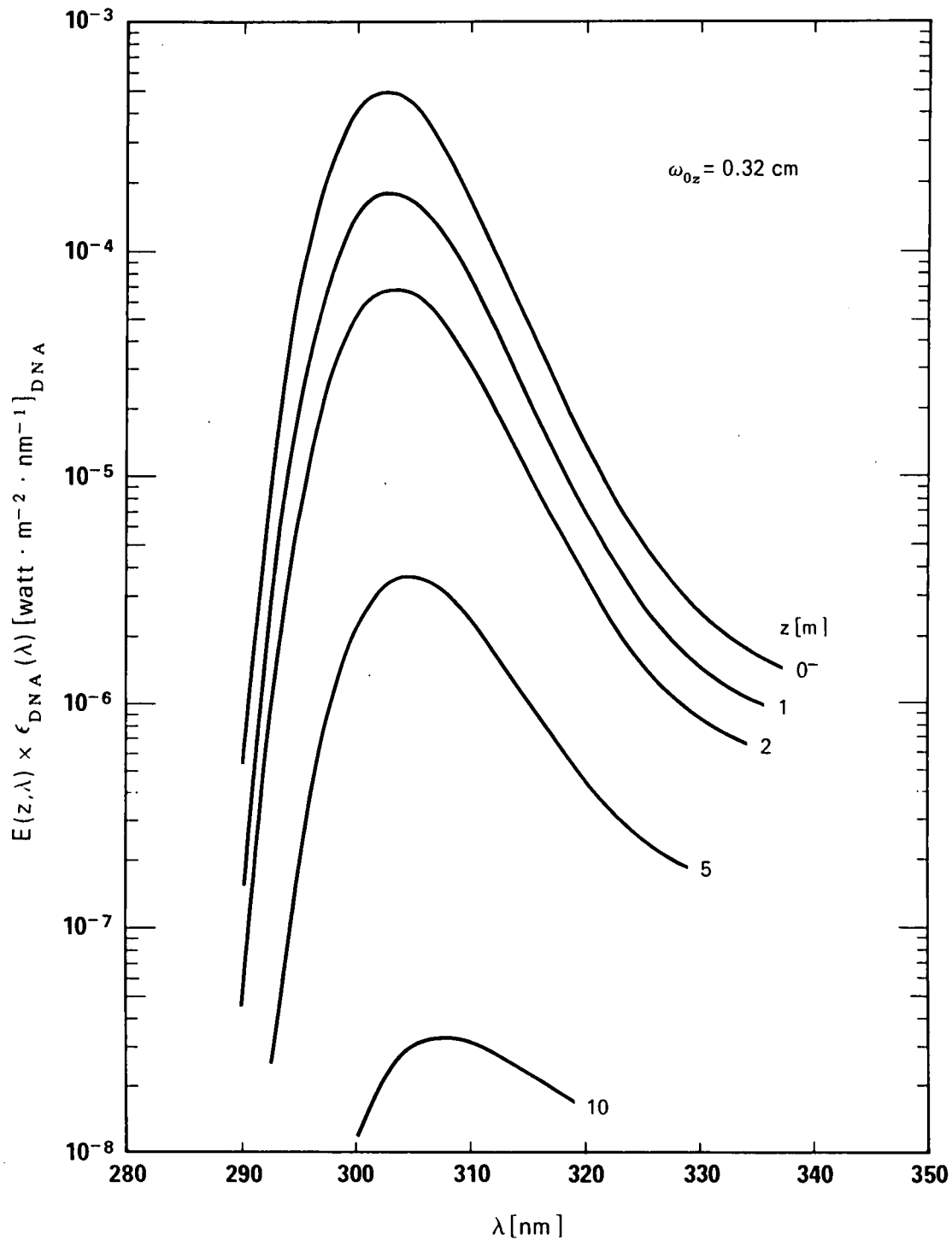


Fig. 4. Downward irradiance, $E_d(z, \theta, \lambda)$, times the Setlow DNA action spectrum, $\epsilon_{DNA}(\lambda)$, for a standard atmosphere ($\omega_{0z} = 0.32 \text{ cm}$) at various depths at San Diego, California on 15 June 1977. Data for clear ocean water, Curve (1) in Fig. 2.

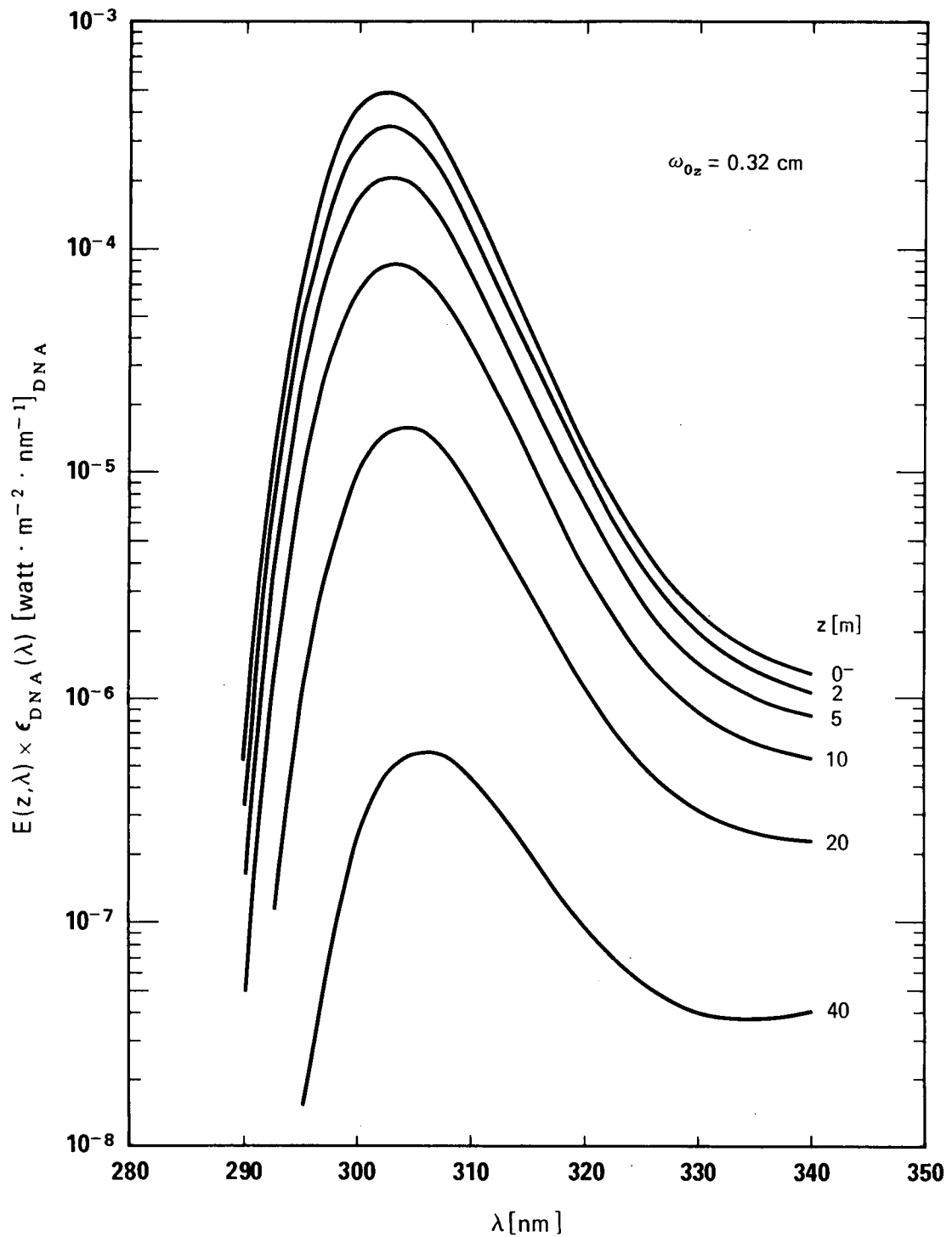


Fig. 5. $E_d(z, \theta, \lambda) \cdot \epsilon_{\text{DNA}}(\lambda)$ vs λ for $\omega_{0z} = 0.32 \text{ cm}$ at various depths at San Diego on 15 June 1977. Data for moderately productive coastal water with relatively high concentration of dissolved organic material, Curve (3) in Fig. 2.

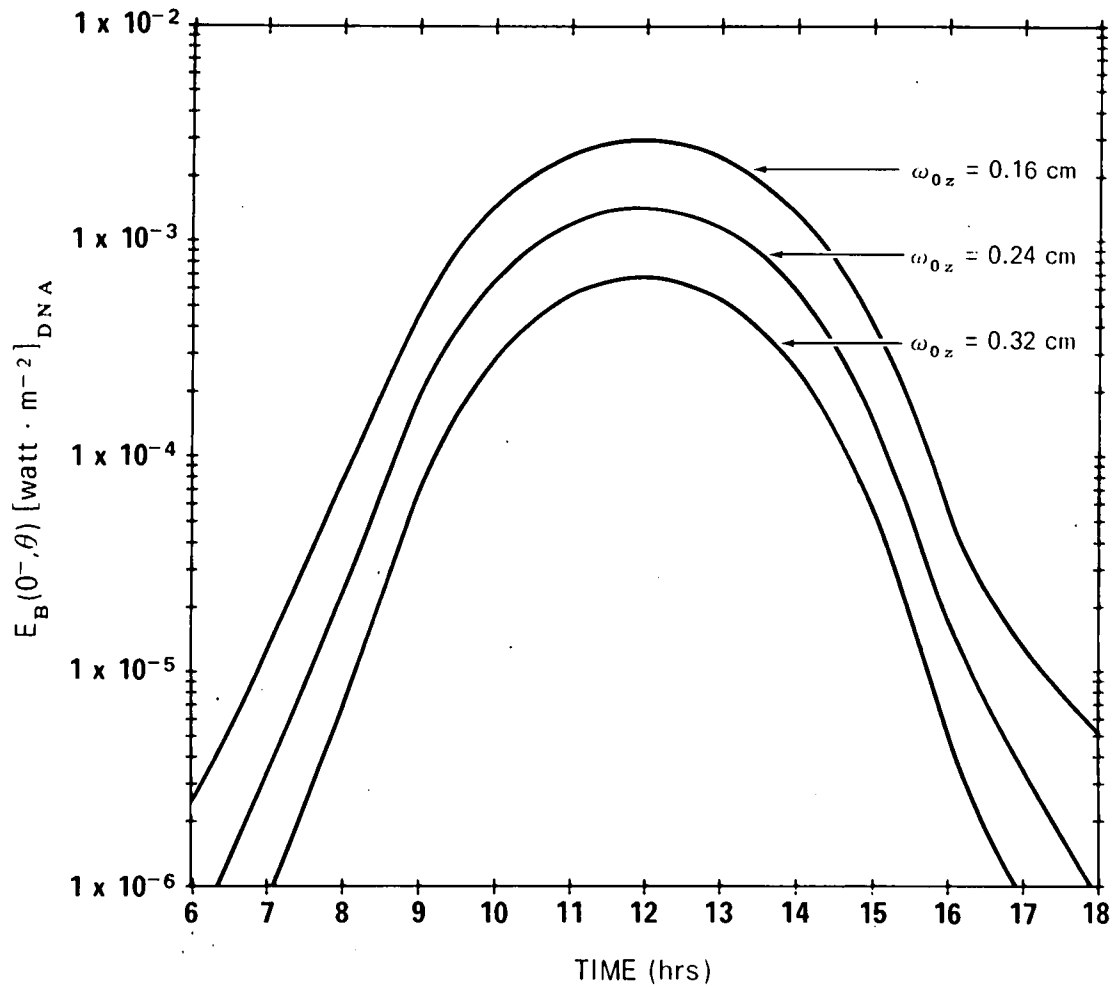


Fig. 6. Dose, $E_B(0^-, \lambda) [\text{watt} \cdot \text{m}^{-2}]_{\text{DNA}}$ (Setlow DNA action spectrum weighted), as a function of local time computed using Green's semi-empirical analytical formulae (Green, et al., 1974a) for 15 June 1977 at San Diego, California (30°N, 120°W) for $\omega_{0z} = 0.16, 0.24$ and 0.32 cm .

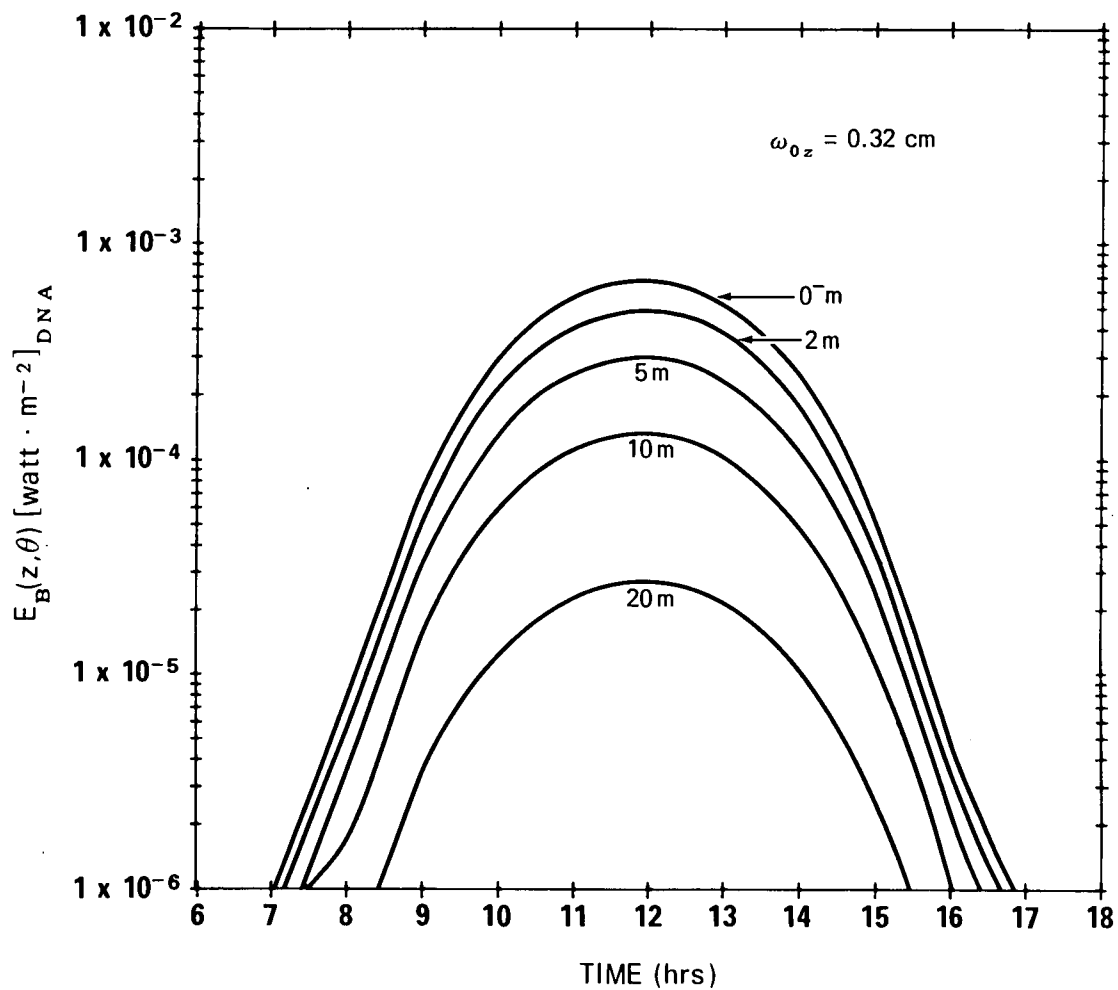


Fig. 7. $E_B(z, \lambda) [\text{watt} \cdot \text{m}^{-2}]_{\text{DNA}}$ vs local time for 15 June 1977 at San Diego for $\omega_{0z} = 0.32 \text{ cm}$ at various depths in clear ocean water, Curve (1) in Fig. 2. These data correspond to the data shown in Fig. 4.

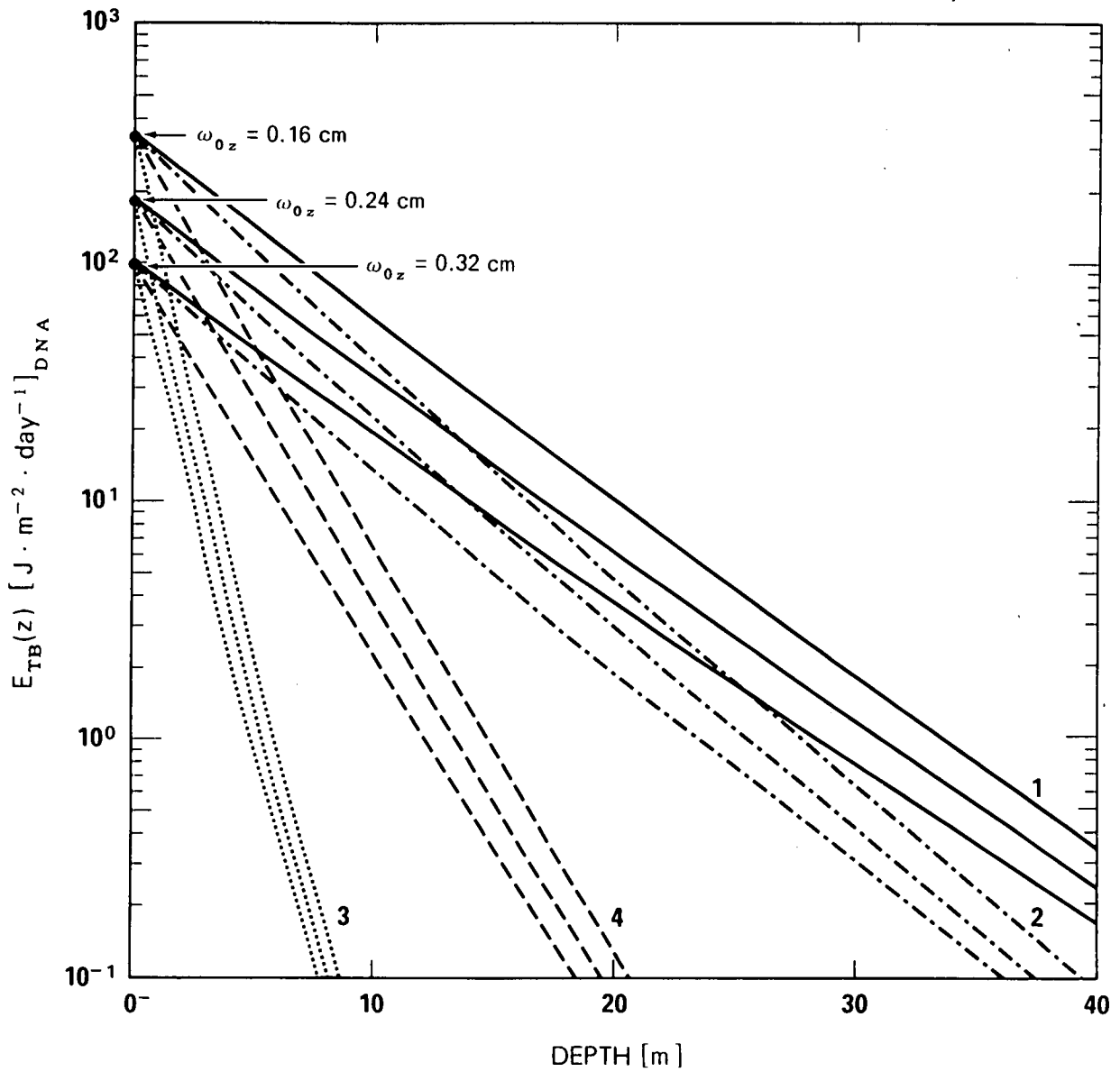
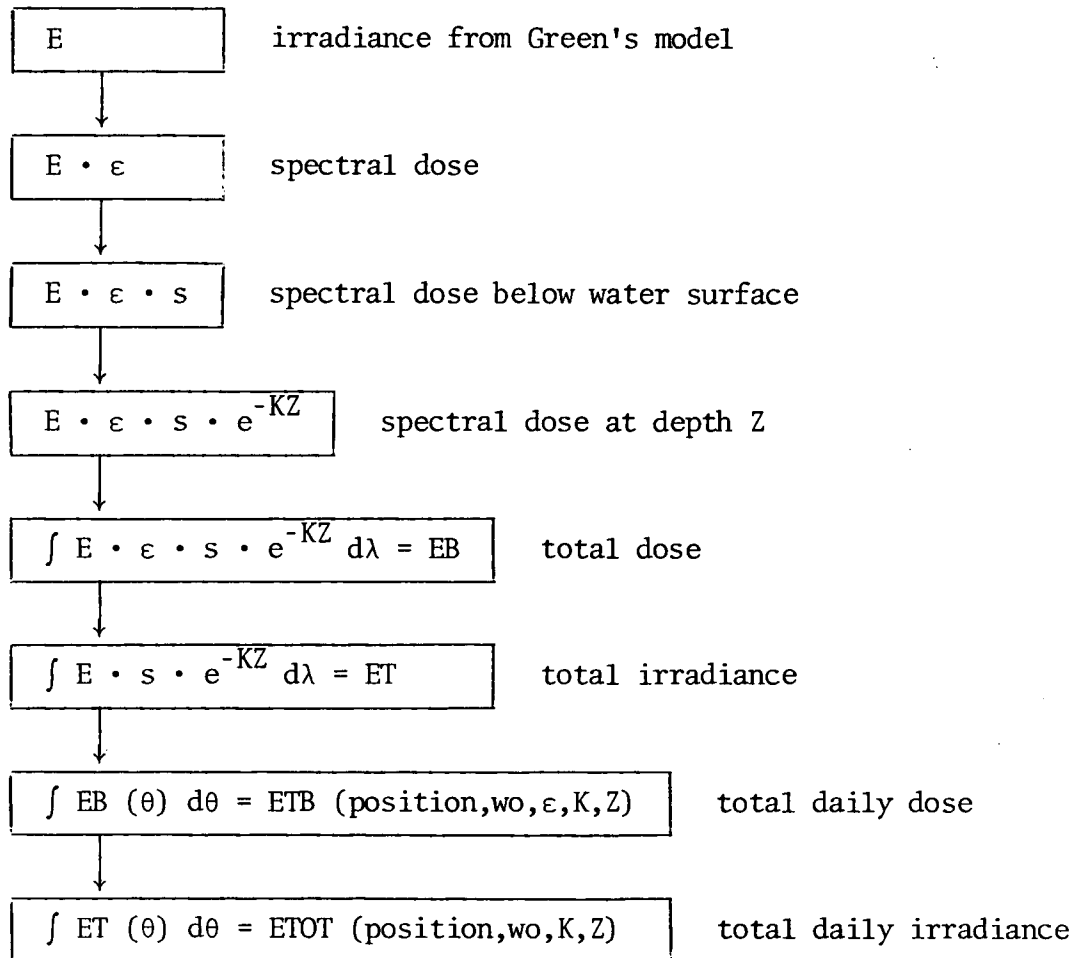
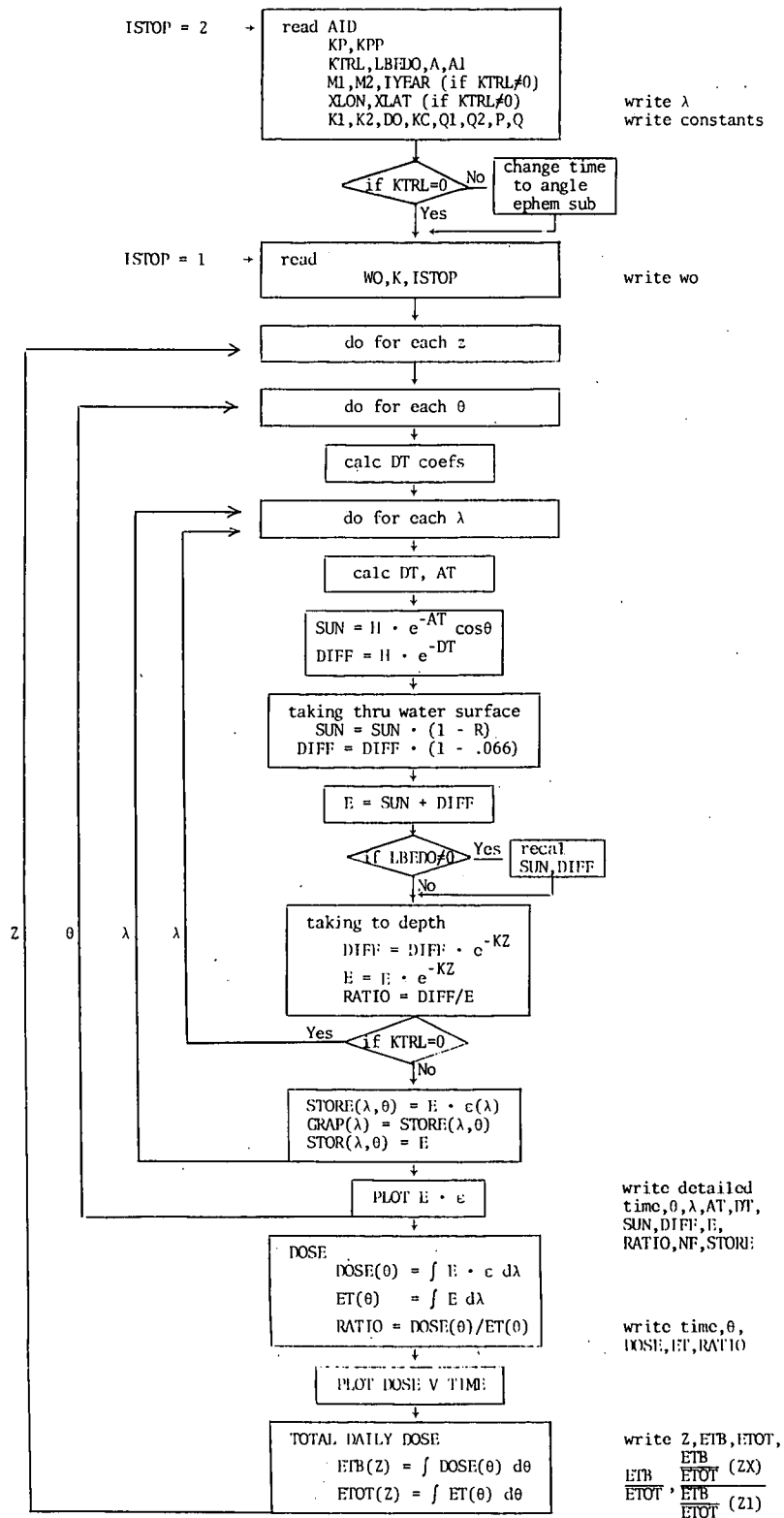


Fig. 8. Total daily dose, $E_{TB}(z)$ [$\text{J} \cdot \text{m}^{-2} \cdot \text{day}^{-1}$]_{DNA} (Setlow DNA action spectrum weighted), versus depth [m] for various water types and ozone thicknesses (ω_{oz}). The solid curves are for water type labeled (1) in Fig. 1, the ----- curves for water type labeled (2), the -.-.- curves for water type labeled (4), and the curves for water type labeled (3).

II. Program Overview



III. Program Flow



IV. Green's Model

E = irradiance = sun component + sky component

$$E = H [e^{-AT} \cos \theta + e^{-DT}]$$

H = extraterrestrial solar flux

AT = attenuation thickness along the direct path
(sum of contributions from ozone, air, aerosol)

DT = diffusing thickness due to multiple scattering

$$1) \quad H = 0.552 \left(1 + \frac{\lambda - 300.}{37.} \right)$$

λ = wavelengths between 280 - 340 nm

$$2) \quad DT = K1 \cdot e^{(KC \cdot \text{TAUO} - \frac{\lambda - 300}{D(\theta)})} \text{SEQ1} + K2 \cdot \text{SEQ2}$$

$$\text{SEQ1}(\theta) = 1 / \sqrt{1 - \frac{\sin^2(\theta)}{Q1}}$$

$$\text{SEQ2}(\theta) = 1 / \sqrt{1 - \frac{\sin^2(\theta)}{Q2}}$$

$$D(\theta) = DO \times \text{SPEQ}(\theta)$$

$$\text{SPEQ}(\theta) = 1 / \left[1 - \frac{\sin^P(\theta)}{Q} \right]^{1/P}$$

TAUO = ozone optical thickness at 300 nm = 10 · WO

parameters: K1, K2, DO, KC, Q1, Q2, P, Q

variables: WO ozone thickness in cm

θ solar zenith angle in degrees

$$3) \quad AT = \text{TAU(OZONE)} \cdot \text{SEQ(OZONE)} + \text{TAU(AIR)} \cdot \text{SEQ(AIR)} + \text{TAU(AEROSOL)} \cdot \text{SEQ(AEROSOL)} ,$$

$$\text{TAU(OZONE)} = \text{TAUO} \cdot e^{-(\lambda - 300)/8}$$

TAUO = ozone optical thickness at
300 nm = 10 · WO

$$\text{TAU(AIR)} = \text{TURBIDITY} \cdot (300/\lambda)^{4.267}$$

TURBIDITY = 1.218

$$\text{TAU(AEROSOL)} = \text{WPKP} \cdot (300/\lambda)^{0.5764}$$

WPKP = aerosol optical depth = .4111

assuming $i = (\text{ozone})$ or $i = (\text{air})$ or $i = (\text{aerosol})$

$$\text{SEQ}_i = 1 / \sqrt{1 - \frac{\sin^2(\theta)}{Q_i}}$$

$$Q_i = [1 + (Y_i/R)]^2$$

$$Y(\text{OZONE}) = 23.5 \text{ KM}$$

$$Y(\text{AIR}) = 5.69 \text{ KM}$$

$$Y(\text{AEROSOL}) = 1.0 \text{ KM}$$

$$R = 6371.23 \text{ KM} = \text{EARTH'S RADIUS}$$

V. Subroutines

- RESP - calculates response functions
FRENEL - calculates Fresnel reflectance at an interface
THETA - changes solar time to solar zenith angle (Green, 1974a)
or
EPHEM - changes solar time to solar zenith angle (Wilson, in preparation)

1) Subroutine RESP

Input variables:

- Y(I) - wavelengths (λ) in nanometers
K - indicates which response (erythema, plant, DNA)
to calculate (see KTRL in data deck Sec. VI)

Output variables:

- S(I) - response function (ϵ) at wavelengths Y(I)

The following equations are used:

- a. erythema (Komhyr and Machta, 1973)

$$\epsilon_e(\lambda) = \frac{4\alpha \exp(\lambda - \lambda_0)/\lambda_f}{\{1 + \exp[(\lambda - \lambda_0)/\lambda_f]\}} + \frac{\alpha'}{\{1 + \exp[(\lambda - \lambda_0')/\lambda_f']\}}$$

$$\begin{array}{ll} \alpha & = .9949 & \alpha' & = .04485 \\ \lambda_0 & = 296.5 & \lambda_0' & = 311.4 \\ \lambda_f & = 2.692 & \lambda_f' & = 3.130 \end{array}$$

b. plant response (Caldwell, 1968)

$$\epsilon_c(\lambda) = \alpha [1 - (\lambda/\lambda_c)^n] \exp - [(\lambda - \lambda_o)/\lambda_f]$$

$$\alpha = 2.618$$

$$\lambda_c = 313.3$$

$$n = 2$$

$$\lambda_o = 300$$

$$\lambda_f = 31.08$$

c. DNA (Setlow, 1974)

$$\epsilon_{DNA}(\lambda) = \exp \left\{ k \frac{1}{1 + \exp (\lambda - \lambda_o)/\lambda_f} - 1 \right\}$$

$$k = 13.82$$

$$\lambda_o = 310$$

$$\lambda_f = 9$$

2) Subroutine FRENEL

Input variables:

RI = 4./3. = air-water index of refraction (n)

THI = angle of incidence (i) in degrees

Output variables:

R = Fresnel reflectance at an interface

The following equations are used:

$$R = 1/2 \left| \frac{\sin^2 (i-j)}{\sin^2 (i+j)} + \frac{\tan^2 (i-j)}{\tan^2 (i+j)} \right|$$

$$j = \sin^{-1} \left(\frac{1}{n} \sin(i) \right)$$

at $i = 0^\circ$

$$R = \frac{(n-1)^2}{(n+1)^2}$$

at $i = 53.1^\circ$

$$R = \frac{1}{2} \left(\frac{n^2-1}{n^2+1} \right)^2$$

3) Subroutine THETA or EPHEM

a. THETA

Input variables:

M1,M2	month, day
X(3),X(4),X(5)	sidereal time (H,M,S) EST
X(6),X(7),X(8)	right ascension
X(9)	right ascension correction
X(10),X(11),X(12)	declination
X(13)	declination correction
X(14)	distance to the sun
XLON,XLAT	longitude and latitude in degrees

Output variable:

EL	sun angle in degrees
----	----------------------

b. EPHEM

Input variables:

M1,M2,IYEAR	month, day, year
XLON,XLAT	longitude, latitude in degrees
TIME	local standard time in hours

Output variables:

AS	sun azimuth angle in degrees
ZS	sun zenith angle in degrees

VI. Data Deck

The input data deck is read in using free format indicated by a '*' in the format statements.

1) form

```
ISTOP=2      AID
              KP,KPP
              KTRL,LBEDO,A,A1
              M1,M2,IYEAR (if KTRL#0)
              XLON,XLAT (if KTRL#0)
              K1,K2,DO,KC,Q1,Q2,P,Q
ISTOP=1      WO,K,ISTOP
```

2) explanation

```
AID          15 characters of data identification
KP,KPP       graphing option
  KP =0      no graph E * ε vs. wavelength
  #0         graph E * ε vs. wavelength
  KPP=0      no graph time vs. dose
  #0         graph time vs. dose
KTRL,LBEDO,A,A1
  KTRL=0     no dose calculation; uses sun angles TET
  1          dose using erythema response; uses TIME
  2          dose using plant response; uses TIME
  3          detailed 1
  4          detailed 2
  5          dose using DNA response; uses TIME
  6          detailed 5
LBEDO=0      standard albedo values .05
  =1         other than standard (DIFF,SUN calculation varied)
A            = albedo value at which flux to be calculated
A1           = albedo value at which flux is known
```

M1,M2,IYEAR (no need if KTRL=0)

M1 month

M2 day

IYEAR year

XLON,XLAT (no need if KTRL=0)

XLON longitude

XLAT latitude

K1,K2,DO... parameters used for calculating diffusing
thickness DT

K1 = 1.320

K2 = 0.873

DO = 7.700

KC = 0.2770

Q1 = 1.120

Q2 = 1.060

P = 2.000

Q = 1.148

WO,K,ISTOP

WO ozone thickness (in cm)

K diffuse attenuation coef. used to take irradiance
down through water column

= 0 K = 0

= 1 K for Chl < .025 (Smith & Tyler extrap.
Sargasso Sea)

= 2 K for Chl = .05 (22 OCT 77 RSS Station 8)

= 3 K for Chl = 0.5 but high DOM (22 OCT 77
RSS Station 3)

= 4 K for Chl = 0.5 (Smith & Baker model)

ISTOP explains next data card set

= 0 this is last set of data

= 1 goes back to read in (WO,K,ISTOP)

= 2 goes back to read in (AID)

3) example

C *** SAMPLE OF DATA FOLLOWS -

0 0
5 0
06 15 1977
120. 30.
1.32 .873 7.7 0.277 1.12 1.06 2. 1.148
.28 1 1
.28 2 1
.28 3 1
.28 4 2

0 0
2 0
12 15 1977
120. 30.
1.32 .873 7.7 0.277 1.12 1.06 2. 1.148
.28 1 1
.28 2 1
.28 3 1
.28 4 2

0 0
5 0
06 15 1977
120. 30.
1.32 .873 7.7 0.277 1.12 1.06 2. 1.148
.28 1 1
.28 2 1
.28 3 1
.28 4 2

0 0
2 0
12 15 1977
120. 30.
1.32 .873 7.7 0.277 1.12 1.06 2. 1.148
.28 1 1
.28 2 1
.28 3 1
.28 4 0
/E END OF JOB

VII. DATA Statements

The following information is put into data statements within the program itself since these variables are changed less often than those input using the data deck. The wavelengths and K values are rarely changed whereas the time (or angle) and the depths depend upon the individual user.

wavelengths to work at (280 to 340)

Y/

time (KTRL≠0)

TIME/ , NTIM/

angle (KTRL=0)

TET/ , NTET/

depths

ZD/ , NZD/

K values

XK1/

XK2/

XK3/

XK4/

```

C      *** PROGRAM IIVT                                IIVT 001
C-----IIVT 002
C      IIVT 003
C THE MIDDLE ULTRAVIOLET REACHING THE GROUND, BY GREEN, SAWADA, SHETTLER IIVT 004
C WEIGHTED AND TAKEN UNDERWATER, BY SMITH, BAKER IIVT 005
C IIVT 006
C-----IIVT 007
C IIVT 008
C INPUT IIVT 009
C (AID(I), I=1, 18) DATA IDENTIFICATION (18A4) IIVT 010
C KP, KPP IIVT 011
C KP=0 NO GRAPH F*R IIVT 012
C #0 GRAPH F*R IIVT 013
C KPP=0 NO GRAPH TIME V. DOSE IIVT 014
C #0 GRAPH TIME V. DOSE IIVT 015
C KTRL, LBEND, A, A1 IIVT 016
C KTRL=0 COMPUTATION REQUIRED AT THE ANGLES 'TET', NO DOSE IIVT 017
C CALCULATION IS REQUIRED. IIVT 018
C =1 COMPUTATION REQUIRED AT THE TIMES 'TIME', DOSE IIVT 019
C CALCULATION IS REQUIRED WITH ERYTHEMA SPECTRUM. IIVT 020
C =2 SAME AS KTRL=1, BUT WITH THE PLANT RESPONSE FUNCTION. IIVT 021
C =3 SAME AS KTRL=1 DETAILED OUTPUT REQUIRED. IIVT 022
C =4 SAME AS KTRL=2 DETAILED OUTPUT REQUIRED. IIVT 023
C =5 SAME AS KTRL=1, BUT WITH DNA RESPONSE IIVT 024
C =6 SAME AS KTRL=5 DETAILED OUTPUT REQUIRED. IIVT 025
C LBEND = 0, STANDARD ALBEND VALUES (0.05) IIVT 026
C = 1, ALBEND VALUES OTHER THAN STANDARD IIVT 027
C A = ALBEND VALUE AT WHICH THE FLUX TO BE CALCULATED IIVT 028
C A1 = ALBEND VALUE AT WHICH THE FLUX IS KNOWN IIVT 029
C M1, M2, IYEAR MONTH, DAY, YEAR (NO NEED IF KTRL=0) IIVT 030
C XLON, XLAT LONGITUDE AND LATITUDE (NO NEED IF KTRL=0) IIVT 031
C K1, K2, D0, K0, Q1, Q2, P, Q SEE THE FORMULA ABOVE FOR DT. IIVT 032
C W0, K, ISTOP IIVT 033
C W0 = OZONE THICKNESS (IN CM) IIVT 034
C K = K VALUES USED TO TAKE IRRADIANCE TO DEPTH IIVT 035
C K=0 K=0 IIVT 036
C =1 K EXTRAP FOR CLEAR WATERS IIVT 037
C =2 22OCT77 STATION R .05 CHL IIVT 038
C =3 22OCT77 STATION 3 0.5CHL (HIGH DOM) IIVT 039
C =4 SMITH AND BAKER MODEL 0.5CHL IIVT 040
C ISTOP = 0, STOP AFTER THIS RUN IIVT 041
C = 1, GO BACK TO NO.50 TO READ IN MORE DATA FOR IIVT 042
C 'W0, ISTOP' AFTER THIS RUN. IIVT 043
C = 2, GO BACK TO NO.1 TO READ IN MORE DATA FROM THE IIVT 044
C BEGINNING AFTER THIS RUN. IIVT 045
C-----IIVT 046
C DATA Y/ = WAVE LENGTH IN NM IIVT 047
C DATA TIME/ = EST IN HOURS (USED WHEN KTRL#0) IIVT 048
C DATA NTIME/= TOTAL NUMBER OF TIMES IIVT 049
C DATA TET/ = SOLAR ZENITH ANGLES (USED WHEN KTRL=0) IIVT 050
C DATA NTET/ = TOTAL NUMBER OF TET. IIVT 051
C DATA ZD/ = DEPTHS CALCULATED IIVT 052
C DATA NZD/ = TOTAL NUMBER OF DEPTHS IIVT 053
C-----IIVT 054
C-----IIVT 055

```

```

C
C
0001      *** SPECIFICATION STATEMENTS ***
0002      INTEGER*4 DTSCN/17/, NCCRD/5/, MLPRT/6/
0003      REAL*8 XLON,XLAT,TIMR,ZS,AS
0004      REAL*4 K1,K2,KC
C
0004      DIMENSION FTOT(20)
0005      DIMENSION XDR(2),YDR(2),ZDR(2)
0006      DIMENSION GRAP(25)
0007      DIMENSION XNAM1(9),YNAM1(4),XNAM2(2),YNAM2(3),ZNAM1(1)
0008      DIMENSION XK1(25),XK2(25),XK3(25),XK4(25),XK5(25)
0009      DIMENSION FTR(20),ZD(10),XK(25),STOR(25,36),FT(36)
0010      DIMENSION Y(25),AID(18), X(14),SEQN(36),SEQA(36),SEQP(36),SNO(
*36),CO(36),HL(25),SN(36),TIME(36),ANGLE(36),TFT(36),STORE(25,36)
*,R(25),DOSE(36)
C
C      *** INPUT FORMATS ***
0011      1000 FORMAT(18A4)
C
C      *** OUTPUT FORMATS ***
0012      301 FORMAT(' OZ=',F6.2,' K=',I3,' Z=',F7.3,/,
* ' PLOT TIME V DOSE NO(0),YES(1)')
0013      306 FORMAT(' TIME,DOSE-XMAX,XMIN,XINT,XLNLG(0,1),YMX,YMN,YINT,YLNLG')
0014      307 FORMAT(' OZ=',F6.2,' K=',F7.3,' Z=',F7.3, ' TIME=',F7.3,
* ' TIME=',F7.3,/, ' PLOT TIME V DOSE NO(0),YES(1)')
0015      311 FORMAT(' WL,*R-XMAX,XMIN,XINT,XLNLG(0,1),YMX,YMN,YINT,YLNLG')
0016      321 FORMAT(' NEW GRAPH NO(0),YES(1)')
0017      1001 FORMAT('1',18A4)
0018      1002 FORMAT(8F10.0)
0019      1003 FORMAT('0THE VALUES OF PARAMETERS FOR THE DIFFUSING THICKNESS DT
*RE '/' K1=',F6.3,' K2=',F6.3,' DO=',F6.3,' KC=',F6.4,' Q1=',
*F6.3,' Q2=',F6.3,' P=',F6.3,' Q=',F6.3/)
0020      1004 FORMAT('0',T50,'H*EXP(-AT)',T91,'GLOBAL'
*
* '/' TIME THETA ZL',8X,'AT',10X,'DT'
* ',5X,'*COS(THETA)',3X,'DIFFUSE',6X,'GLOBAL',3X,'DIFF/GLOR',3X,'NF'
*,3X,'RESPONSE')
0021      1005 FORMAT(F7.2,F8.2,F7.1,1P6E12.3,14,1PF12.3)
0022      1006 FORMAT(F7.2,F7.1,1P5E12.3,14,1PF12.2)
0023      1007 FORMAT('0',2X, 'IF NF IS NOT EQUAL TO ZERO, AT MUST BE INCREASED
*D BY NF*FNORM, WHEREF'/3X,'FNORM=', F8.2,' AND H*EXP(-AT)*COS(THETA)
*) MUST BE MULTIPLIED BY 10**(-NF*50)')
0024      1008 FORMAT('0EXTRATERRESTRIAL SOLAR FLUX H'/
*
* 'O ZL= ',13F6.1/' H= ',13F6.3/'O ZL= ',12F6.1/
* ' H= ',12F6.3/ ' (ZL IS THE WAVLENGTH
* N NM AND H IS IN WATTS PER M**2 PER NM)')
0025      1009 FORMAT('0E=H*(EXP(-AT)*COS(THETA)+EXP(-DT))'//
*11X,'H =EXTRATERRESTRIAL SOLAR FLUX'/
*11X,'AT =ATTENUATING THICKNESS ALONG THE DIRECT PATH'/
*11X,'DT =DIFFUSING THICKNESS DUE TO MULTIPLE SCATTERING'/
* '0THE FOLLOWING ANALYTIC FORMULAS ARE USED FOR AT AND DT'/
* 'O AT =TAU(OZONE)*SEQ(OZONE)+TAU(AIR)*SEQ(AIR)+TAU(AEROSOL)
**SEQ(AEROSOL)'/
*11X,'TAU(OZONE) =TAU*EXP(-(ZL-300)/8)'/
*11X,'TAU(AIR) =1.218*(300/ZL)**4.267'/
*11X,'TAU(AEROSOL) =0.411*(300/ZL)**0.5764'/

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      *11X,'SEQ(Q) =1/SQRT(1-SIN(THETA)**2/Q)'/          IVT 111
      *11X,'Q      =(1+Y/R)**2'/                      IVT 112
      *11X,'Y(OZONE) =23.5 KM'/                      IVT 113
      *11X,'Y(AIR)  =5.69 KM'/                      IVT 114
      *11X,'Y(AEROSOL) = 1 KM'/                    IVT 115
      *11X,'R      =EARTH RADIUS = 6371.23 KM'/      IVT 116
0026 1010 FORMAT(E10.0,I5,2F5.2)                    IVT 117
0027 1011 FORMAT('OZONE CONCENTRATION, WQ=',F6.3,' CM') IVT 118
0028 1012 FORMAT('      DT =K1*EXP(KC*TAU0-(ZL-300)/D(THETA))*SEQ1 + K2*SIIVT IVT 119
      *EQ2'/
      *11X,'TAU0   =OZONE OPTICAL THICKNESS AT 300 NM = 10*W(OZONE)'/ IVT 121
      *11X,'SEQ1  =1/SQRT(1-SIN(THETA)**2/Q1)'/      IVT 122
      *11X,'SEQ2  =1/SQRT(1-SIN(THETA)**2/Q2)'/      IVT 123
      *11X,'THETA =SOLAR ZENITH ANGLE'/            IVT 124
      *11X,'D(THETA)=DQ*SPEQ'/                      IVT 125
      *11X,'SPEQ  =1/(1-SIN(THETA)**P/Q)**(1/P)'/    IVT 126
      *11X,'THE PARAMETERS ARE K1,K2,D0,KC,Q1,Q2,P AND Q' ) IVT 127
0029 1013 FORMAT (2I3,2F4.0,1F7.3,2F4.0,1F6.2,1F7.2,2F4.0,1F5.2,1F7.2, IVT 128
      11F7.4)
0030 1014 FORMAT('MONTH=',I3,' DAY=',I3,' YFAR=',I4) IVT 130
0031 1015 FORMAT('LONGITUDE=',F10.6,' LATITUDE=',F10.6) IVT 131
0032 1016 FORMAT(5I5) IVT 132
0033 1017 FORMAT('D',T42,'H*EXP(-AT)'/ ' THETA ZL',RX,'AT',10X,'D1',6X IVT 133
      '*COS(THETA)',2X,'DIFFUSE',6X,'GLOBAL',4X,'NF',5X,'DIFF/GLOB') IVT 134
0034 1018 FORMAT('DROSE IN WATTS / M**2'/'O TIME',4X,'THETA',6X,'DROSE', IVT 135
      *9X,'FT',RX,'DROSE/FT') IVT 136
0035 1019 FORMAT(FR.2,F9.1,0P3E1Z.4) IVT 137
0036 1522 FORMAT('OK VALUES=',I2,'/','07 ',13F6.1/'OK ',13F6.3/'OZ ',12F6.1/ IVT 138
      *'OK ',12F6.3) IVT 139
0037 1523 FORMAT(' DEPTH=',F6.2) IVT 140
0038 1717 FORMAT(' ',3F15.3) IVT 141
0039 2000 FORMAT(' Z',9X,'ETH',9X,'FTOT',3X,'ETH/FTOT=R',4X,'R(Z)/R(O)') IVT 142
0040 2001 FORMAT(' ',F7.2,3X,4F12.4) IVT 143
C
      DATA Y/280.,282.5,285.,287.5,290.,292.5,295.,297.5,300.,302.5, IVT 145
      *305.,307.5,310.,312.5,315.,317.5,320.,322.5,325.,327.5,330., IVT 146
      *332.5,335.,337.5,340./ IVT 147
0042  DATA TIME/6.,7.,8.,9.,10.,11.,12.,13.,14.,15.,16.,17.,18.,15.3, IVT 148
      * 22*0./, NTIME/13/ IVT 149
0043  DATA TET/0.,30.,50.,70.,80.,85.,30*0./,NTET/6/ IVT 150
0044  DATA ZD/0.,1.,2.,5.,10.,20.,40.,3*0./,NZD/7/ IVT 151
C
      K CHOICES 1 TO 4 IVT 152
0045  DATA XK1/.310.,.290.,.268.,.249.,.237.,.223.,.209.,.198.,.186.,.175.,.166, IVT 153
      *.157.,.150.,.142.,.136.,.129.,.122.,.117.,.113.,.107.,.103.,.098.,.094, IVT 154
      *.090.,.0865/ IVT 155
0046  DATA XK2/.385.,.355.,.332.,.310.,.290.,.271.,.256.,.243.,.228.,.214.,.204, IVT 157
      *.192.,.180.,.170.,.162.,.153.,.146.,.139.,.132.,.126.,.120.,.115.,.110, IVT 158
      *.106.,.102/ IVT 159
0047  DATA XK3/1.43,1.37,1.33,1.29,1.24,1.19,1.145,1.09,1.045,1.00, IVT 160
      *.955.,.91.,.863.,.813.,.760.,.715.,.675.,.633.,.595.,.56.,.526.,.495.,.470, IVT 161
      *.445.,.420/ IVT 162
0048  DATA XK4/.54.,.52.,.50.,.49.,.475.,.46.,.445.,.427.,.41.,.395.,.38.,.37, IVT 163
      *.36.,.35.,.34.,.33.,.32.,.31.,.30.,.295.,.29.,.28.,.27.,.26.,.25/ IVT 164
C
      IVT 165

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C    GRAPH LABELS    IJVT 166
0049    DATA XNAM1/1HT,1HI,1HM,1HE,1H(,1HH,1HR,1HS,1H)/    IJVT 167
0050    DATA YNAM1/1HD,1HD,1HS,1HE/    IJVT 168
0051    DATA XNAM2/1HW,1HL/    IJVT 169
0052    DATA YNAM2/1HE,1H*,1HR/    IJVT 170
0053    DATA ZNAM1/1H /    IJVT 171
0054    DATA XOR/0.,0./,YOR/0.,0./,ZOR/0.,0./    IJVT 172
C    IJVT 173
C    IJVT 174
C-----IJVT 175
C-----IJVT 176
C    IJVT 177
C    IJVT 178
0055    CALL PAUSET(NTSCN)    IJVT 179
0056    NTIMEO=NTIME    IJVT 180
C-----IJVT 181
C    IJVT 182
C    EXTRATERRESTRIAL SOLLAR IRRADIANCEF    IJVT 183
C    IJVT 184
C-----IJVT 185
0057    DO 10 I=1,25    IJVT 186
0058    10 HL(I)=0.552*(1.+(Y(I)-300.)/37.)    IJVT 187
C-----IJVT 188
C    IJVT 189
C    CONSTANTS FOR DT    IJVT 190
C    IJVT 191
C-----IJVT 192
0059    QO=(1.+23.5/6371.23)**2    IJVT 193
0060    QA=(1.+5.69/6371.23)**2    IJVT 194
0061    QP=(1.+1./6371.23)**2    IJVT 195
0062    1 READ(NCCRD,1000) (AID(I),I=1,18)    IJVT 196
0063    WRITE (NLPRT,1001) (AID(I),I=1,18)    IJVT 197
0064    READ(NCCRD,*) KP,KPP    IJVT 198
0065    READ (NCCRD,*) KTRL,LBFD0,A,A1    IJVT 199
0066    NY=1    IJVT 200
C-----IJVT 201
C    IJVT 202
C    TIME INFO IF KTRL#0    IJVT 203
C    IJVT 204
C-----IJVT 205
0067    IF(KTRL.EQ.0) GO TO 20    IJVT 206
0068    READ (NCCRD,*) M1,M2,IYEAR    IJVT 207
0069    WRITE (NLPRT,1014) M1,M2,IYFAR    IJVT 208
0070    READ (NCCRD,*) XLON,XLAT    IJVT 209
0071    WRITE (NLPRT,1015) XLON,XLAT    IJVT 210
0072    NTIME=NTIMEO    IJVT 211
0073    GO TO 30    IJVT 212
C-----IJVT 213
C    IJVT 214
C    TIME INFO IF KTRL=0    IJVT 215
C    IJVT 216
C-----IJVT 217
0074    20 NTIME=NTET    IJVT 218
0075    NY=2    IJVT 219
0076    DO 25 K=1,NTFT    IJVT 220

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0077          25 ANGLE(K)=TET(K)                          IJVT 221
0078          30 DO 40 K=1,NTIME                          IJVT 222
0079          IF(KTRL.EQ.0) GO TO 35                      IJVT 223
0080          TIMB=TIME(K)                                IJVT 224
0081          CALL EPHEMS(XLON,XLAT,IYEAR,M1,M2,TIMB,AS,ZS) IJVT 225
0082          ANGLE(K)=ZS*180./3.141593                   IJVT 226
0083          AS=AS*180./3.141593                         IJVT 227
0084          IF(KTRL.EQ.6) WRITE(6,1717) TIMB,ANGLE(K),AS IJVT 228
C-----IJVT 229
C          IJVT 230
C          CONSTANTS FOR AT                               IJVT 231
C          IJVT 232
C-----IJVT 233
0085          35 T = 3.141593/180.0 *ANGLE(K)            IJVT 234
0086          CN(K)=COS(T)                                IJVT 235
0087          SN(K)=SIN(T)                                IJVT 236
0088          SNQ(K)=SN(K)**2                              IJVT 237
0089          SEQN(K)=1./SQRT(1.-SNQ(K)/QN)                IJVT 238
0090          SEQA(K)=1./SQRT(1.-SNQ(K)/QA)                IJVT 239
0091          SEQP(K)=1./SQRT(1.-SNQ(K)/QP)                IJVT 240
0092          40 CONTINUE                                  IJVT 241
0093          WRITE (NLPRT,1009)                           IJVT 242
0094          WRITE (NLPRT,1012)                           IJVT 243
0095          WRITE (NLPRT,1008) (Y(I),I=1,13),(HL(I),I=1,13),(Y(I),I=14,25),
          * (HL(I),I=14,25)                                IJVT 244
          IJVT 245
0096          READ (NCCRD,*) K1,K2,DO,KC,Q1,Q2,P,Q         IJVT 246
0097          WRITE (NLPRT,1003) K1,K2,DO,KC,Q1,Q2,P,Q     IJVT 247
0098          IF(KTRL.EQ.0) GO TO 45                       IJVT 248
0099          CALL RESP(Y,R,KTRL)                          IJVT 249
0100          45 FNORM=ALOG(10.**50)                       IJVT 250
0101          50 CONTINUE                                  IJVT 251
0102          READ(NCCRD,*) WN,K,ISTOP                     IJVT 252
0103          KQ=K                                         IJVT 253
0104          DO 79 L=1,25                                  IJVT 254
0105          IF(K.EQ.0) XK(L)=0.                          IJVT 255
0106          IF(K.EQ.1) XK(L)=XK1(L)                     IJVT 256
0107          IF(K.EQ.2) XK(L)=XK2(L)                     IJVT 257
0108          IF(K.EQ.3) XK(L)=XK3(L)                     IJVT 258
0109          IF(K.EQ.4) XK(L)=XK4(L)                     IJVT 259
0110          79 CONTINUE                                  IJVT 260
0111          WRITE (NLPRT,1011) WN                        IJVT 261
0112          WRITE (NLPRT,1522) KQ,(Y(I),I=1,13),(XK(I),I=1,13),(Y(I),I=14,25),
          *(XK(I),I=14,25)                                IJVT 262
          IJVT 263
0113          TAU0=10.*WN                                  IJVT 264
0114          WRITE (NLPRT,1007) FNORM                     IJVT 265
C          IJVT 266
C-----IJVT 267
C          IJVT 268
C          DO FOR EACH DEPTH                              IJVT 269
C          IJVT 270
C-----IJVT 271
0115          DO 201 L=1,NZD                               IJVT 272
0116          CALL NUPAGE                                  IJVT 273
0117          WRITE (NLPRT,1523) ZD(L)                     IJVT 274
C          IJVT 275

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C-----UVT 276
C                                     UVT 277
C      DO FOR EACH TIME                UVT 278
C                                     UVT 279
C-----UVT 280
0118      DO 60 K=1,NTIME                UVT 281
C      VALUES FOR DT                  UVT 282
0119      SEQ1=1./SQRT(1.-SNQ(K)/Q1)    UVT 283
0120      SEQ2=1./SQRT(1.-SNQ(K)/Q2)    UVT 284
0121      SPEQ=1./(1.-SN(K)**P/Q)**(1./P) UVT 285
0122      DTET=D0*SPEQ                 UVT 286
0123      IF(KTRL.EQ.1.OR.KTRL.EQ.2.OR.KTRL.EQ.5) GO TO 65 UVT 287
0124      IF(KTRL.GE.3) GO TO 55        UVT 288
0125      IF(K.NE.7) GO TO 718         UVT 289
0126      WRITE (NLPRT,1017)           UVT 290
0127      718 CONTINUE                 UVT 291
0128      GO TO 65                     UVT 292
0129      55 CONTINUE                  UVT 293
0130      IF(K.NE.7) GO TO 719         UVT 294
0131      WRITE (NLPRT,1004)           UVT 295
0132      719 CONTINUE                 UVT 296
C                                     UVT 297
C-----UVT 298
C                                     UVT 299
C      DO FOR EACH WAVELENGTH          UVT 300
C                                     UVT 301
C-----UVT 302
0133      65 DO 90 I=1,25,NY           UVT 303
0134      H=HL(I)                      UVT 304
C                                     UVT 305
C      TURBIDITY                       UVT 306
0135      WAKA = 1.218                 UVT 307
C                                     UVT 308
C      AEROSOL OPTICAL DEPTH = WP*KP   UVT 309
0136      WPKP = 0.4111                UVT 310
0137      AT=TAU0 *EXP(-(Y(I)-300.)/R.)*SEQ0(K)+WAKA *(300./Y(I))**4.267 UVT 311
      * *SEQ0(K)+WPKP *(300./Y(I))**0.5764*SEQ0(K) UVT 312
0138      DT= K1*EXP(KC*TAU0-(Y(I)-300.)/DTET)*SEQ1 + K2*SEQ2 UVT 313
0139      NF=0                          UVT 314
0140      80 IF(AT.LE.FNORM) GO TO 70   UVT 315
0141      NF=NF+1                       UVT 316
0142      AT=AT-FNORM                   UVT 317
0143      GO TO 80                      UVT 318
0144      70 SUN=H*EXP(-AT)*CN(K)       UVT 319
0145      DIFF=H*EXP(-DT)               UVT 320
C-----UVT 321
C                                     UVT 322
C      TAKING THRU WATER SURFACE       UVT 323
C                                     UVT 324
C-----UVT 325
0146      ANG=ANGLE(K)*3.141593/180.   UVT 326
0147      RI=4./3.                      UVT 327
0148      CALL FRENFL(ANG,RI,RZ)        UVT 328
0149      TS=1.-RZ                      UVT 329
0150      TD=1.-.066                    UVT 330

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0151      SUN=SUN*TS                                UVT 331
0152      DIFF=DIFF*TD                              UVT 332
0153      E=DIFF                                    UVT 333
0154      IF(NF.EQ.0) F=E+SUN                        UVT 334
0155      IF ( LBEDD .EQ. 0 ) GO TO 76                UVT 335
0156      RR= 3.33*WD*EXP(-(Y(I)-300.0)/9.8) +2.14*EXP((Y(I)-300.0)/187.0) UVT 336
0157      RR = 1.0 /RR                               UVT 337
0158      ALBD = (1.0-A1*RR)/(1.0 -A*RR)             UVT 338
0159      E = ALBD*E                                  UVT 339
0160      DIFF=ALBD*DIFF +(A-A1)*RR*SUN/(1.0 -A*RR) UVT 340
0161      DFFH= DIFF/H                               UVT 341
0162      IF ( DFFH .LE. 0.0) GO TO 77               UVT 342
0163      DT= -ALOG(DIFF/H)                           UVT 343
0164      GO TO 76                                    UVT 344
0165      77 DT = 1000.0                              UVT 345
0166      76 CONTINUE                                UVT 346
C-----UVT 347
C      UVT 348
C      TAKING TO DEPTH                               UVT 349
C      UVT 350
C-----UVT 351
0167      E=E*EXP(-XK(I)*ZD(L))                      UVT 352
0168      DIFF=DIFF*EXP(-XK(I)*ZD(L))                UVT 353
0169      RATIO=DIFF/E                                UVT 354
0170      IF(KTRL.NE.0) GO TO 85                      UVT 355
0171      IF(K.NE.7) GO TO 720                       UVT 356
0172      WRITE (NLPRT,1006) ANGLE(K),Y(I),AT,DT,SUN,DIFF,E,NF,RATIO UVT 357
0173      720 CONTINUE                                UVT 358
0174      GO TO 90                                    UVT 359
0175      85 STORE(I,K)=E*R(I)                        UVT 360
0176      GRAP(I)=STORE(I,K)                         UVT 361
0177      STOR(I,K)=E                                 UVT 362
0178      IF(KTRL.EQ.1.OR.KTRL.EQ.2.OR.KTRL.EQ.5) GO TO 90 UVT 363
0179      IF(K.NE.7) GO TO 722                       UVT 364
0180      WRITE (NLPRT,1005) TIME(K),ANGLE(K),Y(I),AT,DT,SUN,DIFF,F,RATIO, UVT 365
      * NF,STORE(I,K)                                UVT 366
0181      722 CONTINUE                                UVT 367
0182      90 CONTINUE                                UVT 368
C      END WAVELENGTH                                UVT 369
C      UVT 370
C-----UVT 371
C      UVT 372
C      PLOTTING WL V. F*R                            UVT 373
C      UVT 374
C-----UVT 375
0183      IF (KP.EQ.0) GO TO 310                      UVT 376
0184      WRITE(DTSCN,307) WD,KQ,7D(L),TIME(K),ANGLE(K) UVT 377
0185      READ(DTSCN,*) I                              UVT 378
0186      IF(I.EQ.0) GO TO 310                       UVT 379
0187      WRITE(DTSCN,321)                            UVT 380
0188      READ(DTSCN,*) I                              UVT 381
0189      IF (I.EQ.0) GO TO 309                      UVT 382
0190      KSYM=0                                       UVT 383
0191      WRITE(DTSCN,311)                            UVT 384
0192      READ(DTSCN,*) XMAX,XMIN,XINT,IX,YMAX,YMIN,YINT,IY UVT 385

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0193          CALL GRAPH                               UVT 386
0194          CALL GRAPH(XNAM2,XOR,2,YNAM2,YOR,3,ZNAM1,ZOR,1) UVT 387
0195          CALL GRAPHG(0.,0.,XMIN,XMIN,XMAX,XINT,IX,YMIN,YMIN,YMAX,YINT,IY) UVT 388
0196          309 CONTINUE                               UVT 389
0197          KSYM=KSYM+1                               UVT 390
0198          CALL GRAPH(Y,XMIN,XMAX,IX,GRAP,YMIN,YMAX,IY,25,2,KSYM) UVT 391
0199          310 CONTINUE                               UVT 392
0200          60 CONTINUE                               UVT 393
C            END TIME                                 UVT 394
C                                                    UVT 395
C-----UVT 396
C                                                    UVT 397
C            DOSE INTEGRATION                       UVT 398
C                                                    UVT 399
C-----UVT 400
0201          IF(KTRL.EQ.3.OR.KTRL.EQ.4.OR.KTRL.EQ.6) CALL NUPAGE UVT 401
0202          202 CONTINUE                               UVT 402
0203          IF(KTRL.EQ.0) GO TO 200                   UVT 403
0204          DO 120 K=1,NTIME                           UVT 404
0205          SUM=(STORE(1,K)+STORE(25,K))/6.           UVT 405
0206          SUM1=(STOR(1,K)+STOR(25,K))/6.           UVT 406
0207          CCC=0.6666666                             UVT 407
0208          DO 110 I=2,24                              UVT 408
0209          SUM=SUM+CCC*STORE(I,K)                   UVT 409
0210          SUM1=SUM1+CCC*STOR(I,K)                  UVT 410
0211          CCC=1.-CCC                                 UVT 411
0212          110 CONTINUE                               UVT 412
0213          XINT=2*(Y(25)-Y(1))/24                   UVT 413
0214          DOSE(K)=XINT*SUM                          UVT 414
0215          ET(K)=XINT*SUM1                           UVT 415
0216          120 CONTINUE                               UVT 416
0217          WRITE (NLPRT,1018)                        UVT 417
0218          DO 130 K=1,NTIME                           UVT 418
0219          RATIO=DOSE(K)/ET(K)                       UVT 419
0220          WRITE (NLPRT,1019) TIME(K),ANGLF(K),DOSE(K),ET(K),RATIO UVT 420
0221          130 CONTINUE                               UVT 421
C                                                    UVT 422
C-----UVT 423
C                                                    UVT 424
C            PLOTTING TIME V. DOSE                   UVT 425
C                                                    UVT 426
C-----UVT 427
0222          IF(KPP.EQ.0) GO TO 303                   UVT 428
0223          WRITE(DTSCN,301) W0,K0,ZD(L)              UVT 429
0224          READ(DTSCN,*) K                            UVT 430
0225          IF(K.EQ.0) GO TO 303                     UVT 431
0226          WRITE(DTSCN,321)                          UVT 432
0227          READ(DTSCN,*) K                            UVT 433
0228          IF (K.EQ.0) GO TO 315                    UVT 434
0229          KSYM=0                                    UVT 435
0230          CALL GRAPH                               UVT 436
0231          WRITE(DTSCN,306)                           UVT 437
0232          READ(DTSCN,*) XMAX,XMIN,XINT,IX,YMAX,YMIN,YINT,IY UVT 438
0233          CALL GRAPH                               UVT 439
0234          CALL GRAPH(XNAM1,XOR,9,YNAM1,YOR,4,ZNAM1,ZOR,1) UVT 440

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SCALAR MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
DTSCN	000294	NCCRN	000288	NLPRT	00028C	NTIME	000290	NIFT	000294
N7D	00029F	NTIME0	00029C	I	0002A0	QD	0002A4	QA	0002A8
QP	0002AC	KP	0002B0	KPP	0002B4	KTRL	0002B8	LRFDD	0002BC
A	0002C0	A1	0002C4	NY	0002C8	M1	0002CC	M2	0002D0
IYEAR	0002D4	K	0002D8	T	0002DC	K1	0002E0	K2	0002E4
DD	0002E8	KC	0002FC	Q1	0002F0	Q2	0002F4	P	0002F8
Q	0002FC	FNDRM	000300	WD	000304	ISTOP	000308	K0	00030C
L	000310	TAUN	000314	SFO1	000318	SEQ2	00031C	SF00	000320
DTFT	000324	H	000328	WAKA	00032C	WPKP	000330	AT	000334
DT	000338	NF	00033C	SUN	000340	DIFF	000344	ANG	000348
PJ	00034C	RZ	000350	TS	000354	TD	000358	F	00035C
RR	000360	ALRD	000364	DFEH	000368	RATIO	00036C	KSYM	000370
XMAX	000374	XMIN	000378	XINT	00037C	IX	000380	YMAX	000384
YMIN	000388	YINT	00038C	IY	000390	SIUM	000394	SIUM1	000398
CCC	00039C	INT	0003A0	R	0003A4	C	0003A8	XLON	0003AC
XLAT	0003B8	TMR	0003BC	AS	0003C8	ZS	0003D0		

ARRAY MAP

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
FTOT	0003D8	XOR	000428	YOR	000430	ZOR	000438	GRAP	000440
XNAM1	0004A4	YNAM1	0004C8	XNAM2	0004D8	YNAM2	0004E0	ZNAM1	0004FC
XK1	0004F0	XK2	000554	XK3	000588	XK4	00061C	XK5	000680
ETH	0006E4	ZD	000734	XK	00075C	STOR	0007C0	FT	0015D0
Y	001660	AID	0016C4	X	00170C	SF00	001744	SFOA	0017D4
SEQP	001864	SNO	0018F4	CO	001984	HL	001A14	SN	001A78
TIME	001B08	ANGLE	001B98	TFT	001C28	STORF	001C88	R	002AC8
DNSE	00282C								

SURPROGRMS CALLED

SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
PAUSET	0028BC	IRCON#	0028C0	EPHMS	0028C4	RESP	0028C8	NIIPAGF	0028CC
FRENEL	0028D0	GRAPH	0028D4	GRAPHT	0028D8	GRAPHG	0028DC	GRAPHP	0028E0
COS	0028E4	SIN	0028F8	SQRT	0028FC	ALOG	0028F0	FRXPI#	0028F4
FRXPR#	0028F8	EXP	0028FC						

LABEL MAP

LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION
1000	002DBA	301	002DC8	306	002F0F	307	002E50	311	002EAF
321	002EFO	1001	002F12	1002	002F24	1003	002F32	1004	002FCC
1005	003056	1006	003078	1007	003096	1008	003138	1009	0031D0
1010	003464	1011	003476	1012	0034A4	1013	00360A	1014	003644
1015	00366E	1016	003698	1017	0036A6	1018	003714	1019	003762
1522	003778	1523	00378A	1717	0037D0	2000	0037F2	2001	00381C
10	003850	1	0038C0	20	003A82	25	003A9F	30	003AC8
35	003868	40	003C24	45	003F0C	50	003F30	79	003F22
718	0041D8	55	0041DF	719	004208	65	004208	80	004300
70	004330	77	004510	76	00451C	720	004608	85	00460F
722	004724	90	004724	304	004892	310	004880	60	004880
202	004918	110	00498A	120	004A08	130	004A9C	315	0048FF
303	004C0C	121	004CA4	200	004D10	201	004D10	205	004D14

FORTRAN IV MODEL 44MFT/WW V 3.5 / MAIN44 / DATE 13 DEC 1978 TIME 0815.49 PAGE 0011
TOTAL MEMORY REQUIREMENTS 004F18 BYTES
COMPILER HIGHEST SEVERITY CODE WAS 0

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0001                    SUBROUTINE THETA(TIME,X,K,FL,XLAT,XLON)                    THETA001
C -----
C                    AZIMUTH AND ELEVATION ANGLES TO SUN                    THETA003
C                    SKY BRIGHTNESS PROGRAM                    THETA005
C -----
C                    *** SPECIFICATION STATEMENTS ***                    THETA008
0002                    DIMENSION TIME(36),X(14)                    THETA009
C -----
C                    RTD=57.29578                    THETA015
0003                    DECU=X(10)+(X(11)*60.+X(12))/3600.                    THETA016
0004                    IF(X(10).LT.0.) DECU=X(10)-(X(11)*60.+X(12))/3600.                    THETA017
0005                    RASH=X(6)+(X(7)*60.+X(8))/3600.                    THETA018
0006                    DECRH=X(9)/3600.                    THETA019
0007                    RACORH=X(13)/3600.                    THETA020
0008                    SIDT=X(3)+(X(4)*60.+X(5))/3600.                    THETA021
0009                    DISS=X(14)                    THETA022
0010                    ZSTH=TIME(K)+5.                    THETA023
0011                    DECD=DECU                    THETA024
0012                    4 DLD2=(XLAT-DECD)/(2.*RTD)                    THETA026
0013                    SLD2=(XLAT+DECD)/(2.*RTD)                    THETA027
0014                    SDL2=SIN(DLD2)                    THETA028
0015                    CDLD2=COS(DLD2)                    THETA029
0016                    SSLD2=SIN(SLD2)                    THETA030
0017                    CSLD2=COS(SLD2)                    THETA031
0018                    XHA=-XLON/15.+SIDT-RASH+ZSTH                    THETA032
0019                    BD2=((ZSTH*.00273791+XHA-(ZSTH/24.)*RACORH)*15.)/(2.*RTD)                    THETA033
0020                    F1=COS(BD2)*SDL2                    THETA034
0021                    E1=SIN(BD2)*CSLD2                    THETA035
0022                    HCMA=ATAN2(F1,E1)                    THETA036
0023                    F2=COS(BD2)*CDLD2                    THETA037
0024                    E2=SIN(BD2)*SSLD2                    THETA038
0025                    HCPA=ATAN2(F2,E2)                    THETA039
0026                    E3=SIN(HCMA)                    THETA040
0027                    F3=SIN(HCPA)*SDL2/CDLD2                    THETA041
0028                    BL=(ATAN2(F3,F2))*2.*RTD                    THETA042
0029                    EL=90.-BL-360.                    THETA043
0030                    IF(EL.LT.0.) EL=EL+360.                    THETA044
0031                    202 RETURN                    THETA045
C                    *** END SUBROUTINE THETA ***                    THETA046
C                    END                    THETA047
0033                    END                    THETA048

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SCALAR MAP									
SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
RTD	0000D8	DECU	0000D0	RASH	0000F0	DECRH	0000F4	RACRH	0000F8
SIDT	0000EC	DISS	0000F0	ZSTH	0000F4	K	0000F8	DFCD	0000FC
DL02	000100	XLAT	000104	SLD2	000108	SDLD2	00010C	CDLD2	000110
SSL02	000114	C.SLD2	000118	XHA	00011C	XL0N	000120	RD2	000124
F1	000128	E1	00012C	HOMA	000130	F2	000134	F2	000138
HCPA	00013C	E3	000140	E3	000144	HL	000148	EL	00014C

ARRAY MAP									
SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
TIME	000150	X	000154						

SUBPROGRAMS CALLED									
SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
SIN	000158	COS	00015C	ATAN2	000160				

LABEL MAP									
LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION
4	00033A	202	00048C						

TOTAL MEMORY REQUIREMENTS 000528 BYTES

COMPILER HIGHEST SEVERITY CODE WAS 0

FORTRAN IV MODEL 44MFT/WW V 3.5 / FRENEL / DATE 13 DEC 1978 TIME 0818.42 PAGE 0002

SCALAR MAP									
SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
THI	0000E0	THJ	0000E4	RI	0000E8	A	0000FC	S	0000F0
R	0000F4								

SUBPROGRAMS CALLED									
SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
ARSIN	0000F8	SIN	0000FC	TAN	000100				

LABEL MAP									
LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION
1	0002D8	2	00030E						

TOTAL MEMORY REQUIREMENTS 000388 BYTES

COMPILER HIGHEST SEVERITY CODE WAS 0

FORTRAN IV MODEL 44MFT/WW V 3.5 / RESP / DATE 13 DEC 1978 TIME 0818.54 PAGE 0002

SCALAR MAP									
SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
NLPRT	000118	K	00011C	I	000120	E	000124		

ARRAY MAP									
SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
Y	000128	S	00012C						

SUBPROGRAMS CALLED									
SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION	SYMBOL	LOCATION
IBCOM#	000130	EXP	000134						

LABEL MAP									
LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION	LABEL	LOCATION
1000	0001CE	1001	00020C	1002	00023F	1003	00025C	1005	000272
10	000390	300	0003A8	111	0003CC	100	00043A	110	0004CA
200	0004E0								

TOTAL MEMORY REQUIREMENTS 000688 BYTES

COMPILER HIGHEST SEVERITY CODE WAS 0

BATCH HIGHEST SEVERITY CODE WAS 0

// ACCESS SDSABS	08.19.14
// DELETE SDSABS(UVT)	08.19.15
IA321 DSNAME ERR - UVT	08.19.16
// CONDENSE SDSABS	08.19.16
//UVT EXEC LNKEDT(MAP,NOKEEP)	08.19.17

UVT
LINKAGE EDIT

13 DEC 1978 TIME 0819.17

LIST PHASE UVT,*
LIST INCLUDE UVT,L
LIST INCLUDE UVT00001,L
LIST INCLUDE UVT00002,L
LIST INCLUDE UVT00003,L
LIST AUTOLINK IRCOM#
LIST AUTOLINK EPHEMS
LIST AUTOLINK NUPAGE
LIST AUTOLINK GRAPH
LIST AUTOLINK COS
LIST AUTOLINK SQRT
LIST AUTOLINK ALOG
LIST AUTOLINK FRXP1#
LIST AUTOLINK FRXPR#
LIST AUTOLINK EXP
LIST AUTOLINK ATAN2
LIST AUTOLINK ARSIN
LIST AUTOLINK TAN
LIST AUTOLINK FIICS#
LIST AUTOLINK UNITAR#
LIST AUTOLINK IHCERRE
LIST AUTOLINK DARCS
LIST AUTOLINK DSQRT
LIST AUTOLINK DATAN
LIST AUTOLINK DSIN
LIST AUTOLINK DTAN
LIST AUTOLINK MSGTM
LIST AUTOLINK CHAR
LIST AUTOLINK PLNTP
LIST AUTOLINK XYS
LIST AUTOLINK IBANK2
LIST AUTOLINK SCREEN
LIST AUTOLINK IHCUNPT
LIST AUTOLINK IHCTRCH
LIST AUTOLINK CO
LIST AUTOLINK POINT
LIST AUTOLINK DV1827
LIST ENTRY

CRFATFD
CRFATFD
CRFATFD
CRFATFD
CRFATFD

CRFATFD

		UVT			13 DEC 1978		TIME 0819.17	
PHASE	TRANSFER ADDR.	LOCORE	HICORE	BLOCK NO.	ESD TYPE	LABEL	LOADED	REL-FACTOR
COMMON					COMMON	EPHEMC	008200	000058
COMMON					COMMON	RIFFFF	008258	000080
UVT	008ED8	008ED8	018R77	1384	CSECT	MAIN44E	008ED8	008ED8
					* ENTRY	MAIN44	008ED8	
					CSECT	THETA8	000DF0	000DF0
					* ENTRY	THETA	000DF0	
					CSFCT	FRENFL8	00F318	00F318
					ENTRY	FRENFL	00F318	
					CSECT	RFSPE8	00F6A0	00F6A0
					ENTRY	RESP	00F6A0	
					CSECT	BDAIRCOM	00FD28	00FD28
					ENTRY	IRCOM#	00FD28	
					* ENTRY	EXIT	00F9F8	
					ENTRY	ADCON#	00FF74	
					CSECT	EPHEM8E	011A60	011A60
					ENTRY	EPHEMS	011A60	
					CSFCT	NIIPAGE8	012DB0	012DB0
					ENTRY	NIIPAGE	012DB0	
					CSFCT	GRAPH8	013178	013178
					ENTRY	GRAPH	013178	
					ENTRY	GRAPHT	01321C	
					ENTRY	GRAPHG	013250	
					ENTRY	GRAPHP	013284	
					* ENTRY	GRAPHS	0131F8	
					CSECT	CPLNT	019408	019408
					CSECT	IHCSSCM	015400	015400
					ENTRY	COS	015400	
					ENTRY	SIN	01541C	
					CSECT	IHCSSORT	0155F0	0155F0
					ENTRY	SORT	0155F0	
					CSFCT	IHCALOG	015750	015750
					ENTRY	ALOG	015768	
					ENTRY	ALOG10	015750	
					CSECT	IHCFRXPI	015918	015918

				UVT	13 DEC 1978		TIME 0819.17	
PHASE	TRANSFER ADDR.	LOCORE	HICORE	BLOCK NO.	FSD TYPE	LABEL	LOADED	RFL-FACTOR
					ENTRY	FRXPI#	015918	
					CSECT	IHCERXPR	015880	015880
					ENTRY	FRXPR#	015880	
					CSECT	IHCSEXP	015020	015020
					ENTRY	EXP	015020	
					CSECT	IHCSTATN2	0150F8	0150F8
					ENTRY	ATAN2	0150F8	
					* ENTRY	ATAN	015F10	
					CSECT	IHCASCON	015FC8	015FC8
					ENTRY	AR SIN	015FDF	
					* ENTRY	ARCOS	015FC8	
					CSECT	IHCSTNCT	016100	016100
					ENTRY	TAN	0161F6	
					* ENTRY	QTAN	016378	
					* ENTRY	COTAN	016100	
					CSECT	BOAFINCS	016460	016460
					ENTRY	PAUSFT	016480	
					ENTRY	KCRORG#	017180	
					ENTRY	BUFORG#	017184	
					ENTRY	FI0CS#	016636	
					* ENTRY	NOECHO	016540	
					* ENTRY	ENCODE	016460	
					* ENTRY	DECODE	016460	
					* ENTRY	FI0CD#	016670	
					* ENTRY	ERECHO	016558	
					* ENTRY	IGNJCL	016484	
					* ENTRY	CORE	016460	
					ENTRY	FI0INT	016548	
					* ENTRY	ECHO	016540	
					* ENTRY	FIXRUFESZ	01721F	
					* ENTRY	FI0RST	0165F4	
					* ENTRY	RSTJCL	016486	
					* ENTRY	VDI0CS#	017190	
					* ENTRY	NFECHO	016564	
					CSECT	BOAUNITR	017230	017230
					ENTRY	UNITAR#	017230	
					CSECT	IHCERRMF	017340	017340
					ENTRY	IHCERRF	017366	
					ENTRY	IHCERRM	017370	

				UVT	13 DEC 1978		TIME 0819.17		
PHASE	TRANSFER ADDR.	LOCORE	HICORE	BLOCK NO.	ESD TYPE	LABEL	LOADFN	REF-FACTOR	
					* ENTRY	TSTMP	01735R		
					* ENTRY	TSTFRR	017340		
					* ENTRY	ERRMON	017370		
					CSECT	IHCLASCM	0177CR	0177CR	
					ENTRY	DARCOS	0177CR		
					ENTRY	DARSIN	0177E0		
					CSECT	IHCLSORT	017A40	017A40	
					ENTRY	USORT	017A40		
					CSECT	IHCLATM2	017BA0	017BA0	
					ENTRY	DATAN	017BAC		
					* ENTRY	DATAN2	017BA0		
					CSECT	IHCLSCM	017DFR	017DFR	
					ENTRY	USIN	017E1A		
					ENTRY	UCOS	017DFR		
					CSECT	IHCLTNCT	01807R	01807R	
					ENTRY	DTAN	018090		
					* ENTRY	UCDTAN	01825C		
					* ENTRY	UCDTAN	01807R		
					CSECT	MSGTMA	01837R	01837R	
					ENTRY	MSGTM	01837R		
					CSECT	CHARA	018710	018710	
					ENTRY	CHAR	018710		
					CSECT	PLNTSA	019460	01940R	
					ENTRY	PLNTP	0194FC		
					ENTRY	PLNTA	01956E		
					ENTRY	PLNTR	019556		
					ENTRY	PLNTF	01961C		
					ENTRY	PLNTIA	019562		
					ENTRY	PLNTIP	0194F0		
					* ENTRY	SCALF	019460		
					ENTRY	PLNTIR	01954A		
					* ENTRY	PLTRDY	0194EA		
					* ENTRY	PLTMGR	0194E0		
					* ENTRY	PLNTM	01963R		
					* ENTRY	PLTMG	0194RA		
					CSECT	GPLNTE	01987R	01987R	
					ENTRY	XYS	0198ER		
					ENTRY	LXYS	01991C		

				UVT	13 DEC 1978		TIME 0819.17		
PHASE	TRANSFER ADDR.	LOCORE	HICORE	BLOCK NO.	FSD TYPE	LABEL	LOADED	REF-FACTOR	
					ENTRY	XLYS	019950		
					ENTRY	LXLYS	019984		
					ENTRY	XY	019988		
					ENTRY	LXY	0199FC		
					ENTRY	XLY	019A20		
					ENTRY	LXLY	019A54		
					* ENTRY	GPLNT	019878		
					CSECT	IRANK2	01A918	01A918	
					ENTRY	IRANK2	01A924		
					* ENTRY	IRANK1	01A918		
					CSECT	DATPAN	01AA10	01AA10	
					CSECT	SCRFEN2	01AA20	01AA10	
					ENTRY	SCRFEN	01AA20		
					CSECT	DV1827	01B988	01B988	
					CSECT	IHCUNPT2	01B0F0	01B0F0	
					ENTRY	IHCUNPT	01B0F0		
					* ENTRY	ERRTR2	01B0F0		
					CSECT	IHCETRCH	01B2F0	01B2F0	
					ENTRY	IHCETRCH	01B2F0		
					* ENTRY	ERRTR2	01B2F6		
					CSECT	DIGANLG	01B5F8	01B5F8	
					ENTRY	CO	01B640		
					ENTRY	DI	01B640		
					* ENTRY	NDI	01B5F8		
					* ENTRY	DAC	01B640		
					* ENTRY	NCN	01B5F8		
					* ENTRY	NDAC	01B618		
					* ENTRY	AIP	01B640		
					* ENTRY	NAIP	01B608		
					CSECT	POINT2	01B810	01B810	
					ENTRY	POINT	01B810		

HIGHEST CORE LOADED = 01B877

LINKAGE EDITOR HIGHEST SEVERITY WAS 0 EDITOR TIME = 1 MIN 34 SEC
 // EXFC UVT

08.20.54

IX. References

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